Final Abstract
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Both training for and performing Extravehicular Activities (EVAs) are extremely strenuous for the astronaut. When a suit is pressurized, it becomes difficult for the astronaut to move, making even the simplest tasks very difficult to perform. In addition to researching ways to increase mobility in the suit and reducing the induced torque, some of the major goals in spacesuit design and experimentation include quantifying the resistance to movement, researching new ways to quantify resistance and other measurements of interest, as well as conducting injury analysis. Understanding the specifics of where and how spacesuits can be improved is critical for future generations of spacesuits, allowing for astronauts to work more efficiently and with minimal discomfort. The *EVA Glove Sensor Feasibility II* project focuses on these topics.

The main objectives for the glove project include taking various measurements from human subjects during and after they perform different tasks in the glove box, acquiring data from these tests and determining the accuracy of these results, interpreting and analyzing this data, and using the data to better understand how hand injuries are caused during EVAs.[1] Some of these measurements include force readings, temperature readings, and micro-circulatory blood flow.[1]

The three glove conditions tested were ungloved (a comfort glove was worn to house the sensors), Series 4000, and Phase VI. The general approach/procedure for the glove sensor feasibility project is as follows:

1. Prepare test subject for testing. This includes attaching numerous sensors (approximately 50) to the test subject, wiring, and weaving the sensors and wires in the glove which helps to keep everything together. This also includes recording baseline moisture data using the Vapometer and MoistSense.
2. Pressurizing the glove box. Once the glove box is pressurized to the desired pressure (4.3 psid), testing can begin.
3. Testing. The test subject will perform a series of tests, some of which include pinching a load cell, making a fist, pushing down on a force plate, and picking up metal pegs, rotating them 90 degrees, and placing them back in the peg board.
4. Post glove box testing data collection. After the data is collected from inside the glove box, the Vapometer and MoistSense device will be used to collect moisture data from the subject's hand.
5. Survey. At the conclusion of testing, he/she will complete a survey that asks questions pertaining to comfort/discomfort levels of the glove, glove sizing, as well as offering any additional feedback.

There was a significant amount of data collected for the glove sensor project. A few of the results/findings for both the quantitative and qualitative data are discussed below:

Quantitative Data:

[1] EVA Glove Sensor Feasibility II Test Plan

Laser Doppler Perfusion Monitor (LDPM): In general, as force increased (pinch load, hand grip force), so did the perfusion level. Perfusion was found to be the greatest in ungloved, with perfusion in the other two glove conditions (Series 4000 and Phase VI) to be lower. This is believed to be due to the fact that with the addition of an EVA glove, the fingers become restricted because of the extra bulk with the glove and from the pressurized environment, allowing less blood flow in the fingers, thus resulting in lower perfusion levels. This trend was seen in both subjects.

Strain Gauge Sensors: Some of the tasks in which strain gauges were analyzed included repetitive gripping, button press pad, button press tip, and static hand postures. The results between subjects varied more than expected. The conclusion as of now as to why there is a difference in the results is due to how the subjects performed the task. For example, when the subjects performed the repetitive grip task, the way the subject positioned his/her hand for this task could affect the data, resulting in one subject's data to show compression (negative value) while the other shows tension (positive value). The strain gauge sensor results are still under analysis, however, mainly compression is seen for the pinch tasks. This is thought to be due to the fact that when the subject pinches the load cell, the skin around the nail compresses the nail. This was seen in both subjects.

Force Sensitive Resistors (FSRs): Overall for both subjects, the FSRs did not capture data as well as expected. In cases where the sum of the FSR data should have been showing ten pounds (for example the button press task), the FSR data showed less than a few pounds. The FSRs consistently did not provide expected data; the reason for this is thought to be because of possible misalignment of the sensors.

Piezoresistive Pressure Sensor (Piezos): The Piezos proved to be ineffective. The results from the Piezos showed force readings in the thousands, which was not possible. This was seen for both subjects.

Peg Board Task: The Peg Board task was not analyzed through the usage of sensors, but simply based off of time. For both subjects, the ungloved time was the fastest followed by the Series 4000 glove, with the Phase VI glove time being the slowest.

Qualitative Data:

Finger Circumference: For both subjects, the right hand Series 4000 glove was a nominal fit, as well as being a good fit for Subject 2's left hand. However, the left hand Series 4000 glove was too loose for Subject 1. The right hand Phase VI glove was nominal for Subject 1, but was too tight for Subject 2. The left hand Phase VI glove was too loose for Subject 1's left hand, and again too tight for Subject 2.

Crotch Fit: For both subjects, the crotch fit for both hands was a good overall fit for the Series 4000 glove. The Phase VI glove was also a good fit for Subject 1. For Subject 2, the Phase VI glove was too loose in the crotches for the right hand and was also too loose in the left hand with

no crotch contact for crotches 2-4 (crotches 2-4 correspond to the crotches in between the index and little finger).

Discomfort: In the right hand Series 4000 glove, there was some discomfort observed in both subjects, but nothing too significant (all were categorized as weak, very weak, or none). However, both subjects experienced moderate discomfort in digit 2 (index) and digits 4-5 (ring and little finger) for the left hand Series 4000 glove. For both subjects, there was moderate discomfort observed in digits 2-5 (corresponding to the index through little finger) for the right hand while wearing the Phase VI glove. In addition, Subject 1 experienced moderate discomfort in crotch 3 (crotch in between the middle and ring finger) while wearing the Phase VI glove.

All of the data analysis is not yet complete, but the above information highlights the results/findings of the research so far.

The main conclusions for the glove sensor project thus far are as follows:

1. In general, EVA gloves cause a greater amount of strain on the fingernails than in an ungloved condition, especially when there is a tighter than nominal glove fit. This is potentially why fingernail delamination injuries are observed in EVA training and EVAs.
2. Blood perfusion decreases while wearing an EVA glove due to the constrictive nature of the glove, especially when bending the fingers.
3. A subject cannot produce the same maximum amount of force in an ungloved condition as they can in a gloved condition. As seen in the data from this study, subjects typically could produce an additional 10-20 pounds of force in an ungloved condition than in a gloved condition.
4. For repetitive tasks such as repetitive grip and pinch, the subject's ability to produce a maximum grip or pinch force generally decreases as time progresses. In gloved conditions, this performance degradation is observed more rapidly than in the ungloved condition. This can be attributed to the fact that wearing an EVA glove in a pressurized environment causes the hand to fatigue faster than in an ungloved, non-pressurized environment.

Some recommendations for future work are as follows:

1. Re-align the FSRs or develop a way to hold them in the proper place during testing. With the FSRs, a slight misalignment is significant causing significantly lower force readings, resulting in minimal usable data from these sensors.
2. Remove the piezos from the test. The piezos did not provide any usable data and made the sensor housing more crowded. By removing these, the subject theoretically will be able to move his or her hand more easily, thus providing more accurate results for tactility and mobility tasks.
3. Do a true baseline prior to testing. The ungloved condition used a comfort glove to hold the sensors while the subject performed the task. This comfort gloved was also used in

the Series 4000 and Phase VI glove conditions to hold the sensors in place. For a more accurate comparison, all sensors should be attached directly to the skin and then run through the procedure for testing; these results could then be compared to a comfort glove, Series 4000, and Phase VI condition.