# A Digital Wound Management Ecosystem Architecture to Enable Real-Time Diagnosis and Treatment in Austere Settings

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Getting Connected for Patient Safety™

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## Problem Statement

During large-scale combat operations (LSCO), delayed evacuation and mass casualty events can easily overwhelm Role 1 providers and combat medics. In these prolonged casualty care (PCC) scenarios, unmonitored wounds can rapidly degrade into severe infections or sepsis. A digital Wound Management Ecosystem (WME) can assist medics and improve patient outcomes by automating physiological wound monitoring and delivering targeted care directly at the point of need. However, extending the Integrated Clinical Environment (ICE; ANSI/AAMI 2700-1) to denied, disrupted, intermittent, and limited-bandwidth (DDIL) environments requires a highly resilient architecture. This WME must preserve essential functions and patient safety across austere settings (e.g., underground bunkers) as connectivity fluctuates. These advanced wound management capabilities are currently under consideration for product development by Solventum.

## Methods

A January 2025 military–civilian expert workshop, led by the U.S. Army Institute of Surgical Research, established requirements for a digital WME across three operational states: (1) strict Emissions Control (EMCON) with no connectivity or RF signature, (2) short-range connectivity to a local medic platform without reach-back, and (3) long-range connectivity supporting local and remote data exchange. Leveraging these requirements and ICE principles, we developed the initial Digital WME Architecture. This framework integrates wound sensing, decision support, and targeted therapy (e.g., fluid extraction) to function semi-autonomously, even without reach-back expertise or reliable communications.

We evaluated the architecture's safety, ICE component interoperability, and resilience under network degradation using a theoretical systems engineering analysis that examines logical flow of inputs and outputs during system operation. Finally, we developed alternative algorithmic topologies (medic-focused, casualty-focused, fully distributed, and centralized) and conducted a qualitative SWOT analysis to compare their viability for military applications.

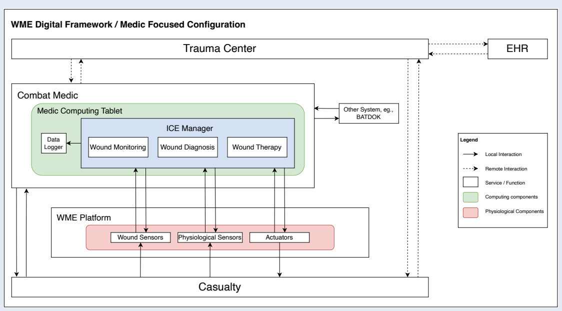
## Results

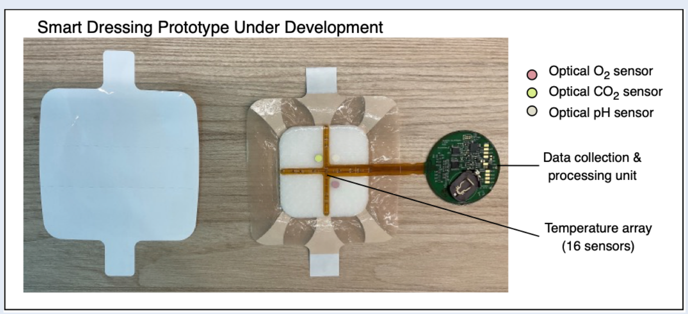
Our analysis revealed that purely centralized topologies failed under DDIL conditions, while fully medic-focused architectures created dangerous single points of failure if a casualty was separated from their provider. Because no single algorithmic topology met the combined demands of autonomous DDIL operation and remote Subject Matter Expert support, we developed a hybrid WME architecture. This solution resolves the challenges through redundancy and hardware modularity. Specifically, it divides the WME into reusable computational and disposable physiological components, while also enabling computational intelligence and data collection at the medic node. ICE functions were successfully mapped across all connectivity states. Under EMCON (State 1), edge computing supports continuous monitoring and protocol-governed autonomous therapy. When links are restored (States 2 and 3), the system seamlessly synchronizes tactical medic applications (e.g., BATDOK), remote experts, and enterprise health records, ensuring essential wound care does not rely on reach-back connectivity.

## Conclusion

The proposed hybrid, ICE-based, WME architecture establishes a modular foundation for interoperable wound monitoring and therapy across all DDIL conditions. By keeping essential sensing, decision-making, and control at the edge, the system reduces reliance on continuous reach-back and supports medic decision-making during PCC. Future steps include implementation, hazard analysis, interoperability and fail-safe verification, and operationally relevant evaluation of clinical performance and medic workload.

**References:**
1. ANSI/AAMI 2700-2-1:2022 - Medical Devices and Medical Systems - Essential Safety and Performance Requirements for Equipment Comprising the Patient-Centric Integrated Clinical Environment (ICE): Part 2-1: Particular Requirements for Forensic Data Logging.
2. ANSI/AAMI 2700-1:2019 - Medical Devices and Medical Systems - Essential Safety and Performance Requirements for Equipment Comprising the Patient-Centric Integrated Clinical Environment (ICE) - Part 1: General Requirements and Conceptual Model.



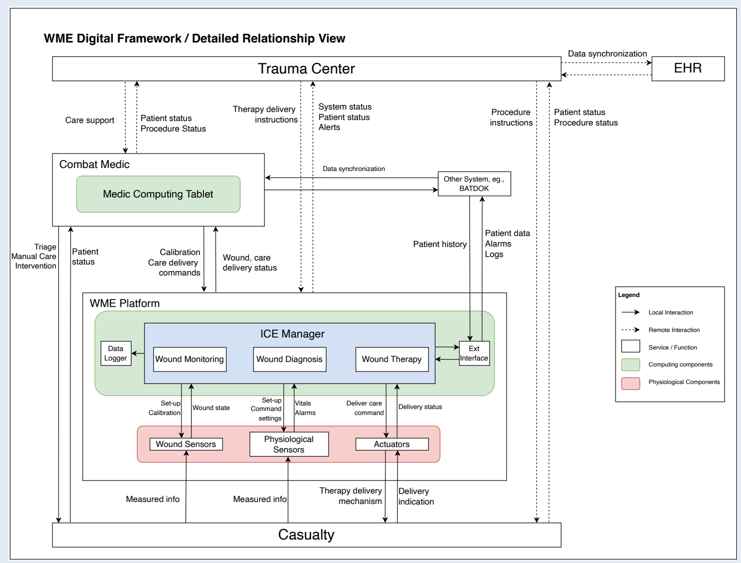




*Figure 1 (left). Medic centric architecture configuration of the digital WME. The computing and physiological components have been identified with colors (refer to legend). Arrows represent interactions between levels of hierarchy.*
*Figure 2 (middle). Smart dressing prototype under development that combines optical sensors ($O_2$, $CO_2$, pH) with an array of 16 temperature sensors in a single bandage. Image curtesy of Solventum.*
*Figure 3 (right). Hybrid Configuration of the WME digital framework architecture. Solid arrows represent local data flow; dashed lines represent remote data flow. Downward arrows denote control actions on lower levels, and upward arrows denote feedback loops to higher levels.*

**Acknowledgement & Disclaimer:** Supported in part by the Defense Health Agency Combat Casualty Care Research Program (CCCRP), with contributions from Solventum and U.S. Army Institute of Surgical Research collaborators. The views expressed are those of the authors and do not necessarily reflect official U.S. Government policy or endorsement.