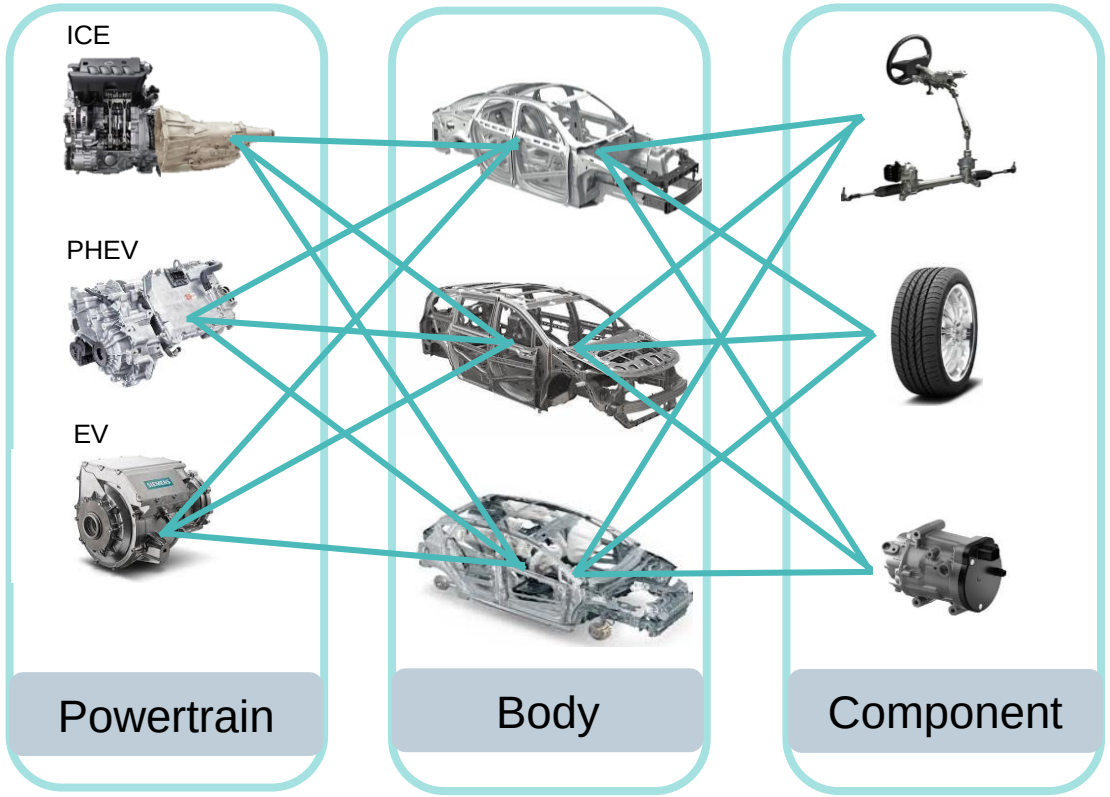
SIEMENS
Ingenuity for life

Vehicle system integration guidelines for component suppliers

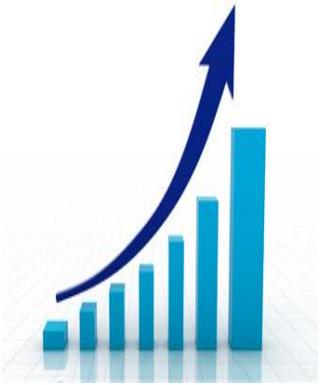
Unrestricted © Siemens 2020

Introduction
Automotive industry trends and needs

SIEMENS
Ingenuity for life

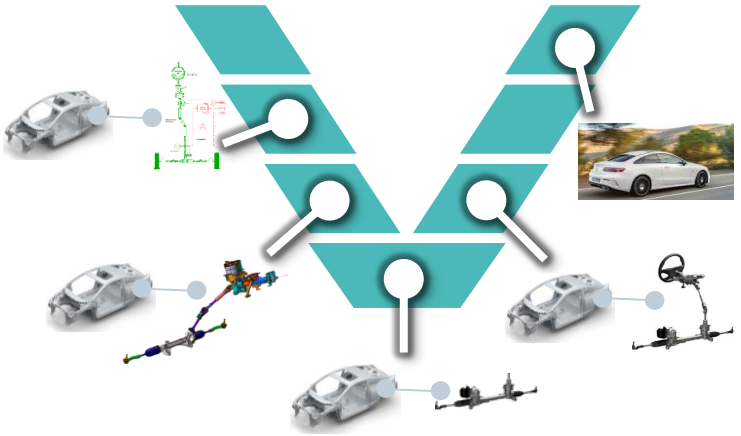


# of vehicle variants



- Increasing testing effort
- Prototype availability?
- Impact of modification?
- …

Throughout the development



How to ensure system performance while keeping development time and cost under control?

Need vehicle-level component evaluation

Unrestricted © Siemens 2020

Introduction
Challenges for suppliers

SIEMENS
Ingenuity for life

More pressure from OEM to **work on integration**

- How to evaluate component behavior at full vehicle level?
- How to cascade targets from full vehicle to component?
- How to solve vehicle integration issues earlier?

Unrestricted © Siemens 2020

How to keep control of the NVH Performance at any stage of the development cycle?

SIEMENS
Ingenuity for life

Can we provide methods that addresses all these challenges?

YES, WE CAN!

Unrestricted © Siemens 2020

Content

SIEMENS
Ingenuity for life

- Full vehicle testing and TPA
- Component-based TPA
- Model-based development
- Model-based system testing

Unrestricted © Siemens 2020

Ensure vehicle-level component NVH evaluation
Throughout the development cycle

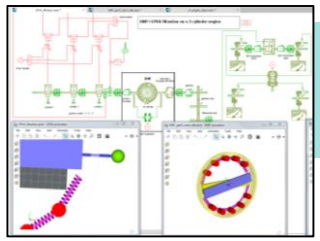
SIEMENS
Ingenuity for life

Target Setting | Concept validation | Detailed Engineering | Validation/Refinement

Bench marking & Target setting

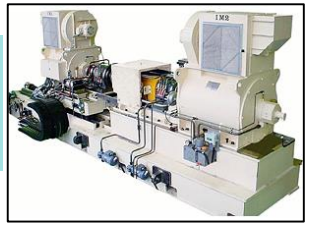
Full Vehicle Testing and TPA

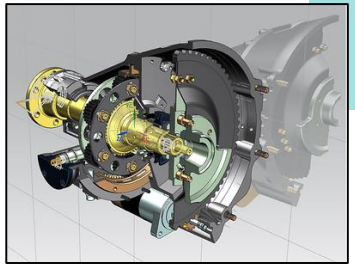
Troubleshooting



Concept Design

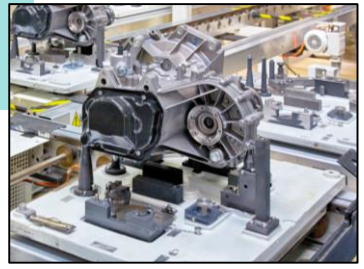
Bench Validation

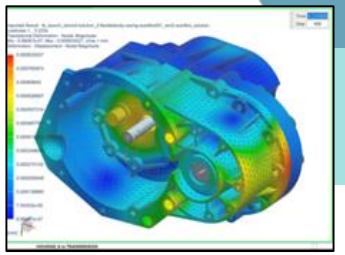




Detailed Engineering

Component Verification





What-if games & optimization

Unrestricted © Siemens 2020

Full vehicle testing and TPA

Testing the component in full vehicle

SIEMENS
Ingenuity for life

Driving Condition:
How the vehicle is controlled by the driver

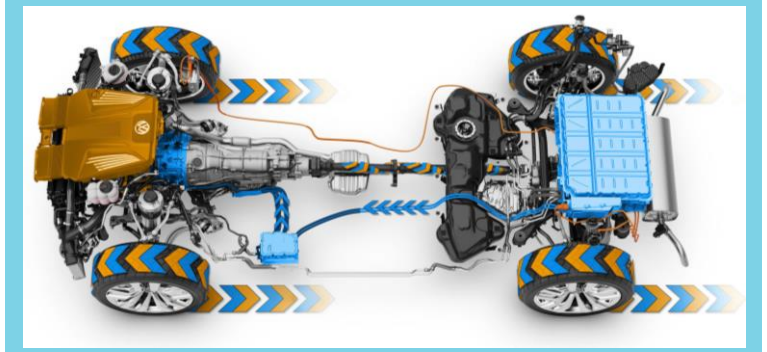
Operating Condition
How the vehicle reacts to the driver input (vehicle status)

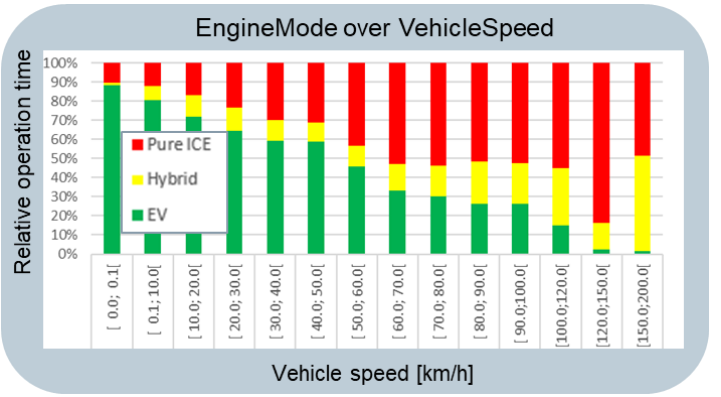
Sub-system Behavior
How the subsystem behaves in that operation

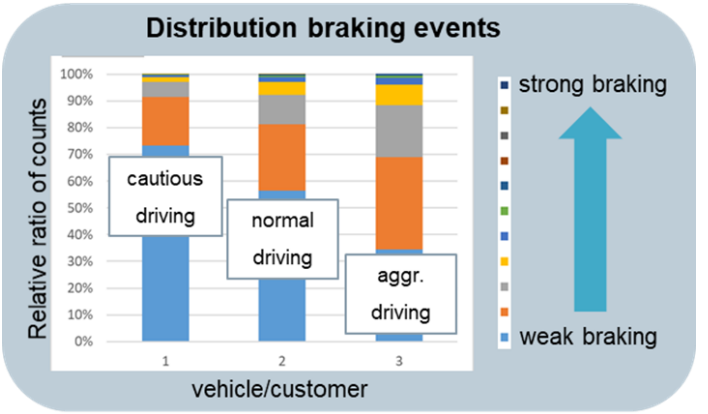
Subjective perception
How the driver perceives the vehicle response

Many potential test scenarios:

- Vehicle Variants
- Markets
- Operating modes (SoC, torque, rpm, temperature, …)





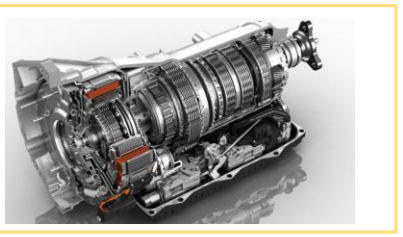


Unrestricted © Siemens 2020

Full vehicle testing and TPA
Transfer Path Analysis

SIEMENS
Ingenuity for life

Transmission



Drive line

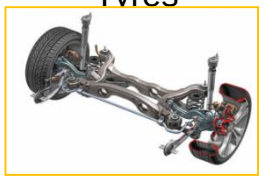
HVAC

Exhaust

Wiper System

EPS

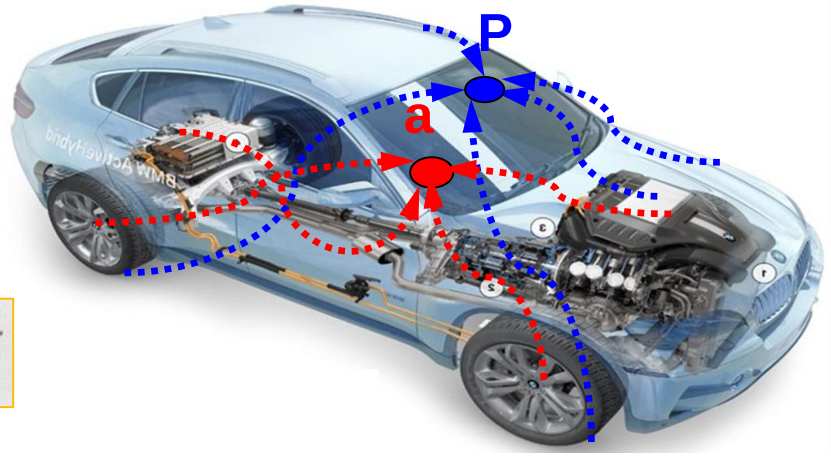
Tyres

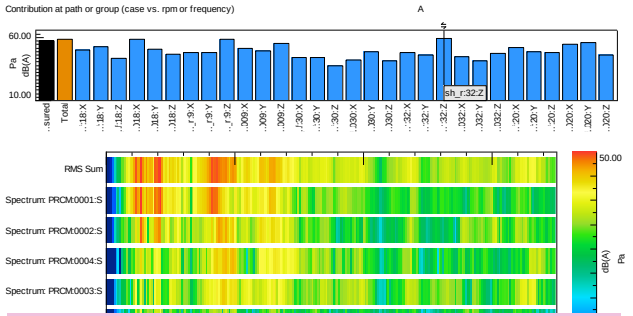


Engine

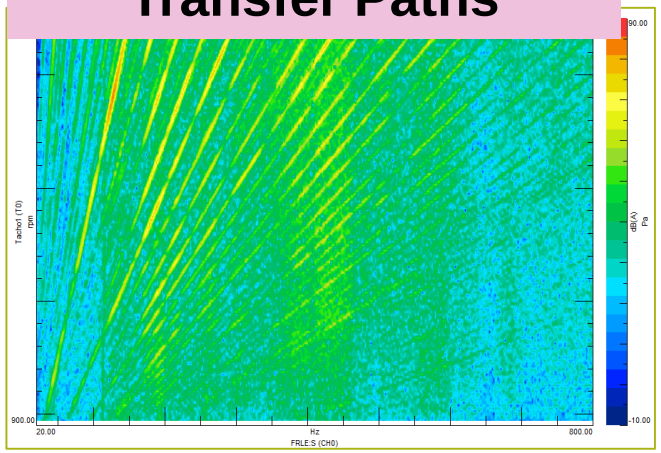
(H)EV

Cascade Targets





Understand Critical Transfer Paths



Source (F_i,Q_j) — X — Transfer (NTF) — = → Receiver (y_k)

Unrestricted © Siemens 2020

Full vehicle testing and TPA

Transfer Path Analysis – HVAC TPA

SIEMENS
Ingenuity for life

Compressor

Active

Airborne

Structure borne

Fluid borne

Structure borne

Airborne

Classical TPA

Body interface source id

Driveline surfaces

Engine mounts

Condenser mounts

Pipe mounts

Evaporator surfaces

Passive or transfer

Receiver

Target

Complexity of HVAC sub-system

- Multiple potential noise & vibration sources: Compressor, Condenser, Tubing, HVAC Module with Blower & Motor, Ducts & vents
- Multiple potential transfer paths & mechanisms
- **Need For Detailed TPA assessment**

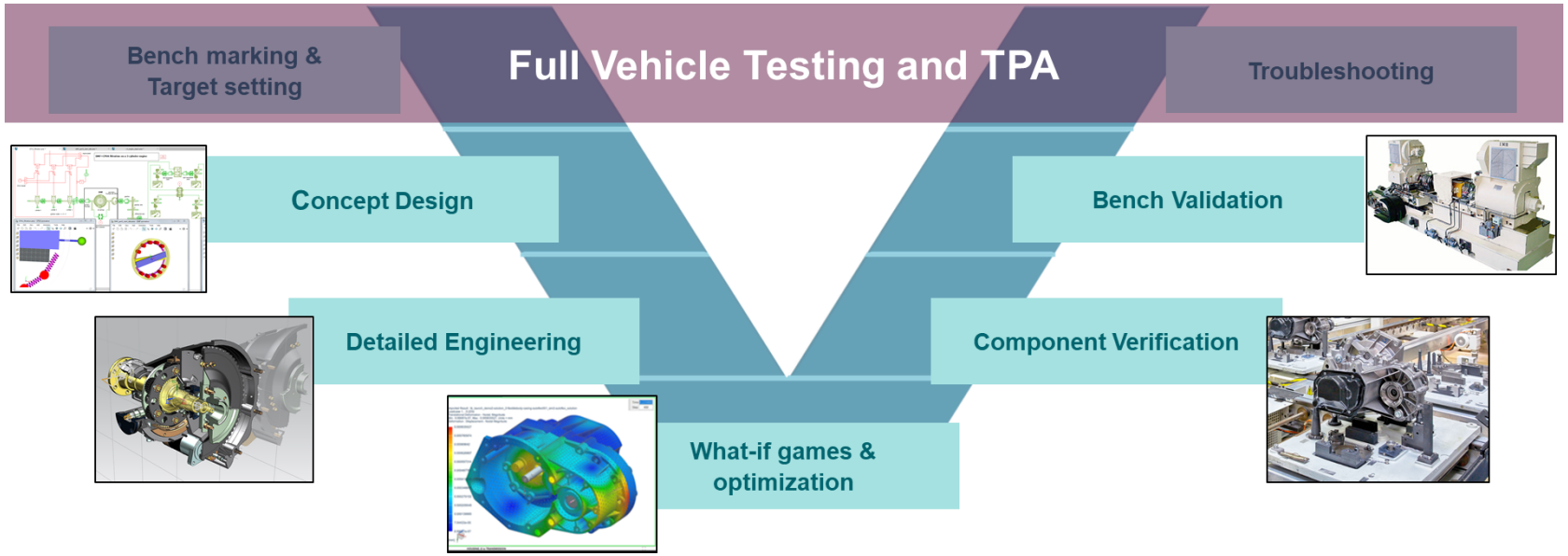
Unrestricted © Siemens 2020

Full vehicle testing and TPA

SIEMENS
Ingenuity for life

Evaluate the sub-system in full vehicle

Cascade targets from system to components



Unrestricted © Siemens 2020

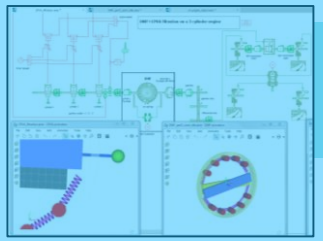
Ensure vehicle-level component NVH evaluation
Throughout the development cycle

SIEMENS
Ingenuity for life

Target Setting | Concept validation | Detailed Engineering | Validation/Refinement

Bench marking & Target setting

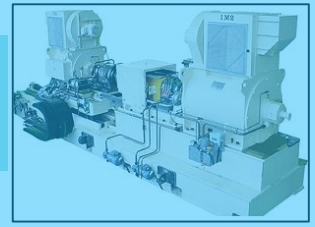
Troubleshooting

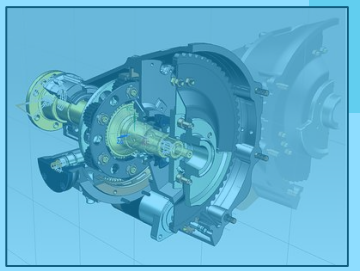


Concept Design

Component-based TPA

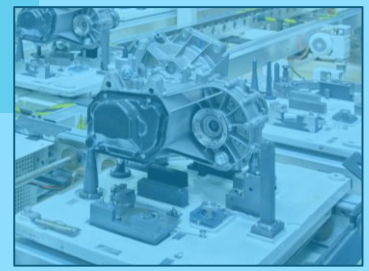
Bench Validation

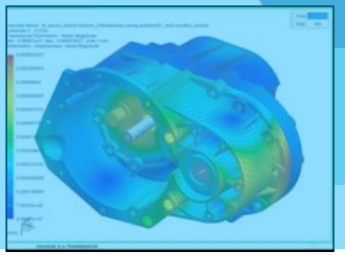




Detailed Engineering

Component Verification





What-if games & optimization

Unrestricted © Siemens 2020

Component-based TPA
Improving OEM – Supplier cooperation

SIEMENS
Ingenuity for life

Compressor

Reduction gearbox

Steering rack

Engine

Motor

Undercarriage

HVAC

Integration

shorter design cycles / reduced prototype availability / more variants / frontloading of engineering / …

Supplier

Invariant load description

Realistic NVH design targets

OEM

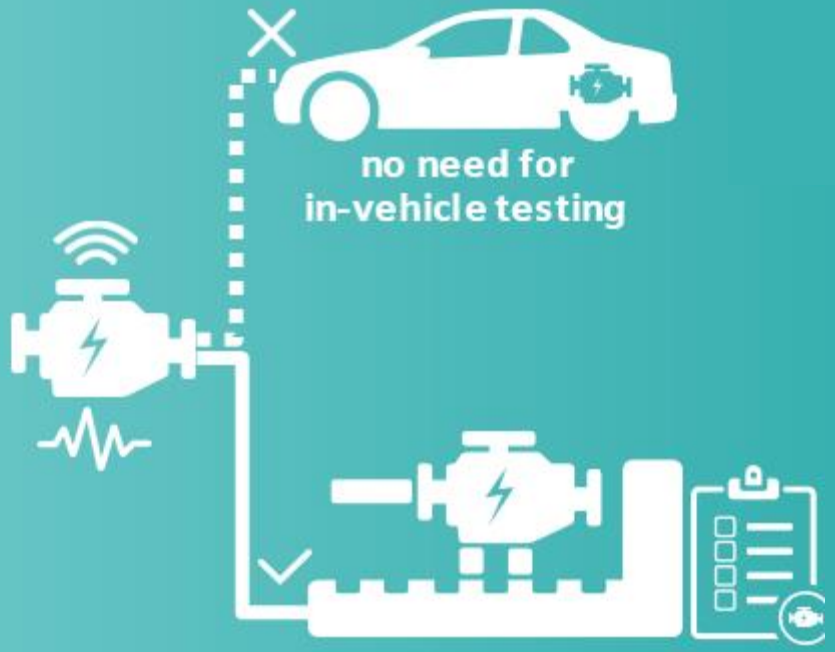
Several ISO initiatives to standardize invariant structure borne source characterization

Unrestricted © Siemens 2020

Component based TPA

Speeding up the development cycle by combining testing and simulation

SIEMENS
Ingenuity for life



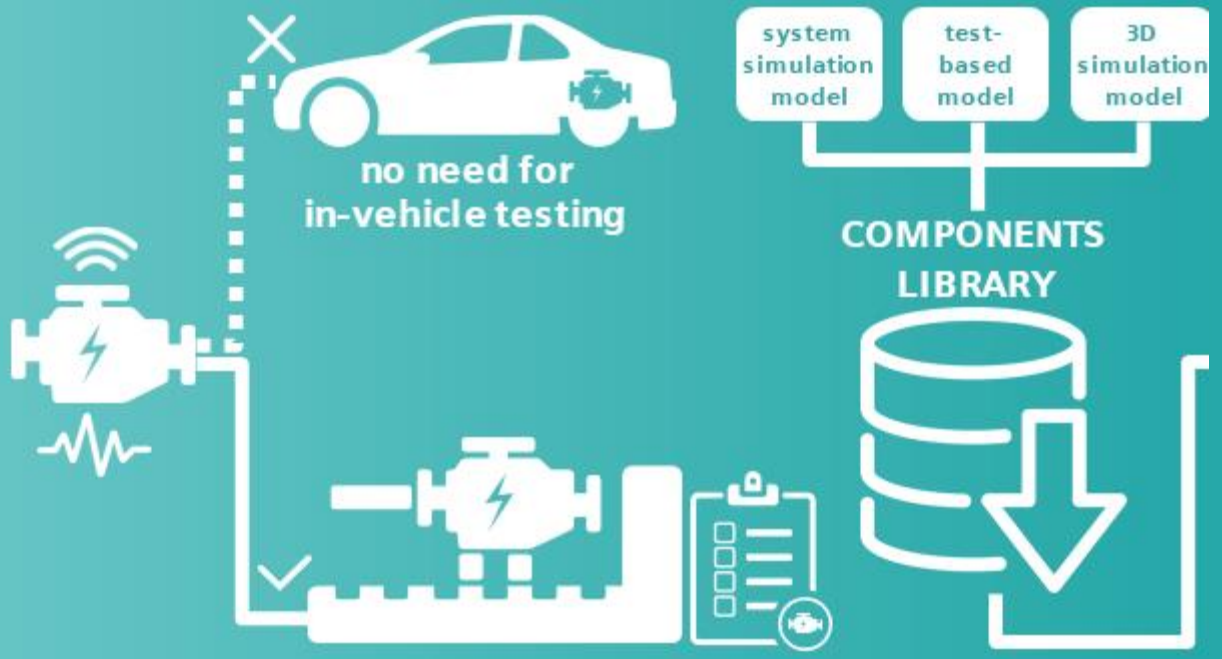
identify key components likely to contribute to noise and vibration issues

isolate components for high quality test bench data collection and independent load characterisation

Component based TPA

Speeding up the development cycle by combining testing and simulation

SIEMENS
Ingenuity for life



identify key components likely to contribute to noise and vibration issues

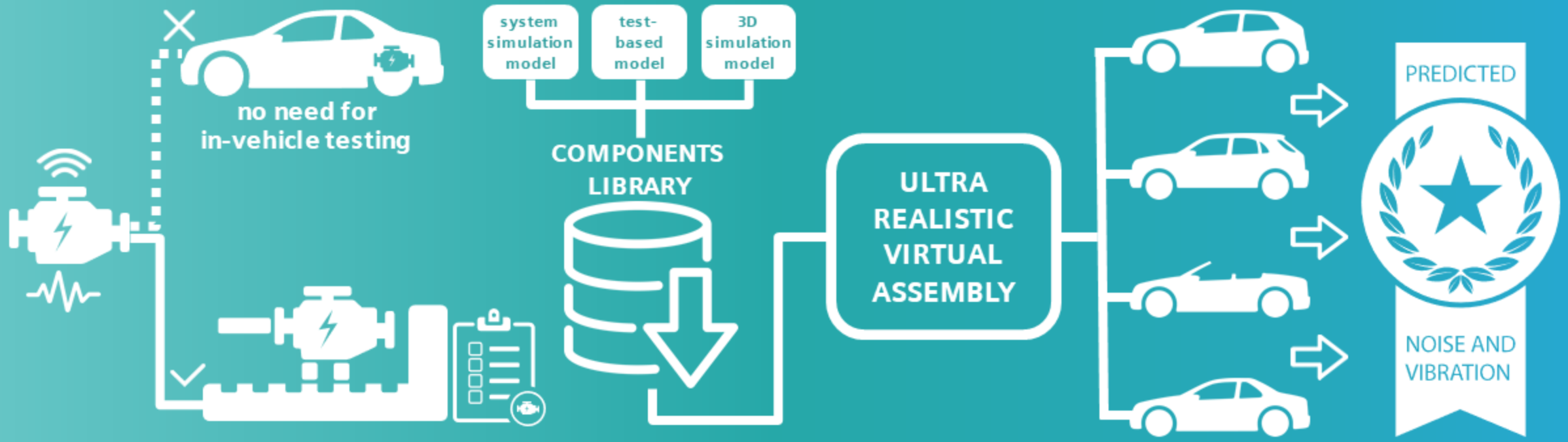
isolate components for high quality test bench data collection and independent load characterisation

create a test and simulation based components library

Component based TPA

Speeding up the development cycle by combining testing and simulation

SIEMENS
Ingenuity for life



identify key components likely to contribute to noise and vibration issues

isolate components for high quality test bench data collection and independent load characterisation

create a test and simulation based components library

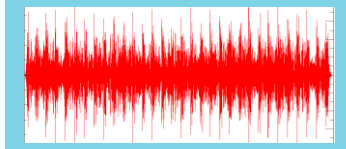
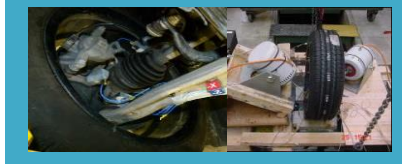
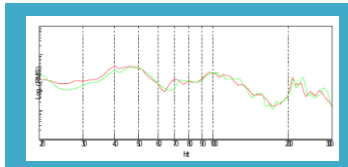
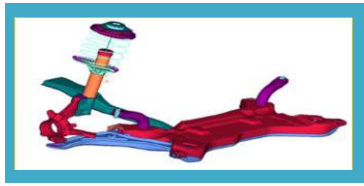
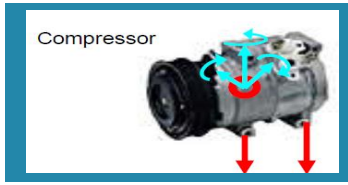
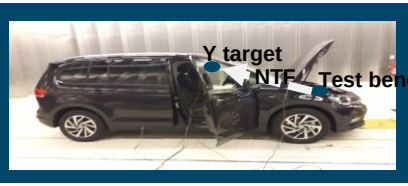
increase realism through seamless integration of system simulation, 3D and test models

combine the component models throughout the different vehicle variants

asses the product's behavior before prototyping

Component-based TPA
Example applications

SIEMENS
Ingenuity for life

Source Mechanism	Invariant Source Synth. Model	Sub-Receiver Connection Elements	Receiver
Steering System	 Blocked Forces & Impedances Mount Pos.	Subframe FEM/TEST FRF	Body FEM/TEST FRF
 Tire Road Noise	 Blocked Forces & Impedances Wheel Center.	 Suspension FEM/TEST FRF	Body FEM/TEST FRF
HVAC Compressor	 Blocked Forces & Impedances Connection.	Vehicle FEM/TEST FRF	
Wiper System	Blocked Forces & Impedances Connection	Mounts TEST Stiffness	Body FEM/TEST FRF
Gearbox Actuator	Blocked Forces or Free Accelerations Volume Velocities Impedances	 Vehicle FEM/TEST FRF	

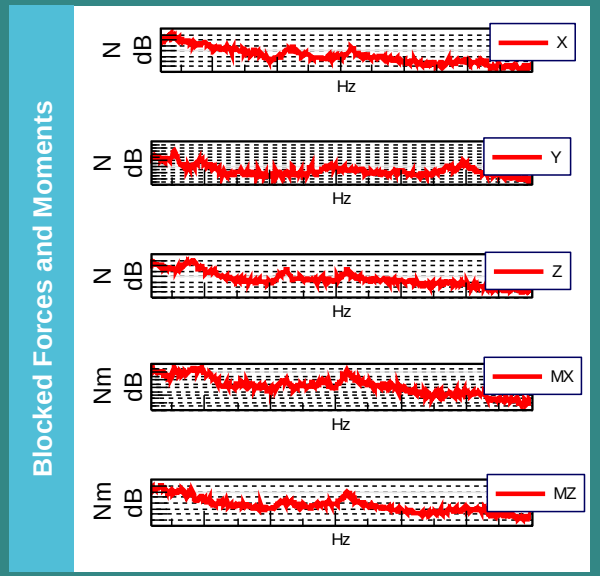
Unrestricted © Siemens 2020

Simcenter Engineering project – Tire supplier

Road noise – Wheel center blocked forces

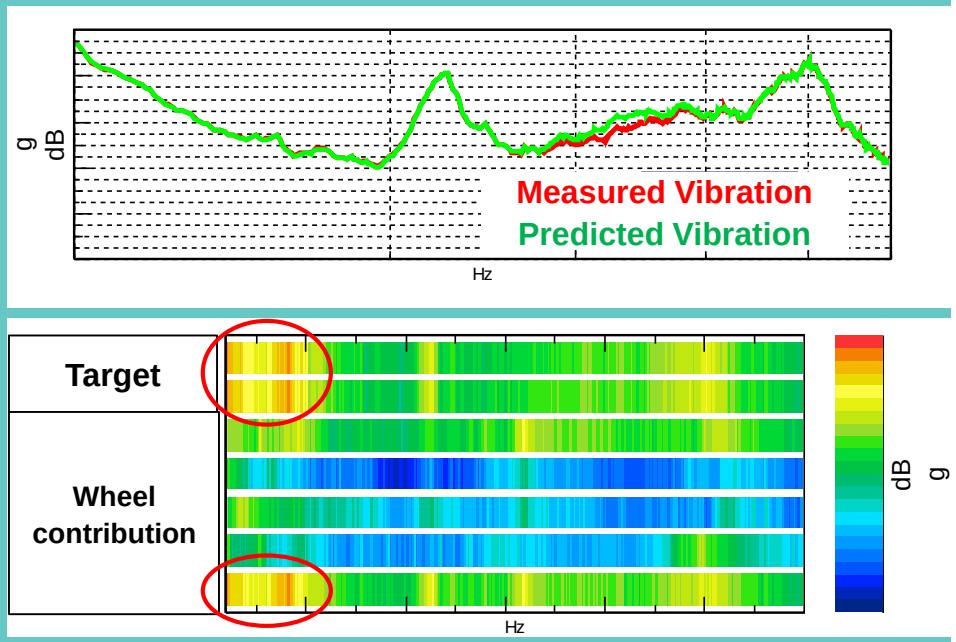
SIEMENS
Ingenuity for life

Identification of blocked forces on test rig



- → Source in operation: 20 / 40 / 60 / 80 / 100 kph.
- → Blocked forces calculated using in-situ TPA: matrix inversion using multiple integral shakers for FRF
- → Blocked forces direct measured on rigid test rig using force cell (usable up to 300 Hz)

On board validation of target response on test rig

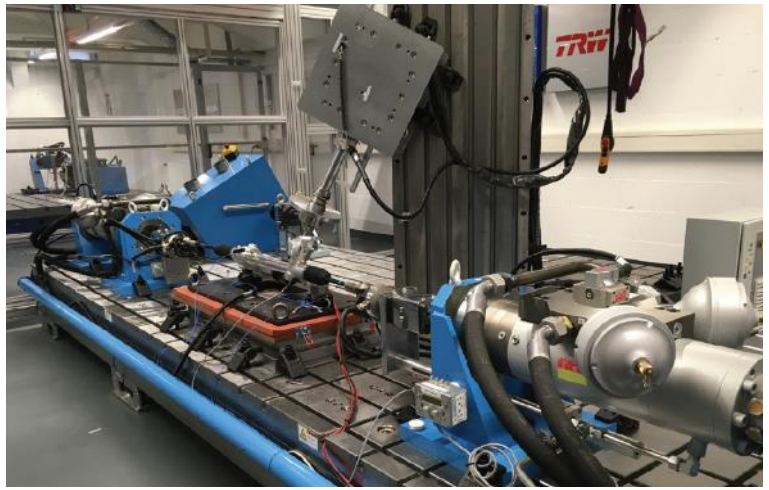


- → **On-board validation**
- → Identification of path contribution
- → Input for realistic target setting & prediction
- → Independent of test rig

Unrestricted © Siemens 2020

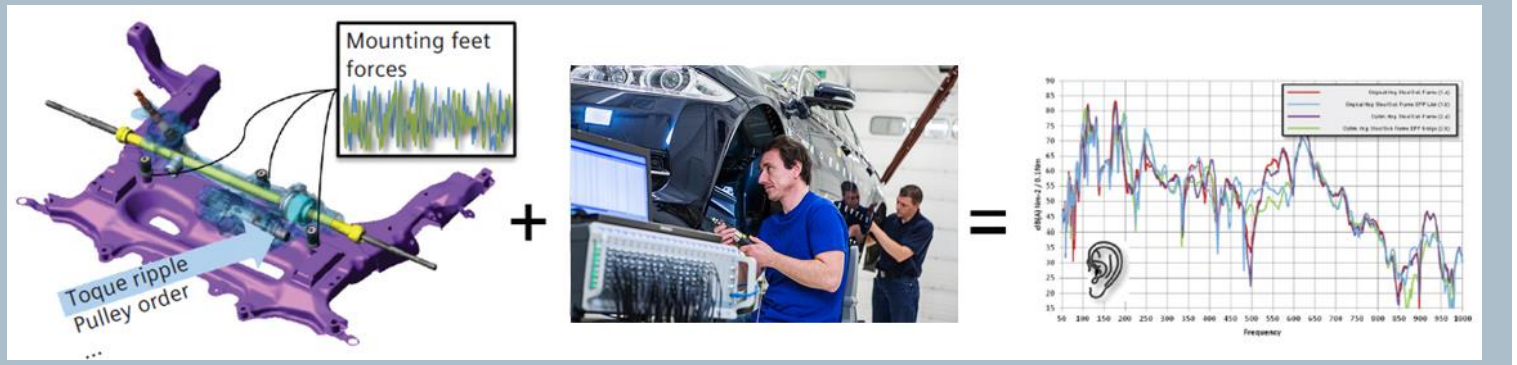
ZF TRW

Positioning steering systems NVH at the front of the development cycle



- **Reduced overall resources to solve NVH-related issues**
- **Accurately estimated resources for NVH resolution upfront**
- **Received positive feedback from customers, who appreciate the output data as well as the approach used to gather it**

Development of the world's first NVH steering system bench



Developing a powerful partnership

- Translate NVH recommendations into real and objective requirements and targets
  Integrate test and simulation to determine and resolve the root causes of problems

"We can establish exactly how much force we are allowed to introduce to a particular car to stay below a given NVH target, and we find that our customers appreciate this approach a lot."

Christian Landsberg, Global Chief Engineer NVH

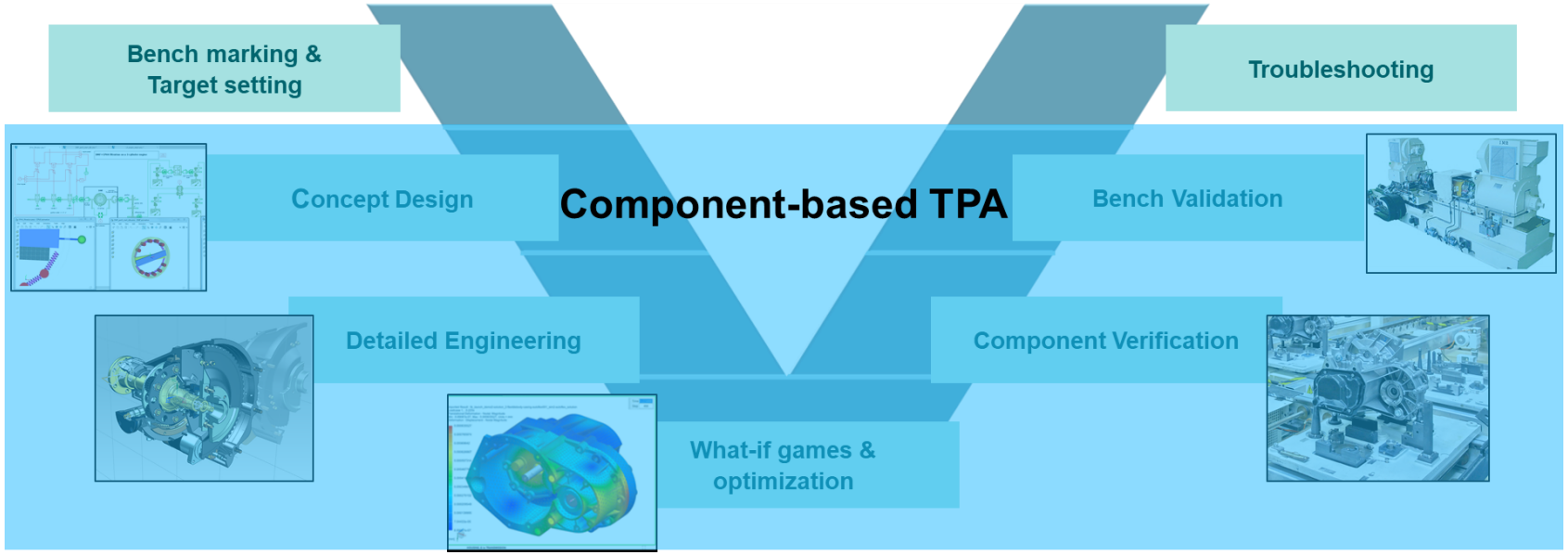
Unrestricted © Siemens 2020

Component-based TPA

SIEMENS
Ingenuity for life

Improve OEM cooperation by setting realistic targets on invariant loads

Enhance usage of bench data to create virtual prototype assembly



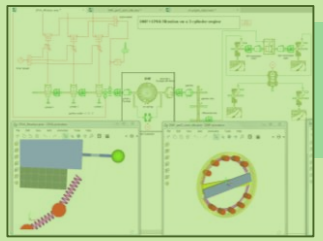
Unrestricted © Siemens 2020

Ensure vehicle-level component NVH evaluation
Throughout the development cycle

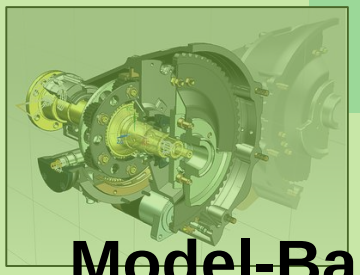
SIEMENS
Ingenuity for life

Target Setting → **Concept validation** → **Detailed Engineering** → **Validation/Refinement**

Bench marking & Target setting



Concept Design

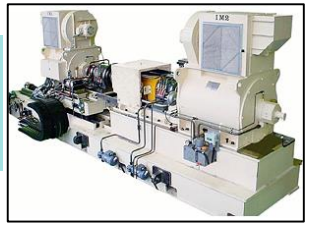


Detailed Engineering

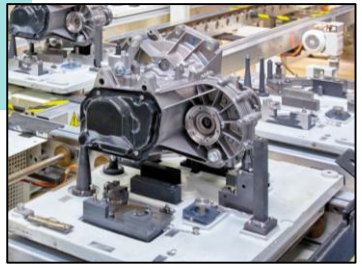
What-if games & optimization

Model-Based Development

Troubleshooting



Bench Validation



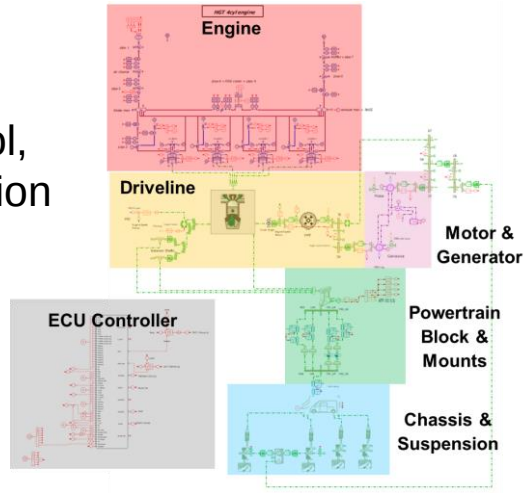
Component Verification

Unrestricted © Siemens 2020

Model-based development
Process deployment for system engineering

SIEMENS
Ingenuity for life

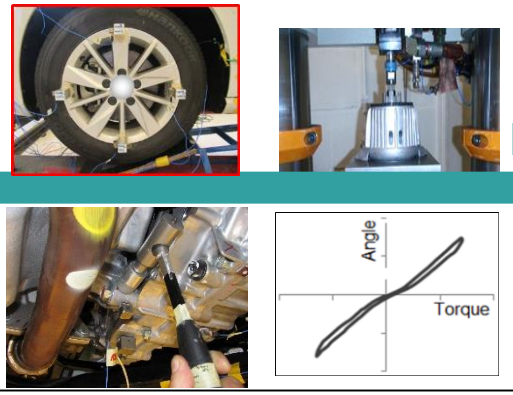
Full vehicle model including engine, motor, ECU control, driveline, suspension and vehicle model



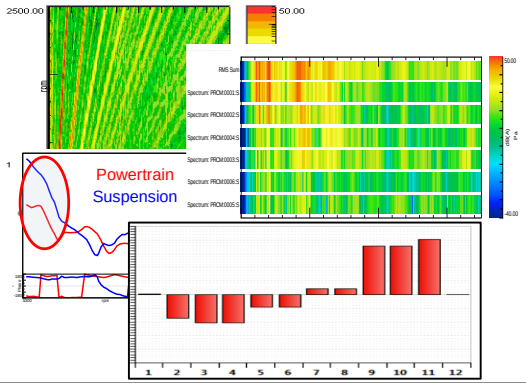
Update & Validate

Complement

Component – system tests
Vehicle tests



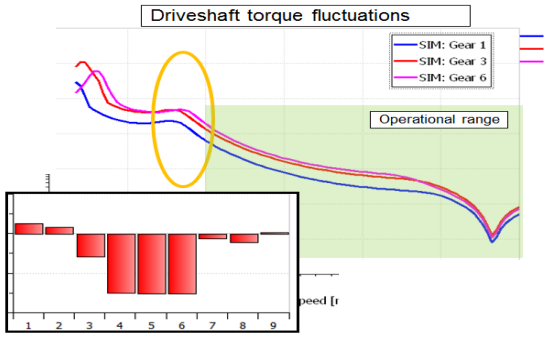
Diagnose
Insights



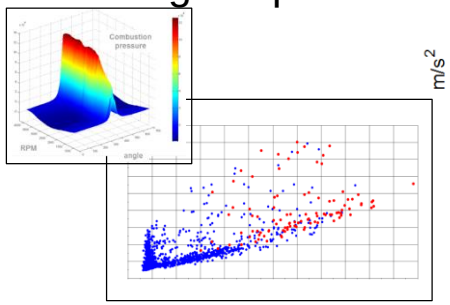
Scalable model complexity
f(accuracy, information)

	Engine	T/M	SUSPENSION	BODY
Master (not to be modeled)	HF engine	All internal details with clearances	3D full physical	FE
Level 1	MVEM	Simple ratio with equivalent inertia	1D	
Level 2	Mapped engine + 3D body	Simple ratio with equivalent inertia and clearance	2D	2D
Level 3	Cylinder pressure tables + 3D body	TM with distributed inertias and stiffness	2D with NVH tire model	2D + FRF

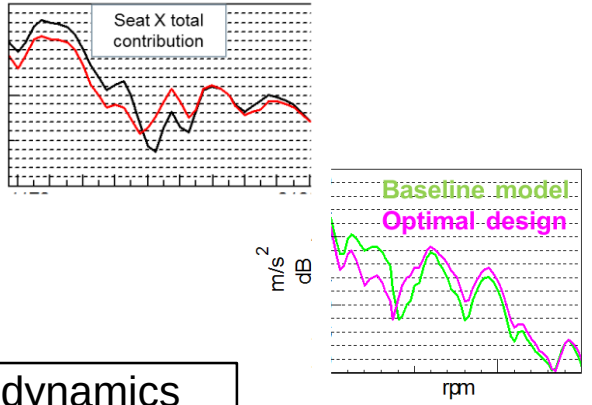
Sensitivity studies



Design exploration
Change impact



Modification studies

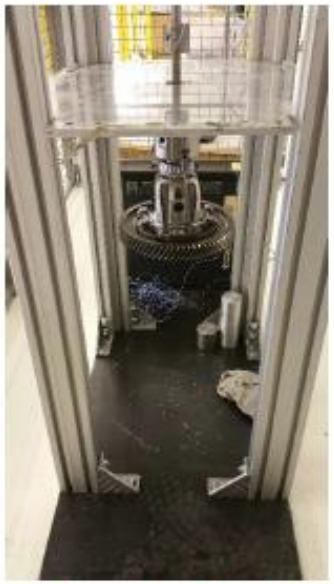


Model provides insight in rotational dynamics & coupling driveline and suspension dynamics

Unrestricted © Siemens 2020

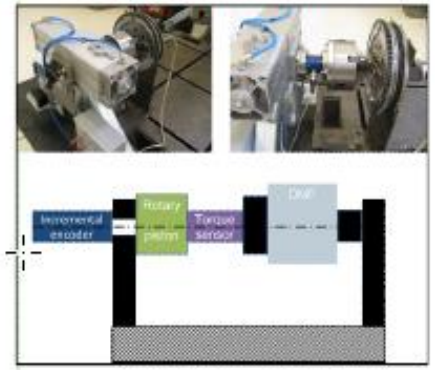
Model-based development
Full vehicle reverse engineering

SIEMENS
Ingenuity for life

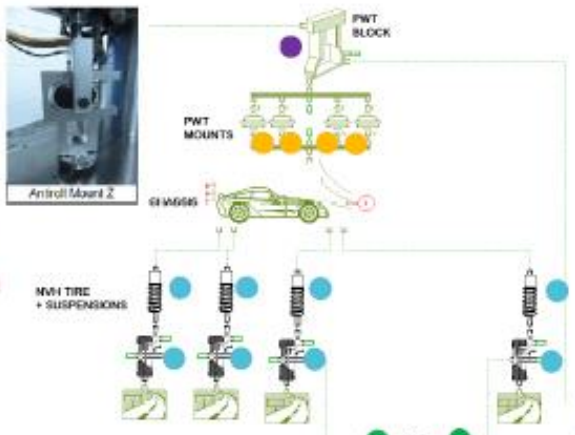


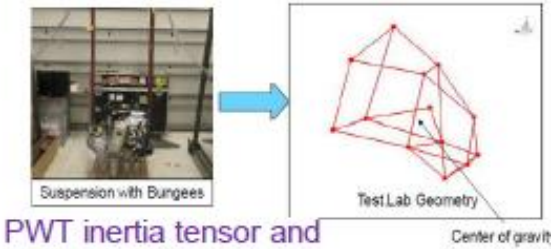
Pendulum bench for rotating part inertia measurement

DMF wind-up curve characterization



PWT mounts characterization



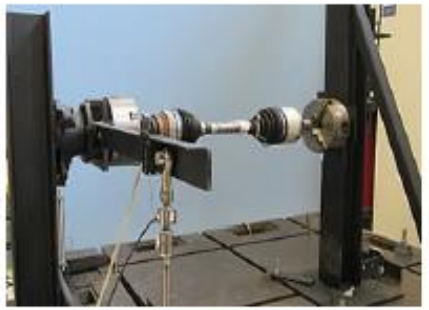


PWT inertia tensor and CoG measurement

wheel instrumentation for NVH tire characterization

Dimensions Metrology

drive shafts characterization



Unrestricted © Siemens 2020

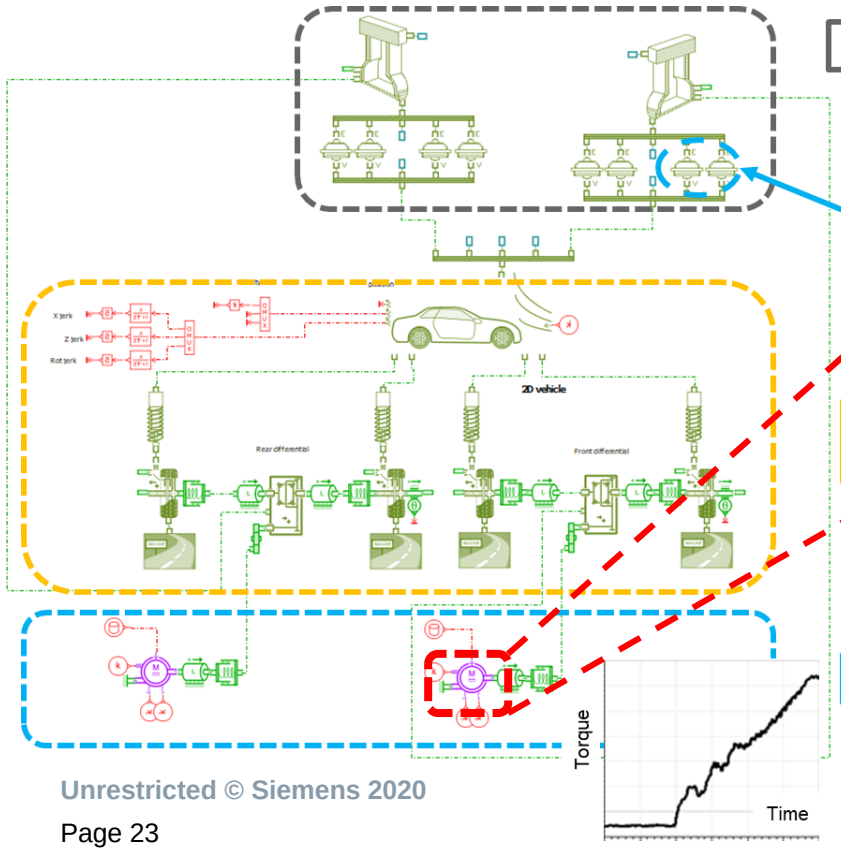
Simcenter Engineering project – Automotive supplier

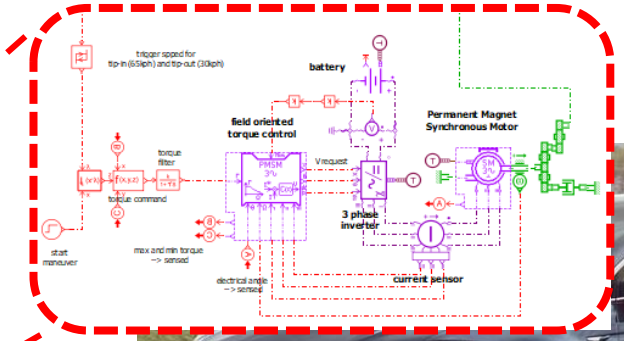
EV full vehicle modeling for component design evaluation

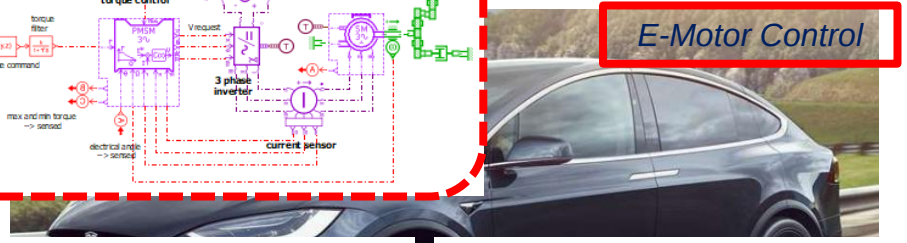
SIEMENS
Ingenuity for life

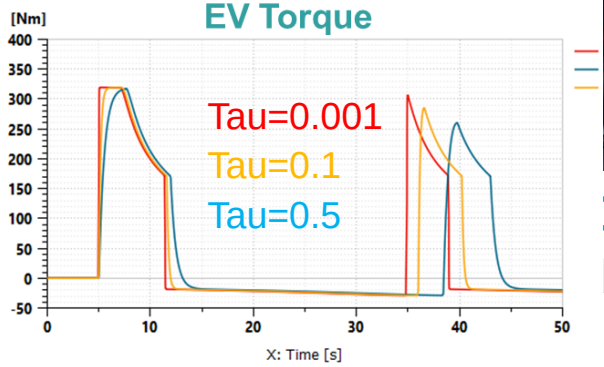
Target: be able to develop full vehicle system simulation models for early design studies of components such as active suspensions, electro-motors, braking systems.

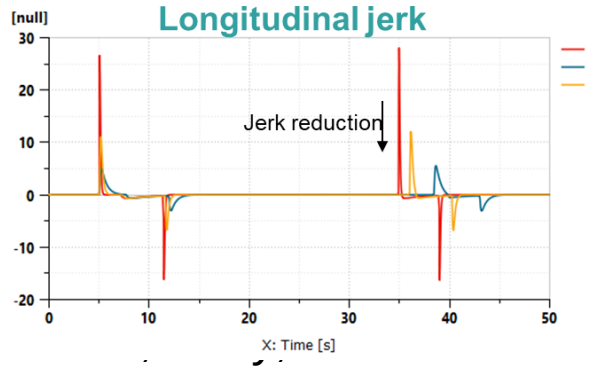
Model for Tip-in / Tip-out











Jerk is mitigated by tuning the torque filtering

Unrestricted © Siemens 2020

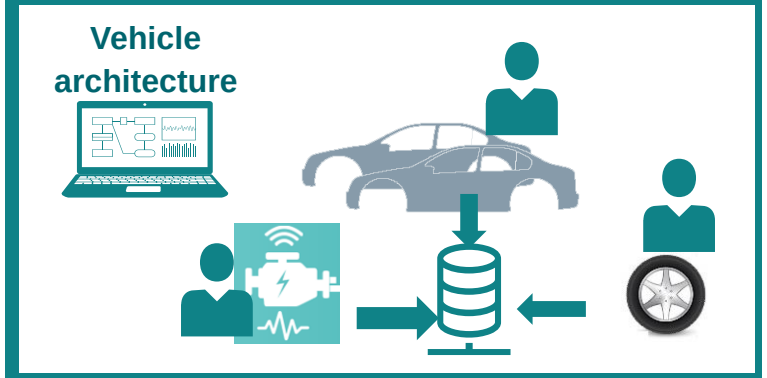
Virtual prototype assembly

Maximized data usage for a wide range of performance predictions

SIEMENS
Ingenuity for life

Accurate component models

Publish component data in standardized component libraries



Available for all

Maximize accessibility of component data

Performance evaluation

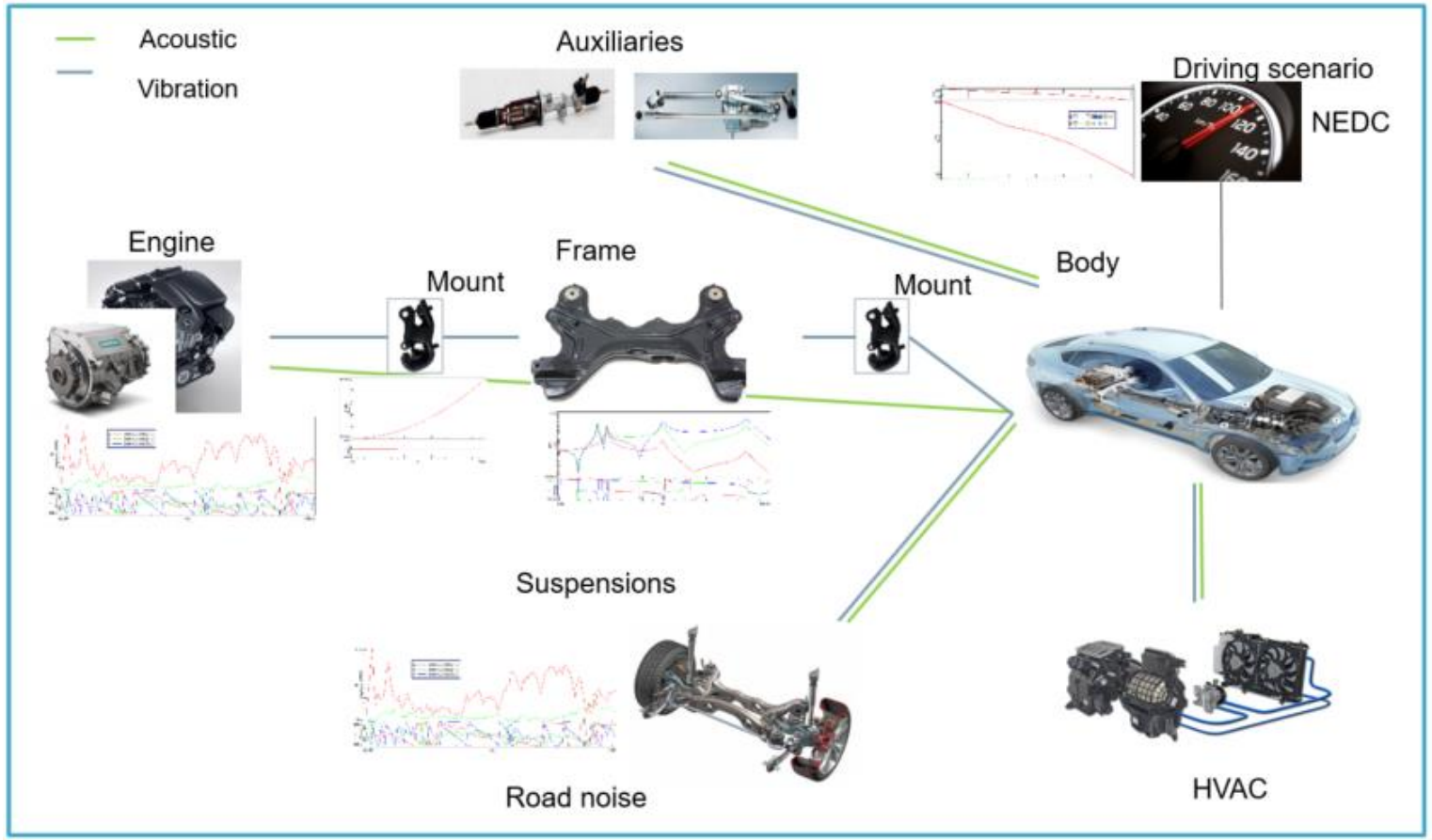
Access models by large group for wide range of performance predictions

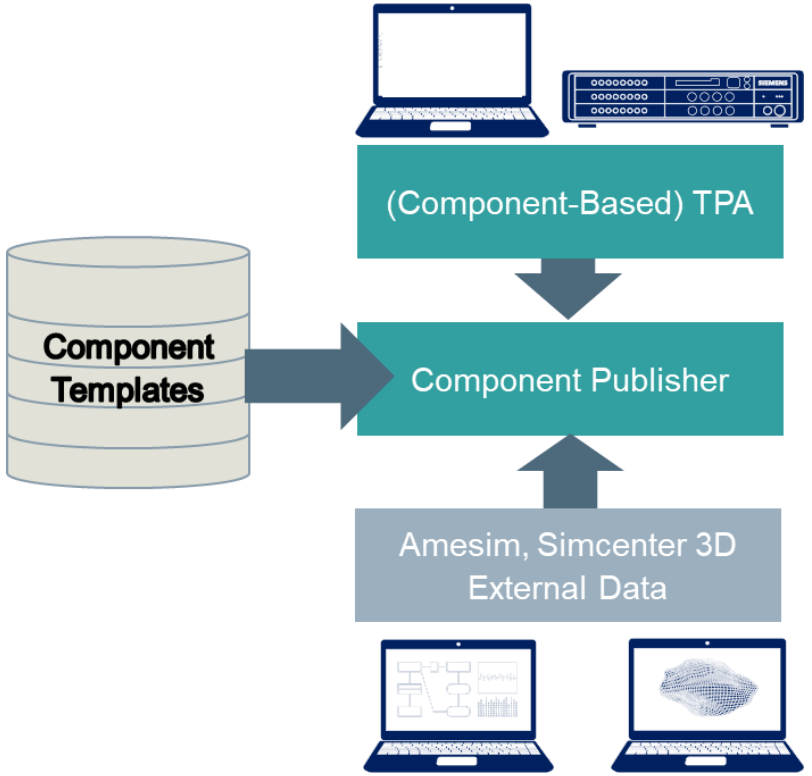
Unrestricted © Siemens 2020

Virtual prototype assembly

Maximized data usage for a wide range of performance predictions

SIEMENS
Ingenuity for life





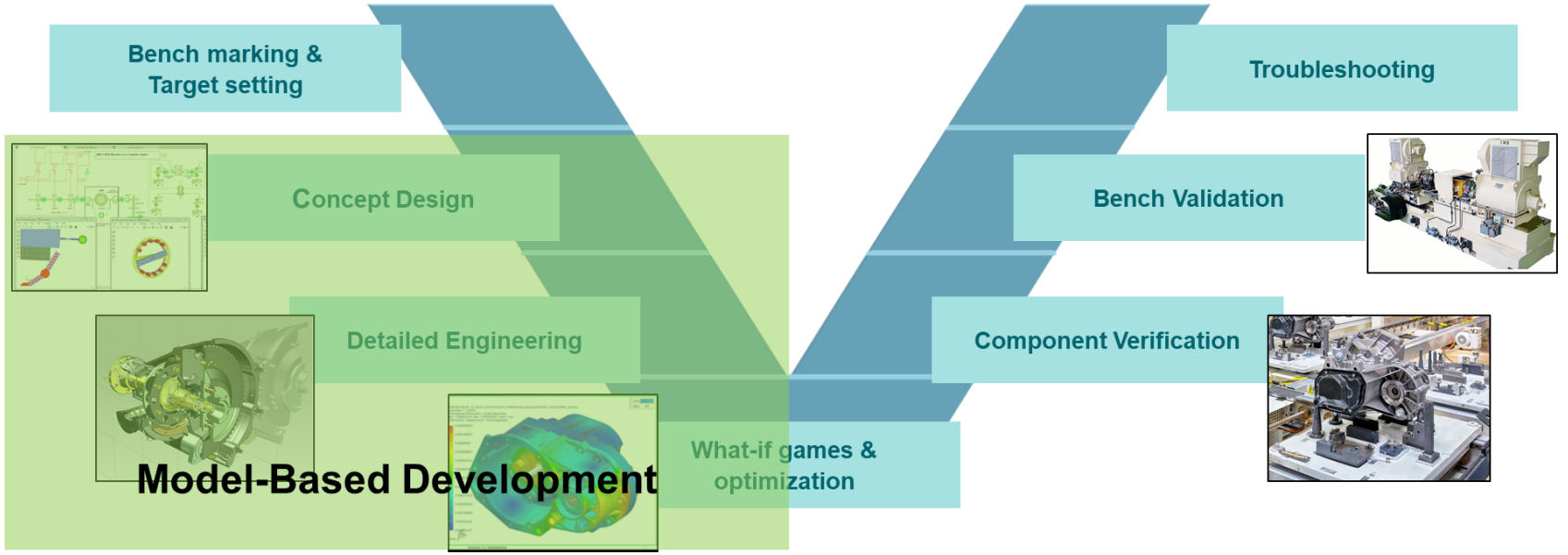
Unrestricted © Siemens 2020

Model-based development

SIEMENS
Ingenuity for life

Enable component concept design with system simulation

Quick assessment of many design variants



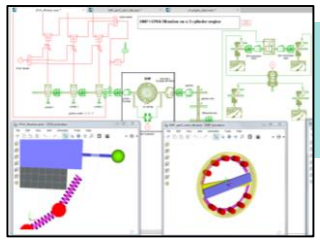
Unrestricted © Siemens 2020

Ensure vehicle-level component NVH evaluation
Throughout the development cycle

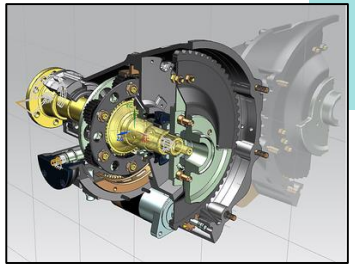
SIEMENS
Ingenuity for life

Target Setting | Concept validation | Detailed Engineering | Validation/Refinement

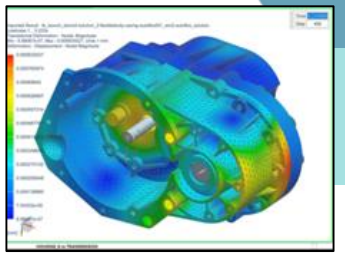
Bench marking & Target setting



Concept Design

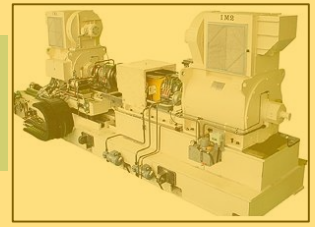


Detailed Engineering



What-if games & optimization

Troubleshooting



Bench Validation

Component Verification

Model-Based System Testing

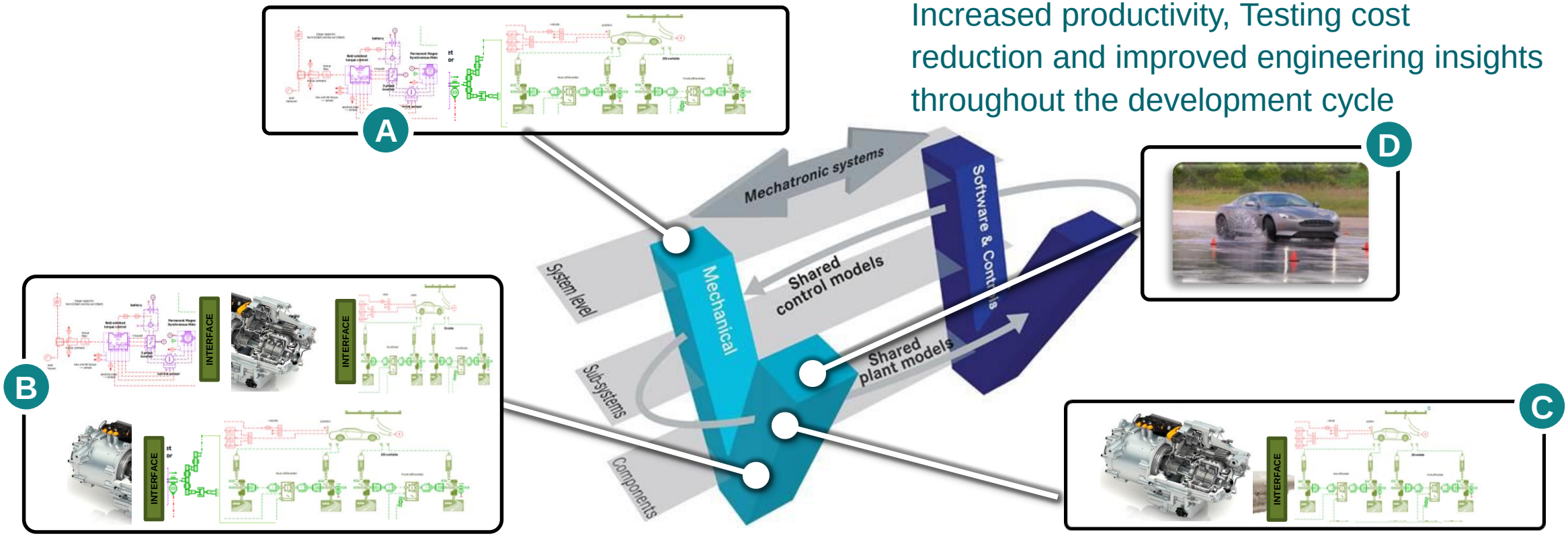
Unrestricted © Siemens 2020

Model-based system testing
Overview

SIEMENS
Ingenuity for life

One testing framework ranging from virtual testing to field testing
Providing consistent validation & verification throughout the development

Increased productivity, Testing cost reduction and improved engineering insights throughout the development cycle

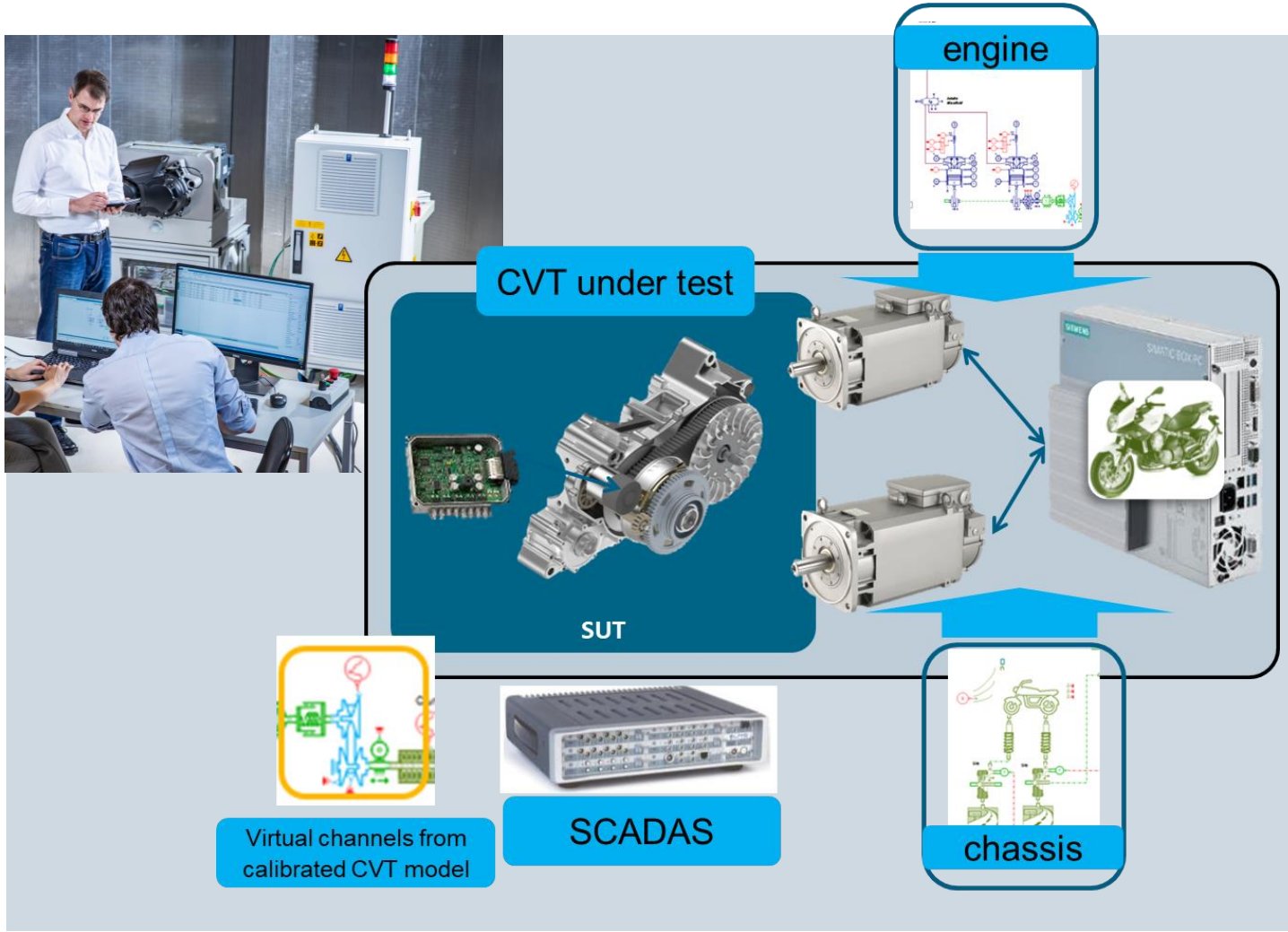


Simulation based cascaded design ← → **Test based cascaded verification**

Unrestricted © Siemens 2020

Simcenter Engineering project - Transmission supplier

Motorcycle e-CVT bench



Challenge

Validate transmission design targets for multiple attributes: Life-time, quietness, weight reduction, low friction

Solution

Model of motorcycle engine and chassis providing real-life test conditions

Benefit

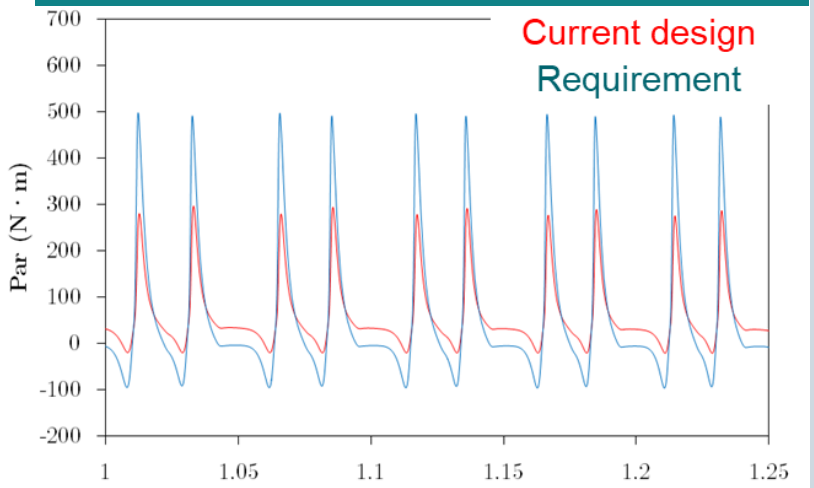
- Validate transmission design before full vehicle prototype is available

Unrestricted © Siemens 2020

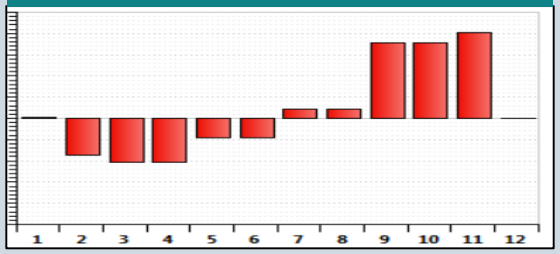
Simcenter Engineering project - Auto OEM
Torsional bench mechanical design

SIEMENS
Ingenuity for life

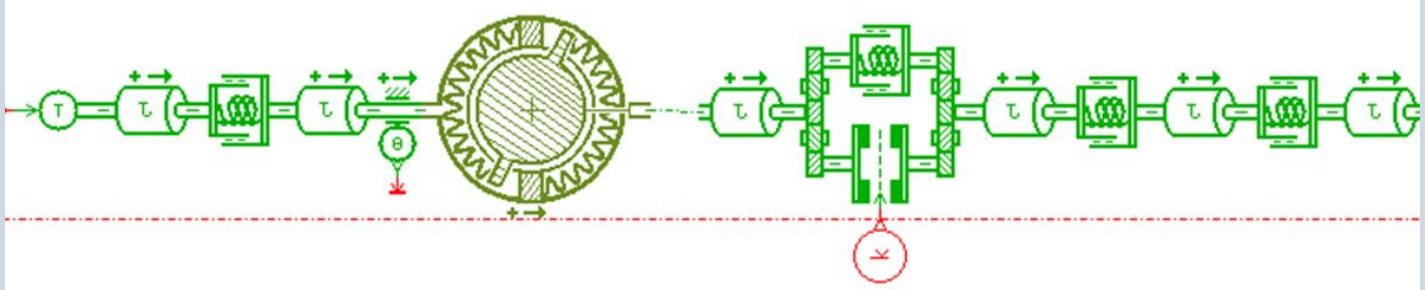
Motor Torque



Torsional Mode



Bench Model



Challenge

Ensure correct bench operations for component validation tests. Testing conditions may be limited due to bench design (torsional resonances, power)

Solution

Deploy a Digital twin of the bench + component to set requirements (motor size, inertia, stiffness) and ensure the correct loading in all scenarios

Benefit

- Easily evaluate broad range of variants and combinations
- Study feasibility of test scenarios during concept phase

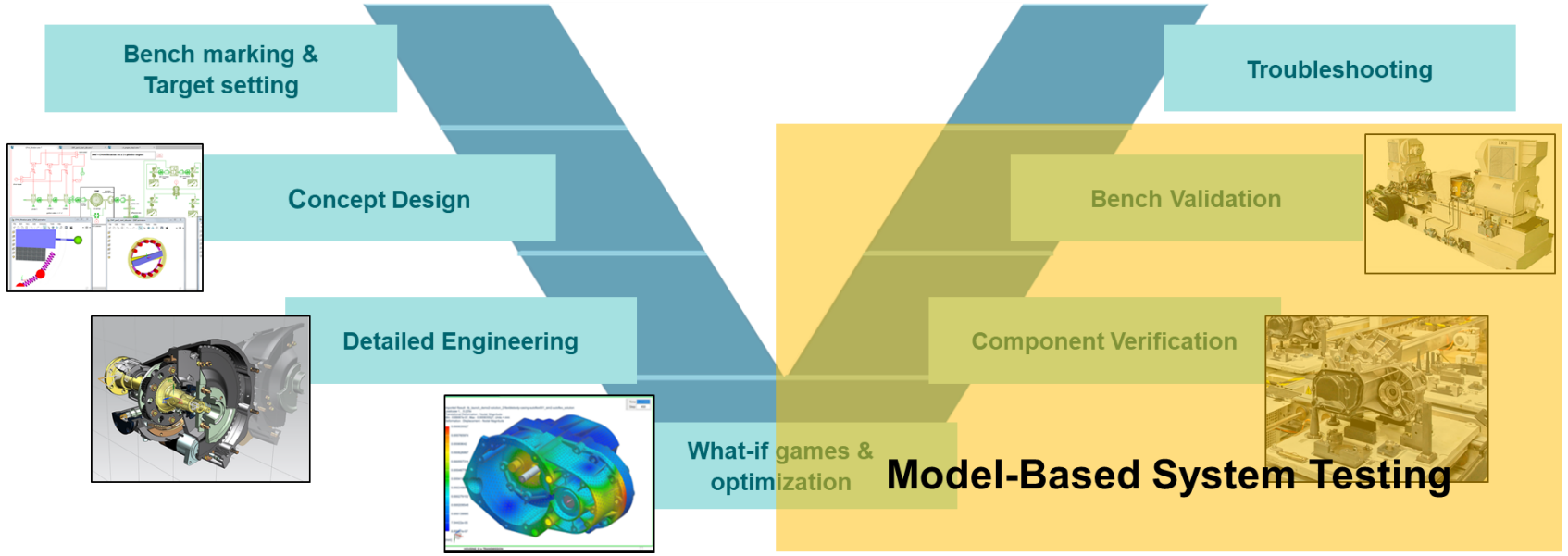
Unrestricted © Siemens 2020

Model-based system testing

SIEMENS
Ingenuity for life

Enable component testing in the lab in real-life conditions

Solve integration issues upfront

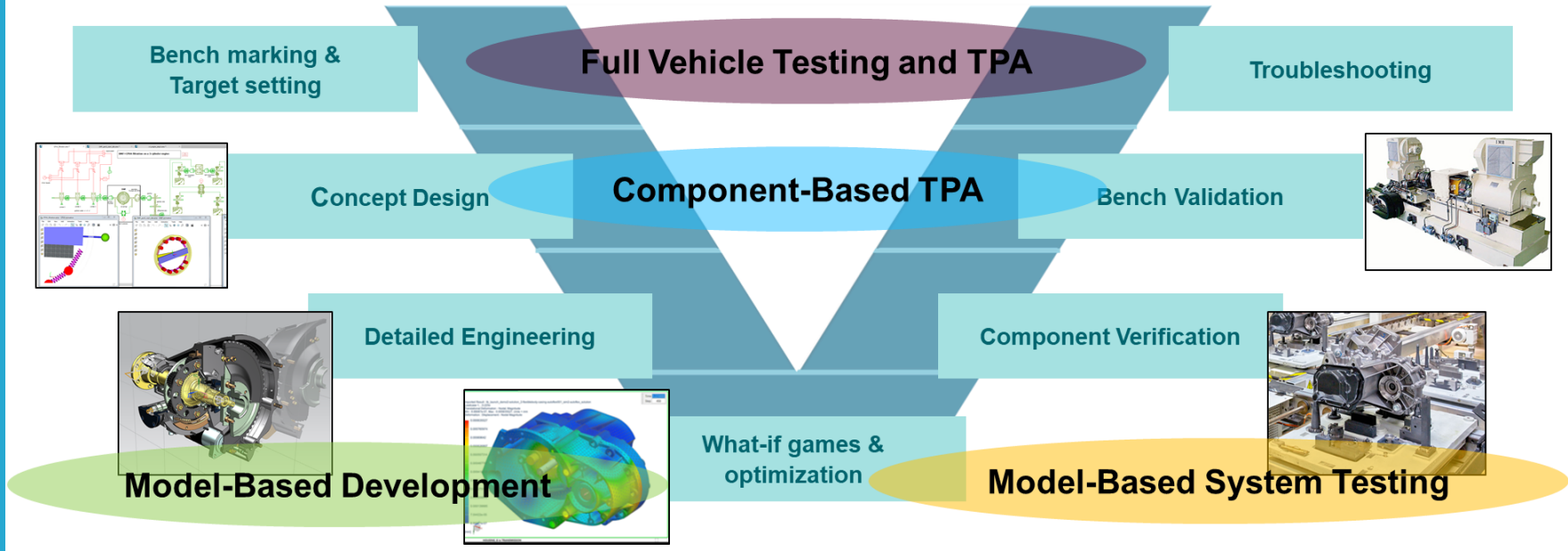


Unrestricted © Siemens 2020

Ensure vehicle-level component NVH evaluation
Throughout the development cycle

SIEMENS
Ingenuity for life

- Evaluate the sub-system in Full Vehicle with test and system simulation technologies
- Cascade Targets from System to Components with TPA
- Improve OEM cooperation by using invariant loads from Component based TPA
- Enable component concept design with Model based Development
- Solve integration issues upfront with Model Based System Testing



Unrestricted © Siemens 2020

SIEMENS
Ingenuity for life

Questions?