MoHSES
CCT Virtual Roundtable

August 30th, 2023

Presented by Vcom3D

www.Vcom3D.com

Origins of Modular Healthcare Simulation and Education System (MoHSES)

- Original Advanced Modular Manikin (AMM) project awarded to the University of Minnesota Center for Research in Education and Simulation Technologies (CREST) with University of Washington CREST and Vcom3D, Inc. as major subcontractors
- Renamed to MoHSES™ in 2021 to reflect the multi-modal capabilities of the platform and for trademark considerations
- Funding from USAMRMC

Special thanks to the U.S. Army Combat Capabilities Development Command Soldier Center (DEVCOM SC), SFC Paul Ray Smith Simulation and Training Technology Center (STTC), which originated concepts for the MoHSES project. They provide expert support and guidance, as well as opportunities and interactions with the respective user communities.

Objectives for this Roundtable

- Inform CCT awardees and stakeholders about the MoHSES specification and free resources available to develop MoHSES-compliant modules and systems
- Examine the MoHSES concept of interoperability and how it might be applied to the CCT project.
- Review how MoHSES has been used to build interoperable simulation modules, including:
  - Where it worked well
  - Where there were limitations
- Discuss how MoHSES can be applied to CCT.

What is MoHSES?

What It Is

- A Platform in support of Experiential Learning for Health Care Education
- A Platform to support interoperable medical simulation training
- Based on Open Standards
- Provided with an Open-Source License
- Designed with a Modular Architecture
- Based on a Distributed Architecture
- Supports Interoperable Segments
- Based on standardized Data Models
- Defined data set for Reference Patient

What It Is Not

- A manikin
- A commercial product
- A complete design that can be sourced
- A final set of standards
- A one company solution
- A research project

Potential Benefits to CCT

MoHSES Specifications Promote Interoperability

- Mechanical
- Anatomical
- Electrical
- Fluids
- Data

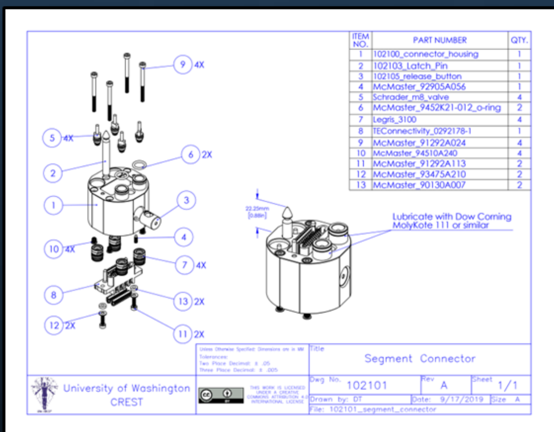
MoHSES Resources Can Reduce Development Cost

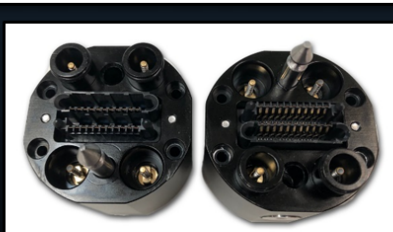
- Open-Source Software
- Connector Drawings
- Reference Implementations

MoHSES Architecture Enables Vendors to Protect IP

- Module interfaces are implementation-agnostic, clinically relevant data

What do I get with MoHSES?





Physical Specification

- CAD Models, Reference Data Sets, and Technical Drawings
  - Standard Male and Female Parameters derived from medical imaging of live subjects
  - Segmentation
  - Core Compute System
  - Fluidics
  - Power
  - Network

Software Component Specification

- API/Documentation
- Open-source 3rd party dependencies
- Reference Implementation Source Code in C++
  - Core Modules
  - MoHSES standard library
  - REST adapter interface to support web-based client Modules
  - TCP bridge interface to support socket-based client Modules
  - Example Module source code

Data Model Specification

- Simulation Control
- Event
  - Render Modification Request
  - Physiology Modification Request
  - Assessment
- Physiology Data
- Configuration
  - Capabilities
  - Operational Status

Where do I get MoHSES Information?

- Specifications: https://www.mohses.org/cdrls.html
- 3D Datasets: https://www.mohses.org/downloads.html#docs
- Connector Drawings: https://www.mohses.org/downloads.html#conn
- Test Results: https://www.mohses.org/cdrls.html#a0010
- Interface Document: https://www.mohses.org/cdrls.html#a0011
- CORE Software:
  https://github.com/AdvancedModularManikin/core-modules

MoHSES Aligns with the Five Principles of Modular Open Systems Approach (MOSA)

1. **Enhance competition**
   - open architecture with severable modules, allowing components to be openly competed.
2. **Facilitate technology refresh**
   - delivery of new capabilities or replacement technology without changing all components in the entire system.
3. **Incorporate innovation**
   - operational flexibility to configure and reconfigure available assets to meet rapidly changing operational requirements.
4. **Enable cost savings/cost avoidance**
   - reuse of technology, modules, and/or components from any supplier across the acquisition life cycle.
5. **Improve interoperability**
   - allow severable software and hardware modules to be changed independently.
     - Defense Acquisition Guidebook 3–2.4.1, Modular Open Systems Approach (2017)

Reference: https://ac.cto.mil/mosa/

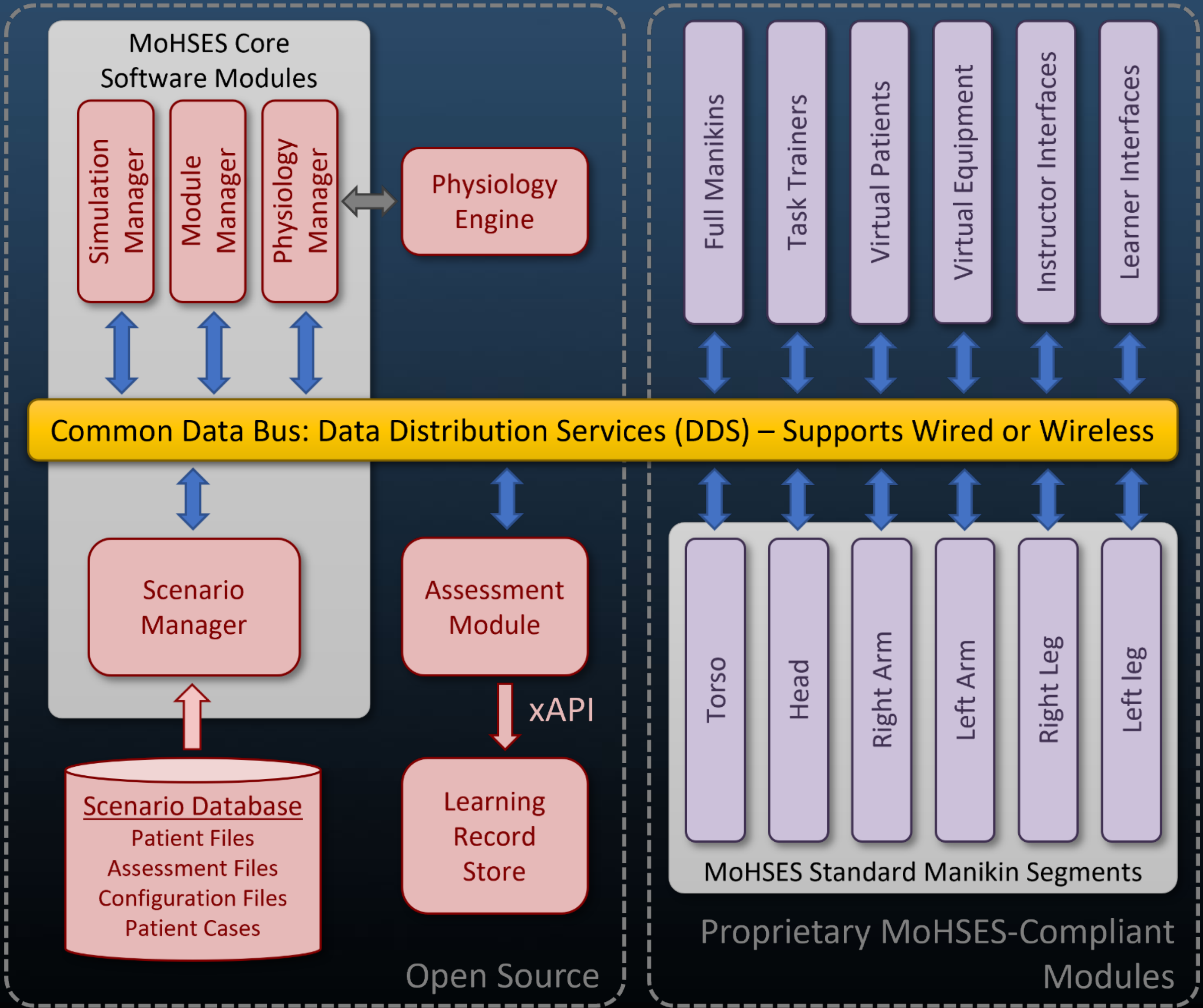
How has MoHSES been used?

- For modular manikins (Advanced Modular Manikin, Advanced Female Trauma Training System) incorporating modules from multiple vendors
- For on-site and remote virtual team trainers (Immersive Modular Patient Care Team Trainer [IMPACTT™])
- To integrate physical and virtual simulations (AMM, Central Venous Access, Lateral Canthotomy/Cantholysis, Humeral Head IO)
- To connect to multi-role patient movement simulations (POINTS)

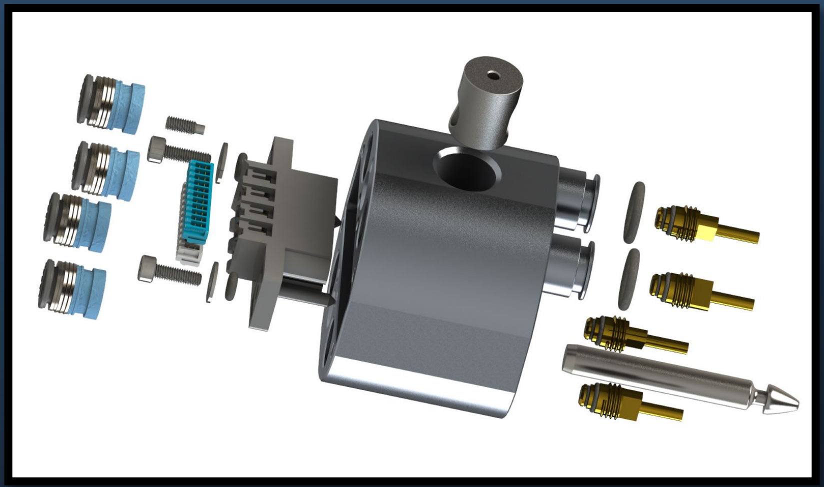
AR and MR applications can require tight synchronization of perceptual cues between manikin and virtual components. For example: synchronized manikin chest motion, virtual wound overlays, breath sounds, and capnograph.

MoHSES has been demonstrated with 30 or more physical and virtual modules, with 50 Hz update of multiple physiological variables, using low-cost, COTS implementations.

MoHSES Modular Architecture

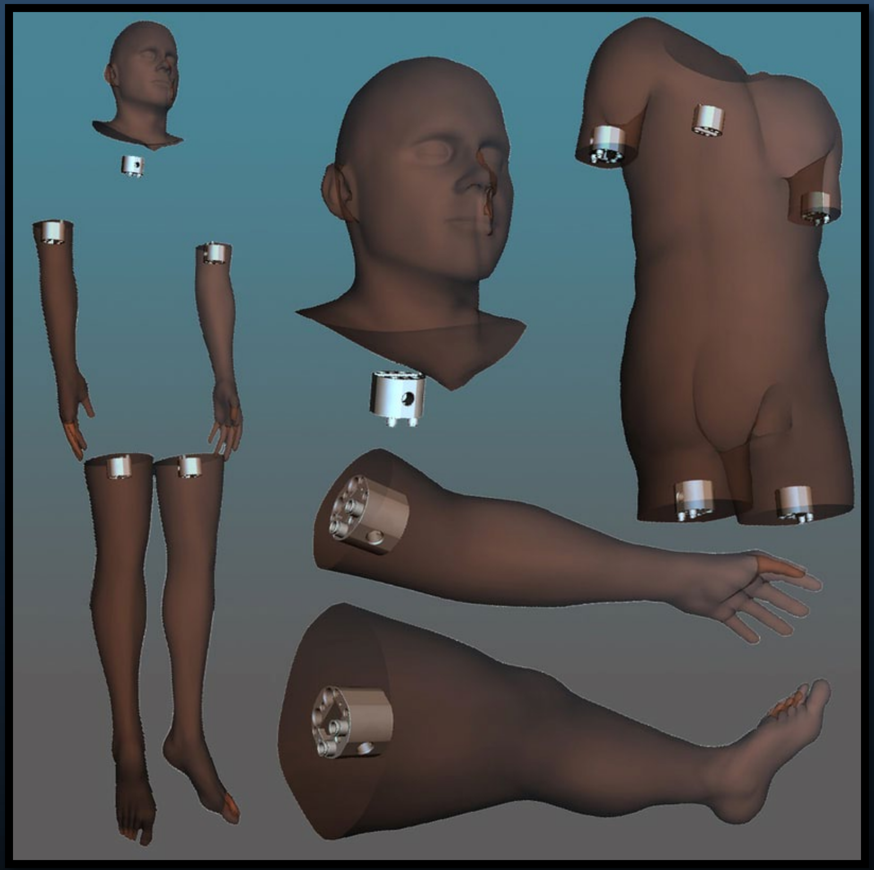


MoHSES Physical Connection Specifications



Universal Segment Connector provides:

- Mechanical Connection (200 lb. axial load, 100 lb. bending).
- 4x Fluid Connections (Air, 2x Liquid, Waste Liquid; 1.03 bar)
- PoE Connection (IEEE 802.3bt)
- Data Connection (CAT 5e/6 Ethernet)
- Blind Connection; Tool-less operation
- Available from One World DMG



- Connectors may be used to connect Torso to Head, 2 x Legs, 2 x Arms

Core Software Components

Module Manager

- Coordinates module participation, initialization, configuration, and termination
- Enable module capabilities
- Configure modules
- Aggregate module operational statuses

Physiology Manager

- Initialize physiology engine
- Setup scenario environment
- Setup scenario patient start state
- Translate between standard data model and physiology engine API

Simulation Manager

- Simulation clock (50 Hz)
- Play, start, and pause simulation

What is a module?

- Modules may be closed and proprietary but will still interoperate with proprietary Modules from other companies.
- Modules can be used in different combinations and configurations for different applications.
- Modules may be physical, virtual, mixed, or gateways to other systems (HLA, STE, JETS).
- Modules may be something yet to be conceived.
- Modules achieve interoperability by implementing a common interface and using a shared Data Model.
- What does a Module need to officially be a Module?

Module Capabilities

Module

- Name
- Manufacturer
- Model
- Serial number
- Model version

Platform Version

- Core
- Hardware
- Specification

Capabilities (for each Capability)

- Published Topics
- Subscribed Topics
- Configuration Options
  - Name
  - Type (float, int, boolean, option)
  - Type parameters (min, max)

Module Capability Configuration Data and Operational Status

Capabilities (for each Capability)

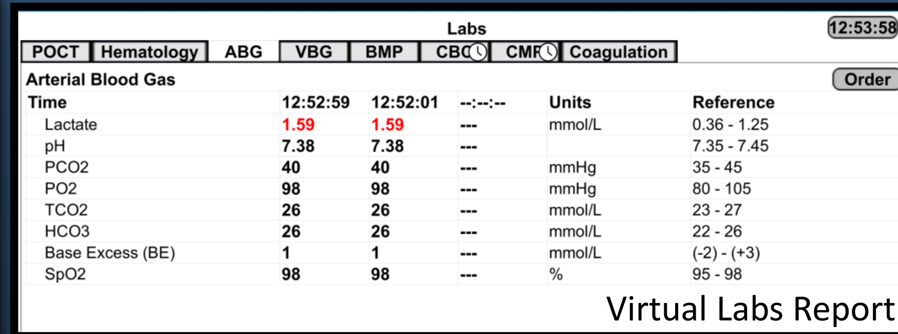
- Capability
  - Name
  - Enabled
- Configuration Data
  - Name
  - Type (float, int, boolean, option)
  - Type parameters (min, max)

Operational Status (for each enabled Capability)

- Module Name
- Capability Name
- Status (OPERATIONAL, HALTING_ERROR, IMPENDING_ERROR)
- Message

Module Examples

UW CREST
Advanced Joint Airway Management System



Labs

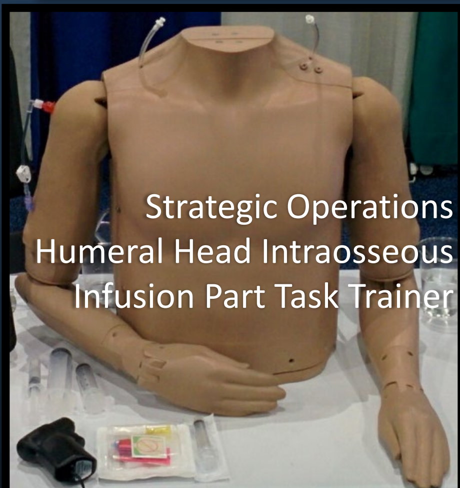
12:53:58

POCT | Hematology | ABG | VBG | BMP | CBC | CMP | Coagulation

Arterial Blood Gas — Order

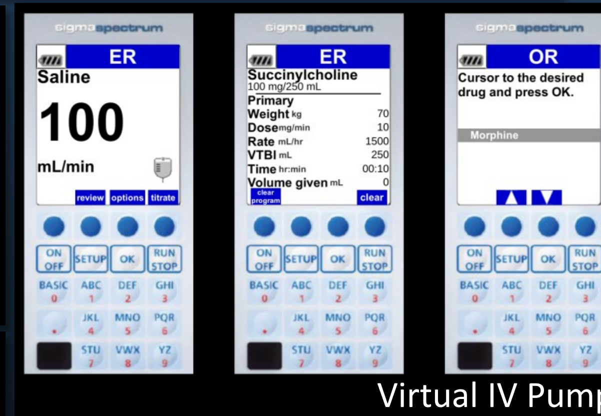
Time	12:52:59	12:52:01	--:--:--	Units	Reference
Lactate	1.59	1.59	---	mmol/L	0.36 - 1.25
pH	7.38	7.38	---		7.35 - 7.45
PCO2	40	40	---	mmHg	35 - 45
PO2	98	98	---	mmHg	80 - 105
TCO2	26	26	---	mmol/L	23 - 27
HCO3	26	26	---	mmol/L	22 - 26
Base Excess (BE)	1	1	---	mmol/L	(-2) - (+3)
SpO2	98	98	---	%	95 - 98

Virtual Labs Report

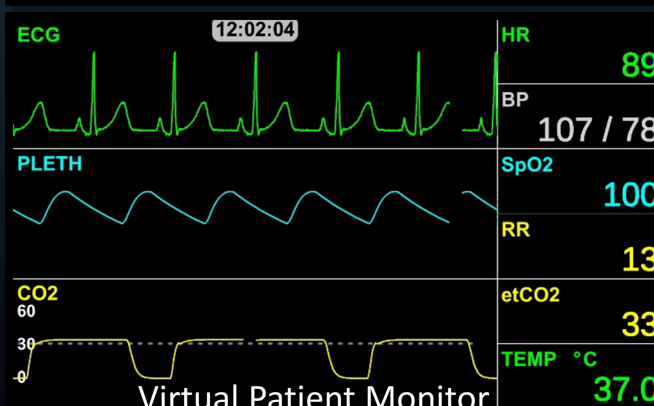


Strategic Operations
Humeral Head Intraosseous
Infusion Part Task Trainer

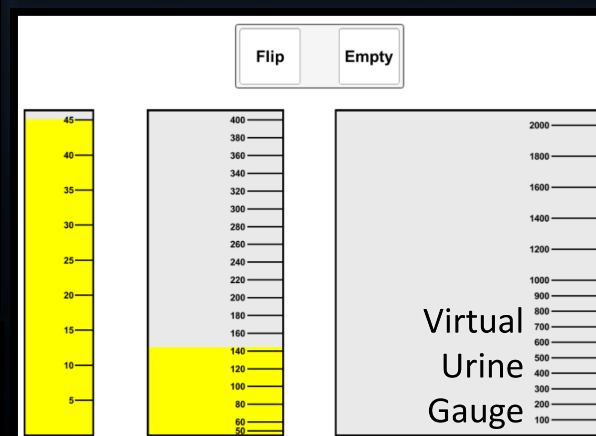
Vcom3D Virtual Patient



Virtual IV Pump

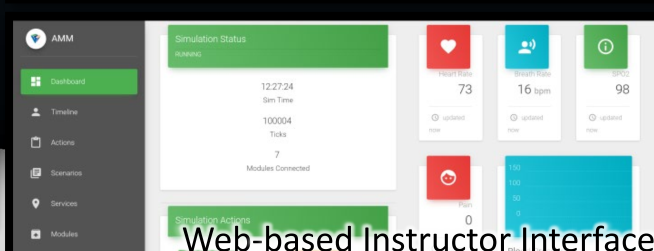


Virtual Patient Monitor



Virtual Urine Gauge

Virtual Ventilator



Web-based Instructor Interface

MoHSES Data Model

MoHSES uses DDS for communications.

DDS uses a topic-based publish and subscribe paradigm.

Event records and physiology data must be human readable and **clinically relevant**.

MoHSES topics include:

- Capabilities, Configuration, Operational Status
- Resource Supply and Demand
- Event Records
  - Physiology Modifications
  - Render Modifications
  - Performance Assessments
- Physiology Data

Common Data Bus

Data Distribution Service (DDS)

- Middle-ware specification from Object Management Group (OMG).
- Describes a data-centric publish/subscribe model for distributed application communication and integration.
- Enables scalable, real-time, dependable, high-performance, and interoperable data exchanges.
- https://www.omg.org/spec/DDS/

FastDDS

- Full Implementation of the OMG Real Time Publish Subscribe (RTPS) protocol.
- Implements required functionality of the DDS standard.
- Extensible to support additional DDS functionality.
- Compatible with other DDS implementations.
- Lightweight.
- Micro XRCE-DDS available for resource-constrained applications.
- **Open source.**

MoHSES Event System

Event Record

ID (UUID)	
Timestamp	'when'
Location (FMA)	'where'
Practitioner	'who'
Type	'what'
Data	'how'

Type examples:
Infusion, injection, IV access, Palpation

Physiology Modification

ID (UUID)
Event ID
Payload

Changes to physiology including insults and interventions. **Examples**: hemorrhage, airway obstruction, sepsis, acute stress, fluid infusion, drug bolus, tourniquet applied.

Render Modification

ID (UUID)
Event ID
Payload

Instructions for how to display an event. Visual, audio, etc. **Examples**: tourniquet placement, IV placement, bleeding stopped.

Performance Assessment

ID (UUID)
Event ID
Assessment:

- Omission Error (skipped step)
- Commission Error (extra/out-of-order step)
- Execution Error (done poorly)
- Success

Comments

Event Payloads

- Event payloads are contextual. The standard does not yet define the exact payload format, but we have implemented examples as a starting point. A few are shown here:

IV Placement
IV needle insertion
Type: iv-access
Data/Payload:

```
<iv-access
  size="cannula size"
/>
```

Hemorrhage
Type: hemorrhage
Data/Payload:

```
<hemorrhage
  flow="what rate"
  units="mL"
/>
```

Palpate
Type: palpate
Data/Payload:

```
<palpate
  pressure="how hard"
  units="some units"
/>
```

Infusion
Used for substance and compound infusions
Type: infusion
Data/Payload:

```
<!-- Use either 'substance' or 'compound' attribute,
as appropriate.  Both may be included if one is
blank (a value of empty string). -->
<infusion
  substance="Substance name here"
  compound="Compound name here"
  flow="what rate"
  units="mL"
/>
```

Pain
Type: pain
Data/Payload:

```
<pain
  severity="what level"
/>
```

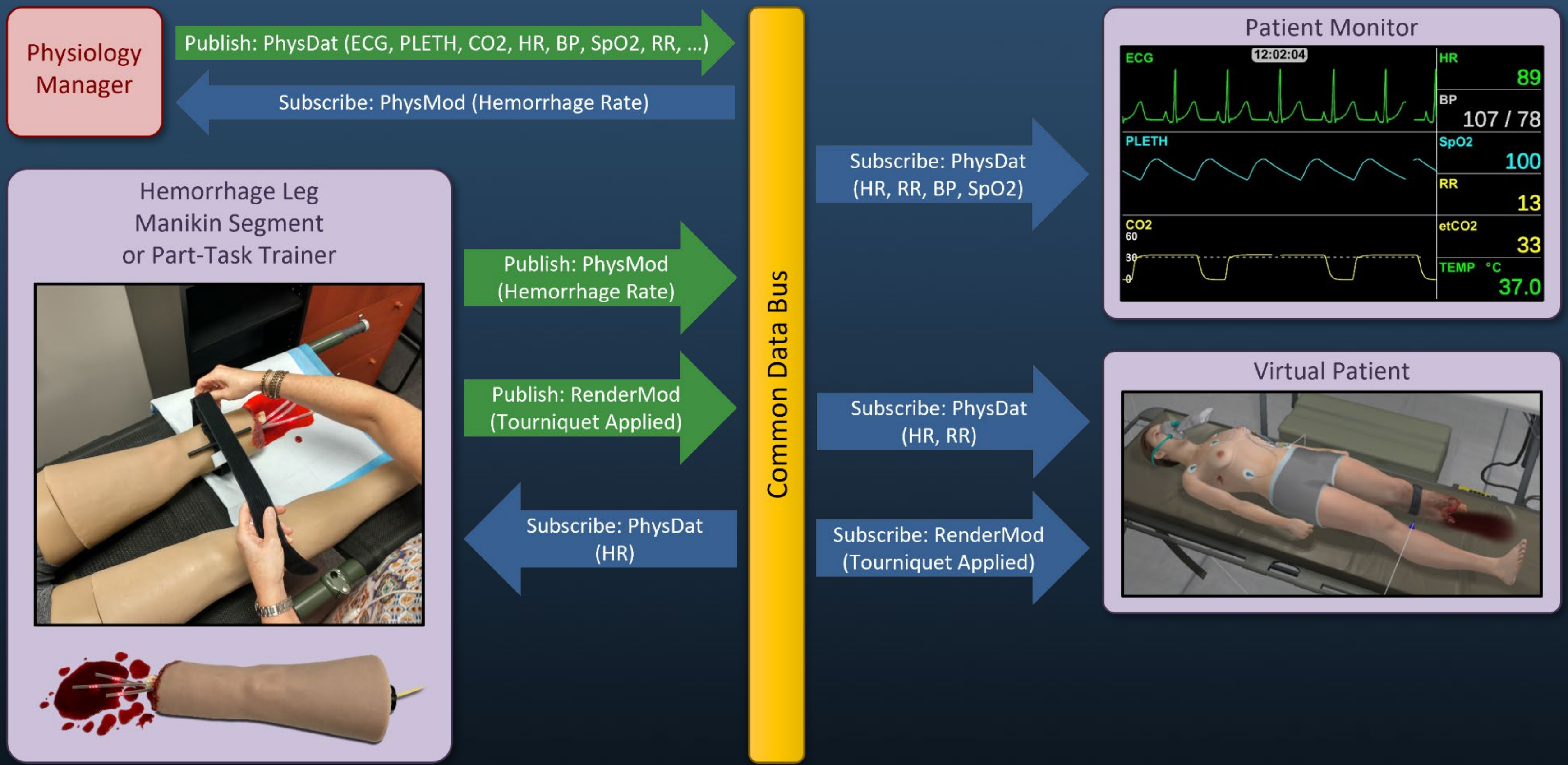
Physiology Data

- Physiology data is published on two different topics: one at 50 frames per second for high-frequency data, one at 5 frames per second for lower-frequency data. Modules can subscribe to only the values they require and can choose the speed at which to receive them.
- Physiology data is published by the physiology engine. Some examples are shown, although this is not an exhaustive list.

BloodChemistry_Arterial_CarbonDioxide_Pressure
BloodChemistry_Arterial_Oxygen_Pressure
BloodChemistry_BloodPH
BloodChemistry_BloodUreaNitrogen_Concentration
BloodChemistry_Hemaocrit
BloodChemistry_Oxygen_Saturation
BloodChemistry_RedBloodCell_Count
BloodChemistry_VenousCarbonDioxidePressure
BloodChemistry_VenousOxygenPressure
BloodChemistry_WhiteBloodCell_Count
Cardiovascular_Arterial_Diastolic_Pressure
Cardiovascular_Arterial_Mean_Pressure
Cardiovascular_Arterial_Pressure
Cardiovascular_Arterial_Systolic_Pressure
Cardiovascular_BloodVolume
Cardiovascular_CardiacOutput
Cardiovascular_CentralVenous_Mean_Pressure
Cardiovascular_HeartRate

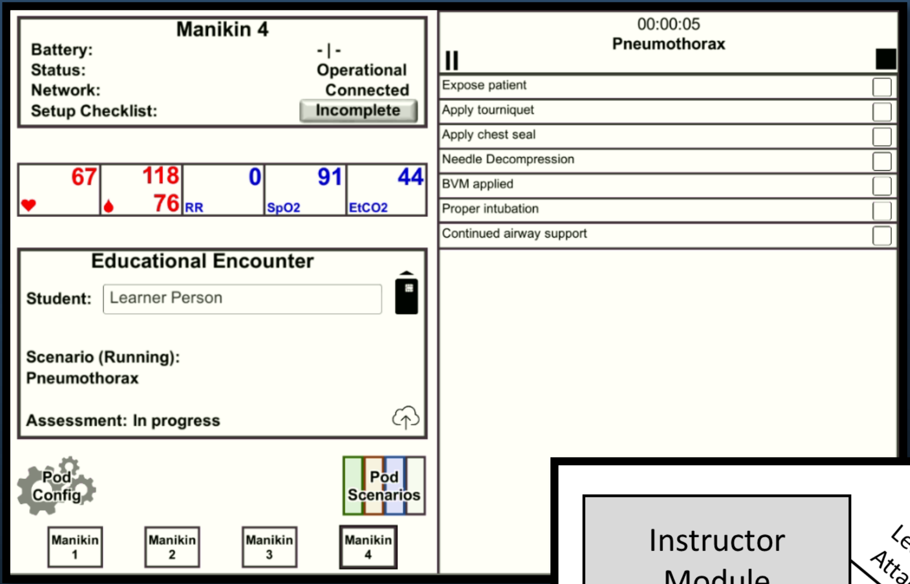
CompleteBloodCount_Platelet
Energy_Core_Temperature
MetabolicPanel_Bilirubin
MetabolicPanel_CarbonDioxide
MetabolicPanel_Chloride
MetabolicPanel_Potassium
MetabolicPanel_Protein
Nervous_PainVisualAnalogueScale
Respiration_EndTidalCarbonDioxide
Respiratory_CarbonDioxide_Exhaled
Respiratory_LeftAlveoli_BaseCompliance
Respiratory_LeftLung_Tidal_Volume
Respiratory_LeftLung_Volume
Respiratory_LeftPleuralCavity_Volume
Respiratory_LungTotal_Volume
Respiratory_Respiration_Rate
Respiratory_RightAlveoli_BaseCompliance
Respiratory_RightLung_Tidal_Volume
Respiratory_RightLung_Volume
Respiratory_RightPleuralCavity_Volume
Respiratory_Tidal_Volume
Substance_Albumin_Concentration
Substance_BaseExcess
Substance_Bicarbonate_Concentration
Substance_Calcium_Concentration
Substance_Creatinine_Concentration
Substance_Glucose_Concentration
Substance_Hemoglobin_Concentration
Substance_Lactate_Concentration
Substance_Sodium_Concentration

How Modules Interoperate



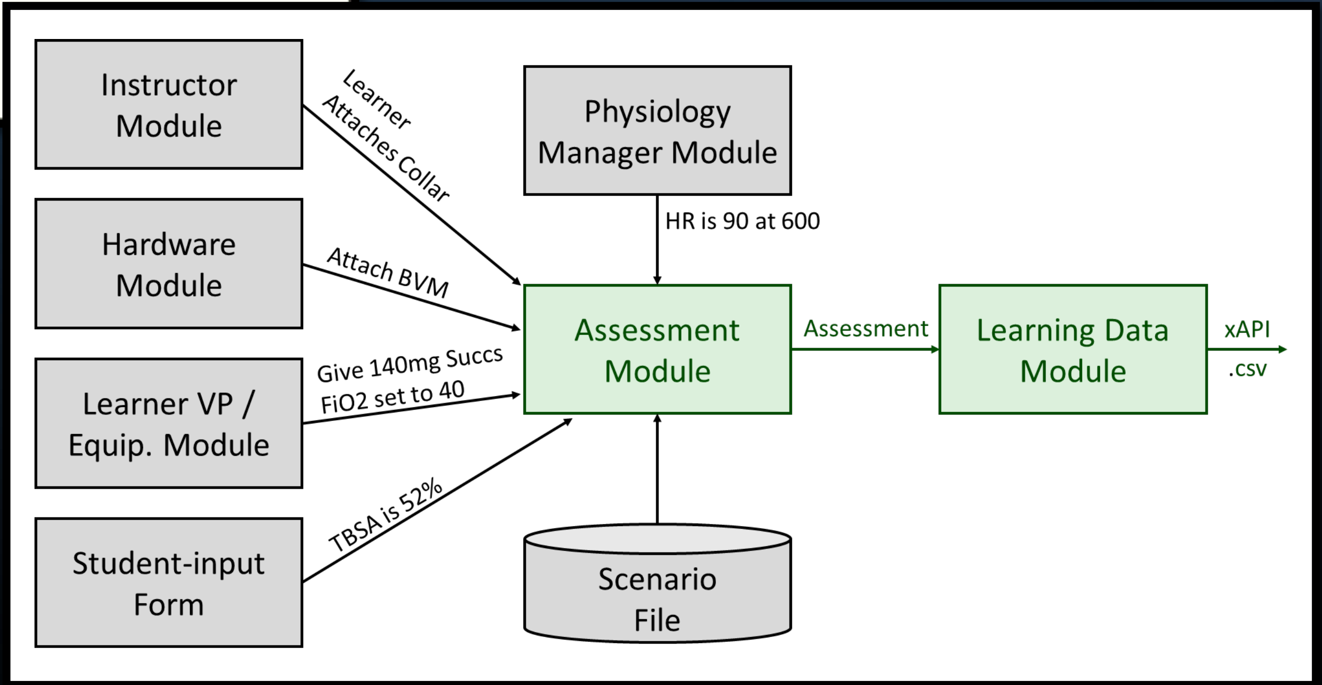
- Modules communicate over the same data bus.
- Modules subscribe to data they require to operate.
- Modules publish data they generate to affect physiology and register student actions.
- Common Data Bus affords synchronization between virtual and physical Modules from different vendors.

Assessing Learner Performance



The Learner Data Module maps MoHSES assessment data into xAPI statements and inserts them into a Learning Record Store (LRS). xAPI statements are queued until the LRS is reachable.

Assessments can be generated by module sensors, instructor observations, or student input.



What is a MoHSES scenario?

A MoHSES scenario defines an educational encounter and the configuration of modules necessary to support it.

The scenario specifies the patient case, starting physiology, available interventions, and assessments.

Scenario Files are XML formatted text that holds Scenario Metadata and Assigned Capabilities.

Metadata and Capabilities

Metadata is information used to define and explain the scenario and it's context. It is intended as a way to catalog scenarios within an LMS or similar system. This data is generally not used during the running of a scenario.

Capabilities define which modules and their capabilities are used within a scenario. For example, if you are building a scenario that includes intubation you may require the simulation to include a module that provides an intubation airway capability.

Multiple modules from multiple vendors can provide the same capabilities.

Example Scenario File

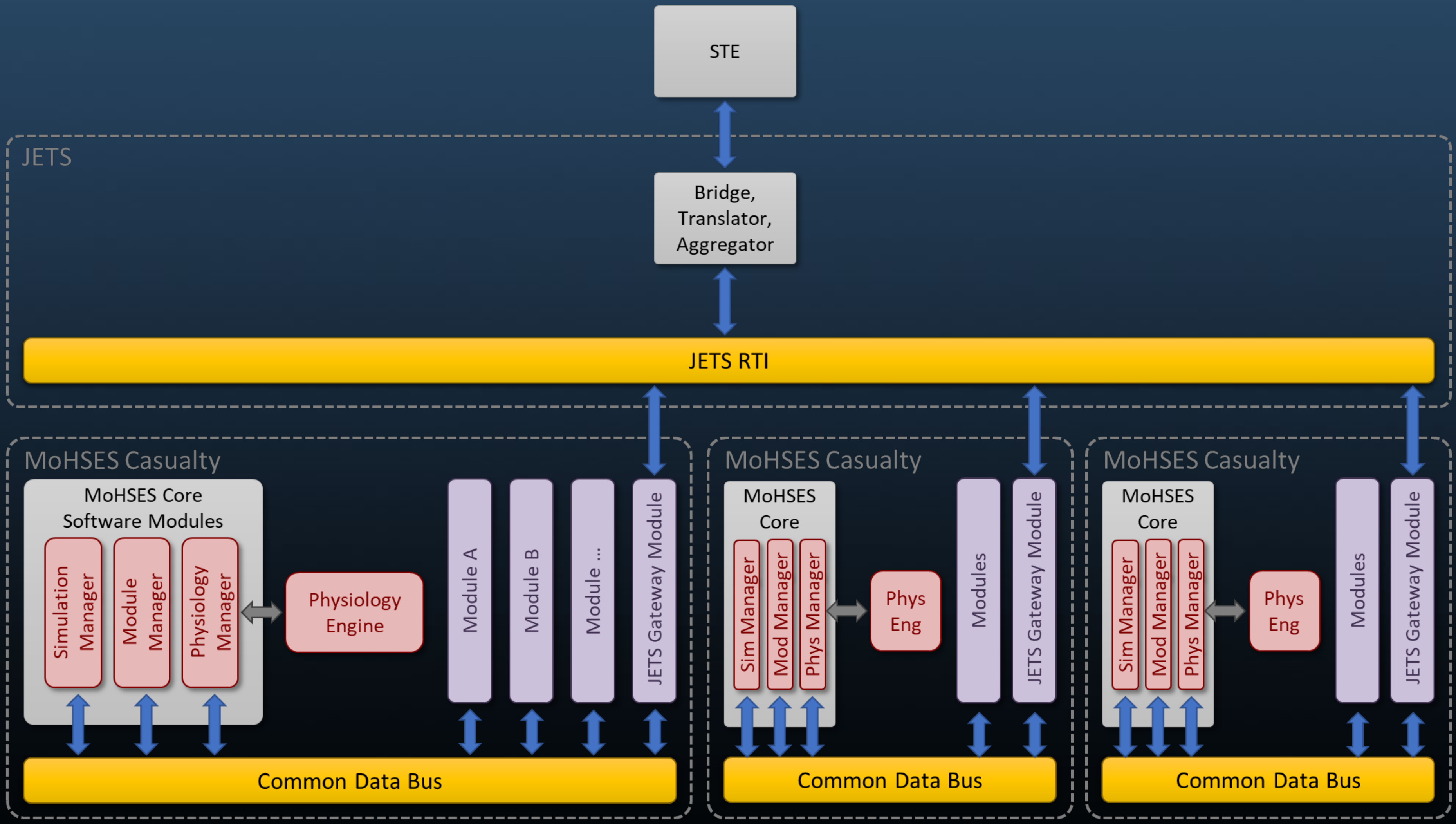
A stub scenario file is provided as a starting point with a bare minimum – only a scenario name is specified in the metadata, and a patient state file is specified as a physiology capability. Placeholders are left in all of the metadata fields, and additional capabilities must be added by using the Operational Description gathered from any modules / capabilities that you wish to use.

The stub scenario file includes a patient file, although if this was omitted it would default to StandardMale:

```
<capabilities>
    <capability name="physiology_engine" required="true" enabled="true">
        <configuration_data>
            <data name="state_file" type="string" value="StandardMale@0s.xml" />
        </configuration_data>
    </capability>
</capabilities>
```

The simplest functional change to make to this stub is to change the state file to some other value – when the scenario is loaded, the physiology engine will then load that state file.

MoHSES / Joint Emergency Trauma Simulation (JETS) Integration



DDS Bridges: Connecting Modules

- Allows data on the DDS bus to be passed to applications and hardware that may not be able to easily implement the complete DDS stack.
- Can be used to rapidly integrate legacy hardware.
- Reduces the time to build new modules.
- Provides pub/sub access to any DDS topic.
- REST Bridge
  - Stateless
  - Supports web applications
    - Instructor Interface (load scenario, play/pause sim, change patient condition)
    - Student Interface (log in, perform certain actions, view score, feedback, and assessment)
    - Technician Interface (monitor simulation health, maintenance, troubleshoot)
- TCP Bridge
  - Stateful
  - Persistent
  - Uses simple TCP sockets.
  - Supports wired and wireless module connections.
- Serial Bridge
  - Stateful
  - Persistent
  - Uses hardware serial communications.
  - Suitable for extremely resource-limited hardware.

MoHSES Integrations

Over 20 organizations have contributed to the MoHSES Ecosystem

- Vcom3D has collaborated with academia and industry through:
  - Providing developer tools and services
  - Integrating products as MoHSES – compliant modules
  - Advancing the MoHSES standards
  - Adapting training content for MoHSES-compliant simulators
- Based on these collaborations Vcom3D commercialized our MedSim DevKit™.

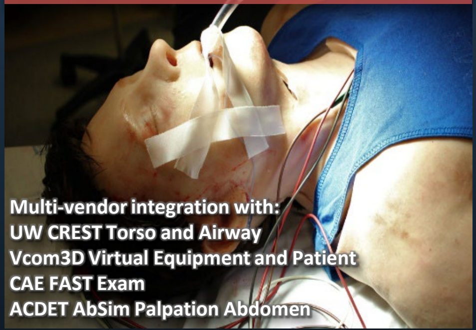
	Organization	Project
1	ACDET	Integrated ABSIM Abdominal Palpation Simulator
2	ARA	Integrated BioGears Physiology Engine
3	Blue Halo	Integrated Virtual Triage System
4	CAE	Integrated FAST Exam Module
5	Design Interactive	Integrated Augmented Reality display
6	Entropic Engineering	Integrated Fluid and Network Managers; Co-developed AMMDK
7	Exonicus	Integrated Virtual Reality Trauma Simulator
8	IngMar	Integrated Lung Simulation as part of Phase I AMM
9	IVIR	JETS Prototype, MoHSES Integration for POINTS
10	Salus Group	Developed multi-modal trauma simulation scenarios
11	Simagine	AJAMS commercialization
12	Simetri	Integrated Fasciotomy Leg
13	SoarTech	Integrated Soliloquy Speech Understanding
14	Sonalysts	Developed MoHSES-compliant Module for Lateral Canthotomy / Cantholysis
15	Strategic Operations	Integrated Humeral Head Intraosseous (HHIO) Trainer
16	TacMed	Integrated MATT Legs as part of Phase I AMM
17	Titan Simulation	Integrated MoHSES Core and Virtual Equipment for Manikin Development
18	University of Florida	Integrated Physical Task Trainer with integrated tutor for Central Venous Access. Designed approach to integrating REBOA trainer
19	University of Minnesota	Developed Phase I AMM
20	University of Washington	Developed Phase II AMM.

MoHSES Example Applications

Central Venous Access Trainer UF Self-Guided Task Trainer Integrated with Vcom3D IMPACTT™ Team Trainer

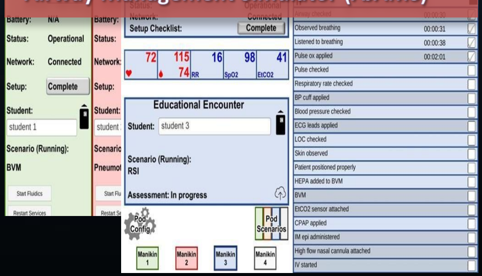
Lateral Canthotomy/Cantholysis Trainer: Sonalysts

Advanced Modular Manikin Phase 2 Trauma Manikin

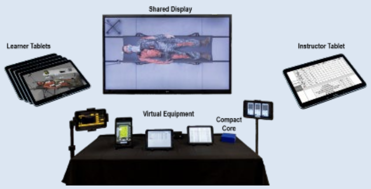


Advanced Modular Manikin Phase I Trauma Manikin

Training Pod Management System (TPMS) Instructor Interface for Advanced Joint Airway Management Simulator (AJAMS)



Vcom3D Commercial Products



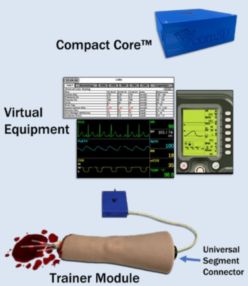
On-Site

Remote

Immersive Modular Patient Care Team Trainer (IMPACTT™)

IMPACTT™ Virtual Equipment

Monitor, Vent, IV Pump, Labs, Urine Gauge



MedSim DevKit™

Modular Physiology:

BioGears
CAE
HumMod (for JETS)

ASPIRE Integration:

SoarTech Speech Understanding

Discussion

Potential Topics

- Sustainment
- Segmentation and Connectors
- Standard Vocabularies
- Operating Environment
- Reference Implementations
- Physiology