Demystify on-center vehicle performance

SIEMENS
Ingenuity for life

What is on-center performance?

"The "on-center" feel, or how "positively" the car would steer straight-ahead, is critical to driving comfort, especially over long distances."
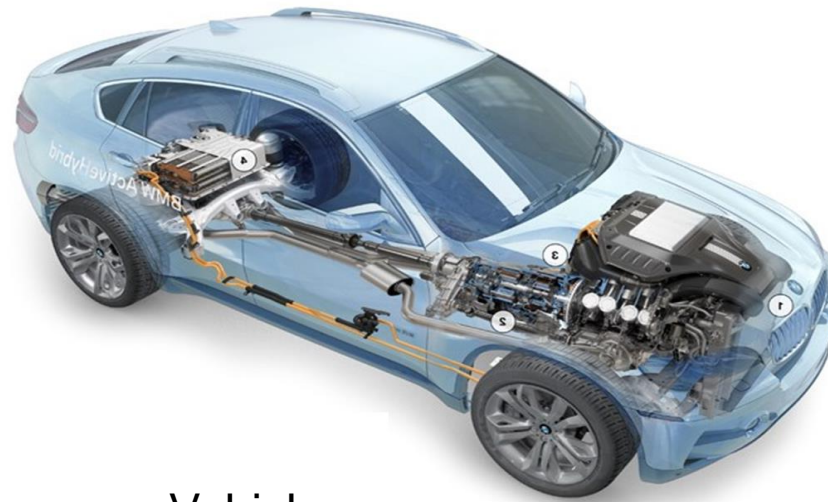
Source: ***The Truth about cars***
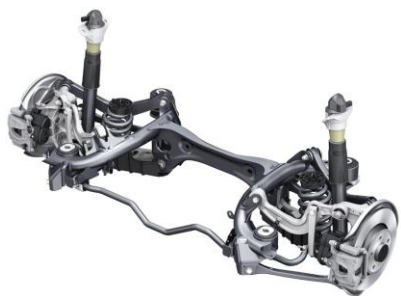
What influences on-center performance?

Tire

Steering system

Vehicle

Rear Suspension

Front Suspension

Siemens Digital Industries Software

Challenges of on-center performance

SIEMENS
Ingenuity for life

Target setting for Handling performance

*Input into design process
Recommendations for design enhancements*

Requires:

Component Metrics

Requires:

Full Vehicle Metrics

Requires:

Subjective Rating

*Challenge 3:
Involve Full Vehicle CAE simulation for frontloading design changes*

*Challenge 4:
Gain efficiency and quality in all the process*

Bigger limitation in case of on-center:
- Big test data variation
- Different metrics for mid & low ay (non-linearity)
- CAE: which physics to model, friction…

*Challenge 1:
Objective characterization*

*Challenge 2:
Link to subjective feeling*

Simcenter solutions for on-center performance
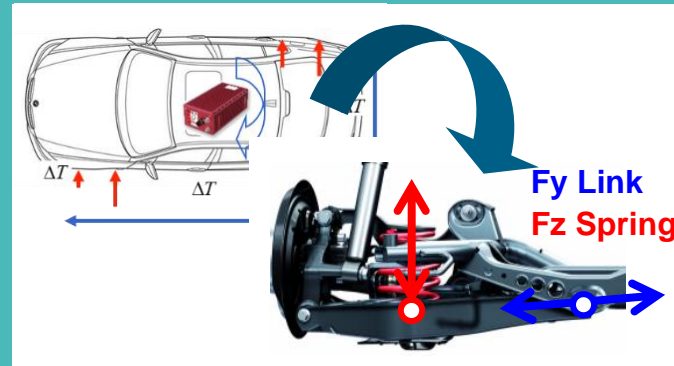
Objective characterization & frontloading design choice	Link to subjective feeling	Gain efficiency & quality in the process
Capturing on-center performance in Test and Simulation	**Decomposition analysis to get insights in vehicle performance**	**Model & Testing integration in all the V-cycle**

Fy Link
Fz Spring

Simcenter solutions for on-center performance

Capturing on-center performance in Test and Simulation

Decomposition analysis to get insights in vehicle performance
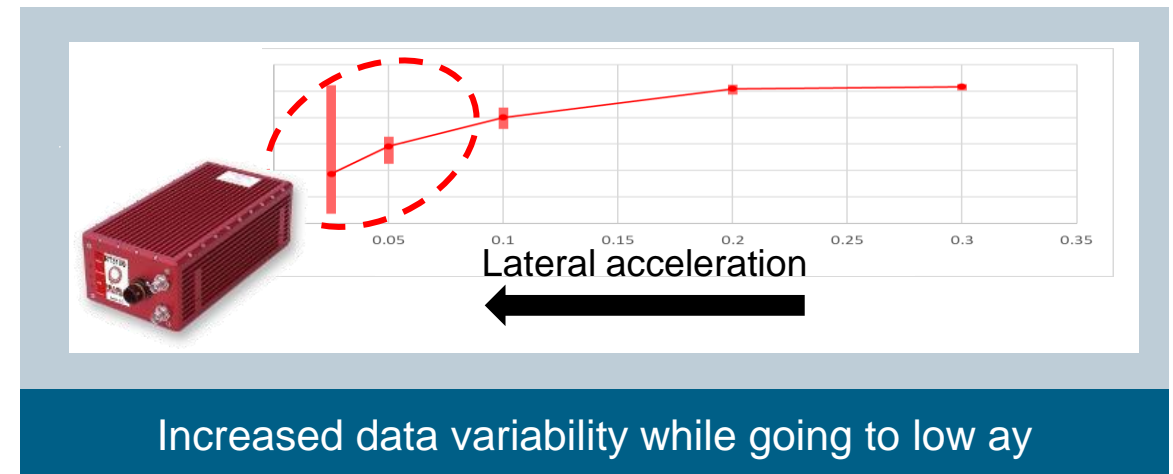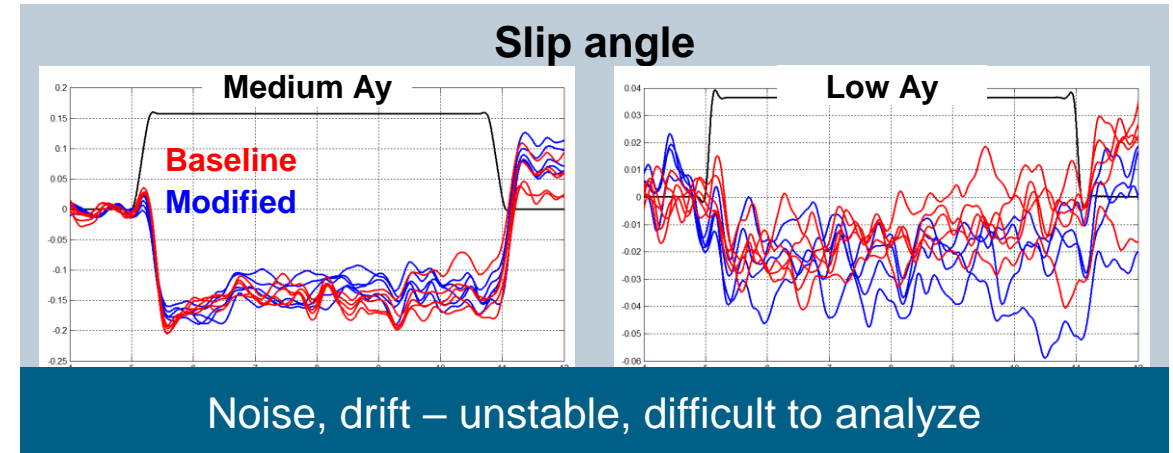

Fy Link
Fz Spring
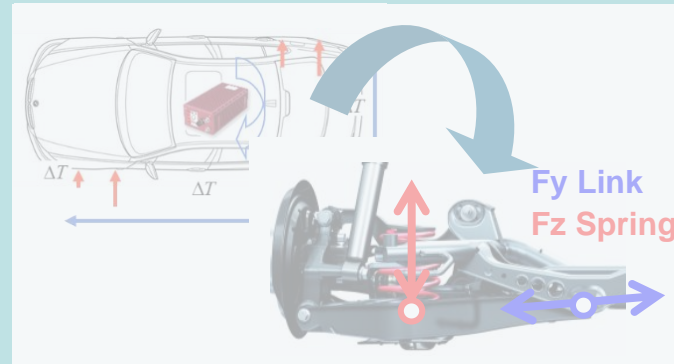
Model & Testing integration to gain efficiency and quality

Simcenter solutions: chassis & body
Testing

Challenges in the standard testing:

- Limited vehicle response, challenging to measure (signal in the noise band?)
- Big data variation while going to low ay

…. how can we improve the testing in low lateral acceleration?

Slip angle

Medium Ay

Baseline
Modified

Low Ay

Noise, drift – unstable, difficult to analyze

Lateral acceleration

Increased data variability while going to low ay

Simcenter solutions: chassis & body
Testing

SIEMENS
Ingenuity for life

Solution:

- Advanced testing technique:
  - Selection of the right maneuvers / excitation levels
- Advanced processing:
  - Time & frequency domain
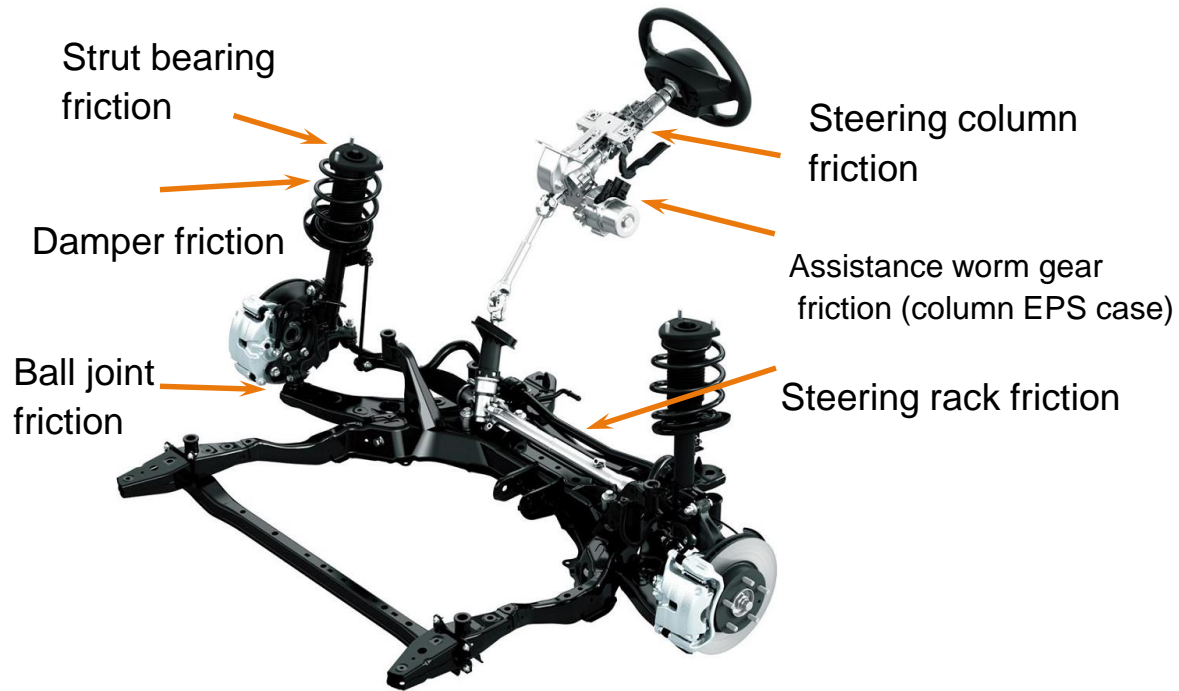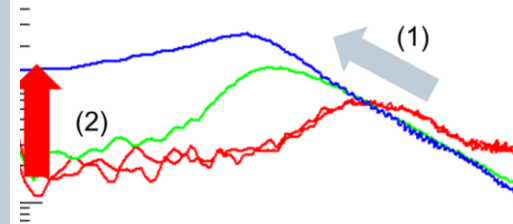 - Capture non-linearity effects

Repeatable, clear difference Base - Modified

Increased data variability while going to low ay
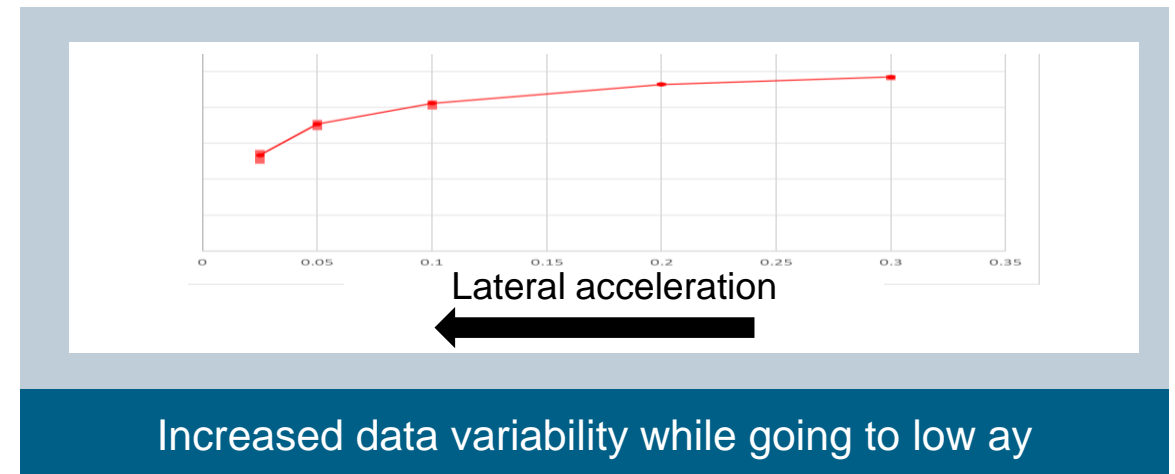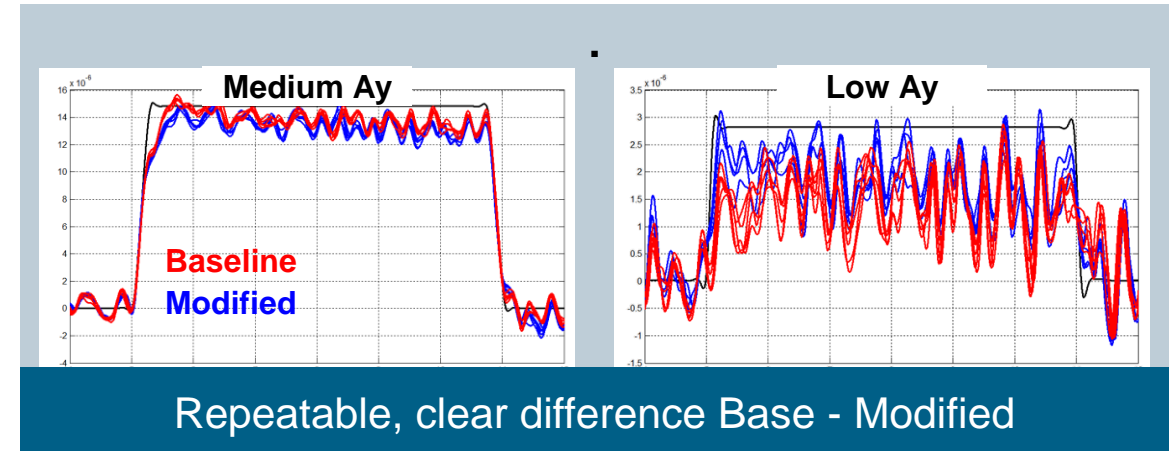
Benefit:
- **Enable stable testing at low Ay**
- **Identify key physics to explain on-center performance**
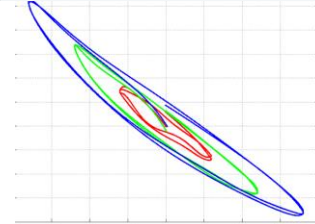
Simcenter solutions: chassis & body
## *Testing and Simulation*

Strut bearing friction

Steering column friction

Damper friction

Assistance worm gear friction (column EPS case)

Ball joint friction

Steering rack friction

Suspension friction has an impact on the vehicle performance

Response on a test bench for 3 inputs: **Low**, **Medium**, **High**

(1)

(2)

Response on the track for 3 inputs: **Low**, **Medium**, **High**

Influence of frictions in frequency and time domains
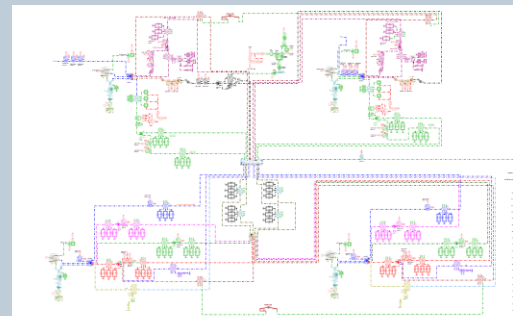
Identification of key phenomena to enhance CAE

Simcenter solutions: chassis & body
Simulation
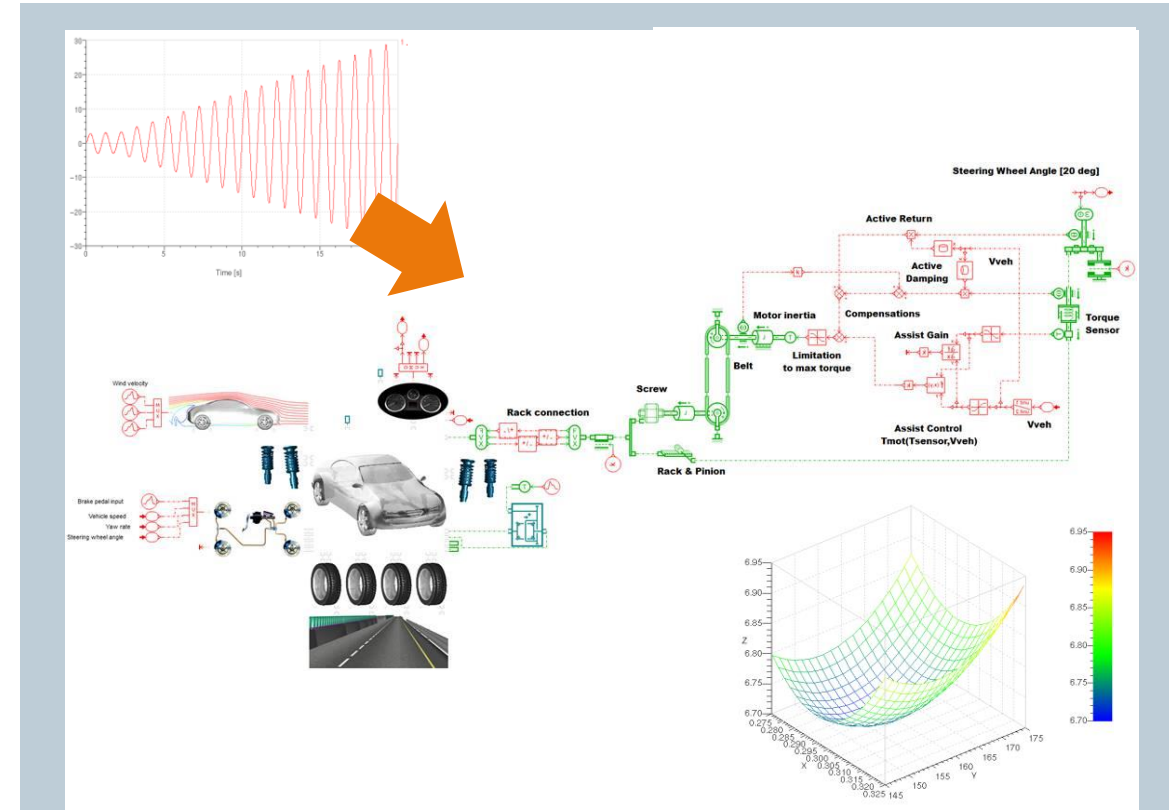
SIEMENS
Ingenuity for life

Challenge:

- Have the right representation of non-linear phenomena in CAE

Solution – step 1:

- Selection of the maneuvers of interest
- Analysis of the performance
- Introduce relevant parameters (friction, stiffness, ratios…) with tolerances
- Build Response Surface Model

Benefit:
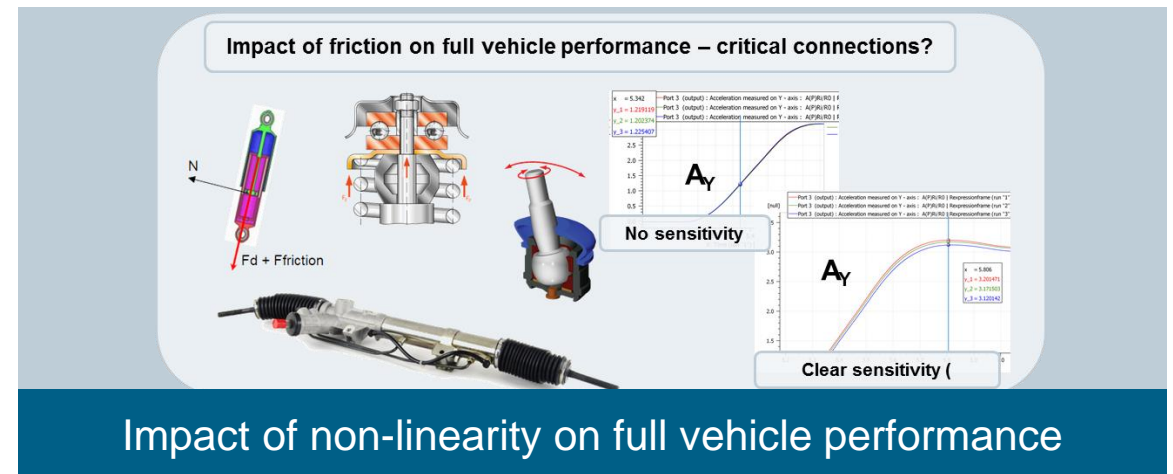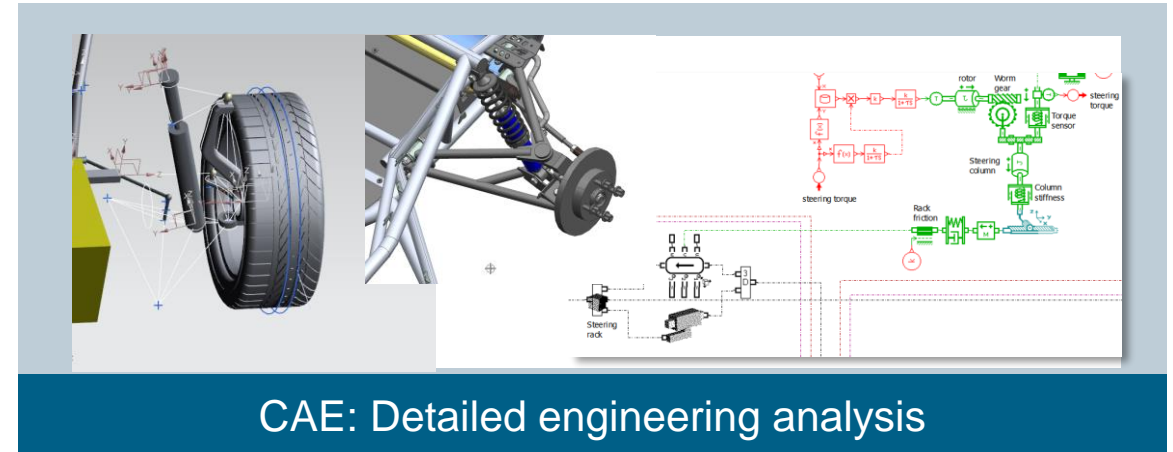**Identify the critical parameters for on-center performance**

Evaluation of key parameters influencing the on-center performance

Siemens Digital Industries Software

Simcenter solutions: chassis & body
Simulation

Solution – step 2:

- Move to more detailed engineering processing
  - Introduction of non-linearity in bushing, links, etc
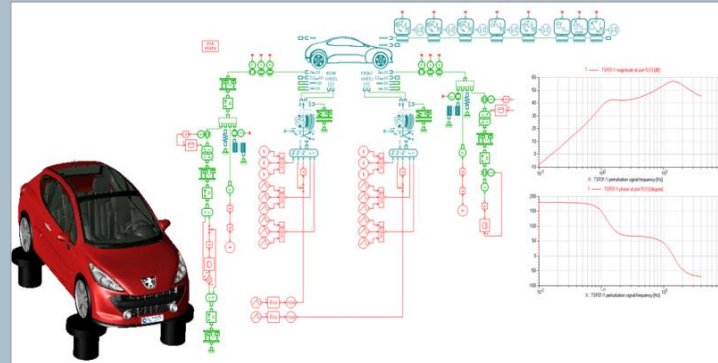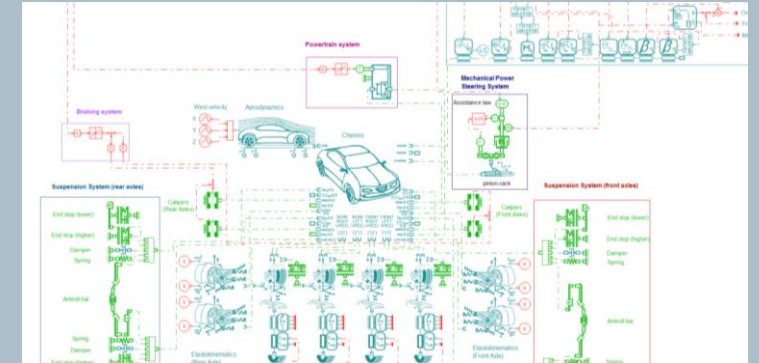 - Evaluate the impact of non-linear phenomena on full vehicle performance

CAE: Detailed engineering analysis

Benefit:
- **Enable CAE driven development for on-center**
- **Frontloading design choice**

Impact of non-linearity on full vehicle performance

PSA Peugeot Citroën
Using Simcenter Amesim as reference platform for vehicle dynamics functional design

- **Reduced development costs and time using a standard simulation tool to share data with supplier**
- **Integrated vehicle dynamics performance from the beginning to the end of development process**
- **Improved vehicle reliability, handling and comfort capabilities**

Strategic integration of the vehicle dynamics solutions

Chassis system components design

Global chassis control strategies analysis

- Evaluate the global vehicle behavior by taking into account subsystem performance
- Benefit from modularity, open-ended architecture and high solver capabilities

"The unique Simcenter Amesim approach enables us to link both specification and subsystem conception stages, and thus to improve innovation and to shorten development cycle."
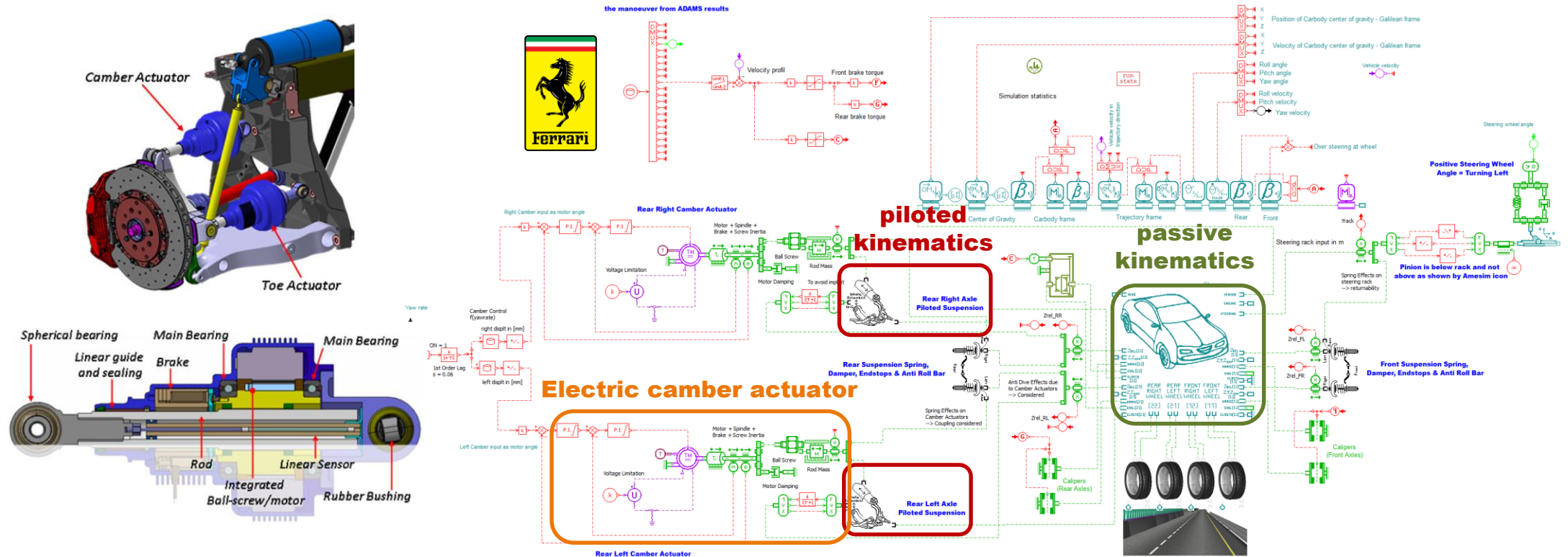
Eric Boittiaux, Simulation Engineer

Electric actuation to modify the rear geometry…

Thanks to modularity the kinematics is split…

From suspension actuation…

… to suspension reaction!

… to camber the suspension like a motorcycle

… in a passive part and a piloted part

Simcenter solutions: chassis
Customer case: Designing a rear steering system with electric actuator

SIEMENS
Ingenuity for life

Action of camber actuator on the suspension geometry and its spring
Reaction of the suspension spring on the camber actuator!

Spring force feedback in camber actuator direction

Spring force feedback in rack direction
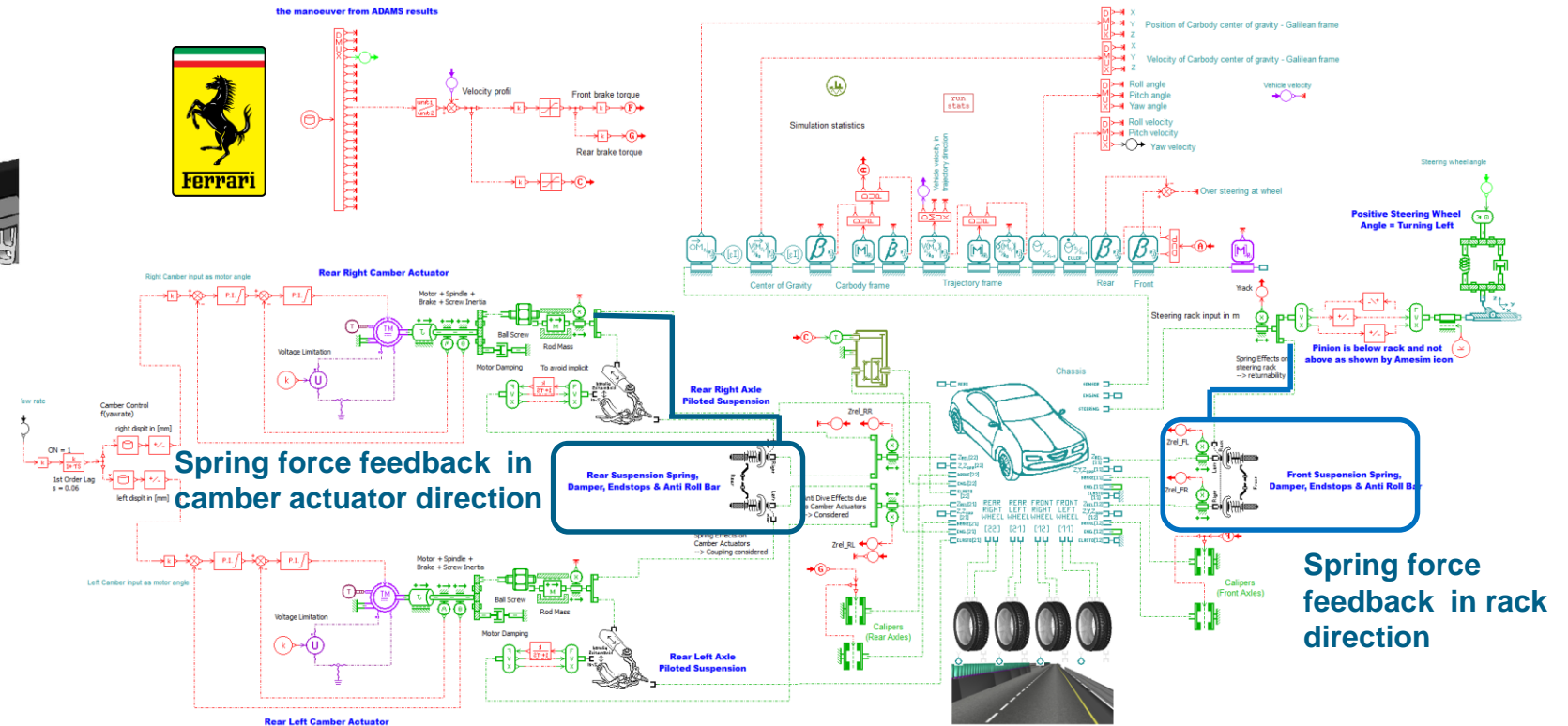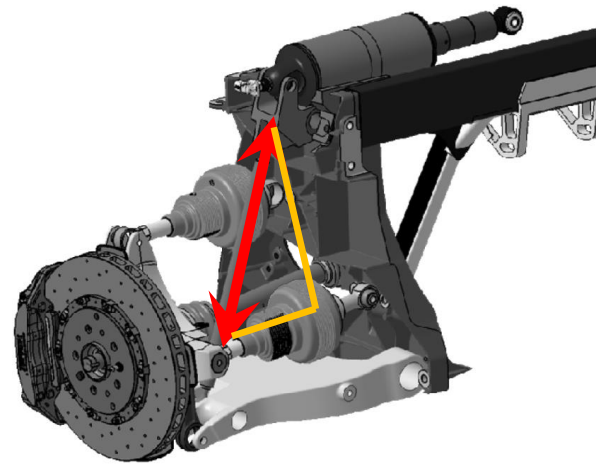
Similarly when steering, the front spring compresses/detents and thus reacts to push back the rack at its center i.e. steering return ability/steer angle jacking forces
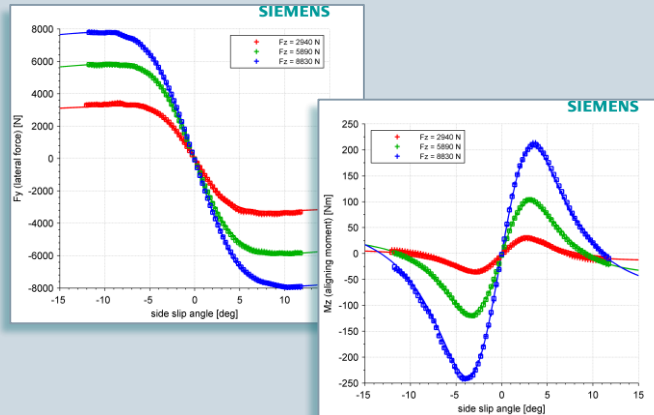
Siemens Digital Industries Software

Simcenter Tire solutions
Overview

Tire Testing	Parameter identification	Simulation

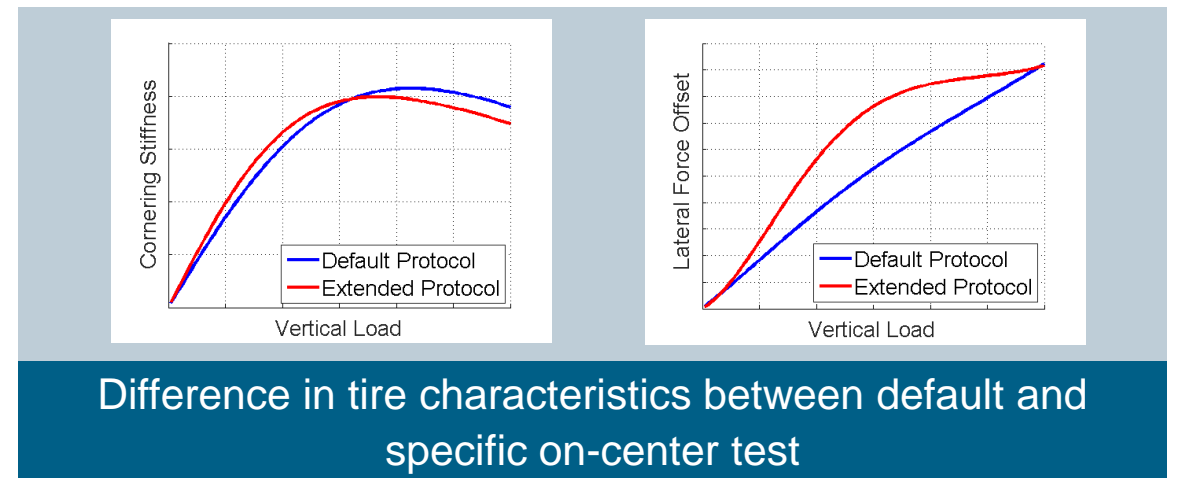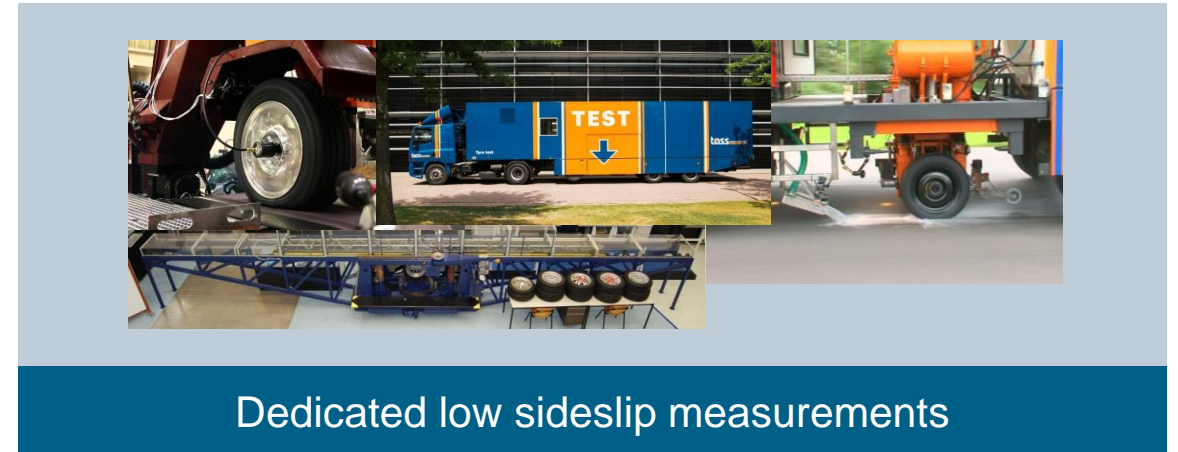| Tire testing in different conditions	Identifying tire parameters	Usage in simulation
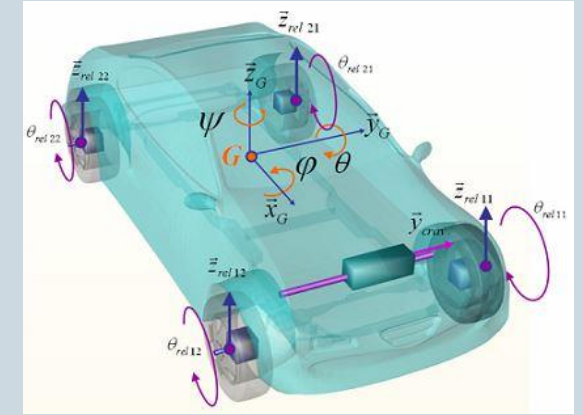
Goal: provide **tire modelling methodology for vehicle dynamic simulations (even at on-center)**

Simcenter Tire solutions
Testing & Simulation

On-center testing and parameter identifications
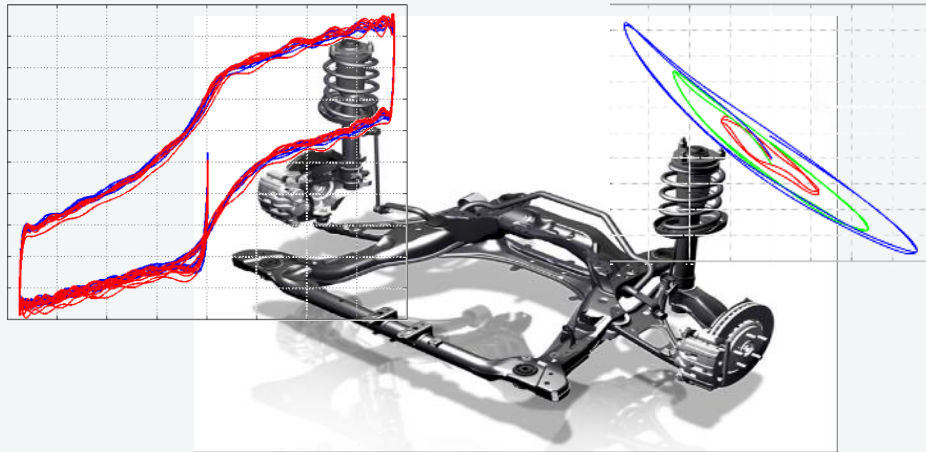
- Dedicated low sideslip angle measurements adds more fidelity in the low slip region

- Increase the tire model accuracy for on-center (e.g. cornering stiffness estimation)

Benefit:
significant improvement in the correlation between simulations and vehicle tests

Dedicated low sideslip measurements

Difference in tire characteristics between default and specific on-center test

Simcenter solutions for on-center
Testing & Simulation solutions – summary

SIEMENS
Ingenuity for life

Test-based approach

Objective characterization of vehicle performance.

Test-based characterization of changing tire performance. Medium vs low Ay behavior.

Simulation based approach

Non-linear phenomena?

Fd + Ffriction

Identify key parameters that can impact performance towards low Ay
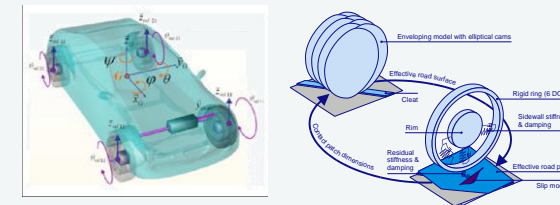
Identify tire models based on data acquired at low Ay
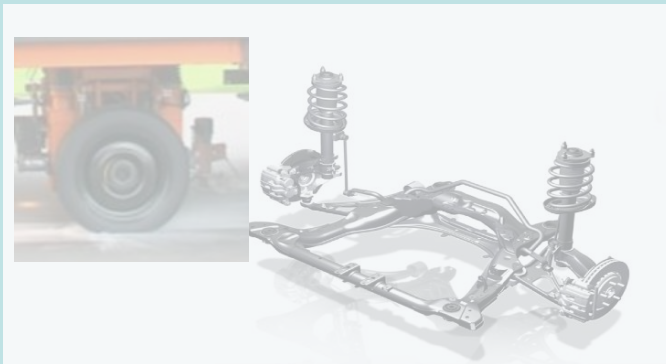
Siemens Digital Industries Software

Simcenter solutions for on-center

Capturing on-center performance in Test and Simulation

Decomposition analysis to get insights in vehicle performance

Fy Link
Fz Spring

Model & Testing integration to gain efficiency and quality

Simcenter solutions
Decomposition analysis – overview

Can't observe what driver

Subjective

subjective perception

Chassis Loads

Objective quantification

Fy Link
Fz Spring

Axle Motion & Load

Objective quantification

Axle Motion & Loads

Subjective

Chassis Loads

Axle Motion & Loads

Chassis Loads

Sensitivity to vehicle performance (change)
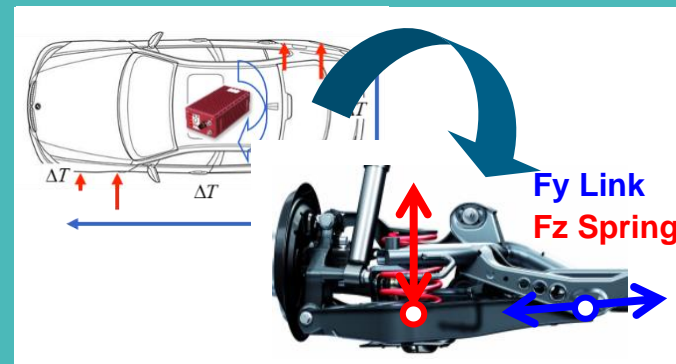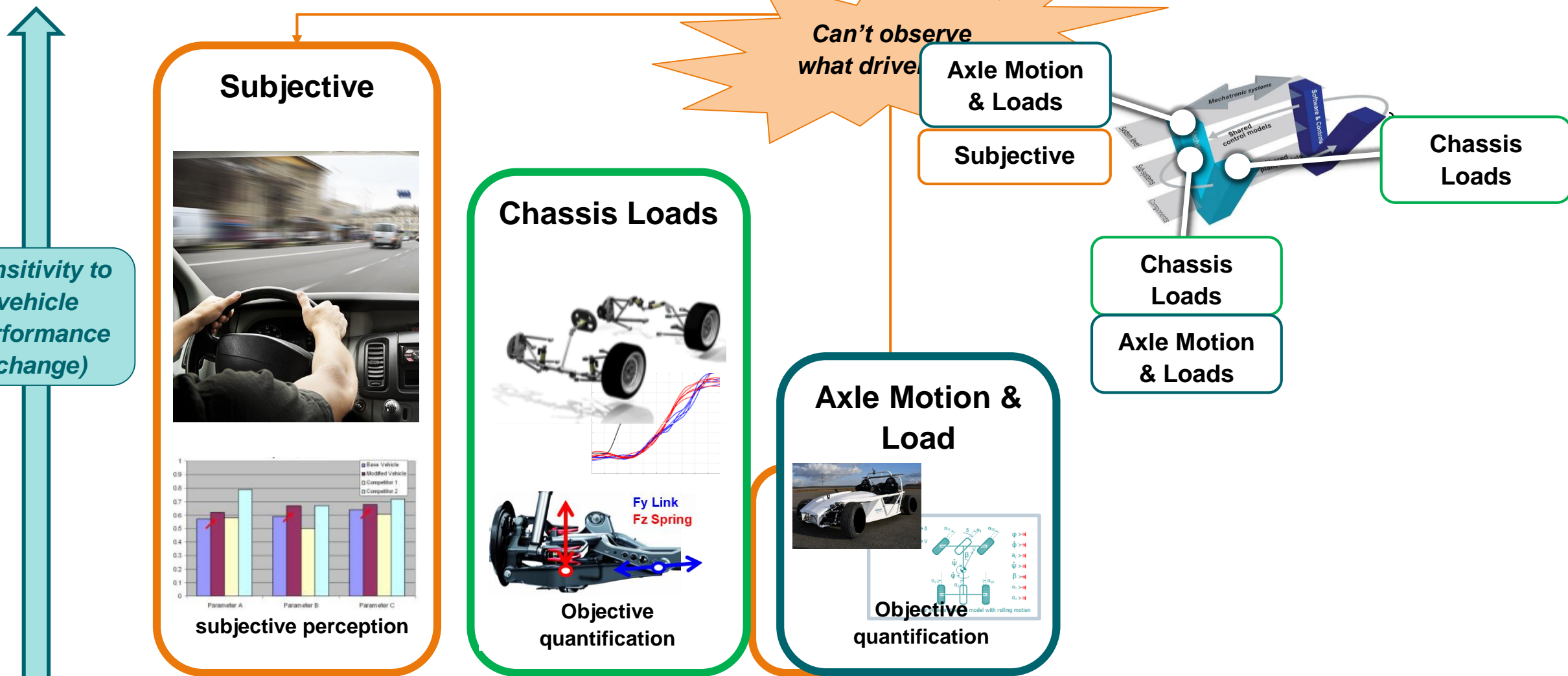
Simcenter solutions
Decomposition analysis – overview

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

Fy Link
Fz Spring
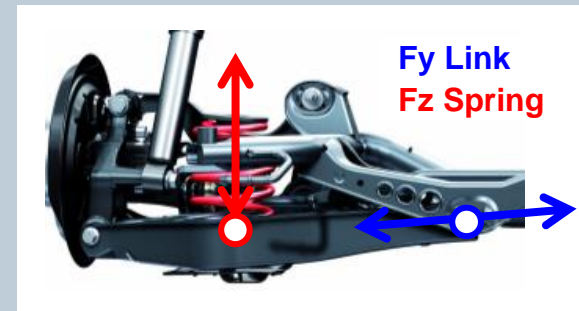
Local vehicle data: **typically clear result changes**

Lateral acceleration

Base
Modified

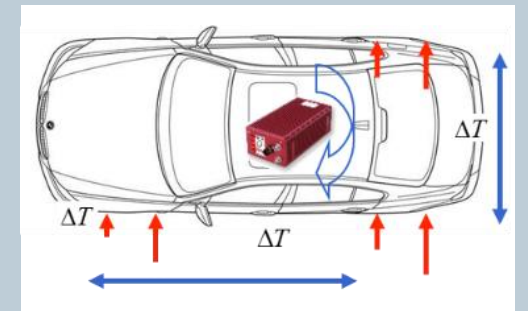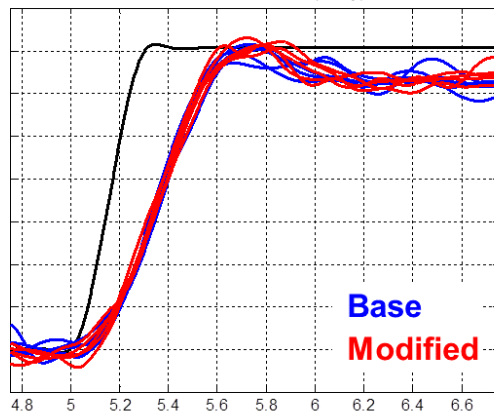A **global vehicle parameter** as lateral acceleration typically doesn't capture the effect of subtle chassis or body modifications

Rear sub frame rear Y-direction

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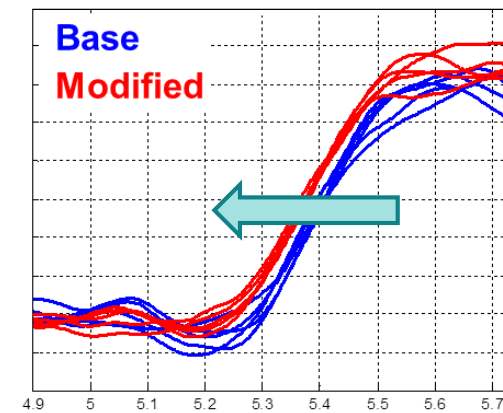
A **lateral suspension-to-body load** (contributor to lateral acceleration) can clearly capture the effect – a much faster rear axle response

Simcenter solutions
Decomposition analysis – overview

Decompose full vehicle behavior towards localized results.

Decomposition analysis to identify:

- Time domain forces (suspension links, axles, wheels)

- Time domain motion (body, wheels)
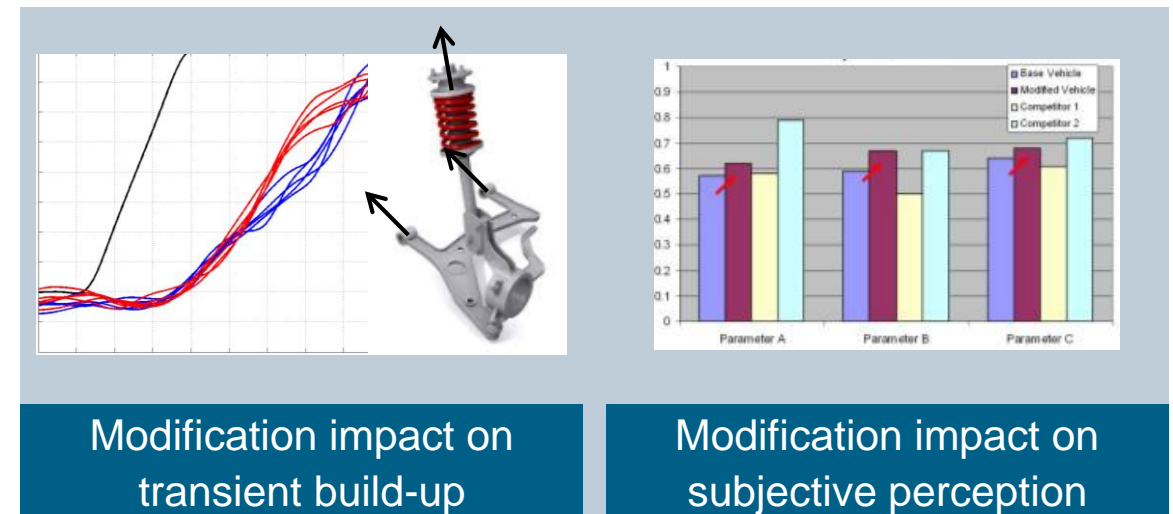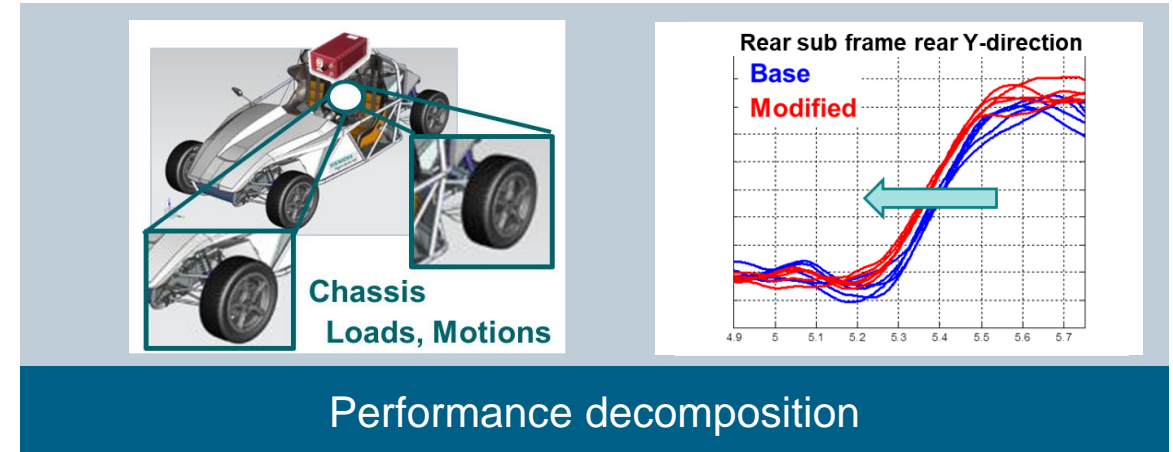
Benefit:
Insight in changing vehicle performance and link to subjective ratings

Performance decomposition

Modification impact on transient build-up

Modification impact on subjective perception

Simcenter solutions
Global vs local info: what happens at low ay?

Challenge when moving to low ay:

- Vehicle performance change (deterioration) towards low Ay (input: perfect sine)

Solution:

- Different metrics at medium and low level of lateral acceleration
- Defined both in time and frequency domain

**Benefit:
Metrics definition at low ay and link to driver feeling**

Sinusodial input

Time domain

presence of non-linear phenomena

Distorted axle response

Response gain

Low Ay
Medium Ay

Response phase

Changing behavior towards low ay

Simcenter solutions
Global vs local info: what happens at low ay?

SIEMENS
Ingenuity for life

Challenges:

- Increasing variability (decreasing data quality) at low level of lateral acceleration

Solution:

- High data repeatability for localized data
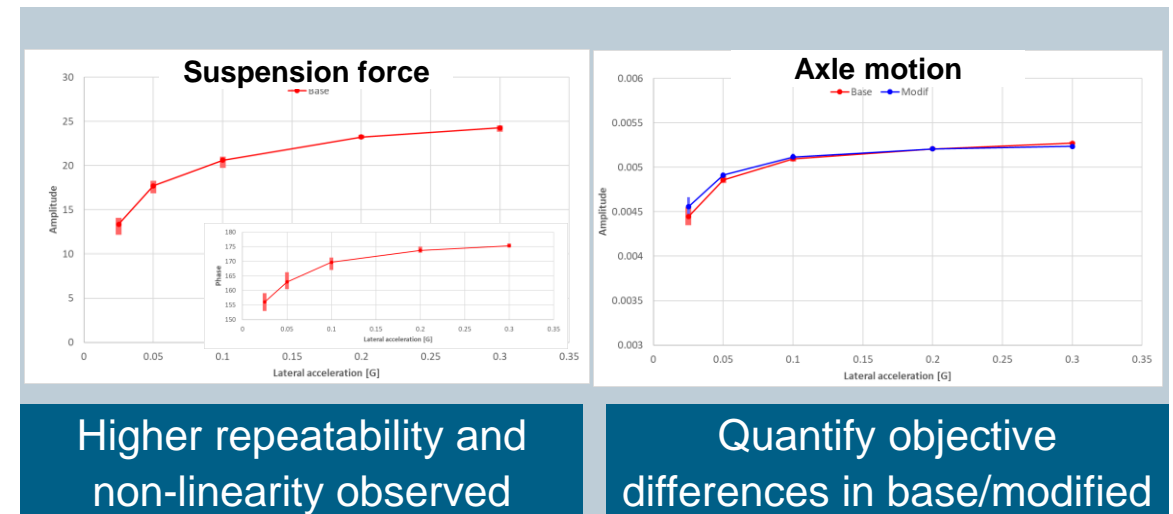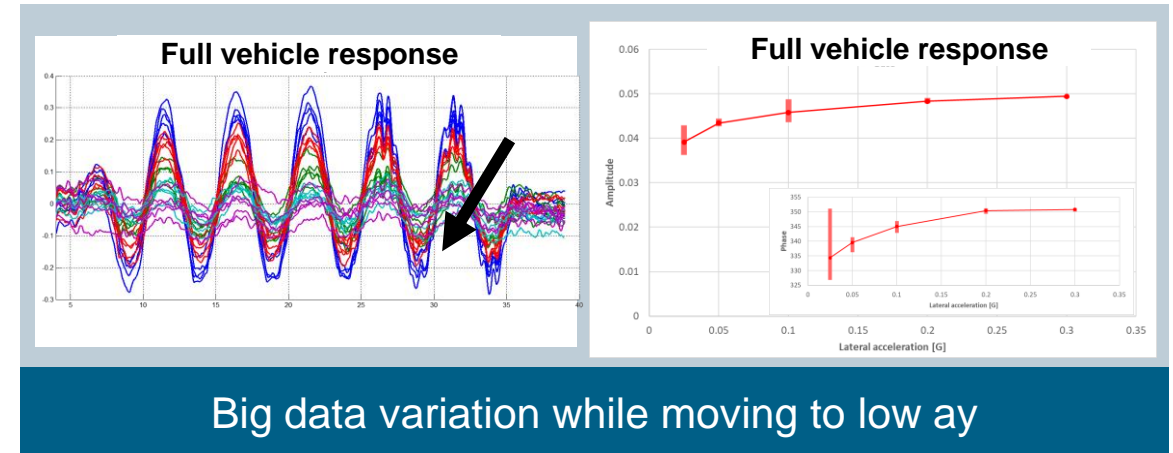
Benefit:
- **Identify non-linear phenomena**
- **Quantify clear objective difference base-modified**

Full vehicle response

Full vehicle response

Big data variation while moving to low ay

Suspension force

Axle motion

Higher repeatability and non-linearity observed

Quantify objective differences in base/modified

Siemens Digital Industries Software

Simcenter solutions
Customer example 1

SIEMENS
Ingenuity for life

Challenges:

- Typical objective metrics don't capture implemented design changes
- Evaluation done subjectively

Solution:

- Objective characterization and metric definition
  - Use chassis loads & motion
  - Focus on time/frequency domain

Benefit:
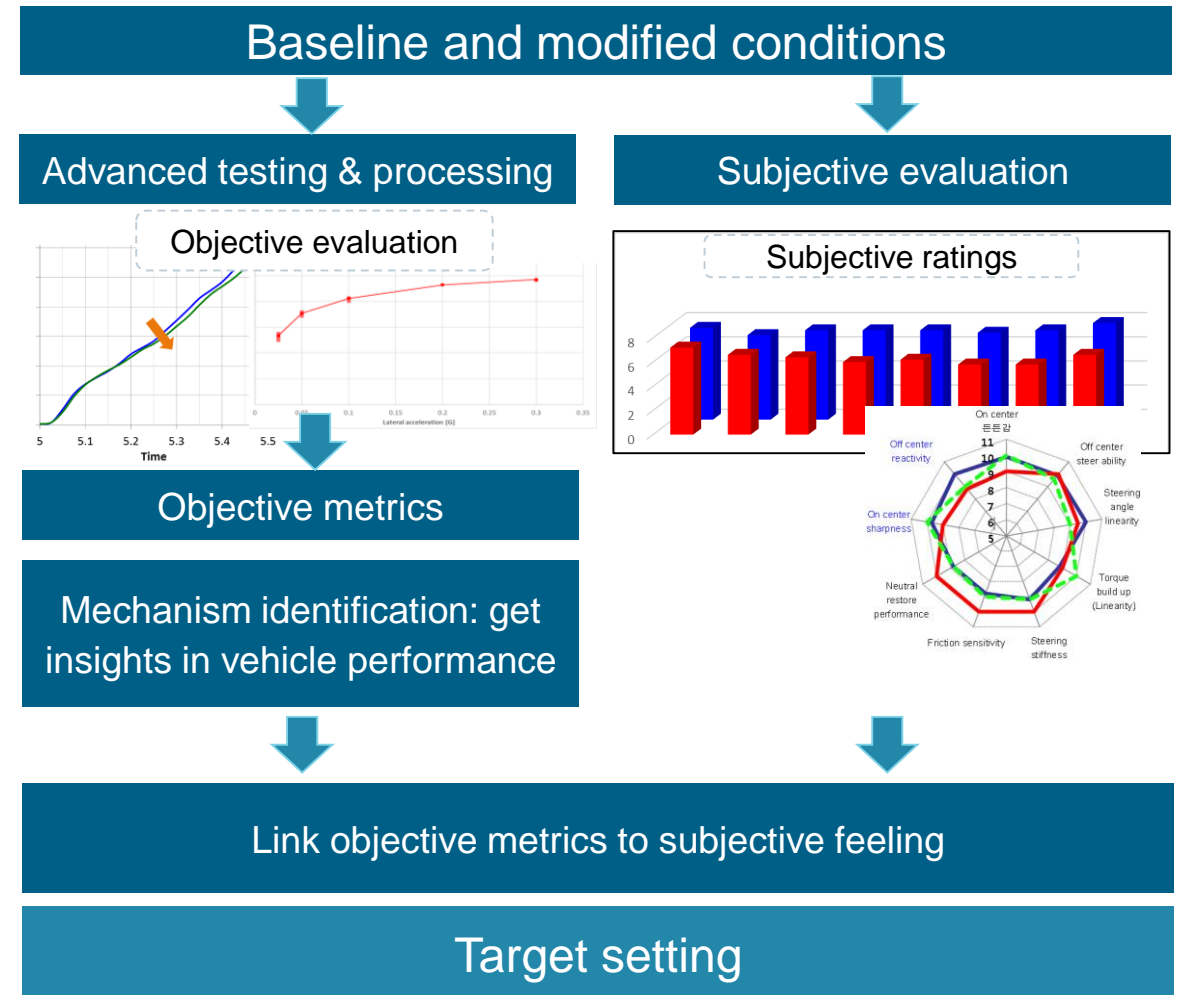- **Link objective metrics to subjective assessment**
- **Set objective target for new vehicles**

Baseline and modified conditions

Advanced testing & processing

Objective evaluation

Subjective evaluation

Subjective ratings

Objective metrics

Mechanism identification: get insights in vehicle performance

Link objective metrics to subjective feeling

Target setting

Siemens Digital Industries Software

Simcenter solutions
Customer example 2

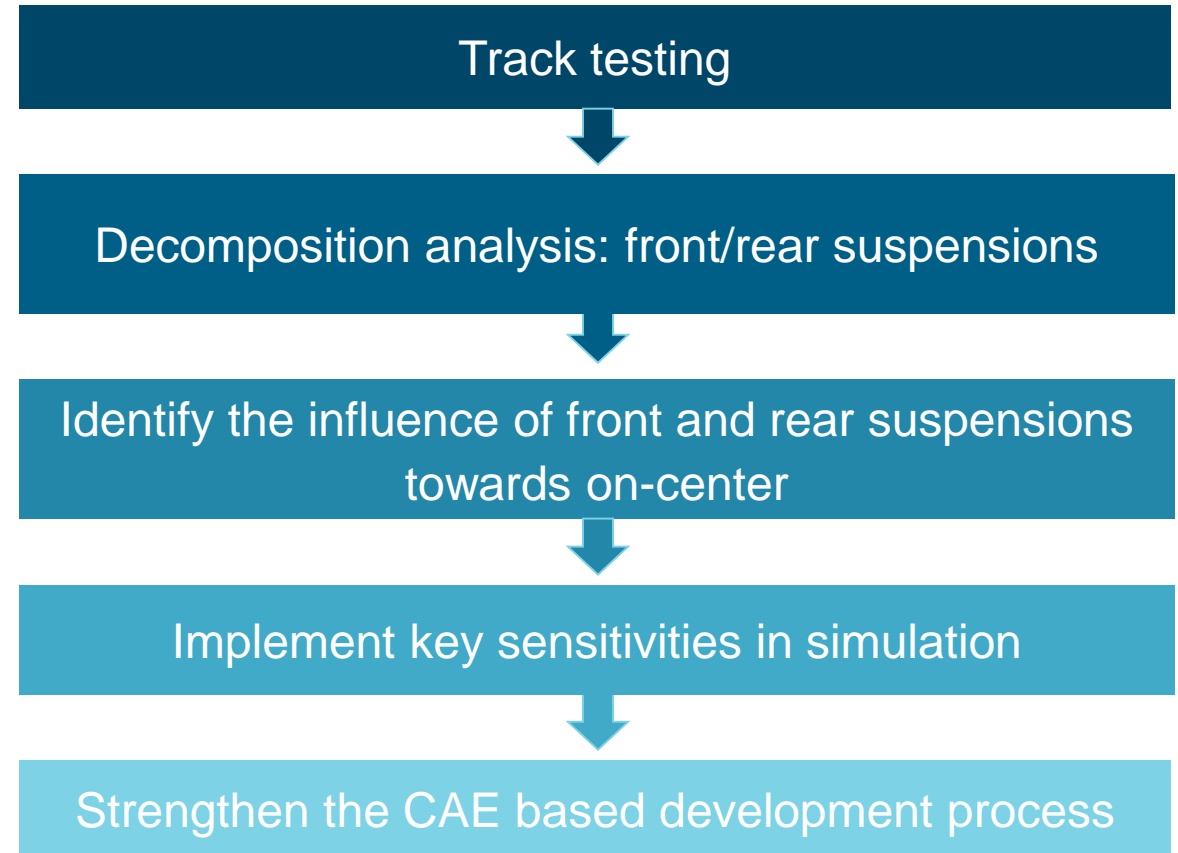**SIEMENS**
Ingenuity for life

Challenges:

- Vehicle evaluation based on experience

- Involve CAE in design choice

Solution:

- Decomposition analysis
- Replicate in simulation what was observed on the track
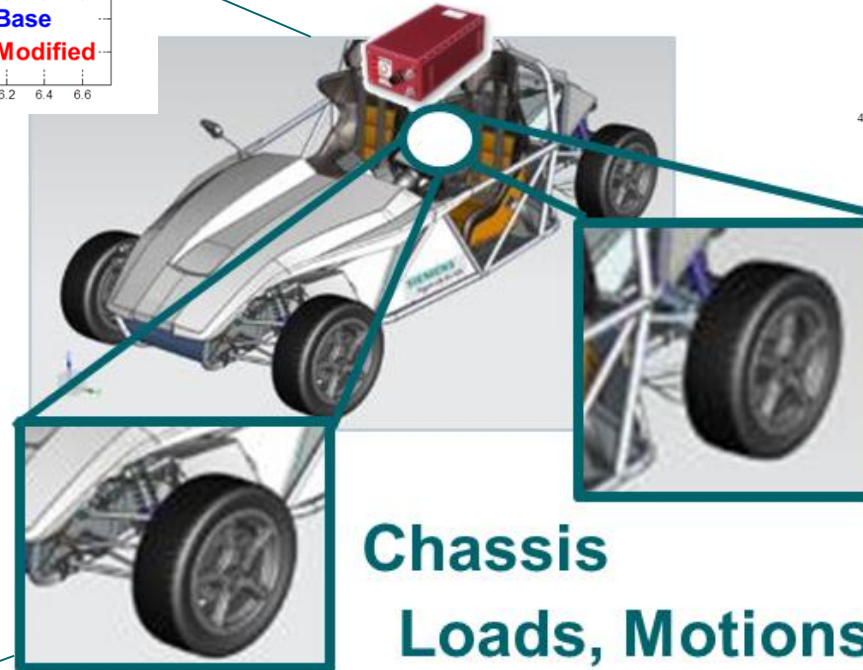
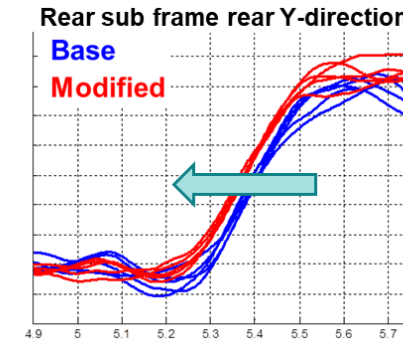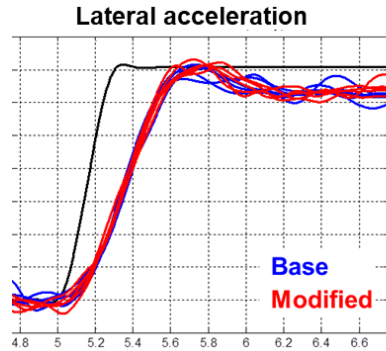**Benefit:**
- **Insight in vehicle performance**
- **Strengthen the CAE based development process**

Track testing

⬇

Decomposition analysis: front/rear suspensions

⬇

Identify the influence of front and rear suspensions towards on-center

⬇

Implement key sensitivities in simulation

⬇

Strengthen the CAE based development process

Siemens Digital Industries Software

SIEMENS
Ingenuity for life

Lateral acceleration

Base
Modified

Rear sub frame rear Y-direction

Base
Modified

☺ … Axle is acting faster…
☺ …Natural, neutral balance

Chassis
Loads, Motions
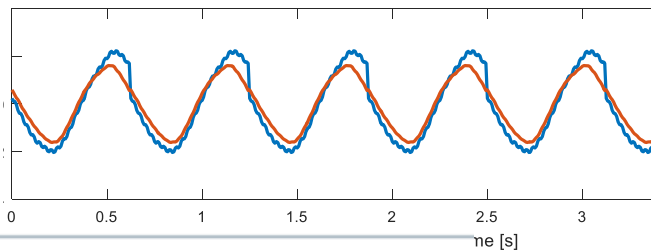
☹ Disappointing
☹ Medium sized deadband,

Performance decomposition:

1. **Enable link to _subjective_**

2. **Enable _metric/target_ definition**

3. **Drives enhancement in _CAE based development_ process**
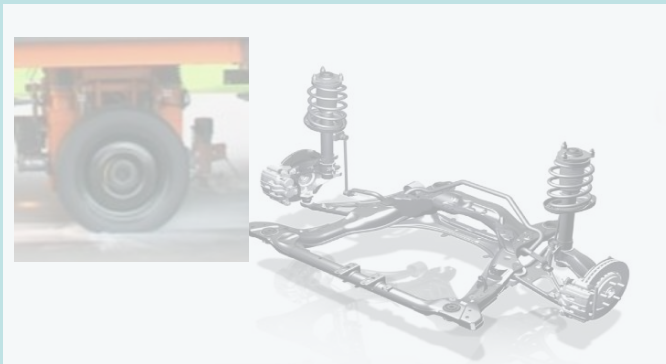
SIEMENS
Ingenuity for life

Capturing on-center performance in Test and Simulation

Decomposition analysis to get insights in vehicle performance

Fy Link
Fz Spring

Model & Testing integration to gain efficiency and quality

Model Based Development
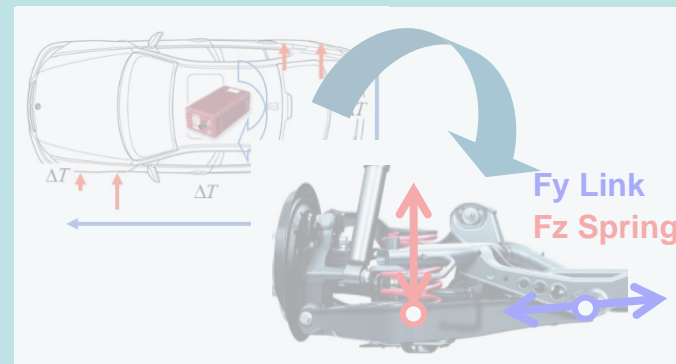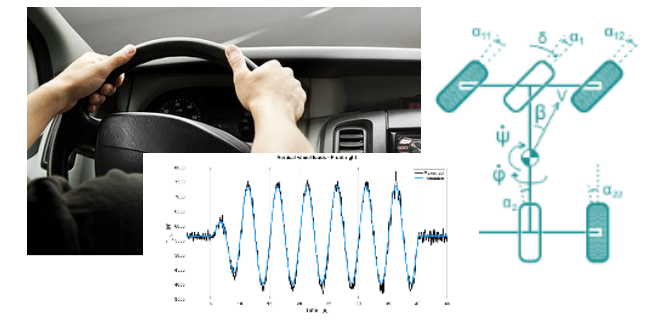## *Trends for physical testing to reduce development costs*

SIEMENS
Ingenuity for Life

100%

50%

Ease of change

Defect identification

Prototype availability

Cost to remove defects

Model-based development

MBST ensures efficiency in the MBD process

Prototype driven design

Productivity
Accelerating Decisions

Confidence
Increasing Realism

Insights
Enabling Exploration

Collaboration
Delivering Continuity

Requirements

Architecture

Design, Implement & Test

Production

Delivery & Commissioning

Operation & Maintenance

Model Based Development
OEM Pains, opportunities, threats and solutions

SIEMENS
Ingenuity for life

MBD challenges

Parameter identification and updating

Model validation

Model accuracy

Opportunities = MBST

Productive parameter updating

Efficient model validation process

Accurate dynamic data acquisition

Test-based performance engineering

Model life cycle

1	2	3	4
Build	**Parameterize**	**Correlate**	**Use**

Simcenter solutions
Expanding test capabilities through model ID and usage
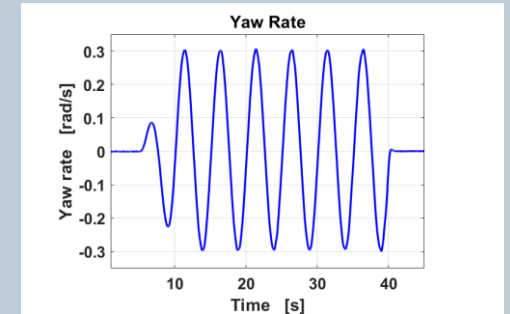
SIEMENS
Ingenuity for life

Challenges:

- Reproduce test data in simulation
- Capture all required response quantities
- Acquire with high resolution, stability
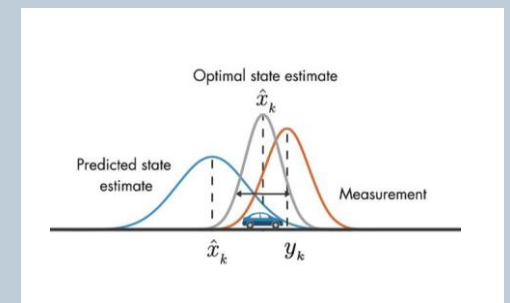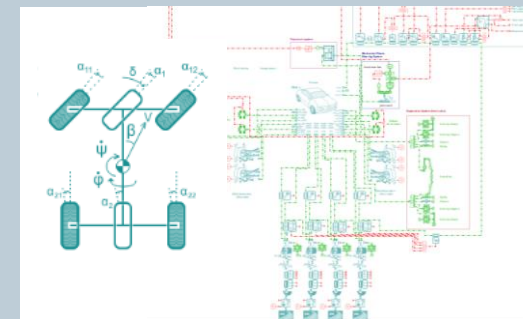- As in on-center vehicle dynamics

Solution:

- Identify vehicle dynamics models from Test
- Expand testing using simplified models
- Maximize test precision through models

Benefit:
- **Gain in efficiency and accuracy**
- **Gain in test outcome**

Advanced testing

Different level of model complexity

Usage of state estimators

Simcenter solutions
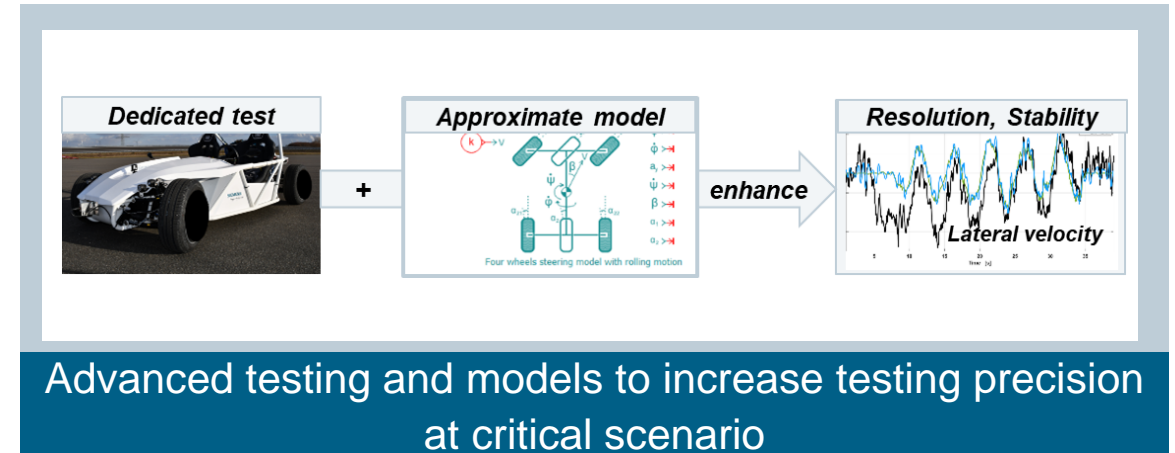## *Expanding test capabilities through model ID and usage*

Challenges:

- Difficult to identify vehicle behavior in low lateral acceleration with typical instrumentation (e.g. lateral velocity)
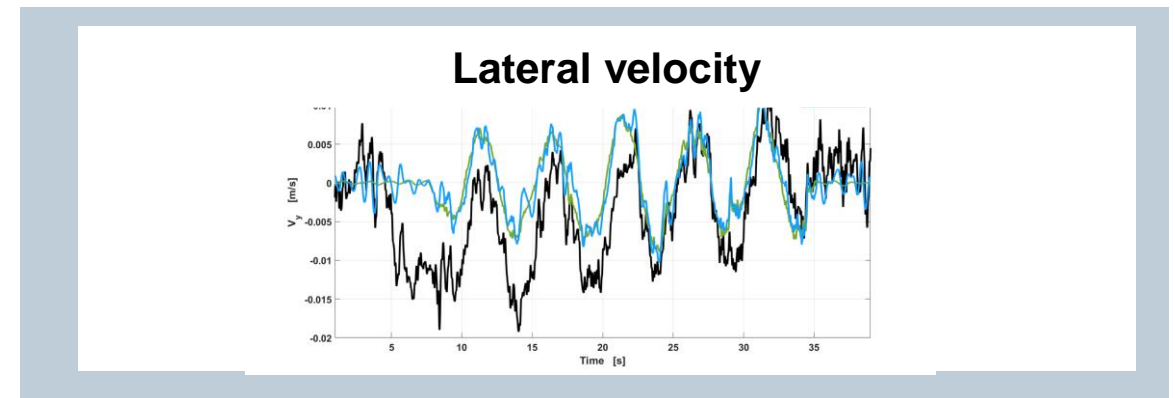
Solution:

- Use advanced state-estimators to enhance standard signals

Benefit:

- **Quality (Increase stability and resolution)**

Advanced testing and models to increase testing precision at critical scenario

Estimated signal does not suffer from drift

Simcenter solutions
Expanding test capabilities through model ID and usage
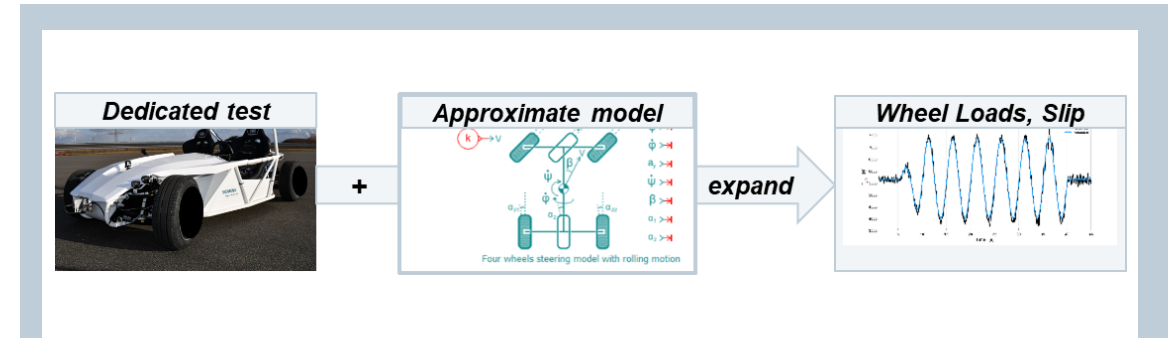
SIEMENS
Ingenuity for life

Challenges:

- Capture response quantities relevant for vehicle dynamics analysis

Solution:

- Combine test and simulation to expand testing capabilities (wheel loads, slip, …)

Use a combination of simulation and testing to get more insight in vehicle performances
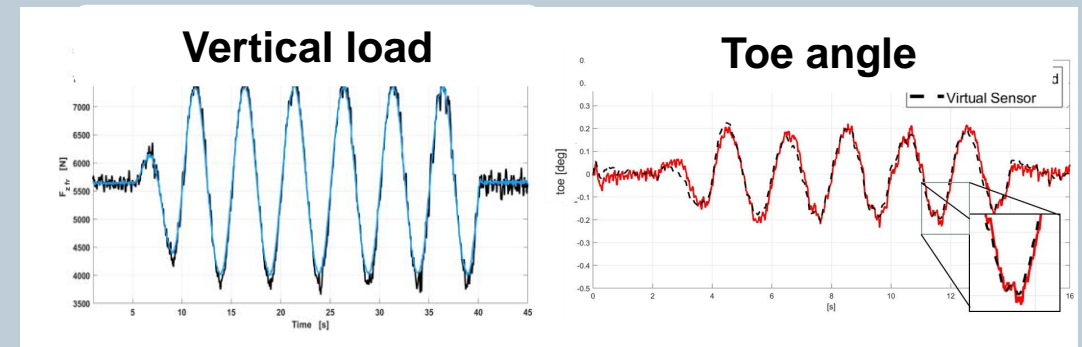
Identify additional quantities – validation with test

Benefit:
- **Efficiency and cost reduction**
- **Easy instrumentation and scalable solution**

Siemens Digital Industries Software

Simcenter solutions
Expanding test capabilities through model ID and usage
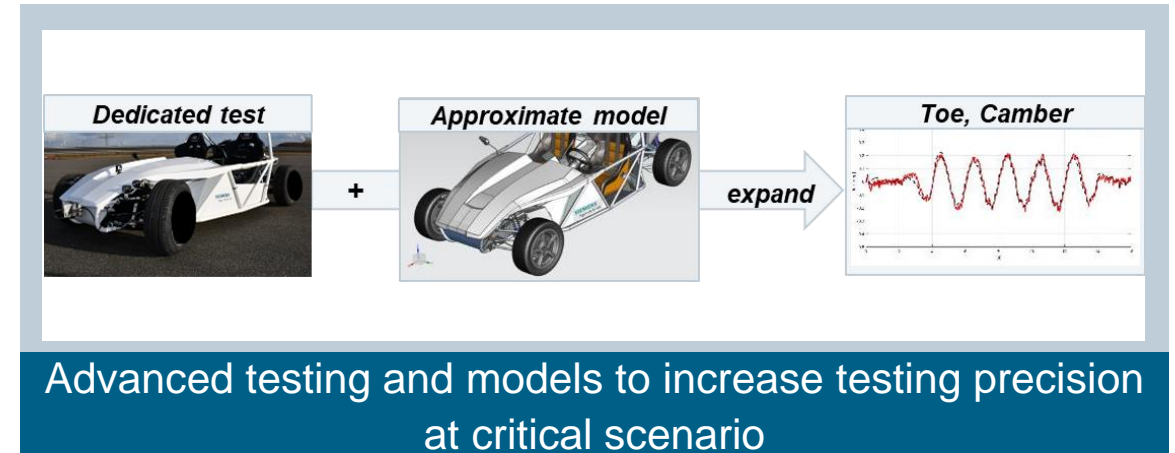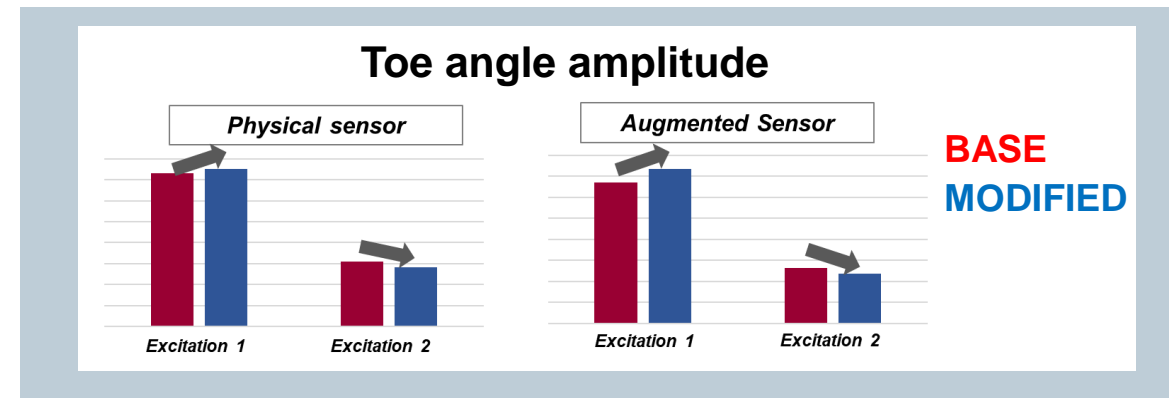
SIEMENS
Ingenuity for life

Challenges:

- Identify wheel and body motion in critical scenario without using expensive motion sensors

Solution:

- Usage of inertial sensors and simple 3D model to estimate body and wheel motion with high accuracy and precision (<0.05G and <0.1deg)

Benefit:
- **Efficiency and cost reduction**
- **Easy instrumentation and scalable solution**

Dedicated test + Approximate model → expand → Toe, Camber

Advanced testing and models to increase testing precision at critical scenario

Toe angle amplitude

Physical sensor | Augmented Sensor

BASE
MODIFIED

Excitation 1 | Excitation 2 | Excitation 1 | Excitation 2

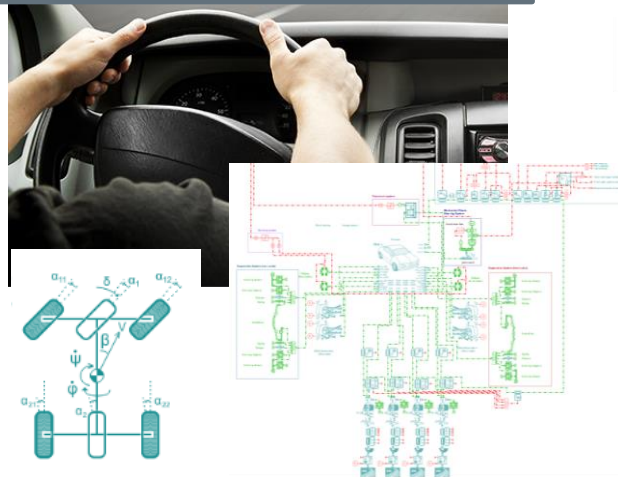Capture significant performance changes due to subtle chassis modifications even at low excitation level
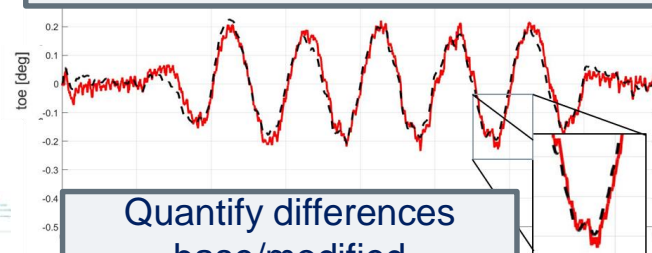
Siemens Digital Industries Software

Simcenter solutions
Expanding test capabilities through model ID and usage

Expand test capabilities through models

Identify additional quantities

Quantify differences base/modified

Excitation 1   Excitation 2
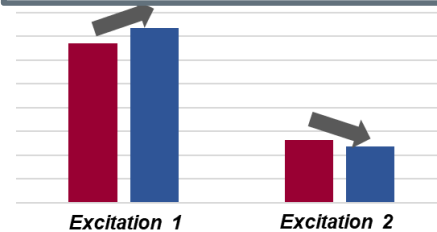
Challenge
- Model accuracy
- Reduce time & cost

Solution
Simcenter virtual sensors:
- Integration of testing and simulation to maximize testing precision

Benefit
- Efficiency and cost reduction
- Expand testing capabilities

Simcenter virtual sensing solution allows cost gain thanks to the improved efficiency and quality in testing

Siemens Digital Industries Software

Simcenter solutions
Conclusions

SIEMENS
Ingenuity for life

Objective characterization & frontloading design choice	*Link to subjective feeling*	*Gain efficiency & quality in the process*
Wide range of solutions for on-center: Test and Simulation, in full vehicle or component levels	**Decomposition analysis allowing to set target on full vehicle or component level and link to subjective**	**Model based development allowing cost gain and efficiency**
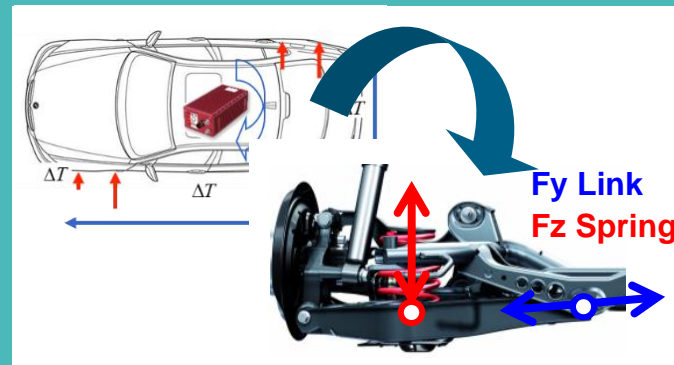
Fy Link
Fz Spring

Siemens Digital Industries Software
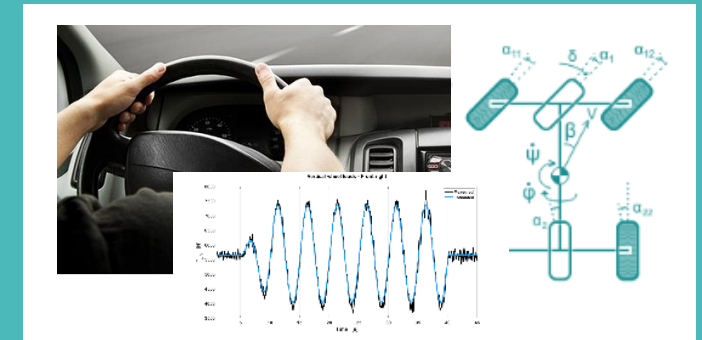
Demystify on-center vehicle performance
Simcenter solution

SIEMENS
Ingenuity for Life

- Objective metrics
- Link to subjective feeling
- Frontloading design choice
- Integration of Simulation & Test

How can Simcenter help you ?

SIEMENS
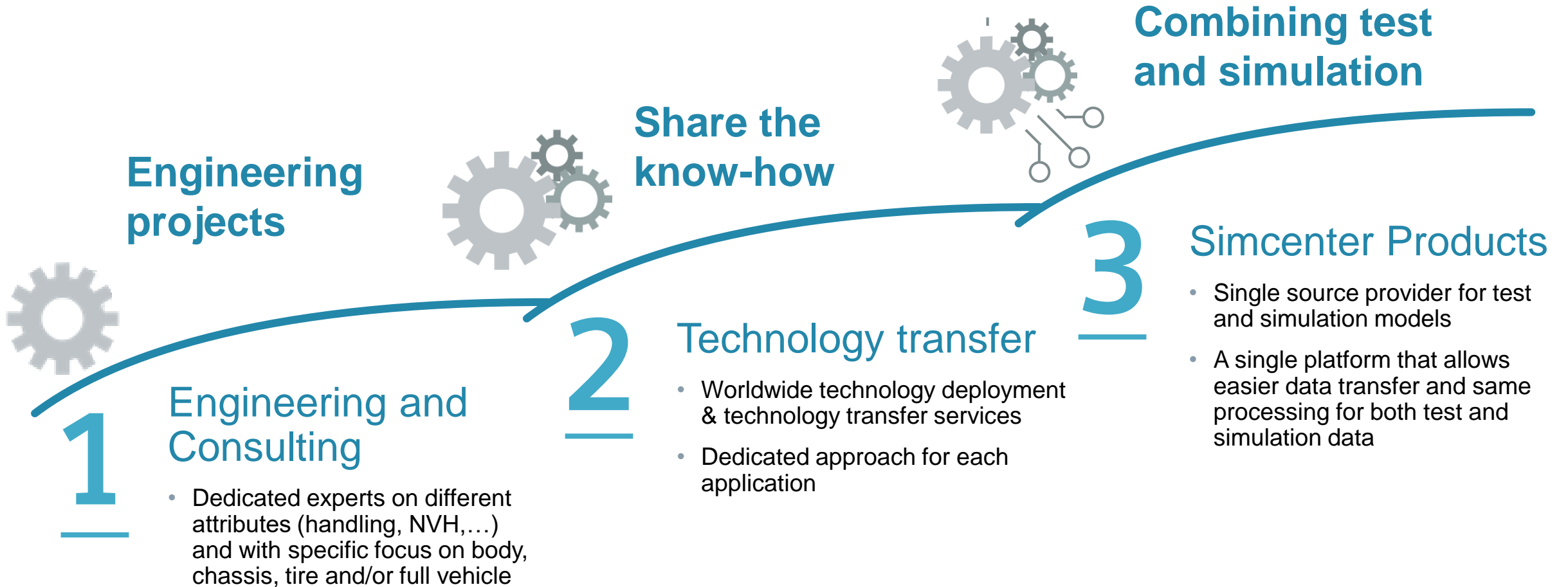*Ingenuity for life*

Combining test and simulation

Share the know-how

Engineering projects

3 Simcenter Products

- Single source provider for test and simulation models
- A single platform that allows easier data transfer and same processing for both test and simulation data

2 Technology transfer

- Worldwide technology deployment & technology transfer services
- Dedicated approach for each application

1 Engineering and Consulting

- Dedicated experts on different attributes (handling, NVH,…) and with specific focus on body, chassis, tire and/or full vehicle

Thank you
Questions?

SIEMENS
Ingenuity for life