National Aeronautics and Space Administration

An Ergonomic Evaluation of the Extravehicular Mobility Unit (EMU) Spacesuit Hard Upper Torso (HUT) Size Effect on Mobility, Strength, and Metabolic Performance

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Photos Courtesy of NASA

Presentation Overview

- Background
- Project Objectives
- Methodology
- Results
- Discussion
- Future Work

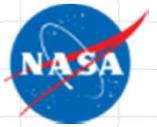
Background

- So imagine having to wear a balloon as a space suit?
  - Positives:
    - Breathing air (Oxygen)
    - Air pressure based mechanical counter-pressure
    - Temperature control
  - Negatives:
    - Reduced hand/limb mobility
    - Reduced hand/limb strength
    - Discomfort
    - Fatigue
    - Increased Risk of Injury
- Now try to work 6-8 hrs. in that suit!!!

Photo Courtesy of Trendhunter.com

Study Objectives

- Utilize ergonomics to develop an initial, yet comprehensive methodology for assessing suit fit in regards to suited human performance
  - Employ varying hard upper torso (HUT) sizes of the EMU spacesuit



Methodology

Methods

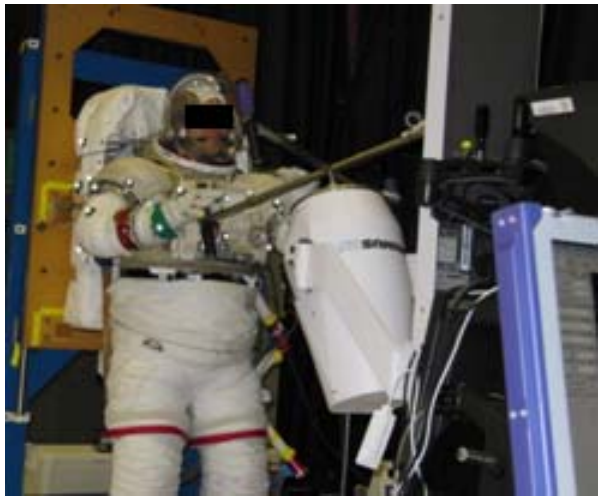
- 8 subjects selected from NASA test subject pool (5 male; 3 female)
- Test conditions included unsuited, nominal HUT, and plus HUT
  - 4 subjects nominally sized for the Medium HUT
  - 4 subjects nominally sized for the Large HUT
- Independent Variables
  - HUT Size
- Dependent Variables
  - Metabolic cost, arm mobility, and arm strength
- Supplemental Variables
  - Suit Fit, Suit-Body Contact/Interaction

Data Collection: Metabolic Cost

- Vertical and Horizontal Translation
  - Cosmed K4b2 system for unsuited (VO_2/VCO_2)
  - Suit inlet flow meter and exhaust umbilical (CD-3A Infrared CO_2 analyzer)

Unsuited Setup

Vertical Translation



Horizontal Translation

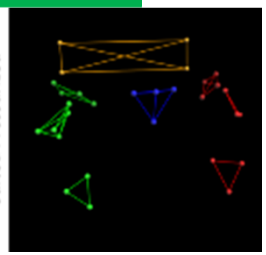
Photos Courtesy of NASA

Data Collection: Arm Mobility & Arm Strength

- Mobility
  - Shoulder:
    - Flexion/Extension
    - Abduction/Adduction
    - Internal/External Transverse
  - Elbow Flexion/Extension

- Strength
  - Shoulder:
    - Flexion/Extension
    - Abduction/Adduction
    - External Transverse
  - Elbow Flexion/Extension

Vicon MX F40 Camera System

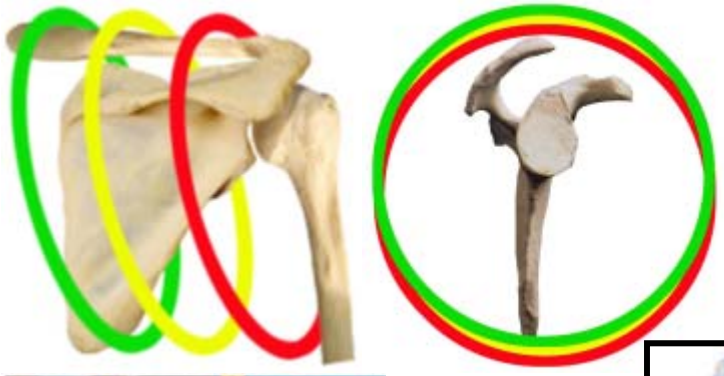


Photos Courtesy of NASA

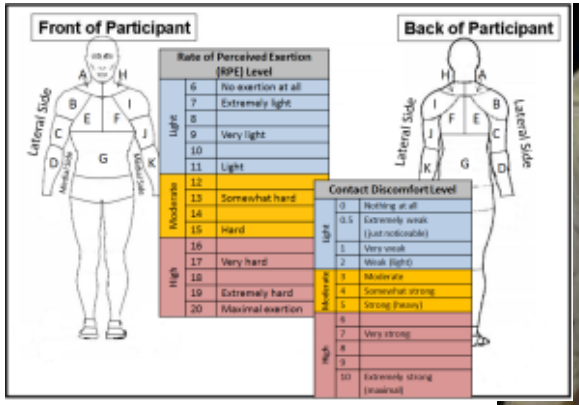
PrimusRS Dynamometer System

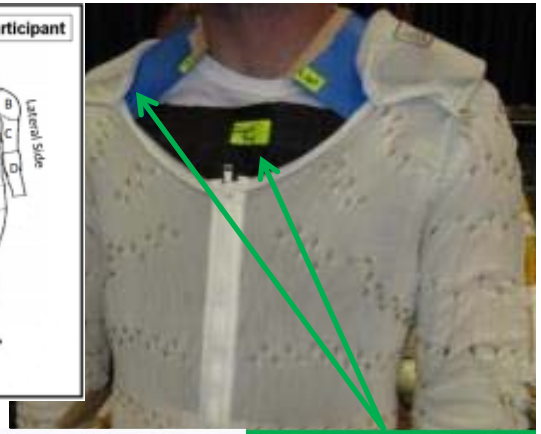
Data Collection: HUT Fit & Suit-Body Interaction

- HUT Fit

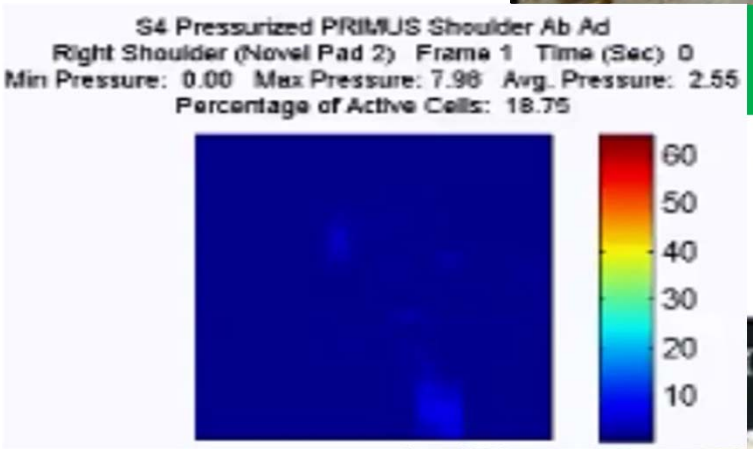


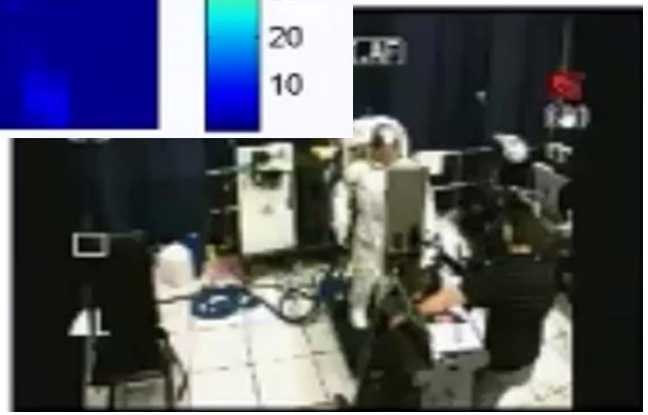
- Suit-Body Interaction





Xsensor & Novel Pressure Pads





Images Courtesy of NASA

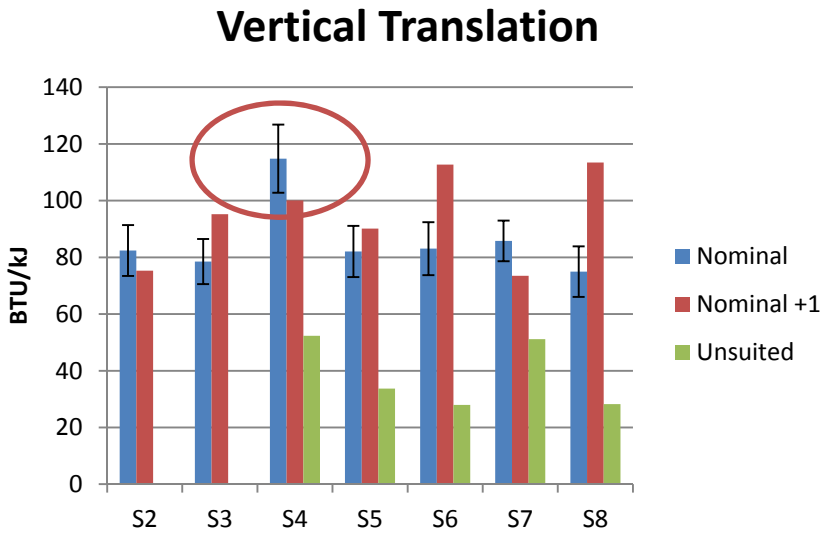
Assumptions, Limitations, and Constraints

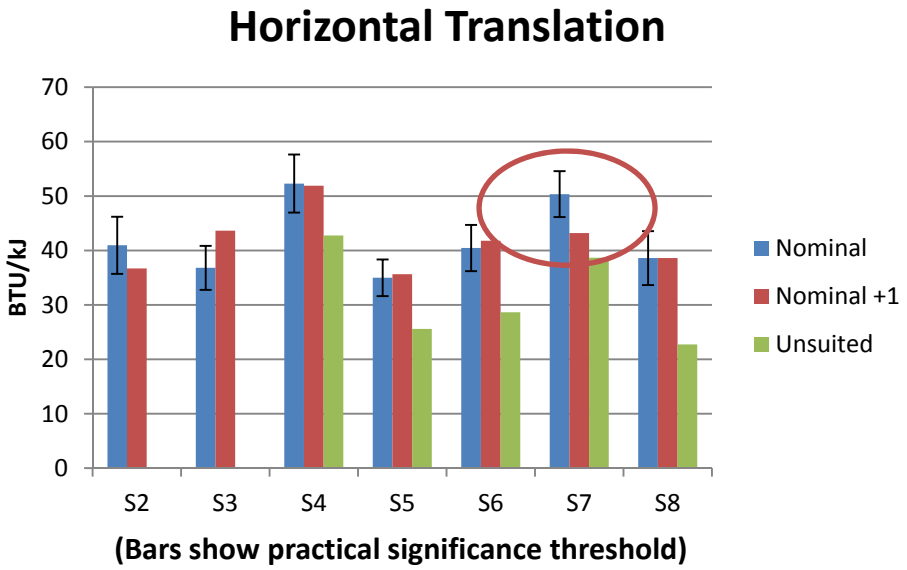
- It was assumed that subjects were assigned to correct HUT and suit sizing components by the suit techs
- Pressure mapping data for the chest/back were removed due to data collection equipment interference
- This study does not account for gravity condition changes that could affect posture
  - Also, this study does not account for being locked into the suit donning stand, which may limit some movement
- Kinematic testing only looked at the extreme isolated motions and not functional tasks/activities

Results

Metabolic Cost for Translation

- Metabolic cost for two translation activities were captured
- Overall, although some subjects saw a practical difference between suit sizes, a **common trend across subjects wasn't found**
- Note: Practical cutoff is based on a ≥ 3.5 mL / min / kg

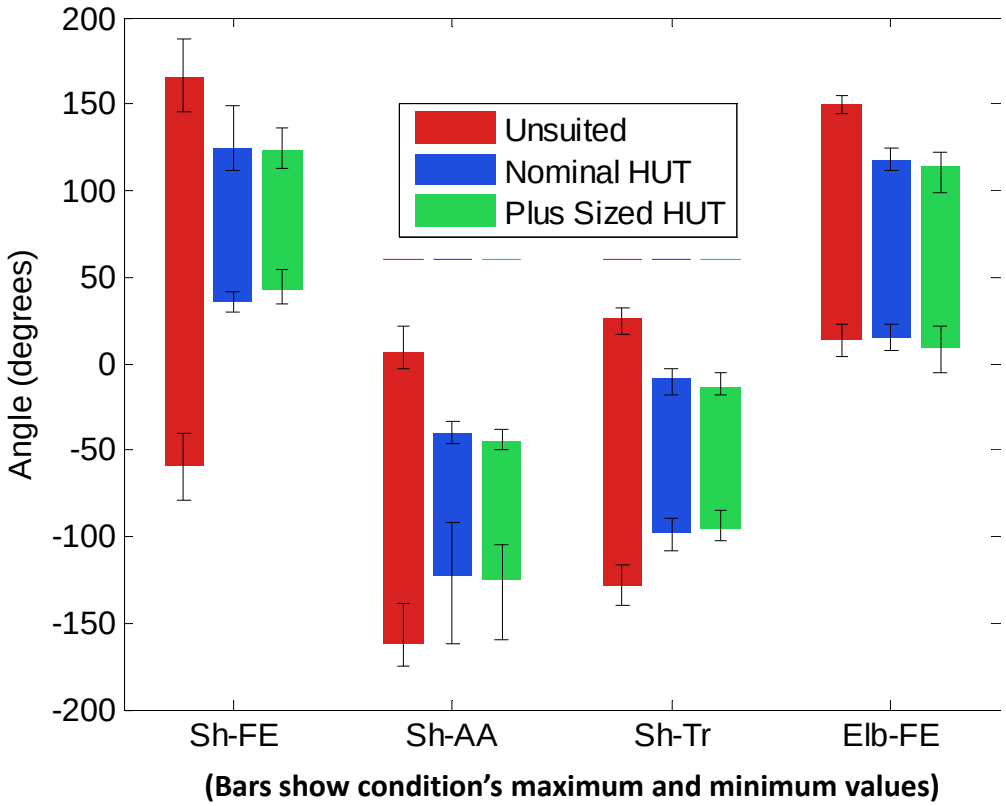




Imgages Courtesy of NASA

Isolated Arm Joint ROM

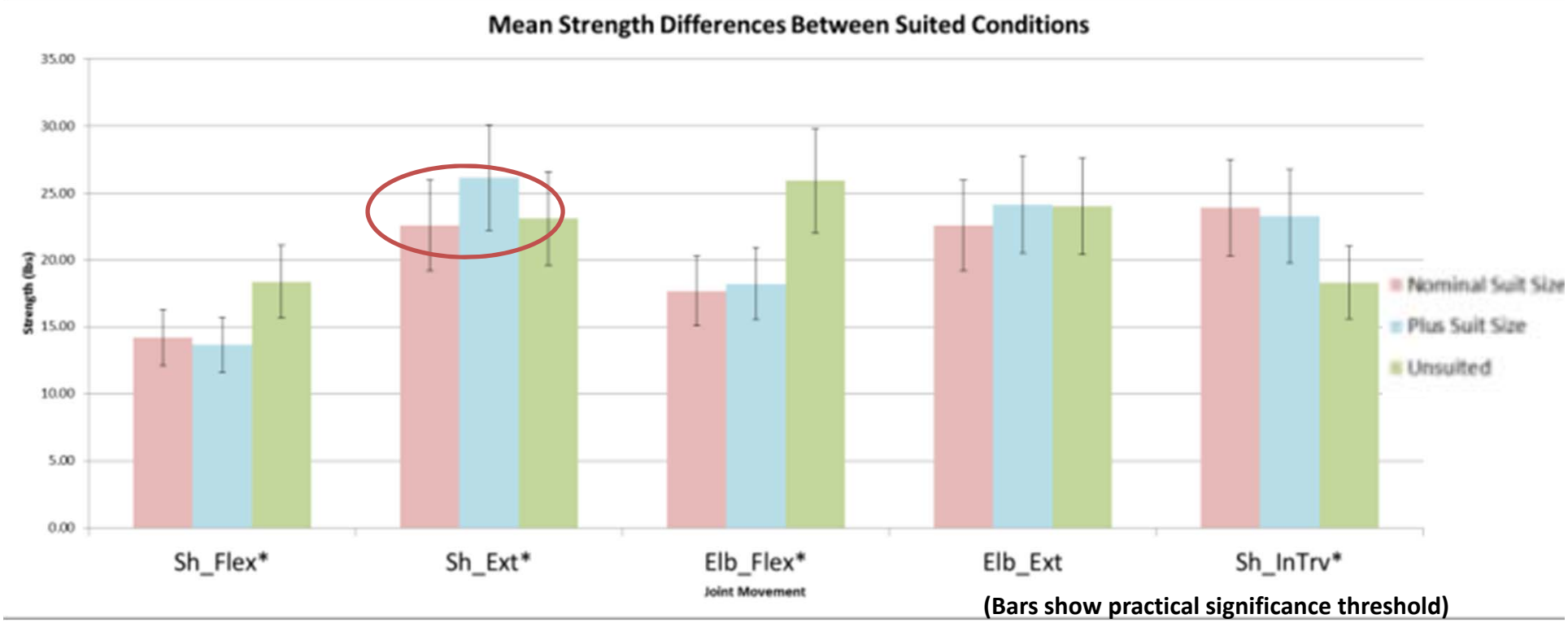
- As seen from previous studies, the isolated ROM of EMU suit wearers is greatly impeded compared to unsuited
- **No practical differences were noted** between the suit sizes
- Note: Practical difference was based on ≥ 10° difference between the max of one condition and the min of another



(Bars show condition's maximum and minimum values)

Imgages Courtesy of NASA

Isolated Arm Joint Strength

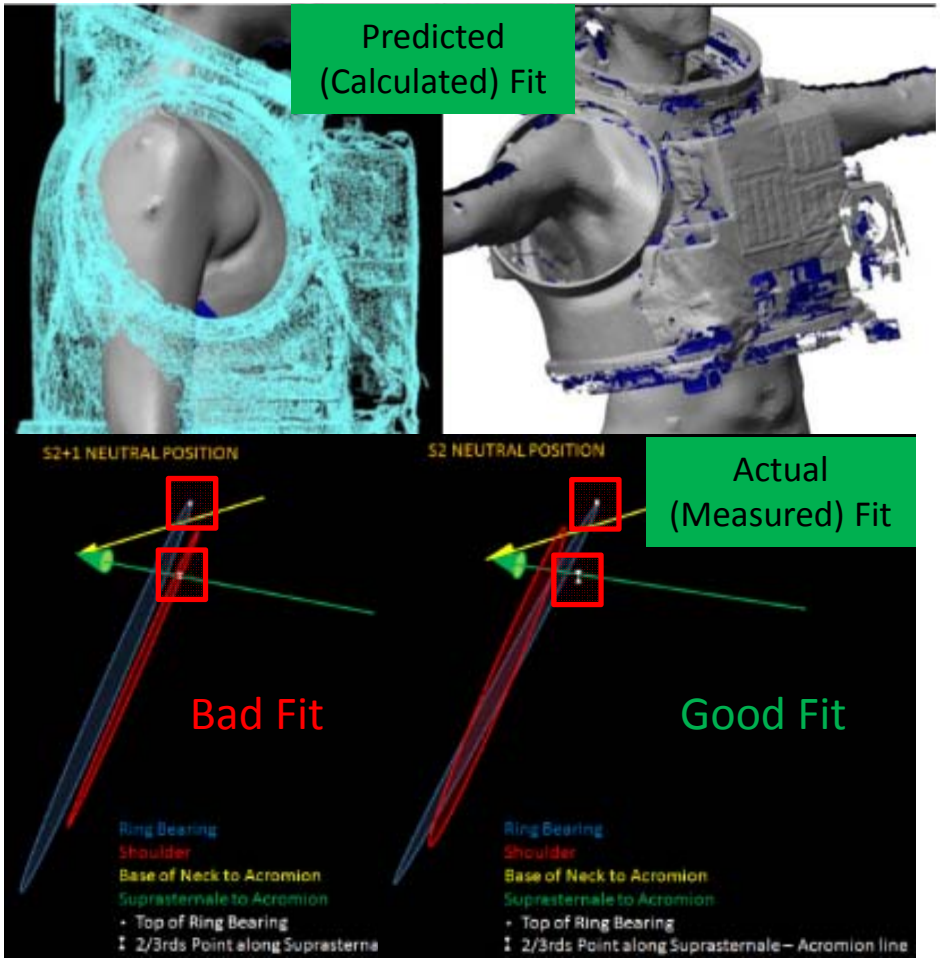


- Strength in general, is also reduced when suited
- The only practical difference noted between HUT sizes was for **shoulder extension**
- Note: Practical cutoff is based on ≥ 15% difference

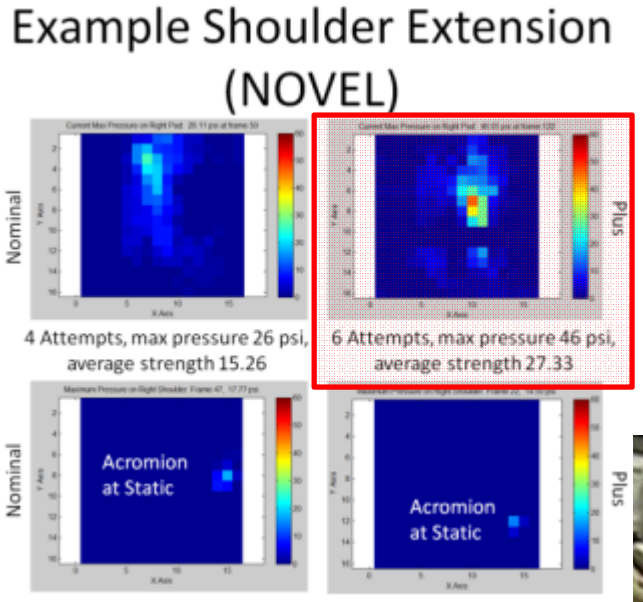
Images Courtesy of NASA

HUT Fit & Suit-Body Interaction

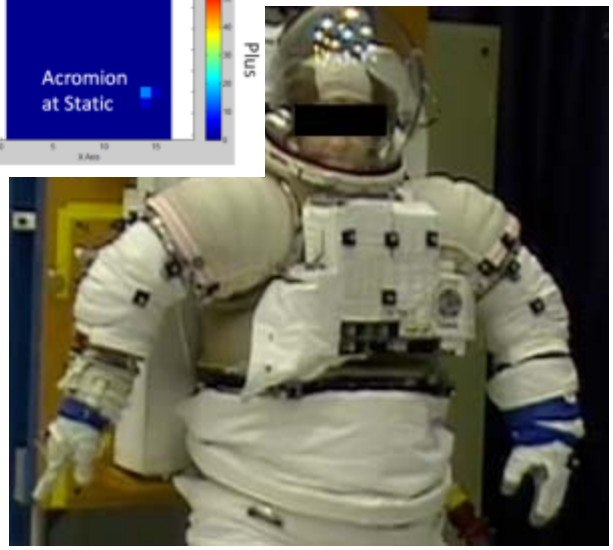
- HUT Fit



- Suit-Body Interaction



50% of subjects increased in subjective intensity in the plus size suit



Images Courtesy of NASA

Discussion: Shoulder Extension

Shoulder extension strength was greater for a majority of people in the plus sized suit by 15.8%

- Predicted/Actual fit of 4 of the subjects were not ideally aligned/fit with the plus sized HUT due to it being laterally larger than their shoulder breadth
- Surveys found that although shoulder intensity levels decreased for the shoulder in the plus size, the deltoid distribution and intensity levels increased, which may corroborate with the pressure mapping data over the frontal deltoid region.
- It is possible that due to the increased room in the HUT subjects may have modified their body posture to find increased leverage in the suit

Future Work

- Objectives:
  - Quantify resistances to movement in the EMU's shoulder and elbow joints
  - Characterize performance degradations caused by a pressurized EVA suit
  - Test out new human performance testing equipment, methods, and protocols with an EVA suit by quantifying arm and torso muscle activation and suit-body interaction contact points
- Relevance:
  - Aid suit designers by looking to minimize injury potential and optimizing human performance.

Acknowledgments

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  - Dan Nguyen, Robert Sweet, Sarah Margerum, Jill Klein, Jim Wessel, and Roxanne Buxton
- Data analysis help from Matt Cowley
- Endorsement from Brian Johnson and Scott Cupples from the NASA EVA Project Office

Any Questions?

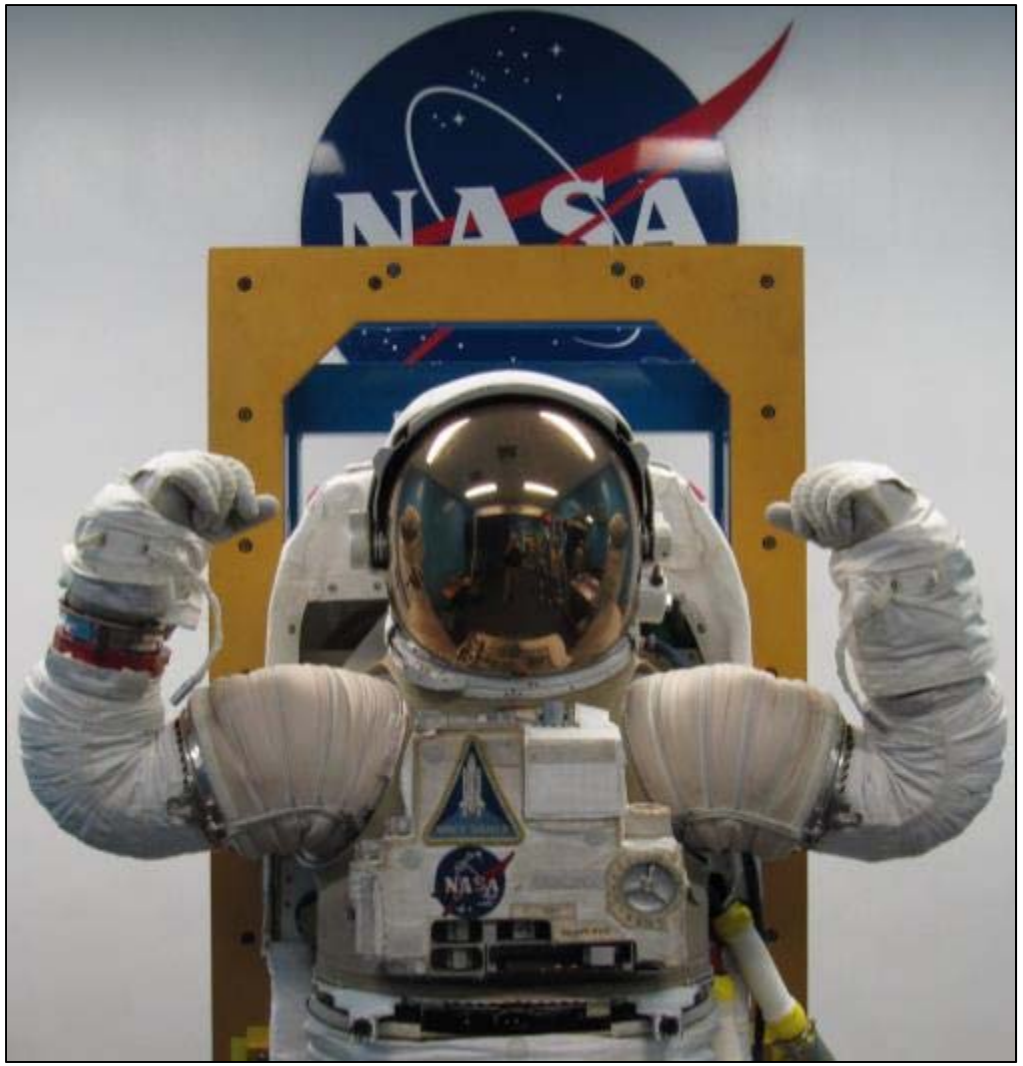

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Photo Courtesy of NASA