National Aeronautics and Space Administration

Collaborative Forum 3.1: Suit Sizing for Optimal Fit

EVA Technology Workshop 2020

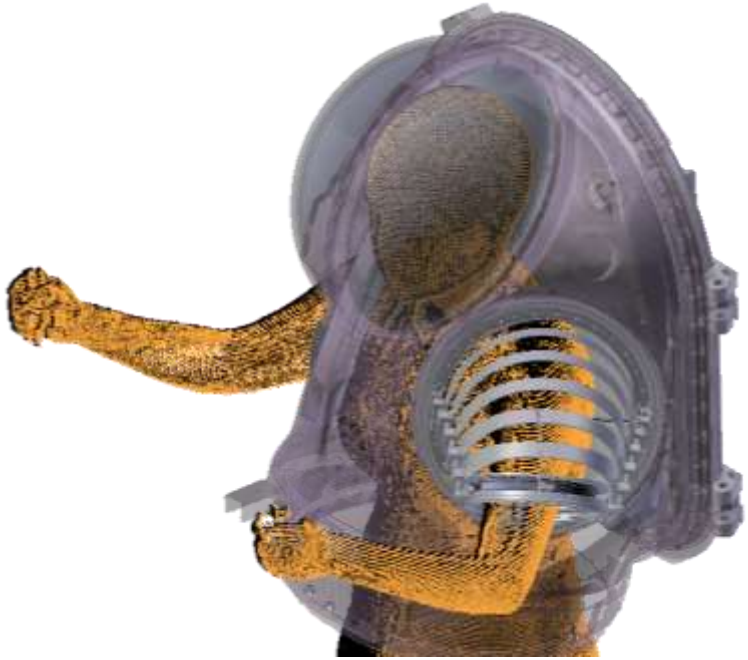
February 20th, 2020
Moderator: Elizabeth Benson (KBR)
Panelists: Richard Rhodes (NASA), Han Kim (Leidos), Leia Stirling (University of Michigan)

SESSION AGENDA

- **Session Objectives (5 min)**
- **Introduction of Panel (20 min)**
  - Richard Rhodes (*NASA JSC*)
  - Han Kim (*NASA JSC*)
  - Rachel Vitali (*University of Michigan*)
- **Questions and Discussion (1 hr)**

SESSION OBJECTIVES

- **Encourage open communication between NASA and the greater EVA community, regarding the complex topic of space suit sizing and fit assessment**
  - Recent advances in suit sizing and fit assessment tools
  - Current challenges in suit sizing and fit assessment
  - The potential for unique sizing and fit challenges on the lunar surface



Virtual fit checking of hardware

What sizing and fit challenges are posed by lunar surface operations in the suit?

Panelist – Richard Rhodes

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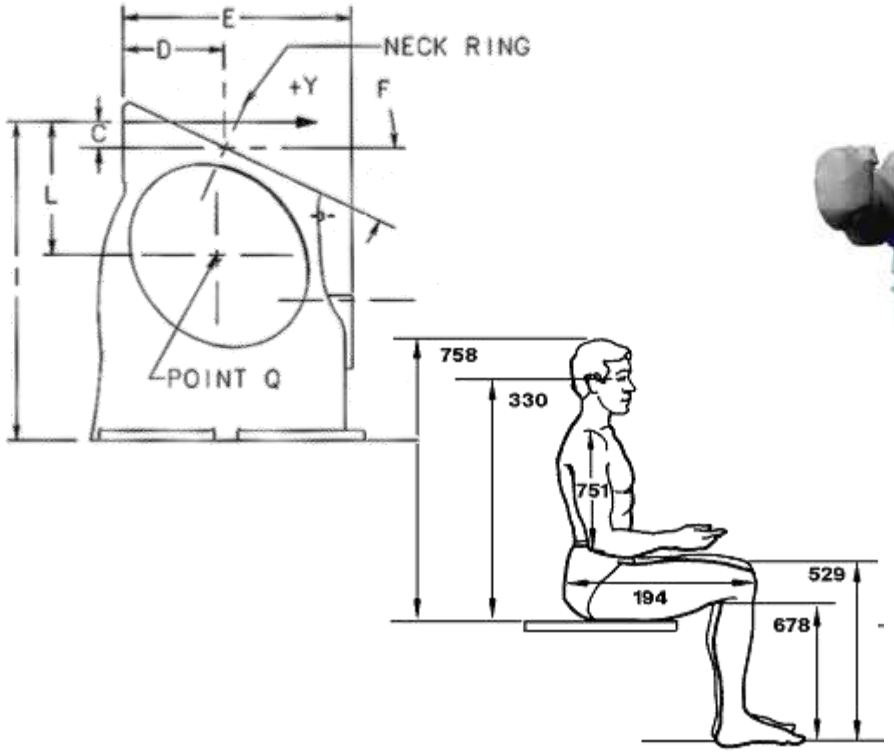
Han Kim (Leidos)

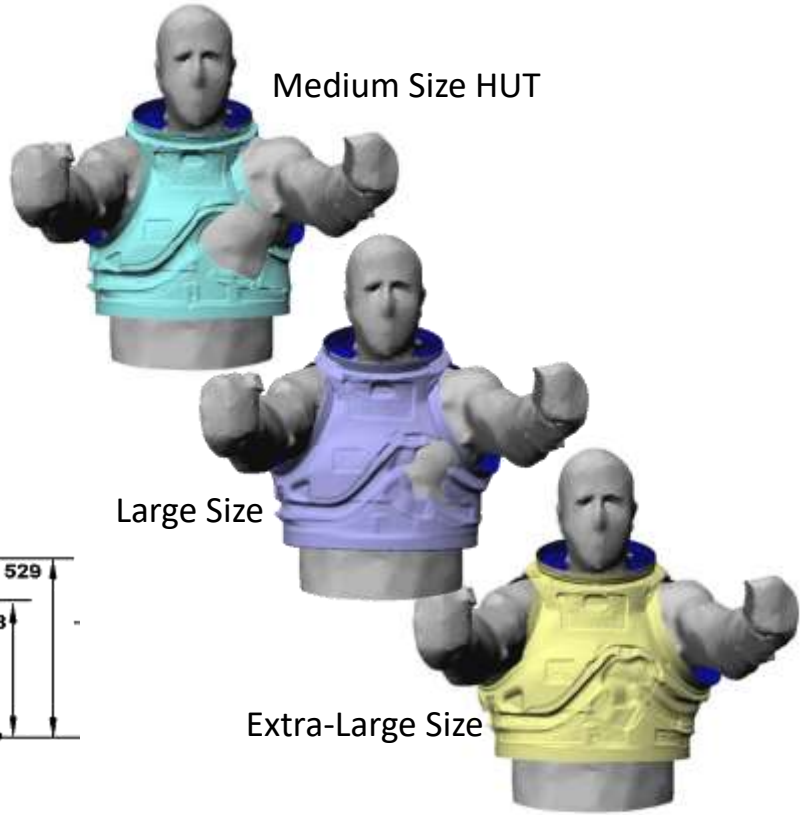
Historical Suit Fit Check Methods

- Shuttle EMU: Linear measurements were compared between the body and suit
- Z-2: A limited number of 3-D body scans were overlaid to check the overlap the suit CAD
- Z-2 & Z-2.5: Increased number of body scans to assess “worst-case” fit testing (”boundary manikins)

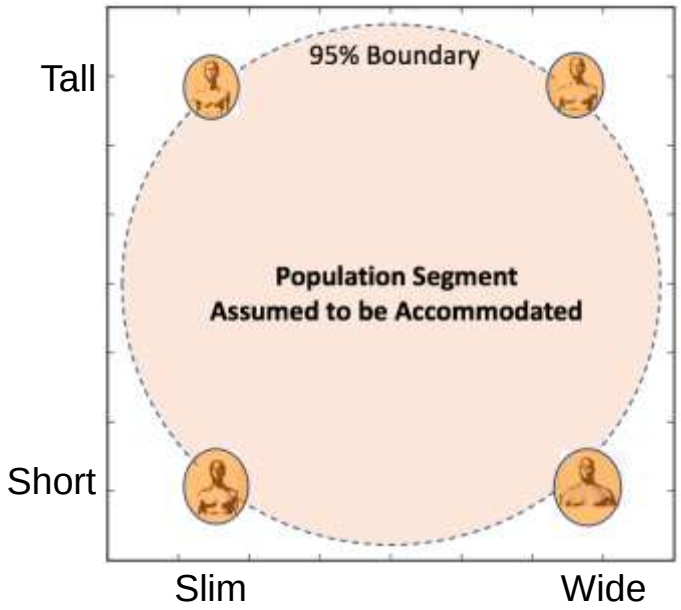
Linear Measurement Based



3-D Scan & CAD Fit Check



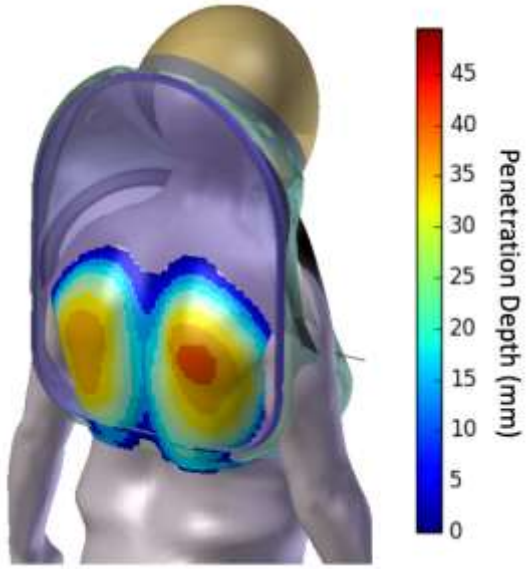
Boundary Manikin Tests



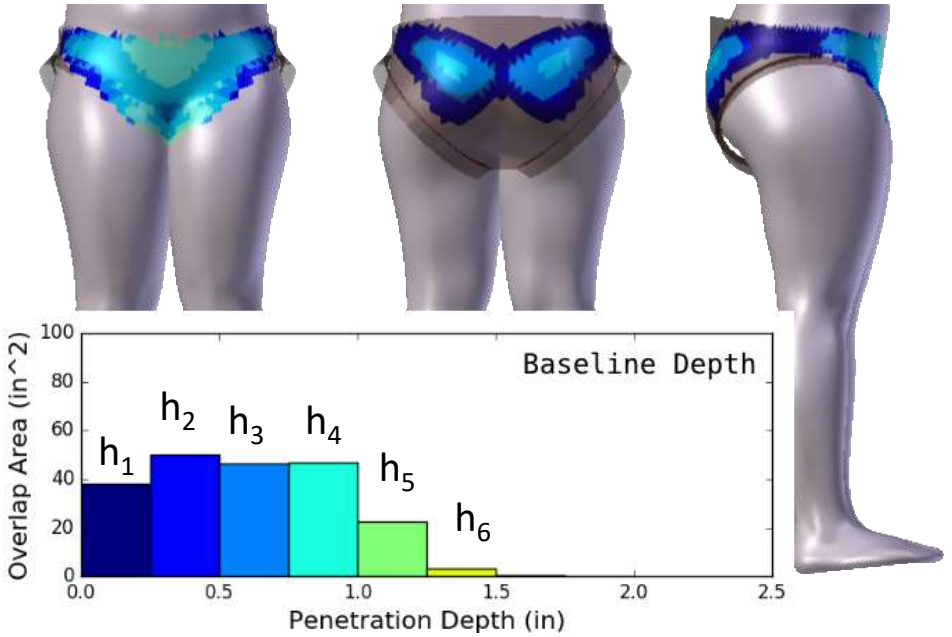
New Method: Large-Scale Testing for Virtual Suit Fit

- Overlay the 3-D body scans with the CAD model of the suit
- Estimate the suit-to-body contact and overlap
- Build a statistical classifier to predict the fit probability as a function of the suit-to-body overlap

Virtual Suit-to-Body
Contact and Overlap Estimation

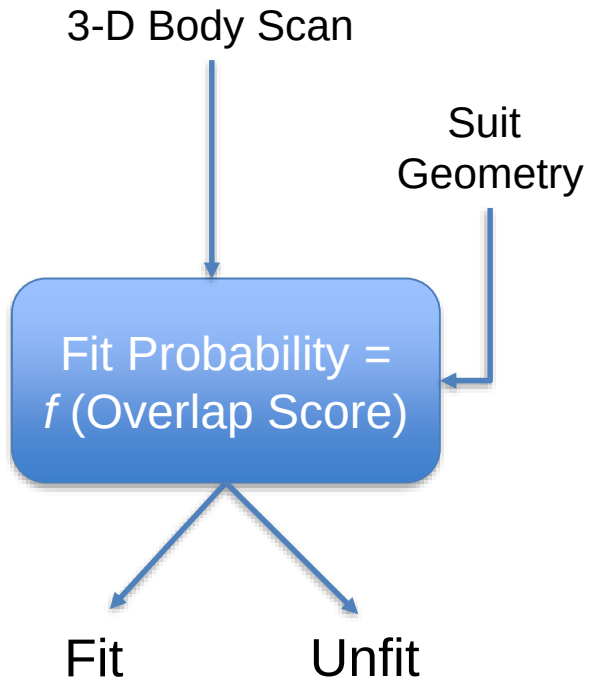


Suit-to-Body Overlap Score Calculation



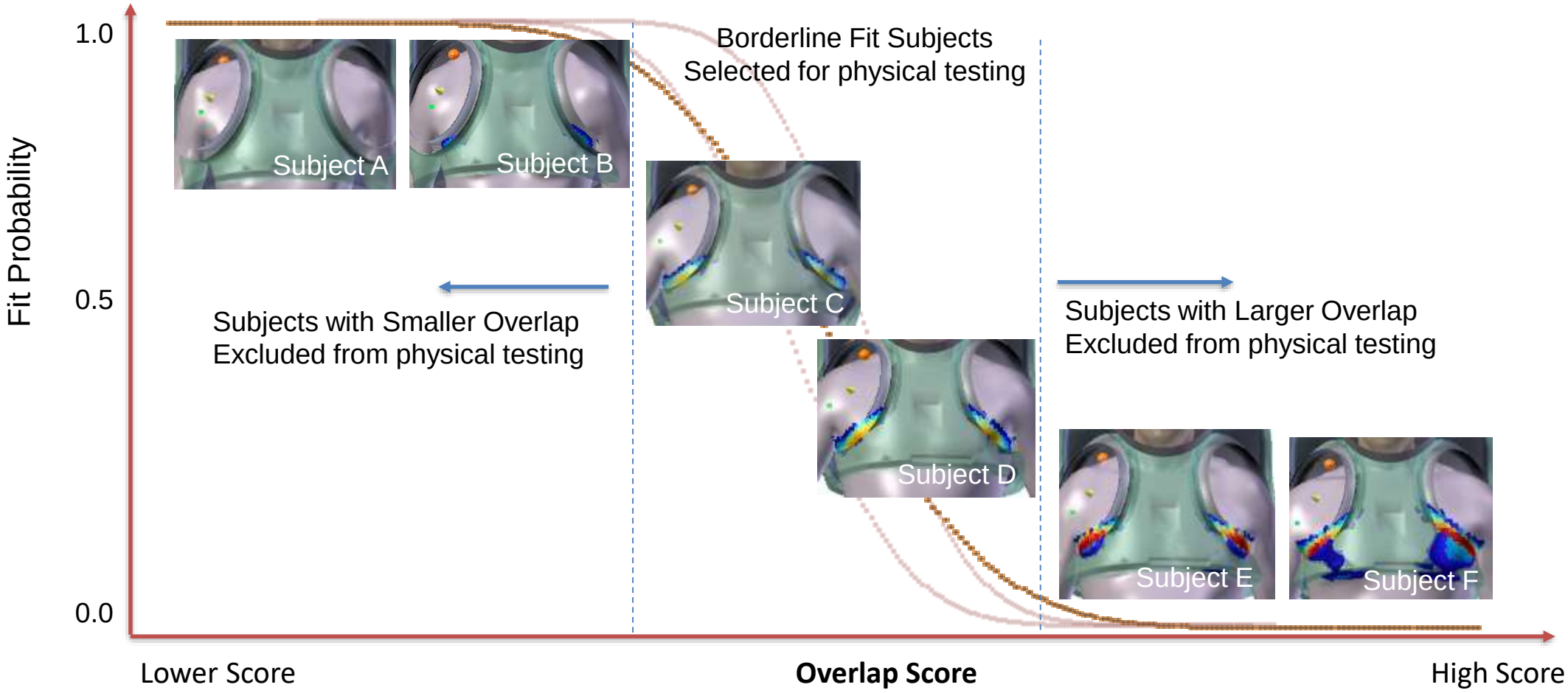
Overlap Score = $w_1 \cdot h_1 + w_2 \cdot h_2 + \ldots + w_n \cdot h_n$

Machine Learning Classifier



Test Subject Selection and Iterative Classifier Training

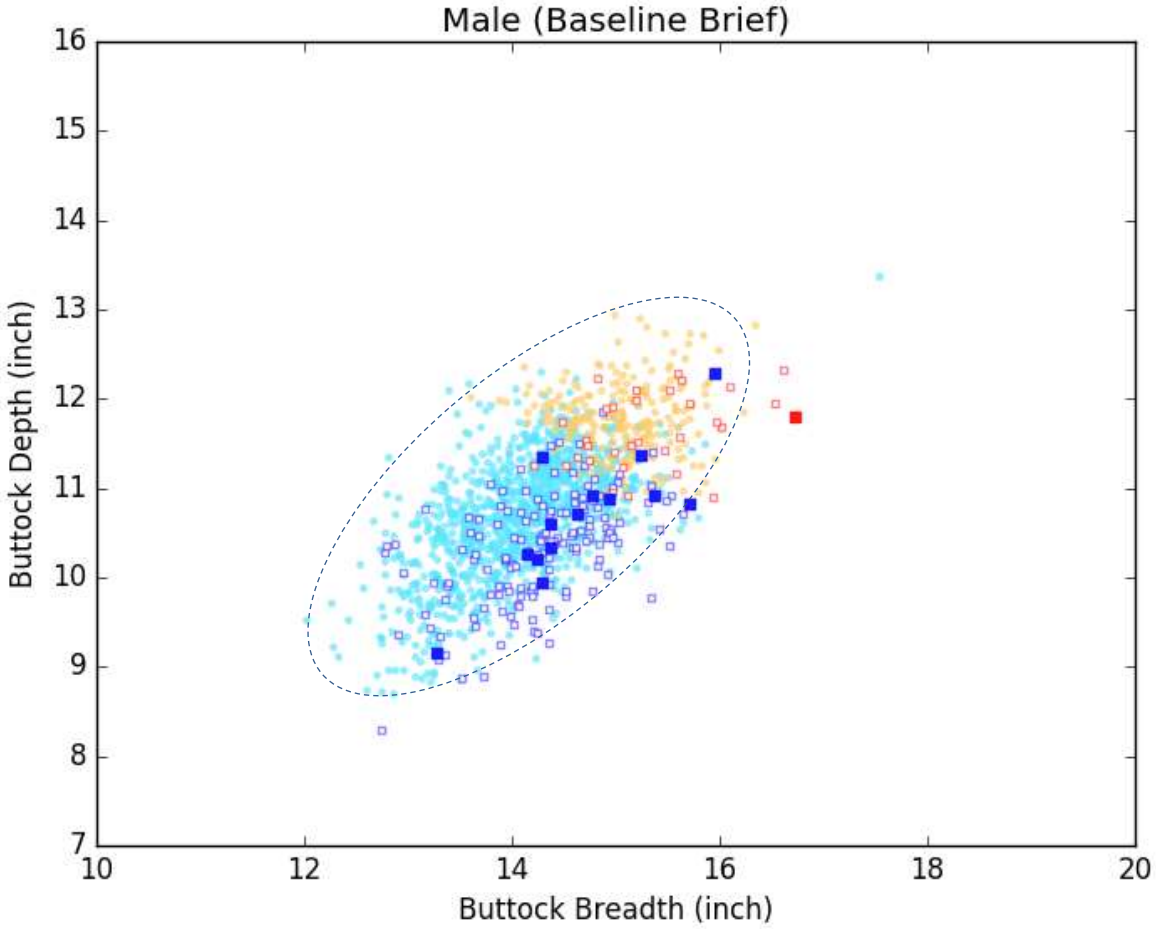
- Sort the potential subjects by overlap score and visually inspect the overlap charts
- From overlap charts, subjects “obviously likely” to fit (or unfit) were excluded from physical testing
- Physical fit tests performed with borderline fit subjects
- Iteratively update the fit classifier by physical fit test outcome



Classifier to Estimate Crew Population Accommodation

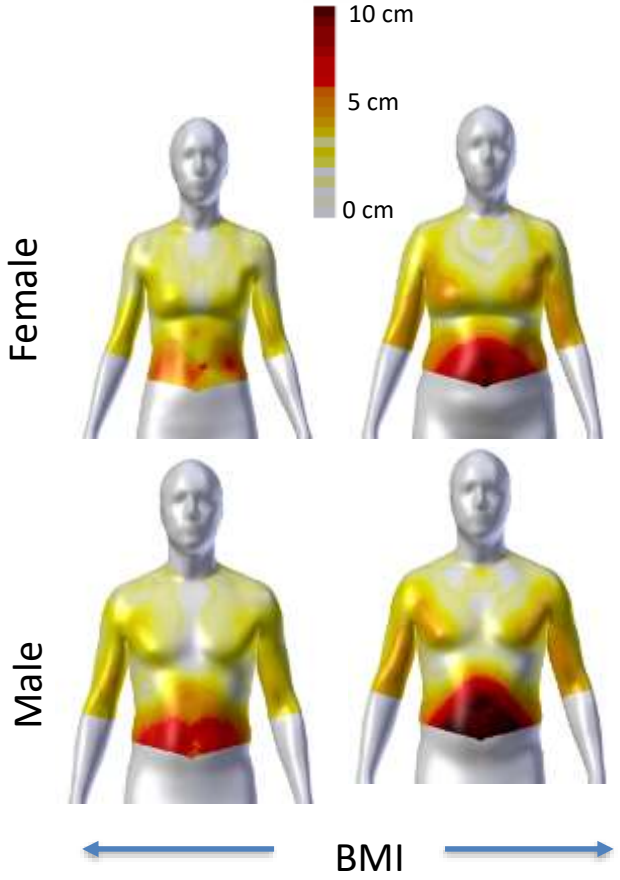
- Project the classifier model to a large population database (US Army; 3,890 Males, 1,712 Females)
- Count fit vs. unfit cases and estimate the accommodated proportion of the crew population
- This method enables identifying marginally fitting cases, i.e., Prob(Fit) ≈ 0.5 and fit surface gradient
- This new information can help to identify the design issues and iteratively optimize the suit design

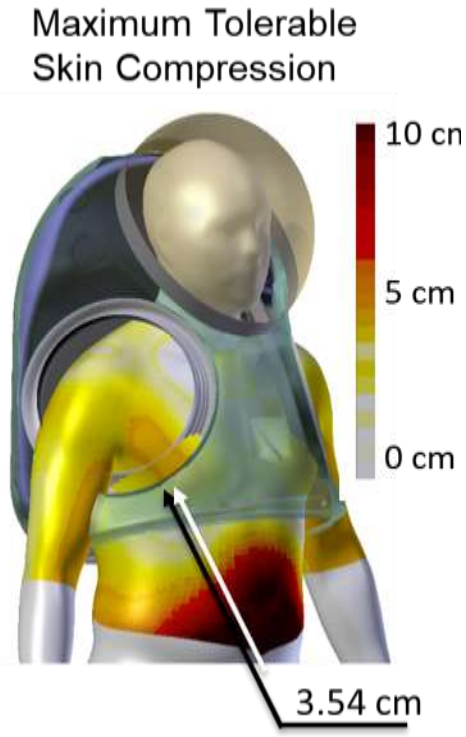
US Army Scan Database

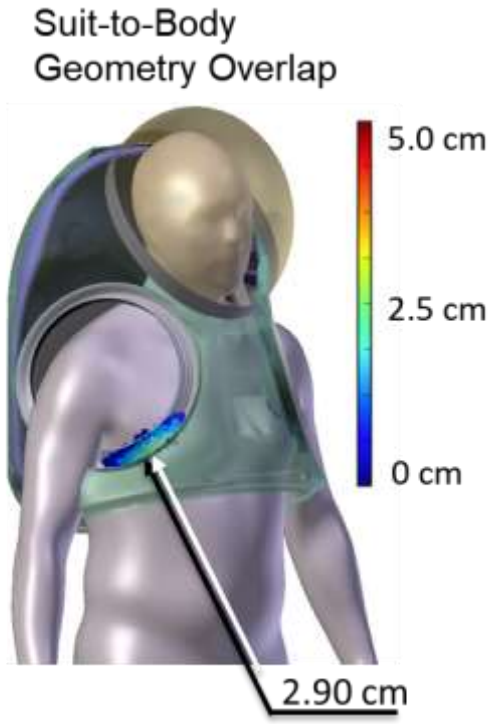


Skin Compression Tolerance

- Suit-to-body overlap is a key metric, but the specific magnitude of acceptable overlap is still unknown
- This study directly measured the maximum tolerable depth of overlap by maximally “pushing” a probe
- Developed a parametric model and the outcome was compared to the virtual fit tests



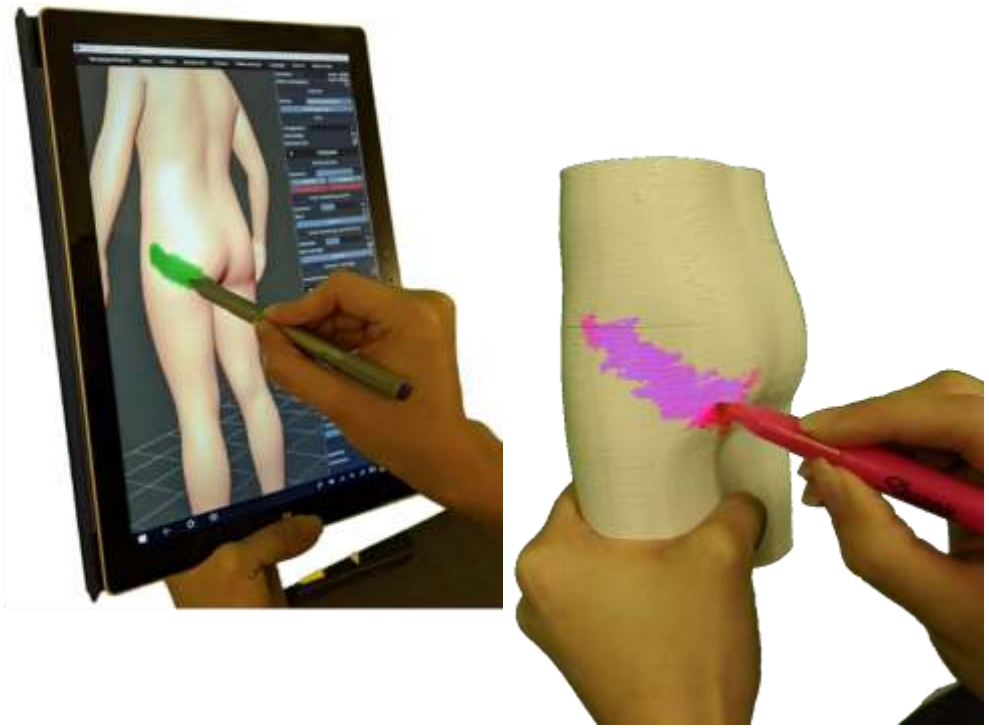




Subjective Reporting of Suit-to-Body Contact

- Physically tested subjects also reported the perceived locations of suit-to-body contacts
- The subjective reporting was compared to physical and virtual suit contact and overlap

Subjective Reporting of
Suit-to-Body Contacts



Compare Outcome to the
Virtual Suit-to-Body Overlap

Panelist – Rachel Vitali

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Topic 1 – Lunar EVAs

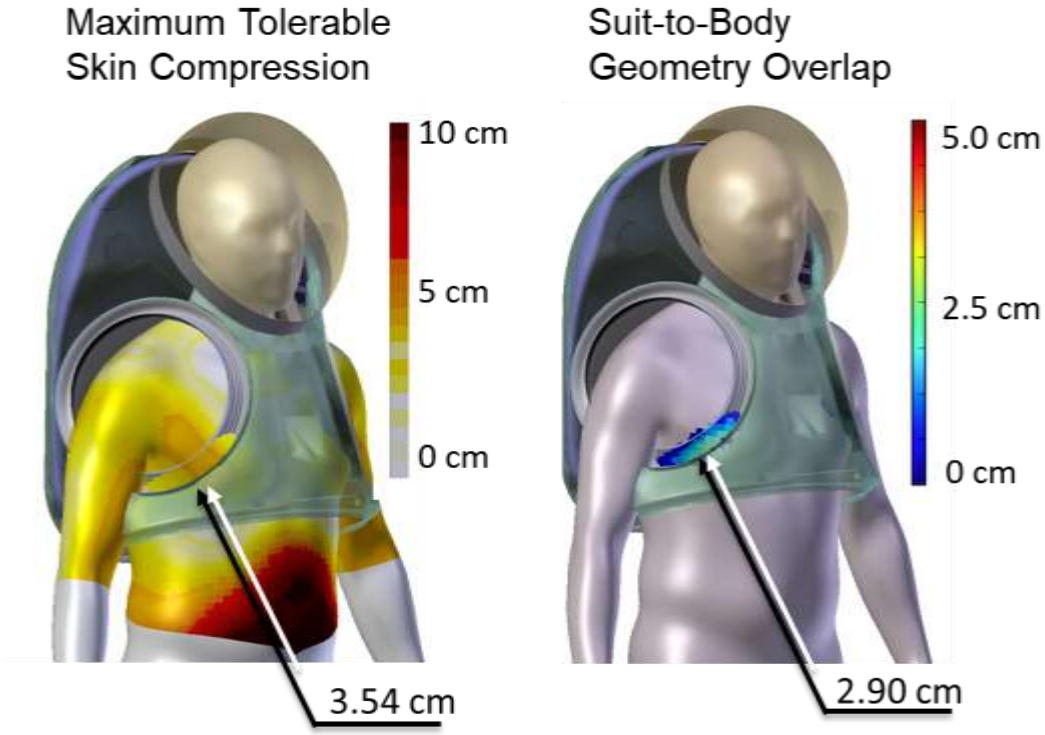
- **What sizing and fit challenges are likely to be unique to planetary suits working in partial gravity?**
- **How will forceful exertions and extreme postures influence fit?**

Subject walking on reduced gravity aircraft

Subject crawling in prototype planetary suit (1-g)

Topic 2 - Suit-Body Contact Assessment

- **How do we discriminate ‘good’ vs. ‘bad’ suit-body contact?**
- **How do the anatomical properties of the contact location change suit fit (for example, bone vs. soft tissue)**

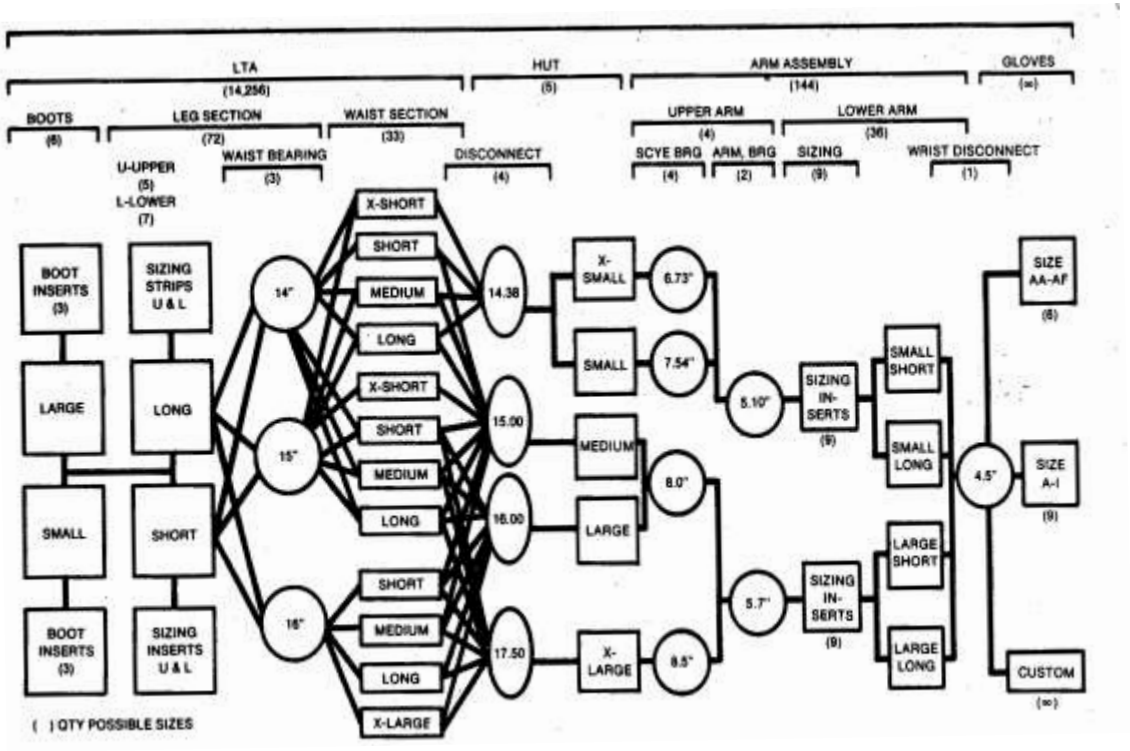


Perceived Suit Contact

Topic 3 – Custom vs. modular sizing

- **Why do we have modular suits, and not custom-fitted suits that are unique to each crewmember?**

Apollo era: Custom sewn suits



Shuttle Era: Modular suit architecture

Topic 4 – Other disciplines

- **What are examples of other fields that have similar fit and sizing challenges, and how have they worked to resolve these issues?**

Firefighting

Exoskeletons

Military

Questions?

- **Panelists:**
  - Richard Rhodes (Richard.Rhodes@NASA.gov)
  - Han Kim (Han.Kim@NASA.gov)
  - Rachel Vitali (vitalir@umich.edu)