

VEHICLE LEVEL UFEA PROCESS USING ANSA, ABAQUS AND SIMULIA SCENARIO DEFINITION

¹Martin Roswall (Speaker), ¹Raphael Bois, ¹Marc Schrank, ¹Yangwook Choi and ¹Sridhar Sankar

¹Dassault Systèmes Simulia Corp., Providence, Rhode Island, USA

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ABSTRACT – Significant challenges confront the automotive industry today, including increasingly stringent fuel economy and emission reduction regulations; stricter crashworthiness and occupant safety legislation; quickly evolving customer preferences; and the ever-increasing market demand for better vehicle performance and reliability.

Simulation can be a key enabler in addressing these challenges; increasing sophistication of simulation software along with continuing gains in high performance computing are making this possible. Robust simulation processes that can be efficiently and repetitively executed are an important factor in achieving the full potential value of simulation. At the full system or full vehicle level, the relevant models are very large and complex; hence assembling the models, executing the simulations, and evaluating simulation results can be somewhat inefficient and error-prone. Incorporating proposed design changes during the vehicle development cycle further complicate the processes.

A workflow has been established using ANSA, Abaqus, and Scenario Definition to efficiently and robustly perform a wide range of performance attribute simulations at the system level. These performance attributes include stiffness, mobility, and crash simulations for targeted models, including body-in-white, body-in-trim, and full vehicle. Scenario Definition is used for overall process and data management and Abaqus is used to execute the performance attribute simulations. The workflow also leverages the capabilities available in ANSA with the use of key features, such as the Generic Entity Builders and Connectors, along with the ANSA Task Manager. With the help of ANSA Task Manager, ANSA Task templates are created, enabling a fast and efficient way to generate run-ready Abaqus input files for the targeted models and simulations. Another important benefit gained from utilizing ANSA Task templates in conjunction with Scenario Definition is that it is then very straightforward to incorporate a proposed design change into the targeted models and subsequently spawn a new series of simulations to determine the impact of the proposed design change. The established workflow also involves the use of μETA for post-processing of the Abaqus results. By using the scripting capability and the built-in Report Composer tool in μETA, customized analysis reports are automatically and efficiently created during the post-processing session for each of the performance attribute simulations.

TECHNICAL PAPER –

1. INTRODUCTION

The automotive industry today is confronted with perhaps some of the most significant technical challenges in its history. In most regions of the world, regulations and legislation are being enacted to enforce higher fuel economy and/or lower tailpipe emissions. Figure 1 shows this trend throughout the world over the past several years, as well as projecting forward for the next several years [1]. In all cases, the trend is upward, and in some regions, the impending regulations are forcing a substantially greater emphasis on improving fuel economy.

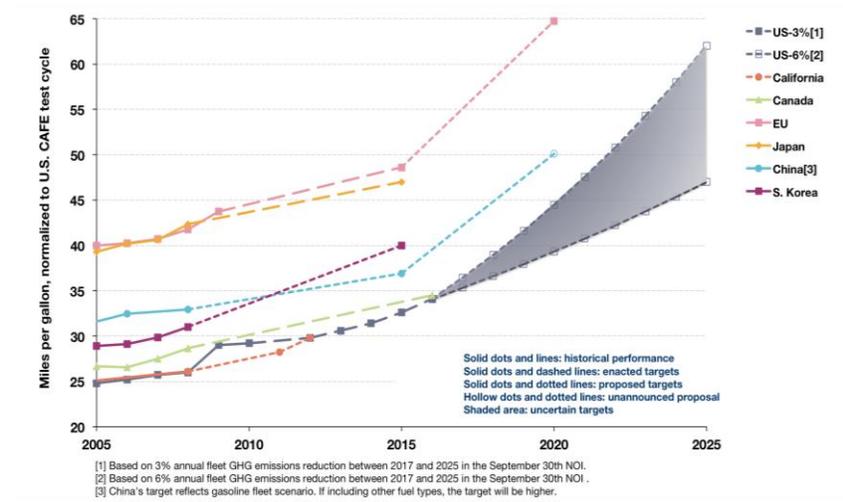


Figure 1 - Actual and projected fuel economy for new passenger vehicles by country/region

In order to meet these stricter requirements, automotive companies are looking to improvements in powertrain technologies, both for internal combustion engines, as well as new powertrain systems, such as hybrid and electric powertrain systems. In addition, reducing vehicle weight continues to gain increasing importance in order to improve fuel economy.

Crashworthiness and occupant safety is another area affecting vehicle design where regulations and legislation are becoming more strict. The National Highway Traffic Safety Administration in the U.S. is in the process of enacting changes to its safety rating program that will be the “most significant since the rating program began in 1979” [2]. Similar changes are underway in Europe and other parts of the world [3].

These challenges, along with quickly changing customer preferences, and the ever-increasing market demand for better vehicle performance and reliability require automotive companies to rethink past approaches and to find better ways to design better vehicles at lower costs in shorter time. Simulation provides a strong opportunity and means to bring about some of the necessary cost efficiencies, while at the same time providing the platform to help drive innovative product development. Moreover, simulation methods continue to advance in sophistication as well as the level of fidelity and accuracy they can provide. This ongoing evolution is partly fueled by the relentless geometric growth in the capacity and availability of high performance computing, as illustrated in Figure 2 [4].



Figure 2 - Computing capacity growth at Top 500 sites worldwide

Ever-advancing simulation methods coupled with the availability of necessary computing resources laid the groundwork to implement a truly simulation-based approach to automotive development at the system-level. Rather than exercising simulation only to verify a final design or to better understand problems that were detected during physical testing of prototypes, a simulation-based approach to design allows for the virtual vehicle to be virtually tested and evaluated at every phase of the development cycle.

A simulation-based approach to automotive design requires more than improving simulation technology and widespread availability of high performance computing in order to be successful. “Simulation-based” infers that simulation is ubiquitous, that it permeates the entire design process. Hence, the simulation user base necessarily has to expand, and it cannot be expected that today’s relatively small community of simulation experts will expand commensurately. Simulation therefore must be presented and made available in such a manner that is effective for a growing community of users that are not trained as simulation experts. This is enabled by providing a scalable suite of simulation products and is an important part of SIMULIA’s vision for Unified Finite Element Analysis (UFEA).

In the automotive industry today, several other issues exist that impede a truly simulation-driven design. Disparate tools are often used along with approaches that in some cases can be considered out-dated. These disparate tools can lead to disconnected islands of knowledge and expertise, resulting in lack of efficiency and insufficient collaboration between the different groups and disciplines that are contributing to the vehicle design and development. Inefficiencies also exist in incorporating design changes in the simulation process and understanding their subsequent impact. From a project management perspective, it is difficult to generate and gather up-to-date information on all performance attributes in order to make informed design decisions.

SIMULIA’s vision for UFEA includes a scalable suite of simulation products that can encompass all potential users, regardless of their expertise at simulation. This enables seamless collaboration among all the stakeholders, not only those that carry out simulation, but those that “consume” the results of simulation in order to make better design decisions.

2. SIMULATION WORKFLOW OVERVIEW

To demonstrate SIMULIA's vision for UFEA, proof-of-concept of a simulation workflow has been established that uses SIMULIA's Scenario Definition and Abaqus, and BETA CAE Systems' ANSA and μ ETA to efficiently and robustly validate a range of performance attributes at the system level. Performance attributes (Figure 3) refers to a collection of product characteristics that needs to be measured in order to support design and validation.

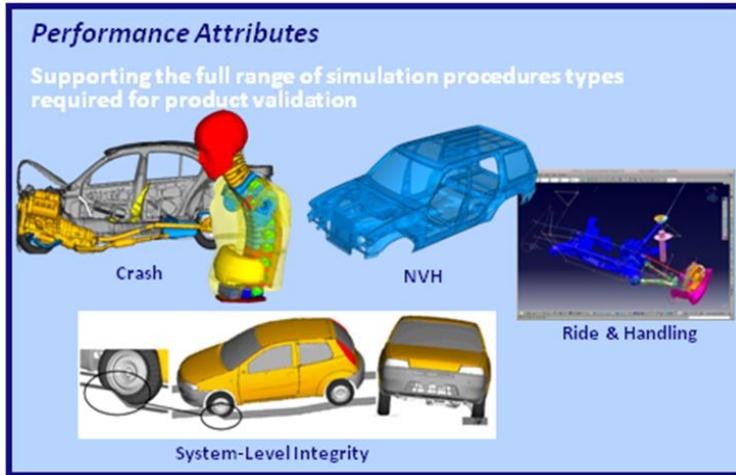


Figure 3 - Performance Attributes

The established workflow allows for various efficiencies and enables sharing of models and associated simulation data across simulation processes. A simulation process here refers to the steps to execute a given performance attribute simulation.

2.1 Simulation workflow

The chosen simulation workflow involves three product families (Figure 4) working closely together to evaluate various performances attributes.

- Scenario Definition – for the overall process and data management
- ANSA and μ ETA – for model assembly and post-processing respectively
- Abaqus – to execute the various performance attributes simulations

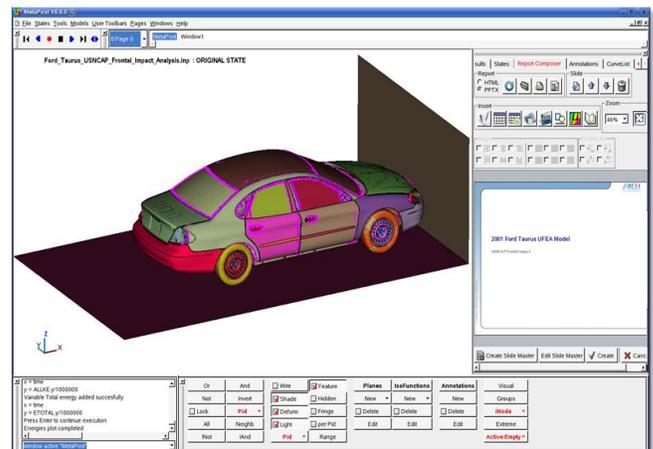
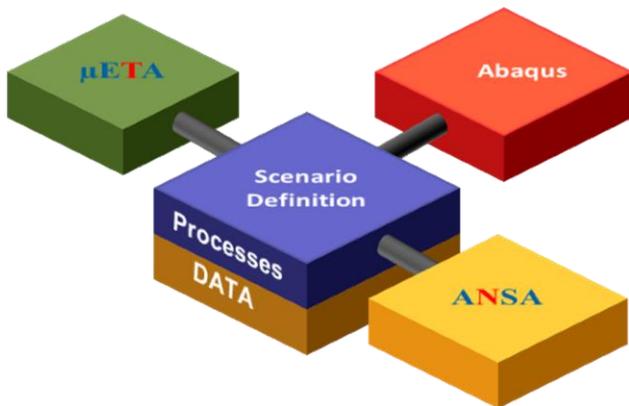


Figure 4 - Simulation workflow

2.2 Scenario Definition

While simulation can be very useful during the product development phase, the overall complexity when applied to a vehicle design can be daunting. Moreover, the range of performance attributes to be considered, along with all the associated data, can also be challenging to manage. Another all-too-common situation is one where different groups that are carrying out simulations are not working on the same iteration of the vehicle design. All this can contribute to a reduction in the overall effectiveness of what simulation can and should deliver. Product Lifecycle Management (PLM) has proven to be an effective business strategy that helps companies share product data, apply common processes, and leverage corporate knowledge for the development of products from conception to retirement. Dassault Systèmes' PLM product suite is well established as a solution for dealing with complex product definitions, and these capabilities are leveraged into the simulation domain for Simulation Lifecycle Management (SLM). Scenario Definition is a SLM tool offered by Dassault Systèmes Simulia Corporation to manage the processes and data associated with simulating a real-world scenario.

The objective of the Scenario Definition in this simulation workflow is to provide a collaborative environment that facilitates concurrent engineering by:

- Handling data – Enforcing that all users are working with the same, up-to-date, data.
- Handling processes – Streamlining simulation processes by using simulation templates to transfer best practices from a set of guidelines into actual finite element modeling techniques.
- Ensuring traceability – Since Scenario Definition is built on a PLM foundation, it includes traditional PLM traceability tools, such as version control, revision control, and data history.

2.3 ANSA and μ ETA

Besides tools that can validate a wide range of performance attributes as well as manage assemblies of various complexities, it is important to have powerful tools that can perform the pre- and post-processing tasks for the performance attributes under consideration. For the simulation workflows described in this paper, ANSA and μ ETA (Figure 5) are chosen as tools for performing the pre- and post-processing tasks.

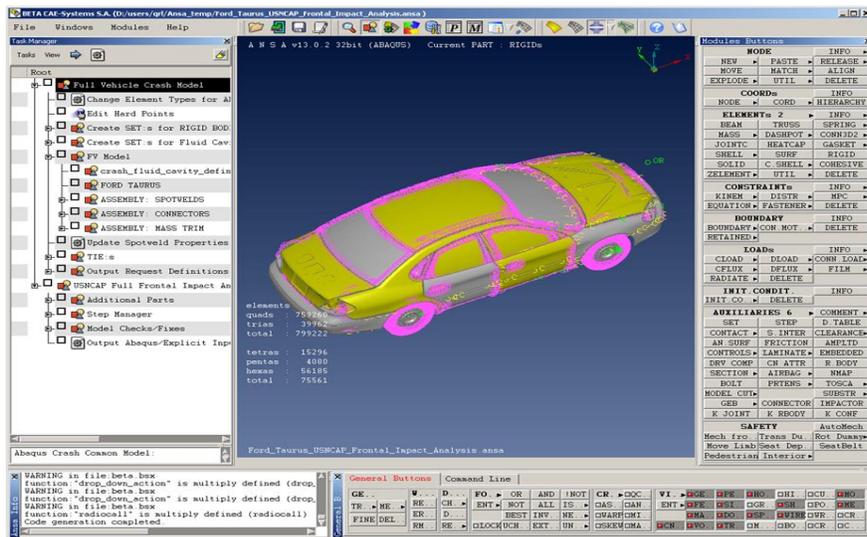


Figure 5 - ANSA (left) and μ ETA (right)

ANSA is an advanced multidisciplinary CAE pre-processing tool that provides all the necessary functionality for full-model build up, from CAD data to ready-to-run solver input file, in a single integrated environment. Some of the key CAE pre-processing tasks that can be achieved in ANSA include, geometry clean up & CAD reconstruction, shell & volume elements generation, batch meshing, parts' assembly & welding modeling, morphing coupling with optimizers, cross-section analysis, fuel tank analysis, Body-in-White bath traps analysis, etc.

μ ETA is a multi-purpose post-processor meeting diverging needs from various CAE disciplines. It incorporates a user-friendly interface, fast graphics, enhanced fringe options, 2D-plot tool coupled with 3D view, multiplicity of cut planes, drawing windows and models, part statistics, reporting and many other features.

For the established workflow, the main features of ANSA and μ ETA used are:

- ANSA Task Manager for model assembly
- ANSA Task lists or Task templates used by ANSA Task Manager to organize, in a hierarchical way, all the modeling steps to be followed for the set-up of any given performance attribute.
- ANSA Generic Entity Builders (GEBs), Connectors, and Connection Manager.
- Report Composer in μ ETA for the post-processing of the Abaqus results.

2.4 Abaqus

The Abaqus UFEA product suite, which includes Abaqus/Standard and Abaqus/Explicit, offers powerful and complete solutions for both routine and sophisticated engineering problems covering a wide spectrum of industrial applications. For instance, in the automotive industry, engineering work groups are able to consider full vehicle loads, dynamic vibration, multi-body systems, impact/crash, nonlinear static, thermal coupling, and acoustic-structural coupling using a common model data structure and integrated solver technology.

In this simulation workflow both Abaqus/Standard and Abaqus/Explicit are used to perform various performance attribute simulations.

2.5 Demonstration model

The vehicle model that is used for this demonstration is a publicly available finite element (FE) model of a 2001 Ford Taurus (Figure 6) from the National Crash Analysis Center at George Washington University [5].

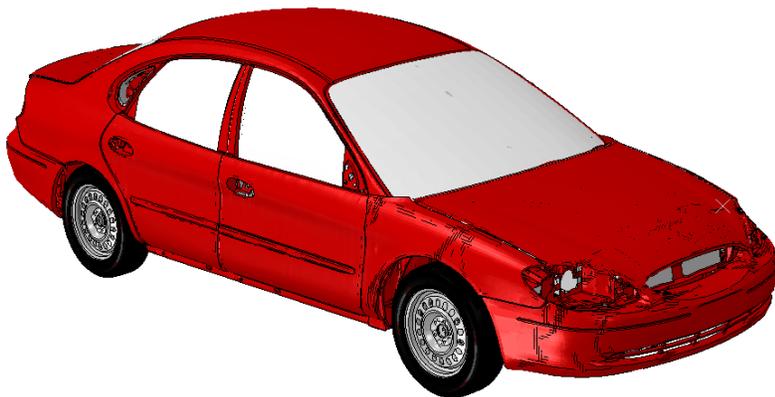


Figure 6 - Demonstration Vehicle: 2001 Ford Taurus

This model contains roughly 1 million elements. While the model is not as large and detailed as full-vehicle models that are commonly used in the industry today, it does contain sufficient details and complexity for the purposes of the work presented in this paper. The original downloaded model was in LS-Dyna format, and a model translation was done to obtain the model in Abaqus format. The translated model was verified by comparing some key output with the LS-Dyna results [5] as well as physical test data available from the National Highway Traffic Safety Administration website [6]. After the translation and verification, the complete model was decomposed to its most basic part and component level and subsequently organized into a hierarchical vehicle structure using the Part Manager tool in ANSA.

With this model as the basis, several performance attributes as shown in Figure 7 can be evaluated.

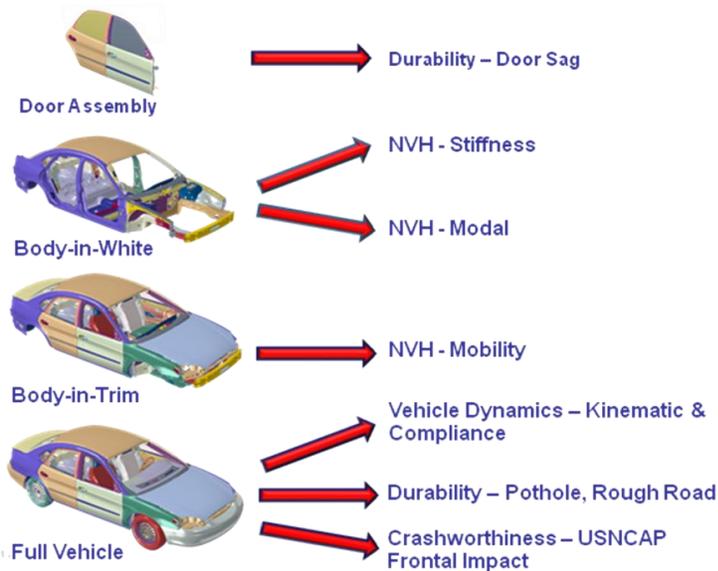


Figure 7 – Examples of Performance Attributes

In this simulation workflow, three different performance attributes are considered for higher-level assemblies, including Body-in-White (BIW), Body-in-Trim (BIT), and full-vehicle level. These three performance attributes are: NVH BIW stiffness analysis, NVH BIT mobility analysis, and USNCAP full-vehicle crash analysis.

3. SIMULATION PRODUCT STRUCTURE

The first step in establishing a simulation workflow is to create a Simulation Product Structure (SPS).

While a modern vehicle is complex in its design, it also has a very hierarchical product structure (Figure 8). In other words, parts are assembled into subassemblies; subassemblies themselves are combined into higher level assemblies; and so on. This hierarchical product structure is leveraged to organize and manage simulation models. The organization of the product structure used for the three different performance attributes under consideration is accomplished using a Simulation Product Structure.

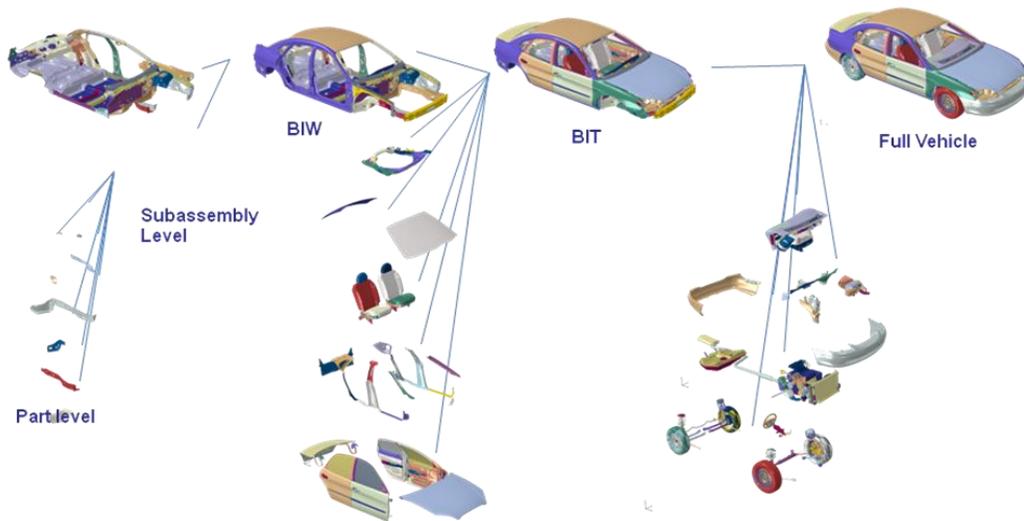


Figure 8 - Hierarchical Vehicle Product Structure

A Simulation Product Structure is a copy of the Design Product Structure (DPS) devoid of any parts or assemblies that are not relevant to simulations (Figure 9). It also contains filters, which can be thought of as non-hierarchical grouping. Different filters are used for each type of performance attribute simulation as shown in Figure 9.

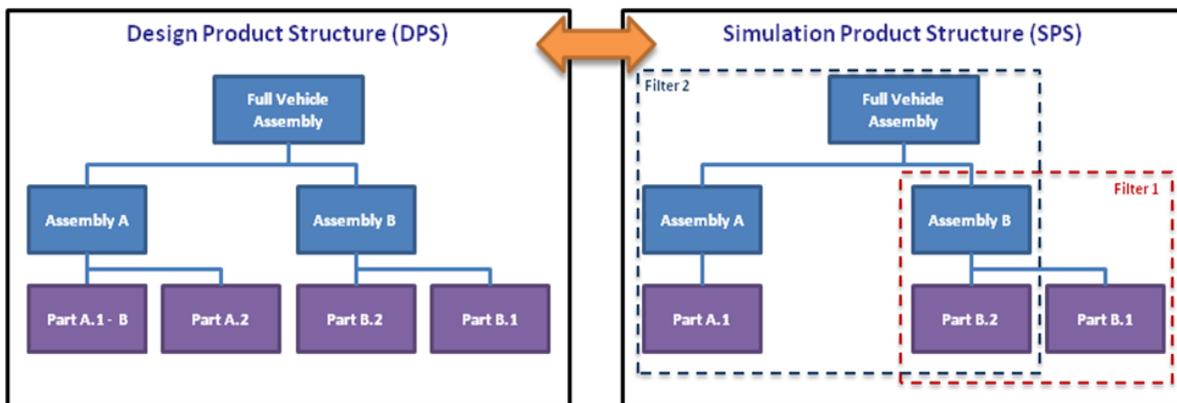


Figure 9 - Design Product Structure (left) and Simulation Product Structure (right)

A link from the SPS to the DPS can be maintained to allow for changes in the design to be propagated to the simulations whenever appropriate. The SPS contains CAD models, which may be different from the models in the DPS, as well as one or more mesh representations or simplifications. For example, a part could contain a de-featured version of the CAD, a fine mesh, a coarse mesh, and a beam simplification. As a result, a single SPS can be used as a baseline for all analysts regardless of the vehicle assembly level on which they work.

The workflow presented in this paper uses this baseline approach; in this example the SPS contains:

- Meshed parts with section properties and unique module IDs.
- Connections between the parts.

This SPS was created by extracting individual parts from the demonstration model and creating a Bill of Material (BOM). The BOM was then interpreted by a script to import the data in Scenario Definition. Since no CAD geometry of the demonstration model was publicly available, no reference to CAD data was maintained for the workflow presented. It should be noted that the future SIMULIA products will use the Dassault Systèmes' V6 platform to create new Simulation Product Structure by leveraging structures created by diverse CAD and CAE applications.

4. SIMULATION TEMPLATES

The next step in the simulation workflow is to create Simulation Templates.

Simulation Templates are developed in Scenario Definition to capture the entire simulation process and to ensure that it can be repeated consistently. These templates also allow for best practices to be enforced more easily. For instance, the Simulation Templates ensure that for a given simulation process the specified software-level is being used, the data are gathered in the specified format, and the results are monitored based on the specified key data points.

Each Simulation Template is targeted toward a specific simulation process (for example, validation of the NVH Body-in-White stiffness performance attribute). A Simulation Template contains an ANSA Task list or Task template, which is used to create the required Abaqus simulation model within ANSA. Each Simulation Template (Figure 10) also contains:

- A. Each step in the process to be run (preprocessing, analysis, post-processing, etc.)
- B. Applications to be used (ANSA, Abaqus/Standard or /Explicit, μ ETA, etc.)
- C. Generic data, such as finite element model templates and context information (barriers, dummies, etc.)
- D. Engineering targets to be met

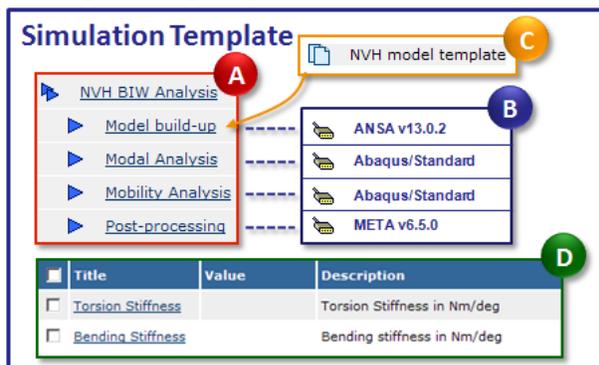


Figure 10 – Simulation Template

Connections are point, curve, or face ANSA entities used to carry welding characteristics, such as the connection position and the connected components. These entities can be “realized” into user-defined finite element representations connecting two or more components. They include spot weld points, gumdrops, bolts, spot weld lines, adhesive lines, seam lines, hemming, and adhesive faces.

Connectors are ANSA entities used to connect two or more parts or sub-assemblies, modeling the kinematic constraints that physically exist between them.

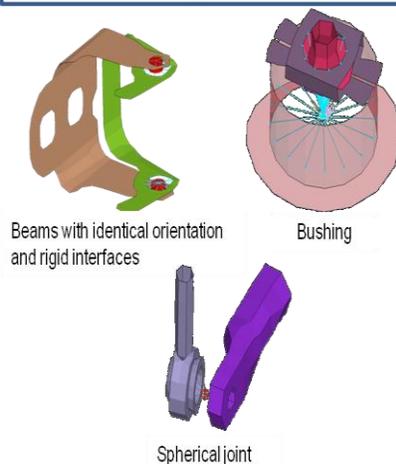
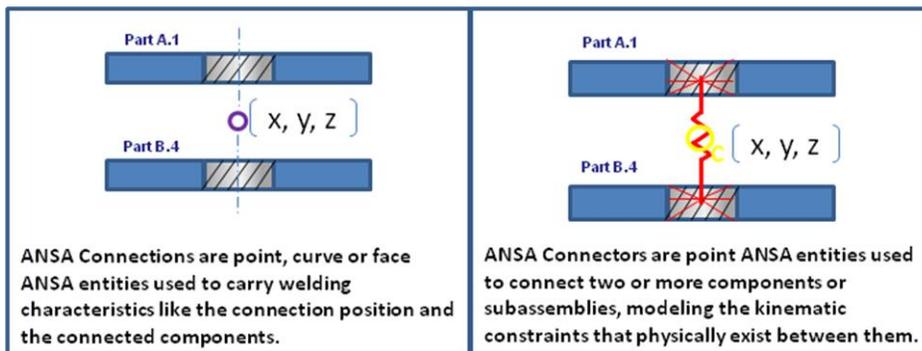


Figure 13 - ANSA Connections and Connectors (Top) and Examples of applications using Connectors (Bottom)

The advantages of creating ANSA Task templates are:

- These Templates can easily be reused and modified to fit different workflows, thereby increasing efficiency and allowing a wider adoption of the analysis best practices.
- It is very straight-forward to incorporate a proposed design change into the targeted models and subsequently spawn a new series of simulation models.

In order to use ANSA Task templates, all necessary data are exported from Scenario Definition into an ANSA_DM repository that contains dedicated directories for all parts, connector templates, output request templates, barriers, etc. Moreover, several ANSA user scripts that are created for the model assembly process are made available to the ANSA Task Manager by adding paths to the scripts in ANSA_defaults.

6. SIMULATION PROCESS: NVH BIW STIFFNESS

6.1 NVH BIW stiffness simulation

The BIW Stiffness simulation for NVH is performed in Abaqus/Standard using two perturbation steps: Static Torsion and Bending Stiffness analyses (Figure 14).

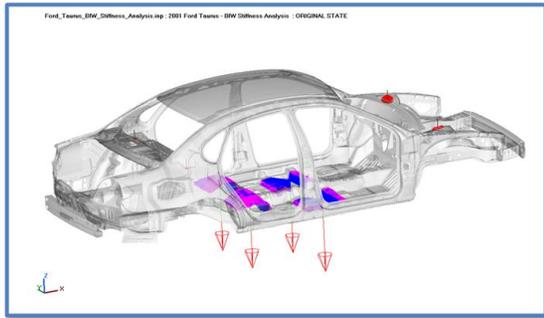


Figure 14 - Static Torsion (Right) and Bending Stiffness (Left)

In the Static Torsion Stiffness analysis a force of 1000 N is applied to the RHS front suspension mount, and the displacements along a path from the RHS rear to the RHS front suspension mounts are measured. In the static bending stiffness analysis a total force of 3000 N (4 x 750 N corresponding to the weight of 4 x 50th percentile dummies) is applied to the middle floor, and displacements along paths between rear and front suspension mounts are measured on both RHS and LHS.

6.2 Simulation process execution

The process is started with the instantiation of a Simulation Template in Scenario Definition (Figure 15) and the selection of the SPS for the vehicle program to be analyzed.

| Simulation Template "NVH BIW Stiffness Analysis Template" rev -: Instantiate and Run | | | |
|--|-------|------------------------------------|------------------|
| Target Folder: Support / SimData | | | |
| <input type="checkbox"/> Instructions <input checked="" type="checkbox"/> Modifiable Only <input type="checkbox"/> Viewable Fields <input type="button" value="Help"/> | | | |
| Title | Image | Value | Description |
| NVH BIW Stiffness Analysis | | | |
| Basic Information | | | |
| Title | | NVH BIW Stiffness Analysis | |
| Description | | | |
| Simulation Referenced Content | | | |
| <i>(If you modify a document that is referenced by name by an export/import rule, you must check that the rule is still functioning correctly.)</i> | | | |
| Vehicle SPS | | <input type="button" value="..."/> | |
| NVH BIW Stiffness engineering targets | | | |
| Bending Stiffness minimum | | <input type="text"/> | target in kN/mm |
| Torsion Stiffness minimum | | <input type="text"/> | target in kN/deg |
| Pre-processing -- ANSA | | | |
| Basic Information | | | |
| Title | | Pre-processing -- ANSA | |
| Execution Options | | | |
| Execution -- Abaqus/Standard | | | |
| Basic Information | | | |
| Title | | Execution -- Abaqus/Standard | |
| Execution Options | | | |
| Post-processing -- META Post | | | |
| Basic Information | | | |
| Title | | Post-processing -- META Post | |
| Execution Options | | | |

Done Cancel

Figure 15 - Simulation Template for NVH BIW stiffness simulation

The result of this instantiation is referred to as a simulation process. When this simulation process is executed within Scenario Definition, the following steps are performed automatically with very minimal manual intervention:

1. Scenario Definition extracts data from the SPS and places it into an ANSA_DM compliant directory structure (Figure 16). It also exports all other necessary information to ANSA, such as material library, connector library, etc.

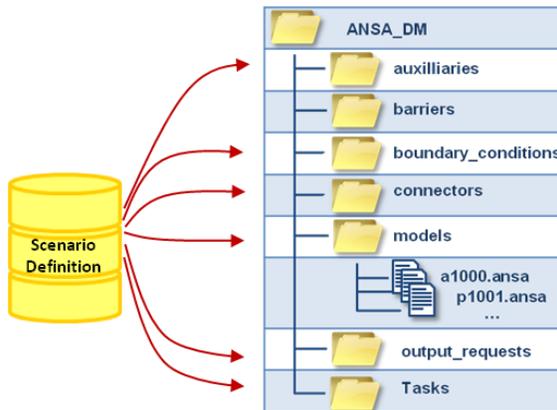


Figure 16 – Extract data from Scenario Definition

2. Scenario Definition then launches ANSA (Figure 17). Since every part and subassembly are stored as individual ANSA database files, a startup script is run automatically to merge the individual databases. When the startup script is complete, the Body-In-White model with the meshed parts and spotweld connections is ready for use.

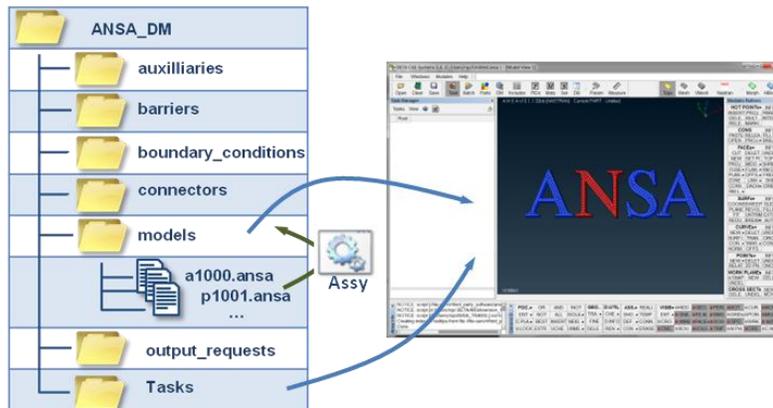


Figure 17 – Launch ANSA and run merge databases

3. Once the database files are merged, Scenario Definition loads the ANSA Task into the ANSA Task Manager. When the ANSA Task template is executed, ANSA automatically creates all the spotwelds, kinematic connections, loads, and boundary conditions. As the ANSA Task templates are built in a generic manner, only a minimal manual intervention is needed within ANSA to obtain an Abaqus input file (Figure 18).

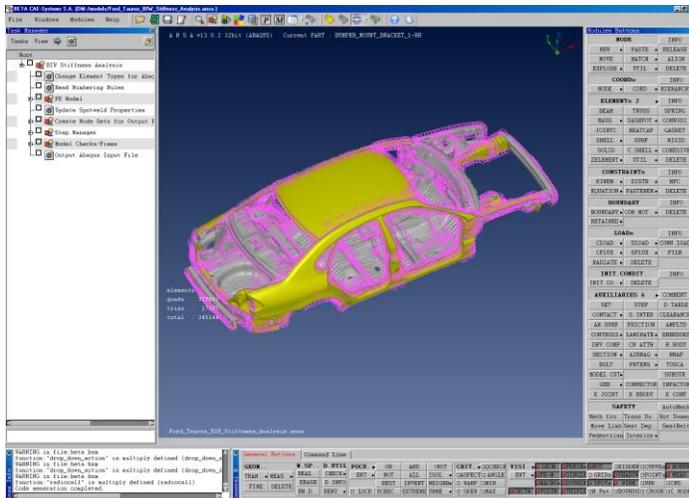


Figure 18 - ANSA with all BIW parts, connections, and task list for stiffness analysis

- Any changes done to the model in ANSA is done through the ANSA Task list. These tasks are then saved in the ANSA_DM as a separate database file (Figure 19). Other outputs, such as the Abaqus input file, are also saved in the ANSA_DM for future use.

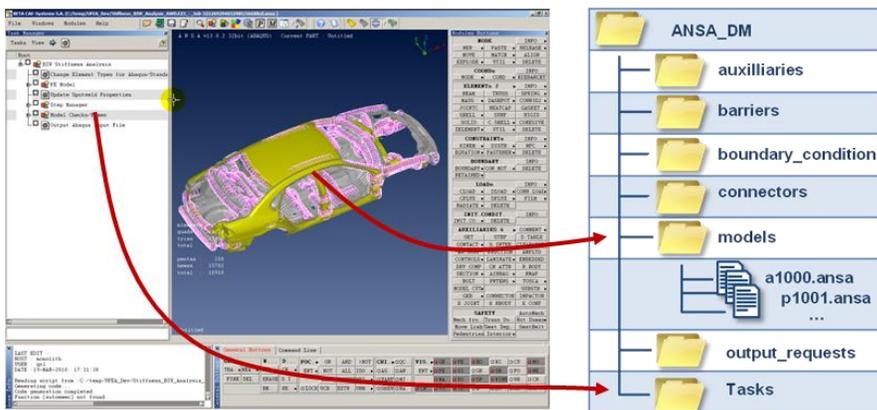


Figure 19 – Save model changes to ANSA_DM

- Upon exiting ANSA, Scenario Definition automatically imports all the new data created (Figure 20).

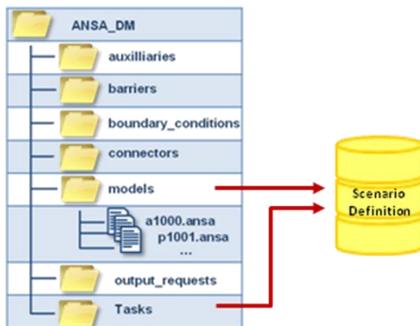


Figure 20 – Import all data into Scenario Definition

6. Once the pre-processing phase is over, Scenario Definition switches to the solving phase, submitting the Abaqus/Standard job to a cluster (Figure 21).

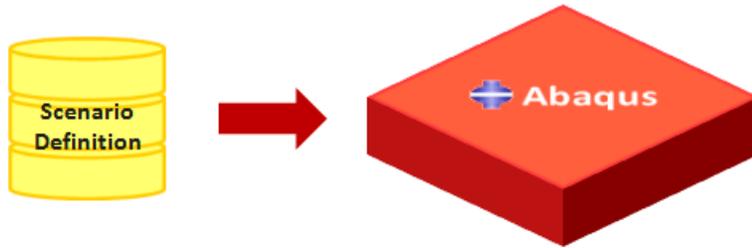


Figure 21 – Run Abaqus/Standard

While the above steps are being executed, the progress of the process is monitored in the Simulation Execution Log window in Scenario Definition.

Once the analysis is successfully completed, the results data generated by Abaqus are imported back into Scenario Definition, and μETA is launched for post-processing of the results (Figure 22).

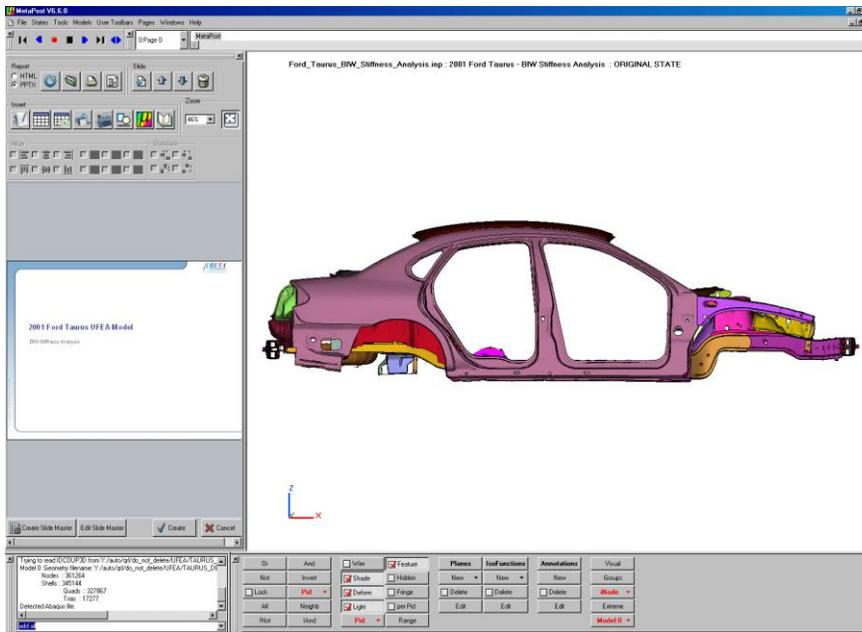


Figure 22 - μETA post with BIW stiffness analysis input and result database loaded

μETA uses the Abaqus input file and the generated output database file to extract results data at predefined locations. The extraction of results is done through a post-processing script, which also organizes all the data gathered into a PowerPoint report, enabling quick high-level reviews. Upon completion of the post-processing task, all the extracted results data and the report files are imported back into Scenario Definition.

7. SIMULATION PROCESSES: NVH MOBILITY AND FULL-VEHICLE USNCAP

A similar process is also followed for creating NVH BIT mobility and full-vehicle USNCAP frontal impact simulations. The established simulation workflow allows for any number of performance attribute simulations to be performed concurrently. In order to perform these two performance attribute simulations, new simulation processes are created by instantiating Simulation Templates in Scenario Definition. In addition, filters for BIT and full-vehicle assembly are applied to the SPS, along with the selection of associated ANSA Task templates. These simulation processes are then executed within Scenario Definition in the same manner described in the previous section. Figure 23 shows the two performance attribute models in ANSA after successful execution of the ANSA Task Manager templates.

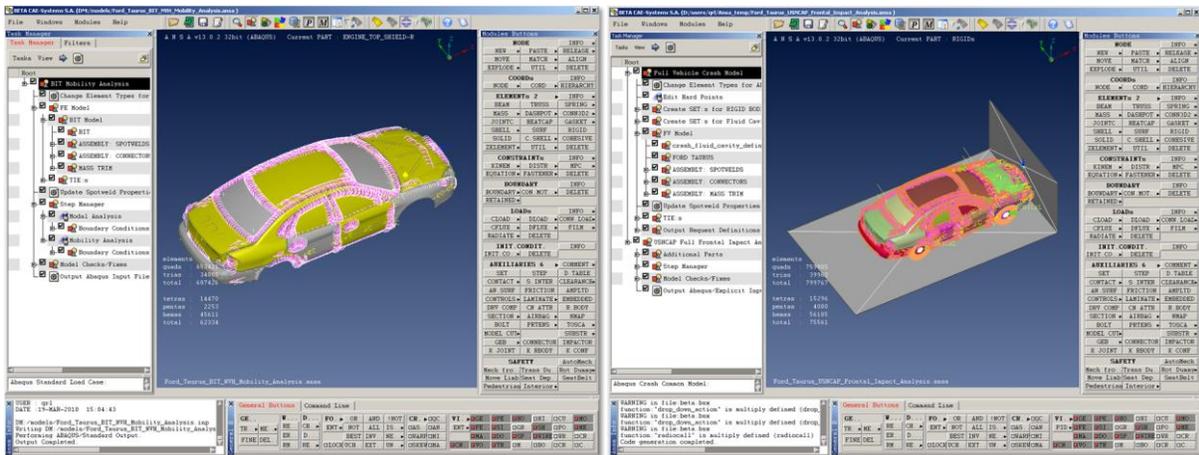


Figure 23 – NVH BIT mobility (left) and full-vehicle USNCAP (right) models in ANSA

8. INCORPORATING A DESIGN CHANGE

While the simulations are being carried out, the vehicle design continues to evolve. The link between the DPS and SPS allows the simulation team to be kept informed of any changes made by the design team. This established simulation workflow allows for a mechanism to ignore or propagate any design changes on a case-by-case basis. Whenever a design change is propagated from DPS to SPS, any performance attribute simulation making use of the affected part or subassembly will automatically be marked as being out-of-date. Scenario Definition allows for re-execution of any given simulation process with the proposed design change, or for manually flagging the affected parts or subassemblies to be up-to-date for cases where the simulations are not considered to be truly impacted by the design change. When the simulation is re-executed, the same steps described previously will be performed. All the parts and assemblies will be merged again, taking the new design into account. Since the ANSA Tasks reference standardized Generic Entities, the regeneration of the finite element model requires very limited user interaction.

For the work in this paper a design change to the TOE PAN located in the floor of the vehicle is chosen as an example. Figure 24 shows the comparison of the old design (white) and the new design (green) of the modified part in ANSA.

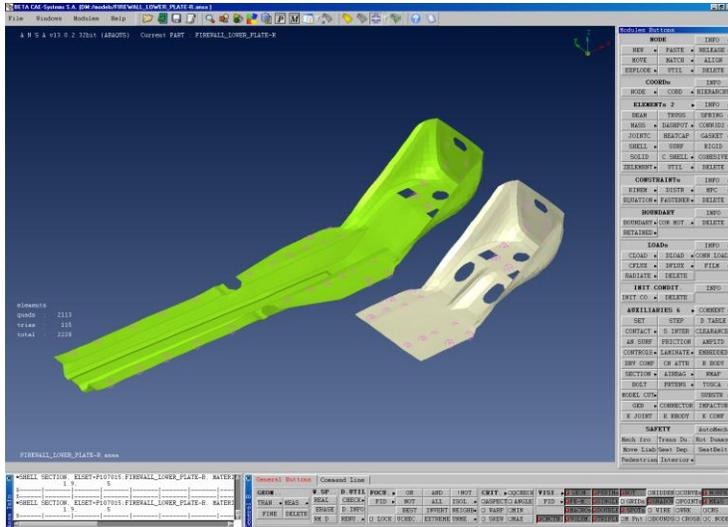


Figure 24 - Design change of the TOE PAN in the Ford Taurus model

The new performance attribute simulations are easily performed by simply re-executing the respective Simulation Templates that have been updated with the latest available revision of the SPS. This latest SPS includes the above design change to the TOE PAN and the updated spotweld information. Since the information about the spotweld connections are saved as ANSA connections, new finite element representations of the spotwelds are automatically created during the execution of the ANSA Task template. Once the simulations with the new design are successfully performed, comparisons between the old and the new design for each of the performance attribute simulations is done by using the comparison templates. Figure 25 and 26 shows some examples of result comparisons in μETA between the models with the old (blue) and the new (red) design for the USNCAP frontal impact simulation.

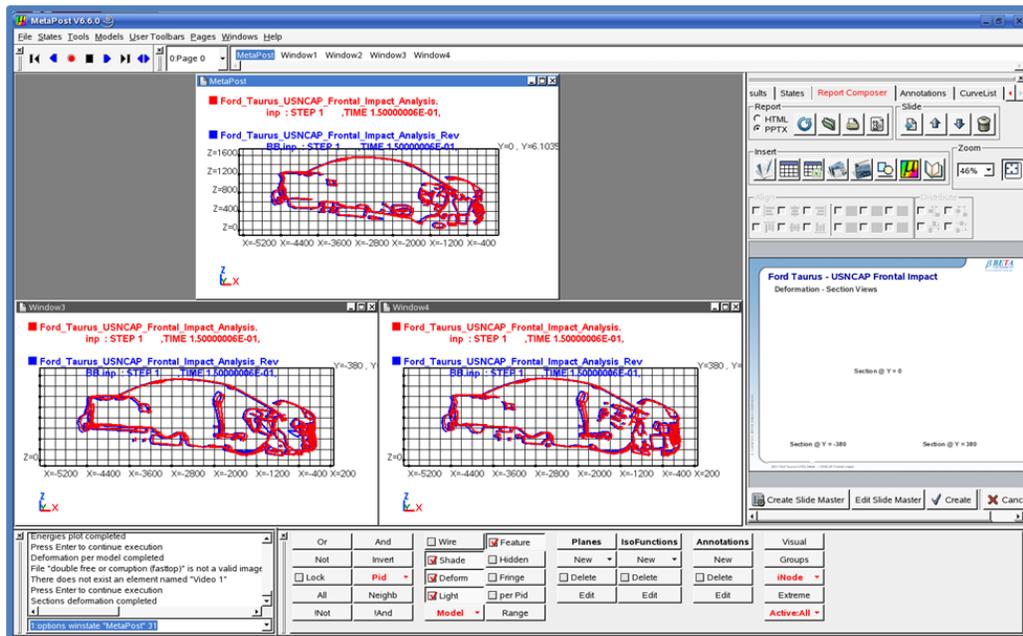


Figure 25 - Comparison between old (blue) and new (red) design in μETA

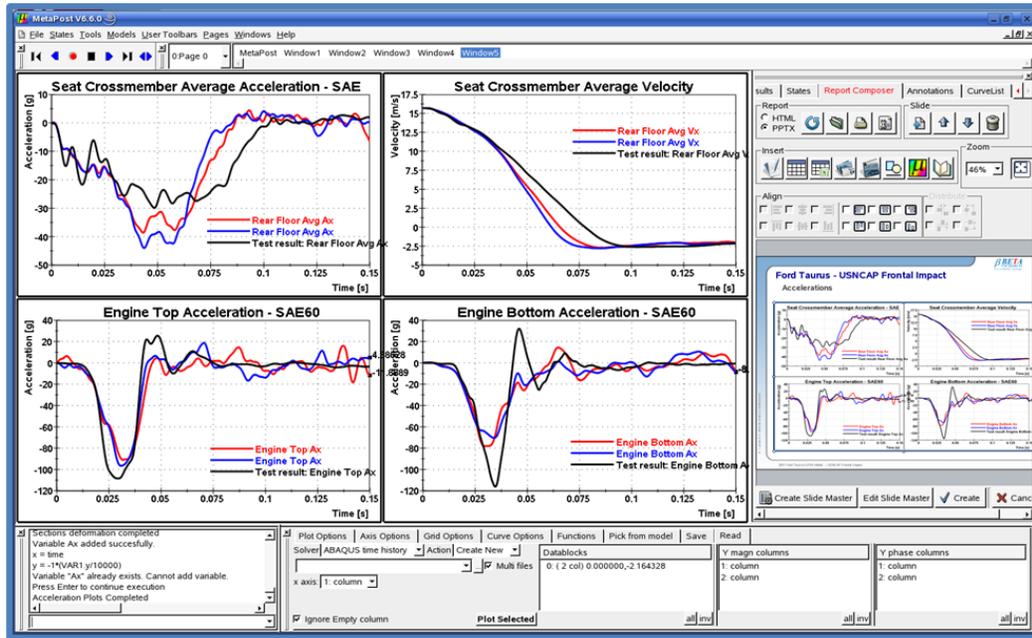


Figure 26 - Comparison of various time history output in μETA

9. PROJECT REVIEW

Different approaches can be taken to offer the kind of high-level overview best suited for a project manager:

- ENOVIA, the underlying platform of Scenario Definition, offers program management tools, which can be used for true project management. Such approach allows handling of resources, deliverables, risk analysis, etc. from within a single application.
- Alternatively, ENOVIA’s reporting capabilities can be used to concatenate information into reports. Since all simulations for a given vehicle program will point to a single SPS, extracting all the information for such a report is a straightforward task. This approach can be used in conjunction with the first approach as well.

For this work, ENOVIA’s reporting capabilities are used. A few checks are run on the results to provide a pass/fail view on the report (Figure 27). An extension of this capability could be used to compare multiple iterations of the design or multiple generations of the same vehicle.

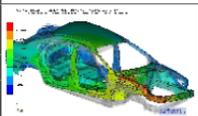
| Stiffness BIW Analysis | | | |
|---|-------|---|-----------|
|  | | Name: Stiffness BIW Analysis-21288979419012 | |
| | | Created: 11/5/2010 1:50:18 PM | |
| | | Status: In Process | |
| | | Owner: Test Everything | |
| Attribute | Value | Acceptance Criteria | Pass/Fail |
| Attr1 | 125 | > 100 | Pass |
| Attr2 | 230 | > 100 | Pass |
| Attr3 | 200 | > 100 | Pass |
| Attr4 | 75 | > 100 | Fail |
| Input Documents: | | Output Documents: | |
| * CAD geometry | | | |
| * Material Definition | | | |

Figure 27 – ENOVIA report view of Simulation Data

10. CONCLUSIONS

Current technical challenges in the automotive industry present a tremendous opportunity for simulation to play a substantial role in the vehicle design process. Increasing sophistication of analysis software, along with continuing gains in high performance computing, allow simulation to become a key enabler in addressing some of these challenges. However, there are several issues impeding a truly simulation-driven design:

- Considerable time is wasted finding the right data and methods.
- Potential dangers in inadvertently using the wrong data and methods.
- Significant effort expended in assembling complex models.
- Inefficiencies in incorporating proposed design changes and understanding their subsequent impact.
- Difficult to generate and gather all up-to-date performance attributes when needed in order to make informed design decisions.

In this paper a workflow that addresses these issues has been presented. The process involves three software product families working closely together: Scenario Definition for simulation data management; ANSA and μ ETA for pre- and post processing; and Abaqus for finite element analysis. The demonstrated process offers several benefits in the vehicle design process:

- Management of data and methods.
- Template-based model assembly substantially speeds up the model creation process and reduces human effort required.
- Automatic tracking of design changes and efficient updating of models.
- Timely availability of all pertinent performance attributes, leading to best informed design decisions.
- Collaborative environment, linking all stakeholders, both simulation users and simulation “consumers”.
- Significant improvement in capturing and leveraging valuable simulation Intellectual Property.

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