# OSCCAR:

# FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

# Virtual environment check tool and documentation

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# TABLE OF CONTENTS


1 EXECUTIVE SUMMARY 6

2 OBJECTIVES 7

**2.1 Checklist work plan 7**

3 DESCRIPTION OF WORK 8

**3.1 Input and output verification checklist FE 9**

3.1.1 Input FE 9
3.1.2 Output FE 9

**3.2 Input and output verification checklist MBS 11**

3.2.1 Verification of facet model 11
3.2.2 Verification of Airbag model 12

**3.3 Implementation and application 13**

3.3.1 Pre-processing checks for FE codes 13
3.3.2 Post-processing checks for FE codes 18
3.3.3 Pre-processing checks for Madymo 19
3.3.4 Contacts visualized in XMADgic pre-processor and listed in reprint file 19
3.3.5 Post- processing checks for Madymo 20

4 DISSEMINATION, EXPLOITATION AND STANDARDISATION 21

5 CONCLUSIONS 22

6 REFERENCES 23

# LIST OF FIGURES

Figure 1: Workflow overview OSCCAR Task 4.1 ... 8
Figure 2: GUI of quality check tool ... 14

# LIST OF TABLES

Table 1: Input check FE ... 9
Table 2: Output check FE ... 10
Table 3: Input check MBS facet model ... 11
Table 4: Output check MBS facet model ... 12
Table 5: Input check MBS airbag model ... 12
Table 6: Output check MBS airbag model ... 13
Table 7: Pre-processing checklist for FE codes ... 16
Table 8: FE input deck protocol ... 18
Table 9: Pre-processing checklist for MBS ... 19
Table 10: MBS input deck protocol ... 20

# ABBREVIATIONS AND DEFINITIONS

This section contains list of terms used in this report.

| Abbriviation | Term | Definition |
|---|---|---|
| CAD | Computer Aided Design | |
| DYNASAUR | | Postprocessing Software which enable a time-efficient harmonised data extraction and calculation of criteria for the postprocessing of simulation results |
| EuroNCAP | European New Car Assessment Program | |
| FE | Finite Element | |
| FE | Finite Element | |
| GUI | Graphical User Interface | |
| HBM | Human Body Model | |
| IMVITER | Implementation of virtual testing in safety regulations | |
| LAB (seat) | Lab Ceesar (seat) | |
| LS-Dyna | | FE solver |
| MB | Multi Body | |
| Madymo | | Multibody simulation solver |
| MBS | Multi Body Simulation | |
| Python | | Programming language |
| VPS | Virtual Performance Solution | FE solver |
| VT | Virtual Test | |
| VT | Virtual Testing | |
| WP | Work Package | |
| XMADgic | | Maymo Pre Processor |

# 1 EXECUTIVE SUMMARY

Nowadays, the approval procedure of a vehicle and its occupant protection systems relays only on hardware tests results as the evidence of the validation for the final acceptance. This reality needs to be changed in the future in order to use the potential of what virtual simulation could provide. Moreover, the current vehicle approval procedure allows the virtual testing as an equivalent approval method to hardware tests, but only for limited regulatory acts. The EU Regulation 2018/858, which came into force from September 1st 2020, provides a list with all regulatory act references, showing the general procedure which can be followed by a specific validation process flowchart, which is indicated in Appendix 3 from Annex VIII [1]. Further, EuroNCAP will give the opportunity to exploit virtual testing to add robustness to the test assessment. There will be a transition process starting in 2022 and is expected to be completed by the end of the roadmap deadline in 2025. This roadmap can be found in page 17 of the EuroNCAP 2025 roadmap document [4].

The OSCCAR homologation test case (Task 4.3.1) conducts occupant simulations in a common environment with different Finite Element (FE) and Multi Body (MB) solvers and different versions of human models. To guarantee comparable simulation results, a harmonized screening of pre- and post-simulation parameters are required.

This deliverable identifies the settings and parameters which need to be checked prior and after simulations to ensure the simulation result comparability and monitor their quality in general. Pre-simulation checks contain simulation settings which guarantee a certain simulation output (certain files, output frequency,…) and the post simulation files contain information concerning the simulation run itself (added mass, energies,…).

The parameters and setting are listed with a general focus at first. Further, they are analysed if they are applicable in the OSCCAR homologation test case. Those which are used for pre-simulation checks are integrated in a tool for the Finite Element (FE) solvers LS-Dyna and Virtual Performance Solution (VPS), which checks the entire simulation input deck and summarizes the keywords and their parameter values in a protocol file. Parameters which are analysed by a post-simulation check are analysed within the software Dynasaur.

Keywords: FE quality check, Pre-and Post-processing checks

# 2 OBJECTIVES

The main objective for work package 4 (WP 4) is the establishment of an integrated, virtual assessment framework. Task 4.1 in particular aims to develop a simulation quality check tool to ensure the input consistency and result comparability. The tool will be used in Task 4.3 in the homologation test case, where various OSCCAR partners will simulate a pre- and in-crash scenario within the same boundary conditions (environment, pulse, sitting position, belt system,..) but with different solvers (LS-Dyna, VPS and Madymo) and with different existing versions of a 50% male HBM.

For this reason the developed tool needs to ensure, that the results of all contributors are comparable in the meaning that “it is possible and sensible to compare the results”. For this reason simulation parameters and settings were identified, which are checked prior to the simulation by the tool. A simple protocol is saved in a text file which contains the parameters and settings. That simplifies the process of monitoring input from various partners. To further ensure the quality of a simulation, the criteria are defined, which are checked within a post simulation tool. As the kinematic and injury assessment is already done with the tool Dynasaur (Task 4.2.3) it was decided to add the post simulation checks there. Nevertheless they are listed in this deliverable.

Task 5.1 identified various requirements to ensure a reasonable level of model quality. Amongst the mentioned simulation settings and post simulation checks, requirements like mesh quality and appropriate material models are listed [8]. As the developed quality check tool in Task 4.1 will be applied for the OSCCAR homologation test case, which works with a validated model, no checks concerning mesh or material quality are conducted. It is assumed that globally defined mesh or material criteria won’t overrule the validation of a sub-model, as for example the interior model or the HBM environment.

## 2.1 Checklist work plan

The work plan consists of identifying the basic criteria that are compatible between the different types of models and simulation code used. After this identification, a generic list has been structured that encompasses all specific inputs and outputs for both FE and MBS models and adapted to the features of each solver. The working group experts have provided the basis of the quality criteria list and after some workshop sessions, the contributions and comments from different partners were taken into account to complete the definition of this input and output list.

The contributors to the Task 4.1 delivery are listed below:

- IDIADA leading and developing the main concept of the task.
- BOSCH and TASS contributing and advising in the implementation of the tool and code independent assessment criteria.
- LMU supporting the implementation of harmonized requirements and participating in dedicated workshops.
- VIF supporting the development and code implementation of the “virtual environment check tool”.
- ESI supporting partners to take into account VPS inputs and outputs specificities.
- MBAGbringing the know-how from IMVITER project.

Finally, the complete list was distributed within the consortium and internal reviewers were assigned.

# 3 DESCRIPTION OF WORK

The simulations which are performed for the OSCCAR homologation test case (Task 4.3) are done in a common environment by all participated partners. More precisely the model of a LAB seat, explained in Deliverable D2.4 [10], is used in LS-Dyna, VPS and Madymo with different versions of a 50% male human (body) model. For this combination of (validated) models, check lists for pre- and post-processing monitoring are identified within this chapter.

Several checklists of verification criteria have been described for different numerical simulation softwares, either FE-type softwares, e.g. LS-Dyna and VPS, or MBS software such as Madymo. This deliverable 4.1 has based the part of the model verification implementation of virtual testing in safety on the document of the European project called Implementation of virtual testing in safety regulations (IMVITER). The aim of IMVITER project was to establish the framework for the implementation of VT in the type approval of vehicles, in which verification and validation processes were included as the essential activities to do. This document has based the input/output verification checklist on the Figure 259 of the IMVITER document D2.1 [1], related to the template for calculation verification. Further, OSCCAR Task 5.1 proposes relevant pre- and post-processing criteria to ensure a reasonable level of model quality.

Part of the quality criteria for the postprocessing defined in this deliverable is based on the document EuroNCAP TB024 of pedestrian human model certification. The list of concepts can be found in chapter 3.2.4 of the TB024 document [3].

Figure 1 shows the work and subchapter structure for Task 4.1 in two blocks. In section 3.1 and 3.2 the definition of the verification checklists for FE and MBS and in 3.3 the implementation and application of the pre-process and post-process is described.

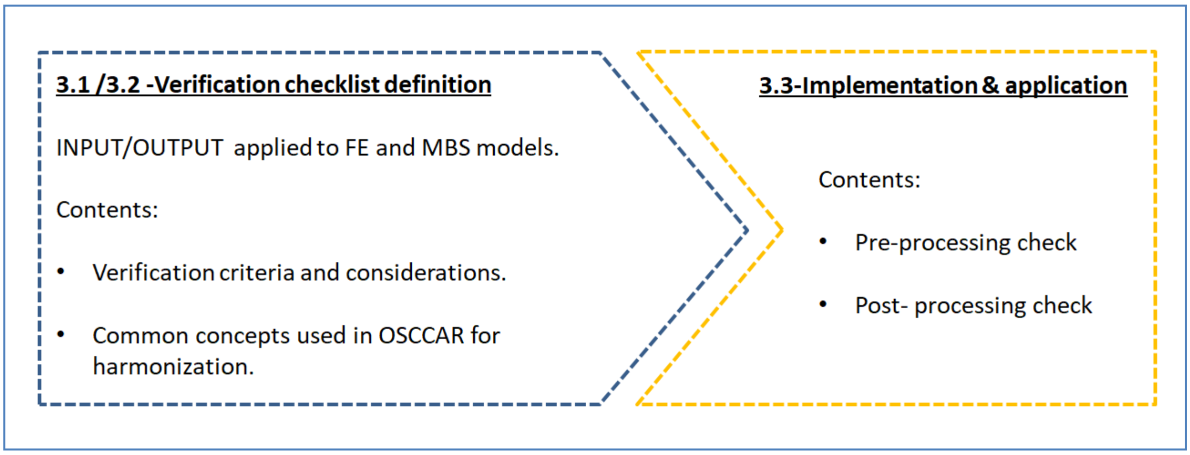


**Figure 1: Workflow overview OSCCAR Task 4.1**

The parameters and criteria which are identified for the pre-processing phase are part of a tool which reads the entire simulation input deck and automatically creates a protocol file. This contains the parameters and its values and eases the comparison of different simulations. The output parameters and criteria are analysed with the tool Dynasaur (Task 4.2.3) since this tool is already used to assess occupant kinematic and injury risks.

These checklists are not a guide for modelling nor a guide for validating models, they describe the basic input and output information that should be checked, all in the same manner to assure that the model can be checked using different FE- or MBS-codes in a comparable way.

The input / output checklists for model verification are represented in tables in sections 3.1and 3.2. These tables are structured in three specific columns; the first column identifies the verification criteria to be used, the second column indicates the method used for verification and the considerations to have into account. The third column indicates which criteria will be applied in common within the OSCCAR project and what are not.

## 3.1 Input and output verification checklist FE

### 3.1.1 Input FE

The input concepts to be checked are the next:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [ YES – NO- why not] |
|---|---|---|
| FE coincidence with CAD | Verification that FE meshes with the relevant parts fit to reference CAD. | No. This verification will be performed internally by each partner, not under OSCCAR verification criteria process. |
| Mesh quality | Verification to assure that the mesh size and quality are the established. | No. Mesh quality will be performed by each partner under their criteria. |
| Control of start and end time | Visual verification. Necessary to establish a control of time range and time step during the simulation. | Yes. |
| Parameters of contact used | Visual verification. Necessary to define the settings for the contacts. | No. This verification will be performed internally by each partner |
| Contact excluded parts | Visual verification. Necessary to define the conditions for the contacts. | No. This verification will be performed internally by each partner. |
| Pre-filter definition(*) option to use pre-filter to obtain a filtered output | Check if previous filter for some results are used. | No, it is not included in the OSCCAR homologation, as indicates the EuroNCAP document TB024 [3] |
| (*)By default do not use pre-filter. Filter of results are used mainly in the output and under regulation requirements. | | |

**Table 1: Input check FE**

### 3.1.2 Output FE

The output concepts to be checked are the next:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Time - Energy | Time history output for energies. Time total energy, elastic contact energy, hourglass energy, kinetic energy. | Yes. Used globally at the level of the component |
| Time history output for displacements | Energy balance check | Yes. |
| Time history output for accelerations | Energy balance check | Yes. Only global information |
| Time animation output deformation | This output will be verified automatically | Yes. Only global information |
| Time animation output strain maps | This output will be verified automatically | Yes. Only global information |
| Time-artificial mass increase of moving parts | Energy balance check | Yes. |
| Monitoring of simulation time step | Time step does not fall / Check time step evolution | Yes. |
| Control penetrations | Visual check between validated sub-models (car interior /HMB environment). Not automated method is applicable | Yes. |
| Control of landmarks | Control of landmarks following ISO, control of nodal displacements and trajectories, control of HBM kinematics | Yes. |
| Requirements for injury criteria assessment | Visual check | No. This point will be applicable only under specification of Task 3.3 |
| Filter for output information | | No, it is not included in the OSCCAR homologation, as indicates EuroNCAP document TB024 [3]. Only use under the regulation requirements, if necessary. |

**Table 2: Output check FE**

## 3.2 Input and output verification checklist MBS

### 3.2.1 Verification of facet model

#### 3.2.1.1 Input verification:

The input to be checked is the next:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Surface definition | Check in the input file to verify the element thickness representing physical thickness of surface. | No. This verification will be performed internally by each partner, not under OSCCAR criteria. |
| Mesh quality | Visual verification to assure that the mesh size and quality are the established. | No. This verification will be performed internally by each partner, not under OSCCAR criteria. |
| Control of start and end time | Necessary to establish a control of time range and time step during the simulation | Yes. |
| Tracking from pre-filter definition | Visual check | No, it is not included in the OSCCAR homologation, as indicates the EuroNCAP document TB024 [3] |
| Control of sample rate of output data | Visual check | No. This verification will be performed internally by each partner, not under OSCCAR criteria. |
| (*)By default do not use pre-filter. Filter of results are used mainly in the output and under regulation requirements. | | |

**Table 3: Input check MBS facet model**

#### 3.2.1.2 Output verification:

The output concepts to be checked are the next:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Time which avoid sub-cycling between MB and FE | Visual inspection. Check the required FE time. | Depends on airbag |
| Time- initial element time step | Time step does not fall / Check time step evolution | Depends on airbag |
| Control penetrations in reprint file | Visual check | Yes. |

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Check kinematic model for missing contacts | Visual animation check | Yes. |
| Check control forces | Visual check | No. This verification will be performed internally by each partner, not under OSCCAR criteria. |
| Control of landmarks present | Visual animation check | Yes. |
| Requirements for injury criteria assessment | Visual animation check | No. This point will be applicable only under specification of Task 3.3 |

**Table 4: Output check MBS facet model**

### 3.2.2 Verification of Airbag model

#### 3.2.2.1 Input verification:

The input concepts to be checked are the next considering airbag is present in the model:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Airbag test | Visual inspection. Check correct position. | Yes, to be discussed whether relevant |
| Control of start and end time | Necessary to establish a control of time range and time step during the simulation | Yes. |

**Table 5: Input check MBS airbag model**

#### 3.2.2.2 Output verification:

The output concepts to be checked are the next considering airbag is present in the model:

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Time step avoiding sub-cycling between MB and FE | Visual inspection. Check the required FE time. Check no sub-cycling | Yes, Check no sub-cycling |
| Time-initial element time step | Time step does not fall and stays excessively low | No, specific for each partner |
| Tracking for airbag suitability checked through testing | Visual check against the physical tests. | No, the component will be already validated |
| Check initial element stretches | Visual animation check | No, specific for each partner |

| Verification criteria (Statement) | Verification method and considerations | Used in OSCCAR [YES-NO-why not] |
|---|---|---|
| Check of working jet | Visual animation check | No. The verification if jet is blocked can be made by each partner. |
| Check elements in “IMM2” have zero stress | Visual animation check | No, specific for each partner |

**Table 6: Output check MBS airbag model**

## 3.3 Implementation and application

The implementation of the defined criteria is separated between pre- and post-processing. The check for the post-processing criteria is implemented in the open source software “DynaSaur” which is enhanced during the OSCCAR project in Task 4.2.3.

### 3.3.1 Pre-processing checks for FE codes

To monitor the criteria for pre-processing, a tool was developed which reads the FE solver input deck. This tool is programmed in PYTHON and has a GUI. In the GUI the folder with the files to be analysed can be specified and the destination for the output file can be declared. Also a preview of the result can be viewed (see Figure 2).The included files are analysed recursively. This tool also checks whether these included files can be found or not. The output of the tool consists of a plain text file containing a summary of all found keywords. If a certain keyword could not be found, “NOT FOUND” will be displayed instead. As mentioned in the defined lists of section 4.2, the aim at the pre-processing is to ensure an input deck setup which creates the necessary output in order to apply quality checks after the simulation. Following list shows the post-processing criteria and which commands need to be part of the simulation input deck.

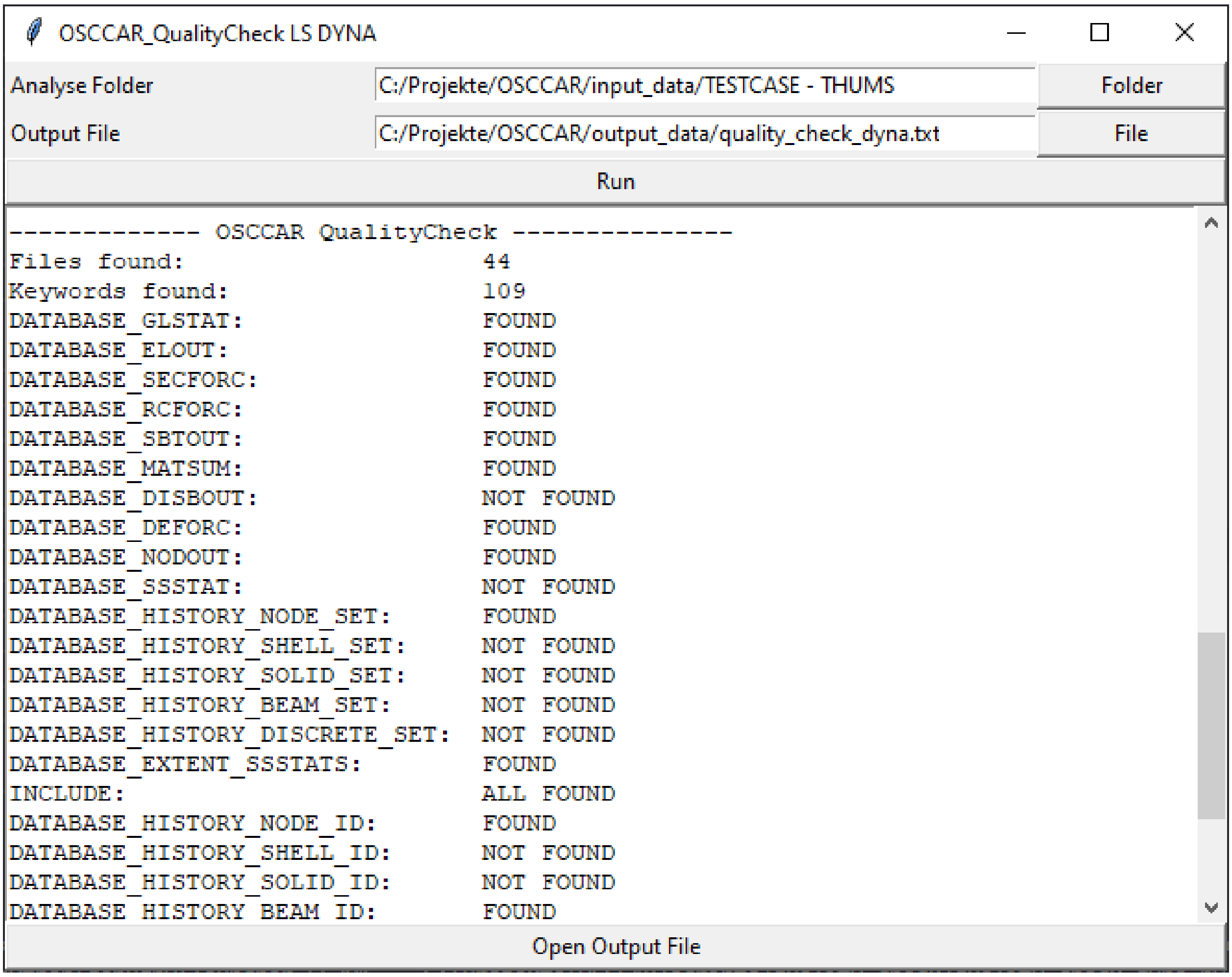


**Figure 2: GUI of quality check tool**

| Verification criteria (Statement) | Necessary output file / command in LS-Dyna<br>*Data from LS-Dyna Manual [5]* | Necessary output file / command in VPS<br>*Data from VPS Manual [6]* |
|---|---|---|
| Time history output for energies | *DATABASE_GLSTAT | In OCTRL /<br>GLBTHP<br>INTE KINE TOTE<br>or<br>DFLT (AVGX + AVGY + AVGZ + BAGS + CNTF + INTE + KINE + MHGL + MINT + SECF + STEP + TOTE)<br>or<br>ALL |
| Time history output for displacements | *DATABASE_NODOUT | In global system: THNOD with NAME ‘landmark’ |

| **Verification criteria (Statement)** | **Necessary output file / command in LS-Dyna**<br>***Data from LS-Dyna Manual [5]*** | **Necessary output file / command in VPS**<br>***Data from VPS Manual [6]*** |
|---|---|---|
| Time history output for accelerations | *DATABASE_NODOUT | In global system: THNOD with Name 'landmark<br>+<br>If Rotational acceleration is needed<br>In OCTRL /<br>GLBTHP<br>RACC<br>or<br>ALL |
| Time animation output deformation | *DATABASE_NODOUT | In OCTRL /<br>CONTOUR_PLOT<br>INTERVAL *value*<br>or<br>To check that this mandatory CARD <u>is not followed by 'NO'</u><br>CONTOUR_PLOT NO (no mesh output to display animation) |
| Time animation output strain maps | | OCTRL /<br>SOLPLOT EPSI (Strain tensor in global coordinate system) or EXYZ (Strain tensor in the global coordinate system)<br>or<br>ALL<br>SHLPLOT EPSI (Lower surface and Upper surface strain in the element's local frame)<br>or<br>ALL<br>BEAPLOT ➔ EPSI (strain<br>or<br>DFLT: ANGL + EINT + ELSI + EPMX + EPSI + ESMA + FDMG + FORC + IMSC + LENG + MOMT + NSMS + RDIS + TDIS)<br>or<br>ALL |

| Verification criteria (Statement) | Necessary output file / command in LS-Dyna<br>*Data from LS-Dyna Manual [5]* | Necessary output file / command in VPS<br>*Data from VPS Manual [6]* |
|---|---|---|
| Monitoring of time step | *DATABASE_GLSTAT | In OCTRL /<br>GLBTHP<br>STEP<br>or<br>ALL |
| Time-artificial mass increase of moving parts | *DATABASE_GLSTAT | **ONLY IF**<br>**in TCTRL /.**<br>DYNA_MASS_SCALE<br>or<br>DYNA_SELECTIVE_MASS_SCALE<br>Then,<br>In OCTRL /<br>GLBTHP (*curve output*)<br>DMAS (total increased mass when dynamic mass scaling)<br>or<br>ALL<br>NODPLOT (*contour on animation*)<br>FACM (Ratio and Amount of mass increase when dynamic mass scaling)<br>or<br>ALL |
| Trajectories of certain landmarks | *DATABASE_HISTORY_NODESET<br>Node IDs and landmark names | In global system : THNOD with NAME 'landmark' |
| Output frequency | Time step definition used for the curve plot and for the animation | In OCTRL /<br>TIME_HISTORY<br>INTERVAL *value*<br>CONTOUR_PLOT<br>INTERVAL *value* |

**Table 7: Pre-processing checklist for FE codes**

Further, the settings for these criteria in the FE input deck are summarized to a protocol which is returned to the user as a text file. Exemplarily a protocol and an explanation are shown in the following table.

| Tool Output (Protocol) | Information |
|---|---|
| -------------------------------------------------------------------------------------<br>Top Folder: C:\Projekte\OSCCAR\scripts\quality_check\.data<br>Files found: 25<br>Keywords found: 27<br>Time: 2020-03-12 08:07:44<br>------------------------------------------------------------------------------------- | Header, general Information<br>**Top Folder**: The folder given to the tool<br>**Files found**: Number of files found in this and all child folders<br>**Keywords**: Number of keywords found that are relevant for the tool.<br>**Time**: The exact point in time when this file was created |
| DATABASE_GLSTAT<br>FILE-------------------------DT--------BINARY--------------<br><br>ControlDatabase.k 30.000 3<br>ControlDatabase_SSTAT_test.k 1.000 3<br>---------------------------------------------------------------------<br><br>DATABASE_NODOUT<br>FILE-------------------------DT--------BINARY--------------<br><br>ControlDatabase.k 25.000 3<br>ControlDatabase_SSTAT_test.k 1.000 3<br>---------------------------------------------------------------------<br><br>DATABASE_SSSTAT<br>FILE-------------------------DT--------BINARY--------------<br><br>ControlDatabase_SSTAT_test.k 1.000 3<br>--------------------------------------------------------------------- | **File:**<br>Input files in which the keyword is found<br>GLSTAT<br>• Energies<br>• Added mass<br>• Time step<br>NODOUT<br>• Kinematic node information<br>SSSTAT<br>• Separated output for PIDs containing energies, added mass and time step<br>**DT:**<br>Output frequency<br>**Binary:**<br>“Mode for saving” |
| DATABASE_HISTORY_NODE_SET<br>FILE--------------------------------------------SET_ID------------------<br><br>SET_NODE_LIST_Seat_3DFoam.k 90800088<br>Thums_interface_springback_allParts.dyn 95<br>ToolOutput/bone_landmarks_node_set - Kopie.k 100001<br>ToolOutput/bone_landmarks_node_set.k 100001<br>------------------------------------------------------------------------- | Node sets for which kinematic data are created<br>**FILE**<br>File in which the keyword has been found<br>**SET_ID**<br>Set ID of the node set |

| Tool Output (Protocol) | Information |
|---|---|
| ------------------------------------------------------------------------<br>DATABASE_EXTENT_SSSTATS<br>FILE---------------SET_ID----PARTS-----TITLE-------------<br><br>boundary.k 101060 98 Skull<br>ControlDatabase.k 200 1580 allTHUMSParts<br>------------------------------------------------------------------------ | Part sets, for which separated information is “outputted”<br>**FILE**<br>File in which the command is called<br>**SET_ID**<br>Part set ID<br>**PARTS**<br>Number of parts in the set<br>**TITLE**<br>Title of the part set |
| INCLUDE<br>FILE------------------------------------INCLUDE------------------------------------FOUND---------<br><br>Main_V5.key Parameter_V2.key YES<br>Main_V5.key Sensors_V1.key YES<br>Main_V5.key Generic_cockpit_v1.0.2_ika_RIGID_IP_V2.key YES<br>Main_V5.key holdBelt.k YES<br>Main_V5.key PRECOONI_SEAT_FOAM_HR_v1_1_ika.key YES<br>Main_V5.key ODB_Pulse_LEIKA.key YES<br>Main_V5.key SET_NODE_LIST_Seat_3DFoam.k YES<br>Main_V5.key ControlDatabase_SSTAT_test.k YES<br>thums_am50_occ_v3-kgmmms_HPointPos_Rot.k Piper_definitions.key YES<br>thums_am50_occ_v3-kgmmms_HPointPos_Rot.k GlenohumeralRotationCenter.k YES<br>thums_am50_occ_v3-kgmmms_HPointPos_Rot.k ToolOutput\main_pos.dyn YES<br>thums_am50_occ_v3-kgmmms_HPointPos_Rot.k Thums_allParts.dyn YES<br>ToolOutput/main_pos.dyn ToolOutput\CURVE.k YES<br>ToolOutput/main_pos.dyn ToolOutput\ele_beam.k YES<br>ToolOutput/main_pos.dyn ToolOutput\motion.k YES<br>ToolOutput/main_pos.dyn ToolOutput\bone_landmarks_node_set.k YES<br>ToolOutput/main_pos.dyn ToolOutput\noeuds_extr_beam.k YES<br>ToolOutput/main_pos.dyn ToolOutput\pelvis_curves.k YES<br>---------------------------------------------------------------------------------------------------- | Structure of the input deck<br>**FILE**<br>The file from which the **INCLUDE** file is called<br>**FOUND**<br>If the file has been found at the given location |
| DATABASE_HISTORY_NODE_ID<br><br>ToolOutput/bone_landmarks_node_set - Kopie.k<br>ID--------HEADING--------------------------------------------<br>8130333 Tip_lateral_malleolus_of_right_fibula<br>----------------------------------------------------------------------------- | Single nodes, for which kinematic data is “outputted”<br>**ID**<br>Node ID<br>**HEADING**<br>Name of the nodes |

**Table 8: FE input deck protocol**

## 3.3.2 Post-processing checks for FE codes

In order to reduce the number of tools which need to be applied prior to the simulations in OSCCAR, it was decided to include the routines for the post processing checks to the tool Dynasaur. This tool is developed in Task 4.2.3 and is therefore documented in Deliverable 4.2 [9].

### 3.3.3 Pre-processing checks for Madymo

| Verification criteria (Statement) | Necessary output element in Simcenter Mafymo simulation file<br>*Data from Madymo Manual [7]* | Necessary output element +attribute under CONTROL_OUTPUT element |
|---|---|---|
| Time step avoiding sub cycling | | TIME_HISTORY_TIME_STEP |
| Time history output for displacements /accelerations | OUTPUT.BODY | TIME_HISTORY_MB > BODY_OUTPUT_LIST |
| Check kinematic model for missing contacts | 3.3.4. Contacts visualized in XMADgic pre-processor, and listed in reprint file. | |
| FE components in Madymo | ANIMATION. Assuming a visual check for placement and orientation. | |
| Control of landmarks present | ANIMATION | EXTENDED = ON |
| Requirements for injury criteria assessment | ANIMATION | No. This point will be applicable only under specification of Task 3.3 |
| Control occupant kinematics | ANIMATION | |

**Table 9: Pre-processing checklist for MBS**

### 3.3.4 Contacts visualized in XMADgic pre-processor and listed in reprint file

The next Madymo dedicated pre-processor

| CONTROL_OUTPUT Elements/Attributes | Description |
|---|---|
| Attributes:<br>TIME_STEP 1.0E-04<br>TIME_STEP_ANI 5.0E-03 | TIME_STEP – time interval for writing time-history output<br>TIME_STEP_ANI – time interval for writing kinematic animation data |
| TIME_HISTORY_TIME_STEP | Output activation and format/file selection for time-step |

| | |
|---|---|
| ANIMATION<br>EXTENDED ON<br>WRITE_FORMAT MAD<br>WRITE_PRECISION PRECISE | Output activation and format/file selection for kinematic animation output<br>EXTENDED – extra co-ordinate system data written to file<br>WRITE_PRECISION – defines decimal precision |
| TIME_HISTORY_MB<br>SYSTEM HumanMale50%<br>BODY_OUTPUT_LIST Pelvis_acc Thorax_acc HeadCG_acc FootL_acc F<br>BODY_REL_OUTPUT_LIST ChestDefl_dis_CFC180 ChestDeflection_dis ChestD<br>JOINT_CONSTRAINT_OUTPU... NeckUp_lce_T NeckUp_lce_F_CFC1000 NeckUp<br>JOINT_DOF_OUTPUT_LIST ALL<br>CONTROL_SYSTEM_OUTPUT... ALL<br>BELT_OUTPUT_LIST ALL<br>SENSOR_OUTPUT_LIST ALL<br>RESTRAINT_OUTPUT_LIST ALL<br>MUSCLE_OUTPUT_LIST ALL | Activates time history output for a particular multi-body system<br>SYSTEM – defines which system<br>*_OUTPUT_LIST – requests the defined outputs to be written to relevant output files |
| TIME_HISTORY_FE<br>**FE_MODEL** **/Airbag_sys/Airbag_fem**<br>AIRBAG_OUTPUT_LIST DriverAirbagChamber_fhs | Activates time history output for a particular FE model.<br>AIRBAG_OUTPUT_LIST – requests the defined outputs to be written to relevant output files |
| TIME_HISTORY_INJURY<br>SYSTEM HumanMale50%<br>**INJURY_LIST** **BrIC_inj HaccRpeak_inj H3MS_inj HIC**<br>TIME_DURATION_INJURY<br>SYSTEM HumanMale50%<br>**INJURY_LIST** **FNICtension_inj FNICshear_inj FNICbe** | This point will be applicable only under specification of Task 3.3 |

**Table 10: MBS input deck protocol**

## 3.3.5 Post- processing checks for Madymo

The routine for the post-process check in Madymo will use the workspace MADpost for the visualization of some output concepts, and other post-processing checks can be carried out on the ".rep" file.

# 4 DISSEMINATION, EXPLOITATION AND STANDARDISATION

This report is intended to be shared through all possible dissemination channels, including publications and conferences on the project, as an example of how to verify the different models in the same manner for different solvers. The work presented in this report establishes the guidelines of a methodology that will contribute to the standardization in the community. It will be disseminated by members of the OSCCAR project e.g. to the EuroNCAP virtual testing group and the EU funded project VIRTUAL.

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The outcome of this Task 4.1 will be used in Task 4.2 and Task 4.3, and will be part of the publications of Task 4.2 and Task 4.3.

# 5 CONCLUSIONS

Since several years, the use of virtual models in simulations has followed the methodology and criteria of each user company. This consideration was taken into account within OSCCAR and for this reason this report tries to contribute to the development of standardized verification procedures to enable and open the way for the use of numerical simulations in the future for homologation procedures.

The checklists and the tool presented in this document allow to conduct simulations with comparable results and to monitor the simulation quality in a post processing step. The developed method is not limited to a certain solver. Its applicability is shown for two FE codes (LS-Dyna and VPS) and for a multibody code (Madymo). Of course, the criteria for FE codes and multibody codes differ.

Beyond OSCCAR, the approach of these lists shall guarantee the simulation quality in terms of input consistency, similar settings for output generation to permit result comparability.

The criteria and the presented tool are developed and selected for the OSCCAR homologation test case. The test case works with valid models and the aim of the list and tool is to prepare the global settings to get comparable results. It was not intended to define parameters and settings, which modify already validated sub models. For example, the question how to merge validated sub models and how to merge their solver controller settings is not answered in this document.

# 6 REFERENCES


[1] REGULATION (EU) 2018/858 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32018R0858 (last accessed March 2021)

[2] Cordero, R. García, J. EU project, Implementation of virtual testing in safety regulations, IMVITER. Document D2.1

[3] Document TB024 version 1.0, Pedestrian Human Model Certification, EuroNCAP.

[4] Euro NCAP 2025 Roadmap, In pursuit of vision zero, EuroNCAP.

[5] LS-Dyna Manual R12.0, Livermore Software Technology (LST), an Ansys Company.

[6] VPS 2019 Solver Reference Manual, 2019, ESI Group.

[7] Madymo V2020.02manuals, Siemens Industry Software and Services.

[8] OSCCAR Deliverable D5.1 Standardised procedure for validating a vehicle environment for VT, v1.0, 2021-02-19

[9] OSCCAR Deliverable D4.2 Demonstrator for continuous integrated virtual assessment of complex crash simulation tasks including HBMs, v2.0, 2021-02-01

[10] OSCCAR Deliverable D2.4 Final virtual design of advanced passenger protection principles, v3.0, 2021-02-26