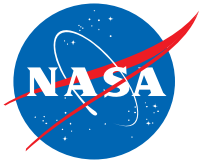

ABF Digital Human Modeling

Human Research Program Investigators' Workshop
Galveston, Texas, January 2017

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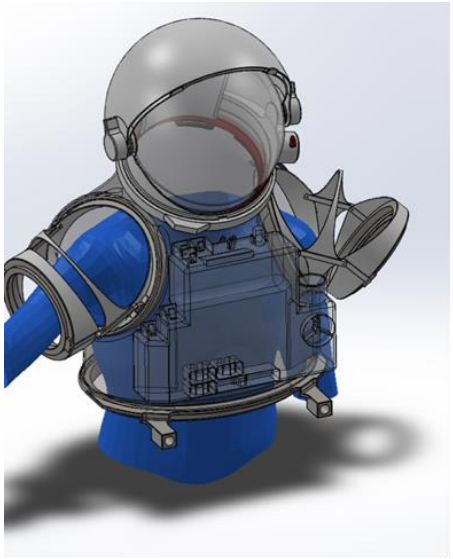
BACKGROUND

- NASA digital human modeling:
  - Evaluates hardware in untested sizes - hardware prototypes can be expensive, and are normally only available in limited sizes
  - Checks for the accommodation of population ranges that cannot be evaluated with Human-In-The-Loop (HITL) testing



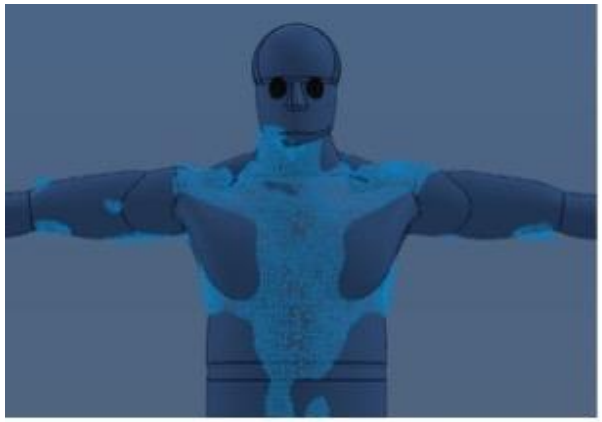
Human Modeling Challenges at NASA

- In addition to the complexities associated with human models in other industries, NASA models must account for:
  - Restrictions and bulk due to pressurized space suits
  - Reduced gravity operations
  - Effects of spinal elongation and fluid shifts on anthropometry
  - A widely variable user population that could include from 1st percentile female to 99th percentile male dimensional ranges

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

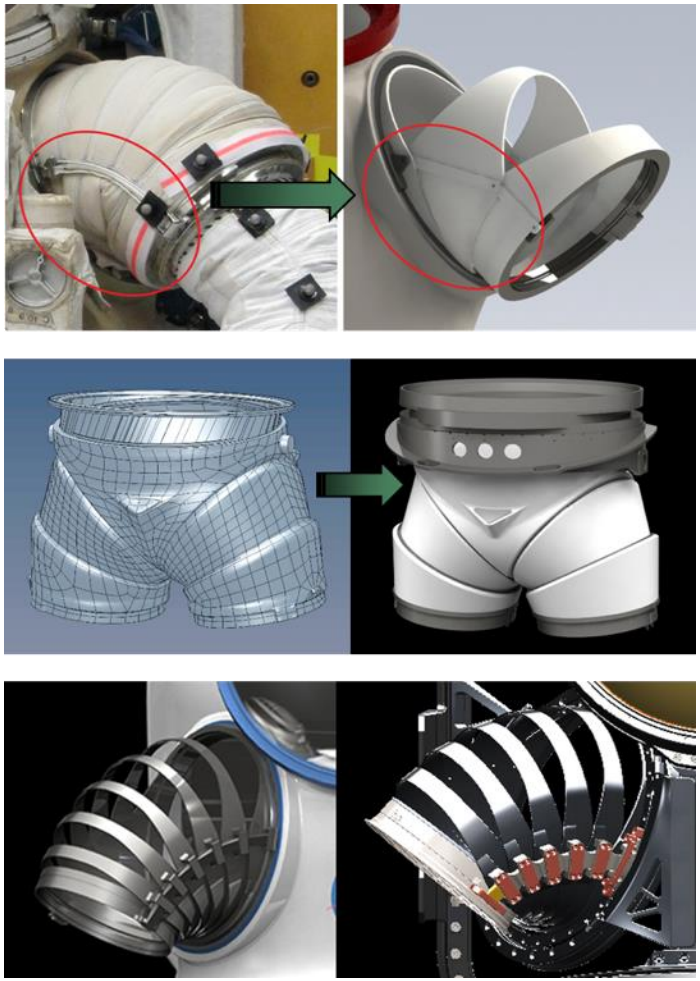
Human Body Model

- The ABF Anthronaut is built of resizable primitives in Solidworks
- In the future, a statistical upper-body model will be developed to simulate skin deformation and shape variations for arbitrary body size and shoulder pose



Suit Models

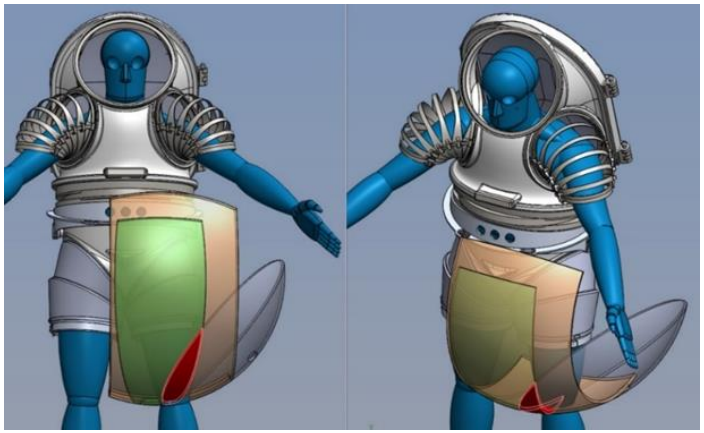
- Suit models are reverse engineered from 3D scans and manual measurements (MK III and EMU), or provided by the suit contractor (PXS)
- Functional component accuracy is within ±2 mm or 2°, for models built by the ABF
- Soft goods are approximated as linkages of inflexible elements
- The EMU model includes only the upper body of the suit, while the MX-III and PXS model also include lower body elements



EMU Shoulder (Top L) and modeled EMU shoulder (Top R). MK III Scan (L) used to model MK III Brief (R). PXS Shoulder (Bottom)

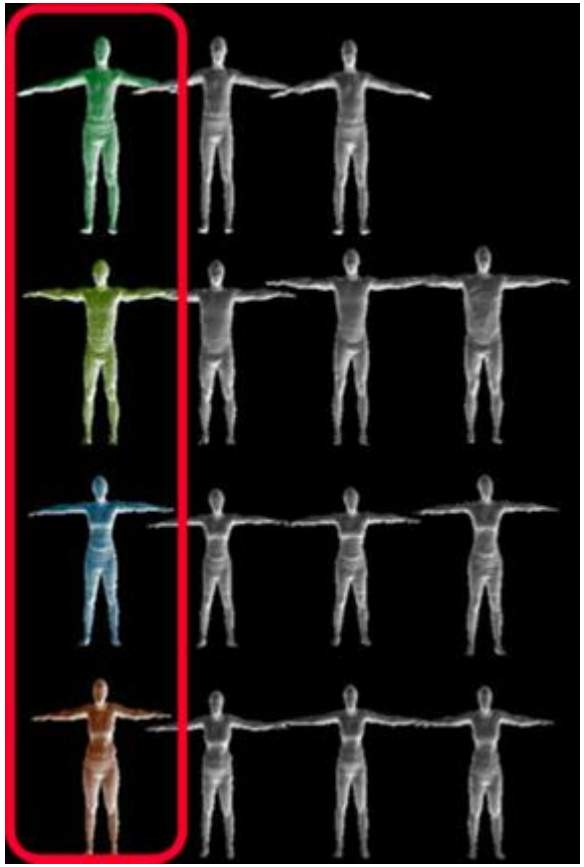
Simulation of Suit-Human Interactions

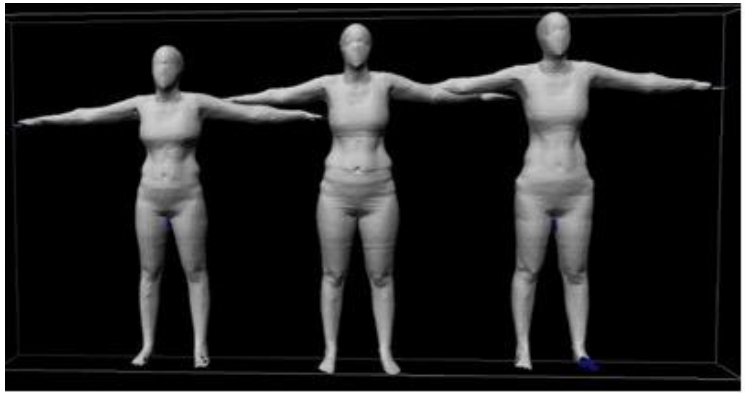
- Past ABF Studies using Suited Human Models:
  - To estimate the range of Motion (ROM) variation, as influenced by the size of the modeled subject
  - To compare the theoretical optimal work envelope to actual capabilities
  - To assess the impact of different design configurations on range of motion
  - Simulated ROM of untested PXS shoulder joint



Volumetric Analysis

- Used to evaluate fit issues, create sizing schemes, enhance injury mitigation
- Example: Create boundary manikins to represent human body size and shape variation
  - Reshape and resize actual scans to match targeted anthropometry
  - Boundary manikins of different body shape and size can allow designers to represent the boundaries of the population





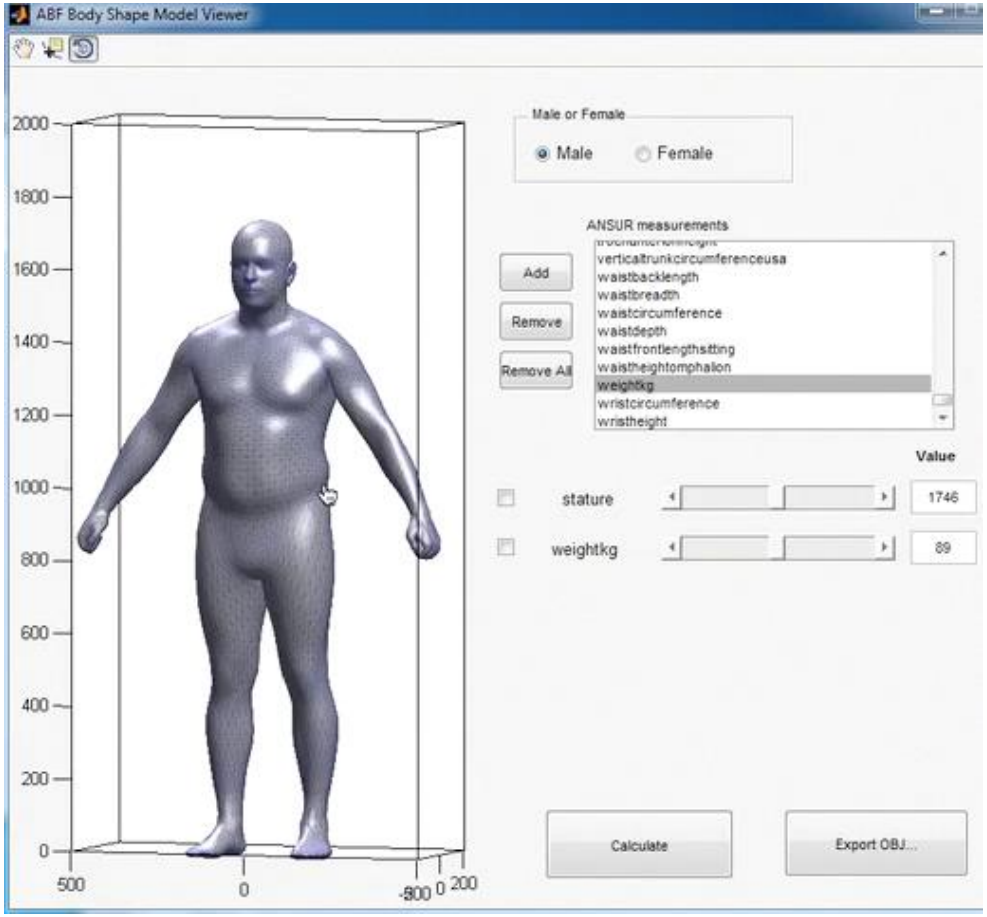
Population Analysis

- Combines HITL testing, posture analysis and an anthropometry database to extrapolate results for individual subjects to the entire population
- Example: Hatch Ingress
  - Analysis Inputs: Subject posture during hatch negotiation, hatch geometry, subject anthropometry
  - Analysis Outputs: Minimum hatch size to accommodate the entire population, given assumptions on ingress method

Population Analysis of Hatch Ingress

Parametric Human Body Model

- A parametric human body models are currently in development to better approximate the human body size and shape
- A model was developed based on the subset of the US Army data sampled with HSIR specifications (*n*=250).
- Model can predict body geometry as a function of any anthropometry parameters



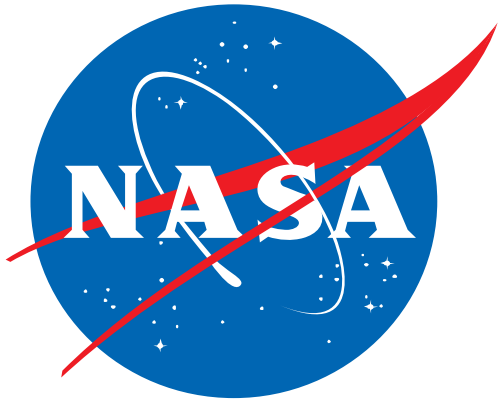
Parametric Shoulder Articulation Model

- Shoulder poses and skin deformation patterns are critical in suit fit, performance and comfort
- A resizable and reposable model was developed using subjects scanned in multiple different shoulder poses
- CAD incorporated model enables the quantification of the contact volume and clearance between the suit and body surfaces

Discussion and Conclusion

- NASA uses Digital Human Modeling (DHM) to extrapolate test data to an untested population, and to evaluate interactions between humans and hardware
- The limitation of the current DHM technologies:
  - The outputs are only as good as your inputs
  - Unknowns related to suit and human, examples:
    - Behavior of space suit soft goods
    - Individual variations in human physiognomy (musculature, soft tissue, bone geometry)
    - Uncertainties in how and where the suit contacts the human wearer

Contact Information



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