Digital Human Modeling at NASA-JSC

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Background

NASA uses digital human modeling to represent untested members of the population when completing analyses, and to simulate hardware that has not yet been created

- Data Collection tools to feed analyses
  - 3D Scans
  - Motion capture
  - Hardware mockups
- Analysis Methods
  - CAD models of human and suit
  - MATLAB stick figures – population analysis
  - Volumetric/Posture analysis

Overlay of scans of a human and a soft suit mockup

Human Modeling Challenges at NASA

- Restrictions and additional bulk due to pressurized space suits
- Crew population could encompass anyone from a 1st percentile female to a 99th percentile male
  - Obviously no one is 1st or 99th percentile in every dimension, so multivariate analyses need to be done to ensure that a simulated population reflects real people and not ‘Franken-people’ who have unrealistic proportion combinations
- Reduced gravity operations

Homogeneous 60’s era crew (above) vs. heterogeneous modern crews (below)

Videos: Walking in a Pressurized Suit

Walking in an LEA Suit

Walking in an EVA Suit

Modeling Inputs: 3D Scanning

- 3D Scanning Hardware:
  - Human Solutions - Vitus Whole Body and Pedus Foot Scanner
    - Horizontal Laser scan
    - Texture only
  - 3DMD – 12 cameras units
    - Photo based
    - Color and texture images
- Uses:
  - Linear anthropometric dimensions
  - Volumetric comparisons
    - Free volume in suit
    - Multi-subject overlay
    - Human/Hardware interface

3 laser scan of a subject

Modeling Inputs: 3D Scanning

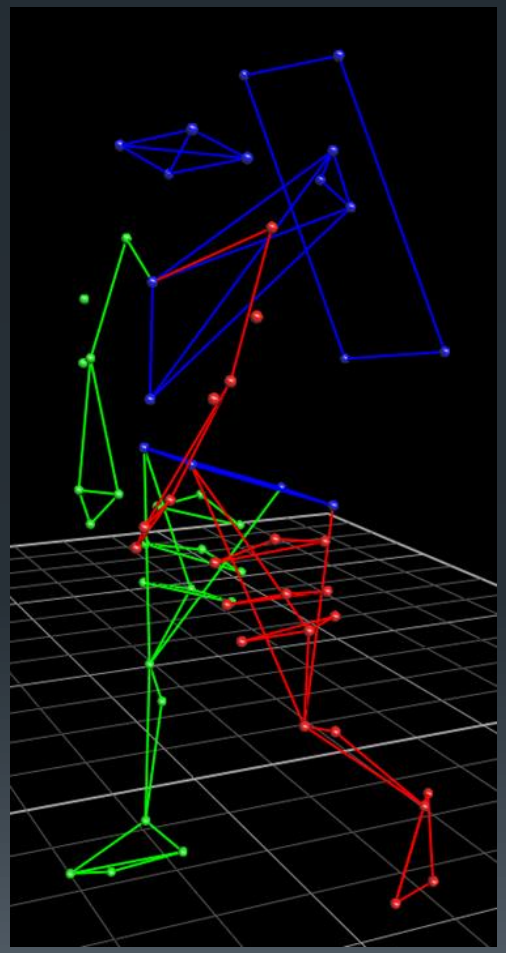
- Limitations
  - Loss of Data (occlusions)
  - Large File Size
  - Scanner Volume limits
  - Can not manipulate posture of 3D model after scanning (static posture)
  - Difficult to replicate suited posture in an unsuited scan

An occlusion in a 3D scan

- Future
  - Dynamic anthropometry
  - Dynamic scanning
  - Increased capture volume

Modeling Inputs: Motion Capture

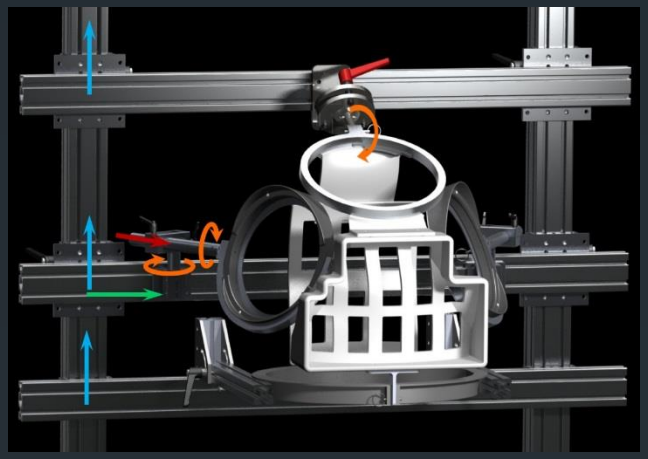
- Motion Capture Hardware:
  - Vicon® Optical Motion Capture System
- Limitations:
  - Complexity of Output
    - Direct Euler angle output can be difficult for designers to interpret
  - Data collection restrictions
    - MX camera system is less efficient in small, cramped spaces
  - Occlusions/data loss
- Future Capabilities:
  - Bonita system for small volumes



Motion capture of ambulation in a space suit

Modeling Inputs: Hardware Mockups

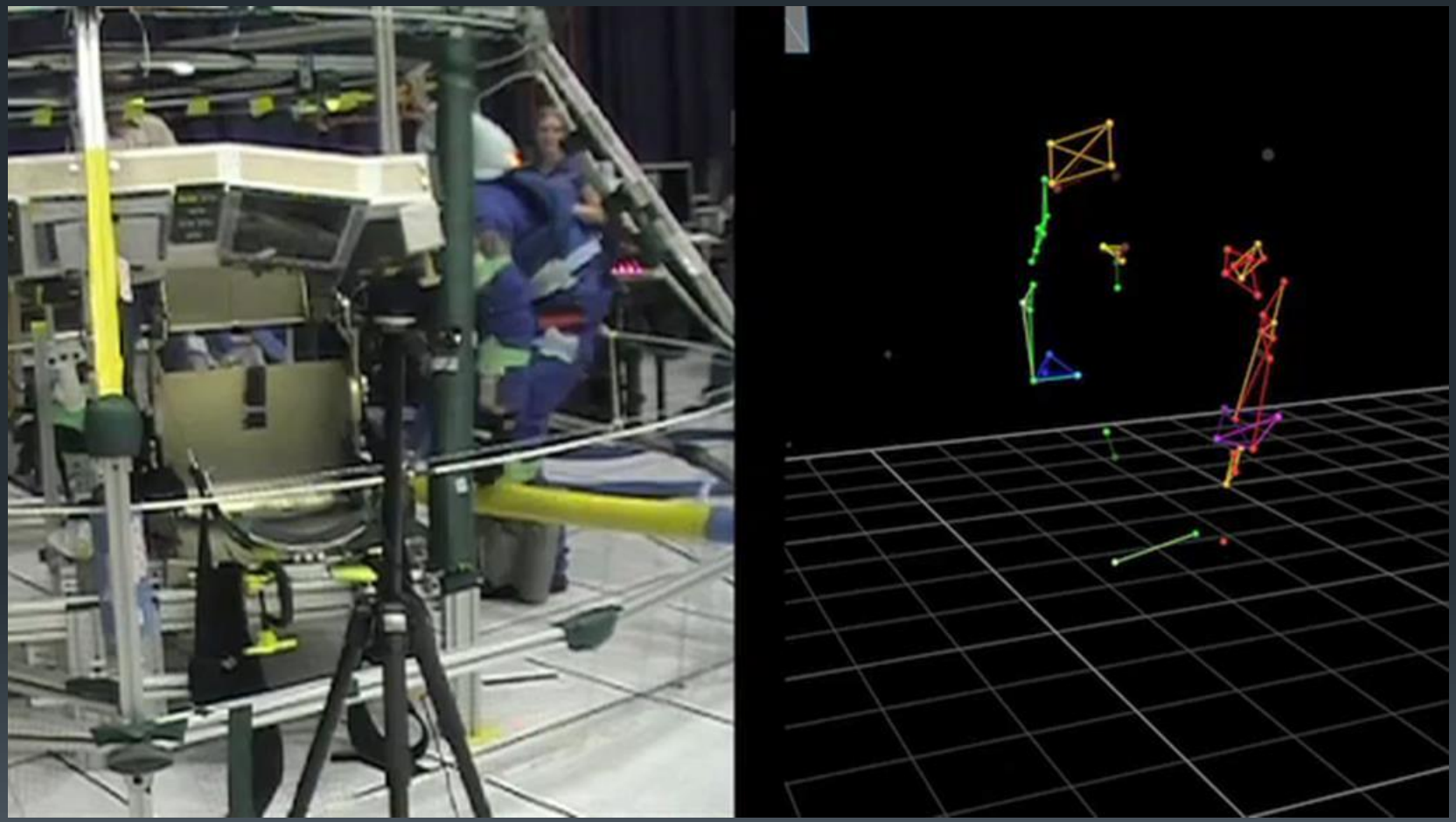
- Uses
  - Collect human in the loop data to import into simulations
- Examples
  - Reconfigurable hard upper torso
    - Mockup space suit hard upper torso that can be reconfigured to accommodate subjects of varying anthropometry
  - Reconfigurable Orion Mockup
    - Space vehicle frame and interior that can be reshaped and resized to account for ongoing design changes
    - Transparent walls allow for data collection within frame



Reconfigurable hard upper torso

Reconfigurable Orion Mockup

Video: Seat Ingress Motion Capture

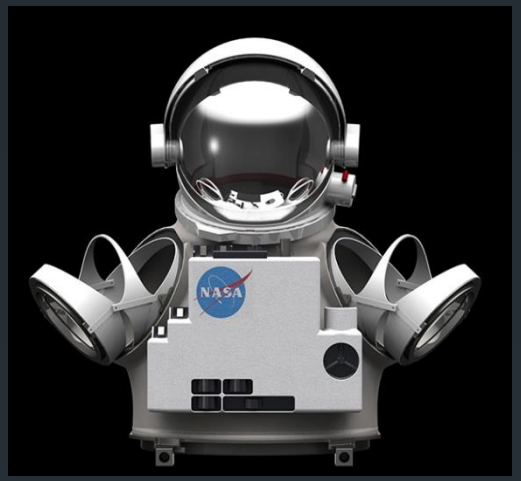


Modeling Inputs: Hardware Mockups

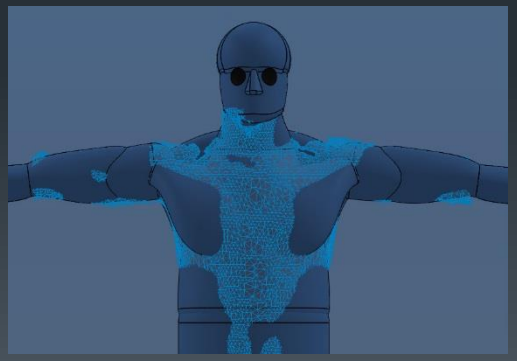
- Limitations
  - Mockups require some degree of simplification
    - Reconfigurable hard upper torso cannot be pressurized
    - Reconfigurable mockup, in order to allow unobstructed data collection, did not include all internal vehicle elements
  - Test subject population may not adequately represent the full potential user population
- Future
  - Mockups of additional suit components and vehicle designs

Simulation: CAD Models

- CAD Models of Suits and Human
  - Software package: Solidworks
  - Currently modeled suits
    - MK III Space Suit Demonstrator
    - Space shuttle extravehicular Mobility Unit (EMU)
    - Reverse engineered from 3D scans and manual measurements
  - Human Model (‘Anthronaut’)
    - Segments are reconfigurable to match anthropometry of simulated subjects
    - Can be used to drive the suit model



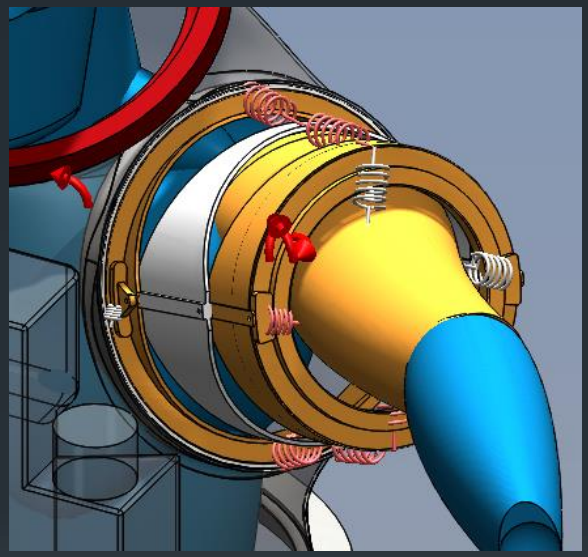
CAD Model of the EMU



CAD Model of the human

Simulation: CAD Models

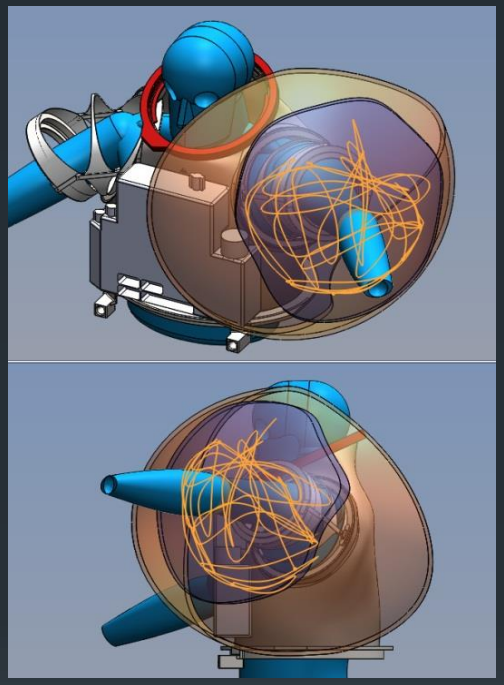
- CAD Model: Suit/Human Interaction
  - Human-Suit Interface Modeling
    - Spring/dampers between suit upper arm and surface of human arm
    - Rigid body contacts between suit components, and between arm and suit
  - Motion Simulation
    - ABF human model is animated using motion drivers; motion of the human drives motion of the suit



Human and suit integrated in model

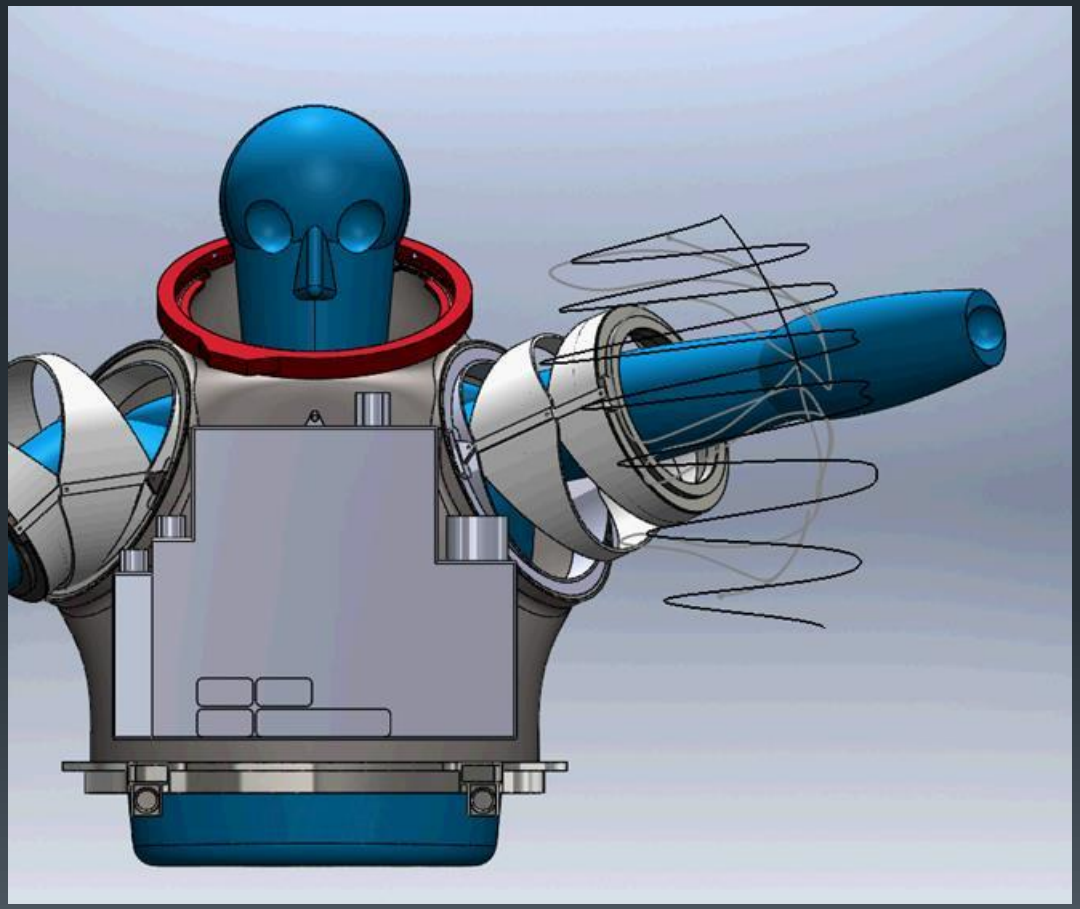
Simulation: CAD Models

- Integrated Suit/Human Model
  - Example usage
    - Look for ‘hard stops’ between suit components, or between the human model in the suit, where motion is restricted
    - Evaluate suited work envelope restrictions as the size and shape of the human and suit models are modified
  - Limitations
    - Simplistic modeling of human material properties and kinetics
    - Suit soft components are currently modeled as linkages, due to complexity of modeling pressurized soft goods



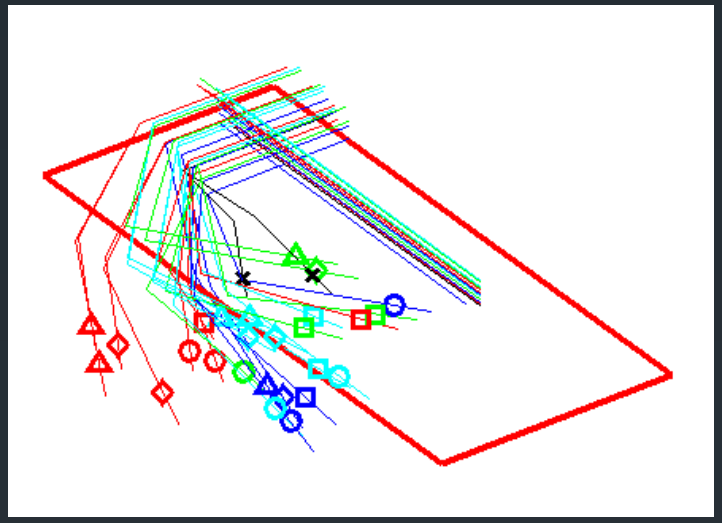
Modeled work envelope (transparent hulls) compared to work envelope from human in the loop data

Video: Suited Work Envelope Sim



Simulation: Population Analysis

- Software Package:
  - MATLAB
  - Analysis of multiple variables simultaneously, taking understanding beyond single dimensional percentiles
  - Integrates human in the loop testing, posture analysis and anthropometry database to extrapolate results for individual subjects to the entire population



Population Analysis for Umbilical Restraint Device Placement

Based on HITL testing

- obtained posture from HITL subjects
- used hardware seat settings to position subjects correctly
- Mutli-variate model built from butt to hand

Result shows HITL subject test data for location of restraint device

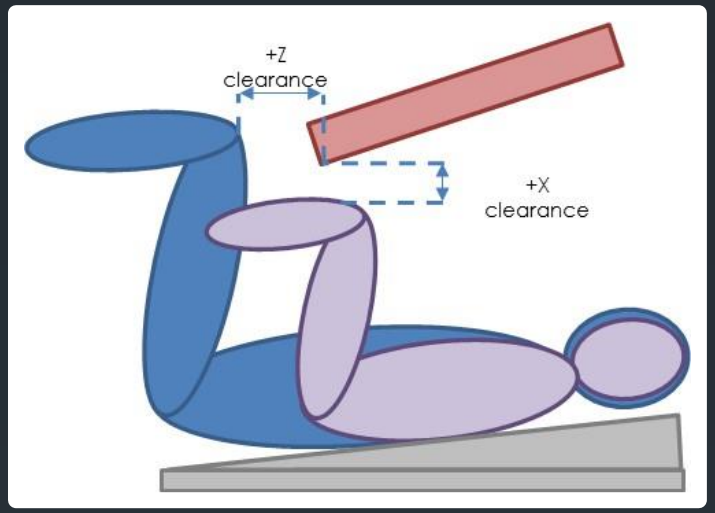
Simulation: Population Analysis

- Example Application:
  - Determine ability of the entire population to ingress a hatch while suited
  - Inputs
    - Subject posture during hatch negotiation
    - Hatch geometry
    - Subject anthropometry
  - Outputs
    - Minimum hatch size to accommodate the entire population, given assumptions on ingress method

Population Analysis for Hatch Entry

Simulation: Population Analysis

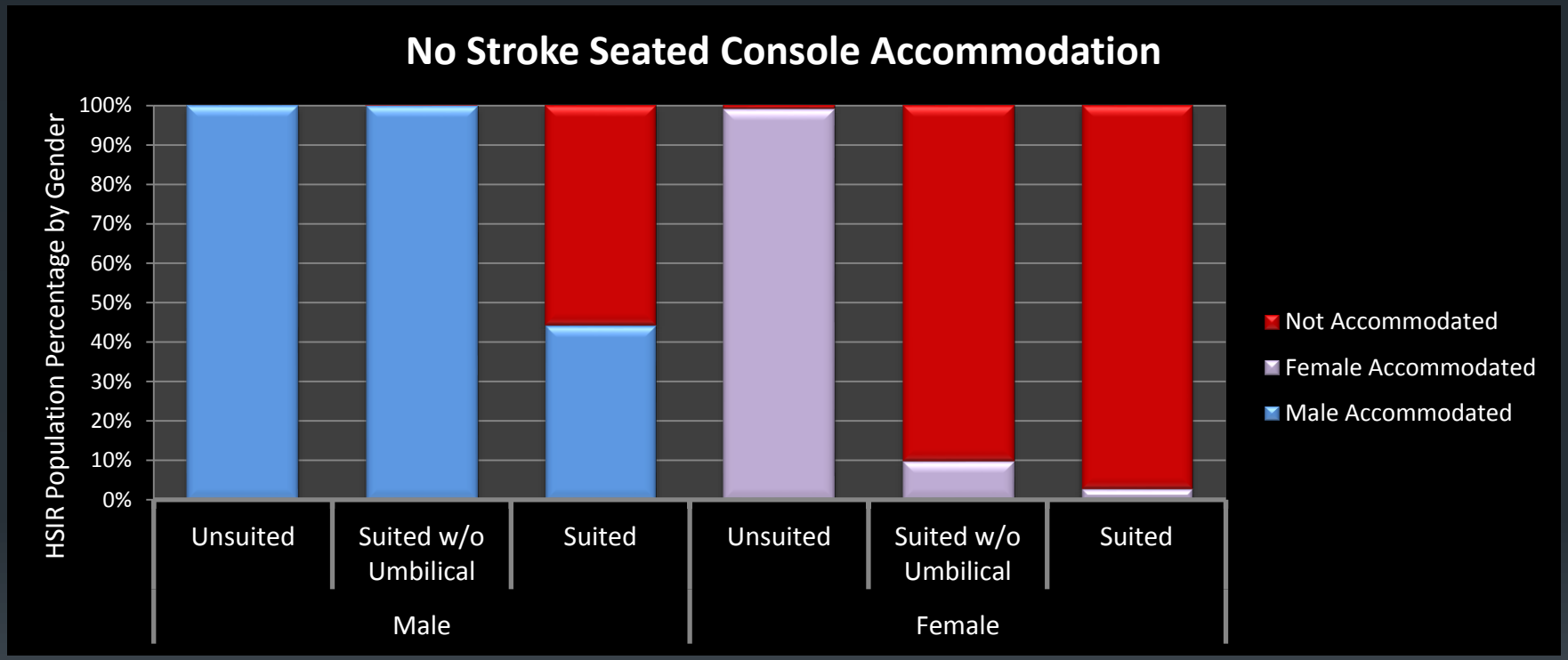
- Example Application:
  - Knee Clearance to Vehicle Display and Control Panel
  - Inputs
    - Subject posture
    - Subject anthropometry
    - Vehicle hardware dimensions
    - Vehicle landing assumptions
  - Outputs
    - Population accommodated by existing vehicle design, given landing conditions



Population Analysis for Knee Clearance

Simulation: Population Analysis

Hardware Accommodation Concern

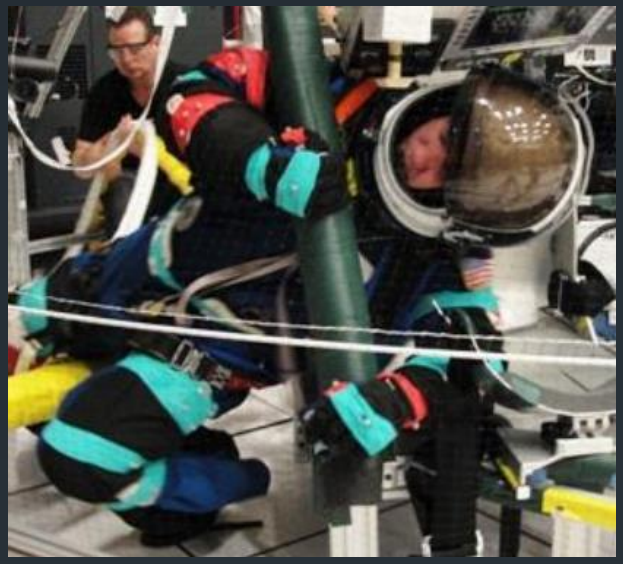


No Stroke Seated Console Accommodation by Gender

	Male			Female		
	Unsuited	Suited w/o Umbilical	Suited	Unsuited	Suited w/o Umbilical	Suited
Percent Accommodated	**100.0%**	**99.8%**	**44.4%**	**99.1%**	**9.9%**	**2.9%**

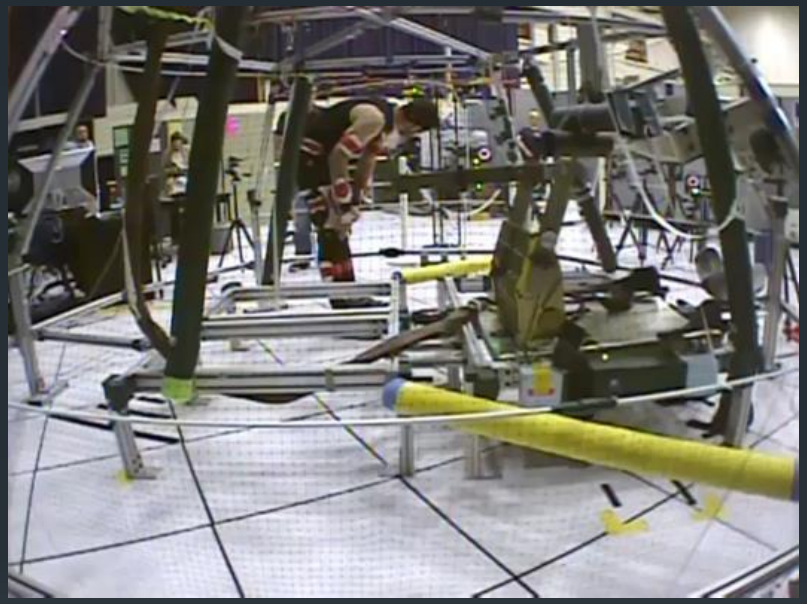
Simulation: Population Analysis

- Limitations:
  - Analysis is based on the general posture and movement strategies of HITL subjects, and may not include all potential strategies or postures
  - If hardware does not accommodate a subject (for example, poor suit fit), it can affect the accuracy of results when extrapolating for that segment of the population
  - Make use of linear anthropometric dimensions vs. volumetric analyses
  - Static postures, not dynamic



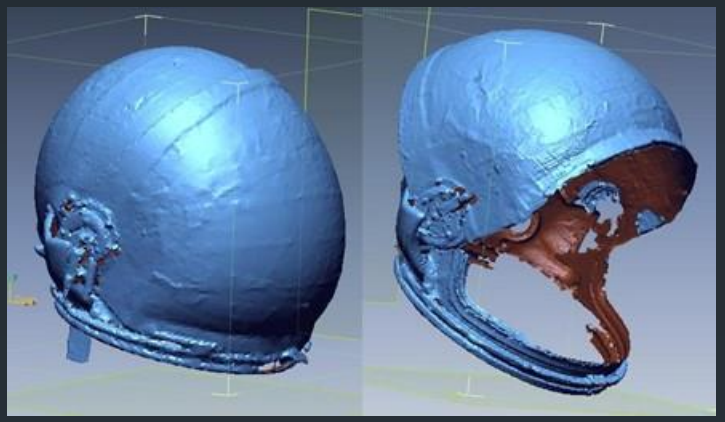
An Example Suited Seat Ingress Method

Video: Different Ingress Strategies



Simulation: Volumetric Analysis

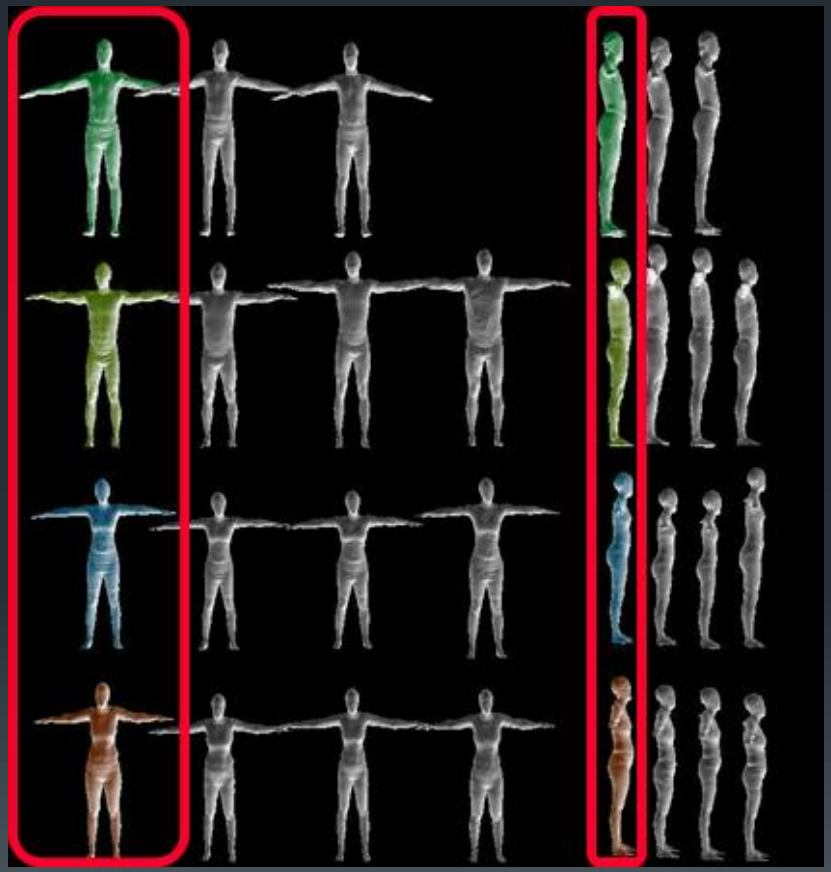
- Software Packages Used:
  - MATLAB, SolidWorks, Polyworks, FARO Arm
  - Anthropometric analyses to consider fit issues with suits, vehicles, and habitats, to create sizing schemas, and to mitigate injury
  - Make use of the ABF 3D scanners, to extend analyses beyond linear anthropometric dimensions



Suit Helmet Scan

Simulation: Volumetric Analysis

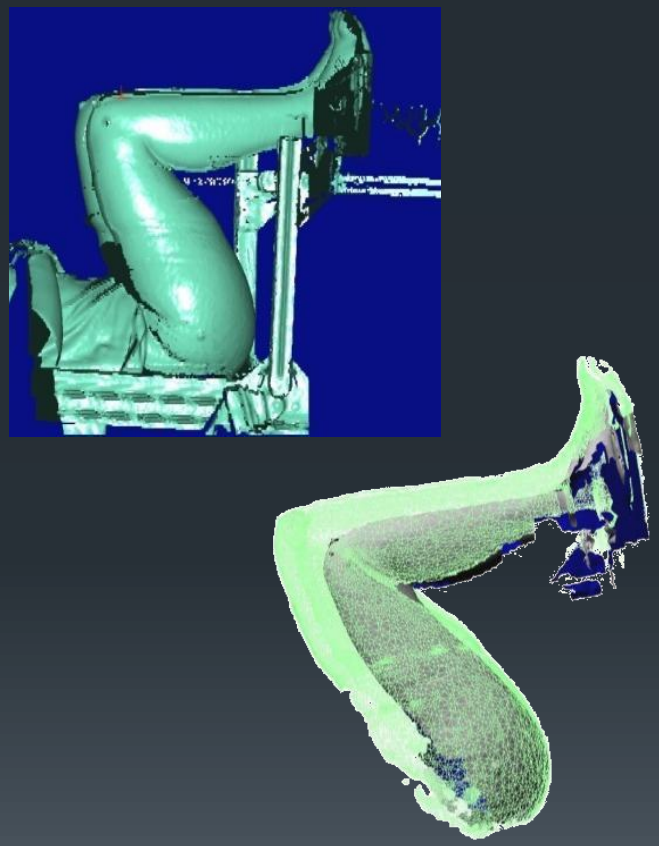
- Example Application
  - Boundary Manikins to represent human body size and shape variations
    - Boundary manikins provide an optimized population spectrum while minimizing the final number of representative scans
    - Represent realistic anthropometric variation by scaling existing surface scans (baseline scans) to targeted anthropometry



Boundary Manikins

Simulation: Volumetric Analysis

- Example Application
  - Conformal seat design
    - Provided recommendations on the overall shapes and sizes of the lower body for conformal seats to accurately represent the curvature of the lower body
    - Linear measurement and surface meshes of the lower body were used with population analyses to determine size ranges and proper curvature



Scan of one subject (top) and multiple scans overlaid (bottom)

Conclusions

- Human modeling at NASA integrates:
  - Software tools
  - Hardware mockups
  - Human in the Loop testing (to drive models)
  - Data collection hardware (laser scans, motion capture)
  - Anthropometric databases
- There are limitations in any modeling method, and simulations are only as good as the data that drives them. However, they are a useful tool for determining how hardware accommodates the potential user population.

Questions?