Hochschule Kempten
University of Applied Sciences

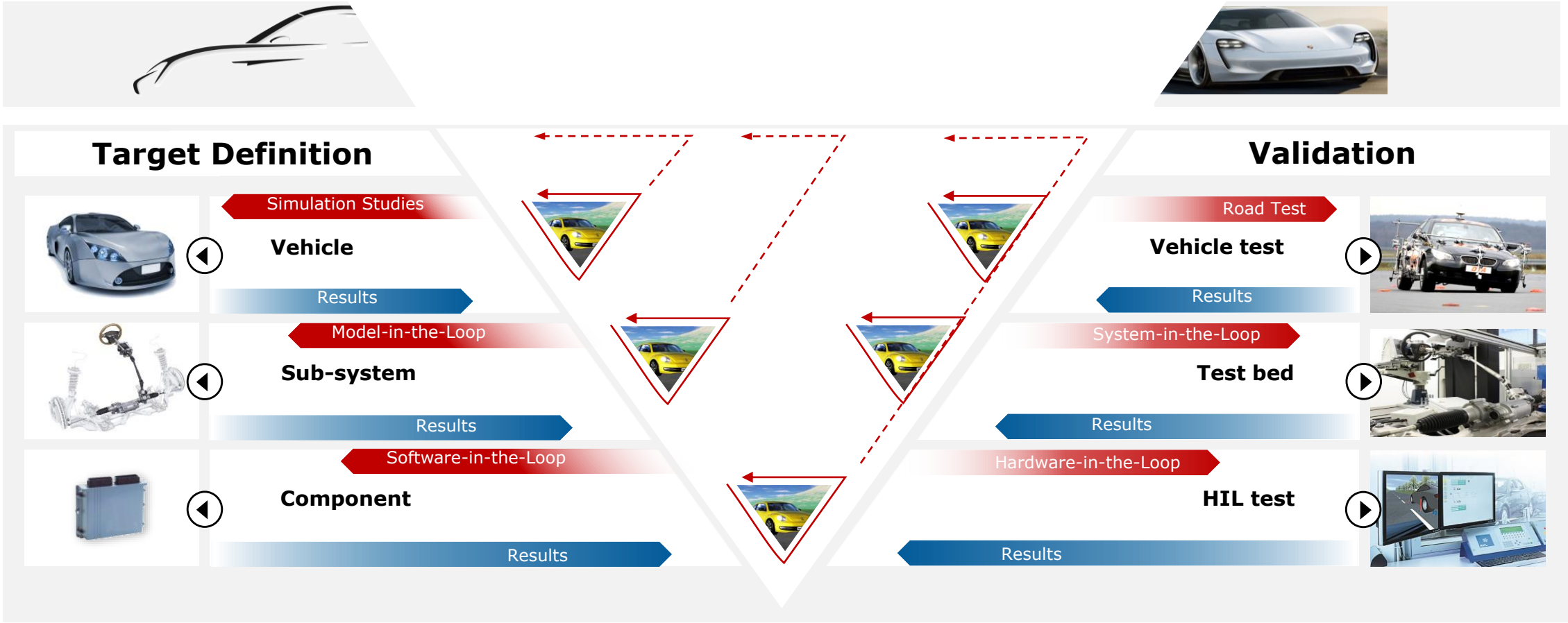
drive livinglab

ADAS Master WS 20/21
Lecture 2

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

Requirements for vehicles and their global attributes

Continuous attribute validation during the development



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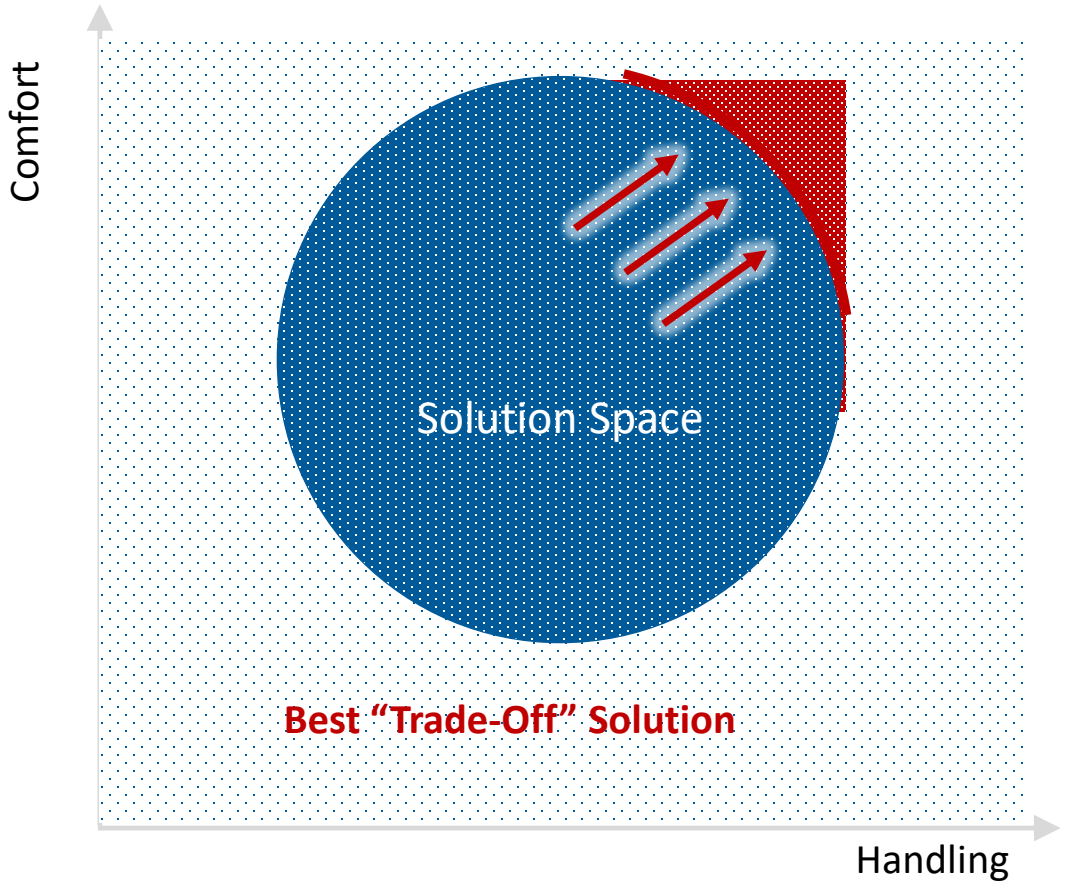
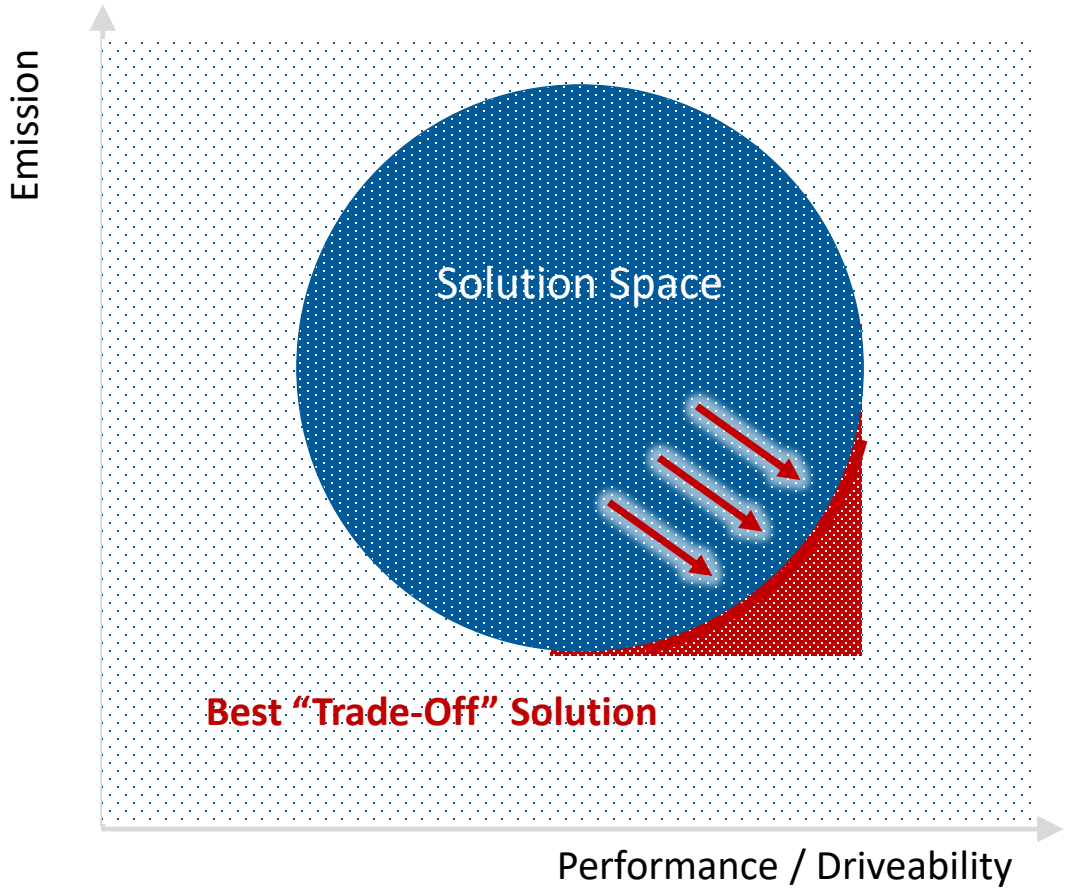
Vehicle dynamics attributes and their target conflicts

Vehicle character is a result of well integrated system & functions.

Vehicle dynamics attributes and their target conflicts

What will be the impact of any change in terms of agility, safety, comfort, emission and costs? Which global vehicle attributes cab lead to a target conflicts?





What is the difference between verification and validation?

Verification = Have we done the things right?

➡ **Fulfillment of specification without errors.**

Validation = Have we done the right things?

➡ **Is the customer happy with the driving behavior of the car?**

Vehicle dynamics attributes and their target conflicts

Subjective and objective evaluation language

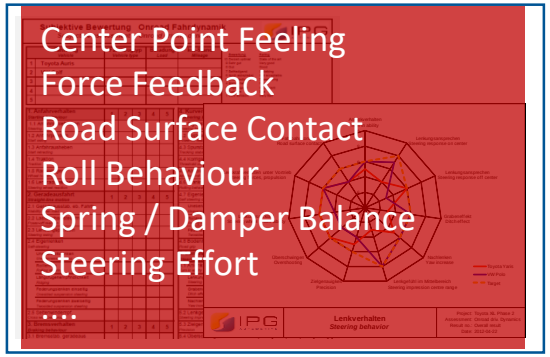
Customer Wishes

Subjective Language

Subjective evaluation

Subjective evaluation criteria in a rating system

Center Point Feeling
Force Feedback
Road Surface Contact
Roll Behaviour
Spring / Damper Balance
Steering Effort
....



Objective Language

Objective measurement data

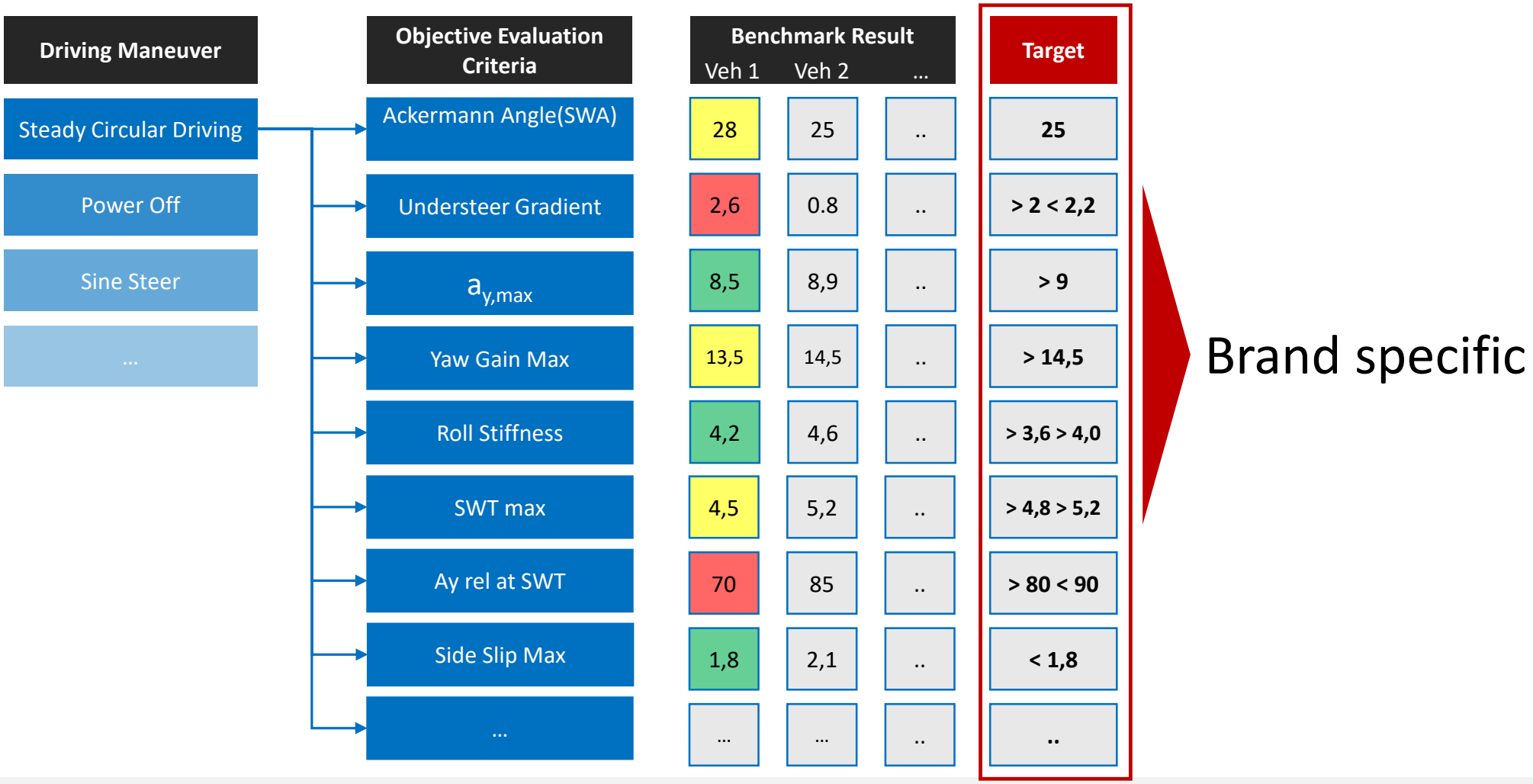
Characteristic values for vehicle behavior

Yaw Gain
Understeer Gradient
Roll Stiffness
Frequency Response
Maximum Force
Linearity
....

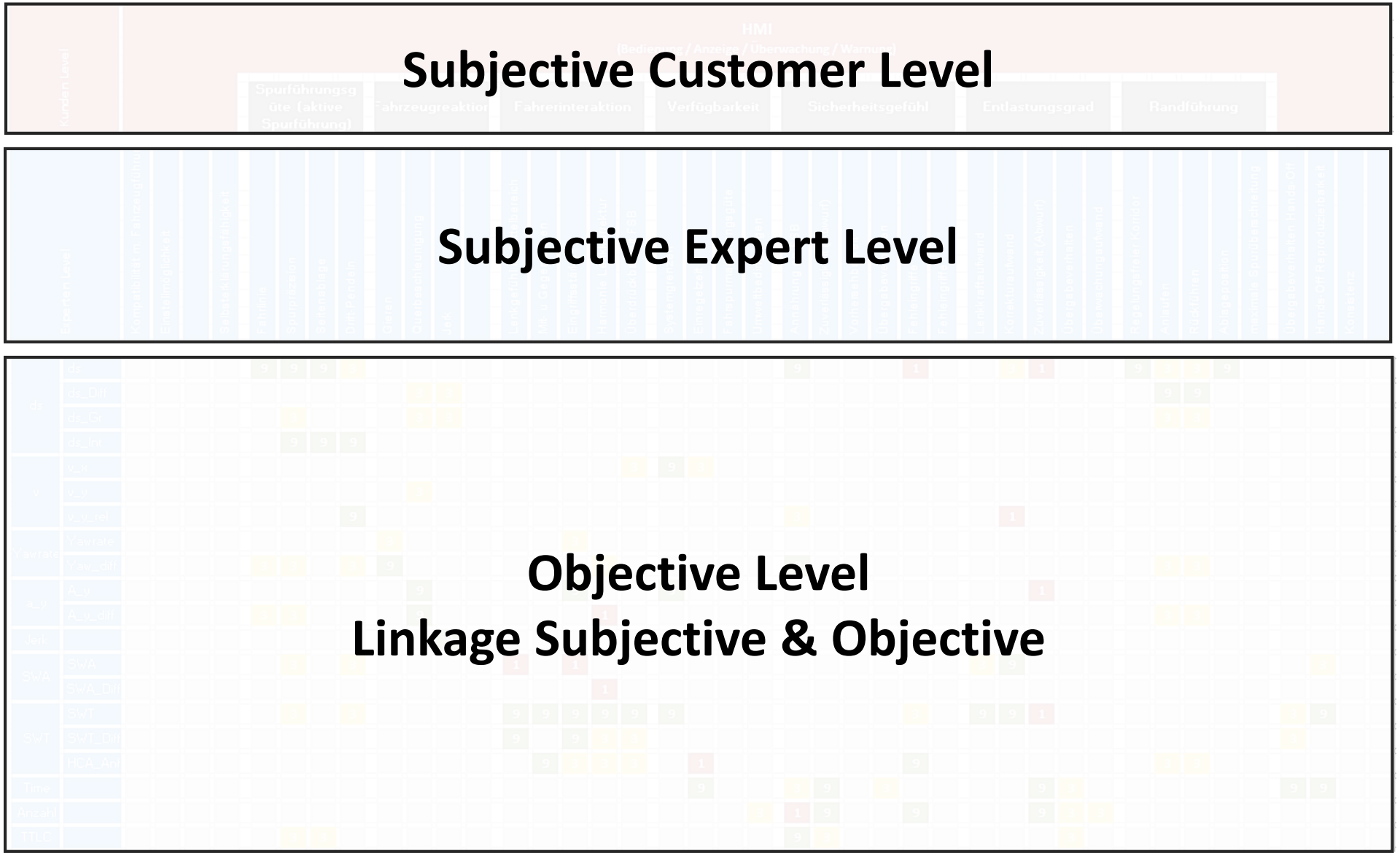
Correlation and linkage between both languages are important

Vehicle dynamics attributes and their target conflicts

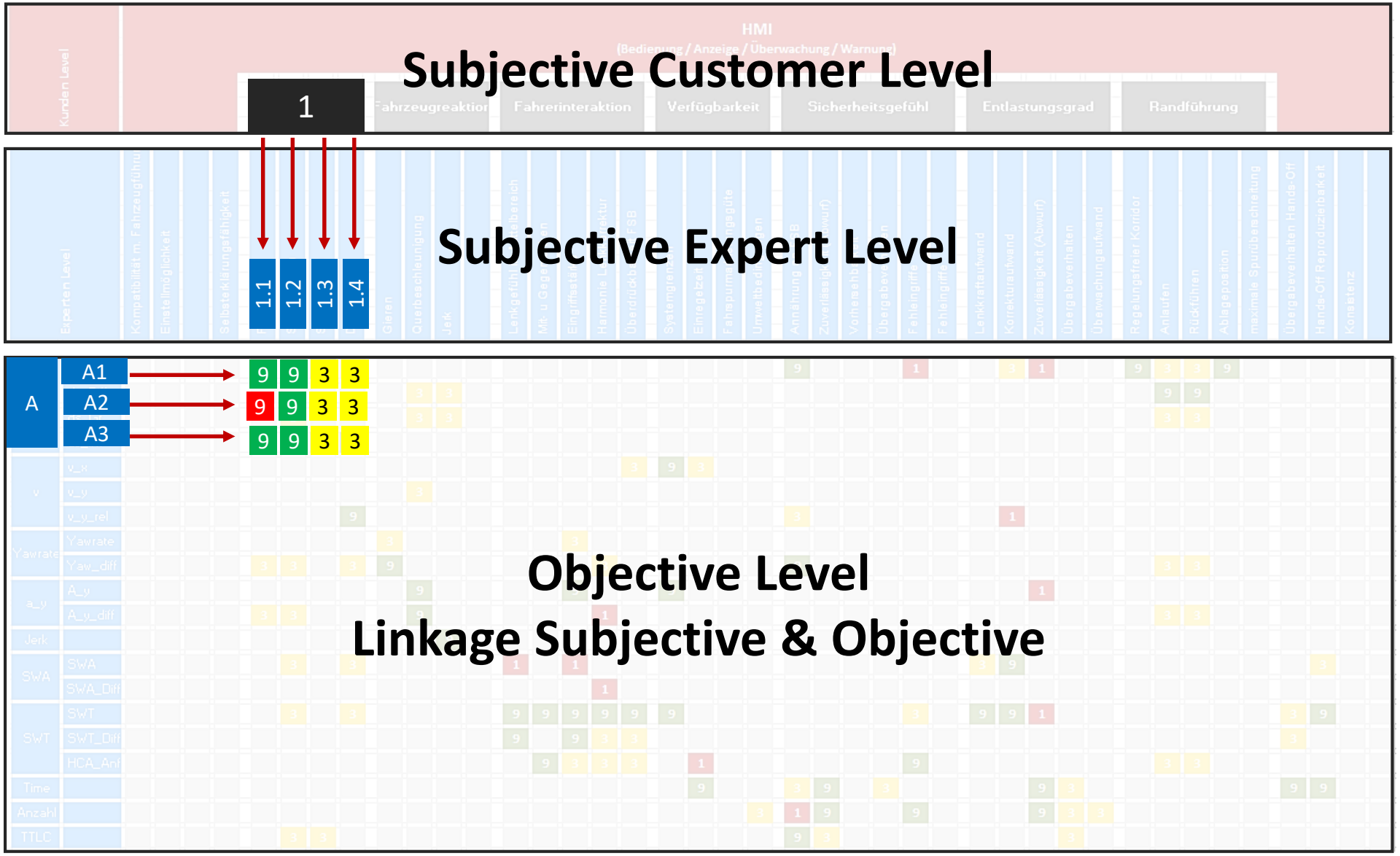
KPI and target matrix within a consistent development process



Vehicle dynamics attributes and their target conflicts

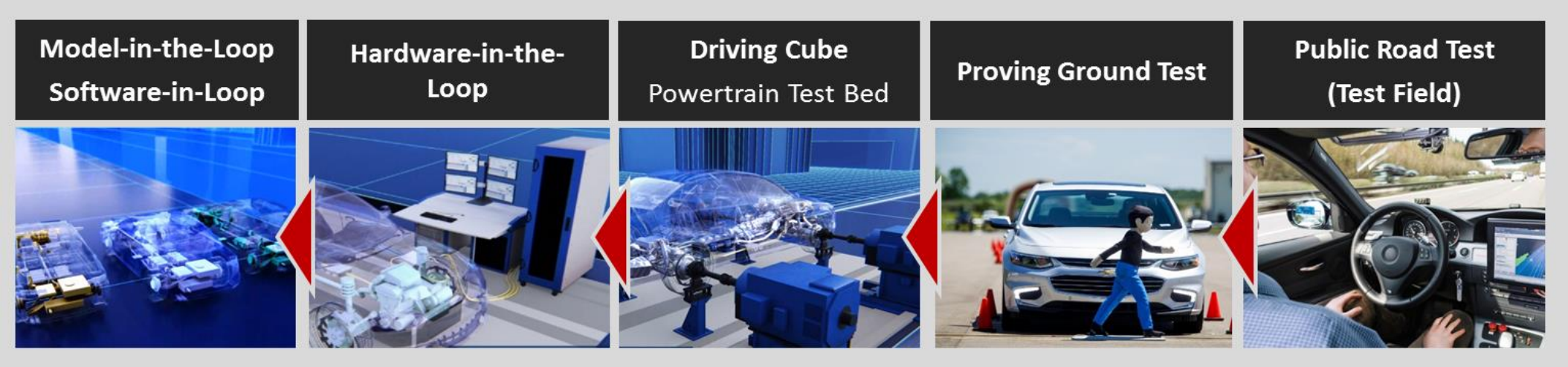


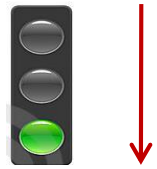
Vehicle dynamics attributes and their target conflicts



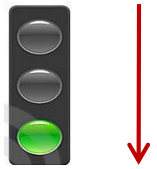
Vehicle dynamics attributes and their target conflicts

KPI’s as an enabler for simulation use, efficient development & comparison





Objective Evaluation Criteria's
Expected Result
(passed/failed)



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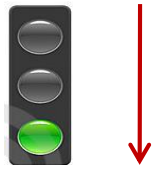

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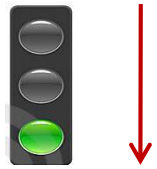

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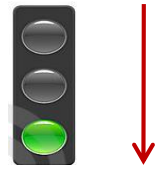


Objective Evaluation Criteria's
Expected Result
(passed/failed)

Vehicle dynamics attributes and their target conflicts

Continuous attribute validation during the development

Subjective Customer Wishes

Vehicle Target Behavior
in realistic driving situation

Vehicle Target Behavior
in realistic driving situation

Virtual Vehicle

Simulation

Virtual Vehicle with real systems

Road Test

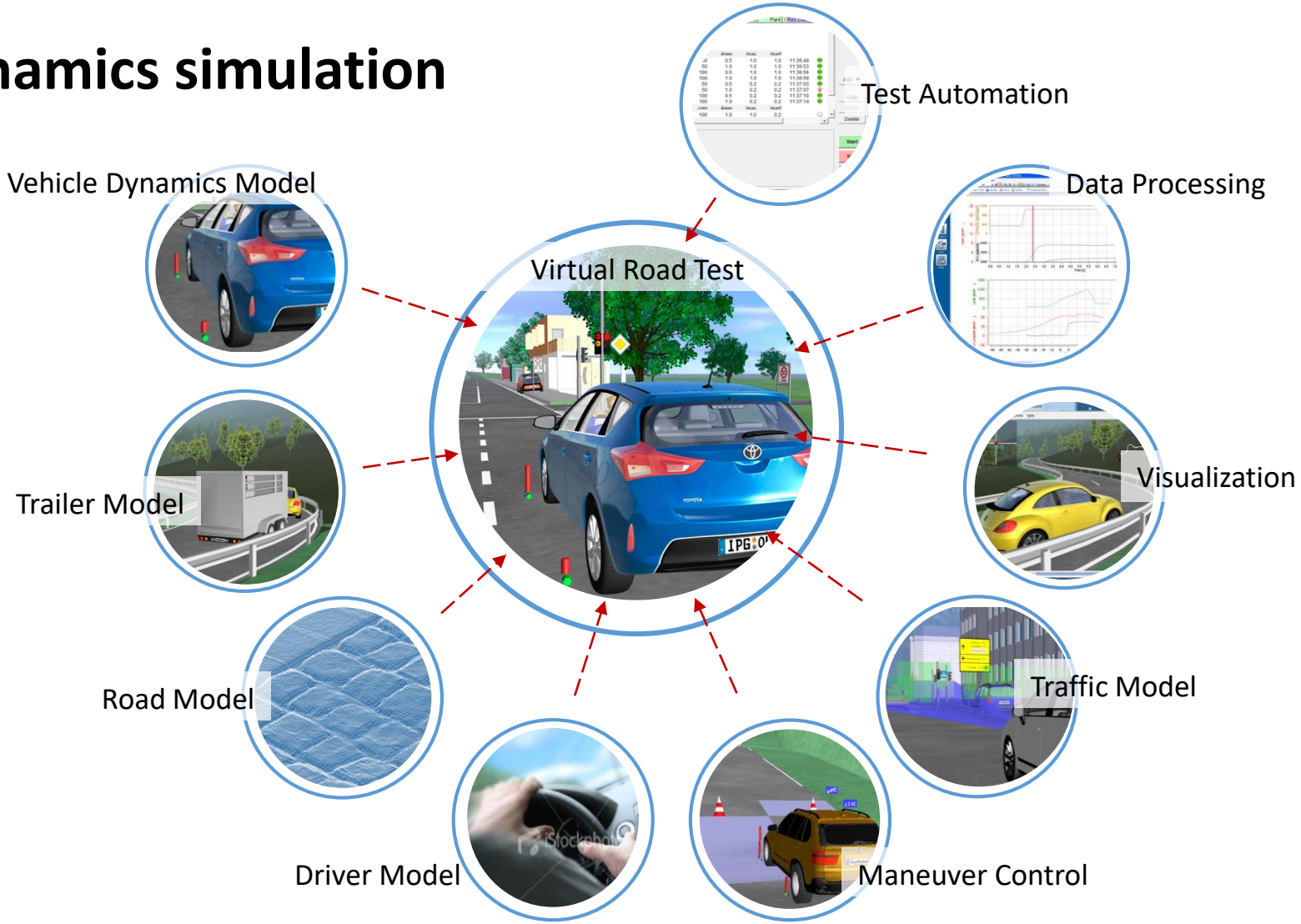
Real Vehicle

Objective Evaluation Criteria's
Expected Result
(passed/failed)

Objective Evaluation Criteria's
Expected Result
(passed/failed)

Objective Evaluation Criteria's
Expected Result
(passed/failed)

Vehicle dynamics simulation

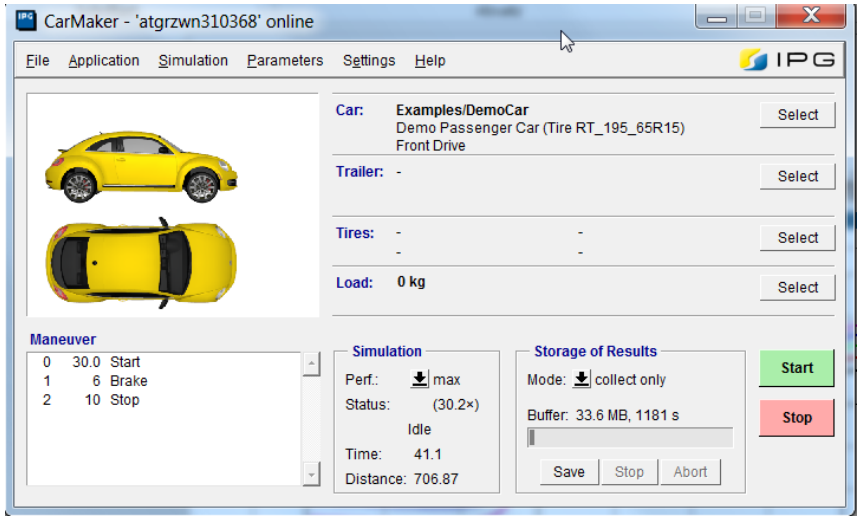


CarMaker command center give access to all functions

Access menu to all functions extendable by user

Control display of vehicle loads

Online display of **maneuver status**



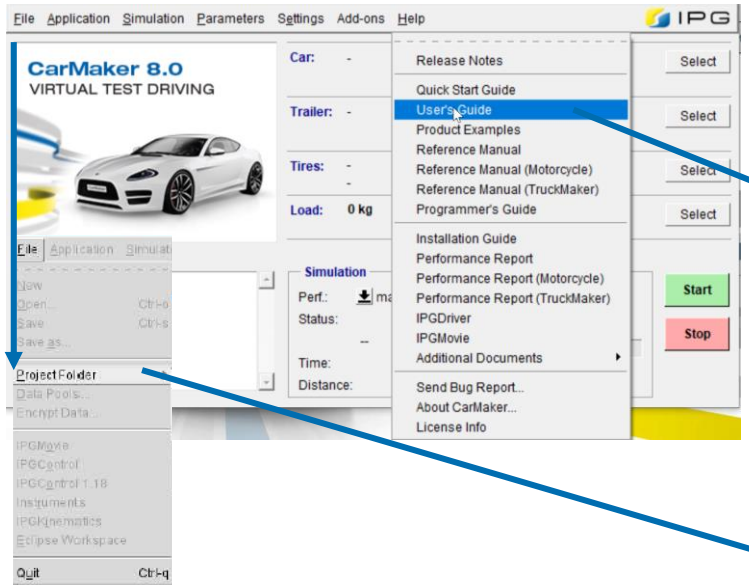
Selection of **parameter files**
Vehicle – Trailer – Tires – Loads

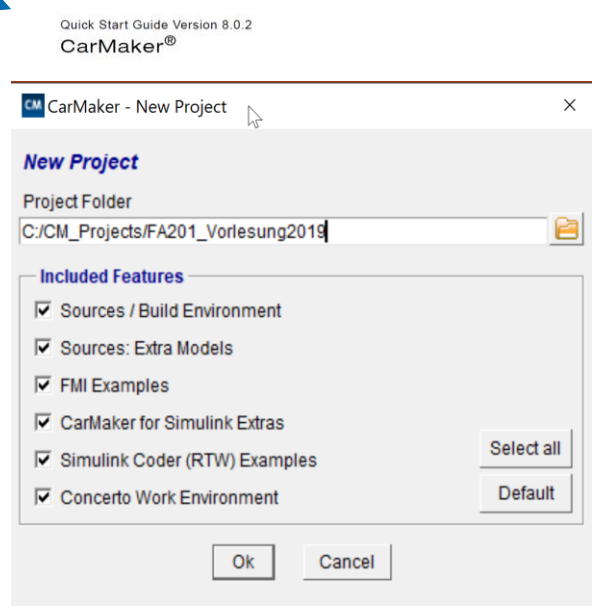
Online **Start & Stop** function of the simulation

Simulations speed and status
0.2, 0.5, 1, 2, 5 x RT up to max

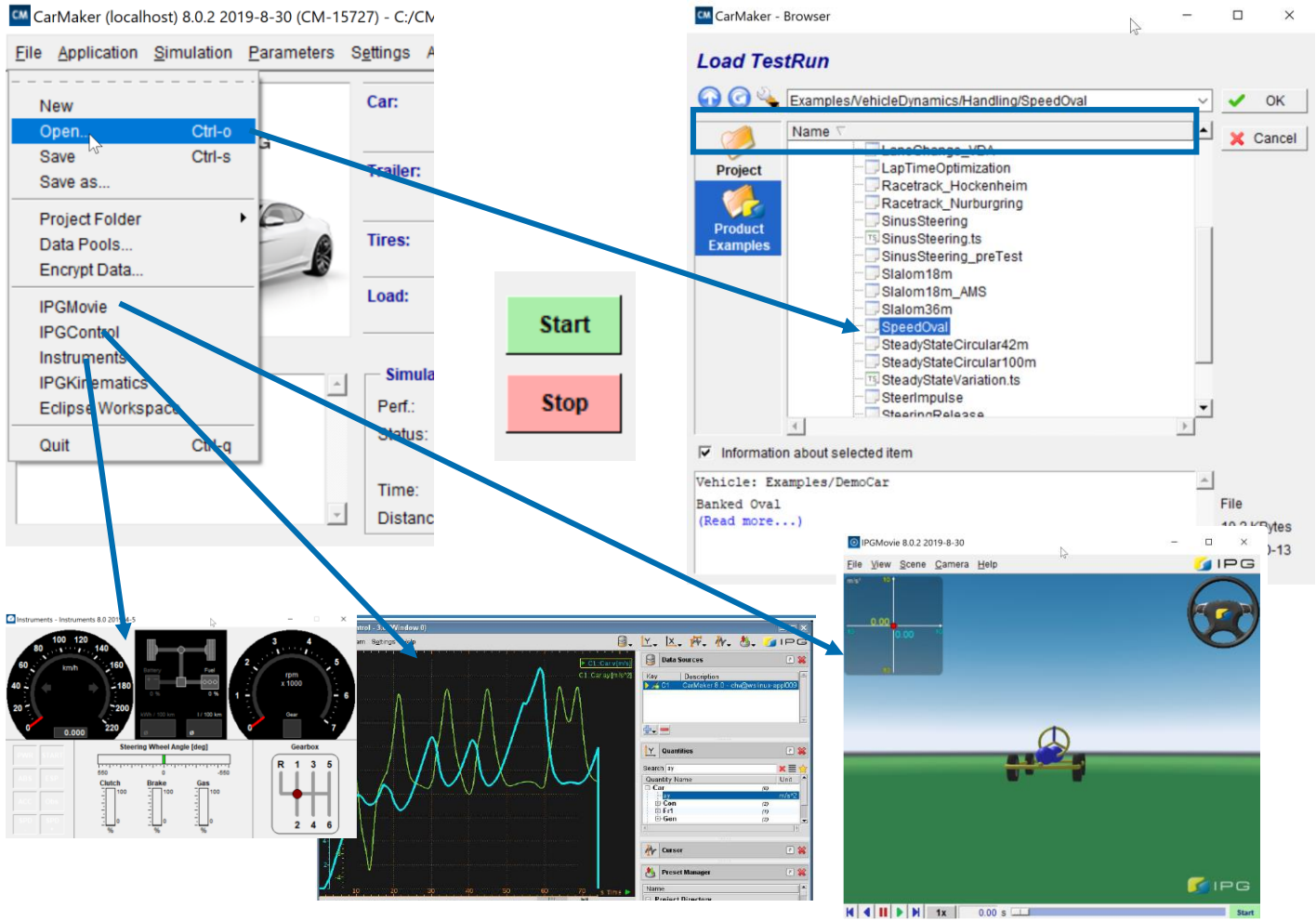
Interactive **storage functions** and buffer view

Vehicle dynamics simulation





Vehicle dynamics simulation



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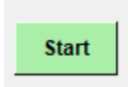
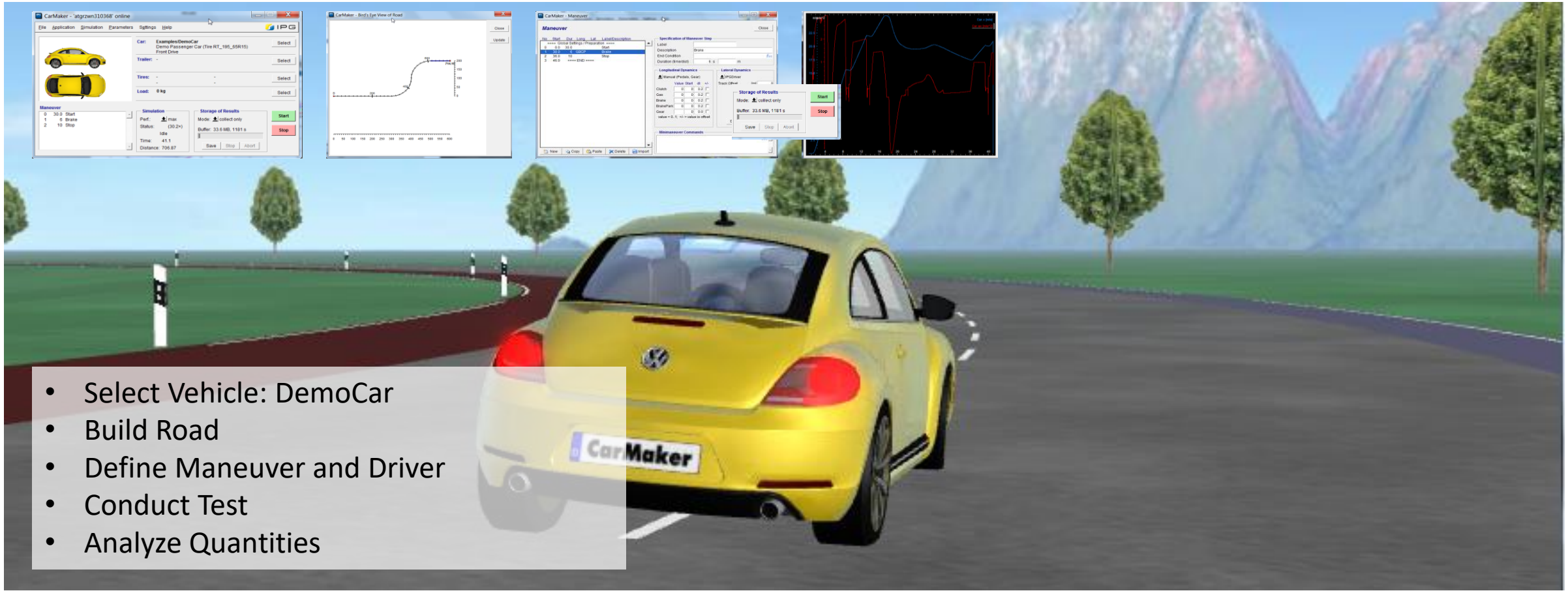
Exercise 1: Loading a Predefined Virtual Vehicle Environment



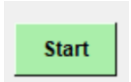
1. Run simulation
2. Select and deselect trailer run simulation and analyze V, ay, ax…
3. Modify road
    1. Width and integrate middle Line
    2. Change banking (lateral slop in curves)
4. Modify driver
    1. Cruising speed to 50 kph and back to 200 kph
    2. Cornering cutting
    3. G-G diagram lateral acceleration to 2 m/s^2

Exercise 2: Test Run from the scratch



- Select Vehicle: DemoCar
- Build Road
- Define Maneuver and Driver
- Conduct Test
- Analyze Quantities

Exercise 2: Test Run from the scratch

1. Select vehicle DemoCar
2. Build Road
    1. 500m straight, 90° left corner, 90° right corner, 500m straight
3. Build maneuver
    1. Accelerate until Car.v>80/3.6
    2. Drive constant 80 kph for 1s
    3. Brake with 6 m/s²
4. Save Test Run and simulating 

5. Change left hand and right hand driving (road) and driver parameter curve cutting
6. **Extend the road as you want**

Exercise 3: Creating µ-Split braking test

Chapter 5 Quick Start Guide

1. Building a Road Network Using the Scenario Editor
2. Defining the Maneuver
3. Saving Your TestRun
4. Selecting a Vehicle and Simulating
5. Analyze Car.ax, Steer.WhlAng, Car.YawRate in IPGControl

Exercise 4: Steady State Circular Driving

Test Condition

- Constant Radius: 100 m
- Speed: 0 – max kph
- da_y: 0,1 m/s²/s

SWA, a_y, Yaw, Radius: steady state condition

Analyze:

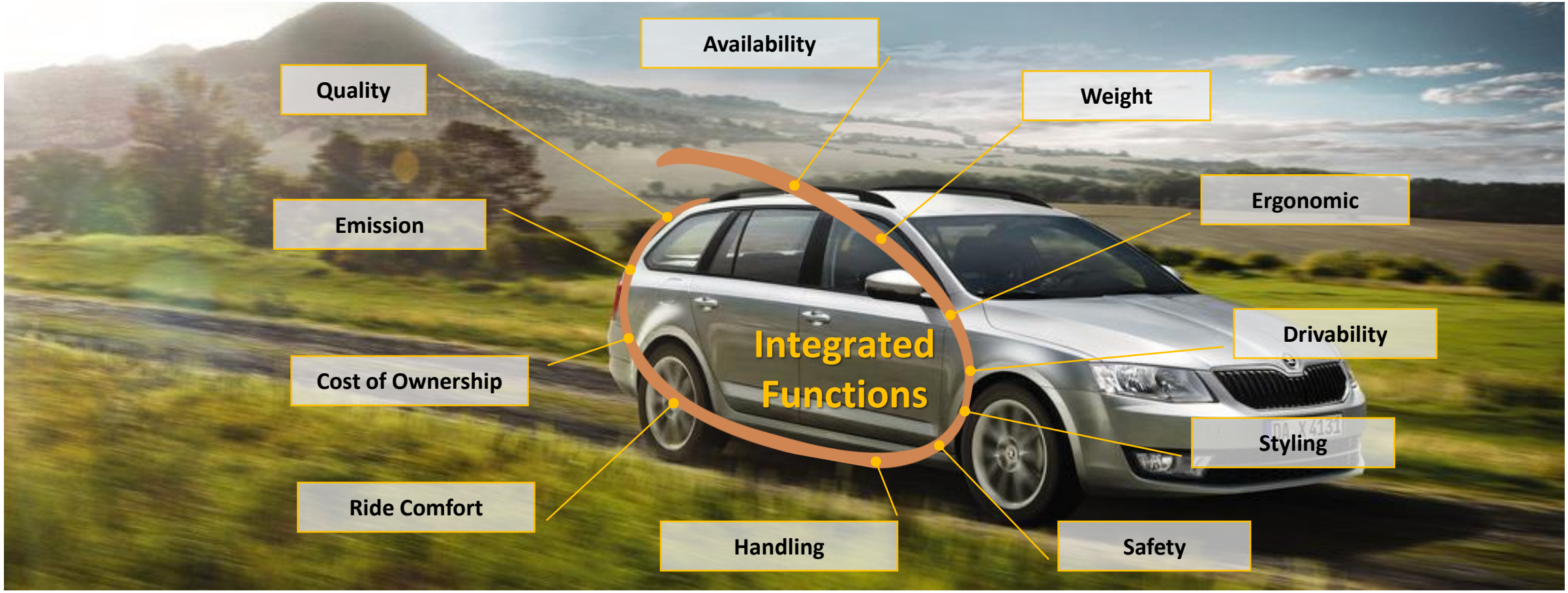
- Car.v
- Car.ay
- Car.Roll
- Car.SideSlipAngle

Change & Analyze:

- Vehicle load 200 kg rear axle / front axle
- Vehicle roof mass 200 kg

Vehicle dynamics attributes and their target conflicts

Typically, vehicles must address a bunch of global attributes



Vehicle dynamics attributes and their target conflicts

What motivates humans to buy a vehicle?

Fuel Consumption


Safety


Costs


Styling


Space

For what?

Where driving?

City

Highway

Transportation?

Persons

Goods

What doing?

Transportation

Representation

Enjoy

For who?

Practitioner

"Schlaumeier"

Gourmets

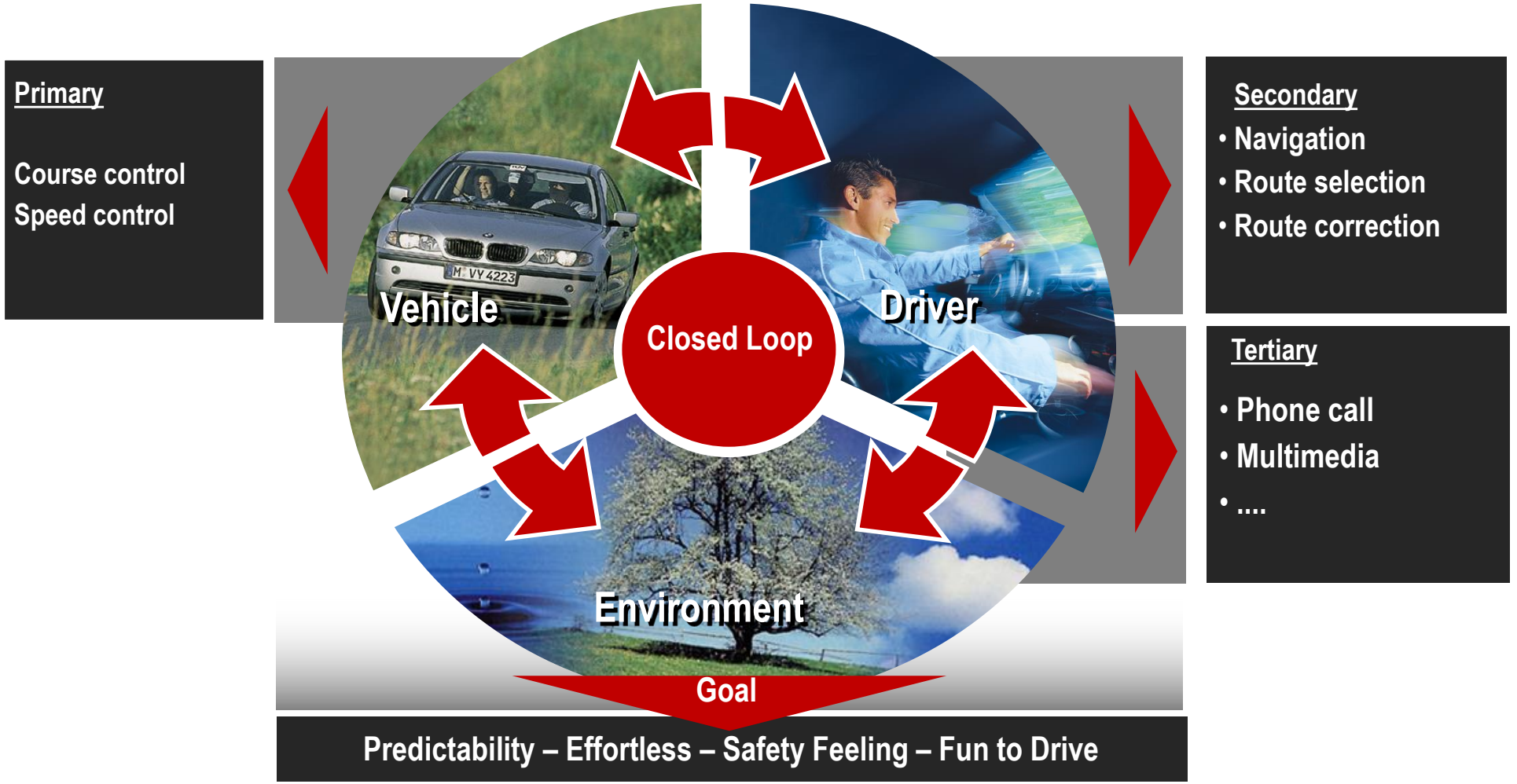
Business man

Vehicle dynamics attributes and their target conflicts

“Driver – Vehicle – Environment” – a closed loop!

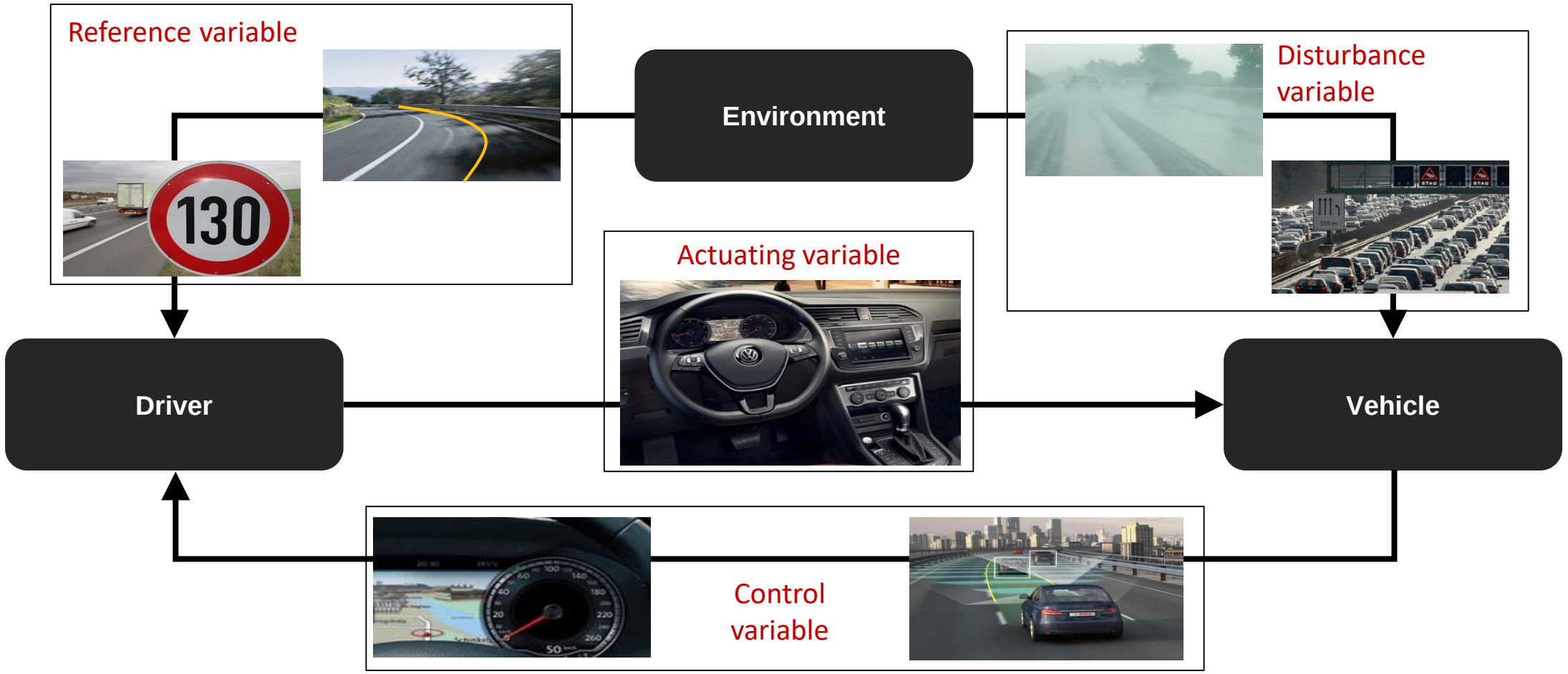
Vehicle dynamics attributes and their target conflicts

“Driver – Vehicle – Environment” – a closed loop!

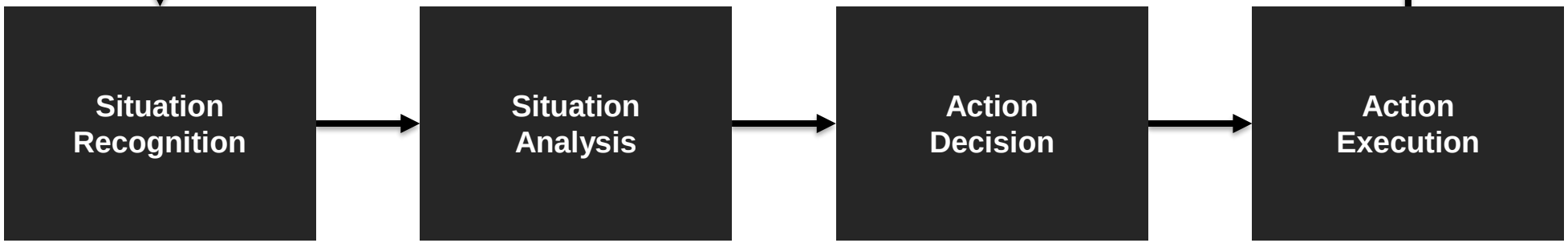


Vehicle dynamics attributes and their target conflicts

“Driver – Vehicle – Environment” – a closed loop!



Cause and effect chain of the human processing



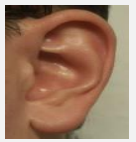
Vehicle dynamics attributes and their target conflicts

Cause and effect chain of the human processing

Sample	**Situation Recognition**	**Situation Analysis**	**Action Decision**	**Action Execution**
	Slower front vehicle on highway. Approaching oncoming traffic	Estimation of own time gap. Estimates of the time gap of oncoming traffic.	Decision: Enough time →o ass Little time → follow.	Motorized implementation of the maneuver.
	Pedestrian steps on the road ahead of the vehicle. No traffic on the adjacent lane.	Estimation of own time gap. Estimating the braking effect.	Decision: • Enough time → brake • Too little time → evasion.	Motorized implementation of the maneuver.

Vehicle dynamics attributes and their target conflicts

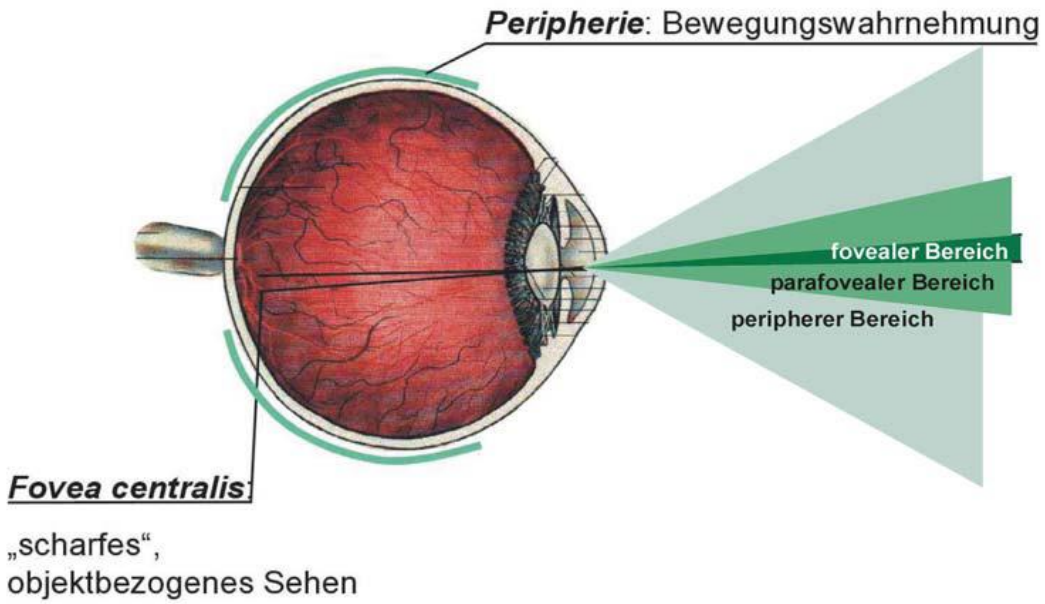
Sensorial modality of the human organism

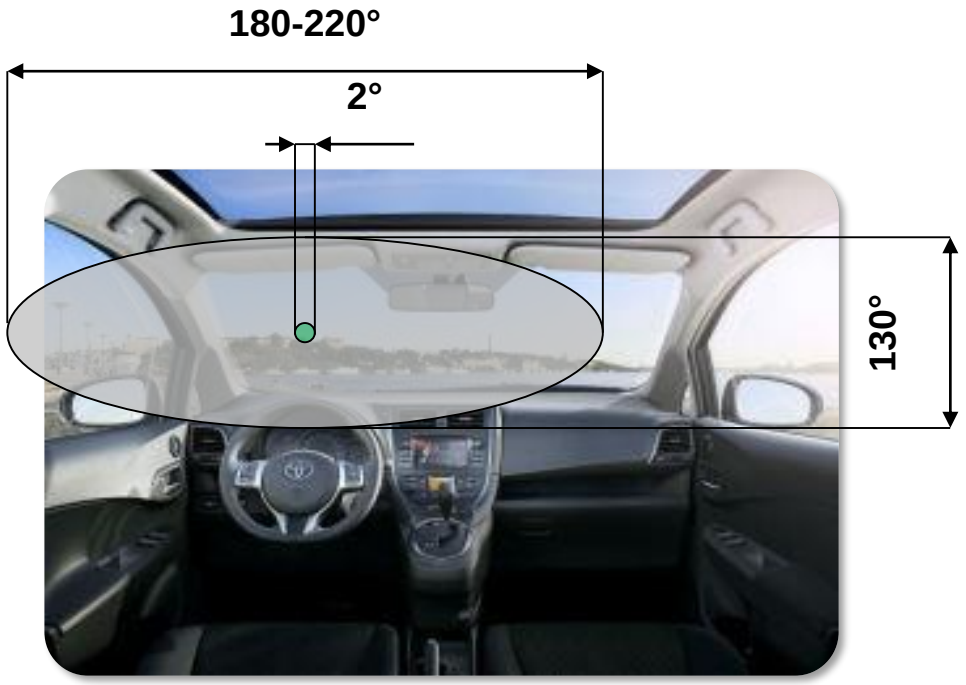
Sensorial modality	Recognition of…	Sense organ	
Visual	• color. • contrast. • 3D vision		Eye
Audio	• Amplitude of tone signal. • Frequency von tone signal. • 3D hearing.		Ear
Haptic (mechanical recognition)			
Tactile	• Pressure. • contact. • vibration.		skin *(mechanical-receptors)*
Kinesthetic (proprioception)			
vestibular	• acceleration. • balance.		Balance organ
proprioceptive	• Relative position and motion of body parts. • Forces.		neuromuscular spindle, tendon waist sensors

Sensorial modality of the human organism

Sensorial modality	Recognition of…	Sense organ	
olfactory	• Smell.		Nose
Gustatory	• Taste.		Tongue
Thermal	• Temperature.		Skin *(Thermo-receptors)*
Nociceptive	• Pain.		Skin *(Nociceptors)*

Sensorial modality – Visual Recognition





Vehicle dynamics attributes and their target conflicts

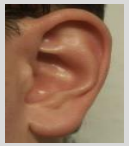
Relevant sensorial modality for the vehicle development

Vehicle Dynamics

- Vehicle evaluation
- Design of suspension and chassis controls (Closed-loop).

Energy Efficiency

- Fuel consumption optimization based on driver profile.
- Design of information systems (HMI).

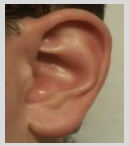


Comfort

Vibration

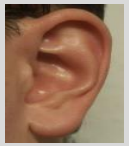
Acoustics

Climatic



Active Safety

- Design of alert and recommendatory systems ADAS.
- Interaction wit autonomous systems.



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Vehicle dynamics attributes and their target conflicts

Cognitive hierarchy model based on Rasmussen

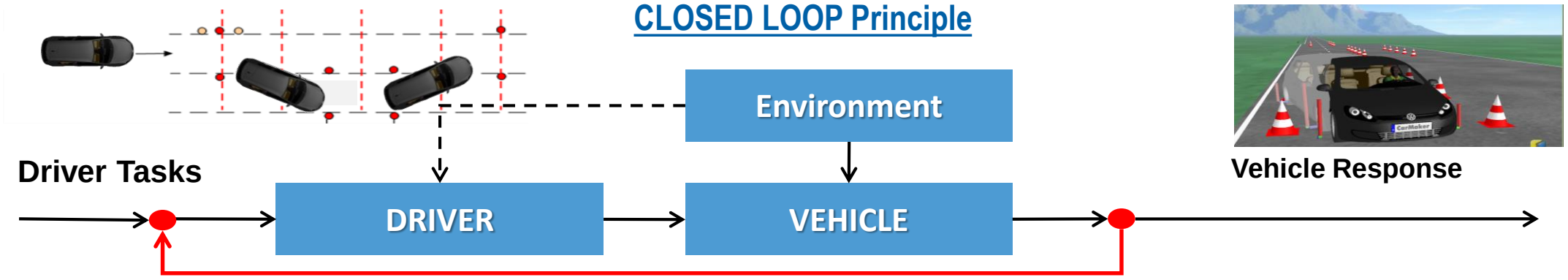
Three-Level-Model of vehicle control (Edmund Donges, 1976)	Target oriented behavior of the human (Jens Rasmussen, 1983)	Discretization
Navigation Level  Possible routes ↓ Selected routes chronological sequence.	Knowledge base behavior	**Minutes up to hours** (before drive or during driving interupts)
Course Control Level  ^Area safe command variables ↓ Performance indicators, target tracking, target speed	**Control based behavior**	**1s up to 10s**
Stabilization Level  Dynamical vehicle reaction. ↓ Actual track, actual speed.	**Skill based behavior**	**Smaller as 1s** (often assumed as continuously)

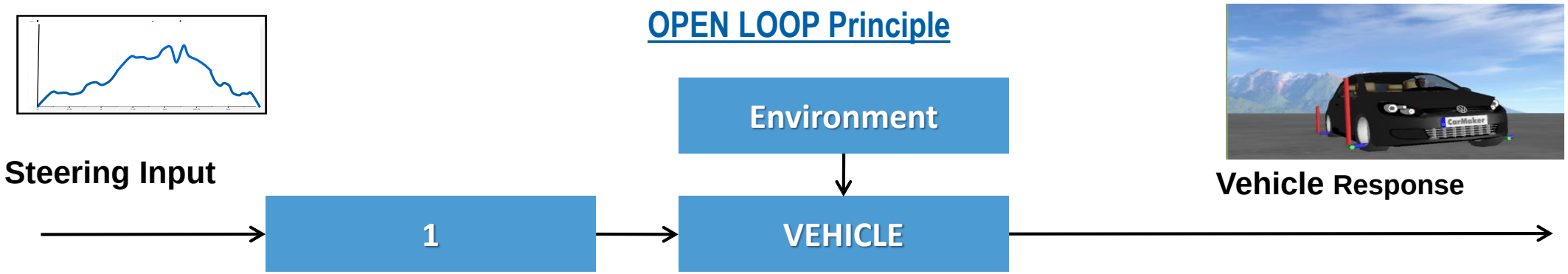
Vehicle dynamics attributes and their target conflicts

Transfer to everyday situations in closed loop

	Vehicle Longitudinal control	Vehicle Lateral control
Typical maneuver	• Following driving. • Free travel. • Brake maneuver.	• Corning driving. • Lane change maneuver. • Turn-off maneuver.
Control variable	• Distance *(*Following driving*, brake).* • Speed *(*free travel*).* • Acc-/Deceleration.	• curvature of the vehicle trajectory. • Lateral deviation of the target curve • Yaw error • Lateral distance
Actuating variable	 	

Open and Closed Loop Principle

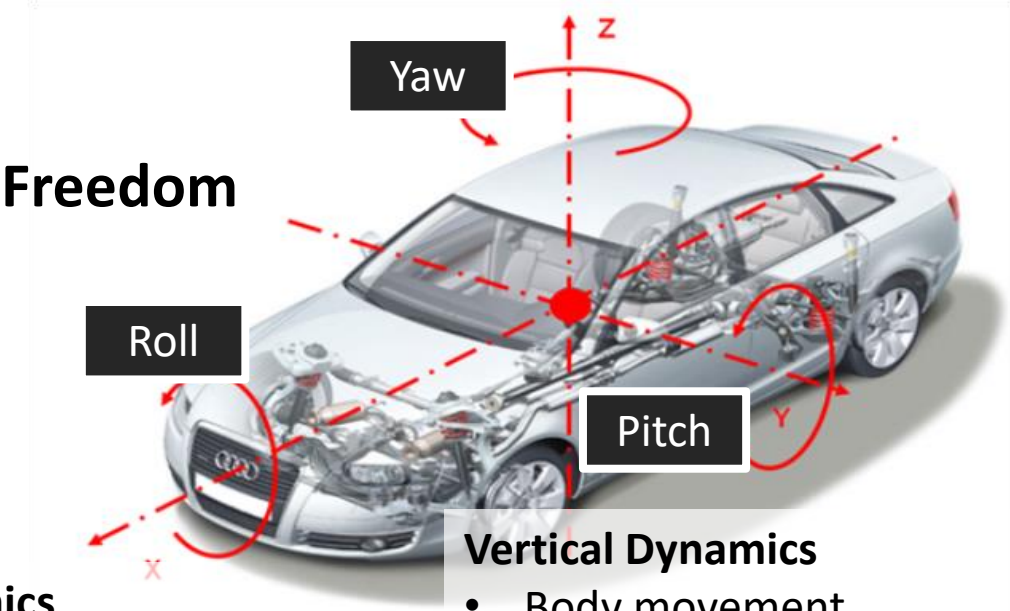




Vehicle dynamics attributes and their target conflicts

What is vehicle dynamics? It describes the full vehicle motion dynamics.

6 DOF - Degree of Freedom



Longitudinal Dynamics
- Driving Resistance
- Acceleration behavior
- Braking behavior

Vertical Dynamics
- Body movement
  - Primary Ride
  - Secondary Ride
- Body acceleration
  - Harshness
  - Vibration
- Wheel Load Oscillation

Lateral Dynamics
- Stationary behavior
- Transient behavior
- Steering behavior

Vehicle dynamics attributes and their target conflicts

Main vehicle characteristics behavior

Longitudinal Dynamics: Drivability Behavior

Descriptions the longitudinal vehicle behavior and performance which results due to driver control input of acceleration, speed and shifting.

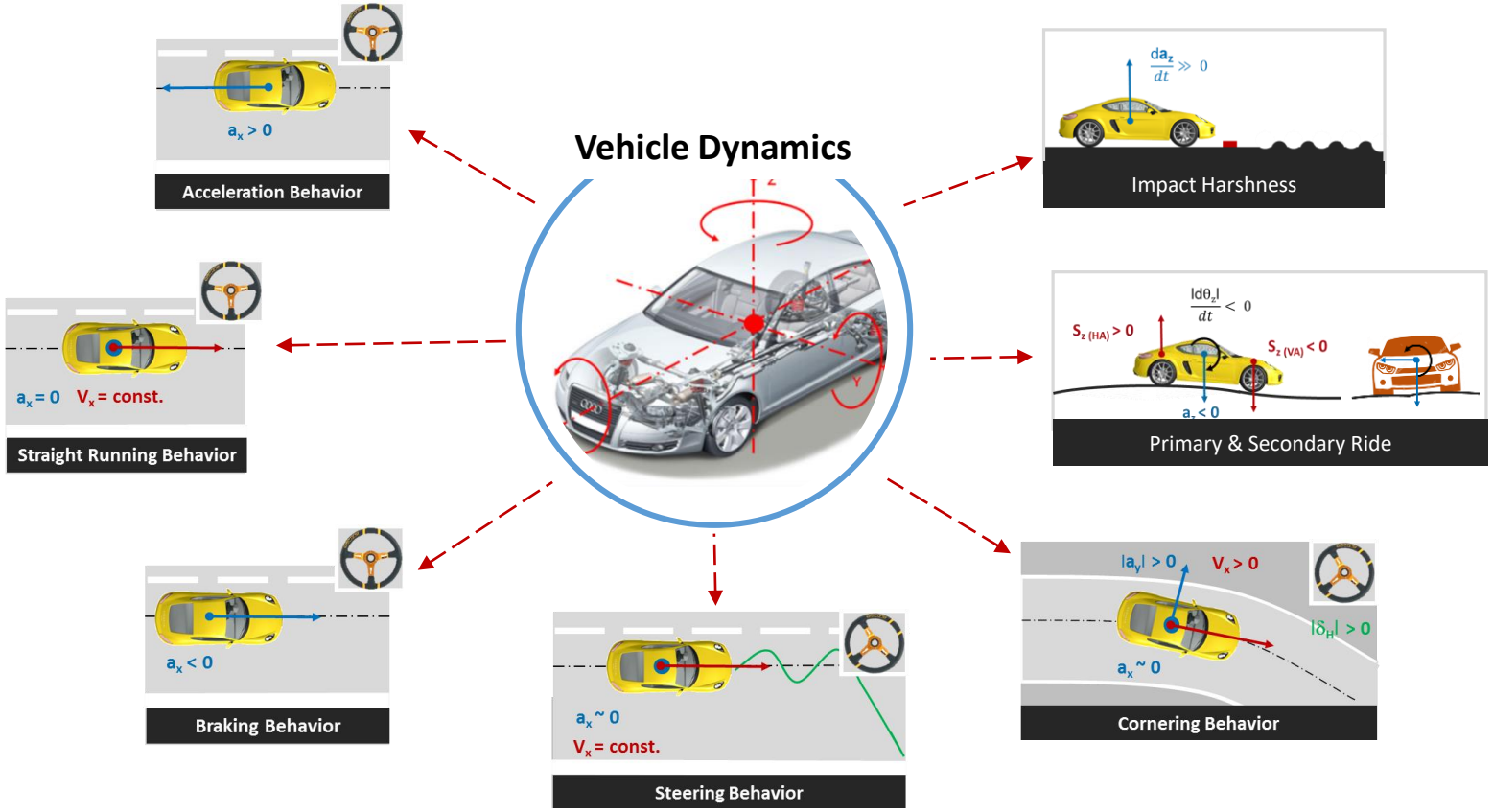
Lateral Dynamics: Handling and Agility Behavior

Descriptions of the way vehicles perform transverse to their direction of motion, particularly during cornering and swerving. It also includes their stability when moving in steady state as well as in transient conditions. Vehicle dynamics are one major component of a vehicle's "active" safety.

Vertical Dynamics: Ride & Comfort Behavior

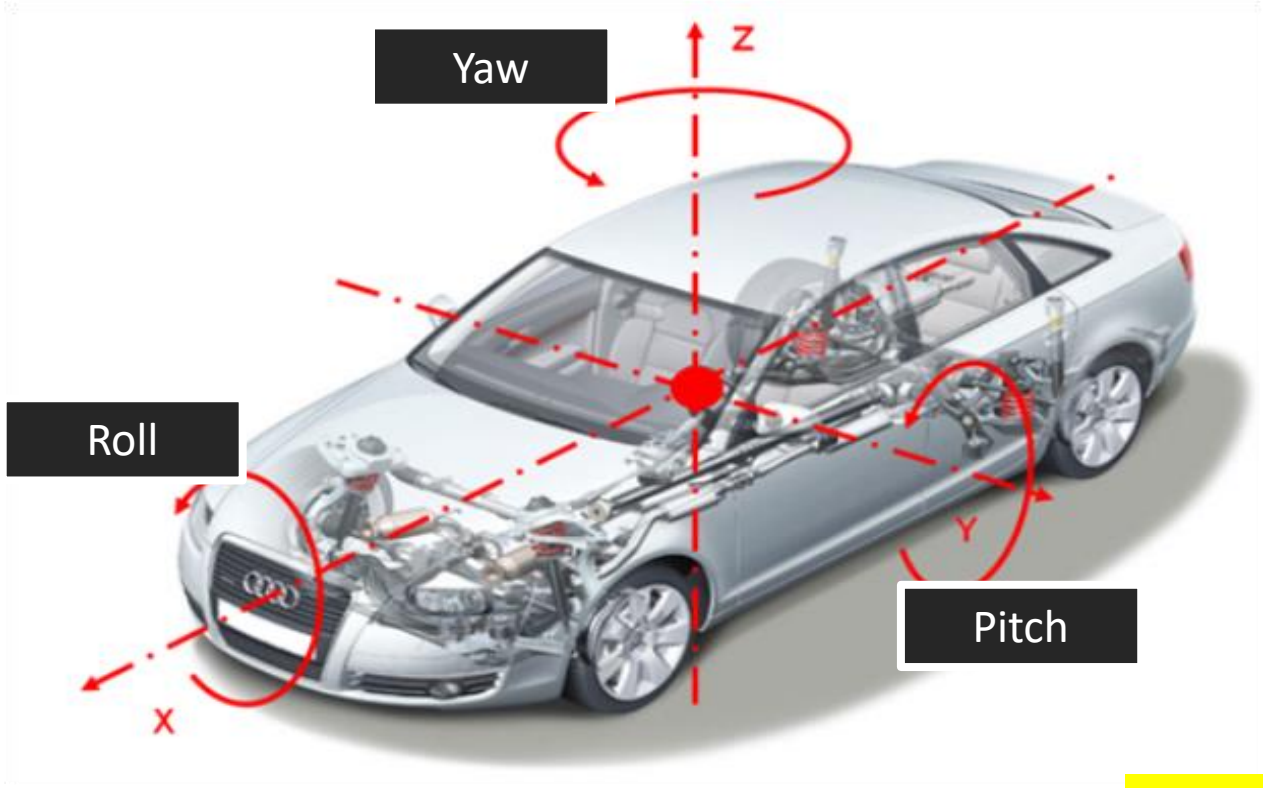
Descriptions annoying driver or passenger impact dynamic due to driver effort, road excitation and vehicle vibrations, which negative influence the work load, effort, comfort feeling and healthiness.

Different groups of ride & handling behavior



Vehicle dynamics attributes and their target conflicts

Analysis of drivers input



Most relevant

Analysis of Driver Input /Wish (Steering, Braking …)

Steer Angle (SWA) δ_H
Steer Moment (SWT) M_H

Brake Force F_{BP}

Gas & Clutch Position, Gear

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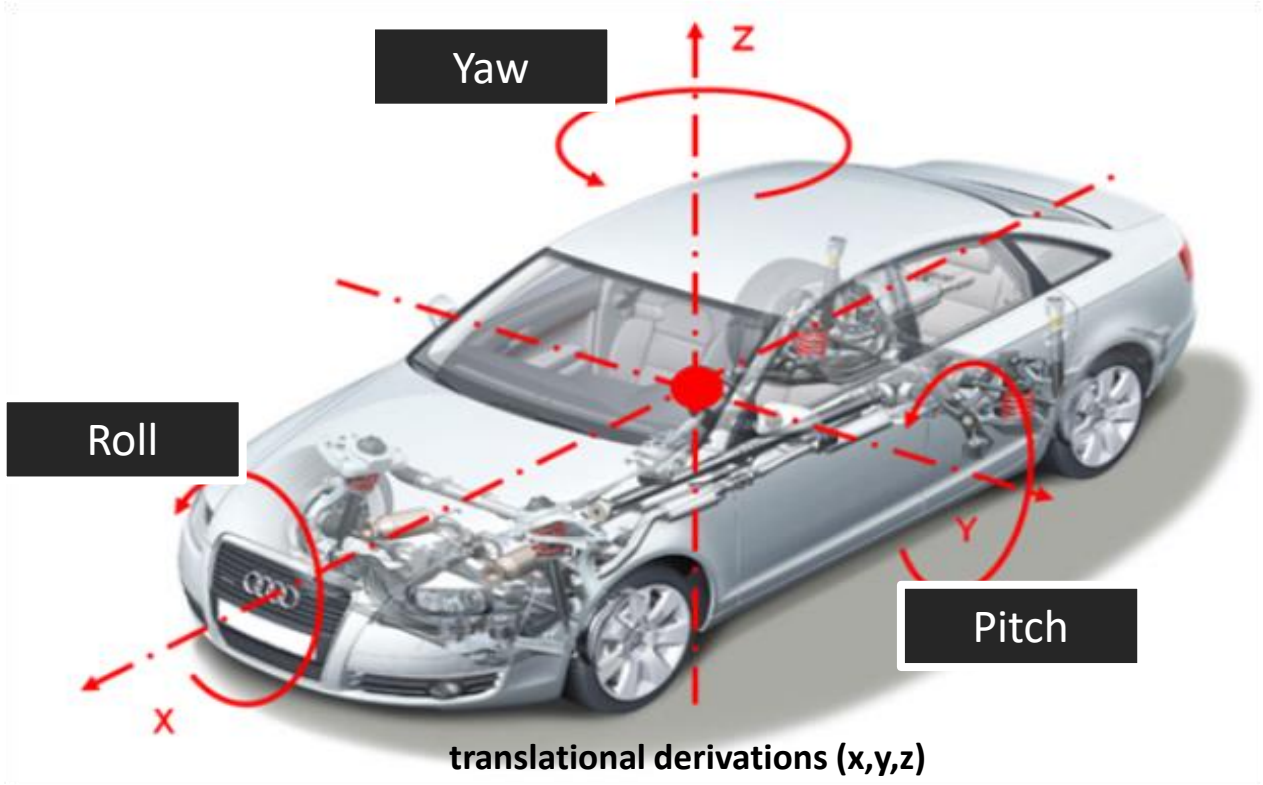
Analysis of Vehicle Response

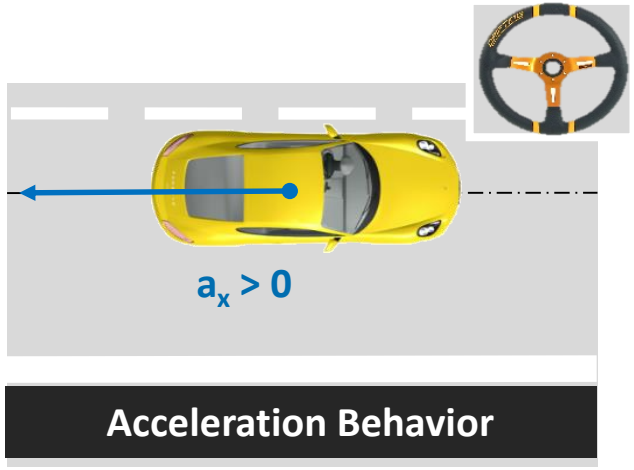


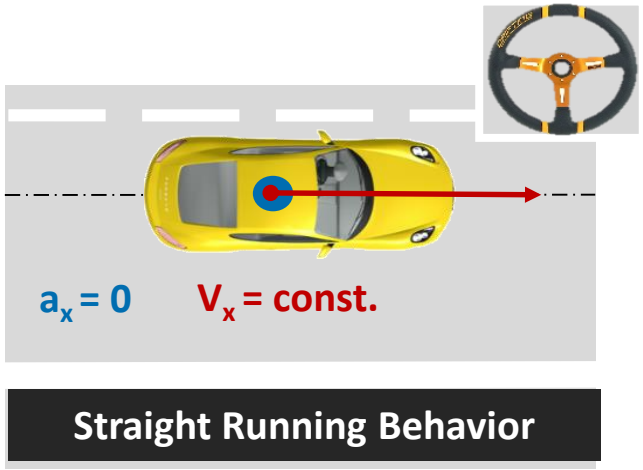
translational derivations (x,y,z)
rotatory derivations (x,y,z)
of vehicle body

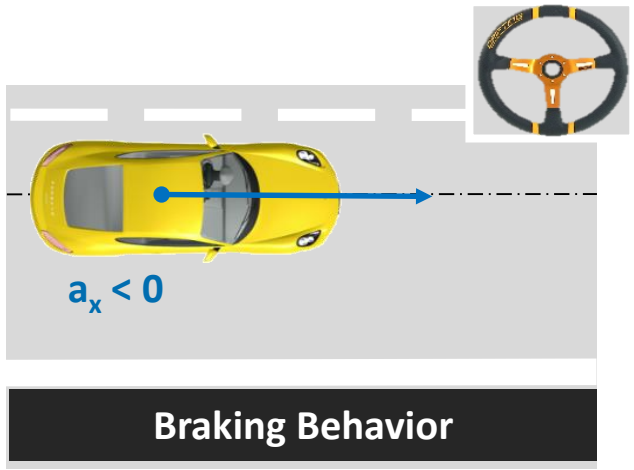
Most relevant

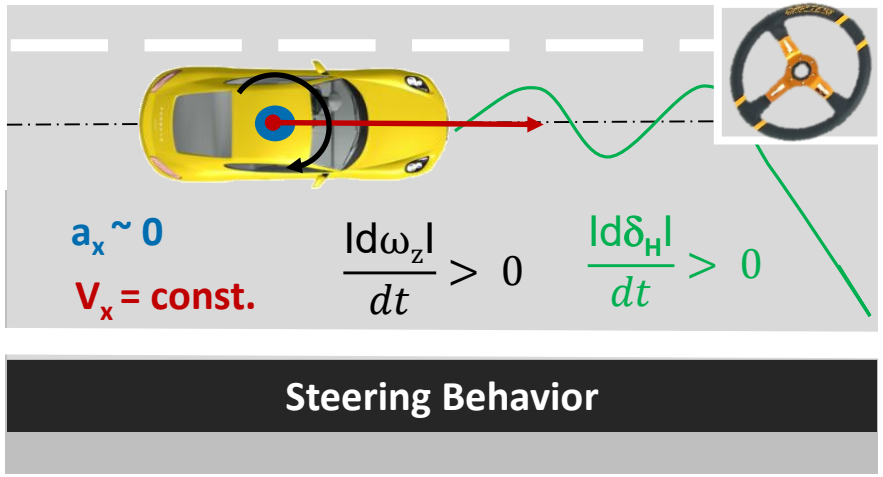
- Roll Angel φ (Vehicle Rotation x-Axle)
- Pitch Angle θ (Vehicle Rotation y-Axle)
- Yaw rate dψ / dt (Vehicle Rotation z-Axle)
- Longitudinal acceleration a_x
- Lateral acceleration a_y
- Vertical acceleration a_z
- Longitudinal velocity V_x
- Lateral velocity V_y
- Drift Angle $\beta = -\arctan V_y / V_x$
- Position x,y,z

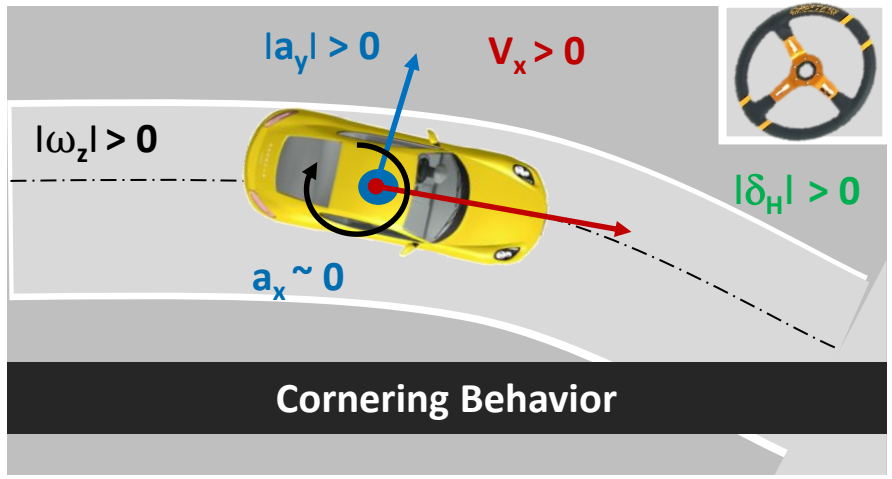
Lateral Dynamics: Handling and Agility Behavior



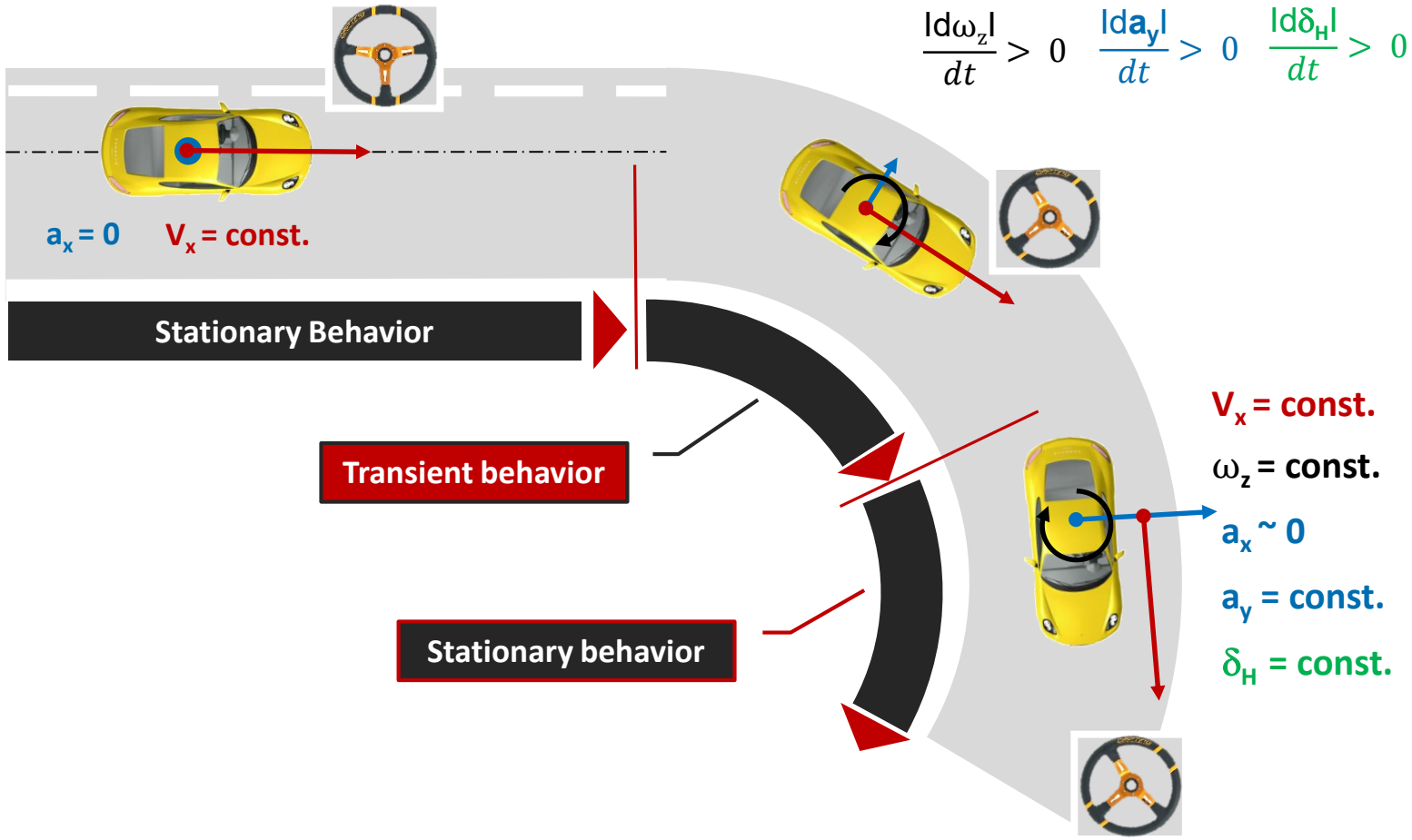






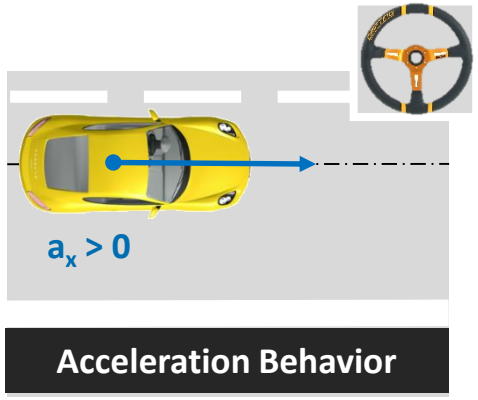


Lateral Dynamics: Stationary and transient behavior

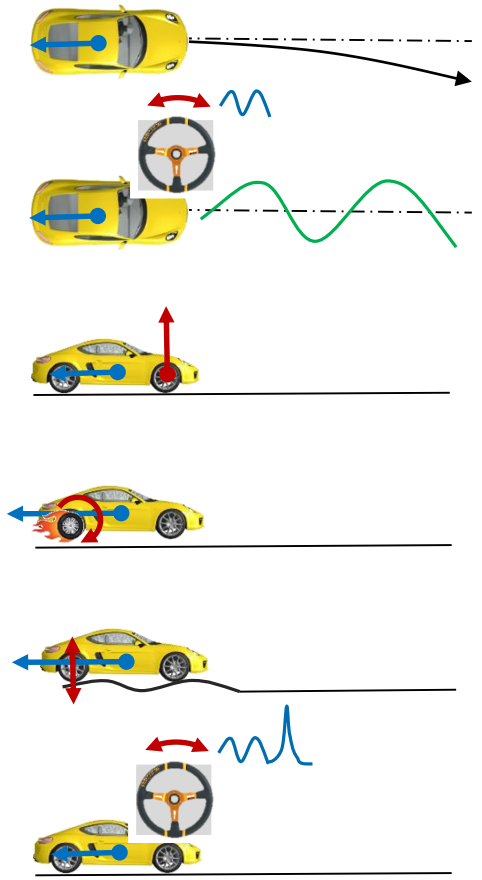


Vehicle dynamics attributes and their target conflicts

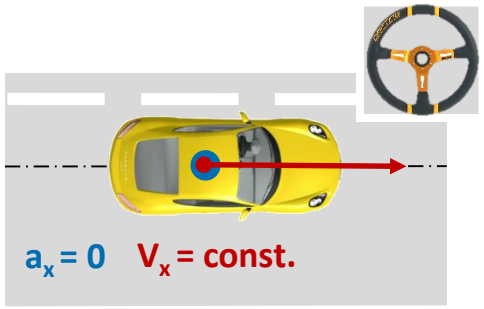
Acceleration Behavior



- Steering drift
- Start swing
- Start retracting
- Traction
- Wheel hopping
- Steering wheel reaction

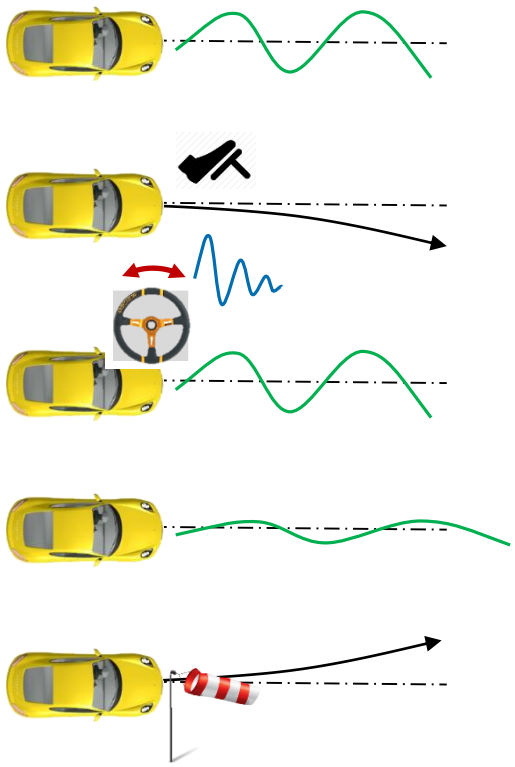


Straight Running Behavior



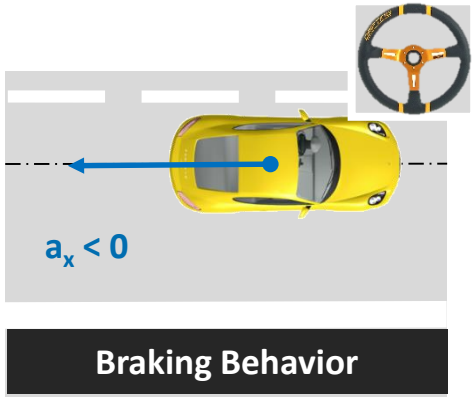
Straight Running Behavior

- Stability even road
- Power-off reaction
- Steering swing
- Self-steering
- Cross wind behavior

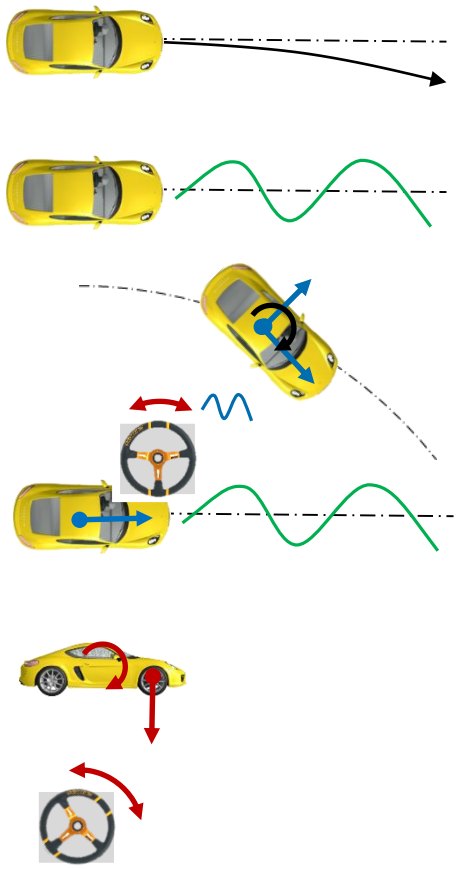


Vehicle dynamics attributes and their target conflicts

Braking Behavior

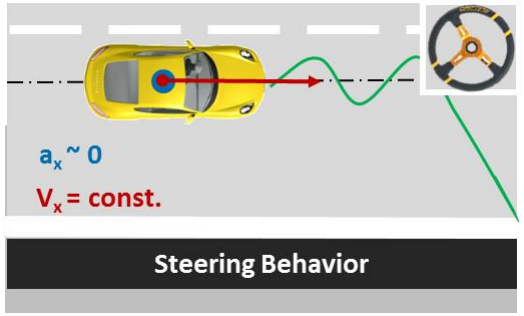


- Brake drift
- Braking stability straight
- Braking behavior cornering
- Braking swing
- Brake pitch
- Steering wheel reactions

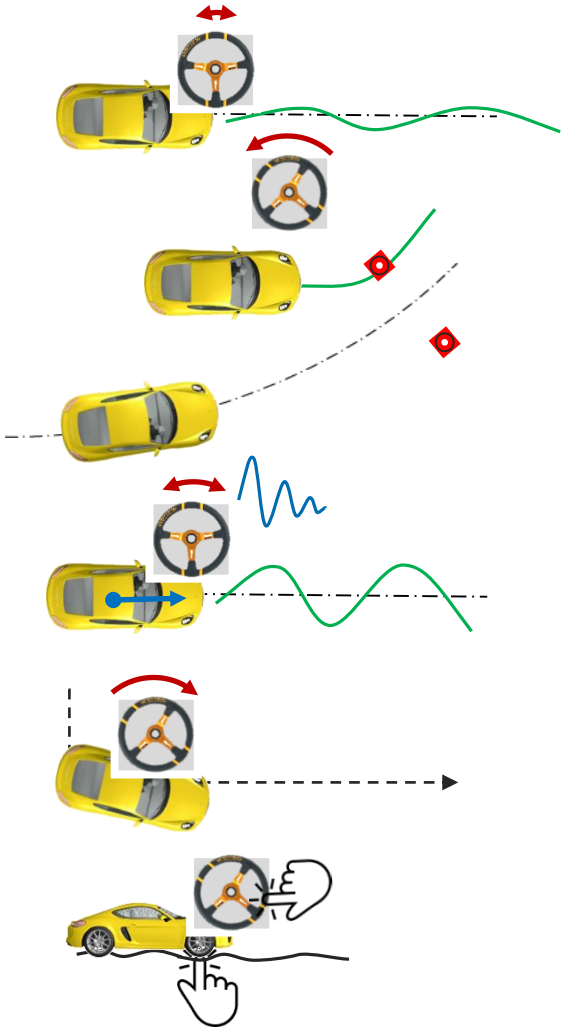


Vehicle dynamics attributes and their target conflicts

Steering Behavior

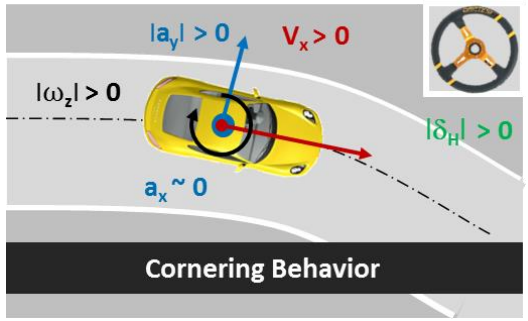


- On-Center Feeling
- Turn in ability
- Precision
- Over-shooting
- Steering wheel return ability
- Road surface contact

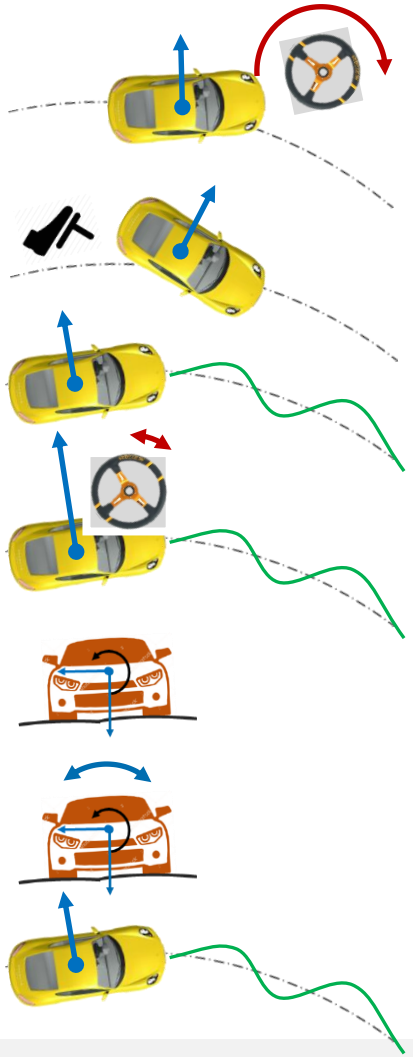


Vehicle dynamics attributes and their target conflicts

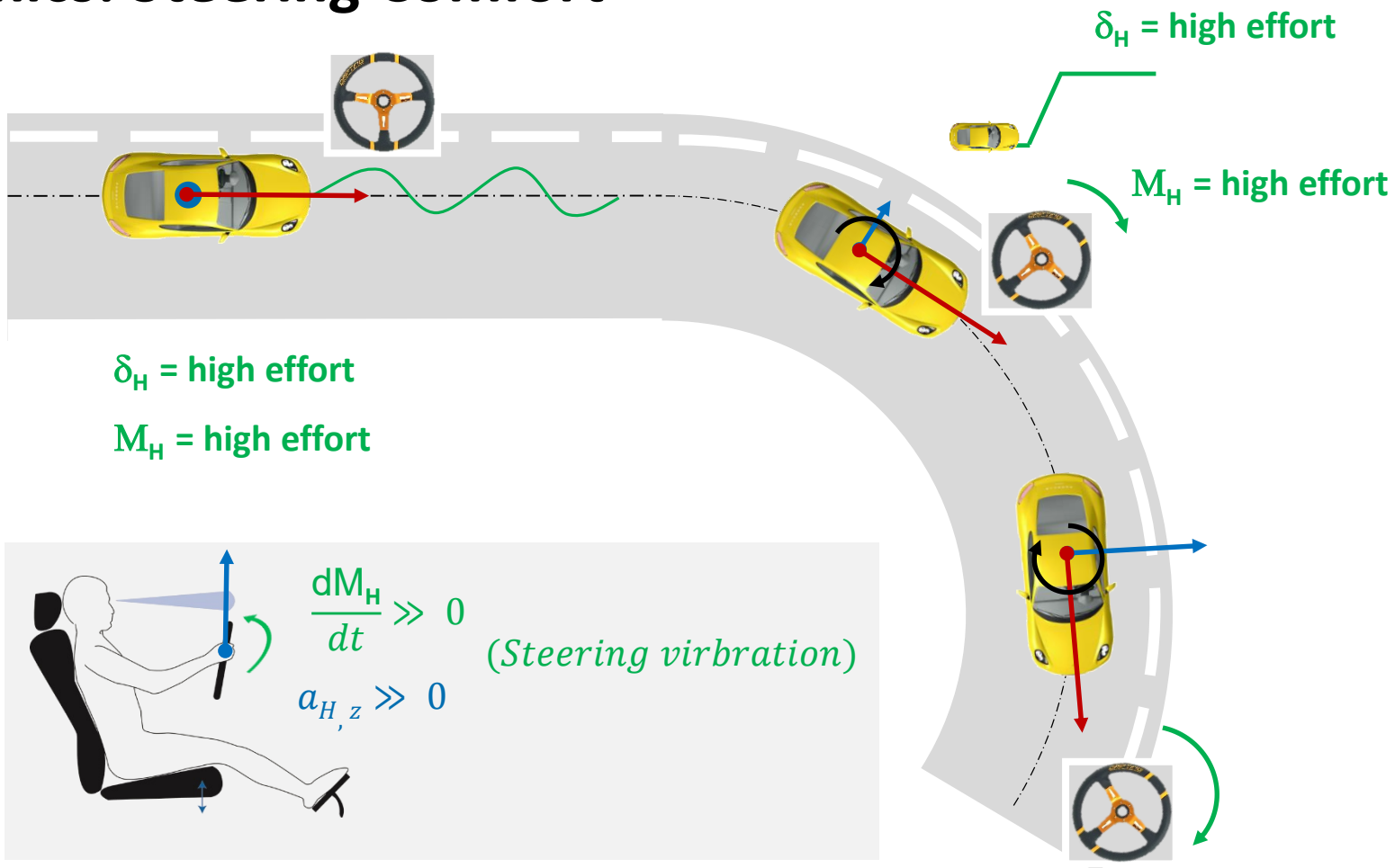
Cornering Behavior



- Understeering behavior
- Power-off reaction
- Tracking stability
- Controllability at the limit
- Absolute roll angle
- Rolling behavior
- Self steering during cornering



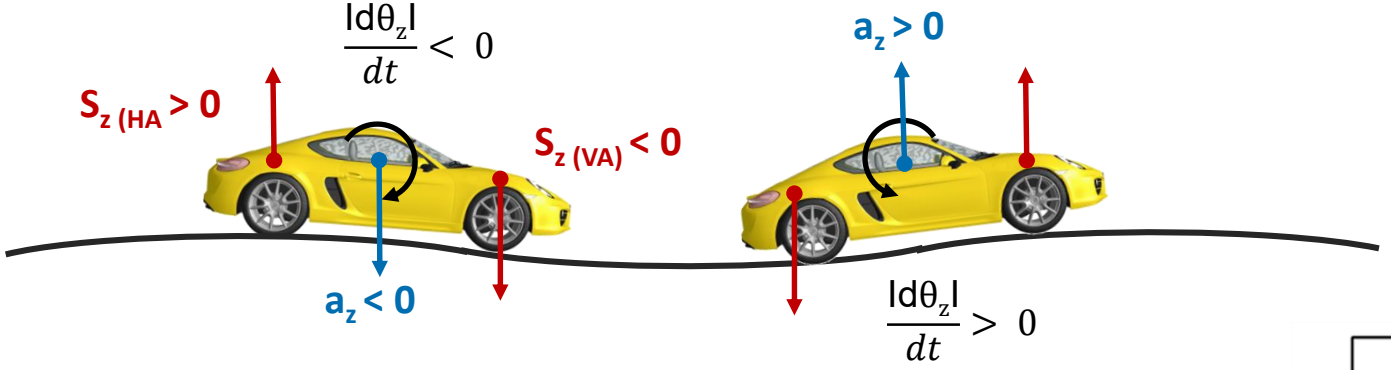
Lateral Dynamics: Steering Comfort



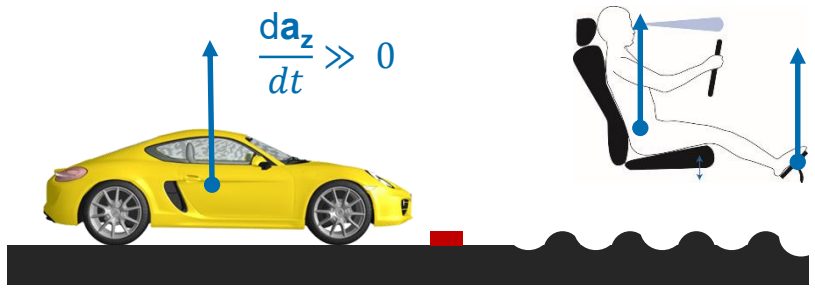
Vehicle dynamics attributes and their target conflicts

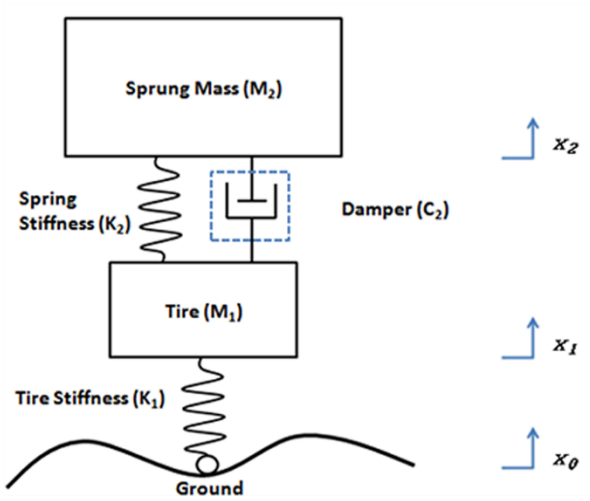
Vertical Dynamics: Ride & Comfort Behavior

Body Movement (Primary & Secondary Ride)



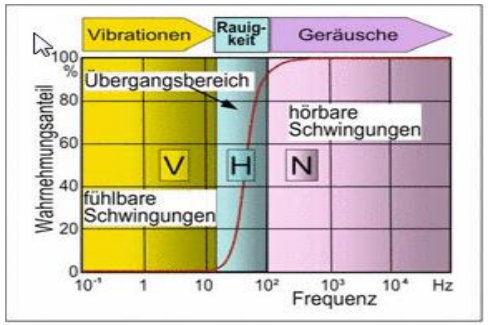
Body acceleration (Harshness, Vibration)





Vehicle dynamics attributes and their target conflicts

Open and Closed Loop Principle



Power off reaction

Brake Jitter

Powertrain noise

Bouncing

Tire roll noise

Steering Vibration

Jitter

Freeway Hop

Axle Osc.

Roaring

Body Movement / Oscillation

Shake

Axle harshness

Primary Ride

Secondary Ride

Harshness

Noise

Vibration

1 2 4 8 16 32 64 128 256 512 Hz

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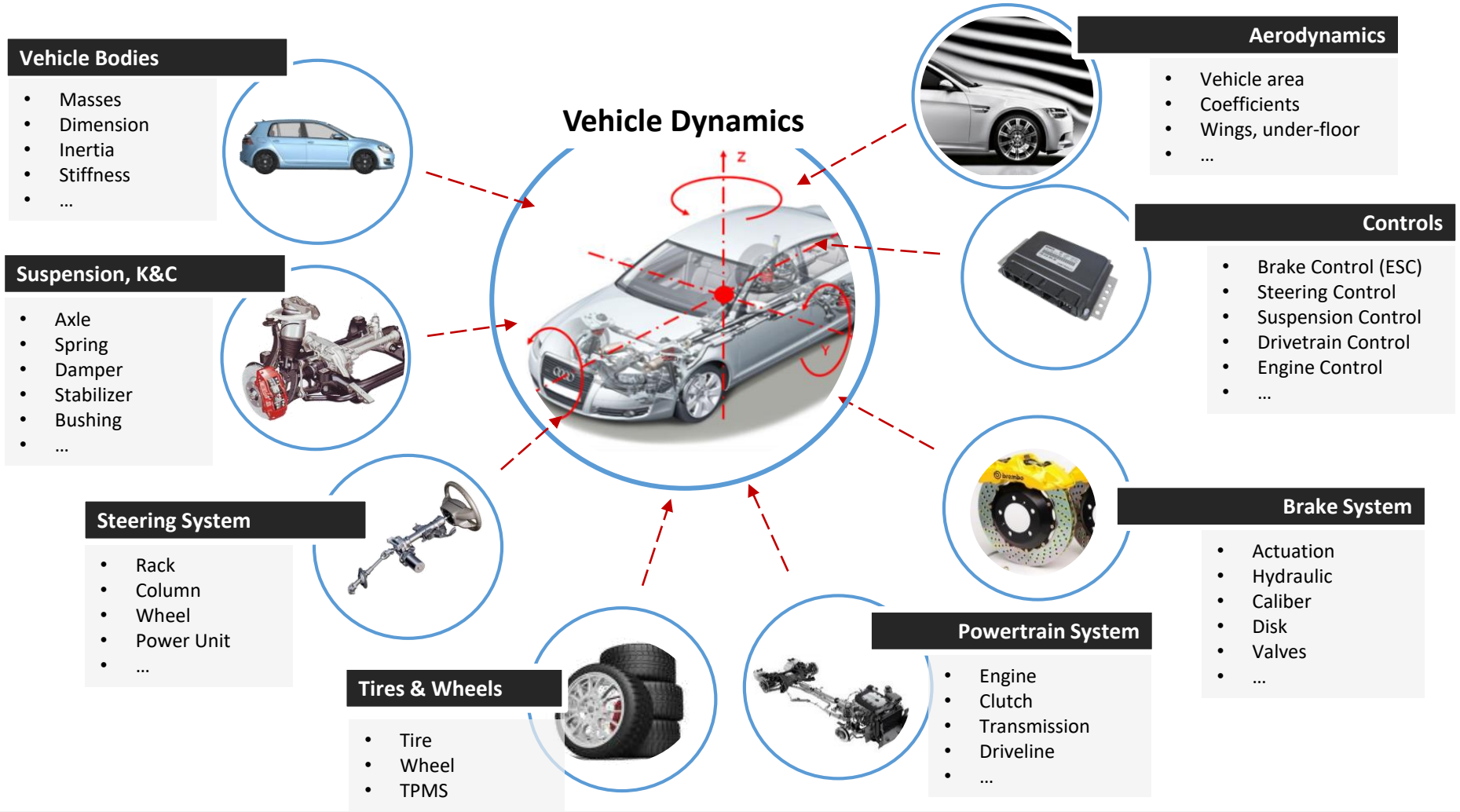
Vehicle dynamics attributes and their target conflicts

Vehicle dynamics behavior is impact by numerous components

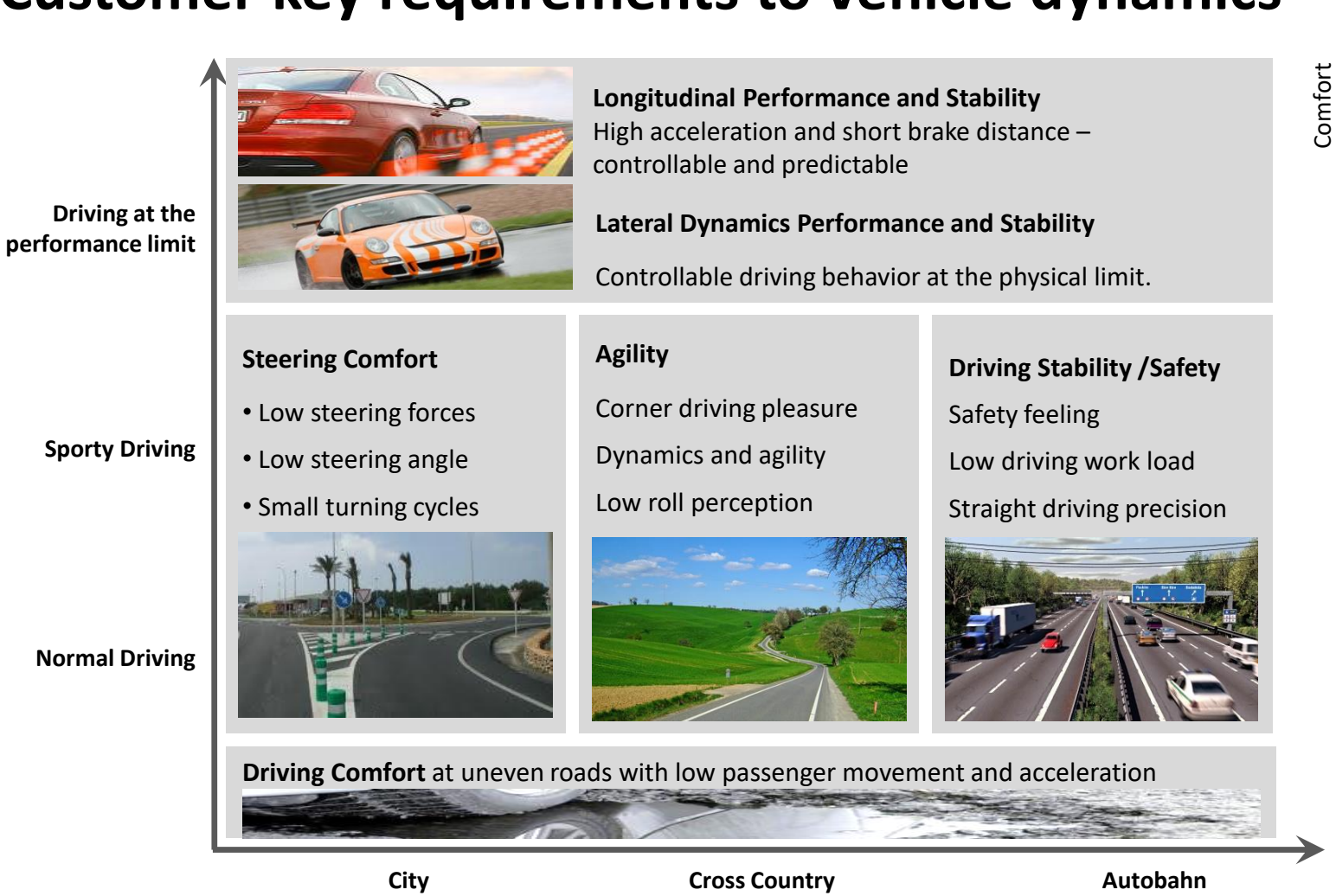


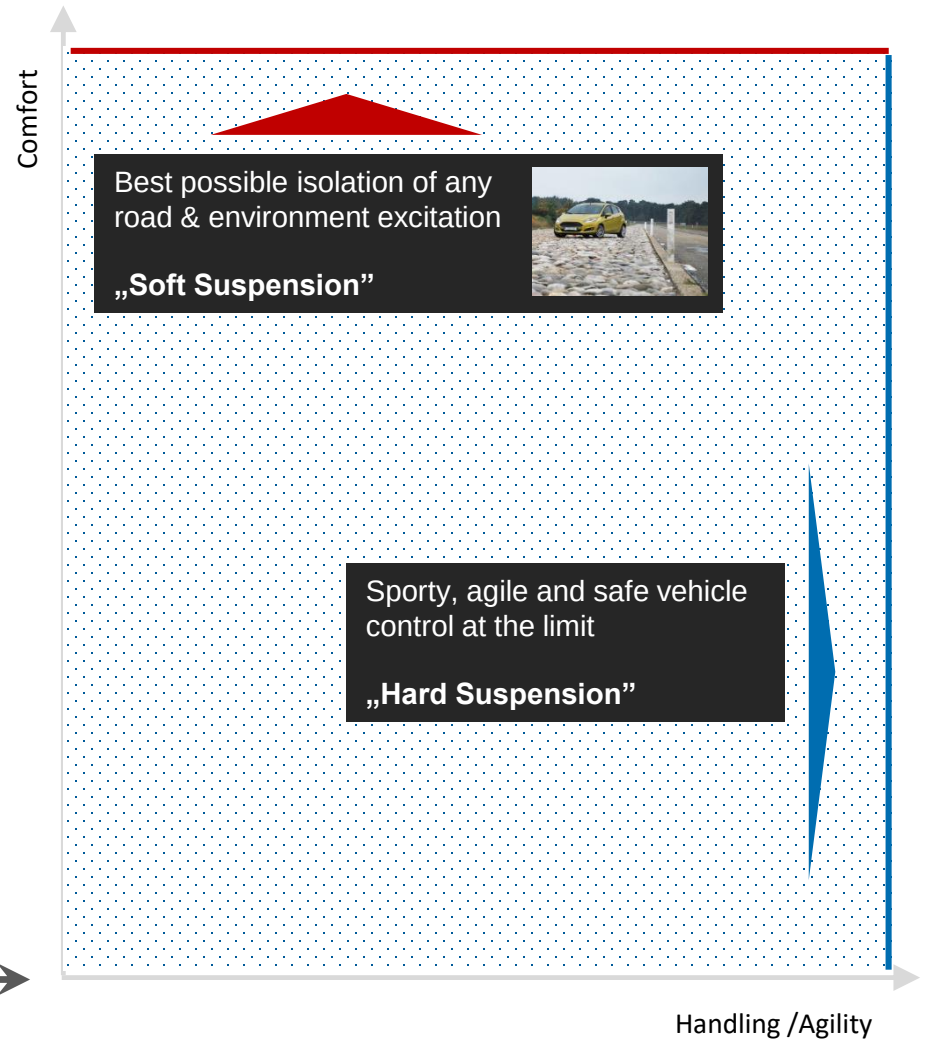
Vehicle dynamics attributes and their target conflicts

Performance	The accomplishment of a given task measured against preset known standards of accuracy, completeness, costs, acceleration and speed.
Agility	Agility is the ability to change the direction of the vehicle based on drivers steering input.
Stability	The vehicle ability of being enduring on the driver given path and free from non-desirable change or variation.
Comfort	Descriptions annoying driver or passenger impact dynamic due to driver effort, road excitation and vehicle vibrations, which negative influence the work load, driver effort, comfort feeling and healthiness.
Safety	Safety is the condition of being protected against physical, social, spiritual, financial, political, emotional, occupational, psychological, educational or other types or consequences of failure, damage, error, accidents, harm or any other event which could be considered non-desirable.

Vehicle dynamics attributes and their target conflicts

Customer key requirements to vehicle dynamics





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Vehicle dynamics attributes and their target conflicts

Which target conflicts do you know?