A Vision for the Future of Military Medical Simulation

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ABSTRACT

The military has been a pioneer in healthcare simulation for decades, rapidly integrating new training technologies into programs of instruction and pushing the utilization of simulation technologies for first responders and beyond. At present, the military training enterprise, in particular that of the Army, are at an historic inflection point, as the Synthetic Training Environment (STE) develops, holding the promise of improving and modernizing the next generation of collective training. Concurrently, key enabling technologies, such as mixed reality, 3D printing, and artificial intelligence, are seeing explosive growth and development across the commercial and defense sectors. To lay the foundation for the next generation of medical training, the military medical community must leverage these ongoing efforts, while also undertaking critical science and technology (S&T) initiatives specific to the medical training use case. Within this paper, representatives from the Office of the Surgeon General, the acquisition community, and the S&T community have envisioned the future of military medical simulation, including a medical STE and the next generation of standalone medical training capabilities. This paper will present a research and development strategy, focusing on the technologies needed to actualize this vision, as well as a data strategy underpinning the technical implementation. To provide context, a series of use cases will be discussed illustrating how the implementation and execution of these strategies can result in improved training capabilities. The paper also includes a comprehensive concept for the evolution of military medical training with actionable steps to achieve this goal.

ABOUT THE AUTHORS

Matthew Hackett is a science and technology manager for the Combat Capabilities and Development Command Soldier Center. Dr. Hackett had led a variety of medical simulation and training research efforts, including holographic display research, serious gaming, training effectiveness, and simulator hardware. Dr. Hackett led the effort to modernize tactical combat casualty care training, resulting in a standardized curriculum and the Deployed Medicine platform. Dr. Hackett also serves as the technology committee chair for the Society for Simulation in Healthcare. Dr. Hackett holds a PhD in Modeling and Simulation, an MS in Biomedical Engineering, and a BS in Computer Engineering.

Beth Pettitt is the Chief for the Medical Simulation Research Branch at the Army's Simulation and Training Technology Center (STTC). Dr. Pettitt is actively involved in pushing research frontiers, testing, evaluating, and transitioning relevant technologies quickly, as well as managing the cost, schedule, and performance of the multi-million-dollar research efforts. Dr. Pettitt has a BS in Mechanical Engineering from Old Dominion University, an MBA from Webster University and a PhD in Modeling and Simulation from the University of Central Florida. She is Program Management Level III certified through the Defense Acquisition University and is a member of the Acquisition Corps. Dr. Pettitt has been applying creative innovations to medical simulation and training technologies for 25 years. Her current research is focused on optimizing and applying the correct level of fidelity according to the level of medical care.

Jack Norfleet is the Chief Engineer for Medical Simulation Research at the Simulation and Training Technology Center (STTC) of the DEVCOM Soldier Center under Army Futures Command. He executes medical simulation R&D while managing a multidisciplinary team of engineers and scientists. His current research seeks to improve medical training effectiveness by applying cutting edge simulation technologies. Interests include tissue characterization, advanced airways, synthetic environments, gender disparities, computer vision, AI, brain measures

of knowledge, multi-modal automated skill measures, and military working dog medical simulations. Dr. Norfleet started his federal career as a GS-1 student trainee in 1984. He has 38 years of experience in developing and fielding modeling, simulation and training technologies for the U.S. Army and U.S. Navy. His degrees include a Ph.D. in Modeling and Simulation, 2018, a Master of Business Administration, 2001, and a Bachelor of Science in electronics Engineering, 1990.

COL Paul Kwon is the Clinical Advisor for the Program Executive Office Simulation, Training and Instrumentation (PEO STRI) and liaison for MEDCOE and OTSG. He provides Subject Matter Expertise in medical simulation and product development as a former Level 3 qualified Acquisition Corps member. He has over 29 years of military experience in Active Duty and Reserves in roles as a Logistics Officer, Medical Officer and Linguists Team Leader. His specialties include Pediatrics, Preventive Medicine, and Occupational Medicine within academia, research, clinical and operational medicine. He has deployed as a General Medical Officer in Operation Iraqi Freedom and the ARCENT Public Health Emergency Officer in Operation Spartan Shield. His degrees include B.S. in Environmental Science and Systems Engineering, M.S. in Environmental and Civil Engineering, MPH in Occupational and Environmental Medicine, and a Doctor of Osteopathy.

LTC Sterling Brodniak is currently serving as the medical AFC LNO to the STE CFT since 2021. He joined the Virginia Military Institute's ROTC program while attending Southern Virginia University, graduating with the Distinguished Military Graduate Award. He then attended and graduated from the Virginia College of Osteopathic Medicine in Blacksburg, VA. He completed his Family Medicine residency in 2012 at Madigan Army Medical Center, JBLM, where he served as Chief Resident. Upon graduation, he served as the Battalion Surgeon in Afghanistan with 1-17th and became 2-2 Brigade Surgeon upon return from deployment. He was selected for his Faculty Development and Leadership Fellowship at Madigan Army Medical Center, where he graduated with his MBA in 2015. He joined the faculty at the NCC Family Medicine Residency, and during his six years there, he served as the Just In Time Trauma Simulation Director, White House Simulation Coordinator, Clinical Competency Chair, Program Evaluation Chair, Associate Program Director and Interim Program Director over the largest and only Tri-Service Family Medicine Program in the military. He loves spending time with his family and friends, going to the beach, sporting events, hiking, traveling, and just relaxing and watching movies.

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INTRODUCTION

The world is changing, and the Army must change to meet its challenges. Today's national security environment is "dramatically different and more diverse and complex…than the one we've been engaged for the last 25 years, and it requires new ways of thinking and new ways of acting," according to the former U.S. Secretary of Defense, Ash Carter. The strategic environment is complex, uncertain, and ambiguous at best. To prepare our Soldiers for this environment, we must create new simulation and training capabilities enabling improved readiness.

Focusing on the future needs of the military medical community, peer and near-peer environments will require significant changes in education and training. In recent operations, the US military was able to rapidly evacuate most casualties, allowing medical providers to focus on the 'golden hour' of patient care. As such, the military trained with a heavy emphasis on tactical combat casualty care (TCCC), which is the military standard of care for the treatment and stabilization of a battlefield casualty (Butler et al., 1996). In future near-peer or peer conflicts, evacuation delays may require providers to render care for significantly longer periods of time, in a concept known as prolonged casualty care (PCC) (Keenan & Reisberg, 2017). Additionally, advanced medical capabilities are being pushed further forward in the operational environment, including the provision of whole blood and the use of ultrasound at the point of injury (Cap et al., 2018). These changes require the medical provider, such as a combat medic, to have additional training, while also being able to adapt to challenging patient care situations over extended periods of time.

At present, Army medical training is conducted using a variety of capabilities based on the required skills of the provider. The Medical Simulation Training Center (MSTC) capability is a fixed facility skills-based training asset, culminating in immersive lane training exercises where individual skills are put to the test in the management of simulated patients. The MSTC is the primary accredited training capability for providing the required medical training and testing for 69 medical Areas of Concentration (AOC) and 8 medical Military Occupational Specialties (MOS). In addition to providing academic and task-based training, the expanded role of the MSTC also includes the training and sustainment of non-medical combat first responders and the support of individual, leader, and collective medical tasks. The MSTC offers the opportunity to train within a synthetic environment in an individual or collective maneuver group, under the chaotic conditions of battle. These training centers have been in existence for the past 20 years and trained 100 of thousands of soldiers. In addition to MSTCs, there are also simulation centers embedded into medical schools and medical treatment facilities; these are largely tailored towards nurses, physicians, and residency programs. The scope and geographic footprint of military healthcare simulation is vast, with the map in Figure 1 showing the various simulation centers within the Army and Army reserves.

The vision for the future requires the existing simulation footprint to continue medical skills training, while also expanding to enable training for prolonged casualty care, training at the Point of Need (PON), and integrating with the Synthetic Training Environment (STE). The future training ecosystem must be agile, interoperable, scalable, personalized, integrated to future systems, and continual for longitudinal learning. This will take feedback and experiential lessons from all users on all levels (tactical, operational and strategic) in order to modernize the way we think, the way we learn, and the way we win. Within this manuscript, a vision for the future of military healthcare simulation will be outlined, including a series of a short use cases and a technical roadmap to achieve this vision.

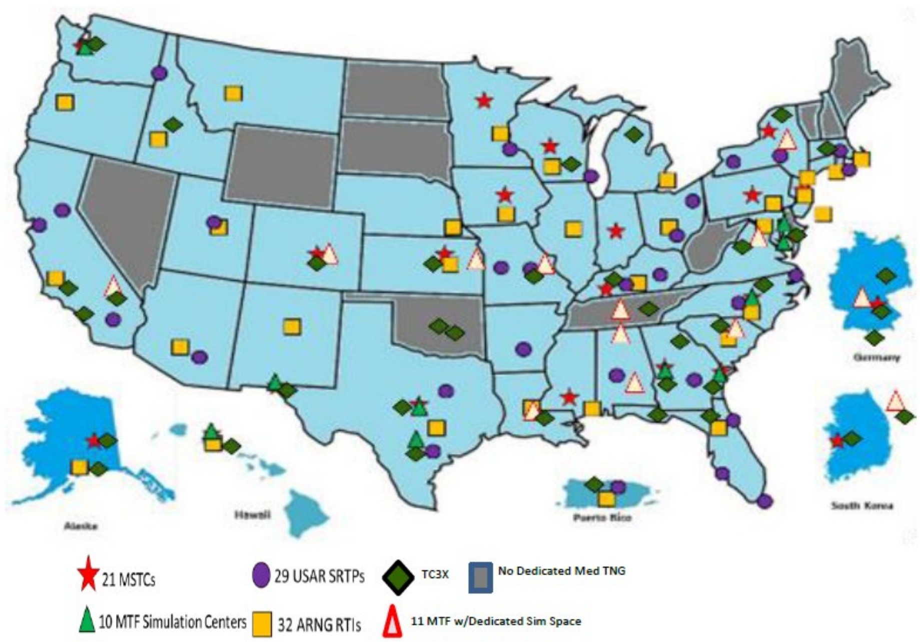

Figure 1: Map of Current MSTC Capabilities

THE FUTURE OF MILITARY MEDICAL TRAINING

In this competitive environment, the Department must pay much more attention to future readiness.
James Mattis, Defense Secretary (2017 House Committee on Armed Services)

The Army and Joint Force are undergoing a significant shift to a concept of Multi-Domain Operations (MDO), with a central focus on the rapid and continuous integration of all domains of warfare (TP 525-3-1, 2018). This requires Army modernization and innovation to compete and defeat near-peer and peer adversaries in a more complicated battlefield. To address the challenges of MDO and innovate the training ecosystem of the Army, the Training and Doctrine Command (TRADOC) Combined Arms Center for Training (CAC-T) is pursuing a comprehensive technology solution in the Army STE which includes Reconfigurable Virtual Collective Trainers (RVCT), a common global virtual terrain from the One World Terrain (OWT) program, robust training management tools, and virtual simulation platforms. TRADOC requires a common training environment that is modular and scalable, as well as utilizing adaptable industry standard data architecture and open-source software such as High Level Architecture (HLA).

The Army Health System (AHS) and U.S. Army Medical Center of Excellence (MEDCoE) must also adapt at the speed of innovation, modernizing training and operation at all echelons. The *Medical Support Concept to U.S. Army Multi-Domain Operations* (2019) identified the following challenges:

1) AHS support in a Joint environment
2) Integrated, interoperable, and synchronized medical alliances and partnerships
3) Flexible, responsive, and trained AHS
4) Prepare for and provide prolonged care
5) Plan, prepare, and execute strategic, operational, and tactical health information management, medical evacuation (intra-theater), and medical logistics that facilitate Joint force maneuver in all domains
6) Provide an integrated medical C2 capability

To define medical simulation and training requirements for MDO and future operations, the MEDCoE and broad military medical community completed a Capabilities Based Assessment (CBA) in 2021. The outcome of the CBA is included in the Draft 2023 STE CFT MS&T Capability Gap List. These gaps are outlined in Table 1.

Table 1: Medical Simulation Capability Gaps

Lack Performance Measures & Feedback	The Army lacks the ability to measure, document and evaluate outcomes via standardized, comprehensive Measures of Performance (MOP) and Measures of Evaluation/Effectiveness (MOE) for assessing and reporting medical provider proficiency and competency.
Lack Standardization/Standards of Practice	The Army lacks standardization of MedSim training capabilities and standards of practice to ensure consistent and effective application across Army units/centers.
Lack Trained SIM Operators/Evaluators	The Army lacks properly trained simulation trainers, facilitators, and evaluators to operate, maintain, and use equipment to its full potential to achieve desired student training performance results.
Lack Operational Realism	The Army lacks medical training capabilities that include required levels of operational realism to simulate the stressors of providing medical care in the FOE and prepare providers for mission effectiveness.
Lack Physiological and Behavioral Realism	The Army lacks medical training capabilities that realistically depict physiological and behavioral symptom presentation and patient responses to stimuli and treatment to train providers to the required level of proficiency.
Lack Replication of Disease/Injuries to meet training needs	The Army lacks training capabilities that replicate the variety of types and severity of injuries and disease to meet training needs
Lack Dynamic Capability – incorporation changes over time	The Army lacks training capabilities that simulate the degradation or improvement of a medical condition over time to ensure readiness of providers to perform under conditions such as prolonged care.
Lack Incorporation and Integration of existing & new Medical Equipment and Technology	Current Army MedSim-T capabilities do not incorporate existing and new medical equipment/medical devices into scenario-based training and curricula leading to provider unfamiliarity with wartime medical equipment sets/TO&E.

Fortunately, there are research and development efforts underway to address some of these gaps. The challenges in the interim include continuing to provide the necessary medical training required at all levels of care, while also investing in critical technologies to support the future Operational Medical Simulation Environment (OMSE) and STE. In this vision, the OMSE will serve as a stand-alone training capability focused on individual skills training. The OMSE will fulfill the current needs related to MSTC training, while greatly expanding technical capabilities to address the aforementioned gaps. Importantly, the OMSE will allow for usage both as a fixed facility as well as a point of need training capability. This will enable the OMSE to fulfill current medical training requirements, while also scaling to address the needs for the Individual Critical Task Lists (ICTL) associated with higher echelon providers.

In addition to individual skills, the OMSE must enable integration with the STE for collective training. The STE has live, virtual, and constructive components, all connected via a common architecture. Medical simulation S&T is working across all three domains and given its maturity, the live STE is targeted for the first STE medical capability. STE live training systems must have a meaningful and realistic casualty generation capability beyond the Multiple Integrated Laser Engagement System (MILES) casualty cards. Wounds must be consistent with the weapon type and hit area in order to communicate the medical and tactical effects of casualties. Treatment at the point of injury is required without changing the collective focus from tactical to medical. Just like the warfighter uses surrogate weapons, S&T is developing smart surrogate medical devices that are applied to actual soldiers with no risk of harm. Smart injuries applied to the soldier or embedded in training uniforms are also being explored. As capabilities mature, wounds and medical equipment are expected to be depicted virtually through the STE head-mounted display. The capability to provide the sensation of touch for assessment and treatment in a virtual is also being explored. This STE medical-live progression is depicted in Figure 2.

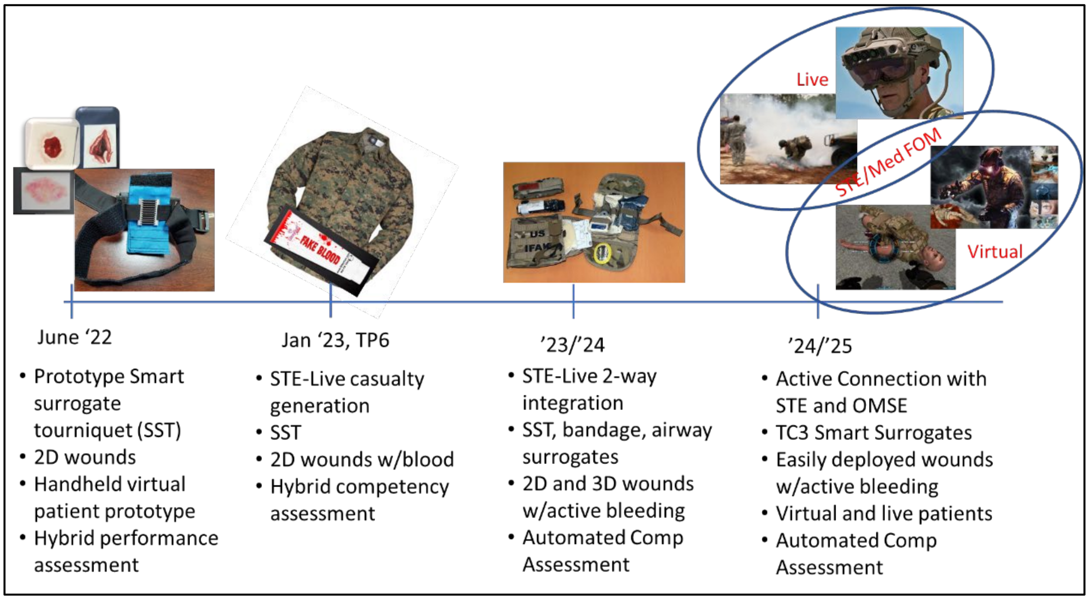

Figure 2: Notional Medical in STE Live

The importance of data in a large joint simulation and training event like STE cannot be understated. Moving informative patient data and medical treatment resource information is essential for the medical community to effectively use a live, virtual, constructive training capability like STE, see Figure 3. The medical data will likely use a standard data structure such as a federated object model (FOM) or something functionally similar. Efforts are underway to define and create a medical FOM for the OMSE that can integrate with the STE.

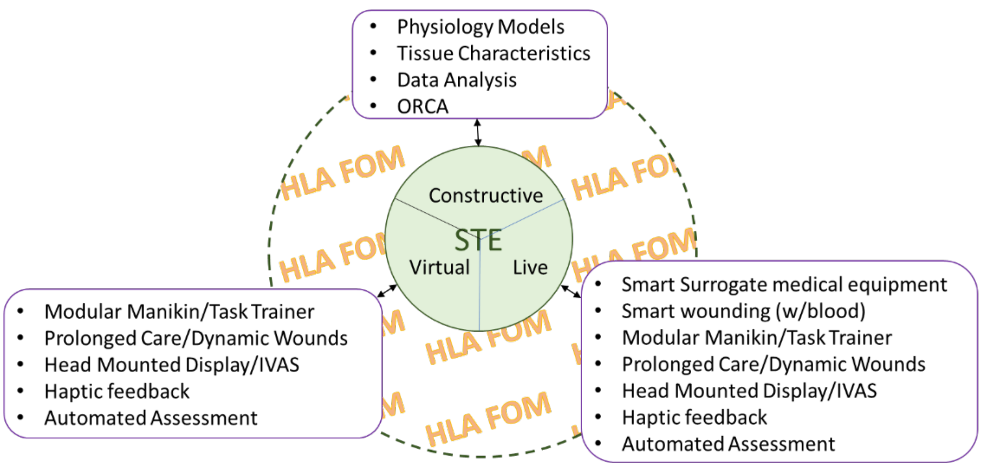

Figure 3: STE Medical

The STE only requires minimal casualty data such as time, injury type, location of wound, vitals/condition, treatments, and transport. OMSE necessitates a much richer data set to create a medically viable patient, requiring a data expansion from the baseline STE data. With expanded patient data, the simulated patient can be instantiated in other domains. In live, moulaged soldiers, manikins and task trainers simulate the patient for hands on skill training while providing natural haptic feedback. The virtual domain provides improved and dynamic visuals but limited haptics. The constructive domain provides physiology and changing patient conditions. Hybrid approaches and mixed reality solutions are being investigated to combine advantages of each domain into more comprehensive training environments. The stimuli will be automatically queued based on the scenario and learning objectives. Additionally, student performance assessments will include automation, allowing the instructor to serve as an expert tutor, reinforcing areas requiring extra instruction. STE will provide the appropriate environmental assets and behaviors such as air and ground units and patient movement and treatment. Detailed medical instruction and task training will occur outside of the STE in the OMSE.

MILITARY MEDICAL SIMULATION USE CASES

To clearly envision the future of military healthcare training, a series of use cases are proposed that demonstrate how the simulation technology ecosystem will apply to various training needs. These use cases cover unit-level training, graduate medical education, and collective training. Additionally, instructor needs are detailed.

Unit Level Training

The first use case focuses on an infantry unit preparing for a deployment. In this case, the unit must complete training related to battlefield medicine, primarily training tactical combat casualty care at the Tier 2 Combat Life Saver level (Hackett et al., 2021). To begin, Tier 2 TCCC requires the knowledge of common injuries, treatments, and phases of care; as such, a didactic component is needed. Further, TCCC focuses heavily on individual psychomotor skills, such as tourniquet application, wound packing, and airway management. Due to time constraints, the unit is unable to travel to a fixed facility for this training, requiring PON training at the unit's current location.

To serve this unit's needs, the future simulation ecosystem must be flexible and portable. In this case, the technology must be easily packaged and delivered to the PON. Mobile applications such as the Deployed Medicine application are ideal for facilitating the didactic component of this use case. The significant psychomotor skill associated with TCCC necessitates training aids focused on individual skills. Since training will occur at the point of demand, training aids with large logistical footprints, such as high-fidelity manikins, will not serve the unit's needs. Task trainers are better suited for this level of training. In some cases, portable, untethered virtual reality (VR) systems can provide immersive training for procedural skills. Importantly, these VR systems should employ inside-out tracking, thereby removing the need for external tracking sensors. This suite of training aids would meet the unit's training objectives and address the logistical considerations necessary for PON training. Notably, the equipment will operate on a common architecture, ensuring modularity and interoperability.

Graduate Medical Education

The graduate medical education (GME) system in the military is unique, as it must train physicians not only in their chosen specialty or subspecialty, but also as a military physician, ready to conserve the fighting strength. The military GME programs benefit greatly by utilizing nationally recognized simulation centers at military academic centers, which have been instrumental in the success of GME programs (Deering et al., 2012). Simulation is used in GME programs in the military to assess and educate the learners on patient care, procedures, communication, professionalism and medical knowledge (McLaughlin, 2008). Simulated procedures and cases have aided in assessing competence and obtaining certifications and credentials during times of decreased patient loads.

While the board scores and pass rates are some of the top in the nation, graduation surveys show that many graduates in many specialties and subspecialties do not feel confident in their roles as military physicians in the operational field. Military GME learners attend a simulated operational medical exercise prior to graduation. These exercises are exciting and give the residents an opportunity to perform critical tasks – sometimes for the first time, and then they will not see or perform these tasks again until they are in a battlefield setting. To fill this gap, the residents will need education, repetition, and validation prior to, and following these training exercises.

The introduction of Individual Critical Task Lists (ICTLs) is an attempt to fill a gap for those who do not perform certain procedures or skills on a regular basis. By implementing ICTLs into the OMSE, resident physicians will be able to practice scenarios in a safe and controlled environment, with standardized cases. By pairing a training platform able to assist with the ICTLs with existing simulation centers, outcomes of improved competencies, increased confidence in the operational environment, and decreased morbidity and mortality on the battlefield can be achieved.

Medical Instructor

The above use cases focused on specific training audiences with diverse needs, highlighting unit level CLS training and GME level education and training. In this use case, the focus is on the needs of the instructor. Military healthcare instructors are often overburdened, with a high student throughput combined with strenuous training objectives. The future training ecosystem must be simple to set up and operate; learnability and usability of these systems is critical (Jordan, 2020), especially as these technologies become more complex with the addition of mixed reality (Akcayir et al., 2017). It's important to emphasize that the instructor's primary role is guiding trainees in pursuit of training objectives, not operating simulation equipment. As such, the ability for simulation technologies to operate autonomously or semi-autonomously is critical to reduce instructor workload and allow them to focus instead on student instruction. Finally, a better understanding of student progress and proficiency is central to the future vision of simulation. The training aids and assessment instruments should aggregate and provide simple visualizations conveying information on student and class performance.

Collective Training

The final use case to highlight is collective training, wherein the military medical provider is embedded with non-medical trainees into a larger exercise. This may occur via live, virtual, or mixed training modalities, and will likely be facilitated via the STE. During these exercises, both medical and non-medical personnel should be able to render appropriate casualty care, without overburdening the overall logistical considerations of the exercise. This requires minimizing the technology footprint of medical simulations, reducing the data passing through the network, and focusing on the key medical treatments for collective training. In short, the STE should focus on collective training objectives, including: casualty stabilization, patient movement, and establishment of a casualty collection point. The delineation of individual skills and collective skills in shown in Figure 4, highlighting the roles of the OMSE and STE.

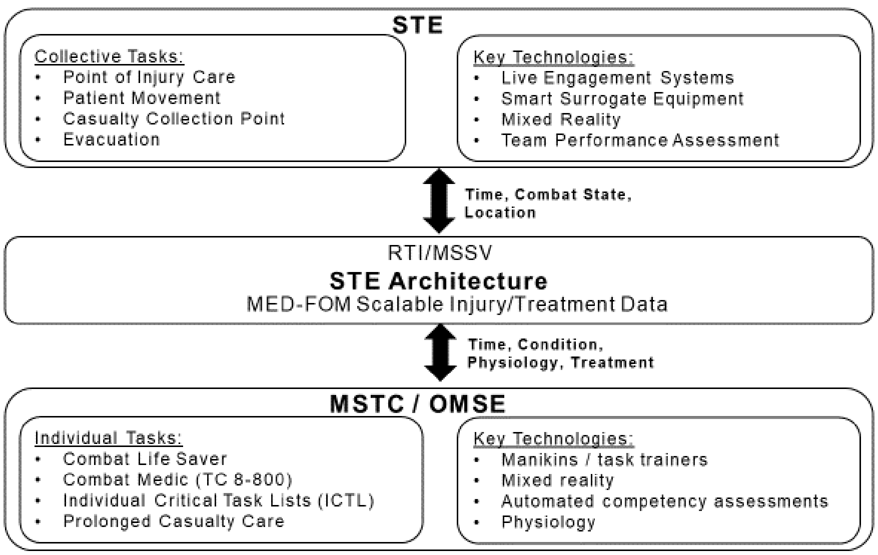

Figure 4: STE and OMSE Skills and Technology Delineation

FOUNDATIONAL TECHNOLOGIES

The diversity of the use cases highlights the challenges to providing a healthcare simulation ecosystem to the military healthcare community. The solution requires scalability, modularity, and portability, while also embracing future technical trends in mixed reality, data engineering, and materials science. Specific enabling and foundational technologies are outlined below, and Figure 5 depicts several.

Figure 5: Technologies including Manikins, Virtual Reality, Haptics and Automated Assessment

Manikins and Part-Task Trainers

Physical medical simulators, including manikins and part-task trainers, have been shown to be effective to improve both procedural and psychomotor skills for civilian and military healthcare providers (McGahie et al., 2010; Sotomayor et al., 2013). Current simulator hardware typically operates on a vendor specific architecture, with limited interoperability. To enable better flexibility and reduce vendor lock-in, efforts are underway to create modular architectures (Hananel et al., 2021). Modular simulator architectures have the potential to tailor simulation capabilities based on user needs, as well as enable best of breed solutions with an integrated solution of marketplace products.

Virtual Reality

VR places the user in an immersive, computer-generated environment, often in a head mounted display (HMD). VR has tremendous industry interest, with the consumer space rapidly advancing the capabilities of HMDs and graphics engines; major corporations such as Meta, Google, Microsoft, HTC, HP, and many more have heavily invested in this space. Training is a notable use case for VR, enabling the practice of complex real-world activities without the cost associated with real world assets. VR has been used across the training spectrum, ranging from power line maintenance (Ayala Garcia et al., 2016) to construction engineering (Wang et al., 2018). In healthcare, VR has been used as a training aid for orthopedic surgery (Aim et al., 2016), anatomical education (Falah et al., 2014), laparoscopic surgery (Akcayir et al., 2017), and trauma skills (Harrington et al., 2018). VR represents a highly useful tool, with the ability to immerse learners in the training environment while maintaining a small logistical footprint. VR also fits nicely as a practice modality, reinforcing lecture and allowing trainees to practice procedural skills prior to higher resource training, such as high-fidelity manikins. The key gaps in VR are related to comfort (size and weight), content, and user interaction.

Augmented / Mixed Reality

Augmented, or mixed, reality (AR/MR) entails the blending of physical and virtual worlds, enabling the presentation of computer-generated visuals overlaid on a real-world scene. HMDs such as the HoloLens and MagicLeap are commercial leaders in this domain, with other companies also developing solutions. With MR, the user can see the surrounding environment, allowing them to interact with real objects during a training session. In medical training, this might include wound overlays on a manikin, augmented visual instructions, or other synthetic visuals overlaid onto a medical environment. Prior research has demonstrated AR success in training minimally invasive surgery (Lahanas et al., 2015), ultrasound (Blum, et al., 2009), and critical care and trauma (Azimi, et al., 2018). Key gaps include field of view, display brightness, dynamic occlusion, and precise image registration.

3D Printing

Historically, 3D printing was used to print hard materials using thermoplastics, notably polylactic acid (PLA). For healthcare training, 3D printing has been used to create anatomical models (Smith et al., 2018), simulated bone (Mowry et al., 2015), or components in task trainers (Pedersen et al., 2017). More recently, advances in 3D printing allow the use of alternative materials, such as latex and silicone, to print soft materials. 3D printing of soft materials enables printing of consumables for task trainers and manikins, such as skin to incise or inject. Additionally, pathology specific components can be printed based on the needs of the trainees. For example, if a unit is deploying to a location with a tropical disease that presents with a distinctive pattern of rash and sores, skin simulants showing that specific pathology could be printed allowing trainees to recognize the symptoms and practice treatments. Broadly speaking, soft tissue printing can increase training capability with high fidelity simulants, while also reducing the logistical burden of ordering consumables.

Physiology Engine

Underpinning nearly all healthcare simulations is a physiology model, which drives patient vitals and responds to trainee interactions. In general, there are two variants of physiology models – state-based physiologies and self-compensating, dynamic physiologies (Talbot, 2013). State-based physiologies have the benefit of simplicity, but struggle as the number of treatment branches and decision points grow. Dynamic physiology engines enable more open-ended interaction without pre-scripted physiological states but are significantly more complex to develop and author new patient cases. To serve the needs of multiple training audiences, a physiology model is needed which is scalable and usable across multiple simulation systems. Multiple engines have been developed over the years, including BioGears (Baird et al., 2020), Pulse (Bray et al., 2019), and Hummod (Hester et al., 2011); each has tradeoffs related to computational efficiency, ease of modification, and level of fidelity. Research is ongoing using these platforms to create validated physiology models with scalable fidelity, enabling use in low fidelity point of injury simulation through high fidelity surgical care.

Haptic Technology

Training medical care requires significant psychomotor skill, and simulator interfaces should be comparable to actual patient / provider interactions. Achieving this is a significant technical challenge with a variety of approaches. To begin, a physical device can be incorporated into an MR setting, such as using a low-fidelity manikin with an HMD for augmented wounding. For pure VR or MR without physical surrogates, alternative technologies will be needed to provide tactile sensation and force feedback. Haptic gloves are one potential solution, which use electromagnetic or pneumatic actuators to provide haptic sensation (Perret & Poorten, 2018). Commercial companies like HaptX, VRGluv, Teslasuit, and BeBop Sensors produce gloves with various capabilities. While current capabilities show promise, research and development is needed to reduce the size and weight of the gloves, improve force feedback, and reduce cost. Non-glove based haptic feedback can be achieved using focused ultrasound (Rakkolainen, 2020) or potentially direct neural interaction, but these techniques are nascent with limited evidence in the body literature.

Automated Assessment

Medicine relies on the "see one, do one, teach one" learning model. While long lived, this subjective model does not always predict future performance. With modern training technologies, objective performance measures are available throughout live and virtual training environments. Patient simulations document condition and events, environmental sensors track movement and position, biometric sensors detect trainee conditions, and video capture documents the exercise. Research is ongoing to utilize these multi-modal measures to build performance and competency models. Computer vision (CV) is showing promise in perceiving and understand the training event. It can detect medical objects and events for multiple trainees working simultaneously (VanVoorst et al., In Press 2022). The output of this new capability is synchronized video for after action reviews (AAR) where the pertinent events and objective metrics are automatically bookmarked across multiple video streams. Since CV can detect medical events, the next logical step is teaching the computer to measure the quality of the medicine and determine when competence is achieved. For this research area, competence is defined as the point where the task performance is successful, and knowledge is transferred. CV based observation can detect successful task performance, and biometrics are being studied as indicators of knowledge transfer. Functional near infrared spectroscopy (fNIRS), eye tracking and pupil reactions have successfully discriminated between experts and novices (Gao et al., 2020). Assessment systems can measure a huge number of factors; the hard part is determining what should be measured to declare competency and confidently predict future performance. This research shows promise for vastly improving understanding of student competency and fostering the personalization of training to individual needs.

DATA STRATEGY

There have been numerous data related efforts and directives across the DoD, Army, and the Advanced Distributive Learning (ADL) initiative. As part of an enterprise-wide response to growing data requirements, the *Enterprise Digital Learning Modernization* (EDLM) reform included the establishment of a DoD Learning Enclave (DLE). This was intended to be a cloud-based set of enterprise digital learning systems with conformant learning activities, and the data management infrastructure to support the DoD education and training community. In parallel with this effort, the ADL initiative completed a multi-year study on the future of learning, developing a path to connect nodes of lifelong learning across time, location, purpose, and context. The ADL envisions a system of systems and network of networks intertwining a blend of formal and informal methods of learning to create the Total Learning Architecture (Folsom-Kovarik & Raybourn, 2016), which adjoins the EDLM, see Figure 6.

Of additional note, the *Modular Open Systems Approach* (MOSA) enacted by the National Defense Authorization Act (NDAA), is an integral acquisition strategy to achieve affordable joint combat simulation training capability. MOSA is an enabler for cost savings, increased operability, and rapid insertion of new technology for Soldier use. There are five key principles of MOSA: 1) Establish Enabling Environment; 2) Employ Modular Design; 3) Design Key Interfaces; 4) Select Open Standards; and 5) Certify Conformance. Further, the Army for Acquisition. Logistics, and Technology (ASA(ALT))'s *Common Modular Open Architecture* initiative is the foundation for the Army's future modernization efforts and data-centric focus. A common architecture allows compliant hardware or software systems to operate under the same standards. Developers who design modular systems can upgrade or change functions rapidly with limited or no impact to the rest of the system.

Understanding the prevailing trends within the DoD, a data strategy for medical training leverages the work of others while addressing issues specific to the healthcare community. The ecosystem uses digital learning technologies and platforms to provide more effective, equitable, and modern learning opportunities across military medical applications. This supports priorities for (a) upskilling and supporting the workforce, (b) enterprise shared services for information technology, and (c) data-centric digital modernization. Further, meaningful, accurate and timely data can enhance the learning experience with direct feedback on skill competencies based on individual and collective training tasks. The STE will have a common open systems architecture and shared software services across each of the major STE components, in line with the MOSA concept. Correspondingly, the OMSE is envisioned using commercial open standards, open APIs, and software development kits to provide ubiquitous state-of-the-art simulation, test and training services in the Army ecosystem to Soldiers at the PON.

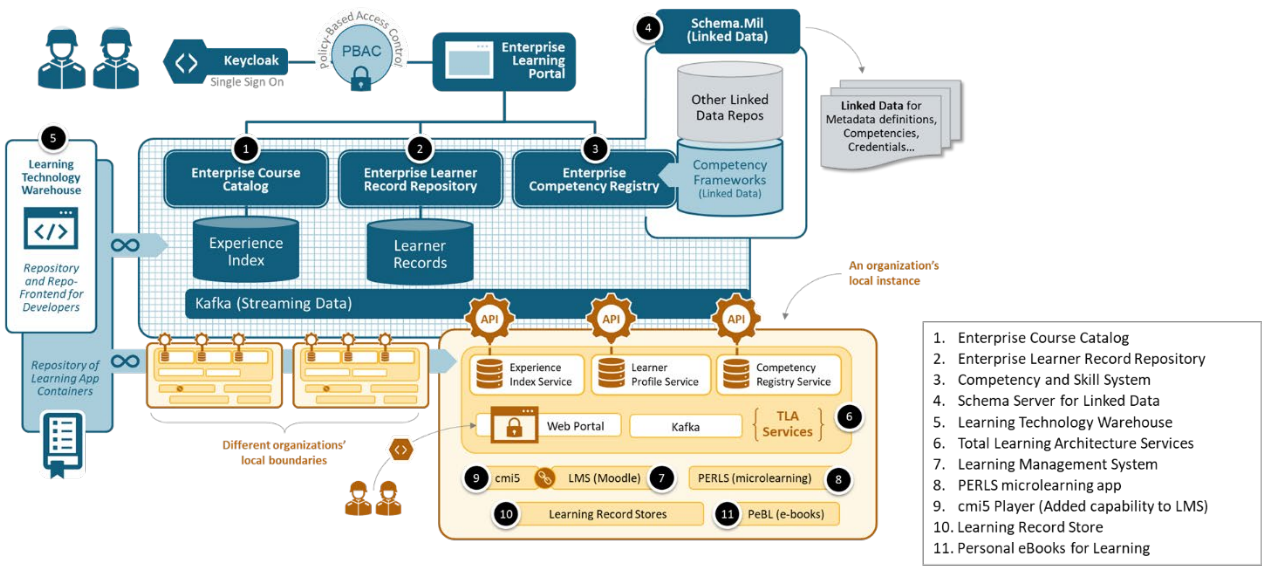

Figure 6: DoD Learning Enclave

CONCLUSION

This vision represents a leap in capability for healthcare training in the military. Advances in a multitude of technical areas, combined with shifting paradigms in data strategy, has the potential to enable improved efficiency in training and ultimately improve medical readiness. These advances are needed to address significant challenges facing the military healthcare system, including preparing for prolonged casualty care and upskilling providers at nearly all levels of care. Further, this directly addresses issues related to provider proficiency and skills decay by supporting training associated with the ICTLs.

Beyond addressing these specific challenges, the next generation of military healthcare simulation and training has the potential to benefit trainees, schoolhouses, and the military health system in myriad ways. VR, MR, and haptics can improve immersion and realism when training in virtual scenarios; this has been demonstrated to improve performance as well as improve trainee engagement (Coulter et al., 2007, Lebdai et al., 2021). These technologies enable improved delivery of training to the PON, which is a critical need for the military due to austere training conditions. A robust physiology model will improve training fidelity, ensuring simulated patients respond accurately. Accurate physiological response is a central component to content validity in healthcare simulations (Shelestak & Voshall, 2014), and is a major contributor to the perceived usefulness and ultimately user acceptance (Davis, 1989). The development and implementation of 3D printing at the PON, including soft tissue printing, has tremendous cost saving potential by reducing the logistical burden of ordering consumables.

Automated assessment and a comprehensive data strategy can drive performance improvement both in the training and operational environment. In all training exercises, debriefing and AAR is an indispensable component, with studies showing the importance of debriefing in improving clinical judgement (Kelly et al., 2014), knowledge acquisition (Dufrene & Young, 2014), and confidence (Buckley et al., 2012). Further, the debrief period enables cognitive reframing and reflection of actions and decisions during the training scenario. Automated assessment provides objective measures of performance to both trainees and instructors, improving AAR capabilities while also unburdening instructors. Importantly, a data strategy that stores and tracks longitudinal learning data provides trainees better understanding of their proficiencies and deficiencies, and allows instructors to better tailor content to learners (Roberson & Stafford, 2017). Importantly, this data is necessary to enable standardized measures of performance and effectiveness, and ultimately inform commanders on a unit's medical readiness.

There are many similarities between the outlined technologies and the larger concept of a metaverse (Lee et al., 2021). While specific metaverse definitions differ, most concepts include mixed reality, natural user interaction, computer vision, and artificial intelligence, all of which are components of the technical roadmap envisioned for medical simulation and training. In many instances, the metaverse is a persistent environment in which your avatar has characteristics which evolve and follow the user through various experiences; this is emblematic to the data strategy outlined above, in which performance data and trainee proficiency is stored and shared across training experiences. As the commercial sector continues to invest heavily in the metaverse, the military training ecosystem will be able to leverage technical advances in many critical areas. In this way, the future medical training ecosystem can be loosely described as a 'military medical metaverse'.

To realize the outlined vision for military healthcare training, significant effort is needed to develop, mature, and integrate multiple technologies and shift current training paradigms. Fortunately, the next evolution of military healthcare training builds upon a robust foundation including extensive facilities and simulation infrastructure, expansive institution knowledge, and a long history of innovation in the simulation community. Using current capabilities as a baseline, creating the future simulation ecosystem will require a collaborative effort across the military healthcare system. In particular, the Office of the Surgeon General and the MEDCoE are needed to represent the user communities and generate the appropriate requirements and needs statements. The definition of these user needs will directly feed into the science and technology community; as research and development is conducted, this definition will ensure that technical capabilities are prioritized in a manner that best serves the needs of the training community. Finally, the acquisition community will need to utilize the existing MSTC program assets and organizational structure, while adapting to new technologies and growing capabilities for prolonged care and point of need training. Importantly, the strategy requires the provisioning of training capabilities for individual skills via the OMSE, while also integrating with the STE for collective training events. To be successful, these groups must collaborate actively with industry and the other Services to leverage capability where appropriate, while developing the medical specific capabilities needed to revolutionize the military healthcare training ecosystem.

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