2022

TC3ICXR Transformational Training Delivery Platform

Anthony Sullivan

MARCO Federal Services LLC

11/30/2022

Special Project Gemini

One Team One Mission

THESE THINGS WE DO THAT OTHERS MAY LIVE


UNIFIED NETWORK.
CONNECTED – ANYTIME. ANYWHERE.
U.S.ARMY

Providing quality facilities and support for the training and readiness of military personnel and units of all branches and components of America's Armed Forces... in EVERY season.

TOTAL FORCE TRAINING CENTER: Fort McCoy's mission is to strengthen Total Force Readiness by serving as a training center, mobilization force generation installation, and strategic support area. As a Total Force Training Center, Fort McCoy's primary responsibility is to support the training and readiness of military personnel and units of all branches and components of America's armed forces. Fort McCoy is a Mobilization Force Generation Installation prepared to support contingency operations as ordered. As a world-class installation, Fort McCoy's continuing goal is to provide excellent customer service and facilities and to enhance the quality of life for all who train, work, play, or live here. The Fort McCoy community truly is unique, with active, reserve, and civilian components working together for the betterment of all facets of life at the installation. **FT. MCCOY MSTC CAPABILITIES 2022**

DCoT_Minutes_Sept_2020

VIP Guest Speaker General Austin Miller: General Miller opened with an introduction and dove right into a question posed to him in the Chat box: “who really owns battlefield medicine?”

His answer was:

“all of us do. There is a obligation of the commander of the field for sure, and that is just a legal responsibility that comes along with command, to make sure that systems are integrated, and that includes not only medica, but I will tell you some of the people do not want to be integrated and it makes it really, really, difficult and we come up short”

Introduction

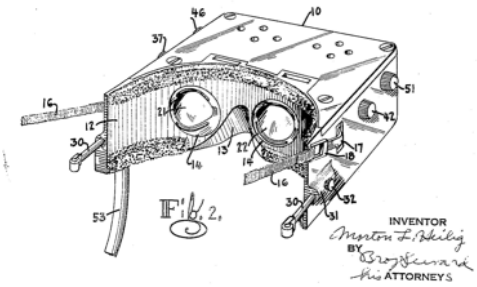
Today's virtual reality technologies build upon ideas that date back to the 1800s, to the very beginning of practical photography. In 1838, the first stereoscope was invented, using twin mirrors to project a single image. That eventually developed into "The View-Master" invented by Wilhelm Gruber to replace, or at least complement, the everyday postcard. It was met with moderately good reception. THE VIEW-MASTER BY SAWYERS, was invented by Wilhelm Gruber to replace, or at least complement, the everyday postcard. It was met with moderately good reception.

The US Army realized that the View-Master could help train troops, so they ordered hundreds of thousands of them. This money gave Sawyer's what they needed to dominate the View-Master market for the next 40 years. The use of the term "Virtual Reality," however, was first used in the mid-1980s when Jaron Lanier, founder of VPL RESEARCH, BEGAN TO DEVELOP THE GEAR, including goggles and gloves, needed to experience what he called "virtual reality."

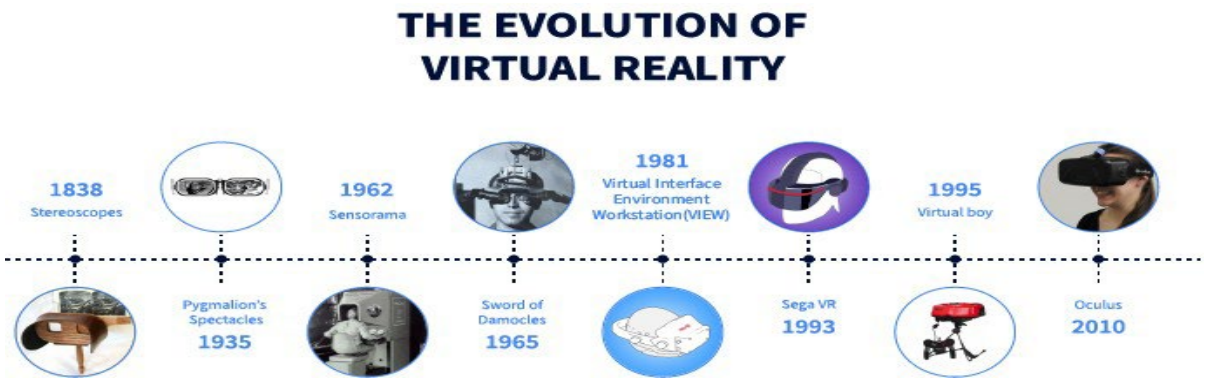
Even before that, however, technologists were developing simulated environments. One milestone was the Sensorama in 1956. Morton Heilig's background was in the Hollywood motion picture industry. He wanted to see how people could feel like they were "in" the movie. Heilig was a California-based filmmaker and an inventor who has often been dubbed the 'father of virtual reality.' THE SENSORAMA EXPERIENCE SIMULATED A REAL CITY ENVIRONMENT, which you "rode" through on a motorcycle. Multisensory stimulation let you see the road, hear the engine, feel the vibration, and smell the motor's exhaust in the designed "world."

Morton Heilig Patent: Stereoscopic-Television Apparatus

Heilig also patented a head-mounted display device, called the Telesphere Mask, in 1960. Many inventors would build upon his foundational work. While Sensorama is the device that Heilig is famous for, what you might not know is that he also patented the 'Telesphere Mask." or 'STEREOSCOPIC-TELEVISION APPARATUS FOR INDIVIDUAL USE. "This device is the first-ever head-mounted display device. THE PATENT (LINK) WAS FILED IN MAY 1957 AND WAS GRANTED IN OCTOBER 1960. Besides the attention to detail on how the optical system works, it is noteworthy that Heilig also discusses ergonomic objectives, such as weight of the unit being evenly distributed so that the device would be comfortable to wear without hands. These are design issues headset manufacturers are still challenged with today, in trying to find a form-factor that would suit various head sizes and shapes, different hair styles, etc. The USC School of Cinematic Arts and the Hugh M. Hefner Moving Image Archive provided photograph of the actual device:



Besides the obvious audio-visual capabilities of the device, the mask also displays a consistent theme in Heilig's inventions. He writes: *"Another object is to provide means for conveying to the head of the spectator, air currents of varying velocities, temperatures and odors."* The more detailed technical description of the device's parts mentions 'perfumed air' scents and air currents.



However, the overall objective is 'a complete sensation of reality': ***"by placing one small television tube and peripheral vision lens system before each eye of the user, one earphone by each ear, and one air duct before each nostril, the spectator is given a complete sensation of reality, i.e., moving three dimensional images, which may be in color, with 100% peripheral vision, binaural sound, scents, and air breezes."***

By 1965, another inventor, **IVAN E. SUTHERLAND, INFORMATION PROCESSING TECHNIQUES OFFICE, ARPA, OSD, OFFERED "THE ULTIMATE DISPLAY,"** a head-mounted device that he suggested would serve as a "window into a virtual world."

The Ultimate Display

"We live in a physical world whose properties we have come to know well through long familiarity. We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well-known shapes look from other angles, and how much force is required to push objects against friction."

The 1970s and 1980s were a heady time in the field. Optical advances ran parallel to projects that worked on haptic devices and other instruments that would allow you to move around in virtual space. At NASA Ames Research Center in the mid-1980s, for example, the VIRTUAL INTERFACE ENVIRONMENT WORKSTATION (VIEW) combined a head-mounted device wide-angle, stereoscopic display system controlled by operator position with gloves, voice, and gesture to enable the haptic interaction. The (VIEW) system provides a multisensory, interactive display environment in which a user can virtually explore a 360-degree synthesized or remotely sensed environment and can viscerally interact with its components, 40 years later, VR (Virtual Reality), MR (Mixed Reality) and AR have converged into XR (eXtended Reality), which has begun to achieve public acceptance. Approaching the fidelity of a feature film, development of ICVR with 360-degree Cinematic XR (CXR) 4K media and film, is accelerating. Unlike traditional VR, CVR limits the level of control users have within the environment, choosing viewpoints rather than directly interacting with objects in the "Story World" space.

To be interactive, VR, MR, AR and CVR must coexist within the story world space. (DISGUISE LAUNCHES NEW UNREAL ENGINE 5 PLUGIN FOR NEXT-GENERATION VISUALS ACROSS LIVE AND VIRTUAL PRODUCTION). Multi-sensory, immersive, innovative, and interactive, an ICXR enabled "OMNIVERSE" must access, augmented, mixed and virtual realities simultaneously. (SPECIAL PROJECT GEMINI ZEROSPACE DISQUISEXR ICXR). Using an array of advanced haptics, capture suits and head mounted displays, JTEDP TC3ICXR will need to integrate Interactive Digital Narratives (IDNs). XR is fundamentally transforming healthcare training, lowering the cost, providing highly scalable massive multi-domain "Zenith Enterprise Unified Simulations", combining Combatant Command Space with Medical Command Space for Joint Tactical Combat Casualty Care "Anytime & Anywhere" training on-demand.

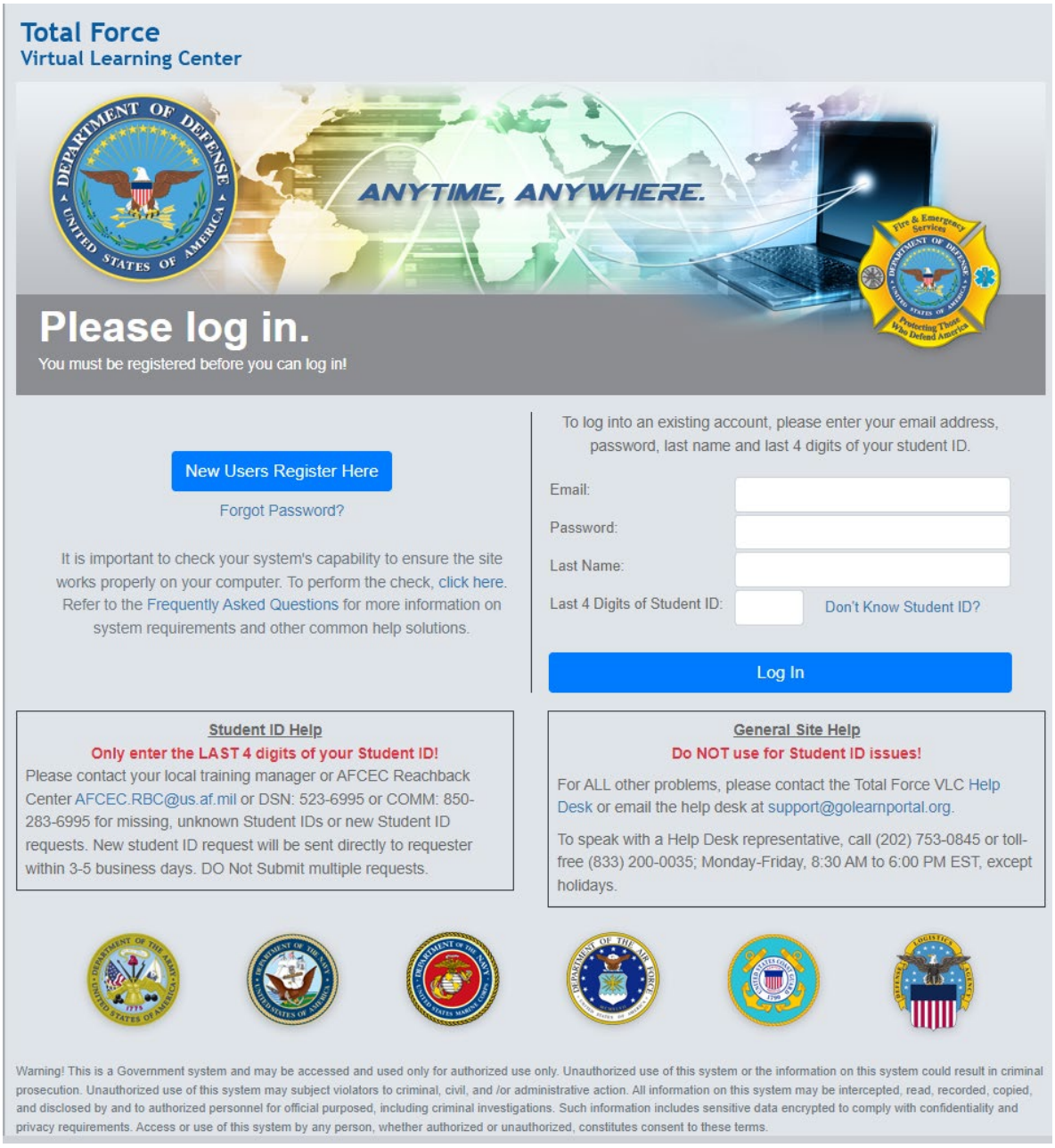
For the past two years, disguise and Epic Games have been partnering to democratize the delivery of 3D graphics across all types of industries including virtual production, broadcast, corporate events, and beyond. Where Unreal Engine continues to push the boundaries in photorealistic 3D graphics, disguise offers a seamless way to deliver this real-time generated content into LED (Light Emitting Diode) volumes, projection setups, and any physical display configuration – at any scale. "Unreal Engine 5 unlocks the most photorealistic real-time content we have ever seen, and, with the help of disguise, users can implement it into the Medical Simulation Joint Trauma and Education Training Delivery Platform productions with minimal setup requirements so they can focus on delivering their best creations," disguise Technical

Solutions Director Peter Kirkup said in a statement. disguise is *the* platform to imagine, create and deliver spectacular visual experiences. Its award-winning extended reality (XR) solution has powered over 400 immersive real-time productions in the past year, for enterprise businesses like SAP and Siemens, educational institutions like the University of Michigan, broadcast TV shows, commercial brands, US Government, and on-set virtual productions in more than 40 countries. Working alongside the most talented visual designers and technical teams partnered with MARCO Federal Services Special Project Gemini, disguise is building the next generation of collaborative tools to enable Total Force Learning Centers and the Joint Trauma Education and Training Directorate realize their vision.

DHA's goal for the Omnibus initiative is to transition findings and innovations from the R&D phase into medical practice to better delivery combat casualty care for patients suffering an injury or illness. Omnibus 4 represents a significant expansion from the prior iteration, which had seven companies that were awarded their seats in 2015.

The vision of NMMAST is to pursue high reliability by maturing the medical simulation infrastructure throughout One Navy medicine through centralized management, standardization, coordination, and strategic partnerships.

NMMAST Provides Strategic Guidance for Navy Medical Simulation



A System Requirements Review (SRR) is a formal review conducted to ensure that system requirements have been completely and properly identified and that a mutual understanding between the government and contractor exists. It ensures that the system under review can proceed into initial systems development and that all system and performance requirements derived from the Initial Capabilities Document (ICD) or draft Capability Development Document (CDD) are defined and testable, and are consistent with cost, schedule, risk, technology readiness, and other system constraints.

- Assess all potential solutions for a stated need
- Develop a preliminary Acquisition Strategy,
- Develop a Technology Development Strategy (TDS)
- Develop program goals for any needed development of critical enabling technologies
- Conduct an Analysis of Alternatives (AoA) leading to selection and approval of a materiel
- Develop a draft Capabilities Development Document (CDD)
- Develop a Systems Engineering Plan (SEP)
- Develop Initial Support and Maintenance Concepts (Life-Cycle Sustainment Plan)
- Understand Research and Development Costs
  To create the framework for system validation.

CHAOS report by the Standish Group (2006), reasons for technology project failure in the United States, found that only 34 percent of projects were successful; 15 percent completely failed, and 51 percent were only partially successful.

Five of the eight (highlighted below) most frequently cited causes of failure were poor user requirements:

- *13.1 percent, incomplete requirements*
- *12.4 percent, lack of user involvement*
- *10.6 percent, inadequate resources*
- *9.9 percent, unrealistic user expectations*
- *9.3 percent, lack of management support*
- *8.7 percent, requirements keep changing*
- *8.1 percent, inadequate planning*
- *7.5 percent, system no longer needed*

Articulate a shared vision of a new computing platform that encompasses creators and participants (Metaverse, Multiverse, Omniverse, Digital Twin, etc.).

This paper describes our work to date in identifying requirements for such a training system, current state of the art and limitations in commercial augmented reality tools, and our technical approach in developing a portable training system for medical trainees.

- Combat Life Savers, Combat Medics, Flight Medics, and Medical Corpsman are the first responders of the battlefield, and their training and skill maintenance is of preeminent importance to the military.
- While the instructors that train these groups are exceptional, the simulations of battlefield wounds are extremely simple and static, typically consisting of limited moulage with sprayed-on fake blood.
- These simple presentations often require the imagination of the trainee and the demanding work of the instructor to convey a compelling scenario to the trainee. Augmented Reality (AR) tools offer a new and potentially valuable tool for portraying dynamic, high-fidelity visual representation of wounds to a trainee who is still able to see and operate in their real environment.
- To enhance medical training with more realistic hands-on experiences, we are working to develop the Combat Casualty Care Augmented Reality Intelligent Training System (C3ARESYS). C3ARESYS is our concept for an AR-based training system that aims to provide more realistic multi-sensory depictions of wounds that evolve over time and adapt to the trainee interventions.

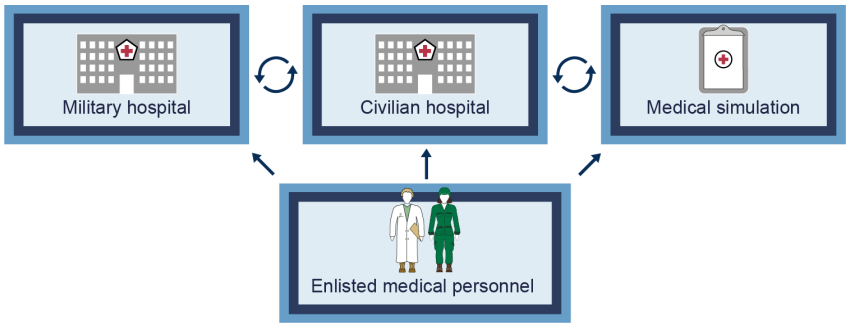
Due to the advantages that AR technology offers; several programs have been successfully implemented in the field of medicine. Broadly, these can be categorized into two subgroups. The first involves treatment programs which help patients and/or practitioners within a hospital or clinical setting, such as therapies, rehabilitation, or surgical procedures. The second includes training programs which are instead designed to aid teaching and learning outcomes within the academic university setting [1]. This review will focus on the latter of these two categories and will explore how they have taken advantage of key features of this technology to develop or improve knowledge, learning, and skill outcomes.

GAO Gap Analysis Recommendations

What GAO Found

The military departments have not fully defined, tracked, and assessed wartime medical skills for enlisted medical personnel. The departments have defined these skills for 73 of 77 occupations. However, among other issues,

- the Army and the Air Force have not defined skills for numerous highly skilled subspecialties that require additional training and expertise, such as Army Critical Care Flight Paramedics. Subspecialty personnel are key to supporting lifesaving medical care during deployed operations.
- The Army does not consistently track wartime medical skills training for enlisted medical personnel in its official system.
- The military departments are not able to fully assess the preparedness of enlisted medical personnel because, according to officials, they have not developed performance goals and targets for skills training completion.
- As a result, the military departments lack reasonable assurance that all enlisted medical personnel are ready to perform during deployed operations.
- The Department of Defense (DOD) has not fully developed plans and processes to sustain the wartime medical skills of enlisted medical personnel. While the Defense Health Agency (DHA) has initiated planning efforts to assess how the military departments' three primary training approaches sustain readiness (see figure), these efforts will not fully capture needed information. For example, DHA's planned metrics to assess the role of military hospitals and civilian partnerships in sustaining readiness would apply to a limited number of enlisted occupations. As a result, DHA is unable to fully assess how each training approach sustains readiness and determine current and future training investments.



Source: GAO analysis of Department of Defense information. | GAO-21-337

DOD officials have identified challenges associated with implementing its training approaches. For example, DOD relies on civilian partnerships to sustain enlisted medical personnel's skills, but DOD officials stated that licensing requirements and other issues present challenges to establishing and operationalizing civilian partnerships. DOD has not analyzed or responded to such risks and may therefore be limited in its ability to sustain wartime medical skills.

Military medical personnel must be ready to provide life-saving care to injured and ill servicemembers in an expeditionary setting, using their wartime medical skills.1 While recent Department of Defense (DOD) efforts to assess and improve the wartime medical skills of military personnel have focused on officers, particularly physicians, enlisted medical personnel constitute over two-thirds of all active-duty medical personnel. In fiscal year 2019, there were 73,454 active duty enlisted medical personnel across the Army (38%), the Navy (37%), and the Air Force (25%), spanning 80 occupations. These personnel perform key roles in the delivery of healthcare in an expeditionary environment, including serving as first responders that provide point-of-injury care, serving as members of highly mobile surgical teams, and working in field hospitals and hospital ships.

In recent years, DOD has taken steps in response to congressional mandates to further establish military medical treatment facilities (MTF) as platforms for sustaining the operational readiness of active-duty medical providers while increasing efficiency.

We are making the following 30 recommendations to DOD, including six to the Secretary of Defense, nine to the Secretary of the Army, six to the Secretary of the Navy, and nine to the Secretary of the Air Force.

Specific Recommendations

1. The Secretary of the Army should ensure that the Commanding General, U.S. Army Medical Center of Excellence, takes corrective action to define wartime medical skills for enlisted medical subspecialties with an expeditionary role. (Recommendation 1)
2. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, takes corrective action to define and implement wartime medical skills for enlisted medical subspecialties with an expeditionary role. (Recommendation 2)
3. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, establishes guidance that requires the development of wartime medical skills for current and future enlisted medical subspecialties with an expeditionary role. (Recommendation 3)
4. The Secretary of the Army should ensure that the Commanding General, U.S. Army Medical Center of Excellence, takes corrective action to fully incorporate joint wartime medical skills into Army wartime medical skills checklists. (Recommendation 4)

5. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, takes corrective action to fully incorporate joint wartime medical skills into Air Force wartime medical skills checklists. (Recommendation 5)

6. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, issues guidance requiring the incorporation of joint wartime medical skills into Air Force checklists. (Recommendation 6)

7. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, takes corrective action to review and update outdated wartime medical skills checklists for enlisted medical occupations. (Recommendation 7)

8. The Secretary of the Army should ensure that the Commanding General, U.S. Army Training and Doctrine Command, updates its guidance to require the specification of acceptable methods of sustainment training for wartime medical skills for enlisted medical personnel. (Recommendation 8)

9. The Secretary of the Army should ensure that the Commanding General, U.S. Army Medical Center of Excellence, incorporates findings on skills degradation from DOD's project on highly perishable and mission- essential medical skills into its processes to identify appropriate training frequencies of wartime medical skills. (Recommendation 9)

10. The Secretary of the Navy should ensure that the Surgeon General of the Navy incorporates findings on skills degradation from DOD's project on highly perishable and mission-essential medical skills into its processes to identify appropriate training frequencies of wartime medical skills. (Recommendation 10)

11. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, incorporates findings on skills degradation from DOD's project on highly perishable and mission-essential medical skills into its processes to identify appropriate training frequencies of wartime medical skills. (Recommendation 11)

12. The Secretary of the Army should ensure that the Surgeon General of the Army requires the consistent tracking of training on wartime medical skills for enlisted medical personnel. (Recommendation 12)

13. The Secretary of the Army should ensure that the Surgeon General of the Army establishes performance goals and targets for the completion of training on wartime medical skills for enlisted medical occupations and tracks performance toward achieving the goals and targets. (Recommendation 13)

14. The Secretary of the Navy should ensure that the Surgeon General of the Navy establishes performance goals and targets for the completion of training on wartime medical skills for enlisted medical occupations and tracks performance toward achieving the goals and targets. (Recommendation 14)

15. The Secretary of the Air Force should ensure that the Surgeon General of the Air Force, in coordination with the Commander, Air Force Medical Readiness Agency, establishes performance goals and targets for the completion of training on wartime medical skills for enlisted medical occupations and tracks performance toward achieving the goals and targets. (Recommendation 15)

16. The Secretary of Defense should ensure the Director, DHA, develops metrics to assess the contributions of MTF workload to sustaining wartime medical skills that include the medical care provided by enlisted medical personnel. (Recommendation 16)

17. The Secretary of Defense should ensure the Director, DHA, develops the required inventory of civilian partnerships to include all partnerships in which enlisted medical personnel may participate. (Recommendation 17)

18. The Secretary of Defense should ensure the Director, DHA, develops a process to identify opportunities to streamline or add military-civilian training partnerships. (Recommendation 18)

19. The Secretary of Defense should ensure the Director, DHA, develops metrics to assess the contributions of civilian partnerships to sustaining wartime medical skills that include the medical care provided by enlisted medical personnel. (Recommendation 19)

20. The Secretary of Defense should ensure the Director, DHA, performs the proposed assessment of available simulation programs, demand for them, and gaps in clinical training and simulation requirements. (Recommendation 20)

21. The Secretary of the Army should ensure the Surgeon General develops and implements a consistent clinical readiness assessment process for wartime medical skills maintenance to identify and address gaps in training. (Recommendation 21)

22. The Secretary of the Navy should ensure the Surgeon General develops and implements a consistent clinical readiness assessment process for wartime medical skills maintenance to identify and address gaps in training. (Recommendation 22)

23. The Secretary of Defense should ensure the Director, DHA, in conjunction with the Surgeons General of the Army, the Navy, and the Air Force analyzes and responds, as appropriate, to risks to sustaining enlisted personnel wartime medical skills associated with: (1) staffing challenges at MTFs; (2) managing rotations of non-MTF personnel to MTFs; (3) barriers to civilian partnerships; and (4) challenges in providing enlisted medical personnel opportunities to train on expeditionary medical equipment. (Recommendation 23)

24. The Secretary of the Army should develop annual retention goals, by skill level, for enlisted medical personnel. (Recommendation 24)

25. The Secretary of the Navy should develop annual retention goals, by skill level, for enlisted medical personnel. (Recommendation 25)

26. The Secretary of the Air Force should develop annual retention goals, by skill level, for enlisted medical personnel. (Recommendation 26)

27. The Secretary of the Army should consider incorporating data on civilian pay for comparable occupations in the Army's decision-making processes for awarding retention bonuses. (Recommendation 27)

28. The Secretary of the Navy should consider incorporating data on civilian pay for comparable occupations in the Navy's decision-making processes for awarding retention bonuses. (Recommendation 28)

29. The Secretary of the Air Force should consider incorporating data on civilian pay for comparable occupations in the Air Force's decision- making processes for awarding retention bonuses. (Recommendation 29)

30. Agency Comments and Our Evaluation The Secretary of the Navy should include information on the cost of training in its decision-making process for awarding retention bonuses. (Recommendation 30)

Purpose and Intended Audience

OBJECTIVE: Develop an Augmented Reality protocol and prototype to create visual replication (with visual and haptic cues) of simulated wounds/injuries based on Force-on-Force combat casualty assessments and care. The research would focus on the development and modeling of various wounds and injuries, and couple with a motion sensing (hand tracking) and speech recognition technology to allow for Combat Life Savers and/or medic treatment (treatment actions) of the injuries while in out in the field conditions.

Ft. McCoy Medical Simulation Training Center

Purpose: Identify training environment, current problems and challenges associated with complying with DoD (Department of Defense) Instruction 1322.24.

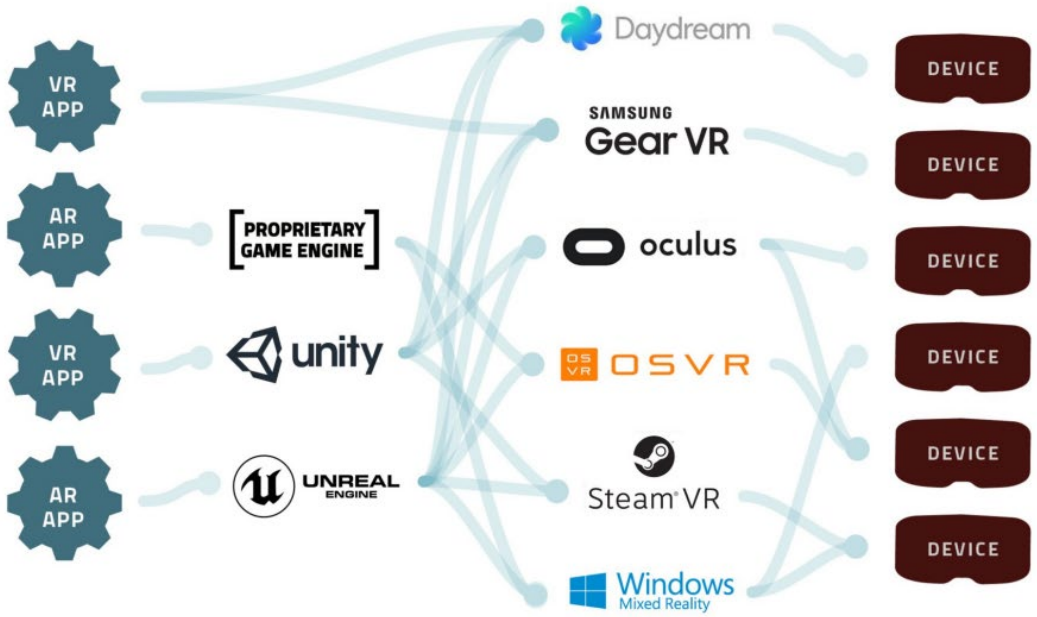
- M3TS Provides Better Care Under Fire Training Using Cost-Effective AR/Haptic Tech - Team Orlando News
- Multi Modal Medical Training System (M3TS) | SBIR.gov
- Jude Tomasello Discusses Saving Lives with Simulation: 5+1 Interview
- DHA's PM MST: Save Lives and Improve Healthcare Through Simulation - Team Orlando News
- A Decisive Action Training Environment to support Unified Land Operations – Combined Arms Maneuver for Infantry Brigade Combat Teams and Wide Area Security for Maneuver Enhanced and Sustainment Commands in a four-season environment.
- Premier Total Force Training Center Army Installation for Army Early Response Force (AERF) Early Deploying Units to meet the Army's Operational Demand Requirements.
- Live, Virtual, Constructive Integrated Training Environment – Mission Training Center Capabilities.

- Support Total Force and Total Army Training and Readiness for all branches and components of America's Armed Forces. More than 150,000 joint, interagency, and multinational forces conduct integrated training annually.

The Problem

LIEUTENANT GENERAL ROBERT I. MILLER

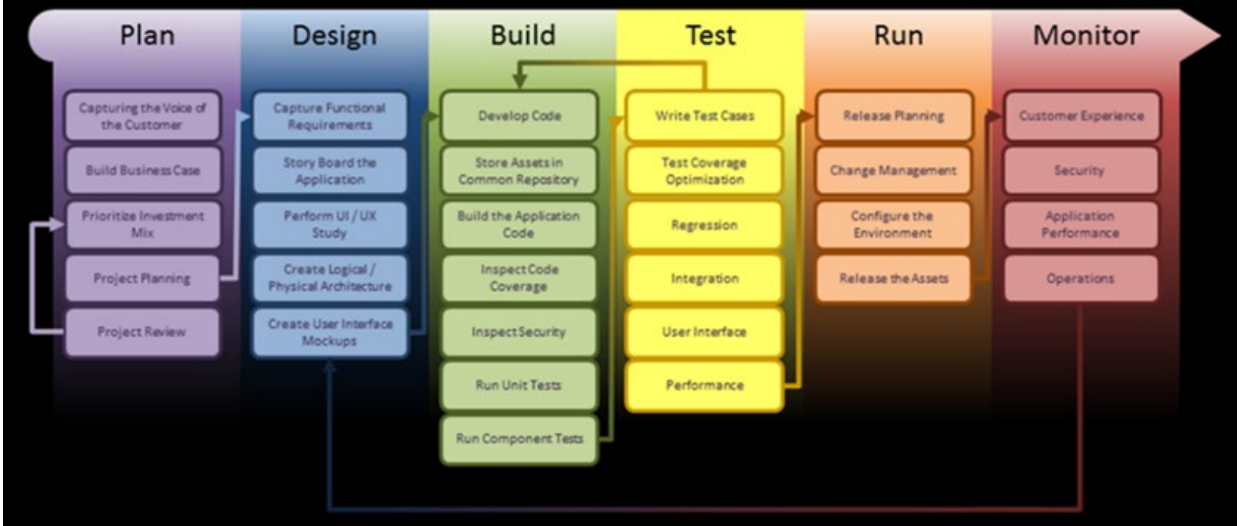
General Miller's overall message for Medical Leaders was INTEGRATION…to get involved in the Operational side of the deployment. To be present at meetings and listen in. If Medical Leadership integrates with Operational Commanders, they will gain respect and a mutual understanding and both leaders will begin to understand individual capabilities, as well as how to have mission success.

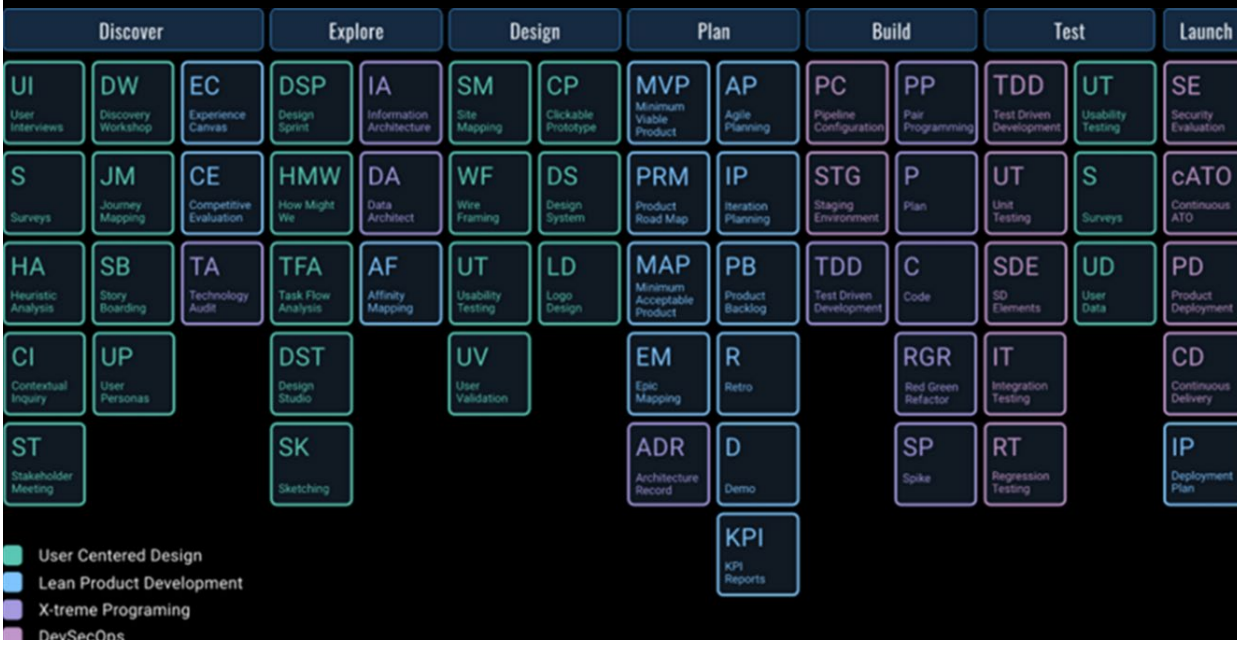


- AIR FORCE SURGEON GENERAL'S PRIORITY IS CREATING HIGH PERFORMING AIRMEN, GUARDIANS (PART 1)
    - The Air Force Surgeon General's top priority is creating and sustaining high performing Airmen and Guardians who are medically ready for the future fight.
- AIR FORCE SURGEON GENERAL EYES MODERNIZING CAPABILITIES FOR JOINT COMMANDERS (PART 2)
    - Since assuming his role of Air Force Surgeon General, Lt. Gen. Robert Miller has worked to advance the Air Force Medical Service's capabilities, ensuring it is ready for an evolving joint fight.

Brig Gen Friedrichs emphasized the importance of the JTS being involved in the combat development space, or envisioning what we need for surgical capabilities, resuscitative care, those sorts of things, that ultimately should be nested under joint concepts. "Not that we are interchangeable. That is not what this is about. But in a way that we are interoperable.

Software Factory Activities





Mission

The mission of the Combat Casualty Care Research Program is to reduce the mortality and morbidity resulting from injuries on the battlefield through the development of new life-saving strategies, new surgical techniques, biological and mechanical products, and the timely use of remote physiological monitoring.

Background and Environment

Soldiers face many threats in hostile fire arenas, whether conducting large-scale mechanized warfare, low-intensity conflicts, or operations other than war. Military casualties may wait for hours before definitive health care can be provided. Furthermore, initial treatment and subsequent evacuation occur in austere environments characterized by limited supplies and limited diagnostic and life-support equipment; and provision of acute and critical care is labor intensive and must frequently be provided by non-physician medical personnel. The primary challenge for combat casualty care research is to overcome these limitations by providing biologics, pharmaceuticals, and devices that enhance the capability of first responders to effectively treat casualties as close to the geographic location and time of injury as possible.

Combat casualty care is constrained by logistics, manpower, and the hostile operational environment. Since mid-World War II, nearly 50 percent of combat deaths have been due to exsanguinating hemorrhage. Of those, about half could have been saved if timely, appropriate care had been available. Head injuries and lung injuries are also major causes of death where proper treatments and training could significantly reduce mortality and morbidity. The treatment of battlefield casualties is exacerbated by the long evacuation times often found in military operations. This requires battlefield medics and physician's assistants to stabilize patients for extended periods and makes battlefield trauma care markedly different from civilian trauma care. Because approximately 86 percent of all battlefield deaths occur within the first 30 minutes after wounding, the ability to rapidly locate, diagnose, and render appropriate initial treatments are vital to reversing the

historical outcomes of battlefield injuries. The need to provide such care with a reduced logistics footprint is the cornerstone around which the future of combat casualty care research is built.

Top issues affecting Combat Casualty Care:

PROJECT CONVERGENCE.

VIP General Officer Panel (RDML Kuehner, BG Talley, RDML Via, BG Appenzeller): COL Gurney introduced and welcomed the GO Panel. The first question posed to the Panel was to discuss their thoughts on the SPECIAL PROJECT

RDML Via – *"If we end up in an competitive war in the near future, I am afraid we are behind the curve. Have we identified the right requirements for equipment, and I'll be aligning them to the platform?*

BG Talley –

"Future operation environments will be dispersed. So the training is key. We certainly have to think about if we are going to create capabilities, our design for a physician or a highly trained medic…I think we have to think as to what are the skills in the floor for what we are going to need in our healthcare system. One initiative that has become a top modernization priority, it is called project convergence. A mission commander needs to understand where they are taking the DNBI injuries, and how to apply them to combat power to mitigate risk."

"Covid-19 has awakened the lion like never before. So there is a new appetite. There is a new understanding. When I go to the table and ask for funding for certain things, they say, no, we will apply to a weapon system, and answer I may have gotten eight months ago, that is not the case. So I think there is a great opportunity that is upon us now, and it behooves us to stay integrated with the line so we continue to garner their championship."

RDML Kuehner –

"Our task…my task in Navy medicine is to be prepared to win. With and alongside our war fighter, again, any theater, any threat. I think that unfolds this new way of looking at how we manage combat casualty care… How do we distribute it beyond our limited resources? We are not going to have a trauma surgeon in all of the places that trauma may happen. We have to figure out what to do differently and what to let go of… And sometimes our passions get wrapped around what we know. And this is a time, when more than anything, it is important for us to understand systems and understand the value of every single piece of that system."

BG Appenzeller –

> *"COVID has shown how important it is to focus on readiness as well as non-trauma casualty care. Second, how do we focus on how to sustain readiness through standardization, stabilization and synchronization? Interoperability is key."*

COL Gurney presented the second question to the Panel: Moving into near-peer or maritime environment, can you please identify the biggest challenge we need to be preparing for?

RDML Via –

> *"As a whole we have to get engrained into execution not just strategy of the system. Capabilities are out there but not codified in doctrine. My fear is processes are taking entirely too much time…we have to pressure the system to move more quickly. Keep doing what you're doing and focus on interoperability not interchangeability. I think our lack of ability to do things the same way and communicate, with each other, and then synchronize our medical activities across the force of the total joint force, I think that causes us problems. An example is when I was in Africa, and we had an 80 surgical team*

Tactical Research and Development Group (TRDG).

TC3ICXR Multi-Domain Intelligent, Interoperable, Immersive, Interactive Training Platform

Combat Life Savers and combat medics provide battlefield medical care under austere conditions therefore the training, objective assessment, certification, and maintenance of life saving skills used by soldiers and/or combat medics is of critical concern to the U.S. Military. This system of systems seeks to improve first responder and combat medic training via Augmented Reality (AR) technology with virtual haptic feedback, and gesture and speech recognition.

The use of augmented reality is intended to enhance visualization of severe trauma and underlying physiological mechanisms and to support trainee performance (e.g., guide trainees, provide feedback, and assess actions). More lives are saved on the battlefield by Soldiers (Combat Life Savers) than medics. Research shows that Soldiers are not trained well enough in the basics of Tactical Combat Casualty Care. The proposed research would have support Tactical Combat Casualty Care training as well as more in-depth medic training.

The proposed research and development will use AR technology to superimpose synthetic imagery onto real soldiers and/or medical mannequins instrumented with virtual haptic feedback devices. The proposed system will need to recognize and respond to user actions (e.g., chest compressions, or airway clearing). The proposed system will need to integrate with the Live Training Force-on-Force technology for obtainment of casualty information (type, location, and time of occurrence).

The visual representation will need to be time based to align with injury escalation. The proposed research and development will need to leverage/advance on-going work in dynamic occlusion reasoning, Optical-See-Through (OST) display overlays, and 6-DOF head and hand tracking. The proposed research will need to include speech recognition from the medic under training and provide appropriate responses/sounds from the patients (based on queries or actions taken).

PHASE I: Determine the feasibility/approach for the development of an integrated augmented reality technologies to meet training requirements in support of US Army medical first responder training within live training domain (field, Force-on-Force) environment. The tasks include a cognitive task analysis to understand the competencies and knowledge requirements associated with combat medicine; a technology analysis to guide the application; and research conducted to evaluate the impact of augmented reality technologies on trainee understanding.

PHASE II: Develop a prototype augmented reality medic training capability that can be utilized within live domain (field) training environments, utilizes/interfaces with the Multiple Integrated Laser Engagement System (MILES) as fiducial markers and for wound identification. Prototype system will need to track injury timing, soldier/medic actions taken, and provide visual/haptic cues in response to the actions taken. Development of prototype AR capability that can be utilized with medical mannequins for the visual display of injuries/wounds, haptic responses, etc. **DEMONSTRATIONS WILL BE AT TRL 6.**

PHASE III: DUAL USE APPLICATIONS, refine design and continue technology investigation and integration into a prototype baseline, and implement basic modeling methods, algorithms, and interfaces. Pursue fill integration within the Live Training Transformation (LT2) and Tactical Engagement Simulation Systems (TESS) product lines, to define an implementation solution. Continue to develop models, procedures, actions and reactions for injuries and medic actions, ensure complete traceability to medic training requirements. Ensure product line development between live domain and mannequin solutions. Focus on environmental stability and reliability enhancements. Commercial applications include extending technology to other medical applications and EMT programs.

Interoperable Project Solutions

DCoT 2020:

General Miller opened with an introduction and dove right into a question posed to him in the Chat box: "who really owns battlefield medicine?" His answer and impactful statements.

"All of us do. There is an obligation of the commander of the field for sure, and that is just a legal responsibility that comes along with command, to make sure that systems are integrated, and that includes not only medical, but I will tell you some of the people do not want to be integrated and it makes it really, really difficult and we come up short."

"At my level he always hears talk about those big success stories, and we never talk about the things that were not successful…And it was not real clear what was happening from the ground up. So, I took the education piece and just in my mind mistakenly assumed there was a level of collaboration and integration that was in play…but there is a level of disconnected views that are spreading across the operational environment."

"I think when you're talking to a commander, I think you have to talk in terms of risks, risks and gains, because ultimately why is battlefield medicine important for us?" "I think we have to capture what exceptional looks like. And explain that to the community."

General Miller's overall message for Medical Leaders was **INTEGRATION**…to get involved in the Operational side of the deployment. To be present at meetings and listen in. If Medical Leadership integrates with Operational Commanders, they will gain respect and a mutual understanding and both leaders will begin to understand individual capabilities, as well as how to have mission success.

Brig Gen Friedrichs reiterated GEN Miller's point: "there are a lot of things happening that are challenging and challenging to the entire U. S. healthcare system. Now we need to balance risk. That was a point that General Miller made this morning…. we are having to reprioritize within the entire U. S. government, as well is within the Department of Defense." Brig Gen Friedrichs emphasized the importance of the JTS being involved in the combat development space, or envisioning what we need for

surgical capabilities, resuscitative care, those sorts of things, that ultimately should be nested under joint concepts. “Not that we are interchangeable. That is not what this is about. But in a way that we are interoperable. The annual joint assessment is due back this fall. Very specific questions… for the first time, medical questions included. We are looking for responses...Say yes when we reach out, looking for volunteers to help with some of these documents, and some of these efforts, whether the JTS asking for help, DHA, service chain, or us knuckleheads of the joint staff. We need your help.”

4Wall OpenXR Interoperability & Integration

SPECIAL PROJECT

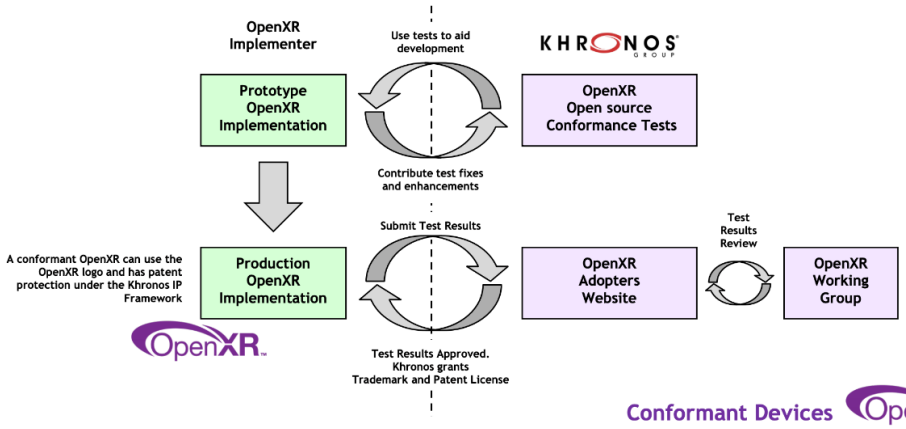
4WALL UE5 TC3ICXR HOLODECK

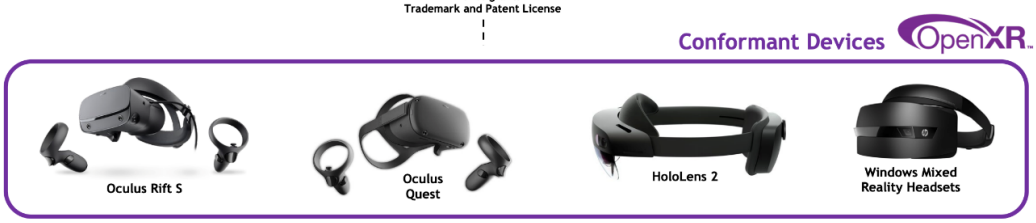
- JPC-1 MEDICAL SIMULATION AND INFORMATION SCIENCES
- MEDICAL RESEARCH AND DEVELOPMENT COMMAND
- COMBAT CASUALTY CARE RESEARCH PROGRAM (CCCRP)
- JOINT TRAUMA & EDUCATION TRANSFORMATIONAL TRAINING DELIVERY PLATFORM
    - Development Time, Cost, Deliverables
    - Unity has complications related to nesting prefabs within other prefabs, which limit their role as extensible building blocks.
    - In Unreal Engine, you can create a new Blueprint Class which extends an existing Blueprint Class and augments it with new properties, components, and visual scripting functionality.
    - Unreal Engine 5 has full support for Windows Mixed Reality (VR) and HoloLens 2 (AR) devices.
- WINDOWS MIXED REALITY (WMR) PLUGIN REPLACED BY OPENXR AND MICROSOFT OPENXR PLUGIN (MARKETPLACE OR GITHUB)
    - 5.0 changes
        - In 5.0, the Windows Mixed Reality (WMR) plugin that ships with Unreal Engine is deprecated in favor of the OpenXR plugin (available on Unreal Marketplace or GitHub). The WMR plugin will be removed in future engine releases, so developers should move to OpenXR.

- OpenXR vs Microsoft OpenXR
    - The OpenXR plugin that ships with the engine can be used to create an application, but any MSFT-specific OpenXR features (including Holographic App Remoting) will only exist in the Microsoft OpenXR plugin, so it does need to be downloaded to create a full-featured experience.
    - Microsoft OpenXR plugin updates release when ready instead of in-engine updates

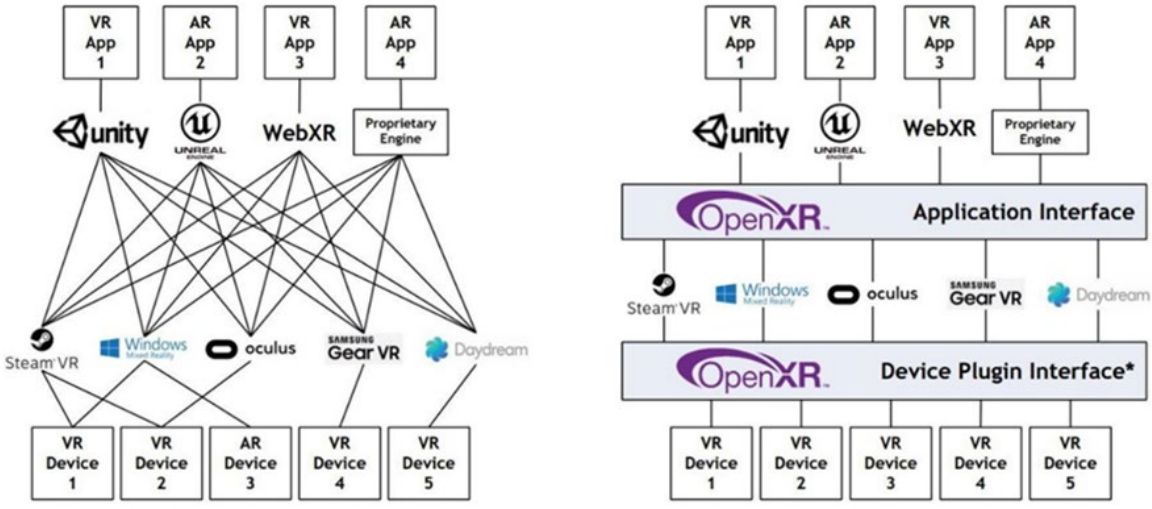
- **Cross-platform Development for Unreal Engine With Rider**
  Rider is a fast and powerful IDE for cross-platform Unreal Engine development.
    - RIDER EARLY ACCESS JET BRAINS
    - JET BRAINS RIDER
    - JET BRAINS RIDER UNREAL ENGINE
    - Smart C++ and Blueprints support to craft the best games.
- OPENXR MIXED-REALITY GITHUB
- MICROSOFT-OPENXR-UNREAL GITHUB
- UNREAL ENGINE 5: THE OPENXR CONVERGENCE

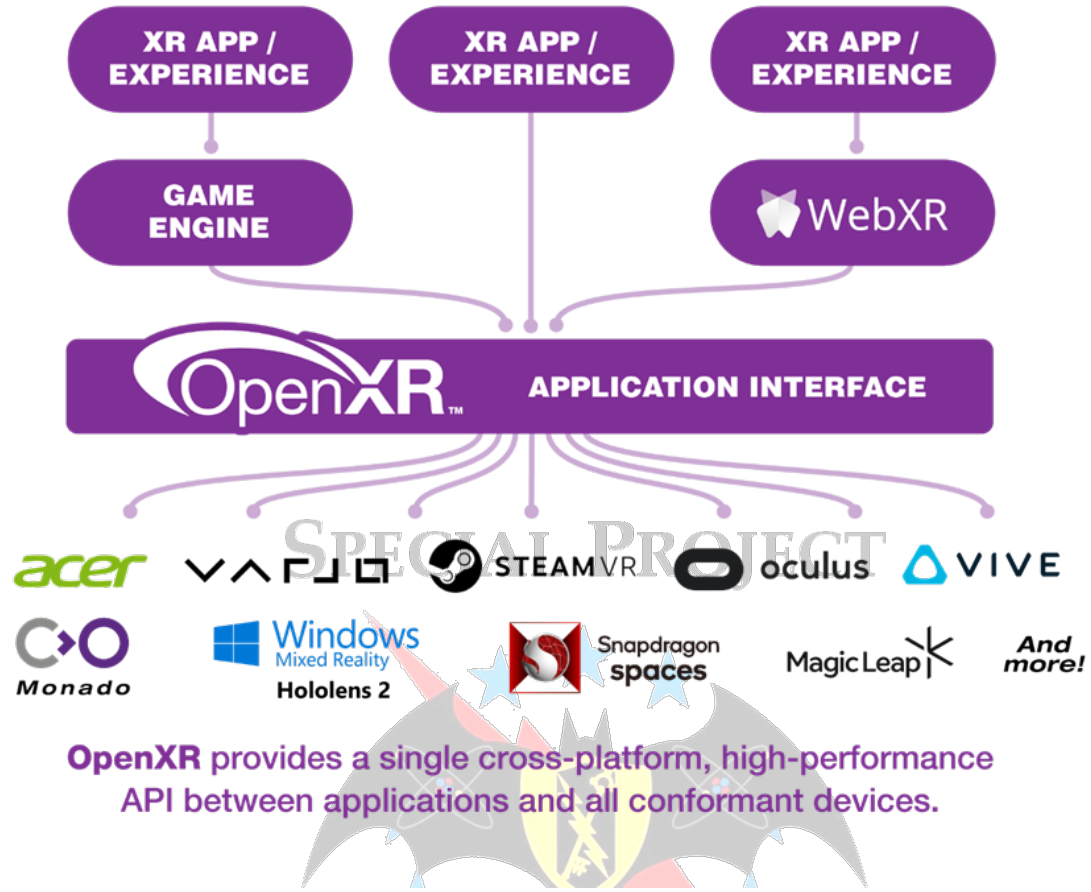
First Conformant OpenXR Devices

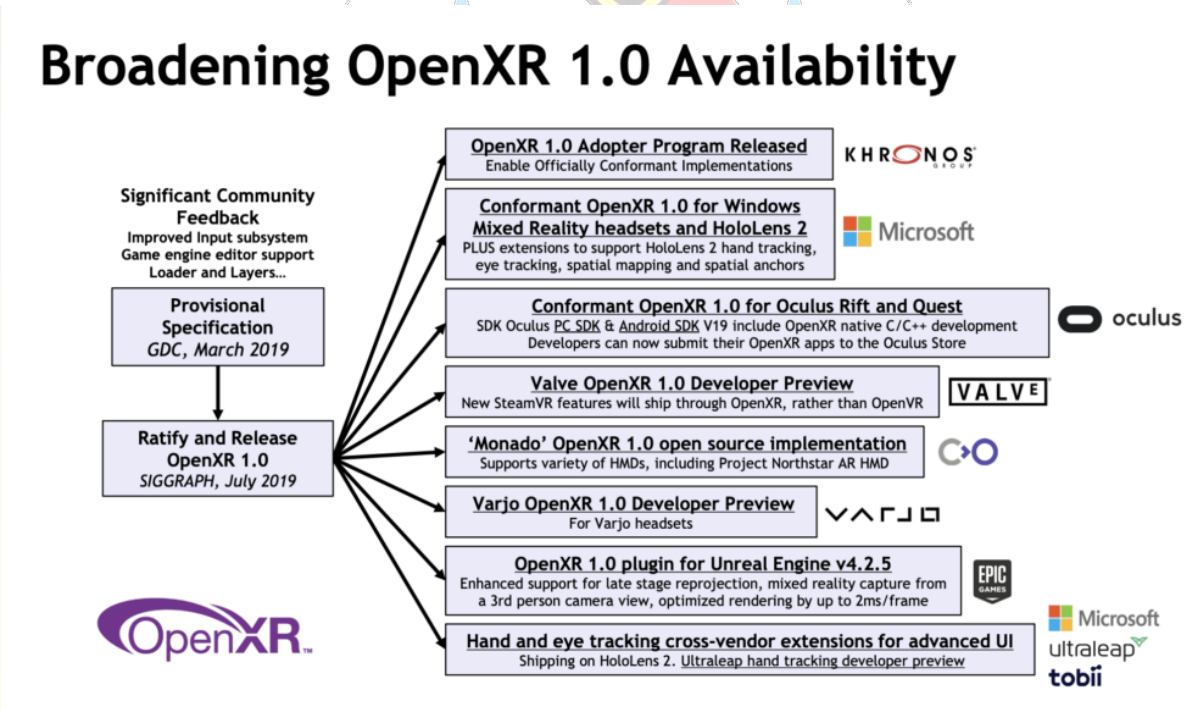




OpenXR - Solving XR Fragmentation





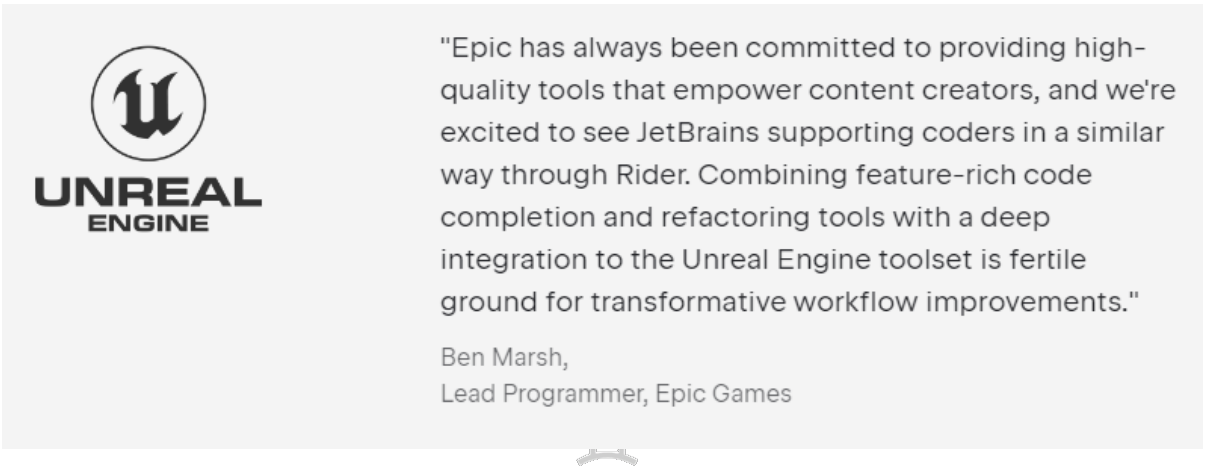


Microsoft and Oculus each have multiple conformant OpenXR-enabled devices showcasing how OpenXR enables portability across diverse platforms. PC-enabled

virtual reality devices include Microsoft's Windows Mixed Reality and Oculus' Rift headsets, enabling these HMDs, and any future OpenXR-compatible devices, to run the same application executable on Windows. In addition, Microsoft has released an OpenXR-conformant runtime for the HoloLens 2 headset, and Oculus has shipped a conformant runtime for the Android-based Quest, demonstrating OpenXR's flexibility to enable portable VR and AR applications across standalone and tethered XR devices—using different underlying operating systems.

With the release of the conformance tests and the official launch of the Adopters Program, widening availability of OpenXR across diverse devices, and expanding use in large open-source projects, OpenXR is now ready for developers to take advantage of being able to create truly portable XR applications and experiences.

*



When the Antoinette Project took to the road, the world got a chance to see firsthand how a game engine can bring an unprecedented level of realism, immersion, and portability to flight simulators. Epic Games talked to industry innovators about what they see for the simulation industry, now and in the future. Check out the full video series to hear what they had to say.

" The visuals in the flight simulator that I just experienced were unmatched. It really felt like I was inside of that airplane. And when I took the goggles off, there wasn't any negative transfer. It went from real life to real life and didn't miss a beat at all."

Mattie Bohanan, Certified Flight Instructor, Auburn University

"What I saw today was vastly superior in terms of the smoothness, and in terms of the level of detail."

Jamie Starr, Deputy Head of Flight Training, ATR

"The digital transformation that's taking place requires an enormous amount of training. If we can reduce that footprint—not just the physical footprint, but the resources that are required, then that's going to be a good thing. So, I see simulation, in 5-10 years' time, being an integral part of the individual and collective training."

Angus Macgregor-Millar, General Manager | World Wide Defense & Intelligence, Microsoft

- Check out the full video series to hear what they had to say.
    - Simulation Trends | VR & AR: https://youtu.be/e4dmjUHREPE?t=20
    - Simulation Trends | Photorealism & Accuracy: https://youtu.be/grrw5by9zaM?t=20
    - Simulation Trends | Interfaces & Pipelines: https://youtu.be/e5RP7upeGmA?t=20
    - Simulation Trends | Open Standards Interoperability: https://youtu.be/GDy0sv6Y2Jw?t=20
    - Simulation Trends | Cost Efficiency & Deployment: https://youtu.be/vt4RoG5fQEM?t=20
    - Simulation Trends | Training Transfer Benefit: https://youtu.be/0hD3NlWb98g?t=20
    - Explore the Antoinette Project here: https://www.unrealengine.com/en-US/bl...
- RIDER for Unity
- RIDER for AWS

Port SimCentric from UE4 to Unreal Engine 5

- Migrate RAVEN and SIMCENTRIC to UE5 to facilitate Combat Environments
- Virtual Production and Broadcast Unreal Engine 5
    - Capabilities development time, cost, and delivery Digital Twins ZEROSPACE VIRTUAL PRODUCTION AND BROADCAST STUDIO for massive muti-domain interoperable unified common automatic virtual environments.
    - Massive Multi Domain Unified Training Analytics Integration

Increasing adoption of 3D motion capture in the healthcare industry to provide alternative training methods in medical studies, diagnosis, rehabilitation, posture analysis, and treatment of physical conditions is acting as another growth-inducing factor. Additionally, the integration of artificial intelligence (AI) and machine learning (ML) to create realistic animations without using extensive equipment, such as reflective markers and multi-camera systems, is providing an impetus to market growth. Moreover, the rising demand from sports and allied activities to train athletes, review performance, and analyze injury processes is supporting the market growth. Other factors, including favorable initiatives by several governments to establish art studios for visual effects and animation, increasing utilization in the military sector for training soldiers through simulations, and rising demand from the education industry, are anticipated to drive the market toward growth.

Movella™

Bringing meaning to movement

Medical Modeling, Simulation, Informatics, and Visualization

"We've modeled what 'expert' looks like," said Miller, "so now let's give that expertise to everybody."

Geoffrey Miller, division chief for the Medical Modeling, Simulation, Informatics, and Visualization program at TATRC

MCUBE REBRANDS AS MOVELLA

Movella™ – a global provider of innovative solutions in sensing, capturing, and analyzing movement data. Movella products serve four primary markets: entertainment, sports, health, and industrial, by bringing meaning to movement.

The acquisition of Kinduct in 2020, a market leader in the athlete and health data management space, along with the continued integration of Xsens from 2017, has enabled the combined companies to create a full-stack total solution across hardware, software, and data analytics. The new brand encapsulates the value and technologies from mCube, Xsens, and Kinduct. Movella is focused on a bold vision and is dedicated to providing actionable insights for customers and partners to create extraordinary outcomes that move humanity forward.

The mission of the company is to digitize movement so that people can extract meaning and impact positive change by providing intelligent solutions for sensing, capturing, and analyzing motion and states of being. Movella products accelerate innovation in entertainment, sports, health, and industrial markets.

- **In Entertainment:** Movella brings meaning to movement by empowering digital artists to unleash their creativity with the most advanced & easy-to-use motion capture technology.
- **In Health:** Movella brings meaning to movement by providing technology-enabled insights that remove barriers to human motion.
- **In Sports:** Movella brings meaning to movement by providing teams and athletes the tools and insights needed to push their limits.
- **In Automation & Mobility:** Movella brings meaning to movement by providing superior positioning and orientation systems within complex industrial and commercial environments.

Movella was founded in 2009 as mCube, launched as an innovator of inertial sensor components that supplied the world's smallest and lowest power consumption accelerometer products and related software to manufacturers of industrial and mobility systems.

Commenting on the new era of the company, Ben Lee, Movella CEO, said, "With our history and our new mission in mind, we are now working on uniting all our expertise together to unleash the true power of movement. As one, we are much stronger than the previous separate companies which accelerates our innovation and growth momentum."

MOVELLA/XSENS CAPABILITIES

- Development Time, Cost, Deliverables
- PEER REVIEWED ORTHOPEDIC
- DEPARTMENT OF VETERANS AFFAIRS
- 3D MOTION CAPTURE MARKET US$ 334.83 MILLION BY 2027 IMARC GROUP
- VORTEX FIRE CONTROL INTEGRATION
- UE5 TC3ICXR Time, Cost Deliverables

DIGITAL MEDICINE: A Soldier relays information via a cell phone during an exercise on the TATRC grounds, to highlight the capabilities of the NEXUS laboratory on May 25.

NEXUS Laboratory charts the future of medical performance.

by Ramin A. Khalili

It starts with chaos and so everyone acts accordingly. The Soldier picks up his radio and calls for air support—then motions to a buddy, who helps him carry an injured squad member about 50 yards away, setting up shop behind a barely-there wall of concrete blocks. There's yelling, of course—more like screaming, constant motion. Another Soldier runs over to help and now all three are busy administering combat casualty care to the person laying on the ground between them.

Standing just a few feet away, monitoring the action via computer, is Geoffrey Miller—who serves as the division chief of the Medical Modeling, Simulation, Informatics, and Visualization program at the U.S. Army Medical Research and Development Command's (USMRDC) Telemedicine and Advanced Technology Research Center (TATRC). Just as the action hits a crescendo, Miller turns to a

nearby crowd and says, “What we’re really trying to understand here is what kind of data matters in any given situation.”

“Any questions?” he says casually.

Geoffrey Miller, division chief for the Medical Modeling, Simulation, Informatics, and Visualization program at TATRC, spoke to a group of Soldiers and scientists during a tour of the NEXUS lab on May 25. Miller wants to provide everyone with the expertise they need through the science of data. (Photos by Ramin A. Khalili, USAMRDC Public Affairs)

If you haven’t guessed by now, the Soldiers described here are engaged in a training scenario. Their efforts—and indeed the entire simulation taking place in the TATRC parking lot on this sunny morning in late May; from the medical equipment in the nearby tents to the scientists wearing motion-capture suits in the foam-padded studio just yards away—is part of a planned tour of USAMRDC’s new NEXUS laboratory; a

next-generation research environment designed to explore and analyze the intersection of humans, data, and technology across the Military Health System. But it's the end result of all that data collection—the overall impact that this newly-christened laboratory can truly, ultimately provide—that has heads turning at USAMRDC and beyond.

MEDIC: NEXUS laboratory researchers monitor Soldiers as they carry a wounded "casualty" to a new location on the TATRC grounds during an exercise on May 25.

THE RIGHT DATA

The NEXUS laboratory is, as the name surely implies, a sleek and high-tech medical performance measurement laboratory; one that ultimately seeks to record military medical professionals as they perform various medical tasks (both with and without certain medical devices and technologies) in order to better understand human clinical procedural

performance. The ultimate goal is then the codification of that performance.

"We like to talk a lot about the reliability of data, but I like to talk about the feasibility and practicality of data, too," said Miller, who began his career as a paramedic—logging 31 years on the job, in fact—before stepping into his current role at USAMRDC. "What's the right piece of data at the right time that's going to help make the right decision?"

If that's the question, then the NEXUS laboratory is indeed primed to find an answer, as it combines such cutting-edge tools as volume capture technology (a technique that digitizes three-dimensional spaces), psychophysiological monitoring (including sensors to document skin sweating and blood pressure), and electromagnetic motion tracking (a technology that allows human movement to be followed and then gathered and processed), among others, to develop a so-called "master model of performance" as it pertains to any given medical procedure—a process Miller likes to call "finding out what 'right' looks like." Once that baseline is achieved, the plan is to then train current and future medical professionals off of that new, master standard.

"Everybody's heard the old adage [that] practice makes perfect, but that's one hundred percent not true," said Miller. "Practice makes permanent, because if your practice is imperfect, you will be permanently imperfect."

TEN PERCENT

The NEXUS laboratory hopes to shore up those imperfections in a number of ways, chiefly by employing its capabilities to monitor both the physical and psychological efforts of its participants—including medics and other military medical personnel—performing various tasks related to combat casualty care. For instance, by monitoring physiological responses such as heart rate, blood pressure, respiratory response and electrodermal activity (i.e., sweat production) to a range of efforts—anything from establishing an airway to applying a tourniquet—researchers can then quantify and describe actions in which those aforementioned "master performers" excel—and, conversely, quantify those in which novice performers do not excel. Additionally, by using an electroencephalogram, or EEG, to measure the electrical activity of the brain during a given task, researchers can objectively measure the cognitive load of said task on any participant; information that could, in turn, allow researchers to pinpoint

when a particular Soldier is experiencing heavier stress and, additionally, which specific tasks caused that stress.

Further, and as a more specific example, the laboratory's motion capture system allows researchers to begin the process of finding answers to how, exactly, medical professionals must position their owns bodies to perform a particular procedure—everything from intubation to performing chest compressions—at an expert level.

CAPTURED CARE: Two Soldiers perform routine medical care on a mannequin in the NEXUS laboratory's motion capture studio while their actions are recorded using cameras and sensors. "How someone lays out their equipment to prepare for a surgery or a procedure may be significant, or it may not matter, but we don't know until we explore that, until we measure it," said Miller. For instance, and as Miller described it, if 50 percent of medics always put their instruments in a certain order for a certain procedure, and those medics are then able to perform that procedure with a 10 percent better efficiency than the medics who put their instruments in a different order—does that 10 percent time savings ultimately impact the casualty? For Miller and the team at TATRC, we simply won't know unless we record the data and crunch the numbers.

According to Miller, "These are the questions we're hoping to explore and understand, because if we realize we got one hundred percent of people to save that 10 percent, then it could make care 10 percent better in the long run."

In short, Miller said, the ultimate goal of collecting such voluminous data is for the expertise to be transferred from a single person (or a single "master performer") to the modeling itself, which can then be inserted into other computer-based systems to allow any student to practice independently with expert feedback, guidance, and assessment.

SPECIAL PROJECT

REMOTE INSTRUCTION: A NEXUS laboratory tour participant, left, completes a complex surgical task while a scientist instructs him on how to perform said task from another room, while wearing virtual reality goggles. These capabilities are in turn important to the larger Army modernization strategy as both the Army and DOD begin to capture, process, and apply that collected data for the purposes of accomplishing overmatch on the multi-domain battlefield. According to military experts, future adversaries will likely have spent years studying previous U.S. military processes and procedures—or, more specifically, how exactly the U.S. military approaches and engages in combat. In the face of this likely reality, the NEXUS laboratory positions itself as integral to the overall USAMRDC and DOD missions, as maximizing Soldier readiness—in this case, via data collection—may ultimately translate to increased Soldier lethality.

"Our intent here is to take all the data we're collecting and whittle it down to the data that's going to help the caregiver," said Col. Jeremy Pamplin, the director at TATRC since August 2018, commenting on the laboratory and its capabilities. "If we can figure out the best technique as supported by data, regardless of what the prevailing opinion is, then we can take that information to the [Food and Drug Administration], to our partners in industry."

In a quip that essentially sums up the entire purpose of the NEXUS laboratory, Miller said, "Basically we've democratized expertise for any trainee, anywhere."

NICE SUIT: A Soldier wearing a motion capture suit surveys data in the NEXUS laboratory while the screen records his movements.

TWIN PILLARS OF THE FUTURE

Given the outsize role technology will likely play on the future battlefield—and indeed, perhaps reflecting the outsize role it plays in all our daily lives—the NEXUS laboratory is further designed to test human interaction with modern medical technology in order to discern if such tools truly benefit the caregiver—and, in turn, the person receiving care.

"What we're doing here is testing these technologies in actual environments that simulate what Soldiers would see on the battlefield," said Nate Fisher, chief of TATRC's Medical Robotics and Autonomous System Division.

As part of the aforementioned focus on the multi-domain battlefield of the future, recent military medical research efforts have focused almost exclusively on two areas: making key tools and technologies smaller and studier and finding ways to employ the substantial gains being made in the field of artificial intelligence. The NEXUS laboratory team hopes to put both of those efforts under the microscope. From the perspective of the team at TATRC, efforts to study these emerging technologies in such a unique setting will eventually allow researchers

to more quickly identify the products likely to help caregivers complete their mission—a factor of chief importance when faced with the constraints of austere and operational environments. As a result, the NEXUS laboratory offers the ability to inform the development of better tools and technologies at a much faster rate than the current research and development process.

"We come here, we push [the product] to the point of failure, then figure out how we can make it better," said Miller. "And so, when it comes to project convergence, we now have a more mature product to test in the larger medical battlefield ecosystem."

CONCLUSION

In moments of candor—and perhaps as a means to simplify the complexities behind such vast data collection—Miller is keen to compare the mission of the NEXUS laboratory to something far more familiar: the game of baseball. Indeed, baseball teams and their respective scouts have been gathering data on chosen prospects for decades, calculating everything from the speed at which a player swings a bat to how much energy a player exerts when stealing a base. And still, while baseball has yet to find a find a way to use that data to create the perfect ballplayer—the player who can approach each challenge in the most precise and efficient way possible—Miller believes the NEXUS laboratory may be able to do just that when it comes to teaching future generations of caregivers.

Field Connection to Military Doctors via AR/MR Headsets

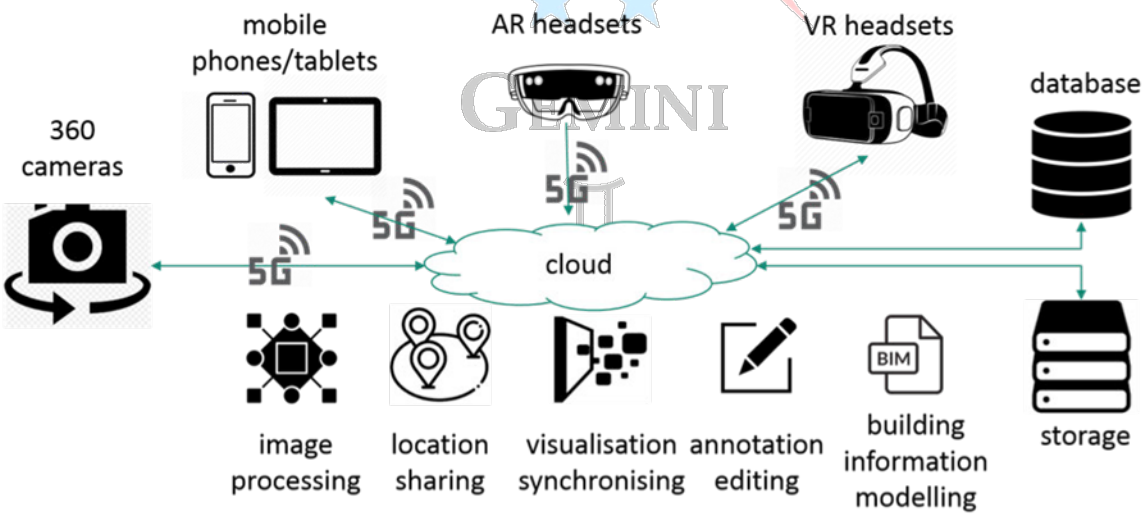
Presented by:

SphereGen

Microsoft Partner | Mixed Reality

Microsoft Gold Partner

Microsoft | AZURE PARTNER



Introduction

MARCO Federal Services would like a custom software application that will facilitate remote medical guidance for field personnel. The goal of this program is to provide a platform that allows doctors to connect to field personnel through multiple Augmented Reality (AR) or Mixed Reality (MR) Headsets.

To enable the field personnel the greatest flexibility in use, the intention for this phase is to include functionality for 3 headsets - the Microsoft HoloLens 2, Vuzix M4000, and Lenovo A3. The field personnel can choose whatever AR/MR headset they feel most comfortable with according to their use case. The doctors will experience the same user interface, no matter which headset is used.

SphereGen is a leading provider of Mixed Reality experiences and is in discussion with MARCO Federal Services to offer our services in the proposed solution outlined in this Statement of Work (SOW). SphereGen is a Microsoft Mixed Reality Partner and Unity Development Shop, who provides application development and product deployment, relying on experienced project teams to leverage the knowledge of the industry in order to maximize development efficiency and deliver timely, quality products.

SphereGen's experience in connecting doctors with remote medical personnel is referenced here –> MT. SINAI PARTNERS WITH SPHEREGEN TO BRING REMOTE SURGERY TO UGANDA

This use case was accomplished with the Microsoft HoloLens 2 using Dynamics 365 Remote Assist. The technology can be leveraged and expanded to any headset requiring remote collaboration.

Requirements

Opportunities

MARCO Federal Services would like to use Augmented and Mixed Reality devices to remotely support military operations and medical personnel. The application to accomplish this goal would need to be Microsoft agnostic and be able to operate on a minimum of 3 AR/MR devices for the initial POC.

Business Value

The value of providing field medical personnel the ability to access specialist medical guidance and collaboration in a timely manner, is unmeasurable. Therefore, the underlying requirements of this application supporting the remote connection are critical in several areas:

1. Speed of the connection – Real time feeds are imperative for urgent lifesaving care
2. Ability to communicate/ collaborate between the two parties in a seamless manner using voice, video.
3. The ability to transfer information/ data (limited to PDF, JPEG, PNG files for initial project scope).

Some of the features may not be able to work on all headsets, however the functionality will be created so that future headsets require less time for development.

SphereGen is planning to use Six Sigma and Agile software development methodologies in the Program build, to achieve ease of seamless integration across all development teams.

Scope of Work and Deliverables

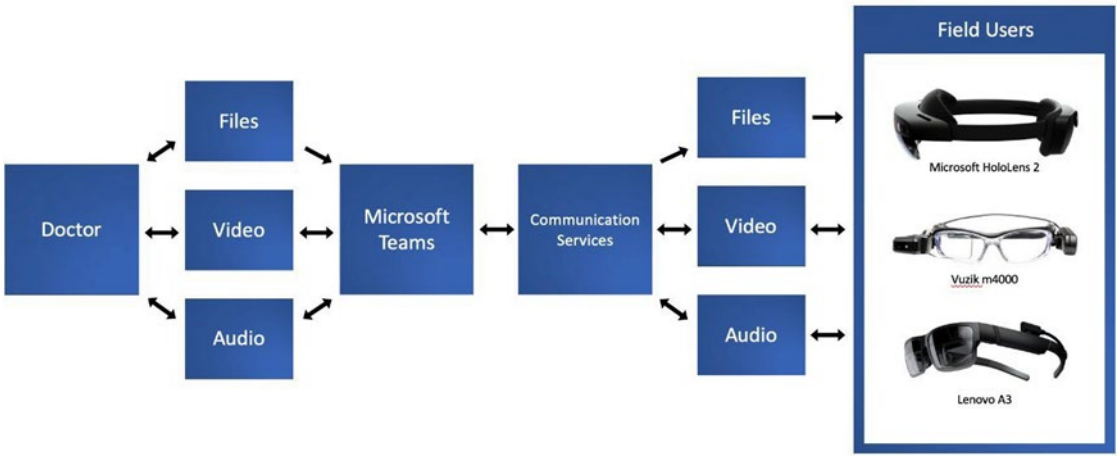
Program Scope

MARCO Federal Services needs a custom solution that can provide downrange remote medical assistance for NATO forces. The scope of the project will be broken down into the following sections:

1. Developing a custom application using DoD guidelines which will work on the specified AR/MR headsets.

2. The Application will have the following functionality

- Audio / Video calling on demand/scheduled to other Teams client user or group calling
- Text Chat enabled
- Record a call (Audio / Video) {Azure Public pre-view}
- The ability to transfer information/ data (limited to PDF, JPEG, PNG files for initial project scope) {Azure Public pre-view}
- IT Administrative portal
    - ❖ Dashboard
    - ❖ Audit logs
    - ❖ Various Administrative functions
    - ❖ Reports
    - ❖ Report Data Extract



Program Deliverables

Following are the deliverables for the program:

- Custom application for AR/MR headset(s)
- IT Administrative Portal
- User Manual
- Training to 10 SME's – 1 month Duration
- 1 year of technical support (2nd Level)
- 7 Days a week – 8AM EST to 5PM EST

Customer Responsibility

MARCO Federal Services needs to allocate internal resources to assist in completing this Program. These resources can be consolidated, as one individual may fill several of the roles outlined below:

Role	Client Responsibilities
Project Manager	• Orchestrate project specifics for the internal team and SphereGen.
Business Owner	• Individual responsible for identifying business goals, value, and scope. SphereGen uses the Agile terminology of "Business Owner".
Subject Matter Experts	• Individuals who provide needed detail to develop and validate the solution. • Subject Matter Experts (SMEs) play an important part in projects.
IT Administrator	• Key point of contact within IT who has Administration rights and access/permission to O365 environment
Acceptance Testers	• Designated individuals who are briefed on the project and who can test and accept the final solution.

Program Scope Phases: In meeting MARCO Federal Service's request developing an application for remote assistance, SphereGen is recommending the Program be broken down into phases. A phased approach allows the generation of a technical POC to validate the structural design for a workable solution, before continuing to finalize the product.

We will be using a mix of Six Sigma and Agile software development methodology to plan and maximize the team utilization.

This SOW covers 10 phases in this approach.

1. Discovery
2. Design phase
3. User Interface for App and IT Portal
4. Development Sprints
5. Security, regression, load, and redundancy testing
6. Deployment to Test environment
7. UAT
8. Training to SME's
9. Deployment to Production environment
10. Technical Support for 1 year Timeline

Discovery

During the discovery phase the goal is to assess the current environment, so that architecture designs align with environment requirements; further define the requirements; discover the system architecture and communication needs; interviewing the key users to determine roles and responsibilities.

Deliverable: Discovery Document

Design Phase

The goal of the design phase is to architect and design a platform that enables multiple devices to connect to the current DoD Microsoft Teams infrastructure. This design should include the flexibility that allows future phases to include integration of other backend solutions, such as Apple Facetime.

The Headset functionality will need to be architected according to the hardware's capability.

Deliverable: Design Document

User Interface for App and IT Portal

This phase will include the creation of a user storyboard mockup for the application and IT administrative portal.

Deliverable: Mockups of user screens and device app screens

Development Sprints

Develop Minimum Connections Phase

A Technical POC to develop an application that integrates with the HoloLens, Vuzix, and Lenovo via Open XR into the Microsoft Teams interface of Azure Communication Services (ACS). This will be divided into the following milestone levels:

- Basic Connection Hololens to ACS Basic
- Connection Vuzix to ACS Basic Connection
- Lenovo to ACS

Deliverables:

- Custom Application POC which runs on the HoloLens and seamlessly facilitates calls back to a Microsoft Teams user (doctor)
- Administration Portal which performs security and permissions checks and provides user interface for IT support and management
    - Authentication against an agreed upon user database
    - Point of Access determined based on User Defined Roles with access levels
    - IT Support dashboard
    - Add/remove users from service
    - Report generation
    - Display history of calls made by users, duration and number called API configuration
    - Maintain Keys necessary for controlling appropriate Powertrain Military Communications Server

MVP Functions

After the technical POC of providing the basic connection of each device to the Microsoft teams environment is completed, each of these connectors will then be enhanced for the following functions:

- Call on demand from the remote back to doctors on Microsoft Teams
- Video Stream
- Audio Stream
- Chat Function
- Share Files

Deliverables: Modified Technical POC to include functionality of video streaming from the AR/MR Headset to remote users. Ability to share across files from Teams users to headset users. Ability to view text chat from Teams users.

Security, Regression, Load, and Redundancy Testing

For this phase of the program, SphereGen will be testing compatibility across a wide range of systems and software. The application will undergo stress/load testing with high volume input. Security will be up to DoD standards per requirements.

Deliverable: Security Review Report

Deployment to Test environment

SphereGen will use the military test network to deploy software locally for testing.

Deliverable: Deployment Guide

UAT

SphereGen envisions this phase will be supporting the testing of the application.

Deliverable: Bug fixes and patches

Training to SME's

SphereGen will be creating training materials to teach Subject Matter Experts how to use the hardware and software applications.

Deliverable: User manuals

Deployment to Production Environment

SphereGen will support client deployment of the application to the production environment.

Deliverable: Support of the application move to the production environment

Technical Support for 1 year

SphereGen will be providing 2nd level support for 1 year beyond deployment of application. Support will be provided 5 days a week Monday through Friday from 9AM to 5PM EST.

Deliverable: Ongoing support Assumptions

Technical POC Assumptions	
Test Environment	• MARCO Federal Services will provide a test environment, a Microsoft Teams environment, Microsoft Teams license with calling enabled
Voice Connection	• MARCO Federal Services will have a SIP enabled Microsoft Teams Environment for Voice Calling to Phone Numbers

Screen Sharing	• Azure Communications Services does not support Screen Sharing. The application will be able to see video feeds from remote users and cameras, but cannot share desktop screens with headset users from a Desktop User
Development Device	• MARCO Federal Services will provide SphereGen with a HoloLens that is managed by their network and IT, for testing purposes. This HoloLens will be returned to MARCO Federal Services at the end of development.
Bug Tracking/Source Control	• Bug tracking and source control will be either SphereGen or MARCO Federal Service's chosen solution, to be determined and agreed upon before the start of work.
Internal Application Usage Only	• Any resulting application from this work will be a Line of Business Application only, deployed internally by MARCO Federal Services or Sideloaded onto their devices. As a part of this Program, it will not be published on the Microsoft Windows Store, or Microsoft Windows Store for Business.
License Costing	• All associated licensing cost for the service will be borne by MARCO Federal Services
Connectivity	• This assumes there will be sufficient bandwidth for the communications to work as desired by Global Solution Initiative
Hardware	• Vetting Hardware for the specific Use Cases is the responsibility of Global Solution Initiative • Direct Sunlight can create interference with some sensors used in AR glasses; any issues with tracking due to the environment where the equipment is used is not our responsibility
SDK's and API's	• Documentation and access to SDK or APIs for any systems which SphereGen needs to integrate with, must be provided in its entirety for this project to succeed
Security Vetting	• Vetting hardware architecture and security is the responsibility of Global Solution Initiative. SphereGen can assist with only software security
Video Resolution Quality	• SphereGen assumes the video streaming resolution available on the provided hardware will suffice for the use case.

Audio Resolution Quality	• SphereGen assumes the audio quality, volumes and noise filters (if available on specific Hardware) will be sufficient for the use case.
File Sharing	• File Sharing Capabilities can only operate from Doctor to Field Specialist, not from Field Specialist to Doctor
Power Supply	• SphereGen assumes the operating lifetime of a single battery charge on the targeted hardware is sufficient for the use case.
Usage of devices	• SphereGen assumes the Standard Operating Procedures produced out of the MVP will be followed

Out of Scope: The following are considered to be out of scope of this program.

Anything not listed in the deliverables and/or called out under assumptions is considered out of scope.

Out of Scope Items	Description
Annotations	• Annotations such as drawing capabilities which include but are not limited to, arrows, pen markings, highlighting, circling, etc
Limitations of hardware	• The Vuzix headset does not have spatial awareness, so it can only provide a heads-up display and video and audio streaming.
Travel Costs	• Travel costs are not included in this proposal budget

SphereGen Project Team Roles & Responsibilities

Role	Responsibilities
Project Manager	• Coordinate with client stakeholders and internal team. • Primary contact between SphereGen and client Microsoft Teams. • Make project decisions, impact analysis, and approve changes.
Account Manager	• Works with the client to coordinate project kickoff
Business Analyst	• Working with SME's and understanding requirements, documenting the requirements in RA document.
Content Writer	• Working with internal team to create User Manual, help content for IT portal.
Tester	• Writing test cases and executing them

Tester (Security)	• Security testing and identifying potential security issues • Making sure SGR guidelines are being followed and implemented
Enterprise Architect	• Design the system • Document the system architecture • Help Unity and portal development teams to deliver as per design
Unity Architect	• Work with enterprise architect to deliver mobile app for multiple mobile platform
Portal (Azure) Architect	• Work with enterprise architect to deliver portal
UX Lead	• Responsible for UX design and overall theme of the program.

VSI HoloMedicine® for Education

Introduction

MARCO Federal Services proposes advanced development of The **VSI HoloMedicine®** by apoQlar USA, this custom software application will facilitate Graduate Medical Education and medical guidance and training for DHA/MHA personnel. The goal of this proof-of-concept prototype program is to provide a platform that allows doctors to connect to "APOLLO" the Augmented Physicians Omniverse Learning Lenses Online and DHA/MHS/DoD professionals to "ARTEMIS" the Augmented Reality Training Enterprise Medical Instruction Simulations. The Digital Twins, Apollo and Artemis, work with "ZEUS", the Zenith Enterprise Unified Simulations command, control, and communications system of systems. in direct support of DOD INSTRUCTION 1322.24 MEDICAL READINESS TRAINING.

The **VSI HoloMedicine®** by apoQlar USA, the developer of a medical mixed reality platform that is revolutionizing how medicine is practiced, experienced, learned, and shared globally. **VSI HoloMedicine®** is a medically certified cloud-based software platform that leverages the Microsoft HoloLens 2 hardware to transform medical data, collaboration methods, and medical education into an interactive 3D mixed reality environment. apoQlar achieves this by combining AI neural networks, computer vision, and 3D rendering technology with real world patient data to augment the clinical and academic experience.

Globally, customers (users) are hospitals (doctors) and medical schools (students & professors). Users collaborate with other students, residents, professors, or physicians globally as virtual avatars, conduct surgical training simulations in 3D, engage patients, and educate the doctors-of- tomorrow in medical academia. All of this is just the beginning, however. **VSI HoloMedicine®** is building a suite of next generation medical applications that serves to be the foundational platform for mixed reality-based medicine and disrupt legacy medical equipment and medical education systems.

Finally, **VSI HoloMedicine®** is based on Microsoft Azure and the latest cloud architecture, which allows the solution to be expanded and scaled at anytime and anywhere. In addition, WiFi-6 and 5G are supported, so that the most modern collaboration scenarios and streaming technologies are possible.

In collaboration with 3DMedia Development Team Lead, a Unity3D Verified Solution Provider for many highly classified USAF programs. PowerTrain USAL Federal Learning Enclave SaaS/PaaS. MARCO Federal Services offers our services in the proposed phase 1 solution outlined in this Statement of Work (SOW).

The VSI HoloMedicine® platform brings clinical technology into the medical classroom and training simulation labs. VSI HoloMedicine® is medically certified and currently holds the following certifications & quality standards:

- European Union: CE Class I Medical Certification Approved
- Singapore: HSA Class A Medical Certification Approved
- Canada: R&D Class II Clinical Trial Approval
- USA: FDA 510(k) Pending, Approval Expected 09/2022. *FDA is not needed for education use*
- ISO 13485 and 21 CFR 820 (USA, EU) compliant (passed MDSAP stage 2)
- HIPAA & GDPR Compliant

Reference Videos & Cases:

- Medical students experience medical mixed reality (University of Florida)
- How HoloMedicine® was used to educate and comfort a pediatric patient prior to heart surgery (Nicklaus Children's Hospital Miami)
- Introducing the latest version of VSI HoloMedicine®
- Poland's Jagiellonian University Medical College brings apoQlar and the Microsoft HoloLens 2 into the classroom
- Remote Medical Collaboration in Europe
- Introducing VSI HoloMedicine®
- HoloMedicine® Association Inaugural Summit (APAC)
- HoloMedicine® Association Inaugural Summit (Europe & USA)

Medical Education Use Cases

VSI HoloMedicine® brings clinical technology into the medical classroom. We take a holistic approach to innovating medical education and have reimagined experiential learning in medical mixed reality. VSI HoloMedicine® offers an immersive collaboration platform with real world medical data serving as the foundation of student learning. Finally, Medical Mixed Reality Education gives students and professors the ability to move beyond 2D textbooks and into an immersive 3D experience.

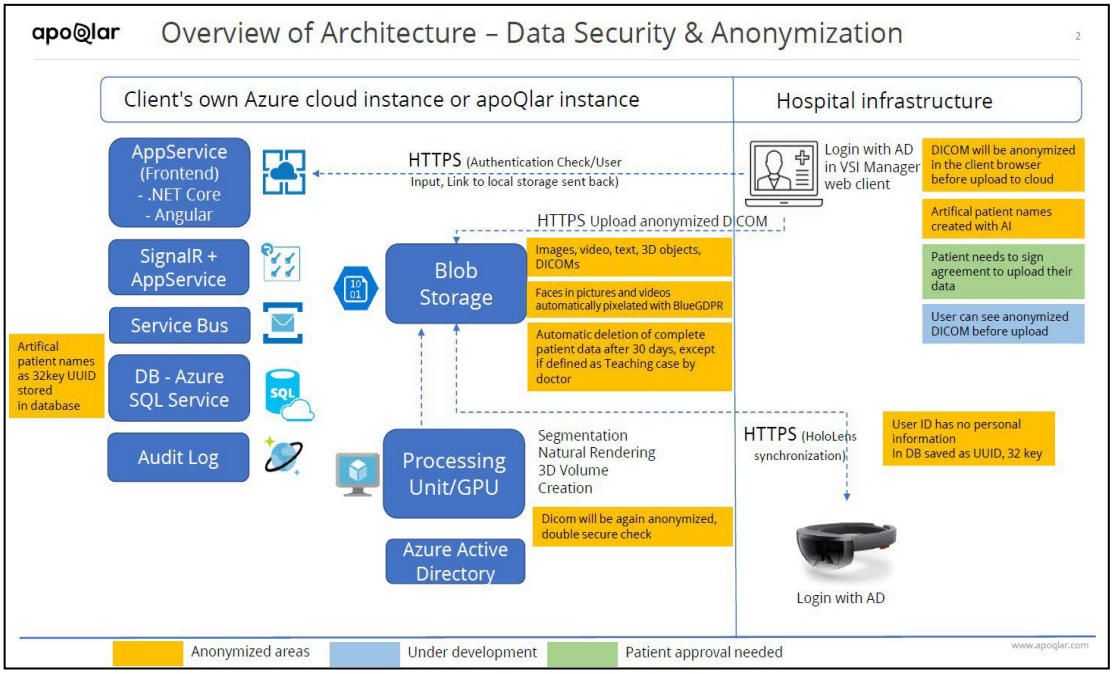
Use Case	Description
3D Cadaver/Anatomy Labs	Combine medical mixed reality collaboration tools and 3D transformation capabilities into the medical classroom and cadaver labs. Provide students with virtual models of cadaver anatomy and digital twins to enhance the learning experience.
Experiential Lesson Plans	Augment your existing curriculum and individual lesson plans by layering interactive medical mixed reality activities into the lecture hall. By leveraging this technology during traditional lectures, the student gains immediate appreciation of complex cases in 3D.
Remote Lectures	Conduct lectures with students or professors remotely via the medical metaverse or stream your mixed reality view through Microsoft Teams.
Automatic CT Segmentation for Isolated Anatomy Visualization	Transform and enhance your view of real-world CT scans utilizing the power of AI. Automatically segment bone and vessel structures in 3D and natural rendering technology for to bring color into an otherwise greyscale scan.
Medical Education Guides & Interactive Quizzes	Create bespoke 3D mixed reality guides or access a future library of pre-made guides that direct your students step by step through a pre-defined module or lesson plan. Combine 3D DICOMs, STL files, images, video, and text with quiz functionality to enable a robust educational experience.
Global Collaboration	Share cases, ideas, and perspectives with your medical community across borders and backgrounds in the medical metaverse or Microsoft Teams view streaming.
Wireless medical imaging Streaming via Streamer Box	apoQlar has developed hardware for R&D and education that connects live imaging equipment, such as ultrasounds, laparoscopy, fluoroscopy, and endoscopy, to a small streaming box that transmits that feed wirelessly into the HoloLens view. This enables students to monitor and observe training scenarios remotely and all in their field of vision.

Medical Education Features

Feature	Description
Digital Avatars in the Medical Metaverse	Using the Microsoft HoloLens 2 and the VSI HoloMedicine® application, a surgeon is able to instantly communicate with colleagues across the hospital campus or even surgical specialists across the globe as virtual avatars in a 3D mixed reality environment. The surgeon's head and hand movements are transmitted into the field of vision of the collaborator in real time and in the form of a 3D avatar hologram. Within this environment, the collaborators can discuss a patient's case, share patient data, and simultaneously manipulate 3D volumetric medical images as if the collaborators were standing in the same room together.
Microsoft Teams Integration	Microsoft Teams is now fully integrated and available for all VSI HoloMedicine® users with the new 1.9 software update. Communicate and collaborate with your colleagues or global medical community anytime, anywhere on one of the most prevalent video conferencing platforms. Microsoft Teams is fully integrated in the VSI HoloMedicine® platform enabling you to stream your view, sounds and speech all hands free. This is especially useful for training and education by streaming your view into a lecture hall or room seamlessly.
AI Segmentation Tools*	apoQlar combines AI neural networks, computer vision, and 3D rendering technology with real world patient data to augment the clinical and academic experience. VSI HoloMedicine® enables students, professors, and physicians to instantly segment real world CT scans using AI. Visualize anatomical structures like bones & vessels by a press of a virtual button in 3D medical mixed reality. *For Research, Training and Education purposes only.

Natural Rendering	Immediately gain appreciation of structural relationships using VSI HoloMedicine® Remote Natural Rendering technology. Transform greyscale objects into vivid color mimicking the view of real-world colors.
Hands Free/Controlled Hologram Manipulation	Eliminate physical contact with nonsterile objects and mouse clicks with interactive holographic technology and voice control commands. Interact with the technology using nothing but your hands and voice commands for a seamless clinical experience.
3D Visualization of Real-World Medical Data	Easily transform any STL/OBJ or DICOM scan such as SPECT CT, PET CT, MRI, ANGIO-CT, CBCT, and many more, as a 3D hologram for an enhanced view of patient's anatomy and pathology. VSI HoloMedicine® then enables the physician to manually superimpose the 3D image onto a patient to enhance their preoperative surgical planning process. Finally, virtually cut into these 3D models to gain a unique 360 perspective.
Choose your View with Virtual Monitors	The days of twisting your neck to receive valuable medical data and input is over. With medical mixed reality and our proprietary streaming technology, you are able to position your virtual monitor anywhere in the room around you or a collaborator to ensure you never lose line of sight or train of thought.

Architecture



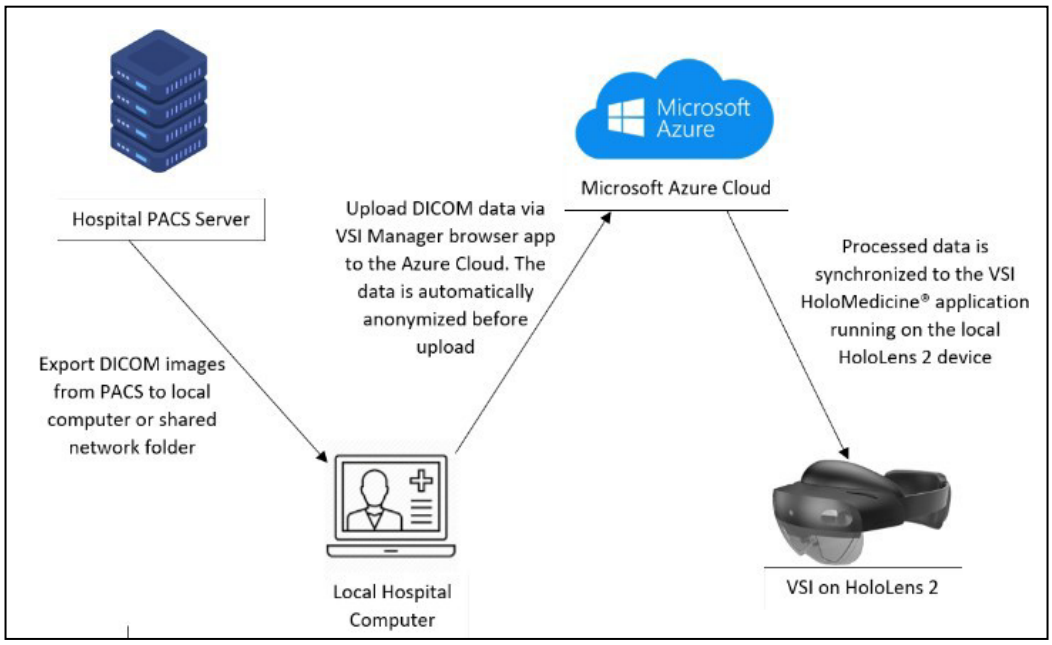
The VSI HoloMedicine® package includes:

- VSI HoloMedicine® – Microsoft HoloLens 2 application to visualize, interact, and share data
- VSI Manager – web application where data can be uploaded by drag and drop functionality
- Automatic data anonymization
- Training & technical support, as defined in SLAs

Additional Required Hardware & Cloud Services:

- Microsoft HoloLens 2 Device: technical specifications available here.
- Microsoft Azure Cloud – VSI HoloMedicine® is entirely based on Azure cloud and can seamlessly scale as your institution scales.
- Depending on cloud requirements, we would be able to transfer our infrastructure/template onto any federal cloud hosting organization via Azure.
- Azure cloud is where the medical data is stored. It is considered one of the most secure cloud solutions and compliant with multiple standards. More information can be found here.

- *The interaction between the different components can be visualized below:*



The following infrastructure is required to ensure the full functionality of VSI HoloMedicine®:

- Wi-Fi or 5G Connection: 30 Mb/s minimum, 50 Mb/s recommended
- Only the following file formats are supported at this stage (more planned): MRI, CT, SPECT CT, PETCT, CBCT, STL, OBJ, JPG, PNG, MP4.

Accompanying Azure Cloud Instance:
Azure Cloud consumption not included and dependent upon number of users and tenants.

The following services are <u>not</u> included:

- Develop the ability to upload different DICOM formats not defined in the technical requirements. In case a new format is required, an extra fee will be charged depending on the technical effort.
- Integration with PACS or other IT infrastructure is possible, costs will be charged additionally.
- Education custom-built 3D models/animated models can be created and will be charged extra.
- Any other development module required going forward will be charged extra after due deliberations.

Readiness Training

- **Course #1 — TACTICAL COMBAT CASUALTY CARE**

    - Tier #1 — **ALL SERVICE MEMBERS**

      Tier #2 — **COMBAT LIFE SAVER**

      Tier #3 — **COMBAT MEDIC**

      Tier #4 — Combat Paramedic - coming soon **INSTRUCTOR/TRAINER TOOLS FOR TACTICAL COMBAT CASUALTY CARE**

- **Course #2 — Prolonged Field Care**

  (Under development)

    - Tier #1 — None

      Tier #2 — Combat Life Saver

      Tier #3 — Combat Medic

      Tier #4 — Combat Paramedic

- **Course #3 — Emergency War Surgery Course (EWSC) aka JTS (JOINT TRAUMA SYSTEM) CPG (Clinical Practice Guideline) Curricula**

    - **VIEW THE EWSC COLLECTION**
    - **CLICK HERE** to learn more about the collection and registration.
    - Module #1 — Advanced Surgical Skills for Exposure in Trauma (ASSET)+ Audience: General Surgeons and Subspecialties, those who assist them, and Surgical Technicians.

- Module #2 — Combat Orthopedic Trauma Surgery (COTS)+ Audience: Orthopedic Surgeons, those who assist them, and Surgical Technicians.
- Module #3 — Expeditionary Skills Course for General Medical Officers: These are the Army Individual Critical Task List and the Air Force Comprehensive Medical Readiness Program.

  Audience: any specialty that may deploy in the role of a general medical officer and includes Family Practice, Internal Medicine and Subspecialties, Pediatrics and Subspecialties, Physician Assistants, Nurse Practitioners, and (likely) Special Operations Medics.
- Module #4 — (under development) — Head and Neck Course.

  Audience: Ears, Nose, and Throat Surgeons, Oral Maxillofacial Surgeons, and Plastic Surgeons, those who assist them, and Surgical Technicians.
- Module #5 — (under development) — Anesthesia. Audience: Anesthesiologists and Nurse Anesthetists.
- Module #6 — (under development) — Critical Care/Emergency Medicine Nursing. Audience: Critical Care and Emergency Medicine Nursing, Med/Surgery, Operative, Peri-operative, and other deployable nursing specialties.

Procedures

MRT PROGRAMS. MRT of all military and DoD-EC personnel serves as the foundation for effective force health protection. Realistic MRT must encompass the broad spectrum of health service support across the full ROMO in all environments and locations. Service and joint readiness training programs will include the required MRT described in this issuance.

MRT GOAL. MRT programs will maximize the use of commercial training simulations, manikins, moulage actors, and cadavers while reducing the reliance on the live animal model, when appropriate, to prepare Service members to provide effective medical care, minimize casualties, and minimize preventable death across the full ROMO.

MRT REQUIREMENTS. All Service members and DoD-EC personnel will receive standardized MRT and maintain proficiency in providing first responder care. The DoD will utilize Service-designated training tracking systems to measure MRT across the total force. The MRT requirements in Table 1 represent the minimum medical training required for medical readiness skills sustainment; however, the DoD Components may increase MRT requirements based on their mission set.

MRT REPORTING.

a) Units will record all assigned Service member and DoD-EC TCCC certifications (initial and recertification) in Service-designated training tracking systems.

b) Any additional MRT metrics identified by the Secretaries of the Military Departments and the CCDRs will be reported into Service-designated authoritative data sources as required.

- AMEDD Medical Skills Sustainment Program (AMSSP)
    - Develops Military-Civilian (MIL-CIV) training partnerships with Level 1 civilian trauma centers to build medical skills sustainment capabilities

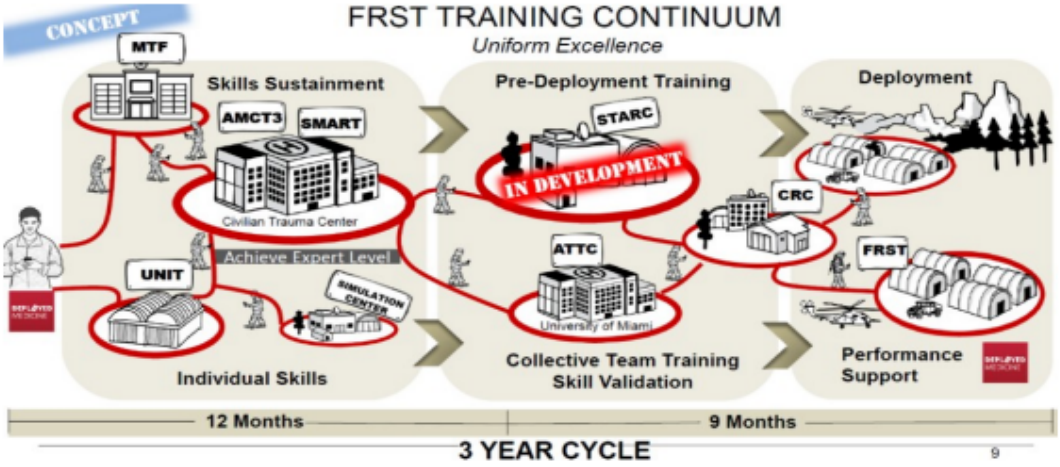


Table 1. MRT Requirements

Service Members	Health Care Personnel (Service Members and DoD-EC)	Health Care Providers (Service Members and DoD-EC) Based on Assignment and Profession
• Complete TCCC training and certification requirements in Section 4. • Train on the early detection of potentially concussive events pursuant to DoDI 6490.11.		
	• Remain certified on the appropriate TCCC skills as recommended by the Director, DHA. Commanders may direct additional or advanced TCCC training based on unit mission set. • Before assignment to a joint task force or joint force Command Surgeon staff, or Service Component or special operations forces headquarters surgeon staff in a leadership position, complete the Joint Medical Operations Course or the Joint Senior Medical Leaders Course. • Before medical planners are assigned to a joint task force or joint force Command Surgeon staff, or Service Component or special operations forces headquarters surgeon staff, complete the Joint Medical Planning Tool and Joint Medical Operations Courses. • Complete the appropriate chemical, biological, radiological, nuclear, and high-yield explosives training on the recognition and medical management of chemical, biological, radiological, nuclear, and high-yield explosives health threats and injuries within 12 months of assignment to operational military units. Sustainment training is required every 3 years. • Obtain a working knowledge of the signs and symptoms of exposure to theater-specific health hazards, including endemic infectious disease agents and countermeasures and treatments for mitigation of the risks. • Upon notification of a deployment involving the treatment of detainees or other detainee matters, complete Medical Ethics and Detainee Operations training before deployment in accordance with DoDI 2310.08.	
		• Obtain a working knowledge of the Joint Trauma System Clinical Practice Guidelines and the CCMD Trauma System. • Complete a trauma and resuscitative skills course that meets the core requirements as determined by the Director, DHA within 12 months before deployment, when assigned to forward resuscitative care teams.

Training

GENERAL.

a. All Service members (officer and enlisted) will complete appropriate role-based (i.e., All Service Members, combat lifesaver, combat medic/hospital corpsman/aerospace medicine technician, combat paramedic/provider) TCCC training and certification as outlined in the JTS's TCCC skills list. TCCC training replaces the core trauma skills currently taught in Service specific first aid, and self-aid and buddy care, courses. Military Services may have additional non-trauma medical training requirements.

b. Service members and DoD-EC certify in TCCC when they successfully complete the appropriate, role-based TCCC training course in accordance with their skill level. Certification in TCCC requires use of the current, standardized curriculums developed by the JTS in accordance with DoDI 6040.47. TCCC certification may be categorized as either an initial certification or recertification.

c. TCCC training applies terminal and enabling learning objectives maintained and published on the Deployed Medicine Website (https://www.deployedmedicine.com) and corresponding mobile application.

Conclusion and Future Research

A systematic mapping study was conducted, focusing on the employment of immersive VR technologies for higher education purposes. Immersive VR technologies, application domains, learning contents, and design elements being used in recent literature on educational VR applications were examined. The review results show that the interest in immersive VR technologies for educational purposes seems to be quite high, which is indicated by the variety of the research domains that have applied this technology in teaching. The majority of authors treated VR as a promising learning tool for higher education, however,

the maturity of the use of VR in higher education is still questionable. Technologies described in most of the reviewed articles remained in an experimental state and were mostly tested in terms of their performance and usability. This article also reveals that very few design-oriented studies constructed their VR applications based on a specific learning theory, which serves as technical development guidance. Moreover, few papers thoroughly describe how VR-based teaching can be adopted in the teaching curriculum.

These facts can hinder the rapid adoption of immersive VR technologies into teaching on a regular basis. We acknowledge that, in some domains such as engineering and computer science, certain VR applications have been used on a regular basis to teach certain skills, especially those that require declarative knowledge and procedural–practical knowledge. However, in most domains, VR is still experimental, and its usage is not systematic or based on best practices. This paper pinpoints key gaps that serve to provide insights for future improvements, especially for VR application developers and teachers in higher education.

Our work will continue with a market analysis of VR technologies that could be employed in higher education as well with a survey of educators. We aim to continue advancing the field now that we have understood its low maturity but nevertheless promising nature.

#	Code	Authors	Title
1	P4	Veronez, Gonzaga, Bordin, Kupssinsku, Kannenberg, Duarte, et al. (2018)	RIDERS: Road inspection driver simulation
2	P5	Webster and Dues (2017)	System usability scale (SUS): Oculus Rift®DK2 and Samsung Gear VR®
3	P12	Papachristos, Vrellis, and Mikropoulos (2017)	A comparison between Oculus Rift and a low-cost smartphone VR headset: Immersive user experience and learning
4	P13	Román-Ibáñez, Pujol-López, Mora-Mora, Pertegal-Felices, and Jimeno-Morenilla (2018)	A low-cost immersive virtual reality system for teaching robotic manipulators programming
5	P15	Kwon et al. (2017)	A virtual reality-based engine training system: A prototype development & evaluation
6	P16	Rosenfield et al. (2018)	AAS worldwide telescope: A seamless, cross-platform data visualization engine for astronomy research, education, and democratizing data
7	P17	Dolezal, Chmelik, and Liarokapis (2017)	An immersive virtual environment for collaborative geovisualization
8	P22	Pena and Ragan (2017)	Contextualizing construction accident reports in virtual environments for safety education
9	P23	dela Cruz and Mendoza (2018)	Design and development of virtual laboratory: A solution to the problem of laboratory setup and management of pneumatic courses in Bulacan State University College of Engineering
10	P24	Zhang, Suo, Chen, Liu, and Gao (2017)	Design and implementation of fire safety education system on campus based on virtual reality technology
11	P25	Bujdosó, Novac, and Szimkovics (2017)	Developing cognitive processes for improving inventive thinking in system development using a collaborative virtual reality system
12	P26	Hickman and Akdere (2018)	Developing intercultural competencies through virtual reality: Internet of Things applications in education and learning
13	P27	Harrington et al. (2018)	Development and evaluation of a trauma decision-making simulator in Oculus virtual reality
14	P29	Smith et al. (2018)	Effectiveness of two varying levels of virtual reality simulation

15	P38	Gerloni et al. (2018)	Immersive virtual reality for earth sciences
16	P46	Muller, Panzoli, Galaup, Lagarrigue, and Jessel (2017)	Learning mechanical engineering in a virtual workshop: A preliminary study on utilizability, utility and acceptability
17	P47	Parong and Mayer (2018)	Learning science in immersive virtual reality
18	P48	Pirker, Lesjak, and Guetl (2017)	Maroon VR: A room-scale physics laboratory experience
19	P50	Shattuck (2018)	Multiuser virtual reality environment for visualizing neuroimaging data
20	P53	Schroeder, Bailey, Johnson, and Gonzalez-Holland (2017)	Presence and usability do not directly predict procedural recall in virtual reality training
21	P54	Parmar, Isaac, Babu, D'Souza, Leonard, Jörg, Gundersen, and Daily (2016)	Programming moves: Design and evaluation of applying embodied interaction in virtual environments to enhance computational thinking in middle school students
22	P55	Zhou, Ji, Xu, and Wang (2018)	Promoting knowledge construction: A model for using Virtual Reality interaction to enhance learning
23	P56	Song and Li (2018)	Research on application of VR technology in art design teaching
24	P57	Bryan, Campbell, and Mangina (2018)	Scenic spheres—An AR/VR educational game
25	P59	Hu, Su, and He (2016)	The design and implementation of the 3D educational game based on VR headsets
26	P61	Chen (2016)	The effects of virtual reality learning environment on student cognitive and linguistic development
27	P62	Yang, Cheng, and Yang (2016)	The impact of three types of virtual reality scene on learning
28	P64	Farra, Smith, and Ulrich (2018)	The student experience with varying immersion levels of virtual reality simulation
29	P66	Buń, Trojanowska, Ivanov, and Pavlenko (2018)	The use of virtual reality training application to increase the effectiveness of workshops in the field of lean manufacturing
30	P67	Zizza et al. (2019)	Toward a social virtual reality learning environment in high fidelity
31	P68	Ekkelenkamp, Koch, de Man, and Kuipers (2016)	Training and competence assessment in GI endoscopy: A systematic review
32	P71	Chin et al. (2017)	Using virtual reality for an immersive experience in the water cycle

33	P72	Němec, Fasuga, Trubač, and Kratochvíl (2017)	Using virtual reality in education
34	P73	AlAwadhi et al. (2017)	Virtual reality application for interactive and informative learning
35	P75	Carruth (2017)	Virtual reality for education and workforce training
36	P78	Ye, Hu, Zhou, Lei, and Guan (2018)	VR interactive feature of HTML5-based WebVR control laboratory by using head-mounted display
37	P79	Misbhauddin (2018)	VREdu: A framework for Interactive Immersive Lectures using virtual reality
38	P80	Cortiz and Silva (2017)	Web and virtual reality as platforms to improve online education experiences

TCCC TRAINING FREQUENCY.

a. Training frequency for Service members and DoD-EC completing the TCCC All Service Member course is at the discretion of the Military Service, with the stipulation that certification be completed prior to deployment.

b. Training frequency for Service members and DoD-EC completing the TCCC combat lifesaver, TCCC combat medic/hospital corpsman/aerospace medicine technician, or TCCC combat paramedic/provider course follows these guidelines:

(1) All active Component Service members and some DoD-EC personnel as defined by job or unit, will complete TCCC recertification at least every 3 years following initial certification. Military Services should consider implementing the triennial certification requirement for RC Service members assigned to rapidly deployable units.

(2) Service members and DoD-EC will certify in TCCC within 12 months of deployment. For personnel who deploy more than once during a 12-month period, certification in TCCC remains current if completed within 12 months of the most recent deployment date.

TCCC REFRESHER TRAINING. The Secretaries of the Military Departments, in coordination with the Director, DHA, may establish TCCC refresher courses as a supplement to TCCC certification courses. TCCC refresher courses are designed to ensure proficiency on TCCC skills and may be tailored to individual Service mission requirements. Refresher training does not certify a Service member in TCCC and will not be recorded as such in Service-designated training tracking systems.

TCCC CERTIFICATION. All TCCC certification courses, trainers, and instructors are certified and approved in accordance with Service-specific policy set by the Secretaries of the Military Departments in coordination with the Director, DHA.

a. At a minimum, all TCCC trainers or instructors will be certified in TCCC and complete the appropriate JTS-developed "train the trainer" course every 3 years. The Military Departments may establish additional training requirements for TCCC trainers or instructors.

b. Standardization of TCCC training throughout the DoD enables the Military Departments to recognize TCCC certifications awarded to their Service members or DoD-EC regardless of the DoD Component conducting the training.

GAP	Joint Gap Alignment
Provide En Route Care	Joint Theater Patient Movement DCR
Provide Forward Resuscitative Care	Joint FRC ISO Dispersed Operations DCR
Provide Prolonged Field Care (PFC)	Joint Combat Casualty Care ICD
Provide Theater Hospitalization	Joint Essential Medical Capabilities DCR
Conduct Medical Operations in CBRNE Environment	Joint Force Health Protection DCR
Provide Blood and Blood Products	
Provide Adaptive and Scalable Force Packages	
Provide Rehabilitative Care In-Theater	
Provide Medical Care for Mass Casualty Operations	
Provide Patient Holding	
Equip the NEHSS Force	Joint Medical Logistics Infrastructure Support DCR
Provide NEHSS Command and control for Forces Afloat and Ashore	
Provide Health Surveillance	Joint Force Health Protection DCR
Provide Medical Intelligence	Theater Medical Information Requirement System CDD
Provide Preventive Medicine and Force Health Protection	Joint Force Health Protection DCR
Manage Warfighter Fatigue	
Provide First Responder Care	Joint Combat Casualty Care ICD

Learning motivation

The following questions are about feelings or thoughts you felt while learning. Please mark the point that most closely matches your experience or opinion

	Questionnaire	Not at all	←		→	Always
1	When I first started taking classes, I thought it would be	1	2	3	4	5
2	There is something interesting that grabs your attention at	1	2	3	4	5

3	The material was more difficult to understand than	1	2	3	4	5
4	After listening to or reading the information that guided the class, I felt confident about what I would learn from this class.	1	2	3	4	5
5	I can clearly see to what extent the content of the material	1	2	3	4	5
6	It contained so much information that it was difficult to	1	2	3	4	5
7	The data caught my eye.	1	2	3	4	5
8	The material showed pictures and examples that people	1	2	3	4	5
9	Successful completion of class is important to me.	1	2	3	4	5
10	The sentences in the class helped me to concentrate.	1	2	3	4	5
11	The class was so abstract that it was hard to keep my	1	2	3	4	5
12	I was confident that I could know the contents during class.	1	2	3	4	5
13	The class was so much fun that I wanted to know more	1	2	3	4	5
14	The class seemed dull and unappealing.	1	2	3	4	5
15	The content of the material was of interest to me.	1	2	3	4	5
16	The way the information was presented helped me stay	1	2	3	4	5
17	There are explanations or examples of how to use	1	2	3	4	5
18	There is something in class that stimulates curiosity.	1	2	3	4	5
19	I really enjoyed studying with this class.	1	2	3	4	5

20	A lot of repetition and sometimes boring.	1	2	3	4	5
21	The content and form of the text makes you want to know	1	2	3	4	5
22	I learned something that I was surprised and did not expect	1	2	3	4	5
23	I am confident that I will be able to pass the exam on this	1	2	3	4	5
24	The class is not so relevant to my needs as I already know	1	2	3	4	5
25	I felt rewarded for my efforts due to feedback after practice	1	2	3	4	5
26	The variety of texts and illustrations helped me to keep my	1	2	3	4	5
27	The writing style was boring.	1	2	3	4	5
28	I cannot connect the content of the class with what I have	1	2	3	4	5
29	Too many words on each screen were annoying.	1	2	3	4	5
30	I have a good feeling that I have successfully completed	1	2	3	4	5
31	The content of this class will be useful to me.	1	2	3	4	5
32	I couldn't understand much of the material in this class.	1	2	3	4	5
33	The content was well organized and helped me to feel	1	2	3	4	5
34	It was well designed, so it was fun to study.	1	2	3	4	5

Learning attitude

Please indicate the score that corresponds to the question below about your learning attitude when learning.

	Questionnaire	Not at all	←		→	Always
1	I enjoy class time.	1	2	3	4	5
2	I have a lot of different thoughts in class.	1	2	3	4	5
3	I want to learn more about the class.	1	2	3	4	5
4	I make sure to prepare in advance of class.	1	2	3	4	5
5	I study hard only for exams.	1	2	3	4	5
6	I listen intently to lectures in class.	1	2	3	4	5
7	I want to know my score quickly after taking the exam	1	2	3	4	5
8	After class, I organize in my head what I learned in that class.	1	2	3	4	5
9	I think this course is essential to working as a nurse.	1	2	3	4	5
10	I want to do better in this subject than other students.	1	2	3	4	5
11	Even if there is something I don't know in class, I don't ask questions and just move on	.1	2	3	4	5
12	I make plans and work hard to do well in my studies	1.	2	3	4	5
13	I always review what I have learned in class.	1	2	3	4	5
14	I like to give presentations in class.	1	2	3	4	5
15	I am bored with the class time for this subject.	1	2	3	4	5
16	I want to study nursing a lot.	1	2	3	4	5

Practice Satisfaction

Please indicate the score that corresponds to the following questions about your satisfaction with practice when you are learning.

	Questionnaire	Not at all ←				→ Always
1	I took the practice seriously and participated actively.	1	2	3	4	5
2	Through practice, interest in this field has increased.	1	2	3	4	5
3	The practice atmosphere was good.	1	2	3	4	5
4	The practice contents are logically organized	1	2	3	4	5
5	Practice textbooks and auxiliary materials were appropriate	1	2	3	4	5
6	The amount of learning presented in the practice time was	1	2	3	4	5
7	The speed of the practice presented in the practice time was	1	2	3	4	5
8	The practical contents were interesting.	1	2	3	4	5
9	The practice method was easy to understand.	1	2	3	4	5
10	The materials that lead the practice contents are properly	1	2	3	4	5
11	The current practice method was understood without any	1	2	3	4	5
12	The goal to be achieved in the practice has been well	1	2	3	4	5
13	Through this practice, I gained the ability to perform actual	1	2	3	4	5
14	Through this practice, I have developed the ability to	1	2	3	4	5
15	Through this practice, the ability to judge a patient's problem	1	2	3	4	5
16	I am satisfied with the current practice method	1	2	3	4	5
17	I gained new knowledge through this practice.	1	2	3	4	5

Requirements:

Identify the customer needs and a plan of action to deliver.

Prioritization Based on Value, Cost, and Risk

Table 1.
Two requirements prioritization scales.

Names	***Meanings***
High	a mission critical requirement; required for next release
Medium	supports necessary system operations; required eventually but could wait until a later release if necessary
Low	a functional or quality enhancement; would be nice to have someday if resources permit
Essential	the product is not acceptable unless these requirements are satisfied
Conditional	would enhance the product, but the product is not unacceptable if absent
Optional	functions that may or may not be worthwhile

Keep the prioritization as simple as possible to help you make the necessary development choices. You may decide to do an initial prioritization at the feature level and then prioritize the functional requirements within a specific high-priority feature separately. This will help you distinguish the core functionality that must be present for that feature to work at all from refinements you could add in a later release. Include even the low-priority requirements in the SRS. Their priority may change over time and knowing about them now will help you plan ahead for future enhancements.

COL Cunningham presented the next question to the Panel: "My question refers to mil/civ partnerships. I know a lot of what we plan to do at the enterprise level was incorporate prehospital providers into the MTF's, and I think from the density of learners, this is extremely challenging to do. What have you all seen at your level from feedback from the partnerships that we've managed to institute and how does that apply to the prehospital providers and the role one?

BG Talley –

> *"I was at regional health command Atlantic about one year ago, and to the efforts of Telita Crossland, we were able to establish a couple of pilot programs where we were able to place the entire forward resuscitative surgical teams and a couple of our civilian platforms. When you look at certainly getting the reps and sets that our providers are going to need, particularly the surgical teams, anytime we can base them at a location where they are seeing complex cases, things that certainly are going to keep them current, the skills current, for not only, not just future operating environments, but for current…and if you look at the cost of that compare to what we expend for weapon systems or exercises, it is pennies to a dollar."*

BG Appenzeller – *"it's the sheer volume. I don't know of any one plan that is going to get at the massive numbers of people that we have to get actual reps.*

COL Cunningham added to the question before getting the Navy perspective: "with the Navy owning most of the global battle space…from a service perspective, what efforts do you see potentially addressing General Appenzeller's approach from either the virtual learning environment of the pre-hospital providers as well as potentially those Mil-Civ partnerships?"

RDML Via –

> *"Requirements don't equal resources...but without a requirement you will have no resources. My frustration, it shouldn't take until POM 23 funding… But the problem is about $2.7 billion across the setup is what Navy medicine has within our MTF readiness dollars that we can spend on the programs…and we have to defend them when they compete against $13 billion for a Navy aircraft carrier. So, we have to take all of that into concept to make sure we are applying the right strategy and executing through it."*

RDML Kuehner –

> *"I would just amplify those partnerships are local. What are we doing to ensure that the individual level, we are making folks better whether they are assigned a platform or not so they are ready for the next assignment? Because it is not operational now, the next one will be."*

Combat in a contested maritime environment will generate casualty rates both at sea and ashore much higher than recent experiences and a different mix of casualties. Mass casualties…Medical logistics system will be disrupted and Blood supplies will need to be readily available and rapidly distributable.

- **Materiel Solutions**
  - Develop role 1-3 afloat and ashore adaptive force packages able to be integrated across fleet platforms to meet distributed operations and expeditionary advanced basing operations. Examples: En Route Care System, Expeditionary Resuscitative Surgical Systems (R2LM), Role 2 Enhanced Ashore and Afloat.
  - Develop multi-modal patient movement capabilities and increased en route care capacity to hold and transport patients for a minimum of 96 hours. Example: T-EPF/EMT
  - Develop through procurement or contracting operations small/agile distributed afloat Theater Hospitalization capabilities
- **Non-Materiel Solutions**
  - Prioritize Programming for medical capabilities development through the establishment of a single resource sponsor in order to provide required capabilities to the fleet
  - Establish relationships with a SYSCOM to develop Program Management functions within NEHSS and integrate within institutional Naval Processes
    - Identify Milestone Decision Authority
  - Organize the NEHSS structure to align expeditionary medical capabilities with the fleet integrated within a TYCOM construct
  - In coordination with NWDC develop DMO CONOPS for NEHSS

AR in Medical Education: Research Papers

Before the use of computers in medical education, textbooks, lectures, cadavers, anatomical models, and live patients were some of the only pedagogical tools available. Basic computer-assisted anatomy programs started to appear in the early 1990s [3,4], and were often accompanied with multimedia approaches such as the 'Slice of Life' videodiscs that served as a visual anatomy encyclopedia [5]. Continuing advancements in hardware allowed for presentation software such as Microsoft PowerPoint to mostly replace blackboards and overhead projections in the 1990s [6], while the World Wide Web made the Visible Human Project [7] and similar programs like the Visible Embryo Project [8] possible. The mid-1990s also saw the use of computer-based stereoscopy, in which slightly offset two dimensional images are displayed in each eye to give the illusion of

three-dimensional depth [9]. Although the first head-mounted display was developed in the late 1960s [10], the adoption of VR within medical education has required more recent technological advancements such as the availability of modern head-mounted displays including Google Glass, Microsoft HoloLens, Oculus Rift VR, and the Samsung Gear VR [11]. AR has also benefited from recent advancements in handheld smartphone and tablet devices, which not only improve the power of such programs, but also expand their accessibility out of traditional learning spaces and into the hands of the learner [12]. This feature of AR has become particularly important during the current COVID-19 pandemic, which caused restricted face-to-face access to many universities and other learning spaces [13].

Enhancement of student experiences and learning outcomes with AR-based medical programs. AR-based training provides a vast potential to prepare medical professionals effectively and efficiently for the real world of practice [15]. Along with offering a safe educational environment and addressing specific professional skills, AR programs for learning in medicine are employed to enhance learners' experiences, as described by Salehahmadi and Hajialiasgari [16].

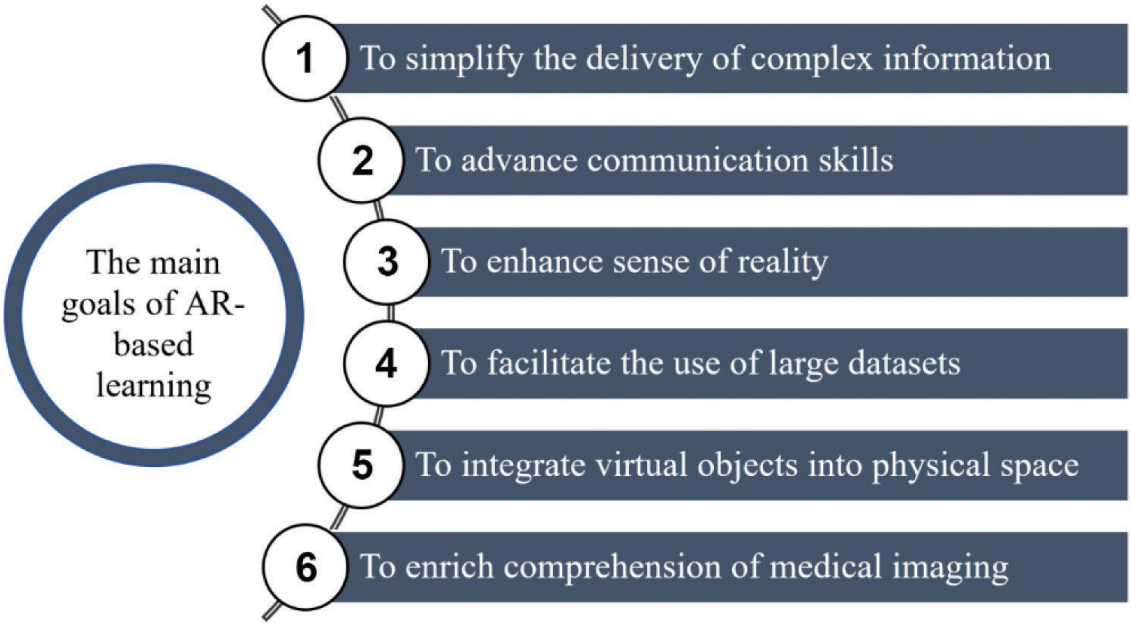


Figure X. The main goals of augmented reality in medical education

AR learning is commonly associated with highly positive subjective personal experiences and can be fun and interesting to use. AR can enhance learning delivery, presentation, and the utilization of sensory systems, which are three crucial elements of Mayer's cognitive theory of multimedia learning [18]. Due to the high level of digital literacy common amongst University students and their familiarity with using tablets and smartphones, students often report that they feel confident with adopting AR alternatives to traditional learning approaches, such as flashcards [19]. The ability to use devices that students already own also facilitates self-paced learning, and non- headset VR programs are less likely to cause adverse effects compared to VR while still achieving similar learning benefits. For example, Moro and colleagues showed that an AR structural anatomy program ran on a tablet achieved similar learning outcomes (e.g., anatomical knowledge test results) compared to a headset VR equivalent. Importantly however, the AR tablet version was less prone to adverse effects including general discomfort, headache, dizziness, nausea, and disorientation, and was also less likely to cause eye-related problems such as blurred vision [20].

Due to the ability of AR-based learning to support students' experiences, not surprisingly, this can also translate into improved learning outcomes [1]. Students who successfully complete learning activities enhanced by AR programs are more likely to achieve both enhanced theoretical knowledge and practical skills. AR-based learning boosts outcomes in several main aspects of training, including professional knowledge, cognitive and practical skills, social skills, innovation, competence, and creativity [21]. Here, we focus on the effect of AR-based programs on students' experience and learning outcomes in relation to the following three domains of impact: knowledge and understanding, practical skills, and social skills.

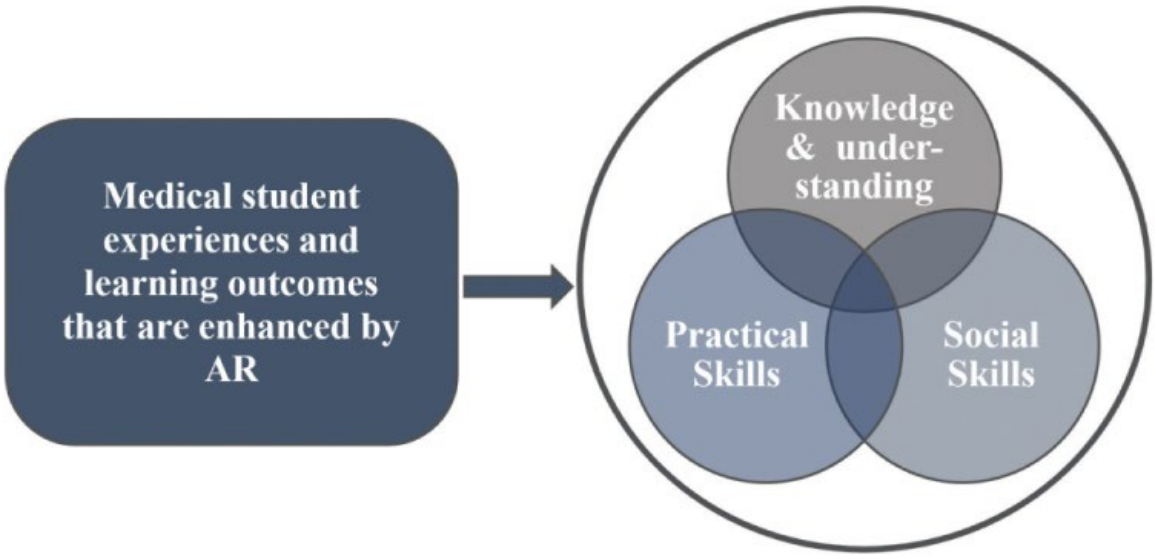


Figure 2. Three main domains of medical student experiences and learning outcomes that are enhanced by AR-based programs.

AR enhancement of knowledge and understanding.

Medical education is associated with an enormous amount of information pertaining to human anatomy and bodily function [22]. Learning this information has been greatly aided with the development of a plethora of digital programs, for example 'virtual cadavers' (Figure 3). Rather than being accessed via a traditional computer mouse, keyboard and screen, AR is able to enhance the way in which medical students interact with digital anatomical representation at all angles, providing a more immersive experience that ultimately aids knowledge and understanding [23].

An important advantage of such programs is that they allow easy manipulation of the digital subject, so that spatial inter-relationships can be identified and explored in three-dimensional space. In regard to anatomy, this for example allows for complicated branching nerve and blood vessel paths to be examined in isolation, which is difficult to do with traditional cadavers as these structures lose shape if dissected away from the surrounding tissue that supports them. Learning the names for the multitude of anatomical structures is also aided by the ability to select regions/ structures of interest and access a range of other information pertaining to them [24].

In addition to pure anatomy, understanding how anatomy relates to function is a particularly important aspect of medical education. This is aided by the ease at which different anatomical structures can be added and removed from the digital subject, such as muscles or underlying skeletal structure including muscle attachment sites. Furthermore, many AR (and VR) anatomy programs include functional features where specific muscles can be flexed, in order to observe the resulting movement that they control [25]. This is especially beneficial for understanding complex systems involving multiple muscle groups such as eye movement, which can be accessed easily at the student desk or at home (Figure 4). Another advantage is that human cadavers and physical models can only logistically represent a limited number of diseased pathologies, and the true range of individual variation is often poorly encapsulated within any given medical school. In contrast, multiple pathologies and subtle anatomical variations can be easily added to virtual representations [26].

AR enhancement of practical skills

It is an expectation that medicine graduates have inculcated not only extensive and in-depth knowledge about the human body, diseases, and associated procedures, but also communication skills, physical examination skills, practical skills, and clinical skills. While the current medical pedagogy and curriculum are undoubtedly delivering competency-based medical and healthcare professionals, there is still room for improvement in terms of their practical and surgical skills training; and face-face patient care and treatment is often limited or lacking. Clinical placements have significantly improved the students' practical skills, but a lack of extensive hands-on training can often hamper their ability to master these procedures [27]. Physical models often help fill this gap, and these are increasingly becoming highly sophisticated and effective. For example, a study conducted in the Medical School of the University of South Carolina used a Cardiopulmonary Patient Simulator called Harvey (i.e., a highly sophisticated manikin), and found that students who were trained for cardiac examination skills using the simulator performed better (on examinations including the USMLE and MCAT) than

those trained on standardized manikins or patient models [28]. However, models such as these can be expensive, and the implementation of novel resources to improve practical skills is warranted [29].

AR is beginning to make an important contribution to this overall goal, and several cohort studies that confirmed that teaching practical procedures such as surgery using AR-based tools contributes to improvements and practical competence in medical teaching and training. These programs can also often aid the performance of the actual surgical procedure itself and can overlay patient-specific anatomical information obtained from imaging scans, such as in spinal surgeries [30,31]. Transrectal prostate biopsy practice and training can also be aided by this technology, to help control robot-assisted apparatus [32]. Multiple AR-based programs are already used for kidney surgery and training (and several more are likely to be soon adopted), including those to aid patient education [33,34]. Wolf et al describe the recent development of an AR program using Microsoft HoloLens 2, for training the surgical procedure of extracorporeal membrane oxygenation cannulation. Compared to conventional training, medical students that received the AR version exhibited a higher level of learning and made fewer procedural errors [35]. Another platform has been developed by Nagayo and colleagues for open surgery training. The movement of surgical instruments and patient anatomy during procedures was first captured and then reconstructed within an AR program. Trainees can manipulate their view to obtain optimal visual angles and can pause/rewind the procedure to focus on stages. Students can also engage in self-practice by manipulating surgical instruments [36].

In addition to AR, VR-based programs are also prominently used to improve practical skills and the performance of surgical techniques. For example, Stanford University introduced the Neurosurgical Simulation and Virtual Reality Center in 2016, which provides medical graduates to explore the structure of the brain and train them to operate [37]. The system has been designed from MRI and CT (Computed Tomography) scans of

real patients, offering trainees an opportunity they would only otherwise get while in the surgery room. They are also able to investigate and operate on a multitude of neurological cases and on virtual cadavers, providing them with real-time experience of the surgical room and how to work under stress and pressure, while being efficient and skilled. Psychomotor skills of surgeons are considered key during laparoscopic procedures, and several programs have been available for a decade or more. For example, a study conducted on surgeons to evaluate the benefits of the Minimally Invasive Surgical Trainer Virtual Reality (MISTVR) tool indicates that it polishes their surgical skills [38]. MISTVR offers the added benefits of providing valuable feedback to the trainee students, including parameters such as their handling of the surgical equipment, the duration of the procedure, and errors that could have been avoided during the virtual surgery. Several simulations- based platforms for teaching colonoscopy to healthcare professional are also available, such as GI Mentor™ and EndoVR™ (CAE Healthcare, the old AccuTouch®, Immersion) [39]. Hysteroscopy has also been taught for many years using a VR- platform called EssureSim, which has been found to contribute to improved precision amongst the trainees [40]. More recently, VR training was found to be more effective than the standard guide passive learning tool for teaching a complicated tibial shaft fracture surgical technique [41]. The Digital Narrative and Interactive Design (DNID) harnesses narrative, world-building, software development, and human computer interface narrative systems through games, literature, virtual reality environments, and other media experiences in a variety of fields. The creation of a new hybrid narrative form, Interactive Fiction in cinematic Virtual Reality (IFcVR), consisting in interactive fiction films developed by means of cinematic virtual reality (360° videos), whose narrative units are interlaced with each other according to an interactive narrative structure. This represents an improvement of cinematic Virtual Reality (cVR), a format that is currently receiving increasing attention by research and cinema but appears limited from the points of view of both narrative and entertainment in that users do not

have any agency in the story world, which strongly restrains the ambition of VR to grant freedom to interactions within the immersive experience. The hybridization process that joins cVR and Interactive Fiction (IF) to create interactive immersive film experiences. Such a process is not a trivial task, it entails integrating scenarios based on diverse ways of transmitting and representing stories and contributing to establishing a suitable narratology for an interactive digital narrative. This study investigates such issues and presents a prototype IFcVR that was created and tested to show the feasibility of the idea. Results show that the narrative hybrid IFcVR is perceived by its users as an entertaining, narrative, and interactive experience. While the technology for creating a Metaverse is new, the concept was first described by Neal Stephenson in his science fiction novel 'Snow Crash' published in 1992. Although derived from cosmological concepts, the evolution of what Metaverse means is becoming synonymous with the virtual world. It is a system of numerous, interconnected virtual and usually user-generated worlds which are accessible through a single user interface. As one searches the on-line space, the term "Metaverse" is becoming increasingly common, and one has certainly seen a spotlight on this ecosystem. Many people are having difficulties trying to understand this new paradigm; however, this has not stopped many early adopters from engaging with these projects and seeing various Metaverse projects take off and catch investor attention. However, the advent of Metaverse might just be the beginning. Virtual space is going to evolve from Metaverse to Multiverse and eventually Omniverse. The concepts of Metaverse, Multiverse, and Omniverse will be familiar and easier to grasp for those interested in Cosmology. These terms are inspired by Cosmology. Metaverse is analogous to our universe but in a digital space. However, this digital space will be more immersive than the digital experiences we are used to now. As the universe is the sum of all existence; space- time and all its contents, Metaverse will be the sum of all an individual's and a community's digital existence. The Multiverse is a collection of multiple observable universes. Each universe in a multiverse shares common laws of

physics, elementary particles, and everything in between with the parent universe. The universes within the multiverse can be called "alternate universes," "parallel universes," or "many worlds." Expanding this hypothesis to the digital sphere, a multiverse will be a collection of numerous metaverses. They can share similar programming languages, be inter-operable, and have some assets and avatars between different metaverses.

Challenges and future directions

Since the first use of AR platforms in orthopedic diseases, the adoption of this technology in medical education has progressed significantly. One of the major challenges faced by the higher education sector is the cost of designing these interactive platforms [48]. This coupled to the lack of availability of resources to meet the needs of growing student numbers impedes their utilization in medical education. Making this digital technology equitable and accessible to all students is the biggest hurdle faced by educators. Another criticism in the use of AR in teaching is the limited hardware that is needed, in addition to the growing problem of social isolation associated with digital learning [49,50]. Nevertheless, these new digital platforms have enabled educators to push the boundaries of traditional pedagogies to create a student-centric, engaging and enriching the learning experience for the students.

With the advancements in the field, a major next step has been postulated to be the adaptation of AR textbooks in medical education, which is an idea that was proposed almost a decade ago [51]. In this proposal, Yuen (2011) eloquently described how AR books would allow students to transport themselves into a scenario/situation and learn by immersing themselves in the experience. While the subsequent years have seen these books being slowly prescribed in the curriculum at the school level, their incorporation in teaching healthcare and medicine-based courses in higher education is still in its infancy [52,53]. However, continued advancements in this direction could be extremely

useful when students are learning about topics including human anatomy and physiology. The ability to read and visualize content such as brain function and nerve impulses (to quote one example) will assist with retention and deeper understanding of the physiology of the human body. When considering the ability of AR designs to allow multiple users to interact in the same platform, this will help tackle the issue of isolation that these AR platforms may create for learners. It is believed that these AR-interfaced books can offer a respite to students from stagnant and dull text-only based learning material that traditional textbooks offer, making them an exciting tool for both students and educators.

Mobile learning (m-learning) and wearable technology is a relatively new digital learning platform, that has enormous potential. AR-based learning software could be provided on students' personal devices such as mobiles, iPads, and tablet computers, or on wearable items such as smart watches, which would make the adaptation of this technology in medical education far more acceptable and cheaper [54,55]. One example of this concept is the use of Google Glass [56] at the University of California, Irvine School of Medicine, in their anatomy courses and hospital rotations [57]. Google Glass offers the ease and flexibility of accessing course content and patient-related information in a hands-free format, at the same time allowing users to communicate via voice command. Another wearable technology that can be potentially used in teaching is the use of monitors that can record the health of patients, which is communicated to the smart device of the students, which allows students to detect a disease. For example, The University of Michigan is developing a vapour sensor that can help monitor the health of patients with diabetes and lung disease [58]. The use of virtual patients and case scenarios during problem-based learning sessions is another approach that may be highly beneficial in medical teaching (Figure 5).

Figure 5. In the HoloPatient system, volumetric 3D video capture of a standardized patient sitting in a chair being assessed by a group of medical students. Students can view the patient and interact with the test results panel and real time vital signs through the use of the Microsoft HoloLens 2. Here the patient describes chest pain associated with myocardial infarction.

Other important potential future uses for AR-based medical education include teaching programs for individuals with reading disabilities (a barrier to traditional textbook-based learning), and in remote learning contexts to transport the user into a virtual space anywhere an internet connection can be made. As AR technologies progress, making these technologies affordable will be a key focus. Collaborations between companies, universities and increased funding for this sector will pave way for newer AR/VR platforms in medical teaching. A classic example is the Medical Virtuality Lab designed by University of Southern California, Institute for Creative Technologies [59]. The primary aim of this institute is to bring individuals and experts from the film and game industry together with computer and social scientists to create and design the platforms for use in healthcare education and training.

The field of AR offers opportunities for educators in the field of medical education to create a rich and engaging curriculum, offering students the opportunity to not only learn but experience the learning content/material as well. The disruption to traditional classroom teaching due to COVID-19 has led to a rapid adaptation of digital teaching tools globally, highlighting the importance of digital technologies, including AR to ensure student learning is not hampered. Optimal utilization and continued usage of digital learning tools has the potential to reform the medical education sector.

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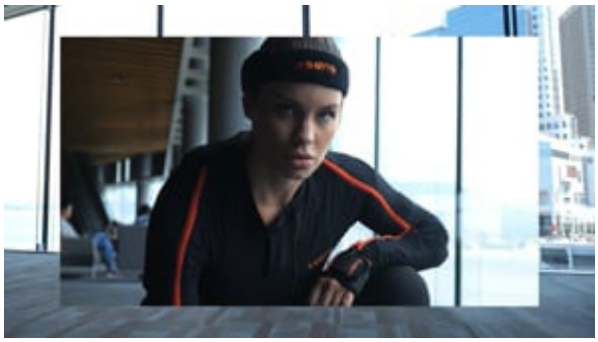


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