

National Aeronautics and Space Administration



Suited ergonomics tools and approaches

Anthropometry and Biomechanics Facility

Linh Vu

Aegis Aerospace / NASA Johnson Space Center

Lauren Hickox

Aegis Aerospace / NASA Johnson Space Center

Nate Newby

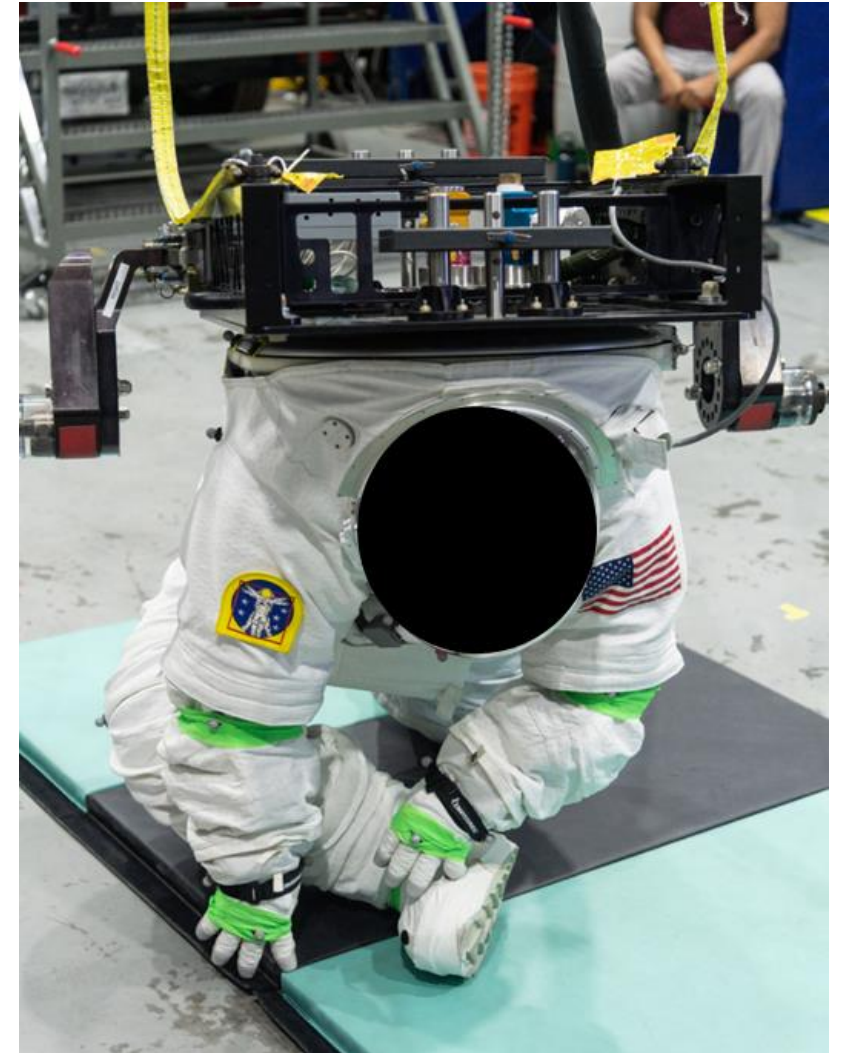
KBR / NASA Johnson Space Center

This work was in part supported by NASA Mars Campaign Office (MCO) and Human Health and Performance Contract (NNJ15HK11B).

Suited ergonomics approach overview

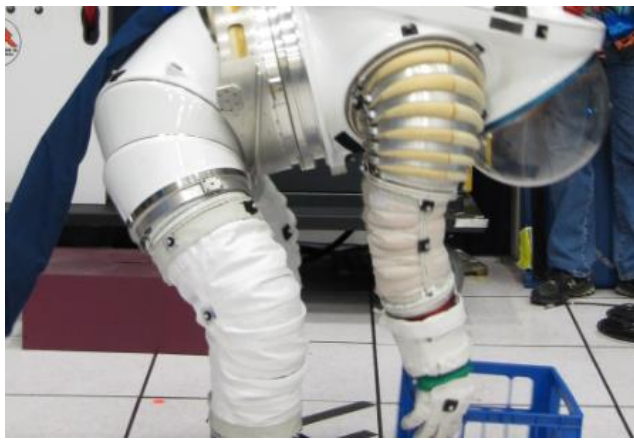
The aim of this presentation is to share our on-going ergonomics work, how these findings can be useful, and future planned efforts

- A variety of techniques is used to study suited ergonomics
 - Video-based observational analysis
 - Subjective feedback surveys
 - Ergonomics modeling
 - Instrumented Human-in-the-loop (HITL) testing



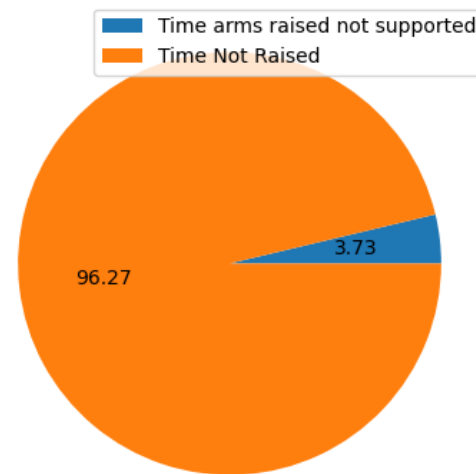
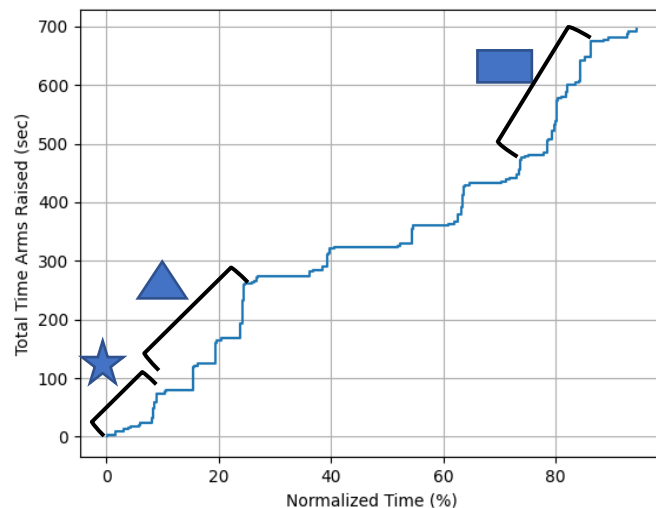
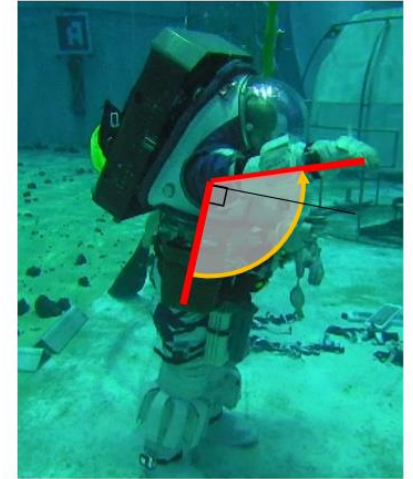
Video-based observational analysis

- Video samples from a variety of EVA tasks across a variety of environments, suits, and subjects were collected
 - Video from a total of 8 ARGOS, 5 NBL, and 2 rockyard test events were assessed

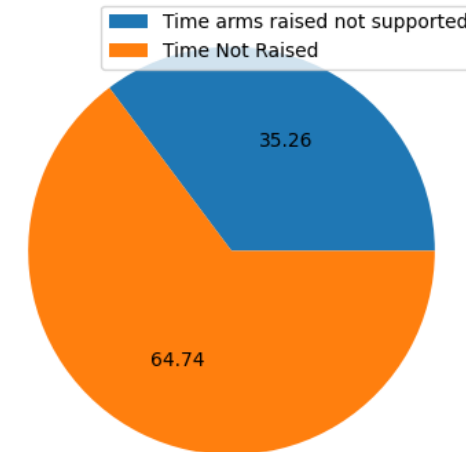


Video-based observational analysis: quantify postural activity

- Video recordings from pilot lunar and microgravity EVA simulations were analyzed
- Arms raised instances were tracked across all events
 - Lunar EVA events: arm at 90 degrees or above with relation to **gravity**
- Lunar surface EVAs introduce a different set of risk factors that effects shoulder injury risk



NBL 1/6G event

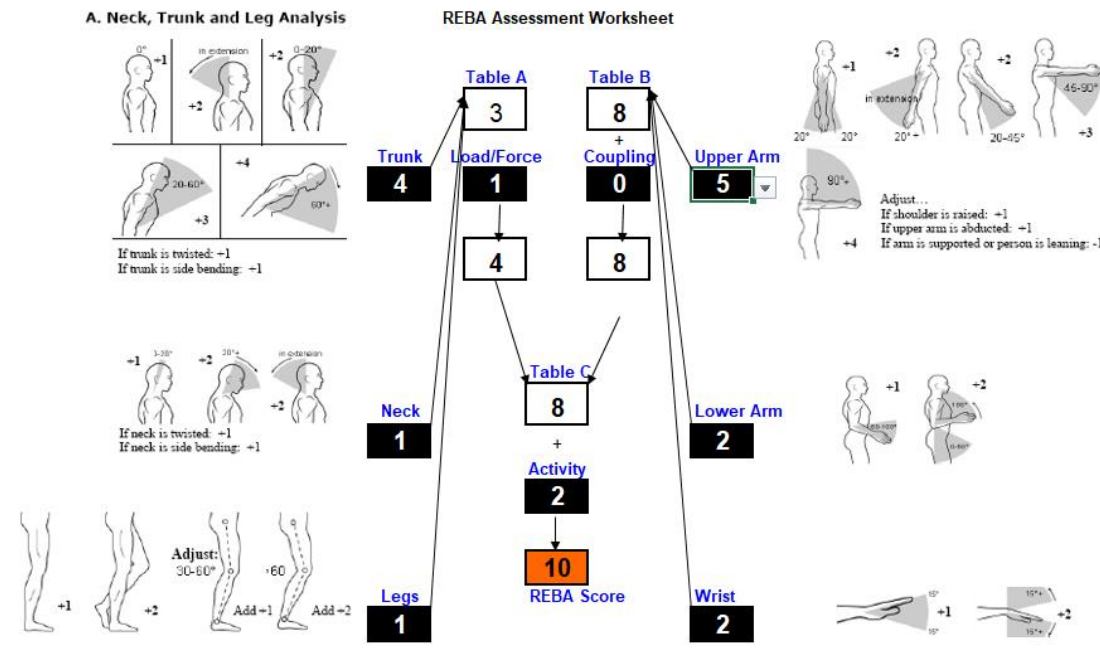


ISS training event reference



Video-based observational analysis: REBA

- The Rapid Entire-Body Assessment (REBA) was used to approximate ergonomic risk for each task
 - Widely used across a diverse range of fields, from manufacturing to health care industries
- Focuses on awkward postures for the whole body
 - upper limbs, lower extremities, trunk and neck



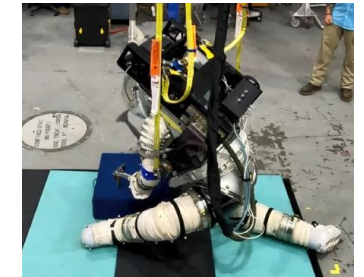
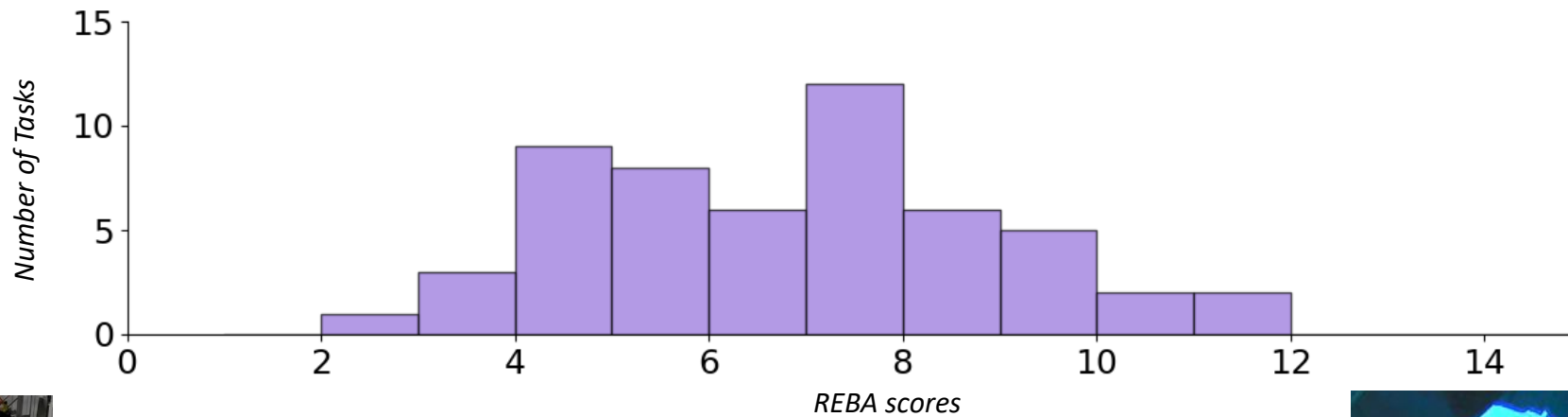
REBA Score	Risk Level
1	Negligable
2-3	Low
4-7	Medium
8-10	High
11-15	Very High

REBA scoring example

Video-based observational analysis: REBA (cont.)

A total of 54 unique EVA postures and tasks across xEMU NBL and ARGOS events were evaluated

- A large number of EVA tasks will involve awkward postures
 - Majority of those tasks involved back bending, kneeling, or a combination of both



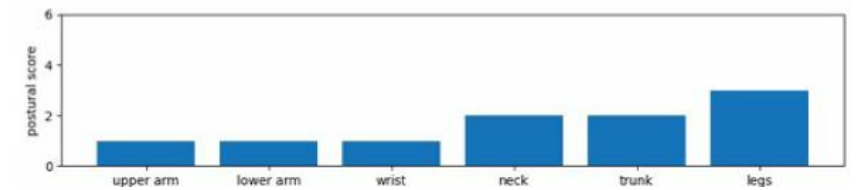
Video-based observational analysis: Limitations and Future work

Future work

- Investigate automated posture tracking from video
 - Minimally invasive ergonomics monitoring applications
- Further examine the dynamic aspects of these tasks

Limitations

- Lunar EVA tasks may not be perfectly simulated
 - e.g. limitations of analog, low fidelity or maturity of hardware interfaces
- Traditional ergonomic assessment tools cannot capture the unique added physical demand provided by the spacesuit
 - Example: pressurized gloves will significantly affect hand grasp ability and hand musculoskeletal loading



Automated REBA score estimation



Increased physical demand (hand fatigue) due to glove pressurization

Ergonomic Risk Factors



REPETITION



AWKWARD POSTURES



VIBRATION



FORCE



CONTACT STRESS

Image source: OSHAcademy

Subjective feedback surveys

- Open-ended ergonomic questions were asked to test subjects after ARGOS and NBL xEMU testing
- Purpose of these questions was to identify and understand ergonomic stressors that may occur during EVA training and missions

AWKWARD POSTURES

Did any of the tasks require extreme reaching, bending, or twisting?

STATIC POSTURES

Did any of the tasks require you to maintain a static posture for a prolonged duration?

FORCEFUL EXERTIONS

Did any of the tasks require a lot of force to perform that lead to fatigue (i.e. excessive pinching, gripping, lifting forces)?

Did any of the tasks lead to a rapid acceleration of movement (e.g. jerkiness?)

Sample questions

Subjective feedback surveys: general insight

There are different ergonomic considerations for different environments

ARGOS

- ARGOS offloads the subject through a single pivot point attachment
 - Arms or legs outside the line of offload are still at 1G
- Geology tasks may require high hand exertions and grip strength for stabilization of the 1G tools
- In ARGOS, some bent over postures can be maintained with very little effort/muscle engagement

NBL

- Extra effort is required to overcome water drag
 - May result in greater fatigue
- Drive tube can be a very challenging task in the NBL
 - Water drag dampens force that can be exerted and increases upper arm demand



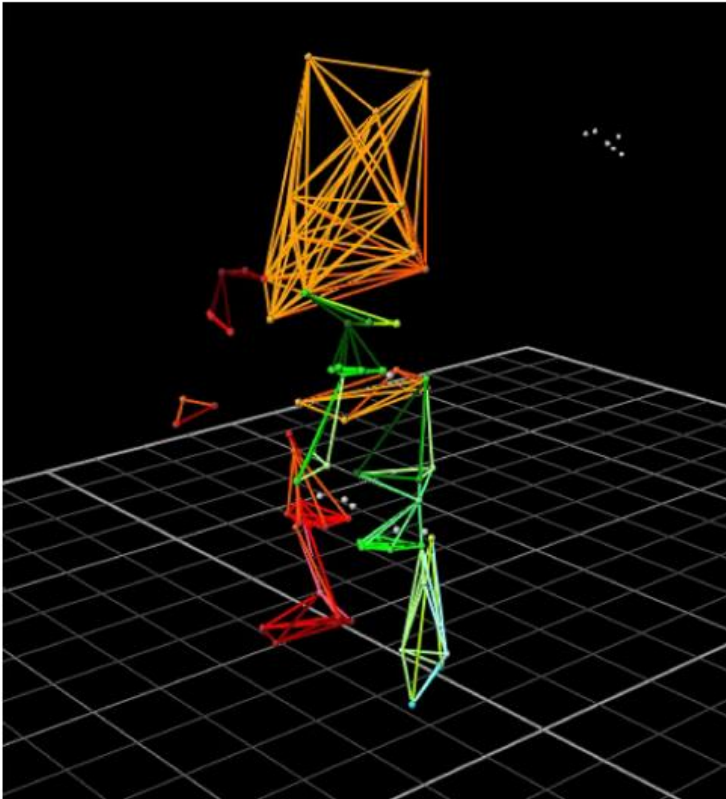
Subjective feedback surveys: Limitations and Future work

Future work

- Identify open questions or knowledge gaps from the subjective feedback
- Corroborate subjective findings with other analysis methods

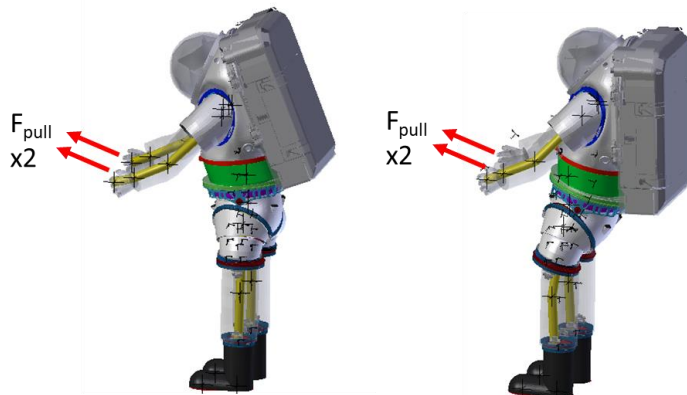
Limitations

- NBL debriefings were conducted after early NBL runs where the weighout process has not been fully developed
- Dependent on subjective perception of discomfort and exertion from a small number of subjects



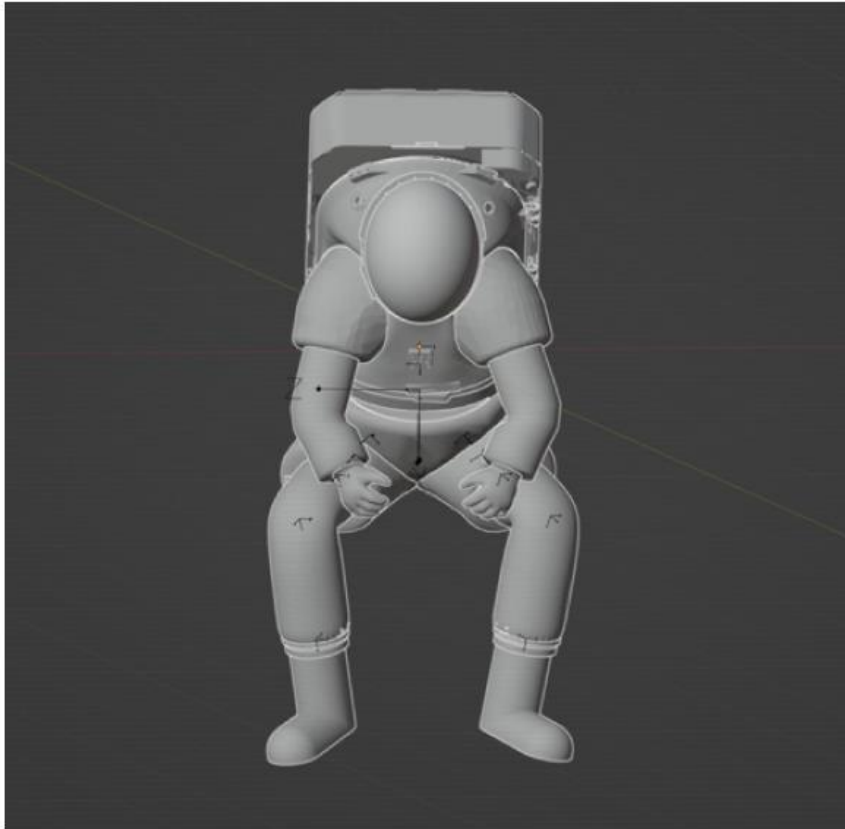
Ergonomics modeling

- A data-driven method was developed to make comparisons between different suited techniques/movements using:
 - Suited motion capture data
 - Suit mass models
- Common suited movements and techniques are characterized with respect to:
 - ergonomic stressors
 - biomechanical demands
- A knowledge base of reference suited motions is being developed

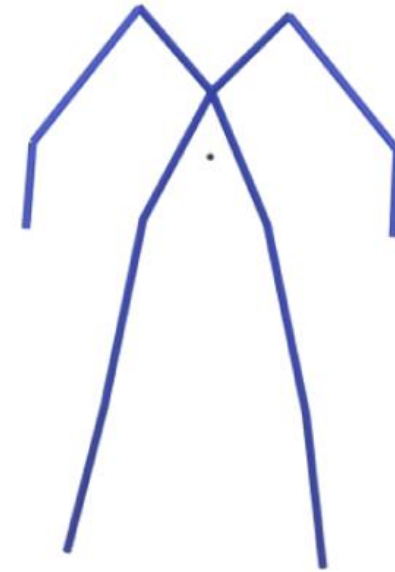


Ergonomics Modeling

3D Model



Stick Figure Animation

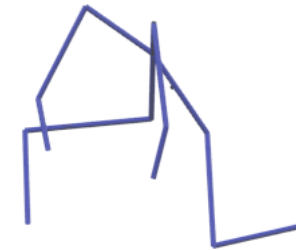


Ergonomic Modeling

Double kneel posture in a prone recovery task

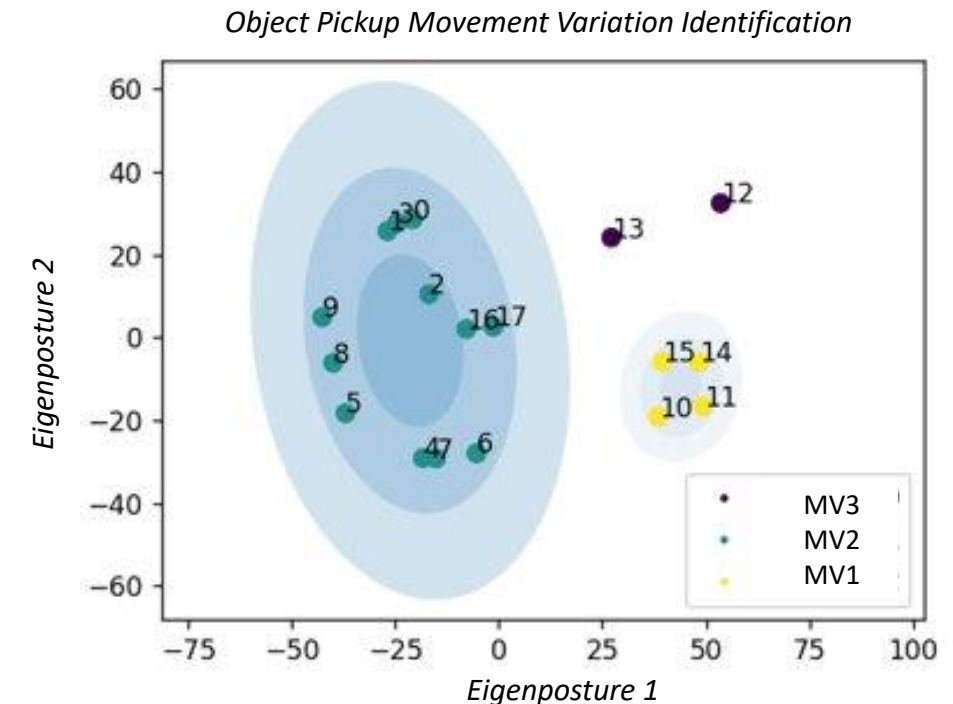


Single kneel posture in a kneel recovery task

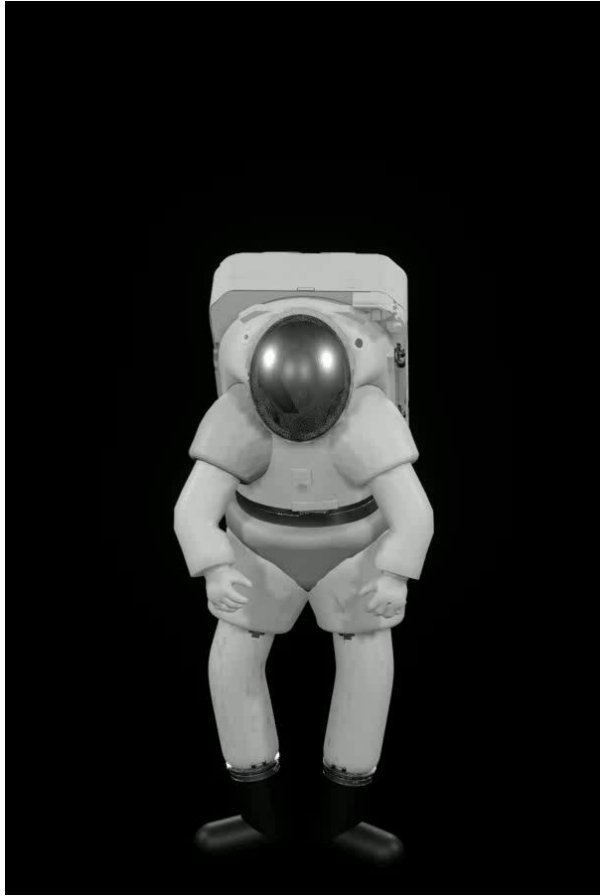


Ergonomic modeling: Movement variation analysis

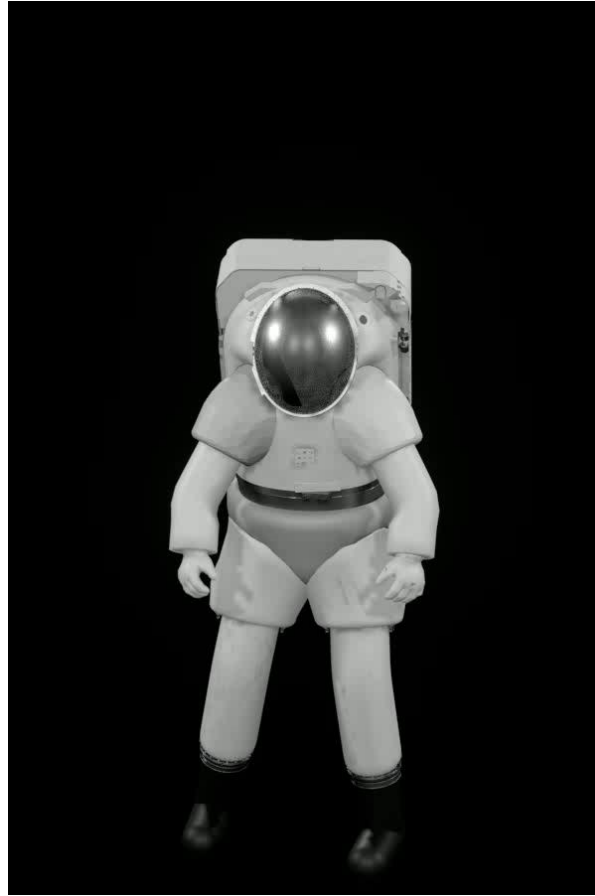
- For the same task, motion capture data from multiple subjects is consolidated
- Movement decomposition is applied using linear factorization techniques to produce “eigenposture” scores
- Eigenposture scores are clustered to identify common EVA movement variations
 - Evaluated for ergonomic stressors and biomechanical demands



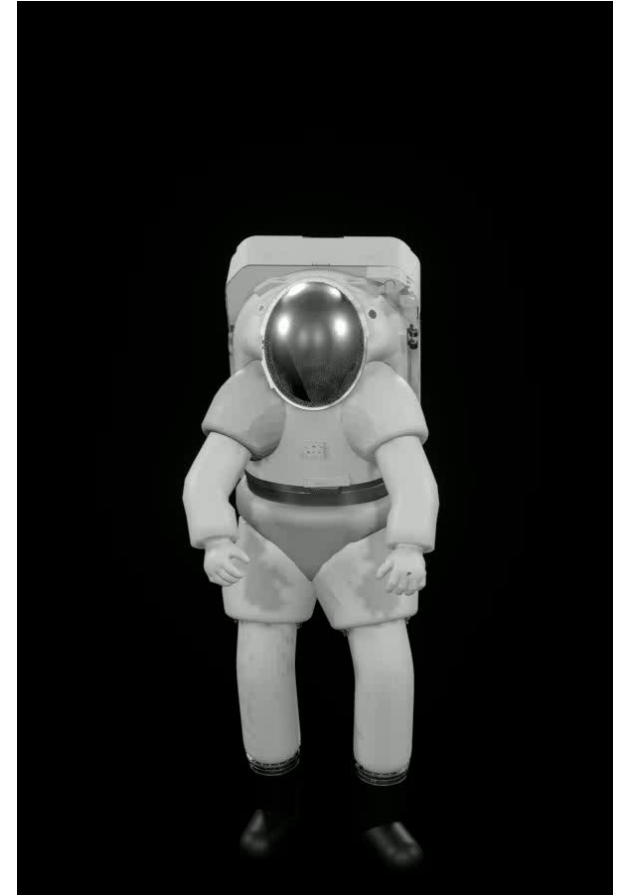
Ergonomic modeling: Movement variation analysis (cont.)



MV1



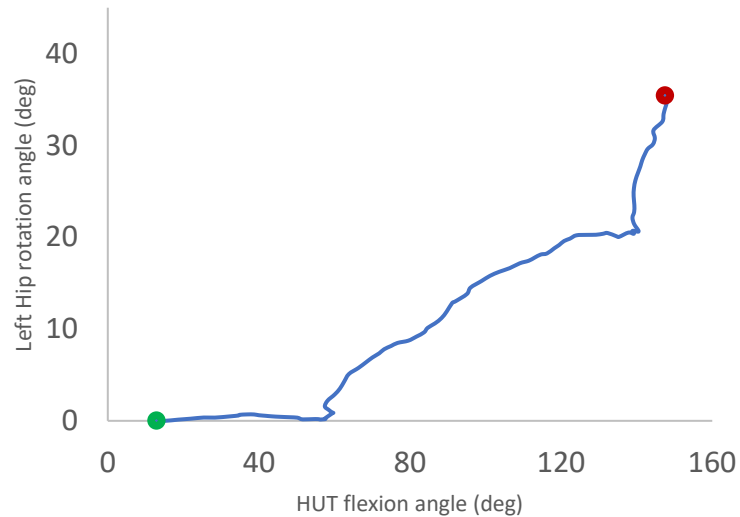
MV2



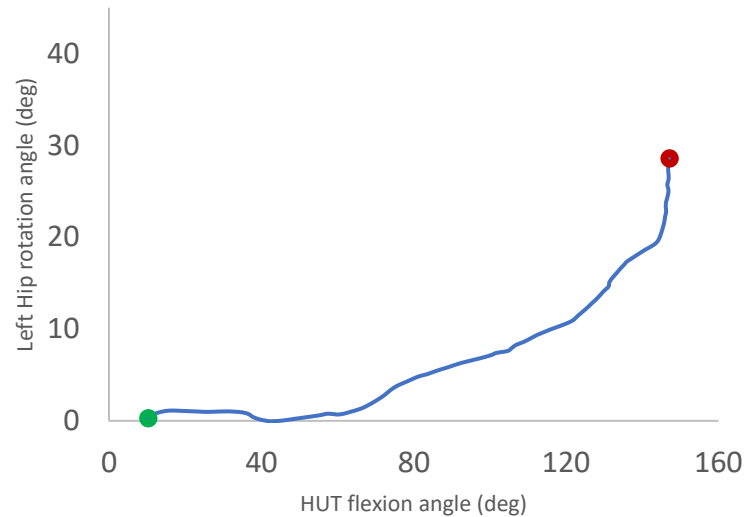
MV3

Ergonomic modeling: Movement variation analysis (cont.)

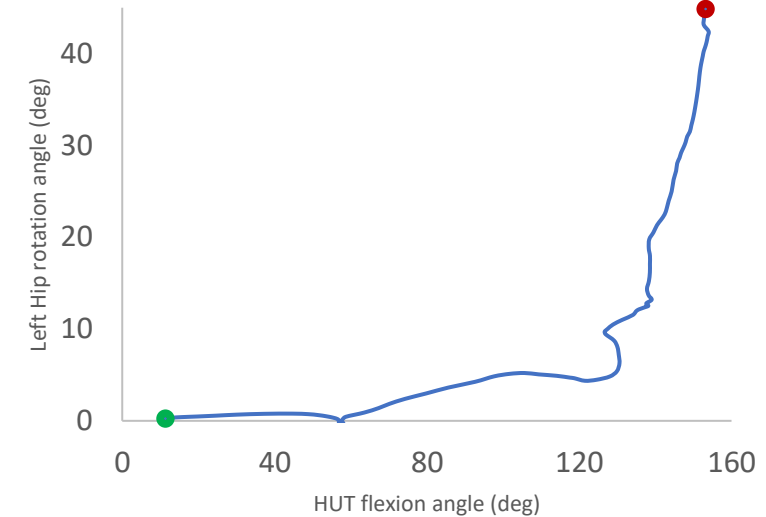
- Using biomechanical analysis, joint coordination patterns were determined using joint-angle cyclograms
 - For each movement, there were distinct left hip/HUT synergy



MV1



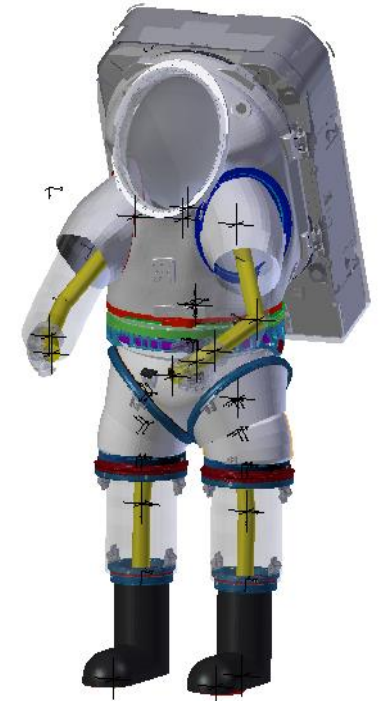
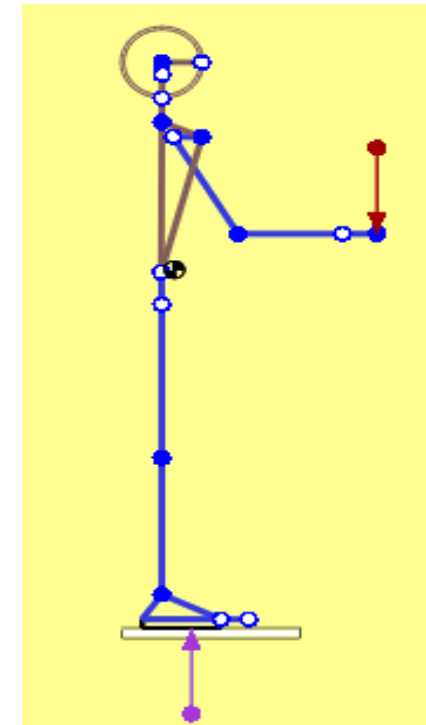
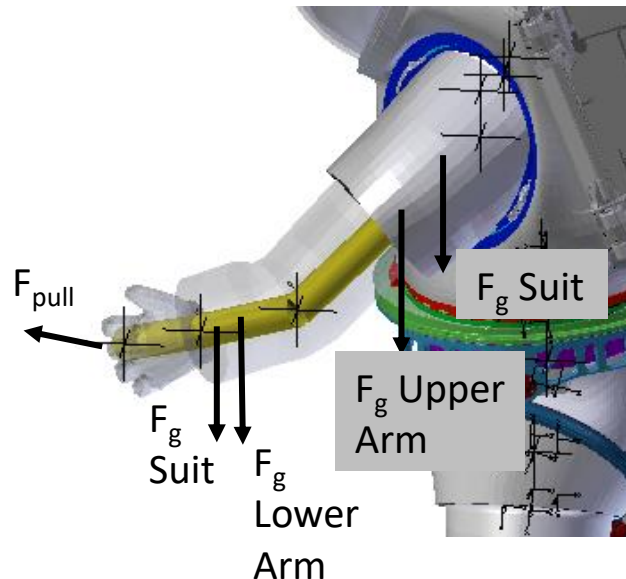
MV2



MV3

Ergonomic modeling: Static Suited Exertion Evaluations

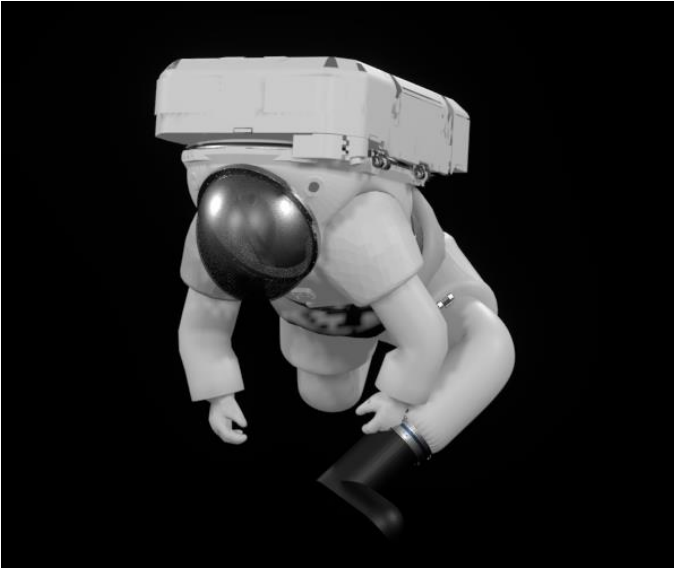
- Building off established human body strength models, mass properties of the suit and human were combined to develop a static human-spacesuit exertion model
- The model can be used to predict joint forces and torques in various postures
- Joint torques can be used to understand task feasibility and as a metric to compare relative ergonomic exertion risk across tasks



3DSSPP human body strength modeling software (right) and human-spacesuit exertion model (left)

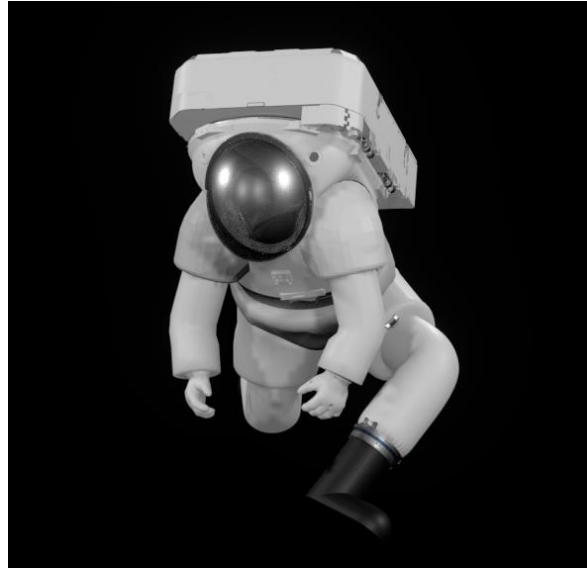
Ergonomic modeling: Static Suited Exertion Evaluations

- Torque differences exist between single kneeling movement variations
 - 1/6g mass properties were used



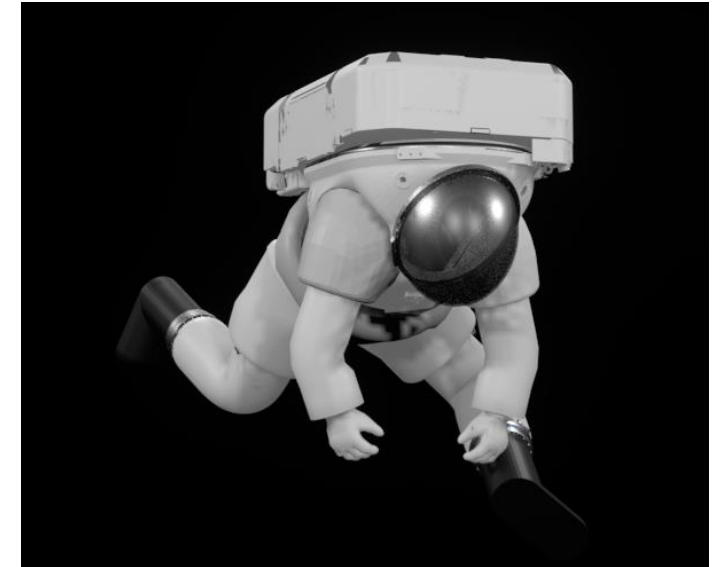
Joint	Torque X [N]	Torque Y [N]
Back	1608	207
Left Ankle	2102	601

Technique 1



Joint	Torque X [N]	Torque Y [N]
Back	1577	104
Left Ankle	1949	587

Technique 2



Joint	Torque X [N]	Torque Y [N]
Back	1621	382
Left Ankle	2515	484

Technique 3

Ergonomic modeling: Discussion

Future work

- Evaluate technique and torque differences between subjects with varying anthropometry
- Compare movement strategies against spacesuit experience
 - Do more experienced users employ more efficient strategies?
- Optimization can be performed to explore less stressful/efficient ways to accomplish the task

Limitations

- This analysis is dependent on having a large and comprehensive dataset
- Static Suited Exertion evaluations is pseudo-dynamic; but could be appropriate these suited tasks
- **Intrinsic suit factors** (e.g., pressurization and stiffness of the suit) and **offload conditions** will influence exertions and torques



Instrumented Human in the loop testing

- Wearables sensors and instrumentation can help us understand what is happening to the human inside the suit and additional injury mechanisms
- Sensor data can inform:
 - Areas of high contact stresses
 - Human kinematics that are decoupled from the suit kinematics
 - Muscle recruitment patterns
 - Asynchronous muscle activations



Instrumented HITL: Mockup suit testing

- Motion capture and wearable sensor data were collected from subjects performing push, pull, and lifting tasks in both the unsuited and mockup suited conditions
 - Mockup suit was used as testbed for procedures and sensor logistics
- In the mockup suit, when push/pull forces were applied at the range of motion boundaries, muscle exertions were found to be higher across back and lower body

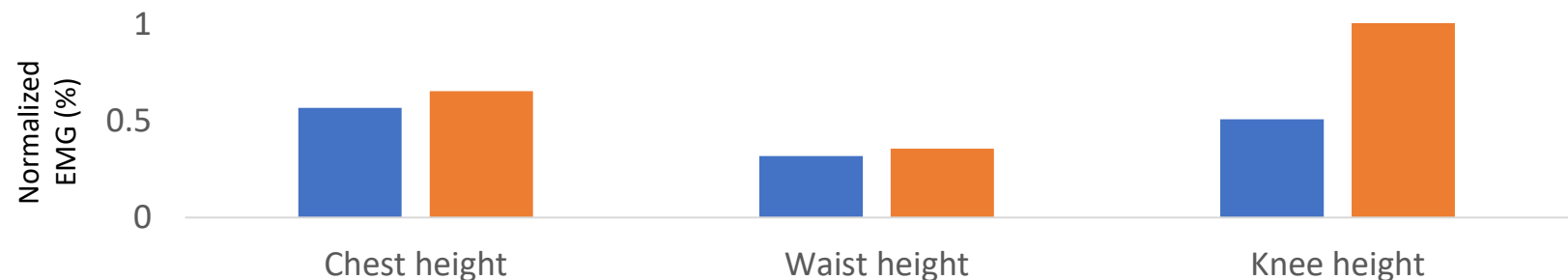


Push exertions at knee and chest height

Lower Body



Torso (back)



Instrumented HITL: Limitations and Future work

Future work

- Pressurized suited testing could be performed with the force measurement sensors and EMG sensors

Limitations

- Only sparse low-fidelity, pilot testing data has been collected to-date