Bringing the Debrief into 3 Dimensions with Augmented Reality

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ABSTRACT

In military aviation, the post-flight debrief has a long tradition and currently retains a robust community of practice. Across military services, the debrief is consistently recognized as a vital step in the learning process. The importance of debriefing as an element of training effective fighting forces is widely recognized but scholarly attention to improving the process remains surprisingly sparse.

The task of accurately recreating spatially complex events like maneuvering combat aircraft remains a consistent challenge for debriefing. Typical methods of recreating events within aviation training have remained surprisingly unchanged over decades of practice. These include using a whiteboard, map, and a small aircraft model attached to short stick. Recent advancements in immersive technology mean that an evaluation -and possible update- of the methods for post-mission debrief is needed. This paper explores the application of Augmented Reality and Virtual Reality (AR/VR) technology to enhance the debrief process. Recently a partnership with Arizona State University and the 56th Fighter Wing at Luke Air Force Base resulted in a prototype model using AR for the post debrief process. The concept and initial application were entered into the US Air Force's AFWERX Spark Tank 2021 competition and has selected as a finalist (Butler, 2020) (SECAF Public Affairs, 2020). This paper examines the debrief process from a theoretical perspective and explores the benefits, challenges, and limitations of using AR/VR to support debrief activities. As a result, a proposal for refining the prototype and evaluating it in a controlled environment relative to current debrief methods is provided.

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INTRODUCTION

Since the advent of military aviation, the post-flight debrief has been central to the process aviators have used to recall and learn from the events of flying missions. At the same time, psychologists and other scholars in the field of pedagogy have explored theories of how human beings learn, clarifying the essential role of the debrief. Theories such as spatial learning and Kolb's experiential learning identify the ways in which an ordered debrief can improve learning and retention of important information and skills. The United States Air Force's (USAF) premier Weapons Instructor Course has published student papers on debriefing techniques and procedures almost annually over the last 20 years, while NASA's Ames Research Center provided insight into further aviation applications for debriefing (Dismukes, 2000). Theories of learning and the procedures and techniques for debriefing within the aviation field have evolved, the tools and systems used for debriefing by military aviators have advanced slowly. Many of the systems and techniques currently used for a USAF debrief would have been familiar to a fighter pilot in the Korean War era. This paper will explore the role that systems and technology can play in debriefing and examine a promising technology area with implications for military training and readiness. Recent growth in Augmented, Mixed and Virtual reality technologies promises display, sharing, and collaborative interaction with spatial information in a way uniquely suited to the challenges of aviation learning.

FLIGHT TRAINING AND THE DEBRIEF

Developing the skills needed to operate an aircraft involves a unique combination of learning challenges. These include acquisition of knowledge about aircraft capabilities, communication procedures, as well as navigation and the use of controls for maneuver (Dismukes, 2000). Learning to effectively employ an aircraft in a military context brings these challenges to another level. For combat pilots, aircraft must be employed in various formations and often according to specific geometric constraints. For instance, Basic Fighter Maneuvering, (BFM) is the foundational understanding of maneuvering of aircraft to gain advantage in proximity with other aircraft. While this is considered a foundational skill for fighter pilot training, it is a spatially complex task which taxes its learners heavily. In fact, like many military aviation skills, even fully trained pilots at operational units continually hone their BFM skills, with specific flights regularly devoted completely to this single competency. The employment of advanced maneuvering capabilities and weapons systems at short and long ranges in three-dimensional space only further increases this complexity.

Naturally, military services (and particularly the USAF) are heavily involved in training aviators and preparing them for combat. Service training curriculums lay out the knowledge and skills in which aircrew must gain proficiency and allocate a mix of academic and "hands-on" training to achieve these learning objectives. For flight training, "hands-on" training means leveraging a mix of simulators (of varying fidelity) and actual aircraft to gain experience in the needed skills. The syllabus typically prescribes a progression of learning objectives that proceed from foundational to advanced, while specially trained instructor pilots are employed to guide and advance student learning. For both live and simulated flights, a well-established sequence of events is executed before and after the actual flight. First, in mission planning, the student creates objectives and a plan for the flight (Alexander et al, 2019). This forms the basis for the pre-flight briefing, where the plan and other relevant information about the training event is communicated to all flight members and/or the instructor pilot (Ibid). The flight training event is conducted, providing practice in the desired skills. Following the flight, the student and instructor share their perspectives about how well the skills were performed during the training flight in the debrief. Assuming that these skills were not executed flawlessly, the instructor and student work together to identify any factors which may have led to deficient performance, as well as potential solutions to these issues.

DEBRIEFING IN LEARNING THEORY

The importance of the debriefing process to effective adult learning is recognized within several theories of learning. Kolb's Experiential Learning model notes the importance of a structured analytical review of experiences to compare theories and expectation with actual practice and execution. (Fanning & Gaba, 2007). According to Kolb, the learning experience can be described in 4 parts: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In this model, the debrief can be viewed as a structured method to improve the transition from action to reflection and conceptualization.

Fanning and Gaba describe the debrief as consisting of common elements across theories and settings (Ibid), while Lederman (1983) breaks the debrief down into seven elements, beginning with the learner (the person or group to be debriefed), the debriefer or debriefers, the experience that will be debriefed, the impact of this experience on those to be debriefed, the recollection of the experience in the minds of the participants and report (the format in which the participants record or codify their recollection of what occurred) and the time elapsed between the event and the debrief.

Debriefing in practice across different contexts

The term and the practice of debrief have military origins, but debriefing has expanded far outside of that original military context. In fact, much scholarship in this field comes from medical and psychological professionals. In the medical context, surgeons, psychologists, and emergency responders have all seen utility in debriefing performance during or after important events, either in simulations or in "real-life" contexts where learning must occur after actual practice during an event, session or emergency (Fanning & Gaba, 2007). For psychologists, the personal or group-reconstruction of an event can be powerful in helping the mind to process and create a manageable mental model of events, particularly if the experience was overwhelming or traumatic. This practice is often referred to as "Critical Incident debriefing" and provides a method to manage stress and improve recovery after these kinds of events (Ibid). Trauma and crisis situations are important and worthy of study, but examples of debrief in action can also be found in more prosaic learning environments such as sports.

Team based sports such as American Football require many players to work together despite each player's limited perspective during execution. To improve player skills and understanding, coaches routinely use some form of debrief to help their teams learn. One commonplace practice for this kind debrief is the watching a videorecording of the play or competition. This "game tape" can give players important perspective they may have lacked while they were executing. Technology may provide additional avenues to expand this impact. In his book *Experience on Demand*, Jeremy Bailenson, describes the powerful effect of combining review and analysis of game tape the medium of virtual reality. Adding virtual reality can allow players to repeat plays with subtle alterations and actively experiment with changes to opposing formations and responses. Piaget (1952), described the importance of a mental model, or schema, as a means for learners to organize and build upon sensory information to understand cause and effect. The debrief and review of game tape is a contributes to the development of mental models that a player can use to understand what is happening in a sports game despite limitations in perspective. Bailenson's VR system enables a learner to rapidly and repeatedly progress through the four steps of Kolb's experiential learning, from initial experience through to active experimentation, at a remarkably low-cost relative to traditional methods of training or simulating these experiences. Video recording is one way that event information can be compiled for review, but it isn't equally suited for all applications. Research has explored a variety of ways that data can be gathered and reviewed to support debriefing.

Ensuring accurate recollection – data compilation

While Fanning and Gaba suggest that debrief follows a natural cycle in human event processing, wherein an event is experienced, reflected upon, and then discussed with others, they note that in this naturally occurring process, the execution of these steps will often tend to be unsystematic (Fanning & Gaba, 2007). They state, "In practice, not everyone is naturally capable of analyzing, making sense, and assimilating learning experiences on their own, particularly those included in highly dynamic team-based activities" (Ibid). Their insight highlights both the role of an instructor within the debrief process and the challenge of structured and timely data compilation. This data compilation challenge can be particularly vexing in the wake of chaotic military events. Even in an ordered training environment, the timing, motion, position, and communication of hundreds or thousands of participants can be fiendishly difficult to reconstruct and analyze upon completion

Within a military aviation context, recognizing and addressing this challenge is important for successful training. While early reconnaissance pilots could observe and reflect verbally on the observed movements of enemy military formations, their ability to accurately relay this information for debriefing was substantially improved through the advent of photo-reconnaissance techniques. As aircraft transitioned from battlefield observers to direct combatants, these techniques were adapted to ensure that the results of combat missions could accurately be quantified in the debriefing through photographic means. Air forces installed "gun cameras" to record the results of air-to-air engagements and bombing cameras to survey the destruction wrought by bombing raids with greater precision. At times, photographic evidence diverged starkly from the recollection of accuracy presented by the pilots and crews executing the mission.

Ensuring accurate recollection – data display and analysis

Even for relatively basic military aviation events, the synthesis of all available data into an accurate and accessible format that provides value to subsequent reflection and analysis is a challenge. For larger exercises, the difficulty becomes extreme. In some cases, numerous additional training staff are employed primarily to assist in this process. Traditionally, to keep the debrief manageable, only certain parts of the event would be highlighted for reconstruction, often being painstakingly illustrated on a chalkboard or whiteboard, with physical props such as the stick-jet (see Figure 1) being used to provide a flexible and relatable visual reference.

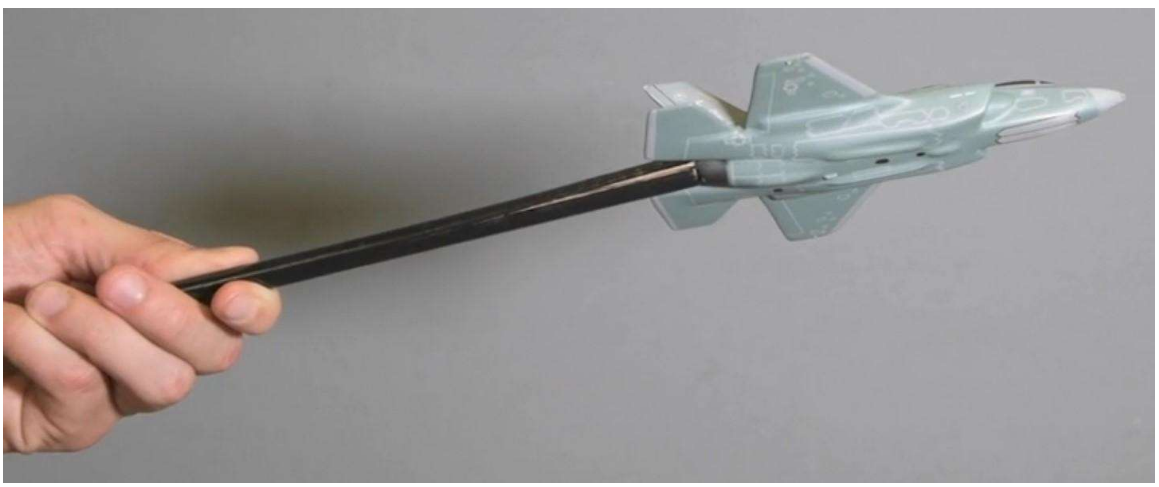

Figure 1. F-35 Lightning II Stick-Jet

Modern computer technology has slowly been incorporated into the debrief process to aid in flight reconstruction. Personal Computer (PC) based debriefing software is used in many modern training situations to help assimilate diverse data streams into a coherent picture of events. There are a variety of software platforms available for this function, each tailored to certain communities and situations. PCDS, the Personal Computer Debriefing System, is commonly used amongst the military aviation community. It is maintained under a joint contract between the USAF and US Navy. In some locations, additional personnel are employed to help manage the data input and display controls for the program. Even the military simulation gaming community recognizes the value of debriefing, commonly employing software such as Tacview (Alexander et al, 2019) to develop their own lessons learned from their simulated aircraft missions. Software such as CloudAhoy has also been adapted from use in the general aviation market for some military flying training environments such as Undergraduate Pilot Training (Vance AFB Public Affairs and CloudAhoy, 2018).

Beyond observation and weapons employment, military forces use a variety of systems to gather position and navigation data, enabling improved reconstruction and analysis of flying missions. In the 1960s, systems were emplaced at training ranges in the United States to measure and record the locations of multiple aircraft in three-dimensional space and relay this information back for use in debriefing. Many aircraft began to fly training missions with special sensors on board to improve the quality of this data such as the Air Combat Maneuvering Instrumentation (ACMI) pod. The deployment and growth of the Global Positioning System has led to proliferation of airborne GPS systems which can store data for later review. Overlaying this data geospatially provides important context that helps weave the entire experience together. Synthesizing all of these data sources presents a tremendous opportunity to develop a holistic understanding of what occurred in the training environment, but obviously also presents a significant technical and procedural challenge as well, since most of these systems for data gathering have been designed as individual, independent systems rather than as a cohesive whole.

PC based debrief software sets vary, but each will plot the position, altitude, and airspeed over time of an aircraft relative to available map and geographic data, often including terrain elevation data. For military use, most include tools for measuring distance and angles between aircraft -important for understanding the "Weapons Engagement Zones" of various missile and sensor systems. Since live-fly aircraft in training missions do not regularly employ live munitions -and therefore no aircraft are actually shot down- some of these systems provide ways to track and visually identify which aircraft are "dead" and which are still participating. Data can be displayed on a standard PC screen but is often displayed for a group on a large wall screen or projector. For a variety of reasons, many relevant pieces of information are not automatically recorded, so significant time may be devoted by pilots to the manual collection this data (for instance, the time and distance at which simulated missile shots were taken). Information on aircraft locations is commonly displayed in a top-down perspective but may also (in most systems) be displayed from a side-on perspective or isometric 3D (stadium view), presenting a more intuitive view of the relevant geometry between maneuvering aircraft and formations.

Figure 2. PC-Based debrief

While these software packages provide a great opportunity to organize important mission information for analysis and reflection after missions, the limitations of these systems, combined with possibilities in the emerging fields of Virtual and Augmented reality, have led some scholars such as Lee (2018) to propose that the future of debrief analysis may lie in the VR/AR realm. Utilizing VR and/or AR for debriefing would enable the three-dimensional flying environment to be visually represented in a manner more intuitively visible in three dimensions thanks to the natural stereographic capabilities built into modern VR and AR equipment. The state of the art for these technologies is rapidly advancing, but the core principles of creating stereographic images to improve natural depth perception is not a new concept.

AR AND VR MECHANICS BACKGROUND

Simple stereographic viewers have delighted users since the middle of the 19th century. Popular 20th Century examples of such devices include the ViewMaster toy and the Anaglyph 3D movie glasses that briefly appeared in movie theaters during the 1970s. These devices use a variety of effects to create binocular differences in vision, either by presenting separate images to each eye, or by actively or passively displaying different elements of an on-screen image to the viewer. Despite limitations in the color, clarity, and lighting effects of some of these methods, they generally provide a convincing sensation of depth.

Doctors and scientists concerned with the biomechanical and neural basis for vision have been studying and refining the empirical understanding of depth perception for centuries. Depth perception includes a combination of both monocular and binocular cues (El Jamiy and Marsh, 2019). The specific categorization of these cues varies somewhat from scholar to scholar, but broadly, monocular clues include occlusion (inferring that when an object appears whole while another object appears partial next to it, the whole object is blocking line of sight to the partial object, and is therefore in front of it.), texture (objects on which greater texture are observable are inferred to be closer), motion parallax (objects crossing our field of view more quickly appear to be closer), and perspective (objects higher up in our field of view are generally perceived to be at a greater distance. Binocular cues are inferred from the slightly disparate images presented to each eye from objects at varying distances. The greater the disparity, the closer the distance to the object being observed. Kourtzi et al included the cues of binocular disparity, perspective, texture, shading and motion, as relevant factors in depth perception. Despite well-documented evidence for these factors, they noted that the neural processes by which ocular images are perceived in three dimensions is not well described by current models, and yet "despite this, we perceive coherent 3D structures" (Kourtzi et al, 2005).

El Jamiy and Marsh noted a tendency for users of VR systems to underestimate the distance to objects presented in VR (El Jamiy and Marsh, 2019). They found the body of research concerning this phenomenon for AR applications to be considerably smaller, and mixed in results, with some studies indicating that AR systems did not reflect the same limitations, while others found it to be similarly biased towards shorter distance measurements. While this might be viewed as a reason to avoid utilizing these kinds of systems for aviation training and aviation debrief. It is worth noting that these limitations were noted in generic contexts and often most pronounced at distances which would be considered quite close by aviation standards. They were particularly noticeable inside the user's "action space", which is characterized as distances within 30 meters (Ibid). These limitations were noted in comparison between egocentric (user-centered) VR and egocentric real-world distance judgements. Unfortunately, direct comparison between distance estimates in VR or AR and judgements based on a two-dimensional screen do not appear to have been considered. Exocentric distance or angle judgements in AR or VR compared to real-world or two-dimensional representations were also not considered in these studies. Research in this area could provide valuable insight into potential benefits of first-person perspective modes for AR or VR debriefing systems.

While AR-enhanced debrief could potentially recreate a pilot's first-person perspective, VR systems provide greater advantages for such a task. Focusing on an exocentric (outside looking in) view maximizes the strength of AR systems, adding value by presenting faster, more accurate and more intuitive judgements about the relative positions of objects presented in a 3D workspace representing the mission environment. These objects may not even be presented at the appropriate size scale depending on the desired learning objectives for the debrief. Since aircraft are quite small relative to the distances over which they commonly engage, this ability to scale and still maintain accurate angular and positional comparisons (particularly where there are elevation differences between participating aircraft) is an asset rather than a liability. The ability to build an exocentric mental model of the mission space which is easily accessible and shareable is a primary advantage of an AR debrief.

A small but growing body of research compares information retention for examining varying kinds of spatial information using modern PC, VR and AR systems. Learning related to the relative positions of objects in space can be studied under the mantle of "spatial learning" (Shelton & Hedley, 2004). Shelton and Hedley were early proponents of the potential to improve Spatial Learning through AR-based presentation and interaction with spatial data. They theorized that "augmented reality interface lends itself well to task-related learning because of the exclusive connectivity between short cycles of visual perceptual activity and physical movements" (Ibid), and their research focused primarily on geospatial data, suggesting an improvement in learning using AR (Ibid). Much of modern air combat occurs at ranges beyond a pilot's line of sight, with distance and judgments an important factor in combat effectiveness. Improved retention of geographical information as demonstrated by Shelton and Hedley could translate well to aviators in the debrief process.

Current AR devices, utilization, and lessons learned

While the origins of virtual reality computing can be traced to work done in the 1970s and 1980s - with a surge in popular interest in the early 1990s - only in the mid 2010's did modern computing truly reach the capability to generate and display two distinct computer-generated images and keep them refreshed at a rate sufficient to reduce motion sickness while providing a convincing construction of a virtual world. Commercial Head-Mounted Displays (HMDs) developed commercially have provided the backbone for government and military utilization of VR. Augmented reality has developed along a similar path to commercial VR devices, but growth has been somewhat slower, and remains focused primarily on the business, industrial, and government markets. Nonetheless, a variety of AR devices are currently on the market, providing several options for consideration in developing a tool for AR debriefing.

Smartphone-based AR has exploded in popularity since the release of the game "Pokémon Go" in 2015. Enabled by increased computational power available within smart phone devices, improved bandwidth available for mobile data, and effective miniaturized camera and motion-sensors embedded within the devices. These are some of the same technological trends that have enabled growth in the Virtual Reality segment. Smartphone-based AR is now often used to project costume-like features digitally into chat, or to envision the appearance of objects in a user's home ahead of purchase. This technology is being utilized across a wide spectrum of educational applications. In the military aviation construct it carries several limitations, however. It abandons any binocular depth cues that would help a learner to rapidly assimilate the shape of a scene, and it is hand-held, requiring the student to constantly direct attention to the movement and placement of the device, while also staring directly at the device instead of being able to direct attention to the instructor.

The HoloLens and HoloLens 2 devices, developed by Microsoft, are notable entries in the field of AR HMDs. Microsoft advertising materials use the term "Mixed Reality (MR)" to describe these products rather than AR, but regardless of nomenclature, which allows a user wearing the device to continue to observe and interact fully with their physical world, while inserting holographic images into the user's perspective. These images are viewable from any angle, and the headset's ability to operate untethered from any external computing or power source enables a user to take advantage of this feature by physically moving around the holographic scene. Elements are "anchored" within the physical space to enable the holograms to appear motionless in physical space while the user moves around, under, over or through them. The HoloLens 2 boasts wider field of view, improved processing power and display density, and improved comfort over the original. Magic Leap, a device with similar overall capabilities to the HoloLens, adds similar capabilities at a lower price point that may be attractive for some use cases.

Versions of the HoloLens headset have been adapted for use and study across a range of applications, from education (Leonard & Fitzgerald, 2018) and surgery to a variety of industrial and military contexts. These include complex maintenance tasks (Valimont Et Al, 2007), mission planning (Alexander Et Al, 2019), and command and control (Ibid). However, researchers found that simply presenting material in VR or AR does not automatically improve learning. Chen et al, for instance, compared anatomy and physiology knowledge retention across instruction methods between AR presentation using a HoloLens and traditional PowerPoint presentation. He found that retention was actually lower for students using AR instruction (Chen et al, 2019). Amongst the AR group, students reported higher feelings of self-efficacy and lower test anxiety. On the surface, lower ability and higher confidence would appear to be a dangerous combination for an aviation environment, but there are several important factors to consider. Shelton and Hedley et al's (2004) research suggests that simply presenting information through a different technological medium that will not lead to improved learning, but instead the right technological medium must be matched to the information or skill desired for learning. They proposed that AR would be well-suited to the acquisition and retention of spatial information (Ibid). Leonard and Fitzgerald (2018) also argued that the design framework for instruction using AR must be fundamentally reconsidered to take advantage of the strengths of the new medium. They identified a tendency for educators to simply graft technological experiences onto existing curricula and learning experiences, rather than designing learning experiences from the ground up in ways that truly leverage the potential of these devices (Ibid). Is the aviation field a good match for AR learning?

Given the previously discussed nature of the spatial and geospatial knowledge that must be constructed in an aviation setting, the case for further examination of methods to incorporate AR debrief is strong. Despite the allure, cost is consistently cited as a barrier to research in the field Leonard and Fitzgerald (2018). It is worth exploring how such research might be conducted, and whether the cost of the research – and even of wider system implementation – would be in proportion to the potential benefits. Lee (2018) calculated the costs within several United States Air Force combat aircraft initial training courses of re-flying training flights that had been failed by the student on the first attempt, based on the average number of failed flights and the average cost per flight-hour tallied for each airframe.

His calculations suggested that the cost of these failures to the USAF is over $16 million annually (Ibid). Because his analysis focused only on fighter aircraft, and only on one military branch, it significantly understates the potential cost of this issue when considered across the context of US and Allied aviation arms. Only accounting for initial flight training also fails to consider that debriefing and training are also key peacetime tasks for nearly every military aviation unit, not just for formal training outfits. Billions of dollars are invested every year in the readiness of aircrew across services and militaries. The combat readiness level of these aviators is clearly not represented by counting flights that formally "failed" during an initial training curriculum. Improved spatial awareness for maneuvering, weapons employment and tactics execution are likely to have a value that far in excess of the minimum bar represented by failed training events. Yet cost of these sorties is one available proxy measurement for pilot learning that may provide analytical value for research, particularly because it is easily measurable, with the data already being actively gathered and maintained.

Figure 3. NextGen Debrief Initial Proof of Concept.

NextGen Debrief – Putting theory into action

The USAF and other military services have gradually recognized that modern, commercially developed VR headsets and flight simulators provide a potential option to improve the quality of training with little to no increase in cost (Sheets and Elmore, 2018). Lee (2018) also discussed the potential of integrating VR devices into the debrief process. One major benefit of a VR approach is the potential to recreate many aspects of both the learning environment (the flight deck or cockpit) and the situational context in which the learning was attempted (weather, time of day, or additional aircraft in the airspace). This recreation provides a means for the student and instructor to "get on the same page" about exactly where and when a particular maneuver or tactic was employed, and what factors may have led to error. VR systems offer a unique capability to the debrief which is worthy of further study.

VR also brings some additional constraints compared to a traditional debrief. With current VR technology, direct visual contact between student and instructor is broken, replaced by the medium of an avatar, a virtual construct representing the user. Designing a system whereby these avatars can accurately reflect the subtle non-verbal cues that indicate student comprehension to an instructor requires an additional level of technical and programming complexity. Additionally, while using VR devices, the traditional elements of a physical-world debrief, such as a whiteboard, map, and stick-jet (a small airplane model at the end of a short pole), cannot be utilized. While these tools may seem archaic, their inherent flexibility and familiarity within the flying community have led to their continued use. A system precluding the use of these tools without providing replacements of equal simplicity, versatility and utility in the virtual world would create a significant additional barrier to entry. Failure to significantly resolve these technical challenges may reduce the willingness or ability of aircrew to fully embrace using VR in the debrief. These issues led to our election to focus work on developing an Augmented Reality debrief solution, which may provide a selection of the same potential benefits as VR, but leaves crucial room to transition easily from relying traditional means of debrief..

At present it is not feasible to perform a satisfactory research experiment on the effectiveness of AR debriefing with HMD-type systems, for the simple reason that no such system exists. The current (at the time of this writing) generation of AR headsets appear to be fully capable of the processing demands imposed by the data, but the software environment required to translate aircraft data into the debrief has not been created. Based on the potential advantages and feasibility of such a system laid down throughout this paper, we have begun work on a prototype system in partnership with Arizona State University. We have set out to create a system for Augmented reality debrief and refine it to a level sufficient to evaluate in a controlled environment relative to current debrief methods. The concept and initial work were entered into the US Air Force's AFWERX Spark Tank 2021 competition and selected as a finalist for the overall competition (Butler, 2020), (SECAF Public Affairs, 2020). NextGen Debrief is currently designed for and deployed to Microsoft's HoloLens 2 headset. Several initial "proof of concept" scenarios have been generated, and work is ongoing to reach the level of functionality that allow for direct comparison with currently fielded debrief methods.

PROPOSED RESEARCH FRAMEWORK

When a suitable system for evaluation is created, research on the effectiveness of debrief with AR can be performed to validate the performance of the system. Tests can be performed in specific applications before system capabilities (and the associated costs) are scaled up to a wider variety of mission contexts. This framework should be executable at relatively modest cost, with little disruption or change required for existing flying training operations. Core elements of the test would be the evaluation of effective instructor interaction within the Mixed Reality training environment. Included in this research or separated for later study could be the efficacy of distributed debriefing, with instructor and student not located together physically but inhabiting the same mixed reality space through the AR debrief system.

The study needs to identify a set of training events or use cases that are spatially challenging to comprehend, requiring awareness the positioning and movement of multiple aircraft, along with terrain and threat systems as appropriate. It will be imperative for initial testing that the tactics and mission sets can be demonstrated without revealing classified weapons capabilities or tactics. Likely candidate airframes and missions could include low-altitude tactical airlift (for instance, with the USAF's C-130 Hercules) or aerial refueling missions (with appropriately equipped MC-130 Combat Talon), close air support (with the A-10 Thunderbolt II) or rescue missions utilizing HH-60 or HC-130 aircraft. Ideally, it would be possible to objectively measure the performance of aircrew on initial and subsequent missions of the same type, debriefed either traditionally or with an AR debrief system. The missions need not necessarily be live-flown either. Improvements in performance within a flight simulator could also be valuable and generalized to live-fly performance based on the body of available research on the value and role of simulators in the training environment. Learning with an AR-based system that enables both traditional physical interaction and an overlay of spatial data should be compared to traditional debrief methods for the chosen airframe/aviation community and mission in question, including whichever form of 2D debriefing software is typically used for the given mission or aircraft.

CONCLUSION

The complex training needs of military aviation units, combined with established institutional tendencies toward rigorous examination of post-training performance, make the evaluation of improved methods for conducting the military aviation debrief a strong proposition. The theoretical benefits of utilizing HMD-based AR devices in this context warrants further evaluation. The scale, costs, and risks associated with military aviation training encourage military aviators and services to maximize value at each step in the learning process. As soon as a system for augmented reality debrief is sufficiently developed to utilize for limited applications, the initiation of research into the efficacy and capability of AR debrief would provide a significant contribution to the practice of aviation training, with the potential to improve learning for thousands of military pilots across the globe.

REFERENCES

Alexander, S. A., Rozo, J. S., Donadio, B. T., Tenhundfeld, N. L., de Visser, E. J., & Tossell, C. C. (Apr 2019). Transforming the air force mission planning process with virtual and augmented reality. Retrieved from https://ieeexplore.ieee.org/document/8735617

Bailenson, J.N., *Experience on Demand: What Virtual Reality Is, How It Works, and What It Can Do.* New York: W.W. Norton. 2018.

Butler, Caleb. Luke Air Force Base Next Gen Debrief submission video for AFWERX Spark Tank 2021 competition. October 2020. https://www.dvidshub.net/video/769748/next-gen-debrief-spark-tank-2021

Chen, C., Zhang, L., Luczak, T., Smith, E., & Burch, R. F. (2019). Using Microsoft HoloLens to improve memory recall in anatomy and physiology: A pilot study to examine the efficacy of using augmented reality in education. Journal of Educational Technology Development and Exchange, 12(1) doi:10.18785/jetde.1201.02

Dismukes R.K., Smith G: Facilitation and debriefing in aviation training and operations. Aldershot; UK: Ashgate, 2000.

Lee, B., MAJ USAF. (2018). “Time to put down the sticks and put on the headset… training fighter aircrew in the 21st century”. Maxwell Air Force Base, Alabama : Air Command and Staff College

El Jamiy, F., & Marsh, R. (May 2019). Distance estimation in virtual reality and augmented reality: A survey. Paper presented at the 063-068. doi:10.1109/EIT.2019.8834182 Retrieved from https://ieeexplore.ieee.org/document/8834182

Fanning, R. M., & Gaba, D. M. (2007). The role of debriefing in simulation-based learning. Simulation in Healthcare : Journal of the Society for Medical Simulation, 2(2), 115-125. doi:10.1097/sih.0b013e3180315539

Hoffman, M. A. and Provence, X. Visualization of molecular structures using HoloLens-based augmented reality, Pg. 73, 2017

John H. Morrow, Jr., “The First World War, 1914-1919” in A History of Air Warfare, ed. John Andreas Olsen (Washington: Potomac Books, 2012), 10, 19-22.

Kourtzi, Z., Welchman, A. E., Conrad, V., Bülthoff, H. H., & Deubelius, A. (2005). 3D shape perception from combined depth cues in human visual cortex. Nature Neuroscience, 8(6), 820-827. doi:10.1038/nn1461

Lederman, LC., Intercultural communication, simulation and the cognitive assimilation of experience: An exploration of the post-experience analytic process. Presented at the 3rd Annual Conference of the Speech Communication Association, Puerto Rico, San Juan, December 1–3, 1983.

Leonard, Simon N., and Fitzgerald, Robert N. (2018). “Holographic learning: A mixed reality trial of Microsoft HoloLens in an Australian secondary school” *Research in Learning Technology*, Vol. 26

Milgram, P., & Kishino, F. (1994). “A taxonomy of mixed reality visual displays” IEICE TRANSACTIONS on Information and Systems, 77(12), 1321–1329.

Piaget, J., & Cook, M. T. (1952). The origins of intelligence in children. New York, NY: International University Press.

Secretary of the Air Force Public Affairs, “Spark Tank Finalists Announced” January 2021, https://www.af.mil/News/Article-Display/Article/2479259/spark-tank-2021-finalists-announced/

Sheets, Travis H., and Matthew P. Elmore. 2018. “Abstract to Action: Targeted Learning System Theory Applied to Adaptive Flight Training.” Maxwell Air Force Base, Alabama : Air Command and Staff College. www.dtic.mil/dtic/tr/fulltext/u2/1053015.pdf.

Shelton, B. E., & Hedley, N. R. (2004). Exploring a cognitive basis for learning spatial relationships with augmented reality Retrieved from https://explore.openaire.eu/search/publication?articleId=od______1459::62a403ad90bd8679bfb0ccfdaad933c1

Vance AFB Public Affairs and CloudAhoy, “Debriefing Final Approach into Colorado Springs” 4 May 2018. https://twitter.com/cloudahoy/status/992411374830710784

Valimont, R. Brian, Gangadharan, Sathya N., Vincenzi, Dennis A., Majoros, Anthony E. (2007). “The Effectiveness of Augmented Reality as a Facilitator of Information Acquisition in Aviation Maintenance Applications” Journal of Aviation/Aerospace Education & Research, Vol 16, No. 2

Wingfield, Nick and Isaac, Mike. “Pokémon Go Brings Augmented Reality to a Mass Audience” The New York Times, 11 July 2016.