Chapter 42

Military Simulations Using Virtual Worlds

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The military has always worked to fight their battles in a synthetic or artificial environment before fighting them in the real world. There are so many variables that getting everything right is extremely difficult. Planning and rehearsal are primary tools for accomplishing this. Sand tables with wooden and stone markers that allowed commanders to explain their plan to dozens of soldiers were some of the earliest virtual worlds. Board wargames replaced the sand with paper and added rules so a player could actually do some predictions in a crude virtual space. New technologies like movies, electronics, hydraulics, computers, and networks have all changed the face and usefulness of these military tools.

In preparation for sending soldiers to Europe during World War II, the United States Army created extensive field maneuvers in the forests and hills of the state of Louisiana [1]. Tens of thousands of soldiers rehearsed their roles and used their new radios to report their actions to commanders who were miles away. This allowed these commanders to rehearse their strategies for positioning and moving large units, as well as the protocols for transmitting that information accurately to the units in the field. These Louisiana Maneuvers planted the seeds for large scale, live rehearsal which would become the primary mission for the world's largest training range, the National Training Center located in the desert of eastern California.

But, live action wargames are expensive to execute and require months of planning. Replicating these with paper or a computer can make the experience much more accessible and repeatable. Weiner believed that ancient Oriental generals may have planned their battles using icons on a map or scribbles in the sand [2]. As far back as the Roman Empire, military leaders used sand tables with abstract icons to represent soldiers and units in battle. These allowed the leaders to visualize and manipulate a small physical copy of the battlefield. It provided a window for them to see information in geographic perspective and enabled multiple players to pit their own ideas against one another. Though the visual representation was the initial value of the practice, the map or playing board upon which multiple options could be compared proved to be even more powerful. These tools allowed leaders and their staff members to compete against each other or against historical records in an attempt to determine which ideas would be the most effective [3].

Sand tables were turned into board wargames using wooden and cardboard maps and markers. One of the most famous was Koenigspiel, or the "King's Game", created by Christopher Weikhmann of Ulam, Germany in 1664 [3]. It consisted of a checkered board, borrowed from the game of chess, and thirty pieces which represented the King, Marshall, Colonel, and lower ranks down to Private. Some critics dismissed this as simply a "fancified" version of chess, but it began a thought process for creating accurate representations of the battlefield that has carried through four centuries. In 1780, Dr. C.L. Helwig created "War Chess" in which he significantly expanded the checkered board to 1,666 squares, coloring each to represent a different type of terrain [3]. He created 120 pieces for the game to increase the complexity of actions that could be modeled. Finally, he introduced the idea of aggregate units, so that a single piece could represent

an entire infantry, cavalry, or artillery unit. Helwig's ideas significantly shaped the direction of wargaming over the next three hundred years. His concepts are clearly present in the board games produced in the late 20th century [3].

Shortly after the first computers were invented, they were applied to wargaming. In 1948, the Army Operations Research Office created the "Air Defense Simulation" which ran on one of the earliest Univac computers [4]. It only represented enemy aircraft, anti-aircraft guns, and naval guided missiles in a generic three dimensional Cartesian space. But it was quickly followed by CARMONETTE which began development in 1953 and was used operationally from 1956 to 1970. CARMONETTE offered a much richer virtual space which included tanks, anti-tank weapons, infantry, helicopters, and radio communications [4]. It also made use of the relatively new "Monte Carlo Method" of statistical modeling which had been invented by Stanislaw Ulam and John von Neumann during their work on the Manhattan Project. From those simple roots, computer wargames became a staple in military training, the analysis of atomic weapon effectiveness, and that prediction of conventional battle outcomes. Most modern military forces now possess a number of computer wargames for use in training, the combat analysis, and weapon design.

Most recently, the military has developed virtual simulators of aircraft, helicopters, tanks, ships, and even squads of infantry. Crude systems of this type began to appear shortly after the commercialization of the first aircraft at the beginning of the 20th century. These devices allowed an aspiring pilot to learn the basic principles behind controlling an aircraft in flight. The most famous of these was Edwin Link's "Blue Box" which he created in 1930 and sold to the budding U.S. Army Air Corps (Figure 1). This machine offered a mechanical and electronic replica of an aircraft that could be used to test a pilot's ability to control an aircraft. Later models included a mechanical "mouse" that sat on a desktop and traced the path of the aircraft by driving across a map, showing the instructor exactly how well the pilot was able to follow directions [5].

Figure 1. Link "Blue Box" Trainer, 1942.

(Image from Wikipedia)

In 1990, Air Force Col. Jack Thorpe began work on a new kind of simulator, one that could be linked to others in the same facility or at bases around the world. The result was the Simulator Networking project (SIMNET) which delivered a standardized tank simulator and a network protocol which allowed the device to send essential information about the location and actions of the tank to other simulators across the computer network [6]. This allowed dozens of devices to participate in the same virtual environment as teammates or opponents. Crews in simulators no longer had to be satisfied with shooting static targets or simple drone objects which were preprogrammed. For the first time, they could pit their skills against a live and unpredictable opponent, forcing all participants to raise their level of competence to remain alive in on the virtual battlefield [7].

Virtual Worlds Dawning

Virtual worlds are a natural extension of the diverse and evolving family of simulators. These raise interesting questions that must be dealt with if this technology is to be used to support actual warfare. For example, in the real world each soldier has a distinct rank, organizational assignment, skill set, code of ethics, legal restrictions, and life supporting relationships. Must a military virtual world identically match all of these in order to provide useful functionality? To what degree do the soldier's real world experiences need to be mimicked in the virtual world? If a soldier is promoted, reprimanded, transferred, or deployed does that same change occur to his

VW avatar as well? Can actions in the virtual world be the basis for a promotion or commendation in the real world? Does the larger military organizational structure exist within the VW? Is it populated by avatars of the same people that populate it in the real world? Does this structure adapt automatically as the real structure changes? Are real world IT systems linked to the VW so that real world information is automatically reflected in the state of the virtual world?

A virtual world that links soldiers together could potentially reach out to their families as well, allowing them to "phone home" by rendezvousing at a shared virtual island to converse with the avatars of family, exchange pictures, and share videos. Should this be allowed? Does it present a security hole through which our enemies could access real battlefield information? Will we ever create systems that are secure enough to allow this kind of dual use?

The answers to these kinds of questions will significantly affect the form and functionality of any virtual world that is widely adopted by the military.

When the data in the virtual world is drawn directly from the state and actions of real world objects, it becomes much more than a training and communication space – it is a mirror of the real world with a number of additional uses. It becomes a tool for understanding and making decisions about the real world. Orson Scott Card's 1985 novel *Ender's Game* depicted a world in which the training exercises of Ender Wiggins were actually part of a galactic struggle to the death between two species vying for control of a planet [8]. Everything that happened in the virtual world was actually carried out in the real world. Was this a flight of fancy or will the next generation of virtual worlds enable this kind of warfare? For decades we have fired weapons at targets beyond visual range. These weapons are guided to a specific point in space using digital maps inside the weapon's computer brain. More recently, we have learned to use remotely piloted drone aircraft to fire lethal munitions at targets seen on a video screen. Several national air forces are aggressively creating Unmanned Combat Aircraft (UCAV) that use a digital map of the world and the enemy threat locations to navigate to a target, identify it, and release weapons – potentially without the need for human intervention. There are already multiple ground robot's equipped with rifles which can be fired by a human operator looking at the target through the robot's camera eyes. These systems use a digital map of the world either on the combat vehicle or in the manned control system. A military virtual world takes this one step further by displaying all of that data with 3D avatars and models. This visualization makes the VW an extremely accessible and useful tool for perceiving what the combat platforms see, understanding the opportunities that surround them, and making a decision to take action. As we enable the tracking of every vehicle and every soldier on the battlefield we can inject that information into a VW in real time. Combining that with surveillance equipment that has near-perfect awareness of enemy movements will allow us to populate a VW with all of the essential information that exists in the real world. Commanders and computer algorithms can evaluate the VW rather than the real world, make lethal decisions, and route orders through the VW to real combat platforms. These kinds of virtual worlds have the potential to reduce friendly fire, more accurately assess battle damage, simulate an action just moments before committing it to real world execution, and support legal reviews of combat activities.

Future military virtual worlds will not just be a playground for rehearsal, but rather an integrated picture of real world data and real world actions. They will be an inseparable blend of the real and the virtual.

Adopting Game Technology

Virtual world technology has come to the military from its roots in entertainment. Early concepts on the use of games were being demonstrated as early as 1996. The Marine Corps modified the extremely popular 3D shooter DOOM and simply labeled it "Marine DOOM" [9,10]. Though they generated a great deal of interest, the game was so primitive that it was very hard to imagine any real value in using these systems for a serious military purpose (Figure 2). Looking forward from 1996, it was almost impossible to imagine the computational and visualization power that would exist in a common desktop computer just ten years later. As a result, the concept of a military training system based on game technologies was delayed for almost a decade as computer technology advanced the power of the desktop systems to a level much closer to that found in the traditional, large scale simulators.

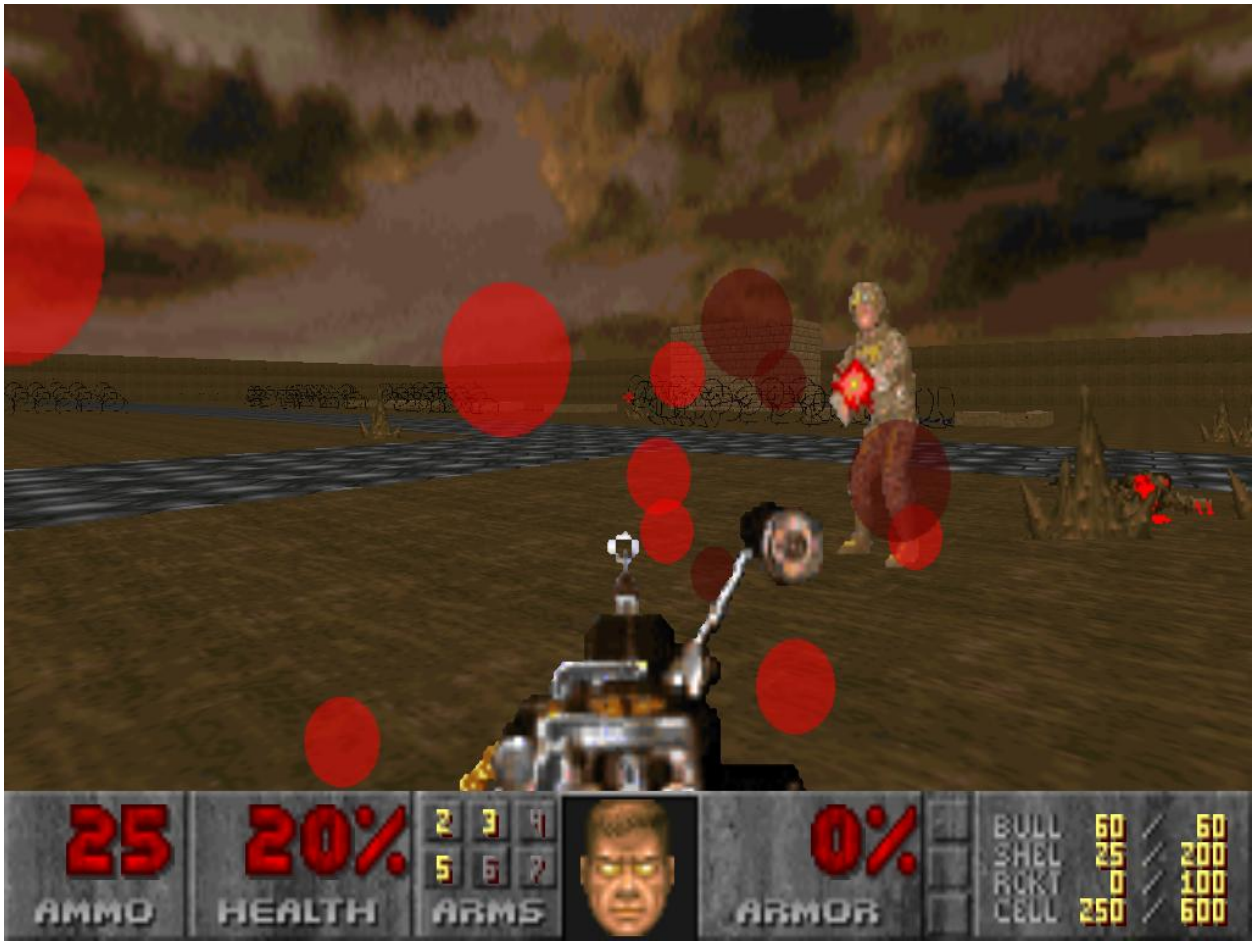

Figure 2. US Marine Corps Modification of DOOM.

(Image from Blog http://doom.starehry.eu/?p=407)

The serious use of game technologies has evolved from niche applications that appear clever, but not particularly useful; to something that is now part of mainstream military training. These tools are currently becoming certified applications where the representations within the games are

validated just as any other simulation. Games have taken their place alongside big simulators as accepted training tools. This adoption pattern from fringe users to the core body of trainers has been driven by at least five major forces (Figure 3).

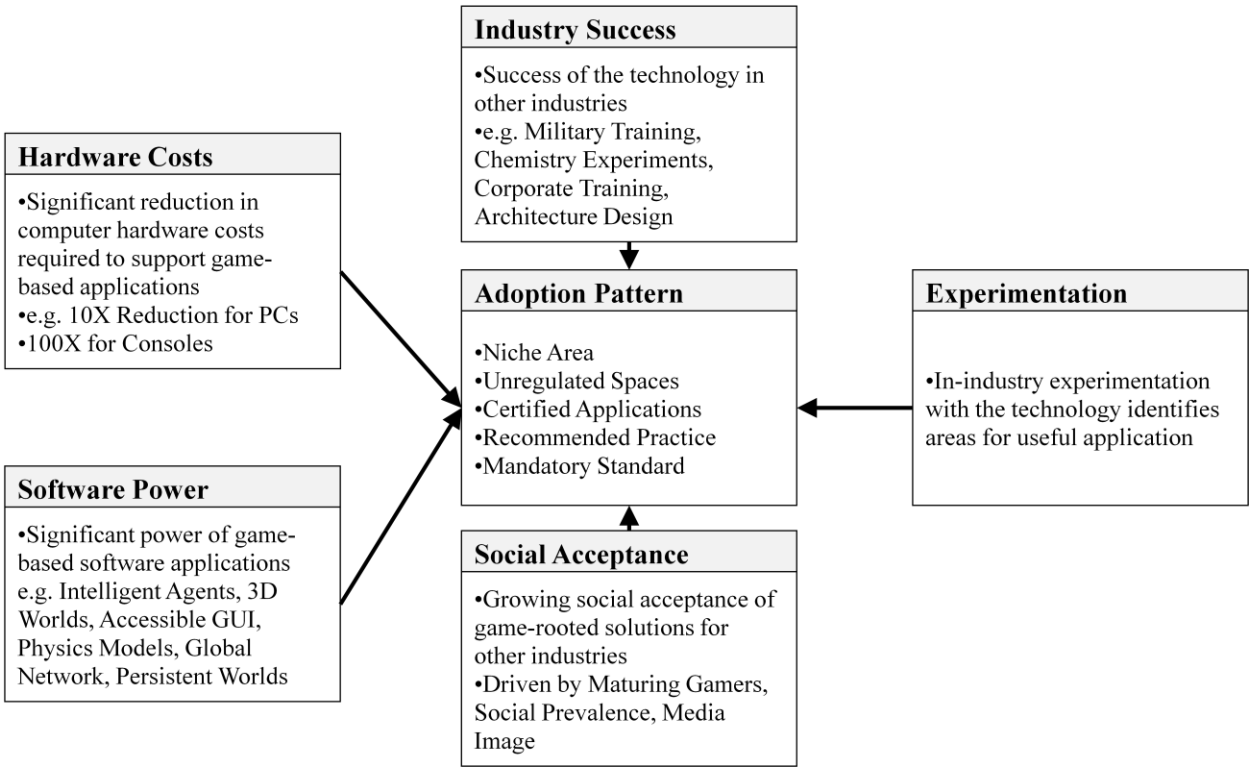

Figure 3. Five Forces of Game Technology Adoption [11].

Advances in game technology to a level acceptable to military users, is based firmly upon advances in computer hardware and software. As computer chips and graphics cards became more powerful, the amount of work that could be done in a very small and affordable package became increasingly impressive. This made it possible to create simulation models on a standard desktop computer that are sufficiently accurate to represent the physical and behavioral characteristics of the real world. As these technologies were discovered by other industries they began to show up in new systems for conducting science, designing buildings, delivering teleconferences, providing psychological counseling, and hundreds of other applications. The constant coverage of these systems by the media led to significant social acceptance around computer games. They grew from toys used by a small demographic of teenage boys to something that is now part of almost everyone's casual entertainment. This level of social acceptance opened the doors for their acceptance by the military as well. Finally, within the military research and experimentation communities, there were literally hundreds of independent experiments going on with game technologies, each of which identified a unique and valuable application. These five forces seemed to surround and drive the adoption of the technology to a point where it is now accepted on a par with the traditional live, virtual, and constructive training systems [11].

Virtual worlds can potentially follow this same path.

Though slightly different from game technologies, VWs are similar enough that they can benefit from the same five forces. If a 3D shooter game with a small play area and a short time focus can provide useful training, then a virtual world for a much larger space and longer time horizon should be applicable to even larger military problems. The most compelling feature of virtual worlds is the fact that the worlds they create are constantly active regardless of the participation of any individual player or group. These worlds are alive and changing 24 hours a day, 7 days a week [11]. This allows them to become an integrator of thousands of real world data sources, creating an up-to-date mirror of the real world.

"Always On" Training

Soldiers need a training space that is "always on" and within which they have the power to design custom content and schedule collective training. Our current simulators and wargames require a large number of support staff and specialized facilities. A military virtual world would move the complex server-side operations into a professionally managed IT center, while allowing soldiers to access it from a simple client on their desktops. This would enable 24/7 training operations that are focused on the needs of the soldier, rather than limiting them to a single week at a specific training center. With such a system soldiers and units could create the scenario that they want to train against and coordinate the event with other units to provide support functions and enemy role playing. The real power of such a system is in putting training within the immediate reach of each soldier and unit.

The 21st century is a time of constant planning, preparation, decision making, and action for the military. The missions that our soldiers are asked to perform are unconventional and constantly changing. To prepare for this, they need training tools that are flexible and always available. They need access to a 24/7 training range that can be configured by the soldiers to match their next mission. For such a range to be "always on", globally accessible and integrated it must be an online digital space, not a traditional physical space.

This shift to 24/7 availability has not yet been applied in military training. Training facilities are still difficult for military units to get access to and they rely on a very limited staff of specialists to use them. A globally accessible virtual world in which training can be designed and conducted without the help of a dedicated staff is the only way to provide 24/7 access to training. This would create a training space that is located within reach of every soldier and every unit. It would allow planning and preparation to be conducted immediately after the conception of a new mission. It would also allow soldiers to refresh their skills and build their knowledge at any time. When they are ready to learn, the tools to support them would be at their fingertips.

The technical support for this is the desktop computer that has evolved into a supercomputer in your home. A typical desktop computer today has more computing power than resided in an entire simulation center just a decade ago. With this kind of affordable and available power, each soldier's computer can become a personal training range. Once connected to the internet, it becomes a powerful node in a global training network. There would no longer be a need for soldiers to travel to a specially configured training center to conduct virtual training. These old central training hubs could be transitioned into a training service available within a military cloud computing environment.

Military units should be able to enter this virtual space, coordinate with other users, and create scenarios that address their training needs. This kind of ad-hoc, just-in-time game play is currently available to high school students in online games that support thousands of simultaneous users. A similar, but more realistic world can certainly be created for military training. These virtual worlds would include the tools necessary for users to create objects from scratch, arrange them into a customized training vignette, and script behaviors for computer controlled avatars.

Imagine ten thousand soldiers securely logging into a virtual world from computers inside of the military's protected internet domain. Each soldier is identified by their official credentials and assigned an avatar, unit association, and virtual location to match their real world identity. Using virtual radios like Voice Over IP (VOIP), virtual C4I systems like map applications, and virtual vehicles they are connected to each other just as they would be in a physical formation and physical training event. Leaders within the group use in-world editing tools to create a specific lay down of the enemy, friendly, and neutral forces across a 100 square mile area. The terrain for this play box is imported directly from military terrain databases and is an exact match to its real counterpart. Finally, the behaviors of thousands of automated avatars are activated based on their identities, intentions, and past experiences. Selected from a toolbox of custom pieces, this scenario would allow units to come together according to their own schedules to train against a customized, but still validated set of enemy behaviors.

The soldiers in these units might be viewed as a "flash mob" coming together when needed for a specific purpose and then dissipating just as quickly once the training event was finished. This model is significantly different from what is possible today. Our current training capabilities are dominated by systems and databases that require dedicated experts to prepare an event, that are available for a short period, and that must be scheduled months or even years in advance. The power of an "always on" virtual world, patterned from "always on" online games like *World of Warcraft*, is within reach for military training.

The military has a long history of posing the same question every time a new technology for training is introduced – "Will this totally replace older forms of training?" Looking back over many hundreds of years of sand tables, board wargames, computer games, and virtual simulators, it is clear that the answer has always been, "No." New technologies allow us to train in new ways. Sometimes those improvements replace older, less effective methods. But they have never completely replaced an existing method. Even with the near-perfect computer and electronic technology in a flight simulator, there are aspects of operating an aircraft and flying a mission that have to be done in the real equipment. Also, no matter how good an infantry rifle simulator is, it cannot completely replace the experience of marching through rough terrain with a 100 pound pack and having to bring your weapon to bear on a threat within a few seconds. Military training began as purely live training, to which hawse have added sand tables, wargames, computer games, and virtual simulators over the centuries. Virtual Worlds will join this family, offering new capabilities, replacing some previously ineffective methods, and becoming part of an integrated fabric for preparing soldiers for the dangers of war.

Virtual World Education Theater

"Always on" virtual worlds offer many more powerful capabilities than just training the soldiers in a shared environment. They also create a virtual education theater in which students in classrooms can observe real operations. These can be viewed in real time as they happen or delayed to match the teaching schedule at the school. Connecting as a passive viewer without an avatar in the world, individual students or instructor-led classrooms can navigate the world and watch any event that has occurred whether it was a few hours ago or a few seconds ago. The data stream can also be edited automatically and in real time to eliminate sensitive information and to provide anonymity to the units who are actually under training.

Unlike a television program, this data stream is not fixed and permanent. It represents orders for specific avatars to take specific actions within a virtual world. As that data stream is recorded it becomes a script in which every object and every event is recorded. This can be modified and replayed with variations. This creates the opportunity for a classroom of students to use the data as a basis for planning and creating their own versions of the events. Instructors can make assignments for groups of students to begin with a small vignette in the virtual world and incorporate the knowledge they have gained in class to see how it would play out within a larger scenario drawn from real world training. The multiple outcomes that result would provide a rich set of data to consider, compare, judge, grade, and learn from in a classroom setting.

For centuries, military schools and courses have studied historical battles and analyzed the brilliant and fatal decisions that were made. An always on virtual world would take this one step further, allowing students to direct these battles and insert their own solutions.

Robert Putnam argued that humans seek a number of different spaces in their lives where they can express different aspects of their personalities. Specifically, he looked at the impact that the internet was having on traditional social activities, like a bowling league. He found that internet social groups were meeting a number of needs that previously required face-to-face interaction. As a result of this new form of socialization, physical participation in a number of traditional activities was declining because the social need was being satisfied more conveniently in online communities [13]. Virtual worlds for military education, training, and rehearsal will have a similar effect. The space and the activities will be distinctly different, just as bowling and attacking virtual trolls are very different, but will satisfy the underlying need to learn and understand a challenging situation. The degree to which a virtual world accomplishes this is only partly driven by its ability to create a realistic space. It may present a familiar, but unique and different environment and still accomplish the same objective or meet the same need. Scott McCloud explained a similar trait in comics. They do not have to exactly imitate the real world to effectively communicate their message. In fact, in most cases, there is a better way to tell a story when you can take artistic license with the environment, emphasizing what is most important and minimizing the surrounding noise [14]. Massively Multiplayer Online Games and virtual worlds create "realistic" spaces, but they also retain a unique rendition of that reality and combine it with features that are intentionally fantastic. This modification of the real is not necessarily a negative trait when using that world for training. Applying the works of Putnam and McCloud, these unique renderings could be more effective at communicating a message and conveying new skills, than would a perfect replication of the real world. With realism comes unnecessary detail, complexity, and confusion. A military virtual world is trying to do a better job of training than can be accomplished in the real world, and being better may require being different by reducing the exactness of the real world.

Visual Integration Space

This type of virtual space is also a natural integration medium for data collected from the real world. As we instrument every soldier and vehicle in the military we have the means to track their movements and actions in real time. When combined with near perfect surveillance of enemy assets, we have all of the data necessary to create a window into real world operations. It will no longer be science fiction to imagine actions in a virtual world being tied directly to outcomes in the real world, ala *Ender's Game* [8]. The virtual world will become a medium for transferring information and orders to and from the real battlefield. We have become comfortable with a UAV pilot flying a drone from thousands of miles away and releasing deadly weapons based on the video images from remote cameras. A really robust virtual world would give us the ability to apply this kind of warfare to almost every platform on the battlefield. A military virtual world could become the global command and control system of the future. When this does happen, these virtual worlds become the most important computer applications in our arsenal -- and attractive targets for our cyber enemies.

Virtual worlds can provide an integration space for data of all kinds. In the late 1990's Col. Jack Thorpe and others envisioned a global network of training simulators [15,6,7]. These would be able to share data between widely distributed sites and significantly different systems. At that time, scientists and military thinkers expected all data to reside in and be managed by the training system at the end of the network. Today, we have expanded on that concept and have introduced intermediary computer servers where this data can be translated, integrated, redirected, and stored. The complete virtual world now resides in a cloud of networked computer services and is available to anyone who needs it.

This middle tier of computers means that integrated data can be directed to any node on the network. More recently, computer scientists have also moved all calculations within the virtual world to these middle servers, delivering only the finished results of computation and visualization to the end nodes. When this happens, the user's computer need not be a high-powered computer, but can be any device with the ability to render images and pass user commands back to a cloud-based server. Suddenly, every computer, no matter how powerful, becomes a potential node in the global training network. Suddenly a cell phone can present a rich virtual world for soldier participation because all of the heavy computation is being done on a server in the cloud, not on the device in the palm of his hand.

As networks become faster, the servers residing in the internet cloud are no longer remote storage devices, but become personal computing resources that appear to be almost as close as the device in your hand. This effectively places a complete training system in the palm of every soldier who has the need to use it.

Cybersecurity

Today, CyberSecurity and CyberWarfare refer to the protection, injury, and death of digital bits in communication messages, databases, and stored files. When a military virtual world becomes an exact replica of the real world, our cyber defenses will need to protect the virtual world much

more rigorously because it has the power to directly trigger real world actions. Breaking into a VW database could mean the death of real people and the destruction of real objects [16]. This potential has been identified in science fiction for at least three decades [17,18]. We are finally reaching the point where those visions can be realized.

In a future where virtual worlds mirror the positions and actions of real world objects, there is a one-to-one correlation between the cyberworld and the real world, with little need for complex analysis to understand what the data means. Anyone who can access and manipulate the virtual world has a window into real world plans, actions, and objects, and can potentially influence those by changing data in the virtual world.

This direct correlation makes the virtual world one of the most attractive and valuable targets for cyberattack and cyberdefense. This includes protecting training data, which is actually a map of the future plans and future capabilities of a country's military. These rich virtual worlds will attract the most talented hackers once they understand the real nature of the data contained within them. Cybersecurity needs to be applied to the virtual world with the same diligence that it has been applied to classified real world data.

When the cyberworld/virtual world is so tightly knit with the real world, it becomes a valuable pressure point in conflicts between two nations that use this technology. Currently, disagreements are addressed first with diplomacy. When that does not solve the problem, actions might escalate to economic sanctions and military blockades. These could be followed by Special Forces intervention and finally full-scale war. A cyber attack could fit into this escalation of conflict. Spying upon, manipulating, and destroying cyber/virtual data may become a form of persuasion following diplomacy, but preceding intervention or warfare. The impact of cyber/virtual actions may sway one side or the other to turn to negotiation, rather than continuing to escalate. Or, conversely, cyber attacks could push a nation into escalation because they hope to be more competitive and effective with their special forces than as digital adversaries.

Could warfare in virtual space take on the leverage that currently resides in diplomatic, economic, terrorist, and combat actions? Such leverage would require that the virtual world be inseparable from the operations of a country's military or economy. The loss of the virtual world would have to significantly weaken the country itself. Today's electronic banking systems have become just such an essential digital dimension of society. Its loss would significantly weaken and even destroy important parts of our country. One could imagine a virtual world becoming so useful and so widely adopted that it held a similar status, at which point its defense would be just as important as defending the physical borders of the country.

Conclusion

A virtual world is an information space that has been rendered in three dimensions. It is not just a training space or an entertainment space. The virtual world can be a playground, a training range, or a command and control space depending upon the information that is being rendered. It can be a visually literal mirror of the world, or contain modifications that make the real information even more valuable. Realism and value are not measured visually; they are measured by the degree of understanding that is achieved by their representation.

Creating virtual worlds for training is an excellent first step for introducing them to a national military and demonstrating the power of an integrated world in 3D. This can potentially stimulate the spread of the technology into other important military functions like command and control, logistics management, and intelligence. Over time, virtual worlds could become a standard tool for all types of military operations that deal with the actions and locations of real objects of interest.

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