Augmented Reality for Marine Fire Support Team Training

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ABSTRACT

Marine Fire Support Teams (FiSTs) consist of four or five Marines who direct aircraft, artillery, mortar, and naval fire in support of friendly troops on the ground. Traditional FiST training has been hindered by high costs and a limited availability of range time and associated supporting arms. Because of this, practicing together in the field is rare. To address this issue and provide FiSTs with the "sets and reps" required to develop and maintain proficiency, the Office of Naval Research 3D Warfighter Augmented Reality (3D WAR) program is developing an affordable augmented reality (AR) field simulator. AR is a technology that inserts computer-generated virtual objects in the user's real-world environment. The 3D WAR Marine Augmented Reality Team Trainer (MARTT) system allows for FiSTs in a field exercise to train with virtual entities and battlefield effects in their actual environment. Users wear an occlusive head-mounted display (HMD) which allows them to see virtual objects inserted over a camera feed of the real-world. Each FiST member wearing a MARTT system can see the same virtual scene from their own perspective, allowing for true team training.

Since 2019, MARTT demonstration and feedback events have been conducted at schoolhouses and training exercises throughout the Marine Corps. More recently, as the technology has matured, more in-depth assessments and studies have been held on the technology's effectiveness. In this paper, we present the results of multiple evaluations of MARTT systems in training Marine FiSTs. Data collected includes assessments on the system's usability, immersion, and overall training utility.

ABOUT THE AUTHORS

Mr. Colin Sullivan is a Senior Software Engineer at Lockheed Martin Rotary and Mission Systems (RMS). He received his B.S. degree in Computer Science from the University of Michigan in 2018 and has worked in augmented reality and training simulations since graduating. Colin is currently the Deputy Project Engineer of the 3D Warfighter Augmented Reality team, helping develop AR training and tactical systems for the Office of Naval Research.

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INTRODUCTION

In 2018, the Office of Naval Research 3D Warfighter Augmented Reality (3D WAR) program began developing an augmented reality (AR) training system for Marine Fire Support Teams (FiSTs). Marine FiSTs are responsible for directing fire in support of friendly forces on the ground. Historically, FiST training has been hindered by high costs and a limited availability of range time and associated supporting arms. To make FiST training more affordable and accessible, the 3D WAR team developed the Marine Augmented Reality Team Trainer (MARTT). The MARTT system allows Marine FiSTs in a field exercise to train as a team with virtual entities and battlefield effects in their actual environment.

Since its first prototype was introduced at the end of 2019, the MARTT system has been demoed at various Marine Corps schoolhouses and training events across the country. More recently, as the technology has matured, more formal studies and evaluations of the system's efficacy have been conducted. In this paper, we will analyze four major studies and evaluations of the MARTT system that occurred between September 2020 through March 2022. Data collected includes assessments on the system's usability, immersion, and overall training utility.

In this paper, we will analyze data collected from various surveys to determine how well the MARTT system performed in training Marine FiSTs. We will investigate whether factors such as a Marine's age affects their perception of the system. We will determine the strengths and weaknesses of the current system in training FiSTs. And we analyze improvements that can be made to make the system more effective going forward.

As you will see, our findings show that Marines agree that the MARTT system makes FiST training more affordable and accessible. Marines found the AR technology intuitive, immersive, and easy to use. Our findings also showed that improvements are needed, most notably regarding reducing simulator sickness and increasing the fidelity of the AR display.

MARTT SYSTEM OVERVIEW

FiST Overview and Current Training Limitations

In the United States Marine Corps, Joint Terminal Attack Controllers (JTACs) are responsible for calling in close air support (CAS) missions, which are action by fixed- or rotary-wing aircrafts against hostile units near friendly forces. Marine Forward Observers (FOs) direct supporting artillery, mortar, and naval fire assets. JTACs and FOs rarely work alone, instead operating in Marine FiSTs, which are teams of 4 or 5 Marines who direct lethal fire in support of friendly forces on the ground. FiSTs consist of a JTAC, FiST Team Lead, Artillery FO, Mortar FO, and possibly a Naval FO depending on location.

Traditionally, FiST training has been hindered by high costs and a limited availability of range time and associated supporting arms. JTACs, for example, must train with live aircrafts, which are difficult to schedule time with and can cost over $40,000 an hour to fly. FOs must coordinate with artillery, mortar, and naval squadrons, and deal with their

Figure 1. FiST training at an impact area

associated expense of providing supporting fire. Additionally, there are only a finite number of impact areas where live fire is permitted. When it comes to training an entire FiST, the logistics and expense of assembling JTACs; FOs; aircrafts; artillery, mortar, and naval squadrons at an impact area make practicing together in the field rare (United States Joint Chiefs of Staff, 2009, p. ix).

Over the years, a few technologies have attempted to address these problems. These technologies include the Supporting Arms Virtual Trainer (SAVT) and the Deployable Virtual Training Environment (DVTE). While both systems have helped FiSTs train over the years, SAVT is expensive, requiring Marines to book time in a large, indoor simulation. Additionally, DVTE lacks immersion, as it forces FiSTs to train using a mouse and keyboard (Reynolds et al., 2013). An affordable, accessible, and immersive FiST trainer is needed to fill this gap.

MARTT System

Funded through the Office of Naval Research (ONR), in 2018 the 3D WAR Team began developing an affordable, AR FiST trainer designed exclusively with commercial off-the-shelf (COTS) components. This system built upon previous ONR technology developed years earlier under the Augmented Immersive Team Training (AITT) program. For detailed information on the AITT program, see Schaffer et al., 2013.

The MARTT system is an affordable, COTS-based, unit-worn AR FiST trainer. This novel solution to FiST training allows Marines in a field exercise to train with virtual entities and battlefield effects in their actual environment. Each member of the FiST wears a head-mounted display (HMD) while a camera inserts the real-world view onto the screen. Virtual objects including tanks, aircrafts, and weapon effects are accurately inserted into the scene. Multiple devices are wirelessly connected through a Wi-Fi network, allowing each member of the FiST to see the same scene from their own perspective. Batteries, GPS, and navigation sensors allow for untethered mobile training. For a detailed overview of the MARTT system, see Sullivan et al., 2021 and *JTAC and Fire Support Marine Virtual and Augmented Reality Training*.

Figure 2. Two FiST members training with MARTT systems at Camp Lejeune

Figure 3. AR scene Marines might see while wearing MARTT system. In the image on the left, there is a virtual BTR tank and virtual hostile technical pickup truck in a field. In the image on the right, a virtual 500lb bomb is destroying both the BTR and technical.

PARTICIPANTS IN SURVERYS

Location of Events

Since its introduction in 2019, MARTT system demonstration and feedback events have been conducted at schoolhouses throughout the Marine Corps. For this paper, we will focus on 4 MARTT events that occurred from September 2020 through March 2022. These events included 3, week-long studies at:

- Camp Lejeune for 2nd Air Naval Gunfire Liaison Company (ANGLICO) and 10th Marines.
- Marine Corps Air Station Yuma for Marine Aviation Weapons and Tactics Squadron One (MAWTS-1).
- Muscatatuck Urban Training Center for International JTACS and Fire Supporters during Bold Quest 2022.

Along with a 4-month study, where 4 MARTT systems were left for Marines to train with, at:

- Fort Sill for the Marine Artillery School.

All demonstrations were held overlooking open fields with no trees or other objects present. Demonstrations at Fort Sill and Muscatatuck were shown at small fields, with a maximum view of less than 0.5 km. Demonstrations at Camp Lejeune and Yuma were held at large fields with a maximum view of over 5 km.

Role and Age of Marines Surveyed

During the demonstrations, a variety of Marines were surveyed. All Marines were members of Marine FiSTs (JTACs, FiST Instructors, Artillery FO, Mortar FO, or Naval FO). Additionally, Marines surveyed included both FiST trainees and FiST instructors. The age of Marines varied from early 20s to late 40s. Regardless of role and age, all Marines received the same demonstration and surveys. About 40 Marines in total participated in all 4 events.

METHOD FOR COLLECTING DATA

For each of the 4 collection events, 3D WAR engineers would first hold a 45-minute training session to teach Marines how to use the system. Once Marines were familiar with the technology, a formal scenario was conducted. This scenario was generated by FiST subject matter experts (SMEs) and 3D WAR engineers. When generating the scenario, SMEs made sure it included all relevant FiST operations trainees go through during a normal exercise, while engineers ensured all system capabilities were tested.

The generated scenario involved 4 FiST trainees putting on MARTT systems. A FiST instructor would use the iPad instructor station to place virtual friendly and hostile units on the field in front of them. First, the instructor would have the FiST trainees go through a call for fire (CFF) operation on one of the virtual hostile units. Once the CFF operation was complete, instructors would have the FiST go through a CAS operation on a hostile virtual unit. Both operations were performed while the FiST was stationary. Finally, the instructor would have the FiST move to a different, nearby location and have the trainees perform a second CFF and CAS mission.

The duration of the scenario was about 20 minutes. Once completed, Marines immediately filled out the surveys that are described in the next section.

Figure 5. FiST trainees using MARTT at Camp Lejeune, NC

DATA COLLECTION MATERIALS AND PROCESS

Two main surveys were filled out upon completion of the scenario. The first was a 2-page After Action Report (AAR) generated by a retired Marine colonel who is a fire support expert. The second survey was the System Usability Scale (SUS), an industry standard survey for measuring system usability.

The AARs asked questions regarding the specific value the MARTT system could provide in respect to the Marine Corps Ground Training and Readiness (T&R) standards. This survey allows the quantification of the MARTT system's readiness to meet this standard at the individual and collective level, in addition to the overall utility seen by the participants of the demonstrations. This overall utility is the total sum of the sentiment gathered from potential decreases in training time, enhancements of current training, and gaps the MARTT system can fill while training. The AAR consisted of 15 open-ended questions regarding the likelihood Marines would use the MARTT system for training, the ways that current training could be enhanced by using the system, the perceived ease of use, and the desire for interoperability between the MARTT system and current fielded hardware/software. The responses were parsed into overall sentiment using the relative proportional difference between positive and negative-coded words. These sentiments were grouped into three main sub-categories: The MARTT system's ease of use, its ability to enhance training, and the respondents desire for interoperability.

The SUS is an industry standard method of quantifying a product's ease of use and is referenced in over 1300 articles and publications. It is a beneficial tool for collecting feedback due to its quick completion time for the participants and standard score calculation to quantify a system's usability. The standard SUS survey consists of 10 questions which the respondent would answer on a scale of 1-5, with 1 representing strongly disagree while 5 represents strongly agree. Odd numbered questions have a positive sentiment while even numbered questions are negative. The sum of the values of the odd questions are subtracted by 1 and summed with the value of the sum of the even questions subtracted by 5. By using the formula in Figure 6, a usability score, *U*, ranging from 0-100 is generated. Q_n represents the value the respondent gave on question number *n (*Brooke et al., 1996).

$$U = 2.5 \sum_{n=1}^{5} ((Q_{2n-1} - 1) + (5 - Q_{2n}))$$

Figure 6. Formula for calculating SUS score

Generally, scores below 68 are considered below average, above 68 are above average, and above 80 is excellent.

RESULTS

System Usability Survey (SUS)

The MARTT system received an average score of an 80 on the SUS, which is considered excellent. Respondents appreciated the convenience that the system provides and would see themselves using a MARTT unit frequently. Additionally, Marines found the system easy to use, with consistent, well-integrated features. While the MARTT system scored well in most fields, it scored about average for user confidence while operating. The MARTT system received 3's here, meaning Marines neither agreed nor disagreed that they felt confident operating it. This is to be expected considering the relatively short time in which the FiSTs participated in the demonstration. Other key data points included Marines' approval of the simplicity of the system, using the MARTT system proficiently after only a few minutes of detailing the systems functions. Marines scored the MARTT at an average of a 1.6, meaning they strongly disagreed that they needed to learn a lot of things before using the system. One of the other questions in the SUS survey queries the user's need of the support of a technical person to properly use the system. That question received an average of a 2.2, meaning that Marines disagreed that they need a technical person present. This was apparent during the four-month study at Fort Sill, where Marines trained with the systems on their own and even held a demonstration of the technology for high-ranking Joint Staff members without any engineers present. In Figure 7 below, you can see how the MARTT SUS average score ranks against percentile.

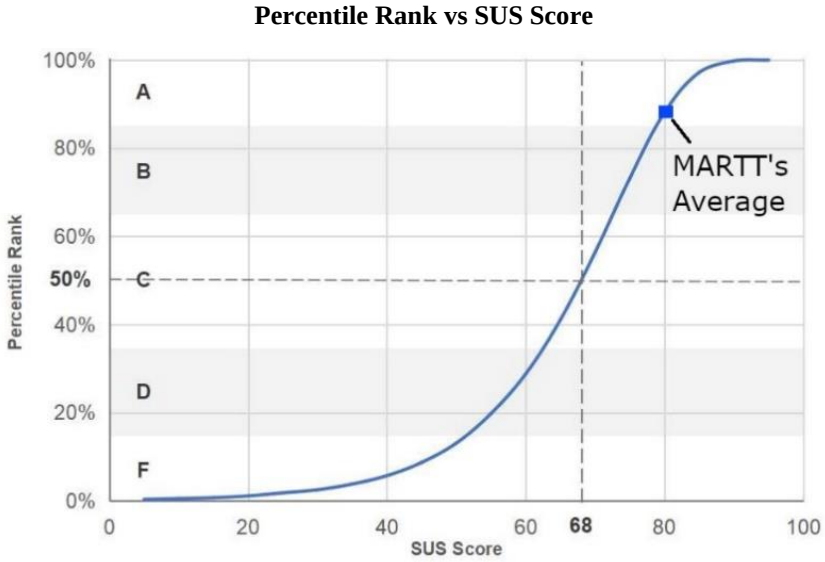

Figure 7. Chart that shows MARTT's average SUS score charted against percentile rank

After Action Report (AAR) Generated by SME

When analyzing the AARs generated by the retired fire support colonel, the ease of use and ability to enhance training scored highly, with 93% and 87% positive sentiments respectively. The respondents all noted the speed in which they were able to understand the system and put it to use simulating fire support missions. Marines were excited at the prospect of using the MARTT system as a tool to enhance their current training, with 87% of respondents stating that they do not believe they would need to change any existing battle drills when using the equipment. The respondents were clear in their lack of desire for interoperability, leaving feedback such as "No, this is a good standalone system." Marines also responded positively to the MARTT system meeting T&R standard training objectives. Many saw very high potential for it meeting simulation code requirements, with respondents stating that it would meet most, if not all, simulation training objectives.

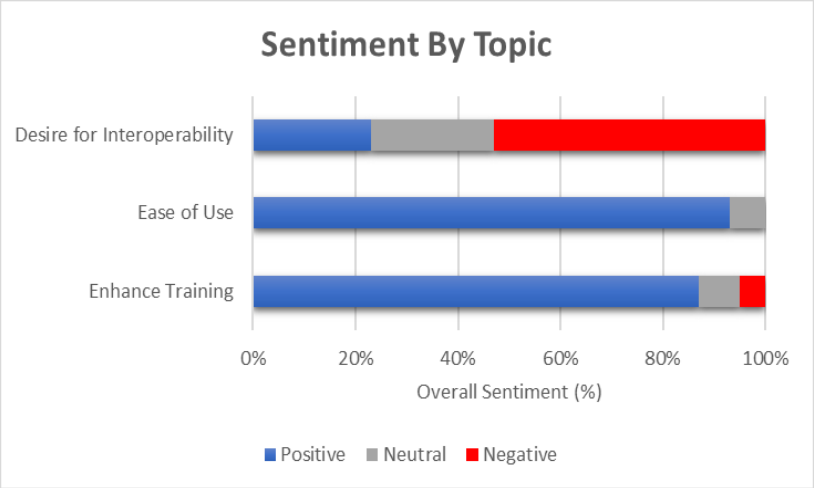

Figure 8. Chart that shows MARTT's average SUS score charted against percentile rank

The AAR received from the long-term demonstration at Fort Sill provided valuable insight into the MARTT system's potential performance as a fielded piece of hardware. The FiST that received the set of 4 units utilized the systems weekly, taking advantage of the whitespace training time in their schedule to simulate CFF and CAS missions. The team praised the mobility and reliability of the MARTT system, having no issues operating the units over the entire duration they were using it. The FiST additionally conducted their own demonstration to high-ranking Joint Staff Marines with no tech present, an event which when well and is leading to a future demonstration in 2022. Marines also noted some limitations, one being the effective range of the MARTT system during operation. All units are networked together by a single Wi-Fi router which is attached to 1 of the 4 MARTT systems in the FiST. All units need to be within about 20 feet of the router. This range was not an issue when Marines at Fort Sill were conducting exercises in the parking lot behind their barracks, but at large fields the Marines needed to be sure to stay close enough so that connection was not lost.

An interesting parallel between all the demonstrations was that the respondents' age had a noticeable effect on the scores they submitted. Younger Marines were thoroughly impressed with the MARTT system, they were interested in the technology and believed that it would provide great benefits to their training routines. One corporal stated, "I would choose to use the systems as much as possible; it adds more diversity in forward observer training… It gets monotonous as well going to the same observation posts and conducting CAS/artillery missions on the same targets." Some older Marines, however, were much more critical of the technology. One major was wary of the system's ruggedness commenting, "I do not see bringing this device to the field."

Figure 9. Marines using MARTT at Camp Lejeune

OBSERVED FEEDBACK

While the demonstrations unfolded, engineers and SMEs observed how the Marines used the MARTT system. Occasionally, engineers noticed that Marines were interacting with the system in different ways than expected. For example, the MARTT system has a Vector 21 prop which is designed to replicate the full functionally of the Marine Corps binoculars. For background information on the binocular's functionality, please see Oskiper et al., 2014. The

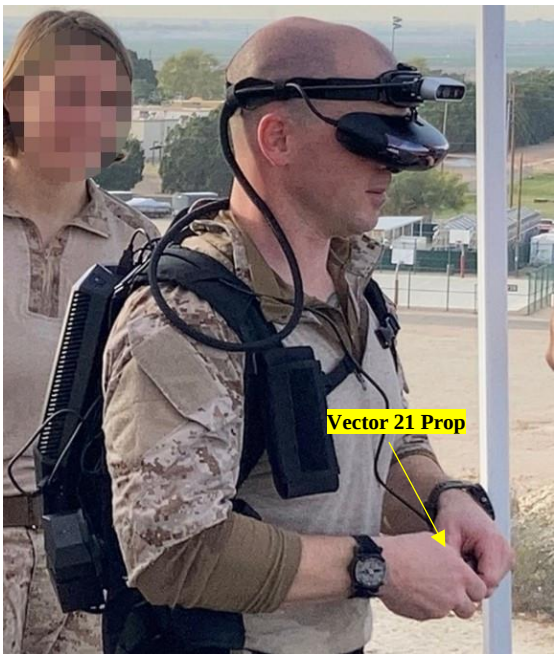

Figure 10. FiST trainee using Vector 21 prop without bringing it in front of the

MARTT system's Vector 21 prop is designed to be used while held in front of the user's HMD, mimicking how the actual binoculars are brought to one's eyes. However, nearly all Marines did not use the prop this way and instead, simply held it in their hands and pressed the buttons (see Figure 10). While no Marines complained or commented on this issue, it could reduce the realism of the simulation since actual Vector 21 binoculars must be held in front of one's eyes. If this continues to be a problem, a modification can be made to ensure the prop only functions when it is held in front of the HMD.

Additionally, the MARTT system is designed so that Marines can train with much of their actual equipment including maps, protractors, notebooks, and tactical tablets. Engineers intended for Marines to never have to take off their HMD while using the system, as doing so can reduce the realism of the simulation. However, engineers noticed that Marines would constantly take off their HMD when looking at their maps, notebooks, and tactical tablets and would then put the HMD back on when they wanted to see the virtual entities. Marines complained that it was uncomfortable reading text through the HMD. Adding higher resolution HMDs and cameras may reduce this problem going forward.

Additionally, Marines were strong proponents of using AR to train over more traditional simulations. At Camp Lejuene for example, a lance corporal commented that "AR is a much more realistic training environment than the current DVTE." DVTE is the fielded latop-based FiST trainer described earlier. A gunnery sergeant commented that the MARTT system "can add realistic training scenarios where GENSIM cannot;" GENSIM is a component of DVTE. However, while Marines did appreciate the realism and immersiveness of the AR simulation, they believed that it should not replace trianing with live fire all together. One sergeant said, "live experience is still necessary, but [the MARTT system] could be done in the event that live assets aren't available (as they aren't always)."

RECOMMENDATIONS FOR IMPROVEMENTS

Figure 11. Three FiST trainees wearing MARTT systems

The MARTT system's HMD and the Vector 21 prop received mixed reviews. Regarding the HMD, Marines believed that improvements to the camera's frame rate are needed. The FiSTs were concern about simulator sickness occurring when using the system for extended periods of time, a big factor of which is due to the latency of the camera. The demonstrations typically had the FiSTs wearing the system continuously for 30 minutes with no issues. At Fort Sill though, a FiST was able to wear the system for roughly 2 hours with no complaints. The camera is currently running at 15 frames per second (fps) to allow maximum performance of the navigation software, and research is underway to improve the framerate and reduce latency. Increasing the framerate would allow for a smoother visual experience and alleviate concerns for potential discomfort.

Additionally, some Marines argued that the Vector 21 prop's digital zoom provided an unclear, blurry image. While many FiSTs gave positive feedback on the physical interface's ability to emulate the actual Vector 21 binoculars, they found the magnified image to be blurry at long ranges. This was more apparent at large demonstration areas such as in Yuma, where Marines commented that it was difficult to see targets more than 2 kilometers away. This feedback was less common at demonstrations in smaller fields. The MARTT system uses a 7x digital zoom when emulating Vector 21 functionality, which compromises the image quality when zooming. Mitigation would be the inclusion of a 7x camera lens to perform optical zoom, allowing for higher clarity at far distances.

Finally, Marines wanted additional functionally on the iPad instructor station application. Marines liked how the instructor station performed overall but felt that it was too simple and did not provide all the controls they needed to execute detailed CFF and CAS missions. Marines suggested adding additional inputs and features to make the station more robust. The next section details ongoing work porting to a new instructor station that contains all the functionality Marines have requested.

FUTURE WORK

Work is underway integrating the MARTT System with the JTAC Virtual Trainer (JVT) simulation, an indoor virtual reality (VR) fire support trainer currently under development with the support of ONR. Unlike AR which places virtual objects in the user's real-world environment, VR creates simulated experiences that are independent of the user's current environment. JTACs in training put on the VR HMD and practice executing CAS missions from fixed locations in pre-generated virtual environments. What makes JVT useful for the MARTT system is its instructor station application, which currently runs on a laptop. Much like MARTT's iPad instructor station application, the JVT instructor station controls the JVT application and allows for the creation of virtual entities and CAS missions. Currently, the JVT instructor station is much more robust than the MARTT system's iPad application, containing many of the after-action report and scheduling worksheet features that are currently missing. It also contains additional vehicle models and flight profiles. Work is underway to transition the MARTT system to be controlled by the JVT instructor station. Both applications are built with the Unity 3D engine and using the same High Level Architecture (HLA) network standard, making integration quicker and easier.

CONCLUSION

The MARTT system has, through the feedback collected from demonstrations, shown its potential as a training tool for FiST teams to train in more diverse locations and scenarios. As one corporal commented, "this will increase the amount of training we can acquire in a much more efficient timeline and lessen the logistical load that is normally required for this type of training." The MARTT system was especially lauded for its ease of use and mobility, allowing FiSTs to get simulation sets and reps quicky and efficiently compared to current training standards. Feedback also indicated that improvements are necessary, particularly with the HMD image fidelity and adding additional features to the iPad instructor station application. In the MARTT's current state, many saw the value the system would add as part of their training, to enhance current training objectives.

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REFERENCES

Brooke, J. (1996). *SUS: A Quick and Dirty Usability Scale*. In P.W. Jordan, B. Thomas, B.A. Weerdmeester, & A.L. McClelland (Eds.), Usability Evaluation in Industry. London: Taylor and Francis.

US Navy Research. (2021, April 8). *JTAC and Fire Support Marine Virtual- and Augmented-Reality Training*. YouTube. https://www.youtube.com/watch?v=Bp36MelcjfQ

Oskiper, T., Sizintsev, M., Branzoi, V., Samarasekera, S., Kumar, R. (2013). Augmented Reality Binoculars. In *2013 IEEE International Symposium on Mixed and Augmented Reality*.

Oskiper, T., Sizintsev, M., Branzoi, V., Samarasekera, S., Kumar, R. (2014). Augmented Reality Binoculars on the Move. In *2014 IEEE International Symposium on Mixed and Augmented Reality*.

Reynolds, J., Smith, C. (2013). *Virtual Environment Training on Mobile Devices* (Publication No. 0704-0188) [Master's thesis, Naval Postgraduate School]. Semantic Scholar.

Schaffer, R., Cullen, S., Meas, P., & Dill, K. (2013). Mixed and Augmented Reality for Marine Corps Training. In R. Shumaker (Ed.) *Virtual, Augmented and Mixed Reality: Systems and Applications*. Berlin: Springer

Schaffer, R., Cullen, S., Cerritelli, L., Kumar, R., Samarasekera, S., Sizintsev, M. Oskiper, T., Branzoi, V. (2015). Mobile Augmented Reality for Force-on-Force Training. In *Interservice/Industry Training, Simulation, and Education Conference 2015*.

Sullivan, C., Schaffer, R., Samarasekera, S., Kaighn, K., Oskiper, T., Cerritelli, L., Kumar, R. Technology for an Affordable Augmented Reality First Support Team Trainer. In *Interservice/Industry Training, Simulation, and Education Conference 2021*

United States Joint Chiefs of Staff. (2009) *Joint Publication 3-09.3 Close Air Support.*