

The Multimodal Surgical Environment Recording Platform

A synchronized data backbone and clinical-intelligence layer for military medical experimentation and after-action review



Physiology



Device & perfusion telemetry



Audiovisual & environment

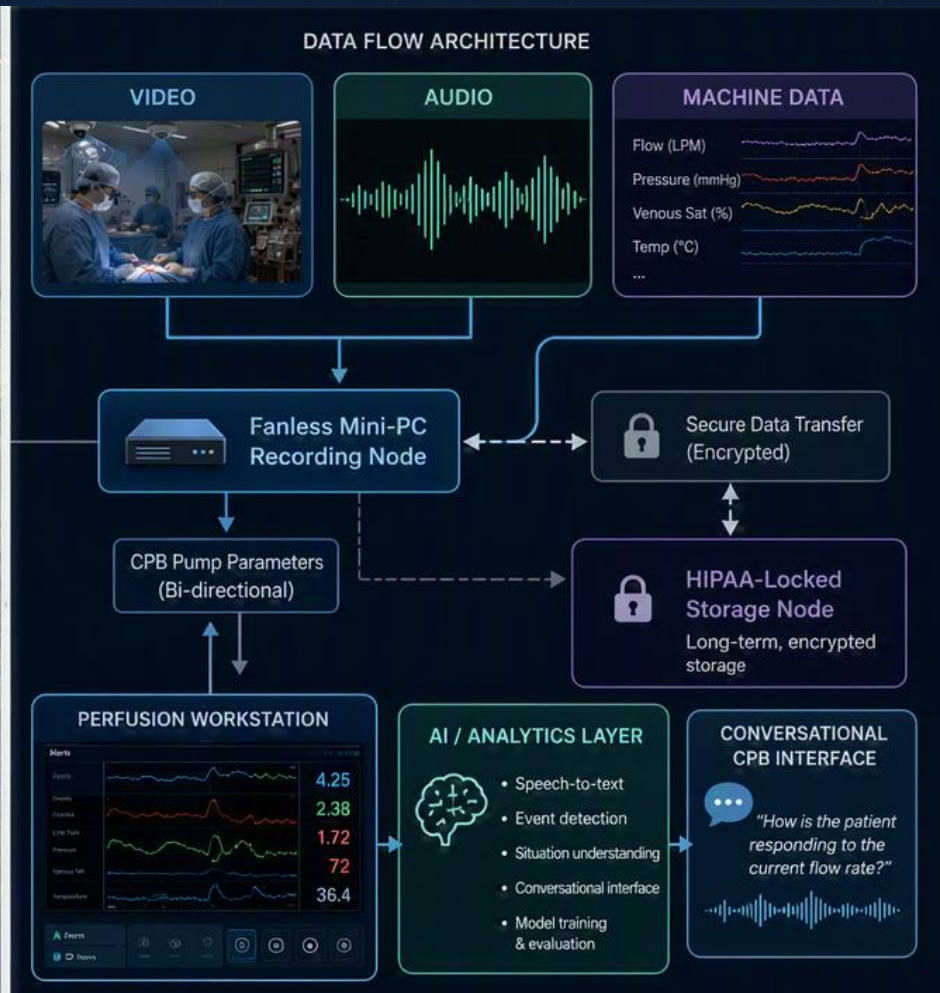
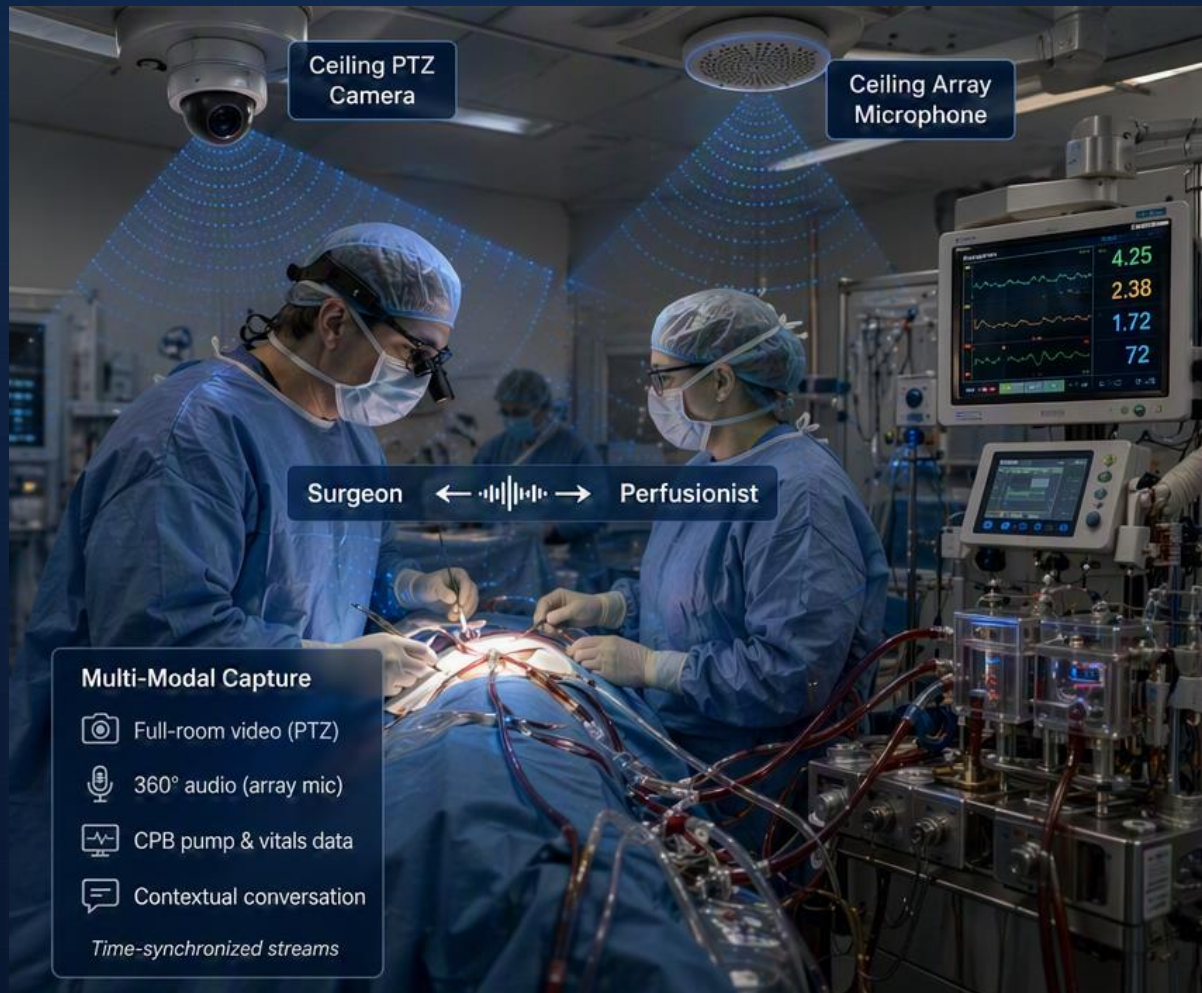
Brian Lima, MD, MBA

Associate Professor of Cardiac Surgery

Abstract MHSRS-26-4268

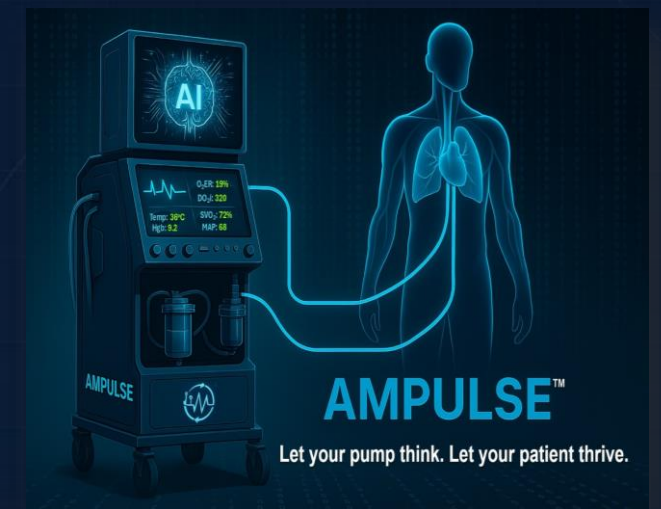
COMPUTATIONAL OPERATING ROOM

Multimodal Recording to enable real-time understanding and continuous learning

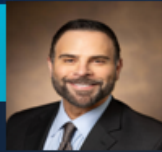


THE TEAM

Autonomous **M**odulation of *P*erfusion *U*sing *L*ogic-based *S*ensing *E*ngine
(AMPULSE™)



Clinical Architecture



Brian Lima, MD MBA
Cardiac Surgeon, Clinical Lead

- Duke MD, Cleveland Clinic training
- 15 yrs cardiac surgery / transplant / MCS
- GDP / O₂ER thought leadership
- >100 publications, Circulation submission
- SpecialtyCare lead ORS consultant

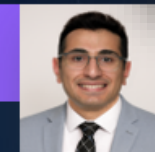
Engineering / Controls



Rei Ukita, PhD
Chief Scientist, Biomedical Engineer

- Carnegie Mellon PhD, VUMC faculty
- Smart-pump dev: >95% O₂ delivery accuracy
- 4 pump platforms validated
- Large animal models (sheep/pig)
- AHA, NIH, DARPA funded (\$2M+ PI)

AI / Modeling



Soheil Kolouri, PhD
AI Architect, Computer Scientist

- Carnegie Mellon PhD, Vanderbilt CS faculty
- NSF CAREER Award recipient
- >100 publications & patents
- Conversational / agentic AI architecture
- PI on DARPA, NSF grants

Vanderbilt Moat



Vanderbilt / VUMC / CTTC

- CTTC commercialization lane active
- VISE + VALIANT AI translation labs
- ELSO Platinum Center of Excellence
- World record heart transplant volume
- ADEPT multicenter validation path

Disclosures

Brian Lima, MD, MBA

- SpecialtyCare (consultant)
- CompuMed (consultant)
- AMPULSE (provisional patent)

Rei Ukita, PhD; Soheil Kolouri, PhD; Matthew Bacchetta, MD

- AMPULSE (provisional patent)—R.U. & S.K.
- M.B. has disclosed no relevant, real, or apparent personal or professional financial relationships proprietary entities that



SECTION 01

The Strategic Imperative

Why large-scale combat operations demand a new foundation for medical readiness

Future conflict will outpace yesterday's medical readiness model



Contested evacuation

Loss of air superiority and extended timelines replace the golden hour with prolonged casualty care.



Resource-constrained surgery

Forward and resuscitative teams operate with limited staff, supplies, and reachback to higher echelons.



Mass-casualty complexity

Higher casualty volumes and polytrauma compress decision time and multiply the cost of every error.



The new variable in readiness is learning speed. Victory increasingly depends on how fast — and how objectively — we learn from every exercise and every casualty, at scale.



We can run the exercise — but we cannot fully see it

TODAY — SUBJECTIVE AAR

- Manual observation by evaluators with clipboards
- Debrief built on memory and competing accounts
- No common clock across people, devices, and patient
- Physiology, device behavior, comms, and actions captured separately — if at all
- Findings vanish when the exercise ends

REQUIRED — OBJECTIVE AAR

- Every stream on one millisecond-accurate timeline
- Critical actions tagged automatically
- Deterioration-to-action measured in seconds
- Closed-loop communication verified, not assumed
- Reusable data backbone for experimentation

The platform closes this gap — capturing physiology, device & perfusion telemetry, and audiovisual streams on a single synchronized timeline.



SECTION 02

The Capability

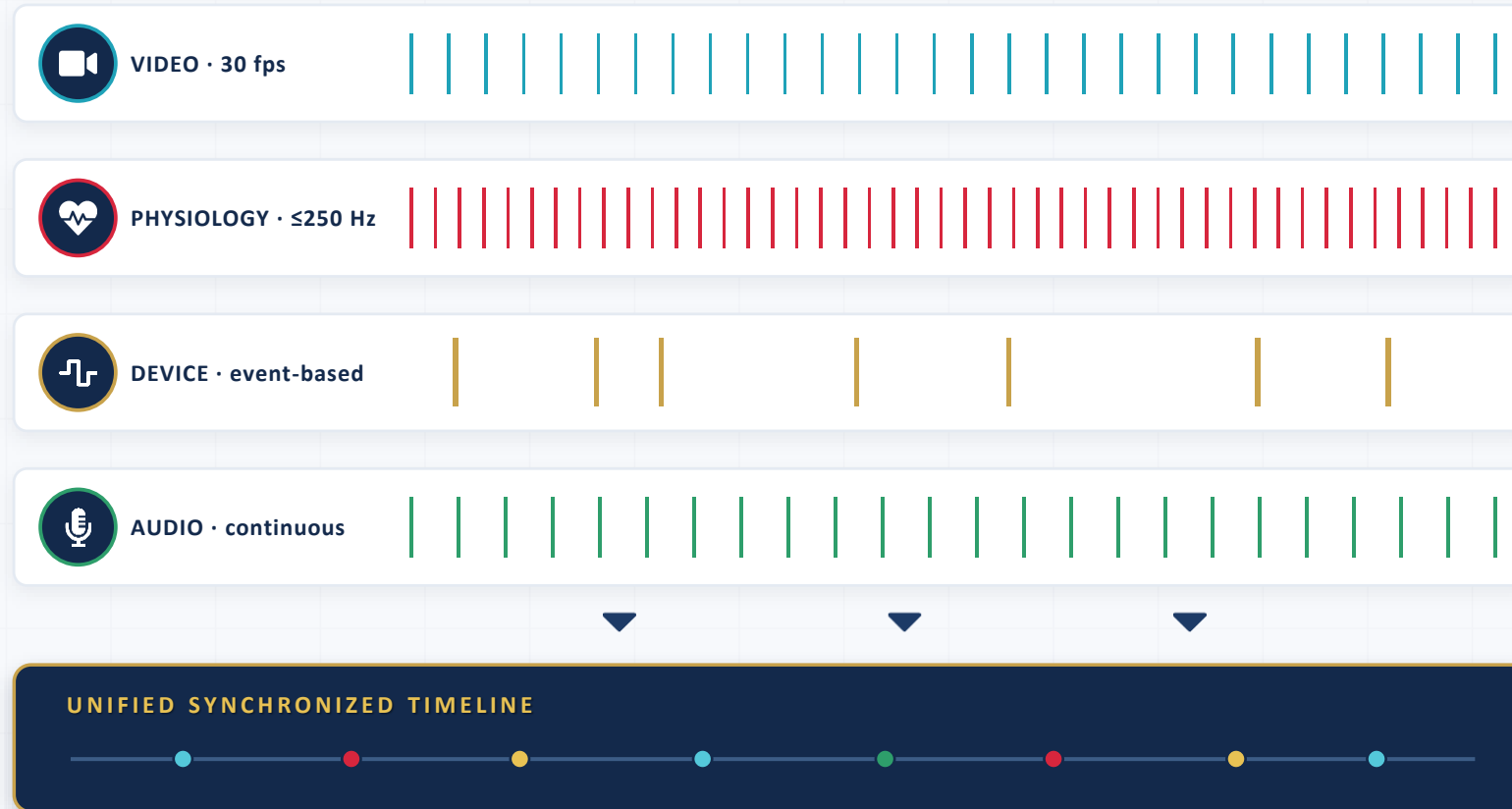
One platform, three data domains, and an intelligence layer that turns capture into insight

One platform. Three data domains. A common operational timeline.



Modular by design. Integrates with existing operating-room and simulation hardware — recording and review only, never autonomous device control.

Disparate sample rates — one millisecond-accurate timeline



Interoperability + ML alignment

- A device-interoperability layer ingests every protocol and format in real time.
- Learned alignment corrects jitter, latency, and dropped packets.
- All streams are projected onto one shared, millisecond-accurate clock.

Four very different streams, aligned to a single clock — the foundation every downstream analytic depends on.

Aggregating data is necessary. Interpreting it is decisive.



After-action review · readiness · doctrine

Decision-grade findings for instructors and leadership



AMPULSE — domain-specific clinical intelligence

Detects deterioration · verifies closed-loop comms · flags workflow deviation



Synchronization & data fabric

Common timeline · interoperability · secure storage



Sensors & devices

Monitors · pumps · ventilators · cameras · microphones

THE STACK

Most platforms stop at storing and visualizing data.

AMPULSE sits above the data fabric as a domain-specific decision layer — purpose-built for the physiology and tempo of acute care. It converts raw multimodal capture into structured, clinically meaningful findings a human instructor can act on.



Born in the cardiac OR

Proven on real perfusion & hemodynamic data from cardiac surgery at VUMC



Hardened for the field

The same logic extends to the full military environment



What the platform extracts from every exercise



Intervention timing

Every critical action time-stamped automatically — no scrubbing through footage.



Deterioration recognition

The delta between physiologic decline and the team's first corrective action.



Closed-loop communication

Orders matched to explicit confirmations; broken loops surfaced.

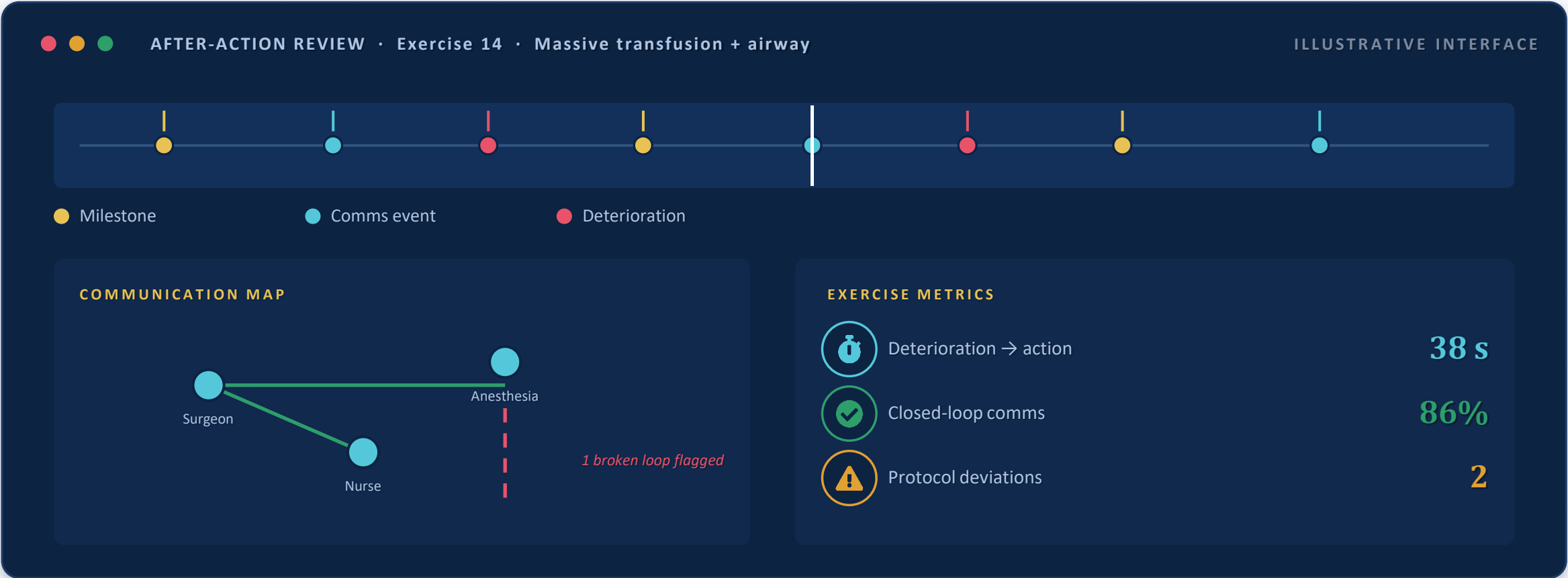


Workflow deviation

The action sequence compared against clinical practice guidelines.

Instructors review insights — not hours of raw footage.

From hours of footage to a decision-grade debrief





SECTION 03

The Evidence

Proven, not theoretical — validated on real VUMC cardiac-surgery data, with multimodal OR capture beginning now

0

3



Not a concept — proven science, deployment imminent

The platform builds on validated science and infrastructure our team already works with at Vanderbilt. The risks the military cares about most are being retired now — on real clinical foundations, not slideware.



Validated on real data

Models published on real VUMC cardiac-surgery cases — earlier perfusion warning (O₂ER) and ECMO prediction at C-index 0.96.



Working intelligence prototype

AMPULSE is demonstrable today as an interactive clinical decision layer — not a slideware concept.



OR capture approved & imminent

Clinical-grade OR cameras approved (VEC) and a multimodal / goal-directed-perfusion registry in IRB — capture beginning shortly.



Proven science, a working prototype, and approved, imminent OR capture — with a mobile design built to translate to austere, forward settings.

We already turn high-frequency physiology into early warning



From the cardiac OR to the casualty bay

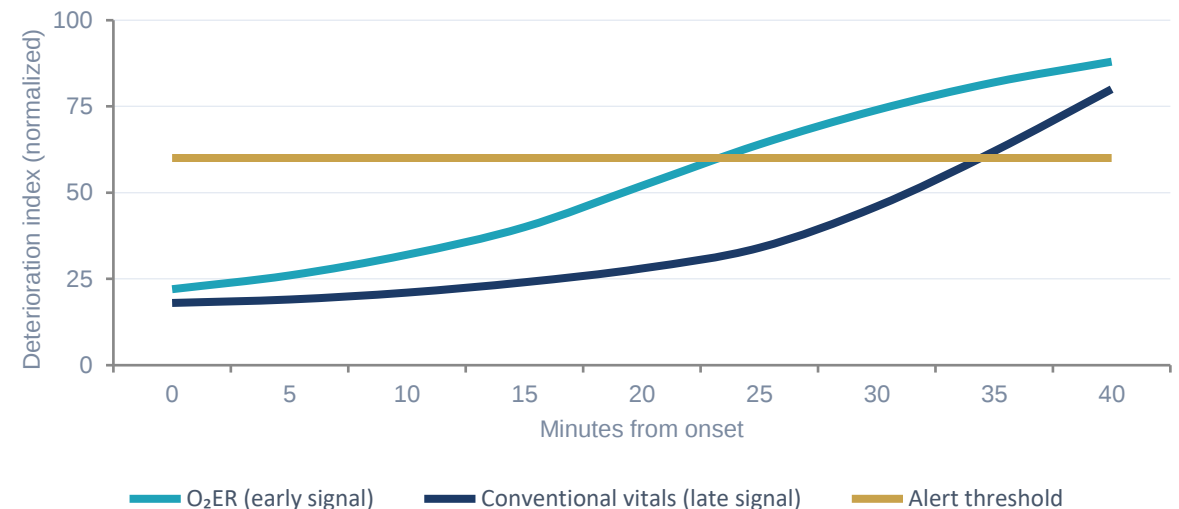
In our published cardiac-surgical work, the oxygen extraction ratio (O₂ER) signals supply–demand mismatch earlier and more reliably than oxygen delivery (DO₂i) alone — the basis of goal-directed perfusion.



The same physiology-aware logic

that flags perfusion mismatch in our operating rooms flags casualty deterioration in a simulated forward environment — before conventional vitals react.

Earlier detection: O₂ER vs. conventional vitals



Illustrative of published goal-directed-perfusion findings.

Routine telemetry, modeled, predicts who will need rescue



0.96

C - INDEX

Discrimination of a perfusion-derived index for predicting the need for mechanical circulatory support (ECMO).



Top-cited 2025 analysis

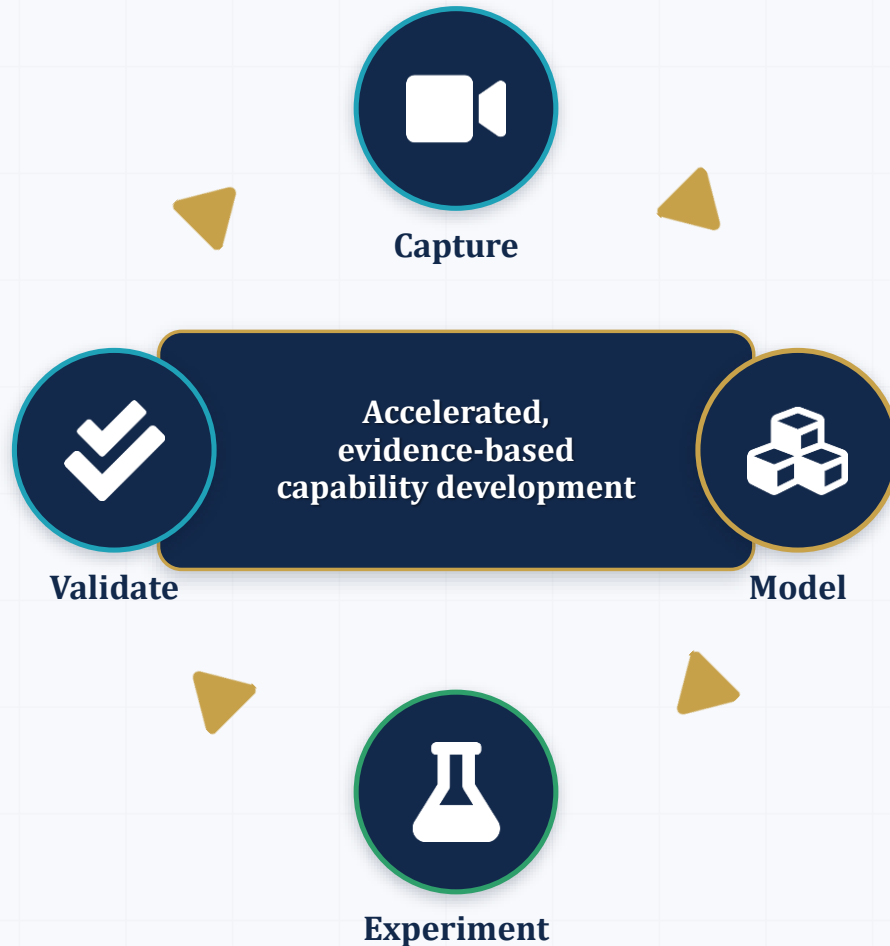
linking perfusion and ischemic-interval data to graft dysfunction — further proof our models work on routinely captured streams.

Model discrimination (illustrative ROC)



Illustrative ROC; published C-index 0.96.

Capture reality. Build the twin. Experiment without risk.



Capture

Record real procedures and exercises across all four streams.



Model

Train and validate a high-fidelity digital twin of physiology and circulatory support on captured data.



Experiment

Run synthetic scenarios, new devices, and workflows against the twin — at scale, with zero patient risk.



Validate

Test predictions back against recorded reality, then feed training and doctrine.



NSF — CPB DIGITAL TWIN (SUBMITTED)



SECTION 04

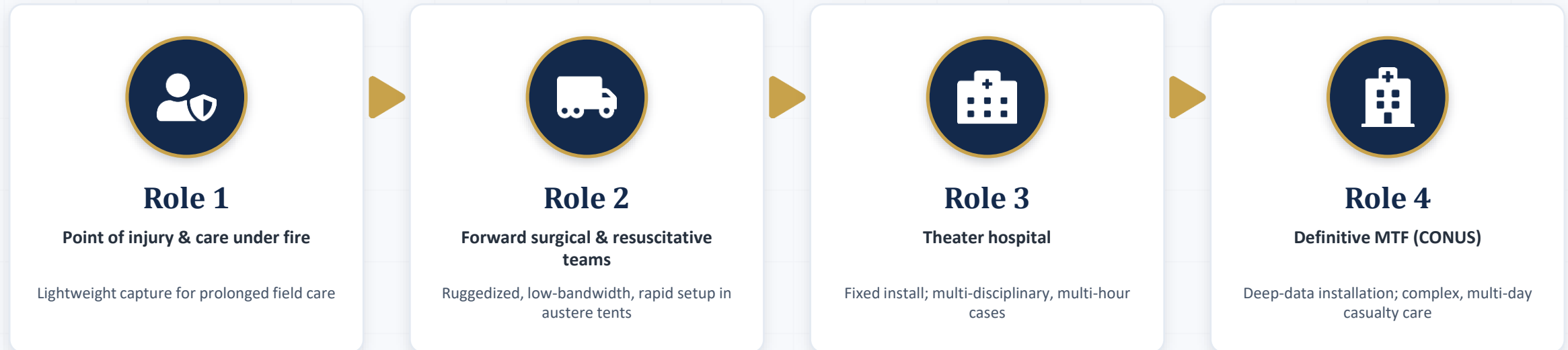
The Mission Fit

Built for the Joint Force — across every echelon of care, with momentum behind it





From the point of injury to the medical center — one standard



*Transfer learning carries models from high-fidelity labs into noisy, low-light, austere settings — **the same objective metrics, everywhere.***



Better debriefs. Better teams. Better doctrine.



Tactical

THE UNIT

Objective debrief replaces memory · faster team cohesion · hidden bottlenecks exposed



Operational

THE FORCE

Standardized readiness benchmarking across units and Roles of Care



Strategic

THE ENTERPRISE

Aggregated data informs training, fielding, and Joint Force medical doctrine

Every exercise becomes a data-generation event — compounding into the empirical backbone for force-wide readiness.

WHY THIS TEAM, WHY NOW

A rare convergence — and real momentum behind it



CONVERGENCE



Cardiac surgery & critical care

Brian Lima, MD, MBA



Machine learning

Soheil Kolouri, PhD



Bioengineering & circulatory support

Rei Ukita, PhD · Matthew Bacchetta, MD



Institutional cardiac-surgery leadership

Ashish Shah, MD

Surgeon-led · engineering-built · institutionally backed.

MOMENTUM



NSF — CPB Digital Twin

Physics-informed twin of cardiopulmonary bypass

SUBMITTED



Google.org — AI for Science

Applied-AI program; VUMC-led work package

SUBMITTED



NIH — R61 / R33

Phased translational development

IN RESUBMISSION



Translational catalyst support

Institutional acceleration funding

ACTIVE

Active, funded research lines — not a slide-ware proposal.

A staged, low-risk path to fielded capability



✓ STATUS: ACTIVE DEVELOPMENT



Phase 1 — Now Foundations specified

- Data streams, sync requirements & event taxonomy defined
- Prototype capture workflows demonstrated
- OR deployment live at VUMC



Phase 2 High-acuity validation

- High-fidelity polytrauma simulation testing
- Data completeness & synchronization fidelity
- After-action report usability with instructors



Phase 3 Military integration

- Staged deployment in DoD simulation & training
- Multi-Role evaluation (forward → fixed)
- Ruggedized, low-bandwidth configurations



Phase 4 Scale & doctrine

- Multi-site readiness registry
- Force-wide benchmarking
- Inputs to training & fielding decisions

Where the Joint Force can plug in



Experimentation partner

Embed the platform in DoD medical experimentation and high-fidelity training events to generate objective, reusable data.



Capability co-development

Co-design Role-specific configurations and the military event taxonomy with operational end-users.



Data & doctrine

Stand up a shared, secure readiness registry that informs training, fielding, and Joint Force doctrine.



Directly aligned with Joint Force priorities for experimentation-driven, data-informed medical readiness.



Three things to carry out of this room

1



Synchronized capture beats subjective observation

Physiology, device & perfusion telemetry, and audiovisual streams on one millisecond-accurate clock.

2



Structured tagging + analytics expose what humans miss

Deviations, deterioration-to-action delays, and broken communication loops — surfaced automatically.

3



A multimodal backbone informs doctrine, training & fielding

A reusable, scalable data infrastructure spanning every Role of Care.

EVERY SIGNAL. ONE TIMELINE.

Capture. Synchronize. Understand.
Improve Outcomes.

MULTIMODAL INPUTS

- VIDEO**
4K Surgical & Room Cameras
- AUDIO**
Team Comms & Room Audio
- VITALS**
Patient & Device Vital Signs
- DEVICE TELEMTRY**
Medical Devices & Equipment



SYNCHRONIZED TIMELINE



ANNOTATIONS & EVENTS

- 00:12:37 Incision
- 00:14:21 Chest Tube Insertion
- 00:16:45 Resuscitation Event
- 00:18:26 Procedure Complete

TIME-SYNCHRONIZED RECORD

All data streams aligned to a single timeline



AFTER-ACTION REVIEW TURN DATA INTO INSIGHT

- Synchronized Playback**
Review every angle in perfect sync
- Timeline & Event Markers**
Jump to key moments instantly
- Performance Analytics**
Objective insights to drive improvement
- Export & Share**
Secure sharing for training, research, and reporting



SECURE STORAGE & SHARING

- Encrypted
- Access Controlled
- Audit Logged



ADVANCING READINESS. IMPROVING OUTCOMES.

Better data. Better decisions. Better care.



Support MME

Standardized data for experimentation



Improve Training

Real-world cases power realistic learning



Enhance Readiness

Continuous feedback loop to optimize performance

JOINT FORCE INNOVATION

Turn the chaos of training into the data that wins the next fight.

The Multimodal Surgical Environment Recording Platform — a synchronized backbone and clinical-intelligence layer for military medical readiness.



Capture



Interpret



Scale



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Questions & discussion welcome

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