Improve vehicle handling by deploying a target setting process for body rigidity

Wednesday November 14, 2018

Vehicle handling news

Manufacturers put significant effort in design of vehicle body & chassis

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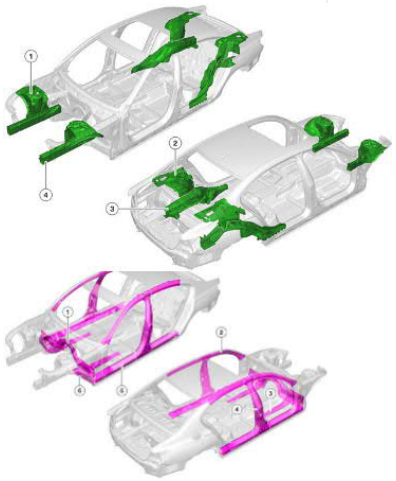
Technical Analysis: The All-New 2017 BMW 5-Series (G30)



youwheel.com

"… big step forward in some areas (for example more lightweight / advanced materials in the body construction …"

businessinsider.com

"you could think of the Odyssey as the BMW of minivans…"

"The minivan is large and weighs over 4000 pounds, but it's easy to maneuver, with responsive steering, …"

Vehicle handling news

Manufacturers put significant effort in design of vehicle body & chassis

businessinsider.com / wardsauto.com

"… built on VW's highly praised MQB platform, which also underpins the Audi A3 and Volkswagen Passat…"

"VW is spending $7 billion on developing is new MEB platform…"

autoexpress.co.uk

"… the Passat is very easy to drive, with precise and ultra-accurate steering, …"

"Because there's less weight, it turns more confidently into bends and has more agility than previous models."

Typical OEM needs & current trends
Challenges

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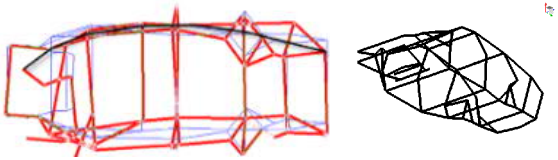
Body light-weight design while keeping performance

'Design the right stiffness in the right place'

Body target-setting for handling performance

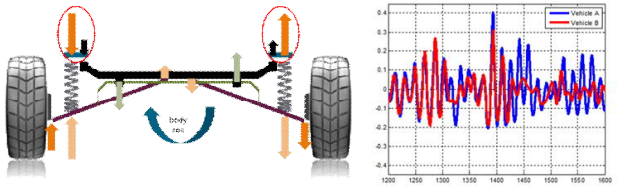
'Identify & improve body weak-points'

'Multi-attribute target setting'



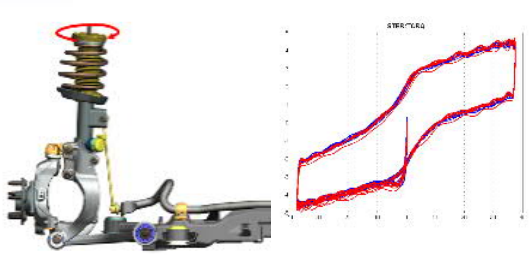
Optimal chassis performance for handling and comfort

'Does the body limit optimal suspension performance?'



Chassis on-center / low lateral acceleration performance

'Performance deterioration at low AY?'



Body target setting for handling performance

Typical process flow at OEM

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Body target setting for handling performance

Input into design process

Requires

Body metrics

Requires

Full vehicle metrics

Requires

Subjective rating

Should involve full vehicle simulation – but CAE techniques have strong **limitations considering body rigidity** analysis and target setting.

Typical OEM challenge:
objective characterization

Importance of body rigidity
Engineering implications

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- **Targets required**

Multi-attribute Optimization

Body design needs to consider multiple attributes:

- Body Targets: ***NVH***
- Body Targets: ***Comfort***
- Body Targets: ***Handling***
- Body Targets: ***…***

- **Mechanism body vs handling?**
- **Subjective vs objective?**
- **Reference data?**

To define body targets, the ***relation of body rigidity vs handling*** performance needs to be understood

- ✓ Influence can **subjectively** be perceived
- ✗ Use established **Test technology**
- ✗ Use established **Simulation technology**

Need for a method that provides a better understanding of the relation body rigidity versus handling performance

Importance of body rigidity

Insights in the relation between body stiffness and driving dynamics performance

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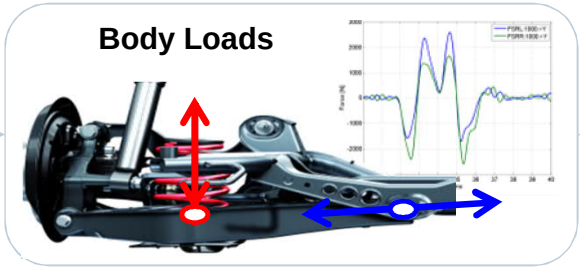
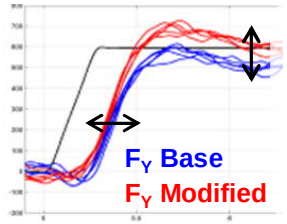
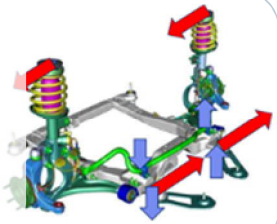
BodyFlex methodology, an approach that combines

Time domain body load identification (strain-based)

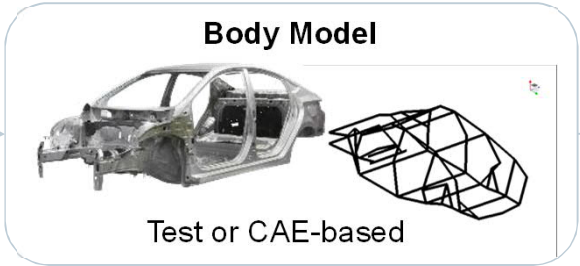


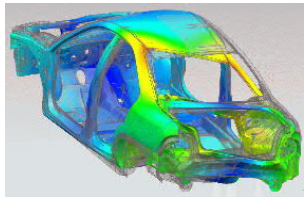


Influence body characteristics on load distribution & driving dynamics

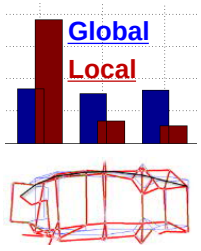


Time domain body deformation calculation and animation





Identify weak-spots by decomposing body deformation in mode contributions and Global / local



Defining body rigidity targets for handling
Building blocks

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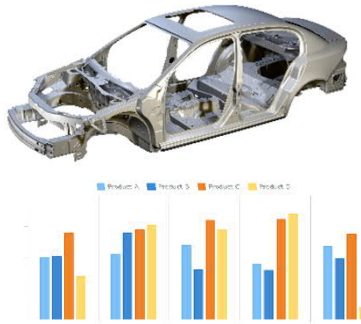
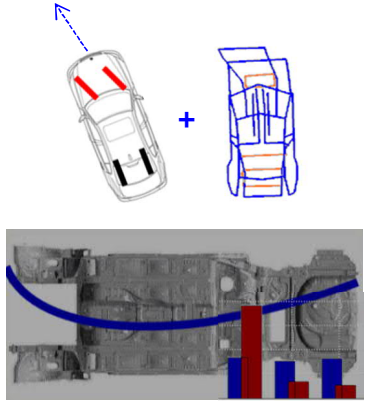
Body

Body characterization

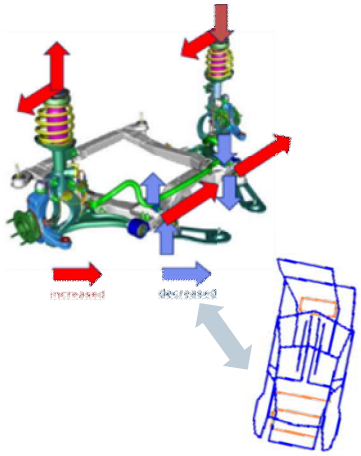


Full vehicle

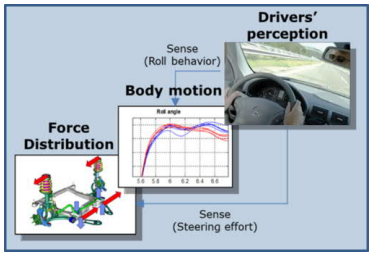
Weak-point identification



Mechanism identification



Link towards subjective



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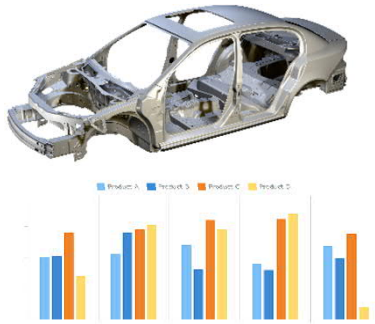
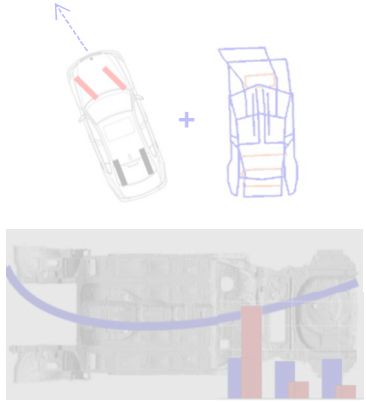
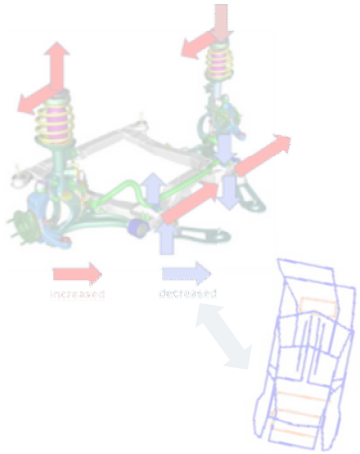


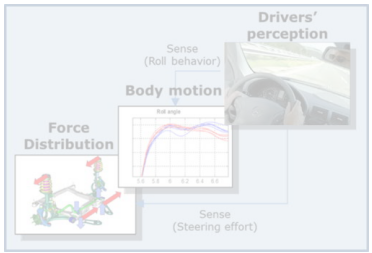
Weak-point identification



Mechanism identification



Link towards subjective



Body characterization
Static from dynamic

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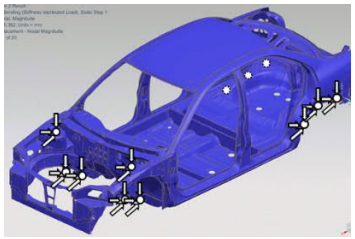
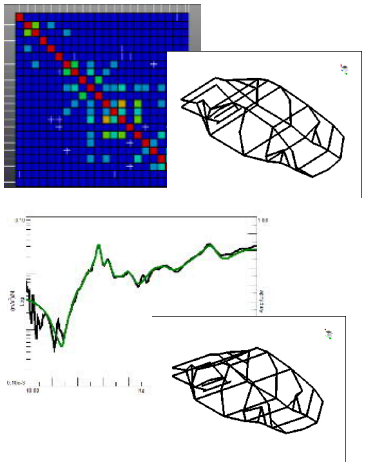
Local and global body static stiffness identification

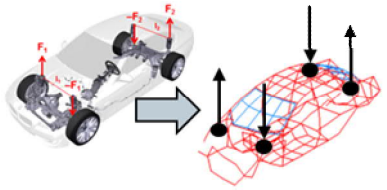
Excitation global + local



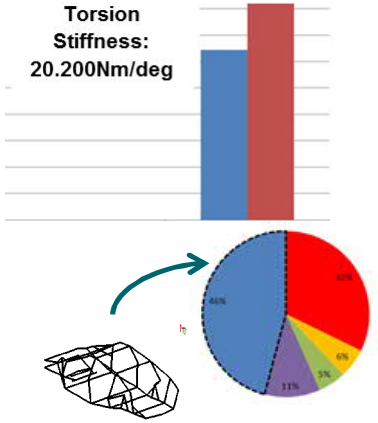
Accurate modal model (ML-MM)



Static load case inputs



Stiffness results & contribution analysis



Body characterization
Hard-point static stiffness

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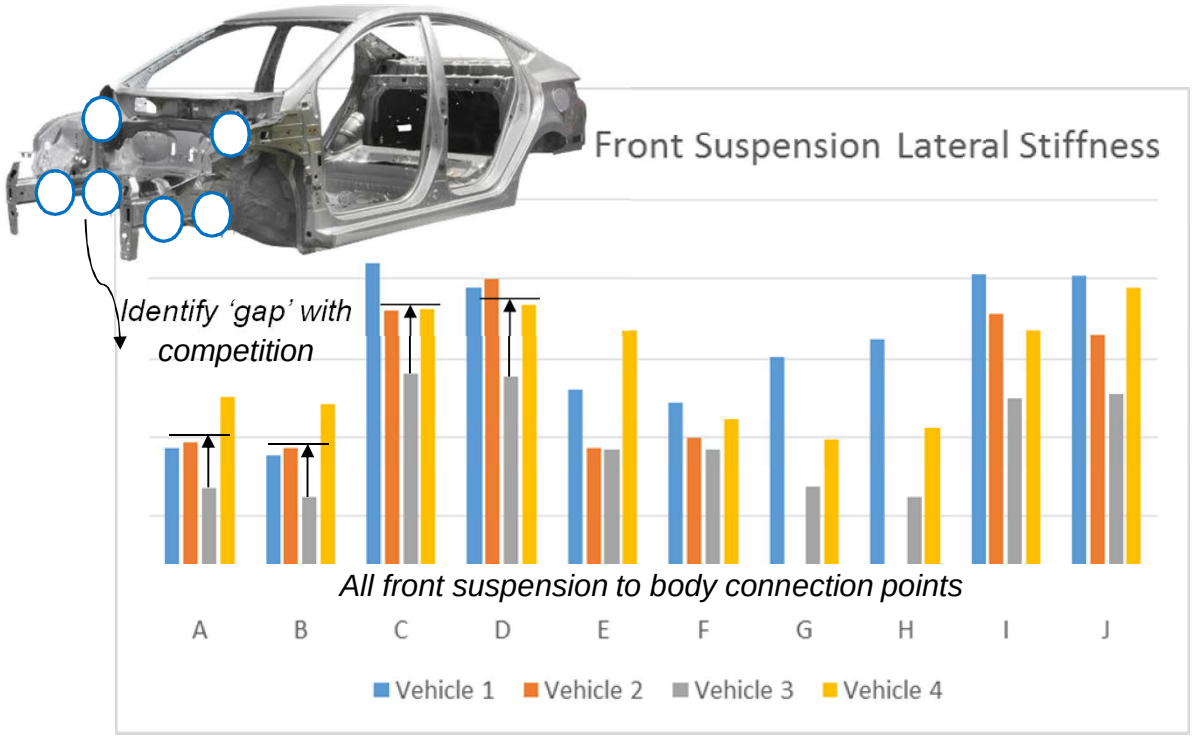
Hard-point static stiffness

Benefits

- Benchmarking database creation
- Identify weak-points
- Input to body design – target setting
- Mode contributions, …

Possible on BOTH
Body-in-White and Trimmed Body



Body characterization
Global body static stiffness

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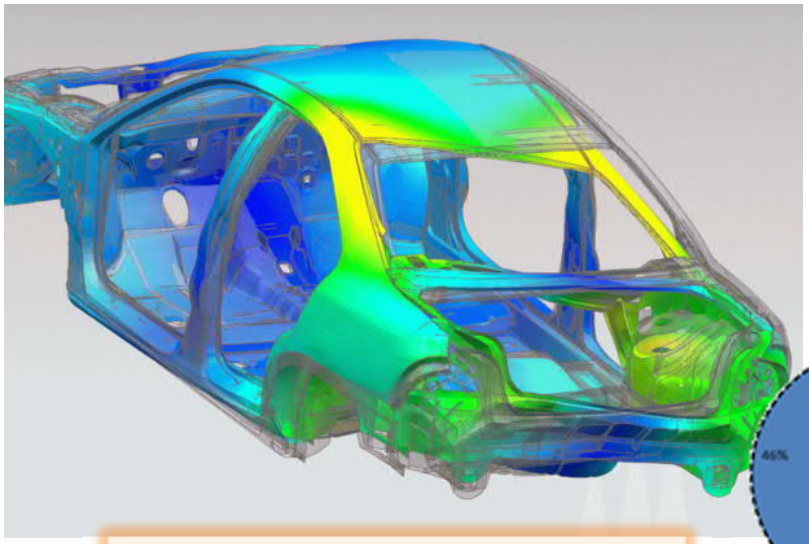
Global body static stiffness

Benefits

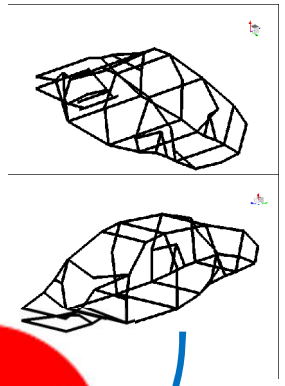
- Freedom for any static input scenario
- No clamping: easy CAE correlation
- Decomposition in mode contributions
- Identify weak-points: front, rear, local, …?
- Input to body design – target setting

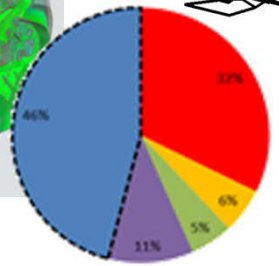
Possible on BOTH
Body-in-White and Trimmed Body

Static torsion stiffness: 20.200Nm/deg



modes





contributions

Impossible on a test-bench

Volkswagen
Trimmed body static stiffness identification and CAE correlation

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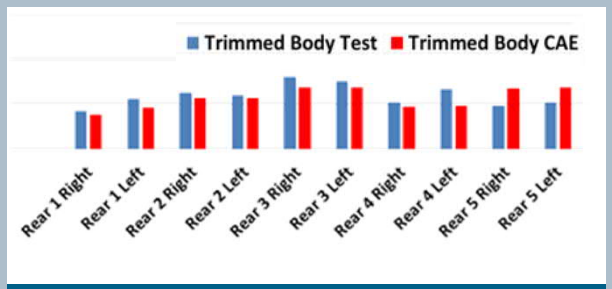
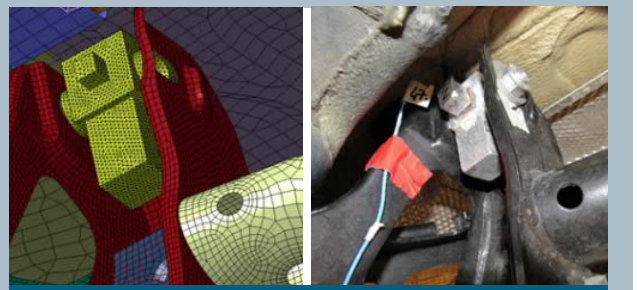
- **Objective approach to identify trimmed body stiffness with static-from-dynamics**
- **Correlate CAE with trimmed body testing**
- **Enhance body target setting process**
- **Enable better balancing of multiple performance attributes**

Objectively identifying trimmed body stiffness with static-from-dynamics



Example of correlation with CAE



Trimmed body CAE and TEST

- Global static stiffness and contribution analysis to get insights in the static performances
- Identification of static stiffness distribution of the body to allow benchmarking and weak-point identification

"The Simcenter Engineering correlation approach supports Volkswagen engineers to get even more insight into the best possible balance between structural stiffness driven vehicle attributes like NVH and Vehicle Dynamics on the one hand and cost and weight performance on the other" *Volkswagen*, **Presented at ISNVH 2018**

Defining body rigidity targets for handling
Building blocks

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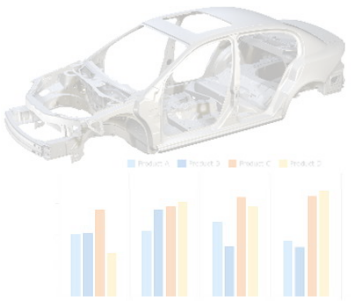
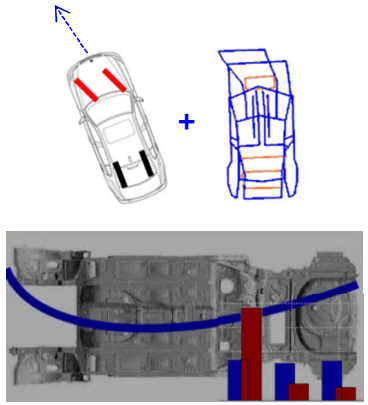
Body

Body characterization

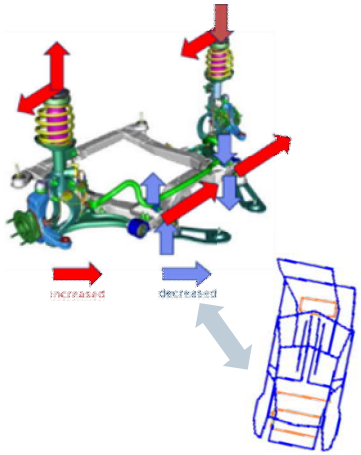


Full vehicle

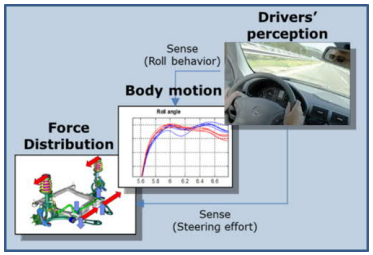
Weak-point identification



Mechanism identification



Link towards subjective



Body loads & body deformation

Body rigidity and Vehicle dynamic performance

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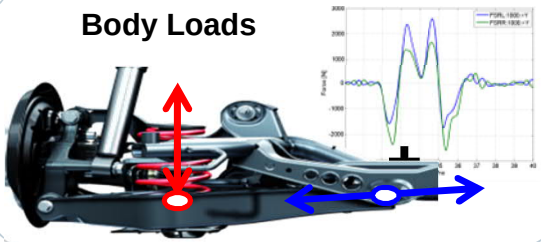
Simcenter Engineering Body flexibility methodology: advanced time-domain body load and deformation analysis

Body Loads

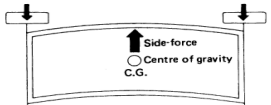


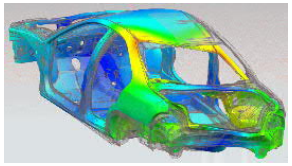
Body Model

Test or CAE-based

$$X(t) = \psi . q(t)$$

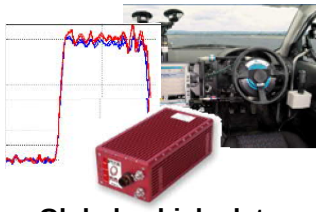
Time-domain Body Deformation





Which steps to take to enable body rigidity analysis for vehicle dynamic performance

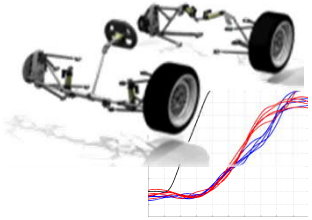
Classic handling data



Global vehicle data
(minor result changes)

+

Body loads



Suspension to body loads
(relevant result changes)

+

Body deformation

Stiffness & deformation
(insight phenomena)

1. Identify objective changes
2. Understand changed performance
3. Establish links to subjective
4. Identify mechanism body - handling

Full vehicle track testing with body load identification

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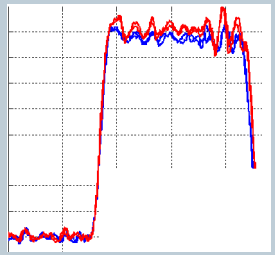
Limitations of traditional handling parameters

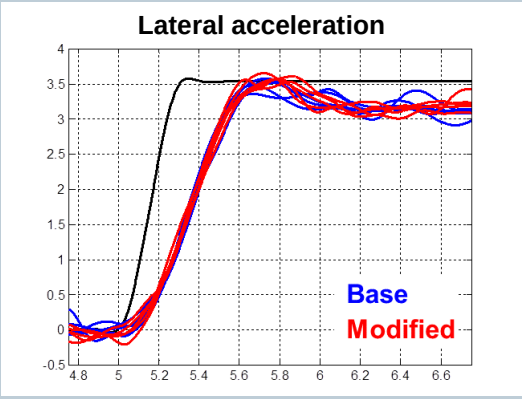
- Classic instrumentation for vehicle performance
  For example: lateral acceleration, roll, slip, yaw-rate

These **global vehicle parameters**

- are defined at **center-of-gravity**
  (global vehicle behavior)
- **result from all loads** that work on the body structure
- **can't capture subtle changes** as 'a faster front response'



Global vehicle data: **typically minor result changes**



A **global vehicle parameter** as lateral acceleration typically doesn't capture the effect of body modifications

Full vehicle track testing with body load identification

Why usage of time-domain loads?

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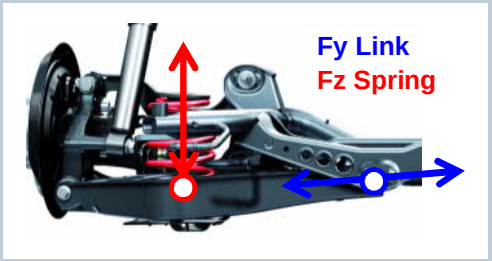
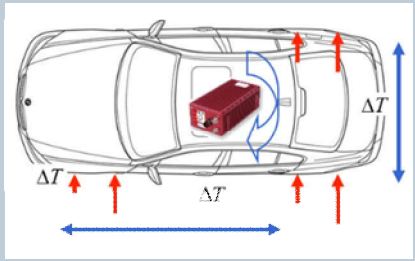
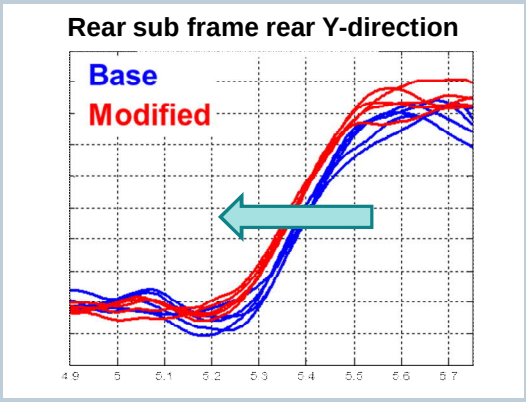
- Body loads are **contributors** to each global vehicle parameter
- Using these **body loads**
  - performance changes can be identified in a **far more detailed** way
  - enable estimation of **time-domain body deformation**
  - enable to **understand interaction** of body and handling performance

Benefit: Identify time-domain body loads, providing in-depth insight in changing vehicle performance and subjective ratings





Local vehicle data: **typically clear result changes**



A **lateral body load** (contributor to lateral acceleration) can clearly capture the effect – a much faster rear axle response

Full vehicle track testing with body load identification
Approach

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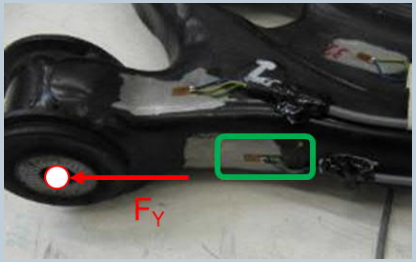
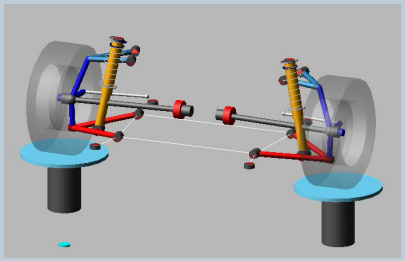
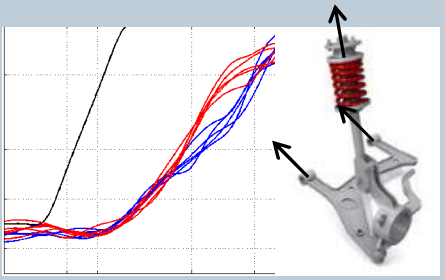
1. Instrumentation & **model-based load calibration** for each suspension component
2. Full vehicle **track measurements** in base / modified condition
3. **Values from track data analysis**
   - Load estimation
   - Quantify & understand impact modification on vehicle performance
   - Data analysis to establish links towards subjective evaluations

Benefit: Identify time-domain body loads, providing in-depth insight in changing vehicle performance and subjective ratings

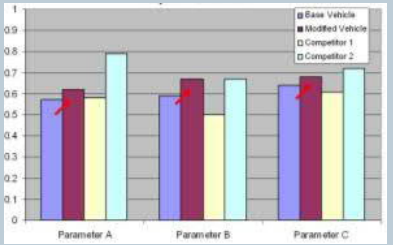




Extract *multiple* load components for a link



Modification impact on transient load build-up



Modification impact on subjective perception

Body deformation analysis & Vehicle dynamic performance

Potential influences of body rigidity on vehicle dynamic performance

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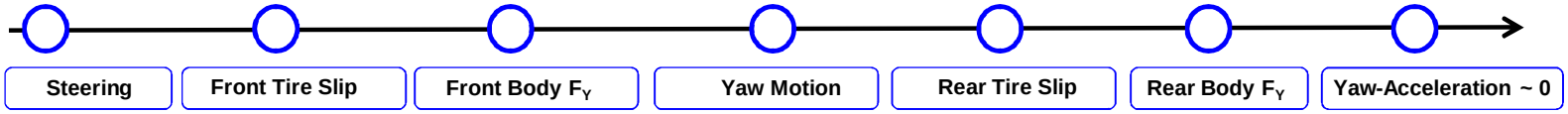

- ‘Slow reaction of rear suspension’
- ‘Understeer feeling. Weak yaw damping.’
- ‘Vehicle response not *‘natural’* or linear’
- …

Or: ***the Body is limiting the suspension (optimal) performance***

Expanding to body deformation estimation
Approach

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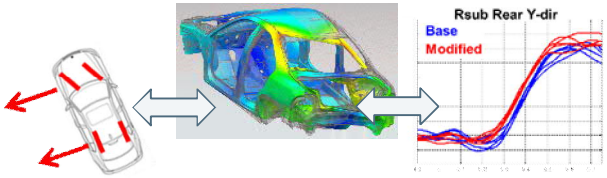
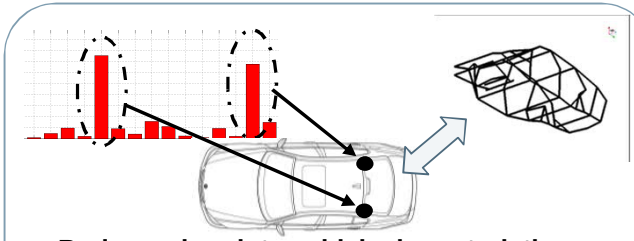
1. Use time-domain **body loads** (base / modified) identified for track-tests

2. Identification of a **body modal model** (Test or CAE)

3. **Body deformation calculation** through load application to body model
   - Visualization and decomposition of body deformation in the maneuver
   - ***Weak-spot identification:*** improvement potential for body structure
   - ***Mechanism identification:*** interaction body with vehicle performance



Understand impact changed body characteristics on vehicle performance (load-distribution)



Body weak-points: which characteristics are important in transient, steady-state?

Benefits
1) Identify the mechanism between body rigidity – vehicle performance
2) In-depth analysis of body behavior – weak-spot identification

Defining body rigidity targets for handling
Building blocks

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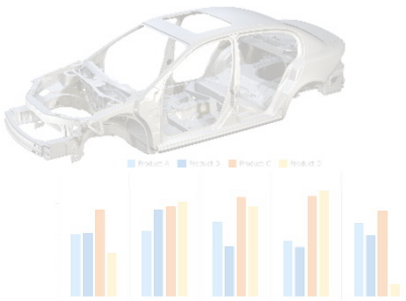
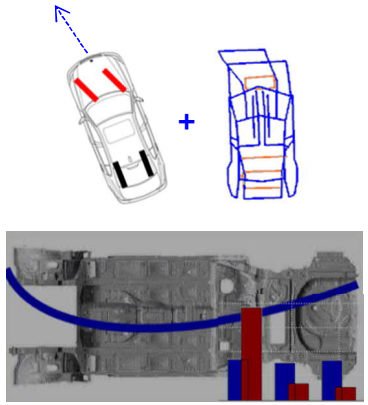
Body

Full vehicle

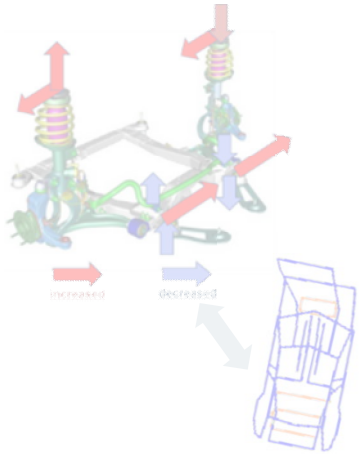
Body characterization



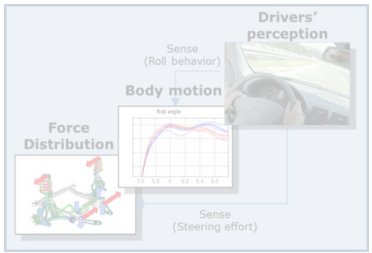
Weak-point identification



Mechanism identification



Link towards subjective



Body loads & body deformation

Body deformation analysis
Identification of weak-spots

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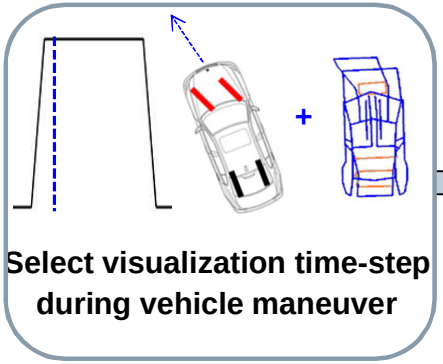
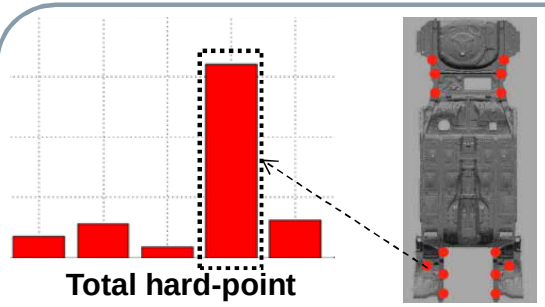
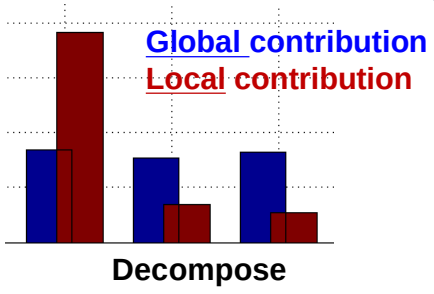


Select visualization time-step during vehicle maneuver



Total hard-point deflection

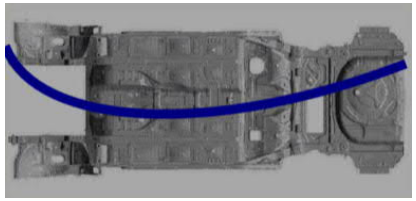


Decompose point deformations

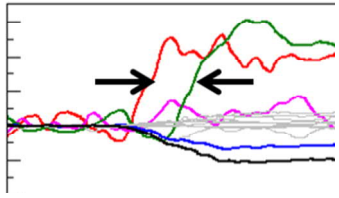
Body deformation analysis
Synchronous visualization:

- Handling parameters
- Loads
- Deformations
- Contributions of modes

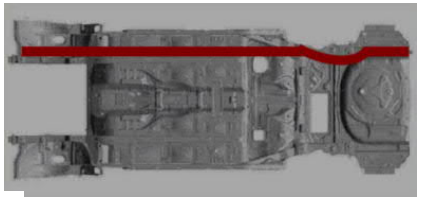
Detailed body analysis, identification of **potential weak-spots**
Identify which **body characteristics** are important in the **transient** or in the **steady state**



Dominating global flexibility contributions?



Which body property is important at steering input?



Dominating local flexibility contributions?

Defining body rigidity targets for handling
Building blocks

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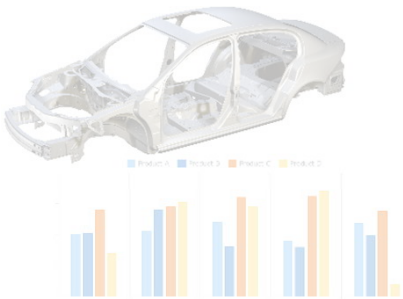
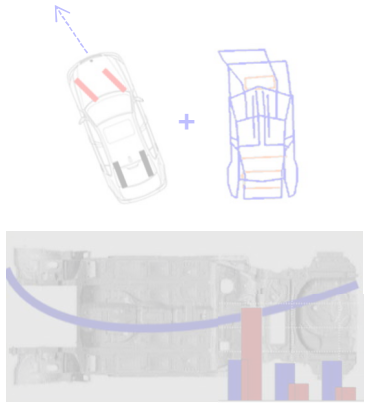
Body

Full vehicle

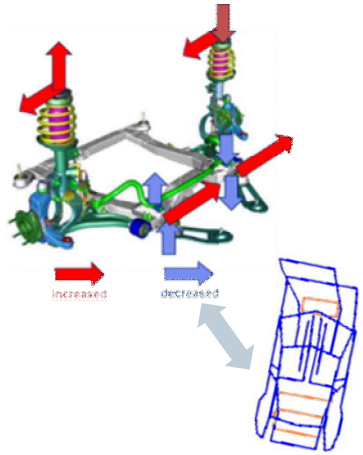
Body characterization



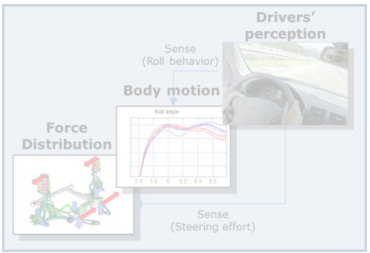
Weak-point identification



Mechanism identification



Link towards subjective



Body loads & body deformation

Body deformation analysis
Weak-point analysis & Mechanism identification

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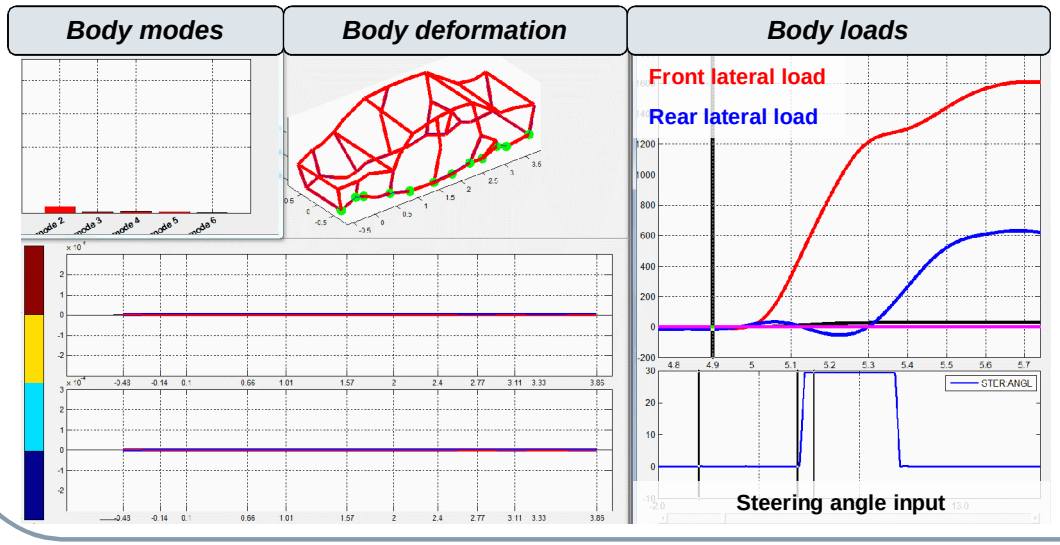
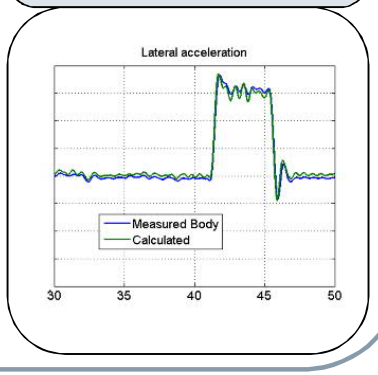
Challenge Improving the vehicle dynamic performance through optimized body characteristics

Solution Body weak-spot analysis, body modification analysis → **input to body target setting**

Animate body deformation together with mode contributions, loads, handling parameters

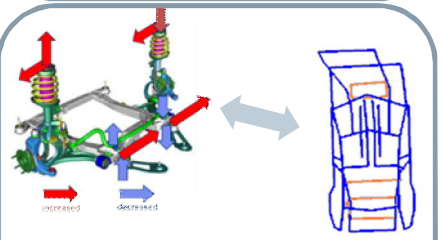


Step steer maneuver @ 100kph



Time-domain loads

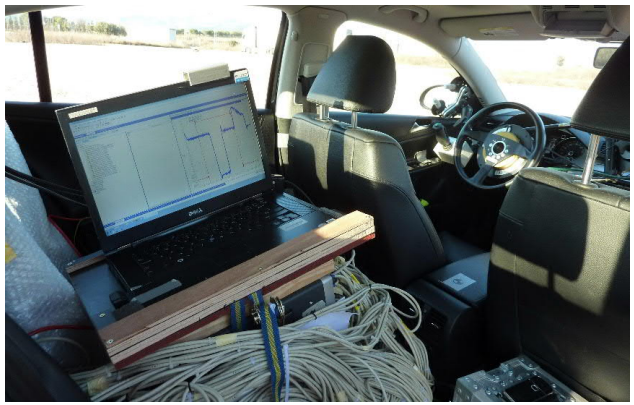
Body weak-point analysis with Siemens toolset



Understand mechanism between body characteristic & vehicle performance

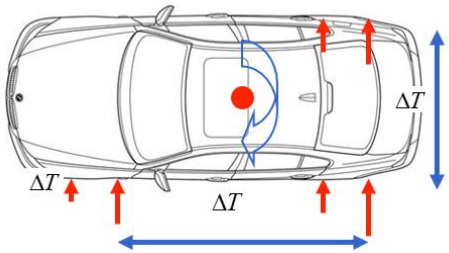
Honda

Importance of body rigidity in the transient stage of the maneuver

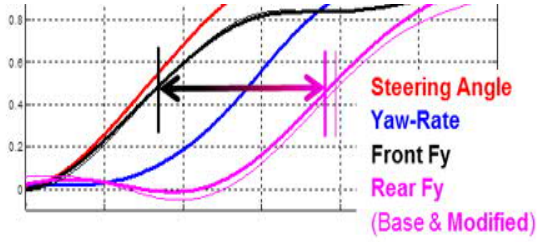


- **Identify key body metrics for transient handling**
- **Link subjective evaluations to objective data**
- **Insights in mechanisms between body and suspension in the transient stage**

Contribution analysis



Handling parameters and load distribution



Modification impact on rear axle response

- Analyze vehicle in base and modified body configuration
- Influence of reinforcements on handling parameters and body load distribution

Gain insights into the relation of body flexibility versus vehicle handling using an combined test and simulation approach.

Presented at Chassis.Tech 2015

Defining body rigidity targets for handling
Building blocks

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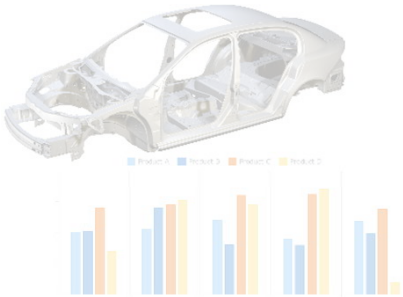
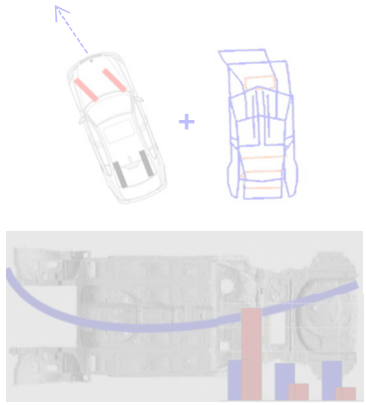
Body

Full vehicle

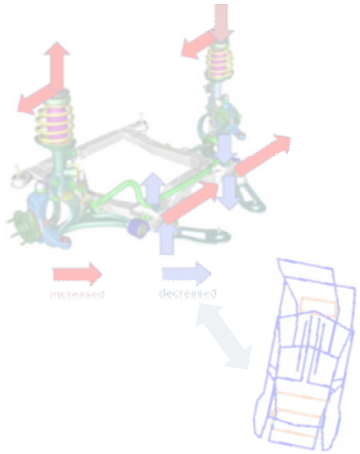
Body characterization



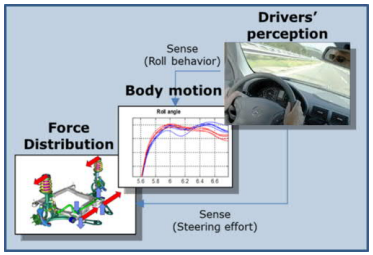
Weak-point identification



Mechanism identification



Link towards subjective



Body loads & body deformation

Body modification analysis
Relation to subjective perception

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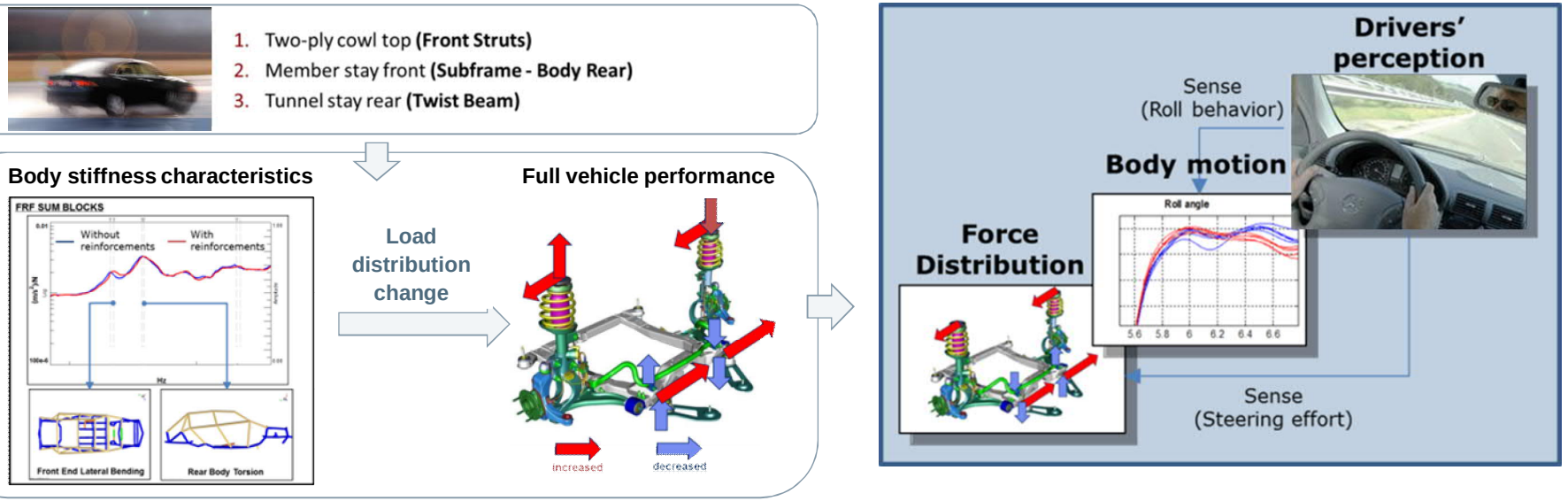
Challenge Identification how **subjective evaluations** are affected by car body stiffening

Solution Load & deformation analysis to identify the **mechanism** body – vehicle performance

Changing body characteristics → Impact on vehicle performance → Link towards subjective



Nissan Motor Company

Uncovering the complex interaction between body flexibility & handling

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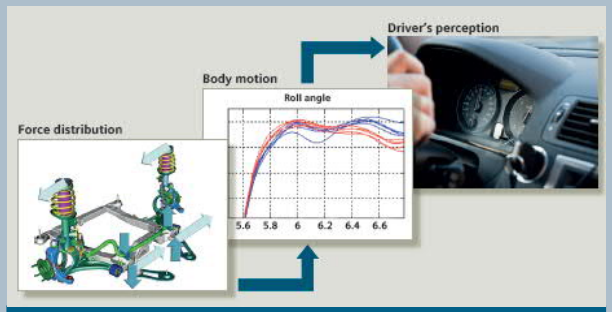
- **Gained insight into the relationship between the subjective perception of an expert driver and the influence of body rigidity changes on the vehicle's dynamic performance**
- **Developed a method that enables insightful decisions on body flexibility earlier in the vehicle development process**

Understanding the relationship between body flexibility & vehicle handling



Targeted body design decisions for optimal vehicle handling in the future

Accurately identifying operational force distribution

- Identify the operational loads between body and suspension in time domain
- Visualize body deformation as well as the contribution of the individual body modes in time domain

"I think Simcenter Engineering has three main differentiators. Firstly, they combine high-end testing with CAE. Secondly, they have a very vast experience with automotive OEMs. And finally, Simcenter Engineering has a very talented global team of experts. Hitoshi Kyogoku, Vehicle Dynamics CAE Group manager

Body modification analysis
Identify key body characteristics

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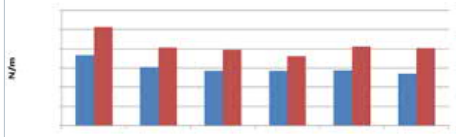
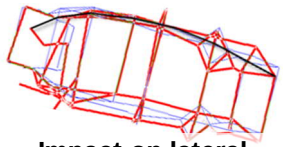
Challenge Identification of **key body characteristics for target setting** for vehicle dynamic performance

Solution **Body modification analysis** to identify which performance relates to which body property

A changed body property '*alpha*' results in:
different stiffness & changed on-track deformation



Changed static hard-point stiffness

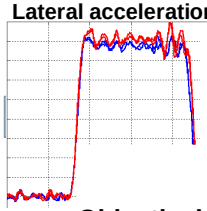


Impact on lateral deflection in maneuver

This analysis of body characteristics allows

- Establish **relation body – performance**
- Establish links to **subjective**
- Improve **body target setting** process
  - focus on body characteristics that are key for performance

Lateral acceleration



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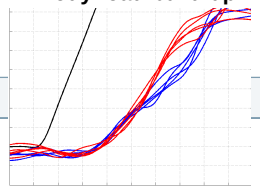
Body-load build-up



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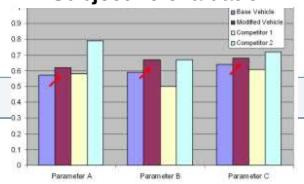
Subjective evaluation



Objectively quantify the impact of body property '*alpha*' on global parameters, transient load build-up and subjective perception

Does '*alpha*' impact
- **Initial responsiveness?**
- **Load build-up capability?**
- **Rear axle timing?**
- **Roll behavior?**

On-center vehicle performance
Application case

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Growing interest in on-center performance

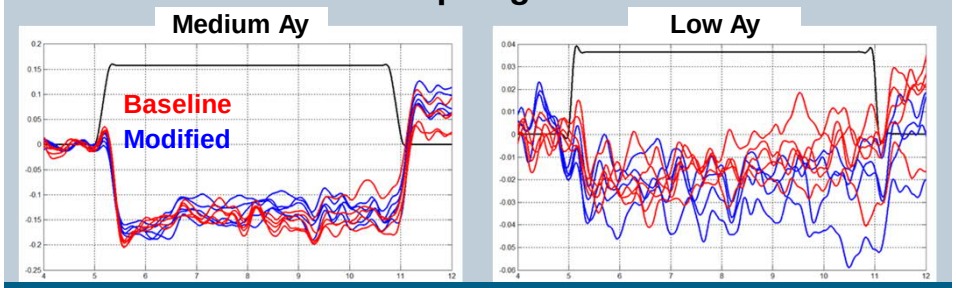
Challenges: Vehicle performance change (deterioration) towards low Ay

- How to measure, quantify objectively?
- How to set targets?
- Non-linearity?

Siemens solutions

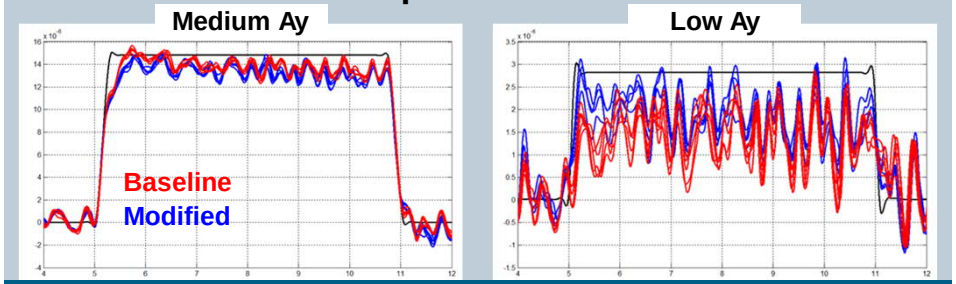
- **Objective characterization method**
  - On both body and suspension level
  - Even at low response levels
  - Using suspension loads
- **Simulation methods**
  - Capture complex suspension phenomena

Slip angle



Noise, drift – unstable, difficult to analyze

Suspension load



Repeatable, clear difference Base - Modified

How to establish a body target setting process & ensure precisely the desired driving characteristics?

➔ By combining these methodologies

Body target setting for handling performance

Typical process flow at OEM

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Body target setting for handling performance

Input into design process

Requires

Body metrics

Requires

Full vehicle metrics

Requires

Subjective rating

Should involve full vehicle simulation – but CAE techniques have strong **limitations considering body rigidity** analysis and target setting.

Typical OEM challenge:
objective characterization

Body target setting for handling performance
Combining Test/CAE

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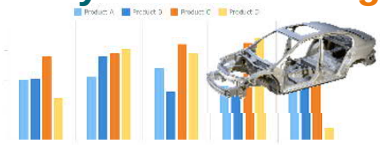
Body target setting for handling performance

Input into design process

Test & CAE

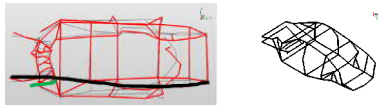
Body metrics

Body benchmarking



CAE

Weak-point analysis of body



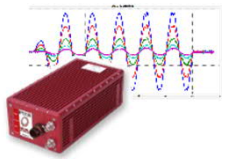
Body design modifications

Test

Full vehicle metrics

Evaluate modifications

Subjective & objective



Efficient process required: OEM setup + **extensions**

Simcenter Engineering solutions

Body characterization
- Benchmarking, weak-point, modifications

Full vehicle testing process
- Track testing or bench testing
- New, efficient & fast methods
- Metric definition

Support target setting process
- On body level, on full vehicle level

Body rigidity and vehicle dynamic performance

Deploying a target setting process for body rigidity

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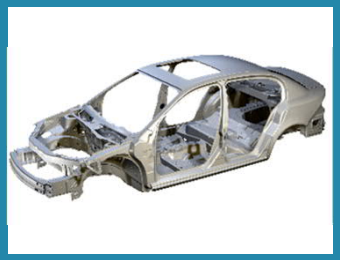
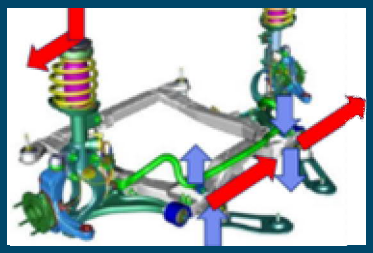


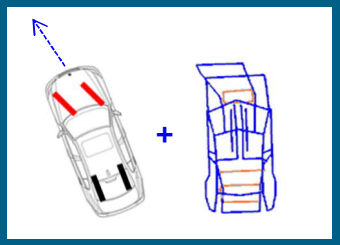
Support input for body target setting

Benchmarking, Body modification analysis (body / full vehicle)



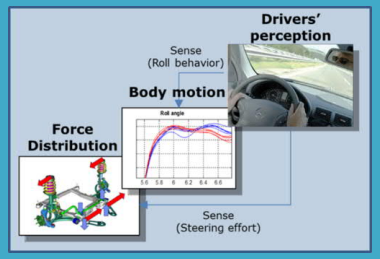
Identify how the body interacts with suspension performance

Input for body design based on mechanism understanding



Body weak-point identification using Test or CAE data

Static cases or Handling maneuver loading scenario



Link objective performances to subjective ratings

Body modification analysis on full vehicle level

Thank you! Want to know more?

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Read more

Explore, share and learn

Watch videos

Contact the expert