BREMSBASIERTE ASSISTENZFUNKTIONEN
-
FAHRDYNAMIKREGELSYSTEME

(ABS, ASR,ESP, **VDC2.0**)

ROBERT BOSCH GMBH
DIPL.-ING. ALBERT LUTZ

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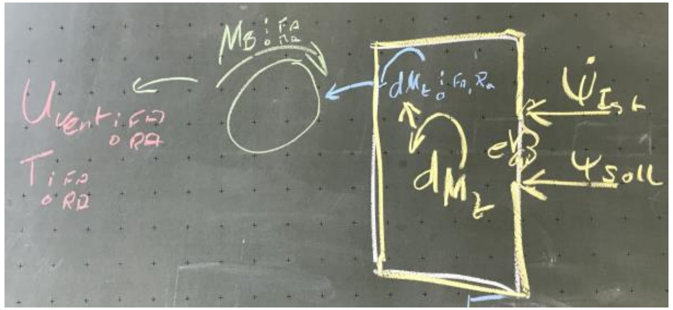
Fahrdynamikregelsysteme
Zusammenfassung: ESP®

- ESP® verwendet das Einspurmodell für eine Modellfolgeregelung der Giergeschwindigkeit *(Regelung)*
- ESP® schätzt mit dem Zweispurmodell den Schwimmwinkel und setzt ein wenn er zu groß wird *(Begrenzung)*
- Entsprechend dem Fahrbahnreibwert wird die Giergeschwindigkeit begrenzt
- Zur Giermomenteneinstellung werden die Reifenkraftvektoren gedreht
- Die Drehung der Reifenkraftvektoren erfolgt durch Reifenschlupfeinstellung
- Sensorsignale werden konsequent verwendet
- ESP® hat eine einheitliche, hierarchische Reglerstruktur für Front-, Heck- und Allradantrieb
- Eine Vielzahl an Zusatzfunktionen (VAFs) verbessern Brems-, Lenk-, Stabilitätsverhalten, bieten dem Fahrer zusätzlich Komfort und Zusatzinformation
- ESP® ist ein zentraler Baustein für ADAS-Systeme mit VMC (Vehicle Motion Control)

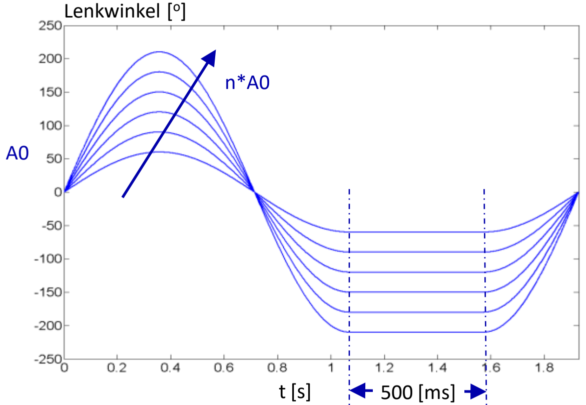


https://www.youtube.com/watch?v=6kR27GjKbIQ

Fahrdynamikregelsysteme
Zusammenfassung: ESP®-Performance Check

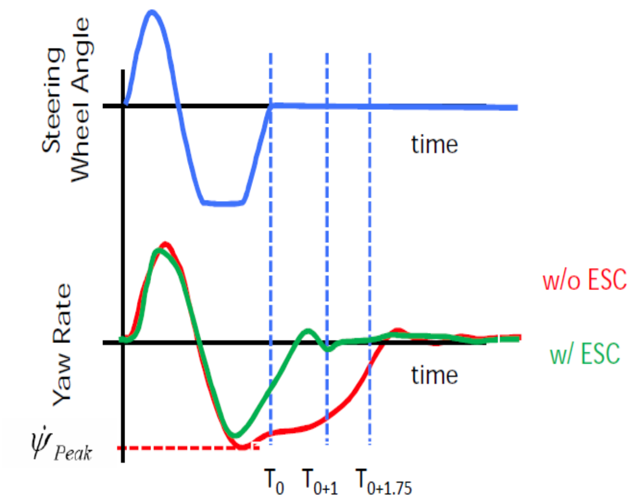
Manöver – Sine with Dwell:

- Fahrbahn: hoch-mue
- 80±2km/h, hoher Gang
- Sinuslenken mit 0.7Hz
- Haltezeit: 500ms
- A_0-Amplitude für a_y=0.3g
- n*A_0@0.3g (n = 1.5(0.5)6.5); max. ~270°
- Ausführung mittels Lenkrobotor



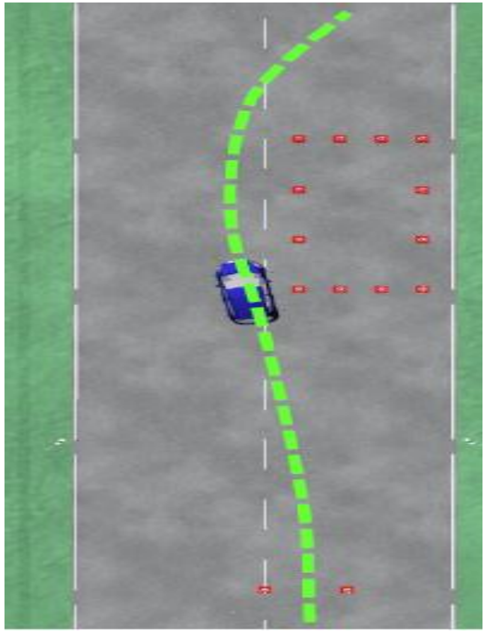
Kriterien:

- Abklingen der Drehrate (Stabilität)



$$YRR = 100 * \left(\frac{\dot{\psi}(\text{at time } t)}{\dot{\psi}_{Peak}}\right) \begin{cases} \text{at } T_{0+1} \leq 35\% \\ \text{at } T_{0+1.75} \leq 20\% \end{cases}$$

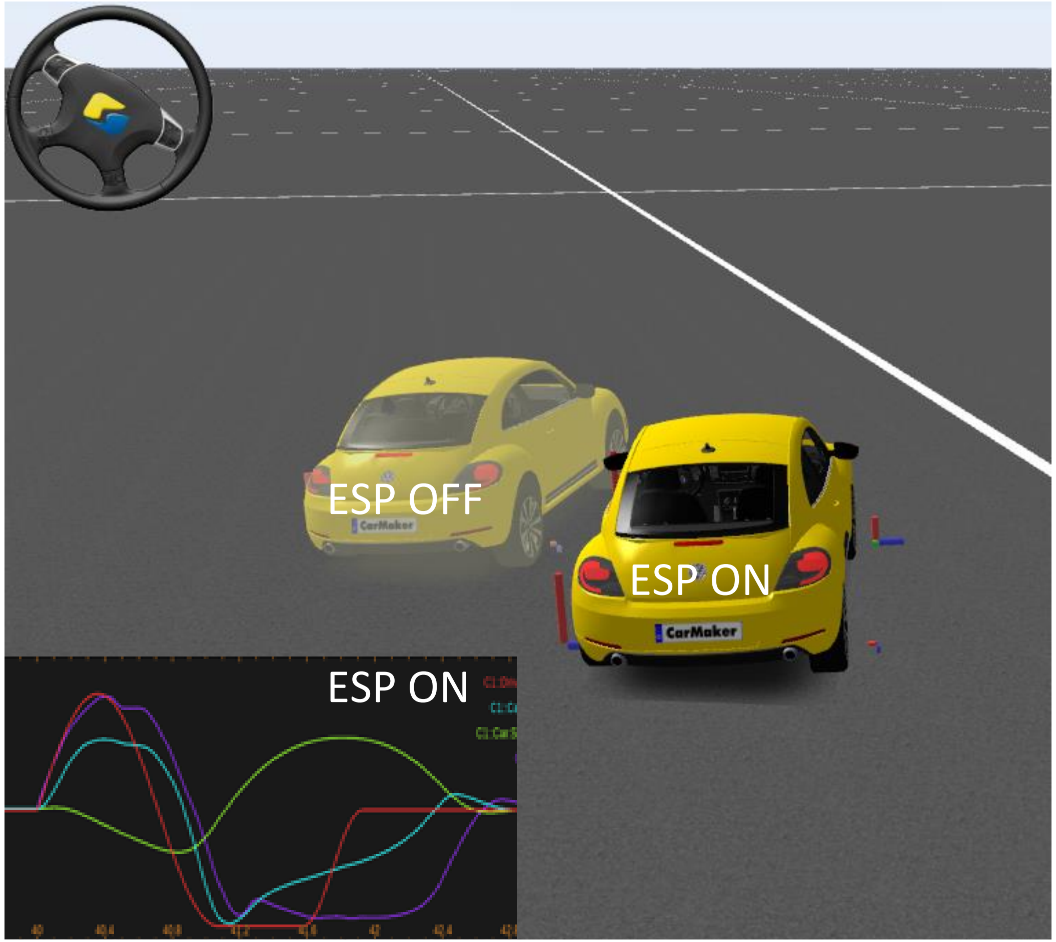
- Lateraler Versatz (Lenkfähigkeit)

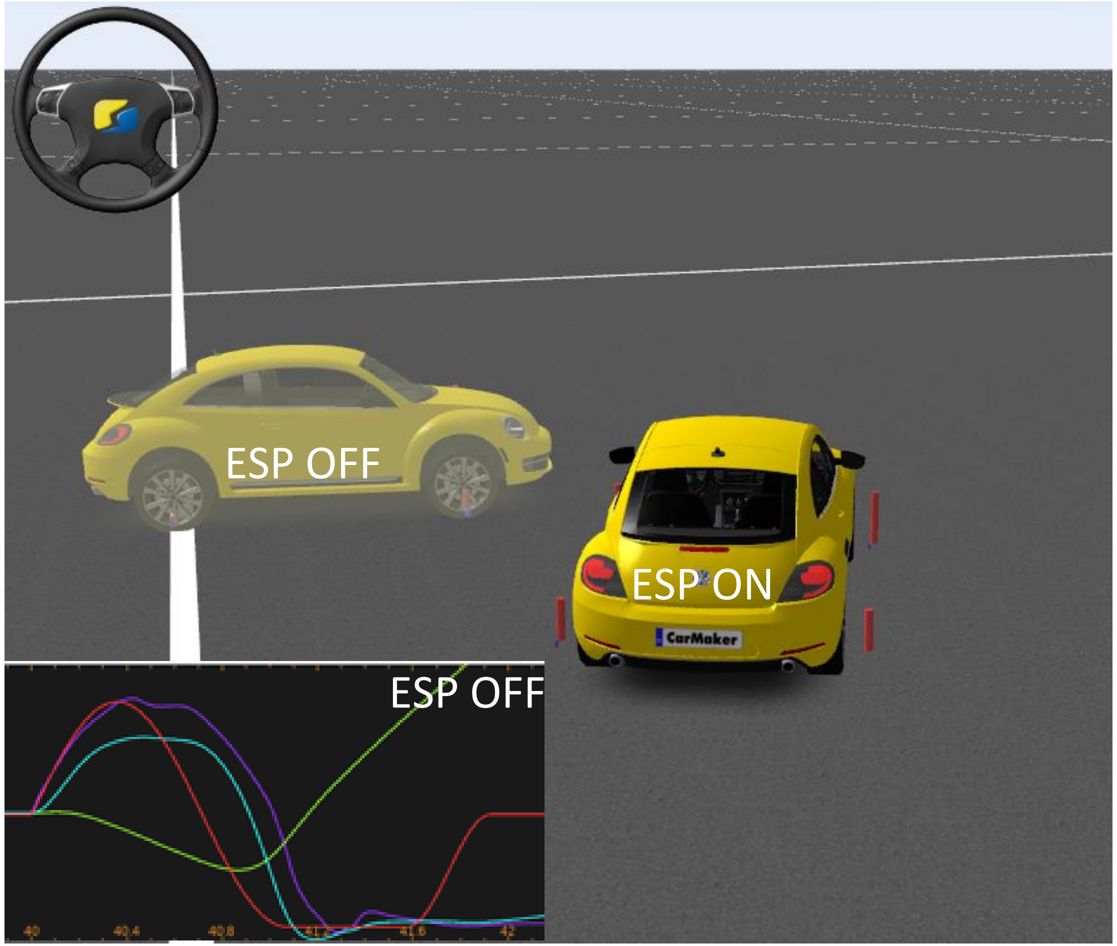


$$\text{Lateral Displacement} = \int_{t_0}^{t_0+1.07} \int_{t_0}^{t_0+1.07} Ay_{C.G.}(t)dt \geq 1.83 \text{ m}$$

Fahrdynamikregelsysteme

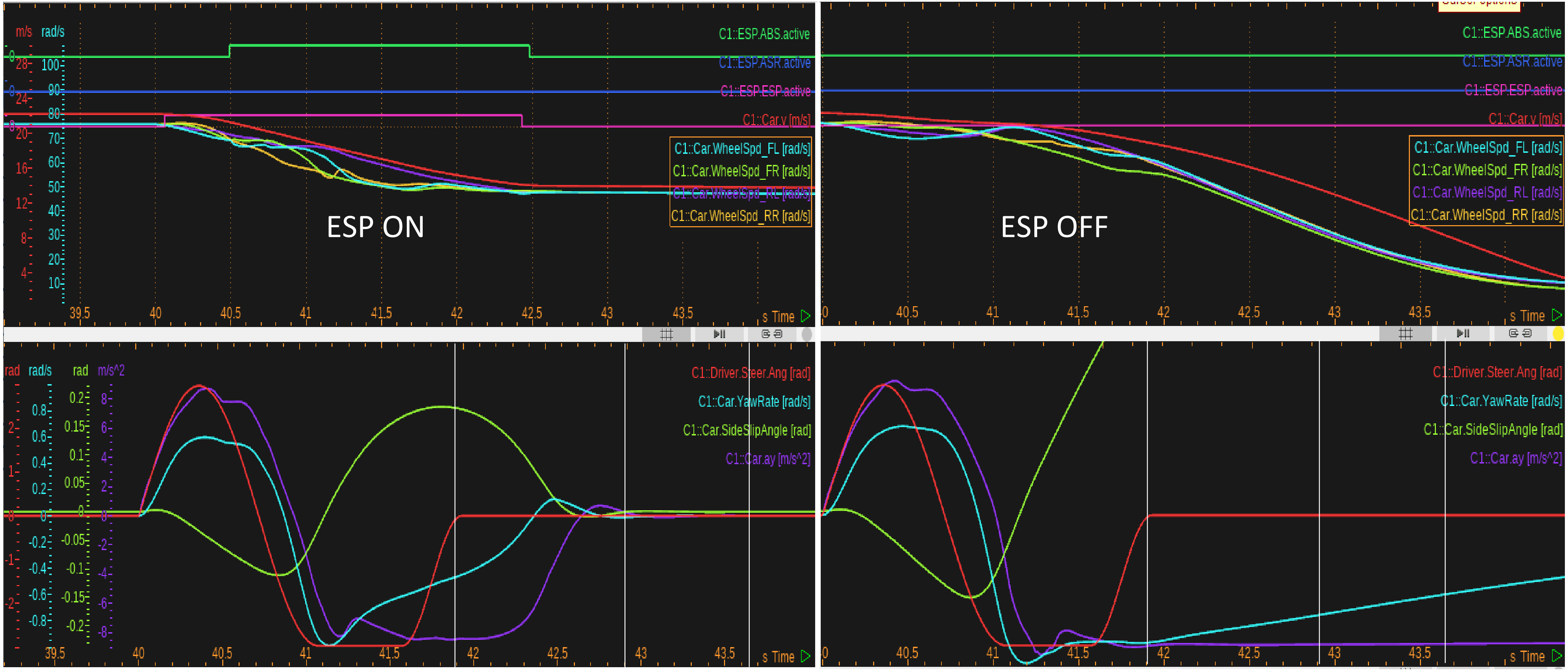
Zusammenfassung: ESP®-Performance Check





Fahrdynamikregelsysteme

Zusammenfassung: ESP®-Performance Check



T0 T0+1 T0+1.75

T0 T0+1 T0+1.75

Fahrdynamikregelsysteme
Simulator: Manöver

Double Step Steer

- Beschleunigen auf 80km/h
- Rollen im hohen Gang
- Lenksprung
  - +150°, Halten ca. 2s
  - -150°, Halten ca. 2s
  - +0°

ESP OFF/ON

ESP default/sportlich

Slalom

- Beschleunigen auf 60km/h
- Durchfahrt mit zunehmender Geschwindigkeit

ESP OFF/ON

ESP default/sportlich

Bremsen in der Kurve

- Zunehmende Geschwindigkeit auf 100m Radius bis Fzg untersteuert
- Vollbremsung
- Lenkwinkel halten

ESP OFF/ON

ESP default/sportlich

Fahrdynamikregelsysteme

Simulator: Kenngrößen der Fahrdynamik - subjektiv

ESP-Bereich

- Wann wird das Fzg instabil oder untersteuernd?
- Sind die Eingriffe
  - plausibel, nachvollziehbar:
  - kommen sie zu früh oder zu spät, zu stark und zu lang?
  - Sind sie reproduzierbar?
- Komfort:
  - sind die Eingriffe hart oder weich, abrupt oder fließend, laut oder leise, störend oder harmonisch?
  - Passt die Abstimmung zur Auslegung des Fahrzeugs (sportlich, lenkwillig, komfortabel)?
- Fährt das Fahrzeug einen Zick-Zack-Kurs?
- Gierbewegungen
  - Ist diese gut gedämpft
  - sind die Überschwinger in der Gierbewegung und in der Querbeschleunigung gering?
- Ist die Fahrerunterstützung bei Links- und Rechtskurven, beim Antrieb, Freirollen und Bremsen gleich?
- Ist die Unterstützung für den Normalfahrer zu gering, ausreichend oder zu stark?

Fahrdynamikregelsysteme

Simulator: Kenngrößen der Fahrdynamik - objektiv

ESP-Bereich

- Wie groß ist der maximale Schwimmwinkel und die maximale Schwimmwinkelgeschwindigkeit? Typisch: Schwimmwinkel kleiner als 6° und Schwimmwinkelgeschwindigkeit kleiner als 2°/s.
- Wie groß ist der Lenkaufwand (Maximalwert, Gradient)?
- Mit welcher maximalen Geschwindigkeit kann ein Ausweichmanöver fehlerfrei ausgeführt werden?
- Wie hoch ist das Geräuschniveau?
- Wie stark sind die Fahrzeugbeschleunigungsänderungen?
- Erfüllt die Gierrate der Spurversatz die SwD-Kriterien?

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ESP® is a milestone on the path to ‘vision zero’ of no more road deaths

Antilock braking system[1]

Traction control system[1]

Vehicle dynamics control (ESP®)[1]

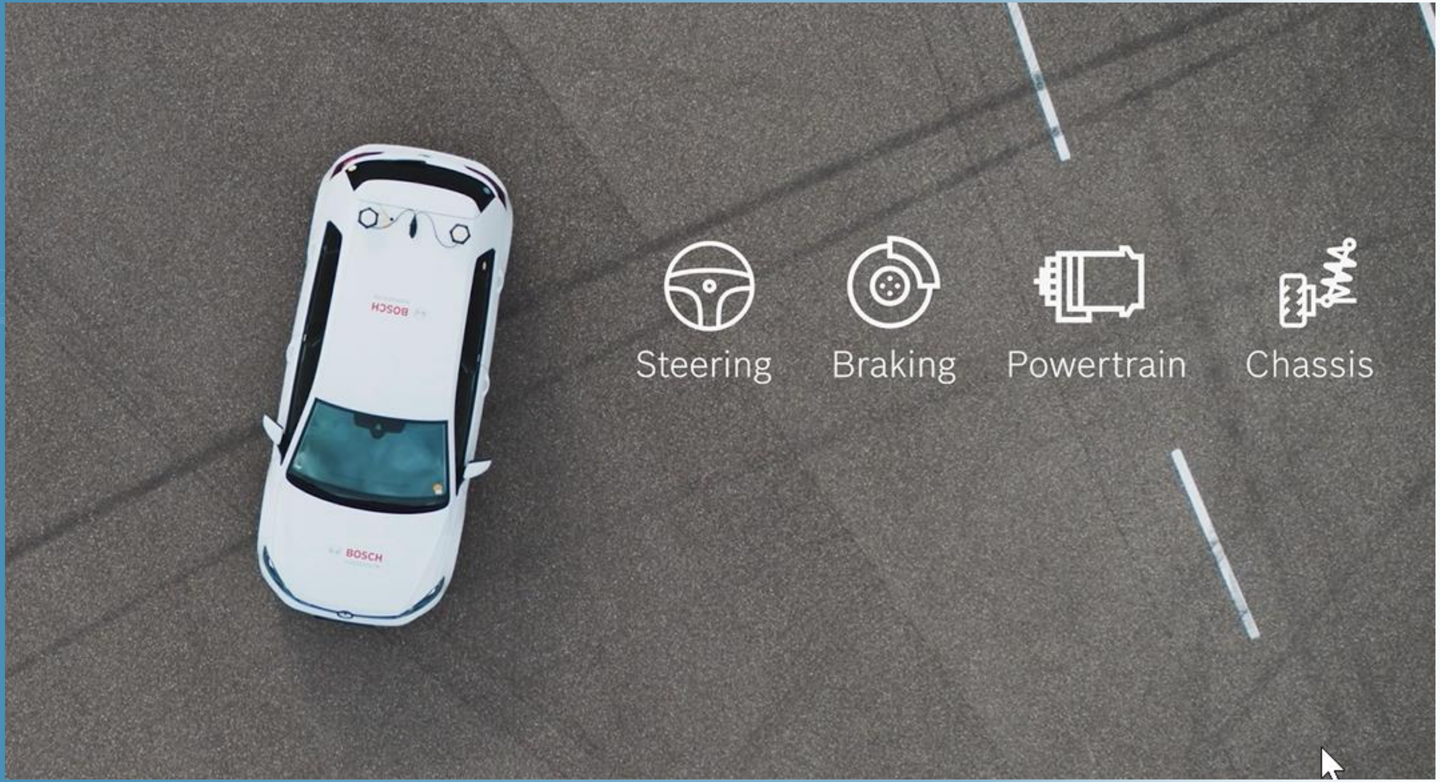
15,000 lives saved in the EU[2]

1978 … 1986 … 1995 … 2020

[1] World’s first
[2] Estimation of Bosch accident research

ESP®: Electronic stability program
EU: European Union

Vehicle Dynamics Control 2.0



Market drivers place new requirements on vehicle dynamics control systems

Software
- Software-defined vehicles
- New E/E architectures

Act by-wire
- Steer by-wire systems

Automation
- Automation, from assisted to automated (SAE level 0 to 5)

Electrification
- Electrified (HEV, BEV) and varying powertrain configurations

Safety and agility
- Electronic stability control
- OEM differentiation

Vehicle dynamics control

- Hardware abstraction
  Software portability
  Standardized interfaces
- Utilize full potential of steer by-wire systems
- Consistent handling of manual and automated driving
- Utilize full potential of electric drives
- Signature driving experience in all vehicle segments

HEV: Hybrid electric vehicle
BEV: Battery electric vehicle
SAE: Society of automotive engineers

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Opening new dimensions

Vehicle dynamics control

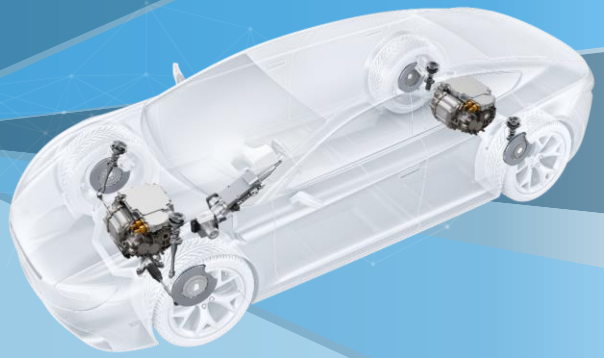
Hardware abstraction
Software portability
Standardized interfaces

Utilize full potential of steer by-wire systems

Consistent handling of manual and automated driving

Utilize full potential of electric drives

Signature driving experience in all vehicle segments



Advanced sensing technology

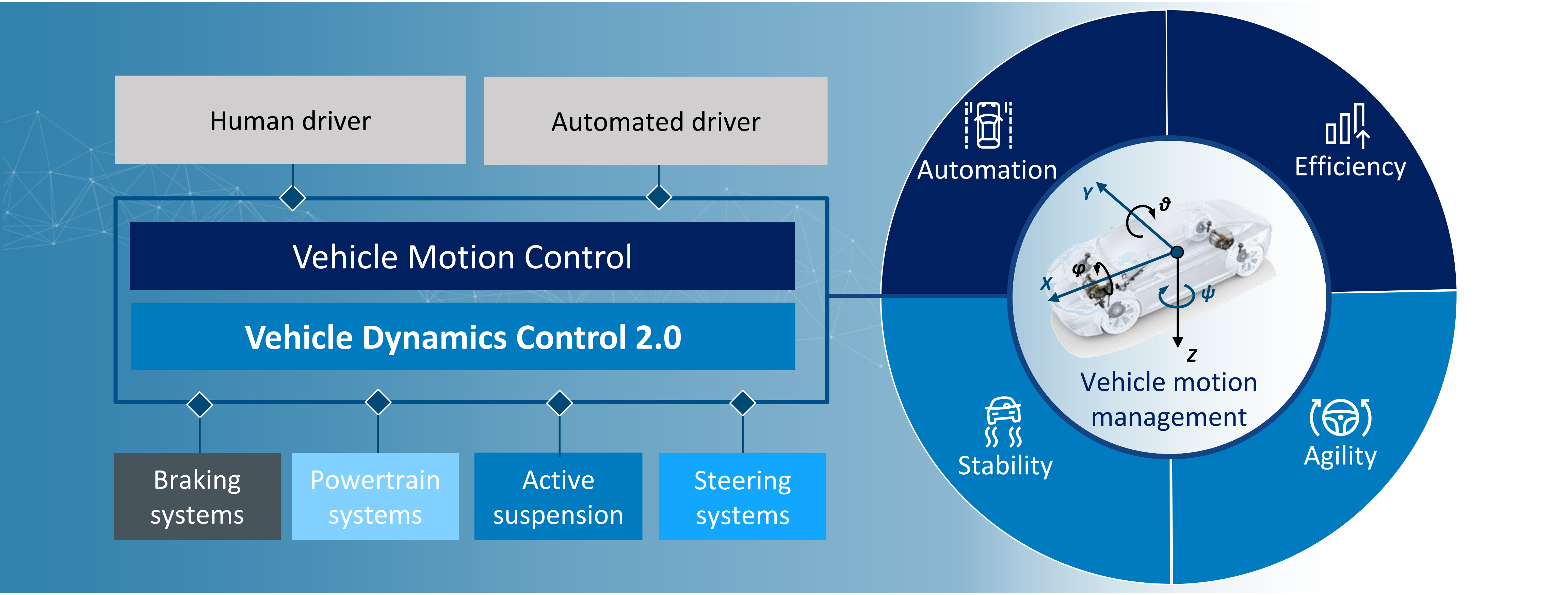
Advanced control technology

Actuation on chassis level

Function deployment and E/E architecture

Cooperation models

Vehicle Motion Management: mastering the complexity of driving modes, maneuvers, and actuator configurations



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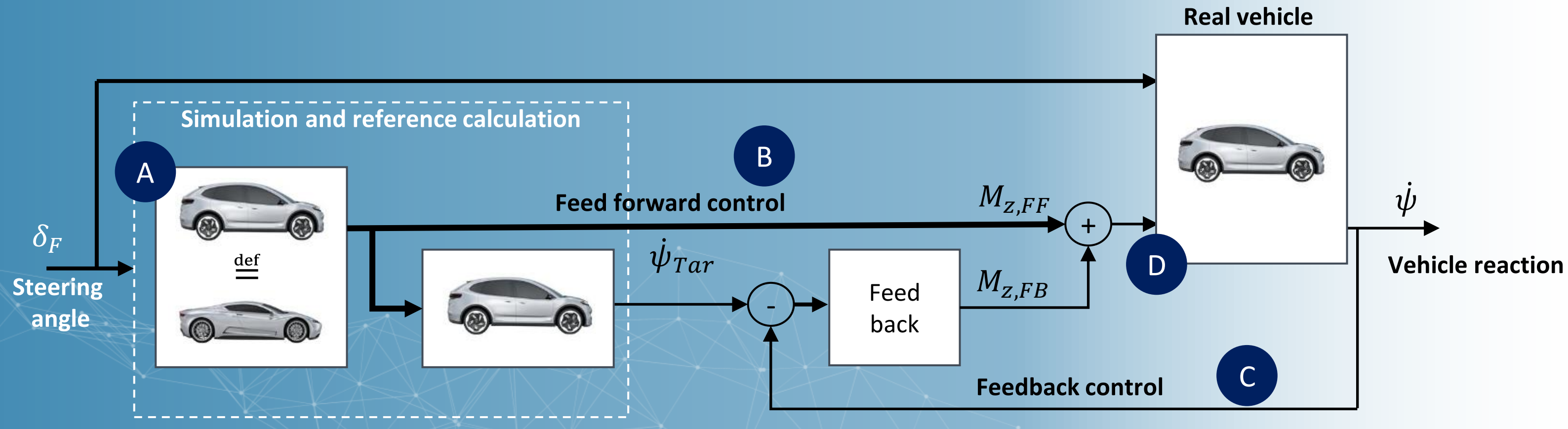
Model-based control concept: from reaction to anticipation – a real evolution

Advanced control technology



δ_F: Steering angle $\dot{\psi}_{Tar}$: Target yaw rate M_z: Yaw torque $\dot{\psi}$: Yaw rate

A **Anticipation**
Vehicle behavior is anticipated and compared to a pre-defined vehicle (e.g. sporty car)

B **Feed forward control** allows to respond strongly without waiting how the real vehicle reacts

C **Reaction**
Feedback control loop to respond to unpredictable disturbances

D **Cross-domain actuator integration**

Steering Braking Powertrain Chassis

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Multi-actuator control: finding the sweet spots

Actuation on chassis level



Driving situation	Braking system	Active suspension	Two-axle electric drive	Four-wheel electric drive	Rear-wheel steering	Steer by-wire
Normal	○	○	○	◐	●	●
Sporty	◐	◐	◐	◐	◐	◐
Emergency	●	◐	◐	●	◐	◐

- ✓ Independent torque distribution to each wheel
- ✓ High availability

- ✓ Supports and influences dynamic vehicle pitch and roll behavior

- ✓ Independent torque distribution (axle/wheel)
- ✓ Positive and negative torque

- ✓ High actuation comfort
- ✓ Direct influence on steering behavior and yaw dynamics

Impact on vehicle dynamics behavior: weak ○ medium ◐ strong ●

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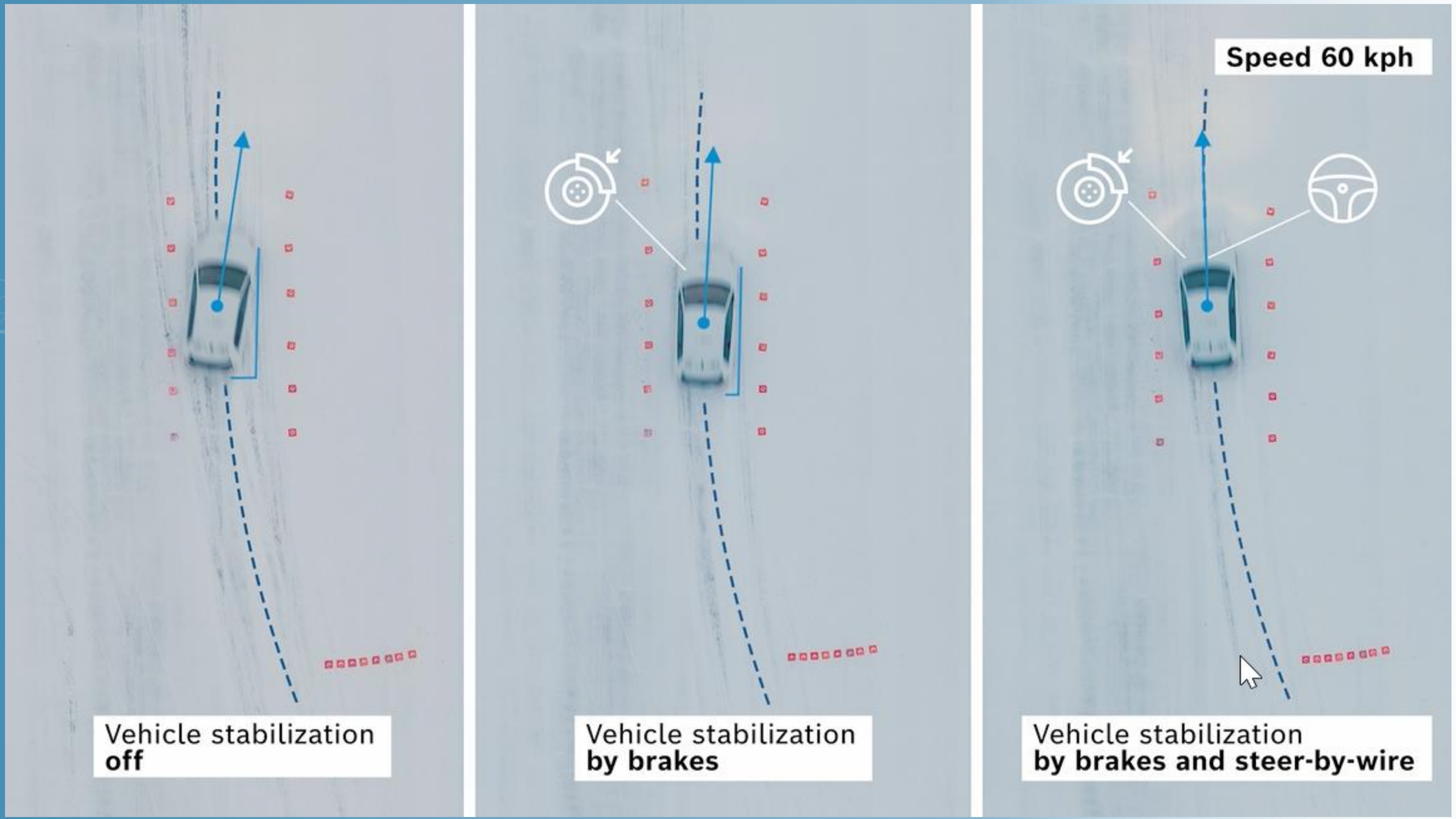
Example: Maximum stability with steering and brakes

Actuation on chassis level



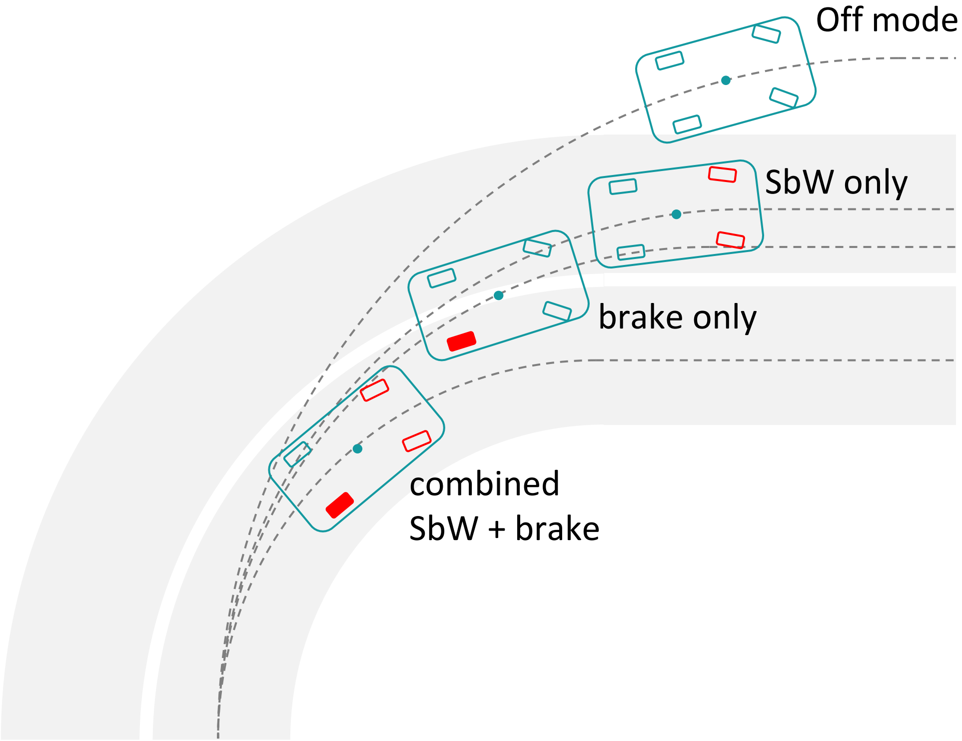
Saving Lives and More – The Future of Brake Systems

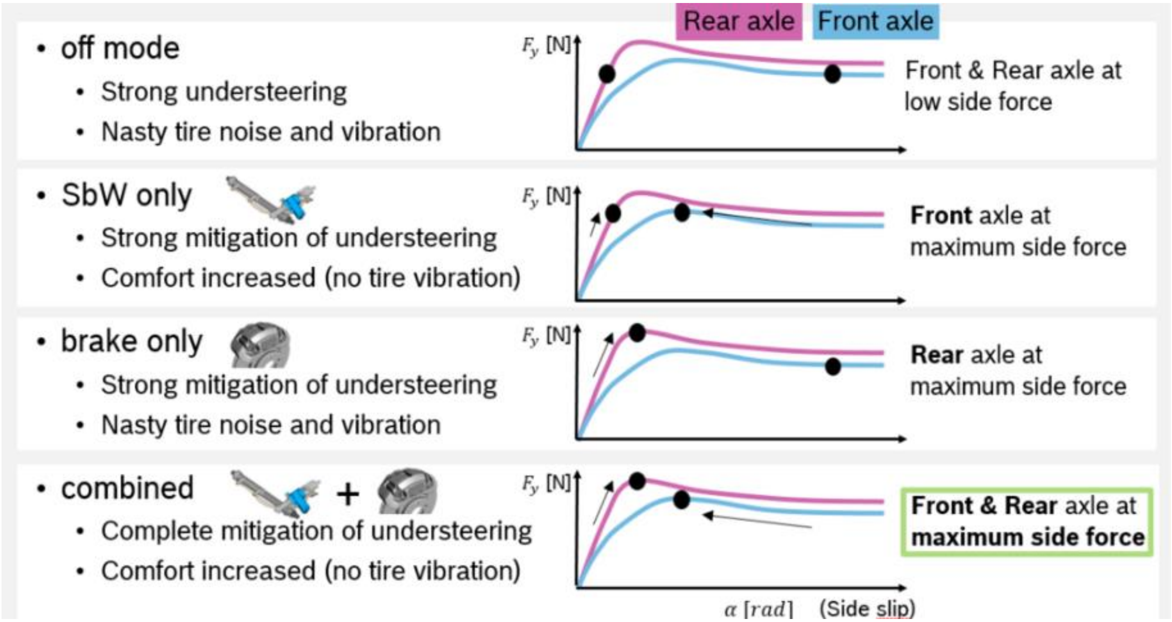
Innovation Example: Multi Actuator Control with Steer-by-wire

Actuation on chassis level

Extension to control steering angle at physical optimum

- Increased dynamics, safety and comfort





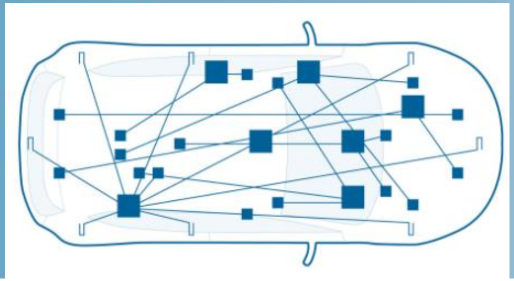
From traditional deployment of vehicle dynamics control on the braking system…

Function deployment and E/E architecture

Human or automated driver

Coordination

Braking control	Drive control	Active suspension control	Steering control
Vehicle dynamics control Traction control Anti-lock control			



…to flexible deployment in zone-oriented and centralized vehicle E/E architectures

Function deployment and E/E architecture

Human or automated driver

Coordination

Vehicle dynamics control 2.0

Traction control

Braking control

Anti-lock control

Drive control

Active suspension control

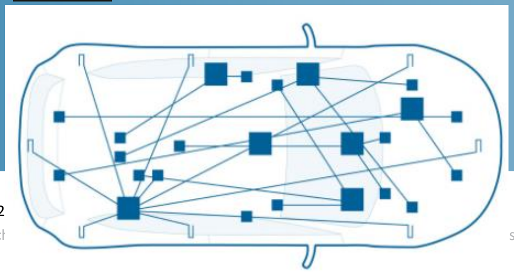
Steering control

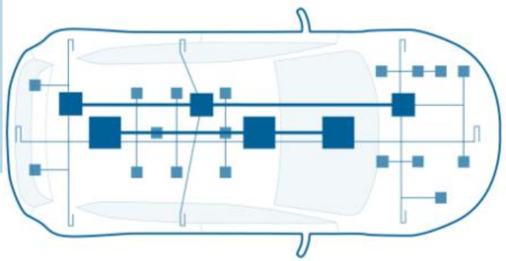
- ✓ Anti-lock control deployed on braking system
- ✓ Keep high dynamic wheel slip control close to actuator

- ? Cost / performance optimum in hydraulic braking systems

- ✓ Deployment on domain, zone or central ECUs
- ✓ Portable software
- ✓ Standardized interfaces

- ? More flexibility and efficiency
- ? Scalability with respect to actuators and vehicle platforms





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Get it done: Vehicle Dynamics Control 2.0 portable

Function deployment and E/E architecture

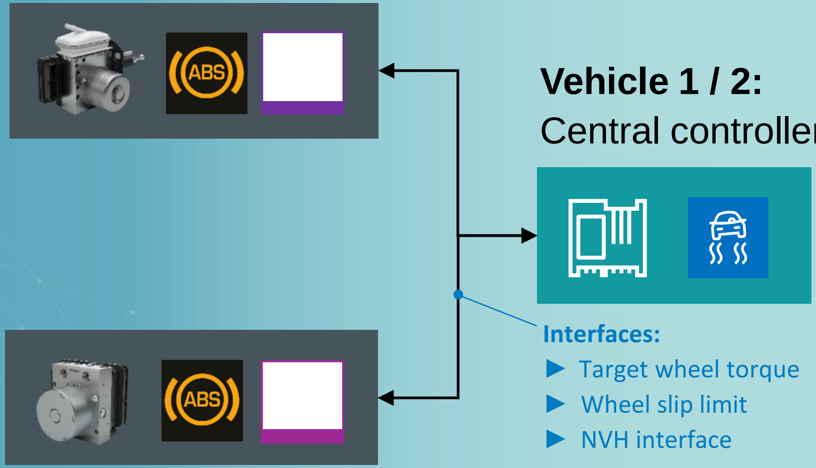
Deployment on braking systems only

Vehicle 1: Integrated Power Brake (IPB)

Vehicle 2: Electronic Stability Program (ESP®)

- Optimization of controller function for specific braking systems
- Hardware/software codesign

Portable Vehicle Dynamics Control 2.0



Vehicle 1 / 2:
Central controller

Interfaces:
- Target wheel torque
- Wheel slip limit
- NVH interface

- Portable vehicle motion software requires
  - Hardware / Software decoupling
  - Functional decoupling
  - Lean and manageable Interfaces
- Standardization is key

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Summary

https://jobs.smartrecruiters.com/BoschGroup/743999863242890-entwicklungsingenieur-fahrdynamikregelung-w-m-div-

Advanced control

Sense Think Act

Vehicle Dynamics Control 2.0 from Bosch opens-up new dimensions through model-based control and multi-actuator integration for more road safety, ride comfort and driving pleasure

Function deployment and E/E architecture

Centralized vehicle E/E architectures require decoupling on software and function level with lean interfaces - **standardization is key**

Cooperation models

Vehicle Dynamics Control 2.0 is prepared for all cooperation models and is also offered as a **standalone software product** – decoupled from hardware

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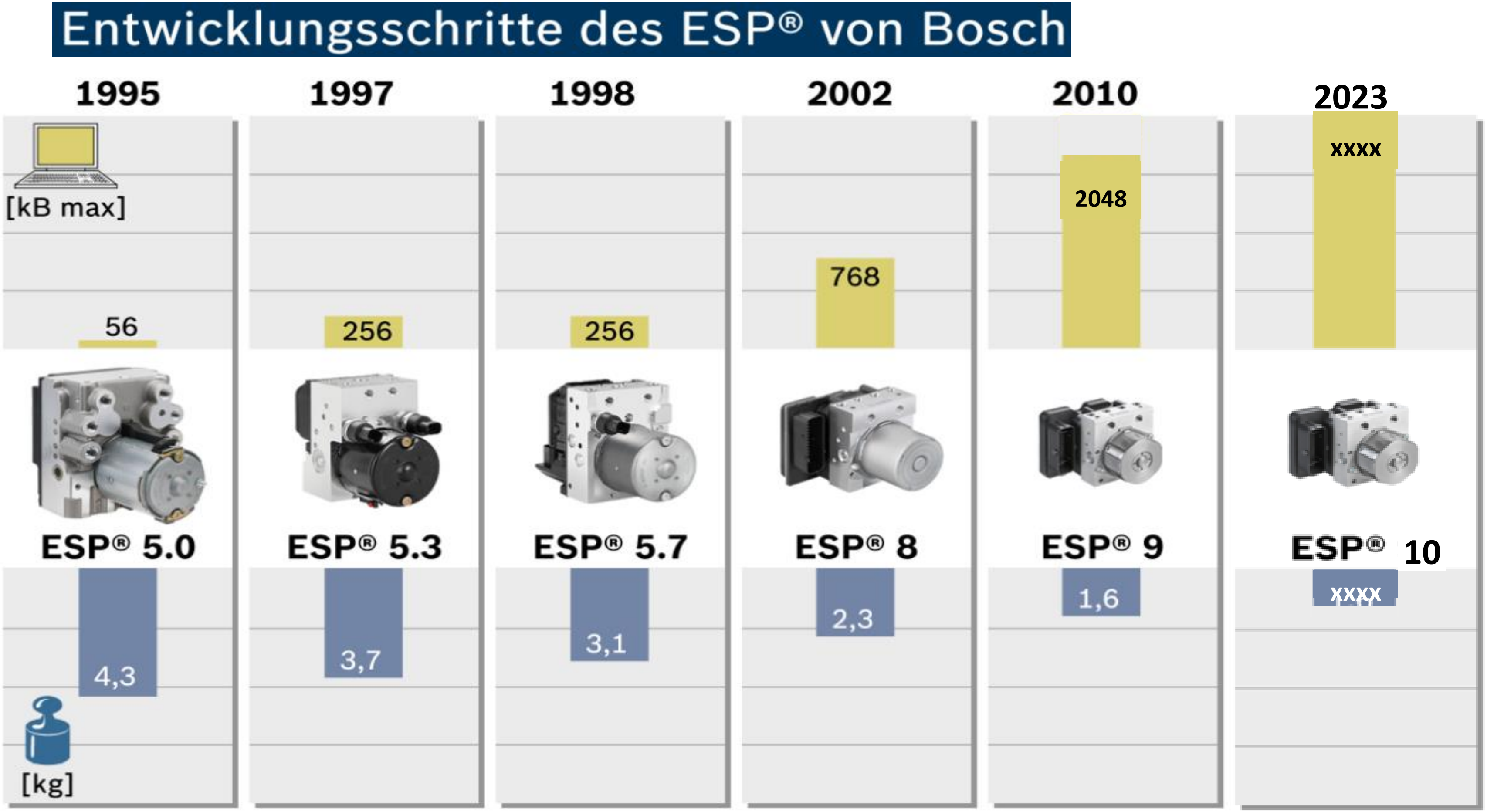
Fahrdynamikregelsysteme
ESP® - Wie geht es weiter? CC-Portfolio für ADAS



Active safety and driver assistance

ESP® - Wie geht es weiter? CC-Portfolio für ADAS

Brake boost → Vacuum-free & dynamics

Vacuum Booster

→

iBooster

Modulation → Regeneration

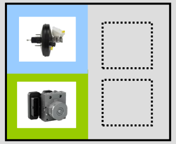
ESP®

→

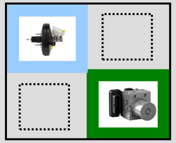
ESP® *hev*

Driving Configuration

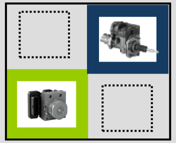
- Conventional
- Assisted



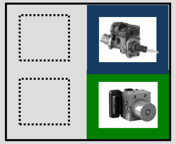
- Conventional
- Assisted



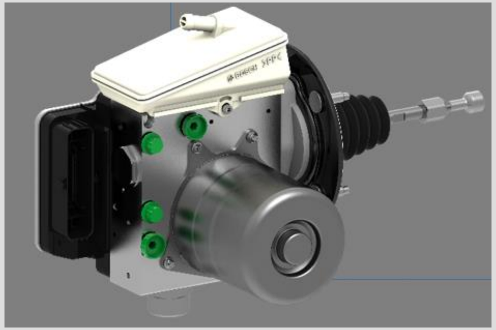
- Conventional
- Assisted
- Automated



- Conventional
- Assisted
- Automated



Brake boost & Modulation



➔ Modularer und integrierter Ansatz um alle Konfigurationen, von konventionellem bis hin zu automatisiertem Fahren, abzudecken

BREMSBASIERTE ASSISTENZFUNKTIONEN
-
FAHRDYNAMIKREGELSYSTEME

(ABS, ASR,ESP, **VAFs**)

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Fahrdynamikregelsysteme
VDC – Value Added Functions (VAFs)

Funktion	Akronym	Release
▶ Enhanced Understeering Control	EUC	06/2004
▶ Roll Movement Intervention	RMI	12/2004
▶ Rollover Mitigation	ROM	02/2005
▶ Trailer Sway Mitigation	TSM	02/2005
▶ Continuous Center Coupling Control	CCC	05/2005
▶ Load Adaptive Control	LAC	06/2005
▶ Dynamic Wheel Torque Distribution	DWT-B	06/2006
▶ Continuous Damper Control	CDC	06/2006
▶ Dynamic Steering Angle Control	DSA	09/2006
▶ Rollover Mitigation w./ Load Adaptive Control	ROM-LAC	11/2006
▶ Dynamic Steering Torque Control	DST-C	11/2007
▶ …	…	…
▶ Side Wind Assist	SWA	03/2013

Fahrdynamikregelsysteme

VDC – Value Added Functions (VAFs) - TSM

Trailer Sway Mitigation (TSM)

- Brake intervention and engine torque limitation mitigates trailer instability

Input parameters *

- Trailer present signal
- Yaw rate

Output parameters

- Brake torque on tow vehicle
- Engine torque limitation

- **Results from accident statistics (ATZ 4/2002):**
  - 609 accidents involving passenger cars with trailers on German motorways were reported in 1999
  - Outside urban areas (excluding motorways), there were 1000 accidents with vehicle trains
- Speed is one cause of such accidents: cars with trailers tend to sway around the vertical axis more or less strongly depending on the speed

Fahrdynamikregelsysteme

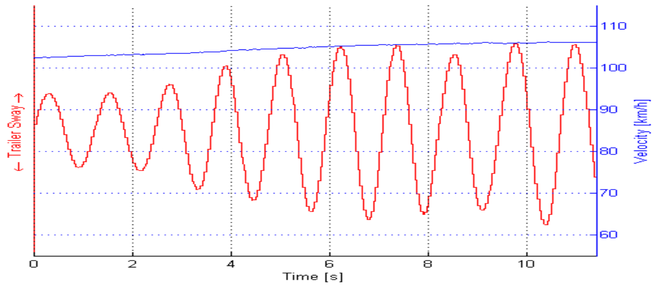
VDC – Value Added Functions (VAFs) - TSM

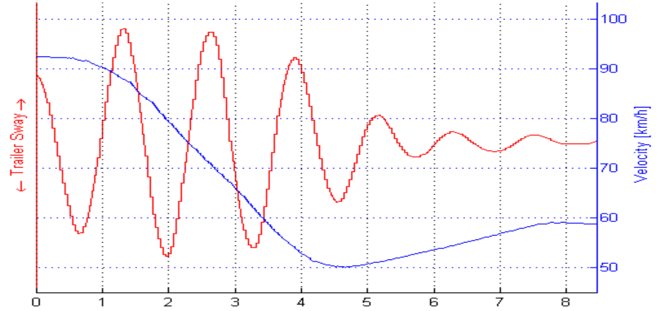
Trailer Sway Mitigation (TSM)

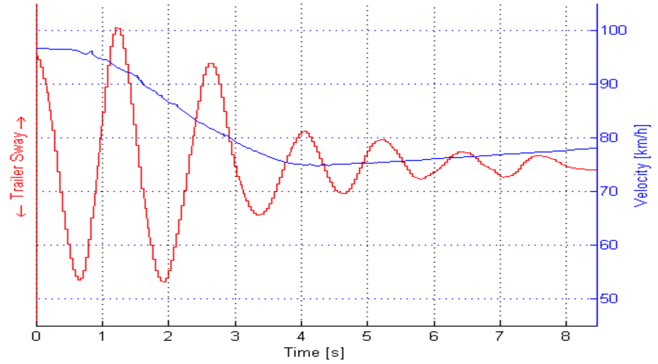
- ➔ Algorithm detects trailer sway dependent on the driving situation
- ➔ Active braking and engine torque limitation decelerates the towing vehicle until the oscillation is stopped

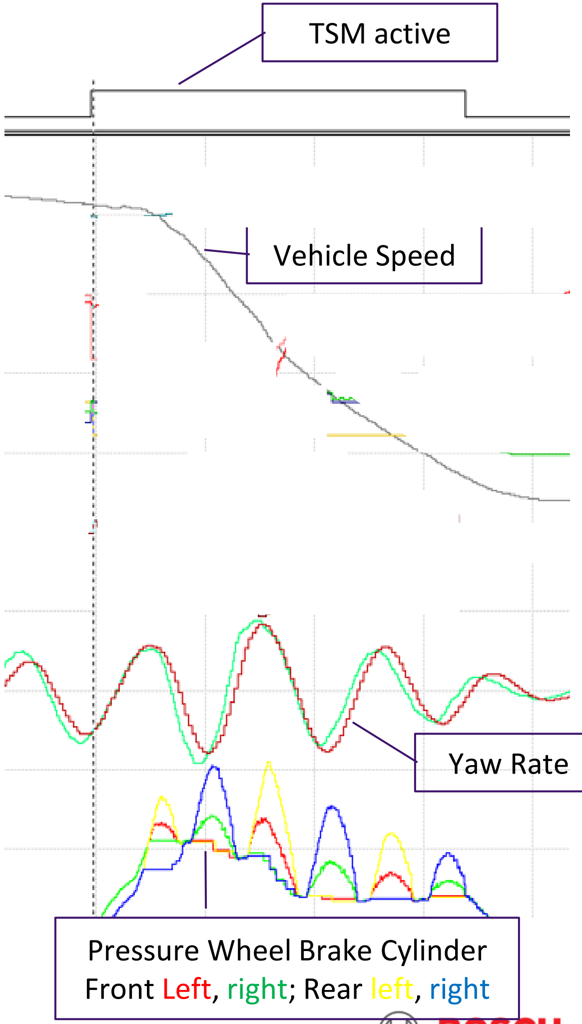
Results: Two strategies to control trailer sway

- ➔ Symmetrical brake intervention with settable front/rear distribution of brake torque decelerates the vehicle train until stabilization
- ➔ Asymmetric interventions superimpose the symmetrical intervention
- ➔ Build up of counter yaw moment stabilizes vehicle train faster and with less deceleration than with symmetrical intervention only









Fahrdynamikregelsysteme

VDC – Value Added Functions (VAFs) - TSM

Trailer Sway Mitigation (TSM)

- Brake intervention and engine torque limitation mitigates trailer instability

- **TSM function is a value added ESP function to prevent unstable snaking motions in vehicle trains:**
  - based on ESP sensor set only
  - special algorithm detects trailer sway dependent on the driving situation
  - to remove the snaking motion the vehicle is decelerated automatically by active brake pressure control
  - TSM helps the driver to control a vehicle train even in critical situations
  - no increase of packaging
  - mechanical sway control devices are not affected

Fahrdynamikregelsysteme

VDC – Value Added Functions (VAFs) – ROM/**RMI**

Roll Movement Intervention (RMI)

- Mitigation of dangerous roll over situations during <u>dynamic</u> driving
- Improved performance during dynamic driving tests, e.g. fishhook, J-turn

Input parameters *

- Yaw rate
- Lateral acceleration
- Wheel speed
- Steering angle

Output parameters

- Brake torque

<u>Results from accident statistics</u>

- Rollover accidents represent approximately 3% of all accidents annually, but represent 32% of all fatalities
- The vast majority of vehicle rollover crashes take place after a driver's loss-of-control (e.g. striking a ditch or embankment after skidding off the road): **tripped rollover**
- in about 4 % of cases, the root cause of a rollover crash is a severe steering maneuver (e.g. obstacle avoidance maneuver): **untripped rollover**

Fahrdynamikregelsysteme

VDC – Value Added Functions (VAFs) – **ROM**/RMI

Roll Over Mitigation (ROM)

- Extension of RMI by mitigation of rollover at quasi-stationary maneuvers, e.g. motorway exit
- Recommended for vehicles with high center of gravity (e.g. SUV)

Input parameters *

- Yaw rate
- Lateral acceleration
- Wheel speed
- Steering angle
- Engine torque

Output parameters

- Brake torque, engine torque (opt.)

Fahrdynamikregelsysteme

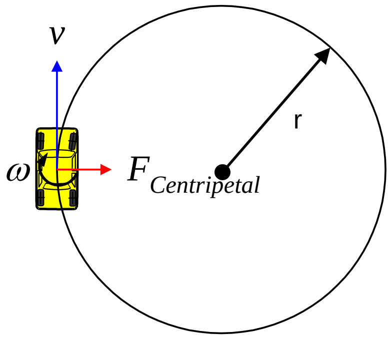
VDC – Value Added Functions (VAFs) – ROM/RMI

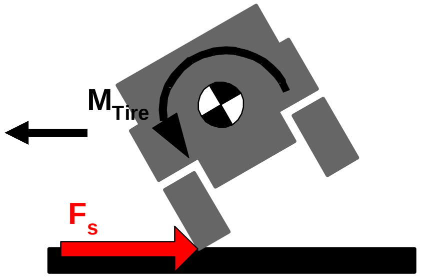
Circular motion (simplified)

$$\omega = \frac{v}{r} \Rightarrow r = \frac{v}{\omega}$$

Centripetal force:

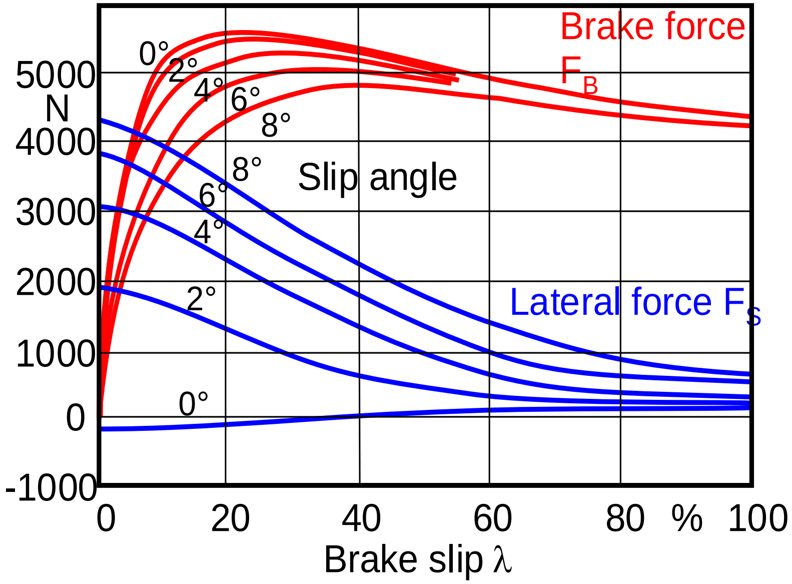
$$F_{Centripetal} = m \cdot \frac{v^2}{r} = m \cdot a_{Lateral}$$





Reducing the centripetal force means reducing the lateral acceleration (vehicle mass cannot be influenced):

Braking the outer front wheel
- increases the wheel slip,
- reduces the yaw rate,
- lessens vehicle velocity.



Fahrdynamikregelsysteme

VDC – Value Added Functions (VAFs) – ROM/RMI

Static rollover risk model (NHTSA):

- (National Highway Traffic Safety Administration) up to MY 03, rating based on ***S****tatic* ***S****tability* ***F****actor*

$$SSF = \frac{T}{2 \cdot h_{CoG}}$$

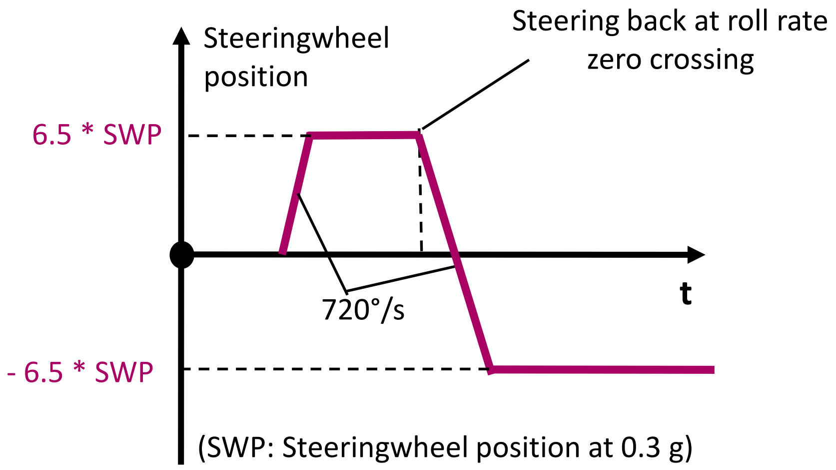
(T: track width; h_{CoG}: height of CoG)

- Rollover risk indicator called „$rollrate_{SSF}$“

$$rollrate_{SSF} = \frac{1}{1 + e^{(2.7546 + 1.1814 * \ln(SSF - 0.90))}}$$

- Brake interventions depending on $rollrate_{SSF}$

Dynamic test: Road Edge Recovery ("Fishhook")



Fahrdynamikregelsysteme
VDC – Value Added Functions (VAFs) – ROM/RMI

Most important driving maneuvers:

- Single lane change
- VDA double lane change
- Consumers Union Short Course (CU-S)
- Consumers Union Long Course (CU-L)
- J-turn
- Fishhook (Road Edge Recovery) according to NHTSA
- ISO slalom (18 m, 36 m)
- Handling course
- Hairpin bends in mountains

Application objectives:

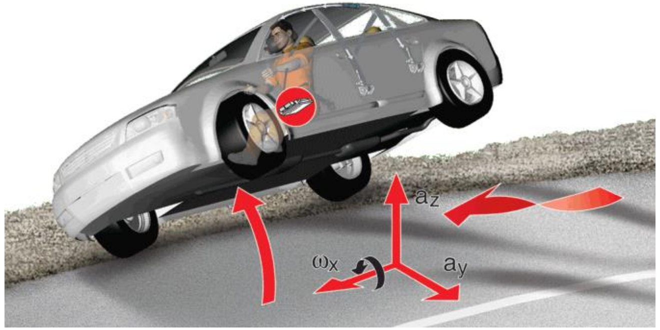
RMI interventions in time and with appropriate strength so that

- the inner wheels do not lift off more than 5 cm at the very most and
- the vehicle tendency to hop especially during slalom driving is reduced.

VDC – Value Added Functions (VAFs) – ROM/RMI

Roll Mitigation Intervention (RMI)
Roll Over Mitigation (ROM)

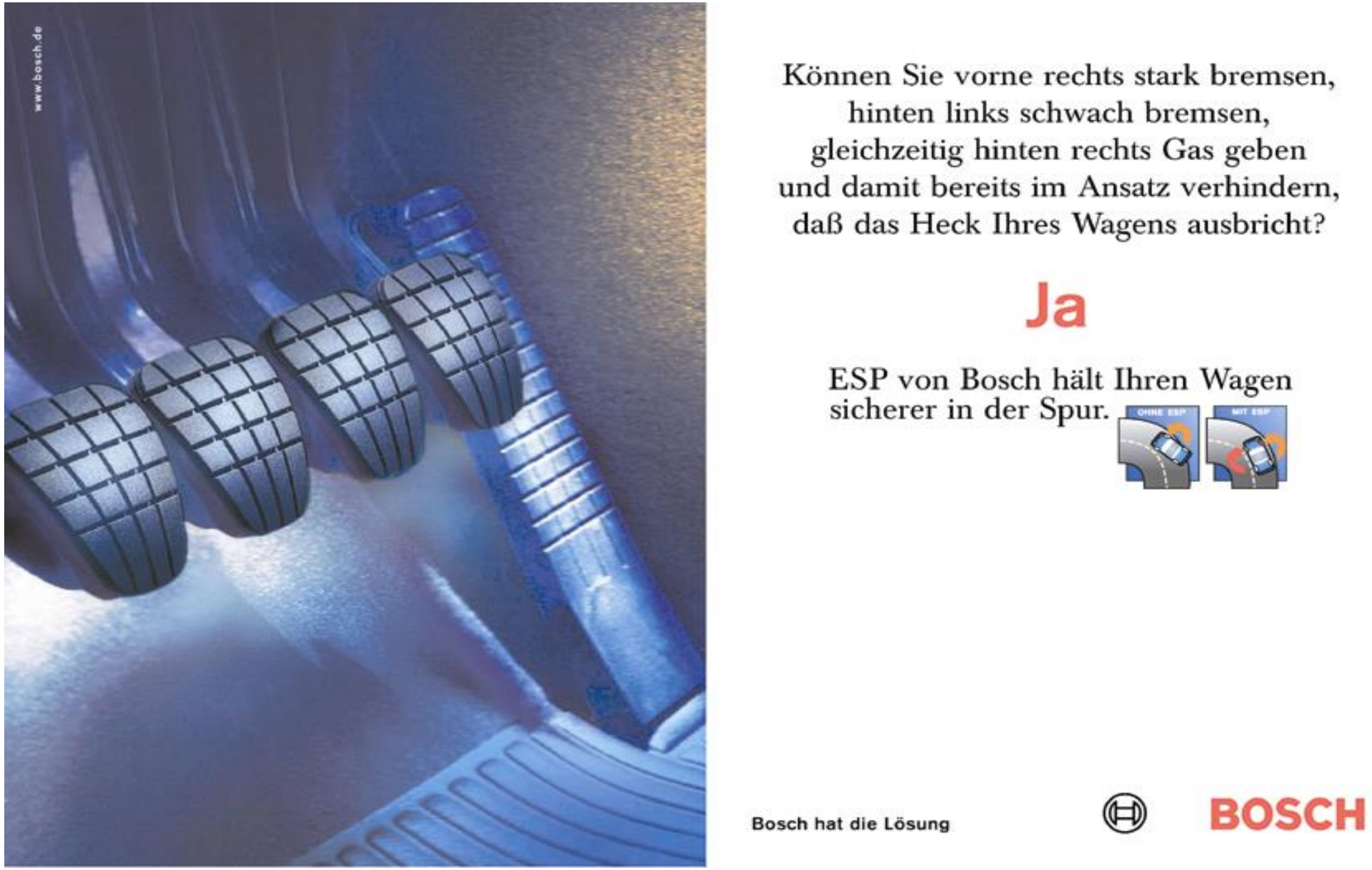
Electronic Stability Program (ESP)
Reduces the risk of tripped rollover (e.g. curb or soil trip) by improving the vehicle's tracking stability and staying on road



- Roll Movement Intervention (RMI)
- Rollover Mitigation (ROM)
- Reduces the risk of untripped (friction) rollover in distinct rollover critical situations and for different vehicle types

BOSCH

Fahrdynamikregelsysteme
… und wie bewerten Sie ESP®?



Fahrdynamikregelsysteme
Zusammenfassung: „Werte, Ziele, Teamgeist“

Gute Unternehmen haben mehr als einen Wert, sie haben Werte. Und diese Werte, ob Verantwortung oder auch Vertrauen, haben sich nicht nur in der Vergangenheit bewährt, sie können auch den Weg in die technologische Zukunft weisen.

von Dr. Volkmar Denner

15 000 gerettete Menschenleben

durch ESP® nach 25 Jahren (allein in Europa).

Das ESP® – wenn Technik zum Schutzengel wird

25 Jahre ESP® – das sind nahezu 15 000 gerettete Menschenleben, das sind gut 450 000 verhinderte Verkehrsunfälle allein in Europa. Das ist eine der ganz großen Innovationsgeschichten von Bosch. „Technik fürs Leben“ vom allerbesten. Bosch selbst hat weltweit bereits rund 250 Millionen Schleuderschutz-Systeme ausgeliefert. Bald war nicht mehr vom Elektronischen Stabilitäts-Programm die Rede, vielmehr vom elektronischen Schutzengel. Und früh gab es dazu spannende Geschichten – Geschichten vom Elchtest und anderen Fahrmanövern, Geschichten, die das Wiedererzählen lohnen.

„Je sinnstiftender das Ziel, desto größer das Engagement der Mitarbeiter.“

Volkmar Denner, CEO Bosch