Virtual Advancement of Learning for Operational Readiness with Non-Collocated Cross-Role Medical Simulation Training

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ABSTRACT

Medical simulation training is a critical component of maintaining readiness for a wide array of medical missions, but high-fidelity manikin training capabilities remain limited. These limitations are particularly acute given the need to train and sustain an agile combat force consisting of multi-capable warfighters who may be called upon to serve in operations with significant casualty burdens. Such warfighters must be ready to provide prolonged casualty care and maintain the quality of care across role transitions from the point of injury through to the point of definitive care.

In this paper, we will discuss the development of the non-collocated cross-role capability adapted into Virtual Advancement of Learning for Operational Readiness program. This VR capability enables trainees physically located at different installations and assigned to different roles of care to train together in a single virtual immersive domain using wireless virtual reality headsets. Casualties can be treated at every role of care and be handed off between roles of care in real time within the shared virtual domain, allowing complete end-to-end simulation training of the entire chain of casualty care. The developed capability is in operational use by US Department of Defense organizations with continued capability development.

1.0 INTRODUCTION

Medical simulation training (MST) provides the opportunity for trainees across the healthcare spectrum to put their knowledge into practice. Clinical evidence demonstrates that rigorous, continuous MST, when incorporated into medical education and sustainment curriculum, can increase provider confidence and competence, and thereby reduce medical errors. [1], [2] For medical military providers, MST becomes increasingly important as servicemembers are expected to provide medical care in collaboration with other teams and roles across the spectrum of injury and requirements. [3], [4]

Traditional MST processes often rely on high-fidelity manikin simulation (HFMS) and field exercises. Both modalities take place at large institutions and consume a high volume of logistical, personnel, and fiscal resources. As such, current MST paradigms include infrequent simulations during training efforts. Maintaining medical readiness hinges on continuous sustainment of medical decision-making and procedural skills to support the wide variety of scenarios encountered by medical warfighters. [5]–[8] A key component of operational medical support is the ability to train across separate roles of care–from the point of injury to forward surgical teams. The logistical complexity of traditional simulation methods is compounded when several teams are required to be in the same geographic location to train, which is not feasible on a regular basis.

There is an unmet need to create accessible, flexible MST tools that can be utilized by non-collocated teams for frequent medical simulation training. Accordingly, SimX, Inc. extended its Virtual Advancement of Learning for Operational Readiness (VALOR) platform to support non-collocated MST for medical handoffs, in collaboration with the USAF 24th Special Operations Wing and AFSOC Special Operations Center for Medical Integration and Development which provided subject matter expertise as well as testing, evaluation, and iterative feedback. This platform includes a moderator interface configured to support multi-team assignment and location, multi-way audio communication between learners and moderators, and handoff documentation. These features are integrated into a final operational medical scenario involving casualty support across three phases of care. The outcomes of this effort support future endeavors to enhance medical readiness training in several scenarios.

1.2 Virtual Reality for Medical Simulation Training

Recent advances in virtual reality (VR) technologies have enabled VR applications to be developed specifically for MST. Virtual reality MST (VR-MST) provides the opportunity to provide more dynamic learning and customizable curriculum experiences for learners. [9]–[12] Traditional simulation is often thought to be something that is only accessible to large institutions, however, VR-MST can be more affordable, accessible, and allows educators to simulate a substantially broader spectrum of realistic patient encounters than traditional modalities. [13] In this way, VR-MST can be done anytime and anywhere to maximize learning throughout one's medical career.

VR-MST can accommodate customized curriculum, something that traditional sim has struggled to accomplish with clunky and expensive manikins and rote scenarios limited to a few experiences with a narrow task list. Expanding one's learning and training ability with VR exposes learners to more realistic patient encounters that include psychosocial care and management as well as diagnosing and treatment. [6] For example, with VR-MST, one can not only diagnose and treat individual patients, but learners can be expected to interact with bystanders who may represent concerned family and friends, bystanders, or enemy actors. The learner can be expected to not only go through the right motions and use the right tools, but to develop the right problem-solving skills necessary to address situations within their environment that may cause further error or complication in the specific scenario they are presented with. In this way, VR-MST is far superior when it comes to simulation that is realistic, accessible, and affordable for both educators and learners.

2.0 VALOR Medical Simulation Training Program

The VALOR (Virtual Advancement of Learning for Operational Readiness) program is SimX's R&D effort whose mission is to increase medical mission readiness across the continuum of combat casualty care through more effective, more accessible, and more affordable medical simulation training. The main VALOR program objectives are to improve realism, increase flexibility, and reduce cost of essential life-saving training for elite military personnel. Efforts accomplished within the VALOR program not only benefit military partners, but also influence and improve civilian care scenarios. The VALOR program's strategic influence involves a shift in the way warfare happens. VALOR cases train military personnel to treat and transport serious injuries during the "golden hour", requiring individuals and groups to maintain a chain of essential movement and actions from injury all the way to final patient care. The VALOR program also addresses TCCC roles and tiers of care to allow learners to "train how they fight," not only with the actions and movements of strategic scenarios, but the psycho-realism of military environments essential to warfighter training.

The core capabilities of the VALOR Program software package include all-in-one headset compatibility, austere/disconnected usability, battlefield environments, debriefing/tracking, and various sets, kits, and outfits (SKOs) relevant to a multitude of scenarios. The system also enables significant flexibility including non-collocated multi-team training, dynamic scenarios, loadouts, and environments, and an increased ease of use.

Capabilities initially developed by the VALOR Program has been deployed to dozens of US DOD installations around the world. These capabilities include approximately 40 TCCC-oriented immersive scenarios, as well as another 60 scenarios for associated requirements (such as aerospace medicine, CBRNE response, field surgical care, and more) in development. These include patient encounters such as: mass casualty, multi-role combat casualty care, various rescue scenarios, and trauma care while under fire. The core technology which enables VALOR is the commercial VRMSS platform, which is a flexible commercial virtual reality medical simulation system which enables rapid development, iteration and deployment of medical simulation scenarios.

2.1 Virtual Reality Medical Simulation System (VRMSS) Platform

The SimX VRMSS (Virtual Reality Medical Simulation System) platform is the VR system that supports all scenarios within the VALOR program and beyond. This system allows moderators and learners to interact with and accomplish dynamic patient encounters in a variety of environments focused not just on essential patient care, but on addressing the psychosocial needs of each patient. Moderators of each scenario have control over and some degree of freedom in how the case unfolds for their learners. While each case follows a state flow pattern, the moderator has control over when each state progresses in the scenario. This gives them the ability to set the right pace for their learners and continue to challenge them throughout the simulation. Moderators can communicate with learners whether they are in the same physical space or remote. Remote communication happens in-game with a feature unique to the VRMSS's multiplayer capabilities. Because multiple learners can join the same scenario, communication is key to the success of each situation. Moderators can plan in advance and either encourage communication within the same space or coach learners remotely. During the scenario, learners are expected to complete a full spectrum of essential tasks from diagnosis to final treatment. For many military personnel, these tasks would include tactics, techniques, and procedures required within TCCC protocols. Scenarios also frequently require students to respond to and act accordingly within specific environments with the tools they would expect to find in real-life situations. Once the scenario is complete, the VRMSS provides feedback as a tool for further improvement. This feedback includes time stamps on each state progression as well as all essential tasks completed.

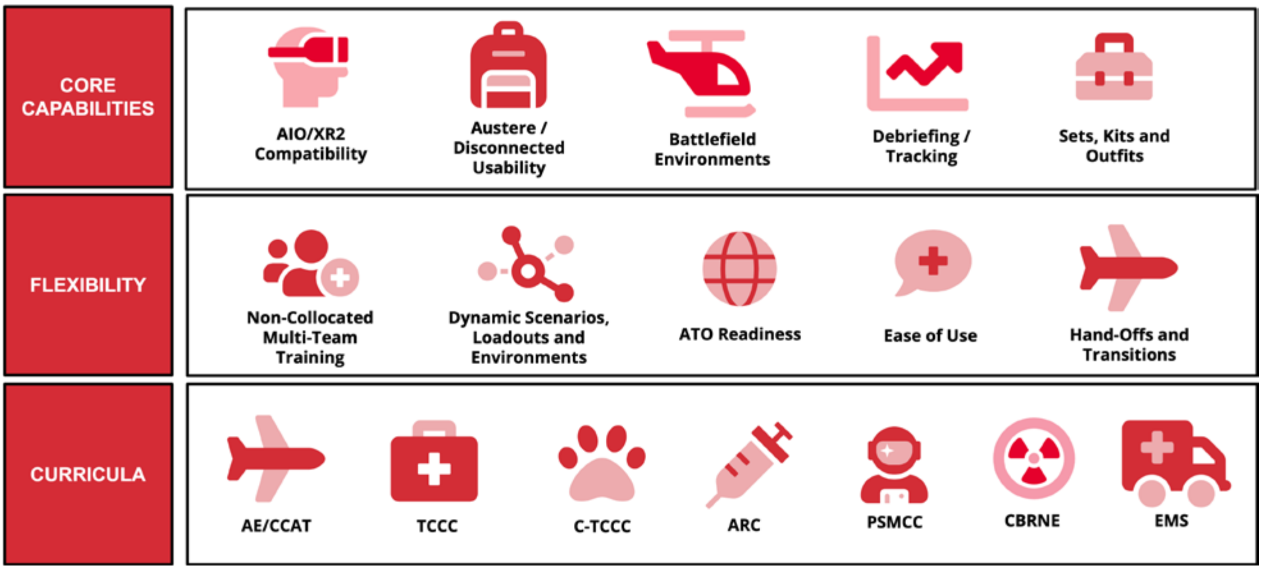

Figure 2-1: Overview of VALOR Program Capabilities.

3.0 NON-COLLOCATED TRAINING

One major potential benefit of VR-MST is the flexibility of choosing whether to train with all participants in the same location, or to train remotely across multiple locations. This contrasts to the requirement of traditional high-fidelity manikin simulation and full mission profile simulation, which require all participants to be physically collocated at the same training site. This requirement creates significant expensive and logistical overhead, reducing the frequency at which personnel stationed at different installations train together. However, modern militaries often must deploy combined forces from multiple components (or even national militaries) in support of operations together, creating a critical need for combined training.

In order to address this need, we built a new capability into the VALOR Platform which allows for all participants in a single simulation–along with moderators–to work together from the same physical space or connect over the internet to collaborate virtually. In this capability, participants (including trainees and moderators) connect via low bandwidth network connections from any physical training site to the virtual medical simulation domain. Once connected, learners are placed into a shared virtual space, in which learners and moderators can see, share, and interact with the same virtual environment while accomplishing the same patient encounter. Using virtual avatar-based telepresence, this capability allows individual trainees to train together in a manner similar to collocated training. A figure demonstrating two examples of non-collocated training situations made possible by VR-MST are shown in Figure 3-1.

An essential component of avatar-based telepresence training is audio communication, which becomes essential when learners and/or moderators are disparately located. Integrated in-headset communication enables participants to speak with each other despite geographical separation. In addition, learners are equipped with a virtual radio in the environment that allows the moderator to speak to the learners directly through the software so the player is fully immersed in the scenario while still communicating effectively with educators.

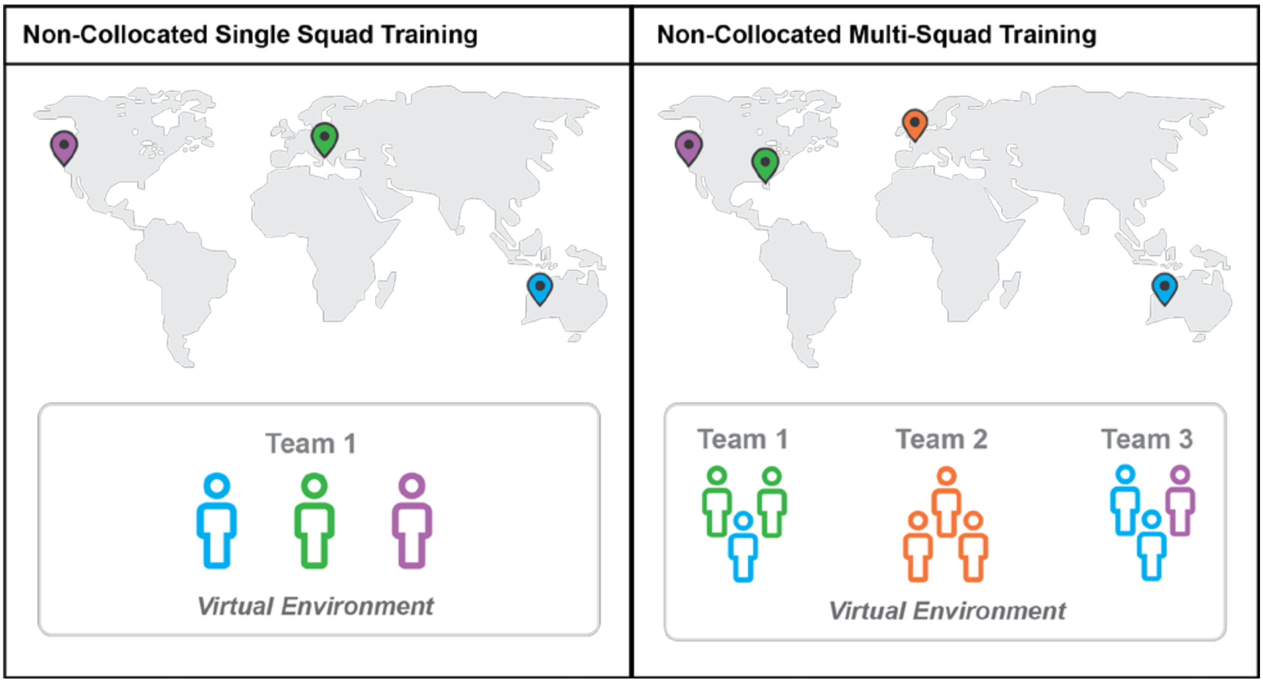

Figure 3-1: Examples of Non-Collocated Training Enabled by VR MST.

4.0 CROSS-ROLE TRAINING:

Another potential benefit of VR-MST is the potential for integrated training of combat casualty care across the roles of care, including both training communication across multiple teams, the handoff and transload process, and the serial management of interventions and injuries previously addressed or temporized at other points in the continuum. In order to address this need, the VALOR Program was adapted with a new capability to enable multiple teams of providers within the same scenario simulation. These teams may be located at the same or multiple virtual locations, and may transition between locations as required by the scenario. For example, a multi-role scenario involving a battlefield combat casualty may require the participation of a Role 1 team at the point of injury, a Role 2 team involved in TACEVAC, and a Role 3 team at a theatre medical facility. The trainees participating in each team may themselves be physically located at the same location, or may be distributed at different installations (see Figure 3-1).

In order to demonstrate this capability, a scenario prototype was developed that requires a single combat casualty to be managed by multiple different teams through the point of injury, TACEVAC, and forward hospital care. When the scenario begins, the teams start in their respective locations, summarized in Figure 4-1(B-D).

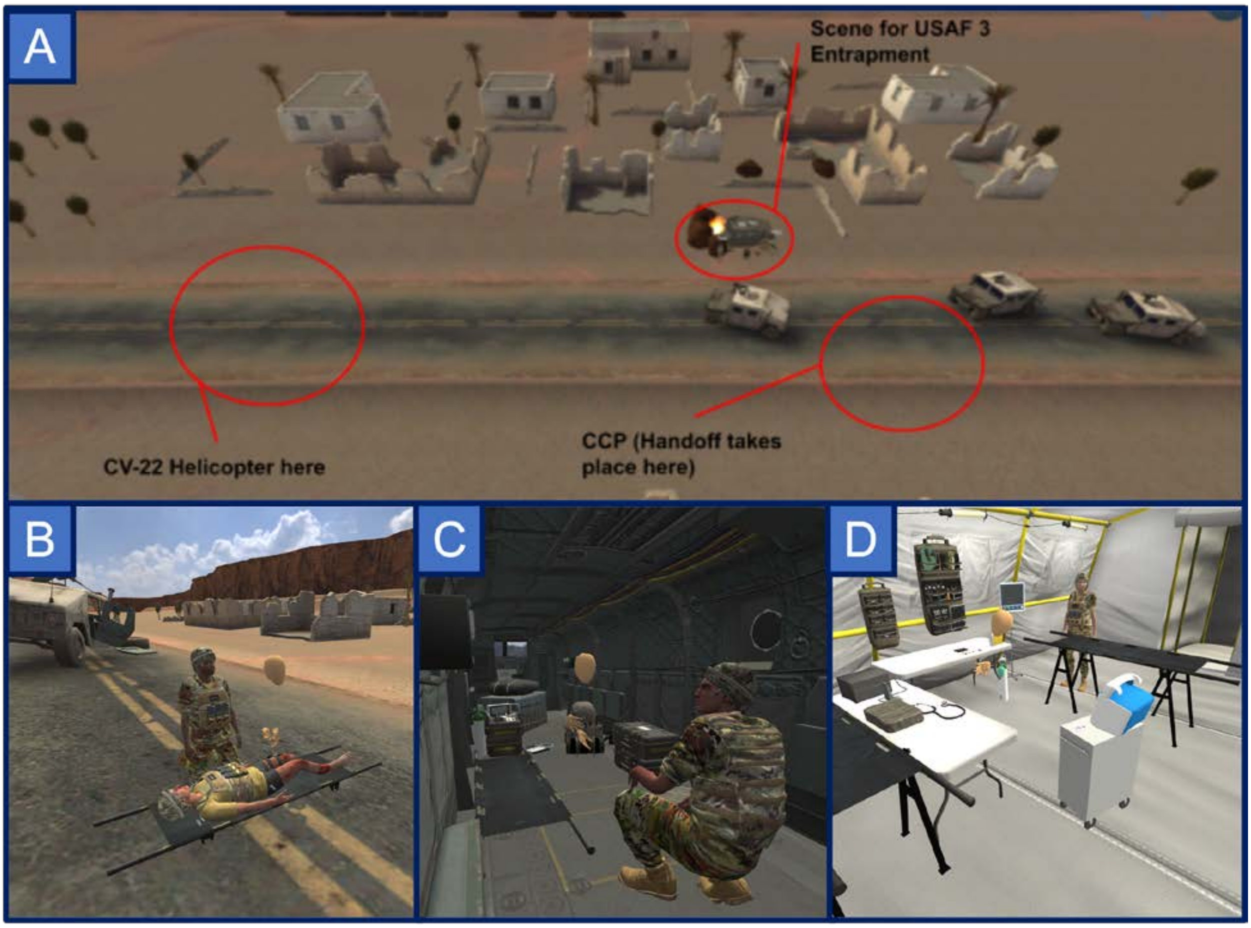

Figure 4-1: Environmental Overview of Training Scenario. A, Aerial Layout of POI Location. B, Ground Team Environment. C, Flight Team Environment. D, Hospital Team Environment.

4.1 Prototype Scenario: Team Overview and Learning Objectives

Team one starts the scenario on the ground managing the newly arrived patient at a casualty collection point (CCP). Team two starts the case en-route in a CV-22 transport helicopter. Team three starts at the receiving hospital. The patient was in a motor vehicle collision, and required a field amputation by a unit medic at the POI for extrication. The learners arrive in this scenario with the patient's leg amputated and a tourniquet in place with multiple other traumatic injuries including the other leg being broken. The patient has evolving injuries throughout the case that need to be managed appropriately to stabilize the patient. These management steps can happen at any phase of care, either at the point of injury, in transport, or at the field hospital environment:

1. Performs MARCH assessment to stabilize a wounded soldier in a casualty collection point (CCP).
    a. Addresses **Massive Hemorrhage**
    b. Evaluates **Airway** and secures when indicated
    c. Evaluates **Respirations**; recognizes pneumothorax and decompresses the chest
    d. Evaluates **Circulation** by reassessing hemorrhage control, diagnoses shock, and initiates resuscitation

        i. Identifies intra-abdominal injury and initiates blood transfusion
        ii. Identifies probable pelvic fracture and places pelvic binder
        iii. Initiates massive transfusion protocol
    e. Evaluates for possible **Head** injury
    f. Warms patient to avoid **Hypothermia**
2. Addresses patient’s **Pain**
3. Provides appropriate **Antibiotics**
4. Cleans and covers **Wounds**
5. **Splints** extremities appropriately
6. Recognize compartment syndrome - pain out of proportion to exam, unresponsive to analgesia, decreased passive range of motion
7. Perform procedural sedation protocol and fasciotomy for compartment syndrome
8. Manages crush injury, treats with fluid and calcium IV

There are also specific objectives to be accomplished by each team during their respective phase of care, summarized in Figure 4-2.

Figure 4-2: Team-Specific Learning Objectives.

4.2 Prototype Scenario: Patient Flow

The first team to manage the patient is the field team that starts the scenario at the CCP with the newly arrived patient. They receive a MIST report from the medic on scene and then begin the initial resuscitation. At this point, they are able to communicate via radio with the transport team that is in the flight transport (CV-22) environment. They are expected to give a report to the transport team who can then give advice on further patient management and execute any required interventions to stabilize the patient for transport. The scenario moderator then advances the scene, the CV-22 lands, and the transport team and the ground team are now both at the point of injury with the patient. The flight team receives a handoff, transloads the patient, and ensures the patient is prepared for transport. The moderator then advances the scene and the transport team and the patient remain on the helicopter en route to the hospital, leaving the ground team behind. The transport team continues medical management and resuscitation of the patient and are able to communicate with the hospital team over radio to give a report. When appropriate, the moderator will advance the scene again; the helicopter lands and the transport team and patient arrive in the field hospital with the hospital provider team. They now perform a handoff for the patient again to the hospital team, which then continues managing the patient. Throughout the scenario, learners are able to document their findings and care in the medical record via a virtual combat medical documentation interface (BATDOK). The patient information can be transferred between devices from the field team to the transport team and to the hospital team. An example of the BATDOK-based handoff interface is illustrated in Figure 4-3.

Figure 4-3: Illustration of BATDOK Handoff Interface with QR Code for Patient Transfer.

5.0 DISCUSSION & CONCLUSION

The resulting VR-MST capabilities allow multiple teams to participate in the same virtual domain while in either co-located or non-co-located physical spaces. This allows for learners to manage a complex injured casualty scenario from point of injury, to transport, and finally to hospital care. Handoff of patient care in a scenario such as this is a highly complex and potentially high-risk period for any errors. Practicing standardized protocols for handoffs and care transfer has the potential to improve communication and overall patient/casualty outcomes. Simulation is a high-fidelity modality to train how warfighters will actually be expected to perform in high-risk and complicated scenarios such as the example demonstrative above. Of course, patient management skills can be trained and developed in multiple modalities–including didactic, procedure skill sessions–however, the increased realism and immersive nature of full mission profile simulation may provide training which better represents the complexity of the continuum of care.

VR-MST offers an alternative to physically executed full mission profile exercises and can provide new capabilities that allow for multiple teams to work together to transition between various phases of care in a manner difficult to replicate with traditional sim. For example, with VR, a simulation can include the full TACEVAC process including the arrival of helicopter transport and transloads on both side of transit. Such an exercise would require significant expense and logistical complexity to arrange physically. Additionally, with the significantly lower logistical complexity, trainees and moderators can spend more time debriefing, repeating scenarios, and providing additional didactics.

Another benefit of the VR-MST approach is that the correct protocols can be programmed into the scenarios via critical actions, with these actions automatically tracked to progress the patient through various states to become stabilized, along with pre-recorded dialog and hints for moderator to guide scenario facilitation. This allows the facilitators to be less knowledgeable of the applicable medicine, and could allow more flexibility in staffing to allow simulation technicians to facilitate the scenarios with less medical expert oversight. Alternatively, because the software can be moderated remotely using the new capability, expert educators could join with remote groups to provide high level medical oversight of the scenarios virtually. The overall outcome is that trainees will be able to run highly complex medical training exercises more frequently with less resources, which we expect would provide improved learner competence, and lead to better patient outcomes.

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