Textile-based Wearable Contact Sensing for Functional Fit Assessment of Body-Wearable System Interactions

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INTRODUCTION

Spacesuits must provide sufficient fit and mobility for crew to successfully perform extravehicular activities (EVAs), particularly for future planetary EVAs [1]. The quality of suit fit is influenced by complex interactions between the suit's geometry, mechanisms, and materials and the wearer's body geometry. **Contact between the suit and the wearer's body is a key metric that can be used to understand body-spacesuit interactions.** A wearable contact sensing technology can be used to measure how contact patterns vary across wearers of different body shapes and sizes performing functional EVA postures.

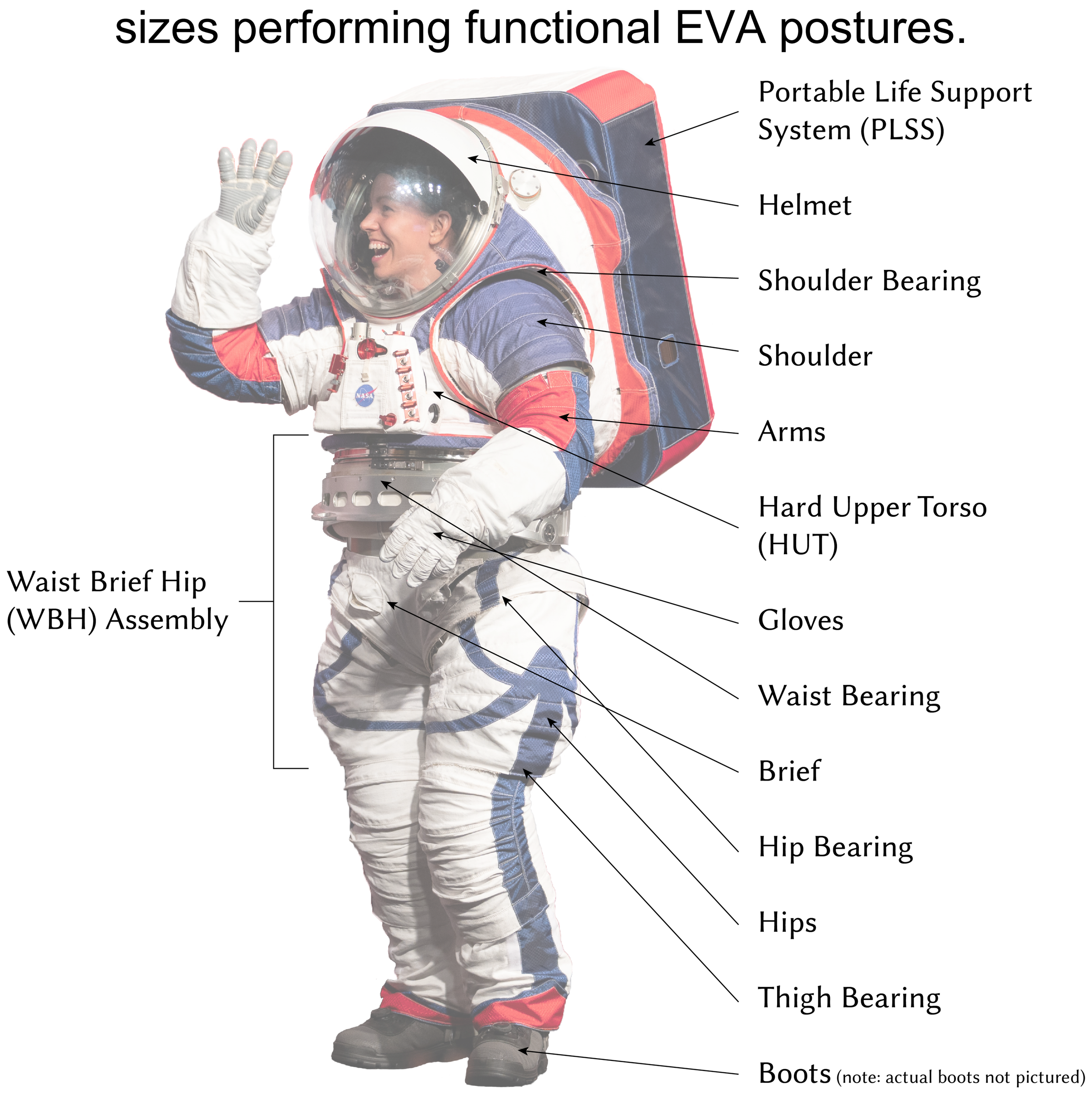

Figure 1. Exploration Extravehicular Mobility Unit (xEMU) Space Suit components.

OBJECTIVES

- **Develop and validate a conformable, textile-based, wearable contact sensing system that can be easily implemented into an existing inner-layer garment.**
- Sensors use a binary approach to **detect contact between two surfaces** when the electrical circuit path is completed.
- Provides quantitative measurements of fit in a spacesuit with minimal intrusiveness.
- This study focuses on the **lower torso assembly (LTA) brief** and its contact with the buttock and pelvis regions of the body, which have been extremely difficult to measure with traditional techniques.

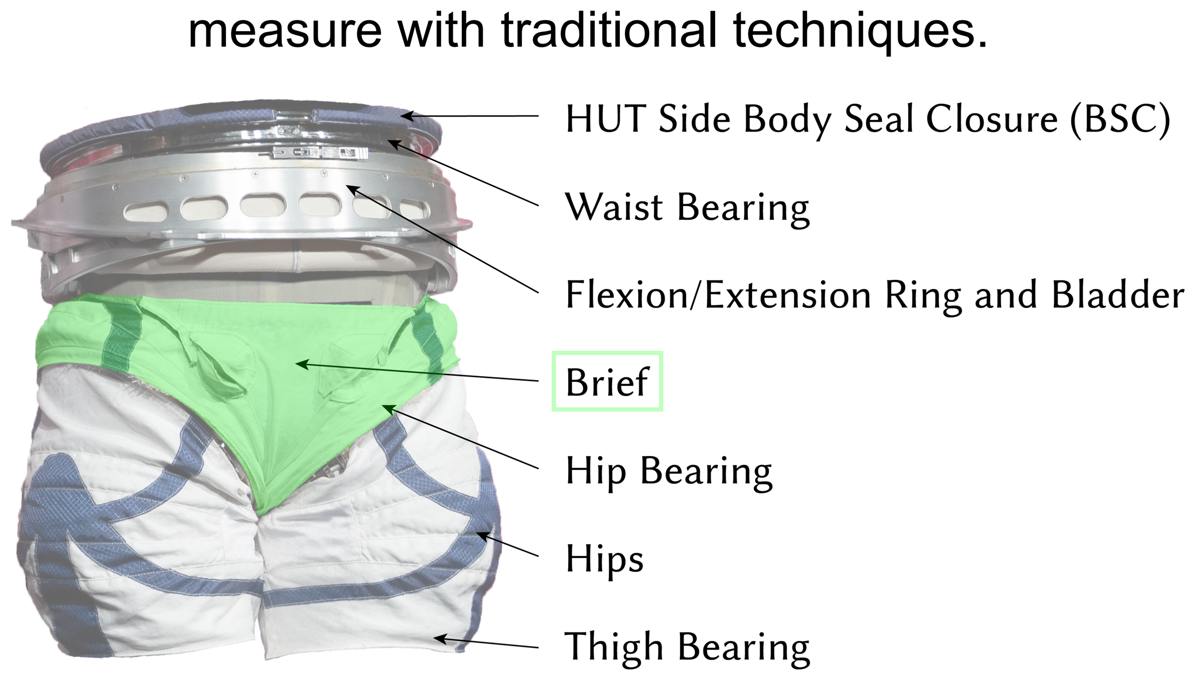

Figure 2. Waist-Brief Hip (WBH) Assembly of xEMU space suit with highlighted brief suit component.

METHODS

1) Sensor Fabrication & Testing/Calibration

- Sensor materials and fabrication methods are explored for the sensors.
- The accuracy and sensitivity of the individual sensors are assessed by applying controlled dynamic force to the sensor.
- A LTA brief space suit mockup is developed and 3D printed for the body (mannequin and human)-suit testing.

2) Mannequin Testing & Sensor Validation

- The sensing system is evaluated using a rigid shell brief (resembling the NASA xEMU suit).
- With a humanoid mannequin performing a cyclic sequence of gait postures to assess the repeatability of contact measurements across the simulated ambulation cycles.

3) Human Shape Assessment Testing

- Human-in-the-loop (HITL) testing with different body shapes is performed to evaluate variations in contact patterns during functional lower-body movements/tasks.

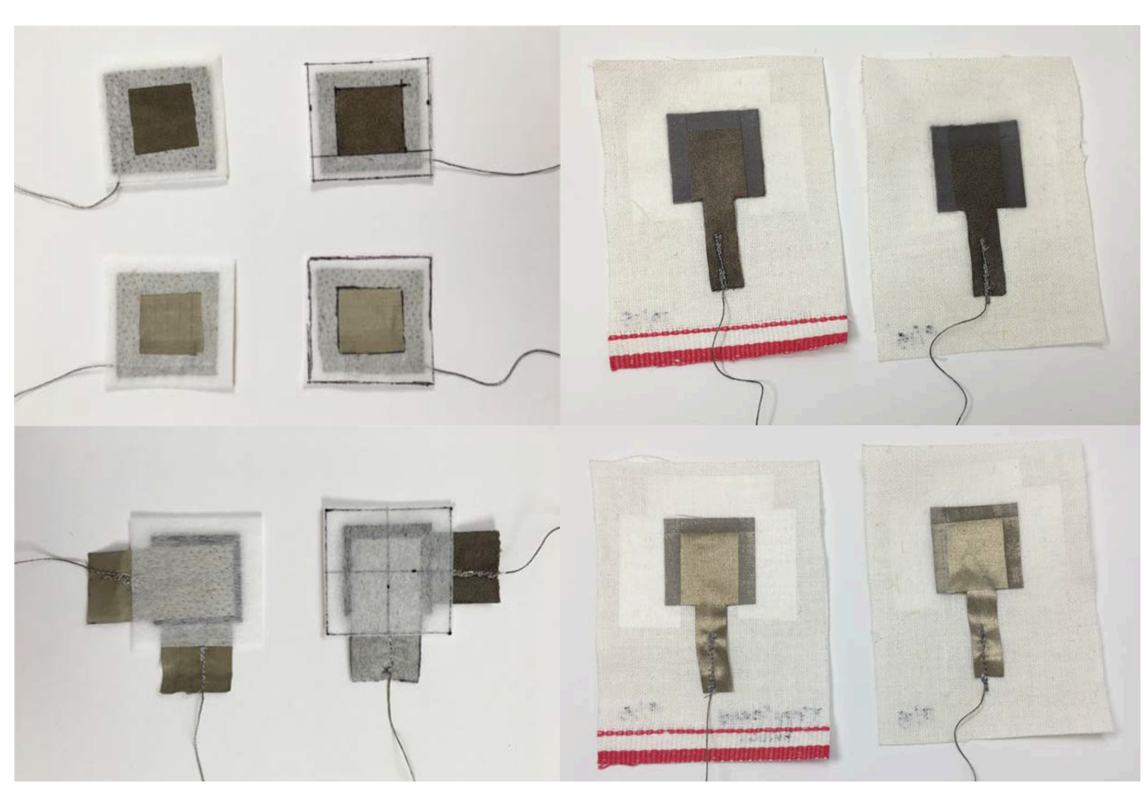

Figure 3.Testing different materials and fabrication methods for textile-based sensors.

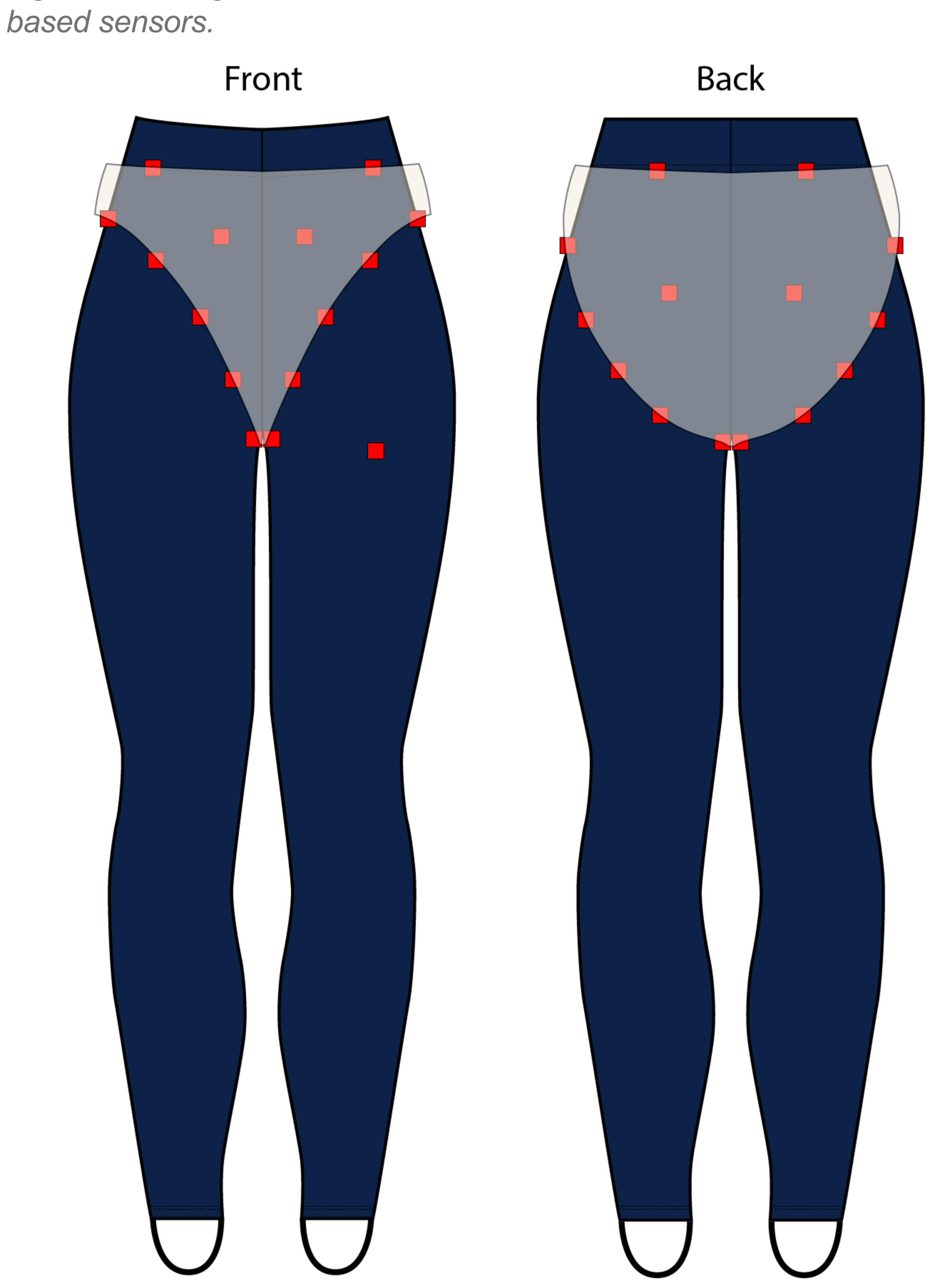

Figure 4. Lower-body contact and force sensing garment with sensor locations and brief overlay.

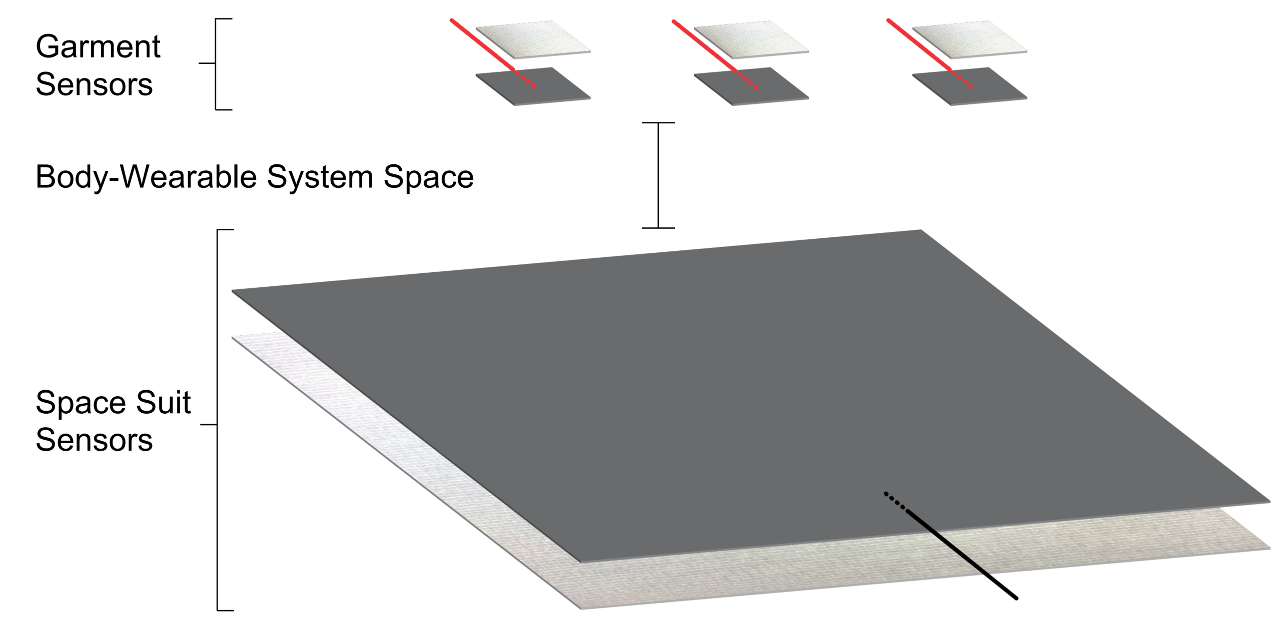

Figure 5. Contact sensing system approach (expanded layer view).

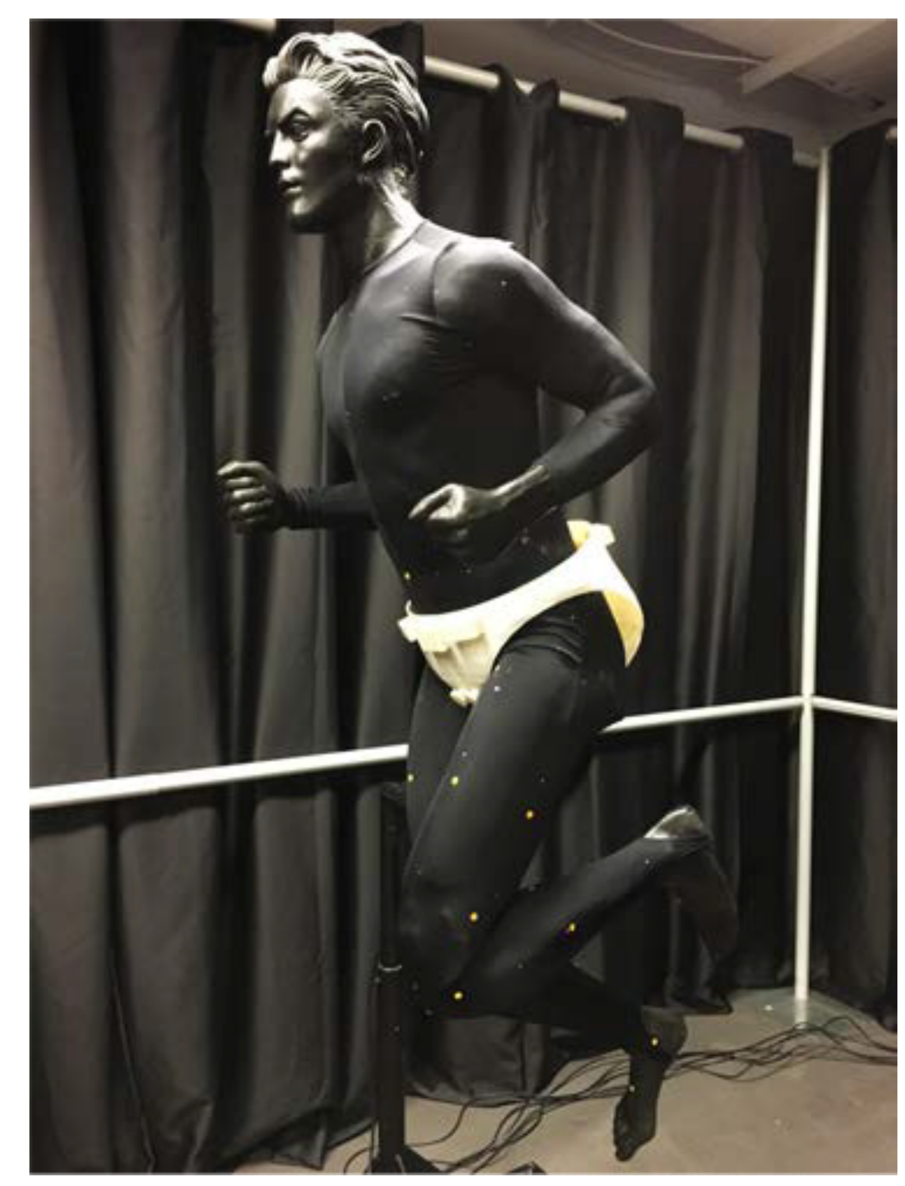

Figure 6. Animatronic running mannequin with 3D printed brief space suit component.

Figure 7. Landmarking mannequin for dynamic 3D modeling.

OUTCOMES

The functional fit assessment method developed here is expected to:

- Provide useful information to improve suit design.
- Define quantitative metrics for suit sizing and fit.
- Enable a more detailed understanding of suit-to-body interactions during dynamic and functional EVA movements.

REFERENCES

[1] K. Davis, R. Rhodes, H. Kim, E. Benson, Y. Hernandez, L. Vu, and S. Rajulu, "xEMU Lower Torso Assembly (LTA) Brief Fleet Sizing Study," in *International Conference on Environmental Systems (ICES)*, 2020.

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