Enhancing Simulation Composability and Reuse with Modular FOMs

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ABSTRACT: Simulation composability and reuse have long represented the "Holy Grail" of distributed simulation. The ability to develop simulation components in a way that enables them to be reused as well as the ability to pull together independently developed simulation components have long promised flexibility and cost savings for Department of Defense simulations.

While the High Level Architecture (HLA) has provided an interoperability standard enabling simulation components to work together, seamless simulation component reuse and composability remain elusive goals. A number of challenges to composability have been identified, and one of the major challenges has always been the data exchange model. Davis [1] and Henninger [2] both address improving composability, and both identify data exchange models as an issue. The Live Virtual Constructive Architecture Roadmap (LVCAR) study [2] recommended standardized common object model components as the highest priority investment for the Department of Defense (DoD) simulation roadmap. Efforts such as the Realtime Platform Reference (RPR) and Space Federation Object Model (FOM) seek to standardize a FOM for a particular community. The Medical Modeling and Simulation (MMS) FOM is expected to do the same for the Medical modeling and simulation community. Modular FOMs are a critical component to improve simulation composability and reuse.

This paper addresses how the Joint Evacuation and Transport Simulation (JETS) system architecture is developing a suite of MMS FOM modules, providing the ability to more easily combine simulation components in various configurations or scale to meet current and future medical training needs.

1. **Background**

Proper medical training is critical to ensure that Service members are prepared for wartime deployment with a particular emphasis to support the en route care of patients from initial point of injury through several echelons of care to continental U.S. (CONUS) based military hospitals. Currently medical training is conducted within each Service "independently" (i.e., Army, Navy, Air Force, etc.). In addition, there is a wide repertoire of tools, devices, and approaches used to provide deployable training to Service members, ranging from devices (e.g., manikins) to computerized simulations to formal didactic training through internet-based, video, or classroom style instruction.

Recent changes to military doctrine now require a multi-Service/Joint response, where many functions will no longer be unique to a particular Service. Therefore, there is a need to develop an operational infrastructure that provides multi-Service training for Joint-Service responses. The construction of integrated simulations and training modules for the Joint Evacuation and Transport Simulation (JETS) system is the first step toward a larger effort to integrate several training platforms toward a more standard, interoperable method of instruction with greater accessibility within an integrated and federated DoD Medical Simulation Enterprise (MSE).

The JETS system is advocated by the Defense Health Agency (DHA) and links the operational needs of the Components (e.g. US Army, US Navy, US Air Force) and Geographic Combatant Commanders to standardize patient movement training within the Military Health System (MHS) continuum of care while sustaining clinical standards of patient treatment and management. JETS does not replace the Components' unique training requirements, but rather it provides a DoD integrated and federated training platform to the Components on which to execute that training. Figure 1 is a depiction of JETS role within the DoD MSE.

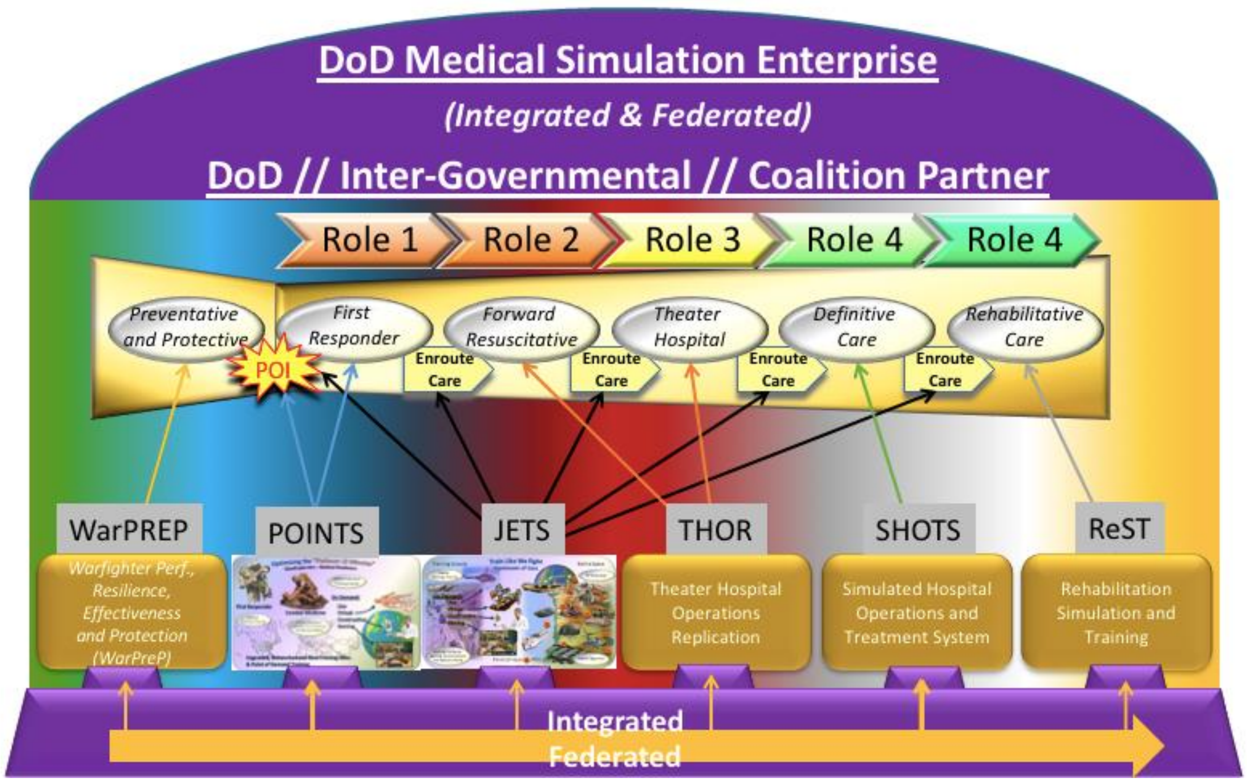

Figure 1 – DoD MSE (DHA JPC-1)

The JETS system will provide the Components with a standardized DoD training platform to include modular training sites, integrated with a global Point of Demand (PoD) distributed training capability across the DoD. It will enable skills and higher level learning of individual, team and unit training of patient movement tasks covering the complete chain of evacuation throughout the full Continuum of Care. It will provide training centers with a modular standardized support system, and an operations system with both common and Component unique systems, that are integrated across the JETS platform. It will deliver a global PoD training capability, linking training centers and Warfighters around the globe with 24 hours a day, 7 days a week, and 365 days a year, available and integrated live, virtual, constructive, gaming (LVCG) training through a DoD enterprise training portal. It will support training of all Joint Patient Movement (JPM) functions (e.g.: en route care; communications; patient evacuation, handoff, movement control;

global patient management, teamwork; logistics; command and control (C2); mission planning & rehearsal; and inter-Component qualifications) across the Components and the Continuum of Care. Figure 2 represents an operational view (OV-1) of the JETS system.

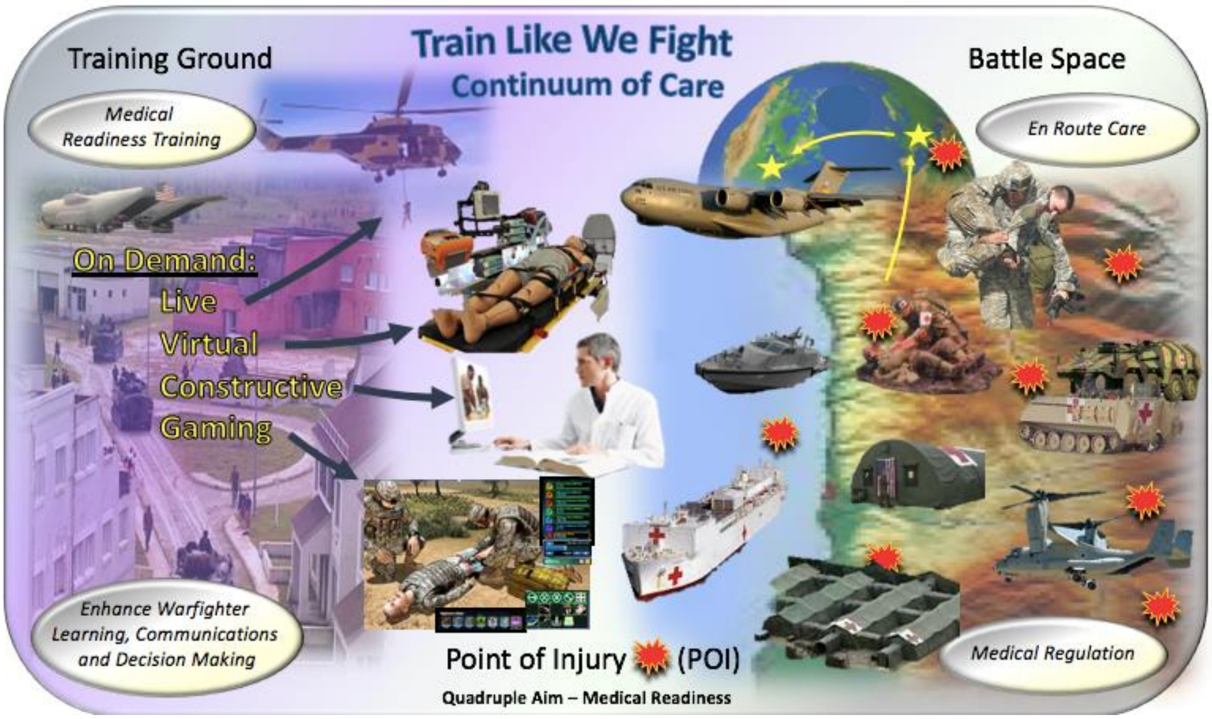

Figure 2 – JETS High Level Operational View (OV-1) (DHA JPC-1)

JETS is sponsored by DHA Education and Training. It is funded by the Joint program Committee-1/Medical Simulation and Information Sciences (JPC-1/MSIS) Defense Medical Research and Development Program, and is managed by JPC-1.

Patient Handoff/Transfer is a critical component in providing a continuum of care for the injured patient, and includes not only the transfer of the patient, but also the exchange of information about patient status, diagnoses and treatments administered. Numerous literature references point to the critical importance of correct and clear information exchange [3]. Breakdown in communication was the leading root cause of sentinel events reported to the Joint Commission in the US between 1995 and 2006 [4]. JETS is focused on the handover and en route care of the injured patient.

2. Modular FOM Overview

In any distributed simulation approach, the data exchange model definition is a critical element for enabling interoperability to support composability and reuse of simulation components. That need in HLA is addressed by the Federation Object Model (FOM). The early HLA FOMs were defined as a single monolithic file containing all the data exchange definitions for a federation. The early expectation was that simulations would develop Simulation Object Models (SOMs) to define their individual data exchange requirements and that SOMs could be merged or mapped to FOMs; however, the widespread use of SOMs never materialized. A major development in defining HLA data exchange models came with the IEEE 1516.2-2010 standard which defined a modular approach to developing HLA FOM components which could then be merged at runtime by the HLA Run Time Infrastructure (RTI) [5]. Communities began to develop reference FOMs such as the Space Reference FOM and the Realtime Platform Reference (RPR) FOM widely used in the DoD training community. Modular FOMs allowed for large complex FOMs to be decomposed into more manageable chunks, potentially developed by different simulation communities. Modular FOM components represent a significant move toward supporting simulation composability and reuse [6].

3. Modular FOM implementation in JETS

JETS will integrate multiple simulations representing different areas of functionality with the capability to adapt to changing medical training needs in the future. In addition, parts of the JETS system may be used in other federations to model medical functionality. As a result, we chose to represent the different functional areas with FOM modules. This module breakdown may change in the future as JETS matures. The JETS Medical Modeling and Simulation (MMS) FOM currently consists of seven modules identified in Figure 3.

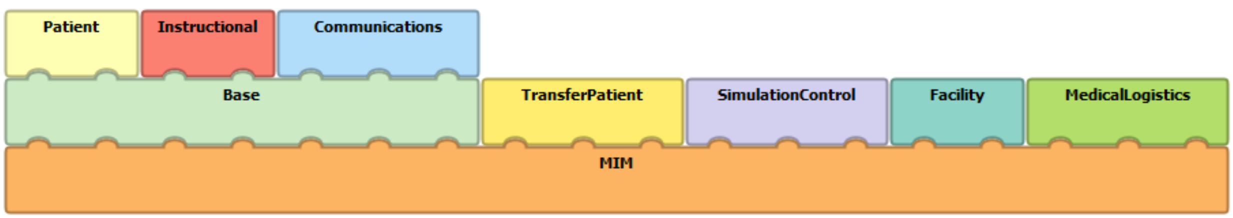

Figure 3 – MMS FOM Modules Overview

- The **Patient** module contains classes representing a patient's physiological state, patient signs and symptom as well as injuries and treatments. Figure 4 describes the Patient module class breakdown.
    - A fundamental class in the Patient module is the *Physiology* class representing the "ground truth" data about a patient. It contains physiological attributes such as heart and respiration rate, O2 saturation, and body temperature. It is important to note that data from this class are not available to the attending medic. These are values provided by the physiology engine, and impact the signs and symptoms represented on the simulated patient. Multiple patients are modeled as instances of the *Physiology* class.

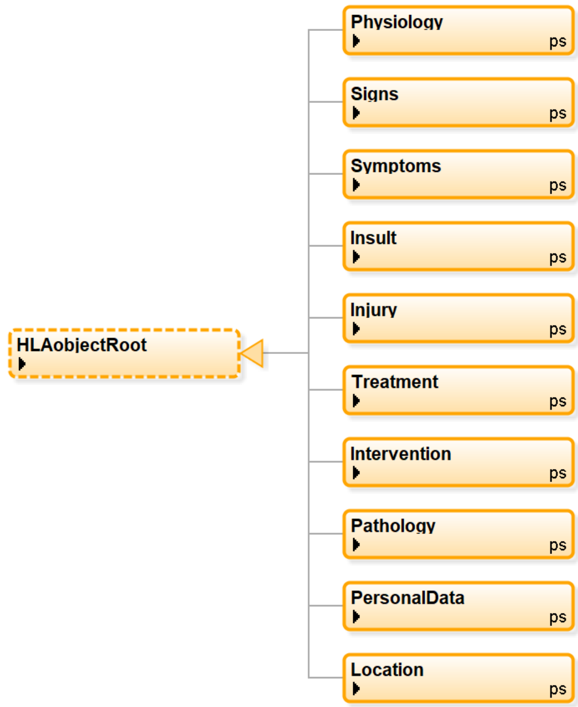

Figure 4 – Patient Module Class Breakdown

- Patient *Signs* and *Symptoms* classes represent "perceived truth" and include those things the medic can observe and/or measure. *Signs* are observable by the medic and can be measured or compared to a known value which is objective (e.g. patient temperature.) *Symptoms* represent those physical characteristics that the patient "feels", but are subjective, (e.g. pain level) and may be real or imagined. The medic has to observe the patient injuries, signs, and take measurements to determine the appropriate treatment options.
- *Insults* and *Injuries* are related classes in that *Insults* represent the physiology engine's perspective of what happened to the patient, while *Injuries* are the medic's perspective of what happened to the patient such as a Gunshot Wound or Burn. For example, a gunshot *injury* might result in a blood loss *insult*. This mapping between these insults and injuries is a manual process in the scenario. The same injury could result in different insults depending on training objectives.
- In the same way, *Treatments* are actions the medic administers to the patient while *Interventions* are the physiology engine's perspective of the treatment. For example, a tourniquet *treatment* on the patient might result in reduced blood flow *intervention* in the physiology engine.
- The *Pathology* class will reflect conditions that might influence the patient's reaction to injury or treatment. Pathologies would include diseases or conditions such as diabetes, tuberculosis, asthma, etc.

- The **Instructional** module contains classes and interactions about Instructor/Observer's actions during simulations as well as actions taken by the trainee. These data are used to assess the trainee or team performance. That data will be stored in a Learning Management System (LMS). The

Instructional component will also provide training scenarios to be executed and, after training, access student training records and store trainee actions for After Action Review (AAR). We are investigating the Experience API (xAPI) as a means of recording student actions for assessment.

- The **Facility** module represents the capabilities of various mobile and fixed facilities offering evacuation and en route treatment to an injured patient. For example a BlackHawk medical evacuation helicopter would have medical treatment as well as evacuation capabilities for a certain number of casualties depending on equipment and litter configurations. Fixed facilities such as field hospitals would have more extensive treatment capabilities and patient capacity.
- The **Medical Logistics** module contains classes related to medical supplies and equipment which may need replenishment during the scenario execution. In Phase 2, we demonstrated the ability to track individual items used to treat an injured soldier. Future logistics will broaden the scope of pharmaceuticals, supplies, as well as medical devices and equipment.
- The **Simulation Control** module contains classes related to monitoring and control of the federation. Typical control functions invoke the HLA services to Start, Stop, Pause, Resume, Save and Restore. JETS will also support pausing components of the federation such as a MEDEVAC mission, while the remainder of the federation continues to execute. Simulation control services will support large scale team training as well as individual training sessions.
- The **Communications** module contains models of patient documentation forms, radio communication, and command and control messages. Current efforts have focused on the forms filled out during the initial phases of injury from Point of Injury (POI) through Role 1. The Medical Evacuation (MEDEVAC) radio message is modeled in the FOM but has not been tested.
- The **Transfer Patient** module will represent those activities involved in patient movement within the medical treatment continuum. Medical evacuation requires a great deal of coordination to ensure that the most severely injured patients receive the fastest response possible, within a set of constraints. Patient transfer takes place at the various roles depicted in Figure 1. Patient transfer may involve wounded U.S. soldiers, coalition partners, civilians, and enemy soldiers.

4. Progress Thus Far:

Military medical doctrine outlines an integrated system to triage, treat, evacuate and return the casualty to duty in the most time-efficient manner [7][8]. This continuum of care is often described using the roles depicted in Figure 1. Role 1 is the first responder rendering medical care at the point of injury. The Role 1 focus is on immediate lifesaving measures and preparation for patient transfer to a higher role. Role 2 provides advanced trauma management and emergency medical treatment including treatments started at Role 1. From Role 1 the patient is evacuated to the most appropriate medical facility, typically a Role 2 or 3 facility. In Role 3, the patient is treated at a field hospital or facility equipped to provide a higher level of care, including surgery and advanced treatment. From Role 3, the patient may be moved to a Role 4 medical care unit which would include US based hospitals and robust overseas facilities.

The JETS Architecture program is entering its third phase. One of the overall goals of the JETS program is to produce designs for an overarching architecture, including a common, objective, and engineering-oriented lexicon. The first phase involved on creating prototype knowledge products that will interoperate and integrate with future programs within the Medical Simulation Enterprise (MSE).

Phase I focused on developing architectural models to guide the construction of integrated simulations and training modules for the JETS system. Phase I also involved developing a proof-of-concept MMS FOM focusing on patient handoffs and transfers throughout the roles of care. The patient handoffs included both communication aspects between providers, and the ability to digitally transfer patient status through simulation events.

Phase II focused on the Point of Injury (POI) and Trauma Simulation (POINTS) architecture. The MMS FOM development focused on the Role 1 Point of Injury (POI) trauma care and documentation of the DD1380/Tactical Combat Casualty Card (T3C) through evacuation to the next level of care. The DD1380 is a document filled out at the POI by the medic or combat life saver (CLS) attendant and contains information about injuries and initial treatment administered to the patient by the medic. It documents the mechanism of injury, patient vitals and any treatment administered to the patient before evacuation. The DD1380 card is physically attached to the patient and is used by the en route care (ERC) medic to provide a quick understanding of the patient injuries and treatment administered by the POI medic. JETS Phase II also added patient documentation, medical logistics, and more detail for the patient handoff to Role 2. Within 24 hours after patient handoff, the en route care provider fills out a DA4700 form in electronic format. The DA4700 documents more detail about the patient injuries, vital signs and any treatments administered during the en route evacuation. The DA4700 becomes a permanent part of the patient's medical record. As JETS continues development, additional documentation will be represented in the MMS FOM.

Phase III began in July of 2019 and is focusing on expanding multiple patient support, multiple learner support, and higher fidelity representation of the patient in the MMS FOM, and will expand the architecture to integrate with an HLA-compliant tactical simulation architecture. The goals of this phase are to tie the capabilities of JETS into a bigger picture, battlefield level training event and improve the fidelity of medical training in a tactical training event. Integration the JETS architecture with other operational architectures can enhance the both the tactical and medical training events.

5. **Conclusions:**

Modular FOMs have allowed us to decompose a large complex problem space into smaller, more manageable areas based on function, and focus to on each these areas individually. It is important to note that the title of this paper is "Enhancing Composability." We are not suggesting that we have solved the "seamless composability" grand challenge [9] [10]. Rather we argue that modular FOMs are a step in the right direction to improve composability and reuse. Also a standardized data model can be a valuable part of specifications to procure training systems that meet JETS requirements and are interoperable by design.

Although this paper is focused on our use of the modular FOM standard, we also want to mention the use of two other SISO standards. Federation development benefits greatly from the use of a rigorous systems engineering process. The Distributed Simulation Engineering and Execution Process (DSEEP) standard offers a systems engineering process tailored to distributed simulation. In the future JETS will likely employ additional interoperability standards such as the Data Distribution Service (DDS) to integrate future manikins into the JETS system [11]. In addition, federation agreements are critical to federation interoperability and reuse. The Federation Engineering Agreements Template (FEAT) provided an outline of the types of agreements needed to enhance promote successful integration. While the prototype FEAT tool was not used nor were the agreements captured in XML format, it did provide guidance for the JETS program [12]. It should also be noted that the LVCAR recommendations [2] identified standardized data exchange models, systems engineering and federation agreements as the top three recommendations for DoD investment. As the JETS program evolves, we anticipate further use of standards.

6. Future Plans:

In the immediate future, the current Phase III effort focuses on creating an extended demonstration system to showcase the architecture, creating and implementing proponent and advocacy plans for JETS and

POINTS, and validating the architecture and designs created in the previous phases. The program will produce designs for an overarching architecture, including a common, objective, and engineering-oriented lexicon, along with a governance strategy, a definition of shared services, and application programming interfaces (APIs) for interoperability. The extended demonstration system will include cross-service training events in geographically separate sites.

With the resetting from a traditional air-land battle concept to a modern mosaic, multi-domain operational concept - where communication systems are degraded and casualty evacuation opportunities transitory, the need for adaptive medical training, novel tools, and disruptive technologies is paramount. Addressing the multitude of future medical battlespace requirements require advanced operating systems that can connect disparate instruments and events, providing training commanders the ability to conduct scalable, relevant live, virtual, and augmented reality, learning opportunities. Preparing warfighters to treat casualties at the point of injury and packaging them for transport to higher echelons is difficult, but when the need arises for prolonged field care of a severely injured soldier in place - without evacuation, medical and logistic issues intensify. The future goal is to take these medical complexities and compete it with our adversaries, and with our superior training and personnel, turn that into an asymmetric advantage.

7. Contract Information

- Funded by the Joint Program Committee-1/Medical Simulation and Information Sciences (JPC-1/MSIS) Research Program
- The contract for this work was issued by the Medical Technology Enterprise Consortium (MTEC)
- Award #: W81XWH-15-9-0001
- PI: Catherine Strayhorn, CEO, IVIR Inc.

- For additional technical information regarding the demonstration system, contact: Erin Honold, Senior Engineer, IVIR Inc., ehonold@ivirinc.com

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Author Biographies

Dannie Cutts is a Senior Computer Scientist supporting Pitch Technologies. He has been involved with the High Level Architecture since 1995, supporting numerous federation development efforts for NASA and the US DoD. A Certified Modeling and Simulation Professional, he holds Masters Degrees in Mathematics and Computer Science and serves on the SISO Product Development Group for the IEEE 1516 HLA standards. He also serves on the SISO Product Development & Support Groups for the HLA Evolved, DMAO/DSEEP and FEAT standards.

Damon Curry has 30 years experience in the simulation industry specializing in distributed training systems, 3D visualization, and 3D terrain. He helped start several successful simulation industry companies and is presently Pitch Technologies' manager for business development in North America. Mr. Curry is co-inventor of a realtime image processing technique and a wireless video transmission method for virtual reality with one patent awarded and another patent pending. Prior to working in the simulation industry, he served 16 years with the US Air Force, including software engineering on cruise missiles and avionics engineering on the F-16. He is a graduate of The Ohio State University with a Bachelor of Science in Electrical Engineering.

Erin Honold is a Biomedical Engineer with IVIR Inc. and has 9 years of experience developing medical simulation technologies for the US DoD. She is currently the systems engineer for the JETS and Prolonged Field Care Training (PFCT) programs for IVIR Inc. Ms. Honold's previous work includes utilizing HLA to design standard architectures for joint medical training focusing on en route care and patient handoffs.

William E. (Bill) Lewandowski II, is the IVIR Inc. Chief Technology Officer. He has a Masters in Software Engineering from Embry-Riddle Aeronautical University and he has worked for the last 21 years in software engineering primarily focused on modeling and simulation in Aviation and the DoD as a senior developer and chief architect. Mr. Lewandowski is currently the lead Architecture Engineer on the JETS and programs for IVIR Inc.

David J. Litteral, CSM, U.S. Army (Retired) is the senior clinical expert at IVIR Inc. Mr. Litteral performed 32 years of service in the U.S. Army Medical Department (AMEDD) to include multiple deployments, culminating as the commandant of AMEDD’s Noncommissioned Officers Academy. He has 26 years’ experience as a certified paramedic. Mr. Litteral's civilian education includes an undergraduate degree in Management and a Master of Arts in Military History. He is currently in the dissertation phase of a PhD in General Psychology. He is projected to defend in May, 2020.