# Overview of the development strategy for an Electronic Stability Control system for trucks

*M. Beenakkers, R. Huisman, B. Veldpaus, E. Demarteau, L. Luijten*
*DAF Trucks N.V.*

*Presented by S. de Cock*

# Vehicle Stability Control

- In 2014 VSC systems will become compulsory on all vehicle configurations in Europe
  - VSC controls in two modes: Roll over protection and yaw control
  - It is expected that yaw control is most critical.

- Legislative constraint:

**VSC shall not deteriorate vehicle behaviour!**

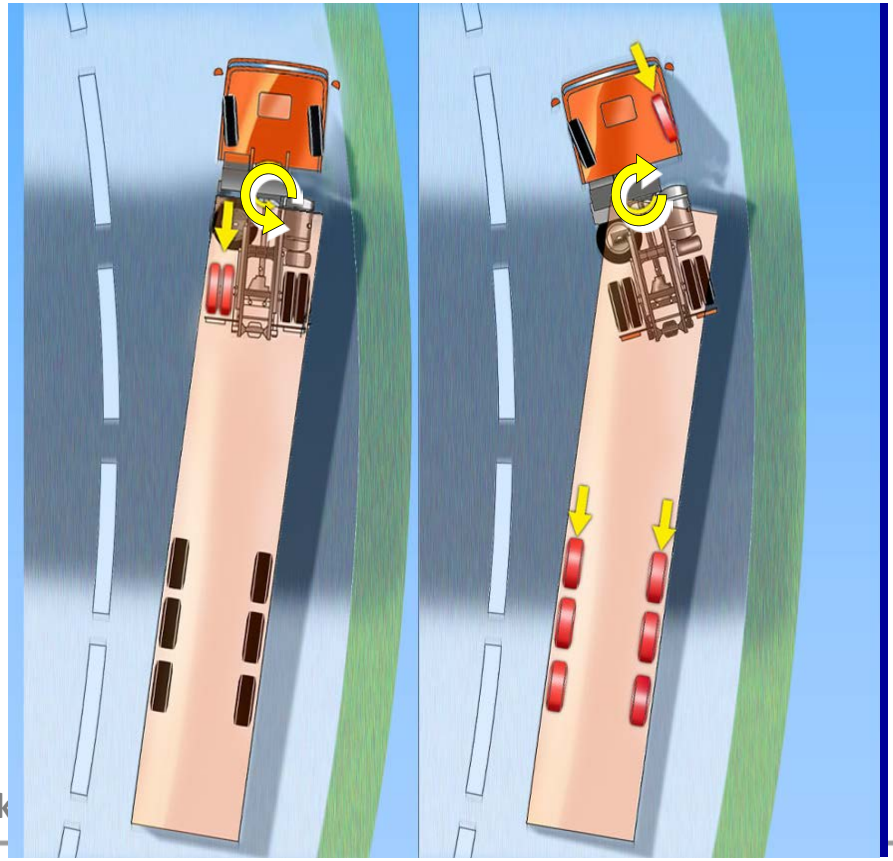
# Content

# 1. Introduction

Objective: electronic stability control for commercial vehicles:

- Combined rollover and yaw control
- For all vehicle combinations considered at risk

Understeer



Oversteer

# 1. Introduction

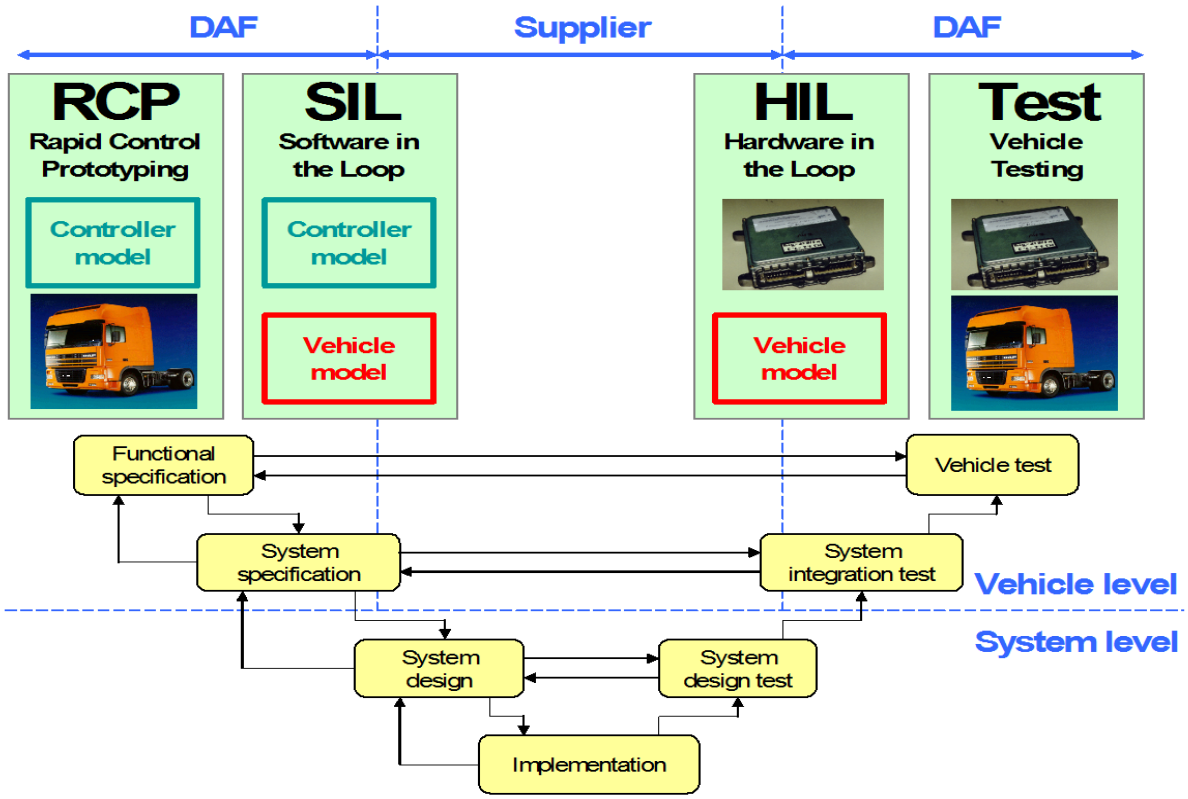
Difficulties:

- Interaction with many other control systems:
  - Engine management system
  - Automatic gearbox controller
  - Driveline brake system
  - Central vehicle controller
- Wide range of possible circumstances:
  - Many vehicle configurations
  - High variety of loads

$\Rightarrow$ SIL and HIL necessary in addition to vehicle tests

# 1. Introduction

Development process: the V-cycle




In case of VSC:

Role DAF:
- implementation
- integration
- verification
- … on vehicle level

Role Wabco:
- specification
- design
- implementation
- verification
- … on system level

# 2. Software-in-the-Loop

- Purpose:
- Verify basic functionality of VSC for all relevant variants:
  - Vehicle configurations
  - Loading conditions
  - Manoeuvres
- Support controller optimization (if needed)

- Identify the critical variants from SIL $\Rightarrow$
  use as input for vehicle tests

# 2. Software-in-the-Loop

Model building

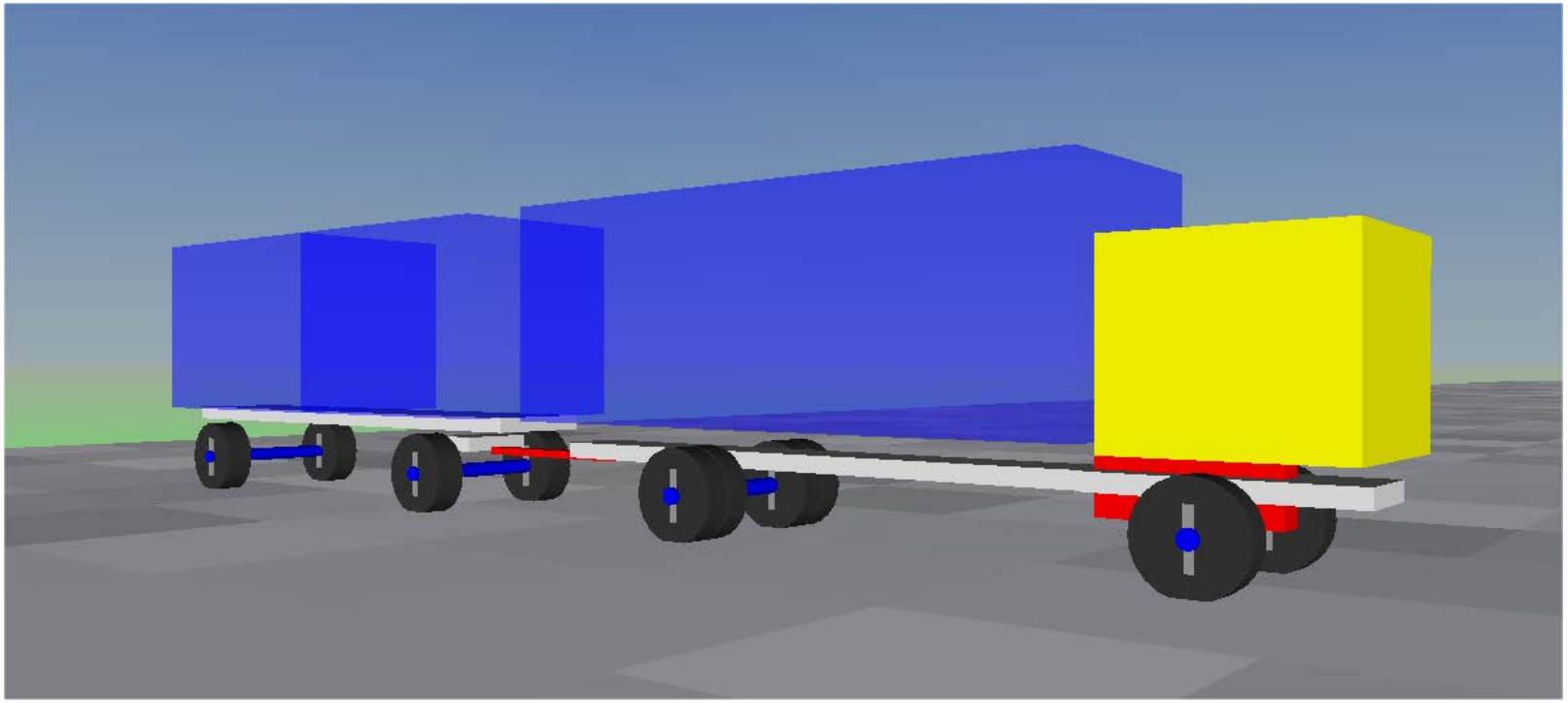
Simulation models are developed to prove safety, Performance and robustness of VSC (for all vehicle configurations)

Approach

Model development in MATLAB®/SIMULINK®
with SimMechanics® toolbox

# 2. Software-in-the-Loop

Model layout of 2-axle truck with 2-axle drawbar trailer



# 2. Software-in-the-Loop

Degrees of freedom in the model:

- tractor chassis: **6**, chassis flexibility with revolute joint: **1**
- front/rear/trailer axles: bounce/roll: **2**, wheel angular motion: **2**
- trailer chassis: pin coupling: **3**, drawbar: **2**, flexibility with revolute
- joint: **1**
- front axle steering: **1** (prescribed angle)

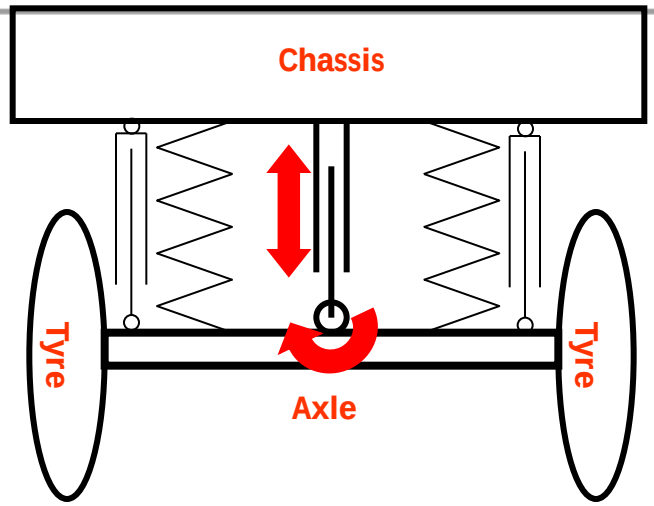
$$6 + 1 + (4x4) + 3 + 2 + 1 = 29 \text{ DOF}$$

Model parameters based on data available at DAF

# 2. Software-in-the-Loop

## *Axle suspension*

- Bump and roll DOF, no roll steer
- Roll centre fixed on axle
- Roll bar: torsional spring in revolute joint
- Tyres: TNO Delft-Tyre (parameters measured for DAF)



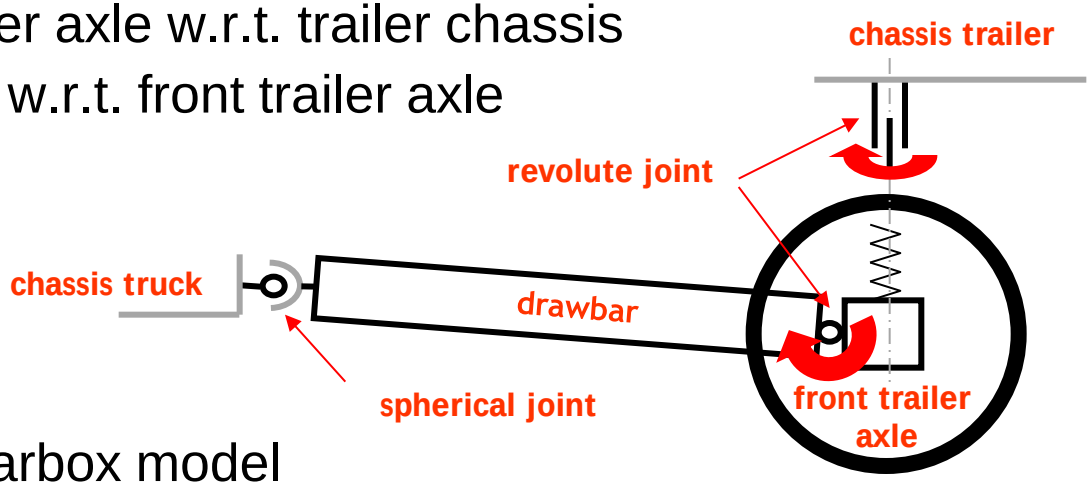

## *Chassis flexibility*

- Torsion spring between rigid chassis members (along x-axis)

# 2. Software-in-the-Loop

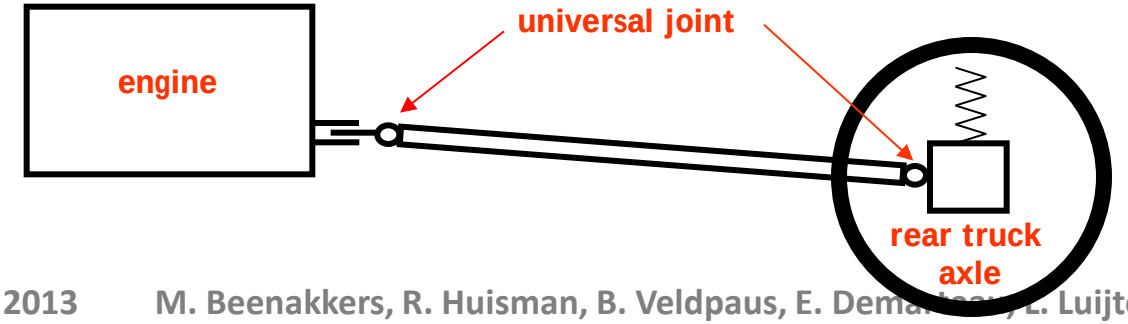
*Drawbar*

- Pin coupling: spherical joint
- Yaw motion front trailer axle w.r.t. trailer chassis
- Pitch motion drawbar w.r.t. front trailer axle




*Powertrain*

- Very basic engine/gearbox model
- (massless) prop shaft connects engine and rear axle
- Includes differential and final drive reduction



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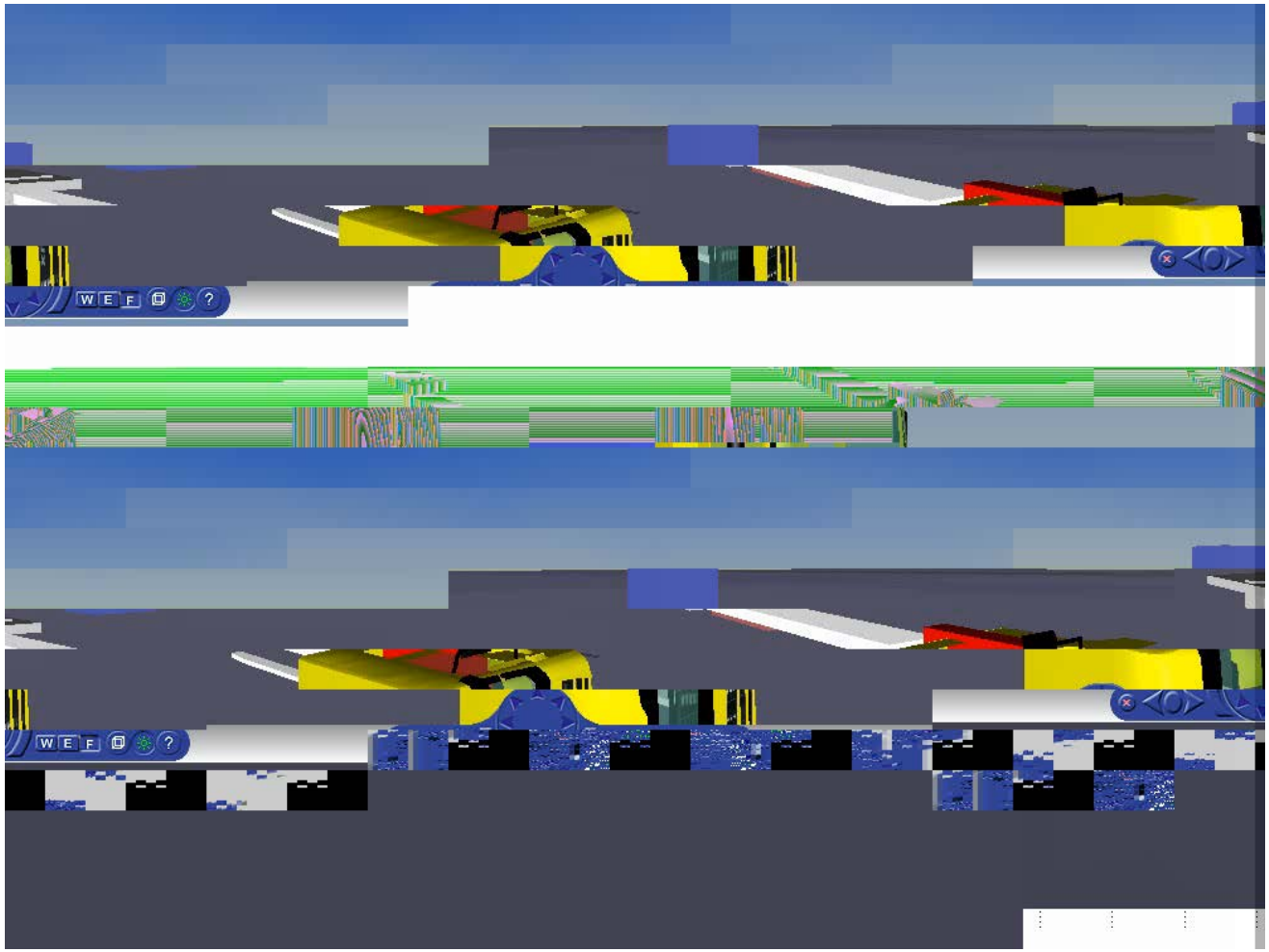
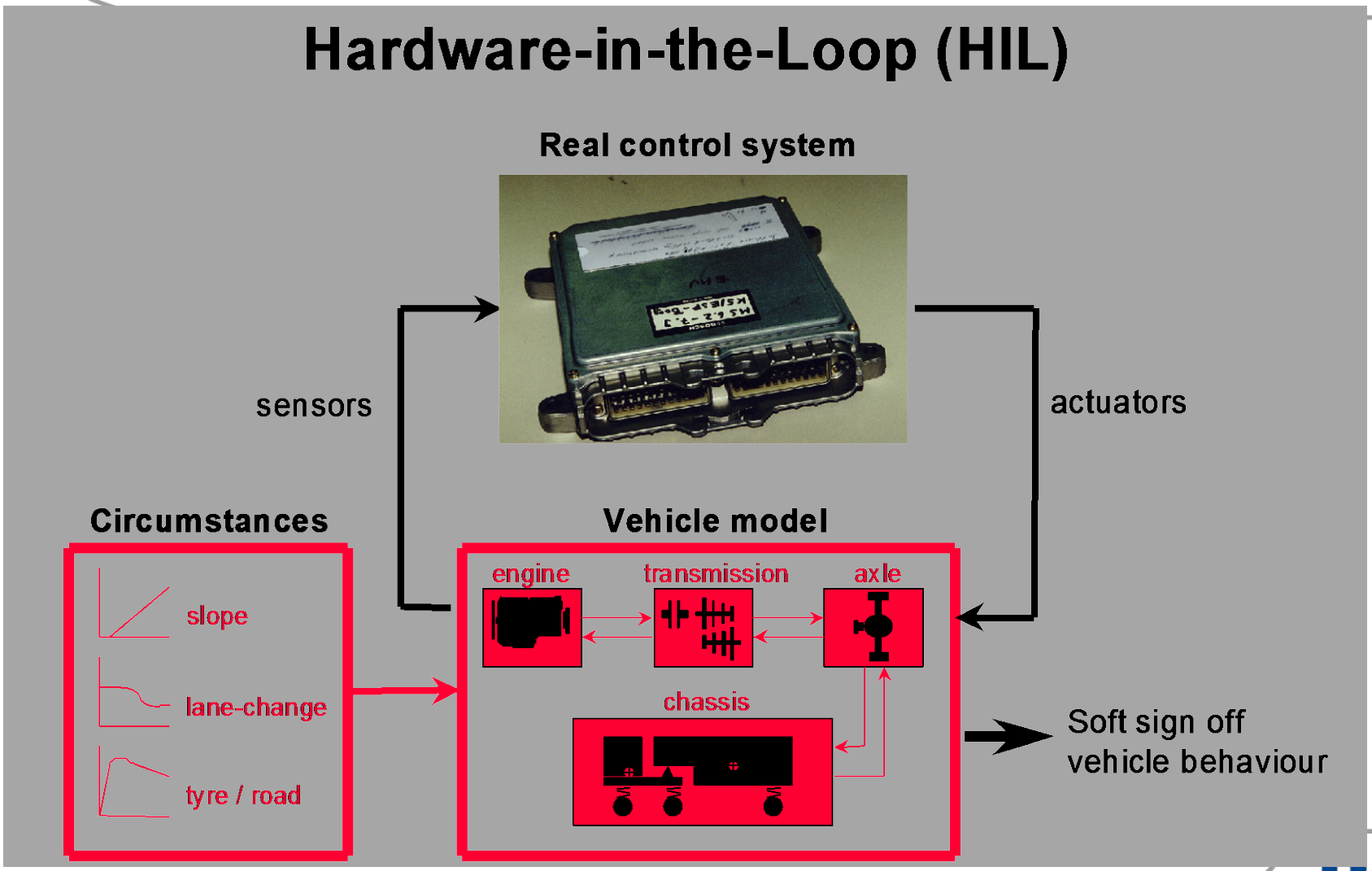


# 3. Hardware-in-the-Loop



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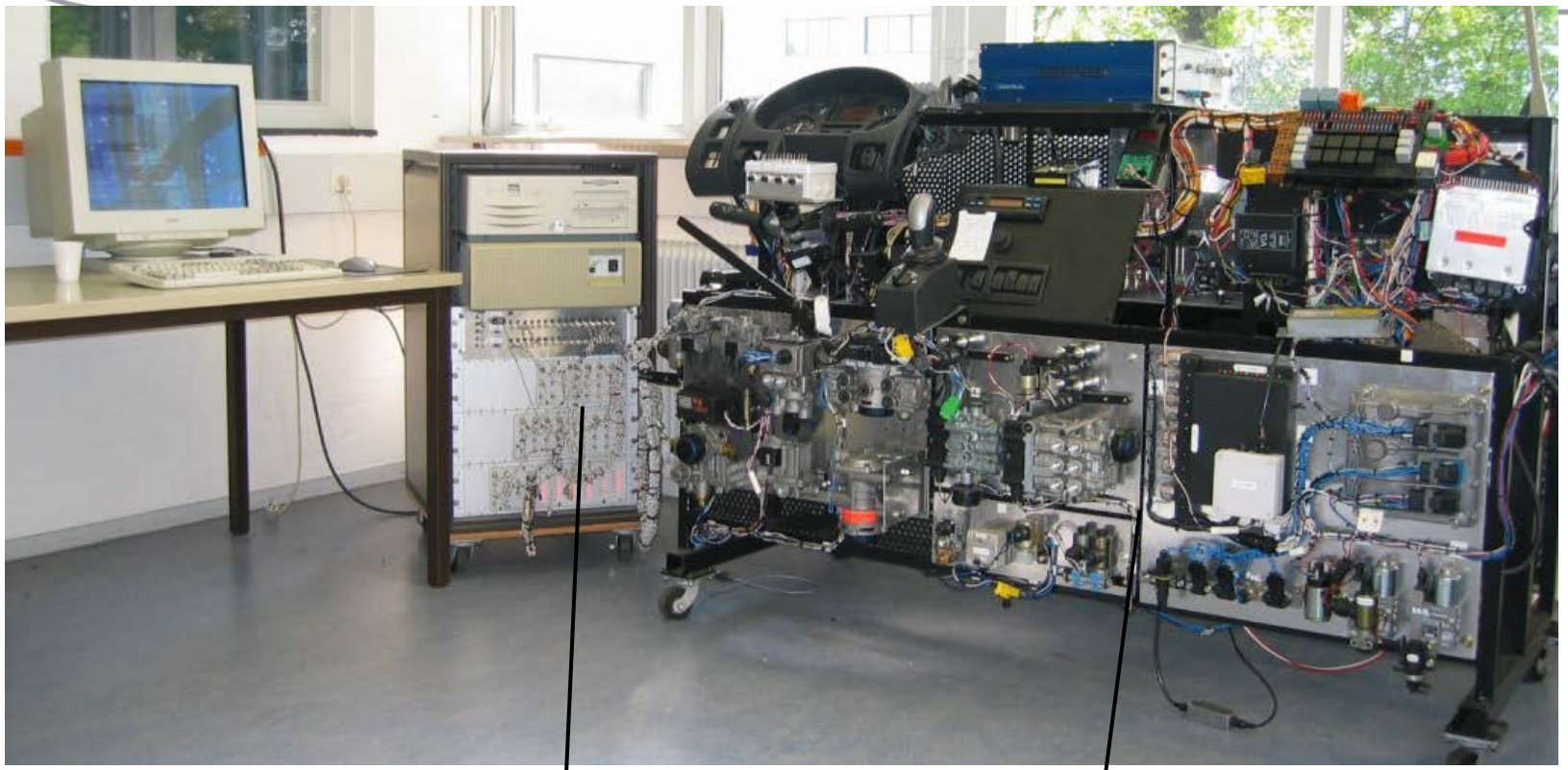


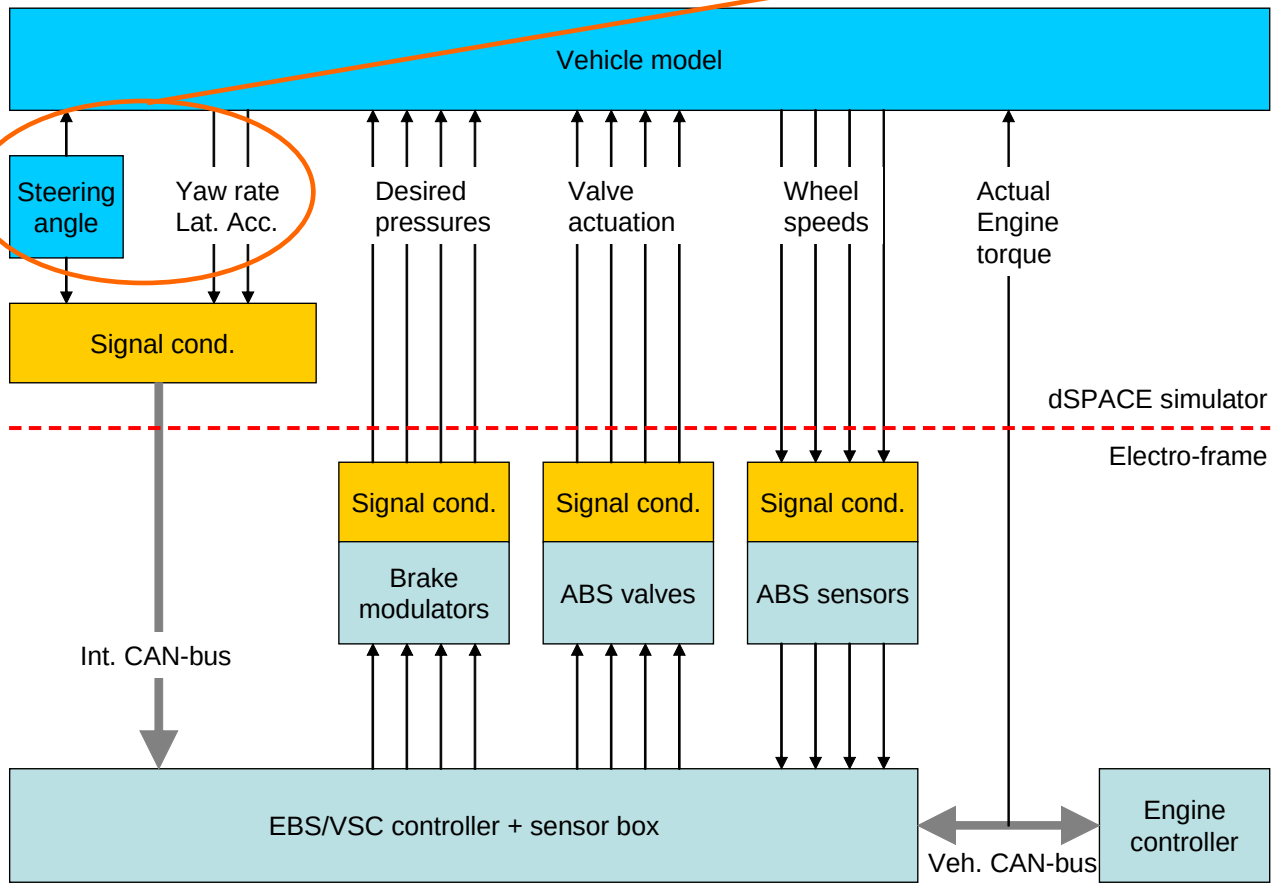
Computer with dSPACE hardware and software, Matlab/Simulink/Stateflow

Test rig with all electronic control units, actuators and sensors

# 3. Hardware-in-the-Loop

VSC vehicle has 3 extra sensors:
- Steering angle
- Yaw rate
- Lateral accel.

## Interface



# 3. Hardware-in-the-Loop

- ***Simulator***
- Vehicle model containing:
  - Flexible driveline
  - Gearbox with clutch
  - Engine plus engine brakes
  - Brakes plus pneumatics
  - 3D tractor-semitrailer
  - MF tire model
  - Cooling system
  - Secondary retarder
- Signal conditioning:
  - Camshaft / crankshaft speed
  - Sensor CAN signals
  - …

- ***Electro frame***
- ECU's from:
  - Engine
  - Automatic gearbox
  - Secondary retarder
  - Central vehicle controller
  - Electronic brake system
  - Air suspension
- All actuators
- All sensors
- Signal conditioning:
  - ABS signals
  - 24 V <=> 10 V
  - …

The scope of the setup greatly exceeds the VSC assessment task

# 4. Software in the Loop trial studies

- VSC Analysis: Goals
- Analytical study
  - Critical vehicle configurations
- Simulation plan
  - Configuration matrix
  - Maneuvers
  - Key Performance Indicators

# 4. Software in the Loop trial studies

The goal of VSC analysis is to prove functional performance of the VSC system by analyzing:

- **Critical Vehicle Configurations**

  An analytical study has been made to assess lateral stability of all DAF vehicle combinations

- **Critical manoeuvers**

  Simulations are performed with each critical vehicle configuration in a variety of load conditions.
  This in a number of yaw-stability-critical manoeuvers

# 4. Software in the Loop trial studies

Results of an analytical study:

- Rearward Amplification (RA) is a good performance measure for yaw stability.
- Parameters which increase RA
  - Decrease wheelbase
  - Increase the number of articulations
  - Increase coupling rear overhang
  - Decrease drawbar length
  - Move the load centre of gravity to the rear
  - Decrease cornering stiffness, e.g. remove axles far from the centre of gravity
- Based on these parameter sensitivities the critical configuration matrix is filled

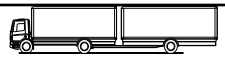
# 4. Software in the Loop trial studies

Large varieties in truck combinations ….

…VSC has to be robust for all variations and the entire vehicle range

# 4. Software in the Loop trial studies

Con-figuration matrix

| **Vehicle Configuration** |  |  |  |
|---|---|---|---|
| **Truck Loading conditions** | **Trailer Loading conditions** | | |
| Empty | Empty | Empty | Empty |
| | Front | Front | Front |
| | Middle | Middle | Middle |
| | Rear | Rear | Rear |
| | Full | Full | Full |
| Front | | Empty | Empty |
| | | Front | Front |
| | | Middle | Middle |
| | | Rear | Rear |
| | | Full | Full |
| Middle | | Empty | Empty |
| | | Front | Front |
| | | Middle | Middle |
| | | Rear | Rear |
| | | Full | Full |
| Rear | | Empty | Empty |
| | | Front | Front |
| | | Middle | Middle |
| | | Rear | Rear |
| | | Full | Full |
| Full | | Empty | Empty |
| | | Front | Front |
| | | Middle | Middle |
| | | Rear | Rear |
| | | Full | Full |
| **Remarks** | | Check for robustness to trailing axle lift switch | Check for robustness to trailing axle lift switch |



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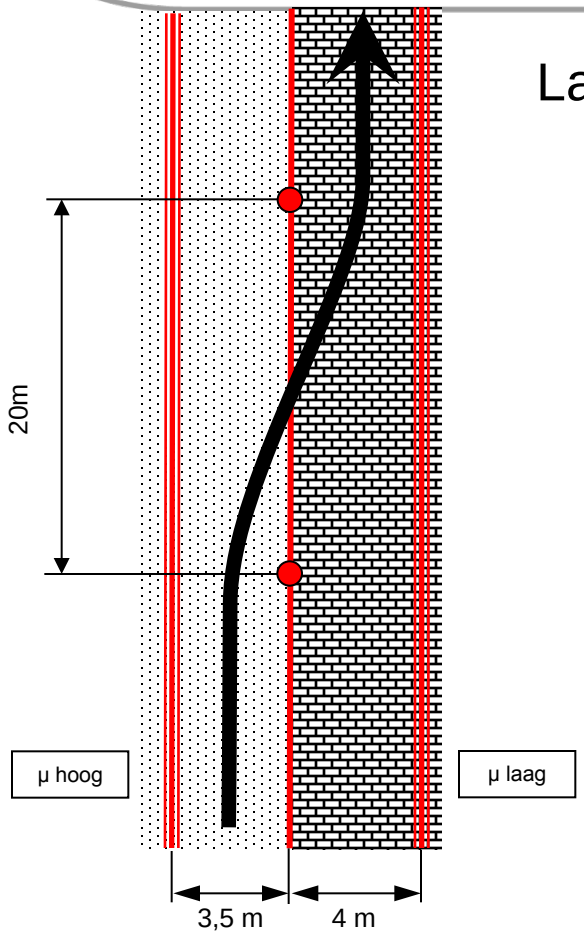
# 4. Software in the Loop trial studies

Manoeuvers and conditions used

- Validation maneuvers
  - Full braking
  - Steady state cornering
  - Step steer
  - Hundekurve
  - Lane change to low μ

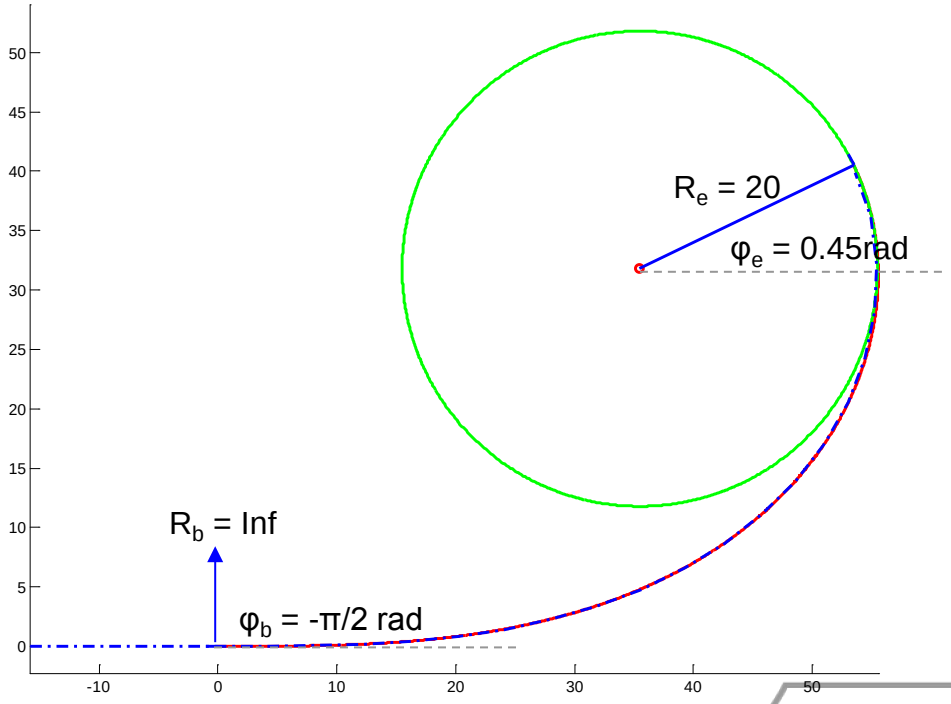
- Vehicle simulations all done under equal conditions
  - Same maneuver
  - Same driver settings
  - Same speed
  - Only VSC switched on and off

# 4. Software in the Loop trial studies




Lanechange to low μ

"Hundekurve" (motorway off ramp)



# 4. Software in the Loop trial studies

## Key performance indicators

Using the insights gained in the studies on vehicle stability several parameters were finally chosen as key stability performance indicators. Clearly the degree of rearward amplification and the road space the vehicle uses are among these.

From these studies and associated testing experience:

- DAF manoeuver signoff criteria have been formulated.
- The most critical configurations were identified and tested for the final sign off.

# 4. Software in the Loop trial studies

## Key Performance Indicator comparison

Select the configurations of interest in the first table and then click "Compare". Now the results of the test are gathered and displayed in the second table. To get a visual impression of the comparison, check a KPI in the list and look in the chart how it compares to the others.

| | ID | Chassis Tru | Chassis Trai | Speed | Load Truck | Load Conditi | Load Trailer | Load Conditi | VSC | Test Pass | Test Pass (W | Filename |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | VSC | Test Pass | Test Pass (W | Filename |
| ☐ | 7 | FAR | CA | 60 | 1 | middle | 1 | middle | off | | | |
| ☐ | 8 | FAR | CA | 60 | 1 | middle | 10000 | middle | on | | | |
| | | | | | | | | | off | | | |
| ☐ | 9 | FAR | CA | 60 | 1 | middle | 4000 | middle | on | | | |
| | | | | | | | | | off | | | |
| ☑ | 10 | FAR | CA | 60 | 1 | middle | 4000 | rear | on | | | |
| | | | | | | | | | off | | | |
| ☐ | 11 | FAR | CA | 60 | 10000 | middle | 4000 | front | on | | | |
| | | | | | | | | | off | | | |
| ☐ | 12 | FAR | CA | 60 | 10000 | middle | 1 | middle | on | | | |
| | | | | | | | | | off | | | |
| ☑ | 13 | FAR | CA | 60 | 10000 | middle | 10000 | middle | on | | | |
| | | | | | | | | | off | | | |
| ☐ | 14 | FAR | CA | 60 | 10000 | middle | 4000 | middle | on | | | |

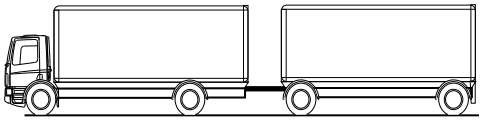
Compare!

Comparing 2 configuration(s).

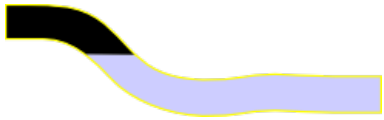
| ID | Chassis Tru | Chassis Trai | Load Conditi | Load Conditi | VSC | ABS | Test Pass | Test Pass (W | Rearward An | Cum Steerin | Max PathDev |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | VSC | ABS | Test Pass | Test Pass (W | Rearward An | Cum Steerin | Max PathDev |
| 10 | FAR | CA | middle | rear | on | on | | | | | |
| | | | | | off | on | | | | | |
| 13 | FAR | CA | middle | middle | on | on | | | | | |
| | | | | | off | on | | | | | |

# 4. Software in the Loop trial studies

## Results

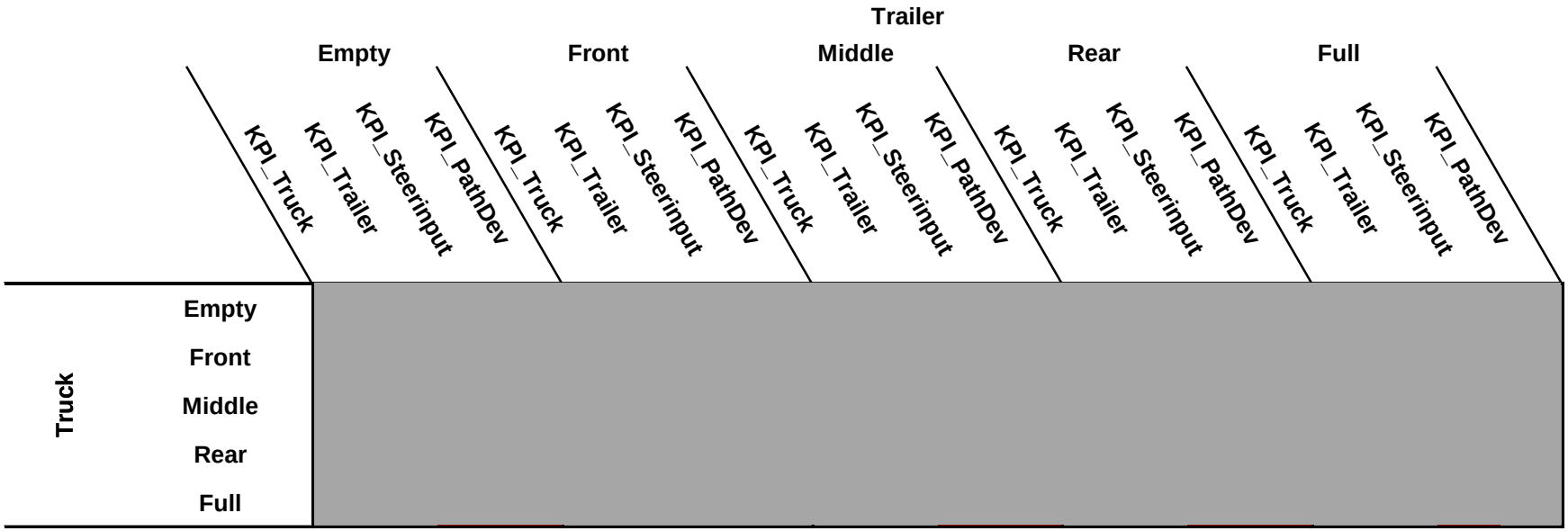


FAR – Full Trailer



Lanechange high2low μ


60km/h



# 5. Conclusion

This successful project has shown that good results may be achieved in the creation of an effective VSC capability for our trucks, requirements are however considerable:

- An all embracing development strategy (V-cycle)
- A capable system supplier
- Close cooperation with the supplier in all phases of development
- Extensive SIL and HIL facilities
- Extensive testing facilities

And…. capable and fully committed staff in all these areas

# 5. Conclusion


DAF

Alleen de Euro-5 trekkers kennen **als optie** VSC.

Dus FT, FTG, FTP,  FTS, FTR, FTT en FTM.