Leveraging Commercial Game Engines for Multi-Domain Image Generation

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ABSTRACT

In response to an increasingly complex and uncertain operational environment, the United States Military requires innovative technologies to enable adaptable, full-spectrum operational training. Live, Virtual, Constructive, and Gaming (LVC&G) environments offer desirable solutions to a myriad of training challenges and support safe, multi-faceted training to improve readiness at the point-of-need. LVC&G offers high return on investment from saving assets for actual operations, lessening overall logistical costs and planning timetables, increasing flexibility and training dynamics, and reducing preventable mishaps during range training. However, often the adaptability and scalability offered by traditional solutions are hampered by closed, stovepipe software applications. In this paper, we will review the use of commercial gaming technology as a development tool and software runtime to address some of these obstacles. Specifically, we will analyze the use of Unity, a commercial game engine, for multi-domain image generation in scalable LVC&G military exercises at the individual, unit, leadership, and international levels. Operation Blended Warrior (OBW), an annual LVC&G event, will be reviewed to highlight the current state of the industry and technical challenges associated with integrating non-traditional gaming technologies into full-scale exercises. Key interoperability and scalability issues including asset reusability and standards-based communication protocols, typically absent in commercial game engines, will be discussed. This paper will offer Industry and Government forward-leaning suggestions to best position both to understand and leverage disruptive commercial gaming technologies in combination with simulation middleware to engineer innovative capabilities to modernize training for operational readiness.

ABOUT THE AUTHORS

Mr. Jordan Dauble is the owner of SimBlocks LLC, a software development company located in Orlando, Florida specializing in the integration of commercial game engines with simulation systems through software middleware for 3D model and geospatial terrain reusability and standards-based communication interoperability. SimBlocks is a graduate of the Starter Studio business accelerator and is a client of the UCF Business Incubation Program at Central Florida Research Park. Prior to launching SimBlocks, Jordan had been developing successful simulation applications for leading companies such as Havok, Microsoft, Cubic, and Meggitt Training Systems. Mr. Dauble graduated from Purdue University with a degree in Computer Science in 2006.

Ashley L. Medford, PMP is an experienced consultant and program manager, specializing in the development and use of immersive technologies for Defense and Government education, training, analysis, and collaboration. Throughout her career, Ms. Medford has led multiple immersive learning technology programs and projects for major clients, including the Air Force Research Laboratory, United States (U.S.) Naval Air Systems Command, Army Research Laboratory, National Aeronautics and Space Administration (NASA), Office of Naval Research, U.S. Special Operations Command, and U.S. Central Command. Ms. Medford has provided consultation and program management for modeling, simulation, and virtual reality training and collaboration environments for over a decade. She is a contributing member of the e-Learning Guild, the American Society of Training and Development (ASTD), the Project Management Institute (PMI), and the National Defense and Industrial Association (NDIA).

James J. Frey, Ph.D., Aero Simulation, Inc., is a nationally recognized expert in training innovation and design. As one of the nation's leading experts in Live, Virtual, Reality (LVC) training design and operation, Dr. Frey was chosen as the Industry lead for 38 technology companies (names like Lockheed Martin, Boeing, Rockwell Collins, etc.) for Operation Blended Warrior (OBW) at the world's largest training and simulation conference, I/ITSEC, for the second year in a row. NATO's Senior Exercise Director, Swedish Major General Branntrom, personally selected Dr. Frey to present on NATO'S behalf to the U.S., EU, NATO, and an International Industry audience at I/ITSEC for the global training exercise "Viking 18" on innovation in operational training (he will present again in Sweden in Spring 2018). Previously, he was an Enlisted Army 12B Combat Engineer, then Enlisted Navy Aviation Electrician, then Commissioned to become a Naval Helicopter Search and Rescue Pilot and advanced Flight Instructor. Now a veteran, he was the recipient of 37 decorations from the U.S. Army, Navy, U.S. Air Force, Coast Guard, and USMC, to include the Bronze Star for combat action in Iraq from the Marine Corps. Dr. Frey has two Master's Degrees and a Ph.D. aligned with 25+ years of experience in advanced training design and presentation.

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INTRODUCTION

Facing an increasingly dynamic and demanding operational environment and limited by constrained fiscal, time, material, and personnel resources, the United States (U.S.) Department of Defense (DoD) must continually seek innovative means to effectively and efficiently prepare the total force. In order to remain relevant, anticipate and rapidly integrate lessons learned, and ensure an agile and adaptive force, the DoD must leverage emerging training technologies to meet these challenges (DoD, 2010). Live, Virtual, Constructive, and Gaming (LVC&G) environments afford advantageous solutions to a variety of these training challenges and support safe, multi-faced training at the point-of-need. For instance, utilizing realistic, synthetic environments enables training using virtual assets; in turn, tangible assets are saved for actual operations, decreasing overall logistical costs and planning timetables. This enhanced flexibility affords additional time for training within more dynamic training scenarios, which can increase cognitive retention and reduce preventable mishaps during range training. However, the adaptability and scalability offered by traditional solutions are often fettered by closed, stovepipe applications, which limits innovation and increases cost.

Traditionally, the U.S. military has developed robust simulation systems to meet lengthy requirements tailored to specific organizational and (far too often) individual needs. Rigorous and drawn-out acquisitions processes with constant readjustments in each phase result in final system deliverables that are frequently and unsurprisingly convoluted, stove-piped, and/or outdated. While the acquisitions community and leadership continue to make strides towards streamlining, conventional policies and processes have acted as an environmental and cultural factor contributing to a propensity for buying outdated legacy and/or proprietary systems, especially within Military Simulation and Training (MS&T). Although these systems meet lower-echelon and specific individual training requirements, their dated graphics, software, and hardware components regularly require overhaul or replacement. Unfortunately, updating traditional, legacy, or proprietary systems is extremely costly and time-consuming. Add in the accelerated rate of technological advances, and this conundrum is further exacerbated with the need for (what seems like) perpetual upgrade expense cycles and results in DoD MS&T always being at least one step behind. With ever-evolving demands to maintain readiness for operational superiority within a resource-constrained environment, traditional LVC systems simply cannot adapt efficiently or rapidly enough to maintain pace nor meet the demands for multi-echelon, joint, and ultimately, the modern training environment – at least not alone.

The commercial gaming industry, by adding the “G” to LVC, may provide the ultimate partner to augment traditional LVC capabilities. In the U.S. alone, the 2017 video game market was valued at $18.4 billion USD with 2016 consumer spending totaling a staggering $30.4 billion USD (Statista, 2017). With billions being funneled into internal Research and Development (R&D) activities, Commercial-Off-The-Shelf (COTS) gaming companies offer consumers access to the latest, cutting-edge advancements in immersive technology. For instance, leading COTS game engines offer support for state-of-the-art Virtual Reality, Augmented Reality, and Mixed Reality (VR/AR/MR) platforms enabling users to develop their own VR/AR/MR applications out-of-the-box. Unlike the “black-box” approach found in the traditional LVC marketspace, commercial gaming business models are built on developing open, accessible, and highly extensible capabilities and service offerings. This converse approach provides MS&T with an opportunity to augment current, traditional offerings and adapt to current operational and readiness requirements.

While commercial gaming’s culture is more amenable to rapid innovation, it can also create obstacles within MS&T. For LVC&G technologies to support large exercises, individual systems must be able to interoperate: that is, system components require *integratability* of infrastructures, *interoperability* of systems, and *composability* of models (Tolk, 2010). As such, communication and interoperability standards and protocols (e.g., Distributed Interactive Simulation (DIS), High-Level Architecture (HLA), or Common Image Generator Interface (CIGI)) have become integral to the development of LVC&G systems for MS&T use. COTS game engines, on the other hand, do not face the same requirements because they were never specifically designed to interoperate within the MS&T domain. This poses a serious challenge to their use in LVC&G; however, we shall offer an approach to transform this roadblock into an opportunity to bolster LVC&G capabilities.

In this paper, we will review the use of commercial gaming technology as a development tool and software runtime to address some of these obstacles. Initially, traditional, military Image Generator (IG) technologies will be examined, along with cultural and environmental factors influencing their current state. While there are miles of cable and millions of bytes behind the movement of players within an environment, the most recognizable aspect of most training interactions to the user is the IG systems' output. The IG is the visual, proprioceptive, and aural world *surrounding* and interacting with the individual or unit. 3D models of buildings and airfields, lighting effects, and time of day controls are primary examples, but an IG also may include air and water effects like current, temperature, humidity, or salinity. Each detail *felt* by the trainee and his or her weapons system should be modeled within the IG for the training to be realistic. This is costly and time consuming, but critical to get right. We will delve further into commercial gaming technology as a valuable augmentation to traditional IGs. We will reveal advantages and disadvantages of COTS game engines with respect to MS&T. More specifically, key interoperability and scalability issues including asset reusability and standards-based communication protocols will be discussed. To highlight the current state of the industry and offer insight into the technical challenges associated with integrating non-traditional gaming technologies into full-scale LVC&G exercises, Operation Blended Warrior (OBW), an annual LVC&G event conducted at the Interservice/Industry Training, Simulation and Education (I/ITSEC) conference, will be reviewed. Overall, this paper will offer Industry and Government forward-leaning suggestions to understand and leverage disruptive commercial gaming technologies, in combination with simulation middleware, to engineer innovative capabilities to modernize training for operational readiness.

GAMING TECHNOLOGY REVIEW

Traditional, Military Image Generators

A serious challenge to the future of simulation and gaming is the past. DoD acquisitions policies and processes for information technology have remained a major source of concern, especially with regard to our ability to maintain pace with the current rate at which technology advances (OUSD AT&L, 2009). Multiple positive changes have been enacted over the years and continue to this day, but the issues are far from resolved (Johnson, 2011; DoD, 2017). Regarding the broad state of MS&T systems, conventional acquisition policies and processes have inadvertently behaved as environmental and cultural barriers to the general state of MS&T system innovation.

Folded into the complexity of budgeting for and acquiring the best gear for our nation's warfighters is the unfortunate reality that multiple efforts with the same basic goal in mind take countless avenues to get there. Traditional government acquisition teams simply are not aligned with other acquisition teams during any part of the process. Still, Congressional and military leadership pay a tremendous amount of attention to calls for the adaptability and scalability of training systems. To answer this call, separate DoD-sponsored initiatives to solve interoperability and more joint-role applications of systems, such as the U.S. Army's Synthetic Training Environment (STE), Air Force's Simulator Common Architecture Requirements and Standards (SCARS), or the Navy's Future Airborne Capability Environment (FACE™) programs (PEO STRI, 2018; US Air Force, 2017; NAVAIR, 2017), are all trying to solve some of these issues on their own. *Interoperability* and *multi-level applications for training* are serious buzz-words during high-level meetings seeking to expand programmatic success. Unfortunately, the resultant solutions do not compute into results at a contractual level. Each iteration of budgeting, planning, designing, building, and testing processes compile a diverse, seemingly innocuous, set of well-hidden concessions to time, budget, and requirements. Each territorial engagement with various budgetary and engineering personalities, then filtered through the fresh-eyes of end-user operational cultures, places emphasis on areas germane to the operational training for that particular client, while shedding *unnecessary* expenses needed for interoperability, scalability, adaptability, and a more complete battlespace depiction. In the end, the leadership who briefed and approved a system will not be the leadership who tests and signs for it. This is not nefarious; it is simply not the same staffer charged with writing the requirements and procuring a specific client's simulator as the one who does its final testing. Neither is that first or last staffer involved likely to be one of the men or women who will actually be using it for training. Ultimately, the lifecycle of a typical MS&T procurement involves one person designing it, another testing it, and another actually employing it. By regulation, the simulation system must do specific tasks for a specific budget and client; anything outside of that evolving checklist is seen as wasted effort and potential cost savings.

Seemingly, this culture has worked well for the both the procurement staff and traditional simulation companies. The government takes delivery of a simulator which meets the exact standards requested. It is easy to quantify and qualify the expense from start to finish. The supplier will have competitively bid and won the contract based on meeting those exact set of standards and principles (and nothing more). It is easy for them to quantify and qualify their expenses in doing so.

Furthermore, the dataset held within the black-box ecosystem making up the simulator will be exactingly customized to the specific customer, the specific mission variables, the exact training requirements, and be proprietary to the supplier. The government does not have to bother with adjustments or wonder whom to call upon to make them. The supplier is the sole-proprietor and fixer of issues and can count on, for long term planning, being the vendor to fix or update the simulator(s). Being the only person who can fix something is good for business, and while not totally cost effective, it is certainly easier for the government to know who to call and what they will pay. This tradition of locked-down proprietary software and complex applications was the acceptable process for the government and the lifeblood of industry who profited from that reality. However, budget constraints and more demanding training requirements require a re-evaluation of the current process (OUSD AT&L, 2009; Johnson, 2011; DoD, 2017).

Enter LVC*&G*. LVC&G offers a nimble and agile methodology of getting disparate combatants in the same battlespace without the years and months of budgetary territorialism accepted as reality before. Where traditional government industry relied on the need to design an image generation system to be proprietary as part of their business model, the gaming industry has a completely different methodology. For gaming, the more accessible your system, the more applicable, interoperable, interactive, user-friendly, and the less black-box, the better. If you are designing a Smartphone App, for example, the more types of carriers, the more brands of phones, and the easier for the user, the better. Traditional government procurement sought to control the use, whereas gaming seeks to proliferate it as far as possible.

Commercial Game Engines

While it may appear desirable to simply require everyone to use the same synthetic environment for joint training (the stated goal of the disconnected efforts led by the U.S. Army's STE, Air Force's SCARS, or the Navy's FACE™ programs), the reality in which we operate is much more complex. The fact is that shifting technologies are not as straightforward as any of us would want them to be, or as universally necessary as many report them to be. The demand signal for complex learning applications and visualization calculations change per user and mission in ways that would degrade other users' systems speed. For instance, an F-35 simulator pilot does not need window curtains properly modeled in a mud parlor as he or she prepares to simulate destroying it. Fifteen thousand feet below her however, the ground personnel designating that target may need those curtains; they may be training to recognize potential hazards, snipers, or other hidden traps. Imagine the wasted time and money to code hundreds of dynamic curtains into hundreds of windows that aren't even visible from 15,000 feet. In such a training scenario, a pilot may be learning to acquire a target with radar or laser designation. On the other hand, the ground units may need their weapons' rifling to be properly modeled within the synthetic environment, so the spin of their bullets reacts appropriately with the correctly modeled micro-atmospheric dynamics. The Soldier is learning why bullets tend to follow walls, or why a bullet rises with a certain cross wind and falls in another; regardless, he or she does not need an IG modeled for the temperature and wind change at 15,000 feet. And none of this level of calculation is needed for the next echelon up the kill chain. Their direct-line leadership, learning to deploy armament and troop solutions in the battlespace, may need only to see the availability of assets and rounds, not necessarily their purely calculated use or accuracy. They may be learning about asset deployment and the logistics required or perhaps projecting enemy reactions to their decisions. The logic required to accurately model these intricate behaviors and attributes are often viewed as critical to simulation-based training. In turn, this is where the argument for gaming solutions meets seemingly appropriate resistance.

When we begin conversations about gaming technology, the granularity requirements of traditional simulation appear as reasonable objections. However, they are only valid if one misunderstands the value gaming provides more than he or she understands why the expensive, high-definition, often pre-historic technologies are ill-suited for the next generation of demand signal(s) in training. That is, the objections are moot; the next generation of training demands more joint, more multi-force, more multi-layered, and more multi-leveled battlefield dynamics that old systems cannot provide. To get there though, each player in the synthetic environment must maturely decide which micro-capabilities can be shed for the good of the whole. The F-35 pilot, for instance, may not get cumulonimbus cloud formation, the ground troops may not get bullet droop calculations in an urban environment, and leadership may not get tidal charts and weather dynamics. But in exchange, all players will interact in the same city, with the same radio frequencies, with the same entity enumerations (the codes used for visualization and behaviors), and all will practice from the same 'big picture' point of view - working together. They should learn skill-based tasks like how to paint a target, operate the radar, or snipe from 2,000 meters independently. These higher-level cognitive learning tasks, requiring advanced procedural and strategic-level knowledge (e.g., leadership, teamwork, problem solving, etc.), do not necessitate the same instructional approach as does more skill-based, system-intrinsic knowledge (e.g., operating an M4 rifle or flying an F-35). There are, via traditional procurements, legions of MS&T systems in place to train air and ground forces alone. But where is the simulator to train all levels and echelons of battlespace operations together, under one Command, on a single battle order or 'big picture' task? There is none.

Under the traditional model of every-man-for-himself acquisitions, the first time the Navy F-18 pilot will have the USAF JTAC, the Army MEDVAC support, the USMC Ground Force Commander, and his or her own (U.S. or NATO/Foreign) Operations Commander *on the horn*, so to speak, at the same time, is during a real operation. That is not where to make mistakes and find gaps in procedures and training. That is the potential LVC&G solution. Commercial gaming provides a flexible and efficient means to address modern, higher-level, tactical training requirements. Rather than replacing established devices and successful methodologies, commercial gaming should augment the current repertoire of complex, legacy simulation systems to finally ensure comprehensive operational readiness within our current, network-centric warfare environment.

A shift in training methods to include capabilities to reuse missions, scenarios, areas, and behaviors that have been meticulously designed in a variety of tools and for specific IG systems in non-traditional, game-based applications, would allow not just for better training, but also better tracking of deficiencies and improvements needed over time. Joint and multi-force training is gaming technologies' perfect entry point.

Demonstrations of commercial game engine technology usually involve high fidelity graphics, intense physical interactions, destructible environments, and dynamic Artificial Intelligence (AI)-driven character behaviors, which appeal to military simulation developers and users. That may seem attractive; but some systems indisputably have some of these features on the individual level already. What we do not do well is *sell* the value of teaching higher-level, strategic knowledge such as joint and multi-force interactions. The F-35 acquisition team is simply not excited to read that their pilot can see and talk on the radio to a live ground pounder. Likewise, the USMC acquisitions team wants to hear about how to train warfighters to kick down doors and take or save lives; talking to an exercise participant safely circling at 30,000' is not on their list of critical functions (costs). The reality is that if a radio fails, or a ground unit cannot contact an air unit, real operations are often cancelled. The value in finding cost-effect methodologies to train and perfect these skills is clear.

Recent disruptive trends in the commercial sector have eliminated the barriers of entry to begin using these game engines. Accenture (2015) pointed toward four major trends driving these industry changes: (1) a growing and increasingly diverse customer base expecting high-value at low costs; (2) an expanding definition of games tied to lower barriers to entry for independent developers and other industries, propelling growth of indie game development and immersive gaming technologies (e.g., VR/AR/MR); (3) normalization of digital delivery, and; (4) shifting business models from single to multiple revenue streams (i.e., high volume, low margin). In today's digital and connected age, successful commercial gaming companies have adapted and continued to remain flexible within a rapidly changing and competitive market. The consequential ease of accessibility to cutting-edge gaming technologies and content provides the MS&T community with a ripe opportunity. There are several high-quality commercial game engines that are available for experimentation and product development including Unity, Unreal, CryEngine, Torque, Lumberyard, Stingray, and others. Small business and independent developers can even begin using these tools at little to no cost. It is important to find ways to adopt these technologies while maximizing reuse of existing content, software libraries, and interoperability standards and architectures.

There are valid reasons to be cautious about rapidly adopting gaming solutions. For example, because defense is not the primary customer segment for game engine developers, COTS engines do not concentrate on necessary features for asset reusability or defense-specific communication interoperability. OpenFlight, Common Database (CDB), or NAVAIR Portable Source Initiative (NPSI) are common 3D datasets used in subsets of the simulation community where the level of granularity shifts from miles to inches (see F-35 example above). Current attempts to ingest and instantly broadcast this data involves a tedious and inefficient conversion process to translate into native formats, such as FBX (Filmbox), that game engine editors support. Open source tools to streamline these processes have been lacking. For example, an open source library was developed to load OpenFlight models into Unity, but the conversion was not optimized and resulted in poor frame rates (Humphries, 2018). Game engines also do not yet support SISO interoperability standards such as DIS, HLA, TENA (Test and Training Enabling Architecture), CIGI, or WebLVC, though several organizations have developed custom libraries for one or more of these protocols. Still, additional features may be missing such as large terrain support, sensor visualization, validated ballistics simulation, or double-precision coordinate calculations, without which the IG may exhibit strange rendering artifacts. As a community, we are on our own to identify capability gaps and develop software features to more easily leverage these COTS technologies without reinventing the wheel whenever a new shiny tool appears. The military client truly depends on predictable and steady solutions, which can be a limitation in a technologically advancing world. Nevertheless, the MS&T industry must overcome these challenges by adopting an agile approach to implementing gaming technology. This is an opportunity to educate the client about what they need and how to ask for it. Together, jointly teamed as it were, modern gaming and traditional IG systems can reach a future that neither can alone.

Commercial Game Engines within the Military

There is a history of COTS game engines being used within modeling and simulation. Recent examples are illustrated below in Table 1.

Table 1. Sample Military Programs using Commercial Game Engines

Game Engine	Program\Application	Contractor
Unity	Distributed Observer Network	NASA
Unity	Crash Cart Countdown	Engineering and Computer Simulations (ECS)
Havok Vision Engine	Call For Fire Trainer (CFFT) 3	Nova Technologies
Havok Vision Engine	Common Driver Trainer	Raydon Corporation
CryEngine 3	Engagement Skills Trainer (EST) II	Meggitt Training Systems
Unreal 4	Littoral Combat Ship (LCS)	Cubic Global Defense
Unreal 4	Enhanced Dynamic Geo-Social Environment (EDGE)	Army Research Laboratory
Unreal 4	Dismounted Soldier Training System (DSTS)	Intelligent Decisions

One example of a COTS military training application is the Patriot Crew Drill multimedia instruction solution, which used the Unity game engine and was fielded in 2010. Developed by D2 TEAM-Sim for Raytheon, it provided on-demand training for Patriot Missile PAC-2 Missile crews at the point of need. Part of TRADOC's Connecting Soldiers to Digital Applications (CSDA) effort, Unity's ability to allow a developed solution to be deployed across different platforms (e.g., the web, iOS, Android, etc.) was key to its success. The award-winning solution was tested at Fort Lewis, Washington and Camp Lejeune, North Carolina and indicated commercial solutions to military training were both viable and effective. (Hypergrid Business, 2010)

Consideration to COTS must also address the integrated training challenges of cross-platform support as the U.S. military focuses upon a computing/network environment that encompasses the command post, mounted elements and dismounted personnel systems. Inherently, a multi-platform simulation solution becomes quite expensive if the solution required is an individual system capability requiring specific, or proprietary, software for not just the individual system but for each computing or network environment. This consequence, given traditional acquisition strategies, leads to a continued high cost associated with developing the middleware required to interoperate between both the training simulations and across the Command and Control (C2) / Mission Command Information System (MCIS) Common Operating Environment (COE). The evolution of the C2 / MCIS, especially within the U.S. Army, is creating an opportunity to further transition singular training system applications towards a more interoperable training environment utilizing industry standards regarding interoperability and programming.

Tomorrow's training simulations face a growing list of user wants-and-needs to incorporate future operational systems (currently under development), upgrades to pre-existing systems, potential enemy capabilities, and multi-domain mission requirements. One advantage of utilizing game engine technology is not just the speed with which industry is able to identify a solution, but the breadth and scope of talented engineers that are already experienced and capable to meet the expanding COE. There are several game engine solutions previously utilized, as exemplified earlier, but the industry itself has now matured to a point in time that engineers are able to rapidly scope, reengineer, iterate and publish a game engine solution across multiple platforms to a broad player audience. This capability is timely in that the U.S. Army, for instance, is likewise addressing virtual environment training challenges that must incorporate pre-existing technology (requirements and systems that address both individual, team and collective training) into a "Synthetic Training Environment" (PEO STRI, 2018) that is, as yet (possibly to our collective advantage), not fully defined. One of the challenges that must be addressed will be identifying a game engine solution that is not just able to incorporate authoritative data (task organization, parametrics, etc.), but also one that is able to be adjusted *easily* and *rapidly* at the point of need to address specific nuances in alignment with the training audience's objectives.

Finally, costs associated with development and fielding of any solution must take into account all associated licenses, royalty fees, and subscription options. In today's fiscal environment, a viable game engine solution will be one that allows the various Product Development teams', both MCIS / C2 COE and pre-existing training systems (to some extent), the ability to not just field a specified training solution, but also lead to a higher likelihood of interoperability across a broad spectrum of networked assets.

CASE STUDY: OPERATION BLENDED WARRIOR

One of the more forward-leaning exercises we have seen in recent years is the National Training and Simulation Association (NTSA) sponsored "Operation Blended Warrior" (OBW), which had its third year at I/ITSEC in 2017. In 2014, Naval Air Warfare Center Training Systems Division (NAWCTSD) worked with NTSA to create this I/ITSEC special event in which a real-time exercise is conducted on the I/ITSEC show floor. Utilizing the LVC capabilities brought by industry and government participants, it endeavors to uncover and document the challenges associated with incorporating LVC capabilities in a training environment. Volunteers from dozens of industry, government, and academic organizations are placed into a single synthetic environment for mock operational and humanitarian missions involving multiple platforms and protocols. The special event not only provides an opportunity to demonstrate LVC concepts and innovations, but also creates a unique research and development environment through the collaboration of exercise participants. OBW has attacked various focus areas including standards, cyber operations, multi-level security/cross domain solutions, performance measurement, live asset integration, and coalition support. For LVC, this is a huge boost in technology, not just in awareness but in experimental application. More often than not, the planning stages result in a constant stream of lessons learned, and technological challenges being discovered.

A continual challenge recognized by OBW2017 is that MS&T's desire for multi-domain training has been hampered in virtual environments since the inception of integrated simulation operations. Our inability to fully synthesize a shared battle space and its visual depiction has moved to the forefront of conversations about the next challenge to solve. The requirement to provide widely distributed simulations, across joint and coalition training audiences, necessitates the capability to provide near seamless, real-time IG. Crucially, this must be executed in such a way that the multi-service training audience does not inadvertently share-or-impose negative training transfer. Image generation must, therefore, account for the shared visual rendering of expected tactics, techniques and procedures (TTPs) that disparate members of the training "team" inherently affect upon participants' training transfer.

During OBW2017, some of the challenges gaming solutions could solve between branches (USMC, USA, USAF) were immediately identified, and in most cases manually adjudicated. For example, collective synthetic environments did not always share entity coding. Entities with their enumeration codes causing a mismatch at one end or the other would cause a ground force to see a beachball instead of tank or (in one case) a turkey instead of human. This amplified operational and environmental issues across many systems that, theoretically, should not experience them given old and current standards and acquisition stated goals. This presented multiple training transfer challenges as the TTPs, described below, were exercised.

During one exercise, the user perceived *realism*, per their pre-brief between training teams, was such that individual members felt they could carry out the tactical scenario regardless the fact that the IG was providing confounding information. The team knew what they were seeing was wrong but felt they were cleared (by the notional ground commander) to continue the mission anyway. Other elements in the same battlespace, seeing something different and not communicating correctly, stopped their scenario (and thus their supportive role in everyone else's). During OBW2017, USMC/USA ground forces identified a target which initiated a tactical air scenario (from one showroom floor booth) to be controlled by the USAF Joint Terminal Attack Controller (JTAC) (at another booth) and carried out by Army Close Air Support (CAS) (at another booth). The JTAC provided shared awareness of enemy forces correctly, but it was disparate from the IG's visual depiction as it was supposed to be according to the USMC's and JTAC's (different) 9-line mission calls. The ground forces would mask their location from the gun-target-line of the incoming CAS and the associated JTAC would likewise seek cover or concealment to enhance survivability. During these tactical scenarios, failure in correlated IG data led to shared negative transfer by all trainees. For instance, the JTAC believed himself to be concealed (from his perspective) behind a rendered object (e.g., building) that did not transfer to the ground system used as the "scenario server". Without this shared virtual asset, the JTAC would appear exposed to participants on other IGs, which often resulted in the enemy identifying the JTAC prior to CAS engaging the enemy. In similar fashion, the CAS asset would frequently be inbound along the gun-target-line and report that friendly ground forces were near and located "in the open" because the building, seen normally by ground forces using a different IG, appeared flat to the CAS pilot. Further, ground forces reported watching the CAS "porpoise" (i.e., erratically jerk up and down in the air) through both stationary objects and the ground, whereas the pilot perception was reported as nap-of-earth and safe.

Given what LVC&G can provide, if each of the three individual simulator devices in this scenario were employing the same low-cost gaming solution environment, instead of three separate (high-dollar) traditional IG solutions, then the mock operation would have reflected better battlespace awareness and better training for all involved. Better yet, if the systems were selected and implemented using a pedagogically-sound approach to training design, versus a technology-focused one, the exercise likely would have resulted in more effective and generalizable training. Without the integration of grounded cognitive psychology and instructional design principles, it's simply a coin toss as to whether or not simulation-based training will produce successful training outcomes. It must be understood that simulation technology is not an end in itself nor should it be used for its own sake; it is purely a medium for delivering training knowledge or experiences.

As it actually played out, there was little value for the operators other than a lesson on how *unreal* simulation can be for joint training. It should not be lost as a *lesson learned* that in an effort to buy and supply the highest-granularity, most comprehensive IG solution, Industry actually provided a sub-par solution with an unfortunate (especially for Industry) *lesson learned* that simulation was bad for multi-domain training. While these robust IG solutions sufficiently met the requirements for individual/service operators, they were simply not intended for a joint operation. Of course, this the exactly the kind of failure the OBW teams were chartered to uncover for Government and Industry. In this specific case, since high granularity and complex modeling logic is not absolutely critical to the more team-based and strategic learning objectives of multi-domain, joint, or full-scale training exercises, COTS gaming technology could offer a viable alternative to rapidly deliver high-quality, low-cost LVC&G solutions. Additional modern gaming capabilities have the potential to compliment traditional IG systems, especially in multi-domain training exercises – we just need to connect the two worlds.

NEXT STEPS

Individual cases aside, traditional LVC&G technologies do enhance military operational training and readiness even with the challenges. A general lack of scalability, adaptability, and interoperability between systems, coupled with the prohibitive time, resource, material, and logistical costs to address these issues, is inherent in many outdated, legacy and closed, stove-piped simulation applications. Moreover, budgetary constraints have contributed to the amount of outdated systems with less-than-modern visualization and realism. On the other hand, bolstered annually by over $18 billion per year (Statista, 2017) in R&D investments, commercial gaming technology offers state-of-the-art advancements in visual rendering, physics engines, artificial intelligence, and other capabilities. It is simply part of the gaming business model to constantly be better, faster, more accessible, more scalable, and more agile than one's competitors. Gaming does not rely on, in fact it cannot survive by looking for, proprietary follow-on business by stove-piping their technologies. Success on this side of the wire fence is in openness and adaptability. Game engines, such as Unity, offer the ability to efficiently develop and deploy applications across mobile, web, traditional desktop, and the latest VR/AR/MR platforms and facilitate flexibility and cost-effective delivery to users in a way that threatens the business model (and comfort-level) of the traditional MS&T communities.

While commercial gaming technology offers a viable alternative solution, its open-ended nature creates its own interoperability challenges. Without integration of standards-based communication protocols, intrinsic to distributed military LVC&G activities, these pioneering technologies offer only stand-alone applications. Furthermore, an inability to straightforwardly import and reuse common simulation assets (e.g., 3D models, geospatial terrain, etc.) in accepted data formats (e.g., OpenFlight, SE Core, NPSI, CDB, GeoPackage, etc.) adds to the current interoperability challenges for all involved.

We pose the use of disruptive commercial gaming engine technology in combination with simulation middleware to bridge the gap between gaming and military simulation. By simplifying the complexities associated with integrating simulation communication protocols into a Software Development Kit (SDK), interoperable training applications can be rapidly developed in preferred game engines. The logic to automatically import common terrain and model assets and populate model details and specifications (e.g., elevation, position, behavior, etc.) into a select commercial game engine can also be engineered to enable users to effectively reuse content without problematic format conversion processes. Additionally, popular game engines like Unity and Unreal have marketplaces, where users may purchase 3D content and software libraries from 3rd party vendors to provide added functionality and value. For MS&T application, the creation of a defense-specific marketplace for niche or controlled software plugins may provide additional value. The reduction in cost of using a commercial game engine as well as the availability of pre-existing models and software plugins have resulted in smaller monetary investments, less time, and smaller teams required to build prototypes (Rodabaugh et al., 2018).

More specifically, a simulation middleware SDK has been developed by SimBlocks.io to connect the Unity game engine with military training simulation systems. In relation to asset reusability, for instance, an OpenFlight model and terrain importer has already been engineered to permit OpenFlight files to be directly loaded into Unity's editor (see Figure 1). While popular commercial game engines like Unity and Unreal support import of interchange formats such as FBX and OBJ files in their editors, they do not support import of models saved in either format at runtime out-of-the-box. This middleware, on the other hand, enables run-time conversion of OpenFlight models into Unity's native asset format eliminating the need to import through the editor. In other words, both game-ready interchange and runtime formats for rapid model and terrain streaming on the client are generated.

Figure 1. Vacaville OpenFlight Database Provided by AVT Simulation Loaded into Unity

This approach enables existing simulation assets to be leveraged within a commercial game engine to support enhanced LVC&G training. For instance, this middleware has already been used to integrate Army defense terrain database insets with geospatial rendering of the whole Earth in Unity. On-demand access and streaming of highly detailed terrains within a one world terrain supports on-demand streaming of both sparsely populated and dense urban training environments. This capability to visualize OpenFlight content from multiple commercial vendors and government-provided SE Core databases has been successfully demonstrated in the Unity game engine at OBW (see Figure 2). By leveraging a lightweight and flexible middleware-SDK integration with the Unity game engine, disruptive commercial gaming technology was injected into a full-scale LVC&G exercise during OBW2017.

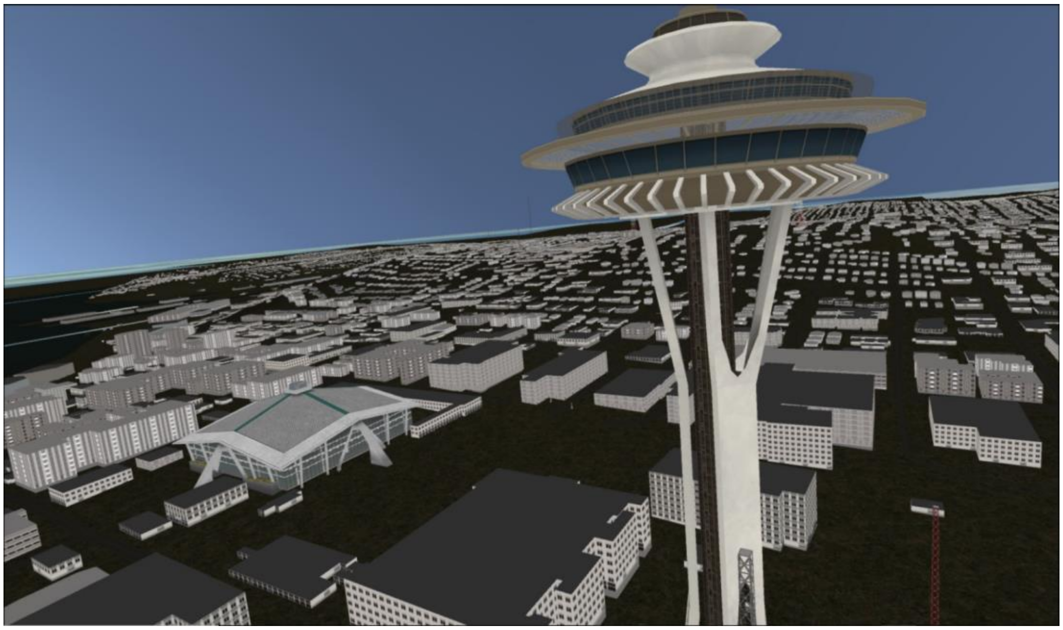

Figure 2. Emerald City SE Core Database Provided by U.S. Army Loaded into Unity

Lingering challenges remain which must be addressed to enable the MS&T community to fully leverage advanced gaming technologies for multi-domain IG solutions. While there are still LVC&G challenges requiring attention, such as MS&T standards, security, or general policies and approval processes, each are independently complex and are beyond the scope of this paper. Still, there are steps the community can take to better understand and leverage disruptive commercial gaming technologies. Flexible integrations of simulation middleware with game engines to support DoD MS&T interoperability standards is critical. Additionally, organizations can take advantage of COTS gaming tools by working with developers to integrate existing data libraries. Using a more collaborative, multi-vendor approach would accelerate innovation and all-inclusive growth for effective and efficient use of commercial game engine technology for LVC&G, multi-domain IG solutions.

CONCLUSION

In conclusion, the MS&T domain is in a state of transition. Reality compels us all to shift from a primarily rigid, black-box ecosystem to one that is more adaptable, accessible, and modular in nature. The complexity of modern warfare means that joint and multi-level operators can no longer train alone and then hope to integrate seamlessly on the battlefield. Training must be more timely and realistic. Fueled by overarching strategies to facilitate expedited development and updates of simulation systems, this transition is clear in current industry and DoD efforts and initiatives, such as OBW, the U.S. Army's STE, Air Force's SCARS, or the Navy's FACE™ programs, although these efforts to discern how to best learn to work together are, ironically, solo efforts. Commercial business trends have created an opportunity to leverage COTS game engine technology to advance DoD operational training and readiness. An open, modular simulation middleware solution which supports both commercial and industry interoperability standards would enable the MS&T community to rapidly engineer innovative LVC&G solutions and modernize military training simulations with game engines. As a result, the military will be empowered with a new shift in the LVC&G ecosystem: autonomy – the ability to select cutting-edge, commercial simulation and visualization technologies that meet their individual requirements, all without being locked-in to a single vendor, and at a fraction of the time, effort, and cost.

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