Medical Autonomous Systems for Improving Healthcare Delivery

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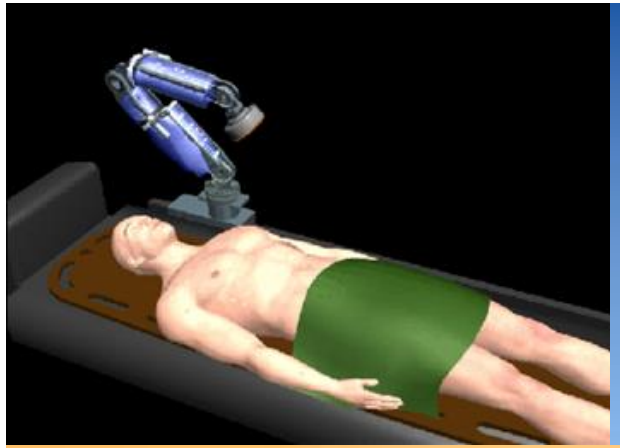
Agenda

- US Military Research Vision / Mission
- Research Focus Areas
- Medical Device Interoperability Challenges
- Invitation for Collaboration

Medical Research and Development Command (MRDC) Mission and Vision



Responsively and responsibly create, develop, deliver, and sustain medical capabilities to support the Warfighter

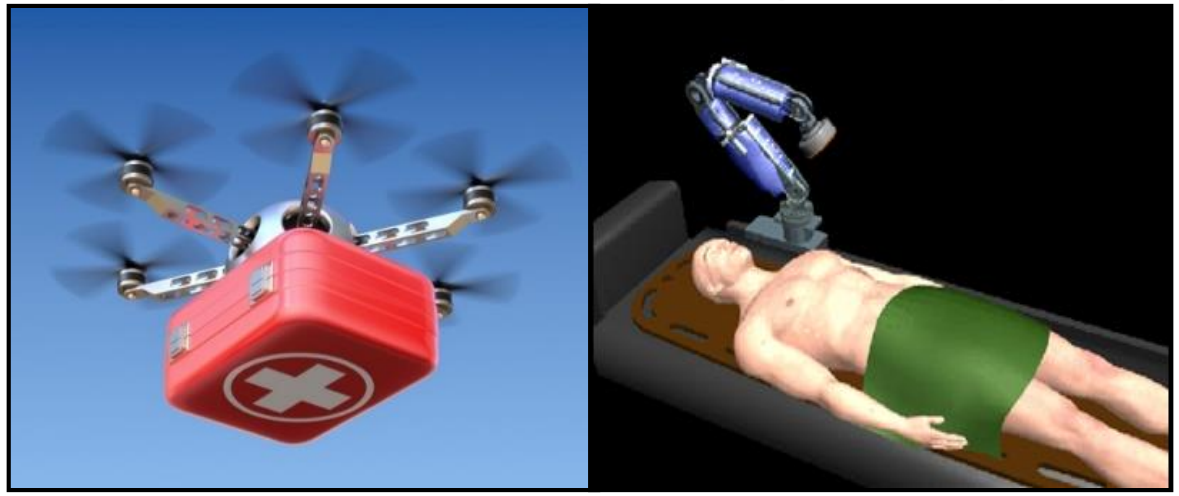
Lead the advancement of military medicine

Medical Assist Support Technologies (MAST) Research Portfolio
Purpose and Objectives

PURPOSE: To support medical care delivery in dispersed and complex environments through futuristic technologies.

TASK AREAS & OBJECTIVES:

MEDICAL ROBOTIC AND AUTONOMOUS SYSTEMS (Med-RAS)



Research, design, and prototype future, next generation medical robotic, autonomous and unmanned medical capabilities to deliver high quality combat casualty care while optimizing the medical logistic footprint in far-forward and dispersed operations with limited or absent medical personnel in support of the Army Multi-Domain Battle concept and the Army Force 2025 and Beyond vision.

VIRTUAL HEALTH

Develop future Virtual Health enterprise process architectures, approaches for delivery of care, and integrated physical solutions capable to supporting prolonged field care and dispersed operations in conditions with limited or lacking traditional field communications and extended enroute care scenarios when providers are in different locations.

Future Operational Environment Implications

Military

- U.S. dominance is not assured
  - Adversaries are contesting all 5 domains (Air, Land, Sea, Space & Cyberspace), to include electromagnetic pulse (EMP), and the information environment
  - Prolonged care at the point of injury, and in denied environments lacking specialty/skilled medical providers
- Smaller forces fight on an expanded battlefield and in multi-domain operations that are increasingly lethal and hyperactive
- Near-peer states more readily compete below armed conflict making deterrence more challenging
- Dramatically increasing rates of urbanization and the strategic importance of cities also ensure that operations will take place within dense urban terrain

Civilian Needs Mirror Military Needs

- More frequent and volatile weather and human-induced disasters (hurricanes, mass shootings, ebola outbreak etc)
- Need for safe, repeatable, consistent, high quality healthcare delivery regardless of geographic location or staff qualifications (rural/urban hospitals and intensive care units)
- Prolonged care may be needed before evacuation or specialty treatment can occur (Hurricane Maria Puerto Rico 2017)

Future View of Medical Support

Autonomous/Semi-Autonomous/Remotely Operated Medical Devices and Medical Data interacting with Healthcare Providers at hospitals around the globe from Theater and thru Casualty Evacuation to the USA

- **Autonomous Critical Care System**
- **Autonomous Intubation**
- **Autonomous Cricothyrotomy**
- **Other autonomous interventional procedures**

Proposed Medical Autonomy Levels

Levels of autonomy

Increasingly human-performed tasks → Increasingly machine-performed tasks

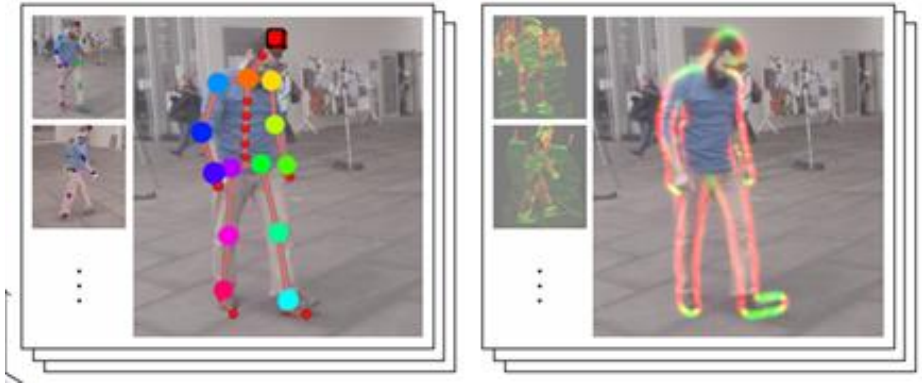
No autonomy	Technology Assistance	Task Autonomy	Conditional Autonomy	High Autonomy	Full Autonomy
Caregiver(s) performs the task	Caregiver(s) is involved in task and technology aids and enhances effectiveness	Caregiver(s) initiates a task and has discrete control over technology that executes it	Caregiver(s) defines and initiates a task & technology executes the task with caregiver supervision	Technology decides course of action and executes it with caregiver supervision	Technology decides course of action and executes it without supervision

Varying levels of autonomy across tasks




Medical Robotic and Autonomous Systems (Med-RAS) and Virtual Health

Medical Robotics



Purpose:

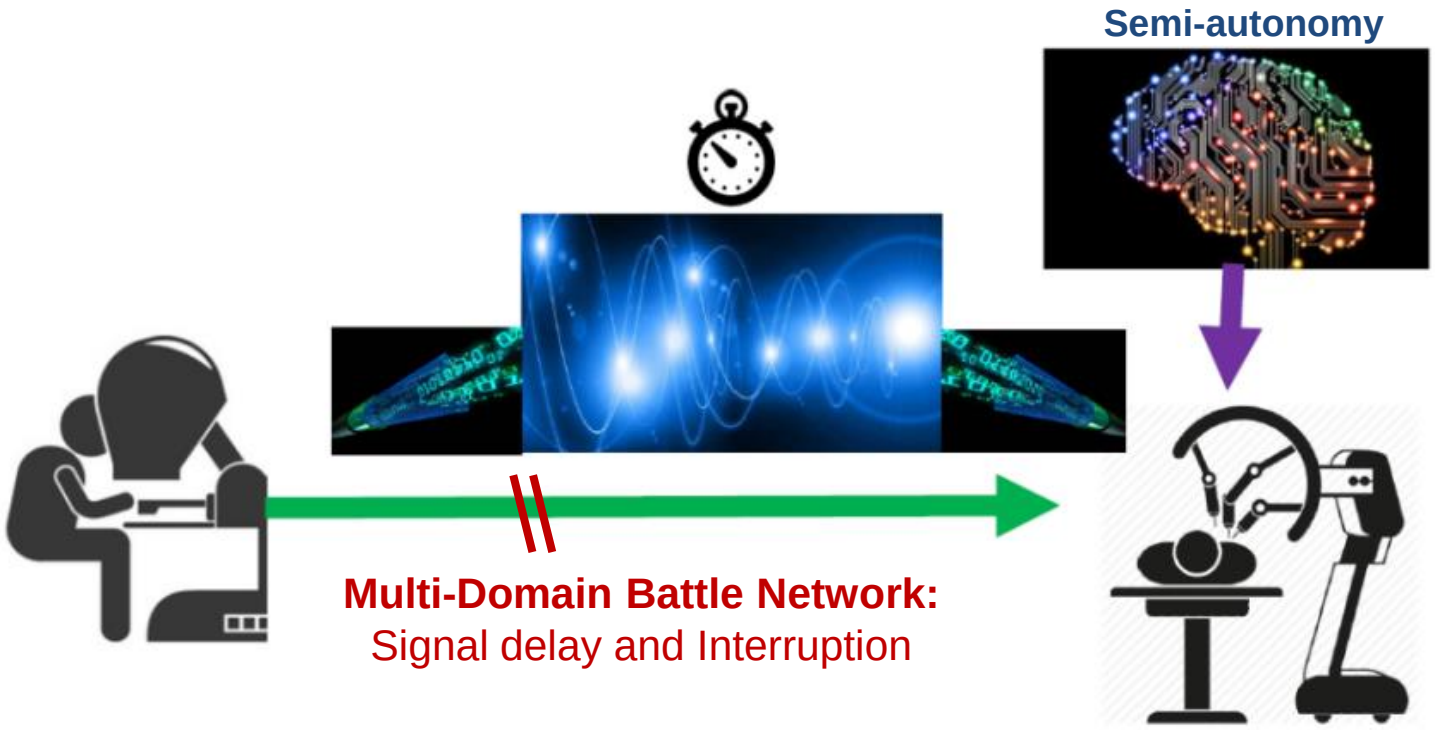
Develop medical robotic systems capable of providing or supporting combat casualty care while optimizing the medical logistic footprint in far-forward and dispersed geographic environments in support of the Army Multi-Domain Battle concept.

Research Areas:

- Robotic Enroute Trauma Care System
- Tele-surgical Robotic Operative Network
- Robotic Perception & Intelligence for Combat Casualty Care

Medical Robotic and Semi Autonomous Procedures

Objective: Conduct foundational research to determine next generation technology approaches to semi-autonomous/autonomous robotic surgery



Challenges and Knowledge Gaps:

- Approaches to improve the safety profile and efficacy of tele-robotic surgery in remote, austere, and/or combat environments
- Explore potential semi-autonomous robotic assistance protocols as signal latency counter-measures
- Conceptual frameworks for semi-autonomous/autonomous medical behaviors supporting creation of a future library of surgical tasks as stored knowledge for automatic recall

Medical Autonomous and Unmanned Systems

6.1 Objective: Conduct basic, exploratory research in future conceptual technology designs leading to medical care, transport and resupply through autonomous and UMS supporting complex environments including the MDB concept of operations.

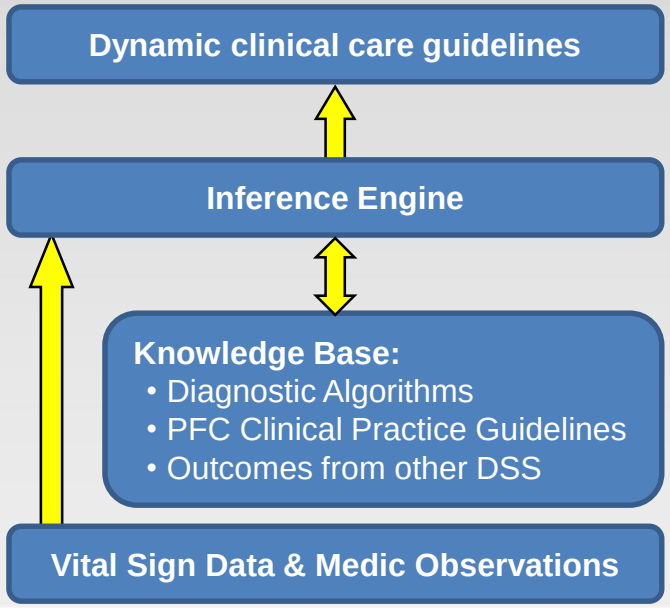
Concept for Model-Based Autonomous Cardiovascular-Respiratory Resuscitation

Challenges and Knowledge Gaps:

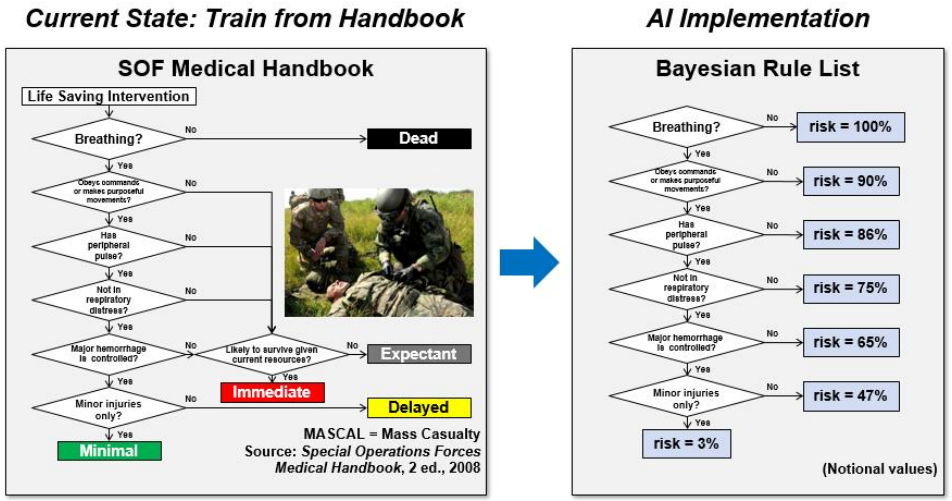
- Develop novel approaches to automated vascular access, automated needle thoracotomy, Functional Hemodynamic Monitoring (FHM), and closed loop resuscitation.
- Models pathophysiologies of injuries in trauma simulations
- Research strategies for incorporating and de-conflicting multiple closed-loop autonomous systems

AI/Machine Learning Challenges

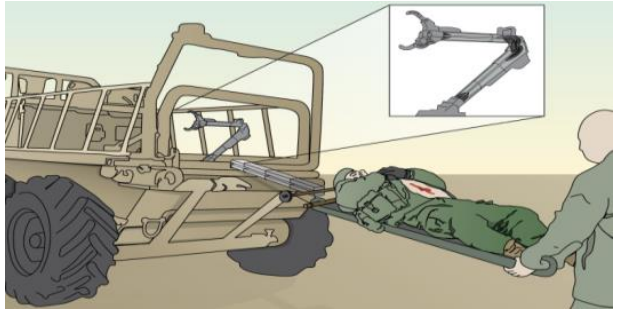
- Need to resolve uncertain and conflicting inputs regarding patient state in polytrauma cases
- Explainability of heuristic systems
- US Food and Drug Administration (FDA) approvals
- Heterogeneous data sources (medic observations/NLP, physiological waveforms, Electronic Health Records, computer vision, medical imaging), need for medical interoperability
- Knowledge Engineering- capturing expert knowledge for the knowledge base
- Lack of combat trauma data for machine learning applications
- Shortage of medical AI/medical robotics expertise and lab facilities within the DoD



Medical Autonomous and Unmanned Systems



Purpose: Develop semi-autonomous and autonomous closed loop combat casualty triage, diagnosis, physiological monitoring, therapeutic intervention, casualty evacuation, and emergency medical resupply technologies for integration with multi-purpose Army autonomous & unmanned systems (UMS) platforms.



Research Areas:

- Closed Loop Trauma/Critical Care Systems
- Multipurpose UMS Platforms for Medical Missions
- AI Assist for Combat Medic
- Combat Evacuation Mission Module
- UAS Research Platform for Emergency Medical Resupply and Enroute Care

Virtual Health

Program Goal:
To develop future Virtual Health enterprise process architectures, approaches for delivery of care, and integrated physical solutions capable to supporting prolonged care in remote areas and dispersed operations in conditions with limited or lacking traditional field communications and evacuation assets.

Research Areas:

- Tele Mentoring & Tele Consultation
- Remote Patient Monitoring and Automated Diagnosis
- Artificial Medical Intelligence
- Clinical Decision Support Technologies
- Medical Data Compression and Cyber-Security
- Medical Device Interoperability and Related Standards
- Just-in-time Medical Training
- Virtual Psychological Assessment Support

Medical Device Interoperability Reference Architecture Research Collaboration

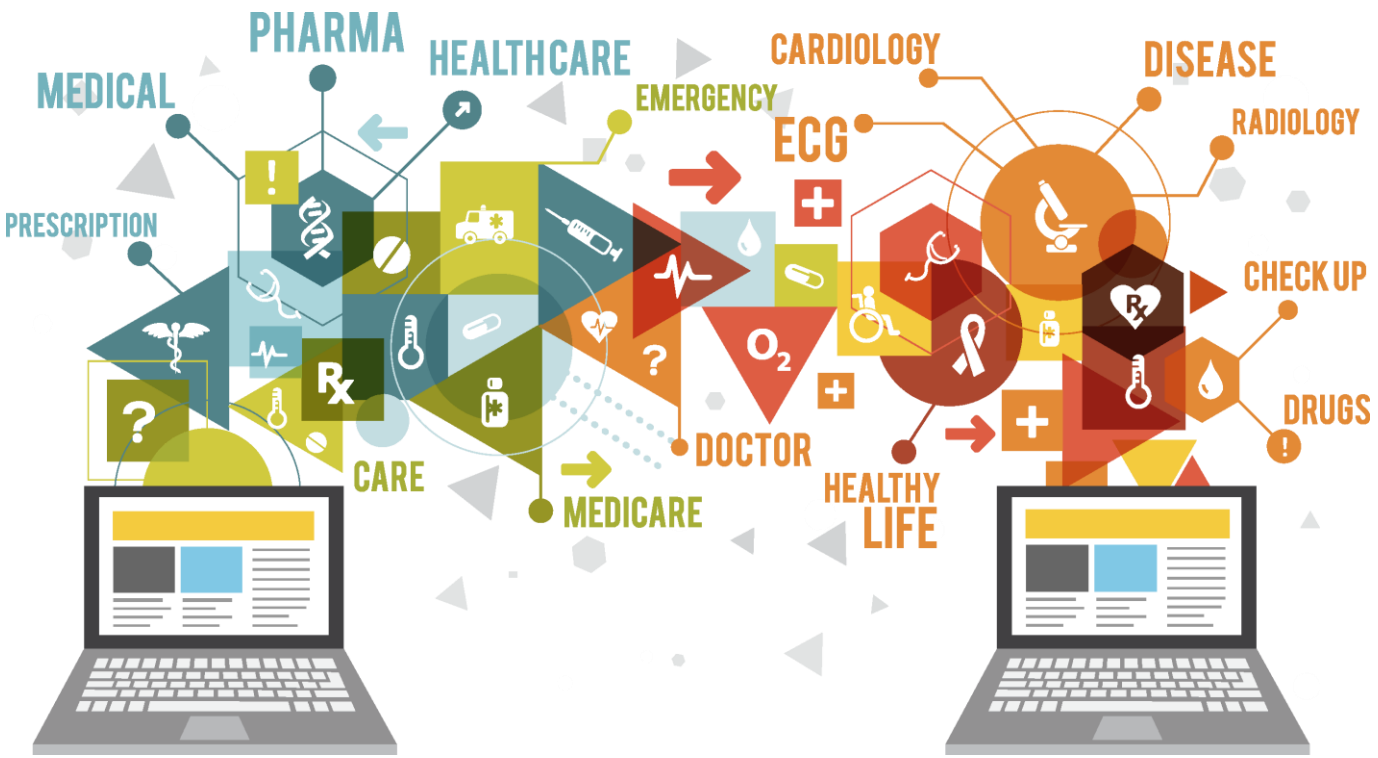
Medical Device Challenges

Interoperability and Integration of Medical Devices for Autonomous Care and Virtual Health are in Early Stages:

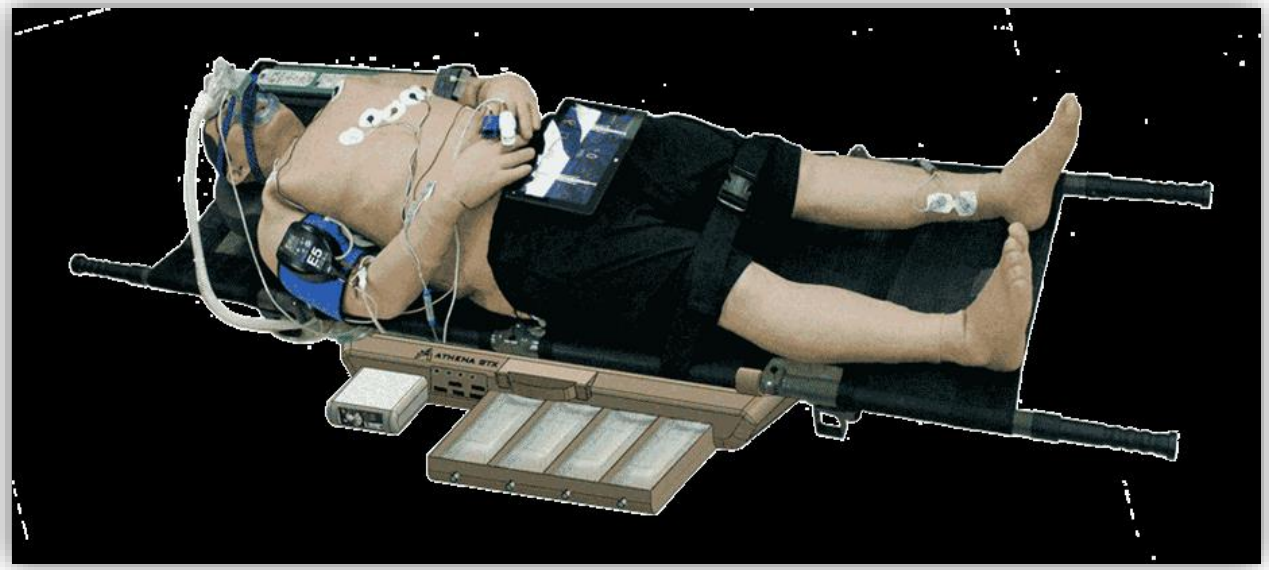
- Research needed on treatment decisions with semi-autonomous algorithms in demonstrations and prototypes
- Devices need to be able to “talk” and self-manage in real time on changes in clinical conditions

International and Industry Standards Needed:

- Device data exchanges, interfaces, algorithms
- Standardized methods to provide and improve AI for autonomous care



ONR SBIR: Automated Critical Care System Prototype



Closed-loop-control (CLC) for casualty evacuation, land and sea-based medical treatment facilities (MTFs)

Features:

- Capable of managing a severely wounded casualty for >6 hours
- Closed loop drug infusions (pressors) and ventilator support
- Controlled by algorithms
- Decision assist or autonomous modes
- Low power requirements, onboard battery, accepts variety of power inputs

Medical Device Interoperability Showstopper Issues:

1. No plug and play, i.e. cannot swap O_2 Sat with another manufacturer
2. No standardization of data outputs for devices to interoperate
3. Must have the exact make/model to replace a faulty device or system will not work

Medical Device Interoperability (MDI) Reference Architecture Research Collaboration

Award:

- Prime Performer: Johns Hopkins University Applied Physics Laboratory (JHU-APL)
- Period of Performance: 24 months (start: SEP-2018)

Objectives:

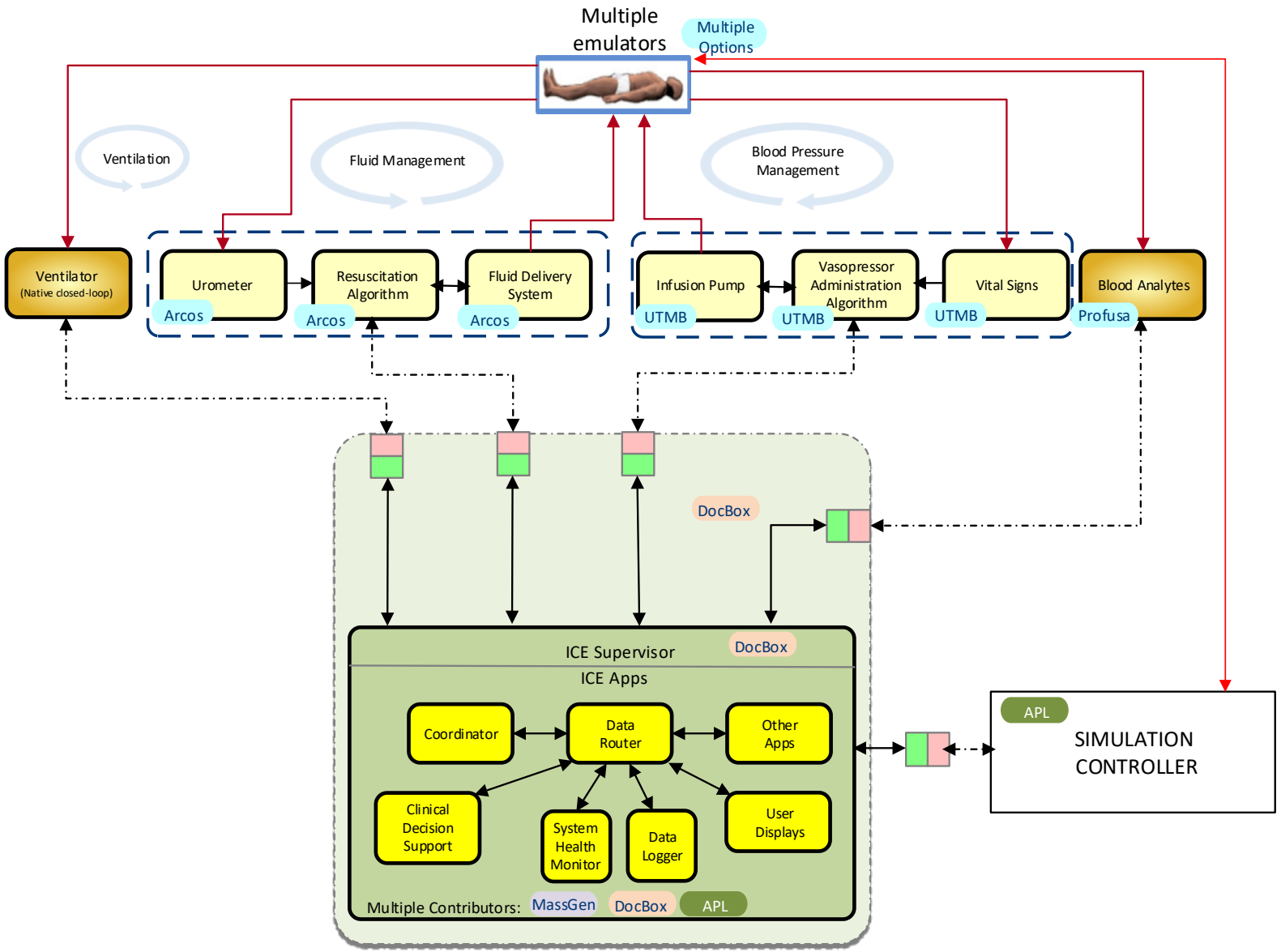
- Advance MDI to improve patient safety through standardization of healthcare delivery
- Identify a collaborative Federal/industry approach in pursuing answers to the questions
- Conduct multiagency/multi partner collaborative research to develop a sustainable framework of autonomous /closed loop prototypes for military health care which are dual use for the civilian healthcare system

Research Deliverables

Incremental deliverables are expected to support the end deliverables, which are:

- Prototype an overhauled medical device infrastructure that shows a national, sustainable and interoperable medical device technical, clinical and policy framework
- Prototype autonomous, closed loop applications for the following disease processes that are most common for military casualties (and civilian trauma/accidental injuries)
  - Cranio-cerebral trauma
  - Hemorrhagic shock and coagulopathy
  - Septic shock
  - Multi-system organ failure
  - Burns
  - Acute renal failure
  - Pulmonary insufficiency

Reference Implementation



What the MDI Reference Architecture Can Provide

- ***Specifies an environment into which combinations of medical devices, some under closed-loop control, can be quickly integrated to meet immediate trauma care needs***
- ***Provides a common terminology and taxonomy for physical and functional elements***
- ***Identifies operational interfaces and operational support assumptions***
- ***Identifies the pertinent interoperability standards as well as requirements (e. g. for medical devices) not yet addressed in the standards (stimulates enhancements to standards)***
- ***Supports development of Reference Implementations of core components***
- ***Enables an open-systems business model***

Collaboration Benefits

Invitation to collaborate/focus on the difficult cross-cutting research and development challenges to realize military research goals:

- Attempts to establish architectures for secure sharing of data use and reuse will facilitate advances in healthcare diagnosis and treatment, as well enhance computational methods to extract new knowledge from these data
- Synergy between designing systems for dual use in the military and civilian sectors that insures uncompromised safety while allowing operators to adapt to changing conditions
- Collaborative efforts are needed to define technical aspects of interoperable platforms, architecture, medical devices, standards and data models that can be used across multiple medical areas



Thank You!!

QUESTIONS?

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