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Precision. Passion. Partnership.

Active Yaw Systems: Re-experience Front Wheel Drive with ***SCHNELLSTER*** and ***TWINSTER®+***

Peter Obergünner

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- Investigation of different driveline configurations
- Functional Description
  - Speed lead ***SCHNELLSTER***
  - Torque lead ***TWINSTER®+***
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  - High-µ
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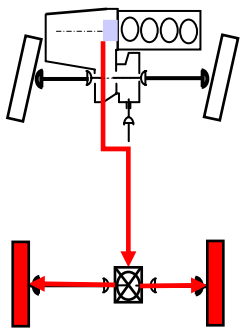
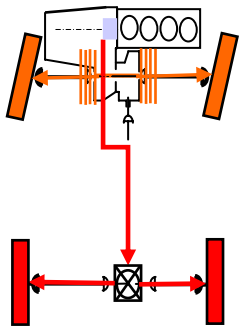
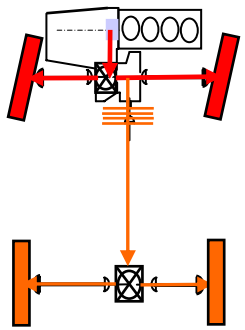
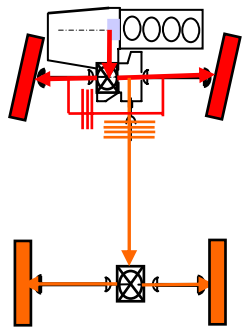
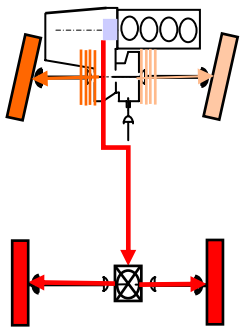
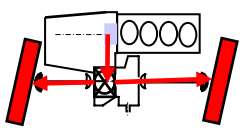
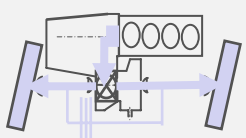
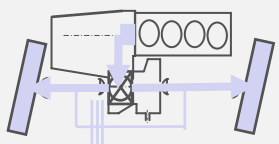
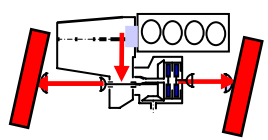
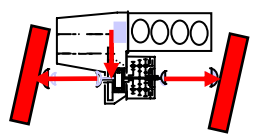
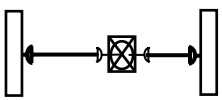
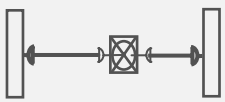
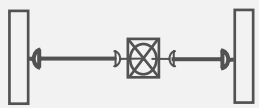
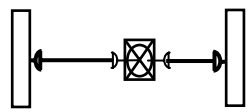
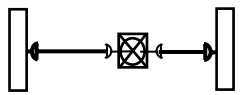
Investigation of Different Driveline Configurations on a R53 MINI Cooper S

GETRAG MINI AWD Investigated Driveline Configurations

RWD	RWD + Hang-On front ***BOOSTER***	FWD + Hang-On rear ***BOOSTER***	FWD + Hang-On + e-LSD ***BOOSTER & TRACKSTER***	RWD + Active Yaw front ***TWINSTER®***
				

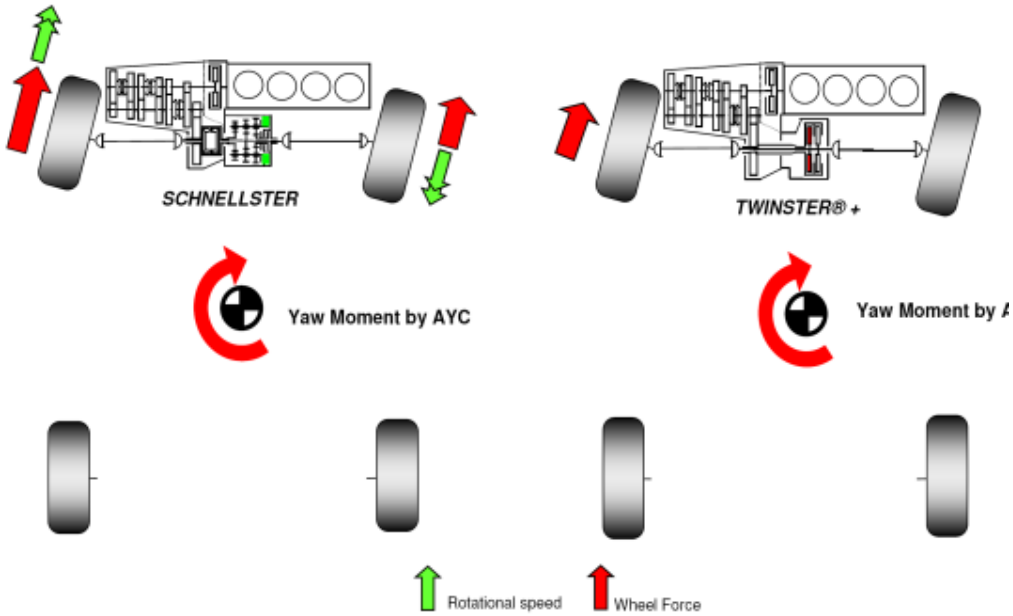
GETRAG MINI FWD Investigated Driveline Configurations

FWD Production	FWD + Passive LSD	FWD + e- LSD front *TRACKSTER*	FWD + Active Yaw *TWINSTER®+*	FWD + Active Yaw *SCHNELLSTER*
				
				

Motivation for Development of FWD Active Yaw Systems

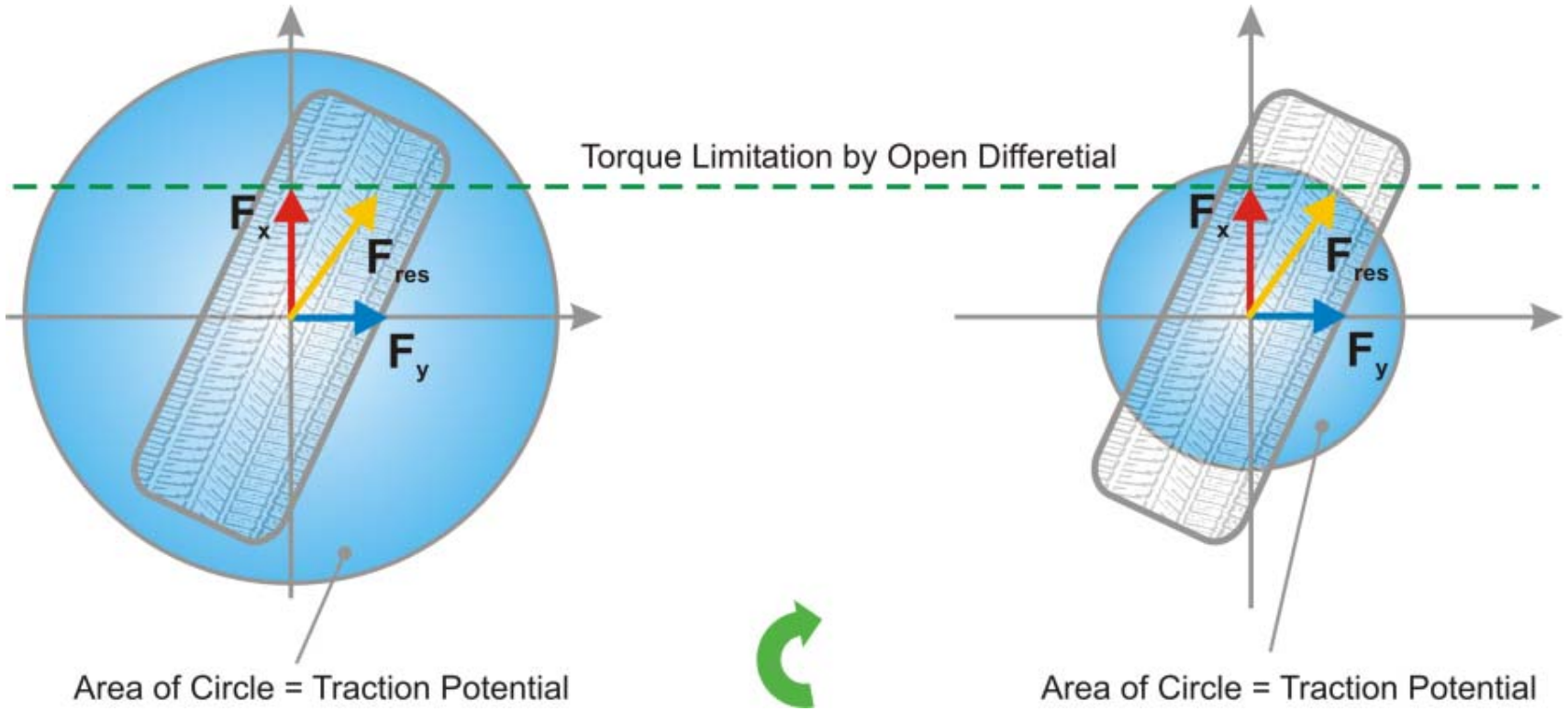
Motivation for Development of FWD Active Yaw Systems

- Today's trend is to equip high performance AWD with AYC systems on rear axle to:
  - avoid AWD understeering
  - increase agility
- Basically Active Yaw Function is independent from
  Front- or Rear Axle installation!
- FWD vehicles with open differential
  Advantage: high stability easy controllable
  Disadvantage: strong understeering when:
    - high engine power installed or power independent
    - driving on µ-low (wet, snow, ice)
- On FWD AYC can**not** generate uncontrollable oversteering in power on
    - Light understeering at the limit is still there
      - predictable, safe and easy controllable
- The average driver can feel the performance improvement easily because AYC is not dependent on lateral acceleration or corner speed

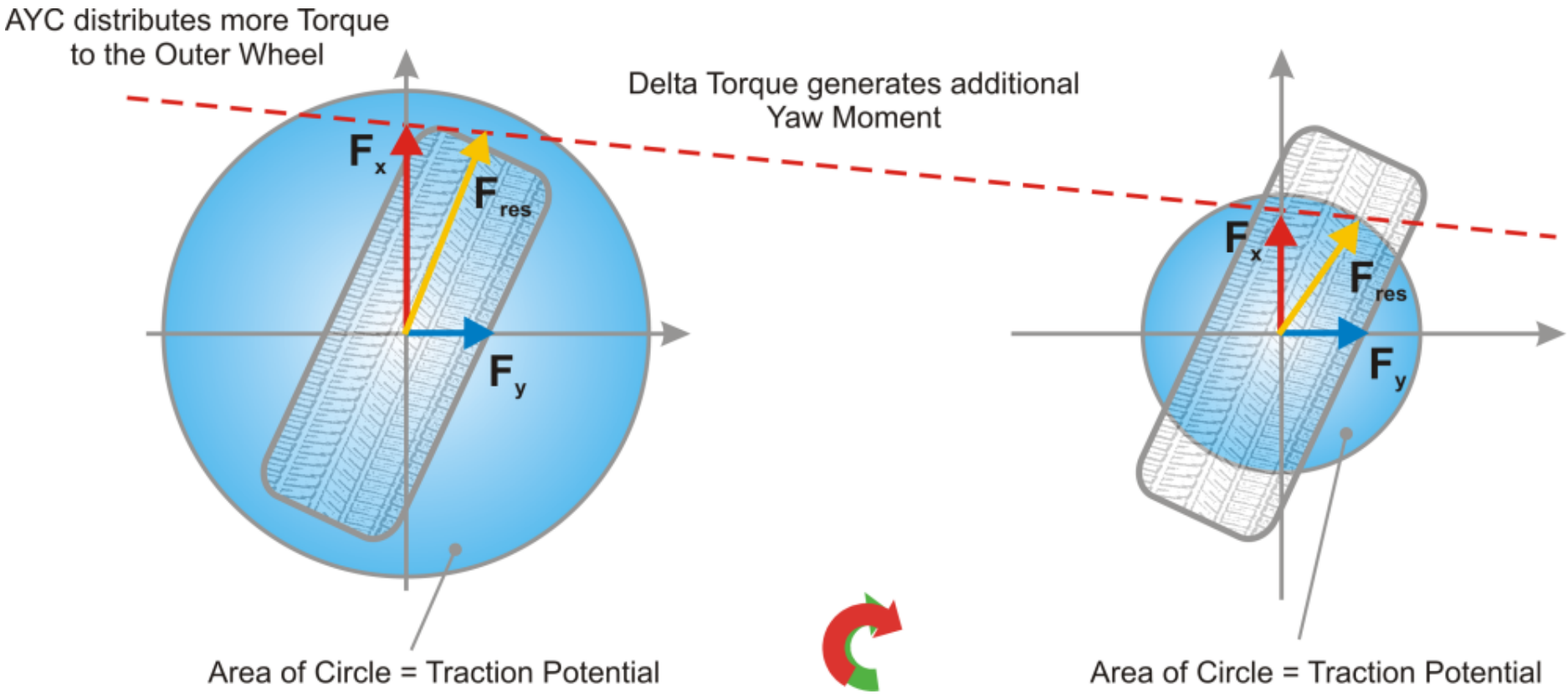


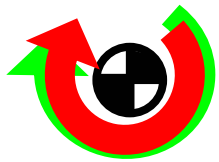
Effects by Active Yaw System

„Kammscher“ Circle
During Cornering with Constant Load: open Differential



„Kammscher“ Circle
During Cornering with Constant Load: AYC System





Options to Generate a Yaw Moment on Vehicle's Cog

Options to Generate a Yaw Moment on Vehicle´s Cog

- Superimposed planetary gear system (speed lead)
  - ***SCHNELLSTER***
- Coupling system (Torque lead)
  - ***TWINSTER®+***
- Single wheel brake intervention

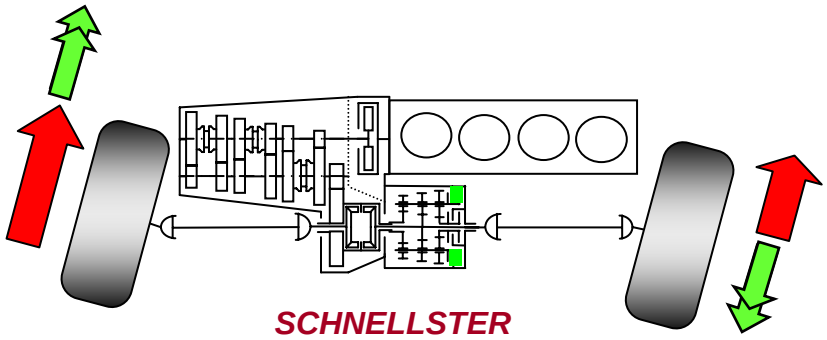
  →Not taken into account because of high energy losses

- Clutch and gear systems can be introduced on
  - Front axle
  - Rear axle
  - Transfer case (AWD)

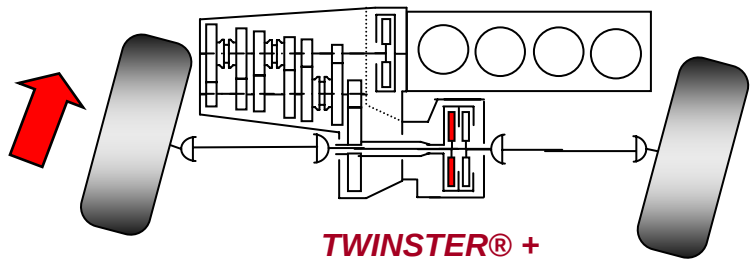
    →Not taken into account because of low efficiency

SCHNELLSTER and *TWINSTER®+*

Influence on Yaw Behavior by Different Solutions



SCHNELLSTER



TWINSTER® +

Yaw Moment by AYC

Yaw Moment by AYC

Rotational speed

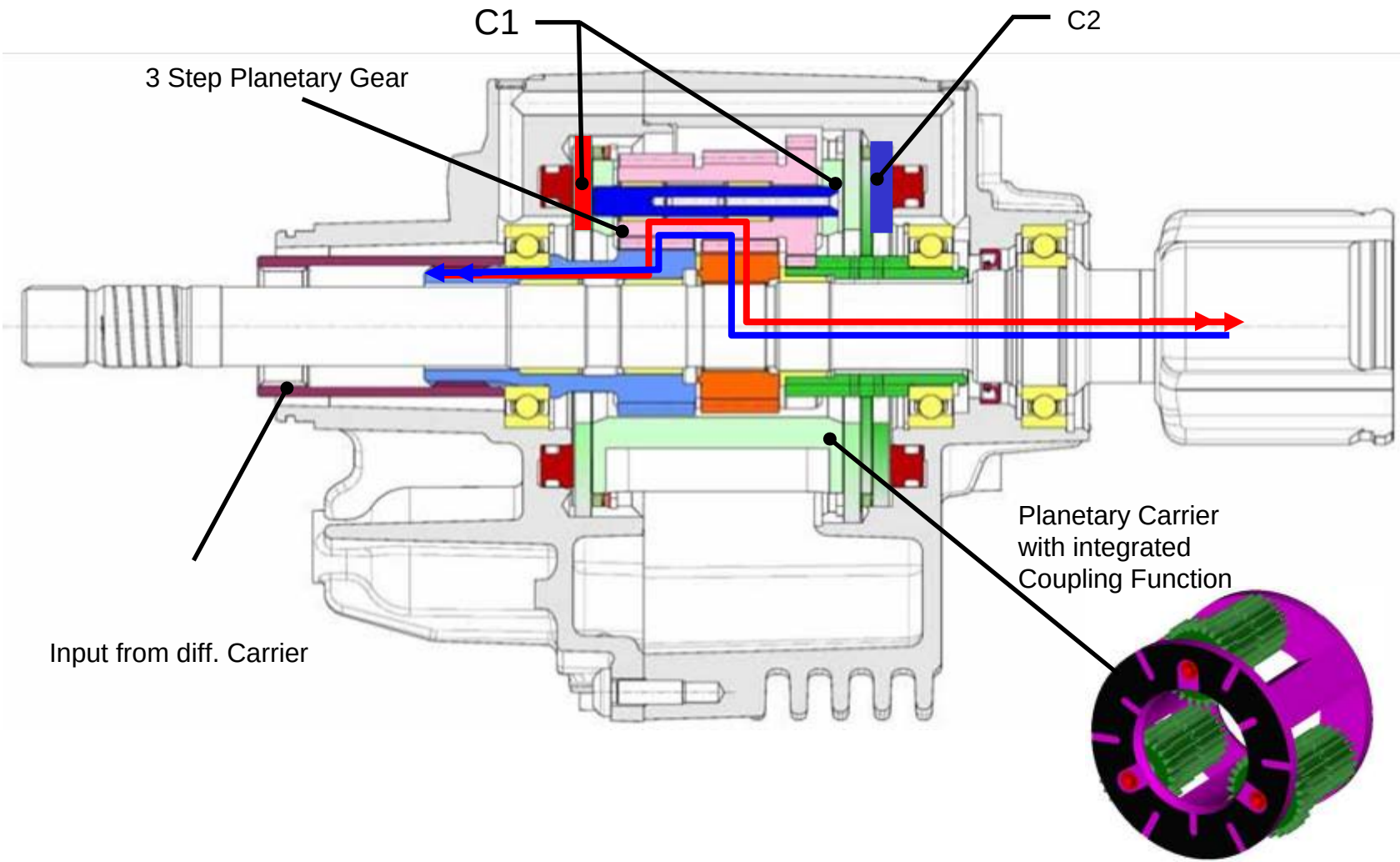
Wheel Force

SCHNELLSTER

Superimposed Planetary Gear System
Speed Lead

SCHNELLSTER

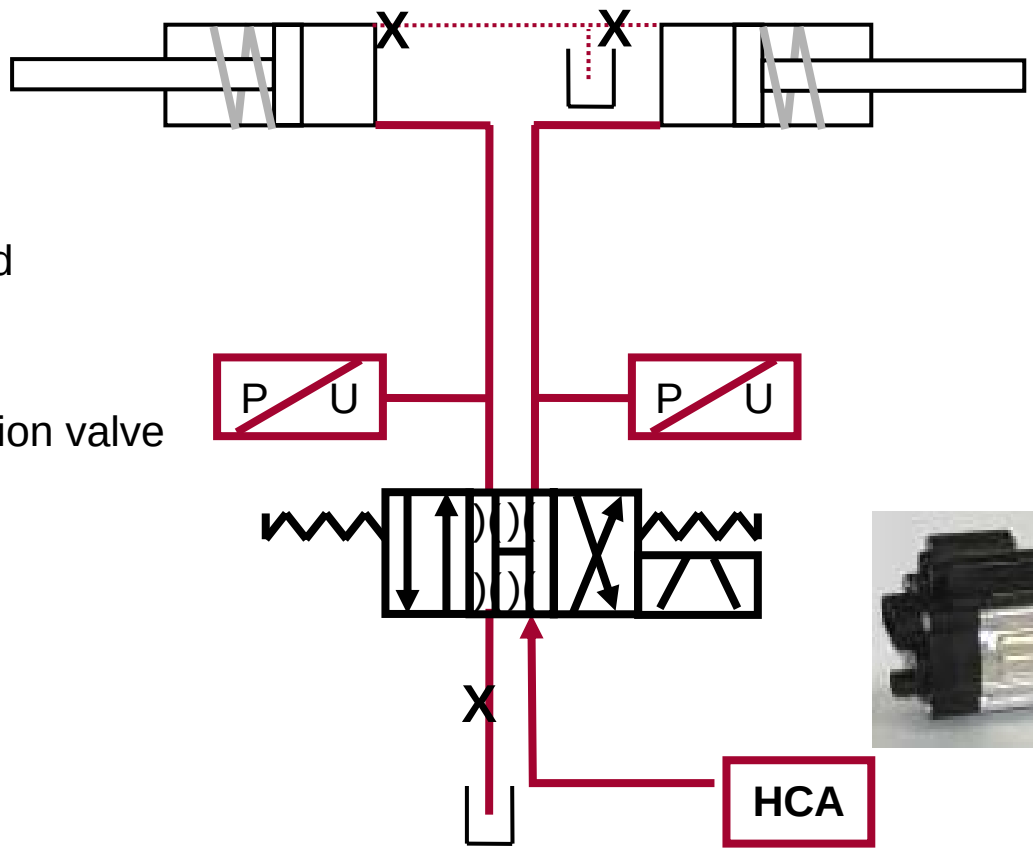
System description Mechanical Part / Torque Flow



SCHNELLSTER

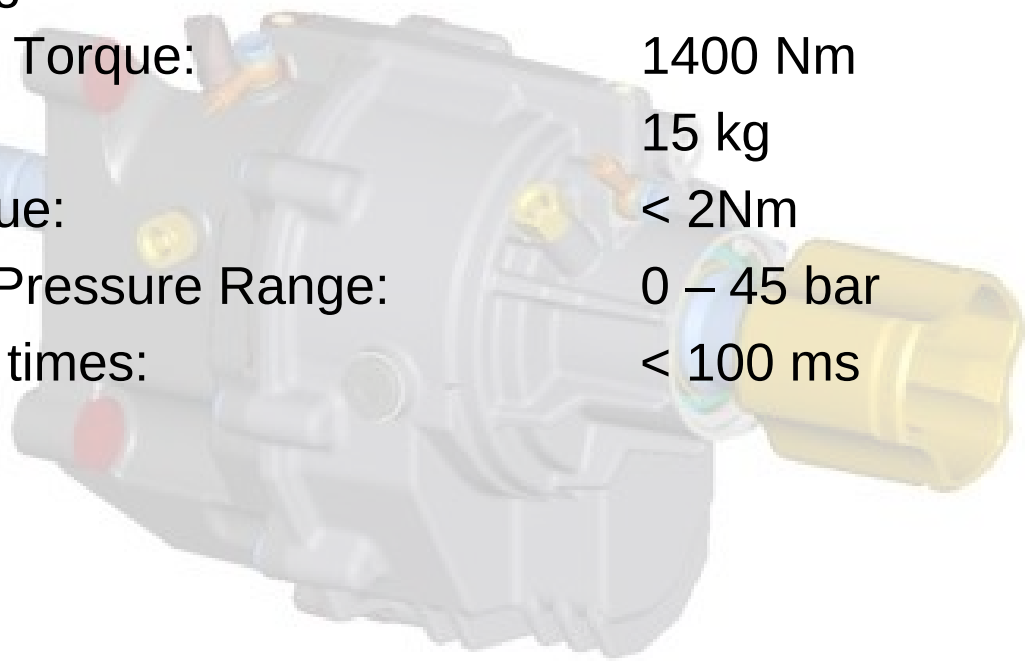
System description Hydraulic Part

- One Actuator
- Pressure Controlled
- 4-port/2-way valve
- No Accumulator
- No Pressure limitation valve
- High Dynamic
- High efficiency

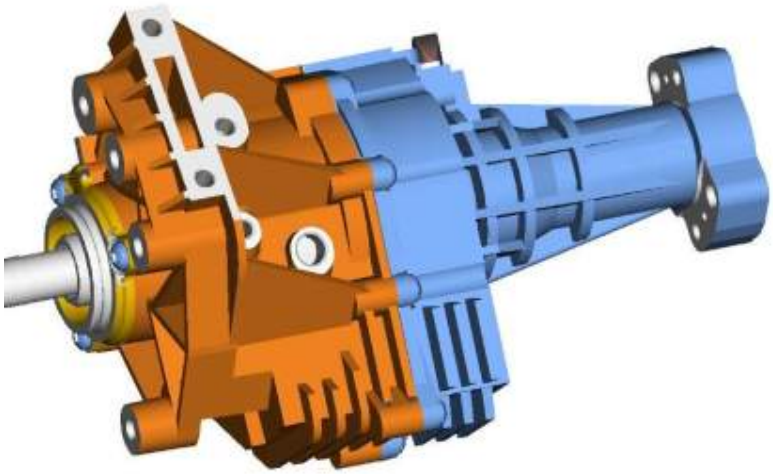


SCHNELLSTER

Current Lay Out for MINI R53



- Planetary gear offset: 10%
- Max. delta Torque: 1400 Nm
- Weight: 15 kg
- Drag Torque: < 2Nm
- Hydraulic Pressure Range: 0 – 45 bar
- Response times: < 100 ms



GETRAG ***TWINSTER®*** +
TWIN Clutch System
Torque lead

TWINSTER®+
Approach

- Approach
  - „Kammscher“ Circle
    - Frontaxle transmits tractive forces (longitudinal) and steering forces (lateral)
  - Assumption: during cornering without longitudinal wheel force vehicle drives on the “ideal” path
  - Target: to compensate occurring understeering, through increasing longitudinal wheel force, by delta torque between inner and outer front wheel

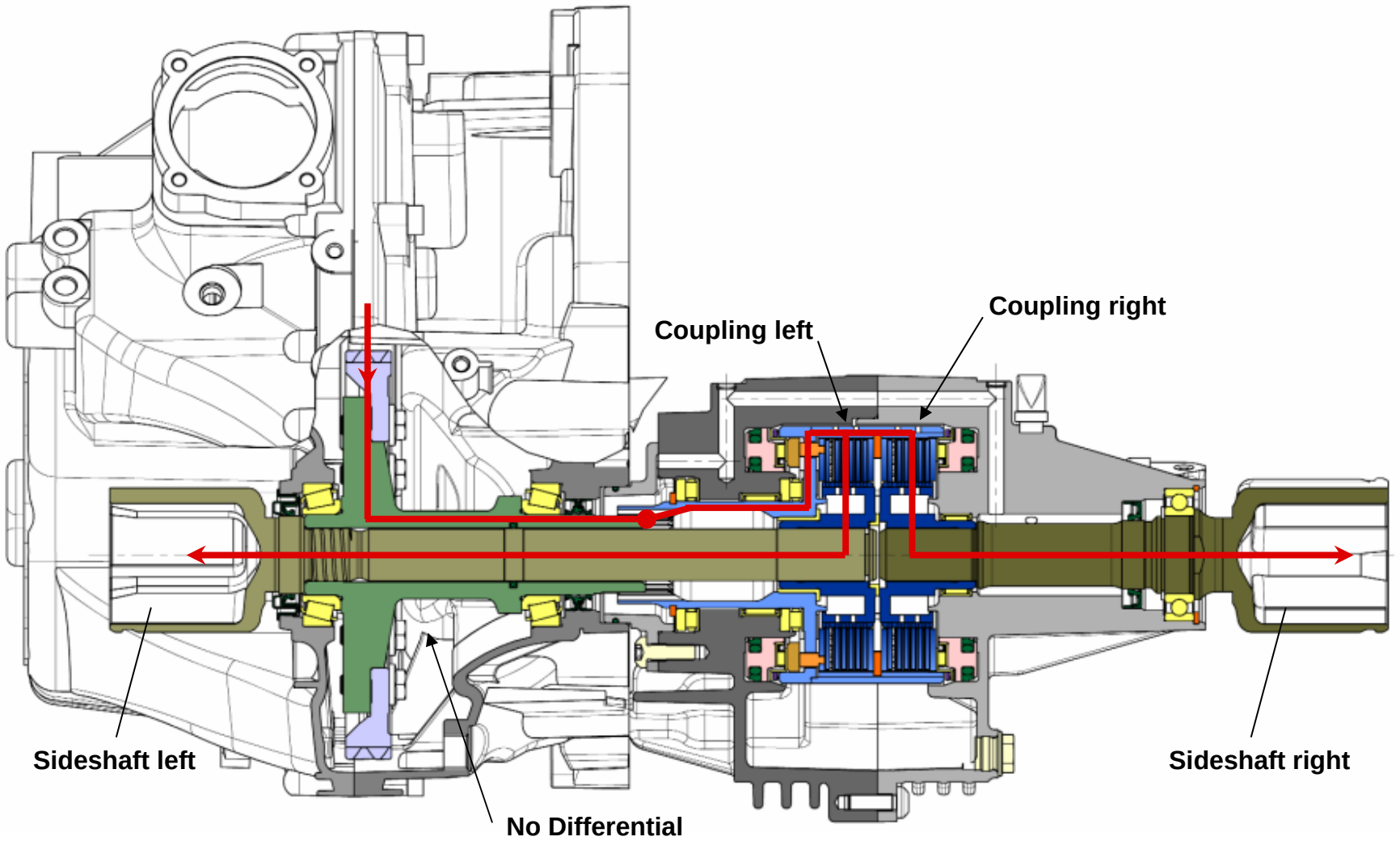
TWINSTER®+

Specific Previous Considerations about Torque Lead Systems

- Feasibility Study
  - Thermal capacity of coupling
    - delta speed during tight cornering
    - permanent slip during normal driving
  - Coupling capacity
    - wheel slip torque needs to be achieved
  - Torque steering effects
    - wheel delta torque can generate torque steering
  - Efficiency
    - losses on coupling
    - HCA current consumption

TWINSTER®+

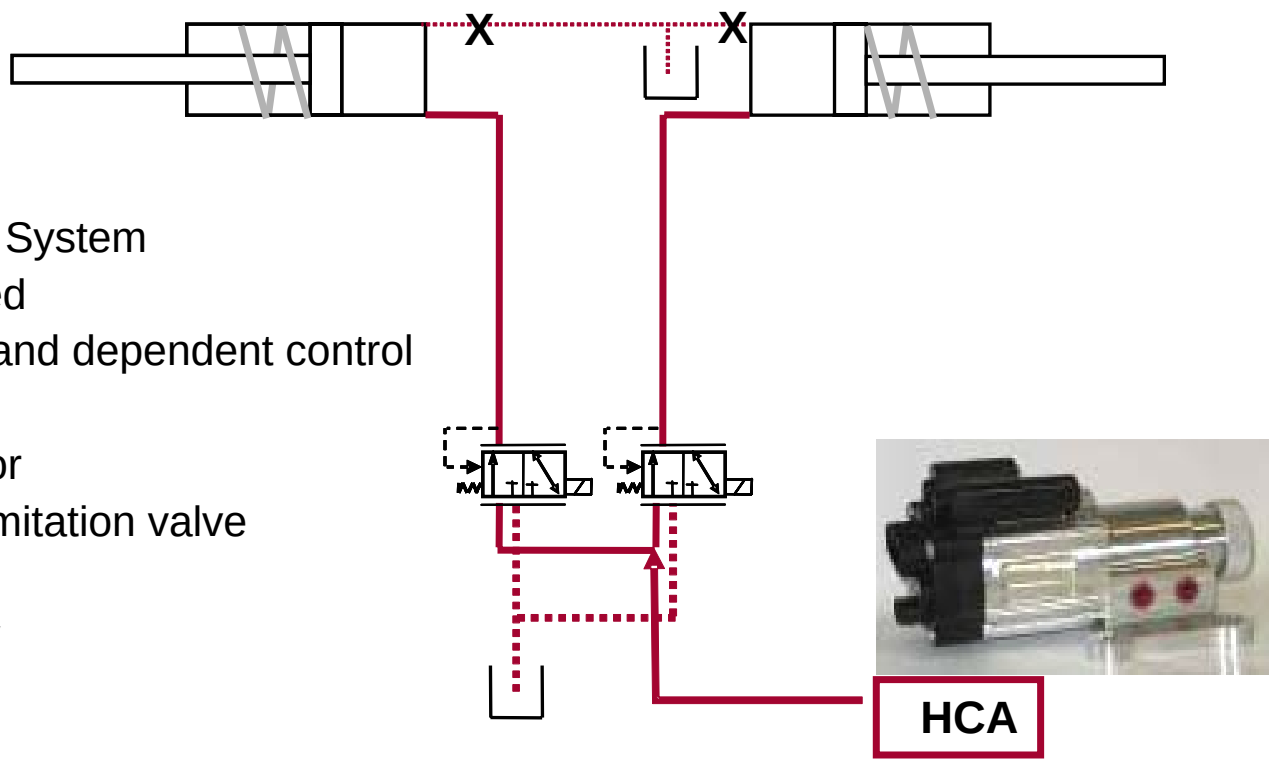
System description Mechanic Part / Torque Flow



TWINSTER®+

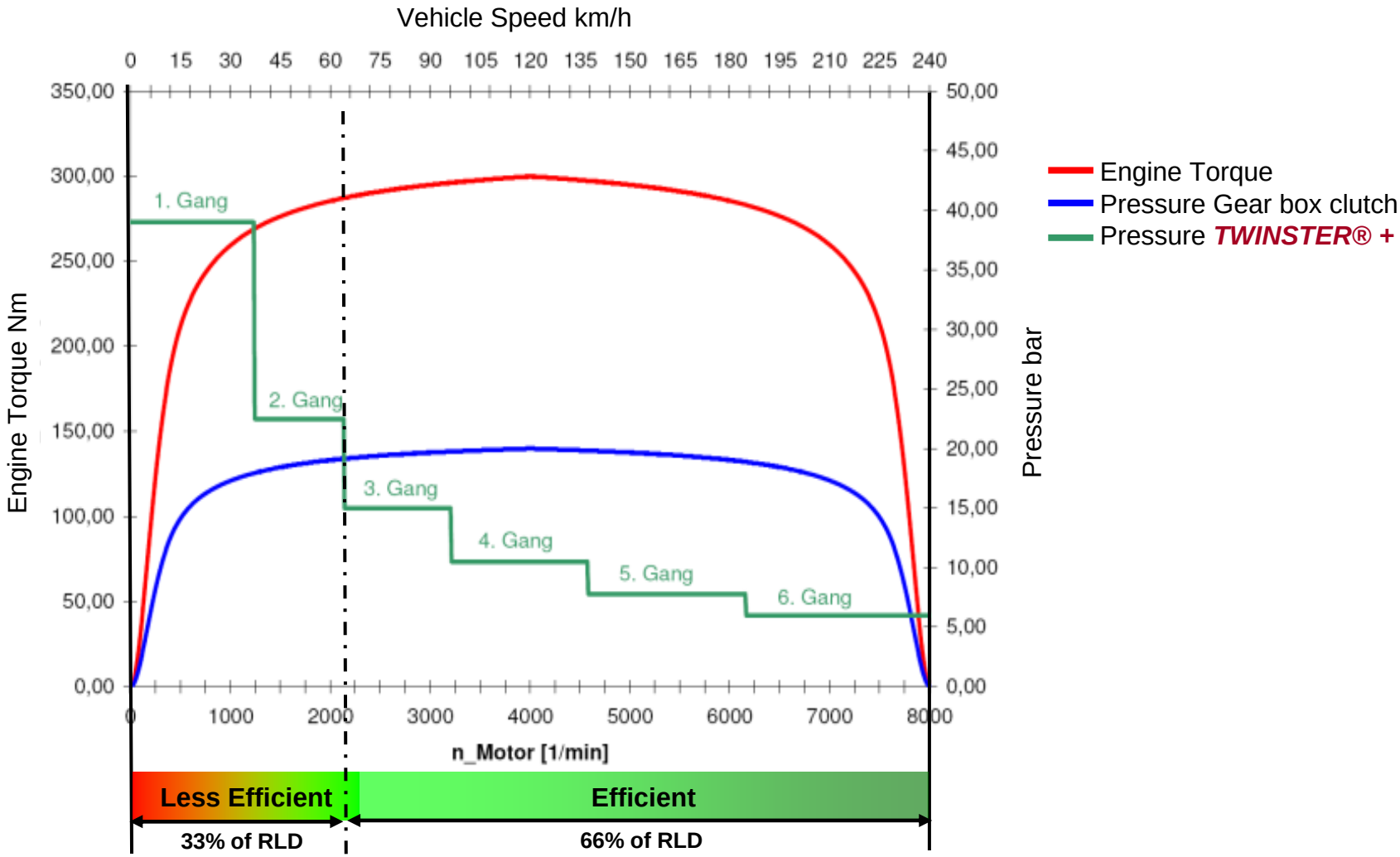
System description Hydraulic Part

- Twin Coupling System
- Valve controlled
- Pressure demand dependent control
- One actuator
- No accumulator
- No pressure limitation valve
- High dynamic
- High efficiency



TWINSTER®+

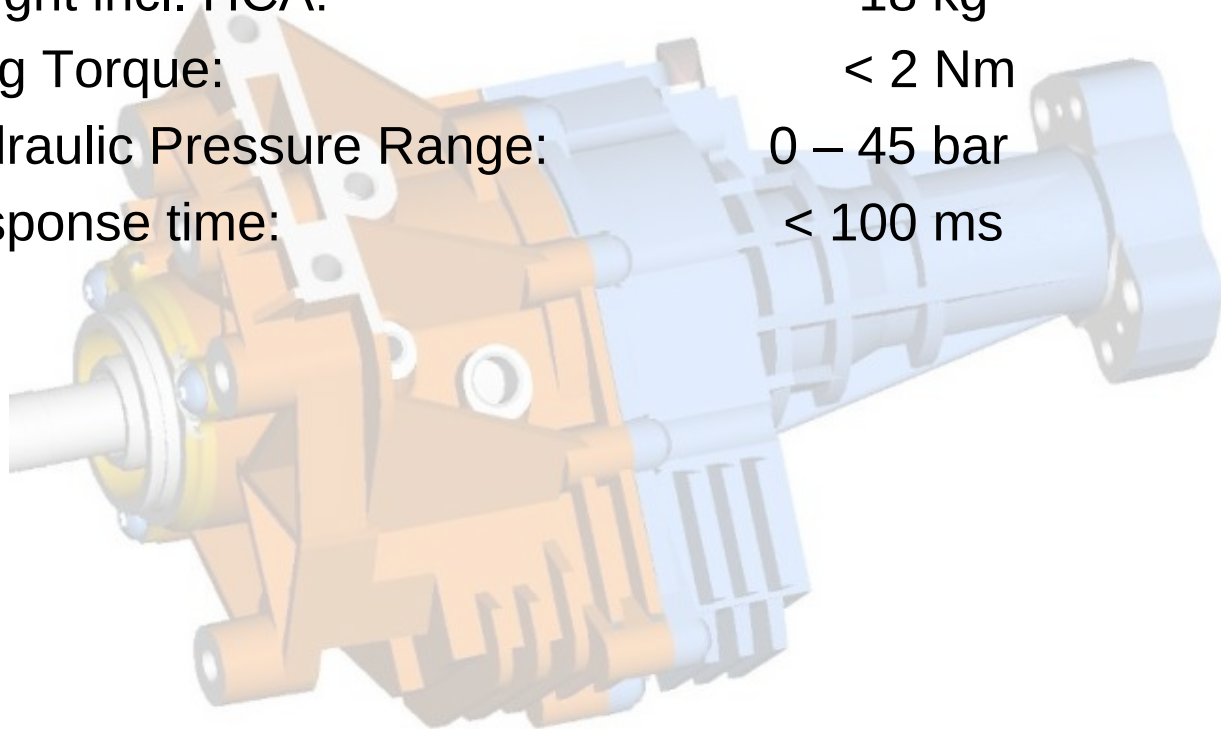
Pressure Demand versus Vehicle Speed Current Lay Out for MINI



TWINSTER®+

Current Lay Out for MINI R53

- Skid Torque for each Coupling: 1800 Nm
- Weight incl. HCA: 18 kg
- Drag Torque: < 2 Nm
- Hydraulic Pressure Range: 0 – 45 bar
- Response time: < 100 ms



TWINSTER®+
Overview of System Potentials

- Differential Function
  - eliminate differential (cost / weight compensation)
- Gearbox Main Clutch Function
  - eliminate main clutch including actuation (cost / weight compensation)
  - different clutch characteristic possible (normal- sport or snow mode)
- Torque Limiter Function
  - Protect drivline for overload
  - Eliminate stamping front axle (e.g. acceleration on wet asphalt)
  - Prevent for spinning front wheels
  - Provide best acceleration performance independent from friction coefficient
- Limited Slip Differential (eLSD) Function
- Active Yaw Control
  - Yaw support
  - Yaw damping
- Friction Coefficient Detector Function
  - pressure mirrors transmittable wheel torque
- Freewheel Function (sailing)
  - switch engine in coast off (fuel saving)
  - decouple while Braking or during ABS/ESP intervention
- Hybrid
  - instead of eliminated coupling this area can be used for a hybrid disc
- Cost reduction by Integration into DCT
  - one ECU
  - one hydraulic system
  - same pressure control valves

TWINSTER®+

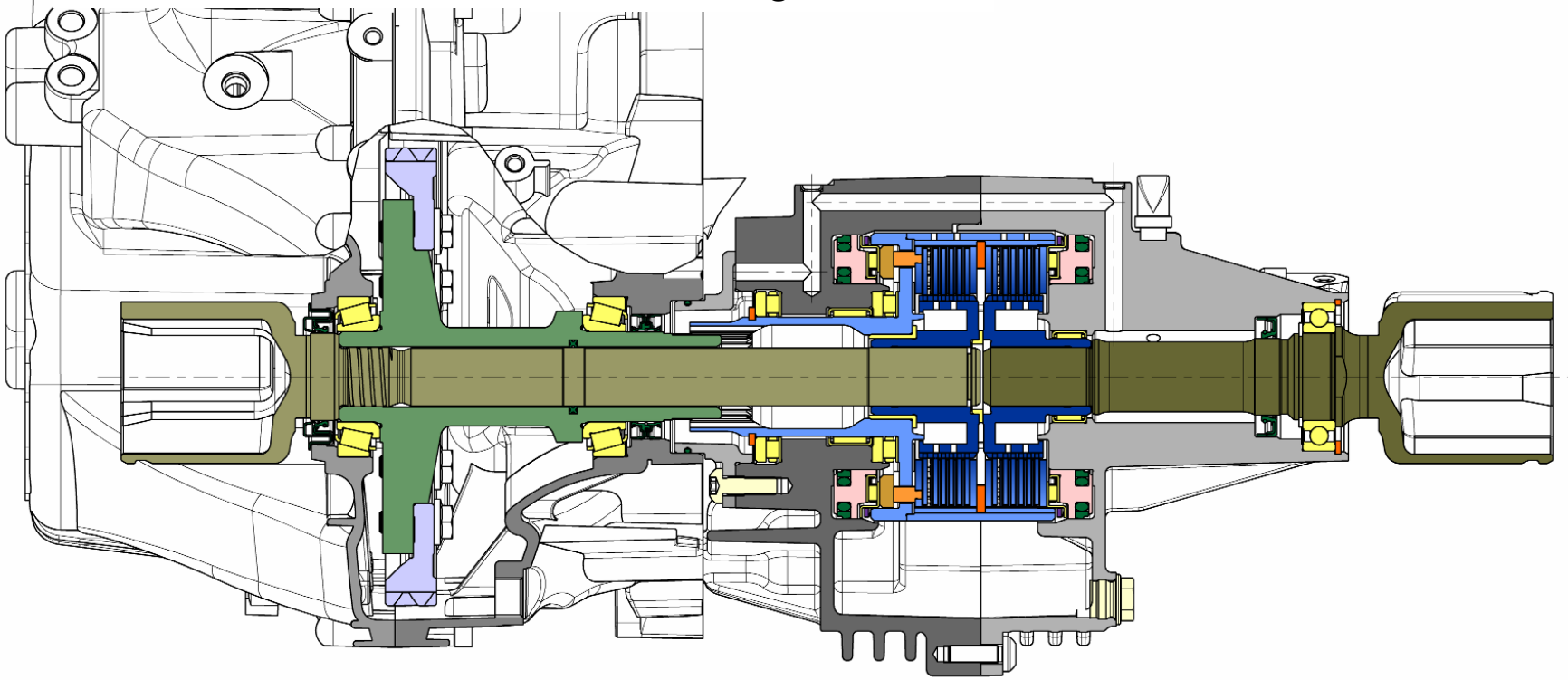
Weight compensation potential by integration into man. transmission

Weight reduction:
- Differential
- Clutch
- Actuation

→ -9.0 kg

External solution:
- HCA: 2 kg
- ***TWINSTER®+***: 16 kg
- :overall 18 kg

→ **Add 9.0 kg**



TWINSTER®+

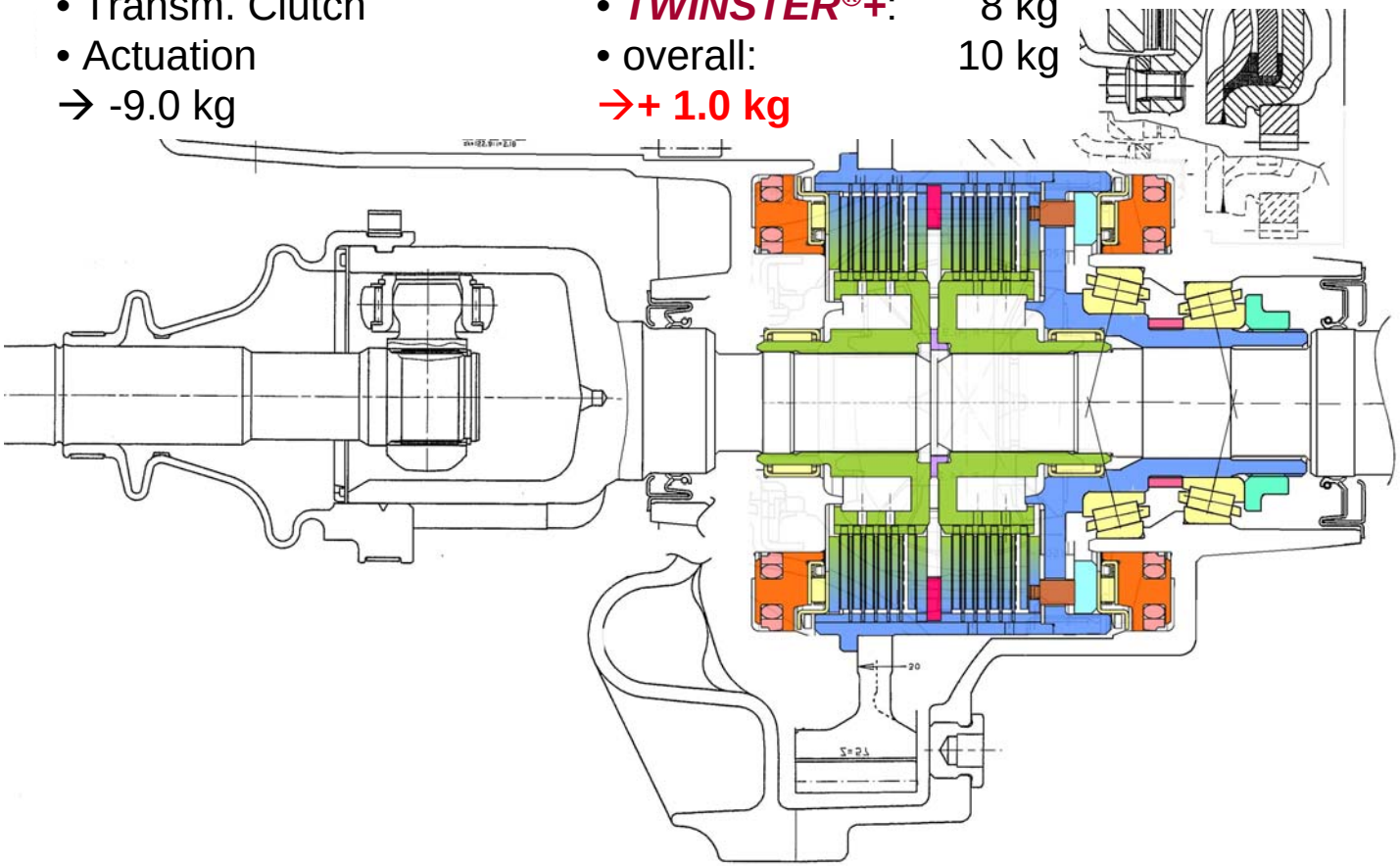
Weight compensation potential by integration into man. transmission

Weihgt reduction:
- Differential
- Transm. Clutch
- Actuation

→ -9.0 kg

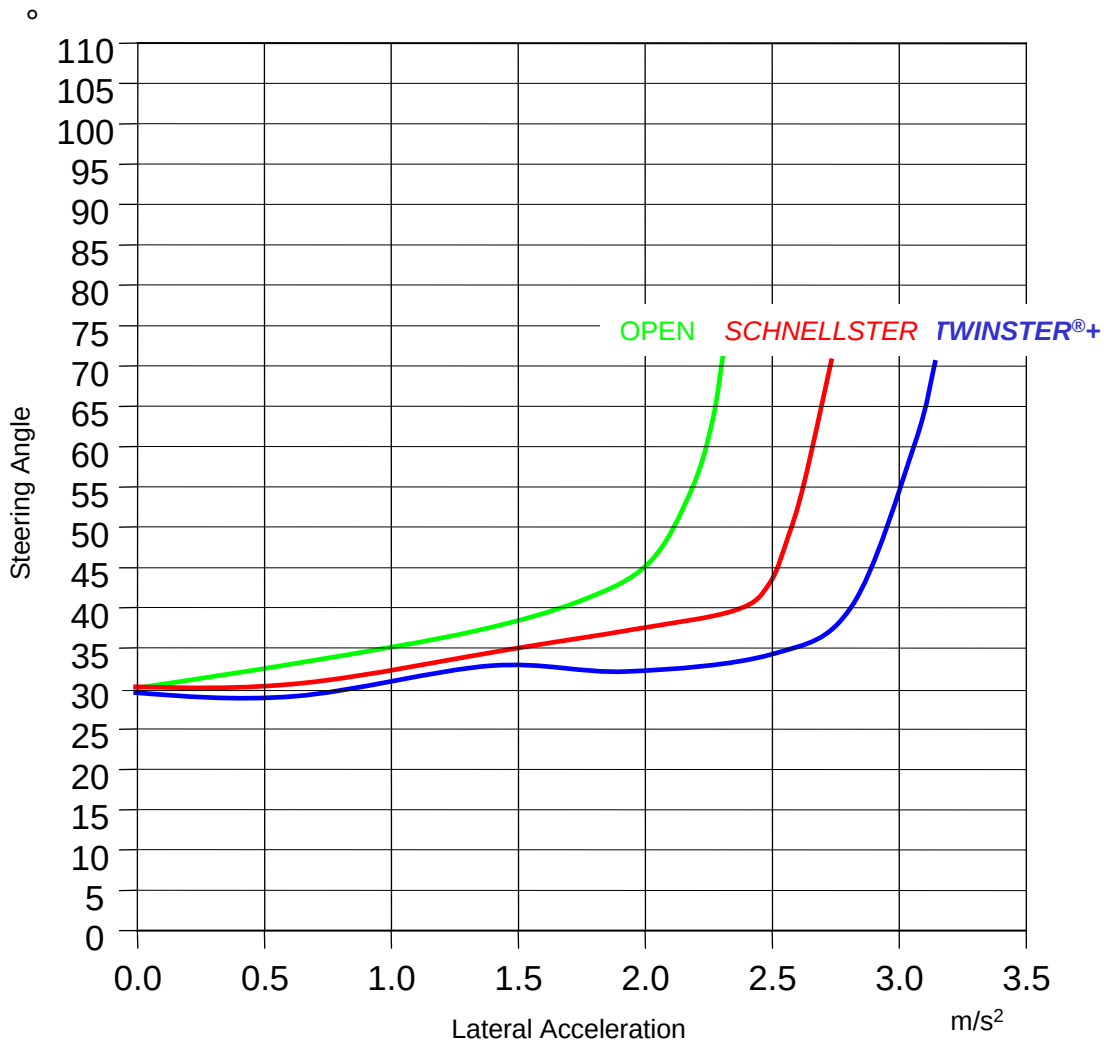
With integration:
- HCA: 2 kg
- ***TWINSTER®+***: 8 kg
- overall: 10 kg

→+ 1.0 kg

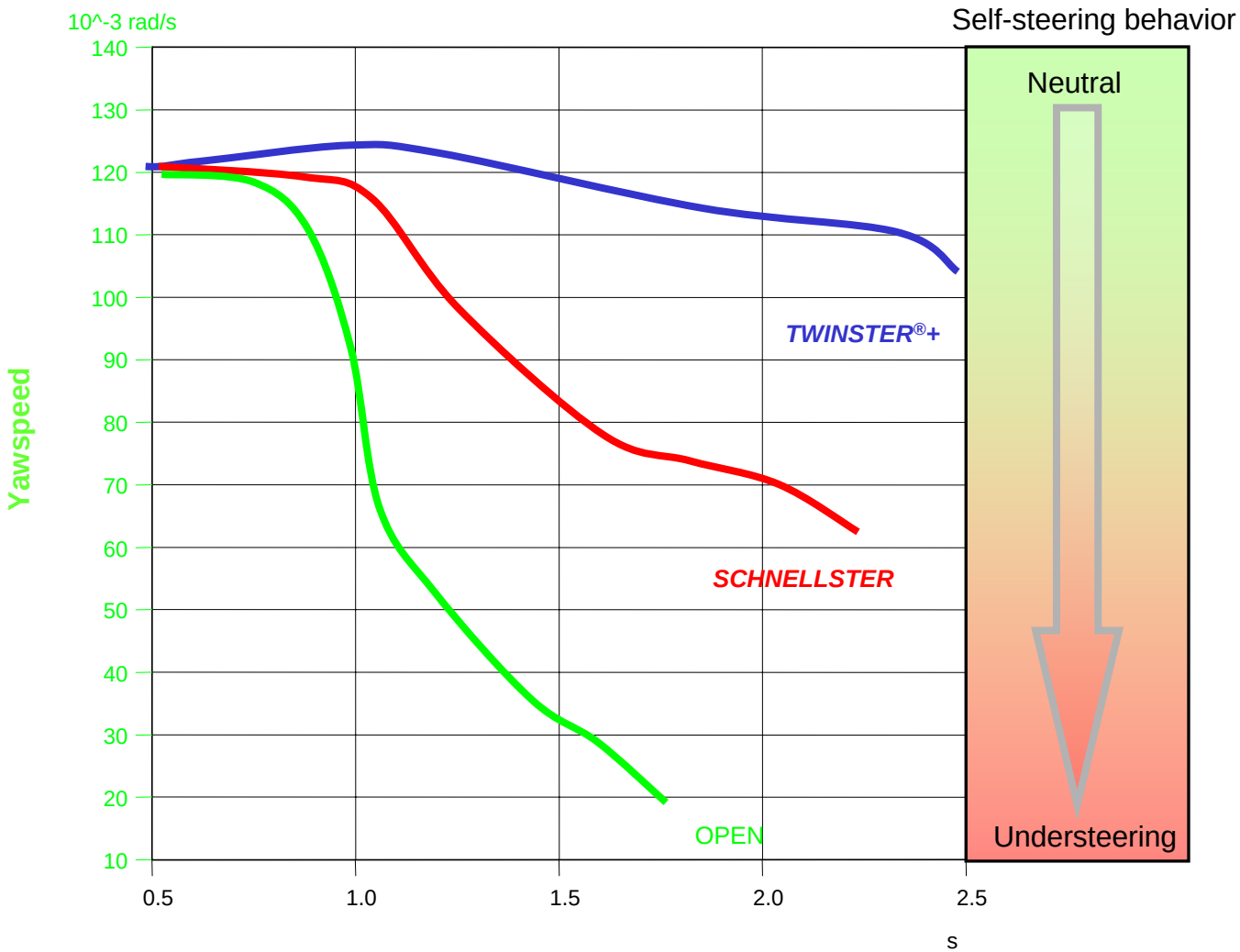


Vehicle Test Results
µ-low

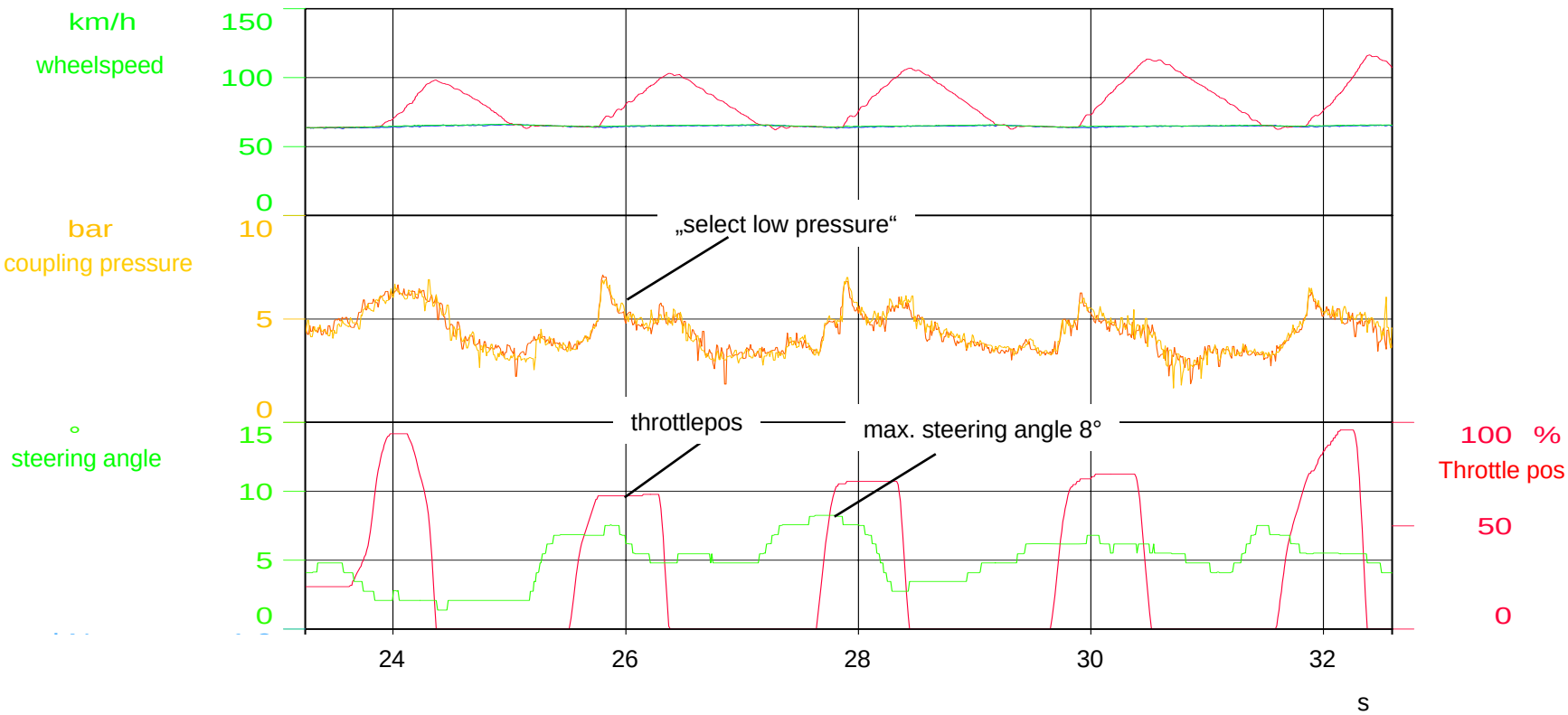
Self-steering behavior, packed Snow, Circle dia= 230m
Open, *SCHNELLSTER, TWINSTER®+*



WOT from Steady State Cornering, packed Snow, Circle dia= 230m
Open, *SCHNELLSTER, TWINSTER®+*

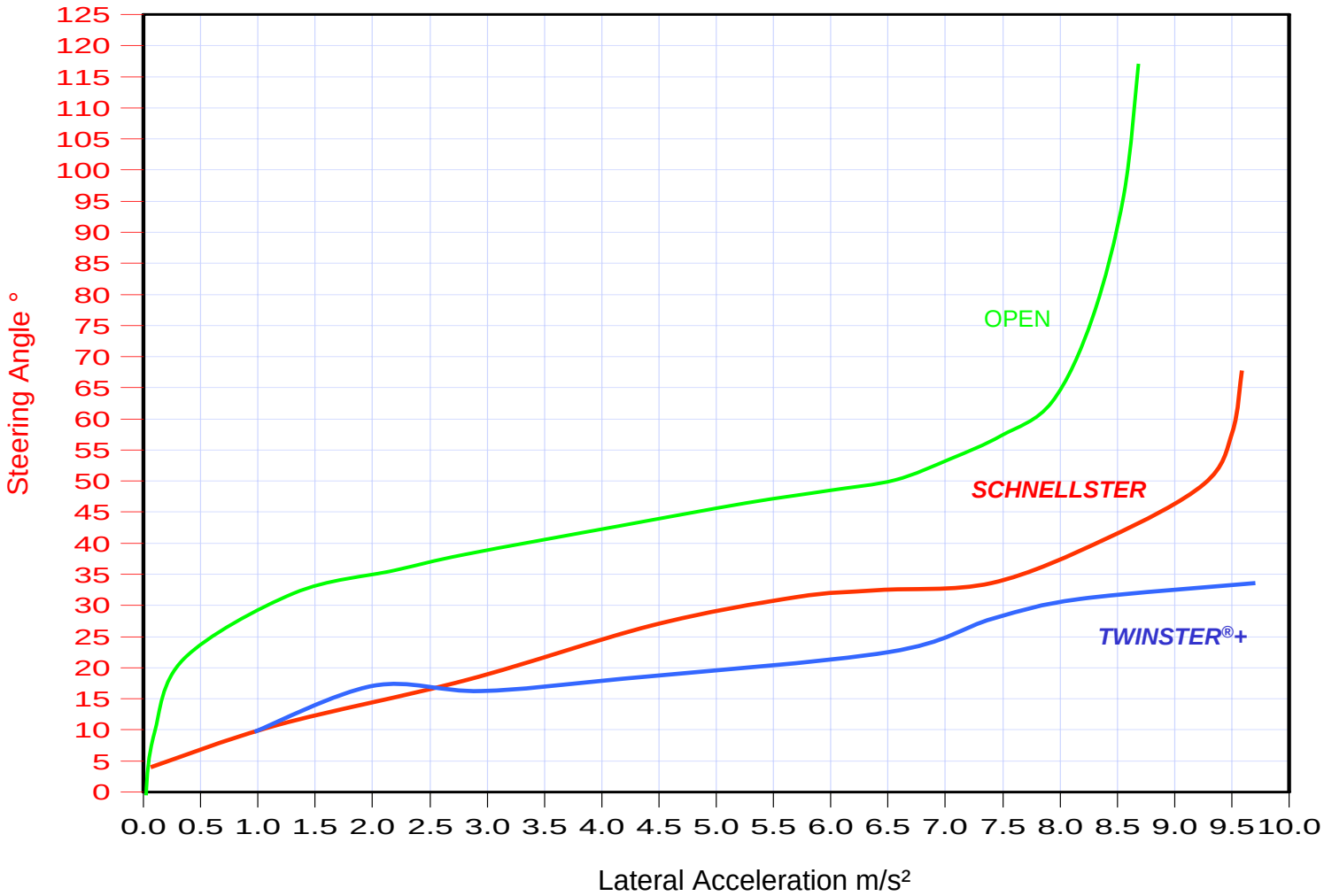


WOT Acceleration on split-µ
TWINSTER®+ Steering angle demand for yaw compensation

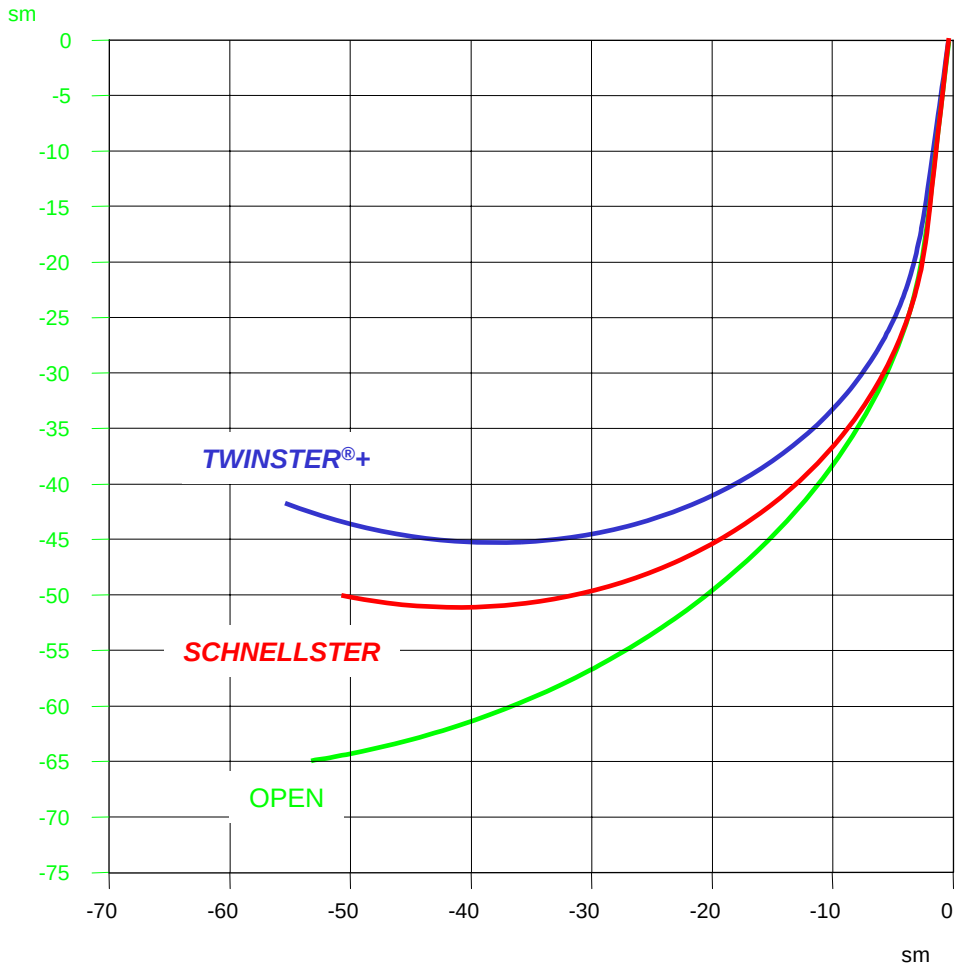


Vehicle Test Results
µ-high

Self-steering behavior µ-high, dry asphalt, circle r=80 m
Open, *SCHNELLSTER*, *TWINSTER®+*



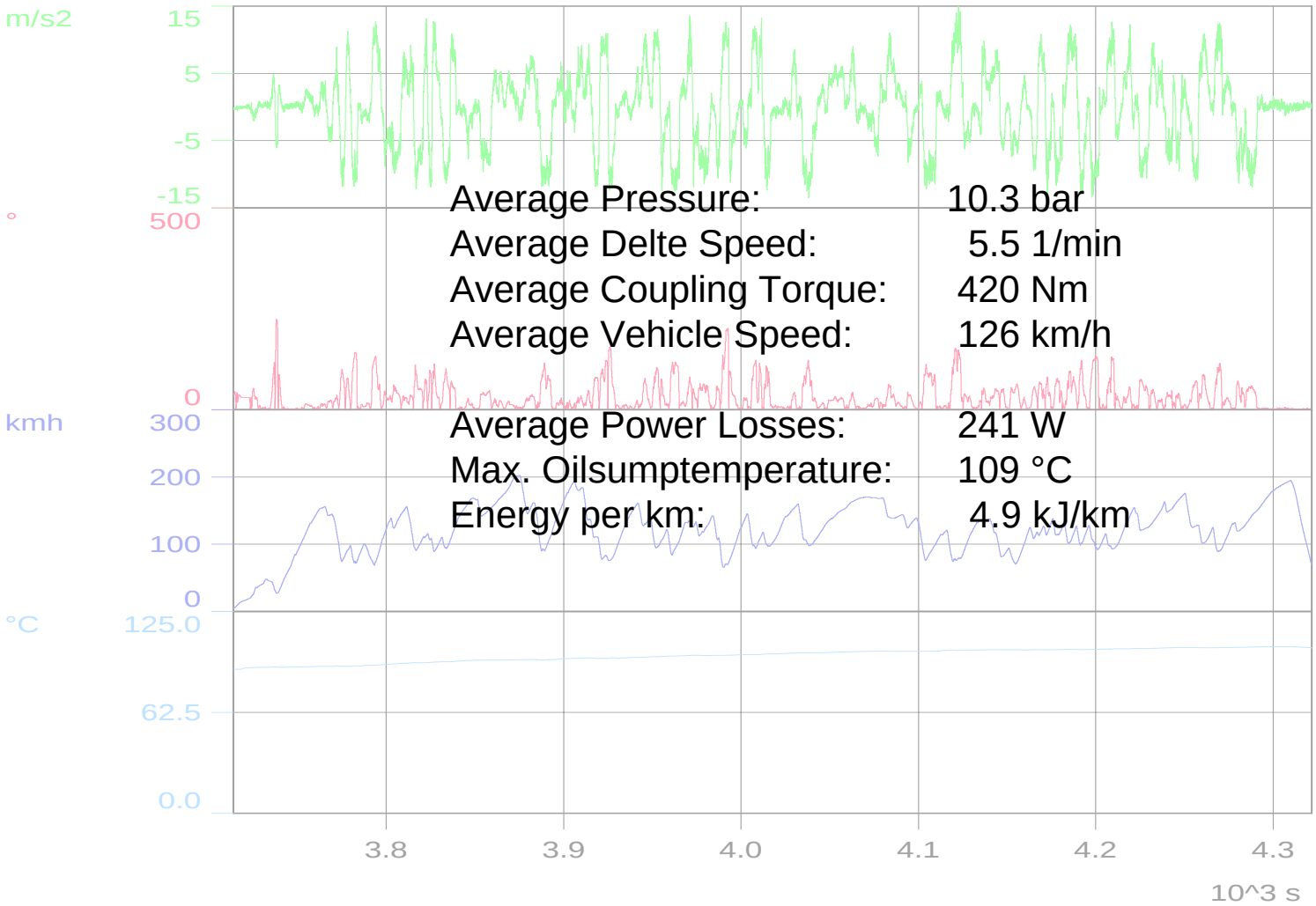
Position Plot, Steer Step Input in WOT, 50 km/h, dry Asphalt, 2. Gear, **Open, *SCHNELLSTER*, *TWINSTER®+***



Vehicle Test Results
Road Load Data Acquisition ***TWINSTER®*** + Thermal Capacity

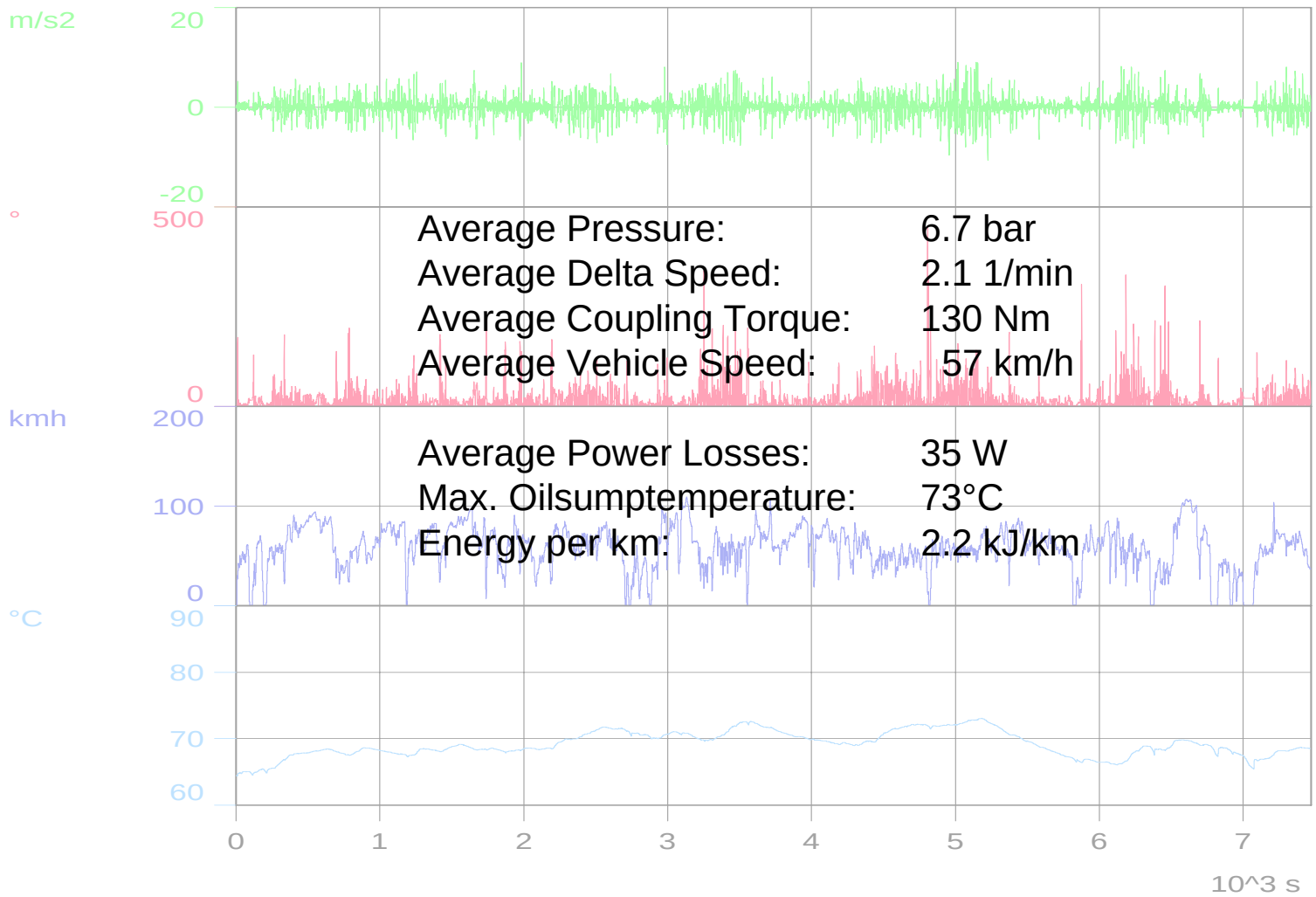
TWINSTER®+

Road Load Data Acquisition: Nürburgring North loop (Race style)

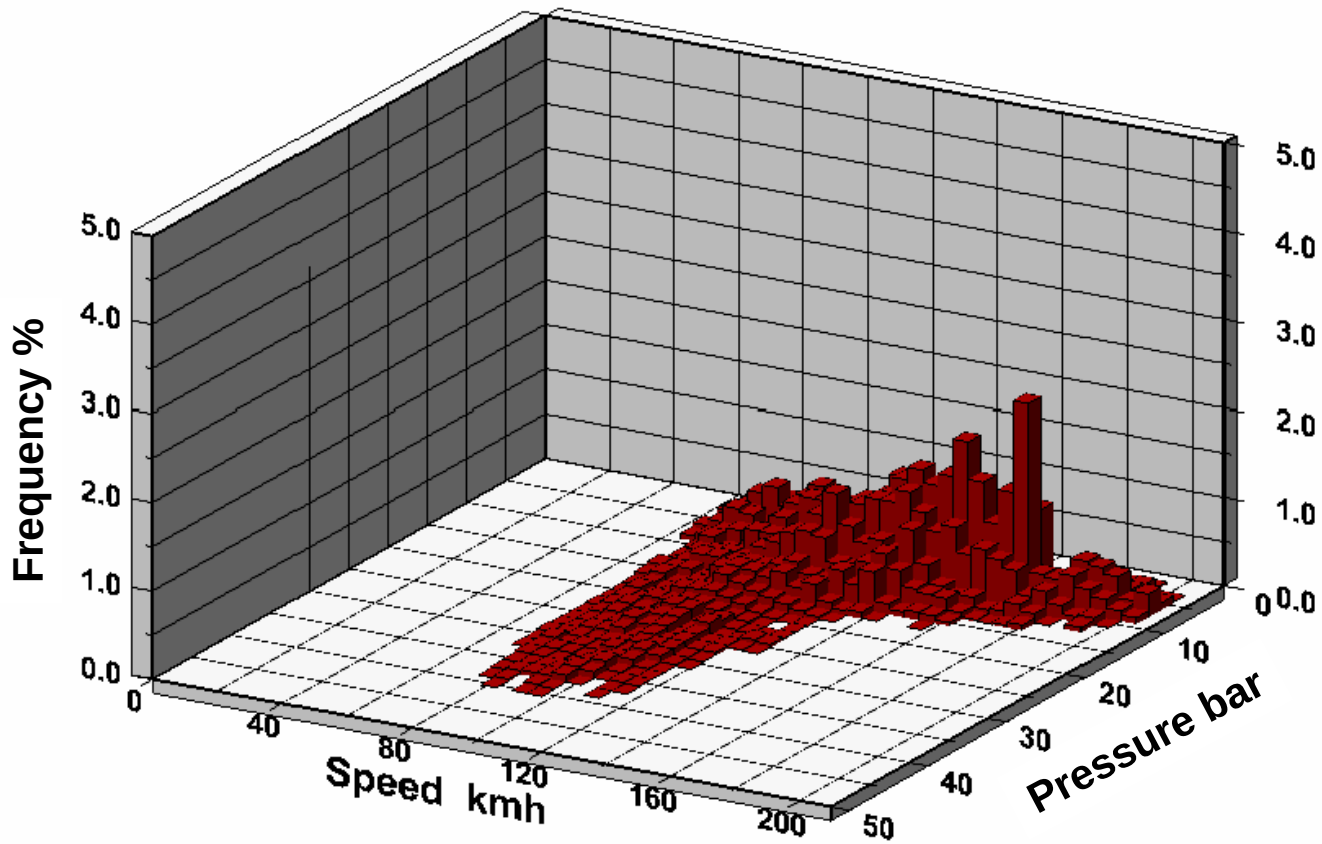


TWINSTER®+

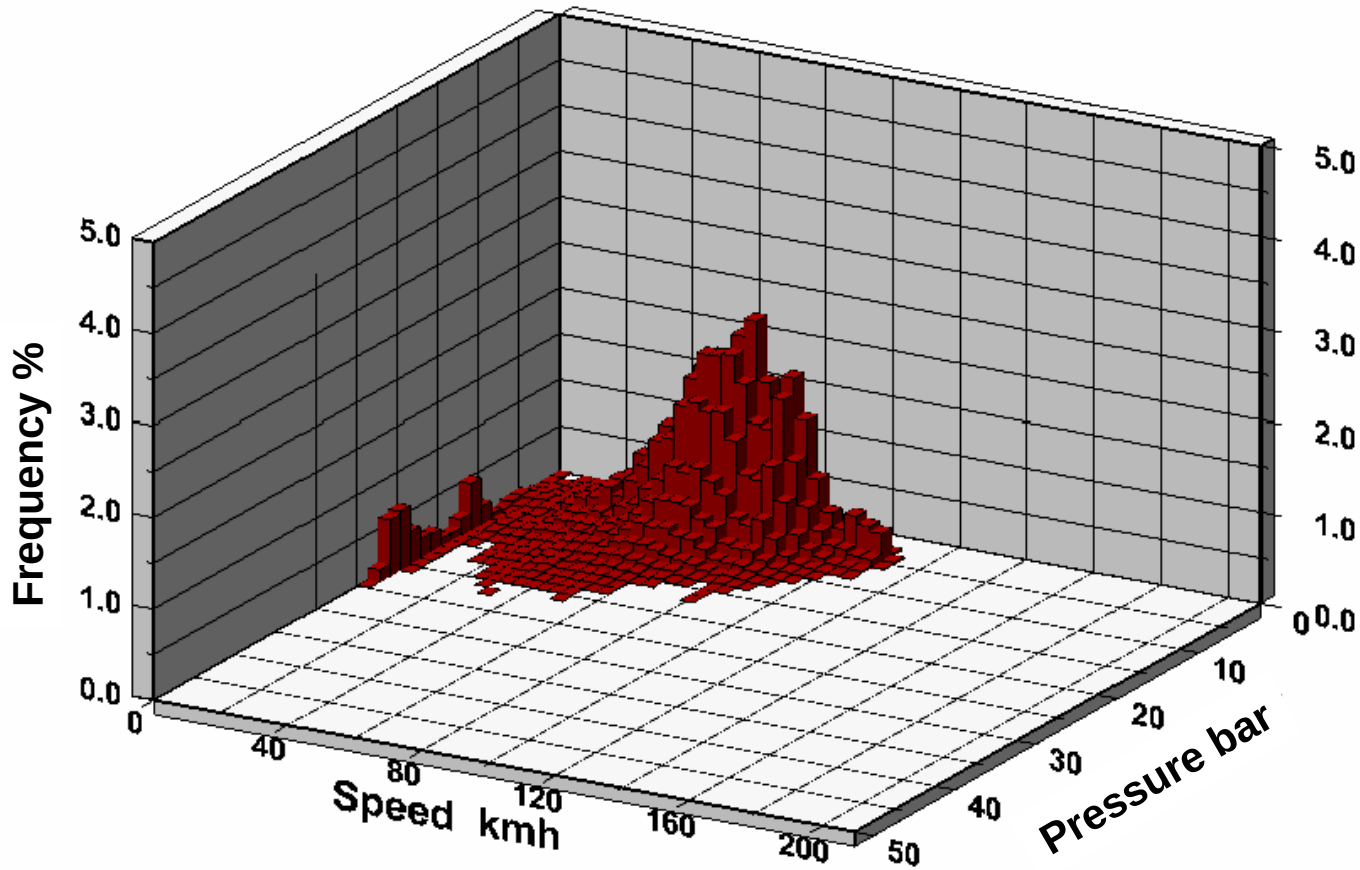
Public Roads Country (normal style) 120 km Distance



TWINSTER®+ Nürburgring North loop (race style)
Pressure Distribution left Coupling versus Vehicle Speed

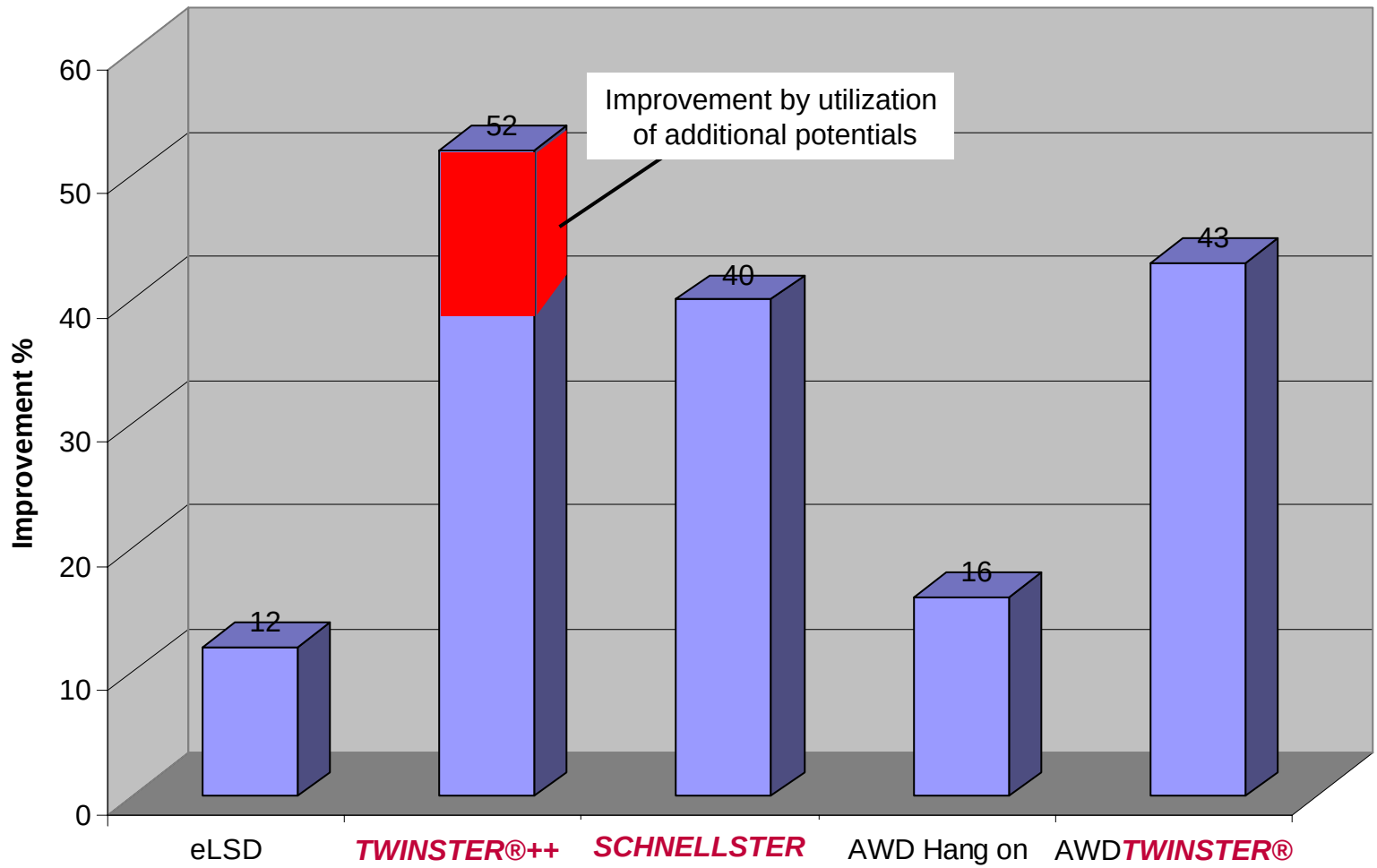


TWINSTER®+ Public Roads Country (normal style)
Pressure Distribution left Coupling versus Vehicle Speed



Summary

TWINSTER®+ improvement with Utilization of Potentials
Comparison to FWD “open Differential” and other Driveline Systems



Summary

- On FWD Active Yaw Systems are feasible and provide an outstanding new handling behavior
- Active Yaw Control improves traction and handling independent from lateral acceleration or corner speed
  - Typical FWD understeering behavior can be impressively reduced
    - behavior is transparent, predictable and easily controllable
  - Every driver can experience the benefits without being an experienced sport driver
- Unique selling point for the OEM to differentiate from other competitors
- By utilization of all potentials of the ***TWINSTER®+*** the system can become the future “differential” in FWD

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Thank you for your attention!