Template Driven LS-DYNA Model Build-up with ANSA Task Manager

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Summary:

In the presently CAE-driven vehicle design process a great number of discipline models must be built and analyzed for the validation of a new vehicle model design. The increasing number of vehicle model variants further increases the number of the load-cases that must be studied. This process introduces a great amount of disparate data that need to be handled by the CAE teams. However, due to the multiple sources and the diversity of the CAE data, the current level of organization and data management deployed does not account for them.

Setting as a target the reduction of the CAE turnaround cycle and cost, the pre-processing tools are required to streamline all "input" data and at the same time the simulation model build-up process itself. These tools must be able to distinguish the model build-up stages, reduce the error-prone procedures involved in the CAE cycle while at the same time ensure the repeatability and versatility of the complete model build-up process.

This paper will present the means provided by BETA CAE Systems S.A. towards the development of realistic, repeatable and robust crash simulation models for LS-DYNA. ANSA Task Manager, using template processes, supervises the generation of the simulation models, while ANSA Data Management, in the background, facilitates the components management, ensuring that the engineering teams will always work with the most up-to-date data. The simulation model set-up becomes a repeatable and user-independent procedure, safeguarding the model quality and fidelity.

Keywords:

Template-driven model build-up, crash-test simulation, repeatability, robustness, ANSA Data Management, ANSA Task Manager

1 Introduction

The build-up of crash-test simulation models is a process complex and time-consuming, vulnerable to model parameter changes and error-prone. Moreover, despite of the very detailed specifications provided by OEMs for the set-up of simulation models, the overall model quality is always dependant upon the engineer’s expertise. Thus, the “weak” points in the current crash-test simulation models set-up process can be roughly outlined as follows:

- Organization: The necessary data must be invoked from numerous locations in various formats.
- Flexibility: CAE engineers have a hard-time incorporating component updates at late stages of the model build-up. Furthermore, there is a great difficulty in monitoring and resolving the dependencies among modelling actions.
- Repeatability: The simulation model build-up requires great expertise and cannot be reproduced by inexperienced engineers. This keeps the overall model quality highly dependant on the individual.
- Robustness: Small changes in the model parameters may lead to a great scatter in the simulation results.
- Model validation: The model checks prior to the output of the deck file are incomplete.

All these deficiencies maintain the CAE productivity at low level.

In this paper, the capabilities of ANSA Task Manager in combination with ANSA Data Management are explored, having as target the elimination of the physical drawbacks that arise during the crash-test simulation models build-up. ANSA Data Management collects all the engineering data under a common location while ANSA Task Manager is used to safeguard the best practices for the crash simulation models set-up, as these are determined by the CAE analysis expert, scoping to the increase of CAE teams flexibility, efficiency and productivity.

As an example, a full vehicle model (Fig.1) will be used for the set-up of a front-impact 40% offset analysis, with an initial velocity of 64 km/h (FMVSS 208) for LS-DYNA.

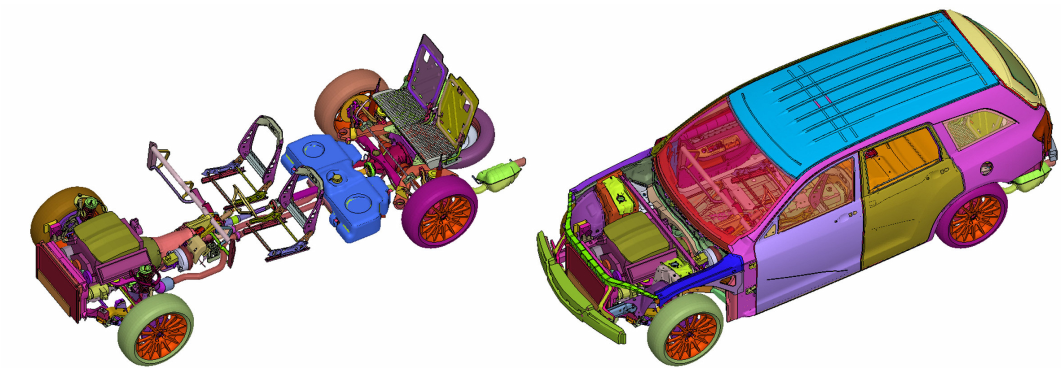


Fig. 1: Full vehicle model

2 ANSA Data Management as a data pool

The great variety of data that need to be incorporated and taken into account in the analysis model studied are gathered under ANSA Data Management (ANSA DM). Such data are:

- Model assembly components: Geometric description and mesh representations
- Engineering data, e.g. material databases
- Auxiliary components, e.g. barrier models
- Custom-made templates for the simulation of model entities, i.e. connector entities, mass trim items, boundary conditions, output requests
- Process templates, set up by the CAE-analysis expert, which outline the modelling actions that need to be performed during the simulation model build-up

ANSA DM, stores all these diverse data in a structured and hierarchical form, which enables their flawless retrieval at any stage of the model build-up process. All the data stored in ANSA DM are complete and ready to be used in the model build-up.

The highlight feature of the ANSA DM is the parts' management. ANSA DM is capable of identifying component updates upon request. Such component updates may be based either on a new CAD version of the component or on modifications performed by another member of the CAE team. Once a component update is identified, the engineer can track the changes between the new design and the version which is currently used and thus decide whether the new version will be incorporated in the assembly model or not.

3 Streamlining the LS-DYNA model build-up in ANSA Task Manager

ANSA Task Manager is a tool that organizes in a hierarchical way all the distinct modelling actions that have to be followed for the set-up of a discipline model. It includes all individual steps of the model development process, considering at the same time the dependencies among related actions.

The Tasks in Task Manager are built-up from CAE experts, who set the order and boundaries between distinct modelling actions and predetermine all modelling parameters that must be taken into account at each stage. Each Task, once built for a model, is saved as a template process in ANSA DM and can then be invoked to guide the set-up process for all similar analyses.

ANSA Task Manager "discretizes" the model build-up in three distinct stages: The *Common Model,* the *LS-DYNA Common Model* and the *LS-DYNA Load-case.* Each stage groups several *task items* which represent certain modelling actions. During the *Task* execution, the actions implied by the *task items* are realized and verified. Possible dependencies among modelling actions are automatically detected and treated appropriately.

- The *Common Model* contains all modelling actions which are common for all the discipline analyses that will be conducted on the model (i.e. front impact, side impact, rear impact analyses, durability analyses etc.). Thus, the *Common Model* is stripped of any solution dependant entities and it is ready to be "transformed" in a form suitable for the analysis that follows.

- The *LS-DYNA Common Model* contains those modelling actions which are not common for all the discipline analyses, but are certainly common for all the load-cases that will follow. The *LS-DYNA Common Model* also plays another significant role: It dictates the "transformation" of the *Common Model* into a form suitable for the analysis that will follow.

- Finally, the *LS-DYNA Load-case* contains the modelling actions that are load-case dependent.

4 The Common Model in ANSA Task Manager

The *Common Model* defines the model that will participate in the analysis. It consists of all the components, BiW connections, connectors and mass trim items that are common to all disciplines (Fig.2).

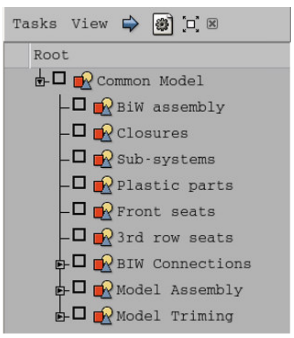


Fig. 2: The Common Model Task

The *Common Model*, in the same manner as all other ANSA Task Manager groups, represents a process that must be followed exactly as dictated by the sequence of *Task Items.* In the following paragraphs, the *Common Model* Task contents are explored.

4.1 Gathering the components that comprise the model

ANSA Task Manager allows for a model grouping suitable for the discipline models' build-up. This grouping simplifies the assembly hierarchy tree coming from VPM systems, enables direct access to the actual sub-assemblies and eases the communication of ANSA Task Manager with ANSA Data Management system.

The model grouping created for the goals of this study consists of six sub-models:

- BiW assembly
- Closures
- Sub-systems
- Plastic parts
- Front seats
- 3rd row seats

The physical data related to each sub-assembly can either be native ANSA models or include files. The contents of all sub-models comprise the model considered to be under the influence of ANSA Task Manager (Fig. 3).

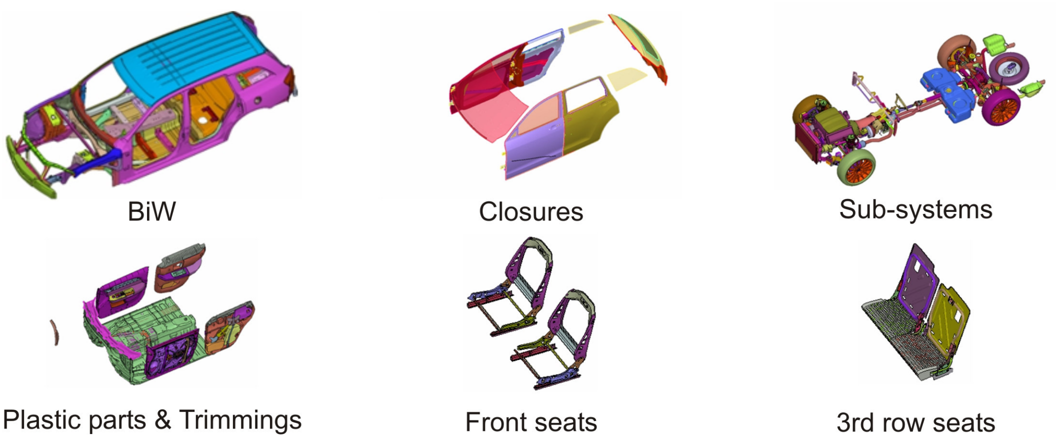


Fig. 3: Task Manager sub-models

All the capabilities of ANSA Data Management with respect to the parts' management can be directly accessed from within the Task tree. Most important:

- The retrieval of a suitable mesh representation for the front-impact analysis
- The notification for component updates and their incorporation in the model assembly

During the execution of the *Common Model,* ANSA Task Manager verifies that there are no missing components among the ones referenced by the sub-models. The assembly up to this point is not meshed. The mesh is a discipline-dependent feature.

4.2 BiW connections

After the validation of the sub-model items comes the BiW assembly. The BiW is assembled using connection points and curves. The welding information is input at this point. ANSA Task Manager will verify the connectivity specified in each connection entity, with respect to the availability of the components referenced.

The welding information neutral file is retrieved from ANSA DM. During the execution of the *BiW Connections* group of items and with the aid of the Connection Manager, Task Manger validates every single connection entity (Spot weld points, Spot weld lines, Adhesive lines, Bolts).

The connection entities do not take an FE-representation at this stage. The FE-representation is a discipline-dependent feature.

4.3 Model Assembly: The Connector Entities

In order to impose the kinematic constraints that physically exist between parts and sub-assemblies Connector Entities are used. A Connector Entity can carry information regarding:

- Its location in space
- Its orientation
- Connectivity; which components are connected?
- Representation; what FE-representation should be used?
- Interface; which is the interface entity between the representation entities and the connected components?

The kinematic conditions modelled by Connector Entities can vary, from the simple rigid connection to template and parameterized universal joints and bushings. All the Connector Entities that exist in the model are hosted in the *Model Assembly* task item. During the execution of the *Model Assembly* group of items, Task Manager validates every single Connector Entity with respect to the availability of the components referenced in its connectivity information.

At this stage, the Connector Entities do not take any FE-representation. The FE-representation is a discipline-dependant feature.

4.4 Model Trimming: The Mass Trim items

Mass trimming takes place either with the addition of lumped mass on certain components or with the addition of distributed mass in the form of point mass on components. All cases where mass addition is common for all discipline models are collected under the *Mass Trimming* group in the form of *Mass Trim* items. A Trim Item can carry information regarding:

- Its location in space.
- Connectivity; on which components should the mass be added?
- Representation; what FE-representation should be used?
- Interface; which is the interface entity between the representation entities and the components?

All the Mass Trim items that exist in the model are hosted in the *Model Trimming* task item. During the execution of the *Model Trimming* group of items, Task Manager validates every single Mass Trim item with respect to the availability of the parts and properties referenced in its connectivity information.

The characteristic features of the model assembly after the validation of all *Common Model* contents are summarized below:

1. There are no components missing among the sub-models that comprise the model assembly.
2. The welding information exists in the form of connection entities (connection points and curves) and is verified with respect to their connectivity information.
3. The locations where kinematic constraints exist between parts and sub-assemblies are marked with Connector Entities, These entities are verified with respect to their connectivity information.
4. The locations where mass trimming takes place for all discipline models are marked with Mass Trim items. These entities are verified with respect to their connectivity information.

This error-free assembly model (Fig. 4) comprises the base for the generation of any discipline model, since it is ready to adopt any suitable form.

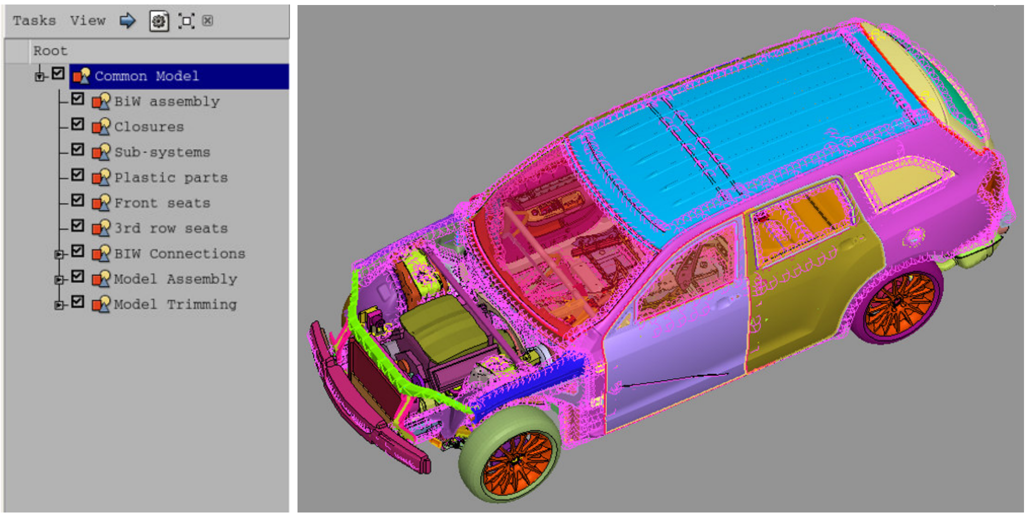


Fig. 4: Common Model Task completed

5 The LS-DYNA Common Model

The significance of the *LS-DYNA Common Model* group of items lies in the fact that it is the linkage between the *Common Model* and the *LS-DYNA Load-case*. It is the *LS-DYNA Common Model* that dictates the “transformation” of the *Common Model* in a form suitable for the analysis to be conducted.

The *LS-DYNA Common Model* safeguards a part of the model build-up process in the form of a sequence of modelling actions. Once built by the CAE analysis expert, it is saved as a process template in ANSA Data Management system so that it can be easily retrieved and re-used for several applications.

As soon as the *LS-DYNA Common Model* is invoked, ANSA Task Manager is notified that the actual model built within the *Common Model* must adopt a form suitable for the LS-DYNA analysis. All the *Common Model* task items that will be affected by the “transformation” of the *Common Model,* automatically become un-checked (Fig. 5). Thus, the user is forced to execute them again, this time with the conditions dictated by the *LS-DYNA Common Model.*

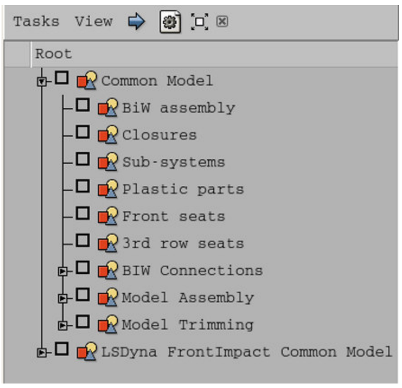


Fig. 5: Addition of the LS-DYNA front-impact Common Model

5.1 “Transforming” the Common Model in a form suitable for front-impact analysis

During the re-execution of the *Common Model*, the components referenced by the sub-model items must adopt a suitable for front-impact analysis mesh representation, the BiW connections must be “realized”, connecting the parts they reference with suitable for the LS-DYNA analysis entities, the Connector Entities and the Mass Trim items must be also “realized”, using built-in or custom template representations. In the following paragraphs, the “transformation” of the *Common Model* is explored, following the Task sequence.

5.1.1 Sub-model items: FE-representation

With the *LS-DYNA Common Model* present, ANSA Task Manger does not validate any sub-model item unless the components it references do not contain any unmeshed macro areas or volumes. Therefore, for each sub-model the proper representation is retrieved from ANSA DM, with the aid of the *Part Representation Manager* (Fig. 6). All functionality related to the communication of the Task Manager model with ANSA DM is directly accessed from within Task Manager.

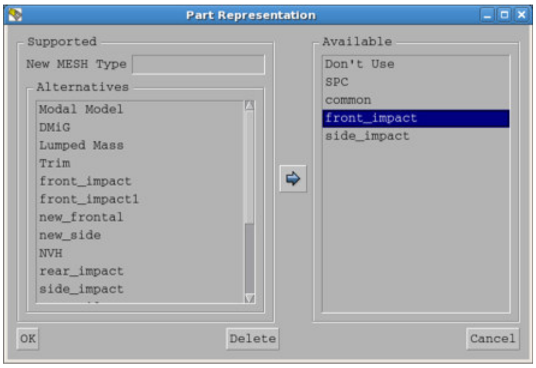


Fig. 6: Retrieving the front-impact mesh representation from ANSA DM

After the retrieval of the front-impact mesh representation for each sub-model item (Closures, Sub-systems, Plastic parts, Front seats, 3rd row seats), ANSA Task Manager validates their definition with respect to the existence of unmeshed areas and volumes (Fig. 7).

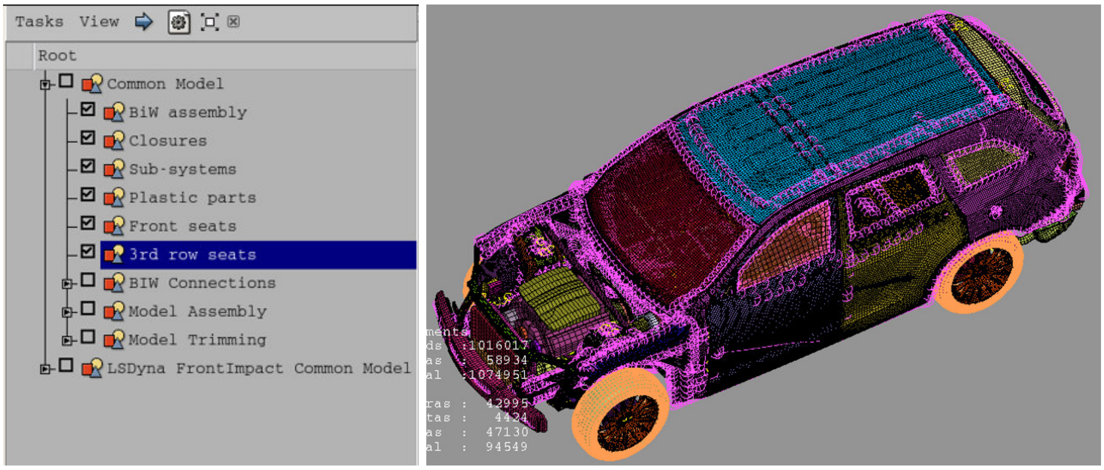
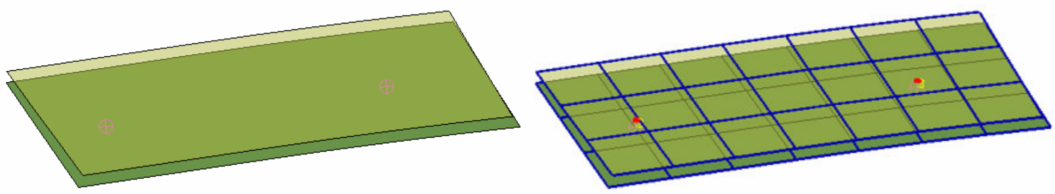


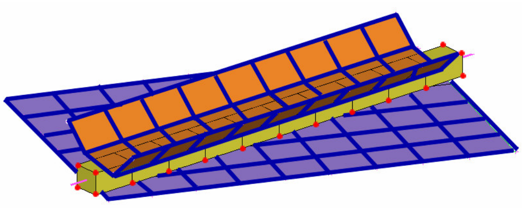
Fig. 7: Front-impact mesh representation for the sub-models of the Common Model

5.1.2 BiW Connections: Realization of welding information

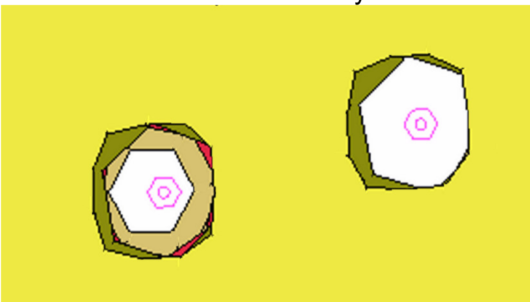
With the *LS-DYNA Common Model* present, ANSA Task Manger does not validate any BiW connection entity type item unless all the entities of this type are "realized" with suitable FE-representations. Figure 8 shows examples of connection entities realization patterns.

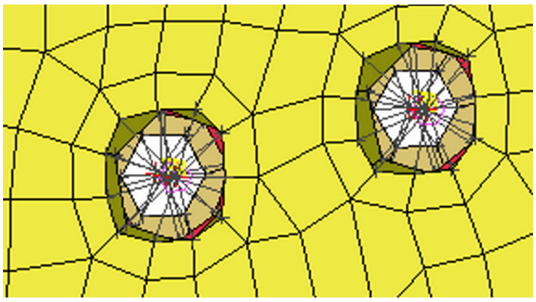


Spot weld point connection entities DYNA SPOTWELD pattern



Adhesive line connection entity HEXA CONTACT pattern





Bolt connection entity Rigid interface, rigid body pattern

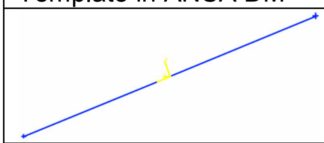
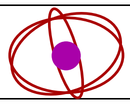
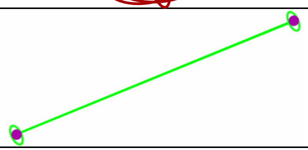
Fig. 8: Realization patterns of BiW connections

5.1.3 Model Assembly: Realization of Connector Entities

With the *LS-DYNA Common Model* present during the execution of the *Model Assembly* group of items, ANSA Task Manager applies the Connector Entities' FE-representation. Some characteristic features of the Connector Entities' realization are:

1. The Connector Entities are defined using *mesh density independent* patterns for the identification of the connected entities. Thus, a connector can be applied on a hole, a circular feature, a certain number of nodes or elements, in a pre-defined search domain.
2. Connector Entities that connect a rigid with a deformable component with rigid interface automatically detect the case and create *CONSTRAINED_EXTRA_ NODE instead of *CONSTRAINED_NODAL_RIGID_BODY entities
3. Connector Entities that connect rigid components together with rigid interface, automatically detect the case and create *CONSTRAINED_RIGID_BODY entities
4. The Connector Entities can use the built-in representations (i.e revolute and spherical joints) or even custom made ones, retrieved as templates from ANSA DM libraries, promoting the model robustness

Table 1 summarizes the custom templates used for the representation of Connector Entities. Such templates once created, are saved in ANSA DM libraries so that they can be re-used for various applications.

Template in ANSA DM	Description
	*ELEMENT_BEAM_ELFORM_1 Parameters: diameter, length and orientation according to application
	*CONSTRAINED_JOINT_SPHERICAL Parameters: Value of added mass on both ends
	*CONSTRAINED_JOINT_REVOLUTE Parameters: Value of added mass on both ends, orientation according to application

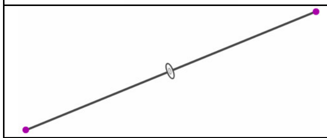
	*ELEMENT_DISCRETE for 6 dofs Predefined: *DEFINE_SD_ORIENTATION vectors, *SECTION_DISCRETE Parameters: Value of added mass on both ends
	*CONSTRAINED_JOINT_UNIVERSAL Parameters: Value of added mass on central nodes, orientation according to application
	*CONSTRAINED_JOINT_CYLINDRICAL Parameters: Value of added mass on both ends, orientation according to application

Table 1. Parameterized templates for connectors retrieved from the ANSA DM library

Figure 9 shows an example of Connector Entities' realization.

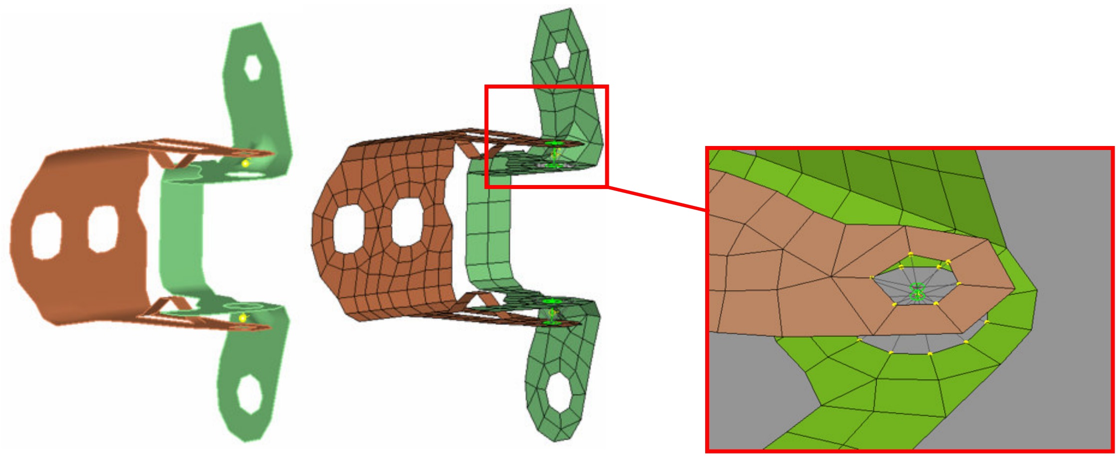


Fig. 9: Connector Entities before and after their realization to revolute joints

5.1.4 Model Trimming: Realization of Mass Trim items

With the *LS-DYNA* Common Model present during the execution of the Mass Trimming group of items, ANSA Task Manger applies the Mass Trim items FE-representation. The FE-representations of Mass Trim items for LS-DYNA can be:

1. Pre-defined amount of added mass distributed over pre-defined components in the form of *ELEMENT_MASS.
2. Pre-defined amount of added mass attached on pre-defined components at specified locations in the form of *lumped mass.*
3. Pre-defined amount of mass added as non-structural mass in the component's *SECTION_SHELL MAREA field. The mass per area is automatically calculated so as to result to the desired total weight.
4. The substitution of the detailed FE-representation of a component by an equivalent amount of mass, distributed over the nearby components.

After the realization of Mass Trim items with the pattern dictated by the *LS-DYNA Common Model*, the *Common Model* has adopted a form suitable for the front-impact analysis.

5.2 Front-impact related items

The items added by the *LS-DYNA Common Model* are common for all the front-impact load-cases that may follow. Such items can be additional components, boundary or initial conditions, output requests and of course model checks. In this study, the first items to be added by the *LS-DYNA Common Model* are the additional components:

- Passengers' mass: These mass elements of pre-defined value are added in the form of *lumped masses* and are attached on specified components (i.e. seats, rear floor) with the aid of Mass Trim items.
- Instrumentation mass: This mass of pre-defined value is added in the trunk, in the form of *lumped mass* and is attached to pre-defined components, again using the Mass Trim items.
- Closures interior plastic components: The detailed FE-representation of these components is substituted by a *Trim* representation, spreading mass elements of an equivalent total weight over the nearby inner panel components (Fig. 10).

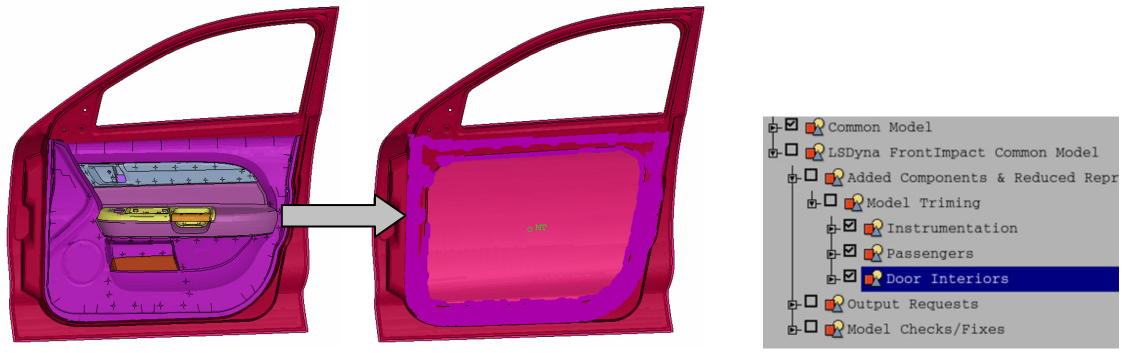


Fig. 10: Trim representation created with the aid of Mass Trim items

The creation of section forces output requests, a tedious and time-consuming procedure, becomes really flexible and efficient with the use of Output Request Generic Entities. The positions, cutting planes and the components cut are pre-defined in the Output Request Generic Entities by the CAE analysis expert. Once defined, they can be applied during the Task execution with no extra input.

Output Request Generic Entities are also used for the positioning and assembly of accelerometer sensors at pre-defined locations. The representation of accelerometer sensors, again pre-defined by the CAE analysis expert, is stored as custom template in ANSA DM library (Table 2). Each output request definition contains information for the location and the connectivity of the accelerometer sensor to be created. Figure 11 shows the accelerometers and sections created by Output Request Generic Entities.

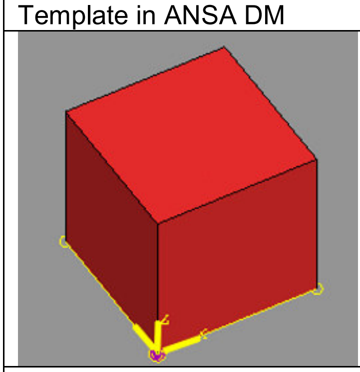
Template in ANSA DM	Description
	*ELEMENT_SEATBELT_ACCELEROMETER Each accelerometer is attached on a 10x10x10 rigid hexa element. A mass element is attached to the accelerometer reference node.

Table 2. Custom template for accelerometer sensor, retrievd from the ANSA DM library

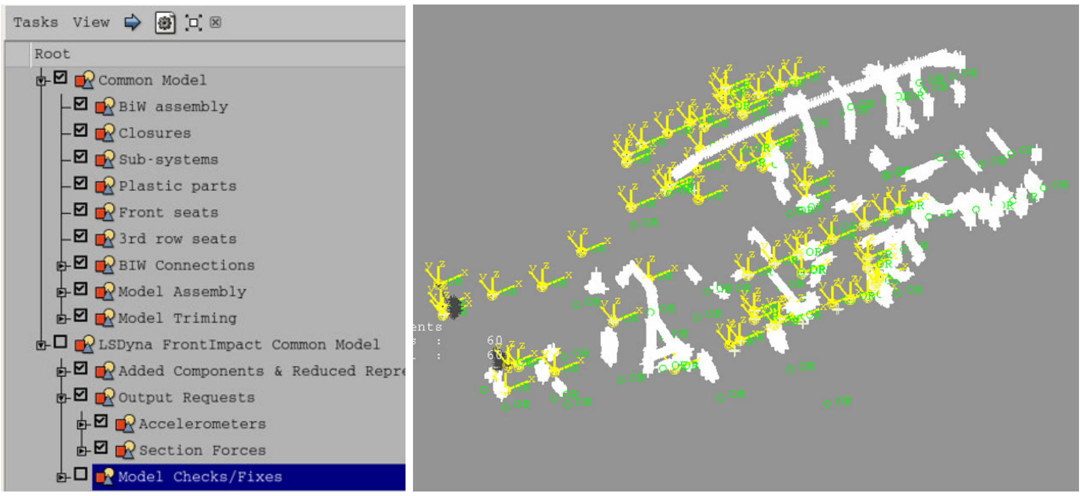


Fig. 11: Accelerometers and sections created by Generic Entities

After the addition of output requests, the model integrity is checked. Apart from the various available checks, the CAE analysis expert is flexible to add custom checks with the aid of user scripts. ANSA Task Manager does not proceed until all checks are successfully implemented.

After the implementation of model checks and the correction of possible errors, the *LS-DYNA Common Model* is ready (Fig.12). The model built up to this stage can be used for the creation of any LS-DYNA front-impact load-case.

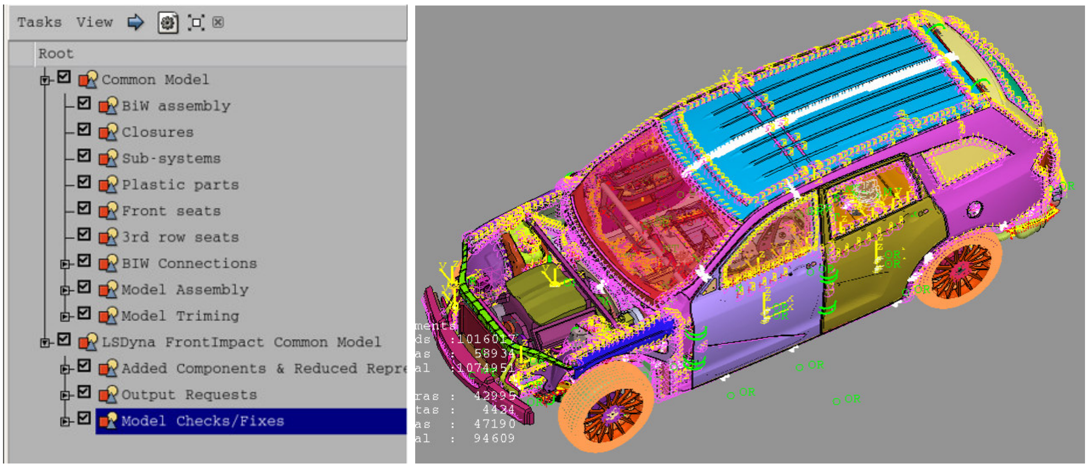


Fig. 12: LS-DYNA front-impact Common Model completed

6 The LS-DYNA Load-case

All the entities that differentiate the front-impact load-cases from each other are added by the *Solver Load-case* group of items. This Task is again invoked from the ANSA DM data pool. The most important aspects of the *LS-DYNA Load-case* Task are outlined below:

1. *Solver controls*: The solver controls are set-up once for each load-case by the CAE analysis expert and are safeguarded in the Task
2. *Contact interface cards*: The contact interface cards, along with their parameters, are set-up once during the Task build-up. During the Task execution, Task Manager automatically fills the contact sets and there is no need for user-intervention in the contact definition.
3. *Barrier file definition and positioning*: The barrier file to be used in each load-case is pre-defined in the *Barrier Positioning* item of ANSA Task Manager along with information for the positioning procedure. During the Task execution, the barrier is retrieved from the ANSA DM data pool and is automatically positioned and de-penetrated according to the load-case specifications.

4. *Rigid road*: The attributes of the rigid wall used as the boundary road are saved along with the Task.
5. *Initial velocity and acceleration field*: The solver cards parameters are defined once by the CAE analysis expert. There is no need for user intervention during the Task execution, since Task Manager automatically fills the sets referenced in these cards with the appropriate entities
6. *Model checks*: The model is checked prior to the output with respect to load-case specific entities definition.

All the aforementioned *Solver Load-case* attributes find application in the front-impact load-case. Additionally, in this *LS-DYNA Load-case* nodal time history is requested at pre-defined locations with the aid of Output Request Generic Entities. These output requests are retrieved from the ANSA DM library in the form of *DATABASE_HISTORY_NODE_SET entities. Figures 13-14 show the items added sequentially by the *LS_DYNA Load-case.*

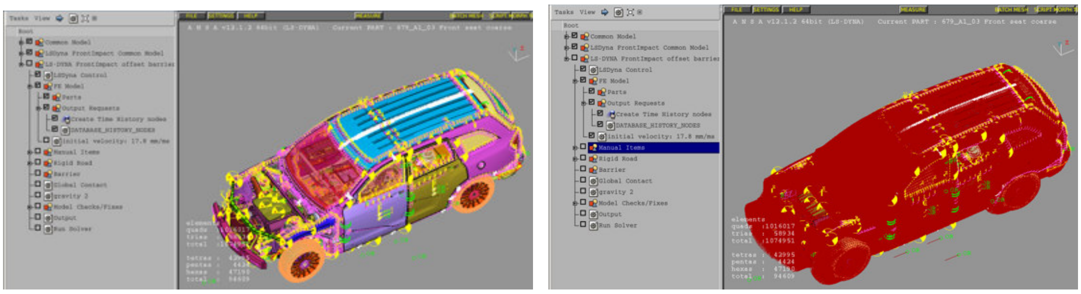


Fig. 13: Addition of time history nodes and initial velocity

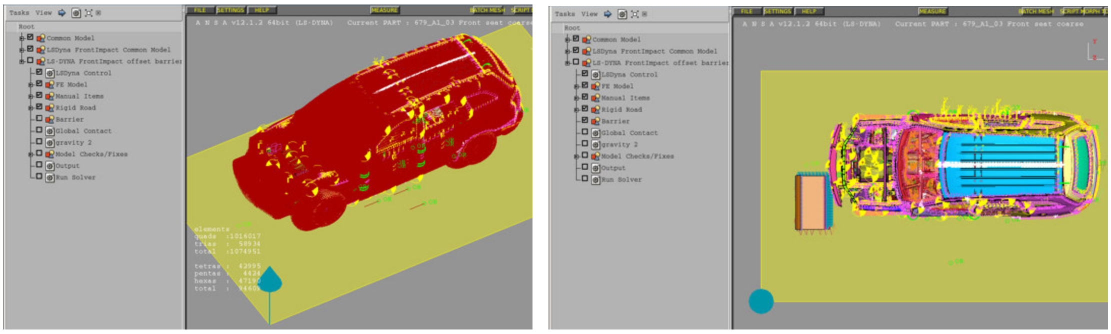


Fig. 14: Addition of rigid-road and barrier

The *Barrier Positioning* tool assures that the barrier will be positioned properly relatively to the vehicle body, with no penetration between them. Figure 15 shows the *Barrier Positioning* control card, which requires the minimum information for a front-impact load-case.

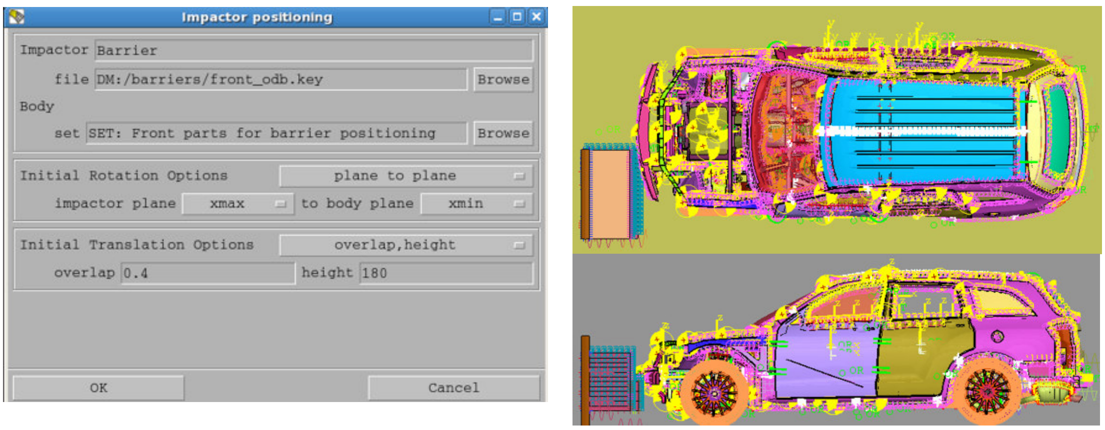


Fig. 15: Barrier positioning: Pre-defined set-up of the offset and height

Finally, the global contact definition and gravity are added and the model is checked with respect to load-case specific definitions. After the execution of model checks, the analysis model is ready for output. The complete model is shown in figure 16

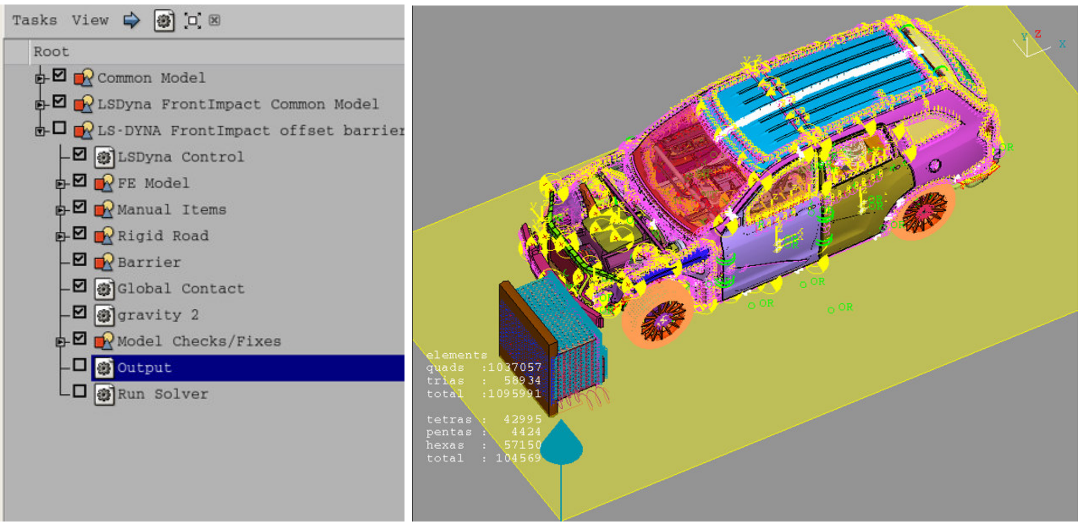


Fig. 16: LS-DYNA Front-impact 40% offset 64 km/h complete model

7 Conclusion and remarks

The data organization and process standardization necessary for the demanding task of crash-test simulation models build-up can be achieved with the use of ANSA Task Manager in combination with ANSA Data Management. With the aid of ANSA Task Manager, OEMs can safeguard the model quality and promote knowledge transfer, capturing the best-proven practices for the analysis model build-up as a sequence of modeling actions. ANSA Data Management assures the organization of all data, storing them in a structured form under a common location, enabling their easy retrieval by Task Manager.

Tasks in Task Manager are created by the CAE analysis expert, who collects all the modeling actions and considerations that must be taken into account during the model build-up and interprets them as distinct task items. The completed tasks are saved in ANSA DM as template processes and can be reused for application on the vehicle model assemblies.

ANSA DM libraries carry custom template definitions for connectors, output requests and boundary conditions, assuring that model entities are defined with the proper parameters. Multi-parametric solver cards (e.g. contact definitions, initial velocity, acceleration field, solver controls) are incorporated in ANSA Task Manager with parameter values set by the CAE analysis expert, eliminating error-prone procedures and promoting the model robustness.

During the execution of pre-defined Tasks, ANSA Task Manager makes sure that all task items are properly executed, considering at the same time possible dependencies between them. The validity of model entities definitions is checked prior to the output with the aid of various built-in check algorithms. The model quality is safeguarded and the build-up of crash-test simulation models becomes fast and efficient.

