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ADDRESSING PHYSIOLOGICAL EPISODES IN FIGHTER, ATTACK, AND TRAINING AIRCRAFT

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ADDRESSING PHYSIOLOGICAL EPISODES IN FIGHTER, ATTACK, AND TRAINING AIRCRAFT

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON TACTICAL AIR AND LAND FORCES,
Washington, DC, Tuesday, February 6, 2018.

The subcommittee met, pursuant to call, at 3:30 p.m., in Room 2118, Rayburn House Office Building, Hon. Michael R. Turner (chairman of the subcommittee) presiding.

STATEMENT OF HON. MICHAEL R. TURNER, A REPRESENTATIVE FROM OHIO, CHAIRMAN, SUBCOMMITTEE ON TACTICAL AIR AND LAND FORCES

Mr. TURNER. Everyone, take a seat. We are under the pressure of votes. They are going to happen sometime around 4:00, 4:15, so we are going to try to make certain we get through everybody's statements and maybe some initial comments.

So beginning with my opening comments, the subcommittee meets today to receive an update on how the Departments of the Navy and the Air Force are addressing physiological episodes [PE] in tactical and training aircraft. I would like to welcome our distinguished panel of witnesses. We have Mr. Clint Cragg—is that correct? Okay—Principal Engineer from the NASA [National Aeronautics and Space Administration] Engineering and Safety Center [NESC]; Rear Admiral Sara Joyner, Physiological Episodes Action Team Lead for the U.S. Navy; and Lieutenant General Mark Nowland, Air Force Deputy Chief of Staff for Operations. I want to thank each of you for your service and for your important testimony today.

For over 2 years now, this subcommittee has held briefings, hearings, and conducted site visits regarding the occurrences of physiological episodes, or PEs, in tactical and training aircraft. As I stated before, I believe Navy leadership was initially slow to respond to this issue that is having a direct effect on overall readiness and affecting the confidence of our pilots, as well as their ability to perform their missions.

Because it is not just that these events are occurring; it is also the anxiety that these events occur in succession. As a result of the subcommittee's activity, the National Defense Authorization Act [NDAA] for fiscal year [FY] 2017 included legislation that required an independent report of the Navy's efforts to resolve these issues. That report was delivered to the subcommittee in mid-December, and a copy has been provided to members' offices.

According to the report, the Navy was addressing the PE problem as an aircraft problem, not a human problem. We have to acknowledge that physiological episodes happen to people, not aircraft. I was just talking to the Secretary of the Air Force, and the human body as a sensor is perhaps different than just our technological sensors and can give us a gap in the information or data that we are receiving, but we have to trust those pilots, those human responses and reports that we are having of these issues.

The report also concludes that the F/A–18 systems that support human health are "complex, dynamic, and interactive." As a result, the more complex, dynamic, and interactive a system is, the more important it is to have a well-coordinated systems approach to design and operations.

Finally, the report notes that the physiological episodes will persist in the F/A–18, and all high-performance aircraft, if there is a piecemeal approach to human systems integration. Our witness, Mr. Cragg, was the primary author of this report, and he is prepared to provide the subcommittee with a summary of the report's findings and recommendations.

On September 15th of last year, Ms. Tsongas and I visited the Naval Air Station Pax [Patuxent] River to receive briefings on the root cause and corrective action processes from members of the Navy's Physiological Episodes Action Team [PEAT]. We spoke with engineers and pilots and learned about the Navy's process to find the root cause of these events. We were also briefed on the Navy's attempts to alert and protect the aircrew and monitor the system.

Additionally, we spoke with engineers at some of the labs who are analyzing specific portions of the primary systems that make up the Environmental Control System, ECS, and the On-Board Oxygen Generating System, OBOGS. I believe the Navy has taken a step in the right direction by establishing a formal action team directly responsible for addressing physiological episodes. The team is led by our Navy witness today, Rear Admiral Joyner.

However, despite these efforts, pilots are continuing to experience physiological episodes, and I am concerned about the increased frequency. For example, since the subcommittee's last event in May of last year, the Navy as well as the Air Force have continued to report incidences of PE in aircraft.

This past summer, the Navy made the decision to ground T–45 training aircraft due to increasing occurrences of pilots experiencing hypoxia symptoms in the aircraft. The decision was made after a significant number of instructor pilots at all three T–45 training locations refused to fly the aircraft due to safety concerns with the oxygen systems. It is an incident that we were very concerned about in this committee that would have to go to the level of the pilots themselves intervening and refusing to fly, prior to leadership understanding the need to intervene.

The Air Force grounded F–35 Joint Strike Fighters [JSF] at Luke Air Force Base in June of last year due to oxygen problems, and the F–35 fleet has experienced 29 physiological episodes to date.

In early December of last year, the subcommittee was informed that 13 A–10 aircraft at Davis-Monthan Air Force Base have been grounded due to problems with the oxygen systems. And just last week, the Air Force grounded all T–6 training aircraft at six operating locations due to an increasing rate of unexplained physiological episodes in the T–6 aircraft.

There is no doubt this remains a complex problem to solve that requires a well-coordinated systems approach to include all factors, such as the aircraft, the pilot, and the environment. So in closing, we need to be reassured that this remains a top priority for the Navy and the Air Force and that the two services are coordinating efforts and that such a systems approach to solve this problem is being taken.

The increasing frequency of these physiological episodes is having a direct effect on overall readiness, and as such we expect to receive your professional assessments on what we as members of this subcommittee can do to help you address this critical problem. In addition to effects on readiness, this has a direct correlation and effect on morale.

Before we begin with witnesses' opening statements, I would like to turn to my good friend from Massachusetts, Ms. Niki Tsongas, for any comments that she may want to make.

[The prepared statement of Mr. Turner can be found in the Appendix on page 29.]

STATEMENT OF HON. NIKI TSONGAS, A REPRESENTATIVE FROM MASSACHUSETTS, RANKING MEMBER, SUBCOMMITTEE ON TACTICAL AIR AND LAND FORCES

Ms. TSONGAS. Thank you, Mr. Chairman, and good afternoon to our witnesses. It is good to have you here. And I want to thank Chairman Turner for holding this hearing and continuing the subcommittee's focus on this really important issue.

One of the reasons for today's hearing is a completion of the independent review of the Navy's efforts to address persistently high rates of physiological episodes experienced by aviators in F/A–18 aircraft, a critical issue since these episodes can put a pilot's life at risk.

The review was mandated by the fiscal year 2017 NDAA and conducted by the NASA Engineering and Safety Center under the leadership of Mr. Clinton Cragg, who is here with us today, and I would like to thank you, Mr. Cragg, and your entire team for your diligent work on the report.

I am also pleased that Rear Admiral Joyner is with us today, but I must point out that the Navy has decided to move the Admiral out of her current position overseeing the service's response to physiological episodes after less than a year in the position. While I understand that the Navy is working to find another talented officer to take over the position, I do believe that making the change so soon sends an unfortunate message to the entire Navy aviation community, including their families. This important issue deserves unified leadership and I would urge Navy leadership to prioritize continuity in this position moving forward.

After reviewing the report, it appears its findings and recommendations fall into three broad categories. First, it makes several findings and recommendations related to the, quote, "human factors", unquote, underlying the Navy's physiological episode problem. The report states upfront that, quote, "Physiological episodes happen to people, not aircraft", unquote. It goes on to point out numerous areas where human factors research, data gathering, and testing is needed to provide a true end-to-end understanding of the problem.

I will have several questions on some of the issues raised in the report in this area.

Second, the report points out several specific concerns with the design and specifications of the F/A–18 aircraft related to aircrew life support. It places particular attention on the aircraft's oxygen generation and cabin pressure systems, raising significant questions regarding both.

Finally, the report examines internal Navy organizational challenges that may be making it much harder to address the PE issue. In particular, the report focuses attention on the need for the Navy's medical community to be more tied into the Navy's ongoing lines of effort.

And of special concern to me, given what we learned about the situation the Navy faced this summer in its T–45 training community, the report also raises concerns about, quote, "a breakdown of trust in leadership within the pilot community," unquote, regarding the Navy's efforts on this issue.

I know that hundreds of dedicated people in the Navy are working very hard to address this problem. But the report points out that we have a long way to go and that in some areas we can do much, much better. I am hopeful that the Navy is carefully examining the findings of this report and acting on them as quickly as possible and hope to learn more on this front today.

The other reason for today's hearing is to get an update from the Air Force on its challenges with its own physiological episodes, most recently in F–35A, A–10s, and T–6A aircraft fleets. In the case of the T–6A, the Air Force's fleet remains grounded. We need to know the full story of what happened and how the Air Force plans to stay ahead of this problem moving forward. I look forward to today's testimony and yield back.

Mr. TURNER. Thank you, Ms. Tsongas. Without objection, all our witnesses' prepared statements will be included in the hearing record.

Mr. Cragg will begin, followed by Admiral Joyner and General Nowland. Mr. Cragg.

STATEMENT OF CLINTON H. CRAGG, PRINCIPAL ENGINEER, NASA ENGINEERING AND SAFETY CENTER

Mr. CRAGG. Chairman Turner, Ranking Member Tsongas, and members of the subcommittee, thank you for this opportunity to discuss the NASA Engineering and Safety Center's, or NESC's, independent assessment of the Navy's efforts to understand and mitigate the F/A–18 fleet physiological episodes.

Mr. TURNER. I am sorry, sir. If I could interrupt you for a second, if you could move that microphone to in front of you, because we are not hearing you— they are directional. If you could point it at you, there you go. Thank you.

Mr. CRAGG. Too complicated for me. I am honored to be serving as the lead for this NESC team. The NESC performs independent testing, analysis, and assessments to help address some of NASA's tougher challenges.

We can draw upon technical experts from all 10 NASA centers, from industry, from academia, and other governmental agencies.

This allows us to bring the country's best experts to bear on the problems and challenges of NASA programs.

In February 2017, the U.S. Navy's Naval Air Systems Command requested NASA's assistance in assessing the Navy's efforts to understand the causes of physiological episodes affecting aircrew on their F/A–18 fleet. In March of 2017, the NESC assembled a multidisciplinary team with a broad range of expertise that included flight surgeons, life support system experts, engineers, and several subject matter experts.

In the course of this investigation, the team reviewed data from a variety of sources, visited multiple manufacturing sites and Navy commands, and held numerous discussions with knowledgeable personnel. The NESC team's findings and recommendations are based on this data and not an exhaustive review of all F/A–18 documentation.

To address the complex causes of physiological episodes, the NESC team used a multi-systems trends analysis approach and formed the following resulting findings. First and foremost, physiological episodes are a human phenomenon. Although the Navy has put a significant effort into investigating the physiological episodes, the bulk of their efforts to date have been directed at the aircraft, rather than human physiology. Centering our investigation on the human element revealed new information about the character of physiological episodes.

Second, hypoxia—determined to be the most prevalent cause of physiological episodes—is not a condition of insufficient oxygen in the breathing gas. It is insufficient delivery of oxygen to tissues of the body, importantly, the brain.

Third, a key reliable On-Board Oxygen Generating System performance is uniform operating conditions, which the F/A–18 design and dynamic operating environment rarely provides.

Fourth, the F/A–18 program has a large amount of aircraft performance data, but a shortage of evidence related to human health and performance in an F/A–18 environment.

Fifth, the F/A–18 systems that support human health are complex, dynamic, and interactive. This requires a well-coordinated systems approach to design requirements, interfaces, and operations.

Finally, an unacceptable number of physiological episodes will persist in the F/A–18 program if there continues to be a piecemeal approach to the human systems integration.

The NESC team made the following observations regarding the Navy processes. Until recently, the absence of a single leader to coordinate and prioritize the Navy's physiological episodes efforts resulted in organizational stove-piping and exclusion of key stakeholders. Investigations have been structured as if the physiological episodes were isolated events, rather than a series of related events.

Furthermore, troubleshooting efforts used a top-down approach that emphasized component-level behaviors instead of evaluating the performance of the system as a whole. In this case, the system means the aircraft, the pilot, and the environment.

The NESC team asserts that a dedicated, coordinated, cross-organizational, and cross-discipline program—under the direction of a single leader with clearly defined authority—would improve the U.S. Navy's effectiveness in finding and fixing the causes of physiological episodes.

The NESC team has identified a number of near- and long-term recommendations. Near-term tasks are focused on gathering key evidence about human health and performance and understanding hypoxia in the F/A–18 flight environment. Long-term tasks which may provide substantial benefit include utilizing a data-driven causal analysis effort, updating the F/A–18 to conform to MIL–STD–3050 [Military Standard], and developing a systems-level understanding of bleed air management systems.

In conclusion, and although key data is lacking, the NESC believes that the majority of F/A–18 physiological episodes are a result of hypoxia. This hypoxia, it is believed, is caused by a combination of issues affecting the various stages of oxygen delivery process, including those stages within the human.

We applaud the Navy's efforts to gather the necessary data to resolve these issues. The NESC report has provided a conceptual framework to view the issue of physiological episodes in a new light and offers recommendations that may guide future processes and technological improvements.

I thank you for the opportunity to testify before the subcommittee and look forward to your questions.

[The prepared statement of Mr. Cragg can be found in the Appendix on page 32.]

Mr. TURNER. Admiral Joyner.

STATEMENT OF RDML SARA A. JOYNER, USN, NAVY PHYSIOLOGICAL EVENTS ACTION TEAM LEAD, U.S. NAVY

Admiral JOYNER. 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 ongoing efforts to address physiological episodes, or PEs, in fighter and attack and training aircraft.

Addressing PEs remains the Navy's number one safety priority and encompasses naval and Marine Corps aviation communities. We have implemented numerous technical and operational measures to mitigate the risk to our aircrew. Utilizing every resource available to resolve these issues, the Department of the Navy has engaged a broad spectrum of internal and external partners, including subject matter experts from the United States Air Force, National Aeronautics and Space Administration, Federal Aviation Administration, industry, academia, medical communities, and the Navy's dive communities. In addition, we have established regular fleet communication to share all data and progress related to PEs.

I would like to first focus on the efforts of the Physiological Episodes Action Team, or PEAT. In April 2017, the Chief of Naval Operations directed a comprehensive review of PEs be conducted. As a result, the PEAT was formed to serve as a single-source Navy and Marine Corps entity which unites both Department of Defense [DOD] and non-DOD entities as a cohesive force to combat PEs.

The PEAT follows three lines of effort: Warn the aircrew, fix the machine, protect and prevent. Our efforts rely on understanding of an inherently challenging environment encountered at altitude and its effects on the human body.

The PEAT has served to synchronize efforts to resolve physiological episodes between NAVAIR [Naval Air Systems Command], Commander Naval Air Forces, Bureau of Medicine and Surgery, the Naval Safety Center, our industry partners, and academia.

Coordinating multiple agencies, the PEAT's focus is on finding the root causes of PEs, correcting deficiencies that they are identified, and equipping existing agencies with long-term resources to address PE issues effectively.

Additionally, the PEAT is responsible for providing timely information to aircrew and maintainers regarding past PEs, present research, ongoing mitigation efforts, and future plans. Direct fleet engagement has been established where representatives from the PEAT, NAVAIR, and the Naval Safety Center are available for frank and direct dialogue with aircrew, providing an open forum between warfighters and leadership.

We provide a response triage reports to aircrew to improve feedback and communication. These efforts combined have made a great impact in restoring aircrew confidence in their equipment and the efforts to resolve the PE problem.

Why haven't we solved the issue yet? Our incredibly talented engineers at NAVAIR have worked diligently to ensure the aircraft are operating according to required specifications and that material solutions met engineering requirements. As our aircraft capabilities have advanced, we have encountered challenges in how to best support the human in the cockpit in an ever more dynamic environment.

Today, we benefit from oxygen systems that no longer limits prolonged operations. Rather it is limited only by the constraints of fuel, ordnance, and human endurance. Routinely operating for 8 hours or longer on a combat mission, by flying higher, faster, and longer, we have come to realize that there are aspects of our operational environment that need to be more fully understood.

The NASA report was valuable in reminding us that we need to consider not just what we were most comfortable with addressing—the engineering elements—but also the human performance element of the aviation environment.

The effects of pressure and breathing gas composition on the human body. It became apparent that in order to discover physiological episode root causes, we needed to start with the human, the aviator, and the cockpit. The close relationship between our aeromedical specialists and our engineers had atrophied, and we are working actively to restore this relationship in combatting PEs.

Today we acknowledge that there is more we need to learn about human physiology in a pressurized environment and incorporate that into our engineering design. We are moving forward to close our knowledge gap through research and instrumentation on humans in flight and to develop a thorough and holistic understanding of environmental challenges in the flight regime that results in PEs.

I would like to thank Congress for supporting the Navy's and our efforts to address PEs. We were able to combine congressional funding with other resources to immediately put into motion research and material solutions to address physiological episodes, as well as expedite longer-term solutions.

We are moving forward in optimizing the cockpit environment with measurable improvements, providing our aviators with every tactical advantage in a dynamic environment in which they operate. It is appropriate that I appear today with our Air Force partners. Not present today are our international partners who continue to assist us in gathering data and providing solutions to the PE issue.

Right now, the Royal Australian Air Force and the Swiss Air Force fly with instrumentation to gather further data in support of our efforts. I have no doubt that through our coordinated efforts we will be successful in resolving this issue for the U.S. Navy, the Marine Corps, the Air Force, and our international partners.

Thank you for the opportunity to present our progress today. I look forward to your questions.

[The prepared statement of Admiral Joyner can be found in the Appendix on page 39.]

Mr. TURNER. General Nowland.

STATEMENT OF LT GEN MARK C. NOWLAND, USAF, DEPUTY CHIEF OF STAFF FOR OPERATIONS, U.S. AIR FORCE

General NOWLAND. Chairman Turner, Ranking Member Tsongas, and distinguished members of the subcommittee, thank you for the opportunity to provide an update on our physiologic events within your United States Air Force.

Today I will address some of the risk our airmen face defending our Nation, as well as multiple initiatives underway to address physiological events. Operating high-performance aircraft is fundamental to air superiority. Inherently, the nature of our profession means there will always be risk to the human body. It can be caused by unforeseen mechanical issues in our increasingly complex aircraft or by overstressing our bodies when we are max performing those aircraft to their combat capability.

As the Deputy Chief of Staff for Operations, I believe that training our pilots is the critical factor between life and death. Whether it is executing the right procedures during in-flight emergency or the maneuvers necessary to defeat an adversary in combat, training is paramount. Therefore, we make sure it goes hand-in-hand with material solutions when we implement recommendations for physiologic events.

The Air Force tracks and provides historical data on physiological events. And even though the probability that Air Force pilots will experience a physiological event remains much less than 1 percent per year, the Air Force takes flight safety very serious. The service investigates every incident that may impact our most valuable asset, our people.

And we are in complete agreement with actually the NASA report. This is really about people, as we have discovered over our incidents over time. The Air Force increased the budget of our 711th Human Performance Wing nearly by $60 million over the past 10 years, which goes back to the F–22 incidents we had, because we recognized we needed to look at the human element here.

This funding has supported multiple research vectors into hypoxia, biomechanics, and toxicology studies.

Additionally, the Air Force was able to add five pilot physicians last year. I have Dr. Bill Mueller behind me who is an example of those. He is a rated Air Force pilot, but he is also a physician, so he flies the airplanes that were actually out there and able to talk to the aviators. This unique critical program qualifies aerospace physicians to fly the airplane and then care for the airmen.

We have also made organizational changes to the Headquarters Air Force Operations staff. I have appointed a general officer to be the singular point of contact for physiologic events. We learned from the Navy essentially. Brigadier General Bobbi Doorenbos will integrate the flow of information during physiological event investigations. She couldn't be here today because she has something with her family, her father, but she is hand-in-hand with Admiral Joyner.

General Doorenbos provides a single nexus to pass information from aircrew to senior leaders and across multiple stakeholders. We continuously strive to improve our processes which we share information between multiple agencies and our joint partners during these events. The Air Force stood up an investigative team called the Characterizing and Optimizing the Physiological Environment in Fighters. Typical, we have a five-letter name as opposed to the Navy's four. We call it COPE Fighter. This multiple service interagency team identifies solutions to optimize human performance and minimize unexplained physiologic events in our high-performance aircraft.

But they are not always high-performance aircraft. So I would like to provide a quick update on our T–6, which is our primary trainer, which is critical to United States Air Force. The trainer fleet experienced multiple unexplained physiological events since the beginning of 2018. The first one happened at Columbus on the 19th of January, and I happened to be there on the day when it happened. It was an extremely cold day.

We took an operational pause last Friday after we had multiple events across the fleet, to include Sheppard and Vance—and if you remember, Vance had had previous events. We did it because we needed to think about the safety of our student pilots and the instructors. This pause will remain in effect until we are certain that aircraft and procedures ensure flight safety.

Major General Patrick Doherty, the commander of the 19th Air Force and our Air Education and Training Command, and his wing leaders are actively meeting in person with T–6 instructors and student pilots to discuss the current situation and to listen to their concerns. We have learned this from our F–22 Raptor, our F–15, and our F–35. Direct interface with the leadership to the pilots is critical.

But it is also critical that they meet with the spouses, because we need to ensure the family members that we put safety first and to explain what actions we are undertaking to repair and return the fleet to flying status. The key is trust. If the aircrew doesn't trust their system, the family doesn't trust the Air Force, we lose. That is why training is critical to this whole as we move forward.

In our experience, we have studied the OBOGS, the onboard generating systems, and for the most part, we have not really discovered anything that is not working properly. We had some A–10 issues, which was a maintenance issue. We think we are discovering in the T–6 it is a maintenance issue right now. The system and the way the systems work is sound. Maintaining it is the critical factor.

Your Air Force T–6s have flown 2.1 million hours with a physiological rate of 1.95. That means 1.95 incidents for every 100,000 hours flown. But in 2018, the rate is soaring. So what is going on? That is why we paused to look at it. But we also need to get in the training, and we totally agree with the Navy—I mean with the NASA. We need to instrument our pilots. We are looking into that as we move forward.

I thank you for the opportunity to provide you an update, and I appreciate the opportunity to answer any questions.

[The prepared statement of General Nowland can be found in the Appendix on page 52.]

Mr. TURNER. General Nowland, I got to tell you, I could not be more disappointed by your presentation. I mean, we have hearing after hearing after hearing on this, and we have this report in front of us, and the report and the presentation that we have is that the human factor is not being taken into consideration and your answer is training.

Now, I got to tell you, what I have in front of me—and I just had the Secretary of the Air Force in my office, and she does not agree with you. And I am glad, because you didn't ground your aircraft, your T–6 aircraft, just last week because of training. And this is a significant issue, and it is not just listen and talk. This is pure safety.

Now, when we first started having hearings on this, the issue that individuals who are testifying before us came forth with was the difficulty to replicate the conditions in which the physiological episode happened. No one ever came to us and tried to blame the pilots and say it is just an issue of training. There is something wrong with the systems that these pilots are relying on for their lives and that we are asking them to rely on.

Now, I was just telling the Secretary—and I mentioned this in the very first hearing that we had on this—I had this issue when I was a mayor, and it was with my firefighters and their breathing apparatus and equipment. And we, too, could not replicate anything that was happening with their equipment except situation after situation they found themselves in where their breathing apparatus was failing. And it had an impact of morale on the entire fire department.

And what I am stunned by is that here I am—and I don't even know how many hearings we have had on this—and I still have someone who is representing one of the most important service branches for our pilots come and say this is an issue of training and listening and we need to talk to spouses. I mean, I have this report in front of me, and one of the headlines on this report is "No Physiological Monitoring of the Pilot's Breathing Air Has Been Conducted." This isn't an issue of talking.

I mean, the Secretary of the Air Force is concerned that the T–6 training aircraft are grounded not because somebody doesn't have training. Now, I realize what they have done in the past, but I realize what they are doing now. And I realize the problem that we had in the failure of the leadership in the Navy because we had pilots that refused to fly because the leadership of the Navy continued to treat this as if it was not a physiological episode that was happening to people, but that it was something that, because they were not able to replicate it, didn't need to be addressed.

Now, we asked for this report and to move forward with this, because we didn't feel like we were getting the right answers. But if you continue to come before us and say this is just an issue of training the pilots, I mean, you know, General, should we start doing hearing training where we ask you to come before us and then let's have you hold your breath for a minute during the first hearing, and the second hearing we will have you hold your breath for the second for 2 minutes during the second hearing? It makes no sense.

Mr. Cragg, give us some sense here. I know the OBOGS system has been tested. There are certainly concerns of maintenance. There are certainly concerns of where to identify this. But clearly something is wrong for these number of pilots to have these incidences and these planes to be grounded versus just we just have to train them to understand what happened when the incidents happen.

What should be happening to try to fix this so our planes fly again and people can get the training and our pilots have the confidence in their equipment?

Mr. CRAGG. Well, sir, as we looked at the situation, we tried to come up with some hypotheses on what was causing the problems with the pilots. And we went through and looked—at least on the Navy side, we went through and looked at all the cases and our flight surgeons came up with a consensus that over 80 percent of those cases were due to hypoxia.

Then we looked at the systems onboard the aircraft, and they have what is called an OBOGS degrade light, which comes on when the percentage of oxygen gets below certain values. So what we—we did a little further digging and found out that many or most of the physiological episodes that occurred happened without this OBOGS degrade light on. So in other words, they were getting enough proper oxygen in the cockpit.

And so when we went to look further, what we found was there is hardly any information on the human in the cockpit. We don't have the amount of oxygen in his mask, the amount of CO_2 [carbon dioxide] in his mask, the kind of pressure that you would want to know about in the cockpit, the breathing rates, those kind of things where we could do some kind of physiological assessment of what is happening to the pilot.

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Now, in our report, you may have noticed we had an oxygen diagram that showed how oxygen was—how we think oxygen is being taken away in little certain steps by different circumstances like an aircrew vest that is too tight, maybe they didn't have enough water to drink before they went on a flight, some things like that. But what we really need is to get a picture of the pilot, and we don't have that yet.

Mr. TURNER. Do you have any sense that that step is being taken? I mean, because as we try to do the data, pulling just off of these systems that are producing the oxygen, and being unable to replicate it, do you see any steps that are occurring to be able to get that data of what the human is experiencing?

Mr. CRAGG. Absolutely. As a matter of fact, I get a weekly summary from the Navy on what they are doing to assist in the physiological episodes. And the one I got end of last week, they have made some remarkable progress on getting those type of instruments in the cockpit that are going to measure just those things we talked about.

Mr. TURNER. What is the data saying?

Mr. CRAGG. Well, I haven't seen the data, but what they have is they are out testing it with the VX–23, I guess it is, so—I mean, it is a heck of a lot further on than it was when we delivered our report.

Mr. TURNER. Admiral, what are you finding?

Admiral JOYNER. So where we are today is, we went to what was easy in T–45. We put in a system that could do cockpit pressure and oxygen delivered at the regulator outside of the OBOGS system to the pilot, because we could do that. And when we did that on the T–45, we had the discovery that we had a flow problem in that aircraft, and that was able to give us that.

But that was an easier solution than what we are pursuing right now. What he is speaking of is something called an AMS—it used to be called AMS, now it is called VigilOX—which is an attempt to measure breathing gas at the pilot. And we have tried several systems so far, and there are a lot of difficulties. It is probably one of the most difficult aspects of this problem. We are working closely with the Air Force to do this, and we are leveraging a lot of their early findings in F–22.

So we are—these systems come forward. They are not perfect, but we have flown three flights now with the VigilOX system. We are just starting to collect the data. And it is really early with the three flights. Right now we don't see a lot of problems with the oxygen——

Mr. TURNER. I know you can't tell us anything that is conclusive, but are you at least being able to capture something that indicates that there is a problem?

Admiral JOYNER. We are able to capture the information of what is being delivered at the pilot level. Right now it will take those medical professionals and those researchers for us to better understand the data that is being delivered—because it is not apparent from the data that we are seeing what the shortfall would be, but it is three flights in, so it is very immature at this point. We are taking those steps. Those steps were brought forward by the 711th Human Performance Wing, some of their early work with the system, and through NASA prompting and also the oxygen labs at NAVAIR, there is a lot of work to make these systems work and make the data actually speak to us.

Mr. TURNER. So speak to us about the F–35. Apparently 29 physiological episodes have occurred. What can we learn from what you are doing now? And how does that apply to the F–35?

Admiral JOYNER. I would say with the F–35, I talk to them constantly. A through C. I am sure the general also is collecting that data, as well. They enjoy an airframe that speaks to you more clearly than any other airframe we have ever had. So if I take my legacy Hornet, you are looking at my 1978 Corvette. If I go to a Super Hornet, I am looking at maybe a 2016 Lincoln Navigator. And I am in a JSF, I am flying the newest and greatest, and it is telling us more data than we have ever had.

So they are actually accelerating a lot of their learning, and they just finished testing their OBOGS system, and they have a good understanding of that system. And it was a very positive outcome. But obviously we have issues that we have to pull apart that are not—we haven't discovered yet at this point.

Mr. TURNER. Ms. Tsongas.

Ms. TSONGAS. Thank you. I would like to talk about the role of the medical community, as you have wrestled with these very troubling episodes. And I think one of the—obviously the finding that we are all most taken by from the independent report is that this is so much about people.

So I am going to quote again from it, just to sort of restate that. So chapter 12 states the following. Quote, "PEs happen to people, not to aircraft. The U.S. Navy is addressing the PE problem as an aircraft, not a human problem. Remembering that PEs afflict people and not aircraft may help focus activities on better understanding human systems, human system requirements, and human system impacts caused by conditions of flight."

Later, in Appendix A of the report, it goes further and says, quote, "The naval medical community as a whole has not been involved with attempting to solve the PE issue." From the beginning, PEs have been viewed as an engineering issue. And you have even referenced that, Admiral Joyner. "Therefore, a proactive investigative U.S. Navy medicine effort never really got underway," unquote.

As an example of a lack of U.S. Navy medical involvement, the report points out that the decision to deploy hyperbaric chambers to treat altitude-induced decompression illness appears to have been taken at the operational level. That is to say that it was made without any senior-level medical involvement. So, Mr. Cragg, can you please elaborate on these statements in the report and what you and your team think should be done about it?

Mr. CRAGG. Well, I think we were clear that the medical community needed to get involved. And I am happy to say that they currently are. One of the flight surgeons on my team participates with this meeting of naval medical people that is just now getting underway to help support the PE processes that Admiral Joyner has started.

You know, it is unfortunate, but when everybody was saying this was an engineering problem, they weren't asked, and so they didn't participate.

Ms. TSONGAS. And were you surprised to find that?

Mr. CRAGG. Yes, we were actually very surprised to find that. And——

Ms. TSONGAS. So now that we found this to be a real shortcoming, Admiral Joyner, these two findings and this particular example, you know, are obviously quite troubling. And I think most members would assume that the Navy's medical community would be tightly integrated in all aspects of addressing the PE issue. Those of us here certainly would be.

So what is the Navy currently planning to do in this area of its overall PE response? And is there a plan going forward for U.S. Navy medical to be involved and in some way that we can depend upon?

Admiral JOYNER. Yes, ma'am. Part of the standup of the PEAT was to bring in the Bureau of Medicine and Surgery underneath the PEAT in order to coordinate those efforts better. And that is what having a single entity to try to bring this entire fabric together has allowed us.

So what did we do? We set up something called the Aeromedical Scientific Advisory Board, environmental advisory board, and they are a group of professionals, both medical, academia, oxygen specialists, our research scientists, some of the ones from Dayton, Ohio, toxicology out of our NAMRU [Naval Medical Research Unit] Dayton group, that are dedicated to advising us as we move forward on the PE issue.

We also have an aeromedical team that is immediately involved in all the responses on the flight lines and analyzing and making sure that we are coming up with clinical practice guidelines that are coherent and are tied in well with that research community and with our medical community.

And then on top of that is we have the root cause corrective analysis team who has—one of the members is an operator who has become a flight surgeon, much like the Air Force was talking about, General Nowland was talking about, and we have those professionals, as well, involved in the root cause analysis to make sure that we don't lose that human element as we go forward to try to find the root cause of the PE. So those are several examples.

Ms. TSONGAS. Have you found that by engaging the medical community in a more structured way, has it changed your clinical practice guidelines? So, for example, have you revisited the treatment you might—the ways in which you dealt with hypoxia or dealt with decompression illness?

Admiral JOYNER. I think it has standardized the response across the flight line, and it has energized further research in those areas that we are not as knowledgeable as we need to be for what the type of treatment should be. We also engage NASA, has been involved in several case reviews for us on some of the difficult issues of what the treatment should be.

So we are extending beyond even within our internal resources to external resources like NASA, Duke oxygen specialists, and other people that we are bringing onboard to better understand this problem. So I think it has increased the scope. It has increased our consistency with the clinical practice guidelines. And we know that the chambers themselves, it is a do no harm. We know that they improve in conditions under those treatments, and we are not going to stop treating them effectively until we can find something better. But we have a full research community dedicated to finding out better ways to treat our aviators at this point.

Ms. TSONGAS. Thank you, I yield back.

Mr. TURNER. They have called votes. I think we can get to Mr. Kelly and Mr. Langevin, and then we will take a break. Mr. Kelly.

Mr. KELLY. Thank you, Mr. Chairman and the Ranking Member. This is a very important issue. I think most of the people in here have either soldiers—I mean, sailors or airmen that are affected, airpeople, airwomen. I have Columbus Air Force Base, and, General Nowland, we just talked beforehand. And I know your son just graduated from there, so I know that you are personally invested in getting this right, because you have got skin in the game. And I think that applies to all of us who have served.

I kind of agree—there is multiple issues. And we haven't figured it out at any level, and we have got to figure this out, what is causing this, whether it is maintenance, whether it is lack of training, whether it is the improper use of equipment, whether it is the equipment itself. We have been going over this a long time, but it is critical that we get it right and that we get it right quickly, but it is more important that we get it right.

What type of—I don't see any movement in finding the solution, and that is very, very difficult. So, I mean, you have got to start with seeing what those are. What things do you think or is there any indication that we are getting close to finding at least what is causing it, whether it is the maintenance of the system, which I heard you say, General Nowland—and I think that is important. If we don't maintain the system right and don't do that, then we get those episodes.

Do either of you—and this would—anybody on the board, do we have any idea what may be causing this?

General NOWLAND. Congressman Kelly, thank you very much. And, Chairman Turner and Ranking Member Tsongas, and the distinguished members, if you got the impression from my testimony that we are blaming pilots, we are not. We are not.

When I meant training, I am talking holistic training, exactly back to your part. Part of our suspicion with the T–6 is that the time change technical order for the On-Board Oxygen Generating System does not exist. We are formulating it right now. So we never trained our technicians on how to maintain that piece of equipment.

What we found in the F–22s is the equipment that we had—the aircrew flight equipment, the life support equipment, we didn't have our crews trained properly to wear the equipment properly, and we noticed the valve on the chest was part of the solution.

Back to the altitude chambers, we have 10 altitude chambers, but the altitude chamber that we did training 10 years ago or 20 years ago is different than what we do today. So it is a holistic view of all of it.

So I think right now our suspicion is that the maintenance of our On-Board Oxygen Generating System for our T–6s, after having flown them for 2.1 million hours, needs to be repaired. So we believe there is a repair that—but we don't know that for sure.

The human physiological episode, we absolutely believe—as I said with the NASA—that that—we have got to collect data. We have ear cups data that we use in the F–35 that allows us to take the blood. One of the things that we found is when we have a physiological episode, we do not have the time quite right, because the blood alkalinity changes. So we are putting testing equipment that will meet the aircrew right at the airplane to try to get the best data that we can get from the pilots in the meantime.

So to answer your question, sir, we are working multiple solutions. We think it is maintenance on the T–6 right now.

Mr. KELLY. One other quick question. And this is to both of you. Grounding of the T–6 or the T–45 or whatever equipment, we already have a pilot shortage across the board. What impact does this have on the training pipeline? And what are we doing to make sure that we don't have a prolonged impact which gets, you know, the accordion effect as we go in time?

General NOWLAND. Sir, General Doherty, the 19th Air Force commander, is working two solution sets. One is trying to get the On-Board Oxygen Generating System to work properly. The second one is an interim solution where we would modify the CRU-60, which is what we connect our oxygen mask to, take it off of the onboard generating system, use the ambient pressure, and then modify the flight profile so that we stay between 6,000 and 7,000 feet on cabin pressure, and then we would stop all solos. We would always fly our crews dual as we working the simultaneous. We lose 700 sorties a day right now with the T–6 grounding. That will have an effect on our pilot training.

Admiral JOYNER. For the T–45, we have turned the curve. Our rate is maybe one-fifth of what it was at the point where we were approaching the grounding, and that is a significant change. We assess that we have identified the flow problem in the T–45 as being the primary issue. We have taken steps to mitigate it. We have long-term steps to solve it.

For right now, though, we have a training impact that is—we are trying to absorb in all different phases of flight through our follow-on training. We are bringing the Reserves to bear against the training problem. We are extending the resources of the contract support that we have on the T–45. And we are trying to buffer that impact across the system, longer term relying on some of our aviators to operate longer on a volunteer basis at sea in order to try to blend this across the system.

But there are impacts. And you can't deny those. We are just trying to mitigate them at this point.

Mr. KELLY. Thank you, Chairman. My time is expired.

Mr. TURNER. Thank you. Before I get to Mr. Langevin, General, thank you for clarifying that. This is our fifth hearing and briefing on this. We just sort of expect a progression of shared values on issues, and I appreciate your clarifying your language, because when we began this, as Mr. Cragg has said, it is not just the human value, the pilot value is not being honored. I appreciate you making that clarification statement. Because there is at times when you have something like this the question of, is it real? And this committee certainly believes that what is occurring is real.

Mr. Langevin.

Mr. LANGEVIN. Thank you, Mr. Chairman. I want to thank our witnesses for being here today. It is a very important issue that we need to get to the bottom of.

I haven't heard a whole lot that makes clear sense of all this yet, except for some of the information I have before me right now, so I will put this out there and then ask Mr. Cragg to respond first. But the NASA review report states on page 15 that, quote, "A problem with the breathing gas system as a whole is that the onboard oxygen generation system gets fed last. The enormous amounts of cooling air required for the avionics and radars (especially on the E/A–18G Growlers) means that the ECS [environmental control system] controls preferentially direct flow to them" instead of the OBOGS.

Then finding 10–7 of the report states that, and I quote, "Avionics flow has priority over cabin flow in some operational cases . . . data from the PE flights has directly demonstrated cases in which high avionics flow results in lower than required cabin airflow."

Finally, observation 10–2 in the report states that, and I quote, "The Navy appears to have little insight into elements of the ECS control programming logic. Discussions with engineering teams at the Patuxent River and fleet support activity North Island suggest that the logic programming control sets were not part of the contract deliverable for the F–18 and, therefore, may no longer be documented in any form."

So if I had to summarize these three statements, it would be that the crew's airflow comes last. But the Navy doesn't seem to know exactly why that is the case. So given the aircraft can't operate without its crew, one would think that the opposite would be true.

So, Mr. Cragg, to you, would you agree with the overall assessment? And what else would you like to add to what is in the report on this subject?

Mr. CRAGG. Thank you. Yes, I would agree with that statement. The Navy does not fully understand the pressure control logic, because as you mentioned, it wasn't part of the F–18 design that was supplied to the Navy by Boeing.

But this somewhat gets to the theme—one of the themes of our report that we think the Navy needs to do some human system integration where they look at all aspects of what is going on with the human, what is going on with the environment, and how the system of the airplane itself operates. And if they don't have an idea of how the logic control portion of a key component, the environmental control system, that is a deficiency.

And they need to do that. They need to figure out how that operates so—you know, one, they can troubleshoot the system properly, but at the other side, they need to do this human system integration where they put everything together and understanding exactly how your systems operate is key to that.

Mr. LANGEVIN. Admiral Joyner, I also have several questions for the Navy following the statements in the report. First of all, what can be done to fix this? Does the Navy have all the technical data on the F/A–18 to address this issue? And if airflow to the crew was given first priority on the aircraft, how would that affect mission systems? And then finally, does the Navy have an effort in place with Boeing to address this design issue in the current and new F/A–18s?

Admiral JOYNER. I would say I vary in my opinion and my status on the ECS system. The OBOGS is the primary system that is fed. And cooling air is not removed from the OBOGS system in order to feed it elsewhere. There are instances where if the avionics are overheating that it won't pull it from the OBOGS, it will pull it from the cooling for the pilot in order to make sure the avionics function. None of us want our avionics to shut down, because it will result in an ejection, and that is not something we want to see.

So overall, I would say that when I look at the ECS system on the F/A–18, we need to regulate it better. That is where our emphasis has been. Due to the timing of the legacy system in the F/A–18, a lot of what is available on the ECS system is analog. It is in vaults and it is stored elsewhere. We have access to those, but it is not as simple as looking it up on a system. You have to go find that. And we are working directly with Boeing to make sure we have access to all the support material we need.

The engineers at NAVAIR reassure me and have walked me through the system to explain to me why they know that the pressure system and how they have tested it, but we realize we want to test it further on the OBOGS system, and we are taking advantage of the 711th lab that they have that they are able to do dynamic testing that recreates the flow that is given to that system in the OBOGS. So we are going to take advantage of that testing, as well, to do dynamic testing, not just point testing.

Mr. LANGEVIN. Did I understand you, though, that you completely disagree with NASA's findings that the OBOGS system is fed last?

Admiral JOYNER. My understanding of the system is that OBOGS is prioritized first, ECS is second. The third system that goes is the avionics cooling, except if it starts to compromise those avionics systems. And then we are going to pull heat but not pressure out of the system. The F/A–18 has a lot of pressure, and it is—from what I see to date, it is more about regulating that pressure, because we are causing over-pressurization at times within that system. And that is an issue that we have to—we are putting in eight corrections to the ECS system in order to try to regulate that pressure better and try to smooth the flow.

So we realize that our concentrator, our OBOGS system, could have a better system and we are pursuing that, but we don't necessarily agree that the—how it is prioritized is done incorrectly.

Mr. TURNER. We are going to have to take a recess. We do have votes we have to run to. And I know Mr. Gaetz has questions, and we will be returning for those.

[Recess.]

Mr. TURNER. Okay, we will call the hearing back to order. Please have a seat. Mr. Gallego, your questions, please.

Mr. GALLEGO. Thank you. My question is about the GGU–12 On-Board Oxygen Generation System on our F/A–18s.

At three separate points in the report, NASA advises us of testing and practices for the critical system that seem abnormal. First, the report states that the Navy and Boeing have not followed well-known industry best practices in a system that is critical to the life support of our F/A–18 aircrews. Further, it appears that current test equipment does not simulate real flight conditions actually encountered by the F/A–18s.

So if that is true, it could generate false positive results, as we are hearing from now, that may conceal underlying problems with the system as it operates under real conditions. And third, it appears that some of the underlying design specifications for the F/A–18's oxygen generation system are decades, decades out of date and do not reflect the latest scientific knowledge on aircrew breathing demands.

One of the report's key recommendations to bring these specifications up to date to conform to standards developed in 2015. So, Mr. Cragg, taken together, these examples from the report indicate that the breathing system of the F/A–18 has serious problems. Do you agree?

Mr. CRAGG. Yes, sir.

Mr. GALLEGO. And how would you summarize what these problems are?

Mr. CRAGG. Well, I would say unfortunately the original OBOGS specifications were not put through the human systems integration process that would have highlighted the fact that it cannot deliver for all conditions, like high-stress portions of the flight. That is why a key recommendation of our report is to re-examine the OBOGS in light of the human system integration effort. And additionally, as you pointed out, some of the testing that is done on the OBOGS doesn't utilize in-flight conditions. But I understand they are getting better and closer to the real thing.

Mr. GALLEGO. They are getting better and closer to the real thing. Is there a time period we understand that this is going to be happening?

Mr. CRAGG. I think you have got to ask the Navy that, sir.

Mr. GALLEGO. Lieutenant General Nowland, while you are not Navy, do you have anything to add to Mr. Cragg's answer?

General NOWLAND. On the F/A–18, no, sir, I do not.

Mr. GALLEGO. Okay. I think many of us are a little anxious to see some form of conclusion or time period, especially involving the lives of our service members. I yield back.

Mr. Chairman, I yield back.

Mr. TURNER. Mr. Carbajal.

Mr. CARBAJAL. Thank you, Mr. Chairman. Thank you all for your service and for addressing us today.

The report makes two statements regarding leadership and communications within the naval aviation community that I want to touch on.

First, in finding 10–29, it states that, quote, "There has been a breakdown of trust in leadership within the pilot community" and that "one notable area leading to a lack of trust in leadership is the completion of Parts A/B/C of the Physiologic Episode report. Once these questionnaires are completed, they disappear through the 'system,' only to be examined months later. None of the pilots interviewed ever received official word as to the cause of the incident or the mitigation the U.S. Navy would be taking to reduce the likelihood of a repeated event."

Second, with regard to feedback from aviators, the report observation 10–20 points out that, quote, “The Navy has not conducted a fleet wide survey of their F/A–18 air crew to understand the PE problem from the human perspective, where these events actually occur.”

Taken together, it appears that the communication issue noted in the Navy’s own comprehensive review conducted earlier this year remains a problem.

Rear Admiral Joyner, what is the Navy doing to get feedback on PE event investigations back to the crew members that experience them?

Admiral JOYNER. Yes, sir. What we do right now is we have a quick look that we are doing. We start in T–45s, where we try to come back at the 48-hour point, and we brief out our quick look response of what we are receiving from the Parts A, B and C, and information that we receive from the aircraft itself. And we present that to the aircrew. Approximately 30 days later, we come back with a full report, which outlines what we found on the aircraft as far as any system failures, any additional information we were able to derive from the data sets.

So in F/A–18, we are using Slam Stick data, which tests the pressure inside the cockpit. We are getting the OBOGS information for any type of malfunctions we are able to find. We also have a quick response force that falls in on the aircraft. And rather than breaking the system, as we have historically, we holistically analyze a system with a team on station that includes a medical professionals. It includes engineers. A Boeing rep [representative] is also onboard. And the pilots are also involved with the pilot maintenance and the aviation physiology, the aeromedical safety officer, all fall in on the aircraft to do this analysis and try to figure out root cause for each of the events.

That is all communicated back to the pilots. Part of that communication plan is also what we call the PE road show, which is—I just returned from Japan doing one out there, both Atsugi and Iwakuni, and we addressed the pilots directly on what we are finding with their aircraft, different trends. We are getting a health monitoring system up online that basically shows the prognostic health of their airframes by BUNO [bureau number], and we are showing them on their aircraft what we are seeing with the data. So the feedback loop has been strengthened, and we are making sure that we are getting that back down to the deckplates, to the aviators, site by site.

The second part is the survey. We just completed the survey last Friday. We did get over 500 responses out of our aviation community, but we also did maintainers, as well. It was a large response. We got about 22 percent of aviators and maintainers responded to the survey. And that survey is designed to go ahead and solicit that feedback and get information about different things that have impacted the pilots and how they are operating.

So we did take both of those onboard, and we did move forward on them quite regularly. And then we also have the weekly newsletters and engagements that we do with the fleet. I go site to site.

Mr. CARBAJAL. And was this done, this survey of the F/A–18 community, as well?

Admiral JOYNER. Yes, sir, that was F/A–18 and T–45.

Mr. CARBAJAL. Great. May I ask how long this feedback loop has been in place?

Admiral JOYNER. The T–45 feedback loop has been in place for roughly I think 3 months. When we stood it up and went back to flying, back in September timeframe, we realized that we needed to push that information down. And so in September, the T–45 led the way, and now we have brought that onboard with F/A–18 and we started that roughly November, December timeframe.

Mr. CARBAJAL. Great. Thank you very much, Mr. Chair. I yield back.

Mr. TURNER. Mr. Panetta.

Ms. Tsongas.

Ms. TSONGAS. Thank you all for being here. I am sorry for the break, but appreciate your patience. Admiral Joyner, I just have a couple of quick questions, really only take a yes or no answer, or a maybe if it is not clear that it is one or the other.

The report states in finding 10–20 that there has been no definable effort to use the OBOGS laboratory at the 711th Wing at Wright-Patterson Air Force Base to assess effects on OBOGS output gas. Is there currently a plan in place to conduct this testing?

Mr. TURNER. I was going to ask that, but I felt like I had a conflict, so thank you for asking that. I did not ask her to ask that, but that is important. That is in the report, and that is a question.

Admiral JOYNER. Yes, ma'am. We are intending to use the 711th Dynamic Testing Lab that they have on site.

Ms. TSONGAS. It is an important resource, and it is a shame it took this study to lead to that. Does the Navy intend to issue a request for proposal in the near future for a new On-Board Oxygen Generation System for the F/A–18?

Admiral JOYNER. Yes, ma'am.

Ms. TSONGAS. Does the Navy intend to develop and install a new cabin air pressure monitoring and alerting system for the F/A–18?

Admiral JOYNER. Yes, ma'am.

Ms. TSONGAS. Does the Navy intend to design and replace the F/A–18's cabin pressure regulator valves?

Admiral JOYNER. Yes, ma'am.

Ms. TSONGAS. Is the Navy doing——

Admiral JOYNER. We are looking into a suitable replacement for that. We have gone through to repair them and to make sure that the maintenance, when they come back out to the fleet, is accurate. We are looking at a couple of different options for that valve, but right now we have concerns about some of the solutions we have been offered. So I wanted to clarify that.

Ms. TSONGAS. Okay. Is the Navy doing upgrades to the ECS software on F/A–18s and EA–18Gs to deal with icing in the ECS-related water lines?

Admiral JOYNER. Yes, ma'am.

Ms. TSONGAS. And is the Navy planning to install an automatic backup oxygen system in the T–45?

Admiral JOYNER. Yes, ma'am.

Ms. TSONGAS. Is it planning to do so for F/A–18s?

Admiral JOYNER. It is not at this time.

Ms. TSONGAS. Thank you.

Mr. TURNER. Admiral, help us. We have had a total of five now hearings and briefings. Ms. Tsongas and I both traveled to you and have received briefings on this. We asked for this report, and, Mr. Cragg, thank you so much for the detailed information that is in this, and this is very, very helpful, of, unfortunately, things that aren't happening after things that aren't happening after things that aren't happening.

This has got to be fixed. This has got to stop. And I don't have confidence that we are getting nearer to that. I believe that there are a number of things that are being done and a number of things that are not being done that are now being done because the report said to do them.

But this would seem to me to be something that needs to be done quickly and expeditiously and that this should not be a research project. This should be a fix-it project. Help me get some sense that we have in place things that are going to do that, knowing that this started with our having an understanding that pilots had to revolt and say, "I won't fly" because the chain of command wasn't even recognizing their complaints and their incidences, you know, all the way to there is still a sense of morale of lives are at risk.

Help us get a sense that the work that we are doing and the work that you are doing is going to result in something.

Admiral JOYNER. Right now, T–45s are fully operational. They operate every day. We have over 27,000 flight hours. We have had six events in those aircraft, all mild in nature, one of which was a system failure that was identified by the system.

So we have turned the corner on T–45. We have long-term corrections in place, design changes to the aircraft to fully address it, so we are not declaring victory. We have an RCCA, root cause corrective analysis, team that goes line by line, starting with the human, ending with the human, trying to find root cause for both the T–45 and the F/A–18.

Industry is involved. Aeromedical is involved. NASA helps consult and keep us on track so that we don't lose sight of things that may be falling out. We have a long-term goal of adding a robust human systems integration effort on par with our aircraft design requirements and engineering force. So we are looking to fully integrate them within our efforts.

On F/A–18, we are turning the corner. We see now that we are able to influence the pressure response on the aircraft. We have been able to make noticeable and observable, measurable changes to the F/A–18, which are resulting in a better, more stable ECS system. There are long-term design changes in place to ensure that we further stabilize that system and we have an OBOGS concentrator that we are looking for a request for proposal.

We are open to added things that are found along the way in order to make sure that we are not missing anything. That root cause effort is a longer-term effort that will lead us—the medical force outcomes will take more time. Those are fully funded through the FYDP [Future Year Defense Program] type of efforts to fully define pressure and oxygen requirements for pilots. We are working with the Air Force actively, and we are pursuing all those answers long term.

I don't—every day I ask myself, what else could we be doing that we are not doing? I turn to NASA and I ask those questions. I work with the Air Force. And we make sure in academia, as well. And we want to make sure that we are not missing a single thing, and we have gotten your assistance, as well, which is helping us do those efforts.

So all I can tell you is, my effort doesn't stop. I will have somebody who will relieve me in this effort, and we won't stop until we resolve it.

Ms. TSONGAS. I want to thank Mr. Cragg for this very important study that I think has helped create a path forward. And I appreciate, Admiral Joyner, the seriousness of purpose you have brought to this effort. Again, as I said in my opening remarks, I am very concerned that you are being rotated out in less than a year into this effort and remain very hopeful that somebody will be put in your place who can stick with it a little longer, because we know change does lead to setbacks. And we can't afford to lose any more time.

And just wanted to say, as we are here, as we sit here today, new F/A–18s are rolling off the production line at a cost of about $69 million per aircraft. At some point, paying $69 million for an aircraft we know has serious problems with its life support system has to be questioned. So I am not calling for stopping production, but it seems clear that the Navy and Boeing need to work together and come up with improvements to the F/A–18 that make them safer for our brave men and women in the military to operate, because we know it puts their lives at risk, and to make sure every single new F/A–18 has those improvements built in from day one and we are not back here a good number of years hence revisiting these same problems yet again.

Thank you, and I yield back.

Mr. TURNER. Thank you. Mr. Cragg, many times this committee authorizes a request for a report to be done. You and NASA have outdone yourselves. This was a phenomenal and excellent report. It is great to see that work product translated from our request. And thank you for the dedication of which you approached this.

Appreciate all of your efforts for this. I hope as we get to our—what will have to be a sixth hearing and/or briefing on this, that we have a greater sense—although, Admiral, I appreciated your closing comments of things that you are accomplishing—a greater sense that this is being advanced in a way that hopefully the committee can feel as if it is being done in a way that our oversight is no longer necessary and these can be just incidences that go into reports instead of incidences that in the aggregate require congressional action.

Thanks. With that, we will adjourn.

[Whereupon, at 5:40 p.m., the subcommittee was adjourned.]

A P P E N D I X

FEBRUARY 6, 2018

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

FEBRUARY 6, 2018

Opening Statement of Hon. Michael R. Turner
Chairman, Subcommittee on Tactical Air and Land Forces
Hearing on
"Addressing Physiological Episodes in Fighter, Attack, and Training Aircraft"

February 6, 2018

The hearing will come to order.

The subcommittee meets today to receive an update on how the Departments of the Navy and Air Force are addressing physiological episodes in tactical and training aircraft.

I'd like to welcome our distinguished panel of witnesses:

- Mr. Clint Cragg, Principal Engineer from the NASA Engineering and Safety Center
- Rear Admiral Sara Joyner, Physiological Episodes Action Team Lead for the U.S. Navy, and
- Lieutenant General Mark Nowland, Air Force Deputy Chief of Staff for Operations

I thank you all for your service and look forward to your important testimony today.

For over two years now this Subcommittee has held briefings, hearings and conducted site visits regarding the occurrences of physiological episodes or PEs in tactical and training aircraft.

As I stated before, I believe Navy leadership was initially slow to respond to this issue that is having a direct effect on overall readiness and affecting the confidence of our pilots as well as their ability to perform their missions.

Because it is not just these events occurring, it is also the anxiety of these events occurring in succession.

As a result of Subcommittee activity, the National Defense Authorization Act for Fiscal Year 2017 included legislation that required an independent report of the Navy's efforts to resolve these issues. That report was delivered to the subcommittee in mid-December and a copy has been provided to Member offices.

According to the report, the Navy was addressing the PE problem as an aircraft problem, not a human problem. We have to acknowledge that physiological episodes happen to people, not aircraft.

The report also concludes that the F/A-18 systems that support human health are "complex, dynamic, and interactive." As a result, the more complex, dynamic, and interactive a system is – the more important it is to have a well-coordinated, systems approach to design and operations.

Finally, the report notes that Physiological Episodes will persist in the F/A-18, and all high-performance aircraft, if there is a piecemeal approach to human systems integration.

Our witness Mr. Cragg was the primary author of this report and he is prepared to provide the subcommittee with a summary of the report's findings and recommendations.

On September 15th of last year, Ms. Tsongas and I visited Naval Air Station "Pax" River to receive briefings on the root cause and corrective action processes from members of the Navy's Physiological Episodes Action Team.

We spoke with engineers and pilots and learned about the Navy's process to find the root cause of these events. We were also briefed on the Navy's attempts to alert and protect the aircrew, and monitor the system.

Additionally, we spoke with engineers at some of the labs who are analyzing specific portions of the primary systems that make up the Environmental Control System (ECS) and on-board oxygen generating system (OBOGS).

I believe the Navy has taken a step in the right direction by establishing a formal action team directly responsible for addressing physiological episodes. That team is led by our Navy witness today, Rear Admiral Joyner.

However despite these efforts pilots are continuing to experience physiological episodes and I am concerned about the increased frequency.

For example, since the subcommittee's last event in May of last year, the Navy as well as the Air Force have continued to report incidences of PEs in aircraft.

This past spring and summer, the Navy made the decision to ground all T-45 training aircraft due to increasing occurrences of pilots experiencing hypoxia symptoms in the aircraft. The decision was made after a significant number of instructor pilot's at all three T-45 training locations refused to fly the aircraft due to safety concerns with the oxygen system.

The Air Force grounded F-35 Joint Strike Fighters at Luke Air Force base in June of last year due to oxygen problems, and the F-35 fleet has experienced 29 physiological episodes to date.

In early December of last year, the subcommittee was informed that 13 A-10 aircraft at Davis-Monthan Air Force base have been grounded due to problems with their oxygen systems.

And just last week, the Air Force grounded all T-6 training aircraft at six operating locations due to an increasing rate of unexplained physiological episodes in the T-6 aircraft.

There is no doubt this remains a complex problem to solve that requires a well-coordinated "systems approach" to include all factors such as the aircraft, the pilot, and the environment.

So in closing we need to be reassured this remains a top priority for the Navy and Air Force, that the two services are coordinating efforts, and that a "systems approach" to solving this problem is being taken.

The increasing frequency of these physiological episodes is having a direct effect on overall readiness, and as such we expect to receive your professional assessments on what we as members of this subcommittee can do to help you address this critical problem.

Without objection, all witness' prepared statements will be included in the hearing record.

Mr. Cragg please proceed followed by Admiral Joyner and General Nowland.

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
Febraury 6, 2018

Statement of
Mr. Clinton H. Cragg
NASA Engineering Safety Center Principal Engineer
National Aeronautics and Space Administration

before the

Subcommittee on Tactical Air and Land Forces
Committee on Armed Services
United States House of Representatives

Chairman Turner, Ranking Member Tsongas and Members of the Subcommittee, thank you for this opportunity to discuss the NASA Engineering and Safety Center's (NESC) independent assessment of the Navy's efforts to understand and mitigate the F/A-18 Fleet Physiological Episodes. I am honored to be serving as the Lead for this NESC team. The NESC performs independent testing, analysis, and assessments to help address some of NASA's tougher challenges. We can draw upon technical experts from all ten NASA centers, industry, academia, and other government agencies. This allows us to bring the country's best experts to bear on the problems and challenges of NASA programs.

In February 2017, the US Navy's Naval Air Systems Command requested NASA's assistance in assessing the Navy's efforts to understand the causes of physiological episodes affecting aircrew on their F/A-18 fleet. NASA was requested to conduct an independent review of:

- the Navy's efforts to understand the causes of the F/A-18 Physiological Episodes
- the aircraft mishaps potentially related to such physiological episodes
- factors that may reduce the physiological episode rate and
- the performance of the relevant F/A-18 subsystems.

In March 2017, the NESC assembled a multi-disciplinary team with a broad range of expertise that included flight surgeons, Life Support System experts, Engineers, and several subject matter experts.

In the course of this investigation, the team reviewed data from a variety of sources, visited multiple manufacturing sites and Navy Commands, and held numerous discussions with knowledgeable personnel. The NESC team's findings, and recommendations are based on this data and not an exhaustive review of all F/A-18 documentation.

To address the complex causes of physiological episodes, the NESC team used a multi-systems trends analysis approach and formed the resulting findings.

First and foremost, physiological episodes are a human phenomenon. Although the Navy has put significant effort into investigating the physiologic episodes, the bulk of their efforts to date have been directed to the aircraft rather than human physiology. Centering our investigation on the human element revealed new information about the character of physiological episodes.

Second, hypoxia—determined to be the most prevalent cause of physiological episodes —is not a condition of insufficient oxygen in breathing gas; it is insufficient delivery of oxygen to tissues in the body, importantly, the brain.

Third, a key to reliable Onboard Oxygen Generating System (or OBOGS) performance is uniform operating conditions, which the F/A-18 design and dynamic operating environment rarely provides.

Fourth, the F/A-18 program has a large amount of aircraft performance data but a shortage of evidence related to human health and performance in an F/A-18 environment.

Fifth, the F/A-18 systems that support human health are complex, dynamic, and interactive; this requires a well-coordinated, "systems approach" to design requirements, interfaces and operations.

The team found that the technical aspects of physiological episodes that cause the greatest concern relate to the variability of complex system interactions. Finally, an unacceptable number of physiological episodes will persist in the F/A-18 program if there continues to be a piecemeal approach to human systems integration.

The NESC team made the following observations regarding the Navy processes.

Until recently, the absence of a single leader to coordinate and prioritize the Navy's physiological episodes efforts resulted in organizational stove-piping and the exclusion of key stakeholders.

Investigations have been structured as if physiological episodes were isolated events rather than a series of related events. Furthermore, troubleshooting efforts used a top down approach that emphasized component level behaviors instead of evaluating the performance of the system as a whole. In this case, the system means the aircraft, the pilot and the environment.

The NESC team asserts that a dedicated, coordinated, cross-organizational, and cross-discipline program – under the direction of a single leader with clearly defined authority – would improve US Navy effectiveness in finding and fixing the causes of physiological episodes.

The NESC team has identified a number of near-and long-term recommendations. Near-term tasks are focused on gathering key evidence about human health and performance and understanding hypoxia in the F/A-18 flight environment. Long-term tasks which may provide substantial benefit include utilizing a data-driven causal analysis effort, updating the F/A-18 to conform to MIL-STD-3050, and developing a systems level understanding of bleed air management systems.

In conclusion, and although key data is lacking, the NESC believes that the majority of F/A-18 physiological episodes are a result of hypoxia. This hypoxia, it is believed, is caused by a combination of issues affecting the various stages of the oxygen delivery process, including those stages within the human. We applaud the Navy's efforts to gather the necessary data to resolve these issues. The NESC report has provided a conceptual framework to view the issue of physiological episodes in a new light and offers recommendations that may guide future processes and technology improvements.

I thank you for the opportunity to testify before this Subcommittee and look forward to any questions you may have.

Clinton H. Cragg - Principal Engineer

Clint Cragg, upon graduating from the U.S. Naval Academy in 1978, entered the submarine and naval nuclear power training program. His first submarine assignment was the USS Sand Lance, which at the time was undergoing a major engineering overhaul in Bremerton, Washington. In 1984, he was assigned as the Assistant Engineer on board the USS Trepang, then home-ported in New London, Connecticut. Later, as the Ship's Engineer on the USS Alabama, he supervised a department composed of 6 divisions and was directly responsible for the maintenance, operation and safety of the ship's S8G nuclear reactor. In 1990, he reported to his first shore tour at the Naval War College where he earned M.A. degrees in Strategic Studies and International Relations. In his next assignment as the Executive Officer of the USS Tunny, he prepared the ship and crew for four separate overseas deployments. Selected for command, Clint took over as the Commanding Officer of USS Ohio in October of 1996. After completing four strategic deterrent patrols, he was assigned as the Chief of Current Operations, US European Command. While in Europe he participated in a number of operations, which included the wars in Kosovo, Afghanistan, and Iraq. In 2003, he joined NASA as a founding member of the NASA Engineering and Safety Center (NESC). Assigned as a Principal Engineer, he leads teams of engineers to solve some of NASA's toughest challenges.

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THE HOUSE ARMED SERVICES COMMITTEE
TACTICAL AIR AND LAND FORCES
SUBCOMMITTEE

STATEMENT OF

REAR ADMIRAL SARA JOYNER
PHYSIOLOGICAL EPISODE ACTION TEAM LEAD

BEFORE THE

TACTICAL AIR AND LAND FORCES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

PHYSIOLOGICAL EPISODES WITHIN NAVAL AVIATION

February 06, 2018

NOT FOR PUBLICATION UNTIL RELEASED BY
THE HOUSE ARMED SERVICES COMMITTEE
TACTICAL AIR AND LAND FORCES SUBCOMMITTEE

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:

Date Range	F/A-18A-D	F/A-18E-F	EA-18G
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:

Date Range	F/A-18A-D	F/A-18E-F	EA-18G
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.

Calendar Year	Calendar year rate per 100K flight hours	Cumulative rate per 100K flight hours
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 18th, 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 711th 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.

RDML Sara "Clutch" Joyner received her commission in 1989 graduating with merit from the Naval Academy with a B.S. in oceanography. After graduation, Joyner attended flight school and earned her naval aviator wings in July 1991 from VT-24 in Beeville. Her first assignment was at VC-5 at Cubi Point Philippines flying A-4E as an adversary pilot in 1992. With the closure of the base, she transferred to VC-8 in Roosevelt Roads Puerto Rico where she continued to execute adversary and ships services through 1994. She transferred to COMSTRIKFIGHTWINGPAC in 1994 and served as the Assistant Operations officer until, due to the repeal of the combat exclusion law, she was able to transition to the FA-18 Hornet. Upon completion of her training as a Hornet Pilot, she reported to VFA-147, the "Argonauts," in May of 1997. Remaining with VFA-147 for both her Junior Officer and Department Head tours, she completed two Western Pacific Cruises to the Arabian Gulf aboard USS NIMITZ (CVN 68) in 1997 and 1999 aboard USS JOHN C. STENNIS (CVN 74) in support of Operation SOUTHERN WATCH . In November of 2001, she again deployed with VFA-147 aboard USS JOHN C. STENNIS in support of Operation ENDURING FREEDOM. In January 2002, she reported to United States Joint Forces Command, Norfolk, Virginia where she served in the Current Operations Branch as Force Deployment Officer for the NORTHCOM, EUCOM, and CENTCOM Areas of Responsibility in support of Operations ENDURING FREEDOM and IRAQI FREEDOM. She reported to VFA-105 in November of 2006 as Executive Officer. In 2007, Joyner assumed leadership of Super Hornet Strike Fighter Squadron "Gunslingers" (VFA) 105 and deployed in support of the surge in Iraq. In 2013, she took command of Carrier Air Wing (CVW) 3 and deployed aboard the USS TRUMAN to the Arabian Gulf. Joyner has flown the A-4E Skyhawk, as well as the F/A-18 Hornet, Super Hornet and Growler.

RDML Sara Joyner established her place in naval history as the first woman to command a strike fighter squadron (VFA-105) in 2010, and as the first female commander of a carrier air wing (CVW-3) in 2013. As of 2017, RDML (select) Joyner has held numerous other leadership positions in the Navy including assignment as the Joint Strike Fighter Requirements Officer, with the CNO's Strategic Studies Group and as Director, Navy Senate Liaison, Office of Legislative Affairs.

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COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE
PRESENTATION TO THE SUBCOMMITTEE ON READINESS
COMMITTEE ON ARMED SERVICES
UNITED STATES HOUSE OF REPRESENTATIVES

SUBJECT: PHYSIOLOGIC EPISODES UPDATE

STATEMENT OF: Lieutenant General Mark C. Nowland, USAF
Deputy Chief Of Staff
(Operations)

February 6, 2018

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BY THE SUBCOMMITTEE ON READINESS
COMMITTEE ON ARMED SERVICES
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Introduction

Chairman Turner, Ranking Member Tsongas and distinguished members of the subcommittee, thank you for the opportunity to provide you an update on aircraft physiologic events within the United States Air Force. This written statement addresses recent historical trends in aircraft physiologic events in addition to how the Air Force is responding to physiologic events by assessing trends and utilizing lessons learned. For seventy years the United States Air Force has provided combat air power for the joint force to deter and decisively defeat our nation's enemies. Airmen continue to fly, fight and win today, in combat missions in Afghanistan, Iraq and Syria, as well as over our skies in defense of the homeland.

Operating combat aircraft to their maximum performance will always carry inherent risk, but it is our solemn duty as a service to provide the best equipment and training for our Airmen to ensure their safety is never placed in unnecessary jeopardy. The Air Force takes flight safety seriously. The service investigates every accident, every mishap, and any issues that impact the presentation of airpower to the joint force. The extensive aviation history of the Air Force gives the service a wealth of data to draw from when assessing physiologic events that occur in flight. Investigations and resolutions to physiologic events are shared across multiple agencies within the Air Force to ensure a holistic approach to solutions.

The Air Force has a robust and extensive process to respond to physiologic events. Investigations into physiologic events are shared between Air Force Material Command, Air Force Flight Safety, Air Force Research Lab, the 711th Human Performance Wing, our sister services and other government agencies. While this federated process ensures a holistic approach, the Air Force recognizes that process improvements can still be made. In Nov 2016, the Air Force stood up a joint research effort called "Characterizing and Optimizing the

Physiologic Environment in Fighters" or COPE-Fighter. Their mission is to identify solutions for high performance aircraft that optimize human performance in tactical aviation, and eliminate or minimize the impact of unexplained physiologic incidents. Membership in the team is both multi-service and inter-agency. Additionally, I have appointed a General Officer, Brigadier General Bobbi Doorenbos to be the singular point of contact on the Headquarters Air Force Operations staff to integrate our efforts.

Definitions

A physiologic event occurs when aircrew are physically impaired, experiencing decreased performance due to a variety of factors. There are three types of possible physiologic events referenced in this testimony. Hypoxia related events, which occur when there is a lack of oxygen delivered to the body, hypocapnea which occurs when there is reduced carbon-dioxide in the blood stream due to hyperventilation, and hypercapnia which is the opposite of hypocapnea, in which there is too much carbon-dioxide in the blood stream.

Historical Trend Rate Data

Despite the serious nature of physiologic events, the overall rate of hypoxia-like physiologic episodes occurring across the Air Force fighter and trainer fleet remains incredibly low. In fact, the probability of a fighter pilot experiencing a physiologic episode remains less than 1% per year.

Table 1 shows hypoxia-like events for the eight Air Force fighter and trainer aircraft in the service's fleet over the past ten years. It is challenging to pinpoint exact trends across air frames. The occurrence of these events seem to have no correlation or causation with the rollout of new technology or increased flight hours. Evident are the spikes which occur surrounding the

F-22A and F-15C/D. Several studies show the tendency for increased reporting and awareness alongside high profile events, like that of the F-22A in FY12 or the F-15C/D in FY16.

Hypoxia-like Events									
	F-22A	F-15C/D	F-15E	F-16C/D	A-10C	F-35A	T-38C	T-6A	Totals
FY08	2	1	0	2	1	N/A	0	2	8
FY09	2	0	0	7	3	N/A	1	3	16
FY10	2	3	1	4	1	N/A	0	5	16
FY11	10	1	5	6	0	N/A	1	3	26
FY12	15	2	3	10	2	1	1	4	38
FY13	5	3	3	7	2	1	0	3	24
FY14	2	2	2	11	2	1	1	2	23
FY15	2	12	1	13	3	1	5	4	41
FY16	5	20	2	12	1	2	3	3	48
FY17	1	1	2	12	6	6	2	4	34
FY18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22	N/A
Totals	46	45	19	84	21	12	14	55	296

No Common Root Causes Identified

Multiple agencies in the Air Force are responsible for addressing physiologic events. Air Force Flight Safety is the lead for the flight investigation assessing probable causes of a flight mishap, while also making recommendations to prevent future issues. The Air Force Life Cycle Management Center provides equipment solutions, training experts, and liaisons across military services to share expertise and lessons learned. Finally, the aircraft program offices have the ultimate control on developing and fielding material solutions for the aircraft if deficiencies or improvements are found.

According to extensive analysis by Air Force Flight Safety and the Air Force Life Cycle Management Center, there is no single root cause tied to a manufacturing or design defect that would explain multiple physiologic event incidents across airframes or within a specific airframe. Some events are due to issues outside the aircraft or equipment, and some physiologic events remain unexplained and cannot be replicated.

The Air Force rigorously investigates each event, and has implemented multiple solutions and advancements. Where applicable, the Air Force installs systems to prevent future recurrences. For example, in response to the F-22A physiologic events from 2010 to 2012 we installed a backup oxygen system and additional sensors to allow pilots increased awareness of cabin pressure and oxygen quality. Not all events result in material solutions, often procedural or training changes remain sufficient. Solutions prescribed differ widely across airframes and situation. I will now give specific examples and resolutions related to incidents surrounding the F-15C/D, F-22A, F35A and T-6A.

F-15C/D

The F-15C/D fleet experienced an increase in the number of physiologic events in late FY15 and throughout FY16. This spike was highlighted by several incidents involving failures of the cockpit pressurization system and/or perceived failures of the oxygen system. It should be noted that the F-15C/D does not use an onboard oxygen generating system found in other fighter and trainer aircraft models. Instead, the F-15C/D uses a liquid oxygen system to supply aircrew with oxygen.

Following extensive investigation of the physiologic events, the Air Force developed additional cockpit instrumentation within the F-15C/D that will be fielded starting in FY18. The instrument, called a Cockpit Pressure Indicator, will give aircrew an audible and visual warning if the cockpit pressurization schedule deviates from the desired range. Additionally, the F-15C/D/E flight manuals have been updated with guidance on hypocapnia at altitude with functioning oxygen systems, time of useful consciousness, and improved emergency procedures for physiologic events.

F-22A

Physiologic events with the F-22A generated very high profile coverage and attention between 2010 and 2012. The Air Force testified before Congress and this committee, regarding the extensive investigation the service conducted to identify root causes and corrective actions. The F-22A's onboard oxygen generation system was extensively evaluated by multiple agencies to include the National Aeronautics and Space Agency and the Air Force Scientific Advisory Board. The system was determined not to be a cause in any of the physiologic events reported during that time frame; however, based on recommendations from the investigations, material solutions, and training and procedural changes were made to the F-22A, such as the addition of the automatic backup oxygen system.

Since 2016, the F-22A has had four discrepancy reports related to degraded partial pressure oxygen sensors, a component of the environmental control system within the aircraft. This is a known issue with degraded oxygen sensors, according to the F-22A program office and Air Force Life Cycle Management Center. The supplier has been made aware of the deficiency and has implemented a design improvement to address the issue.

F-35A

Within five weeks, from May 2017 to June 2017, there were five airborne physiologic events with the F-35A at the 56th Fighter Wing, Luke Air Force Base, Phoenix, Arizona.

The Air Force investigation into the issue determined that the onboard oxygen generation system was not at fault for any of the airborne related events. Investigators noted possible causes could have been attributed to:

a) Ingestion of increased carbon monoxide during ground operations
b) Rate and depth of breathing exacerbated by positive pressure flow from the onboard oxygen generation system
c) Procedural and systems knowledge
d) Psychological factors

Despite no mechanical faults being presented, recommendations have been made to change the algorithms that deliver oxygen and changes to training and maintenance have been put in place.

Following the initial five physiologic events listed above, there were four additional airborne events between July and November 2017. Of these nine total events at the 56th Fighter Wing, only one appears to have a definitive root cause related to a loss of cabin pressurization caused by a mechanical malfunction. The other eight events do not have a definitive root cause – these are referred to as unexplained physiologic events.

In addition to the above, the 56th Fighter Wing has revised training and aircrew procedures to further decrease the risk of physiologic events. New procedures require aircrew to wear oxygen masks on the ground once the system is operational and through engine shutdown.

Annual physiologic training is conducted to educate aircrew on symptoms and responses to hypoxia, hypocapnia, and hypercapnia, as well as training on rate and depth of breathing. The Air Force is confident that these actions taken by the 56th Fighter Wing and actions by the F-35A Physiologic Event Team, will ensure an extremely low likelihood of future events.

T-6A

The T-6A fleet has suffered from a recent rash of unexplained physiologic events beginning in 2018. Since the start of the New Year, there have been twenty-one physiologic events reported. The Air Force was already in the process of investigating the onboard oxygen generation system of the aircraft due to two physiologic events experienced at the 71st Flying Training Wing at Vance Air Force Base, Oklahoma during November of 2017. The events at Vance Air Force Base resulted in a forty eight hour operational pause of T-6A flying sorties locally while flight safety agencies within the Air Force convened to investigate the issue. Inspections on the remaining aircraft tested at Vance found nothing unusual, and normal flight operations resumed.

The most recent events involving the T-6A have occurred at Columbus Air Force Base, Columbus, Mississippi. Immediate testing of the equipment has been inconclusive, and the human factors involved, such as the symptoms reported by the aircrew, have varied greatly. Following these events, 19th Air Force commander Major General Patrick Doherty directed an operational pause in the T-6A flying operation to allow them to study the problem and devise mitigating or corrective measures.

While the investigation continues, the T-6A unexplained physiologic event investigation is a proving ground for the Air Force's cross-service, multi-agency top down approach to quickly address and resolve these issues. Major General Doherty has traveled to all the Undergraduate Pilot Training bases to meet with student and instructor pilots, as well as wing leadership and apprise them of details learned so far in the investigation, procedures for moving forward, and to listen to their concerns. The Air Force is also trying to address a pilot production problem, the service is not producing enough to meet demand, so the lost training sorties for the stand down doubles the pain inflicted on operations due to these events. Nevertheless, aircrew safety is paramount, so we will double our efforts to return to flying operations as soon as possible.

Sharing Lessons Learned

The Air Force and the Navy are committed to working together to find solutions to the causes of physiologic events in our aircraft, ensuring that our pilots are not exposed to unnecessary risk, and restoring confidence in our aircraft. We have engaged a broad range of internal and external partners, including subject matter experts from the Air Force and Navy, National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA), industry, academia, medical, and dive communities to resolve these issues.

Headquarters Air Force has appointed a General Officer to lead an Unexplained Physiologic Event Integration Team, which will serve as the Air Force's focal point for recommending actions to prevent future physiologic events. Similarly, the Navy has stood up a General Officer-led Physiological Episodes Action Team (PEAT), and both teams work closely together to investigate in a complimentary manner. By providing senior leadership, the services seek to ensure all physiologic event investigations receive the appropriate level of advocacy for resources and assistance required for timely resolution, and that recommendations from these investigations are fully implemented.

In addition to these headquarter-level initiatives, multiple joint forums are working at the Action Officer level to identify and implement efforts which will mitigate the risk and impact of physiologic events. Examples include aeromedical expertise as part of the COPE-Fighter physiologic team, program office/engineering expertise as part of AFLCMC and NAVAIR Oxygen System Cross Talk, and the upcoming 19AF-hosted senior leader cross-talk meeting to ensure senior leaders and decision makers from both services have a common understanding of the problem and are working together to solve it.

Conclusion

The safety of Air Force aircrew is tantamount to the execution of the service's mission to deter and decisively defeat the nation's enemies in air, space and cyberspace. Operating high performance combat aircraft, especially as aircraft age, will always carry some inherent risk. The Air Force takes every mishap or event seriously, and investigates to the furthest extent possible these events to determine root causes. Increased awareness of physiologic events has led to increased reporting of possible episodes, which in turn is driving aggressive response actions from the Air Force and its joint partners to address these events and implement recommendations that make air operations safer.

Lieutenant General Mark C. Nowland

Lt. Gen. Mark C. Nowland is the Deputy Chief of Staff for Operations, Headquarters U.S. Air Force, Washington, D.C. He is responsible to the Secretary of the Air Force and the Chief of Staff for formulating policy supporting air, space, cyber, and irregular warfare, counter proliferation, homeland security and weather operations. As the Air Force operations deputy to the Joint Chief of Staff, the general determines operational requirements, capabilities and training necessary to support national security objectives and military strategy.

General Nowland is a 1985 graduate from the U.S. Air Force Academy. He previously commanded at the squadron, wing, and numbered Air Force levels. He also served on the Joint Staff, US SOUTHCOM and two Air Force major command staffs. The general has flown combat operations in support of operations Southern Watch and Iraqi Freedom. He is also a graduate of the School of Advanced Air and Space Studies and was a National Security Fellow at the Olin Institute at Harvard University. Prior to his current assignment, General Nowland was the Commander, 12th Air Force, Air Combat Command, and Commander, Air Forces Southern, U.S. Southern Command, Davis-Monthan Air Force Base, Arizona.

General Nowland is a command pilot with more than 3,600 flying hours, primarily in the A-10, F-15A/C/D, T-37B, T-38A/C A/T-38B and T-6.

EDUCATION
1985 Bachelor of Science degree in electrical engineering, U.S. Air Force Academy, Colorado Springs, Colo.
1990 Squadron Officer School, Maxwell AFB, Ala.
1998 Air Command and Staff College, Maxwell AFB, Ala.
1999 School of Advanced Air and Space Studies, Maxwell AFB, Ala.
1999 Master of Aviation Sciences degree, Embry-Riddle Aeronautical University, Daytona Beach, Fla.
2003 Air War College, by correspondence
2004 John M. Olin Institute for Strategic Studies, Harvard University, Cambridge, Mass.
2008 Air Force Enterprise Leadership Seminar, Kenan-Flagler Business School, University of North Carolina, Chapel Hill
2009 Joint and Combined Warfighting School, Joint Forces Staff College, Norfolk, Va.
2011 Joint Force Air Component Commander Course, Maxwell AFB, Ala.
2012 National and International Security Leadership Seminar, Latin America Forces, Washington, D.C.
2013 Combined Force Maritime Component Commander Course, Miami, Fla.
2014 Joint Flag Officer Warfighting Course, Maxwell AFB, Ala.
2015 National Defense University Pinnacle Course, Suffolk, Va.
2016 Leadership at the Peak, Center for Creative Leadership, Colorado Springs, Colo.

ASSIGNMENTS
1. July 1985 - July 1986, student, undergraduate pilot training, Williams AFB, Ariz.
2. July 1986 - July 1988, T-37B Instructor Pilot, Williams AFB, Ariz.
3. July 1988 - December 1989, T-37 Instructor Pilot, Randolph AFB, Texas
4. December 1989 - August 1990, student, AT-38B lead-in fighter training, 435th Tactical Fighter Training Squadron, Holloman AFB, N.M.
5. August 1990 - May 1991, student, F-15C Replacement Training Unit, 1st Tactical Fighter Training Squadron, Tyndall AFB, Fla.
6. May 1991 - July 1995, F-15 Instructor Pilot, 71st Fighter Squadron, Langley AFB, Va.
7. July 1995 - July 1997, F-15 Fighter Flight Commander, 85th Operations Support Squadron, Naval Air Station Keflavik, Iceland
8. July 1997 - July 1999, student, Air Command and Staff and the School of Advanced Air and Space Studies, Maxwell AFB, Ala.
9. July 1999 - February 2000, Chief, Doctrine Branch, Headquarters U.S. Air Forces in Europe, Ramstein

AB, Germany
10. February 2000 - May 2001, Deputy, Commander's Action Group, Headquarters U.S. Air Forces Europe, Ramstein AB, Germany
11. June 2001 - June 2002, Assistant Operations Officer, 94th Fighter Squadron, Langley AFB, Va.
12. June 2002 - May 2003, Operations Officer, 71st Fighter Squadron, Langley AFB, Va.
13. May 2003 - May 2004, Commander, 1st Operations Support Squadron, Langley AFB, Va.
14. June 2004 - May 2005, Olin Fellow, Institute for Strategic Studies, Harvard University, Cambridge, Mass.
15. June 2005 - May 2006, Chief, Program Support Division (J39), Joint Staff, the Pentagon, Washington, D.C.
16. May 2006 - June 2007, Executive Assistant to the Director of Operations (J3), Joint Staff, the Pentagon, Washington, D.C.
17. June 2007- July 2008, Vice Commander, 48th Fighter Wing, Royal Air Force Lakenheath, England
18. July 2008 - May 2010, Commander, 71st Flying Training Wing, Vance AFB, Okla.
19. May 2010 - June 2012, Director, Plans, Programs, Requirements and Assessments Directorate, Air Education and Training Command, Randolph AFB, Texas
20. July 2012 - June 2013, Director for Strategy, Policy and Plans (J5), Headquarters U.S. Southern Command, Miami, Fla.
21. June 2013 - December 2014, Chief of Staff, Headquarters U.S. Southern Command, Miami, Fla.
22. December 2014 - October 2016, Commander, 12th Air Force, Air Combat Command, and Commander, Air Forces Southern, U.S. Southern Command, Davis-Monthan AFB, Ariz.
23. October 2016 - present, Deputy Chief of Staff, Operations, Headquarters, U.S. Air Force, Washington, D.C.

SUMMARY OF JOINT ASSIGNMENTS
1. June 2005 - May 2006, Chief, Program Support Division (J39), Joint Staff, the Pentagon, Washington, D.C., as a colonel
2. May 2006 - June 2007, Executive Assistant to the Director of Operations (J3), Joint Staff, the Pentagon, Washington, D.C., as a colonel
3. July 2012 - June 2013, Director for Strategy, Policy and Plans (J5), Headquarters U.S. Southern Command, Miami, Fla., as a brigadier general
4. June 2013 – Dec 2014, Chief of Staff, Headquarters U.S. Southern Command, Miami, Fla., as a brigadier general and major general

FLIGHT INFORMATION
Rating: command pilot
Flight hours: more than 3,600 hours
Aircraft flown: A-10, F-15A/C/D, AT-38B, T-38A/C, T-6 and T-37

MAJOR AWARDS AND DECORATIONS
Defense Superior Service Medal with oak leaf cluster
Legion of Merit with oak leaf cluster
Bronze Star Medal
Meritorious Service Medal with three oak leaf clusters
Air Medal
Aerial Achievement Medal with oak leaf cluster
Air Force Commendation Medal with oak leaf cluster
Air Force Achievement Medal with two oak leaf clusters

OTHER ACHIEVEMENTS
Chilean Cross for Aeronautical Merit
SICOFAA Legion of Merit Medal In Grade of "Great Cross"

EFFECTIVE DATES OF PROMOTION
Second Lieutenant May 29, 1985
First Lieutenant May 29, 1987

Captain May 29, 1989
Major May 1, 1996
Lieutenant Colonel May 1, 2000
Colonel July 1, 2005
Brigadier General Aug. 6, 2010
Major General Dec. 31, 2013
Lieutenant General Dec. 19, 2014

(Current as of November 2016)

QUESTIONS SUBMITTED BY MEMBERS POST HEARING

FEBRUARY 6, 2018

QUESTIONS SUBMITTED BY MR. TURNER

Mr. TURNER. a) By centering your investigation on the human element, what new information was revealed?

b) What were the shortages of evidence related to human health in an F/A–18 environment that you encountered?

Mr. CRAGG. 4a: 1. NASA flight surgeons, reviewing pertinent Physiological Episode (PE) Medical information as a whole instead of just individual cases, determined that > 80 percent of the PEs were Hypoxia related. 2. The human system, specifically the requirements for meeting human needs, was not represented in the integrated end-to-end description of the F/A–18. This omission made it difficult for system hardware engineers to find end-of-the line problems when isolated individual systems appeared to be working well.

4b: There was and is hardly any data or measurements being taken in the F/A–18 that addresses the human response to the flight environment. Data needed includes:

i. breathing patterns (rate, depth, volume) in flight

ii. cabin pressure

iii. Oxygen levels, flow and pressure in the breathing gas system

iv. Exhaled CO2 levels in the mask

Data such as the above serve two purposes: 1) as a monitor of human health in the dynamic flight environment, and 2) as specific diagnostic checks on components of the integrated life support system.

Data that was collected included inflight sorbent tube samples from EA–18 Growlers of pilot breathing gas. This data, when investigated by NASA, demonstrated an unambiguous relationship between increased contamination and the occurrences of PEs. The Navy did not and has yet to conduct proper analysis on these samples. It is important to note that the relationship is one of correlation; NASA did not conclude that contamination was the cause of PEs.

Mr. TURNER. a) Is the U.S. Navy capable of solving the PE problem?

b) Has the Navy been forthcoming with all of their data?

Mr. CRAGG. 6a: Yes. When the NASA investigation started, the NASA team saw dedicated individuals across the U.S. Navy doing their best to find and fix the PE problem. However, they weren't working together in an organized way, and their central focus was on the plane—not on the pilot and importantly, not on the dynamic plane/pilot/environment interaction.

6b: Yes. The Navy quickly provided us with everything we asked for.

Mr. TURNER. The report notes in several observations and findings that your team found specific design problems with the F/A–18's environmental control system, onboard oxygen generation system, and CRU–103 regulator. Can you explain those in detail?

Mr. CRAGG. The F/A–18's Environmental Control System (ECS) is fed high pressure air from a direct connection to the engine that varies in its pressure whenever the pilot changes the throttle. The ECS feeds other systems that must account for these pressure changes. One of these systems, the cabin pressure control system, is prone to instability which leads to pressure excursions in the cockpit. Others, like the onboard oxygen generation system (OBOGS) and CRU–103 regulator, appear to be delivering oxygen to the pilot in a manner inconsistent with nominal pilot performance for some flight regimes. Put simply, all evidence supports that the pilot is not getting the stable cabin pressure and breathing oxygen supply that he/she needs in some cases, due to complex system interactions and deficiencies in the design of the jet as an integrated system.

However, more generally and more importantly, these problems are rooted in the lack of a (human system) "requirements driven" approach to the design and engineering of the integrated environmental control system, onboard oxygen generation system, and CRU–103. While these systems may indeed meet individual documented requirements; it remains evident that documented requirements are insufficient to comprehensively support pilot physiological needs. There remains a dearth of data surrounding the pressure and breathing performance needs of a human being operating the F/A–18; and by extension a dearth of data to support or refute when these performance needs are being met or not met operationally by the aircraft.

Put simply again; the ECS, OBOGS, and CRU–103 were specified based on an evolution of operational history and aircraft design legacy, rather than validated performance data used to evaluate pilot demands in the tactical jet flight environment. While this approach for hardware design is sufficient to support pilot performance in most cases; it supports no understanding of where the actual performance envelope lies, and therefore no ability to anticipate or evaluate when the performance envelope may be exceeded and result in a Physiological Episode. Additionally, the GGU–12 OBOGS unit and oxygen delivery schedule falls significantly short of meeting the newest requirements of MIL–STD–3050. This new standard collects the best information on meeting pilot breathing requirements for aircraft using OBOGS. The NASA team also pointed out that the CRU–103 pilot breathing regulator, while capable of providing additional pressure during periods of high-g force, as is done for example in the F–22, is not used in this manner in the F/A–18. This minor change in usage has been found to help pilots breath more easily during high-stress combat maneuvers. NASA has not monitored the continuing execution of the program. However, the agency has been informed that the Department of Defense has fully accepted NASA's finding that Physiological Episodes happen to people, not aircraft. According to the DOD, these findings have driven their Navy Physiological Episode Action Team (PEAT) to shape a holistic strategy that examines Physiological Episodes as an interactive condition between the human and the aircraft. Although physiological monitoring is not a near-term capability, the DOD has indicated the PEAT is aggressively pursuing acceleration opportunities and accelerating mitigations to the fleet, where DOD is looking at mechanical fixes to the machine but also directly assessing human health and performance in the cockpit.

Mr. TURNER. The report notes numerous concerns with the Navy's "Human System Integration" process. One finding stated that the process is "deficient". Can you elaborate on those concerns?

Mr. CRAGG. The Navy's Human System Integration process is indeed "deficient." The Finding in question states: F10–30: Currently the Human-Systems Integration (HSI) process within the U.S. Navy is deficient; it appears to be associated with a decrease in the available subject matter expertise in the fields of Aerospace Medicine, Physiology, Human Factors Engineering, Cognitive Psychology, and Human Systems Integration, as well as organizational barriers to meaningful interaction amongst these disciplines across the U.S. Navy. NOTE: This finding is similar to one made in the USAF F–22 Life Support System review several years ago. In 2012, NASA was asked by the USAF to provide a review of the F–22 Life Support System. One of the major findings was a significant increase in the work-of-breathing for pilots during flight. This issue was primarily the result of a lack of thorough human-machine interface testing in the flight environment. The work-of-breathing theory was evaluated by simply instrumenting a pilot wearing standard aircrew flight equipment and placing them in a centrifuge configured to replicate the life support system an operational F–22 aircraft. These data led to improvements in the F–22 design and in the human performance associated with piloting an F–22.

In 2012, USAF General Gregory S. Martin testified before Congress that (from the NASA report):

"Over the past 20 years, the capabilities and expertise of the USAF to perform the critical function of Human Systems Integration have become insufficient, leading to:

—The atrophy of policies/standards and research and development expertise with respect to the integrity of the life support system, altitude physiology and aviation occupational health and safety.

—Inadequate research, knowledge, and experience for the unique operating environment of the F–22, including routine operations above 50,000 feet.

—Diminution of Air Force Materiel Command (AFMC) and Air Force Research Laboratory (AFRL) core competencies due to de-emphasis and reduced workforce to near zero in some domains."

Many of these same underlying Human-Systems Integration deficiencies are evident in F/A–18.

Human-Systems Integration (HSI) is defined as the "interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice" (Haskins, 2007). The goal of HSI is to integrate the human into the system as a critical element; the human is as critical to system design considerations as the hardware or software.

With regard to fighter aircraft, the interaction of the human with the aircraft (i.e., human factors) is one particular domain that demands a great deal of attention because of the complexities involved, and because of significant consequence associated with failure. This domain is the comprehensive integration of human capabilities and limitations (physical, sensory, cognitive, and team dynamics) into systems designed to optimize human interfaces and facilitate human performance in training, operation, maintenance, support, and sustainment of a system. The Department of Defense has formalized the role of HSI. There are nine domains of HSI: manpower, personnel, training, human factors engineering, occupational health, environment, safety, habitability, and human survivability. A commonly accepted HSI success story was the development of the F119 engine for the F–22 by Pratt & Whitney. Because both the USAF and Pratt & Whitney were dedicated to HSI the development constantly included the human element. The resulting design increased ease of assembly, maintenance, and repair thereby reducing overall labor costs, servicing frequency, and number of tools required. The USAF elevated the visibility of this process and the contractor also shared in this vision by creating testing facilities designed to better evaluate the engine to ensure reliability. Ultimately, the key to successful HSI is the fervent commitment from top-level leadership in maintaining the integral nature of HSI. This has not been the case in the F/A–18.

To maintain the combat edge, weapon systems must change over their life cycle. This is a fact. However, these changes must be appropriately evaluated using an HSI analysis to explore the potential impact to the human. The F/A–18 life cycle has been extended for years beyond what was originally planned and has undergone a number of modifications ranging from structural to digital. There is a vast difference between the original F/A–18A "Hornet" and the EA–18G "Growlers". The oxygen system changed from liquid oxygen (LOX) to the OBOGS. The EA–18G received advanced radar, various electronics counter-measures components, and a second aircrew member who acts as the Weapons Systems Operator (WSO). These changes impacted the demand for engine bleed air but no rigorous assessment was conducted to determine if the engine bleed air can meet these demands while maintaining appropriate OBOGS oxygen concentration and flow throughout all phases of flight. Just as the aircraft changes over time, new understandings of human physiology also occur that must be considered in terms of the overall system. Indeed, even during initial design phases, assumptions about the human are made and sometimes these assumptions are not valid. Thus, the requirements based on incorrect assumptions or an incomplete understanding of human physiology can be costly to correct. In 1993, a study identified that pilots could over-breath the on-board oxygen generation system (OBOGS). A recommendation was made to change MIL–D–85520 to require the oxygen systems of tactical aircraft to produce peak inspiratory flow rates of at least 260 LPM (NAVAIR TM–93–59 SY). This recommendation was not implemented. It is noteworthy that MIL–STD–3050 (2015) now contains a similar minimum flow requirement. During the early stages of the spike in reports of F/A–18 PEs, the Navy assumed that the PEs resulted from a defect in the aircraft. The aircraft was taken out of service and inspected. No consideration was given to the integration of the human and machine during flight operations. While an inspection could determine if a component was operating within spec in a controlled environment, it remained unknown if the component performed as expected on the aircraft during dynamic flight. Furthermore, it remained unknown if these established specifications met the demands of the human system during flight, and if they continued to meet those demands following various system changes. The human was not considered as a critical element; the HSI was deficient. As new information about the machine and the human is learned, we now recognize that the physiologic requirements determined for the original system design were already partially inadequate. Due to the increased cooling needs in latest models of the F/A–18, this inadequacy has increased. The greatest concern is the lack of data to answer the question: how inadequate?

It's impractical to instrument an entire system of any significant complexity, however, key pieces of information are required to correctly diagnose problems. For example, the F/A-18's pressure fluctuations are difficult to assess because there is no inlet or output sensor that directly records these data for analysis. This is a knowledge gap in terms of characterizing and assessing the machine performance. Similarly, there are critical knowledge gaps in characterizing the human system. In fact, the most important data required to identify and solve PEs is entirely absent; there is no data collected to objectively define the human physiological experience in the cockpit during operational flight. There is no routinely recorded data about oxygen pressure, flow, or percentage. Additionally, there is little data on pilot breathing rates, breathing volume, cabin pressure, etc. Without data, the human subjective report of a PE cannot be compared with in-flight exposure and potential causal factors cannot be confirmed or dismissed. Furthermore, without measurements to characterize the current conditions, it will be challenging to know if the results of the

Navy's changes positively or negatively impacted the human. To be clear, the PE rate is a deeply insufficient metric as human participation can be influenced by various factors far easier than data. This is a hindrance to exploring and assessing the validity of any solution.

Like the USAF in 2012, the Navy's critical core competency of HSI expertise has atrophied due to a lack of investment and support. Currently, the emphasized expertise is aircraft engineering solutions. The best way to affect change for a human-machine system is by integrating the human into the system and assessing that integration with each subsequent design modification. Without appropriate HSI expertise at the table, the most integral, intelligent, and valuable part of the system—the human—isn't represented.

Mr. TURNER. In the FY17 NDAA, this Congress directed the Secretary of the Navy to conduct an independent review of the plans, programs, and research of the Department of the Navy with respect to physiological episodes affecting aircrew of the F/A–18 Hornet and F/A–18 Super Hornet aircraft, as well as the efforts of the Navy to prevent and mitigate the effects of such physiological events. This subcommittee is interested in hearing what the Navy found valuable from NASA's report and how are you using NASA's findings today to inform future efforts with the F/A–18 series aircraft?

Admiral JOYNER. The Navy found NASA's report useful in identifying organizational constructs that were not working well to respond to the urgent issue of physiological episodes (PEs), including communication shortfalls, stove-piping of information, and lack of a single clear leader for PE efforts. NASA's recommendations provided a catalyst for reorganization and the adoption of a broader view of the Naval Air Systems Command's (NAVAIR's) systems engineering boundaries when addressing the PE problem, specifically inclusion of the human factors and physiological needs in system design and function of the aircraft. Additionally, NASA bolstered support for a comprehensive Root Cause Corrective Action (RCCA) investigation that the Navy has fully embraced as the path to solving the PE issue. Below are NASA's 8 key recommendations and the Navy's actions: 1. Measure parameters that directly assess human health and performance. Make measurements in the cabin environment whenever possible. The Navy is exploring every option to measure and record meaningful data in the cockpit. Several development efforts are ongoing in coordination with PMA–202, the Aircrew Systems Program Office and the Navy Bureau of Medicine and Surgery (BUMED) to field sensors that can directly measure human performance and physiological response while not being intrusive or interfere with cockpit duties. While human-mounted sensor technology matures, integration of multiple sensors in the aircraft cockpit and aircrew flight gear continues. One example of a newly fielded sensor is the SlamStick, a small pressure sensing and recording device carried in aircrew pockets. SlamSticks are carried on every F/A–18 and E/A–18 sortie. Data is downloaded after flight and uploaded to a central database for analysis. This data has been used extensively to characterize and understand the cockpit environment.

Mr. TURNER. Navy leadership has consistently said physiological episodes are the number one safety priority within Naval Aviation as it is directly related to aircrew health. This Congress has consistently asked what it can do to help in this effort. As a result, the Budget Request for Fiscal Year 2018 was shaped to provide the financial resources required to address the issue. Can you briefly describe to the subcommittee what solutions are being accomplished with these funds?

Admiral JOYNER. To address issues in the T–45, the Navy received resources in FY18 in the form of additional O&M funds which are funding the ongoing T–45 Root Cause and Corrective Action (RCCA) investigations. The funds will also be utilized to fund a contract with the OEM (Boeing) to support the RCCA and provide Field Service Representatives (FSRs) at all Chief of Naval Air Training (CNATRA) T–45 training sites. Some examples for T–45 include: Enhanced Emergency Oxygen System (EEOS). Maximizes the oxygen storage capacity of the emergency oxygen system for retrofit of the SKU–10/A (F–18) and SKU–11/A (T–45) Seat Survival Kit Assembly. T–45 Oxygen Concentrator. Obsolescence issues with the T–45 OBOGS concentrator (GGU–7A), coupled with a need for additional reliability and safety enhancements drive a need for a replacement OBOGS concentrator. The GGU–25 was designed in 2008 by Cobham and was partially tested for use with the T–45. In FY18, the Navy funded F/A–18 PE efforts targeting three primary areas. The first was to fully fund all the RCCA requirements. The RCCA is investigating 427 branches on the fault tree. Closure of these branches will require a massive data collection effort and engineering analysis. Below are some of the examples of RCCA efforts underway being funded by FY18 budget: Flight test—Multiple flight test effort are ongoing to collect data in support of the RCCA. The major effort is the extensive instrumentation of an F/A–18C to execute a flight test plan that will fully characterize the dynamics of the ECS and breathing gas delivery systems. Manned and Unmanned aircrew and life support systems testing (KBRWyle Brooks, San Antonio)—will test aircrew and life support systems using pressure chambers and centrifuge to create realistic operational conditions to characterize and measure performance in a controlled environment.

Mr. TURNER. The subcommittee understands the Navy stood up the Physiological Episodes Action Team (PEAT) to unify mitigation efforts across Naval Aviation, and address shortfalls in communication and data sharing between PEAT core members and external fleet stakeholders. While the subcommittee believes establishing the PEAT for these purposes makes sense for the Navy, we are interested in hearing what the PEAT is doing to find synergies within the Department of Defense, and how are these efforts being executed to find a solution?

Admiral JOYNER. Finding synergies between organizations is part of the PEAT charter, which did not limit the team from looking outside of the Department of the Navy or Department of Defense. There are several aspects to investigating PEs: from analysis of the aircraft, determining what system effects are on the human, and developing strategies for current and future aircraft. The PEAT has engaged a broad swath of internal and external partners, including subject matter experts from United States Air Force (USAF), National Aeronautics and Space Administration, 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. While investigating the aircraft, we have leveraged work that was done by the USAF while conducting a review of the F–22 aircraft in 2012. Specifically, the methodology of using a Root Cause Corrective Action team and performing a rigorous analysis of root cause has enabled us to employ high-velocity learning and not repeat mistakes of past efforts. While determining human and physiological understanding, the PEAT has employed the efforts of the Naval Medical Research Unit-Dayton (NAMRU–D) to actively research multiple topics where medical understanding is immature. NAMRU–D enjoys a strong partnership with the USAF 711th Human Performance Wing (HPW) providing complementary capabilities for aeromedical research while supporting cross service collaboration in both research and experimentation. As we continue to research strategies for future aircraft, it should be noted that we are currently developing joint solutions for two shared aircraft-the T–6 and the F–35, and we are embedded with the Joint Program Office as well as the USAF's PE team, being led by Brig Gen Doorenbos. We are sharing information and resources, which will yield a higher quality product for the warfighter.

Mr. TURNER. The Chairman and Ranking Member of this subcommittee visited Naval Air Station Patuxent River, Maryland, on 15 September 2017 in an effort to see firsthand what the Navy is doing to address physiological episodes. It was a very informative visit and impressive to see the number of both active duty service members and DOD civilians dedicated to solve the current issues affecting F/A–18 and T–45 aircraft. As it was thoroughly described during the visit, could you please briefly explain to the subcommittee the processes set in place when a physiological event happens, how the investigative process is performed and what the feedback mechanism is to return findings and information back to the aviators?

Admiral JOYNER. Physiological Episode (PE) reporting protocol commences when aircrew reports physiological symptoms during or after flight. Safe recovery and aircrew treatment are prioritized above any and all data collection or reporting requirement. Aircrew are met plane-side by an ambulance for initial evaluation and treatment, if required. The data collection and reporting effort are guided by three Naval Safety Center forms, Parts A/B/C. Part A is used to capture the aircrew's narrative of the flight and PE event, mission type and profile, environmental conditions and self-reported aircrew symptoms. Part B directs the aircraft be placed in a "down" status and prescribes numerous diagnostics tests and inspections of the aircraft and aircrew flight gear as well as a thorough review of the aircraft maintenance history. Part C documents the medically relevant data collected during post-flight evaluation by a flight surgeon, including previous medical history, 24-hour physiological and human factors history, all post PE findings and treatment. The reporting squadron is assisted by the PE Rapid Response Team (PERRT). Upon report of a PE, the squadron's Safety Officer (or duty officer in his absence) will notify the cognizant Aeromedical Safety Officer (AMSO—aerospace physiologist), flight surgeon, and Naval Aviation Technical Representative or Field Service Representative. The PERRT is collectively responsible for ensuring all data collection and reporting requirements are complete. Additionally, they will assist the squadron in the decision to return both the aircraft and aircrew to flight. The data collected by the PERRT, including SlamStick cockpit pressure data, recorded aircraft flight data, and post-flight findings are immediately shared with all stakeholders for review and analysis. Ideally, there is enough data within the first 24 hours to provide immediate feedback to aircrew and the squadron on causality of the PE. In some cases, where more extensive testing or engineering investigation is needed, feedback may be delayed up to 30 days. Ultimately, PE information that is collected and investigated is submitted into the Naval Safety Center's WESS Aviation Mishap and Hazard Reporting System (WAMHRS) as a hazard or mishap investigation report. The hazard or mishap investigation report is released using WAMHRS providing a link to the report. This link is transmitted to safety personnel using a collection of email addresses called a community of interest. This provides feedback on evidence, analysis, causal factors and recommendations to prevent recurrence as well as subsequent endorsements and responses to recommendations in the report.

Mr. TURNER. The NASA report states that "The Navy has not conducted a fleet wide survey of their F/A–18 air crew to understand the PE problem from the human perspective, where these physiological events actually occur". Why has such a survey not been conducted?

Admiral JOYNER. The Physiological Episode Action Team, in concert with Naval Postgraduate School (NPS) developed and administered a comprehensive aircrew survey. The survey was broadly distributed amongst F/A–18, EA–18, and T–45 aircrew and maintainers. The survey concluded 02 Feb 2018. Over 1,400 responses were received, reflecting participation from 21.6 percent of the Fleet, which is considered statistically significant to provide a representative sample of Fleet opinion. NPS, in conjunction with the Center for Naval Analysis, are currently compiling and analyzing the data and results which will be used to inform the Root Cause Corrective Action investigation.

Mr. TURNER. The NASA report notes that the F/A–18's oxygen monitor—the CRU–99—does not log data, but that the plan to replace it with the more advanced CRU–123 was cancelled. Is that the case and if so why was this upgrade canceled?

Admiral JOYNER. The CRU–123 program was launched to incorporate a low pressure warning and data logging capability for the aircraft's oxygen system. Funding constraints at the time resulted in these requirements being allocated to a new oxygen monitor: the CRU–123. PMA–265 spent years developing the CRU–123 for the F/A–18. Numerous setbacks eroded confidence in the manufacturer's ability to produce a product that would meet the reliability requirements for the F/A–18. The Navy cancelled the CRU–123 program for the F/A–18 after a lengthy development effort in which the CRU–123 repeatedly failed qualification standards and was unable to survive the harsher operating conditions encountered by the F/A–18 as opposed to the T–45 which has successfully flown with CRU–123. PEAT acknowledged the need for data logging, and current planning includes the installation of a limited number of CRU–123s to assist in data collection while waiting for Cabin Pressure and OBOGS Monitoring System (CPOMS) development and fielding. In addition to needing a robust and reliable system for this critical function, the Navy shifted course to the CPOMS to take advantage of additional capabilities that could provide aircrew increased real-time in-cockpit situational awareness of critical life support systems' health. CPOMS will incorporate a digital display that will replace the current analog cabin pressure altimeter and provide an easy to read display of cabin pressure and warnings for schedule deviations of cockpit pressure, oxygen concentration and flow. CPOMS also has critical growth potential for desired features such as integrated cautions and warnings on current aircraft displays, and the ability to automatically perform actions, such as selection of emergency oxygen under certain degraded conditions or system malfunctions. The requirement to log critical OBOGS performance data is now allocated to the CPOMS and the new concentrator for the F/A–18, which is in development by the Aircrew Systems and F/A–18 and EA–18G program (PMAs-202 and 265) concentrator. This new approach will provide data recording on the aircraft's data bus, which is a significant improvement over the earlier approach to record it remotely on the CRU–123.

Mr. TURNER. How is the Air Force addressing physiological events, and onboard oxygen generation system issues with sister services?

General NOWLAND. The Headquarters Air Force Unexplained Physiologic Event (UPE) Integration Team and the Navy's Physiological Episodes Action Team (PEAT), both led by General Officers, continue to work closely together to investigate in a complimentary manner. Together, they have engaged abroad range of internal and external partners, including subject matter experts from the Air Force and Navy, National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA), Industry, academia, along with medical and dive communities to resolve these issues.

One area where the USN and USAF are working together is in aircrew air quality assessment. The 711th Human Performance Wing has developed systems to test aircrew air quality in flight such as the real time air quality sensor (RTAQS) which is in-line air supply monitor that detects contaminants and elucidates OBOGS function. It is being used to baseline T–6 (USN/USAF), T–45 (USN), and F–18 (USN) aircraft and is also prepared for use in the F–16 (USAF). Additionally, we have established an OBOGS lab that allows us to replace flight conditions and test the performance of OBOGS to detect abnormal performance. This lab has been used to support both USAF and USN UPE investigations.

Another area of collaboration is in aircrew physiological sensing. The 711th HPW in collaboration with industry, academia and government partners have developed several aircrew physiological state sensing systems. Some, such as VigilOx and Mask Sensing System (MASES), monitor inhaled and exhaled air but others assess tissue oxygen saturation, core temperature, heart rate, etc. VigilOx is slightly ahead of some of these other technologies and is undergoing verification and validation testing. Due to the urgency of the UPE issue, it has been flight tested in the T–38 (USAF) and F–18 (USN). Four devices have been delivered, two for testing and one each to the USAF and USN for preemptive operational assessments. Our end goal with this sensor development is to feed into an autonomous life support system that will adjust to keep the pilot in a physiologically safe condition.

Finally, the 711th Human Performance Wing has a robust collaborative relationship with Naval Aeronautical Research Unit-Dayton (NAMRU–D). The 711th HPW with NMRU–D have collaborated with several academic, governmental, and industry partners in exploring how the human body responds to the unique stressors of the flight environment. We continue to explore such topics as hypocapnia, hyperoxia, hypobaria, work of breathing, contamination, pulmonary function, and environmental priming—all issues that may precipitate "hypoxia-like" symptoms. The 711th HPW's unique location with NAMRU–D is particularly fortunate as this affords the two organizations to leverage each other's expertise and move forward as one entity on many of the research efforts.

Mr. TURNER. Why is root cause attribution to physiological events so difficult to ascertain?

General NOWLAND. The root cause for Unexplained Physiologic Events (UPEs) has been difficult to ascertain, primarily due to the lack of in-flight cockpit sensors to verify both the content of the breathing gas mixtures from the oxygen system (oxygen concentration, flow, pressure), and the physiologic status of the aircrew (expired oxygen/carbon dioxide levels, heart rate, respiratory rate, blood oxygen saturation). Such sensors are currently in development and will be able to objectively determine the root cause of physiologic events by measuring these variables and characterizing the integration between the human, the cockpit environment, and aircrew flight equipment. Until such sensors are in place, investigations to assess the cause of UPEs must resort to modeling human physiological response based on extrapolated assumptions of aircraft system performance as gas delivery, rather than the actual data itself. In addition to the lack of sensors, the extremely low rate of UPEs makes it difficult to identify trends which could be used to indirectly identify possible root cause of these events.

The two principal means to mitigate the hazards associated with high altitude flight are to provide increased concentrations of oxygen in aircrew breathing gas mixtures (to prevent hypoxia), and to pressurize cockpits to prevent adverse effects associated with a hypobaric environment. In modern aircraft, cockpit pressurization is provided by engine bleed air supplied to the Environmental Control System (ECS). Oxygen for the breathing gas mixture comes from either a Liquid Oxygen Supply or an "On-Board Oxygen Generating System (OBOGS), which also uses engine bleed air to supply breathing gas to aircrew. The non-specific nature of UPE symptoms (e.g., lightheadedness, headache, confusion) and the complexity of the interaction between the oxygen system, aircrew flight equipment, and the aircrew, makes it challenging to identify the root cause of many Pes.

Current aircrew monitoring systems undergoing testing and evaluation at the 711th Human Performance Wing include, Canary, VigilOx, physiologic health status of isolated personnel (PHYSIO), and mask sensing system (MASES).

QUESTIONS SUBMITTED BY MS. TSONGAS

Ms. TSONGAS. The committee has been examining the issue of elevated PE rates in F–18 aircraft for more than two years. Throughout that time, we have been told that improvements to the GGU–12 onboard oxygen generation system were an important part of reducing the risks of such events. As a result, I was troubled by several things the NASA report had to say about this specific piece of critical equipment on F–18s. First, in paragraph 10.2.2 the report states that "The first and most significant thing to note about the GGU–12 is the disconnect between best practices of pressure swing absorption systems and operating conditions of the GGU–12 . . . Best engineering practices for effective gas separation using PSA is constant conditions. [However], the GGU–12 is fully dynamic—nothing about the GGU–12 is constant.'' The report further states that ''The GGU–12 is tested in the lab and in the field with clean, dry air with a fixed flow rate and fixed inlet pressure. This does not match any actual operating conditions. The GGU–12 testing program does not adhere to the best practice summarized by 'fly what you test and test what you fly'.''

Finally, the report's finding 10–1 has this to say about the underlying design standards for the GGU–12: ''The NESC team found evidence that traced the oxygen peak flow rate requirement to outdated information from the 1960s, which apparently neglected to address newer information on pilot breathing demands document in Navy TM–93–59–SY. The GGU–12 OBOGS maximum performance requirement does not meet human system demand requirements for flow and oxygen concentration during all phases of flight.'' Does the Navy have a plan to upgrade the OBOGS system in the F–18? What is the schedule? Is there a cost estimate? When would fielding commence and be complete? When will Navy OBOGS systems in F–18s meet the updated military specifications published in 2015?

Admiral JOYNER. NASA is correct that best practices for a Pressure Swing Adsorption (PSA) technology is to maintain constant operating conditions. While this practice is well suited for a stationary industrial air separation plant, it certainly presents a challenge for an advanced high altitude all weather fighter aircraft operating in extreme conditions. The F/A–18 OBOGS actually represents a significant step forward in the maturation of supply air integrity and stability. The F/A–18 was the first fighter attack aircraft to move the bleed air supply from a direct engine bleed port where the temperature and pressures vary widely, to a diversion off of the aircraft's Environmental Control System (ECS) where the temperature, pressure, and water content of the air supply is significantly more stable. The F/A–18 was also first to introduce a redundant bleed air route that continues to provide source air to the OBOGS in the event of an ECS failure. Finally, the GGU–12 was fully qualified across environmental conditions which include bleed air temperatures ranging from −15 to +250F and in ambient temperatures from −65 to +160F. In actuality, the GGU–12 as installed in the F/A–18 receives conditioned air from the ECS that are well within these design parameters. Regarding testing, NASA is confusing routine performance checks with qualification testing. The GGU–12 was fully qualified against robust temperature and pressure extremes that exceed the actual environment in which it operates. Decades of reliable performance would attest to this assertion as well as more recent checks conducted to support the Root Cause Corrective Action (RCCA) investigation. It is true that many of the performance checks conducted by the fleet are performed at ground level using hangar air with flow conditions that are not reflective of aggressive flight. However, it is incorrect to assume that these conditions are inadequate to identify a failing system. It is noteworthy that the U.S. Navy is the only service that performs routine testing of the OBOGS for prognostic health monitoring. This test, which is performed on the aircraft every 84 days is designed to catch a failing OBOGS before it results in an aborted flight or physiological event. This comprehensive system test checks the system's ability to produce oxygen, the health of the sieve beds, the timing circuits, the accuracy of the low oxygen warning sensor, the oxygen plumbing integrity, and the ability of the system to enunciate failure conditions. In addition, the GGU–12 is removed from the aircraft every 400 flight hours for a more stringent off-aircraft test. This approach is in compliance with MIL–STD–3050. It is fair to say, however, that there is a dearth of information across the services and our international partners regarding the life and longevity of an OBOGS. The validity of the pass/fail criteria used by the Navy is being validated under a surveillance program to better understand the natural degradation in OBOGS. To date, none of the 28 F/A–18 or 28 T–45 aircraft that have undergone this very demanding test have shown significant degradation in their molecular sieve or carbon monoxide catalyst. NASA is also incorrect in applying the recommendation of Navy TM–93–59–SY to the GGU–12 oxygen concentrator. The intent of TM–93–59–SY was to establish dynamic breathing requirements for OBOGS plumbing and breathing regulators. The F/A–18 OBOGS plumbing is designed to absorb the pneumatic shocks and cyclic flow demands of human breathing. It does this by using a 100 cubic inch plenum for each cockpit. The size of the plenum and the diameter of the oxygen plumbing are designed to maintain the oxygen pressure at the pilot's breathing regulator so that it performs well. Thousands of data files from F/A–18 and EA–18G operations using pilot monitoring equipment have confirmed that there is more than adequate supply pressure being provided at the pilot's breathing regulator to meet human system demand requirements. The primary shortcomings of the GGU–12 center on the lack of oxygen concentration control and the lack of recorded data. Both of these requirements are new since the CY2015 release of MIL–STD–3050. PMA–265 and PMA–202 are developing a new concentrator for the F/A–18 that will address these issues.

QUESTIONS SUBMITTED BY MR. GAETZ

Mr. GAETZ. I understand that many in the military and aerospace communities feel that the reasons for the physiological events plaguing military aviation are mechanical. However, in light of the continuing problems with hypoxia in our frontline fighter and training aircraft, has anyone within your respective Services collaborated with academic institutions with known expertise in human performance and aerospace physiology/medicine. Has that option been talked about or explored in any way?

Mr. CRAGG. We believe this question is better answered by both the U.S. Navy and the U.S. Air Force.

Mr. GAETZ. I understand that many in the military and aerospace communities feel that the reasons for the physiological events plaguing military aviation are mechanical. However, in light of the continuing problems with hypoxia in our frontline fighter and training aircraft, has anyone within your respective Services collaborated with academic institutions with known expertise in human performance and aerospace physiology/medicine. Has that option been talked about or explored in any way?

Admiral JOYNER. Yes, Navy is actively engaging with academia. The Johns Hopkins University Applied Physics Laboratory will assist in contaminant evaluation of the collected Hydrocarbon Detectors and Sorbent Tube Adapters. The Naval Air Systems Command (NAVAIR) Educational Partnership Program will be hiring a PhD Chemist from St. Mary's College to assist in PE efforts. Also, NAVAIR AIR–4.6 has hired Aeromedical experts to consult on the review of PEs in the Aviation Environment Scientific Advisory Board. Stanford University's "Hacking 4 Defense" will start working on this problem in April 2018. This is a no-cost collaboration with graduate and undergraduate students who will look at the OBOGS-Hypoxia linkage with a naïve/fresh set of eyes. Members of the team will be from disciplines that include pre-med, computer science, engineering, etc. Stanford University has recently done work with the U.S. Navy to include proposals to prevent/reduce PEs with Special Warfare SEAL Delivery Vehicle drivers caused by multiple ascents/descents during long missions.

Mr. GAETZ. I understand that many in the military and aerospace communities feel that the reasons for the physiological events plaguing military aviation are mechanical. However, in light of the continuing problems with hypoxia in our frontline fighter and training aircraft, has anyone within your respective Services collaborated with academic institutions with known expertise in human performance and aerospace physiology/medicine. Has that option been talked about or explored in any way?

General NOWLAND. The Air Force remains committed to solving unexplained physiologic events across the fighter and training aircraft. Academic institutions play a vital role in helping understand the role of human factors in physiologic episodes. The 711th Human Performance Wing (HPW), the Air Force's aeronautical research facility, with Naval Medical Research Unit—Dayton (NAMRU–D) have collaborated with several academic institutions like Case Western Reserve University, Norwegian University of Science and Technology, and the University of Notre Dame in exploring how the human body responds to the unique stressors of the flight environment. We continue to explore such topics as hypocapnia, hyperoxia, hypobaria, work of breathing, contamination, pulmonary function, and environmental priming—all issues that may precipitate "hypoxia-like" symptoms.

The Air Force continually explores additional options to collaborate with other academic institutions to leverage their expertise in contribution to help better understand the problem space. Institutions like Embry-Riddle Aeronautical University have specialized expertise the Air Force can leverage to help identify human errors associated with physiologic episodes; provide data-driven recommendations for addressing human error; and recommend improvements for current human factors data collection.

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