CALL SIGNS

USN AEP SOCIETY

DECEMBER/ **2019**

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The digital future

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THE BANDIT WARS

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A bi-annual publication of the US Naval Aerospace Experimental Psychology Society

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CALL SIGNS is a bi-annual publication of the US Navy Aerospace Experimental Psychology Society (USNAEPS).

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FROM THE PRESIDENT

On behalf of the United States Aerospace Experimental Psychology Society (USNAEPS) Executive Committee (EXCOM), welcome to another issue of **Call Signs**. This July, it was my honor to assume the role of USNAEPS President, and I am pleased to announce that LT Andrew Miranda joins the EXCOM as Secretary, LT Mike Natali continues to serve as Treasurer, and LT Todd Seech assumes the role of Principal Editor for Call Signs. We are also fortunate to retain CAPT(Ret) Mike Lilienthal as our Emeritus Member at Large, and deeply honored to welcome CAPT(Ret) Frank Petho as USNAEPS Historian, in which role he is supported by our longtime historian and new Vice-President Eric Vorm. CAPT Petho brings a wealth of knowledge and a trove of historical documentation and information to this role, for which we are most grateful. Next, on behalf of the Society, the EXCOM would like to express our sincere appreciation to LCDR Stephen Eggan for his leadership as USNAEPS President over the previous term, and to the other members who selflessly dedicated their time and talents in service of the Society during this period.

In this issue of Call Signs, we feature a broad set of articles organized around the promise and applications of Mixed Reality in naval aviation. The contributions featured in this issue include many by guest contributors. These include a piece on aviation applications for augmented reality from Dr. Adam Braly, who will hopefully be joining us soon as SNAEP LT Braly. Dr. Anthony Ries of the Army Research Lab offers an article focused on efforts to improve our understanding of visual search and situation awareness in complex environments through eye tracking and mixed reality applications.

LT Adam Biggs, Research Psychologist, describes mixed reality applications in surface warfare in our Allied Specialties Column. In our Fleet Perspective Column, LCDR Nathan Williams, an F/A-18 E/F pilot and selectee for the Navy's Professional Flight Instructor Program, offers a line aviator's insights on the use of Virtual Reality in Flight Training. A group of US Air Force Academy Cadets has provided a piece on the USAF's Pilot Training Next - Experimental (PTN-X), moving the USAF's existing work on VR in training to the next stages of capability and technology integration. This issue of Call Signs also includes a piece by LT Joe Mercado and LT Mike Natali on the Navy's efforts to incorporate extended reality into undergraduate flight training, as well as a summary of future training technologies designed to move naval aviation survival training forward, from incoming Assistant Specialty Leader LCDR Lee Sciarini. Finally, our new historian, CAPT(Ret) Petho, provides an historical summary of training devices in naval aviation, illustrating how cutting edge technologies have frequently been used first in military training.

On behalf of the USNAEPS EXCOM, I hope you enjoy this issue of Call Signs. Thank you for your continued support of the Society!

U.S. Navy Extended Reality Pilot Training

By: LT Joe Mercado[1] and LT Mike Natali[2]

Above: An image of the Augmented Reality Vitrual Simulator of a T-45C jet training at Naval Air Station Kingsville, TX. This simluator uses BISim, and allows the student pilot to see both a virtual environment, as well as his/her own physical environment.

Across the Department of Defense (DoD), each service is suffering with an ever-growing shortage of operational pilots and is unable to fill the gaps fast enough due to constraints on available training aircraft, fewer instructors, and a legacy training system structured around 1970s technology. As of 2017, the U.S. Navy had a 26% shortage in fighter pilots which has only grown since and is predicted to reach its peak in 2021 (United States Government Accountability Office, 2018). This shortage is being felt not only in the Navy, and highlights the need for all the DoD services to increase the amount of pilots being recruited, improve incentives to remain on active duty as an aviator, increase aviation training production capability, and increase the speed with which students are able to complete aviation training.

One of the major efforts the U.S. Navy, U.S. Air Force (USAF), and U.S. Army have all started to address their shortage of aviators is to leverage and integrate emerging technologies into their pilot training curriculums. The USAF has been at the forefront of these experimental efforts with their “Pilot Training Next” (PTN) program initiated in 2018. PTN utilizes a modified pilot training curriculum designed to incorporate emerging technology such as Virtual Reality (VR), combined with a new paradigm for pilot training based on individual skill-attainment, versus traditional group block learning, to discover ways to create “unit-ready Airmen”, ready for operational aircraft training, within 12 months. To date, PTN has demonstrated success in delivering winged aviators to begin training on operational aircraft in less than 12 months and is preparing to start Version 3 in January 2020, improving on lessons learned from previous iterations.

Taking lessons learned from the USAF PTN program, the U.S. Army officially kicked off their “Aviator Training Next” program in 2019 focusing on their rotary training, leveraging emerging technologies, primarily VR, to produce aviators more efficiently by reinforcing basic flight training maneuvers. One of the main questions they are investigating is how much to integrate VR into the training and whether it can replace aircraft flight time without degradation in skillsets at the completion of training. Initial results are promising but inaugural classes are still completing training.

In 2018, the USN began evaluating how to leverage new technologies into aviation training such as VR and Mixed Reality (MR) to supplement student learning and skill acquisition. The Chief of Naval Air Training’s vision for the “Naval Aviation Training Next” (NATN) program is to “close the gap in training systems currently utilized in undergraduate Naval Aviation training” in order to “increa-

[1] Naval Air Warfare Center, Training Systems Division, Orlando, FL
[2] Chief of Naval Air Training, Corpus Christi, TX

Left: Two flight students at Naval Air Warfare Center, Training Systems Division in Orlando, FL use the VR-Part Task Trainer (PTT), learning to operate a T-45C Goshawk jet using Oculus Rift head mounted displays and Prepar3D simulation software.

se flight training capacity through faster skill acquisition, reduced re-fly's, and targeting training to individual needs" (Harris, 2019). By leveraging Extended Reality (XR) technologies, the overarching term that covers the spectrum between all real and virtual combined environments (VR, augmented reality (AR), and MR), the Navy hopes to alleviate the pilot shortage by developing more qualified aviators in less time and at a lower cost.

To improve its chances for success, NATN program is a multi-command endeavor, involving the Chief of Naval Air Training (CNATRA), Naval Aviation Training Systems and Ranges Program Office (PMA 205), and Naval Air Warfare Center Training Systems Division (NAWCTSD), in addition to leveraging results and lessons learned from the Air Force's and Army's parallel efforts. In March 2019 Rear Adm. Gregory Harris, while serving as Chief of Naval Air Training, wrote a letter to OPNAV N98 outlining CNATRA's vision and intent to integrate emerging, affordable technology in NATRACOM undergraduate pilot training (Harris, 2019).

CNATRA, PMA 205, and NAWCTSD have worked together to assess the impact of various XR devices on Student Naval Aviator (SNA) training performance outcomes. Specifically, the team evaluated four separate XR devices, which are shown throughout this review.

Over the past year, this multi-command effort to assess the impact of XR on SNA training performance outcomes has caught the eye of U.S. Navy Leadership. The team received the PMA-205 Team of the Quarter Award for FY19 Quarter 3 for their tireless work successfully integrating emerging, affordable technology into the NATRACOM undergraduate pilot training. In addition, both the USAF and U.S. Army Leadership have contacted the team and requested the results of the team's assessment and discussions for further collaborations. Throughout the course of the assessment, the team collected data from 966 SNAs. There were several AEPs involved in various aspects of the assessment including: CDR Chris Foster, LCDR Pete Walker, LCDR Ken King, LT Mike Natali, LT Joe Mercado, and LT Heidi Keiser.

The initial assessment found evidence indicating the use of XR devices relates to improved training performance in the T-45C, with a trend towards improved training performance in the T-6B. In addition, though students reported some mild symptoms of virtual reality sickness immediately after using the XR devices, those reported symptoms subsided within 30 minutes. The symptoms experienced were attributed to eyestrain and disorientation rather than the traditional motion sickness symptoms of nausea and fatigue. As the technology develops further, simulator sickness symptoms will likely decrease in frequency and magnitude.

Left: A MR T-45C Goshawck Jet merging a simulator cockpit with a virtual environment, was created by BISim and integrated with the 2F138D Operational Flight Trainer (OFT) at NAS Kingsville. This system is called the Augmented Reality Visual System (ARVS) and leveraged a Varjo HMD.

Where Virtual Waves Meet Physical Motion

By: LT Adam T. Biggs, PhD[1] and Dr. Kyle A. Pettijohn, PhD[1]

Above: A mixed reality system simluates the motion of a US Navy Destroyer in order to study the effects of subtle motion on object tracking and accuracy tasks. In this study, a participant is given targets at which to fire a simulated M2 Browning Machine Gun.

Training exercises are nothing new to the Department of Defense (DoD), although ever-evolving technology has produced new simulation capabilities in the form of virtual reality and augmented reality. Aviators are already familiar with the fixed-based and motion-based flight simulators that fall broadly into these categories. However, recent advancements in mixed reality technology have opened up other avenues of potential training for the surface and submarine communities. As with any new technology, these advancements come with potential improvements and potential problems—each requiring more information and new solutions. This article is going to take the high flying mixed reality discussion and introduce a few more grounded problems to the discussion. And yes, for you flyers, the pun is very much intended.

More than Words: Virtual versus Augmented versus Mixed Reality

The foremost issue to address is terminology. Although these terms are sometimes used interchangeably, it is critical to be direct since each variant brings unique challenges and advantages. Virtual reality (VR) describes a simulated experience in a self-contained world often created through an immersive headset. VR is the most common term in this group and the one with the longest history, stretching back to the "Sensorama" introduced in 1962 as one of the earliest immersive and multi-sensory devices (Heilig, 1962). Modern advancements have generated commercial products such as the HTC Vive or the Oculus Rift that make VR experiences available for only a few hundred dollars. Still, the last two decades have seen virtual reality leap forward from the blocky mid-90's simulations à la the classic (or terrible) science fiction of Johnny Mnemonic to the library of first-person shooting games available on commercial VR systems today.

Along with the commercial advancements of VR devices, augmented reality (AR) has come storming into the discussions about virtual environments. AR is best differentiated from VR because AR blends simulated elements into the real world. Whereas VR simulates an entirely new room with new objects for an individual to engage, AR blends computer-generated objects into the physical environment the individual currently occupies. The difference is in simulating your coffee cup and simulating the desk underneath it (VR), or simulating a virtual coffee cup sitting on the physical desk in front of you (AR). As such, AR tends to use headsets and similar technology that interweave these computer-generated elements in the physical world through a heads-up display worn by the user. A critical challenge further underscoring the difference—and creating any number of technological headaches—involves maintaining the physical placement of virtual objects in relation to a geographical coordinate system maintained by the AR device. That is, placing a virtual coffee cup on your desk means mapping out the height of the desk, the slope of its surface, other items on the desk so that the cup does not interfere with them, and most importantly, the ability to maintain those relationships in that physical space even if the observer is moving around.

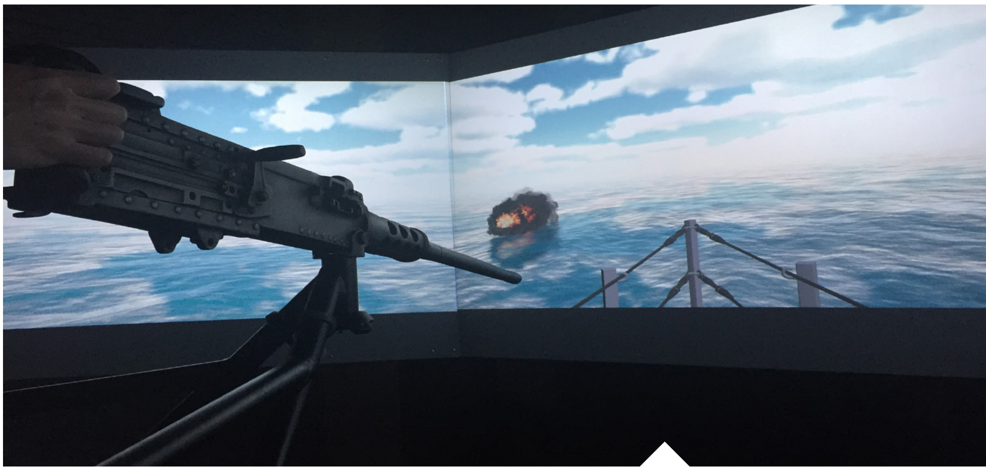
The third category, mixed reality (MR), represents some combination of virtual elements and physical elements. This label is the broadest description but is also the most accurate description of the experience provided by most mili-

[1]Naval Special Warfare Command, Coronado, California

tary training equipment. For example, the fixed-base and motion-base flight simulators used in aviation would be best described as MR systems. The presence of a physical cockpit or input devices means the entire simulation does not occur in a self-contained environment, and is therefore not purely VR. Computer-generated elements are used to depict the external environment but are not blended into a heads-up display or into the cockpit in some other capacity. Thus, the simulator is not purely AR. Any MR scenario represents instances where the simulation is intended to represent a virtual version of the environment by integrating both physical objects and some virtual elements. These lines are often blurred, and it can create significant confusion when addressing the different systems. In summary, both AR and MR mix virtual elements into the physical environment. And though all AR scenarios are MR, not all forms of MR are AR.

Mixed Reality Applications for Surface Warfare Simulations

For surface warfare simulations, including operations on ships ranging from Arleigh Burke class destroyers (DDGs) to rigid hull inflatable boats (RHIBs), mixed reality simulations become the go-to technique for one simple reason: motion. Virtual reality alone can never truly simulate conditions aboard a ship because the physical deck environment needs to incorporate sea state into the manipulation. Motion is perhaps the most obvious, unavoidable, and yet understudied component of human performance in naval operations. Yes, understudied is the intended term here as, while the concept is not new to naval training, the concept is understudied in how to document motion-related performance deficits or how performance in a moving environment can be enhanced. The bulk of research effects go into motion sickness countermeasures or helping people get their "sea legs." Both sickness-centric approaches operate under the principle that performance will be fine as soon as people stop feeling nauseated or dizzy. Centrifuge runs in aviation operate on similar principles. Essentially, expose someone to the motion until they become accustomed to the moving environment, then let them operate as normal.



Above: Accuracy dropped significantly as a result of adding motion to the simulation. The US Navy hopes systems like this may be utilized to train and equip sailors to learn how to shoot accurately while enduring at-sea conditions .

There is a major flaw in this logic that mixed reality simulations have helped identify—namely that reducing the motion-related performance detriments does not return human performance to 100%. Motion continues to impair performance even if people are no longer suffering from motion sickness symptoms. Motion sickness and similar issues will impair performance, but even if the person feels well while doing a task, it does not mean the person is doing the task well. Compare the difference to an individual who is having trouble landing an aircraft. The landing procedures are unquestionably important, but just because the aviator learns not to crash while landing does not mean that he or she has become an ace pilot. Human performance and motion sickness operate the same way—removing motion sickness from the equation does not automatically produce optimal performance.

Using a mixed reality simulation with a virtual headset to create the visual environment and a motion platform to provide physical motion, the Naval Medical Research Unit Dayton (NAMRU-D) has explored the impact of motion-related human performance detriments. No one will be surprised that motion impairs performance, although the goal is not to identify that a performance impairment exists, but to document the extent of motion-related performance impairments that we as a Service seem to accept as a cost of doing business. This specific scenario simulated someone standing at the bow of a ship operating an M2 Browning .50 caliber machine gun. Hostile craft would come down the port and starboard sides while shooters were given commence fire signals and cease fire signals if the hostile craft was successfully disabled or moved out of the weapon's range. Accuracy was 60% with the weapon without any motion. Simulating gentle motion onboard a DDG equivalent to calm seas in the open Pacific—the gentlest possible motion conditions for the craft—accuracy dropped to 30%. Accuracy further dropped to 13% with motion simulating a RHIB operating on Monterey Bay during normal sea state conditions.

Consider the implications here if we are only addressing motion sickness. The maximum performance would be 13% accuracy on a RHIB, which motion sickness could only reduce to 0%—meaning that all the effort invested to prevent motion sickness has been to avoid a maximum 13% error rate while ignoring other factors causing 87% of the errors. These numbers are cherry-picking the data a little bit as the values would not be as extreme from the DDG simulation, but the underlying point is that we have long been accepting extreme performance deficits while effectively saying, "welp, that's just Navy problems."

The Next Steps

Mixed reality simulations are an important first step in changing the attitude. Foremost, these simulations can help identify the extent of the problems by quantifying their effects under controlled conditions. The actual detriments are likely to be even more severe once factors such as experience,

Above: Using mixed reality simulators opens up a wide variety of both advanced applications, as well as basic research opportunities to study human performance, visual search, vigiliance, attention, and others.

different sea states, weapon recoil, and enemy fire are added to create appropriate realism and anxiety, yet mixed reality allows for controlled and quantifiable explorations of these effects. The next question then becomes the potential for training. If performance detriments can be observed in these mixed reality environments, can the same environments be used to improve performance? Practice is one option to enhance performance by simply repeating the exercise under the motion conditions. Another possibility involves using cognitive training methods to address human performance limitations in moving environments. Specifically, adaptive training methods can be used to promote near transfer of skills for practical military applications (Blacker, Hamilton, Roush, Pettijohn, & Biggs, 2019). In practice, this approach would mean altering the motion profile to be more or less extreme based upon performance of the individual. As the shooter does better, the motion becomes more extreme; as the shooter starts performing poorly, the motion reduces until their accuracy improves. Adaptive training is a core premise of cognitive enhancement, and in theory, the same principle could be applied to improving human performance in a moving environment by using mixed reality.

Finally, as with all things addressed to a wing-wearing audience, we need to bring the topic back to naval aviation. Despite the obvious differences in mission, there is a substantial amount of overlap in the problems encountered by using mixed reality platforms for operational purposes in surface warfare as there are in using these platforms for naval aviation. Medical issues alone are predominant problems as simulator sickness presents numerous challenges for naval aviation training (for a full review, see Geyer & Biggs, 2019). Then there are the simple, but practical, questions to address. For example, many of these mixed reality platforms were not designed to be used in moving environments. If someone is using virtual reality aboard ship, there is a high likelihood that motion in the simulation will be different from the physical motion of the ship—an asynchrony that is practically designed to induce simulator sickness. The issue does not cause a severe problem under relatively normal sea state conditions (Pettijohn, Peltier, Lukos, Norris, & Biggs, 2019), although it has yet to be tested in more extreme motion environments. For aviators, the parallel is the introduction of computer-generated elements in a heads-up display that could produce eye strain or vergence-accommodation conflict over a flight lasting several hours. These problems are not unique to military operations, but when evaluating this technology, a military audience must always remember that the recent forward leaps in this technology were designed for entertainment—not sustained operations.

Ultimately, there is a lot of untapped potential in virtual systems. The emphasis here was on training-related initiatives, although mixed reality platforms have the potential to assist in everything from maintenance operations to in-flight activities. The surface community could take advantage of these new technologies as they would help many different service members, from aviation maintenance personnel to Special Warfare Combatant-craft Crewmen (SWCCs) trying to operate riverine craft. Mixed reality has a growing impact on naval operations with a profile that will continue to grow. One of our biggest concerns, however, won't be if mixed reality platforms will have an impact, but rather how accurately we will be able to plan and predict the coming changes from a technology that evolves so rapidly. After all, for those individuals who actually remember that Johnny Mnemonic movie about virtual reality, the film supposedly took place in the year 2021—and the only thing that has aged well from it is Keanu Reeves.

Future Training Technologies for the Naval Aviation Survival Training Program

By: LCDR Lee Sciarini, PhD[1]

The Naval Survival Training Institute (NSTI) is the headquarters for eight Aviation Survial Training Centers (ASTCs) located across the United States. Along with directorates for administration, logistics and resources, NSTI has three directorates that are directly responsible for ensuring that the NASTP is delivered in a high quality manner to approximately 20,000 aviators and aircrew every year. These are the Directorate of Training Technology (DOTT), the Directorate of Education and Training (DET), and the Directorate of Safety and Standardization (DOSS). Working with the DET and DOS, DOTT is tasked with: 1) investigating and applying new and innovative technologies for use in the NASTP, 2) the development of new NASTP aviation physiology and water survival curriculum and materials to support training, and 3) the assessment of new, improved, and modified survival equipment and procedures. Over the past two-plus years, there have been numerous prototype demonstrations aimed at enhancing the delivery of the NASTP for both instructors and students. As is the case with many programs across the Naval Aviation Enterprise (NAE), the NASTP is often low on the list of priorities when it comes to the fulfilment of funding requirements. In such an environment, the NASTP relies heavily on the in-house capabilities of our partners at the Naval Air Warfare Center Training Systems Division (NAWCTSD) to help fill training gaps. Together, NAWCTSD, PMA-205, the NASTP Trainer Management Team (TMT), and the NASTP Integrated Product Team (IPT) continue to ensure that NSTI and the ASTCs have the best possible training systems. Support for the NASTP comes in many forms, whether it is NAWCTSD's FabLab filling a training gap for collective hypoxia training or Ms. Beth Atkinson's team guiding Small Business Innovative Research (SBIR) efforts, it takes a team effort to conceptualize and develop technologies that improve the training effectiveness, realism, and supportability for the many NASTP curriculum areas. Examples include the Normobaric Hypoxia Trainer (NHT), a virtual reality (VR) parachute procedures trainer, a spatial disorientation (SD) mishap recreation tool, a reconfigurable cockpit, and the On-Demand Hypoxia Trainer (ODHT). The NHT is currently being delivered to each ASTC and prototypes of the other systems listed have been delivered to ASTC Pensacola with plans to field additional prototypes at other ASTCs in order to have early feedback that will inform design and development decisions.

Normobaric Hypoxia Trainer

The NHT is replacing the Low Pressure Chambers (LPCs), which were decommissioned in 2016. Each ASTC will have an NHT and they are in varying stages of construction and acceptance testing at the time of this article. This new training capability is a reality thanks to a considerable amount of effort from the NASTP IPT, TMT, partners from the Naval Air Warfare Center Training Systems Division (NAWCTSD), PMA-205, and BUMED. Since the decommissioning of the LPCs, ASTCs have relied on the Mask-On Hypoxia Trainer (MHT), formerly known as the Reduced Oxygen Breathing Device (ROBD), in order to train hypoxia awareness for Class 2 and Class 4 aviators and aircrew. While the interim solution of training with the MHT did ensure that the hypoxia awareness training requirement was basically met for these trainees, it created a gap due to the use of equipment and tasks that did not align with those common to their aircraft. It is important to note that the normobaric environment of the NHT results in the inability to pro-

[1] Naval Survival Training Institute, Pensacola, Florida

Above: ARCHER, the on-demand hypoxia trainer. This image shows two reconfigurable cockpits, making ARCHER a highly flexible system for testing and evaluation.

vide rapid decompression events like its predecessor, however, it does provide increased fidelity for cockpit, aircrew station, and oxygen-related Aviation Life Support Systems (ALSS) familiarization training for multi-place aircraft over both the MHT and LPC. The first NHT has been installed and is currently being used for training at ASTC Jacksonville. An important addition to the NHT is a tablet-based aircrew task that was supported by the Naval Research Program (NRP) at the Naval Postgraduate School (NPS) and developed by LCDR Brennan Cox's team of researchers and students. It is anticipated that each ASTC will have a fully operational NHT by the spring of 2020.

Parachute Descent Procedures Training

The current Virtual Reality Parachute Descent Trainer (VRPDT) in use for the NASTP has significant issues that impact training quality and effectiveness. Additionally, limited instructional support for standardized training, along with maintainability issues, were clear indicators that an improved training capability was needed. Ultimately, the NASTP requires a fully functional parachute descent procedures trainer capable of allowing trainees to demonstrate the ability to execute full IROK (Inspect, Inflate, Release, Options, Koch) procedures. Such a system must be compatible with operational flight gear, allow for rapid student throughput, easy to startup and use, and have a low operation and maintenance burden. To this end, the current prototype being considered eliminates the use of an outdated head-mounted display, utilizes a contemporary and open source virtual environment, is comparatively inexpensive, designed with modular commercially available components, provides support for multiple aircraft platforms with minimal reconfiguration requirements, incorporates a streamlined instructor interface, and provides an automated debriefing tool for post training assessment. ASTC Pensacola and ASTC Lemoore currently have prototypes that are being evaluated by subject matter experts and there are plans to add an additional unit to ASTC Miramar's facility.

Above: The parachute descent trainer prototype, currently undergoing user testing and evaluation at locations in Pensacola, Florida and Lemoore, California

Spatial Disorientation Mishap Recreation Tool

The SD mishap recreation tool is a customizable software program built using an open source gaming platform. The system is capable of providing a suite of training tools and technologies that will allow NSTI and ASTC personnel to recreate aviation mishaps. Currently, the NASTP relies on lecture based SD training at each ASTC and an optional laboratory demonstration during NASTP indoctrination training at ASTC Pensacola. The goal is to provide ASTC instructors a method to convey lessons learned and improve SD awareness training through high definition videos and interactive, immersive visualization techniques. The concept is to take information about recent mishaps and automate input, integration, and time synchronization of aircraft state data to virtually recreate the incident. Input data for these scenarios can come from a flight data recorder, incident audio recordings (such as Air Traffic Control recordings), cockpit voice recorders, and unstructured text-based information such as transcripts and scene descriptions via text parsers. Currently, the tool can develop scenarios capable of replaying aggregate mishap data in a first-person 3D out-the-window visualizer and export narrative playbacks to a variety of formats suitable for delivery on desktop computers, mobile devices, and in VR displays. While already demonstrated to be functional and available for use at NSTI and ASTC Pensacola, the SD mishap recreation tool is still relatively early in development. Future work will focus on increasing instructional support capability to augment content for either instructorless or instructor aided training (audio overlays, image overlay for supplemental material), an expanded library of airframe and surface ship models, the inclusion of interactive knowledge checks (NATOPS, course rules, NASTP SD knowledge), advanced interactive instructional overlays, and the optimization for use with mobile platforms.

Reconfigurable Cockpit for Mask-On Hypoxia Training

Any recent participant in the dynamic hypoxia (MHT) lab of the NASTP will note that the physical and functional fidelity of the simulator's ALSS, controls, and displays are lacking. In addition to documented concerns with training transfer and training effectiveness, novice and experienced trainees have consistently reported dissatisfaction (Kirkpatrick's Level 1) with the fidelity of the MHT as a whole. These issues helped frame the requirements for, and have resulted in, the development of a reconfigurable cockpit for use in MHT. The system is designed with rapidly reconfigurable software and hardware components that accurately replicate the controls, displays, and emergency oxygen systems of a variety of aircraft (F/A-18, F-35). While a seemingly small piece of the overall NASTP, the development of the reconfigurable cockpit aims to close gaps with the credibility and effectiveness of dynamic hypoxia training. This ongoing effort is working to add T-6 and T-45 configurations with other aircraft to quickly follow. Further, the system was deliberately designed to be compatible with the SD mishap recreation tool which could eventually provide a more immersive training experience. Three systems have been delivered to ASTC Pensacola and there are plans underway to deliver additional prototypes to each ASTC beginning with those that support the Navy's three master jet bases.

On-Demand Hypoxia Trainer

profile creation and editing, the ability to annotate observed and experienced symptoms of hypoxia. Instructors can also select observed symptoms and an AAR that shows students the altitude experienced, heart rate, symptomology, and recorded SpO2.

In addition to the developmental work described above, NSTI DOTT has several ongoing efforts designed to assess and improve the NASTP. These include recently delivered spatial disorientation training lectures, a Center for Naval Analyses (CNA) instructional review of key curriculum areas, and three Defense Health Program (DHP) efforts that will enhance NHT, SD, and VR parachute

Sailors don their oxygen masks to verify their operational status at the start of a training in the newly operational Normobaric Hypoxia Trainer (NHT) at Aviation Survival Training Center Jacksonville, FL. The sailors will attempt to simulate pilot and aircrew activities at altitudes greater than 24,000 feet to become aware of the signs and symptoms of hypoxia. Photo by Mass Communications Specialist Second Class Nick A. Grim, US Navy.

In 2009, Artino, Folga, & Vacchiano, reported that almost 45% of NASTP students participating in mask-on hypoxia training experienced air hunger. These researchers also observed that the ROBD's airflow rate of 50 liters per minute presented a fidelity mismatch that could significantly impact the efficacy of mask-on hypoxia training. Concerns centered on the ability of students to recognize subtle or insidious symptoms of hypoxia, the inability to replicate the air delivery method of aircraft systems, and system-induced air hunger. Taking advantage of an electrochemical reaction to manipulate the gas mixture delivered to trainees, the ODHT was purposefully designed to address these issues as well as reduce the large footprint and limited portability of the ROBD, alleviate the logistic and bureaucratic burdens of housing and replenishing compressed gases, and enhance local maintainability. Another feature of the ODHT is an improved instructor/operator graphic user interface. The intuitive design supports the effective management of the system, training

training. When considering new training systems, NSTI DOTT's main goal is to objectively assess training requirements and to translate those requirements into training systems and methods that are valid, useable, maintainable, and most importantly, provide world class survival training to the fleet. The next time you visit an ASTC for a refresher ride in the dunker, take an extra minute to consider the new technologies and approaches in context to those that you previously experienced. Beyond that, take a moment to recognize the dedicated staff of officers, enlisted, civilians, and all of the phenomenal partners that continuously strive to improve the already world class NASTP training.

Bandits, Planes, and Leadership: The Ascent of US Military Air Power in pre-World War I

By: CAPT (Ret) Frank Petho[1]

The Border War, or if you were Texan, you called it the Bandit War, occurred along the US—Mexican border from 1910 to 1919. The conflict along the 2,000-mile stretch simmered for a year between July 1915 and June 1916, but during that year, Mexican forces raided the United States 38 times and killed 37 Americans.

In response, the US Army built a string of twelve forts from Texas to Southern California. As of 01 January 1919, these fortifications consisted of seven districts, four entirely in Texas, one partly in Texas and partly New Mexico, one in Arizona, and one in California. Meanwhile, the First World War had already begun on 1 August 1914 when Germany declared war on Russia; the United States then declared war on Germany on 6 April 1917 and American troops started landing in France in late June 1917.

Pancho Villa Attacks New Mexico

The bandit war peaked in 1916 when Francisco Pancho Villa and almost 500 villistas attacked Columbus, New Mexico, on 09 March 1916. Columbus is about three miles north of the US border. Villa's intelligence wrongly estimated the American force at 30 soldiers, but there were about 330 troops of the 13th Cavalry garrisoned there and the garrison included a Machine Gun Troop. The American regular forces, and armed citizens, repulsed the villista, reportedly firing 20,000 rounds from four Hotchkiss M1909 Benet-Mercie machine guns. Villa called off the attack and retreated, leaving 67 of his men dead and five taken as prisoners by the Americans. The villistas killed 18 Americans and wounded eight.

Woodrow Wilson Attacks Mexico

A week after Villa's attack on Columbus, President Woodrow Wilson authorized a punitive expedition into Mexico. The United States retaliated with a 4,800-man force deployed into northern Mexico under the leadership of then Brigadier General John J. Pershing who was stationed in El Paso, Texas. The expedition's objective was to capture or kill Villa.

Operations started on 14 March 1916 and ended on 7 February 1917, and collectively, were called the Mexican Expedition or more popularly, Pershing's Punitive Expedition. Pershing neither killed nor captured Villa, nor did he stop border raids, which continued unabated during the expedition. He did successfully engage Villas' forces across northern Mexico, and by the time Villa retired in 1920 and was assassinated three years later on 20 July 1923, the insurgent's fighting force was largely dispersed and ineffective. Most of the American forces returned to the United States by January 1917 and soon after shipped out to France to fight in the First World War.

The 1st Aero Squadron, also called the 1st Reconnaissance Squadron, is the oldest US military flying unit and Columbus, New Mexico was the first tactical military airfield in the United States. The 1st Aero Squadron's Curtiss JN3 Jenny biplanes provided observation and communication for the Punitive Expedition although many of the aircraft crashed in the Mexican mountains. The 6,800 JN3's that were manufactured during this time used a V-8 air-cooled

[1] USNAEPS Historian

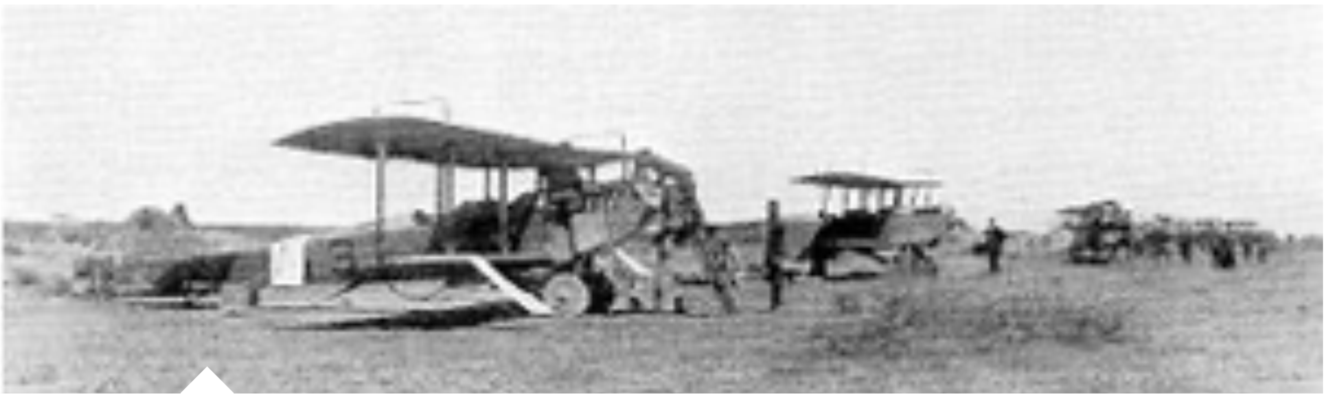
The United States Government acquired 8,553.78 acres in Oklahoma and quickly established the Naval Air Gunnery School to train sailors with skeet and trap shooting (shotguns), machine guns, small arms, and machine guns on moving target ranges.

piston engine rated at 90 horsepower, giving it a top speed of 75 mph, and flew an average mission range of 36 miles at a service ceiling of 6,500 feet. Camp Furlong located next to Columbus was headquarters for more than 5,000 troops and also had supply facilities and repair yards for the early motor trucks and planes used in Mexico.

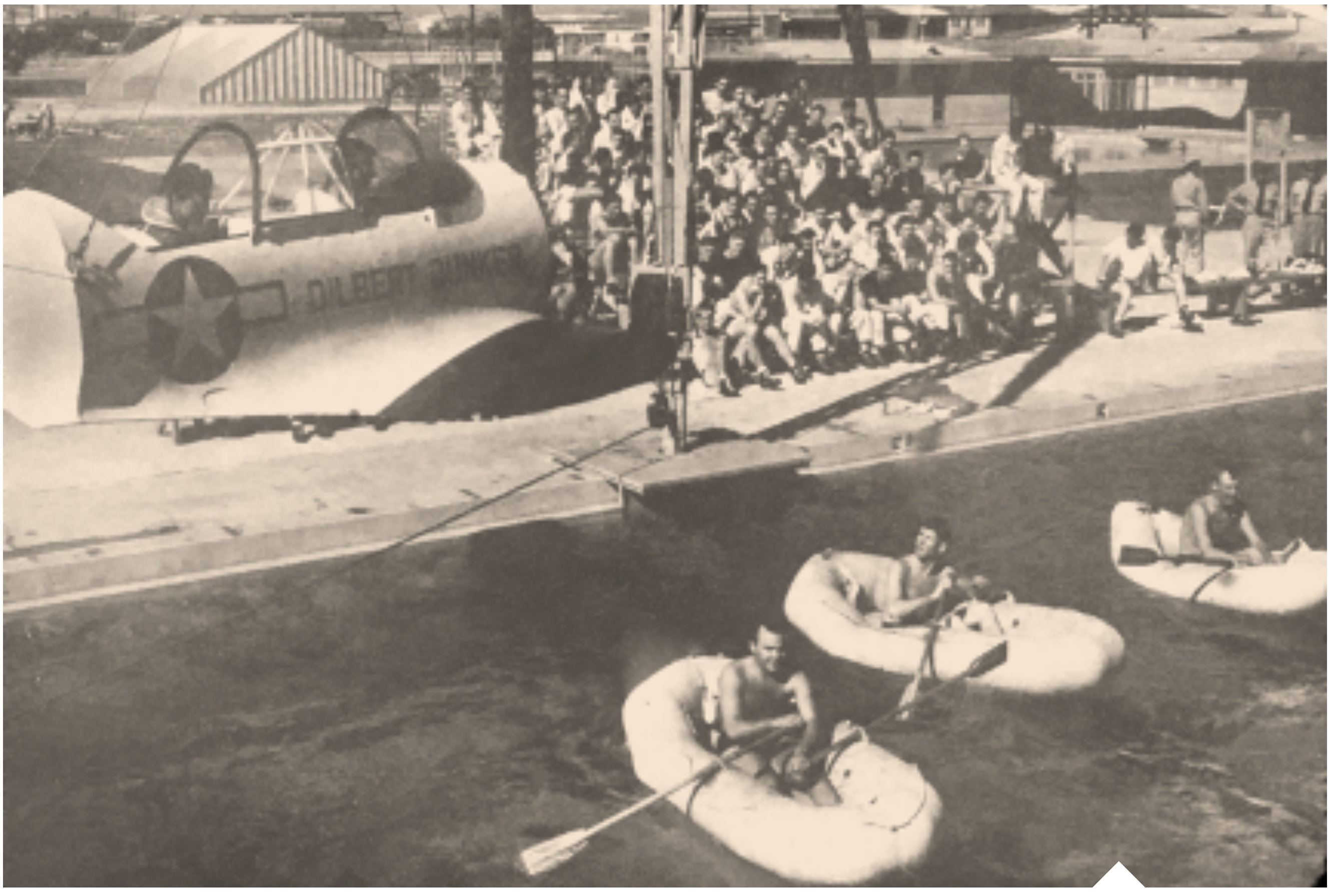
The Curtiss JN-2's and 3's were 'cutting edge' when they deployed, but little research had gone into their development. The plane was unsafe because of low power which was insufficient to fly over the Sierra Madre Mountains. The plane's shoddy construction, lack of stability especially in turbulent mountain passes, and an overly sensitive rudder also contributed to its significant flaws. Some of the airplanes were actually made by the pilots who flew them.

Crashes were common. Repair was time-consuming and difficult. Laminated, mahogany propellers had to be dismounted after each flight and placed in humidors to keep their glue from disintegrating. Under these conditions the propellers lasted about thirty days. The pilot fatality rate was high. Flight lessons were almost unheard of, and frequently consisted of general guidelines given by word of mouth on the ground. Orville Wright actually taught one of the early pilots to fly by mail. These early conditions cost the United States much in the way of both manpower and material. Lessons learned during this period, however, paved the way for what would become a critical component for the US involvement in WWI. Training devices, such as the Dilbert Dunker and Link Trainer (first page and above) were born out of early observations of the many shortcomings in both the design and implementation of early aviation.

The development of leadership in early aviation



Above: 6,800 Curtiss JN2 and JN3 aircraft were developed during the Bandit Wars with Mexico. Although terribly unsafe, they played an important role in early aviation, teaching America new tactics and concepts of operations that would soon be used with greater success in WWI.



Above: The “Dilbert Dunker” was an early training device used to teach aviators how to successfully escape an aircraft in the event of a water ditching. Today’s aviation dunker devices retain many of the original designs found in the Dilbert Dunker.

The early period of the First World War was essentially a clash of waning 19th-century military science with emerging 20th-century technology, which ultimately created ineffective battles with huge numbers of casualties on both sides. But the American leadership that emerged from the Bandit War was strong, persistent, and present.

For example, **“Black Jack” Pershing**, earned his fourth star and commanded the American Expeditionary Force in Europe during WWI. Lieutenant **George S. Patton** of the 8th Cavalry, launched the first armored vehicle attack on enemy forces on 14 May 1916 with three Dodge armored cars and 15 men. He shot three villistas, strapped their corpses to his car’s fenders, put three notches onto his Colt Peacemakers, and returned the bodies to Pershing’s headquarters in El Paso. Pershing dubbed Patton the “Bandito.”

Second Lieutenant **James H. Doolittle** was a flight instructor at Camp John Dick located on the State Fairgrounds in Dallas, Texas from January 1918 until January 1919. He also served at Kelley Field outside of San Antonio, Texas and at Eagle Pass, Texas. Eagle Pass, is on the Rio Grande about 40 miles south of Del Rio, Texas. At Eagle Pass, his detachment from the 90th Aero Squadron patrolled the Mexican Border. Doolittle retired as a four star general and recipient of the Medal of Honor. He led a surprise bombing raid (“Doolittle’s Raiders,”) of 16 B-25 Mitchell bombers launched from an aircraft carrier—USS Hornet—on the Japanese homeland on 18 April 1942.

The Bandit War Ended Two Years after it started. Nonetheless, activities on the border were far from dull. The troops had to be on constant alert as border raids still happened. The Mexican Expedition proved to be an excellent training environment for the officers and men of the fledgling aviation community, who would be recalled to Federal Service later that same year of 1917 for duty in World War I. Many of these officers and men gave their first federal service during the Mexican Expedition.

Many artifacts of this period can still be seen in today’s aviation training, such as training devices descended from early ones such as the Dilbert Dunker (above). Hence, we can trace many of the developments and lessons learned in early aviation this relatively obscure, but vitally important conflict.

Pilot Training Next Experimental

Streamlining undergraduate pilot training using VR simulators

By: Howard Bermudez[1], Alex Duppstadt[1], Kellen Rau[1], Isaiah Sanders[1], Anna Claire Tuma[1], and Jacob Wilbers[1]

This article was written by first-class cadets (seniors) at the US Air Force Academy. These students are part of LT Todd Seech's Warfighter Effectiveness Lab in the Department of Behavioral Sciences & Leadership at the US Air Force Academy. LT Seech is a US Navy Aerospace Experimental Psychologist stationed as an assistant professor at the US Air Force Academy as part of an interservice exchange program. LT Seech's research serves to inform and update both Air Force and Navy policies and practices in aviation training and organizational development.

Virtual Reality (VR) is a vastly growing technology that has permeated multiple pre-existing systems such as video games, television, and training. It has adapted over the years to become extremely realistic and versatile, with both contributing to its increasing popularity. The incorporation of VR into training simulators has become more and more popular, particularly in the military.

Pilot Training Next (PTN) is a newly developed program intended to streamline Undergraduate Pilot Training (UPT) in the United States Air Force (USAF). It incorporates VR simulators for the T-6 Texan II trainer aircraft to mimic and simulate the real UPT T-6 environment as closely as possible. Students in this program have a strict training regimen in the VR simulators, both before they ever enter the T-6 as well as throughout the rest of their training as a supplement. Furthermore, these students have the ability to practice in their own home, as each student has his or her own VR kit to keep at home. Not many students have completed this program thus far, making it difficult to analyze how successful VR training is in streamlining UPT.

At the United States Air Force Academy (USAFA) in Colorado Springs, CO, there is a team of First Class Cadets (Seniors) studying the effects of VR training, specifically related to improving the future of PTN. A program at the USAFA has recently been implemented that incorporates principles of PTN to its Powered Flight Program - which is intended to expose cadets to powered aircraft and help them determine if they want to pursue pilot training. There are several different levels of this program, ranging from a few flights in a powered aircraft to a strict ground school using VR before entering the actual plane with the intent to solo.

Our team is researching the effectiveness of programs like this and how they fit into the future of pilot training. Air Education Training Command (AETC) has placed a huge emphasis on the addition of VR training to UPT, so it is imperative that we figure out the best way to optimize this training with minimal negative effects. We are working with various stakeholders such as Lockheed Martin and ACME Worldwide to create the optimal and cost effective VR flight training kit.

There is already ample research on the effects of VR training on humans, including both positive and negative effects. Some of the main problems existing for VR are fidelity, transfer of training, eye strain, cyber sickness, and field of view. We will be studying the effects of an ACME motion chair on students flying in a virtual reality environment. The chair we will use has the ability to mimic the first response of an aircraft turning, pulling gravitational force (Gs), and changing speeds. It does not, however, sustain Gs, which could end up actually causing more sickness and negative transfer of training. We hope to collect data from people with real flying experience to understand the effects of this specific motion chair and whether it should be included in our kit. Similarly, we will collect data from students going through the Powered Flight program at USAFA to see if the kit we develop is actually helpful in streamlining the training process. We are specifically interested in whether training in our kit will result in reduced time to reach solo flight on the real aircraft, or if there will be any difference at all in overall flight performance.

So far, we have had experience in VR

The team members for this research project are back from left to right: Jacob Wilbders, Isaiah Sanders, Kellen Rau, Howard Bermudez. Front from left to right: Alex Duppstadt, Anna Claire Tuma

[1] First-Class Cadets, US Air Force Academy

simulators similar to the system used in PTN and we spoke with some of the students who recently went through the actual USAF program. Thus, we have started to understand its limitations, capabilities, and areas we hope to improve in our kit. We have also done research to identify the main problems with VR flight simulators, the most prevalent apparently being field of view constraints, fidelity, and sickness. We hope to find ways to minimize these issues in our kit so that students can remain in the VR environment for a longer time with more effective training. We have determined a system for introducing students to our kit and teaching them how to use it, which we will begin testing in the near future. We are optimistic that this testing will identify the pros and cons of VR training and areas where we can feasibly improve it, given the resources provided to us.

Above: Sgt. William Lexa (left) and Senior Airman Raymond Pettit conduct virtual reality research at Brooks Air Force Base, Texas, on pilot/cockpit systems to help make their training more realistic. Photo by Master Sgt. Fernando Serna, USAF

A successful project will entail any positive strides towards a more realistic, effective, and tolerable VR training environment to help AETC improve their current PTN system. If we can identify even one enhancement area that contributes to accelerated success of students in the PTN program, we will consider the project a success. Hopefully our kit will be a useful tool for AETC and PTN leaders to use in the future for further development and incorporation of VR in training systems.

Below: A student practices basic flight maneuvers using a VR trainer at Naval Air Station Corpus Christi, Texas

Technical adviser, Sergeant First Class William Roth, uses the –ENVG-B in an overnight hike (Patrick Ferraris/ PEO Soldier)

Visual Search and Situation Awareness in Complex Environments

By: Anthony J. Ries[1,2]

Visual search is a ubiquitous component of our everyday interactions with the environment. It is critical for obtaining and maintaining situational awareness (SA) in complex, dynamic environments, and is especially true for the Soldier in combat situations. Rapidly evolving technology is creating unique opportunities to advance our scientific understanding of visual search and perception in real-world environments while also providing cutting-edge applications for Soldiers on the battlefield. At the forefront of this technology is virtual reality (VR) and augmented reality (AR). VR is a real-life environment generated by a computer simulation. It separates the user from the physical world and immerses them in a digital replica using a head-mounted display (HMD). AR, on the other hand, overlays digital details onto real-world elements to enrich perception of the current environment. Incorporating eye tracking technology into VR/AR devices provides a new level of context and understanding by knowing precisely where a person is looking (Sostel, 2019). Additionally, eye tracking information can be used as direct input to adapt AR/VR behaviors. The Army is integrating VR and eye tracking in order to examine visual perception during search tasks. Advances in AR/VR are helping to enhance performance in the field. VR Experimentation Much of our understanding of visual search is derived from experiments using two-dimensional stimuli on a computer monitor. This approach is relevant to many real-world tasks, such as baggage screening, radiology, and general interaction with computer interfaces. However, it limits our understanding of visual search in many everyday interactions requiring depth information (e.g. driving; dismounted Soldiers searching for threats). While prior experiments have evaluated visual search with depth as a binary feature (McSorley & Findlay, 2001), only recently have researchers begun to investigate ocular metrics with depth as a continuous third dimension (Pomplun, Garaas, & Carrasco, 2013). Many of these experiments have been limited to searching a small portion of the visual field due to the size of the stimulus display and the relativelocation of the participant, in cases with eye tracking. As a result, this prior work often requires the use of a head-constrained chin rest in order to minimize head movements. Contrary to these experimental constraints, visual search in operational environments necessitates concomitant head and eye movements to scan large portions of the visual field in three dimensions.

Recent advances in HMD technology and mobile eye tracking provide a means to alleviate these limitations by

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[2] Warfighter Effectiveness Research Center, U.S. Air Force Academy, CO

A USAFA Cadet First Class Santiago Garcia performs a visual search task in VR while simultaneous eye tracking and EEG data are recorded.

integrating eye-sensing hardware into a AR/VR headset. For an introduction to using eye tracking in VR, see Clay, König, & König, 2019. Experimentation in VR allows researchers to investigate visual search and other constructs more naturally using 3D experiences. Many HMDs use Fresnel lenses to collimate incoming light. This enables better accommodation of the lens in the eye and produces less eye strain compared to 2D computer monitors. Additionally, eye tracking hardware embedded in HMDs provides accurate, continuous sampling of gaze position – supporting 360 degrees of tracking in 3D space. In sum, using VR as an experimental platform provides a high degree of realism while still affording critical experimental control.

Research in VR

The United States Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED) is working with the Warfighter Effectiveness Research Center (WERC) at the United States Air Force Academy (USAFA) to experiment with new eye tracking technology embedded in HMD VR devices. ARL and the WERC are using the HTC Vive VR headset with embedded eye tracking from Tobii to record various behavioral and eye gaze metrics while participants perform visual search tasks (Figure 1). The goal of this project is twofold: to create an experimental research platform to investigate ocular dynamics in 3D search tasks, and to provide critical data for algorithm development. The platform uses the Unity engine, a system which is easily configurable to manipulate multiple display variables and collect several measures of behavioral performance. For example, visual target arrays can be presented with or without distractors, statically or dynamically (e.g. observer moving/stimuli static or vice versa) and with various eccentricities, speeds and sizes. Performance measures include, but are not limited to, reaction time (saccade and button press), accuracy, fixation duration and frequency, head position and acceleration. The core of the research platform is its capability to broadcast data to Lab Streaming Layer (LSL), open-source software designed to collect and bundle time series data from multiple sources into a unified data structure (i.e. Extensible Data Format – XDF (Kothe, 2014)). LSL allows the VR research platform to synchronize multiple data streams (e.g. eye tracking, Unity variables and states, HMD position, behavioral responses, etc.) within the experiment, regardless of sampling rate. Additionally the system offers the flexibility to easily add other external data inputs such as electroencephalography (EEG), audio recording, keyboard input, etc. The impetus behind the VR research platform development was inspired by a recently established Army program focusing on applications of VR and multimodal data fusion.

Towards an Application

Under the Tactical Awareness via Collective Knowledge (TACK) program, ARL-HRED scientists are using VR and eye tracking technology together with brain activity from EEG to provide a moment to moment index of target SA. Detecting a target-relevant object elicits a unique neural response in the brain, which can be measured using EEG sensors worn on the head. Analyzing brain activity time-locked to eye tracking eye fixations reveals whether a given fixation was on, or near, a target-relevant object. ARL-HRED researchers have designed an online neural classification system, the Hu man Interest Detector (HID, Figure 2), which uses deep learning algorithms to create a fixation–by-fixation snapshot of target-relevant information in the environment (Touryan & Gordon, 2018). The HID synthesizes data from EEG, eye tracking, and scene cameras. This allows for an analysis of the momentary neural response with fixation points and Region-of-Interest (ROI) information. Researchers have demonstrated the HID system reliably distinguishes task-specific objects from background objects in the environment without any disruption to the user's primary tasking. Based on this research, SA could become an emergent property of the group and, thus, more fault-tolerant to individual errors.

Integrated Visual Augmentation System (IVAS)

The HID system uses fixation-locked neural activity across multiple observers to create a map of mission relevant objects (red markers). Fusing these data with other physiological inputs or information from unmanned aerial assets provides a powerful approach to measure, and graphically depict, group situational awareness. Yellow numbers indicate the current location of three dismounted Soldiers with the path shown in the white trail. Right – Physiological information from each Soldier (heart rate, respiration, pupil diameter, and blink frequency is presented along with current fixation highlighted and overlaid on video taken from a body camera.

Soldiers perform an after-action review through their IVAS devices after navigating through a shoot house. IVAS is designed to increase Soldier lethality, mobility and situational awareness by providing enhanced night and thermal vision capabilities, map displays and data collection capabilities. (Photo by PEO Soldier)

As mentioned previously, VR is a fully digitally rendered simulation, but AR uses digital input to modify perception of the existing environment. The Army is investing heavily in AR technology to enhance Soldier SA, training effectiveness, and lethality. Specifically, the Army's Soldier Lethality Cross Functional Team is using Microsoft's HoloLens 2 to develop the Integrated Visual Augmentation System (IVAS, Figure 4). The IVAS uses AR to create a synthetic training environment, giving Soldiers the ability to train for, and replay, specific combat scenarios over multiple iterations (Cox, 2019). Additionally, the IVAS can project the site reticle of the Soldier's firearm directly onto the heads-up AR display, thereby increasing target acquisition and lethality. The IVAS also proves beneficial for navigation, as IVAS technology can place digital objects and maps onto the real-world terrain (Figure 3). This enables the Soldier to continue the mission without having to look down at a tablet or computer (Haselton, 2019). While the HoloLens 2 provides eye tracking capability for developers and researchers, it is currently not implemented in IVAS.

Enhanced Night Vision Goggle-Binocular (ENVG-B)

In addition to IVAS, the Army is leveraging AR technology in its Enhanced Night Vision Goggle – Binocular (ENVG-B). The ENVG-B is a product of PEO Soldier with close collaboration with the Soldier Lethality Cross Functional Team and Army Futures Command (United States Army Acquisition Support Center, 2019, Figure 5). Similar to IVAS, the ENVG-B presents the site reticle from the weapon directly to the goggles. This gives Soldiers the ability to engage their weapon in circumstances which do not require shouldering it, such as when shooting from the hip or when shooting from around corners (South, 2019). The ENVG-B is a binocular system, rather than the traditional monocular, giving the Soldier increased depth perception. Other perceptually enhancing benefits the ENVG-B provides to the Soldier include (United States Army Acquisition Support Center, 2019) :

- Better contrast of targets by using white phosphor tubes instead of the traditional green.
- Fused thermal imagery for increased target recognition in degraded environments (e.g. dust, smoke, zero illumination, subterranean, etc).
- Inclusion of augmented reality aspects from the Nett Warrior display.

Summary

Advances in AR and VR technology provide exciting opportunities for research in visual perception by balancing real-world context with experimental control. These technologies are already showing their effectiveness to the Soldier, whether in training at home or lethality on the battlefield. Fusing eye tracking and other measures, such as EEG, within AR/VR systems provides both the experimenter and developers additional insight into an operator's attentional allocation, cognitive state, and situational awareness.

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Petty Officer 2nd Class Vincent Rodriguez inspects the tail rotor drive shaft as he performs a preflight check on an H-60H Seahawk helicopter on the aircraft carrier USS Abraham Lincoln (CVN 72) as the ship operates in the Pacific Ocean. Photo by Petty Officer 2nd Class James R. Evans, U.S. Navy

Augmented Reality in Aviation Maintenance

By: Adam Braly[1]

Augmented reality (AR) is a technology that has the potential to mitigate operator costs associated with cognitive distance.

Training human operators to perform tasks efficiently and safely is a critical aspect of aviation safety. One major area of research focuses on human performance in aviation maintenance, repair, and overhaul (MRO) operations (Garg & Deshmukh, 2006; Ma, Drury, & Marin, 2009; Patankar & Taylor, 2017; Rashid, Place, & Braithwaite, 2010). MRO operations often involve procedural work, in which an established sequence of activities is performed to accomplish a particular outcome. Procedural tasks are common for installation, assembly, inspection, maintenance, and repair work, which are often presented on a paper medium. For example, once maintenance or inspection is scheduled on an aircraft, the work is translated into a set of job cards or task cards that outline the procedural instructions that must be followed in order to carry out the task. These cards present textual information and static images to supply visual cues necessary for the task, and their complexity scales with the complexity of the task itself. As a result, operators devote a significant amount of time to studying paper instructions (Henderson & Feiner, 2009). In fact, one report noted that operators spend as much as 45% of their work-shift sear-

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Aviation Machinist's Mate 2nd Class Alexandra Mimbela performs maintenance on an F/A-18F Super Hornet attached to the Fighting Black Lions of Strike Fighter Squadron (VFA) 213 aboard the aircraft carrier USS George H.W. Bush (CVN 77). U.S. Navy photo by Mass Communication Specialist 3rd Class Brian Stephens

ching and reading procedural instructions (Ott, 1995).

Procedural instructions, such as task cards, are often physically separate from the equipment they accompany. This inherent division of work creates two distinct task spaces: one for task information and one for the physical task itself (Neumann & Majoros, 1998). In the information task space, the work is primarily cognitive. Operators read, search, interpret, and translate instructions to the physical task space. In the physical task space, the work is primarily kinesthetic, and operators inspect, adjust, and manipulate equipment. This inherent division between informational and physical tasks creates cognitive distance for the operator (Kim & Dey, 2009). Both task spaces require cognitive and attentional resources, but the added cognitive distance imposes additional demands on operators because of the need to integrate information between the two task spaces. To integrate information between the two spaces, operators must switch their attention between the two task spaces, which is associated with increased demands on working memory (Arrington & Logan, 2004; Monsell, 2003).

Augmented reality (AR) is a technology that has the potential to mitigate operator costs associated with cognitive distance. AR systems superimpose virtual objects onto the physical environment which creates an immersive experience for task operators. Specifically, it is possible to superimpose the information task space onto the physical task space, which can enhance the operator's perception of and interaction with the physical task space. For example, one recent study showed that an off-the-shelf AR head-mounted display (HoloLens) can enhance procedural work on spaceflight science hardware (Braly, Nuernberger, & Kim, 2019). In that study, participants completed a procedure that was analogous to installation and maintenance procedures for the specific instrument. They were tasked with searching for named cables to make a connection to a port on the device (mate) or disconnect the cable from a port on the device (demate) using a paper instruction method (similar to a task card) and an AR instruction method.

In the paper instruction method, participants viewed a simplified version of normal procedural instructions that allowed for direct experimental comparison to the AR instruction method. In the AR instruction method, participants viewed a virtual checklist that was fixed in space at the center of the instrument and did not obstruct task areas. Participants controlled the AR instruction method using voice communication. The same information was provided to participants in both conditions, with the exception of three AR cues that were provided to enhance operator performance: a virtual bounding box to assist in the location of the task area; a virtual nametag that was located near the target port; and an attention director that cued participants' attention to the target port when it was not currently in the field of view. Participants completed one block of unique experimental trials using each instruction method—half of the participants used the paper instruction method first and the other half used the AR instruction method first. They were given practice trials to familiarize themselves with the task and the instruction method, and were allowed to practice until they felt comfortable performing the task. Immediately following each block of experimental trials, participants completed paper versions of the NASA-TLX (Hart & Staveland, 1988) and the System Usability Scale (SUS; Brooke, 1996) to assess subjective workload and usability, respectively, of the instruction method. After both blocks were completed, participants filled out a short questionnaire designed to elicit feedback about the perceived pros and cons of each instruction method and were asked which instruction method they preferred.

Results showed there was a significant interaction between instruction method and instruction method order, $F(1, 18) = 19.68$, $p < .001$, $\eta p2 = .52$. As depicted in Figure 1, mean trial completion time was significantly faster for the AR instruction method compared with the paper instruction method but only when participants completed the paper instruction method first. In other words, when participants performed the task using the paper instruction method first, they were significantly faster in the AR instruction method compared with the paper instruction method. When participants performed the task using the AR instruction method first, there was no significant difference in mean trial completion time between the two instruction methods. These results suggest that using an AR instruction method first resulted in a transfer of training that improved subsequent procedure execution using a paper instruction method. As shown in Figure 2, the AR instruction method received significantly lower ratings on both mental workload, $t(19) = -2.996$, $p = .007$, $d = 0.67$, and temporal workload, $t(19) = -2.511$, $p = .021$, $d = 0.56$. Results showed that the number of errors committed were not significantly different between AR instruction method (four total) and the paper instruction method (eight total), $t(19) = -1.710$, $p = .104$, $d = 0.38$. In general, participants committed fewer errors overall, and the authors attributed this to the relative simplicity of the task. Results also showed that there was no significant difference between the mean SUS score for the AR instruction method ($M = 81.50$, $SD = 13.39$) and the mean SUS score for the paper instruction method ($M = 78.00$, $SD = 13.27$), $t(19) = 1.294$, $p = 0.211$, $d = 0.29$. The authors attributed this to the relative simplicity of the paper instruction method.

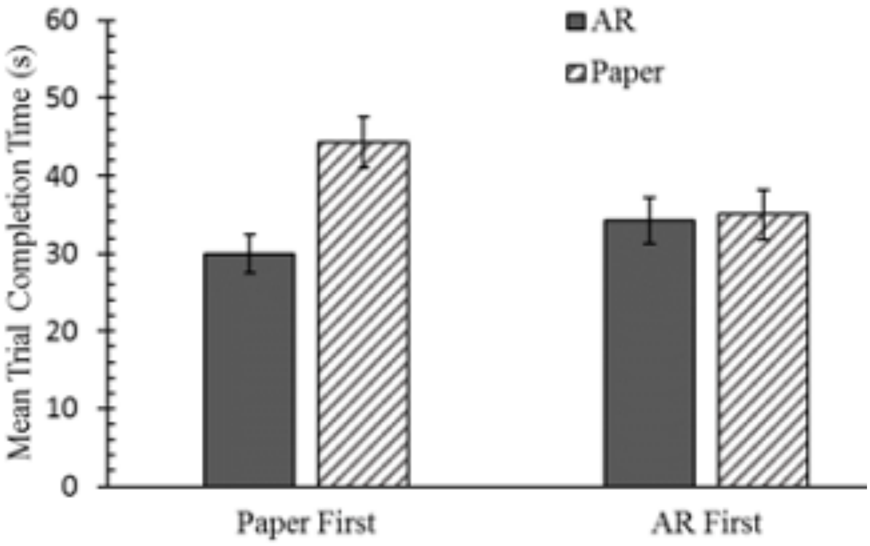

Figure 1: Reprinted from Braly, Nuernberger, & Kim (2019). The effect of instruction method on mean trial completion time (seconds) for each instruction method order. Error bars represent ± 1 standard error of the mean.

Overall, these results provide preliminary support for the notion that AR can enhance operator performance for procedural tasks. Because the paper instruction method was simplified and because the task was relatively simple, it is reasonable to expect greater performance benefits for an AR instruction method when compared to original documentation or more complex tasks. It is also important to note that several factors may have contributed to the transfer of training from the AR instruction method to the paper instruction method: voice recognition, the attention director, the virtual bounding box, target port highlighting, and reduced visual scanning by presenting a virtual checklist. The study described was not designed to independently assess each of these factors, and future studies are needed to examine which of these factors result in improved operator performance. Additionally, more research should be conducted to examine whether the training observed was due to modality per se, or due to repeated exposure to the task. For example, what would happen if participants performed the task with paper instructions multiple times before using AR?

"The technicians failed to follow the written procedures" or "procedure not followed" is a recurring regularity in aviation incident and accident reports (Drury & Johnson, 2013). Under the Code of Federal Regulations, the rule on manuals is quite clear: you must use a manual for all work. Although it is clearly stated, this rule is often neglected. In fact, one study of major aviation malfunctions reported that the number one contributor to malfunction was failure to comply with maintenance documentation (Johnson & Watson, 2001). Thus, it is critical to identify the specific reasons that operators are not following written procedures. Is the task too complex, and they are mentally overloaded? Are the written procedures inadequate to describe complex 3D procedures?

How can we design procedures such that operators can perform the task efficiently, correctly, safely, and willingly? It's a little early to claim that AR is the answer, but results from early studies on AR procedural work are promising, and suggest that immersive procedures can enhance operator performance.

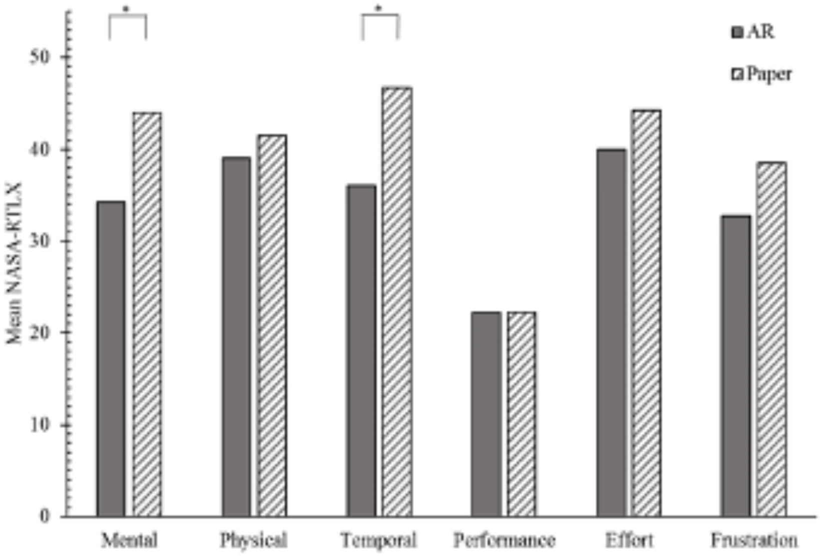

Figure 2: Reprinted from Braly, Nuernberger, & Kim (2019). The effect of instruction method on mean NASA-TLX score for each of the six subscales. Error bars represent ± 1 standard error of the mean.

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MEET AN AEP

Commander Chris Foster, AEP # 125, shares what made him want to join the US Navy, and talks about what he loves about the job

AEPs are a small, diverse group of professionals who come from a variety of backgrounds and experiences. In this series, we give individuals an opportunity to share more about themselves in a one-on-one interview format in order to narrow that gap, and foster relationships and collaboration across our community.

In this issue we will meet CDR Chris Foster. He is currently assigned to PMA-205 at Naval Air Station Patuxent River, MD, where he serves as the Air Warfare Training Development Integrated Product Team (IPT) Lead: Science and Technology, and Strategic Planning.

What is your academic background?

I received my BA in Psychology at Southwestern University in Georgetown Texas in 1994, followed by an MS in Industrial/Organizational Psychology in 1996. I was awarded my PhD in Industrial/Organizational Psychology in 2006 from the University of Houston.
What made you want to be an AEP?
While working on my PhD, I worked for a consulting firm called the Vandaveer Group. I ended up working full time as a consultant and starting a family. During my 8 years with the Vandaveer Group I worked primarily with companies in the oil industry, both domestically and internationally.

CDR Foster and his children enjoy holiday at their home in Texas. CDR Foster served at the Chief of Naval Air Training Naval Air Station Corpus Christi.

The focus of consulting was always on the bottom line and eventually I became a little disillusioned with the work I was doing. I got frustrated that I was doing work and delivering good products; handing them off to customers who might or might not use them at all. I never got to see whether the products I built were used or made a positive difference to the organization. I liked the idea of being part of an organization whose mission I could buy into and do work where I could see it making a difference.

Then 9/11 happened.

That day I was running a meeting with a client when the attack happened. The client meeting continued even as the attack was happening. While we didn't know just how serious it was at the time, these priorities didn't feel right. Shortly thereafter, then-LT Hank Phillips contacted me about the AEP community. Hank and I had started the University of Houston PhD program together. I was still ABD at the time. Once I was closer to completing my dissertation, I was able to join the community. I was commissioned in 2004 and designated AEP #125 in May, 2005.

What was hardest about your training?

I personally found Officer Indoctrination School (OIS; now Officer Development School [ODS]) to be the most difficult part of training. The family separation was tough. Beyond that I had been working in the private sector for 8 years, I was in my early thirties, and I did not enjoy my time with the Chiefs who were running OIS at the time.

What was your most vivid memory about training?

1. Battlestations at OIS – at the time it was an all-night evolution. Saving the Buttercup was memorable. And when conducting the firefighting drill, I remember that my glasses under my mask instantly fogged up, making it very difficult to see where to point the hose. The advice I got was very good – "Point the hose at the bright spot."

2. On my first helo flight, I was in the right seat, and my door came open. I told the IP, and his nonchalant response was "Close it." What seemed like a very big deal to me was not even noteworthy to him.

3. Remember doing all of my T-34 training as cross-country flights. I believe we were the first class to do that and it gave us a chance to overnight in Key West. I got in and out of VT-2 very quickly.

4. Receiving my Wings of Gold with Tatana and Will. Thanks to the magic of alphabetic order I took AEP# 125. They had to settle for 126 & 127 respectively.

Why did you decide to remain on active duty after meeting your service obligation?

I decided to stay for both personal and professional reasons. My decision came at the end of two tours at NAS Corpus Christi, after serving first in the Navy Human Performance Center and then as N7P for the Chief of Naval Air Training (CNATRA). CNATRA clearly valued AEP data analytic skills and training expertise. I felt like I was making a difference, had a path to progress and promote, and to do additional worthwhile work. I realized I needed to move on from hands-on data collection and analyses at this point. I was comfortable with this tran-

CDR Chris Foster next to his T-34 Turbomentor training aircraft at Naval Air Station Key West, Florida.

sition because the scope of my work's impact on the fleet increased as a result. Being able to guide and direct the work of others to ensure it was targeted to best address Fleet needs was very rewarding as a result.

While there were challenges associated with moving, and I haven't always been able to move where I expected to, my family has been resilient to the change, and able to adapt. It actually really made my family closer and helped us to be more tight-knit. I have 3 kids who really get along, care about each other, and like each other. We have enjoyed the different locations that we have had the opportunity to live and have gotten to see more of the country than we otherwise would have.

What is your current billet and job title?

My billet is at PMA-205 at Naval Air Station Patuxent River, and my job title is Air Warfare Training Development IPT Lead: Science & Technology (S&T) and Strategic Planning.

I also serve as a Level 1, a direct report to the Program Manager, with Department Head-level responsibilities. My IPT is comprised of 28 people. On the Science and Technology (S&T) side, I manage an annual budget of ~$1.7M and my team guides an S&T portfolio of ~$70M across ~60 active projects.

Our S&T portfolio is aligned with the Program Offices 5 Key Focus Areas and related capability gaps that LT Mercado and I developed in coordination with Level 1 & 2 IPTs and with Fleet inputs. On the Strategic Planning side I shepherd issues through the POM process, prepare the PMA's OPNAV Program Review briefs, represent the command at a variety of events (e.g., TS ENARG, Fleet Training Wholeness), and manage the Strategic Plan. Our POM-22 submissions total ~$1.75B across the FYDP.

What are you working on, and how will it impact the Navy?

A key focus is in the area of Extended Reality (XR) technologies: my team is working with the Chief of Naval Air Training (CNATRA), who is interested in how to use XR to revolutionize naval aviation training. We have deployed 22 devices in the last year alone. My AR/VR Training Development Team won the PMA-205 Team of the Quarter for Qtr 3 FY19, the PMA-205 Innovation Team of the Year for FY19, and has been nominated for NAVAIR Commander's Award for FY19.

Beyond this we are exploring the use of Augmented Reality (AR) tech for maintainers (e.g., P-8, F/A-18, H-60, and Firescout). We have an active Direct to Phase II SBIR for P-8 and F/A-18 AR for Maintainers.

The On-Demand Hypoxia trainer (ODHT) is supported by NAWCTSD's Battle Lab. That technology will eventually replace all the ROBD II's at all of the ASTCs and the form factor of the device has the potential for integration with Visual FTDs. This device begins delivery this FY.

Our IPT is also working on the next parachute descent trainer with General Training and NAWCTSD, which will significantly enhance both initial and refresher training at all ASTCs.
On the Strategic Planning side a key area of focus is on developing and delivering LVC training (LVCT) capability by 2025. Our POM-22 inputs include Aviation LVC which would be a $799M POR. If funded, this program will, among other capability improvements, deliver necessary updates to the F/A-18, EA-18G, E-2D, H-60, P-8, and JSF OFPs. Glad to talk off-line about any additional details of this program.

What are your career goals?

I continue to be interested in jobs in which I feel like I can make a positive difference for the warfighter and for my community. I have been very lucky to serve in a range of billets and assignments: working directly with the Fleet at CNATRA, working in Navy Medicine during my time at NAMI, working with the acquisition community at NAWCAD and NAVAIR, working closely with the Navy's research communities (e.g., ONR, NRL, NMRC, NMRU-D) and learning the ins and outs of our community as Assistant Specialty Leader. While I expect to go where it best benefits the community, I am interested in leveraging the experience I have gained at NAVAIR by following up my time at PMA-205 with a rotation as Military Director at 4.6. I am also very interested in serving our community as Specialty Leader though we have a number of talented officers who I expect will also be interested in serving the community in this way.

What advice do you have for junior AEPs?

A few thoughts:
- Most important is to be proactive and look for opportunities where you can leverage your skills to make a difference for the warfighter and your community. This is actually a redundant statement because I believe that our community is essential to the success of the warfighter. Our tiny community of ~30 AEPs is one of the secret weapons in the success of Naval Aviation. We need to continue to work to make it less of a secret.

- If you believe in the community and its importance to our service, your actions should benefit both yourself and the community. Our community's continued success and viability depends on our ability to position our community to best support the Fleet's needs.

- Remember that you are in the military. Respect the hierarchy and learn how to work within the service you are a part of. I know there was a learning curve for me.

- Finally, one of my mentors, CDR(Ret) Jim Hooper, told me, "If you don't have anything to do, don't do it here." What he meant was that there will be plenty of times when you must pull long hours and sacrifice family time, so use the opportunity to be with your family when you can get it.

Can you tell us a little about your family?

I met my wife Shannon in college at Southwestern University and we married in 1997. We have three kids: Noah (18 at Southwestern University), Caitlyn (14, 9th grade), and Aiden (11, 6th grade). Shannon is a certified English & Theatre teacher and taught High School English and Theatre prior to my commissioning in the Navy. She is passionate about theatre, musical theatre, literature, travel, and our family. Not necessarily in that order. After I was commissioned, she stayed home with the kids. The original plan was for her to go back to teaching high school, but we decided that our kids would benefit from homeschooling. I helped with science and math and she took care of the rest. After Noah graduated high school, our other two kids wanted to be more involved in extra-curricular activities. So this past year we enrolled them in traditional school and my wife began teaching 12th grade AP English at my daughter's school.

CDR Chris Foster at Naval Air Station Whiting Field, Milton, Florida flying in a TH-57C Bell helicopter. Aerospace Experimental Psychologists like CDR Chris Foster attend flight training in both fixed wing and rotary wing aircraft in order to better understand the flight environments in which aviators operate.

Final Thoughts

Not that I'm going anywhere anytime soon, but an active duty career goes quickly. Take advantage of opportunities when you get them. Building relationships with your fellow AEPs and the line officers we interact with will help shape you as an officer and ensure you get the most out of your time in uniform.

CDR Chris Foster, his wife Shannon, and their three children enjoy the sights at Warwick Castle in England. AEPs serve in a variety of roles, functions, and locations across the United States. Being a small community means having the opportunity to ensure a good work-life balance in order to maintain ideal fitness, readiness, and productivity.

Bravo Zulu!

Some recent accomplishments from around the US Navy Aerospace Experimental Psychology community

Left: LCDR David Rozovski was named Navy Medicine Subspecialty Officer of the Year for 2019 (AEP of the Year). This award is designed to recognize Medical Service Corps officers whose leadership, professional knowledge, and expertise have made significant contributions toward enhancing warfighter performance, operational capabilities, and Navy Medicine. Awardees receive letters of commendation from the Director, Navy Medical Service Corps, and the selection results will be highlighted in the Medical Service Corps Newsletter. LCDR Rozovski received the award for developing solutions to two long-standing human factors problems affecting readiness within the Navy Helicopter Maritime Strike (HSM) community. By identifying a self-contained commercial off-the-shelf attitude indicator and shepherding it through the Navy's airworthiness process, he provided the HSM community with the first instrument to combat spatial disorientation among sensor operators in its history. His thorough analysis of the physics and human factors underlying mishaps that result in the loss of the MH-60R dipping sonar, the single largest driver of Class A mishaps in the HSM community, resulted in the development of two proposed solutions that are currently under review for implementation by PMA-299, the MH-60 Program Office.

Above: Selection of Unammed Aerial Systems Personnel (SUPer) Team received the American Psychological Association (APA) 2019 Julius E. Uhlaner Award for outstanding contributions to research on military selection and recruitment. In the image above, CDR Olson receives the award from Col (ret) Stephen Bowles, President of Division 19, the Society for Military Psychology (left) and CAPT (ret) Russell Shilling, APA Chief Scientific Officer and retired Navy Aerospace Experimental Psychologist.

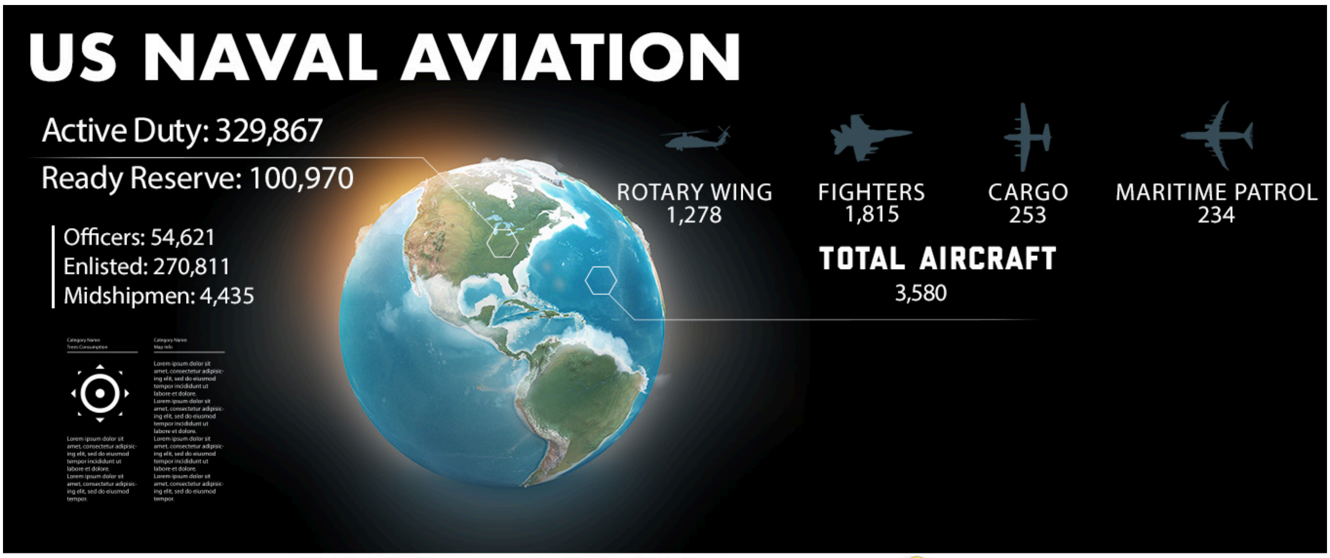
BZ to LCDR Cox for organizing and leading a multidisciplinary Naval Research Program team of aviators, scientists, engineers, and subject matter experts in the development of design, development, and delivery of the Dynamic Aircrew Task for the Normobaric Hypoxia Trainer.

BZ to LCDR Lee Sciarini for his role in a team award from the National Training and Simulation Association 2019 Modeling and Simulation Award for Training / Simulation for the work completed this past year for Hypoxia Training Research & Development NAWC-AD Innovation Award - Technical Category for Hypoxia Training Research and Development Team

Above: LT Joe Mercado (left) and CDR Chris Foster received PMA-205 Team of the Quarter (FY19 Q3) Award and the first ever PMA-205 Innovation Team of the Year for leading the successful integration of emerging, affordable technology into NATRACOM undergraduate pilot training over the past year.

Above: LCDR Joe "MOBO" Geeseman promoted to O4! In this image, LCDR Geeseman's wife, Tonya, pins on his new oak leaf, while CDR Brent Olde looks on. Congratulations, MOBO!

Above: LT Eric Vorm successfully defended his dissertation and completed his doctorate at Indiana University 6 months ahead of schedule. LT Vorm joined the AEP community in 2012, coming from the Fleet Marine Force community where he served eight years as a Corpsman. LT Vorm's PhD education was made possible by the Navy Medicine Professional Development Center, which provided him the opportunity to attend doctorate training full-time at Indiana University. LT Vorm's dissertation topic was titled "Behind the Black Box: Designing for Transparency in Artificial Intelligence." His research in designing for effective human-machine teams was featured by Indiana University, and is now continuing at the US Naval Research Laboratory's Center for Advanced Studies in Artificial Intelligence in Washington, DC.



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