



EUROPEAN NEW CAR ASSESSMENT PROGRAMME
(Euro NCAP)



VIRTUAL FAR SIDE SIMULATION & ASSESSMENT PROTOCOL

Implementation 2024

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Preface

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1. INTRODUCTION

This document summarises the Euro NCAP Virtual Testing Crashworthiness (VTC), procedure applied to far-side impact. The aim of the procedure is to add more robustness to the evaluation of far-side protection through the deployment of additional, virtual CAE simulations. These simulations are based on load case variations of the Euro NCAP far-side sled procedure defined in the Euro NCAP Far Side Occupant Test & Assessment protocol. In this procedure, the vehicle manufacturer carries out the physical sled tests and the virtual simulations, and both sets of results are used by Euro NCAP to score the performance. The qualification procedures of the WorldSID model, used throughout this procedure, are included in Technical Bulletin TB043-1.

1.1 Definitions

Throughout this protocol the following terms are used (listed in alphabetical order):

AC – Assessment criteria, as defined in the Euro NCAP Euro NCAP FAR SIDE OCCUPANT TEST & ASSESSMENT PROCEDURE.

AC_{Limit} – Assessment criteria performance limits.

dAC – The difference in ratio between the simulations and physical tests.

rAC – The ratio between the derived assessment criteria and assessment criteria limits. This ratio can be for the simulations rAC_{sim} and for the physical tests rAC_{test} .

Crash Time Zero (t₀) – The time when crash is starting.

Far Side Sled Test Protocol - Euro NCAP FAR SIDE OCCUPANT TEST & ASSESSMENT PROCEDURE v2.4.

ISO Scores – As validation criteria, ISO scores are calculated according to the implementation of the python script ‘Objective Rating Metric for non-ambiguous signals according to ISO/TS 18571’ available at <https://openvt.eu/validation-metrics/ISO18571>, which is based on ISO TS 18571¹.

Qualified WSID Model – The CAE model of a WorldSID (mid-sized male World Side Impact Dummy, ISO 15830), which fulfils all qualification criteria defined in Technical Bulletin 043-1 and can therefore be used for validation of the vehicle environment as well as for the virtual test cases.

S_i – Individual axis sensor score.

S_{Sensor} – Individual sensor ISO score.

Simulation Data – Prescribed outputs from simulations of the virtual far side tests in the prescribed format according to Section 5.

Test Data – Measurement data and documentation from sled tests according to the Euro NCAP FAR SIDE OCCUPANT TEST & ASSESSMENT PROCEDURE and TB 021.

¹ An updated version of ISO TS 18571 is currently posted for vote by ISO. As soon as the new version of the standard is released, the reference to the latest ISO 18571 document will be added after reconfirming verification of the tool using the latest validation dataset.

Validation – The process of determining the degree to which a model represents the real world in the context of its intended use. The model response is compared to a ground-truth. The model's prediction capabilities are tested.

Validation Load case – Load cases for which simulations and tests are available and can be therefore compared to validate the virtual vehicle model.

Vehicle Manufacturer (VM) – Vehicle/car manufacturer, or supplier, contractor/consultant performing simulations for the virtual assessment.

Vehicle Simulation Model – A virtual model of the vehicle and/or body in white on a sled, which has been calibrated (parameters have been optimised to reach a target response (reference) defined) and validated by the VM beforehand. This happens based on material and component tests as well as observations from sled tests. It covers the model of the sled, the vehicle structure, seat and restraint systems.

Virtual Testing (VT) Load case – Robustness load cases that are simulated to assess the specific car, where no hardware sled test data is available.

VTC Server – Virtual Testing Crashworthiness Web Application to upload, process and review the provided data and store it on the Euro NCAP Server. It is accessible by VMs through the link <https://vtc.euroncap.com> and can be accessed with the user account used for data upload on the Euro NCAP data exchange server.

W_i – Weighting factors.

WSID Model – The CAE model of a WorldSID (World Side Impact Dummy) dummy.

1.2 Overall Process

1.2.1 The overall procedure for the virtual far side occupant assessment is outlined in Figure 1, with further explanation on the individual steps as follows:

- Step 1 – The VM is free to use whichever WorldSID simulation model is used for virtual assessment. However, to gain trust in the WorldSID simulation model(s) used, Euro NCAP has prescribed certain qualification requirements that models must meet for virtual testing. These model acceptance requirements are specified in Euro NCAP Technical Bulletin TB 043-1.
- Step 2 – Simulations of the predefined simulation matrix consisting of two far-side validation load cases and additional virtual testing load cases are to be performed by the VM with their vehicle simulation models and the qualified WorldSID model. The results are to be shared with Euro NCAP in the prescribed format via the VTC server² no less than two weeks before the physical sled tests. The datasets must include all specified information and fulfil the specified quality criteria. When the simulation data is approved, a unique far side test reference number will be provided to the vehicle manufacturer by Euro NCAP.
- Step 3 – After step 2 is completed, physical sled tests of the two validation load cases are to be performed in accordance with the current *Far Side Sled Test Protocol*. Test results shall be submitted to Euro NCAP via the VTC server in the prescribed format. A unique far side reference number, to be supplied by the Euro

² vtc.euroncap.com

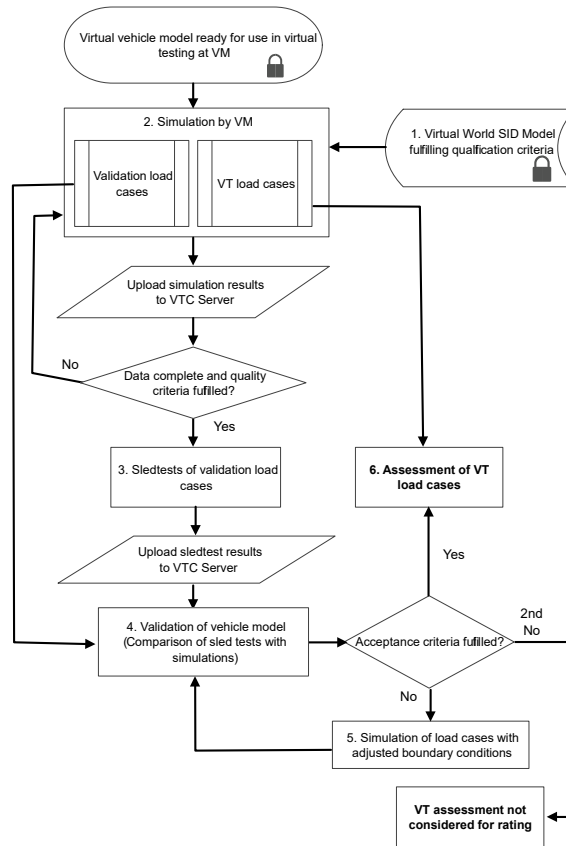


Figure 1: Overview of VTC Process

NCAP Secretariat, must be placed physical on the sled and visible all videos and referenced in the .mme file.

- Step 4 – Euro NCAP makes a comparison of the hardware sled test results and simulation-based predictions to validate the VM’s virtual model of the vehicle environment (including seat, seatbelt, airbag, centre console). In doing so, Euro NCAP can establish the necessary confidence in the VM model, without physically requiring access to the model.
- Step 5 – If the validation results of step 4 are sufficient, i.e. hardware and simulation results closely match, this step (5) can be skipped. If the validation results are not sufficient, the VM must provide evidence showing this was caused by the specific hardware test conditions, deviating from simulation parameters. The simulations of the two standard validation load cases may be repeated with adjustments to only the prescribed boundary conditions from the sled tests.

Note: Within the monitoring phase, two trials will be allowed according to the specification in Section 7. If validation criteria are still not fulfilled after boundary condition adjustment, the results submitted in step 2 will not be considered for the assessment, otherwise step 6 follows.

- Step 6 – The results from the virtual testing load cases submitted in step 2 are considered for the vehicle rating.

1.2.2 It is essential that simulation results are provided and accepted (are complete and all quality criteria are fulfilled) before the sled tests are performed. The date of the hardware

sled tests (validation load cases) shall be communicated to the Euro NCAP secretariat. Only if this date is known to Euro NCAP, the upload of the simulation data is enabled to Euro NCAP's VTC server.

- 1.2.3 The sled tests must take place after the relevant type-approval processes and carried out with original car components. Any changes of the test date are to be communicated to the Euro NCAP Secretariat.
- 1.2.4 Finally, the VTC server closes six weeks before publication date. All required data, including boundary condition adjustment, must be submitted prior to that date.

1.3 General Requirements

- 1.3.1 Throughout this process, the exact same vehicle and dummy models shall be used. This specifically applies to:
 - All control settings (time step, mass scaling, etc.),
 - Material cards (including fracture mode),
 - Contact cards including all settings,
 - Constraints,
 - Airbag Models,
 - Seatbelt Models (including pretensioner and load limiter),
 - Output definitions (IDs and coordinate systems used for outputs),
 - Geometries and represented components.
- 1.3.2 This requirement does not apply to parameters that need to be adjusted to define the different load cases. For example, node coordinates can be adjusted for replicating different positions of the dummy relative to the seat, the seatbelt and the seat relative to the car as well as the initial seat cushion deformations and load curves have to be adjusted to simulate the different loading scenarios.
- 1.3.3 Furthermore, it is important that all simulations are performed with *consistent settings*. This applies to:
 - Solver-Version and Processing Type,
 - Solver-Precision (Single, Double Precision),
 - Time-step settings (relating to initial and dynamic mass scaling),
 - Contact settings (especially between occupant and vehicle simulation model),
 - Control settings (which ensure also equal distribution of the model on the CPUs).
- 1.3.4 Ideally, all simulations shall be performed on the same computer system and with the same number of CPUs.
 - If the cluster architecture does not allow simulations to be performed with a consistent number of CPUs and/or on the same computer system and/or, equal distribution of the model on the CPUs, a report demonstrating the scatter shall be provide to with the Euro NCAP Secretariat. Within this report, the exact same simulation shall be repeated twice and resulting curves of all signals specified in Table 5 shall be overlayed for comparison.

2. WORLDSID SIMULATION MODEL

2.1 Requirements

- 2.1.1 The WorldSID model (WSID) used in this procedure must be qualified beforehand to ensure that it behaves consistently when compared to its physical counterparts. The qualification of the WSID models must be performed according to the specifications in Euro NCAP Technical Bulletin TB 043-1.
- 2.1.2 Documentation on the WSID qualification shall be uploaded together with the simulation results to the VTC server. The VM is responsible for ensuring that all requested dummy outputs are available with:
- A sampling frequency of at least 10 kHz,
 - The coordinate systems according to SAE J1733_201811 with the correct orientation of the sensors.
- 2.1.3 The compression of shoulder, thorax and abdominal ribs must be converted to the lateral displacement (DS) according to TB 021, Section 3.3.2 to be comparable with the hardware dummy. The channels DC (sensor length) and AN (sensor rotation) for the ribs can be shared, but only DS (lateral displacement) will be considered for the assessment criteria and ISO Score calculation.

3. VEHICLE SIMULATION MODEL

3.1 Requirements

- 3.1.1 The vehicle model is to be calibrated in advance and the VM must have confidence that the model is ready to predict occupant response in Euro NCAP far side test cases.
- 3.1.2 No modifications of the vehicle models are allowed during the virtual testing procedure and all settings are to remain constant.
- 3.1.3 This does not apply to boundary conditions, such as the initial position of the seat or dummy, initial seat deformation, belt routing and load curves describing the sled acceleration, especially if validation simulations need to be rerun, see Section 7.

4. SIMULATION SETUP

4.1 Simulation Time

- 4.1.1 All simulations need to be run until the maximum head excursion in y-direction is reached with an additional time margin of +20%. Equation 1 below must be fulfilled for all simulations.

Equation 1

$$\text{simulation time} > \text{time of max. y head excursion} * 1.2$$

- 4.1.1.1 No data before t0 needs to be shared. If it is shared, the time offset needs to be specified in all channel files as “Time of first sample”.

4.2 Global Coordinate System

- 4.2.1 The global coordinate system to be used is as follows:
- x-direction is facing rearwards,
 - z-direction is facing upwards (according to ECE/TRANS/WP.29/78/Rev.6 Annex 1-Appendix 2).

- 4.2.2 The vehicle centreline always defines the x-z plane. A clearly identifiable reference point to define the y-z and x-y plane must be selected by the VM. The same origin shall be used in the simulations and the tests.

4.3 Dummy Positioning inside the Vehicle

- 4.3.1 The qualified WSID simulation model is to be positioned in the vehicle environment in line with the *Far Side Sled Test Protocol*.
- 4.3.2 The tables below (Table 1 and Table 2) detail measurements that have to be provided as part of the uploaded data for each validation load case together with the test data. For the tests, the measurements on the outboard side of the dummy are sufficient (as it may be difficult to reach the inboard side of the dummy).

Table 1: Documentation of initial position of the WSID in simulations and sled tests.

	Simulation Models						Lab Sled Tests		
	Left			Right			Non-Struck Side		
	X	Y	Z	X	Y	Z	X	Y	Z
Head CoG									
Shoulder crew									
Arm tip									
H-Point									
Knee									
Ankle									

	Simulation Models			Lab Sled tests		
	X	Y	Z	X	Y	Z
Neck bracket edge front						
Neck bracket edge rear						
Head tilt angle						
Chest tilt angle						
Pelvic tilt angle						
Femur tilt angle						

Table 2: Documentation of seat and belt adjustment in simulations and sled test.

	Simulation Models						Lab Sled test					
	Left			Right			Left			Right		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Headrest stay hole												
Striker hole												
Seatback angle												
Seatbelt routing (measured on sternum)												

- The measures shall be taken in the global vehicle coordinate system and must be as close as possible between simulation and test (target values from simulations must be available and provided to test engineers to adjust the positions as close as possible within the specifications of the *Far Side Sled Test Protocol*).
- The method by which the seatback angle is measured must be documented and the method must be consistent between test and simulation. Table 2 must also be provided for all virtual load cases as part of the submitted simulation data.
- For the seatbelt routing, the point of intersection on the sternum with the upper edge of the shoulder belt is to be measured.

- The dummy shall be settled in the seat, so that no non-physical spring-back occurs at the simulation start (see quality criterion on initial displacement of H-Point specified in section 6.1)³.

4.4 Load Cases

4.4.1 The two load cases shown in Table 3 related to the hardware test specified in the *Far Side Sled Test Protocol* are used for validation of the vehicle model (as described in section 6.3). Hardware test and simulation data according to Section 5 needs to be provided for these load cases.

Table 3: Validation load cases.

Pulse	Impact angle	Seat position x	Seat position z	Subtype of the test	Virtual Testing reference ID for Hardware Tests	Virtual Testing reference ID for Simulations
Pole	75°	x-ref	z-ref	Pole 75 degree	FS_Pole_75_x-ref_z-ref_50M_Test_1	FS_Pole_75_x-ref_z-ref_50M_Sim_1 - FS_Pole_75_x-ref_z-ref_50M_Sim_3
AE-MDB	75°	x-ref	z-ref	AE-MDB 75 degree	FS_AEMDB_75_x-ref_z-ref_50M_Test_1	FS_AEMDB_75_x-ref_z-ref_50M_Sim_1 - FS_AEMDB_75_x-ref_z-ref_50M_Sim_3

4.4.2 The virtual testing load cases are specified in Table 4. Only simulation data must be provided for these load cases. Crash pulses, orientations and seat positions are to be adjusted. Please take note of the following:

- The crash pulses and red lines (as described in the *Far Side Sled Test Protocol*) for Pole and AE-MDB must be set by the VM based on in-house information. After the official Euro NCAP Pole and AE-MDB crash tests have been performed, Euro NCAP will check if the distance between red line to vehicle centreline deviates more than 100 mm between VM internal data and Euro NCAP crash tests, and if the pulse used in the sled tests (derived from internal pulse) is not fulfilling the pulse check. If this is the case, additional information will be requested by Euro NCAP.
- To vary the impact angle, the x- and y-acceleration signals shall be applied/converted according to impact angles for the respective load cases. The vehicle model must not be rotated around the z-axis to represent the different impact angles as this would lead to incorrect calculation of head excursion.
- Firing times of active restraints must be consistent between simulations and tests and fulfil the criterion defined in the *Far Side Sled Test Protocol* for both pulses.
- The uppermost position (z-high) is determined by the following procedure:
 - Firstly, the seat must be positioned into the reference position according to the AE-MDB protocol (adjust seatback angle, lateral position, etc.).
 - After this, the seat must be positioned to the uppermost vertical position from that position.

³ It is recommended to apply gravity and achieve realistic contact forces.

- If this causes contact between the WSID head and roof, the seat position should be lowered as little as possible to avoid initial contact between the head and the roof.
- If the vertical adjustment causes implausible seatback angles (e.g. outside of the design limits of the WSID, in a position where the head level cannot be oriented according to the far side protocol anymore), the seatback angle shall be adjusted to the seatback angle in the reference position or the closest notch.
- If initial contact occurs between the steering wheel (column) and the WSID, the steering wheel column shall be slightly adjusted, just to avoid the initial contact with the WSID.
- If this adjustment is still not sufficient, the seat can be adjusted laterally (x-position) as little as possible to avoid initial contact between steering wheel (column) and WSID.
- The resulting position needs to be documented in Table 2.
- The passenger seat position is adjusted according to the *Far Side Sled Test Protocol* and not changed in-between the load cases.

Table 4: Virtual Testing Load cases.

Pulse	Impact angle	Seat position x	Seat position z	Subtype of the test	Virtual Testing reference ID for Simulations:
Pole	75°	x-ref@z-high	z-high	Pole 75 degree (z-high)	FS_Pole_75_x-ref_z-high_50M_Sim_1
Pole	90°	x-ref	z-ref	Pole 90 degree	FS_Pole_90_x-ref_z-ref_50M_Sim_1
AE-MDB	60°	x-ref	z-ref	AE-MDB 60 degree	FS_AEMDB_60_x-ref_z-ref_50M_Sim_1
AE-MDB	75°	x-ref@z-high	z-high	AE-MDB 75 degree (z-high)	FS_AEMDB_75_x-ref_z-high_50M_Sim_1
AE-MDB	90°	x-ref	z-ref	AE-MDB 90 degree	FS_AEMDB_90_x-ref_z-ref_50M_Sim_1
AE-MDB	90°	x-ref@z-high	z-high	AE-MDB 90 degree (z-high)	FS_AEMDB_90_x-ref_z-high_50M_Sim_1

5. SIMULATION DATA

5.1 Requirements

- 5.1.1 All simulation results must be uploaded in the prescribed format to the Euro NCAP VTC server⁴. Data that are not provided in the correct format, are provided incomplete or that is not with the stated time window, will be rejected.
- 5.1.2 The following files are requested for each assessment:
- PDF file – including the documentation of the dummy qualification (TB 043)
 - Any additional documentation required to explain deviations.
 - After the physical sled tests are performed, a report on the initial positions according to 4.3.2 must be uploaded for the two validation load cases (Table 3).

⁴ vtc.euroncap.com

5.2 Required Simulation Results per Load Case

5.2.1 Videos of the animated simulation results, meeting the following requirements:

- Animations need to be analysed with an output interval of 2 ms or less.
- Videos are accepted with the following specification:
 - Format: .mp4 or .avi
 - Codec: H.264
 - Frame rate: 10 frames per second
 - File size: 1-10 MB

Note: the resolution/frame size shall be maximised within the file size limit.
- Six videos need to be prepared per load case, as illustrated in Figure 2.

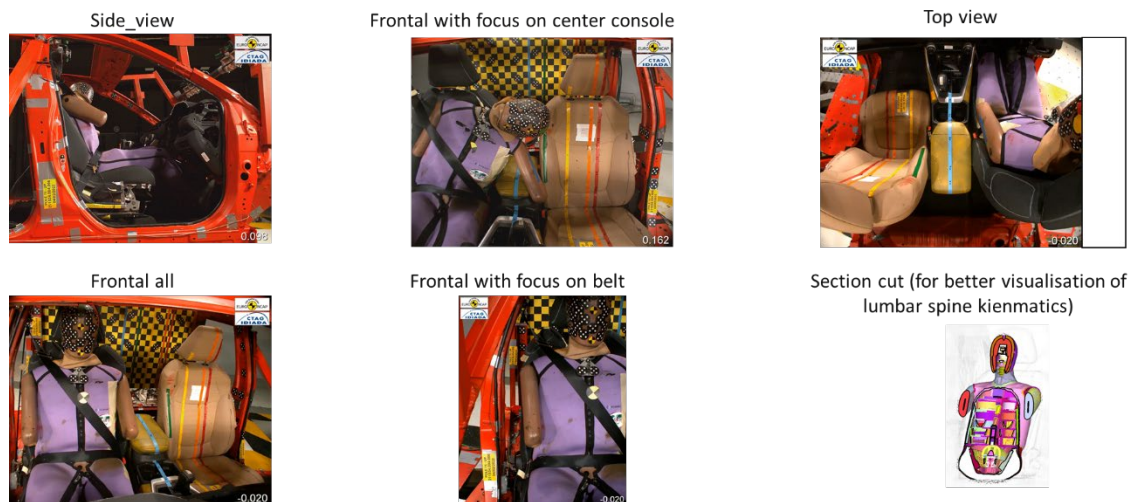


Figure 2: Video views for animated simulation results.

- The coronal cutting plane for the section cut must be normal to the x-axis and cut through the dummy pelvis and the sternum as shown in Figure 2. The aim is to have a detailed view of the lumbar spine kinematics.
 - The cross-section cut shall be fixed relative to the dummy and move with the dummy throughout the simulation.
 - The videos must be recorded from $t=0$ to “simulation time” according to Equation 1. The timestamp must be clearly visible in all videos. The videos have to be named according to the load case, as shown in Table 3 and Table 4 and the view name in Figure 2. For example, for FS_Pole_75_x-ref_z-ref_50M_Sim_1, the six videos are named as follows:
 1. FS_Pole_75_x-ref_z-ref_50M_Sim_1_side
 2. FS_Pole_75_x-ref_z-ref_50M_Sim_1_front
 3. FS_Pole_75_x-ref_z-ref_50M_Sim_1_front_centre
 4. FS_Pole_75_x-ref_z-ref_50M_Sim_1_front_belt
 5. FS_Pole_75_x-ref_z-ref_50M_Sim_1_top
 6. FS_Pole_75_x-ref_z-ref_50M_Sim_1_X-section
 - All videos shall be shared as one .zip folder (no specific naming of the .zip file required).
- 5.2.2 Zipped ISO MME Files with .mme, .chn and all requested channels.
- 5.2.3 Each load case shall be put into a separate folder. The test and simulation name shall be according to Table 4. e.g. FS_Pole_75_x-ref_z-ref_50M_Sim_1.

5.3 Content of ISO MME Files

- 5.3.1 All outputs must be provided with an output frequency of 10 kHz and no additional filtering shall be applied⁵ on the raw data.
- 5.3.2 Orientation of coordinate systems:
- All “Global coordinates” (x, y, z location) have to be in the global coordinate system according to Section 4.2, while all forces, moments, displacements, velocities and accelerations have to be in a local coordinate system according to SAE J1733.
 - If polarity is not correct in the simulations, it needs to be rectified before uploading the MME files.
- 5.3.3 The units of the outputs must be checked by the VM and must be provided in each channel file. They shall be in SI units. If not, the VTC server app will scale them to SI units before filtering.
- 5.3.4 All channels must be named according to the ISO MME channel codes listed in the APPENDIX I. The position of the dummy (either posn 1 or posn 3) within all far side data sets and the related ISO MME codes have to be consistent between physical sled tests and simulations.
- 5.3.5 All channels listed in the table below are to be provided. If any channel is missing (except airbag-related channels, if no airbag is present), the data upload will be automatically rejected from the VTC server.

Table 5: Required output channels for each simulation load case.

Location	Parameter	Axis
Head CoG accelerometer	Global coordinates	x, y, z
	Angular velocities	x, y, z
	Velocities	x, y, z
	Accelerations	x, y, z
Upper neck loadcell	Forces	x, y, z
	Moments	x, y, z
Lower neck loadcell	Forces	x, y, z
	Moments	x, y, z
Spine – T4 accelerometer	Global coordinates	x, y, z
	Accelerations	x, y, z
	Velocities	x, y, z
Spine – T12 accelerometer	Global coordinates	x, y, z
	Accelerations	x, y, z
	Velocities	x, y, z
Lumbar spine loadcell	Forces	x, y, z
	Moments	x, y, z
Shoulder joint	Forces	x, y, z
Shoulder – rib facing centre console	lateral displacement	1D
Thorax - Upper rib facing centre console	lateral displacement	1D
Thorax - Mid rib facing centre console	lateral displacement	1D
Thorax - Lower rib facing centre console	lateral displacement	1D
Abdomen – Upper rib facing centre console	lateral displacement	1D
Abdomen – Lower rib facing centre console	lateral displacement	1D
Pelvis accelerometer	Global coordinates	x, y, z
	Velocities	x, y, z

⁵ In LS-Dyna IACCOP has to be set to 1 to get meaningful accelerations. If accelerations are still very noisy, it is recommended to derive accelerations from velocities.

Location	Parameter	Axis
	Accelerations	x, y, z
Pubic Symphysis Loadcell	Force	1D
B-Pillar (non-struck side)	Global coordinates	x, y, z
	Global velocities	x, y, z
	Accelerations	x, y, z
Lap Belt (B6)	Force	1D
Shoulder Belt (B3)	Force	1D
Contact Dummy – Centre Console	Force	x, y, z
Contact Dummy – Seat	Force	x, y, z
Contact Dummy – Seatbelt	Force	x, y, z
Contact Dummy – Airbag ⁶	Force	x, y, z
Total Setup	Global Kinetic Energy	-
	Global Internal Energy	-
	Global Hourglass Energy	-
	Global External Work	-
	Total Energy	-
	Added Mass (absolute)	-
Dummy	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Driver Seat	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Sled ⁷	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Centre Console	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Airbag ⁶	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
Total number of requested channels:		115

5.3.6 The minimum content of the .mme file shall be in accordance with APPENDIX I, and Section 1.3 has to be provided for each simulation load case. Where this is not the case, the simulation results will not be accepted. Further lines can be added but will be not interpreted by the server. The name of the subtype of the test has to be according to Table 3 and Table 4. Otherwise, the simulation and test will not be correctly matched, and the dossier will be incomplete.

5.3.7 In each channel (e.g. .001 file) the header according to APPENDIX I, Section 1.3 must be included.

⁶ If present. Otherwise, these channels do not have to be shared.

⁷ The vehicle environment (if present, model of the sled + Body in white without the seat, centre console and airbag)

6. QUALIFICATION OF SIMULATION SETUPS

6.1 Simulation Set-up

6.1.1 The simulation set-ups are only accepted for virtual testing if all quality criteria and validation criteria for all load cases are fulfilled. If any of them fails, the simulation dossier will not be accepted. The quality criteria are calculated automatically on the VTC server as soon as the data is uploaded. A preview is provided to the user and the upload needs to be confirmed by the user after checking the preview.

6.1.2 Quality Criteria

- Max. Hourglass Energy of full setup must be $< 10\%$ of max. internal energy.
- Max. Hourglass Energy of all WSID components must be $< 10\%$ of max. internal energy of WSID.
- Max. mass added due to mass scaling to the total model is less than 5 % of the total model mass at the beginning of the run.
- Less than 10 mm H-point z-displacement recorded in first 5 ms of the simulation (5 ms after t_0).
- The simulation time needs to exceed time of maximum head y displacement + 20% (Equation 1).

6.1.3 The following parameters are monitored and therefore calculated on the VTC server, but currently no criteria are defined:

- Hourglass energy / internal energy at time of max. y head excursion for setup, dummy, sled and seat.
- Max. added mass (Dummy, seat, sled).

6.2 Sled Testing

6.2.1 After all simulation load cases are shared and all quality criteria are fulfilled, the physical far side sled tests can be performed.

- The tests and documentation shall be in line with the *Far Side Sled Test Protocol* using original vehicle components.
- Please make sure the data are correct, especially in terms of naming of the load cases, channel codes, polarity of the sensors.

6.2.2 The complete data sets, prepared according to TB 021 (Data format and Injury Criteria Calculation v4.0.2), must be uploaded to the VTC server. All channels shall be unfiltered (only Butterworth pre-filtering done within data acquisition is allowed).

6.2.3 All injury criteria are processed automatically based on the provided raw data according to TB 021. If any offset of the channels is needed for the correct calculation (e.g. for rib sensor rotation to calculate corrected lateral thoracic or abdominal displacement) this has to be done prior to the data upload.

6.2.4 All curves of the simulation data and the test data are processed according to the steps described in APPENDIX I, Section 2 automatically on the VTC server as soon as they are uploaded.

6.3 Validation Criteria

6.3.1 Validation criteria 1 (ISO Scores) and 2 (Injury Criteria) must be fulfilled for both load cases.

- 6.3.2 The ISO scores of all channels listed in Table 6 are calculated⁸. An overview of all calculated scores S_i is presented on the VTC server interface. The VM must confirm that the plausibility of each sensor was checked to rectify any major issues (e.g. wrong polarity or unit errors in test or simulation data).
- 6.3.3 For all sensor locations where more than one axis is measured, weighting factors w_i are calculated for each axis based on the maximum amplitude of the axis in the sled tests according to Equation 2:

Equation 2

$$w_i = \frac{\max(|Channel_{test_i}|)}{\max(|Channel_{test_x}|) + \max(|Channel_{test_y}|) + \max(|Channel_{test_z}|)} \quad \text{with } i = X, Y, Z$$

Table 6: List of channels for which ISO scores are calculated/summarised per sensor location.

Sensor	Axis	Mandatory in Monitoring Phase (2024-2025)
Head CoG Angular velocities	x, y, z	Yes
Head CoG Accelerations	x, y, z	No
Head CoG Accelerations derived from velocities (for simulations)	x, y, z	No
Upper neck Forces	x, y, z	No
Upper neck Moments	x, y, z	No
Lower neck Forces	x, y, z	No
Lower neck Moments	x, y, z	No
Spine – T4 Accelerations	x, y, z	Yes
Spine – T12 Accelerations	x, y, z	Yes
Pelvis accelerations	x, y, z	Yes
Lumbar spine loadcell Forces	x, y, z	No
Lumbar spine loadcell Moments	x, y, z	No
Shoulder joint Forces	x, y, z	No
Shoulder – rib Displacement (corrected)	1D	No
Thorax - Upper rib Displacement (corrected)	1D	No
Thorax - Mid rib Displacement (corrected)	1D	No
Thorax - Lower rib Displacement (corrected)	1D	No
Abdomen – Upper rib Displacement (corrected)	1D	No
Abdomen – Lower rib Displacement (corrected)	1D	No
Pubic Symphysis Loadcell Forces	1D	No
B-Pillar (non-struck side) Accelerations	x, y, z	Yes
Lap Belt (B6) Force	1D	No
Shoulder Belt (B3) Force	1D	Yes

- 6.3.4 The weighting factors are then used to summarise the individual ISO scores for each axis S_i of one sensor to one score per sensor (S_{Sensor}) according to Equation 3

Equation 3

$$S_{Sensor} = \sum_i w_i * S_i \quad \text{with } i = X, Y, Z$$

- 6.3.5 For those sensors which are marked as mandatory in Table 6, the calculated Sensor Score must exceed 0.5 to fulfil Validation Criterion 1.

⁸ The ISO score implementation used on the VTC server is publicly available <https://openvt.eu/validation-metrics/ISO18571>

Validation Criterion 1 (ISO Scores): $S_{Sensor} > 0.5$.

- 6.3.6 Currently, the scores for all other Sensors are only monitored and have no consequence on the acceptance of the data and the scoring. ⁹
- 6.3.7 All assessment criteria (AC) specified in the *Far Side Sled Test Protocol* are calculated and compared between simulations and tests.

Table 7: List of analysed assessment criteria and lower performance limits applied to decide for which of the assessment criteria the validation criterion must be fulfilled.

Assessment criterion AC	Limit AC_{limit}
HIC15	700
a3ms	80 g
Upper Neck Fz	3.74 kN
Upper Neck MxOC	248 Nm
Upper Neck MyOC	50 Nm
Lower Neck Fz	3.74 kN
Lower Neck Mx(base of neck)	248 Nm
Lower Neck My(base of neck)	Monitored only
Chest compression	50 mm
Abdomen compression	65 mm
Pubic Symphysis Force	2.8 kN
Lumbar Fy	2 kN
Lumbar Fz	3.5 kN
Lumbar Mx	120 Nm
Head excursion	Lateral distance between original head CoG and orange line – 80 mm

- 6.3.8 The ratio (r_{AC}) between the derived assessment criteria AC_{test} and the limits AC_{limit} shown in Table 7 is calculated as defined in Equation 4 for each criterion and for simulations and tests. The limits in the table are in line with the lower performance limits of the *Far Side Sled Test Protocol*.

Equation 4

$$r_{AC_{test}} = \frac{AC_{test}}{AC_{limit}}$$

$$r_{AC_{sim}} = \frac{AC_{sim}}{AC_{limit}}$$

- 6.3.9 For any assessment criteria where the ratio r_{AC} according to 6.3.8 exceeds 50%. I.e. the AC calculated from the sled test data exceeds 50% of the limit specified in Table 7, the difference in ratios between simulations and tests is calculated as defined in Equation 5.

Equation 5

$$\text{if } r_{AC_{Test}} \geq 50\%$$

$$d_{AC} = |r_{AC_{Test}} - r_{AC_{Sim}}|$$

⁹ From 2026 onwards the other sensors will become also mandatory when the resultant value exceeds a threshold which will be defined during the monitoring phase.

6.3.10 These deviations between the ratios must be $< 30\%$ ¹⁰ for each considered (based on the condition specified in 6.3.9) assessment criteria to fulfil the validation criterion 2.

Validation Criterion 2 (Assessment Criteria): $d_{AC} < 30\%$

7. RERUN SIMULATIONS WITH ADJUSTED BOUNDARY CONDITIONS

7.1 Procedure

7.1.1 If the qualification of the simulation model was not successful after uploading the tests data (not all validation criteria were fulfilled), Euro NCAP will give permission for the VM to re-run simulations and re-upload simulation data of the two validation load cases. In this case, the VM can adjust only the following parameters to be closer in line with the laboratory tests:

- Initial position of the dummy (node coordinates),
- Initial seat deflection (node coordinates of the seat covering foam, wire mesh etc.),
- Initial belt positions (node coordinates of seatbelt including buckle),
- Load curve describing the crash pulse.

7.1.2 During the monitoring phase, the VM also has the possibility to upload a third set of simulation results of the two validation load cases with further changes. The changes shall be clearly documented and motivated in a report. Only changes that cover unexpected deviations between the test setup and simulations will be accepted. Other changes, which are not related to boundary conditions and/or initial condition deviations between simulations and tests (e.g. material properties, element formulations) will not be accepted. Evidence from the test setup must be provided to justify any change.

8. VIRTUAL FAR SIDE OCCUPANT ASSESSMENTS

8.1 Scoring Scheme

8.1.1 The scoring scheme within the monitoring phase is summarised in Table 8 below, the final scoring in Table 9.

8.1.2 If the validation criteria are still not met for the third upload, or no or incomplete simulation data is provided, the virtual assessment will be considered as failed and the scores from the hardware far side sled tests (before possible modifiers are applied) will be halved.

8.1.3 If the validation criteria and all quality criteria for the provided complete simulation load cases are fulfilled, the full scores of the hardware far side sled tests will be included in the rating.

- During the monitoring phase, the exact assessment criteria values (i.e. injury criteria and head excursions) predicted in the virtual testing load cases are not considered. The total far side sled score is based only on the hardware far side sled result.
- After the monitoring phase, the scoring of the virtual load cases will be aligned with the sled tests and based on the criteria and performance limits. All virtual load cases will be equally considered with 1/3 pt maximum for each of the 6 load cases coming from virtual testing for the final score. The total far side sled score is based on the hardware sled result and the sum of virtual results.

¹⁰ This threshold is defined for the monitoring phase only and is planned to be reduced by 2026.

Table 8: Scoring for far side assessment based on sled tests and provided virtual testing results during monitoring phase (2024-2025).

	Max. scores from farside hardware sled tests based on performance limits (without penalty)	Scale Factor	Max. farside scores considered for rating
No simulation data is uploaded to VTC server	4	0.5	2
Uploaded data is incomplete or not accepted: <ul style="list-style-type: none"> Not all quality criteria of simulations are fulfilled, Not all requested load cases are uploaded. 	4	0.5	2
Validation criteria are not fulfilled for the validation load cases (even after boundary condition adjustment)	4	0.5	2
Data sets are complete and all validation criteria required for the monitoring phase are fulfilled for both validation load cases	4	1	4

Table 9: Scoring for far side assessment based on sled tests and provided virtual testing results in assessment phase after monitoring phase (2026-)

	Max. Scores from Farside hardware sled tests based on performance limits	Max. Scores from Farside Virtual Testing Load cases based on performance limits
Data sets are complete and all validation criteria required are fulfilled for both validation load cases	2 (1 per load case)	2 (1/3 per load case)
Uploaded simulation data is incomplete or not accepted. <ul style="list-style-type: none"> Not all quality criteria of simulations are fulfilled Validation criteria are not fulfilled for the validation load cases (even after boundary condition adjustment) No simulation data is provided	2	0

APPENDIX I: OUTPUT DEFINITIONS & PROCESSING ON VTC SERVER

1 REQUIREMENTS FOR CHANNEL OUTPUT FORMATS

1.1 Channel Codes

The following ISO MME Channel codes for the simulation outputs must be used. Otherwise, the VTC server will not allow you to upload the simulation files or misinterpret the provided results. The placeholders indicated with “?” must match the position of the driver seat (left or right) and must be consistent between tests and simulations.

Table 10: required channels and corresponding ISO Codes for all virtual tests

Location	Parameter	Axis	ISO Code
Head CoG accelerometer	Global coordinates	x	1?HEAD0000WSDCX0
		y	1?HEAD0000WSDCY0
		z	1?HEAD0000WSDCZ0
	Angular velocities	x	1?HEAD0000WSAVX0
		y	1?HEAD0000WSAVY0
		z	1?HEAD0000WSAVZ0
	Accelerations	x	1?HEAD0000WSACX0
		y	1?HEAD0000WSACY0
		z	1?HEAD0000WSACZ0
	Velocities	x	1?HEAD0000WSVEX0
		y	1?HEAD0000WSVEY0
		z	1?HEAD0000WSVEZ0
Upper neck load cell	Forces	x	1?NECKUP00WSFOX0
		y	1?NECKUP00WSFOY0
		z	1?NECKUP00WSFOZ0
	Moments	x	1?NECKUP00WSMOX0
		y	1?NECKUP00WSMOY0
		z	1?NECKUP00WSMOZ0
Lower neck load cell	Forces	x	1?NECKLO00WSFOX0
		y	1?NECKLO00WSFOY0
		z	1?NECKLO00WSFOZ0
	Moments	x	1?NECKUP00WSMOX0
		y	1?NECKUP00WSMOY0
		z	1?NECKUP00WSMOY0
Spine – T4 accelerometer	Global coordinates	x	1?THSP040000DCX0
		y	1?THSP040000DCX0
		z	1?THSP040000DCX0
	Accelerations	x	1?THSP0400WSACX0
		y	1?THSP0400WSACY0
		z	1?THSP0400WSACZ0
	Velocities	x	1?THSP0400WSVEX0
		y	1?THSP0400WSVEY0
		z	1?THSP0400WSVEZ0
Spine – T12 accelerometer	Global coordinates	x	1?THSP120000DCX0
		y	1?THSP120000DCX0
		z	1?THSP120000DCX0
	Accelerations	x	1?THSP1200WSACX0
		y	1?THSP1200WSACY0
		z	1?THSP1200WSACZ0
	Velocities	x	1?THSP1200WSVEX0
		y	1?THSP1200WSVEY0
		z	1?THSP1200WSVEZ0
Lumbar spine load cell	Forces	x	1?LUSP0000WSFOX0
		y	1?LUSP0000WSFOY0

Location	Parameter	Axis	ISO Code
		z	1?LUSP0000WSFOZ0
	Moments	x	1?LUSP0000WSMOX0
		y	1?LUSP0000WSMOY0
		z	1?LUSP0000WSMOZ0
Shoulder joint	Forces	x	1?SHLD??00WSFOX0
		y	1?SHLD??00WSFOY0
		z	1?SHLD??00WSFOZ0
Shoulder – rib	Compression corrected	1D	1?SHRI??00WSDS00
Thorax - Upper rib	Compression corrected	1D	1?TRRI??01WSDS00
Thorax - Mid rib	Compression corrected	1D	1?TRRI??02WSDS00
Thorax - Lower rib	Compression corrected	1D	1?TRRI??03WSDS00
Abdomen – Upper rib	Compression corrected	1D	1?ABRI??01WSDS00
Abdomen – Lower rib	Compression corrected	1D	1?ABRI??02WSDS00
Pelvis accelerometer	Global coordinates	x	1?PELV000000DCX0
		y	1?PELV000000DCY0
		z	1?PELV000000DCZ0
	Accelerations	x	1?PELV000000ACX0
		y	1?PELV000000ACY0
		z	1?PELV000000ACZ0
	Velocities	x	1?PELV000000VEX0
		y	1?PELV000000VEY0
		z	1?PELV000000VEZ0
Pubic Symphysis Loadcell	Force	y	1?PUBC0000WSFOY0
B-Pillar (non-struck side)	Global coordinates	x	1?BPILLO0000DCX0
		y	1?BPILLO0000DCY0
		z	1?BPILLO0000DCZ0
	Global velocities	x	1?BPILLO0000VEX0
		y	1?BPILLO0000VEY0
		z	1?BPILLO0000VEZ0
	Accelerations	x	1?BPILLO0000ACX0
		y	1?BPILLO0000ACX0
		z	1?BPILLO0000ACX0
Lap Belt (B6)	Force	1D	1?SEBE0003B6FO00
Shoulder Belt (B3)	Force	1D	1?SEBE0003B3FO00
Contact Dummy – Centre Console	Force	x	1?CEC00000WSFOX0
		y	1?CEC00000WSFOY0
		z	1?CEC00000WSFOZ0
Contact Dummy – Seat	Force	x	1?SEAT0000WSFOX0
		y	1?SEAT0000WSFOY0
		z	1?SEAT0000WSFOZ0
Contact Dummy – Seatbelt	Force	x	1?SEBE0000WSFOX0
		y	1?SEBE0000WSFOY0
		z	1?SEBE0000WSFOZ0
Contact Dummy – Airbag ¹¹	Force	x	1?ARBG0000WSFOX0
		y	1?ARBG0000WSFOY0
		z	1?ARBG0000WSFOZ0
Total Setup	Global Kinetic Energy	-	00EKINSU0000EN00
	Global Internal Energy	-	00EINTSU0000EN00

¹¹ If present. Otherwise, these channels do not have to be shared.

Location	Parameter	Axis	ISO Code
	Global Hourglass Energy	-	00EHOUSU0000EN00
	Global External Work	-	00EXWOSU0000EN00
	Added Mass (absolute)	-	00MINCSU00000000
	Total Energy	-	00ETOTSU0000EN00
Dummy	Kinetic Energy	-	1?EKINSU00WSEN00
	Internal Energy	-	1?EINTSU00WSEN00
	Hourglass Energy	-	1?EHOUSU00WSEN00
	Added Mass (absolute)	-	1?MINCSU00WSMA00
Driver Seat	Kinetic Energy	-	1AEKINSU0000EN00
	Internal Energy	-	1AEINTSU0000EN00
	Hourglass Energy	-	1AEHOUSU0000EN00
	Added Mass (absolute)	-	1AMINCSU0000MA00
Sled	Kinetic Energy	-	S0EKINSU0000EN00
	Internal Energy	-	S0EINTSU0000EN00
	Hourglass Energy	-	S0EHOUSU0000EN00
	Added Mass (absolute)	-	S0MINCSU0000MA00
Centre Console	Kinetic Energy	-	10EKINSU0001EN00
	Internal Energy	-	10EINTSU0001EN00
	Hourglass Energy	-	10EHOUSU0001EN00
	Added Mass (absolute)	-	10MINCSU0001MA00
Airbag ⁶	Kinetic Energy	-	10EKINSU0002EN00
	Internal Energy	-	10EINTSU0002EN00
	Hourglass Energy	-	10EHOUSU0002EN00
Total number of requested channels:		115	

Table 11: Placeholder definitions for left and right-hand drive vehicles for far side tests on driver's side.

	Left-hand drive vehicle	Right-hand drive vehicle
2 nd for dummy sensors e.g. 1?HEAD0000WSDCX0	1 e.g. 11HEAD0000WSDCX0	3 e.g. 13HEAD0000WSDCX0
7 th and 8 th digit e.g. 1?SHRI??00WSDS00	RI e.g. 11SHRIRI00WSDS00	LE e.g. 13SHRILE00WSDS00
2 nd digit for B-Pillar accelerometer e.g. 1?BPILLO0000ACX0	4 e.g. 14BPILLO0000ACX0	6 e.g. 16BPILLO0000ACX0

Tests can either performed on left- or right-hand drive vehicles, independent of the nomination. However, it must be consistent between simulations and lab tests, if left or right-hand drive vehicles are used throughout the procedure (no mix is allowed).

1.2 Header Requirements for .MME FILE

Below is an example for a .mme file. The lines with examples must be filled in. The rest may remain empty (but needs to be in the file).

Table 12: Content of .mme file.

Item	Header	Remarks
Data format edition number	:1.6	
Laboratory name	:<lab name>	
Customer name	:Euro NCAP	

Item	Header	Remarks
Customer test ref. number	:<test number>	Full file name (Reference-Extension-Run)
Customer project ref. number	:<test series number>	4 digits number
Title	:Euro NCAP <year of test>	
Timestamp	:<date> <time>	
Type of the test	: Side Impact	see table in TB021
Subtype of the test	: <subtype of the test>	See Table 3 & 4 e.g. Pole 75 degree
Virtual Testing reference ID:	: <Virtual Testing reference ID>	Identifier according to Table 3&4 e.g. FS_Pole_75_x-ref_z-ref_50M_Test_1
Euro NCAP Validation Test Reference Number	:<FS reference number provided by Euro NCAP>	Only included in hardware tests used for validation of virtual tests. Empty for simulations.
Regulation	:<test protocol version>	
Date of the test	:<date>	Date of hardware test or when simulation was executed
Name of test object 1	:<make and model>	
Ref. number of test object 1	:<VIN number>	
Velocity test object 1 lon.	:<VUT longitudinal velocity>	Desired (scenario) velocity
Velocity test object 1 lat.	:<VUT lateral velocity>	Desired (scenario) velocity
Mass test object 1	:<VUT mass>	
Driver position object 1	:<1/3>	LHD=1, RHD=3
Impact side test object 1	:<LE,RI>	LHD=RI, RHD=LE
Type of data source	:<type>	Simulation or Hardware
Additional mandatory lines for Virtual Tests:		
Dummy Simulation Model Specification	:<dummy simulation model type> <name> <version> (<supplier>)	e.g. WSID 50 M v3.4.1. (Humanetics)
Reference to Dummy Model Qualification Documentation	:<name of pdf>.pdf	Document name e.g. WSID-v3_2022-11-03.pdf
Solver Name	: <FE software name>	e.g. LS-Dyna
Solver Version	:<FE software solver version>	e.g. ls-dyna_mpp_s_R9_3_1_x64_centos65_ifort131_sse2_openmpi183
Solver Precision	:<Solver precision>	SP or DP
Platform Name	:<name of platform on which simulations have been run>	e.g. centos78_openmpi2.1.3

Item	Header	Remarks
Number of CPUs	:<cores x CPUs>	e.g. 2x32
Time step setting	:<min. time step size in seconds>	e.g. min. time step 1-e7 s
Contact Type between dummy and seat	:<contact documentation>	S2S SOFT2 nu=0.2
Contact Type between dummy and seatbelt	:<contact documentation>	S2S SOFT2 nu=0.
Number of contacts used in the overall simulation setup	: <total number of contacts>	e.g. 10
Number of elements	: <total number of contacts>	e.g. 20000
Mass of total setup (used for quality checks)	: <total mass in kg>	Fill in in kg e.g. 1500
Mass of dummy in kg	: <total mass in kg>	Fill in in kg e.g. 75
Mass of seat in kg	: <total mass in kg>	Fill in in kg e.g. 50
Mass of sled in kg	: <total mass in kg>	Fill in in kg e.g. 500
Mass of centre console in kg	: <total mass in kg>	Fill in in kg e.g. 500
Distance between head CoG and green line	: <distance in meters>	Fill in in meters e.g. 0.2.
Distance between head CoG and yellow line	: <distance in meters>	Fill in in meters e.g. 0.3.
Distance between head CoG and orange line	: <distance in meters>	Fill in in meters e.g. 0.4.
Distance between head CoG and red line	: <distance in meters>	Fill in in meters e.g. 0.5.

1.3 Header requirements for each channel file

Below an example of a header for any channel files (e.g. .001, .100 file is given). Only the lines with examples must be filled in. The rest can remain empty. If the simulation results include a settling phase before t_0 , the “time of first sample” has to be included (e.g. -0.2 for a 200 ms settling phase).

```

Test object number           :    1
Name of the channel          :    e.g. Head x acceleration
Laboratory channel code      :
Customer channel code        :
Channel code                 :    e.g. 11HEAD0000WSACX0
Unit                         :    e.g. m/(s*s)
Reference system             :
Pre-filter type              :
Cut off frequency            :
Channel amplitude class      :
Sampling interval            :    1E-4

```

Bit resolution	:	
Time of first sample	:	e.g. 0
Number of samples	:	e.g. 6200

2 DATA PROCESSING

- Read “sampling interval” from the individual channel file and resample data to 10 kHz if needed (if 20 kHz are uploaded, every second value is used)¹²
- Filter all Channels with filter class according to TB 021. For the unspecified channels in TB 021 (e.g. energies or displacement, no filtering is applied).
- „Time of first sample“ (t_{0_MME}) and sampling interval is read in from channel file.
 - If not included, t_{0_MME} is set to 0.
 - If filled in: $t_{0_MME} = \text{„Time of first sample“} / \text{„sampling interval“}$
- Remove data before t_{0_MME}
- Calculate time of maximum y head excursion
- Remove data after maximum y head excursion + 20% of time
 - store " t_{end_calc} "

After test data has been uploaded:

- Calculate ISO scores for all channels, which are listed in Section 6.3.2, Table 6.
- Calculate weighting factors for all sensors where more than one axis is measured.
- Summarise the individual channels of one sensor to S_{sensor}
- All injury criteria specified in the *Far Side Sled Test Protocol* are calculated according to TB 021.
- The head displacement of the test data is calculated from the measured accelerations and rotational velocities of the head CoG. To consider the distance between the head CoG, an offset of 80 mm is added for the max. head excursion calculation for the simulations and the tests.

All data is used as provided and rounded only at the very last steps. A minimum of 8 digits has to be provided for each channel.

¹² The sampling rate shall be reviewed based on the results received in the monitoring phase. The downsampling is performed as the reference data from ISO is available at 10 kHz and therefore the ISO tool can be only validated for this sample rate for now.