Hochschule Kempten
University of Applied Sciences

drive livinglab

ADAS Master WS 21/22
Lecture 8

Vehicle Dynamics in context of Advanced Driver Assistance Systems and Automated Driving.

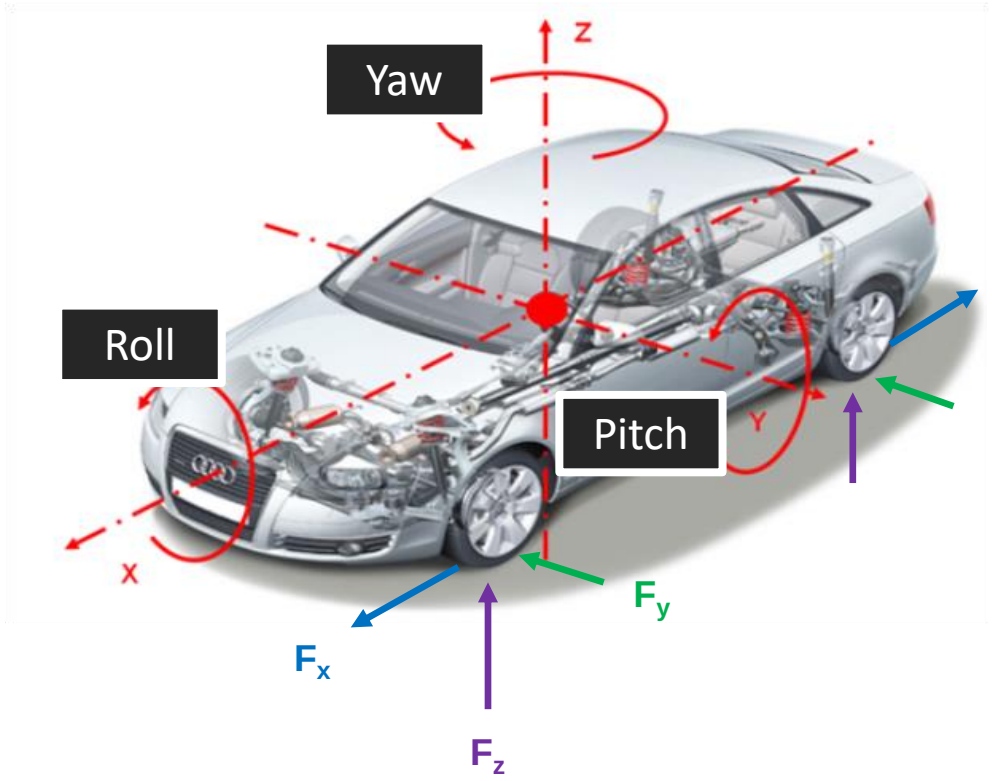
Lecture program

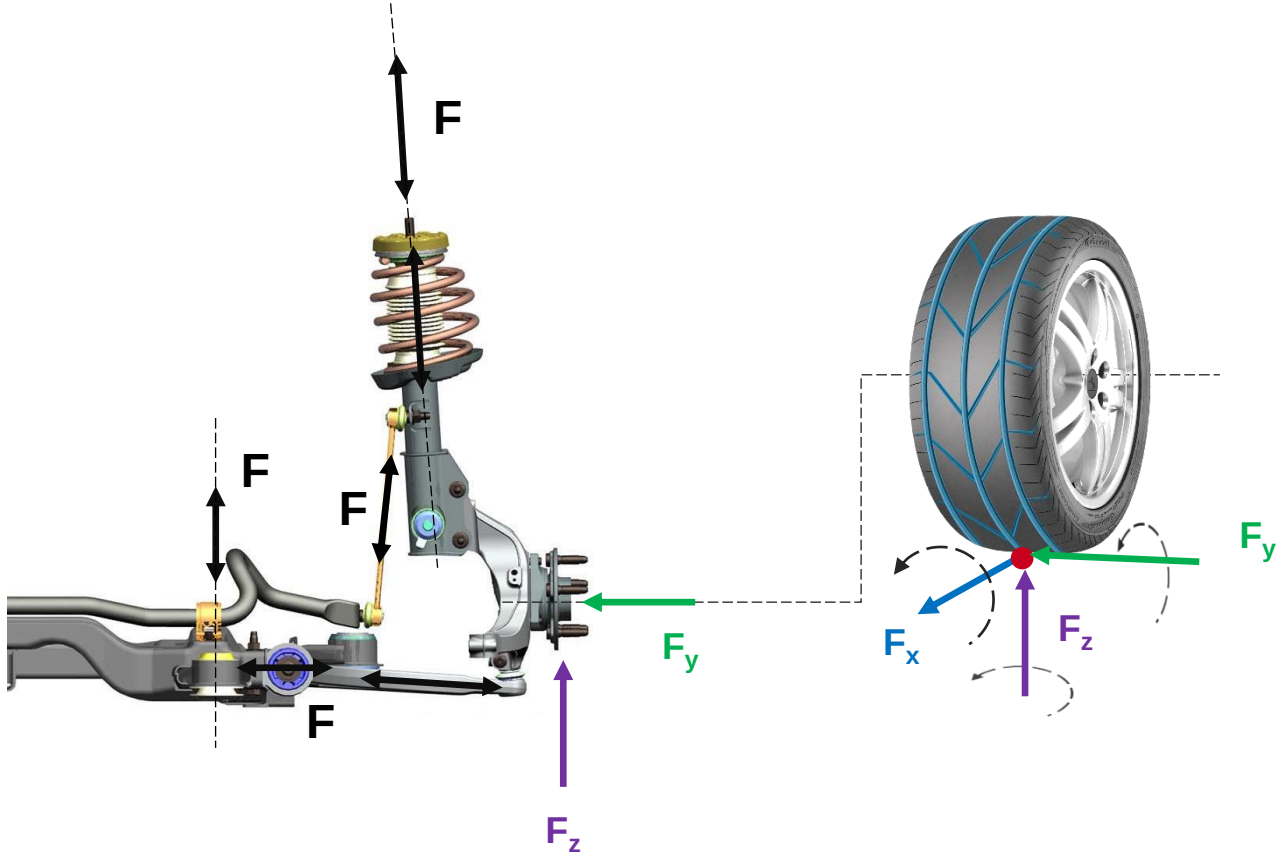
https://moodle2.hs-kempten.de/moodle/course/view.php?id=2914

Nr.	Datum	Inhalt	Ort	Von Wem
0		**Virtual Test Driving (VTD)** **CarMaker Quick Start Guide**	**T314** **T318**	**Self-study**
1	07.10.	Requirements for vehicles and their global attributes	T314 T318	Schick
3	14.10.	Vehicle dynamics attributes and their target conflicts	T314 T318	Schick
3	21.10.	Test and evaluation methods for vehicle attributes (1) **with practical simulation**	T314 T318	Schick
4	28.10.	Test and evaluation methods for vehicle attributes (2) **with practical simulation**	T314 T318	Schick
5	04.11.	Basic vehicle dynamics calculation and vehicle models with exercise	T314 T318	Böhle
6	11.11.	**ADAS DRIVING EVENT** Measurement Tech. Introductions **PSA - Introduction**	**IFM**	Günther/Riedlmüller/ Schwandke
7	18.11.	Chassis components and functions (1) Tire & Wheels **with practical simulation**	T314 T318	Schick
8	25.11.	Chassis components and functions (2) Axle & Suspension **w. practical simulation**	T314 T318	Schick
9	02.12.	Chassis controls and functions (1) Overview & Brakes & Steering	T314 T318	Schick
10	09.12.	Chassis controls and functions (2) ESP–Functions & Application & Process	T314 T318	Albert Lutz (BOSCH)
11	16.12.	**Chassis controls and functions (3)** **ESP–Application & Hands-On Workshop**	T314 T318	Albert Lutz (BOSCH)
12	13.01.	**Chassis controls and functions (4)** **ESP–Application & Hands-On Workshop**	T314 T318	Albert Lutz (BOSCH)
13	20.01.	TEND: ADAS Development for a sports car manufacturer	T314 T318	Manuel Höfer (Porsche)

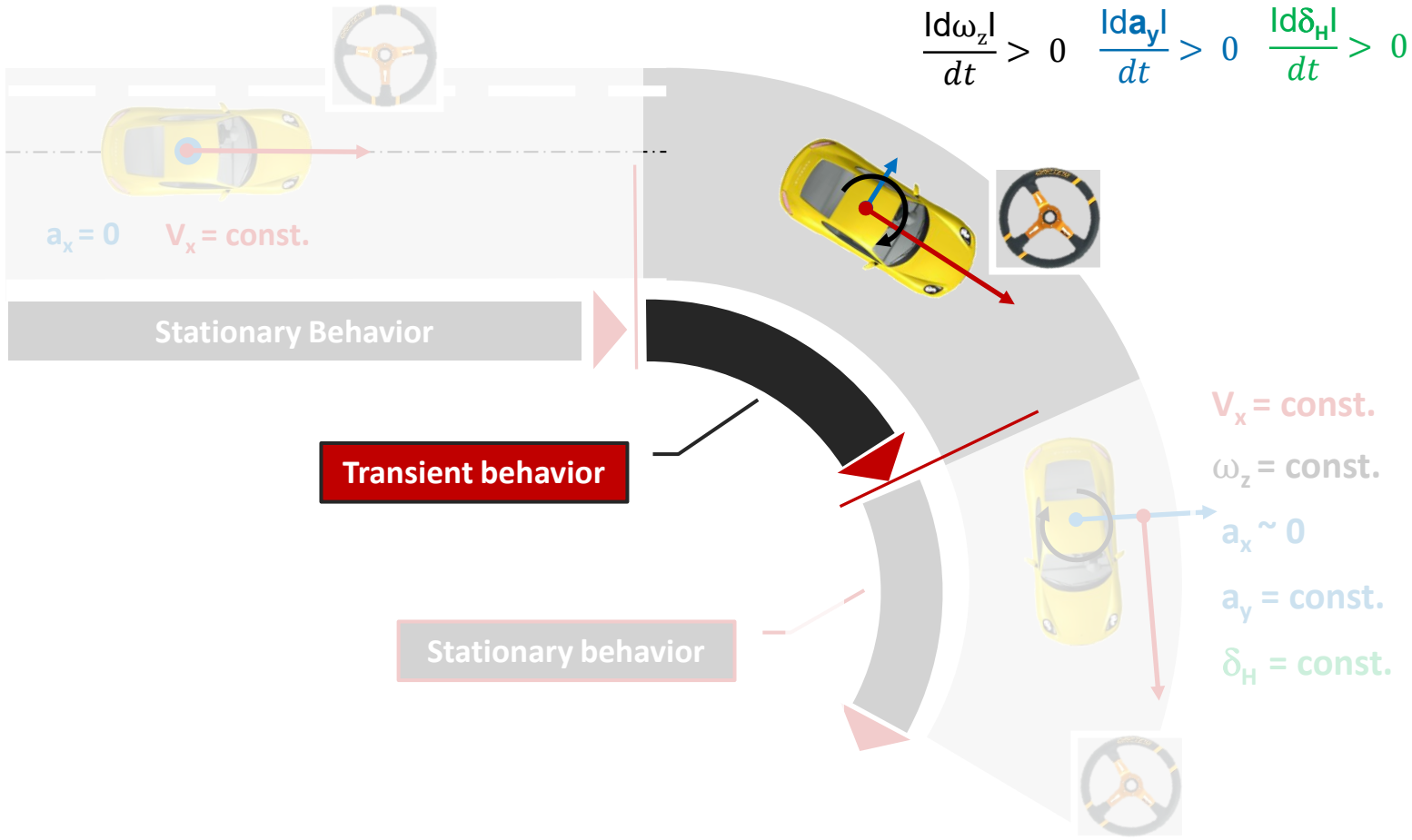
Chassis components and functions – axle & suspension

The **vehicle motion dynamics** is a result of **external forces & moments** and leads to **internal forces & moments!**

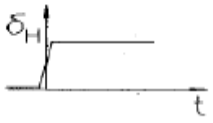
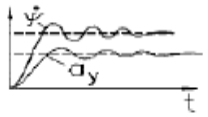
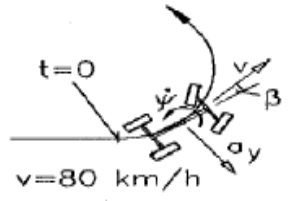
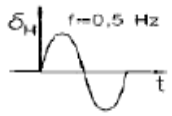
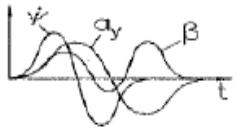
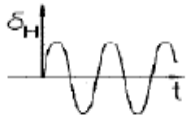
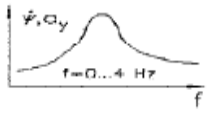




Lateral Dynamics: Stationary and transient behavior

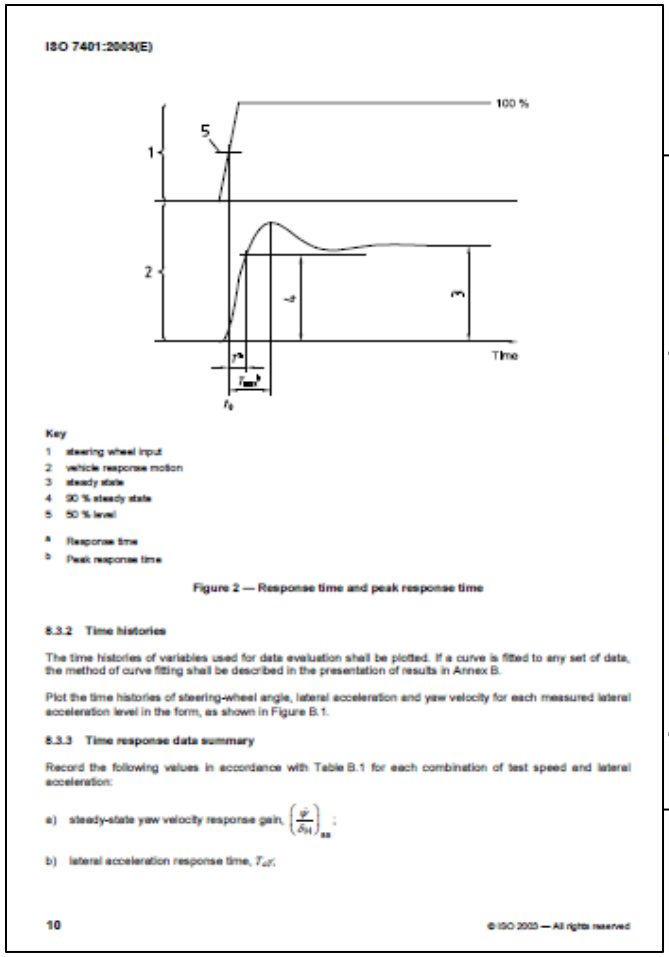


Lateral response tests to evaluate transient behavior

Lenkwinkel-sprung DIN ISO 7401	Sprungfunktion des Lenkrad-winkels: 	Querbeschleunigung a_y, Gierwinkelgeschwindigkeit $\dot{\psi}$: 	
Lenk-Einzel-Sinus DIN ISO 7401	Lenkradwinkel-Vorgabe: 	(Bestimmung von Zeitverzügen) 	
Lenk-Sinus DIN ISO 7401	Lenkradwinkel-Vorgabe: 	(Auswertung im Frequenzbereich) 	

Time Domain:
- Step Steer
- Sinus Steer (one cycle)

Frequency Domain:
- Step Steer
- Stochastic Steer Input
- Triangle Impulse
- Sine Steer (continuous cycles, sweep)



ISO 7401:2003(E)

Key
1 steering wheel input
2 vehicle response motion
3 steady state
4 90 % steady state
5 50 % level
a Response time
b Peak response time

Figure 2 — Response time and peak response time

8.3.2 Time histories

The time histories of variables used for data evaluation shall be plotted. If a curve is fitted to any set of data, the method of curve fitting shall be described in the presentation of results in Annex B.

Plot the time histories of steering-wheel angle, lateral acceleration and yaw velocity for each measured lateral acceleration level in the form, as shown in Figure B.1.

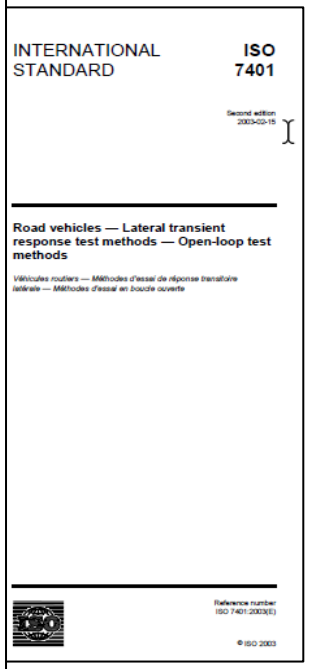
8.3.3 Time response data summary

Record the following values in accordance with Table B.1 for each combination of test speed and lateral acceleration:

a) steady-state yaw velocity response gain, $\left(\frac{\dot{\psi}}{\delta_H}\right)_{ss}$;

b) lateral acceleration response time, T_{ay};

10



INTERNATIONAL STANDARD **ISO 7401**

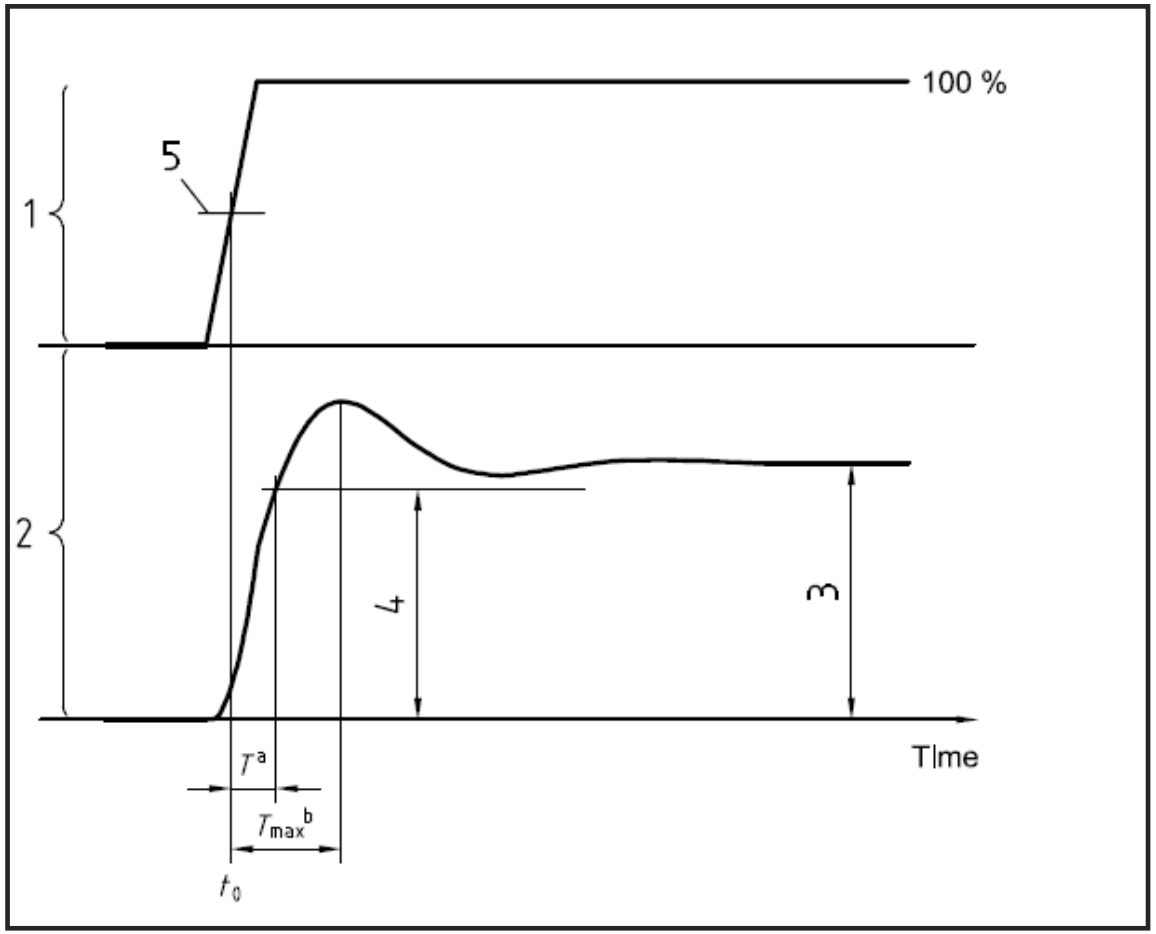
Second edition 2003-02-15

Road vehicles — Lateral transient response test methods — Open-loop test methods

Véhicules routiers — Méthodes d'essai de réponse transitoire latérale — Méthodes d'essai en boucle ouverte

Reference number ISO 7401:2003(E)

Lateral response tests to evaluate transient behavior



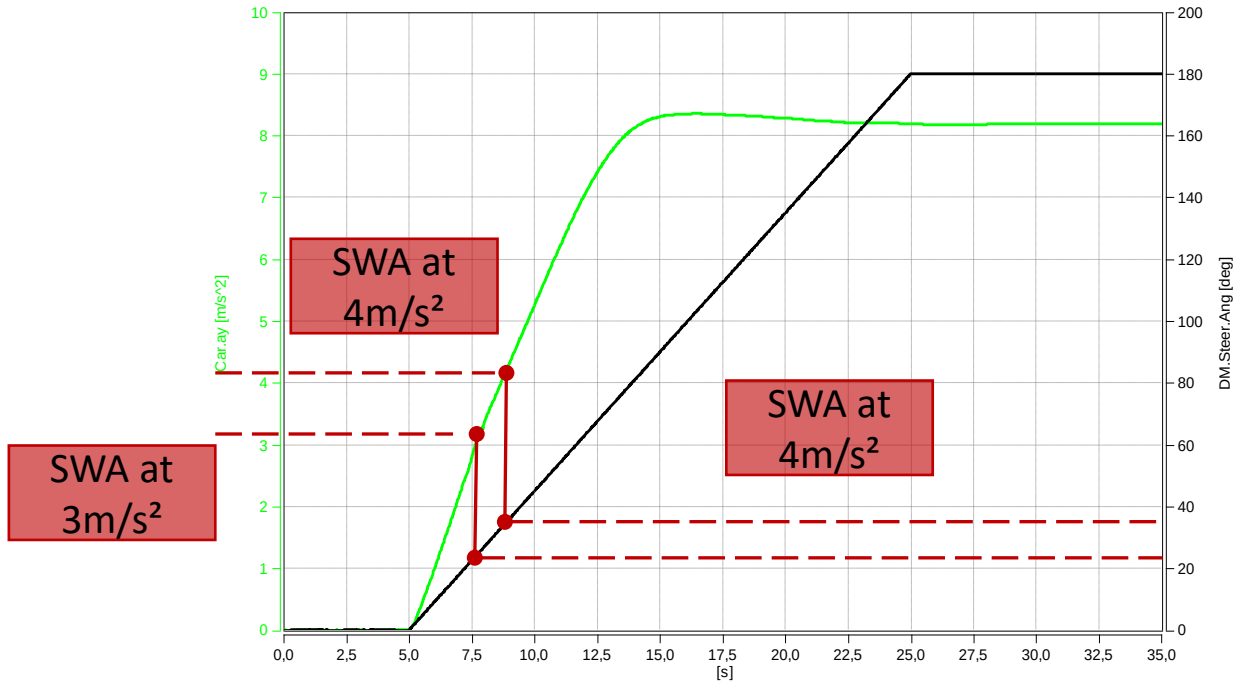
Parameter	Symbol	Unit	Left turn	Right turn	Average
Steady-state yaw velocity response gain	$\left(\frac{\dot{\psi}}{\delta_H}\right)_{ss}$	s^{-1}			
Lateral acceleration response time	T_{aY}	s			
Yaw velocity response time	$T_{\dot{\psi}}$	s			
Lateral acceleration peak response time	$T_{aY,max}$	s			
Yaw velocity peak response time	$T_{\dot{\psi},max}$	s			
Overshoot value of lateral acceleration	U_{aY}	—			
Overshoot value of yaw velocity	$U_{\dot{\psi}}$	—			

Key

1. steering wheel input
2. vehicle response motion
3. steady state
4. 90 % steady state
5. 50 % level

A. Response time
B. Peak response time

Slowly increase steer test (SIS) an option for steady state circular driving and identify maneuver parameter

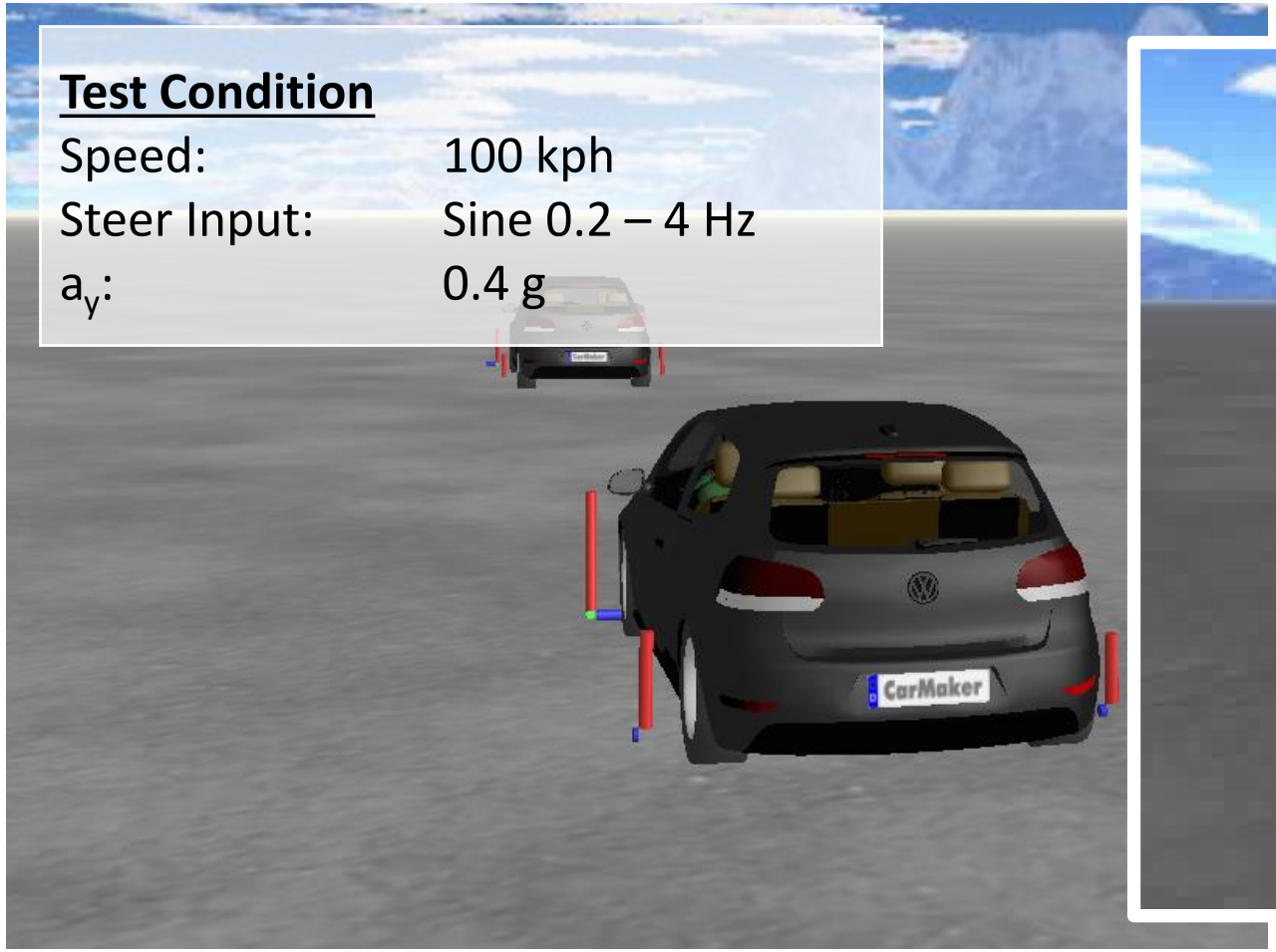


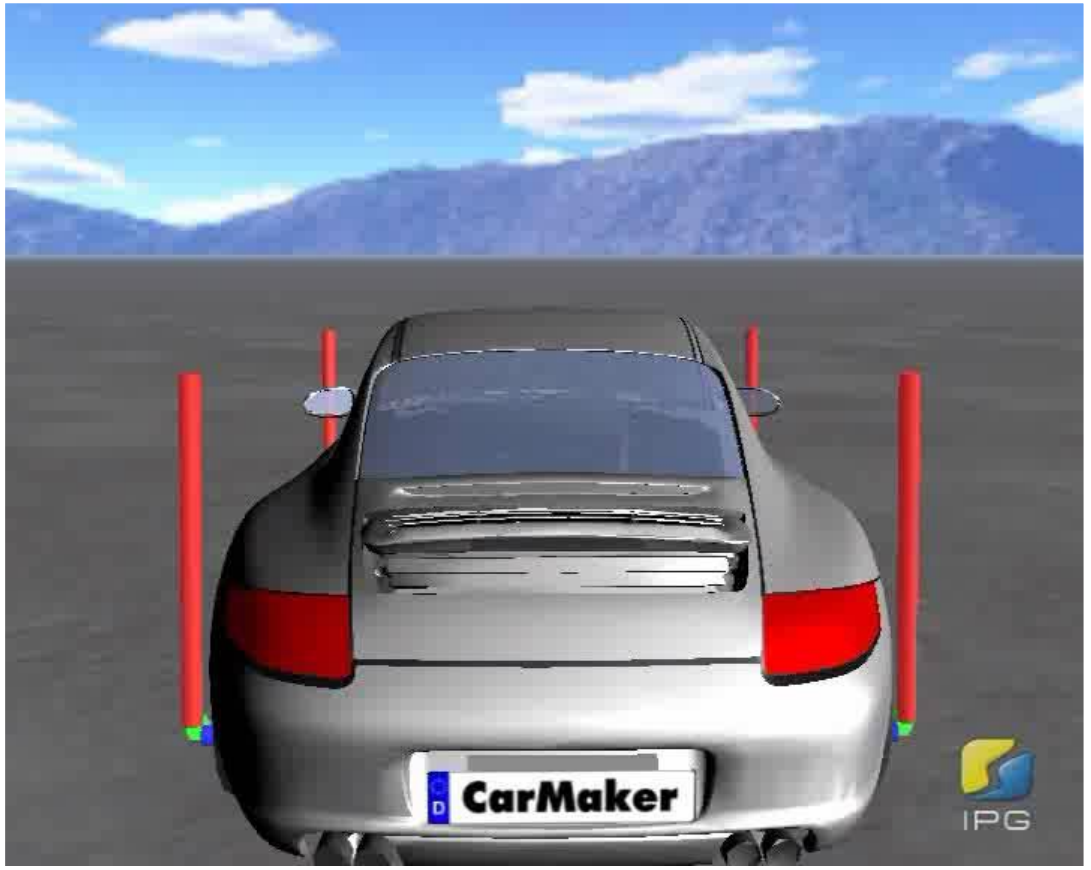
V= 80/100 kph constant SWA Gradient < 13,5°/s

SWA at 4m/s² used for steering angle identification

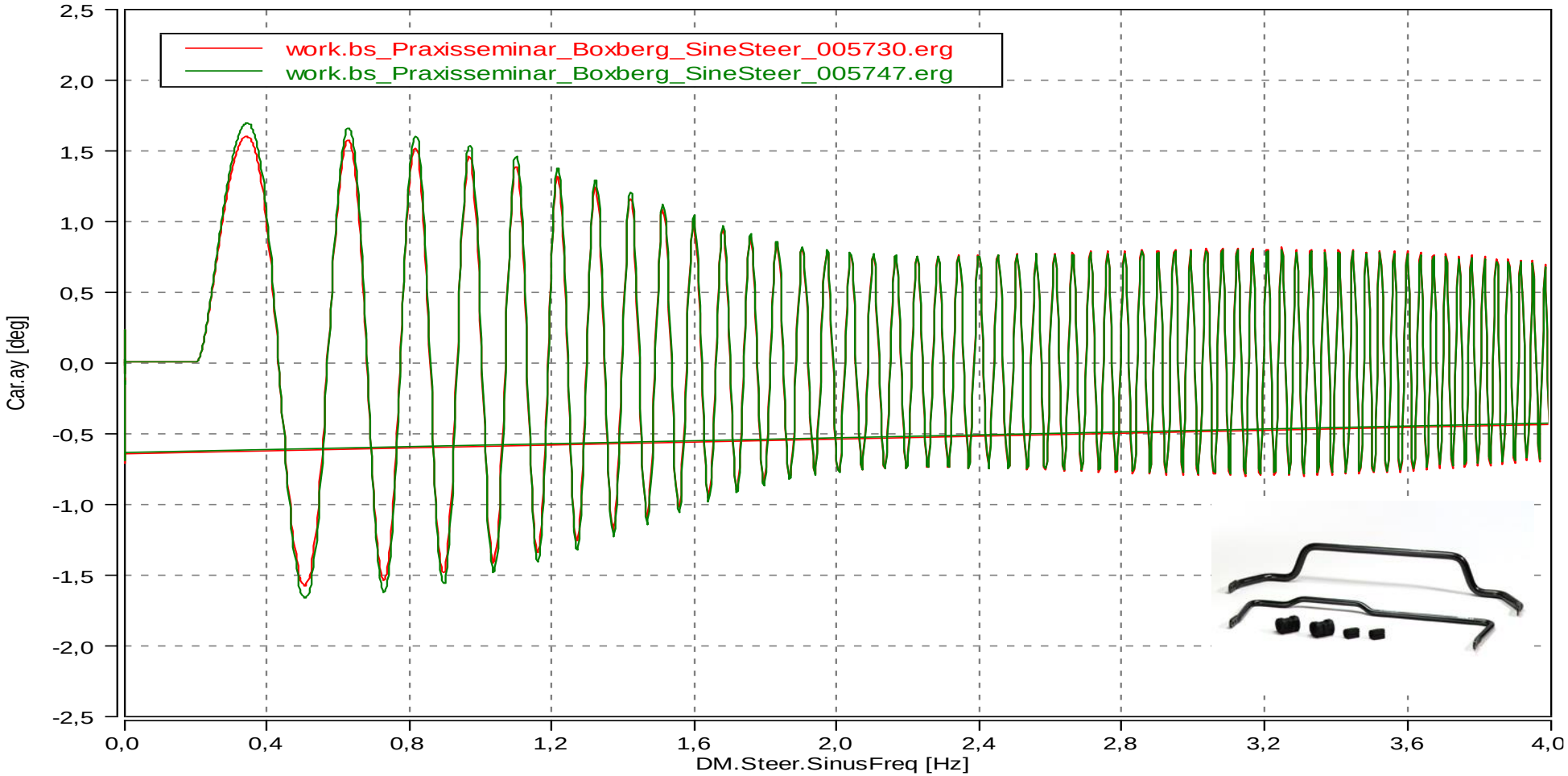
- Step steer (4m/s²)
- Sine steer (4m/s²)
- Sine with Dwell (3m/s²)
- …

Lateral response tests to evaluate transient behavior



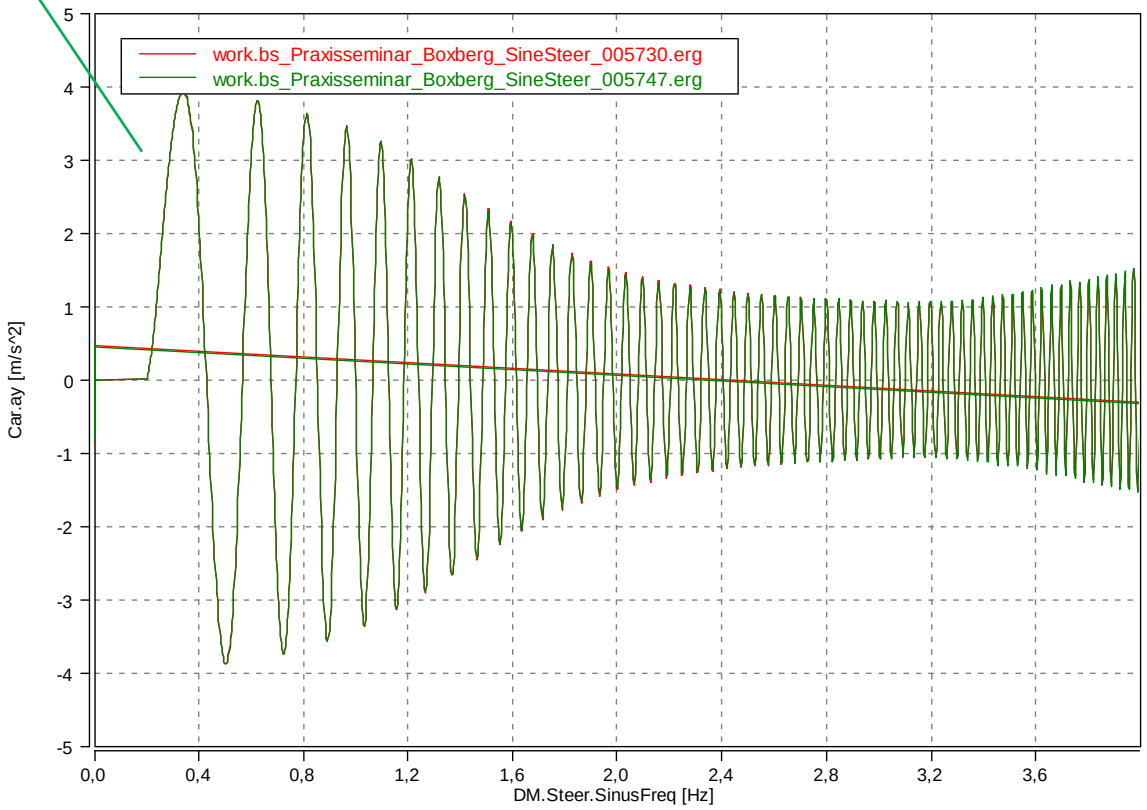


Lateral response tests to evaluate transient behavior

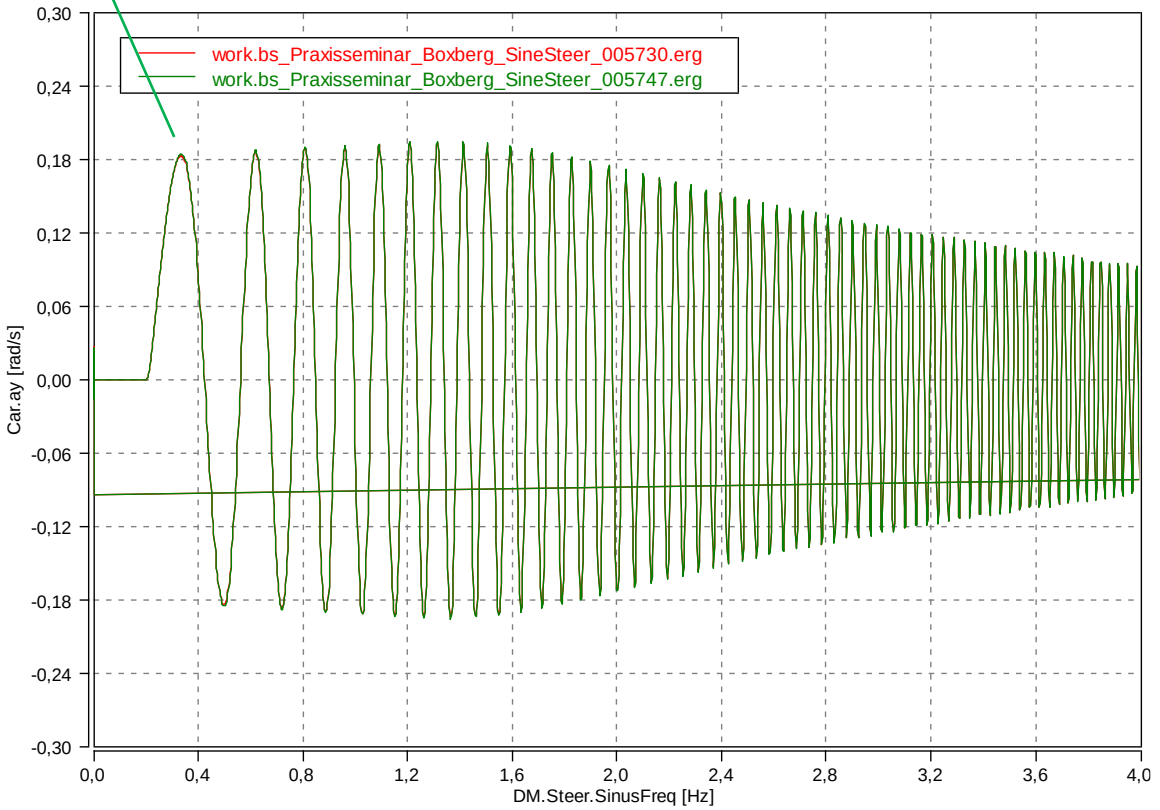


Lateral response tests to evaluate transient behavior

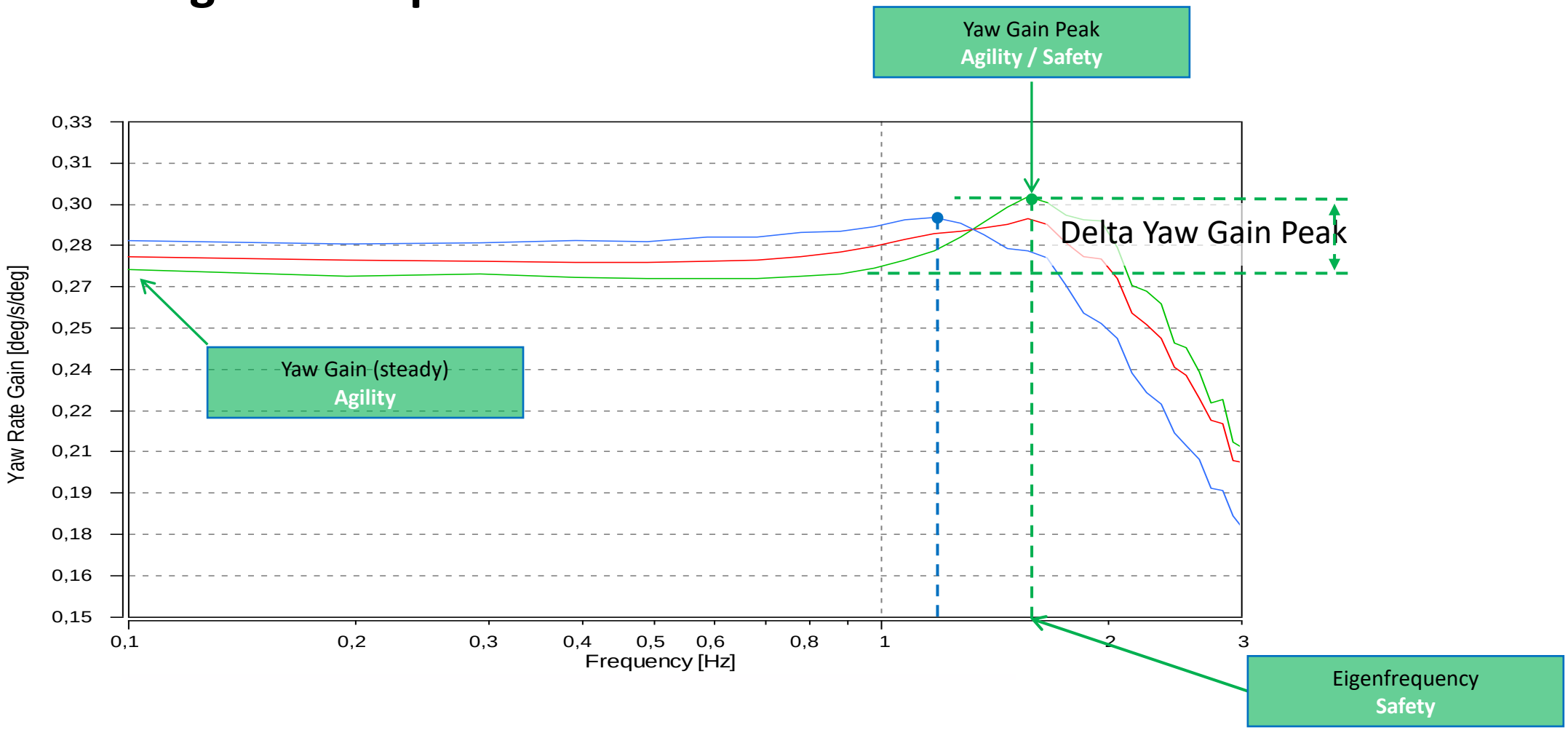
Lateral Acceleration Gain



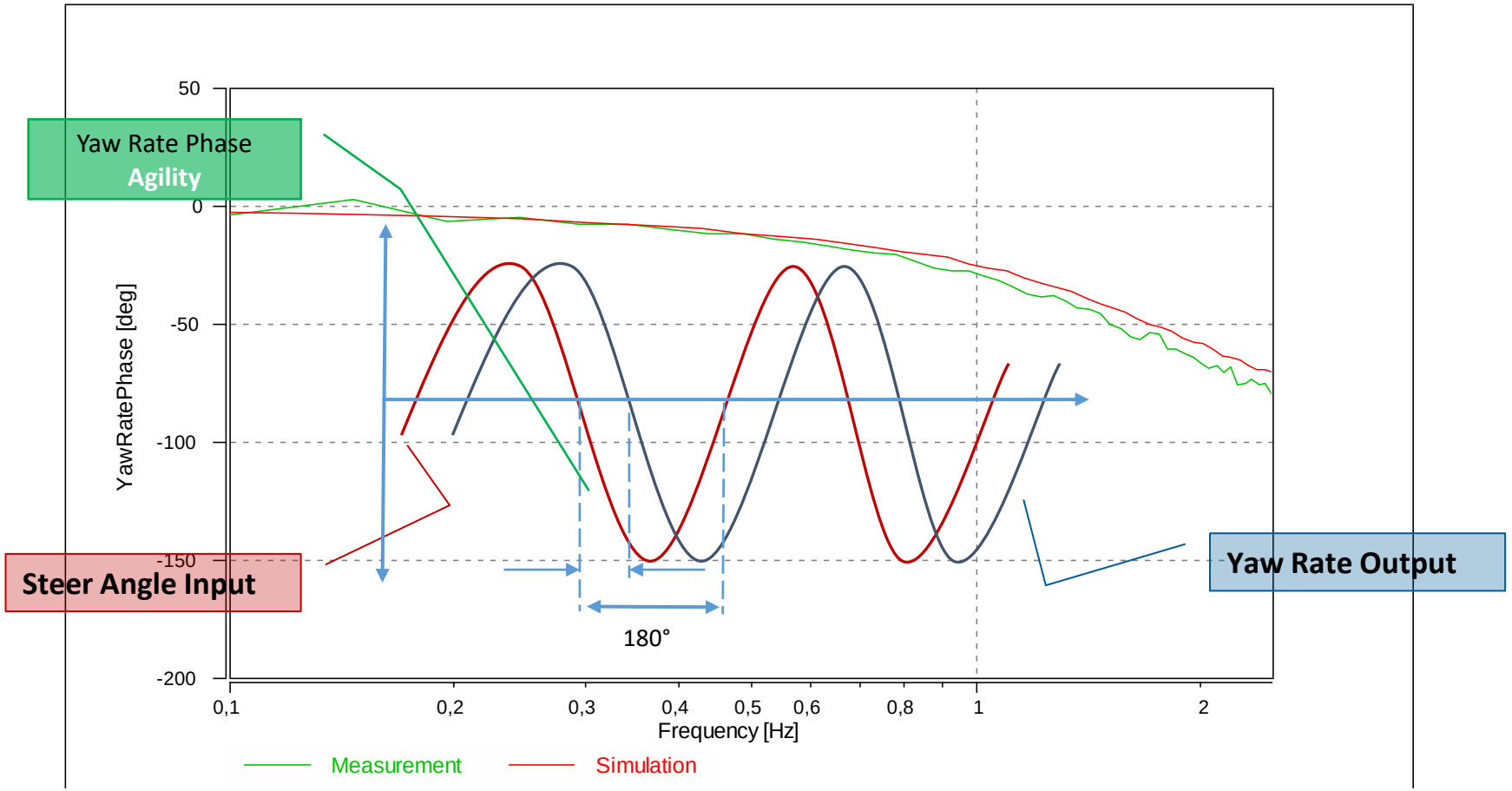
Yaw Gain



Bode Diagram: Amplitude Gain



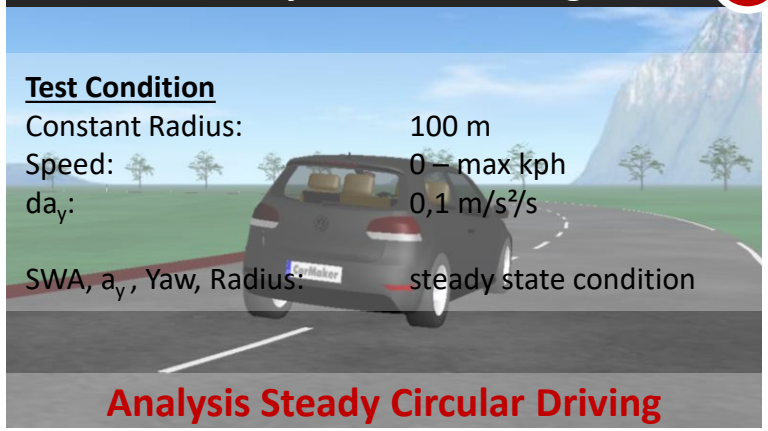
Bode Diagram: Yaw Rate Phase



Parameter Study for K&C, spring, damper, roll bar

Steady Circular Driving

1

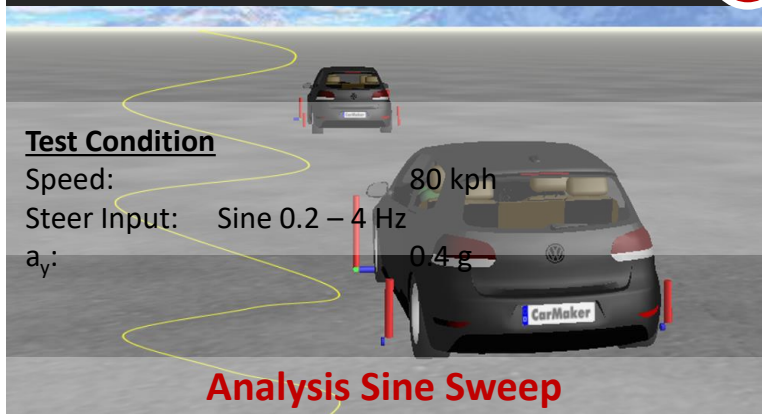


Find the sensitivity of parameters such as

- Roll bar stiffness
- Spring, buffer
- Toe change front / rear (K&C)
- Camber change front / rear (K&C)
- …

Sine Sweep

2

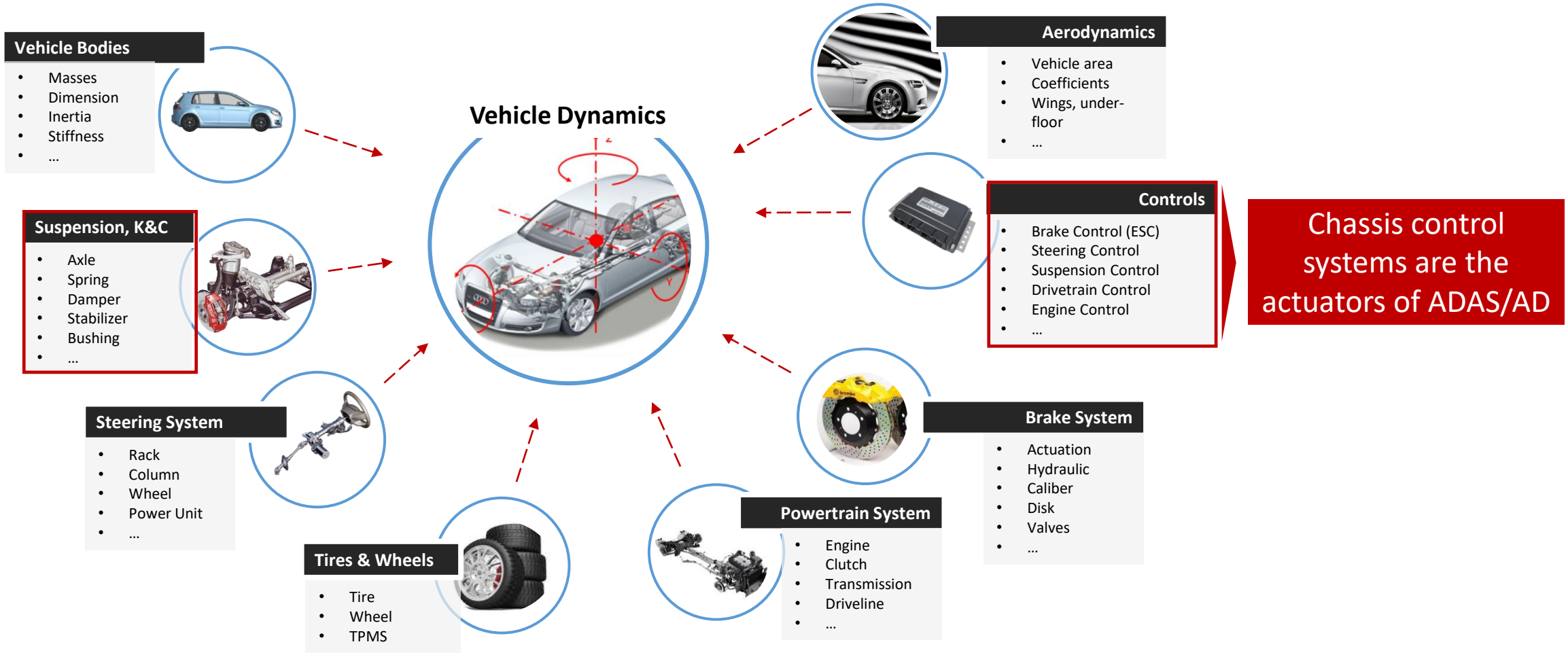


Find the sensitivity of parameters such as

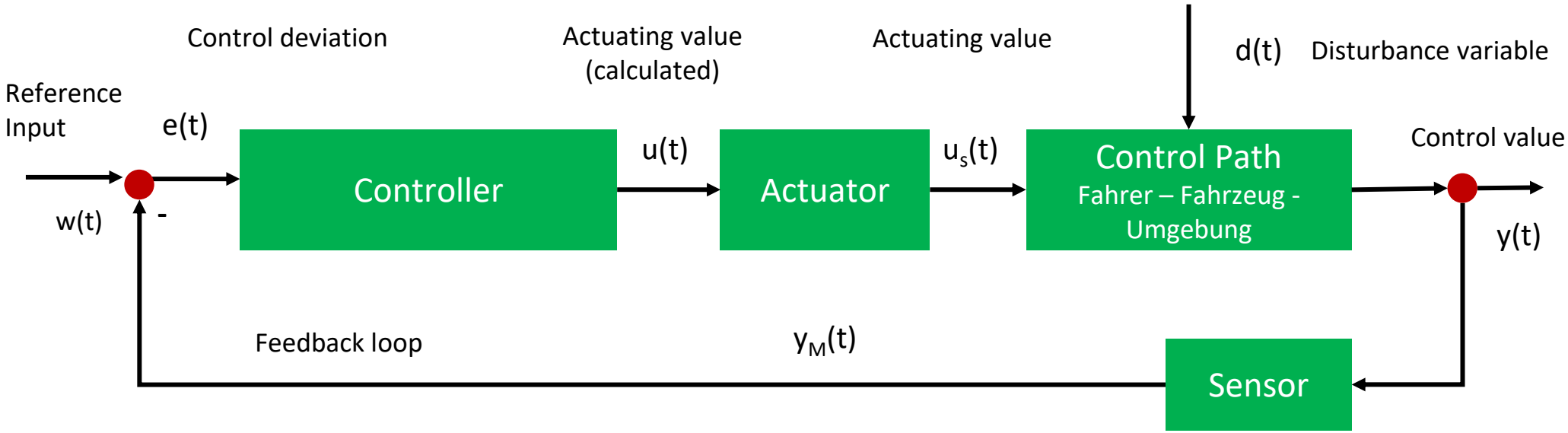
- Mass/Mass distribution / inertia
- Roll bar stiffness
- Damper
- Tire side slip stiffness
- …

Chassis controls and functions (1)

Vehicle dynamics behavior is impact by numerous components



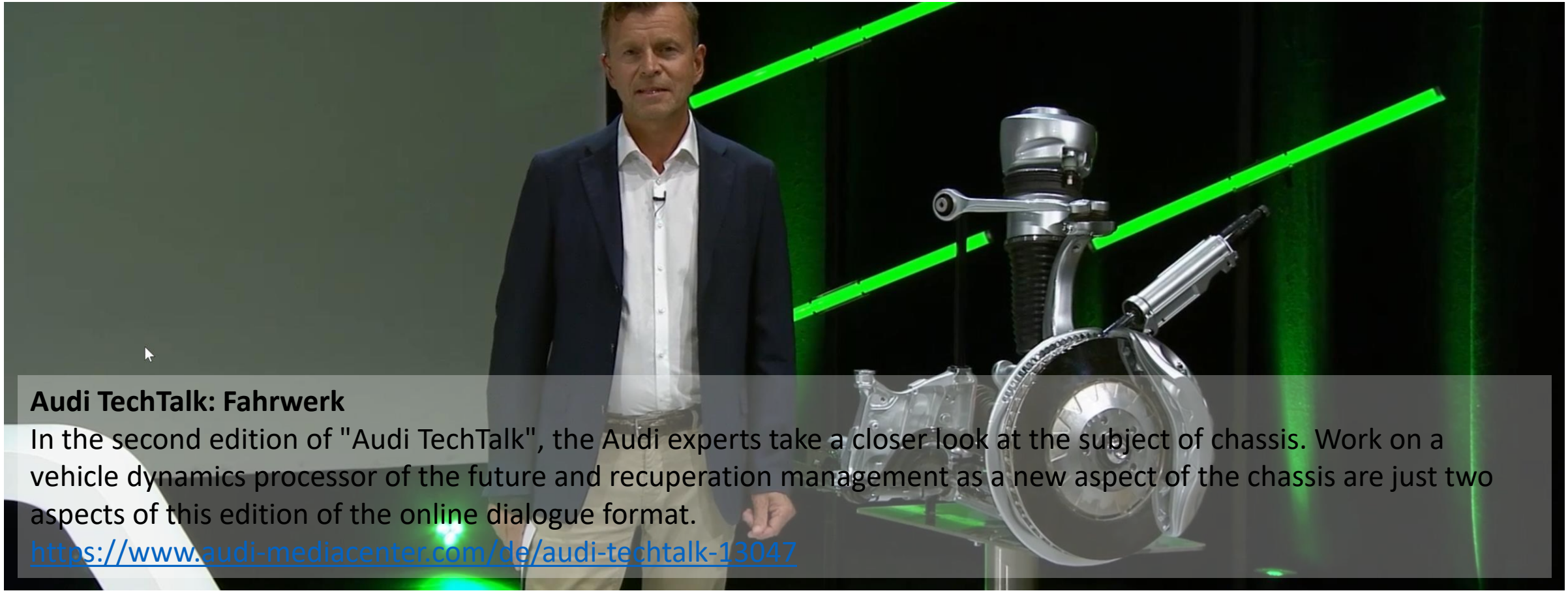
Chassis control principle and systems



- Antilocking System (ABS) → longitudinal control
- Traction Control (ASR) → longitudinal control
- Electronic Stability Program (ESP) → lateral control
- Steering Control (EPS) → lateral control
- Roll Bar Control (ARS) → Vertical / lateral control

- Air Suspension Control (→ Vertical control
- Continuous Damper Control (CDC) → Vertical control
- Electronic Differential (EDC) → Long/ lat control
- Torque Vectoring Control (TVC) → Long/ lat control

Audi Talk – Chassis technologie from rigid axle to intelligent chassis



Audi TechTalk: Fahrwerk
In the second edition of "Audi TechTalk", the Audi experts take a closer look at the subject of chassis. Work on a vehicle dynamics processor of the future and recuperation management as a new aspect of the chassis are just two aspects of this edition of the online dialogue format.
https://www.audi-mediacenter.com/de/audi-techtalk-13047

Hydraulik Brake system and brake control systems

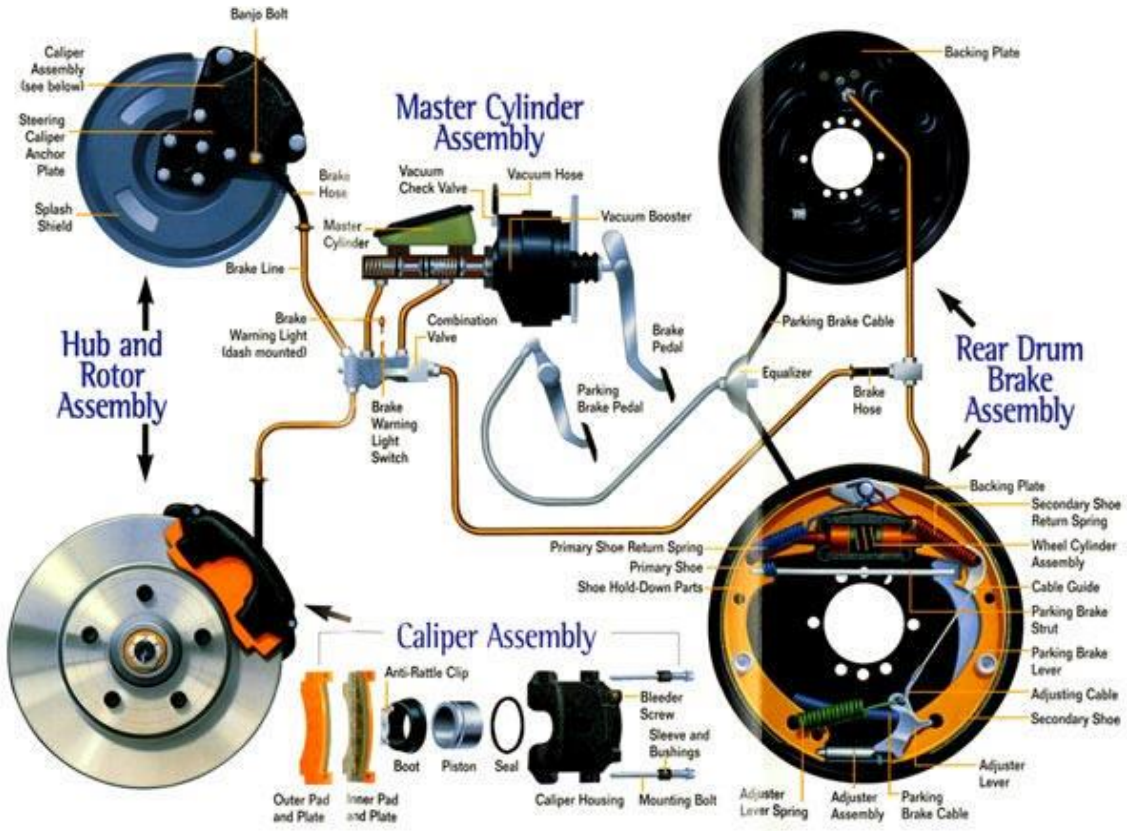
Classification of braking systems

- **Service brake system (BBA - Betriebsbremsanlage)**
  The service brake system must be operated in steps can and usually consists of two brake circuits.

- **Auxiliary braking system (HBA-Hilfsbremsanlage)**
  The deceleration achievable with the secondary braking system must be at least half the size of the BBA.

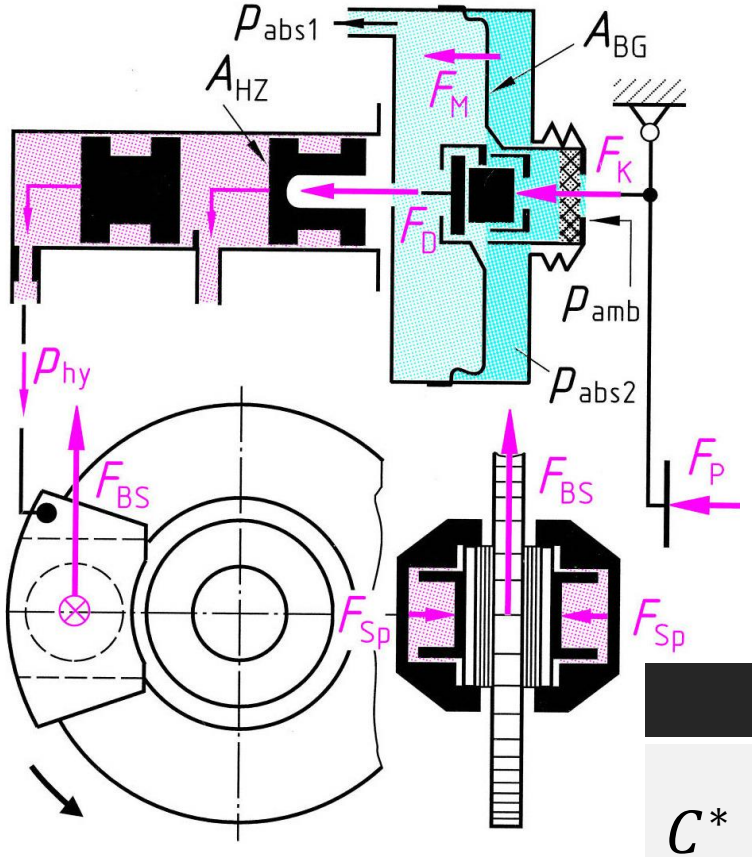
- **Parking brake system (FBA-Feststellbremsanlage)**
  The parking brake system must be able tocan maintain a slope of 20%.

- **Continuous braking system (DBA -Dauerbremsanlage)**
  Continuous braking systems are wear-free brakes for longer steady-state braking of commercial vehicles and buses.



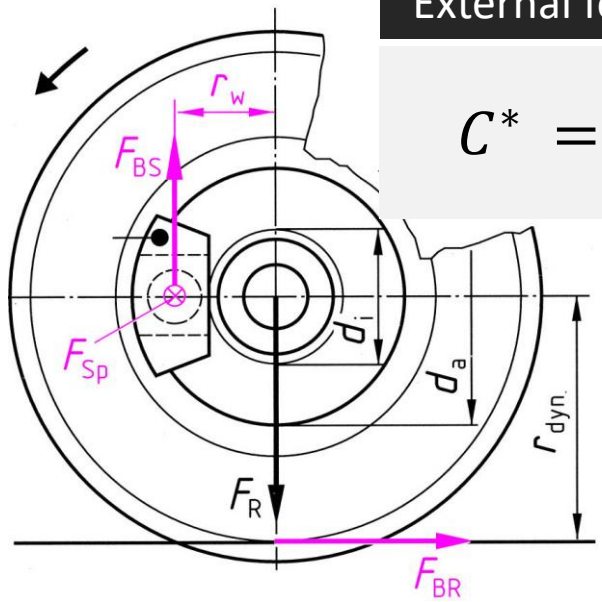
https://www.youtube.com/watch?v=ugtrRmyPSfE

External and internal force ratio of a brake system



External force ratio

$$i_{ext} = \frac{F_{SP}}{F_P}$$



External force ratio

$$C^* = \frac{F_{BS}}{F_{SP}}$$

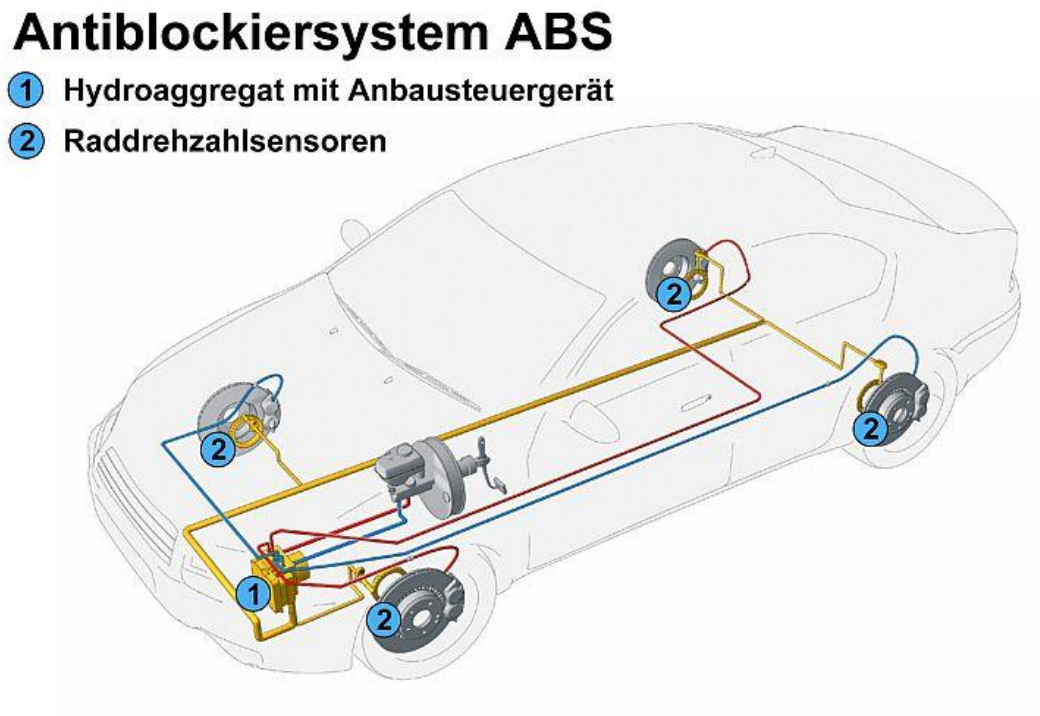
Brake disk characteristics

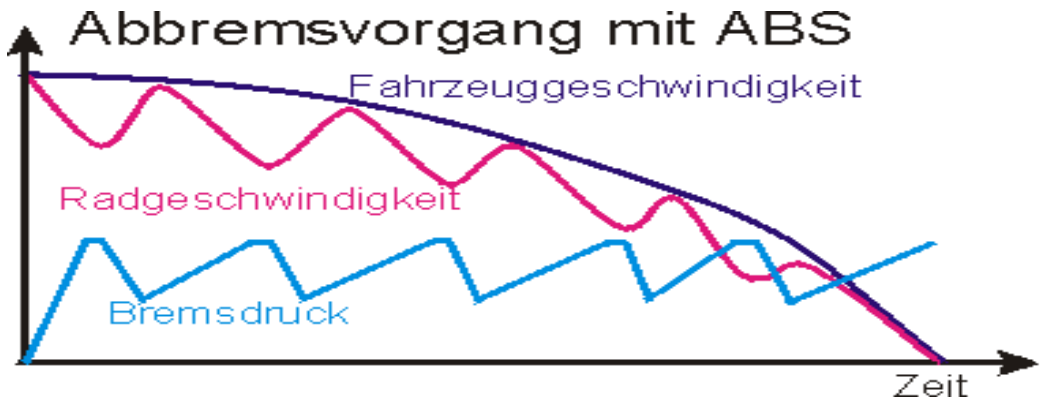
$$C^* = \frac{F_{BS}}{F_{SP}} = \frac{2\mu * F_{SP}}{F_{SP}} = 2\mu$$

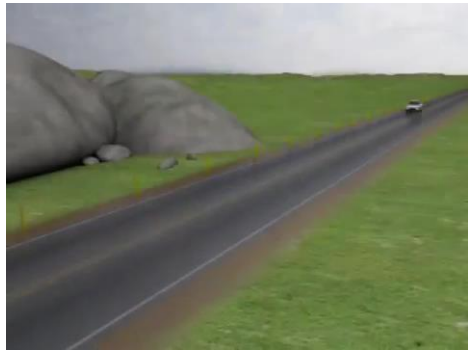
Wheel brake force

$$F_{BR} = F_P * i_{ext} * C^* \frac{r_w}{r_{dyn}}$$

ABS – Antiblockiersystem (Antilocking System)

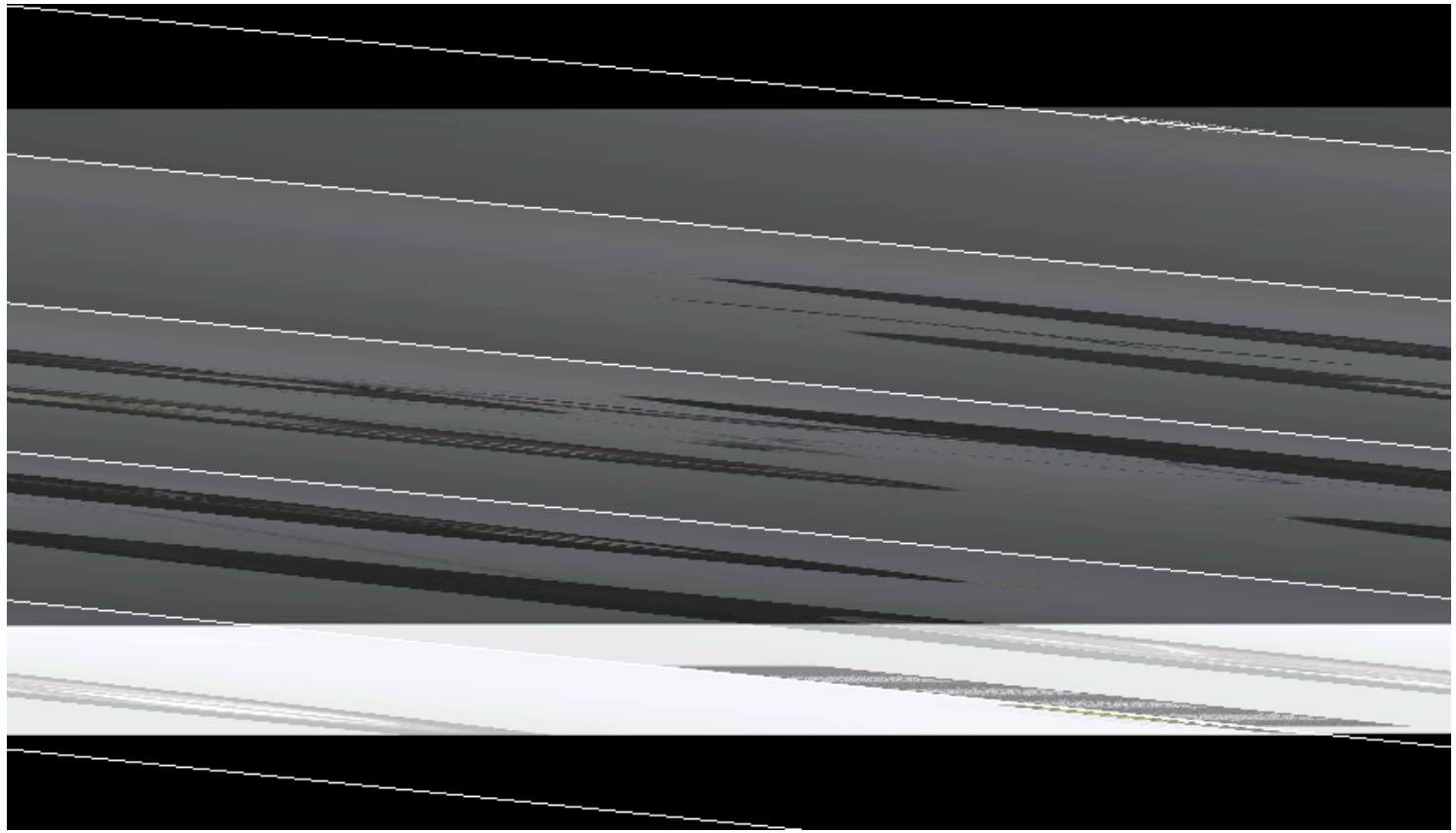






Chassis controls and functions (1)

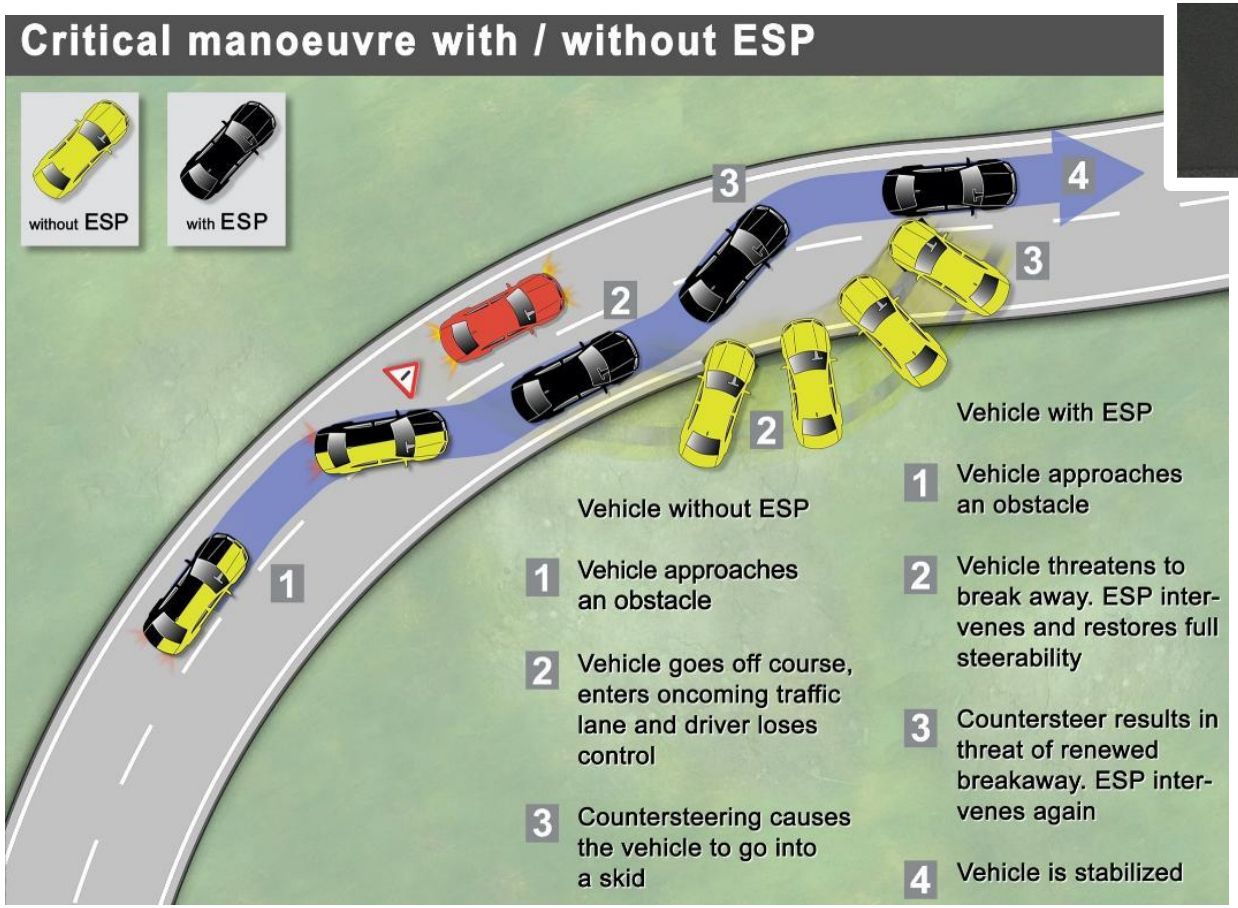
Hydraulik Brake system and brake control systems



https://www.youtube.com/watch?v=GHt0u_7abvs

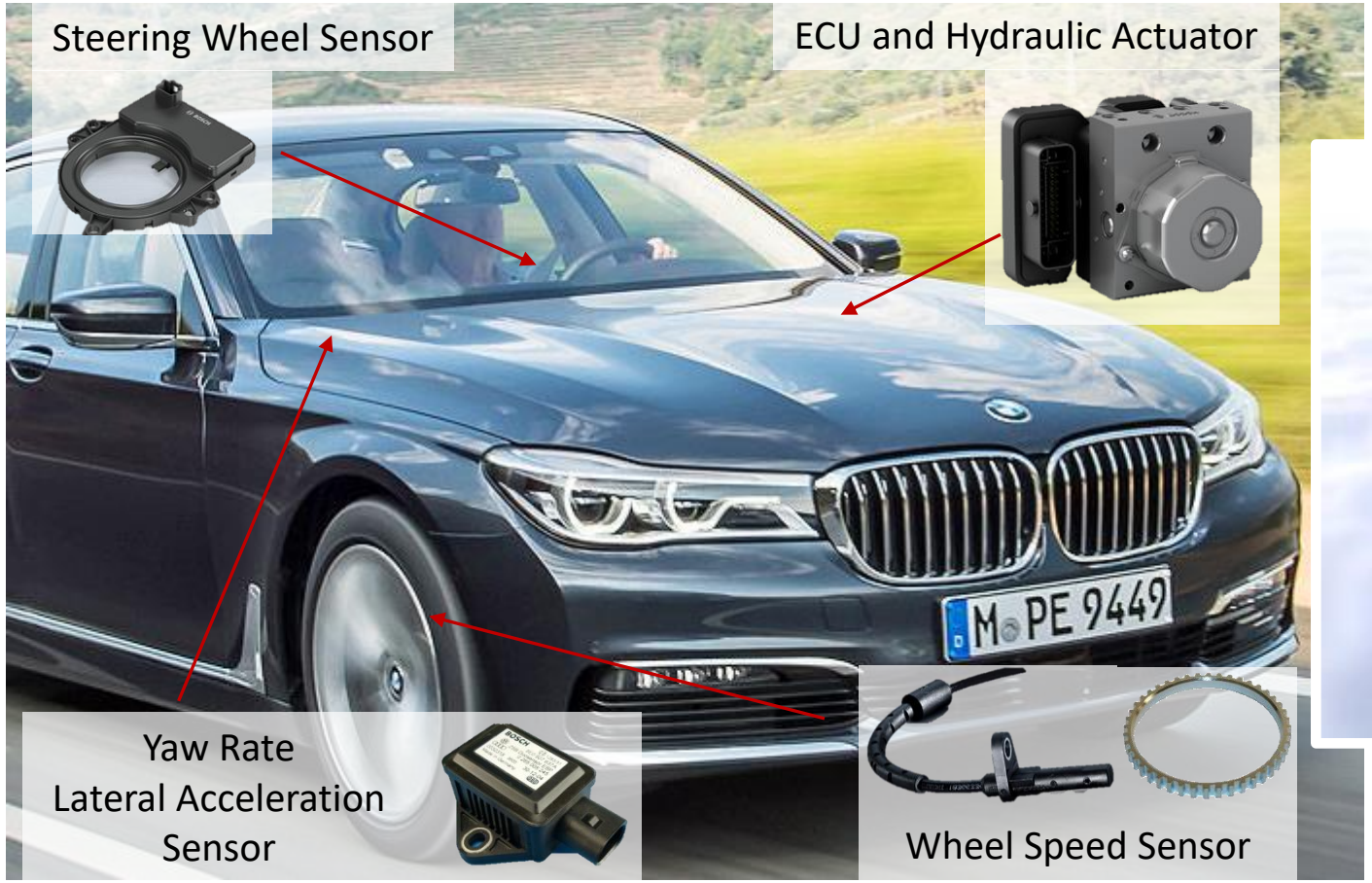
https://www.youtube.com/watch?v=CzEBVdZeyQs

Electronic Stability Program (ESP)



Chassis controls and functions (1)

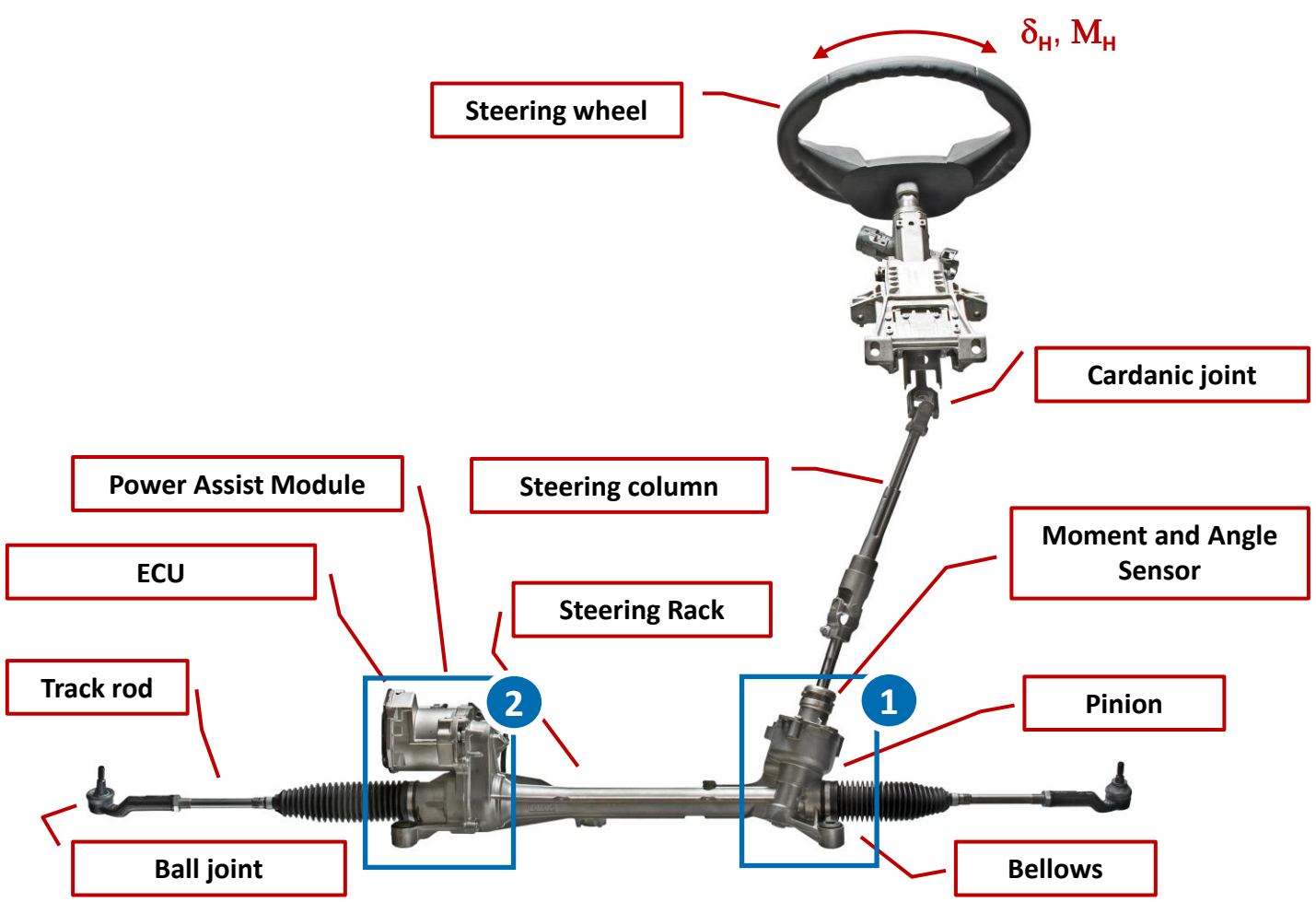
Electronic Stability Program (ESP)

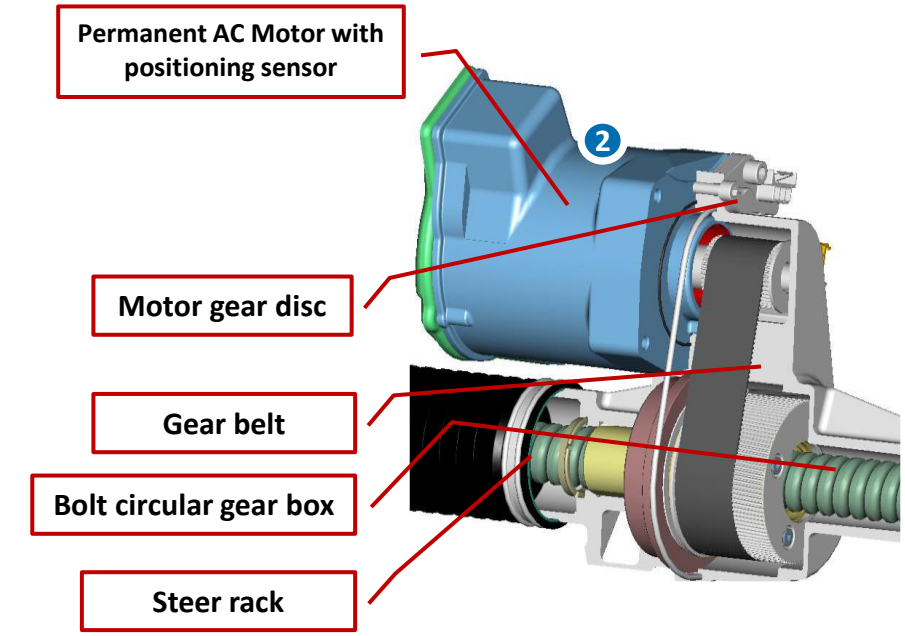


Sample “Added Value Functions”

Steering System

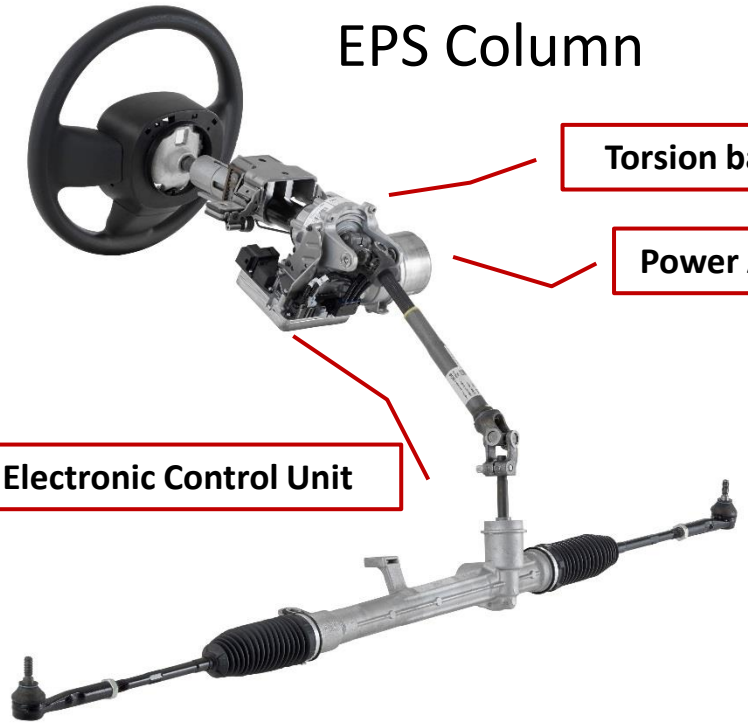
Steering system – Electrical Power Steer (EPS) EPS apa (axle parallel)



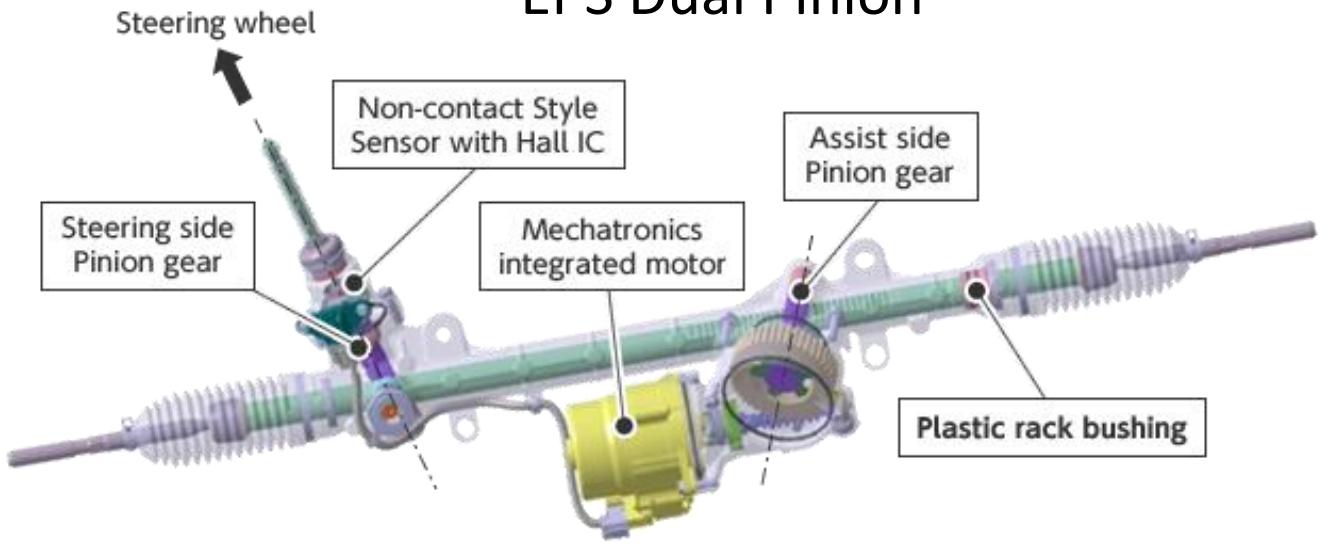


Steering system – Electrical Power Steer (EPS)

EPS Column



EPS Dual Pinion

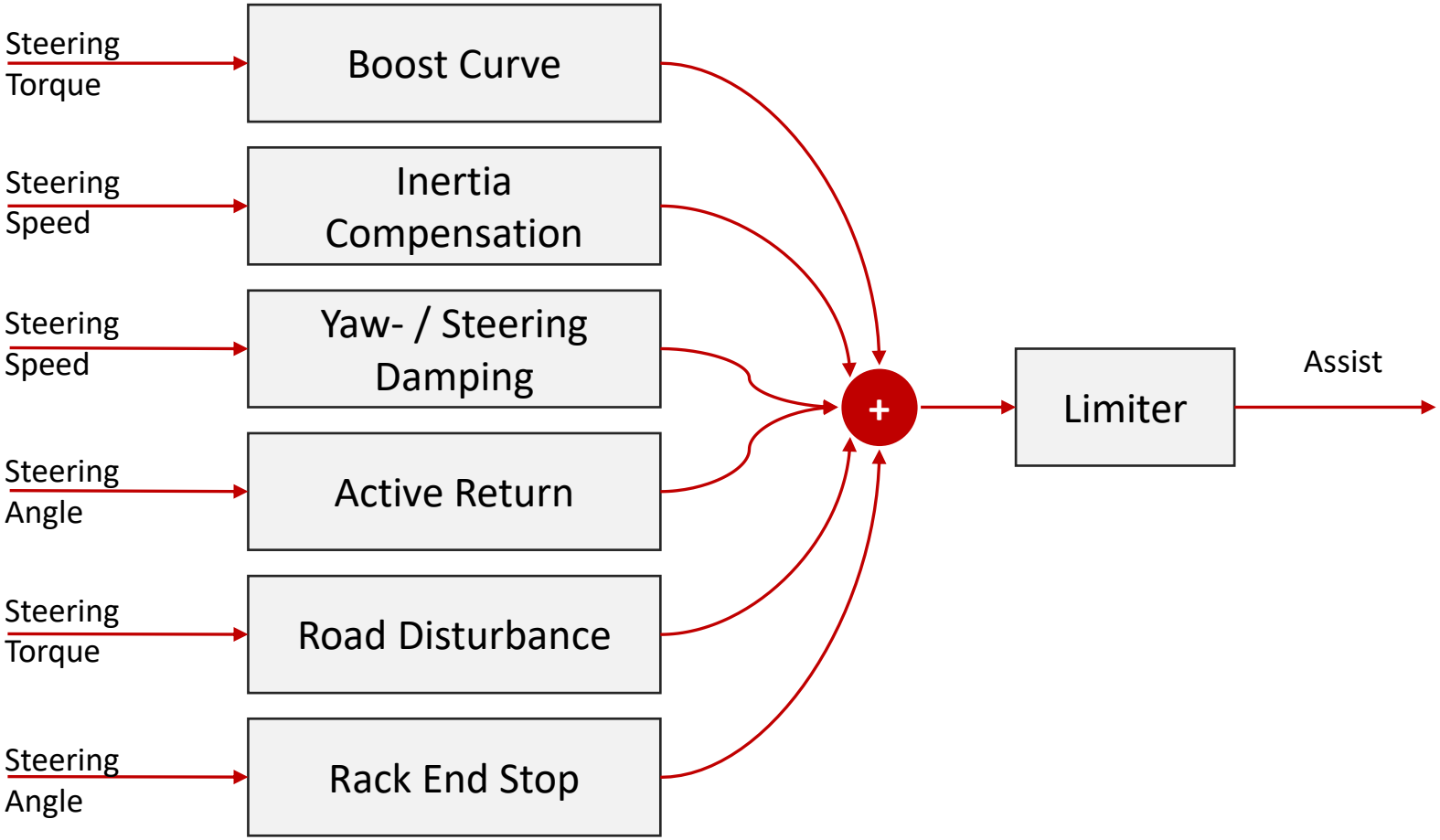


Chassis controls and functions (1)

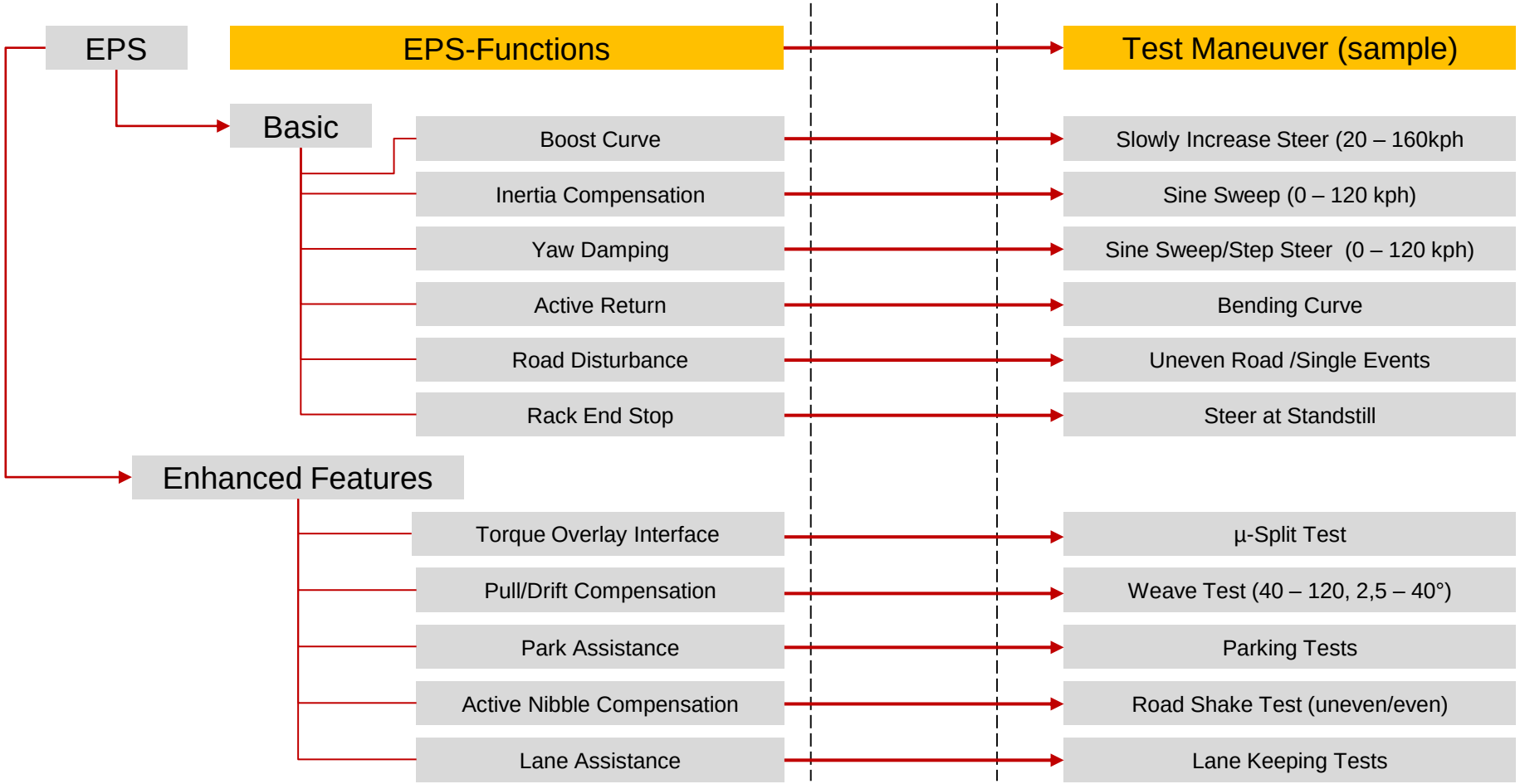
Rack an pinion steering system

https://www.youtube.com/watch?v=DC6Opx_3EUo

EPS Basic Functions



EPS functions and test maneuver for validation



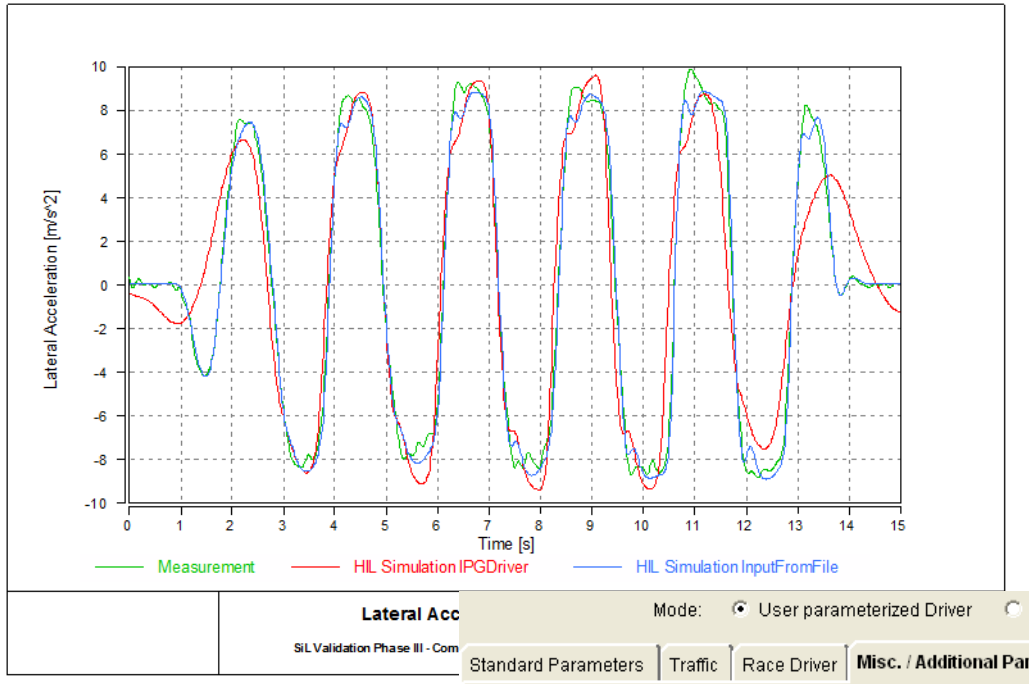
Chassis controls and functions (1)

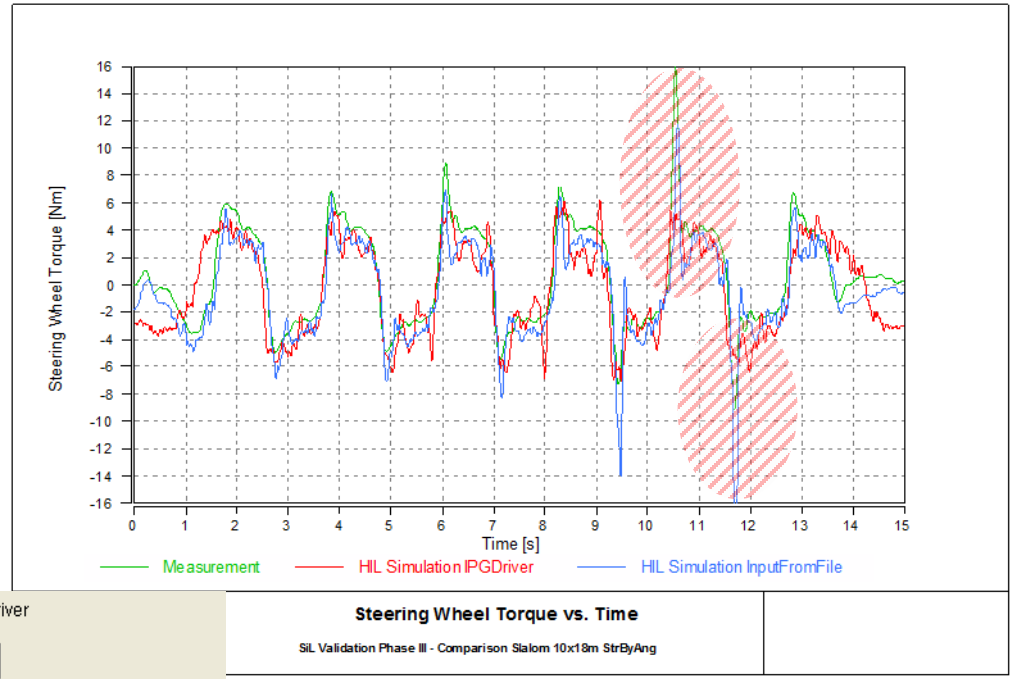
EPS functions and test maneuver for validation

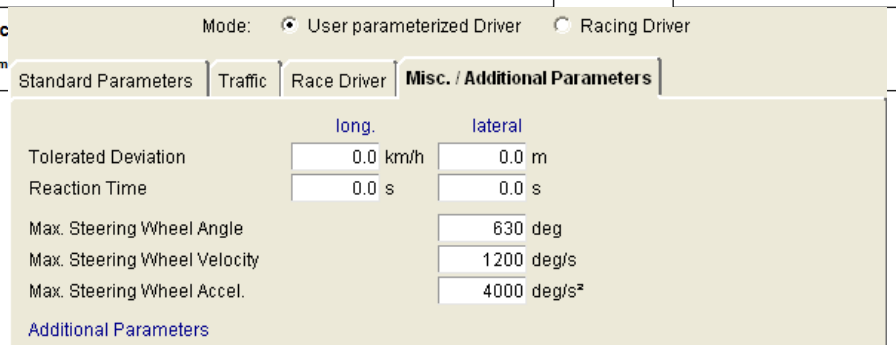
FailSafeTests	Function Tests	Performance Tests
▪ High/Low Voltage ▪ Controller stability in different situations ▪ Sensor signal cut / interrupt ▪ Sensor offset / drift error ▪ Sensor noise error ▪ Sensor signal jump ▪ Failure moment ▪ CAN failure ▪ Starting condition ▪ Short cycle ▪ Loose contact ▪ Diagnostic messages ▪ Interface and (lost) communication ▪ …	▪ end stop control ▪ high speed damp control ▪ motor save function ▪ on- center control ▪ active friction controller ▪ active return control ▪ active inertia comp. ▪ pull & drift control ▪ active road slope control ▪ side wind control ▪ road disturbance rejection ▪ active nibble compensation ▪ active steering support (e.g. µ split) ▪ park assist functions… ▪ ….	▪ Power tests of steering support ▪ Turn-in ability ▪ On-center handling ▪ Pull behavior ▪ Drift behavior ▪ Straight running precision ▪ Steering wheel return ability ▪ Torque cut off ▪ Parking comfort ▪ Slalom performance ▪ Lane change performance ▪ Nuerburgring test (Fuchsröhre) ▪ Catch-up behavior ▪ Starting behavior ▪ ….

Chassis controls and functions (1)

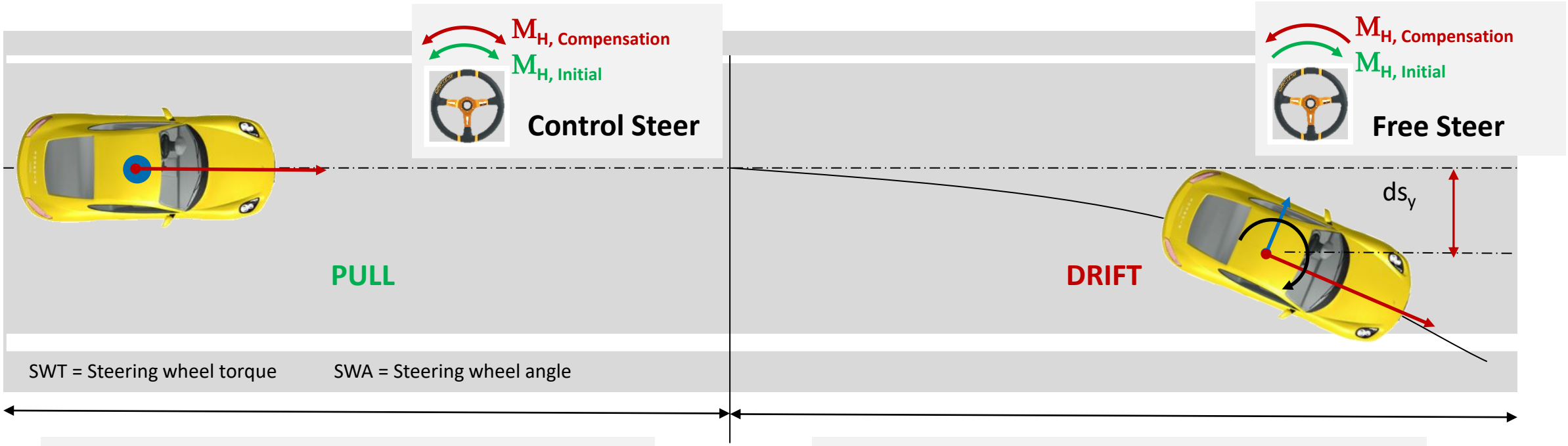
Sample Function and Test: Catch-up during virtual vehicle test → Slalom







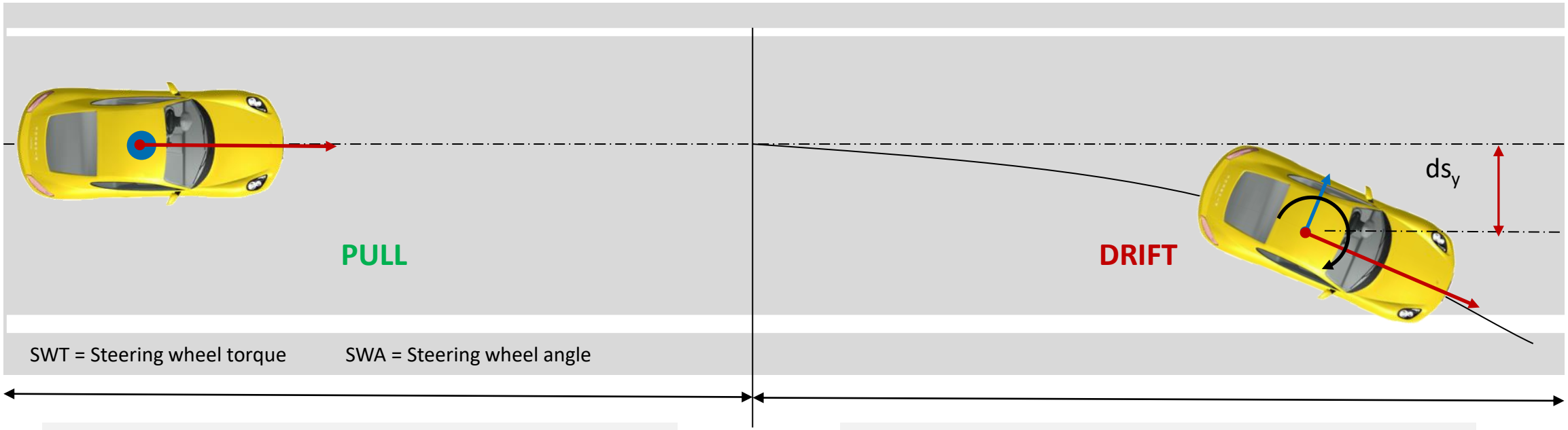
Sample Function and Test: Pull-Drift Compensation (PDC)



- The driver has to pull steering torque to drive straight ahead
- This steering torque is measured and automatically supported to reduce the drivers effort

- The vehicle is drift off the center line. The vehicle response with a yaw rate
- The yaw rate is measured and a steering angle support is applied to reduce the yaw rate to zero.

On-Center Steering Behavior



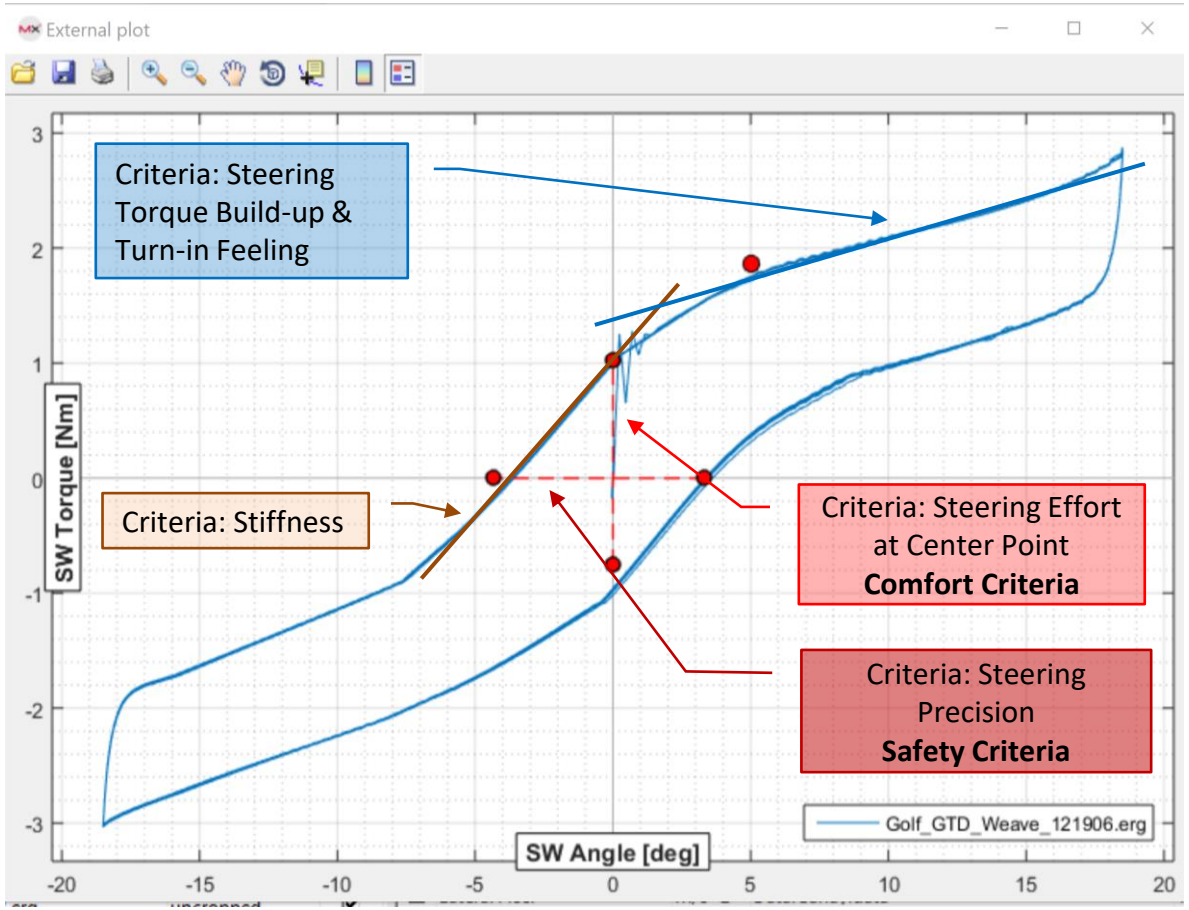
COMFORT

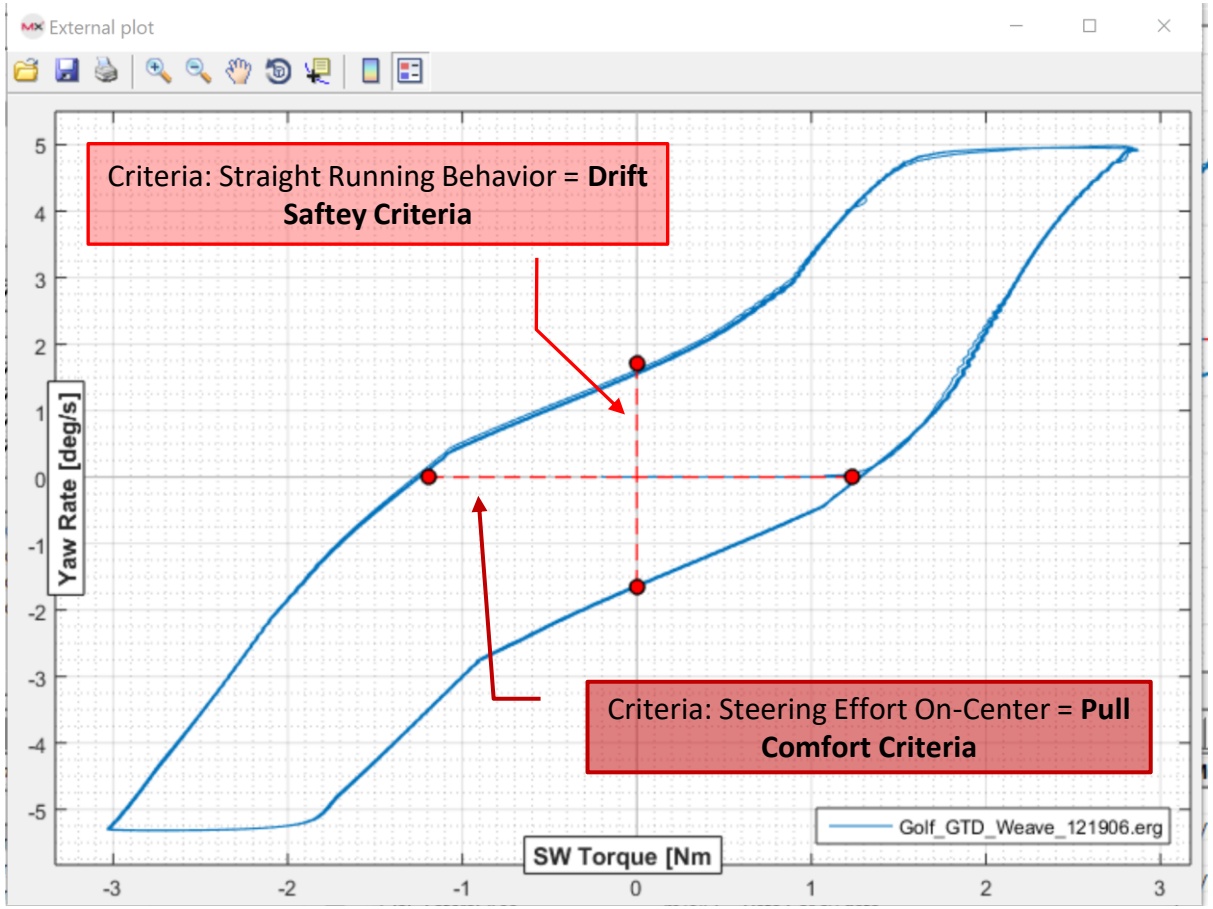
- **Subjective:** Steering Effort Center Point
- **Objective:** SWT / SWA Effort at YawRate = 0

SAFETY

- **Subjective:** Straight running behavior
- **Objective:** YawRate Response at SWT = 0

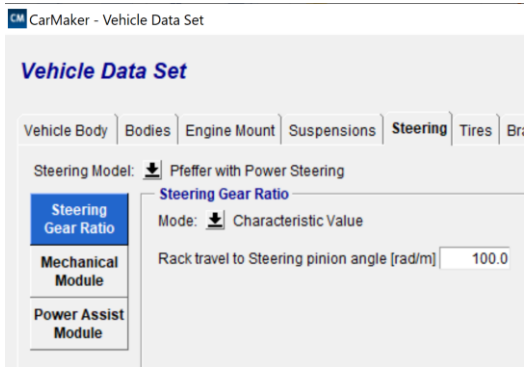
Steering On-Center Evaluation: On-Center Handling Test (ISO 13674)

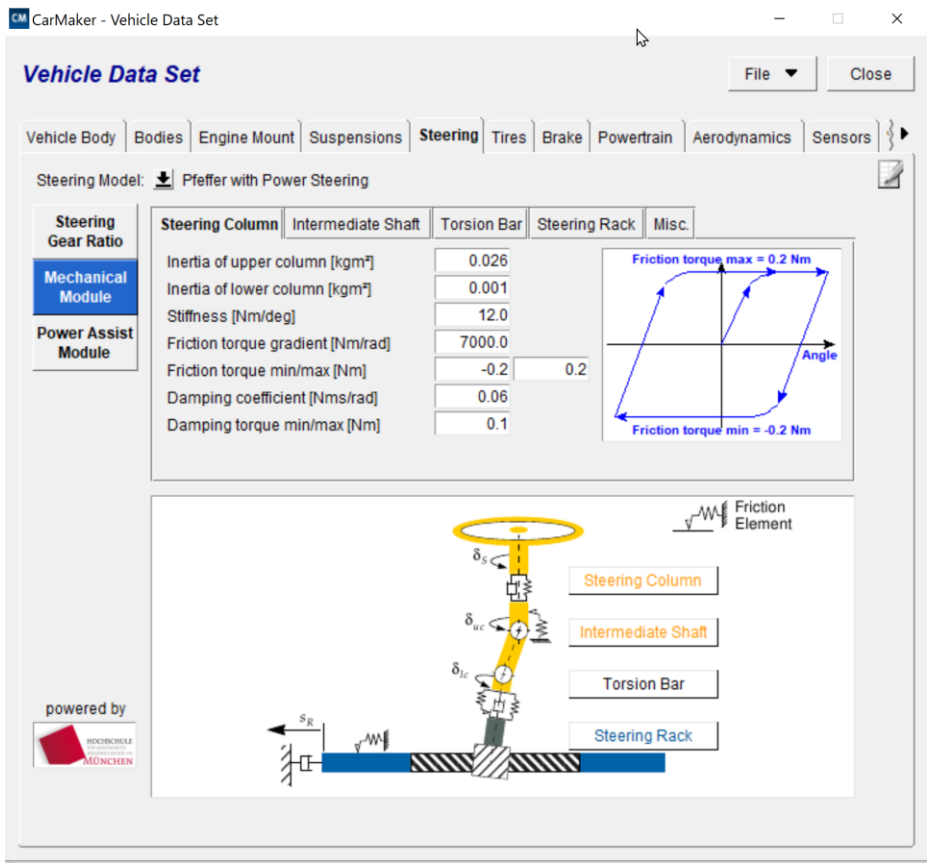


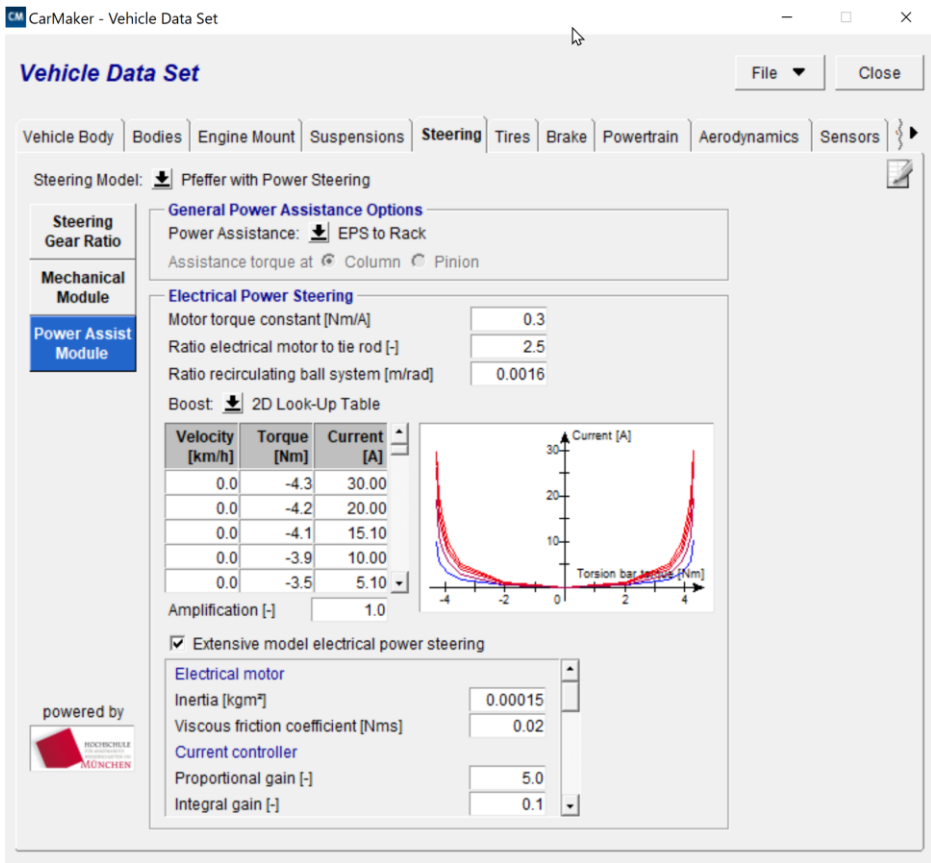


Chassis controls and functions (1)

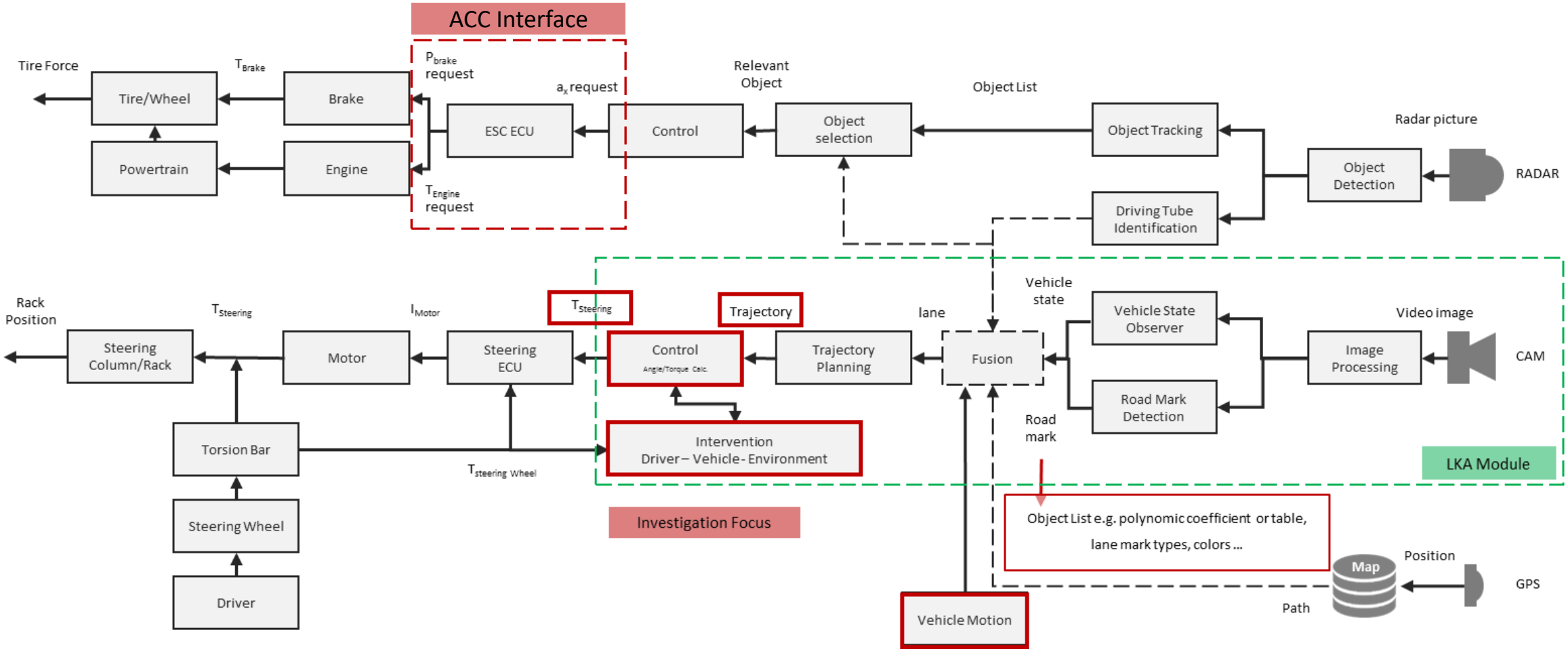
EPS Steering Model and related parameter



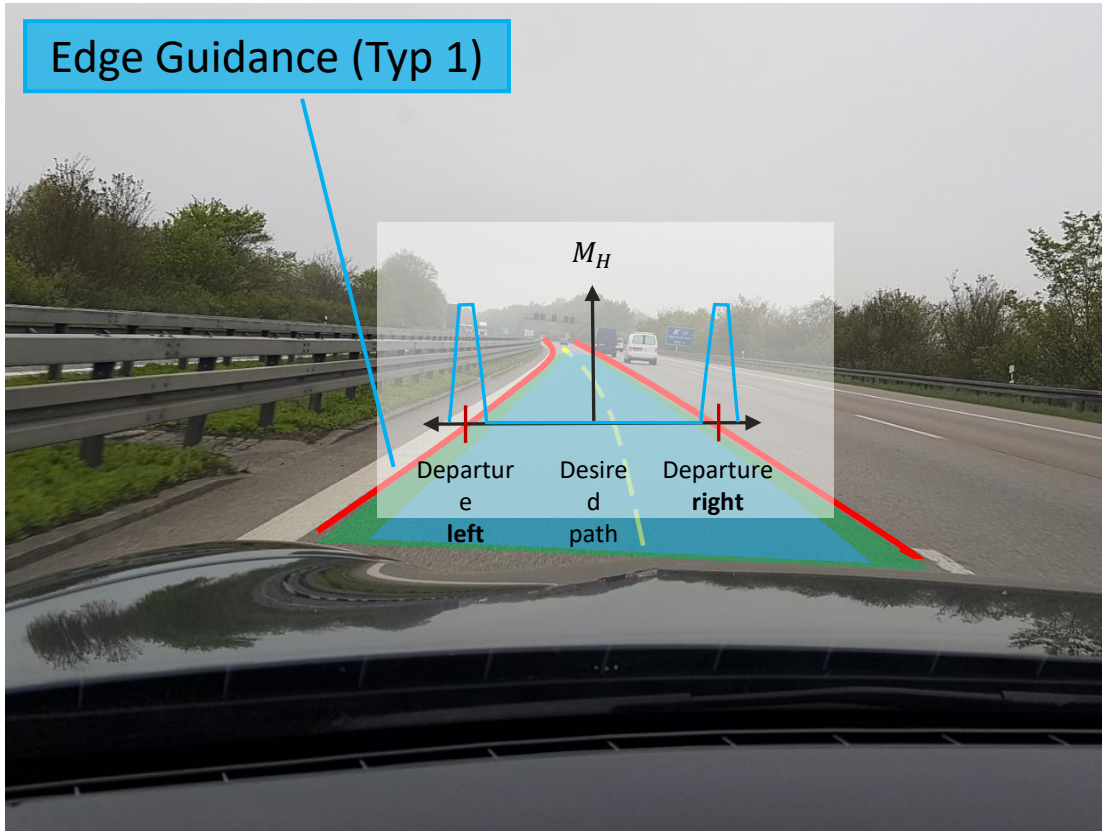


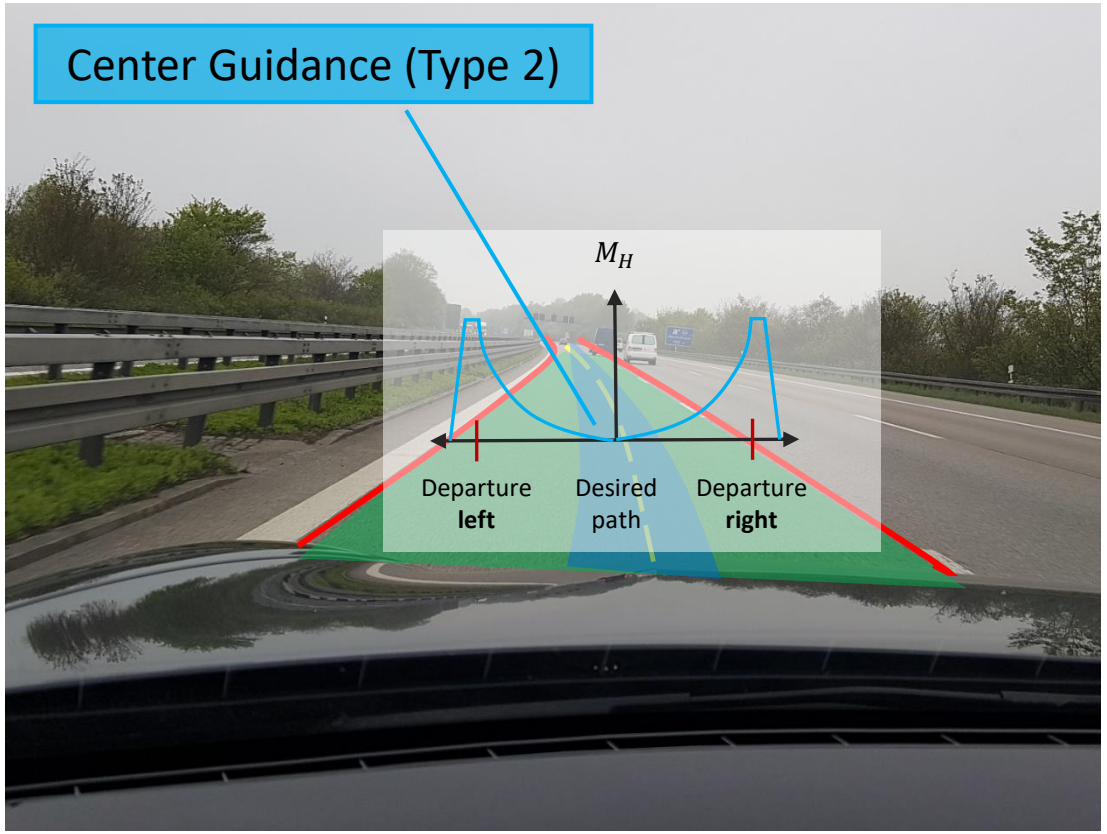


Lateral Control Function: Lane Keeping Assistance Systems



Lateral Control Function: Lane Keeping Assistance Systems

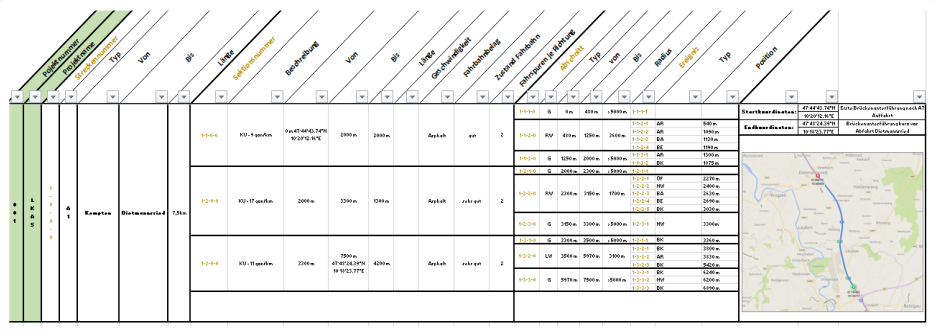


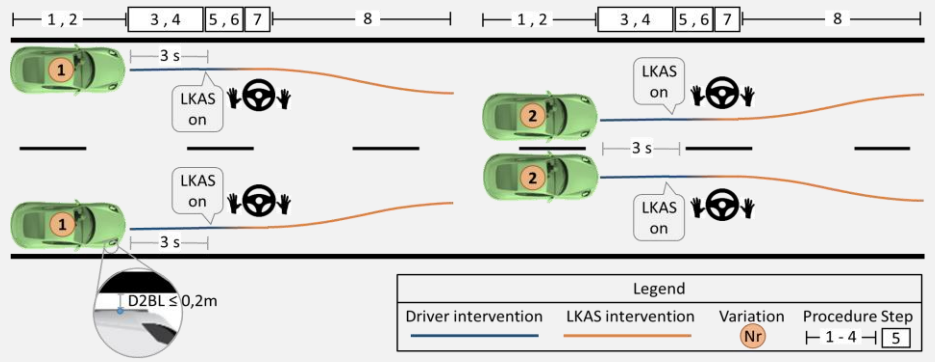


Chassis controls and functions (1)

LKAS driving maneuver catalogue for public road and proving ground

Road Catalogue & Maneuver Definition





Driving Maneuver

- Free Ride Test
- Lane Change Test
- Transient Test
- Hands-Off Test at FSB
- Driver Feedback Test
- Stationary Cornering as Drop and Performance Test
- On-Center Handling Test
- Step Steer Test

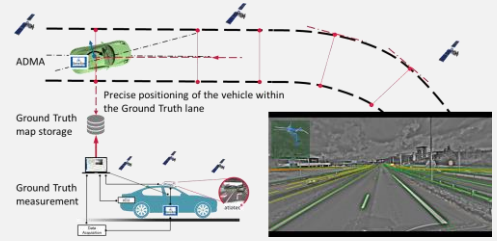
Vehicle Measurement

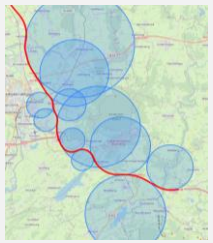
<u>Benchmark vehicles w/o bus access:</u>

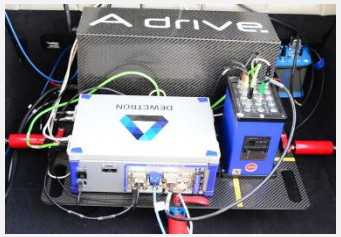
- Genesys ADMA IMU
- Kistler Steering Measurement Wheel
- System Status at Instruments

<u>Vehicles with bus access:</u>

- CAN/FR Bus Signals e.g. Object List

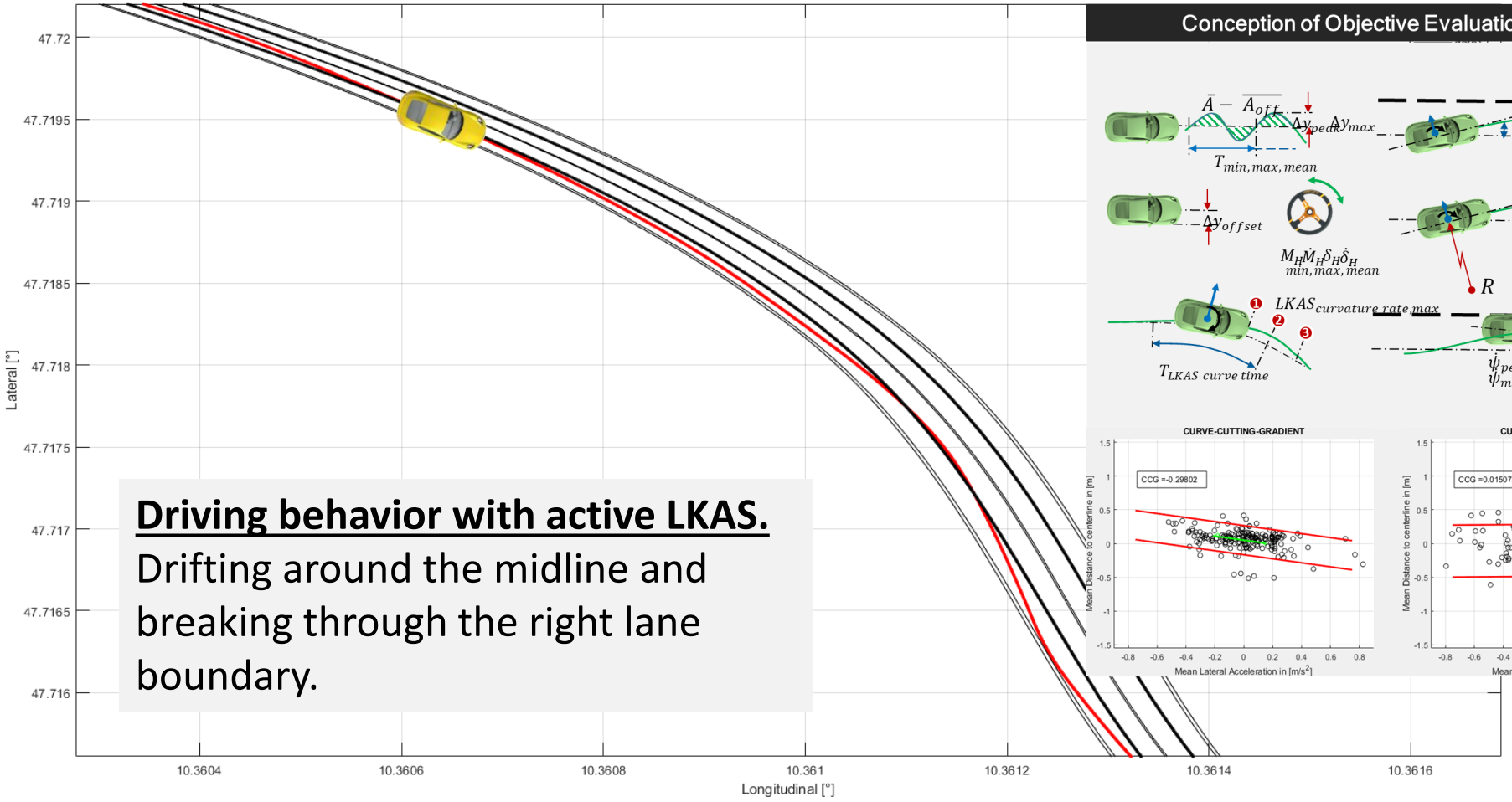




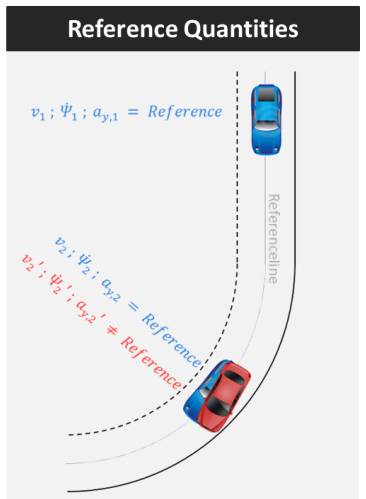


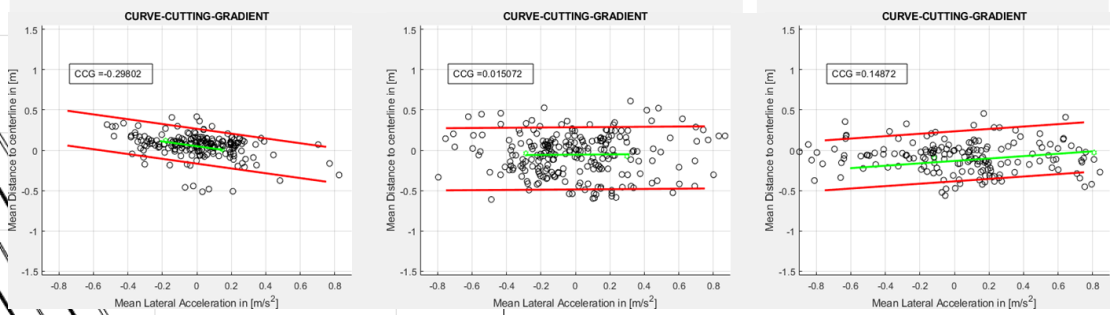
Chassis controls and functions (1)

Accurate location of the vehicle in the lanes and vehicle motion evaluation



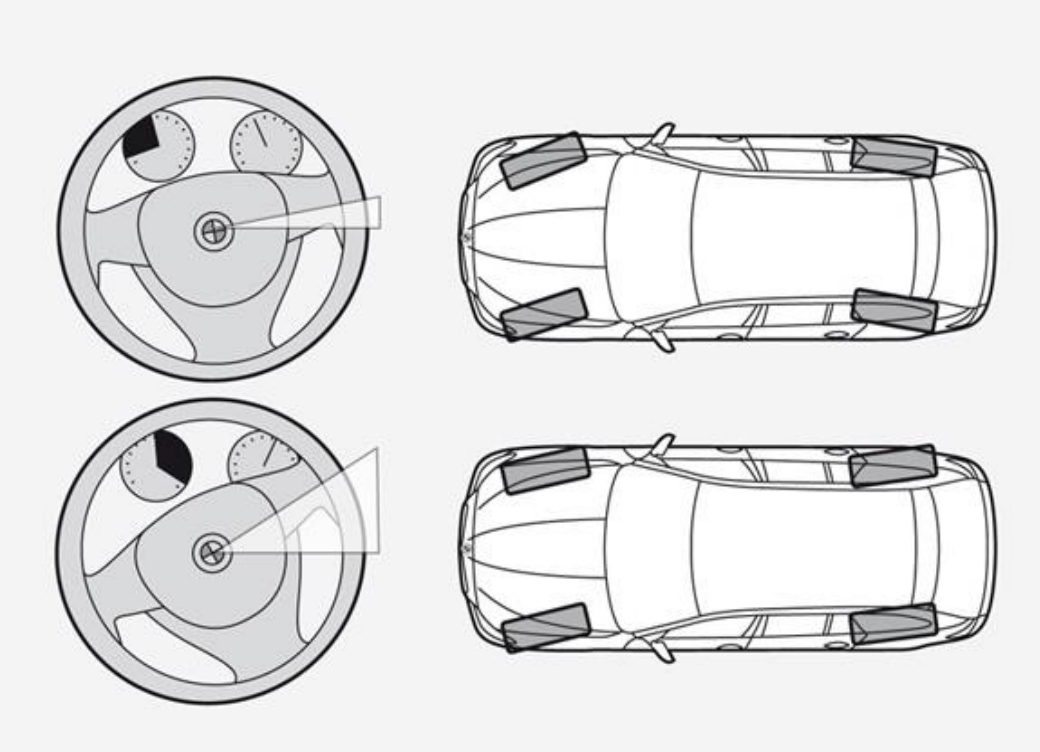
Driving behavior with active LKAS.
Drifting around the midline and breaking through the right lane boundary.





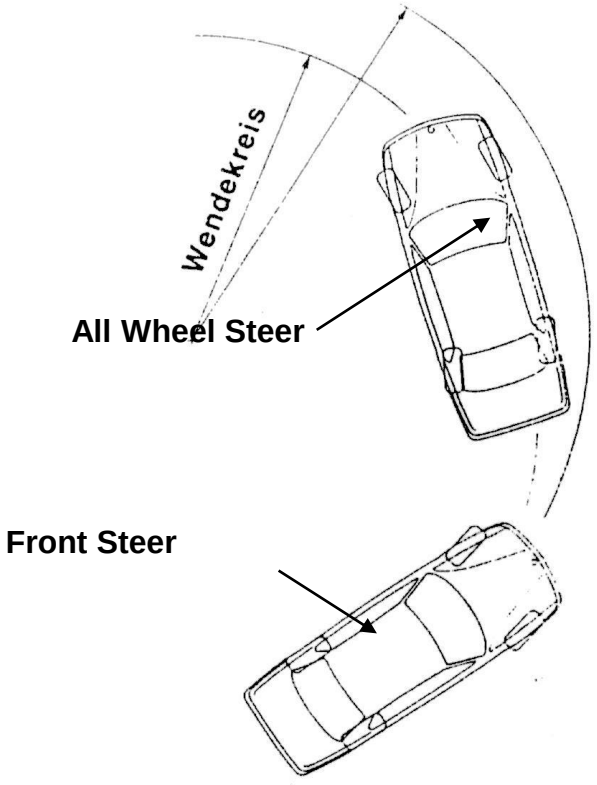
drive livinglab

All Wheel Steering System

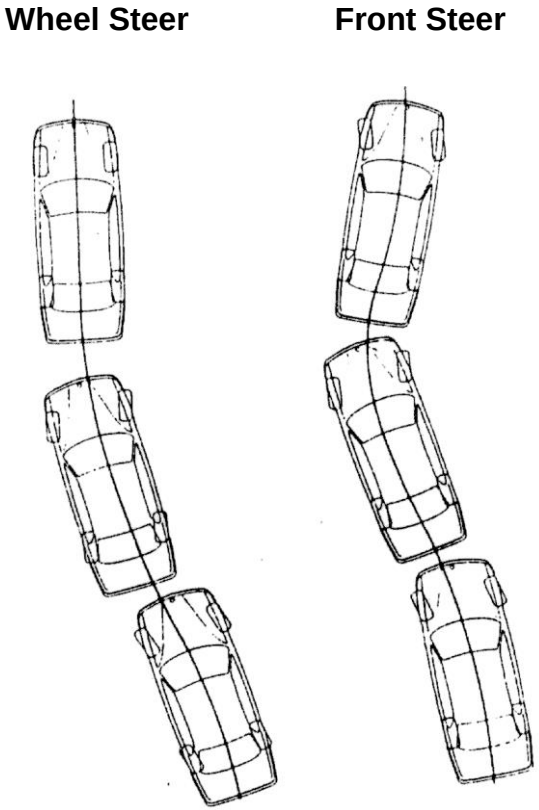


All Wheel Steering System

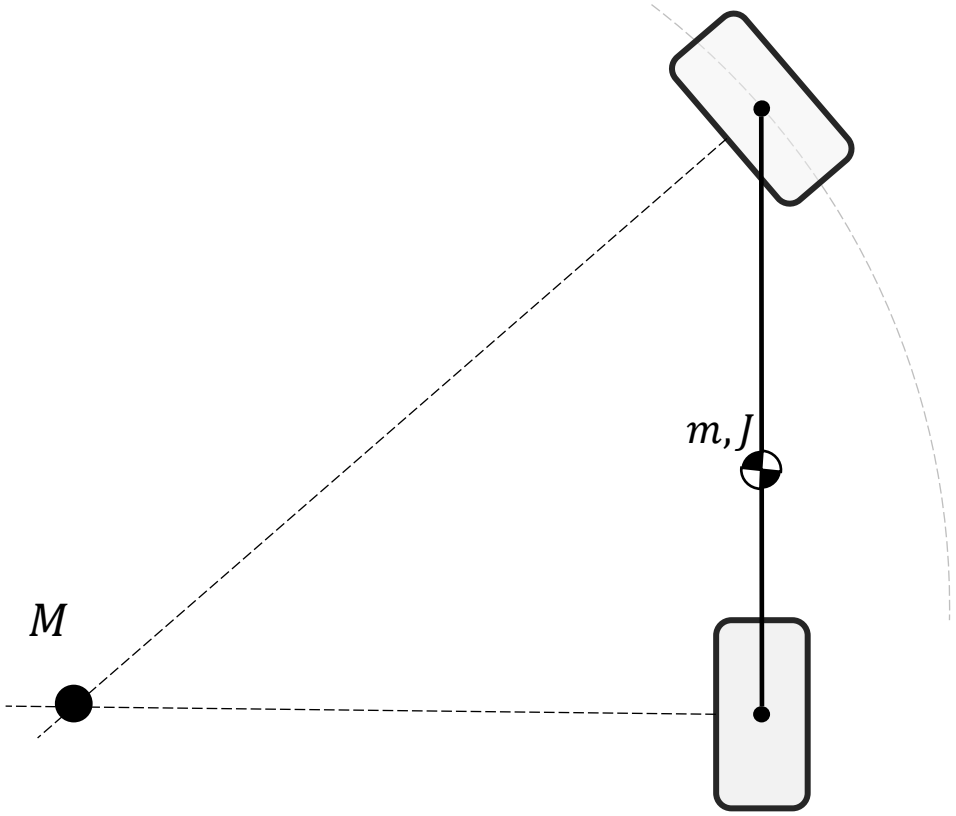
Steering in the opposite direction of rear wheels to achiev a small turning circle

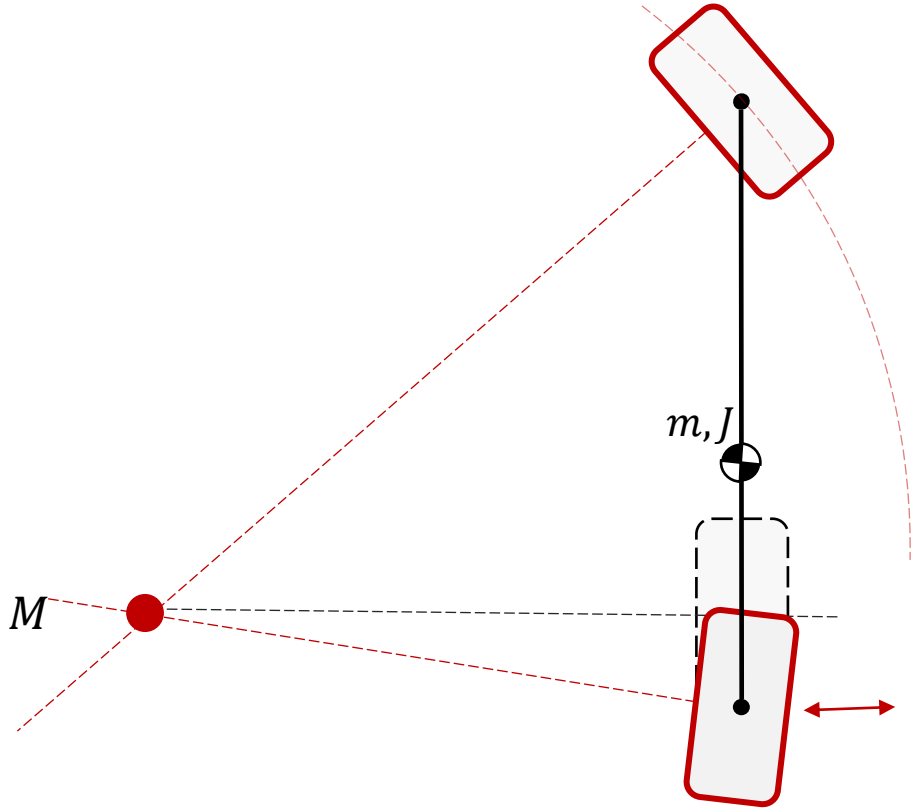


Steering in the same direction of rear wheels to achiev stability

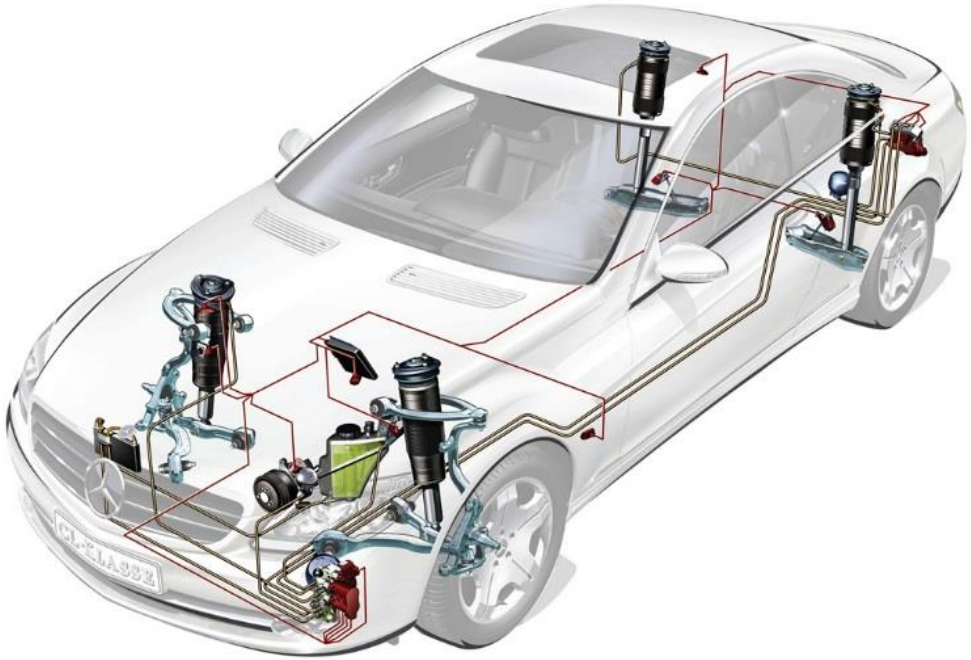


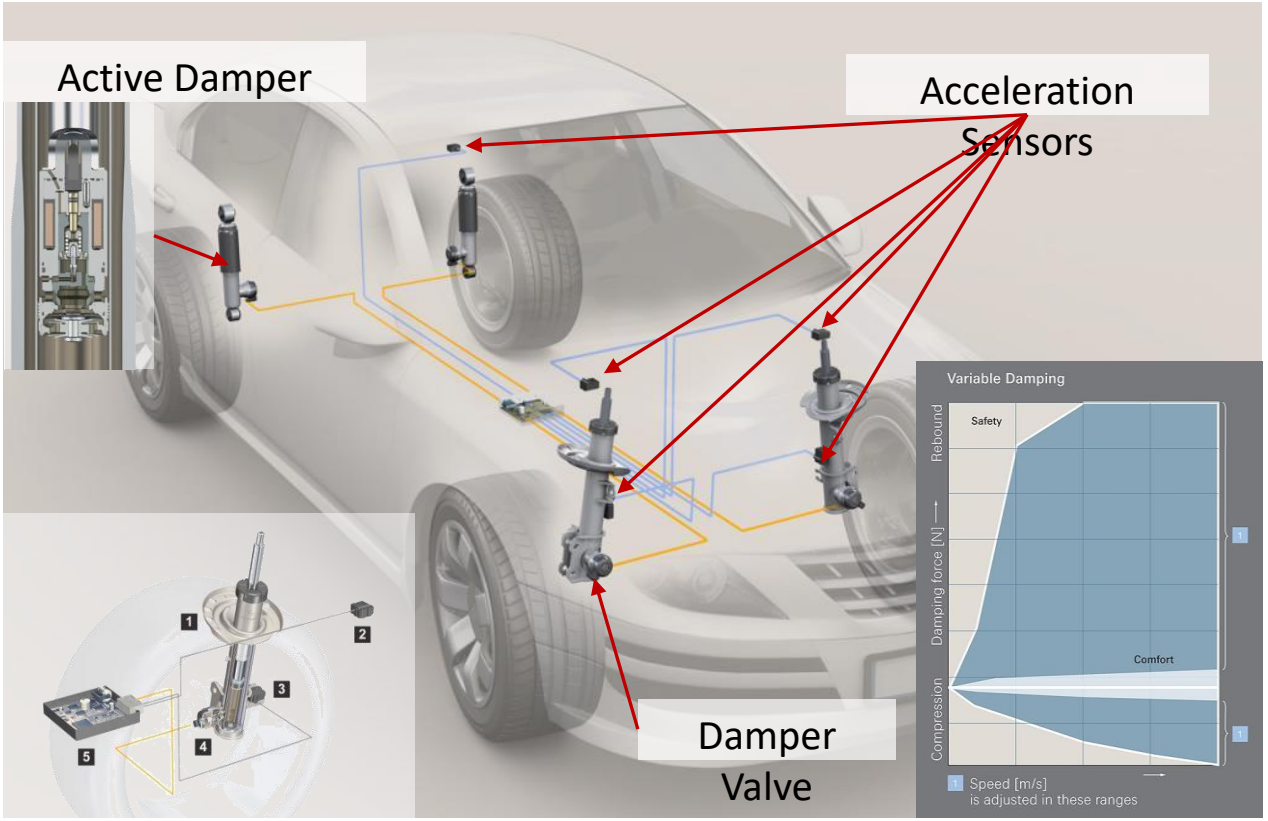
All Wheel Steering System - Principle of Action



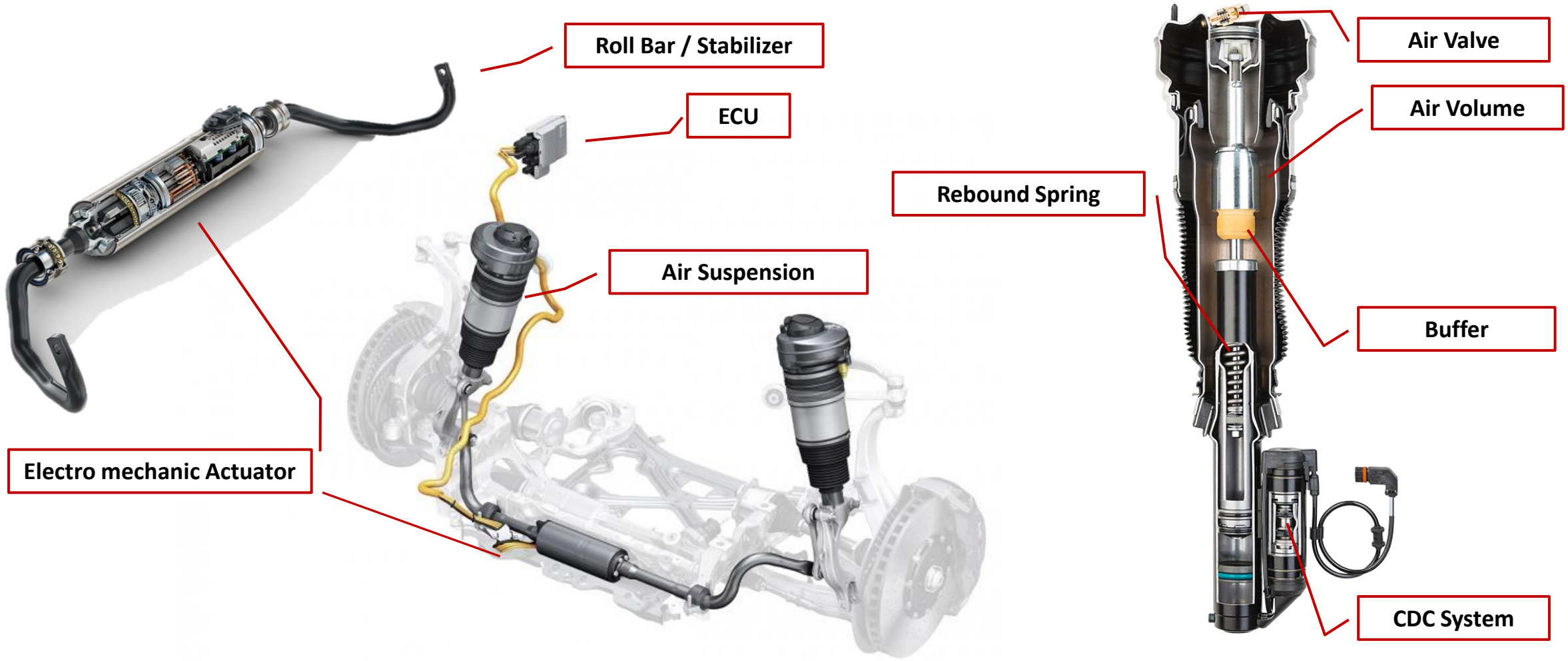


Active suspension control with CDC – Continuous Damping Control

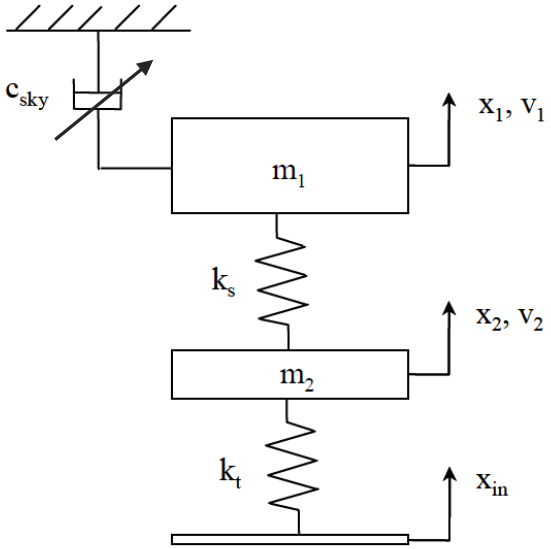


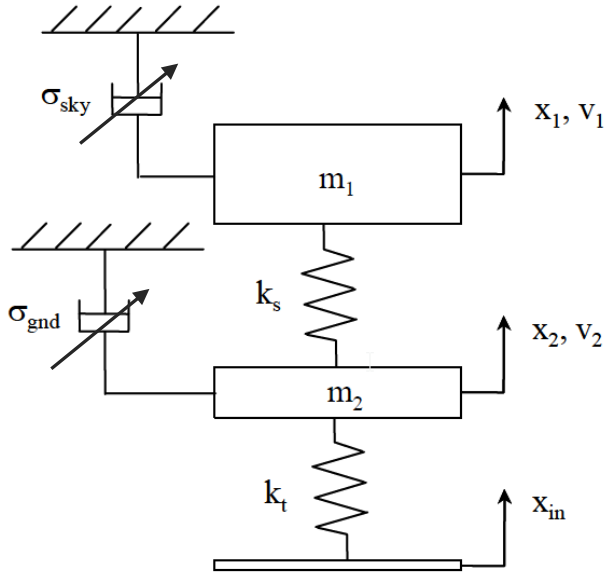


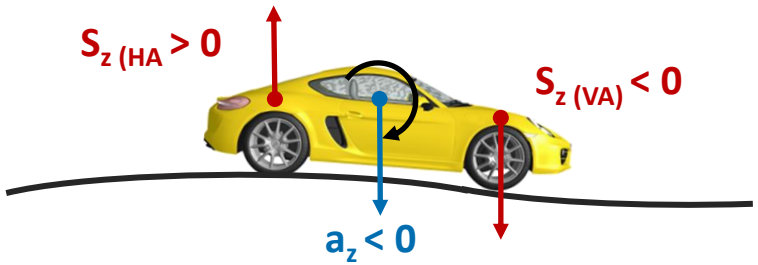
Active suspension control with CDC – Continuous Damping Control

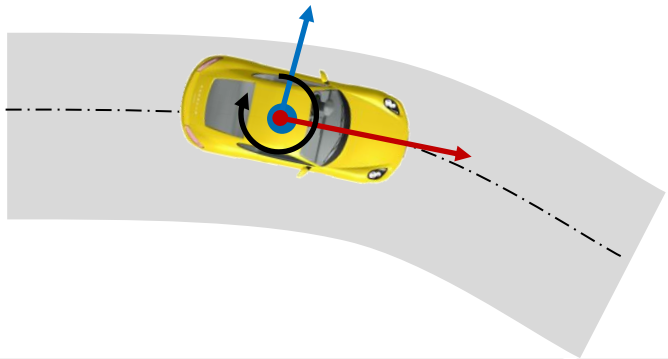


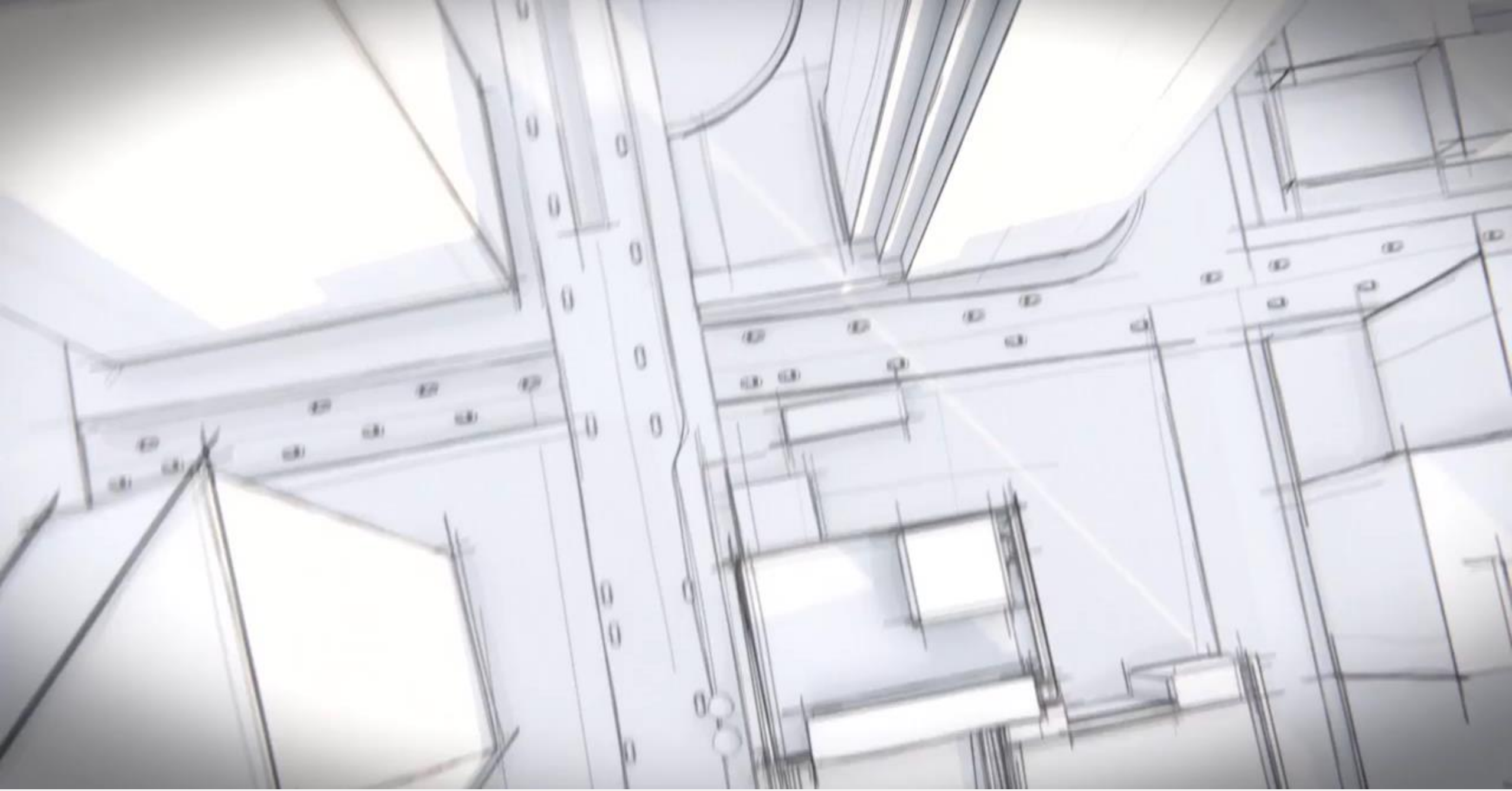
Groundhook principle for longitudinal & lateral dynamics











Chassis controls and functions (1)