Report No. DODIG-2021-120

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INSPECTOR GENERAL

U.S. Department of Defense

AUGUST 31, 2021

Audit of the Department of the Air Force's Actions Taken to Mitigate Physiological Events

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Results in Brief

Audit of the Department of the Air Force's Actions Taken to Mitigate Physiological Events

August 31, 2021

Objective

The objective of this audit is to determine whether the Department of the Air Force implemented corrective actions on fixed-wing aircraft to improve safety by reducing physiological events.

Background

A physiological event (PE) is any injury, illness, or abnormal physiological condition experienced by aircrew or others because of the flight environment. During this audit, we reviewed the Air Force's actions taken to reduce PEs in the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle aircraft. We selected fighter aircraft and trainer aircraft with the highest pilot-reported rate of PEs. The fighter aircraft with the highest rate of pilot-reported PEs was the F-15E Strike Eagle. The trainer aircraft with the highest rate of pilot-reported PEs was the T-6A Texan II. We included the F-15C Eagle and F-15D Eagle in our audit scope because the same system program office manages the F-15E Strike Eagle, F-15C Eagle, and F-15D Eagle.

Findings

The Air Force has implemented corrective and preventative actions to improve safety and reduce PEs for the aircraft we

Findings (cont'd)

reviewed—the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically as of March 22, 2021, the Air Force:

- closed 47 of 79 recommendations resulting from Air Force investigations of mishaps to address safety and reduce PEs in the four aircraft;
- conducted 67 research studies since FY 2010 on Air Force aircraft and aircrew breathing systems in an effort to identify the causes and reduce the rates of PEs experienced by aircrew;
- was researching and updating the military standard that will contain design criteria for aircrew breathing systems, which the Director of the Air Force Physiological Episode Action Team stated should decrease the possibility of PEs for future acquisitions of aircrew breathing systems;
- modified aircraft maintenance procedures and upgraded and modified aircraft to improve safety, minimize the number of PEs, and react to PEs while implementing recommendations; and
- provided aircrew training that included identifying potential PE causes, symptoms, prevention, and emergency procedures.

While the Air Force has taken actions to address potential causes of PEs, according to Air Force officials it cannot completely eliminate PEs caused by unanticipated aircraft malfunctions or human factors. Ongoing and planned actions by the Air Force are comprehensive and address potential areas to mitigate PEs.


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August 31, 2021

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION,
AND SUSTAINMENT
AUDITOR GENERAL, DEPARTMENT OF THE AIR FORCE

SUBJECT: Audit of the Department of the Air Force's Actions Taken to Mitigate Physiological Events (Report No. DODIG-2021-120)

This final report provides the results of the DoD Office of Inspector General's audit. We considered managements' comments on a discussion draft copy of this report when preparing this final report. We did not make any recommendations; therefore, no management comments are required.

We appreciate the cooperation and assistance received during the audit. If you have any questions, please contact me at [redacted]

Richard B. Vasquez
Assistant Inspector General for Audit
Readiness and Global Operations

Contents

Introduction

Objective

The objective of this audit is to determine whether the Department of the Air Force implemented corrective actions on fixed-wing aircraft to improve safety by reducing physiological events (PE). See Appendix A for scope and methodology and prior coverage.

Background

Physiological Event

The Air Force defines a PE as any injury, illness, or abnormal physiological condition experienced by aircrew or others because of the flight environment.[1] According to Air Force Manual 91-223, there are seven sub-types of PEs that aircrews can experience.[2] Table 1 describes the conditions for each of the seven sub-types of PEs, as defined by the Air Force. Examples of symptoms an aircrew member might exhibit when experiencing a PE include light-headedness, tingling sensation in the extremities, and slower responsiveness. These symptoms can hinder the aircrew's ability to fly safely and effectively. For the purpose of this report, we defined PE data based on all seven sub-types of PE as defined by Air Force Manual 91-223. We requested PE data from Air Force Safety Center (AFSEC) based on all seven sub-types of PE and not just hypoxia-like events. The PE information reported to Congress included only hypoxia, hyperventilation, and hypoventilation.

Table 1. Seven Sub-types of Physiological Events

Physiological Event	Condition
Hypoxia/ Hyperventilation/ Hypoventilation	Symptomatic exposure to reduced oxygen pressure and/or concentration or abnormal rate and/or depth of breathing.
Decompression Sickness	Confirmed decompression sickness is considered an injury and is reported and investigated as a mishap. Suspected decompression sickness with symptoms, which resolved on descent or within 2 hours at ground level, did not recur after the flight, and which required no treatment beyond supplemental oxygen is a PE.

[1] Air Force Manual 91-223, "Aviation Safety Investigations and Reports," September 14, 2018 (the Secretary of the Air Force directed immediate changes to Air Force Manual 91-223 via Air Force Guidance Memorandum 2020-01, "Air Force Guidance Memorandum to Air Force Manual (AFMAN) 91-223, Aviation Safety Investigations and Reports," August 6, 2020).

[2] Air Force Manual 91-223, "Aviation Safety Investigations and Reports," September 14, 2018 (the Secretary of the Air Force directed immediate changes to Air Force Manual 91-223 via Air Force Guidance Memorandum 2020-01, "Air Force Guidance Memorandum to Air Force Manual (AFMAN) 91-223, Aviation Safety Investigations and Reports," August 6, 2020).

Table 1. Seven Sub-types of Physiological Events (cont'd)

Physiological Event	Condition
Barotrauma	Trapped gas disorders in the middle ear, sinuses, teeth, and intestinal tract.
Acceleration Effects	Gravity-induced loss of consciousness (G-LOC), visual disturbances, or other acceleration effects. Report actual G-LOC, aircrew-reported partial G-LOC, or significant symptoms that impaired aircraft control. When reporting, the aircrew should include 72-hour and 7-day histories in the report.
Spatial Disorientation or Visual Illusions	A failure to correctly sense aircraft position, attitude, or altitude.
Toxic Smoke, Fumes, or Liquids Exposure	Symptomatic exposure to toxic substances.
Other	Any physiological condition the aircrew or flight surgeon determined to be a health concern.

Source: Air Force Manual 91-223.

History of Physiological Events in the Air Force

According to a March 2019 Air Force Report to Congressional Committees, the Secretary of the Air Force reported that, since 2010, the Air Force has experienced an increase in the rate of PEs affecting aircrews across multiple fighter and trainer platforms, including the T-6A Texan II and F-15C Eagle.[3] As a result of increased PEs, the Air Force has been working in close collaboration with the Navy, National Aeronautics and Space Administration (NASA), academia, and industry partners to investigate, understand, and implement solutions for PEs. Further, according to the Air Force report, the Secretary of the Air Force reported that investigations of these PEs have increased the Air Force's understanding of the physiological factors affecting aircrew performance, improved aircraft safety, and optimized weapon system lethality.

Congressional Interest in Physiological Events

Congress has expressed an increased interest in the efforts of the Air Force to reduce the occurrence of PEs. Public Law 115-91, section 1089, authorized the Secretary of Defense, in consultation with the Secretary of the Navy, the Secretary of the Air Force, the Commandant of the Marine Corps, and the heads of any other appropriate Federal agencies that have experience in prize competitions, and when appropriate, in coordination with private organizations, to establish a prize competition designed to accelerate identification of the root cause or causes of, or find solutions to, physiological episodes experienced in Navy, Marine Corps,

[3] Air Force Report to Congressional Committees, "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 1, 2019.

and Air Force training and operational aircraft.[4] In December 2018, the Air Force Physiological Episode Action Team (AF PEAT) held a "hackathon" to help mitigate PEs.[5] A hackathon is an event where subject matter experts from different organizations and professional backgrounds collaborate intensively to solve problems or establish a course of action.

House Report 115-769 to accompany House of Representatives (H.R.) 6157, "Department of Defense Appropriations Bill, 2019," directed the Secretaries of the Navy and Air Force, in consultation with the Surgeons General of the Navy and Air Force, to provide a report on cross-Service collaborative efforts to reduce the occurrence of hypoxia or other PEs, and how FY 2018 and FY 2019 funding was being used to support PE reduction.[6] In January 2019, the Secretaries of the Navy and Air Force submitted a joint report to Congress in response to the House Report.[7] The joint report summarized the collaboration and investigations which led to a better understanding of physiological factors affecting human performance in high-performance aircraft. In the joint report to Congress, the Navy and Air Force reported that the lessons learned from the investigations had resulted in aircraft modifications, aircrew training and education modifications, and the improvement of maintenance practices and medical responses to PEs.

Public Law 115-232 directed the Secretary of the Air Force to provide a report to the congressional defense committees on all efforts the Air Force has taken to reduce the occurrence of, and mitigate the risk posed by, PEs affecting aircrew. The report was required to include the rate of PEs, a description of the upgrades or modifications made to address PEs, schedules and cost estimates for upgrades and modifications, and an explanation of any organizational changes within the Air Force to address PEs for covered aircraft.[8] Public Law 115-232 defines covered aircraft as the F-35A Lightning II, T-6A Texan II, and any aircraft determined by the Secretary of the Air Force to be a covered aircraft.[9]

In response to Public Law 115-232, the Secretary of the Air Force submitted report, "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 2019, which detailed investigations of aircraft with increased rates

[4] Public Law 115-91, "National Defense Authorization Act for Fiscal Year 2018," December 12, 2017.

[5] Secretary of the Air Force Public Affairs, "Hacking Road Map to Physiological Episodes Mitigation in Air Force," December 21, 2018.

[6] House of Representatives Report 115-769, "Department of Defense Appropriations Bill, 2019: Report of the Committee on Appropriations Together With Additional Views (to Accompany H.R. 6157)," June 20, 2018.

[7] Navy and Air Force Joint Report to Congress, "Report to Congress on Hypoxia and Physiological Episode Research," submitted January 17, 2019.

[8] In the Navy and Air Force Joint Report to Congress, "Report to Congress on Hypoxia and Physiological Episode Research," submitted January 17, 2019, the Air Force only reported hypoxia-like PEs.

[9] Public Law 115-232, "John S. McCain National Defense Authorization Act for Fiscal Year 2019," August 13, 2018, Section 243.

of PEs. The report stated that, as a result of the findings and recommendations, the Air Force corrected problems and its rates of PEs have returned to historic norms.[10] Specifically, the Secretary of the Air Force reported the following instances of PEs and subsequent corrective actions.

- In 2014, an F-15C Eagle experienced a Class A mishap over West Virginia where hypoxia was suspected to be a contributing factor.[11] In addition, F-15C Eagle aircrews experienced an increased rate of PEs in FY 2015 and FY 2016. To prevent aircrew from losing confidence in the F-15C Eagle life support system, the Air Force Chief of Staff directed an independent review of these incidents with the goal of identifying root causes and potential corrective actions.
    - Corrective actions taken included installing cockpit pressure warning systems to alert aircrews in the event of a loss of pressure, improving maintenance procedures, and tracking regulator test performance data. Additional actions taken included improving depot-level maintenance to reduce the likelihood of canopy seal failure and cockpit depressurization, and improvements in aircrew PE training to ensure aircrew are familiar with corrective actions necessary to recover from an in-flight PE.
    - Implementing corrective actions resulted in PE rates returning to baseline levels, and restored aircrew confidence in the F-15C Eagle life support system.
- In November 2017, the Air Force began experiencing a sharp increase in the rate of PEs affecting the T-6A Texan II. This ultimately led to a 1-month operational pause of the T-6A Texan II fleet in February 2018, while maintenance personnel conducted inspections and repairs on the fleet in accordance with three Time Compliance Technical Orders.[12] After the inspections and repairs, the T-6A Texan II fleet returned to flight, but PEs persisted.
    - An investigation found that most of the PEs in the T-6A Texan II were attributed to fluctuations in oxygen concentration versus low oxygen partial pressure, as is seen in hypoxia. This discovery led to procedural, hardware, and software improvements to the aircraft to mitigate the PEs.

[10] Air Force Report to Congressional Committees, "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 1, 2019.

[11] A mishap is an unplanned occurrence, or series of occurrences, 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; damage to public or private property; or injury or illness to non-DoD personnel caused by DoD activities. Mishaps are classified by total direct mishap cost and the severity of injury or occupational illness. Class A mishaps occur when there is more than $2.5 million in damage to the aircraft, the aircraft is destroyed, or the pilot or crew is killed or permanently, totally disabled.

[12] Time Compliance Technical Orders provide instructions to modify military systems or assets within specified time limits, initiate special one-time inspections to impose temporary restrictions, and track support system and equipment configuration on systems or equipment.

- The Air Force took action to mitigate the PEs by retrofitting oxygen concentrators on the aircraft, developing an automatic backup oxygen system for incorporation into the aircraft, and improving physiology training to ensure aircrew are aware of causes and recovery procedures for all types of PEs.

Nonstatistical Sample of Air Force Aircraft

We selected a nonstatistical sample of Air Force aircraft and reviewed Air Force actions taken to improve safety and reduce PEs in these aircraft. We used the "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 2019, report to identify four aircraft (T-6A Texan II, F-15C Eagle, F-22 Raptor, and F-35 Lightning II) that the Air Force reported to Congress as having high rates of PEs. We also used AFSEC data for PEs reported from FYs 2010 through 2020 to see the number of PEs per aircraft, per year. The AFSEC provided a universe of all PEs reported from FYs 2010 through 2020 for five aircraft (the T-6A Texan II, F-15C Eagle, F-15D Eagle, F-22 Raptor, and F-35 Lightning II) for which aircrew members reported experiencing a PE. Table 2 shows the number of PEs per year for these aircraft.

Table 2. Total Number of Aircrew Physiological Events Reported per Year, per Aircraft for FYs 2010 Through 2020

Fiscal Year	F-15C and F-15D Eagle (Fighter)	F-15E Strike Eagle (Fighter)	F-22 Raptor (Fighter)	F-35A Lightning II* (Fighter)	T-6A Texan II (Trainer)
2010	8	2	2	0	12
2011	6	11	26	0	58
2012	3	14	31	0	39
2013	3	8	7	1	8
2014	4	3	2	1	5
2015	10	6	3	1	6
2016	14	3	5	3	9
2017	3	10	4	9	18
2018	2	5	2	5	86
2019	6	3	5	3	44
2020	3	5	5	5	38
Totals	**62**	**70**	**92**	**28**	**323**

* The Air Force did not fly the F-35A Lightning II in FYs 2010 and 2011.

Note: PEs include all sub-types of PE as stated in Air Force Manual 91-223.

Source: Air Force Safety Center.

Using the data in Table 2, we selected the fighter aircraft and trainer aircraft with the highest rates of aircrew-reported PEs. For fighter aircraft, the highest rate of aircrew-reported PEs were for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle combined. For trainer aircraft, the highest rate of aircrew-reported PEs was for the T-6A Texan II. We considered the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle together because the same system program office manages the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Therefore, the nonstatistical sample for our review included the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.

Background on Aircraft Selected for Review

The T-6A Texan II is a single-engine, two-seat aircraft used to train students in basic flying skills common to Air Force, Navy, and Army aircrews. The T-6A Texan II is the first aircraft flown by students learning basic aircraft training procedures. The first T-6A Texan II entered the Air Force inventory in 2000. The trainer aircraft features a pressurized cockpit with an anti-gravity system, ejection seat, and an advanced avionics package with sunlight-readable liquid crystal displays. The T-6A Texan II is part of a joint group with the Air Force and Navy called the Joint Primary Aircraft Training System. Figure 1 shows the T-6A Texan II.

Figure 1. T-6A Texan II
Source: Defense Visual Information Distribution Service.

The F-15C Eagle and F-15D Eagle are all-weather, tactical fighter aircraft. The single-seat F-15C Eagle and two-seat F-15D Eagle models entered the Air Force inventory in 1979. Figure 2 shows the F-15C Eagle.

Figure 2. F-15C Eagle
Source: Defense Visual Information Distribution Service.

The F-15E Strike Eagle is a dual-role fighter aircraft designed to perform air-to-air and air-to-ground missions. The F-15E Strike Eagle joined the Air Force inventory in 1988. Figure 3 shows the F-15E Strike Eagle.

Figure 3. F-15E Strike Eagle
Source: Defense Visual Information Distribution Service.

Air Force Organizations Involved in Reducing Physiological Events

The Air Force has multiple organizations that share an interest and are involved in reporting, monitoring, and mitigating PEs in the Air Force.

- AF PEAT
- AFSEC
- Air Force Materiel Command (AFMC)
- Air Force Life Cycle Management Center (AFLCMC)
- Air Force Research Laboratory (AFRL)
- lead Major Commands (MAJCOM) for the aircraft[13]

The Air Combat Command is the lead MAJCOM for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. The Air Education and Training Command (AETC) is the lead MAJCOM for the T-6A Texan II. Table 3 summarizes the roles of these organizations in reporting, monitoring, and mitigating PEs.

Table 3. Air Force Organizations Involved in Reducing Physiological Events

Organization	Roles
Air Force Physiological Episodes Action Team	Makes tactical aviation safer and more effective by collaborating, innovating, and accelerating solutions to PEs.
Air Force Safety Center	Oversees mishap investigations, evaluates corrective actions, ensures the Office of Primary Responsibility provides adequate documentation to close a recommendation and maintains the mishap database Air Force-wide.
Air Force Materiel Command	AFMC functions as quality control for recommendations assigned to AFMC subordinate commands developed out of the safety and mishap investigation process.
Air Force Life Cycle Management Center	Provides technical expertise upon request to support mishaps and responds to Air Force Safety Automated System recommendations.
Joint Primary Aircraft Training System Program Office (T-6A Texan II)*	Controls the development and fielding of materiel solutions for the T-6A Texan II aircraft if deficiencies are discovered or improvements are required.
F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle System Program Office	Controls the development and fielding of materiel solutions for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle aircraft if deficiencies are discovered or improvements are required.

[13] A lead MAJCOM is the command that flies the aircraft the most or owns the majority of that particular aircraft type.

Table 3. Air Force Organizations Involved in Reducing Physiological Events (cont'd)

Organization	Roles
Air Force Research Laboratory, 711th Human Performance Wing	Uses biological, medical, and cognitive science and technology to improve and protect the airman's capabilities.
Air Combat Command	Prepares Air Force aircrews for combat and performs aircrew testing and training to address issues related to PEs.
Air Education and Training Command	Provides training to aircrew when updates to training and manuals are made regarding aviation safety systems, including PEs.

* The T-6A Texan II is part of a joint group with the Air Force and Navy called the Joint Primary Aircraft Training System. Air Force personnel assigned to the joint office report to the AFLCMC.

Source: The DoD OIG.

See Appendix A for additional information about these Air Force commands.

Physiological Event Reporting Process

The PE reporting process begins when a member of an aircrew experiences an injury, illness, or abnormal physiological condition because of the flight environment. The experienced PE is a reportable aviation mishap. According to Air Force Manual 91-223, a reportable aviation mishap is an unplanned occurrence, or series of occurrences, which results in:

- damage to Air Force property;
- injury to Air Force military personnel;
- injury to on-duty civilian personnel;
- occupational illness to Air Force military or civilian personnel; or
- damage to property, injury, or illness to non-DoD personnel caused by Air Force operations.

Once an aircrew member reports the occurrence of a PE, both the flight surgeon and an Interim Flight Safety Board take action.[14] The flight surgeon will provide appropriate medical care to members of the aircrew and collect medical data for the PE worksheet.[15] The Interim Flight Safety Board will initiate a PE event report in the Air Force Safety Automated System (AFSAS) and collect PE data in

[14] An Interim Flight Safety Board may consist of one individual or several, depending on the judgement of the installation commander. The interim safety board gathers, preserves, and protects evidence after a mishap occurs until it can be transferred to a safety investigation board. The interim safety board does not determine factors or causes of the mishap.

[15] The AFSEC developed the PE worksheet as a tool to standardize capturing PE data through a series of questions.

the same PE worksheet. The Interim Flight Safety Board will coordinate with the flight surgeon to gather medical data. This data will be transferred to the safety investigation board, which will enter the PE data into AFSAS.

The Air Force creates a safety investigation board or assigns a single investigator to investigate mishaps. The mishap class dictates whether a safety investigation board is created or a single investigator is assigned to the mishap. A convening authority will appoint a safety investigation board to conduct an investigation for Class A and B mishaps. A convening authority can appoint a single investigator and add additional investigators, if needed, for Class C through E mishaps and hazards.[16] The safety investigation board or a single investigator develop investigation reports that contain conclusions and recommendations based on physical evidence, other factual data, and other non-privileged evidence. The investigation report recommendations are tracked in AFSAS.

A safety investigation board or safety investigator records PEs in AFSAS, assigns one of the five mishap classes, or classifies the PE as a hazard, depending on the level of severity and the damage incurred by either the aircrew or the Air Force asset. Aviation mishaps or events that require safety investigations and reports are categorized as one of the following five mishap classes, or as a hazard.

1. Class A mishaps occur when there is more than $2.5 million in damage to the aircraft, the aircraft is destroyed, or its pilot or crewmember is killed or permanently, totally disabled.
2. Class B mishaps occur when aircraft damage ranges from $600,000 to $2.5 million, a crewmember faces permanent partial disability, or three or more persons are sent to the hospital due to the accident.
3. Class C mishaps occur when the damage is between $60,000 and $600,000 or an injury results in loss of time from work or a permanent change in job.
4. Class D mishaps occur when the damage is between $25,000 and $60,000 or an injury results in the crewmember working only partial days with restricted duties.
5. Class E mishaps occur when the damage is below $25,000.
6. A hazard is any real or potential condition that can cause injury, damage, or occupational illness.[17]

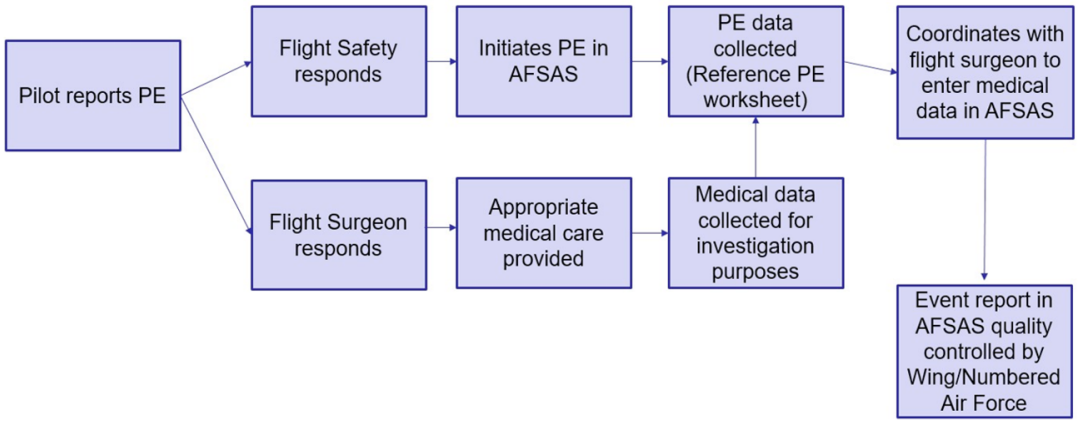
[16] A convening authority is the commander who has the responsibility and authority to order a safety investigation.

[17] Air Force Manual 91-223, "Aviation Safety Investigations and Reports," September 14, 2018 (the Secretary of the Air Force directed immediate changes to Air Force Manual 91-223 via Air Force Guidance Memorandum 2020-01, "Air Force Guidance Memorandum to Air Force Manual (AFMAN) 91-223, Aviation Safety Investigations and Reports," August 6, 2020).

Assistant Secretary of Defense for Readiness Memorandum, "Revision to Accident Severity Classification Cost Thresholds and Recording of Injury and Fatality Costs," October 15, 2019.

At the close of the investigation, the Operational Wing or Numbered Air Force that the aircrew member who reported the PE was assigned to will conduct a quality control check and review the PE data in AFSAS.[18] Figure 4 shows the Air Force PE reporting process.

Figure 4. Air Force PE Reporting Process



Source: Air Force Safety Center.

Review of Internal Controls

DoD Instruction 5010.40 requires DoD organizations to implement a comprehensive system of internal controls that provides reasonable assurance that programs are operating as intended, and to evaluate the effectiveness of the controls.[19] We did not identify internal control weakness related to the Air Force's actions taken to reduce PEs in the aircraft we reviewed.

[18] A Wing is the Air Force unit normally composed of one primary mission group and the necessary supporting organizations.

[19] DoD Instruction 5010.40, "Managers' Internal Control Program Procedures," May 30, 2013.

Finding

The Air Force Has Taken Actions to Improve Safety and Reduce Physiological Events

The Air Force has implemented corrective and preventative actions to improve safety and reduce PEs for the aircraft we reviewed—the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the Air Force:

- closed 47 of 79 recommendations resulting from Air Force investigations of mishaps to address safety and reduce PEs in the four aircraft;
- conducted 67 research studies since FY 2010 on Air Force aircraft and aircrew breathing systems in an effort to identify the causes and reduce the rates of PEs experienced by aircrew;
- is researching and updating the military standard that will contain design criteria for the Aircrew Breathing System (ACBS), which the Director of AF PEAT stated should decrease the possibility of PEs for future acquisitions of the ACBS;
- modified aircraft maintenance procedures and upgraded and modified aircraft to improve safety, minimize the number of PEs, and react to PEs while implementing recommendations; and
- provided aircrew training that included identifying potential PE causes, symptoms, prevention, and emergency procedures.

While the Air Force has taken actions to address potential causes of PEs, according to Air Force officials it cannot completely eliminate PEs caused by unanticipated aircraft malfunctions or human factors. Ongoing and planned actions are comprehensive and address potential areas for the Air Force to improve safety for its aircrews.

The Air Force Is Implementing Corrective Action to Improve Safety and Air Breathing Systems

The Air Force has implemented corrective and preventative actions to improve safety and reduce PEs for the aircraft we reviewed—the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the Air Force implemented recommendations resulting from Air Force investigations of mishaps, conducted research studies to identify the causes and reduce the rates of PEs, is researching and updating the military standard for the ACBS, modified aircraft maintenance procedures and upgraded and modified aircraft, and provided aircrew training.

The Air Force is Implementing Recommendations to Improve Safety and Reduce Physiological Events

The Air Force closed 47 of 79 recommendations resulting from Air Force investigations of mishaps to address safety and reduce PEs in the four aircraft. Air Force safety investigation boards or assigned single investigators developed 79 recommendations to address PEs after investigating mishaps. According to the information in AFSAS, the assigned office of primary responsibility closed 47 recommendations to address safety concerns and reduce PEs in the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.[20]

The Air Force creates a safety investigation board or assigns a single investigator to investigate mishaps. The level of the mishap dictates whether a safety investigation board is created or a single investigator is assigned to the mishap. According to Air Force Manual 91-223, the investigator determines PE contributing factors and develops recommendations.[21] The recommendations are recorded in AFSAS and assigned an office of primary responsibility to take action on the recommendation.

According to Air Force Instruction 91-204, all recommendations should target one or more of the mishaps or hazards identified and documented during the investigation.[22] The office of primary responsibility is required to evaluate the nature and seriousness of the information in the recommendation, determine the appropriate response, and issue required instructions to the applicable Air Force organizations to respond to the recommendation. Should the office of primary responsibility choose not to implement the recommendation, the recommendation will be transferred to the lead command for risk acceptance during the hazard review board.[23] Air Force Instruction 91-204 states that, when requesting closure in AFSAS, the office of primary responsibility must upload supporting documentation such as affected technical order pages, risk analysis, training plans, and hazard review board results. Once the approval authority reviews the supporting documentation and determines that sufficient documentation has been provided, the approval authority will close the recommendation in AFSAS.

[20] The office of primary responsibility is any headquarters, agency, or activity having the primary functional interest in, and responsibility for, a specific action, project, plan, program, or problem.

[21] Air Force Manual 91-223, "Aviation Safety Investigations and Reports," September 14, 2018 (the Secretary of the Air Force directed immediate changes to Air Force Manual 91-223 via Air Force Guidance Memorandum 2020-01, "Air Force Guidance Memorandum to Air Force Manual (AFMAN) 91-223, Aviation Safety Investigations and Reports," August 6, 2020).

[22] Air Force Instruction 91-204,"Safety: Safety Investigations and Reports," March 10, 2021.

[23] A hazard review board is established by each command during the recommendation followup process and addresses hazards throughout the command regardless of the organizational level of the office of primary responsibility.

From 2009 through 2019, safety investigation boards or assigned single investigators developed 79 recommendations related to PEs. Of the 79 recommendations, the safety investigation boards or single investigators made 7 recommendations related to the onboard oxygen generating system (OBOGS). The remaining 72 recommendations address PEs tied to the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. According to the information in AFSAS, the Air Force implemented and closed 47 of the 79 recommendations. See Table 4 for a summary of the status of the 79 recommendations as recorded in AFSAS.

Table 4. Status of Recommendations for Aircraft and Onboard Oxygen Generation System

Aircraft/OBOGS	Total number of Recommendations Open	Total number of Recommendations Closed	Total number of Recommendations
T-6A Texan II	21	30	51
F-15C/D Eagle	9	9	18
F-15E Strike Eagle	2	1	3
OBOGS	0	7	7
Totals	**32**	**47**	**79**

Source: Air Force Safety Center.

AFSAS designates recommendations as "In Work," "In Coordination," and "Closed." See Appendix B for the status of each of the 79 recommendations.

We reviewed the 32 open recommendations and grouped them into six categories—guidance, maintenance, training, new design and development, research, and testing. We evaluated and categorized each recommendation based on the subject areas that the recommendation addresses. See Table 5 for the number of open recommendations by subject area.

Table 5. Summary of Open Recommendations by Subject Area

Subject Area	In Work	In Coordination	Total
Guidance	3	0	3
Training	3	0	3
Testing	5	0	5
Maintenance	4	0	4
New Design/ Development	7	5	12
Research	5	0	5
Total	**27**	**5**	**32**

Source: The DoD OIG.

According to Air Force Instruction 91-204, the office of primary responsibility must update the actions taken to address a recommendation in AFSAS every 6 months until the recommendation is closed. In addition, Air Force Instruction 91-204 states that Air Force commanders must document the risk of not implementing recommendations and accept the risk in AFSAS. According to a recent AFSEC publication, AFSAS has a new option that allows the office of primary responsibility to close a recommendation by an action differently than the recommendation is written if the appropriate approval authority accepts the alternate action.[24] Air Force Instruction 91-204 states that the office of primary responsibility must request closure from the approval authority who determines if the actions taken are acceptable to close the recommendation. See Figure 5 for which office has approval authority to close recommendations based on event type and office of primary responsibility requesting closure. The approval authority approves closure of the recommendation after all actions have been completed and sufficiently documented in AFSAS.

Figure 5. Closure Approval Authority for Recommendations

<table>
<tr><td></td><td></td><td colspan="7">If the OPR is:</td></tr>
<tr><td></td><td></td><td>HAF</td><td>FOA/DRU</td><td>MAJCOM</td><td>NAF</td><td>Wing</td><td>Group</td><td>Sqdn</td></tr>
<tr><td colspan="2">Event Type</td><td colspan="7">Closure Approval Authority is:</td></tr>
<tr><td rowspan="5">Mishap Class</td><td>A</td><td rowspan="7">AFSEC/CV</td><td>AFSEC/CV</td><td colspan="4">AFSEC/CV if On-Duty Mishap
MAJCOM if Off-Duty Mishap</td></tr>
<tr><td>B</td><td rowspan="3">FOA/DRU/SE</td><td rowspan="3">MAJCOM/SE</td><td rowspan="3">NAF/SE</td><td rowspan="3" colspan="3">Wing/SE</td></tr>
<tr><td>C</td></tr>
<tr><td>D</td></tr>
<tr><td>E</td><td rowspan="2">Incident, Hazard, & Safety Study</td></tr>
<tr><td colspan="2">Nuclear</td><td>AFSEC/CV</td></tr>
</table>

LEGEND

AFSEC/CV	Air Force Safety Center/Vice Commander
FOA/DRU	Field Operating Agency/Direct Reporting Unit
FOA/DRU/SE	Field Operating Agency/Direct Reporting Unit/Chief of Safety
HAF	Headquarters Air Force
MAJCOM	Major Command
MAJCOM/SE	Major Command/Chief of Safety
NAF	Numbered Air Force
NAF/SE	Numbered Air Force/Chief of Safety
OPR	Office of Primary Responsibility
Sqdn	Squadron
Wing/SE	Wing/Chief of Safety

Source: Air Force Instruction 91-204, "Safety: Safety Investigations and Reports," March 10, 2021.

[24] *Blue Four News and Flying Safety Monthly*, "Special Edition – End of Year Summary Fiscal Year 2020."

AFSEC maintains AFSAS, which includes all of the closed recommendations. According to Air Force Instruction 91-204, the approval authority should close recommendations only after all actions have been completed and properly annotated in AFSAS. We reviewed the 47 closed recommendations and grouped them into six categories—guidance, maintenance, training, new design and development, research, and testing. We could not determine the category for one recommendation because AFSEC removed privileged safety information.[25] Table 6 shows the length of time it took to close the 47 recommendations in AFSAS.

Table 6. Length of Time to Close Recommendations in AFSAS

Subject Area	Closed Within 1 Year	Closed Within 1 to 2 Years	Closed Within 2 to 3 Years	Closed Within 3 to 4 Years	Closed After More Than 4 Years	Total*
Guidance	7	3	3	1	1	15
Training	3	4	1	0	1	9
Testing	2	2	1	0	0	5
Maintenance	4	3	1	0	0	8
New Design/ Development	3	0	1	0	0	4
Research	2	2	1	0	0	5
Unknown	1	0	0	0	0	1
Total*	**22**	**14**	**8**	**1**	**2**	**47**

* AFSEC only provided the year a recommendation was open to prevent the information from being privileged safety data. The DoD OIG used January 1 of the following year to calculate how long a recommendation had been open.

Source: The DoD OIG.

(~~CUI~~) Table 6 shows that the Air Force had closed 47 of the 79 recommendations as of March 22, 2021. In implementing these 47 recommendations, the Air Force has identified, eliminated, or mitigated potential root causes of PEs for the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, four recommendations were related to new design and development. [redacted]

[25] DoD Instruction 6055.07, "Mishap Notification, Investigation, Reporting, and Record Keeping," June 6, 2011, Incorporating Change 1, August 31, 2018, defines privileged safety information as Information that is reflective of a deliberative process in the safety investigation or given to a safety investigator pursuant to a promise of confidentiality, which the safety privilege protects from being released outside safety channels or from being used for any purpose except mishap prevention. Privileged safety information also includes information given to a safety investigator pursuant to a promise of confidentiality and any information derived from that information or direct or indirect references to that information.

(~~CUI~~) [redacted] The actions that the Air Force has taken show that the Air Force is continuing to work to resolve PEs.

According to AFSEC personnel, some recommendations (18 of 79) require that Air Force publications be updated or changed to address a recommendation and possibly prevent future PEs. AFSEC personnel informed us that updating or making a change to Air Force publications following a recommendation is challenging because the process involves the Secretary of the Air Force and could take from 12 to 18 months before the publication has been updated or changed. Department of the Air Force Guidance Memorandum 2020-01 states that the process to update or consolidate guidance in another publication could take up to 1 year.[26]

Based on our review of the 32 open recommendations identified in Table 7, we noted that 7 recommendations have been open in AFSAS for more than 4 years. See Table 7 for the length of time the 32 recommendations were open in AFSAS.

Table 7. Length of Time Recommendations Were Open in AFSAS

Subject Area	Open 1 to 2 Years	Open 2 to 3 Years	Open 3 to 4 Years	Open More Than 4 Years	Total*
Guidance	0	0	2	1	3
Training	0	3	0	0	3
Testing	0	4	1	0	5
Maintenance	0	4	0	0	4
New Design/ Development	0	6	0	6	12
Research	1	3	1	0	5
Total*	**1**	**20**	**4**	**7**	**32**

* AFSEC only provided the year a recommendation was open to prevent the information from being privileged safety data. The DoD OIG used January 1 of the following year to calculate how long a recommendation had been open.

Source: The DoD OIG.

(~~CUI~~) As Table 7 shows, the Air Force had not implemented 32 of the 79 recommendations as of March 22, 2021. Of the 32 open recommendations, 12 recommendations related to new design and development. According to AFSEC personnel, some recommendations require that an entire fleet of aircraft be upgraded or modified to close the recommendation. This process could take time and may require additional funding. [redacted]

[26] Department of the Air Force Guidance Memorandum, "Department of the Air Force Guidance Memorandum to Department of the Air Force Instruction 33-360, Publications and Forms Management," August 7, 2020.

(~~CUI~~) [redacted]

The Air Force is implementing corrective actions through recommendations to improve safety and reduce PEs. However, according to AFSEC officials, other PEs are not eliminated because they are hazards inherent to the aviation occupation. All occupations have some hazards that cannot be eliminated. Hazards are mitigated to the degree that leadership decisions affect likelihood, severity, resources, and risk tolerance. This work is ongoing in multiple agencies across the Air Force. AFSEC officials stated that the development of effective hazard mitigation to humans in aviation best comes from gathering data on the human body and comparing it to environmental and aircraft data. This enables the first step of characterizing a hazard. For example, sensors are being developed to gather data on humans, but their development and integration into the aircraft is a long-term project and requires significant resources. However, some resources are not available for legacy aircraft.

The Air Force is Performing Research and Testing to Reduce Physiological Events

The 711th Human Performance Wing conducted 67 research studies since FY 2010 on Air Force aircraft and aircrew breathing systems in an effort to identify the causes and reduce the rates of PEs experienced by aircrew. Specifically, the 711th Human Performance Wing researched ACBS and human factors to reduce PEs. Of the 67 research studies, the 711th Human Performance Wing performed 2 research studies related to the F-15C Eagle and 9 research studies related to the T-6A Texan II.

The 711th Human Performance Wing conducts both system program office-sponsored research and testing, and AFRL-funded research and testing to support system program office requirements; however, the system program office is responsible for making changes. The 711th Human Performance Wing researches and tests fielded units and developmental systems. For example, some 711th Human Performance Wing research includes efforts to address adverse physiological symptoms in-flight, monitor and sense aircrew in the cockpit, assess the quality of air that aircrews breathe, test and study aircrew flight equipment functionality, and optimize aircrew flight physiological training. The following examples illustrate the research and testing of the F-15C Eagle and the T-6A Texan II.

Research and Testing on the F-15C Eagle

Of the 67 research studies, the 711th Human Performance Wing conducted 2 research studies related to the F-15C Eagle since FY 2016. In January 2017, the 711th Human Performance Wing tested a limited number of F-15C Eagle aircrew oxygen regulators. The 711th Human Performance Wing reported that the F-15C Eagle was experiencing cabin decompressions which resulted in aircrew experiencing PEs. The F-15C Eagle uses a Crew Regulator Unit (CRU)-98 oxygen regulator and a liquid oxygen converter. The 711th Human Performance Wing reported that after testing, a regulator oxygen performance anomaly was discovered during simulated slow decompression conditions and low breathing demand flows and that several CRU-98 regulators appeared to produce the same anomaly. This anomaly is similar to a delayed increase in oxygen percentage with an ascending cabin altitude and had the potential to cause an aircrew PE.

In January 2018, the Air National Guard requested that the 711th Human Performance Wing conduct a research project on an additional F-15C Eagle CRU-98 aircrew oxygen regulator, with the result that the 711th Human Performance Wing discovered the same anomaly that it had reported in January 2017. The Air Force Materiel Command issued a memorandum on April 17, 2020, approving the decision of the Technical Review Board to proceed with the award of a contract to update the design of the CRU-98 based on the research studies on the CRU-98.

The 711th Human Performance Wing conducted a research study from November 2016 until April 2018 on hypocapnia in tactical aircrew resulting in hypobaria that originated from an investigation into the rise of F-15C Eagle and F-15D Eagle PEs.[27] Due to the consistent human factor readings, additional research needs to be conducted to better understand the human factors and environmental impacts. Based on the results of this study, the Naval Medical Research Unit Dayton conducted a second study, completed in 2020. The study concluded that measurements of carbon dioxide through the pilot's skin cannot be used in the environment of tactical aviation and that end tidal gas measurements are unlikely to be feasible in tactical aircraft.[28] The Naval Medical Research Unit Dayton study recommended that skin monitoring not be adapted for use in flight; that direct measurement of end tidal partial pressure carbon dioxide from an aviator's mask not be made; and that entirely different measures should be used for measuring hyperventilation.

[27] Hypocapnia is the state of having a low level of carbon dioxide (CO^2) in the bloodstream as a result of hyperventilation and can cause blood vessels to constrict.

Hypobaria results from decreasing barometric pressure on the body without hypoxia. Gases in body cavities tend to expand and gases dissolved in body fluids tend to come out as bubbles.

[28] End tidal gas measurements measure the amount of carbon dioxide present at the end of each breath.

Research and Testing on the T-6A Texan II

Since November 2017, the 711th Human Performance Wing has conducted nine research studies relating to the T-6A Texan II. Four of the nine studies were the result of a recommendation made in AFSAS. The nine studies are related to OBOGS, unexplained PE biomarkers, safety pressure, sampling, hyperoxic oscillation, and breathing resistance in the T-6A Texan II. As of June 2021, three studies were complete and six studies were ongoing.

For example, the 711th Human Performance Wing performed a study of the T-6A Texan II and unexplained PE biomarkers. The objective of the study was to analyze volatile chemicals during sorties at five Air Force bases using a custom mounted tube collection system and laboratory-grade gas chromatography-mass spectrometry analysis. The 711th Human Performance Wing found that for the standard samples, none of the flight samples at this stage of analysis are at or near a threshold limit value exceeding a safe level of exposure to each of these individual chemicals. There are a small number of chemicals detected for which there are no established safe exposure standards. This action by the 711th Human Performance Wing was sponsored by the AFLCMC T-6A System Program Office.

(~~CUI~~) [redacted]

(~~CUI~~) [redacted]

(~~CUI~~) [redacted]

(~~CUI~~) [redacted]

In May 2018, the T-6A System Program Office sponsored the 711th Human Performance Wing to perform test and evaluation of the T-6A Texan II OBOGS from incident and non-incident aircraft. The objective of this study was to assess the performance of OBOGS and OBOGS concentrators in simulated on-aircraft operating conditions. This study is scheduled to be completed in September 2021.

The 711th Human Performance Wing has and is continuing to conduct research studies on Air Force aircraft, breathing systems, and human factors in an effort to identify the causes and reduce the PEs experienced by aircrew. Therefore, we are not making any recommendations.

The Air Force is Updating the Military Standard for the Aircrew Breathing System for Future Acquisitions of the Aircrew Breathing System

The Air Force is researching and updating the Military Standard 3050 that will contain design criteria for the ACBS, which the Director of AF PEAT stated should decrease the possibility of PEs for future acquisitions of the ACBS. In response to increasing PEs, the Air Force worked in close collaboration with Navy, NASA, academia, and industry partners to investigate, understand, and implement solutions to address the increase in PEs. Specifically, the Air Force prepared an update to the May 2015 Military Standard 3050 to clarify which acquisitions, including new retrofits, upgrades, and modifications, require compliance with military standard criteria.[29]

The May 2015 Military Standard 3050 establishes the minimum design criteria for ACBS using an OBOGS. The May 2015 Military Standard 3050 development was coordinated between the DoD, prime aircraft manufacturers, and life support subsystem suppliers to meet the need to provide a minimum set of criteria to ensure the safety and effectiveness of flight critical systems. The May 2015 Military Standard 3050 only applies to ACBS utilizing an OBOGS. The proposed update to the military standard will apply to the acquisition of all systems related to the ACBS, incorporating physiological parameters as design criteria for an ACBS used in military aircraft. A team composed of ACBS engineers, subject matter experts, flight surgeons, and aerospace and operational physiologists from the Navy, the Air Force, and NASA worked to update the military standard

[29] Military Standard 3050, "Department of Defense Design Criteria Standard, Aircraft Breathing Systems Using On-Board Oxygen Generating System (OBOGS)," May 11, 2015.

that incorporates physiological parameters as design criteria for the ACBS used in military aircraft. According to an AF PEAT representative, the new military standard will only apply to new aircraft.

We obtained and reviewed both the May 2015 Military Standard 3050 and the proposed update to the military standard.[30] Both the May 2015 Military Standard 3050 and the proposed update:

- established requirements and covered the design, integration, certification, and sustainment and maintenance requirements for an ACBS; and
- provided a minimum set of criteria to ensure the safety and effectiveness of these flight-critical systems.

The proposed update to the military standard included ACBS variants such as OBOGS and liquid oxygen breathings systems, while the current May 2015 Military Standard 3050, only focused on OBOGS. According to an AFLCMC technical advisor and AF PEAT representative, the proposed update to the military standard incorporated recent pulmonary, medical, and breathing studies and knowledge focused around these human factors.

We reviewed and analyzed the proposed update to the military standard. The proposed update includes a set of criteria for future acquisitions of ACBS to correct weaknesses in fluctuations of oxygen levels in the cockpit to ensure aircrew safety across all aircraft platforms. The proposed update to the military standard will not require the Air Force to upgrade or modify existing aircraft to comply with the standard. AFLCMC personnel stated that it was up to the individual system program office to decide whether to upgrade or modify any existing aircraft.

The Air Force's proposed update to Military Standard 3050, once finalized, will impact ACBS for all future Air Force aircraft platform acquisitions and is intended to ensure adequate physiological parameters are incorporated into designs. The Air Force actions show that PEs are a serious issue and the Air Force functions as a team with collaborating partners to address a weakness in the fluctuations of oxygen levels in the cockpit to ensure aircrew safety across all aircraft platforms. Therefore, we are not making any recommendations.

[30] Military Standard 3050A, DRAFT, "Department of Defense Design Criteria Standard, Aircraft Breathing Systems (ACBS)," November 17, 2020.

Air Force Actions Taken to Reduce Physiological Events

The Air Force modified aircraft maintenance procedures and modified aircraft to improve safety, minimize the number of PEs, and react to PEs while implementing recommendations.

The Air Force Modified Aircraft Maintenance Practices and Performed Upgrades

To reduce PEs, the Air Force modified aircraft maintenance procedures and performed upgrades to the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the Air Force:

- updated the maintenance schedule of the T-6A Texan II OBOGS;
- has taken corrective maintenance and upgrade actions on the identified issues with the F-15C Eagle canopy; and
- upgraded the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle by installing a cockpit pressure monitoring and warning system and performing maintenance on the canopy seal assembly.

These Air Force maintenance and equipment upgrade actions were performed to reduce PEs in the identified aircraft.

AIR FORCE UPDATES TO THE T-6A TEXAN II INSPECTION AND MAINTENANCE SCHEDULE

The Air Force updated the inspection and maintenance schedule of the T-6A Texan II OBOGS. In November 2017, the Air Force began experiencing a sharp increase in the rate of PEs affecting the T-6A Texan II. To address the rise in PEs, the AFLCMC issued three Time Compliance Technical Orders (TCTO) in February 2018. The three TCTOs provided inspection, maintenance, and upgrade instructions for the T-6A Texan II OBOGS, air hoses, and air valves.

- (~~CUI~~) [redacted]

- (~~FOUO~~) [redacted]
- (~~CUI~~) [redacted]
  - (~~FOUO~~) [redacted]
- (~~CUI~~) [redacted]
  - (~~FOUO~~) [redacted]
- (~~CUI~~) [redacted]
  - (~~FOUO~~) [redacted]

THE AIR FORCE MODIFIED AIRCRAFT MAINTENANCE PRACTICES AND PERFORMED UPGRADES FOR THE F-15C EAGLE, F-15D EAGLE, AND F-15E STRIKE EAGLE

The Air Force modified aircraft maintenance procedures and performed upgrades to reduce PEs for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the Air Force performed canopy-related upgrades, installed cockpit pressure monitoring and warning systems, and updated maintenance procedures.

On April 6, 2016, the Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics) and AFLCMC established an independent review team to identify root causes and recommend corrective actions for the increased rate of PEs

in the F-15C Eagle and F-15D Eagle from August 2014 through March 2016.[31] The independent review team identified three interrelated areas which contributed to the increased rate of PEs: hypobaric physiologic effects, cockpit depressurization, and oxygen systems.

Subsequently, the independent review team recommended corrective actions, which should reduce the risk of PEs across aircraft including the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. The independent review team report included recommendations requiring the Air Force to perform maintenance and upgrades to aircraft components in the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. In addition, the Air Force updated maintenance procedures based on lessons learned from repeated issues.

THE F-15 SYSTEM PROGRAM OFFICE IS PERFORMING CANOPY-RELATED UPGRADES

The F-15 System Program Office performed upgrades related to the canopy of the F-15C Eagle and F-15D Eagle. Specifically, the independent review team report identified canopy seal leaks that could lead to cockpit depressurization in the F-15C Eagle and F-15D Eagle. Cockpit pressurization requires an adequately functioning environment control systems and tight canopy seals. If the environment control system is not adequate or seals leak, the cockpit can experience either a slow or rapid depressurization. In addition, exposure to higher cockpit altitudes increases the likelihood of the pilot experiencing hypobaric effects, such as hypocapnia.

The independent review team recommended that the Air Force improve the F-15C Eagle programmed depot maintenance canopy overhaul process and ensure the programmed depot maintenance process addresses all canopy components. According to F-15 System Program Office officials, the Air Force performed a one-time inspection of canopy seal bellows for the F-15C Eagle and is in the process of performing canopy seal bellows replacement on the F-15D Eagle and F-15E Strike Eagle, and procuring new canopies for the F-15C Eagle aircraft.

We obtained and reviewed TCTOs and TCTO compliance reports the Air Force issued to comply with independent review team recommendations. Specifically, we reviewed TCTO 1F-15C-546, which required a one-time inspection of the canopy seal bellow assembly.[32] According to the TCTO compliance report, as of December 11, 2020, the one-time inspection had been completed on all 210 F-15C Eagle aircraft identified in the TCTO compliance report. In addition,

[31] Bullet Background Paper, "F-15 Independent Review Team Findings And Recommendations," April 6, 2016.

[32] TCTO 1F-15C-546, "One-time Inspection of Canopy Seal Bellows Assembly (PN ST7M255-1)," June 16, 2017.

we reviewed TCTO 1F-15-1707, which required replacement of the canopy seal bellows assembly.[33] According to the TCTO compliance report, as of July 26, 2021, the Air Force had replaced canopy seal bellows assemblies for 22 F-15D Eagles and 217 F-15E Strike Eagles.

THE F-15 SYSTEM PROGRAM OFFICE IS INSTALLING THE COCKPIT PRESSURE MONITORING AND WARNING SYSTEM

As of August 31, 2021, the F-15 System Program Office is installing the cockpit pressure monitoring and warning system. According to the independent review team report, the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle do not have a cockpit pressure monitoring and warning system. The cockpit pressure monitoring and warning system is an upgraded digital cockpit pressure gauge and alert system created to replace the legacy analog cockpit pressure gauge in the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.

To mitigate issues related to the cockpit pressure monitoring and warning system, the independent review team recommended that the Air Force finalize and install a cockpit altitude warning system modification. According to the Air Force Operational Flight Program Combined Test Force, the cockpit pressure monitoring and warning system enhances aircrew awareness of low cockpit pressure by displaying the cockpit altitude and providing visual and aural warnings to alert the aircrew of a low cockpit pressure situation. These warnings should improve the aircrew's ability to recognize factors contributing to a potential or actual physiological event due to low cockpit pressure. The system also records cockpit pressure data to the aircraft's data recorder for maintenance troubleshooting and safety mishap reports.

Subsequently, the Air Force approved and authorized the fielding of the cockpit pressure monitoring and warning system on April 1, 2020. The Air Force then issued TCTO compliance report No. 1F-15-1683 for the F-15C Eagle and F-15D Eagle, and TCTO compliance report No. 1F-15E-891 to install the cockpit pressure monitoring and warning system in the F-15E Strike Eagle.[34] We obtained and reviewed the TCTO compliance reports the Air Force issued to install the cockpit pressure monitoring and warning system. According to the TCTO compliance reports, as of December 11, 2020, the Air Force completed the installation of the cockpit pressure monitoring and warning system in 44 F-15C Eagle, 5 F-15D Eagle, and 1 F-15E Strike Eagle aircraft. The Air Force's cockpit pressure monitoring and warning system installation is scheduled to continue until July 29, 2023. According

[33] TCTO 1F-15-1707, "Replacement of Canopy Seal Bellows Assembly (PN ST7M255-1) on F-15D/E Aircraft," July 9, 2019.

[34] TO 1F-15-1683, ""Installation of Cockpit Pressurization Monitoring Warning System into F-15C/D Aircraft," April 1, 2020. TO 1F-15E-891, "Installation of Cockpit Pressurization Monitoring Warning System into F-15E Aircraft," July 29, 2020.

to an F-15 System Program Office official, as of May 5, 2021, the Air Force is on schedule to complete the installation of the cockpit pressure monitoring and warning system by the completion date identified in each TCTO. Specifically, for TCTO 1F-15-1683, the Air Force plans to complete installation by April 1, 2022, and for TCTO 1F-15E-891, the Air Force plans to complete installation by July 29, 2023.

THE F-15 SYSTEM PROGRAM OFFICE IMPLEMENTED NEW MAINTENANCE GUIDANCE

The Air Force has implemented new maintenance procedures for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the F-15 System Program Office updated Technical Manual TO 1F-15A-6 and Technical Manual TO 1F-15E-6 and included new hypoxia response procedures and supplementary steps in its 180-day maintenance interval.[35] F-15 System Program Office officials stated that all hypoxia- and PE-related events are reported to F-15 officials via technical assistance requests through the technical analysis data system. F-15 System Program Office officials further explained that technical assistance requests help engineers identify repeat issues, and learn of PE-related issues. The lessons learned by F-15 System Program Office officials and engineers have led to procedural changes in technical guidance and flight manuals.

We obtained and reviewed updated Technical Manuals TO 1F-15A-6 and TO 1F-15E-6. According to updated Technical Manual TO 1F-15A-6, maintenance personnel are required to perform operational tests and inspections on liquid oxygen converters in the F-15C Eagle and F-15D Eagle when aircrews report hypoxia related symptoms. Similarly, updated Technical Manual TO 1F-15E-6 requires maintenance personnel to perform operational tests and inspections on the molecular sieve oxygen generating system in the F-15E Strike Eagle. Both updated technical manuals included a new hypoxia response procedure that requires maintenance personnel to complete leakage tests in the oxygen regulator panel and the oxygen system and inspect the environment control system for F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle aircraft. Furthermore, both updated technical orders added steps in the Air Force 180-day maintenance interval requiring maintenance personnel to complete oxygen system purging procedures and oxygen regulator control panel leakage tests for F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle aircraft.

[35] Technical Manual TO 1F-15A-6, "Inspection and Maintenance Requirements Manual, USAF Series F-15C/D Aircraft, Change 25," September 15, 2019.
Technical Manual TO 1F-15E-6, "Inspection and Maintenance Requirements Manual, USAF Series F-15E Aircraft, Change 25," September 15, 2019.

As the Air Force identified an issue related to PEs, it performed maintenance or upgrades to the aircraft to resolve the issue. Air Force actions show that it modified aircraft maintenance procedures and performed upgrades to reduce PEs for the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle to address equipment malfunctions related to PEs. Therefore, we did not make any recommendations.

The Air Force Provides Training on Physiological Event Recognition

The AETC is providing aircrew training that identifies potential PE causes, symptoms, prevention, and emergency procedures. In January 2019, the Secretary of the Air Force stated that the improved physiology training is designed to ensure aircrew are aware of the most up-to-date information regarding causes and recovery procedures for all types of PEs. Specifically, the AETC provided aircrew initial and refresher PE training as part of a mandatory aerospace physiology training program. In addition, the Air Combat Command provided a roadshow to educate aircrew on PEs.

INITIAL AEROSPACE PHYSIOLOGY TRAINING FOR PHYSIOLOGICAL EVENTS

In August 2020, the Secretary of the Air Force issued Air Force Manual 11-403, which stated that the AETC is the lead MAJCOM for the aerospace physiology training program.[36] As the lead MAJCOM, the AETC provides aircrew training to identify, recognize, and respond to PEs. Air Force Manual 11-403 states that initial physiological training is provided as part of Undergraduate Flying Training. As part of initial Undergraduate Flying Training, aircrew are required to complete the following 13 aerospace physiology training courses, which are detailed in the Aerospace Physiology Syllabus.[37]

- **Physiological Effects of Altitude.** In the classroom, the aircrew will be taught about the characteristics of structures and functions of the respiratory and circulatory systems. Also, the aircrew will learn characteristics of hypoxia, signals for recognizing hypoxia and methods for preventing hypoxia, hyperventilation/hypocapnia, and characteristics of decompression sickness. For example, after the course is over, the aircrew should be able to list the phases of respiration, list the structures of the circulatory system, recognize the characteristics of hypoxia, and identify factors that induce hypoxia and change the onset rate of symptoms.

[36] Air Force Manual 11-403, "Flying Operations: Aerospace Physiological Training Program," August 13, 2020.
[37] Instructor Guide: AETC Syllabus S-O-B/A-APH, "Instructor Guide: Aerospace Physiology Syllabus," November 1, 2020.

- **Self-Imposed Performance Threats.** In the classroom, the aircrew will be taught about the effects over-the-counter medication have on the crewmember, the residual effects of alcohol on the crewmember in-flight, hazards associated with smoking and chewing tobacco products, physiological need for proper diet and nutrition, and impact of dehydration on aircrew member performance. Also, the aircrew learn causes of acute and chronic fatigue, the effects of caffeine on the body, and the importance of physical fitness on aircrew. For example, after the course is over, the aircrew should be able to identify the effects of over the counter medications, identify the effect of alcohol on the body specifically on in-flight performance, describe the effects of smoking and smokeless tobacco specifically on in-flight performance, recall the physiological effect of carbon monoxide, list the signs and symptoms associated with dehydration, and understand the impacts of caffeine on in-flight performance.
- **Physiology Considerations of Aircrew Flight Equipment.** In the classroom, the aircrew will be taught how to identify and operation aircraft oxygen systems, and know the pressure breathing requirements and techniques. For example, after the course is over, the aircrew should be able to identify the proper use of helmet mask and connector assemblies, identify and operate emergency oxygen sources, and describe why and when pressure breathing is necessary for the aircrew member.
- **Cabin Pressurization/Depressurization.** In the classroom, the aircrew will be taught how aircraft pressurization affects crewmembers. For example, after the course is over, the aircrew should be able to recall the process for maintaining cabin pressurization, recall the types of cabin decompression and characteristics of each, and list the physical indications of rapid decompression.
- **Vision.** In the classroom, the aircrew will be taught the anatomy and function of the eye, the characteristics of the visual field, the limitations and visual illusions associated with daytime flight, the limitations and visual illusions associated with low-light levels and night flying environments, comprehend night vision conditions that contribute to illusions. Also, the aircrew will be taught the measures that help ensure visual acuity in night flying conditions, and the characteristics of lasers and associated actions upon exposure. For example, after the course is over, the aircrew should be able to describe the correct scanning technique used to identify objects, list factors that can cause daytime visual illusions, define the night blind spot, demonstrate how flash blindness produces debilitating effects on dark adaptation, and identify methods to prevent night visual illusions.

- **Spatial Disorientation.** In the classroom, the aircrew will be taught the characteristics of spatial disorientation, the characteristics of the orientation sensory systems, the characteristics of the types of vestibular induced spatial disorientation. Also, the aircrew will be taught factors affecting spatial disorientation, how to prevent and overcome spatial disorientation, and the causes of and techniques to prevent and overcome motion sickness in-flight. For example, after the course is over, the aircrew should be able to list the four sensory systems used in orientation, select the sensory system that provides the strongest and usually most reliable orientation information, and recall environmental and physiological factors that can lead to spatial disorientation.
- **Noise and Vibration.** In the classroom, the aircrew will be taught the characteristics of noise, the effects of hazardous noise on hearing capability, protective measures used to minimize hazardous noise exposure, and the potential effects of prolonged exposure to aircraft vibration. For example, after the course is over, the aircrew should be able to list characteristics of noise that affect hearing, identify the potential non-auditory effects of noise on crewmembers in-flight performance, list devices that help minimize hazardous noise, and identify how vibration energy is passed through the body.
- **Attention Management Threats to Situational Awareness.** In the classroom, the aircrew will be taught the levels of awareness, comprehend some of the cognitive causes of a loss of situational awareness, know how to recognize, prevent and treat lost situational awareness resulting from attention management threats and comprehend the impacts of physiological issues on situational awareness. For example, after the course is over, the aircrew should be able to identify attention threats, identify inappropriate motivations, identify tools for preventing lost situational awareness and identify physiological issues that can degrade an individual's decision making.
- **Acceleration.** In the classroom, the aircrew will be taught the definition and characteristics of G forces, know the characteristics of the factors that determine the effects of G forces on a crewmembers' body, comprehend the characteristics of G-LOC, know the methods used to help prevent G-LOC, and know the common errors in performing the Anti-Gravity Straining Maneuver. For example, upon course completion, the aircrew should be able to identify the types of acceleration, the types of G force, the factors determining the effect of G force on a crewmember's body, recognize what causes blackout and how it is different from G-LOC and describe the symptoms of each of the phases of incapacitation.

- **Physiology Considerations of Aircraft Egress.** In the classroom, the aircrew will be taught the principle courses of action to minimize injury during aircraft egress. For example, after the course is over, the aircrew should be able to understand the principles of aided and unaided escape in relation to design, describe common aided and unaided escape injuries, describe ways to improve survivability before, during, and after a crash.
- **Altitude Chamber.** In the altitude chamber, the aircrew will be given proper aviation equipment and will apply previously taught academic principles in a controlled hypobaric environment. For example, after the training is over, the aircrew should be able to recognize and treat symptoms of hypoxia without the physical assistance of an inside observer; discuss conditions, which could produce hypocapnia and corrective procedures; use proper positive pressure breathing techniques; and perform appropriate in-flight checks of oxygen equipment.
- **Barany Chair/Spatial Disorientation Trainer.** In a Barany Chair, the aircrew accomplish physical maneuvers to gain a practical understanding, and recognition of visual and vestibular limitations and their susceptibility to error, and accomplish basic aviation procedures in conditions that promote visual illusions due to spatial disorientation factors. For example, after the training is over, the aircrew should be able to practice and perform recovery methods to maintain aircraft control while disoriented and observe how other students respond to illusions to understand the effects of spatial disorientation and the physiological responses to spatial disorientation illusions. Figure 6 shows an aircrew member using a Barany Chair.

Figure 6. Barany Chair
Source: Defense Visual Information Distribution Service.

- **Unaided Night Vision Trainer.** In a classroom, the aircrew are provided an enhanced understanding of night vision threats and develop measures to optimize situational awareness at night. For example, after the training is over, the aircrew have experienced reduced visual acuity as a result of exposure to a darkened environment, experienced a shift or loss in color perception, and experienced focal and peripheral vision degradation. They should also be able to discuss how flash blindness produces debilitating effects on dark adaptation, and discuss strobe light demonstration and its effects of visual acuity.

According to Air Force Manual 11-403, all initial physiological training is accomplished in an altitude chamber. The altitude chamber provides a training system that replicates the effects of barometric pressure changes on the human body. The effects include exposure to a low barometric pressure environment for recognition of personal hypoxia symptoms as well as physical effects of pressure changes at various training altitudes.

According to AETC officials, aircrews are trained to recognize the symptoms of a PE and how to declare and report PE emergencies during aerospace physiology training. Aircrews have also been instructed on what to do once safely on the ground after flight in order to preserve necessary evidence so that safety and medical staff can perform an adequate evaluation to provide resolution for the emergency.

In addition, the AETC official stated that the AETC had enhanced the T-6A Texan II training program by implementing reduced oxygen breathing device training. The reduced oxygen breathing device training provides hypoxia recognition and emergency procedures training using normobaric-reduced oxygen gas mixtures.[38] According to AETC officials, reduced oxygen breathing device training has expanded PE training from the basic chamber flight where only basic PE recognition is accomplished and instead, allows aircrews to experience PE effects while trying to accomplish basic aircrew duties to see how PE effects can negatively affect operations. Finally, all initial physiological training courses must be completed before the aircrew is certified to fly the T-6A Texan II.[39]

REFRESHER AEROSPACE PHYSIOLOGY TRAINING FOR PHYSIOLOGICAL EVENTS

Air Force Manual 11-403 requires that refresher training for PEs must be completed no later than 5 years from the end of the month during which the training had been provided. The Manual also states that aircrew must receive refresher training no later than 5 years from the date that initial aerospace physiology training was

[38] Normobaric describes a normal barometric pressure equivalent to pressure at sea level.

[39] Air Force Manual 11-2T-6, Volume 1, "Flying Operations, T6A Aircrew Training," April 1, 2020.

accomplished.[40] Required refresher training courses are grouped based on common aircraft characteristics called "tracks." The T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle are considered track A aircraft. Track A aircraft are for aircrew that fly in high performance, high G-force aircraft.[41] According to Air Force Manual 11-404, a high G-force aircraft is capable of generating a G-loading in excess of 6.0G.[42] According to Air Force Manual 11-403, the following nine refresher aerospace physiology training courses are required for Track A aircrew.

- Physiological Effects of Altitude
- Self-Imposed Performance Threats
- Physiology Considerations of Aircrew Flight Equipment
- Vision
- Spatial Disorientation
- Noise and Vibration
- Attention Management Threats to Situational Awareness
- Acceleration
- Altitude Chamber or Reduced Oxygen Breathing Device[43]

Aircrew have the option to take the altitude chamber or reduced oxygen breathing device training as a refresher. According to Air Force Manual 11-403, all refresher training should emphasize aircraft-specific oxygen equipment re-familiarization and emergency procedures, to the greatest extent possible. According to Air Force guidance, if personnel are not current on the required training, they will be not be allowed to fly.[44] Occasionally, unique circumstances may warrant special consideration and possible waiver of policy provisions.

ROADSHOWS ON PHYSIOLOGICAL EVENTS DESIGNED TO MITIGATE PHYSIOLOGICAL EVENTS

The Air Combat Command developed and presented a roadshow to educate aircrew on PE. The Air Combat Command provided this training for both academic and practical training to mitigate physiological events. Since April 2017, the Air Force has been presenting a roadshow to discuss high performance breathing issues and present recognition recovery procedures to aircrew for their familiarization.

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40 Air Force Manual 11-403, "Flying Operations: Aerospace Physiological Training Program," August 13, 2020.

41 G-force is a force acting on a body as a result of acceleration or gravity, informally described in units of acceleration equal to 1 g. For example, a 12-pound object undergoing a g-force of 2g experiences 24 pounds of force.

42 Air Force Manual 11-404, "Flying Operations: Fighter Aircrew Acceleration Training Program," November 27, 2019.

43 Aircrew can take either Altitude Chamber or Reduced Oxygen Breathing Device to meet hypoxia refresher training requirements.

44 Air Force Manual 11-403, "Flying Operations: Aerospace Physiological Training Program," August 13, 2020.

According to an Air Combat Command official, as Air Combat Command learns new information about PEs it updates the physiology curriculum that it presents to leadership and aircrew.

The Air Combat Command developed a roadshow for recognition and recovery that highlighted the procedures to identify oxygen malfunction and hypoxia symptoms in the F-15C Eagle and F-15E Strike Eagle. Specifically, the 422nd Test and Evaluation Squadron developed and briefed a roadshow presentation on High Performance Breathing Issues with the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. The roadshow also provided a detailed explanation of hypoxia and emphasized that the problem is not specific to one type of aircraft or mission, noting that the Navy has also experienced an increase in PEs in both tactical and training aircraft. Aircrew were informed of the suspected causes of hypoxia. The roadshow emphasized that aircrew not self-diagnose their physical symptoms in a fighter jet, but avoid the temptation to panic, which often leads to hyperventilation. According to an Air Force official, the roadshow had been presented over 100 times since the presentation was developed.

Air Force policy requires aircrew to take several aerospace training courses that identify potential PE causes, symptoms, prevention, and emergency procedures.[45] In addition, the policy requires aircrew to take refresher aerospace physiology training on identifying potential PE causes, symptoms, prevention, and emergency procedures every 5 years. Since April 2017, the Air Force has presented a roadshow that includes identifying potential PE causes as well as PE symptoms, prevention, and emergency procedures. Those actions show that the Air Force recognizes that PEs are a serious issue that the Air Force is working to address. Therefore, we did not make any recommendations.

Conclusion

The Air Force has taken steps to address potential causes of PEs in the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Specifically, the Air Force reported that it has implemented 47 of the 79 safety recommendations proposed by the safety investigation boards or single investigators and is working to implement the remaining 32 recommendations in the areas of guidance, maintenance, training, new design and development, research, and testing. In addition, the 711th Human Performance Wing conducted 67 research studies to investigate human factors, aircraft, and aircrew equipment to better understand and address the causes of PEs. For example, the 711th Human Performance Wing

[45] Air Force Manual 11-403, "Flying Operations: Aerospace Physiological Training Program," August 13, 2020.

conducted studies related to OBOGS, unexplained PE biomarkers, safety pressure, sampling, hyperoxic oscillation, breathing resistance, and the regulator in the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.

The Air Force led an effort to rewrite Military Standard 3050. The update to Military Standard 3050 is parameter-driven, and allows for the development of a new system that is not an OBOGS. The update is expected to impact ACBS for all future Air Force aircraft platform acquisitions to ensure adequate physiological parameters are incorporated into designs. The Air Force modified aircraft maintenance procedures, upgraded and modified aircraft, and improved training on PE recognition for aircrews.

The Air Force has modified aircraft maintenance procedures and performed upgrades to reduce PEs. For example, the Air Force is in the process of performing canopy seal bellows replacement, and procuring new canopies for the F-15C Eagle aircraft. In addition, the Air Force indicated that it will continue to perform the change implemented into the Inspection and Maintenance Requirements Manual and perform additional hypoxia procedures and supplementary steps in its 180-day maintenance interval.

The Air Force's actions helped reduce PEs per 100,000 flight hours from FYs 2010 to 2020 for two of the four aircraft we reviewed. Also, the reductions were not consistent each year across all reviewed aircraft. See Table 8 for the number of PEs, the number of flight hours, and the rate of PEs per 100,000 flight hours from FYs 2010 through 2020 for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.

Table 8. Total PEs, Flight Hours, and Average Rate of PEs per 100,000 Flight Hours for FYs 2010 to 2020 for F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle Aircraft

Fiscal Year	F-15C/D Eagle			F-15E Strike Eagle		
	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours
FY 2010	8	59,093	13.54	2	65,264	3.06
FY 2011	6	36,280	16.54	11	64,569	17.04
FY 2012	3	42,333	7.09	14	53,112	26.36
FY 2013	3	39,116	7.67	8	39,985	20.01
FY 2014	4	40,660	9.84	3	50,890	5.90
FY 2015	10	40,990	24.40	6	66,451	9.03
FY 2016	14	40,440	34.62	3	65,089	4.61
FY 2017	3	39,865	7.53	10	65,912	15.17

Table 8. Total PEs, Flight Hours, and Average Rate of PEs per 100,000 Flight Hours for FYs 2010 to 2020 for F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle Aircraft (cont'd)

Fiscal Year	F-15C/D Eagle			F-15E Strike Eagle		
	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours
FY 2018	2	39,090	5.12	5	61,763	8.10
FY 2019	6	41,375	14.50	3	64,447	4.65
FY 2020	3	36,395	8.24	5	58,750	8.51

Note: To calculate the average rate of PEs per 100,000 flight hours from FYs 2010 through 2020, we divided the total number of PEs by the total number of flight hours and multiplied by 100,000.

Source: The DoD OIG.

Table 9 shows that for the T-6A Texan II, the Air Force reduced the number of PEs per 100,000 flight hours from FY 2018 through FY 2020. Further, Table 9 shows that the T-6A Texan II total number of reported PEs per fiscal year have fluctuated from as low as 5 PEs in FY 2014 to as high as 86 PEs in FY 2018. The T-6A Texan II is flown by Air Force aircrew during Undergraduate Pilot Training before moving on to their specialized career track. According to AF PEAT officials, because the T-6A Texan II is the first aircraft flown by Air Force aircrew, the nerves of the aircrew could be a factor in the increase of reported PEs. See Table 9 for the number of PEs, the number of flight hours, and the rate of PEs per 100,000 flight hours from FYs 2010 through 2020 for the T-6A Texan II.

Table 9. Total PEs, Total Flight Hours, and Average Rate of PEs per 100,000 Flight Hours for FYs 2010 to 2020 for the T-6A Texan II

Fiscal Year	T-6A Texan II		
	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours
FY 2010	12	180,887	6.63
FY 2011	58	190,535	30.44
FY 2012	39	177,348	21.99
FY 2013	8	167,547	4.77
FY 2014	5	168,182	2.97
FY 2015	6	161,454	3.72
FY 2016	9	172,743	5.21
FY 2017	18	175,691	10.25

Table 9. Total PEs, Total Flight Hours, and Average Rate of PEs per 100,000 Flight Hours for FYs 2010 to 2020 for the T-6A Texan II (cont'd)

Fiscal Year	T-6A Texan II		
	Total Number of PEs	Total Flight Hours	Average Rate of PE per 100,000 Hours
FY 2018	86	159,407	53.95
FY 2019	44	172,495	25.51
FY 2020	38	151,093	25.15

Note: To calculate the average rate of PEs per 100,000 flight hours from FYs 2010 through 2020, we divided the total number of PEs by the total number of flight hours and multiplied by 100,000.

Source: The DoD OIG.

As Tables 8 and 9 show, the PEs per 100,000 flight hours did not consistently decrease for the aircraft we reviewed. The four aircraft models we reviewed (the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle) reported fewer PEs per 100,000 flight hours in FY 2020 compared to FY 2011. However, the aircraft did not experience a consistent decline in the PE rate each year from FY 2011 through FY 2020. In Tables 8 and 9, we identified the number of PEs and the number of flight hours and calculated the rate of PEs per 100,000 flight hours for each of the four aircraft. The F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle do not fly 100,000 flight hours per year; therefore, the rate per 100,000 hours is skewed for those three aircraft.

Although the Air Force has not eliminated PEs across the four aircraft platforms we reviewed, it plans to continue researching, training, maintaining, upgrading, and testing to identify root causes for PEs and to improve safety. The Air Force has taken steps in its initial aerospace physiology training program and requires refresher training in identifying the causes of PEs as well as symptoms, aid prevention, and improved emergency procedures no later than 5 years from the date of initial aerospace physiology training. The ongoing and planned actions by the Air Force are comprehensive and address potential areas to mitigate PEs.

According to Air Force officials, PEs cannot be eliminated because PEs are a broad range of subjective symptomatic reports in several categories. Some have correctable causes such as a mechanical malfunction. Others are not preventable such as from human error or hazards inherent to the aviation occupation. Air Force officials also stated that other PEs occur from undiscovered hazards and Air Force officials encourage reporting to enhance safety.

Appendix A

Scope and Methodology

We conducted this performance audit from August 2020 through August 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Audit Universe and Sample Selection

We selected a nonstatistical sample of Air Force aircraft and reviewed Air Force actions taken to improve safety and reduce PEs in these aircraft. We selected the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle to review. We chose these aircraft based on the "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 2019, report and data obtained from AFSEC for PEs reported from FYs 2010 through 2020.

We used the "Air Force Efforts to Mitigate Physiological Episodes Affecting Aircraft Crew," March 2019, report to identify four aircraft (T-6A Texan II, F-15C Eagle, F-22 Raptor, and F-35 Lightning II) that the Air Force reported to Congress as reporting high rates of PEs. We also used AFSEC data for PEs reported from FYs 2010 through 2020 to see the number of PEs per aircraft, per year. AFSEC provided a universe of 575 PEs reported from FYs 2010 through 2020 for five aircraft platforms in which aircrew members reported experiencing a PE. For the purpose of this report, we defined PE data based on all seven sub-types of PE as defined by Air Force Manual 91-223. We requested PE data from AFSEC based on all seven sub-types of PE and not just hypoxia-like events. See Table 10 for the number of PEs that Air Force aircrew members reported.

Table 10. Total Aircrew Physiological Events Reported Per Year, Per Aircraft for FYs 2010 Through 2020

Fiscal Year	F-15 C and D Eagle (Fighter)	F-15E Strike Eagle (Fighter)	F-22 Raptor (Fighter)	F-35A Lightning II* (Fighter)	T-6A Texan II (Trainer)	Total
2010	8	2	2	0	12	24
2011	6	11	26	0	58	101
2012	3	14	31	0	39	87
2013	3	8	7	1	8	27
2014	4	3	2	1	5	15
2015	10	6	3	1	6	26

Table 10. Total Aircrew Physiological Events Reported Per Year, Per Aircraft for FYs 2010 Through 2020 (cont'd)

Fiscal Year	F-15 C and D Eagle (Fighter)	F-15E Strike Eagle (Fighter)	F-22 Raptor (Fighter)	F-35A Lightning II* (Fighter)	T-6A Texan II (Trainer)	Total
2016	14	3	5	3	9	34
2017	3	10	4	9	18	44
2018	2	5	2	5	86	100
2019	6	3	5	3	44	61
2020	3	5	5	5	38	56
Totals	**62**	**70**	**92**	**28**	**323**	**575**

* The Air Force did not fly the F-35A Lightning II in FYs 2010 and 2011.

Note: PEs include all sub-types of PE as stated in Air Force Manual 91-223.

Source: Air Force Safety Center.

As shown in Table 10, the T-6A Texan II had the highest number of reported PEs in FYs 2010 through 2020. Table 10 illustrates that the F-22 Raptor had two outlier years in FYs 2011 and 2012 with 26 and 31 PEs reported respectively, but had consistently shown a low rate of PEs as of October 21, 2020. Table 10 also illustrates that the F-35A Lightning II had a consistently low rate of PEs, except for a small spike in FY 2017.

We used the total annual flight hours in conjunction with the total number of PEs to calculate the rate of PEs per 100,000 hours by fiscal year, for each aircraft. See Table 11 for the total annual flight hours for each type of aircraft in our sample from FYs 2010 through 2020.

Table 11. Total Annual Number of Flight Hours from FYs 2010 Through 2020

Fiscal Year	F-15C/D Eagle	F-15E Strike Eagle	T-6A Texan II
2010	59,093	65,264	180,887
2011	36,280	64,569	190,535
2012	42,333	53,112	177,348
2013	39,116	39,985	167,547
2014	40,660	50,890	168,182
2015	40,990	66,451	161,454

Table 11. Total Annual Number of Flight Hours from FYs 2010 Through 2020 (cont'd)

Fiscal Year	F-15C/D Eagle	F-15E Strike Eagle	T-6A Texan II
2016	40,440	65,089	172,743
2017	39,865	65,912	175,691
2018	39,090	61,763	159,407
2019	41,375	64,447	172,495
2020	36,395	58,750	151,093
Totals	**455,637**	**656,232**	**1,877,382**

Source: Air Force Safety Center.

As shown in Table 11, the T-6A Texan II had the highest number of flight hours in FYs 2010 through 2020. Table 11 illustrates that the F-15C Eagle and F-15D Eagle decreased flying hours from FYs 2010 and 2011, but continued to have a consistent amount of flight hours from FYs 2011 through 2020.

We selected the fighter aircraft and trainer aircraft with the highest rate of aircrew-reported PEs. For fighter aircraft, the highest aircrew-reported rate of PEs was for the F-15E Strike Eagle. For trainer aircraft, the highest aircrew-reported rate of PEs was for the T-6A Texan II. We also included the F-15C Eagle and F-15D Eagle in our audit scope because the same system program office manages the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. Therefore, the audit scope included the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle.

Review of Documentation

We obtained and reviewed mishap recommendations related to PEs from the Air Force Safety Automated System (AFSAS) for 2010 through 2020. We determined whether the Air Force implemented actions to reduce the number of reported PEs. We reviewed Air Force reports to Congress, documents on the PE reporting process, training slides on recognizing the symptoms of PE and emergency responses, guidance updates on the ACBS, organization charts, and documentation outlining aircraft equipment upgrades. We also obtained and reviewed Air Force recommendations made to address reported PEs for selected aircraft.

We used the following criteria as our basis for our analysis.

- Public Law 114-328, "National Defense Authorization Act for Fiscal Year 2017," December 23, 2016
- Public Law 115-91, "National Defense Authorization Act for Fiscal Year 2018," December 12, 2017
- Public Law 115-232, "John S. McCain National Defense Authorization Act for Fiscal Year 2019," August 13, 2018
- House Report 115-769, "Department of Defense Appropriations Bill, 2019," June 20, 2018
- Military Standard 3050, "Department of Defense Design Criteria Standard: Aircraft Crew Breathing Systems Using On-Boarding Generating System," May 11, 2015
- Air Force Policy Directive 91-2, "Safety: Safety Programs," September 3, 2019
- Air Force Manual 91-223, "Aviation Safety Investigations and Reports," August 6, 2020
- Air Force Instruction 91-204, "Safety: Safety Investigations and Reports," March 10, 2021

Interviews Conducted

We met with Air Force personnel to gain an understanding of the Air Force's efforts to mitigate aircrew PEs. We interviewed personnel from the following organizations that are responsible for researching, maintaining, upgrading, training, and testing in response to an aircrew-reported PE.

- Air Combat Command, Joint Base Langley-Eustis, Virginia
- Air Education and Training Command, Joint Base San Antonio-Randolph, Texas
- Air Force Physiological Episodes Action Team, Arlington, Virginia
- Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio
- Air Force Life Cycle Management Center, Wright-Patterson Air Force Base, Ohio
- Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio
- Air Force Safety Center, Kirtland Air Force Base, New Mexico

Air Force Physiological Episodes Action Team

AF PEAT represents and acts on behalf of the Air Force Deputy Chief of Staff, Operations Plans and Requirements, on matters regarding PEs in operations, including all Air Force-owned or -operated aircraft or other operational platforms. AF PEAT advocates for policy and resourcing to mitigate PEs at the Headquarters,

Air Force level, and consolidates PE-related information from Air Force organizations to inform Air Force senior leaders and answer congressional inquiries. AF PEAT also facilitates communication and collaboration between the AFRL, the AFLCMC, Naval Medical Research Unit-Dayton, and academic and industry scientists, engineers, and aeromedical specialists to initiate PE-related research and development. AF PEAT also collaborates with the Navy PEAT to leverage PE-related discoveries from both Services.

Air Force Safety Center

AFSEC develops, implements, executes, and evaluates Air Force aviation, occupational, weapons, space, and systems mishap prevention and nuclear surety programs and policy. In addition, AFSEC oversees mishap investigations, evaluates corrective actions, and maintains AFSAS, a mishap database. AFSEC uses AFSAS to collect data related to PE incidents. AFSAS is a web-enabled mishap reporting and analysis system that can be accessed worldwide. The system can dispatch mishap messages and track mishap prevention recommendations. AFSAS has a featured analytics section that emphasizes safety-related reports that users can tailor to meet their specific needs. In addition, AFSEC conducts research to promote safety awareness and mishap prevention and develops and directs safety and risk management education for all safety disciplines.

Air Force Materiel Command

The AFMC conducts research and development, acquisition, testing, and maintenance of existing and future weapons systems and their components. The AFMC primarily serves an oversight role with respect to PE, functioning at times as a quality control for recommendations. The AFMC oversees six centers. The two centers involved with PEs are the AFLCMC and the AFRL.

AIR FORCE LIFE CYCLE MANAGEMENT CENTER

The AFLCMC is responsible for total life cycle management of all aircraft, engines, munitions, and electronic systems. The AFLCMC provides technical expertise to support mishap investigations. In addition, the AFLCMC tracks investigation recommendations in AFSAS. The AFLCMC manages the acquisition lifecycle of PE-related equipment and modifications provided to aircrews or installed in aircraft. The AFLCMC also provides technical expertise upon request to support PE mishap investigations. The system program offices for the T-6A Texan II, F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle report to the AFLCMC.[46] The system program offices manage the development and fielding of materiel

[46] The T-6A Texan II is part of a joint group with the Air Force and Navy called the Joint Primary Aircraft Training System.

solutions for aircraft if deficiencies are discovered or improvements are required. For example, the system program offices assist in investigations of PEs as required, research root causes of PEs, and implement plans of action to mitigate reoccurring PEs in aircraft platforms.

AIR FORCE RESEARCH LABORATORY

The AFRL mission is leading the discovery, development, and integration of warfighting technologies for U.S. air, space, and cyberspace forces. The AFRL operates one of four high performance computing centers in the DoD to tackle large-scale problems. In addition, the AFRL provides a vast array of services in a collaborative environment which includes Government, industry, and academia. The AFRL has nine technical directorates, one of which is the 711th Human Performance Wing. The 711th Human Performance Wing, established in March 2008 under the AFRL, investigates the causes of PEs, develops technology to acquire more physiological data during flights to integrate physiologic warnings with flight deck instruments, and improve the ACBS. Scientists of the 711th Human Performance Wing perform research based on requests from system program offices and lead MAJCOMs of the aircraft.

Air Combat Command

The Air Combat Command operates fighter, reconnaissance, battle-management, and electronic combat aircraft. In addition, the Air Combat Command provides command, control, communications, and intelligence systems, and conducts global information operations. The Air Combat Command is the lead MAJCOM for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle. As the lead MAJCOM for the F-15C Eagle, F-15D Eagle, and F-15E Strike Eagle, the Air Combat Command is responsible for standards, tasks, and training requirements for the fielding, operation, support, maintenance, configuration control, and sustainment of the system or activities for these aircraft.

Air Education and Training Command

The AETC recruits, trains, and educates aircrews to deliver airpower for the United States. The AETC provides training to aircrews when updates to training and manuals are made in regard to aviation safety systems, including PEs. For example, the AETC aerospace physiology training portfolio consists of 115 training systems that include altitude chambers, reduced oxygen breathing devices, hypoxia familiarization trainers, and Barany Chairs. The AETC is the lead MAJCOM for the T-6A Texan II.

Use of Computer-Processed Data

To perform this audit, we obtained PE data from AFSAS to identify the universe of reported PEs. AFSEC manages AFSAS, the system of record the Air Force uses to track mishaps and report recommendations. AFSAS is a web-enabled mishap reporting and analysis system that can be accessed worldwide. The system can dispatch mishap messages to registered users and track mishap prevention recommendations. AFSAS has an analytics section that emphasizes safety-related reports that users can tailor to meet their specific needs. The data contained within AFSAS is privileged safety information. AFSEC officials provided PE-related recommendation information after they removed privileged safety information. To verify that AFSAS data were reliable, we interviewed MAJCOM and system program office personnel knowledgeable of the data. We determined that the data used were sufficiently reliable for the purposes of this audit.

We obtained total flight hours for the selected aircraft from the Reliability and Maintainability Information System. The Reliability and Maintainability Information System is an automated information system that provides the Air Force with the capability to receive, process, store, and retrieve performance and readiness information on Air Force weapons systems and equipment. We did not test the reliability of the computer-processed data in the Reliability and Maintainability Information System because the focus of our audit was on whether the Air Force implemented corrective actions to improve safety and reduce PEs. Therefore, we determined that the reliability of the computer-processed data did not affect the conditions and findings in this report.

Prior Coverage

During the last 7 years, the Government Accountability Office (GAO) and the DoD OIG issued three reports discussing physiological events and related issues. Unrestricted GAO reports can be accessed at http://www.gao.gov. Unrestricted DoD OIG reports can be accessed at http://www.dodig.mil/reports.html/.

GAO

Report No. GAO-18-321, "F-35 Joint Strike Fighter: Development Is Nearly Complete, but Deficiencies Found in Testing Need to Be Resolved," June 13, 2018

> The GAO determined that the DoD made progress in completing the F-35 Lightning II baseline development program, but plans to finish testing later than expected. Specifically, the DoD plans to defer resolving some critical deficiencies found in testing until after its full-rate production in October 2019, even though the DoD's policy states that critical deficiencies

generally will be resolved before then. In addition, the DoD plans to spend billions of dollars to modernize the F-35 Lightning II with new capabilities and is requesting $278 million to begin that process before establishing a reasonable business case.

DoD OIG

Report No. DODIG-2021-004, "Audit of the Department of the Navy Actions Taken to Improve Safety and Reduce Physiological Events," November 4, 2020

The DoD OIG determined that the Navy took action to improve overall safety and reduce PEs for the eight aircraft reviewed. Specifically, the Navy performed research, training, maintenance upgrades, and testing with the goal of improving safety and reducing PEs. In addition, through this research, training, maintenance, upgrading, and testing, the Navy has taken actions to reduce, mitigate, and identify causes for PEs related to the T-45 Goshawk, F/A-18 A-D Legacy Hornet, F/A-18 E/F Super Hornet, and EA-18G Growler.

Report No. DODIG 2015-092, "F-35 Lightning II Program Quality Assurance and Corrective Actions Evaluation," March 11, 2015

The DoD OIG determined that the F-35 Program generally conformed to requirements and showed improvements in quality management system performance since the DoD OIG's previous evaluation; however, challenges still remain, as shown by 57 nonconformities to Aerospace Standard 9100, "Quality Management Systems – Requirements for Aviation, Space, and Defense Organizations," and 4 opportunities for improvement.

Appendix B

Summary and Status of Reviewed Recommendations

We reviewed the 79 recommendations (32 open and 47 closed) to determine whether the Air Force addressed recommendations made by a safety investigation board or a single investigator after a PE was identified. The office of primary responsibility has the responsibility to analyze each recommendation and take action. Each recommendation in AFSAS falls into one of three of the following defined categories.

- In Work (27 Recommendations) – Investigations are being addressed by the office of primary responsibility for implementation, alternate paths, or closure without action.
- In Coordination (5 Recommendations) – The office of primary responsibility has submitted a closure request and is awaiting coordination with other offices.
- Closed (47 Recommendations) – Recommendation closure action has been approved and closed in AFSAS. The closed recommendations fall into the following three categories.
    - Recommendations identified as closed, action completed (31)[47]
    - Recommendations identified as closed without action, risk accepted (12)
    - Recommendations identified as closed with alternate action, risk accepted (4)

We reviewed the 79 open and closed recommendations and grouped them into six categories: guidance, maintenance, training, new design and development, research, and testing. We could not determine the category for one recommendation because AFSEC removed privileged safety information.[48]

The DoD OIG is presenting the information in the following tables as provided by AFSEC. AFSEC revised the 79 recommendations to remove privileged safety information.

Table 12 lists the recommendations categorized as "In Work." Table 13 lists the recommendations categorized as "In Coordination." Table 14 lists the closed recommendations.

[47] This number includes one duplicate recommendation. That is, two incidents resulted in two recommendations that were substantially the same.

[48] DoD Instruction 6055.07, "Mishap Notification, Investigation, Reporting, and Record Keeping," June 6, 2011, Incorporating Change 1, August 31, 2018, defines privileged safety information as Information that is reflective of a deliberative process in the safety investigation or given to a safety investigator pursuant to a promise of confidentiality, which the safety privilege protects from being released outside safety channels or from being used for any purpose except mishap prevention. Privileged safety information also includes information given to a safety investigator pursuant to a promise of confidentiality and any information derived from that information, or direct or indirect references to that information.

Table 12. Recommendations "In Work"

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Date of Last Update	Subject Area	Narrative of the Recommendation
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] (~~CUI~~)

Table 12. Recommendations "In Work" (cont'd)

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Date of Last Update	Subject Area	Narrative of the Recommendation
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] (~~CUI~~)

Table 12. Recommendations "In Work" (cont'd)

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Date of Last Update	Subject Area	Narrative of the Recommendation
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] (~~CUI~~)

Table 12. Recommendations "In Work" (cont'd)

~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Date of Last Update	Subject Area	Narrative of the Recommendation
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Note: AFSEC removed privileged safety information and replaced the information with Xs.

LEGEND

CRU Crew Regulator Unit
MSL Mean Sea Level
OPR Office of Primary Responsibility
USAFAM United States Air Force School of Aerospace Medicine

Source: Air Force Safety Center.

Table 13. Recommendations "In Coordination"

~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Date of Last Update	Subject Area	Narrative of the Recommendation
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Source: Air Force Safety Center.

Table 14. Recommendations "Closed"

~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] (~~CUI~~)

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
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~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

(~~CUI~~) Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] (~~CUI~~)

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Table 14. Recommendations "Closed" (cont'd)

~~(CUI)~~ Aircraft	Approval Authority	Creation Date	Closure Date	Subject Area	Narrative of the Recommendation	Action Taken
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted] ~~(CUI)~~

Note: AFSEC removed privileged safety information and replaced the information with Xs.

LEGEND

AFI	Air Force Instruction
AFMAN	Air Force Manual
DCMA	Defense Contract Management Agency
FTS	Flying/Fighter Trainer Squadron
IAW	In accordance with
MDG	Medical Group
MSL	Mean Sea Level
NAF	Numbered Air Force
OGV	Operations Group Standardization and Evaluation
OPR	Office of Primary Responsibility
OSS	Operations Support Squadron
ROBD	Reduced Oxygen Breathing Device
SIF	Security Information File
SPO	System Program Office
T.O.	Technical Order

Source: Air Force Safety Center.

Acronyms and Abbreviations

ACBS	Aircrew Breathing System
AETC	Air Education and Training Command
AFLCMC	Air Force Life Cycle Management Center
AFMC	Air Force Materiel Command
AF PEAT	Air Force Physiological Episode Action Team
AFRL	Air Force Research Laboratory
AFSAS	Air Force Safety Automated System
AFSEC	Air Force Safety Center
CRU	Crew Regulator Unit
G-LOC	Gravity induced Loss of Consciousness
MAJCOM	Major Command
NASA	National Aeronautics and Space Administration
OBOGS	On-board Oxygen Generation System
PE	Physiological Event
TCTO	Time Compliance Technical Orders

Glossary

Aircrew Breathing System. The total system within the aircraft that produces, utilizes, generates, and delivers breathing gas to the aircrew.

Air Force Safety Automated System. A web-enabled mishap reporting and analysis system that Air Force personnel can access worldwide. The system can send mishap messages and track mishap prevention recommendations. AFSAS has an analytics section that emphasizes safety-related reports that users can tailor to meet their specific needs.

Lead Command. The Air Force Major Command or agency possessing an mission design series that is designated by Air Force Policy Directive 10-9 as responsible for the coordination of mission design series specific activities.

Liquid Oxygen Breathing System. This system uses ground-serviced liquid oxygen, which is converted to a gas before it is delivered to the aircrew. The system then makes use of a dilution regulator in the cockpit to mix the gaseous oxygen with cockpit air to achieve the appropriate partial pressure of oxygen for the cabin altitude.

Office of Primary Responsibility. Any headquarters, agency, or activity having the primary functional interest in, and responsibility for, a specific action, project, plan, program or problem.

On-board Oxygen Generating System. A system that uses a process to enrich breathing air with oxygen while removing contaminants.

Physiological Event. A physiological event is any injury, illness or abnormal physiological condition experienced by aircrew or others as a result of the dynamic flight environment.

Technical Order. A technical order contains operational or maintenance instructions, parts list or parts breakdown, or other related technical information or procedures for a weapon system, a component of a weapon system, support equipment, or other items procured by the DoD.

Time Compliance Technical Orders. A time compliance technical order is an authorized method of directing and providing instructions for modifying equipment and performing one-time inspections. Time compliance technical order is categorized as either immediate action, urgent action, routine action, or record depending on the compliance period.


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