Distributed Live/Virtual Environments to Improve Joint Fires Performance

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ABSTRACT

An infantry platoon maneuvers toward a village; above them, an unmanned aerial system (UAS) provides a video feed to the operations center. The platoon reacts to nearby mortar strikes, while a Joint Terminal Attack Controller (JTAC) assigned to the company Tactical Operations Center (TOC) confirms the target with radio communication and the UAS's video. The platoon leader is relieved when an AC-130 takes out the mortar pit, but has to handle additional hostile contact from the village itself as the insurgents inside are emboldened by the mortar fire. It takes only a few moments for the situation to spiral out of the platoon leader's control; the company commander calls mission end to the virtual scenario. The pilot in the AC-130 simulator continues his own training mission. After the after action review (AAR) with the ground forces, the JTAC turns his attention from the virtual mission and resumes controlling live aircraft from his observation post (OP) in the desert, 1,500 miles away from the ground forces.

Building on three years of live and virtual environment development during Bold Quest (Reitz & Richards, 2013), BQ 14.2 will assess methods to improve joint fires performance using a mix of distributed live and virtual training systems. As a first for the Bold Quest live-virtual event, seasoned JTACs will be inserted into the virtual environment while they are still at their live OP, allowing them to control virtual aircraft in their natural environment with their real equipment.

This paper discusses the planning, execution and initial results of using a mixed live/virtual environment to improve individual and team performance in joint fires.

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INTRODUCTION

An infantry platoon maneuvers toward a remote village; above them, an unmanned aerial system (UAS) provides a video feed to the operations center. The platoon reacts to mortar fire from nearby insurgent forces, while a Joint Terminal Attack Controller (JTAC) assigned to the company Tactical Operations Center (TOC) confirms the target with radio communication and the UAS's video. The platoon leader is relieved when an AC-130 takes out the mortar pit, but has to handle additional hostile contact from the village itself as the insurgents inside are emboldened by the mortar fire. It takes only a few moments for the situation to spiral out of the platoon leader's control; the company commander calls mission end to the virtual scenario. The fire control officer in the AC-130 simulator moves on to his next training mission with another unit in central Europe. After an after action review with the ground forces, the JTAC turns his attention from the virtual mission and resumes controlling live aircraft from his observation post (OP) in the New Mexico desert, 1,500 miles away from the ground forces.

The scenario above outlines the promise of Live, Virtual and Constructive (LVC) training – an integrated and demanding training environment where warfighters come together to train in realistic joint and coalition operations. This vision was perhaps best captured ten years ago in the Department of Defense's Training Transformation Implementation Plan that described an LVC training environment that "[w]ill prepare forces by providing units and command staffs with an integrated live, virtual, and constructive training environment that includes appropriate joint context, and allows global training and mission rehearsal in support of specific operational needs." (Department of Defense, 2004)

Bold Quest, the Joint Staff-led coalition capability demonstration and assessment event originally conceived in 2001, provides a repeatable mechanism for multi-national, multi-initiative capability development and testing in a coalition operational context. Bold Quest 14.2 (BQ14.2) was conducted in May 2014 at White Sands Missile Range (WSMR) and Holloman Air Force Base, NM in conjunction with the Army's Network Integration Evaluation (NIE) and a Joint Training Exercise conducted by 1st Armored Division (1AD) at Fort Bliss, TX and WSMR. The combined NIE/BQ14.2 event represented an especially ripe venue for experimentation and assessment of LVC capabilities. Building on three years of live and virtual environment development during Bold Quest (Reitz & Richards, 2013), BQ14.2 assessed methods to improve joint fires performance using a mix of distributed live and virtual training systems. As a first for the Bold Quest series of events, BQ14.2 inserted seasoned JTACs into the virtual environment while they were still at their live observation post (OP), allowing them to control virtual aircraft in their natural environment with their real equipment.

JTAC READINESS

JTACs play a crucial role in the safe and effective integration of air and ground operations. They occupy a position in joint and coalition military services that is at once unique and yet highly representative of many military skillsets: highly qualified individuals performing a challenging set of tasks, requiring regular recertification to provide these critical services during operations. The doctrinal definition of a JTAC is "a qualified individual who, from a forward position on the ground or in the air, directs the action of combat aircraft engaged in close air support of land forces" (Joint Chiefs of Staff, 2009). Close air support (CAS) is defined as "Air Action against hostile targets which are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of those forces" (Joint Chiefs of Staff, 2009). The precise provision of CAS has been a feature of warfare since the advent of aircraft, and the continued development of the JTAC skillset has assisted in decreasing the risk associated with combining air and ground forces.

These skills include assisting the aircrew in locating the target; determining the safety of own troops; assuring and planning to provide for the safety of the aircraft (ground fire, other aircraft, weather); coordination with the movement of friendlies and of supportive fire; coordinating to limit the impact of collateral damage; weapons recommendations based on the circumstances; and damage assessment (NATO, 2011). In recent years these tasks have been complicated by the addition of UAS platforms in the airspace. Flexibility and quick judgment skills are required of the soldiers and airmen performing these tasks as they must adapt their decisions quickly in response to time sensitive changes in the battlefield, and disposition of friendly and enemy forces. While combat identification is currently accomplished through a mixture of human and technology solutions, the primary focus of the emphasis is placed on technology (Gadsden & Outteridge, 2006). JTACs are above all human decision makers, trained to use technology to support their decisions, but ultimately responsible for those decisions – the last gate-keeper in determining the safety of the troops for whom they are coordinating the close air support.

In controlling aircraft in and out of a battle space, there are three main types of controls that JTACs perform. "Type 1 control is used when the JTAC must visually acquire the attacking aircraft and the target for each attack" (Joint Chiefs of Staff, 2009). In this case the pilot may not release the weapon until the JTAC has visual contact with the aircraft and issues clearance for delivery of ordnance. "Type 2 control is used when the JTAC requires control of individual attacks and any or all of the following conditions exist: the JTAC is unable to visually acquire the attacking aircraft at weapons release, the JTAC is unable to visually acquire the mark/target, and/or the attacking aircraft is unable to acquire the mark/target prior to weapons release" (Joint Chiefs of Staff, 2009). Type 2 is often used at night, in poor weather, or when the JTAC is receiving information on the target from a remote observer, such as a Joint Fires Observer (JFO). "Type 3 control is used when the JTAC requires the ability to provide clearance for multiple attacks within a single engagement subject to specific attack restrictions, and any or all of the conditions exist: JTAC is unable to visually acquire the attacking aircraft at weapons release; JTAC is unable to visually acquire the target; and/or the attacking aircraft is unable to acquire the mark/target prior to weapons release" (Joint Chiefs of Staff, 2009).

The JTAC certification and qualification process is lengthy and requires at least one year experience in fires or air operations prior to commencing training, completion of a course of instruction at an accredited JTAC schoolhouse, at least 12 successful controls under the supervision of a qualified JTAC Instructor, and completion of an initial JTAC evaluation. Once they are certified, JTACs must remain qualified, and the requalification process is equally stringent. To be qualified, a JTAC must have six successful controls completed within a six month period. The six controls must consist of the following:

- Minimum of two Type 1 controls
- Minimum of one Type 2 control
- Minimum of three fixed-wing controls
- Minimum of one control must employ a ground laser designator
- Minimum of one must expend live or training ordnance
- Minimum of two "non-permissive" controls (where a high target area threat necessitates increased aircraft standoff distances)
- Minimum of one must be at night

These task-performance items do not include the rigorous theoretical and academic testing which must be passed every 18 months. The flexibility inherent in a JTAC's tasks is made clear in the definition of a successful control: "consists of at least one aircraft (fixed/rotary wing) attacking a surface target. Begins with a briefing from the [JTAC] and ends with an actual/simulated weapons release report from the attacking aircraft. Must have been in position to engage with the target by means of the weapons loaded, using the prescribed attack procedures. These successful attacks can also include runs where there is a positive abort called due to target misidentification, risk of fratricide, or safety" (NATO, 2014).

The Ongoing Case for JTAC Virtual Trainers

The ability to maintain an adequate population of qualified JTACs is constrained by the availability of live aircraft sorties, range access, and equipment to keep personnel trained and ready. In response to financial and throughput pressures, and increased demands for qualified individuals able to perform these complicated tasks, simulation-based training capabilities have been approved as providing credit for live aircraft controls (Joint Staff, 2013). According to the JTAC MOA, simulation devices must be assessed and accredited by the Joint Fire Support Executive Steering Committee (JFS ESC) for their capability to replace live controls for qualification training. Units with an accredited simulation device may replace a maximum of two live terminal attack controls per six month period. BQ14.2 was fortunate enough to have four participating simulation technologies that represented accepted and developing capabilities for JTAC training technologies:

- Air National Guard (ANG) JTAC Training System (AAJTS): JFS ESC-accredited system that supports JTAC currency training for Type 1, 2 and 3 controls, both day and night in accordance with the JTAC Memorandum of Understanding (Joint Staff, 2013). A new, highly capable JTAC virtual training system being deployed to ANG sites worldwide, AAJTS was fielded and supported at BQ14.2 by the prime contractor, QuantaDyn Corporation, and a team of subcontractors.

- Augmented Reality (AR) JTAC Trainer: Sponsored by the Office of Naval Research, the AR JTAC trainer was fielded at BQ14.2 by SRI International and Lockheed Martin Corporation. While not an accredited system, the AR JTAC system employs new and promising AR[1] technologies that augment the JTAC's view of the real world through standard optics that are modified to accept computer-generated virtual characters, vehicles and effects overlaid on that view. AR represents a blended mix of live and virtual JTAC training capabilities.

- Artificial Intelligence (AI) CAS Capabilities: Developed and fielded at BQ14.2 by Discovery Machine, Inc., the AI CAS system uses advanced AI modeling and voice recognition software to automate simulated CAS aircraft. The JTAC interacts directly with the AI model through voice communications and the model performs doctrinally-correct CAS behaviors. CAS aircraft models fielded at BQ14.2 included F-16 and MQ-9 (Reaper) aircraft.

- Predator Mission Aircrew Training System (PMATS): USAF's 16th Training Squadron at Holloman Air Force Base hosted JTAC teams for coordinated CAS and Intelligence, Surveillance and Reconnaissance (ISR) missions with MQ-1 (Predator)/MQ-9 (Reaper) aircrew students. Coordinated missions between JTACs and UAS aircrews provided opportunities for both sides to increase their understanding of the others' tactics, techniques and procedures (TTP), capabilities and limitations.

The AAJTS simulator represents a state of the art capability for accredited JTAC virtual training. It is a high fidelity, five-meter immersive dome with high resolution visual displays. Field of view is 270 degrees horizontal and 100 degrees vertical with 360 degree surround sound. The AAJTS visual displays can be populated with a full range of three-dimensional representations of operating environments, threats, and simulated forces. The virtual environment is rendered by a high fidelity image generation system that can produce all variations of day and night conditions. JTACs conduct training in AAJTS with a full suite of JTAC equipment, to include radios, binoculars, laser range finders, laser target designator, video downlink displays, night vision devices, etc. With these capabilities, AAJTS has been accredited by the JFS ESC as capable of supporting JTAC currency training (Joint Staff, 2012).

TOWARD INTEGRATED LVC FOR THE JTAC COMMUNITY

While LVC training may someday deliver on its original promise of providing an environment where warfighters can train in realistic joint and coalition operations, there are significant issues today in realizing that vision first described over a decade ago. A fundamental problem is the fact that we cannot yet fully represent the immersive virtual environment to the live warfighter. Generally, in an LVC environment the live player is unable to sense, communicate, or engage with virtual or constructive participants; therefore, there is no way for live participants to validly interact with other LVC participants, except with other live participants on the same training range. Essentially, during an LVC training event, the live player is simply not a full participant.

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[1] Augmented reality (AR) is a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

To better describe the current situation, we offer one of many possible examples. Imagine a simple LVC training exercise that consists of two infantry squads conducting training on basic dismounted patrolling tasks. One squad conducts a security patrol through an actual Military Operations on Urban Terrain (MOUT) site populated with live civilian and enemy role players, all of whom are instrumented. The second squad, located in a virtual replication of the same MOUT site, conducts a simultaneous supporting patrol in a virtual system, such as the Army's Dismounted Soldier Training System (DSTS). To enhance the richness of the LVC scenario, constructive systems may provide additional computer-generated friendly and enemy forces. Data from the live environment – live radios, live state data and certain weapons engagement data from instrumentation systems – can be translated into the virtual environment through interface technologies so that the second squad can observe the live participants, maneuver in and around them, communicate with them, and engage the enemy. However, because most current LVC technologies do not support full two-way interoperability between live and virtual domains, the first squad receives little if any information on events occurring in the virtual domain. For the virtual squad, this event may represent an effective and relatively complex training opportunity; for the live squad, who cannot see, locate or target the virtual participants, there is no "LVC" training, only live training.

This lack of bidirectional interoperability is a critical deficiency, especially at a time when DoD resource constraints are driving a reduction in live training opportunities – field training exercises, aircraft sorties, ship underway days – and an increase in the use of virtual and constructive training systems (Department of Defense, 2010). DoD's post-Operation Enduring Freedom resource outlook will remain constrained for the foreseeable future, while our force posture will demand that our training environment, especially that available from home-station, reflect the uncertainty and complexity of the future operational environment. While LVC capabilities must continue to advance to make the live warfighter an integral part of the LVC environment, joint trainers will continue to look to LVC environments to help improve the ability of U.S. forces to fight more effectively as a joint and coalition team.

Mixed Live/Virtual Training: Live JTAC – Virtual AC-130 Vignette

During BQ14.2, we decided to focus on assessing one method to allow a live JTAC team to control a virtual AC-130 gunship during a three-day field experiment as one small step toward closing the LVC gap. The AC-130 was selected due to its nature as a "high demand, low density" platform that most U.S. and coalition JTACs have little opportunity to work with in live training. Our plan called for the JTAC team to be located at a live OP on the range at WSMR with support from a live Predator UAS providing full-motion video downlink to the JTAC. C2 for the event was provided from an actual Air Support Operations Center (ASOC). Additionally during one of the three days, this mixed live/virtual vignette was planned to be augmented by a Quick Reaction Force (QRF) mission conducted by 1st Armored Division as part of an integrated NIE/BQ14.2 scenario vignette. During the QRF mission, the JTAC team came under attack from opposition forces (OPFOR) and required extraction by helicopter. To support this mission, additional live forces were added, including attack and transport helicopters (AH-1D, UH-60 and CH-47), a Platoon (minus) of QRF mounted on the transport helicopters, and a squad-sized element of dismounted OPFOR. Both the QRF and OPFOR on the ground were equipped with instrumentation.

To support the experimental portion of the event six JTAC teams (two per day) were originally scheduled to rotate through the OP; however, due to time and distance factors at a large range like WSMR, just three teams were scheduled. These teams consisted of a conventional U.S. Air Force team on day one; an Air Force Special Operations Command (AFSOC) team on day two; and a JTAC team from the Australian Army on day three. During their time at the OP, most of the JTAC teams were scheduled to control live aircraft too, so their mission preparation, equipment and mindset were as closely aligned to live training preparation as possible. The austere environment at WSMR also ensured that the JTAC teams had to deal with the real environment at the OP, to include mid-May desert temperatures, bright sunlight and gusting winds. The only planned virtual participant was the AC-130 Virtual Call for Fire Trainer, provided by U.S. Special Operations command's Joint Training Support Center at Hurlburt Field, FL.

The objective during this event was to make all interactions between the live and virtual participants – sensing, targeting, engagement and C2 – valid. This meant that the JTAC and the AC-130 had to be able to see the targets (fixed site and dismounted infantry), locate them with enough precision to engage them, and communicate air-to-ground to coordinate and execute joint fires. Our intent was to support these actions via full motion video downlink from the supporting live UAS; instrumentation from the JTAC team, QRF, OPFOR and fixed targets; and an interface device provided for the event by Advanced Simulation Technology, Inc. (ASTi) that bridged live radio transmissions from the OP to the virtual gunship at Hurlburt Field (see Figure 1).

As planning for execution evolved, there were a number of limiting factors. First, due to limitations in the instrumentation systems available, we decided not to try to represent weapons effects on the targets. Additionally, we encountered a number of issues during event execution with sporadic data feeds from the instrumentation systems. Second, the live Predator missions became unavailable just prior to BQ14.2 execution due to higher priority commitments and there was not enough time to coordinate a substitute platform to provide the requisite ISR support. Third, we conducted all missions with the AC-130 during the day rather than the more tactically correct night missions due to timing of live fly windows on the WSMR range. Finally, day two of the experiment with the AFSOC team was scrubbed because of a range fire in the area of the planned OP. Regardless of these limitations, the experiment was successful in collecting data sufficient to make some preliminary judgments and adjustments to future events.

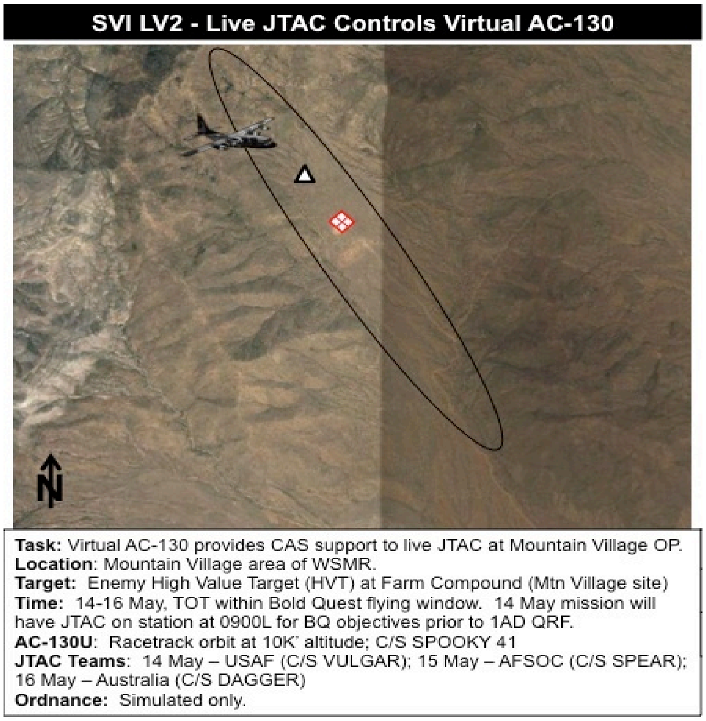

Figure 1. QRF Live/Virtual Activity OV1.

Participant Feedback

Thirteen U.S. and coalition JTAC teams cycled through the available simulators being assessed during BQ14.2 with many of them returning for a second round in certain systems. During this process, participants were asked to provide structured survey feedback on the mix of already accredited and still under development systems. While it has been proven that there is utility in providing training systems to JTACs, there is still much developmental ground to be gained to provide not only high visual fidelity systems but systems high in environmental stressors and task fidelity. Table 1 below depicts survey results for all JTAC simulators and for the mixed live/virtual AC-130 vignette, in particular.

Table 1. Participant feedback survey responses, post simulator training. 1=Not at all Adequate; 2= Generally NOT adequate; 3= Neither adequate nor inadequate; 4= Generally Adequate; 5= Very Adequate

	All simulators (N=18)	AC-130 Scenario (N=5)
Was the length (time) of the scenario adequate for the training exercise?	4.32	4.2
Was the scenario realistic enough for you to feel immersed in the exercise?	4	4
Was the scenario complex enough to challenge you?	3.78	3.25
Were the terrain, landscape, and buildings realistic enough not to cause a distraction to training?	4.17	3.5
Were the audio cues distinct enough to replicate patterns of life?	3.72	3.5
Were the visual cues distinct enough to replicate patterns of life?	4.22	3.75
Were the visual clues distinct enough to discriminate non-combatants?	3.83	3.75
Were the visual clues distinct enough to identify key individuals?	3.67	3.75
Were the audio cues distinct enough to identify the location of enemy forces?	3.78	3.75
Were the visual cues distinct enough to identify the location of enemy forces?	4	4
Was the opposing force ratio sufficient enough to evaluate the unit?	4.11	4

While the sufficiency of the training environment that was offered was rated “Generally Adequate” (score of 4), in terms of visual and audio quality, the task sufficiency results were the more important ratings. Participants gave a simple yes or no answer on whether they were able to accomplish the mission in the simulator they were assigned to. These ratings spanned multiple systems, though no one system’s score deviated from any other; thus results are provided in aggregate. Notably, separated out, the participants’ interaction with the virtual AC-130 integrated into the live environment was rated slightly lower than the aggregated group of virtual simulators.

This lower rating appears to be the result of us encountering many of the same problems in mixing live and virtual participants that we knew would be problematic. The lack of live UAS and somewhat sporadic instrumentation did not help, but even if those two areas had been fully functional, there would still have been gaps in the LVC environment we were trying to create for the JTACs. Even with a live video downlink, we still would not have been able to provide a representation of the virtual environment for the JTAC to perceive with his standard tools, such as binoculars, laser range finder or other optics. Even if we had accurately modeled the location of an approaching virtual OPFOR unit and delivered a realistic representation of the location and movement of that virtual unit via the live video downlink, the JTAC would still not have been able to look up and see anything with his eyes.

Despite the lower overall rating, we found that JTAC training with a platform like the AC-130 (which most JTACs do not get an opportunity to work with until they are in theater) is valuable, even with the limitations of our experiment construct. The AC-130 team at Hurlburt was very professional and responsive to interactions with the JTACs, providing each team a current brief on gunship capabilities prior to heading out to the OP and skillfully coaching the less experienced JTACs through tactical problems they encountered. JTACs were overall positive on the benefits of practice with the gunship crew. Additionally, interactions between JTAC and virtual AC-130 appeared to be realistic, to the extent that when one JTAC team received an on-station call from a live aircraft during a mission with the virtual gunship, the JTAC immediately de-conflicted the live aircraft’s altitude with that of the virtual aircraft.

Participants stressed that the virtual controls needed to be reinforced with live controls. Type 1 controls with UAS need to be added as well. Weapons effects on the targets should also be provided to the JTAC to support decision-making about reengaging the target. As one participant stated, “the fidelity and effects on the ground need to be realistic. Real aircraft make real mistakes; this is essential for a JTAC.”

In future collections, some items of expectation capture will be added as well, due to the subjective nature of asking a wide range of individuals and experience levels what is ‘sufficient’. One long-time coalition JTAC provided the following tempered feedback after his experience with the AAJTS trainer: “No further improvements necessary - there will always be a gap between a representation and actual live training. The sim meets the intent and no further improvement required.”

RECOMMENDATIONS

While delivering the virtual environment to a live warfighter is a challenging technical problem, the deficiency we describe here is not a new problem and is relatively common in today’s LVC training (Dean et al, 2004). However, we see several areas that show promise for improving JTAC training, but need additional research and analysis before implementation.

First, based on data collected over the last two Bold Quest events, augmented reality (AR) is a potential means to close this gap in LVC capabilities. Representing many of the best aspects of live and virtual training, AR allows a JTAC to train at a live range in actual weather, with real equipment, yet still enjoy the many advantages of virtual training – no need for live aircraft sorties, weapons or OPFOR. Providing regular training with live aircraft, weapons and OPFOR will become harder and harder to do as availability of aircraft diminishes, and could impinge on the ability to keep JTACs relevant and trained for the next conflict. AR technology has the potential to be a key component of the solution to providing bidirectional interoperability between live and virtual participants. While AR technology is still relatively immature, the AR technology demonstrated at BQ14.2 is evolving rapidly and has tremendous potential to contribute to the creation of more fully integrated LVC environments. Nine participants who used the system completed a post-use survey, rating it an average of 4.5 (strongly agree) in response to the question

"Other personnel in my unit could benefit from this capability as it is." Future Bold Quest events will serve as venues to more thoroughly examine how AR can contribute.

Second, one of the deficiencies in joint CAS identified as far back as 2003 is the limited opportunity for ground and air forces to train together in a joint environment (GAO, 2003). While training has come a long way since then, especially in our use of simulation to maintain JTAC currency, it is still difficult to compose simulation systems into an integrated joint fires team-training capability. In fact, the JTAC MOA suggests that "JTACs should satisfy their qualification requirements with ground maneuver units and JFO/FAC(A) [Joint Fires Observer/Forward Air Controller (Airborne)] integration whenever possible." While most simulators are built to use common international technical standards that enable distributed simulation, there are still many nuanced incompatibilities between simulators that are obstacles to building team-training capabilities. Past Bold Quest events have explored aspects of this challenge, but there is more work to do. One way to move forward in creating these complex training environments is to investigate the use of accredited JTAC simulators integrated with other select LVC training capabilities to improve joint fires team performance. While accredited JTAC trainers like AAJTS can add considerable value to allowing JTACs to maintain currency, they may not lend themselves as easily to integrated training in an LVC environment with live participants. Particular challenges are the difficulty and expense in generating and maintaining high fidelity virtual terrain databases and the relatively static nature of their technical configuration. Establishing the optimum mix of simulation tools across the spectrum of JTAC training – initial certification, currency maintenance and integrated team training – deserves further experimentation and assessment.

Finally, in addition to the demanding tasks of controlling aircraft, there is also an extensive mission essential task list that requires JTACs to develop proficiency in all aspects of providing CAS to maneuvering ground elements. Training in decision-making in uncertain situations must be carefully designed, but could address many aspects of combat-identification-focused training (e.g., see Greitzer & Andrews, 2010) and improve overall JTAC performance. This is also an area that deserves more analysis in future Bold Quest events.

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