HIGHLY RECLINED SEATING (HRS): DRIVER CAD ACCOMMODATION MODEL VERIFICATION REPORT

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1. VERIFICATION REPORT EXECUTIVE SUMMARY

Military ground vehicles are currently designed using requirements from MIL-STD-1472, the *Department of Defense Design Criteria Standard: Human Engineering*. The MIL-STD, however, is difficult for designers to apply properly because it is often open to interpretation. Easy-to-use Computer-Aided Design (CAD) tools are needed by the ground vehicle community to address this issue. The CAD tools being developed are called accommodation models. Accommodation models are constructed from 3D empirical data for a given seating configuration to provide population workspace boundaries that include the effects of both anthropometry and posture. The verification effort is intended to build confidence in accommodation models for use in ground vehicle design.

The model described in this verification report is the Ground Vehicle Systems Center (GVSC) Highly Reclined Seating (HRS): Driver CAD accommodation model. The model was developed to address the need of certain vehicles to have a reduced vehicle profile, requiring the crew to sit in a more reclined position, and where the crew performs most of the tasks fully under-armor. The model is intended to provide the composite boundaries representing the body of the defined user population, including the effects of posture and protective equipment and gear. The boundaries defined include the required space needed for the equipped users' helmet, torso, elbows, knees, eyes, and boots. The model also generates preferred yoke and pedal locations. Clearances between the user and surrounding interior vehicle surfaces have been added per MIL-STD-1472 (e.g. head clearance required from head (helmet) to vehicle roof line). Direct vision zones, including to screens at eye level, have been added based on MIL-STD-1472 and SAE Recommended Practice J1050.

The HRS: Driver CAD accommodation model is a statistical model created utilizing data collected from Soldiers at Fort Hood, Texas, and is documented in the report *Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configurations* completed by the University of Michigan Transportation Research Institute (UMTRI). Two additional studies were conducted at UMTRI in 2021-2022 and 2023. The first study from 2021-2022 expanded the range of seat back angles for greater recline. The study included seat back angles from 40 to 70 degrees and varying hip locations (full rearward, full forward, and sitter-selected). The second study in 2023 reviewed a prototype Molded Contour Seat (MCS) to add to the model. The CAD version of the model, created using PTC Creo® 3D CAD software, is a stand-alone geometric reproduction of the output found in the UMTRI Microsoft Excel spreadsheet.

This CAD accommodation model can be applied early in the vehicle design process to ensure accommodation requirements are met and help explore possible design tradeoffs when conflicts with other design parameters exist. Vehicle designers can use the HRS: Driver CAD accommodation model for the following scenarios: 1) during the concept and design phase of new acquisition programs, 2) while upgrading existing ground vehicle platforms, and 3) for assessing a commercial off-the-shelf (COTS) system. Human factors engineers could benefit by working with vehicle designers to perform virtual assessments in CAD when there is not enough time and/or funding to translate vehicle models into formats compatible with human figure modeling and simulation software.

The intention of verification is to build confidence in the CAD accommodation model. Model verification includes twelve test scenarios for comparing the HRS: Driver CAD accommodation model outputs against predefined requirements and acceptability criteria. Specifically, when given the same inputs, accommodation model geometry from the CAD model will be compared to the outputs of the UMTRI *HRS_Accommodation_Models.28, 2024-10-08* spreadsheet; and boundary manikin hip and eye locations were compared to the outputs of the *HRS_Highly Reclined Posture Prediction.11, 2022-10* spreadsheet. Because no other models for comparison exist, Subject Matter Experts (SMEs) were used to determine that CAD model outputs for occupant clearances matched the agreed upon interpretation of MIL-STD-1472 and that direct vision zones matched the agreed upon interpretation for combining concepts presented in MIL-STD-1472 and SAE Recommended Practice J1050.

No issues were discovered during the verification of the model. The final outcome from the review was team consensus that the HRS: Driver CAD accommodation model passed verification.

2. PROBLEM STATEMENT

Military ground vehicles are currently designed using requirements from MIL-STD-1472, the Department of Defense Design Criteria Standard: Human Engineering. The requirement to accommodate the central 90 percent of the user population in which the fully equipped user can sit safely and comfortably while performing all required functions, requires multivariate analysis methods so that both the users' anthropometry and posture can be considered [5]. MIL-STD-1472 is often open to interpretation and is therefore difficult for designers to apply consistently. Easy-to-use, valid design tools and procedures based on these methods are needed to effectively design vehicle workstations. The chosen tools are Computer-Aided Design (CAD) based accommodation models adapted for users in military ground vehicles, that directly parallel long-standing SAE recommended practices used in the commercial automotive and truck domains [14]. The fifth such CAD model to be developed is the GVSC Highly Reclined Seating (HRS): Driver CAD accommodation model, Figure 1.

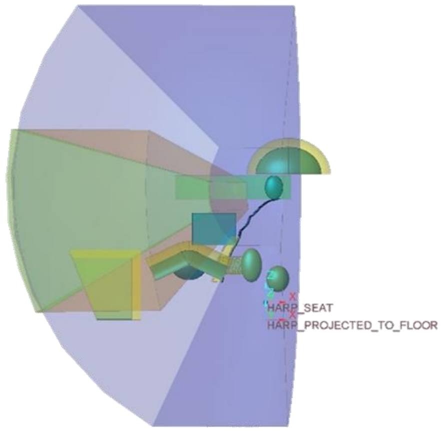

Figure 1: Highly Reclined Seating (HRS): Driver CAD Accommodation Model

2.1. Intended Use

The HRS: Driver CAD accommodation model described in this verification report is being developed to address the need of certain vehicles to have a reduced vehicle profile, requiring the crew to sit in a more reclined position, and where the crew performs most of the tasks fully under-armor.

The HRS: Driver CAD accommodation model is intended to provide the composite boundaries representing the body of the defined user population, including the effects of body size, protective equipment and gear. In particular, the accommodation boundaries indicate the adjustment range needed for vehicle controls and the resulting positions for the equipped user population's eyes, helmet, torso, elbows, knees and boots. Clearances between the user and surrounding interior vehicle surfaces have been added per MIL-STD-1472 (e.g. head clearance required from head (helmet) to vehicle roof line). Crew field of view to displays is developed using a combination of MIL-STD-1472 and SAE Recommended Practice J1050 [13] applied to the eyellipse, the geometric entity that describes the distribution of the user's eye locations.

It should be noted that CAD accommodation models serve as a design tool and are not intended to replace, but rather complement, Human Factors Engineering (HFE) assessment tools.

2.2. M&S Overview

The HRS: Driver CAD accommodation model is a statistical model created utilizing data collected from Soldiers at Fort Hood, Texas, and is documented in the report *Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configurations* [10] completed by the University of Michigan Transportation Research Institute (UMTRI). Two additional studies were conducted at UMTRI in 2021-2022 and 2023. The first study from 2021-2022 expanded the range of seat back angles for greater recline. The study included seat back angles from 40 to 70 degrees and varying hip locations (full rearward, full forward, and sitter-selected). The second study in 2023 reviewed a prototype Molded Contour Seat (MCS) to add to the model [9]. The CAD version of the model, created using PTC Creo® 3D CAD software, is a stand-alone geometric reproduction of the output found in the UMTRI Microsoft Excel spreadsheet.

Model inputs are used to define both the occupant population and vehicle environment (see Table 1). Occupant inputs include the definition of the target design population (a subset of the Army Anthropometric Survey (ANSUR) II) [2], the ensemble (clothing and equipment worn by the user), the desired level of accommodation (for example, 90%), and the target population gender mix. Ideally, the level of accommodation will be set at the central 90% of the target design population to be consistent with MIL-STD-1472 requirements. The vehicle inputs define the seat and its position above the floor heel surface. It should be noted that the 2010 MCANSUR of U.S. Marine Corps (USMC) Personnel [3] can also be added to the model if USMC anthropometry is needed for design.

The HRS: Driver CAD accommodation model represents the posture and position variability for the entire selected target user population (e.g., central 90%, 85% male). The model can guide vehicle designers in creating an optimized workspace for the user. The CAD accommodation model, along with additional added space claims for human factors, can be used to visualize MIL-STD-1472 requirements. This eliminates the concern of inconsistent application of the MIL-STD by vehicle designers when creating the occupant workspace [14].

2.3. M&S Application

The use of the HRS: Driver CAD accommodation model provides the opportunity to apply Human Systems Integration (HSI) very early in the acquisition process. The model can be utilized during the Material Solution Analysis Phase prior to Milestone (MS)A and up through and including MSB. Past programs have not actively engaged HSI until MSB or the Engineering Manufacturing and Development (EMD) Phase, resulting in significant design and cost changes.

This HRS: Driver CAD accommodation model can be used to explore possible design tradeoffs when conflicts with other design parameters exist. Vehicle designers can use the model for the following scenarios: 1) during the concept and design phase of new acquisition programs, 2) while upgrading existing ground vehicle platforms, and 3) for assessing a commercial off-the-shelf (COTS) system. Human factors engineers could benefit by working with vehicle designers to perform virtual assessments in CAD when there is not enough time and/or funding to translate vehicle models into assessment software compatible formats and perform detailed human figure modeling.

2.3.1. Model Origin

The seat Human Accommodation Reference Point (HARP) is the origin for the HRS: Driver CAD accommodation model, Figure 2. The HARP is a reference point for predicting human posture and position with respect to the seat. The HARP is defined and measured using the ISO 5353 SIP device and the associated procedures presented in UMTRI-2014-33 [11]. All outputs are determined with respect to the HARP.

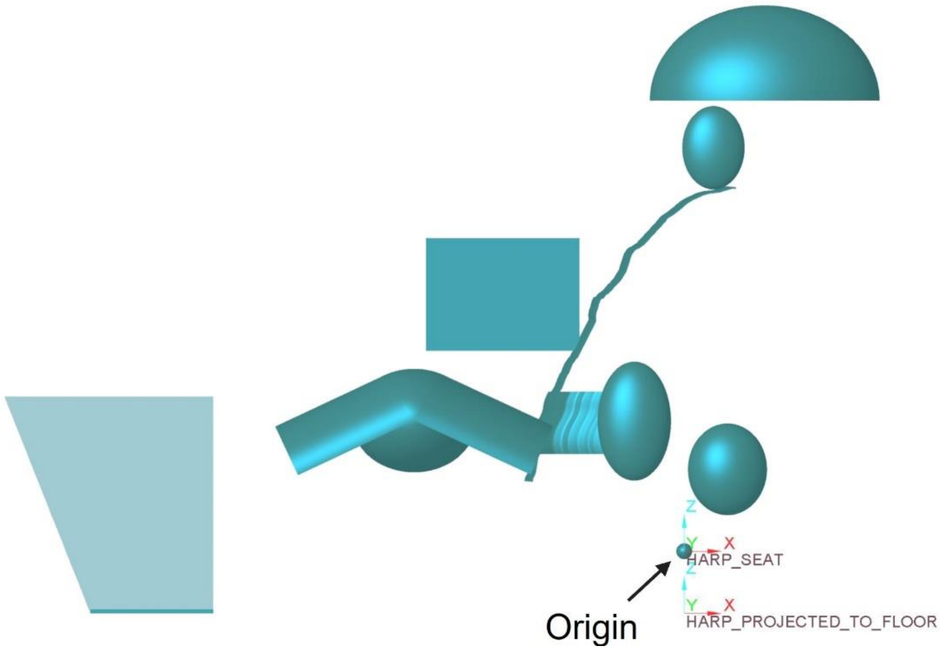

Figure 2: HRS: Driver CAD Model Origin

2.3.2. Model Inputs

The HRS: Driver accommodation model requires eight inputs, listed in Table 1:

Table 1: Highly Reclined Seating (HRS): Driver CAD Accommodation Model Inputs and Definitions

Model Input	Description
Target Accommodation	The percentage of the target design population to be accommodated. The occupants not accommodated are evenly split between the smaller and larger extremes of the population. In MIL-STD-1472 (2020), the accommodation target has been set at 90%.
Fraction Male	The percentage of males in the defined target design population.
Ensemble	Clothing and equipment available for selection in the model: • [1]PPE = ACU + IOTV + ACH • [2]ENC = ACU + PPE + Rifleman, minus the hydration pack • MSV (plates) = ACU + MSV, with plates + ACH • MSV (no plates) = ACU + MSV, without plates + ACH
Seat Type	Seats for which data were gathered: • UMTRI = generic or unknown seat • MCS = Molded Contour Seat
Human Accommodation Reference Point (HARP)	The seat height as measured above the heel rest surface.

HARP Location	Where HARP is measured on seat (i.e., position of the hips): • Rearward • Forward Use forward for seat back angles of 40 degrees or more.
Seat Back Angle	Lower support surface of the seat back measured from vertical.
Head Support	Whether head support is used.

[1] Personal Protective Equipment (PPE), Advanced Combat Uniform (ACU), Improved Outer Tactical Vest (IOTV) that included Enhanced Small Arms Protective Insert (ESAPI) plates, Enhanced Side Ballistic Inserts (ESBI), and Advanced Combat Helmet (ACH).
[2] Encumbered (ENC), Rifleman Ensemble defined in the Soldier Load Configurations in Ground Vehicles [6] and Seated Soldier Study [12].

2.3.3. Model Outputs – Occupant Composite Body Boundaries and Adjustment Ranges

The primary model outputs include the occupant population boundaries for helmet, torso, elbows, knees, and boots; eye locations; and the resulting adjustment ranges for the yoke and pedal. Model outputs are described below in Table 2 and shown in **Error! Reference source not found.**.

Table 2: HRS: Driver CAD Model Accommodation Boundary Outputs and Definitions

Model Output	Description
Eyellipse	The eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of occupant eye locations in the vehicle.
Helmet Boundary	The helmet boundary depicts the distribution of target design population helmet locations in the vehicle. In this model, the Advanced Combat Helmet (ACH) is used. The helmet boundary has a tangent cutoff characteristic and is used to determine or set clearances to the vehicle ceiling and nearby equipment.
Elbow Boundary, Dynamic	This elbow boundary depicts the distribution of occupant elbow locations when hands are on the steering mechanism (i.e., in a driving posture).
Elbow Boundary, Resting	This elbow boundary depicts the distribution of occupant elbow locations when not performing tasks (i.e., in a relaxed posture).
Torso Boundary PPE	The torso boundary depicts the distribution of user torsos, including the effects of ensemble.
Yoke (Steering Mechanism) Travel Range	The yoke travel range depicts the amount of adjustment (fore/aft and up/down) needed to accommodate the desired percentage of the user population.
Knee Boundary, including Leg and Thigh	The knee boundary with leg and thigh depicts the top, forward, and lateral distribution of the resting knee locations in vehicle.
Pedal Fore-aft Adjustment	The pedal location travel depicts the fore-aft range of preferred pedal positions relative to the HARP location.
Boot Boundary	The boot contour is based on placing an estimated 95th percentile male boot at the front end of the calculated pedal location travel. The contour takes into account the seat height via the leg angle, so the boot is assumed to be on a pedal or footrest holding it perpendicular to the leg.

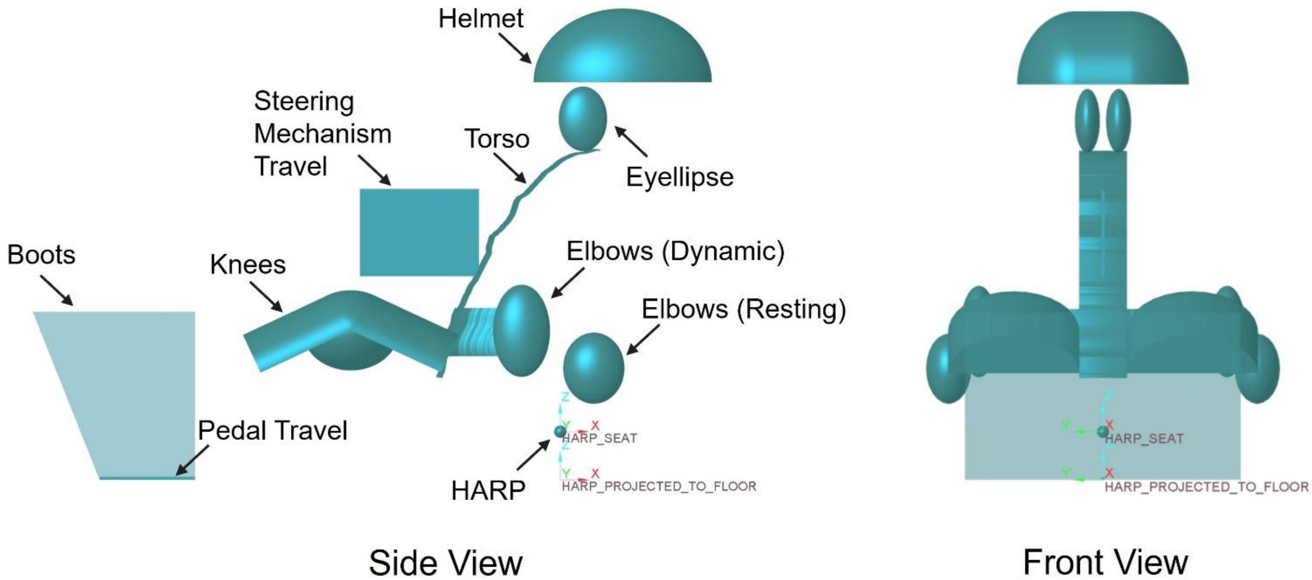

Figure 3: HRS: Driver CAD Model Composite Body Boundaries and Adjustment Ranges

2.3.4. Model Outputs – Occupant Clearances Based on MIL-STD-1472

Occupant clearance zones based on MIL-STD-1472 are included for the vehicle designer to utilize when creating the occupant workspace. Clearances consist of an additional 2-inch space claim required between the body boundaries and the vehicle environment. Model outputs are described below in Table 3 and shown in Figure 4.

Table 3: HRS: Driver CAD Model Clearance Outputs and Definitions

Model Output	Description
Clearance, Helmet	The helmet clearance consists of an additional 2 inches of space claim between the helmet boundary and the vehicle ceiling and nearby equipment.
Clearance, Abdomen	The abdominal clearance consists of an additional 2 inches of space claim between the equipped seated occupant and the steering mechanism.
Clearance, Knee with Leg and Thigh	The knee, leg, and thigh clearance consists of an additional 2 inches of space claim between the knees and any surrounding components such as doors, consoles and racks. The space between the legs is included in the clearance zone.

Model Output	Description
Clearance, Elbow	The elbow clearance consists of an additional 2 inches of lateral space claim between the elbows and nearby vehicle structures such as door trim. Clearance is provided for both driving and resting elbow boundaries.
Clearance, Boots	The boot clearance consists of an additional 2 inches of space claim between the boots and any surrounding components such as a center console or door trim. The space between the boots is included in the clearance zone.

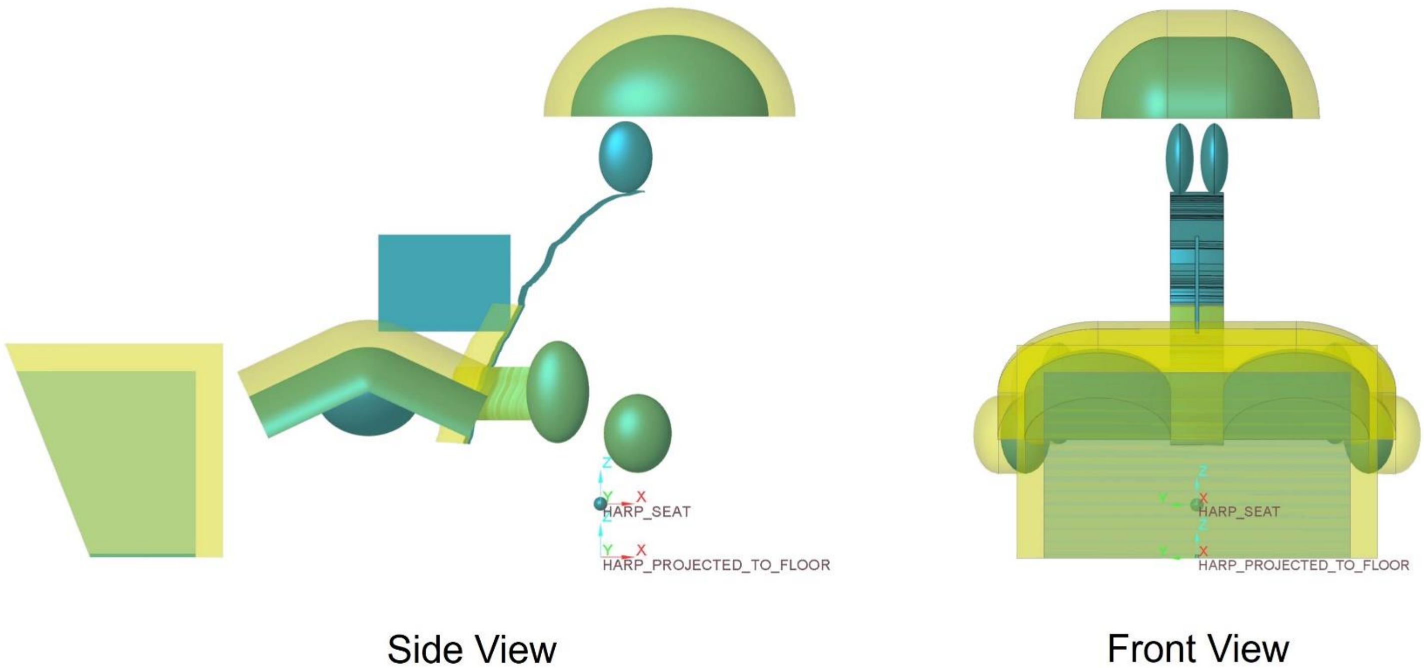

Figure 4: HRS: Driver CAD Model Clearance Zones

2.3.5. Model Outputs - Direct Field of View Based on MIL-STD-1472 and SAE J1050

The direct field of view has been divided into primary, secondary, and tertiary zones. The zones were developed with DAC and UMTRI using a combination of vertical and horizontal visual fields described in MIL-STD-1472 and SAE J1050. When members of a population have different eye points, tangents to the eyellipse are used to determine field of view [4]. Model outputs are described below in Table 4 and shown in Figure 5.

Table 4: HRS: Driver CAD Model Vision Zone Outputs and Definitions

Model Output	Description
Vision Zone, Primary	The primary vision zone indicates space viewable by all occupants from at least one eye using a minimum of “easy” eye rotation. Combining the limits of MIL-STD-1472 and SAE J1050, “easy” eye rotation is defined laterally as 15 degrees side-to-side from the occupant’s centerline and vertically as +15/-30 degrees from horizontal [4].
Vision Zone, Secondary	The secondary vision zone includes both “easy” eye rotation and “easy” head turn. Combining the limits of MIL-STD-1472 and SAE J1050, “easy” eye rotation and “easy” head turn is defined laterally as 60 degrees side-to-side from the occupant’s centerline (15 degrees eye + 45 degrees head) and vertically as +15/-30 degrees from horizontal (eye rotation only) [4].
Vision Zone, Tertiary	The tertiary vision zone includes both “max” eye rotation and “max” head turn. Combining the limits of MIL-STD-1472 and SAE J1050, “max” eye rotation and “max” head turn is defined laterally as 95 degrees side-to-side from the occupant’s centerline (35 degrees eye + 60 degrees head) and vertically as +45 degrees/-65 degrees from horizontal (eye rotation only).
Vision Zone, Screen Adjustment	The vision zone for screen adjustment allows for horizontally directed vison to the center of a screen around a 180-degree arc centered on the neck pivot. Each member of the population will have a viewing distance of 15 to 20 inches if the entire zone is utilized.

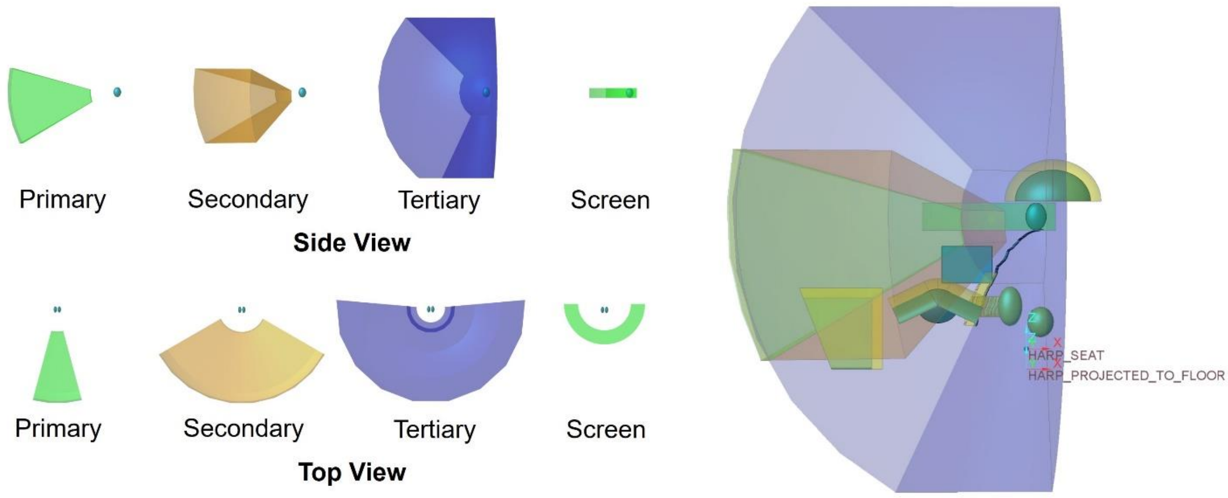

Figure 5: HRS: Driver CAD Model Vision Zones

2.3.6. Model Outputs - Manikin Placement

Using the same data underlying the creation of the accommodation boundaries, boundary manikins representing the anthropometric extremes of vehicle workstation design are placed in their nominal positions. This is helpful in understanding how specific individuals in the population fit into the vehicle and aids visualization for those unfamiliar with the accommodation boundaries [4]. Model outputs are described below in Table 5 and shown in Figure 6.

Table 5: HRS: Driver CAD Model Manikin Posture and Position Output and Definitions

Model Output	Description
Boundary Manikin Posture and Position	The boundary manikin posture and position output predicts position and torso posture for a family of simulated drivers based on the vehicle configuration and the anthropometric inputs of stature, body weight, and erect sitting height.

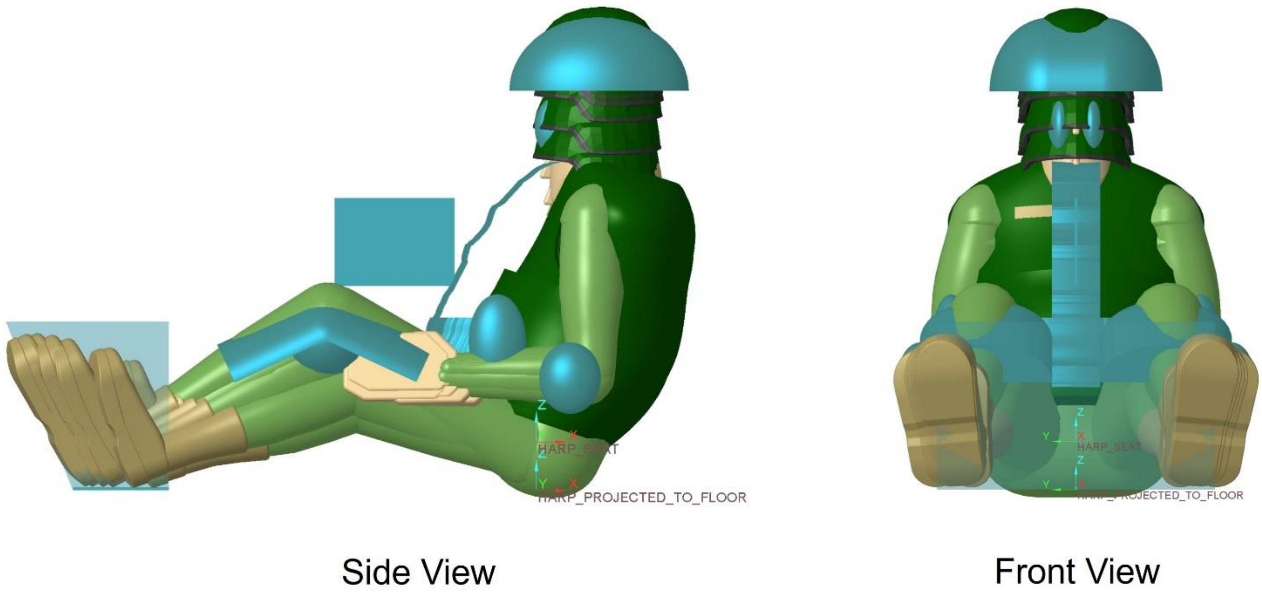

Figure 6: HRS: Driver CAD Model Manikin Posture and Position

2.4. VERIFICATION SCOPE

This report documents the verification of the HRS: Driver CAD accommodation model, including the activities, results, and recommendations that were gathered during the verification effort. This report will be managed by the DEVCOM GVSC accommodation model Project Lead and will be used to support any future enhancements to the HRS: Driver CAD accommodation model.

Verification of the model was completed on 03 January 2025 by the Verification Agents listed in Table 9, Section 7. DEVCOM GVSC led the verification effort and requested review, feedback, and concurrence from the key participants listed in Table 9, Section 7.

The goal of verification was to evaluate the PTC Creo® 3D CAD version of the HRS: Driver CAD accommodation model, per the following:

1) Determine if the accommodation boundaries calculated by the GVSC CAD model match those calculated by the UMTRI Microsoft Excel spreadsheet *HRS_Accommodation_Models.28, 2024-10-08* [8]

2) Determine if the clearance zones calculated by the GVSC CAD model match the Subject Matter Expert (SME) interpretation of MIL-STD-1472 [5]

3) Determine if the direct fields of view (primary, secondary, and tertiary) calculated by the GVSC CAD model match the SME interpretation of MIL-STD-1472 [5] and SAE J1050 [13]

4) Determine if the hip and eye points calculated by the GVSC CAD model match those calculated by the UMTRI Microsoft Excel spreadsheet *Highly Reclined Posture Prediction.11, 2022-09-28* [8]

3. REQUIREMENTS AND ACCEPTABILITY CRITERIA

The HRS: Driver CAD accommodation model shall meet the requirements shown in Table 6 below:

Table 6: Requirements Relationship Table for Accommodation Model

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for a target population input (e.g. 90%)	1.1 Target accommodation input option in model	1.1 Representative (Pass) / Non-Representative (Fail)
2	Model allows for input of the population gender mix (e.g. 85% Male : 15% Female)	2.1 Fraction male input option in model	2.1 Representative (Pass) / Non-Representative (Fail)
3	Model allows for selection of ensemble as either PPE, ENC, MSV (plates), or MSV (no plates)	3.1 Ensemble selection of PPE in model	3.1 Representative (Pass) / Non-Representative (Fail)
		3.2 Ensemble selection of ENC in model	3.2 Representative (Pass) / Non-Representative (Fail)
		3.3 Ensemble selection of MSV (plates) in model	3.3 Representative (Pass) / Non-Representative (Fail)
		3.4 Ensemble selection of MSV (no plates) in model	3.4 Representative (Pass) / Non-Representative (Fail)
4	Model allows for selection of seat as either UMTRI or MCS	4.1 Seat selection of UMTRI in model	4.1 Representative (Pass) / Non-Representative (Fail)
		4.2 Seat selection of MCS in model	4.2 Representative (Pass) / Non-Representative (Fail)
5	Model allows for input of the HARP height above heel rest surface	5.1 HARP input option in model	5.1 Representative (Pass) / Non-Representative (Fail)
6	Model allows for selection of HARP location as either rearward or forward	6.1 HARP selection of rearward in model	6.1 Representative (Pass) / Non-Representative (Fail)
		6.2 Ensemble selection of forward in model	6.2 Representative (Pass) / Non-Representative (Fail)
7	Model allows for input of the lower seat back angle	7.1 Lower seat back angle input option in model	7.1 Representative (Pass) / Non-Representative (Fail)
8	Model allows for input of head support	8.1 Head support input option in model	8.1 Representative (Pass) / Non-Representative (Fail)

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
9	Model predicts the dimensions and location of the eyellipse	9.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with different inputs	9.1 Representative (Pass) / Non-Representative (Fail)
		9.2 CAD model matches the UMTRI spreadsheet	9.2 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the helmet contour boundary (helmet locations) with respect to the eye location and fitted to the eyellipse	10.1 Model outputs a helmet contour for the given population and gender mix that adjusts with different inputs	10.1 Representative (Pass) / Non-Representative (Fail)
		10.2 CAD model matches the UMTRI spreadsheet	10.2 Representative (Pass) / Non-Representative (Fail)
11	Model predicts dynamic elbow contours	11.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	11.1 Representative (Pass) / Non-Representative (Fail)
		11.2 CAD model matches the UMTRI spreadsheet	11.2 Representative (Pass) / Non-Representative (Fail)
12	Model predicts resting elbow contours	12.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	12.1 Representative (Pass) / Non-Representative (Fail)
		12.2 CAD model matches the UMTRI spreadsheet	12.2 Representative (Pass) / Non-Representative (Fail)
13	Model predicts the forward abdominal boundary for PPE ensemble	13.1 Model outputs an abdominal boundary for the given population, gender mix, and Soldier equipment configuration	13.1 Representative (Pass) / Non-Representative (Fail)
		13.2 CAD model matches the UMTRI spreadsheet	13.2 Representative (Pass) / Non-Representative (Fail)
14	Model predicts the steering mechanism (e.g. steering yoke) travel range	14.1 Model outputs a fore/aft and vertical steering mechanism travel window for the given population and gender mix that adjusts with different inputs	14.1 Representative (Pass) / Non-Representative (Fail)
		14.2 CAD model matches the UMTRI spreadsheet	14.2 Representative (Pass) / Non-Representative (Fail)
15	Model predicts the knee contour with leg and thigh segment angles based on location of resting occupants' knees in vehicle	15.1 Model outputs a knee ellipsoid for the given population and gender mix that adjusts with different inputs	15.1 Representative (Pass) / Non-Representative (Fail)
		15.2 CAD model matches the UMTRI spreadsheet	15.2 Representative (Pass) / Non-Representative (Fail)

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
16	Model predicts the fore/aft pedal location for the occupants	16.1 Model outputs a fore/aft pedal travel range for the given population and gender mix that adjusts with different inputs	16.1 Representative (Pass) / Non-Representative (Fail)
		16.2 CAD model matches the UMTRI spreadsheet	16.2 Representative (Pass) / Non-Representative (Fail)
17	Model predicts boot contours based on location of resting occupants' boots in vehicle	17.1 Model outputs boot contours for the given population and gender mix that adjusts with different inputs	17.1 Representative (Pass) / Non-Representative (Fail)
		17.2 CAD model matches the UMTRI spreadsheet	17.2 Representative (Pass) / Non-Representative (Fail)
18	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD- 1472 requirements	18.1 Model outputs a 2 inch clearance zone from the top of the helmet contour that adjusts with different inputs	18.1 Representative (Pass) / Non-Representative (Fail)
19	Model provides a clearance zone for the torso, when PPE is selected, based on MIL-STD-1472 requirements	19.1 Model outputs a 2 inch clearance zone for the torso that adjusts with different inputs	19.1 Representative (Pass) / Non-Representative (Fail)
20	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472 requirements	20.1 Model outputs a 2 inch clearance zone from the top and front of the knee contour and the front of the leg segment and top of the thigh (in side-view) that adjusts with different inputs	20.1 Representative (Pass) / Non-Representative (Fail)
21	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472 requirements	21.1 Model outputs a 2 inch clearance zone laterally for the resting elbow contours that adjusts with different inputs	21.1 Representative (Pass) / Non-Representative (Fail)
22	Model provides a clearance zone for the boot based on MIL-STD-1472 requirements	22.1 Model outputs a 2 inch clearance zone from the top of the boot contour that adjusts with different inputs	22.1 Representative (Pass) / Non-Representative (Fail)
23	Model provides direct field of view (primary, secondary, and tertiary zones) based on MIL-STD-1472 and SAE J1050	23.1 Model outputs direct field of view from the eyellipse that adjusts with different inputs	23.1 Representative (Pass) / Non-Representative (Fail)
24	Model predicts screen center fore/aft and up/down adjustment range that matches the intent of MIL-STD-1472	24.1 Model outputs a fore/aft and up/down adjustment range for the center of the screen, based on the eyellipse, that adjusts with different inputs	24.1 Representative (Pass) / Non-Representative (Fail

Along with using the HRS: Driver CAD accommodation model, ground vehicle designers will use boundary manikins when creating the interior workspace. The boundary manikins are postured and positioned in CAD using equations from the posture prediction model created by UMTRI. The requirements for posture prediction are shown in Table 7 below:

Table 7: Requirements Relationship Table for Posture Prediction of Boundary Manikins

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the HARP	1.1 Model outputs the location of the hip with respect to the HARP that matches the UMTRI spreadsheet	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the HARP	2.1 Model outputs the location of the eye with respect to the HARP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

Numerical values calculated by both the GVSC CAD model and the UMTRI Microsoft Excel spreadsheets must match within +/- 0.100 inches or +/- 0.100 degrees to be considered equivalent.

4. CAPABILITIES, LIMITATIONS, & ASSUMPTIONS (CLA), RISKS/IMPACTS

4.1. M&S CAPABILITIES

The HRS: Driver CAD accommodation model will provide government and industry partners with the following M&S capabilities:

- Relevant population size/shape boundaries for the user population in an occupant workspace
- Posture prediction for the identified boundary manikins
- Clearances based on interpretation of MIL-STD-1472 and HFE recommendations
- Field of View (FOV) based on interpretation of MIL-STD-1472 and SAE J1050

4.2. M&S LIMITATIONS

The HRS: Driver CAD accommodation model has limitations based on the ground vehicle requirements for the occupant workspace, as follows:

- Since little is known about highly reclined seating and what may eventually be developed to address this type of seating position, the HRS seat (in the UMTRI study) may not be representative of any particular vehicle seat intended for reclined conditions [10].

- The UMTRI seat has a flat bottom section, allowing the person to sit "forward" or "rearward" in the seat where the Molded Contour Seat (MCS) allows the person to sit "forward" in the seat [9]. Seat design influences postures and the seat contour matters, so changes to the contour from what was tested will introduce uncertainty in the accuracy of the predictions. More human measurements can eliminate this uncertainty.
- Predicts where users ideally want to posture and position themselves but does not include vehicle limitations such as low ceiling height or limited leg room.
- Model was created with a specific range of clothing and equipment kit weights and depths, so it will have to be reevaluated if the clothing and equipment kits drastically change.
- CAD accommodation models serve as a design tool and are not intended to replace, but rather complement, HFE assessment tools.

4.3. M&S Assumptions

The development of a valid HRS: Driver CAD accommodation model is based on the following assumptions:

- The fixtures created and used by UMTRI to collect the occupant data are representative of a highly reclined seat type environment where the seat has a flat bottom section, allowing the person to sit "forward" or "rearward" for a driver or workstation with screens and hand controls.
- The Molded Contour Seat (MCS) tested to collect the occupant data is representative of a highly reclined seat type environment where the seat allows the person to sit "forward" for driver or workstations with screens and hand controls.
- Analysis methods used by UMTRI accurately predict the users' preferred posture and position.
- Position data collected in a static environment over a short period of time are reasonably similar to users' preferred postures and positions during long-duration driving.

4.4. M&S Risks/Impacts

The constraints and limitations highlighted above could potentially result in an interior workspace design that is not fully optimized. This risk will be mitigated by collaborating with DEVCOM Analysis Center (DAC) HSI SMEs who complete human factors assessments on the proposed designs, COTS vehicles, and demonstrators during the acquisition process IAW AR 602-2. This assessment will be captured in documentation completed by the DAC HSI SMEs.

5. VERIFICATION TASK ANALYSIS

5.1. Data Verification Task Analysis

No specific data verification tasks were completed because UMTRI, as the data developer, documented the methods and results of the data collection. The data and statistical techniques employed by UMTRI are appropriate for the creation of the models. Standard anthropometric data, which correlated to ANSURII data, was collected on the study participants. A whole-body laser scanner was used to record body shape in both seated and standing postures. Statistical analysis of body landmark data was conducted by UMTRI and validation of the data for the models to predict occupant posture, as a function of vehicle factors, was completed [10]. Additional seat [9] and armor studies were conducted to add Modular Scalable Vest (MSV), "forward" vs "rearward" hip position, and extended seat back angles (up to 70 degrees from vertical) to the spreadsheet based on lessons learned during model development. The UMTRI documents capturing this work are listed below:

- *Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configuration: Final Report UMTRI-2020-5*
- *HRS_Accommodation_Models.28, 2024-10-08,* UMTRI Excel spreadsheet
- *Highly Reclined Posture Prediction.11, 2022-10*, UMTRI Excel spreadsheet
- *Driving Postures in a Highly Reclined Prototype Seat*. *January 2023*

The information provided by UMTRI was utilized to create the HRS: Driver CAD accommodation model. GVSC ACT reviewed each of UMTRI's Excel spreadsheets to verify that they aligned with the written reports and then used the information as the basis for the creation of the CAD model.

5.2. Model Verification Task Analysis

Model verification included a total of twelve tests, shown below in Table 8, to compare outputs from the HRS: Driver CAD accommodation model to the UMTRI *HRS_Accommodation_Models* (2024) and *Highly Reclined Posture Prediction* (2022) spreadsheets. The blue highlighted values in the table indicate which inputs were changed from the baseline tests (Test #1 and Test #8). The primary distinguishing feature between the baselines is the seat type.

Table 8: HRS: Driver CAD Model Test Matrix

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
1	90%	85%	PPE	UMTRI	3.9 (100 mm)	30	Rearward	No	Baseline test
2	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Rearward	No	Vary seat height and back angle
3	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Forward	No	Correct for HARP location
4	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Forward	Yes	Provide head support
5	90%	85%	PPE	UMTRI	7.9 (200 mm)	50	Forward	No	Vary seat height and back angle
6	90%	85%	ACU	UMTRI	7.9	50	Forward	No	Vary ensemble
7	90%	85%	MSV (no plates)	UMTRI	7.9	50	Forward	No	
8	90%	85%	ENC	UMTRI	7.9	50	Forward	No	
9	90%	85%	PPE	MCS	7.9	50	Forward	No	Change seat; MCS baseline
10	90%	85%	MSV (no plates)	MCS	7.9	50	Forward	No	Vary ensemble
11	95%	85%	PPE	MCS	7.9	50	Forward	No	Increase accommodation level
12	90%	50%	PPE	MCS	7.9	50	Forward	No	Rebalance gender mix

All tests are compared back to their respective baselines. General observed trends are as follows:

- With increased seat height, knees (including thighs and shins) and the boot contour adjust in shape
- Moving the HARP forward increases the effective seat back angle
- The addition of a head support moves the eyes rearward and affects vertical position
- Composite body boundaries adjust with respect to chosen ensemble

- With increased Target Accommodation, composite body boundaries increase in volume and Vision Zones decrease
- Geometry for composite body boundaries decreases in volume with a smaller proportion of males

Results from the above tests have been reported both in terms of passing or failing the requirements and acceptability criteria presented previously in Section 3 and a comparison of calculated numerical results between the GVSC CAD and UMTRI spreadsheets. Please refer to Appendix B – Requirements and Acceptability Criteria Results.

6. VERIFICATION RECOMMENDATIONS

Team consensus from the verification package review is that the HRS: Driver CAD accommodation model passed verification with no outstanding issues requiring corrective action. There are no recommendations from the team for the model.

7. KEY PARTICIPANTS

Table 9 identifies the participants involved in the verification effort, including their roles and responsibilities.

Table 9: Key Participants for HRS: Driver CAD Model Verification Effort

Verification Function	Description	Responsible M&S
M&S Proponent	The organization that has primary responsibility for M&S planning and management that includes development, verification and validation, configuration management, maintenance, use of the model or simulation, and others as appropriate. A Government entity.	Frank J. Huston II, GVSC ACT Gale. L. Zielinski, GVSC ACT
M&S User	The individual, group, or organization that uses the results or products from a specific application of the model or simulation.	Mark D. Shafer, GVSC GVSP Eric S. Paternoster, GVSC PIF HSI SMEs, DEVCOM DAC Government Contractors
Verification Agent	The organization designated by the M&S proponent to perform verification of a model, simulation, or federation of M&S.	Frank J. Huston II, GVSC ACT Gale L. Zielinski, GVSC ACT

Verification Function	Description	Responsible M&S
M&S Developer	The individual, group or organization responsible for developing or modifying a model or simulation in accordance with a set of design requirements and specifications.	Frank J. Huston II, GVSC ACT Matthew P. Reed, Ph.D, UMTRI
SMEs	Individual who, by virtue of education, training, or experience, has expertise in a particular technical or operational discipline, system, or process.	Frank J. Huston II, GVSC ACT Gale L. Zielinski, GVSC ACT Cheryl A. Burns, DAC David A. Hullinger, DAC Matthew P. Reed, Ph.D, UMTRI

8. ACTUAL VERIFICATION RESOURCES EXPENDED

8.1. VERIFICATION RESOURCES EXPENDED

Table 10 identifies the resources used to create the HRS: Driver CAD accommodation model and complete associated activities, including verification.

Table 10: Verification Resources

Document/Deliverable	Required Resources	POC
Development of HRS Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configuration	M&S Developer and SME support	UMTRI
HRS: Driver Verification Plan	Verification Agent, M&S Developer and SME support	GVSC ACT
HRS: Driver Accommodation Model Build	M&S Developer and SME support	GVSC ACT
HRS: Driver Accommodation Model Verification packet completed	Verification Agent, Validation Agent, M&S Developer and SME support	GVSC ACT
HRS: Driver Model Release into PDMLink	M&S Developer	GVSC ACT
OPSEC of HRS: Driver Verification Report and CAD Model	M&S Proponent	GVSC ACT
Release of HRS: Driver Verification Report and CAD Model to the GVSC public website	M&S Proponent	GVSC ACT

8.2. ACTUAL VERIFICATION MILESTONES AND TIMELINE

Table 11 identifies the major milestone achievements in the creation of the HRS: Driver CAD accommodation model and completion of associated activities, including verification.

Table 11: Verification Milestone Timeline

Document/Deliverable	Delivery Date
Draft *HRS_Accommodation_Models.5* Excel spreadsheet	May 2019
Draft *Highly Reclined Posture Precition.4* Excel spreadsheet	May 2019
HRS: Driver CAD template development started	Jun 2019
HRS data applied to Government combat vehicle concepts	Aug 2019
UMTRI HRS study forming the basis for the original HRS: Driver accommodation model spreadsheet. Report UMTRI-2020-5	May 2020
Draft *HRS_Accommodation_Model.12* Excel spreadsheet	Mar 2022
HRS: Driver CAD model Verification Plan	Apr 2022
Complete dataset and integrated model from UMTRI based on latest study data expanding on recline seatback angles	Aug 2022
HRS: Driver CAD model development started	Sep 2022
Final *Highly Reclined Posture Precition.11* Excel spreadsheet	Oct 2022
Seat and Armor Study (SAS) (included addition of Modular Scalable Vest (MSV) to the model); data collection complete, report pending	Jan 2023
HRS data provided to DAC for crew space assessment of Industry partner vehicle demonstrator	May 2023
HRS data provided to Industry partner for vehicle demonstrator crew space development	Nov 2023
HRS data applied to Government combat vehicle concepts	Jan 2024
HRS data applied to Government combat vehicle crew station demonstrators	Mar 2024
Final *HRS_Accommodation_Model.28* Excel spreadsheet	Oct 2024
HRS: Driver CAD model development complete	Nov 2024
HRS: Driver CAD model Verification complete	Jan 2025
HRS: Driver CAD Final Model Release into PDMLink	Apr 2025
Verification Report (Final)	Apr 2025

9. VERIFICATION LESSONS LEARNED

Verification of the HRS: Driver CAD accommodation model marks the fifth time that GVSC has verified such a product. Based on lessons learned from the previous verifications, the M&S Proponents and Developers determined that verifying CAD outputs against UMTRI's spreadsheet, given the number of calculations involved, would be too time intensive to complete in front of a live audience. Alternatively, a PowerPoint document (see Appendix B) was compiled for distribution to all participants. This gave participants flexibility to review the document and provide feedback. If particular tests were of interest, the M&S developer could provide more detailed feedback and conduct a live review for the requesting party. This was the most efficient way to complete a verification without having a scheduled live verification event.

9.1. APPENDIX A – M&S DESCRIPTION

9.1.1. M&S Development and Structure

The information in this Appendix, is extracted from *Creation of the Driver Fixed Heel Point (FHP) CAD Accommodation Model for Military Ground Vehicle Design* (2016) and *Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configuration* (2020).

Ensuring that a given percentage of the population can sit safely and naturally while performing all required functions requires multivariate analysis methods that consider the physical dimensions of the Soldier (anthropometry) and behavioral effects (posture) in a three-dimensional space. This analysis is available for the Highly Reclined Seat position as Soldier-specific statistical population accommodation models, developed by UMTRI, that parallel long-standing SAE recommended practices used in the commercial automotive and truck domains. Because vehicle designs are developed from the early concept stages forward using CAD software, UMTRI's work has been encoded into a parametric CAD template that adjusts based on user inputs describing the Soldier population, desired accommodation level, and vehicle environment.

The primary developments that have made it possible to create a reusable CAD template representing user accommodation are UMTRI's predictive models for Soldier posture and the utilization of automated design capabilities available in many current CAD systems.

The automotive industry began introducing statistical population models into vehicle design in the 1960s to better understand various aspects of driver posture. The *Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configuration* (Reed et al, 2020) was completed to capture Soldier preferred posture and position data on driver workstations with three configurations: a fixed eye point, an out-of-hatch posture with a high seat height, and highly reclined postures. HRS designs are increasingly relevant for scenarios in which users are fully under armor, completing their tasks using camera-based systems with screen displays, and where the interior space is reduced to manage vehicle profile and weight.

The UMTRI study (2020) gathered data on Soldiers at Fort Hood, Texas, September through November 2014. Soldiers wore three levels of clothing and equipment including: 1) the advanced combat uniform (ACU), consisting of the Soldier's own jacket, trousers, shirt, and combat boots; 2) personal protective equipment (PPE), consisting of the ACU plus an Improved Outer Tactical Vest (IOTV), Enhanced Small Arms Protective Insert (ESAPI) plates, Enhanced Side Ballistic Inserts (ESBI), and an Advanced Combat Helmet (ACH); and 3) encumbered (ENC), consisting of the ACU and PPE, minus a hydration pack and a Tactical Assault Panel (TAP) with a Rifleman equipment kit [10].

The mockup used in the study at Fort Hood simulated a workstation with a Highly Reclined Seat. The HARP was established using the SAE J826 H-point manikin and was measured with the seat back at 30 degrees. The aft part of the two-part seat pan was fixed in position and the angle of the forward part (under the thighs) was adjusted with the seat back angle. The height and fore-aft position of the yoke and fore-aft position of the foot plate could be adjusted manually. The upper portion of the seat back was fixed relative to the lower portion. These two sections pivoted as a unit around a location aft of the pan to provide back angle adjustment. Testing was conducted at three seat back angles (angle of the lower portion of the seat back at 30, 40, and 50 degrees to vertical). At the middle seat back angle, data were gathered with three seat heights. All data were gathered at the PPE ensemble level, except that the condition with the middle seat back angle and highest seat height was repeated with ACU only [10].

Two additional studies were conducted at UMTRI in 2021-2022 and 2023. The first study (conducted at UMTRI because of travel restrictions due to COVID) gathered data on 120 military-age men and women with a wide range of body size. These participants were measured wearing IOTV (with plates) and MSV (without plates). The study (unpublished) used a modified version of the seat used previously in the highly reclined data collection at Ft Hood. The new study expanded the range of seat back angles for greater recline up to 70 degrees and included a range of hip locations (full rearward, full forward, and sitter-selected). The second study was conducted using a prototype seat, known as a Molded Contour Seat (MCS) instead of the laboratory seat used in prior work. Fourteen military age men and women with a range of body size were measured in the MCS at a range of back angles wearing the same ensembles. The study quantified postures for comparison with data from prior studies and determined participant preferences for upper back rest angle [9].

The final valid ranges for the model developed from the different studies mentioned above include the following:

- HARP above heel rest surface 100 to 200 mm, +/- 50mm (~4 to 8 inches)
- Lower seat back angle range of the model using the UMTRI seat is from 30 to 70 deg, +/- 5 deg
- Lower seat back angle range of the model using the MCS seat is from 50 to 70 deg, +/- 5 deg

The CAD version of the HRS: Driver CAD accommodation model was created by GVSC ACT using PTC Creo® 3D CAD software. Functionally, the foundation of the model is a stand-alone geometric reproduction of UMTRI's Microsoft Excel spreadsheets. Clearances between the Soldier population and surrounding interior vehicle surfaces were layered onto the model per the intent of MIL-STD-1472, along with direct vision zones and a display zone that incorporates concepts from both MIL-STD-1472 and SAE Recommended Practice J1050, *Describing and Measuring the Driver's Field of View*, 2009. To aid in understanding how workstation design affects individuals, boundary manikins representing the anthropometric extremes for workstation design were placed in their predicted postures.

After building a static version of the accommodation model (i.e., a single instance of the possible combinations of Soldier population, desired accommodation level, and vehicle environment inputs), the process of automating the model began. This was done using a tool within Creo known as Pro/PROGRAM. Most CAD users already take advantage of the parametric nature of today's design software. For example, depending on how a model is constructed, simple changes can be propagated throughout by delving into a model's geometry and modifying dimensions. Pro/PROGRAM takes this concept a step further and allows for control of a model from outside the model tree, using relations and rules. End users of the HRS: Driver CAD accommodation model are able to modify a list of parameters that are tied to the underlying geometry. Logical expressions are used to determine which portions of the Pro/PROGRAM code to execute for a given set of input values.

UMTRI's spreadsheets provide the values necessary to reproduce the relatively simple geometric elements comprising the accommodation boundaries (e.g. centroids and axis lengths for several ellipsoids). It was possible to encode the equations from UMTRI's spreadsheets into Creo without modification or the need for further calculations, with two notable exceptions. Because the majority of human anthropometric dimensions are normally distributed, the standard normal cumulative distribution function (CDF) is used throughout UMTRI's work to determine values at the desired level of accommodation. Creo does not contain an equivalent to Microsoft Excel's NORM.DIST function, so the following logistic approximation, having a maximum error of 0.00014 at z = ± 3.16, was used instead [1].

$$F(z) \sim \frac{1}{1 + e^{-(0.07056 * z^3 + 1.5976 * z)}}$$

The second exception involves the positioning of manikins. UMTRI provides coordinates of body landmarks with respect to the geometric origin of the accommodation model (i.e., the HARP) sufficient to locate the hips, torso articulation, and head. To place these coordinates into the reference systems of the boundary manikins (an axis system located between the hips of each manikin and aligned with the torso) and calculate the joint angles needed to position the limbs in three-dimensional space, Euclidean transformations for both translation and rotation were used.

9.1.2. M&S Use History

The HRS: Driver CAD accommodation model has been applied for vehicle concepting and crew demonstrator development starting in 2021 to present day. Since this is the fifth model in a suite of CAD accommodation models, there was not a concern that the opportunity did not present itself to apply the model early in the development process. The development of the final model was an iterative process between the CAD M&S Developer and UMTRI to add and refine features.

9.1.3. Configuration Management

GVSC ACT will manage any changes to the HRS: Driver CAD accommodation model and upload the latest version.

The HRS: Driver CAD accommodation model is released in PDMLink at the following location:

Libraries > STANDARD CAD TEMPLATE LIBRARY, 19207 > Accommodation

The following top assemblies have been released:
12702073 GVSC HIGHLY RECLINED SEATING DRIVER

Questions related to the CAD model development and application should be sent to:

DEVCOM GVSC Advanced Concepts Team

6501 E. 11 Mile Road
Bldg. 200, FCDD-GVR-MSS
MS 207
Warren, MI 48397-5000

Gale L. Zielinski (Project Lead)
E-mail: gale.zielinski2.civ@army.mil

Frank J. Huston II (Model Developer)
E-mail: frank.j.huston.civ@army.mil

9.2. Appendix B – Requirements and Acceptability Criteria Results

The requirements and acceptability criteria results for accommodation and posture prediction are shown below in Table 12 and Table 13, respectively. Metrics are noted as pass or fail. None of the metrics produced a failing result, so no corrective action plans are required.

Table 12: Accommodation Model Requirements Results

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for a target population input (e.g. 90%)	1.1 Target accommodation input option in model	1.1 Representative (Pass) / Non-Representative (Fail)
2	Model allows for input of the population gender mix (e.g. 85% Male : 15% Female)	2.1 Fraction male input option in model	2.1 Representative (Pass) / Non-Representative (Fail)
3	Model allows for selection of ensemble as either PPE, ENC, MSV (plates), or MSV (no plates)	3.1 Ensemble selection of PPE in model	3.1 Representative (Pass) / Non-Representative (Fail)
		3.2 Ensemble selection of ENC in model	3.2 Representative (Pass) / Non-Representative (Fail)
		3.3 Ensemble selection of MSV (plates) in model	3.3 Representative (Pass) / Non-Representative (Fail)
		3.4 Ensemble selection of MSV (no plates) in model	3.4 Representative (Pass) / Non-Representative (Fail)
4	Model allows for selection of seat as either UMTRI or MCS	4.1 Seat selection of UMTRI in model	4.1 Representative (Pass) / Non-Representative (Fail)
		4.2 Seat selection of MCS in model	4.2 Representative (Pass) / Non-Representative (Fail)
5	Model allows for input of the HARP height above the heel rest surface	5.1 HARP input option in model	5.1 Representative (Pass) / Non-Representative (Fail)
6	Model allows for selection of HARP location as either rearward or forward	6.1 HARP selection of rearward in model	6.1 Representative (Pass) / Non-Representative (Fail)
		6.2 HARP selection of forward in model	6.2 Representative (Pass) / Non-Representative (Fail)
7	Model allows for input of the lower seat back angle	7.1 Lower seat back angle input option in model	7.1 Representative (Pass) / Non-Representative (Fail)

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
8	Model allows for input of head support	8.1 Head support input option in model	8.1 Representative (Pass) / Non-Representative (Fail)
9	Model predicts the dimensions and location of the eyellipse	9.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with different inputs	9.1 Representative (Pass) / Non-Representative (Fail)
		9.2 CAD model matches the UMTRI spreadsheet	9.2 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the helmet contour boundary (helmet locations) with respect to the eye location and fitted to the eyellipse	10.1 Model outputs a helmet contour for the given population and gender mix that adjusts with different inputs	10.1 Representative (Pass) / Non-Representative (Fail)
		10.2 CAD model matches the UMTRI spreadsheet	10.2 Representative (Pass) / Non-Representative (Fail)
11	Model predicts dynamic elbow contours	11.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	11.1 Representative (Pass) / Non-Representative (Fail)
		11.2 CAD model matches the UMTRI spreadsheet	11.2 Representative (Pass) / Non-Representative (Fail)
12	Model predicts resting elbow contours	12.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	12.1 Representative (Pass) / Non-Representative (Fail)
		12.2 CAD model matches the UMTRI spreadsheet	12.2 Representative (Pass) / Non-Representative (Fail)
13	Model predicts the forward abdominal boundary for PPE ensemble	13.1 Model outputs an abdominal boundary for the given population, gender mix, and Soldier equipment configuration	13.1 Representative (Pass) / Non-Representative (Fail)
		13.2 CAD model matches the UMTRI spreadsheet	13.2 Representative (Pass) / Non-Representative (Fail)
14	Model predicts the steering mechanism (e.g. steering yoke) travel range	14.1 Model outputs a fore/aft and vertical steering mechanism travel window for the given population and gender mix that adjusts with different inputs	14.1 Representative (Pass) / Non-Representative (Fail)
		14.2 CAD model matches the UMTRI spreadsheet	14.2 Representative (Pass) / Non-Representative (Fail)
15	Model predicts the knee contour with leg and thigh segment angles based on location of resting occupants' knees in vehicle	15.1 Model outputs a knee ellipsoid for the given population and gender mix that adjusts with different inputs	15.1 Representative (Pass) / Non-Representative (Fail)

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#	M&S Requirement	Acceptability Criteria	Metrics/Measures
		15.2 CAD model matches the UMTRI spreadsheet	15.2 Representative (Pass) / Non-Representative (Fail)
16	Model predicts the fore/aft pedal location for the occupants	16.1 Model outputs a fore/aft pedal travel range for the given population and gender mix that adjusts with different inputs	16.1 Representative (Pass) / Non-Representative (Fail)
		16.2 CAD model matches the UMTRI spreadsheet	16.2 Representative (Pass) / Non-Representative (Fail)
17	Model predicts boot contours based on location of resting occupants' boots in vehicle	17.1 Model outputs boot contours for the given population and gender mix that adjusts with different inputs	17.1 Representative (Pass) / Non-Representative (Fail)
		17.2 CAD model matches the UMTRI spreadsheet	17.2 Representative (Pass) / Non-Representative (Fail)
18	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD- 1472 requirements	18.1 Model outputs a 2 inch clearance zone from the top of the helmet contour that adjusts with different inputs	18.1 Representative (Pass) / Non-Representative (Fail)
19	Model provides a clearance zone for the torso, when PPE is selected, based on MIL-STD-1472 requirements	19.1 Model outputs a 2 inch clearance zone for the torso contour that adjusts with different inputs	19.1 Representative (Pass) / Non-Representative (Fail)
20	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472 requirements	20.1 Model outputs a 2 inch clearance zone from the top and front of the knee contour and the front of the leg segment and top of the thigh (in side-view) that adjusts with different inputs	20.1 Representative (Pass) / Non-Representative (Fail)
21	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472 requirements	21.1 Model outputs a 2 inch clearance zone laterally for the resting elbow contours that adjusts with different inputs	21.1 Representative (Pass) / Non-Representative (Fail)
22	Model provides a clearance zone for the boot based on MIL-STD-1472 requirements	22.1 Model outputs a 2 inch clearance zone from the top of the boot contour that adjusts with different inputs	22.1 Representative (Pass) / Non-Representative (Fail)
23	Model provides direct field of view (primary, secondary, and tertiary zones) based on MIL-STD-1472 and SAE J1050	23.1 Model outputs direct field of view from the eyellipse that adjusts with different inputs	23.1 Representative (Pass) / Non-Representative (Fail)

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
24	Model predicts screen center fore/aft and up/down adjustment range that matches the intent of MIL-STD-1472	24.1 Model outputs a fore/aft and up/down adjustment range for the center of the screen, based on the eyellipse, that adjusts with different inputs	24.1 Representative (Pass) / Non-Representative (Fail

Table 13: Posture Prediction Model Results

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the HARP	1.1 Model outputs the location of the hip with respect to the HARP that matches the UMTRI spreadsheet	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the HARP	2.1 Model outputs the location of the eye with respect to the HARP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

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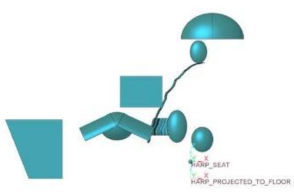
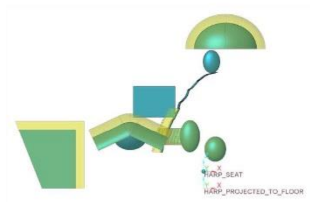
9.2.1. Test #1 – UMTRI Seat Baseline

TEST #1: UMTRI SEAT BASELINE

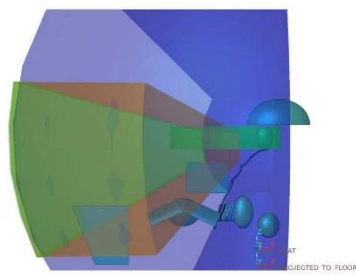
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
1	90%	85%	PPE	UMTRI	3.9 (100 mm)	30	Rearward	No	Baseline test



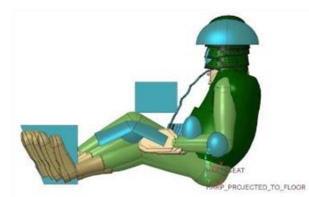
Basic Accommodation



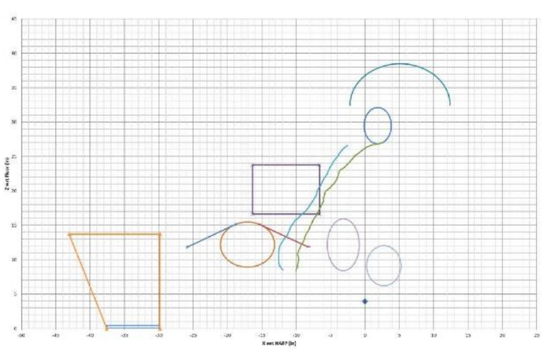
Clearance (2.0 inches)



Vision Zones



Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

14

TEST #1: RESULTS, ACCOMMODATION

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	3.937	in	3.937	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	1.850	in	1.850	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	29.489	in	29.490	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.000	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-11.504	in	-11.504	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	20.197	in	20.197	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.003	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary

	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	5.098	in	5.098	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	32.473	in	32.474	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040	in	12.041	in	0.000	in

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-17.112	in	-17.112	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	12.209	in	12.209	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.876	in	7.878	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.548	in	6.552	in	0.004	in
KNEE_SHIN_ANGLE	64.884	deg	64.884	deg	0.000	deg
KNEE_THIGH_ANGLE	24.847	deg	24.847	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	-3.161	in	-3.161	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	12.176	in	12.176	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	2.741	in	2.741	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.680	in	12.680	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	9.124	in	9.124	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-43.072	in	-43.075	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.720	in	13.721	in	0.001	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary

	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232	in	-5.233	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	21.185	in	21.185	in	0.000	in
TORSO_ROTATION_WRT_HARP	-4.230	deg	-4.230	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

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TEST #3: RESULTS, MANIKIN POSITIONING

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM1_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM1_EYE_Z	25.092	in	25.092	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM2_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM2_EYE_Z	27.340	in	27.340	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM3_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM3_EYE_Z	29.768	in	29.768	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM4_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM4_EYE_Z	31.061	in	31.061	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM5_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM5_EYE_Z	31.578	in	31.578	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM6_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM6_EYE_Z	31.066	in	31.066	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM7_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM7_EYE_Z	32.526	in	32.526	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

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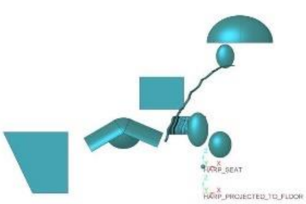
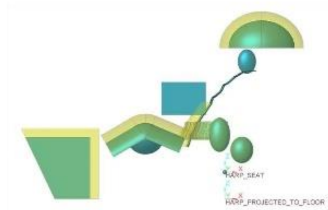
9.2.2. Test #2 – Vary Seat Height and Back Angle

TEST #2: VARY SEAT HEIGHT AND BACK ANGLE

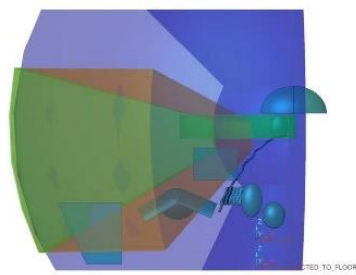
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
2	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Rearward	No	Vary seat height and back angle



Basic Accommodation

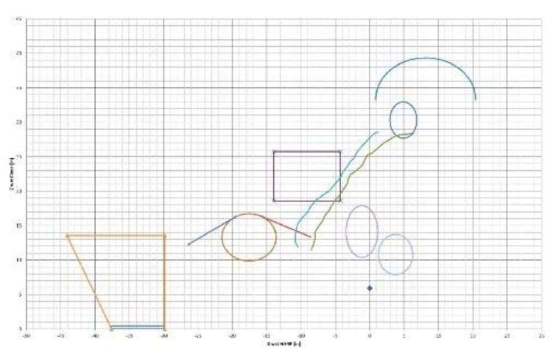


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

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TEST #2: RESULTS, ACCOMMODATION

HARP	UMTRI Value	GVSC Value	Difference
HARP_X	0.000 in	0.000 in	0.000 in
HARP_Z	5.906 in	5.906 in	0.000 in

Eyellipse	UMTRI Value	GVSC Value	Difference
EYELLIPSE_CENTROID_X	4.882 in	4.882 in	0.000 in
EYELLIPSE_CENTROID_Y (+/-)	1.280 in	1.280 in	0.000 in
EYELLIPSE_CENTROID_Z	30.335 in	30.336 in	0.001 in
EYELLIPSE_X_AXIS_LENGTH	3.950 in	3.953 in	0.003 in
EYELLIPSE_Y_AXIS_LENGTH	2.059 in	2.061 in	0.002 in
EYELLIPSE_Z_AXIS_LENGTH	5.269 in	5.269 in	0.001 in

Pedal Position	UMTRI Value	GVSC Value	Difference
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731 in	-33.731 in	0.000 in
PEDAL_POS_FORE_AFT_TRAVEL	7.777 in	7.781 in	0.004 in

Steering Position	UMTRI Value	GVSC Value	Difference
STEERING_POS_CTR_OF_TRAVEL_X	-9.134 in	-9.134 in	0.000 in
STEERING_POS_CTR_OF_TRAVEL_Z	22.165 in	22.165 in	0.000 in
STEERING_POS_FORE_AFT_TRAVEL	9.723 in	9.726 in	0.003 in
STEERING_POS_VERTICAL_TRAVEL	7.135 in	7.137 in	0.002 in

Helmet Boundary	UMTRI Value	GVSC Value	Difference
HELMET_CONTOUR_CENTROID_X	8.130 in	8.130 in	0.000 in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185 in	2.185 in	0.000 in
HELMET_CONTOUR_CENTROID_Z	33.320 in	33.321 in	0.001 in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553 in	14.555 in	0.003 in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729 in	9.730 in	0.002 in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040 in	12.041 in	0.001 in

Knee Boundary	UMTRI Value	GVSC Value	Difference
KNEE_CONTOUR_WEIGHTED_CENT_X	-17.580 in	-17.580 in	0.000 in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332 in	7.332 in	0.000 in
KNEE_CONTOUR_WEIGHTED_CENT_Z	13.312 in	13.312 in	0.000 in
KNEE_CONTOUR_X_AXIS_LENGTH	7.863 in	7.865 in	0.002 in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782 in	10.785 in	0.003 in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.830 in	6.833 in	0.004 in
KNEE_SHIN_ANGLE	59.734 deg	59.734 deg	0.000 deg
KNEE_THIGH_ANGLE	22.697 deg	22.697 deg	0.000 deg

Elbow Boundary	UMTRI Value	GVSC Value	Difference
ELBOW_CON_DYN_WEIGHTED_CENT_X	-1.165 in	-1.165 in	0.000 in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (·	10.201 in	10.201 in	0.000 in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.145 in	14.145 in	0.000 in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638 in	4.641 in	0.003 in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114 in	3.115 in	0.001 in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519 in	7.523 in	0.004 in

Elbow Boundary -- Resting	UMTRI Value	GVSC Value	Difference
ELBOW_CON_REST_WEIGHTED_CENT_X	3.761 in	3.761 in	0.000 in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.899 in	12.899 in	0.000 in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	10.805 in	10.805 in	0.000 in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000 in	5.004 in	0.003 in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756 in	3.757 in	0.001 in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798 in	5.800 in	0.003 in

Boot Boundary	UMTRI Value	GVSC Value	Difference
BOOT_CONTOUR_X_FRONT	-44.094 in	-44.097 in	0.003 in
BOOT_CONTOUR_X_REAR	-29.842 in	-29.840 in	0.002 in
BOOT_CONTOUR_Y_LATERAL	11.332 in	11.332 in	0.000 in
BOOT_CONTOUR_Z_TOP	13.575 in	13.576 in	0.001 in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619 in	-37.622 in	0.002 in

Torso Boundary	UMTRI Value	GVSC Value	Difference
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232 in	-5.233 in	0.001 in
TORSO_WEIGHTED_REF_PT_PPE_Z	23.153 in	23.153 in	0.000 in
TORSO_ROTATION_WRT_HARP	-11.370 deg	-11.370 deg	0.000 deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

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TEST #2: RESULTS, MANIKIN POSITIONING

Small Overall Female	UMTRI Value	GVSC Value	Difference
POSTURE_DHM1_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM1_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM1_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM1_EYE_Z	26.214 in	26.214 in	0.000 in
POSTURE_DHM1_AHP_X	-31.762 in	-31.762 in	0.000 in
POSTURE_DHM1_AHP_Z	0.000 in	0.000 in	0.000 in

Small Overall Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM2_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM2_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM2_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM2_EYE_Z	28.462 in	28.462 in	0.000 in
POSTURE_DHM2_AHP_X	-33.292 in	-33.292 in	0.000 in
POSTURE_DHM2_AHP_Z	0.000 in	0.000 in	0.000 in

Average Size Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM3_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM3_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM3_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM3_EYE_Z	30.890 in	30.890 in	0.000 in
POSTURE_DHM3_AHP_X	-34.984 in	-34.984 in	0.000 in
POSTURE_DHM3_AHP_Z	0.000 in	0.000 in	0.000 in

Widest Shoulders Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM4_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM4_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM4_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM4_EYE_Z	32.183 in	32.183 in	0.000 in
POSTURE_DHM4_AHP_X	-35.740 in	-35.740 in	0.000 in
POSTURE_DHM4_AHP_Z	0.000 in	0.000 in	0.000 in

Longest Torso Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM5_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM5_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM5_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM5_EYE_Z	32.700 in	32.700 in	0.000 in
POSTURE_DHM5_AHP_X	-34.917 in	-34.916 in	0.000 in
POSTURE_DHM5_AHP_Z	0.000 in	0.000 in	0.000 in

Longest Legs Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM6_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM6_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM6_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM6_EYE_Z	32.189 in	32.188 in	0.000 in
POSTURE_DHM6_AHP_X	-37.141 in	-37.141 in	0.000 in
POSTURE_DHM6_AHP_Z	0.000 in	0.000 in	0.000 in

Large Overall Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM7_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM7_HIP_Z	5.709 in	5.709 in	0.000 in
POSTURE_DHM7_EYE_X	4.882 in	4.882 in	0.000 in
POSTURE_DHM7_EYE_Z	33.648 in	33.648 in	0.000 in
POSTURE_DHM7_AHP_X	-36.596 in	-36.596 in	0.000 in
POSTURE_DHM7_AHP_Z	0.000 in	0.000 in	0.000 in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

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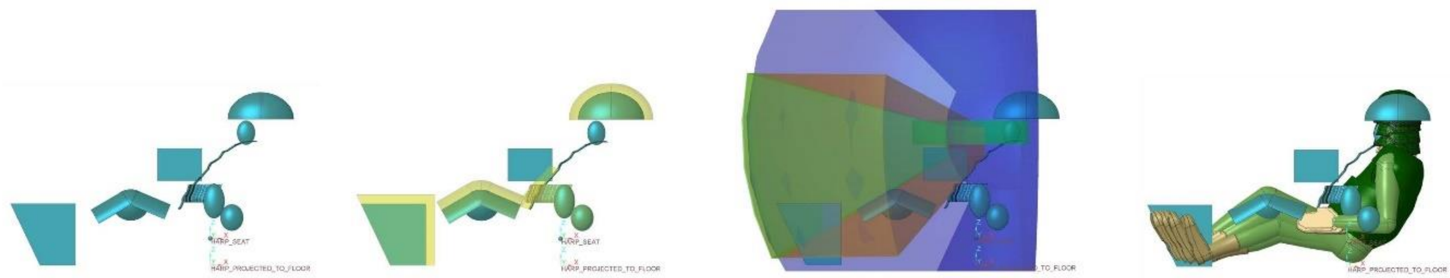
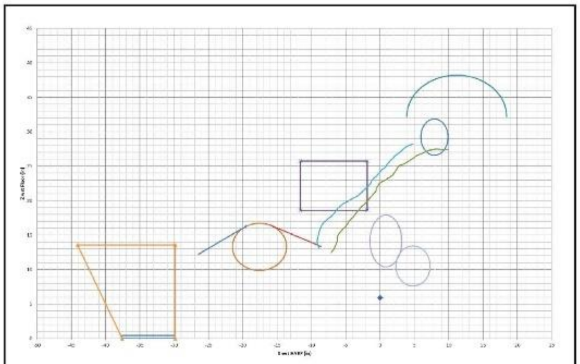
9.2.3. Test #3 – Shift Hips Forward

TEST #3: SHIFT HIPS FORWARD

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
3	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Forward	No	Correct for HARP location



Basic Accommodation   Clearance (2.0 inches)   Vision Zones   Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

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Test #3: Results, Accommodation

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	5.906	in	5.906	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	7.913	in	7.913	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	29.213	in	29.214	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.001	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-6.764	in	-6.764	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	22.165	in	22.165	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary

	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	11.161	in	11.161	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	32.197	in	32.199	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040	in	12.041	in	0.001	in

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-17.580	in	-17.580	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	13.312	in	13.312	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.863	in	7.865	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.830	in	6.833	in	0.004	in
KNEE_SHIN_ANGLE	59.734	deg	59.734	deg	0.000	deg
KNEE_THIGH_ANGLE	22.697	deg	22.697	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	0.831	in	0.831	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.145	in	14.145	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	4.781	in	4.781	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	13.118	in	13.118	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	10.518	in	10.518	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-44.094	in	-44.097	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.575	in	13.576	in	0.001	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary

	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232	in	-5.233	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	23.153	in	23.153	in	0.000	in
TORSO_ROTATION_WRT_HARP	-18.510	deg	-18.510	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

22

Test #3: Results, Manikin Positioning

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM1_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM1_EYE_Z	25.092	in	25.092	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM2_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM2_EYE_Z	27.340	in	27.340	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM3_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM3_EYE_Z	29.768	in	29.768	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM4_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM4_EYE_Z	31.061	in	31.061	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM5_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM5_EYE_Z	31.578	in	31.578	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM6_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM6_EYE_Z	31.066	in	31.066	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM7_EYE_X	7.913	in	7.913	in	0.000	in
POSTURE_DHM7_EYE_Z	32.526	in	32.526	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

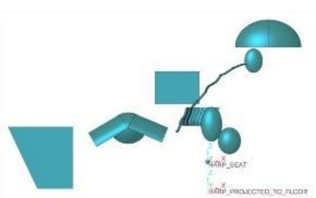
Values in agreement

23

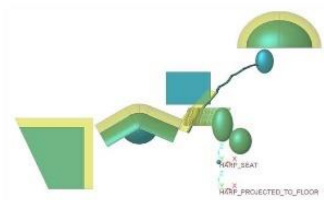
9.2.4. Test #4 – Provide Head Support

TEST #4: PROVIDE HEAD SUPPORT

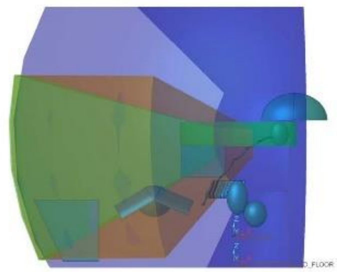
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
4	90%	85%	PPE	UMTRI	5.9 (150 mm)	40	Forward	Yes	Provide head support



Basic Accommodation

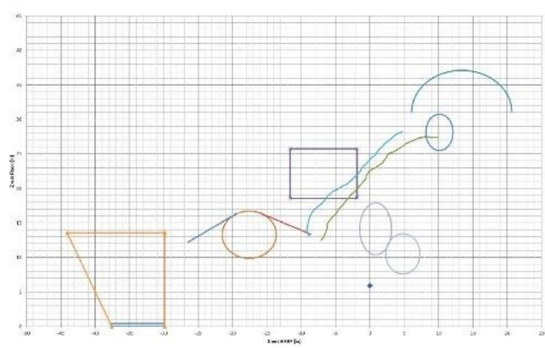


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

25

Test #4: Results, Accommodation

HARP	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	5.906	in	5.906	in	0.000	in

Eyellipse	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.118	in	10.118	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	28.111	in	28.112	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.001	in

Pedal Position	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-6.764	in	-6.764	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	22.165	in	22.165	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	13.366	in	13.366	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	31.095	in	31.096	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040	in	12.041	in	0.001	in

Knee Boundary	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-17.580	in	-17.580	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	13.312	in	13.312	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.863	in	7.865	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.830	in	6.833	in	0.004	in
KNEE_SHIN_ANGLE	59.734	deg	59.734	deg	0.000	deg
KNEE_THIGH_ANGLE	22.697	deg	22.697	deg	0.000	deg

Elbow Boundary	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	0.831	in	0.831	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.145	in	14.145	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	4.781	in	4.781	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	13.118	in	13.118	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	10.518	in	10.518	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-44.094	in	-44.097	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.575	in	13.576	in	0.001	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232	in	-5.233	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	23.153	in	23.153	in	0.000	in
TORSO_ROTATION_WRT_HARP	-18.510	deg	-18.510	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

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Test #4: Results, Manikin Positioning

Small Overall Female	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM1_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM1_EYE_Z	23.990	in	23.990	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM2_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM2_EYE_Z	26.237	in	26.238	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM3_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM3_EYE_Z	28.665	in	28.665	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM4_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM4_EYE_Z	29.959	in	29.958	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM5_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM5_EYE_Z	30.476	in	30.476	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM6_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM6_EYE_Z	29.964	in	29.964	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	5.709	in	5.709	in	0.000	in
POSTURE_DHM7_EYE_X	10.118	in	10.118	in	0.000	in
POSTURE_DHM7_EYE_Z	31.424	in	31.424	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

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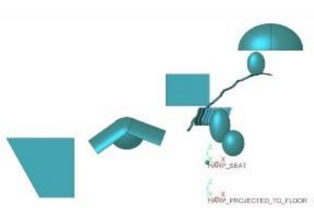
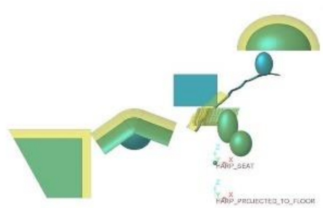
9.2.5. Test #5 – Vary Seat Height and Back Angle

TEST #5: VARY SEAT HEIGHT AND BACK ANGLE

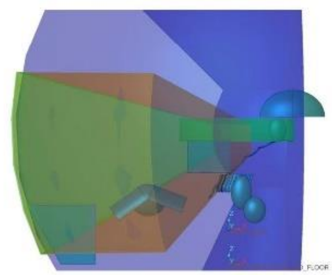
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
5	90%	85%	PPE	UMTRI	7.9 (200 mm)	50	Forward	No	Vary seat height and back angle



Basic Accommodation

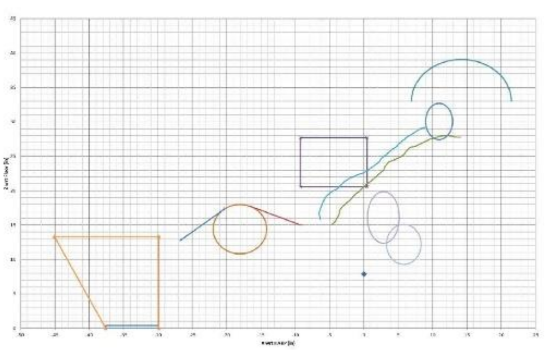


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

29

TEST #5: RESULTS, ACCOMMODATION

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.945	in	10.945	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	30.060	in	30.061	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.001	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-4.394	in	-4.394	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	24.134	in	24.134	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary

	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	14.193	in	14.193	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	33.044	in	33.045	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040	in	12.041	in	0.001	in

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817	in	7.820	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197	in	7.200	in	0.004	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	2.827	in	2.827	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (·	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	16.113	in	16.113	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	5.800	in	5.800	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	13.337	in	13.337	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	12.199	in	12.199	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.064	in	-45.067	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary

	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232	in	-5.233	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	25.122	in	25.122	in	0.000	in
TORSO_ROTATION_WRT_HARP	-25.650	deg	-25.650	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

30

TEST #5: RESULTS, MANIKIN POSITIONING

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM1_EYE_Z	25.939	in	25.939	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM2_EYE_Z	28.186	in	28.186	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM3_EYE_Z	30.614	in	30.614	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM4_EYE_Z	31.907	in	31.907	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM5_EYE_Z	32.425	in	32.425	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM6_EYE_Z	31.913	in	31.913	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	10.945	in	10.945	in	0.000	in
POSTURE_DHM7_EYE_Z	33.373	in	33.373	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

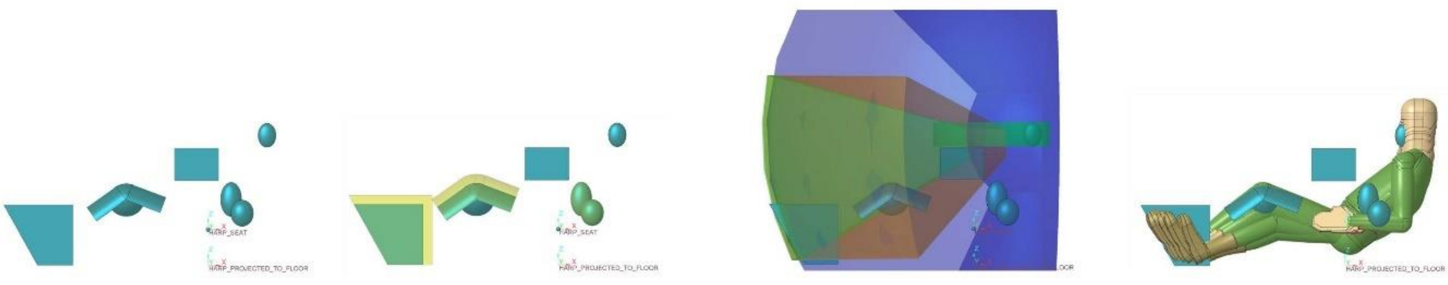
Values in agreement

31

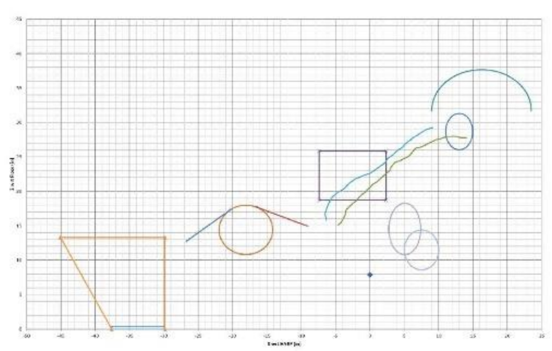
9.2.6. Test #6 – Vary Ensemble

TEST #6: VARY ENSEMBLE

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
6	90%	85%	ACU	UMTRI	7.9	50	Forward	No	Vary ensemble



Basic Accommodation | Clearance (2.0 inches) | Vision Zones | Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

33

Test #6: Results, Accommodation

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	12.992	in	12.992	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	28.682	in	28.683	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.001	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-2.544	in	-2.544	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	22.283	in	22.283	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary

The ACU ensemble does not include a helmet.

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817	in	7.820	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197	in	7.200	in	0.004	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	5.071	in	5.071	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	9.650	in	9.650	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.538	in	14.538	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	7.493	in	7.493	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.624	in	12.624	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	11.502	in	11.502	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.064	in	-45.067	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary

The ACU ensemble does not include the calculation of a torso boundary.

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

34

Test #6: Results, Manikin Positioning

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	3.740	in	3.740	in	0.000	in
POSTURE_DHM1_EYE_X	1.850	in	1.850	in	0.000	in
POSTURE_DHM1_EYE_Z	25.368	in	25.368	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	3.740	in	3.740	in	0.000	in
POSTURE_DHM2_EYE_X	1.850	in	1.850	in	0.000	in
POSTURE_DHM2_EYE_Z	27.615	in	27.616	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	3.740	in	3.740	in	0.000	in
POSTURE_DHM3_EYE_X	1.850	in	1.850	in	0.000	in
POSTURE_DHM3_EYE_Z	30.043	in	30.043	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	3.740	in	3.740	in	0.000	in
POSTURE_DHM4_EYE_X	1.850	in	1.850	in	0.000	in
POSTURE_DHM4_EYE_Z	31.337	in	31.336	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	3.740	in	3.740	in	0.000	in
POSTURE_DHM5_EYE_X	1.850	in	1.850	in	0.000	in
POSTURE_DHM5_EYE_Z	31.854	in	31.854	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM6_EYE_Z	30.535	in	30.535	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM7_EYE_Z	31.995	in	31.995	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

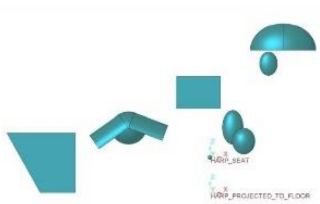
Values in agreement

35

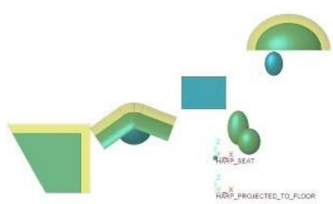
9.2.7. Test #7 – Vary Ensemble

TEST #7: VARY ENSEMBLE

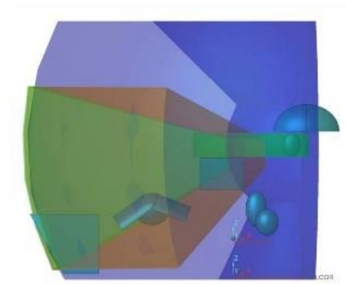
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
7	90%	85%	MSV (no plates)	UMTRI	7.9	50	Forward	No	Vary ensemble



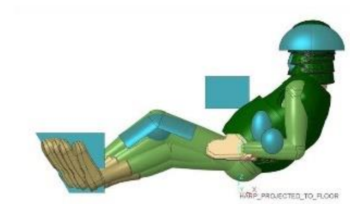
Basic Accommodation



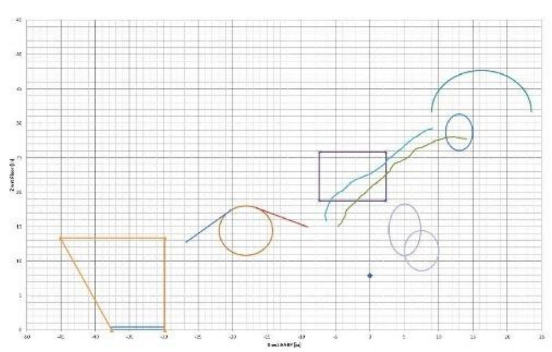
Clearance (2.0 inches)



Vision Zones



Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

37

TEST #7: RESULTS, ACCOMMODATION

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	12.992	in	12.992	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	28.682	in	28.683	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	5.269	in	5.269	in	0.001	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-2.544	in	-2.544	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	22.283	in	22.283	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary

	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	16.240	in	16.240	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	31.666	in	31.667	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040	in	12.041	in	0.001	in

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817	in	7.820	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197	in	7.200	in	0.004	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	5.071	in	5.071	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	9.650	in	9.650	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.538	in	14.538	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	7.493	in	7.493	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.624	in	12.624	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	11.502	in	11.502	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.064	in	-45.067	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary

The MSV (no plates) ensemble does not include the calculation of a torso boundary.

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

38

TEST #7: RESULTS, MANIKIN POSITIONING

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM1_EYE_Z	24.561	in	24.561	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM2_EYE_Z	26.808	in	26.808	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM3_EYE_Z	29.236	in	29.236	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM4_EYE_Z	30.529	in	30.529	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM5_EYE_Z	31.047	in	31.047	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM6_EYE_Z	30.535	in	30.535	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	-0.571	in	-0.571	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	12.992	in	12.992	in	0.000	in
POSTURE_DHM7_EYE_Z	31.995	in	31.995	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

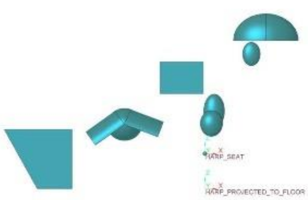
Values in agreement

39

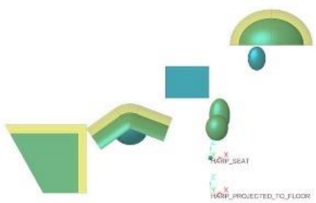
9.2.8. Test #8 – Vary Ensemble

TEST #8: VARY ENSEMBLE

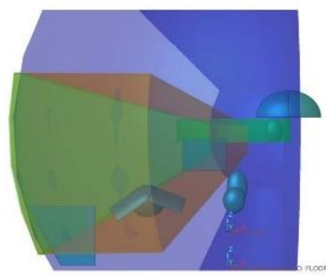
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
8	90%	85%	ENC	UMTRI	7.9	50	Forward	No	Vary ensemble



Basic Accommodation

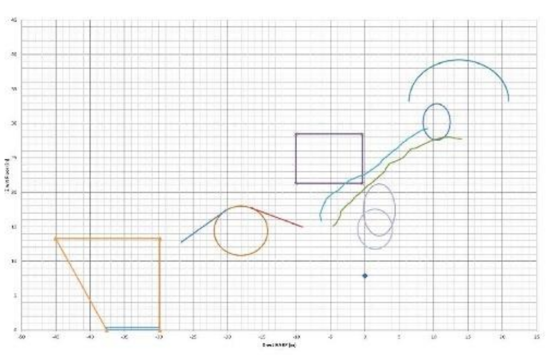


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

41

Test #8: Results, Accommodation

HARP	UMTRI Value	GVSC Value	Difference
HARP_X	0.000 in	0.000 in	0.000 in
HARP_Z	7.874 in	7.874 in	0.000 in

Eyellipse	UMTRI Value	GVSC Value	Difference
EYELLIPSE_CENTROID_X	10.433 in	10.433 in	0.000 in
EYELLIPSE_CENTROID_Y (+/-)	1.280 in	1.280 in	0.000 in
EYELLIPSE_CENTROID_Z	30.217 in	30.218 in	0.001 in
EYELLIPSE_X_AXIS_LENGTH	3.950 in	3.953 in	0.003 in
EYELLIPSE_Y_AXIS_LENGTH	2.059 in	2.061 in	0.002 in
EYELLIPSE_Z_AXIS_LENGTH	5.269 in	5.269 in	0.000 in

Pedal Position	UMTRI Value	GVSC Value	Difference
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731 in	-33.731 in	0.000 in
PEDAL_POS_FORE_AFT_TRAVEL	7.777 in	7.781 in	0.004 in

Steering Position	UMTRI Value	GVSC Value	Difference
STEERING_POS_CTR_OF_TRAVEL_X	-5.221 in	-5.221 in	0.000 in
STEERING_POS_CTR_OF_TRAVEL_Z	24.882 in	24.882 in	0.000 in
STEERING_POS_FORE_AFT_TRAVEL	9.723 in	9.726 in	0.002 in
STEERING_POS_VERTICAL_TRAVEL	7.135 in	7.137 in	0.002 in

Helmet Boundary	UMTRI Value	GVSC Value	Difference
HELMET_CONTOUR_CENTROID_X	13.681 in	13.681 in	0.000 in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185 in	2.185 in	0.000 in
HELMET_CONTOUR_CENTROID_Z	33.201 in	33.203 in	0.001 in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553 in	14.555 in	0.003 in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729 in	9.730 in	0.002 in
HELMET_CONTOUR_Z_AXIS_LENGTH	12.040 in	12.041 in	0.000 in

Knee Boundary	UMTRI Value	GVSC Value	Difference
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049 in	-18.049 in	0.000 in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332 in	7.332 in	0.000 in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415 in	14.415 in	0.000 in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817 in	7.820 in	0.002 in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782 in	10.785 in	0.003 in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197 in	7.200 in	0.004 in
KNEE_SHIN_ANGLE	54.584 deg	54.584 deg	0.000 deg
KNEE_THIGH_ANGLE	20.547 deg	20.547 deg	0.000 deg

Elbow Boundary	UMTRI Value	GVSC Value	Difference
ELBOW_CON_DYN_WEIGHTED_CENT_X	2.079 in	2.079 in	0.000 in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (	10.713 in	10.713 in	0.000 in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	17.452 in	17.452 in	0.000 in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638 in	4.641 in	0.003 in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114 in	3.115 in	0.001 in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519 in	7.523 in	0.004 in

Elbow Boundary -- Resting	UMTRI Value	GVSC Value	Difference
ELBOW_CON_REST_WEIGHTED_CENT_X	1.470 in	1.470 in	0.000 in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	15.569 in	15.569 in	0.000 in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	14.648 in	14.648 in	0.000 in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000 in	5.004 in	0.003 in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756 in	3.757 in	0.001 in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798 in	5.800 in	0.003 in

Boot Boundary	UMTRI Value	GVSC Value	Difference
BOOT_CONTOUR_X_FRONT	-45.064 in	-45.067 in	0.003 in
BOOT_CONTOUR_X_REAR	-29.842 in	-29.840 in	0.002 in
BOOT_CONTOUR_Y_LATERAL	11.332 in	11.332 in	0.000 in
BOOT_CONTOUR_Z_TOP	13.321 in	13.321 in	0.000 in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619 in	-37.622 in	0.002 in

Torso Boundary

The ENC ensemble does not include the calculation of a torso boundary.

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

42

Test #8: Results, Manikin Positioning

Small Overall Female	UMTRI Value	GVSC Value	Difference
POSTURE_DHM1_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM1_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM1_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM1_EYE_Z	26.096 in	26.096 in	0.000 in
POSTURE_DHM1_AHP_X	-31.762 in	-31.762 in	0.000 in
POSTURE_DHM1_AHP_Z	0.000 in	0.000 in	0.000 in

Small Overall Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM2_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM2_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM2_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM2_EYE_Z	28.344 in	28.344 in	0.000 in
POSTURE_DHM2_AHP_X	-33.292 in	-33.292 in	0.000 in
POSTURE_DHM2_AHP_Z	0.000 in	0.000 in	0.000 in

Average Size Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM3_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM3_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM3_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM3_EYE_Z	30.772 in	30.772 in	0.000 in
POSTURE_DHM3_AHP_X	-34.984 in	-34.984 in	0.000 in
POSTURE_DHM3_AHP_Z	0.000 in	0.000 in	0.000 in

Widest Shoulders Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM4_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM4_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM4_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM4_EYE_Z	32.065 in	32.065 in	0.000 in
POSTURE_DHM4_AHP_X	-35.740 in	-35.740 in	0.000 in
POSTURE_DHM4_AHP_Z	0.000 in	0.000 in	0.000 in

Longest Torso Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM5_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM5_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM5_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM5_EYE_Z	32.582 in	32.582 in	0.000 in
POSTURE_DHM5_AHP_X	-34.917 in	-34.916 in	0.000 in
POSTURE_DHM5_AHP_Z	0.000 in	0.000 in	0.000 in

Longest Legs Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM6_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM6_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM6_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM6_EYE_Z	32.070 in	32.070 in	0.000 in
POSTURE_DHM6_AHP_X	-37.141 in	-37.141 in	0.000 in
POSTURE_DHM6_AHP_Z	0.000 in	0.000 in	0.000 in

Large Overall Male	UMTRI Value	GVSC Value	Difference
POSTURE_DHM7_HIP_X	-0.571 in	-0.571 in	0.000 in
POSTURE_DHM7_HIP_Z	7.677 in	7.677 in	0.000 in
POSTURE_DHM7_EYE_X	10.433 in	10.433 in	0.000 in
POSTURE_DHM7_EYE_Z	33.530 in	33.530 in	0.000 in
POSTURE_DHM7_AHP_X	-36.596 in	-36.596 in	0.000 in
POSTURE_DHM7_AHP_Z	0.000 in	0.000 in	0.000 in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

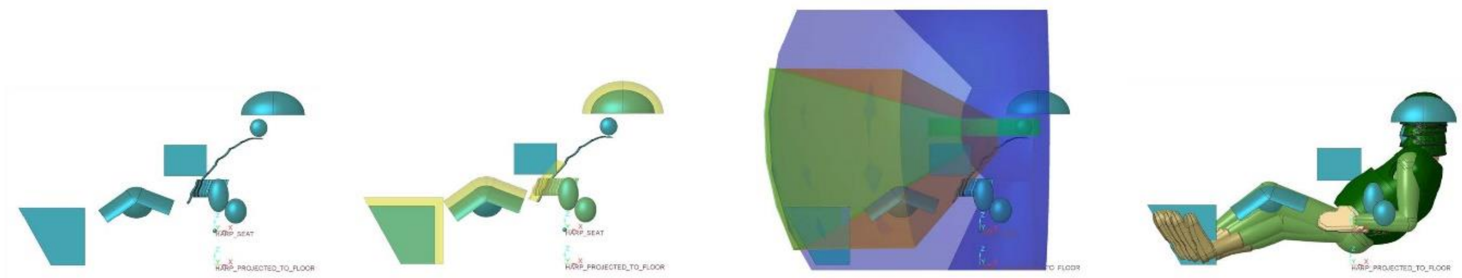
Values in agreement

43

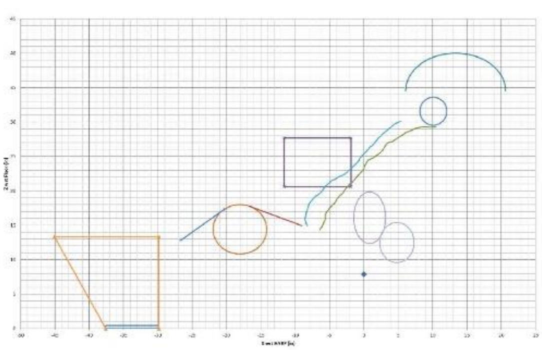
9.2.9. Test #9 – MCS Seat Baseline

TEST #9: MCS SEAT BASELINE

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
9	90%	85%	PPE	MCS	7.9	50	Forward	No	Change seat; MCS baseline



Basic Accommodation   Clearance (2.0 inches)   Vision Zones   Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

45

Test #9: Results, Accommodation

HARP	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.093	in	10.093	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	31.593	in	31.594	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	4.068	in	4.069	in	0.001	in

Pedal Position	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-6.764	in	-6.764	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	24.134	in	24.134	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	13.341	in	13.341	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	34.578	in	34.578	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	10.840	in	10.841	in	0.001	in

Knee Boundary	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817	in	7.820	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197	in	7.200	in	0.004	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	0.831	in	0.831	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	16.113	in	16.113	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	4.781	in	4.781	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	13.118	in	13.118	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	12.486	in	12.486	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.064	in	-45.067	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.232	in	-5.233	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	25.122	in	25.122	in	0.000	in
TORSO_ROTATION_WRT_HARP	-18.510	deg	-18.510	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

46

Test #9: Results, Manikin Positioning

Small Overall Female	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM1_EYE_Z	29.006	in	29.006	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM2_EYE_Z	30.569	in	30.569	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM3_EYE_Z	32.420	in	32.420	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM4_EYE_Z	33.374	in	33.374	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM5_EYE_Z	33.409	in	33.409	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM6_EYE_Z	33.731	in	33.731	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM7_EYE_Z	34.236	in	34.236	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

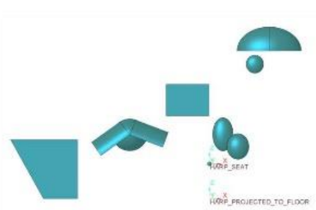
Values in agreement

47

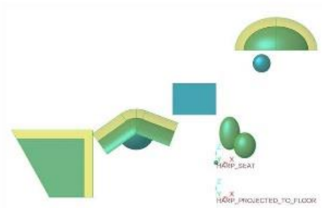
9.2.10. Test #10 – Vary Ensemble

TEST #10: VARY ENSEMBLE

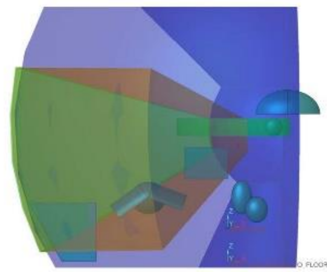
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
10	90%	85%	MSV (no plates)	MCS	7.9	50	Forward	No	Vary ensemble



Basic Accommodation

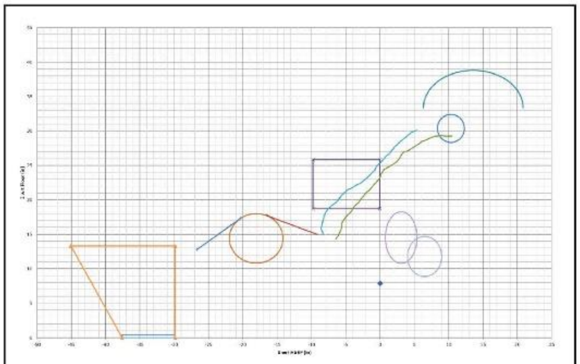


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

49

TEST #10: RESULTS, ACCOMMODATION

HARP	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.315	in	10.315	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	30.385	in	30.385	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	4.068	in	4.069	in	0.001	in

Pedal Position	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.731	in	-33.731	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.777	in	7.781	in	0.004	in

Steering Position	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-4.914	in	-4.914	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	22.283	in	22.283	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.723	in	9.726	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	13.563	in	13.563	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	33.369	in	33.370	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	10.840	in	10.841	in	0.001	in

Knee Boundary	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.817	in	7.820	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.782	in	10.785	in	0.003	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.197	in	7.200	in	0.004	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	3.075	in	3.075	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	9.650	in	9.650	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	14.538	in	14.538	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.638	in	4.641	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.114	in	3.115	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.519	in	7.523	in	0.004	in

Elbow Boundary -- Resting	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	6.474	in	6.474	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.405	in	12.405	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	11.789	in	11.789	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.000	in	5.004	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.756	in	3.757	in	0.001	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.798	in	5.800	in	0.003	in

Boot Boundary	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.064	in	-45.067	in	0.003	in
BOOT_CONTOUR_X_REAR	-29.842	in	-29.840	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.619	in	-37.622	in	0.002	in

Torso Boundary	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X		in		in	0.000	in
TORSO_WEIGHTED_REF_PT_PPE_Z		in		in	0.000	in
TORSO_ROTATION_WRT_HARP		deg		deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

50

TEST #10: RESULTS, MANIKIN POSITIONING

Small Overall Female	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM1_EYE_Z	27.797	in	27.797	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM2_EYE_Z	29.360	in	29.360	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM3_EYE_Z	31.211	in	31.211	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM4_EYE_Z	32.166	in	32.166	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM5_EYE_Z	32.200	in	32.200	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM6_EYE_Z	32.522	in	32.522	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	10.315	in	10.315	in	0.000	in
POSTURE_DHM7_EYE_Z	33.028	in	33.028	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

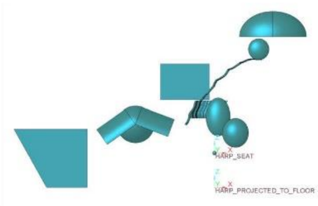
Values in agreement

51

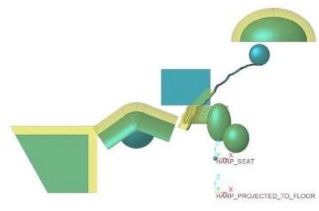
9.2.11. Test #11 – Vary Target Accommodation

TEST #11: VARY TARGET ACCOMMODATION

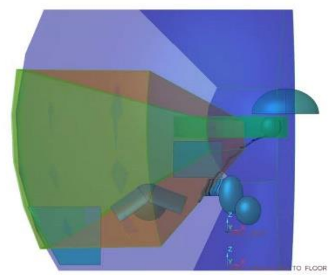
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
11	95%	85%	PPE	MCS	7.9	50	Forward	No	Increase accommodation level



Basic Accommodation

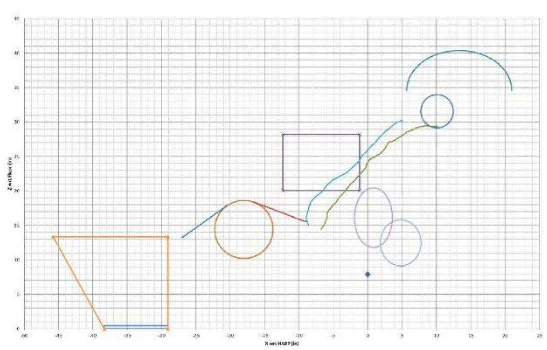


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.010 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

53

TEST #11: RESULTS, ACCOMMODATION

HARP

	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse

	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.092	in	10.093	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	31.565	in	31.567	in	0.001	in
EYELLIPSE_X_AXIS_LENGTH	4.707	in	4.708	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	2.454	in	2.454	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	4.852	in	4.850	in	0.001	in

Pedal Position

	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.723	in	-33.724	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	9.268	in	9.269	in	0.001	in

Steering Position

	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-6.764	in	-6.764	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	24.134	in	24.134	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	11.158	in	11.148	in	0.010	in
STEERING_POS_VERTICAL_TRAVEL	8.189	in	8.181	in	0.008	in

Helmet Boundary

	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	13.341	in	13.341	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	34.550	in	34.551	in	0.001	in
HELMET_CONTOUR_X_AXIS_LENGTH	15.309	in	15.310	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	10.123	in	10.124	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	11.623	in	11.622	in	0.001	in

Knee Boundary

	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-18.049	in	-18.049	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	7.332	in	7.332	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	14.415	in	14.415	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	8.534	in	8.535	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	12.027	in	12.027	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	8.431	in	8.432	in	0.001	in
KNEE_SHIN_ANGLE	54.584	deg	54.584	deg	0.000	deg
KNEE_THIGH_ANGLE	20.547	deg	20.547	deg	0.000	deg

Elbow Boundary

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	0.831	in	0.831	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	10.201	in	10.201	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	16.113	in	16.113	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	5.526	in	5.528	in	0.002	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.720	in	3.719	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	8.694	in	8.696	in	0.002	in

Elbow Boundary -- Resting

	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	4.781	in	4.781	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	13.118	in	13.118	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	12.486	in	12.486	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.958	in	5.959	in	0.002	in
ELBOW_CON_REST_Y_AXIS_LENGTH	4.493	in	4.491	in	0.002	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	6.647	in	6.648	in	0.001	in

Boot Boundary

	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-45.802	in	-45.803	in	0.001	in
BOOT_CONTOUR_X_REAR	-29.089	in	-29.089	in	0.000	in
BOOT_CONTOUR_Y_LATERAL	11.332	in	11.332	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.321	in	13.321	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-38.357	in	-38.358	in	0.001	in

Torso Boundary

	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.544	in	-5.545	in	0.000	in
TORSO_WEIGHTED_REF_PT_PPE_Z	25.122	in	25.122	in	0.000	in
TORSO_ROTATION_WRT_HARP	-18.510	deg	-18.510	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.010 inches
0.000 degrees

Values in agreement

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TEST #11: RESULTS, MANIKIN POSITIONING

Small Overall Female

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM1_EYE_Z	29.006	in	29.006	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM2_EYE_Z	30.569	in	30.569	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM3_EYE_Z	32.420	in	32.420	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM4_EYE_Z	33.374	in	33.374	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM5_EYE_Z	33.409	in	33.409	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM6_EYE_Z	33.731	in	33.731	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male

	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM7_EYE_Z	34.236	in	34.236	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

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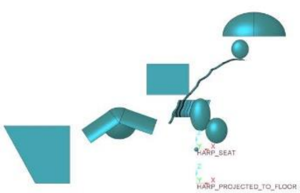
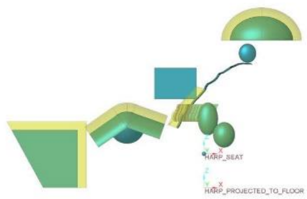
9.2.12. Test #12 – Vary Gender Mix

TEST #12: VARY GENDER MIX

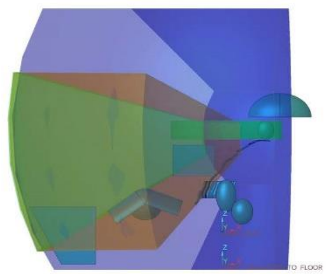
Test #	Target Accommodation	Fraction Male	Ensemble	Seat Type	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
12	90%	50%	PPE	MCS	7.9	50	Forward	No	Rebalance gender mix



Basic Accommodation

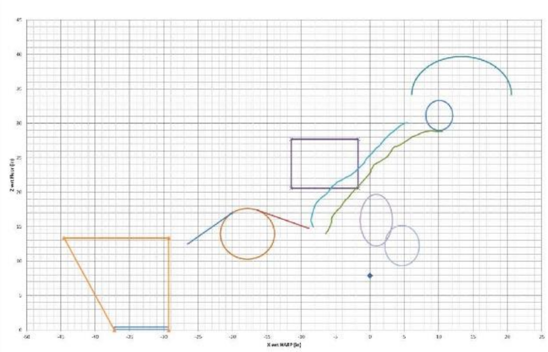


Clearance (2.0 inches)



Vision Zones

Boundary Manikins



UMTRI Spreadsheet

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences

Basic Accommodation:
0.004 inches
0.000 degrees

Manikin Placement:
0.000 inches

Values in agreement

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Test #12: Results, Accommodation

HARP	UMTRI Value		GVSC Value		Difference	
HARP_X	0.000	in	0.000	in	0.000	in
HARP_Z	7.874	in	7.874	in	0.000	in

Eyellipse	UMTRI Value		GVSC Value		Difference	
EYELLIPSE_CENTROID_X	10.093	in	10.093	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	31.151	in	31.151	in	0.000	in
EYELLIPSE_X_AXIS_LENGTH	3.950	in	3.953	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	2.059	in	2.061	in	0.002	in
EYELLIPSE_Z_AXIS_LENGTH	4.358	in	4.358	in	0.000	in

Pedal Position	UMTRI Value		GVSC Value		Difference	
PEDAL_POS_CTR_OF_TRAVEL_X	-33.258	in	-33.258	in	0.000	in
PEDAL_POS_FORE_AFT_TRAVEL	7.934	in	7.938	in	0.003	in

Steering Position	UMTRI Value		GVSC Value		Difference	
STEERING_POS_CTR_OF_TRAVEL_X	-6.594	in	-6.593	in	0.000	in
STEERING_POS_CTR_OF_TRAVEL_Z	24.134	in	24.134	in	0.000	in
STEERING_POS_FORE_AFT_TRAVEL	9.715	in	9.717	in	0.002	in
STEERING_POS_VERTICAL_TRAVEL	7.135	in	7.137	in	0.002	in

Helmet Boundary	UMTRI Value		GVSC Value		Difference	
HELMET_CONTOUR_CENTROID_X	13.341	in	13.341	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	34.135	in	34.135	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	14.553	in	14.555	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.729	in	9.730	in	0.002	in
HELMET_CONTOUR_Z_AXIS_LENGTH	11.130	in	11.130	in	0.000	in

Knee Boundary	UMTRI Value		GVSC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	-17.826	in	-17.826	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/	6.884	in	6.884	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	13.951	in	13.951	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.900	in	7.902	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	10.885	in	10.888	in	0.002	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.361	in	7.363	in	0.002	in
KNEE_SHIN_ANGLE	55.194	deg	55.194	deg	0.000	deg
KNEE_THIGH_ANGLE	19.379	deg	19.379	deg	0.000	deg

Elbow Boundary	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_DYN_WEIGHTED_CENT_X	0.921	in	0.921	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Y (-	9.920	in	9.920	in	0.000	in
ELBOW_CON_DYN_WEIGHTED_CENT_Z	15.935	in	15.935	in	0.000	in
ELBOW_CON_DYN_X_AXIS_LENGTH	4.636	in	4.639	in	0.003	in
ELBOW_CON_DYN_Y_AXIS_LENGTH	3.186	in	3.187	in	0.001	in
ELBOW_CON_DYN_Z_AXIS_LENGTH	7.502	in	7.506	in	0.004	in

Elbow Boundary -- Resting	UMTRI Value		GVSC Value		Difference	
ELBOW_CON_REST_WEIGHTED_CENT_X	4.660	in	4.660	in	0.000	in
ELBOW_CON_REST_WEIGHTED_CENT_Y (	12.727	in	12.727	in	0.000	in
ELBOW_REST_DYN_WEIGHTED_CENT_Z	12.263	in	12.263	in	0.000	in
ELBOW_CON_REST_X_AXIS_LENGTH	5.006	in	5.009	in	0.003	in
ELBOW_CON_REST_Y_AXIS_LENGTH	3.857	in	3.857	in	0.000	in
ELBOW_REST_DYN_Z_AXIS_LENGTH	5.843	in	5.845	in	0.002	in

Boot Boundary	UMTRI Value		GVSC Value		Difference	
BOOT_CONTOUR_X_FRONT	-44.558	in	-44.560	in	0.002	in
BOOT_CONTOUR_X_REAR	-29.291	in	-29.289	in	0.002	in
BOOT_CONTOUR_Y_LATERAL	10.884	in	10.884	in	0.000	in
BOOT_CONTOUR_Z_TOP	13.357	in	13.357	in	0.000	in
BOOT_CONTOUR_X_FRONT_BOTTOM	-37.225	in	-37.227	in	0.002	in

Torso Boundary	UMTRI Value		GVSC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	-5.139	in	-5.140	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	24.730	in	24.730	in	0.000	in
TORSO_ROTATION_WRT_HARP	-18.755	deg	-18.755	deg	0.000	deg

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.000 degrees

Values in agreement

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Test #12: Results, Manikin Positioning

Small Overall Female	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM1_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM1_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM1_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM1_EYE_Z	29.006	in	29.006	in	0.000	in
POSTURE_DHM1_AHP_X	-31.762	in	-31.762	in	0.000	in
POSTURE_DHM1_AHP_Z	0.000	in	0.000	in	0.000	in

Small Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM2_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM2_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM2_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM2_EYE_Z	30.569	in	30.569	in	0.000	in
POSTURE_DHM2_AHP_X	-33.292	in	-33.292	in	0.000	in
POSTURE_DHM2_AHP_Z	0.000	in	0.000	in	0.000	in

Average Size Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM3_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM3_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM3_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM3_EYE_Z	32.420	in	32.420	in	0.000	in
POSTURE_DHM3_AHP_X	-34.984	in	-34.984	in	0.000	in
POSTURE_DHM3_AHP_Z	0.000	in	0.000	in	0.000	in

Widest Shoulders Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM4_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM4_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM4_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM4_EYE_Z	33.374	in	33.374	in	0.000	in
POSTURE_DHM4_AHP_X	-35.740	in	-35.740	in	0.000	in
POSTURE_DHM4_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Torso Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM5_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM5_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM5_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM5_EYE_Z	33.409	in	33.409	in	0.000	in
POSTURE_DHM5_AHP_X	-34.917	in	-34.916	in	0.000	in
POSTURE_DHM5_AHP_Z	0.000	in	0.000	in	0.000	in

Longest Legs Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM6_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM6_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM6_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM6_EYE_Z	33.731	in	33.731	in	0.000	in
POSTURE_DHM6_AHP_X	-37.141	in	-37.141	in	0.000	in
POSTURE_DHM6_AHP_Z	0.000	in	0.000	in	0.000	in

Large Overall Male	UMTRI Value		GVSC Value		Difference	
POSTURE_DHM7_HIP_X	0.000	in	0.000	in	0.000	in
POSTURE_DHM7_HIP_Z	7.677	in	7.677	in	0.000	in
POSTURE_DHM7_EYE_X	10.093	in	10.093	in	0.000	in
POSTURE_DHM7_EYE_Z	34.236	in	34.236	in	0.000	in
POSTURE_DHM7_AHP_X	-36.596	in	-36.596	in	0.000	in
POSTURE_DHM7_AHP_Z	0.000	in	0.000	in	0.000	in

GVSC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

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9.3. Appendix C – References

[1] Bowling, S., Khasawneh, M., Kaewkuekool, S., and Rae Cho, B. (2009). "A Logistic Approximation to the Cumulative Normal Distribution." Journal of Industrial Engineering and Management, 114-127.

[2] Gordon CC, Blackwell CL, Bradtmiller B, Parham JL, Barrientos P, Paquette SP, Corner BD, Carson JM, Venezia JC, Rockwell BM, Muncher M, and Kristensen S (2014) 2012 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics. NATICK/TR-15/007. Natick, MA: U.S. Army Natick Research, Development, and Engineering Center. Retrieved from https://www.dtic.mil/document;accessionNumber=ADA634277;type=TR;searchText=2012%20Anthropometric%20Survey%20of%20

[3] Gordon CC, Blackwell CL, Bradtmiller B, Parham JL, Hotzman J, Paquette SP, Corner BD, Hodge BM (2013) 2010 Anthropometric Survey of Marine Corps Personnel: Methods and Summary Statistics. NATICK/TR-13/018. Natick, MA: U.S. Army Natick Research, Development, and Engineering Center.

[4] Huston II, F., Zielinski, G., and Reed, M. (2016). Creation of the Driver Fixed Heel Point (FHP) CAD Accommodation Model for Military Ground Vehicle Design. DTIC Technical Report TR-28004. NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS) Modeling and Simulation, Testing and Validation (MSTV) Mini-Symposium August 2 – 4, Novi, Michigan. Retrieved from https://gvsc.devcom.army.mil/wp-content/uploads/sites/9/2025/04/Fixed-Heel-Point-Conference-Paper-Report-Number-TR-28004.pdf

[5] MIL-STD-1472H, Department of Defense Design Criteria Standard, Human Engineering. 15 September 2020.

[6] McNamara, J. (2012). Soldier Load Configuration in Ground Vehicles. DTIC Technical Report No. 23726, U.S. Army Natick Research, Development and Engineering Center, Natick, MA. Retrieved from https://www.dtic.mil/document;accessionNumber=ADB391501;type=TR;searchText=soldier%20load%20configuration%20in%20ground%20vehicles

[7] Reed, M. (2024). HRS_Accommodation_Models.28 (2024-10-08) [Microsoft Excel Spread Sheet]. MI: University of Michigan Transportation Research Institute.

[8] Reed, M. (2022). Highly Reclined Posture Prediction.11 (2022-09-28) [Microsoft Excel Spread Sheet]. MI: University of Michigan Transportation Research Institute.

[9] Reed, M. (2023). Driving Postures in a Highly Reclined Prototype Seat. Unpublished Report. unpublished. Ann Arbor, MI. University of Michigan Transportation Research Institute.

[10] Reed, M., and Ebert, S. (2020). Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configurations. Report No. UMTRI-2020-5 Ann Arbor, MI. University of Michigan Transportation Research Institute. Retrieved from https://deepblue.lib.umich.edu/handle/2027.42/163365.

[11] Reed, M., and Ebert, S. (2014). Evaluation of the Seat Index Point Tool for Military Seats. Report No. UMTRI-2014-33. Ann Arbor, MI. University of Michigan Transportation Research Institute. Retrieved from https://deepblue.lib.umich.edu/handle/2027.42/111823.

[12] Reed, M., and Ebert, S. (2013). The Seated Soldier Study: Posture and Body Shape in Vehicle Seats. Report No. UMTRI-2013-13. University of Michigan Transportation Research Institute, Ann Arbor, MI. Retrieved from https://deepblue.lib.umich.edu/handle/2027.42/109725.

[13] SAE Recommended Practice, SAE J1050 Describing and Measuring the Driver's Field of View, SAE, 2009.

[14] Zielinski, G., Huston II, F., Kozycki, R., Kouba, R., and Wodzinski, C. (2015). Introduction to Boundary Manikins and Accommodation Models for Military Ground Vehicle Occupant Centric Design. DTIC Technical Report TR-26516. U.S. Army Tank Automotive Research, Development, and Engineering Center, Warren, MI. Retrieved from https://www.dtic.mil/document;accessionNumber=ADB407583;type=TR;searchText=Introduction%20to%20Boundary%20Manikins%20and%20accommodation%20models

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9.5. Appendix E – Verification Plan

The *Highly Reclined Seat (HRS) CAD Accommodation Model Verification Plan* (2022) can be found on the DEVCOM GVSC website at https://gvsc.devcom.army.mil/home/what-we-do/accommodation-models/highly-reclined-seat-hrs-cad-accommodation-model-verification-plan-28apr2022v1-0-dist-a/

The reference for the final plan is below:

Zielinski, G. and Huston II, F. (2022). U.S. Army DEVCOM Ground Vehicle Systems Center (GVSC) Highly Reclined Seat (HRS) Accommodation Model Verification Plan 28Apr2022v1. https://gvsc.devcom.army.mil/home/what-we-do/accommodation-models/highly-reclined-seat-hrs-cad-accommodation-model-verification-plan-28apr2022v1-0-dist-a/. U.S. Army DEVCOM GVSC, Warren, MI.