

# Creating a complete crash model with GNS. High accurate Barriers, handy preprocessing with dummy positioning and fast tailored result analysis

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## 1 Abstract

The current transformations in the automotive industry are forcing all car manufacturers to check their processes constantly and repeatedly for economic efficiency. Regarding the areas of body development, vehicle safety and occupant as well as pedestrian protection, economic efficiency can only be achieved through a high degree of automation in virtual product development.

Such a degree of automation is only feasible, if the software used and the integrated models are well coordinated.

In this presentation it will be shown how a high precision barrier model and several dummy models can be combined and positioned for any vehicle model within the pre-processor Generator4 with ease. Both direct positioning tools and simulation driven ones can be fully automated in a simple way. Information on positioning and kinematic relationships can be taken directly from the input files. This simplifies the following processes and reduces the error rate due to less manual data input. Generator4 is then able to directly start the simulation with LS-Dyna or other solvers.

After the simulation, the generated result files can be evaluated with the postprocessor Animator4. Predefined session files are available for obtaining all the result values defined by the commonly used regulations. Curves, images, videos, and slides in standard format can be generated directly in Animator4 for the management-suitable presentation.

This short-coordinated sequence can be completely encapsulated and integrated into larger data management systems or HPC environments. In this way it is possible that the interactive work of the simulation engineer and the automated generation of variants is carried out in the same software with identical work steps.

## 2 Motivation

In an industry that is constantly evolving and reducing the development cycles, a key aspect for the success of any vehicle design nowadays is the reduction of the processing times when it comes to simulation and FEM.

This reduction of times must also come with an increase of reliability of those created models and their postprocessing and evaluation.

This is only possible with accurate models and powerful pre- and postprocessing software that allow for a high automation of the daily basis work yet leaving space for the different users to tailor these processes to their own needs in an easy way.

Generator4 and Animator4, the FEA pre- and postprocessors from GNS mbH target this necessity and are constantly evolving and improving to offer or worldwide clients with reliable solutions.

To ensure a comfortable and automated process, one of the recently improved and expanded rating tests, the NCAP frontal impact test, was taken as reference case.

Starting in 2020, the NCAP organization assesses vehicle safety for frontal impacts tests performing a frontal car to barrier crash, which is held with a new designed Movable Progressive Deformable Barrier (MPDB).

The test vehicle is equipped with a THOR 50th percentile male dummy (THOR50M) on the driver seat and a Hybrid III 50th percentile male dummy (H-III 50M) on the front passenger seat.

In the second row, a Q10 dummy is placed on the struck side while the Q6 dummy is seated on the non-struck side, the results of which are used for the Child Occupant Protection assessment in Euro NCAP.

The overlap is moderate at 50 percent of the total vehicle width. The moving trolley carries the progressive deformable barrier on the front outboard side and has a mass of 1400kg, as shown in next picture.

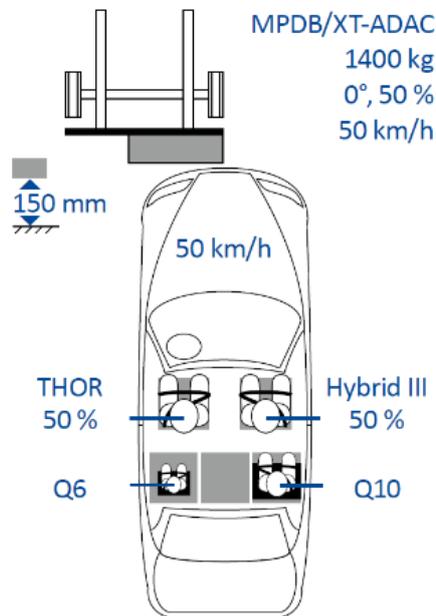


Fig. 1: Front crash test assessment protocol according to NCAP [2]

This test is used as procedure for different NCAP organizations around the world from 2020. With some of the largest automotive markets using this assessment, the new test rating is crucial for the success of any product

Generator4 and Animator4 can help the engineer to set up, start and evaluate such test simulations, using complex models such as the MPDB barriers or anthropomorphic dummies. Calculating the loads on the occupants and the deformation in the barrier becomes an easy task.

To ensure the required accuracy levels and improve the process workflow, GNS targeted three crucial aspects:

- Develop a good and highly reliable Barrier model for the complex MPDB.
- Create a tailored barrier positioning dialog, specially designed for the new barrier requirements.
- Offer a comfortable and precise method to position any dummy models. (THOR, child and ATD models, but also any other dummy such as for example: Human Body Models)
- Offer an automated way to perform the evaluation of such calculations.

### 3 Used models

To set up a crash model to reproduce the NCAP front test procedure, the following models were used:

#### 3.1 Vehicle: NHTSA Honda Accord

A full vehicle finite element model with interior and occupant restraint systems for the driver and front-seat passenger. The finite element model represents a Honda Accord mid-size sedan. [8]

### 3.2 Barrier: MPD Barrier model developed by GNS

According to the barrier specifications [3], the impactor consists of three stacked aluminum honeycomb blocks:

- The front block offers constant levels of force with deflection.
- The middle block has been processed to give a progressively increasing level of force with increasing deflection.
- The rear block offers again a constant level of force with deflection.

The rear block is then bonded to an aluminum back plate which is also used for mounting the impactor. The three blocks are bonded by three aluminum sheets and the entire impactor is covered by an aluminum skin (cladding) riveted to the front face.

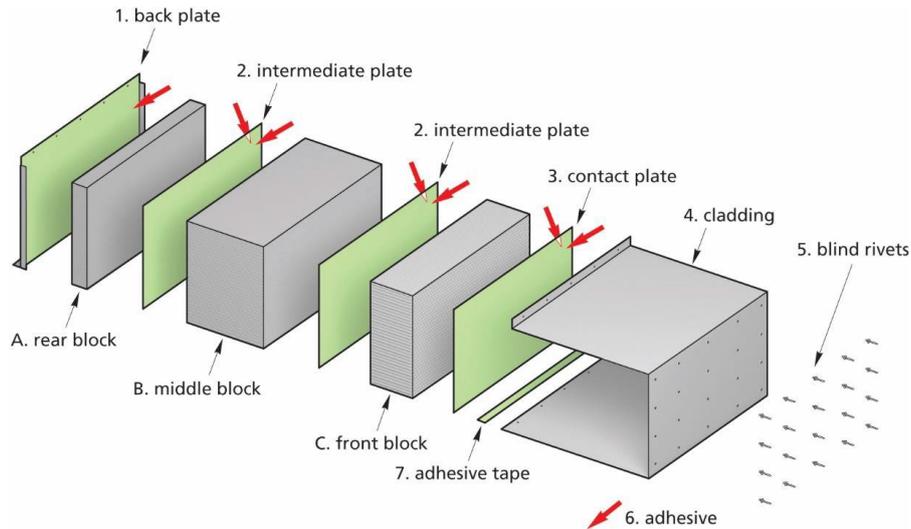


Fig.2: Exploded isometric view of MPDB [3]

This deformable impactor is then attached to the moveable trolley conforming to the specifications of Technical Bulletin TB022 [3], taking into consideration that the outboard edge of the MPDB must be 850 ± 10mm from the centerline of the trolley.

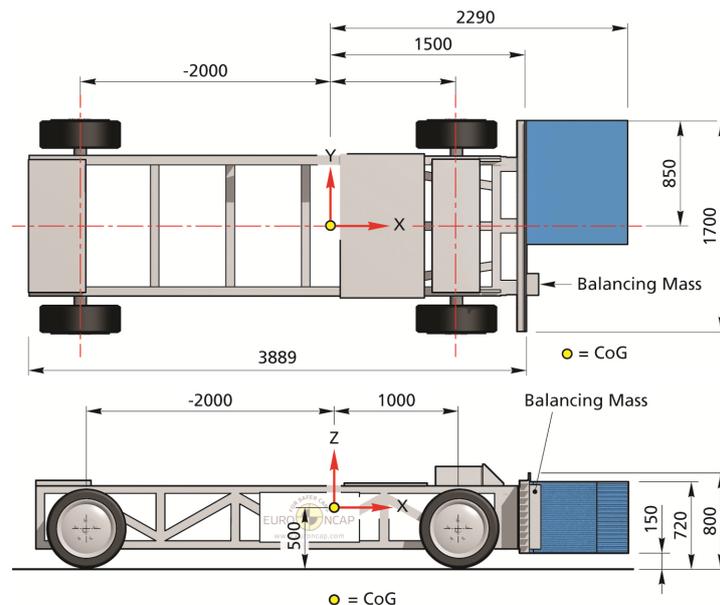


Fig.3: MPD Barrier and trolley specifications [1]

This barrier model has to be tested both statically and dynamically in order to be validated and considered suitable for its usage at the NCAP test.

As it can be seen, the necessary requirements for the new barriers and their design have been increased with the objective of representing as accurately as possible the reality of traffic accidents.

In the same way, the requirements, and expectations for the virtual models of these barriers are bigger now. With models reaching high levels of complexity in terms of modeling the materials or the geometries. Good example of this is the modelling of the aluminum honeycomb blocks or the glue used between them. Representing the geometries of the deformable honeycombs and the dynamic behavior of the contacts involved is a great challenge.

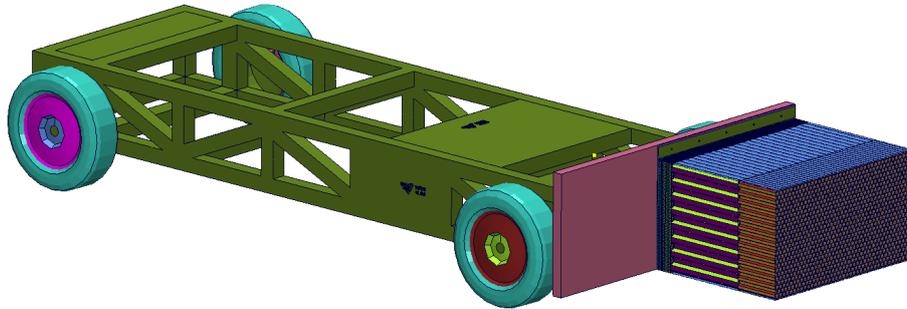


Fig.4: GNS mbH own F.E. MPDB model.

To meet the needs of the market in this regard, GNS mbH has developed an MPDB barrier model, making use of a great experience of more than 20 years in the field of numerical simulation. Providing accurate results and ensuring clean and reliable simulations, the model frees the engineer and allows him to focus on product design, thus achieving better results in terms of safety.

### 3.3 Driver dummy: THOR 50% model from

The NCAP test specification refers to the usage of an advanced frontal-impact 50th percentile adult male ATD. The virtual model from ATD-MODELS GmbH was chosen.



Fig.5: Used model for THOR 50% dummy

### 3.4 Passenger dummy: ATD H350 model from ATD-MODELS GmbH



According to the test specification an ATD H350 must be seated at the passenger seat. In this case the virtual model from ATD-MODELS GmbH is used. This model was chosen for the project thanks to its handling easiness that couples perfectly with the GNS software solutions. On top of that, the model present enhancements such as:

- Pre-tensioning of the chest and jacket
- Pre-tensioning of the joint buffers
- Realistic mapping of the geometries

Fig.6: Adult H350 dummy model from ATD-MODELS GmbH

### 3.5 Child 1 dummy: Q10 dummy model from Phitec Ingegneria srl

A 10-year-old child is used also for the NCAP front test. In this case placed at the rear part of the vehicle, on the struck side. In this case the model used is courtesy of Phitec Ingegneria srl, being positioned and its belt adjusted during a pre-process simulation produced with Generator4.

### 3.6 Child 2 dummy: Q6 dummy model from Phitec Ingegneria srl

The last occupant included for the NCAP front test is a 6-year-old child, seating on the non-struck side of the vehicle at the rear seats.

For this dummy, also a model from Phitec Ingegneria srl was used, taking advantage of its accuracy and ease of handling within Generator4 for the positioning process.

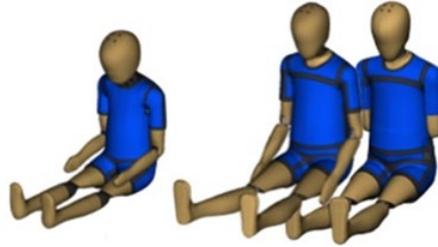


Fig.7: Child dummy models from Phitec Ingegneria srl

## 4 Preprocessing of barrier and dummies

Generator4 is a general-purpose preprocessor, combining the car safety functionality with geometry treatment and mesh generation under a friendly user interface, characterized by its flexibility and easiness.

Available for both Unix and windows platforms, allows the users to set-up LS\_Dyna© models as well as those from other F.E. solvers.

Among the different GNS products, Generator4 stands out in the field of vehicle safety, taking dummy, impactor, and barrier positioning as its very best.

### 4.1 Barrier positioning

Good example of this, is the dedicated “Barrier Position” dialog, allowing the engineers to position all types of crash barriers in an intuitive, quick and accurate way.

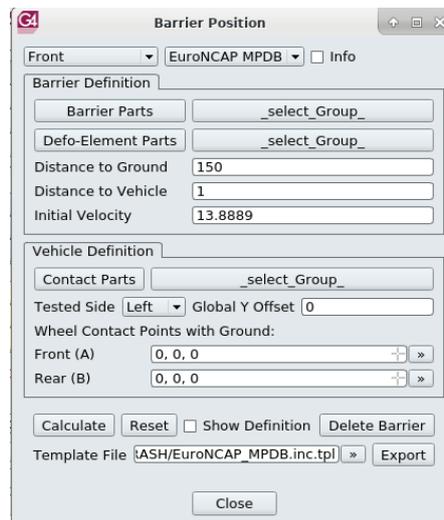


Fig.8: Generator4 customized dialog for MPD barrier positioning.

Graphically picking the used properties to model the barrier and the external parts of the vehicle in contact with it together with the vehicle center definition are enough for automatically positioning the new MPDB models according to the new test regulations.

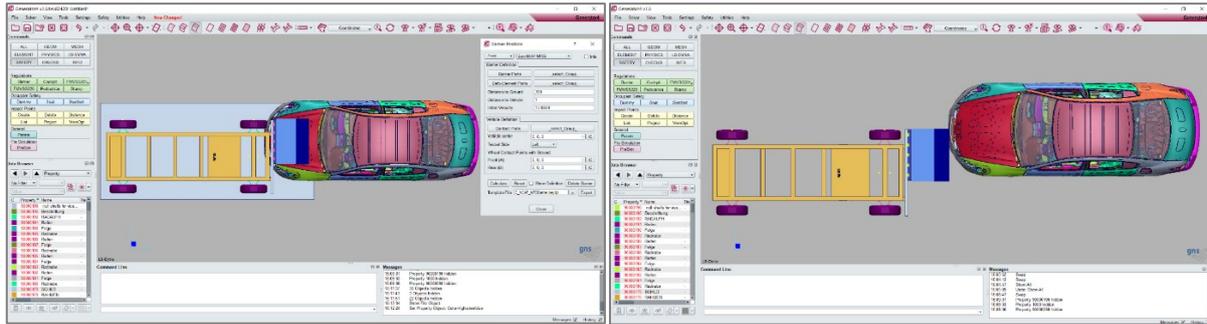


Fig.9: Generator4 barrier positioning process

Once the desired position is reached, Generator4 offers the possibility to store the position in an easy-to-handle solution based on customizable templates. By taking advantage of the template approach, the necessary definitions used by LS-Dyna© are obtained.

This includes not only the `*DEFINE_TRANSFORMATION` keyword used for the positioning itself, but also the additional `*SET` and `*CONTACT` definitions that must be present between the barrier model and the tested vehicle.

Moreover, all these definitions are created and exported in an extra key-file that can be directly packed along with the rest of the model, without having to adapt any of the other key-files. This ensures a flexible and easy to manage model structure, while decreasing the human error factor.

## 4.2 Dummy positioning

With increasing levels accuracy in all aspects of the crash modelling, the position of the different dummies and its effects on their surroundings has become a key aspect of good modeling practices. Requested is not only an exact dummy position, but also a realistic deformation of the seat cushions, pretensions, and material effects on the model.

Special energy is being taken on obtaining realistically deformed belt systems, where the complexity of the dummy position and other external systems such as kid seat-boosters play a key role.

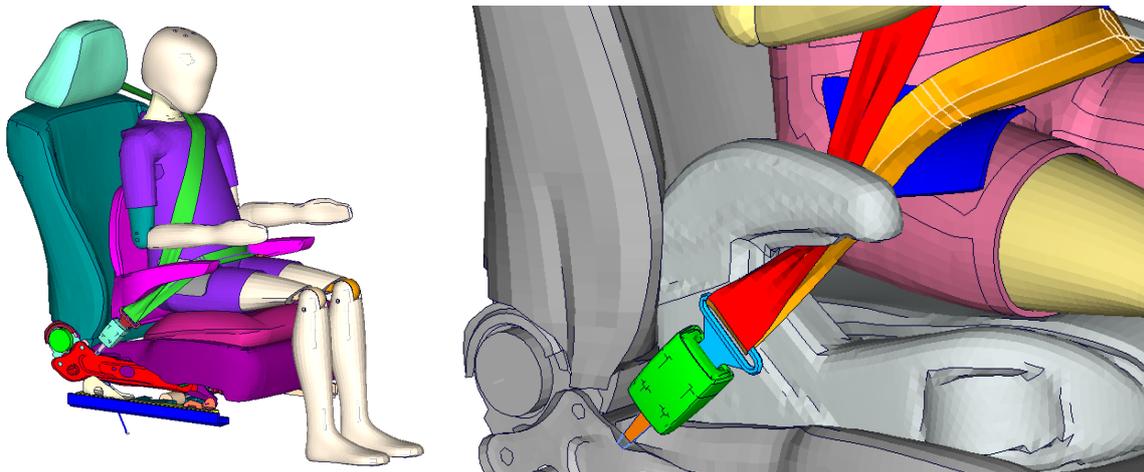


Fig.10: Q10 dummy model positioned using Generator4 and its simulation-based process. Realistic belt deformations at narrow or intricate areas.

Generator4 has a specific dialog for seat positioning as well as its own for dummy positioning.

This dialog is designed to position and articulate the dummy based on its mechanism or articulation definitions via intuitive actions. It offers different tabs that structure the different actions:

- **Transform:** To define the dummy general transformation and rotation, also offering an overview of the current position and several options to manage the articulation definition files.
- **Articulation:** To adapt the joint angles and position of any articulation or lumbar definition. It offers a good overview of the dummy structure and its position thanks to the tree representation of all the articulations.

For each articulation, several positioning methods are offered. From directly setting the desired angle to make any of its nodes up at a concrete position.

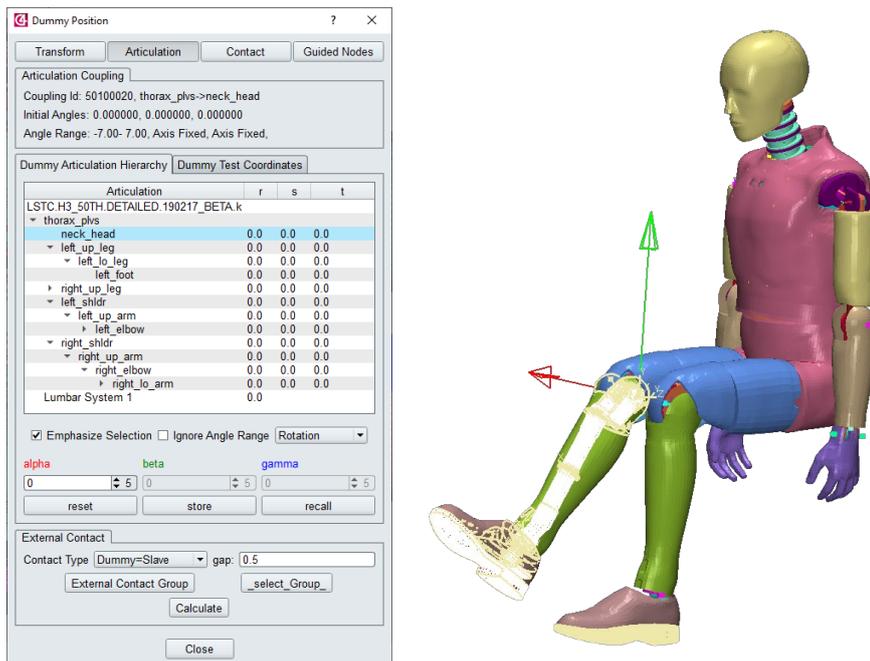


Fig.11: Dedicated dummy positioning dialog from Generator4

Everything can also be done in a single step with the help of a list of points and destination coordinates for them.

This technique is available at the "Dummy test coordinates" tab and results specially interesting when having measurement data from an already driven test, or predefined positions. Generator calculates all necessary adjustments to the joints and the H-point to achieve this position in the best possible way.

The last two tabs of the dedicated dialog, give access to some extended actions:

- **Contact:** To detect and remove internal penetrations within the dummy itself.
- **Guided nodes:** to define the so-called "Guided Nodes". Normally used in simulation-based positioning, they are nodes recommended by the manufacturer for the puppet method and similar pre-processing techniques.

Once the desired position is reached at the preprocessor, some penetrations may appear between the dummy and the seat or within the dummy itself. Also, the belt should be adapted to a new shape.

Although Generator4 offers several tools to adapt the belts and avoid penetrations between the dummy and the seat cushion using its own embedded implicit solver (OFSolv), for large deformations where the dummy shape itself may become transformed, an external solver-driven positioning is recommended.

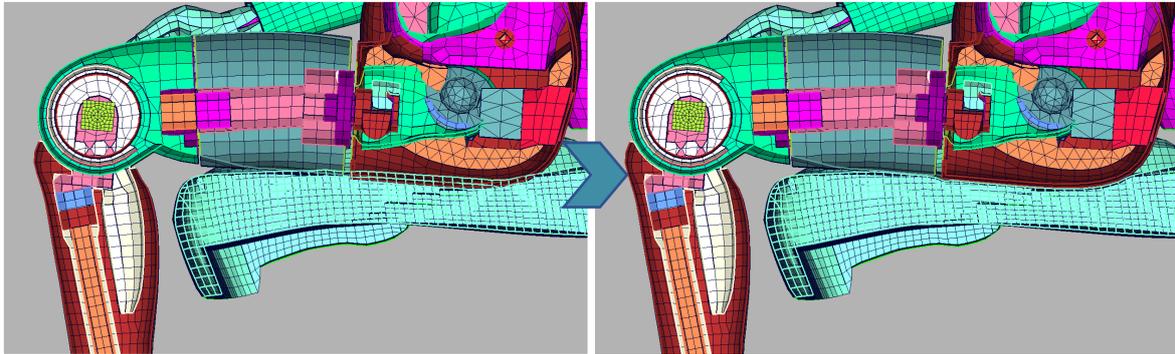


Fig.12: Seat-dummy penetrations removed in Generator4, using its embedded implicit solver.

Due to the increased complexity of both the dummy and seat models, the definition of these processes tended to be cumbersome and time consuming, especially considering that it is a process to be carried out repeatedly and for models with similar characteristics.

With its PreSimulation module, Generator4 offers a clear and simple answer to this need, while also adding important improvements to the usual process.

The module offers several tools to build up all required definitions in an easy way, basing the definition on the so called “Operations”, “Steps” and “actions” that structure the process. Thus, the user can design the process in a natural way, leaving all the technical and solver specific definitions to Generator4.

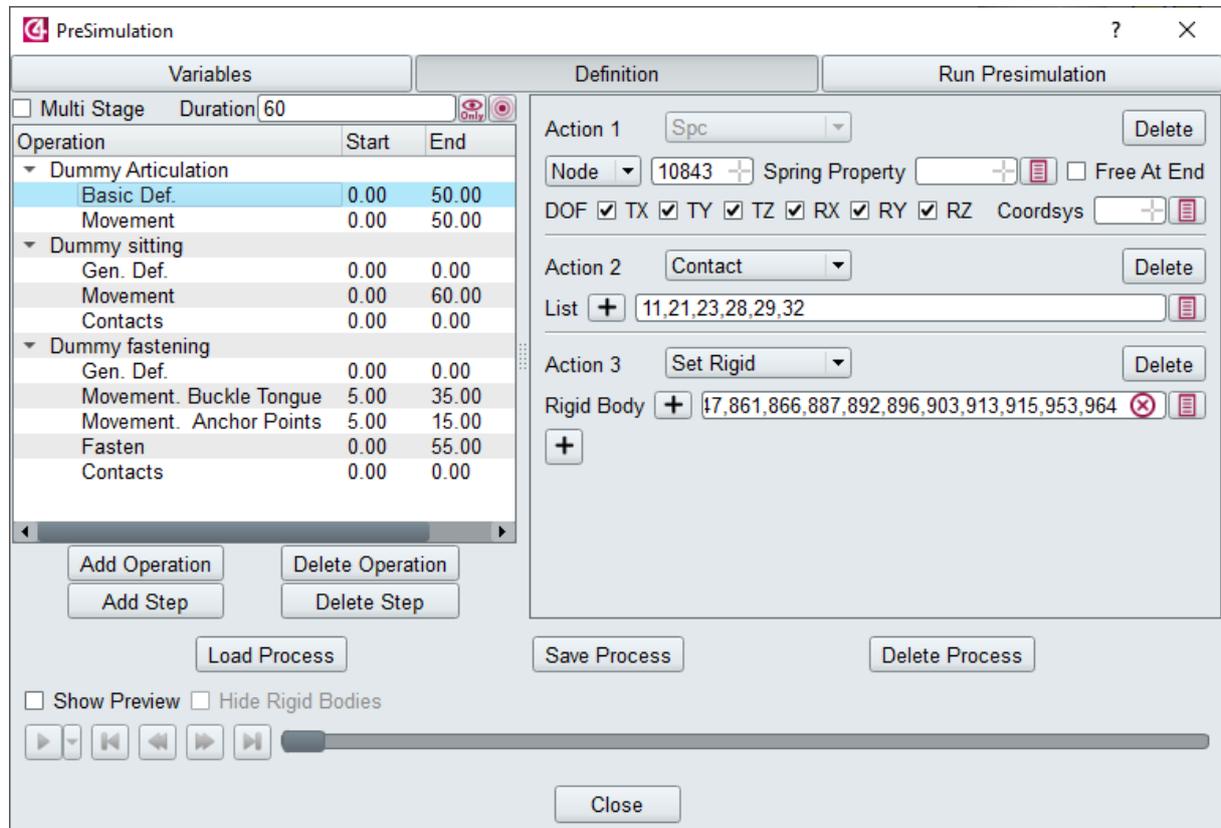


Fig.13: PreSimulation dialog in Generator4. Process definition used for positioning and fastening the H350 model used for the NCAP front test procedure.

The defined process is represented at the dialog, giving a powerful representation of the complete process at one glance. Moreover, the preview options offered, add an extra tool for checking all the definitions done.

Once the process is defined, it can be directly sent to the external solver to be calculated. The calculations can be submitted either locally or remotely and the results can be automatically imported afterwards to continue with the modelling process, based on obtained results.

Processes can be also stored in an XML-based format, allowing the user an easy and fast access to realized work. Engineers can take advantage of this to use the same defined process for different dummies or positions.

Thanks to the storage and reutilization of defined processes, defining significantly more complex methods is rewarding and even convenient.

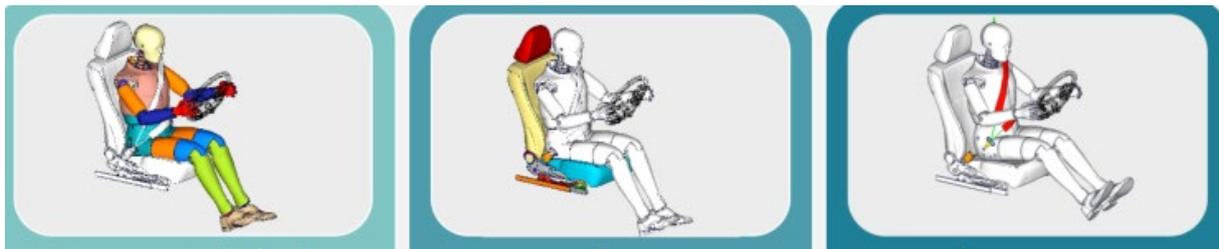


Fig.14: Calculating the dummy articulation, seat deformation and belt fastening process within the same simulation-driven positioning process with pre-defined processes.

While articulating the dummy to its final position, it is possible to calculate the deformation of the seat cushion or even simulate a realistic fastening process for the dummy seatbelt simultaneously.

The calculation of the seat belt adjustment provides several benefits to the user: Compared with the position obtained with any other pre-processing/geometric procedure, a much more realistic adjustment is achieved. It becomes possible to obtain tension values in the chest of the dummy or the retractors. On top of that, manual readjustments of the model and its mesh for the various required positions is avoided. From this derives another advantage to be considered: the engineer can afford the use of much more complex models, since a single model is valid for any dummy and position.

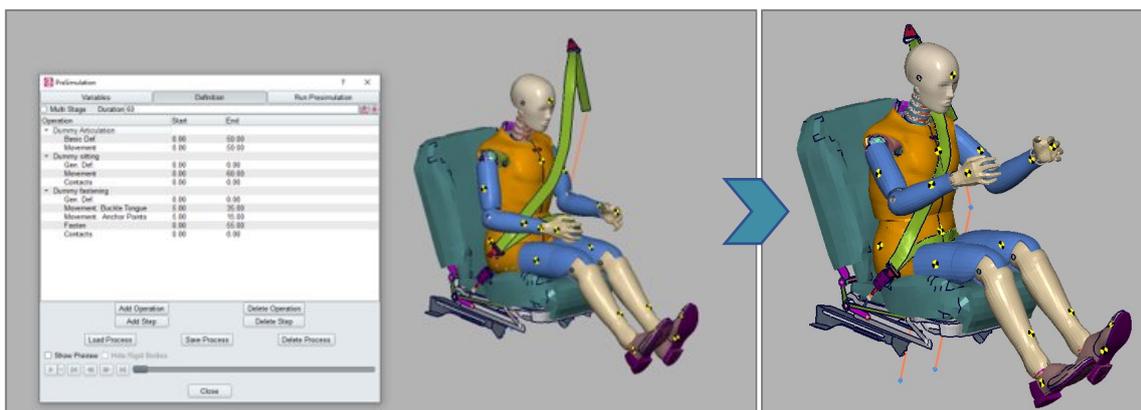


Fig.15: Definition in Generator4 PreSimulation's module of a process for dummy positioning, seat deformation and belt fitting. Results shown at the right side.

## 5 Postprocessing of simulation

### 5.1 Process of postprocessing

Postprocessing a large number of simulations is a very time-consuming task in current automotive engineering. As the number of regulations and assessments grow on the different markets; the number of key values that must be extracted from the simulation data also increases.

Since these generation of results must be reliable and comparable, automation is a concept which can be very helpful at this point.

Standardized fact sheets sum up the results and give the management a helpful overview about the achieved development results.

As the target values are defined, the measured nodes are defined by any up-to-date SDM system, the calculation of key results can be integrated in an automated job handling process very easy.

Looking at the used example, Animator4 is able to calculate the intrusion and standard deviation of the deformed barrier, checking for bottoming-out and for all occupant related safety values. These calculated results are presented on a pre-defined presentation template. They are also stored as Animator4 variables. These enables a usage of the result values on user-added presentation sheets or the export of the key values for following process steps outside of Animator4.

For example, the Euro NCAP spreadsheet can be filled from an exported ascii file.

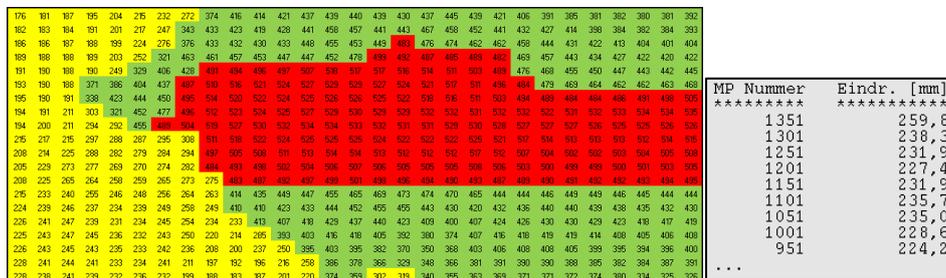


Fig.16: Euro NCAP spreadsheet filled with values, exported from Animator4

### 5.2 Definition of the process steps

All the definitions needed in the process, relation between nodes in the simulation model and measurement points in the regulations, are defined in XML files. Customer specific limit values are defined there also.

XML as file format offers a possibility for highly automated processes and is also human readable. This enables the users to adapt predefined workflows to their specific needs, by changing small parts of the definition files.

## 6 Summary

GNS offers a large package of tools around automotive safety development. Starting with the new area of barrier development, where not only the MPDB but also an ODB and AEMDB barrier are available for dyna as solver. Followed by the preprocessor Generator4, originating from the safety development and on the way being a feature complete preprocessor for FEA analysis. Animator4, the postprocessor, helps the engineer getting an overview about the large amount of data.

The two pieces of software can be used in interactive work, as well as integrated in batch processes controlled by different SDM systems ad job control software.

This leads in the end to a fast and standardized process which saves costs and time. The clear and unified documentation which results from the process enables you to focus on product quality and deliver successful products to the end-customer.

## 7 Literature

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