Design of an Integrated Biomonitoring System for IVA/EVA Suits Using the Patient Assessment System (PAS)

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Abstract

Advancing human spaceflight requires autonomous health monitoring when real-time Earth support is delayed. This project designed an integrated biomonitoring platform for IVA/EVA suits using the Patient Assessment System (PAS). The wearable architecture combines PPG heart rate/SpO2 sensing, infrared temperature measurement, thoracic impedance respiration sensing, IMU-based motion context, local storage, BLE communication, and embedded alert logic. Controlled tests and simulation showed acceptable measurement accuracy, real-time response, and about 40% signal-quality improvement after motion compensation. The system provides a scalable proof of concept for Earth-independent physiological assessment.

Problem

- IVA/EVA crewmembers may face hypoxia, thermal imbalance, cardiovascular strain, fatigue, and motion-related sensor artifacts.
- Existing wearable systems can acquire and transmit physiological data, but high-risk EVA operations require local interpretation and alerts when communication with Earth is delayed.
- Objective: design a suit-compatible, MCU-centered platform that monitors heart rate, SpO2, respiratory rate, and temperature, then translates values and trends into PAS-inspired alert states.

Methodology

The project followed a four-step engineering design process:

1. **Requirements Definition**
Selected key physiological parameters: heart rate, SpO_2, respiratory rate, temperature, and motion.
2. **Sensor Selection**
Identified wearable sensing methods, including PPG, infrared temperature sensing, impedance respiration, and IMU-based motion tracking.
3. **Embedded Processing**
Used a central MCU concept for data acquisition, signal processing, local storage, BLE communication, and PAS-based alert logic.
4. **Validation**
Evaluated system behavior using controlled test conditions and simulation scenarios, including rest, walking, post-exercise, and abnormal physiological alerts.

System Design

System Design describes the engineering methodology for transforming physiological monitoring objectives into a wearable hardware system.

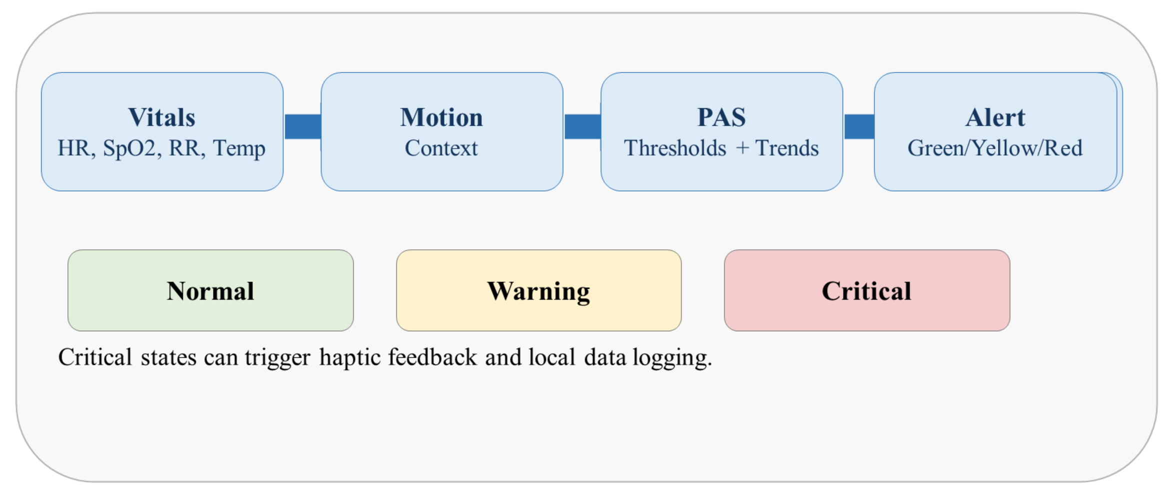

Figure 1: Health Logic

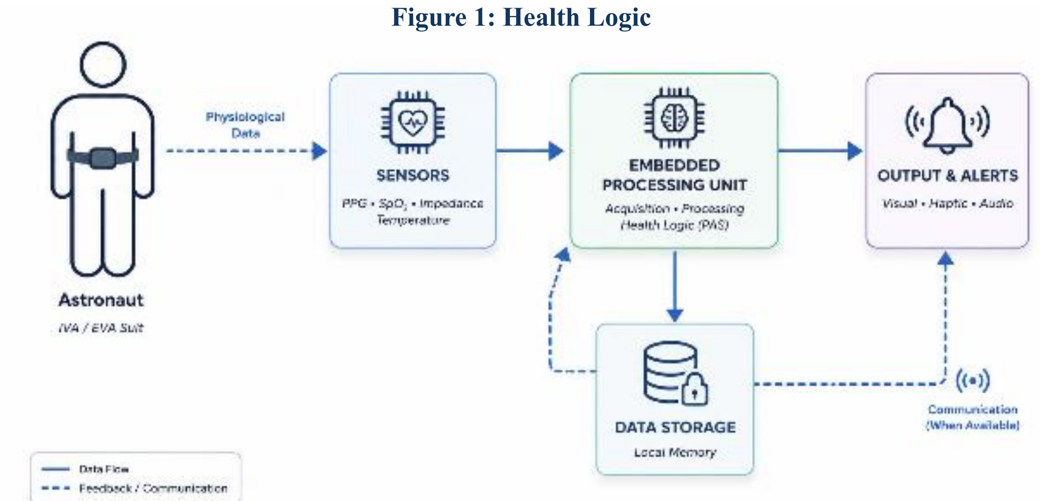

Figure 2: MCU-centered biomonitoring architecture.

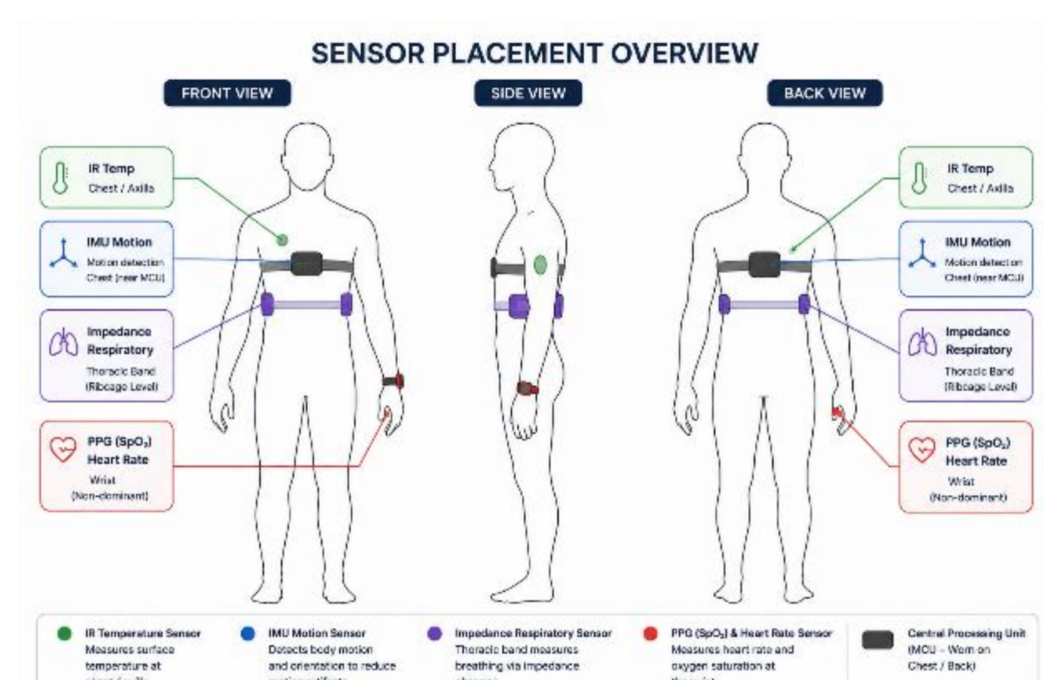

Figure 3: Sensor placement concept for suit integration.

Results and Discussion

- All selected sensors met the prototype target ranges under simulated and controlled test conditions.
- Temperature and respiration errors were +0.1 C and +1 breath/min, respectively; heart rate and SpO2 showed larger deviations during motion or low perfusion.

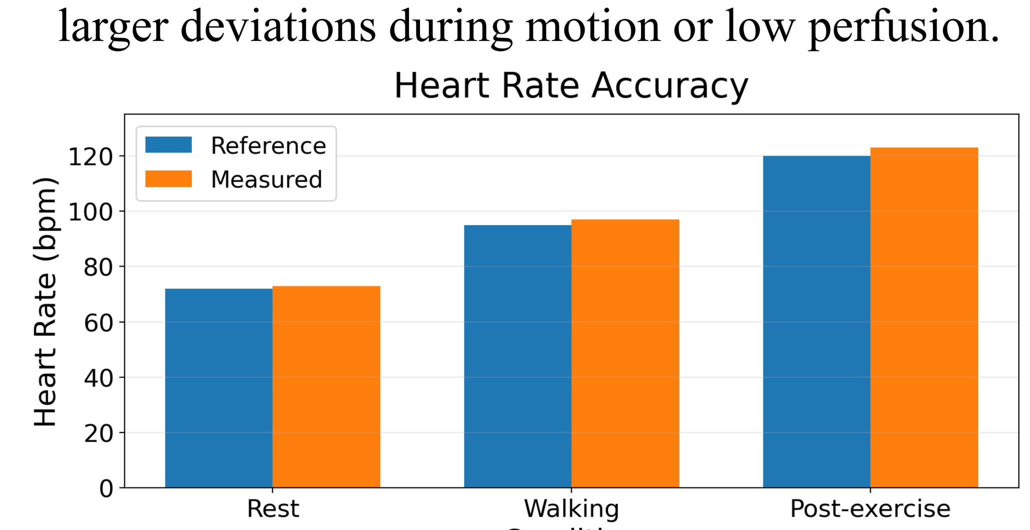

Figure 4: Heart Rate Accuracy

Results and Discussion (Cont.)

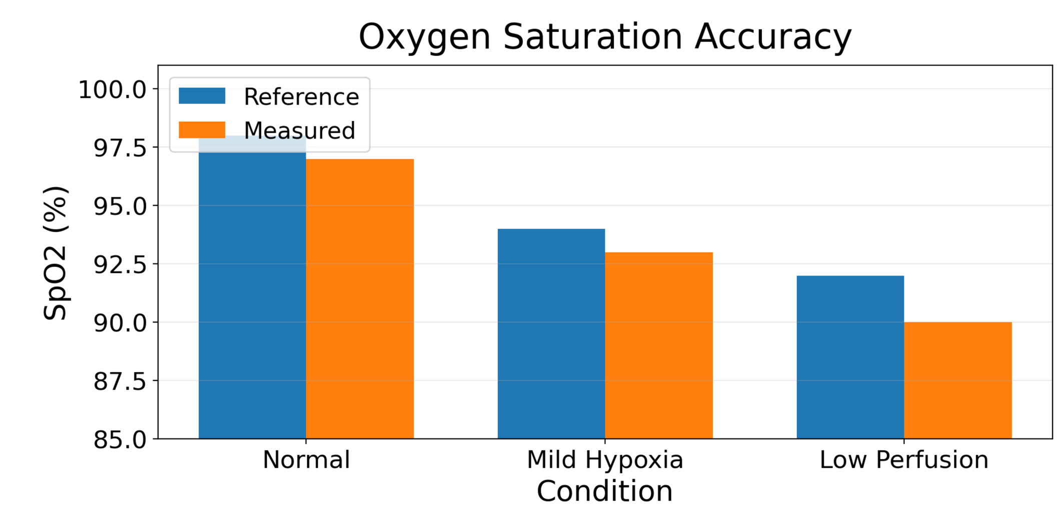

Figure 5: SpO2 Accuracy

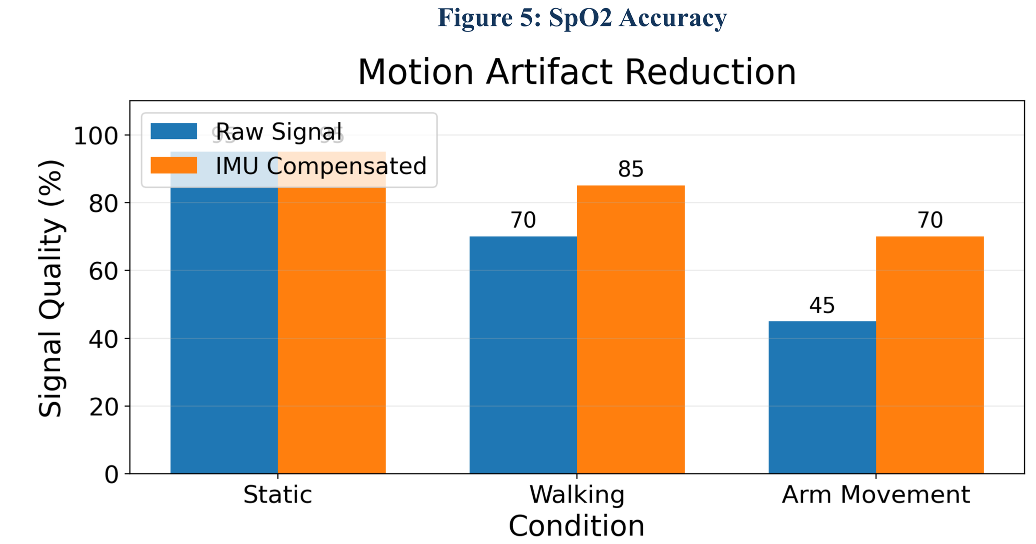

Figure 6: Motion Artifact Reduction

Simulation Validation

- The Google Apps Script interface generated real-time physiological and system data, including HR, SpO_2, respiration, temperature, battery level, and stress index.
- Simulated abnormal conditions successfully activated the expected PAS-inspired warning/critical alert states and updated the display in real time.

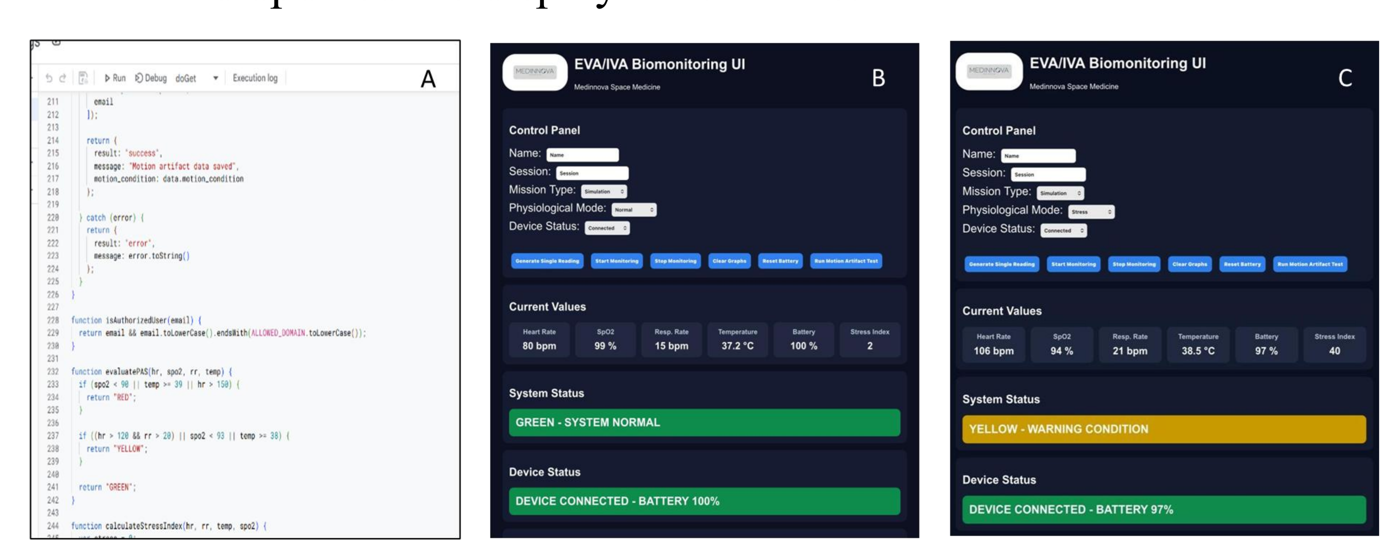

Figure 7: Simulation Alert: A-Scrip, B – Normal, Alert C – Stress Alert

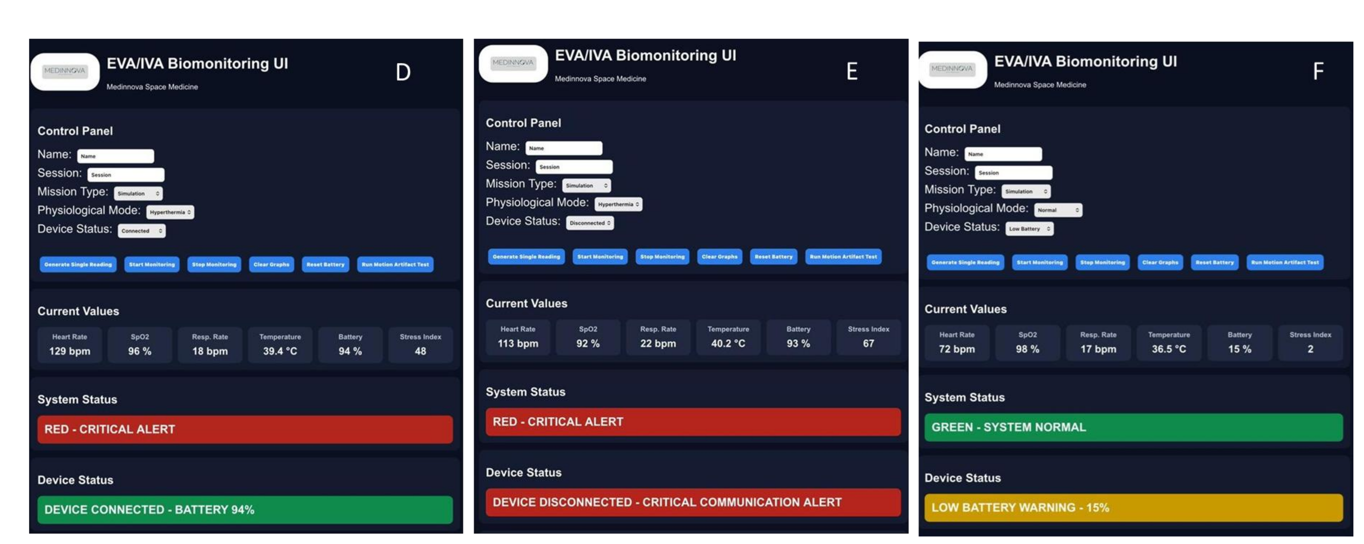

Figure 8: Simulation Alert: D-Hypoxia/Hyperthermia , E – Device Disconnect, Alert F – Low Battery

Simulation Validation (Cont.)

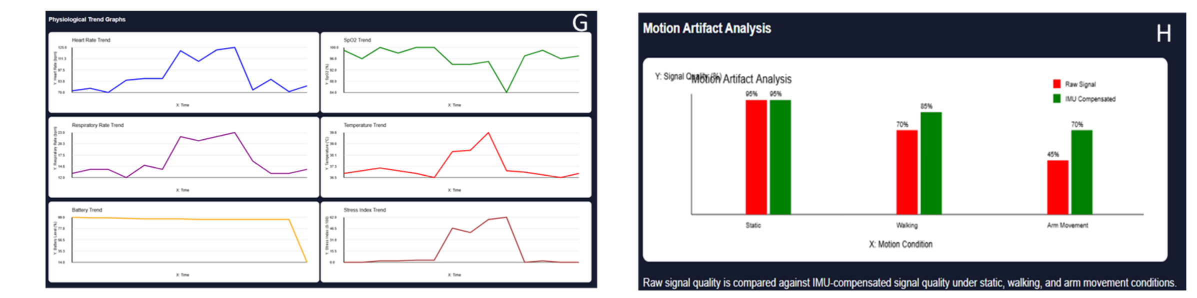

Figure 9: Simulation: G- Simulation Graphics (B,C,D,E,F), H – Motion Artifact Analysis

Conclusions

- The integrated MCU-based platform measured heart rate, SpO2, respiration, and temperature in a self-contained wearable architecture.
- Embedded processing enabled local acquisition, storage, wireless visualization, and PAS-inspired alert generation.
- Experimental and simulation results demonstrated acceptable accuracy and real-time response under simulated IVA/EVA conditions.
- The proof of concept supports autonomous physiological awareness, but it is not a substitute for clinical diagnosis or flight-surgeon evaluation.

Future Work

- Improve sensor packaging for wearable use.
- Test the prototype under more realistic analog IVA/EVA conditions.
- Improve adaptive filtering and motion artifact reduction.
- Add patient-specific thresholds and additional physiological parameters.
- Perform longer battery endurance and reliability testing.

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