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EXTENDED REALITY FOR PRE-MISSION TRAINING AND PLANNING

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Biography

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Abstract

The nature and methods by which war is fought is constantly evolving. Militaries are constantly looking for ways to be the most advanced and gain an operational advantage over enemies. As military operations have evolved to be fought in urban environments, so too must the training, technology, and methods. The ability to simulate a common operating picture that provides realistic and accurate experiences and representations of the operational environment (OE) provides an immense advantage. While in the near future military operations will continue to take place in urban environments, the world is anticipating a cyberwar to come. As extended reality technology continues to evolve, a real possibility exists that future wars may not be fought on a real world battlefield at all, but rather a visual one.

Introduction

It should come as no surprise that the defense sector finds itself increasingly at the forefront of emerging technology. These technological advancements have the ability to enhance combat situational awareness, planning, and training. Extended reality (XR) systems are essentially the first technology source which effectively transports users and eliminates the time and distance gap between participants. The relatively low cost of virtual reality (VR) systems which have been made available to the public will do much to garner popularity, while creating a niche in the gaming industry which will drive the technology further. The defense sector will benefit from the technological advancements of VR gaming systems in order to save defense development costs and pave the way for future mixed reality interface systems such as Microsoft's HoloLens.

The nature and methods by which war is fought is constantly evolving. Militaries are constantly looking for ways to be the most advanced and gain an operational advantage over enemies. As military operations have evolved to be fought in urban environments, so too must the training, technology, and methods. The ability to simulate a common operating picture that provides realistic and accurate experiences and representations of the operational environment provides an immense advantage. While in the near future military operations will continue to take place in urban environments, the world is anticipating a cyberwar to come. As extended reality technology continues to evolve, a real possibility exists that future wars may not be fought on a real world battlefield at all, but rather a visual one.

In order to address the needs for technological advancements to help with operations in urban environments, the U.S. military will need to evolve faster than their enemies. Military

operations in urban terrain (MOUT) anticipates the evolution in military training and operations which will allow them to view the OE from a three-dimensional perspective. [Livingston]

Key factors to securing operational safety are the ability to increase situational awareness, train as we fight, and proper and thorough operational planning. These factors can be improved through the use of augmented/virtual/mixed/extended reality (AR/VR/MR/XR) systems which can create more adaptive personnel and units, develop cognitive response, and create a higher readiness level through the use of head-mounted displays (HMDs), scent collars, tracking systems, and more.

Urban environments carry with them inherent risks. There are various locations in which the enemy can conceal themselves and their activities. Enemy small teams can hide themselves in and around buildings, snipers lie in wait and can be concealed anywhere which gives them line of site, and weapons caches can be hidden anywhere. Not only do these environments vary in complexity, they can be dynamic, changing the once known environment into an unknown one. "…a damaged building can fill a street with rubble, making a once-safe route impassable." [Livingston] Add to this the need to minimize civilian casualties and damage to civilian key infrastructure, and the dangers of an urban environment becomes compounded.

The defense sector has seen the potential of the gaming industry to provide realistic simulated environments for military training and has further looked to capitalize on advanced technologies in augmented, virtual, mixed and extended realities. Agencies such as the Army's Communications Electronics Research, Development, and Engineering Center (CERDEC), The Pentagon's Defense Advanced Research Projects Agency (DARPA) and various other service components research labs have been working on variations of the heads up navigation, tracking, and reporting (HUNTR) system since at least the 1980s. These technologies will help to increase

the military's ability to visualize, navigate, and maneuver an operational environment more efficiently. Through the use of devices such as heads up displays (HUDs), a soldier can see locational data, maps, and a compass without having to pause to remove items from their pockets. This allows a soldier to be hands-free of such data so that they do not need to break contact with their weapon. These HUDs will eventually replace the need for separate night vision googles, GPSs, target data, and communications devices, as well. Add to this the ability to immediately distinguish friendly forces from the enemy, such technologies have the ability to save lives on multiple levels, increase situational awareness on the battlefield, create more adaptive personnel and units, and increase the overall readiness level of a unit.

Background

In order to understand where the technology is going and how it should be applied, it is important to know where it has been and how it is currently and previously been used. It is also important to know the differences in extended reality spaces in order to understand their applications. While terms such as 'augmented reality' or 'virtual reality' have only hit the mainstream within the last decade, the truth is that these advanced concepts have been in the works for some time. "Not only are mixed reality headsets said to be the future of computing, they're also the past and future of entertainment." [augment.com]

Anyone with a smartphone has likely used an application which uses augmented reality (AR) in some form. AR takes a user's physical view and overlays computer-generated graphics to create a holistic composite view of a space. It is arguably the most advanced of the extended reality technologies. While today's AR is often thought of as a futuristic visualization technology, AR has been around in its simplest form for decades. A mainstream example of this is the yellow down line we see during televised football games. In the defense sector, heads-up displays (HUDs) have been used since the 1990s in fighter aircraft. Today these HUDs overlay location, direction, altitude, speed, and target position.

Who can forget how Google advanced the technology by making it a more portable and wearable form of the technology by rolling out the Google glass in 2013? Google Glass combined micro projector technology to overlay images and videos on the user's lens. Once more, it had the ability to project sound and respond to voice commands. While Google Glass only lasted a couple years, it can be credited as one of the first major attempts to bring the technology more mainstream in a daily and practical usable form.

Smartphones and tablets have become a more familiar form of AR, which is now commonly available to the average user. Applications on both devices allow a user to receive data on their surrounding using global positioning system (GPS) technology and the devices camera. This set the stage for mobile AR games such as the AR application 'Pokémon Go'. The application used the devices camera and GPS to superimpose Pokémon characters in various locations. Users would capture the Pokémon and use them to battle. At its pinnacle, 'Pokémon Go' gained an estimated 100 million users and has made around $2 billion.

AR is both similar to and different than virtual reality (VR). Essentially, AR adds to a users present reality, whereas VR replaces the user's reality. VR is a form of computer generated three-dimensional interactive space in which users can connect, explore, engage, and collaborate. In order to put users into that space, VR uses a combination of tools and sensors, to include headsets, grip controllers, gloves, body suits, and omni-directional treadmills, just to name a few. These components are combined to incorporate multiple senses in order to create the illusion of reality and a sense of presence.

VR not only has the ability to simulate an known environment, but to make the impossible possible. It has made the impractical practical, and allowed users to participate in otherwise dangerous situations from the comfort and safety of their living room. For these reasons, VR found a solid home in the gaming industry, where first person shooter games, aircraft simulations, and and zombie attacks have gained popularity. In these environments, a user can visit a museum on the other side of the word, fly like a bird without a plane, or explore underwater coral reefs at the click of a few buttons.

Because of the ability for VR to create this a near realistic representation of an environment, the defense sector has sought to use it for safe, realistic, and cost effective military training.

Mixed Reality (MR) and extended reality are terms often used interchangeably, although erroneously. MR and XR are, in themselves, not technology such as VR and AR. They are rather a combination of technologies. In layman's terms, MR is a combination of VR and AR, while XR is an over-arching term for the three.

MR is designed to combine the most positive aspects of AR and VR. It is the blending of real and virtual environments to produce new spaces and visualizations. In these environments, physical and fabricated objects co-exist and interface with one another. Essentially, MR allows users to see the real world as it exists in AR with the addition of virtual graphics as they would exist in VR. Those virtual objects are then locked to a point real space, allowing for them to be viewed as real during an MR experience. As the user changes their perspective or distance from an object, the visualization changes with it, unlike the experience in VR. MR creates a more seamless representation of the environment, making the illusion of that environment more difficult to break.

A significantly notable piece of MR technology which has the potential to drive the future of military operations is Microsoft's HoloLens. The $480 million contract secured by Microsoft to provide the Army with 100,000 AR devices has been somewhat controversial amongst Microsoft employees. Beating out its competitor Magic Leap, Microsofts HoloLens will provide signifiant momentum to the AR enterprise. As part of the US Army's Integrated Visual Augmentation System project, the headsets will be integrated into existing helmets with thermal sensing, night vision, and GPS capabilities. It will go a step further by providing health

statistics of the user and is expected to save many lives. The first 2,500 prototypes are expected to be delivered within two years of the contract award. [Finnegan]

Microsoft seems poised to find itself at the pinnacle of defense AR technological advancement. Microsoft has made moves to secure a $10 billion contract through the Pentagon for the Joint Enterprise Defense Infrastructure (JEDI). While Microsoft's biggest competitor for this contractor appears to be Amazon, there are growing concerns in the industry that Microsoft will create a monopoly of sorts in the defense sector. [Finnegan]

Extended Reality (XR) is a little more difficult to explain, as it has become, more or less, an umbrella term, comprised of real, virtual, augmented and mixed environments. XR also encompasses future extended realities and immersive technologies, as well. XR is essentially the continuous evolution of extended technology to expand the human experience.

Extended reality technologies have been in development behind the scenes for decades. As they become more mainstream they will find their way into various sectors in our lives. While the gaming industry has been at the forefront of this technological advancement, the military will continue to capitalize on them.

Train As We Fight

The defense sector is largely at the forefront of technological advancements to augment and enhance training combat training. Extended reality technologies are having a major effect on defense and military training capabilities. They will have significant implications for training, allowing troops to participate in exceedingly realistic scenarios. These technologies allow soldiers at all levels, from all operational specialties, to engage in highly realistic and

authentic combat simulated environments, with the added factor of safety. One cannot deny the benefits of training in a realistic environment as opposed to a simulated one. Realistic training provides visible and audible queues which requires users to react and make split second decisions. The same can be said when using an AR and/or VR system to conduct operational planning. These technologies allow users to participate in "if/then" scenarios – "if we enter the compound from this direction, then these obstructions will need to be overcome." The military has capitalized on the use of such advanced technologies to conduct combat training in low risk environments through the use of scenarios which simulate realistic environments and situations. Whether training to kick down a door in a village in Afghanistan or conducting simulated anti-drug operations south of the border, extended reality systems offer increased frequency in training with low reset time. Additionally, conducting training in VR is more cost effective than the price tag associated with current training methods when the hefty price tag of military mobility, equipment, and maintenance is taken into account. "When it comes to investing, as a rough estimate, the U.S. spends approximately 14 billion dollars on so-called "synthetic" training every year." [Mosorov] This becomes evident when considering the risks and costs of flight or submarine pilot training. The US Army spends an estimated $3500 per one hour of training in an attack helicopter, while a simulation costs a mere $500. [Beyond.com] Introducing a pilot to scenarios in a simulator prior to putting them in an actual aircraft or submarine allows for them to make mistakes in a low threat environment. Once more, it allows for them to continue to train without the risk of loss of a multi-million dollar aircraft and the additional expense of fuel. In comparison VR allows for an increased frequency of training due to the low costs associated with maintaining systems and equipment with a significantly shorter time to reset scenarios. It is, therefore likely we will see mobilized training teams move to units rather than seeing entire units

mobilize to a training center, removing them from their primary duties and raking up expensive price tags. It is also likely that we will soon see military bases set up their own training labs equipped with mixed reality systems, ready to give dedicated, frequent training, at a moments notice. This in turn will contribute to a better trained workforce due to repetition. Once more, training in extended reality environments will allow for training between units at different bases, as well joint force training across oceans. In short, the implementation of XR will allow the military to modify their "train as we fight" motto to something more closely resembling "train as we fight and often".

While the use of VR in itself is not costly, development of software for defense needs can be. Companies such as Cubic Corporation and AUGGMED typically have large teams comprised of software developers, electrical engineers, hardware designers, instructional systems designers, human factor engineers, technical producers, gaming experts and other subject matter experts working on one specific simulation product. [Cubic3, AUGGMED] This can get costly for the department of defense if they were to outsource work to develop immersive technologies. This is why the defense industry is relying heavily on advancements in the hundred billion dollar a year entertainment industry to fill the gaps the defense budget cannot satisfy. In some cases, the defense sector is allow the gaming sector to advance the technology as far as it can take it, prior to pushing the technology to the private sector for further advancement. [de Silva, 2]

In his article *Military Applications of Virtual Reality,* Jim Baumann discusses how the military is not only using virtual reality to simulate reality, but to extend their senses though telepresence. [Baumann] This is further supported by Jen Judsen's article *Operation Overmatch: US Army Launches Prototyping in Virtual Reality,* describes how the military is using virtual reality to prototype is future innovations. [Judsen] These articles support the notion that virtual

reality will continue to expand the military's capabilities at a significantly lower cost. Using such technology to develop future technology will continue to be the way of the future, while identifying applicability prior to the creation of expensive equipment.

Figure 1: Operation Overmatch. US Army TRADOC [Panzino]

Cubic Corporation is currently offering Chemical, Biological, Radiological, Nuclear enhanced (CBRNe) training. These simulations emulate realistic conditions under which CBRN and toxic industrial chemicals (TIC) / toxic industrial materials (TIM) threats are evident. These environments allow for "real-time monitoring and analytics all objective performance measurement of soldier, unit and commander." [Cubic 1]

Cubic is also working with the Navy to develop aviation simulations. Using Cubic's Immersive Visual Shipboard Environment (IVSE) in concert with the Littoral Combat Ship

training program to immerse trainee users into 3-dimensional realistic simulated environments.

These augmented environments can trigger other human physiological factors that a two-dimensional training scenario cannot. Factors such as increased heart rate, sweating, and overall heightened tension can drastically change the outcome of any training scenario, plan, or operation. It is therefore important to train under such duress in order to not only develop military personnel to react, problem solve, and critically think under such circumstances, but to also control and manipulate the environments in which they are operating. Stressors and the way an individual reacts to them can change the operational environment.

Operational Planning

The ability for a command team to create an operational picture of the theater and share that common picture to the warfighter at the lowest level provides a tactical advantage. With the realization that extended reality technologies can augment, complement, and even enhance the operational picture and capabilities, it is evident that these technologies have a substantial future in enhancing operational command capabilities on the battlefield. It is difficult to argue that the exposure of a realistic training environment and experience is far better than the alternative. Examples of how virtual reality could have interceded to develop a more cohesive and comprehensive operations plan can help to strengthen the argument. Examples such as OIF operational planning for air operations are a prime example. [Woods, et all]

Virtual environments may help to identify unforeseen issues that could not be identified in 2D. Using the example of Kevin Woods' article *A view of Operation Iraqi Freedom from Saddam's Senior Leadership* we can see how the Iraqi regime viewed the US's Air Campaign and sought to disrupt it. [Woods, et all]. While there are many stated negative aspects of continuous video game playing, researchers have stated many benefits, as well. Research proves

video gamers develop a heightened sense of awareness of surroundings. It also helps to develop multi-tasking skills, navigation, and reflex reaction time. "According to the report of the Official Naval Research (ONR), people who do not play video games have a less developed field of vision, are worse at memorizing visual objects and process new information slower if compared to gamers." [Morozov]

Sandtables in various forms have been an instrument of military operations planning for centuries. In recent decades, it had evolved to include a table with scalable models of the operational environment. They typically include some representation of friendly and enemy troops along with key pieces of equipment. In 2015, the Army Research Laboratory (ARL) developed an AR sand table using readily available equipment available to anyone. Using a standard projector, LCD screen, Microsoft Kinect and a laptop, the Augmented Reality Sandtable (ARES) provides a collaborative battlefield visualization of the operational environment. ARES cuts down the time needed to create scalable terrain and scenarios and keeps users engaged from onset. Additionally, ARES provides scalability for a variety of terrain types, intuitive interface, ease of control with a literal waive of the hand. [Mosorov]

Figure 2: Augmented Reality Sandtable

As Richard de Silva explains in his article *Virtual Reality for Defence Less About 'Reality' Than Results*, there is no shortage of developers looking to exploit the need for more more realistic and efficient training. [de Silva] However, the defense sector differs from the private sector, in that the need is less about realism and high end graphics, and more about true operational outcomes. This may be for the best, as there are growing concerns that training that is too realistic could trigger post traumatic stress disorder (PTSD) in military members who have previously participated in operation in the past, or could in fact cause PTSD in members who have not.

Where is the Technology Headed?

Sharing a common view of an operational environment is a means which can provide a staunch operational advantage. Collaborative visualization, night vision capability, and health monitoring are just a few capabilities expected to be integrated into heads-up displays (HUDs) for military use. As there is no shortage of developers advancing XR technologies, it goes without saying that the advancements in the military sector will grow exponentially, as well. Additionally, as the technology becomes more mainstream, it will become cheaper for the average user to engage, as well as the defense sector. Helping to pave the way for defense use of such technology is Microsoft.

In 2018, Microsoft was awarded a $480 million contract, beating out competitor Magic Leap. The contract is for the outfitting of US Army Soldiers with 100,000 of a version of Microsoft's HoloLens device to be used for training and combat operations. As part of the US Army's Integrated Visual Augmentation System project, the Army's version of the HoloLens be integrated into their helmets and will include thermal sensing and night vision capability. It will also include concussion detection and the ability to monitor heart and breathing rate. [Finnegan]

Figure 3: Microsoft HoloLens [Chevrier]

The Microsoft - US Army partnership is not the first of its kind for Microsoft. The Company recently competed against Amazon for a $10 billion contract by the Pentagon in a venture called the Joint Enterprise Defense Infrastructure (JEDI) contact. While Microsoft received some blowback from employees at the company for using its technology for military and defense pursuits, it is partnerships such as these which will further advance mixed reality technologies, pushing them to the mainstream. [Finnegan]

The Pentagon's JEDI program is not it's only attempt to capitalize on modern technology. The Pentagon is looking to exploit the popularity and advanced capabilities of first person shooter games through their heads up navigation, tracking, and reporting (HUNTR) system. Through the partnership of the Army Research Lab (ARL) and the Communications

Electronics Research, Development, and Engineering Center (CERDEC), such technology is quickly making its way to the forefront of military training and operational planning. [RT Question More]

Figure 4: View from heads-up display (HUD) [beyond.com]

Cubic Corporation is developing ways to bring in other senses to make the technology more immersive. Concepts such as scent collars can add a level of authenticity not yet being experienced in VR or AR. Knowing how an area smells during training and operations planning can help users gain familiarity with environments. Understanding not only the seasonal temperature changes in an area, but the scent of the trees, flowers, and food conducive with those seasons help set the scene and limit complications, disturbances, and diversions for a soldier.

Knowing what a remote farming village in Afghanistan smells like when the poppy are in full bloom can help prepare soldiers for any possible distractions their sense of smell might create. It may also help identify how things should smell, and what is there that shouldn't be. For example, adding in the smell of jet fuel during a flight simulation can help prepare for life and death situations that a pilot may actually encounter. [Cubic 3]

If you add in environmental factors, like heat, humidity, and cold to an operational environment, troops can prepare stateside for factors they will encounter in unfamiliar territories overseas. One way of doing this is to create a simulated environment which is akin to a first person shooter game. This can be accomplished through many avenues which can help to replicate and mirror any number of environmental factors. Tactical augmented reality (TAR) heads-up display (HUD) headsets provide a visual representation of the area, while integrating essential information to the picture display aimed at providing comprehensive situational awareness to the user. The HUDs overlay graphical representations and icons onto the visual display in order provide real-time information at a glance.

ESRI has been experimenting with using AR for visualizing geographic information system (GIS) content. GIS, in itself, is a method of viewing spatially enabled data from a desktop or mobile device. Additionally ESRI has created a 360 VR experience for use with either Oculus Go or Samsung Gear VR. While ESRI has extensive defense contracts in the works there seems to be some room for a VR and/or AR application to GIS data that is not fully explored.

Currently, military analysts use LiDAR point cloud data with a tool called Quick Terrain Modeler (QTM) which allows analysts to add or remove items which have moved. QTM then exports the data into a three-dimensional, interactive, PDF product. These products are useful

for operational planning, as they allow a commander to see the best avenues for ingress or egress as well as slope data and density. ESRI could further expand on this already existing process to create an immersive experience for a user who can view an operational area from the ground level.

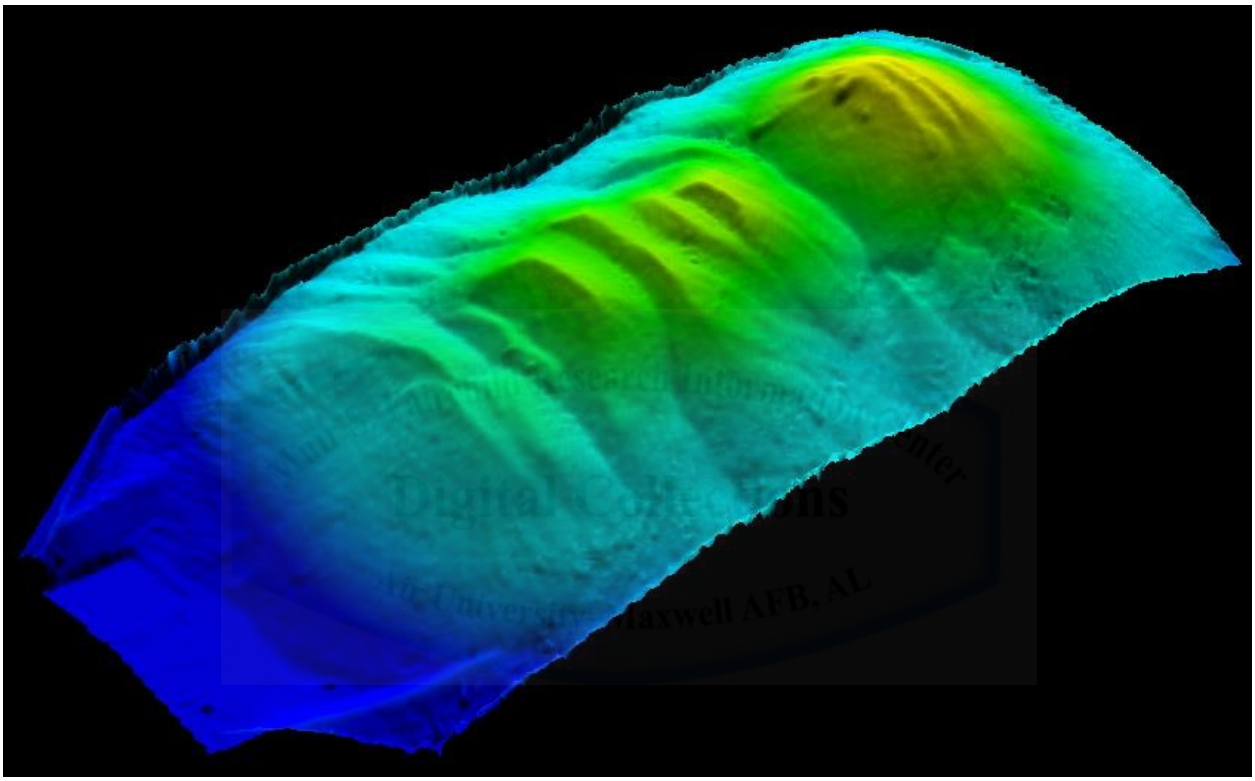

Figure 5: View of LiDAR data through QTM [stack]

Problems and Limitations

There is no doubt that advanced technologies have many benefits, but as with everything, there is a downside. Some negative aspects include physiological impacts, the ability for the technology to be used against us, vulnerability to hacking, and delays and latency in the

technology itself. With all the benefits AR technologies can offer the military, we would be remiss if we did not consider the risks. That is to say, with the continued advancement in technologies around the world, there are of course concerns that will need to be mitigated. Considering the substantial possibilities extended reality technologies offer, risks must be considered and weighed to ensure the best and safest possible applications.

Users have experienced higher rates of stress and anxiety following the use of full occlusion VR devices. Others have reported eyestrain, headaches, increased heart rate, sweating, and symptoms similar to motion sickness. This can largely be attributed to the latency issues associated with VR. "Recent studies of lab rats at the UCLA Keck Center of Neurophysics have revealed negative side effects including 'cyber sickness' and abnormal patterns of activity in rat brains, including 60 percent of neurons that simply shut down in virtual reality environments." [Magyari] This can primarily be attributed to the frame rate and the fact that we are essentially manipulating the human brain into believing it is in motion. [Morozov]

Developing XR technology to mimic first person shooter games can have both positive and negative effects. This technology has the ability to desensitize users to killing, particularly as the technology begins to become more realistic. But, do we really want soldiers who are desensitized to killing? This brings us back to the conversation that the more life-like the technology becomes, the more likely it is to trigger PTSD in soldiers who have seen combat. Additionally, it has the ability to cause PTSD in soldiers who might not have otherwise had it. Then there are those who may not be able to separate reality from augmented reality. [Morozov]

Will the benefits of continued growth of virtual reality technologies, and its applicability to multidisciplinary research, continue to outweigh the possible risks? These concerns should be

considered, particularly when working with soldiers operating in simulated operational environments, as the pursuit of realistic conditions and situations may take a mental and physical toll prior to the soldier ever stepping foot on foreign soil. Additionally, soldiers who may be returning to a theater could experience post-traumatic stress disorder (PTSD) symptoms brought on or exacerbated by the technology." [Magyari] While there are many positives to using virtual reality, those advances may come at a cost elsewhere. While our military is using virtual reality to conduct training against enemy nations, it stands to reason that our enemies are doing the same. Additionally, it is still unknown if our current technological infrastructures will be to evolve fast enough to accommodate the continued evolution. Once more, there are still unknown security concerns which may pose a problem in the near future.

In Clay Wilson's 2008 CRS report to Congress, he outlines such possibilities. He further explains that terrorist networks could use virtual reality to plan and conduct terrorist attacks in the US without ever actually stepping foot on American soil prior to attack execution. [Wilson] The possibility of manipulated data being ingested into US defense infrastructure is compounded as defense industry becomes increasingly data-driven. Not only are US direct defense networks vulnerable, but so too are US defense contract corporations. Once more, the connections between US defense organizations and contract organizations at risk, so too is the data which is shared with multinational partner defense organizations and the partners in which they share data. Therefore, it is important for the defense industry to grow their network defense capabilities at the same rate, or faster, than the rest of the technology industry.

Training in virtual environments affords all parties the opportunity to train while avoiding detection. As the technology is still relatively new, it is still unclear as to whether virtual reality

can be hacked, and to what extent. It also allows parties to participate in training events that would otherwise be detectible and observed by other parties.

Virtual reality adds a layer of undetectability that we are currently not used to. While this is an asset in the hands of US forces, it could quite literally be a ticking time bomb in the hands of our enemies. In the hands of a terrorist cell, for example, virtual reality affords them the opportunity to operate virtually invisibly. As of now, it is typically in the planning phase that we are able to intervene before an attack takes place. But if the planning and training takes place in their home country, terror networks will not be detectible until just before execution.

As previously stated, AR devices work by overlaying digital information over the real-world visualization. In order to do so, the AR device must capture and analyze the real-world scene. Therefore, there is a concern as to who can intercept and see that information. To add to these concerns, the device will have to capture information regarding the user in order to function properly. These devices will inherently capture data on people being view through the devices as well. This concerns many who view these devices as a potential invasion of privacy. When it comes to the military and defense industry's use of the devices, much will have to be done to preserve the privacy of the civilian population. Just as collecting imagery or signals data on civilians is an intelligence oversight violation under Executive Order 12333 and Department of Defense Manual 5240.01, so will the data collected by AR devices. It will become imperative that the security and privacy technologies develop at a faster rate than the XR technologies themselves in order to stay ahead of the possible risk concerns.

Technological delay or glitches can cause any number of problems. When it comes to VR, for example, that latency can cause a break in the immersive experience. Add to this the existence of latency, the moments of time between when a user moves their head and when the

visual picture catches up, and this could spell trouble for military training scenarios. If there is a noticeable delay between an individual's actions the the system's response, it can create a less believable and enjoyable experience. When these delays occur in the defense sector, however, it can have greater implications. More than just ruining a training experience, it can delay responses in simulations which will prevent the user from achieving real world results. If those delays are responsible for training a user incorrectly, it can transfer into real world execution.

It is important for technology developers to anticipate and consider problems and negative impacts of technology as they are in the development process. This will help ensure that XR technology will remain a force enabler, and not a hindrance, distraction, or source of counterattack against the U.S. Predicting and addressing such possibilities in the process will help ensure the technology continues in a positive direction and the unnecessary delay to not impact the program development.

Conclusion

Warfare itself contains many variables and is constantly evolving. In order to be competitive on the battlefield, militaries continuously adapt and refine their tactics. Future wars may not be fought on an actual battlefield at all, but rather a virtual one. Therefore, it is imperative the defense industry exploits the existence of off the shelf technologies, rather than starting from scratch to recreate it. Governments will continue to look for ways to get ahead technologically and apply that technology to their militaries. The U.S. needs to stay ahead of the development power curve in order to maintain their hegemonic status and ensure national security.

While much VR/AR/MR technology is still in its infancy and requires more research and development, it would behoove the defense sector to partner with companies who are at the forefront of advancements. The same HUDs which drive the gaming industry can be adapted for defense purposes.

There are still a number of obstacles which need further attention to mitigate possible negative aspects of MR technologies. Users have experience fatigue, stress, vertigo, anxiety, and more. Additionally, concerns that prolonged exposure to training scenarios which mimic first person shooter games could desensitize users to killing. Once more, security and privacy concerns will always be a factor, and technology which would ensure that security and privacy must develop at a faster rate than the XR technologies themselves.

As defense use of MR technologies becomes more commonplace, it will do much for the advancement of MR technology in the private sector, as well. AR and similar technologies can provide safer, more cost effective training environments, while increasing frequency of rehearsal, variations in training environment, and more. For these same reasons, MR technologies can be a key component of operational planning, as well. However, the challenge is to ensure the information provided through AR technology is not a hindrance or distraction to the wearer, but rather a force enabler.

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Notes

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