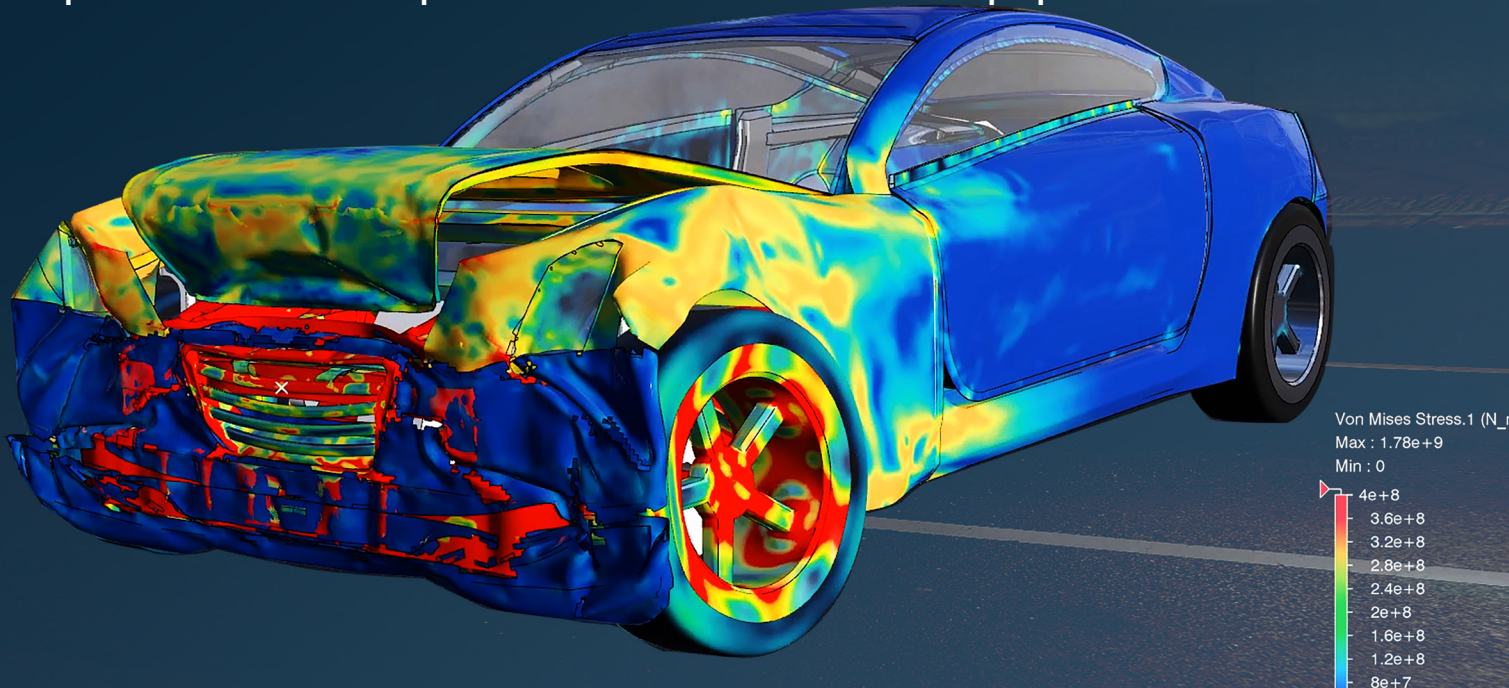


CONCEPTUAL STRUCTURE OPTIMIZATION FOR CRASHWORTHINESS

Develop crash efficient Vehicle structures, through evaluation and optimization of load paths and sections in the concept phase.



INTRODUCTION

The automotive industry faces dramatic changes with electric vehicles in terms of design, business paradigm, and shortening the product cycle.

A flawless process from product planning to product manufacturing can reduce the cost and time of the production. Upfront simulation supports the idea by providing the simulation technique as early as the concept design phase to reduce or eliminate possible late design changes. The automotive structure needs simulation of the three performance attributes: crashworthiness, NVH (noise, vibration, and harshness), and durability.

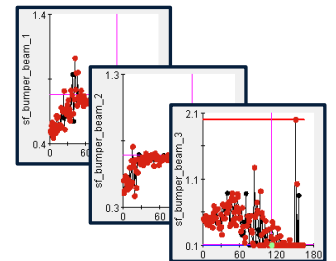
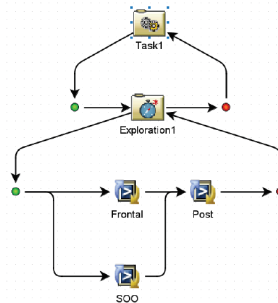
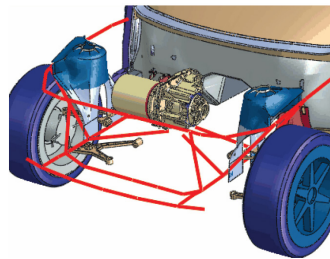
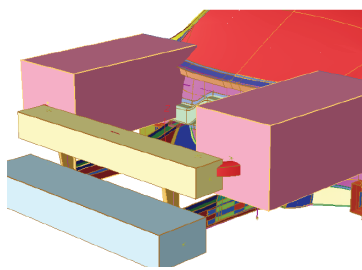
There are hurdles in applying the FE simulations of the three attributes at the early concept design. FE models require complete geometry for meshing, but the concept design may not have the detailed geometry and the design may frequently change. The architecture design in the concept phase is the most effective solution for optimal crashworthiness performance. However, the crashworthiness simulation takes a significantly longer time than the other two.

CONCEPTUAL STRUCTURE OPTIMIZATION FOR CRASHWORTHINESS (CONT)

Several attempts have been made to shorten crash simulation, including the incorporation of a method known as the lumped mass-spring method. This method has not been widely accepted, as it includes numerous difficulties in modeling and replicating the existing structure. Physical or Finite Element tests are required for all structural components in order to obtain the spring properties, and it is then difficult to convert the optimized spring properties into the real design of the structural components.

SIMULIA has been studying lumped mass-spring method and developed a "reversed" workflow for using the lumped mass-spring method and parametric optimization to overcome the difficulties. The workflow is used to construct a structure with a well-balanced load path, and to find the proper component geometry easily with RSM approach.

This workflow comprises of 6 different steps, leveraging multiple applications within the SIMULIA and CATIA portfolio, showcasing the power of combining Modeling and Simulation, to address some process challenges and speeding up the development cycle.



Define Design Space

Build Stick Model

1

2

PROCESS FLOW

3

Optimization

6

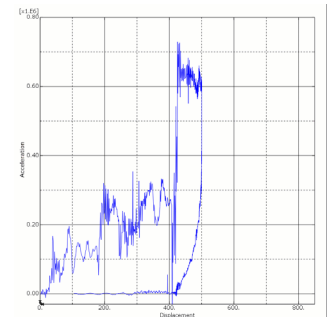
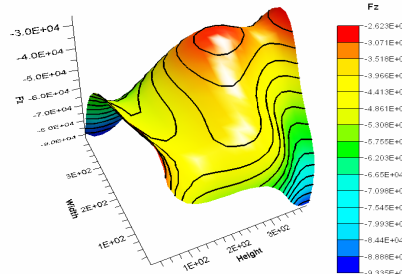
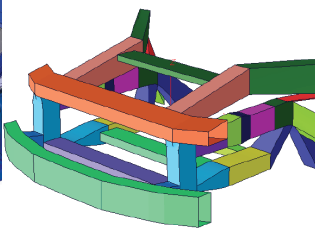
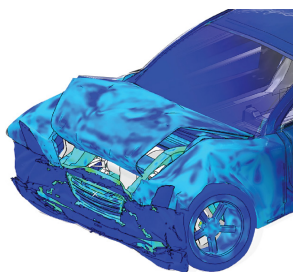
Crash Analysis

5

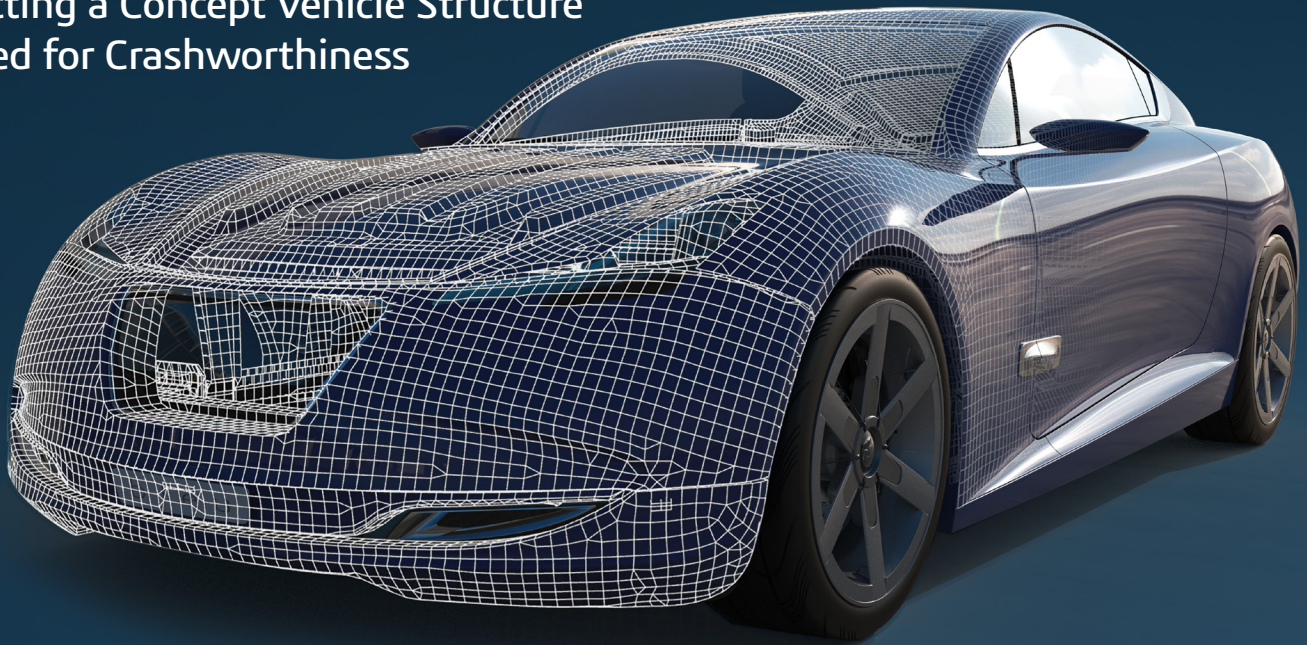
Propose Optimized Structure

4

Meta Model

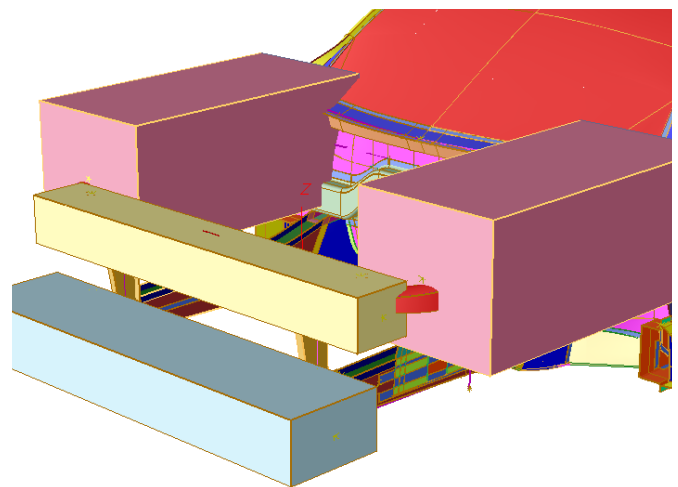


Constructing a Concept Vehicle Structure Optimized for Crashworthiness



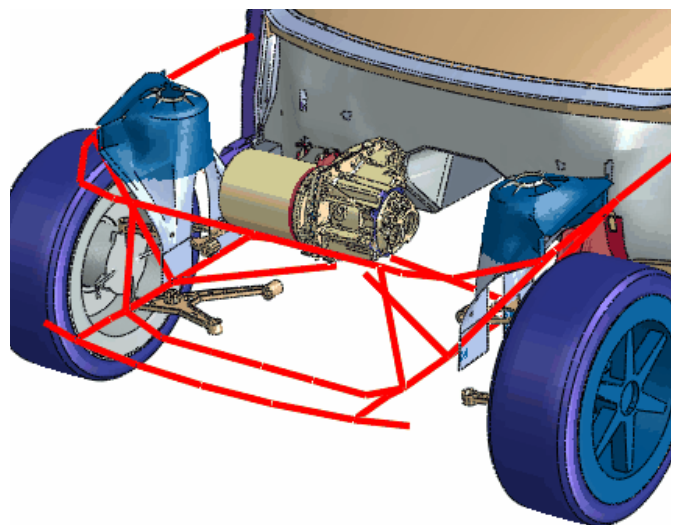
(1) Define design space

When starting a new vehicle project, designers would know the specs and the driving system, suspension types, sizes, hardpoints, wheelbase, passenger compartment size, etc., which are essential for the layout. In addition, the vehicle structure has a typical architecture per the type of the cars such as sedan, coupe, van, and trucks. Therefore, with the styling, specs, and distinct architecture, the design engineer can define the design spaces for the paths of the load-carrying structural components.



(2) Build a STICK model

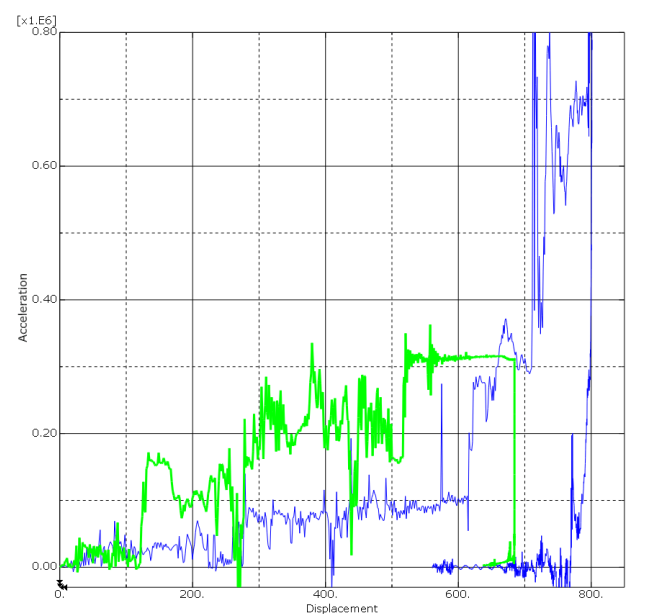
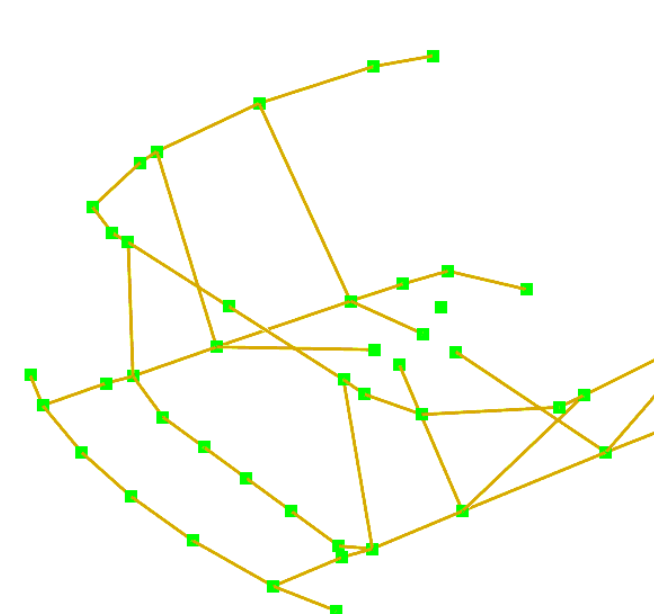
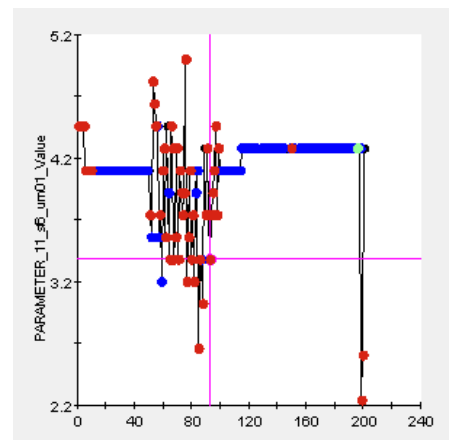
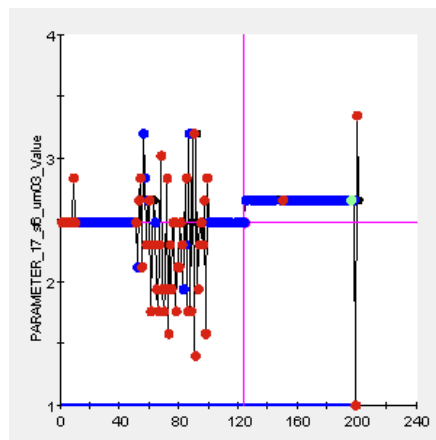
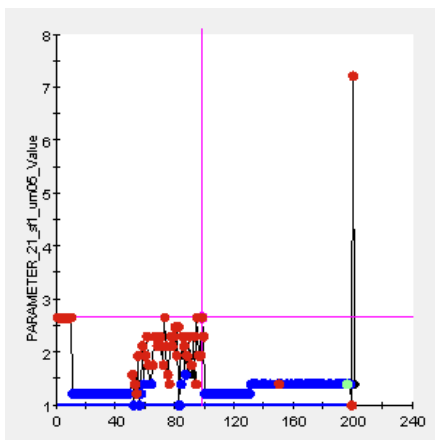
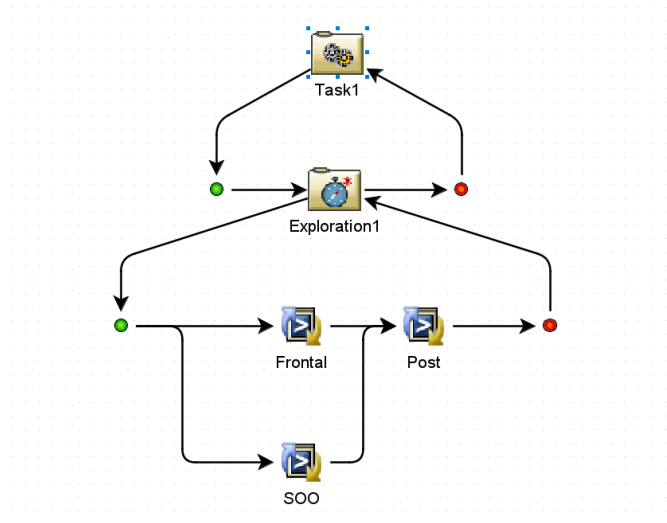
Using the given constraints and the typical architecture for the given vehicle, the engineer builds the stick model. The nodes are locating at the c.g. of rigid-like bodies, hardpoints, and the connections of the structural components. The springs connect the nodes and represent deformable components. A crash expert should build the STICK model so that this high abstracted model will work correctly in the optimization process.



CONCEPTUAL CRASHWORTHINESS (CONT)

(3) Optimization of the structure for crashworthiness

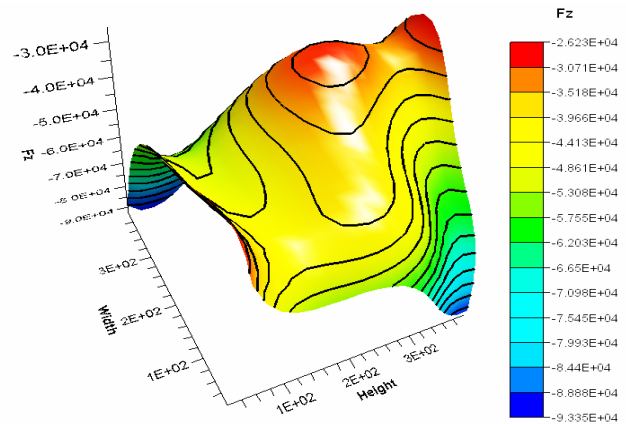
The optimization aims to design the best routes of the load-carrying paths of the structural components. The serial and parallel connection and the crash energy absorbing capacity (crash resistance) of the structural components determine the load paths. Hence, the coordinates of the nodes and the crash behavior of the members are design variables, which vary to make the structural responses toward the target values. We tried to get the crash resistance to apply the lumped mass-springing model. However, it took quite a lot of effort to get the crash resistance by physical tests or by FE model. Therefore, we propose to reverse the order: run the model on parametric optimization with making the crash resistance as design variables to find the optimal load path. the structural components.



CONCEPTUAL CRASHWORTHINESS (CONT)

(4) Metamodel

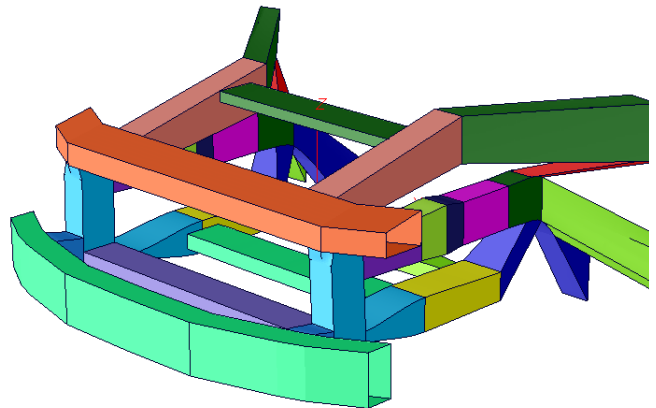
The crash resistance of the structural members is relevant to the cross-section geometry. Here, we propose to use the database to find an approximation function for the crash resistance for the given cross-section geometry. We demonstrate the creation of the metamodel with a rectangular shape cross-section since we assumed that most members of the vehicle structure are rectangular. With the metamodel, we can get the crash resistance for a given cross-section immediately. Furthermore, we can reversely get the cross-section geometries that correspond to a given crash resistance quickly.



(5) Proposing an optimized structure:

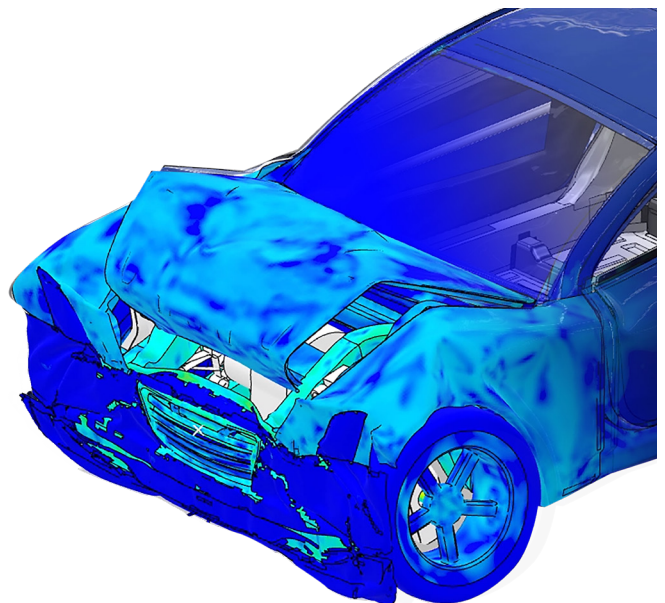
Once we compute the corresponding cross-section geometry from the metamodel, we get the optimal load paths with well-balanced crash resistances for all structural members. Now these members need to be converted into full scale 3D Model, to increase the level of fidelity and maturing the load paths further.

This achieved by creating a full-scale 3D parametric geometry in SFE CONCEPT. We have developed a semi-automated process for building this 3D model; which reduces the model building time by 70%. The geometry built in SFE CONCEPT is implicitly parametric, which allows the user to access complex design changes with ease and fully explore the available design space. With this, we can identify and define, parameters for start and end points of each member and their section sizes to fine-tune the load paths further.



(6) Crash Analysis

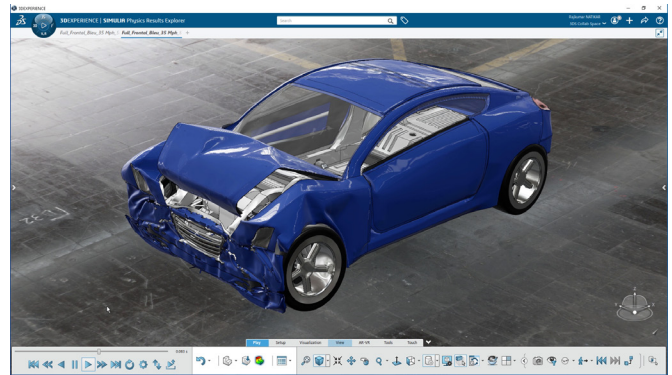
SFE CONCEPT also drastically reduces the time required for a finite element model, as all of the simulation requirements such as material & physical properties, along with connections that are assigned directly on geometric surface, and are converted to a finite element model at push of a button. SFE CONCEPT seamlessly integrates into Isight and can generate finite element models, which can be evaluated in Abaqus/Standard and Abaqus/Explicit for linear static and nonlinear crash analysis. Crashworthiness simulation of a fully FE model is used to verify the optimized design with more realistic representation, and it will be available for various loading cases and for multiple domain optimization.



CONCLUSION:

This workflow, lets the Function (vehicle crashworthiness) drive the Form (load paths and cross-section), of the Body in White or Chassis. It helps the simulation teams, to provide the design teams with valid design inputs based on simulation results, and reserve a minimum required design space for essential load carrying members. This method is scalable, and can be applied to specific modules/assemblies or even sub-assemblies of the vehicle and can be initiated with varying levels of input data.

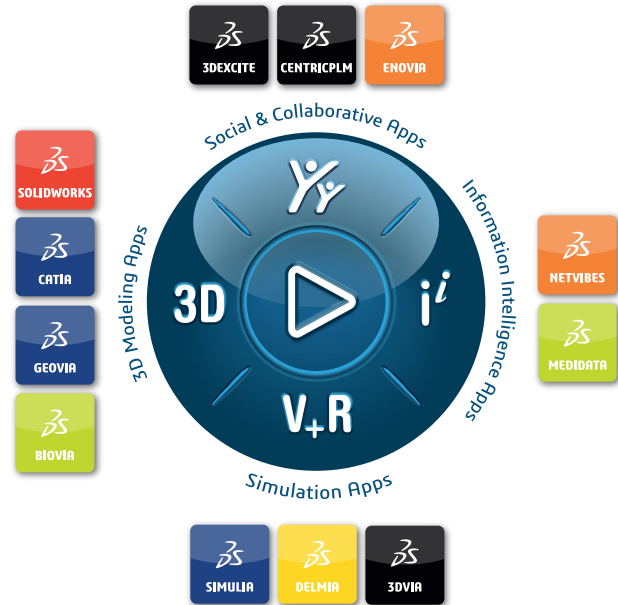
Above all, it brings the Modeling and Simulation much closer and increases the speed of innovation in the crucial conceptual phase of development.



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