# LS-DYNA® Impact Model Build-up: Process Automation With ANSA Data Management and Task Manager

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## Abstract

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, .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

## Introduction

The preparation and built up of a crash simulation is a technically demanding and time consuming process. This makes the process susceptible to error and vulnerable to model parameter changes. The week points of the links in the process chain of building a crash test simulation can be roughly outlined as follows:

- Organization: The required data need to be retrieved from multiple locations and in various formats.
- Flexibility: It is very difficult to incorporate and manage updates at a later design stage of the model build-up, such as part version updates, study versions etc. In addition there is a further difficulty monitoring and resolving the affects these updates will have to the whole model.
- Repeatability: The simulation model construction requires high level of expertise from the engineering team. This makes the success of the simulation dependant to the individual. In addition the load-case may need to be applied in many variants of the same or similar model.
- Robustness: Changes in the model may lead to undetected errors that will impact the validity of the simulation results.
- Model Validation: Models go to the solver, for solution, incomplete and with errors.

In this paper the capabilities of the ANSA pre-processor are presented, targeting the elimination of the above drawbacks that arise during crash simulation model built-up. ANSA Data Management (ANSA DM) collects and organizes all the engineering data under one common location, while that ANSA Task Manager (ANSA TM) is used to organize the build-up of simulation load cases, accounting for the load-case hierarchy, dependency between task actions and safeguarding the best practices provided by the technical expert.
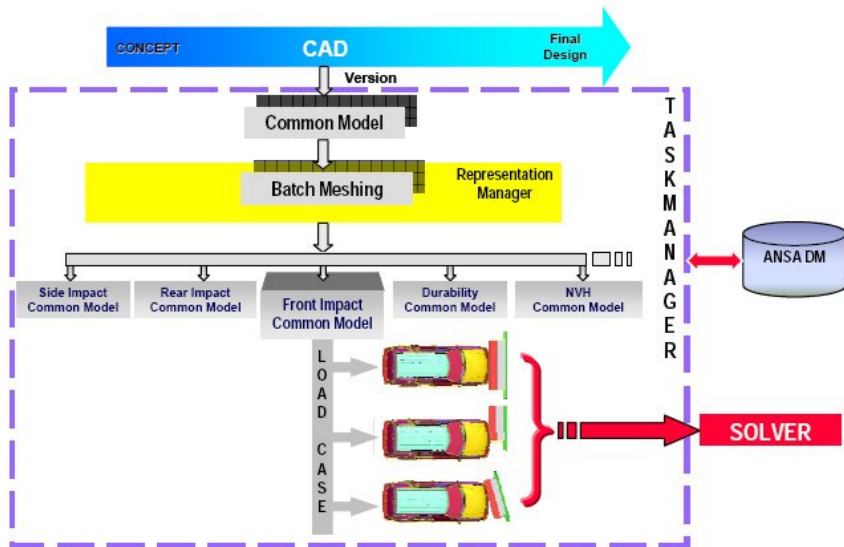


Figure 1. ANSA Task Manager and ANSA Data Management working together concept.

As an example a full vehicle will be used to set up a front-impact 40% offset analysis at 40mph (64km/h) based on the IIHS standards.
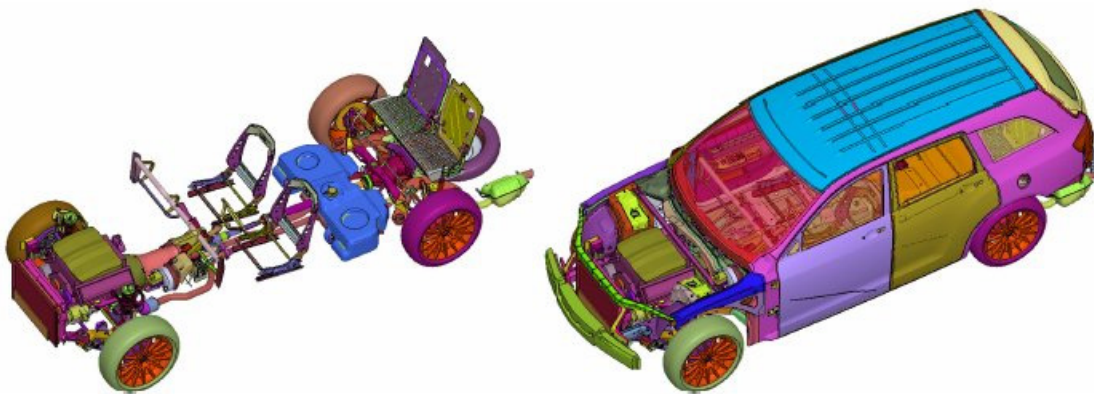


Figure 2. Full vehicle model.

## ANSA Data Manager

ANSA DM is a structured and centralized data management system. It assures that all engineering data, which are used for the creation of the model, are stored securely and are organized in a way that can be easily retrievable by all CAE engineers working on various CAE

disciplines. ANSA DM in cooperation with ANSA's batch mesher creates the different mesh representations for the every part. Typical data that reside inside the DM are:

- Model assembly components: Parts (geometry), sub-assemblies, Mesh representations
- Auxiliary components: Dummies, barriers etc.
- Engineering Data: material databases, connection files etc.
- Library items: Custom made entities such as connector entities, mass trim items, boundary conditions, output requests.
- Task Manager Processes: Task manager processes, created by the CAE expert who outlines the actions needed to be performed to set up the simulation load-case.
- Post processing results

ANSA DM is capable of indentifying any change that has taken place and automatically updates the users. Such change maybe a new CAD version of a part or a new modification of an existing part version performed by another member of the CAE group. Once a new part has been identified, the user can select to bring the updated version into the working ANSA database. A recently added capability is a comparison tool that compares the part or a sub-assembly with the updated version in the ANSA DM. The tool lists the differences in the geometry (visualization of the geometry differences is possible), Part & Section properties, and in material properties. Thus the user can make an informed decision if the new version needs to be included in the model or not.

## ANSA Task Manager

The ANSA Task Manager is a tool that organizes in hierarchical form all the different modeling actions that need to take place in order to build a discipline specific simulation model. In addition all the dependencies between the related actions are taken into account by the task manager.

- The *Common Model*. It contains all the non-analysis specific (common) tasks. These tasks include the creation of mesh representations, assembly of the sub-models, mass trimming.
- The *LS-DYNA Common model*. This group of task contains modeling actions that are common for the load-cases that will follow. These tasks can be addition of parts, creation of common output requests such as cross sections and accelerometers, positioning and restraining of dummies etc.
- The *LS-DYNA load-case*. This group of tasks contains all the load-case specifics that are needed to complete and run the model. These actions are definition of initial velocity, global contact, barrier and road positioning, and output of the model. In addition checks of the integrity of the model can also be performed.

## The Common Model in ANSA Task Manager

The common model is the starting point for the creation of solution specific model. The *Common Model* includes all the modeling actions that are common between multiple CAE disciplines such as Crash, NVH, Durability etc. A *Common Model* is composed of the following entities.
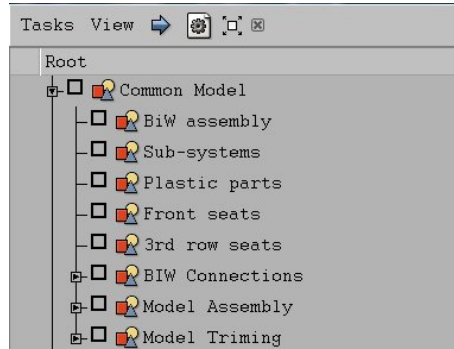
Figure 3. The Common Model Task.

- Sub models: They are grouped parts inside ANSA that make up sub-assemblies. They can include geometry, complete FE sub-assemblies or include files.
- BiW Connections: The connection information is read from an xml, vip, vip2, any ASCII file and many more formats.
- Model Assembly Data (Generic Connectors): This Data contain information regarding the connection between sub assemblies i.e. the doors and the body.

### Collecting the data that construct the Model

ANSA has the ability to group the individual parts per sub-assembly. The parts hierarchy can be created though a VPM tree xml output.
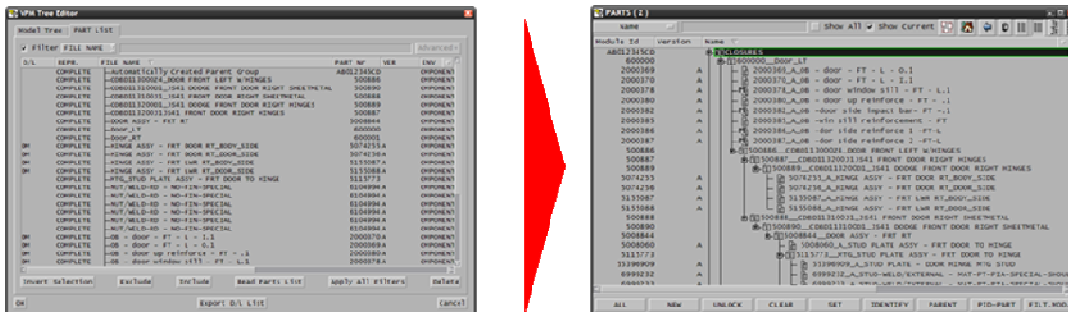

Figure 4. VPM tree to ANSA Parts.

The example case of this paper consists of six sub-models, which are BiW assembly, closures, sub-systems, Plastic parts and trimming, front seats and third raw seats.
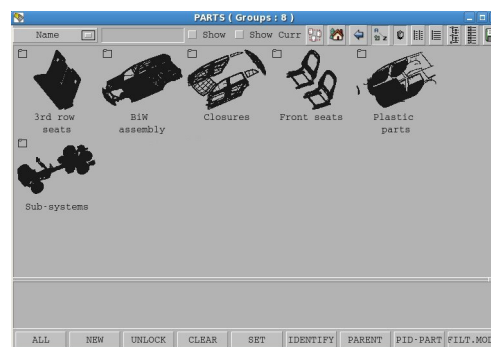

Figure 5. ANSA Parts Manager.

Through the ANSA Data Management a suitable mesh representation can be called for the front crash analysis. In addition the system will notify the user for any part updates that will be available for to be incorporated in the model. During the execution of the Common Model Task, the task manager verifies that there are no parts missing from the referenced sub-models.

### BiW Connections - Welding

The BiW connections come next in the order of the common model task. The data that can be retrieved from the ANSA DM is of the form of connection points and connection lines. The TM runs through every connection and verifies its realization. The connections are grouped per type such as spotwelds, spotlines gumdrops, adhesive lines, seamwelds, adhesive faces, hemming and bolts.
The connection entities are solution independent and their FE representation will be applied during the built-up of the solution specific loadcase.

### Model Assembly: The Connector Entity

Connectors are ANSA entities that are used to connect sub-models. Connectors can model any type of kinematic constrain that exists in the particular location. A connector entity is created with the following information:
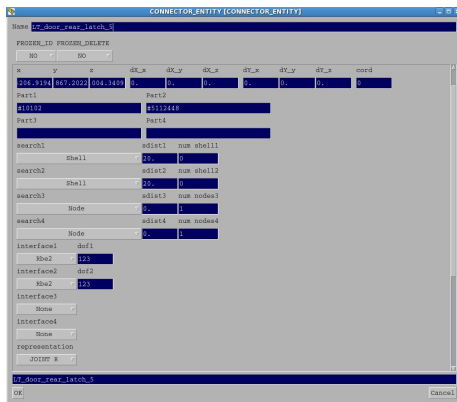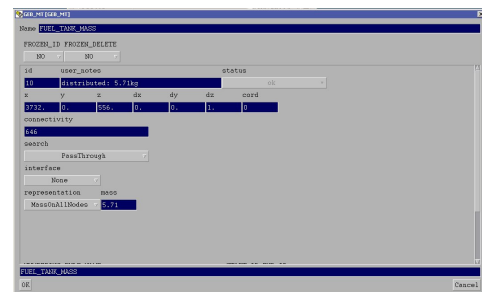


- The x,y,z location in space.
- Connectivity information. A connector can connect up to four different parts. In addition search type information needs to be given in order to find the parts in space
- FE Interface of the connector with the parts. For example RBE2, RBE3.
- FE Representation. It can be any type of built-in kinematic element or a custom made item called in through the ANSA DM as a library item.

The FE interface and representation are solution specific and they will be applied when the discipline common model, in this case DYNA common model, is created.

### Model Trimming: The Mass Trim Item

Mass trim items are entities that are used to add extra mass in on specific parts. The information needed for the application of the trim item id shown below:



- The x,y,z location in space.
- Connectivity information. Parts for the mass trim to be applied.
- FE Interface for mass elements. For example RBE2, RBE3.
- FE Representation. It can be any type of point or built-in mass repesentation or a custom made representation that can be called in through the ANSA DM as a library item.

During the execution of the model trim group of items, the task manager validates every single trim item with respect to availability of the part or properties that are referenced in the connectivity information.

With the completion of the *Common Model* task the assembly of model has a reached a level that is described below:

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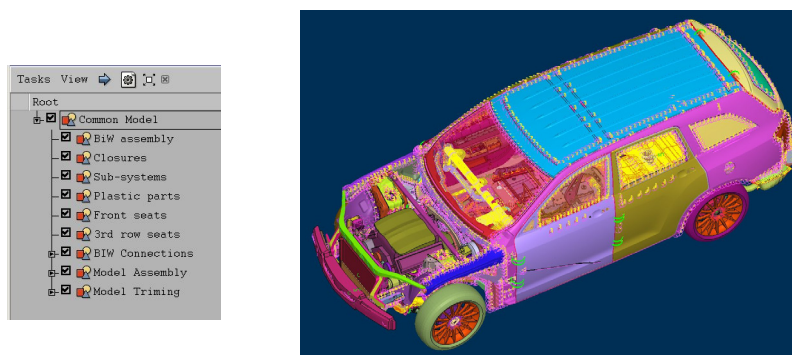


Figure 6. A completed Common Model.

# The LS-DYNA Common Model

The *LS-DYNA Common Model* is the group of items that tie together the *common model* and the *LS-DYNA load-case*. The *LS-DYNA common model* dictates the conversion of the *common model* to solver specific model.

As soon as the LS-DYNA common model gets called, the task manager switches the *Common Model* tasks to be adapted to entities that are suitable for an LS-DYNA analysis. All the common model items will be affected by this conversion, resulting to all of them getting unchecked. The *common model* needs to be re-run to adapt to the LS-DYNA requirements.
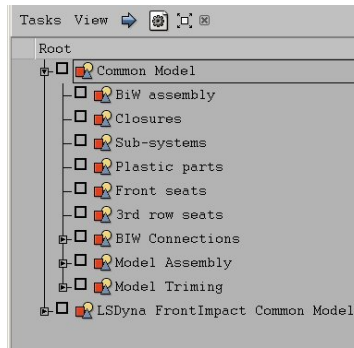
Figure 7. Task Manager with the new LS-DYNA common task.

The *LS-DYNA common model* is a group of tasks that are common to all the LS-DYNA load cases that will follow.

**Transforming the Common Model to a form suitable for frontal crash analysis**

During the re-run of the *Common Model*, the parts referenced by the sub-models items need to get a meshed representation based on the front impact analysis mesh requirements and BiW connections must be applied to connect the referenced parts with the required LS-DYNA entities. In addition the connector and trim item entities must also be applied with the required built-in or custom made representations. In the following paragraphs, the transformation of the common model is explored following the task sequence.

*Sub-model items: Fe-representation*

With the *LS-DYNA Common Model* task in the Task Manager, the common model sub-models will not get checked (validated) unless all the macro area or volumes are meshed. For each sub-model a proper representation needs to be retrieved from the ANSA DM, with the assistance of the *Part*
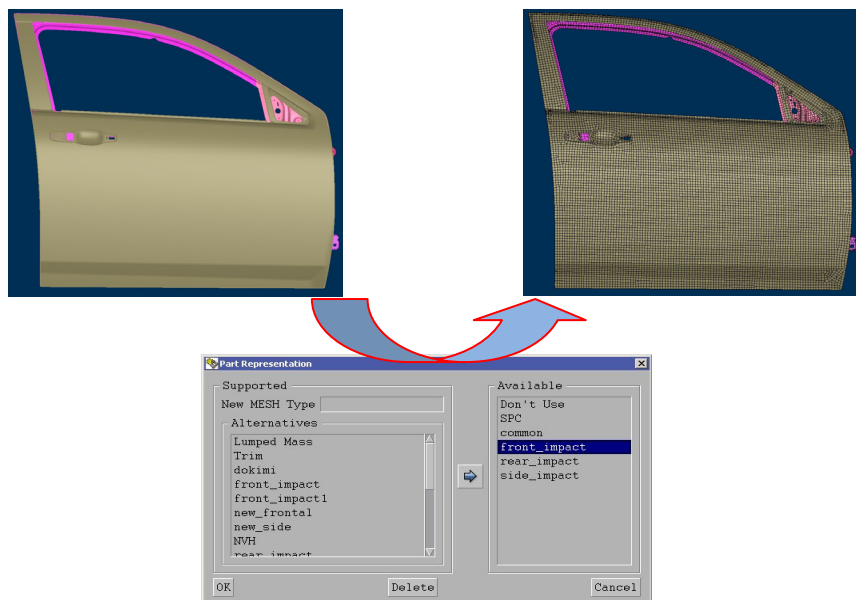
*Representation Manager*.



Figure 8. Retrieval of the front-impact mesh representation through the Part Representation manager.

The *Part Representation Manager* will look into the ANSA DM to find available representations. In the case where representations are not available for a sub-model or parts of a sub-model, the manager calls the batch mesher to mesh the parts and create the missing representations.
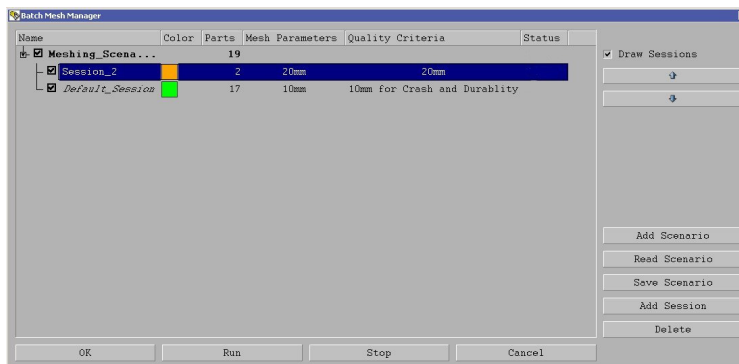


Figure 9. Batch Mesh Manager.

After the retrieval of all the required representations, the ANSA Task Manager verifies their definition with respect to unmeshed areas and volumes, and checks the items as valid.
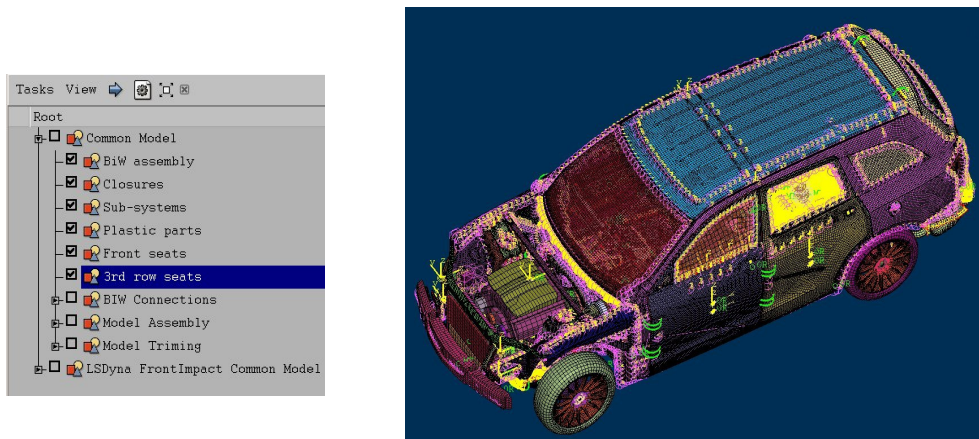


Figure 10. Front Impact Mesh representation of the model.

*BiW Connections: Realization of welding information*

The Task Manager will validate all the connections entities that are correctly realized per connectivity information and per LS-DYNA entities. The table below shows connection entities that are supported per LS-DYNA modeling requirements.
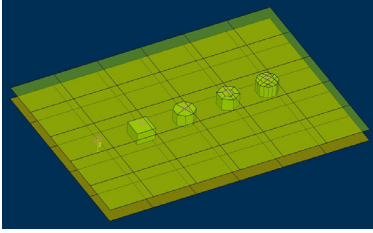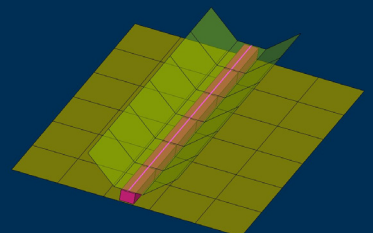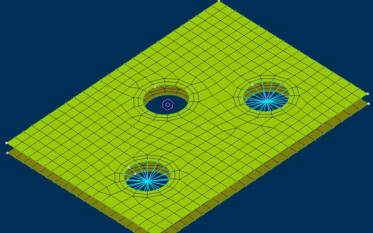
| BiW Connection type | | Description |
|---|---|---|
|  | | LS-DYNA Spotweld. They can be PBEAM or PSOLID with 1, 3, 8 and16 HEXA elements patent.<br><br>*DEFINE_HEX_SPOWELD_ASSEMBL Y card can automatically be created for all or selected spotwelds. |
|  | | Adhesive Line. Created from connection line data. The type of the connection is HEXA-CONTACT |
|  | | Bolt connections. Options are available for both the interface and the body. It this model the interface and the body are rigid bodies. |
| Table 1. Types of BiW connections | | |

*Model Assembly: Realization of Connector Entities*

The Connector Entities are applied during the execution of the Model assembly group of items. 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, 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 *CONTRAINED_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 custom made ones, retrieved as templates from ANSA DM libraries. LS_DYNA deck card values of the library items can also be parameterized so that they can be editable during the set-up of the connector.

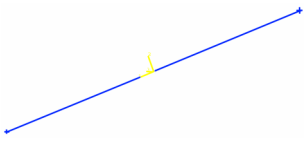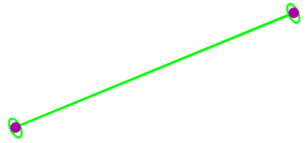Table 2 below summarizes the custom templates used for the representation of Connector entities.
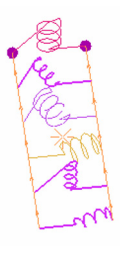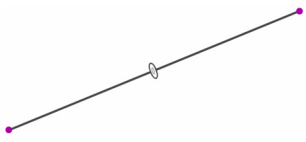
| Template in ANSA DM | Description |
|---|---|
|  | *ELEMENT_BEAM_ELFORM_1<br><br>Parameters: diameter, length and orientation according to application |
|  | *CONSTRAINED_JOINT_SPHERICAL<br><br>Parameters: Value of added mass on both ends |
|  | *CONSTRAINED_JOINT_REVOLUTE<br><br>Parameters: Value of added mass on both ends, orientation according to application |
|  | *ELEMENT_DISCRETE for 6 dofs<br><br>Predefined: *DEFINE_SD_ORIENTATION vectors, *SECTION_DISCRETE<br><br>Parameters: Value of added mass on both ends |
|  | *CONSTRAINED_JOINT_UNIVERSAL<br><br>Parameters: Value of added mass on central nodes, orientation according to application |
|  | *CONSTRAINED_JOINT_CYLINDRICAL<br><br>Parameters: Value of added mass on both ends, orientation according to application |

*Table 2. Parameterized templates for connectors retrieved from the ANSA DM library*

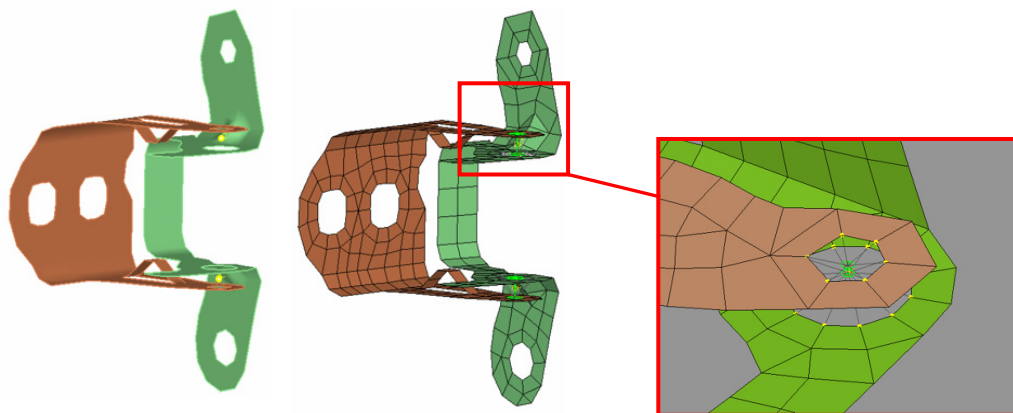Figure 11 below shows an example of Connector Entities realization.



Figure 11. Connector Entities before and after their realization of revolute joints.

*Model Assembly: Realization of Connector Entities*

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.

**Front -Impact Related Items**

As previously discussed, the *LS-DYNA Common Model* task items are common to all front-impact load-cases that may follow. Additional components may enter in the model at this stage:

1.  Dummies: Dummies can be inputted, positioned and restrained.
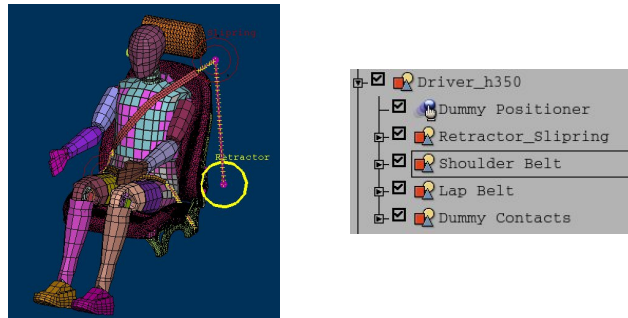


Figure 12. Dummy positioning and restraining.

2.  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 parts via a Mass Trim Items.
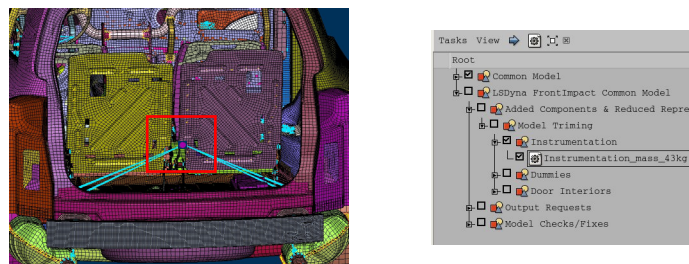


Figure 13. Instrumentation trim mass attached with nodal rigid bodies to the vehicle.

3. Closures interiors 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.
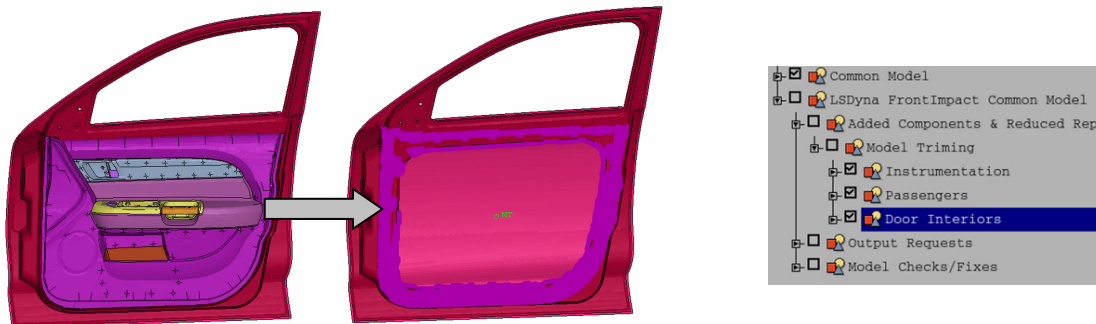


Figure 14. Trim representation created to replace plastic geometry.

The creation of section forces using the Output Request Generic Entities. The positions, cutting planes and the components cut are pre-defined in the Output Request Generic. 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 3).
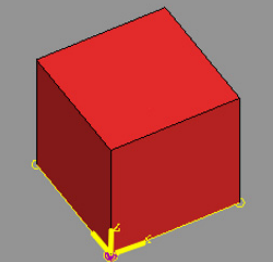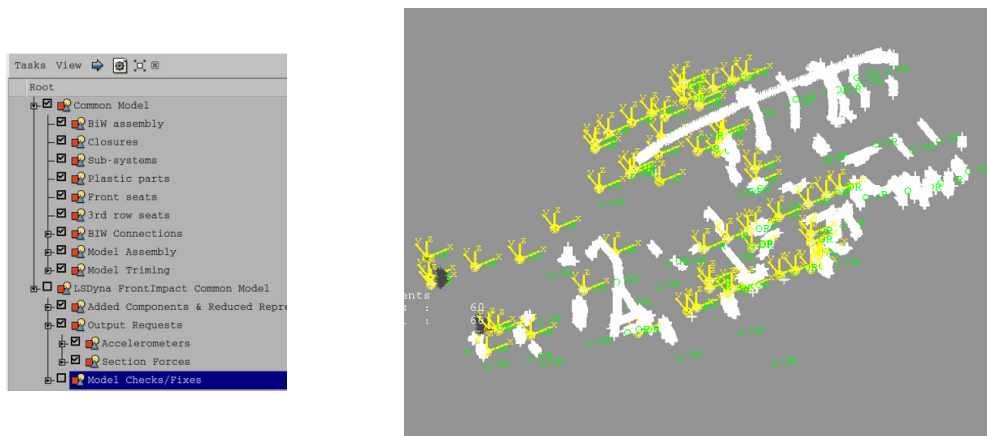
| Template in ANSA DM | Description |
|---|---|
|  | *ELEMENT_SEATBELT_ACCELEROMETER<br><br>Each accelerometer is attached on a 10x10x10 rigid hexa element. A mass element is attached to the accelerometer reference node. |

*Table 3. Custom template for accelerometer sensor, retrievd from the ANSA DM library*



Figures 15: 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. The model built up to this stage can be used for the creation of any LS-DYNA front-impact load-case.
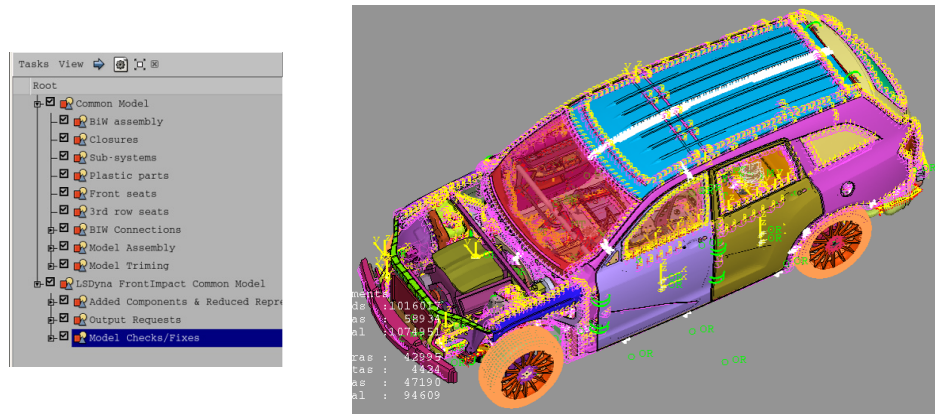


Figure 16. LS-DYNA front-impact Common Model completed

## 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 17-18 show the items added sequentially by the *LS-DYNA Load-case*.
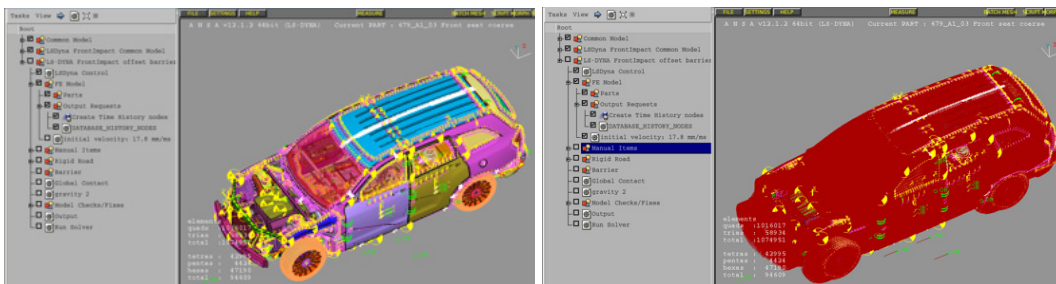
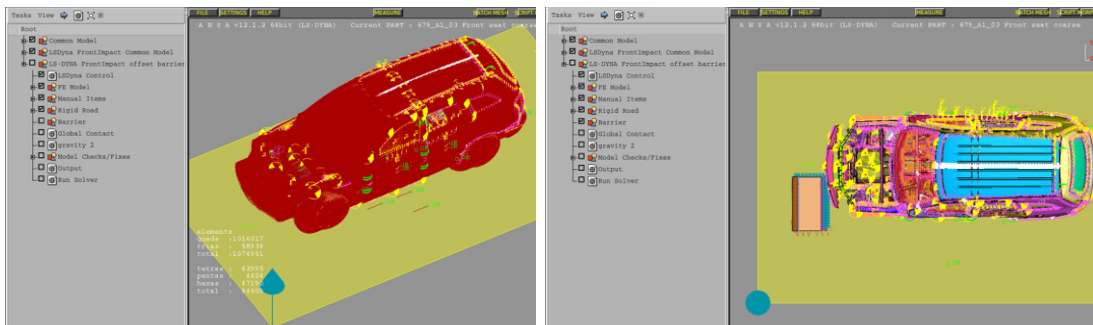Figure 17: Addition of time history nodes and initial velocity.


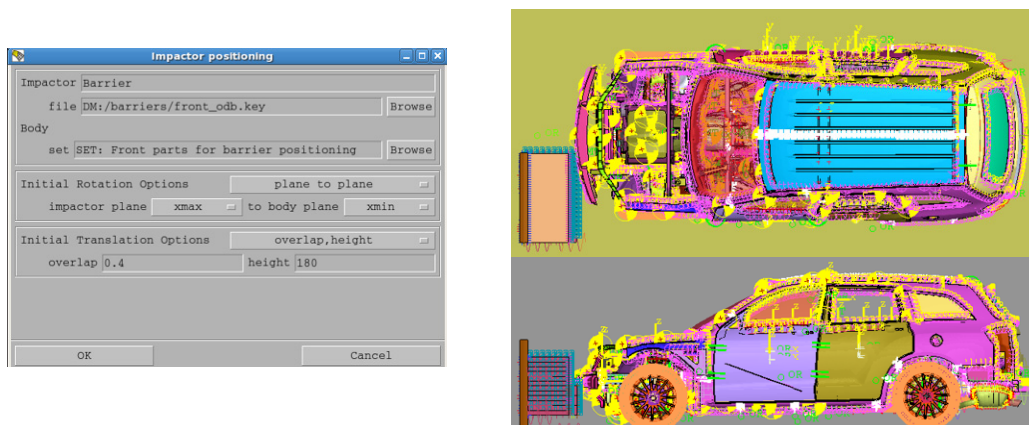Figure 18: Addition of rigid-road and barrier.


Figure 19. 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 20
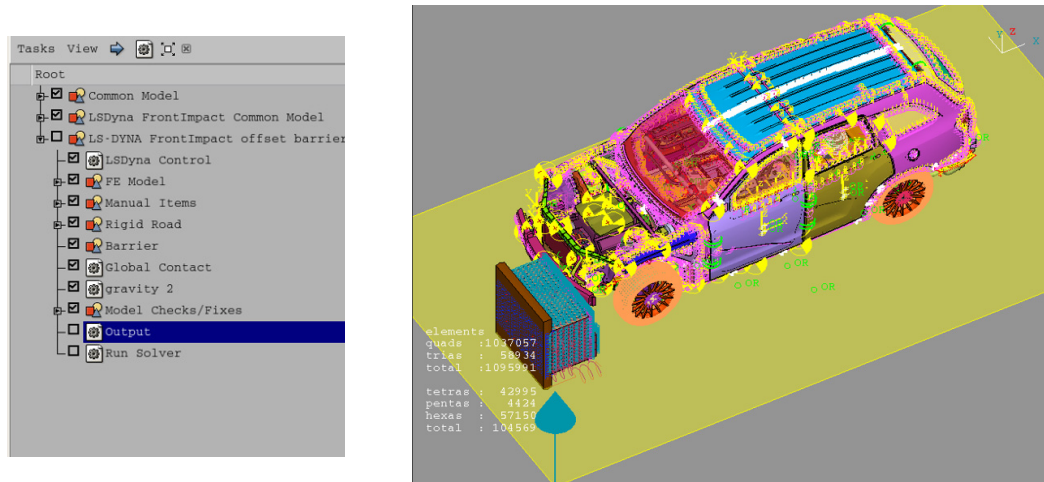
Figure 20. LS-DYNA Front-impact 40% offset 64 km/h complete model

## 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.

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.

## References

1.  Makropoulou, I., "Template Driven LS-DYNA Model Build-up with ANSA Task Manager", 6th LS-DYNA Anwenderforum, Frankenthal, 2007.

2.  Nikolaidis, G., Zafeiropoulos, D., Ntamagkas, K.,"Building Discipline Specific FE-Models with the Common Model Concept", 2nd ANSA & META International Congress, Halkidiki, Greece, 2007.

3.  Pavlidids, V., Trifonidis, M.,"Automated Built-up and Analysis of NVH Models with ANSA/META Package", 2nd ANSA & META International Congress, Halkidiki, Greece, 2007.

4.  BETA CAE Systems SA, "ANSA Data Management Users' Guide", ANSA v12.1.3 Documentation, Thessaloniki, Greece, 2007.

5.  BETA CAE Systems SA, "ANSA User's Guide" ANSA v12.1.3 Documentation, Thessaloniki, Greece, 2007.

6.  Halquist, J.O., LS-DYNA® Keywords User's manual. Version 971, Livermore Software Technology Corporation, Livermore, 2007.