EUROPEAN NEW CAR
ASSESSMENT PROGRAMME

Technical Bulletin

Qualification Procedure for Virtual Dummy Models

Part 1: WorldSID AM50

Version 1.0

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TB 043-1

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Preface

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EUROPEAN NEW CAR ASSESSMENT PROGRAMME (Euro NCAP)

Table of Contents

1. Introduction

This document supports the Virtual Testing – Crashworthiness Far side Assessment Protocol by providing details of the data required in qualification of WorldSID CAE models. From 2024 onwards VTC simulation data will be required for all vehicles assessed by Euro NCAP.

The WorldSID AM50 model qualification process is divided into three stages beginning with normative standard requirements, component test simulations and full scale far side sled test simulations performed in a simplified environment. In addition to this document, it is also necessary to refer to the Standard ISO 15830, the Euro NCAP VTC Simulation and Assessment Protocol as well as Euro NCAP Technical Bulletin TB 021. Additional reference documents and additional information are available using the following links:

Euro NCAP | Protocols

https://openvt.eu/EuroNCAP/wsid-model-qualification

In future, additional sizes of WorldSID model will be incorporated into the VTC assessment and this document will also be updated accordingly.

2. Stage 1 – Normative Dummy Requirements

2.1 Normative references

2.1.1 The model evaluation is based on the following normative references:

- Mass properties according to ISO 15830-2 & -5
- External dimensions according to ISO 15830-5
- Range of motion according to ISO 15830-1
- Sensors according to ISO 15830-3
- Dummy dynamic qualification procedures according to ISO 15830-2

2.1.2 The ISO 15830 is currently under revision, therefore the referenced documents are given undated and the latest version of the ISO document shall be used.

2.2 Simulation Setup

2.2.1 All qualification procedures described in the ISO 15830-2 must be simulated with the WorldSID AM50 model. All setups must also meet the following simulation-related requirements:

- Dummy-related control cards must match in all three stages
- Active gravity
- Signals must be outputted and filtered according to the specification in the ISO 15830-2

2.2.2 The last specification requires an output of signals before t0 to perform filtering and offset correction as requested in the norm, this is why the simulation must start with some time in advance of t0.

3. Stage 2 – Component Level Tests

3.1 Dummy model suitability – sub-system simulation

In Stage 2, the application-specific suitability of the dummy model is checked at component level via mini-sled tests. The first test setup is used to validate the model's head-neck performance whereas the second setup focuses on the lumbar spine performance. In both setups, lateral and oblique load cases are included. The same acceleration pulse is used in all the four load cases, which is shown in Figure 1.

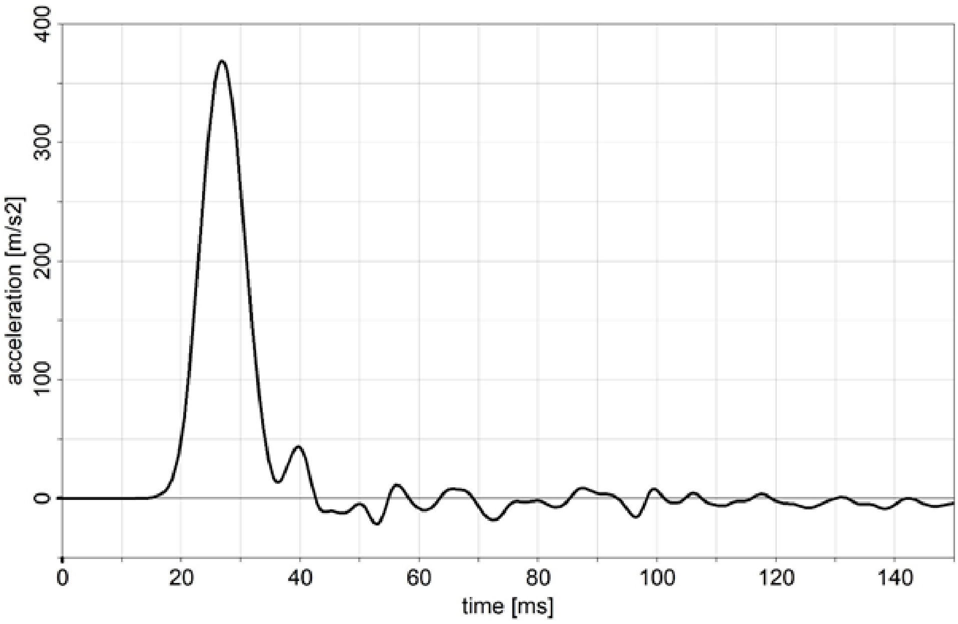

Figure 1: Acceleration pulse in component tests

3.2 Reference Data

The following finite element reference meshes and reference data sets are needed for this stage:

3.2.1 Reference mesh for head-neck mini-sled environment

- 11_reference_meshes/Head-Neck/lateral/master_input_lateral.key
- 11_reference_meshes/Head-Neck/oblique/master_input_oblique.key

3.2.2 Reference mesh for lumbar spine mini-sled environment

- 11_reference_meshes/Lumbar_spine/lateral/master_input_lateral.key
- 11_reference_meshes/Lumbar_spine/oblique/master_input_oblique.key

3.2.3 Reference signal data of head-neck test

- 10_reference_data/Head-Neck_lateral
- 10_reference_data/Head-Neck_oblique

3.2.4 Reference signal data of lumbar spine test

- 10_reference_data/Lumbar_Spine_lateral
- 10_reference_data/Lumbar_Spine_oblique

3.3 Head-neck Load case

3.3.1 The head-neck assembly is mounted on a mini-sled and loaded with an acceleration profile of 350 m/s² (see Figure 2) in pure lateral (load case 1) and oblique (75-degree, load case 2) directions.

3.3.2 Simulation Setup

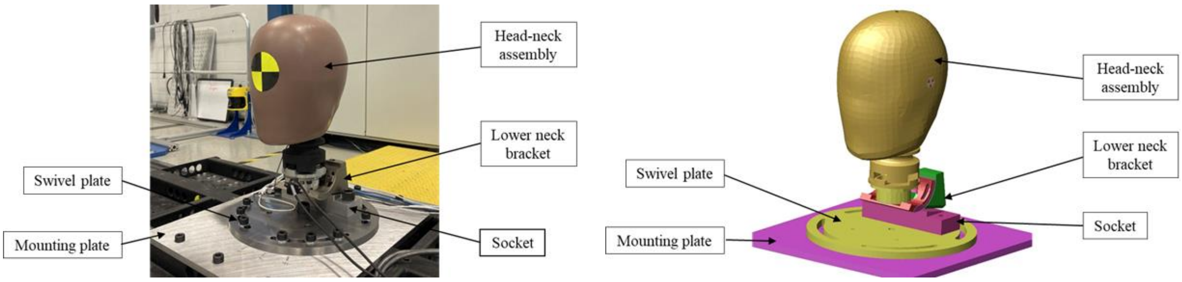

Figure 2: Test setup and FE mesh of lateral head-neck test with description of parts

3.3.2.1 Environment

The geometry of the sled environment must be based on the reference mesh. It includes mounting plate, swivel plate and socket. All components must be modelled rigidly as well as the connection within the sled environment. The properties of all parts are listed in Table 1. The provided mesh in combination with the specified density (hard requirement, see Table 1) defines the remaining properties of the components like mass, centre of gravity and moments of inertia. The lower neck adaptor bracket of the dummy head-neck assembly has to be rigidly connected to the socket.

Table 1: Properties of parts of the sled environment for head-neck load case

Name of reference geometry	**Density**	**Target mass***	**Material**	**Part ID in reference mesh**
Socket	7.85E-6 kg/mm³	0.24 kg	steel / rigid	9003
Swivel plate	7.85E-6 kg/mm³	1.04 kg	steel / rigid	9002
Mounting plate	7.85E-6 kg/mm³	2.10 kg	steel / rigid	9001

* Included for verification

3.3.2.2 Dummy Model Preparations

The head-neck assembly of the WorldSID must include all components down to, and including, the lower neck bracket. The bracket is rigidly connected to the sled environment as described in Section 3.3.2.

3.3.2.3 Loading and other configurations

The following conditions must be considered:

- The sled must be loaded with the accelerations specified in the reference load case, Figure 1
- Gravity shall be applied
- Dummy-related control cards must match in all three stages
- Simulation time ≥ 150 ms

3.3.3 Outputs

For the measurement of head and neck signals, the standard load cells of the WorldSID model must be used. Table 2 lists all required outputs per test setup.

The sampling rate of all outputs must be set to 20 kHz.

Table 2: List of required outputs of the load cases for the head-neck test

Test	**Head-neck lateral / oblique**
Angular rates	Head X/Y/Z
Forces	Upper neck X/Y/Z
	Lower neck X/Y/Z
Moments	Upper neck X/Y/Z
	Lower neck X/Y/Z

3.4 Lumbar spine

3.4.1 The lumbar spine, with an additional replacement mass, is mounted on a mini-sled and loaded as shown in Figure 3. It is loaded with an acceleration profile of 35g in pure lateral (load case 3) and oblique (60-degree, load case 4) directions.

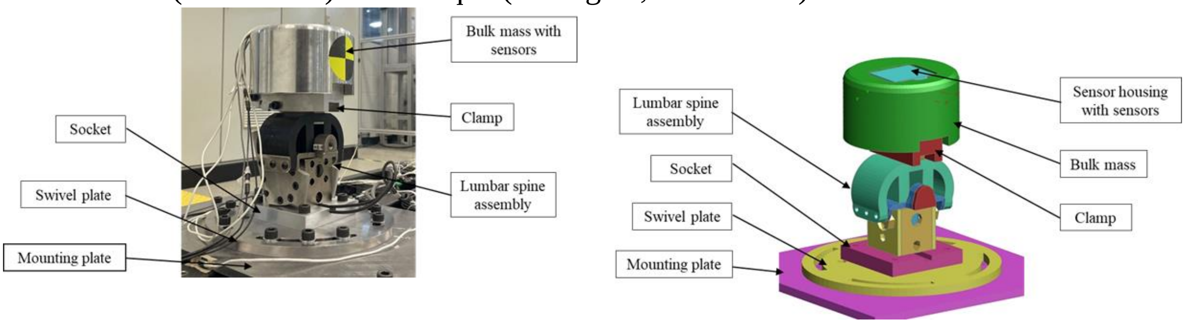

Figure 3: Test setup and FE model of lateral lumbar spine load case with description of parts

3.4.2 Simulation setup

3.4.2.1 Environment

The geometry of the sled environment must be based on the reference mesh for the lumbar test. It includes mounting plate, swivel plate, socket and clamping bolt. All four parts must be rigidly connected and have to be modelled as rigid bodies.

The replacement mass assembly on top of the lumbar spine must also be based on the reference mesh. It includes clamp, bulk mass, bolt and sensor housing. As before, the connection between all components in this assembly must be rigid and all parts must be modelled as rigid bodies.

The lumbar spine load cell is rigidly attached to the socket of the sled environment. The connection between lumbar spine and replacement mass assembly via clamp and lumbar mounting wedge shall also be rigid.

Each part density in Table 3 is a fixed requirement that must not be changed. In combination with the mesh, it defines the remaining properties of the components like mass, centre of gravity and moments of inertia. The additional information in Table 3 is collected for verification purposes.

Table 3: Properties of the additional components for lumbar spine load case

Name of reference geometry	Density	Target mass*	Material	Part ID in reference mesh
Sensors	1.5E-6 kg/mm³	0.01 kg		9014
Sensor housing	1.485E-6 kg/mm³	0.20 kg	rigid	9013
Bolt	7.85E-6 kg/mm³	0.10 kg	steel / rigid	9012
Bulk mass	7.85E-6 kg/mm³	4.21 kg	steel / rigid	9011
Clamp	7.85E-6 kg/mm³	0.54 kg	steel / rigid	9010
Clamping bolt	7.85E-6 kg/mm³	0.33 kg	steel / rigid	9004
Socket	7.85E-6 kg/mm³		steel /rigid	9003
Swivel plate	7.85E-6 kg/mm³	1.04 kg	steel /rigid	9002
Mounting plate	7.85E-6 kg/mm³	2.10 kg	steel / rigid	9001

* For verification

The positions of the accelerometer and angular rate sensor of the replacement mass are listed in Table 4.

An appropriate contact between the outer surfaces of the replacement mass assembly and the lumbar spine must be defined. The contact shall be checked, so that the edge to surface contact is working properly (e.g. no large penetrations or sticky nodes).

Table 4: Location of sensors in the reference mesh in lumbar spine load case

Sensor	x	y	z	Node ID in reference mesh
Accelerometer	175.3	189.9	273.7	2016319
Angular rate sensor	167.4	200.0	284.0	2090572

3.4.2.2 Dummy model preparations

Only the lumbar spine, the lumbar mounting wedge on top and the lumbar load cell are used in the simulation.

3.4.2.3 Loading and other configurations

The following conditions must be considered:

- The sled must be loaded with the accelerations specified in the reference load case, Figure 1
- Gravity shall be applied
- Dummy-related control cards must match in all three stages
- Simulation time ≥ 150 ms

For the measurement of the signals in lumbar spine tests, the standard load cell of the WorldSID model and the additional sensors must be used.

The sampling rate of all outputs shall be 20 kHz. Table 5 lists all required outputs per test setup.

Table 5: List of required outputs of the load cases for the lumbar spine load case

Test	Lumbar spine lateral / oblique
Angular rates	Replacement mass X/Y/Z
Forces	Lumbar X/Y/Z
Moments	Lumbar X/Y/Z

4. Stage 3 – Full Scale Tests

4.1 Dummy model suitability – full assembly simulation

In stage 3, the models' application-specific suitability is checked at a full assembly level using two sled tests. Both tests are based on the same generic environment with a 75° oblique direction pulse, see Figure 4. However, in the first test, target delta v = 8 m/s (slow), whereas in the second sled test target delta v = 11 m/s (fast).

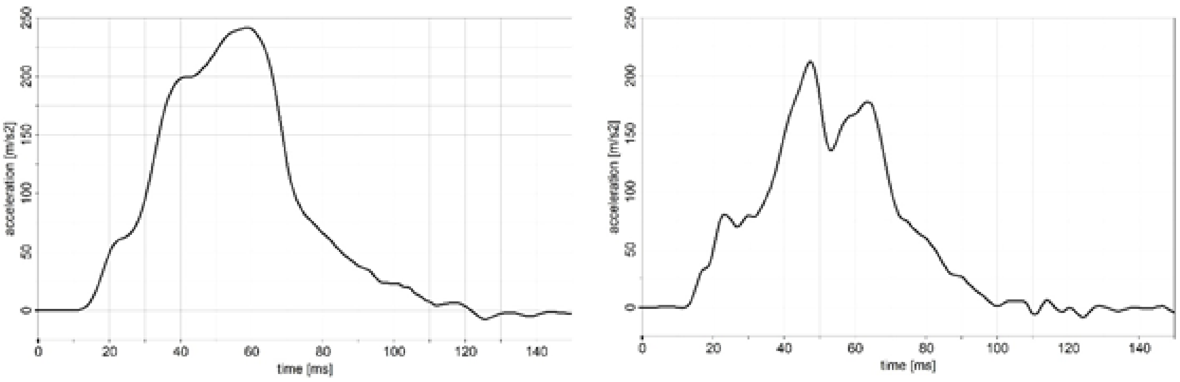

Figure 4: Acceleration profile for v = 11 m/s (left) and v = 8 m/s (right)

4.2 Reference signals

Data for the two sled tests were generated under the following projects:

- For Δv = 8 m/s, data was generated within experiments performed in the OSCCAR project (funded under EU Horizon 2020 research and innovation programme, under grant agreement No. 768947)
- For Δv = 11 m/s, data was generated using CEESAR-LAB test data (Petit. et al., 2019)

4.3 Reference Data

The following finite element reference models and reference data sets are needed for this procedure:

4.3.1 Reference CAE data: mesh for sled environment, boundary conditions restraint settings and target position reference for model's posture alignment for sled test with Δv = 8 m/s

- 11_reference_meshes/Far side_8mps/master_8mps.key

4.3.2 Reference CAE data: mesh for sled environment, boundary conditions, restraint settings and target position reference for model's posture alignment for sled test with Δv = 11 m/s

- 11_reference_meshes/Far side_11mps/master_11mps.key

4.3.3 Reference signal data for sled test with Δv=8 m/s

- 10_reference_data/Far side_8mps

4.3.4 Reference signal data for sled test with Δv=11 m/s

- 10_reference_data/Far side_11mps

4.4 Simulation setup

4.4.1 Environment

4.4.1.1 The sled test setup consists of separated components assembled in a common rigid frame as shown in Figure 5 & Figure 6. Apart of the rigid frame, the setup includes a rigid inclined seat pan, a rigid frame with two horizontal bars as seatback, rigid footrest, two centre consoles (one for legs and one for pelvis), 3-point belt, retractor, and belt attachment points.

Note: The test setup is provided in a left-handed drive car seat configuration.

4.4.1.2 The dummy model is seated on a rigid seat pan mounted on a rigid frame through load transducers. The model's feet rest on a rigid support, which is mounted on a rigid frame. The rigid frame is fixed onto the catapult sled system. The rigid consoles are covered with 50 mm thick Polyethylene foam (Ethafoam TM 180, density 16 kg/m³). The 3-point belt is not connected to the seat (left-hand drive car seat), but to the rigid frame though attachment points. A preload in the shoulder belt was applied and maintained at a force of 200 N.

4.4.1.3 The following contacts shall be defied with coefficients of friction between 0.10-0.60:

- WorldSID-seat
- WorldSID-seatbelt
- WorldSID-centre console

All contacts shall be checked to work properly (no large penetrations or sticky nodes).

The applied contact settings (type and friction coefficient) must be reported in the qualification documentation report.

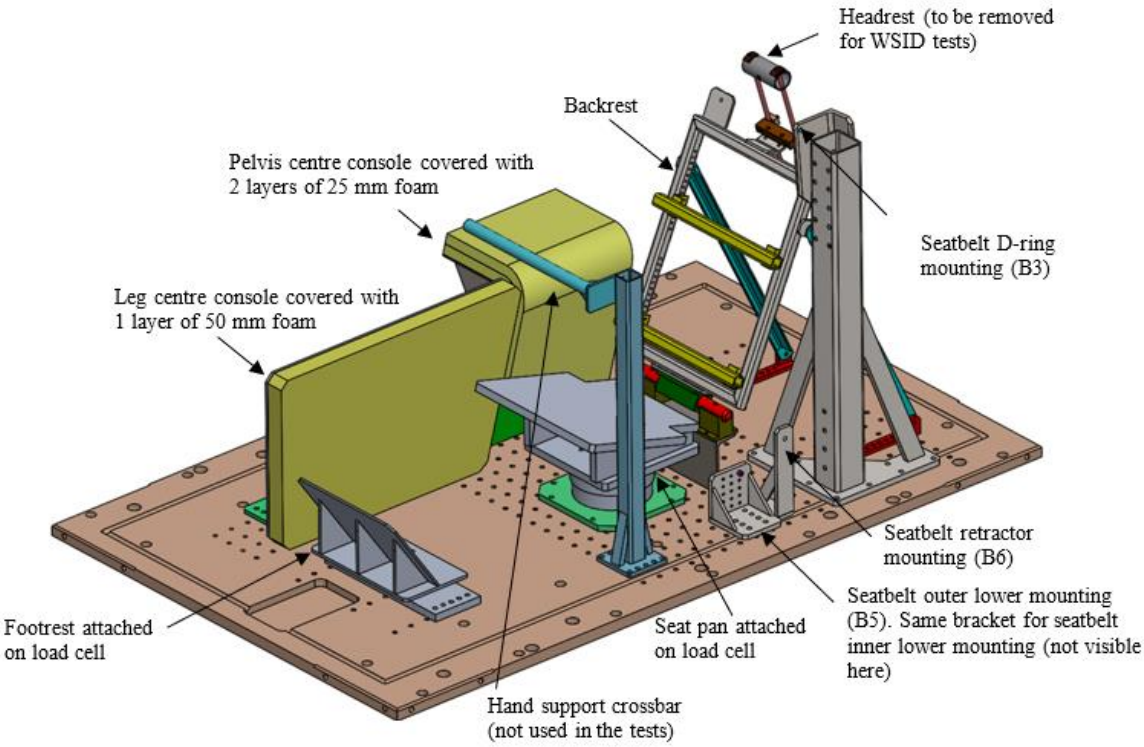

Figure 5: Sled environment as CAD image with description of individual parts

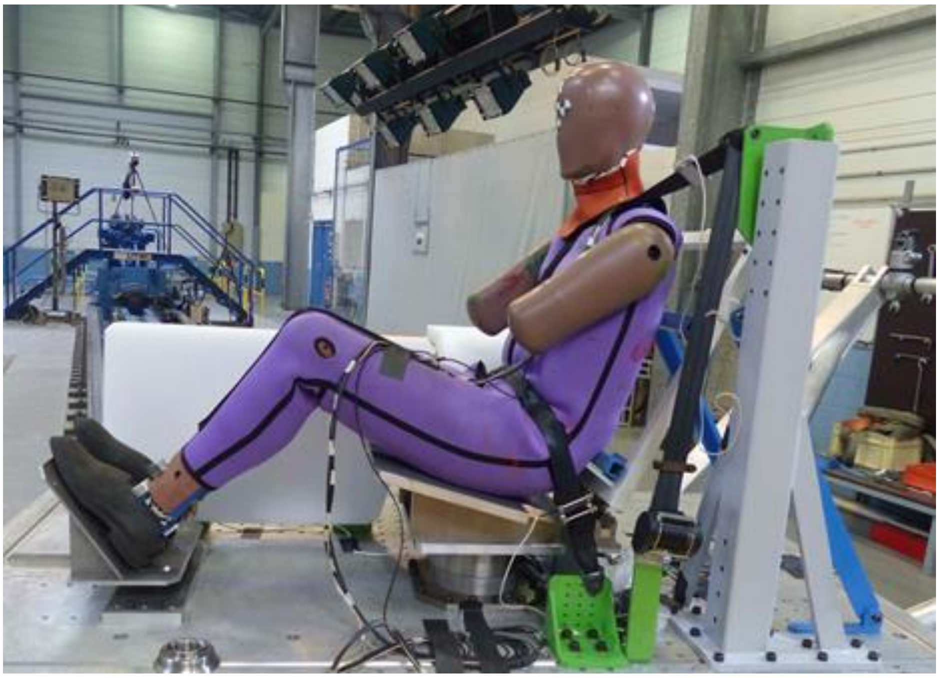

Figure 6: Dummy in sled environment

4.4.2 Dummy Model Preparation

4.4.2.1 The dummy model is seated, targeting the hip point, head centre point and surface data of the WorldSID in the physical test position. The target postures for the two sled tests are provided in reference CAE data files.

4.4.2.2 Due to the seat's flat shape, the model's deformation at the bottom shall be considered to avoid initial penetration between model's bottom and seat plate when the model is seated.

4.4.2.3 It is noted that the target posture of the WorldSID provided for the CEESAR environment (sled test with $\Delta v = 11$ m/s) was not straight but leaning slightly to the dummy's left side. This is intentional to simulate the laboratory setup as close as possible. The described leaning posture is not present in OSCCAR target posture provided (sled test with $\Delta v = 8$ m/s).

4.4.2.4 The belt path shall be as close as possible to the provided reference belt path in the reference CAE file and adapted to the dummy's achieved body position.

4.4.2.5 Contact definitions between model and the generic environment are pre-defined and provided together with the target posture in the reference CAE file.

4.4.3 Loading and other configurations

The following conditions must be considered:

- The sled must be loaded with pulses matching the provided reference signal data. The loading applied as 'velocity-time' boundary prescribed motion is provided in reference CAE data files.
- The simulation must be performed with active gravity.
- Dummy model-related control cards must match in all three stages.
- End time ≥ 200 ms.

5. Outputs

5.1 Postprocessing of output channels

5.1.1 For each output channel generated, the sampling rate must be 20 kHz. Units and directions of each channel must be aligned to the reference data, which is recorded and provided in SAE J211 standard.

5.1.2 For dummy model related outputs, the standard load cells of the dummy model must be used with their original orientation! A list of required outputs is provided in Table 6.

Table 6: List of required outputs of stage 3 sled tests

Test	**Sled test slow / fast**
Accelerations	Head X/Y/Z
	T1 X/Y/Z
	T12 X/Y/Z
	Pelvis X/Y/Z
Angular rates	Head X/Y/Z
Forces	Upper Neck X/Y/Z
	Lumbar X/Y/Z
Moments	Upper Neck X/Y/Z
	Lumbar X/Y/Z
Displacement	Second abdominal rib right

5.1.3 The outputs of stages 2 and 3 are rated with the method described in the following sections.

5.1.4 References

The following documents are referenced throughout this chapter and are essential to perform the calculation of the rating:

- ISO/TS 18571 Road vehicles – Objective rating metric for non-ambiguous signals
- ISO 6487, Road vehicles – Measurement techniques in impact tests – Instrumentation
- SAE J211-1, Instrumentation for impact test – Part 1: Electronic instrumentation
- Reference signal data of neck tests:
    - o 10_reference_data/Head-Neck_lateral
    - o 10_reference_data/Head-Neck_oblique
- Reference signal data of lumbar spine tests:
    - o 10_reference_data/Lumbar_Spine_lateral
    - o 10_reference_data/Lumbar_Spine_oblique
- Reference signal data of sled test:
    - o 10_reference_data/Far side_8mps
    - o 10_reference_data/Far side_11mps

The references are given undated, therefore the latest version must be used.

5.1.5 Pre-processing of signals

Prior to any score calculations, all signal data from the simulations shall be pre-processed according to the instructions described below.

5.1.5.1 Filter all channels with CFC60 according to SAE J211 or ISO 6487

5.1.5.2 Apply 'bias removal' of all channels between t = 5 ms and t = 10 ms by calculating the mean value of the given interval and offsetting the signal by the mean value (see Figure 7 below)

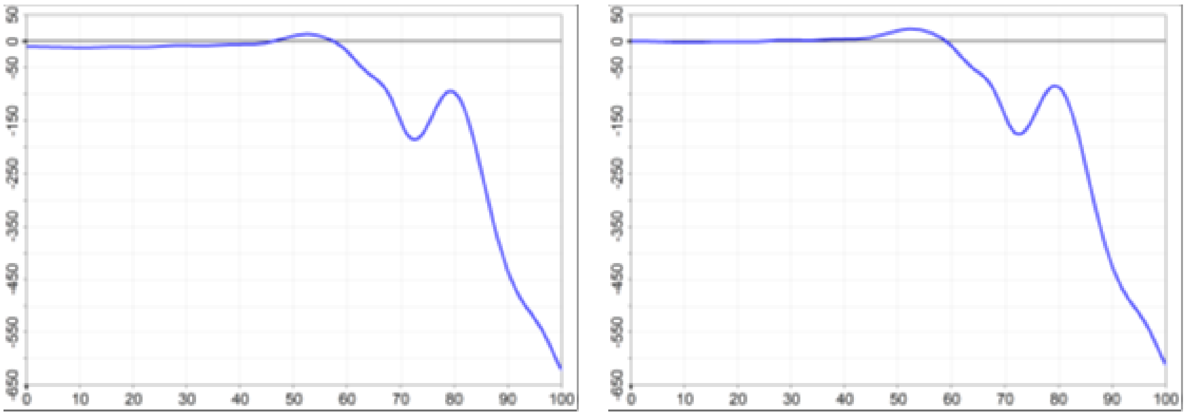

Figure 7: Channel bias removal

The test data has already been prepared, so that it can be directly used for the calculation of the ISO scores. In addition to filtering with CFC60, 'bias removal' was applied for all channels between t = 5 ms and t = 10 ms.

5.1.6 Calculation of scores

The overall evaluation is composed of several scores, which are calculated sequentially one after another.

5.1.6.1 Channel score

The score of a channel must be calculated for a specific interval by application of the ISO metric as specified in ISO/TS 18571. The interval of evaluation for each load case is listed in Table 7. All necessary channels are listed in Table 2, Table 5 and Table 6. The provided reference data must be used as reference curves, whereas the simulation data must be used as evaluated curves.

Table 7: Interval of evaluation for each load case

Load case	**Interval of evaluation**
Head-neck, all	15 ms – 100 ms
Lumbar spine, all	15 ms – 115 ms
Full-dummy sled test Δv = 8 m/s	40 ms – 180 ms
Full-dummy sled test Δv = 11 m/s	40 ms – 160 ms

5.1.6.2 Sensor score

The sensor score is calculated by summarising all three weighted channel scores per sensor according to Equation 1. All weighting factors per channel, sensor and load case are listed in Table 13, Table 14 and Table 15.

Equation 1

$$S_{Sensor} = \sum_{i} w_i * S_i \;\; and \; i = X, Y, Z$$

with w_i weighting factor of directional component of sensor
S_i Channel score of directional component of sensor

Table 8: Weighting factors per channel and sensor for the head-neck tests

Sensor	Channel	Weighting factor w_i for load case	
		Lateral	Oblique
Head angular velocity	S0HEAD0000WSAVXP	0.7589	0.6677
	S0HEAD0000WSAVYP	0.0486	0.1663
	S0HEAD0000WSAVZP	0.1925	0.1660
Upper neck force	S0NECKUP00WSFOXP	0.0990	0.1680
	S0NECKUP00WSFOYP	0.4776	0.4304
	S0NECKUP00WSFOZP	0.4234	0.4016
Upper neck moment	S0NECKUP00WSMOXP	0.7662	0.6966
	S0NECKUP00WSMOYP	0.1000	0.1794
	S0NECKUP00WSMOZP	0.1286	0.1240
Lower neck force	S0NECKLO00WSFOXP	0.0712	0.1728
	S0NECKLO00WSFOYP	0.6015	0.4948
	S0NECKLO00WSFOZP	0.3273	0.3324
Lower neck moment	S0NECKLO00WSMOXP	0.8735	0.7470
	S0NECKLO00WSMOYP	0.0600	0.1926
	S0NECKLO00WSMOZP	0.0742	0.0604

Table 9: Weighting factors per channel and sensor for the lumbar spine tests

Sensor	Channel	Weighting factor w_i for load case	
		Lateral	Oblique
Replacement mass angular velocity	S0ABDO0000WSAVXP	0.8838	0.5467
	S0ABDO0000WSAVYP	0.0500	0.3215
	S0ABDO0000WSAVZP	0.0721	0.1318
Lumbar spine force	S0LUSP0000WSFOXP	0.0386	0.2500
	S0LUSP0000WSFOYP	0.3936	0.3768
	S0LUSP0000WSFOZP	0.5678	0.3673
Lumbar spine moment	S0LUSP0000WSMOXP	0.8960	0.5650
	S0LUSP0000WSMOYP	0.0486	0.3331
	S0LUSP0000WSMOZP	0.0554	0.1100

Table 10: Weighting factors per channel and sensor for the sled tests

Sensor	Channel	Weighting factor for load case	
		Slow	Fast
Head angular velocity	S1HEAD0000WSAVXD	0.6624	0.6339
	S1HEAD0000WSAVYD	0.1839	0.1761
	S1HEAD0000WSAVZD	0.1600	0.1900
Head acceleration	S1HEAD0000WSACXD	0.0530	0.0405
	S1HEAD0000WSACYD	0.4203	0.3314
	S1HEAD0000WSACZD	0.5267	0.6281
Upper thoracic acceleration (T1)	S1THSP0100WSACXD	0.2342	0.1292
	S1THSP0100WSACYD	0.4793	0.5220

	S1THSP0100WSACZD	0.2865	0.3488
Lower thoracic acceleration (T12)	S1THSP1200WSACXD	0.2078	0.1577
	S1THSP1200WSACYD	0.6765	0.7546
	S1THSP1200WSACZD	0.1100	0.0877
Pelvis acceleration	S1PELV0000WSACXD	0.0167	0.1582
	S1PELV0000WSACYD	0.7487	0.6216
	S1PELV0000WSACZD	0.2346	0.2202
Upper neck force	S1NECKUP00WSFOXD	0.0400	0.0713
	S1NECKUP00WSFOYD	0.2483	0.1919
	S1NECKUP00WSFOZD	0.7066	0.7368
Upper neck moment	S1NECKUP00WSMOXD	0.5774	0.5721
	S1NECKUP00WSMOYD	0.3138	0.3075
	S1NECKUP00WSMOZD	0.1088	0.1204
Lumbar force	S1LUSP0000WSFOXD	0.0833	0.0675
	S1LUSP0000WSFOYD	0.2493	0.2311
	S1LUSP0000WSFOZD	0.6674	0.7014
Lumbar moment	S1LUSP0000WSMOXD	0.6726	0.6942
	S1LUSP0000WSMOYD	0.2371	0.1827
	S1LUSP0000WSMOZD	0.0903	0.1300
Second abdominal rib right displacement	S1ABRIRI02WSDS0D	1.0000	1.0000

5.1.6.3 Load case score

The load case score is calculated as the arithmetic mean of all sensor scores per load case according to Equation 2. It has to be calculated for all six load cases of the stages two and three.

Equation 2

$$S_{Loadcase} = \frac{\sum_{i=1}^{n} S_{Sensor_j}}{n}$$

with S_{Sensor_j}: All sensor scores of the current load case

n: Number of sensors of the current load case

5.1.6.4 Overall score

There are two overall scores, one for the component tests and one for the sled tests. Each are calculated as the arithmetic mean of the load case scores according to Equation 3 & Equation 4.

Equation 3

$$S_{component} = \frac{S_{Neck_{lateral}} + S_{Neck_{oblique}} + S_{Lumbar_{lateral}} + S_{Lumbar_{oblique}}}{4}$$

Equation 4

$$S_{sled} = \frac{S_{sled_{slow}} + S_{sled_{fast}}}{2}$$

6. Qualification Requirements for WorldSID Models

6.1 Stage 1

6.1.1 The properties of the dummy model must meet the following requirements:

- Mass properties according to ISO 15830-2
- External dimensions according to ISO 15830-5
- Range of motion according to ISO 15830-1
- Sensor positions according to the drawings as stated in ISO 15830-2
- Dummy dynamic qualification procedures according to ISO 15830-2

6.2 Stage 2

6.2.1 The simulations must fulfil the following criteria:

- 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 simulation run
- Visual plausibility of animation must be checked: no intersections, sticky nodes, shooting nodes affecting the kinematics

6.2.2 The overall score of the component tests $S_{component}$ must be ≥ 0.7.

6.3 Stage 3

6.3.1 The simulation must meet the following quality criteria:

- Max. hourglass energy of full setup has to be < 10% of max. internal energy
- Max. hourglass energy of all WorldSID components has to be < 10% of max. internal energy of WorldSID
- 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 in first 5 ms of the simulation
- Visual plausibility of animation must be checked: no intersections, sticky nodes, shooting nodes affecting the dummy kinematics (focus on contact between dummy and environment)

6.3.2 The overall score of the sled tests S_{sled} must be ≥ 0.61.

[1] The threshold will be assessed during the monitoring phase and might be increased from 2026 onwards.

7. Documentation

7.1 Reporting

7.1.1 To document the fulfilment of the qualification requirements, a report with diagrams showing all curves comparing simulation and reference curves must be provided.

7.1.2 All individual ISO scores and the resulting overall scores per load case (for each of the six load cases) must be provided as well as the overall score for stages 2 and 3.

8. Additional Information on the Development of WorldSID Model Qualification

This Section describes how the reference data was generated.

8.1 Test curve processing

The following general procedure was used in all case to generate the reference data out of the test data sets.

8.1.1 Identify the reference channel(s), see Table 11.

8.1.2 If multiple reference channels are listed, create average of reference channels and use average as reference channel.

8.1.3 Filter all channels with CFC60.

8.1.4 Identify the starting time of reference channel (t0 preliminary).

8.1.5 Apply bias removal of reference channel between t0 preliminary = -50 ms and t0 preliminary = -10 ms.

8.1.6 Time zero t0 is defined as the time when the first data sample of the reference channel exceeds the search level, see Table 11.

8.1.7 Apply a test specific final time shift to all measured channels, see Table 11.

8.1.8 Apply a test specific bias removal of all signals except the reference channel, IR-TRACC angle and length, see Table 11.

8.1.9 Calculate the mean of all test repetitions for each signal excluding failed channels listed in Table 12.

Table 11: Details for steps 1 and 6 to 8 of the instruction

Test	**Reference channel**	**Search level**	**Final time shift**	**Bias removal interval**
	Step 1	Step 5	Step 6	Step 7
Far side 11 mps / fast	S1SLEDLE0000ACYA S1SLEDRI0000ACYA	5 g (= 49.03325 m/s²)	20 ms	-50 ms to -10 ms
Far side 8 mps / slow	S0SLED000000ACXP S0SLED000001ACXP	5 g (= 49.03325 m/s²)	20 ms	-50 ms to -10 ms
Lumbar spine all	S0SLED000000ACXP	5 g (= 49.03325 m/s²)	20 ms	-50 ms to -10 ms
Neck all	S0SLED000000ACXP	5 g (= 49.03325 m/s²)	20 ms	-50 ms to -10 ms

Table 12: Failed channel list; exclude in calculation of mean

Test setup	**Test no.**	**Signal**
Far side 8 mps / slow	Far side_8mps_2	S1THSP0400WSACXD
Head-Neck oblique	neck_35g_75deg_ET3245_1	S0HEAD0000WSAVZD
Head-Neck oblique	neck_35g_75deg_ET3245_2	S0HEAD0000WSAVZD
Head-Neck oblique	neck_35g_75deg_ET3245_3	S0HEAD0000WSAVZD
Head-Neck lateral	neck_35g_90deg_ET3245_1	S0HEAD0000WSAVZD
Head-Neck lateral	neck_35g_90deg_ET3245_2	S0HEAD0000WSAVZD
Head-Neck lateral	neck_35g_90deg_ET3245_3	S0HEAD0000WSAVZD

The reference data set includes only channels needed in the dummy model certification process.

The sled pulses are modified in such a way, that a(t0) = 0 m/s².

8.2 Values for determination of weighting factors

8.2.1 The following tables list the absolute maximum value of each channel per test for the calculation of the weighting factor according to Equation 5:

Equation 5

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

with $\max\left(\left|Channel_{test_i}\right|\right)$ maximum absolute value of the channel in the respective axis direction.

8.2.2 If the summed weighting factors of a signal are not equal to 1.0000, the lowest weighting factor is modified accordingly.

Table 13: Absolute maximum value and calculated weighting factor of each channel for the full dummy sled tests (abs. max. values given in SI units)

	Channel	Max.	w_i		Channel	Max.	w_i
Fast sled tests	S1HEAD0000WSAVXD	68.06	0.6339	Slow sled tests	S1HEAD0000WSAVXD	59.34	0.6624
	S1HEAD0000WSAVYD	18.90	0.1761		S1HEAD0000WSAVYD	16.48	0.1839
	S1HEAD0000WSAVZD	20.40	0.1900		S1HEAD0000WSAVZD	13.77	0.1600
	S1HEAD0000WSACXD	41.52	0.0405		S1HEAD0000WSACXD	36.27	0.0530
	S1HEAD0000WSACYD	339.86	0.3314		S1HEAD0000WSACYD	287.56	0.4203
	S1HEAD0000WSACZD	644.06	0.6281		S1HEAD0000WSACZD	360.39	0.5267
	S1THSP0100WSACXD	83.89	0.1292		S1THSP0100WSACXD	146.41	0.2342
	S1THSP0100WSACYD	338.91	0.5220		S1THSP0100WSACYD	299.69	0.4793
	S1THSP0100WSACZD	226.50	0.3488		S1THSP0100WSACZD	179.15	0.2865
	S1THSP1200WSACXD	121.06	0.1577		S1THSP1200WSACXD	107.13	0.2078
	S1THSP1200WSACYD	579.28	0.7546		S1THSP1200WSACYD	348.85	0.6765
	S1THSP1200WSACZD	67.36	0.0877		S1THSP1200WSACZD	59.67	0.1100
	S1PELV0000WSACXD	162.88	0.1582		S1PELV0000WSACXD	121.68	0.0167
	S1PELV0000WSACYD	640.24	0.6216		S1PELV0000WSACYD	449.02	0.7487
	S1PELV0000WSACZD	226.80	0.2202		S1PELV0000WSACZD	140.69	0.2346
	S1NECKUP00WSFOXD	236.94	0.0713		S1NECKUP00WSFOXD	94.06	0.0400
	S1NECKUP00WSFOYD	637.09	0.1919		S1NECKUP00WSFOYD	517.38	0.2483
	S1NECKUP00WSFOZD	2446.25	0.7368		S1NECKUP00WSFOZD	1472.59	0.7066
	S1NECKUP00WSMOXD	64.18	0.5721		S1NECKUP00WSMOXD	53.25	0.5774
	S1NECKUP00WSMOYD	34.50	0.3075		S1NECKUP00WSMOYD	28.94	0.3138
	S1NECKUP00WSMOZD	13.50	0.1204		S1NECKUP00WSMOZD	10.04	0.1088
	S1LUSP0000WSFOXD	336.09	0.0675		S1LUSP0000WSFOXD	379.57	0.0833
	S1LUSP0000WSFOYD	1152.21	0.2311		S1LUSP0000WSFOYD	1135.45	0.2493
	S1LUSP0000WSFOZD	3496.52	0.7014		S1LUSP0000WSFOZD	3040.23	0.6674

	S1LUSP0000WSMOXD	85.40	0.6942		S1LUSP0000WSMOXD	80.50	0.6726
	S1LUSP0000WSMOYD	22.48	0.1827		S1LUSP0000WSMOYD	28.38	0.2371
	S1LUSP0000WSMOZD	15.14	0.1300		S1LUSP0000WSMOZD	10.81	0.0903
	S1ABRIRI02WSDS0D	-	1.0000		S1ABRIRI02WSDS0D	-	1.0000

Table 14: Absolute maximum value and calculated weighting factor of each channel for the head-neck tests (abs. max. values given in SI units)

	Channel	max	w_i		Channel	max	w_i
Head-Neck lateral	S0HEAD0000WSAVXP	34.62	0.7589	Head-Neck oblique	S0HEAD0000WSAVXP	33.16	0.6677
	S0HEAD0000WSAVYP	2.22	0.0486		S0HEAD0000WSAVYP	8.26	0.1663
	S0HEAD0000WSAVZP	8.78	0.1925		S0HEAD0000WSAVZP	8.24	0.1660
	S0NECKUP00WSFOXP	86.82	0.0990		S0NECKUP00WSFOXP	157.02	0.1680
	S0NECKUP00WSFOYP	418.78	0.4776		S0NECKUP00WSFOYP	402.01	0.4304
	S0NECKUP00WSFOZP	371.28	0.4234		S0NECKUP00WSFOZP	375.10	0.4016
	S0NECKUP00WSMOXP	47.90	0.7662		S0NECKUP00WSMOXP	45.34	0.6966
	S0NECKUP00WSMOYP	6.58	0.1000		S0NECKUP00WSMOYP	11.68	0.1794
	S0NECKUP00WSMOZP	8.04	0.1286		S0NECKUP00WSMOZP	8.07	0.1240
	S0NECKLO00WSFOXP	75.55	0.0712		S0NECKLO00WSFOXP	210.15	0.1728
	S0NECKLO00WSFOYP	638.84	0.6015		S0NECKLO00WSFOYP	602.04	0.4948
	S0NECKLO00WSFOZP	347.66	0.3273		S0NECKLO00WSFOZP	404.43	0.3324
	S0NECKLO00WSMOXP	97.76	0.8735		S0NECKLO00WSMOXP	94.49	0.7470
	S0NECKLO00WSMOYP	5.85	0.0600		S0NECKLO00WSMOYP	24.36	0.1926
	S0NECKLO00WSMOZP	8.31	0.0742		S0NECKLO00WSMOZP	7.64	0.0604

Table 15: Absolute maximum value and calculated weighting factor of each channel for the lumbar spine tests (abs. max. values given in SI units)

	Channel	max	w_i		Channel	max	w_i
Lumbar spine lateral	S0ABDO0000WSAVXP	31.88	0.8838	Lumbar spine oblique	S0ABDO0000WSAVXP	29.06	0.5467
	S0ABDO0000WSAVYP	1.59	0.0500		S0ABDO0000WSAVYP	17.09	0.3215
	S0ABDO0000WSAVZP	2.60	0.0721		S0ABDO0000WSAVZP	7.01	0.1318
	S0LUSP0000WSFOXP	66.80	0.0386		S0LUSP0000WSFOXP	453.84	0.2500
	S0LUSP0000WSFOYP	680.51	0.3936		S0LUSP0000WSFOYP	668.16	0.3768
	S0LUSP0000WSFOZP	981.82	0.5678		S0LUSP0000WSFOZP	651.33	0.3673
	S0LUSP0000WSMOXP	74.93	0.8960		S0LUSP0000WSMOXP	61.70	0.5650
	S0LUSP0000WSMOYP	4.07	0.0486		S0LUSP0000WSMOYP	36.38	0.3331
	S0LUSP0000WSMOZP	4.63	0.0554		S0LUSP0000WSMOZP	11.13	0.1100

9. References

Petit, P., Trosseille, X., Uriot, J., Poulard, D., Potier, P., Baudrit, P., ... & Tsurui, K. (2019). Far Side Impact Injury Threshold Recommendations Based on 6 Paired WorldSID/Post-Mortem Human Subjects Tests. *Stapp car Crash Journal*, *63*, 127-146.