



MILITARY AVIATION LOSSES FY2013-2020

224 LIVES
\$11.6 BILLION
186 AIRCRAFT



National Commission on Military Aviation Safety

Report to the President and the Congress of the United States

DECEMBER 1, 2020



National Commission on Military Aviation Safety

Report to the President and the Congress of the United States

DECEMBER 1, 2020

Cover image: U.S. Air Force F-22 Raptors from the 199th Fighter Squadron Hawaii Air National Guard and the 19th Fighter Squadron at Joint Base Pearl Harbor-Hickam perform the missing man formation in honor of fallen servicemembers during a Pearl Harbor Day remembrance ceremony. The missing man formation comprises four aircraft in a V-shape formation. The aircraft in the ring finger position pulls up and leaves the formation to signify a lost comrade in arms. (Department of Defense photo by U.S. Air Force Tech. Sgt. Michael R. Holzworth.)



The National Commission on Military Aviation Safety dedicates its work to the men and women who serve in the aviation units of the U.S. Army, U.S. Navy, U.S. Marine Corps, and U.S. Air Force.

OUR COMMITMENT

More than 6,000 U.S. noncombat military aviation mishaps occurred between 2013 and 2018. These mishaps occurred during training or routine operations. They claimed the lives of 198 servicemembers and civilians and cost the nation more than \$9.41 billion in damages, including 157 destroyed aircraft.

The U.S. Congress created the National Commission on Military Aviation Safety in 2019 to examine the rates and causes of mishaps and recommend ways to improve aviation safety. While this Commission was conducting its study, military aviation mishaps claimed another 26 lives, 29 aircraft, and \$2.25 billion.

The seven commissioners represent a diversity of individual experiences in military operations, national defense policy, aircraft manufacturing, and aviation safety. We share a devotion to saving lives and improving readiness in the Services' aviation units. Supported by a dedicated staff led by Major General Gregory A. Feest, U.S. Air Force Retired, this Commission reviewed the military aviation mishap reports from 2013–2018, consulted previous studies, interviewed experts in military and commercial aviation safety, and met with servicemembers in aviation units across the Services.

We visited more than 200 aviation-related military and civilian organizations across the spectrum of missions and aircraft, meeting with thousands of aviation professionals of all ranks. In nonattribitional town halls

and roundtables, servicemembers shared their experiences and concerns. The insights and information they shared with us aligned with trends we saw in the empirical data. We came away from our visits impressed with the patriotism, dedication, and level of effort throughout the ranks of America's military aircrews and maintainers. We also came away deeply troubled by the chronic fatigue we saw among these brave servicemembers. The current operations tempo (OPTEMPO) is leading to unsafe practices and driving experienced aviators and maintainers out of the force.

In addition to the operational demand, our findings focus on four areas where Congress and the Department of Defense can take immediate steps to reduce aviation mishaps: Pilots should fly; maintainers should maintain; data can save lives; funding should be consistent.

We, the members of the National Commission on Military Aviation Safety, thank the Services' safety centers for their assistance to the Commission throughout the course of this study. We thank the commanders who hosted us and provided unfettered access to the people serving in their units. We thank every one of those men and women for their service and for their candid comments. Protecting their safety is a moral imperative and critical to ensuring that they can continue to serve the United States of America as effective, experienced aviation professionals so essential to our national security.



General Richard A. Cody (USA, Retired), Chairman



The Honorable Scott C. Donnelly



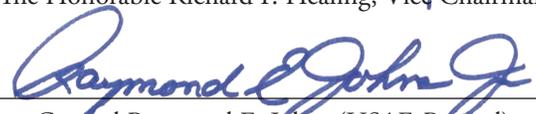
The Honorable Preston Geren



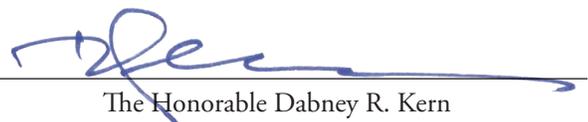
The Honorable Joseph W. Hagin



The Honorable Richard F. Healing, Vice Chairman



General Raymond E. Johns (USAF, Retired)



The Honorable Dabney R. Kern

TABLE OF CONTENTS

Our Commitment	i	Chapter 6: Sustaining the Machine	37
Executive Summary	v	Aviation Supply System	37
Aircrews and Maintainers	v	Overcoming Supply Deficiencies	38
Data Deficiencies and the Need for a Joint Safety Council	vi	Depot Maintenance	38
Consistent and Predictable Resourcing	vi	Facilities	38
Conclusion	vii	Aircraft Transition Issues	39
Mission and Method	1	Chapter 7: The Need for Consistent and Predictable Funding	41
Conducting Its Study	2	Continuing Resolutions	41
The Human-Machine-Environment Framework	3	Chapter 8: The Demand Environment	45
Chapter 2: Assessing Mishap Rates	5	More Demand than Capacity	45
Assessing and Characterizing Mishap Rates	5	Additional Duties	47
Visualizing and Contextualizing the Rates	5	Chapter 9: Maintainers as Aviation Professionals	51
Comparing the Period Means	9	Measuring Training Efficacy	52
Identifying Troubling Trends	10	On-the-Job Training	52
The Commission’s Assessment and Findings	12	Experience Matters	53
Additional Assessment	13	Talent Management for Aviation Maintainers	55
Chapter 3: Military Aviation Safety Data	15	Maintainers Want to Maintain	55
Assessing the Causes and Contributing Factors of Mishaps	15	Chapter 10: Protecting Investment in Aircrews	59
The Human Factors Analysis and Classification System (HFACS)	15	Pilot Training	59
The Limitations	16	The Right Training Medium	62
Preemptive Aviation Safety Data Collection	20	In Memoriam	67
Chapter 4: The Joint Safety Council	23	Appendixes	
The Safety Success of Commercial Aviation	23	A. Congressional Charter for the National Commission on Military Aviation Safety	A-1
Establishing a Joint Safety Council	25	B. Recommendations	B-1
Chapter 5: The Human/Machine Interface	29	C. Commissioners and Staff	C-1
Physiological Episodes	29	D. Commission Engagements	D-1
No Single Problem, No Single Solution	29	E. Bibliography	E-1
Prioritizing the Human	32	F. Technical Appendix	F-1
		G. Key Military Aviation Safety Policy Guidance	G-1
		H. Joint Safety Council Proposed Legislation	H-1
		I. Glossary and Acronym List	I-1

List of Graphics

Figure 1-1: Mishaps, Fatalities, Destroyed Aircraft, and Estimated Costs Across DoD for Fiscal Years 2013–2018	1	Figure 9-1: Army AH-64 Helicopter Maintainer Average Months of Service by Skill Level and Fiscal Year	53
Figure 1-2: Mishap Classifications During Study Period, Fiscal Years 2013–2018	2	Figure 9-2: Army Aircraft Maintenance Senior Sergeant Average Months of Service by Skill Level and Fiscal Year	54
Figure 1-3: Human-Machine-Environment Framework	3	Figure 9-3: Air Force Refuel/Bomber Aircraft Maintainer Average Years of Service by Skill Level and Fiscal Year	54
Figure 2-1: Visualizing Class A Mishap Rates	6	Figure 10-1: Army AH-64D Course Changes	59
Figure 2-2: Class A Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018	6	Figure 10-2: Navy and Marine Corps F-18 Course Changes	59
Figure 2-3: Visualizing Class B Mishap Rates	7	Figure 10-3: Air Force F-16 Course Changes	59
Figure 2-4: Class B Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018	7	Figure 10-4: Examples of Cost Comparison of Actual Flight Hours to Simulators, Fiscal Year 2019	62
Figure 2-5: Visualizing Class C Mishap Rates	8	Figure F-1: Class A Mishap Rates	F-1
Figure 2-6: Class C Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018	8	Figure F-2: Class B Mishap Rates	F-2
Figure 2-7: Comparing the Fiscal Years 2007–2012 and Fiscal Years 2013–2018 Rate Means Across the Services and Mishap Classes	9	Figure F-3: Class C Mishap Rates	F-2
Figure 2-8: Class A Mishap Rates and Rolling Averages by Service for Fiscal Years 2007–2018	10	Figure F-4: Class A–C Mishap Rates	F-3
Figure 2-9: Class B Mishap Rates and Rolling Averages by Service for Fiscal Years 2007–2018	11	Figure F-5: Fatalities and Destroyed Aircraft by Service for Fiscal Years 2007–2018	F-4
Figure 2-10: Class C Mishap Rates and Rolling Averages by Service for Fiscal Years 2007–2018	11	Figure F-6: Mishap Classification Criteria Changes per DODI 6055.07, Mishap Notification, Investigation, Reporting, and Record Keeping	F-5
Figure 2-11: Visualizing Class A-C Mishap Rates	12	Figure F-7: Army Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018	F-6
Figure 2-12: Mishap Rates for Fiscal Years 2013–2019	13	Figure F-8: Air Force Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018	F-6
Figure 3-1: Aviation Mishap Categories and Subcategories	16	Figure F-9: Navy Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018	F-7
Figure 3-2: Flight, Flight-Related, and Ground Mishaps by Class and Service for Fiscal Years 2013–2018	17	Figure F-10: Marine Corps Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018	F-7
Figure 3-3: The DoD HFACS	18	Figure F-11: Army Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018	F-8
Figure 5-1: Air Force Physiological Episodes by Aircraft Type for Fiscal Years 2013–2018	30	Figure F-12: Air Force Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018	F-8
Figure 5-2: Navy and Marine Corps Physiological Episodes by Aircraft Type for Fiscal Years 2013–2018	30	Figure F-13: Navy Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018	F-9
Figure 5-3: Air Force Physiological Episodes in Fighter and Trainer Aircraft for Fiscal Years 2013–2018	30	Figure F-14: Marine Corps Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018	F-9
Figure 5-4: Navy and Marine Corps Physiological Episodes in Fighter and Trainer Aircraft for Fiscal Years 2013–2018	30	Figure F-15: Army Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018	F-10
Figure 5-5: Human Systems Integration in the Acquisition Planning Process	34	Figure F-16: Air Force Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018	F-10
Figure 7-1: Days Under a Continuing Resolution: Department of Defense, Fiscal Years 2002–2019	42	Figure F-17: Navy Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018	F-11
Figure 8-1: OPTEMPO	46	Figure F-18: Marine Corps Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018	F-11



Marines with Marine All Weather Attack Squadron 224, Marine Aircraft Group 31, 2nd Marine Aircraft Wing, prepare an F/A-18 for flight at Naval Air Facility El Centro, California. (Department of Defense photo.)

EXECUTIVE SUMMARY

“What do you think will cause the next aviation mishap?”

The National Commission on Military Aviation Safety asked thousands of pilots and maintainers this question during visits to military flight lines. Across the country, certain answers were consistently repeated, regardless of Service, rank, or airframe: insufficient flight hours, decreasing proficiency levels, inadequate training programs, excessive administrative duties, inconsistent funding, risky maintenance practices, and a relentless operations tempo.

The Commission also independently assessed this same question. The Commission reviewed thousands of mishap reports, consulted volumes of secondary research, and conducted data analysis to determine why mishap rates have increased. The Commission also utilized its resident knowledge and experience: two retired four-star military aviators; a former member of the National Transportation Safety Board and Director of Safety and Survivability for the Navy; a former Secretary of the Army who had previously served as Acting Secretary of the Air Force and as a member of Congress; an engineer turned CEO for major aircraft manufacturers; a White House Deputy Chief of Staff for Operations who served four presidents; and a former Navy helicopter pilot who oversaw Air Force One and Marine One while director of the White House Military Office.

This report shares critical perspectives from the flight line and addresses the safety concerns that so many aviators and maintainers candidly shared. This report also covers broader topics in the Commission’s statutory charter, such as aviation mishap rates, unexplained physiological episodes, and aviation maintenance delays. The complete list of the Commission’s recommendations is provided in Appendix B.

During its study, the Commission realized that many aviation safety issues are uniquely interconnected and require collaborative, cross-cutting solutions. For example, increasing spare parts inventories does little good if there are not enough experienced maintainers to install them. Fixing one issue may require fixing several related issues, and all solutions must be crafted to work

in concert. In this report, the Commission took special care to balance competing and sometimes conflicting priorities, and its recommendations are proposed with an understanding of the importance of harmonization.

Our findings and recommendations focus on four areas where Congress and the Department of Defense can take immediate steps to reduce aviation mishaps: Pilots should fly; maintainers should maintain; data can save lives; and funding should be consistent.

Aircrews and Maintainers

The Commission found that aviation and maintenance experience, the key to doing a job safely and efficiently, is declining. Newly trained pilots and maintainers are reporting to operational units without basic skills. Flight hours are being replaced with simulator hours, yet the simulators are often outdated, out of service, or unavailable. Aircrews and maintainers are saddled with additional nonaviation duties that are more valued than their primary duties for purposes of promotion. Furthermore, on top of their experience gaps, some aircrews are experiencing physiological episodes when an aircraft’s environmental systems fail to meet the needs of the pilot.

“Additional Duties. . . We have an instructor pilot trying to get a forklift license.”

—USAF Junior Officer

This report addresses these issues in detail. Two chapters address the shortcomings in initial training, follow-on training, and personnel management of aircrews and maintainers. One chapter examines the effects of a relentless pace on military aviation for both machine and personnel. Another chapter discusses the human-machine interface and recommends changes in the acquisition process to better meet the needs of the pilot during aircraft design and modification.

However, while addressed in separate chapters, these are compounding problems. A reduction in flight hours for new pilot training adds to the requirements for operational units. These units, already overtasked from a high operations tempo, must then conduct training to develop basic skills for new personnel. This stagnates the units' ability to conduct high-level training. In other words, junior pilots and maintainers are starting their careers a lap behind, and then never catching up, all while their units buckle under the additional stress of getting them up to speed. This, in turn, leads to further costs. By being overworked, overstressed, and overloaded with additional duties unrelated to aviation, the morale and readiness of aircrews and maintainers erode. Experienced aircrews and maintainers leave the Services and are replaced by personnel with no expertise. The average level of experience falls, and the cycle repeats.

**"We are doing 12-hour days, five days a week, and hardly flying."
—F-22 Pilot**

To address these issues, the Commission recommends a multipronged approach. As outlined in the report, the Services must improve the training of new pilots and maintainers to broaden their experience and limit the burden on operational units. Additionally, the Services must increase the retention of experienced aircrews and maintainers through better personnel management, increased bonuses, and better schooling opportunities. The Services, having invested years and millions of dollars in initial, on-the-job, and advanced training, must focus the careers of aviation professionals on their aviation duties. Furthermore, to increase safety and readiness, the Services must ensure that aircraft are designed to match the needs of the aircrew who fly them. Without such complementary solutions, the U.S. military could be left with the worst of all worlds: increased costs, decreased readiness, and eroded safety margins.

Data Deficiencies and the Need for a Joint Safety Council

During its study, the Commission identified numerous data deficiencies in military aviation. Due to poor data collection and analysis, the Services and the Department of Defense are missing out on valuable opportunities to reduce risk, prevent mishaps, and optimize human performance. This is repeatedly referenced in the report. For example, one chapter explains how the Department lacks sufficient data collection methods and analysis

capabilities to reduce risks and improve safety, while the Services lack standardized procedures and consistent processes in their mishap reporting. Another chapter examines how improved pilot monitoring could help identify, understand, and reduce unexplained physiological episodes. Additional chapters discuss the need for improved data collection to measure training efficacy for pilots and maintainers.

In studying these issues, the Commission reviewed the current practices of commercial aviation, which has successfully used data analytics to identify and reduce safety risk. While certain commercial practices are limited in their applicability to military aviation, the Commission identified policies and practices that offer opportunities to reduce risk and improve safety.

For example, compared to the commercial sector, the Commission determined that the Department

of Defense is not properly organized to conduct data analytics, coordinate aviation safety activities, develop safety standards or data collection requirements, or review the Services' implementation of aviation safety programs.

The Commission recommends creating a Joint Safety Council. Reporting to the Deputy Secretary of Defense, the council would be responsible for establishing military aviation safety standards, collecting and analyzing safety data, and developing safety priorities. Led by safety officials from the Services, the council would have the necessary expertise and authority to monitor and coordinate aviation safety programs across the Department. This recommendation is further outlined in Chapter 4, and a legislative proposal is contained in Appendix H.

**"Guys are going to take risks they don't even know is a risk."
—Marine Supervisor**

Consistent and Predictable Resourcing

The question of the next mishap was not hard to answer at one Marine base, where a junior Marine told the Commission that his unit was reusing expendable \$5 filters on aircraft. The unit, he explained, still had missions to do even if there was no money to purchase new filters. This was one of the egregious examples the Commission found, and it was a direct result of funding suddenly being withdrawn to meet other priorities. Inconsistent funding, and the tolerance it fosters for maintenance shortcuts, were the likely causes of the next mishap at this unit.

A lack of consistent funding is especially pernicious to military aviation safety. Flying, like surgery and other highly technical professions, is a perishable skill that needs routine practice to maintain proficiency. When a unit's funding is restored in the last part of a fiscal year, it simply cannot make up for lost training and deferred maintenance.

"I can always use more money, but the thing I really need is predictability: budget for five years, [and] get it on October 1."

—Senior USAF Leader

Late funding, no matter the amount, cannot reverse the impact of months of insufficient flying hours, missing parts, and deferred maintenance. Timing is everything.

By far the greatest and most preventable source of unpredictable funding is Congress's use of continuing resolutions. The Department of Defense has begun the fiscal year with a continuing resolution for 13 of the past 18 fiscal years. As continuing resolutions have become more common, their average duration has also increased. There is near universal agreement that continuing resolutions significantly degrade readiness, waste money, and put the lives of Servicemembers at unnecessary risk.

The Commission concurs and heard examples from every Service of how inconsistent funding degrades

virtually every aspect of military aviation. However, empirical research on the impact of continuing resolutions is lacking. Therefore, while the Commission first recommends that the Department of Defense and Congress resource military aviation in a consistent and predictable manner, the Commission also recommends that Congress require a comprehensive, data-driven analysis of continuing resolutions' impact on military aviation.

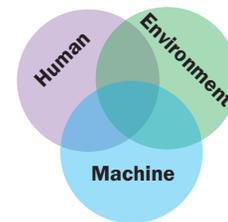
Conclusion

In line with the Commission's statutory charter, this report provides a comprehensive review of military aviation safety. The issues outlined above remain illustrative, not exhaustive. Overall, this report addresses numerous topics related to military aviation, including mishap rates, safety data, unexplained physiological effects, sustainment management systems, funding, operations tempo, training, and talent management. Each of these topics warrants careful review and attention, particularly due to the stakes involved.

During the Commission's six-year study period, aviation mishaps cost the U.S. military 198 lives, 157 aircraft, and well over \$9 billion in damages. To reduce these unacceptable costs, the Commission stresses that systemic problems require integrated solutions that prioritize safety. The cost of doing anything else is simply too high.



Members of the National Commission on Military Aviation Safety speak with an advanced individual training student at Joint Base Langley-Eustis, Virginia. (U.S. Air Force photo by TSgt. Robert Hicks.)



Chapter 1:

MISSION AND METHOD

One hundred ninety-eight military personnel and civilians died in U.S. military aviation mishaps between fiscal years 2013 and 2018 in non-combat operations. The total cost of equipment lost or damaged in these mishaps was more than \$9.41 billion, including 157 aircraft destroyed (Figure 1-1).

Beginning in the summer of 2017, all of the Services experienced a series of high-profile mishaps over the next 12 months that called into question the overall state of military aviation safety. A Marine Corps KC-130 came apart in the sky over Mississippi, killing 15 Marines and one Navy corpsman. An Army UH-60 crashed into the sea during a night exercise off the coast of Oahu, Hawaii, killing all five aboard. A Navy C-2A Greyhound ditched into the Philippine Sea with three fatalities. An Air Force Thunderbird F-16C crashed in Nevada, killing the pilot. A Puerto Rico Air National Guard C-130H Hercules on its retirement flight to Davis-Monthan Air Force Base, Arizona, crashed after takeoff in Georgia, killing all nine aboard. During the same time period, Air Force and Navy pilots experienced a mysterious spike in unexplained physiological episodes (hypoxia-like

symptoms). As investigators struggled to find the root causes for these episodes, both the Air Force and Navy grounded their fleets of T-6 trainers.

This spate of fatal mishaps combined with the increase of reported physiological episodes prompted the U.S. Congress to establish the National Commission on Military Aviation Safety in the John S. McCain National Defense Authorization Act (NDAA) for Fiscal Year 2019. The Commission’s charter, as spelled out in that law, charged the commissioners to “undertake a comprehensive study of United States military aviation mishaps that occurred between fiscal years 2013 and 2018.” The charter (see Appendix A) gave the Commission five tasks to accomplish in its study:

1. to assess the rates of military aviation mishaps between fiscal years 2013 and 2018 compared to historic aviation mishap rates;
2. to assess the underlying causes contributing to the unexplained physiological effects;
3. to assess the causes contributing to delays in aviation maintenance and limiting operational availability of aircraft;

Figure 1-1:

Mishaps, Fatalities, Destroyed Aircraft, and Estimated Costs Across DoD for Fiscal Years 2013–2018

	2013	2014	2015	2016	2017	2018	2013-2018
Number of Class A Mishaps ¹	48	49	53	42	52	56	300
Number of Class B Mishaps ¹	78	80	85	90	83	82	498
Number of Class C Mishaps ¹	786	836	869	909	982	899	5,281
Number of Class A-C Mishaps ¹	912	965	1,007	1,041	1,117	1,037	6,079
Number of Fatalities ²	24	22	38	39	36	39	198
Number of Destroyed Aircraft ²	30	27	24	28	27	21	157
Class A–C Mishaps Estimated Total Derived Costs (in billions) ²	\$1.57	\$1.48	\$1.31	\$1.78	\$1.87	\$1.39	\$9.41

Source: ¹Service safety centers; ²Force Risk Reduction database.

4. to assess the causes contributing to military aviation mishaps; and
5. to make recommendations on the modifications, if any, of safety, training, maintenance, personnel, or other policies related to military aviation safety.

The charter also directed the Secretary of Defense, in coordination with the Secretary of each military department, to submit, within 120 days from the Commission’s delivery of its report, an assessment of the Commission’s findings and conclusions and a plan for implementing the recommendations.

Conducting Its Study

The Commission approached these tasks with an understanding that readiness is inextricably tied to safe operations. The Commission’s view of aviation mishaps encompassed both the events leading directly to the mishaps as well as the incidents themselves. The study analyzed the full spectrum of operational conditions and institutional factors far beyond quantitative data.

The Commission conducted its own primary research and analysis to arrive at its assessments and recommendations. The study focused on three streams of information: analyzing the mishap reports and quantitative data; consulting volumes of secondary research; and, most importantly, traveling to 82 locations to meet with aviation professionals. In addition to extensive quantitative data, the Commission found significant value in hearing personal experiences and concerns directly from Service personnel. The Services’ safety centers connected the Commission with points of contact for the site visits and with subject matter experts and other data sources.

Mishap Reports and Quantitative Data

The Commission reviewed Class A, B, and C mishap reports (see Figure 1-2) from the military departments’ safety centers for the 2013–2018 time period of the study, plus data from fiscal years 2007 through 2012 for historical comparison. The Commission studied and analyzed all of the mishap reports and looked for trends in the types of mishaps and the circumstances that directly or indirectly contributed to these incidents. The Commission did not reinvestigate or re-adjudicate any incident, investigation, or Service determination: the Commission accepted the thousands of mishap reports’ narration and findings as presented.

Figure 1-2:

Mishap Classifications During Study Period, Fiscal Years 2013–2018

Class A	At least \$2 million in damage and/or death or permanent disability.
Class B	More than \$500,000 but less than \$2 million in damages, and/or permanent partial disability or three or more people hospitalized.
Class C	At least \$50,000 but less than \$500,000, and/or nonfatal injuries that require time off from work.
Class D	At least \$20,000 but less than \$50,000, and/or recordable injury or illness that cannot be classified as an A, B, or C mishap.
Class E	Depends on Service definition.

Additional data the Commission gathered included flight hours, staffing levels, readiness rates, maintenance experience levels, changes in training syllabi, and DoD budgets. To broaden its analytical efforts, the Commission employed the Research and Analysis Center at the Naval Postgraduate School in Monterey, California, drawing on the resources of the multi-Service Research Facilitation Laboratory.

Literature and Document Review

The Commission also benefited from consulting an abundance of studies, directives, and instructions covering military aviation safety over the past 25 years. Studies came from government sources (Congress, the Congressional Research Service, the Office of Management and Budget, the Congressional Budget Office, the Government Accountability Office, and professional military education institutions), federally funded research and development centers (CNA, RAND, and IDA), think tanks, academic and research institutions, and government-commissioned evaluations produced by consulting and professional services organizations. A bibliography is included in Appendix E. The Commission also elicited information, insights, advice, and recommendations from subject matter experts inside and outside the Department of Defense.

Flight Line Experience

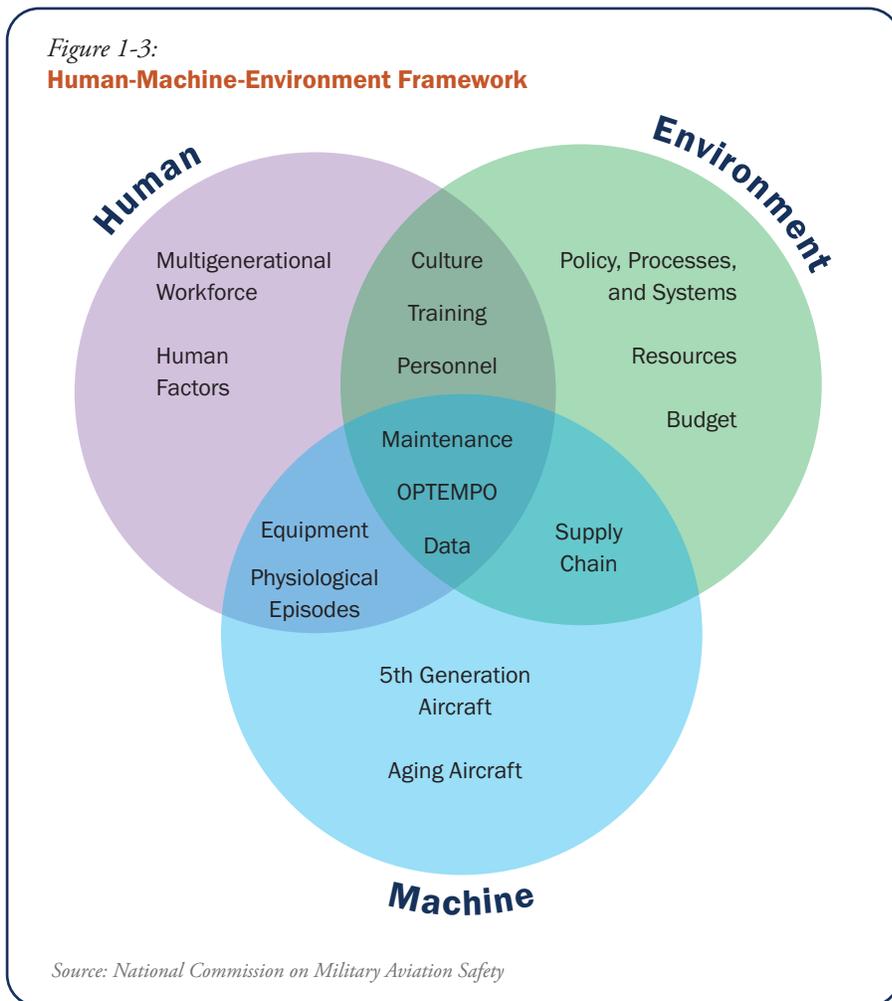
The Commission met with more than 200 organizations and military aviation units, reaching all of the many different types of flying communities in each of the Services, a distinction that separates this report from previous studies. The Commission hosted hundreds of

town halls and roundtable discussions with thousands of Service personnel. The purpose was to hear firsthand the experiences and concerns of aircrews and maintainers across all Services, components, and ranks. In addition to meeting with each unit's senior leaders, the Commission intentionally sought out junior personnel for their insights. To encourage candor from participants, commanders did not attend the town halls with their subordinates, and comments were noted without direct attribution. This fostered open and uninhibited dialogue. Additionally, the Commission visited major air carriers, civilian helicopter operators, Federal Aviation Administration officials, and aircraft manufacturers to explore best practices in commercial aviation and safety-related trends in aviation technology. A list of the Commission's site visits and other engagements is in Appendix D.

The Human-Machine-Environment Framework

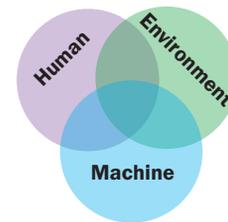
Early in this process, the Human-Machine-Environment interface emerged as the framework for the Commission's study (see Figure 1-3). The *Human* includes not only the physiology, experience, proficiency, and currency of aviators and maintainers, but also the ethos that comes with being a Soldier, Sailor, Marine, or Airman: a devotion to duty, a make-it-work attitude, and an earnest commitment to professionalism and leadership. The *Machine* is the aircraft, the complex technical platform designed to accomplish a wide array of missions, and the equipment needed to sustain it. The *Environment* includes operations ranging from peacetime training to combat preparation during which aircrews accomplish their mission and maintainers sustain the aircraft. *Environment* also includes the institution and infrastructure that support these operations:

resources, policies, budgets, organizational structures, logistics, facilities, accountability, and operations tempo (OPTEMPO). The Human, Machine, and Environment must work together in harmony to optimize safety and readiness. The Commission found that any imbalance, misalignment, or disharmony increases the risk of a mishap. A system of systems is at play, with interdependencies and vital connections among them.





A pilot with Marine Fighter Attack Squadron 211 completes preflight checks in an F-35B Lightning II Joint Strike Fighter aboard HMS Queen Elizabeth at sea. (Department of Defense photo.)



Chapter 2:

ASSESSING MISHAP RATES

Advancing technology and concerted safety efforts have made recent years the safest period in aviation history. According to the Bureau of Transportation Statistics, the U.S. air carrier total accident rate per 100,000 flight hours has decreased from 1.77 in 1965 to 0.20 in 1990 and reached 0.17 in 2017. A 2020 Massachusetts Institute of Technology study finds that the risk of traveling on commercial airlines has dropped from one death per 350,000 boardings globally from 1968–1977 to one death per 2.7 million boardings from 1998–2007 to a current rate of one death per 7.9 million boardings. Similarly, military aviation has recorded substantial improvements in mishap rates since the 1950s.

Within this broader context, Congress tasked this Commission “to assess the rates of military aviation mishaps from fiscal years 2013 through 2018 compared to historic aviation mishap rates.” The Commission calculated mishap rates by Service and across the Department of Defense for fiscal years 2013–2018, comparing the rates of those years against the previous six fiscal years, 2007–2012. The Commission’s assessment addressed two questions: (1) Are mishap rates higher or lower in fiscal years 2013–2018,

and (2) are mishap rates moving in the right direction? This chapter’s purpose is to show what the rates are and how they have changed over the years.

Assessing and Characterizing Mishap Rates

The Commission used a widely accepted standard for measuring mishaps: mishaps per 100,000 flight hours. Each of the Services’ safety centers provided the Commission with historical mishap data and flight hours. The Commission calculated the mishap rates for each Service as well as an aggregated rate for DoD.

$$\text{Mishap Rate} = (\# \text{ of mishaps per year} / \# \text{ of flight hours per year}) \times 100,000$$

These calculations allowed the Commission to compare mishap rates across the Services using a common standard while accounting for differing flight hours among the Services. The mishap rate reflects the occurrence of a mishap and is not influenced by the number of fatalities or extent of damage. A mishap that results in more than one fatality is counted as a single mishap.

The Commission used visualizations, basic descriptive statistics, and rolling averages to better understand the characteristics and relationships among the mishap rates. The Commission examined Class A, Class B, and Class C mishaps, the costliest as measured by deaths, injury, and aircraft repair costs. Reporting for the less severe Class D and Class E mishaps was inconsistent throughout fiscal years 2007 to 2018 and not included in this analysis.

Visualizing and Contextualizing the Rates

The bottom line is that overall DoD mishap rates increased in fiscal years 2013–2018. These higher rates are largely due to an increase in Class C mishaps. However, as outlined below, the increase in Class C mishaps could be a harbinger of more serious safety issues. Indeed, the 2019 fiscal year data substantiates the Commission’s concerns.

CURRENCY AND PROFICIENCY

Aviators and maintainers depend on being current and proficient in their tasks to limit their risk for a mishap.

Currency, or being current, describes having successfully demonstrated a skill or maneuver within a certain period of time.

Proficiency, or being proficient, emphasizes how skilled an individual is at performing a task or maneuver, not whether the individual is able to perform the task. Each of the Services assess proficiency with a tiered scale describing the level of skill at which an individual is able to successfully complete a task.

The following visualizations illustrate the changes in the mishap rates by class and by Service for fiscal years 2007–2018. They are supplemented by tables providing the annual estimated costs of mishaps by class and by Service for context and perspective.

Figure 2-1 shows the Army, Air Force, and Navy had moderate fluctuations in Class A mishap rates during the fiscal years 2013–2018 study period. However, the Marine Corps consistently had higher Class A mishap rates. The higher mishap rates in the Marine Corps are consistent with problems the Commission observed during site visits. These included low morale, pilots struggling to maintain enough flight hours for currency, over-stressed aircrew and maintenance personnel overloaded with additional duties, poor facilities, and a pattern of using shortcuts to keep aircraft flying. The Commission assesses that these issues contributed to the spike in Class A

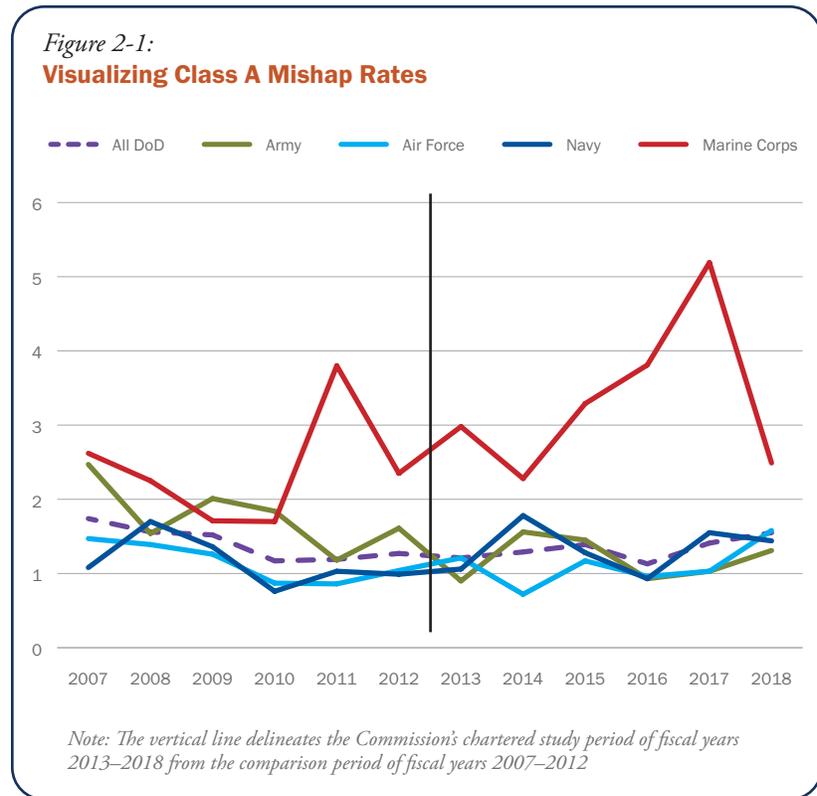


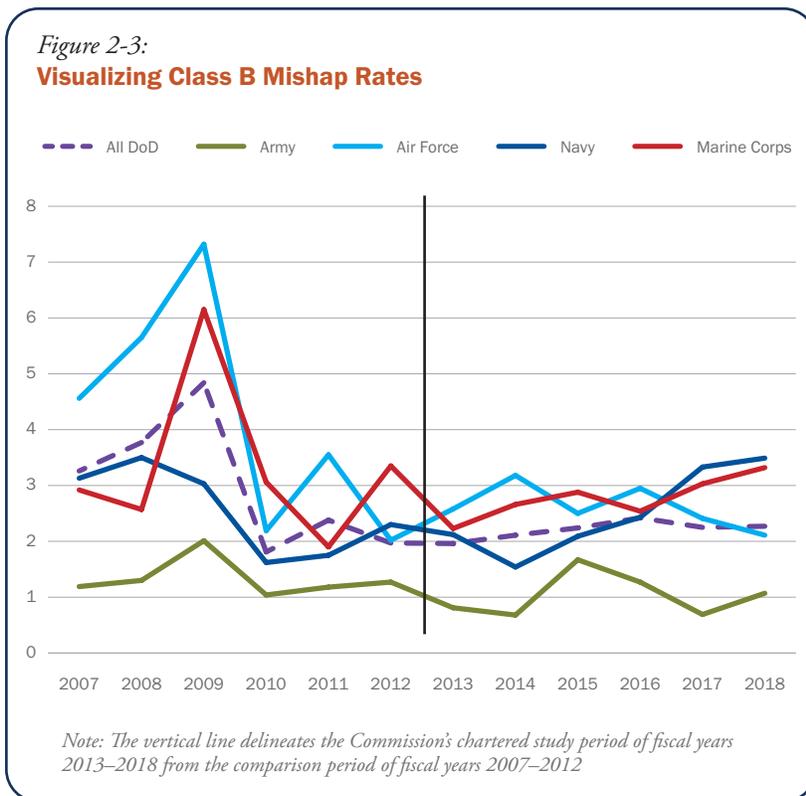
Figure 2-2:
Class A Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2012	2013-2018
Army	\$311.7	\$126.6	\$128.1	\$237.7	\$164.4	\$162.9	\$42.0	\$263.6	\$141.8	\$167.9	\$228.8	\$194.1	\$1,131.3	\$1,038.1
Air Force	\$364.4	\$2,158.6	\$470.8	\$462.6	\$325.5	\$498.3	\$899.2	\$214.1	\$405.6	\$435.4	\$242.0	\$489.1	\$4,280.2	\$2,685.4
Navy	\$227.0	\$616.0	\$225.4	\$265.8	\$201.0	\$435.2	\$196.1	\$538.1	\$295.8	\$431.1	\$367.5	\$230.0	\$1,970.4	\$2,058.6
Marine Corps	\$160.6	\$217.0	\$161.1	\$232.4	\$232.2	\$261.3	\$259.7	\$292.6	\$274.8	\$542.8	\$832.8	\$283.6	\$1,264.6	\$2,486.3
All DoD	\$1,063.7	\$3,118.2	\$985.4	\$1,198.4	\$923.0	\$1,357.8	\$1,396.9	\$1,308.4	\$1,118.0	\$1,577.2	\$1,671.1	\$1,196.7	\$8,646.5	\$8,268.4

Source: FR2 Database

Note: The gray boxes emphasize data entirely from the Commission's chartered study period, fiscal years 2013–2018.

Figure 2-3:
Visualizing Class B Mishap Rates



mishaps from fiscal year 2015 to 2017. Chapters 9 and 10 explore in greater detail the challenges aviation maintainers and aircrew face.

Figure 2-2 shows that the aggregate mishap materiel costs for Class A mishaps exceeded \$1.1 billion during each year of the study period. A single \$1.4 billion mishap destroying a B-2 Stealth Bomber in 2008 drove the higher total DoD-wide costs for fiscal years 2007 through 2012.

Figure 2-3 shows that fiscal year 2009 had a massive spike in Class B mishaps. While that year is outside the Commission's study period, the Commission notes this spike may be partially attributable to a change in how mishaps were classified that year (additional explanation provided in Appendix F). During the fiscal years 2013–2018 study period, Class B mishap rates were generally stable across the Services with the exception of the Navy, which had a continuous increase in Class B mishaps from fiscal years 2014–2018. The Navy increase

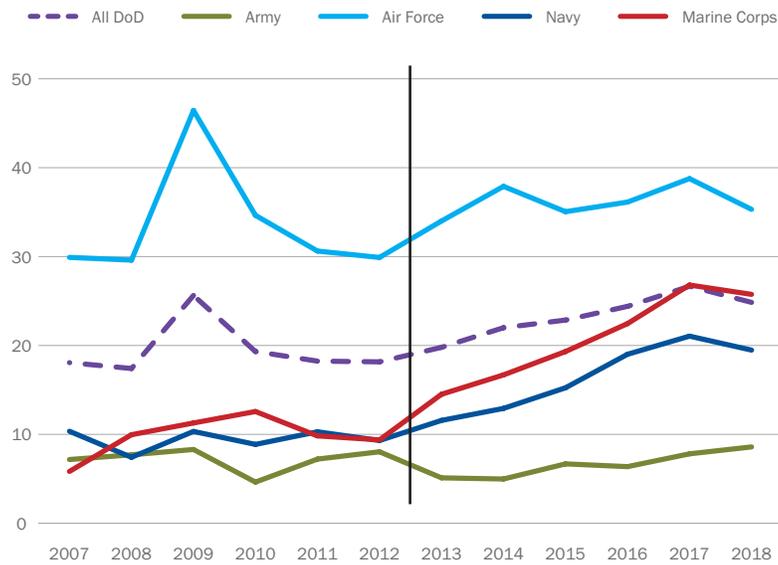
Figure 2-4:
Class B Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2012	2013-2018
Army	\$5.61	\$6.48	\$10.20	\$10.50	\$13.95	\$10.49	\$5.99	\$6.12	\$13.20	\$11.95	\$3.51	\$8.54	\$57.24	\$49.31
Air Force	\$42.64	\$55.84	\$69.06	\$36.95	\$62.76	\$34.03	\$42.95	\$47.48	\$47.88	\$49.35	\$40.43	\$49.52	\$301.30	\$277.62
Navy	\$13.54	\$15.23	\$14.24	\$10.14	\$12.63	\$13.64	\$16.35	\$13.84	\$12.41	\$16.83	\$21.69	\$26.31	\$79.42	\$107.43
Marine Corps	\$5.87	\$3.63	\$8.74	\$5.65	\$6.74	\$9.22	\$3.89	\$4.47	\$6.06	\$6.13	\$5.89	\$4.86	\$39.85	\$31.31
All DoD	\$67.67	\$81.19	\$102.25	\$63.24	\$96.08	\$67.38	\$69.18	\$71.92	\$79.56	\$84.26	\$71.53	\$89.22	\$477.80	\$465.67

Source: FR2 Database

Note: The gray boxes emphasize data entirely from the Commission's chartered study period, fiscal years 2013–2018.

**Figure 2-5:
Visualizing Class C Mishap Rates**



Note: The vertical line delineates the Commission's chartered study period of fiscal years 2013–2018 from the comparison period of fiscal years 2007–2012

coincided with an inordinate increase in the number of F/A-18 variants experiencing Class B mishaps, both in flight and on the ground, compared to the rest of the fleet. A Navy Safety Center investigation found no “smoking gun” but pointed to potential environmental factors, such as foreign object debris (FOD) and bird strikes. The majority of ground mishaps, which disproportionately happened during night operations, occurred when moving aircraft.

Figure 2-4 shows that the costs of Class B mishaps during the study period were generally lower than the previous six years. The total cost of mishaps across DoD declined when comparing the six-year study period to the previous six years.

Figure 2-5 illustrates a steady increase in DoD Class C rates from fiscal years 2013 through 2018. These increases are concerning and are consistent with the Commission's observations. Many Class C mishaps are aviation ground

**Figure 2-6:
Class C Aggregate Mishap Estimated Derived Costs (in Millions) by Service for Fiscal Years 2007–2018**

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2012	2013-2018
Army	\$6.18	\$7.57	\$6.45	\$6.97	\$12.91	\$11.56	\$6.10	\$8.87	\$9.61	\$7.64	\$8.52	\$7.99	\$51.65	\$48.73
Air Force	\$38.77	\$37.49	\$46.98	\$70.66	\$68.52	\$68.92	\$72.69	\$70.20	\$80.79	\$78.09	\$86.24	\$72.42	\$331.34	\$460.43
Navy	\$7.74	\$5.65	\$7.75	\$14.80	\$12.96	\$14.20	\$16.42	\$17.47	\$18.91	\$22.75	\$26.15	\$19.89	\$63.10	\$121.60
Marine Corps	\$1.71	\$3.87	\$2.83	\$8.06	\$5.37	\$4.72	\$6.13	\$7.40	\$7.04	\$7.99	\$9.47	\$8.29	\$26.57	\$46.32
All DoD	\$54.40	\$54.57	\$64.01	\$100.50	\$99.77	\$99.40	\$101.34	\$103.95	\$116.35	\$116.47	\$130.38	\$108.60	\$472.65	\$677.08

Source: FR2 Database

Note: The gray boxes emphasize data entirely from the Commission's chartered study period, fiscal years 2013–2018.

mishaps due to mishandling of aircraft by inexperienced maintenance personnel and insufficient supervision. That cause is most apparent in the noticeable increase in Navy and Marine Corps Class C rates. Figure 2-5 also shows that Air Force Class C rates are notably higher than the other Services and varied between 35 and 40 Class C mishaps per 100,000 flight hours during the fiscal years 2013–2018 period. The Commission attributes these consistently higher rates, in part, to the higher repair cost of Air Force aircraft. The Army Class C rate remains low compared to the other Services, which may be attributed to the lower cost of repairing damage to the aircraft operated by the Army.

Figure 2-6 shows that as Class C mishap rates have increased within DoD, so have the aggregate costs to repair the damage. Overall, Class C mishap costs increased during the study period and peaked at over \$130 million in DoD-wide costs in 2017.

“It is a matter of inches or seconds that make the difference between a Class C or a Class A,” the commanding general of the Army’s Combat Readiness Center said in June 13, 2018, testimony before a House subcommittee.

The Commission is concerned with the Class C trends, which can be leading indicators of more serious Class A and B mishaps. Commercial aviation enterprises thoroughly record and closely track minor mishaps and near misses as a way to prevent major accidents.

Comparing the Period Means

To directly compare the mishap rates of fiscal years 2013–2018 with those of fiscal years 2007–2012, the Commission calculated a mean rate for the two periods. This statistic takes into account any changes across the period and does not emphasize any one year.

Period Mean Mishap Rate = (sum of # of mishaps in period / sum of # of flight hours in period) x 100,000

The Commission calculated the mean for each period by Service and by mishap class, as shown in Figure 2-7.

The changes in the means help answer whether the rates for fiscal years 2013 through 2018 have increased, decreased, or stayed the same compared to fiscal years 2007 through 2012. Figure 2-7 shows that the Army experienced decreases in all mishap classes with the greatest rates of reduction in the Class A and B rate means. The Air Force had a small decrease in Class A rate means, a larger decrease in Class B means, and an increase in Class C means. The Navy and Marine Corps both experienced increases in Class A and Class C rate means, with a dramatic increase for the Marine Corps.

Figure 2-7:

Comparing the Fiscal Years 2007–2012 and Fiscal Years 2013–2018 Rate Means Across the Services and Mishap Classes

MISHAP RATE CATEGORY	SERVICE	FY07-12 MISHAP RATE MEAN	FY13-18 MISHAP RATE MEAN
Class A	Army	1.77	1.19
	Air Force	1.15	1.11
	Navy	1.15	1.34
	Marine Corps	2.43	3.30
	All DoD	1.41	1.33
Class B	Army	1.33	1.03
	Air Force	4.21	2.62
	Navy	2.55	2.50
	Marine Corps	3.29	2.78
	All DoD	3.00	2.23
Class C	Army	7.16	6.47
	Air Force	33.44	36.18
	Navy	9.44	16.54
	Marine Corps	9.70	20.69
	All DoD	19.45	23.37

Source: National Commission on Military Aviation Safety analysis

Overall, Navy and Marine Corps Class B means both decreased, a small decrease for the Navy and greater decrease for the Marine Corps. The largest increase was in Class C mishap rates, particularly the Marine Corps, which more than doubled its mishap mean between the two periods. The Navy also had a significant increase.

Identifying Troubling Trends

The Commission also calculated four-year rolling averages to identify trends and determine if rates were heading in the right direction.

Rolling Average = (Mishap rates of the current year + prior year + two years prior + three years prior) / 4

In Figures 2-8, 2-9, and 2-10, the scales of the vertical axes vary among the graphs to more easily visualize trends. The Commission concentrated on the rolling averages for fiscal years 2016–2018 because it includes data entirely from the Commission’s assigned study period.

The Army Class A rolling averages have largely decreased since fiscal year 2007. The Air Force similarly showed decreasing rolling averages, a trend that is threatened by the increase in Class A mishaps in fiscal year 2018. In the Navy, the trend of decreasing rolling averages ended in fiscal year 2013 and has been generally increasing since. Likewise, while the Marine Corps had a notable drop in its fiscal year 2018 Class A mishap rate, its increasing rolling averages are concerning.

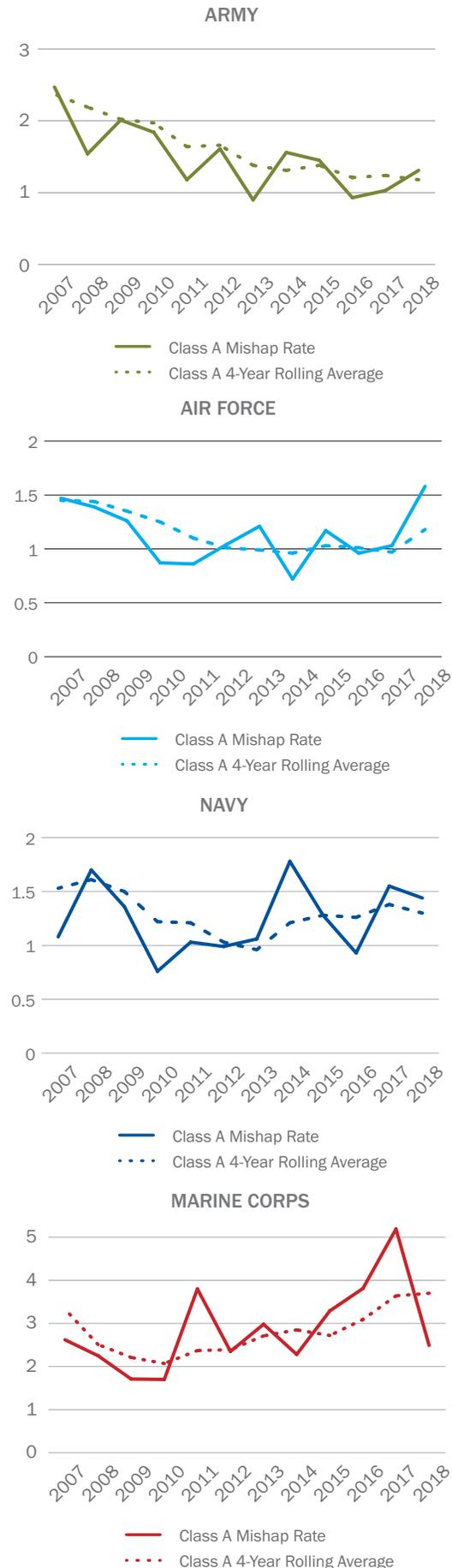
The Class B rolling averages for the Navy increased for fiscal years 2015–2018, and increased for the Marine Corps for fiscal years 2016–2018. By contrast, the Air Force Class B rolling averages decreased for fiscal years 2016–2018. The Army rolling averages remained consistently low, but did increase in fiscal years 2014 and 2018.

Most notably, the Air Force Class C rolling averages are substantially higher than the other Services, and the Navy and Marine Corps Class C rolling averages significantly increased during fiscal years 2013–2018. The Army rolling averages have remained consistently low, particularly when compared to the other Services, but did increase for fiscal years 2016–2018.

Further information and charts are in Appendix F.

Figure 2-8:

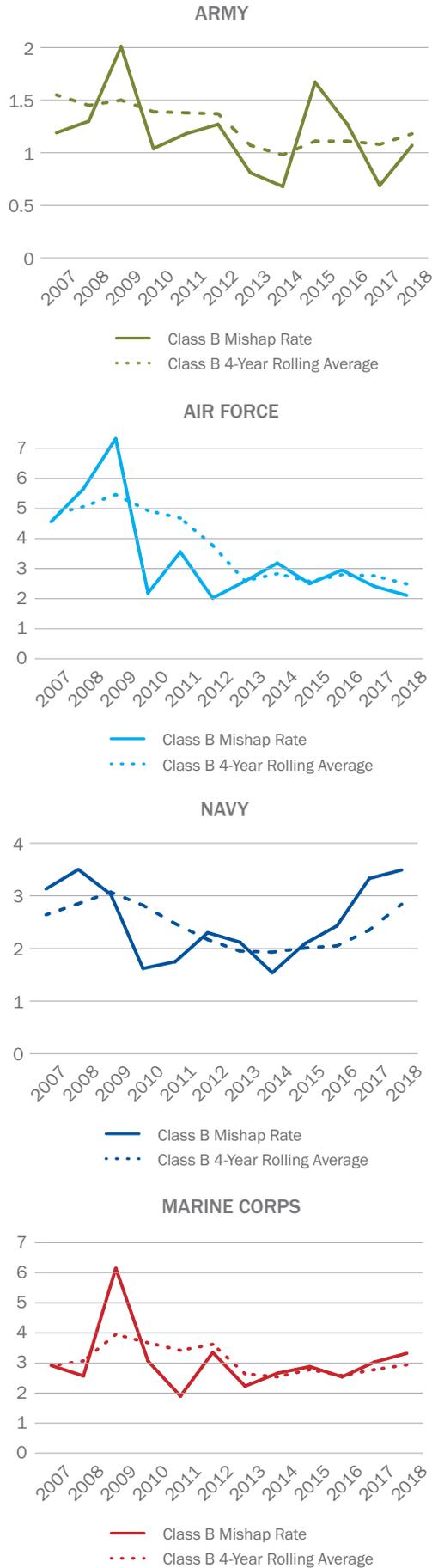
Class A Mishap Rates and Rolling Averages by Service for Fiscal Years 2007–2018



Note: The scales of the vertical axes vary to more easily visualize trends. To compare across the Services or see the overall perspective, please refer to Figure 2-1.

Figure 2-9:

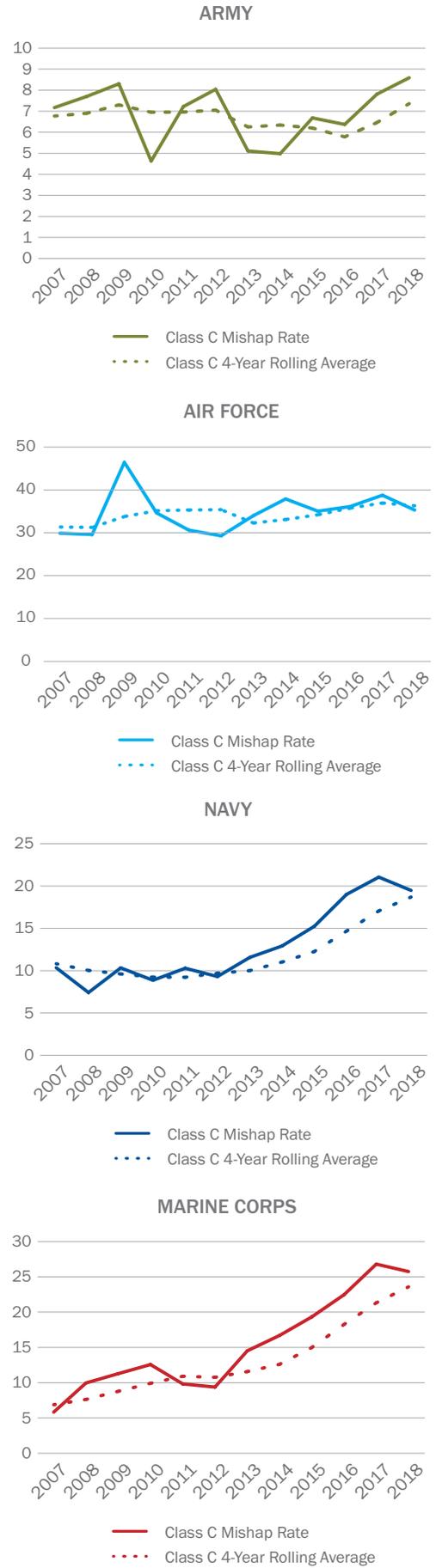
Class B Mishap Rates and Rolling Averages by Service for Fiscal Years 2007-2018



Note: The scales of the vertical axes vary to more easily visualize trends. To compare across the Services or see the overall perspective, please refer to Figure 2-3.

Figure 2-10:

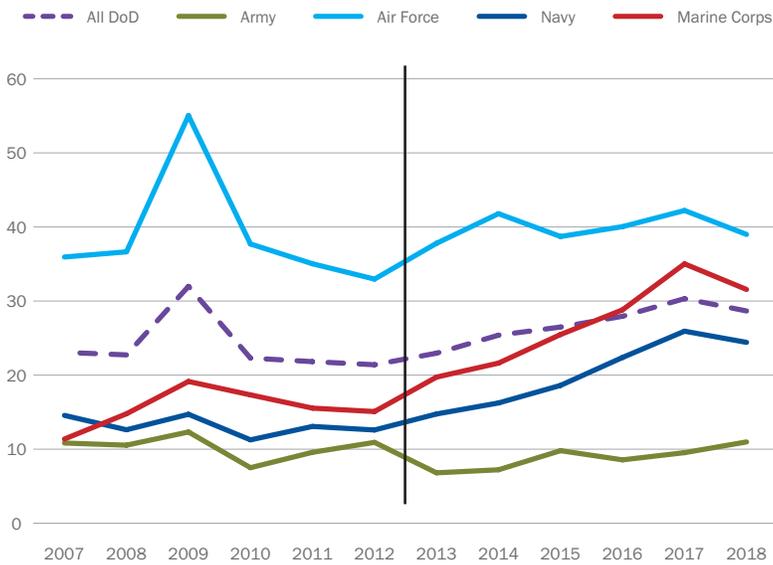
Class C Mishap Rates and Rolling Averages by Service for Fiscal Years 2007-2018



Note: The scales of the vertical axes vary to more easily visualize trends. To compare across the Services or see the overall perspective, please refer to Figure 2-5.

Figure 2-11:

Visualizing Class A-C Mishap Rates



Note: The vertical line delineates the Commission's chartered study period of fiscal years 2013–2018 from the comparison period of fiscal years 2007–2012

The Commission's Assessment and Findings

To address any questions about general trends in mishaps between the study period and the historical period, the Commission looked at the Class A-C aggregate results. Overall, mishap rates in DoD increased in fiscal years 2013–2018 (Figure 2-11). As the previous sections demonstrated, the higher rate is largely due to an increase in Class C mishaps.

In reflecting on the totality of its assessment, the Commission is particularly concerned with the increases in Navy and Marine Corps Class A mishap rates, especially Marine Corps Class A mishap rates. The higher mishap rates in the Marine Corps are consistent with Commission site visits where Marine Corps aviation units were some of the most over-tasked, over-stressed, and under-resourced units the Commission observed.

The Commission heard concerns from many in the field that the conditions were set for a potential increase in mishap rates. Subsequent chapters provide greater explanation of where latent risk resides throughout the Human-Machine-Environment framework and conclude with recommendations to abate the risks, hopefully in time.

Additional Assessment

Although Congress ended the Commission’s study window at 2018, the mishap rate data for fiscal year 2019 became available as the Commission continued its work through 2020 (Figure 2-12). The Commission reviewed the fiscal year 2019 data and found that it underscored the concerns the Commission heard on its site visits.

The Army and Air Force mishap rates in fiscal year 2019 did not significantly change the Commission’s assessment discussed earlier in this chapter. However, the Navy and Marine Corps both had significant increases that warrant discussion. Most notably, the Navy’s 2019 Class A mishap rate was higher than any other year the Commission examined (fiscal years 2007–2018).

The Marine Corps Class A mishap rate also increased in fiscal year 2019 and continued to be the highest of any Service, but was still lower than in fiscal year 2017. Additionally, the Marine Corps Class B mishap rate more than doubled from fiscal year 2018 to 2019, which easily constituted the highest Class B mishap rate of any Service during the Commission’s entire study period.

Class A-C mishaps resulted in 198 fatalities and cost the Services more than \$9.4 billion between fiscal years 2013 and 2018. These are human and financial costs that should not be trending upward by any percentage. These trends can be reversed if the full range of causes for all classes of mishaps are fully understood and addressed. The first step is identifying those causes.

Figure 2-12:

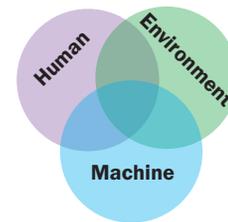
Mishap Rates for Fiscal Years 2013–2019

FISCAL YEAR	2013	2014	2015	2016	2017	2018	2019
Army A Mishap Rate	0.90	1.56	1.45	0.93	1.03	1.31	1.38
Air Force A Mishap Rate	1.21	0.72	1.17	0.96	1.03	1.58	1.54
Navy A Mishap Rate	1.06	1.78	1.28	0.93	1.55	1.44	2.41
Marine Corps A Mishap Rate	2.98	2.28	3.29	3.81	5.19	2.49	3.36
All DoD A Mishap Rate	1.21	1.29	1.39	1.13	1.41	1.55	1.82
Army B Mishap Rate	0.81	0.68	1.67	1.27	0.69	1.07	0.92
Air Force B Mishap Rate	2.58	3.18	2.50	2.95	2.41	2.11	2.06
Navy B Mishap Rate	2.12	1.54	2.09	2.43	3.33	3.49	2.29
Marine Corps B Mishap Rate	2.23	2.66	2.88	2.54	3.03	3.32	7.14
All DoD B Mishap Rate	1.96	2.11	2.24	2.42	2.25	2.27	2.17
Army C Mishap Rate	5.11	4.98	6.68	6.37	7.81	8.59	5.06
Air Force C Mishap Rate	34.00	37.90	35.05	36.13	38.77	35.31	36.32
Navy C Mishap Rate	11.57	12.92	15.24	19.01	21.05	19.48	17.62
Marine Corps C Mishap Rate	14.51	16.69	19.32	22.46	26.80	25.75	21.85
All DoD C Mishap Rate	19.79	22.00	22.86	24.40	26.66	24.85	23.80

Source: Services’ safety centers



A Naval Aircrewman prepares for a training flight in an MH-60S Knighthawk assigned to the "Black Knights" of Helicopter Sea Combat Squadron 4, during a training exercise at Naval Air Facility El Centro, California. (U.S. Navy photo by Chief Mass Communication Specialist Shannon Renfroe.)



Chapter 3:

MILITARY AVIATION SAFETY DATA

To make an assessment of causes contributing to military aviation mishaps, the Commission took an expansive look at aviation data collection practices within the Department of Defense (DoD). The Commission first reviewed more than 6,000 mishap reports from fiscal years 2013 through 2018. Second, the Commission studied military and civilian data collection methods aimed toward preventing or mitigating aviation losses. Throughout this effort, the Commission found a number of issues and concerns for present and future military aviation safety. Aviation safety data collection, processing, and analysis must be improved before the data can be used effectively to improve military aviation safety across the DoD.

In reviewing and analyzing aviation safety data collection within the Defense Department, the Commission:

- Utilized Class A through Class C military aviation mishap reports provided by the Services' safety centers and DoD's safety database, the Force Risk Reduction (FR2) database managed by the Office of the Undersecretary of Defense for Personnel and Readiness;
- Studied safety investigation reports for Class A mishaps to identify trends in the most severe mishaps;
- Reviewed relevant DoD and Service directives and memorandums;
- Researched military aircraft and aviation personnel data collection equipment and programs;
- Reviewed previous government and academic reports;
- Interviewed DoD and Service leaders about their safety programs;
- Collaborated with the individual Service safety centers on data collection and analysis;
- Elicited input from aviators, maintainers, unit commanders, and senior military leadership;
- Interviewed academic and commercial aviation experts on safety best practices and the Human Factors Analysis and Classification System (HFACS);
- Visited several commercial aviation companies;
- Consulted with the Federal Aviation Administration to review their safety management systems, data collection processes, and analysis of mishap data.

DoD and the Services collect safety-related data in varying ways with equally varying degrees of success and utility for improving safety. Service safety center leaders noted a decrease in aviation mishaps over the past few decades, but that the same mishaps continue to occur year after year. In an era of limited financial resources and manpower, the ever-escalating price tags of modern aircraft and the cost of training aircrew and maintainers require constant vigilance to keep aviation personnel and assets safe. The Department and Services have failed to take full advantage of commonly available trend analysis models and tools that could give them the ability to effectively collect, analyze, and operationalize safety data. As we have learned from industry and society at large, good data is the starting point for best practices and for making actionable military aviation safety decisions.

Assessing the Causes and Contributing Factors of Mishaps

As the Commission turned to understanding the “causes contributing to military aviation mishaps,” it used some of the standard fields that are required to be included for all mishaps. First, it analyzed the type of mishap, categorized as flight, flight related, and ground mishaps (see Figure 3-1).

Figure 3-2 indicates that flight mishaps were the most frequent category among Class A mishaps while ground operations mishaps were most frequent among Class C mishaps. The number of flight-related mishaps was significantly lower for all classes than the other two categories. The vast majority of flight mishaps are attributed to aircrew errors. Service safety officials reported that most ground operations Class C mishaps are related to maintenance incidents.

The Human Factors Analysis and Classification System (HFACS)

In its review of mishap safety data, the Commission found the information provided a historical perspective on individual mishaps. Historical records show that 80 percent of aviation mishaps are attributed to human

Figure 3-1:

Aviation Mishap Categories and Subcategories

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.

Source: DoD Instruction 6055.07, June 6, 2011 Table 1

factors (aircrew and maintenance errors). The remaining 20 percent of mishaps are attributed to aircraft issues (malfunctions or design errors) and nature-related issues (bird strikes or weather).

Like the Services and DoD, the Commission used the DoD Human Factors Analysis and Classification System (HFACS) codes to understand the causal and contributing factors in its analysis of the human element of mishaps. DoD’s HFACS is a solid framework and a key component of every investigation. This system identifies a broad range of human errors within 1) unsafe acts of operators (e.g., aircrew), 2) preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences. The goal of HFACS is not to attribute blame but to understand the underlying operational or cultural factors that led to a mishap. Such knowledge can spur measures that prevent future mishaps.

A single mishap may include many codes from various categories or bins as investigators identify all of the events, decisions, and conditions leading to the mishap. Comprehensively identifying even second- and third-level causes are key to identifying trends that create risks, paving the way for proactive preventive measures.

As Figure 3-3 on pages 18-19 shows, individual HFACS codes are grouped into four larger categories (the boxes with orange headings) and subdivided into smaller bins (the boxes with gray headings). They are given an individual alphanumeric code to indicate their category and bin.

Based on the Commission’s review of all Class A mishap reports from fiscal years 2013 through 2018, the distribution across the four largest HFACS categories

was 43 percent as Acts, 38 percent as Preconditions, 10 percent as Organization, and 9 percent as Supervision. Looking at the next lower echelon, “Performance-Based Errors” and “Judgment and Decision-Making Errors” were the most common errors cited by mishap investigators.

Analysis at the code level revealed the top three most commonly applied codes are “Procedure Not Followed Correctly” (AE103), “Inadequate Real-Time Risk Assessment” (AE 201), and “Wrong Choice of Action during an Operation” (AE206). Charts with the most commonly applied codes by mishap class and Service during the study period, the Commission’s most granular analysis, are in Appendix F.

All these codes can lead the safety center investigators to research underlying causes for these occurrences, which, in turn, could lead to studying such factors as training, staffing, maintenance delays, and other core issues that led to that mishap and remain present and unaddressed.

The Limitations

Military Mishap Data Collection

Precise data collection from an aviation mishap is critical in understanding what happened and can be a valuable source of information to prevent future mishaps. The Services’ safety centers usually conduct extensive investigations on Class A and B mishaps. Safety officials at the command or unit level perform investigations of Class C and below mishaps. Causal and contributory

Figure 3-2:

Flight, Flight-Related, and Ground Mishaps by Class and Service for Fiscal Years 2013–2018

	FISCAL YEAR	CLASS A MISHAP COUNTS				CLASS B MISHAP COUNTS				CLASS C MISHAP COUNTS			
		ARMY	AIR FORCE	NAVY	MARINE CORPS	ARMY	AIR FORCE	NAVY	MARINE CORPS	ARMY	AIR FORCE	NAVY	MARINE CORPS
Flight	2013	10	19	4	8	8	32	10	3	44	264	57	19
	2014	15	7	15	5	6	37	1	7	42	289	51	19
	2015	12	20	9	8	14	36	9	4	45	290	57	19
	2016	7	12	7	8	11	38	13	2	38	281	80	21
	2017	9	12	9	10	6	36	17	3	52	323	75	22
	2018	10	23	8	5	8	26	21	5	54	273	49	22
Flight Related	2013	0	1	3	0	1	0	1	0	4	30	3	3
	2014	1	2	0	1	1	2	2	0	3	24	4	5
	2015	1	1	0	0	1	0	1	0	3	29	5	3
	2016	0	2	0	0	0	0	2	0	6	27	2	4
	2017	0	1	1	0	0	0	1	0	7	21	8	1
	2018	1	0	2	0	1	0	1	0	3	31	4	3
Ground	2013	0	1	2	0	0	13	7	3	9	298	38	17
	2014	0	3	0	0	0	14	10	0	6	319	54	20
	2015	0	0	2	0	0	9	8	3	12	312	69	25
	2016	1	3	1	1	0	14	6	4	11	329	82	28
	2017	0	5	3	2	0	6	10	4	9	331	94	39
	2018	0	4	2	1	0	10	7	3	15	299	109	37

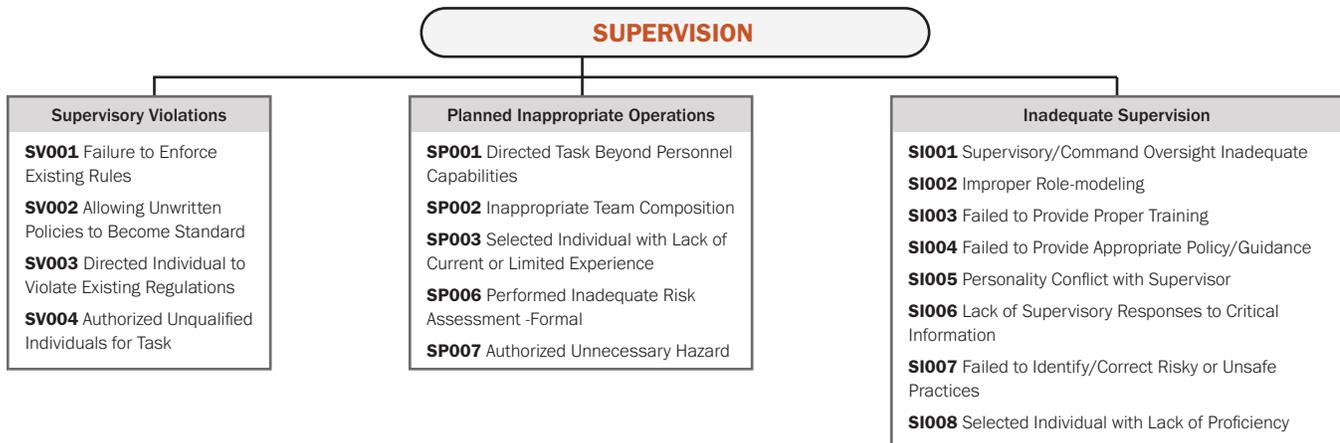
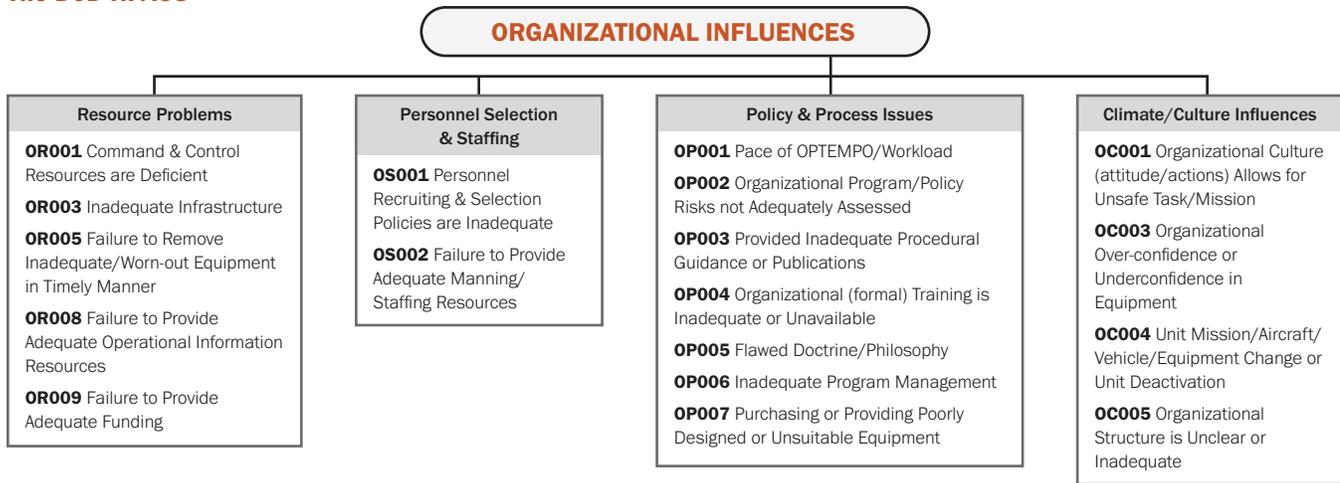
information for Class A and B mishaps generally is comprehensive. However, the Commission noted a lack of standardization and inconsistent reporting structures across the Services even in the Class A mishap reports, which are prepared with the highest degree of expertise among the mishap classes. Reporting on Class C investigations also is inconsistent and often incomplete, though Service safety leaders note that Class C mishaps are potentially the best indicators of elevated risk for more serious mishaps. Commercial enterprises actively track and react to Class C-type incidents as a preventive measure and to promote a reporting culture. Military aviation does not. Given the increasing numbers of Class C mishaps described in the previous chapter, this is an area of concern the Services should address.

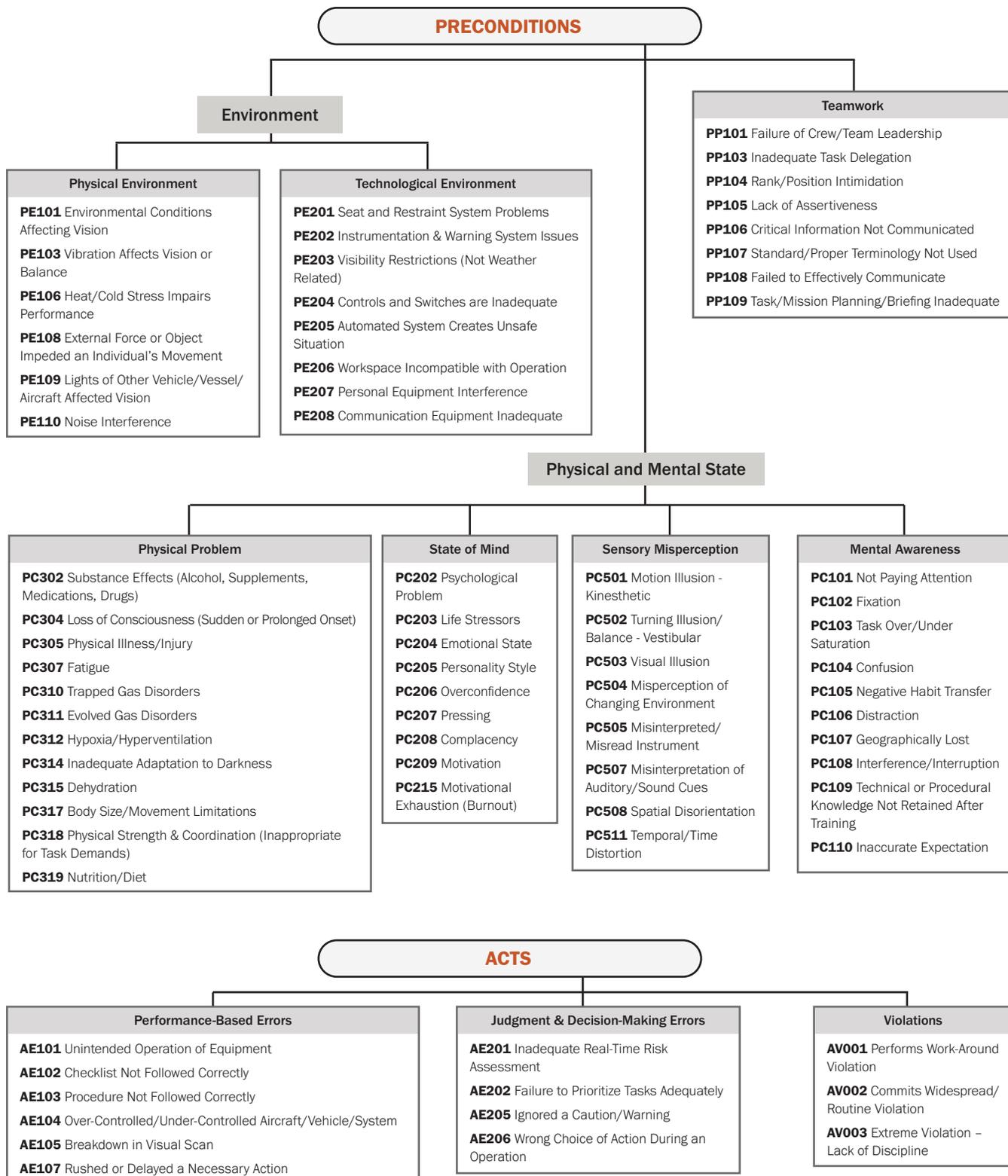
Both a 2003 Congressional Research Service report to Congress and a 2018 Government Accountability Office report also identified these problems. “DoD has taken a number of steps to ensure that the safety centers provide more complete and consistent data to [the Office

of the Secretary of Defense] on aviation mishaps,” the GAO report said. “However, there are several gaps in its current approach to collecting, reporting, and analyzing aviation mishap data. Specifically, because standardized data elements are not being collected across the safety centers, DoD is limited in its ability to compare mishap data across the military services and must engage in inefficient and time-consuming efforts to align the data with reporting requirements.” The Commission confirmed these findings are still true of the data reviewed for this study. Until this problem is addressed fully, the DoD safety program will languish and continue to repeat its safety and mishap mistakes.

The Services cited inconsistencies in how investigations are conducted when they cautioned the Commission against using only the mishap reports for analysis and conclusions, especially for Class C mishaps. An official at a safety center said the system is not appropriate for data mining because people do not fill in the data fields correctly. “The reports are only as good

Figure 3-3:
The DoD HFACS





LEARNING FROM A NEAR MISS

The difference between a near miss and a Class A mishap could be as little as inches or seconds. Administratively, the difference is a Safety Investigation Board (or Aircraft Mishap Board) for a Class A and a hazard report for the near miss. “If you treat the near-miss as a task that you want to just get out of the way because it’s a hazard report, you are doing a disservice to the enterprise,” said CAPT John D. Boone, director of the Naval School of Aviation Safety at Naval Air Station Pensacola, Florida.

He is not suggesting treating every hazard report as a Class A or B investigation, but because the squadron Aviation Safety Officer could use the hazard as a standing Class A and B learning event, “Why not take one of those near misses and use that as a Class A or B exercise?” Doing a full mishap investigation on that near miss would then serve the unit as lessons learned.

as what they put into it,” echoed an official at one of the other Service safety centers about Class C investigations. A human factors expert at a Service safety center told the Commission that this is a DoD-wide issue, pointing out that about seven of ten Class A mishap investigation reports cite at least one HFACS code, but only three out of ten Class C mishap reports cite an HFACS code.

The Commission found that the mishap reports do not fully or consistently utilize the HFACS framework that can reveal potentially larger or institutional causes contributing to mishaps. In addition to needing complete data in the mishap reports, analysts need access to supplemental personnel, training, acquisition, and certain operational data to develop predictive and actionable safety plans. For example, personnel shortages leading to improperly trained personnel could contribute to a flying or maintenance mishap. Safety center investigators do not consistently access that information to assess causes or contributing factors. Initiatives are underway by each of the safety centers to improve its utility of data, but that will require broader Service data collection, access, and analytical support to develop an effective predictive and actionable aviation mishap prevention program.

The Commission heard from the Services’ safety centers that if the HFACS limitations were corrected and the system used as designed, the mishap reports would provide a clearer connection to other important factors, including operations tempo, funding, supply chains, training, and personnel shortages.

Aggregating and Analyzing at Higher Levels

Current DoD policy requires the Services to provide information to DoD that could identify risk, recommend mitigation strategies, and offer lessons learned throughout the Department and outside agencies as appropriate. However, the lack of data standardization across the Services creates interpretation challenges for any comprehensive study of military aviation safety. Several safety experts in DoD and the Services expressed concern to the Commission that the differences in data collection, reporting methodologies, and investigation standards within the Services stymie attempts to achieve clear analysis from mishap report data. Even the structure of the reports and the manner in which they are recorded and presented hampered the work of the Commission, as it has other DoD-level organizations attempting to make comparisons and improve aviation safety. Army mishap reports, for example, require cross-referencing up to three different documents to get all available information on one single mishap. The Commission sees value in a standard form or cover sheet that includes standardized data and HFACS checkboxes that can expedite ongoing data collection and analysis across all the Services. While the investigations provide causal and contributory information on a mishap, they fall short in providing DoD or the Services the standardized, comprehensive analysis and information needed to build a mishap prevention program comparable to commercial aviation.

The Commission finds that after years of attempts to coordinate efforts, and despite the requirements in current policy, the Services have fallen short of what is needed. A new organizational approach is necessary in gathering and analyzing data to effectively improve safety and reduce mishaps in military aviation.

Preemptive Aviation Safety Data Collection

The Services’ investigations and mishap reports should be a more effective tool in proactively preventing further mishaps. The Department and the Services have some preventative safety programs in place. However, consistency and standardization in collecting mishap prevention program data are needed. DoDI 6055.19 establishes the standards for effective data collection programs. The Services need to follow that guidance to execute an effective mishap mitigation program. Data gathering and regular analysis are essential to an effective safety program. As the data grows, its diagnostic, predictive, and prescriptive analytic power grows as well.

Current DoD instructions direct the Services to develop and implement safety programs aimed at

THE ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING REVOLUTION

Artificial intelligence algorithms can analyze vast amounts of data: the more quality data, the better the output. The Services and DoD underutilize artificial intelligence and machine learning, which offer untapped potential to improve safety.

Three types of analytics could be applied to aviation safety. Diagnostic analytics can explain past events and make visible what was previously invisible. Predictive analytics model future outcomes, such as determining a pilot's likelihood of success completing specific tasks. Prescriptive analytics enhances decision making by, for example, optimizing the pace of a pilot's training.

The advanced analytics available through artificial intelligence and machine learning could improve safety by providing commanders visibility into safe and unsafe practices. Across an organization as large as the Department of Defense, these analytics could reduce human error by better understanding pilot task saturation and limitations.

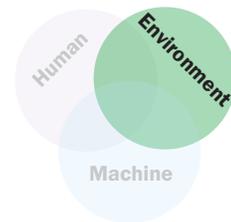
Though much of the data gathered through aircraft recorders, pilot sensors, and simulator programs might not be immediately applicable, its value for diagnostic, predictive, and prescriptive analytics will grow as the amount and quality of data grows.

analyzing safety-related issues before a mishap occurs. These safety management system programs, such as military flight operations quality assurance (MFOQA), aviation safety action program (ASAP), line operations safety audit (LOSA), and simulator operations quality assurance (SOQA) are aimed at gathering information from the machine and the human to improve safety. The use of these prescriptive tools would help leaders develop solutions to mitigate risks before they become mishaps. See Appendix G for more information on DoD's efforts to initiate such programs.

DoDI 6055.19 has not been and currently is not enforced across the Department. The Services established safety programs but failed to implement the tools directed by policy, which could have significantly improved their programs. If all the Services fully employed MFOQA, ASAP, LOSA, and SOQA equally, DoD and the Services would have an invaluable collection of data that would support the development of predictive analysis safety programs. That could lead to the reduction or even the elimination of repeated mishaps.



A pilot from Company F, 2nd Battalion, 238th Aviation Regiment, 40th Combat Aviation Brigade, finishes a mission aboard a UH-60 Black Hawk helicopter at Camp Buehring, Kuwait. (U.S. Army photo by SSgt. Ian M. Kummer.)



Chapter 4:

THE JOINT SAFETY COUNCIL

The Commission sees a seesaw pattern of effort and focus with regard to military aviation safety. The Services aggressively apply attention and resources when there is a major incident, but once the spotlight fades, leadership focus and resources move elsewhere. While over the long term mishap rates have declined, recent progress has flattened and, in some cases, reversed.

Military aviation faces a complex series of challenges in seeking further improvements. As the previous chapters have established, flight and mishap data collection across the Services is insufficient for effective predictive analysis. Additionally, without organizational change, the Services are limited in their efforts to predict and avoid the next mishap. To help chart the path forward, the Commission looked at how the commercial aviation community addressed a comparable situation.

FINDING

Military aviation safety is inconsistently prioritized by the Department and the Services. The chorus of concerns heard on site visits coupled with the trends in mishap rates are evidence that a data-driven, organization-wide approach to achieve proactive aviation safety is warranted.

The Safety Success of Commercial Aviation

Nearly 25 years ago, civil aviation safety was in a similar situation to what the Services face today. The accident rate had significantly declined over time, but by the mid-1990s it had largely flattened, and the rapidly increasing civilian air traffic necessitated additional improvements to avoid an increase in the number of accidents. Simply put, the accident rate was good, but a “flat” accident rate in a rapidly growing industry ultimately means more accidents. Following a rash of commercial air disasters in 1994, Congress established the National Civil Aviation Review Commission and the President established the White House Commission on Aviation Safety and

Security. Both commissions recommended numerous changes to improve aviation safety.

These commissions provided the framework to establish the Commercial Aviation Safety Team (CAST), a government-industry partnership that developed an integrated, data-driven strategy to reduce commercial aviation risk in the United States. CAST’s goal was to reduce the U.S. commercial aviation fatal accident rate by 80 percent in 10 years. The results speak for themselves: CAST exceeded its aggressive goal as the fatal accident rate fell 83 percent by 2007. Seeking opportunity for further improvement, CAST has raised its goal and is seeking to reduce the remaining fatality risk an additional 50 percent by 2025. A closer examination into CAST’s success highlights potential improvements for military aviation.

CAST and ASIAs

CAST’s mission is to build a continuous improvement framework by proactively identifying safety risks followed by developing mitigation strategies and monitoring the effectiveness of implementation. CAST’s members are commercial airline trade associations, aircraft manufacturers, airline and air traffic control employee associations, and U.S. and Canadian government aviation agencies, including the U.S. Department of Defense. To accomplish its mission, CAST works closely with the FAA’s Aviation Safety Information Analysis and Sharing (ASIAs) program, a collaborative initiative based on data analysis and information sharing designed to discover safety concerns *before* an accident occurs.

CAST uses a disciplined, data-driven approach to analyze safety information; identify hazards and underlying contributing factors; develop safety enhancements to address risk; and continuously monitor implementation and effectiveness of the safety mitigations. CAST also charters joint working groups that analyze a variety of systemic safety issues in commercial aviation. Significantly, commercial aviation is persistent in focusing on and resourcing safety.

The Commission met with FAA officials about CAST and was impressed by the program’s collaborative success and the functional utility of ASIAs. Despite significant

CIVIL AVIATION COMMISSIONS

The Federal Aviation Reauthorization Act of 1996 established the National Civil Aviation Review Commission, which, pursuant to its statutory charter, established task forces related to aviation funding and aviation safety. The task forces produced individual reports, which were then combined into the Commission's final report in December 1997.

Titled "A Consensus for Change," the report highlighted the looming aviation gridlock due to increased growth and demand. "If this gridlock is allowed to happen, it will result in a deterioration of aviation safety, harm the efficiency and growth of our domestic economy, and hurt our position in the global marketplace." The report also noted the catastrophic impact of a flat accident rate. "If there is no change in the accident rate, and the anticipated growth occurs, there will be a large airliner accident somewhere in the world every 7–10 days by the year 2010."

To avoid such heavy costs, the Commission recommended "broad and sweeping changes in the ways the FAA is managed, sets its priorities, assesses and achieves performance outcomes, and is financed." To reduce the accident rate, the Commission recommended "a comprehensive and concerted program by government and industry that will require new ways of doing business with each other and a greater emphasis on cooperation and collaboration."

As one example, the Commission recommended the FAA and aviation industry "develop a strategic plan to improve safety, with specific priorities based on objective, quantitative analysis of safety information and data." A recommendation for improving aviation safety programs included looking "deeper than accidents and incidents to identify latent and emerging problems and fix them before a mishap occurs."

differences between the commercial and military aviation communities, adopting many of the attributes of these commercial safety practices is possible in military aviation.

FINDING

Facing a similar situation 25 years ago, the nation's commercial aviation community created CAST (the Commercial Aviation Safety Team), a collaborative, government-industry partnership that was successful in driving down commercial aviation fatal mishap rates. It employed comprehensive data analysis and sharing to proactively identify and implement safety enhancements before an accident occurs. Based on the tenets and success of that program, the Commission has determined that the Department of Defense needs a similarly focused program tailored to the military's unique missions and organizational structure.

Different Missions, Different Organizations

Military aviation, by its nature, will always involve more risk than commercial aviation. To reduce risk in combat, military aircrews accept greater risk in training. Unlike commercial aviation, additional safety features on aircraft must be weighed against the cost to the combat mission. Since space on the aircraft is limited, additional safety systems may mean less combat

capability. Military aviation requires a careful balance between military mission and aviation safety.

In studying military aviation mishaps, the Commission found that the overwhelming majority of mishaps could not be attributed to the inherent risk of military aviation. Avoiding mishaps caused by pilot error, mechanical failures, or inadequate training does not require lowering standards or abandoning the warrior ethos. In fact, just the opposite is true.

To achieve success comparable to civil aviation, the military aviation community needs to reexamine how it approaches safety. Identifying risks and reducing fatalities require accumulating and analyzing data to facilitate accident mitigation and prevention. Additionally, DoD has no central clearinghouse to analyze this data. There needs to be a single organization that empowers the Services' safety officials, has attention from the highest echelons of Department leadership, closely coordinates aviation safety efforts, and monitors their sustained implementation.

The potential savings in lives and materiel from effective safety initiatives could be enormous. As outlined in Chapter 2 and Appendix F, Class A mishaps cost the Department of Defense 450 lives and almost \$17 billion from fiscal years 2007 to 2018. These losses can be reduced by adopting key lessons from commercial aviation. For example, if the military were nearly as successful in implementing a CAST model to reduce Class A mishaps, it would save over two dozen lives and more than a billion dollars each year. Achieving such

The White House Commission on Aviation Safety and Security, established by Executive Order 13015 on August 26, 1996, was tasked with developing “a strategy designed to improve aviation safety and security, both domestically and internationally.” Six months later, the White House Commission released its final report.

For aviation safety, the Commission determined “the principal focus should be on reducing the rate of accidents by a factor of five within a decade.” To achieve this ambitious goal, the Commission proposed focusing “on several key areas: expanded use of partnerships; reengineering of the FAA’s regulatory and certification processes; greater focus on human factors and training; and the faster introduction of proven new technologies.” The Commission provided 14 recommendations related to aviation safety.

Several of these recommendations addressed data collection and training. For example, the Commission recommended the FAA “work with the aviation community to develop and protect the integrity of standard safety databases that can be shared in accident prevention programs.” In explaining this recommendation, the Commission pointed out “[t]here are a number of separate safety data collection efforts,” but “[m]any of these efforts either duplicate existing data, report the same information, or are not interconnected or integrated.” In another recommendation, the Commission highlighted the prevalence of flight crew errors and determined that additional “[r]esearch, technology, training, and sharing of safety data can reduce human error.” Furthermore, the Commission recommended the FAA “develop better quantitative models and analytic techniques to inform management decision-making.”

success is certainly easier said than done. Any attempt to adopt safety practices from commercial aviation must consider how it differs from military aviation.

In June 2003, DoD chartered the Defense Safety Oversight Council (DSOC) to “provide governance on DoD-wide efforts to reduce mishaps, incidents, and occupational illnesses and injuries.” The DSOC, chaired by the Under Secretary of Defense for Personnel and Readiness, was directed to meet quarterly to discuss safety and occupational health issues. Over the years, the DSOC lost its top-level support, resulting in diminished stature and impact. The DSOC did not meet from fiscal year 2010 to July 2018.

It is this Commission’s assessment that DoD needs a fully funded aviation safety organization with greater visibility within the Office of the Secretary of Defense.

FINDING

The Department of Defense currently lacks a single authority focused solely on aviation safety. Without empowered leadership focused on aviation safety at a high level within the Department, aviation safety will never get the consistent emphasis and resourcing it needs to make saving lives and protecting investments in personnel and equipment a priority.

Establishing a Joint Safety Council

To help bridge the gap between commercial aviation practices and military aviation realities, the Commission recommends that Congress establish a Joint Safety Council (JSC) to provide DoD leadership the information needed to strengthen DoD aviation safety initiatives and coordinate aviation safety activities across the Department and the Services. The JSC will develop aviation safety standards and evaluate the Services’ implementation of aviation safety programs. A legislative proposal for establishing the Joint Safety Council is provided in Appendix H.

Recognizing that the successful implementation of aviation safety programs requires cooperation from the Services, the Commission recommends that the JSC be composed primarily of Service representatives. This will ensure that the JSC’s directives, recommendations, and programs properly account for each Service’s unique aircraft, culture, and mission. The Commission’s intent is for the JSC to augment and support, not supplant, the Services’ existing safety programs.

FINDING

The military departments’ safety centers are best positioned to investigate their aviation mishaps and manage the Services’ safety programs. A formal collaborative effort among the Services, working with the Department of Defense, will result in better data management and analysis and the infrastructure to support improvement in aviation safety.

This intent is further demonstrated by the JSC's proposed voting structure. The voting members of the Council would be each military Department's directors of safety and an additional member from each military Service. A member of the Senior Executive Service (SES) would serve as a full-time JSC deputy, assisting the chair in managing the responsibilities of the JSC. One of the directors of safety would serve as the chair and be dual hatted as DoD's Director of Aviation Safety. The deputy would serve as vice chair of the council.

To ensure sufficient status, oversight, and accountability, the Commission recommends that the

Council report to the Deputy Secretary of Defense and that each of the Services' directors of safety be an officer in the grade of O-8. The Council's duties would include setting DoD standards for aviation safety, identifying and prioritizing aviation safety programs throughout the Department, and overseeing and inspecting the Services' implementation of such programs.

While this Commission's mandate is limited to proposing recommendations for improvements to aviation safety, Congress should consider expanding this Commission's recommendation to all military operational safety.

RECOMMENDATIONS

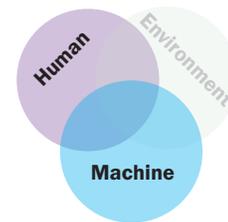
The Department of Defense must establish aviation safety responsibilities within the Office of the Secretary of Defense to ensure sufficient status, experienced and highly qualified personnel, and adequate funding to be effective in preventing injury, death, and damage. The following recommendations will create a coordinated, robust, proactive, data-driven aviation safety program that incorporates the best aviation safety practices from all relevant sources to become effectively predictive and preventive instead of reactive.

The Commission recommends:

- 4.1 Congress mandate, authorize, and fund the creation of a Joint Safety Council that reports to the Deputy Secretary of Defense. The Joint Safety Council would support and coordinate the capability of the Services' safety centers to identify and mitigate safety risks to reduce the number of aviation mishaps. The Joint Safety Council must be fully funded, staffed, and charged with developing and overseeing Defense-wide safety policies for the Secretary of Defense. It must have funding as a program element and unlimited access to the requisite databases.
- 4.2 The Joint Safety Council oversee the Services' implementation of robust Safety Management Systems that include programs such as MFOQA (military flight operations quality assurance), LOSA (line operations safety assessment), HUMS (health and usage monitoring system), and CVFDR (cockpit voice and image flight data recorders) from aircraft; SOQA (simulator operational quality assurance) from simulators; in-flight physiological data from aviators; and ASAP (aviation safety action programs) from aviators and maintainers. These programs should be based on best practices from commercial and military enterprises.
- 4.3 The Joint Safety Council set the requirements for mishap investigations in each of the Services to include the same Human Factors Analysis and Classification System (HFACS) codes for all Class A, B, and C mishaps. The Secretary of Defense will mandate that Class C mishap investigations use DoD reporting standards and data collection fields including HFACS codes.
- 4.4 That members of the Joint Safety Council will be the military Departments' chiefs of safety, all of whom should be the grade of O-8, and an additional representative from each of the military Services. The chair, selected among the military Departments' chiefs of safety every two years, would serve in a dual-hatted role as the Department of Defense's Director of Aviation Safety. The vice chair should be a career Senior Executive Service position appointed by the Secretary of Defense. The vice chair's responsibilities should be focused entirely on the mission and activities of the Joint Safety Council. The vice chair will report to the chair.



An F-35B pilot connects an air hose to her flight suit at Marine Corps Air Station Beaufort. (U.S. Marine Corps photo by Sgt Ashley Phillips.)



Chapter 5:

THE HUMAN/MACHINE INTERFACE

As aircraft become more technologically advanced, the need for a better understanding of the Human-Machine interface grows. For the past 10 years, the Services have been aggressively pursuing unexplained physiological episodes (UPEs) in military aircraft. For the next generation of aviators, aircraft will reach new levels of performance and pose increasing physiological challenges. Keeping the aviator safe while performing at the highest levels requires a fuller knowledge of the human in high-performance flight in order to build both human *and* machine survival into the aircraft's design.

Congress tasked the National Commission on Military Aviation Safety to assess the underlying causes contributing to unexplained physiological episodes in military aircraft, a major safety issue that surfaced with F-22 pilots experiencing an unusual number of hypoxia-like episodes around 2010.

The Commission pursued several avenues of information. It examined the studies and mitigation efforts of the Department of Defense spanning the past nine years in numerous aircraft communities. The Commission met with organizations researching the physiological episodes: the Air Force's 711th Human Performance Wing; the Navy Medical Research Unit Dayton; the Air Force Life Cycle Management Center; the Army Aeromedical Research Laboratory; the Navy Physiological Episodes Action Team (PEAT); the Air Force PEAT; the Air Force, Army, and Navy safety centers; and members of the NASA Engineering and Safety Center. The Commission gained valuable information and understanding from members of a collaborative ad hoc working group called Characterizing and Optimizing the Physiologic Environment in Fighters (COPE-Fighter), comprised of medical practitioners, physiological experts, aviation researchers, engineers, and aviators. The Commission also discussed the issue with military personnel on visits to operational units and

interviewed engineers and managers developing the next generation of Air Force aircraft.

Technological advancement incorporated in new and in-development aircraft is critical to developing the most effective warfighting capabilities possible. Still missing is a full understanding of the physiological limits of human performance. The Commission found that even the newest aircraft in the inventory lack the sensors and recorders required to achieve that understanding.

Physiological Episodes

In 2011, the Air Force grounded the F-22 for five months because of the increasing number of unexplained physiological episodes. What initially surfaced as a fifth-generation platform's problem quickly proliferated as pilots began to report similar hypoxia-like symptoms in other aircraft, new and old, and across multiple Services and communities: the F-15, F-16, F/A-18, and F-35 fighters; the T-6, T-45, and T-38 trainers; the low-altitude A-10 attack jet; even C-130 transports. Different oxygen systems, different cockpits, different missions, different ages of airframes, all had aircrews experiencing varying degrees of physiological episodes.

From fiscal years 2013 through 2018, the Air Force experienced 718 physiological episodes. The Navy and Marines experienced 699 physiological episodes. Figures 5-1 and 5-2 show which fighter and training aircraft experienced the most physiological episodes; Figures 5-3 and 5-4 display the top five aircraft per fiscal year.

No Single Problem, No Single Solution

Although initially unexplained, the overwhelming majority of physiological episodes have been explained with in-depth research. The physiological symptoms arising from these episodes, in addition to hypoxia-like symptoms, include dehydration, temporal

distortion, mental exhaustion, spatial disorientation, and hyperventilation. The broad range of physiological episodes made finding root causes extraordinarily challenging for researchers. They are unpredictable and inconsistent, even when the same aviator is flying the same aircraft and executing the same maneuvers. They also are not easily replicable by researchers trying to

better understand what is happening to the individual inside the aircraft.

FINDING

No single cause is responsible for physiological episodes.

Figure 5-1:
Air Force Physiological Episodes by Aircraft Type for Fiscal Years 2013–2018

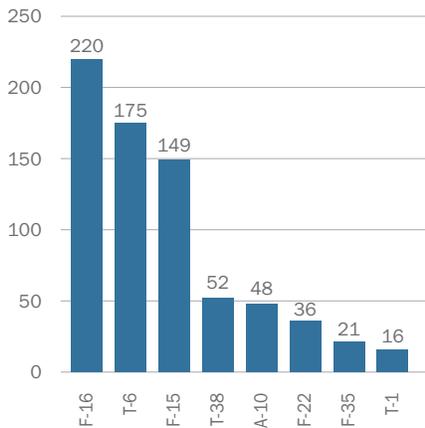
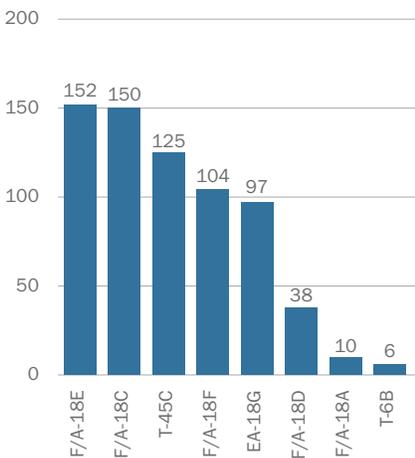


Figure 5-2:
Navy and Marine Corps Physiological Episodes by Aircraft Type for Fiscal Years 2013–2018



Source: National Commission on Military Aviation Safety

Figure 5-3:
Air Force Physiological Episodes in Fighter and Trainer Aircraft for Fiscal Years 2013–2018

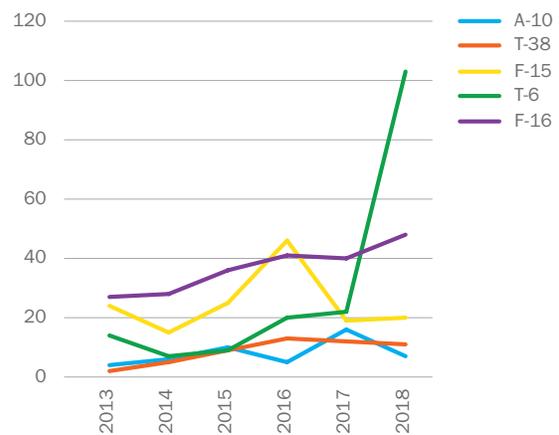
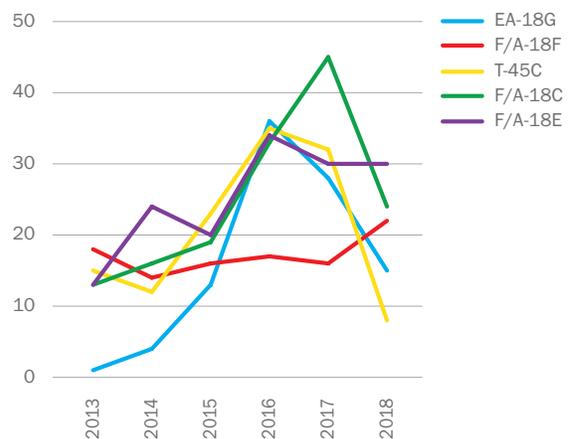


Figure 5-4:
Navy and Marine Corps Physiological Episodes in Fighter and Trainer Aircraft for Fiscal Years 2013–2018



Source: National Commission on Military Aviation Safety

The Services have made significant progress in addressing the problem, with almost 94 percent of reported physiological episodes now explained. The Services used directed funding from Congress and reallocated resources to mount collaborative research initiatives and address specific issues, community by community. The Navy and Air Force Physiological Episodes Action Teams responded to physiological episodes as they occurred, finding causes and developing solutions for many of the previously unexplained physiological episodes. The PEATs visited installations to provide training for aviators, maintainers, and their families.

The Commission considers the co-location of the Air Force Research Lab, the 711th Human Performance Wing, and the Navy Medical Research Unit Dayton at Wright-Patterson Air Force Base, Ohio, a best practice. The ability to share resources, researchers, and results have greatly advanced physiological studies for the benefit of all the Services.

FINDING

Several organizations and ad hoc groups have aggressively pursued this issue. The Commission finds that more seamless collaboration and integration among stakeholders could spur further and faster advancement in the discovery of the remaining unexplained root causes for physiological episodes.

In 2017, the T-6 began experiencing issues with its Onboard Oxygen Generating System (OBOGS). Studies by the Navy and other government and academic institutions revealed problems in the OBOGS hose component. In 2019, to resolve the issue, the Navy altered cleaning procedures for the system. The Air Force later adopted the procedures. Aircrews also received additional briefings to recognize and respond to physiological episodes and mitigate their effects.

FINDING

After the causes of physiological episodes have been determined, the Services have taken aggressive action to alleviate the problem through equipment fixes or mitigating practices by aircrew and maintenance. Long-term fixes sometimes encounter funding challenges.

As researchers identify potential solutions, their findings and recommendations move to aircraft program offices where they must compete with other priorities for limited resources. Despite the unexplained physiological issues impacting the jet aircraft community, and the efforts the Navy and Air Force have undertaken to find and mitigate root causes, no program of record has been established to coordinate efforts directly focused on eliminating the problem.

Factoring In Humans

The Commission found that military aviators at all levels of flying experience remain concerned about physiological episodes. Some aviators expressed reluctance to report physiological episodes, concerned that the resulting medical attention would lead to grounding or greater scrutiny. There is a widespread perception that episodes are the pilot's fault, not a failing or inadequacy of the machine or training. Given that some pilots also are unaware they have had a physiological episode, the Commission is confident, and operational aviators corroborate, that an undeterminable number of episodes go unreported. Unreported physiological episodes will continue without some means of monitoring the aviator in flight.

Experts in every organization expressed a common refrain: "More study is needed on the human." Much of an aviator's mission performance in flight is measured and assessed; however, the physiological response of the aviator is not. Measuring difficulty with breathing is complicated by factors such as altitude, tactical maneuvers, G-suit constrictions, and the aviator's physiology and physical condition at the time of flight. The research laboratories can neither replicate all conditions of flight nor capture the full range of physical conditions aviators encounter over a succession of flights.

Lacking physiological recording devices, researchers are unable to persistently gather objective data from aviators in flight sufficient to enhance their understanding of physiological episodes. Researchers are exploring biometric monitoring systems that can be integrated into flight suits, helmets, and masks in order to collect the necessary data without interfering with the aviator's operation of the aircraft. In the interim, the Services are using commercially available data collection tools, such as "slam sticks" that measure cabin pressure, and smart watches that measure blood pressure and heart rate. A more promising step in studying the human in flight is a joint U.S. Navy/NASA initiative placing sensors inside the mask that measure pressure, temperature, and CO2 concentration.

FINDING

The most effective means to understand and prevent future unexplained physiological episodes is to gather and evaluate data on what is happening real time to aircrew during actual flight, from initial aircraft development throughout the operational life cycle—akin to a “black box” for the pilot. Greater understanding of the warfighter’s capabilities—including the task of breathing—during actual flight is as important as measuring the machine’s capabilities. Such data also offers other benefits, such as establishing substantive physiological standards or accommodations for aircraft assignments.

The Commission heard many comments from experts about the lack of in-flight biometric monitoring of the pilot. The aircraft is fully wired to document its performance through a wide range of maneuvers and conditions; yet the operator is not monitored. Such data collection is integral to understanding the pilot’s experience. With that information, the pilot can be properly equipped and prepared to carry out missions, allowing the Services to protect their multibillion-dollar investments in both pilot and machine.

FINDING

The most effective investment in preventing physiological episodes occurs in the design, development, and test phases. Instrumentation that monitors the pilot in flight as part of the weapons system provides early problem detection and at the lowest cost to resolve human-machine interface problems.

Prioritizing the Human

The Commission identified challenges in using standards set for an outdated notion of a military pilot, first established in the 1940 Pensacola Study of Naval Aviators when virtually all military pilots were male. Until recently, minimum size design specifications for Air Force acquisitions were based on a 1967 male-only pilot survey. Today’s diverse community of military aviators is not the same homogeneous group as in the past. The Services need to match 21st century aviators to their 21st century machines. Systems need to work for a wider anthropometric and demographic range of individuals—male and female, short and tall, those who breathe faster or slower. Such factors should be built into the standard rather than treated as deviance from the norm. Designing systems for the full range of today’s aviators will improve

FEMALE FIT OF EQUIPMENT

Women military aviators must often use equipment designed for men. Uniforms, body armor, and facilities that were neither designed nor intended for women impact their safety, readiness, and proficiency.

Female fighter pilots have issues with G-suits, the overgarment designed to help pilots maintain consciousness in high performance aircraft. The Air Force Life Cycle Management Center told the Commission that only limited sizes were available. “If a G-suit is impinging on your lungs, it will impact your breathing,” said an official there. A pilot told the Commission of a female pilot who was being medically retired because of nerve damage resulting from wearing an issued G-suit that was not designed for her body. The Commission also heard about women having problems with bladder relief systems, survival vests, harnesses, and ejection seats.

The Services are addressing fit for all sexes, heights, and body types, the Air Force Life Cycle Management Center

official said. “We are doing exoskeletons for loadmasters to help them carry heavy loads. We are looking for vests for women in particular. They are currently unisex and that really means male. We are looking to find a better fit for them that works with the body armor they need.”

One female Air Force squadron commander told the Commission that logistics cannot effectively manage female-tailored equipment. “They don’t have women’s [size] boots. I wore 60 pounds of gear, running in shoes that don’t fit me.” During the Commission’s visit to NAVAIR, a representative described two primary problems: “There’s either a lack of knowledge of customizable solutions, or women do not take the other solutions because they want to fit in.”

Lagging efforts to remedy these issues are unacceptable. As a female Air Force pilot said, “When we talk aviation safety, it isn’t just mishaps. It is also about making sure our equipment doesn’t hurt us and works for us.” The Commission agrees.

human performance and prevent the expenditure of hundreds of millions of dollars to retrofit aircraft systems after production.

Acquisition Standards and Processes

The Commission closely reviewed new aircraft in development to see if the lessons learned from the Services' analysis of physiological episodes in today's aircraft are being applied to tomorrow's aircraft. The Commission found that in the early stages of aircraft development, programs remain overly focused on aircraft capabilities without the proper consideration of the human. There must be a balance. The Commission sees two areas where this imbalance could be addressed: by adding aircrew safety into the force protection key performance parameter; and by incorporating human systems integration, safety technologies, and data-collecting systems earlier in the design process.

Key Performance Parameters

Key Performance Parameters (KPPs) are the evaluation criteria that systems must meet or exceed to be credited as meeting operational goals. Currently, DoD's acquisition process has four mandatory KPPs: system survivability, force protection, energy, and sustainment. KPPs are specified in the Capabilities Development Document that directs requirements for system-level performance attributes. After gathering information from the Joint Staff J8 Force Protection Division, the Commission determined that the force protection KPP is the best place to incorporate additional requirements to give greater priority to human safety.

Updating the KPP would enhance the performance of the aircrew in the aircraft and provide better protection against injury or death for the occupants. Mishap prevention measures could include systems for ground and aircraft collision avoidance and spatial disorientation recovery. With the vital need for data collection to enhance predictive initiatives, the force protection KPP should also include cockpit voice and flight data recording systems as well as biometric sensing for the aircrew.

The technology for such systems already exists. To fully evaluate costs and benefits, acquisition officials should factor in the potential for achieving long-term lifecycle savings. For example, the Air Force has fielded in its F-16 Block 40/50 aircraft the Automatic Ground Collision Avoidance System (Auto-GCAS), which prevents controlled flight into terrain (CFIT). Air Force statistics show that CFIT was responsible for 75 percent of all F-16 pilot fatalities. Since being fielded in 2014, Auto-GCAS has prevented the crash of 10 aircraft and

FORCE PROTECTION KPP STANDARDS OF PROTECTION

The Force Protection KPP includes protection from environmental effects, which covers standards for acceptable pressure/oxygen levels for personnel, including pressurization and/or supplemental oxygen; acceptable temperature limits for personnel (with or without PPE); standards for acceptable vibration/acoustic limits for personnel (with or without PPE); and acceptable G-force loading limits for personnel (with or without PPE) under normal operations. Protection from crash events attributes include standards for crash survivable G-force loading limits for personnel (with or without PPE); protection from impact trauma, including seats and retaining systems; preservation of occupied space; and protection from post-crash fuel spills and fires.

saved the lives of 11 Air Force pilots. Similarly, cockpit voice and flight data recorders and military flight operations quality assurance (MFOQA) systems discussed in Chapter 3 have proven to produce critical information needed to improve safety performance through incident/mishap reconstruction, training, procedural changes, and predictive maintenance.

FINDING

From the earliest stages of acquisition, the machine's operational capabilities dominate the development of aircraft while aircrew safety gets too little attention. Current acquisition practice does not give enough consideration to the cost avoidance and savings that mishap avoidance systems and aircraft and simulator data collection and analysis processes can provide when prioritizing capabilities.

Human and Safety Systems Integration

Two engineering disciplines, system safety engineering and human factors engineering, should play an essential role in balancing the human and machine from the beginning of the requirements and acquisition process. According to Military Standard 882E, human systems integration (HSI) is "the integrated and comprehensive analysis, design, assessment of requirements, concepts,

SYSTEMS ENGINEERING DISCIPLINES

System Safety Engineering is a discipline that employs specialized knowledge and skills in applying scientific and engineering principles, criteria, and techniques to identify hazards and then to eliminate those hazards or reduce the associated risks when the hazards cannot be eliminated.

Human Factors Engineering is a multidisciplinary effort to generate and compile information about human capabilities and limitations. This information is applied to equipment, systems, software, facilities, procedures, jobs, environments, training, staffing, and personnel management to produce safe, comfortable, and effective human performance. It focuses on how people interact with tasks, machines or computers, and the environment.

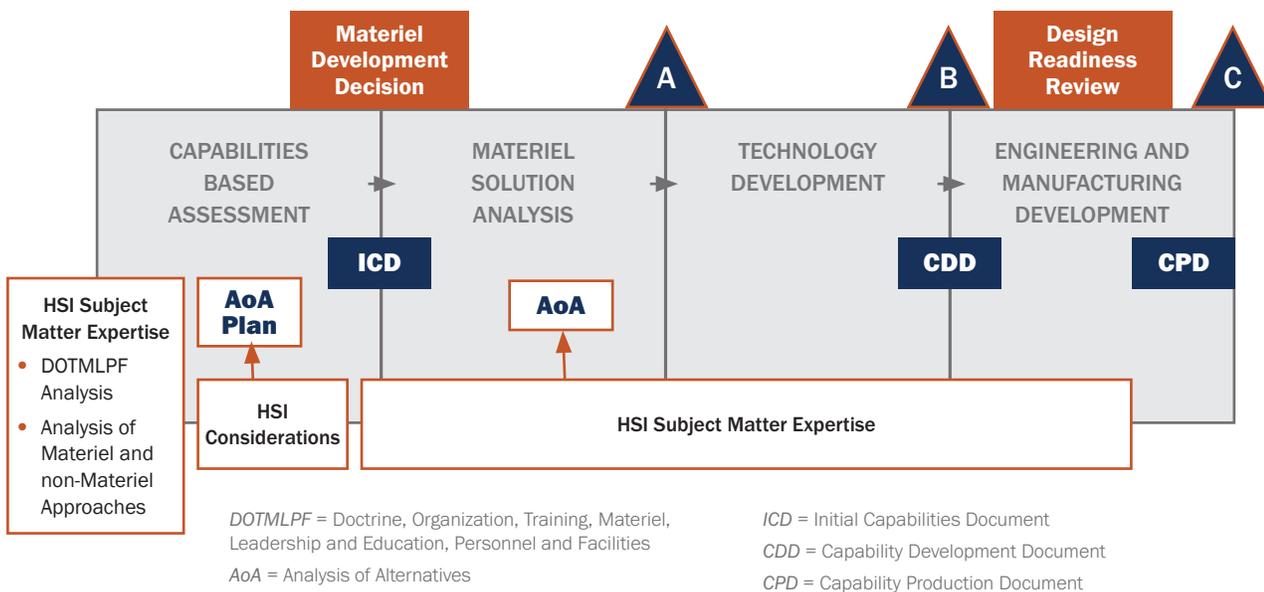
[Source: AcqNotes.com.]

and resources for system manpower, personnel, training, safety and occupational health, habitability, personnel survivability, and human factors engineering.” Department of Defense Directive 5000.01, *The Defense Acquisition System*, September 9, 2020, states that “Human systems integration planning will begin in the early stages of the program life cycle. The goal will be to optimize total system performance and total ownership costs, while ensuring that the system is designed, operated, and maintained consistent with mission requirements.” The timeline in Figure 5-5 shows where human systems integration subject matter experts and strategies can be employed for significant positive impact on system development.

The Commission reviewed recent and current aviation acquisition programs and found that the recommendations in the *Air Force Human System Integration Guidebook* were often overlooked during the requirements process.

The latest jet fighter to enter the Services’ inventory, the F-35 Joint Strike Fighter, first flew in 2006, before unexplained physiological episodes began surfacing with

Figure 5-5:
Human Systems Integration in the Acquisition Planning Process



Source: Department of Defense Directive 5000.01, *The Defense Acquisition System*, September 9, 2020

the F-22. The Services began taking possession of F-35 variants in 2015. To date, a total of 49 physiological episodes have been reported across the three variants. Better human systems integration could have mitigated or even prevented these physiological episodes.

The Commission believes every multimillion-dollar investment in weapons systems and aviator training must be accompanied by proactive efforts to ensure that the pilot is physiologically capable of safely operating the aircraft through all of its designed flight regimens.

RECOMMENDATIONS

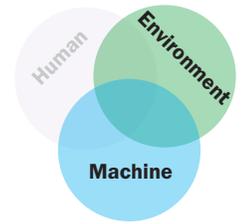
With modern aviation machines placing unprecedented stress on human physiology, the Department of Defense and the Services must adopt an aggressive, proactive approach to understanding the physiological needs of aviators and to developing additional capabilities that improve the human-machine interface, including aircraft and cockpit design, testing, and subsequent modifications.

The Commission recommends:

- 5.1 The Joint Safety Council (Commission recommendation on page 27) lead a robust review into the effects on humans in aviation operational environments, including physiological episodes. The JSC shall have a program element to conduct further research into determining and mitigating unexplained physiological episodes.
- 5.2 Program offices address human physiology concerns and analyze physiological effects throughout the aircraft testing phases for T-7, B-21, Future Vertical Lift, and other next-generation platforms early in the initial aircraft and cockpit design and with any materiel modification of the aircraft.
- 5.3 The Department of Defense and the Services develop physiological standards for each airframe to use in screening and training to ensure that the pilot/operator is able to successfully perform at optimal levels across the spectrum of the weapons system's capabilities.
- 5.4 The Department of Defense, with input from each of the safety centers, update and modify the Force Protection key performance parameters (KPP) to better incorporate Aviation Human Systems Safety.
- 5.5 That the Force Protection Functional Capability Board include representative capabilities such as ground and other aircraft collision avoidance; cockpit voice and flight data recording; biometric sensing for aircrew; and a spatial disorientation recovery system used for instrument meteorological conditions and brownout.



An Air Force aircraft maintenance craftsman with the 435th Contingency Response Squadron conducts “hot pit” refueling for an F-16 Fighting Falcon assigned to the 510th Fighter Squadron, Aviano Air Base, Italy, during an exercise at Graf Ignatievo Air Base, Bulgaria. (U.S. Air Force photo by SrA Savannah L. Waters.)



Chapter 6:

SUSTAINING THE MACHINE

Across the spectrum of site visits, interviews, and town halls, the Commission observed and heard problems relating to aircraft parts, depot work, facilities, and fleet transitions.

Among these several issues, obtaining parts—on time and functional—was a constant complaint. Notably, at one Navy installation, when noncommissioned officers (NCOs) were asked about parts, the Sailors replied with laughter. Simply put, the current supply systems are not meeting the needs of unit-level maintainers and are a significant cause of non-operational aircraft.

During its study, the Commission saw and heard of worrisome shortcuts taken by maintenance crews trying to meet their mission. In seeking to deliver mission capable aircraft, maintainers stated they often resort to cannibalizing parts from other aircraft, using shortcuts, and fielding aircraft with numerous deferred repairs. Although cannibalization is not a new practice, maintainers from all Services told the Commission this has been an increasing practice over the past several years. While no maintainer told the Commission that they were knowingly putting unsafe aircraft in the air, they acknowledged the danger of compounding risks on top of each other.

Aviation Supply System

The DoD aviation supply system is large, complex, and confusing. The Commission heard from hundreds of Servicemembers about the daily problems they face in getting parts to keep aircraft flyable. The complaints about spare parts came in three forms: (1) parts cannot be obtained in a timely manner; (2) parts do not work; and (3) parts do not exist.

First, for a military that operates around the globe and must maintain combat readiness, parts need to be available in a timely manner. For example, as the Commission heard during a visit at one Air Force base, when an actuator failed on a deployed aircraft in the Pacific, the only replacement parts were in two locations on the other side of the world. The maintenance group commander was forced to have an actuator taken off of a working plane at his home base in the United States and flown to the aircraft so it could be fixed. “The

powers that be don’t understand the positioning of parts strategically around the globe,” that commander told the Commission. “I need it fixed today.” He called this lack of supply chain visibility a “systemic subversion of established business rules.” By contrast, in the modern commercial and retail markets, customers around the world are able to order, track, and quickly receive aviation parts through a variety of suppliers.

Second, the Commission heard many complaints that spare parts in their existing stock often do not work. In one instance, a maintenance squadron pulled the same component from the supply shelf *three times* before getting one that was serviceable. The Commission also heard numerous complaints that components repaired by contractors failed to perform when needed.

Finally, in some cases, and especially with legacy aircraft, the necessary parts simply do not exist. As aircraft are extended beyond their planned service life, parts that were designed to last the originally planned life of the aircraft begin to fail. In many cases, the industrial base to produce these parts is insufficient or non-existent, especially when planned retirement dates are extended, and second- and third-tier vendors have moved on to other products. For example, when the Air Force set the retirement date of the A-10 Thunderbolt, small and mid-size companies producing parts for that aircraft began retooling for other projects. When the retirement was postponed, the supply system was no longer in place. A Marine Corps CH-53E commander told the Commission that the supply system was not designed to support an aircraft so far beyond its published planned retirement date.

AIRCRAFT AVAILABILITY

Aircraft availability is the percentage of a fleet in mission-capable condition and not in a depot-possessed or unit-possessed nonreportable (UPNR) status. UPNR status includes aircraft in the unit awaiting completion of planned or unplanned maintenance or that require engineering dispositions.

In sum, the lack of a functioning supply system that delivers working parts in a timely manner has a significant negative impact on aircraft availability and readiness. The Commission visited commercial aviation entities with supply systems that use inventory tracking and robust delivery systems to get parts delivered anywhere in the world the next day. For commercial enterprises, responsive customer service is essential to the business's bottom line. For the military Services, the lack of parts creates aircraft availability issues that hinder pilots from getting their required flight hours.

Overcoming Supply Deficiencies

When parts are not available, maintainers routinely resort to aircraft cannibalization, stripping parts from one aircraft to make other aircraft operational. "We are cannibalizing multiple times a day," a Marine senior NCO told the Commission. Further emphasizing the prevalence of cannibalization, or "canning," across all military fleets, the Commission saw a sign prominently displayed in one unit that said, "Supply can't...so we CAN [cannibalize]."

Cannibalization impacts aircraft availability and maintenance efficiency. Instead of simply replacing the part, maintenance crews must remove the part from one aircraft and install it on another aircraft. This increased workload further exacerbates readiness problems. Each step also incurs some risk that the aircraft or part will be damaged.

Additionally, when replacements for expired parts are not available from any source, maintainers must turn to engineers to determine whether the part's life can be extended. As a senior Air Force maintainer told the Commission, when parts would not be available for over a year, "we're going to the engineers to get a work-around. That's why we've been able to fly aircraft well past their service life." When engineers make the decision to extend the service life, aircrew are forced to accept the additional risk. As one maintainer noted, "We could negate those risks by having a more robust supply system, and then the engineers don't need to do the workarounds."

Depot Maintenance

A 2019 Government Accountability Office report found ongoing problems at military depots and rated five of seven aviation depot facilities as poor performers. From fiscal years 2008–2018, the Navy's on-time performance rating fell by nearly a third, even as the number of aircraft scheduled for repair declined. The Air Force similarly experienced decreased on-time performance despite

a decreasing number of aircraft scheduled for repair. According to the GAO, "depot maintenance delays, among other challenges, limit the Navy, Air Force, and Marine Corps' ability to keep aviation units ready by reducing the number of aircraft that are available to squadrons for conducting full spectrum training."

The GAO report's conclusion matched what the Commission heard on its visits. For example, in one roundtable, maintenance group personnel described fixing up aircraft delivered from other wings, saying it takes about two months to get those planes up to their standards. "Is there a base where you hate to get an airplane from?" the Commission asked. "The depot," someone replied, followed by general consensus.

Most troubling, Navy and Air Force units described finding foreign objects in aircraft—tools in engines, gloves in fuel tanks, old wiring still in place. "We get interesting stuff coming out of depots," said a maintainer with a Navy helicopter wing. "We had a stuck control, took apart the floor, and found bolts in there." One Air Force major command representative told the Commission that "jets are coming out of the depot in worse shape than when they started."

FINDING

The aircraft sustainment system, from the supply of parts to depot maintenance, is not providing aviation units with the quality products and timely services they need to sustain operations. Accordingly, aviation units are often resorting to cannibalization of other aircraft.

Facilities

At Naval Air Station Oceana, Virginia, the Commission entered a hangar by passing under steel letters that were falling off the wall above the hangar's doors. Broken doors forced Sailors to use aircraft tugs to pull the massive doors open and closed, one time accidentally hitting an F/A-18 and causing substantial damage. Commissioners stepped around buckled drain gratings marked in yellow as a warning to keep aircraft away. The fire suppression system was inoperable, and only two of eight bays had working power for aircraft maintenance.

The Commission found similarly unsatisfactory conditions at numerous installations across the Services. As a Navy senior executive told the Commission, "I've toured two naval aviation depot maintenance facilities; both are maintaining fifth-generation fighters with advance avionics in pre-first generation—I'm talking World War

II—aviation maintenance facilities.” The GAO specifically noted that more than one-third of the Navy’s aviation depot square footage was built in the 1940s. The GAO added that outdated facilities have “electrical systems built for different weapon systems, historical preservation requirements, and suboptimal layouts. It can be difficult for a depot to maintain complex, modern weapon systems, such as the F/A-18, with facilities that were designed for less complex systems.”

Poor facilities and a lack of equipment delay maintenance. When only two of eight hanger bays can be used to power an aircraft during maintenance, maintainers must spend hours moving aircraft from one bay to the next. A Marine aircraft wing commander estimated his maintainers put in 1,000 miles of towing per year, “and we tell them not to have a tow accident.”

Aircraft Transition Issues

Once a Service announces it is replacing a legacy aircraft with a new platform, the old aircraft’s support system shuts down. As the transition begins, personnel are reassigned to the new platform, legacy facilities are neglected, and parts availability dwindles. Then, delays in acquiring the new platform extend the life of the old platform for years. By their nature, aircraft transitions are fraught with unpredictability, a process the Commission sees repeated over and over again.

F-35 Lightning II and Legacy Aircraft: According to feedback from line units, the F-35 program is perhaps the best example of DoD’s pursuit of new technology via an erroneous acquisition and planning construct. As an F-35 maintenance squadron commander told the Commission, “The bean counters got it wrong. They said the F-35 is going to be easier to maintain, they will need less maintenance. These aircraft take a lot more man hours than previously thought, but they’ve already appropriated smaller staffing.” The Services are devoting critical resources to the F-35 program while simultaneously being forced to extend the service lives of legacy aircraft. This creates a case of haves and have-nots as limited resources are used to support multiple aircraft simultaneously. The Commission received numerous complaints regarding the F-35’s impact on the AV-8B, A-10, and F-16. For example, one commander said his F-35 squadrons have 85 Marines just in avionics, while his Harrier squadrons have 85 Marines total.

KC-46 Pegasus and Legacy Aircraft: The Commission received similar feedback regarding the delayed transition to the KC-46 tanker. For example, one unit reported drawing down its KC-135 operations before the first KC-46s were delivered. Another unit is

already divesting its KC-10s even though the first KC-46 is not scheduled to arrive at the base until the first quarter of fiscal year 2022. One commander said, “We may lose KC-10s before we get KC-46s.” The Commission also received feedback that the Air Force is having trouble with failing parts and filling KC-10 flight engineer positions. Overall, as reported to the Commission, the attempt to prepare for the new tanker’s arrival while stretching the life of its predecessors is straining resources.

CH-53K and CH-53E: In response to continued delays with the CH-53K and the need for continued mission capacity, the Marine Corps began the RESET program to reinvigorate the CH-53E legacy aircraft. Personnel at the unit level, who are both sustaining aircraft and receiving those returning from RESET, expressed concerns to the Commission. For example, a squadron leader at Marine Corps Air Station New River said that, even after RESET, a lot of his aircraft “don’t work. We fly an aircraft that would get antique plates from any DMV.” Said a Marine at Marine Corps Base Kaneohe Bay, “We have issues with the damper and the rotor blades. There’s also some stuff with the hydraulics. The Echo is going to be around until 2030. Is the Kilo going to fix all of it?”

FINDING

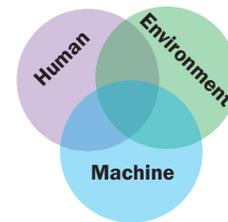
Deteriorating maintenance facilities and significant issues with transitioning from legacy platforms to new aircraft are contributing to delays in aviation maintenance and limiting operational availability of aircraft.

RECOMMENDATION

The Department of Defense and Services must improve their planning, contracting, and program management processes to ensure timely availability of spare parts, improve maintenance efficiency, increase mission capable rates, and better sustain the investment made in aircraft. The Services should improve sustainment management systems, particularly for legacy aircraft and service life extensions, to provide the necessary visibility on expiring parts and production upgrades.

A pilot assigned to Helicopter Sea Combat Squadron 26 performs preflight checks on an MH-60S Seahawk helicopter aboard the Wasp-class amphibious assault ship USS *Kearsarge*. (U.S. Navy photo by Mass Communication Specialist 2nd Class Michael R. Sanchez.)





Chapter 7:

THE NEED FOR CONSISTENT AND PREDICTABLE FUNDING

On nearly every site visit, the Commission heard about funding problems: not necessarily that there was not enough funding, but that it was erratic and came in waves. “I can always use more money,” said a senior Air Force leader, “but the thing I really need is predictability: budget for five years, [and] get it on October 1.”

In May 2019, as a direct result of funding being suddenly withdrawn for other priorities, a Marine Aircraft Wing Commander issued an order for aviation units to minimize ordering new parts through the end of the fiscal year. Therefore, rather than order new \$5 filters, Marine maintainers cleaned old ones by flushing them backwards before reinstalling them on the aircraft. “Nobody wants to *not* make the mission,” a Marine Corps junior aviation officer told the Commission.

As Secretary of Defense James Mattis said two years ago, “Let me be clear: As hard as the last 16 years of war have been on our military, no enemy in the field has done as much to harm the readiness of the U.S. military than the combined impact of the Budget Control Act’s defense spending caps, worsened by operating for 10 of the last 11 years under continuing resolutions of varied and unpredictable duration.”

The Commission’s primary concern is not the amount of money currently allocated to military aviation, but the predictability and reliability of funding. The problems with erratic funding ripple through all levels of military aviation. Units cannot adequately plan for exercises and training. Pilots have reduced flight hours at various points throughout the year, interfering with their ability to maintain currency and proficiency. Maintainers cannot buy parts, resulting in cannibalization or inappropriate maintenance. When funding is restored, it is most often too late to be spent optimally.

The inconsistency and unpredictability of funding increases costs and decreases readiness. This forces the Services to defer new contracts for maintenance and parts. In one of several examples, the Commission learned of brand-new aircraft, freshly delivered from the assembly line, being cannibalized for parts in order to make several other aircraft operational. “This is no way to run a railroad,” a Marine Aircraft Wing commander told the Commission.

Congress tasked the Commission specifically “to make an assessment of causes contributing to delays in aviation maintenance and limiting aircraft availability; to make an assessment of the causes contributing to military aviation mishaps; and to make recommendations on the modifications, if any, of safety, training, maintenance, personnel, or other policies related to military aviation safety.” In the Commission’s assessment, unpredictable funding compromises maintenance operations, degrades the quality of training, and is a significant cause of unavailable aircraft. In the aggregate, inconsistent funding increases safety risks.

FINDING

Consistent, reliable, and timely funding is key to sustaining military and aviation readiness and safety.

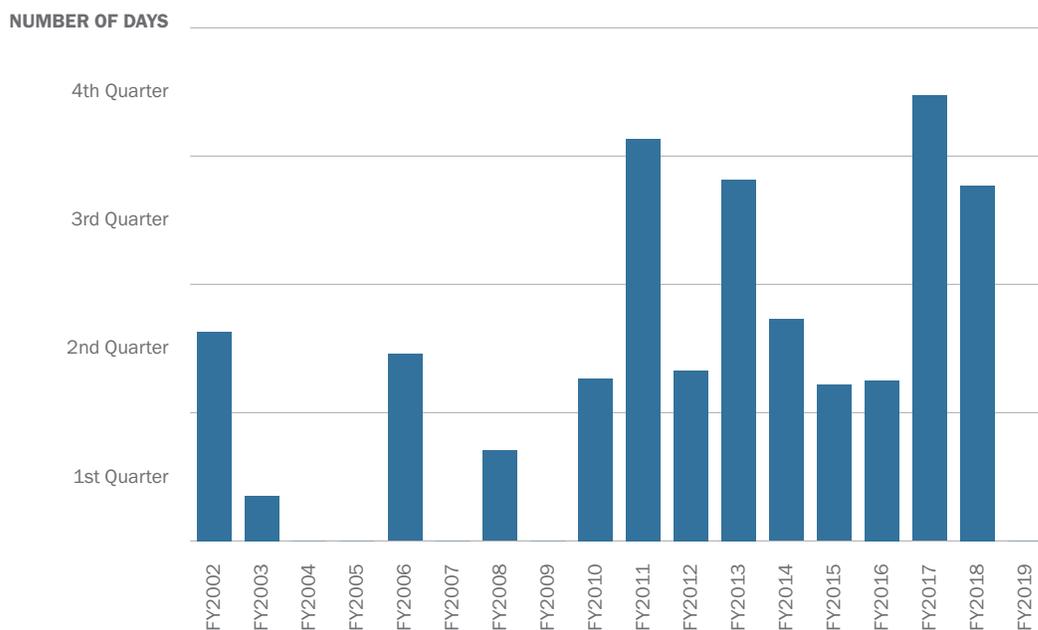
Continuing Resolutions

The primary source of unpredictable funding is Congress’s perennial use of continuing resolutions (CRs). The budget has been increasingly subjected to CRs, particularly in the years since the 2011 Budget Control Act. In fact, the Department of Defense has started 13 of the past 18 fiscal years under a CR (see Figure 7-1). As CRs have become more common, their average duration has also increased. In fact, from 2002 through 2009, CRs lasted an average of 33.6 days; from 2010 through 2018, CRs averaged 103 days; and the four longest CRs (2011, 2013, 2017, and 2018) averaged 190.5 days, creating uncertainty for longer than six months in each of those years.

The issue of unpredictable funding repeatedly came up during site visits. “We don’t plan exercises and [mission-related travel] because you don’t know if you will have funding,” an Air Force squadron commander told the Commission. “I can’t plan my budget and make the purchases [needed] and can’t get them the [equipment] they need to do safe flight operations.” A Navy mid-grade officer told the Commission that

Figure 7-1:

Days Under a Continuing Resolution: Department of Defense, Fiscal Years 2002–2019



funding predictability “is a big issue for everyone. We don’t know how to plan against the unpredictability.” For example, a contractor who supports the Navy by providing “adversaries” for air combat maneuver training said his company is told to stand down at the beginning of almost every fiscal year. Then, months later, the company is told to ramp back up, a practice consistent with workarounds caused by continuing resolutions.

This issue is not limited to active duty units or personnel. One Air Force Reserve unit commander told the Commission, “I redo the annual budget twice a quarter.” Reserve component aviation professionals described the yo-yo effects of preparing months for a deployment that suddenly drops off the schedule at the last minute due to cancelled funding. “Reservists need predictability for their family and civilian job,” said an Air Force Reserve aviator.

FINDING

Continuing resolutions are disruptive, compromise safety, and place lives at risk.

Vulnerability of Military Aviation

The Commission understands that problems related to inconsistent funding are not unique to DoD. However, military aviation and operational safety suffer disproportionate impacts from inconsistent funding in three ways.

First, military flying is an extremely perishable skill. The multitude of complex tasks require frequent training. Pilots who do not consistently practice demanding missions such as low-level flight, flying with night vision goggles, air-to-air refueling, or certain combat profiles will lose their currency in these skills quickly. Regaining currency requires several flights with an instructor pilot, costing more than it would have cost to maintain the skill in the first place.

Second, aviation maintenance has minimal surge capacity. When funding is delayed, aircraft remain grounded waiting for spare parts. When funding is restored and the pilots are flying more to regain currency and proficiency, the maintenance system struggles to catch up on deferred maintenance while keeping pace with the higher level of flying. Delayed funding, no matter how much, cannot make up for lost time.

Finally, the high cost of military aviation makes it an attractive “bill payer” during unexpected funding shortfalls. While the DoD budget is large, many costs are fixed. A continuing resolution keeps funding flat, and when fixed costs such as salaries or health care increase, that money often comes out of the military aviation budget.

FINDING

Continuing resolutions create a domino effect that harms maintenance, the ability to purchase parts, aircraft availability, and pilot proficiency.

Assessing Costs

Continuing resolutions often leave military aviation with the worst of both worlds. CRs increase costs while simultaneously reducing the readiness of pilots and aircraft. On site visits, the Commission found inoperable aircraft and noncurrent aircrews—exactly what one would expect after a history of inconsistent funding.

The Commission looked to empirical research to better understand the issue. As the Congressional Research Service (CRS) explained in a 2019 brief on Defense spending under an interim CR, “Published reports on the effect of CRs on agency operations . . . typically do not provide data that would permit a systematic analysis of CR effects.” Instead, these reports, as with this Commission’s, “typically provide anecdotal assertions that such funding measures increase costs and reduce efficiencies.” In fact, the CRS found only one recent report that successfully quantified the effects of continuing resolutions to any degree. That study, conducted by RAND in 2019, intentionally limited its focus to a discrete and measurable impact: procurement awards. The study’s authors acknowledged that “many variables can mask CRs’ effects,” and any study must “contend with limitations in the available data,” so they conducted their analysis by solely focusing on one specific area.

The same type of targeted analysis is necessary for military aviation. The Commission cannot overemphasize the importance of the effects of CRs on the military

aviation professionals who brought it up frequently in town halls and roundtables. Analysis of prior CRs is complicated by the lack of readily available data. This issue must be analyzed in a targeted and focused manner. Therefore, while the Commission believes that Congress first must resource the Department and military aviation in a consistent and predictable manner, the Commission also sees the need for a comprehensive, data-driven report of any future CR’s impact on military aviation.

FINDING

Previous research has not been able to produce a comprehensive assessment of the impacts of continuing resolutions on military aviation safety, readiness, and cost effectiveness. Additional data gathering and empirical study is necessary.

RECOMMENDATION

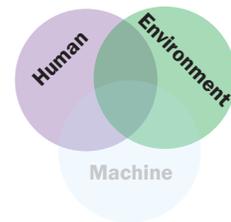
Congress and the administration must recognize that consistent, reliable, and timely funding is key to sustaining military aviation readiness and safety.

The Commission recommends:

- 7.1 Congress and the administration ensure predictable and reliable funding for military aviation and stop using continuing resolutions to fund national security, military readiness, and aviation safety.
- 7.2 Congress task the Congressional Budget Office to study and report on the negative impacts of continuing resolutions on military aviation readiness and safety.



Air Force Reserve pilots with the 709th Airlift Squadron at Dover Air Force Base, Delaware, prepare for a mission in the C-5M Super Galaxy during an off-station training event at Naval Air Station Pensacola, Florida. (U.S. Air Force photo by Capt. Bernie Kale.)



Chapter 8:

THE DEMAND ENVIRONMENT

The persistent demand and Servicemembers' can-do ethos have resulted in a chronic state of fatigue across military aviation. The all-volunteer force has been flying combat missions for more than 30 years. The U.S. military has many diverse missions, ranging from deterring American adversaries to providing disaster relief and humanitarian assistance. While the number of missions has increased in each of the past three decades, the size of the force has decreased (see Figure 8-1). This unsustainable imbalance negatively impacts safety.

More Demand than Capacity

"The business model is terrible," said a Marine squadron commander in a roundtable discussion with the Commission. He told of personnel shortages in his unit and said, "we're being tasked with more requirements, but we have to do those with the same or a smaller force. 'Do more with less': you can't. I know the risk of having a mishap is going to go up. This is just reality." The Commission heard similar comments across all four Services from regular and reserve components, from junior enlisted maintainers to senior Service leaders.

DEFINING OPTEMPO AND PERSTEMPO

Title 10 of the U.S. Code defines OPTEMPO and PERSTEMPO as follows:

- *Operating tempo* means the rate at which units of the armed forces are involved in all military activities, including contingency operations, exercises, and training deployments.
- *Personnel tempo* means the amount of time members of the armed forces are engaged in their official duties at a location or under circumstances that make it infeasible for a member to spend off-duty time in the housing in which the member resides.

"I just had a phone call...about preparing for [a new mission], and like everyone else, nothing is coming off our plate," a high-ranking Pentagon official told commissioners. "The volume and frequency of our operations are unprecedented." An Air Force Reserve maintainer attending an enlisted roundtable told the Commission that "there's times I've felt we were performing tasks and we shouldn't do it because we don't have the manning. But the tempo requires we need to do it." The other maintainers around the table nodded in agreement.

Senior NCOs, the foundation of the military's get-it-done ethos, revealed their frustrations. "Not only do I have a shortage of manpower, it's a shortage of time," an Army combat aviation brigade first sergeant said. "Your maintainers are working past duty day and then working weekends and then 24-hour operations. It's completely unchecked." Asked about safety concerns, a senior Marine Corps NCO replied, "The OPTEMPO. I do what I can to slow that down. I tell the boss we can't do things. The recipe is there for something to occur."

Taskings from the Services and from combatant commands are piling up. "We need the Air Mobility Command to go to Transportation Command and say enough," said a squadron commander during an Air Force town hall. "We need to ask for something to drop off the back end when we add something else." A general officer on the staff of a major command also spoke of pressure from combatant commands: "At some point someone needs to bring discipline to the demand signal. We don't have what they need." Yet, no one feels they can say "No."

The tempo is particularly challenging for some career fields, such as flight engineers. One KC-10 squadron commander said the unit is well below required manning, in large part because so many people are leaving the unit. "Most of them are getting out before retirement date because of burnout. Deploy, deploy, deploy. TDY [temporary duty away from home] 270 days a year, the rest of the time they are in the [simulators]. They are getting one or two weekends a month to [be] with their families. A couple people just made tech sergeant, but they are never going to sew it on because they're done. Even promotion doesn't keep them in." OPTEMPO and PERSTEMPO is putting the health of the force at risk.

Degrading Future Readiness

Mission requirements are overtaking current military personnel while at the same time undercutting the training of new entrants. During combat operations, military members will accept higher risk. However, during routine training and operations, military members view the increased risk as a failure of leadership to adjust the planning assumptions to reflect actual conditions.

Aviators told the Commission that OPTEMPO demands deny them adequate time for the ongoing training necessary to keep their warfighting skills current. The latest National Defense Strategy and National Military Strategy projects greater global competition in the airspace and the need to prepare for a high-end fight with near-peer adversaries—a radical change from operating in largely uncontested airspace over the past 30 years. If units are always responding to routine taskings, they are unable to devote the necessary time and flight hours to develop the skills needed for future conflicts. “I can’t train to fight Russia and China. I need relief from hauling crap around the [area of responsibility] so that I can actually train,” said an Air Force commander.

FINDING

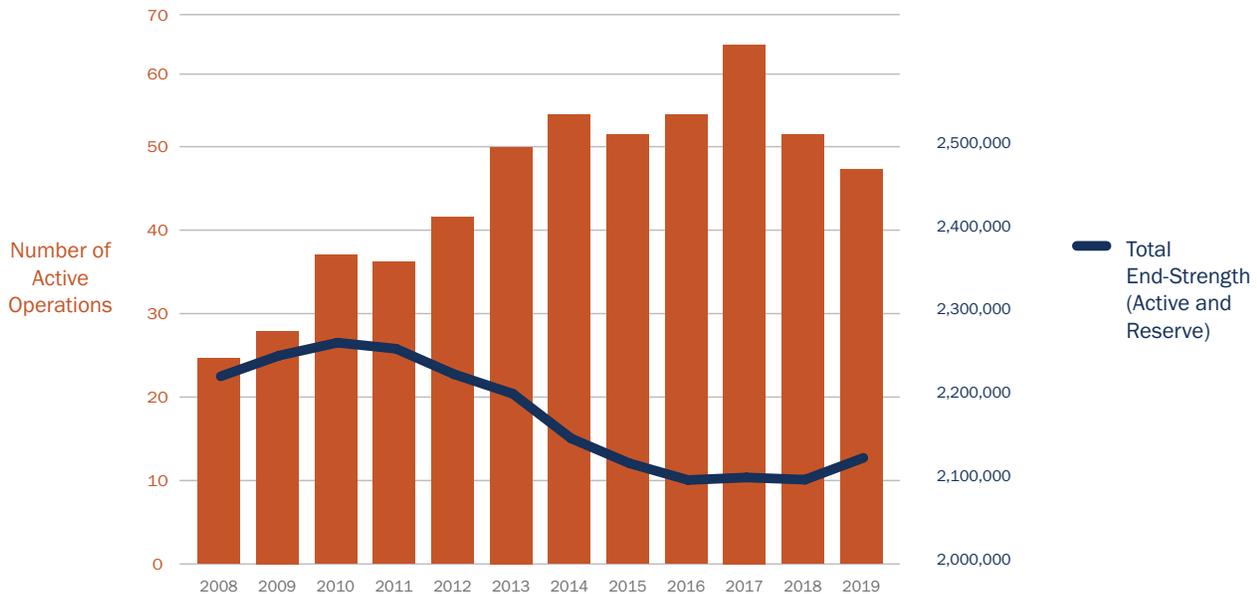
The PERSTEMPO and OPTEMPO are overstressing the current military aviation force structure and compromising the readiness standards required of military aviation.

Chronic Fatigue and Burnout

The Commission heard of chronic fatigue and the term *burnout* many times during visits to installations across the Services, in both active and reserve components.

- An Army pilot: “So much is being required of IPs [instructor pilots] at the unit, and we have a shortage of IPs, and they are getting burned out. That’s why our retention rates suck.”
- A Navy leader: “Old jets make us work our people harder. We have to work them to death. That’s a safety issue. We burn them out.”
- A Marine Corps aviator: “My kids don’t know who I am.” Due to deployments, exercises, and constant long days, he said, “they don’t know when I am

Figure 8-1:
OPTEMPO



Source: National Commission on Military Aviation Safety

going to be home. That stuff leads to the burnout and distraction while flying.”

“Task saturation is a problem,” said a senior Air Force maintainer in an F-16 wing, who kept coming back to the word *tired*. “They are tired, sleep deprived. They are tired, and with increasing mission and lower manning levels and the lack of proficient NCOs to help, NCOs are tired. It is just being tired. Knowing that with task saturation and sleep deprivation, work performance suffers. We see human factors and an increase in mishaps. They don’t have experience and are tired. They are tired and are crying for help. The response is shut up and color.”

Chronic fatigue manifests itself in retention. “It’s not the money or their character or attitude; it’s the OPTEMPO. They are getting crushed,” said an Air Force logistics officer who was a prior-enlisted crew chief. A safety officer for an Army combat aviation brigade stated: “Everybody wants more money, but it’s the quality of life for me. I’m gone (so often), and it’s just not worth it.” A senior Air Force NCO told the Commission that one of his staff sergeants left the Air Force to be an automobile mechanic. “They’re burned out.”

FINDING

The pervasive sense of burnout and chronic fatigue that exists throughout the military aviation enterprise is contributing to unsafe conditions. Aircrew and maintainers cite the compounding factors of OPTEMPO, PERSTEMPO, and the resulting fatigue and staffing shortages as the likely cause of “the next mishap.”

Additional Duties

A pilot with an Army combat aviation brigade told the Commission he hated driving into work every day. Asked why, he replied, “Flying is 5 percent of what I do; about 95 percent is administrative [duties].” Administrative and logistics support personnel have been cut from units because of decreasing end-strength or budgets. The burden of fulfilling those roles has shifted to aircrew and maintainers as “additional duties” that add significantly to their OPTEMPO burden while taking time away from developing their professional skills. Some report that their additional duties have become their full-time jobs. “We signed up to be combat fighter pilots, but that’s the fifth or sixth most important thing we do,” said a Marine Corps pilot. “It’s not the lack of flying, it’s the 12- to 15-hour

SKILLS DEGRADATION

The 433rd Airlift Wing is the Air Force Reserve’s only formal training unit providing initial and advanced C-5 training. The wing’s instructor pilots (IPs) told the Commission that when pilots return for advanced training after years in operational units, their skills have degraded compared to when they graduated from initial training. “Because of OPTEMPO, their experience has improved, but their flying skills are some of the weakest we’ve seen,” one IP said, offering several reasons:

- they are not flying enough because of additional duties;
- they do not have experienced instructors in the operational units to properly train them;
- they are not getting opportunities to train on the techniques they will need to fly against a near-peer adversary.

days [doing administrative work]. Allow us to focus on flying, putting more priority on that than other duties.”

Additional duties add to the already unsustainable tempo, but their negative impact does not stop there. “I would go so far as to say 90 percent of Army aviation problems fall under the umbrella of conflicting requirements,” one Soldier wrote to the Commission after attending a town hall meeting. “Pilots and crew members cannot maintain proficiency on any single task if their focus is elsewhere. [Increased personnel] could impact the problem we face and would have positive impacts on morale, retention, proficiency, and accident rates. Soldiers don’t leave the Army because they can make more money elsewhere. They leave because they are sick of dealing with BS that is outside of their job description.” Aviation professionals are overtaxed with too many wrong tasks.

FINDING

Diverting aviation professionals from their primary aviation duties with additional duties adds to an unsustainable workload. Due to personnel cuts, military aviation units have experienced cuts in administrative support over the past two decades, forcing aviators and maintainers to undertake additional administrative duties that interrupt their primary aviation tasks and contribute to fatigue and burnout.

Tracking PERSTEMPO

A significant shortcoming is the lack of quantitative data to effectively measure PERSTEMPO and assess its impact on units and individuals. Tracking individual PERSTEMPO is a necessary first step toward understanding the health of the force. The absence of focused policy that produces reliable data limits DoD and Service leaders' ability to research, analyze, and understand the stress on the force so that they can mitigate safety risk. It also impairs efforts to fully understand and draw definitive conclusions about the impact of PERSTEMPO on military aviation safety and readiness.

In a 2018 report, the Government Accountability Office concluded that DoD lacked sufficient policy and reliable data to monitor PERSTEMPO. This Commission concurs with the GAO's assessment and with Congress' recent efforts to address this issue.

The Services carefully track the hours of use for aircraft and components; the Commission asserts the same careful attention should be spent tracking the people who fly and maintain these aircraft.

FINDING

The Services are not adequately tracking PERSTEMPO for units and individuals and the resulting impact on the health of the force.

RECOMMENDATIONS

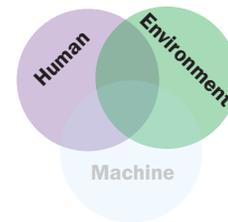
Policy at all levels must reflect that aviation is a high-demand, low-density specialty with routinely insufficient capacity to satisfy all of the demand placed on it. This has overextended the aviation force beyond sustainable levels, resulting in chronic fatigue and burnout, which negatively impacts retention. The current high demand is forcing the Services to shortchange safety to accomplish current missions. The Services must increase aviator and maintainer capacity, reduce additional duties, and focus on proficiency to mitigate the risk.

The Commission recommends:

- 8.1 The Services ensure aviation units have sufficient administrative personnel to allow aviators and maintainers to concentrate on their primary mission, sustain currency and proficiency, and meet the unit's mission readiness rates.
- 8.2 The Department of Defense and the Services report aviation units' personnel experience levels and member PERSTEMPO.
- 8.3 The Department of Defense and the Services require that proper policies, practices, staffing, and all other necessary resources are in place to ensure that the military's high demand/low density aviation units always are fully prepared and standing ready to perform at levels commensurate with the critical and unique role they perform in securing and maintaining our nation's security.



An Aviation Structural Mechanic 2nd Class oversees maintenance on an MH-60R Seahawk from the "Battlecats" of Helicopter Maritime Strike Squadron 73 on the flight deck of the aircraft carrier USS Nimitz. (U.S. Navy photo by Mass Communication Specialist 3rd Class Elliot Schaudt.)



Chapter 9:

MAINTAINERS AS AVIATION PROFESSIONALS

Maintaining military aircraft requires highly trained and skilled specialists. However, new training methods and outdated personnel policies are interfering with maintainers' duties and skill development. This comes at a time when operational units are short on experience and OPTEMPO is high. Strategic investments in developing well-trained maintainers will go far in increasing operational readiness and mitigating safety risks on the flight line.

FINDING

Military aviation requires a significant and constant investment of time and resources to train and develop fully capable maintenance professionals.

Initial Training

Failing to sufficiently invest in initial training programs is a safety risk—one that aggregates over time. “This seems irreversible,” said a Navy squadron commander. “I have increasingly unqualified people to teach the new generation who are then going to be less qualified to train the next generation.”

Interviews with entry-level trainees and maintenance school instructors reveal that many students have little to no mechanical or maintenance experience before joining the military. These deficiencies are not addressed during initial training. “Coming out of the schoolhouse, most don't know the difference between a Phillips head and a standard screwdriver,” a senior Marine Corps maintainer said. An Air Force maintenance NCO concurred. “We are teaching basic tools now. A lot don't know what a ratchet set is. If you ask for a ratchet set, they bring a socket.”

FINDING

Initial training across the Services is intended to provide maintainers with the basic skills to perform primary requirements. The Commission heard grave concerns from operational units that the skills of student graduates are deficient.

Mixed Reality for Maintainers

The Services are not shortening their maintenance training courses. However, they are relying less on traditional hands-on training and more on augmented reality (AR) training, including computer-based learning, simulators, and virtual reality (VR) to overcome personnel shortages. Maintenance supervisors across the Services told the Commission that overreliance on computer-based training is resulting in undertrained maintainers arriving at operational units. They lack the basic skills needed for immediate integration into the unit.

Even entry-level maintainers agree their training is inadequate. On one site visit, the Commission heard a story about a recently graduated maintainer who was instructed to remove a panel. The maintainer did not know which tool to use because the computer-based training program removed the panel with a click of the mouse. When the maintainer actually removed the panel for the first time, it landed on his foot. “VR will give you familiarization before you walk out and do it,” a senior level chief training officer told the Commission. “The issue is, when you use VR to remove a panel by touching it [on a screen], you don't realize it's 35 pounds, and you're out there in 100 degrees—and not an air-conditioned room—and you drop it on the ground.”

Throughout the Commission's travels, personnel in other units shared similar stories about VR learning. One young enlisted Air Force maintainer admitted to the Commission that he did not know how to remove a panel upon arriving at his first unit, and a junior Marine Corps maintainer described the training this way: “I checked a box that said I got on the computer, moved my person to this place [on the screen], pushed this button to take off a panel, and I did it safely. It's a joke.”

Maintenance students typically undergo two phases of instruction during training. The first phase is designed to introduce the trainee to basic mechanics and tools. Instructors told the Commission that this training has shifted significantly from hands-on to virtually augmented training methods. The second phase turns to more aircraft-specific and specialty skills training. Hands-on training is the teaching method of choice during

REALITIES DEFINED

Simulators are training devices replicating the environment and controls of an aircraft or system (such as aerial refueling or de-icing equipment) for the purpose of creating a realistic experience operating that aircraft or system in a safe environment. In addition to providing an accurate representation of the system's controls, advanced simulators use high-fidelity motion and visuals to simulate the system's physical and psychological sensations.

Virtual reality is a computer system that generates three-dimensional images on screens inside helmets or goggles, creating visual environments the user can physically manipulate or respond to by using gloves or devices fitted with sensors.

Augmented reality overlays real-world surroundings with computer-generated images, ranging from textual labels to immersive experiences.

this phase. However, schoolhouses often substitute this training with virtual instruction when there is insufficient equipment. The outcome is unprepared graduates who are not ready for flight line operations. As a result, the receiving unit must divert resources to conduct basic-level training instead of actual maintenance.

The need to produce more maintainers to compensate for personnel cuts in previous years has prompted the recent changes to teaching methodology. Use of virtual training has increased in all Service training programs. Recent graduates told the Commission they would have liked more hands-on training before arriving at their operational units. An Air Force training group commander said he often hears such comments. He considers hands-on training for young people a novel, cool experience. "Us old guys, we think that for the young guys that VR and AR are their bailiwick," he said. "In fact, what's new to them is actually doing it, the hands-on work. That's what fires them up."

FINDING

The Services' training organizations are relying more on simulation and virtual reality technologies. Operational units believe these decisions result in less-skilled graduates.

To be effective, hands-on training must be conducted on realistic equipment that mirrors the actual aircraft the students will maintain at operational units. Across all Services, the Commission found a need for repairing, upgrading, or increasing the number of mock-up trainers and tools that students use for hands-on instruction. Mock-up trainers should match the Services' operational fleets of aircraft.

FINDING

There is an urgent need for repair and upgrades of equipment at training installations. The Commission repeatedly heard reports of outdated, out-of-service, or non-available trainers. Mock-up trainers are not kept current with the aircraft the aviation professionals will maintain in operational units.

Measuring Training Efficacy

Augmented reality training tools can enhance maintenance skills if quickly reinforced with hands-on training. In reviewing training syllabi, the Commission found that augmented reality training rarely occurs in conjunction with hands-on training, primarily because of personnel reductions. Overreliance on augmented reality training is having a negative impact on skill retention.

The training programs do not have sufficient data collection to reliably measure virtual training's impact on trainees' skill retention. The Commission also noted the lack of an effective feedback loop between the operational units and the schoolhouses. Current feedback systems have little success gathering the operational units' perspectives and effectively integrating them into revisions to training programs. The feedback loop with the receiving units is broken.

FINDING

Training commands have not been applying data-driven measurements for their training methods. The feedback loop with the receiving units is broken.

On-the-Job Training

The impact of initial training shortfalls in the schoolhouse is exacerbated by current challenges facing on-the-job training (OJT). On-the-job training has

always been integral to the education and training of aviation maintainers as they hone their skills. The Services count on a cadre of experienced NCO maintainers at the operational units to provide that OJT. At almost every unit the Commission visited, commanders and senior NCOs reported that they were overextended for mission requirements and did not have sufficient NCOs to provide the necessary OJT.

An important factor in the effectiveness of OJT is the ratio of trainers to trainees. The Air Force reported that its usual trainer to trainee ratio should be 1:5 or 1:6. In one career field, Air Force maintenance crew chief ratios are closer to 1:8 or 1:9. The Commission saw the same issue in all the Services. With this higher ratio, supervisors cannot properly supervise and develop the new maintainers. “That peanut butter gets spread so thin that people aren’t really getting any peanut butter,” an Air Force commander told the Commission.

The units are caught between competing demands: the need to meet readiness goals with aircraft safe to fly today, and the need to invest the time to supervise and train new maintainers who will be effective tomorrow. “We just got a lot of junior Marines,” said a junior Marine Corps maintainer. “We are down to five people with qualifications. We have guys doing [maintenance] without someone supervising them. We don’t have the people to do OJT.”

Operational units expect to receive schoolhouse graduates who are able to support basic flight line operations when they arrive. The Service training commands told the Commission that they saw the role

of initial training differently. Rather than graduate an operationally proficient maintainer ready to contribute on the first day, their goal was to produce graduates needing OJT before being ready for initial flight line duties. The Services need to align their expectations and adjust their training strategies and resources.

Experience Matters

“More maintainers would help,” an airlift squadron leader told the Commission; “but what would really help is more experienced maintainers. It takes about three years to get good at your job, doing it every day. We’re not even getting to that point with our young airmen.”

Even when fully manned, many units do not have enough skilled personnel with the requisite experience and qualifications for certain roles. A unit may have the right number of personnel yet still lack the proficiency needed to accomplish the mission. For example, a Marine Air Group told the Commission it was manned at 103 percent, but only 60 to 70 percent met qualifications. “We don’t have the skills and experience,” the commander said.

The problems the Commission heard during site visits also appear in the personnel data. The Commission requested experience-level data from the Services and received information from the Army and Air Force.

Figures 9-1 and 9-2 show examples of Army maintainer experience levels in two specialties, measured in average months of military service by skill level. It reveals substantial decreases in average experience across the board. The downward trend in experience was

Figure 9-1:

Army AH-64 Helicopter Maintainer Average Months of Service by Skill Level and Fiscal Year

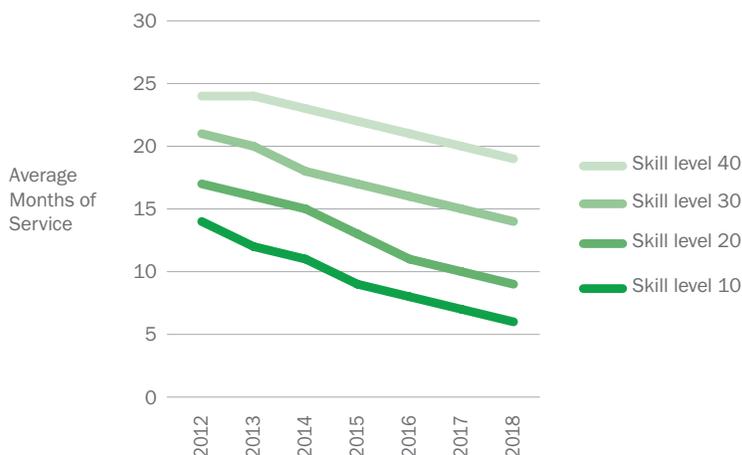


Figure 9-2:

Army Aircraft Maintenance Senior Sergeant Average Months of Service by Skill Level and Fiscal Year

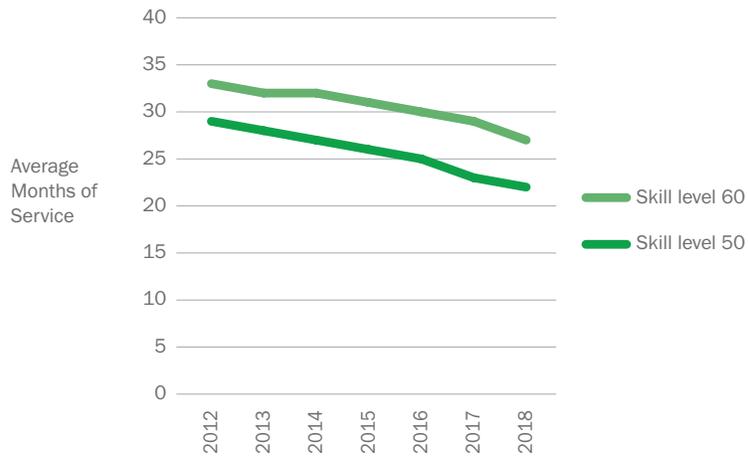
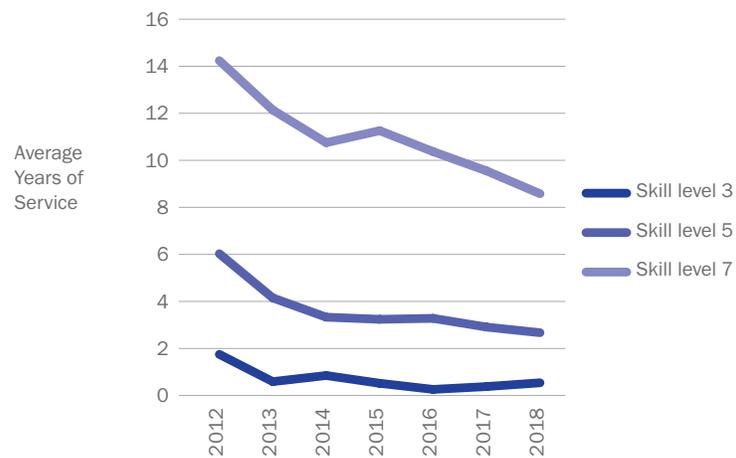


Figure 9-3:

Air Force Refuel/Bomber Aircraft Maintainer Average Years of Service by Skill Level and Fiscal Year



equally true for both entry-level maintainers and senior supervisors. The Aircraft Maintenance Senior Sergeant specialty saw a drop in the average months of experience between fiscal years 2012 and 2018, a particular cause for concern. A decrease in junior maintainer experience is not being offset by experienced leaders, as the experience is declining across the board.

Analysis of Air Force experience levels of the Refuel/Bomber Aircraft Maintenance specialty illustrates a trend seen broadly across aviation maintenance. Figure 9-3 visualizes the changes in average years of service by skill level between fiscal years 2012 and 2018. It shows a worrisome decrease in the average years of experience for 7-levels (the senior maintenance leaders) and a shocking decrease of more than 50 percent in average years of experience for 5-levels (the first-line trainers and leaders).

These steady declines in maintainer experience negatively affect readiness and safety.

FINDING

Maintainer experience has decreased across military aviation, especially at mid-levels.

Talent Management for Aviation Maintainers

The Services' investment in aviation professionals requires an effective plan to retain experienced maintainers.

"Aviation should be separated and fenced off," said one Marine aviator. "The ground guys don't feel that way. On the ground, you can replace a [infantry] squad leader and train someone in two weeks. It takes 3 1/2 years to train an aviation squad lead." The Services need to manage this community differently.

Fully qualified aviation maintainers frequently find themselves redirected to other assignments, such as drill instructor or recruiter. Enlisted maintainers told the Commission that, despite their flight line experience, their assignments as a drill instructor or recruiter were required for promotion. However, a multiyear absence from maintenance duties results in lost proficiency. Many maintainers returning to the flight line require refresher training before they regain minimum currency to perform maintenance supervisory functions.

Another challenge occurs when maintainers are reassigned from one type aircraft to another. While the foundational principles of aviation maintenance are similar, each aircraft type is its own complex machine and requires specific knowledge. Aviation maintainers told the

Commission they were forced to move from one platform to another, sometimes switching between fixed wing and rotary wing. Many of these Servicemembers reported that they often did not receive additional training before their reassignment. This lack of aircraft-specific training fostered negative habit transfer, degraded OJT instruction, and resulted in inadequate supervision. If the Services improve their policies and training requirements when transferring or transitioning maintainers between aircraft, experienced maintainers would be better prepared to apply their experience appropriately.

FINDING

Maintenance professionals with technical expertise are often assigned non-aviation duties, reducing aircraft availability.

Maintainers Want to Maintain

Readiness and safety would improve if aviation maintenance professionals stayed in the maintenance career field. The current aviation maintenance force is distracted, under-resourced, inexperienced, and therefore struggling to maintain aircraft. Gate guard duty, motor pool duty, and other non-aviation tasks and ancillary training distract maintainers from their best use. The Services should focus aviation maintainers on doing the work only they can do and that will improve aircraft availability rates.

The Commission also explored other ways to support the professionalism, long-term development, and retention of maintainers. A system of aviation proficiency badges or milestone credentials would recognize a maintainer for proficiencies. Similarly, payment for outside schooling, such as an A&P (Airframe and Powerplant) license, in exchange for an additional service commitment would foster greater professionalism and pride while simultaneously increasing skills and retention.

As aircraft have become more complex, the technical skills required to keep them operational have advanced commensurately. Providing enlisted maintainers with a promotion system that recognizes technical expertise would help keep personnel in uniform. There is room for both technical experts and leaders in the ranks of the Services' senior NCOs. Maintainers want the opportunity to become masters of their trade while still advancing their careers. This would provide a dedicated cadre of experts to support new maintainer training and generate the aircraft needed to sustain readiness. Let maintainers maintain.

RECOMMENDATIONS

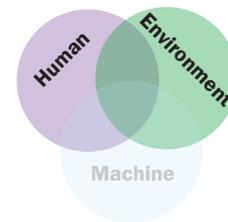
Because of the significant investment in time and resources required to train and sustain fully qualified military aviation maintainers, and a commercial marketplace competing for such high-demand talent, Congress, the Department of Defense, and the Services must regard and manage aviation maintainers as a specialty and their training as a career-long pursuit. The Services must develop personnel management processes and career paths that account for the complexities of aviation and support aviation safety, readiness, and OPTEMPO. DoD and the Services must execute the following measures to recognize achievement and enable aviation professionals to focus on their flight line duties, sustain their skills, and promote advancement of their proficiencies.

The Commission recommends:

- 9.1 The Services mandate and enforce assignments and performance evaluation guidance that focus aviation maintainers primarily on areas of performing, sustaining, and advancing their aviation professional skills, knowledge, and experience. The Services must discourage using aviation professionals for assignments and additional duties unrelated to their aviation-related warfighting fitness, skills requirements, or essential supervisory responsibilities. DoD and the Services should reduce mandated, nonaviation-related ancillary training to the minimum.
- 9.2 The Services experiment with technical specialty enlisted ranks for aviation maintenance personnel that include unique career paths to ensure that maintenance personnel achieve and are able to sustain the highest level of proficiency and professionalism.
- 9.3 The Services reward and incentivize the professional achievements of aviation maintainers with recognition and professional development throughout their careers.
 - a. The Services should establish aviation maintenance proficiency badges or credentials that would recognize and incentivize excellence in aviation maintainers and empower supervisors with support from leaders at the unit level to keep aviation maintainers focused on their primary flight line responsibilities.
 - b. The Services should institute a tuition-paid A&P (Airframe and Powerplant) license option in return for an extended enlisted commitment meeting a cost/benefit threshold.
- 9.4 The Services implement policies and training for transitioning maintainers among platforms that require and certify proficiency, promote retention, and leverage experience for both legacy and new platforms.



A U.S. Army AH-64E Apache helicopter pilot assigned to Task Force Tigershark, 16th Combat Aviation Brigade, 7th Infantry Division, prepares to depart for a mission at Jalalabad Airfield, Afghanistan. (Department of Defense photo.)



Chapter 10:

PROTECTING INVESTMENT IN AIRCREWS

The Apache AH-64D was conducting a low-level, night training mission when a part failed, leading to damage of the engine, main rotor head and blades, tail rotor head and blades, main transmission, gearbox, and multiple drive shafts.

Cause of mishap: materiel failure.

Notwithstanding the materiel failure, the damage to the aircraft was avoidable. The training program, flight manuals, and simulator did not prepare the two pilots to properly diagnose the failure and take remedial steps. The training and information had been removed from qualification courses and the operators' manual in 2010.

Present and contributing cause of mishap: training standards.

Pilot Training

The process of turning men and women into proficient military pilots requires a complementary series of progressive training programs. Students begin with initial pilot training where they learn basic flight skills, then progress to advanced training for their specific aircraft. Pilot training continues at their operational unit with flight qualifications, unit-level training, and exercises.

Pilot shortages have increased pressure on the Services' training commands to produce more pilots in less time. The Commission examined an advanced training program for one airframe from each Service. Figures 10-1, 10-2, and 10-3 demonstrate changes the Services have made in these aircraft-specific pilot training syllabi to move pilots through the pipeline faster.

An Apache pilot graduating from training in 2018 had 21 fewer flight hours and 13.6 fewer simulator hours than a pilot who graduated in 2012. The number of flight hours, simulator hours, and the total course length were all shortened. The Army attributed the changes in the syllabus to a lack of available aircraft.

Unlike the Army, Marine and Navy pilots learning to fly the F-18 did not have their flight and simulator hours cut. For both Services, the number of simulator hours increased from fiscal years 2010 and 2019.

Air Force pilots learning to fly the F-16 in 2018 had 28.1 fewer flight hours as compared to a pilot trained

just eight years earlier. While some of this time was replaced by additional simulator hours, a pilot in 2018 would report to their operational unit with significantly less flight experience. Twenty flights were cut from the syllabus.

This reduction in training impacted operational flying units. Squadron commanders and instructor pilots told the Commission that recent flight school graduates

Figure 10-1:

Army AH-64D Course Changes

PROGRAM AND YEAR	FLIGHT HOURS	SIMULATOR HOURS
FY12 AH-64D	95.5	61.6
FY18 AH-64D	74.5	48

Figure 10-2:

Navy and Marine Corps F-18 Course Changes

PROGRAM AND YEAR	FLIGHT HOURS	SIMULATOR HOURS
FY10 Navy F-18E/F	111.9	80.3
FY19 Navy F-18E/F	108.4	87.9
FY10 Marines F-18C/D	99.9	78.3
FY19 Marines F-18C/D	101.7	82.4

Figure 10-3:

Air Force F-16 Course Changes

PROGRAM AND YEAR	FLIGHT HOURS	SIMULATOR HOURS
FY10 F-16	84.3	52.5
FY18 F-16	56.2	68

BREAKS IN TRAINING

Many aviators described long breaks in their training, either during a course because of aircraft or instructor pilot shortages or between assignments because of backlogs.

One student reportedly took a year to complete a 27-week training syllabus. “You get good training, but there were a lot of breaks,” a student pilot at a training wing told the Commission. “Some of us were only flying every two weeks.”

Some students reported as much as a six-month gap between initial pilot training and advanced training. During that time, there’s no requirement to fly. Air Force aircrew also have to wait for an opening to attend the Survival, Evasion, Resistance, and Escape (SERE) school at Fairchild Air Force Base, Washington. “When I get to my unit, it will be six months since I’ve flown,” said an advanced pilot training student.

are not reporting to the unit adequately prepared for their first assignment. As a result, operational units must dedicate limited training hours to basic flying skills, reducing the hours preparing for combat missions. Combat capability decreased as instructors were forced to teach new pilots basic flight skills instead of more advanced combat tactics, techniques, and procedures. “I get guys struggling to get qualified,” said a Navy pilot and department head while discussing the quality of graduates coming from a flight training program. In his view, the program has the primary goal of “just get them out of the door. And it’s a snowball effect. I’m doing final check rides, and I’m appalled: they’ve gotten that far without learning basic stuff?”

FINDING

Pilot training is intended to provide military aviation professionals with their basic flying skills. Across the Services, the flying skills of pilots graduating from the schoolhouses are deficient.

The Commission heard from commanders who were frustrated with not having the requisite number of instructor pilots or senior personnel to provide sufficient

training for new pilots and aircrew. One Air Force training unit conducting aircraft-specific training was authorized 114 instructor pilot billets, but filled only 82 despite lowering the IP qualification from 500 hours to 400 hours.

The pressure to get people qualified is not limited to the schoolhouses. Instructor pilots reported feeling pressure to quickly advance new aviators to higher qualifications to offset personnel shortages. “I had seven progression flights quickly,” a junior Army aviator told the Commission. “The demand for aviators is so high that there’s pressure to push people into positions that their experience doesn’t support.” Said a junior Marine aviator, “We just need pilots so desperately” that pilots are getting “qualifications that they don’t deserve because we have to have them.” This pressure to quickly progress and qualify aviators is also extending to more advanced credentials such as instructor pilots.

FINDING

Unit instructor pilots are conducting basic skills training to make up for deficiencies at the schoolhouse. Operational units are not resourced to provide basic flight training.

Flight Hours

Flight time is the lifeblood of military aviation safety and readiness. More flight hours lead to more proficient aircrews. Too little flight time leads to a lack of proficiency and the experience necessary to accomplish operational missions.

Studies have shown a relationship between career flight hours and increased pilot mishap causal factors. A 2009 CNA study found that P-3 Orion pilots with low career flight hours tended to have greater numbers of pilot error mishaps. A second 2009 CNA study of Marine Corps aviators reported that junior F/A-18, AV-8B, CH-46E, and AH-1W/UH-1N pilots had greater numbers of pilot error mishaps than their more senior counterparts. A 2010 CNA study described a “well-established relationship between low pilot career flight hours and higher mishap frequency.”

The Commission heard multiple comments that total career flight hours have decreased. Across the Services, mid-career pilots reported having as many as 200 fewer career flight hours than previous generations.

Other CNA studies also found a relationship between more frequent pilot error mishaps and lower recent hours. A 2007 study found that an operational strike fighter pilot with 10 or less flight hours in the

previous 30 days was three to four times more likely than a pilot with 16 or more hours to have an “unsafe flight incident.” CNA’s further studies concluded that the trend held regardless of career experience level.

FINDING

Decreased flight hours, inexperience, and failure to sustain currency and proficiency are contributors to aviation mishaps. Sustained investment in the flying hour program is necessary to ensure aviation safety and readiness.

Many aviators told the Commission that they are not getting the flight hours they need. Servicemembers across all four Services spoke about the challenge of getting at least 15 flight hours per month. Army aviators say they are flying just short of 15 hours per month. Air Force airlift squadrons are not getting the flight hours for training. Navy aviators said they are not getting 11 hours per month unless they are preparing to deploy. Although the Marine Corps’ goal for CH-53E pilots is 15 flight hours per month, one pilot said, “We too often are in the single digits for flight hours per pilot per month, a dangerously low number of flight hours to be decent at a very difficult trade.” Many Marine Corps aviators said they averaged about five hours per month. The Commission recognizes the importance of sustained investment in the flying hour program.

Waivers

With fewer flight hours, pilots risk losing currency. The Commission found evidence that the Services have increased their reliance on waivers to operate despite currency and proficiency shortcomings. The Commission often heard that commanders are relying on waivers to qualify instructor pilots, conduct operations, and train during deployments. An Army pilot told the Commission that “except for the trainers and evaluators, everyone in my flight company had minimums waived.”

Reserve Component units have relied on waivers to overcome challenges in meeting flight hour requirements. “Last year, of our 78 pilots, 26 got waivers,” said a Navy Reserve aviator. “One-third of our folks didn’t meet the minimum number of flying hours.” Army and Marine Reserve Component pilots echoed similar concerns, with a Marine telling the Commission that he had not flown at night for two months, despite being an instructor pilot.

FEEDBACK FROM THE FIELD

A Chief Warrant Officer 4 and Aviation Safety Officer for his unit, who attended a roundtable discussion, shared the following with the Commission.

One big thing that was noted is the lack of sufficiently trained pilots from flight school. As we get more and more junior pilots and keep up with the OPTEMPO of training deployments, field exercises, operational deployments, etc., these pilots end up stagnating and waiting for long periods of time before they are available to use on missions. Some even wait long periods to start flying at all at a unit. Here alone, we have had an influx of junior aviators: 18 Warrant Officer 1s and five second lieutenants. These will all take the Instructor Pilots away from their own continuation training. This will end up burning out the IPs as they fly non-stop RL Progressions [readiness-level progressions continuation training]. This lends itself to mistakes, cut corners, close-calls, and things of that nature, all of which can change the seconds and inches that separate a non-event from an accident. This also puts the senior guys at the back of the line when they come in and need local training before they can get up to an operational level, further removing them from the normal consistency of flying their aircraft.

Another thing we have to deal with, that runs along with the mass influx of junior pilots, is the lack of flight hours. When manned at or near 100 percent, some units do not have the required flight hours for all personnel to make their minimum required flight times, let alone provide hours for the progression of junior pilots, retraining of regressed pilots, or any contingency that may come up. If this is allowed to continue, either the minimums will have to be lowered or flight hours increased. The cost for adding flight hours would be a thing that will be considered over most; however, if we continue to lower the standards, we continue to get sub-par products. Sub-par products require more time and effort to bring to an operational level and will end up costing more time and money.

The Commission noted that waivers have shown up among causal factors in mishap reports, including fatal Class A mishaps. Yet, the Commission found there was no centralized tracking of waivers across the Services or Department of Defense that leaders could use to identify and research this risk. The proliferation of waivers represents a new normal and acceptance of degraded standards. The Commission found senior leaders and safety officials unaware to what appears to be an erosion of safety. This vulnerability must be addressed.

FINDING

In many units, the minimum flight hour requirements for currency are not being met, leading to flight waivers that are increasing risks and impacting the safety culture of military aviation.

The Right Training Medium

For years, aviation has used simulators to supplement real flight training and experience in a safe, nonthreatening environment. Modern simulators are effective mediums for teaching core skills, enhancing mission techniques, practicing emergency procedures, and providing orientation to specialized operational skills. Simulator hours cost considerably less than actual flight hours, as Figure 10-4 shows.

Figure 10-4:
Examples of Cost Comparison of Actual Flight Hours to Simulators, Fiscal Year 2019

AIRCRAFT	COST OF FLYING HOUR ¹	COST OF SIMULATOR HOUR ²
F-16	\$14,000-\$16,000	\$900
F/A-18 (A-F)	\$11,000-\$22,000	\$875
AH-64	\$5,000-\$7,000	\$300
KC-135	\$13,000	\$650
C-130	\$5,000-\$14,000	\$650
C-17	\$15,000	\$650
F-35	\$17,000-\$23,000	\$340-\$600

Constrained budgets, decreased aircraft availability, instructor pilot shortages, and reduced training range availability have led to greater simulator usage. The Commission heard concerns from pilots in all the Services about the increased use of simulation in lieu of actual flying. Recognizing that simulation is a cost-effective flight training tool, it is a supplement or enhancement, not a replacement, for actual flight training. There is great value in both.

Simulators cannot replicate carrier landings or simulate G-forces, but they do provide the safest environment for training on emergency procedures and aircrew coordination. Achieving the proper balance between actual flight and simulator training is crucial for both safety and readiness.

For simulators to be effective, they must mirror the specifications of the aircraft they simulate. In many cases, units lack simulators with the same configurations and flight characteristics as the actual aircraft. Several units reported that contracts limit simulator availability and do not provide the engineering support necessary to keep their simulators operating and up to date. This results in “negative training,” pilots practicing skills contrary to how they would employ them in actual flight.

The units with the worst simulator support are those flying legacy aircraft, such as the F-16, AV-8B, KC-135, and T-38. These aircraft receive inadequate funding as resources are invested in new aircraft. Nonetheless, history shows that these older aircraft will remain mission essential and in the operational inventory for years. The KC-135, for example, continues carrying the bulk of refueling missions as the KC-46 encounters delays in becoming fully operational. In anticipation of a faster transition to the KC-46, the Air Force removed the KC-135 simulator at McConnell Air Force Base, Kansas, in 2017. Those KC-135 aircrews must now travel to other air bases to get simulator time. The 509th Bomb Wing at Whiteman Air Force Base, Missouri, operates T-38As, but has no T-38A simulator.

The Federal Aviation Administration, which oversees civilian simulator certification, requires regular software updates so that training facilities and flight simulators continue to meet strict standards of performance and operations.

FINDING

Simulators are an essential tool for training military aviation professionals. Installations have outdated and out-of-service simulators.

Source: ¹Office of the Secretary of Defense Comptroller; ²Aircraft Program Offices

Retaining Experience

Retaining experienced personnel, especially seasoned instructors and supervisors, is imperative to sustaining the training pipelines for aircrew. A 2019 report from the Department of Defense to the Congressional Armed Services committees warned that flooding units with untrained pilots would have a cascading effect, when too few experienced pilots are available to train the new aircrews: “[A]bsorption models show a typical fighter squadron should be comprised of 55 percent experienced pilots. As that percentage decreases, it lengthens the time it takes for junior pilots to gain the experience they need to be fully mission capable, as inexperienced pilots require experienced pilots to lead them in training.” The report states that increasing pilot production to mitigate a pilot shortage results in units “saturated with inexperienced pilots.”

Accordingly, the Commission sees an urgent need to invest in retaining experienced military pilots. Demand from the airlines for military pilots will continue in the future. Notwithstanding the current pandemic, the Services need to be prepared for when that demand resumes.

A decrease in retention affects not only readiness and safety, it also ineffectively utilizes resources. As many mid-level aviators leave the Services looking for greater stability, higher pay, or improved quality of life, an increased workload will fall on the less experienced personnel left behind.

A 2019 Report to Congress on Initiatives for Mitigating Military Pilot Shortfalls explained that “replacing an experienced pilot at the end of his or her initial obligated service commitment (10–12 years of service) will take a minimum of 6–8 years of training and experience and millions of dollars for every pilot lost.” A 2019 RAND study estimated the total costs of training a basic qualified Air Force pilot is expensive. The study concluded,

The cost of training a basic qualified fighter pilot ranges from \$5.6 million for an F-16 pilot to \$10.9 million for an F-22 pilot. Bomber pilot training cost is also high, ranging from \$7.3 million for a B-1 pilot to \$9.7 million for a B-52 pilot. Costs for training transport pilots and mobility pilots are somewhat lower, but still considerable, ranging from \$1.1 million for a C-17 pilot to \$2.5 million for a C-130J pilot. Training cost per pilot for command, control, intelligence, surveillance, and reconnaissance operations (e.g., the RC-135) is about \$5.5 million.

Notably, these cost estimates only cover initial training and not the subsequent years of continuous investment as aircrew hone their skills and accumulate experience.

In other words, increasing aircrew experience by increasing retention saves money and improves safety and readiness. To maximize efficiency, safety, and readiness, the Services must have the flexibility to adjust retention incentives. Because it costs millions of dollars to train a replacement pilot, the Services must be able to offer competitive compensation. Granting the Services standing authority to increase their annual aviation retention bonuses up to \$100,000 would allow the Services to respond to retention challenges in a dynamic environment. See 37 U.S.C. § 334.

Improving Career Management

Many aviators told the Commission that assignments to nonaviation billets diminished their aviation proficiency just as they were gaining experience.

Most pilots have fairly structured career paths and important developmental experiences that must be met along the way. These assignments are designed to create well-rounded officers, but they can also be a detour on the road to making good aviators. “We spend a lot of time training pilots,” said a Navy senior NCO crew chief. “We get them good at flying and then they go fly a desk. Their next assignment is coming back to fly and they aren’t good.” The degradation in proficiency during the time away from the cockpit diminishes the Services’ return on investment.

Similarly, aircrews believe the current promotion and evaluation systems do not sufficiently take into account their aviation skills. “We are told from day one in flight school, when you get to the fleet, they tell you that your ground job is what gets you promoted,” said a Marine aviator.

The overall failure to address problems with pilot training and experience results in an aggregation of risks over time: a cohort of aviators who have inadequate training and lack the skills and experience they will need as they advance through their careers. The Commission learned of students who completed a rushed initial training program, who were pushed through their follow-on training by less-experienced instructors, and then became instructors and leaders themselves. They are at higher risk of making costly mistakes and lack the experience to train the next generation. Without action, military aviators will not be exposed to what “right” looks like. Inexperience will become institutionalized and jeopardize the safety of a future generation of aviators.

RECOMMENDATIONS

Because of the significant investment in time and resources required to train and sustain fully qualified military aviation personnel, and a commercial marketplace competing for such high-demand talent, Congress, the Department of Defense, and the Services must regard and manage aircrews as a specialty and their training as a career-long pursuit. The Services must develop personnel management processes that account for the complexities of aviation and support aviation safety, readiness, and the demands of OPTEMPO. Congress and the Services must execute the following measures to focus aviation professionals on their flying duties, sustain their skills, and promote advancement of their proficiencies.

The Commission recommends:

- 10.1 The Services mandate and enforce assignments and performance evaluation guidance that focus aircrews primarily on areas of performing, sustaining, and advancing their aviation professional skills, knowledge, and experience. The Services must discourage using aircrews for assignments and additional duties unrelated to their aviation-related warfighting fitness, skills requirements, or essential supervisory responsibilities. DoD and the Services should reduce nonaviation-related ancillary training to the minimum.
- 10.2 The Services restore flight hours to not less than fiscal year 2010 levels for schoolhouse and operational units.
- 10.3 The Services centrally track waivers, create a baseline, and monitor them to identify trends, assess risk, and predict potential problems and resource shortfalls.
- 10.4 Congress grant the Services standing authority to increase the aviation bonuses from up to \$35,000 to up to \$100,000 per year to retain pilots in exchange for a commensurate additional service commitment.
- 10.5 The Services upgrade data collection to improve training programs and training tool selections that better measure student learning. Data collection must include classroom, pilot task training, full-motion simulators, and flying training plus feedback from the field as a measure of training efficacy.
- 10.6 The Services link simulator sustainment to aircraft production, upgrades, and modifications and have the same operational flight plan as the aircraft. The Department of Defense and the Services must eliminate software and system upgrade lags that hamper simulator training.



F/A-18 Super Hornets from Strike Fighter Squadron (VFA) 31, VFA-32, VFA-87, and VFA-105 honor the late Sen. John McCain with a missing man formation flyover of the U.S. Naval Academy during his burial service, Sept. 2, 2018. (U.S. Navy photo by Mass Communication Specialist 2nd Class Nathan Burke.)

IN MEMORIAM

The National Commission on Military Aviation Safety honors the military aviation professionals and other servicemembers, civilians, and contractors who paid the ultimate sacrifice in U.S. military aviation mishaps during the period of this Commission's study. The following are the released names of those individuals as provided by the military Departments.

Second Lieutenant David Samuel Albandoz, Puerto Rico
Air National Guard

First Lieutenant Kenneth Allen, U.S. Air Force
Mr. Ruslan Alymkulov, Civilian

Master Sergeant Jean M. Audiffred-Rivera, Puerto Rico
Air National Guard

First Lieutenant Kathryn M. Bailey, U.S. Army

Corporal Daniel E. Baker, U.S. Marine Corps

Corporal Daniel I. Baldassare, U.S. Marine Corps

Captain Paul J. Barbour, U.S. Air Force

Lance Corporal Joshua E. Barron, U.S. Marine Corps

Staff Sergeant Marcus S. Bawol, U.S. Marine Corps

Captain Andrew Christopher Becker, U.S. Air Force

Staff Sergeant Lance Jacob Bergeron, Louisiana Army
National Guard

Technical Sergeant Marty B. Bettelyoun, U.S. Air Force

Staff Sergeant Steven P. Blass, U.S. Army

Staff Sergeant Trevor P. Blaylock, U.S. Marine Corps

Master Sergeant Mario Braña-Ortega, Puerto Rico Air
National Guard

Captain Travis W. Brannon, U.S. Marine Corps

Staff Sergeant Dashan J. Briggs, U.S. Air Force

Major James M. Brophy, U.S. Marine Corps

Chief Warrant Officer 2 Kevin F. Burke, U.S. Army

Mr. William Burnette, Contractor

Sergeant Dwight W. Burns, U.S. Army

Major Shawn M. Campbell, U.S. Marine Corps

Chief Warrant Officer 2 Stephen Travis Cantrell,
U.S. Army

Chief Warrant Officer 2 Alex Caraballo-Leon, U.S. Army

Captain Clayton Carpenter, U.S. Army

Mr. Carlos J. Carrasco, Contractor

Chief Warrant Officer 2 James J. Casadona, U.S. Army

Sergeant First Class Toby A. Childers, U.S. Army

Master Sergeant Eric Circuns, Puerto Rico Air National
Guard

Corporal Justin R. Clouse, U.S. Army

Aircrewman Helicopter 3 Brian A. Collins, U.S. Navy

Master Sergeant Victor J. Colon, Puerto Rico Air
National Guard

Staff Sergeant Cole Condiff, U.S. Air Force

Chief Warrant Officer 3 Ryan Connelly, U.S. Army

Chief Warrant Officer 3 Stephen B. Cooley, U.S. Army

First Lieutenant Clayton R. Cullen, U.S. Army

Captain Sara M. (Knutson) Cullen, U.S. Army

Captain Brandon Lee Cyr, U.S. Air Force

Captain Kenneth Stephen Dalga, U.S. Air Force

Major Stephen Del Bagno, U.S. Air Force

Lieutenant Junior Grade Valerie C. Delaney, U.S. Navy

First Lieutenant Frederick Drew Dellecker, U.S. Air
Force

Lance Corporal Matthew J. Determan, U.S. Marine
Corps

Staff Sergeant Sean Samuel Devoy, U.S. Army

Staff Sergeant Richard A. Dickson, U.S. Air Force

Mr. Ralph Dietz, Contractor
Corporal Matthew R. Drown, U.S. Marine Corps
Captain William H. Dubois Jr., U.S. Air Force
Lieutenant Colonel Ira S. Eadie, U.S. Air Force
Captain Sean E. Elliott, U.S. Marine Corps
Staff Sergeant Carl P. Enis, U.S. Air Force
Staff Sergeant Adam Erickson, U.S. Air Force
Senior Airman Roberto A. Espada-Gali, Puerto Rico Air National Guard
Staff Sergeant Daniel N. Fannin, U.S. Air Force
Staff Sergeant Maximo A. Flores, U.S. Marine Corps
Staff Sergeant Thomas C. Florich III, Louisiana Army National Guard
Staff Sergeant Liam A. Flynn, U.S. Marine Corps
Lieutenant Colonel Morris M. Fontenot Jr., Massachusetts Air National Guard
Captain James E. Frederick, U.S. Marine Corps
Chief Warrant Officer 2 Kirk T. Fuchigami Jr., U.S. Army
Chief Warrant Officer 3 Taylor J. Galvin, U.S. Army
Master Sergeant Joshua M. Gavulic, U.S. Air Force
Chief Warrant Officer 4 Stien P. Gearhart, Idaho Army National Guard
Chief Warrant Officer 3 Jonathan S. Gibson, U.S. Navy
Captain Jonathan Joseph Golden, U.S. Air Force
Master Sergeant Martin Gonzales, U.S. Air Force
Major Caine M. Goyette, U.S. Marine Corps
Captain John Francis Snavely Graziano, U.S. Air Force
Chief Warrant Officer 4 G. George Wayne Griffin Jr., Louisiana Army National Guard
Chief Warrant Officer 3 James E Groves III, U.S. Army
Major Lucas F. Gruenther, U.S. Air Force
Staff Sergeant Ryan David Hammond, U.S. Air Force
Lance Corporal Steven M. Hancock, U.S. Marine Corps
Lance Corporal Ty L. Hart, U.S. Marine Corps
Chief Warrant Officer 4 Jon L. Hartway, Idaho Army National Guard
Sergeant Justin R. Helton, U.S. Army
Chief Warrant Officer 2 Bryan J. Henderson, U.S. Army
Lieutenant Colonel Kevin R. Herrmann, U.S. Marine Corps

Lance Corporal Jacob A. Hug, U.S. Marine Corps
Corporal Thomas J. Jardas, U.S. Marine Corps
Sergeant Ward M. Johnson IV, U.S. Marine Corps
Senior Airman Quinn Lamar Johnson-Harris, U.S. Air Force
Lieutenant Commander Landon L. Jones, U.S. Navy
Captain Elizabeth R. Kealey, U.S. Marine Corps
Staff Sergeant Kerry M. Kemp, U.S. Marine Corps
Captain Brian T. Kennedy, U.S. Marine Corps
Lieutenant Colonel John M. Kincade, U.S. Air Force
Chief Warrant Officer 2 David C. Knadle, U.S. Army
Mr. Shane Krogen, Civilian
Master Sergeant Gregory T. Kuhse, U.S. Air Force
Captain Jeff M. Kuss, U.S. Marine Corps
Mr. Matthew LaCourse, GS-13
Staff Sergeant Jonathan E. Lewis, U.S. Marine Corps
Chief Warrant Officer 2 Lucas M. Lowe, Texas Army National Guard
Captain Dustin R. Lukasiewicz, U.S. Marine Corps
Technical Sergeant Herman Mackey III, U.S. Air Force
Mr. Alberto Marin, Contractor
Staff Sergeant Vincent P. Marketta, U.S. Army
Mr. Kevin A. Mason, Contractor
Technical Sergeant Dale E. Mathews, U.S. Air Force
Chief Warrant Officer 3 Andrew L McAdams, U.S. Army
Chief Warrant Officer 4 Jason W. McCormack, U.S. Army
Staff Sergeant Jason A. McDonald, U.S. Army
Lieutenant Junior Grade William B. McIlvaine III, U.S. Navy
Corporal Sara A. Medina, U.S. Marine Corps
Staff Sergeant Abigail R. Milam, U.S. Army
Chief Warrant Officer 3 Dustin L. Mortenson, Texas Army National Guard
Captain Reid B. Nannen, U.S. Marine Corps
Sergeant Michael L. Nelson, U.S. Army
Captain Reid Kijiro Nishizuka, U.S. Air Force
Mr. Kristopher L. Noble, Contractor
Chief Warrant Officer 2 Charles P. Nord, Minnesota Army National Guard
Captain Christopher L. Norgren, U.S. Marine Corps

Major Richard S. Norton, U.S. Marine Corps
 Technical Sergeant Timothy A. Officer Jr., U.S. Air Force
 Captain Andreas B. O’Keeffe, U.S. Air Force
 Corporal Christopher J. Orlando, U.S. Marine Corps
 Senior Master Sergeant Jan A. Paravisini-Ruiz, Puerto Rico Air National Guard
 Lieutenant Commander Alan A. Patterson, U.S. Navy
 Major Phyllis J. Pelky, U.S. Air Force
 Major Carlos Perez-Serra, Puerto Rico Air National Guard
 Captain Ryan S. Phaneuf, U.S. Air Force
 Captain Jordan Pierson, U.S. Air Force
 Captain Victoria A. Pinckney, U.S. Air Force
 Sergeant Kort M. Plantenberg, Minnesota Army National Guard
 Lieutenant Nathan Poloski, U.S. Marine Corps
 Sergeant Afton M. Ponce, U.S. Air Force
 Master Sergeant William R. Posch, U.S. Air Force
 Master Sergeant Christopher J. Raguso, U.S. Air Force
 Chief Warrant Officer 4 Paul J. Reidy, U.S. Army
 Captain Jahmar F. Resilard, U.S. Marine Corps
 Staff Sergeant Emil Rivera-Lopez, U.S. Army
 Captain Kevin T. Roche, U.S. Marine Corps
 Chief Warrant Officer 2 James A. Rogers Jr., Minnesota Army National Guard
 Major José R. Román-Rosado, Puerto Rico Air National Guard
 Corporal William C. Ross, U.S. Marine Corps
 Captain Sean M. Ruane, U.S. Air Force
 Chief Warrant Officer 3 Matthew P. Ruffner, Pennsylvania Army National Guard
 Mr. Christopher J. Ruiz, Contractor
 Airman First Class Kcey Elena Ruiz, U.S. Air Force
 Major Taj Sareen, U.S. Marine Corps
 Senior Airman Nathan Cole Sartain, U.S. Air Force
 First Lieutenant Adam C. Satterfield, U.S. Marine Corps
 Master Sergeant Thomas Arthur Vaughan Saunders, U.S. Marine Corps
 First Lieutenant David John Schmitz, U.S. Air Force
 Sergeant Adam C. Schoeller, U.S. Marine Corps
 Lieutenant Colonel Eric Schultz, U.S. Air Force
 Staff Sergeant Marc A. Scialdo, U.S. Army
 Sergeant Drew M. Scobie, U.S. Army
 Sergeant Eric M. Seaman, U.S. Marine Corps
 Staff Sergeant Andrew C. Seif, U.S. Marine Corps
 Sergeant Dillon J. Semolina, U.S. Marine Corps
 Sergeant Jeffrey A. Sempler, U.S. Marine Corps
 Specialist Zachary L. Shannon, U.S. Army
 Major Stanford H. Shaw III, U.S. Marine Corps
 Sergeant Tyler M. Shelton, U.S. Army
 Lieutenant Christopher C. Short, U.S. Navy
 Chief Warrant Officer 3 Jacob M. Sims, U.S. Army
 Chief Warrant Officer 3 Brandon A. Smith, U.S. Army
 Sergeant First Class Jason M. Smith, U.S. Army
 Technical Sergeant Mark A. Smith, U.S. Air Force
 Lieutenant Sean C. Snyder, U.S. Navy
 Corporal Jordan L. Spears, U.S. Marine Corps
 Captain James Michael Steel, U.S. Air Force
 Captain Christopher S. Stover, U.S. Air Force
 Chief Warrant Officer 4 George David Strother, Louisiana Army National Guard
 Staff Sergeant Scott R. Studenmund, U.S. Army
 Chief Warrant Officer 3 Michael F. Tharp, U.S. Army
 Specialist Jeremy D. Tomlin, U.S. Army
 Private Second Class Andrew Toppen, U.S. Army
 Captain Steven R. Torbert, U.S. Marine Corps
 Sergeant William J. Turner, U.S. Marine Corps
 Lieutenant J. Wesley Van Dorn, U.S. Navy
 Captain Mark T. Voss, U.S. Air Force
 Lieutenant Colonel Paul K. Voss, U.S. Air Force
 Lieutenant Charles Z. Walker, U.S. Navy
 Captain Mark K. Weber, U.S. Air Force
 Chief Warrant Officer 2 Kevin M. Weiss, U.S. Army
 Major Matthew M. Wiegand, U.S. Marine Corps
 Second Lieutenant Travis B. Wilkie, U.S. Air Force
 Chief Warrant Officer 3 Brian Marshall Woeber, U.S. Army
 Chief Warrant Officer 2 Jarett M. Yoder, Pennsylvania Army National Guard
 Captain Christopher T. Zanetis, U.S. Air Force



An Air Force F-22 Raptor from the 95th Fighter Squadron, Tyndall Air Force Base, Florida, flies over Tallinn, Estonia. (U.S. Air Force photo by TSgt. Jason Robertson.)

Appendix A:

CONGRESSIONAL CHARTER FOR THE NATIONAL COMMISSION ON MILITARY AVIATION SAFETY

John S. McCain National Defense Authorization Act for Fiscal Year 2019

SEC. 1087. NATIONAL COMMISSION ON MILITARY AVIATION SAFETY.

(a) ESTABLISHMENT; PURPOSE.—

- (1) ESTABLISHMENT.—There is established the National Commission on Military Aviation Safety (in this section referred to as the “Commission”). The Commission shall be considered an independent establishment of the Federal Government as defined by section 104 of title 5, United States Code, and a temporary organization under section 3161 of such title.
- (2) PURPOSE.—The purpose of the Commission is to examine and make recommendations with respect to certain United States military aviation mishaps.

(b) MEMBERSHIP.—

- (1) COMPOSITION.—The Commission shall be composed of eight members, of whom—
 - (A) four shall be appointed by the President;
 - (B) one shall be appointed by the Chairman of the Committee on Armed Services of the Senate;
 - (C) one shall be appointed by the Ranking Member of the Committee on Armed Services of the Senate;
 - (D) one shall be appointed by the Chairman of the Committee on Armed Services of the House of Representatives; and
 - (E) one shall be appointed by the Ranking Member of the Committee on Armed Services of the House of Representatives.
- (2) APPOINTMENT DATE.—The appointments of the members of the Commission shall be made not later than 90 days after the date of the enactment of this Act.
- (3) EFFECT OF LACK OF APPOINTMENT BY APPOINTMENT DATE. — If one or more appointments under subparagraph (A) of paragraph (1) is not made by the appointment date specified in paragraph (2), the authority to make such appointment or appointments shall expire, and the number of members of the Commission shall be

reduced by the number equal to the number of appointments so not made. If an appointment under subparagraph (B), (C), (D), or (E) of paragraph (1) is not made by the appointment date specified in paragraph (2), the authority to make an appointment under such subparagraph shall expire, and the number of members of the Commission shall be reduced by the number equal to the number otherwise appointable under such subparagraph.

- (4) EXPERTISE.—In making appointments under this subsection, consideration should be given to individuals with expertise in military aviation training, aviation technology, military aviation operations, aircraft sustainment and repair, aviation personnel policy, aerospace physiology, and reserve component policy.
- (5) PERIOD OF APPOINTMENT; VACANCIES.—Members shall be appointed for the life of the Commission. Any vacancy in the Commission shall not affect its powers but shall be filled in the same manner as the original appointment.
- (6) CHAIR AND VICE CHAIR.—The Commission shall select a Chair and Vice Chair from among its members. The Chair may not be a Federal officer or employee.
- (7) STATUS AS FEDERAL EMPLOYEES.—Notwithstanding the requirements of section 2105 of title 5, United States Code, including the required supervision under subsection (a)(3) of such section, the members of the Commission shall be deemed to be Federal employees.
- (8) PAY FOR MEMBERS.—
 - (A) IN GENERAL.—Except for the Chair, each member of the Commission who is not an officer or employee of the Federal government shall be paid at a rate equal to the daily equivalent of the annual rate of basic pay payable for level IV of the Executive Schedule under section 5315 of title 5, United States Code, for each day (including travel time) during which the member is engaged in the actual performance of duties vested in the Commission. All members of the Commission who are officers or employees of the United States shall serve without compensation in addition to that received for their services as officers or employees of the United States.
 - (B) CHAIR.—The Chair of the Commission shall be paid at a rate equal to the daily equivalent of the annual rate of basic pay payable for level III of the Executive Schedule under section 5314, of title 5, United States Code, for each day (including travel time) during which the member is engaged in the actual performance of duties vested in the Commission.
 - (C) TRAVEL EXPENSES.—The members of the Commission shall be allowed travel expenses, including per diem in lieu of subsistence, at rates authorized for employees of agencies under subchapter I of chapter 57 of title 5, United States Code, while away from their homes or regular places of business in the performance of services for the Commission.

(c) ADDITIONAL STAFF.—

- (1) EXECUTIVE DIRECTOR.—
 - (A) APPOINTMENT.—The Commission shall appoint and fix the rate of basic pay for an Executive Director in accordance with section 3161 of title 5, United States Code.
 - (B) LIMITATIONS.—The individual appointed to serve as Executive Director may not have served on active duty in the Armed Forces or as a civilian employee of the Department of Defense during the one-year period preceding the date of such appointment.
- (2) COMMISSION STAFF.—The Executive Director, with the approval of the Commission, may appoint and fix the rate of basic pay for additional personnel as staff of the Commission in accordance with section 3161 of title 5, United States Code.
- (3) DETAILEES.—Not more than half of the personnel employed by or detailed to the Commission may be on detail from the Department of Defense and other Federal departments or agencies.

(d) MEETINGS.—

- (1) IN GENERAL.—The Commission shall meet at the call of the Chair.
- (2) INITIAL MEETING. — Not later than 30 days after the date on which all members of the Commission are required to have been appointed under subsection (b)(2), the Commission shall hold its initial meeting.
- (3) QUORUM.—A majority of the members of the Commission shall constitute a quorum, but a lesser number of members may hold hearings.

(e) SPACE FOR COMMISSION.—Not later than 90 days after the date of the enactment of this Act, the Administrator of General Services, in consultation with the Secretary of Defense, shall identify and make available suitable excess space within the Federal space inventory to house the operations of the Commission. If the Administrator is not able to make such suitable excess space available within such 90-day period, the Commission may lease space to the extent that funds are available for such purpose.

(f) CONTRACTING AUTHORITY.—The Commission may enter into contracts for the acquisition of administrative supplies and equipment for use by the Commission, to the extent that funds are available for such purpose.

(g) PROCUREMENT OF TEMPORARY AND INTERMITTENT SERVICES.—The Chair of the Commission may procure temporary and intermittent services under section 3109(b) of title 5, United States Code, at rates for individuals which do not exceed the daily equivalent of the annual rate of basic pay prescribed for level V of the Executive Schedule under section 5316 of such title.

(h) DUTIES.—

- (1) STUDY ON MILITARY AVIATION SAFETY.— The Commission shall undertake a comprehensive study of United States military aviation mishaps that occurred between fiscal years 2013 and 2018 in order—
 - (A) to assess the rates of military aviation mishaps between fiscal years 2013 and 2018 compared to historic aviation mishap rates;
 - (B) to make an assessment of the underlying causes contributing to the unexplained physiological effects;
 - (C) to make an assessment of causes contributing to delays in aviation maintenance and limiting operational availability of aircraft;
 - (D) to make an assessment of the causes contributing to military aviation mishaps; and
 - (E) to make recommendations on the modifications, if any, of safety, training, maintenance, personnel, or other policies related to military aviation safety.
- (2) REPORT.—Not later than March 1, 2020, the Commission shall submit to the President and the congressional defense committees a report setting forth a detailed statement of the findings and conclusions of the Commission as a result of the study required by paragraph (1), together with the recommendations of the Commission for such legislative and administrative actions as the Commission considers appropriate in light of the results of the study.

(i) POWERS.—

- (1) HEARINGS.—The Commission may hold such hearings, sit and act at such times and places, take such testimony, and receive such evidence as the Commission considers advisable to carry out its duties under this subtitle.
- (2) INFORMATION FROM DEPARTMENT.—The Commission may secure directly from any element of the Department of Defense such information as the Commission considers necessary to carry out its duties under this subtitle. Upon request of the Chair of the Commission, the head of such element shall furnish such information to the Commission.

(j) PROTECTION OF PRIVILEGED SAFETY INFORMATION.—

- (1) REQUEST OF INFORMATION.—The Commission may request privileged safety information from the Department of Defense.
- (2) TREATMENT OF INFORMATION.—Any privileged safety information provided to the Commission by the Department of Defense shall be handled by the Commission as though the Commission were a non-Department of Defense Federal Government agency under Enclosure 5, Section 8, of Department of Defense Instruction 6055.07, Mishap Notification, Investigation, Reporting, and Record Keeping.
- (3) PROHIBITION ON USE OF INFORMATION IN PUBLIC HEARINGS.—No privileged safety information shall be allowed in any public hearing of the Commission. The Commission may only consider privileged safety information in camera, and no record of the proceedings of the Commission may include privileged safety information.
- (4) PROHIBITION ON PUBLICATION.—Any privileged safety information secured by the Commission from the Department of Defense—
 - (A) may not be published or revealed to anyone outside the Commission;
 - (B) may not be retained but shall be returned to the originating Department of Defense organization; and
 - (C) may not be included in any Commission report.
- (5) USE OF AGGREGATED DATA.—Aggregated data based on privileged safety information or information that has been completely sanitized in accordance with Department of Defense Instruction 6055.07, such that individual mishaps are not identifiable, may be included in the report produced by the Commission.
- (6) DEFINITION OF PRIVILEGED SAFETY INFORMATION.—In this subsection, the term “privileged safety information” has the meaning given it in Department of Defense Instruction 6055.07, dated June 6, 2011.

(k) TERMINATION.—The Commission shall terminate 90 days after the date on which the Commission submits the report required under subsection (h)(2).

(l) AUTHORIZATION OF APPROPRIATIONS.—Of the amounts authorized to be appropriated for fiscal year 2019, as identified in division D of this Act, \$5,000,000 shall be available for the National Commission on Aviation Safety.

National Defense Authorization Act for Fiscal Year 2020

SEC. 1738. NATIONAL COMMISSION ON MILITARY AVIATION SAFETY.

- (a) Extension of Deadline for Report.—Subsection (h)(2) of section 1087 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Public Law 115-232) is amended by striking “March 1, 2020” and inserting “December 1, 2020”.
- (b) Secretary of Defense Report.—Such section is further amended by adding at the end the following new subsection:
 - “(m) Report to Congress.—Not later than 120 days after the date of the submittal of the report under subsection (h)(2), the Secretary of Defense, in coordination with the Secretary of each of the military departments, shall submit to the Committees on Armed Services of the Senate and House of Representatives a report that includes each of the following:
 - (1) An assessment of the findings and conclusions of the Commission.
 - (2) The plan of the Secretaries for implementing the recommendations of the Commission.
 - (3) Any other actions taken or planned by the Secretary of Defense or the Secretary of any of the military departments to improve military aviation safety.”
- (c) Authorization of Appropriations.—In addition to any other amounts authorized to be appropriated for the National Commission on Military Aviation Safety established under section 1087 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Public Law 115-232), of the amounts authorized to be appropriated for Operation and Maintenance, Defense-wide for fiscal year 2020, as specified in the funding table in section 4301, \$3,000,000 shall be available for the National Commission on Aviation Safety.

Appendix B:

RECOMMENDATIONS

Chapter 4: The Joint Safety Council

The Department of Defense must establish aviation safety responsibilities within the Office of the Secretary of Defense to ensure sufficient status, experienced and highly qualified personnel, and adequate funding to be effective in preventing injury, death, and damage. The following recommendations will create a coordinated, robust, proactive, data-driven aviation safety program that incorporates the best aviation safety practices from all relevant sources to become effectively predictive and preventive instead of reactive.

The Commission recommends:

- 4.1 Congress mandate, authorize, and fund the creation of a Joint Safety Council that reports to the Deputy Secretary of Defense. The Joint Safety Council would support and coordinate the capability of the Services' safety centers to identify and mitigate safety risks to reduce the number of aviation mishaps. The Joint Safety Council must be fully funded, staffed, and charged with developing and overseeing Defense-wide safety policies for the Secretary of Defense. It must have funding as a program element and unlimited access to the requisite databases.
- 4.2 The Joint Safety Council oversee the Services' implementation of robust Safety Management Systems that include programs such as MFOQA (military flight operations quality assurance), LOSA (line operations safety assessment), HUMS (health and usage monitoring system), and CVFDR (cockpit voice and image flight data recorders) from aircraft; SOQA (simulator operational quality assurance) from simulators; in-flight physiological data from aviators; and ASAP (aviation safety action programs) from aviators and maintainers. These programs should be based on best practices from commercial and military enterprises.
- 4.3 The Joint Safety Council set the requirements for mishap investigations in each of the Services to include the same Human Factors Analysis and Classification System (HFACS) codes for all Class A, B, and C mishaps. The Secretary of Defense will mandate that Class C mishap investigations use DoD reporting standards and data collection fields including HFACS codes.
- 4.4 That members of the Joint Safety Council will be the military Departments' chiefs of safety, all of whom should be the grade of O-8, and an additional representative from each of the military Services. The chair, selected among the military Departments' chiefs of safety every two years, would serve in a dual-hatted role as the Department of Defense's Director of Aviation Safety. The vice chair should be a career Senior Executive Service position appointed by the Secretary of Defense. The vice chair's responsibilities should be focused entirely on the mission and activities of the Joint Safety Council. The vice chair will report to the chair.

Chapter 5: The Human/Machine Interface

With modern aviation machines placing unprecedented stress on human physiology, the Department of Defense and the Services must adopt an aggressive, proactive approach to understanding the physiological needs of aviators and to developing additional capabilities that improve the human-machine interface, including aircraft and cockpit design, testing, and subsequent modifications.

The Commission recommends:

- 5.1 The Joint Safety Council (Commission recommendation on page 27) lead a robust review into the effects on humans in aviation operational environments, including physiological episodes. The JSC shall have a program element to conduct further research into determining and mitigating unexplained physiological episodes.
- 5.2 Program offices address human physiology concerns and analyze physiological effects throughout the aircraft testing phases for T-7, B-21, Future Vertical Lift, and other next-generation platforms early in the initial aircraft and cockpit design and with any materiel modification of the aircraft.
- 5.3 The Department of Defense and the Services develop physiological standards for each airframe to use in screening and training to ensure that the pilot/operator is able to successfully perform at optimal levels across the spectrum of the weapon system's capabilities.
- 5.4 The Department of Defense, with input from each of the safety centers, update and modify the Force Protection key performance parameters (KPP) to better incorporate Aviation Human Systems Safety.
- 5.5 That the Force Protection Functional Capability Board include representative capabilities such as ground and other aircraft collision avoidance; cockpit voice and flight data recording; biometric sensing for aircrew; and a spatial disorientation recovery system used for instrument meteorological conditions and brownout.

Chapter 6: Sustaining the Machine

The Department of Defense and Services must improve their planning, contracting, and program management processes to ensure timely availability of spare parts, improve maintenance efficiency, increase mission capable rates, and better sustain the investment made in aircraft. The Services should improve sustainment management systems, particularly for legacy aircraft and service life extensions, to provide the necessary visibility on expiring parts and production upgrades.

Chapter 7: The Need for Consistent Predictable Funding

Congress and the administration must recognize that consistent, reliable, and timely funding is key to sustaining military aviation readiness and safety.

The Commission recommends:

- 7.1 Congress and the administration ensure predictable and reliable funding for military aviation and stop using continuing resolutions to fund national security, military readiness, and aviation safety.
- 7.2 Congress task the Congressional Budget Office to study and report on the negative impacts of continuing resolutions on military aviation readiness and safety.

Chapter 8: The Demand Environment

Policy at all levels must reflect that aviation is a high-demand, low-density specialty with routinely insufficient capacity to satisfy all of the demand placed on it. This has overextended the aviation force beyond sustainable levels, resulting in chronic fatigue and burnout, which negatively impacts retention. The current high demand is forcing the Services to shortchange safety to accomplish current missions. The Services must increase aviator and maintainer capacity, reduce additional duties, and focus on proficiency to mitigate the risk.

The Commission recommends:

- 8.1 The Services ensure aviation units have sufficient administrative personnel to allow aviators and maintainers to concentrate on their primary mission, sustain currency and proficiency, and meet the unit's mission readiness rates.
- 8.2 The Department of Defense and the Services report aviation unit's personnel experience levels and member PERSTEMPO.
- 8.3 The Department of Defense and the Services require that proper policies, practices, staffing, and all other necessary resources are in place to ensure that the military's high demand/low density aviation units always are fully prepared and standing ready to perform at levels commensurate with the critical and unique role they perform in securing and maintaining our nation's security.

Chapter 9: Maintainers as Aviation Professionals

Because of the significant investment in time and resources required to train and sustain fully qualified military aviation maintainers, and a commercial marketplace competing for such high-demand talent, Congress, the Department of Defense, and the Services must regard and manage aviation maintainers as a specialty and their training as a career-long pursuit. The Services must develop personnel management processes and career paths that account for the complexities of aviation and support aviation safety, readiness, and OPTEMPO. DoD and the Services must execute the following measures to recognize achievement and enable aviation professionals to focus on their flight line duties, sustain their skills, and promote advancement of their proficiencies.

The Commission recommends:

- 9.1 The Services mandate and enforce assignments and performance evaluation guidance that focus aviation maintainers primarily on areas of performing, sustaining, and advancing their aviation professional skills, knowledge, and experience. The Services must discourage using aviation professionals for assignments and additional duties unrelated to their aviation-related warfighting fitness, skills requirements, or essential supervisory responsibilities. DoD and the Services should reduce mandated, nonaviation-related ancillary training to the minimum.
- 9.2 The Services experiment with technical specialty enlisted ranks for aviation maintenance personnel that include unique career paths to ensure that maintenance personnel achieve and are able to sustain the highest level of proficiency and professionalism.
- 9.3 The Services reward and incentivize the professional achievements of aviation maintainers with recognition and professional development throughout their careers.
 - a. The Services should establish aviation maintenance proficiency badges or credentials that would recognize and incentivize excellence in aviation maintainers and empower supervisors with support from leaders at the unit level to keep aviation maintainers focused on their primary flight line responsibilities.
 - b. The Services should institute a tuition-paid A&P (Airframe and Powerplant) license option in return for an extended enlisted commitment meeting a cost/benefit threshold.

- 9.4 The Services implement policies and training for transitioning maintainers among platforms that require and certify proficiency, promote retention, and leverage experience for both legacy and new platforms.

Chapter 10: Protecting Investment in Aircrews

Because of the significant investment in time and resources required to train and sustain fully qualified military aviation personnel, and a commercial marketplace competing for such high-demand talent, Congress, the Department of Defense, and the Services must regard and manage aircrews as a specialty and their training as a career-long pursuit. The Services must develop personnel management processes that account for the complexities of aviation and support aviation safety, readiness, and the demands of OPTEMPO. Congress and the Services must execute the following measures to focus aviation professionals on their flying duties, sustain their skills, and promote advancement of their proficiencies.

The Commission recommends:

- 10.1 The Services mandate and enforce assignments and performance evaluation guidance that focus aircrews primarily on areas of performing, sustaining, and advancing their aviation professional skills, knowledge, and experience. The Services must discourage using aircrews for assignments and additional duties unrelated to their aviation-related warfighting fitness, skills requirements, or essential supervisory responsibilities. DoD and the Services should reduce nonaviation-related ancillary training to the minimum.
- 10.2 The Services restore flight hours to not less than fiscal year 2010 levels for schoolhouse and operational units.
- 10.3 The Services centrally track waivers, create a baseline, and monitor them to identify trends, assess risk, and predict potential problems and resource shortfalls.
- 10.4 Congress grant the Services standing authority to increase the aviation bonuses from up to \$35,000 to up to \$100,000 per year to retain pilots in exchange for a commensurate additional service commitment.
- 10.5 The Services upgrade data collection to improve training programs and training tool selections that better measure student learning. Data collection must include classroom, pilot task training, full-motion simulators, and flying training plus feedback from the field as a measure of training efficacy.
- 10.6 The Services link simulator sustainment to aircraft production, upgrades, and modifications and have the same operational flight plan as the aircraft. The Department of Defense and the Services must eliminate software and system upgrade lags that hamper simulator training.

Appendix C:

COMMISSIONERS AND STAFF

Commissioners

General Richard A. Cody (USA, Retired)

Chairman, National Commission on Military Aviation Safety

General Richard Cody recently retired from L3 Technologies, which he joined in 2008 after concluding a 36-year U.S. Army career with four years as Vice Chief of Staff of the Army.

A Master Aviator with over 5,000 hours of flight time, General Cody served in several command and staff assignments, including Deputy Chief of Staff for Operations (G-3); Commanding General of the 101st Airborne Division (Air Assault); Director of Operations, Readiness, and Mobilization in the Office of the Deputy Chief of Staff for Operations and Plans, Department of the Army; Deputy Commanding General of Task Force Hawk in Tirana, Albania; Commander of the 160th Special Operations Aviation Regiment; Commander of 4th Brigade, 1st Cavalry Division; Aide-de-Camp to the Commanding General of the Combined Field Army, Korea; and Director of Flight Concepts Division.

He is Chairman of the Board for Homes For Our Troops, which builds mortgage-free custom homes for severely wounded war veterans.

A graduate of the Military Academy at West Point, General Cody's professional military education includes the Transportation Corps Officer Basic and Advanced Courses; the Aviation Maintenance Officer Course; AH-1, AH-64, AH-64D, UH-60, and MH-60K Aircraft Qualification Courses; Command and General Staff College; and the Army War College.

The Honorable Richard F. Healing

Vice Chairman, National Commission on Military Aviation Safety

Mr. Richard Healing is a professional engineer and internationally recognized transportation safety expert who founded Air Safety Engineering LLC in 2015, a company that provides safety analysis and solutions in general, military, and commercial aviation.

He served as a Board Member of the National Transportation Safety Board, holding the Safety Engineering position and providing technical inputs on several transportation accident investigations from 2003 to 2005. As Director of Safety and Survivability for the Department of the Navy from 1985 to 2002, he worked on aviation safety and developed initiatives to rapidly bring state-of-the-art safety and survivability technology into the Navy and Marine Corps.

Mr. Healing retired as a captain from the U.S. Coast Guard Reserve in 1993. During his 32-year combined active and reserve Coast Guard career, he held four commands, including a coastal patrol boat on combat missions in Vietnam from 1966 to 1967 and, prior to his retirement, the Secretary of Defense Crisis Coordination Center Joint Reserve Unit in the Pentagon during Operations Desert Shield and Desert Storm.

Mr. Healing attended the U.S. Coast Guard Academy and graduated from Worcester Polytechnic Institute. He graduated from the Naval War College and was a Senior Executive Fellow at Harvard University.

The Honorable Scott C. Donnelly

Commissioner, National Commission on Military Aviation Safety

Mr. Scott Donnelly is the Chairman, Chief Executive Officer, and President of Textron Inc. He has more than two decades of business experience in innovation, manufacturing, sales and marketing, business processes, research and development, design engineering, and industrial systems control.

Mr. Donnelly joined General Electric and spent 20 years leading the design and development of GE products in aerospace, industrial systems, health care, and aircraft engines. He started his career in the aerospace and semiconductor industries as a design engineer developing advanced computer architectures and devices for special-purpose processors and systems. In 1995, he moved to GE's Industrial Control Systems business as Manager of Technology and System Development. He advanced through management positions across GE's divisions, including Vice President of Global Technology Operations for GE Medical Systems, Senior Vice President and Director of Global Research, and President and Chief Executive Officer for GE Aviation.

Mr. Donnelly joined Textron in 2008, serving as the Chief Operating Officer prior to becoming the company's CEO. Mr. Donnelly has been active in many industry associations. In 2010, he served as chairman of the Aerospace Industries Association's board of governors.

Mr. Donnelly attended the University of Colorado and graduated with a bachelor's degree in electrical and computer engineering in 1984.

The Honorable Preston Geren

Commissioner, National Commission on Military Aviation Safety

Mr. Preston "Pete" Geren, who served in the U.S. Congress and at the highest levels of the Department of Defense, is president of the Sid W. Richardson Foundation, which provides grants to educational, health, human service, and cultural nonprofit organizations in Texas. He assumed that position in 2011.

Mr. Geren's Department of Defense career included several senior positions from 2001 to 2009, including Special Assistant to the Secretary of Defense, Acting Secretary of the Air Force, Under Secretary of the Army, and Secretary of the Army. In recognition of his service, he was twice awarded the Distinguished Civilian Service Award, the Department of Defense's highest civilian award.

The 12th District of Texas elected Mr. Geren to four terms in the U.S. House of Representatives from 1989 to 1997. He was also an assistant to U.S. Senator Lloyd Bentsen. As a lawyer and former business executive, he has held leadership positions in numerous civic, educational, business, and philanthropic organizations in Texas.

He earned his Doctor of Jurisprudence at the University of Texas Law School and his Bachelor of Arts in history at the University of Texas at Austin. He studied architecture at Georgia Tech before transferring to the University of Texas.

The Honorable Joseph W. Hagin

Commissioner, National Commission on Military Aviation Safety

Mr. Joseph Hagin was Deputy Chief of Staff for Operations for President Donald Trump from 2017 to 2018 and for President George W. Bush from 2001 to 2008. He served in that role longer than any other member of the White House senior staff.

Among his many duties was responsibility for White House communications, logistics, Air Force One operations, and security for President George W. Bush and President George H.W. Bush. He oversaw the activities of 4,000 civilian and military personnel. As Deputy Chief of Staff, Mr. Hagin traveled with the president and has interacted with world and business leaders around the globe.

Mr. Hagin was Chief Executive Officer at Jet Support Services Inc. from 2008 to 2009 and has held senior management positions at Chiquita Brands and Federated Department Stores. He has been chairman of SMobile International Advisory Board since August 2008 and was chairman of SMobile Corporation from 2008 to 2010.

Mr. Hagin serves on the Board of Directors of SMobile Systems, Jet Support Services Inc., The Franklin Mint, and Fox Factory Inc. He was a director of Fox Factory Holding Corp from 2013 to 2016. He holds a Bachelor of Arts degree in economics from Kenyon College.

General Raymond E. Johns (USAF, Retired)**Commissioner, National Commission on Military Aviation Safety**

General Ray Johns recently retired from FlightSafety International serving as Co-CEO and President of Government and Manufacturing following a 36-year career in the U.S. Air Force. A test pilot, including chief test pilot and test program manager for the VC-25 Air Force One, he has over 5,000 hours in more than 83 different aircraft.

He concluded his military career as Commander of Air Mobility Command, overseeing 135,000 personnel, 1,300 aircraft, and an annual operating budget of \$20 billion. Previously, he was Air Force Deputy Chief of Staff for Strategic Plans and Programs, developing, integrating, and analyzing the Air Force's annual \$120 billion budget, the Future Years Defense Program, and Air Force Long-Range Plan.

General Johns has served in senior strategy, planning, and fiscal policy positions at U.S. European Command and U.S. Pacific Command. He was a White House Fellow in the Office of National Service working on the Points of Light initiative for President George H.W. Bush.

General Johns received a Bachelor of Science degree in aeronautical engineering from the Air Force Academy and a Master of Science degree in administration from Central Michigan University. He is a graduate of the U.S. Air Force Test Pilot School, the Industrial College of the Armed Forces, and the John F. Kennedy School of Government at Harvard University.

The Honorable Dabney Kern**Commissioner, National Commission on Military Aviation Safety**

Mr. Dab Kern is Senior Vice President for Corporate Homeland and National Defense at CACI International Inc. He served 20 years in the U.S. Navy as a pilot with a space subspecialty, a career that led to several government posts.

He served as Director of the White House Military Office and Deputy Assistant to the President from 2014 to 2017, combining nearly 3,000 personnel in over 20 commands and directorates, including the White House Communications Agency, Presidential Airlift Group (which operates Air Force One and other associated platforms), Marine Helicopter Squadron One (with 22 rotary platforms including the V-22 Osprey and Marine One), the White House Medical Unit, and Camp David. He was Senior Director for Response and Recovery Policy at the National Security Council from 2009 to 2011.

He spent the last seven years of his Navy career in national security appointments in the White House and the Department of Homeland Security, including Director of Homeland Security's Mt. Weather Emergency Operations Center from 2005 to 2009.

Mr. Kern studied information systems management, computer, and military science at Jacksonville University. He has degrees in information technology management from the Naval Postgraduate School and maritime security from the Naval War College.

National Commission on Military Aviation Safety Staff

Major General Gregory A. Feest (USAF, Retired)

Executive Director, National Commission on Military Aviation Safety

Major General Greg Feest concluded his 34-year U.S. Air Force career as Commander of the Air Force Safety Center and Air Force Chief of Safety. He since has worked at L3 Technologies as Vice President of USAF Programs and at Lockheed Martin's Advanced Development Programs (Skunk Works) as Deputy Director of Operations, Business, and Strategy Development.

A command pilot with over 5,600 flying hours, more than 800 in combat operations, Major General Feest has commanded at all levels, including an F-117A stealth fighter squadron, the 379th Air Expeditionary Wing in Southwest Asia, and 19th Air Force, the largest numbered Air Force with over 38,000 personnel, 1,500 aircraft, and 27 bases.

With Air Education and Training Command, he served as Director of Logistics, Installations, and Mission Support and as Deputy Director of Operations for all Air Force flying training.

He graduated from the University of Wisconsin, Madison, with a Business Administration degree in finance and management. He has an MBA in management and a Master of Science in national security strategy from the National War College. He attended the Systems Acquisition Management General Officer Course, the Syracuse University National Security Management Course, and Harvard University's John F. Kennedy School of Government.

Carvell Akuffo	Research Assistant	Kevin D. Mickie	Human Resources
Destini Berry	Operations Analyst	Eric Minton	Editor
Michael J. Blaine	Executive Assistant	Laurel Prucha Moran	Graphic Designer
Corey Bradley	Deputy General Counsel	Charles Risio	Research Analyst
Cody Cheek	Deputy General Counsel	Chad Schumacher	Congressional Liaison
Amy Grace P. Donohue	Deputy Editor	Ray B. Shepherd	Director of Research and Analysis
Clark D. Frederick	Research Analyst	Leslie H. Smith	Staff Director, Director of Operations
Jamie Hammon	Finance and Budget Administrator	Marian Veld	Librarian
Denise Jade Hlavaty	Public Outreach Specialist	Bryan G. Whitman	Director of Government and Public Engagement
Madison Ianniello	Research Assistant	Stefan R. Wolfe	General Counsel

Appendix D:

COMMISSION ENGAGEMENTS

Military Organizations

1/25th Aviation Regiment, Fort Wainwright, Alaska

1/52nd Aviation Regiment, Fort Wainwright, Alaska

101st Airborne Division, Fort Campbell, Kentucky

104th Fighter Wing, Massachusetts Air National Guard, Barnes Air National Guard Base, Westfield, Massachusetts

108th Wing, New Jersey Air National Guard, Joint Base McGuire-Dix-Lakehurst, New Jersey

110th Aviation Brigade, Fort Rucker, Alabama

115th Fighter Wing, Wisconsin Air National Guard, Madison, Wisconsin

11th Air Force, Joint Base Elmendorf-Richardson, Alaska

126th Airlift Wing, U.S. Air Force Reserve, Scott Air Force Base, Illinois

128th Air Refueling Wing, Wisconsin Air National Guard, Milwaukee, Wisconsin

128th Aviation Brigade, Fort Eustis, Virginia (U.S. Army Aviation Maintenance Training)

133rd Airlift Wing, Minnesota Air National Guard, Minneapolis, Minnesota

139th Air Wing Advanced Airlift Tactics Training Center, San Antonio, Texas

143rd Airlift Wing, Rhode Island Air National Guard, Providence, Rhode Island

150th Special Operations Wing, New Mexico Air National Guard, Kirtland Air Force Base, New Mexico

154th Wing, Hawaii Air National Guard, Joint Base Pearl Harbor-Hickam, Hawaii

157th Air Refueling Wing, New Hampshire Air National Guard, Portsmouth, New Hampshire

15th Fighter Wing, Joint Base Pearl Harbor-Hickam, Hawaii

160th Special Operations Aviation Regiment, Fort Campbell, Kentucky; Joint Base Lewis-McChord, Washington

16th Combat Aviation Brigade, Joint Base Lewis-McChord, Washington

173rd Fighter Wing, Oregon Air National Guard, Kingsley Field, Klamath Falls, Oregon

176th Wing, Alaska Air National Guard, Joint Base Elmendorf-Richardson, Alaska

19th Air Force, Joint Base San Antonio, Texas

1st Armored Division Combat Aviation Brigade, Fort Bliss, Texas

1st Fighter Wing, Langley Air Force Base, Virginia

20th Fighter Wing, Shaw Air Force Base, South Carolina

22nd Air Force, U.S. Air Force Reserve, Dobbins Air Reserve Base, Georgia

22nd Air Refueling Wing, McConnell Air Force Base, Kansas

23rd Flying Training Squadron, Fort Rucker, Alabama

244th Expeditionary Combat Aviation Brigade, Joint Base McGuire-Dix-Lakehurst, New Jersey

25th Combat Aviation Brigade, Wheeler Army Airfield, Hawaii

2nd Air Force, 81st Training Wing, Keesler Air Force Base, Mississippi

2nd Marine Air Wing, Marine Corps Air Station Cherry Point, North Carolina

2nd Operations Group, Barksdale Air Force Base, Louisiana

305th Air Mobility Wing, Joint Base McGuire-Dix-Lakehurst, New Jersey

306th Flying Training Group, Colorado Springs, Colorado

309th Aerospace Maintenance and Regeneration Group, Davis-Monthan Air Force Base, Arizona

310th Fighter Squadron, Luke Air Force Base, Arizona

33rd Fighter Wing, Eglin Air Force Base, Florida

355th Fighter Wing, Davis-Monthan Air Force Base, Arizona

375th Air Mobility Wing, U.S. Air Force Reserve, Scott Air Force Base, Illinois

388th Fighter Wing, Hill Air Force Base, Utah

3rd Marine Air Wing, Marine Corps Air Station Miramar, California

4/160th Special Operations Aviation Regiment, Joint Base Lewis-McChord, Washington

419th Fighter Wing, U.S. Air Force Reserve, Hill Air Force Base, Utah

422nd Test and Evaluation Squadron, Nellis Air Force Base, Nevada

433rd Airlift Wing, U.S. Air Force Reserve, Joint Base San Antonio, Texas

436th Airlift Wing, Dover Air Force Base

439th Airlift Wing, U.S. Air Force Reserve, Westover Air Reserve Base, Massachusetts

442nd Fighter Wing, U.S. Air Force Reserve, Whiteman Air Force Base Missouri

446th Airlift Wing, U.S. Air Force Reserve, Joint Base Lewis-McChord, Washington

46th Aviation Support Battalion, Joint Base Lewis-McChord, Washington

477th Fighter Group, Joint Base Elmendorf-Richardson, Alaska

479th Flying Training Group, Naval Air Station Pensacola, Florida

49th Wing, Holloman Air Force Base, New Mexico

4th Combat Aviation Brigade, Fort Carson, Colorado

4th Fighter Wing, Seymour Johnson Air Force Base, North Carolina

509th Bomb Wing, Whiteman Air Force Base, Missouri

512th Airlift Wing, Dover Air Force Base

552nd Air Control Wing, Tinker Air Force Base, Oklahoma

55th Electronic Combat Group, Davis-Monthan Air Force Base, Arizona

56th Fighter Wing, Luke Air Force Base, Arizona

57th Wing Maintenance Group, Nellis Air Force Base, Nevada

58th Special Operations Wing, Kirtland Air Force Base, New Mexico

62nd Airlift Wing, Joint Base Lewis-McChord, Washington

645th Aeronautical Systems Group, Wright-Patterson Air Force Base, Ohio

711th Human Performance Wing, Wright-Patterson Air Force Base, Ohio

80th Flying Training Wing, Sheppard Air Force Base, Texas	Air Force Life Cycle Management Center, Hill Air Force Base, Utah
82nd Training Wing, Sheppard Air Force Base, Texas	Air Force Lifecycle Management Center, Wright-Patterson Air Force Base, Ohio
916th Air Refueling Wing, Seymour Johnson Air Force Base, North Carolina	Air Force Maintenance Next, Kelly Field, Texas
931st Air Refueling Wing, U.S. Air Force Reserve, McConnell Air Force Base, Kansas	Air Force Program Executive Office Simulation, Wright-Patterson Air Force Base, Ohio
932nd Airlift Wing, U.S. Air Force Reserve, Scott Air Force Base, Illinois	Air Force Recruiting Service, Joint Base San Antonio, Texas
940th Air Refuel Wing, Beale Air Force Base, California	Air Force Research Lab, Wright-Patterson Air Force Base, Ohio
94th Airlift Wing, U.S. Air Force Reserve, Dobbins Air Reserve Base, Georgia	Air Force Reserve Command, Robins Air Force Base, Georgia
97th Air Mobility Wing, Altus Air Force Base, Oklahoma	Air Force Safety Center, Kirtland Air Force Base, New Mexico
9th Reconnaissance Wing, Beale Air Force Base, California	Air Force Safety School, Kirtland Air Force Base, New Mexico
Air Combat Command, Langley Air Force Base, Virginia	Air Force Sustainment Center, Tinker Air Force Base, Oklahoma
Air Education and Training Command, Joint Base San Antonio, Texas	Air Force Warfare Center, Nellis Air Force Base, Nevada
Air Force Acquisition Safety Systems Personnel, The Pentagon, Virginia	Air Force Weapons School, Nellis Air Force Base, Nevada
Air Force Agency for Modeling and Simulation, Orlando, Florida	Air Mobility Command, Scott Air Force Base, Illinois
Air Force Air National Guard, National Guard Bureau, The Pentagon, Virginia	Air National Guard Air Force Reserve Test Center, Davis-Monthan Air Force Base, Arizona
Air Force Aircrew Crisis Task Force, The Pentagon, Virginia	Alaska Army National Guard, Joint Base Elmendorf-Richardson, Alaska
Air Force Airworthiness Office, Wright-Patterson Air Force Base, Ohio	Army Aeromedical Research Lab, Fort Rucker, Alabama
Air Force Central Command, Shaw Air Force Base, South Carolina	Army Analytics Group Lab-Monterey, Monterey, California
Air Force Directorate of Plans and Integration Force Support Career Field Management and Readiness Division, The Pentagon, Virginia	Army Aviation and Missile Command, Huntsville, Alabama
Air Force Global Strike Command, Barksdale Air Force Base, Louisiana	Army Aviation Safety School, Fort Rucker, Alabama
Air Force Initial Flight Training, Pueblo, Colorado	Army Combat Readiness Center, Fort Rucker, Alabama
	Army Directorate of Training and Doctrine, Fort Rucker, Alabama
	Army Material Command, Huntsville, Alabama

Army National Guard, National Guard Bureau, The Pentagon, Virginia

Army Pacific, Fort Shafter, Hawaii

Army Program Executive Office Aviation, Huntsville, Alabama

Army Research Office, Durham, North Carolina

Army Training and Doctrine Command, Fort Eustis, Virginia

Aviator Training Next, Fort Rucker, Alabama

Center for Naval Aviation Technical Training Detachment Lakehurst, Joint Base McGuire-Dix-Lakehurst, New Jersey

Center for Naval Aviation Technical Training Unit Cherry Point, Marine Corps Air Station Cherry Point, North Carolina

Center for Naval Aviation Technical Training Unit Lemoore, Naval Air Station Lemoore, California

Center for Naval Aviation Technical Training, Naval Air Station Pensacola, Florida

Coast Guard Headquarters, Washington, District of Columbia

Corpus Christi Army Depot, Naval Air Station Corpus Christi, Texas

Defense Logistics Agency, Fort Belvoir, Virginia

Defense Safety Oversight Council, The Pentagon, Virginia

Detachment 24, Air Force Pilot Training Next, Joint Base San Antonio-Randolph, Texas

DoD Acquisition Environment, Safety, and Occupational Health Integrated Production Team, The Pentagon, Virginia

Electronic Attack Wing, Naval Air Station Whidbey Island, Washington

F-35 Joint Program Office, Arlington, Virginia

Fleet Logistics Support Squadron 1, Washington Naval Air Facility, Maryland

Fleet Logistics Support Squadron 30, Washington Naval Air Facility, Maryland

Fleet Logistics Support Squadron 53, Washington Naval Air Facility, Maryland

Fleet Readiness Center East Detachment, Joint Base McGuire-Dix-Lakehurst, New Jersey

Fleet Readiness Center East, Marine Corps Air Station New River, North Carolina

Helicopter Maritime Strike Squadron 41, Naval Air Station North Island, California

Helicopter Sea Combat Weapons School Atlantic, Naval Air Station Norfolk, Virginia

Joint Staff Force Structure, Resources, and Assessment Directorate (J8), Functional Capability Board, The Pentagon, Virginia

Marine Air Group 11, Marine Corps Air Station Miramar, California

Marine Air Group 13, Marine Corps Air Station Yuma, Arizona

Marine Air Group 14, Marine Corps Air Station Cherry Point, North Carolina

Marine Air Group 16, Marine Corps Air Station Miramar, California

Marine Air Group 24, Marine Corps Base Kaneohe Bay, Hawaii

Marine Air Group 29, Marine Corps Air Station New River, North Carolina

Marine Air Group 31, Marine Corps Air Station New River, North Carolina

Marine Air Group 49, Joint Base McGuire-Dix-Lakehurst, New Jersey

Marine Aviation Logistics Squadron 11, Marine Corps Air Station Miramar, California

Marine Aviation Weapons and Tactics Squadron 1, Marine Corps Air Station Yuma, Arizona

Marine Corps Forces Pacific, Camp H. M. Smith, Hawaii

Marine Wing Support Group 37, Marine Corps Air Station Miramar, California

Naval Air Facility Command, Washington Naval Air Facility, Maryland

Naval Air Force Reserve, San Diego, California	Office of the Assistant Secretary of the Navy (Research, Development, and Acquisition), The Pentagon, Virginia
Naval Air Forces, Naval Air Station North Island, California	Office of the Secretary of the Air Force, The Pentagon, Virginia
Naval Air Forces Pacific, Safety Office, Naval Air Station North Island, California	Office of the Secretary of the Army, The Pentagon, Virginia
Naval Air Systems Command, Naval Air Station Patuxent River, Maryland	Office of the Under Secretary of Defense, Acquisition and Sustainment, The Pentagon, Virginia
Naval Air Warfare Center Training Systems Division, Orlando, Florida	Office of the Under Secretary of Defense, Personnel and Readiness, The Pentagon, Virginia
Naval Aviation Enterprise Total Force Cross Functional Team, Naval Air Station North Island, California	Office of the Under Secretary of Defense, Research and Engineering, The Pentagon, Virginia
Naval Aviation Safety School, Naval Air Station Pensacola, Florida	Ogden Air Logistics Complex, Ogden Air Force Base, Utah
Naval Aviation Warfighting Development Center, Naval Air Station Fallon, Nevada	Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma
Naval Epidata Center, Portsmouth, Virginia	Pacific Air Forces, Joint Base Pearl Harbor-Hickam, Hawaii
Naval Postgraduate School, Monterey, California	Patrol and Reconnaissance Wing 10, Naval Air Station Whidbey Island, Washington
Naval Safety Center, Norfolk, Virginia	Patrol and Reconnaissance Wing 11, Naval Air Station Jacksonville, Florida
Navy Aeromedical Research Unit, Wright-Patterson Air Force Base, Ohio	Program Executive Office Simulation, Training, and Instrumentation, Orlando, Florida
Navy Physiological Episodes Action Team, Arlington Annex, Virginia	Program Management 202, Naval Air Station Patuxent River, Maryland
Navy Strike Fighter Wing Atlantic, Naval Air Station Oceana, Virginia	Program Management 209, Naval Air Station Patuxent River, Maryland
Navy Strike Fighter Wing Pacific, Naval Air Station Lemoore, California	Program Management 265, Naval Air Station Patuxent River, Maryland
Navy Training Air Wing 4, Naval Air Station Corpus Christi, Texas	Program Management 275, Naval Air Station Patuxent River, Maryland
Navy Training Air Wing 5, Naval Air Station Whiting Field, Florida	Program Management 299, Naval Air Station Patuxent River, Maryland
Navy Training Air Wing 6, Naval Air Station Pensacola, Florida	T-7A Program Office, Wright-Patterson Air Force Base, Ohio
Office of the Assistant Secretary of Defense for Acquisition, The Pentagon, Virginia	U.S. Army Alaska, Joint Base Elmendorf-Richardson, Alaska
Office of the Assistant Secretary of the Navy (Energy, Installations, and Environment), The Pentagon, Virginia	

U.S. Central Command, Tampa, Florida

Virtual Test and Training Center, Nellis Air Force Base, Nevada

Warner Robins Air Logistics Complex, Robins Air Force Base, Georgia

Western Army Air Training School, Arizona National Guard, Pinal Airpark, Red Rock, Arizona

Civilian and Academic Organizations

Air Methods (Helicopter Emergency Medical Services), Greenwood Village, Colorado

Airbus, Grand Prairie, Texas

American Airlines, Fort Worth, Texas

Applied Research Laboratory Head, Materials and Manufacturing Office, Penn State University, State College, Pennsylvania

Bell Helicopter, Fort Worth, Texas

Boeing Defense, St. Louis, Missouri

Center for Naval Analyses, Arlington, Virginia

Congressional Research Service, Washington, District of Columbia

Dr. Mary L. Cummings, Duke University, Durham, North Carolina

Dr. Scott Shappell, Embry-Riddle Aeronautical University, Daytona Beach, Florida

Dr. Thomas Morgan

Dr. Thomas Travis, Uniformed Services University of the Health Sciences, Bethesda, Maryland

DuPont Corporation, Wilmington, Delaware

Everett Smith, Spiegare Aviation Safety, Albuquerque, New Mexico

Federal Aviation Administration, Office of Accident Investigation and Prevention, Washington, District of Columbia

Helicopter Association International, Alexandria, Virginia

Institute for Defense Analyses (IDA), Alexandria, Virginia

JetBlue Airways, Queens, New York

Leonardo DRS, Arlington, Virginia

Lockheed Martin, Grand Prairie, Texas

RAND Corporation, Santa Monica, California

Textron Aviation Wichita Service Center, Wichita, Kansas

Truth Data Systems, Fort Worth, Texas

U.S. House of Representatives Armed Services Committee Washington, District of Columbia

U.S. Senate Armed Services Committee, Washington, District of Columbia

United Airlines, Chicago, Illinois

Conferences

Air Force Association Air Warfare Symposium “Multi-Domain Operations from Vision to Reality,” Orlando, Florida

Air Force Association Air, Space, and Cyber Conference, National Harbor, Maryland

Air National Guard Air Force Reserve Command Test Center Weapons and Tactics Conference, Tucson, Arizona

Human Factors Analysis and Classification System Educational Seminar, Las Vegas, Nevada

Interservice / Industry Training, Simulation and Education Conference, Orlando, Florida

Joint Service Safety Chiefs Conference, Fort Rucker, Alabama

Military Flight Training Conference, San Antonio, Texas

National Transportation Safety Board Symposium on Improving the Safety of Part 135 Safety Operations, Reston, Virginia

Weapons and Tactics Conference, U.S. Air Force, Nellis Air Force Base, Nevada

Appendix E:

BIBLIOGRAPHY

- AcqNotes. "JCIDS Process: Key Performance Parameter (KPP)." AcqNotes: Defense Acquisitions Made Easy, October 25, 2018. <http://acqnotes.com/acqnote/acquisitions/key-performance-parameter>.
- Acquisition Law Advisory Panel. "Streamlining Defense Acquisition Laws: Report of the Acquisition Law Advisory Panel to the United States Congress," 1993.
- Adams, Charlotte. "Military FOQA Next Step in Safety." Aviation Today, February 1, 2006. <https://www.aviationtoday.com/2006/02/01/military-foqa-next-step-in-safety/>.
- Air Combat Command. "Logistics Maintenance Performance Indicator Reporting Procedures." Air Combat Command Instruction 21-118. Langley AFB, VA: Air Combat Command, July 2, 2018.
- Air Force Research Lab. "AFRL Team Wins Laureate Award for Life Saving Aircraft Technology." AFRL, March 28, 2019. <https://afresearchlab.com/news/afrl-team-wins-laureate-award-for-life-saving-aircraft-technology/>.
- Altus Air Force Base Voluntary Protection Program. "EHR/JSA Control Numbers Worksheet," December 3, 2018.
- America's Navy. "Fact Files." Accessed October 8, 2019. <https://www.navy.mil/Resources/Fact-Files/?Search=united+states+navy>.
- Anderson, Lee, Pete Doty, Manuel Griego, Ken Timko, Brian Hermann, and John Colombi. "Solutions Analysis for Helicopter Brownout." Conference presentation presented at the 9th SE Conference, Wright-Patterson AFB, OH, October 2006.
- Andicochea, Chad T., Matthew E. Henriques, Joel Fulkerson, Susan Jay, Howard Chen, and Travis Deaton. "Elevated Environmental Carbon Dioxide Exposure Confounding Physiologic Events in Aviators?" *Military Medicine* 184, no. 11–12 (December 1, 2019): e863–67. <https://doi.org/10.1093/milmed/usz092>.
- Army Combat Readiness Center, Naval Safety Center, Headquarters, United States Marine Corps (Safety Division), United States Coast Guard Health and Safety Directorate, and Air Force Safety Center. "Policy on the Collection and Analysis of Mishap Human Factors Data." Memorandum of Agreement. Washington, DC: U.S. Department of Defense, May 10, 2005.
- Arnold, Kyle. "American Airlines Leads Pilot Hiring Surge As U.S. Airlines Set Traffic Records." *The Dallas Morning News*, December 16, 2019. <https://www.dallasnews.com/business/airlines/2019/12/16/pilot-hiring-still-surg-ing-as-us-airlines-set-traffic-records/>.
- Asch, Beth J. "Setting Military Compensation to Support Recruitment, Retention, and Performance." Santa Monica, CA: RAND Corporation, 2019. https://www.rand.org/pubs/research_reports/RR3197.html.
- Asch, Beth J., James Hosek, Michael G. Mattock, David Knapp, and Jennifer Kavanagh. "Workforce Downsizing and Restructuring in the Department of Defense: The Voluntary Separation Incentive Payment Program Versus Involuntary Separation." Santa Monica, CA: RAND Corporation, 2016. https://www.rand.org/pubs/research_reports/RR1540.html.
- Ausink, John. "The Military Pension, Compensation, and Retirement of U.S. Air Force Pilots." In *Advances in the Economics of Aging*, edited by David A. Wise, 83–114. Chicago, IL: University of Chicago Press, 1996. <http://www.nber.org/chapters/c7319>.

- Ausink, John A., Anthony D. Rosello, Timothy Marler, Michael Vasseur, Brynn Tannehill, Dara Gold, Kelly Klima, and Laura Kupe. "Fifth-Generation Aircraft Operational Training Infrastructure: Practices, Gaps, and Proposed Solutions." Santa Monica, CA: RAND Corporation, 2018.
- Barnett, Arnold. "Aviation Safety: A Whole New World?" *Transportation Science* 54, no. 1 (January 6, 2020). <https://doi.org/10.1287/trsc.2019.0937>.
- Baumann, Jason R. "Analysis of Navy Hornet Squadron Mishap Costs with Regard to Previously Flown Flight Hours." Master's thesis, Naval Postgraduate School, 2017.
- Beaman, J. J., S. Y. Wang, and G. Y. Masada. "Cycle Time Control of an Onboard Oxygen Generation System." *Aviation, Space, and Environmental Medicine* 58, no. 12 (December 1987): 1225–29.
- Beaubien, Jeffrey M., Sterling L. Wiggins, Lisa C. Lucia, and E. Webb Stacy. "How Can We Measure Learning? Let's Count the Ways!" In *Pushing the Training Envelope: Live-Virtual-Constructive*. Arlington, VA: National Training and Simulation Association, 2016.
- Beehler, Alex A. "Minimum Data Requirements for Mishap Reports." Official memorandum. Washington, DC: Office of the Under Secretary of Defense for Personnel and Readiness, May 22, 2008.
- Belinsky, Mark. "The Last Continuing Resolution Cost DoD \$19 Billion. Congress Is on Track to Do It Again." MOAA, December 23, 2019. [https://www.moaa.org/content/publications-and-media/news-articles/2019-news-articles/advocacy/the-last-continuing-resolution-cost-dod-\\$19-billion.-congress-is-on-track-to-do-it-again/](https://www.moaa.org/content/publications-and-media/news-articles/2019-news-articles/advocacy/the-last-continuing-resolution-cost-dod-$19-billion.-congress-is-on-track-to-do-it-again/).
- Bleffert-Schmidt, Anita. "The Blended Learning Experience of Community College Students." PhD thesis, Nova Southeastern University, 2011. <https://pdfs.semanticscholar.org/2e21/78a969e22d84c573b5ec5ece262eb5f2a265.pdf>.
- Bloom, Benjamin S., Max D. Engelhart, Edward J. Furst, Walker H. Hill, and David R. Krathwohl. *Taxonomy of Educational Objectives: The Classification of Educational Goals*. Handbook I. New York, NY: David McKay Company, Inc, 1956.
- Blume, Susanna V., and Lauren Fish. "A Brief History of Defense Budget Instability." Center for a New American Security, November 8, 2017. <https://www.cnas.org/publications/reports/a-brief-history-of-defense-budget-instability>.
- Bock, Laszlo. *Work Rules! Insights from inside Google That Will Transform How You Live and Lead*. 1st ed. New York, NY: Twelve, 2015.
- Brainerd, John. "Proactive Safety Programs: AFSOC's Latest Safety and Readiness Tools." Air Force Safety Center, September 3, 2019. <https://www.safety.af.mil/News/Article-Display/Article/1950023/proactive-safety-programs-afsocs-latest-safety-and-readiness-tools/>.
- Brauer, Craig S. "How Accurately Do Leading and Lagging Indicators Predict F-16 Aircraft Availability (AA)?" Thesis, Air University, 2016.
- Brobst, William D., Kelli L. Thompson, Lillianne P. Troeger, and Alan C. Brown. "Analyzing Flight and Simulator Training for Safety of Flight and Tactical Proficiency." Alexandria, VA: Center for Naval Analyses, October 2007.
- Budget Contents and Submission to Congress, 31 U.S.C. § 1105 (2018).
- Burke, Colin. "The Biggest Problems Facing Military Aviation, According to an Army Aviator." Task & Purpose, December 28, 2018. <https://taskandpurpose.com/thelongmarch/the-biggest-problems-facing-military-aviation-according-to-an-army-aviator>.
- Callander, Bruce D., and Adam J. Hebert. "The Pilot Shortage Abruptly Ends." *Air Force Magazine*, July 1, 2006. <https://www.airforcemag.com/article/0706shortage/>.
- Cancian, Mark F., and Seamus P. Daniels. "The State of Military Readiness: Is There a Crisis?" CSIS: Center for Strategic & International Studies, April 18, 2018. <https://www.csis.org/analysis/state-military-readiness-there-crisis>.
- Carey, Benedict. "Those With Multiple Tours of War Overseas Struggle at Home." *New York Times*. May 29, 2016, Online edition. <https://www.nytimes.com/2016/05/30/health/veterans-iraq-afghanistan-psychology-therapy.html>.

- Carl Levin and Howard P. ‘Buck’ McKeon National Defense Authorization Act for Fiscal Year 2015, Pub. L. No. 113–291, U.S. Statutes at Large 128, 3400 (2014).
- Carter, Ashton B. “Revision to Cost Thresholds for Accident Severity Classification.” Official memorandum. U.S. Department of Defense, October 5, 2009.
- Chappelle, Wayne, Amber Salinas, and Kent McDonald. “Psychological Health Screening of Remotely Piloted Aircraft (RPA) Operators and Supporting Units.” Bergen, Norway, 2011. <https://apps.dtic.mil/sti/pdfs/ADA582856.pdf>.
- Cheng, Shing Lai Angie, and Hoan Nguyen. “Controlling Human Errors in Naval Aviation.” CNA Research Memorandum. Alexandria, VA: CNA Analysis & Solutions, March 2019.
- Chief of Naval Operations. “Naval Aviation Policy for Aircraft Avionics Safety Systems.” OPNAVINST 13210.1B, Paragraph 5d. Washington, DC: Department of the Navy, April 15, 2014.
- Chu, Tony, and David A Doll. “Test and Evaluation of Slam Stick Temperature Sensors for the Monitoring of F/A-18 Cabin Environments,” n.d.
- Chu, Tony, David A. Doll, and Ciro M. Lopez. “Characterizing the Cabin Pressure Environments of F/A-18s in the Context of Physiological Episodes.” Arlington, VA: CNA Analysis & Solutions, March 2018.
- Church, Aaron M. U. “Gallery of Weapons: 2018 USAF Almanac.” *Air Force Magazine*, June 2018.
- . “Gallery of Weapons: 2019 USAF Almanac.” *Air Force Magazine*, June 2019.
- Clifford, Regina S., Joseph Callender II, and Norman T. O’Meara. “Maintenance Workforce Characteristics.” Logistics Management Institute, n.d.
- Conant, Joyce M. “MANPRINT Program Integrates Human Element.” U.S. Army, May 9, 2014. https://www.army.mil/article/125592/manprint_program_integrates_human_element.
- Cone, Allen. “Naval Teams Narrow Factors in Physiological Episodes on Jets.” UPI, April 2, 2019. <https://www.upi.com/Defense-News/2019/04/02/Naval-teams-narrow-factors-in-physiological-episodes-on-jets/2331554212413/>.
- Congressional Budget Office. “Reduce the Size of the Fighter Force by Retiring the F-22,” December 13, 2018. <https://www.cbo.gov/budget-options/2018/54765>.
- Contract Administration Functions, 48 CFR § 42.302 (1983). https://www.acquisition.gov/far/part-42#FAR_42_302.
- Copp, Tara. “Aviation in Crisis Military Times Crash Database, Fiscal 2011 through 2018.” *Military Times*, April 9, 2019. <https://www.militarytimes.com/news/your-military/2019/04/09/military-times-crash-database-fiscal-2011-through-2018/>.
- . “Marine Corps Aviation Mishaps on the Rise, up 80 Percent.” *Military Times*, April 8, 2018. <https://www.militarytimes.com/news/your-military/2018/04/08/marine-corps-aviation-mishaps-on-the-rise-up-80-percent/>.
- . “Navy’s Spike in Aviation Mishaps Is the Military’s Worst, up 82 Percent.” *Military Times*, April 8, 2018. <https://www.militarytimes.com/news/your-military/2018/04/08/navys-spike-in-aviation-mishaps-is-the-militarys-worst-up-82-percent/>.
- Cox, Matthew. “SOCOM Close to Eliminating the Danger of Brownout Landings for Helo Pilots.” *Military.com*, May 16, 2020. <https://www.military.com/daily-news/2020/05/16/socom-close-eliminating-danger-brownout-landings-helo-pilots.html>.
- Cragg, Clinton H. *Statement of Mr. Clinton H. Cragg NASA Engineering Safety Center Principal Engineer National Aeronautics and Space Administration before the Subcommittee on Tactical Air and Land Forces Committee on Armed Services United States House of Representatives*, 115th Cong., 2nd sess., 2018.
- Curtin, Neal P. “Military Aircraft: Cannibalizations Adversely Affect Personnel and Maintenance.” Testimony. U.S. General Accounting Office, May 22, 2001. <https://www.gao.gov/products/GAO-01-693T>.

- Cutler, Thomas, J. "Chaos at the Devil's Jaw." *Naval Institute Proceedings* 146/2/1, no. 405 (March 2020): 95.
- Daniels, Seamus P. "Assessing Navy Readiness Funding." Washington, DC: Center for Strategic and International Studies, November 1, 2017. http://defense360.csis.org/wp-content/uploads/2017/11/171101_Daniels_NavyReadiness.pdf.
- Daniels, Seamus P., and Todd Harrison. "What the Continuing Resolution Means for Defense Spending in FY 2018." *CSIS: Center for Strategic & International Studies* (blog), September 27, 2017. <https://www.csis.org/analysis/what-continuing-resolution-means-defense-spending-fy-2018>.
- Davis Institute for National Security and Foreign Policy. "U.S. Military Power." In *The 2019 Index of U.S. Military Strength*, edited by Dakota L. Wood, 309–457. Washington, DC: The Heritage Foundation, 2019. http://thf-graphics.s3.amazonaws.com/2018/2019%20Index%20of%20Military%20Strength/Section%20PDFs/2019_IndexOfUSMilitaryStrength_ASSESSMENT_POWER_ALL.pdf.
- Defense Acquisition University. "Functional Capabilities Boards." Defense Acquisition University. Accessed June 12, 2020. <https://www.dau.edu/cop/rqmt/Pages/Topics/Functional%20Capabilities%20Boards%20FCBs.aspx>.
- Defense Manpower Data Center. "DoD Personnel, Workforce Reports & Publications." Accessed June 15, 2020. https://www.dmdc.osd.mil/appj/dwp/dwp_reports.jsp.
- "Department of Defense Efficiency Initiatives Fiscal Year 2012 Budget Estimates." Office of the Under Secretary of Defense (Comptroller), February 18, 2011. https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2012/FY2012_Efficiency_Justification_Book.pdf.
- Dobbins, James, Michele A. Poole, Austin Long, and Benjamin Runkle. "After the War Nation-Building from FDR to George W. Bush." Santa Monica, CA: RAND Corporation, 2008. <https://www.rand.org/pubs/monographs/MG716.html>.
- Driessen, Grant A., and Megan S. Lynch. "The Budget Control Act: Frequently Asked Questions." CRS Report to Congress. Congressional Research Service, October 1, 2019. <https://www.everycrsreport.com/reports/R44874.html>.
- Duncan Hunter National Defense Authorization Act for Fiscal Year 2009, Pub. L. No. 110–417, U.S. Statutes at Large 122, 4486 (2008).
- During, A. M., and Paul Widish. "Naval Airport Infrastructure Safety." Official memorandum. Naval Safety Center, April 30, 2019.
- Eckstein, Megan. "Less Experienced Maintainers Contribute to Rise in Naval Aviation Mishaps." USNI News, June 22, 2018. <https://news.usni.org/2018/06/22/less-experienced-maintainers-contribute-rise-naval-aviation-mishaps>.
- . "Navy Taking Major Steps to Prevent Future Physiological Events in Jets." USNI News, May 2, 2019. <https://news.usni.org/2019/05/02/navy-taking-major-steps-to-prevent-future-physiological-episodes-in-jets>.
- Ellis, Claire. "Are VR Flight Simulators the Future of Pilot Training?" *Air Charter Service* (blog), September 10, 2019. <https://www.aircharterservice.com/about-us/news-features/blog/are-vr-flight-simulators-the-future-of-pilot-training>.
- European Commission Directorate-General for Mobility and Transport. "Statistical Data, Data Analysis and Recommendation on Collection of Data in the Field of General Aviation in Europe: Final Report." Brussels, Belgium: European Commission Directorate-General for Mobility and Transport, 2015. <https://ec.europa.eu/transport/sites/transport/files/modes/air/studies/doc/2015-12-analysis-and-recommendation-on-collection-of-data-in-the-field-of-general-aviation-in-europe.pdf>.
- Farrell, Jennifer, and Andrew Klien. "Air Force Life Cycle Management Center Brief to NCMAS." September 12, 2019.
- Fear, Nicola T., Margaret Jones, Dominic Murphy, Lisa Hull, Amy C. Iversen, Bolaji Coker, Louise Machell, et al. "What Are the Consequences of Deployment to Iraq and Afghanistan on the Mental Health of the UK Armed Forces? A Cohort Study." *The Lancet* 375, no. 9728 (May 2010): 1783–97. [https://doi.org/10.1016/S0140-6736\(10\)60672-1](https://doi.org/10.1016/S0140-6736(10)60672-1).
- Feest, Gregory A. "Air Force Guidance Memorandum to AFI 91-202, the US Air Force Mishap Prevention Program." Official memorandum. Washington, DC: Department of the Air Force. Safety, July 11, 2012.

- “Force Management Questions and Answers.” United States Air Force, December 11, 2013. <https://www.af.mil/Portals/1/documents/news/ForceManagementQAs.pdf>.
- Freudenberger, Herbert J. “Staff Burn-Out.” *Journal of Social Issues* 30, no. 1 (January 1974): 159–65. <https://doi.org/10.1111/j.1540-4560.1974.tb00706.x>.
- Fuzy, Anna. “A Quantitative Analysis of Aviation Maintenance SRB Effectiveness.” Master’s thesis, Naval Postgraduate School, 2019.
- Gallagher, Sean. “Fighting Falcon Puts off Retirement: F-16 to Fly for USAF through 2048.” *Ars Technica*, April 13, 2017.
- Gates, Susan M. “Shining a Spotlight on the Defense Acquisition Workforce — Again.” Santa Monica, CA: RAND Corporation, 2009. https://www.rand.org/pubs/occasional_papers/OP266.html.
- Gates, Susan M., Edward G. Keating, Adria D. Jewell, Lindsay Daugherty, Bryan Tysinger, Albert A. Robbert, Ralph Masi, et al. “The Defense Acquisition Workforce: An Analysis of Personnel Trends Relevant to Policy, 1993-2006.” Santa Monica, CA: RAND Corporation, 2008. https://www.rand.org/pubs/technical_reports/TR572.html.
- Gates, Susan M., Brian Phillips, Michael H. Powell, Elizabeth Roth, and Joyce S. Marks. “Analyses of the Department of Defense Acquisition Workforce: Update to Methods and Results through FY 2017.” Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2492.html.
- Gates, Susan M., Elizabeth Roth, Sinduja Srinivasan, and Lindsay Daugherty. “Analyses of the Department of Defense Acquisition Workforce: Update to Methods and Results through FY 2011.” Santa Monica, CA: RAND Corporation, 2013. https://www.rand.org/pubs/research_reports/RR110.html.
- Gebicke, Mark E. “Military Pilots: Observations on Current Issues.” Testimony. Washington, DC: U.S. General Accounting Office, March 4, 1999. <https://www.govinfo.gov/content/pkg/GAOREPORTS-T-NSIAD-99-102/pdf/GAOREPORTS-T-NSIAD-99-102.pdf>.
- Gibb, G.D., T. Nontasak, D.L. Dolgin, and W.R. Helm. “Factors That Influence Career Motivation in the Fighter Community.” Naval Aerospace Medical Research Laboratory, January 1987.
- Giffi, Craig, Jennifer McNelly, Ben Dollar, Gardner Carrick, Michelle Drew, and Bharath Gangula. “The Skills Gap in U.S. Manufacturing: 2015 and Beyond.” New York, NY: Deloitte and The Manufacturing Institute, 2015.
- Gigova, Radina. “Who Vladimir Putin Thinks Will Rule the World.” CNN.com, September 2, 2017. <https://www.cnn.com/2017/09/01/world/putin-artificial-intelligence-will-rule-world/index.html>.
- Global Security. “U.S. Military Aircraft,” n.d. <https://www.globalsecurity.org/military/systems/aircraft/index.html>.
- Grand View Research. “Military Simulation & Virtual Training Market Size, Share & Trends Analysis Report By Platform Type (Flight, Vehicle, Battlefield, Virtual Boot Camp), By Application (Ground, Air, Naval), and Segment Forecasts, 2018 - 2025.” San Francisco, CA: Grand View Research, December 2018.
- Headquarters Department of the Army. “The Army Safety Program.” Army Regulation 385-10. Washington, DC: Headquarters Department of the Army, June 14, 2010. https://www.wbdg.org/FFC/ARMYCOE/ARMYCRIT/ar385_10.pdf.
- Heubel, Eric, and Adi Zolotov. “Physiological Episode Digital Pilot: Interim Report.” Alexandria, VA: Center for Naval Analyses, June 2018.
- Hoar, Margaux. “Overcoming Pathologies in Military Organizations.” Arlington, VA: Center for Naval Analyses, February 4, 2019. https://www.cna.org/CNA_files/PDF/DSI-2019-U-019362-Final.pdf.
- Holmes, Mike. “Rebuilding the Forge: Reshaping How the Air Force Trains Fighter Aviators.” War on the Rocks, January 28, 2019. <https://warontherocks.com/2019/01/rebuilding-the-forge-reshaping-how-the-air-force-trains-fighter-aviators/>.

- Hopkins, Joseph D., William E. Nelson, David S. Burch, James N. Cantrell, Benjamin A. Clapp, Charles D. Clinton, Michael T. Dietrich, et al. "T-6A Life Support System Performance and Breathing Gas Quality Evaluation." Technical Report. Wright-Patterson AFB, OH: Air Force Research Laboratory, August 2018.
- Horowitz, Stanley A., Colin P. Hammon, and Paul R. Palmer. "Relating Flying-Hour Activity to the Performance of Aircrews." Alexandria, VA: Institute for Defense Analyses, December 1987.
- Hosek, James. "How Is Deployment to Iraq and Afghanistan Affecting U.S. Service Members and Their Families? : An Overview of Early RAND Research on the Topic." Santa Monica, CA: RAND Corporation, 2011. https://www.rand.org/content/dam/rand/pubs/occasional_papers/2011/RAND_OP316.pdf.
- Hosek, James, Michael G. Mattock, and Beth J. Asch. "A Wage Differential Approach to Managing Special and Incentive Pay." Santa Monica, CA: RAND Corporation, 2019. <https://doi.org/10.7249/RR2101>.
- Huff, Jared, Mikhail Smirnov, Gregory Schell, and James Grefer. "Estimating the Retention Effects of Continuation Pay." Center for Naval Analyses, April 2018.
- Huntington, Samuel P. *The Soldier and the State: The Theory and Politics of Civil-Military Relations*. Cambridge, MA: Belknap Press, 1957.
- Ike Skelton National Defense Authorization Act for Fiscal Year 2011, Pub. L. No. 111–383, U.S. Statutes at Large 124, 4237 (2011).
- Imhoff, Patrick J. "The Impact of Commercial Aviation on Naval Aviation." Master's Thesis. Monterey, CA: Naval Postgraduate School, June 2016.
- Interagency Task Force in Fulfillment of Executive Order 13806. "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States: Report to President Donald J. Trump." Washington, DC: Office of the Under Secretary of Defense for Acquisition and Sustainment, Office of the Deputy Assistant Secretary of Defense for Industrial Policy, September 2018. <https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/ASSESSING-AND-STRENGTHENING-THE-MANUFACTURING-AND%20DEFENSE-INDUSTRIAL-BASE-AND-SUPPLY-CHAIN-RESILIENCY.PDF>.
- Jane's. "Inventories." Accessed August 24, 2020. <https://janes-ihs-com.pentagonlibrary.idm.oclc.org/Inventory>.
- John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115–232, U.S. Statutes at Large 132, 1797 (2018).
- John, Sarah K., James M. Bishop, Laura A. Hildreth, Jamie M. Lindly, W. Patrick Luan, Madeline Minneci, and George M. Prugh. "Analysis of DoD Accession Alternatives for Military Physicians: Readiness Value and Cost." Alexandria, VA: Institute for Defense Analyses, November 2019.
- John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109–364, U.S. Statutes at Large 120, 2083 (2006). <https://www.govinfo.gov/app/details/PLAW-109publ364>.
- Johnson, Marie. "Voluntary Protection Program (VPP) Worksite Representative Training." Presentation, Altus Air Force Base, June 2, 2020.
- Joint Staff J8 Force Structure, Resources, and Assessment Directorate. "Joint Capabilities Integration and Development System (JCIDS) Manual." U.S. Department of Defense, August 31, 2018. <https://www.dau.edu/cop/rqmt/DAU%20Sponsored%20Documents/Manual%20-%20JCIDS,%2031%20Aug%202018.pdf>.
- Judy, Aaron D. "A Study of Flight Simulation Training Time, Aircraft Training Time, and Pilot Competence as Measured by the Naval Standard Score." PhD thesis, Southeastern University, 2018.
- Kelso, Eric W. "Improving the Efficiency of Aviation Retention Bonuses through the Use of Market Mechanisms." Thesis. Naval Postgraduate School, June 2014.
- Kiernan, Kristine. "Calculating the Cost of Pilot Turnover." *Journal of Aviation/Aerospace Education & Research*, 2018. <https://doi.org/10.15394/jaer.2018.1737>.

- Kline, Anna, Maria Falca-Dodson, Bradley Sussner, Donald S. Ciccone, Helena Chandler, Lanora Callahan, and Miklos Losonczy. "Effects of Repeated Deployment to Iraq and Afghanistan on the Health of New Jersey Army National Guard Troops: Implications for Military Readiness." *American Journal of Public Health* 100, no. 2 (February 2010): 276–83. <https://doi.org/10.2105/AJPH.2009.162925>.
- Koglbauer, Ioana, Michael Riesel, and Reinhard Branstingl. "Positive Effects of Combined Aircraft and Simulator Training on the Acquisition of Visual Flight Skills." *Cognition, Brain, Behavior. An Interdisciplinary Journal* XX, no. 4 (December 2016): 309–18.
- Le, Damien. "An Analysis of the Relationship of Flight Hours and Naval Rotary Wing Aviation Mishaps." Master's thesis, Naval Postgraduate School, 2017.
- Leiter, M. P., and Christina Maslach. "A Mediation Model of Job Burnout." In *Research Companion to Organizational Health Psychology*, by Alexander-Stamatios Antoniou and Cary Cooper, 544–64. New Horizons in Management. Cheltenham, UK: Edward Elgar Publishing, 2005. <https://doi.org/10.4337/9781845423308>.
- Lippert, Michael T. "Life or Death in 250 Milliseconds." *U.S. Naval Institute Proceedings* 143, no. 1/1367 (January 2017). <https://www.usni.org/magazines/proceedings/2017/january/life-or-death-250-milliseconds#footnotes>.
- Lockheed Martin. "Saving the Good Guys with Auto-GCAS Technology," June 14, 2020. <https://www.lockheedmartin.com/en-us/products/autogcas.html>.
- Losey, Stephen. "Aircraft Mission-Capable Rates Hit New Low in Air Force, Despite Efforts to Improve." *Air Force Times*, July 26, 2019. <https://www.airforcetimes.com/news/your-air-force/2019/07/26/aircraft-mission-capable-rates-hit-new-low-in-air-force-despite-efforts-to-improve/>.
- . "Breathing Easier: After Years of T-6 Hypoxia Scares, the Air Force Thinks It Has the Fix." *Air Force Times*, February 11, 2019.
- Lytell, Maria C., Kenneth Kuhn, Abigail Haddad, Jefferson P. Marquis, Nelson Lim, Kimberly Curry Hall, Robert Stewart, and Jennie W. Wenger. "Force Drawdowns and Demographic Diversity: Investigating the Impact of Force Reductions on the Demographic Diversity of the U.S. Military." Santa Monica, CA: RAND Corporation, 2015. https://www.rand.org/pubs/research_reports/RR1008.html.
- Maddox, Todd. "Training for Retention in Virtual Reality and Computer-Based Platforms." *Training Industry*, November 14, 2017. <https://trainingindustry.com/articles/learning-technologies/training-for-retention-in-virtual-reality-and-computer-based-platforms/>.
- Mahan, Thomas F., Danny Nelms, and Christopher Ryan Bearden. "Work Institute 2018 Retention Report: Truth Trends in Turnover." Franklin, TN: Work Institute, April 30, 2018.
- Malmin, O. Kim, and Lyle A. Reibling. "The Contribution of Aircraft Simulators to the Training and Readiness of Operational Navy Aircraft Squadrons." Alexandria, VA: Center for Naval Analyses, 1995.
- Manacapilli, Thomas, Alexis Bailey, Christopher Beighley, Bart E. Bennett, and Aimee Bower. "Finding the Balance between Schoolhouse and On-The-Job Training." Santa Monica, CA: RAND Corporation, 2007. <https://www.rand.org/pubs/monographs/MG555.html>.
- Management of Deployments of Members and Measurement and Data Collection of Unit Operating and Personnel Tempo, 10 U.S.C. § 991 (2018).
- . "Secretary of Defense Jim Mattis House Armed Services Committee Written Statement for the Record Tuesday, February 6, 2018." U.S. Congress. House of Representatives. Armed Services Committee, February 6, 2018. <https://docs.house.gov/meetings/AS/AS00/20180206/106833/HHRG-115-AS00-Wstate-MattisJ-20180206.pdf>.
- . "Summary of the 2018 National Defense Strategy." Washington, DC: U.S. Department of Defense, 2018. <https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>.

- Mattis, James. "NDS Implementation: Mission Capability of Critical Aviation Platforms." Official memorandum. Washington, DC: U.S. Department of Defense, September 17, 2018. <https://assets.documentcloud.org/documents/4999250/390505410-180917-Mattis-Memo.pdf>.
- Mattock, Michael G., and Beth J. Asch. "An Initial Look at the U.S. Air Force Aviation Professional Pay Proposal." Santa Monica, CA: RAND Corporation, 2019. <https://doi.org/10.7249/PE309>.
- Mattock, Michael G., Beth J. Asch, James R. Hosek, and Michael Boito. "The Relative Cost-Effectiveness of Retaining Versus Accessing Air Force Pilots." Santa Monica, CA: RAND Corporation, 2019. https://www.rand.org/pubs/research_reports/RR2415.html.
- Mattock, Michael G., James R. Hosek, Beth J. Asch, and Rita Karam. "Retaining U.S. Air Force Pilots When the Civilian Demand for Pilots Is Growing." Santa Monica, CA: RAND Corporation, 2016. https://www.rand.org/pubs/research_reports/RR1455.html.
- Maucione, Scott. "DoD Ready, but Not Happy about Another Continuing Resolution." *Federal News Network*, December 21, 2017. <https://federalnewsnetwork.com/defense/2017/12/dod-ready-but-not-happy-for-shutdown-or-cr/>.
- Maurino, Dan. "Threat and Error Management (TEM)." Vancouver, BC: International Civil Aviation Organization, 2005. <https://www.skybrary.aero/bookshelf/books/515.pdf>.
- May, Stephen. "F/A-18 and E/A-18 Physiological Episodes." Presentation, August 15, 2019.
- Meadows, Sarah O., Stephanie Brooks Holliday, Wing Yi Chan, Stephani L. Wrabel, Margaret Tankard, Dana Schultz, Christopher M. Busque, Felix Knutson, Leslie Adrienne Payne, and Laura L. Miller. "Air Force Morale, Welfare, and Recreation Programs and Services: Contribution to Airman and Family Resilience and Readiness." Santa Monica, CA: RAND Corporation, 2019. https://www.rand.org/pubs/research_reports/RR2670.html.
- Metrolis, Charles E. "Divergent Stability: Managing the USAF Pilot Inventory." Thesis, Air University, 2003. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.909.6357&rep=rep1&type=pdf>.
- MIGFLUG: Be a Fighter Pilot for a Day. "Fifth Generation Fighter Jets – a Chinese, Russian, Indian and US Arms Race." Accessed August 20, 2020. <https://migflug.com/jetflights/fifth-generation-fighter-jets-a-chinese-russian-and-us-arms-race/>.
- Military.com. "Military Aircraft." Accessed August 3, 2020. <https://www.military.com/equipment/military-aircraft>.
- "Military Aviation Safety." CRS Report for Congress. Washington, DC: Congressional Research Service, November 25, 2003.
- "Military Flight Operations Quality Assurance (MFOQA)." *Flying Safety Magazine*, May 2007. <https://www.safety.af.mil/Portals/71/documents/Magazines/FSM/FSM%20May%2007.pdf?ver=2016-08-19-145212-450>.
- Military Leadership Diversity Commission. "Reenlistment Rates across the Services by Gender and Race/Ethnicity." Arlington, VA: Military Leadership Diversity Commission, April 2010.
- "Mishap Reduction Initiatives." Program Budget Decision 705. Washington, DC: U.S. Department of Defense, December 2004.
- Modesto, Maurizio. "Beating Brownout." *Joint Air Power Competence Centre Journal*, no. 24 (2017): 68–73.
- Murcia-Lopez, Maria, and Anthony Steed. "A Comparison of Virtual and Physical Training Transfer of Bimanual Assembly Tasks." *IEEE Transactions on Visualization and Computer Graphics* 24, no. 4 (April 2018): 1574–83. <https://doi.org/10.1109/TVCG.2018.2793638>.
- Myers, Meghann. "The Pilot Shortage: The Army's Struggle to Fix Its Aviation Problem." *Army Times*, August 7, 2019. <https://www.armytimes.com/news/your-army/2019/08/07/the-pilot-shortage-the-armys-struggle-to-fix-its-aviation-problems/>.
- NASA Engineering and Safety Center. "NASA Engineering and Safety Center Technical Assessment Report Volumes I and II: F/A-18 and E/A-18 Fleet Physiological Episodes." Washington, DC: NASA, 09/14/2017.

- National Civil Aviation Review Commission. "Avoiding Aviation Gridlock and Reducing the Accident Rate: A Consensus for Change." Commission report. National Civil Aviation Review Commission, December 1997. <https://www.enotrans.org/wp-content/uploads/membersOnly-Mineta-Commission-Study1.pdf>.
- National Defense Authorization Act for Fiscal Year 2000, Pub. L. No. 106–65, U.S. Statutes at Large 113, 637 (1999). <https://www.energy.gov/sites/prod/files/gcprod/documents/NNSAAAct.pdf>.
- National Defense Authorization Act for Fiscal Year 2008, Pub. L. No. 110–181, U.S. Statutes at Large 122, 167 (2008).
- National Defense Authorization Act for Fiscal Year 2010, Pub. L. No. 111–84, U.S. Statutes at Large 123, 2353 (2009).
- National Defense Authorization Act for Fiscal Year 2012, Pub. L. No. 112–81, U.S. Statutes at Large 125, 1450 (2011).
- National Defense Authorization Act for Fiscal Year 2013, Pub. L. No. 112–239, U.S. Statutes at Large 126, 1777 (2013).
- National Defense Authorization Act for Fiscal Year 2014, Pub. L. No. 113–66, U.S. Statutes at Large 127, 781 (2013).
- National Defense Authorization Act for Fiscal Year 2016, Pub. L. No. 114–92, U.S. Statutes at Large 129, 839 (2015).
- National Defense Authorization Act for Fiscal Year 2017, Pub. L. No. 114–328, U.S. Statutes at Large 130, 2158 (2016).
- National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115–91, U.S. Statutes at Large 131, 1422 (2017).
- National Safety Council. "Take Safety to the Next Level." NSC. Accessed October 8, 2020. <https://www.nsc.org/work-safety/tools-resources/safety-for-business/ask-us>.
- Naval Air Systems Command. "NAVAIR Zeroes in on Causes, Solutions for Physiological Episodes." NAVAIR, April 1, 2019. <https://www.navair.navy.mil/news/NAVAIR-zeroes-causes-solutions-physiological-episodes/Thu-04182019-0652>.
- Naval Air Systems Command PMA209. "Collision Avoidance Solutions." NAVAIR, n.d. <https://www.navair.navy.mil/product/Collision-Avoidance-Solutions-CAS>.
- Naval Safety Center. "Current Mishap Definitions and Reporting Criteria." Accessed November 3, 2020. <https://navalsafetycenter.navy.mil/Resources/Current-Mishap-Definitions/>.
- Navy League of the United States. "2018 Almanac." *Seapower*, January 2018. http://www.seapower-digital.com/seapower/january_2018/MobilePagedArticle.action?articleId=1297096.
- Niemeyer, Lucian. *Statement of Honorable Lucian Niemeyer, Assistant Secretary of Defense (Energy, Installations and Environment) Before the House Committee on Appropriations Subcommittee on Military Construction, Veterans Affairs and Related Agencies Fiscal Year 2019 Department of Defense Budget Request for Energy, Installations and Environment*, 116th Cong., 1st sess., 2018. <https://www.acq.osd.mil/eie/Downloads/Testimony/FY19%20EI&E%20Posture%20Statement%20-%20HAC-M.pdf>.
- Niemeyer, Lucian, Charles G. Chiarotte, and Ricky L. Williamson. *Statement of the Honorable Lucian Niemeyer Department of the Navy Acting Assistant Secretary of the Navy (Energy, Installations and Environment); Lieutenant General Charles G. Chiarotti, Deputy Commandant, Installations and Logistics; Vice Admiral Ricky L. Williamson Deputy Chief of Naval Operations for Fleet Readiness and Logistics before the House Subcommittee on Military Construction, Veterans Affairs, and Related Agencies of the Committee on Appropriations*, 116th Cong., 2nd sess., 2020, HHRG-116-AP18-W.
- Norquist, David L. "Safety and Occupational Health Policy and Oversight Functions." Official memorandum. Washington, DC: Office of the Deputy Secretary of Defense, April 10, 2019.
- Oberman, Albert, Robert E. Mitchell, and Ashton Graybiel. "Thousand Aviator Study: Methodology." United States Naval School of Aviation Medicine; United States Public Health Service; National Aeronautics and Space Administration, July 1965.
- Office of the Under Secretary of Defense for Personnel and Readiness. "Accident Reduction History," October 2020.

- . “Aviation Hazard Identification and Risk Assessment Programs (AHIRAPS) [Change 2 Effective June 10, 2019].” DoD Instruction 6055.19. Washington, DC: U.S. Department of Defense, April 11, 2017. <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/605519p.pdf?ver=2019-06-10-105620-087>.
- . “Report to Congress on Initiatives for Mitigating Military Pilot Shortfalls.” Office of the Under Secretary of Defense for Personnel and Readiness, January 16, 2019. <https://prhome.defense.gov/Portals/52/Documents/Report%20to%20Congress%20on%20Initiatives%20for%20Mitigating%20Military%20Pilot%20Shortfalls%20cleared%20for%20public%20release.pdf>.
- Office of the Under Secretary of Defense for Personnel and Readiness, Personnel Risk and Resiliency, Commander, U.S. Army Combat Readiness Center, Commander, U.S. Naval Safety Center, and Commander, U.S. Air Force Safety Center. “Department of Defense Safety & Occupational Health (SOH) Data Sharing.” Memorandum of Understanding, August 7, 2017.
- Owens, Katherine. “Next-Gen Biometric Sensors Monitor Pilot Distress.” Defense Systems, July 18, 2017. <https://defensesystems.com/articles/2017/07/cw/biometrics-army.aspx>.
- Parrish, Karen. “Congress Probes Military Pilot Shortage.” U.S. Department of Defense, March 30, 2017. <https://www.defense.gov/Explore/News/Article/Article/1135200/congress-probes-military-pilot-shortage/>.
- Parsons, Dan. “US Army Safety Chief: No Link between Flight Hours, Fatal Mishaps.” *Rotor and Wing International Magazine*, June 14, 2018. <https://www.rotorandwing.com/2018/06/14/us-army-safety-chief-no-link-flight-hours-fatal-mishaps/>.
- Pawlyk, Oriana. “Aging B-1 Bomber May Soon Have to Restrict the Way It Flies.” Military.com, December 8, 2019. <https://www.military.com/daily-news/2019/12/08/aging-b-1-bomber-may-soon-have-restrict-way-it-flies.html>.
- . “F-35A Ready for Action in the Pacific If Necessary, SecAF Says.” Military.com. Accessed July 7, 2020. <https://www.military.com/dodbuzz/2017/08/25/f-35a-ready-action-pacific-necessary-secaf-says>.
- . “Rise of the Machines: AI Algorithm Beats F-16 Pilot in Dogfight.” Military.com, August 24, 2020. <https://www.military.com/daily-news/2020/08/24/f-16-pilot-just-lost-algorithm-dogfight.html>.
- . “The Air Force Is Calling Off Its ‘Fly-Only’ Track Experiment.” Military.com, March 2, 2020. <https://www.military.com/daily-news/2020/03/02/air-force-calling-its-fly-only-track-experiment.html>.
- . “The Air Force Is Dropping Mattis’ 80% Aircraft Readiness Goal.” Military.com, May 8, 2020. <https://www.military.com/daily-news/2020/05/08/air-force-dropping-mattis-80-aircraft-readiness-goal.html>.
- Pendley, Scotty A. “Factors and Interactions That Affect Air Force C-17 Aircraft Mission Capable Rates.” Thesis. Air Force Institute of Technology, August 2006.
- Pneuman, Robert W. “Charting a New Path: Modernizing the U.S. Air Force Fighter Pilot’s Career Development.” Thesis. Air University, 2015.
- Pope, Talon M. “A Cost-Benefit Analysis of Pilot Training Next.” Master’s thesis, Air Force Institute of Technology, 2019.
- Potochney, Peter. *Statement of Mr. Peter Potochney, Acting Assistant Secretary of Defense (Energy, Installations, and Environment), Before the Senate Appropriations Committee Subcommittee on Military Construction, Veterans Affairs, and Related Agencies. Fiscal Year 2018 Department of Defense Budget Request for Energy, Installations, and Environment*, 115th Cong., 1st sess., 2017.
- Povenmire, H. Kingsley, and Stanley N. Roscoe. “The Incremental Transfer Effectiveness of a Ground-Based General Aviation Trainer.” Savoy, IL: Aviation Research Laboratory Institute of Aviation, 1972. <https://apps.dtic.mil/sti/pdfs/AD0754213.pdf>.
- Price, Kevin. “Automatic Collision Avoidance Technology (ACAT) & Autonomy.” Powerpoint presentation presented at the Air Force Research Laboratory, January 14, 2020.

- Randolph, Randy, and Defense Science Board, Office of the Under Secretary of Defense (Acquisition & Technology). "Report of the Defense Science Board Task Force on Aviation Safety." Washington, DC: Defense Science Board, Office of the Under Secretary of Defense (Acquisition & Technology), 1997. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a327417.pdf>.
- Reason, James T. "Human Error: Models and Management." *BMJ (Clinical Research Ed.)* 320, no. 7237 (March 18, 2000): 768–70. <https://doi.org/10.1136/bmj.320.7237.768>.
- . *Human Error*. Cambridge: Cambridge Univ. Press, 1990.
- Reisman, Ron. "A Brief Introduction to the Art of Flight Simulation." In *Virtuelle Welten*, edited by Gottfried Hattinger, Morgan Russel, Christine Schöpf, and Peter Weibel, Band II:159–70. Ars Electronica. Linz, Austria: Veritas-Verlag, 1990.
- "Report to Congress: Out of Breath: Military Aircraft Oxygen Issues." *USNI News*, June 28, 2017. <https://news.usni.org/2017/06/28/report-congress-breath-military-aircraft-oxygen-issues>.
- Richardson, Rebecca. "NASA Begins Flights to Advance Military Research on Pilot Breathing." NASA, April 2, 2020. https://www.nasa.gov/centers/armstrong/features/pilot_breathing_flight_testing_begins.html.
- Roof, Robert S. "Naval Aviation's Use of Simulators in the Operational Training Environment: A Cost Analysis Perspective." Master's Thesis, Naval Postgraduate School, 1996. <https://core.ac.uk/download/pdf/36724861.pdf>.
- Roper, William B. "Anthropometric Design Specifications for the Department of the United States Air Force (DAF) Acquisitions Programs." Official memorandum. afgm2020-63-148-01. Washington, DC: Office of the Assistant Secretary, Department of the Air Force, August 6, 2020. https://static.e-publishing.af.mil/production/1/saf_aq/publication/afgm2020-63-148-01/afgm2020-63-148-01.pdf.
- Rosello, Anthony, James Bigelow, Maya Buenaventura, Christopher Carson, Rebecca Herman, Michael McGee, Jaime Hastings, et al. "Can the Air Force and Airlines Collaborate for Mutual Benefit? An Exploration of Pilot and Maintenance Workforce Options." Santa Monica, CA: RAND Corporation, 2016. <https://doi.org/10.7249/RR1412>.
- Rumsfeld, Donald. "Military Flight Operations Quality Assurance Process Implementation." Official memorandum. Washington, DC: U.S. Department of Defense, October 11, 2005.
- . "Reducing Preventable Accidents." Official memorandum. Washington, DC: U.S. Department of Defense, May 19, 2003. <https://joint.safety.army.mil/ResourceDocs/SecDef-Reducing-Preventable-Accidents-Memo-051903.pdf>.
- Saturno, James V., and Brendan W. McGarry. "Defense Primer: Defense Appropriations Process." Washington, DC: Congressional Research Service, December 23, 2019. <https://crsreports.congress.gov/product/pdf/IF/IF10514>.
- Schank, John F., Harry J. Thie, Clifford M. Graf II, Joseph Beel, and Jerry M. Sollinger. "Finding the Right Balance: Simulator and Live Training for Navy Units." Santa Monica, CA: RAND Corporation, 2002. https://www.rand.org/pubs/monograph_reports/MR1441.html.
- Schulker, David, and Tara L. Terry. "Evaluating the Impact of a Total Force Service Commitment Policy on Air Force Pilot Manning: An Exploratory Application of Inventory Modeling." Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2400.html.
- Schulte, Jennifer, and Shannon Desrosiers. "Prior Literature on the Propensity of Women to Become Pilots." Center for Naval Analyses, June 2016.
- Schwartz, Moshe, Kathryn A Francis, and Charles V O'Connor. "The Department of Defense Acquisition Workforce: Background, Analysis, and Questions for Congress." Washington, DC: Congressional Research Service, July 29, 2016.
- Secretary of the Air Force Public Affairs. "Aircraft and Equipment Maintenance Management." Air Force Instruction 21-101. Washington, DC: Secretary of the Air Force, January 16, 2020. https://static.e-publishing.af.mil/production/1/af_a4/publication/afi21-101/afi21-101.pdf.

- . “New Acquisition Guidance Leverages Diverse Talent Pool for Competitive Edge.” U.S. Air Force, August 7, 2020. <https://www.af.mil/News/Article-Display/Article/2304220/new-acquisition-guidance-leverages-diverse-talent-pool-for-competitive-edge/>.
- Secretary of the Navy. “Department of the Navy Safety Program.” Secretary of the Navy Instruction 5100.10K. Washington, DC, May 12, 2015. <https://www.secnav.navy.mil/doni/Directives/05000%20General%20Management%20Security%20and%20Safety%20Services/05-100%20Safety%20and%20Occupational%20Health%20Services/5100.10K.pdf>.
- Shanahan, Patrick M. “Realignment of Safety and Occupational Health Policy and Oversight Functions in the Office of the Secretary of Defense.” Official memorandum. Washington, DC: Office of the Deputy Secretary of Defense, July 16, 2018.
- Simpkiss, Bridget. “Human Systems Integration Requirements Pocket Guide.” Falls Church, VA: Air Force Human Systems Integration Office, 2009.
- Sleight, Deborah Alpert. “A Developmental History of Training in the United States and Europe.” MSU, December 1993. <https://msu.edu/~sleightd/trainhst.html>.
- Smallwood, Calvin R. “Consequences of Separation Incentives: The Effects of VSP and TERA on the Marine Corps Aviation Community.” Master’s thesis, Naval Postgraduate School, 2019.
- SMCX: DoD Safety Management Center of Excellence. “SMCX News.” Accessed November 4, 2020. <https://www.smscx.org/>.
- Smith, V Reid, and William D. Brobst. “Air Wing Training Study: Analyzing Reduced Flight Hours, Safety of Flight and Tactical Proficiency.” Alexandria, VA: Center for Naval Analyses, October 2010.
- Special Aviation Incentive Pay and Bonus Authorities for Officers, 37 U.S.C. § 334 (2011).
- Spencer, Larry. *How a CR Would Impact the Air Force*. Government Matters. Accessed May 5, 2020. <https://govmatters.tv/how-a-cr-would-impact-the-air-force/>.
- Stevenson, Sarah A., V. Reid Smith, and William D. Brobst. “Evolving Role of Simulator Time in Defining Pilot Experience Levels: F-35B Flight/Simulator Relationship.” Alexandria, VA: Center for Naval Analyses, January 2011.
- Straight, Ryan M. “An Exploratory Study of Augmented Reality and Mobile Games Examining Ingress Player Motivation and Potential Educational Value.” PhD thesis, Ohio University, 2015. https://etd.ohiolink.edu/!etd.send_file?accession=ohiou1426691458&disposition=inline.
- Sweeney, Nolan J. “Predicting Active Duty Air Force Pilot Attrition Given an Anticipated Increase in Major Airline Pilot Hiring.” RGSD-338. PhD thesis, Pardee RAND Graduate School, 2015. https://www.rand.org/pubs/rgs_dissertations/RGSD338.html
- Terry, Tara L., Jeremy Michael Eckhause, Michael McGee, J. H Bigelow, and Paul Emslie. *Projecting Air Force Rated Officer Inventory Across the Total Force: Total Force Blue Line Model for Rated Officer Management*. Santa Monica, CA: RAND Corporation, 2019.
- The Blue Ribbon Panel on Aviation Safety. “The Blue Ribbon Panel on Aviation Safety.” Washington, DC: United States Air Force, September 5, 1995.
- “The Cost of Replacing Today’s Air Force Fleet.” Washington, DC: Congressional Budget Office, December 2018. <https://www.cbo.gov/system/files/2018-12/54657-AirForceAviationFunding.pdf>.
- “The Cost of Replacing Today’s Army Aviation Fleet.” Washington, DC: Congressional Budget Office, May 2019.
- “The Cost of Replacing Today’s Naval Aviation Fleet.” Washington, DC: Congressional Budget Office, January 2020.
- “The Navy’s Pilot Shortage: A Selective Bonus and Other Actions Could Improve Retention.” Report to the Congress of the United States. Washington, DC: Comptroller General of the United States, February 15, 1980.
- Thompson, Kelli L, and William D Brobst. “Air Wing Training Study: Analyzing P-3 Orion Safety.” Alexandria, VA: Center for Naval Analyses, October 2009.

- Thompson, Kelli L, Andrew H. Brown, and William D. Brobst. "Marine Corps Flight Hours and Safety of Flight: Summary and Recommendations." Center for Naval Analyses, June 2009.
- "Three Faces of Naval Aviation." *Navy Times*, October 1, 2018.
- Tirpak, John A. "Pilot Shortage Is Even Worse Than Announced." *Air Force Magazine*, November 16, 2017.
- Tong, Patricia K., Leslie Adrienne Payne, Craig A. Bond, Sarah O. Meadows, Jennifer Lamping Lewis, Esther M. Friedman, and Ervant J. Maksabedian Hernandez. "Enhancing Family Stability during Permanent Change of Station: A Review of Disruptions and Policies." Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2304.html.
- Torreón, Barbara Salazar, and Sofia Plagakis. "Instances of Use of United States Armed Forces Abroad, 1798-2020." R42738. Washington, DC: Congressional Research Service, January 13, 2020. <https://crsreports.congress.gov/product/pdf/R/R42738>.
- Towell, Pat, Kate P. McClanahan, and Jennifer M. Roscoe. "Defense Spending Under an Interim Continuing Resolution: In Brief." Washington, DC: Congressional Research Service, 2019.
- U.S. Air Force. "Air Force Fact Sheets." U.S. Air Force. Accessed August 24, 2020. <https://www.af.mil/About-Us/Fact-Sheets/>.
- U.S. Air Force Human Systems Integration Office. "Human Systems Integration Requirements Pocket Guide," September 2009.
- U.S. Air Force. Scientific Advisory Board. "Report on Aircraft Oxygen Generation." Washington, DC: United States Air Force. Scientific Advisory Board, February 1, 2012. http://everyspec.com/USAF/USAF-General/SAB-TR-11-04_01FEB2012_53925/.
- U.S. Bureau of Transportation Statistics. "U.S. Air Carrier Safety Data," December 18, 2019. <https://www.bts.gov/content/us-air-carrier-safety-data>.
- U.S. Congress. House of Representatives. Committee on Armed Services. *Consequences to the Military of a Continuing Resolution*, 115th Cong., 1st sess., 2017, H.A.S.C. No. 115–33.
- . *The Fiscal Year 2019 National Defense Authorization Budget Request from the Department of Defense*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–98.
- . *The National Defense Strategy and the Nuclear Posture Review*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–67.
- . *Hearing on National Defense Authorization Act for Fiscal Year 2020 and Oversight of Previously Authorized Programs*, 116th Cong., 1st sess., 2019, H.A.S.C. No. 116–17.
- U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee on Readiness. *Aviation Readiness: What's the Flight Plan?*, 115th Cong., 1st sess., 2017, H.A.S.C. No. 115–61.
- . *Aviation Mishap Prevention: A Progress Report*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–112.
- U.S. Congress. House of Representatives. Committee on Armed Services. Subcommittee on Tactical Air and Land Forces. *The Effect of Sequestration and Continuing Resolutions on Army Modernization and Readiness*, 115th Cong., 1st sess., 2017, H.A.S.C. No. 115–19.
- . *The Effect of Sequestration and Continuing Resolutions on Marine Corps Modernization and Readiness*, 115th Cong., 1st sess., 2017, H.A.S.C. No. 115–15.
- . *Combat Aviation Modernization Programs and the Fiscal Year 2018 Budget Request*, 115th Cong., 1st sess., June 7, 2017, H.A.S.C. No. 115–53.
- . *Department of Defense Aviation Safety Mishap Review and Oversight Process*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–108.
- . *Physiological Episodes in Fighter, Attack, and Training Aircraft*, 115th Cong., 2nd sess., 2018.

- . *Addressing Physiological Episodes in Fighter, Attack, and Training Aircraft*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–68.
- . *Fiscal Year 2019 Budget Request for Combat Aviation Programs*, 115th Cong., 2nd sess., 2018, H.A.S.C. No. 115–99.
- . *Navy and Marine Corps Tactical Aviation and Ground Modernization*, 116th Cong., 1st sess., 2019. <https://www.govinfo.gov/content/pkg/CHRG-116hrg36902/pdf/CHRG-116hrg36902.pdf>.
- U.S. Congress. Senate. Committee on Armed Services. *U.S. Military Operations and Stabilization Activities in Iraq and Afghanistan*, 109th Cong., 1st sess., 2005, S. Hrg. 109-386.
- . *The Impacts of Sequestration and/or a Full-Year Continuing Resolution on the Department of Defense*, 113th Cong., 1st sess., 2013, S. Hrg. 113-173.
- . *The Impact of the Budget Control Act of 2011 and Sequestration on National Security*, January 28, 2015. <https://www.govinfo.gov/content/pkg/CHRG-114shrg95604/pdf/CHRG-114shrg95604.pdf>.
- . *The Long-Term Budgetary Challenges Facing the Military Services and Innovative Solutions for Maintaining Our Military Superiority*, 114th Cong., 2nd sess., 2016, S. Hrg. 114–765.
- . *Department of Defense Authorization for Appropriations for Fiscal Year 2018 and the Future Years Defense Program*, 115th Cong., 1st sess., 2017, S. Hrg. 115–448, Pt. 1.
- . *The Defense Budget for Fiscal Year 2018 and Onwards*, 115th Cong., 1st sess., January 24, 2017, S. Hrg. 115–167.
- . *Hearing to Receive Testimony on the Department of Defense Budget Posture In Review of the Defense Authorization Request for Fiscal Year 2020 and the Future Years Defense Program*, 116th Cong., 1st sess., 2019. <https://www.armed-services.senate.gov/imo/media/doc/19-25-03-14-19.pdf>.
- . *Hearing to Receive Testimony on the Department of Defense Budget Posture In Review of the Defense Authorization Request for Fiscal Year 2021 and the Future Years Defense Program*, 116th Cong., 2nd sess., 2020. https://www.armed-services.senate.gov/imo/media/doc/20-13_03-04-2020.pdf.
- U.S. Department of Defense. “Afghanistan Campaign Medal: Approved Campaign Phases,” 2019.
- . “Armed Forces Expeditionary Medal (AFEM): Approved Operations,” 2019.
- . “Armed Forces Service Medal (AFSM): Approved Operations,” 2019.
- . “Department of Defense Design Criteria Standard: Aircraft Crew Breathing Systems Using On-Board Oxygen Generating System (OBOGS).” MIL-STD-3050, May 11, 2015.
- . “Department of Defense Human Factors Analysis and Classification System (DoD HFACS) Version 7.0.” Washington, DC: U.S. Department of Defense. Accessed August 26, 2020. https://www.dcms.uscg.mil/Portals/10/CG-1/cg113/docs/pdf/DoD_HFACS7.0.pdf?ver=2017-02-23-152408-007.
- . “Department of Defense Infrastructure Capacity.” Washington, DC: U.S. Department of Defense, October 2017. <https://fas.org/man/eprint/infrastructure.pdf>.
- . “Department of Defense Standard Practice System Safety.” MIL-STD-882E, May 11, 2012. <https://www.dau.edu/cop/armyesoh/DAU%20Sponsored%20Documents/MIL-STD-882E.pdf>.
- . “DoD Defense Safety Oversight Council Charter.” Washington, DC: U.S. Department of Defense, April 2019.
- . “DoD Fire and Emergency Services (F&Es) Program.” DoD Instruction 6055.06. Washington, DC: U.S. Department of Defense, October 3, 2019.
- . “DoD Modeling and Simulation (M&S) Management.” DoD Directive 5000.529. Washington, DC: U.S. Department of Defense, August 8, 2007. <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/500059p.pdf>.

- . “DoD Safety and Occupational Health (SOH) Program.” DoD Instruction 6055.01. Washington, DC: U.S. Department of Defense, August 31, 2018.
- . “Global War on Terrorism Expeditionary Medal: Approved Operations,” 2019.
- . “Global War on Terrorism Service Medal: Approved Operations,” 2019.
- . *HFACS 7.0 Checklist*. Rev. 01. Quebec, Canada: QuickSeries Publishing, 2016.
- . “Humanitarian Service Medal (HSM): Approved Operations.” Washington, DC: U.S. Department of Defense, 2019.
- . “Inherent Resolve Campaign Medal: Approved Campaign Phases,” 2019.
- . “Iraqi Campaign Medal: Approved Campaign Phases,” 2019.
- . “Kosovo Campaign Medal (KCM): Authorized Kosovo Operations,” 2019.
- . “Military Operations and Activities Necessary for the Safety of Life or the Protection of Property (National Security).” Washington, DC: U.S. Department of Defense, February 6, 2018. <https://fas.org/irp/agency/dod/milops-2018.pdf>.
- . “Mishap Notification, Investigation, Reporting, and Record Keeping.” DoD Instruction 6055.07. Washington, DC: U.S. Department of Defense, April 10, 1989.
- . “Mishap Notification, Investigation, Reporting, and Record Keeping. Incorporating Change 1, April 24, 2008.” DoD Instruction 6055.07. Washington, DC: U.S. Department of Defense, October 3, 2000.
- . “Mishap Notification, Investigation, Reporting, and Record Keeping. Incorporating Change 1, August 31, 2018.” DoD Instruction 6055.07. Washington, DC: U.S. Department of Defense, June 6, 2011.
- . “Mishap Notification, Investigation, Reporting, and Record Keeping. [Incorporating Change 1, February 27, 1987].” DoD Instruction 6055.07. Washington, DC: U.S. Department of Defense, December 16, 1981.
- . “Southwest Asia Service Medal (SWASM): Approved Operations,” 2019.
- . “Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)).” DoD Directive 5134.01. Washington, DC: U.S. Department of Defense, December 9, 2005.
- . “Under Secretary of Defense for Personnel and Readiness (USD(P&R)).” DoD Directive 5124.02. Washington, DC: U.S. Department of Defense, June 23, 2008. <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/512402p.pdf>.
- . “Vietnam Service Medal: Approved Campaign Phases,” 2019.
- U.S. Department of the Air Force. “Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew.” Report to Congressional Committees. U.S. Department of the Air Force, March 2019.
- . “Air Force 2017 Maintenance Retention Survey Outbrief.” Headquarters U.S. Air Force, 2017.
- . “Equipment Inventory, Status, and Utilization Reporting.” U.S. Department of the Air Force, April 30, 2020. https://static.e-publishing.af.mil/production/1/af_a4/publication/afi21-103/afi21-103.pdf.
- . “Safety Programs.” Air Force Instruction 91-255. Washington, DC: U.S. Department of the Air Force, September 20, 2019.
- . “The U.S. Air Force Mishap Prevention Program.” Air Force Instruction 91-202. Washington, DC: U.S. Department of the Air Force, March 20, 2020.
- . “The U.S. Air Force Mishap Prevention Program, Incorporating Change 1, Feb 15, 2017.” Air Force Instruction 91-202. Washington, DC: U.S. Department of Air Force, June 24, 2015.
- U.S. Department of the Navy. “Comprehensive Review of Physiological Episodes.” U.S. Department of the Navy, June 4, 2017.

- . “Naval Aviation Safety Management System.” U.S. Department of the Navy, May 13, 2019.
- U.S. Department of the Navy. Naval Aviation Enterprise. “Naval Aviation Vision: 2016-2025.” U.S. Department of the Navy. Naval Aviation Enterprise, 2016.
- U.S. Department of the Navy. Naval Sustainment Systems Steering Committee. “Naval Sustainment Systems.” Powerpoint presentation, October 17, 2019.
- U.S. Federal Aviation Administration. “Aircraft Maintenance Technician Schools (AMTS).” Federal Aviation Administration, n.d. https://www.faa.gov/licenses_certificates/airline_certification/amts/.
- . “Fact Sheet: Commercial Aviation Safety Team.” FAA, July 2, 2020. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=23035.
- . “Safety Management Systems for Aviation Service Providers.” FAA Advisory Circular. Federal Aviation Administration, January 18, 2015.
- U.S. General Accounting Office. “Air Force Pilots: Need for Pilots in Selected Non-Flying Staff Positions.” Report to the Chairman, Subcommittee on Manpower and Personnel, Committee on Armed Services, U.S. Senate. Washington, DC: U.S. General Accounting Office, November 1989. <https://www.gao.gov/assets/220/211852.pdf>.
- . “Air Force Pilots: U.S. Air Force Requirements, Inventory, and Related Data.” Report to the Chairman, Subcommittee on Manpower and Personnel, Committee on Armed Services, U. S. Senate. Washington, DC: U.S. General Accounting Office, June 1988.
- . “Air Force Training: Delaying Pilot Training Could Avert Unnecessary Costs.” Washington, DC: U.S. General Accounting Office, November 1993.
- U.S. General Services Administration. “Tacoma Union Station, Tacoma, WA,” December 19, 2019. <https://www.gsa.gov/historic-buildings/tacoma-union-station-tacoma-wa>.
- U.S. Government Accountability Office. “Air Force Training: Actions Needed to Better Manage and Determine Costs of Virtual Training Efforts.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, July 2012. <https://www.gao.gov/assets/600/592736.pdf>.
- . “Army and Marine Corps Training: Better Performance and Cost Data Needed to More Fully Assess Simulation-Based Efforts.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, August 2013. <https://www.gao.gov/assets/660/657115.pdf>.
- . “Aviation Workforce: Current and Future Availability of Airline Pilots.” Washington, DC: U.S. Government Accountability Office, February 2014. <https://www.gao.gov/products/GAO-14-232>.
- . “Aviation Workforce: Current and Future Availability of Aviation Engineering and Maintenance Professionals.” Washington, DC: U.S. Government Accountability Office, February 2014.
- . “Defense Health Care: DOD Should Collect and Use Key Information to Make Decisions about Incentives for Physicians and Dentists.” Washington, DC: U.S. Government Accountability Office, January 2020. <https://www.gao.gov/products/GAO-20-165>.
- . “Defense Strategy: Revised Analytic Approach Needed to Support Force Structure Decision-Making.” Report to the Congress of the United States. Washington, DC: U.S. Government Accountability Office, 2019. <https://www.gao.gov/assets/700/697533.pdf>.
- . “Department of Defense: Actions Needed to Address Five Key Mission Challenges.” Washington, DC: U.S. Government Accountability Office, June 2017. <https://www.gao.gov/products/GAO-17-369>.
- . “DoD Needs to Reevaluate Fighter Pilot Workforce Requirements.” Washington, DC: U.S. Government Accountability Office, April 11, 2018. <https://www.gao.gov/products/GAO-18-113>.
- . “DoD Training: DoD Has Taken Steps to Assess Common Military Training.” Washington, DC: U.S. Government Accountability Office, May 23, 2017. <https://www.gao.gov/products/GAO-17-468>.

- . “Military Aviation Mishaps: DoD Needs to Improve Its Approach for Collecting and Analyzing Data to Manage Risks.” Washington, DC: U.S. Government Accountability Office, August 15, 2018. <https://www.gao.gov/products/GAO-18-586R>.
- . “Military Depots: Actions Needed to Improve Poor Conditions of Facilities and Equipment That Affect Maintenance Timeliness and Efficiency.” Washington, DC: U.S. Government Accountability Office, April 2019. <https://www.gao.gov/products/GAO-19-242>.
- . “Military Personnel: Collecting Additional Data Could Enhance Pilot Retention Efforts.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, June 21, 2018. <https://www.gao.gov/products/GAO-18-439>.
- . “Military Personnel: DoD Needs to Reevaluate Fighter Pilot Workforce Requirements.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, April 11, 2018. <https://www.gao.gov/products/GAO-18-113>.
- . “Military Personnel: Strategy Needed to Improve Retention of Experienced Air Force Aircraft Maintainers.” Washington, DC: U.S. Government Accountability Office, February 5, 2019. <https://www.gao.gov/products/GAO-19-160>.
- . “Military Readiness: Clear Policy and Reliable Data Would Help DoD Better Manage Service Members’ Time Away from Home.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, April 25, 2018. <https://www.gao.gov/products/GAO-18-253>.
- . “Navy Training: Observations on the Navy’s Use of Live and Simulated Training.” Washington, DC: U.S. Government Accountability Office, June 29, 2019. <https://www.gao.gov/products/GAO-12-725R>.
- . “Service Contract Approach to Aircraft Simulator Training Has Room for Improvement.” Washington, DC: U.S. Government Accountability Office, September 2006. <https://www.govinfo.gov/content/pkg/GAOREPORTS-GAO-06-830/pdf/GAOREPORTS-GAO-06-830.pdf>.
- . “Weapon System Sustainment: Selected Air Force and Navy Aircraft Generally Have Not Met Availability Goals and DoD and Navy Guidance Need to Be Clarified.” Report to Congressional Committees. Washington, DC: U.S. Government Accountability Office, September 2018. <https://www.gao.gov/assets/700/694571.pdf>.
- U.S. Naval Safety Center, and Naval Postgraduate School. School of Aviation Safety. “Aviation Maintenance Human Factors Accident Analysis: HFACS-ME: Human Factors Analysis and Classification System – Maintenance Extension.” Student Guide v3.0, n.d.
- U.S. Navy. “Platforms.” In *Vision, Presence, Power 2005: A Program Guide to the U.S. Navy*, 46–56. U.S. Navy, 2005. <https://www.navy.mil/navydata/policy/vision/vis98/vis-p08.html>.
- Venable, John. “Fighter Pilots Aren’t Flying Enough to Hone the Skills of Full-Spectrum War.” *Defense One*, November 21, 2016. <https://www.defenseone.com/ideas/2016/11/fighter-pilots-arent-flying-enough-hone-skills-full-spectrum-war/133328/>.
- Whealin, Julia M., Wayne B. Batzer, Charles A. Morgan, Howard F. Detwiler, Paula P. Schnurr, and Matthew J. Friedman. “Cohesion, Burnout, and Past Trauma in Tri-Service Medical and Support Personnel.” *Military Medicine* 172, no. 3 (March 2007): 266–72. <https://doi.org/10.7205/MILMED.172.3.266>.
- White House Commission on Aviation Safety and Security. “Final Report to President Clinton.” Commission report. Washington, DC: White House Commission on Aviation Safety and Security, February 12, 1997.
- Wild, Kevin H., and Kenneth J. Glueck, Jr. “United States Marine Corps Aviation Related Ground Mishap Study Final Report.” McLean, VA: Booz Allen Hamilton, March 3, 2017.
- Womack, Steve. “Budget Digest: Continuing Resolutions and National Defense.” Budget: House Republicans, November 12, 2019. <https://republicans-budget.house.gov/budget-digest/budget-digest-continuing-resolutions-and-national-defense/>.

Woodie, Clay, Claire Goldie, Kevin O'Brien, Chris Aura, and Cristina Delgado-Howard. "Aviator Training Next Technical Report #1: Performance and Demographic Analysis." Fort Rucker, AL: Department of Systems Engineering (DSE)/ Operations Research Center (ORCEN) U.S. Army Aeromedical Research Laboratory, May 22, 2020.

Wyckoff, Christopher A. "The Slippery Slope of Air Force Downsizing: A Strategy Connection." Thesis, Air War College, 2013. <https://apps.dtic.mil/dtic/tr/fulltext/u2/1018894.pdf>.

Young, Stephanie, and J. Gilmore. "Operating Under a Continuing Resolution: A Limited Assessment of Effects on Defense Procurement Contract Awards." Santa Monica, CA: RAND Corporation, 2019. <https://doi.org/10.7249/RR2263>.

Ziezulewicz, Geoff. "Bullet's Bold Blueprint to Save Navy Aviation." *Navy Times*, September 24, 2018.

———. "Most Navy C-130s Remain Grounded Nearly One Year after Fatal Crash." *Navy Times*, April 26, 2018.

Appendix F:

TECHNICAL APPENDIX

This technical appendix provides more information beyond the mishap rates and HFACS analysis within Chapters 2 and 3.

Additional Mishap Rate Information

Chapter 2 provides the Commission’s assessment of fiscal years 2013 through 2018 mishap rates compared against historical trends. Following are tables with the

Commission’s calculated mishap rates. This section also presents additional information about the relationship between fatalities and destroyed aircraft in Class A mishaps and changes in the mishap classification criteria.

Figures F-1, F-2, F-3, and F-4 illustrate the mishap rates by class and by Service for the fiscal years 2013–2018 study period (shaded in gray on the tables) and the comparative historical period of fiscal years 2007–2012.

Figure F-1:
Class A Mishap Rates

FISCAL YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Army A Mishap Rate	2.47	1.54	2.01	1.84	1.18	1.61	0.90	1.56	1.45	0.93	1.03	1.31
Air Force A Mishap Rate	1.47	1.39	1.26	0.87	0.86	1.04	1.21	0.72	1.17	0.96	1.03	1.58
Navy A Mishap Rate	1.08	1.70	1.36	0.76	1.03	0.99	1.06	1.78	1.28	0.93	1.55	1.44
Marine Corps A Mishap Rate	2.62	2.25	1.71	1.70	3.80	2.35	2.98	2.28	3.29	3.81	5.19	2.49
All DoD A Mishap Rate	1.74	1.56	1.52	1.17	1.19	1.27	1.21	1.29	1.39	1.13	1.41	1.55

Note: The gray boxes emphasize data entirely from the Commission’s chartered study period, fiscal years 2013–2018.

Figure F-2:
Class B Mishap Rates

FISCAL YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Army B Mishap Rate	1.19	1.30	2.01	1.04	1.18	1.27	0.81	0.68	1.67	1.27	0.69	1.07
Air Force B Mishap Rate	4.56	5.65	7.32	2.19	3.55	2.02	2.58	3.18	2.50	2.95	2.41	2.11
Navy B Mishap Rate	3.13	3.50	3.03	1.62	1.75	2.30	2.12	1.54	2.09	2.43	3.33	3.49
Marine Corps B Mishap Rate	2.92	2.57	6.15	3.06	1.90	3.35	2.23	2.66	2.88	2.54	3.03	3.32
All DoD B Mishap Rate	3.26	3.77	4.84	1.81	2.38	1.97	1.96	2.11	2.24	2.42	2.25	2.27

Note: The gray boxes emphasize data entirely from the Commission's assigned study period, fiscal years 2013–2018.

Figure F-3:
Class C Mishap Rates

FISCAL YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Army C Mishap Rate	7.17	7.70	8.30	4.63	7.22	8.04	5.11	4.98	6.68	6.37	7.81	8.59
Air Force C Mishap Rate	29.91	29.60	46.44	34.64	30.62	29.90	34.00	37.90	35.05	36.13	38.77	35.31
Navy C Mishap Rate	10.35	7.42	10.33	8.87	10.29	9.31	11.57	12.92	15.24	19.01	21.05	19.48
Marine Corps C Mishap Rate	5.83	9.96	11.28	12.57	9.83	9.38	14.51	16.69	19.32	22.46	26.80	25.75
All DoD C Mishap Rate	18.07	17.41	25.63	19.32	18.24	18.16	19.79	22.00	22.86	24.40	26.66	24.85

Note: The gray boxes emphasize data entirely from the Commission's assigned study period, fiscal years 2013–2018.

Figure F-4:
Class A–C Mishap Rates

FISCAL YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Army A-C Mishap Rate	10.83	10.54	12.32	7.50	9.58	10.92	6.81	7.22	9.80	8.56	9.53	10.98
Air Force A-C Mishap Rate	35.94	36.64	55.03	37.70	35.03	32.96	37.79	41.79	38.71	40.04	42.22	38.99
Navy A-C Mishap Rate	14.56	12.62	14.71	11.26	13.07	12.59	14.75	16.24	18.61	22.38	25.93	24.42
Marine Corps A-C Mishap Rate	11.37	14.78	19.14	17.33	15.54	15.08	19.73	21.62	25.48	28.81	35.02	31.56
All DoD A-C Mishap Rate	23.07	22.73	31.98	22.30	21.82	21.40	22.96	25.39	26.49	27.94	30.32	28.66

Note: The gray boxes emphasize data entirely from the Commission's assigned study period, fiscal years 2013–2018.

Fatalities and Destroyed Aircraft

The Commission looked for a fuller understanding of the relationship between fatalities and destroyed aircraft and how that distinguished and characterized the types of Class A mishaps the Services were experiencing during the two comparison periods (Figure F-5). For example, higher numbers of fatalities and fewer destroyed aircraft indicate one or more mishaps with additional personnel on board.

The Commission compared the numbers of fatalities, destroyed aircraft, and also calculated the number of fatalities per destroyed aircraft to better understand the relationship and how it changed over time. The Army and Navy decreased their ratio of fatalities per destroyed aircraft during the fiscal years 2013–2018 period. The Air Force saw a significant increase, the Marine Corps a slight increase.

Figure F-5:

Fatalities and Destroyed Aircraft by Service for Fiscal Years 2007–2018

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2012	2013-2018
Army Fatalities	39	17	9	27	15	12	8	6	14	8	10	6	119	52
Air Force Fatalities	2	13	6	9	2	9	11	10	5	16	5	19	41	66
Navy Fatalities	14	6	7	8	2	2	5	4	0	1	1	9	39	20
Marine Corps Fatalities	9	0	7	13	7	17	0	2	19	14	20	5	53	60
All DoD Fatalities	64	36	29	57	26	40	24	22	38	39	36	39	252	198
Army Destroyed Aircraft	18	10	10	16	9	10	6	9	6	4	6	5	73	36
Air Force Destroyed Aircraft	14	15	8	7	8	10	14	2	7	9	7	10	62	49
Navy Destroyed Aircraft	8	13	5	7	5	8	4	11	6	7	4	3	46	35
Marine Corps Destroyed Aircraft	8	5	3	5	6	6	6	5	5	8	10	3	33	37
All DoD Destroyed Aircraft	48	43	26	35	28	34	30	27	24	28	27	21	214	157
Army Fatalities/Destroyed Aircraft	2.17	1.70	0.90	1.69	1.67	1.20	1.33	0.67	2.33	2.00	1.67	1.20	1.63	1.44
Air Force Fatalities/Destroyed Aircraft	0.14	0.87	0.75	1.29	0.25	0.90	0.79	5.00	0.71	1.78	0.71	1.90	0.66	1.35
Navy Fatalities/Destroyed Aircraft	1.75	0.46	1.40	1.14	0.40	0.25	1.25	0.36	0.00	0.14	0.00	3.00	0.85	0.54
Marine Corps Fatalities/Destroyed Aircraft	1.13	0.00	2.33	2.60	1.17	2.83	0.00	0.40	3.80	1.75	2.10	1.67	1.61	1.65
All DoD Fatalities/Destroyed Aircraft	1.33	0.84	1.12	1.63	0.93	1.18	0.80	0.81	1.58	1.39	1.33	1.86	1.18	1.26

Source: Force Risk Reduction database.

Note: The gray boxes emphasize data entirely from the Commission's assigned study period, fiscal years 2013–2018.

Changes in Mishap Classification Criteria

Starting in fiscal year 2010, DoD changed the aircraft damage criteria for classification to “account for inflationary growth in the cost of military systems [since 1989] and the resulting cost for mishaps of similar severity” (Figure F-6). The Commission, however, did not adjust or reclassify mishaps across the years of its assessment, consistent with mishap rate analyses in academic literature.

Figure F-6:

Mishap Classification Criteria Changes per DODI 6055.07, Mishap Notification, Investigation, Reporting, and Record Keeping

	PRE-FY2010 MISHAP CLASSIFICATION CRITERIA ¹	POST-FY2010 MISHAP CLASSIFICATION CRITERIA ²
Class A Aviation Mishap	<ul style="list-style-type: none"> at least \$1 million in damage ; death or permanent disability; and/or aircraft destroyed 	<ul style="list-style-type: none"> at least \$2 million in damage ; death or permanent disability; and/or aircraft destroyed
Class B Aviation Mishap	<ul style="list-style-type: none"> total cost of reportable property damage is \$200,000 or more, but less than \$1,000,000; an injury and/or occupational illness results in permanent partial disability; and/or when three or more personnel are inpatient hospitalized. 	<ul style="list-style-type: none"> more than \$500,000, but less than \$2 million, in damages, three or more people hospitalized; and/or permanent partial disability
Class C Aviation Mishap	<ul style="list-style-type: none"> total cost of property damage is \$20,000 or more, but less than \$200,000; or a nonfatal illness or disability that causes loss of time from work or disability at any time 	<ul style="list-style-type: none"> at least \$50,000, but less than \$500,000, and/or nonfatal injuries that caused loss of one or more days from work not including the day or shift it occurred

¹ Department of Defense, “Mishap Notification, Investigation, Reporting, and Record Keeping. Incorporating Change 1, April 24, 2008”; Department of Defense, “Mishap Notification, Investigation, Reporting, and Record Keeping.”

² Department of Defense, “Mishap Notification, Investigation, Reporting, and Record Keeping. Incorporating Change 1, August 31, 2018.”

Additional HFACS Analysis

The Commission determined the most frequently applied Human Factors Analysis and Classification System (HFACS) applications for each mishap class and Service from fiscal years 2013 through 2018 in addition to the HFACS analysis provided in Chapter 3. The top 10 results are provided in the figures below.

Class A

Figure F-7:

Air Force Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS A APPLICATIONS
PC206	Overconfidence	33
PE102	Vision Restricted by Meteorological Conditions	28
PC208	Complacency	20
SI001	Supervisory/Command Oversight Inadequate	19
PP102	Cross-Monitoring Performance	17
PC504	Misperception of Changing Environment	16
PP106	Critical Information Not Communicated	16
AE103	Procedure Not Followed Correctly	13
AE105	Breakdown in Visual Scan	13
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	11
PC101	Not Paying Attention	11

Figure F-8:

Air Force Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS A APPLICATIONS
No Data	No Data	470
AE103	Procedure Not Followed Correctly	49
PC208	Complacency	47
AE201	Inadequate Real-Time Risk Assessment	46
AE206	Wrong Choice of Action During an Operation	45
PC102	Fixation	37
PC504	Misperception of Changing Environment	36
PE101	Environmental Conditions Affecting Vision	34
OP003	Provided Inadequate Procedural Guidance or Publications	31
PP108	Failed to Effectively Communicate	29
PC110	Inaccurate Expectation	25

Figure F-9:

Navy Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS A APPLICATIONS
AE103	Procedure Not Followed Correctly	44
AE201	Inadequate Real Time Risk Assessment	43
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	23
AE206	Wrong Choice of Action During an Operation	17
AE202	Failure to Prioritize Tasks Adequately	16
AE102	Checklist Not Followed Correctly	13
AE105	Breakdown in Visual Scan	13
AE107	Rushed or Delayed a Necessary Action	11
AV002	Commits Widespread/Routine Violation	9
AV003	Extreme Violation/Lack of Discipline	7

Figure F-10:

Marine Corps Top 10 HFACS Applications in Class A Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS A APPLICATIONS
AE201	Inadequate Real Time Risk Assessment	21
AE103	Procedure Not Followed Correctly	17
AE206	Wrong Choice of Action During an Operation	8
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	6
AE202	Failure to Prioritize Tasks Adequately	5
AE102	Checklist Not Followed Correctly	4
AE105	Breakdown in Visual Scan	4
AE107	Rushed or Delayed a Necessary Action	3
AE205	Ignored a Caution/Warning	3
AV002	Commits Widespread/Routine Violation	2

Class B

Figure F-11:
Army Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS B APPLICATIONS
PC206	Overconfidence	21
PE102	Vision Restricted by Meteorological Conditions	13
PC208	Complacency	12
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	10
PP102	Cross-Monitoring Performance	10
AE103	Procedure Not Followed Correctly	8
PC504	Misperception of Changing Environment	8
PP106	Critical Information Not Communicated	8
PC101	Not Paying Attention	4
SI001	Supervisory/Command Oversight Inadequate	4

Figure F-12:
Air Force Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS B APPLICATIONS
No Data	No Data	468
AE103	Procedure Not Followed Correctly	64
PC208	Complacency	53
OP003	Provided Inadequate Procedural Guidance or Publications	42
AE201	Inadequate Real-Time Risk Assessment	31
PC101	Not Paying Attention	30
OP007	Purchasing or Providing Poorly Designed or Unsuitable Equipment	26
PC206	Overconfidence	18
PC504	Misperception of Changing Environment	18
PC109	Technical or Procedural Knowledge Not Retained after Training	17
PC110	Inaccurate Expectation	17
PP108	Failed to Effectively Communicate	17

Figure F-13:

Navy Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS B APPLICATIONS
AE103	Procedure Not Followed Correctly	62
AE201	Inadequate Real Time Risk Assessment	51
AE206	Wrong Choice of Action During an Operation	22
AE107	Rushed or Delayed a Necessary Action	16
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	15
AE102	Checklist Not Followed Correctly	11
AE105	Breakdown in Visual Scan	11
AE202	Failure to Prioritize Tasks Adequately	8
AE300	Perception Error	8
AV003	Extreme Violation/Lack of Discipline	7

Figure F-14:

Marine Corps Top 10 HFACS Applications in Class B Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS B APPLICATIONS
AE103	Procedure Not Followed Correctly	14
AE201	Inadequate Real Time Risk Assessment	6
AE202	Failure to Prioritize Tasks Adequately	3
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	2
AE105	Breakdown in Visual Scan	2
AE206	Wrong Choice of Action During an Operation	2
AV001	Performs Work-Around Violation	2
AE102	Checklist Not Followed Correctly	1
AE107	Rushed or Delayed a Necessary Action	1
AE301	Error due to Misperception	1
AV003	Extreme Violation/Lack of Discipline	1

Class C

Figure F-15:
Army Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS C APPLICATIONS
PC206	Overconfidence	97
PC208	Complacency	76
PC101	Not Paying Attention	61
PP106	Critical Information Not Communicated	48
PP102	Cross-Monitoring Performance	44
PC504	Misperception of Changing Environment	43
AE103	Procedure Not Followed Correctly	42
PE102	Vision Restricted by Meteorological Conditions	40
AE105	Breakdown in Visual Scan	38
AE102	Checklist Not Followed Correctly	24
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	24

Figure F-16:
Air Force Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS C APPLICATIONS
No Data	No Data	2201
PC101	Not Paying Attention	374
AE201	Inadequate Real-Time Risk Assessment	371
AE103	Procedure Not Followed Correctly	291
AE206	Wrong Choice of Action During an Operation	259
PC208	Complacency	171
PC102	Fixation	143
AE107	Rushed or Delayed a Necessary Action	138
PP108	Failed to Effectively Communicate	129
PC504	Misperception of Changing Environment	113
AE105	Breakdown in Visual Scan	111

Figure F-17:

Navy Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS C APPLICATIONS
AE103	Procedure Not Followed Correctly	285
AE201	Inadequate Real Time Risk Assessment	225
AE206	Wrong Choice of Action During an Operation	112
AE105	Breakdown in Visual Scan	81
AE107	Rushed or Delayed a Necessary Action	66
AE202	Failure to Prioritize Tasks Adequately	61
AE102	Checklist Not Followed Correctly	60
AE104	Over-Controlled/Under-Controlled Aircraft/Vehicle	53
AE101	Unintended Operation of Equipment	52
AV001	Performs Work-Around Violation	26

Figure F-18:

Marine Corps Top 10 HFACS Applications in Class C Mishaps for Fiscal Years 2013–2018

TITLE CODE	CODE TITLE	CLASS C APPLICATIONS
AE103	Procedure Not Followed Correctly	78
AE201	Inadequate Real Time Risk Assessment	76
AE206	Wrong Choice of Action During an Operation	36
AE102	Checklist Not Followed Correctly	27
AE107	Rushed or Delayed a Necessary Action	18
AE202	Failure to Prioritize Tasks Adequately	15
AV001	Performs Work-Around Violation	15
AE105	Breakdown in Visual Scan	13
AE205	Ignored a Caution/Warning	11

Appendix G:

KEY MILITARY AVIATION SAFETY POLICY GUIDANCE

Department of Defense Directive (DoDD) 4715.1E, March 18, 2005, Updated December 30, 2019, *Environment, Safety, and Occupational Health*. This directive establishes policies on environment, safety, and occupational health to sustain and improve the DoD mission. This directive also establishes the Defense Safety Oversight Council (DSOC) and its structure.

Department of Defense Instruction (DoDI) 6055.07, June 6, 2011, *Mishap Notification, Investigation, Reporting, and Record Keeping*. This instruction provides guidance collecting, aggregating, and analyzing military aviation mishaps. This instruction updates procedures for mishap notification, investigation, reporting, and record keeping. It also establishes the DoD Mishap Data Requirements Working Group.

DoDI 6055.19, April 11, 2017, *Aviation Hazard Identification and Risk Assessment Programs*. This instruction establishes policy, assigns responsibilities, and provides direction for developing and implementing safety management systems around military flight operations quality assurance (MFOQA), Aviation Safety Action Program (ASAP), and line operations safety audit (LOSA). This instruction highlights quantitative and qualitative data collection in mitigating aviation risks.

Memorandum of Understanding (MOU) between the Office of the Under Secretary of Defense Personnel and Readiness, Personnel Risk and Resiliency, and Commander, U.S. Army Combat Readiness Center; Commander, U.S. Naval Safety Center; and Commander, U.S. Air Force Safety Center, August 7, 2017, *Department of Defense Safety and Occupational Health Data Sharing*. This MOU is intended to describe standard practices and procedures for collecting mishap data. Notably, this MOU identifies 57 aviation mishap data elements that would be collected and shared.

Department of Defense Human Factors Analysis and Classification System Guidance, May 10, 2005, updated 2014. Human factors describe how human interaction with tools, tasks, working environments, and other people influence human performance. Human factors are the leading cause of DoD mishaps. The Human Factors Analysis and Classification System guidance, initiated by Interservice MOU *Policy on the Collection and Analysis of Mishap Human Factors Data* and finalized by the DSOC Human Factors Working Group, explains how DoD mishap investigators and analysts can use a common human error category system to investigate, report, and analyze DoD mishaps. The DoD HFACS model presents a systematic, multidimensional approach to error analysis and mishap prevention. It is designed for use by all members of an investigation board in order to accurately capture and re-create the complex layers of human error in context with the individual, environment, team, and mishap or event.

Key Service Aviation Safety Directives

Army

AR 385-10, Army Safety Program, November 27, 2013.

AR 385-95 Army Aviation Accident Prevention, February 24, 2010

AR 70-62 Airworthiness Qualification of Army Aircraft Systems, July 7, 2000

AR 385-42 Investigation of NATO Nation Aircraft or Missile Accidents and Incidents, May 15, 1980

DA PAM 385-40, Army Accident Investigations and Reporting, March 18, 2015.

Marines

MCO 5100.29C: Marine Corps Safety Management System, October 19, 2020

MARADMIN 202/19, Marine Corps Aviation Safety Awareness Program, March 28, 2019

Navy

OPNAVINST 3750.6S, Naval Aviation Safety Management System, May 13, 2014.

OPNAVINST 5100.19E Navy Safety and Occupational Health Program Manual for Forces Afloat, May 30, 2007.

OPNAVINST/MCO 5102.1 D Navy and Marine Corps Mishap and Safety Investigation, Reporting, and Record Keeping, January 7, 2005.

Air Force

AFI 91-202, Air Force Mishap Prevention Program, May 25, 2017, updated March 12, 2020

AFI 91-204, Safety Investigations and Hazard Reporting, April 27, 2018

AFI 91-207, The Air Force Traffic Safety Program, July 26, 2019

AFI 62-601, Air Force Airworthiness, June 11, 2010

AFI 63-101/20-101, Integrated Life Cycle Management, May 9, 2017

AFMAN 91-223, Aviation Safety Investigations and Reports, September 14, 2018

Joint Directives

MIL-STD-882E, Department of Defense Standard Practice for System Safety, May 11, 2012

NATO STANAG 3101, Exchange of Flight Safety Information, November 3, 2016

NATO STANAG 3102, Flight Safety Cooperation in Common Ground/Air Space, March 27, 2007

Safety Management Systems

MFOQA

The **military operations quality assurance** program involves collecting raw recorded flight data that is processed to identify potential safety concerns within an aircraft or fleet of aircraft. Consistent data collection can assist an aviation group in identifying risk trends *before* a mishap. It can also be used for mishap investigation.

ASAP

The **aviation safety action program** is a voluntary, individual reporting program used to detect safety hazards in flight and maintenance operations before a problem causes a mishap. The Federal Aviation Administration describes the focus of ASAP as encouraging voluntary reporting of safety issues and events that come to the attention of aircrews and maintenance personnel. ASAP programs share aviation hazards information across multiple communities, often displaying the report narrative, recommended actions, and resolutions.

LOSA

Line operations safety audits were developed to analyze aircrew behavior in real time, providing the qualitative data of human perspective. All LOSA programs are designed to identify errors and measures for mitigating those errors as well as other hazards and threats. This proactive formal process uses trained observers collecting safety-related data on environmental conditions, operational complexity, and human performance on the flight deck. It is an ideal way to identify threats and understand flight crew responses, revealing how crews manage errors and undesired states. Notably, LOSA is confidential and nonpunitive and is not a compliance audit, a key to a proactive safety program.

SOQA

Simulator operational quality assurance is a relatively new aviation data collection program using flight simulator-based data. Simulators can provide opportunities for gathering data on pilot performance, especially in abnormal conditions and emergency procedures. Using SOQA to record all simulator data and using artificial intelligence to sort through that data improves aviation safety via predictive analysis. This data can be correlated to the weapon system or associated with a single pilot over the course of his or her flying career.

Appendix H:

JOINT SAFETY COUNCIL PROPOSED LEGISLATION

Sec. ___ Establishment of Joint Safety Council

Chapter 7 of Title 10 is amended by adding a new section immediately following section 183a as follows:

“Section 184 Joint Safety Council

- (a) *In general.* There is established, within the Office of the Deputy Secretary of Defense, a Joint Safety Council (in this section referred to as the “Council”).
- (b) *Composition; Appointment; Compensation.*
 - (1) The Council shall be composed of voting members as follows:
 - (A) the Director of Safety for the Department of the Army, appointed by the Secretary of the Army;
 - (B) the Director of Safety for the Department of the Air Force, appointed by the Secretary of the Air Force;
 - (C) the Director of Safety for the Department of the Navy, appointed by the Secretary of the Navy;
 - (D) a member of the Senior Executive Service, appointed by the Deputy Secretary of Defense; and
 - (E) one member from each military service, appointed by the Secretary concerned.
 - (2) Qualifications; Removal; Replacement.
 - (A) The Director of Safety for each military department shall be a uniformed officer in the grade of O-8.
 - (B) The person appointed under paragraph (1)(D) shall be a career member of the Senior Executive Service with a history of successfully running programs within the Department of Defense.
 - (C) Members of the Council serve at the will of the official who appointed them.
 - (D) Vacancies on the Council shall be filled in the same manner as the original appointment.
 - (3) Compensation. Members of the Council shall serve without compensation in addition to that received for their services as officers or employees of the United States.
- (c) *Chair and Vice Chair.*
 - (1) Chair. The Secretary of Defense, or his designee, shall select one of the uniformed members of the Council to serve as Chair. Unless earlier removed, the Chair shall serve for a term of two years. The Chair shall serve as the Director of Aviation Safety for the Department of Defense.
 - (2) Vice Chair. The Vice Chair shall be the person appointed under subsection (b)(1)(D). The Vice Chair shall report to the Chair and shall serve as Chair in his or her absence.

(d) *Staff.*

- (1) Permanent Staff. The Council may appoint staff in accordance with 5 U.S.C. § 3101.
- (2) Detailees. The Council may accept persons on detail from within the Department of Defense and from other Federal departments or agencies on a reimbursable or non-reimbursable basis.

(e) *Contract Authority.*—The Council may enter into contracts for the acquisition of administrative supplies, equipment, and personnel services for use by the Council, to the extent that funds are available for such purposes.

(f) *Procurement of temporary and intermittent services.*—The Chair may procure temporary and intermittent services under section 3109(b) of title 5, United States Code, at rates for individuals which do not exceed the daily equivalent of the annual rate of basic pay prescribed for level V of the Executive Schedule under section 5316 of such title.

(g) *Data Collection.*

- (1) Under regulations issued by the Secretary of Defense, the Council shall have access to Department of Defense databases necessary to complete its duties and responsibilities.
- (2) Under regulations issued by the Secretary of Defense, the Council may enter into agreements with the Federal Aviation Administration, the National Transportation Safety Board, and any other federal agency regarding the sharing of aviation safety data.
- (3) Except as the Secretary of Defense may choose to provide, and notwithstanding any other provision of law, data collected by the Council under this subsection shall be privileged from disclosure or discovery to any person.

(h) *Meetings.*—The Council shall meet quarterly and at the call of the Chair.

(i) *Duties.*—The duties and responsibilities of the Council are as follows:

- (1) Subject to subsection (j), be responsible for issuing, publishing, and updating regulations related to military aviation safety, to include regulations on the reporting and investigation of aviation mishaps.
- (2) Mishap Data. The Council shall –
 - (A) establish uniform data collection standards for aviation mishaps in the Department of Defense;
 - (B) review the compliance of each military service in adopting and using the uniform data collection standards required under subparagraph (A);
 - (C) review aviation mishap data to assess, identify, and prioritize risk mitigation efforts in military aviation.
- (3) Non-Mishap Data. The Council shall –
 - (A) establish standards and requirements for the collection of aircraft, simulator, airfield, and pilot data;
 - (B) establish requirements for each military service to collect and analyze the issuance of any waiver related to pilot qualifications or standards.
- (4) Safety Management System. The Council shall –
 - (A) establish, in consultation with the Federal Aviation Administration, a requirement for each military service to implement a safety management system;
 - (B) review for approval each military services' safety management system proposal;
 - (C) review each military services' implementation of a safety management system.
- (5) Review and assess civil aviation safety programs and practices and determine their suitability for implementation in military aviation.

(j) *Review.* The decisions and recommendations of the Council are subject to review and approval by the Deputy Secretary of Defense.

Appendix I:

GLOSSARY AND ACRONYM LIST

Cannibalization: The extent to which mechanics and maintenance personnel remove serviceable parts, supplies, or equipment from one vehicle, vessel, or aircraft in order to render a different vehicle, vessel, or aircraft operational.

Class A: Any mishap with a fatality, permanent total disability, or aircraft destroyed. For fiscal years 2010–2019, any mishap costing more than \$2 million in total property damage was considered a Class A. For fiscal year 2020, it was increased to any mishap costing more than \$2.5 million.

Class B: Any mishap with a permanent partial disability or three or more persons hospitalized. For fiscal years 2010–2019, any mishap costing between \$500,000 and \$2 million in total property damage was considered a Class B. For fiscal year 2020, it was increased to any mishap costing between \$600,000 and \$2.5 million.

Class C: Any mishap with a nonfatal injury resulting in loss of time from work beyond the day or shift when the injury occurred. For fiscal years 2010–2019, any mishap costing between \$50,000 and \$500,000 in total property damage was considered a Class C. For fiscal year 2020, it was increased to any mishap costing between \$60,000 and \$600,000.

G-suit: A garment with pressurized pouches that are inflatable with air or fluid, worn by fighter pilots and astronauts to enable them to withstand high forces of acceleration

Mishap: An unplanned event or series of events that results in damage to DoD property; occupational illness to DoD personnel; injury to on- or off-duty DoD military personnel; injury to on-duty DoD civilian personnel; or damage to public or private property, or injury or illness to non-DoD personnel, caused by DoD activities.

Study period: Fiscal years 2013 through 2018, the Commission's assigned period to assess military aviation mishap rates and compare them to historic rates.

Acronyms

AFB	Air Force base	IDA	Institute for Defense Analyses
AI	artificial intelligence	IP	instructor pilot
AoA	analysis of alternatives	J8	Joint Staff Force Structure, Resources, and Assessment Directorate
AR	augmented reality	JSC	Joint Safety Council
ASAIS	Aviation Safety Information Analysis and Sharing	KPP	key performance parameter
ASAP	aviation safety action program	LOSA	line operations safety assessment
Auto-GCAS	Automatic Ground Collision Avoidance system	MCB	Marine Corps base
CAST	Commercial Aviation Safety Team	MFOQA	military flight operations quality assurance
CDD	capability development document	MIL-STD	military standard
CFIT	controlled flight into terrain	NAS	Naval air station
CNA	Center for Naval Analyses	NASA	National Aeronautics and Space Administration
CO2	carbon dioxide	NAVAIR	Naval Air Systems Command
CPD	capability production document	NCO	noncommissioned officer
CR	continuing resolution	NDAA	National Defense Authorization Act
CVFDR	cockpit voice and image flight data recorders	O-8	eighth officer rank or grade, Major General or Rear Admiral (upper half)
DoD	Department of Defense	OBOGS	onboard oxygen generation system
DODI	Department of Defense Instruction	OJT	on-the-job training
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel, facilities	OPTEMPO	operations tempo
DSOC	Defense Safety Oversight Council	PE	physiological episode or event
FAA	Federal Aviation Administration	PEAT	Physiological Episodes Action Team
FR2	Force Risk Reduction database	PERSTEMPO	personnel tempo
FRCSE	Fleet Readiness Center Southeast	PPE	personal protective equipment
FRCSW	Fleet Readiness Center Southwest	RAND	RAND Corporation
FY	fiscal year	SES	Senior Executive Service
GAO	Government Accountability Office	SOQA	simulator operational quality assurance
HFACS	Human Factors Analysis and Classification System	TDY	temporary duty
HSI	human systems integration	UPE	unexplained physiological episode or event
ICD	initial capabilities document	VR	virtual reality

