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Author(s): Gale L. Zielinski and Frank J. Huston, II

U.S. Army Combat Capabilities Development
Command Ground Vehicle Systems Center
Detroit Arsenal
Warren, Michigan 48397-5000

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Gale L. Zielinski and Frank J. Huston II

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U.S. Army DEVCOM Ground Vehicle Systems Center (GVSC)
Attn: FCDD-GVR-MSS
MS 207
6501 E. 11 Mile Road, Warren, MI 48397-5000

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14. ABSTRACT

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, such as accommodation models, are needed by the ground vehicle community to address this issue. The fifth in a series of accommodation models being created is the Highly Reclined Seat (HRS) accommodation model. Verification is intended to build confidence in the HRS CAD model for use in ground vehicle design. The model described in this verification report is the Ground Vehicle Systems Center (GVSC) HRS CAD model. This model 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 model provides the composite boundaries representing the body of the defined user population, including the effects of body size, protective equipment and gear. The accommodation boundaries indicate the adjustment range needed for vehicle controls and the resulting positions for the equipped Soldier 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. Crew field of view to displays is developed using a combination of MIL-STD-1472 and SAE Recommended Practice J1050 applied to the eyellipse.

15. SUBJECT TERMS

Highly Reclined Seat (HRS), occupant workspace, equipment, verification, Computer-Aided Design (CAD), accommodation model, ground vehicle design, interior workspace, occupant, target design population, posture prediction, Human Accommodation Reference Point (HARP).

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1. VERIFICATION PLAN 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 (Zielinski et al 2015). The verification effort is intended to build confidence in accommodation models for use in ground vehicle design.

The model described in this verification plan is the Ground Vehicle Systems Center (GVSC) Highly Reclined Seat (HRS) CAD model. The HRS CAD model 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 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 Soldier 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 applied to the eyellipse. The HRS 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* (Reed et al 2020) completed by the University of Michigan Transportation Research Institute (UMTRI). An additional study was conducted at UMTRI in 2021-2022 to expand 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 original model, as provided by UMTRI, consists of a Microsoft Excel workbook. The CAD version of the model was created using PTC Creo® 3D CAD software and 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 GVSC HRS 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 compatible formats for assessment and perform detailed human figure modeling.

The HRS CAD accommodation model verification effort will produce a verification report that captures the results of the activities completed as described in this plan. Any areas that do not meet the defined verification acceptability requirements will be reviewed and an action item will be assigned to correct the issue. The verification report will be signed off by the model developers along with the respective Verification and Validation (V&V) SMEs.

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 (DOD, 2020). 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 (Zielinski et al 2015). The fifth such CAD model to be developed is the Highly Reclined Seat (HRS) accommodation model, Figure 1.

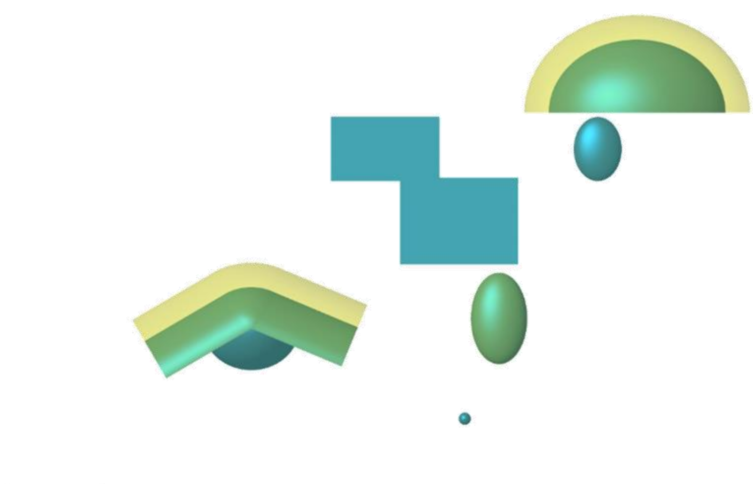

Figure 1: Highly Reclined Seat (HRS) CAD Accommodation Model

2.1 INTENDED USE

The HRS CAD model described in this verification plan 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 CAD 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 applied to the eyellipse, the geometric entity that describes the distribution of the user's eye locations.

2.2 M&S OVERVIEW

The HRS CAD 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* (Reed et al 2020) completed by the University of Michigan Transportation Research Institute (UMTRI). An additional study was conducted at UMTRI in 2021-2022 to expand 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 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 include the definition of the target design population (a subset of the Army Anthropometric Survey (ANSUR) II) (Gordon et al 2014), the ensemble (clothing and equipment worn by the user), the desired level of accommodation (for example, 90%), and the target population gender mix. The ensemble is selectable as either Personal Protective Equipment (PPE) which includes the Improved Outer Tactical Vest (IOTV) or Encumbered (ENC) which includes the PPE and Tactical Assault Panel (TAP) with Rifleman kit, both of which are defined in UMTRI-2020-5 (Reed et al 2020). 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 only vehicle input to the model is the Human Accommodation Reference Point (HARP) which is the height of the seat above the floor surface. It should be noted that the 2010 MCANSUR of U.S. Marine Corps (USMC) Personnel (Gordon et al 2013) can also be added to the model if USMC anthropometry is needed for design.

The HRS CAD 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 (Zielinski et al 2015).

2.3 M&S APPLICATION

The use of the HRS CAD 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 CAD 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 (HARP_PROJECTED_TO_FLOOR) for the HRS CAD model, Figure 2. All outputs are determined with respect to the HARP.

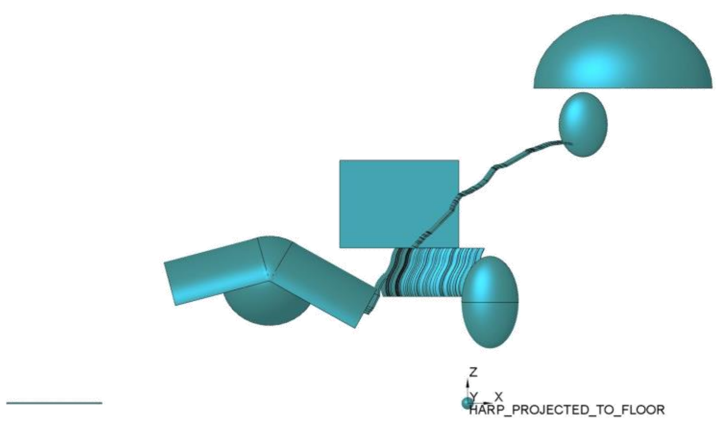

Figure 2: HARP Example for the HRS CAD Model

2.3.2 MODEL INPUTS

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

Table 1: Highly Reclined Seat Accommodation Model Inputs

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
Head Support	The selection if head support is used.
HARP	The seat height measured above the floor surface and a selection of forward or rearward based on seat design.
Seat Back Angle	Lower support surface of the seat back measured from vertical.

[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 (McNamara, 2012) and Seated Soldier Study (Reed et al 2013). ENC for HRS model does not include a hydration pack.

2.3.3 MODEL OUTPUTS – YOKE/PEDAL TRAVEL AND OCCUPANT COMPOSITE BODY BOUNDARIES

The primary model outputs include the yoke and pedal adjustment range needed and the resulting positions for occupant population boundaries for helmet, torso, elbows, knees, and boots. Model outputs are described below in Table 2 and shown in Figure 3.

Table 2: HRS CAD Model Accommodation Boundary Outputs and Definitions

Model Output	Description
Yoke 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.
Pedal Fore-aft Adjustment	The pedal location travel depicts the fore-aft range of preferred pedal positions relative to the HARP location (Reed, 2020).
Eyellipse	The eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of occupant eye locations in the vehicle (Reed, 2015).
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 (Reed, 2015).

Torso Boundary ENC and Torso Boundary PPE	The torso boundary depicts the distribution of user torsos, including the effects of ensemble
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.
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) (Reed, 2020).
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 foot rest holding it perpendicular to the leg.

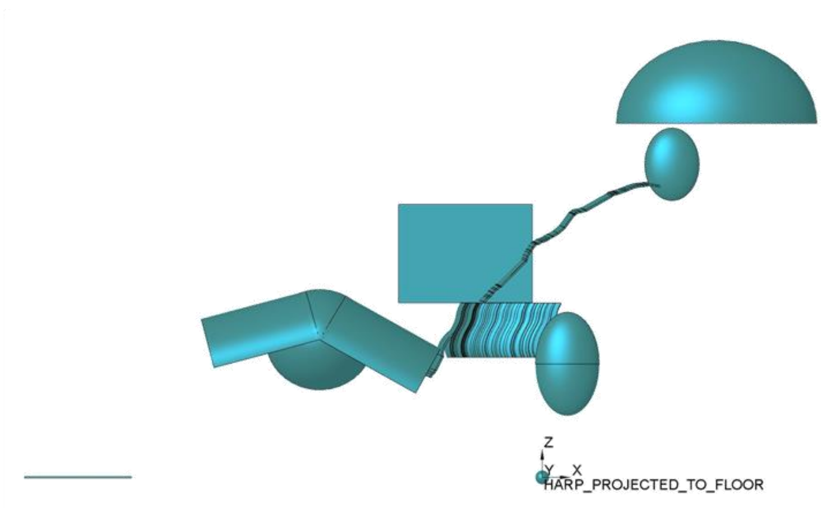

Figure 3: HRS CAD Model Example Output

2.3.4 MODEL OUTPUTS – BASED ON MIL-STD-1472 AND SAE J1050

Additional outputs of the model include interpretation of MIL-STD 1472 for the vehicle designer to utilize when creating the occupant workspace. Field of view to displays is developed using a combination of MIL-STD-1472 and SAE Recommended Practice J1050. Model outputs are described below in Table 3 and shown in Figure 4.

Table 3: HRS 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.
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.
Field of View (FOV) with Minimum Distance to Displays	The FOV represents the area where items that occupants may need to view, while seated, should be placed along with the minimum viewing distance to displays.

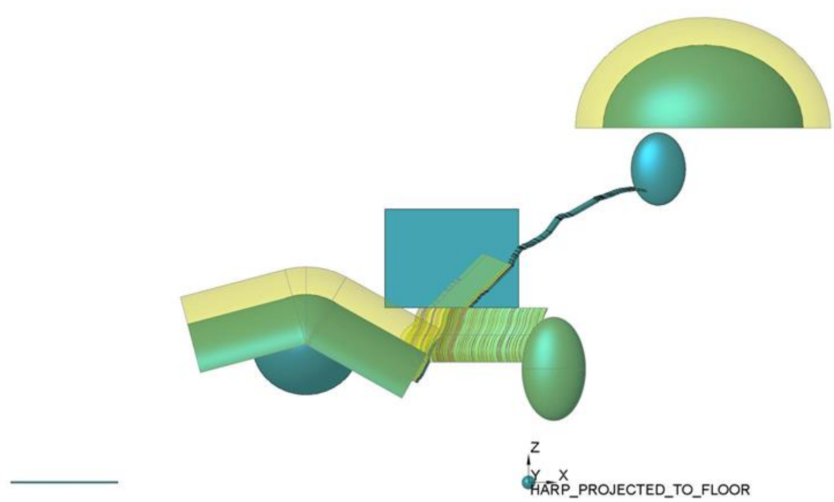

Figure 4: HRS CAD Accommodation with Clearance Zone Outputs

2.3.5 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. Model outputs are described below in Table 4 and shown in Figure 5.

Table 4: Posture Prediction Model Output and Definitions based on Seated Soldier Study

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.

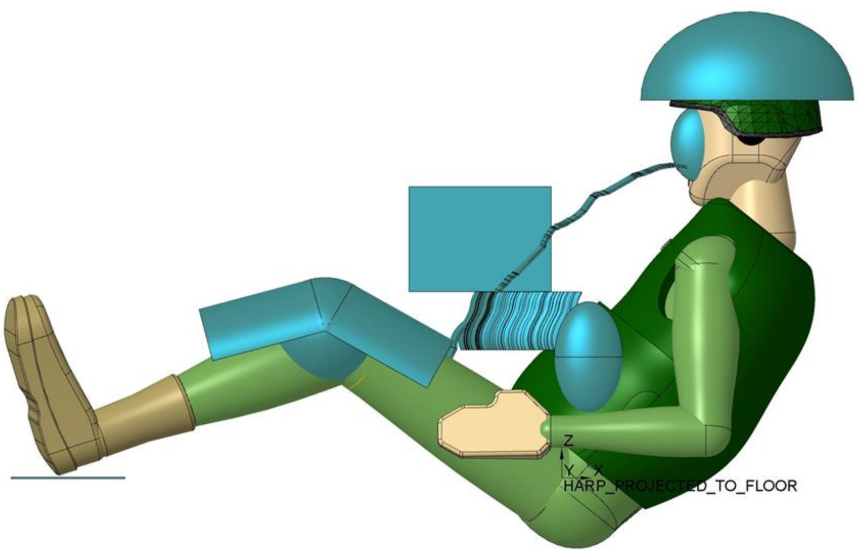

Figure 5: HRS CAD Accommodation Model with Boundary Manikin Overlay

2.4 VERIFICATION SCOPE

The scope of this effort is to verify the GVSC CAD accommodation model for a HRS position where the user interacts with controls and displays. 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. The verification is intended to build confidence in the HRS accommodation model for use in the ground vehicle design community.

Verification per the *Department of Defense Standard Practice Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulation* (2008) is defined as follows:

> Verification is the process of determining that a model, simulation, or federation of models and simulations implementations and their associated data accurately represents the developer's conceptual description and specifications.

3. REQUIREMENTS AND ACCEPTABILITY CRITERIA

The HRS CAD model shall meet the requirements shown in Table 5 below:

Table 5: 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 or ENC	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)
4	Model allows for input of the lower seat back angle	4.1 Lower seat back angle input option in model	4.1 Representative (Pass) / Non-Representative (Fail)
5	Model allows for input of the HARP height above floor	5.1 HARP input option in model	5.1 Representative (Pass) / Non-Representative (Fail)
6	Model allow for input of head support	6.1 Head support input option in model	6.1 Representative (Pass) / Non-Representative (Fail)
7	Model predicts the dimensions and location of the eyellipse	7.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with different inputs	7.1 Representative (Pass) / Non-Representative (Fail)
		7.2 CAD model matches the UMTRI spreadsheet	5.2 Representative (Pass) / Non-Representative (Fail)
8	Model predicts the steering mechanism (e.g steering yoke) travel range	8.1 Model outputs a fore/aft and vertical steering mechanism travel window for a given population and gender mix and matches the UMTRI spreadsheet	8.1 Representative (Pass) / Non-Representative (Fail)
9	Model predicts the helmet contour boundary (helmet locations) with respect to the eye	9.1 Model outputs a helmet contour for the 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 knee contour with leg and thigh segment angles based on location of resting occupants' knees in vehicle	10.1 Model outputs a knee ellipsoid 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 boot contours based on location of resting occupants' boots in vehicle	12.1 Model outputs boot 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	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 fore/aft pedal location for the occupants	14.1 Model outputs the fore/aft travel range for the pedals	14.1 Representative (Pass)/ Non-Representative (Fail)
		14.2 CAD model matches the UMTRI spreadsheet	14.2 Representative (Pass)/ Non-Representative (Fail)
15	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD-1472 requirements	15.1 Model outputs a 2 inch clearance zone from the top of the helmet contour that adjusts with different inputs	15.1 Representative (Pass) / Non-Representative (Fail)
16	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472 requirements	16.1 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	16.1 Representative (Pass) / Non-Representative (Fail)
17	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472 requirements	17.1 Model outputs a 2 inch clearance zone laterally for the resting elbow contours that adjusts with different inputs	17.1 Representative (Pass)/ Non-Representative (Fail)
18	Model provides a clearance zone for the torso based on MIL-STD-1472 requirements	18.1 Model outputs a 2 inch clearance zone from the top of the boot contour that adjusts with different inputs	18.1 Representative (Pass)/ Non-Representative (Fail)
19	Model provides a clearance zone for the boot based on MIL-STD-1472 requirements	19.1 Model outputs a 2 inch clearance zone from the top of the boot contour that adjusts with different inputs	19.1 Representative (Pass)/ Non-Representative (Fail)

Along with using the HRS CAD 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 6 below:

Table 6: Requirements Relationship Table for Posture Prediction of Boundary Manikins

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the eye with respect to the hip	1.1 Model outputs the location of the hip with respect to the eye 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 fore/aft location of the heel with respect to the HARP	2.1 Model outputs the fore/aft location of the heel with respect to the eye that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin heel aligns with the heel 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 CAD model will provide government and industry partners with the following M&S capabilities:

- Relevant population boundaries for user posture in an occupant workspace
- Posture prediction for the identified boundary manikins
- Clearances based on interpretation of MIL-STD-1472 requirements

4.2 M&S LIMITATIONS

The HRS CAD 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 (Reed, 2020).
- 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 CAD 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 for a driver or workstation 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 METHODOLOGY

5.1 PLANNED DATA VERIFICATION TASKS

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 (Reed et al 2020). 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.12, 2022-20-03*, UMTRI Excel spreadsheet
- *Highly Reclined Posture Prediction.4, 2019-12-5*, UMTRI Excel spreadsheet

The information provided by UMTRI was utilized to create the HRS CAD 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 PLANNED MODEL VERIFICATION

The CAD accommodation model developer (GVSC ACT), working with the V&V agent (GVSC and DAC), will compare the output received in CAD to the output shown in the UMTRI *HRS_Accommodation_Models.12 (2022)* Excel spreadsheet and verify that the two correlate.

The model input values will be changed to ensure that the helmet boundary, abdominal boundary, leg, thigh, and knee boundary, elbow boundary, eyellipse, steering mechanism adjustment, and pedal adjustment all morph as expected.

5.2.1 PLANNED MODEL VERIFICATION TEST RUN

An audit of the HRS CAD model will be completed with the M&S proponent, V&V agent, and SMEs. GVSC ACT will adjust input values of the accommodation model and the team will verify that the outputs previously defined in Table 2 adjust as expected. The test matrix to be used for the verification of the model is shown in Table 7 below:

Table 7: FEP Accommodation Model Test Matrix

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Height (in.)	Seat Back Angle (deg.)	HARP Location	Head Support	Remarks
1	90%	85%	PPE	3.9 (100 mm)	30	Rearward	No	Baseline test #1
2	90%	85%	PPE	5.9 (150 mm)	40	Rearward	No	Vary seat height and back angle
3	90%	85%	PPE	7.9 (200 mm)	50	Rearward	No	Vary seat height and back angle
4	90%	85%	PPE	3.9	60	Rearward	No	Vary seat back angle
5	90%	85%	PPE	3.9	60	Forward	No	Vary HARP Location; baseline #2
6	90%	85%	ACU	3.9	60	Forward	No	Vary ensemble
7	90%	85%	ENC	3.9	60	Forward	No	
8	90%	85%	PPE	3.9	60	Forward	Yes	Provide head support
9	95%	85%	PPE	3.9	60	Forward	No	Increase accommodation level
10	90%	50%	PPE	3.9	60	Forward	No	Reduce males in population

5.3 PLANNED VERIFICATION REPORTING

The HRS CAD model verification effort will produce a verification report that captures the results of the activities completed per this verification plan. Any areas that do not meet the defined verification acceptability requirements will be reviewed and a path forward will be provided to correct the issue.

6. KEY PARTICIPANTS

Table 8 identifies the participants involved in the verification effort, including their roles and responsibilities.

Table 8: Key Participants for HRS 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	Mark D. Shafer, GVSC GVSP Eric S. Paternoster, GVSC CSI

	specific application of the model or simulation.	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
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 Mark D. Shafer, GVSC GVSP Cheryl A. Burns, DAC Richard W. Kozycki, DAC David A. Hullinger, DAC Matthew P. Reed, Ph.D, UMTRI

7. PLANNED VERIFICATION RESOURCES

7.1 VERIFICATION RESOURCE REQUIREMENTS

Table 9 identifies the resources used to create the DEVCOM GVSP HRS CAD model and complete associated activities, including verification.

Table 9: 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 Verification Plan	Verification Agent, M&S Developer and SME support	GVSC ACT
HRS Accommodation Model Build	M&S Developer and SME support	GVSC ACT
HRS Accommodation Model Verification packet completed	Verification Agent, Validation Agent, M&S Developer and SME support	GVSC ACT
HRS Model Release into PDMLink	M&S Developer	GVSC ACT
OPSEC of HRS Verification Report and CAD Model	M&S Proponent	GVSC ACT
Release of HRS Verification Report and CAD Model to the GVSC public website.	M&S Proponent	GVSC ACT

7.2 VERIFICATION MILESTONES AND TIMELINE

Table 10 identifies the major milestone achievements in the creation the HRS CAD model and estimated completion of associated activities, including verification.

Table 10: 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 CAD template development started	Jun 2019
HRS data applied to Government combat vehicle concepts	Aug 2019
Development of Driver Posture Prediction and Accommodation Models for Military Vehicles: Fixed-Eye-Point, Out-of-Hatch, and Highly Reclined Driver Configuration	Oct 2020
Draft "HRS_Accommodation_Model.12" Excel spreadsheet	Mar 2022
HRS 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
Final HRS CAD model development started	Sep 2022
HRS CAD model complete	Mar 2023
HRS CAD Model Verification Complete	Mar 2023
HRS CAD Final Model Release into PDMLink	Mar 2023
Verification Report (Final)	Mar 2023

8. APPENDICES

8.1 APPENDIX A – REFERENCES

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8.2 APPENDIX B – ACRONYMS

ACH	Advanced Combat Helmet
ACT	Advanced Concepts Team
ACU	Advanced Combat Uniform
ANSUR	Army Anthropometric Survey
CAD	Computer-Aided Design
COTS	Commercial Off-The-Shelf
CSI	Center for System Integration
DAC	DEVCOM Analysis Center
EMD	Engineering Manufacturing and Development
ENC	Encumbered
ESAPI	Enhanced Small Arms Protective Insert
ESBI	Enhanced Side Ballistic Inserts
FOV	Field of View
GVSC	Ground Vehicle Systems Center
GVSP	Ground Vehicle Survivability and Protection
HARP	Human Accommodation Reference Point
HFE	Human Factors Engineering
HRS	Highly Reclined Seat
HSI	Human Systems Integration
IOTV	Improved Outer Tactical Vest
MCoE	Maneuver Center of Excellence
MS	Milestone
M&S	Modeling and Simulation
PPE	Personal Protective Equipment
SME	Subject Matter Experts
TAP	Tactical Assault Panel
UMTRI	University of Michigan Transportation Research Institute
USMC	United States Marine Corps
V&V	Verification and Validation
VV&A	Verification, Validation, and Accreditation

8.3 APPENDIX C – DISTRIBUTION LIST

US Army DEVCOM Ground Vehicle Systems Center (GVSC):

- Gale L. Zielinski, Mechanical Engineer/Advanced Concepts Team (ACT), DEVCOM GVSC, Warren, MI 48397-5000, E-Mail: gale.l.zielinski.civ@army.mil
- Frank J. Huston, II, Mechanical Engineer/ACT, DEVCOM GVSC, Warren, MI 48397-5000, E-Mail: frank.j.huston.civ@army.mil
- Russell D. Kouba, Team Leader/ ACT, DEVCOM GVSC, Warren, MI 48397-5000, E-Mail: russell.d.kouba.civ@army.mil
- Mark D. Shafer – Interior Blast Mitigation Team (IBMT)/Ground Vehicle Survivability and Protection (GVSP), DEVCOM GVSC, Warren MI 48397-5000, E-Mail: mark.d.shafer14.ctr@army.mil
- Eric S. Paternoster, CSI Systems Integration Team, DEVCOM GVSC, Warren MI 48397-5000, E-Mail: eric.s.paternoster2.civ@army.mil

Human Systems Integration (HSI) DEVCOM Analysis Center:

- Richard W. Kozycki, HSI DEVCOM DAC, Aberdeen Proving Ground, MD 21005-5425, E-Mail: richard.w.kozycki.civ@army.mil
- Cheryl A. Burns, HSI DEVCOM DAC, Fort Knox, KY 40121, E-Mail: cheryl.a.burns12.civ@army.mil
- David A. Hullinger, Human Factors Engineer, HSI – DEVCOM DAC, RDRL-HRM-CU, Warren, MI 48397-5000, E-Mail: david.a.hullinger.civ@army.mil

US Army DEVCOM Soldier Center:

- Steven Paquette, Anthropology Team Leader, DEVCOM Soldier Center, Natick, MA 01760, E-Mail: steven.p.paquette.civ@army.mil
- Joseph L. Parham, Research Anthropologist, DEVCOM Soldier Center, Natick, MA 01760, E-Mail: joseph.l.parham2.civ@army.mil

Maneuver Center of Excellence (MCoE):

- Gustave R. Steenborg, Systems Safety Engineer, Mounted Requirements Division Capabilities Development and Integration Directorate MCoE, Fort Benning, GA 31905, E-Mail: gustave.r.steenborg.civ@army.mil

Naval Surface Warfare Center – Warfare Systems Department:

- Brian Keeven, Engineer - Human System Integration, Dahlgren, VA 22448, E-Mail: brian.g.keeven.civ@us.navy.mil

Air Force

- Jennifer J. Whitestone, Biomedical Engineer, Air Force Life Cycle Management Center (AFLCMC)/WNU, Wright-Patterson Air Force Base (WPAFB), OH 45433-7017, E-Mail: jennifer.whitestone@us.af.mil
- Jeffrey A. Hudson, PhD., Biological Anthropologist, U.S. Air Force (USAF) Cockpit/Crewstation Accommodation SME, Infoscitex, E-Mail: jeff.hudson@sti-tec.com

University of Michigan Transportation Research Institute (UMTRI):

- Matthew P. Reed, PhD., Research Professor and Head Biosciences Group, UMTRI, Ann Arbor, MI 48109-2150, E-Mail: mreed@umich.edu