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Executive Summary

Future military operating environments are anticipated to fall mainly into two categories: large-scale combat operations (LSCO) or multi-domain operations (MDO). In either scenario, the casualty care context is significantly impacted. The ability to move casualties and patients to higher echelons of care within an optimal timeframe is significantly reduced and the locations of care delivery may be suboptimal. Planning assumptions would also conclude that if casualties cannot get out, the opportunity for unit resupply and resources to be brought in will also be limited.

In such scenarios, US military forces must be ready and equipped with materiel solutions that support effective and efficient delivery of medical care outside doctrinal times, in locations with limited resources.

An FDA-approved materiel solution, MOVES[®] SLC[™] addresses identified Requirements gaps for Prolonged Field Care (PFC) and Prolonged Care (PC) scenarios for combat casualty and Disease Non-Battle Injuries (DNBI) patient groups, across all Roles of Care.

MOVES[®] SLC[™] is the micro-integrated life support system that combines an oxygen (O₂) concentrator, a unique O₂-conserving ventilator, suction, and complete vital signs monitoring in a single compact, rugged, portable, battery-operated system, which operates without the need for O₂ cylinders. Developed in partnership with the US Department of Defense, MOVES[®] SLC[™] extends the critical care window on the battlefield and serves as a force multiplier in today's – and tomorrow's – military operating environments.

The Future Battlefield: Large-Scale Combat Operations (LSCO) and Multi-Domain Operations (MDO)

Future military engagements will require globally responsive combined arms teams capable of maneuvering from multiple locations and domains to present multiple dilemmas to the enemy, limit enemy options, avoid enemy strengths, and attack enemy weaknesses.^{1,2}

To respond globally, Army forces must conduct expeditionary maneuvers effectively. Expeditionary maneuver is the rapid deployment of task-organized combined arms forces able to transition quickly and conduct operations of sufficient scale and ample duration to achieve strategic objectives. Army forcible and early entry (EE) forces, protected by joint support, must achieve surprise, and bypass or overcome enemy anti-access/area denial (A2AD) capabilities through inter-theater and intra-theater maneuvers to multiple locations.

Medical equipment and personnel must extend lifesaving capability, operational reach, and evacuation capability.

Medical Readiness

Nested in the US Army Operating Concept: Win in A Complex World and the Capstone Concept for Joint Operations: Joint Forces 2021, the Army Medicine Vision 2020 identifies the need to:

- build readiness and health of the force;
- modernize doctrine, equipment, and formations;
- reform Army Medicine to maximize time, money, and manpower; and
- strengthen alliances and partnerships to create synergistic energy and teamwork required to support the Army.

This requires equipping skilled professionals and proficient teams on the battlefield with the equipment to appropriately support the lethality of the Army.³

Medical Modernization

The Army Futures Command Concept for Medical 2028⁴ and the Army Medical Modernization Strategy⁵ continuously define and codify the requirements for the Army Health System to modernize and maximize Joint Force health care in the future operating environment.

Army Futures Command Concept for Medical 2028⁴ Highlights

Provide Medical Support Forward to Enable Semi-Independent Operations

- Align capabilities that directly and routinely impact warfighter survival forward of the corps.
- Decrease sustainment demand.
- Simplify Class VIII replenishment.
- Employ lighter, smaller, and modernized equipment.
- Optimize Evacuation and Maximize Return to Duty.
- Optimize patient evacuation capacity and capability.
- Employ treatment capabilities to return Soldiers to duty as far forward as possible.

Army Medical Modernization Strategy Highlights⁵

- Medical multi-domain formations will leverage advanced robotics, artificial intelligence, and optionally manned systems, and with humans in the on-the-loop, to enable decision-making to inform advanced clinical care and prioritize evacuation.
- Reduce the logistical burdens and footprints required of the 20th-century field hospital capabilities.

The Challenges

The past twenty years of operations in Iraq and Afghanistan allowed US military forces optimal advantages when moving forces, establishing forward operating bases, and sustaining large operational footprints. Freedom of movement of air and ground assets allowed equipment and troops to move around the area of operations largely uncontested. This freedom of movement enabled casualties and patients to be rapidly evacuated through the continuums of care, yielding unprecedented survivability rates. But this is not the future sphere of operations and, therefore, readiness is critical.

The challenges for providing medical support in EE operations, LSCO, and MDO are vast. A2AD inhibits the availability of aeromedical or ground evacuation of casualties, necessitating forward resuscitative efforts at or near the point of injury and treatment and management of patients outside traditional doctrinal timelines.

Units must be prepared for medical capacity to be overwhelmed, or for medical evacuation to be compromised or delayed.

This challenge encompasses all Roles of Care: First Responder Care Capability (Role 1), Forward Resuscitative Care Capability (Role 2/Division Level Care), Hospitalization Capability (Role 3), En Route Care Capability (unregulated and regulated Patient Movement) through patient arrival at Definitive Care Capability (Role 4) outside the area of operations.⁶

> Limited strategic lift dictates the deployment of smaller, more mobile medical capabilities. Limited access to robust medical care resources dictates improved and enhanced medical skills training and equipment for all personnel involved in care delivery.

Delivering Prolonged Field Care & Prolonged Care in Complex Scenarios

Prolonged Field Care (PFC) is "field medical care, applied beyond doctrinal planning timelines to decrease patient mortality and morbidity, utilizing limited resources, and is sustained until the patient arrives at an appropriate level of care."^{7,8} PFC efforts are focused prior to a casualty arriving at a Medical Treatment Facility (MTF).

Prolonged Care (PC) further builds on the concept of operating outside of expected or optimal operational timelines once a casualty has arrived at an MTF. PC is currently defined as: "holding patients in locations where the current system(s) in place were not designed to care for patients with these conditions beyond the designated evacuation timelines."^{9,10} For example, if a patient has reached a "hospitalization" capability and has received, or is receiving treatment, but cannot be evacuated for further necessary treatment or evaluation, the patient will face a prolonged care (PC) scenario.⁹

Core PFC Clinical Capabilities

- (1) Monitor.
- (2) Resuscitate.
- (3) Ventilate/oxygenate.
- (4) Gain definitive control of the airway.
- (5) Use sedation/pain control.
- (6) Physical exam/diagnostic measures.
- (7) Provide nursing/hygiene/comfort measures.
- (8) Perform advanced surgical interventions.
- (9) Perform telemedicine consult.
- (10) Prepare the patient for flight.

PFC and PC Wound Patterns in current operations

- (1) Cranio-cerebral trauma.
- (2) Hemorrhagic shock and coagulopathy.
- (3) Infection and Septic Shock.
- (4) Pulmonary insufficiency.
- (5) Burns.
- (6) Acute renal failure.
- (7) Acute psychological conditions(to include suicidal and homicidal behaviors).
- (8) Multi-system organ failure.
- (9) Ocular trauma.

Additional Anticipated Treatment Considerations during LSCO and MDO

- Generalized physiological resuscitation.
- (2) Respiratory support capabilities.
- (3) Tourniquet conversion.
- (4) Wound debridement.
- (5) Advanced pharmacologicintervention (to include intravenous[IV] medication delivery).
- (6) Psychological stabilization.
- (7) End of life care.



Capabilities Gaps in Delivering Prolonged Field Care and Prolonged Care in Complex Scenarios

LSCO and MDO Medical Readiness

The Joint Trauma System Department of Defense Trauma Registry review identified two critical capability gaps¹⁰:

- PFC should target resources, technology, and training to prevent death from hemorrhage.
- Resources that provide advanced airway and ventilator support in the PFC environment are required.

PC Capability Based Assessment Gaps

In 2017, the Prolonged Care in Support of Conventional Military Forces Capability Based Assessment (PC CBA) working group identified numerous capability gaps, including:

- Army units lack the capability to provide PC when evacuation is delayed to decrease patient mortality and morbidity in 100% of patients with survivable wounds, injuries, and illness.
- Army units lack the capability to provide En Route care to casualties as part of, during, and following PC scenarios to reduce morbidity and mortality.
- Army units lack the capability to provide sufficient medical supplies and blood to all roles of care to facilitate the provision of PC.

Additional considerations

In an A2/AD or EE scenario, the Role 3 will not be available, thus requiring the Role 2 to increase its clinical capabilities and holding capacity until patient evacuation lines to a Role 3 are established.

Sets, Kits, and Outfits (SKO) and Medical Equipment Sets (MES) Supporting PC

Today, caring for critically injured or ill patients requires equipment that can be large and bulky when applied to the patient, including ventilators, vital signs monitors, suction machines, and replenishable oxygen cylinders. The patient may also have other clinical equipment such as chest tubes, wound vacuums, and urinary catheters on the litter. Equipment sets are typically designed for 72 hours of care. Estimates in the Prolonged Casualty Care Guidelines Clinical Practice Guidelines anticipate the need for equipment beyond 96 hours to include ventilation, oxygenation, and sedation support.¹¹

The Prolonged Care Working Group specifically identified that Materiel solutions, must be considered in the design of SKO and MES that support PFC scenarios.

FRSDs and Field Hospitals: Shifting from Past Paradigms

Force Design Updates of the Forward Resuscitative and Surgical Detachment (FRSD) and Theater Hospital (Field Hospital and Combat Support Hospital) highlight the operational need for units to be more modular, agile, and mobile. The FRSD must transport 100 per cent of their personnel and equipment in a single lift using organic vehicle assets and has set a target of 2 hours to achieve initial operational capability.¹² Meanwhile, the 32-bed Field Hospital requires 35 percent of its table of organizations and equipment (TO&E) equipment to be transported in a single lift using authorized vehicles in the HHD, Hospital Center.¹³

The emphasis on mobility and agility marks a shift from recent history. Medical units of current and recent past operations worldwide have benefited from working at mostly fixed sites where they have not been held to standards for mobility. Teams conducting split-based operations were common. Medical units fell in on robust Theater Pre-positioned Equipment (TPE) property books. They did not have to account for vast amounts of clinical care devices that require multiple cases for the equipment, and their supporting consumables, that add weight, size, and cube to a unit's mobility plan.

As future battlefield operations transition to more complex scenarios with access restrictions and other constraints, optimizing portability and interoperability becomes more important than ever.

Healthcare Provider Cognitive Overload

In complex operational and clinical environments with decreased resources, solutions must consider the health care providers using the medical equipment. Cognitive overload can happen during situations in which demands placed on a person by mental work are greater than the person's ability to cope and effectively respond to complex decision-making.¹⁴

Legacy systems are disjointed and do not interface with each other; they are stand-alone systems requiring health care providers to monitor multiple screens spread across the patient, often in environments where access to patients is restricted. Documentation of clinical actions and activities is required but challenging when obtaining data and information from numerous sources.

Patient-to-healthcare provider ratios are expected to increase at all Roles of Care as the ability to evacuate patients is significantly decreased. Complex care being performed on multiple patients by fewer health care providers increases the risk of adverse events and outcomes and adds to the cognitive overload of health care providers. After Action Reports from past operations identify a validated need to provide incorporated principles of PFC into clinical training to decrease the health care provider stress and decrease patient risk found in limited-resource environments.¹⁵

Disease and Non-Battle Injuries (DNBI)

Efforts to develop PFC and PC capabilities must also consider the clinical management of commonly encountered injuries and illnesses with the potential for rapid decompensation found in otherwise healthy and generally fit young adults.

Historically, DNBI have significantly impacted medical resources and will continue to do so in future operating environments. Furthermore, unique environmental factors — including altitude, ambient temperature, endemic diseases, and vector-based infections — affect the DNBI rate.

In addition to supporting overseas operations, the US military has been tasked to support the domestic response during the SARS-CoV-1 virus (COVID 19) pandemic.^{16,17}

Personnel and equipment were deployed to sites across the US to set up operational footprints within civilian structures.

The competition for clinical and logistical resources (e.g., monitoring equipment, ventilators, and oxygen) traditionally found in austere environments overseas was widespread across the US healthcare system.



Filling the Capabilities Gaps in Delivering Prolonged Field Care & Prolonged Care in Complex Scenarios

Gap analysis across the Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy (DOTMLPF-P) domains identifies a myriad of possible solutions to the challenges of LSCO and MDO.

Materiel solutions that address the gaps identified in care delivery in future operations need to be deliberate to support extended doctrinal timelines and enhance the capability to resuscitate and monitor patients at all Roles of Care and En Route Care. Combatant Commanders and their subordinate medical formations, US Army Capability Developers, and US Army Medical Logistics Command need access to materiel solutions to meet the identified gaps of today and tomorrow.

MOVES[®] SLC[™]: a solution to filling Capabilities Gaps

MOVES[®] SLC[™] is an FDA-approved materiel solution which addresses identified Requirements for PFC for combat casualties and DNBI patient groups and supports on-going US Military Medical Modernization efforts.

MOVES[®] SLC[™] is a micro-integrated portable life support system that combines an oxygen concentrator, a unique O₂-conserving ventilator, suction, and complete vital signs monitoring in a single, rugged, portable, battery-powered unit without the need for heavy, dangerous oxygen tanks.

Developed to meet US DoD need and specifications

In 2012, the US Marine Corps Program Manager Combat Support Equipment identified performance specifications for a Portable Patient Transport Life Support System to be used during the transport of wounded Marines and Sailors from the battlefield.¹⁸

In a joint effort, including the need to reduce oxygen requirements in the field, Thornhill Medical integrated several critical pieces of equipment into one, creating the MOVES[®] platform, which has been deployed by the US Marine Corps.

The MOVES® SLC[™] supports multiple critical tasks associated with PFC and PC scenarios when care may be delivered in a location of opportunity or during a lift of opportunity. Additionally, it directly supports and facilitates care tasks identified in the Prolonged Casualty Care Guidelines (CPG ID: 91).¹¹

Integrated Clinical Capabilities

Portable, packed in 2 compact Pelican cases, MOVES[®] SLC[™] features multiple, microintegrated enhanced clinical capabilities which support PFC, PC, and DNBI, while decreasing cube and weight requirements by at least 70%.

- **Micro-integrated Oxygen Concentrator:** eliminates the need for heavy, hard- to- find and -fill, hard to transport and hard to store oxygen bottles.
 - Up to 85% FiO₂ (independent of minute ventilation) for ventilated patients in cyclic mode
 - Greater than 85% (independent of minute ventilation) for ventilated patients in continuous mode
 - Up to 93% O₂ concentrated breathing gas at 2.5 LPM for non-ventilated patients via nasal cannula
 - Accepts an external oxygen source with flows up to 15 LPM to flush or prime the circuit as required
- **Mechanical Ventilator:** may provide modes that are not currently available on ventilators currently in medical equipment sets (MES)
 - Closed-circuit
 - Pressure or volume-controlled
 - Airway Pressure Release Ventilation (APRV)
 - Intermittent Mechanical Ventilation (IMV)
 - Synchronous Intermittent Mechanical Ventilation (SIMV)
 - SIMV plus Pressure Support
 - Assist Control (AC)
 - Pressure Support Ventilation (PSV, can be configured for invasive CPAP or BiPAP)
- Suction: integrated functionality
 - -100 and -325 mmHg with flow rates of 20 L/min
 - Suction wand to clear wounds and oral cavities
 - Intermittent suctioning and removal of fluids, tissue, bones, gases, bodily fluids and other materials.

- **Temperature** (continuous invasive monitoring via core or probe for oral/axillary/rectal)
- Respiration Rate
- Supports 3 and 12-lead ECG
- Non-invasive blood pressure (NIBP)
- Invasive monitoring
 - arterial blood pressure (ABP)
 - central venous pressure (CVP)
 - intracranial pressure (ICP)

• Masimo Rainbow SET® Pulse CO-Oximeter

- arterial oxygenation saturation (SPO₂)
- perfusion index (PI)
- hemoglobin (SpHb)
- total oxygen content (SpOC)
- carboxyhemoglobin (SpCO)
- methemoglobin (SpMet)
- pleth variability index (PVI)
- Continuous Capnography Reading
 - End Tidal CO₂
- Remote screen interface: provides full device operation and allows healthcare providers to toggle between different screen views to monitor ventilator, vital signs monitoring and graphs (up to 4 charts or trends simultaneously: 2 on the MOVES[®] SLC[™] screen and 2 on the Remote Screen)

Improving Sets, Kits, and Outfits (SKO) and Medical Equipment Sets (MES)

Reduced cube and weight

With the consolidation of vital signs, suction, mechanical ventilation, invasive monitoring, and oxygenation devices, MOVES[®] SLC[™] reduces cube and weight by 70%, making medical teams more mobile and efficient, thus enabling them to achieve full operational capability status quickly.

Reduced Power Needs

Increasing power requirements by adding extra medical equipment is of particular concern to units that rely on small portable generator power or while providing care on rotary or fixed-wing aircraft.

Power requirements are reduced with MOVES[®] SLC[™]. Power consumption is 143.75 watts, representing a reduction of power consumption of >85 % compared to that required for the stand-alone devices required to deliver the same functions.

Oxygen Capabilities

MOVES SLC's integrated oxygen capabilities address a significant challenge of existing solutions: namely, the challenge of procuring, storing, handling, and refilling portable high-pressure oxygen (O_2) cylinders. These cylinders must be refilled when empty; yet access to oxygen refill sites may be limited. Furthermore, handling and managing portable O_2 cylinders poses risks and requires safe storage space, which may be limited.

The current D-sized cylinder used in mechanical ventilation has a cube of 240 inches and weighs approximately 5 lbs. Based upon a 24-hour oxygen consumption requirement of a ventilated patient, it takes 2 tanks per patient per day. With its integrated oxygen concentrator and related functions, $MOVES^{@}$ SLCTM eliminates many of the challenges associated with O₂ cylinders.

Medical Logistics Capabilities

In addition to the direct patient benefits and enhanced capabilities in the SKO and MES, MOVES[®] SLC[™] supports the JP 4-O task of Medical Logistics requirements to centralize the management of patient movement items (PMI). The directive supports "in-transit patient movement without degrading medical capabilities and provides coordination in recycling PMI back from the patient's final destination to the assigned unit or the appropriate theater of operation as applicable." Consolidating multiple PMI items into a streamlined device reduces tracking items' burden and the supporting medical maintenance requirements.

MOVES[®] SLC[™] has been validated by the United States Army Aeromedical Research Laboratory (USAARL) against Joint En Route Care Equipment Test Standards (JECETS); USAARL Report No. 216-1. It is approved for use on all transport platforms (CASEVAC, rotary-wing MEDEVAC, and fixed-wing aeromedical evacuation).

Attention to Healthcare Provider Cognitive Overload

Patient care is simplified as monitoring, ventilation, suction, and oxygen concentration functions are controlled through a single device, with one user interface powered by a battery or a single power source. This decreases the cognitive burden on healthcare providers monitoring multiple systems with multiple screens requiring multiple cords to multiple power outlets.

Additionally, with an integrated O_2 concentrator, MOVES[®] SLCTM eliminates the health care providers' need to calculate complex formulas to estimate O_2 consumption rates in forward locations or during En Route Care. It also eliminates the need to monitor the O_2 tanks closely to ensure oxygen does not run out during care.

Documentation of care is simplified when a healthcare provider only has to refer to information from one device to update the healthcare record.

Supporting On-going Modernization Efforts

Thornhill Medical is actively collaborating with the DoD using the MOVES® SLC[™] in proposed minimally-manned capabilities and utilizing real-time remote monitoring for vital sign activity and ventilator management. The MOVES® SLC[™] leverages the ability to be a Materiel solution that optimizes the basic requirements of the end-user, with high-tech decision-support that maximizes the opportunity to increase the survivability of combat and non-combat injuries and illness.

Conclusion

Thornhill Medical's MOVES[®] SLC[™] provides a Materiel solution directly supporting current and future operational scenarios requiring medical equipment to extend lifesaving capability, operational reach, and evacuation capabilities. It directly supports efforts to close capability gaps identified in PFC Capability Based Assessments and US Military Medical Modernization Strategies.

> MOVES® SLC[™] provides enhanced PFC and PC capability when evacuation is delayed, supporting the US Army objective of decreasing patient morbidity and mortality in 100% of patients with survivable wounds, injuries, and illness.

MOVES® SLC[™] can provide enhanced enroute care to casualties as part of, during, and following PFC and PC scenarios in order to reduce morbidity and mortality.

> MOVES[®] SLC[™] can decrease the burden of providing sufficient medical supplies to all roles of care to enable effective PFC and PC.

As an integrated, portable life-support system uniquely tailored to current and future LSCO and MDO environments, MOVES[®] SLCTM extends the critical care window timeline on the battlefield and is a force multiplier supporting our warfighters.

Author Bio

Randall M. Schaefer (Lieutenant Colonel, USA, Retired), DNP, RN, ACNS-BC, CEN, served for 20 years as an Emergency/Trauma Nurse in operational units and fixed facilities in clinical and staff officer roles. She deployed three times in support of Operation Iraqi Freedom and Operation Inherent Resolve. She earned her 7Y (Capabilities Development) Additional Skill Identifier while serving as a Clinical Consultant at the Capabilities Development Integration Directorate (CDID) at Fort Sam Houston, Texas. She was the lead action officer and lead author for the development and writing of the US Army Health Readiness Center of Excellence "Early Entry Medical Capabilities Concept of Operations". Upon retirement from Active Duty in 2017 until 2021, she worked at the Southwest Texas Regional Advisory Council (STRAC) as the Director of Research overseeing the DOD-funded RemTORN grant. She served as the program manager for the development and implementation of the country's first multi-institutional, multi-disciplinary Regional Whole Blood Program comprised of 18 ground EMS agencies, ten helicopter EMS bases, and numerous hospitals throughout South Texas.

Dr. Schaefer received her Bachelor of Science in Nursing from the University of San Francisco, her Master of Science in Nursing from Widener University, and her Doctor of Nursing Practice from the University of Texas Health-San Antonio.



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