Manage multi-disciplinary load cases in SDM: Model setup and evaluation of results

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Abstract

Due to the continuously increasing demand in Computer Aided Engineering (CAE), it is essential for high efficiency and transparency to automate and standardize processes. In many cases, Simulation Data Management (SDM) software is used for this purpose.

To achieve all mechanical target values of a product, there are several standard disciplines in the field of CAE, such as Crash, Noise Vibration Harshness (NVH) or Fatigue. Assembly, solving and postprocessing for these disciplines can differ greatly from one another. For this reason, it is best practice in many companies to carry out the optimization of a model in each discipline separately and to compare the results and structural adjustments with other disciplines at regular intervals. This approach can lead to two disadvantages:

Firstly, this results in redundant work. Model adjustments successful for one discipline must be redone in other disciplines later on. Secondly, deterioration in other disciplines may be discovered late: Model modifications that produce positive results for one discipline can have a negative impact on the results in other disciplines. This can lead to short-term changes of plans, postponements, or additional costs for optimizations.

With the help of a base model and SDM, several disciplines can be covered based on a single source of truth. The basic approach is not to work directly on the solver specific files, but on the base model itself. All discipline and solver specific files are generated from this file via SDM automatically. As an example, the two disciplines Crash and NVH are considered in this paper. LS-Dyna is used as solver for both disciplines. Due to the functionality of this approach, it is also possible to use different solvers for the disciplines, like LS-Dyna for crash, Nastran for NVH or Abaqus for fatigue.

There are several criteria that must be met to successfully carry out multidisciplinary variant creation and result evaluation:

A complete database for all discipline-specific information, such as load case definitions or connection configuration is essential. Furthermore, a flexible and simple selection of the load cases is needed. It is also crucial to have an automatic process flow from the creation of the include to the finished report. This report must be designed according to the discipline-specific load case. A clear overview of all created variants is as important as a dynamic variant comparison of the results for each discipline.

The SDM software SCALE.sdm fulfills all these points. In addition, it is already being used successfully and effectively by a large corporation with over 1100 users [1], which underlines the scalability of this SDM solution. For these reasons SCALE.sdm is used as the basis for this paper.

So far, SCALE.sdm is used by users in the industry like in the best practice example mentioned above: For each discipline there is a separate variant tree that is considered independently. However, by customizing specific key features such as an automatic creation of the include- and inter-include-connections, it would also be possible to display all disciplines together with a single variant tree.

This approach makes it possible to avoid the above-mentioned disadvantages of the separate discipline approach: All the desired disciplines could then be covered by a single model modification, allowing the user to work effectively on structural optimizations while minimizing resources.

1 Motivation

1.1 State of the art

Due to the continuously increasing demand in Computer Aided Engineering (CAE), it is essential for high efficiency and transparency to automate and standardize processes. In many cases, Simulation Data Management (SDM) software is used for this purpose. Especially in larger organizations where hundreds of engineers need to work together to evaluate many different load cases to meet regulatory requirements and collaborate with many stakeholders worldwide, the usage of SDM systems has proven to significantly increase the efficiency and scale up the business of CAE from a few experts to a large number of engineers of different domains throughout multiple departments.
To achieve all mechanical target values of a product, there are several standard disciplines in the field of CAE, such as Crash, Occupant Safety, Noise Vibration Harshness (NVH) or Fatigue. Assembly, solving and postprocessing for these disciplines can differ greatly from one another. For this reason, it is best practice in many companies to carry out the optimization of a model in each discipline separately and to compare the results and structural adjustments with other disciplines at regular intervals.

1.2 Disadvantages

The above approach can work well for each discipline individually. However, it can become problematic as soon as a project must be optimized across several disciplines. In this case, the above scheme can lead to the following disadvantages:
Redundant workload: Model modifications that are successful in one discipline have to be redone later in other disciplines. Furthermore, deteriorations in other disciplines may be discovered late in the process: model adjustments that lead to positive results in one discipline may have a negative impact on the results of other disciplines. Short-term changes to plans, postponements or additional costs for optimizations can be the consequence.

1.3 Solution with SCALE.sdm

To find an efficient solution for this problem, Simulation Data Management (SDM) is used. SDM is a technology in which processes in CAE can be carried out in a structured way and data can be stored. The SDM software SCALE.sdm is used in this paper. Here, relevant data for different disciplines can be stored and modified in one database. Various attributes and parameters are used to assign this data to the respective load case configurations. This feature can be used so that a single base model can be applied for different disciplines. For the purpose of this project, a prototype with a defined process flow is being developed, which is described in the following.

2 Concept

2.1 Single Source of truth for all disciplines

In order to be able to create different disciplines with one base model, it is important to consider the concept of “single source of truth”. There must be only one base model from which all discipline-specific models are derived. For this purpose, this model must have all relevant information available at all times. Data may not be subsequently added or changed after the discipline-specific models have been derived. This would make the present concept inaccurate, as the user would be missing data when viewing and editing the base model. In order to make this project possible, the prototype, which has all the important information available at all times, is presented below.

2.2 Prototype

2.2.1 Define goals for prototype

To create the appropriate prototype, it is important to define the relevant objectives that it must fulfill, as shown in Fig.1.

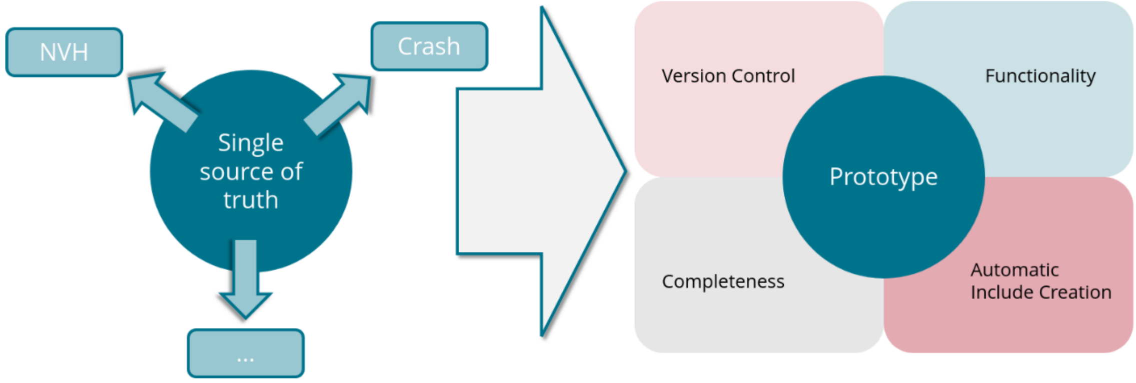


Fig.1: Goals of Prototype

- Version control of the base model in SCALE.sdm:
  To get an overview of the history of each component and to be able to effectively create new variants, it is important to have each saved version available in a single database.
- Full functionality for editing models for all disciplines:
  All components must be editable in every discipline and the modifications created must be applicable in all disciplines.
- All discipline-specific data/settings/parameters available at any time:
  It must be possible to access all discipline-relevant data such as settings or parameters at any time, for example for the connection technology. The data must be viewable, applicable and editable for this purpose.
- Complete and automatic derivation of discipline-specific models:
  It must be possible to create the desired discipline-specific solver files from the base model according to the user's requirements. It is important that the conversion is complete and that no settings or parameter from other disciplines influence the created includes. It is also important that no post-editing of the includes is necessary.

2.2.2 Preprocessor integration for basemodel

In order to be able to display and edit the base model correctly, it is important to select a suitable preprocessor. Due to the fact that SCALE.sdm is agnostic, various preprocessors can be considered, which should provide similar tools for the purposes of this concept, such as Hypermesh. For this paper the decision was made to use Ansa from BETA CAE Systems. This tool has many useful features which are used for this prototype and are described in more detail in the following sections.

2.2.3 Modular assembly with Ansa subsystems

In general, larger CAE models such as cars are represented using so-called modules or components. Each component is a subassembly of a model, for example in a vehicle the body in white (BIW) or the doors. These components are represented in the LS-Dyna solver via includes. In general, there is a master file in LS-Dyna (or other solvers) in which all includes are called. In addition to these entries, control cards for the solver or the load case definition are normally contained here. The material cards for the mechanical definition of the structural components are also called up here. These are also includes.
For the success of the prototype, it is important to develop a system in which these includes, including the master file, can be created from a single base model for different disciplines. For the creation of the includes for the material cards and the master file, please refer to the next chapter, where this will be discussed in more detail. For the creation of the includes, which represent the actual model structure, the so-called Ansa subsystems are used for this concept. These are special Ansa units that can be loaded and edited in an Ansa session, shown in Fig.2. Ansa-DM, which is an Ansa-specific database, is used for saving and versioning subsystems. An advantage of the subsystems is that there are many features for the modular assembly of CAE models, that are used in this concept. One important feature is the creation of intermodular connections, which is described in more detail in the next section.

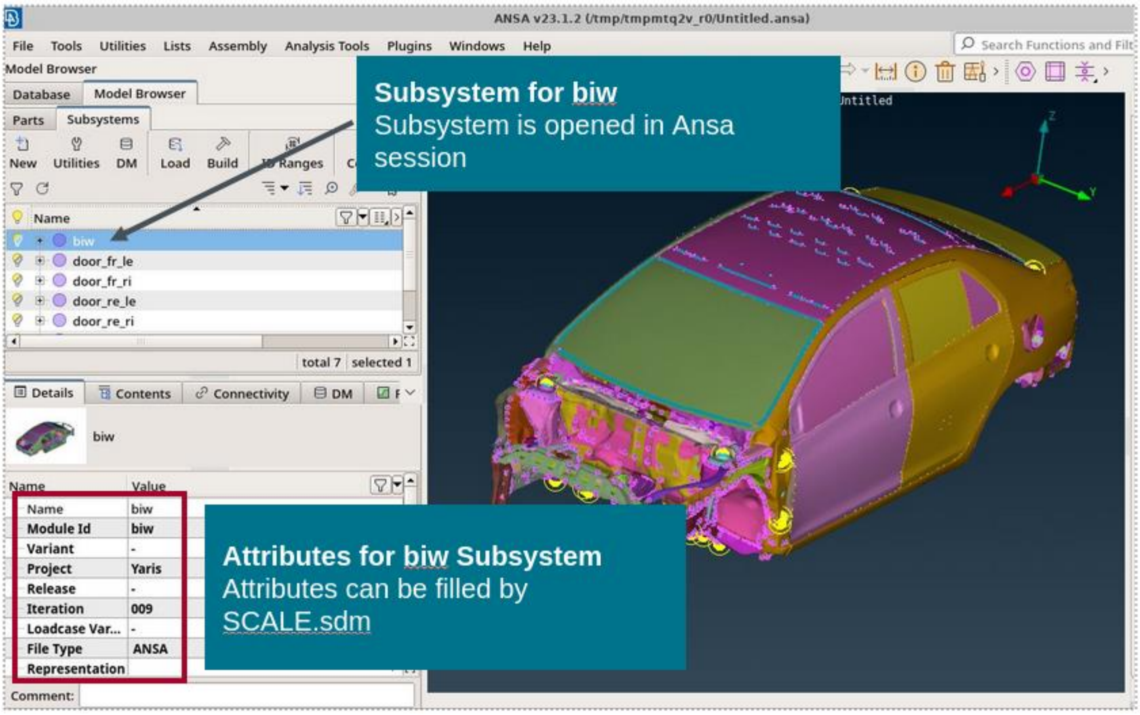


Fig.2: Ansa session with opened subsystems like biw

To be able to use the Ansa subsystems effectively, it is essential to functionally integrate the already mentioned Ansa-DM in SCALE.sdm. For this purpose, scripts are used which trigger the creation of this data structure in the current working process when subsystems are opened in an Ansa session.
In order to integrate the Ansa subsystems in SCALE.sdm, they are saved as individual Ansa DB files. An Ansa DB file is a single Ansa session. These files are stored as components in SCALE.sdm, shown in Fig.3. Metadata for the categorization of components is transferred to the subsystems and Ansa-DM in order to have a consistent data set for each subsystem.

Name	Short Description	FileType	Discipline	Version
	ansa			
Axle	Ansa_subsystem_front_axle_-_ANSAv23	ansa	CRASH,OS_FRONT,PEDESTRIAN,NVH	2
Axle	Ansa_subsystem_rear_axle_-_ANSAv23	ansa	CRASH,OS_FRONT,NVH	2
ANSA DB	Ansa_subsystem_body_in_white_-_ANSAv23	ansa	[illegible]PEDESTRIAN,OS_FRONT,FATIGUE,NVH	9
s_Door_rear_left	Ansa_subsystem_door_re_le_-_ANSAv23	ansa	CRASH,OS_FRONT,NVH	2
s_Door_rear_right	Ansa_subsystem_door_re_ri_-_ANSAv23	ansa	CRASH,OS_FRONT,NVH	1
s_Door_front_left	Ansa_subsystem_door_fr_le_-_ANSAv23	ansa	CRASH,OS_FRONT,NVH	5
s_Door_front_right	Ansa_subsystem_door_fr_ri_-_ANSAv23	ansa	CRASH,OS_FRONT,NVH	2
Hatch	Ansa_subsystem_hatch_-_ANSAv23	ansa	!TEST	2

Fig.3: Subsystems like biw saved as components in SCALE.sdm

For this concept, no LS-Dyna includes are stored in SCALE.sdm to guarantee the purpose of the “single source of truth”. The base models for the individual discipline-specific includes are the subsystems.

2.2.4 Provision of discipline-specific data

To provide the correct and complete data for the components in each discipline, it is important to define which data sets are necessary for this. Since the discipline-specific modeling runs via Ansa, Ansa tools are used for this purpose. The following list provides information about which Ansa entity can cover which data set for modeling:

- Ansa Connections:
  With Ansa Connections, intra-modular connection technology is presented, such as spot welds, seam welds or adhesives.
- A_POINTs:
  The A_POINTs are used as interface points for intermodular connections. They can be seen as a kind of marker for a connection point between two modules. They are located in the module itself.
- CONNECTORs:
  CONNECTORs represent the actual intermodular connection between two or more modules. The connection points are the above mentioned A_POINTs.

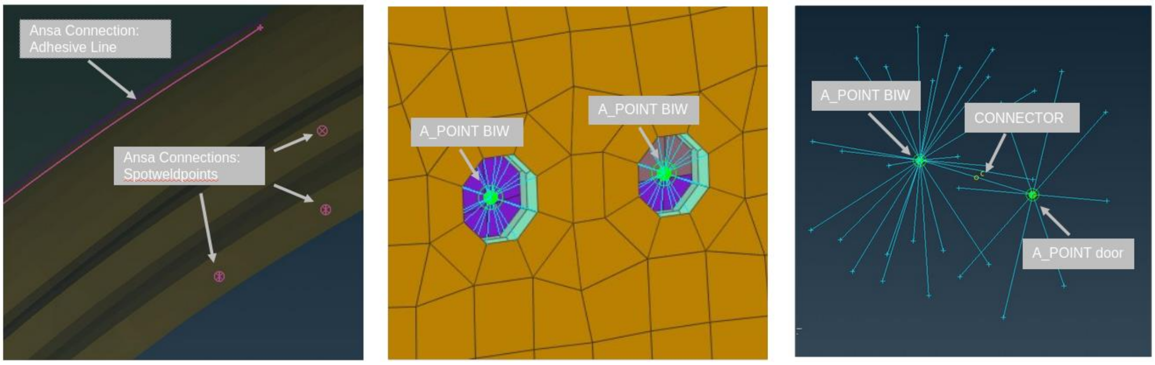


Fig.4: Examples for Ansa Connections, A_POINTs and CONNECTORs

All these Ansa entities must have the right parameters available for each discipline so that the correct representation can be created. These settings are saved in SCALE.sdm as a yaml file or as a parameter table. It is important that every parameter can be clearly assigned to each discipline and Ansa entity.
In addition to the connection technology, the includes for the master file and material cards mentioned in the previous section are essential for the complete assembly of the CAE model. For this purpose, the discipline-specific includes are stored directly in SCALE.sdm. Consequently, there are several versions for a material include or a master file, which differ in discipline-specific details. The attributes in SCALE.sdm allow each include to be assigned to the correct run configuration

2.2.5 Configurations for BIW

In addition to discipline-specific data, the implementation of the ANSA-DM interface can also include various configurations for the BIW subsystem. For instance, there can be a configuration called Roof Type that contains the options Normal Roof (NR) or Sun Roof (SR), or a configuration Hand Drive that has the options Left Hand Drive (lhd) or Right Hand Drive (rhd). All associated parts can be stored in the same subsystem. Ansa has a feature that allows the selection and calling of configurations. However, this functionality is limited with the implementation of subsystems. For this reason, sets and a SCALE.sdm script is used to select the appropriate configurations. An example for a selection of configurations can be seen in Fig.5.

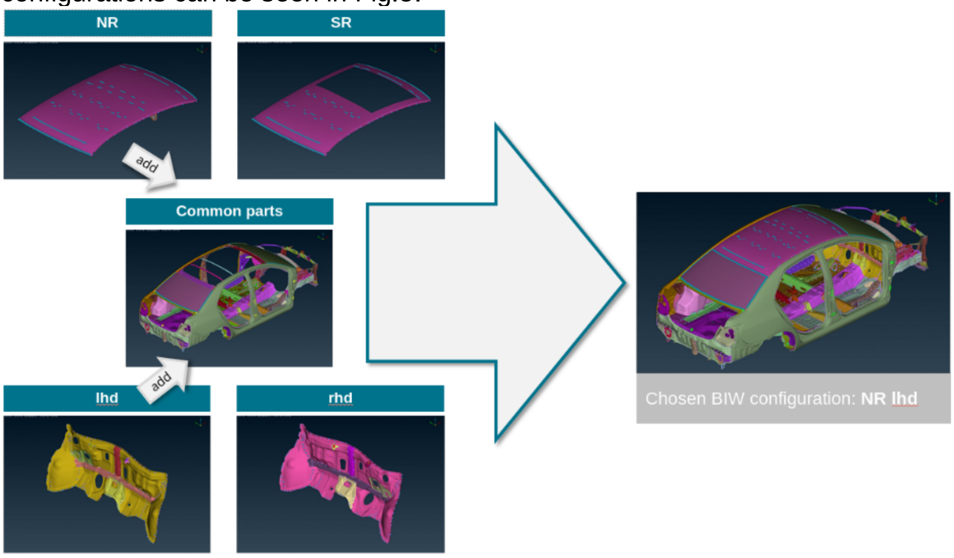


Fig.5: Example for chosen BIW configurations

2.2.6 Process flow for assembly of jobs

During the assembly of a job in SCALE.sdm, the setup of the simulation model is carried out for the selected run configuration with subsequent calculation of the simulation. The run configuration is an expression consisting of attributes, which defines the selection of associated includes and other important simulation data.
The precise creation of the solver-specific includes is essential for the correct execution of this assembly. The process for this is shown in Fig.6.

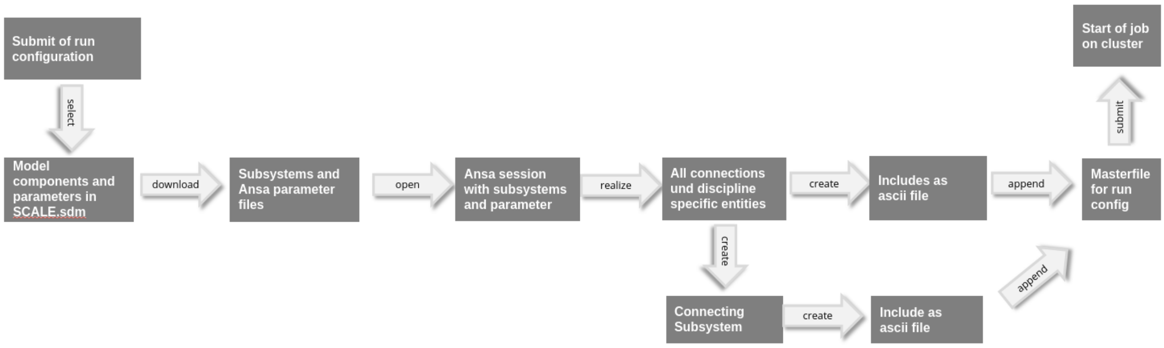


Fig.6: Process flow for job assembly

First, the desired run configuration that is to be started must be selected, for example a load case in Crash. Then all the associated components and files for parameter data and settings are selected from the database and downloaded to a temporary directory. If all files are available, an ansa session is started and all subsystems and parameter data/settings are loaded. Based on the selected run configuration, the Ansa-DM interface can recognize the selected discipline and filter out the matching data. Subsequently, all Ansa Connections, A_POINTS and other Ansa entities such as Generic Entity Builder (GEB) are realized with the appropriate representations. As soon as the modules are ready for output, the CONNECTORs are realized and moved into the Connecting Subsystem. Once this process is complete, the actual includes are exported as ASCII files from all subsystems. For each include created, a so-called snippet, an expression with various solver-specific commands, is attached with the call of this include in the master file. Once the structural includes have been created, the snippets for calling the material includes are generated and also added to the master file. Consequently, the complete finished model can be read by the solver via this master file. The calculation can now be started.

2.3 Handling of result data

Once the calculations have been completed, the results must be extracted, saved and evaluated. This will be described in more detail in the following section.
To obtain the results of a successful simulation, these must be extracted via postprocessing scripts and loaded into SCALE.sdm. All simulations are available in a large Excel-like list, the so-called grid. By selecting a simulation, the results can be viewed in several ways, for example in the attachments. It is also possible to display a dynamic web report. To do this, simply select the desired simulations in the grid and select the corresponding template and then the relevant results are displayed in the form of a report, see Fig.7.

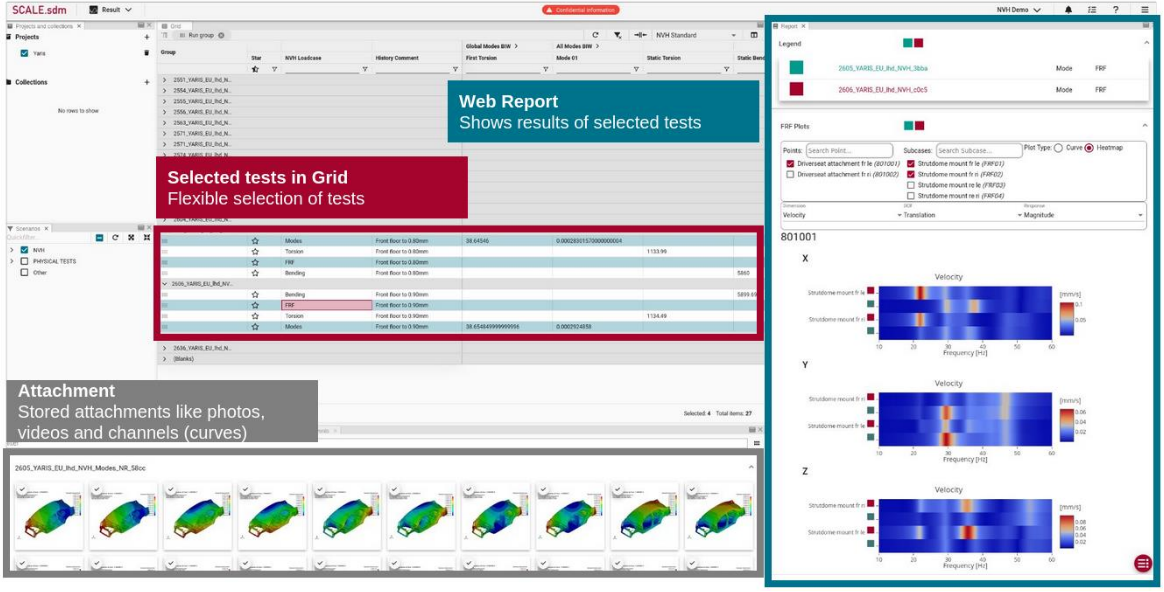


Fig.7: Selected simulations in SCALE.sdm

SCALE.sdm can also be used to define milestones in projects or to create thresholds for certain attributes. For thresholds, several ranges can be defined, which can divide the results into different evaluation levels, see Fig.8. These ranges can be provided in the relevant report in order to be able to make a better statement about the results determined.

Fig.8: Defined Thresholds

3 Execution example for the created concept

For a better understanding of the developed concept with the Ansa-DM integration in Scale.sdm, an example will be used to illustrate this. For this purpose, a CAE model is selected as a base, on which a new variant with a structural modification is created. Subsequently, the includes for the disciplines Crash and NVH are created and the load cases are started. For both disciplines, the load cases to be considered are briefly described and then the results are evaluated and presented visually in the form of a web report.
The aim of this example is not the optimization of the CAE model in the individual load cases, but the testing of all functions of the created concept in SCALE.sdm, both in the model and in the result aspect.

3.1 Base model for analysis

As a CAE base, the demo model of the Toyota Yaris available in SCALE.sdm is used. Numerous simulated variants are already available here. This CAE model is used for crash and runs with the solver LS-Dyna.

3.2 Disciplines and loadcases to be considered

The concept described in this paper is to be examined on the basis of two disciplines: Crash and NVH. The solver used for both cases is LS-Dyna. The load cases considered are briefly described below.

3.2.1 Crash

For crash, the focus is on the front crash load cases with the barriers Rigid Wall (RW) and Offset Deformable Barrier (ODB). For the first barrier, the load case of the rating system USNCAP [2] is used. The second refers to EuroNCAP [3]. The following table provides a brief overview of the further data for the two load cases.

Impact Location	Rating System	Barrier	Speed	Overlap	Angle
Front	USNCAP	RW [2]	56 km/h	100%	0 deg
Front	EuroNCAP	ODB [3]	64 km/h	40%	0 deg

Table 1: Overview crash loadcases

The maximum intrusion of the firewall is evaluated for each of the two crash load cases. The deformation behavior of the front longitudinal beams is also considered.

3.2.2 NVH

Two different vehicle configurations are considered for NVH: Body in White (BIW) and Trimmed Body (TB). The TB load cases are important to check the inter-modular connections. For the BIW this is not possible, since in this case only one subsystem and thus module is available. The TB for this paper is a reduced form of the vehicle configuration used in the industry. For this study, the TB only includes the BIW, the doors, the tailgate and the front and rear axles. In industry, power units and the front hatch are also used. Deviations from this configuration are possible.
For the load cases, both static and frequency-dependent load cases are examined.
Table 2 shows a simple overview of all the load cases considered.

Vehicle Configuration	Loadcase	Short description
BIW	Modalanalysis	Analysis of the first 20 eigenmodes
BIW	Static Torsion	Determining the torsional stiffness of the BIW
BIW	Static Bending	Determining the bending stiffness of the BIW

TB	Modalanalysis	Analysis of the first 30 eigenmodes
TB	FRF	Frequency-dependent analysis from 10 Hz to 60 Hz

Table 2: Overview NVH loadcases

Special focus in the modalanalysis for both BIW and TB is on the following three global modes: first torsion, first U-bending and first S-bending. For this purpose, the respective frequencies are determined and summarized in a table.
For the two static load cases torsion and bending, the vehicle is clamped at both rear suspension strut mounts in all degrees of freedom. For bending, the vehicle is also clamped at the front suspension strut mounts. Here, the translational degree of freedom in x remains free to avoid any constraints in bending. For torsion, a force of 1kN is applied to the front suspension strut mounts in the z-direction. The force directions for both mounts are opposite to each other. For the bending, a total force of 1kN in the negative z-direction is applied to the middle cross beams in the front floor. For both load cases, the displacement at the load application points is measured in order to determine the stiffness.
The frequency response function (FRF) is a frequency-dependent analysis in which the response to an excitation in a structure is examined. The response can be any point in the structure. A force unit is used as the excitation in this study. Displacement, velocity and acceleration are the evaluation dimensions. For the force excitation, the front and rear suspension strut mounts are loaded in z again. The output is generated at the driver's seat connections. A frequency spectrum from 10 Hz to 60Hz is analyzed. The vehicle configuration used is TB.

3.3 Create variant with new Ansa-DM integration in SCALE.sdm

3.3.1 Modelling in preprocessor

As a simple modification, the lower inner A-pillar is reinforced. The wall thickness is increased from 0.85mm to 1.5mm, see Fig.9.

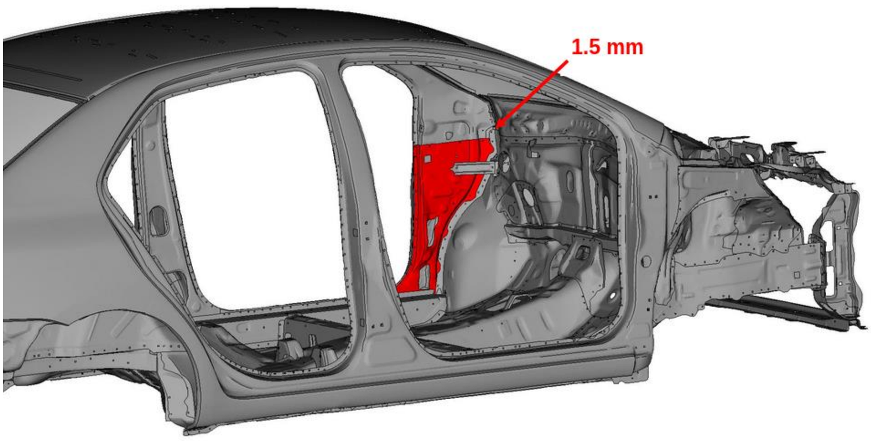


Fig.9: Increase wall thickness of lower inner A-pillar to 1.5mm

To carry out this modification, the subsystem is opened directly in Scale.sdm via the context menu. The intended wall thickness is then set in the property card in Ansa. The subsystem can then be saved. This is done via the so-called userscriptbuttons, which can call scripts created by SCALE in the open Ansa session. The subsystem is then saved as a new iteration in the local Ansa-DM directory. This is recognized by SCALE.sdm and the subsystem is saved as Ansa-DB file including the subsystem as a new version.

3.3.2 Assembly of crash and NVH loadcases with new variant

After completing the new component version in SCALE.sdm, the load cases from section 3.2 can now be started with the corresponding models. For the crash load cases, a complete vehicle is simulated with an SR lhd configuration. An NR lhd is used for the NVH load cases.
To start the job assemblies and the computation of the simulations, the intended run configurations are selected and then started via a button in the menu. An automatic process is started, which is described in section 2.2.6.

After successful calculation on the cluster, postprocessing is carried out via scripts and the extracted results are uploaded to SCALE.sdm. This process is described in more detail in section 2.3.

3.4 Evaluation of the results

The results of all simulated load cases of the new variant can be viewed in SCALE.sdm and compared with the base version. A dynamic web report can be used here for each discipline, as described in Section 2.3.
For this paper, only an excerpt of the report is shown in order to keep the context concise.
In general, a created variant in a tree in SCALE.sdm is called a pool version (PV). For example, in this paper the base version is PV 2636. The new variant is PV 2647.
In the static load cases, there is an improvement in both torsion and bending: The torsional stiffness increases from 2131 N/mm to 2199 N/mm. In static bending, an improvement from 5118 N/mm to 5200 N/mm can be seen. The deformation difference can be viewed directly using the 3d Viewer add-on available in SCALE.sdm, see Fig. 10. It is recognizable that the bulging of the lower inner A-pillar is significantly less in the new variant.

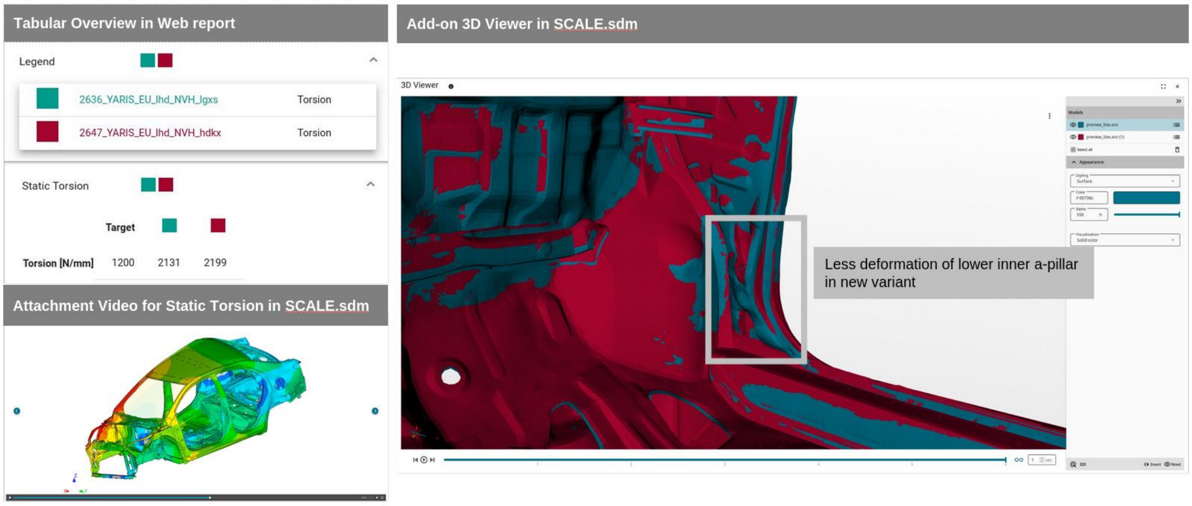


Fig.10: Results of PV 2636 and PV 2647 in SCALE.sdm for static Torsion

An improvement can also be seen in the modal analysis for BIW: The first global torsion increases from 37.3 Hz to 37.5 Hz. Both global modes for first S-bending and first U-bending also improve from 39.5 Hz to 40.0 Hz and 45.9 Hz to 46.1 Hz, see Fig.11. No improvement can be observed in the modal analysis for TB. Here the frequencies for the modes remain the same.

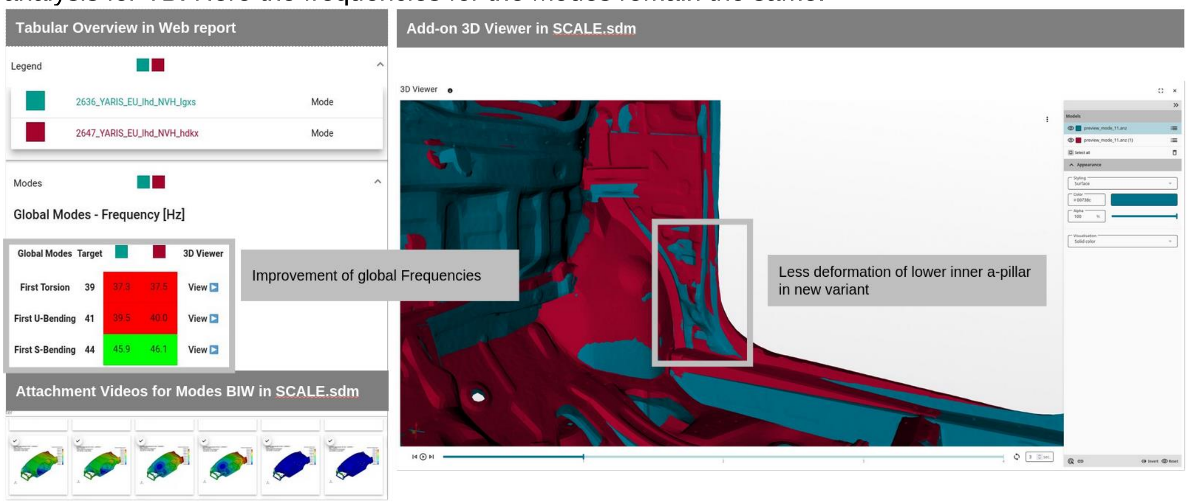


Fig.11: Results of PV 2636 and PV 2647 in SCALE.sdm for modes BIW

In the FRF load case, the maximum for various excitation points can be reduced when analyzing the speed for the evaluation points. For example, the peak at the front left attachment point of the driver seat at 24 Hz is reduced significantly, visible in Fig. 12.

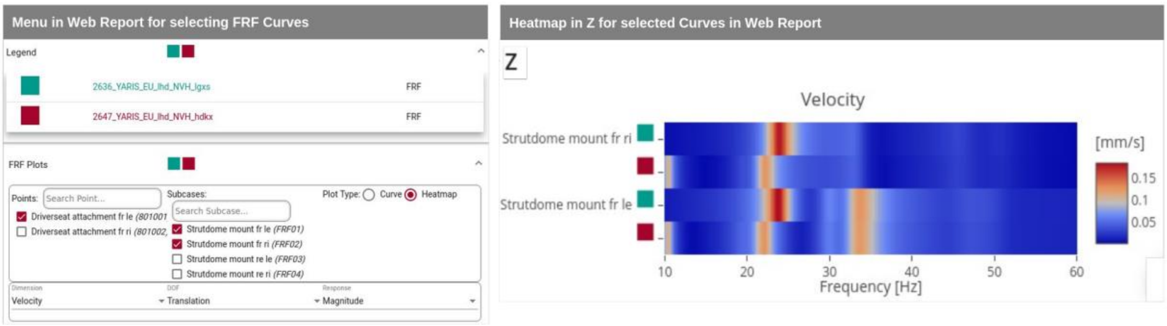
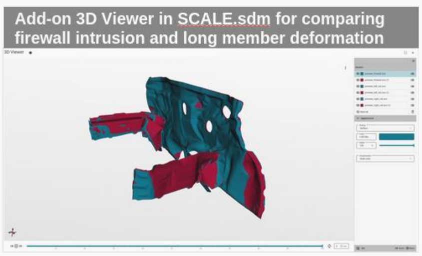


Fig.12: Results of PV 2636 and PV 2647 in SCALE.sdm for FRF TB

Further improvements can also be identified for the RW crash loadcase. The maximum intrusion of the firewall is reduced from -140.21mm to -130.83mm. The deformation of the firewall, including the front longitudinal beams, can be viewed in isolation using the 3D Viewer add-on previously mentioned. Fig 13. shows the overlay of both variants.

Overview selected Tests in Web Report

	Test Name	Directive	Vehicle speed	Firewall intrusion
(teal)	2636_YARIS_USNCAP_RW____________f_56kmh_lhd__NR_-_lsdyna_ac19	USNCAP	56.00 km/h	-140.21 mm
(red)	2647_YARIS_USNCAP_RW____________f_56kmh_lhd__NR_-_lsdyna_b3ab	USNCAP	56.00 km/h	-130.83 mm



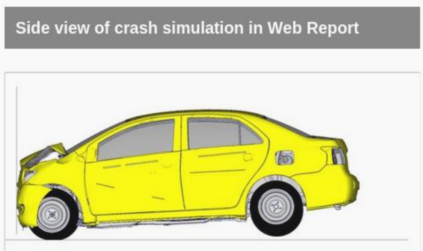


Fig.13: Results of crash RW loadcase in web report

The ODB loadcase shows a similar improvement to the RW loadcase. The firewall intrusion is reduced from -119.28mm to -106.75mm. Fig.14 shows a fringe plot for the firewall of both variants at maximum intrusion.

Overview selected Tests in Web Report

	Test Name	Directive	Vehicle speed	Firewall intrusion
(teal)	2647_YARIS_EuroNCAP_ODB__________f_64kmh_lhd__SR_-_lsdyna_ff62	EuroNCAP	64.00 km/h	-106.75 mm
(red)	2636_YARIS_EuroNCAP_ODB__________f_64kmh_lhd__SR_-_lsdyna_7fb2	EuroNCAP	64.00 km/h	-119.28 mm

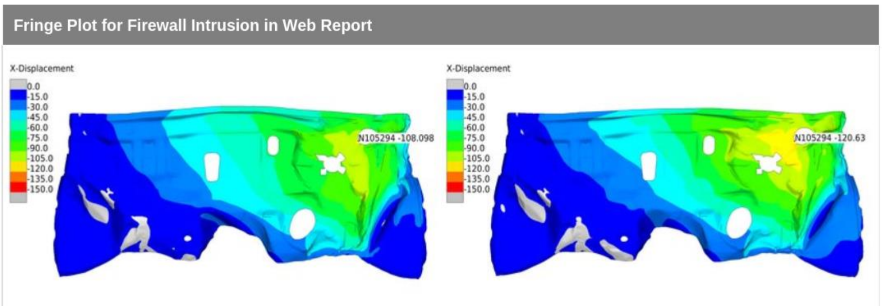


Fig.14: Results of crash ODB loadcase in web report

4 Summary

The aim of this paper is to develop a concept with which it is possible to cover different disciplines in CAE with a single base model. For this purpose, SCALE.sdm is used. This enables the integration of Ansa subsystems, whereby many features are available for the creation of intra- and intermodular joining technology. Using parameter tables or files controlled by attributes, it is possible to apply the appropriate parameters for the respective discipline to the base model and thus derive the discipline-specific includes. It is also possible to integrate BIW configurations such as Roof Type or Hand Drive.
The results of the simulations for each discipline can be viewed and evaluated in SCALE.sdm with several possibilities. For example, web reports can be used for this purpose, which can dynamically display the results for the selected simulations. For the integration of target values SCALE.sdm can be used to define thresholds.
The Ansa-DM integration is tested for the disciplines crash and NVH using an example variant. This test is carried out successfully from model buildup to evaluation of the results.
The goals for the prototype are defined at the beginning of the paper: Version control, functionality, completeness and automatic include creation. All these points are fulfilled, which can be demonstrated by the described process flow and the example variant. The concept created in this paper for managing multi-disciplinary load cases in SDM with one base model can therefore be classified as successful.

5 Literature

[1] Luijkx R. (AUDI AG), Thiele M. (SCALE GmbH): “Collaborating with CAE-processes and -data across several brands of the VW-group”, NAFEMS DACH Konferenz, 2024, page 5

[2] carhs: “Safety Companion – Knowledge for Tomorrow’s Automotive Engineering”, https://www.carhs.de/en/companion-poster/product/safetycompanion-2024-pdf-download.html, 2024, page 30

[3] EuroNCAP: Offset-Deformable Barrier - ODB, https://www.euroncap.com/en/car-safety/the-ratings-explained/adult-occupant-protection/previous-tests/offset-deformable-barrier/