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THE HOUSE ARMED SERVICES COMMITTEE  
TACTICAL AIR AND LAND FORCES  
SUBCOMMITTEE

STATEMENT OF

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BEFORE THE

TACTICAL AIR AND LAND FORCES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

PHYSIOLOGICAL EPISODES WITHIN NAVAL AVIATION

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## **Introduction**

Mr. Chairman, Representative Tsongas, and distinguished members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the Department of the Navy's (DoN) ongoing efforts to address physiological episodes (PEs) in fighter, attack, and training aircraft.

Addressing PEs remains the #1 safety priority for the entire Naval Aviation community and we have implemented numerous technical and operational measures to mitigate the risk to our aircrew. Utilizing every resource available in our efforts to resolve these issues, the DoN has engaged a broad swath of internal and external partners, including subject matter experts from United States Air Force, National Aeronautics and Space Administration (NASA), Federal Aviation Administration, industry, academia, medical, and dive communities. In addition, we've established regular fleet communication to share all data and progress related to PEs.

The Navy and Marine Corps are performing a variety of actions to prevent and mitigate the effects of PEs in our F/A-18/EA-18G and T-45 aircraft. These efforts focus on determining and removing root causes, promptly and reliably alerting aircrew when malfunctions occur, and providing effective training and emergency procedures to enable safe aircraft recovery.

PEs occur when aircrew experience a decrement in performance related to disturbances in tissue oxygenation, depressurization or other factors present in the flight environment. PEs are generally categorized into two groups, those related to the Onboard Oxygen Generation System (OBOGS) or pilot breathing gas and those caused by problems in the Environmental Control System (ECS) (i.e., unscheduled pressure changes in the flight station). These phenomena jeopardize flight operations.

In 2009 the F/A-18 Program Office (PMA-265) began to see an increase in reported PE events across the fleet and, therefore, established a Physiological Episode Team (PET) in 2010 to begin to address the issue. In 2014, The Naval Air Systems Command (NAVAIR) established a Systems Command PET, revamping the PMA-265 team, to also include T-45 aircraft, which were beginning to see a rise in PE events at that

time. That team remained in place until March of 2017, when the PET was reorganized into two platform-led PE Integrated Product Teams (IPTs), F-18 and T-45, to focus on unique solutions required for each platform and established formal Root Cause and Corrective Action analysis teams for both platforms.

A comprehensive review of PEs was directed by the Chief of Naval Operations and conducted in April 2017, resulting in the establishment of the Physiological Episode Action Team (PEAT). Led by a Flag Officer, the PEAT is a unified, single-source entity which directs Department of the Navy efforts to combat PEs and synchronizes these efforts with the Department of Defense, non-DoD entities and our foreign partners . Within the DoN, the PEAT is responsible for coordination between the Office of the Chief of Naval Operations, CNAF, NAVAIR, BUMED, and the Naval Safety Center (NAVSAFECEN). External to the DoN, the PEAT provides a single leader to discuss DoN PE efforts.

Integrated with the PEAT, NAVAIR platform specific-PE IPTs are co-led with the Boeing Company, under formal charters, and also include participation from Northrop Grumman, the NAVAIR Engineering Fleet Support Team (FST), NAVAIR Air Vehicle Department (AIR-4.3) ECS Team, NAVAIR Human Systems Team (AIR-4.6), the Bureau of Medicine and Surgery (BUMED) Aeromedical Action Team, and the Aviation Environmental Scientific Advisory Board (AESAB). These PE IPTs work closely with other program offices, cross-service affiliates, industry partners, and foreign partner nations in evaluating each episode for root cause and appropriate corrective action. The PEAT follows three lines of effort, warn the aircrew, fix the machine, protect and prevent.

Warn the aircrew. The PEAT has synchronized efforts between NAVAIR and the NAVSAFECEN to provide timely information to aircrew regarding past PEs, present research and mitigation efforts, and future plans. Direct fleet engagement has been established through PE “roadshows”, where representatives from the PEAT, NAVAIR, and NAVSAFECEN are available for frank and direct dialogue with aircrew, providing an “open forum” between warfighters and leadership. Additionally, revised reporting

procedures from CNAF, rapid investigation of events by NAVAIR, and wide dissemination of information through the PEAT and NAVSAFECEN, have made great impact in restoring aircrew confidence in their equipment.

**Fix the Machine.** In March 2017, NASA was commissioned to independently review the ongoing F/A-18 PE mitigation efforts and to provide a fresh perspective leveraging a team with experience from the F-22 PE investigation. NASA and the comprehensive review provided the catalyst to achieve broader collaboration between DoD agencies, NAVAIR and BUMED. The PEAT was formed as a recommendation from both reviews to take the lead in unifying multiple DoD agencies, industry partners, and foreign partner nations to facilitate collaboration and reduce redundant efforts. By leveraging lessons learned from across the DoD and fostering relationships between entities, the PEAT is aiming to establish a “best of breed” solution across the Naval Aviation Enterprise and consolidated funding profiles.

**Protect and Prevent.** Paralleling the first line of effort, the PEAT persists in fostering the same relationships in developing methodologies to protect and prevent our aircrew from the underlying risks associated with PE. Integral to this effort is development of equipment to measure and report health of the cockpit environment, and when necessary, to provide warnings or automated actions to minimize aircrew exposure to hazardous conditions. The PEAT is investing in advanced data analytics to coalesce the plethora of historical and current aircraft data to identify trends with the objective of identifying "bad-acting" aircraft or degrading systems before failure. The ultimate goal is to optimize the cockpit environment for human performance to give our aviators every tactical advantage in the dynamic environment in which they operate.

Historical data of F/A-18 physiological events prior to May 2010 is based on safety reports. The rate per 100,000 flight hours during FY 2006-FY 2010 is as follows:

<b>Date Range</b>	<b>F/A-18A-D</b>	<b>F/A-18E-F</b>	<b>EA-18G</b>
FY06	3.66	2.18	0.00
FY07	1.63	3.73	0.00
FY08	3.72	4.28	0.00
FY09	6.19	8.33	0.00
FY10	4.95	11.96	0.00

In May 2010, the Commander, Naval Air Forces (CNAF) directed specific reporting procedures to collect more data on the occurrence of PEs. Following implementation of the new reporting protocol, the rate per 100,000 flight hours beginning in May 2010 is as follows:

<b>Date Range</b>	<b>F/A-18A-D</b>	<b>F/A-18E-F</b>	<b>EA-18G</b>
05/1/2010 - 10/31/2010	12.20	8.98	0.00
11/1/2010 - 10/31/2011	10.90	8.65	5.52
11/1/2011 - 10/31/2012	16.39	23.35	5.42
11/1/2012 - 10/31/2013	21.01	26.23	9.80
11/1/2013 - 10/31/2014	29.54	26.39	15.05
11/1/2014 - 10/31/2015	30.20	28.02	42.89
11/1/2015 - 10/31/2016	57.24	31.05	90.83
11/1/2016 - 10/31/2017	101.42	30.47	65.52

The process for investigating a physiological episode begins with the submission of data describing the event. Engineers from the ECS FST and the Aircrew Oxygen Systems In-Service Support Center work with the squadron maintenance department to identify which components of the aircraft should be removed and submitted for engineering investigation. The squadron flight surgeon also submits data on the medical condition of the pilot and in-flight symptoms that were experienced.

After completion of the component investigations, the incident is examined holistically by members of the engineering teams and Aeromedical specialists to identify the most likely cause of the incident. Of the 588 cases adjudicated to date, 212 involved ECS component failures, 194 were attributed to breathing gas issues, including 51 OBOGS component failures and 13 breathing gas delivery component failures, 92 involved human factors, and 87 were inconclusive or involved another aircraft system failure. Of note, some of the events resulted in assignment to more than one category.

### **T-45 Physiological Episodes**

Data recorded since introduction of the T-45 Physiological Event Reporting Protocol form in November 2011 is presented below by calendar year. Prior years' data for T-45 aircraft is incomplete and is not included.

<b>Calendar Year</b>	<b>Calendar year rate per 100K flight hours</b>	<b>Cumulative rate per 100K flight hours</b>
2012	11.86	11.86
2013	16.22	13.94
2014	18.43	15.36
2015	44.99	22.70
2016	46.97	28.01
2017	66.19	32.06
2017 (pre-mods)	110.65	32.94
2017 (post mods)	22.28	32.27

The 2017 rate is broken into two parts. The first is prior to the CNAF directed operational pause and the second is post return to OBOGS flight on July 18<sup>th</sup>, 2017. Six events have been reported since returning to OBOGS flight and of those, only one event has been attributed to aircraft systems causal factors. The other events have all been linked to other human factors, but are still counted as Physiological Episodes.

In the summer of 2017, the investigation methods associated with reported Physiological Episodes changed. NAVAIR and the Chief of Naval Air Training (CNATRA) implemented new reporting guidelines to ensure information is rapidly gathered and communicated. Additionally, new aircraft and flight gear data recording devices allow expeditious and thorough reviews of all reported physiological episodes. The new procedures are captured in a CNATRA instruction and follow the guidelines that were recently outlined by NAVSAFECEN.

### **Efforts to Mitigate Physiological Episodes on F/A-18 and EA-18G Aircraft**

F/A-18 Physiological Episodes: The PEAT currently considers hypoxia and decompression events as the two most likely causes of recent physiological episodes in aviators. As symptoms related to pressure fluctuations, hypoxia and contamination overlap, discerning a root cause is a complex process. Episodes of decompression illness typically accompany a noticeable loss or rapid fluctuation of cabin pressure, while the cause of hypoxic events is often not readily apparent during flight or post flight. Reconstruction of the flight event is difficult with potential causal factors not always readily apparent during post-flight debrief and examination of aircraft and aircrew. A variety of actions have been undertaken to address the occurrence of PEs in the F/A-18/EA-18G. These include new maintenance rules for handling the occurrence of specific ECS built-in test faults; forward deployment of transportable recompression systems to immediately treat aircrew in the event they experience pressure related symptoms; mandatory cabin pressurization testing on all F/A-18A-F and EA-18G aircraft every 400 flight hours and ECS pressure port testing is performed on all F/A-18A-D aircraft every 400 flight hours; improved overhaul and aircraft servicing procedures for ECS components; revised and expanded emergency procedures; annual hypoxia awareness and biennial dynamic training using a Reduced Oxygen Breathing Device (ROBD) to experience and recognize hypoxia symptoms while operating an aircraft simulator. In addition, aircrew are provided portable barometric recording watches to alert them when cabin altitude reaches preset thresholds or exceed fluctuation thresholds.

Internal components of the F/A-18 OBOGS have been redesigned to incorporate a catalyst to prevent carbon monoxide from reaching the pilot and provide an improved capability sieve material (filter). These new OBOGS components have been installed in 92 percent of the in-service F/A-18 fleet so far.

Improvements to existing maintenance troubleshooting procedures and acceptance and test procedures for reworked components have been incorporated and additional improvements are under evaluation. Hardware and software changes are in work for Super Hornets and Growlers to mitigate cabin pressurization issues due to moisture freezing in the ECS lines. Component redesign, improved performance testing, and newly established life limits will improve component reliability across all F/A-18 configurations.

F/A-18 A-Ds are undergoing a phased ECS overhaul. Phase 1 is the incorporation of Air Frame Bulletin (AFB)-821 to replace seven of the most critical ECS components. Phase 2 is currently under development and is intended to replace valves, duct lines, couplings and brackets to restore ECS system integrity and provide aircrew with a stable cockpit environment. Early indications of our ECS efforts indicate marked improvement to the pressure stability of the system and the cockpit. An increased capacity for the emergency oxygen bottles is under contract. “Sorbent tubes” which collect and identify breathing gas contaminants are attached to aircrew regulators to collect samples of breathing gas for post-flight analysis of potentially harmful compounds. Over 800 sorbent tubes were collected during EA-18G sorties flown from Naval Air Station (NAS) Whidbey Island. Collection efforts are ongoing on F/A-18 A-F at NAS Oceana. To date, the levels of contaminants measured in OBOGS breathing gas are well below published limits known to cause human impairment.

An ECS laboratory has been constructed for investigation and ECS system characterization to support root cause and corrective actions findings. Aircrew carry “SlamSticks,” small pressure recording devices, on 100 percent of sorties to track and collect cabin pressure during ground and flight operations. This data is downloaded post-

flight and synchronized with aircraft maintenance data for rigorous analysis, increased aircrew awareness, and post PE investigation. Future projects include systematic evaluations of technologies to monitor and detect physiological symptoms.

### **Efforts to Mitigate Physiological Episodes on T-45 aircraft**

A variety of actions have been undertaken to address the occurrence of PEs in the T-45, including instituting recurring immersion training at all CNATRA sites using ROBDs. Flight manual procedures were updated to optimize crew posture for PE recognition, response, and avoidance. Maintenance publications at both the operational and intermediate maintenance levels have been revised to increase the minimum oxygen generating performance of the concentrator. Engine wash water intrusion tests have been performed to determine if water was entering the OBOGS supply air. Tests indicated that no water was ingested in the OBOGS supply air lines. Sorbent tubes and hydrocarbon detectors (HCDs) have been installed on aircrew to monitor breathing gasses coming off OBOGS. The sorbent tube and HCD are attached to the aircrew vest and ported off the oxygen mask hose. Approximately 1,800 sorbent tubes have been analyzed as of 24 January 2018, including tubes associated with reported PEs, and contaminant levels have shown values less than that of ambient air, and are well below Occupational Safety and Health Administration (OSHA) standards.

New sieve beds were installed in the Gas Generating Unit (GGU)-7 Oxygen Concentrator. The new sieve beds addressed the possibility of built up contaminants in the sieve bed material by installing all new material, and incorporated a carbon monoxide catalyst to protect against carbon monoxide. New CRU-123 solid state oxygen monitoring units were fielded, which provides aircrew alerting if delivery pressure falls, and it records system performance and faults. A total of 163 new oxygen monitors have been installed as of 24 January 2018. The data logging capability of the new oxygen monitor has provided invaluable insight into the performance of the T-45 oxygen system and has provided new confidence to the aircrew. Additionally, pressure alerting provides an additional level of protection to aircrew.

We've released a draft Request for Proposal for a new oxygen concentrator. The new concentrator (GGU-25) will be a significant increase in capability over the 1980's era concentrator currently flying in the T-45. It will have increased reliability, data logging, incorporate a shutoff valve, and have a lower pressure drop across the sieve beds. A combined team has been formed with Government, Boeing (T-45 Original Equipment Manufacturer (OEM)), and Cobham (Oxygen Concentrator OEM) members to cooperate on multiple lines of effort to address Physiological Episodes. Multiple rounds of high intensity stress testing of the GGU-7 Oxygen Concentrator have been conducted at both NAVAIR and Cobham Laboratories to determine concentrator performance outside of the normal operating limits (high temperature and high humidity).

NAVAIR released an end-to-end cleaning procedure for the OBOGS bleed system and updated regular maintenance procedures to sustain system hygiene. Additional thorough cleaning procedures are being developed. The thermal performance of the OBOGS bleed air system is being evaluated by conducting tests on in-service heat exchangers and temperature switches that provide alerts when over-temperature conditions occur. New water separators have been installed in all T-45 aircraft flying on OBOGS to guard against water intrusion in the concentrator.

Analysis of engineering alternatives was begun to increase the breathing air pressure delivered to aircrew. This effort is being run through Boeing and will lead to follow on efforts to implement an Automatic Backup Oxygen System (ABOS). Lastly, piping was designed and tested that removes the legacy bleed air shutoff valve in the T-45 OBOGS bleed air system. The legacy bleed air shutoff valve was wired open in response to the low reliability of the valve. This new piping removes a source of leaks and decreases the pressure drop as the air moves from the engine to the OBOGS concentrator. A separate effort to incorporate a new, more reliable bleed air shutoff valve is ongoing.

## **Shared Platform Efforts**

Data management and collection has been enhanced through initiation of a new data management plan. In addition, new test procedures were developed and OBOGS and ECS bleed air contaminant testing has been conducted on fleet aircraft to establish measurement thresholds and foment a predictive system performance methodology; developed new test sets to assess oxygen system degraded performance. Flight and maintenance publications have been updated to help prevent inadvertent system damage, ensure leak free system integrity, add periodic inspections, and ensure system cleanliness.

We've begun increased monitoring of the performance of oxygen concentrators in the Fleet through the development of new test equipment that performs all levels of concentrator testing on the aircraft. The new equipment also tests the performance of the carbon monoxide catalyst. The regular monitoring will enable NAVAIR engineers to set the appropriate life limit for the new sieve material, protecting aircrew from degraded performance.

Understanding that PEs happened to humans, we have sought out the most capable experts in aeromedical research. PMA-202 who specializes in Aviation life support and human systems at NAVAIR is working with Naval Aviation Medical Research Unit – Dayton (NAMRU-D) to actively research multiple topics where medical understanding is immature. NAMRU-D is a key member of the new Naval AESAB, tasked with providing recommendations on multiple physiological issues. NAMRU-D enjoys a strong partnership with the USAF 711<sup>th</sup> Human Performance Wing (HPW) providing complementary capabilities for aeromedical research while supporting cross service collaboration in both research and experimentation. Oxygen cross talks, bring specialists from NAVAIR, the 711th HPW and academia altogether to share research and expertise to optimize life support systems for all of our platforms.

## **Conclusion**

The Department of the Navy remains focused on solving this issue and this will remain our top safety priority until we fully understand, and have mitigated, all possible

PE causal factors. Fleet awareness is high, confidence in their platforms and our processes are improving, protocols are in place and we are focused on mitigating risk, correcting known deficiencies. We are integrated in our efforts with our sister services as well as academia, industry and our international partners to resolve the Physiological episodes. Moving forward we continue to fly in defense of our country while applying every resource to solve this challenging problem.