Hochschule Kempten
University of Applied Sciences

drive livinglab

ADAS Master WS 20/21
Lecture 3

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
1	**01.10.**	**Virtual Test Driving (VTD)** **CarMaker Quick Start Guide**	**T314**	**Self-study**
2	08.10.	Requirements for vehicles and their global attributes	T314 Zoom	Schick
3	15.10.	Vehicle dynamics attributes and their target conflicts	T314 Zoom	Schick
3	22.10.	Test and evaluation methods for vehicle attributes (1) **with practical simulation**	T314 Zoom	Schick
4	29.10.	Test and evaluation methods for vehicle attributes (2) **with practical simulation**	T314 Zoom	Schick
5	**05.11.**	**ADAS DRIVING EVENT** Measurement Tech. Introductions	**Living Lab**	Günther/Riedlmüller/ Schwandke
6	12.11.	Basic vehicle dynamics calculation and vehicle models with exercise	T314 Zoom	Schick
7	**19.11.**	Chassis components and functions (1) Tire & Wheels	T314 Zoom	Schick
8	26.11.	Chassis components and functions (2) Axle & Suspension	T314 Zoom	Schick
9	03.12.	**TEND: ADAS Development for a sports car manufacturer**	T314 Zoom	Manuel Höfer (Porsche)
10	10.12.	Chassis controls and functions (1) Overview & Brakes & Steering	T314 Zoom	Schick
11	17.12.	Chassis controls and functions (2) ESP–Functions & Application & Process	T314 Zoom	Herr Lutz (BOSCH)
12	07.01.	**Chassis controls and functions (3)** **ESP–Application & Hands-On Workshop**	T314 Zoom	Herr Lutz (BOSCH)
13	14.01.	Analysis of international standards and application into the simulation	T314 Zoom	Schick
14	**21.01.**	**Exam preparation**	**T314**	**Schick**


John B. Kennedy reports —
"LOOKING FOR TROUBLE"
-- BEFORE IT LOOKS FOR
YOU, IS ANOTHER BIG JOB
IN THIS ONE INDUSTRY

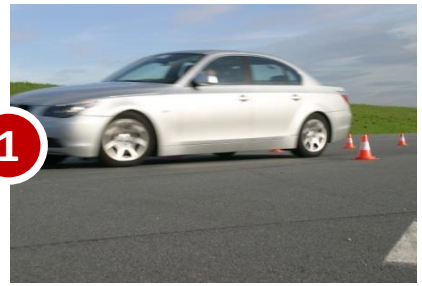
What is a test?

Ein **Test** ist ein Versuch, mit dem Sicherheit darüber gewonnen werden soll, ob ein technischer **Apparat** oder ein **Vorgang** innerhalb der geplanten Rahmenbedingungen **funktioniert** beziehungsweise ob bestimmte **Eigenschaften** vorliegen.

Nachbildung des realen Einsatzes im Fahrversuch, Prüfstand oder Simulation.

Im Allgemeinen **kein Beweis**! Nicht absolut gültig sondern stellt „nur“ eine **Näherung** dar.

Testing and evaluation methods



1

Driving Tests with subjective evaluation of vehicle behaviour → **„Closed Loop“**

Driving Tests with subjective evaluation of vehicle behaviour → **„Open Loop“**

2

Driving Tests with measurement & analysis of vehicle response → **„Closed Loop“**

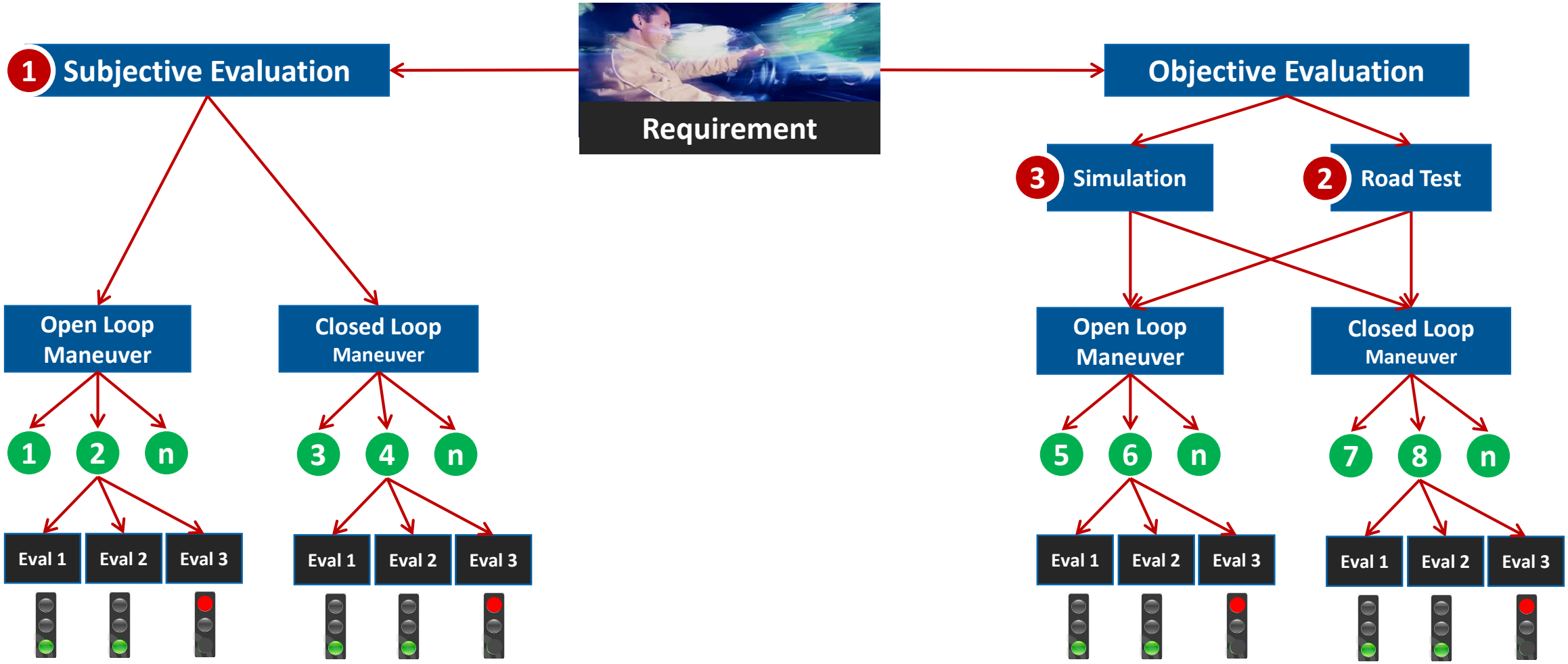
Driving Tests with measurement & analysis of vehicle response → **„Open Loop“**

3

Simulation & analysis of vehicle response →„Closed Loop“

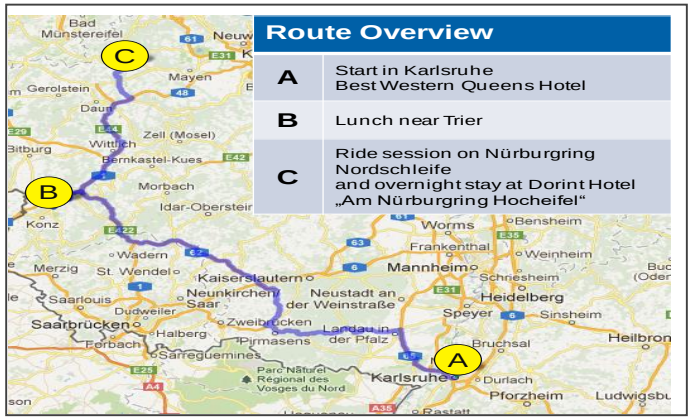
Simulation and analysis of vehicle response → **„Open Loop“**

Summery of testing and evaluation methods



Test and evaluation methods for vehicle attributes

Test tracks for subjective and objective evaluation



Ride session on different public road types

Nürburgring Nordschleife
Handling Performance

Proving Ground
e.g. Bosch Boxberg

- Handling Performance Evaluation
- Ride & Comfort Evaluation
- Acceleration Performance & Drivability Evaluation
- General Impression under Customer Usage

IDIADA China Proving Ground

Typical test modules at a modern proving ground

Off-Road

Off-Road

High-speed oval

Driving-dynamics area

Brake-measurement tracks

Typical test modules at a modern proving ground


Fording and splash water basin


Handling course


Multi-functional area


Rough road tracks

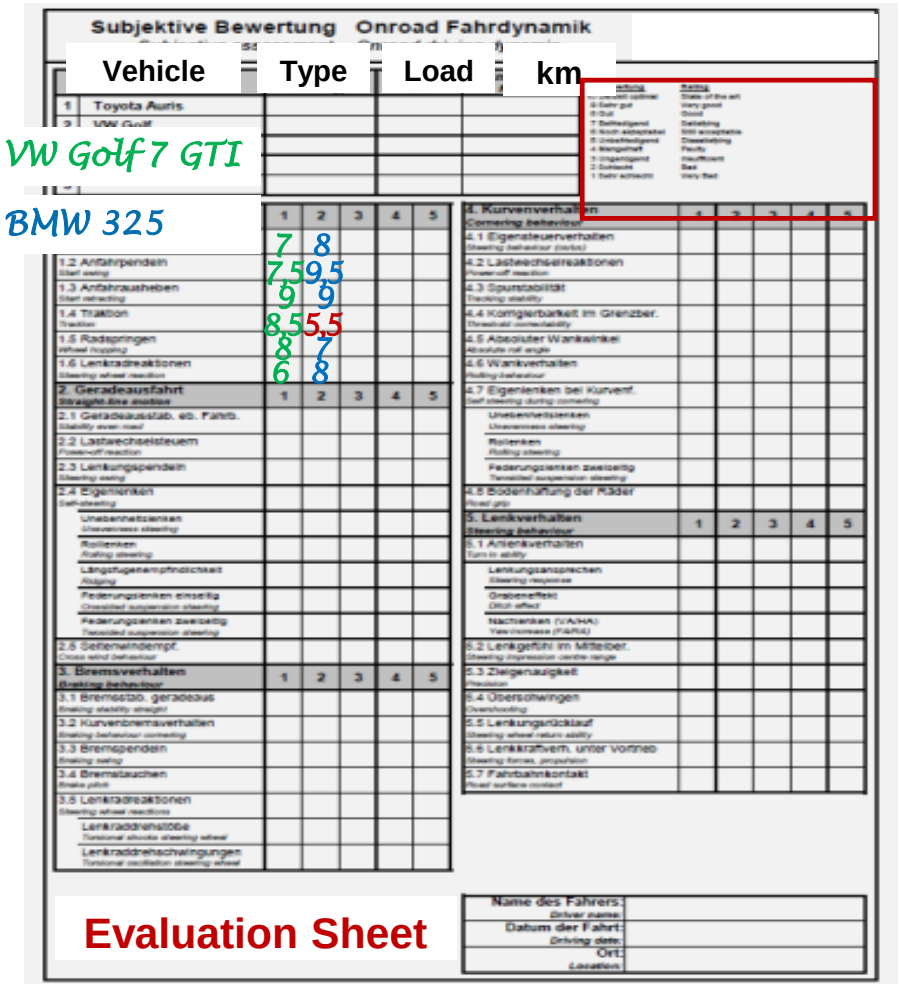

Uphill tracks (5% up to 30%)


ISO noise-measurement track

Nuerburgring the “Green Hell”

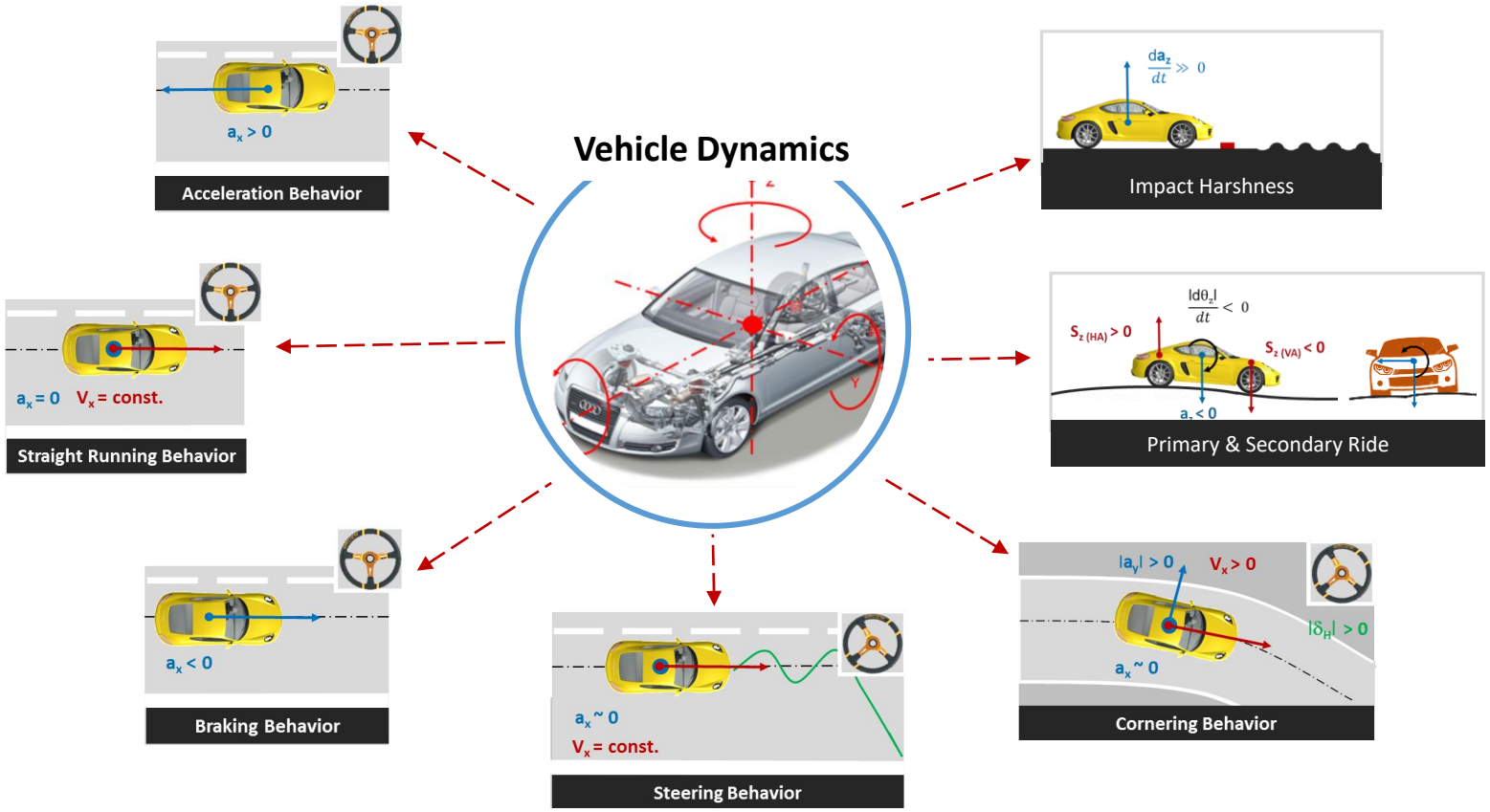
Test and evaluation methods for vehicle attributes

Subjective (quasi-objective) evaluation methods

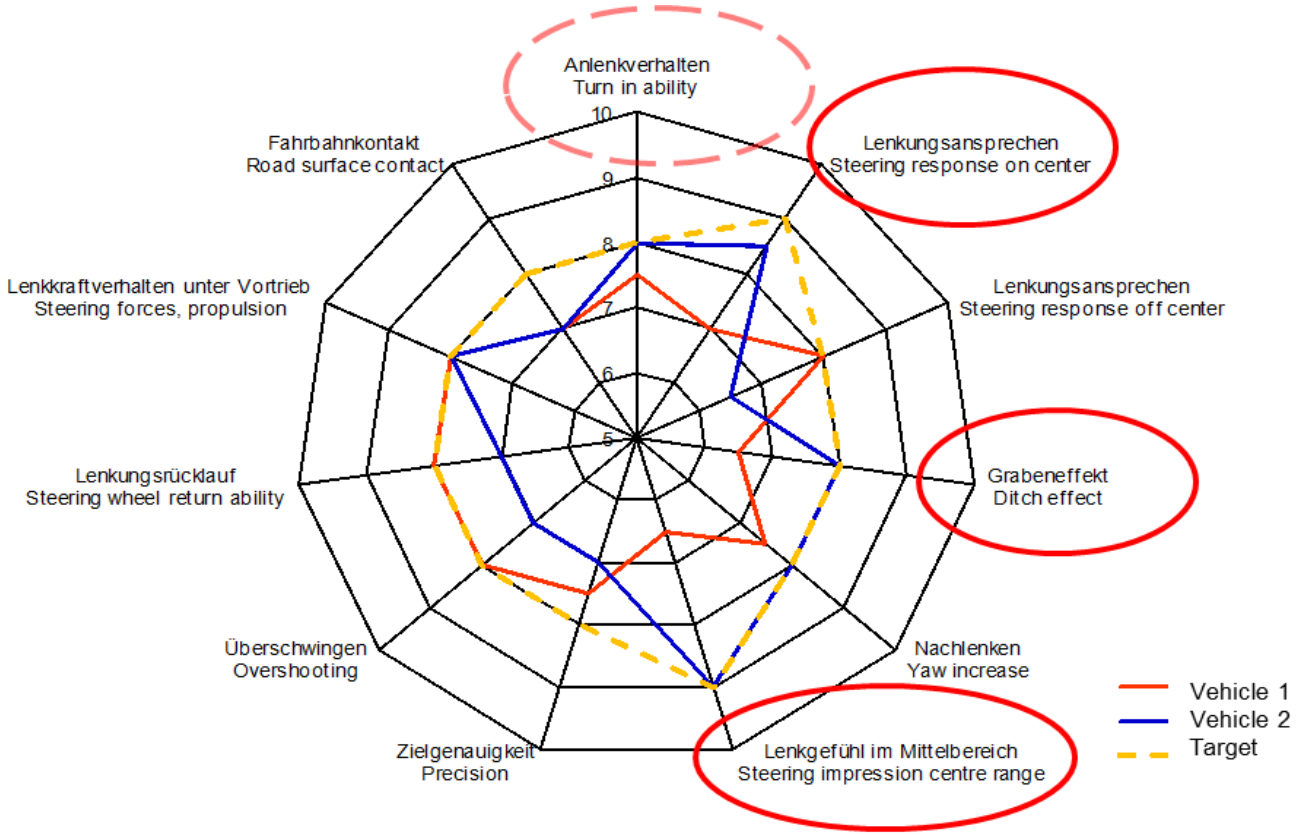


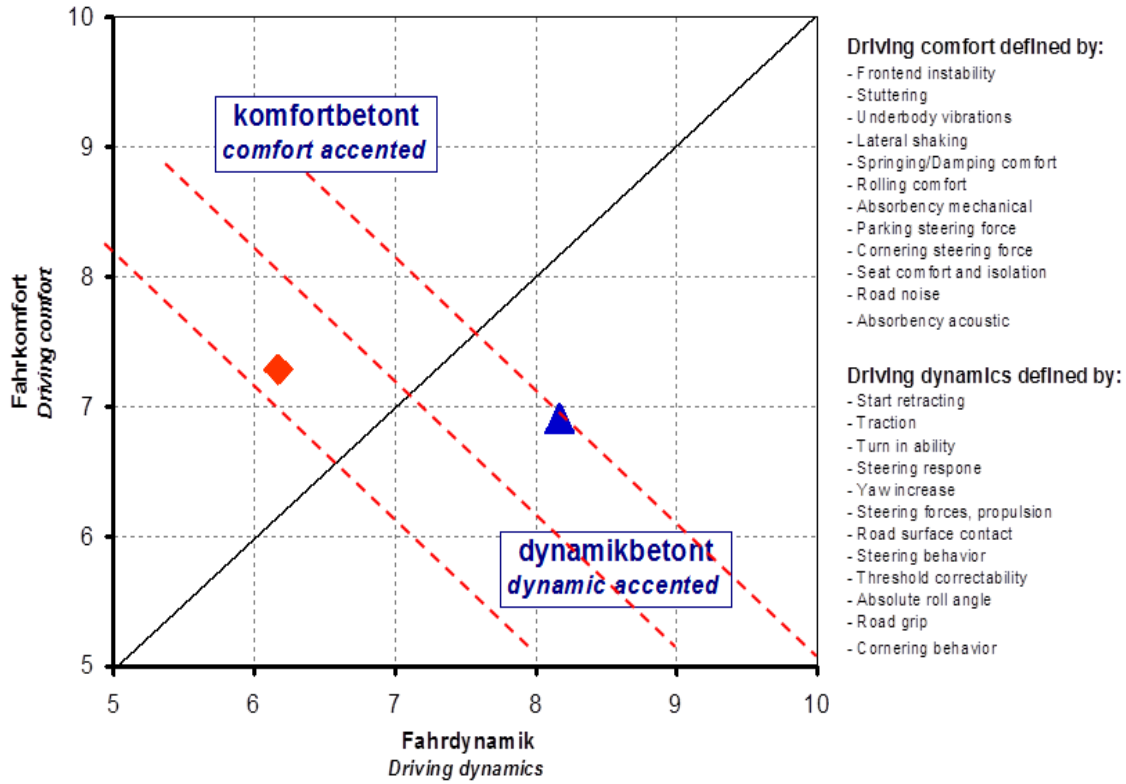
	Bewertung	Beobachter/Mängel
10	Derzeit optimal *(state of the art)*	von Experten nicht wahrnehmbar
9	Sehr gut	von Experten kaum wahrnehmbar
8	Gut	von Experten äußerst gering wahrnehmbar
7	Befriedigend	von kritischem Kunden gering wahrnehmbar
6	Noch akzeptabel	von kritischem Kunden wahrnehmbar
5	Unbefriedigend	von Normalkunden gut wahrnehmbar
		GRENZFALL
4	Mangelhaft	für Normalkunden unangenehm (Reklamation)
3	Ungenügend	für keinen Kunden akzeptabel (Bauteil fehlerh.)
2	Schlecht	für keinen Kunden akzeptabel (bedingte Funk.)
1	Sehr schlecht *(very bad)*	für keinen Kunden akzeptabel (ohne Funktion)

Typical subjective evaluation groups for vehicle dynamics



Subjective Identification of Weaknesses and Positioning



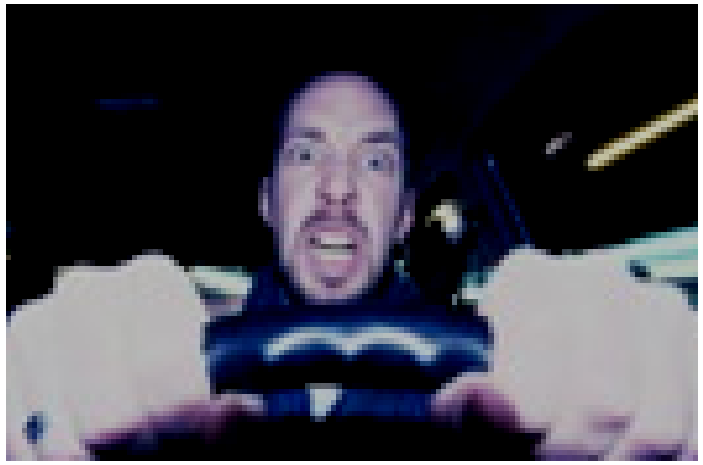


Vehicle test and objective evaluation: Working space vehicle

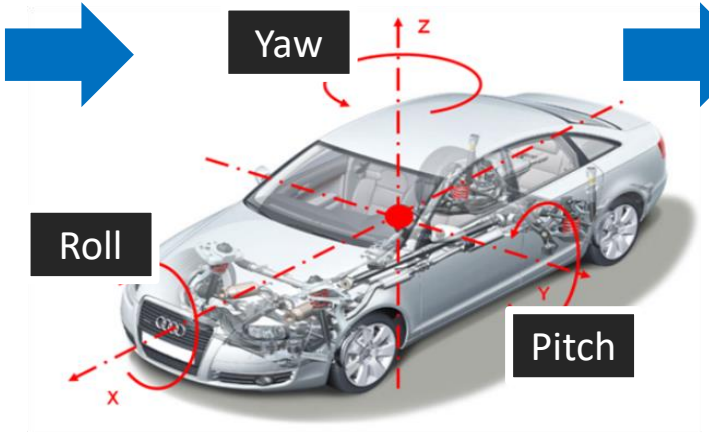
Vehicle dynamics attributes and their target conflicts

Objective Measurement is based on the drivers input and vehicle response

Drivers Input



Steer Angle (SWA)	δ
Steer Moment (SWT)	M
Brake Force	F^{BP}
Gas & Clutch Position, Gear	

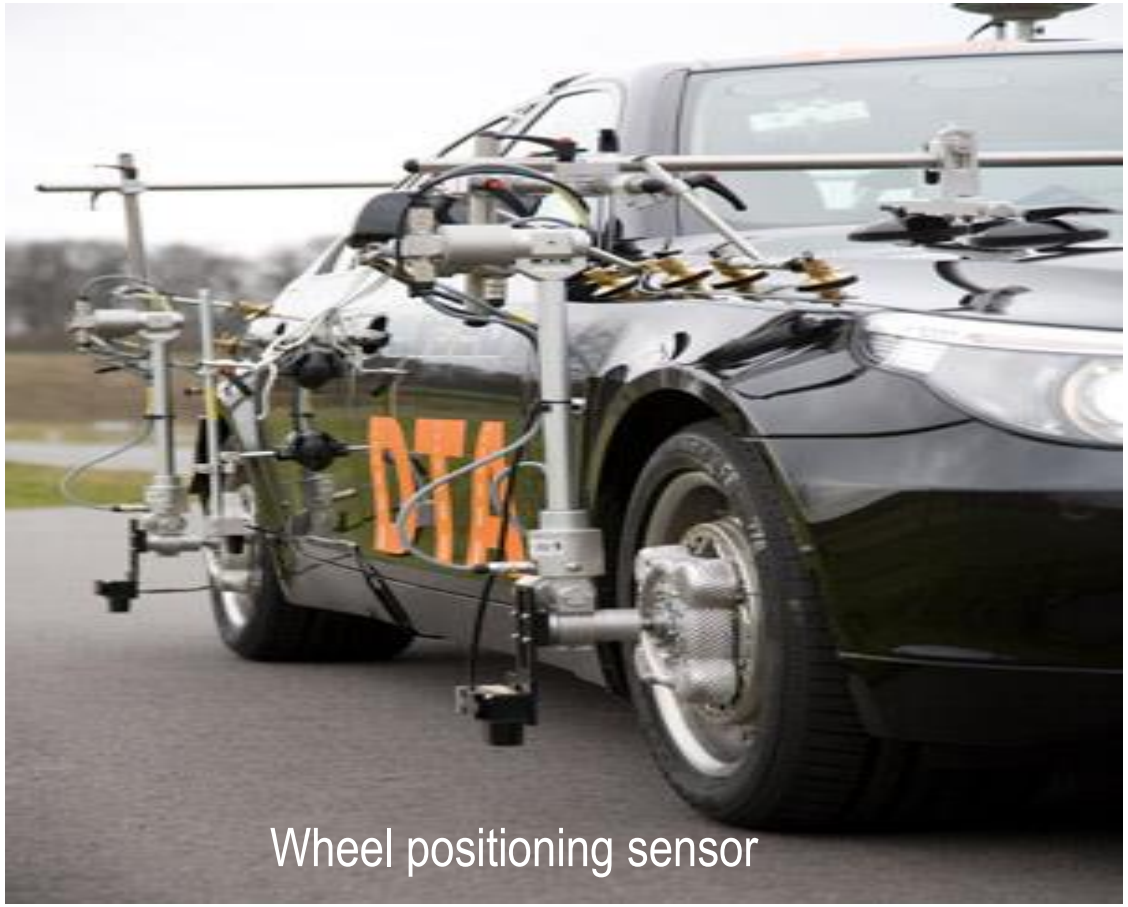


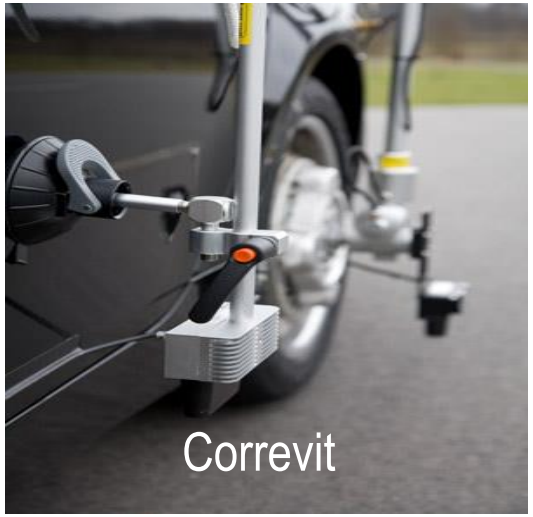
Most relevant

Vehicle Response

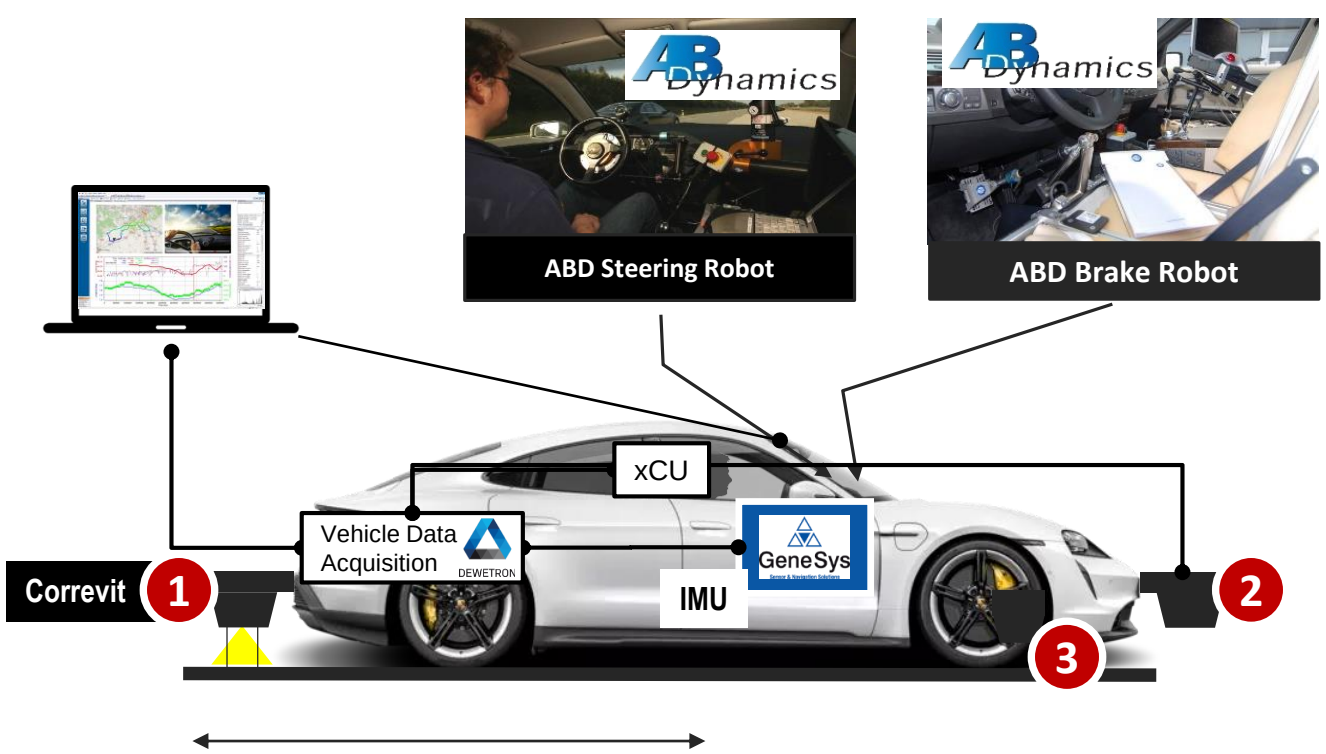
Roll Angel φ (Vehicle Rotation x-Axle)
Pitch Angle θ (Vehicle Rotation y-Axle)
Yaw rate dψ / dt (Vehicle Rotation z-Axle)
Longitudinal acceleration a_x
Lateral acceleration a_y
Vertical acceleration a_z
Longitudinal velocity V_x
Lateral velocity V_y
Drift Angle $\beta = -\arctan V_y / V_x$
Position x,y,z

Objective evaluation methods with vehicle dynamics measurement

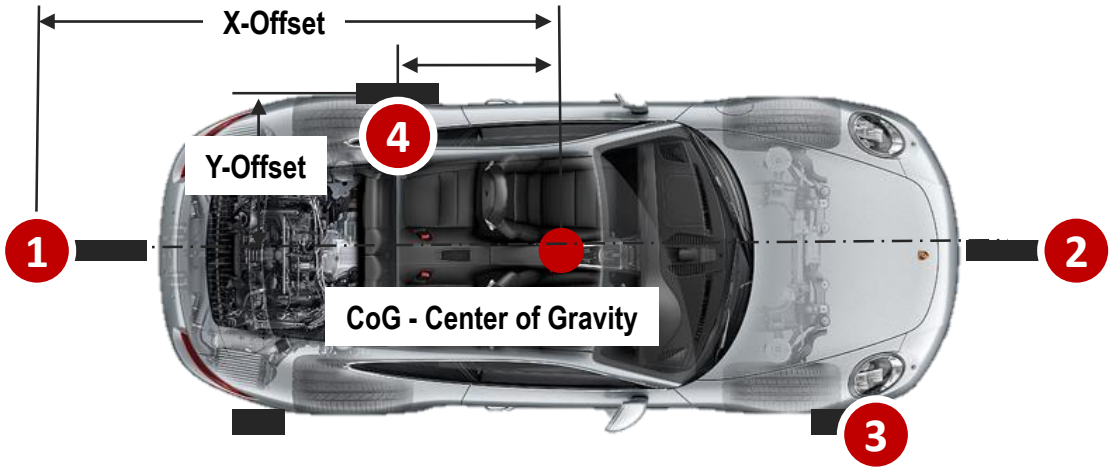




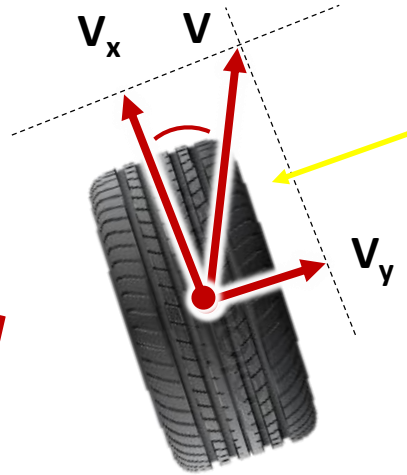
Objective evaluation methods with vehicle dynamics measurement



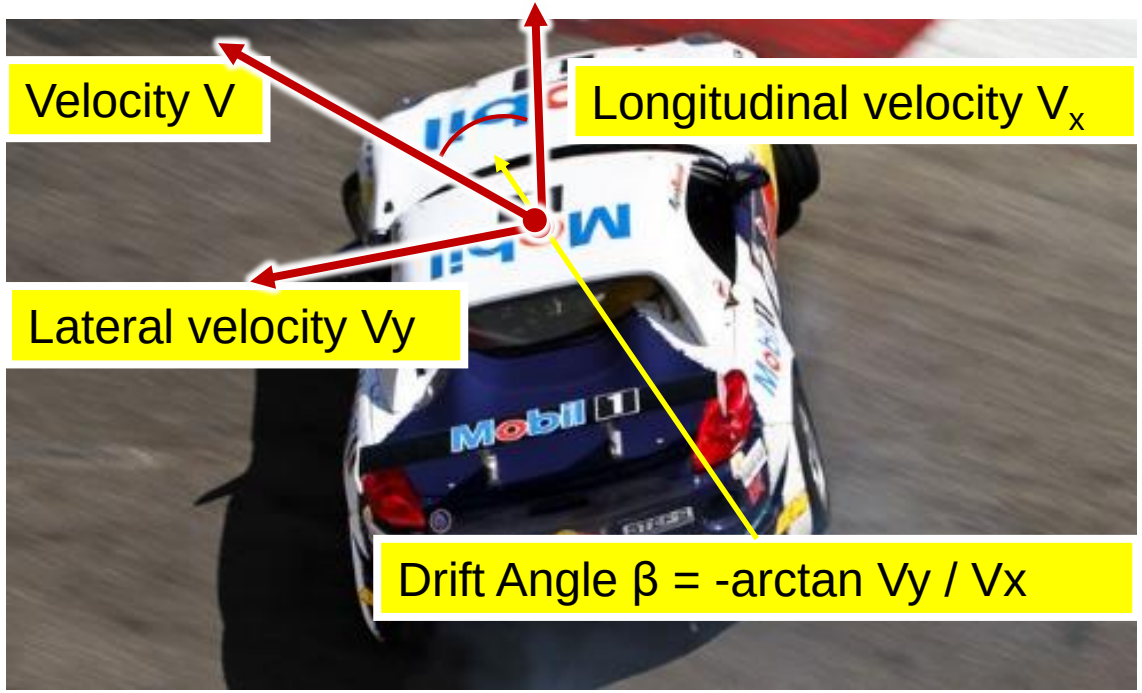
Correvit speed must be corrected to the CoG!



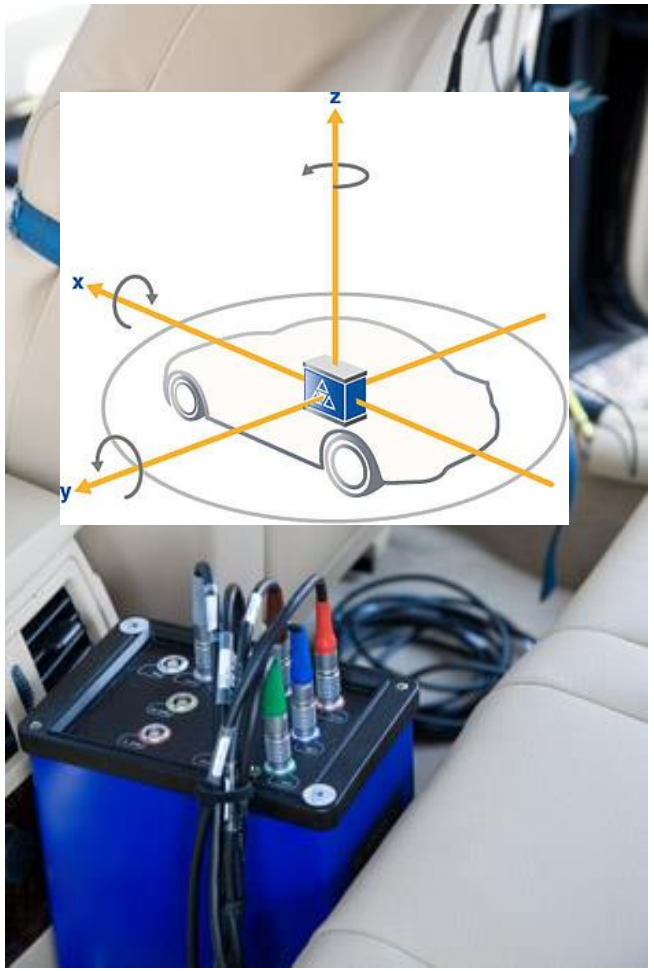
Speed Vx/Vy and calculation of drift and side slip angle



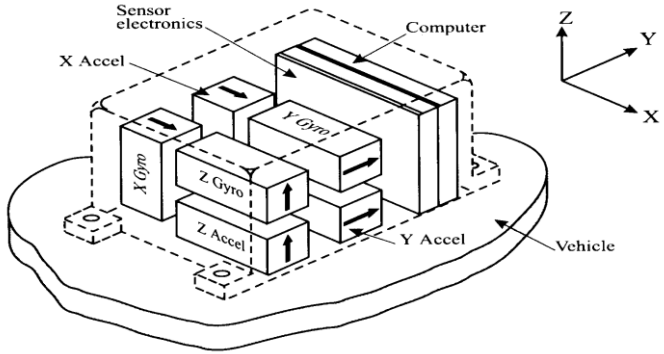
Side Slip Angle α = -arctan Vy / Vx



IMU – Inertia Measurement Unit: Genesys ADMA



Analytisch (Strapdown)



Basics of the gyro technology for the vehicle 3D motion measurement

- **3 gyro measurement axles**
- **3 acceleration measurement axles**

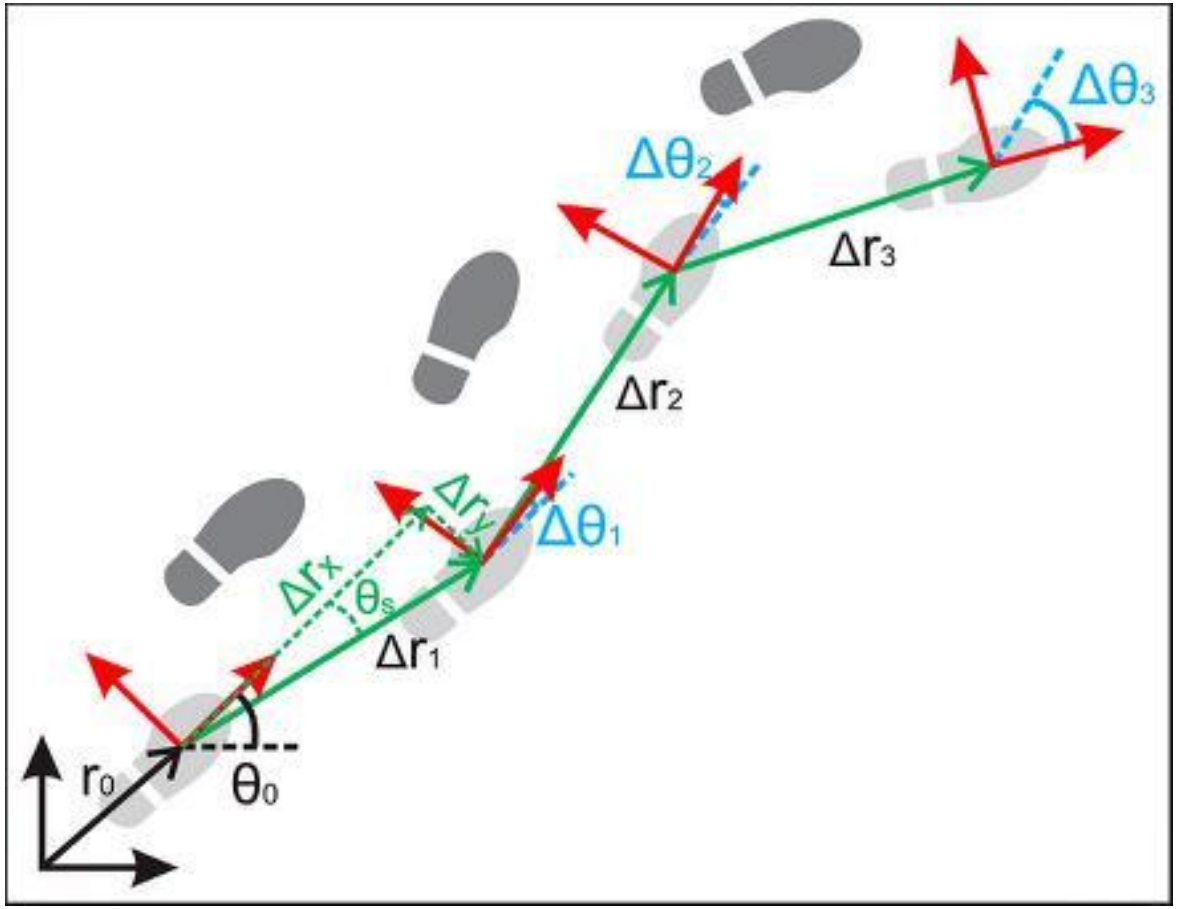
Challenge Integration

$$\alpha = \alpha_0 + \int \omega \, dt$$

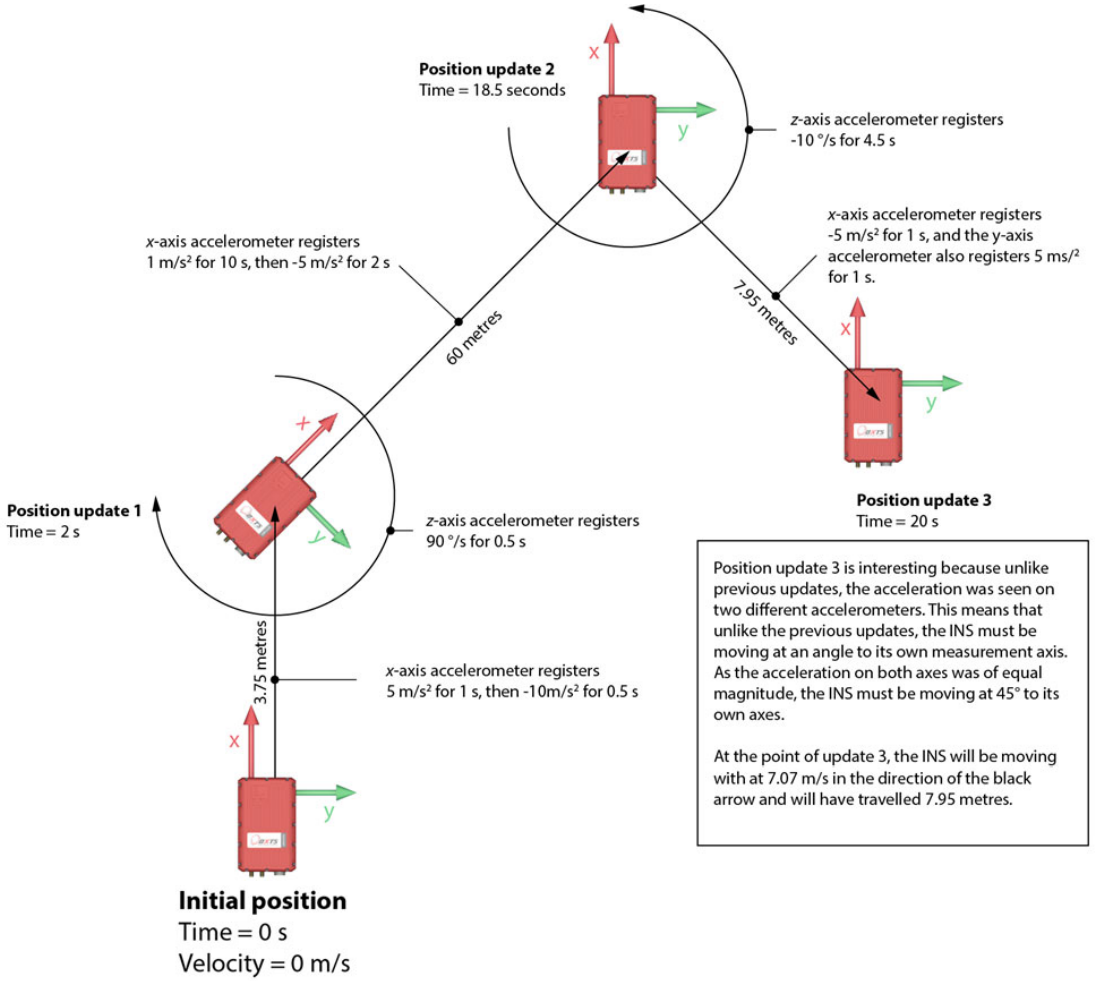
$$v = v_0 + \int a \, dt$$

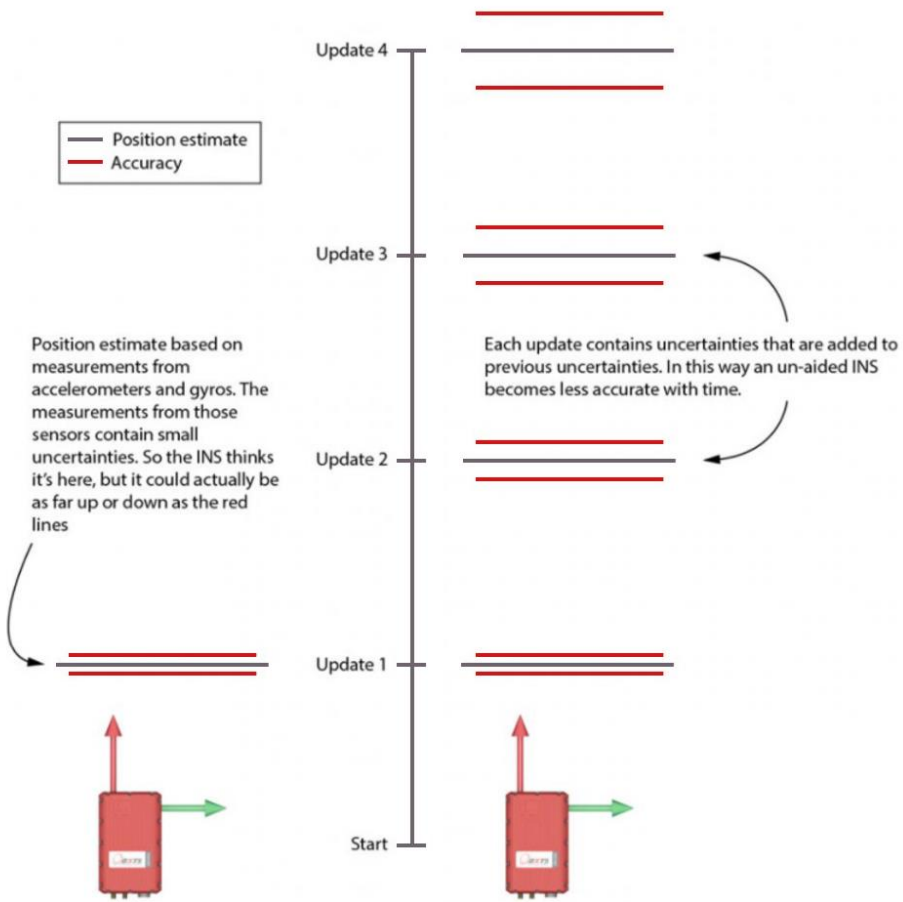
$$s = s_0 + \int \int a \, dt \, dt$$

Principle of Inertial Measurment Units - Dead reckoning (Koppelnavigation)

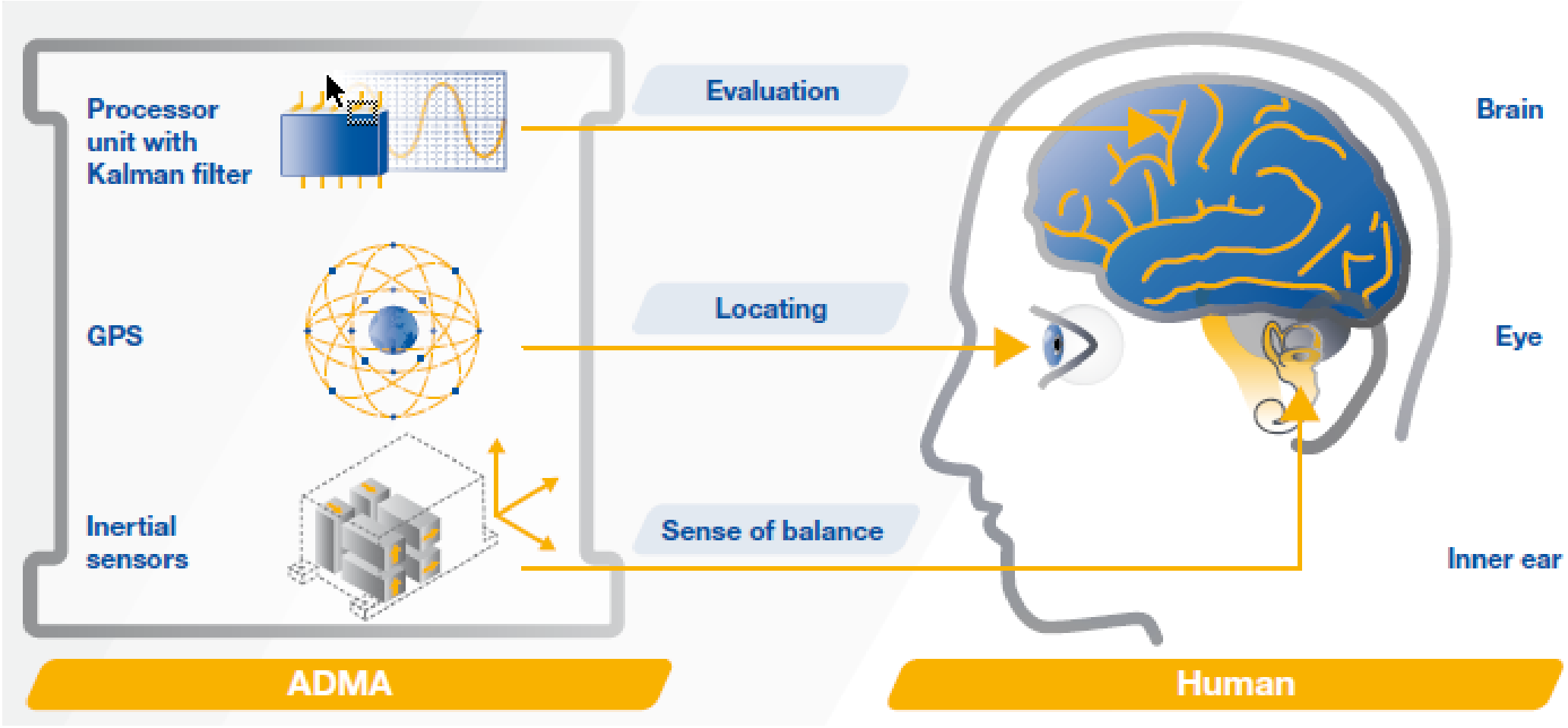


Principle of Inertial Measurment Units - Dead reckoning (Koppelnavigation)



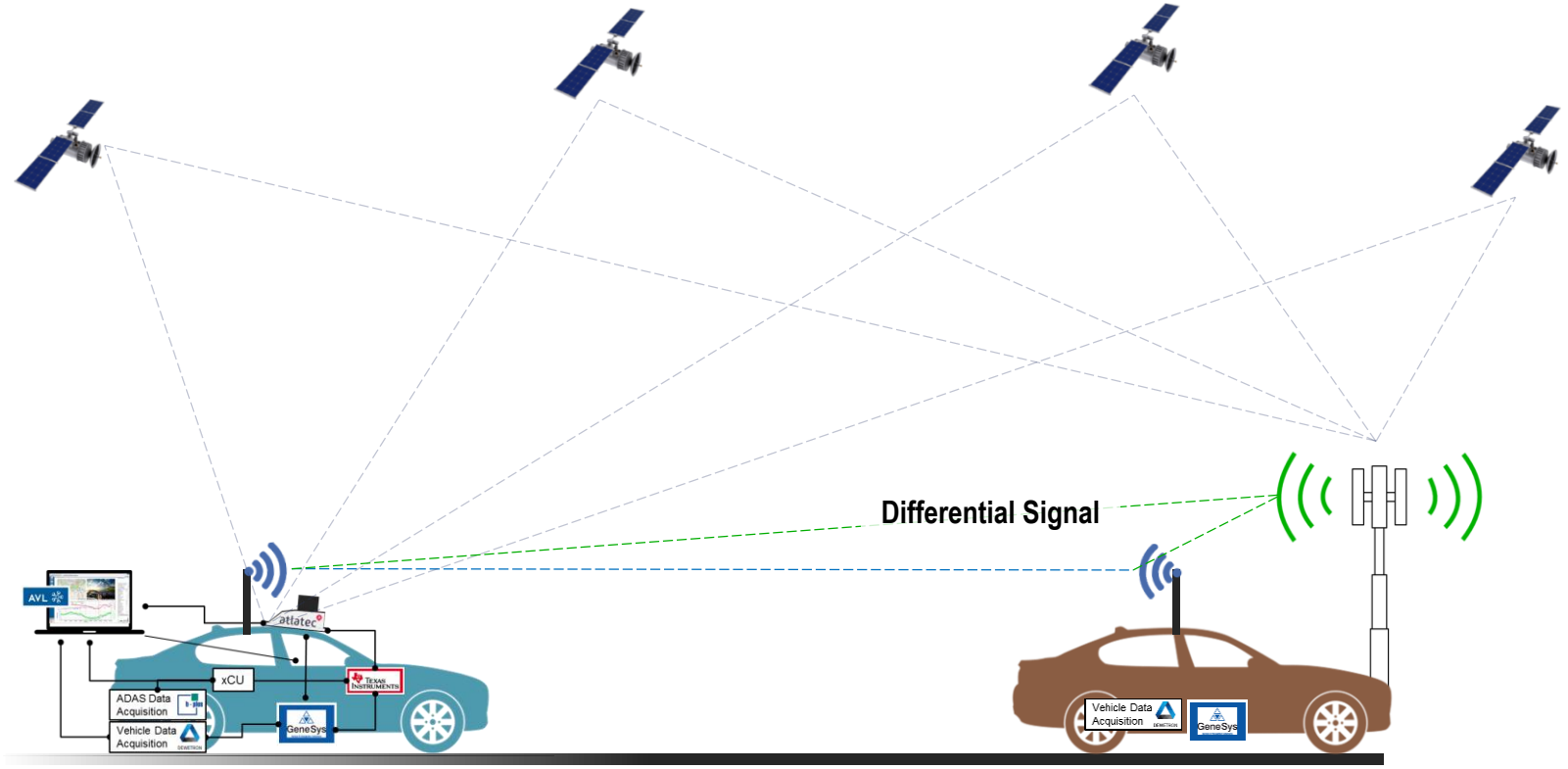


Genesys ADMA is based on the same principal as the inner ear.



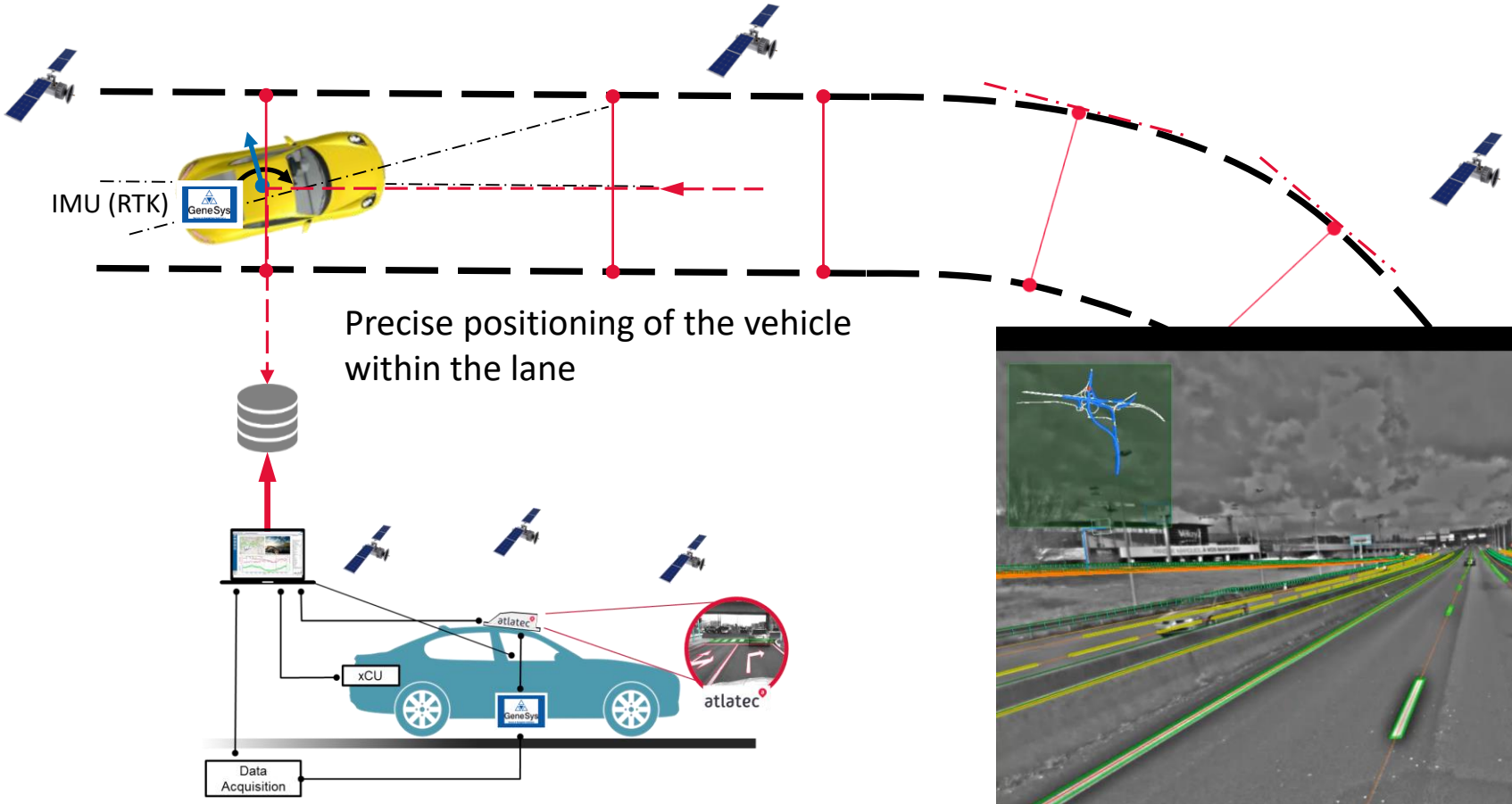
Test and evaluation methods for vehicle attributes

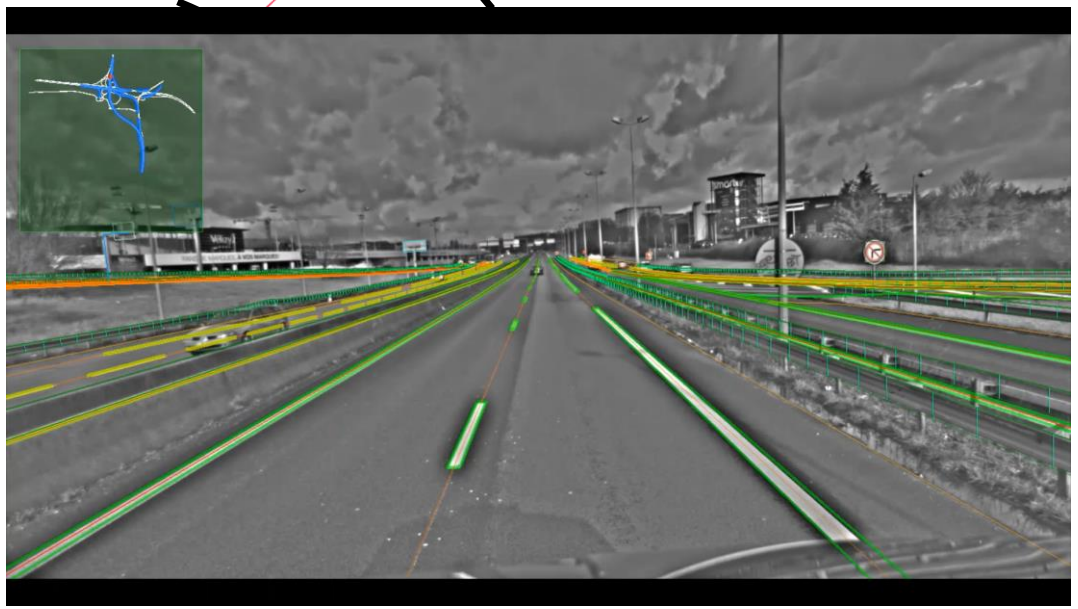
Genesys ADMA is corrected by differential “RTK – Real Time Kinematic” GPS



Ground Truth Method (Grundwahrheit/Referenz) with IMU

Bundesministerium
für Wirtschaft
und Energie

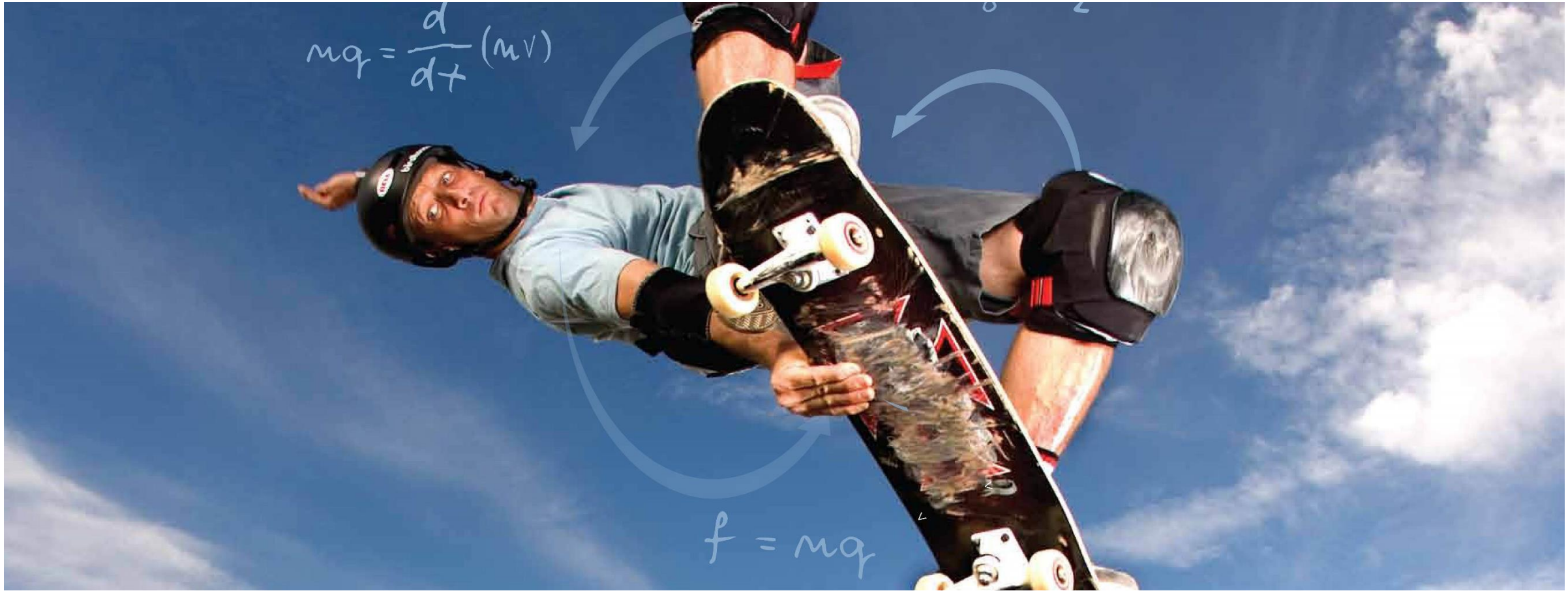




Pre-Measurement of Geo-Referenced Ground Truth Data

Validation Source Test (Quellentest)

What is a maneuver?



Test and evaluation methods for vehicle attributes

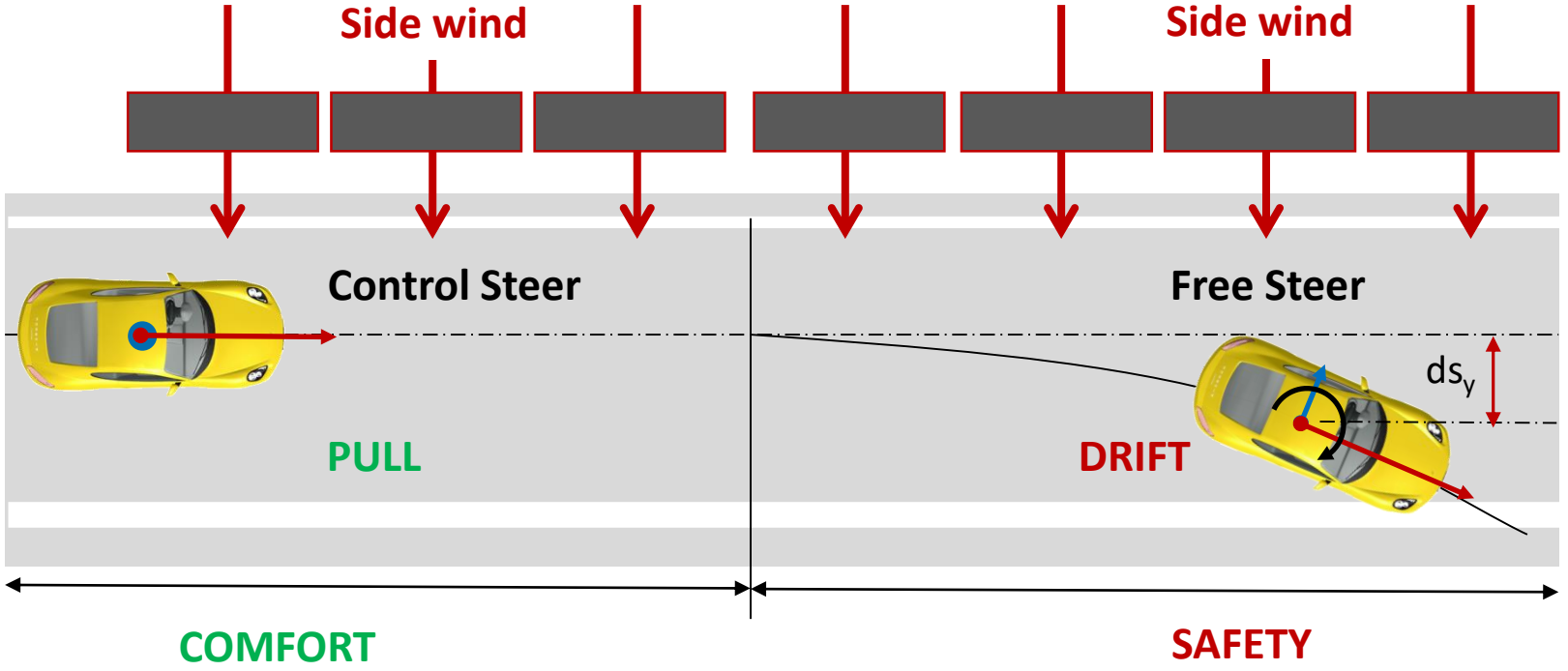
Maneuver (French *manœuvre*, latin: *manuopera* „Handdienst“) stands for:

- Generally: a maneuver is a smart executed change of direction
- **Military:** Troops or fleet exercises under warlike conditions or tactical movement of troops associations
- **Shipping:** Course change in shipping
- **Flying:** a flyable change in direction or figure in aviation
- **Vehicle test: Reconstruction of a real driving situation!**

Testing Principle: Looking for trouble before it looks for you!

Road testing are still a very high effort.

Sample: Driving maneuver and objective & subjective evaluation criteria



- **Subjective:** Steering effort at side wind (SWA/SWT)
- **Objective:** SWT / SWA Effort at YawRate = 0

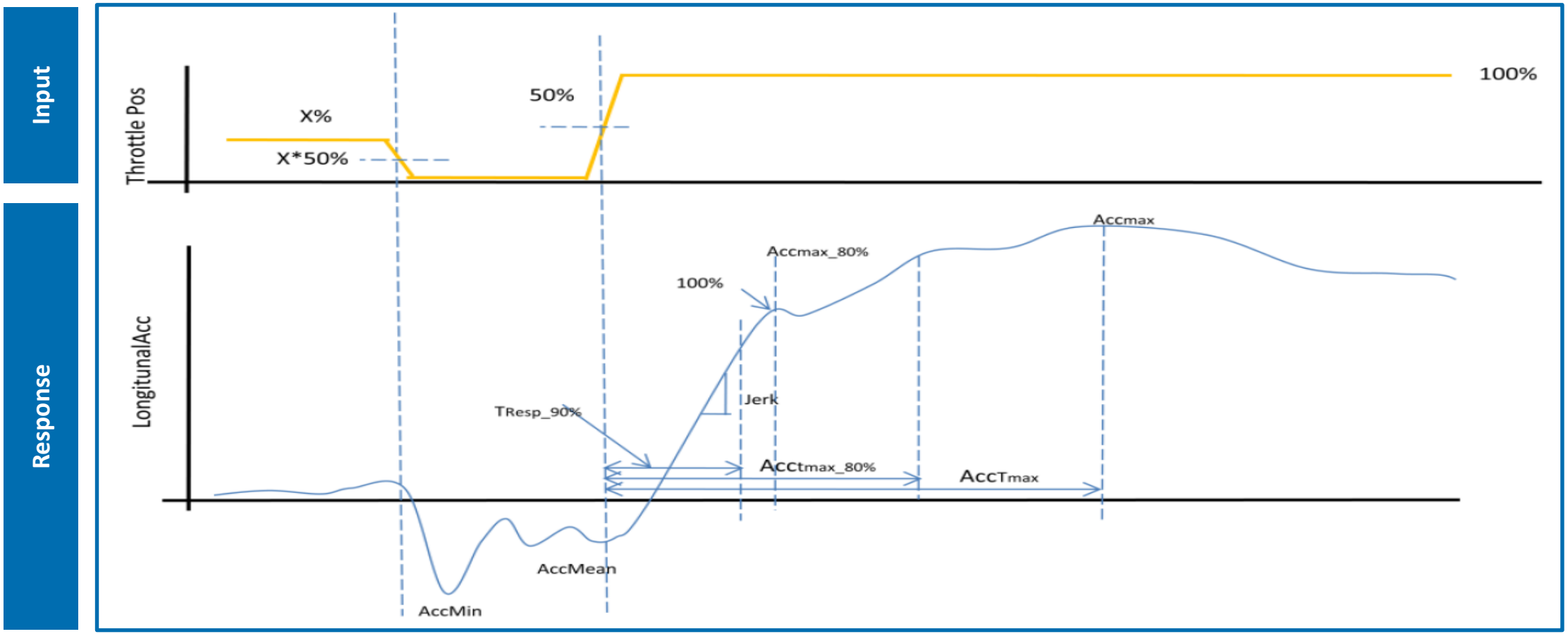
- **Subjective:** Straight running behavior at side wind
- **Objective:** Lateral displacement, YawRate Response

SWT = Steering wheel torque SWA = Steering wheel angle

Driving Maneuver Catalogue (Open/Closed Loop)

- Steady state circular (ISO)
- Frequency response test (ISO)
- Slowly increase steer (ISO)
- Weave test (ISO)
- Transition test (ISO)
- Step input test (ISO)
- Slalom
- Lane change test (ISO 3888)
- Handling Course - Nürburgring
- Braking during cornering (ISO)
- Power-Off Test (ISO)
- µ-Split Braking (ISO)
- Steering Return Ability Test
- Braking test
- Acceleration Test
- …

Objective evaluation via key performance indicators – KPI's



Standardization of driving maneuver and evaluation criteria's

ISO-Standards		
1982	ISO 4138	Road vehicles - Steady state circular test procedure
1988	ISO 7401	Road vehicles - Lateral transient response test methods
1991	ISO 8855	Road vehicles - Vehicle Dynamics road holding ability – Vocabulary
1985	ISO 7975	Road vehicles - Braking in a turn - „open-loop“ test procedure
1991	ISO 9815	Road vehicles - Passenger Car-Trailer combination lateral stability test procedure
1990	ISO 10392	Road vehicles with two axles - Determination of center of gravity
1993	ISO 9816	Passenger Cars - Power-off reactions of a vehicle in turn- “open-loop“ test method
1975	ISO/TR 3888	Road vehicles - Test procedure for a severe lane-change manoeuvre

VDA Verband der Automobilindustrie

DIN

ISO International Organization for Standardization

Standardization of driving maneuver and evaluation criteria's

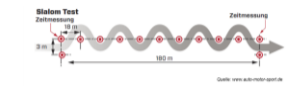
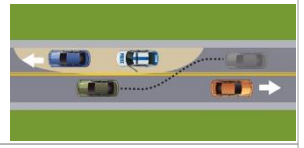
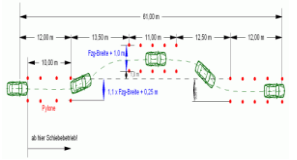
ISO-Technical-Reports		
1986	ISO/TR 8349	Road vehicles - Measurement of road surface friction
1986	ISO/TR 8350	Road vehicles - High-friction test track surface-Specifications
1988	ISO/TR 8725	Road vehicles - Transient „open-loop“ response test method with one period of sinusoidal input
1989	ISO/TR 8726	Road vehicles - Transient „open-loop“ response test method with pseudo-random steering input
2010	ISO 12021	Road vehicles -- Sensitivity to lateral wind -- Open-loop test method using wind generator input
2010	ISO 13674-1	Road vehicles -- Test method for the quantification of on-centre handling -- Part 1: Weave test
2016	ISO 13674-2	Road vehicles -- Test method for the quantification of on-centre handling -- Part 2: Transition test

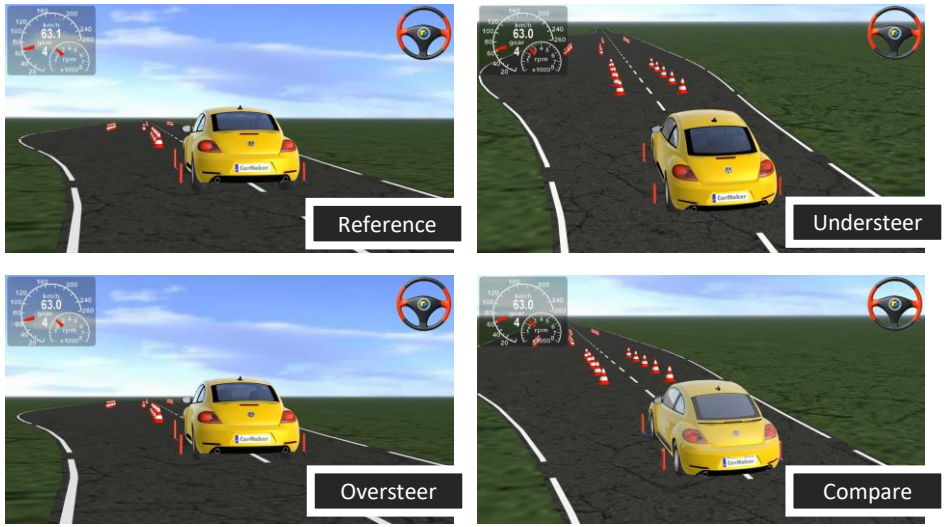
Standardization of driving maneuver and evaluation criteria's

ISO-Technical-Reports		
1999	ISO 14512	Passenger cars -- Straight-ahead braking on surfaces with split coefficient of friction -- Open-loop test procedure
2011	ISO 17288-1	Passenger cars -- Free-steer behavior -- Part 1: Steering-release open-loop test method
2011	ISO 17288-2	Passenger cars -- Free-steer behavior -- Part 2: Steering-pulse open-loop test method
2007	ISO 21994	Passenger cars -- Stopping distance at straight-line braking with ABS -- Open-loop test method
2006	ISO 15037	Road vehicles -- Vehicle dynamics test methods -- Part 1: General conditions for passenger cars
2016	ISO 19365	Passenger cars -- Validation of vehicle dynamic simulation -- Sine with dwell stability control testing

Test and evaluation methods for vehicle attributes

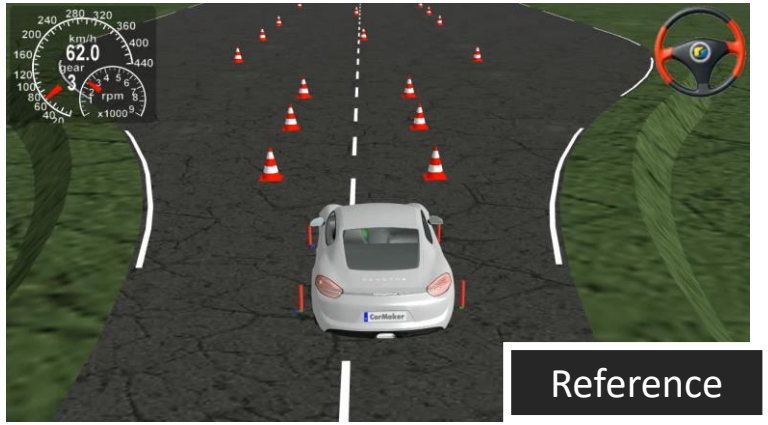
Typical driving maneuvers

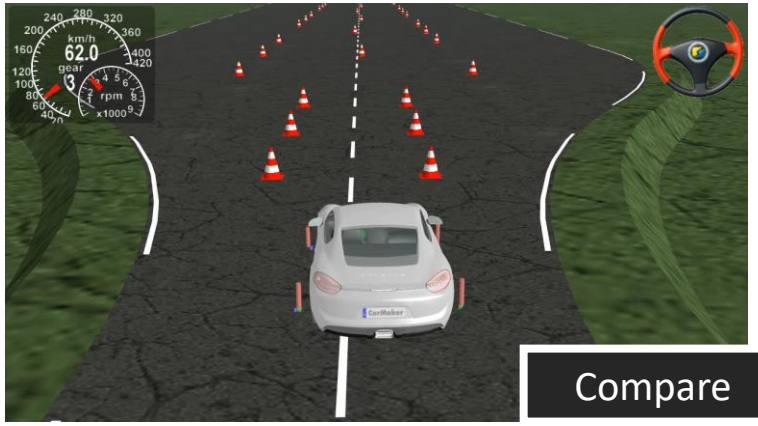
Driving Maneuver	Evaluation	Open Loop	Closed Loop	Picture
Handling Course	Evaluation of the driving behavior in extreme corning situations		X	
Slalom 10x18m 10x36m	Evaluation of the driving behavior in very fast course directions.		X	
Single Lane Change	Simulation of a evasive maneuver at the high way		X	
Double Lane Change 1 (FAST)	Simulation of a fast evasive maneuver with return to the lane (~120km/h; ISO 3888-1 Lane Change)		X	
Double Lane Change 2 (SLOW)	Simulation of a intensive evasive (obstacle avoidance) maneuver with return to the lane (~70km/h; ISO-3888-2 [VDA] Lane Change or „Elk Test“)		X	



Test and evaluation methods for vehicle attributes

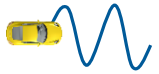
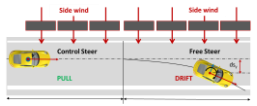
10x18m Slalom & most important maneuver: “Steady State Circular Driving”






SR60 Torus Steering Robot
Swept sine

Test and evaluation methods for vehicle attributes

Driving Maneuver	Evaluation	Open Loop	Closed Loop	Picture
Step Steer	Sudden steer input to a defined value - ISO 7401.	X		
Sine Steer	Harmonic steering in from of a sine or sine sweep with defined amplitude – ISO 8725.	X		
pseudo-random steer	Irregular steer input – ISO 8726.	X		
Steer return-ability test	Evaluation of steering wheel return-ability within a turn-off maneuver	X		
Side wind test	Evaluation of vehicle behavior such as course deviation thru side wind - ISO 12021.	X		
Traction/ acceleration test	Evaluation of the traction and acceleration performance		X	
Car-trailer Stability test	Evaluation of the vehicle and trailer stability - ISO 9815.	X