



## **NASA SBIR 2017 Phase I Solicitation**

### **H4.03 Sensors to Measure Space Suit Interactions with the Human Body**

**Lead Center:** JSC

**Participating Center(s):** JSC

**Technology Area:** TA6 Human Health, Life Support and Habitation Systems

Space suits can be tested unmanned for range of motion and joint torque in an attempt to quantify and compare space suit joint designs and overall suit architecture. However, this data is irrelevant if humans using the suits aren't effective. Characterizing human suited performance has continued to be a challenge, partly due to limitations in sensor technology. One concept is to use sensors placed at/on the human body, underneath the pressure garment to obtain knowledge of the human bodies movements. This data could then be compared against the suit motion. Various sensors, sensor technologies, and sensor implementations have been attempted over two decades of efforts, but each has had issues. Previous efforts have used Force Sensitive Resistors (FSR), TouchSense shear sensors, pressure-sensing arrays (Tek scan etc.), piezo-electric sensors, among others but have not met all requirements. Most issues have centered around accuracy when placed on the pliant surface of the skin, and accuracy when placed over curved surfaces of the skin. Accuracy has been sufficient to delineate low, medium or high levels of force but not a reliable quantitative value. This, combined with aberrant readings when the sensor is bent has led to these sensors only providing a rough idea of the interaction between the suit and the skin: while in a controlled environment the sensors are accurate to within 10% or so, the accuracy falls significantly when measuring the skin and being bent or pressed in inconsistent ways; on the order of 50% accuracy or worse. The sensors also are prone to drift (falling out of calibration) quickly during use. Lastly, the sensors, while pliant, are still relatively thick and as such translates to discomfort and loss of tactility. This is typical during all previous testing but most notable when sensors are bent along an axis (or worse, along two axis such as required to follow a complex anatomical contour). As such, the effect on the suit/skin interface that is being measured is changed, which adds an additional complication to interpreting data output from these sensors. Much of the work within JSC has improved the integration, comfort, and calibration of these sensors, but the accuracy performance characteristics when in use have not been sufficient to meet requirements. A new sensor technology is warranted for use in our application.

Current critical needs that this technology would enable include the ability to optimize suit design for ergonomics, comfort and fit without the sole reliance on subjective feedback. While subjective feedback is important, developing a method to quantify the amount of force or pressure on a particular anatomical or suit landmark will aid in providing a richer definition of the suit/human interface that can be leveraged to make space suits more comfortable while reducing risk of injury. Taken together, these improvements will enhance EVA performance, reduce overhead and reduce personnel and programmatic risk. This technology implementation would require relatively accurate pressure or force readings in the medium to high range.

In the future, alternative space suit architectures such as mechanical counter pressure may be feasible, and a critical ancillary to such an architecture is to verify that necessary physiological pressure requirements are being met to ensure the health and safety of the crew. To this end, the technology should be able to accurately measure mechanical pressure on the human skin in the low pressure (< 10 psi) range.

---

Performance targets vary upon application, but the sensing technology should have the following characteristics:

- Measures force and/or mechanical pressure.
- Accurate to within 10%.
- Resistant to aberrant readings when under moderate bending, shear or torsion.
- Either sufficiently pliant, or high enough spatial resolution, to follow anatomical curves on the human skin without discomfort or lack of mobility.
- Thin profile (~mm).
- Packaged at high spatial resolution (~cm) or sufficiently small to facilitate a custom packaging/substrate solution with a high spatial resolution.
- Free of rigid or sharp points that would cause discomfort.
- Low power (~5V, ~mA).
- Capable of integration to the inside of the pressurized suit surface as well as the human skin (or integrated to conformal garment).
- At this early stage, a simple digital readout capability to evaluate sensor performance.

For this SBIR opportunity specifically, we are looking for a single sensor technology that targets the above requirements including readout capability. They should either be packaged into a component level prototype (shoulder or arm segment with multiple sensors) or a flexible packaging option (multiple sensors that could be integrated ad-hoc into a component level prototype through placement of said sensors on the skin or comfort garment).

The most attention should be paid to maximizing spatial resolution, accuracy and thinness for this prototype. Lastly, as previous work has demonstrated a relatively high failure rate of these sensor types over time, the individual sensor elements should be replaceable and/or spares should be provided.