Connected to the road with the Direction Sensitive Locking Differential (DSLD)

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Double Lane Change: DSLD vs. ESC on

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The role of the differential

- The open differential was developed to enable low speed maneuvering
- The open differential divides the incoming torque evenly between the output shafts by letting the wheel speeds differentiate freely
- The longitudinal forces of the two tires of a driven axle will always be equal, no influence on the yaw moment, perfect for tight corners at low speeds
- The handling balance is determined by the load transfer due to cornering and acceleration/deceleration

The role of the differential

- For given maximum lateral acceleration, the minimum cornering radius is proportional to the square of the vehicle speed
- The actual need for differentiation (at zero longitudinal force) is proportional to the cornering
- Therefore high speed roads have large radiuses >150 m which means < 1% of theoretical differentiation
- This means there is no need for wheel speed differentiation at high vehicle speeds

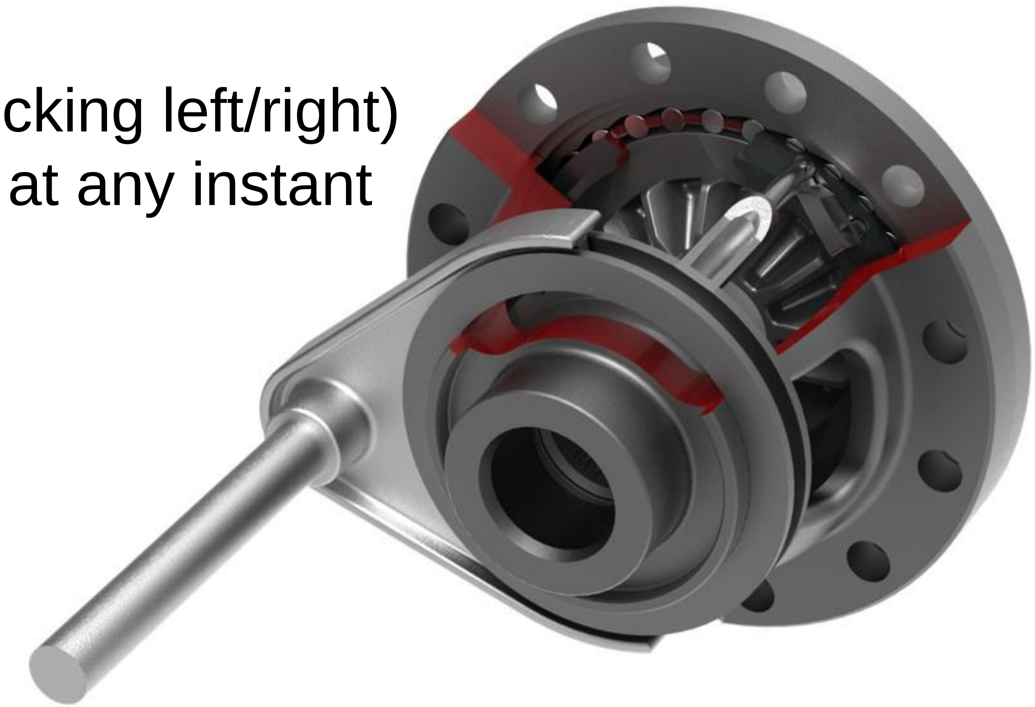
The role of the differential

- The locked differential does not allow free differentiation which can give differentiated longitudinal tire forces
- This compensates for the change in handling balance due to longitudinal load transfer that normally exist with the open differential
- Which gives a more linear handling behavior with respect to throttle/braking inputs
- In the case of an avoidance maneuver the stabilizing yaw moment is substantial

The DsenseD technology

DSLD properties:

- cost and packaging efficient compared to the competition (eLSD)
- four control modes (open, locked, self-locking left/right) that can be changed at any instant
- ESC compatible



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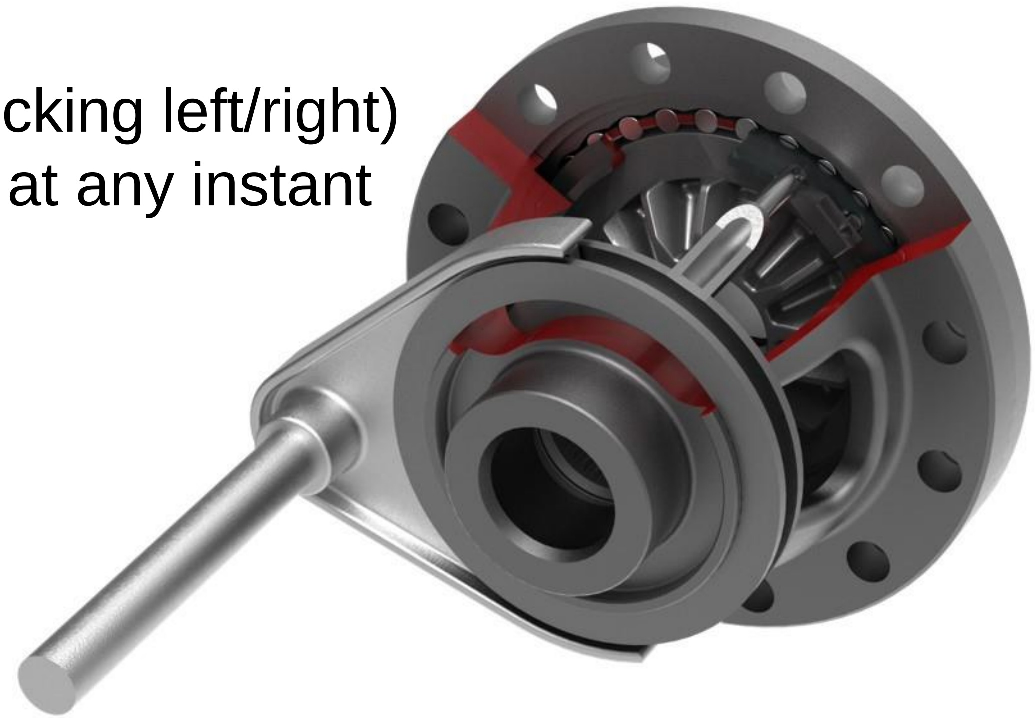

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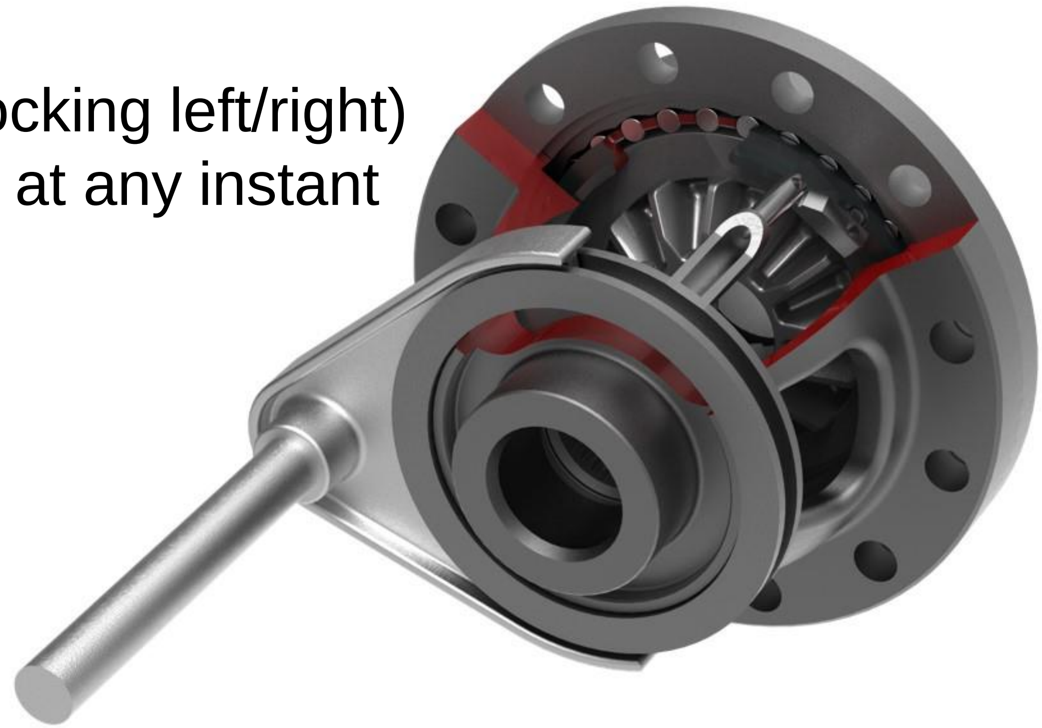

Controlling the ability to differentiate instead of relying on Electronic Stability Control (ESC)

- Controllable differentials are less intrusive as there is no net speed decrease and therefore they can be used more preemptively
- Locking the differential has a high degree of self-regulation which means far less need for advanced control compared to brake based stability control (ESC)
- Additionally, the springing action of the drive shafts reduces the delay of the yaw response making the car much easier for the driver to control during critical avoidance maneuvers.

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Assessment of lateral stability and responsiveness

- A prototype of the DSLD is implemented in a FWD Saab 9-3 Aero
- The stability gain obtained is verified and quantified by locking the differential (DSLD) and compare the performance with ESC on
- The standardized (Open Loop) test maneuver Sine with Dwell is performed using a steering robot
- A (Closed Loop) Double Lane Change maneuver is carried out with a test driver.

Vehicle Prototype Testing

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Saab 9-3 Aero FWD test vehicle

Vehicle Prototype Testing

Testing Maneuvers and Equipment:

- Sine with Dwell. Entry speed 80 km/h. Dry surface
- Double Lane Change. Modified ISO 3888-2. Entry speed almost 80 km/h. Wet surface
- Steering Robot and Motion Pack

Sine with Dwell

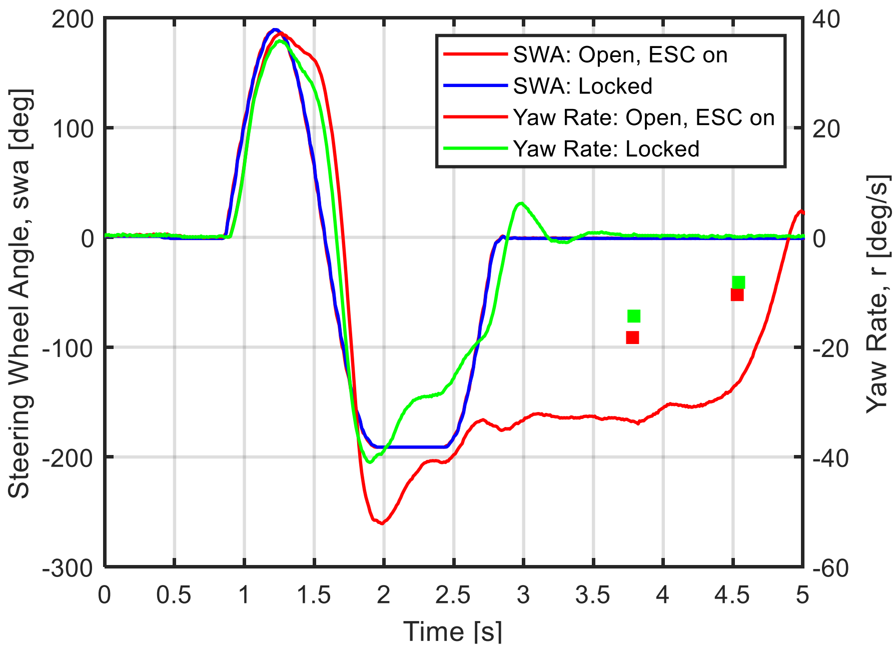

Fig. 4a. SWA & Yaw Rate

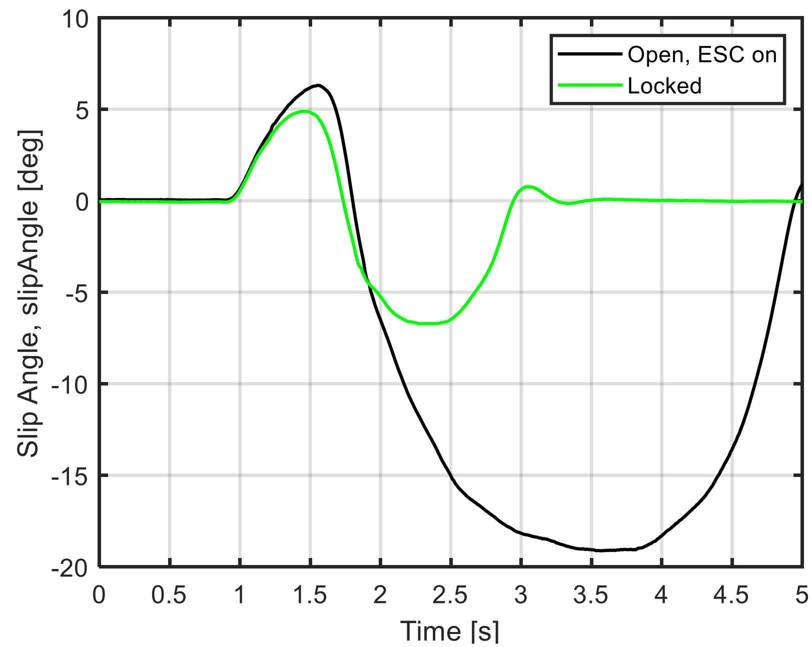

Fig. 4b. Body side slip angle

Sine with Dwell

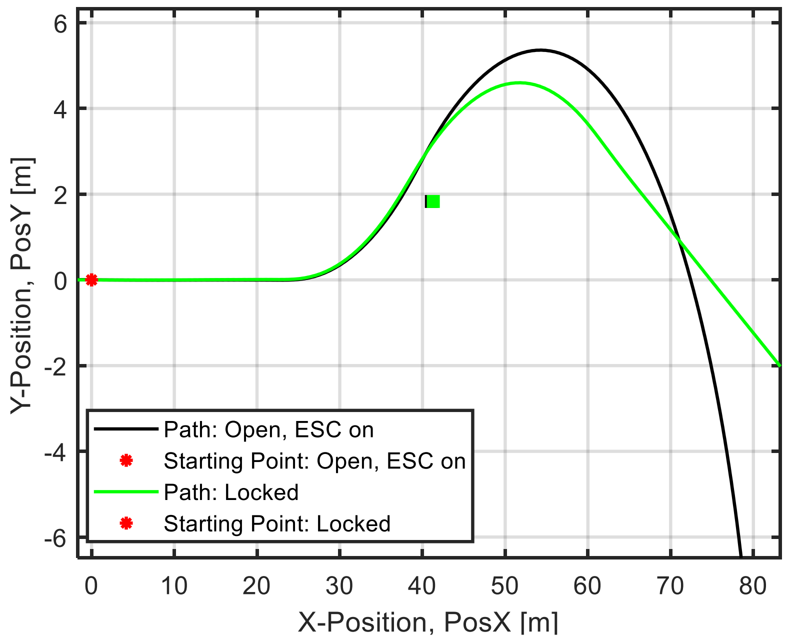

Fig. 5a. Vehicle path

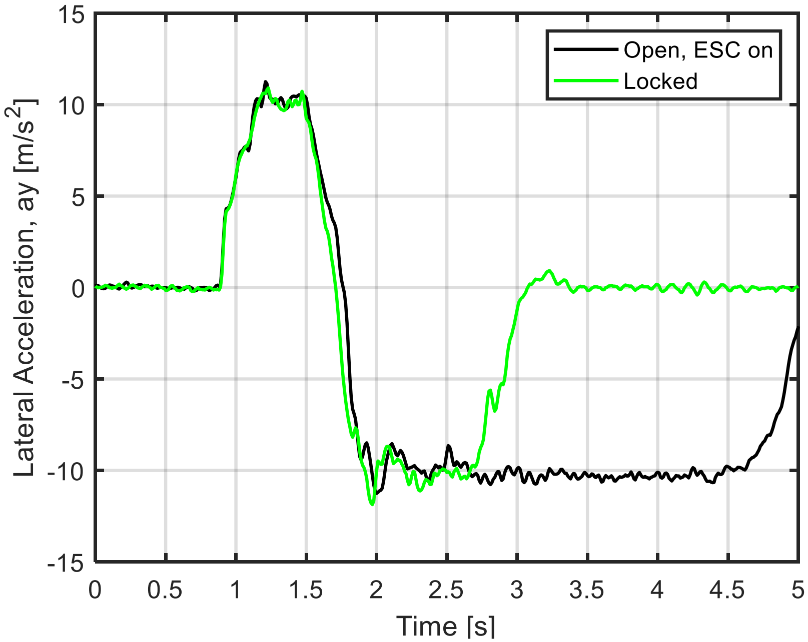

Fig. 5b. Lateral Acceleration

Double Lane Change Maneuver

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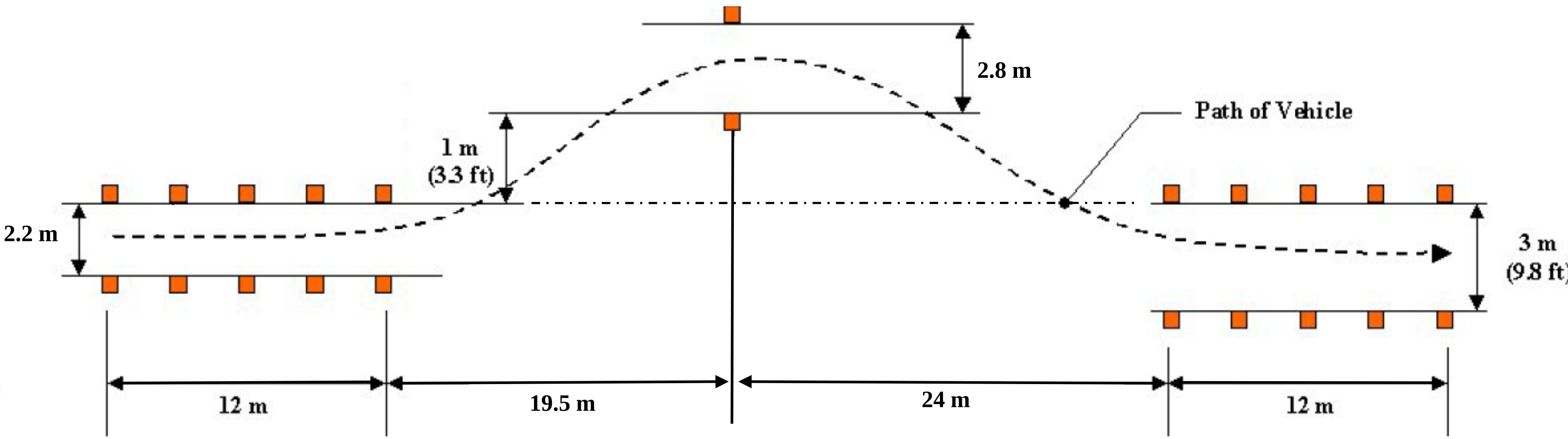
- Modified ISO 3888-2. Throttle off in 5th gear.



Double Lane Change Maneuver

ONE WITH THE ROAD

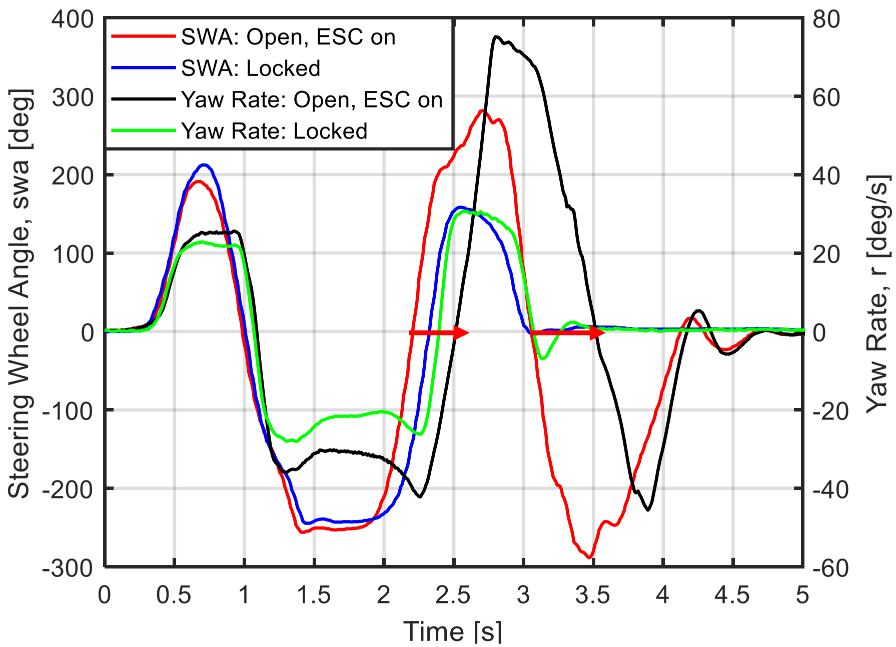


Fig. 7a. SWA & Yaw Rate
Much less yaw overshoot and response phase lag

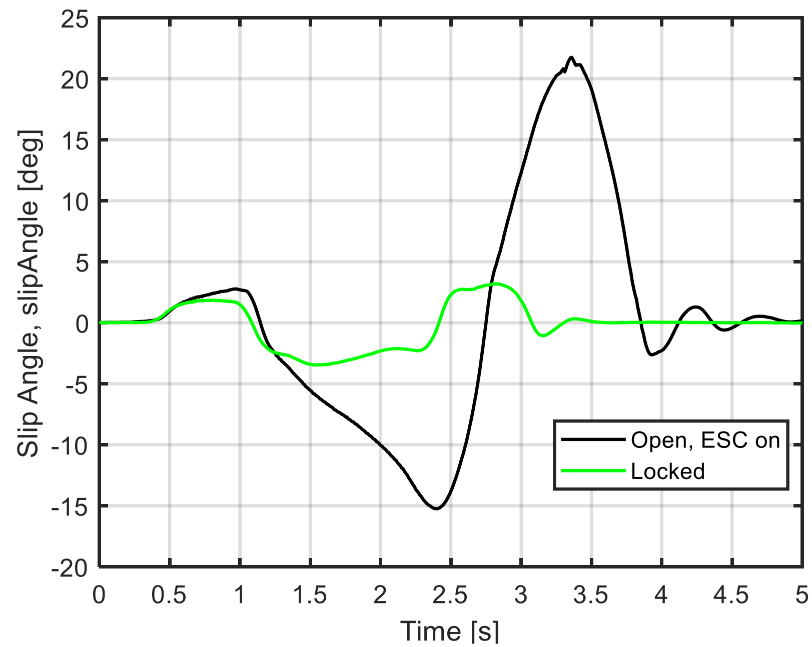


Fig. 7b. Body side slip angle
Car heading is almost identical to travel direction

Double Lane Change Maneuver

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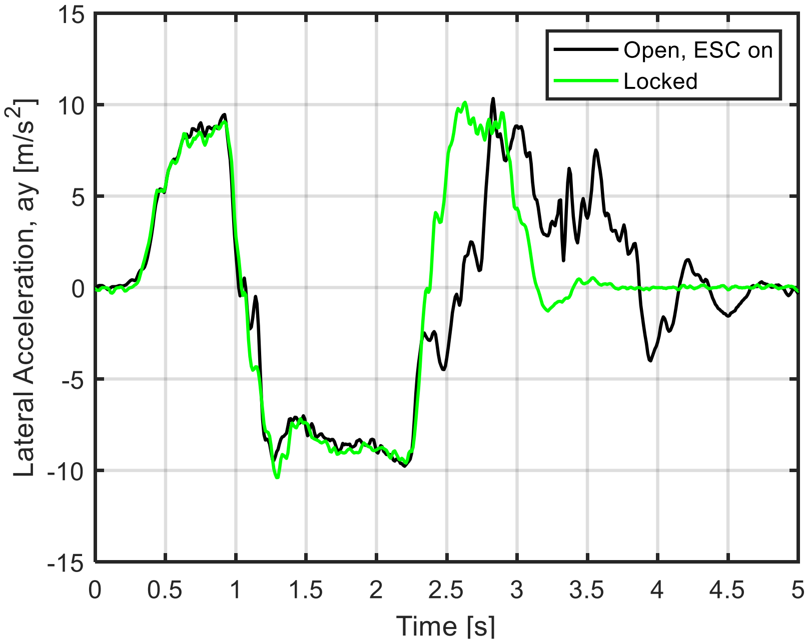


Fig. 8a. Lateral Acceleration

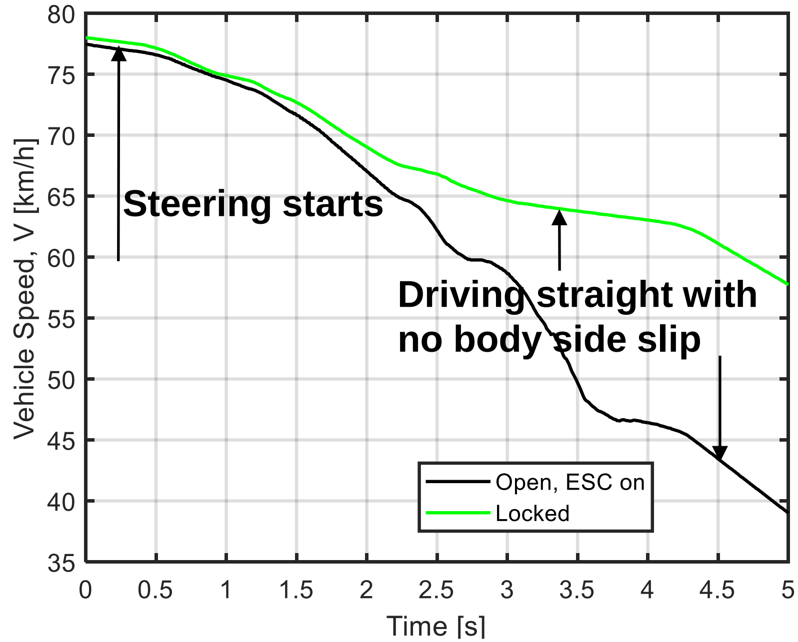
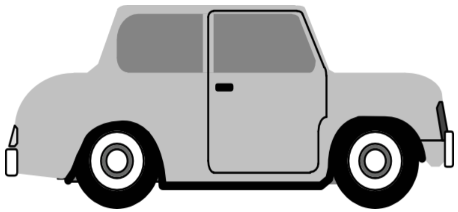
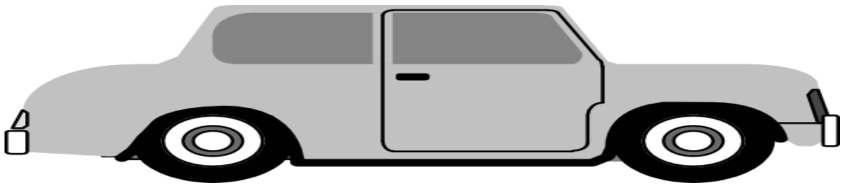


Fig. 8b. Vehicle Speed
No cheating! ☺

Two cars in one!



Short and agile for the twisty bits



Long and stable for the highway

Conclusions

- The semi-active differential (DSLD) gives a significantly greater improvement of the yaw stability than brake based stability systems (ESC) can achieve.
- This allows for a more balanced tuning of the the base car handling and thus less of a compromise between low to medium speed agility and medium to high speed stability.

- For the car customer this will bring the value of a more enjoyable driving experience while simultaneously increasing the safety of the occupants.

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Thanks for your attention!

Today's Demo Vehicle

Vehicle and DSLD:

- NEVS 9-3 MY2014
- DSLD 3rd generation (robust self locking and forced unlocking functionality)

Status:

- The current version of the DSLD and the control system is still a prototype, which means there are some limitations.
- To meet the functional requirements for production, a refinement of the current DSLD is required (4th generation).

Demo: Double Lane Change

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- Objectives: Improved stability
- Procedure: Throttle-Off 5th gear, I. ESC on, II, DSLD active
- You will experience: Less need for counter steering!

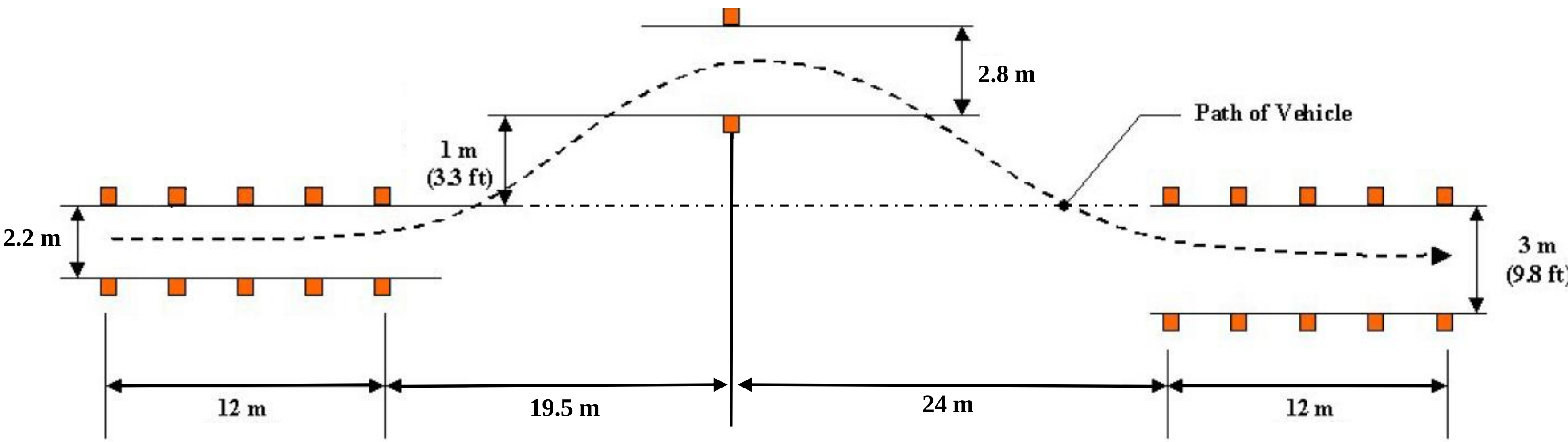

Figure 1. Modified ISO 3888-2 course layout.