



Applied Injury Biomechanics: Engineering Tools

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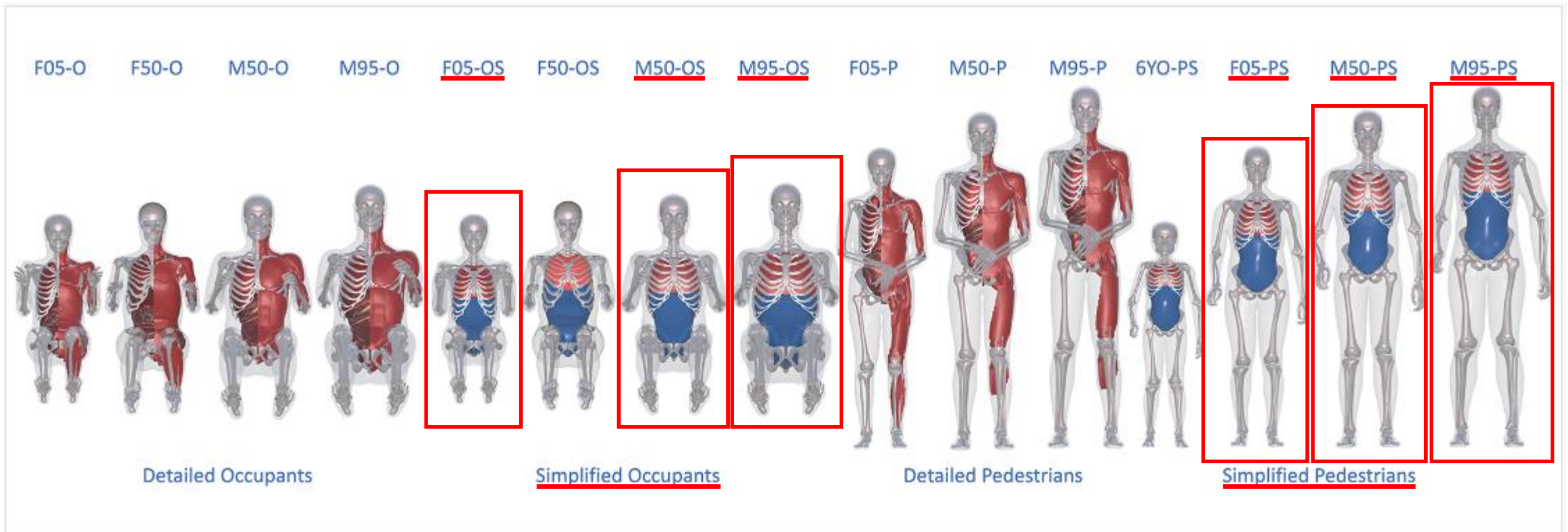


Finite Element Modeling

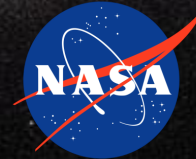
Human Body Finite Element Modeling



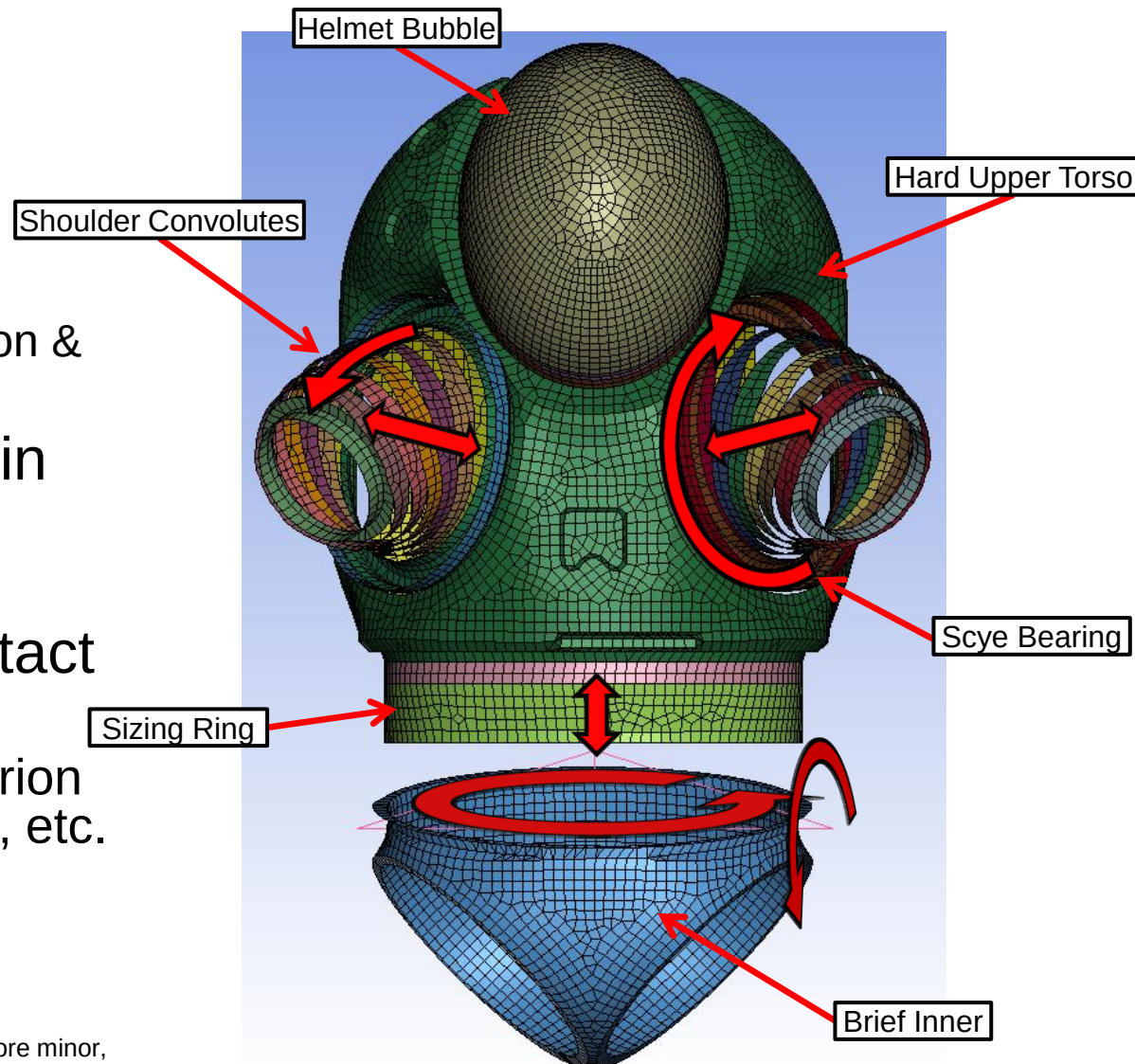
- Global Human Body Models Consortium (GHBMC)
 - “The mission of the GHBMC is to develop and maintain high fidelity Finite Element human body models for automotive crash simulations.” - <https://www.ghbmc.com/>



GHBMC-Suit Interaction Modeling



- Occupant-facing hard suit components modeled
 - Rigid shell element internal suit parts
 - Mathematically defined joints
 - Shoulder convolutes, scye bearing, brief flexion & rotation
- Various occupant models positioned within
 - Sizing modifications: sizing ring, scye in/out configuration
- Investigate standard injury metrics & contact stresses
 - Head Injury Criterion (HIC), Brain Injury Criterion (BrIC), Neck Injury Criterion (Nij), bone loads, etc.
 - No standardized injury metrics for soft tissue contact injuries*



* This is a gap in our current capabilities. These models and standard injury metrics are not designed for more minor, performance hindering injuries like bruises & abrasions.

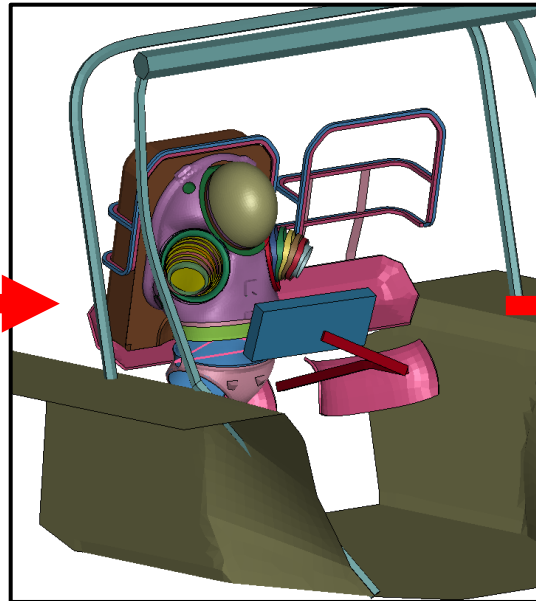
Rover Modeling Capability



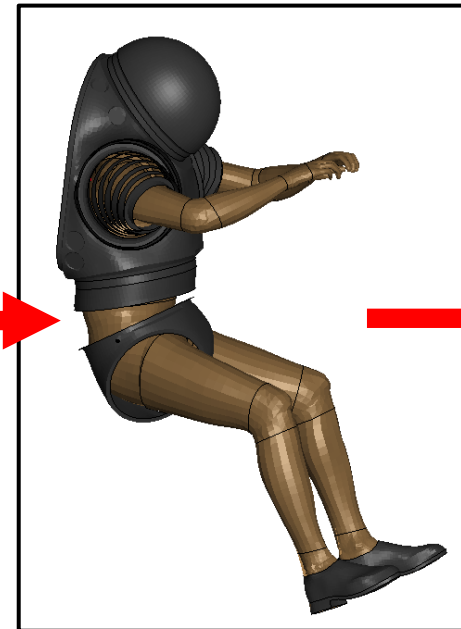
1) NASA rover concept: starting geometry



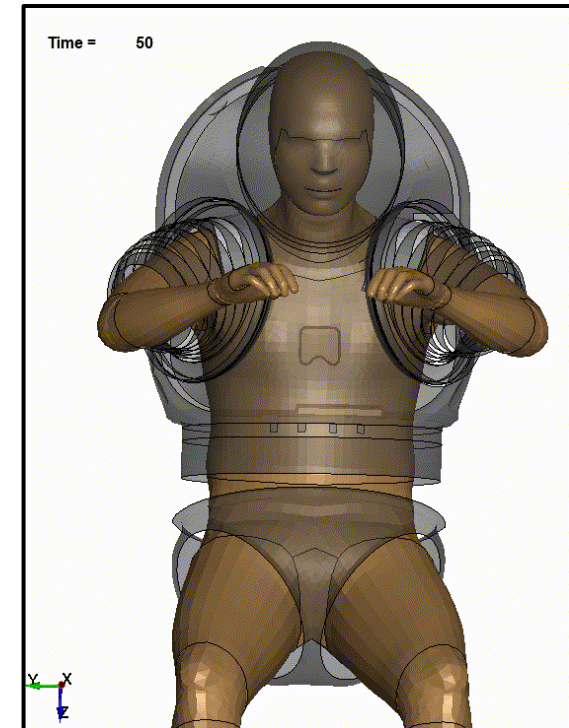
2) Position suit model



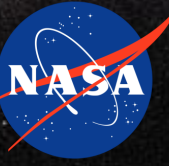
3) Position HBM within suit model



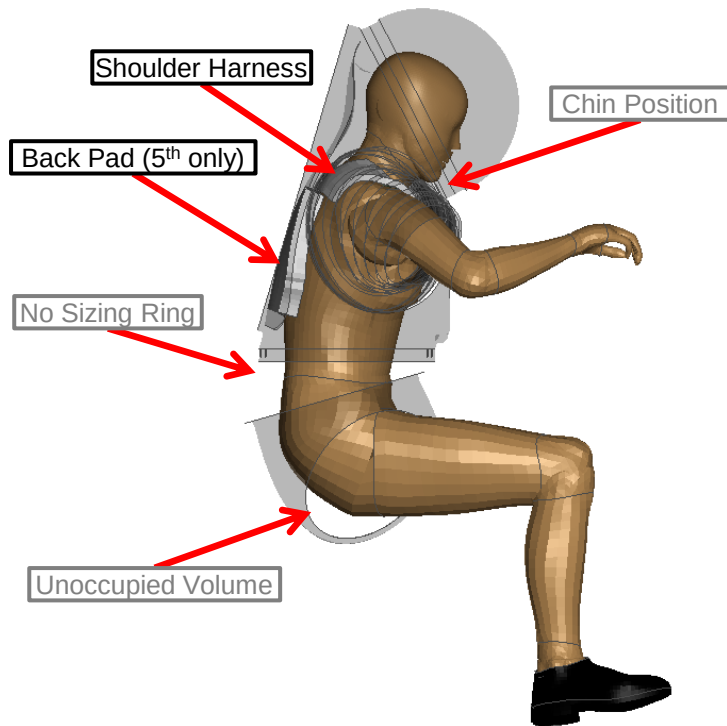
4) Simulate Dynamic Loads



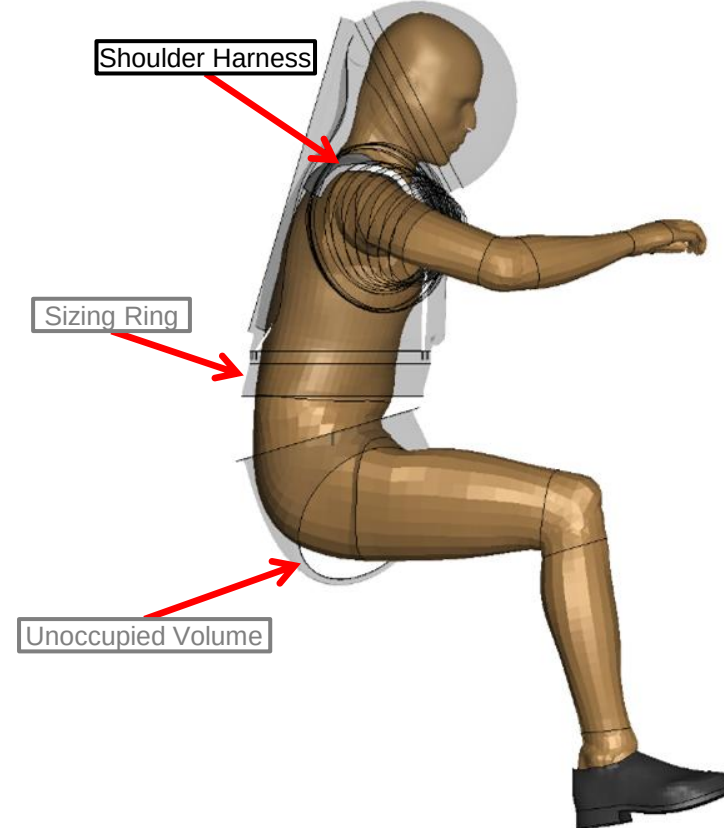
GHBMCSuit Positioning



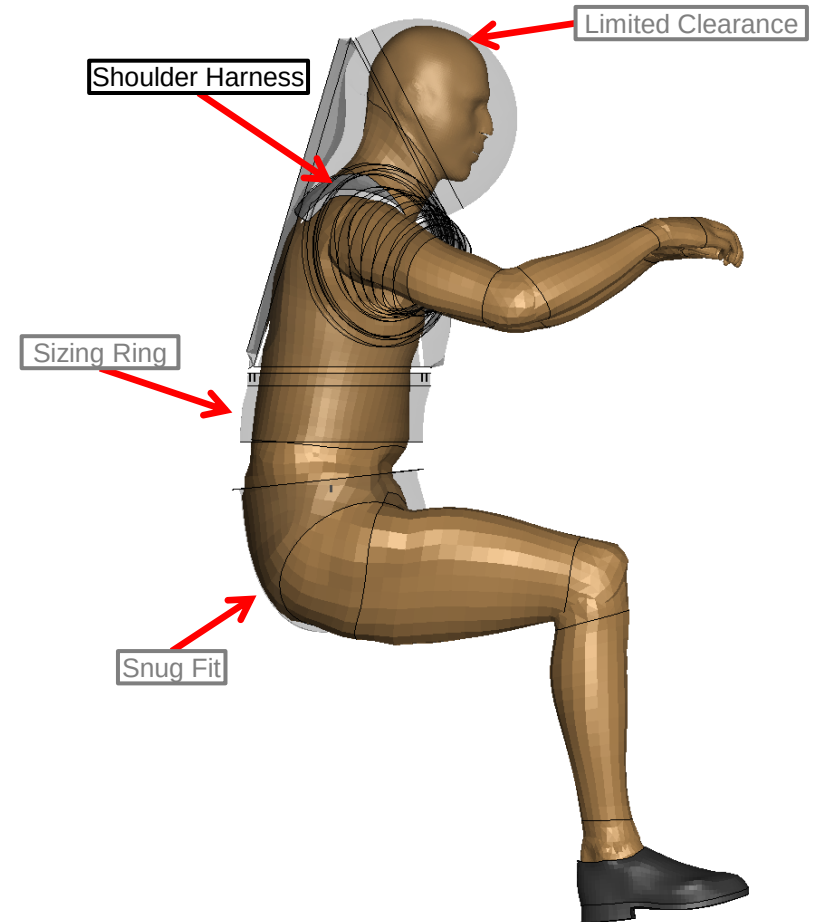
GHBMCSuit 5th %ile female



GHBMCSuit 50th %ile male



GHBMCSuit 95th %ile male

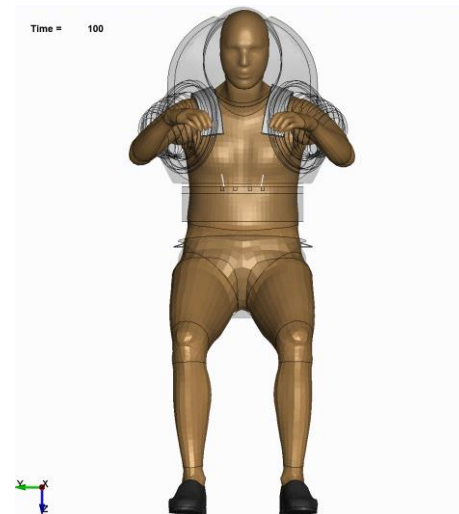
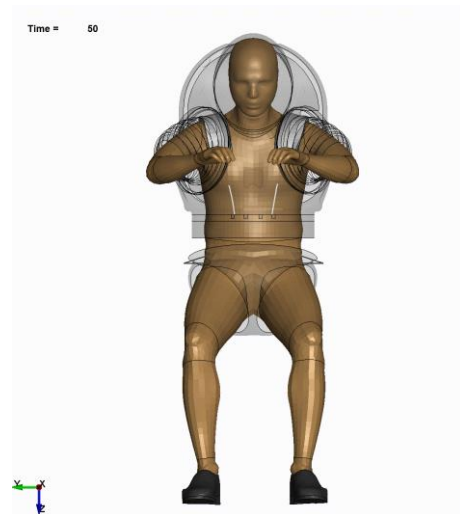
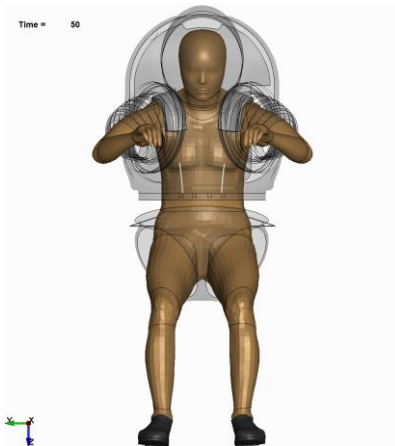


Note: Anthropometries derived from single individuals approximating desired %ile height & weight (not all measurements are representative)

GHBMC-Suit Dynamic Loading



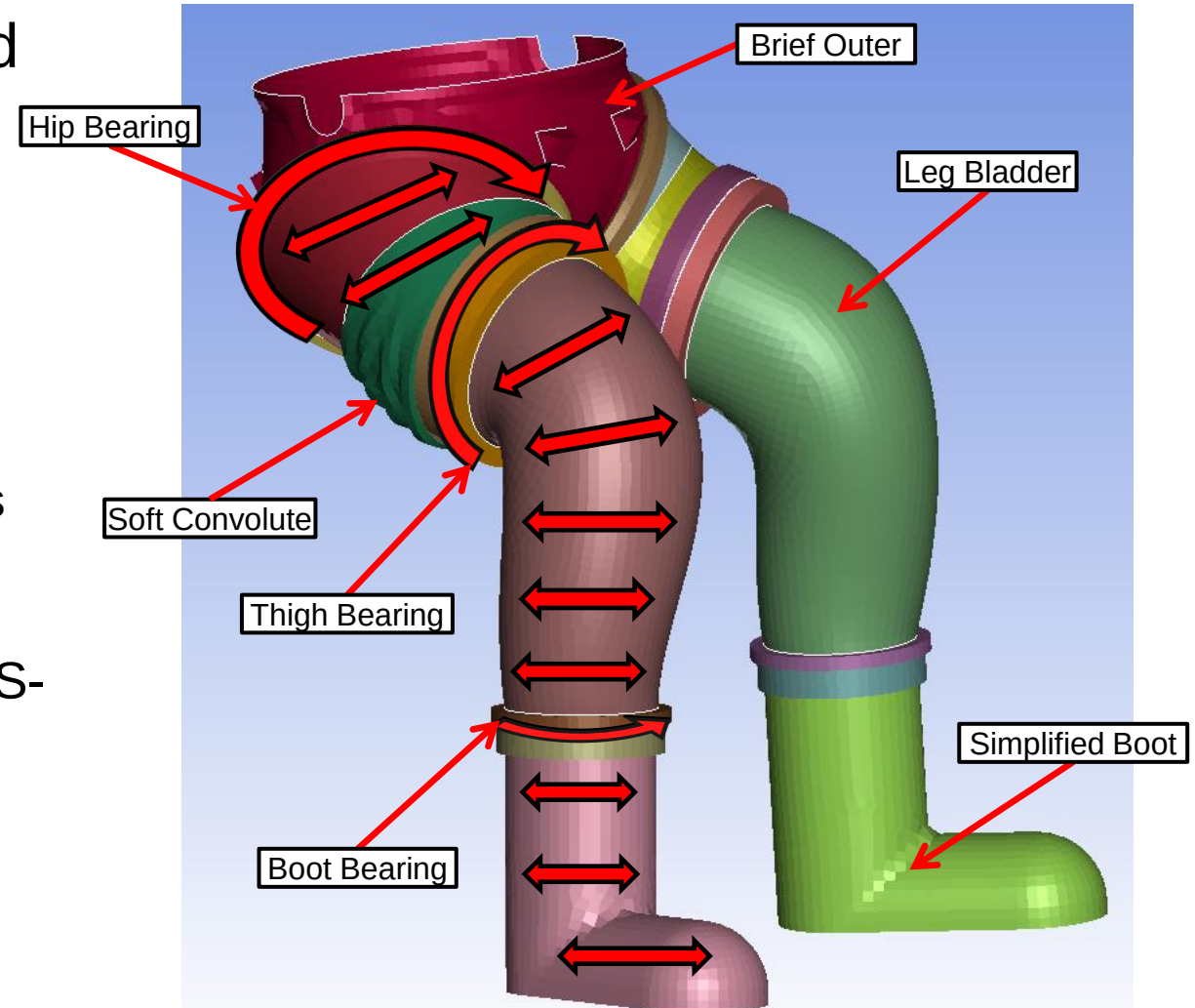
Semi-seated positioning, Combined X/Y/Z loading, Accelerations applied to HUT



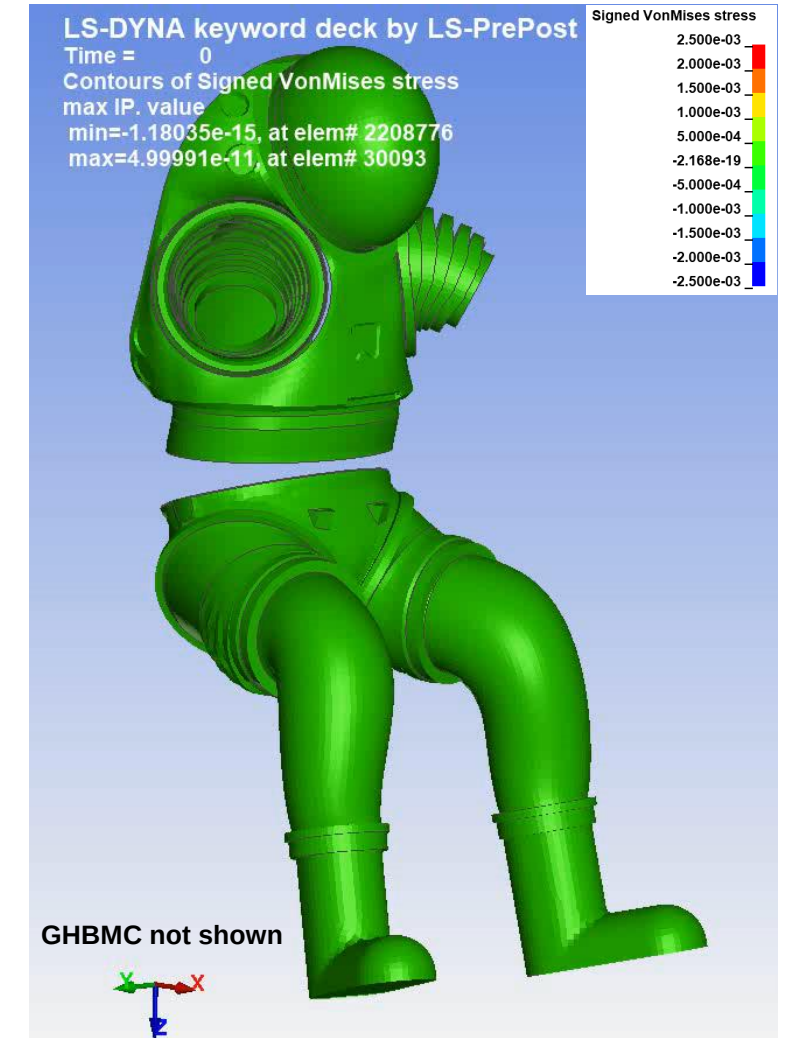
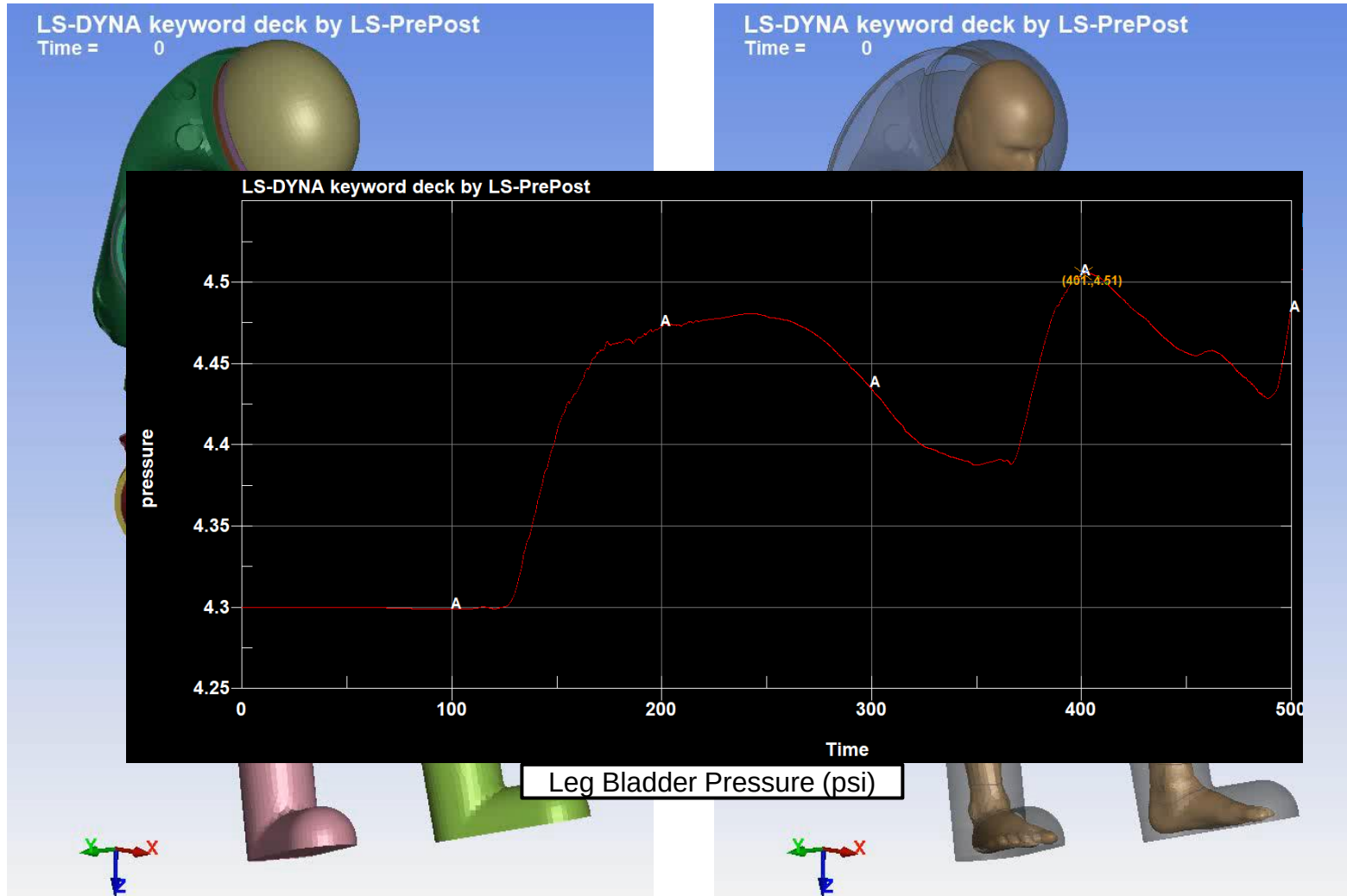
Pressurized Soft Good Modeling



- Preliminary work to model pressurized soft goods
 - Mathematical joints defined at hip, thigh, boot bearings
 - Rigid shell parts
 - Only representing the bladder layer – no restraint layer, axial restraints, EPG
 - Simplified geometry & material definitions
 - Initial focus is on pressurization & HBM interactions
 - Soft goods pressurized to 4.3 psi using LS-DYNA “simple airbag” definition
 - 0.31 mm fabric material definition for soft goods
 - 10 mm neoprene material for boots



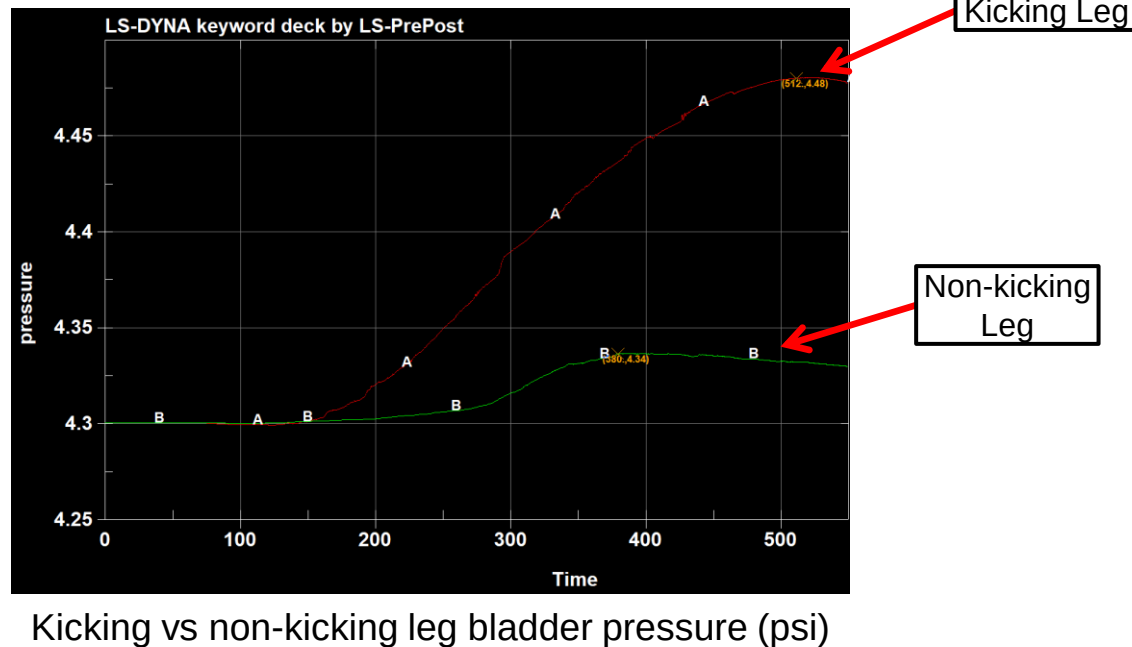
Pressurized Soft Good Modeling



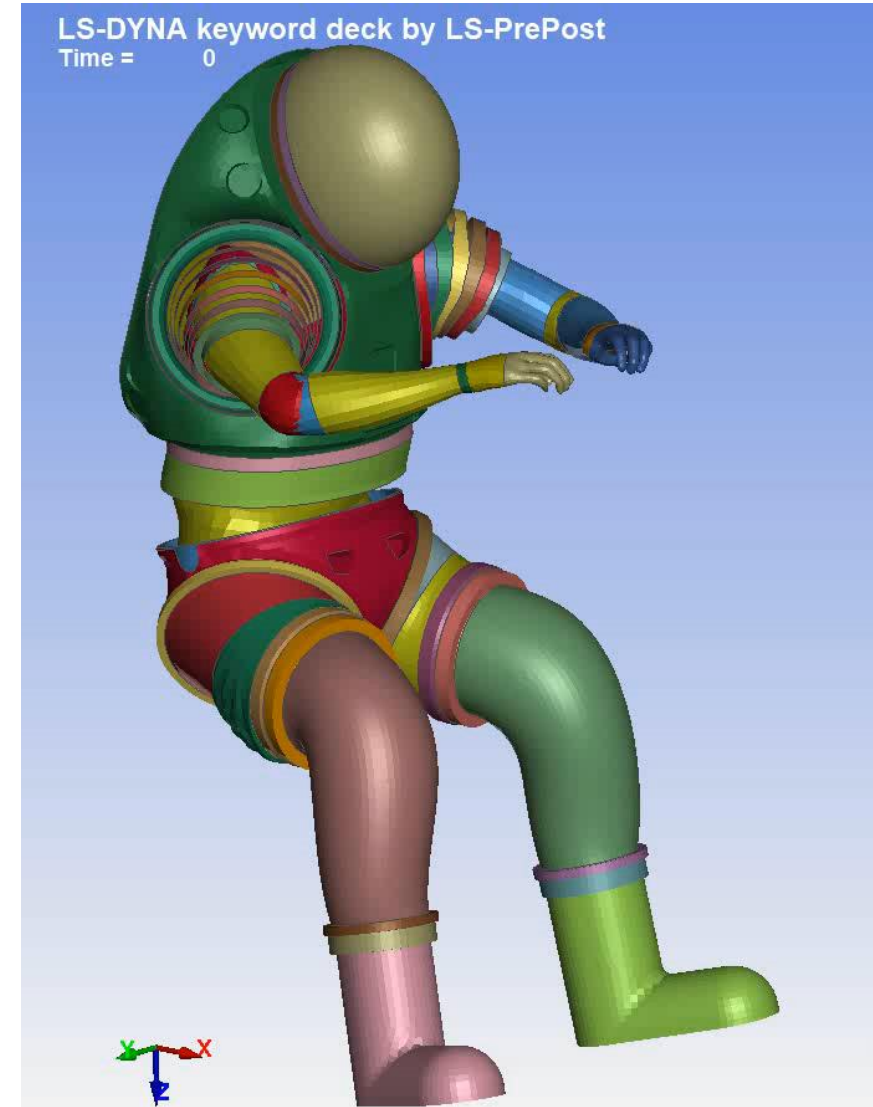
Pressurized Soft Good Modeling



- Potential use cases for pressurized suit model
 - Rover loads: with solid or belted restraints
 - HBM driven loads: occupant working against the suit*
 - Falls from heights
 - Suited landing loads



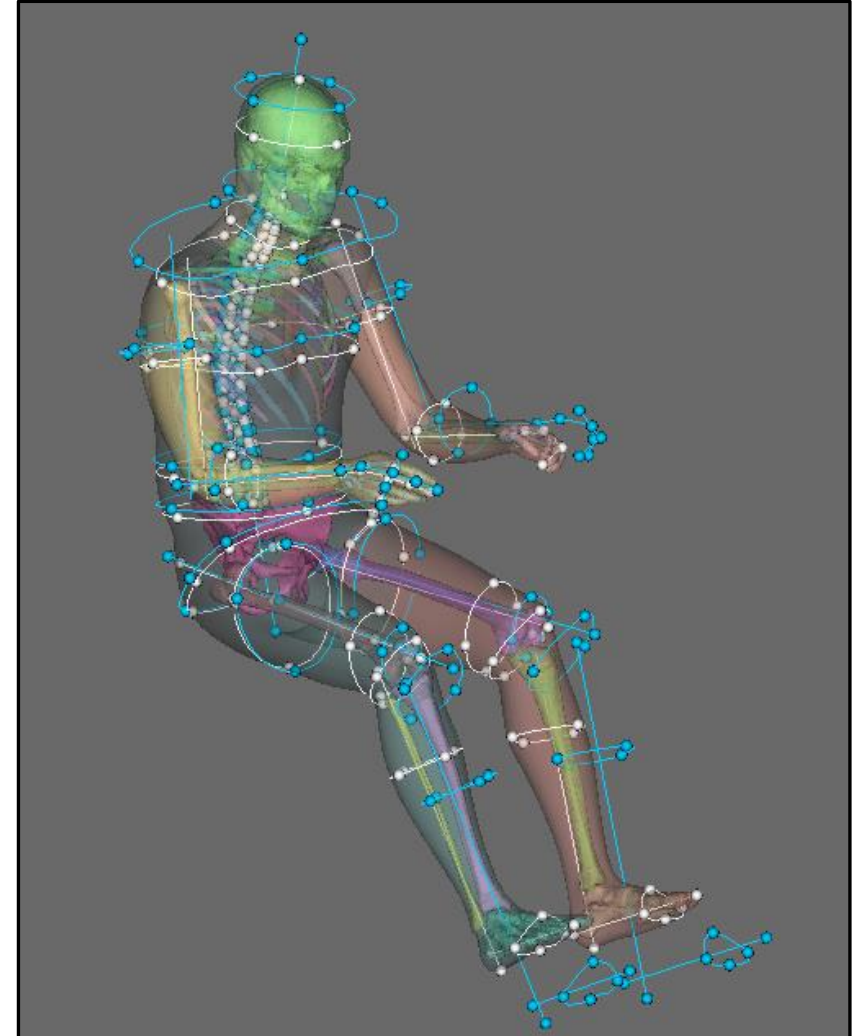
HBM-driven leg kick simulation*



Model Morphing Capabilities: PIPER



- Approach
 - Start with a GHBMC baseline model
 - F-5, M-50, M-95
 - Input anthropometric measurements
 - PIPER interpolates other measures from ANSUR database
 - Software produces a scaled model
- Subject-specific modeling
 - Limited number of crewmembers makes this a viable option
- Worst-case anthropometry assessment
 - Determine injury-driving critical anthro measures
 - Simulate loads with worst-case manikins



Lunar Landing Loads: Active Musculature



Specific Aim 1

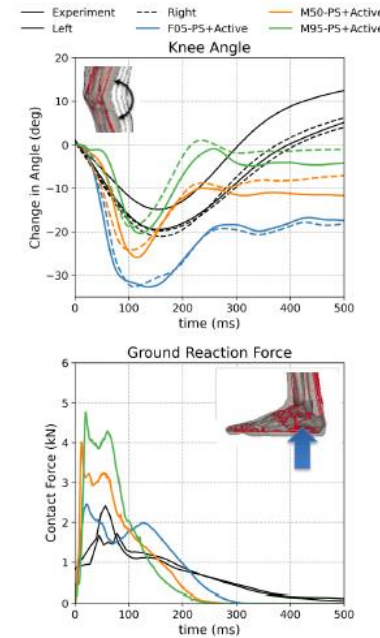


Develop F05-PS+Active and
M95-PS+Active

Specific Aim 2



Lunar landing:
Effects of size and sex

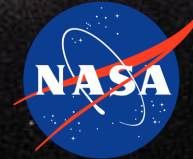


Development of Active Muscle F5 and M95 Models & Simulation of Lunar Stepdown Loads
Wake Forest Center for Injury Biomechanics: Karan Devane



Suited Motion Tracking & Biomechanical Modeling

Suited Motion Tracking & Biomechanical Modeling



Importance

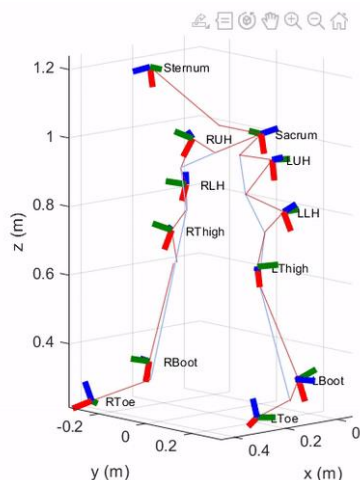
While wearing a pressurized space suit, human motion is notably different from unsuited human motion.

Understanding the unique aspects of suited motion is critical given its potential association with injury risk, and suited kinematics and kinetics are used to drive various injury risk analysis methods.

Suit kinematics will vary across training analogues and simulation conditions.



Unsuited Testing



Suited Testing and Model Validation

Purpose

Kinematic suit characterizations need to be performed across all training environments and analogues.

To be able to conduct pressurized space suit testing outside of traditional laboratory environments (e.g., ARGOS, etc.), alternative technologies need to be investigated and validated outside of the lab-based optical motion capture will be explored.

Suited Motion Tracking & Biomechanical Modeling

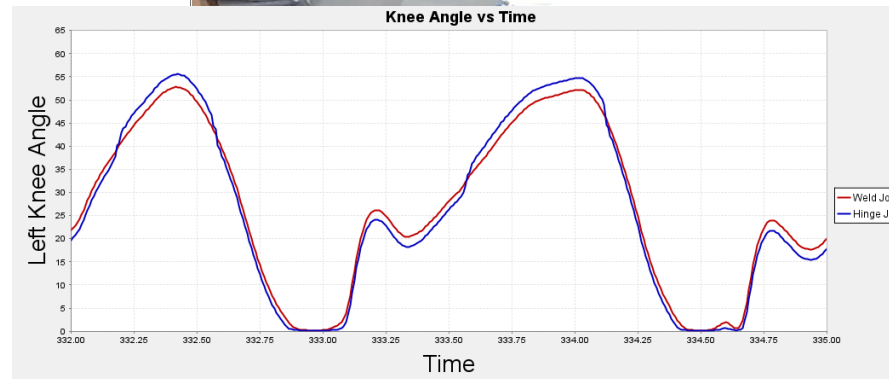
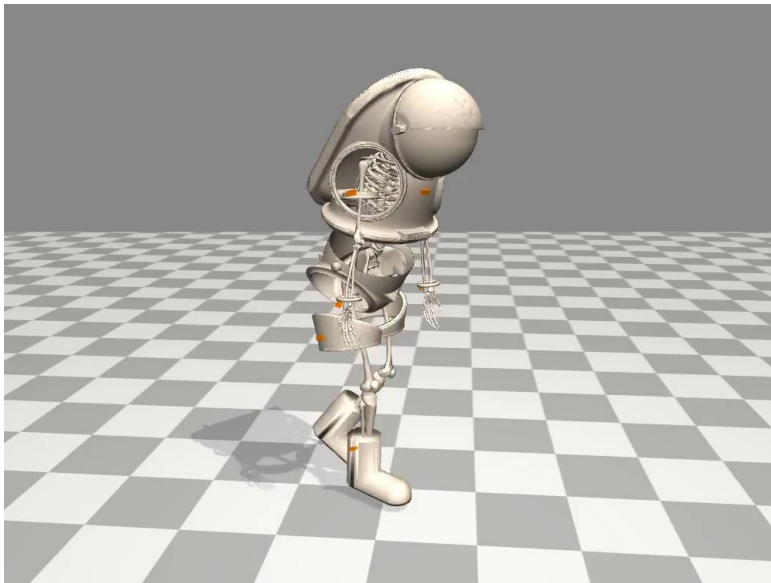
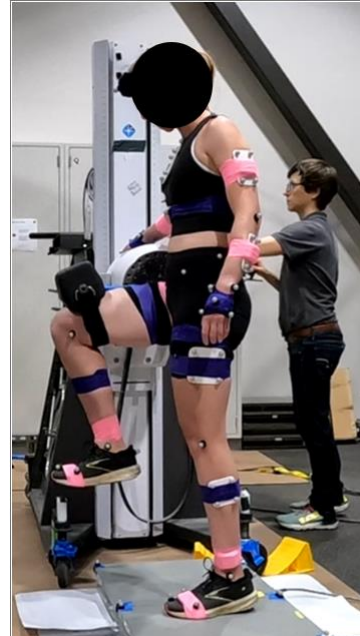


Effective modeling of human and suit kinematics has a range of benefits:

- Injury Assessment
- Task Assessment
- Material Wear of the Spacesuit
- Aids in Metabolic Modeling

Developing models can be used to gain insight into the human kinematics and kinetics during suited and unsuited training tasks.

To quantify what is happening at and about each joint and assist in identifying if approaching injury threshold.



Deriving Human and Spacesuit Kinematics using IMU Data in OpenSim





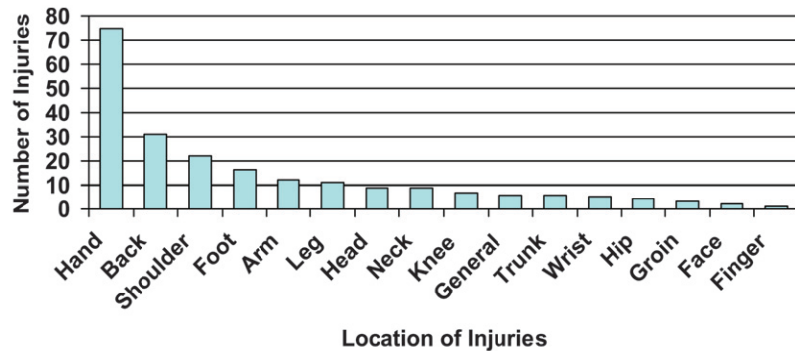
Hand & Glove

Hand and Glove

Importance

Hand injury is the #1 reported issue in a space suit.

Understanding glove exertions is critical for ergonomic, biomechanical, and manual material handling evaluations. However, evaluating glove exertions in a pressurized glove environment is a complex task.



Hand injury is the leading injury location during in-flight throughout the entire U.S. space program. (Scheuring, et al. 2009.)

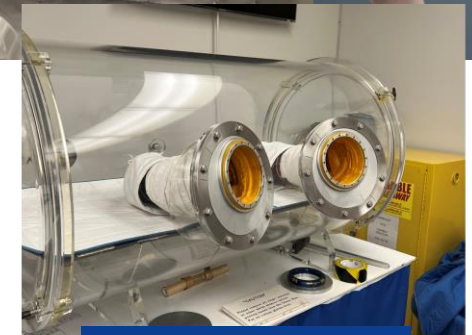


Onycholysis (fingernail delamination) extracted from Scheuring, et al. 2009.

Purpose

Create a hardware/instrumentation suite that enhances our understanding of gloved motion and exertions across the population and how they might impact measurable physical performance outcomes.

Motion Capture Gloves & Task Board



Pressurized Glove Box





SUITS & SAAT

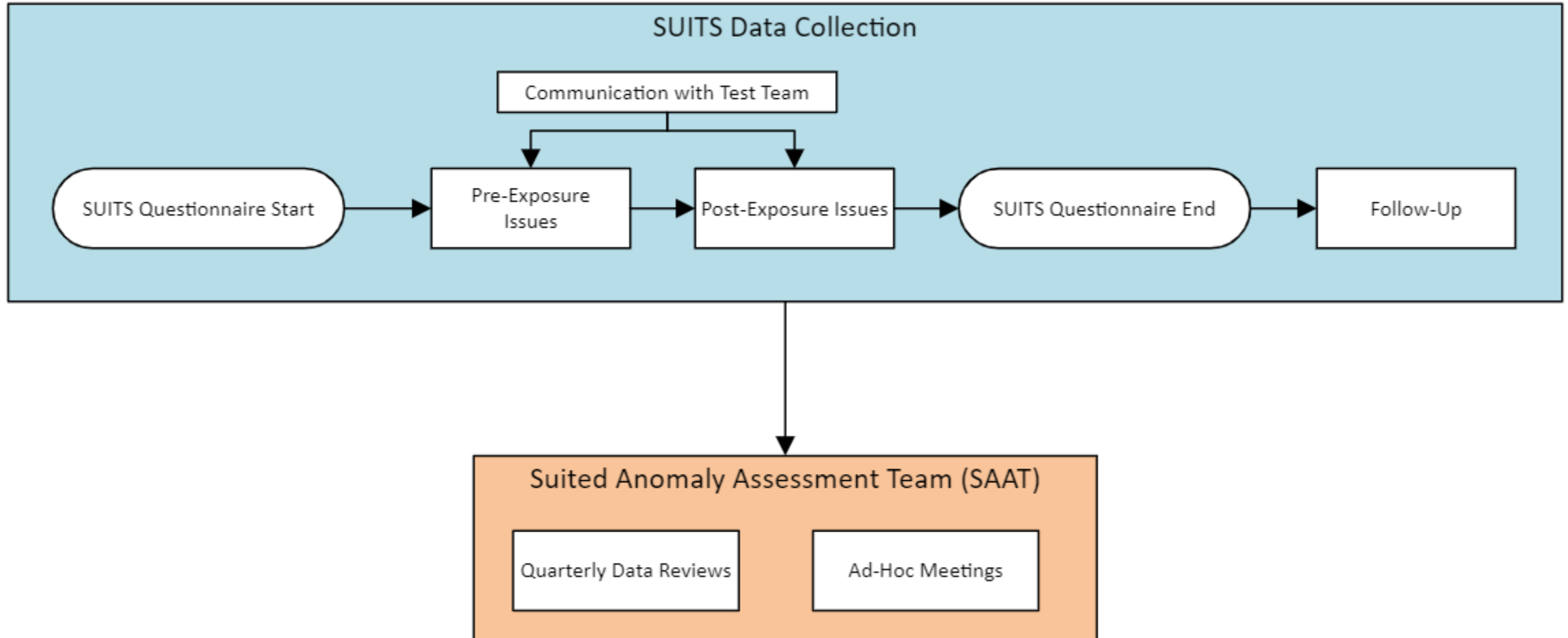
SUITS: Suited User Incident Tracking System

- The SUITS Questionnaire is administered during multiple phases of suited exposures, or events where crew or test subjects are wearing spacesuits
- Data from the SUITS Questionnaire is input into the SUITS Database, a web application that stores the data for later analysis
- The SUITS Database and the SUITS Questionnaire serves to...
 - Enable improvements in human/suit interactions
 - Real-time while collecting the SUITS Questionnaire
 - Document issues encountered by crew from an occupational surveillance standpoint

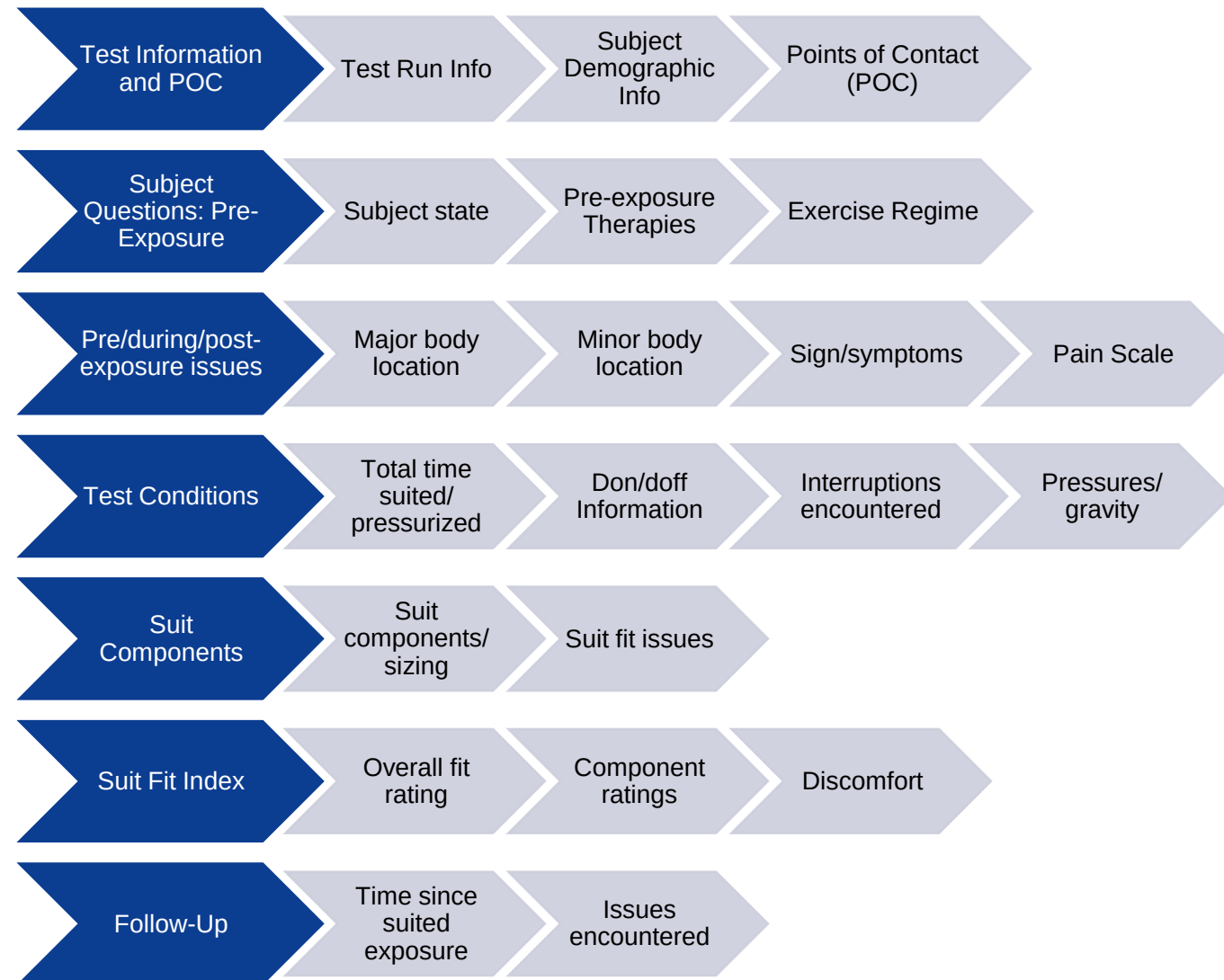
SAAT: Suited Anomaly Assessment Team

- The SAAT was created to:
 - Enable the *communication* of human-suit anomalies to all critical EVA stakeholders
 - Create *solution strategies* for purposes including suit design, EVA operations optimization, and injury characterization
- The SAAT uses data from SUITS to understand suited trends

SUITS Data Workflow



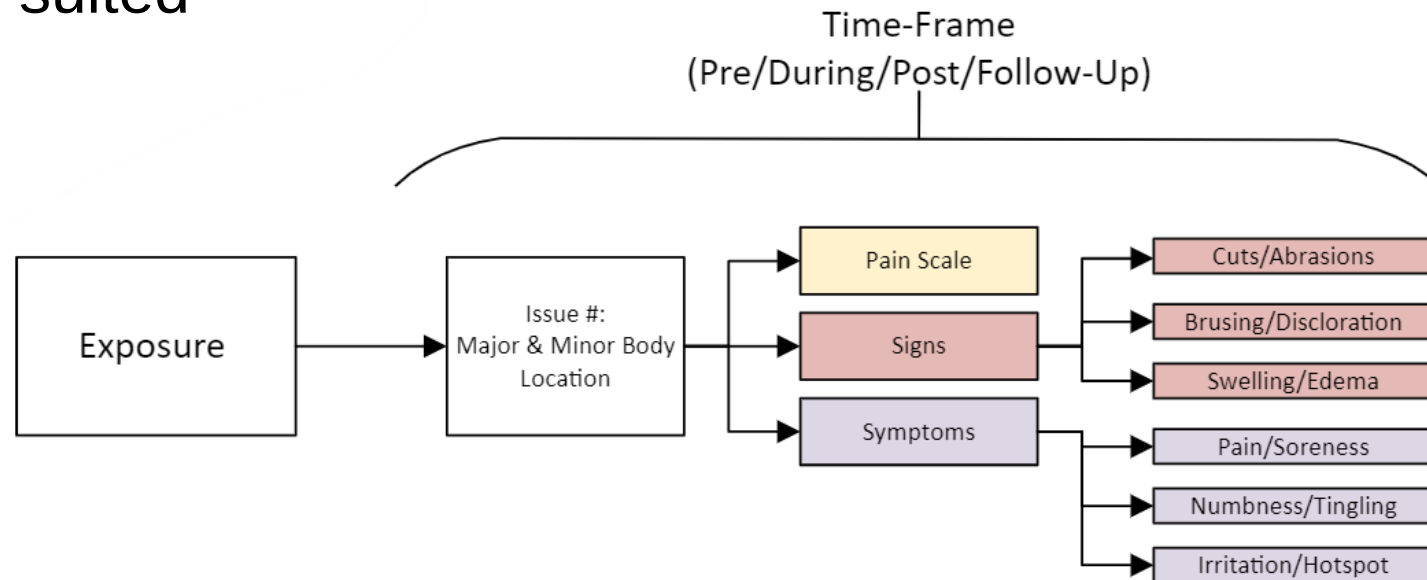
SUITS Overview



SAAT Overview

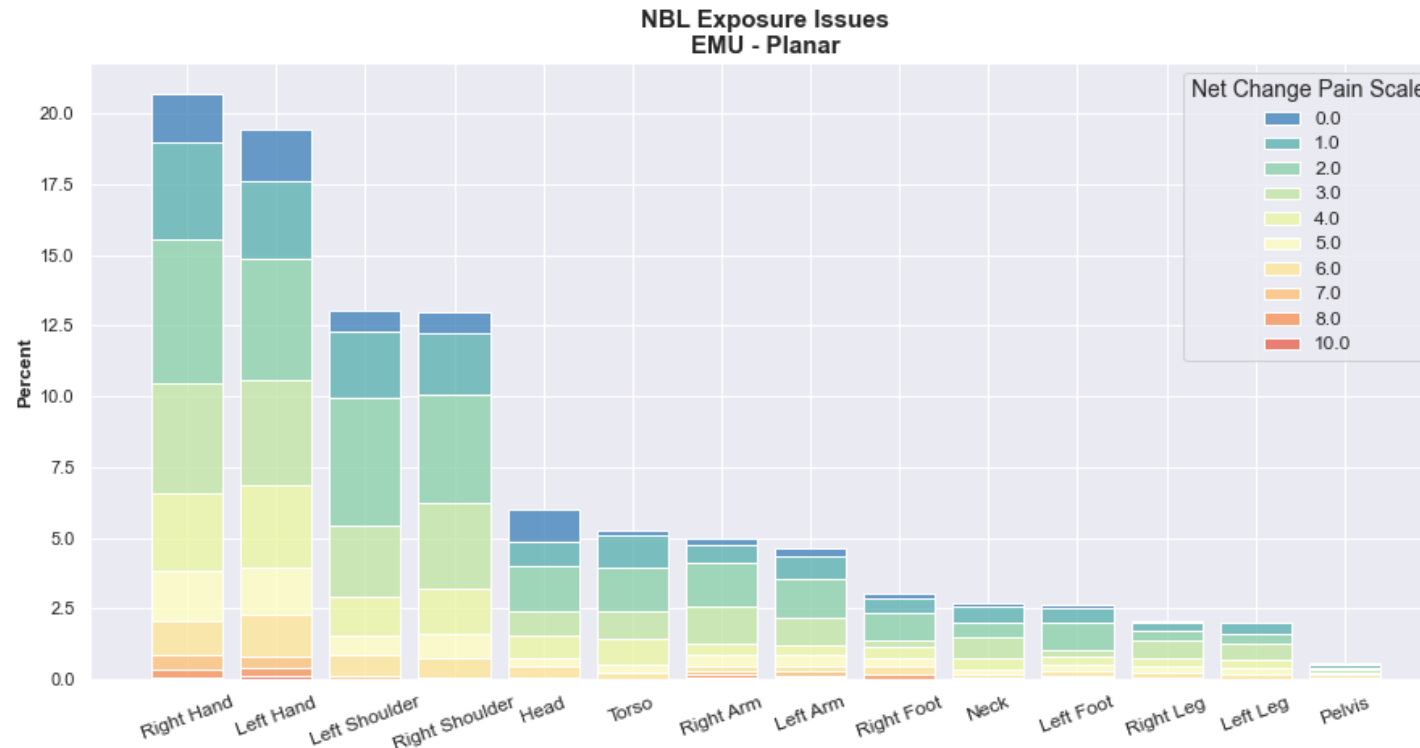


- SAAT meeting types and agenda
 - **Quarterly:** Review SUITS data to give group situational awareness, track effectiveness of any implemented improvements, review actions from past meetings.
 - **Ad-Hoc:** Description of the incident, discussion of cause and any planned mitigations, review forward work.
- Key SUITS data of-interest to the SAAT: Encountered issues while crew or test subjects are suited



Example of SAAT Analyses

- Injuries caused by dives in the Neutral Buoyancy Lab (NBL) were the reason the SUITS Database was created
- NBL dive exposure data can be aggregated to understand what issues commonly occur and of what severity
 - Data can be grouped by suit type to see differences in suits designed for microgravity or lunar ops





Thank You!

Questions & Open Discussion

Up Next... Anthropometry & Biomechanics Facility Engineering Tools