Introduction of the Joint Emergency Trauma Simulation (JETS) System

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ABSTRACT

The Department of Defense's Military Health System has the dual mission of Force Health Protection of all members of the military and the training of uniformed medical personnel. The training and education paradigm of modern military medicine has become more learner-focused while aiming to improve patient outcomes and ultimately battlefield survival rates. Commercial medical simulation tools and devices are often market-driven and frequently limited in design for a specific mission or purpose. This is adequate for individual or small group training but creates silos of proficiency. This paper introduces the Joint Emergency Trauma Simulation (JETS) System and describes the development of the JETS architecture which is intended to facilitate creating micro and macro medical training systems. With JETS, trainers will be able to piece together commercial-off-the-shelf simulation products in a federated system using High-Level Architecture. The goal of this multi-year, DoD-funded project is not to dictate how training is conducted. Instead, the JETS Federated Object Model (FOM) is designed to provide a common platform for medical modeling and simulation. The JETS FOM is a standard data object model that employs a system of systems approach allowing for the integration of live, virtual, constructive, and gaming simulation technologies. The capability to seamlessly link various training tools allows for the local creation of scalable medical simulation systems that will meet the diverse needs of military medical personnel from individual, collective, or multi-echelon objectives with the ultimate goal being the eventual integration of the JETS System into the Synthetic Training Environment (STE).

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Developing Micro and Macro Simulation Systems for Training Tactical Healthcare Personnel

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PURPOSE

This paper introduces the concept of future medical modeling and simulation systems used as training components to prepare tactical healthcare personnel for Multi-Domain Operations (MDO). Further, this presentation explores the development of a federated, modular system of systems that will engage clinicians in researching and training as part of the readiness mission. The next generation of providers within all roles of care will benefit from the work that has been accomplished during the Joint Emergency Trauma Simulation (JETS) System and the Prolonged Field Care Training Programs.

BACKGROUND

Prolonged Casualty Care (PCC) is a rapidly increasing concept of tactical prehospital care that may occur when evacuation times exceed the doctrinal goal of one-hour or the care is rendered in an austere or expeditionary region (JTS, 2021). The Pentagon predicts that the next conflict will likely entail a peer or near-peer competitor. In short, MDO is the preparation to defeat adversaries across the domains of land, sea, air, space, and cyberspace. For nearly two decades, the United States military has been able to move ill and wounded servicemembers from various battlefields within the *Golden Hour* because of its tactical and technical overmatch with recent adversaries. Facing a peer competitor means it may take several days to gain the air superiority necessary to confidently launch helicopter ambulances to evacuate casualties. All levels of providers may have to sustain their wounded for many days. Information Visualization and Innovative Research Inc. (IVIR) has been contracted by the DoD to evaluate the gaps that exist between current tenets of tactical combat casualty care (TC3) and those Key System Attributes (KSAs) likely required during MDO. Further, IVIR is responsible for developing a prototype of a modular Medical Modeling and Simulation (MM&S) architecture to facilitate training for the complexities of providing care over extended time periods across multiple roles of care. This includes situations with patient movements over areas of long-distance.

PROBLEM

Medical training often takes place within organizational silos. There is no singular medical simulation system which fully replicates the human body. An example of one challenge is the Glasgow Coma Scale (GCS). It is a simple, yet critical assessment tool to evaluate a casualty's level of consciousness. Unfortunately, the lack of animation in most mannequins makes an accurate GCS impossible to obtain without the intervention of faculty. The GCS problem can be solved by using a standardized patient or actor, but the vital signs of the actor are not likely to match those prescribed by the simulated patient's condition. Frequently, the solution to one simulation problem results in another limitation or obstacle. Many simulation labs piece together a variety of full-body and part-task trainers, or simply allow learners to ask, "what vital signs am I seeing?" Most workarounds detract from the suspension of disbelief needed to afford participants a deeper learning experience where they must rely on their own observations to develop decision-making abilities. Moreover, the temporary solutions often place greater administrative and cognitive loads on the instructors who are responsible for the training sessions. In addition to the problems attendant to unanimated training devices are the challenges of simulators that lack the sensors necessary to identify the interventions of the learners. This situation limits the physiology engine from independently interpreting the effects of the intervention and publishing a new patient condition. Finally, these systems which lack the sensors necessary to account for the actions of the learner, usually lack the technology to publish those data into the learning management systems.

Within MDO, tactical training scenarios for medical providers at all roles will expand from an average of one hour to possibly several days. Therefore, the complexity of the tasks the medic/corpsmen need to be proficient in and manage will increase. Having a common training architecture will become critical to conduct effective and efficient training events. JETS is designed to enable trainers to digitally link government and commercial off the shelf (COTS) systems together to provide trainers with a beginning-to-end approach to training. JETS will provide the linkage for:

- Learning Management Systems
- Scenario Authoring Tools
- Smart Mannequins (computer enabled)
- Instructor and Student User Interfaces
- Smart Part-task Trainers (computer enabled)
- Virtual or Augmented Reality Patients
- Physiology Engines
- Medical Gamification Systems
- Logistical Tracking Modules
- After-Action Review Tools
- Learning Record Stores

In June 2021, The Department of the Army released sweeping changes to how the Army will train. Commanders are required to train one level down while evaluating two levels down (Department of the Army [DA], 2021). Multi-echelon medical training is encumbered by a lack of information flowing within the simulated roles of care. The JETS system of systems enables commanders and clinicians to take an active role in the training and readiness mission with their superior units as well as their subordinates. Data is communicated to the Learning Record Stores within the JETS architecture which will enable leaders to evaluate the qualification of their medical personnel and accurately determine the fiscal costs associated with doing so. Military Health Services commanders and clinicians can efficiently pull data to evaluate learner performance and adjust training using the authoring tools.

APPROACH

The PFCT/JETS architectures consist of a Medical Modeling and Simulation Federation Object Model (MMS FOM), developed within the Joint Emergency Trauma Simulation System (JETS) and Point of Injury Training Systems (POINTS) contracts as issued by Medical Technology Consortium (MTEC) and sponsored by Joint Program Committee-1 (JPC-1). The programs and the resulting architecture were born out of a need to reduce the silos in which medical training is often conducted and to retrain the force to become proficient in the complexities of PFC (Honold & Curry, 2019). The MMS FOM coupled with the Run Time Infrastructure (RTI) provides a modern mechanism for data transfer which will provide for a more integrated approach to training across the US military services, NATO, and partner nations. JETS is not intended to dictate training content or methodology. JETS employs the High-Level Architecture for the MMS FOM. Rather, it is designed to establish a standard language to enable communication between patient simulators and components. The JETS architecture enables a greater use of live, virtual, constructive, and gaming simulation technologies (LVCGST) to accomplish training needed by tactical medical personnel throughout the various roles of care.

In the early 1990's, the Defense Research and Engineering Department led the development of an interoperable and reusable standard for the purpose of combining numerous simulation systems. That standard known as High Level Architecture (HLA) became an international open source within the Institute of Electrical and Electronics Engineers (IEEE). HLA was not only recognized by NATO, but it was also recommended by NATO (Kuhl, Weatherly, & Dahmann, 1999). JETS is not part of the Synthetic Training Environment (STE). The DoD is in the early stages of determining the best architecture to be utilized for STE and what part medical will play.

With the JETS architecture, simulation components are divided into four essential levels according to the type and complexity of the training objectives. The individual component level consists of individual systems such as patient simulators, serious games, after-action review systems, and learning management systems. Most of those components function independently according to their designs. Any item that can operate on a digital network can likely be adapted to connect to the JETS network. The micro system level consists of multiple individual simulation components interacting together within the JETS architecture to create a single patient or localized training event (see Figure 1).

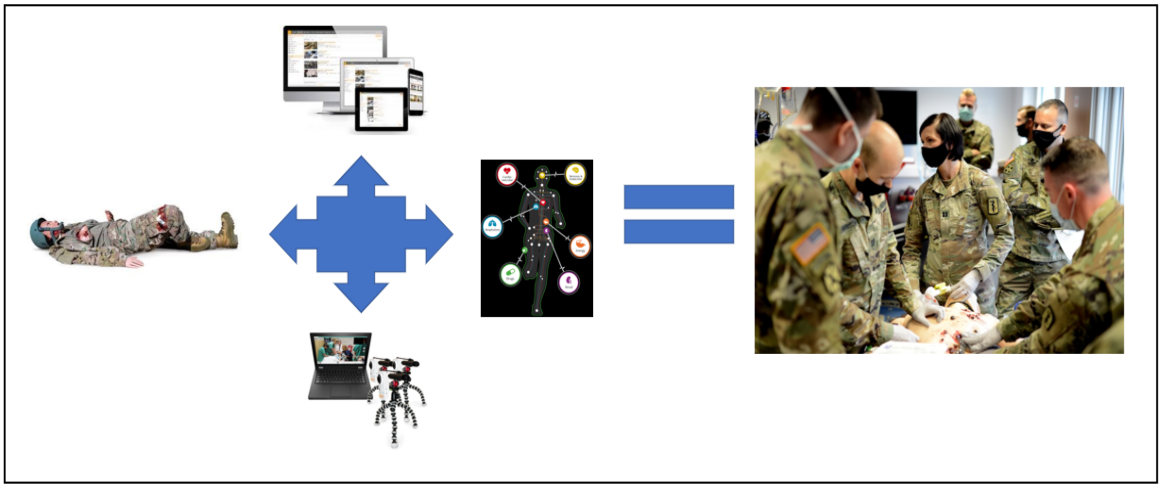

Figure 1. Depiction of a JETS Micro System

As shown in Figure 2, a macro simulation level is created by the JETS federation enabling multiple components and micro systems to communicate. An example of this could be a combined exercise employing two or more micro systems at distant sites such as Medics at Fort Carson, Colorado, working on a simulated patient. Upon completion of the scenario by the medics in Colorado, the physiology of the patient is digitally transferred via the cloud to Flight Paramedics learners at Fort Hood, Texas as they prepare for an upcoming deployment. The data is the only thing that travels allowing the learners to remain at home station. The mega system level is the combination of multiple macro systems and DoD support systems. An example of this could be a pandemic response exercise held at multiple military installations around the world, while the overall exercise is being coordinated at Defense Health Agency Headquarters. The mega system would likely be a depiction of a large-scale medical exercise within the future Synthetic Training Environment (STE) and will use all levels of the components discussed in this paper.

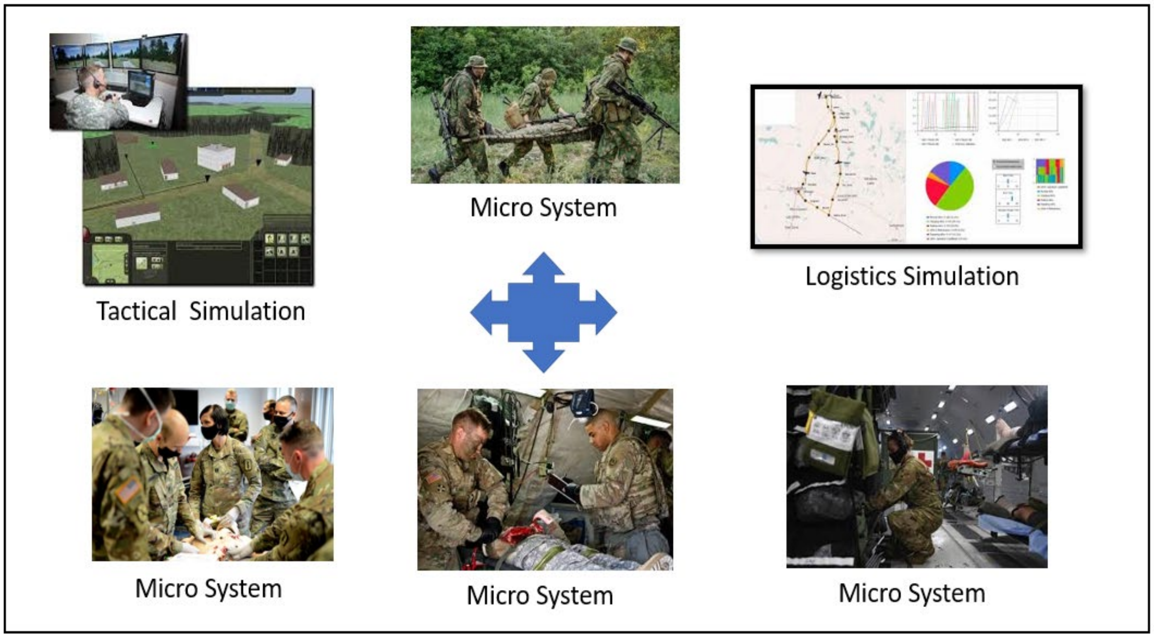

Figure 2. Depiction of Macro System

Many of the mannequins' physiologies at the center of medical simulation are driven by state engines. On command, the state engine moves the condition of the patient from one state or condition to the next. In order to meet the dynamic requirements of the greatest degree of fidelity in medical simulation, a true physiology engine is needed. This is especially true if training scenarios, like those needed for MDO, are designed to demonstrate injuries and illnesses over prolonged periods of time under austere conditions. The researcher's company, IVIR has successfully partnered with HC Simulation, who is affiliated with University of Mississippi, to use HumMod, their proprietary human physiology engine. For the purpose of the PFCT prototype, IVIR contracted HumMod to develop several mathematical models of various patient conditions. Among them were 3rd degree burns, Leishmaniases, Scrub Typhus, Multi-systems Trauma, and Sepsis, to name a few. The goal was to develop realistic trauma and disease, non-battle injury (DNBI) states based on the most likely geographical locations for an MDO confrontation (Eastern Europe and/or Asia). One can see the value in having a mathematical model of an injury or disease state portrayed over 72 to 96 hours (see Figure 3). Independently, the high-fidelity physiology engine is of limited value. However, when combined with a mannequin, serious game, or learning record store, the physiology engine gains in its level of importance.

Lastly, capturing the performance of the learners training with the system is a critical aspect of JETS. The architecture provides an avenue for data to be passed into the learning record stores (LRS) and service-appropriate learning management systems. The collection of data begins by utilizing a federated after-action review system which captures performance and provides event-based bookmarks. Step-by-step learner performance is tracked by the instructor utilizing Training Assessment & Capability Reporting (TrACER) System. Once the scenario is concluded and the skills checklist is completed and saved by the instructor, the performance is translated into Experience API (xAPI) and stored in the LRS. The data in the LRS can then be retrieved and analyzed to track learner competencies. It also provides the fidelity of data needed by researchers seeking to track individual or institutional trends.

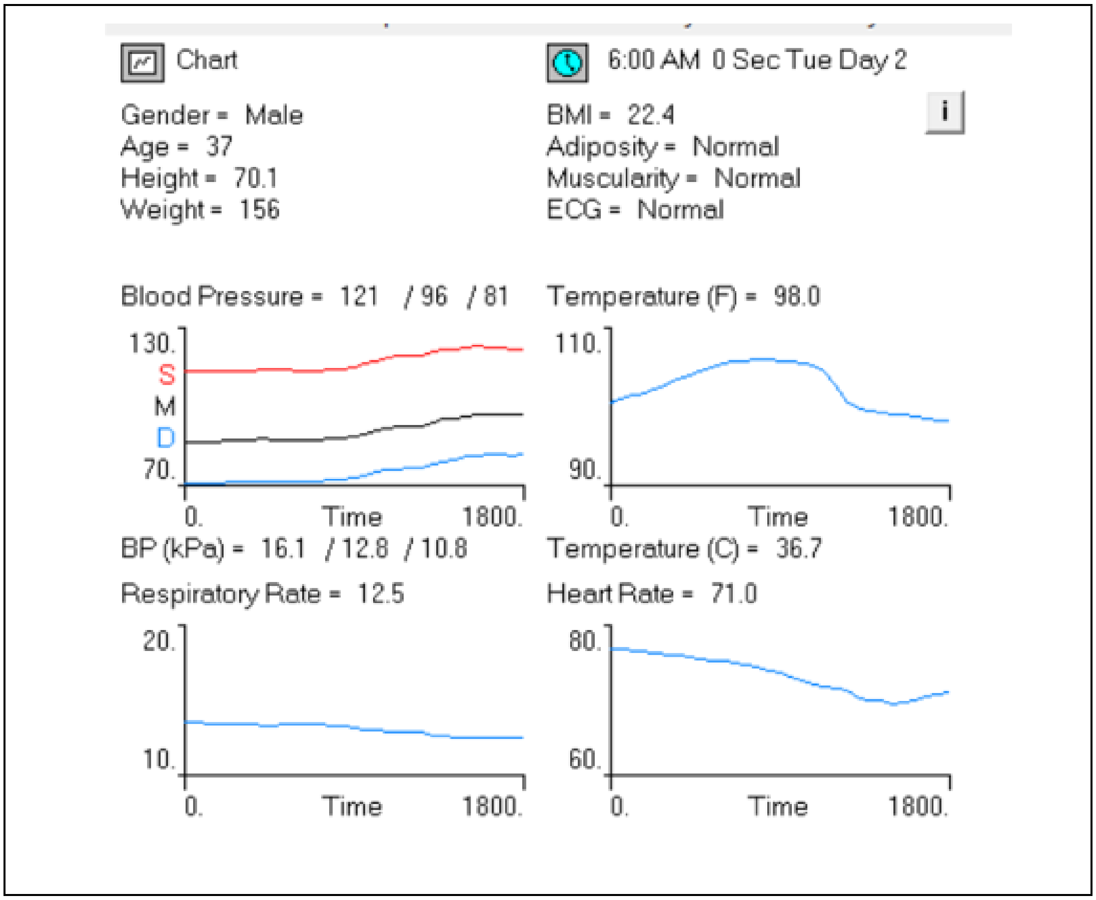

Figure 3. Physiological changes over 30-hour run-time HumMod Physiology Engine

Often, the discussion of physiology engines turns to the utility of speeding up the simulated time to allow for instructional purposes. In other words, speeding up the physiology seems to be an attractive option for teaching medical providers what is going to happen over time to a simulated patient with a given set of injuries or disease state. A problem that frequently occurs revolves around what happens to the patient while it is in the fast-forward mode. The provider is not present to intervene if there are injuries that need tended to. For example, if a simulated patient that is bleeding internally at 5 milliliters per minute, is sped up at 50:1 for a period of 36-hours, the patient will be dead and in cardiac standstill when the mannequin is brought back to real time. Despite this current limitation, the author worked with HumMod to develop the ability to speed up the physiology to 50:1 for the purpose of the demonstration and future development.

To determine what features were necessary for the Prolonged Field Care Training (PFCT) System, IVIR conducted extensive front-end research into the nuances associated with prolonged field care. The review of information included journal articles written by U.S. Special Forces Medics who have served in remote locations. In some of those cases, evacuation of casualties took upwards of 7 days (Keenan & Riesberg, 2017). All of the Clinical Practice Guidelines for Prolonged Field Care (PFC) were also reviewed. Over 400 individual skills were identified as relative to PFC. It should be noted that PFC is preceded by TC3. As such, the skills required for TC3 were included in the clinical gap analysis conducted by IVIR. From the list of skills required for PFC and TC3, a design document was produced to determine what features a mannequin would need to have to facilitate the training necessary for PFC [and TC3]. As previously stated, the JETS architecture was being simultaneously developed alongside the PFCT System. In short, the JETS system of systems would be at the heart of the PFCT System. It should also be noted that the DoD Joint Trauma System recently released *Prolonged Casualty Care Guidelines,* (CPG ID:91) (JTS, 2021). It is also apparent that over the past few years, the DoD has shifted the terminology of prolonged field care to prolonged casualty care. This was done to better encompass those non-field entities such as maritime vessels and extended transportation modalities.

RESULTS

This project demonstrated the initial capabilities of the MMS FOM in 2019 during JETS Phase II. The JETS and PFCT simulation systems are primarily composed of commercial off the shelf items. Individually, those COTS items are technology readiness level (TRL 9). However, when combined with other systems within JETS, the items must be tested as part of the overall PFCT and JETS Systems. At this point in the research and development of PFCT and JETS, the target is to achieve TRL 5. The Prolonged Field Care Training System that was delivered to the government in March 2021, achieved TRL 5 by testing in the environment for which it was designed. An independent medical education company was contracted to expose the system to the rigors of training PFC.

In March 2021, JPC-1 combined PFCT and JETS into a unified project and architecture. A regional demonstration for JETS Phase III was scheduled for 4^{th} QTR FY21 to exhibit the abilities of the MMS FOM while running TC3-based scenarios. Due to COVID-19 constraints, a local dry-run was held in 2^{nd} QTR FY 22, in lieu of the regional demonstration. The objectives of the local demonstration were:

- Joint synchronous and asynchronous demonstration
- Asynchronous micro system demonstration
- Instructional point of demand demonstration
- Faster than real time operation demonstration
- Tactical system integration demonstration
- Lesson plan support demonstration

During the Phase III final demonstration, the technology was shown as an Asynchronous Mode and a Synchronous Mode (see Figure 4). In the former, a Navy scenario was conducted with a high-fidelity mannequin making up a stand-alone micro system not connected to the internet. It functioned as a separate JETS System. Upon completion, the records of the training event and learner performance were uploaded into temporary file storage and then transferred into the LRS once it was connected to the main JETS network. In addition to the mannequin depicting the care at the point of injury, a part-task trainer for the REBOA was mapped into the federation allowing multi-role training. In the Synchronous Demo, a larger deployment with multiple patients and multiple federated systems was displayed. The demonstrations were conducted at Fort Sam Houston on 23 and 25 February 2022. In March 2022, IVIR will deliver the components of the PFCT/JETS systems to the government.

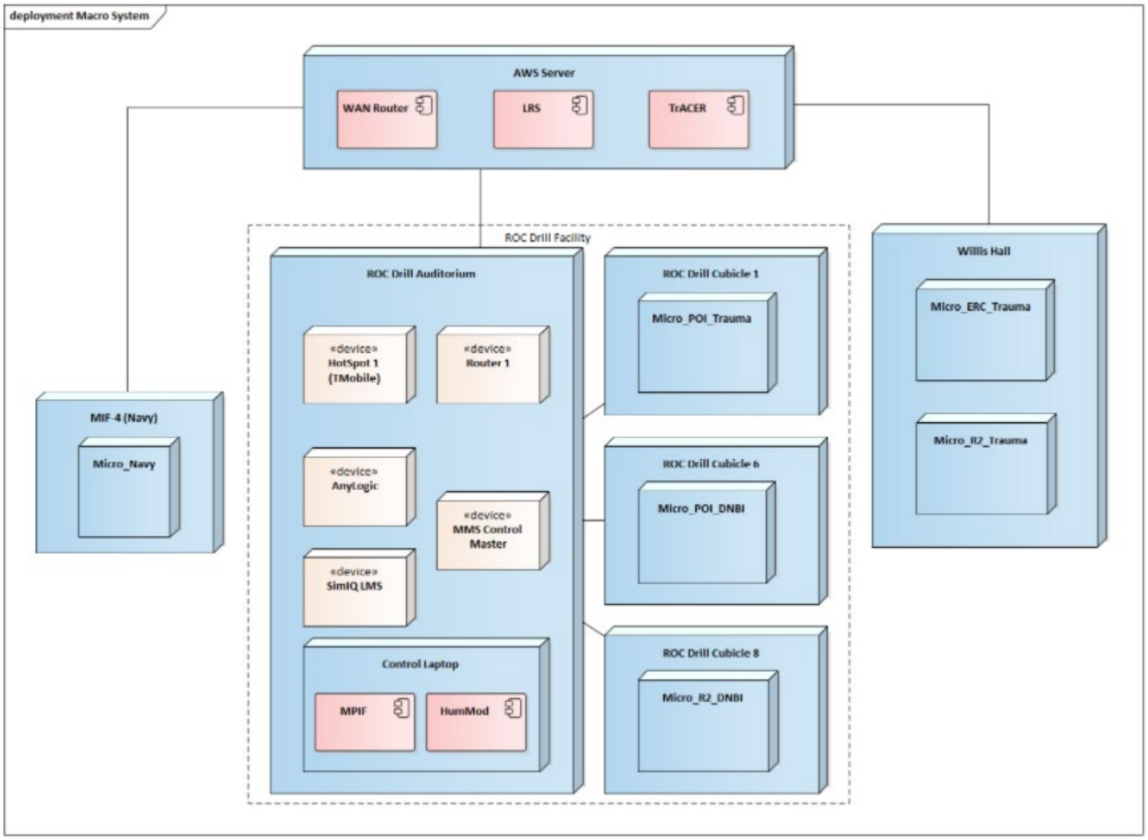

Figure 4. Depiction of the deployment of modules during JETS Phase III Demonstration

CONCLUSION

JETS Phase III project demonstrated the gaps identified in PFCT and JETS research are among the factors that also make it uneconomical for commanders and clinicians to participate in the training of tactical healthcare personnel. The JETS architecture enables a beginning-to-end functionality which optimizes the time spent researching, developing, and evaluating training as part of the readiness mission by using COTS technology. With greater efficiency comes greater engagement. The success of future tactical healthcare providers at all roles during MDO will rely on rapid analysis of emerging wound patterns and authoring of training scenarios based on improved Clinical Practice Guidelines. The JETS architecture successfully provides the interoperability needed for seamless joint medical training of the next generation of medical providers at all roles of care. Additional research and development are necessary in order to achieve TRL 9 and ultimately get JETS into the hands of warfighter trainers.

ACKNOWLEDGEMENTS

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Acknowledgment Citation:
"These research and development projects/programs/initiatives were conducted by Information Visualization and Innovative Research Inc. and were made possible as follows:

PFCT: PFCT No Evacuation, Now What (NENW) by a contract that was awarded and administered by the U.S. Army Medical Research & Development Command (USAMRDC) & Acquisition Activity, and the Joint Program Committee - JPC -1 at Fort Detrick, MD under Contract Number: W81XWH18C0176

JETS: Prototype of Joint Evacuation and Transport Simulation (JETS) System by a research project award that was awarded by Medical Technology Enterprise Consortium, MTEC-10-07-JETS-03; administered by the Joint Program Committee - JPC -1 at Fort Detrick, MD under Contract Number: W81XWH-15-9-0001 Note: The name of the architecture was changed to "Joint Emergency Trauma Simulation" to reflect the evolution of the project and was done so with concurrence from JPC-1.

This paper was prepared by David J. Litteral, IVIR Inc. on 25 January 2022. It does not knowingly contain Government classified or IVIR proprietary information. There are no distribution restrictions.

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