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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 fourth in a series of accommodation models being created is the Fixed Human Accommodation Reference Point (HARP): Commander accommodation model. Verification is intended to build confidence in the Fixed HARP: Commander CAD model for use in ground vehicle design. The model described in this verification report is the Ground Vehicle Systems Center (GVSC) Fixed HARP: Commander CAD model. This model is applicable to ground vehicle commander workstations where the users interact with a keyboard, screen, and have an adjustable seat back. The model also provides 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, eye location, and boots. The model also generates preferred and acceptable ranges of screens and keyboards locations.		
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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) Fixed Human Accommodation Reference Point (HARP): Commander CAD model. This model is applicable to ground vehicle commander workstations where the users interact with a keyboard, screen, and have an adjustable seat back. The Fixed HARP: Commander CAD 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, eye location, and boots. The model also generates preferred and acceptable ranges of screens and keyboard 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 have been added based on MIL-STD-1472 and SAE Recommended Practice J1050. The Fixed HARP: Commander model is a statistical model created utilizing data collected from Soldiers at Fort Riley, Kansas, and is documented in the report *Development of Posture Prediction and Accommodation Models for Military Vehicles: Commander and Gunner Positions* (Reed et al 2021) completed by the University of Michigan Transportation Research Institute (UMTRI). 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 Fixed HARP: Commander 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 Fixed HARP: Commander 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, 2012). 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 fourth such CAD model to be developed is the Fixed HARP: Commander accommodation model, Figure 1.

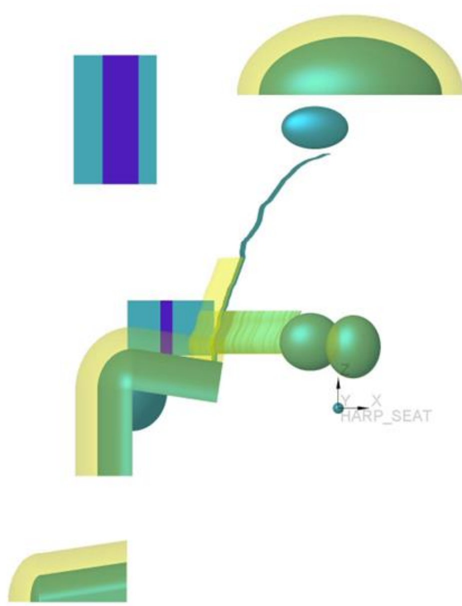

Figure 1: Fixed HARP: Commander Accommodation Model, Side View

2.1 INTENDED USE

The Fixed HARP: Commander CAD model described in this verification plan is applicable to ground vehicle commander workstations where the users interact with a keyboard, screen, and have an adjustable seat back.

The Fixed HARP: Commander CAD 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, eye location, and boots. The model also generates preferred and acceptable ranges of screens and keyboards. 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 have been added based on MIL-STD-1472 and SAE Recommended Practice J1050.

2.2 M&S OVERVIEW

The Fixed HARP: Commander CAD model is a statistical model created utilizing data collected from Soldiers at Fort Riley, Kansas, and is documented in the report *Development of Posture Prediction and Accommodation Models for Military Vehicles: Commander and Gunner Positions* (Reed et al 2021) completed by the University of Michigan Transportation Research Institute (UMTRI). The original model consists of a Microsoft Excel workbook. The CAD version of the model, created using PTC Creo® 3D CAD software and 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), 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 the *Development of Posture Prediction and Accommodation Models for Military Vehicles: Commander and Gunner Positions*. 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 two vehicle inputs to the model are the seat height measured above the floor surface (HARP) and the hydration pack relief in the seat. 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 Fixed HARP: Commander 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 and vision zones, 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 Fixed HARP: Commander 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 Fixed HARP: Commander 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 HARP is the origin for the Fixed HARP: Commander CAD model, Figure 2. All outputs are determined with respect to the HARP.

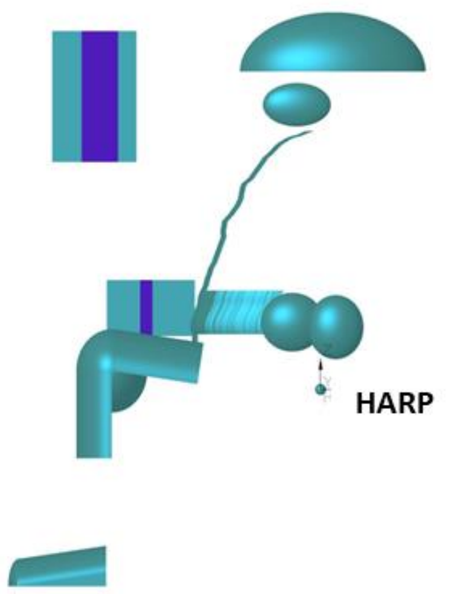

Figure 2: Fixed HARP: Commander Model Origin

2.3.2 MODEL INPUTS

The Fixed HARP: Commander accommodation model requires six inputs, listed in Table 1:

Table 1: Fixed HARP: Commander Accommodation Model Inputs

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 (2012), 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
Human Accommodation Reference Point (HARP)	The seat height measured above the floor surface.
Consider Hydration Pack Relief	A seatback with hydration pack relief can fully accommodate an occupant's hydration pack such that the occupant's position in the seat is the same regardless of wearing a hydration pack. The following selection will be available in the model: • Yes • No
Human Accommodation Reference Point (HARP) Tool	Indicates which HARP measurement device has been chosen for the occupant's seat. The two options of seat design HARP measurement tools are the SAE J826 H-point manikin and Seat Index Point (SIP) tool (Reed et al 2014). The following selection will be available in the model: • SAE J826 • ISO 5353

[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).

2.3.3 MODEL OUTPUTS – OCCUPANT COMPOSITE BODY BOUNDARIES AND ADJUSTMENT RANGES

The primary model outputs include the adjustment range needed for keyboard and screens, adjustment for seat back angle, 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: FEP CAD Model Accommodation Boundary Outputs and Definitions

Keyboard Travel Window (Preferred)	The keyboard travel window depicts the amount of adjustment (fore/aft and up/down) needed to accommodate the desired percentage of the user population.
Keyboard Travel Window (Acceptable)	The keyboard travel window depicts the amount of adjustment (fore/aft and up/down) that is smaller than the preferred range to facilitate trade studies.
Screen Position (Preferred)	The screen position depicts the preferred fore/aft position needed to accommodate the desired percentage of the user population.
Screen Position (Acceptable)	The screen position depicts the preferred fore/aft position needed to accommodate the desired percentage of the user population that is smaller than the preferred range to facilitate trade studies.
Seat Back Angle	A seat back angle adjustment range that will accommodate the desired fraction of the driver population.
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, 2021).
Eyellipse	The eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of occupant eye locations in the vehicle.
Torso Boundary ENC and Torso Boundary PPE	The torso boundary depicts the distribution of user torsos, including the effects of the worn equipment positioned relative to HARP (Reed, 2021).
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 where the lower leg is positioned vertically.
Elbow Boundary, Dynamic	This elbow boundary depicts the distribution of occupant elbow locations when hands are performing tasks (i.e., using keyboard) (Reed, 2021).
Elbow Boundary, Resting	This elbow boundary depicts the distribution of occupant elbow locations when not driving (i.e., in a relaxed posture).

Boot Boundary	The boot contours account for clearance in front of the occupant. Legs were assumed to be vertical so that ankles are directly under the knees. The forward boundary accounts for a 95% of toe points used. Lateral accommodation was developed to include accommodation for the boot.

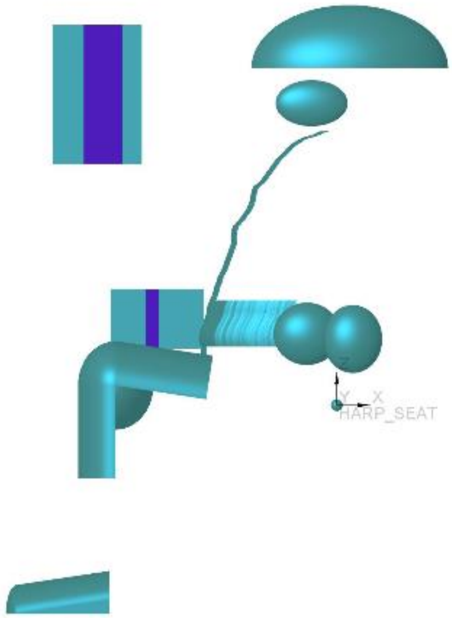

Figure 3: Fixed HARP: Commander Example Output with Travel Ranges for Screen and Keyboard

2.3.4 MODEL OUTPUTS – BASED ON MIL-STD-1472

Additional outputs of the model include interpretation of MIL-STD 1472 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: Fixed HARP: Commander 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.

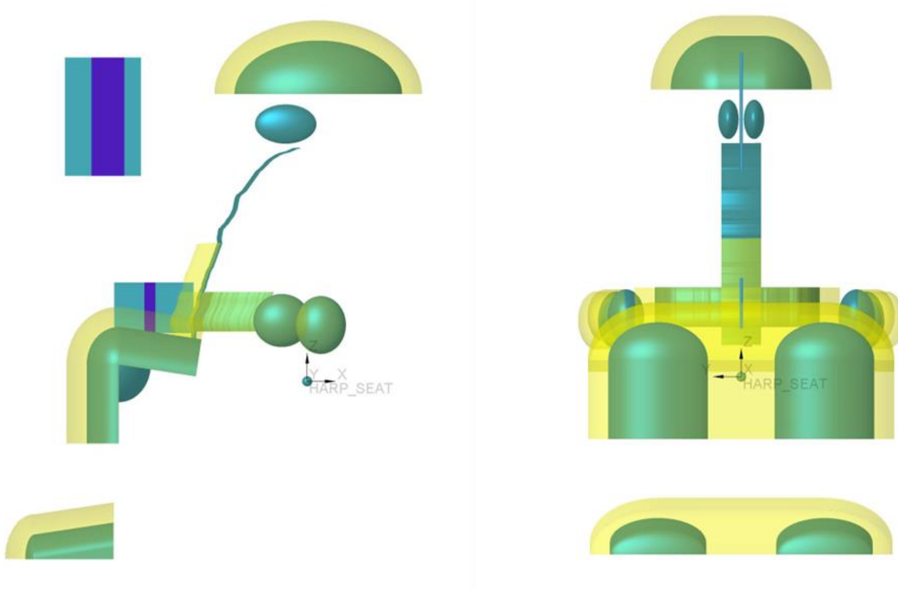

Figure 4: Accommodation Model with Clearance Zones

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 (Huston II et al 2016). Model outputs are described below in Table 4 and shown in Figure 5.

Table 4: Posture Prediction Model 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 (Reed, 2019).

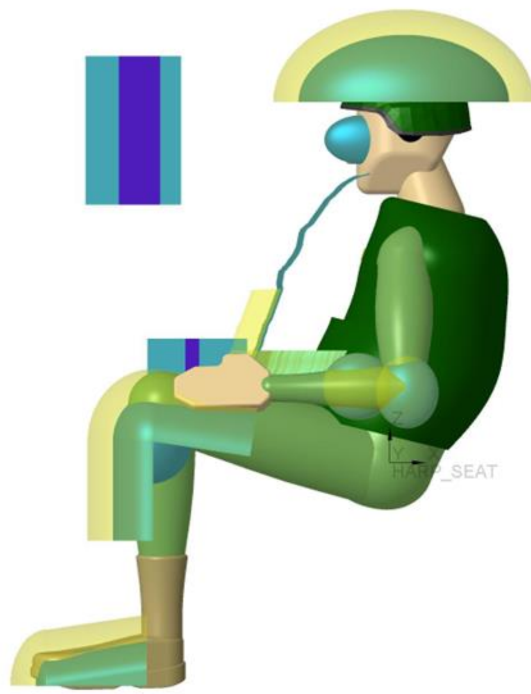

Figure 5: Boundary Manikin and Accommodation Model Overlay Example

2.4 VERIFICATION SCOPE

The scope of this effort is to verify the GVSC CAD accommodation model for a Fixed HARP: Commander position where the user interacts with a keyboard and screen. 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 Fixed HARP: Commander 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 Fixed HARP: Commander 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 HARP	4.1 HARP height input option in model	4.1 Representative (Pass) / Non-Representative (Fail)
5	Model allows for selection of either SAE J826 or ISO 5353 for the Human Accommodation Reference Point (HARP) measurement tool	5.1 HARP measurement tool selection of SAE J826 in model	5.1 Representative (Pass) / Non-Representative (Fail)
		5.2 HARP measurement tool selection of ISO 5353 in model	5.2 Representative (Pass) / Non-Representative (Fail)
6	Model allows for selection of seat hydration pack relief in the seat	6.1 Hydration pack relief selection of "YES" in model	6.1 Representative (Pass) / Non-Representative (Fail)
		6.2 Hydration pack relief selection of "NO" in model	6.2 Representative (Pass) / Non-Representative (Fail)
7	Model predicts the seat back angle	7.1 Model outputs a seat back angle range A seat back angle adjustment range that will accommodate the desired fraction of the driver population that matches the UMTRI spreadsheet	7.1 Representative (Pass) / Non-Representative (Fail)
8	Model predicts the screen fore/aft position	8.1 Model outputs a fore/aft position for a given population and gender mix and matches the UMTRI spreadsheet	8.1 Representative (Pass) / Non-Representative (Fail)
9	Model predicts the keyboard fore/aft and up/down position	9.1 Model outputs a fore/aft and up/down position for a given population and gender mix and matches the UMTRI spreadsheet	9.1 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the dimensions and location of the eyellipse	10.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with the different inputs	10.1 Representative (Pass) / Non-Representative (Fail)

11	Model predicts the forward abdominal boundary	11.1 Model outputs an abdominal boundary for the given population, gender mix, and Soldier equipment configuration that matches the UMTRI spreadsheet	11.1 Representative (Pass) / Non-Representative (Fail)
12	Model provides vertical and horizontal direct field of view based on MIL-STD-1472G and SAE J1050	12.1 Model output provides a vertical and horizontal direct Field-of-View (FOV) that matches the intent of MIL-STD-1472G and SAE J1050	12.1 Representative (Pass) / Non-Representative (Fail)
13	Model predicts the helmet contour boundary (helmet locations) with respect to the eye	13.1 Model outputs a helmet contour for the given population and gender mix that adjusts with different inputs	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 knee contour with leg and thigh segment angles based on location of resting occupants' knees in vehicle	14.1 Model outputs a knee ellipsoid for the given population and gender mix that adjusts with different inputs	14.1 Representative (Pass)/ Non-Representative (Fail)
		10.2 CAD model matches the UMTRI spreadsheet	10.2 Representative (Pass)/ Non-Representative (Fail)
15	Model predicts elbow contours based on location of resting and dynamic occupants' elbows in vehicle	15.1 Model outputs elbow contours 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)
16	Model predicts boot contours based on location of resting occupants' boots in vehicle	16.1 Model outputs boot contours 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 provides a clearance zone for the head (helmet) to roof line based on MIL-STD-1472 requirements	17.1 Model outputs a 2 inch clearance zone from the top of the helmet contour that adjusts with different inputs	17.1 Representative (Pass) / Non-Representative (Fail)
18	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472 requirements	18.1 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	18.1 Representative (Pass) / Non-Representative (Fail)
19	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472 requirements	19.1 Model outputs a 2 inch clearance zone laterally for the resting elbow contours that adjusts with different inputs	19.1 Representative (Pass)/ Non-Representative (Fail)
20	Model provides a clearance zone for the boot based on MIL-STD-1472 requirements	20.1 Model outputs a 2 inch clearance zone from the top of the boot contour that adjusts with different inputs	20.1 Representative (Pass)/ Non-Representative (Fail)

Along with using the Fixed HARP: Commander 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 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 Fixed HARP: Commander 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

4.2 M&S LIMITATIONS

The Fixed HARP: Commander CAD model has limitations based on the ground vehicle requirements for the occupant workspace, as follows:

- 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 Fixed HARP: Commander CAD model is based on the following assumptions:

- The fixtures created and used by UMTRI to collect the occupant data are representative of a Fixed HARP: Commander type of environment or workstation with a keyboard and screens.
- 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 durations.

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 2021). The UMTRI documents capturing this work are listed below:

- *Development of Posture Prediction and Accommodation Models for Military Vehicles: Commander and Gunner Positions: Final Report UMTRI-2021-7*
- *Seated Soldier Elbow Clearance Zones, 2016-12-10*
- *Commander_Accommodation_Models.14, 2022-02-20*, UMTRI Excel spreadsheet
- *Commander Posture Prediction.2, 2020-12-12*, UMTRI Excel spreadsheet

The information provided by UMTRI was utilized to create the Fixed HARP: Commander CAD model. GVSC ACT reviewed UMTRI's Excel spreadsheet to verify that it 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 *Commander_Accommodation_Models.14* (2022) Excel spreadsheet and verify that the two correlate. The model input values will be changed to ensure that the helmet boundary, eyellipse, abdominal boundary, leg, thigh, and knee boundary, elbow boundary, boots, seat back adjustment, keyboard, and screen adjustments all adjust as expected.

5.2.1 PLANNED MODEL VERIFICATION TEST RUN

An audit of the Fixed HARP: Commander 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: Fixed HARP: Commander Accommodation Model Test Matrix

Test #	Target Accommodation	Fraction Male	Ensemble	Seat Height Z (in.) (H30, vertical)	HARP Measurement Tool	Hydration Pack Relief Availability	Remarks
1	90%	85%	PPE	17.1 (435 mm)	SAE J826	No	Baseline test
2	90%	85%	PPE	11.8 (300 mm)	SAE J826	No	Vary seat height down
3	90%	85%	PPE	21.7 (550 mm)	SAE J826	No	Vary seat height up
4	95%	85%	PPE	17.1	SAE J826	No	Increase accommodation
5	90%	50%	PPE	17.1	SAE J826	No	Rebalance gender mix
6	90%	85%	PPE	17.1	ISO 5353	No	Use alternate HARP tool
7	90%	85%	PPE	17.1	SAE J826	Yes	Provide hydration pack relief
8	90%	85%	ENC	17.1	SAE J826	No	Change ensemble; ENC baseline
9	90%	85%	ENC	17.1	SAE J826	Yes	Provide hydration pack relief
10	95%	50%	ENC	11.8	ISO 5353	Yes	Vary multiple elements

5.3 PLANNED VERIFICATION REPORTING

The Fixed HARP: Commander 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 Fixed HARP: Commander 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,	Frank J. Huston, II, GVSC ACT Gale. L. Zielinski, GVSC ACT

	maintenance, use of the model or simulation, and others as appropriate. A Government entity.	
M&S User	The individual, group, or organization that uses the results or products from a specific application of the model or simulation.	Eric S. Paternoster, GVSC CSI HSI SMEs, DEVCOM Analysis Center 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 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 Fixed HARP: Commander CAD model and complete associated activities, including verification.

Table 9: Verification Resources

Document/Deliverable	Required Resources	POC
Development of Posture Prediction and Accommodation Models for Military Vehicles: Commander and Gunner Positions	M&S Developer and SME support	UMTRI
Fixed HARP: Commander Verification Plan	Verification Agent, M&S Developer and SME support	GVSC ACT
Fixed HARP: Commander Accommodation Model Build	M&S Developer and SME support	GVSC ACT
Fixed HARP: Commander Accommodation Model Verification packet completed	Verification Agent, Validation Agent, M&S Developer and SME support	GVSC ACT
Fixed HARP: Commander Model Release into PDMLink	M&S Developer	GVSC ACT
OPSEC of Fixed HARP: Commander Verification Report and CAD Model	M&S Proponent	GVSC ACT

Release of Fixed HARP: Commander 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 Fixed HARP: Commander CAD model and estimated completion of associated activities, including verification.

Table 10: Verification Milestone Timeline

Document/Deliverable	Delivery Date
Draft Fixed HARP: Commander Accommodation Model Spreadsheet	December 2020
Posture Prediction Spreadsheet	December 2020
UMTRI Report for the Fixed HARP: Commander Accommodation Model	September 2021
Feedback provided to UMTRI on the Fixed HARP: Commander Accommodation Model Report	November 2021
Final Fixed HARP: Commander Accommodation Model Spreadsheet	February 2022
Fixed HARP: Commander CAD template development started	January 2022
Fixed HARP: Commander CAD Accommodation Model Verification Plan	August 2022
Fixed HARP: Commander CAD model complete	1QFY23
Fixed HARP: Commander CAD model Verification Complete	2QFY23
Fixed HARP: Commander CAD Final Model Release into PDMLink	2QFY23
Verification Report (Final)	2QFY23

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
GVSC	Ground Vehicle Systems Center
GVSP	Ground Vehicle Survivability and Protection
HARP	Human Accommodation Reference Point
HFE	Human Factors Engineering
HSI	Human Systems Integration
IBMT	Interior Blast Mitigation Team
IOTV	Improved Outer Tactical Vest
MCoE	Maneuver Center of Excellence
MS	Milestone
M&S	Modeling and Simulation
PPE	Personal Protective Equipment
PIF	Prototype Integration Facility
SME	Subject Matter Experts
SIP	Seat Index Point
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

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