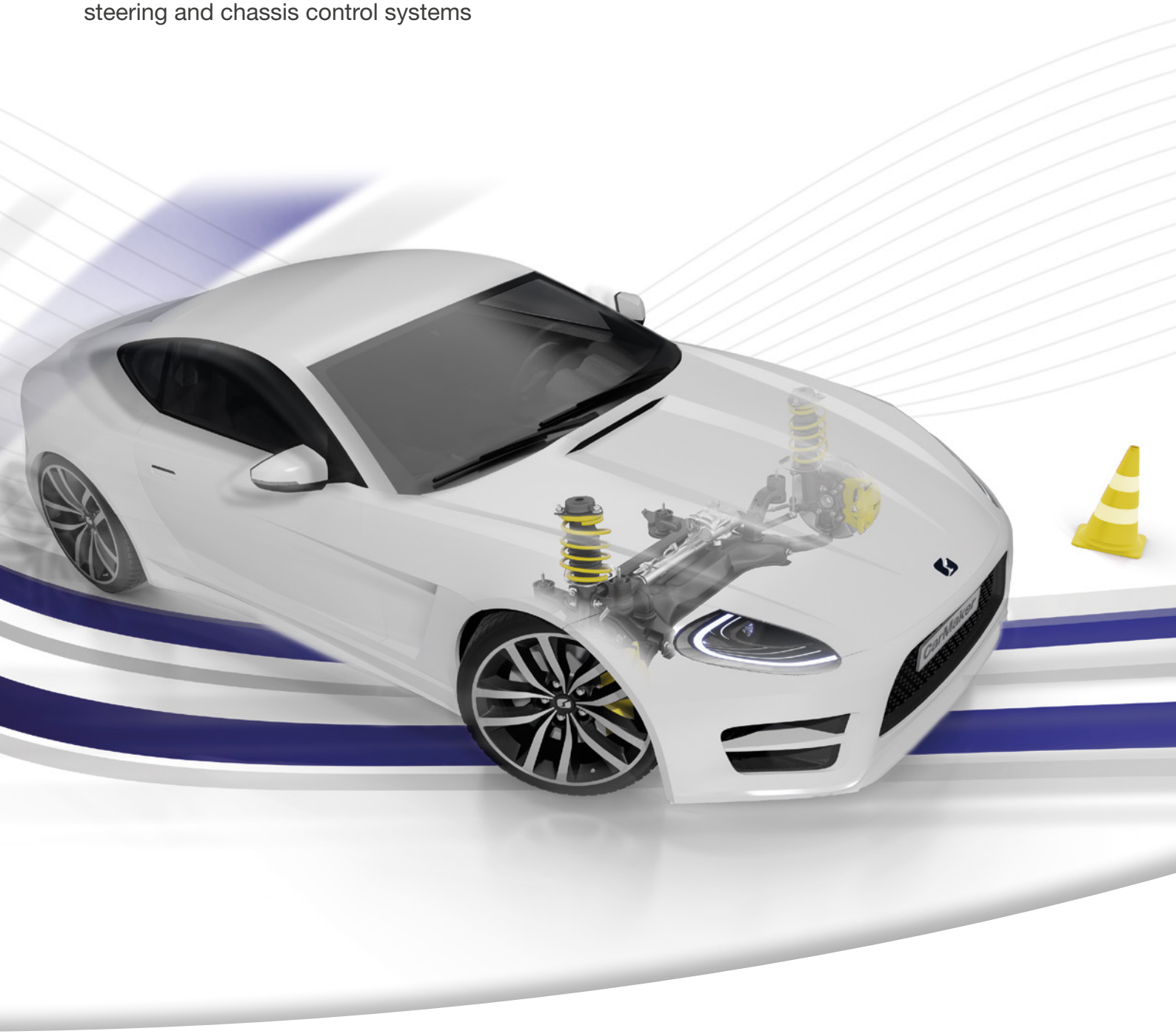
Vehicle Dynamics

Model-based development and validation of suspension, steering and chassis control systems



SOLUTIONS FOR VIRTUAL TEST DRIVING

IPG AUTOMOTIVE

Fun. Comfortable. Dynamic. The perfect ride.

Vehicle dynamics are the root of IPG Automotive's success and vehicle simulation is our passion since more than 35 years. Precise vehicle dynamics modeling is the basis of our CarMaker product family enabling functional and performance testing in real time using virtual vehicle prototypes.

The increasing level of driving safety combined with a rising demand of ride comfort and the development of automated driving functions require powerful and, above all, safe chassis components and systems. This entails an enormous development effort that is reflected in the unprecedented number of required test scenarios to find the best setup for suspension, steering as well as chassis control systems in order to optimize the overall ride comfort and driving experience according to individual preferences. The result is a multitude of test variations and millions of kilometers of test driving required to bring the systems to market. Performing all tests only in the real world is not efficient and downright impossible.

The solution: flexible and efficient testing with our open integration and test platform

Complement your chassis development process with virtual test driving enabled by the simulation solutions of the CarMaker product family. We support your development of steering systems, chassis control systems as well as suspension design, enabling you to quickly and easily build your virtual prototypes already during early stages but also throughout the entire development process (MIL, SIL, HIL).

CarMaker product family

Virtual test driving | **Integration platform** | **Visualization** | **Scalability HPC + cloud** | **Test automation + evaluation**

The end-to-end solution for virtual test driving: Automated and reproducible system and component tests embedded into virtual vehicle prototype driven in realistic scenarios. The principle of openness ensures the smooth integration into your existing tool landscapes thanks to a variety of supported standards and interfaces.

Powerful vehicle modeling for realistic virtual tests in real time up to the dynamic limits

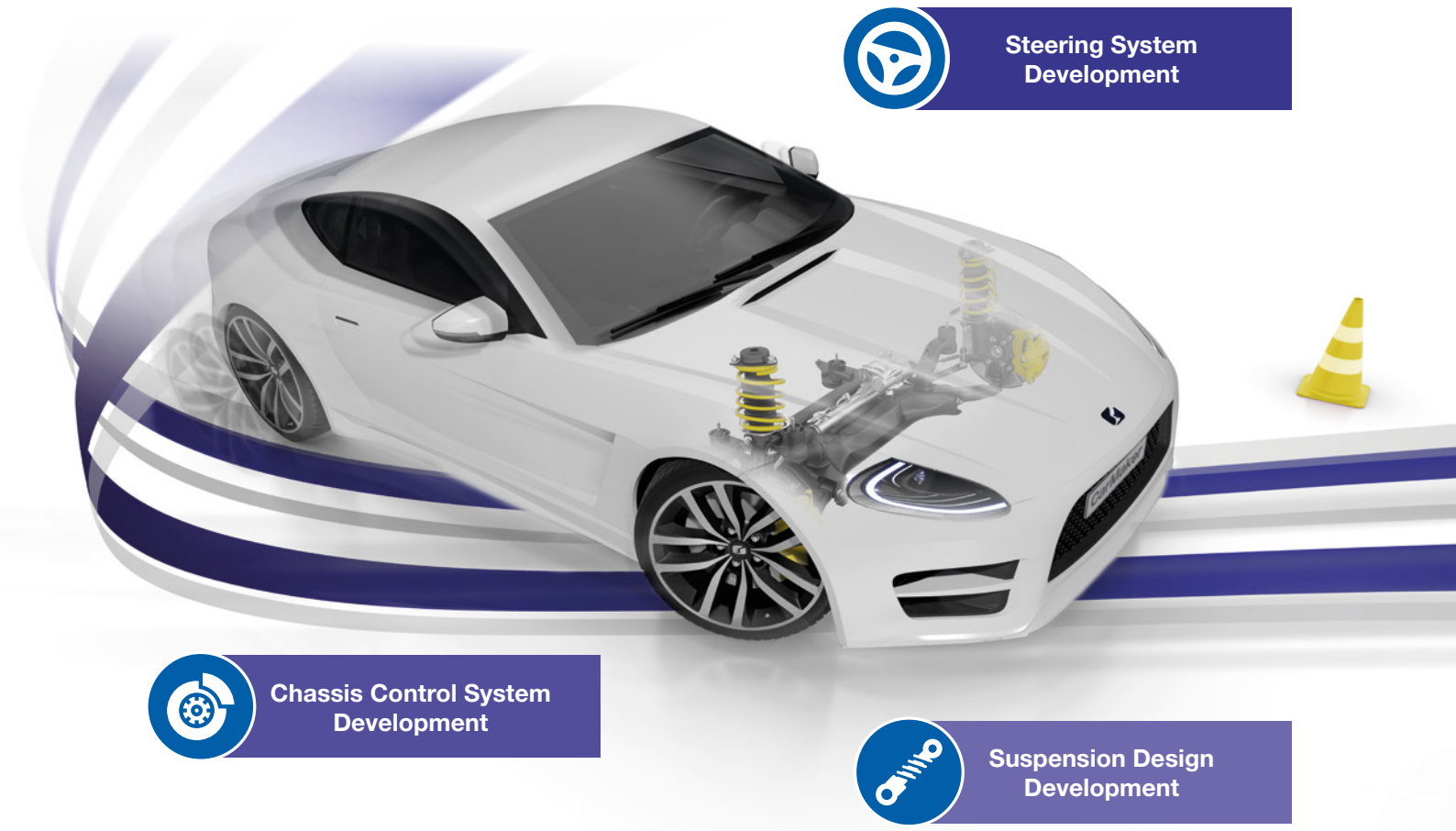
Approved for Homologation

The quality of vehicle dynamics simulation essentially depends on the vehicle model: Only an outstandingly precise, high-performance model is capable of correctly and efficiently modeling vehicle dynamics in the virtual world. The model quality of CarMaker has been proven, as CarMaker is widly used in automotive industry and applied to simulation-based ESC homologation for the virtual approval of vehicle variants, for instance.

Your benefits at a glance

- Best in class real-time capable vehicle model
- Fully non-linear vehicle model – from standstill up to the limit
- Multibody vehicle model with 19 DOF (up to 40 DOF)
- Simulation of moving masses
- Reduced effort and simple adaptability of vehicle variants
- Comprehensive model environment (body, suspension, steering, tire, brake, powertrain, aerodynamics, mounts, sensors)

Main vehicle dynamics applications



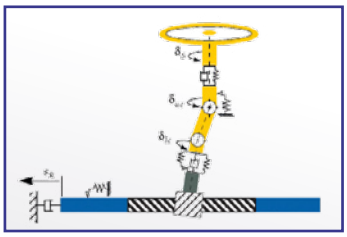
Steering system development: Finely tuned for an optimal driving experience

Steering is not only a significant factor in driving experience, it also plays an increasingly important role in the purchasing decisions of potential customers. Good steering performance ensures that the driver feels safe and comfortable, while also enjoying the ride.

In order to achieve the desired steering feel, the steering system is typically adjusted using a physical prototype. Our simulation solutions allow you to use virtual prototypes as a complement for early maneuver-based testing and optimization as well as the release of the steering system within the context of a whole virtual vehicle. As an actuator the steering system is also of great importance for the development of ADAS/AD functions.

Our product solutions

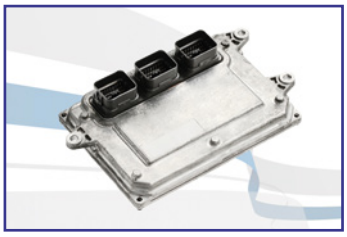
Steering models



High-fidelity steering model / external model

- Coverage of all relevant steering systems
- Easy evaluation of steering characteristics regarding common relevant criteria
- Basis for the development and testing of ADAS systems that interact with steering
- Possibility of driver-in the-loop / driving simulator extension
- Steering model for improved handling feel developed by Prof. P. Pfeffer
- Perfect interaction between the column, rack and the steering assistance unit for precise modeling of steering characteristics

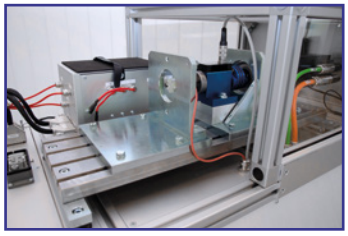
ECU test systems



Steering ECU Test System

- Only EPS-ECU as a real component
- Model of electric motor, sensors and steering

Steering system test benches



Steering Power Pack Test Bench

- EPS including the motor as a real component
- Model of the mechanical steering system

Steering-in-the-Loop Test Bench

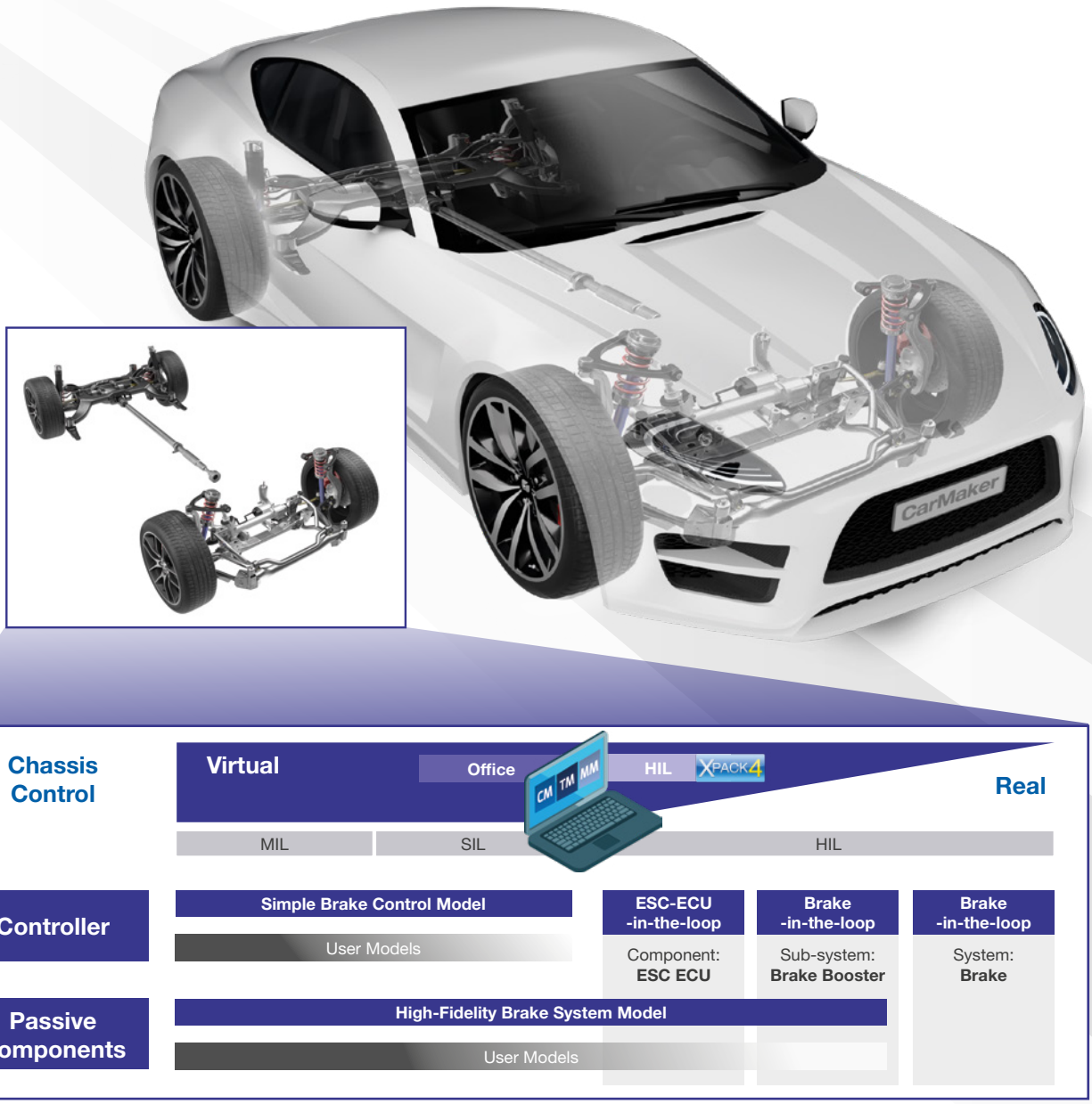
- Entire steering system comprising steering wheel, column and gear
- EtherCAT interface for faster communication and higher data throughput than CAN buses
- Complex closed-loop maneuvers due to short latencies
- EPS integration and functions for automated driving
- Optimized force resolution even at the limits of vehicle dynamics

Your benefits at a glance

- Evaluation of steering characteristics and steering effort in the whole vehicle, e.g. on-center performance
- Integrated development and testing of driver assistance system functions with active steering recommendations such as active steering support, lane keeping assistance or parking assistance systems
- Optimization of control units using safety, function and performance tests
- Steering system virtualization
- Easy and efficient integration of additional mechanical components

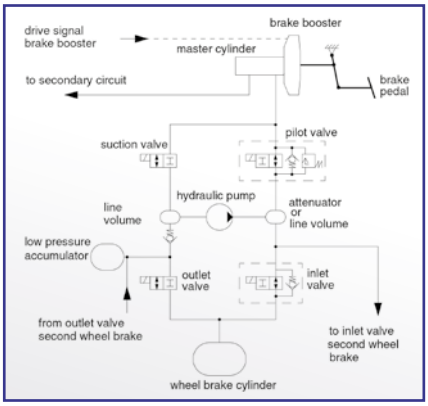
Chassis control system development: Verification and validation for a safe ride

Vehicle dynamics control systems for steering, brake or active wheel suspensions continue to raise the safety and comfort of driving. There is an ongoing development of novel assistance systems that serve the optimization of vehicle dynamics as well as a situational influence on the driver behavior and a selective influence on the driver. The result is a significant increase in the effort required for validation during development. At the same time, more and more vehicle variants are reaching the market for each model. As the system must be tested for each vehicle variant, this is also associated with additional test effort. Use the simulation solutions of the CarMaker product family to test your vehicle dynamics and ride comfort control systems within a virtual prototype right up to the vehicle's approval, long before a physical prototype exists.



Our product solutions

Brake system models



High-fidelity brake system model / external model

- Detailed hydraulic brake model valid for ABS/ESP with
  - Booster
  - Master and brake cylinder
  - Pump
  - Valves
  - Line volume
  - Accumulator
  - Attenuator

ECU test systems

ESC-HIL Test System

- Plug-In Test Box for ESC / EPB ECU
- Valve activity measurement via our Signal Acquisition Box
- Turnkey solution for testing and validating physical ESC units
- Ability to test all ESC functionalities with a single HIL system

Brake system test benches

Electronic Brake Booster Test Bench

- For testing and validating electro-mechanical brake boosters (e.g. iBooster)
- Can be connected with other brake components

Brake-in-the-Loop Test Bench

- For testing and validating complete braking systems
- Wet brake test approach including hydraulic components
- Possibility to set up the ESC test system as a full dual-circuit braking system test bench by mechanically integrating the brakes into the front and rear axle
- Tests of the interplay between multiple mechanical and electronic components such as real EPB calipers and the electronic brake booster unit

Your benefits at a glance

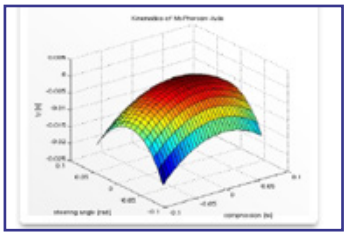
- Safety software tests (fail-safe behavior, diagnostics, sensor defects)
- Function tests (ECU behavior, integrated tests with ESC and EPB, ABS/ASR/ESC function)
- Performance tests and improvement (performance of brake booster behavior, adaptation of pedal characteristics)
- Simulation-based ESC homologation

Suspension design development

Every OEM would like their vehicle to be unique and recognizable by its own specific “vehicle DNA”, on which suspension design and handling performance have a substantial influence. The solutions of the CarMaker product family make your chassis development easier. From pure axle design (kinematics and compliance), to axle testing in the whole vehicle during various driving maneuvers, to lap time optimization on race tracks – set up virtual test benches and simulate and parameterize real-time capable vehicle dynamics models.

Our product solutions

Suspension models

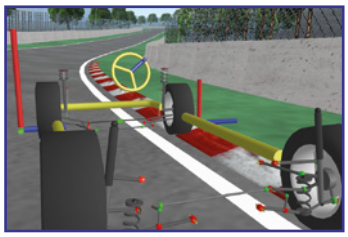


Map-based suspension model

- Selectable linear and non-linear kinematics & compliance tables with up to 3D dependencies
- High efficiency for maximum simulation speed
- Generalized coordinates for compression, roll and steering

IPGKinematics as a tool for designing suspension models

- Virtual axle kinematics test bench to calculate the kinematics, steering kinematics and compliance of all types of suspensions
- Exact characteristics of the suspension kinematics
  - Wheel travel kinematics
  - Steering kinematics
  - Compliance effects
- Development of new suspensions as well as optimization of existing axle designs
- Generation of map-based suspension models



MBS suspension model in CarMaker

- Sophisticated template-based multibody system (MBS) suspension
- Optimized to run multiple times real time
- Includes non-linear bushings and hard point positions
- Supports the inclusion of active elements from third-party tools
- Enables tests of different axle types effectively and at an early stage in a single tool
- Makes axle optimizations extremely efficient by connecting to common design of experiments tools

Your benefits at a glance

- Automated suspension design studies
- Efficient suspension design optimization
- Identify load conditions for durability
- Integration of user test systems
- Conduct lap time optimization
- Analyze ride and handling performance
- Integration into existing MBS toolchain

Guaranteed goal achievement thanks to early system testing

Virtual benchmark: Achieve your goals with confidence

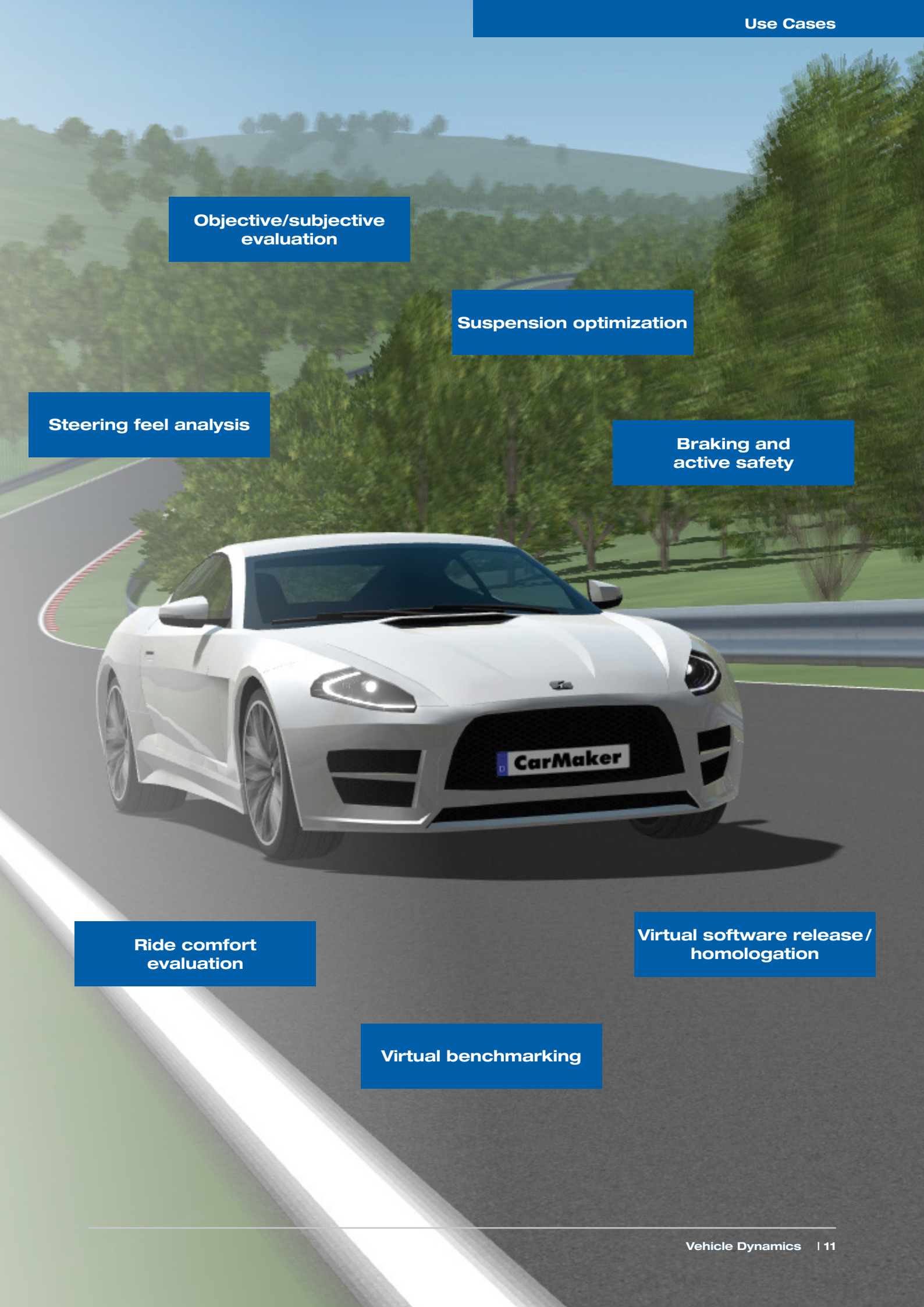
The automotive systems engineering approach enables the early testing of systems within the context of complex system networks and within the whole vehicle. This is also the idea behind virtual benchmarking. Using a virtual prototype allows you to optimize your suspension design, steering and chassis control systems at an early stage and steer the development process in accordance with your goals. There is no need to wait until the physical vehicle or physical components exist. Virtual prototypes make benchmarking possible in the design phase, meaning that you can be confident of reaching your goals right from the start. In addition, virtual benchmarking allows you to compare both the whole vehicle and individual components behavior with those of your competitors at an early stage.

Consumer test rating prediction

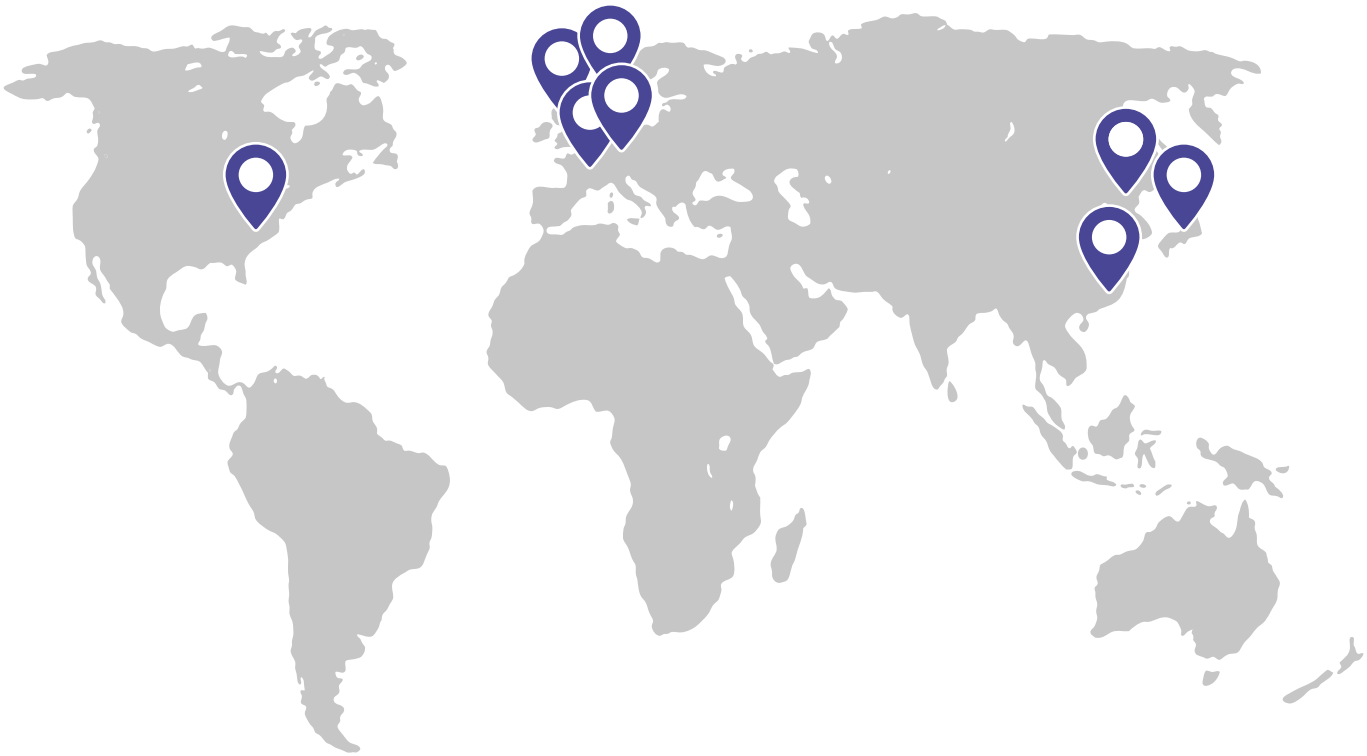
The vehicle ratings published by trade journals represent a particular application scenario for virtual benchmarking, ensuring that you will not be surprised by the results. You can simulate how the vehicle will perform in defined test scenarios such as slalom driving or double lane changes or how consumption will look for a specific test track. This makes it possible to predict the results of trade journal tests and react in advance by adjusting your vehicle development accordingly.

More information on our website at: ipg-automotive.com/areas-of-application/vehicle-dynamics

ECU pre-calibration


Objective/subjective evaluation
Suspension optimization
Steering feel analysis
Braking and active safety
CarMaker
Ride comfort evaluation
Virtual software release / homologation
Virtual benchmarking

About IPG Automotive



Locations: Germany | China | France | Japan | Korea | Sweden | UK | USA
Sales partners: India | Italy | Taiwan | Turkey

As a global leader in virtual test driving technology, IPG Automotive develops innovative simulation solutions for vehicle development. Designed for seamless use, the software and hardware products can be applied throughout the entire development process, from proof of concept to validation and release. The company's virtual prototyping technology facilitates the automotive systems engineering approach, allowing users to develop and test new systems in a virtual whole vehicle.

IPG Automotive is an expert in the field of virtual development methods for the application areas of ADAS & Automated Driving, Powertrain and Vehicle Dynamics. Used across the globe, the solutions of the CarMaker product family enable the generation of high-precision dynamic vehicle models for a realistic modeling of handling characteristics, which are implemented for suspension design as well as the development of vehicle dynamics control systems and ride comfort systems. The simulation also allows for the effective adjustment of steering systems.

IPG Automotive stands for quality, holistic user orientation, efficiency, promotion of innovation and lasting partnership.

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