Preliminary Ergonomic Evaluation Methods for the Extravehicular Mobility Unit (EMU)

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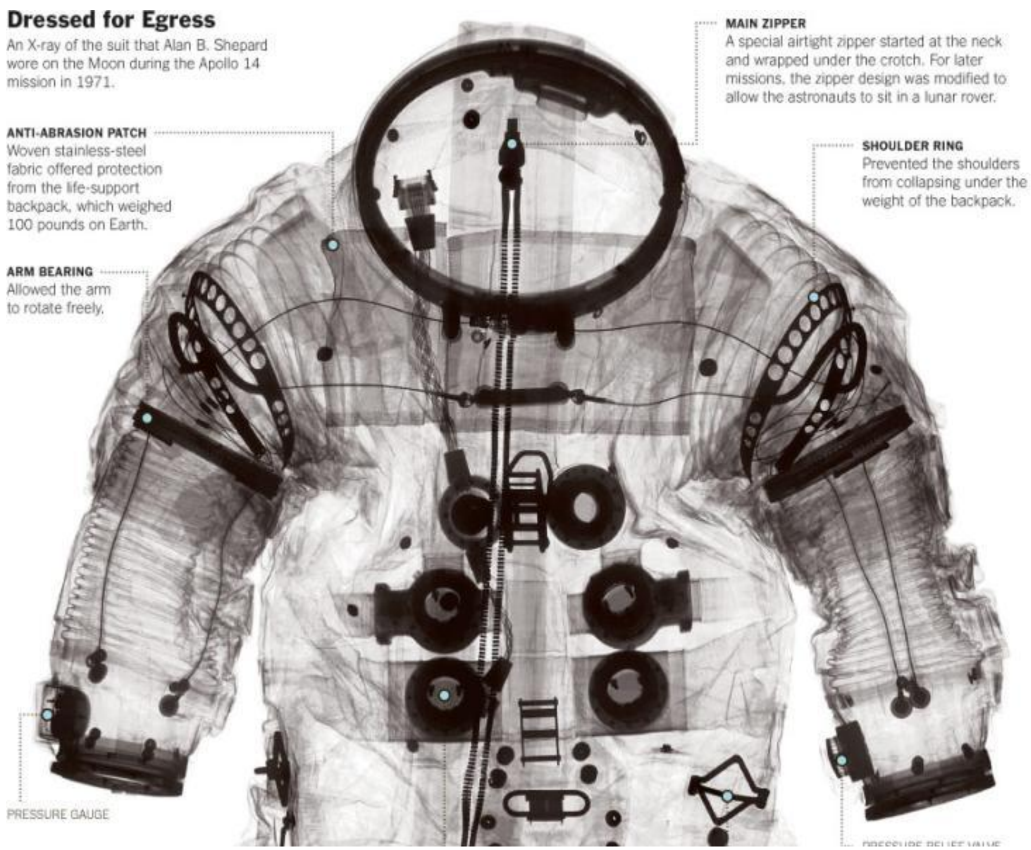
Overview

- Objective: Test different quantification methods to better understand human-suit interaction’s influence on human arm mobility

- Simply Put: Can we see what is going on in the suit to the body?



Courtesy of the New York Times

Method

- Six test subjects (4 male, 2 female)

  average age: 30 years old (+/- 5)

- Suited tests conducted while standing in suit-donning stand
- Performed six right-shoulder movements in the Hard Upper Torso (HUT):

  Flexion/Extension, Adduction/Abduction, and Internal/External Transverse

- Testing conditions

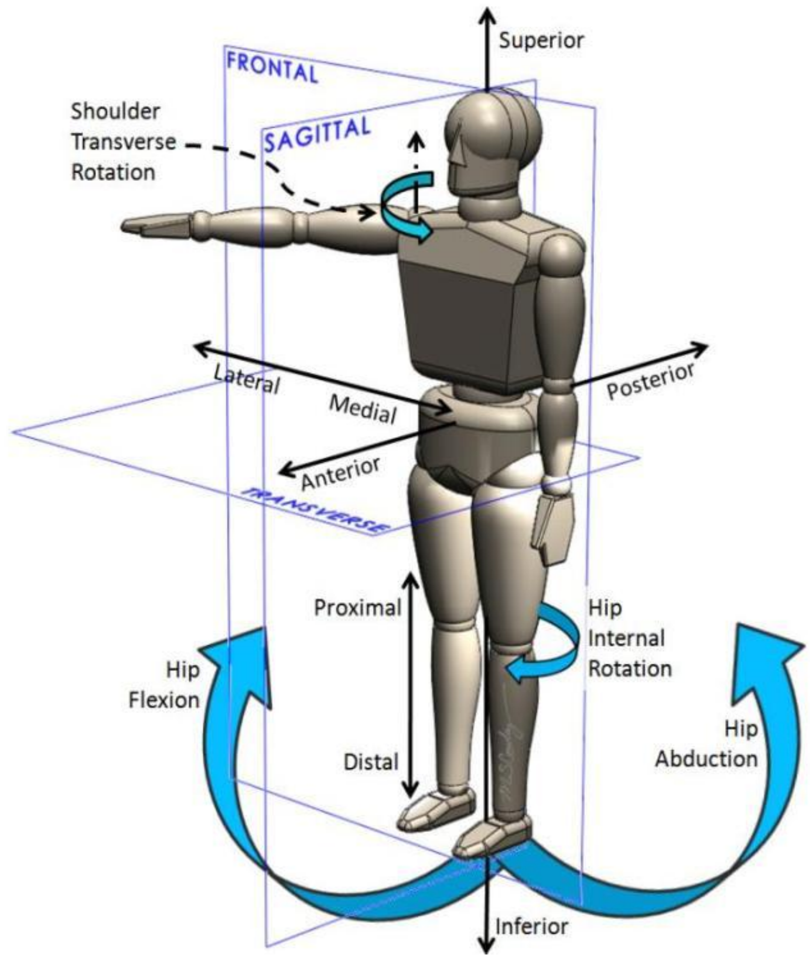
  unsuited, fully suited pressurized, fully suited unpressurized, and suited unpressurized with arm/wrist components removed

EMU attached to Suit-Donning Stand with Thermal Micrometeorite Garment removed from HUT

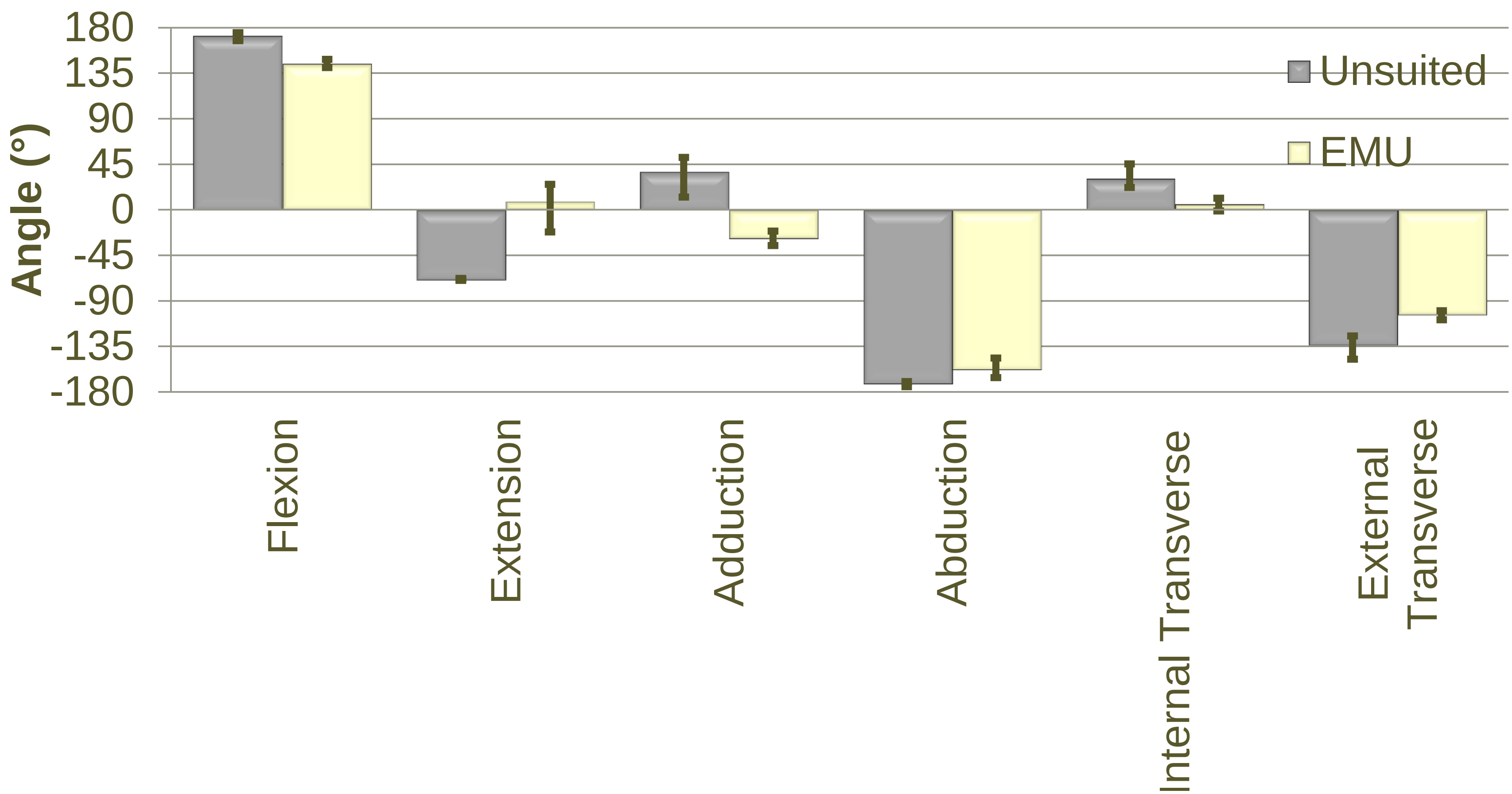
Method (Continued)

- Gathered data on:
  - Shoulder joint range of motion (ROM)
  - Suit-body contact & clearance
  - Wrist bearing displacement
  - Fingertip gap (between glove and middle fingertip)
- Data collection tools included:
  - FARO 3D point clouds (for gathering shoulder bearing-to-body clearance)
  - Vicon motion capture (for gathering range of motion, reach envelope, and displacement of the wrist bearing)
  - Subjective surveys (for gathering human-suit contact information).
- Other than descriptive statistics, no statistical analysis was conducted due to small sample size of subjects

Shoulder Mobility Performance Differences



Mean Isolated ROM Results



(Error bars show subject maximum and minimum values)

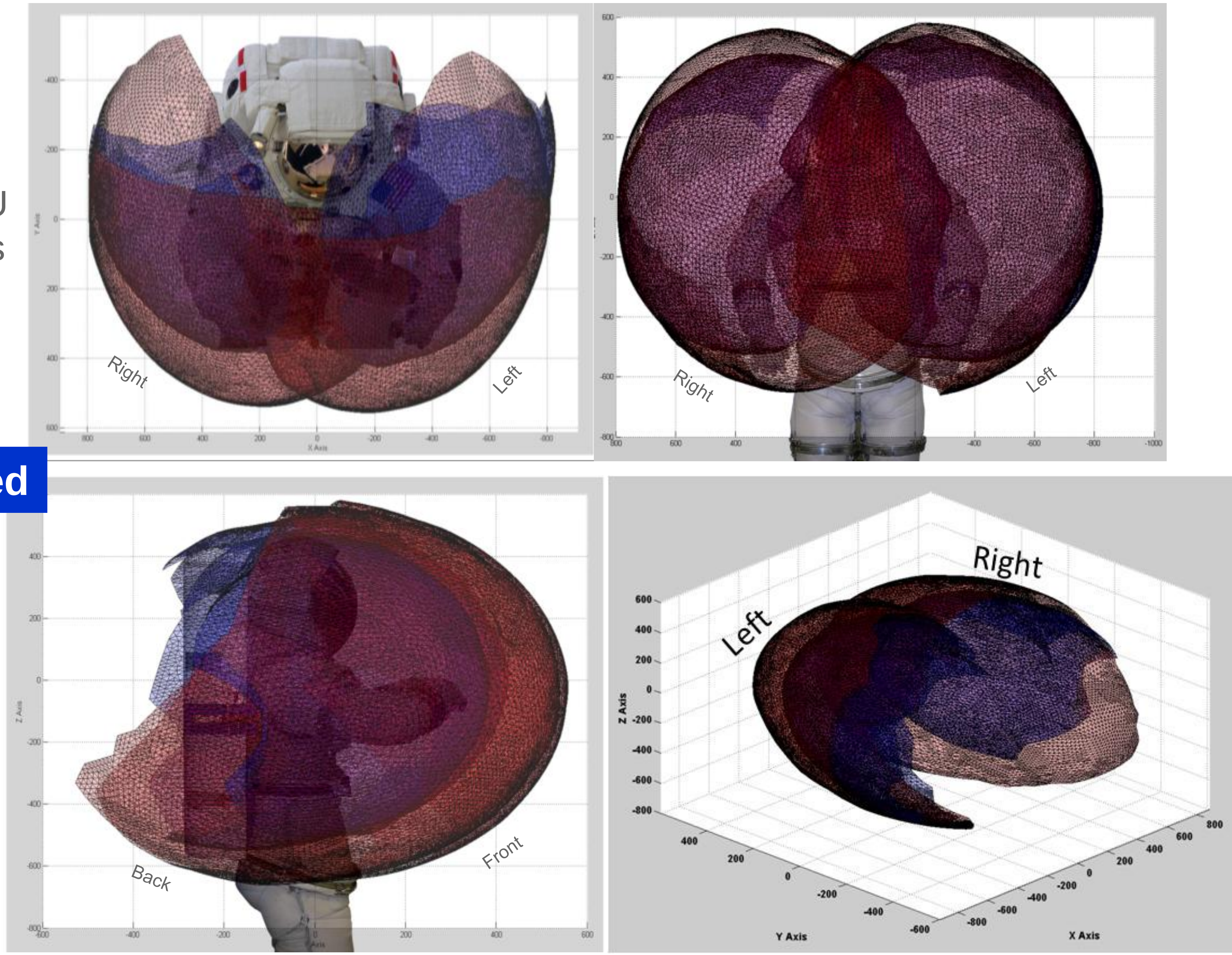
- EMU exhibits suit limitations to isolated mobility, most likely caused by suit-shoulder interactions
- Large restriction for frontal work zone typical for most EVA work & where suited ROM should be closest to unsuited ROM (flexion, adduction, internal transverse)

EMU Reach Envelope

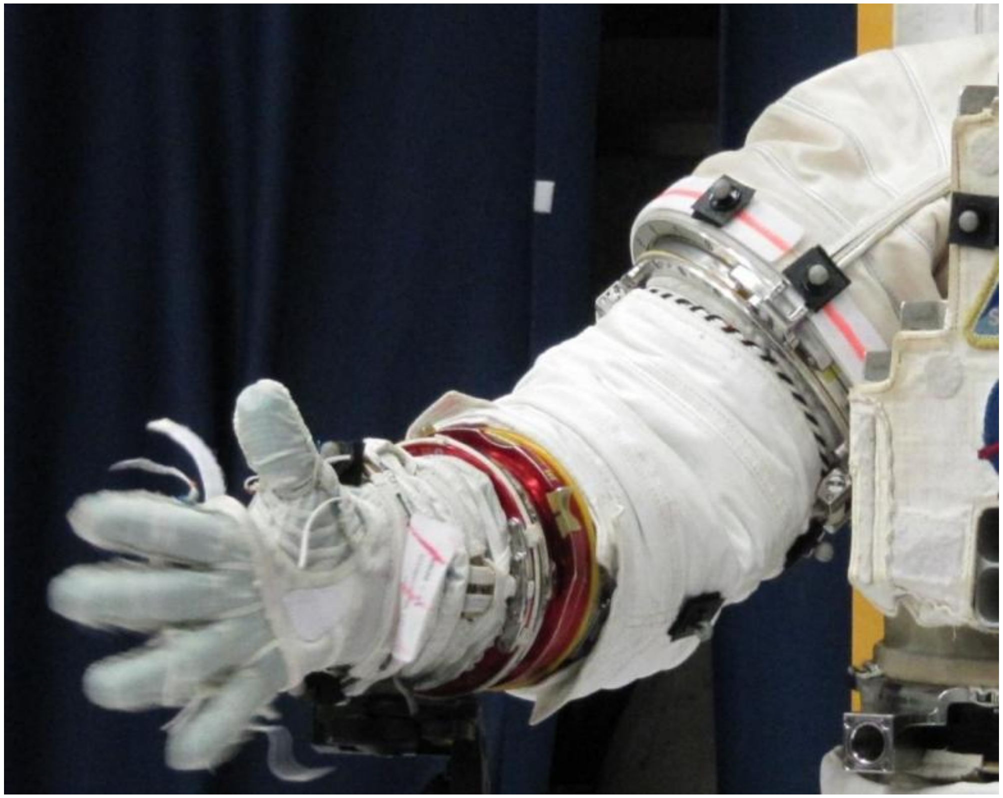
Example of Unsuited vs. EMU Reach Envelopes

Unsuited

EMU Pressurized



Suit Sleeve Displacement and glove Fingertip Gap

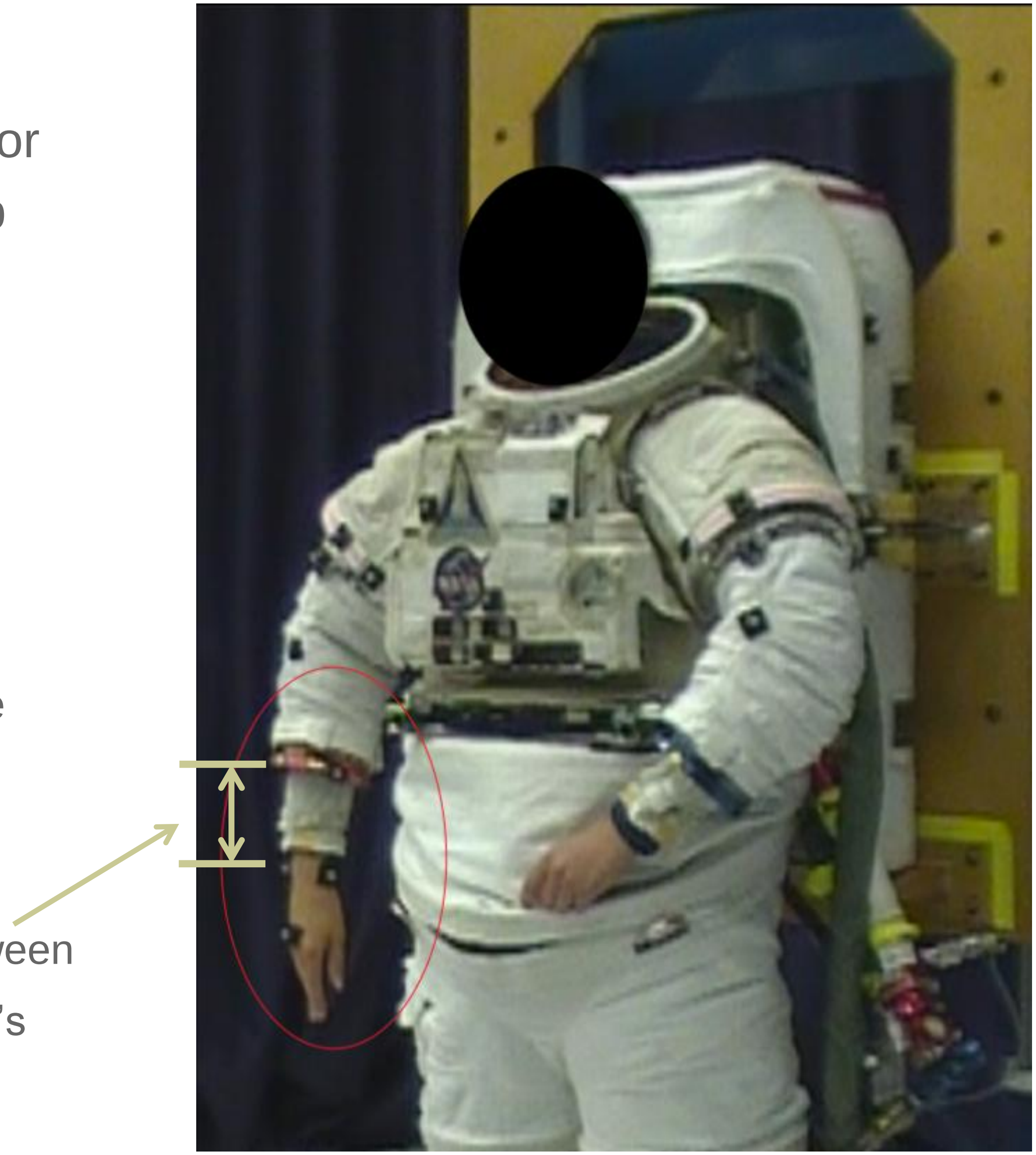


EMU Suit Influence on Phase VI Glove Fingertip Gap

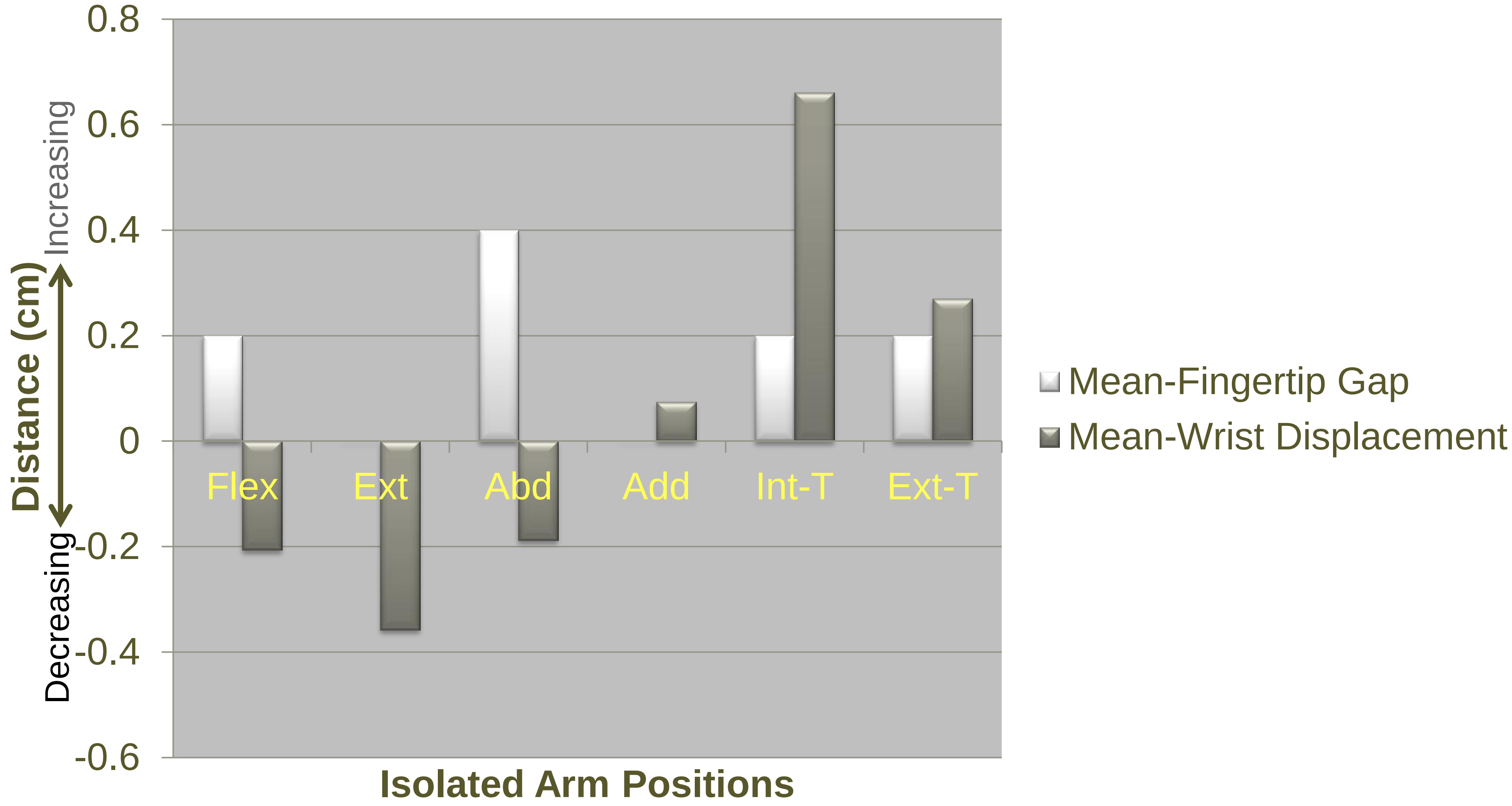
- Testing revealed movement for the wrist bearing and fingertip gap for different isolated arm postures.
- **Definitions:**

  •**Fingertip Gap (FG)**: Distance between the tip of the subject's middle finger and the edge of the Phase VI glove's middle finger (pressurized)

  •**Wrist Gap (WG)**: Distance between the wrist bearing and the subject's wrist joint (unpressurized)



Mean Finger Tip Gap vs. Mean Wrist Bearing Displacement for All Subjects



This chart depicts fingertip gap and wrist displacement information for each isolated arm posture. Negative Wrist values indicate that bearing displacement from hand shortened from neutral position, while positive values showed that displacement increased from neutral

EMU Suit Movement Influence on Phase VI Glove Fingertip Gap - Results

- Is this data showing some form of a relationship between fingertip gap and wrist bearing displacement for flexion and abduction?
  - Mean values depict wrist bearing displacement decreases for some movements, while fingertip gap increases
  - While on others they both increase at the same time
- For subjects that have zero fingertip gap throughout each position, it is difficult to tell if a relationship exists
- Unsure of the wrist bearing influence from pressurized vs. unpressurized as it was gathered unpressurized

EMU Suit-Body Interaction (Contact Points)- 4.3psid

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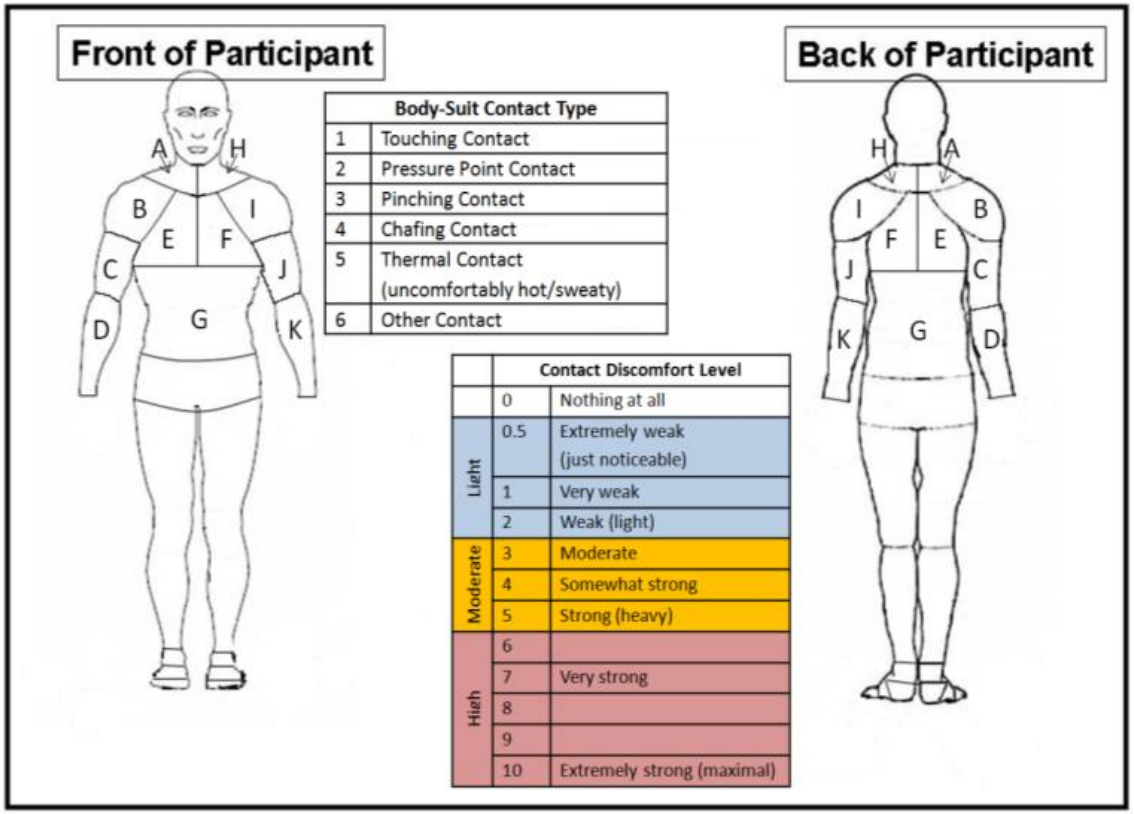


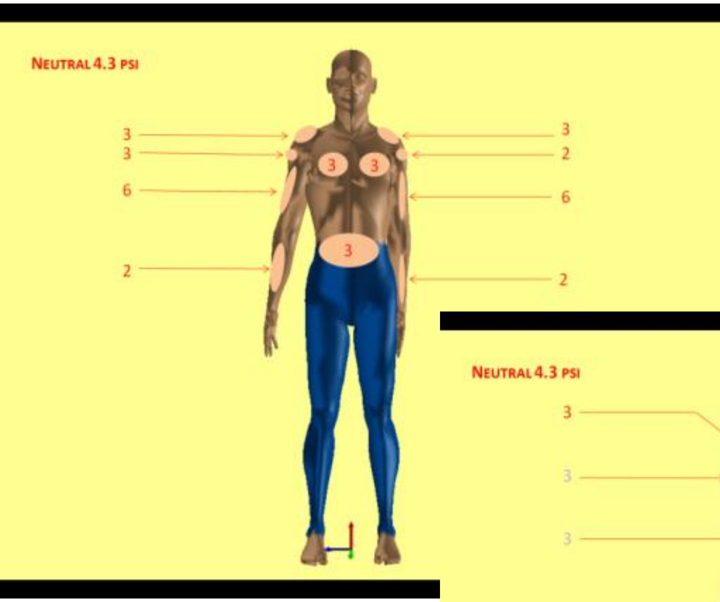
Body-Suit Contact Type	
1	Touching Contact
2	Pressure Point Contact
3	Pinching Contact
4	Chafing Contact
5	Thermal Contact (uncomfortably hot/sweaty)
6	Other Contact

	Contact Discomfort Level	
	0	Nothing at all
Light	0.5	Extremely weak (just noticeable)
Light	1	Very weak
Light	2	Weak (light)
Moderate	3	Moderate
Moderate	4	Somewhat strong
Moderate	5	Strong (heavy)
High	6	
High	7	Very strong
High	8	
High	9	
High	10	Extremely strong (maximal)

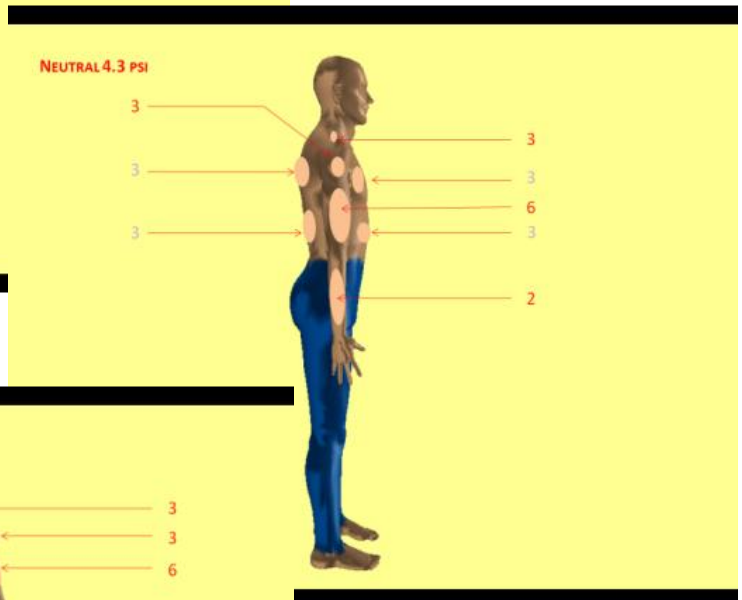
- Subjective surveys were used to gather suit-body contact information
- Information gathered included:
  - Contact Location
  - Contact Type
  - Contact Intensity
    - » (Modified Borg CR10 Scale)

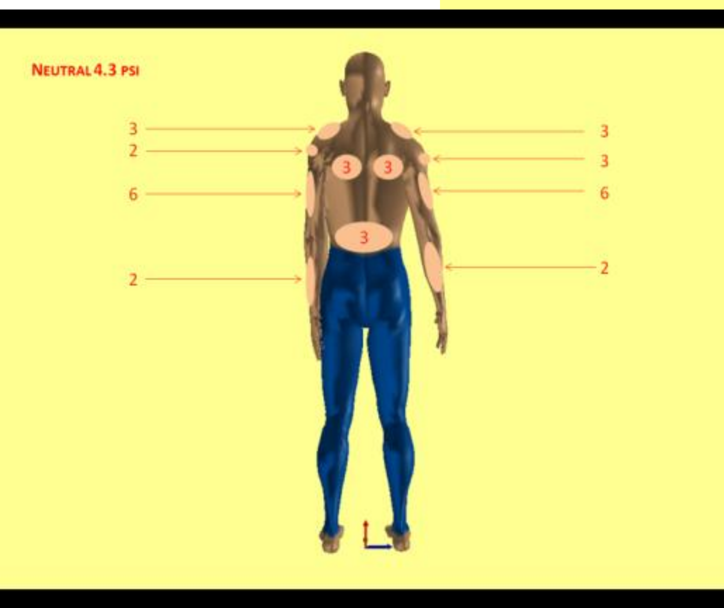
EMU Suit-Body Interaction (Contact Points)- 4.3psid

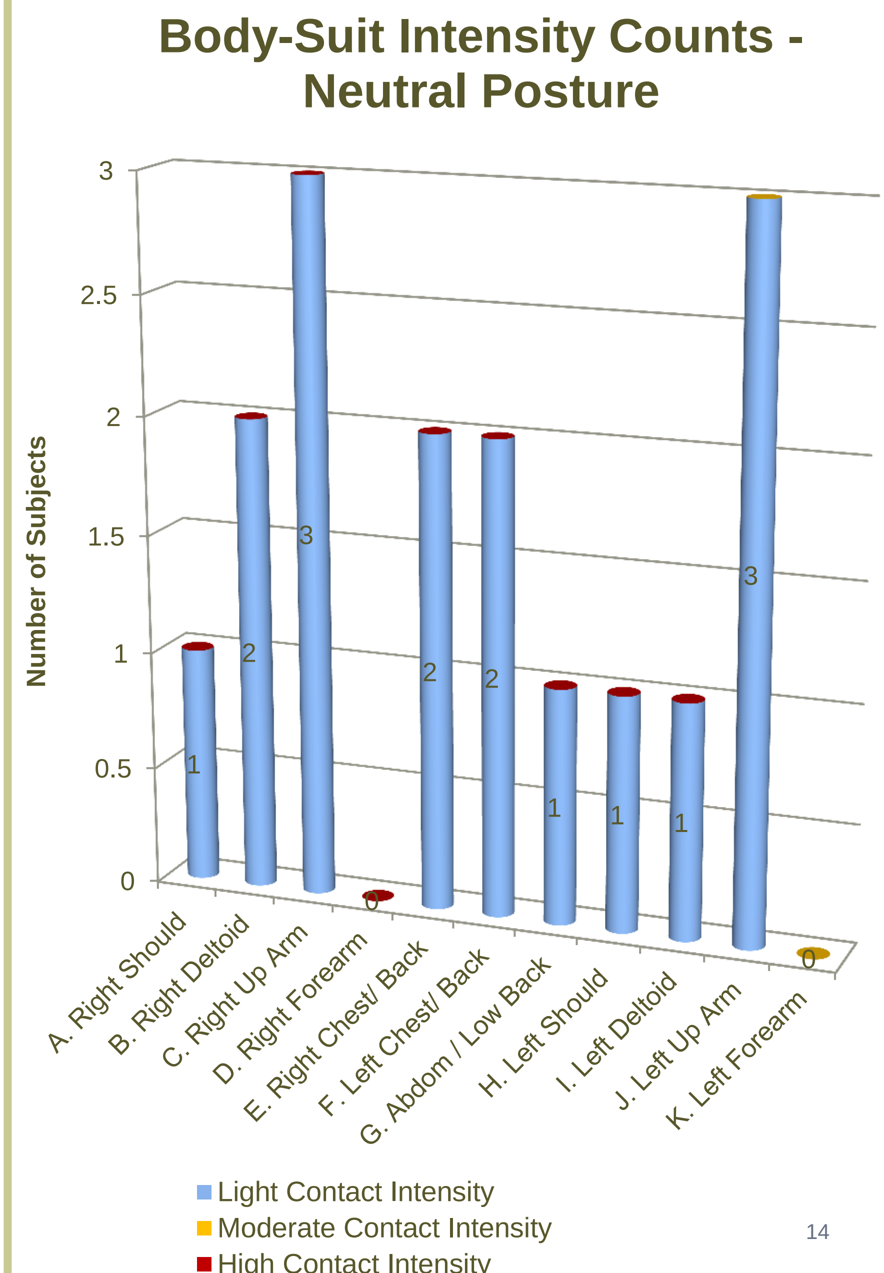
Contact Counts Per Body Region



Numbers represent number of subjects who had contact at that body region



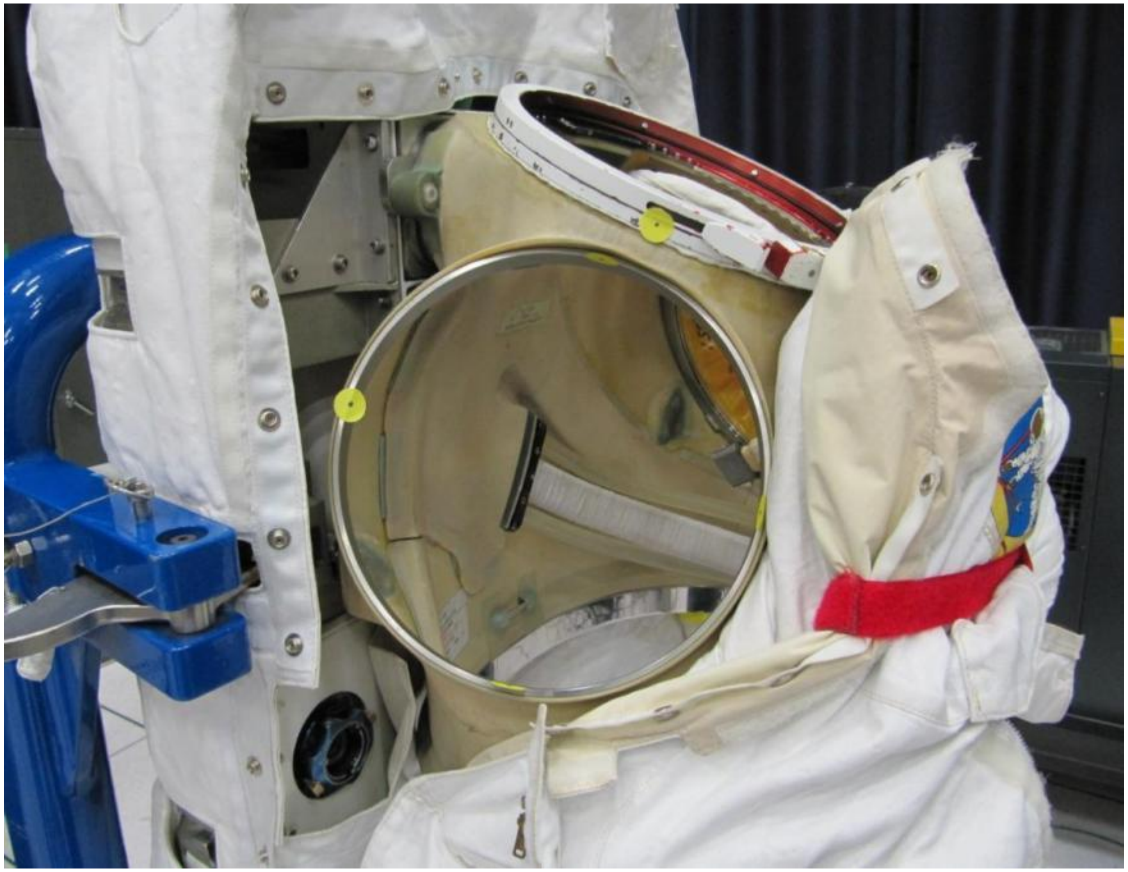




EMU Suit-Body Interaction (Contact Points)- 4.3psid - Results

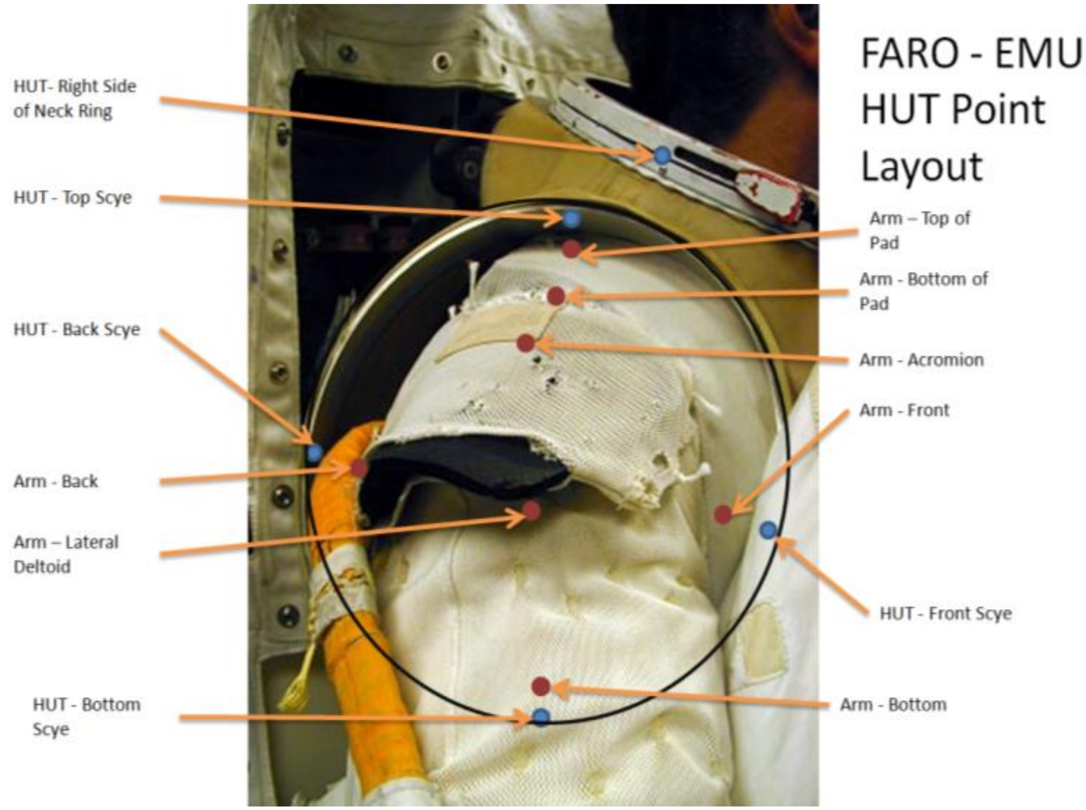
- Of the types of suit-body contacts noticed for the 4.3psid condition, touching and pressure point contacts were the two most noted
- Regardless of arm posture, the upper arms, chest, back, and shoulder/deltoid regions were most noted for contact
- Contact intensity was shown to be between light and moderate contact.
  - Only one arm position (abduction) showed high intensity contact, which was for the left deltoid region

EMU Suit-Body Clearance at Shoulder Joint



EMU Suit-Body Clearance at Shoulder Joint

- Clearance information was gathered between the EMU shoulder bearing (scye) and an approximation of the subjects’ arm scye circumference
- Data was collected using a FARO arm probe on 12 locations (5 HUT and 7 Body)
- 4 primary locations created the depicted modified arm-scye circumferences:
  - •Arm anterior scye
  - •Arm posterior scye
  - •Top of shoulder (under HUT)
  - •Bottom of arm (underarm)
- All resulting figures are 2D representations of the 3D data collected using a sagittal viewing perspective to the EMU shoulder bearing



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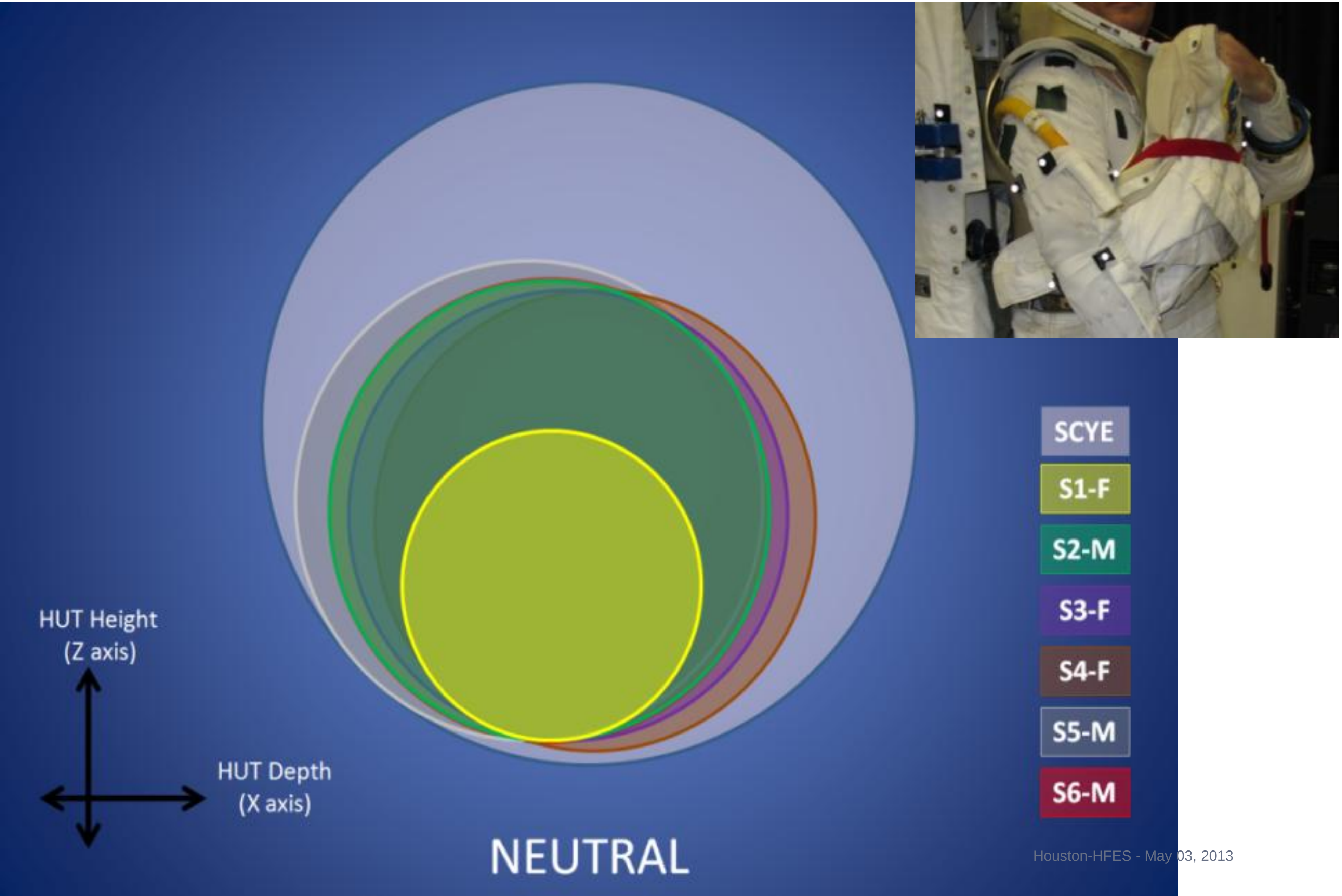

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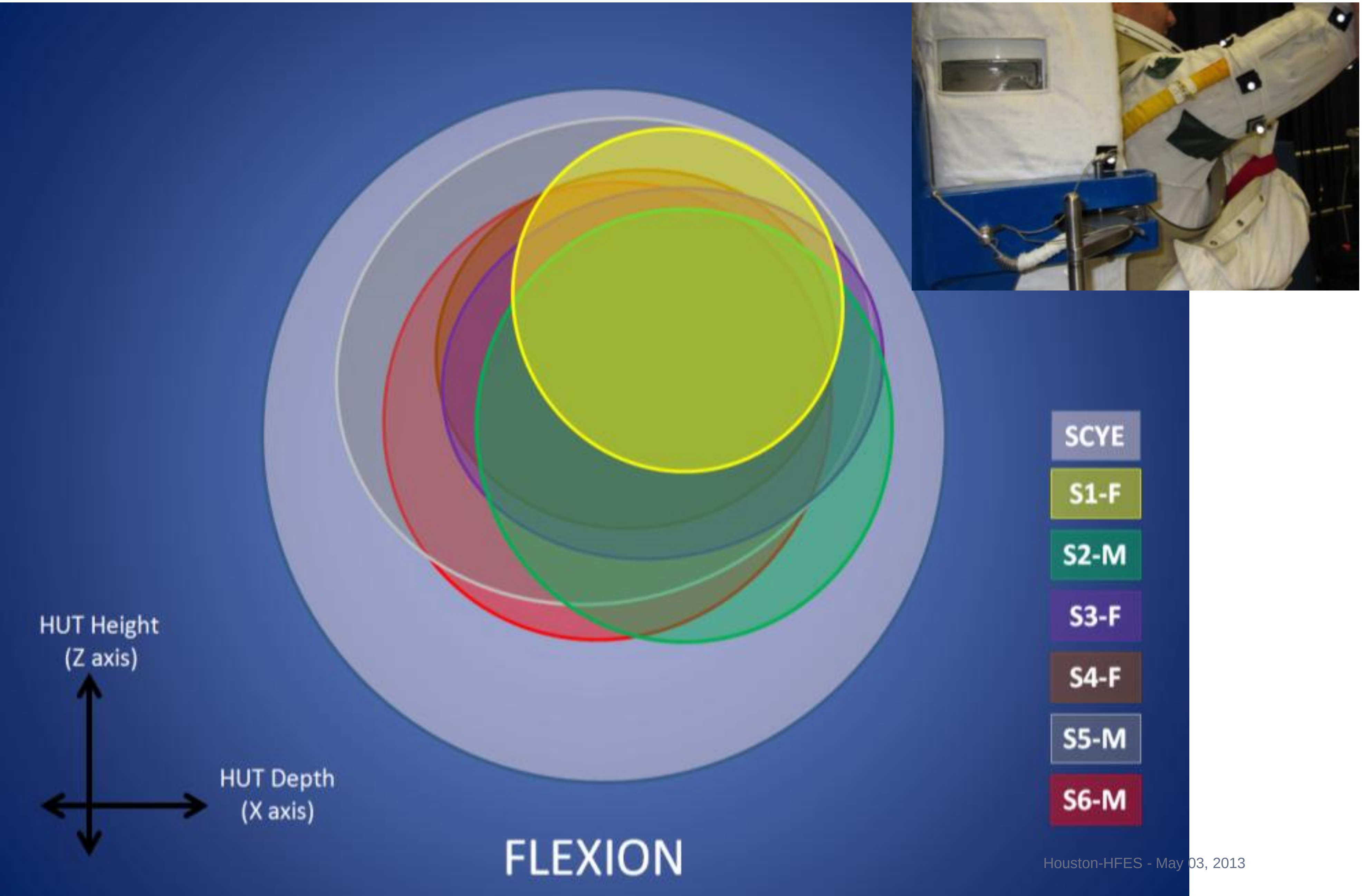

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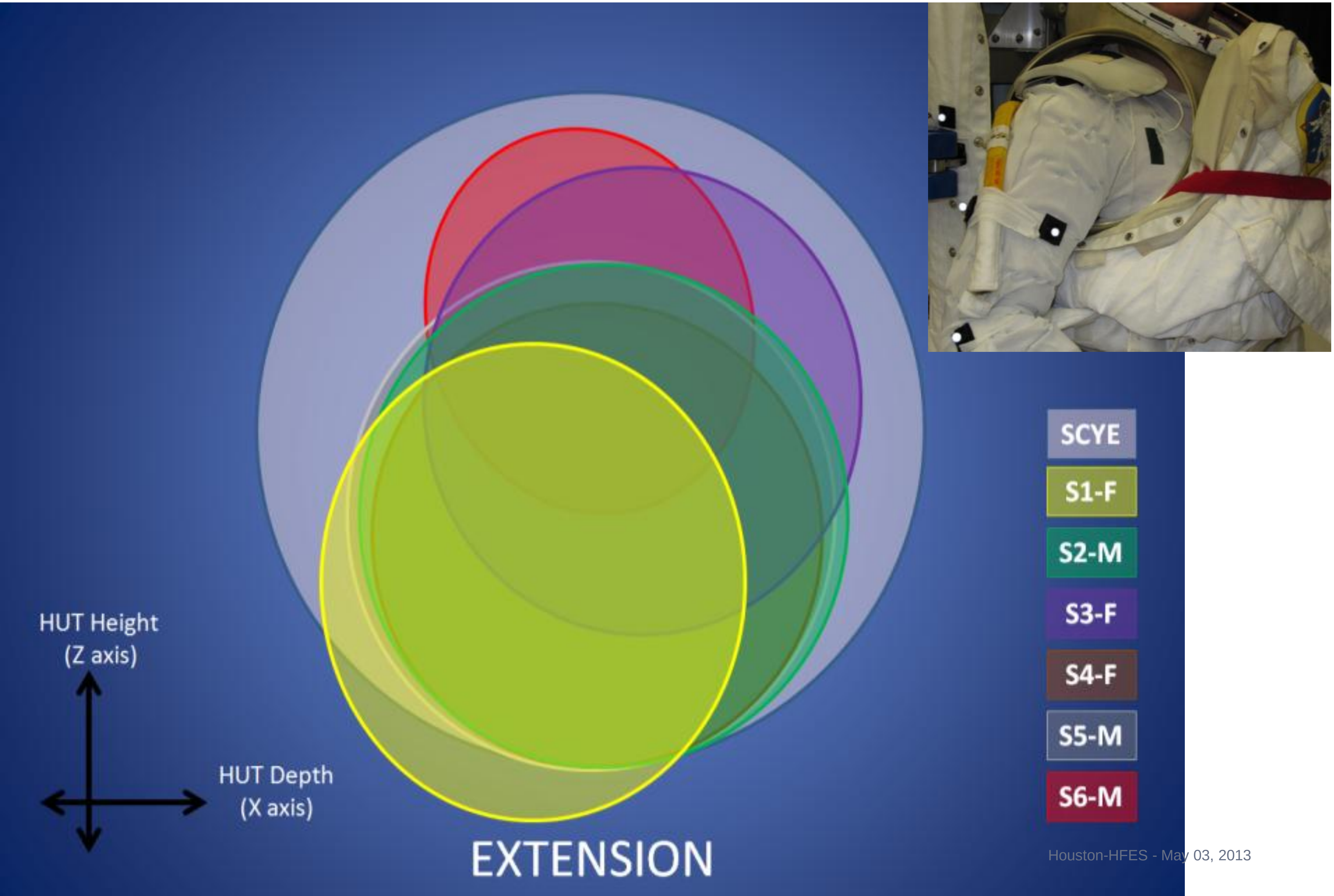

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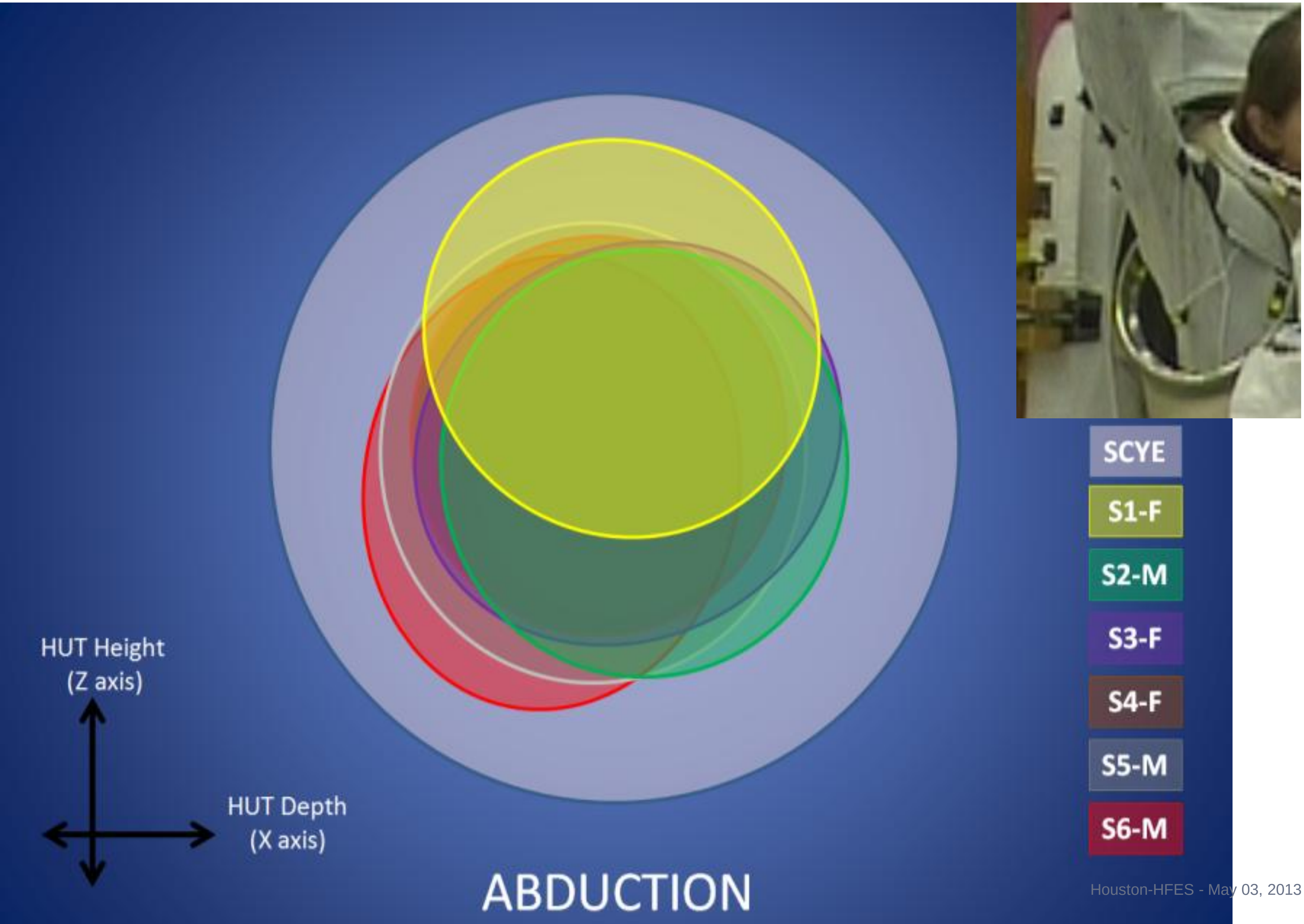

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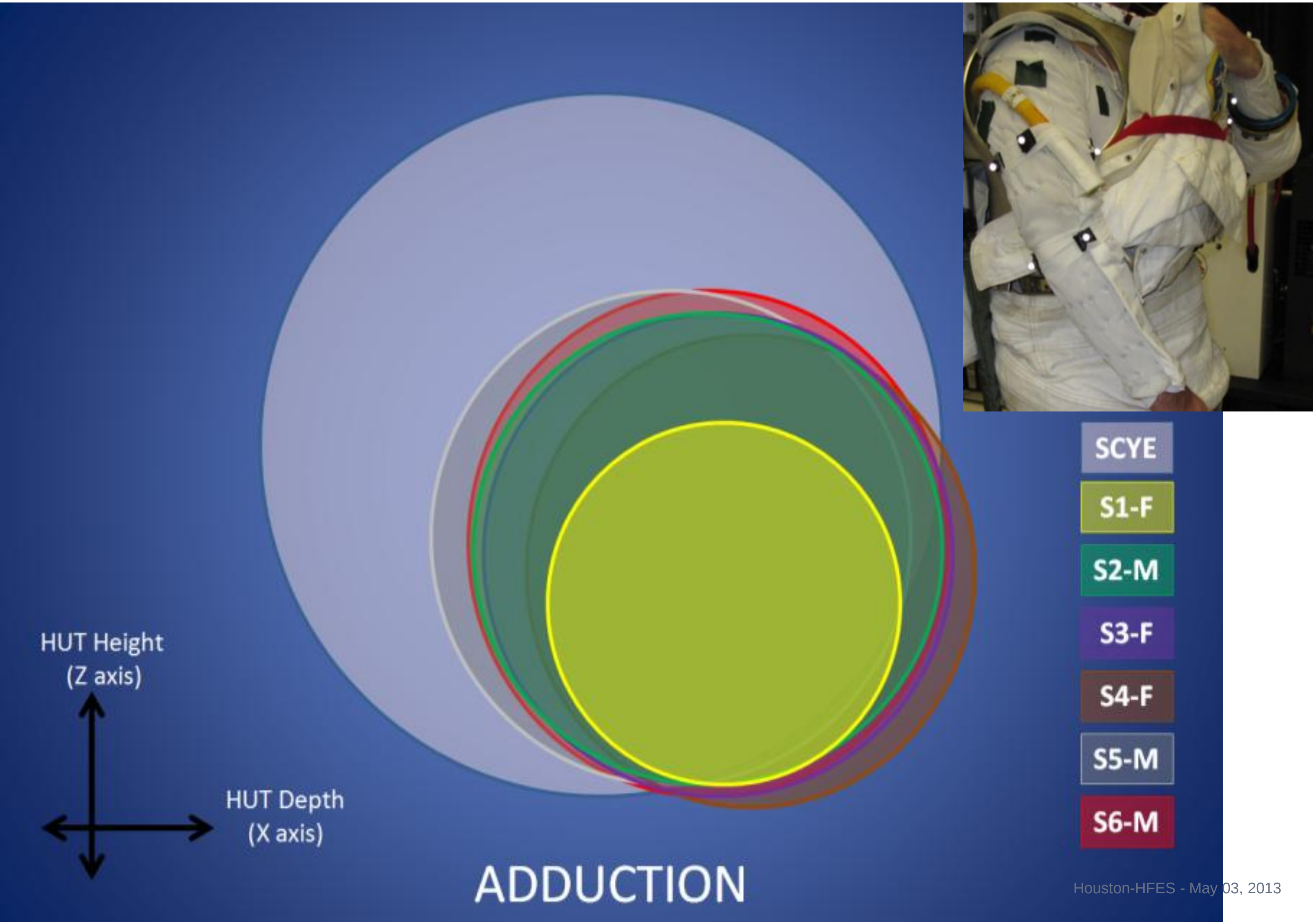

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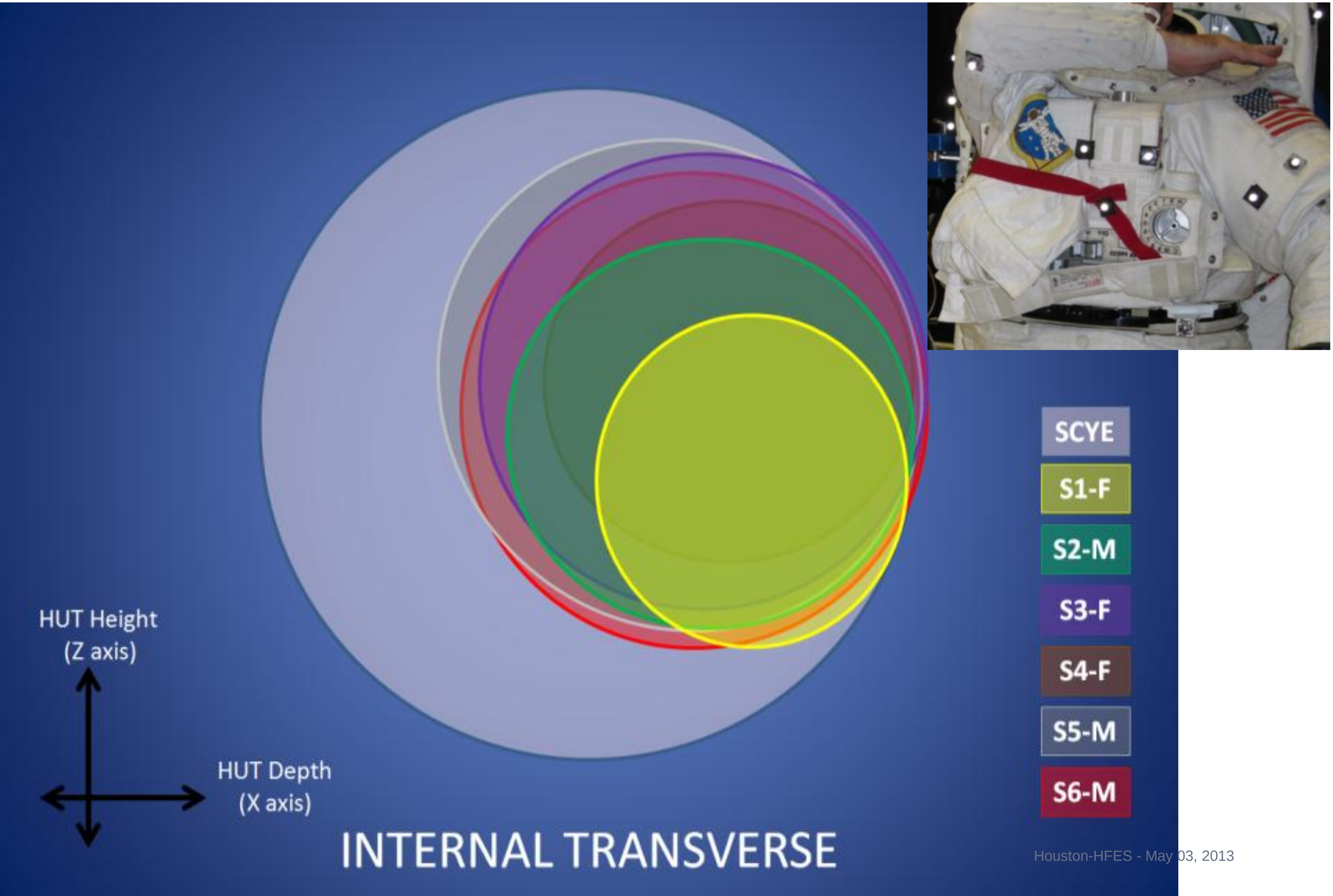
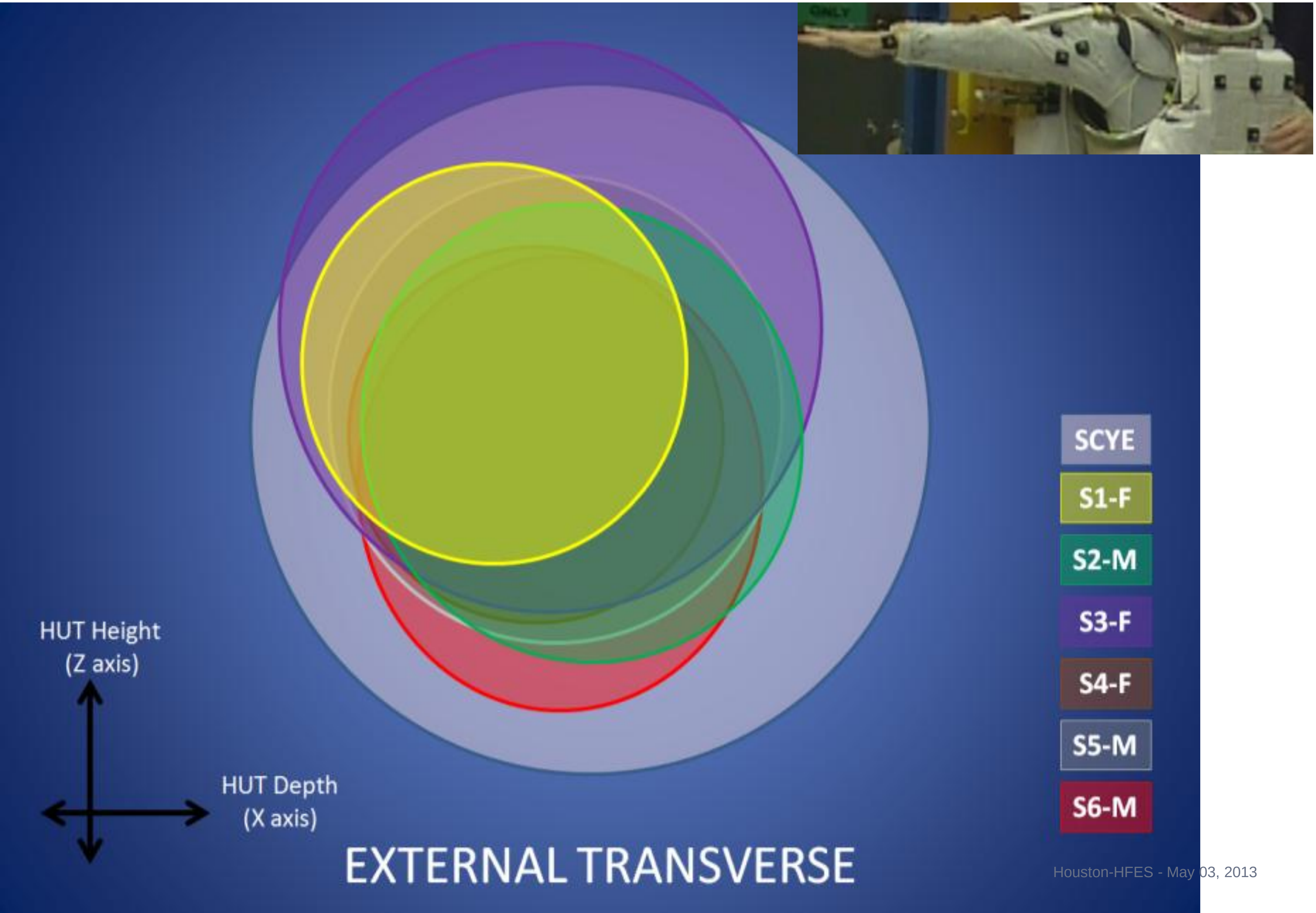


EMU Suit-Body Clearance at Shoulder Joint



EMU Suit-Body Clearance at Shoulder Joint - Results

- The clearance data shows that depending on the shoulder-arm position, the total quantity of clearance around the arm can increase or decrease
  - The subjects depicted show what could be considered as arm-scye clearance envelopes for each shoulder-arm position
- This is one of the first times that investigators are able to see distance between the HUT and the body of the user
  - Unfortunately, this only shows the clearance information for an unpressurized (arm removed) condition with subjects standing upright with a suit stand.
  - The suit-body contact/clearance may differ during 4.3psid conditions with subjects in differing body positions

Overall Conclusion

- Overall for human-suit interaction, we looked at:
  1. Glove-arm sleeve movement

     Method is plausible, but future work should look to implement other types of metric quantification, such as fingertip tactility/pressure sensors with the wrist bearing gap displacement.

     More data is needed in pressurized to better understand what is going on

  2. Use of subjective surveys for human-suit contact

     This method works, but is of lower fidelity than an other possible quantification methods

     Future work should look to use the location information gathered from the surveys and implement other types of metric quantification, such as a pressure system to look at body contact stress.

Overall Conclusion (Continued)

3. Use of 3D shoulder-scye bearing clearance

   This method works, but future work should also look to include how the HUT fits over the shoulder portions as well

- All prove useful, but more subject data is needed to better understand the influence from each of these on the user population
- Future work should also consider:
  - Volumetric analysis between the body and suit
  - Arm bearing movement programming paths

Any Questions???