GETRAG Driveline Systems GmbH

Vehicle Dynamics Expo 2005

“Seven at ONE blow”

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Manager Vehicle Dynamics

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- Control Strategy
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- Test Track
- Test Programme
- Vehicle Test Results
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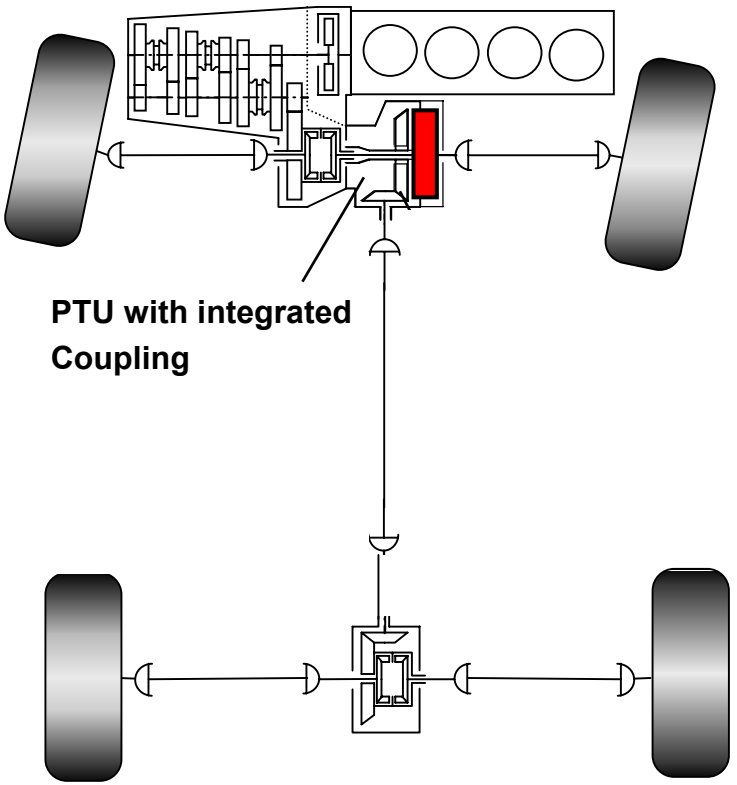
- Outlook

> Introduction <

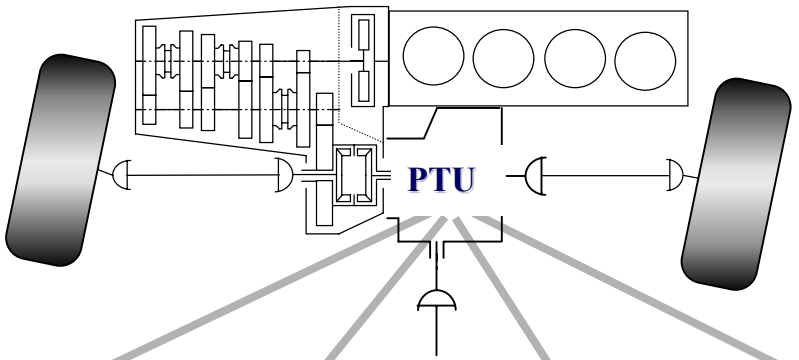
Why Mini ?

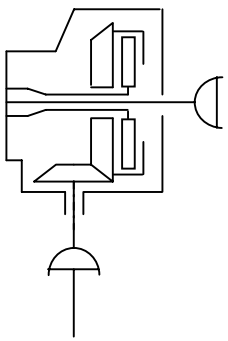
- FWD with East-West Engine
- Cooper S stands for „Freude am Fahren“ (Fun to drive)
- More power than suitable for FWD (>160 HP)
- No AWD available
- Package VERY tight = 4WD Version is challenging
- Benchmark for Vehicle Dynamics
- Objective comparison of different driveline configurations in one vehicle
  - Influence on traction
  - Influence on vehicle dynamics
  - How much improvement does each system deliver?

> Modular PTU <

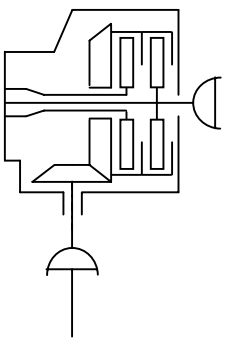


> Modular PTU <

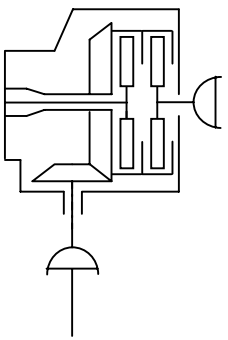




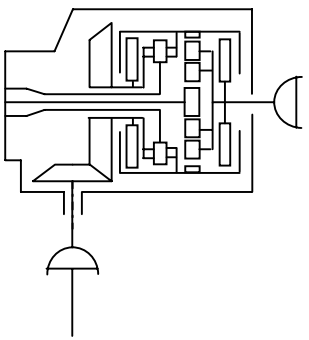
Hang-On



Hang-On & TRACKSTER



TWINSTER



Permanent AWD
& TRACKSTER Front & Centre*

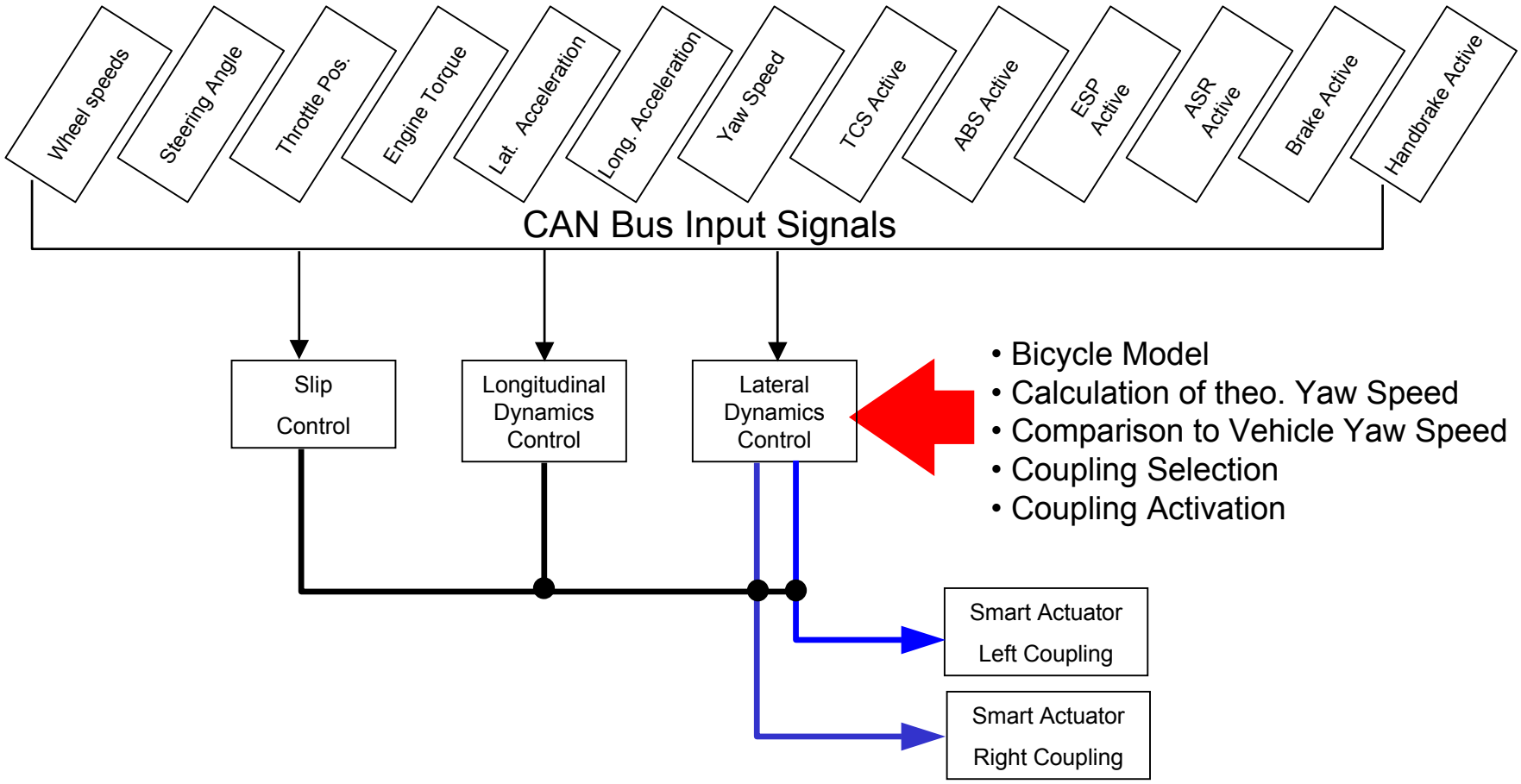
*no hardware available yet

> 7 Driveline Concepts in ONE Vehicle <

By the modular PTU the following driveline concepts can be investigated in ONE vehicle:

1. FWD
2. FWD with TRACKSTER (electronic controlled front axle differential)
3. RWD
4. AWD (primarily FWD with hang on coupling to rear axle)
5. AWD (hang on coupling to rear axle and TRACKSTER)
6. AWD (primarily RWD with hang on coupling to front axle)
7. TWINSTER (primarily RWD with TWIN couplings to front axle (Active Yaw))

> Control Strategy <



> Vehicle Instrumentation <

DGPS Sensor

DGPS Base Station

System Accuracy for Position: +/- 0.2 m

> Test Track Low-μ <

μ-Split Straight Line

Handling

μ-split Hill

Workshop

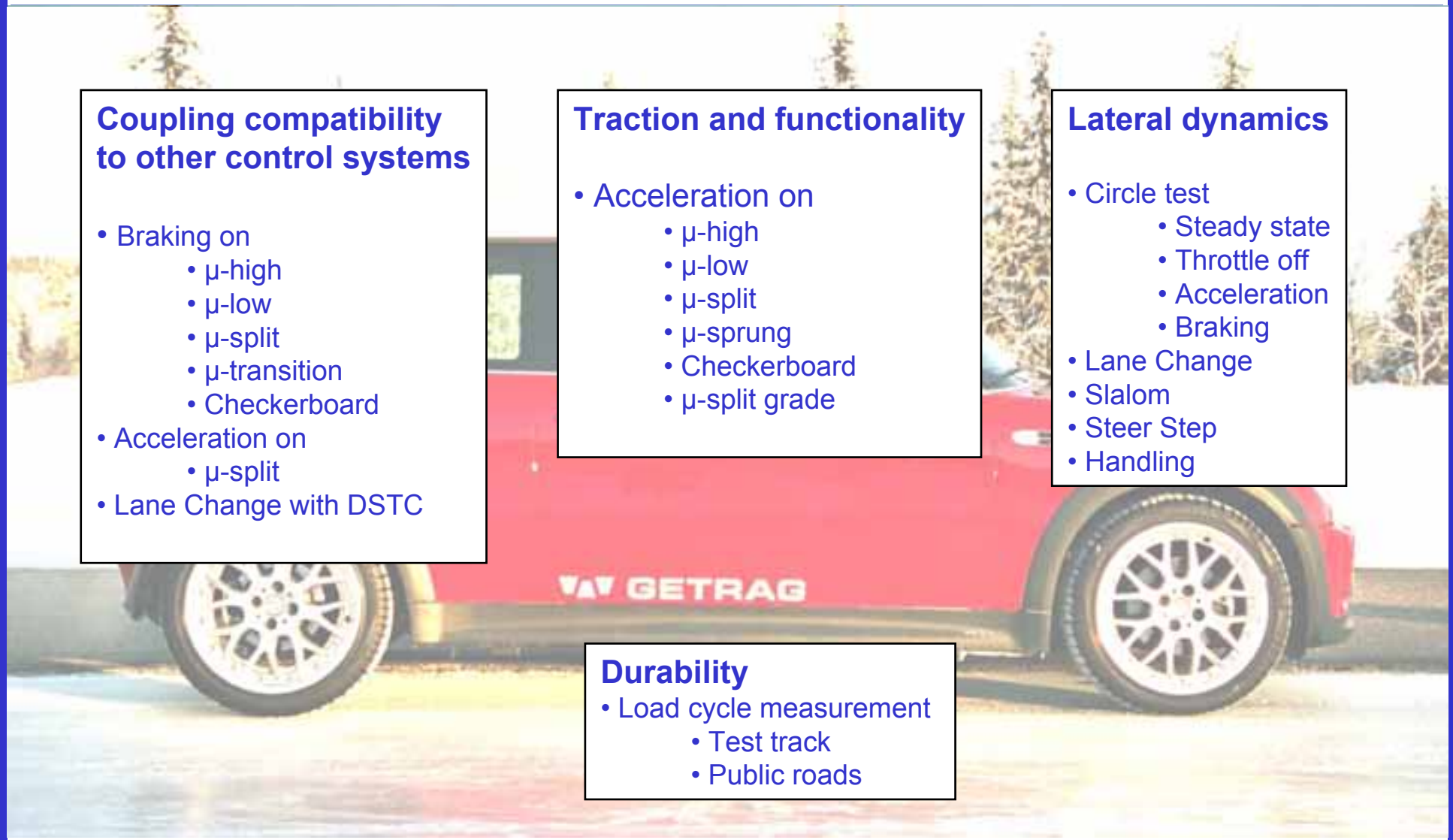
Circular Track

> Test Track High-μ <

Wet Handling Track, Length: 1.1 km

Vehicle Dynamics Area, Diameter: 300 m

> Test Programme <



Coupling compatibility to other control systems

- Braking on
  - µ-high
  - µ-low
  - µ-split
  - µ-transition
  - Checkerboard
- Acceleration on
  - µ-split
- Lane Change with DSTC

Traction and functionality

- Acceleration on
  - µ-high
  - µ-low
  - µ-split
  - µ-sprung
  - Checkerboard
  - µ-split grade

Lateral dynamics

- Circle test
  - Steady state
  - Throttle off
  - Acceleration
  - Braking
- Lane Change
- Slalom
- Steer Step
- Handling

Durability

- Load cycle measurement
  - Test track
  - Public roads

> Test Results on Low-μ <

Traction

- Acceleration on
  - Snow
  - Ice
  - Split-μ

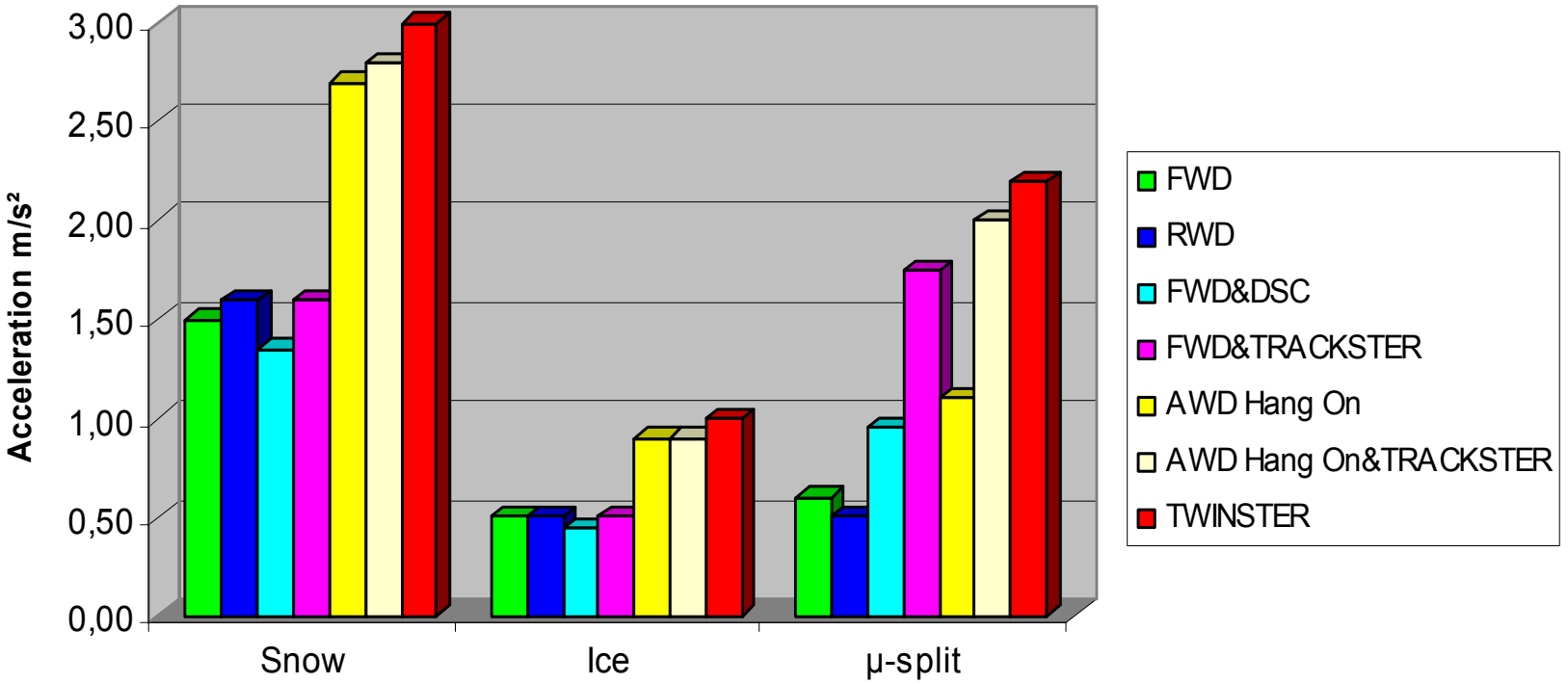
Lateral Dynamics

- Wide Open Throttle from Steady State Cornering
  - Influence of Torque Distribution Control on Lateral Dynamics

> Test Procedure Straight Line Acceleration <

- Test procedure (closed loop test)
  - The vehicle is accelerated straight line from still standing to max. speed
  - The drivers target is to accelerate in a manner that best acceleration behaviour is achieved
  - Torque steering is compensated by counter steering

> Straight Line Acceleration on different Surfaces <



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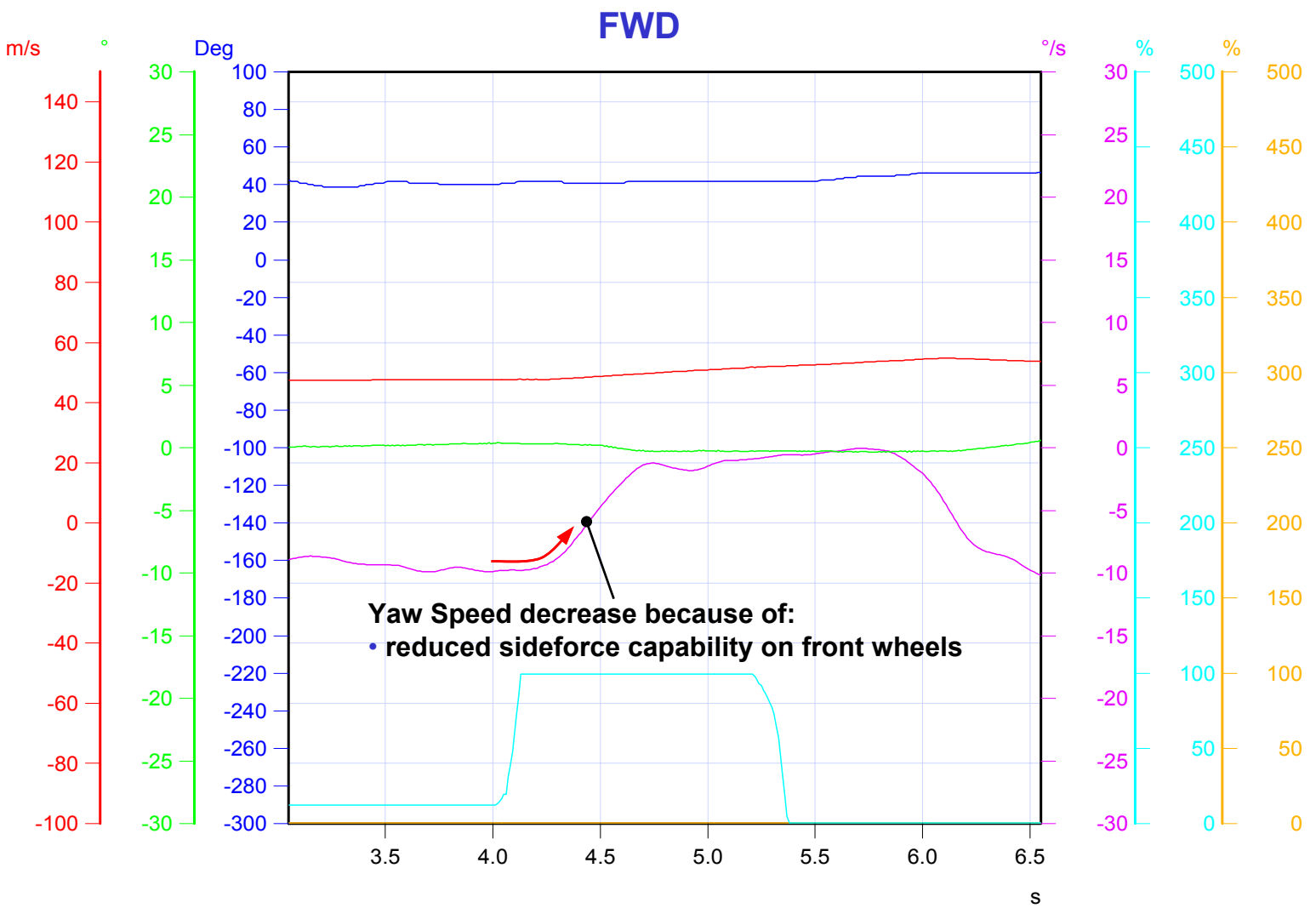
> Test Procedure WOT from Steady State Cornering <

- Testprocedure (open loop test)
  - Surface: packed snow
  - The vehicle is accelerated up to 50 km/h steady state cornering speed
  - After reaching steady state speed a full throttle manoeuvre is done
  - The driver does not change steering wheel and throttle position

> Wide Open Throttle from Steady State Cornering on Low-μ <



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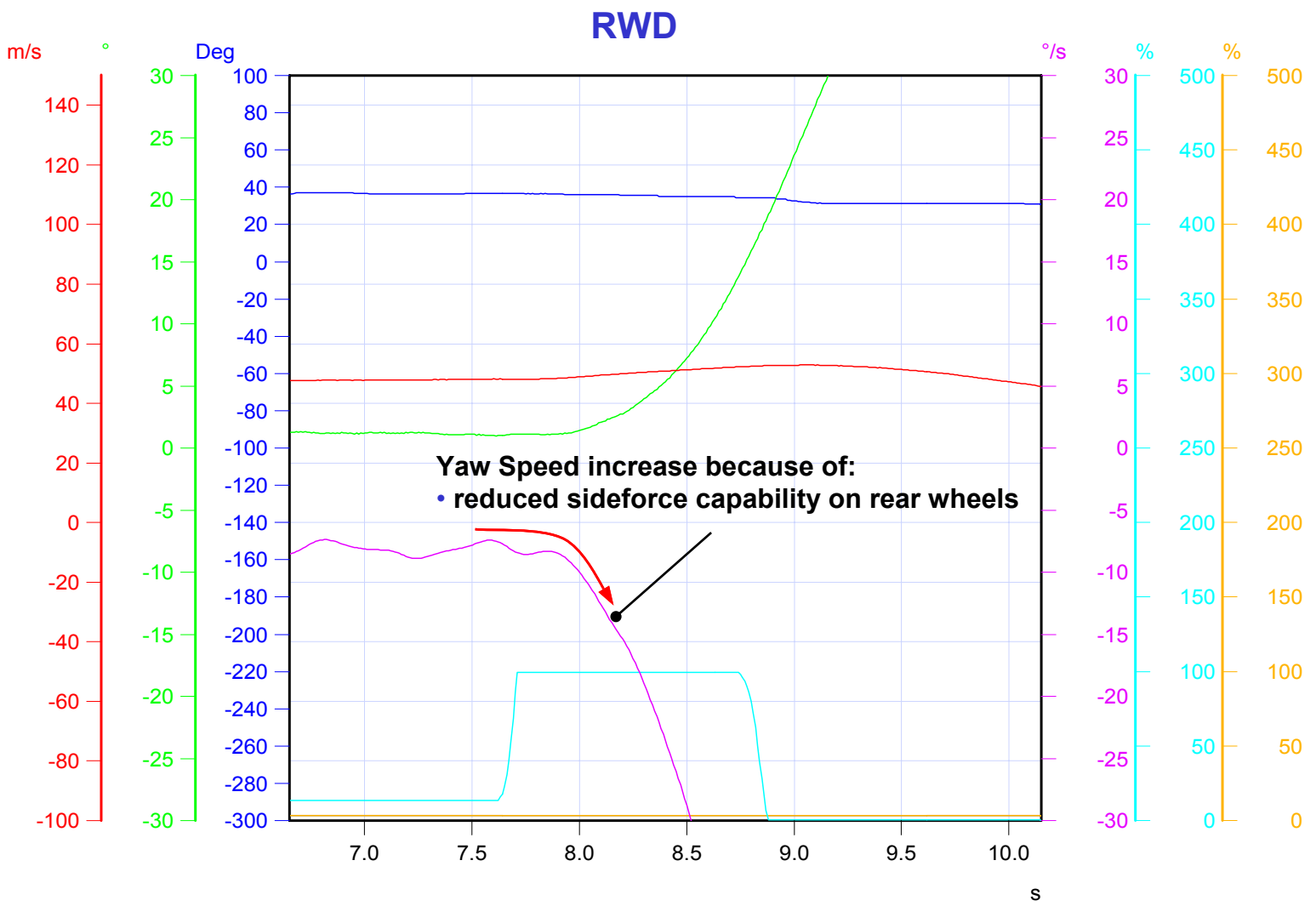

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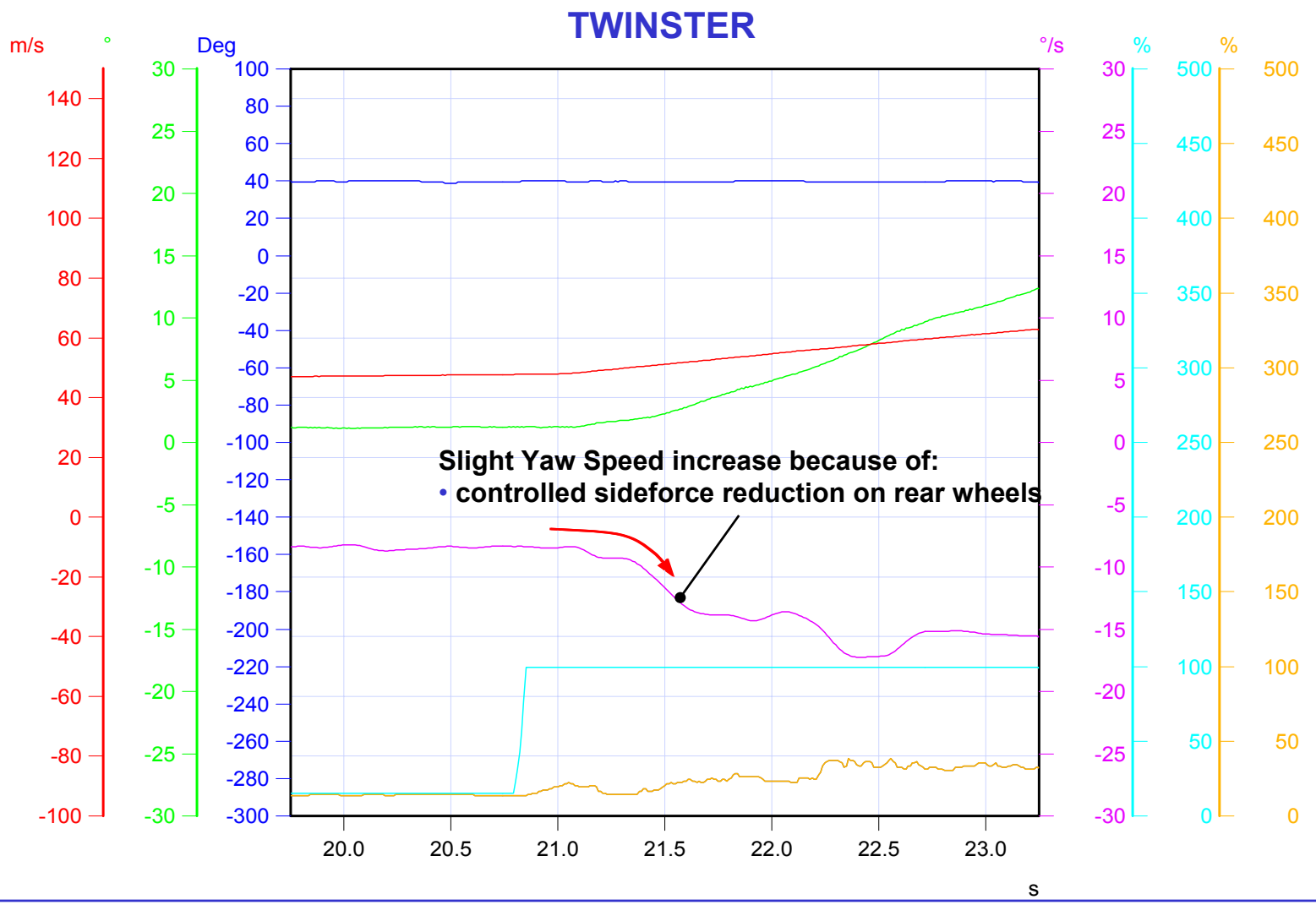

> Comparison of Slip Angle and Yaw Speed <

Wide Open Throttle from Steady State Cornering

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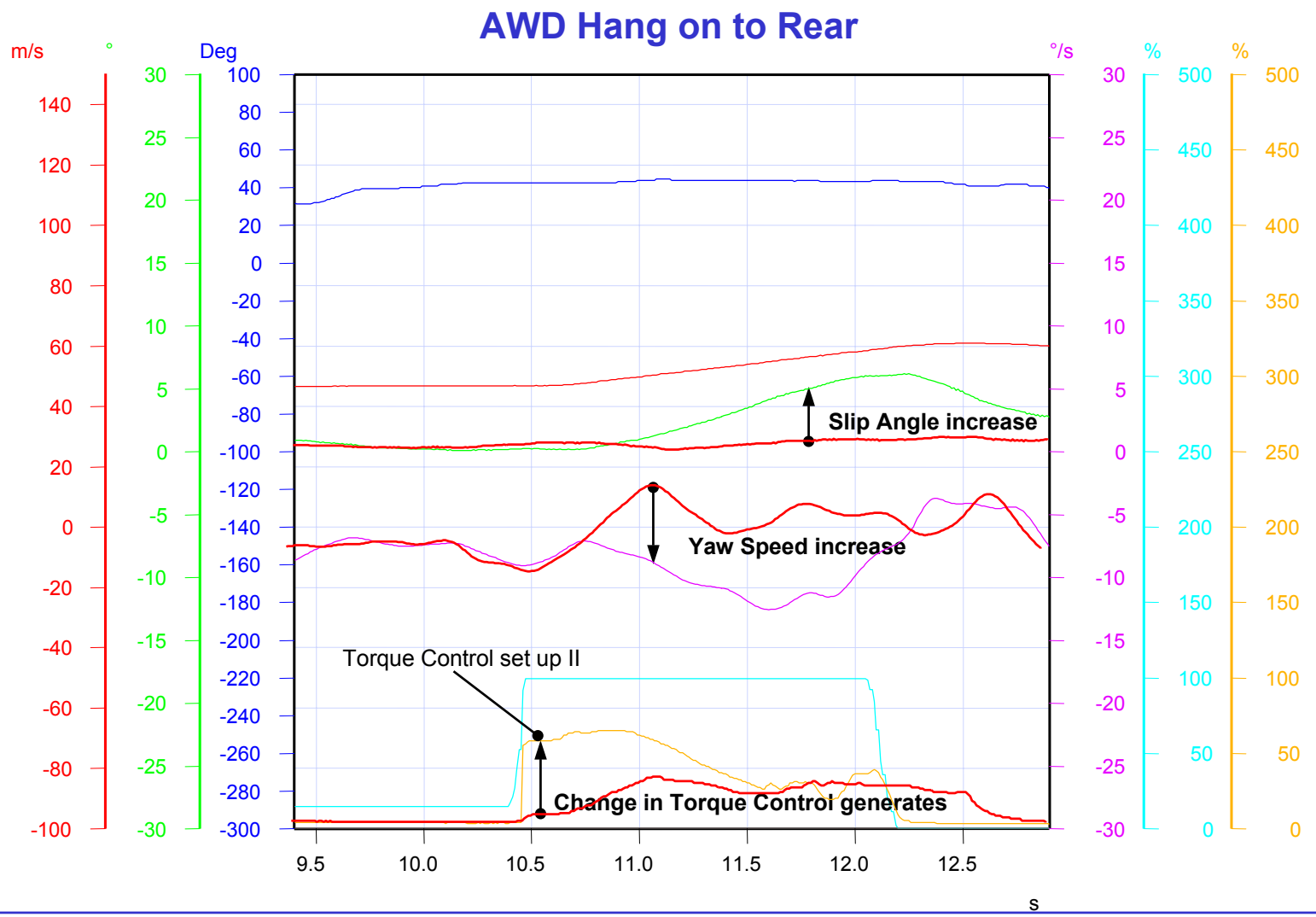
> Influence of Torque Control on Vehicle Dynamics <



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> Test Results on High-μ <

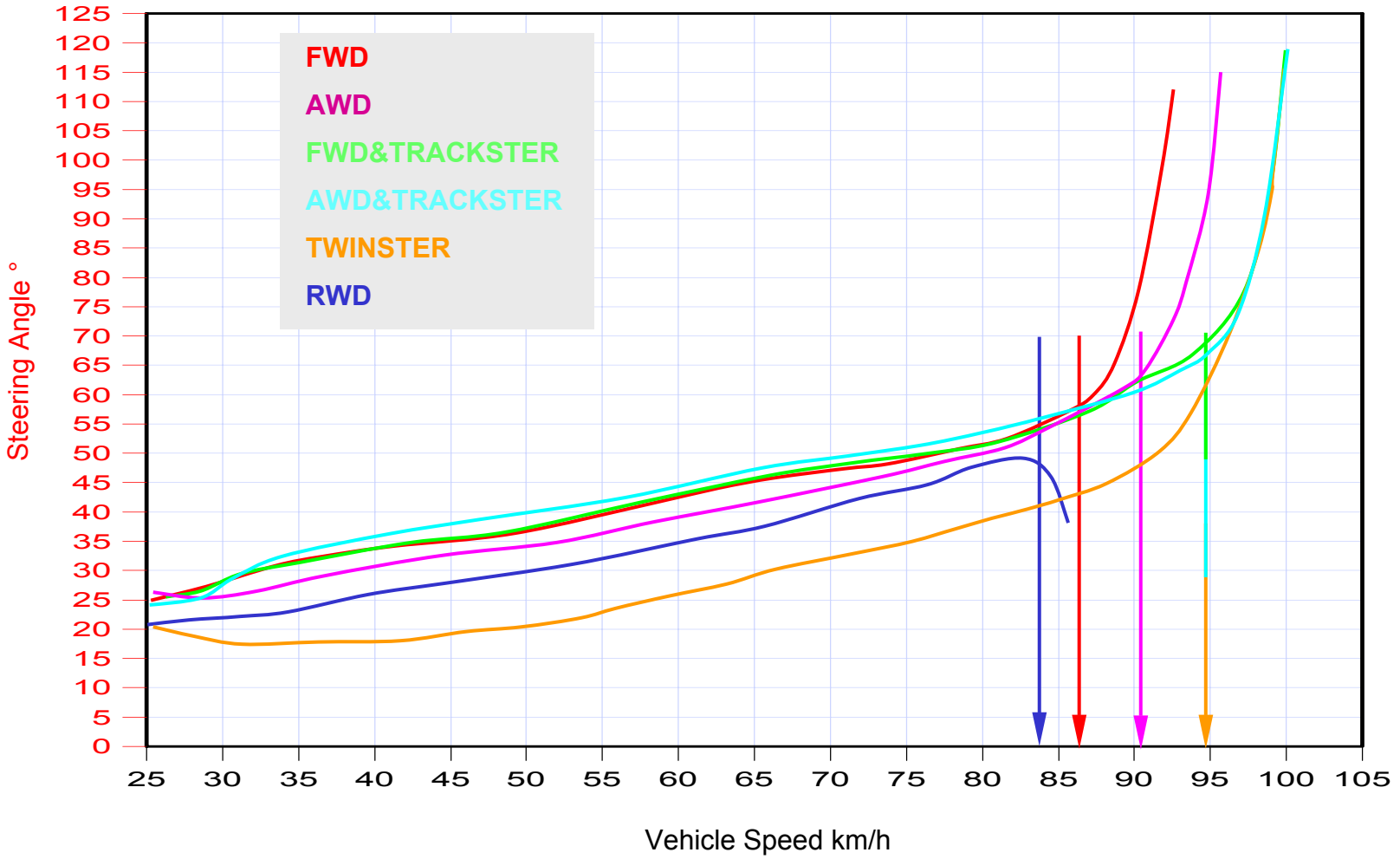
Lateral Dynamics

- Steady State Cornering Self Steering Characteristic
- Steer Step with Wide Open Throttle
- Steer Step Input in Throttle Off
- Yaw Damping with TRACKSTER Differential
- Wet Handling

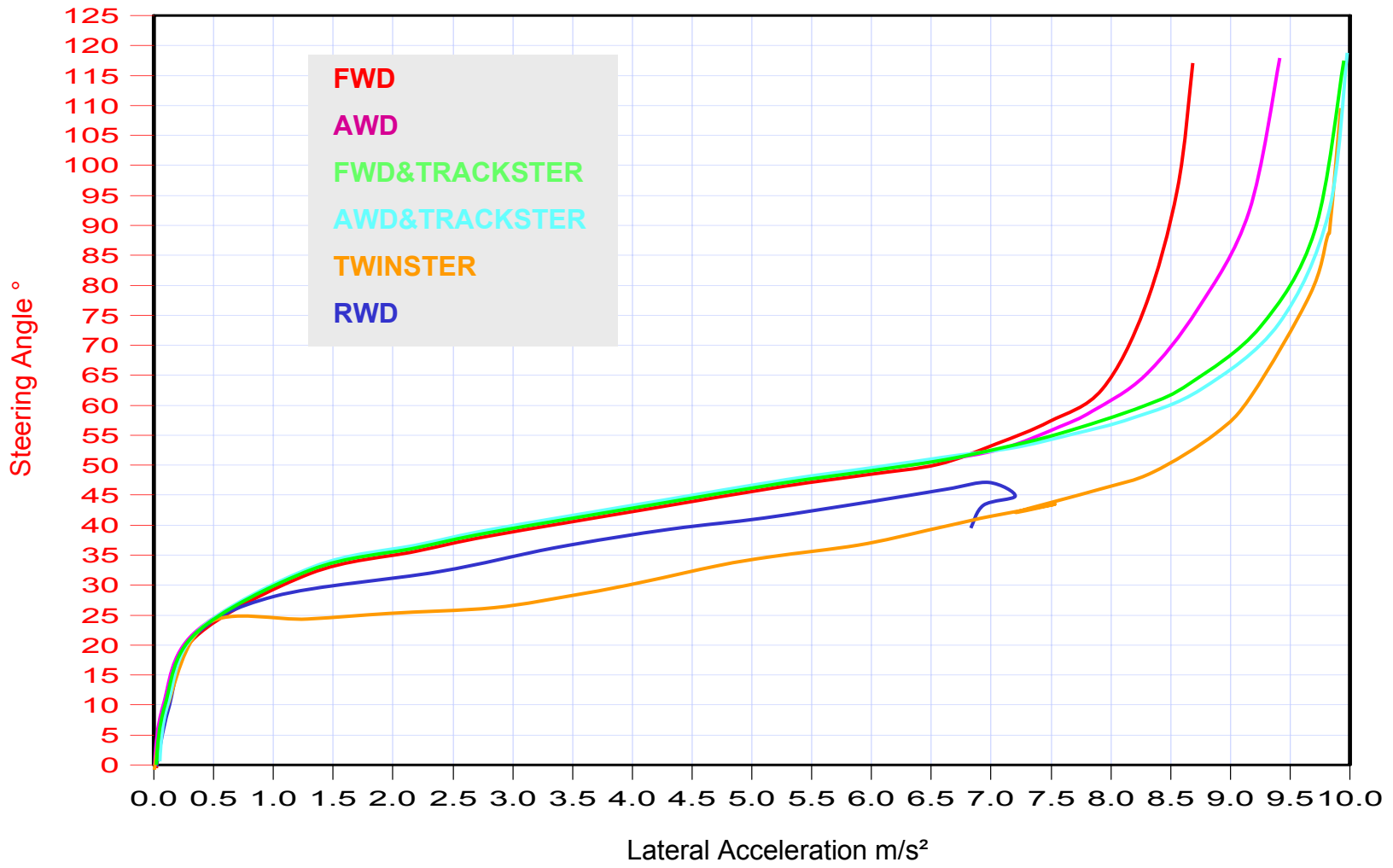
> Test Procedure Quasi Steady State Cornering <

- Test procedure (closed loop test)
  - Surface: dry asphalt, 80 m circle radius
  - The vehicle is accelerated with full throttle in 4th gear from very low speed to max cornering speed
  - The drivers target is to hold the corner radius constant by adjusting the steering wheel angle
  - Throttle position is not changed

> Steady State Cornering Self Steering Characteristic <



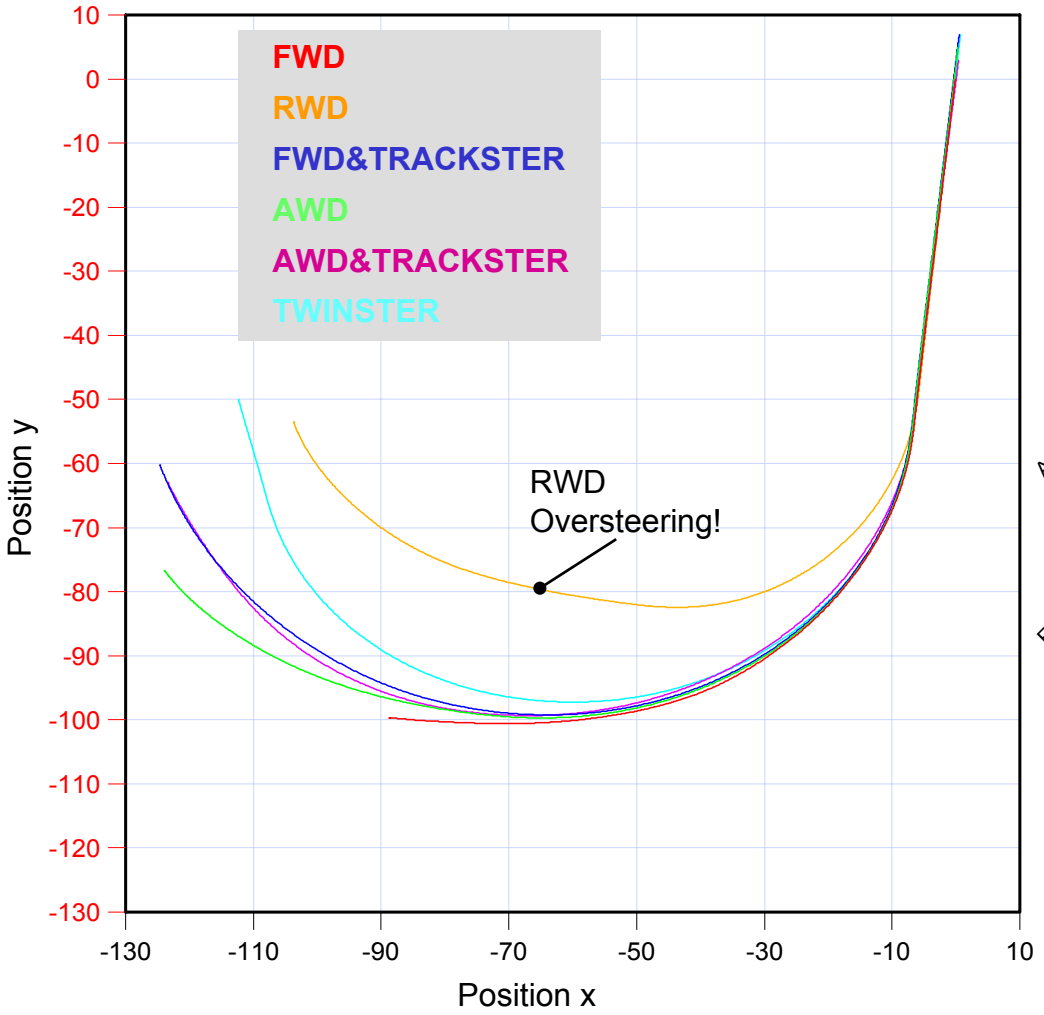
>Steady State Cornering Self Steering Characteristic <

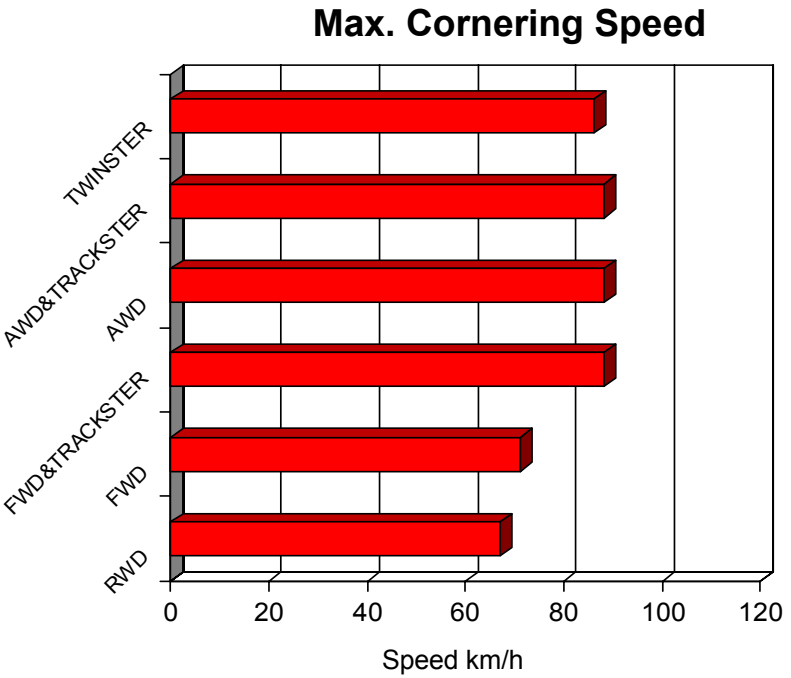


> Test Procedure Steer Step Input WOT <

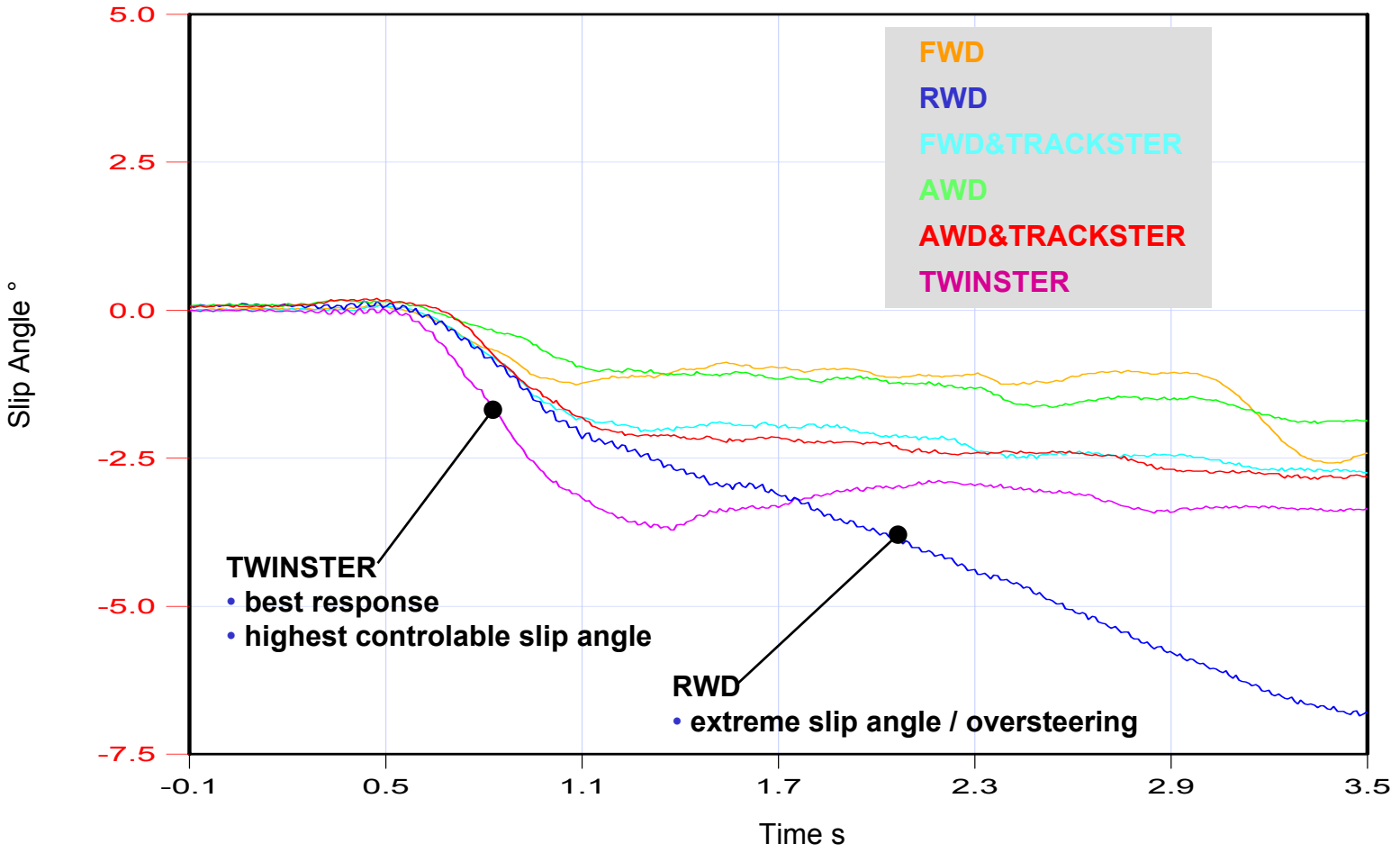
- Test procedure (open loop test)
  - Surface: dry asphalt
  - The vehicle is accelerated up to 60 km/h straight line steady state speed
  - The driver proceeds a full throttle with a steer step manoeuvre from 0° to 80° steering angle
  - The steering wheel and throttle position is not changed

> Steer Step Input with Wide Open Throttle <





> Steer Step Input with Wide Open Throttle <



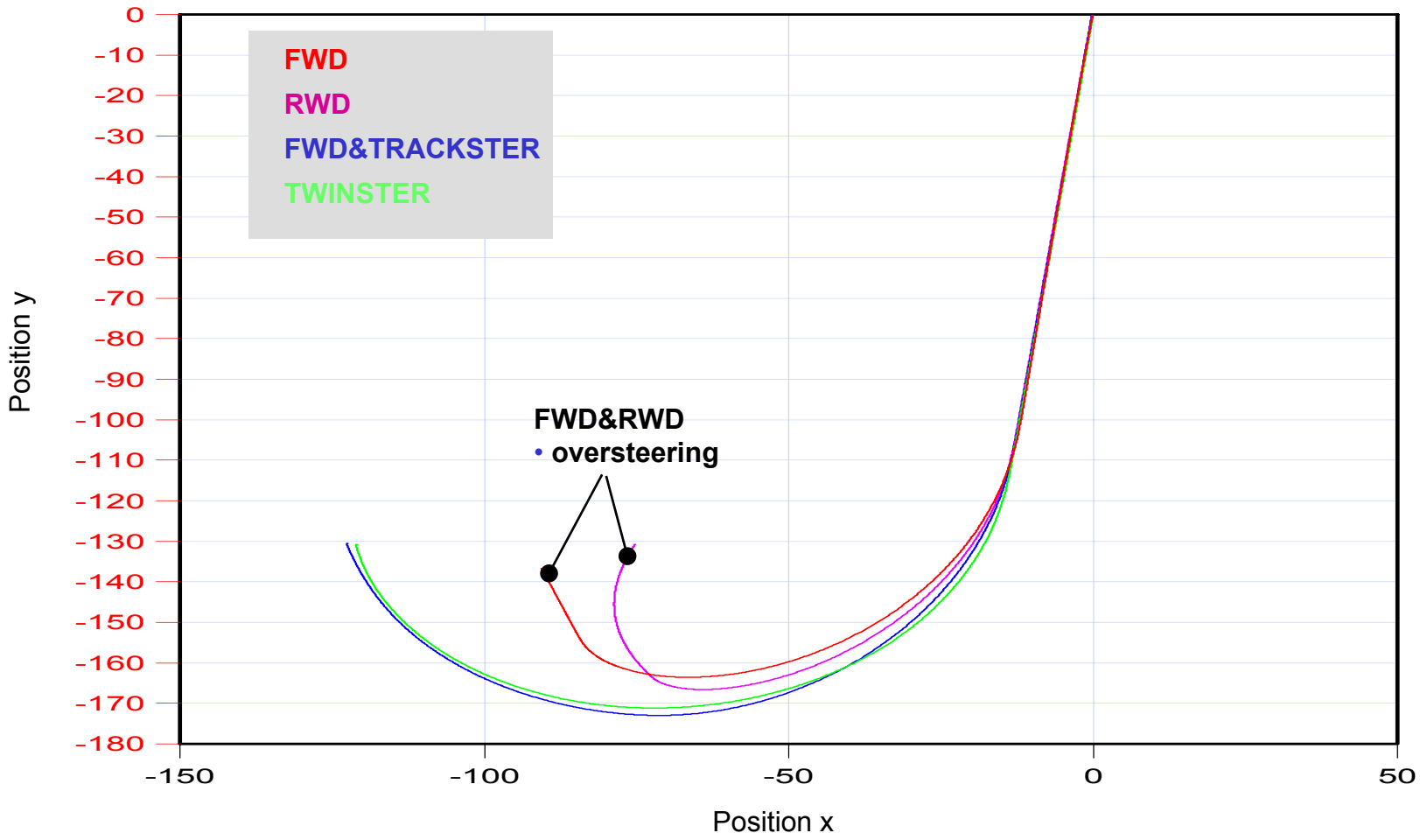
> Test Procedure Steer Step Input in Throttle off <

- Test procedure (open loop test)
  - Surface: dry asphalt
  - The vehicle is accelerated up to 110 km/h straight line steady state speed in 3rd gear
  - The driver proceeds a throttle off with a steer step manoeuvre from 0° to 80° steering angle
  - The steering wheel and throttle position is not changed

> Test Procedure Steer Step Input in Throttle off <

- Test procedure (open loop test)
  - Surface: dry asphalt
  - The vehicle is accelerated up to 110 km/h straight line steady state speed in 3rd gear
  - The driver proceeds a throttle off with a steer step manoeuvre from 0° to 80° steering angle
  - The steering wheel and throttle position is not changed

> Steer Step Input in Throttle off <



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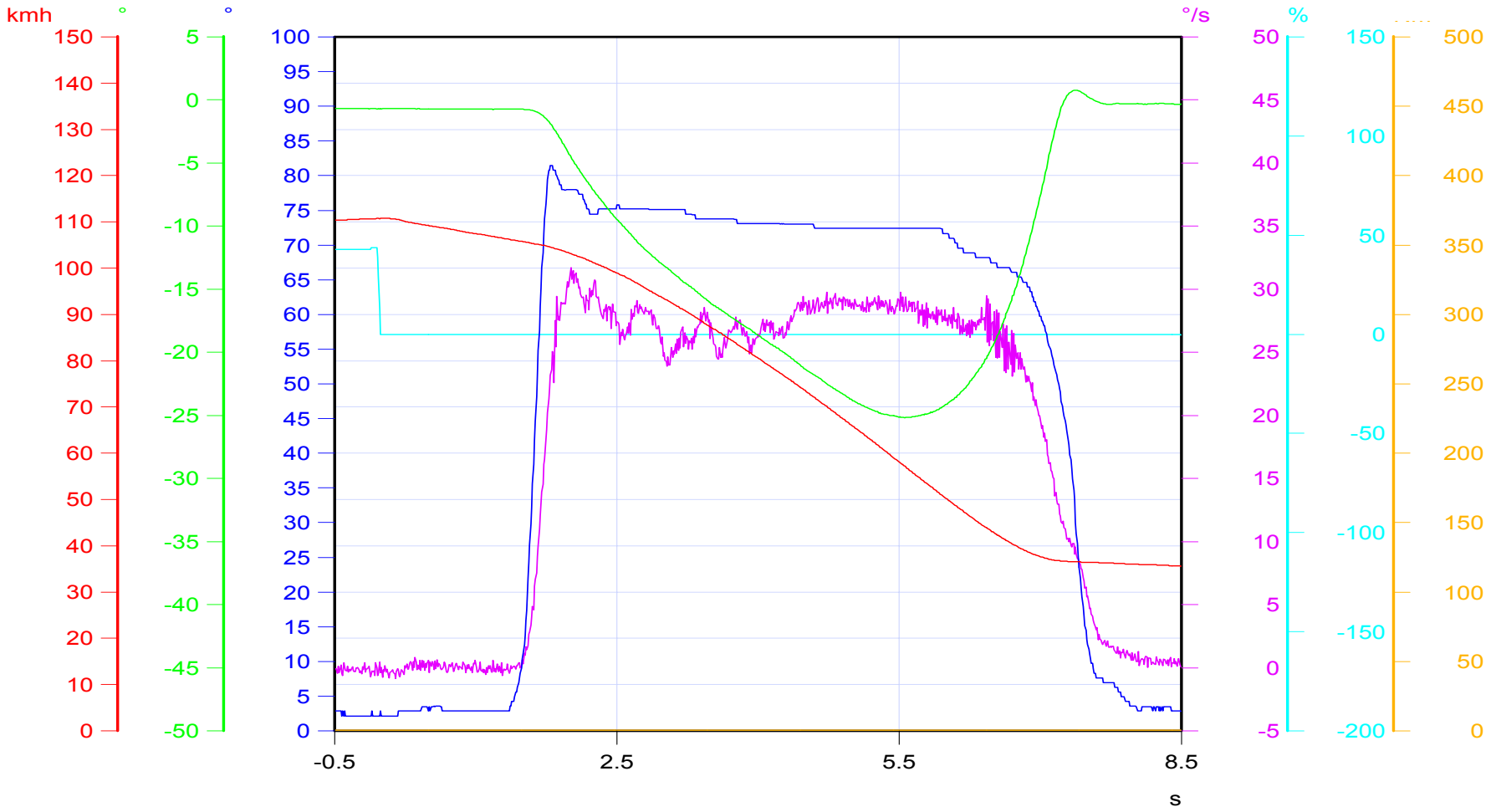
> Yaw Damping with TRACKSTER Differential <

Open Differential DSC off



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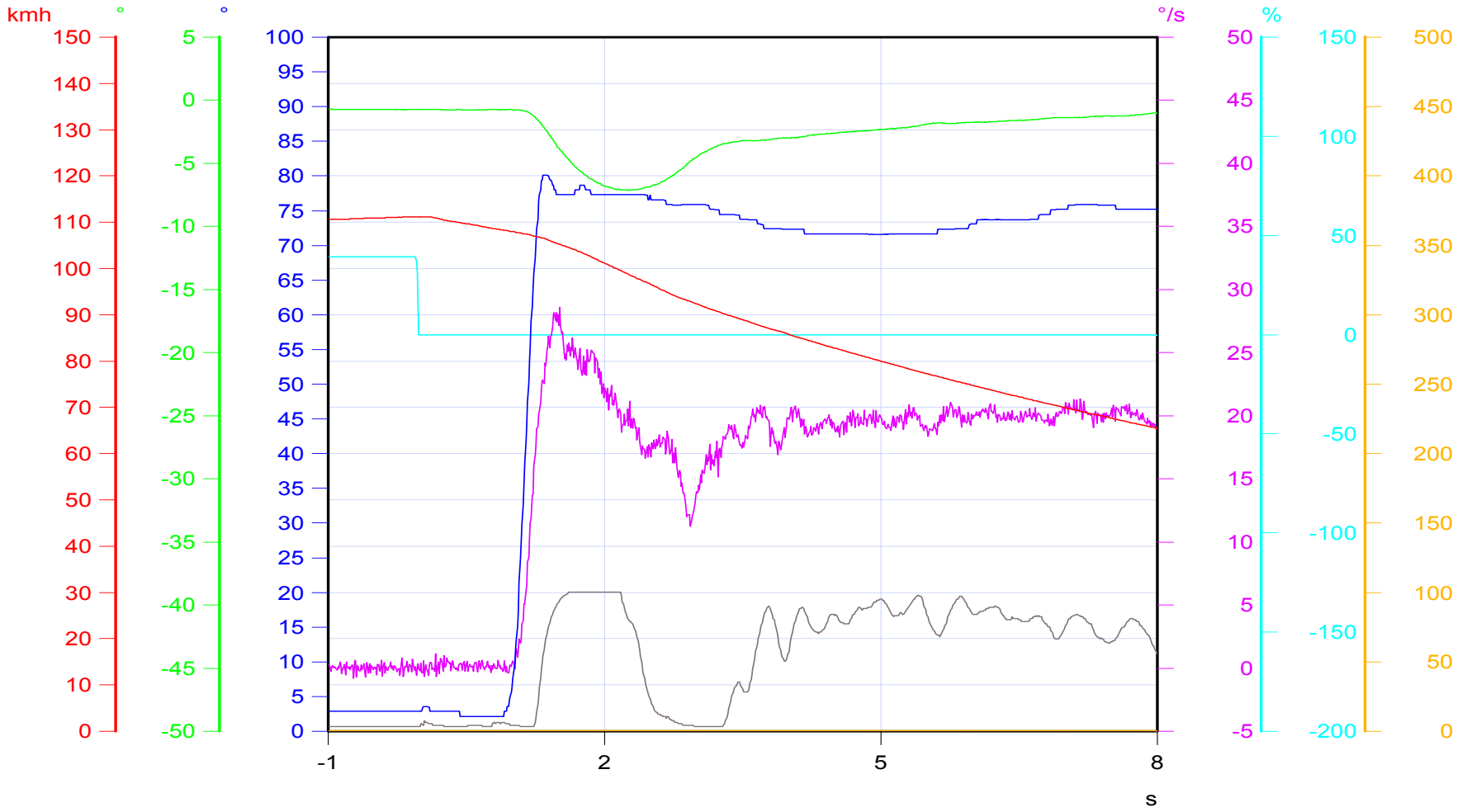
> Yaw Damping with TRACKSTER Differential <

TRACKSTER Differential DSC off



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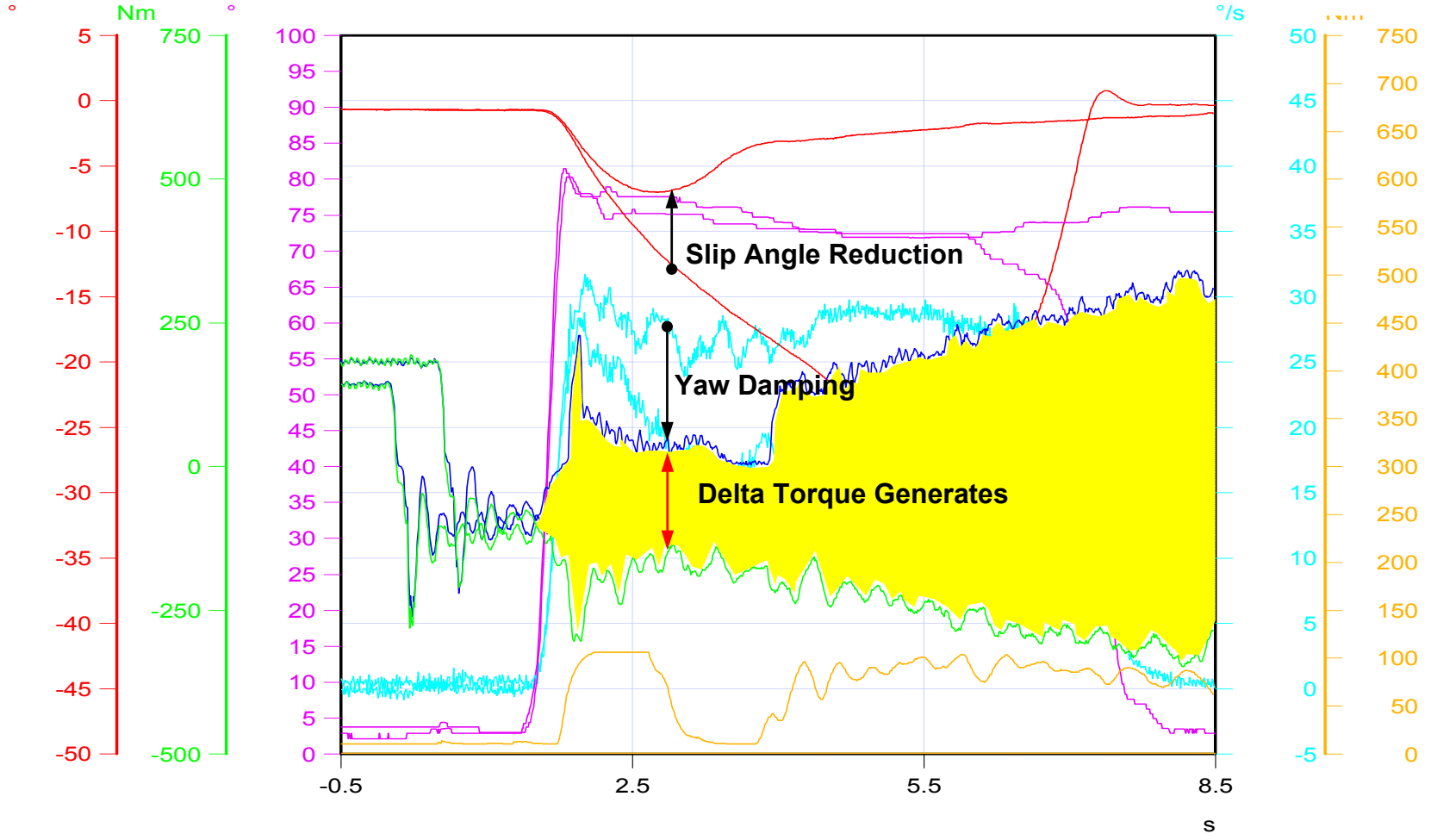
> Yaw Damping with TRACKSTER Differential <

Comparison Open and TRACKSTER Front Differential, DSC off



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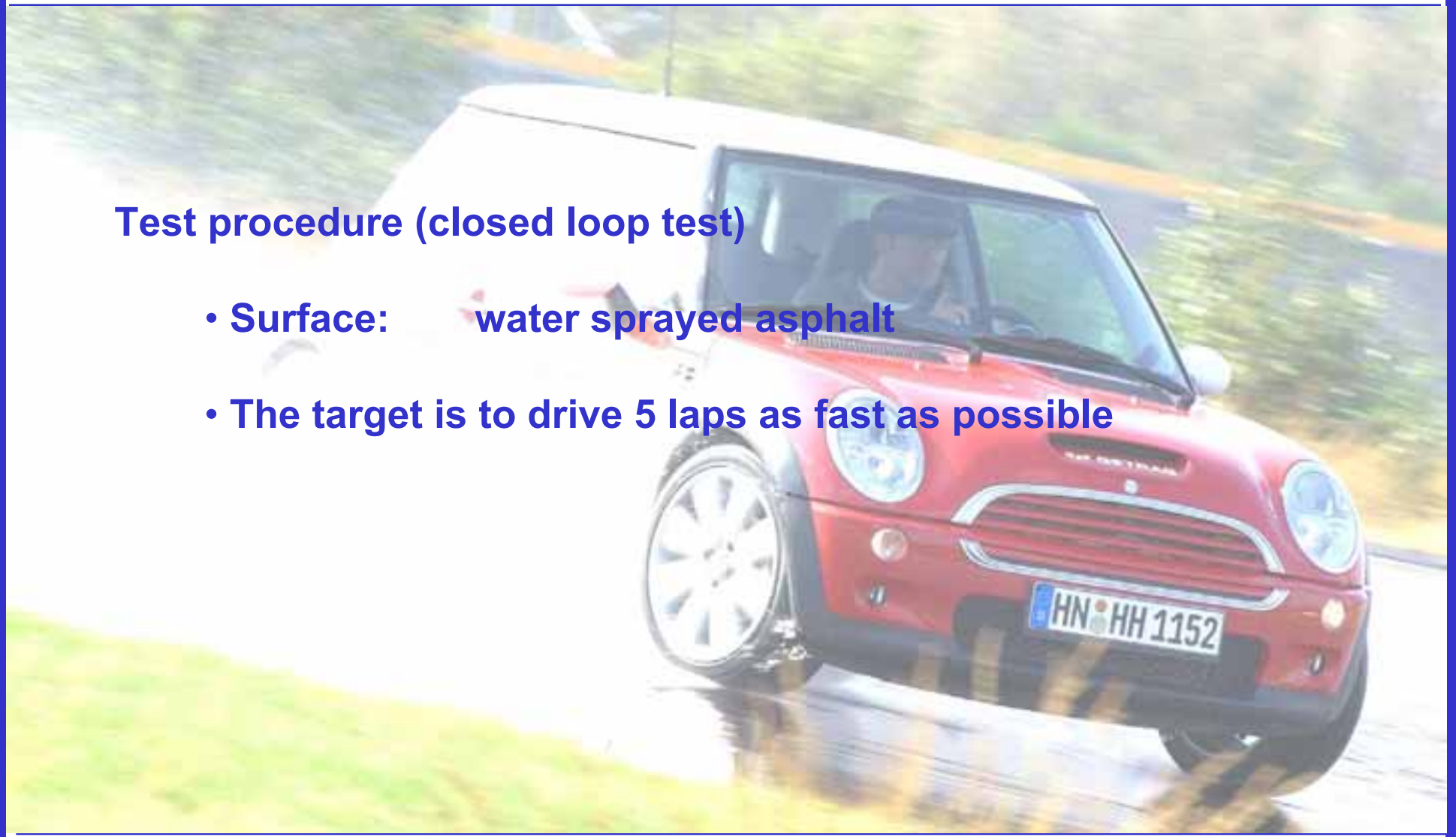
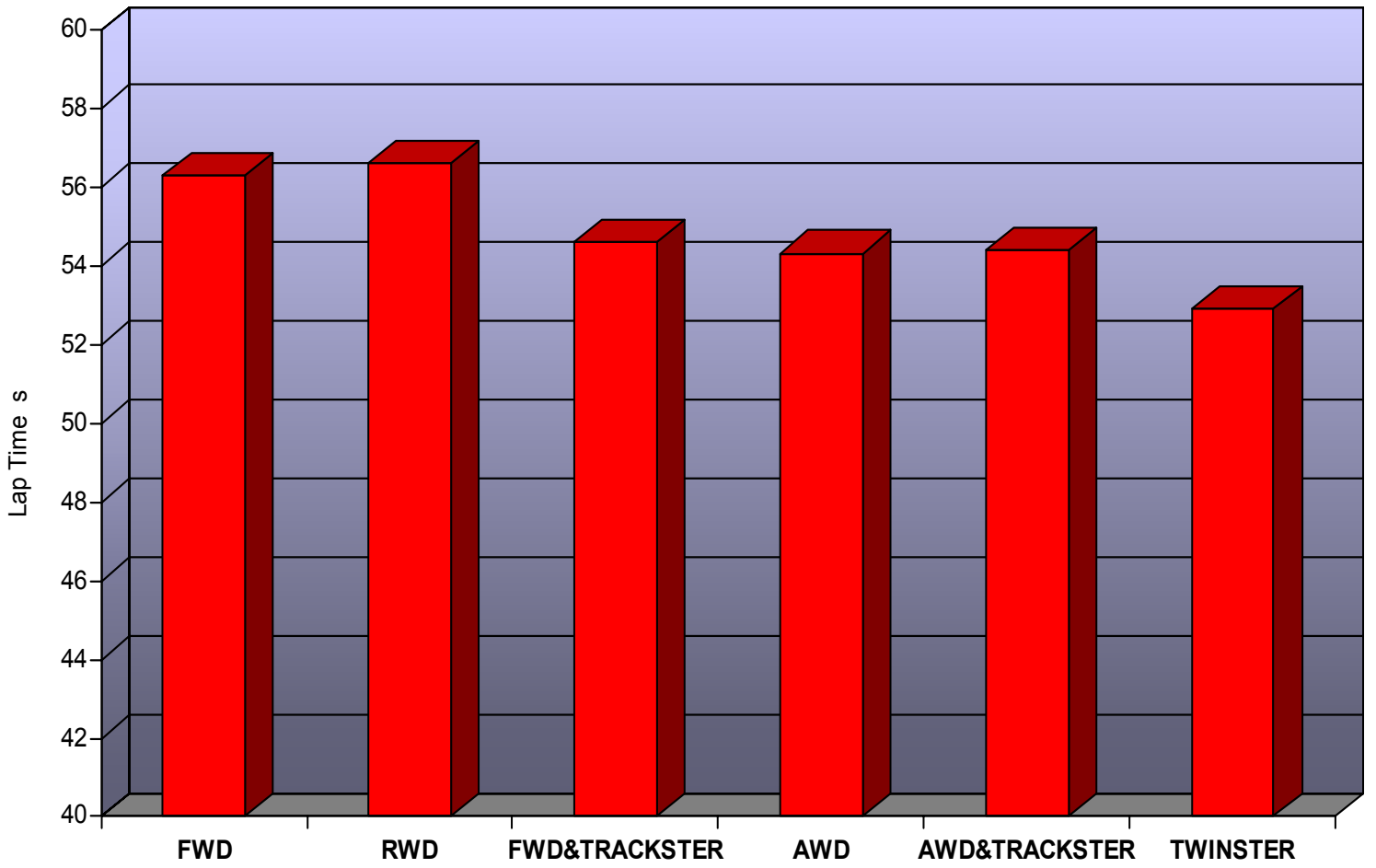
> Wet Handling <



Test procedure (closed loop test)

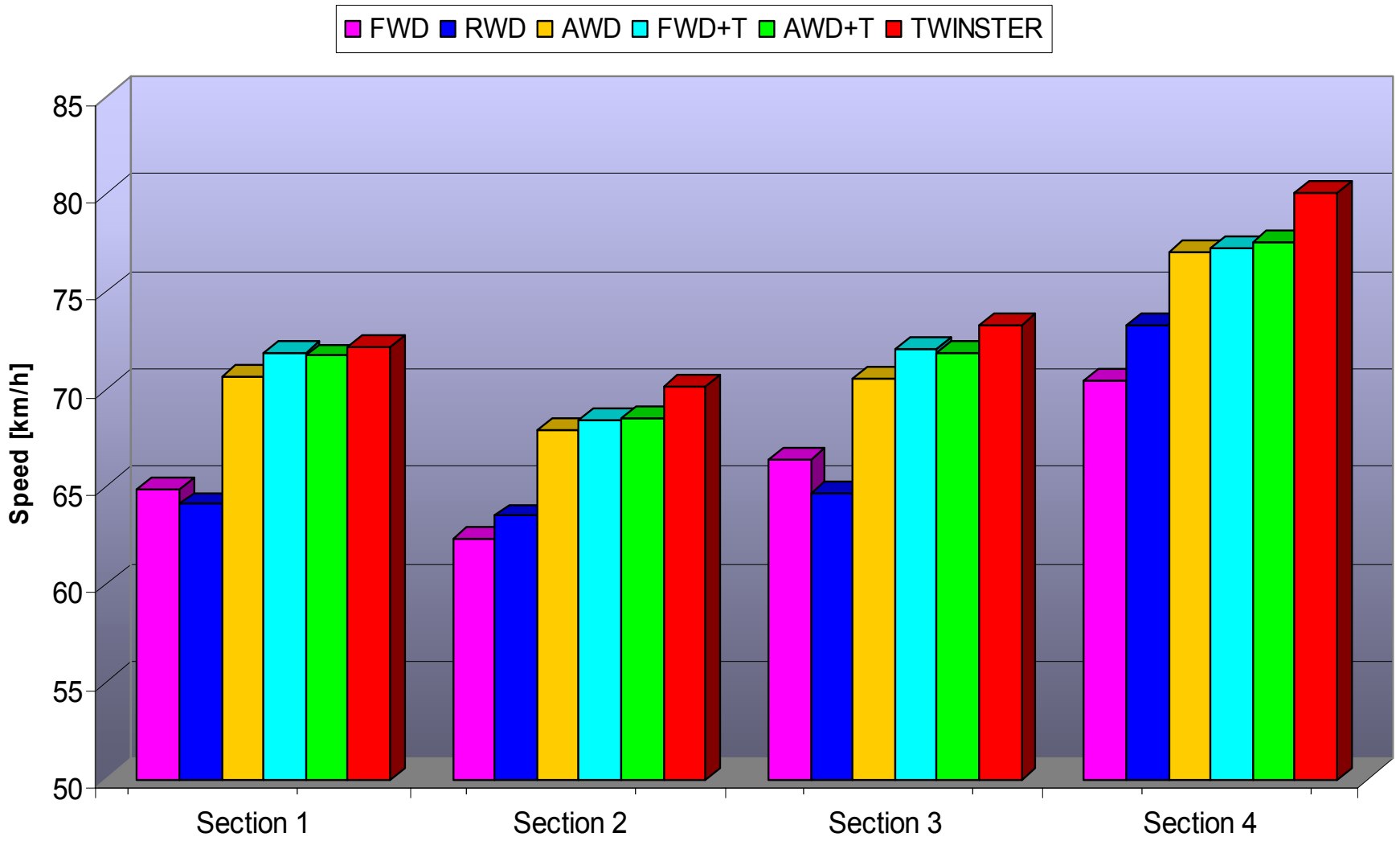
- Surface: water sprayed asphalt
- The target is to drive 5 laps as fast as possible

> Lap Times Wet Handling <



Track Length 1.1 km

>Section Speeds Wet Handling <



> Seven at ONE blow <

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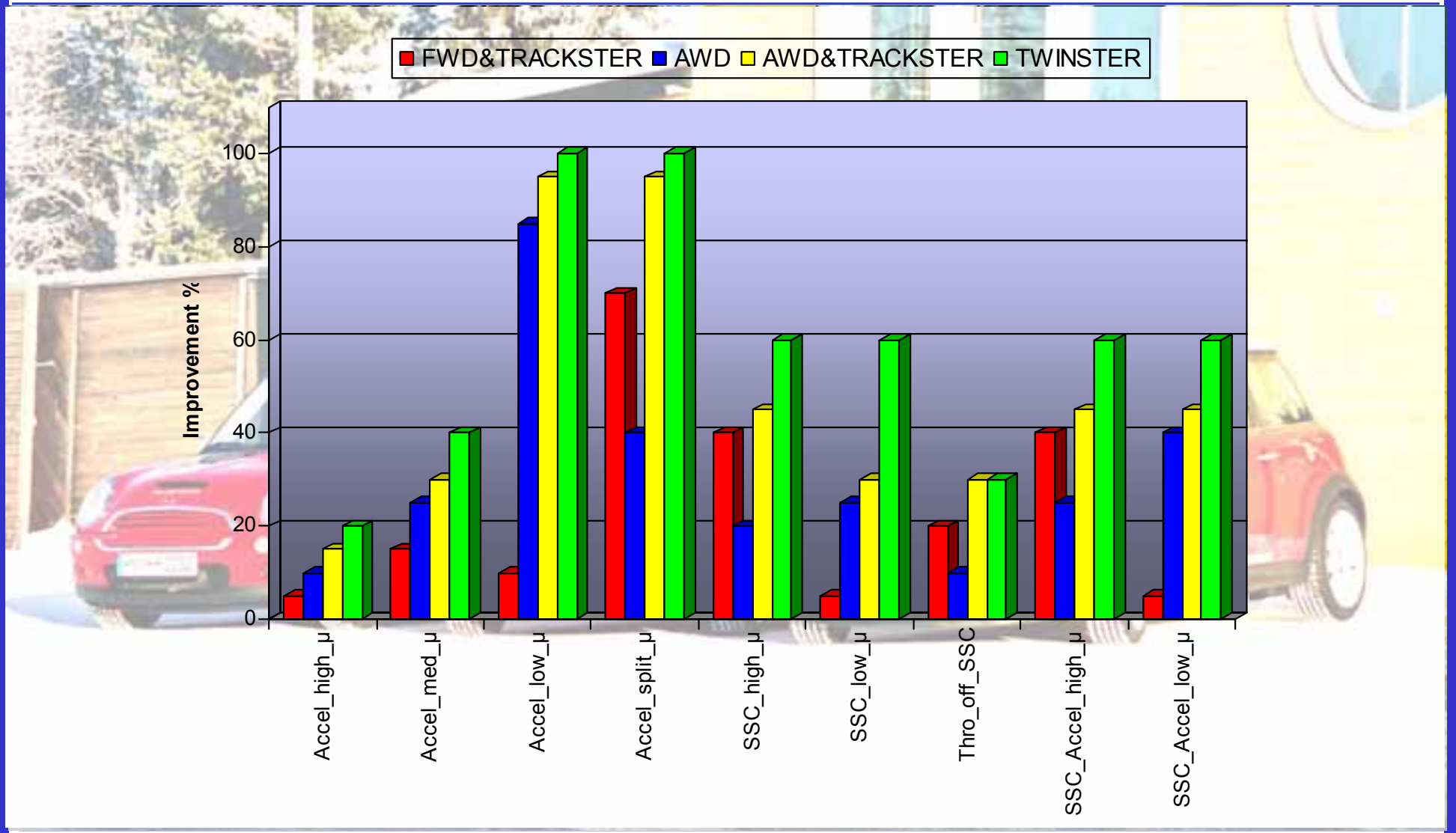
> How much Improvement does each System deliver? <



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>TRACKSTER <

- **TRACKSTER provides all advantages of passive locking differentials by avoiding there disadvantages like**
  - yaw moment build up when driving on split-μ at high speeds
  - understeering when cornering at low speeds
  - ABS / ESP interference

- **Compared to open FWD**
  - TRACKSTER improves traction on
    - split-μ
    - when cornering
    - on inhomogeneous road surfaces
    - less improvements on homogeneous surfaces

  - TRACKSTER improves lateral dynamics by
    - yaw damping
    - increasing cornering speed / lateral acceleration

> AWD “Hang on to Rear Axle” <

Compared to FWD

- “AWD Hang on coupling only” improves mainly traction and lateral dynamics on medium- and low-µ surfaces
- With the combination of AWD „Hang on“ & TRACKSTER all benefits of the active axle locking differential can be added

....and the winner is.....

- The TWINSTER showed the best performance of all tested systems:
  - Best cornering performance by Active Yaw function
    - when cornering
      - lowest steering angle
      - highest Lateral Acceleration
    - best handling performance
    - noticeable reduction of “steer in” understeering under acceleration while cornering
  - Best Traction performance by
    - using dynamical weight increase on the primarily driven axle during acceleration
    - on split-μ the system acts like a combination of axle locking differential and hang on coupling

> Outlook <

TWINSTER and Hang on & TRACKSTER

- Vehicles available for evaluation by OEMs
- Refinement to utilize full potential of all concepts ongoing
  - Control strategy with additional features
    - e.g. Network with ESP, suspension control etc.
- Affordable Active Yaw system (TWINSTER)

- **Direct comparison of 7 drivelines in ONE vehicle**

- **All concepts are commercially available**

- **Distinction of individual brands possible with similar hardware**