The Seated Soldier Study: Posture and Body Shape in Vehicle Seats

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Background

- Current and future vehicle programs face major challenges in providing adequate accommodation for soldiers while ensuring performance and safety
- Current MIL-STD 1472g lacks detailed information on soldier posture and body shape, including the effects of personal protective equipment (PPE) for seat and vehicle interior layout

- Current design guidance is based on outdated anthropometry
- Previous studies of seated anthropometry have not included the effects of PPE on posture and body shape
- Detailed anthropometric data needed for the design of human surrogates used for blast protection assessments.

UMTRI

Methods and apparatus
Project organization
Data processing and analysis

ANTHROTECH
PROVIDING HUMAN DIMENSIONS FOR DESIGN SOLUTIONS

Staffing data collection
Preliminary data processing
Quality checks

TARDEC

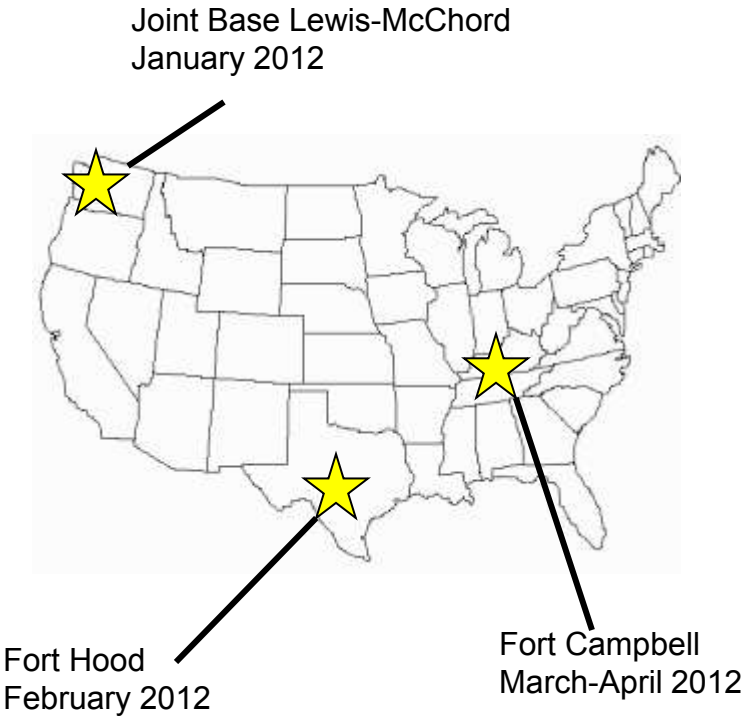
Funding
Coordinating access to facilities
Applications

Objectives

1. Gather detailed data on the **postures of soldiers with a wide range of body sizes sitting in military vehicle seats** as drivers and passengers with and without protective equipment and with and without protective footrests.
2. Gather detailed data on the **position and space requirements for body armor and other gear** in both standing and seated postures.
3. Gather quantitative data on the **locations of protective equipment relative to the soldier and vehicle seat** for use in human modeling and blast event simulation.
4. Develop data-based **tools to represent the postures, positions, and body size** (space claim) for soldiers as drivers and passengers in tactical vehicles as a function of occupant and vehicle characteristics.

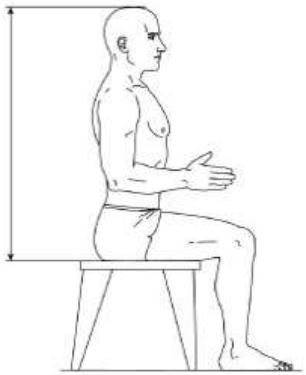
Test Plan

- Data collection January – April 2012 at three Army posts: Joint Base Lewis-McChord, Ft Hood, Ft Campbell
- Goal was to measure 300 soldiers with a wide range of body size, including as many women as possible
- Data collection conducted by subcontractor Anthrotech, Inc., which is providing six trained staff
- Substantial additional coordination by TARDEC and the data collection sites



Methods - Overview

Standard Anthropometry



Hardseat Body Landmarks

Whole-Body Scanning

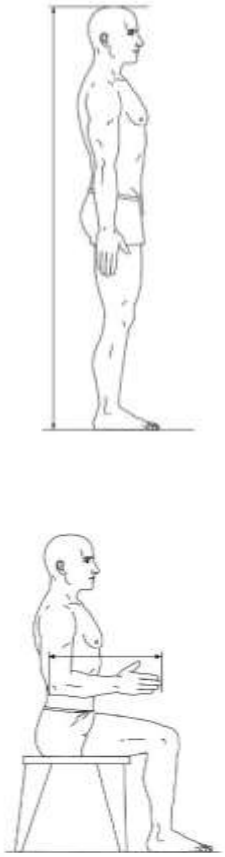
Driving Postures

Squad Postures

Four Garb Levels: minimal, ACU, armor, encumbered

Standard Anthropometry

- Using ANSUR II methods*
- 36 dimensions
- Focus on characterizing subjects relative to ANSUR II
- Minimal garb only



*ANSUR II is the most recent, large-scale Army anthropometry study

Standard Anthropometric Dimensions

Driver Mockup

- Steering wheel, pedals, adjustable seat(fore-aft, up-down, back angle)
- Range of vehicle packages (steering wheel-to-pedal relationships) representing different vehicle types
- Driver adjusts seat to obtain comfortable posture
- Body landmarks defining posture measured using FARO Arm coordinate digitizer
- Garb: ACU, armor, encumbered (not all configurations at all garb conditions)

Squad Mockup

- Fixed seat (no sitter adjustments)
- Range of seat height, seat cushion angle, seat back angle, and foot position (including representation of protective footrest)
- Body landmarks defining posture measured using FARO Arm coordinate digitizer
- Garb: ACU, armor, encumbered (not all configurations at all garb conditions)

Laser Scanning

- Standing and erect sitting postures for reference to other datasets
- Supported sitting postures spanning the range of driver and crew postures
- Garb: minimal, BDU, armor, encumbered (not all postures in all garb conditions)

Laser Scanning

Overview of Data

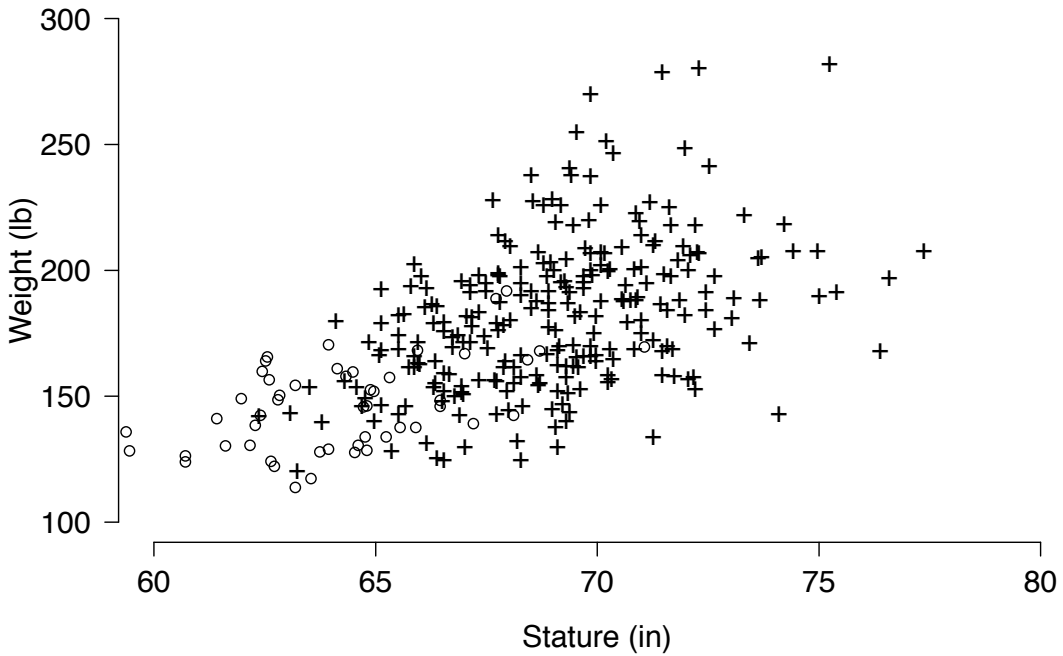
- 310 soldiers total (53 female); **not all soldiers in all conditions**
- Standard anthropometry (36 dimensions)
- Hardseat anthropometry: 3D body landmarks in a standardized seated posture (all soldiers)
- Body landmarks, seat position, and seat back angle in **5 driver conditions** (83 soldiers) in ACU; one package condition included ACU, PPE, and ENC (143 soldiers)
- Body landmarks in **4 squad conditions** (up to 140 soldiers per condition); two conditions included ACU, PPE, and ENC.
- Whole-body surface (scan) data in up to **18 postures** in scanwear (minimally clad). Up to 10 postures in ACU & PPE, 5 postures ENC. **A total of 8207 scans processed.**

Subject Pool

310 soldiers measured

257 men (83%)

53 women (17%)

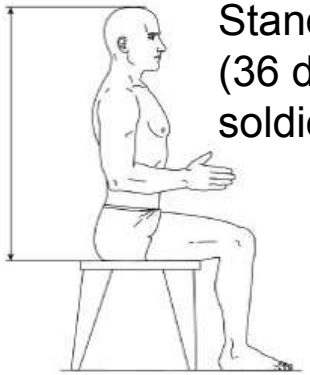


Male Anthropometry Summary

Seated Soldier	5th%ile	50th%ile	95th%ile
Stature (mm)	1654	**1755**	1866
Weight (kg)	63.6	**82.4**	104.3
BMI (kg/m^2)	21.0	26.7	33.8
ANSUR II Pilot			
Stature (mm)	1643	**1755**	1872
Weight (kg)	63.9	**84.2**	110.7

Data Overview

Standard Anthropometry



Standard anthropometry (36 dimensions, all soldiers)

Hardseat Body Landmarks

Hardseat anthropometry: 3D body landmarks in a standardized seated posture (all soldiers)

Whole-Body Scanning

Whole-body surface (scan) data in up to **18 postures** in scanwear (minimally clad). Up to 10 postures in ACU & PPE, 5 postures ENC. **A total of 8207 scans processed.**

Driving Postures

Body landmarks, seat position, and seat back angle in **5 driver conditions** (83 soldiers) in ACU; one package condition included ACU, PPE, and ENC (143 soldiers)

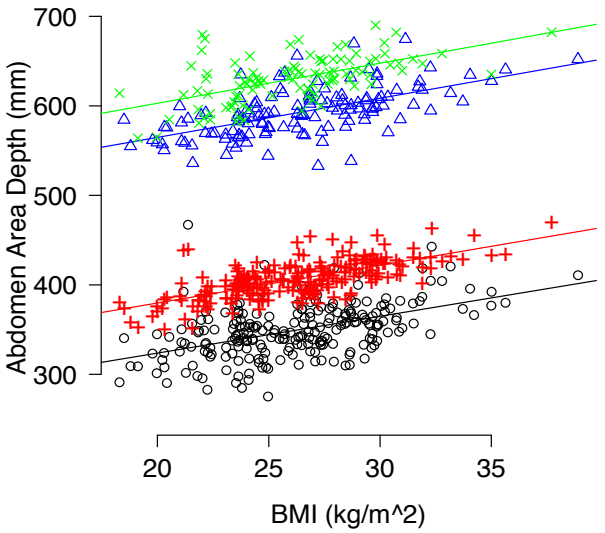
Squad Postures

Body landmarks in **4 squad conditions** (up to 140 soldiers per condition); two conditions included ACU, PPE, and ENC.

Primary Results

- Statistical posture-prediction models for **driver** and **squad**, including the effects of PPE and ENC.
- Analysis of space claim changes with PPE and ENC.
- Statistical model of **male** body shape, **standing**.
- Statistical model of **male** body shape, **seated**.
- Statistical model of **female** body shape, **standing** (incorporates civilian data to get adequate sample size)
- Space claim for encumbered soldiers

Encumbered Space Claim



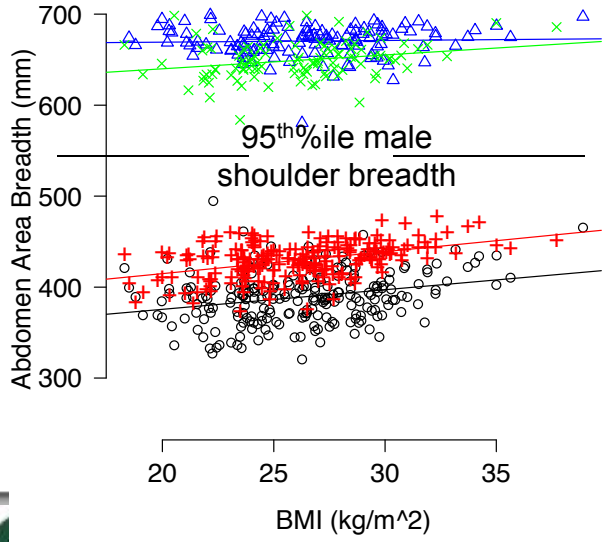
SAW Gunner

Rifleman

PPE

ACU

Fore-aft space claim is *dependent* on BMI



Lateral space claim in the abdomen region is *independent* of body size

Abdomen Area Depth and Breadth

Harness Fit

Lap portion of harness routed **UNDER** gear

51%

Lap portion of harness routed **ON** gear

36%

Lap portion of harness routed **ABOVE** gear

13%

Results suggest an opportunity for improved training on harness use

Summary

- The first large-scale study of Soldier posture and body shape in seated environments yielded data and models for a wide range of applications.
- Results are being integrated into both commercial tools (Siemens Jack model) and into TARDEC's internal design and assessment software.
- The design of the study and the models will allow the results to be reweighted to represent future Army populations
- The outcomes are already contributing to Army programs and will have increasing influence as the results are integrated into more tools and procedures.

Driver Posture Prediction

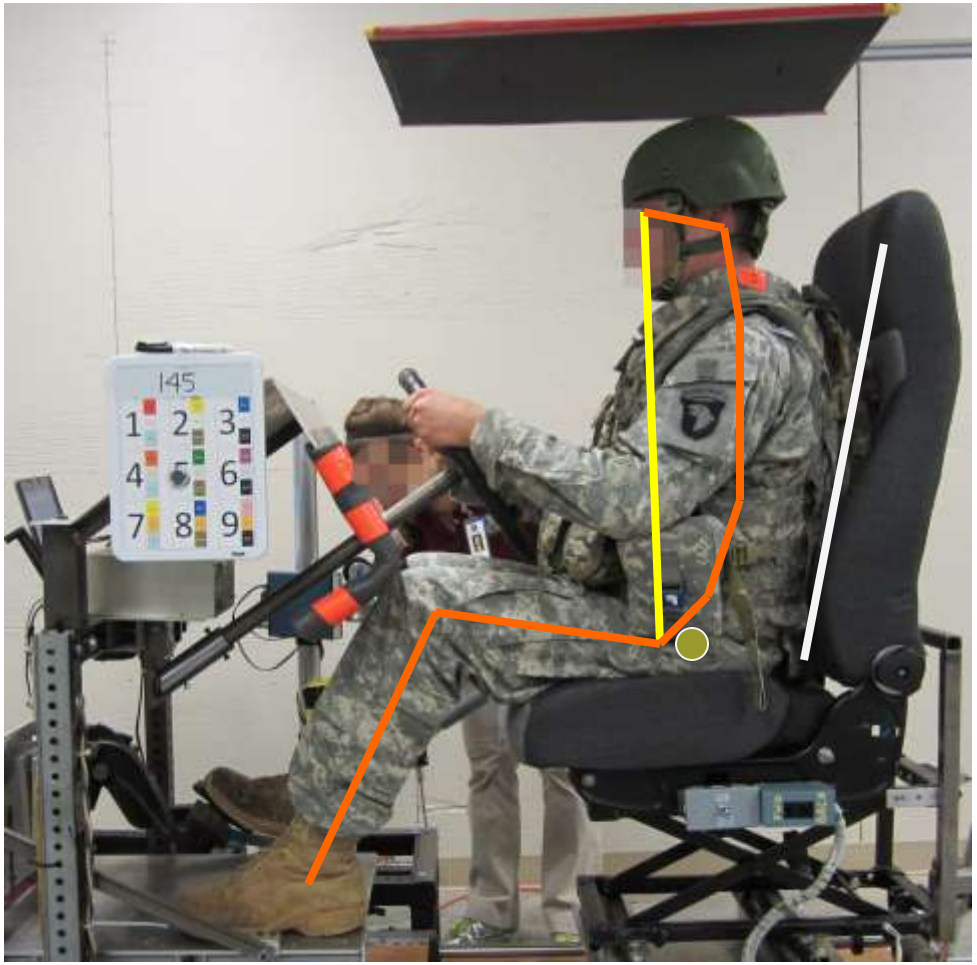
Goal: Predict driving posture

Inputs:

- steering wheel location re accelerator pedal
- driver stature, erect sitting height, body weight, and gear level (ACU, PPE, ENC)

Outputs:

- Seat position
- Seat back angle
- Hip location
- Eye location
- Body segment angles



Squad Posture Prediction

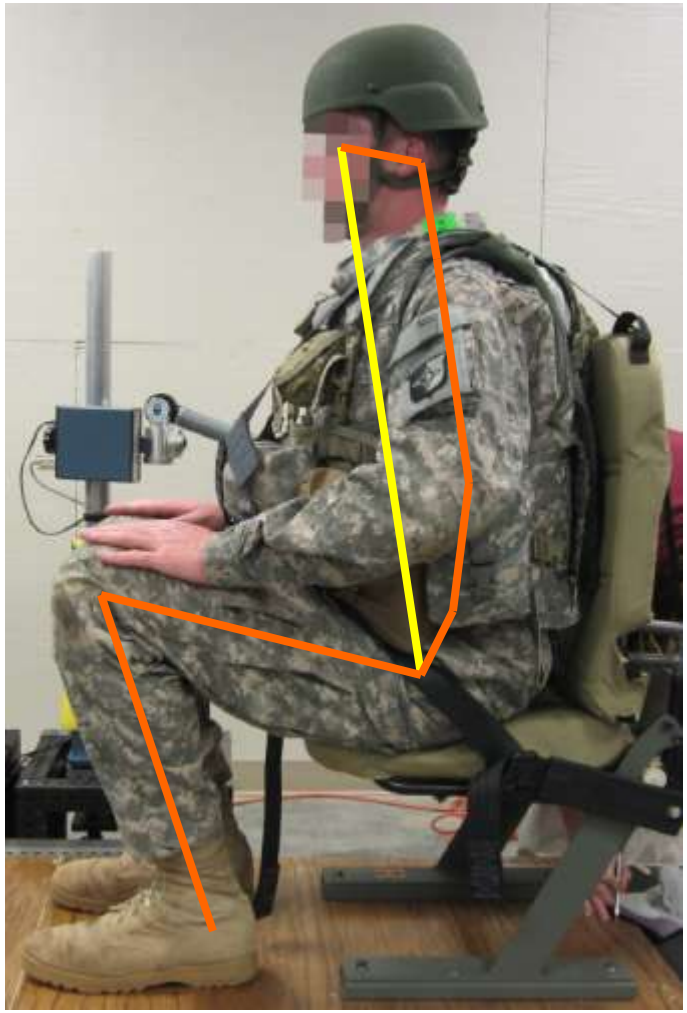
Goal: Predict squad posture

Inputs:

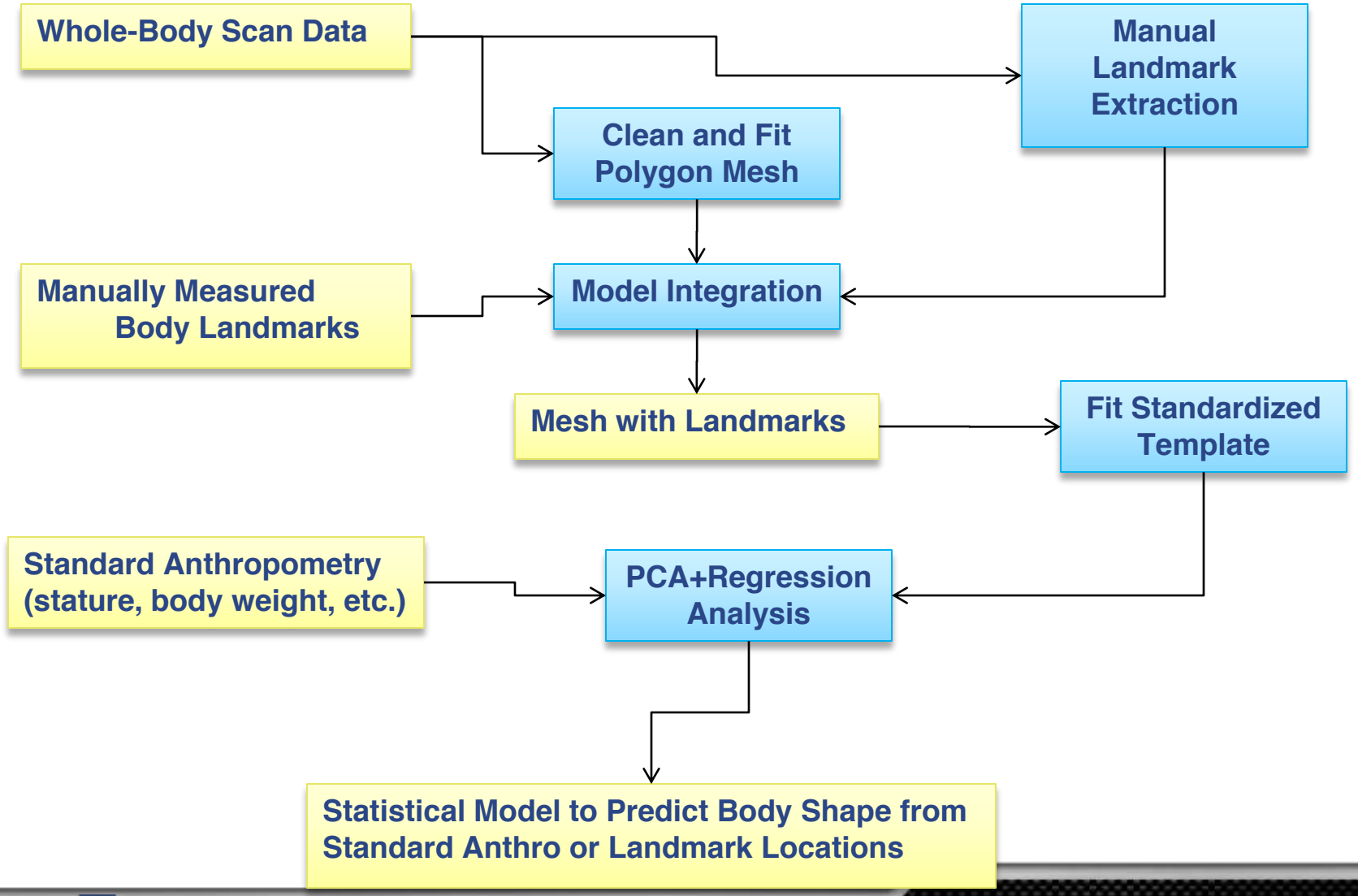
- seat height and back angle
- stature, erect sitting height, body weight, and gear level (ACU, PPE, ENC)

Outputs:

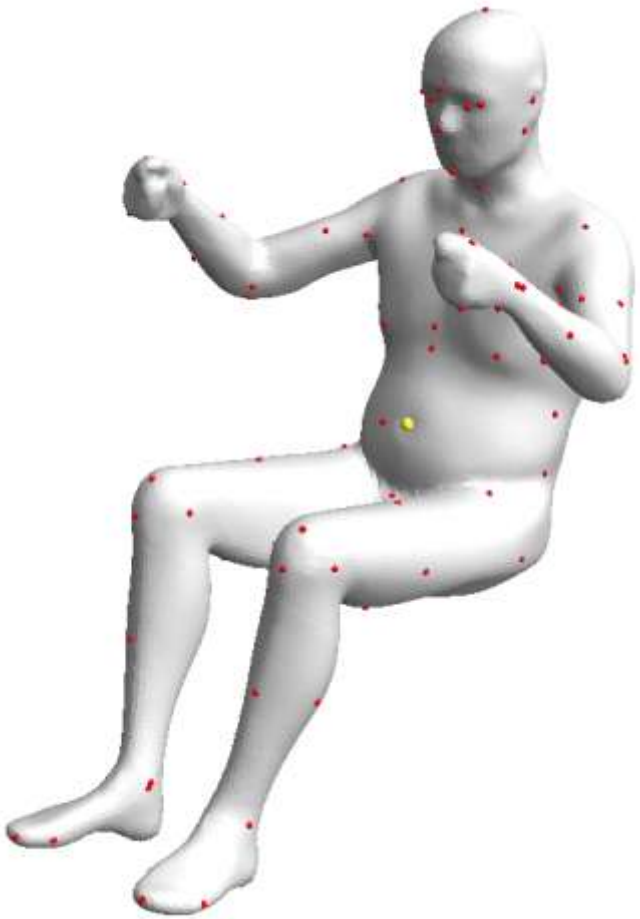
- Hip location
- Eye location
- Body segment angles



Body Shape Modeling



Process Overview: Scan Data



Template for Seated Analysis
showing 137 Landmarks
68072 polygons, 34038 vertices

Template Fit to Data from a Scan
(blue)

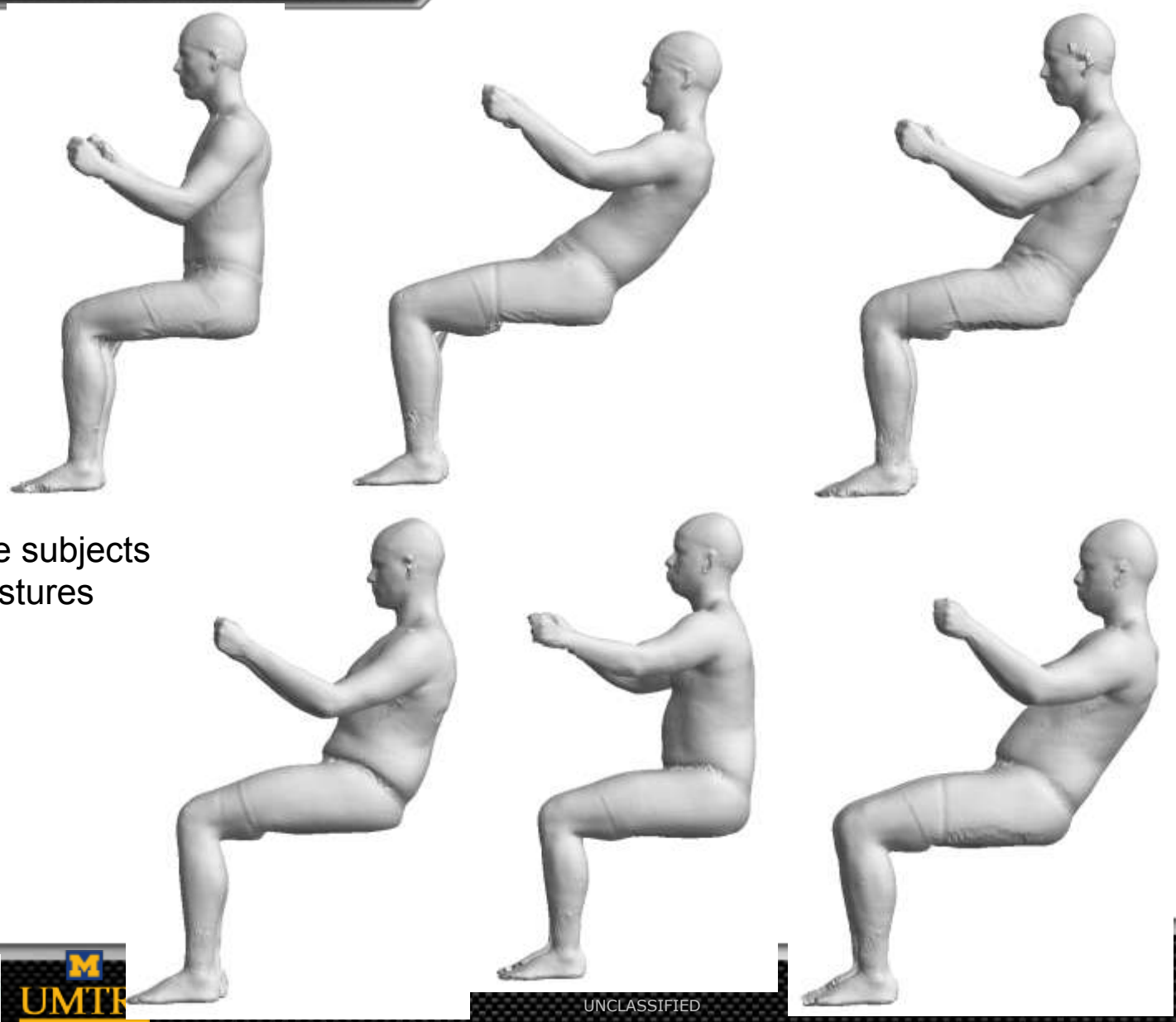
Process Overview: Scan Data

Scanned Mesh and Landmarks

Landmark-Morphed Template

Fitted Scan

Process Overview: Template Fits



Multiple subjects and postures

Output of regression model to predict seated body shape (based on 338 scans from 126 men)

Stature 1600 mm

Stature 1900 mm

Median US Male
Stature 1755 mm
BMI 27.3 kg/m^2

BMI 18 kg/m^2

BMI 40 kg/m^2

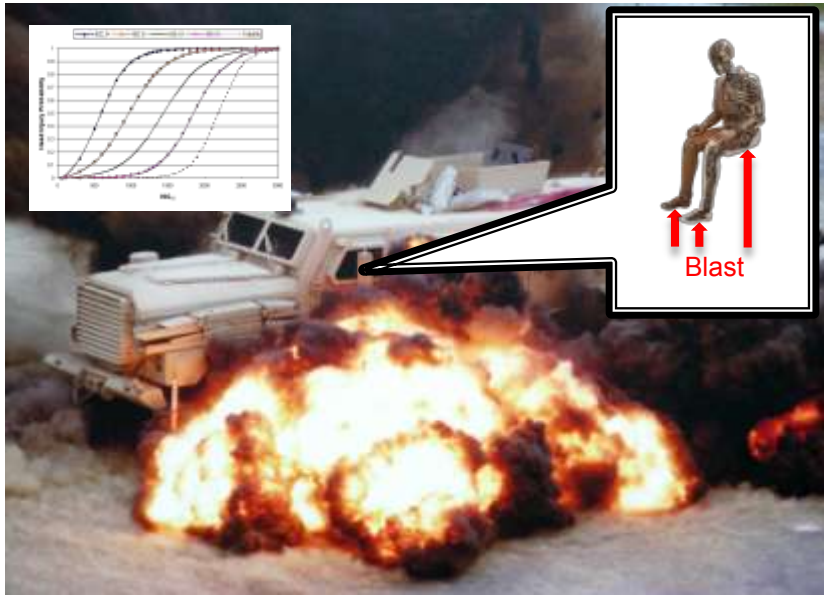
Output of regression model

Torso Recline

Torso Flexion

Random Simulated Men

Applications: WIAMan



Purpose:

1. Develop an improved blast test manikin that incorporates the medical research which provides an increased capability to measure and predict skeletal occupant injury during Under Body Blast events.
2. Conduct cadaveric research to establish a scientific and statistical basis for evaluating **SKELETAL** injuries to occupants during Under Body Blast events.

Outcomes:

1. Improved prototype blast test manikin that incorporates the medical research which provides an increased capability to measure and predict occupant injury during Under Body Blast events
2. A medically validated set of skeletal injury criteria for occupant injury during blast events
3. Human response curves that inform the concurrent design and biofidelity of the blast test manikin

Applications: WIAMan

Body landmark and surface-scan data from 126 Soldiers were analyzed to create a complete 3D representation of the body shape and joint locations of a "50th-percentile" male Soldier.

Body landmarks measured in reference seating condition

Posture Analysis

Whole-body shape in 4 seated postures from laser scanning

Skeletal geometry measured in "hardseat"

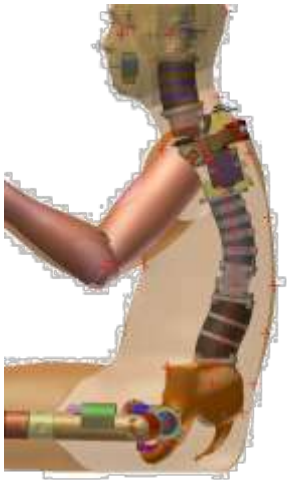
Body Shape Analysis

WIAMan Anthropometry Specification

Applications: WIAMan

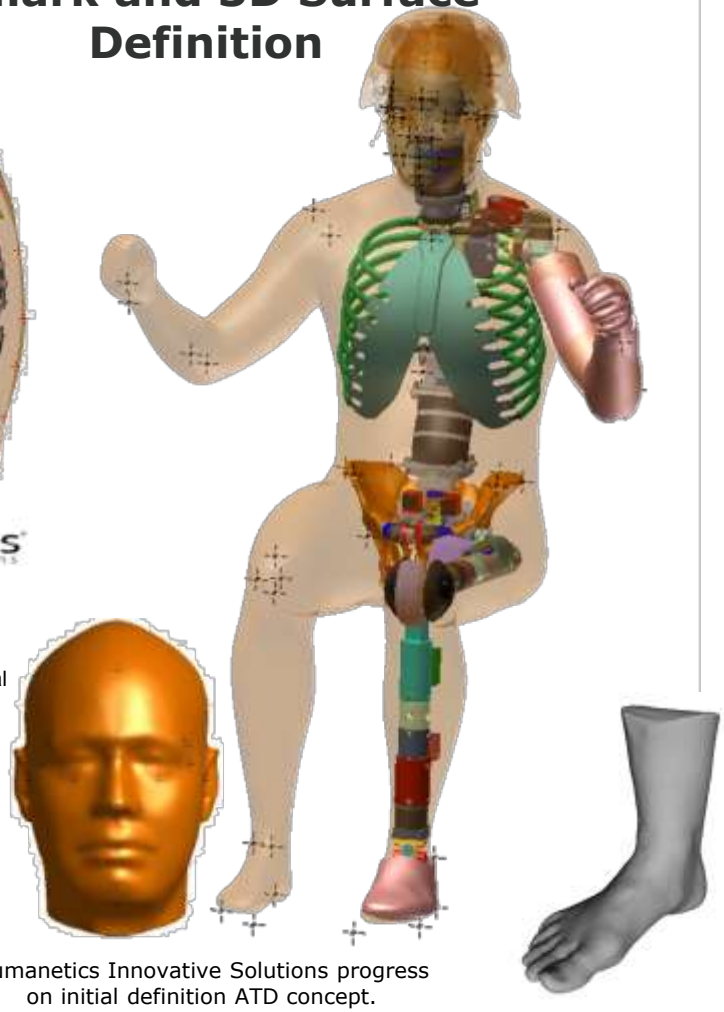
WIAMan Design Development

Landmark and 3D Surface Definition



HUMANETICS Innovative Solutions

U.S. Patent Application: FLEXIBLE SURROGATE SPINE ASSEMBLY FOR CRASH TEST DUMMY Serial No.: 13/427,381 – Filed: March 22, 2012



Humanetics Innovative Solutions progress on initial definition ATD concept.

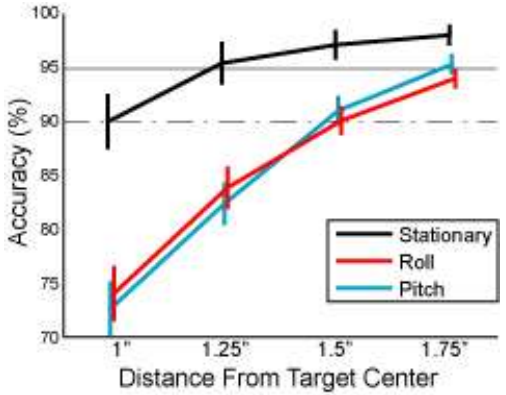
Anthropometric and Postural Requirements for Live Fire & Lab Experiments

Positioning photo from testing.

Applications: Ergonomic Manikins

Army translation of ARC research

- Reach motion
- Ingress/egress
- Encumbered manikins



Army needs and current limitations

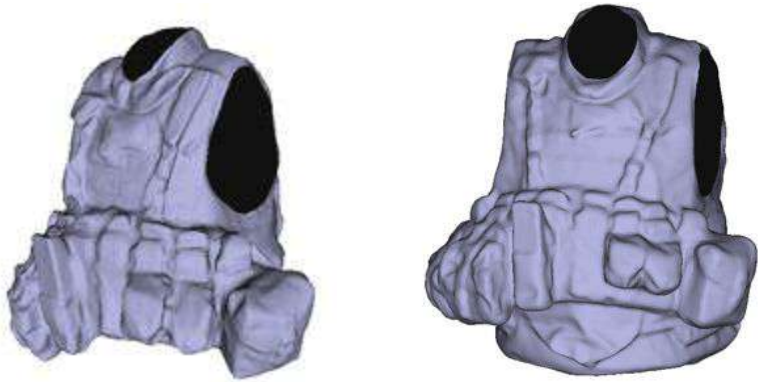
- Vehicle modifications(e.g. seats, windows)
- Comfort and reduced fatigue
- Validated models with motion
- Ingress/egress in rollover

Digital Human Model tools

- Jack
- Pro-E
- Geometry can be incorporated in other products

Applications: Ergonomic Manikins

All applications require accurate advanced body shape and encumbered manikins.

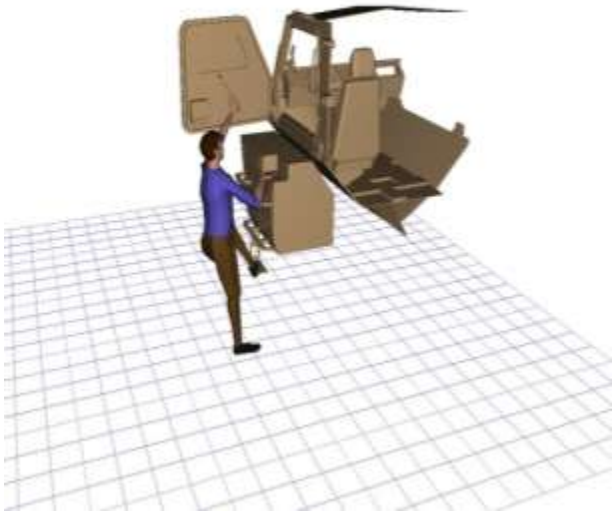


Polygonal models created for IOTV, SAW gunner, rifleman ensembles in S, M, L, XL, 2XL

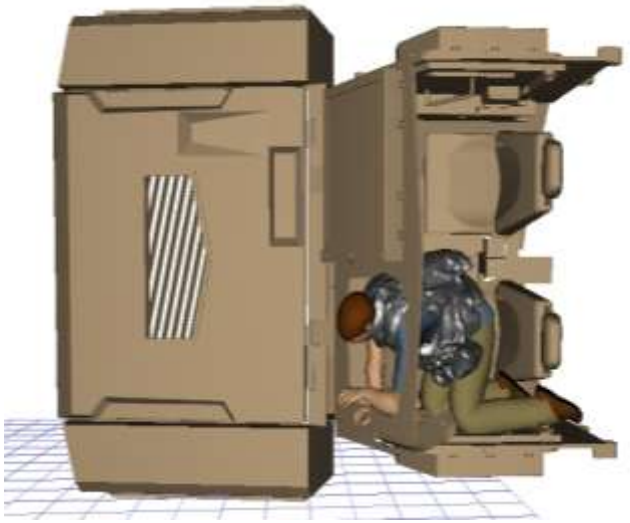
Default "clothed" Jack v7 figures

Ingress/Egress Simulations Using ARC Research

Soldier Ingress Video Capture



Jack Model w/ HUMOSIM Framework No encumbrance



Rollover Egress Thru Windshield w/ encumbrance

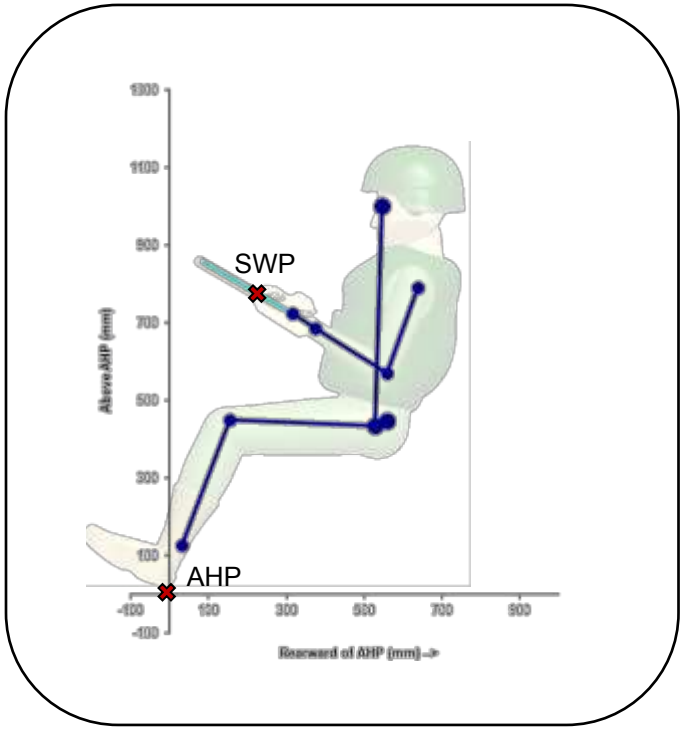
Applications: Occupant-Centered

Occupant Centric Platform (OCP)
Technology Enabled Capability Demonstration (TECD)

Challenge: Formulate an S&T program to make improvements to existing platforms or develop new platforms that provide appropriate increased protection from current and emerging threats and optimal space allocation for Soldiers and their gear...

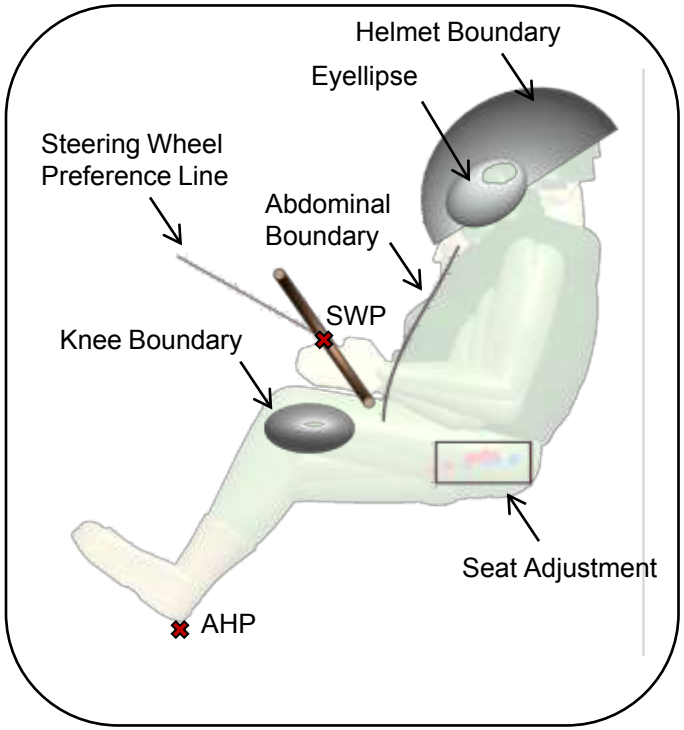
Applications: Occupant-Centered

OCP TECD is representing Soldiers in Pro/E with seven Digital Human Models (DHMs)



Posture Prediction Tool

- Predicts nominal positions of individuals
- Aids in visualizing Soldiers in vehicles

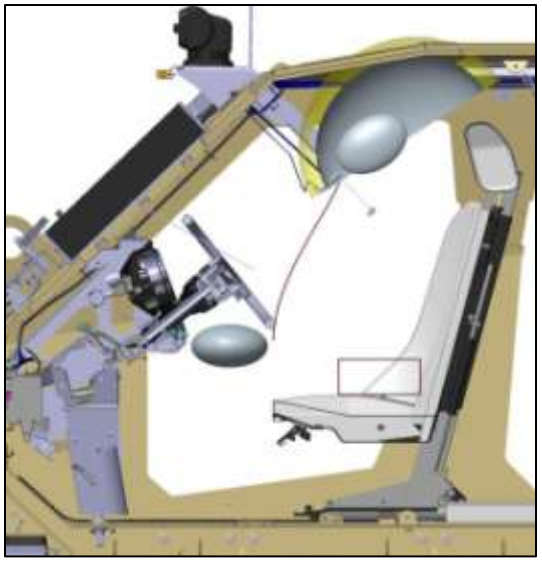


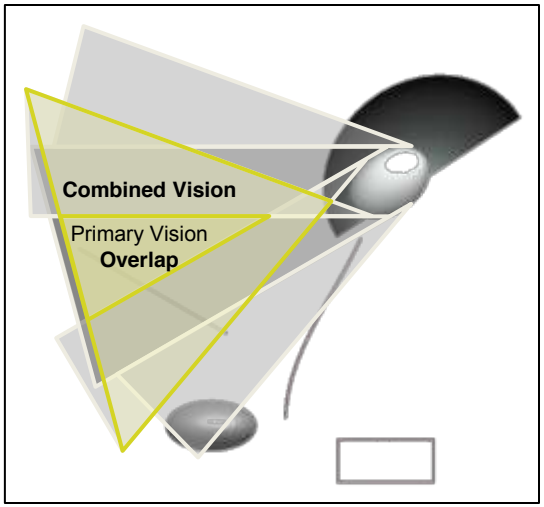
Accommodation Model

- Predicts population body boundaries
- Accounts for postural variability
- Goal: Accommodate central 90% of Soldiers

Model inputs: Soldier anthropometry and steering wheel position

Applications: Occupant-Centered





Applications

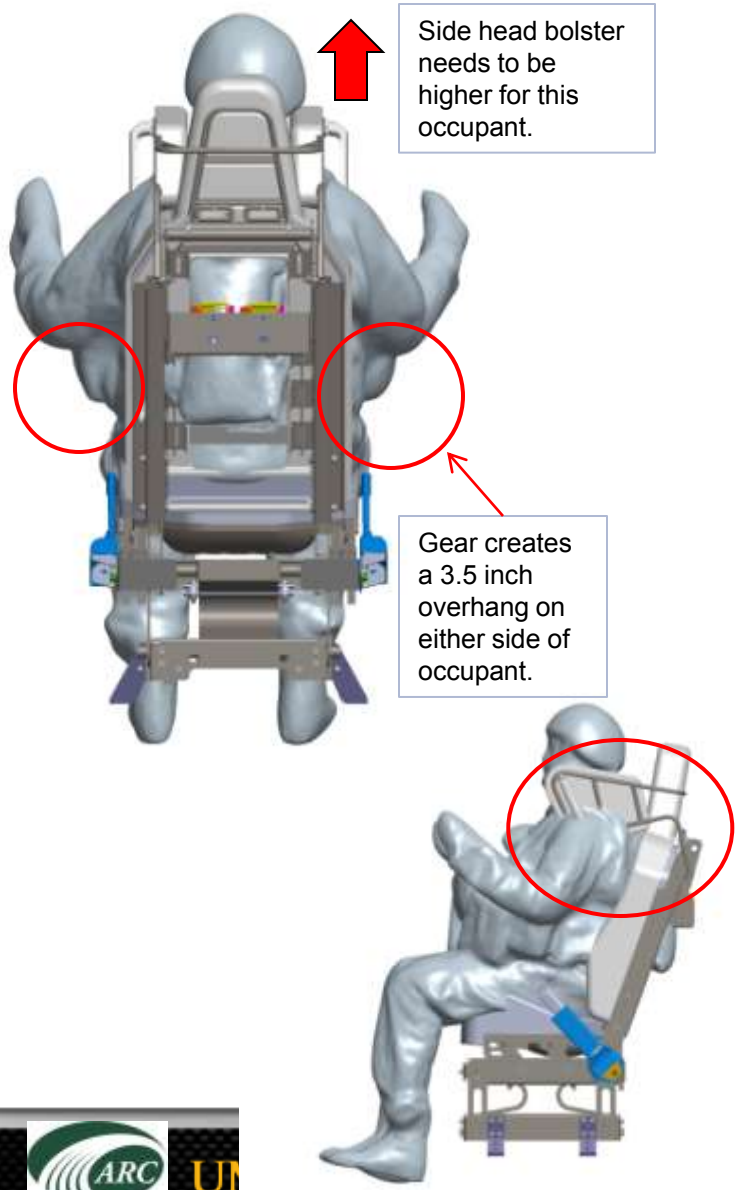
- Models can be used in vehicle concepts to:
  - Provide realistic Soldier space claim around which to develop new vehicles
  - Evaluate integration of additional/replacement technologies in legacy vehicles
- Shown at top left is a legacy vehicle application for a new seat to accommodate the central 90% of Soldiers
- Shown at bottom left is a touch screen placement investigation based on the eyellipse

Future Development

New models are needed to account for the following military driving conditions:

- Fixed eye (driver using vision blocks)
- Out-of-hatch
- Highly reclined (underbody blast protection)

Applications: Occupant-Centered



Applications – Technology Development

3D Scans are currently being used to design a seat to accommodate at least 90% of today's Soldier Population, with and without personal protective gear

Future Development

- Incorporate body mass data and gear effects into 3D models that can be manipulated into the correct seating posture.
- Incorporate posture and shape information into models used for dynamic assessment.

Related Projects and Analyses

Underway:

- Implementing Tactical Vehicle Design Tools for Driver and Crew Stations
- Evaluation of the Seat Index Point Tool for Military Seats
- Measuring and Modeling the Effects of Encumbrance on Seated Reach
- Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed Eye Point, Highly Reclined, and Out-of-Hatch Postures

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- The first large-scale study of Soldier posture and body shape in seated environments yielded data and models for a wide range of applications.
- Results are being integrated into both commercial tools (Siemens Jack model) and into TARDEC's internal design and assessment software.
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Study Team and Collaborators

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US Army Site POCs
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Backup Slides

Seat Index Point Tool

- Pilot testing has been conducted to compare SIP results with the SAE J826 H-point
- An initial conceptual design for a back angle probe is being tested.

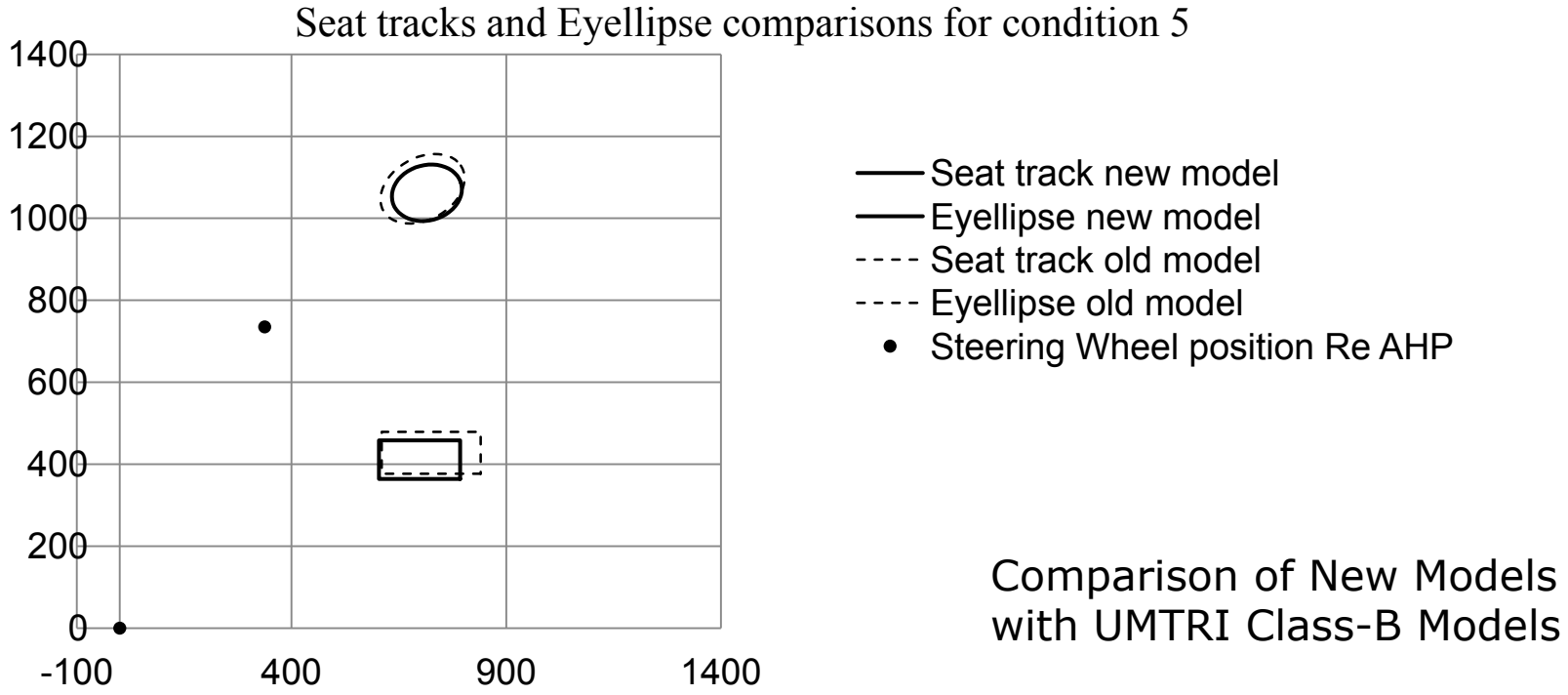
SIP Tool
J1163
ISO 5353

J826 H-point Manikin

Back Angle Probe Prototype

Accommodation Models

- Seating accommodation model predicts driver seat position distributions; used for locating seat track adjustment ranges
- Eyellipse predicts driver eye locations; used for vision analyses and locating displays



Comparison of New Models with UMTRI Class-B Models

Body Shape Modeling

For standing, we've used the mesh of a popular ergonomic model as a template to facilitate application of the results

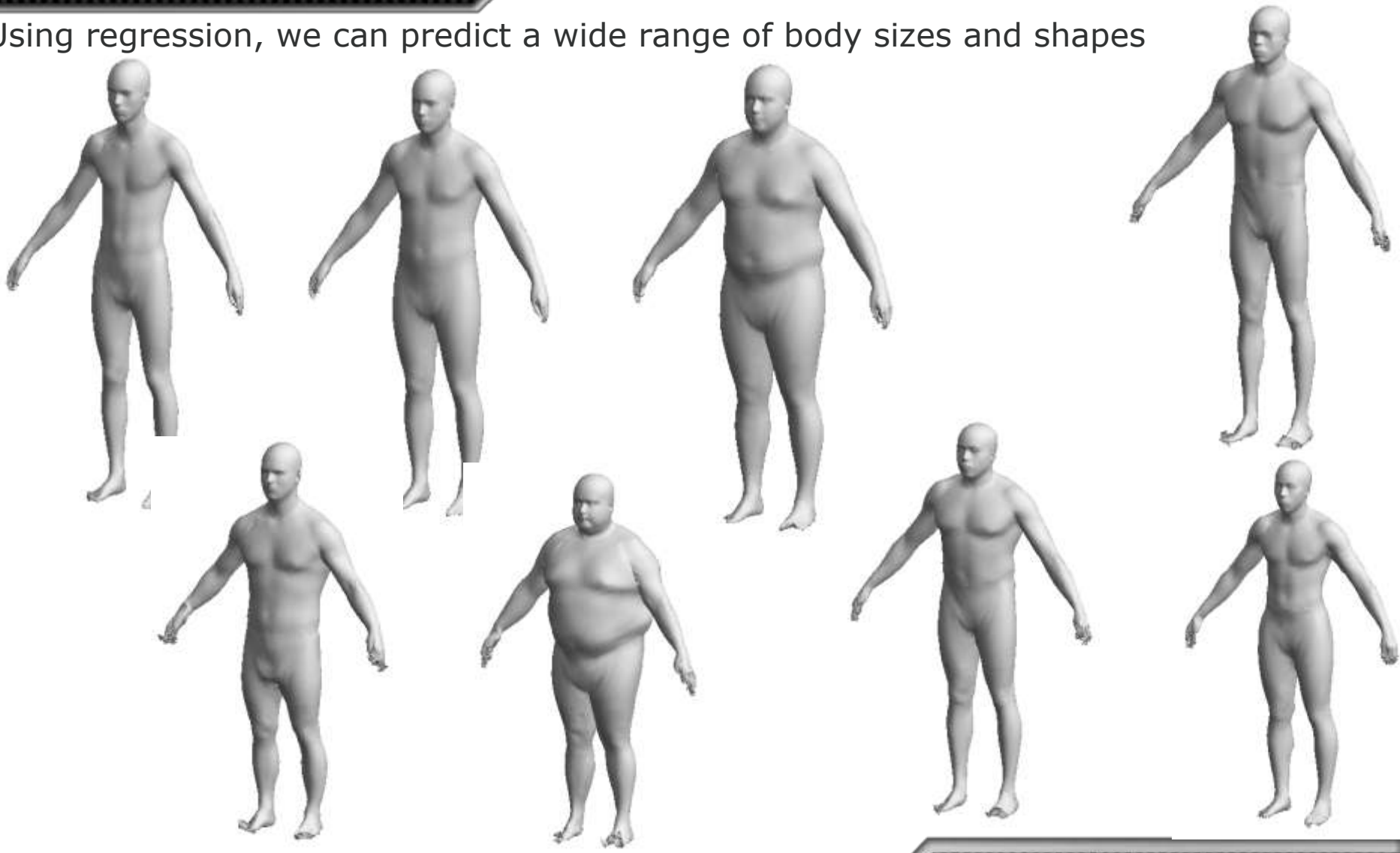
Template

Data

Template Fit To Data

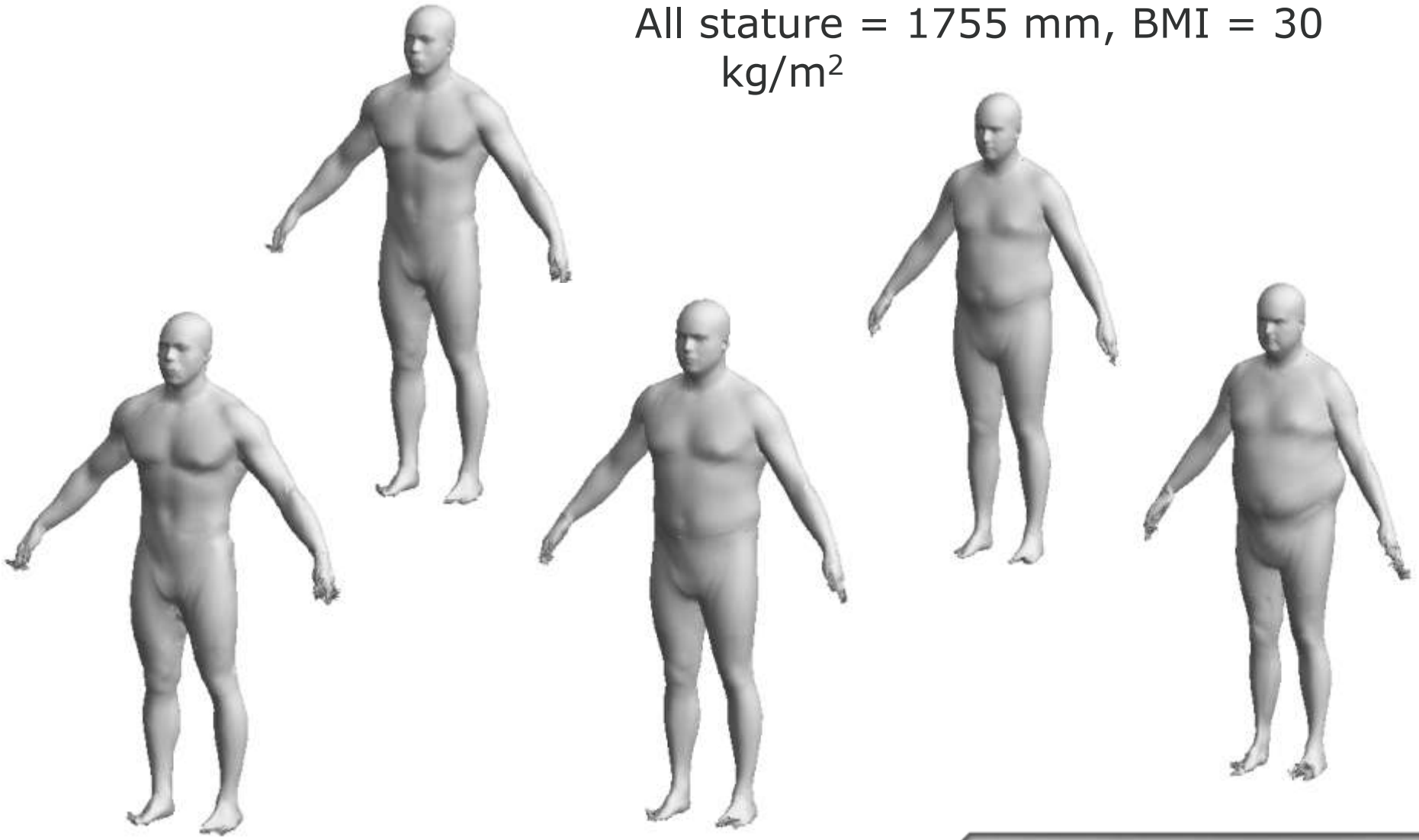
Body Shape Modeling

Using regression, we can predict a wide range of body sizes and shapes



Body Shape Modeling

All stature = 1755 mm, BMI = 30 kg/m^2



Commercial Implementation

- Siemens is underway with integrating the male and female body shape models into the Jack human modeling software
- We are in discussions with Siemens about upgrades to their Occupant Packaging Toolkit to incorporate the new posture-prediction, seating accommodation, and eyellipse models. First estimate is that the new version will be available

Advanced Scaling Prototype in Jack