



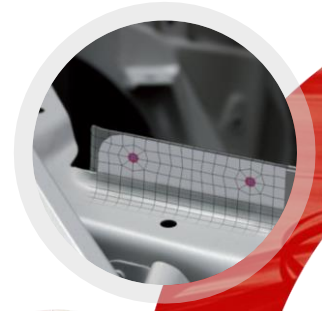
From Inertia Relief to Dynamic Contact Analysis Based Body Fatigue

Markus Breidfuss, Product Manager MAMBA,
Magna / Dr. Oliver Grieshofer, Manager Dynamics & Acoustics Analysis, Magna

ECS Simulation Conference, 10th – 11th May 2023
Linz, Austria

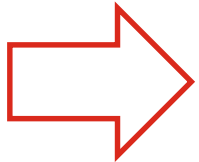
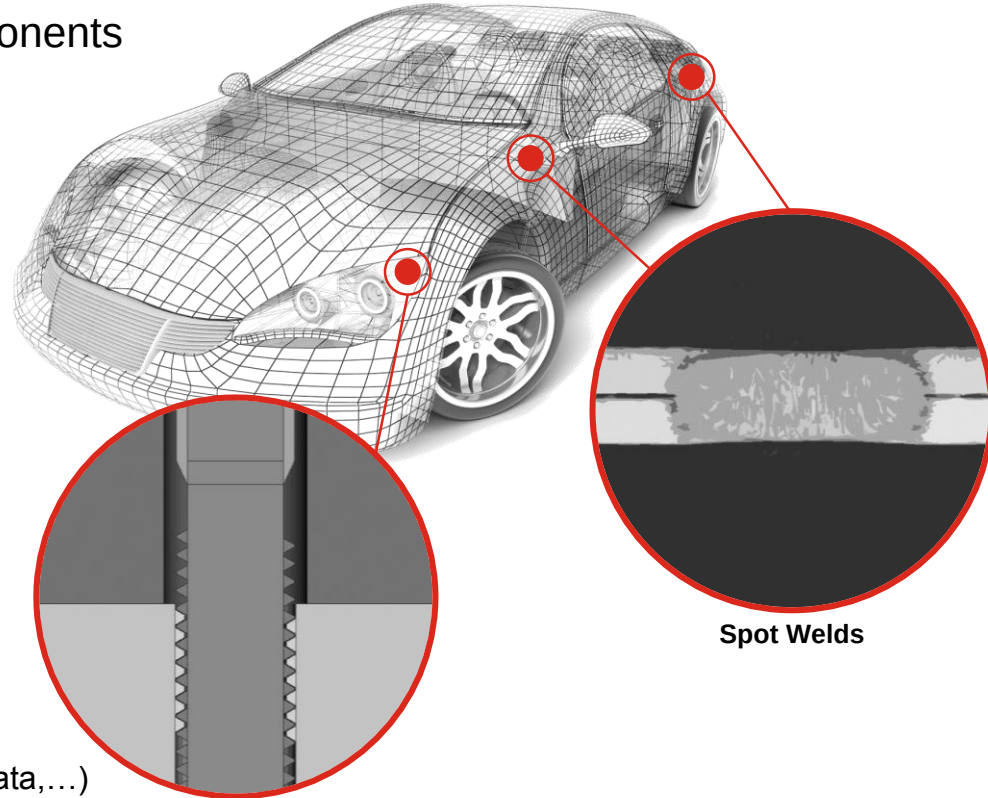
Overview

- Fatigue Assessment of Body Structures
 - Challenges
- Elementary Investigations
 - Inertia Relief Approach
 - Dynamic Analysis Approach
 - Exemplary Assessment of Sedan Car Body
- Extended Investigation
 - Dynamic Contact Analysis Approach with MAMBA
 - Exemplary Assessment continued
- Q&A



Body Structures

- Some Characteristics
 - Typically built up from metal sheet components
 - Comprises spot welded connections
 - Comprises bolted connections
- Dynamic Load induced Vibrations
 - Road load (including cobblestones)
 - Lane change
 - Potholes

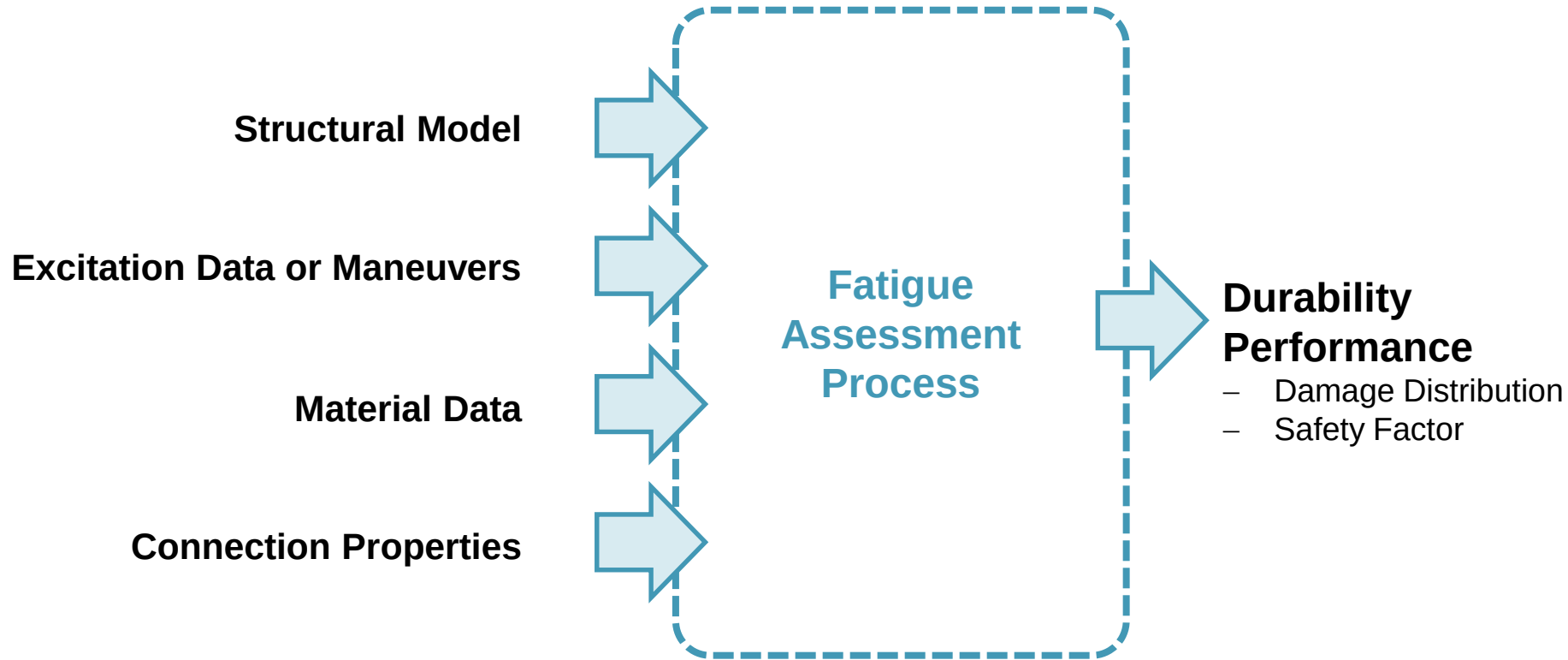


Fatigue assessment is a
challenging task
(modelling, computational effort, amount of data,...)

Bolted Connections

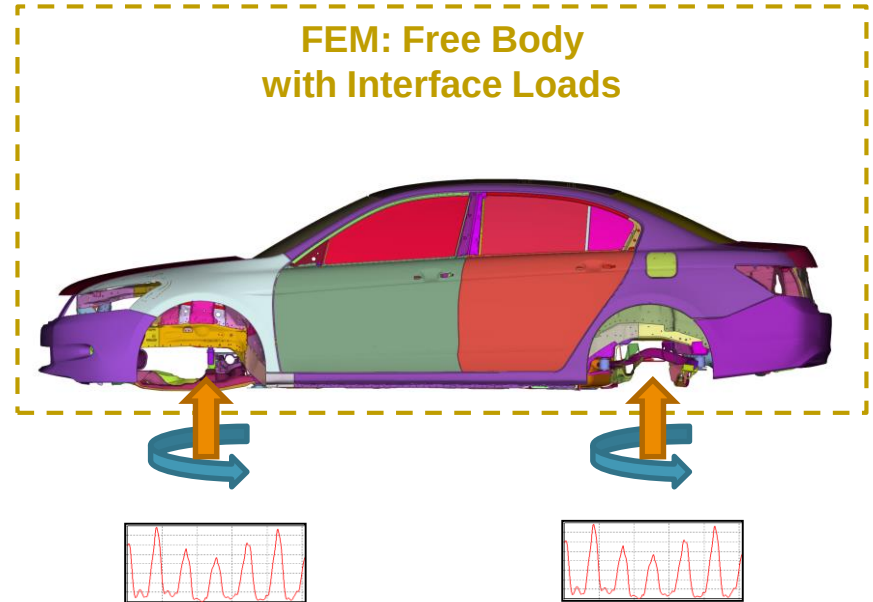
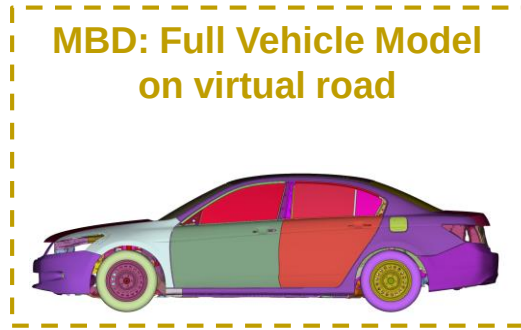
Spot Welds

Fatigue Assessment of Body Structures



Define Reasonable Boundary Conditions

- Analysis as free body with imposed interface loads
- According workflow involves two major steps:



Obtain interface loads once ...

... and utilize during body structure design loops

Obtain Meaningful Stress Time History

Elementary Investigations

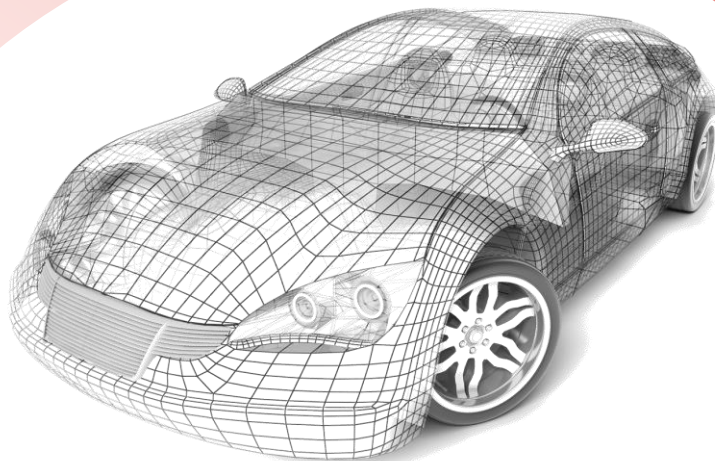
Extended Investigations

Linear
Dynamic
FEM Modal Approach

Non-Linear
Quasi-Static
FEM including contact

Linear
Quasi-Static
FEM Inertia Relief

Non-Linear
Dynamic
Including contact

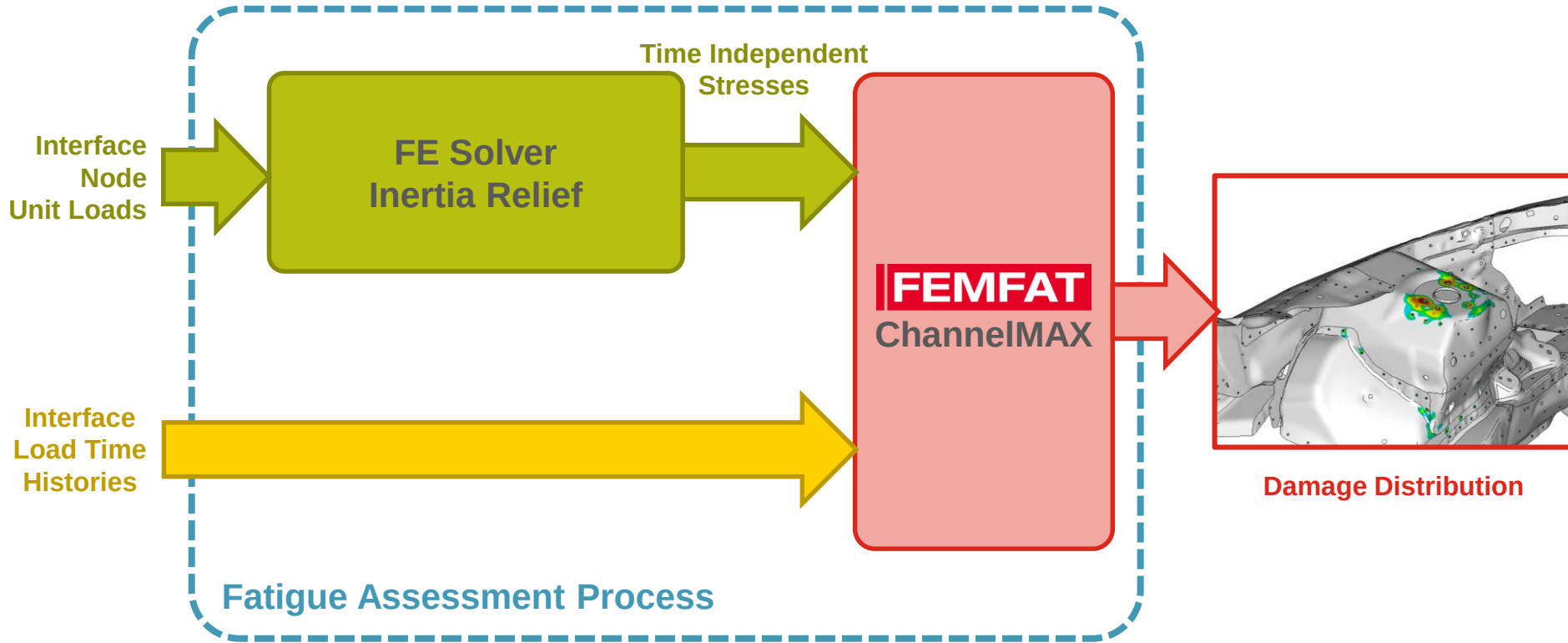


Increasing Accuracy
Increasing Effort

Elementary Investigations

Inertia relief and linear dynamic analysis

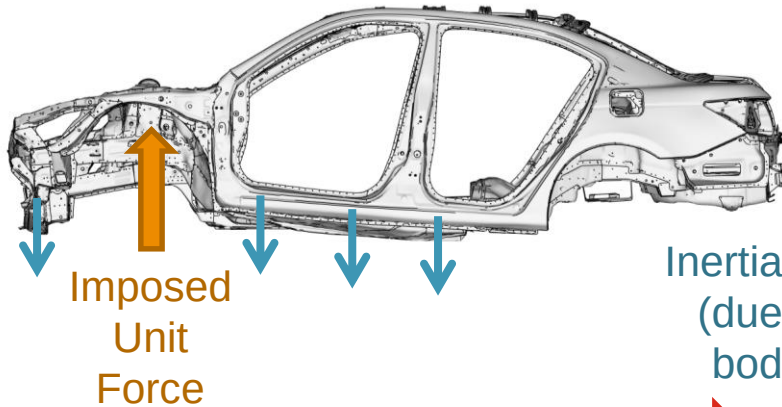
Baseline: Inertia Relief based Fatigue Assessment



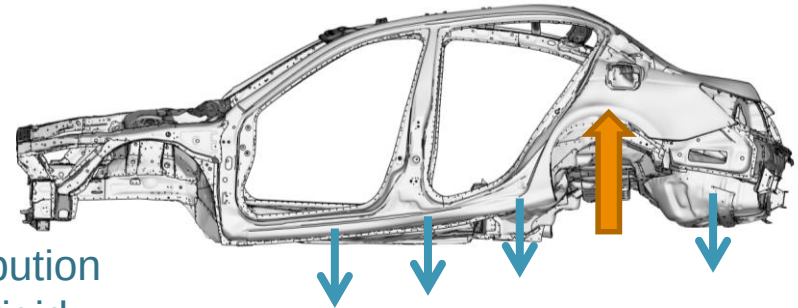
Brief Outline of Inertia Relief Analysis

- Inertia relief displacement shapes are part of Rubin's method for model reduction
- Quasi-static approach as normal modes are not considered

Exemplary Inertia Relief Load
(vertical at front strut mount LHS)



Exemplary Inertia Relief Load
(vertical at rear strut mount LHS)

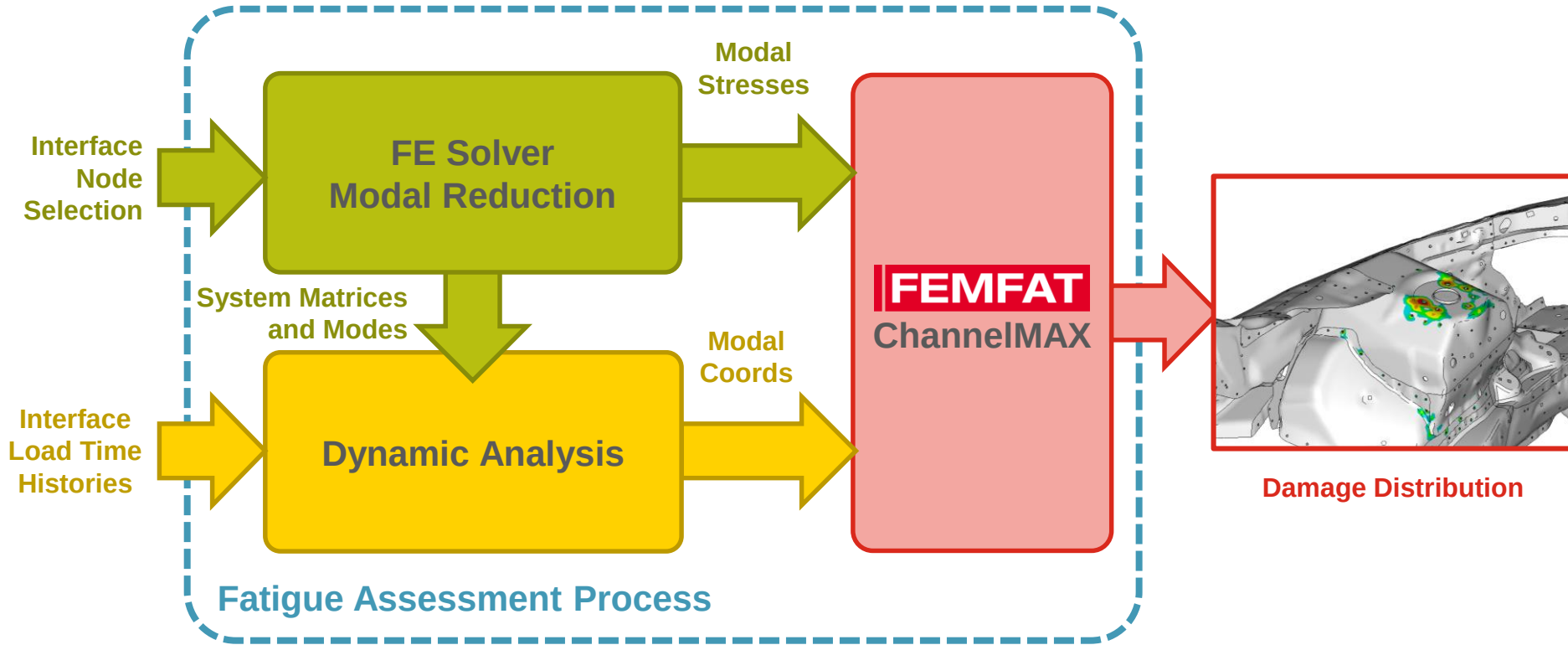


Inertia Force Distribution
(due to resulting rigid
body accelerations)



Displacement and stress time histories are obtained as
superposition of the inertia relief displacement shapes

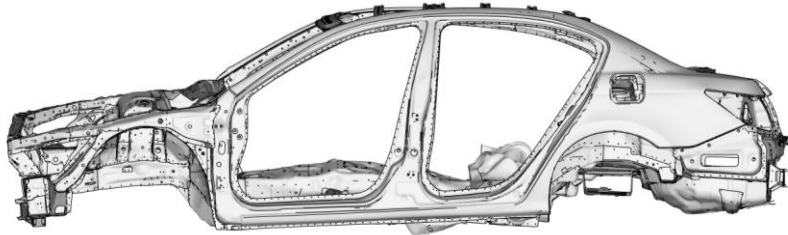
Dynamic Analysis based Fatigue Assessment



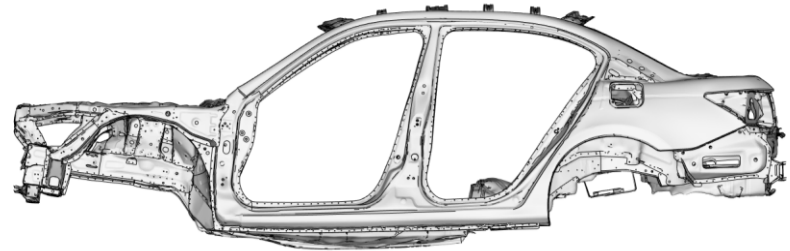
Brief Outline of Mode based Dynamic Analysis

- Component modes according to Craig and Bampton method for model reduction
- Comprise static displacement shapes and normal modes

Exemplary Component Mode
(mainly torsion)



Exemplary Component Mode
(mainly bending)



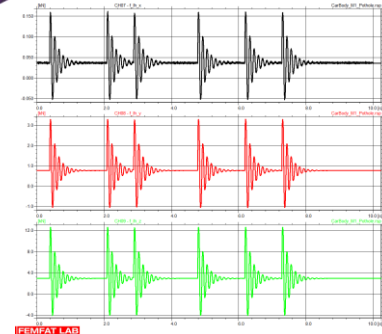
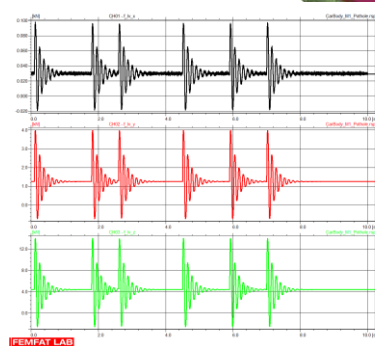
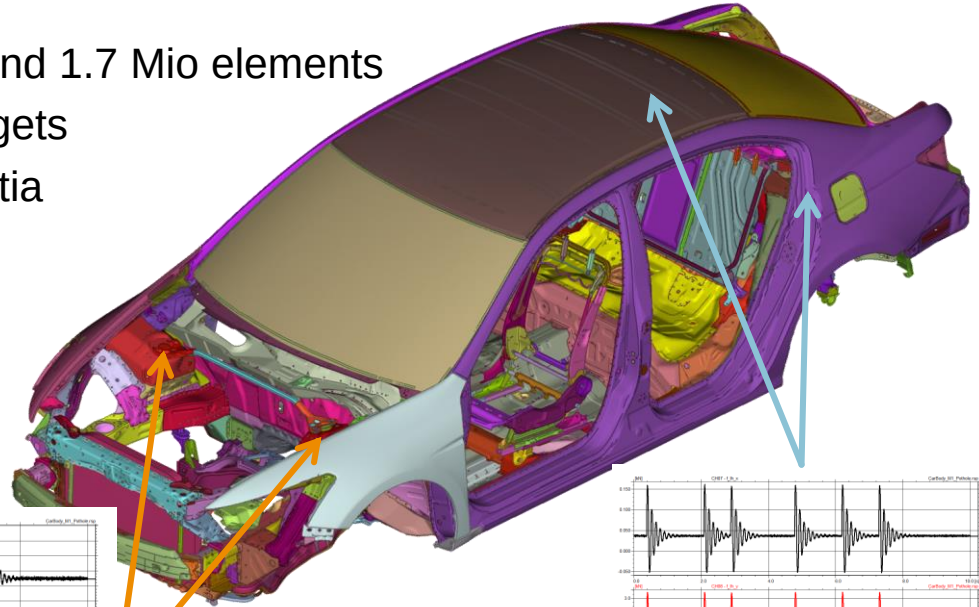
Displacement and stress time histories are obtained as superposition of the component modes

A horizontal banner image showing a wireframe model of a car body. The model is composed of blue lines. Overlaid on the wireframe are several bright red, glowing, curved lines that suggest motion or a specific design path.

Example: Sedan Car Body

Sedan Car Body Structure

- Structural Model
 - FEM discretization with 1.9 Mio grids and 1.7 Mio elements
 - Spot welds modelled via FEMFAT nuggets
 - Attached masses and moments of inertia
 - Hood, doors and tailgate
 - Fuel tank
 - ...
- Generic Maneuver “Curbs”
 - Interface loads applied at front and rear strut mounts

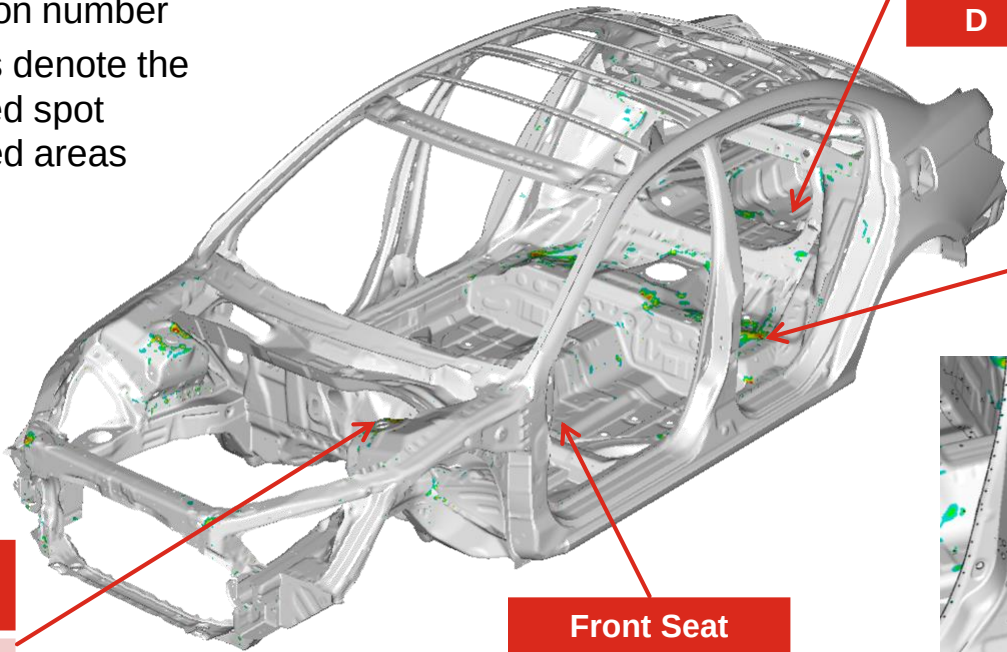


Maneuver “Curbs”: Baseline Fatigue Assessment



FEMFAT Spot Weld Damage

- Artificial repetition number
- Depicted values denote the highest damaged spot welds of selected areas

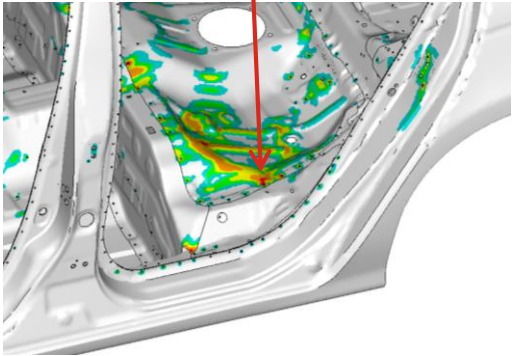


Front Strut Tower	
IR	5.1e-3
D	5.3e-3

Front Seat Mount	
IR	4.3e-3
D	1.4e-2

Spare Tire Area	
IR	3.8e-3
D	5.5e-3

Rear Seat	
IR	4.53
D	7.42



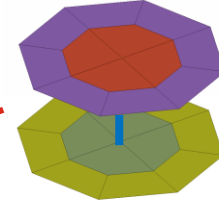
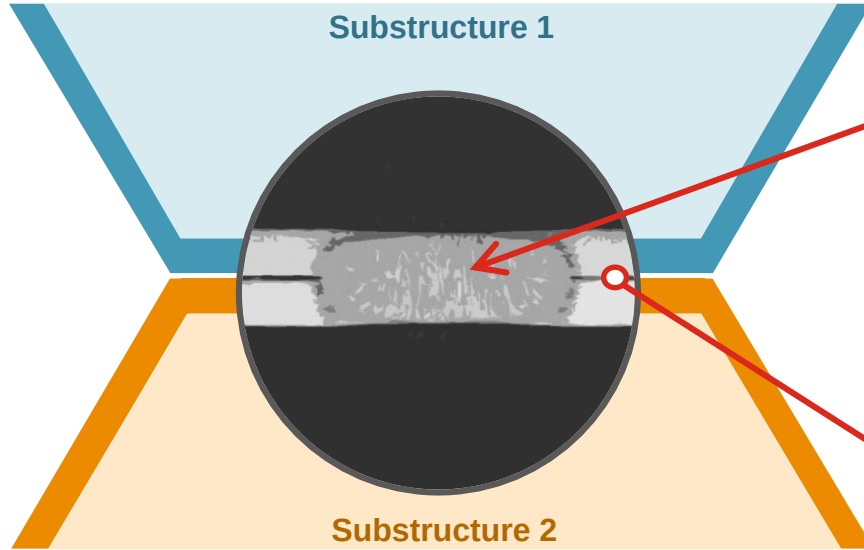
Legend
IR Inertia Relief
D Dynamic

Extended Investigations

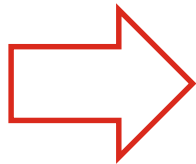
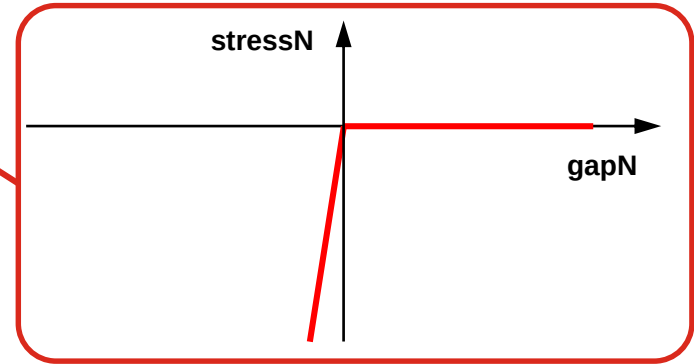
Dynamic contact analysis with MAMBA

Focus is on Spot Weld Fatigue

- Spot Representation within FEM Model



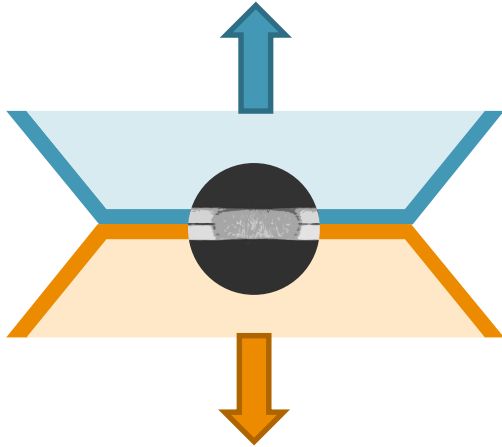
CQUADs-CBAR-CQUADs
(stress based assessment)



Obviously, the contact stresses in the surroundings of spot welds are not considered during a linear analysis

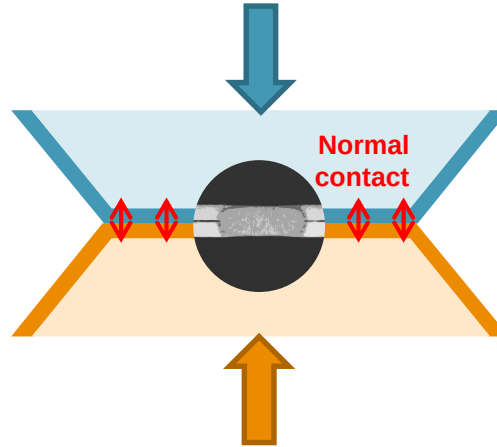
Contact Influence on Predicted Spot Weld Damage

Tension



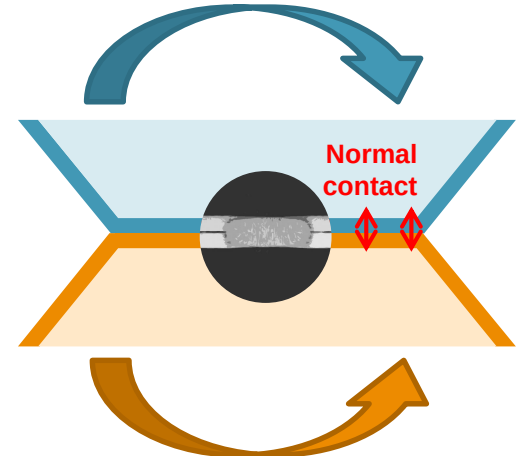
One is satisfied by the linear model

Pressure



Linear model leads to overestimated spot weld damage

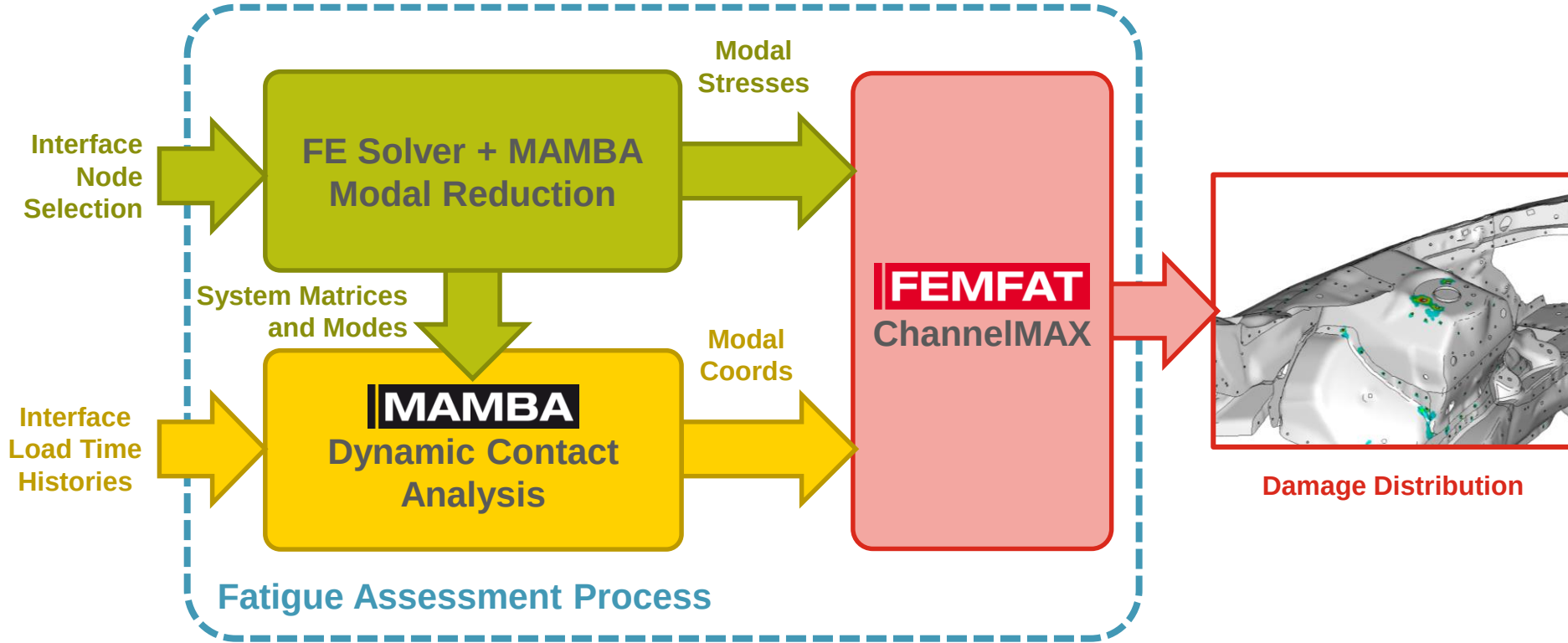
Complex Loading

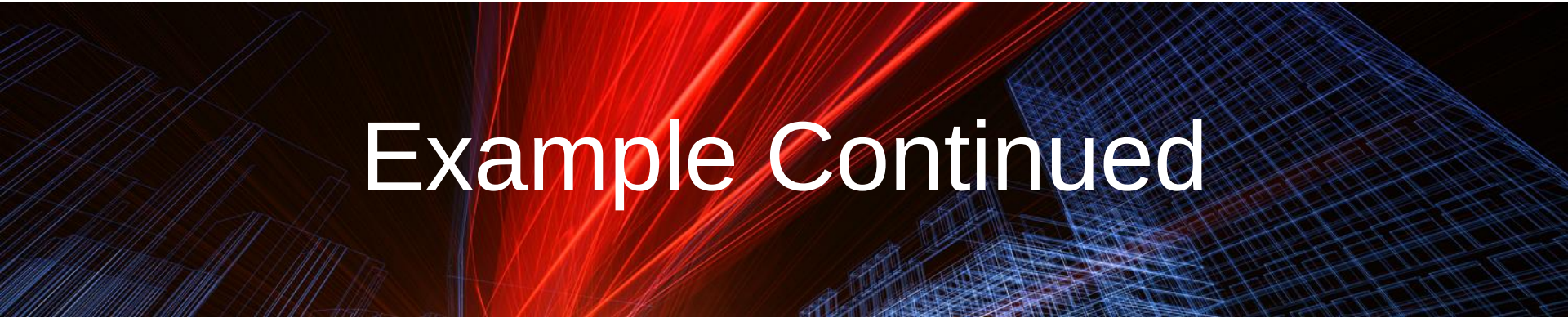


Linear model leads to underestimated spot weld damage

- No guarantee that overestimated and underestimated damage cancels out
- Contact analysis ensures realistic input for spot weld fatigue assessment

Dynamic Analysis based Fatigue Assessment

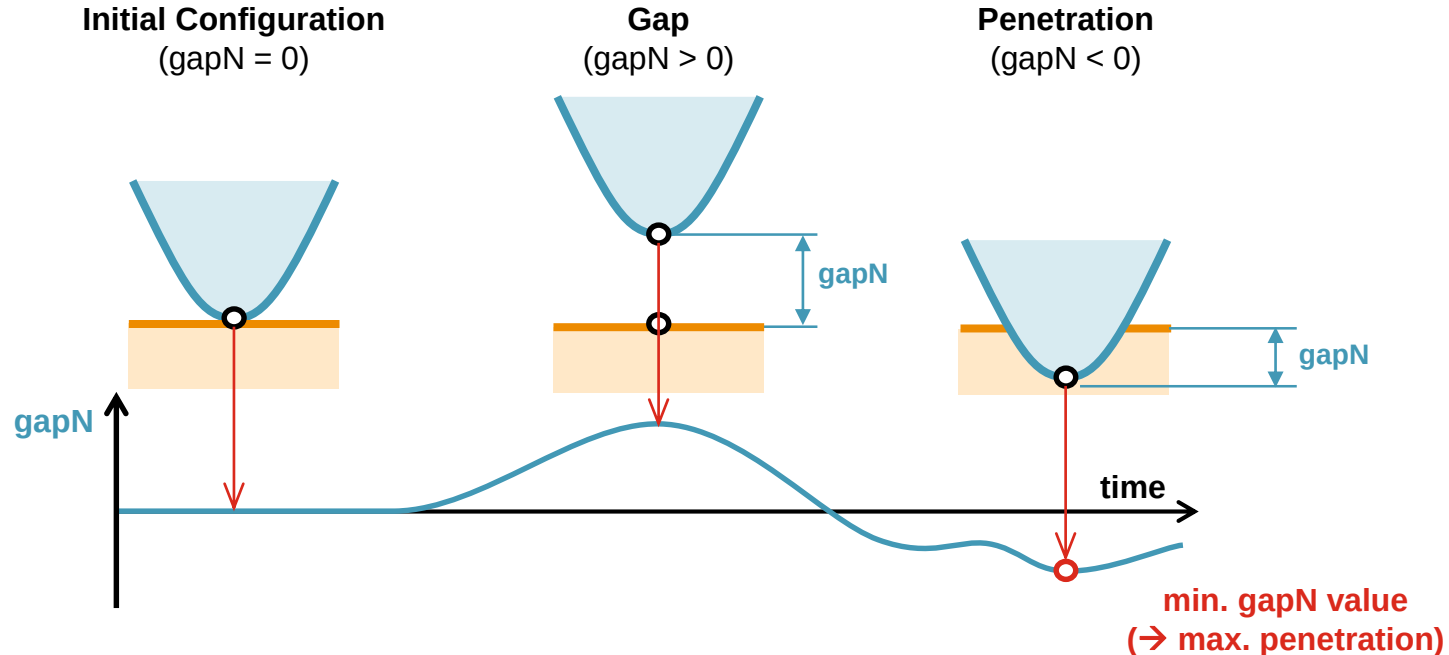


An abstract background featuring a dark field with glowing red and blue wireframe structures. Red light streaks radiate from the center, and blue wireframe cubes are visible on the sides.

Example Continued

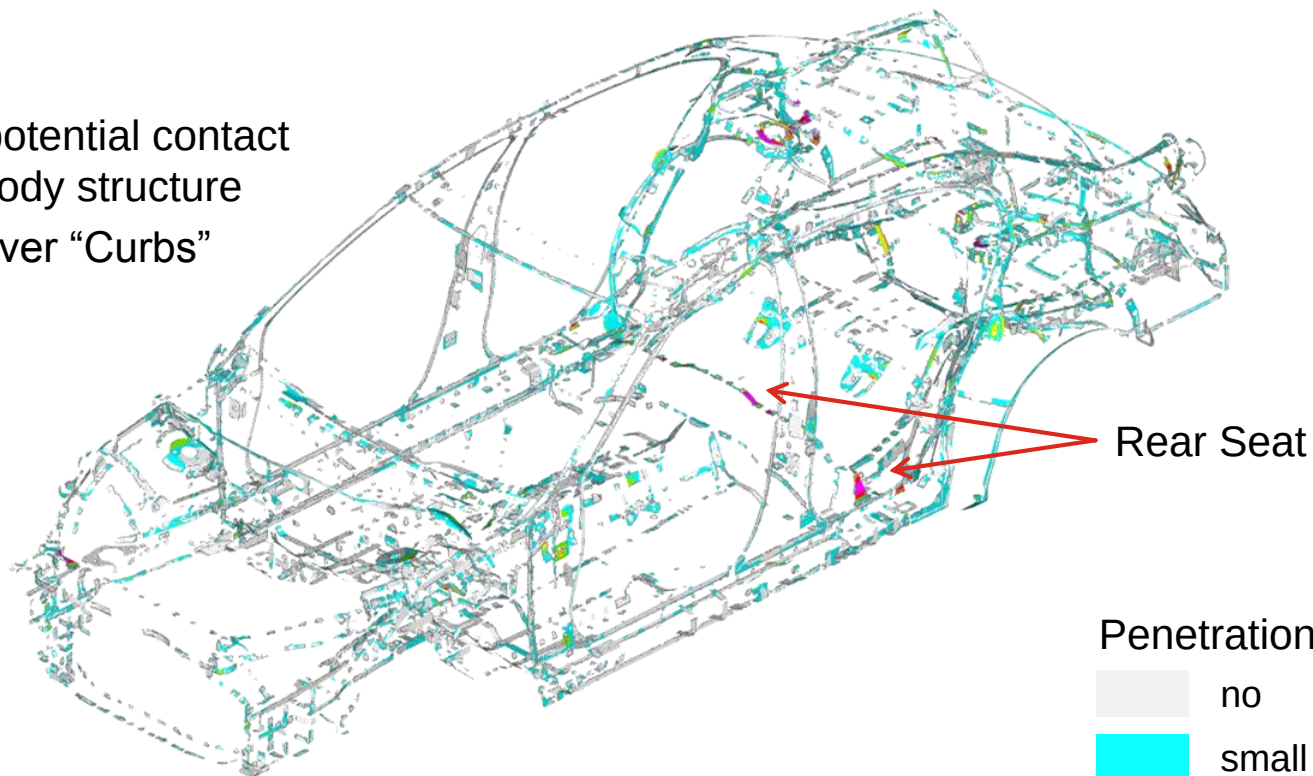
Contact Influence Quantification

- Maximum penetration within the linear model
 - For each contact pair the surface distance (gapN) time history is obtained
 - From each time history the maximum penetration value is collected



Maneuver “Curbs”: Contact Influence Quantification

- Panel penetration
 - Evaluated for all potential contact areas within the body structure
 - Related to maneuver “Curbs”



→ Contact areas with “medium” to “high” penetrations are assumed to have significant influence on fatigue results as well

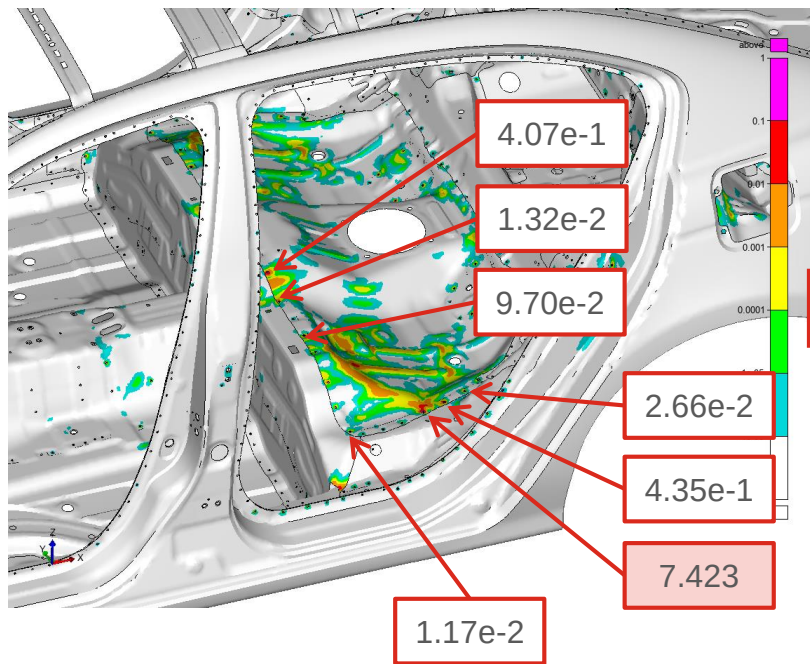
Penetration:

	no
	small
	medium
	high

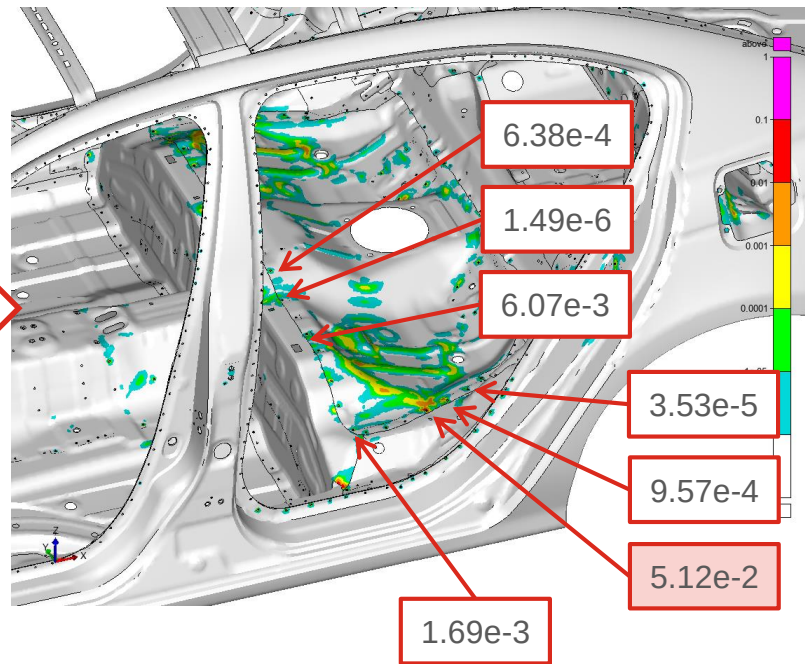
Maneuver “Curbs”: Damage at Rear Seat Spot Welds



Linear dynamic based



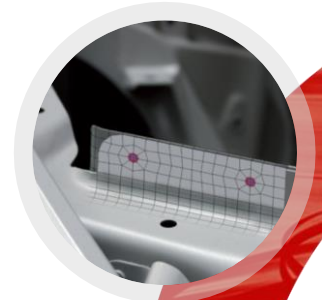
Dynamic contact analysis based



- Contact stresses reduce predicted spot weld damage
- Damage of most critical spot weld decreases by a factor > 100

Car Body Fatigue Assessment based on

- Inertia Relief
 - Requires mass trimmed model and interface load time histories
- Dynamic Analysis
 - Delivers same high damage locations as inertia relief
 - Detects further potentially high damaged areas
- Dynamic Contact Analysis utilizing MAMBA
 - Operates on the same input data as inertia relief/dynamic analysis
 - Delivers more realistic input for improved fatigue assessment
 - Handles long maneuver duration (already applied for >400 sec.)
 - Integrates smoothly with FEMFAT ChannelMAX





Forward. For all.