

# Proceedings from 2023 Vehicle Dynamics seminar

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The contents of these proceedings include both **presentations and poster material** and are published at <https://research.chalmers.se/en/publication/539363>. It will also be available at <https://kth.diva-portal.org/> and <https://www.sveafordon.com/>.

The seminar was arranged by Vehicle Dynamics Competence Area and Swedish Vehicular Engineering Association (SVEA, <https://www.sveafordon.com/>).



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Note that the pdf file is generated with these “headings as pdf bookmarks”, so you can also navigate via the “bookmark pane” in your pdf reader.

# **Announcement of the Seminar**

Vehicle Dynamics seminar 2023

## Testing, development, and verification for Vehicle Dynamics



### About the seminar

The seminar will be in “hybrid format”, meaning that both participation is possible either in-real-life and on-line.

#### In-real-life

Wednesday 2023-05-24, CET 09:00-16:30 at

AstaZero Test Track, <https://www.astazero.com/>

Göksholmen 1, SE-504 91 Sandhult

Location code (Plus Code): QQHH+9V Sandhult

#### On-line:

Link to on-line meeting will be sent to those who register as on-line.

### Registration

Registration is made via <https://www.sveafordon.com/event/test-development-and-verification-for-vehicle-dynamics-2023/>. If you are member, it is good if you log in before registration.

You will get a confirmation that you are registered.

#### Seminar costs

The seminar is free for SVEA members. SVEA will sponsor food (fika and light lunch) for members (incl. pending membership applicants) who attend in-real-life.

For non-members attending in-real-life there will be a fee of 210 SEK (>membership fee).

So, we encourage to apply for SVEA membership (<https://www.sveafordon.com/en/for-members/register/>). SVEA membership fee is 200 SEK/year (junior 0 SEK, senior 100 SEK).



## Purpose with the seminar

- Present and discuss interesting issues within and challenges for Testing, development, and verification for Vehicle Dynamics
- Create understanding and interest for vehicle dynamics
- Develop, increase, and spread competence
- Networking between engineers, organisations, and students

## SVEAs objectives

- To make vehicular technology's voice heard in an increasingly more challenging debate among different vehicle types and transport modes both domestic and globally
- To build a network for efficient distribution of technological information
- To attract the next generation of Swedish vehicular engineers

## Agenda

Moderator: Ingemar Johansson, Chairman of SVEA

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                   |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 09:00-09:40 | <b>Coffee and registration</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                   |
| 09:40-09:50 | <b>Welcome</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Ingemar Johansson (SVEA),<br>Bengt Jacobson (VDCA),<br>Håkan Andersson (AstaZero) |
| 09:50-11:30 | <b>Session 1: Presentations (20+10 min each):</b><br><div> <div>1. <i>Development of frame test rig with MBS simulations</i></div> <div>Joakim Eriksson, Scania</div> </div> <div> <div>2. <i>Vehicle dynamics testing in a moving-base driving simulator</i></div> <div>Sogol Kharrazi, VTI</div> </div> <div> <div>3. <i>Cold Climate Testing: Why Arjeplog and Colmis in northern Sweden become a hub for the global automotive industry every winter</i></div> <div>Per Gyllenberg and Benjamin Minshaw, Colmis</div> </div><br><b>Micro presentations of posters (3 min each):</b><br><div> <div><i>Quantify and mimic the feedback through the steering wheel at some driving conditions</i></div> <div>Aron Dalemo, Polestar &amp; Chalmers</div> </div> <div> <div><i>Using torque vectoring to improve steering predictability while minimizing energy use in Heavy electric vehicles</i></div> <div>Jonas Persson<br/>Jonathan Åkesson, Volvo Trucks &amp; Chalmers</div> </div> |                                                                                   |
| 11:30-12:30 | <b>Demo tour</b><br>4. <i>AstaZero tracks.</i><br>Starts with small presentation, then we join in a bus to go out to the tracks.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                   |
| 12:30-13:30 | <b>Light lunch</b> with networking and poster discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                   |

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13:30-14:45 | <p><b>Session 2:</b> Presentations (20+10 min each):</p> <p>5. <i>Suspension design as part of complete vehicle development</i> Yansong Huang, VCC and Chalmers</p> <p>6. <i>Tyre rolling resistance at various operational conditions and limitations in current tyre labelling</i> Jukka Hyttinen, Scania and KTH</p> <p><b>Micro presentations of posters</b> (3 min each):</p> <p><i>Continuously controlled damping tuning on four poster rig</i> Jesper Ramsberg, VCC &amp; Chalmers</p> <p><i>Optimised force distribution algorithm and model</i> Guglielmo Nappi and Sanjay Banerjee, Scania &amp; KTH</p> <p><i>Modelling and measurements of singularity-induced vehicle motion during low-speed driving</i> Luca Mereu, Politecnico di Torino &amp; Chalmers</p> |
| 14:45-15:15 | <b>Coffee</b> with networking and poster discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 15:15-16:15 | <p><b>Session 3:</b> Presentations (20+10 min each):</p> <p>7. <i>Tyres and the purposes of models</i> Edo Drenth and Niklas Fröjd, Volvo Trucks</p> <p>8. <i>Swedish vehicle engineering education</i></p> <ul style="list-style-type: none"> <li>○ <i>KTH, Vehicle engineering</i> ○ Mikael Nybacka, KTH</li> <li>○ <i>Chalmers, Mobility engineering</i> ○ Dag Henrik Bergsjö, Chalmers</li> <li>○ Discussion ○ All</li> </ul>                                                                                                                                                                                                                                                                                                                                            |
| 16:15-16:30 | <p><b>Wrap-up</b></p> <ul style="list-style-type: none"> <li>• Feedback on present years seminar. Proposals for next year.</li> <li>• Discussion on smaller events beside yearly seminar (“workshops”)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

## Poster exhibition

There will be an exhibition of posters. It can be, e.g., master theses or PhD theses, both concluded and almost concluded. Please contact Lars Drugge [larsd@kth.se](mailto:larsd@kth.se) or Bengt Jacobson [bengt.jacobson@chalmers.se](mailto:bengt.jacobson@chalmers.se) if you would like to propose a poster.

Each poster presenter should do a poster and a “micro presentation” with a few slides. Then also be available for questions at the poster stands.

## Proceedings

There will be proceedings from the seminar. This means that the presenters, including poster presenters, are welcome with a paper, or at least a public version of their presentation material. The proceedings will be published on the web. It will include a list of seminar participants, unless you ask us to not list your name.

*The seminar is arranged by the Swedish Vehicle Dynamics Competence Area (VDCA) and hosted by SVEA. The seminar is arranged with VDCA representatives from:*

AstaZero  
CEVT  
Chalmers  
KTH  
VTI  
AFRY Automotive  
Scania  
Volvo Cars  
Volvo GTT

**VDCA** *Swedish Vehicle Dynamics Competence Area*



# Registered participations

57 registered

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# Introduction to the seminar

# **Introduction**

## **Vehicle Dynamics Seminar 2023**

### **Testing, development and verification for Vehicle Dynamics**

**Wednesday 2023-05-24 at AstaZero**

**Issued by: Bengt Jacobson and Ingemar Johansson**

**Date: 2023-05-23**

# Introduction

- **Introduction Vehicle Dynamics Seminar– Testing, development and verification for Vehicle Dynamics (BJ)**
- **VDCA - Swedish Vehicle Dynamics Competence area (BJ)**
- **SVEA - Swedish Vehicular Engineering Association (IJ)**
- **Why Vehicle Dynamics (IJ)**
- **Practical details and agenda today (BJ)**

## **Purpose with the Seminar:**

- Present and discuss interesting issues within and challenges for Testing, development, and verification for Vehicle Dynamics
- Create understanding and interest for Vehicle Dynamics
- Develop, increase and spread competence
- Networking between engineers, organisations and students

**Thank you to AstaZero for hosting the seminar.**

**Special thank you to Håkan Andersson and Henrik Biswanger who have made this possible**

## **Introductions:**

- **Bengt Jacobson**

**Professor and group leader Vehicle Dynamics,**  
Division of Vehicle Engineering and Autonomous Systems,  
Mechanics and Maritime sciences,

**Chalmers University of Technology**

Gothenburg Sweden

and

**Leader of VDCA**

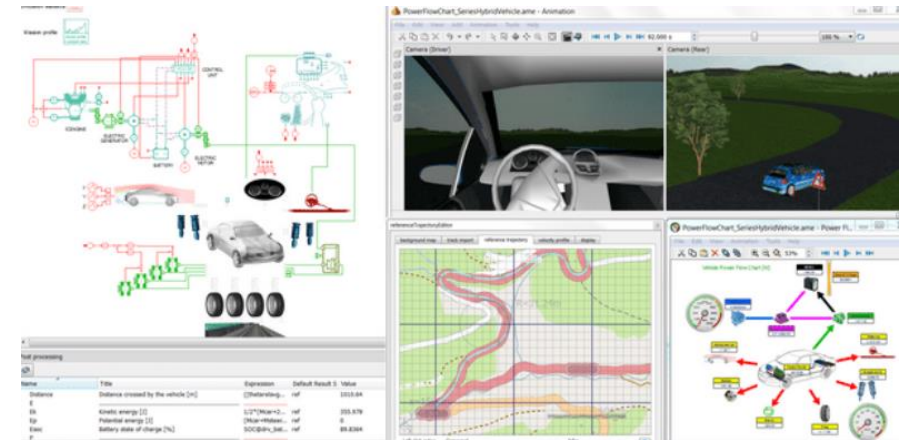
- **Ingemar Johansson**

**Chair of the Board SVEA**



# Testing, development and verification for Vehicle Dynamics

- Vehicle Dynamics Seminar, an annual seminar, since 2013
- This year is the subject for the seminar is: “Testing, development and verification for Vehicle Dynamics”
- There is currently a lot of work ongoing to develop new analysis and simulation tools for the development process for vehicles
- Therefore is the development process for vehicles now more efficient where more alternatives can be tested in analysis tools, lead-times have been shortened and test and development in vehicles has been reduced
- However, test and development in vehicles will still be required to develop the attributes that are important for the driver and to subjectively assess how the complete vehicle works



# VDCA - Swedish Vehicle Dynamics Competence Area

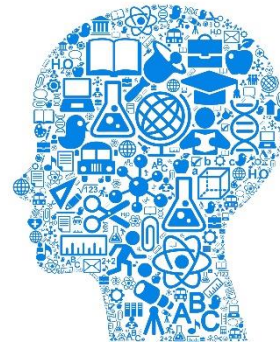
To provide a  
**network** for vehicle  
dynamics



To **coordinate** research  
and thereby close gap and  
avoid double work



To know **state-of-  
the-art** globally



To secure **competence**  
by coordinated training



VDCA is since last year a working group within SVEA

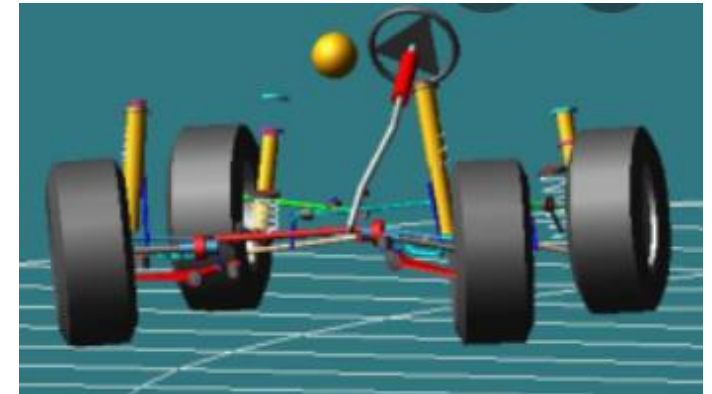
# SVEA - Swedish Vehicular Engineering Association

- SVEA, the Swedish Vehicular Engineering Association, is a society for people working in the Swedish Automotive industry and in the education and research within automotive engineering
- SVEA is a society that keeps itself updated about developments in the automotive industry and in research and informs its members and the public about any changes in e.g. technology and work processes
- SVEA arranges Seminars that can be of interest to its members. The purpose of the seminars is to present the current status and expected future solutions within selected technical areas
- SVEA is a member of FISITA, which gives us access to a world-wide organization for automotive engineers with a reach to over 200,000 engineers in 35 countries. FISITA provides a global platform for knowledge exchange between industry, societies and academia, helping to guide the future direction of the automotive mobility engineering profession
- SVEA has around 200 individual members and several corporative memberships. We are actively working to increase the membership numbers



# Why Vehicle Dynamics

- **Vehicle Dynamics is a vehicle attribute that is critical for the vehicle performance, e.g. passive safety and how the vehicle is perceived by the driver**
- **Vehicle Dynamics is affected by e.g. the suspension systems, the steering system, wheel and tyres, brakes and the propulsion system**
- **The Vehicle Dynamics is developed from the mechanical systems and nowadays also by control systems and active systems**
- **Ride comfort is another vehicle attribute that is related to Vehicle Dynamics. Ride Comfort and Vehicle Dynamics need to be balanced and therefore must the Vehicle Dynamics be at a high level to allow for good Ride Comfort**
- **Automated driving systems need to have good Vehicle Dynamics when the controls systems are developed**
- **Therefore is Vehicle Dynamics a key attribute when a vehicle is developed**



# Practical details and agenda today

## Practical details:

- The Seminar is a Hybrid meeting, i.e. in-real-life meeting and on-line meeting. This may create some difficulties that we need to resolve during the day
- On-line attendees should ask questions in the Comments, but if necessary you can also ask questions directly in the on-line meeting
- Every presentation is planned to take 20 minutes and there are 10 minutes for questions and discussion
- The Poster presentations are planned to take 3 minutes and questions and discussions are planned in breaks

## Agenda points:

- **09:40-09:50 Welcome and Introduction**
- **09:50-11:30 Session 1:** 3 presentations and 2 posters
- **11:30-12:30 Demo Tour AstaZero, presentation and bus tour**
- **12:30-13:30 Lunch, networking and poster discussions**
- **13:30-14:45 Session 2:** 2 presentations and 3 posters
- **14:45-15:15 Coffee, networking and poster discussion**
- **15:15-16:15 Session 3:** 1 presentation and 1 point about Vehicle Engineering Education
- **16:15-16:30 Wrap up**



# Agenda

| Start        | End          | No | What                                                                                                                          | Who                                                    | From                                |
|--------------|--------------|----|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------|
| 09:00        | 09:40        |    | Coffee and registration                                                                                                       |                                                        |                                     |
| 09:40        | 09:50        |    | Welcome                                                                                                                       | Ingemar Johansson<br>Bengt Jacobson<br>Håkan Andersson | SVEA<br>VDCA & Chalmers<br>AstaZero |
| <b>09:50</b> | <b>11:30</b> |    | <b>Session 1 Presentations (20+10 min each)</b>                                                                               |                                                        |                                     |
| 09:50        | 10:20        | 1  | Development of frame test rig with MBS simulations                                                                            | Joakim Eriksson                                        | Scania                              |
| 10:20        | 10:50        | 2  | Vehicle dynamics testing in a moving-base driving simulator                                                                   | Sogol Kharrazi                                         | VTI                                 |
| 10:50        | 11:20        | 3  | Cold Climate Testing: Why Arjeplog and Colmis in northern Sweden become a hub for the global automotive industry every winter | Per Gyllenberg<br>Benjamin Minshaw                     | Colmis                              |
|              |              |    | <b>Session 1 Posters (3 min each)</b>                                                                                         |                                                        |                                     |
| 11:20        | 11:23        |    | Quantify and mimic the feedback through the steering wheel at some driving conditions                                         | Aron Dalemo                                            | Polestar & Chalmers                 |
| 11:23        | 11:26        |    | Using torque vectoring to improve steering predictability while minimizing energy use in Heavy electric vehicles              | Jonas Persson<br>Jonathan Åkesson                      | Volvo Trucks & Chalmers             |
| 11:26        | 11:29        |    |                                                                                                                               |                                                        |                                     |
| <b>11:30</b> | <b>12:30</b> |    | <b>Demo Tour AstaZero test facility</b>                                                                                       |                                                        |                                     |
|              |              | 4  | AstaZero tracks. Short presentation                                                                                           | Håkan Andersson                                        | AstaZero                            |
|              |              |    | Bus tour test facility                                                                                                        |                                                        |                                     |
| <b>12:30</b> | <b>13:30</b> |    | <b>Light lunch with networking and poster discussion</b>                                                                      |                                                        |                                     |

# Agenda

|              |              |   |                                                                                                     |                                    |                                  |
|--------------|--------------|---|-----------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------|
| <b>13:30</b> | <b>14:45</b> |   | <b>Session 2: Presentations (20+10 min each)</b>                                                    |                                    |                                  |
| 13:30        | 14:00        | 5 | Suspension design as part of complete vehicle development                                           | Yansong Huang                      | VCC and Chalmers                 |
| 14:00        | 14:30        | 6 | Tyre rolling resistance at various operational conditions and limitations in current tyre labelling | Jukka Hyttinen                     | Scania and KTH                   |
|              |              |   | <b>Session 2 Posters (3 min each)</b>                                                               |                                    |                                  |
| 14:30        | 14:33        |   | Continuously controlled damping tuning on four poster rig                                           | Jesper Ramsberg                    | VCC & Chalmers                   |
| 14:33        | 14:36        |   | Optimised force distribution algorithm and model                                                    | Guglielmo Nappi<br>Sanjay Banerjee | Scania & KTH                     |
| 14:36        | 14:39        |   | Modelling and measurements of singularity-induced vehicle motion during low-speed driving           | Luca Mereu                         | Politecnico di Torino & Chalmers |
| <b>14:45</b> | <b>15:15</b> |   | <b>Coffee with networking and poster discussion</b>                                                 |                                    |                                  |
| <b>15:15</b> | <b>16:15</b> |   | <b>Session 3: Presentations (20+10 min each)</b>                                                    |                                    |                                  |
| 15:15        | 15:45        | 7 | Tyres and the purposes of models                                                                    | Edo Drenth<br>Niklas Fröjd         | Volvo Trucks                     |
| 15:45        | 16:15        | 8 | Swedish vehicle engineering education                                                               |                                    |                                  |
|              |              |   | KTH, Vehicle engineering                                                                            | Mikael Nybacka                     | KTH                              |
|              |              |   | Chalmers, Mobility engineering                                                                      | Dag Henrik Bergsjö                 | Chalmers                         |
|              |              |   | Discussion                                                                                          |                                    |                                  |
| <b>16:15</b> | <b>16:30</b> |   | <b>Wrap-up</b>                                                                                      |                                    |                                  |
|              |              |   | Feedback on this seminar                                                                            | Ingemar, all                       |                                  |
|              |              |   | Proposals for next year                                                                             | Ingemar, all                       |                                  |
|              |              |   | Discussion on smaller events beside annual seminar ("workshops")                                    | Ingemar, all                       |                                  |

Presentation 1:  
***Development of frame test rig with MBS  
simulations***

Joakim Eriksson, Scania





JOAKIM ERIKSSON, SCANIA

# Development of new frame test rig with MBS simulations



**SCANIA**





# Agenda

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Introduction

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Background

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Simulations contribution

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Timeline

---

Result

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Summary



# Introduction

---

Name: Joakim Eriksson

---

Working experience: 10 years at Scania

---

Position: Calculation engineer at truck chassis department

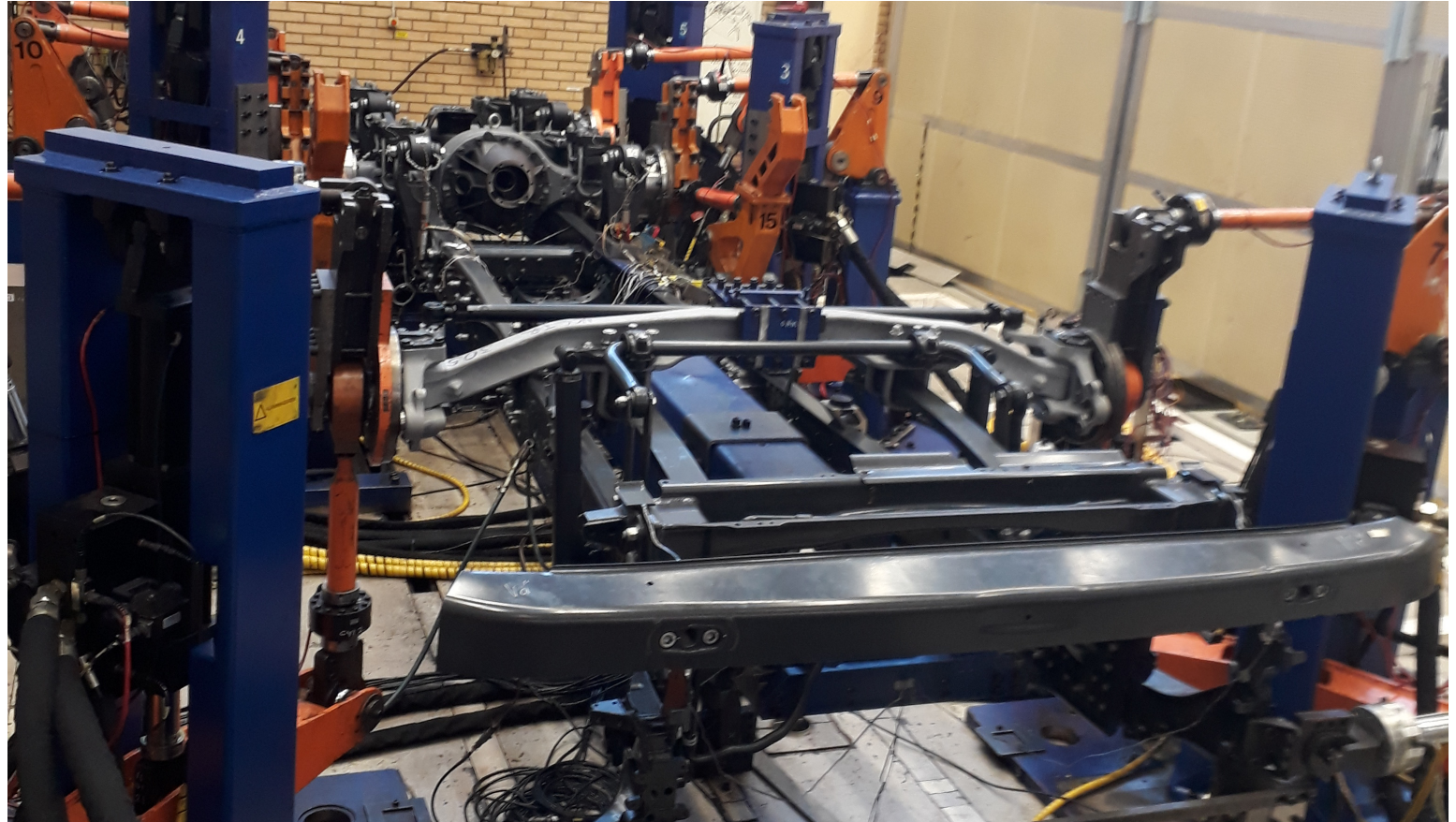
---

Background: Engineering Physics at Umeå University



# Background

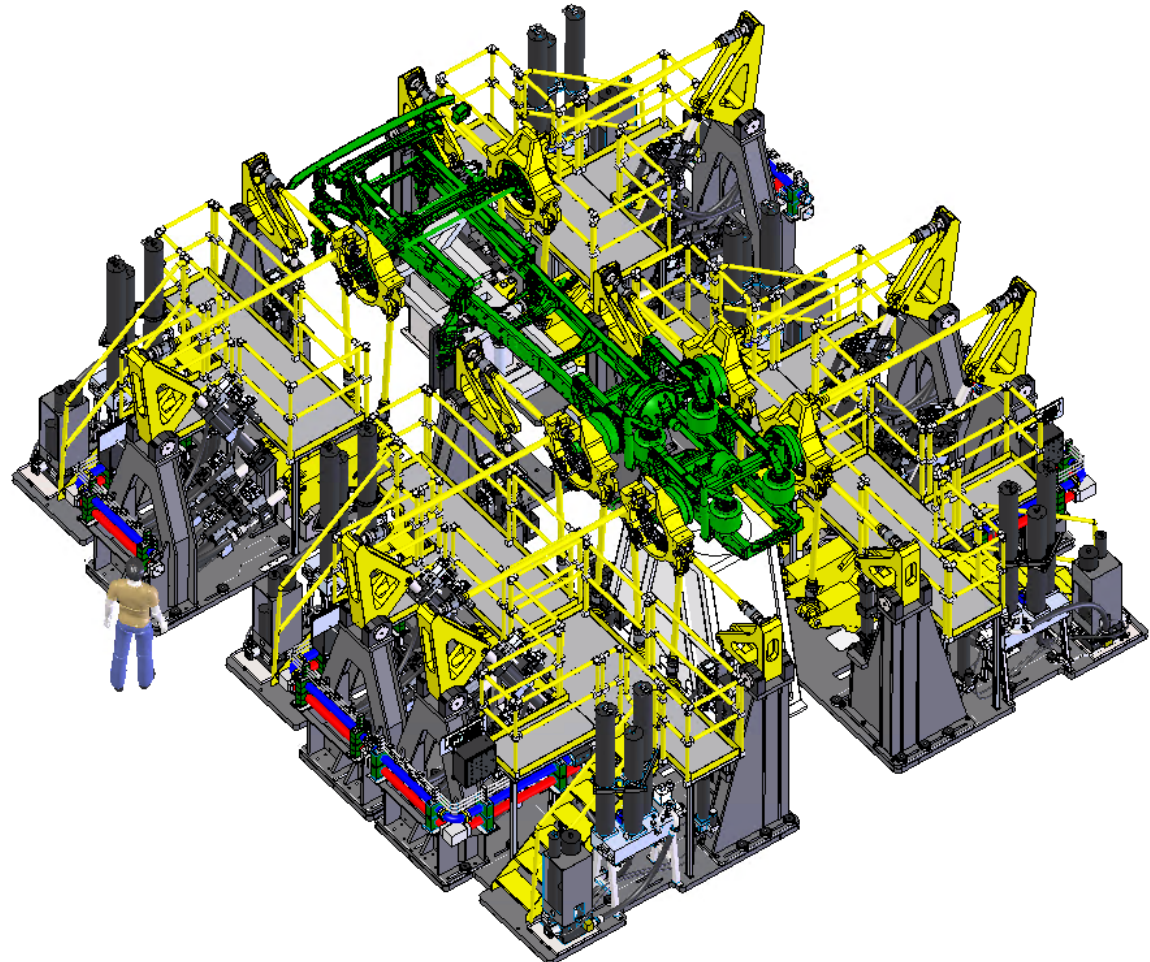
- Existing frame rig was old
- Boundary conditions
- Improved capacity & speed
- More drive channels
- Input channels specific for BEV components



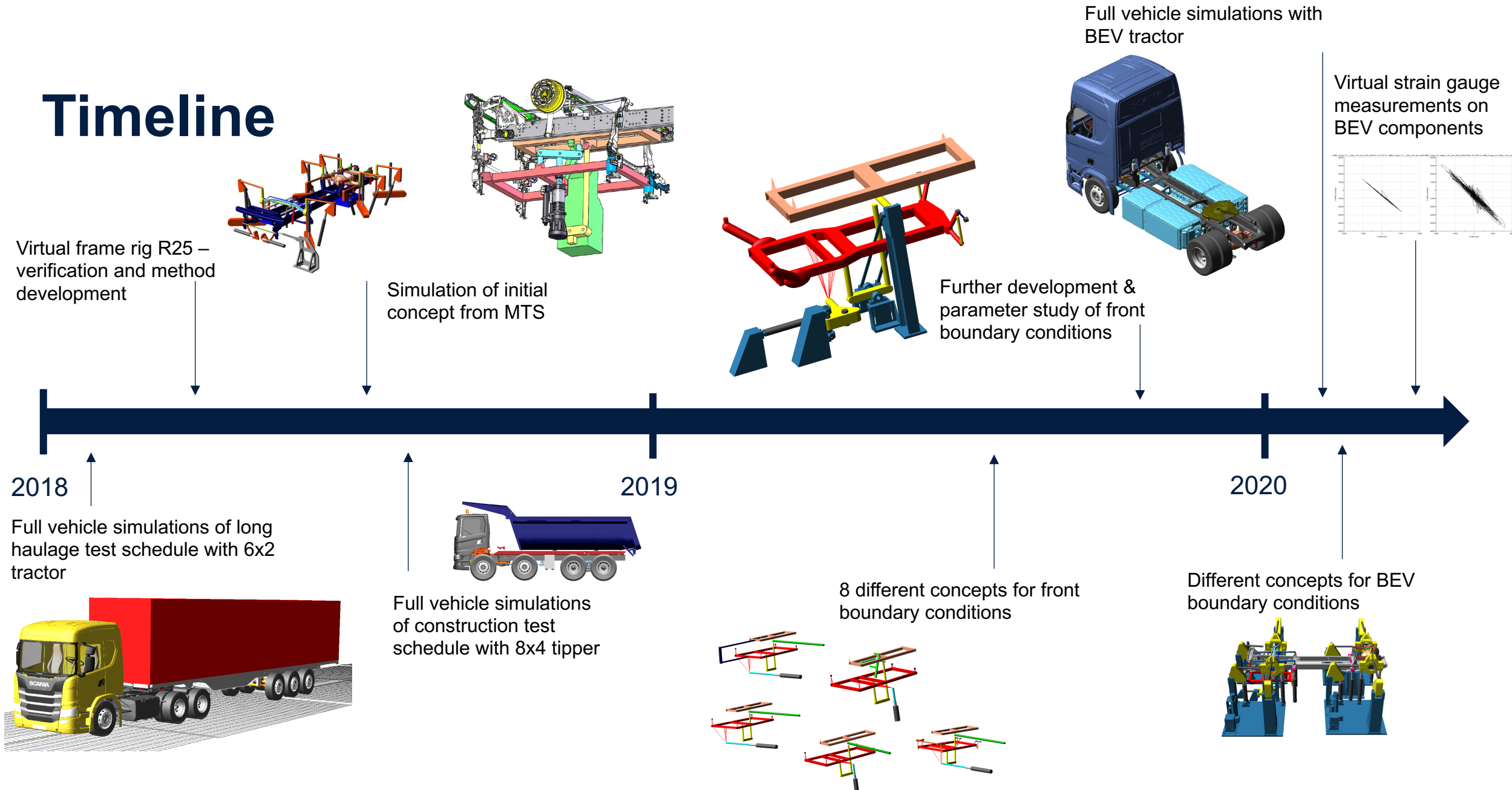


# MBS contribution to frame rig development

- Obtain loads from full vehicle simulations
- Evaluate and rank different concepts for boundary conditions
- Loads & durability of rig components
- Dimensioning of struts & cylinders
- Geometry assurance
- Strategies for obtaining drive signals & editing test track measurements

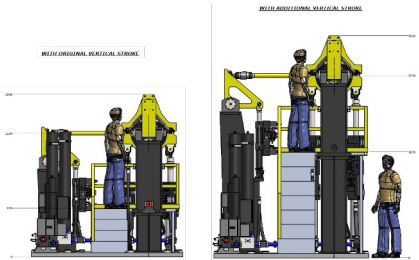
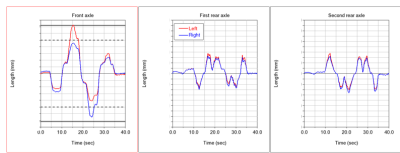


# Timeline

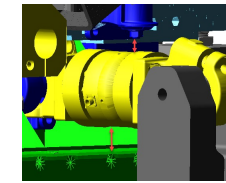
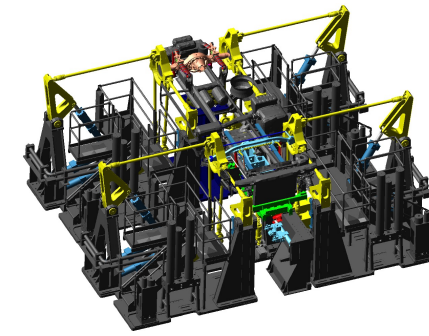
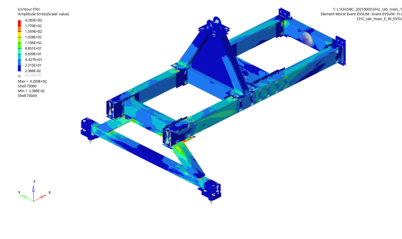


# Timeline

Investigation of increased motion and force demands for construction obstacles



Validation of the boundary conditions together with rig design



Clearance calculations

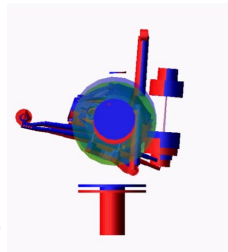
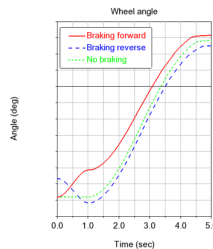
First simulation with measured BEV signals in CH2 ahead of first physical test

2020

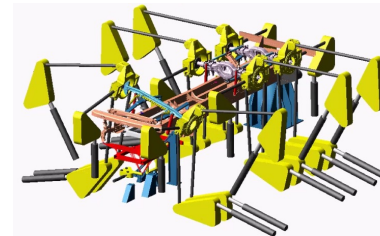
2021

2022

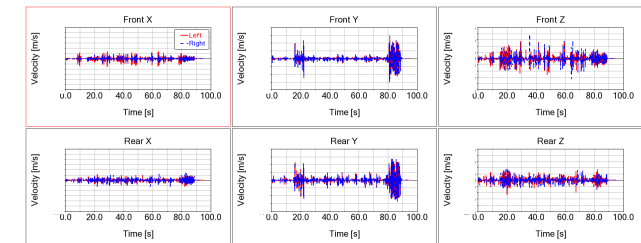
Wheel angle requirements investigation



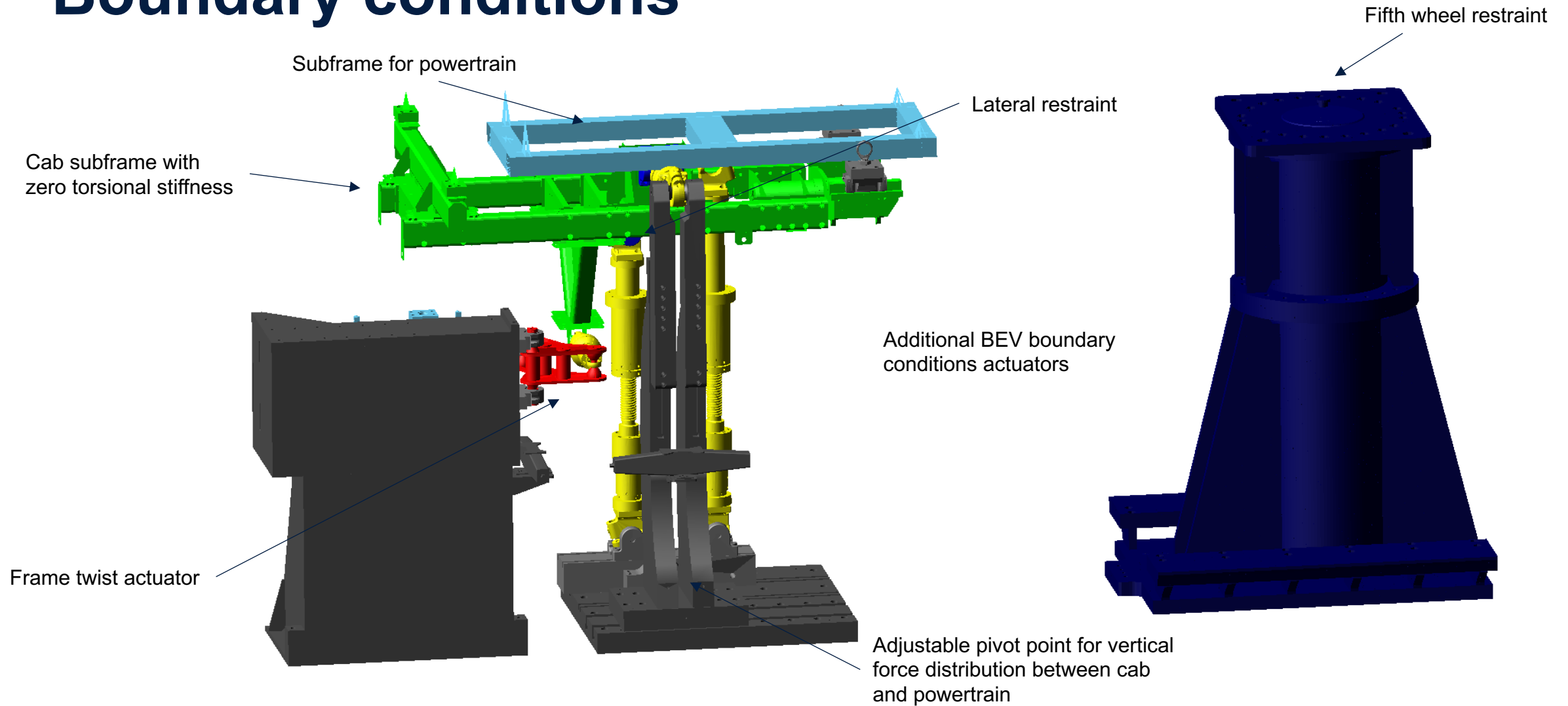
Validation of new corner module concept with increased displacement capabilities



Optimisation of target signal for the physical test



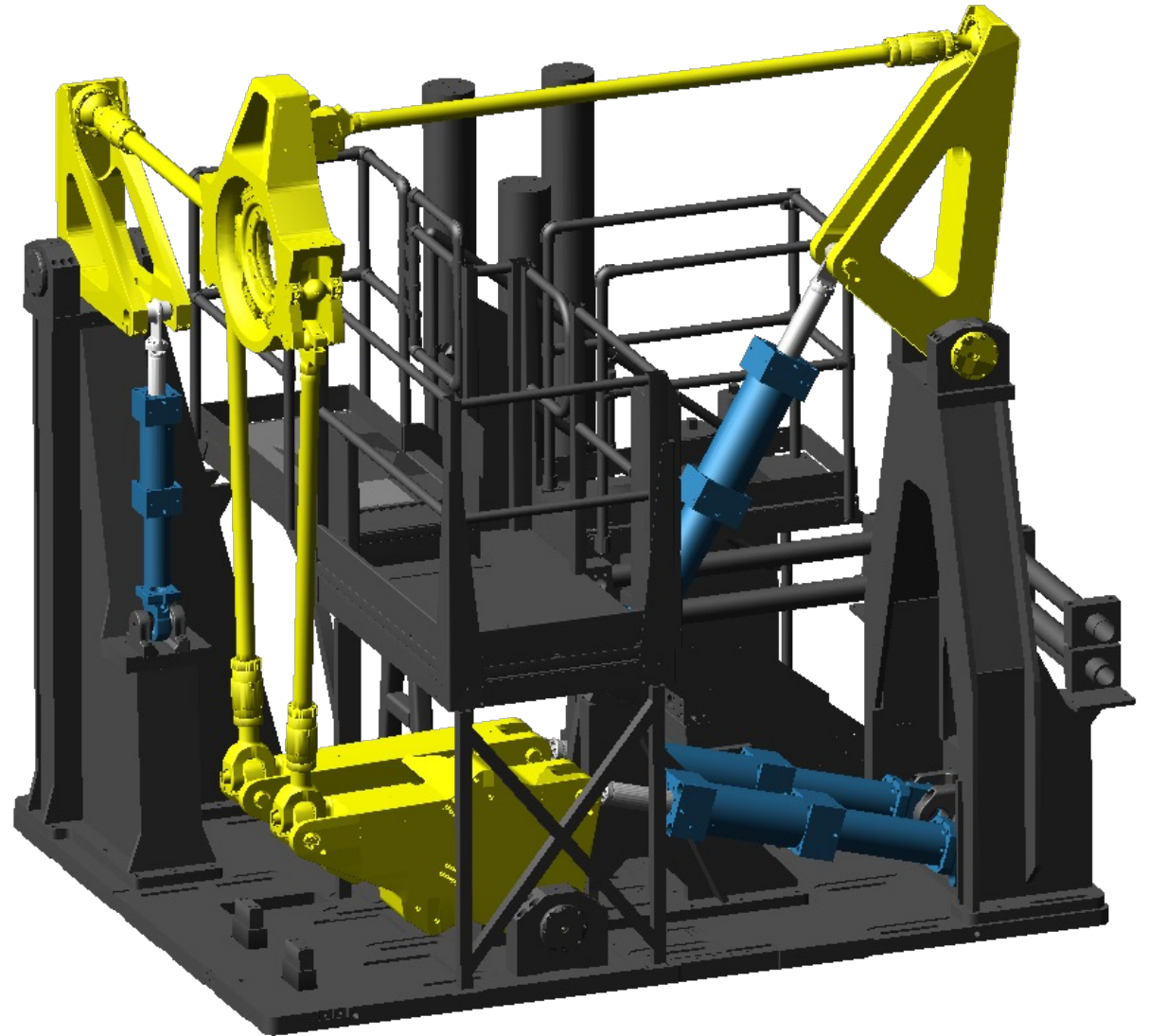
# Boundary conditions





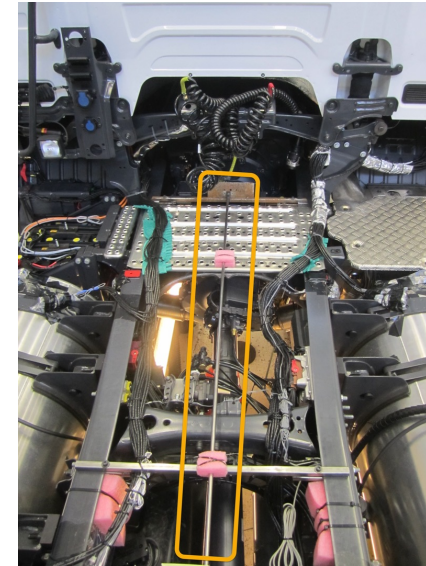
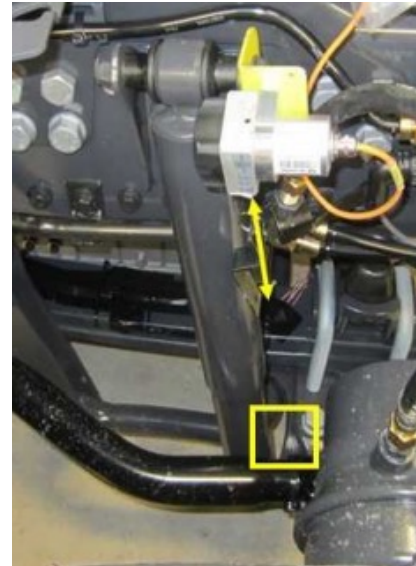
# Corner module

- Four cylinders
- Four degrees of freedom
  - Vertical
  - Lateral
  - Longitudinal
  - Brake torque
- Attaches to the hub
- Available for three axles



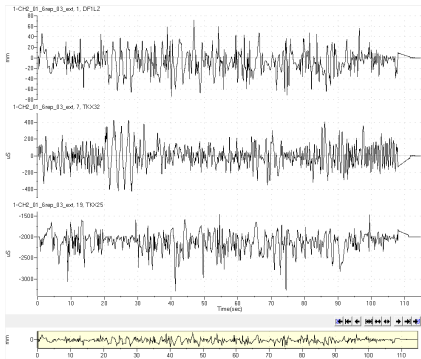
# Required measurement channels for controlling the rig

- Wheel force transducers
  - Longitudinal and lateral wheel actuators
  - Braking torque
- Distance axle – frame
  - Vertical wheel actuators (leaf suspension)
- Air spring force (calibrated strain gauges)
  - Vertical wheel actuators (air suspension)
- Frame twist angle
  - Twist input actuator
- Bending strain gauge on rod
  - BEV boundary condition actuators



# Rig control method

Test vehicle



Measured data

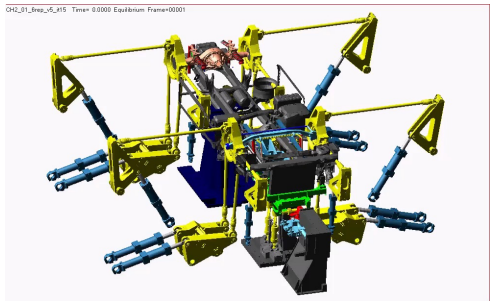
Iterate  
How?  
until



Desired



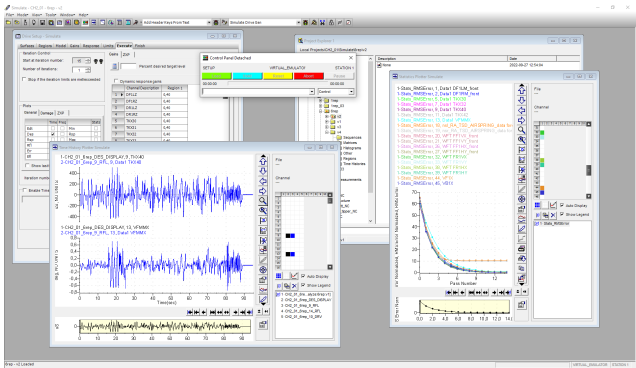
Virtual model



Response



Drive



RPC Pro



# Summary



The rig is now operational



Large increase in test speed



Ability to test BEV vehicles



The rig design will be able to handle any obstacle we have at Scania test track



**SCANIA**





**Joakim Eriksson**

**Calculation Engineer | Truck Chassis Development | Scania CV AB**

Phone: +46 8 553 701 89 Mobile: +46 70 08 781 13

Scania CV AB, By118, 151 87 Södertälje, Sweden

[joakim.y.eriksson@scania.com](mailto:joakim.y.eriksson@scania.com)

**SCANIA**

Presentation 2:

***Vehicle dynamics testing in a moving-base  
driving simulator***

Sogol Kharrazi, VTI

# Vehicle Dynamics testing in a moving-based driving simulator

*Sogol Kharrazi*

SVEA Vehicle Dynamics Seminar, 2023

**vti**

# Short information about me



Senior researcher

VTI, Vehicle systems and driving simulation unit

Adjunct associate professor

Linköping University, Vehicular systems division

I got my PhD from Chalmers in 2012.

# Introduction

Driving simulators are used in a broad spectrum of applications. However, using driving simulators as a tool for vehicle dynamics testing has not been so common.

Driving simulators can be a valuable addition to the tool chain for vehicle dynamics development.

- Flexible: vehicle design, driving scenario and surroundings can be changed
- Repeatable
- Safe
- Immediate changes possible: a fresher recollection of previous experiences





# VTI moving-base driving simulators



SIM III, Linköping



SIM IV, Gothenburg

# Vehicle dynamics in Sim IV

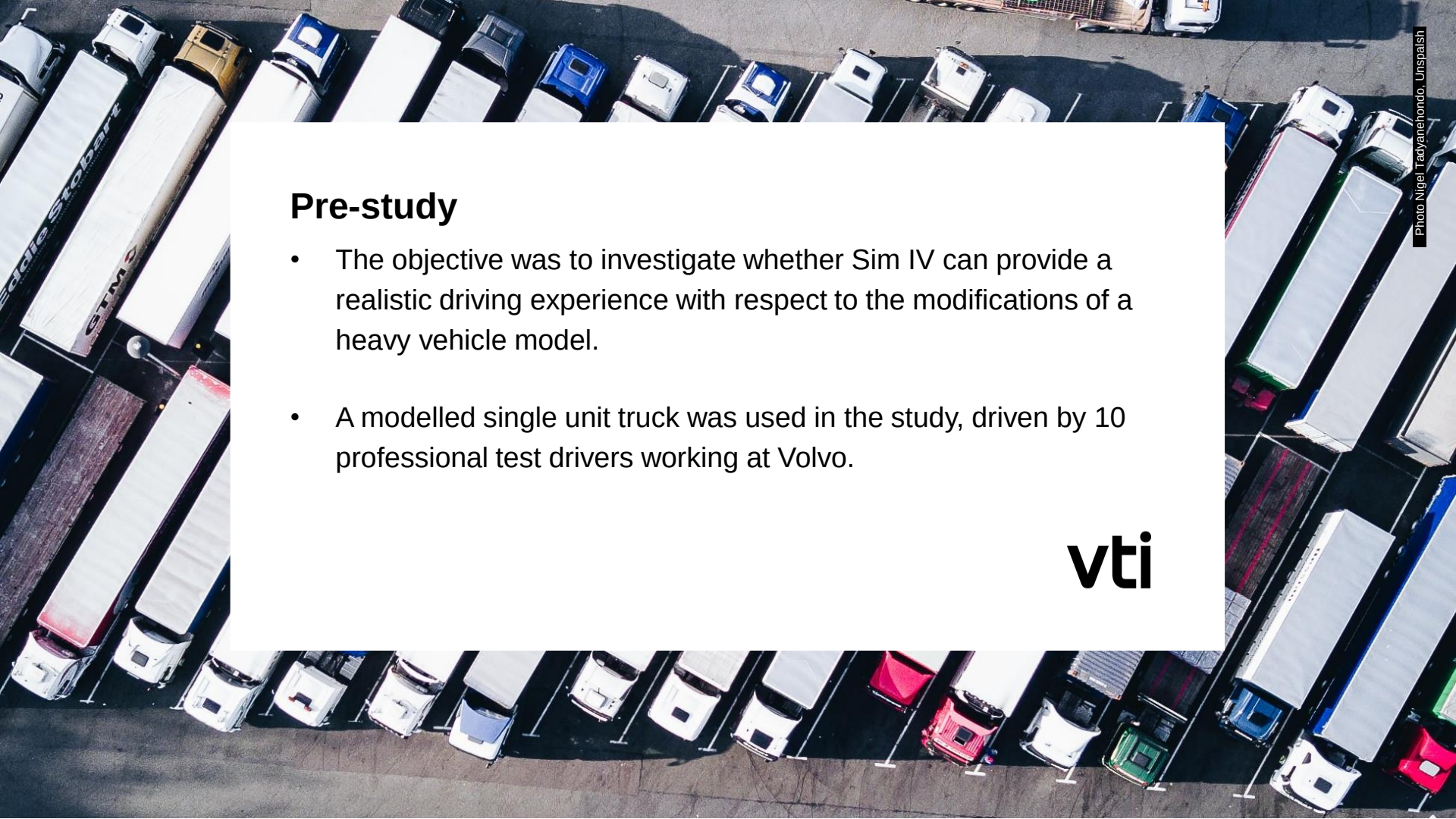
Sim IV has been used to assess and compare the dynamics of different heavy vehicles.

More specifically, to compare driver's perception of performance of High Capacity Transport (HCT) vehicles vs. conventional vehicle combinations.

First step was to tune the motion cueing algorithm for lateral dynamics assessment of heavy vehicles.

Tuning was performed subjectively, with help from a small group of professional test truck drivers





## Pre-study

- The objective was to investigate whether Sim IV can provide a realistic driving experience with respect to the modifications of a heavy vehicle model.
- A modelled single unit truck was used in the study, driven by 10 professional test drivers working at Volvo.

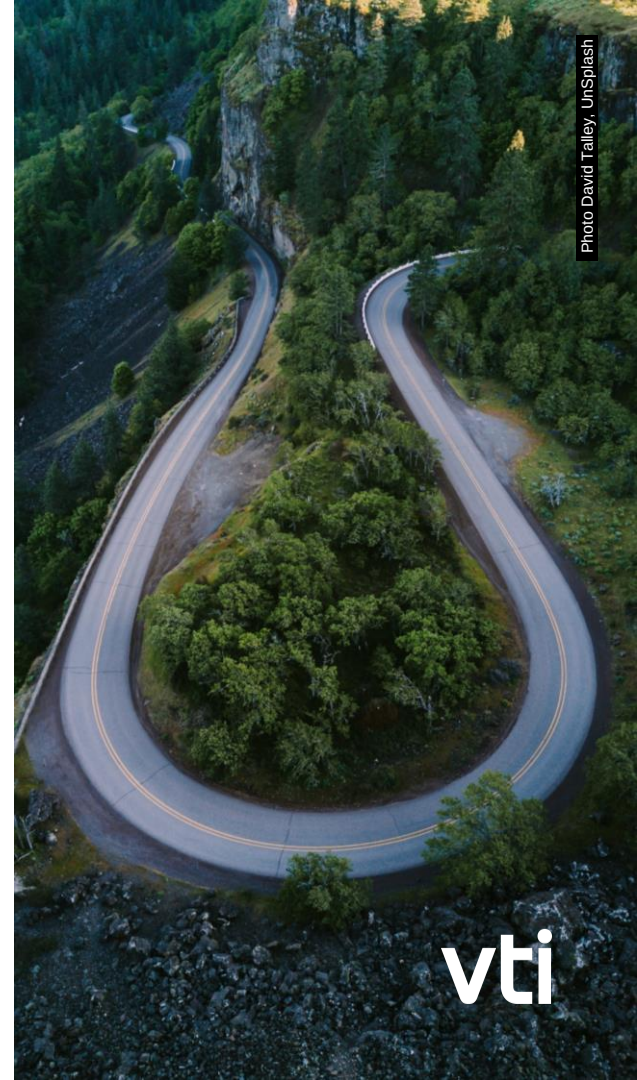
**vti**



# Pre-study

The drivers drove and compared the baseline truck with 4 modified versions of it with different parameter sets.

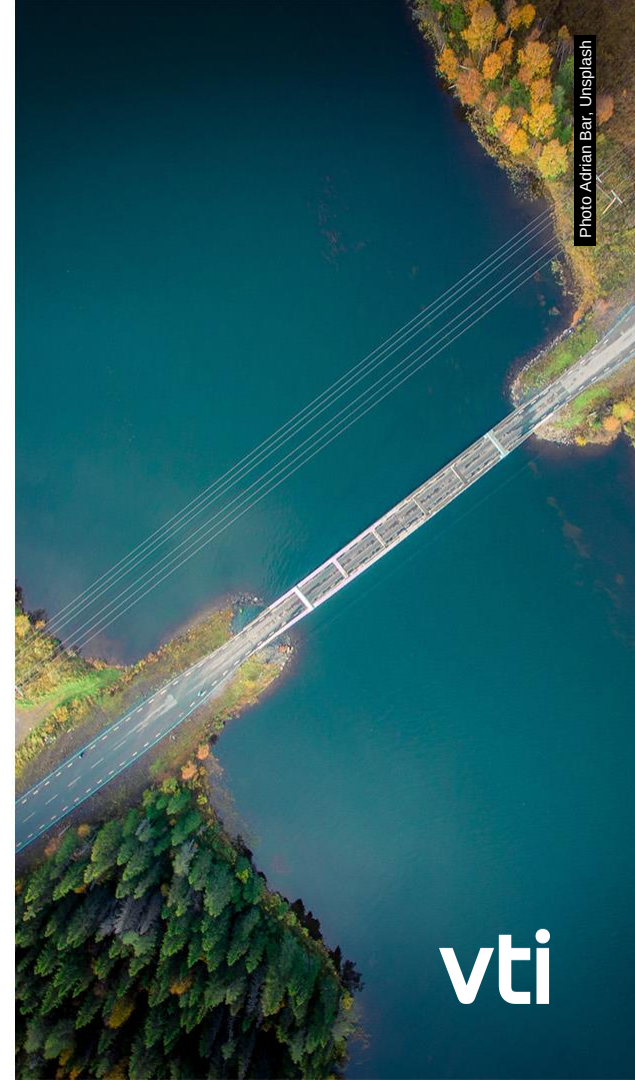
- **Parameter set 1:** Increased roll stiffness: a 100 % and 50% increase of the roll stiffness of the rear and front axles of the truck
- **Parameter set 2:** Decreased roll stiffness: a 40% decrease on the rear axles roll stiffness
- **Parameter set 3:** Softer rear tires: a 25% decrease on the cornering stiffness of the tires at rear axles
- **Parameter set 4:** Increased roll understeer: a roll steer coefficient of -0.45 is considered to model roll understeering, in contrast to a zero roll-steer coefficient for the baseline vehicle



# Results of the pre-study

The drivers' deduction of the applied changes on the truck were categorized as **correct**, **quite correct**, or **incorrect**

- For parameter set 3 (softer rear tires), 75% of the drivers guessed the parameter change completely **correct** while the remaining drivers also had a **quite correct** deduction.
- The results for the other three parameter sets were also very promising.
- There were **only 2 incorrect** answers, out of a total of 32





# Main simulator study

55 truck drivers participated in the study, and each driver drove a pair of vehicles, a conventional heavy vehicle and an HCT vehicle, in SIM IV.

|   | Heavy Vehicle Combination                            |                                                                                    |           |
|---|------------------------------------------------------|------------------------------------------------------------------------------------|-----------|
| 1 | Tractor-Semitrailer                                  |  | 40T/16.5m |
| 2 | Tractor-Semitrailer-Dolly-Semitrailer (Adouble)      |  | 80T/30m   |
| 3 | Truck-Centre Axle Trailer                            |  | 40T/19m   |
| 4 | Truck-Centre Axle Trailer-Centre Axle Trailer        |  | 74T/28m   |
| 5 | Truck-Dolly-Semitrailer (Nordic)                     |  | 64T/25m   |
| 6 | Truck-Dolly-Link Trailer-Semitrailer (Truck-Bdouble) |  | 83T/32m   |

# Main simulator study

After each drive, the drivers were asked to rate different aspects of the vehicle performance, in a 7-grade scale, with questions such as:

- How easy it is to keep the vehicle on the desired path on the curvy roads
- How they perceive the roll stability of the vehicle on the curvy roads
- How they perceive the trailers, stable or oscillatory, during overtaking and lane changes.
- How easy it is to control the vehicle.

There was also one concluding question, asking the drivers to compare the controllability of the two vehicles they drove.

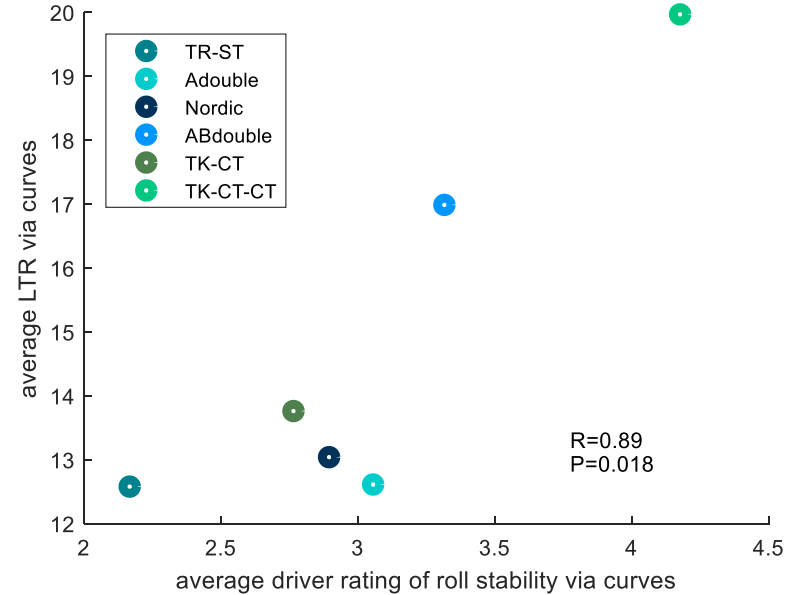
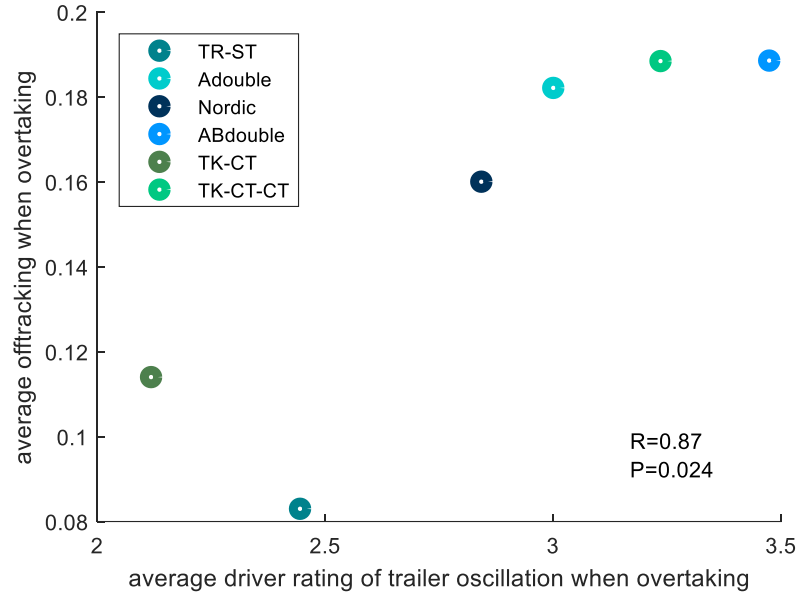


# Results, driving experience

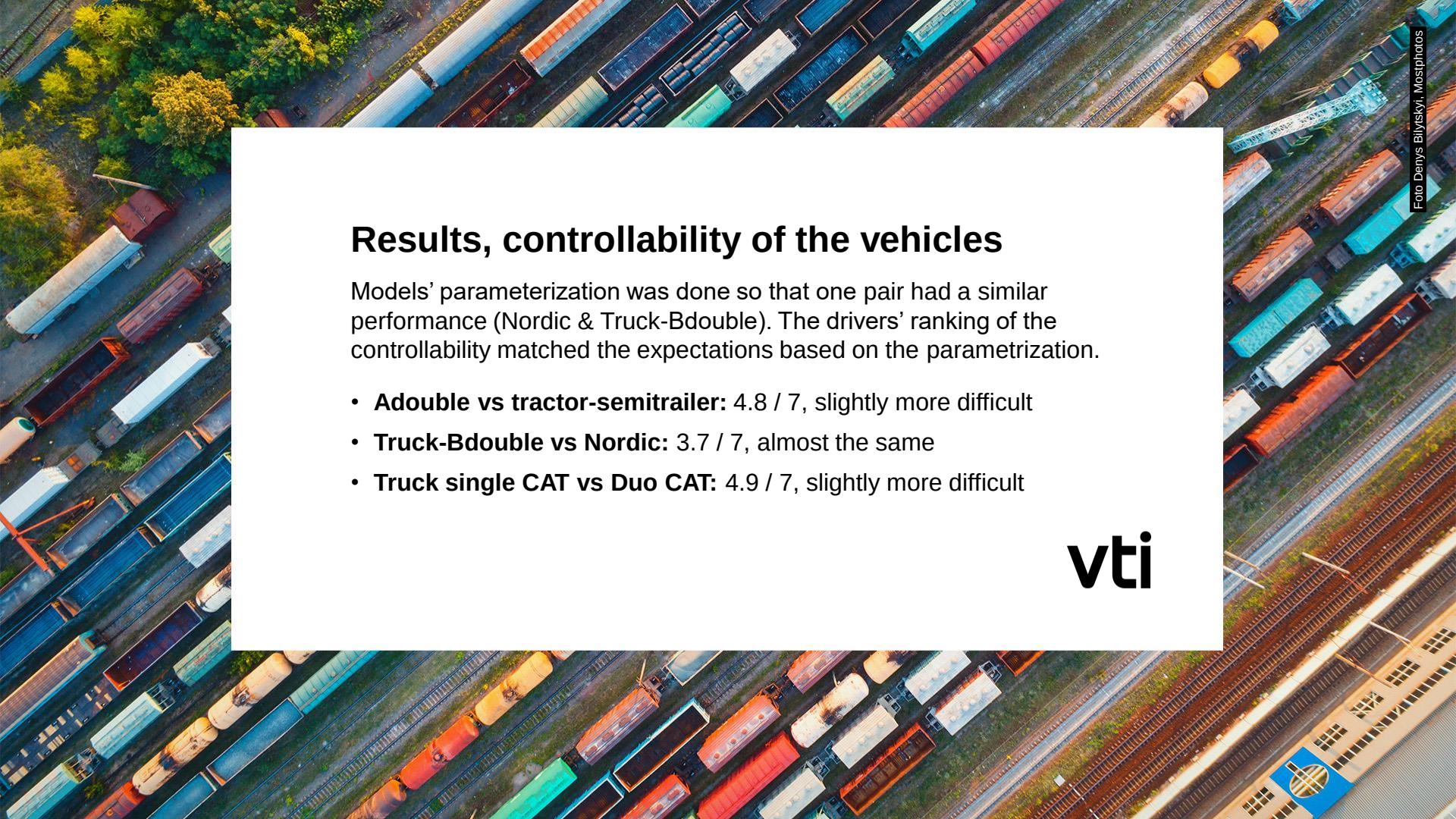
Average ranking of the total driving experience realism was 5.2 out of 7.

|                  | Average rating (?/ 7) | Standard deviation |
|------------------|-----------------------|--------------------|
| Roads            | 5.0                   | 1.23               |
| Surrounding      | 4.6                   | 1.35               |
| Braking          | 4.7                   | 1.44               |
| Accelerations    | 4.8                   | 1.44               |
| Sound            | 4.7                   | 1.55               |
| Suspensions      | 4.8                   | 1.52               |
| Cabin vibrations | 4.9                   | 1.37               |
| Steering feel    | 4.7                   | 1.56               |
| Manoeuvrability  | 4.7                   | 1.33               |
| Speed perception | 4.7                   | 1.55               |

# Results, subjective vs objective evaluation





An aerial photograph of a large railway yard filled with numerous freight trains. The trains consist of various colored railcars, including blue, red, orange, and white. They are parked on multiple tracks that run parallel to each other. In the bottom right corner, a building with a blue and white logo is visible. The overall scene is a busy industrial area for rail transport.

## Results, controllability of the vehicles

Models' parameterization was done so that one pair had a similar performance (Nordic & Truck-Bdouble). The drivers' ranking of the controllability matched the expectations based on the parametrization.

- **Adouble vs tractor-semitrailer:** 4.8 / 7, slightly more difficult
- **Truck-Bdouble vs Nordic:** 3.7 / 7, almost the same
- **Truck single CAT vs Duo CAT:** 4.9 / 7, slightly more difficult

**vti**



# Conclusions

- The tested simulator has the capability of providing satisfactory feedback to the drivers so that they could correctly deduce the vehicle changes and perceive the differences in performance of various vehicles.
- There was a strong correlation between drivers' perceived performance of the vehicles and the objective performance measures.
- Moving base driving simulators can benefit the field of vehicle dynamics testing, not as a replacement but rather a complementing tool in the existing test chain.



An aerial photograph of a city street, likely in Stockholm, Sweden, showing a mix of historic and modern architecture, a river, and a bridge. The image is used as a background for the slide.

## For more information refer to the following publications

- S. Kharrazi, B. Augusto and N. Fröjd, "Vehicle dynamics testing in motion based driving simulators," Vehicle System Dynamics, 2019.
- S. Kharrazi, B. Augusto and N. Fröjd, "Assessing dynamics of heavy vehicles in a driving simulator," Journal of Transportation Research Part F: Traffic Psychology and Behaviour, vol. 65, pp. 306-315, 2019.
- B. Augusto, S. Kharrazi and N. Fröjd, "Vehicle Dynamics Testing in Driving Simulators - A Case Study for Heavy Vehicles," ViP Publication, report 2017-3, 2019.
- S. Kharrazi, F. Bruzelius and U. Sandberg, "Performance based standards for high capacity transports in Sweden-FIFFI project 2013-03881-Final report," VTI, report 948A, 2017.

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# Future plans

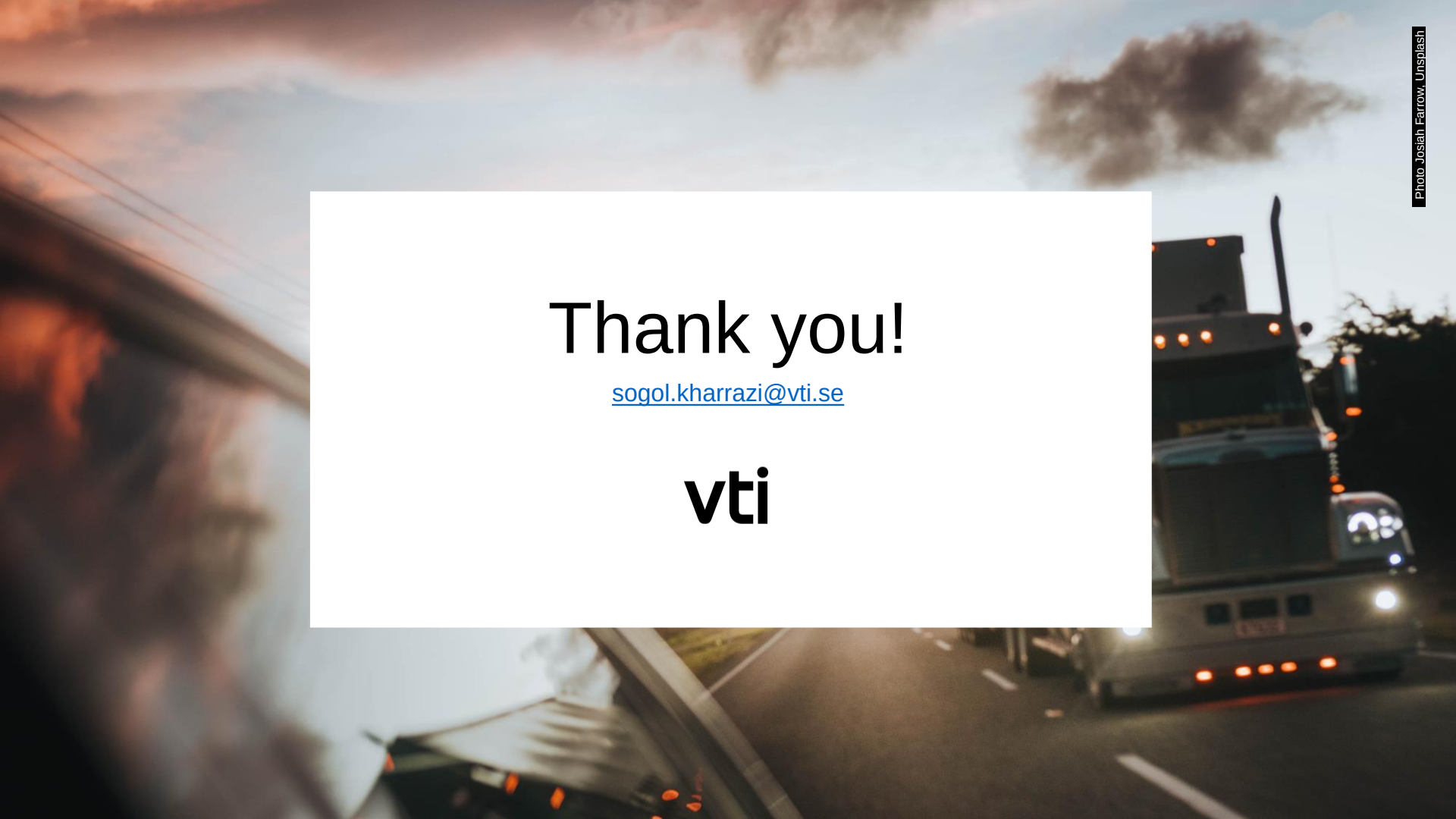
Driveability assessment in Sim III

PREDICTing and evaluating  
driveability and performance  
of zero emission heavy duty  
vehicles

Scania, VTI, LiU, KTH





A semi-truck is driving on a highway at dusk. The sky is a mix of orange, pink, and blue. The truck is white with orange lights. A white text box is overlaid in the center of the image.

# Thank you!

[sogol.kharrazi@vti.se](mailto:sogol.kharrazi@vti.se)

**vti**

## Presentation 3:

***Cold Climate Testing: Why Arjeplog and Colmis in northern Sweden become a hub for the global automotive industry every winter***

Per Gyllenberg and Benjamin Minshaw, Colmis



# About the presenters

## Per Gyllenberg



Deputy Manager @ Colmis

Worked in a variety of roles at the company until becoming the Deputy Manager (2018)

Bachelor Degree in Economics (BSc)

## Benjamin Minshaw



Marketing Manager @ Colmis

Worked in a variety of roles at the company until becoming the Marketing Manager (2019)

Master in Business Administration (MBA)

# **COLMIS**

## **Vehicle Dynamics Seminar 2023**

AstaZero & Online - May 24<sup>th</sup>, 2023



66°03'06"N 18°01'12"E

# COLMIS

The home of  
Winter Testing.

# Agenda

This is Colmis  
Why Arjeplog  
Why Colmis  
Q&A Session



The background is a solid dark blue. It features several light blue geometric elements: a large circle on the left, a smaller circle on the right, and vertical lines extending from the top of these circles. The text 'This is Colmis.' is centered in white.

# This is Colmis.



An aerial photograph of a vast, flat, snow-covered landscape, likely a frozen body of water or a large open field. The terrain is marked with numerous winding, light-colored tracks or roads that snake across the white surface. Several small, dark, forested islands or peninsulas are scattered throughout the scene. In the lower right, a denser area of trees and shrubs is visible, partially covered in snow. The overall scene conveys a sense of isolation and a controlled environment for testing.

An open and independent  
winter proving ground that serves  
the global automotive industry.





Our story.







1985

First electric split-mu track.

1997

ISO certifications.

2009

Rajd & Safety.

2016

New Dynamic Area.

Colmis Proving Ground is established.

1987

SIMLOC Hotel

2007

Open Proving Ground.

2013

ColmisPlus & Driver Training.

2022



An aerial photograph of a vast, calm blue body of water. In the center, there is a small, dark boat. The water's surface is marked by subtle ripples and a few small, dark patches of vegetation or land. The overall tone is a deep, serene blue.

# Our purpose.



Everything you need,  
in one place.  
So that you can  
focus on the testing.



# Our way.





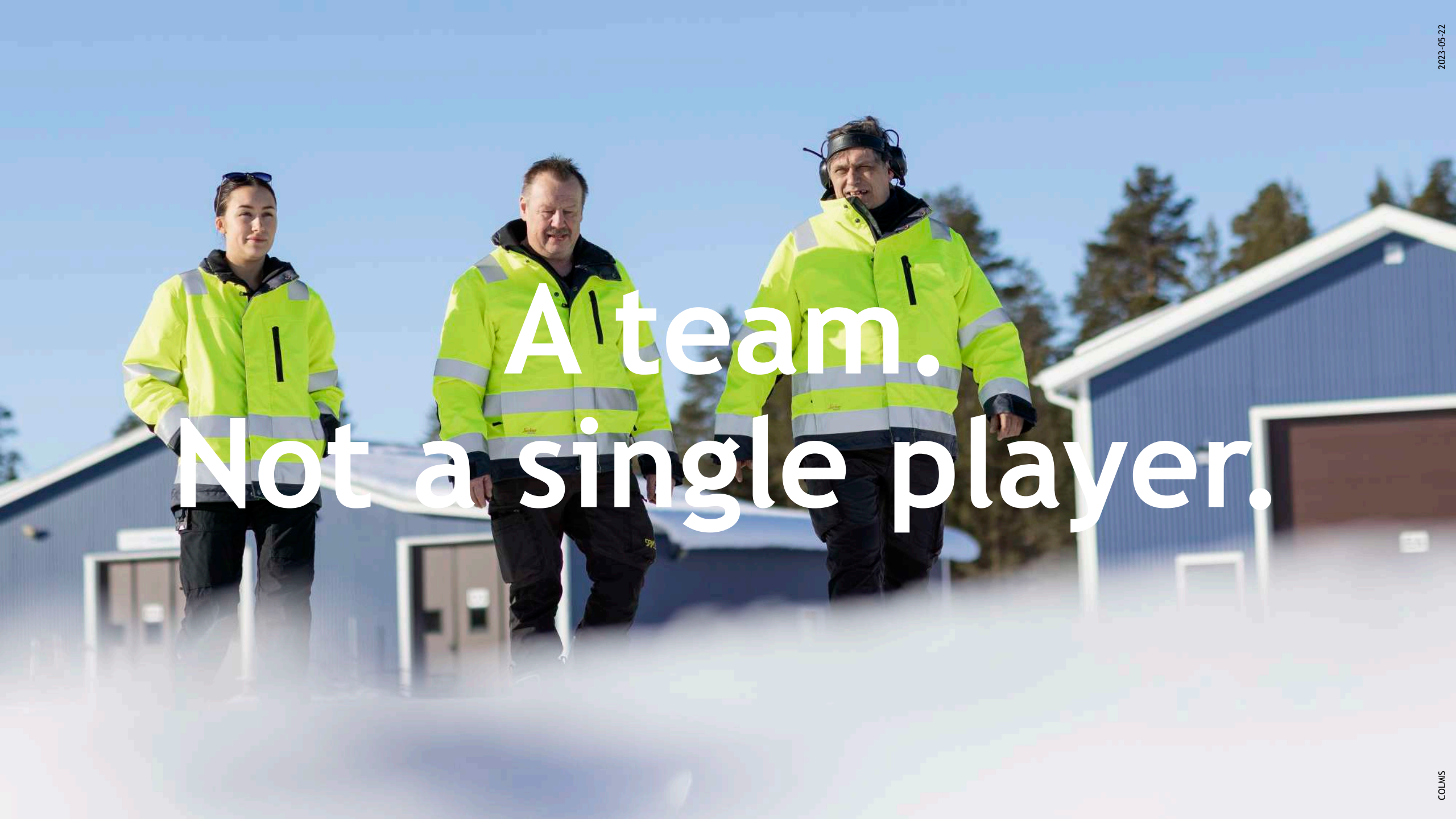
Not a customer,  
a partner.



A customised  
cold test solution.

Your success is our  
success.



A photograph of three construction workers walking towards the camera on a snowy surface. They are wearing bright yellow high-visibility jackets with reflective silver stripes and dark work pants. The worker on the right is also wearing a black headset. In the background, there is a blue building with white trim and some evergreen trees under a clear blue sky. The text "A team. Not a single player." is overlaid in large white font across the center of the image.

A team.  
Not a single player.

*Together we are  
Colmis.*





*"If you are looking for a reliable supplier Colmis is the one to choose."*

Contract customer -23

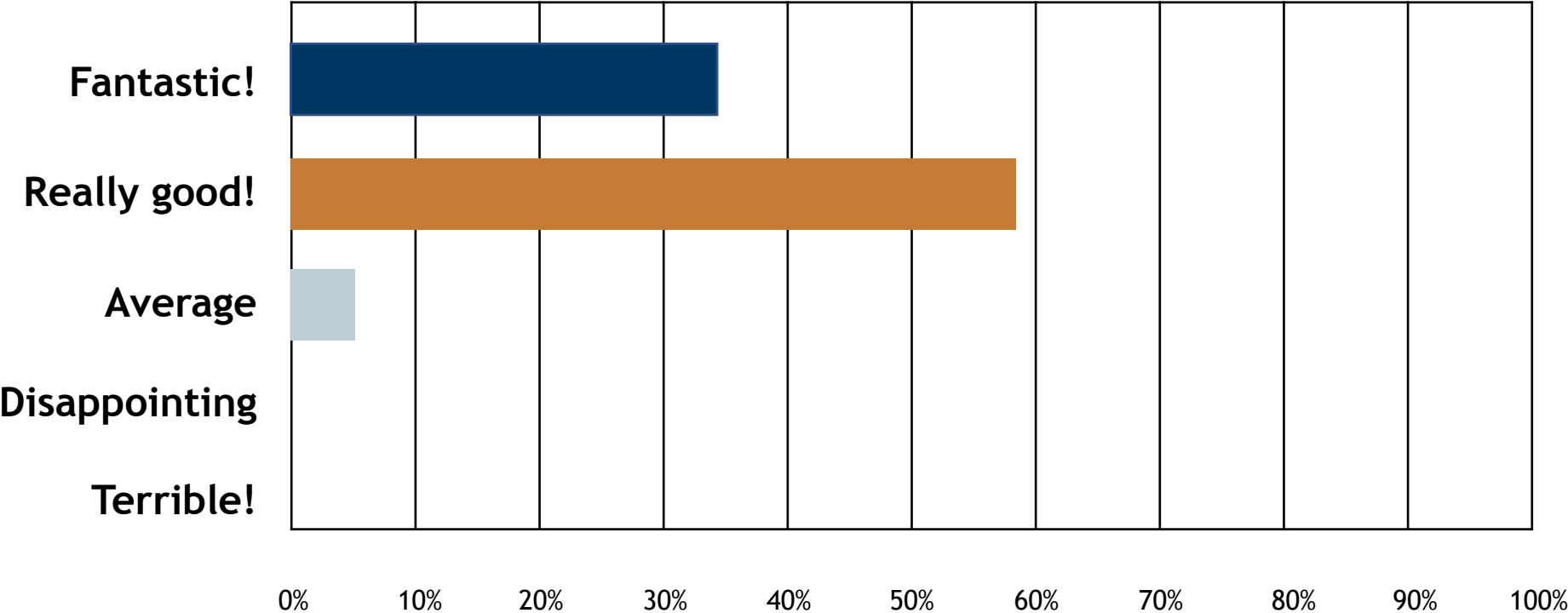
*"Colmis has a relaxed atmosphere, they don't panic, they're friendly and professional. You can have a nice chat with them but you can also have a technical discussion and talk about some problems and they will solve it."*

Spot customer -22

**Source: Independent Consultancy Audit**



How would you rate your overall satisfaction with your stay at Colmis this season (comparing it to previous years, if applicable)?



Source: Customer Survey Season 2022/2023



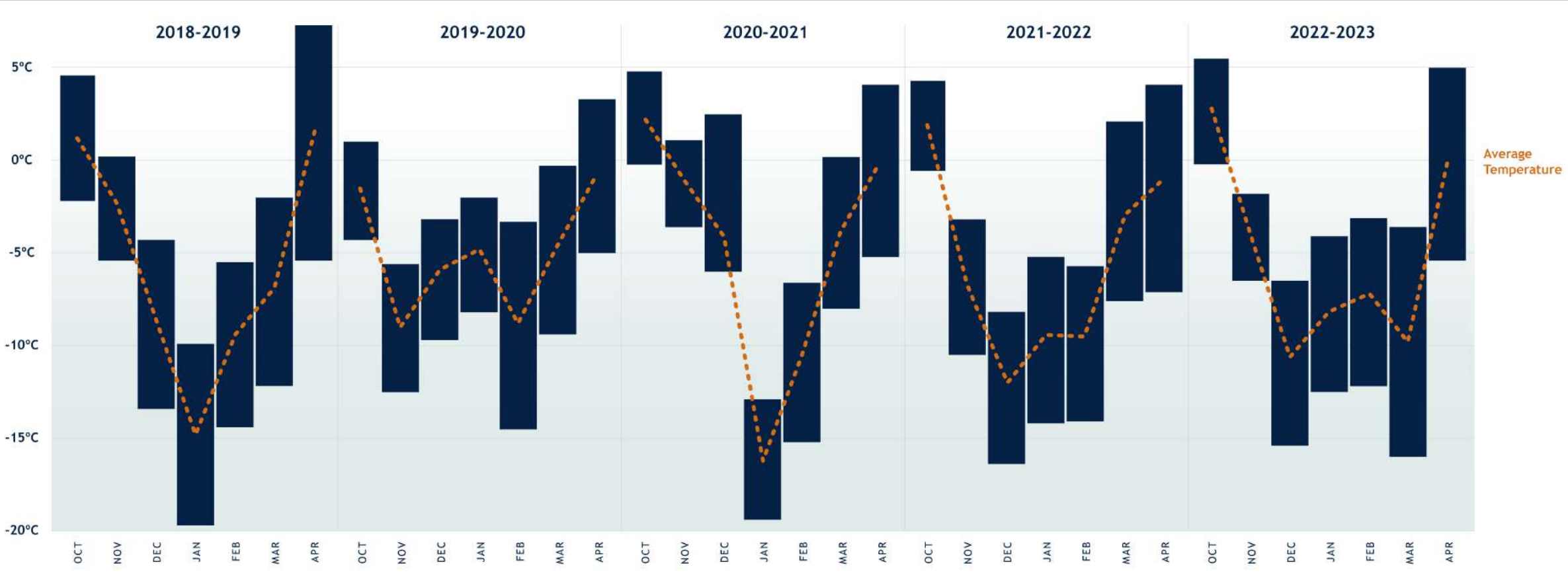
# Why Arjeplog.



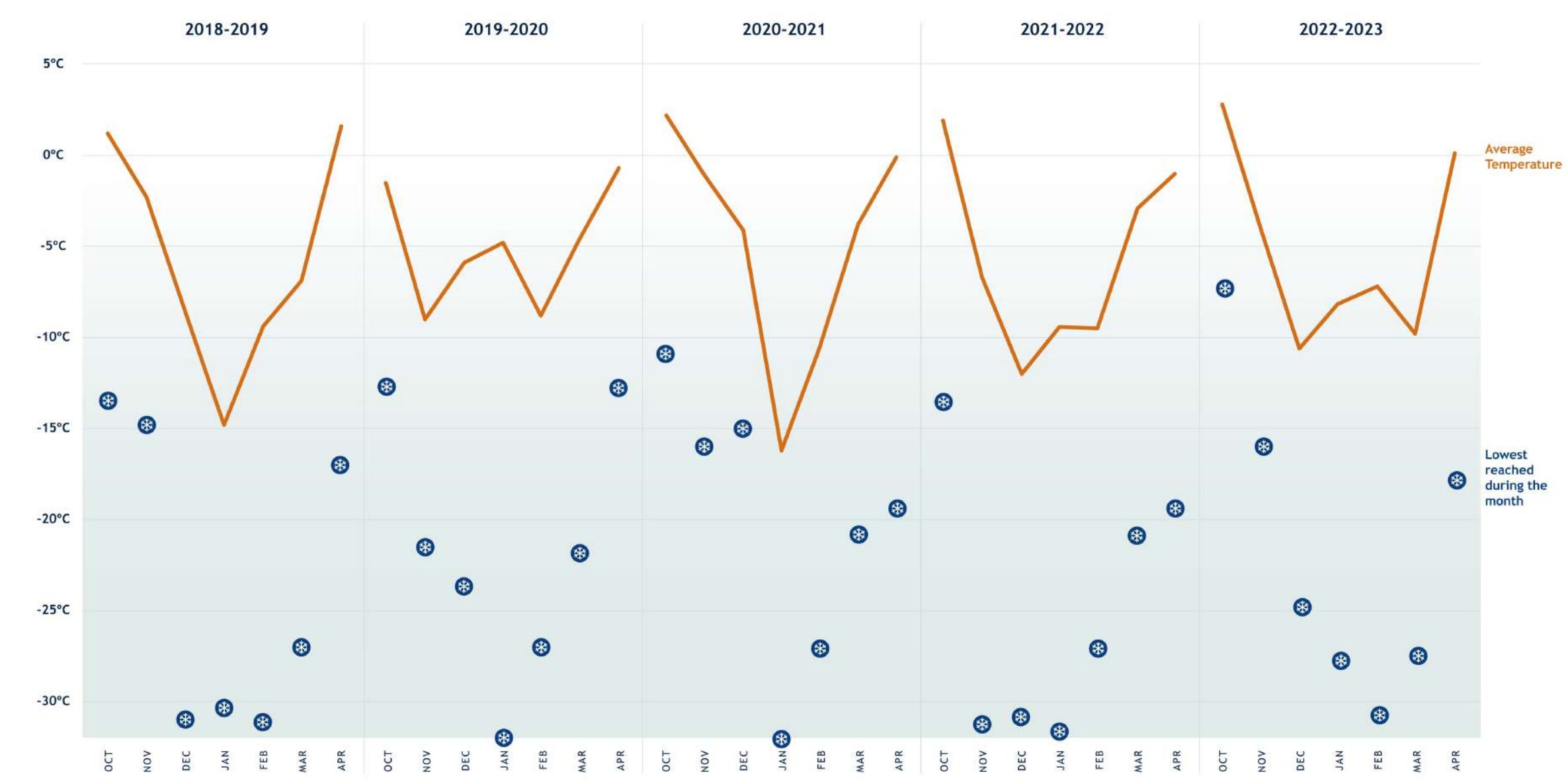
Location.



Maximum temperature to Minimum temperature (average)



# Average Temperature / Lowest reached Temperature during the month





**Global Winter Testing Hub: OEMs & suppliers**

**Confidentiality:** Scarcely populated

**Area infrastructure:** Network of public roads

**Access:** 1h from airport



# Why Colmis?



# Safety First.



# Sustainability & Quality





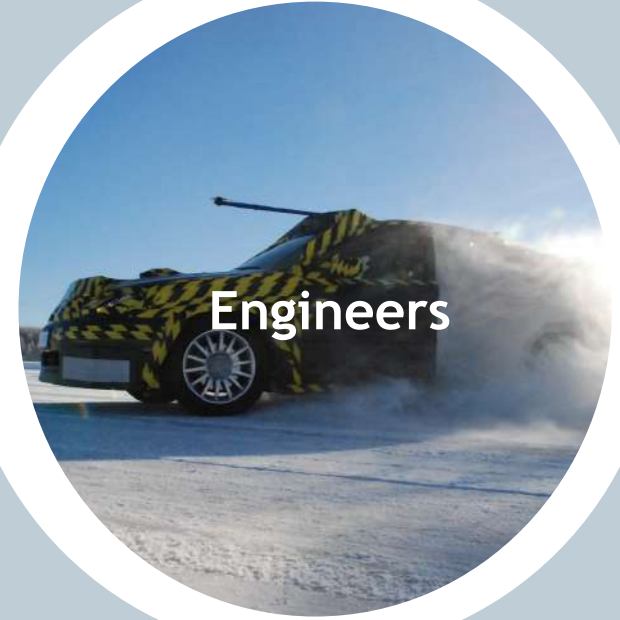
# ColmisPlus Vehicle development support



Mechanics & technicians

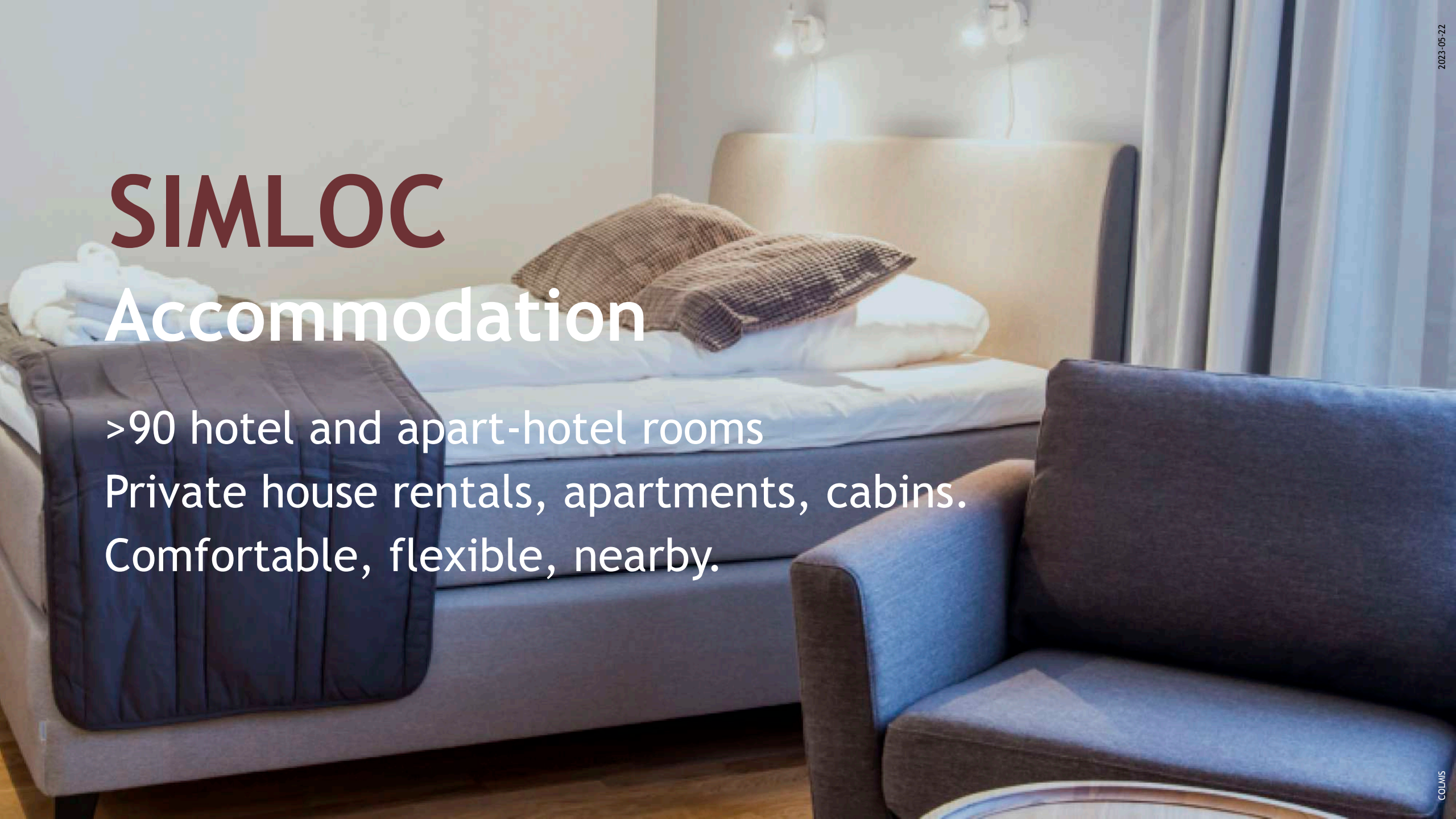


Durability Drivers



Engineers

Also third party supply of materials & equipment for testing, project coordination, and much more...



# SIMLOC

## Accommodation

>90 hotel and apart-hotel rooms

Private house rentals, apartments, cabins.

Comfortable, flexible, nearby.



**12 000** m<sup>2</sup>

Workshops & Office space

**>90**

Hotel rooms  
+ rental of private  
houses/apartments

**>50** land & lake-ice tracks  
**700** km of tracks



**35**

employees



**1850** hectares of land







# The Land Tracks

Some examples of many

Dynamic Area



Circle Track



Split-μ



Twisted Humps and Cobble Stone



Hill Tracks 10-20%



Forest Track



# The Lake Tracks



# The Lake Tracks

| Ice thickness (cm) | Maximum permissible gross weight (also applies to vehicle trailer) (tonnes) | Maximum permissible axle load (tons) | Minimum distance to another vehicle |
|--------------------|-----------------------------------------------------------------------------|--------------------------------------|-------------------------------------|
| 20                 | 2                                                                           |                                      |                                     |
| 25                 | 3                                                                           |                                      |                                     |
| 30                 | 4                                                                           |                                      |                                     |
| 40                 | 7                                                                           | 5                                    | 40                                  |
| 50                 | 12                                                                          | 7                                    | 40                                  |
| 60                 | 16                                                                          | 10                                   | 40                                  |
| 70                 | 20                                                                          | 10                                   | 40                                  |
| 80                 | 25                                                                          | 10                                   | 40                                  |
| 90                 | 30                                                                          | 10                                   | 40                                  |

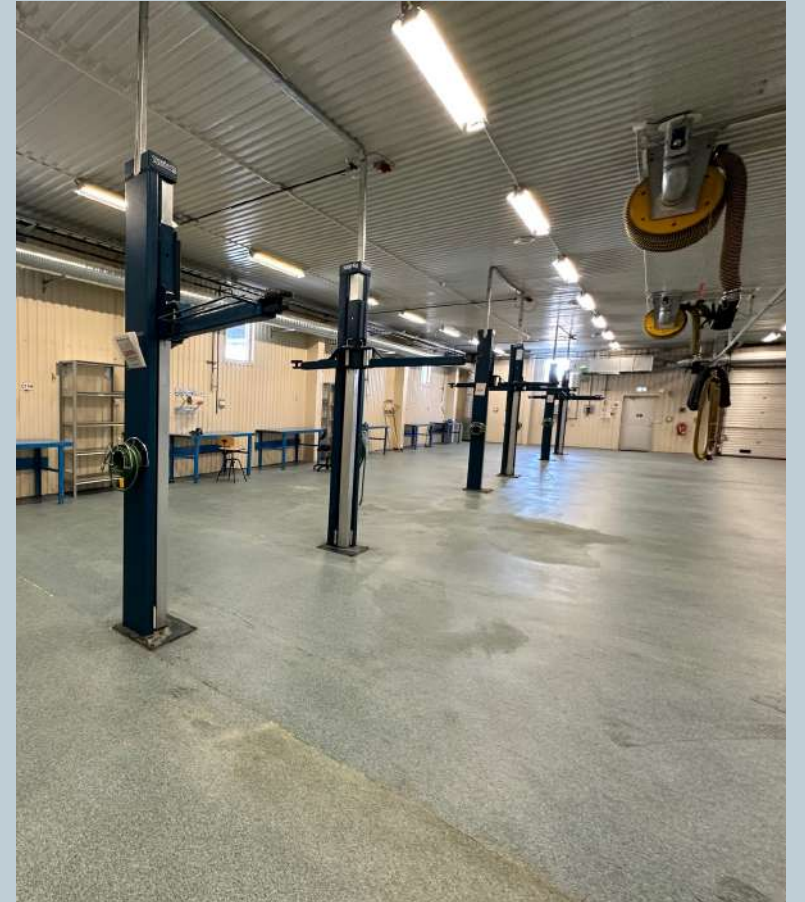


An aerial photograph of a frozen lake, likely in a northern region, showing a series of concentric circular patterns in the ice. These patterns are formed by a combination of natural ice expansion and human-made structures, possibly for water management or recreation. The ice is a light blue-grey color, and the circular features are darker, suggesting they might be filled with water or have a different ice composition. There are several small, dark, forested islands scattered throughout the lake. The overall scene is serene and unique.

Still 84cm today!



# The workshops and offices





# EV Charging



2023-05-22



# Infrastructure.

COLMIS

# Cold Chambers.



**An open proving ground.**



## Contract Customers

ADVICS

BorgWarner

CEVT

Haldex

STELLANTIS

JTEKT

株式会社ジェイテクト

AAM  
DRIVELINE SYSTEMS AB

GKN  
GKN AUTOMOTIVE

HL Mando

AVL

BOSCH

DANA

brembo

FEDERAL  
MOGUL



FEV



Applus<sup>+</sup>  
IDIADA

MIRA

HYUNDAI

nexteer  
AUTOMOTIVE

T-engineering

Perkins

R3E

SSANGYONG

SCANIA



NISSAN

thyssenkrupp

Togg

VOLTA  
TRUCKS

VOLVO

## Spot Customers

# What comes next?

ADAS & Autonomous Driving

More EVs (+ Hybrids) & Hydrogen

New Mobility Trends

Facing Climate Change



# Stay updated.

Follow us @ColmisAB





# Questions?



*A warm welcome.  
To a cold place.  
For a safer road ahead.*

**COLMIS**

[per@colmis.com](mailto:per@colmis.com)

[benjamin@colmis.com](mailto:benjamin@colmis.com)

PHONE: +46(0)730789288



Presentation 4:  
***AstaZero tracks***  
Håkan Andersson, Astazero



Presentation 5:  
***Suspension design as part of complete vehicle  
development***

Yansong Huang, VCC and Chalmers

Presentation 6:

***Tyre rolling resistance at various operational  
conditions and limitations in current tyre  
labelling***

Jukka Hyttinen, Scania and KTH

Presentation 7:

***Tyres and the purposes of models***

Edo Drenth and Niklas Fröjd, Volvo Trucks



# PURPOSE DRIVEN TYRE MODEL FIDELITY

Keeping the Connection

**Volvo Autonomous Solutions**

Volvo | Niklas Fröjd / Edo Drenth | Internal

2023-05-23

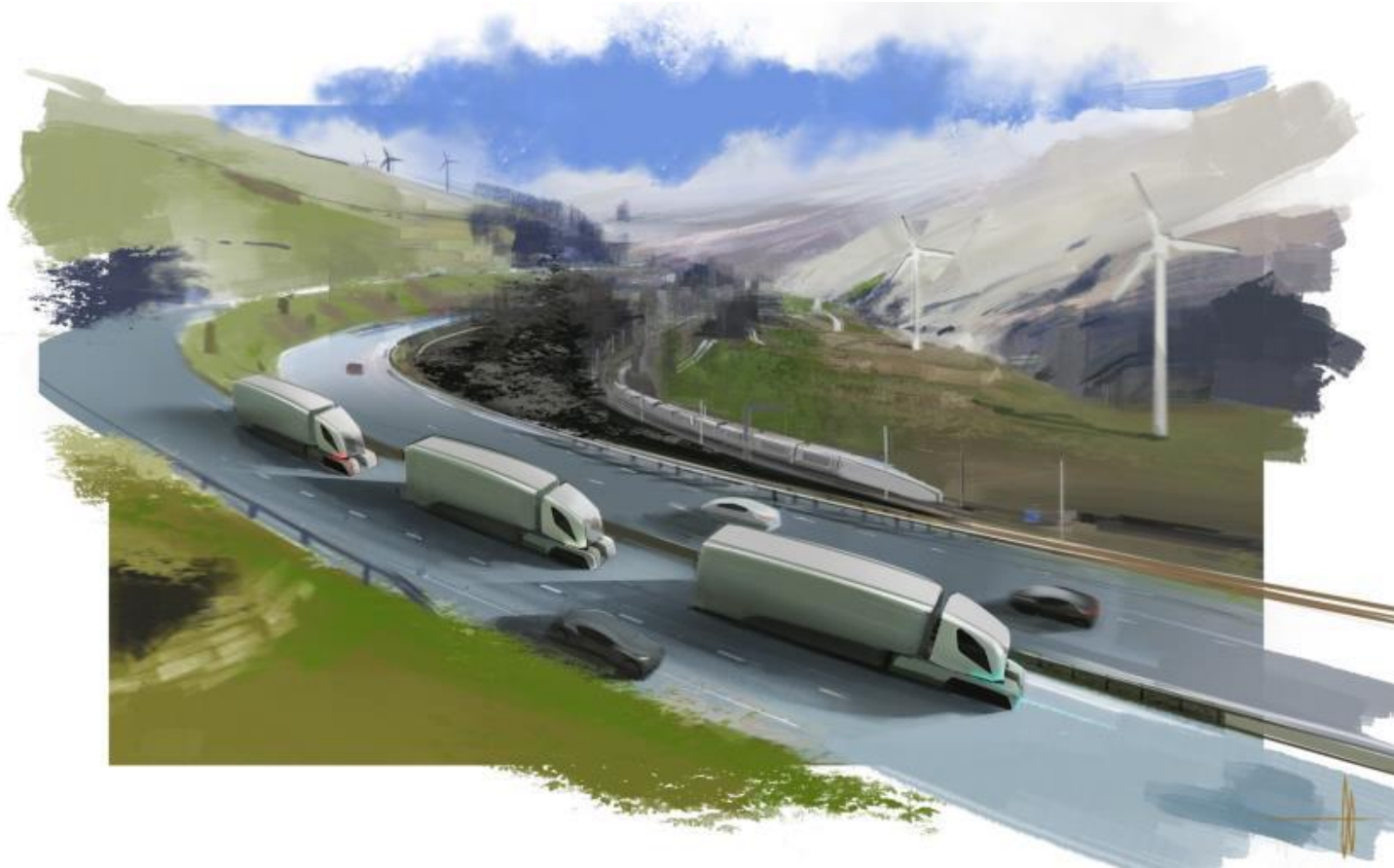
V O L V O

# Volvo Group



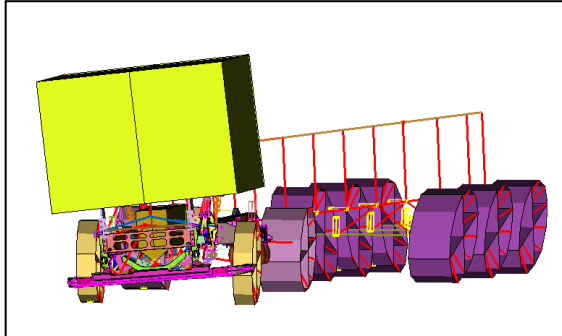
EMPLOY 100.000 PEOPLE,  
PRODUCTION IN 18 COUNTRIES  
SELLS ON 190 MARKETS.

# Group Trucks Technology





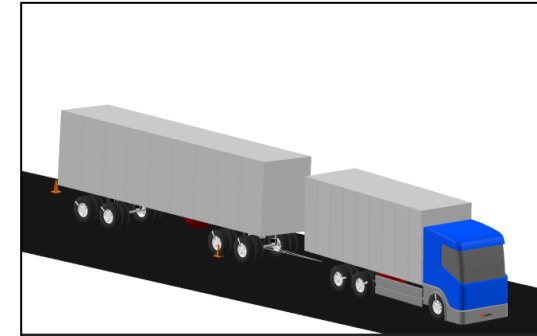
**FEM**



**Semi-detailed 2-track (VTM)**



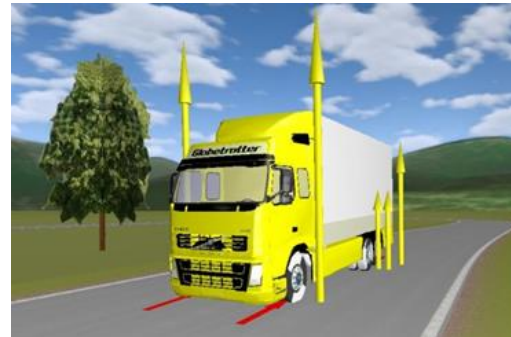
**Modelica**



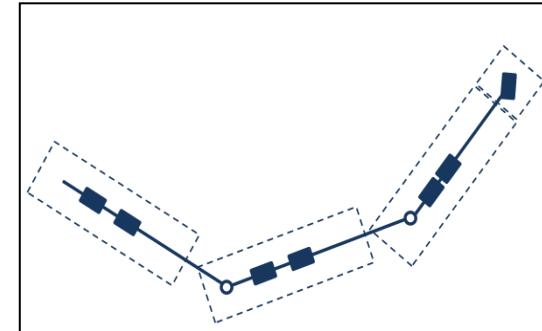
**MBS**



**ASM for HIL/SIL/MIL verification**



**Single-track models for on-line for control design**



# Model data



PDM

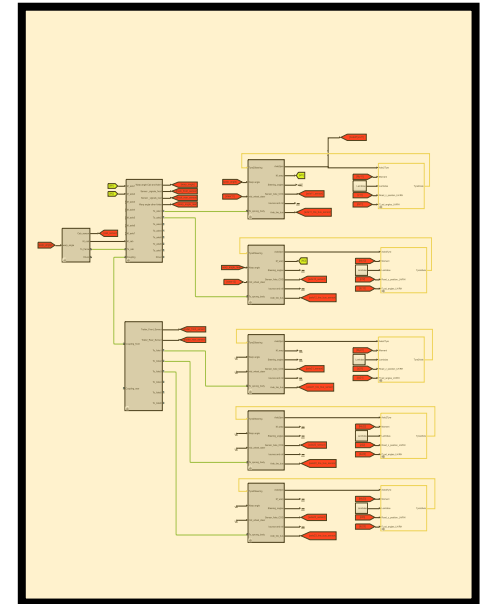
Fetch & Create

```
Ca\vtm_development\VTM16b\Parameter Template Files\Init3_Tractor3_Template.m

EDITOR PUBLISH VIEW
New Open Save Find Files Compare Go To EDIT Breakpoints Run Run and Advance Run Section Run and Time
FILE NAVIGATE BREAKPOINTS RUN

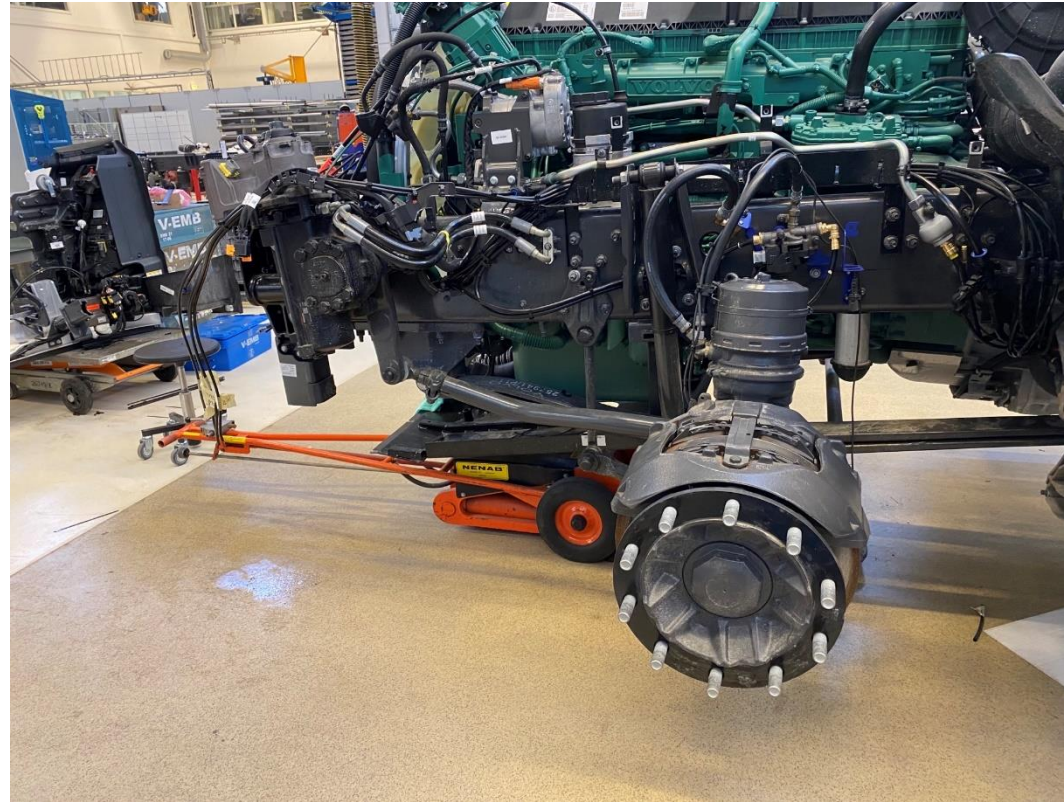
20 %% Basics
21
22 % Short description, reference to spec
23 vtm.dsc(1)='3-axle tractor with single front axle';
24
25 % Number of axles [-]
26 vtm.na(1)=3;
27
28 % Vehicle type (rigid or tractor)
29 vtm.type(1)='tractor';
30
31 % Number of front axles [-]
32 vtm.nfa(1)=1;
33
34 % Type of axle 1=driven 0=nondriven
35 vtm.axletype(1,1:vtm.na(1))=[0 1 1];
36
37 % Type of rear axle steering 1=steered 0=non steered
38 vtm.susprear_steertype(1,1:(vtm.na(1)-vtm.nfa(1)))=[0 0];
39
40 % Axle positions r.t. first axle [m]
41 vtm.ll(1,1:vtm.na(1))=[0 -3.4 -4.77];
42
43 % Coupling positions r.t. first axle [m]
44 vtm.lc(1,1:2)=[0 -3.75];
45
46 % Coupling height r.t. ground [m]
47 vtm.hc0(1,1:2)=[0 1.13];
48
49 % Unladen tractor axle group loads [kg]
50 vtm.fale=[5767.97];
51 vtm.rale=[4151.25];
52
53 %% Axles, wheels and tyres
54
55 % Axle mass [kg]
56 vtm.maxle(1,1:vtm.na(1))=[750 1300 1300];
57
58 % Track width [m]
59 vtm.w(1,1:vtm.na(1))=[2.09 1.85 1.85];
```

Couple & Load



Executable model

## The suspension and steering





## The truck frame



## The swap-body superstructure





V O L V O

## The tipper





# Timber



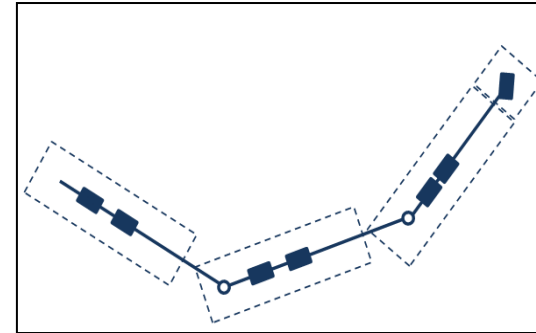
## Tyres



# 1. Useful linear tyre model for single-track modeling

$$F_y = C_\alpha \times \alpha$$

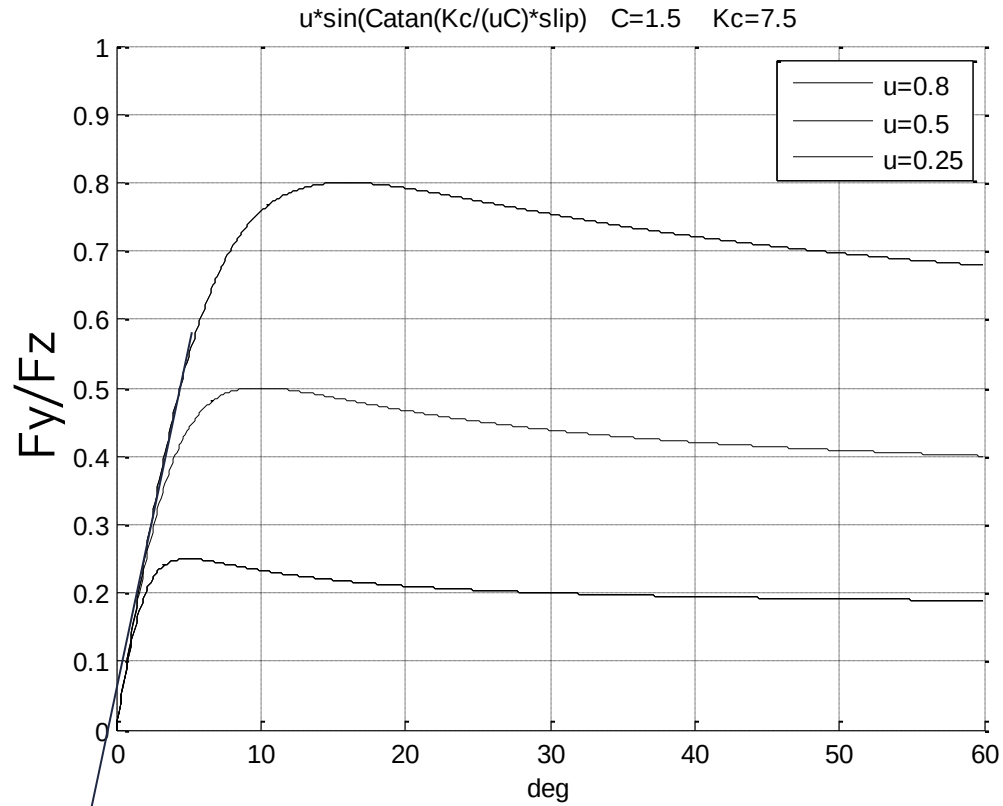
$$C_\alpha = K_c \times F_z$$



|              |                        |
|--------------|------------------------|
| $C_\alpha$ : | Cornering stiffness    |
| $\alpha$ :   | Lateral slip           |
| $K_c$ :      | Cornering coefficient  |
| $F_z$ :      | Vertical contact force |



## 2. Useful non-linear tyre model for two-track modeling



$$K_c = K_{c0} \left( 1 + k \frac{F_z - F_{z0}}{F_{z0}} \right)$$

$$F_y = \mu \times F_z \times \sin \left( C \times \text{atan} \left( \frac{K_c}{\mu C} \alpha \right) \right)$$

# Vision

V.A.S. portable application software can be entirely  
**verified** virtually  
and solely **validated** in the vehicle

SIL



Component  
HIL

System  
HIL



# Mission

Develop reusable and portable vehicle simulation models for all stages of the virtual verification of software applications





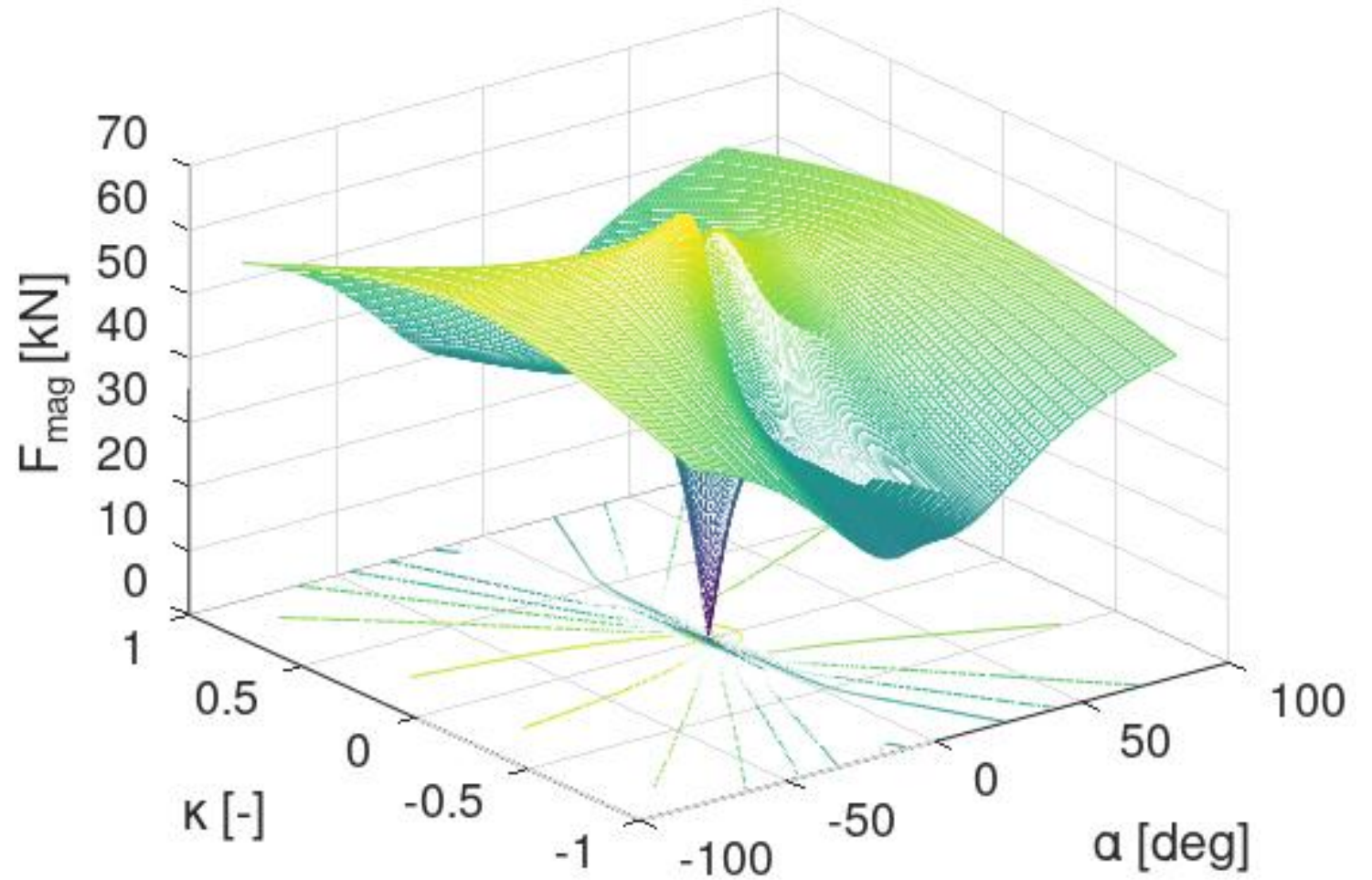
## Starting point

445/65 R22.5

Pacejka 2002 – combined slip

Extrapolated parameters from truck  
tyre parameter sets

The TA15 will be on “rails”

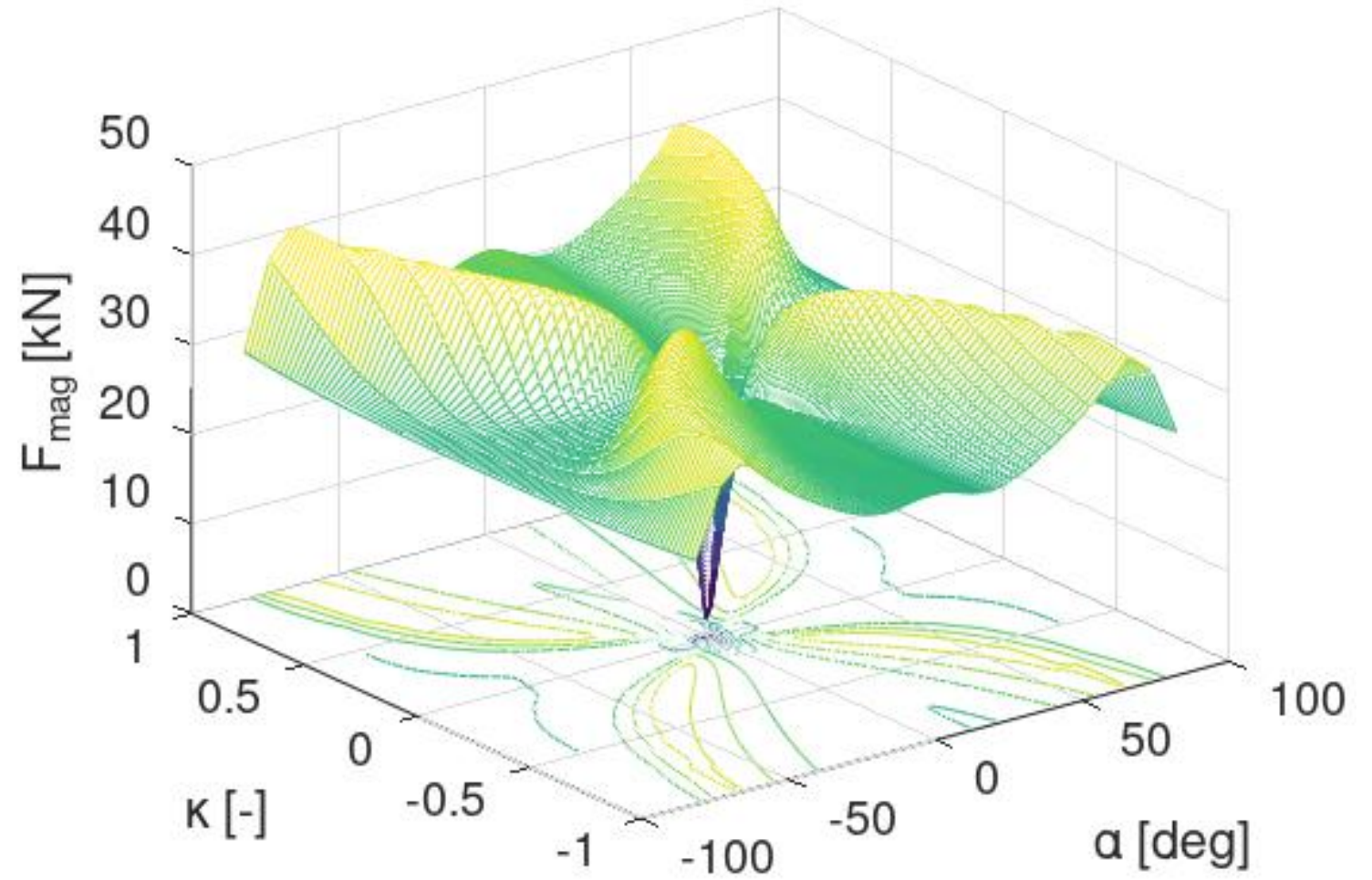


## Measured and fitted

Truck tyre

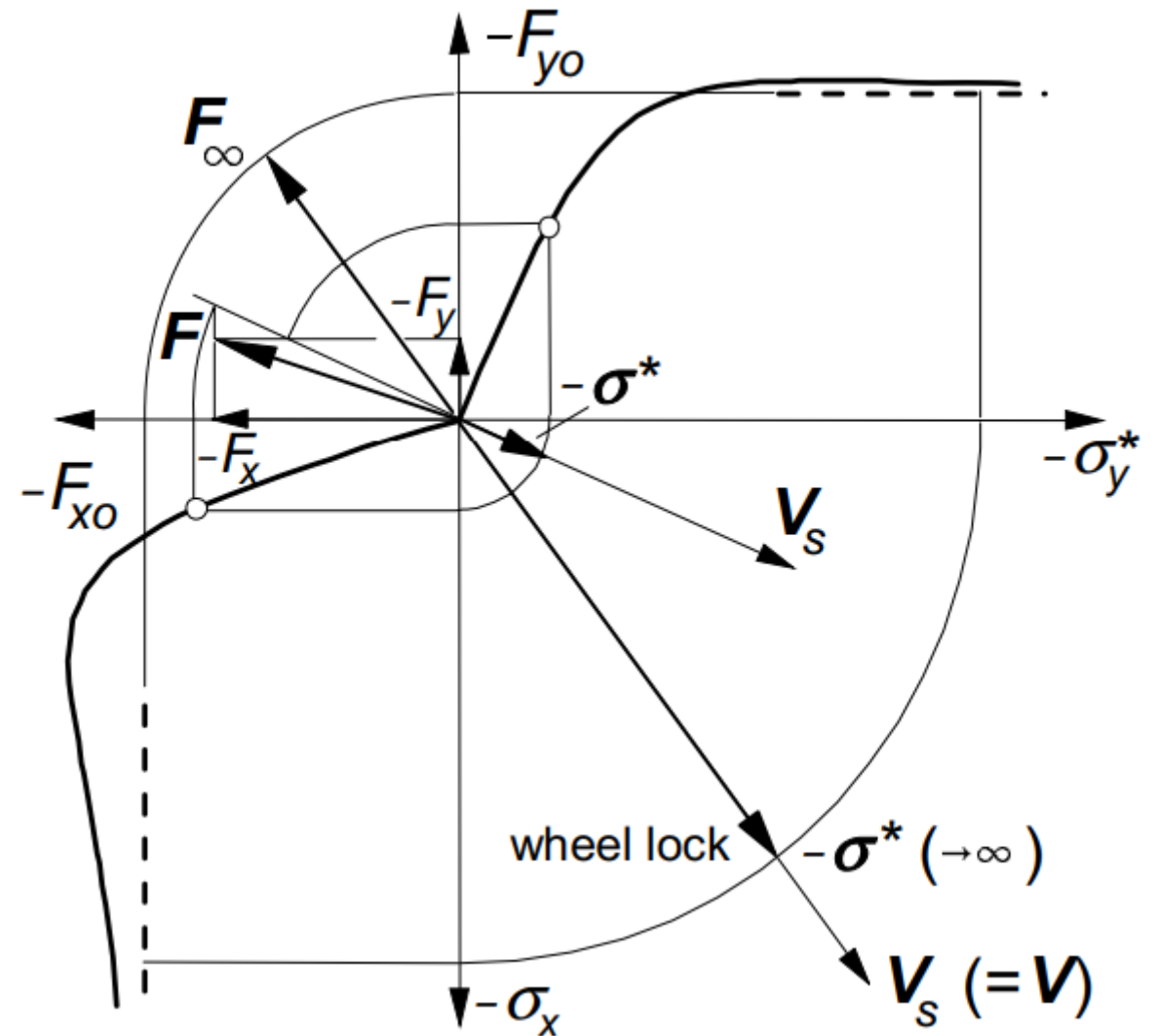
Pacejka 2002 – combined slip

Overfitted within available data?



# What do we have?

- Basic notion of uniaxial slip characteristics
  - Magic Formula
- Similarity methods
  - Theoretical slips
- Longitudinal slip stiffness
- Cornering stiffness
- Peak friction characteristics
  - Declining with load
  - Asymptotic?
- Identical asymptote for friction?

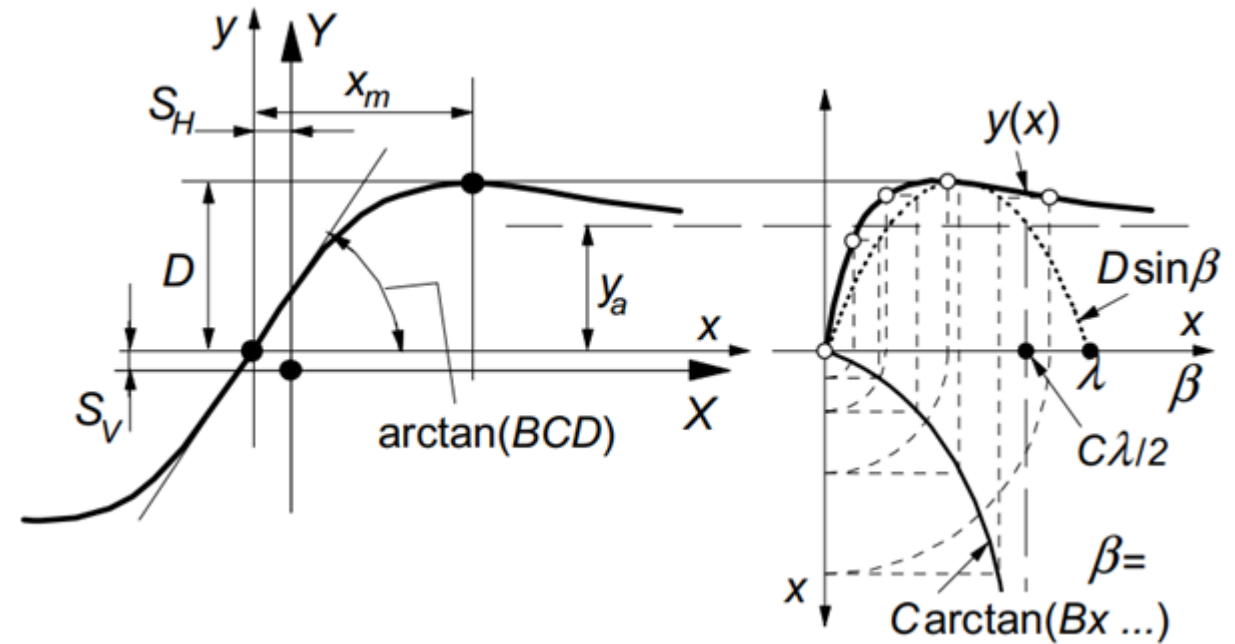


Source: Tyre and Vehicle Dynamics, Hans B Pacejka



# Reverse Engineering

- Use existing parameter sets (backward compatible)
- Remove all shift functions
  - Symmetric tyre characteristics
- Utilise Magic Formula 2002 main parameter interrelationships
  - B, C, D and E
  - Forthcoming ISO standard
  - **Heavy commercial vehicles and buses – Vehicle dynamics simulation and validation – Tyre model for lateral estimation of heavy vehicle combinations operated at dry paved road surface**



Source: Tyre and Vehicle Dynamics, Hans B Pacejka

# VAS22 tyre model features

- 21 parameters
- PAC02 backward compatible
  - The remaining parameters have identical meaning
  - Can read a full set of PAC02 parameters
  - Will throw DTCs for non-plausible parameter values
- Robustness
  - All characteristics are asymptotically sound beyond validity range

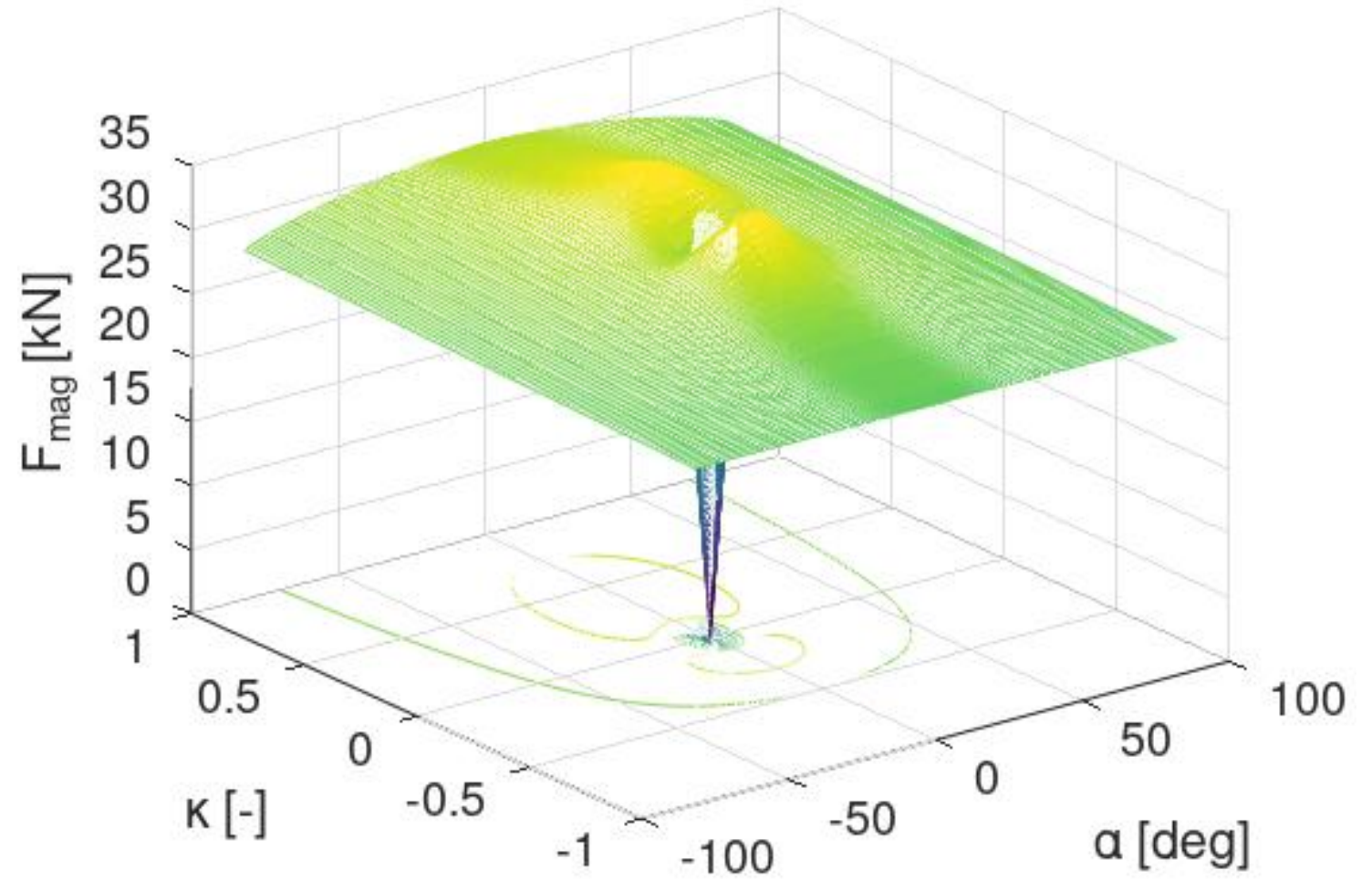
|                           |   |                                                |
|---------------------------|---|------------------------------------------------|
| kappaPeak                 | : | <input type="text" value="-0.15"/>             |
| PCX1                      | : | <input type="text" value="1.45"/>              |
| PDX1                      | : | <input type="text" value="0.85"/>              |
| PDX2                      | : | <input type="text" value="-0.05"/>             |
| PDX3                      | : | <input type="text" value="0"/>                 |
| PKX1                      | : | <input type="text" value="8.0"/>               |
| PKX2                      | : | <input type="text" value="7.0"/>               |
| PKX3                      | : | <input type="text" value="-0.3"/>              |
| Pure slip lateral         |   |                                                |
| alphaPeak                 | : | <input type="text" value="17.1887338539"/> deg |
| PCY1                      | : | <input type="text" value="1.3"/>               |
| PDY1                      | : | <input type="text" value="0.75"/>              |
| PDY2                      | : | <input type="text" value="-0.05"/>             |
| PDY3                      | : | <input type="text" value="0.2"/>               |
| PKY1                      | : | <input type="text" value="-13.0"/>             |
| PKY2                      | : | <input type="text" value="1.8"/>               |
| PKY3                      | : | <input type="text" value="0.2"/>               |
| Pure slip aligning torque |   |                                                |
| QCZ1                      | : | <input type="text" value="1.2"/>               |
| QDZ1                      | : | <input type="text" value="0.1"/>               |
| QDZ2                      | : | <input type="text" value="-0.003"/>            |
| QDZ3                      | : | <input type="text" value="0.0"/>               |
| QDZ4                      | : | <input type="text" value="0.0"/>               |

## Results

445/65 R22.5

VAS22 – combined slip

Minimum set of parameters



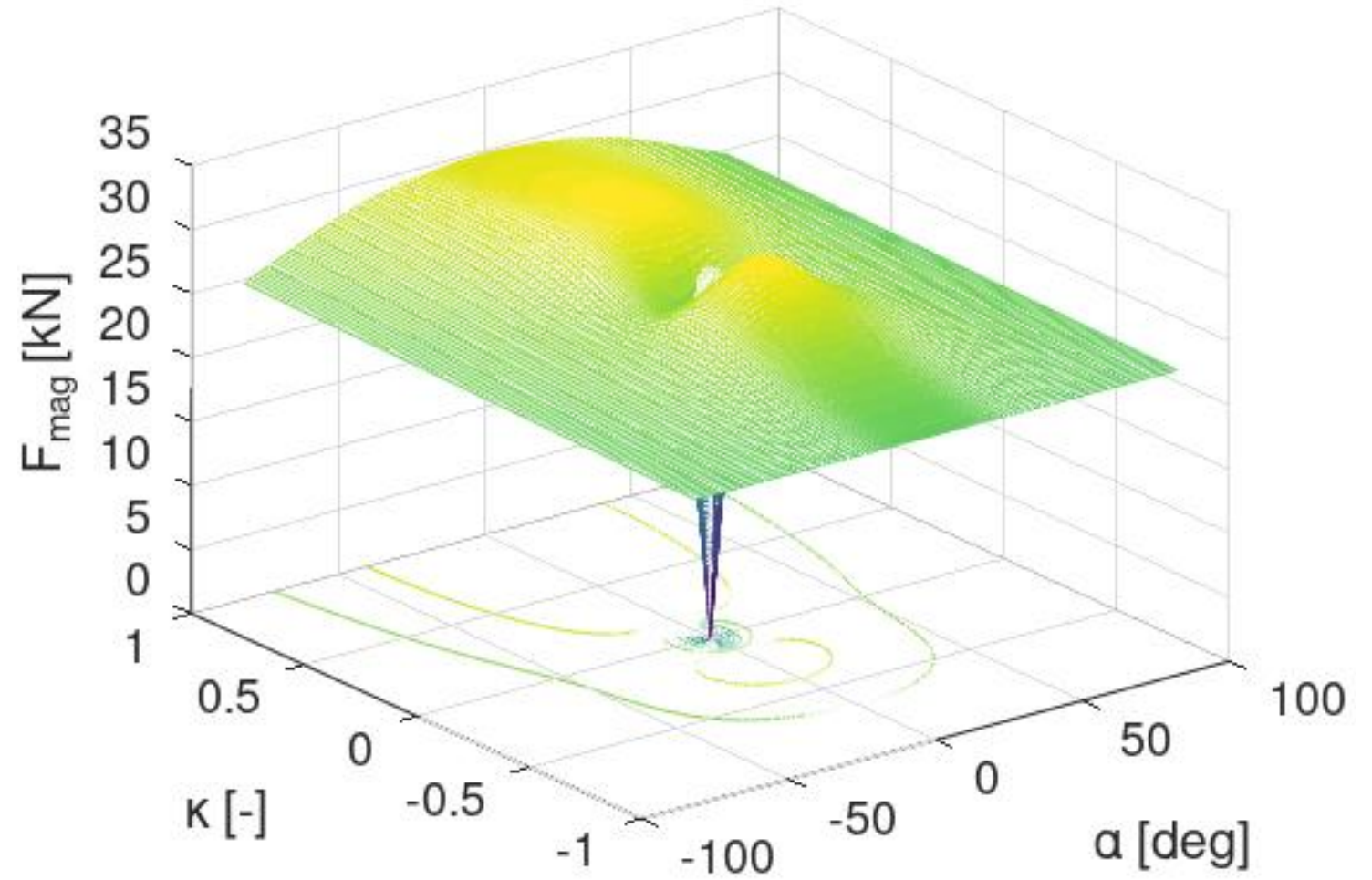


# Results

385/55 R22.5

VAS22 – combined slip

Minimum set of parameters



## Tyre model fidelity

Perhaps vice versa

The tyre model at hand  
represents  
a possible outcome of a real tyre

**V O L V O**



Presentation 8a:  
***Vehicle Engineering MSc programme,***  
**Mikael Nybacka, KTH**

Presentation 8b:  
*Mobility engineering MSc programme,*  
**Dag Bergsjö, Chalmers**

# MASTER'S PROGRAMME MOBILITY ENGINEERING

MCS, 120 CR, 2 YEARS



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY

## DEVELOP TOMORROW'S MOBILITY SYSTEMS!



Program integrating  
aerospace, automotive  
engineering, marine  
technology and railway  
technology

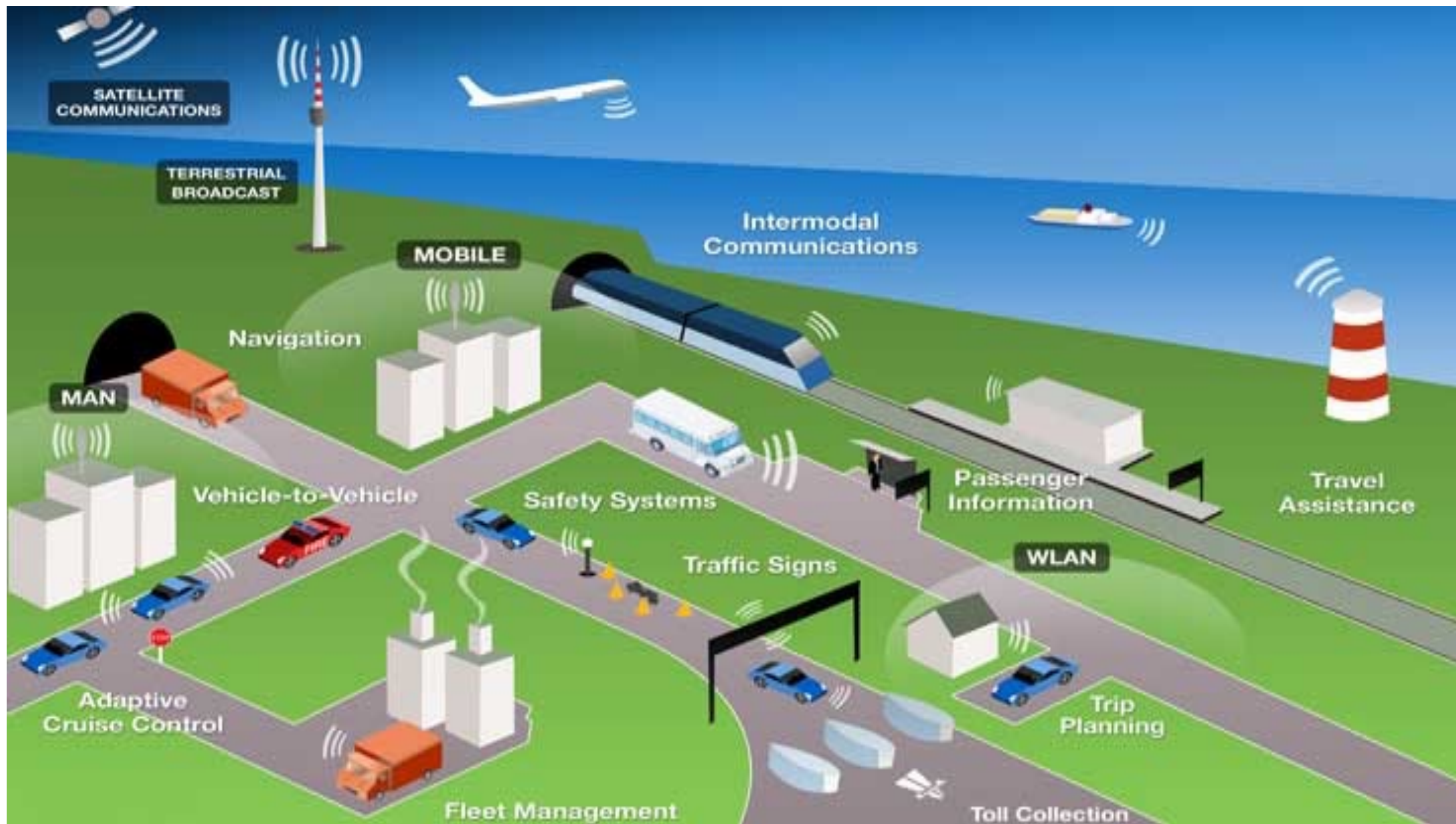


Dag Bergsjö

[dagb@chalmers.se](mailto:dagb@chalmers.se)

Program Director MPMOB





# Aim of MP



Train students:

- To develop safe, sustainable, high-performance mobility solutions.
- To understand features, design requirements and challenges of the present and future mobility solutions.
- To gain a holistic knowledge of mobility solutions and the ability to apply them for different transportation needs and environments.

# MPMOB: programme in a nutshell



## Broad knowledge on mobility

- Mechatronics for mobility
- Propulsion for mobility
- Connected fleets and automated data collection
- Systems engineering

## In-depth knowledge in one of these profiles

- Aerospace engineering
  - Fluids
  - Structural
  - Artificial intelligence
- Automotive engineering
  - Active and passive safety
  - Powertrain and propulsion systems
  - Vehicle engineering and aerodynamics
- Marine technology and naval architecture
  - Structures
  - Fluid
  - Systems engineering
- Railway technology
  - Railway mechanics
  - Structural deterioration
  - Asset management



# MPMOB: facilities for education



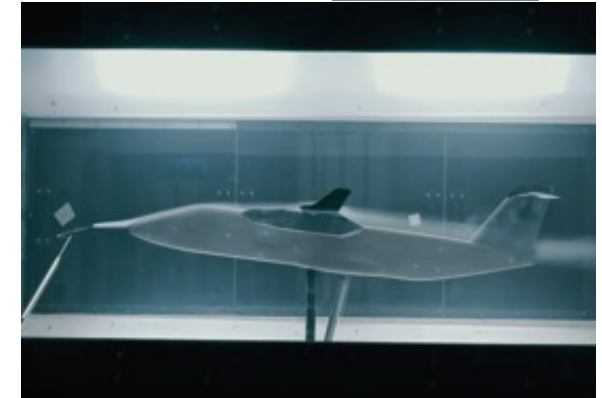
Hybrid powertrain lab



Driving simulator



Brake rig for rail



Low-speed wind tunnel



Resource for vehicle research  
(REVERE)



Maritime simulator



Low-pressure compressor rig

# MPMOB: study plan



| Year 1                                                               |                                |                                |                                                      | Year 2                         |                                |               |     |
|----------------------------------------------------------------------|--------------------------------|--------------------------------|------------------------------------------------------|--------------------------------|--------------------------------|---------------|-----|
| LP1                                                                  | LP2                            | LP3                            | LP4                                                  | LP1                            | LP2                            | LP3           | LP4 |
| Systems and mechatronics for mobility engineering (EEN130)           | Elective / Compulsory elective | Elective / Compulsory elective | Connected fleets in data-driven engineering (MMS210) | Elective / Compulsory elective | Elective / Compulsory elective | Master thesis |     |
| Introduction to propulsion and energy systems for transport (MMS195) | Elective / Compulsory elective | Elective / Compulsory elective | Elective / Compulsory elective                       | Elective / Compulsory elective | Elective / Compulsory elective |               |     |

- Compulsory courses for 52.5 ECTS
- Compulsory elective courses for 37.5 ECTS (to be chosen among 32 different courses)
- Elective courses for 30 ECTS (to be chosen from 12 different Master programmes)

# MPMOB: project work



- Project in aerospace (Aerospace engineering)
- Automotive engineering project (Automotive engineering)
- Marine design project (Marine technology)
- Project in railway technology (Railway technology)
- Chalmers formula students (Automotive engineering)



# MPMOB: industrial connections



- Abetong
- Autoliv
- Alstom
- Consulting companies (Alten, Altran, ÅFRY, Atkins)
- China Euro Vehicle Technology (CEVT)
- GKN Aerospace
- Green Cargo
- Heart Aerospace
- Lucchini
- SAAB
- SSPA
- Stena Line
- SJ
- SweMaint
- Trafikverket
- Volvo Group
- Volvo Cars
- Wabtec

# Lunch Seminars (Fall 2023)

SAS & Heart aerospace (spring 2023)



# MPMOB: research-based education



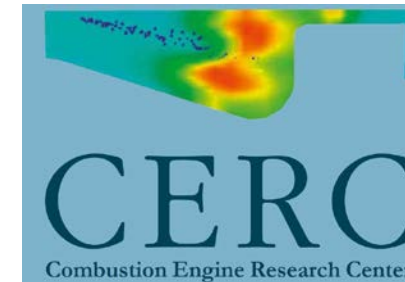
<http://www.charmec.chalmers.se/>



<https://emobilitycentre.se/>



<https://lighthouse.nu/>



<https://www.chalmers.se/en/centres/cerc/Pages/default.aspx>

## TechForH2 – Hydrogen Centre

<https://www.chalmers.se/en/departments/m2/news/Pages/TechForH2---for-a-sustainable-hydrogen-economy-of-tomorrow.aspx>



<https://www.saferresearch.com/>



# MPMOB: international opportunities

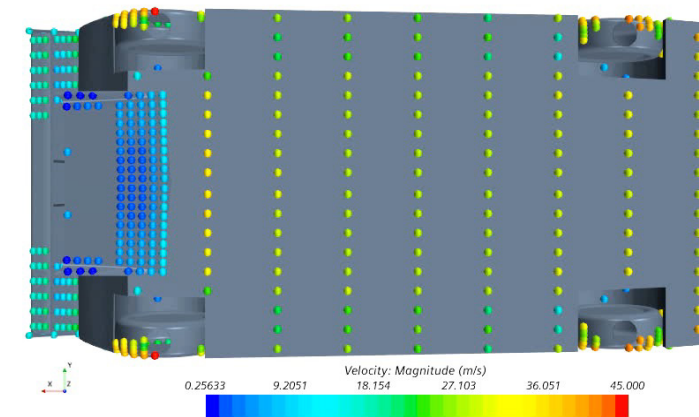
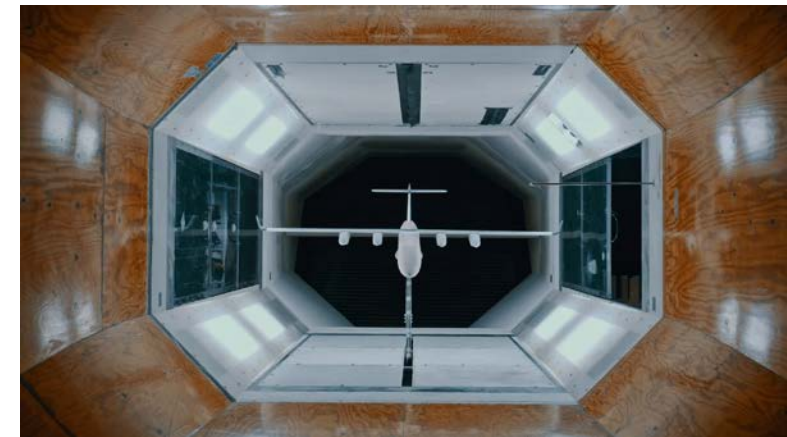


- Double degree with University of Stuttgart (automotive engineering)
- Nordic Master in Maritime engineering, within Nordic Five Tech (marine technology)
- Erasmus exchanges (<https://cth.moveon4.de/publisher/1/eng#>)

# MPMOB: job opportunities



- Design of parts and systems (e.g., yacht designer, powertrain integration engineer)
- Simulation engineer (e.g., crash simulation engineer, vehicle dynamics CAE engineer)
- Asset management (e.g., asset management railway engineer, maintenance engineer)
- Technical sales engineer
- Project manager
- Research & development (e.g., railway technical specialist, traffic safety research specialist)
- Academia (e.g., PhD student)
- Other (e.g., offshore engineer)





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UNIVERSITY OF TECHNOLOGY



Poster 1:

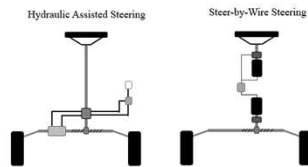
***Quantify and mimic the feedback through the steering wheel at some driving conditions***

Aron Dalemo, Polestar & Chalmers

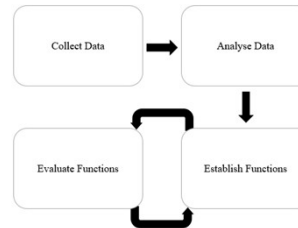
# Master Thesis Micro Presentation

*Aron Dalemo*

## Background & Aim

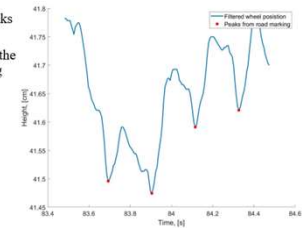


## Method



## Result

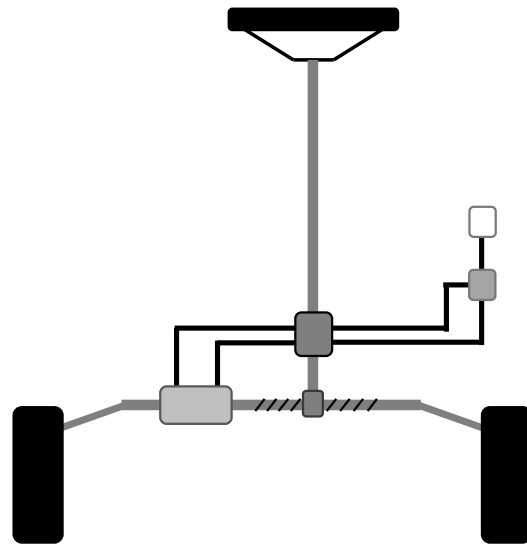
- The general idea is to look at peaks and their placements
- Largest challenge is to not catch the same phenomena in other driving situations
- Shows potential



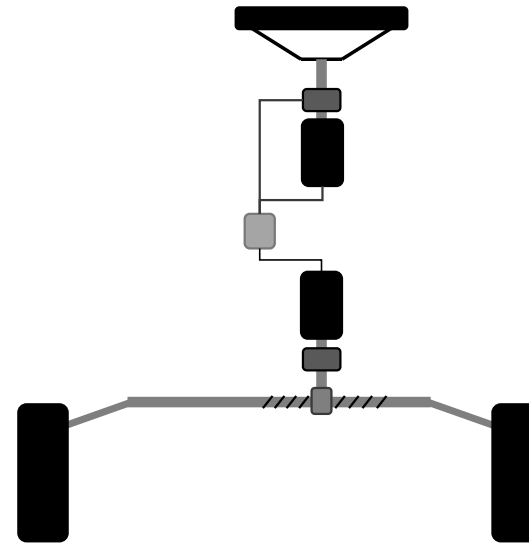


# Background & Aim

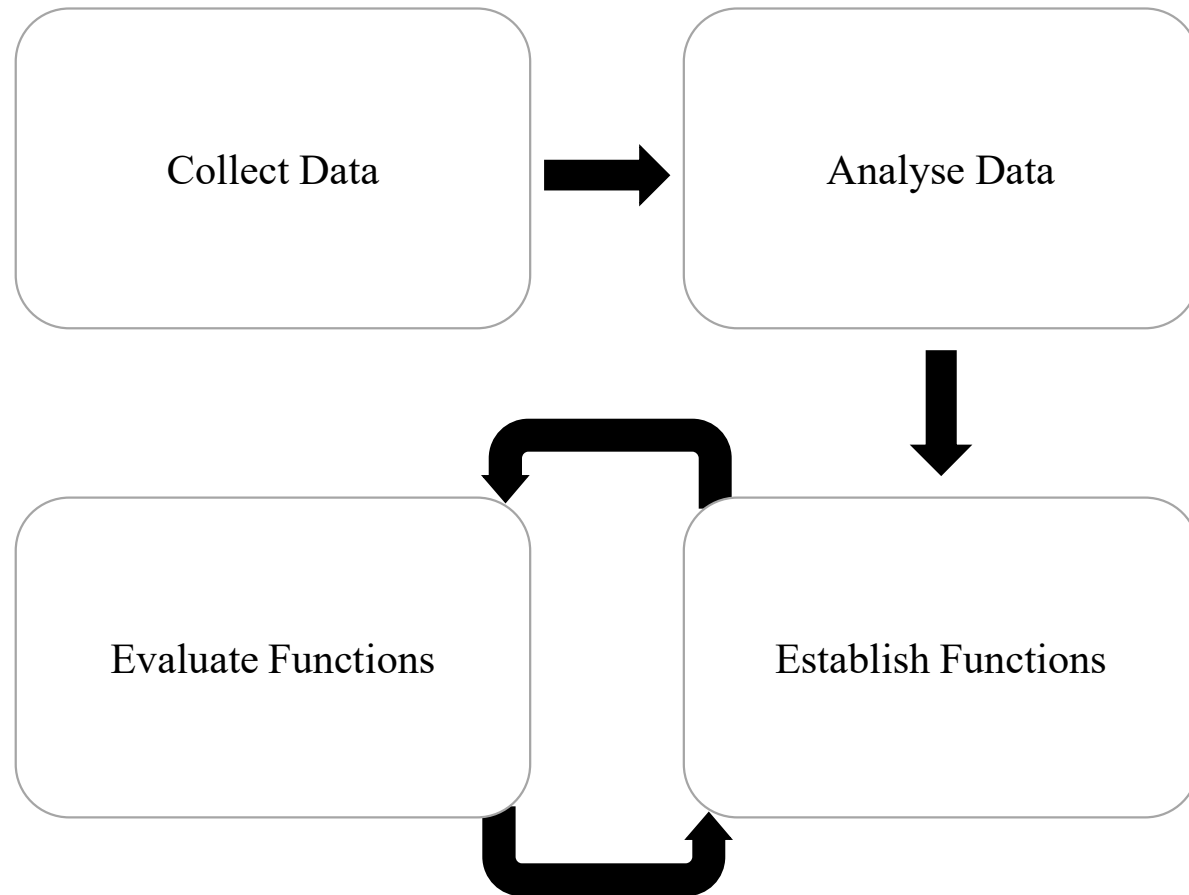
Hydraulic Assisted Steering



Steer-by-Wire Steering

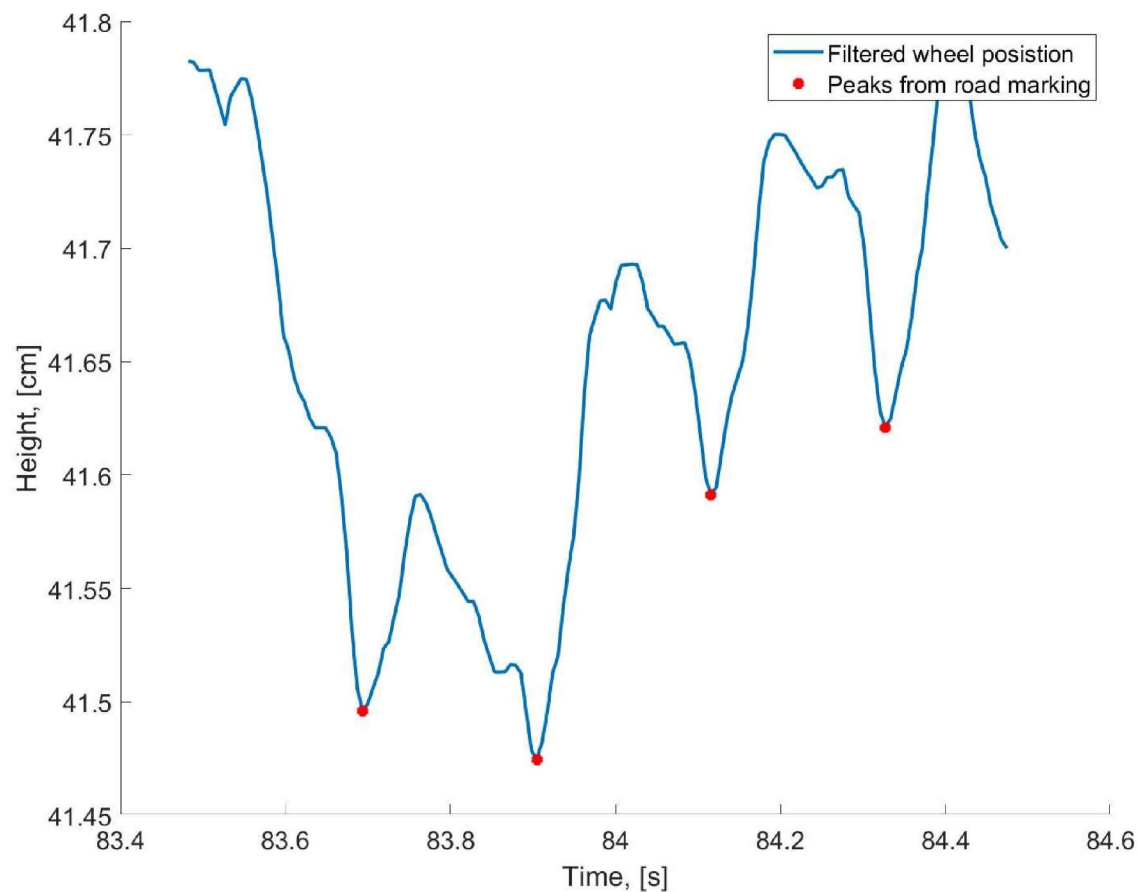


# Method



# Result

- The general idea is to look at peaks and their placements
- Largest challenge is to not catch the same phenomena in other driving situations
- Shows potential

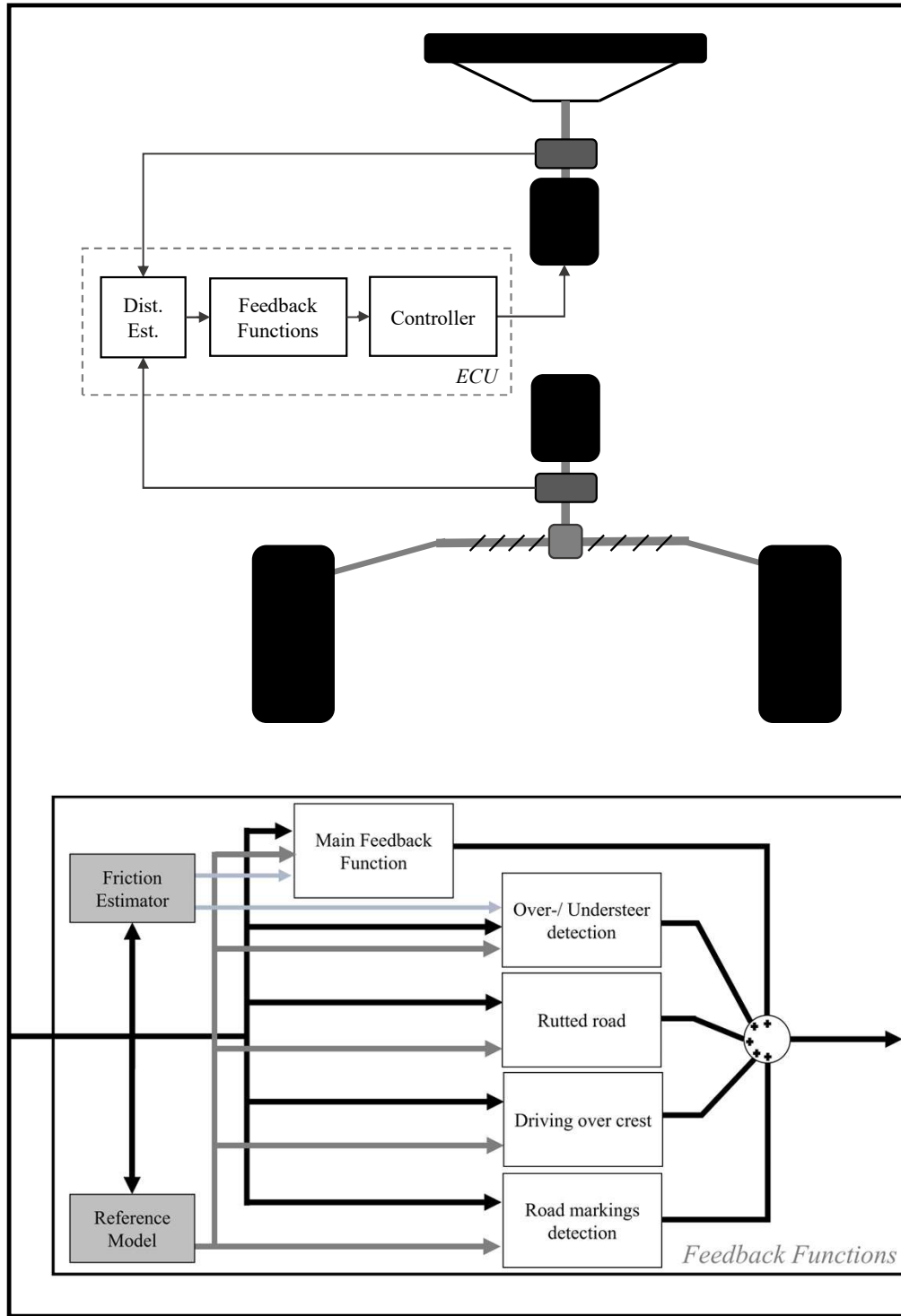


Quantify and mimic the feedback through  
the steering wheel during some driving condition

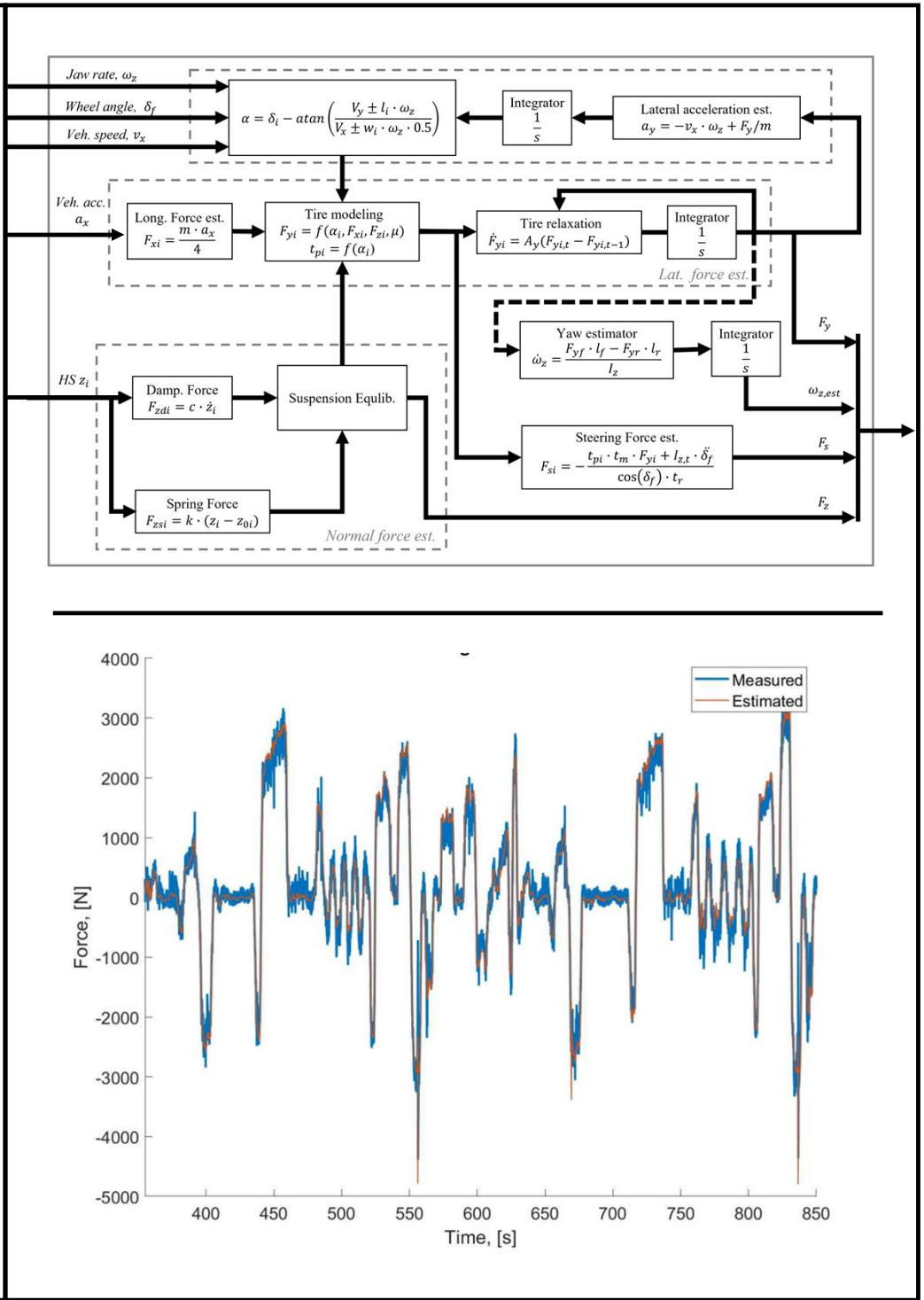
*Aron Dalemo*



# Model



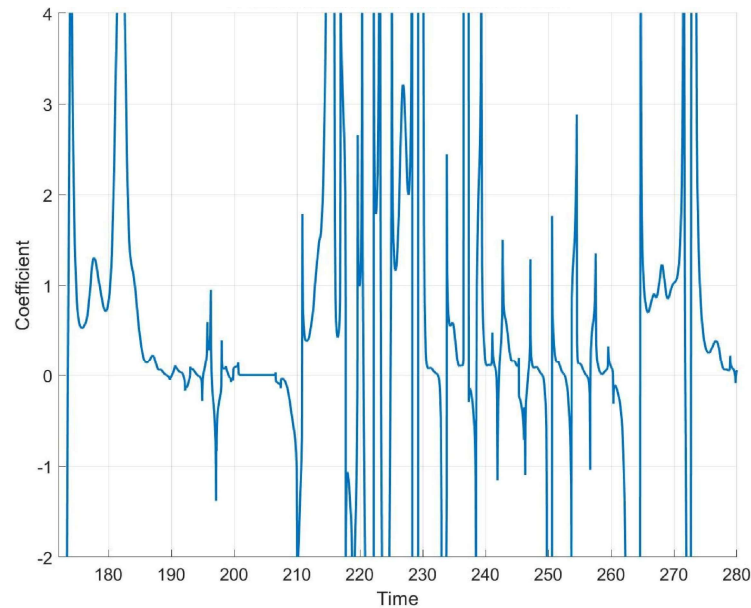
# Reference model



# Different scenarios

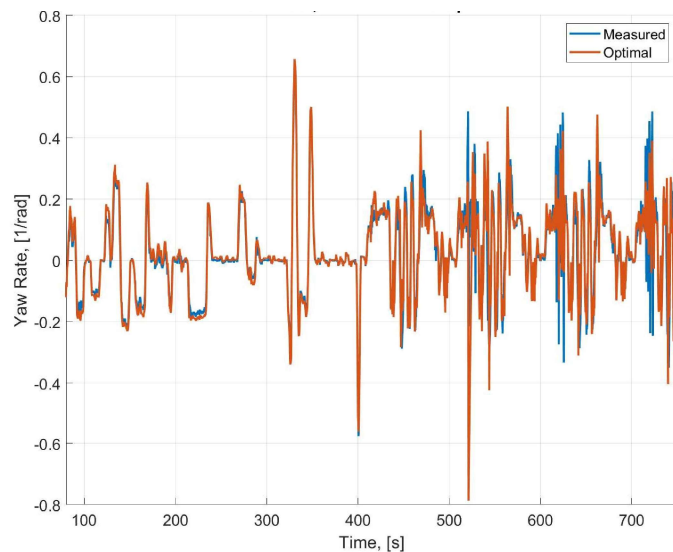
## Low friction

Estimate current friction based on self-aligning torque. Only gives reasonable values when steady state. This could be due to longitudinal dynamics



## Axle saturation

Adds torque to help the driver in scenarios with a saturated axle

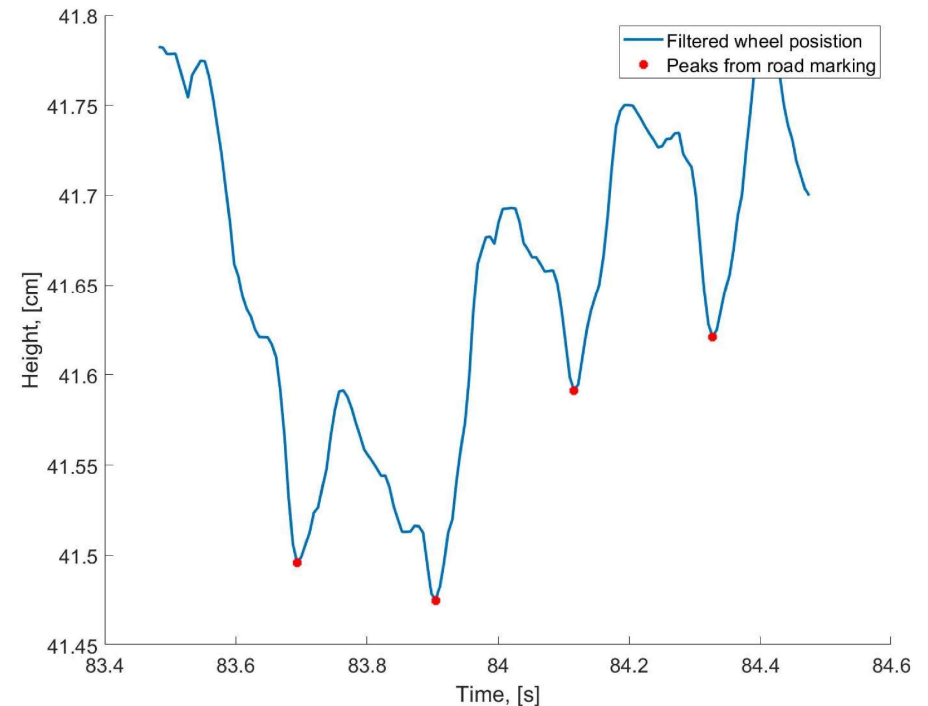


## Dashed road markings

The general idea is to look at peaks and their placements.

The largest challenge is to not catch the same phenomena in other driving situations

Shows potential



## Driving over crest while turning

Is incorporated in the reference model and main transfer function with height sensors

## Rutted roads

The rutted part can be sensed in the tie rods and also in the height sensors.

Not possible to sense in time, more than one wheel has to pass and then it is too late

Poster 2:

***Using torque vectoring to improve steering  
predictability while minimizing energy use in  
Heavy electric vehicles***

Jonas Persson and Jonathan Åkesson, Volvo  
Trucks & Chalmers

V O L V O

# ON TORQUE VECTORING TO IMPROVE STEERING PREDICTABILITY WHILE MINIMISING POWER LOSS IN HEAVY ELECTRIC VEHICLES USING MODEL PREDICTIVE CONTROL

Volvo Trucks

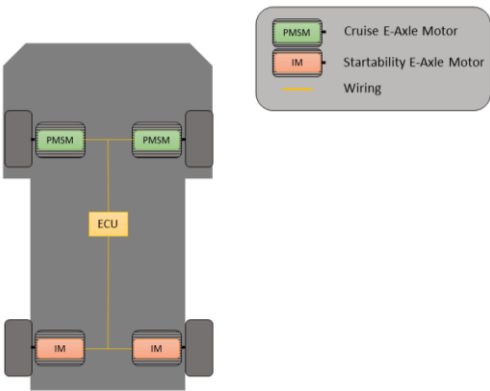
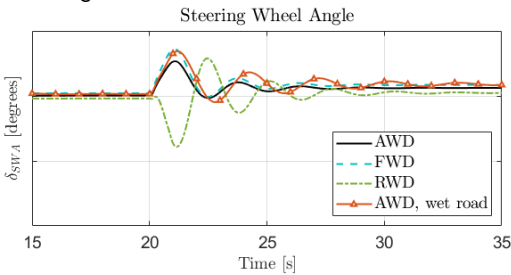
Master's Thesis | Jonas Persson and Jonathan Åkesson | Chalmers University of Technology  
2023-05-22

1

V O L V O

## Background

- Varying distribution of propulsion between e-axes will change the handling characteristics, which can make the vehicle unpredictable to steer.
- Separate motors on left and right side allows for micromanaging of lateral dynamics through torque vectoring.



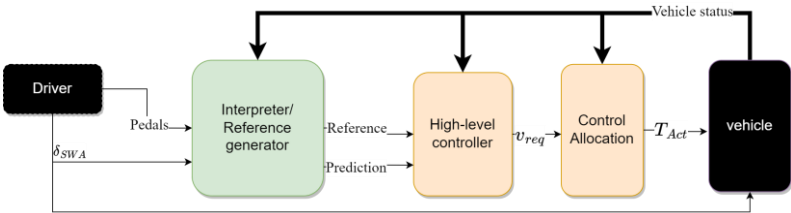
2





# Our Solution

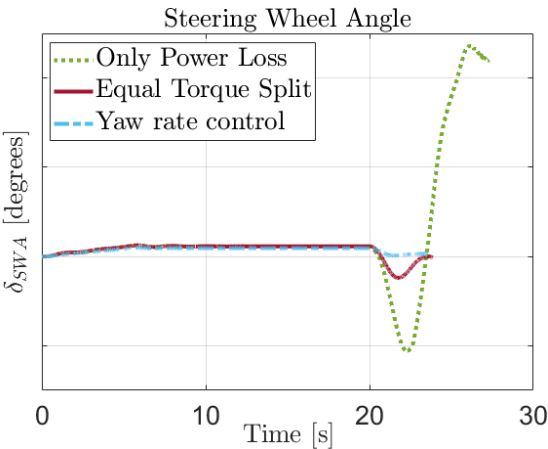
- MPC based approach to generate a global force request to the control allocator
- Control allocator distributing global force to actuator level
- Interpretation of driver’s input to generate references
- Rate of change for steering wheel angle and yaw rate
- Yaw rate controller based on bicycle model



# Predictable steering behaviour with Torque Vectoring

Steering wheel angle for emergency braking during cornering. Yaw rate controller aids in lateral stability, resulting in:

- less lateral sway,
- shorter braking distance
- and a more manageable manoeuvre for the driver.



# ON TORQUE VECTORING TO IMPROVE STEERING PREDICTABILITY WHILE MINIMISING POWER LOSS IN HEAVY ELECTRIC VEHICLES USING MODEL PREDICTIVE CONTROL

Jonas Persson and Jonathan Åkesson

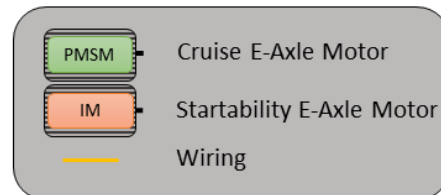
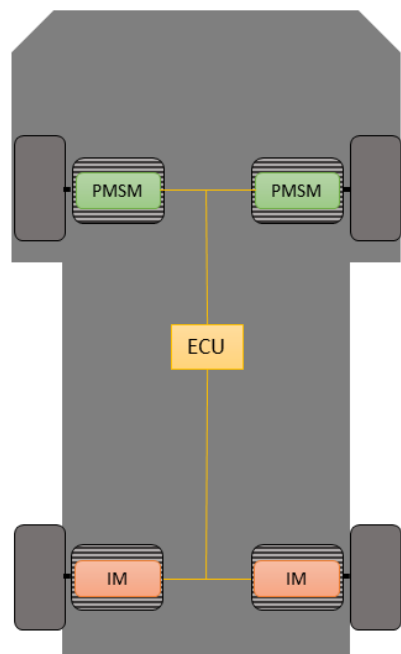
Department of Mechanics and Maritime Sciences  
Chalmers University of Technology



CHALMERS  
UNIVERSITY OF TECHNOLOGY

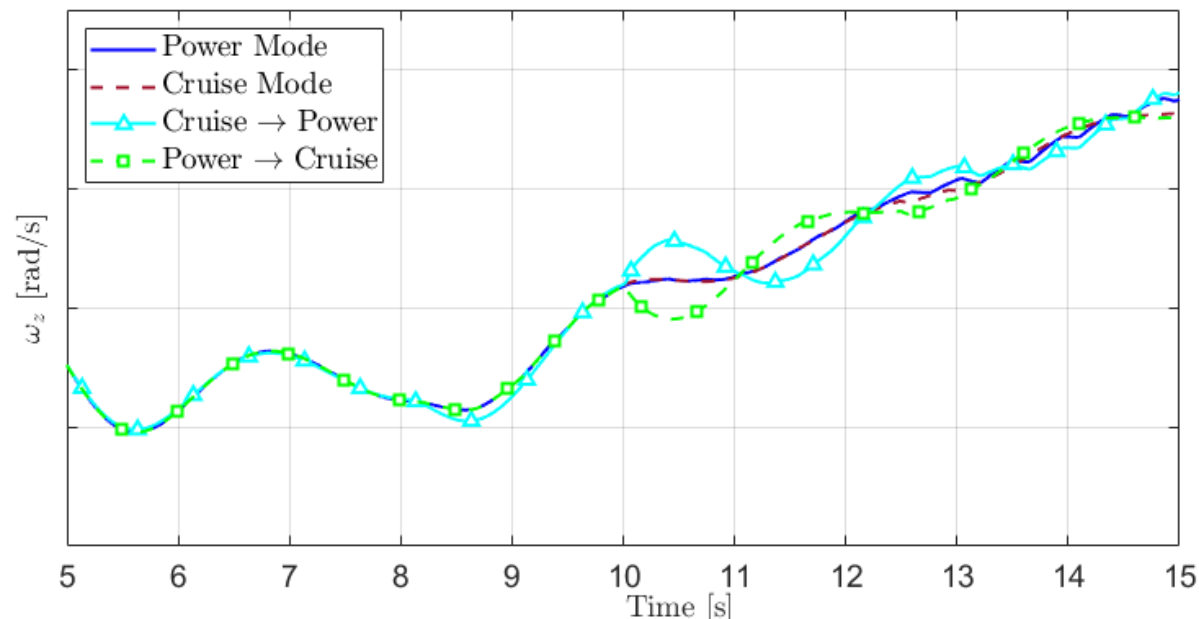
V O L V O

## Background

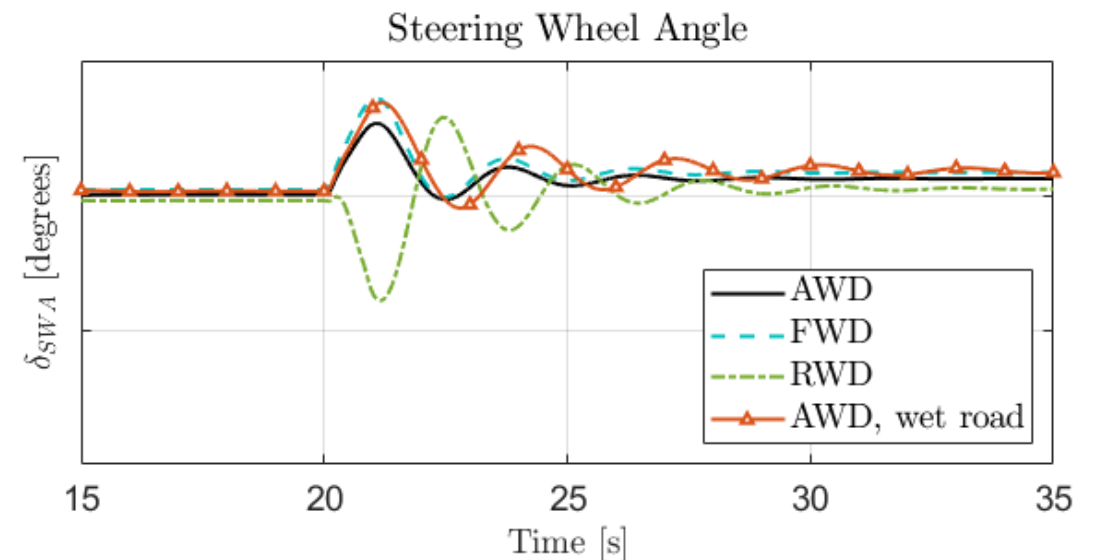


- Varying distribution of propulsion between e-axes will change the handling characteristics, which can make the vehicle unpredictable to steer.
- Separate motors on left and right side allows for micromanaging of lateral dynamics through torque vectoring.

Yaw Rate

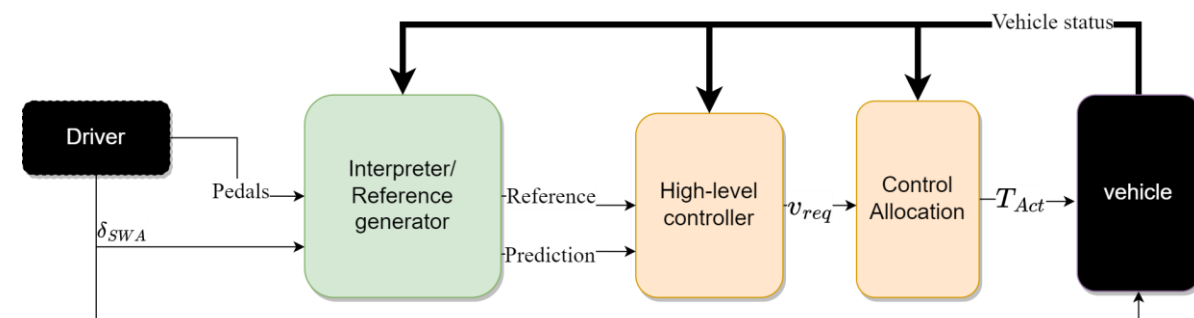


Yaw rate for acceleration during cornering. At 10s, switch in power distribution between e-axes introduce a yaw moment on the vehicle.



Steering wheel angle while accelerating during cornering. At 20s, step increase in speed causing different distributions of power to behave differently.

## Our Solution



- MPC based approach to generate  $v$  to the control allocator
- Control allocator distributing global force to actuator level
- Interpretation of driver's input to generate references
- Rate of change for steering wheel angle and yaw rate
- Yaw rate controller based on bicycle model

# ON TORQUE VECTORING TO IMPROVE STEERING PREDICTABILITY WHILE MINIMISING POWER LOSS IN HEAVY ELECTRIC VEHICLES USING MODEL PREDICTIVE CONTROL

Jonas Persson and Jonathan Åkesson

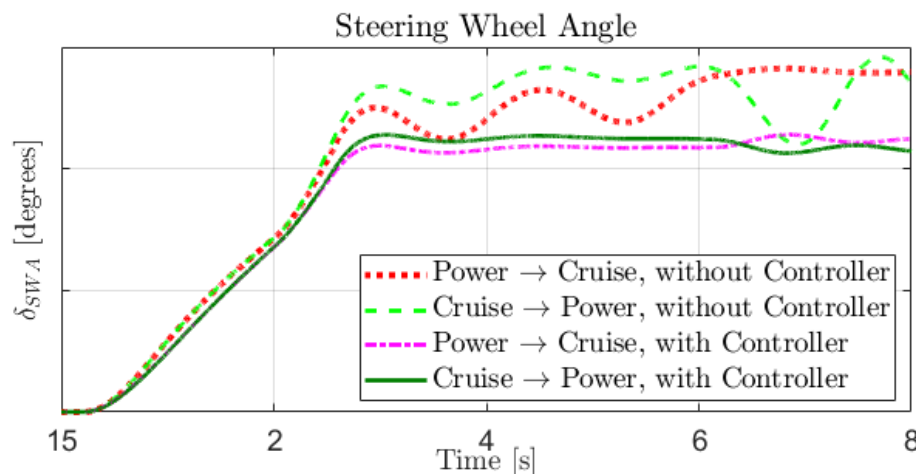
Department of Mechanics and Maritime Sciences  
Chalmers University of Technology



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY

**V O L V O**

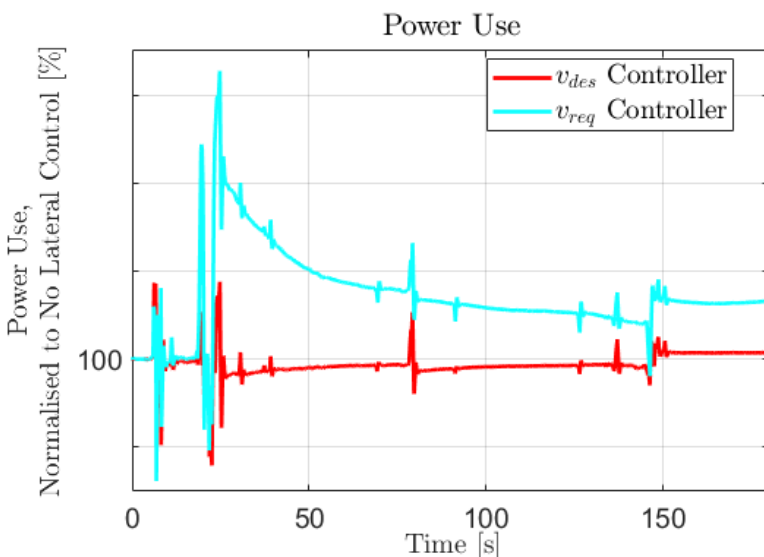
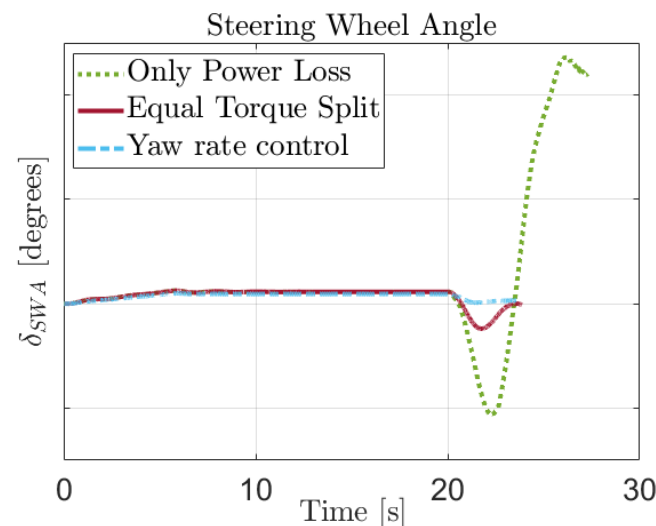
## Predictable steering behaviour with Torque Vectoring



Steering wheel angle for emergency braking during cornering. Yaw rate controller aids in lateral stability, resulting in:

- less lateral sway,
- shorter braking distance
- and a more manageable manoeuvre for the driver.

Switch in propulsion mode during steady state cornering. Yaw rate controller aids the driver in lateral stability during mode switch.



- Short haul driving simulation, road from Hällered to Alingsås (approx. 2.8 km).
- Lateral control reduce degrees of freedom and restricts power loss optimisation.
- A second controller ( $v_{des}$ ) constructed to only engage when necessary, resulting in lower power use compared to previously.

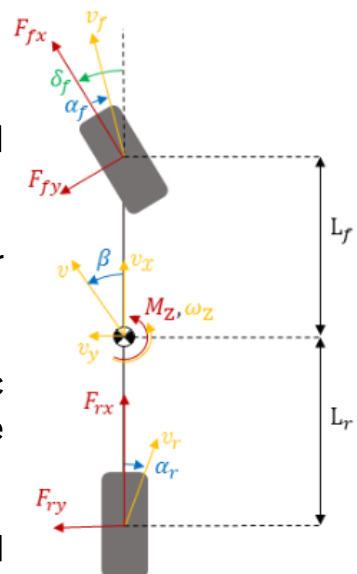
## The Model

$$\dot{x} = Ax + Bu + C\delta_f + D \quad \min_z \quad \frac{1}{2}z^T H z + g^T z$$

$$\text{s.t.} \quad A_{eq} \cdot z = b_{eq} \quad A_{in} \cdot z \leq b_{in}$$

$$x = \begin{bmatrix} \dot{v}_x \\ v_x \\ \omega_z \\ \beta \end{bmatrix} \quad u = \begin{bmatrix} T_{fl} \\ T_{fr} \\ T_{rl} \\ T_{rr} \end{bmatrix} \quad z = \begin{bmatrix} x \\ u \end{bmatrix}$$

- MPC evolves the linear model over a time horizon.
- Single track model with linear tyre dynamics for yaw control.
- MPC solves quadratic optimisation to find the optimal control sequence  $u^*$ .
- Steering angle and external forces are treated as disturbances.



## Conclusion

Lateral control using torque vectoring on heavy vehicles allows for:

- reduced braking distance during cornering;
- increased stability on low friction surfaces;
- reduced steering compensation from driver during emergency manoeuvres;
- and minimised change in vehicle behaviour, originating from power loss optimisation.

All this, with minimal increase in power use.

Poster 3:

***Continuously controlled damping tuning on  
four poster rig***

Jesper Ramsberg, VCC & Chalmers





# Development of method for objective tuning of semi active dampers on a four poster rig

Jesper Ramsberg

Supervisor: Ajay Daniel, Volvo Cars, Examiner: Fredrik Bruzelius, Chalmers

Chalmers University of Technology & Volvo Cars, Göteborg

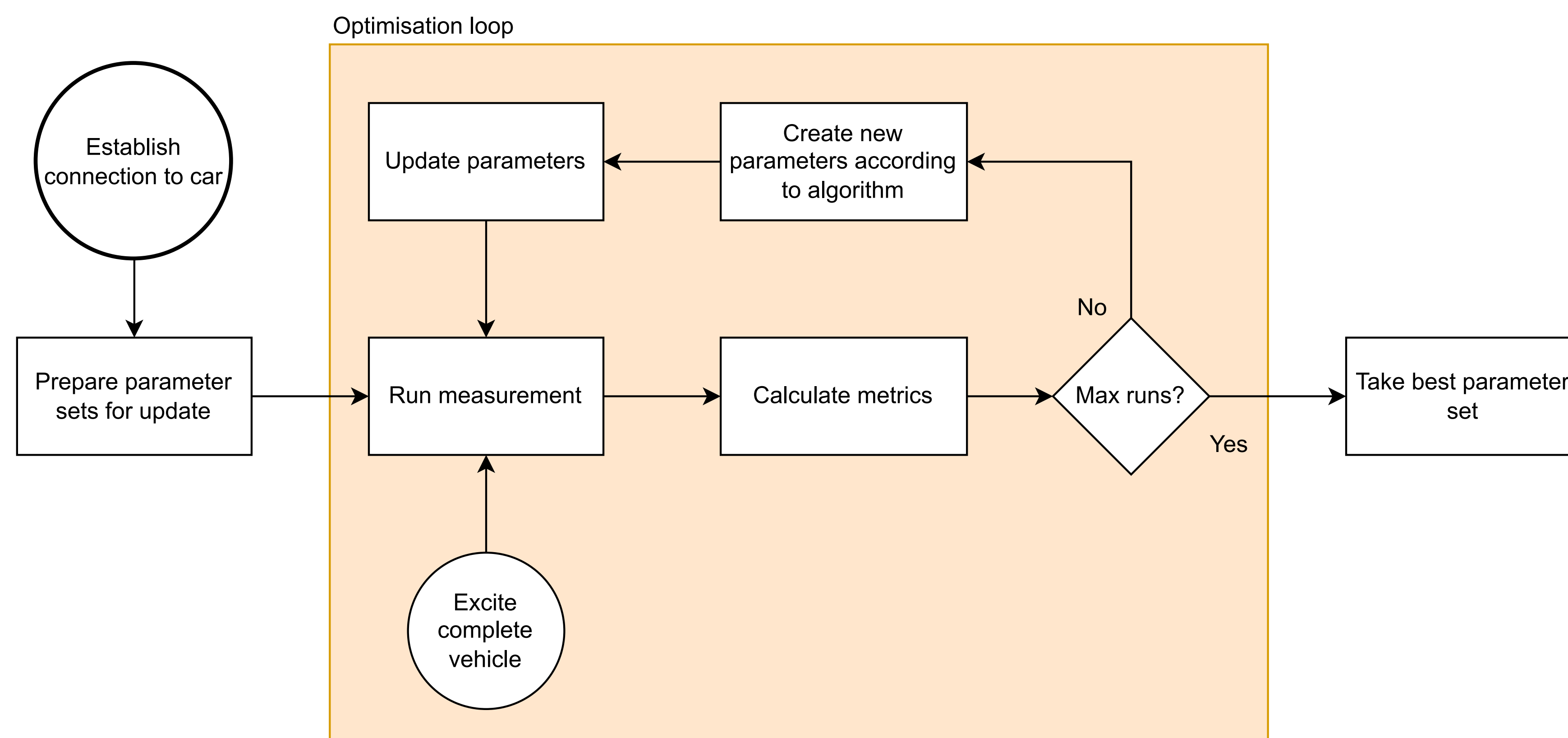


Figure 1: On rig optimisation loop

## Introduction

- Active systems in passenger vehicles can improve comfort without comprising as much in handling as could have been traditionally required.
- Semi active dampers, sometimes called CCD, can improve ride quality and comfort while maintaining good handling characteristics
- CCD is often tuned by experienced vehicle dynamicists that can subjectively interpret the vehicle behavior and understand the measured data.
- An objective method for CCD tuning could complement the subjective tuning to achieve an overall better result.
- A four poster rig is useful when repeatedly exciting a complete vehicle.
- Combining subjective judgement with objective measurement on the rig can be a useful tool for creating damper settings

- An optimisation was setup with the new metric in combination with and abruptness metric
- Genetic algorithm was used in CAE
- Patternsearch was used on the rig
- A complete vehicle with CCD was setup in the optimisation loop



Figure 3: Vehicle setup on rig for optimisation

## What has been done

- Initially a primary ride metric suitable for CCD was found
- Metric was validated on four poster rig in a blind study.
- Experienced vehicle dynamicists took part in the study

- The vehicle is excited continuously with a realistic recorded road
- A computer was connected to the ECU controlling the CCD and updating the controller according to the algorithm.

## Results and further work

- A good metric for primary ride control was found in  $\text{Primary ride control} = \frac{\text{RMS}(V_{\text{body}})}{\text{RMS}(V_{\text{Road}})}$
- Metric has clear trend between control and the amount of damping
- A solid optimisation method on the rig updated the damper parameters in an effective way.
- A blind test done on track proved that the optimisation had effect on the damper settings
- The cost function must be tuned well to achieve desirable results from the optimisation, a good balance between primary ride control and abruptness. Or extended with more ride properties to cover the broader spectrum of ride comfort

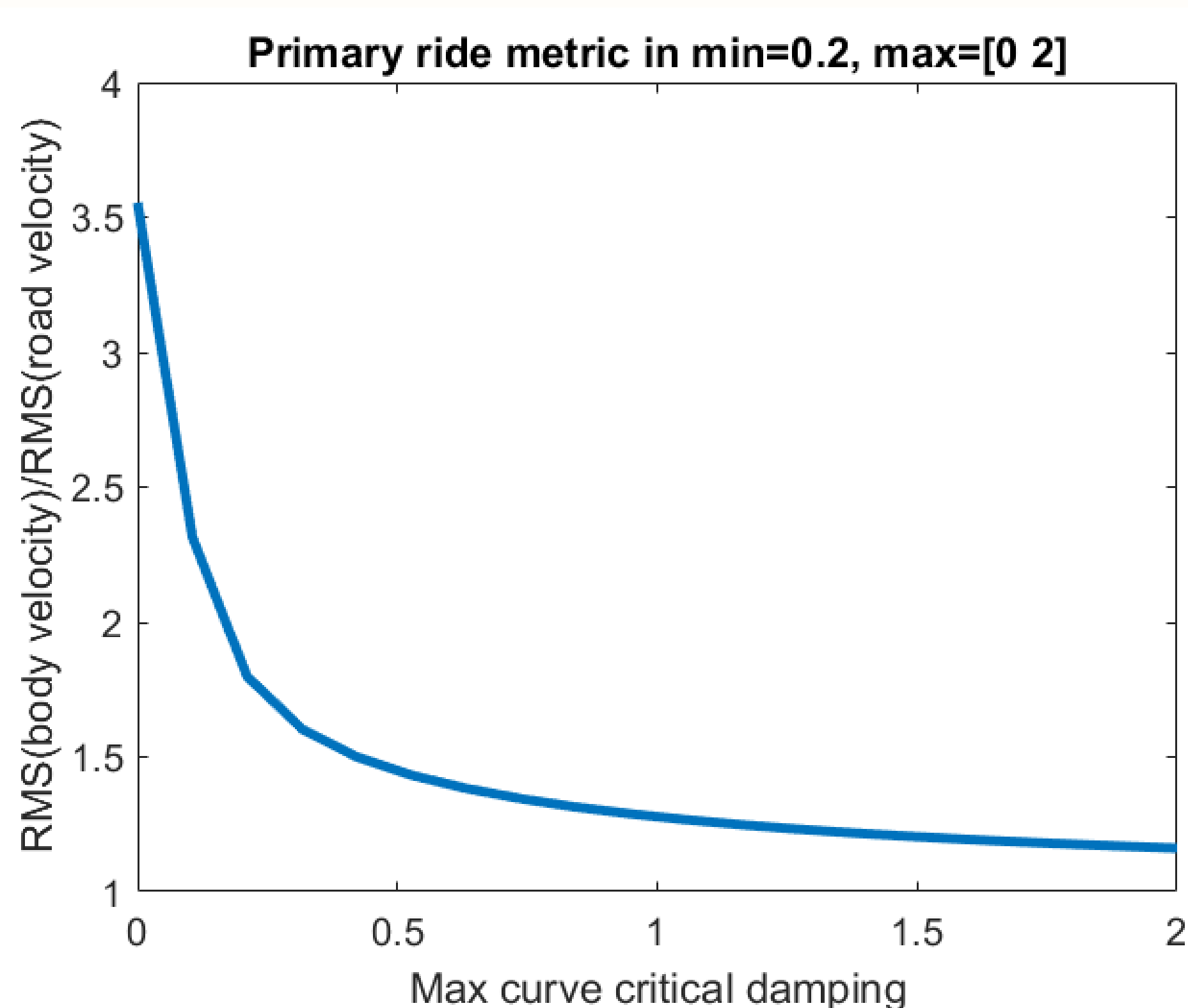


Figure 2: Relation between critical damping and primary ride



Poster 4:

***Optimised force distribution algorithm and  
model***

Guglielmo Nappi and Sanjay Banerjee, Scania &  
KTH



Sanjay & Guglielmo

# Optimised force distribution algorithm and model

# Thesis topic and model overview



## Aim:

Deliver a proven auto-generated vehicle model, limited to longitudinal and lateral forces inputs to solve the optimal force distribution between available force actuators and predict body dynamics.

## Model characteristics:

**Reconfigurable:** The model is auto-generated from the available variant codes for the vehicles.

**Prediction model:** The model is valid and estimates accurately the body dynamics in longitudinal and lateral motion.

**Dynamic model:** Not limited to kinematic approximations as it includes forces in input.

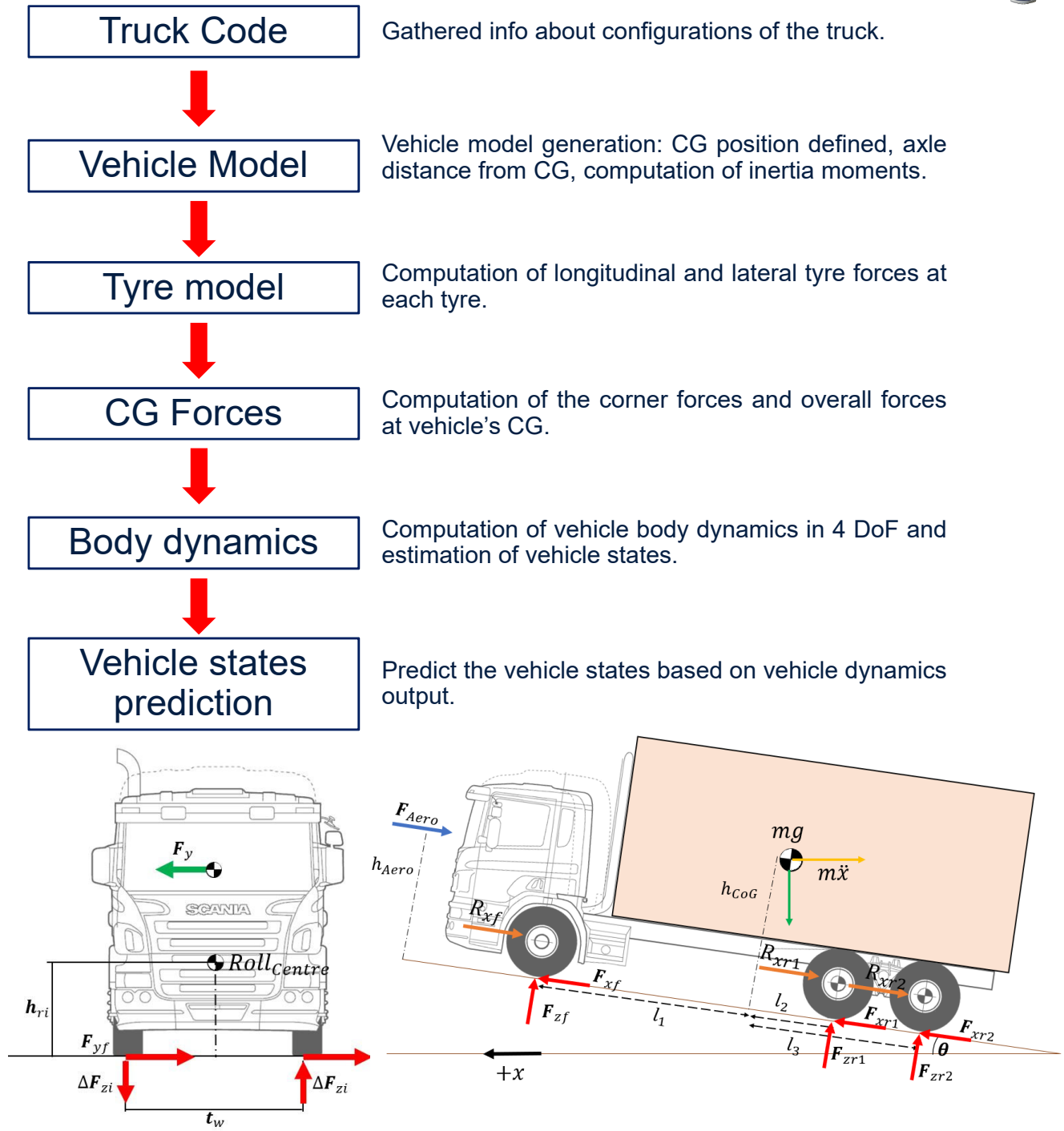
**Controllable:** Includes requested force from the driver.

## Test Procedure:

- Isolated **longitudinal** dynamics manoeuvre
- Isolated **lateral** dynamics manoeuvres
- **Combined** longitudinal and lateral dynamics
- Hill climbs

## Software used:

Vehicle modelling based on Simulink with MATLAB 2020b scripts.



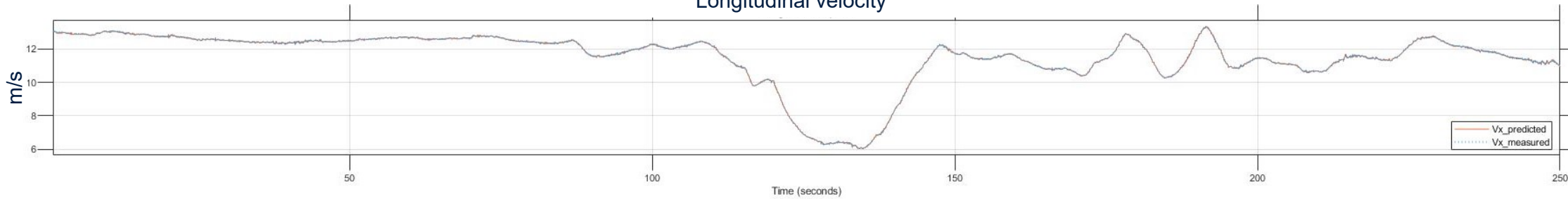


# Test procedure and results

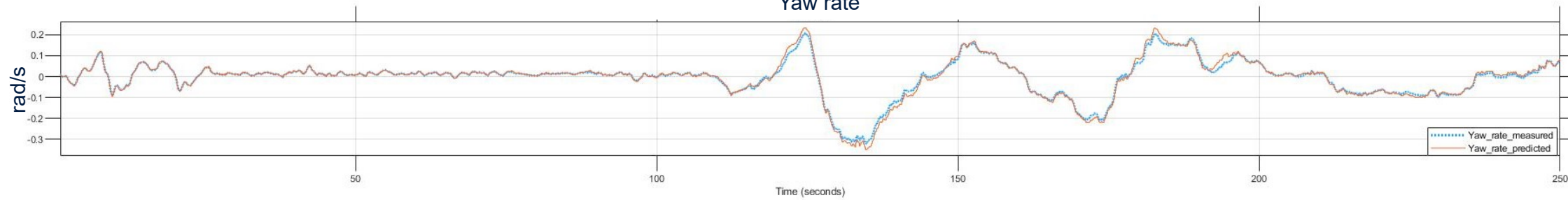


— Measured parameter  
— Estimated parameter

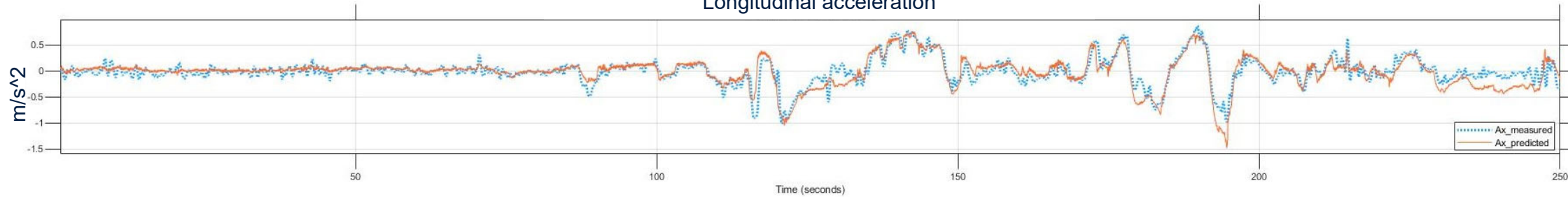
Longitudinal velocity



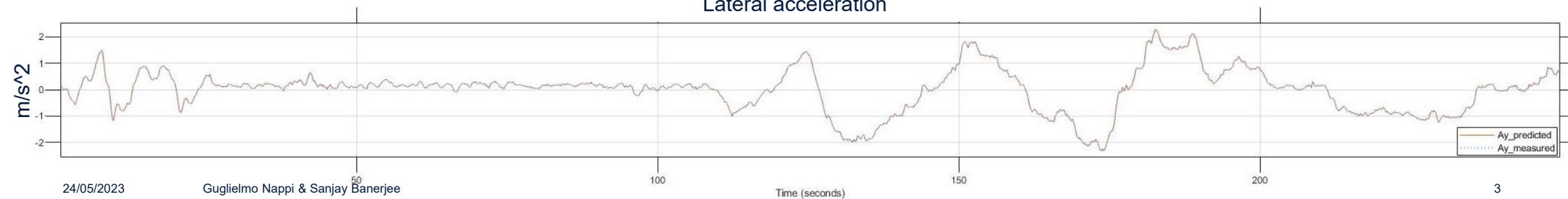
Yaw rate



Longitudinal acceleration



Lateral acceleration



Poster 5:

***Modelling and measurements of singularity-  
induced vehicle motion during low-speed  
driving***

Luca Mereu, Politecnico di Torino & Chalmers



# Modelling and measurements of singularity-induced vehicle motion during low-speed driving

LUCA MEREU

CHALMERS UNIVERSITY OF TECHNOLOGY

Supervisor: Mats Jonasson, VEAS, M2

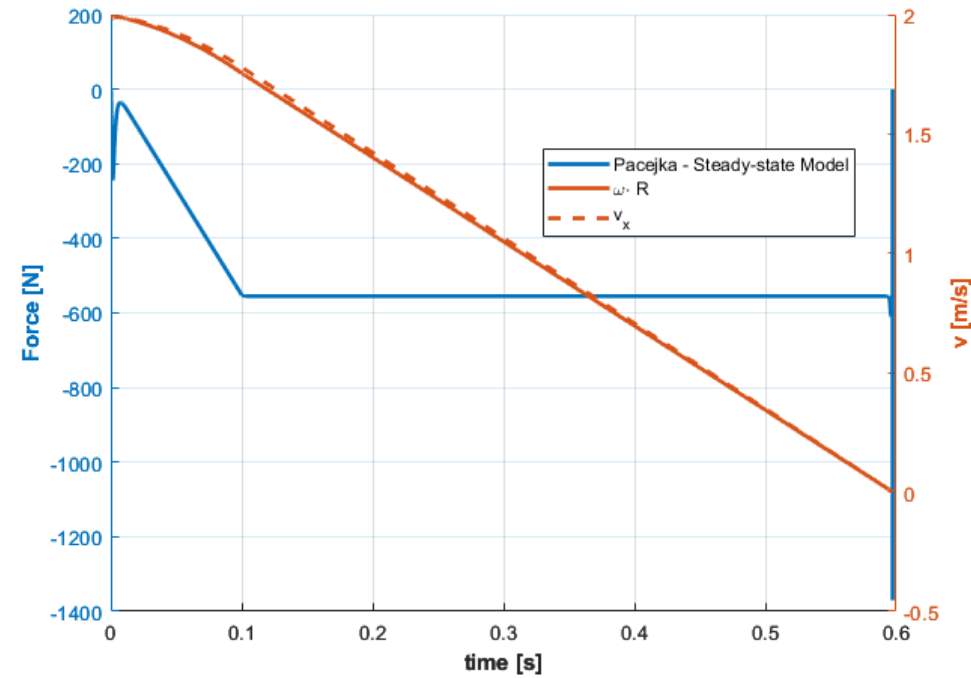
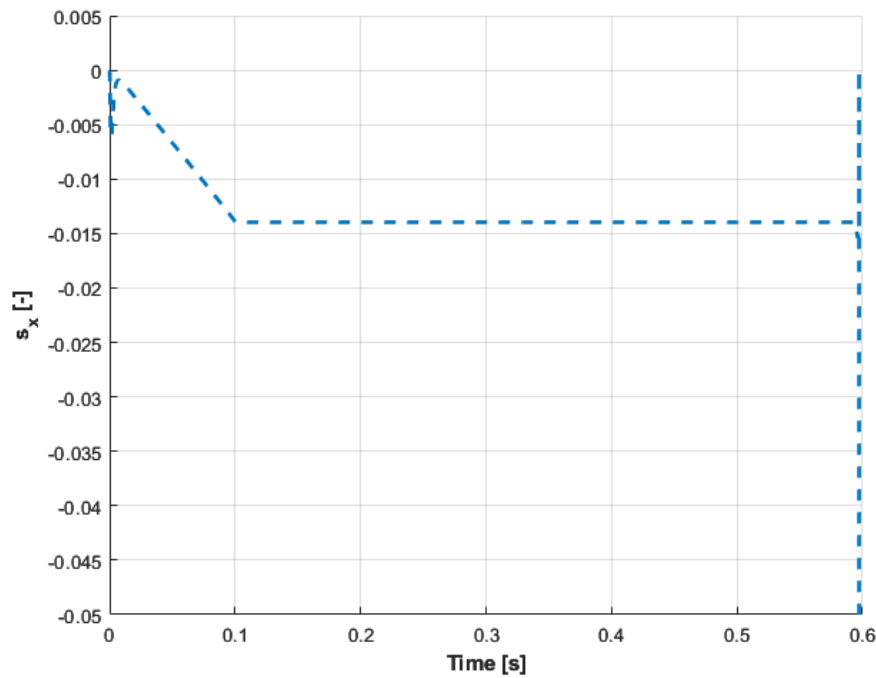
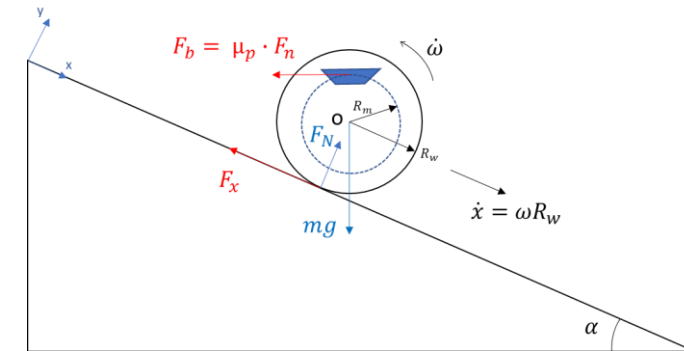
Examiner: Petri Piiroinen, Division of Dynamics, M2

# Background and problems

## slip variable

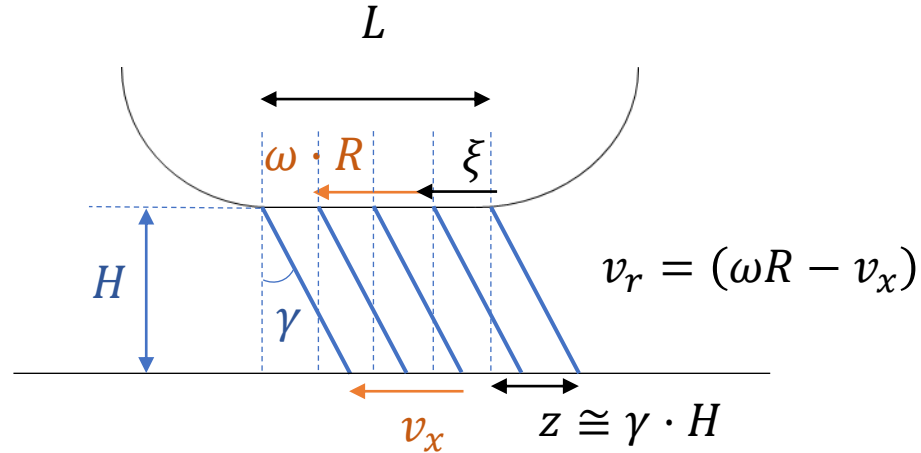
$$s_x = \frac{\omega \cdot R - v_x}{|\omega \cdot R|} \longrightarrow F_x = D \cdot \sin(C \cdot \tan^{-1}(B \cdot (1 - E)) \cdot s_x + E \cdot \tan^{-1}(B \cdot s_x)))$$

What happen when  $\omega \cdot R$  is close to 0?





# LuGre Distributed Tyre Model

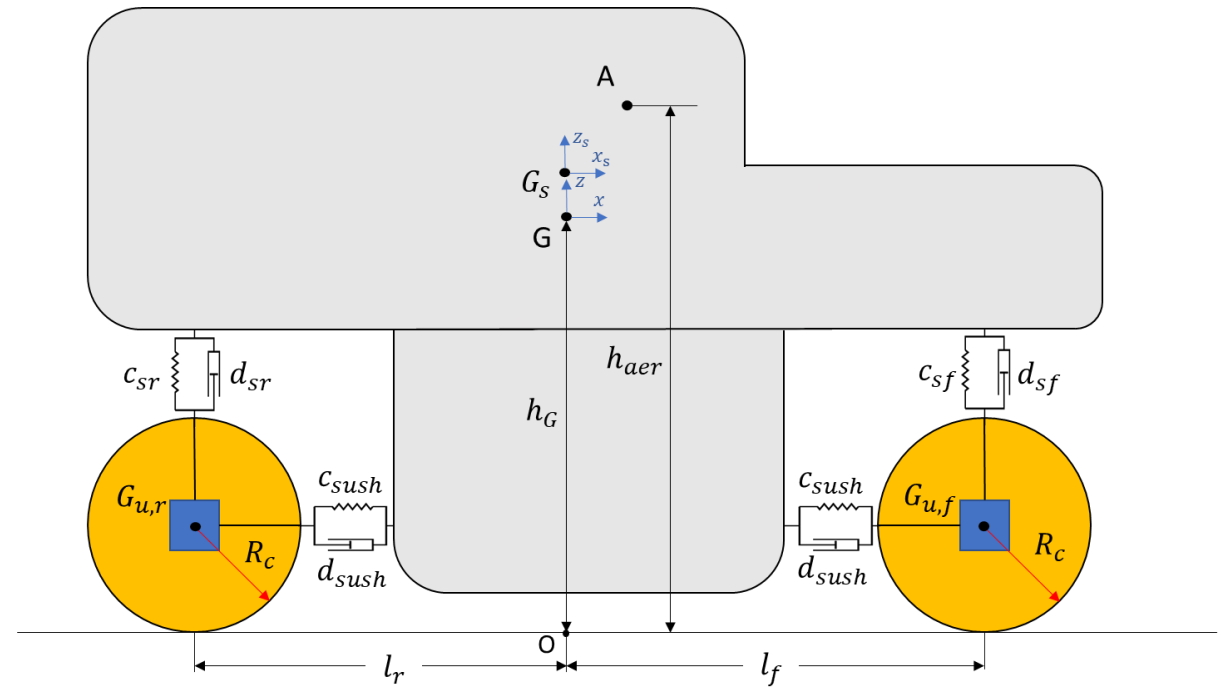


$$F_x = \sum_{i=1}^N \mu(v_r(t), N) \cdot p(N) \cdot \Delta \xi$$

With  $p(\xi)$  being the load distribution within the contact patch.

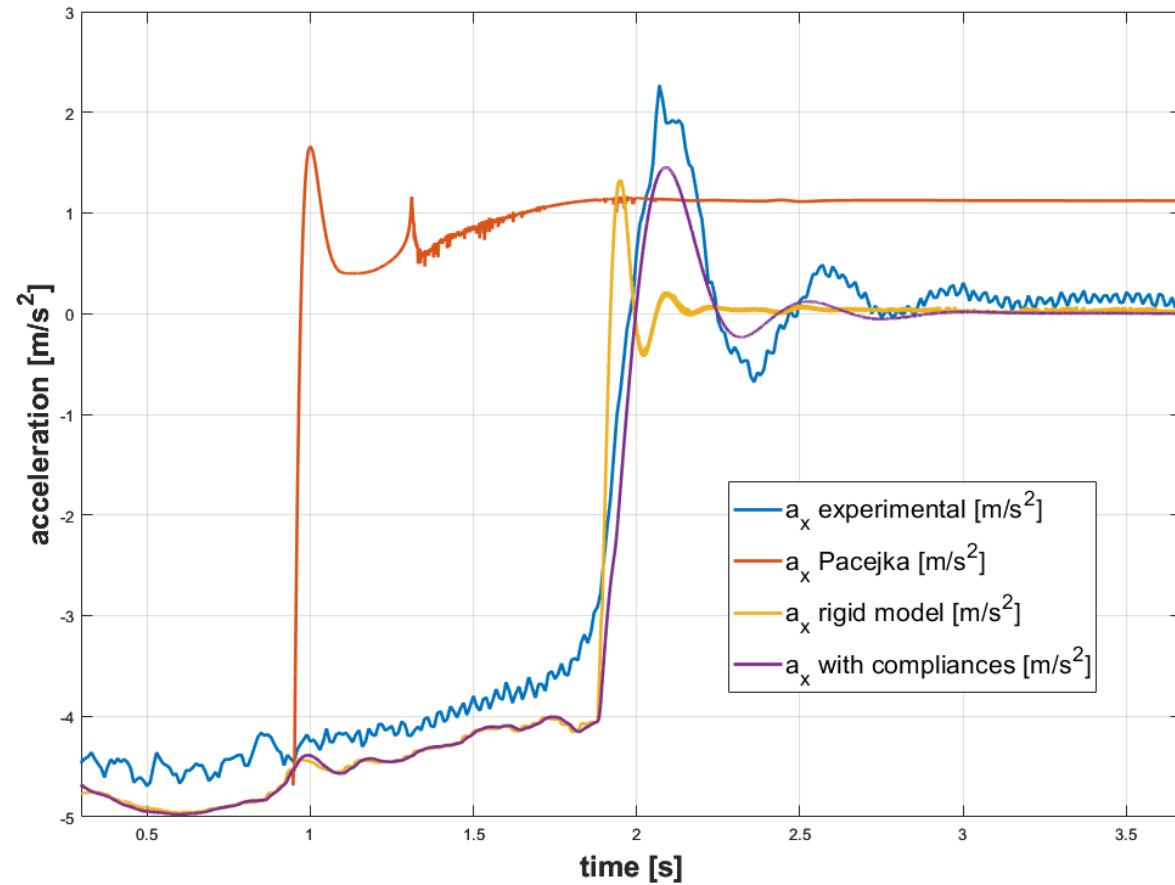
The friction term  $\mu(v_r(t), \xi)$  takes into account the bristles deflection behaviour.

The LuGre friction model is implemented in a complete longitudinal vehicle model to capture and compare the acceleration behaviour of a real car braking manoeuvre.

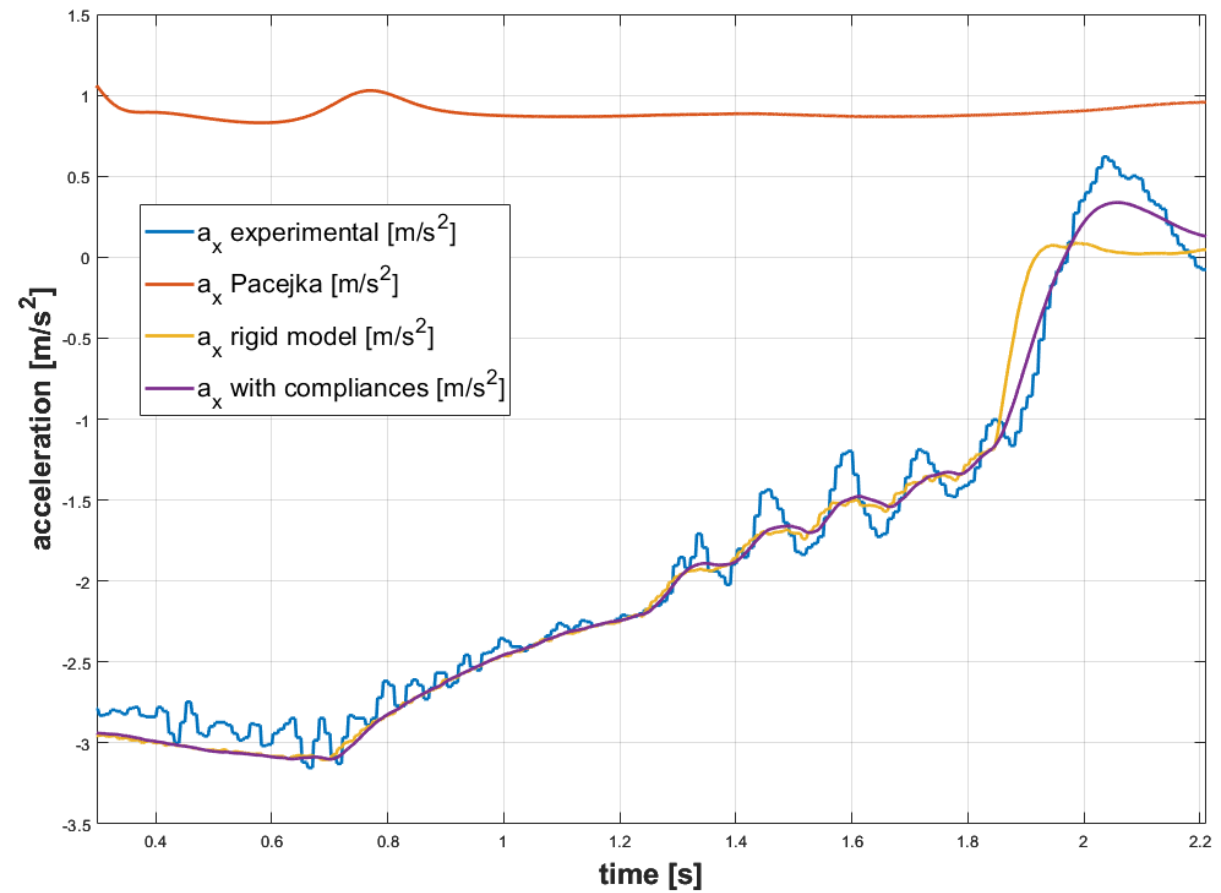


# Vehicle model results

## Braking on asphalt



## Braking on ice



For the classic model, the slip has been modified to run at zero speed.

$$s_x = \frac{\omega \cdot R - v_x}{\max(|\omega \cdot R|, 0.1)}$$



Thanks for your attention

LUCA MEREU

CHALMERS UNIVERSITY OF TECHNOLOGY

Supervisor: Mats Jonasson, VEAS, M2

Examiner: Petri Piiroinen, Division of Dynamics, M2



# Modelling and measurements of singularity-induced vehicle motion during low-speed driving

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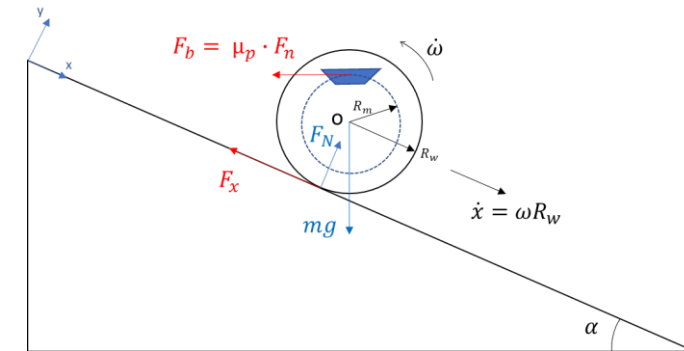


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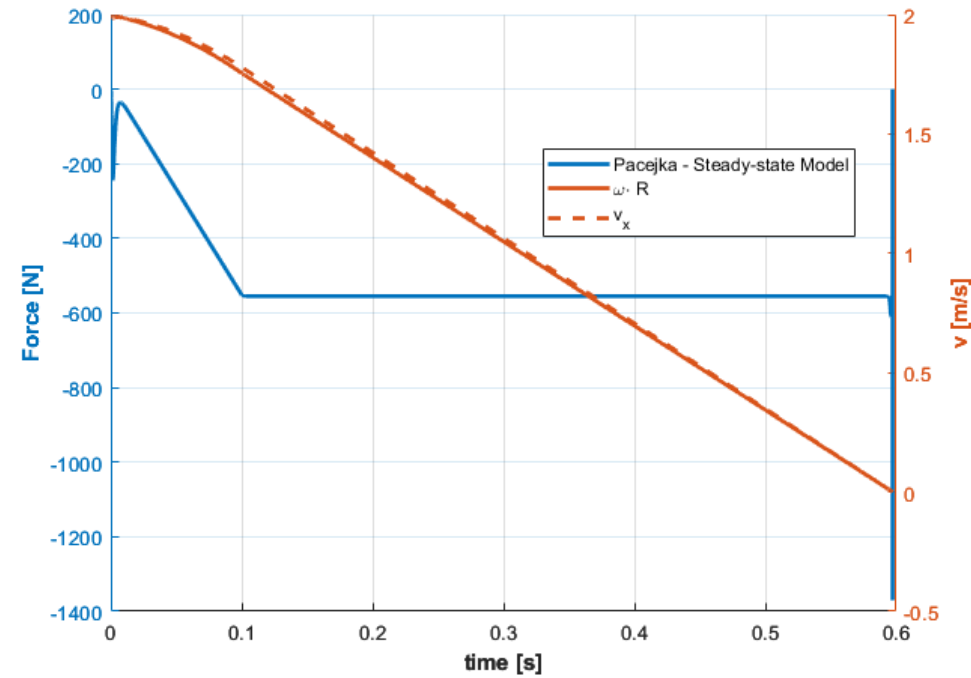
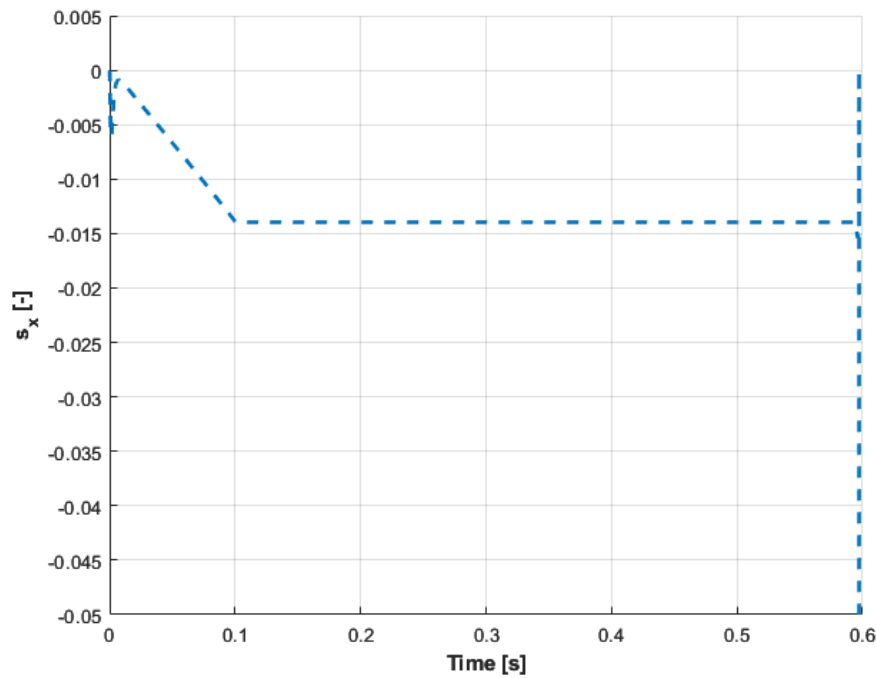
## slip variable

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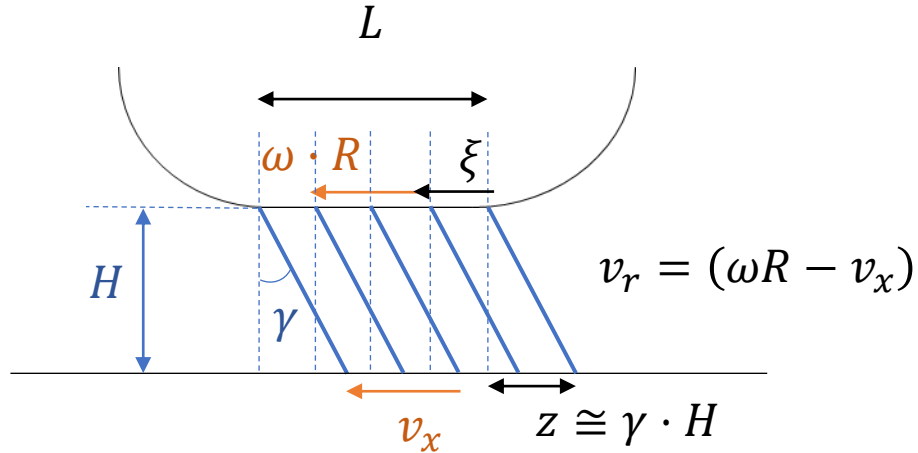
## Classic (Pacejka) force models



What happen when  $\omega \cdot R$  is close to 0?



# LuGre Distributed Tyre Model

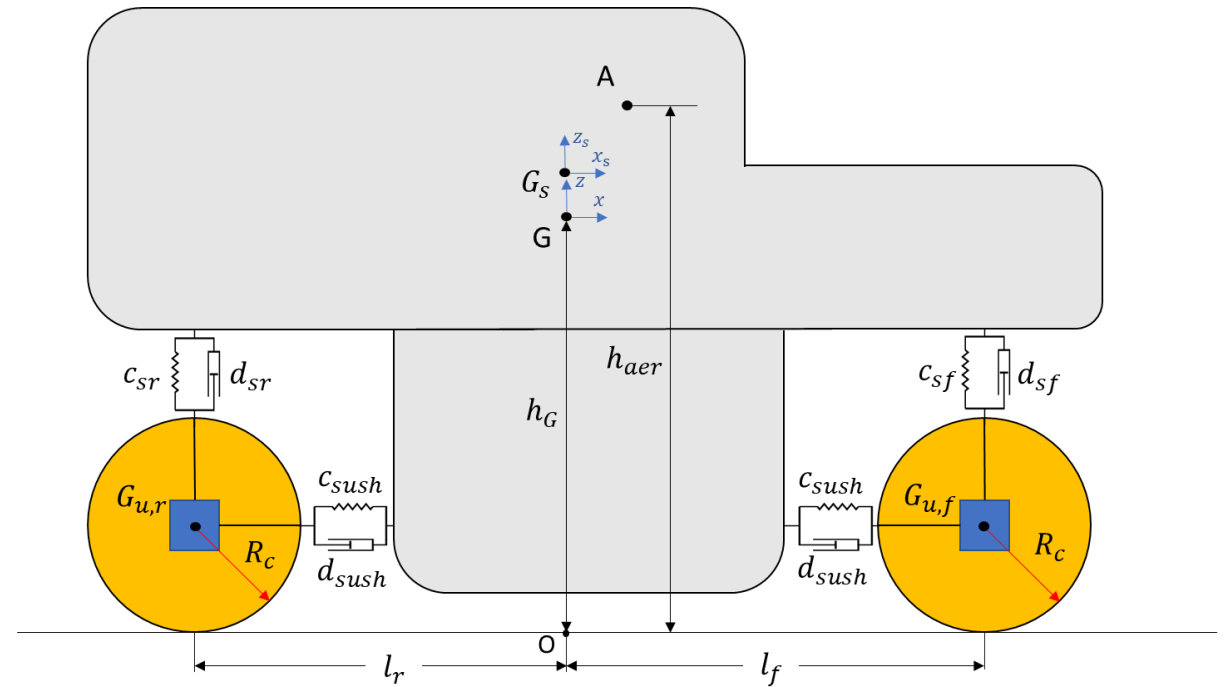


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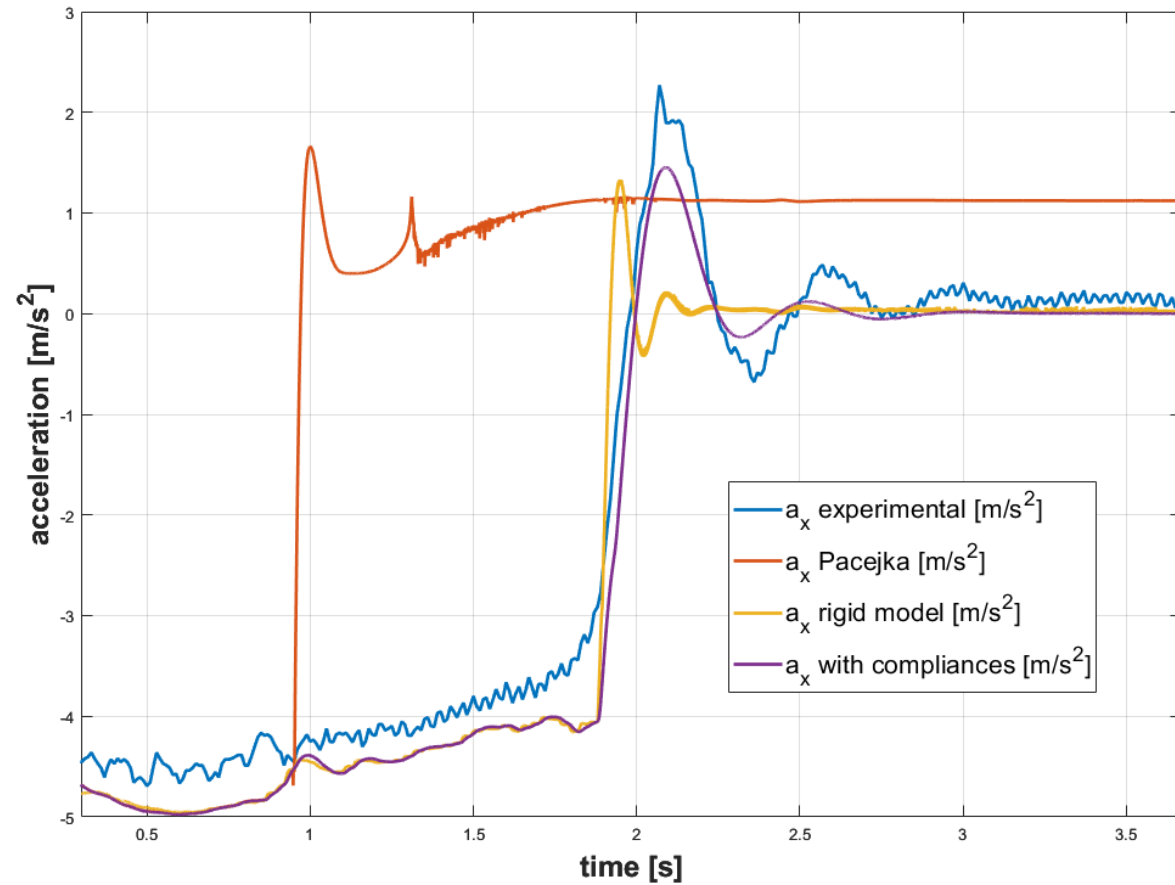
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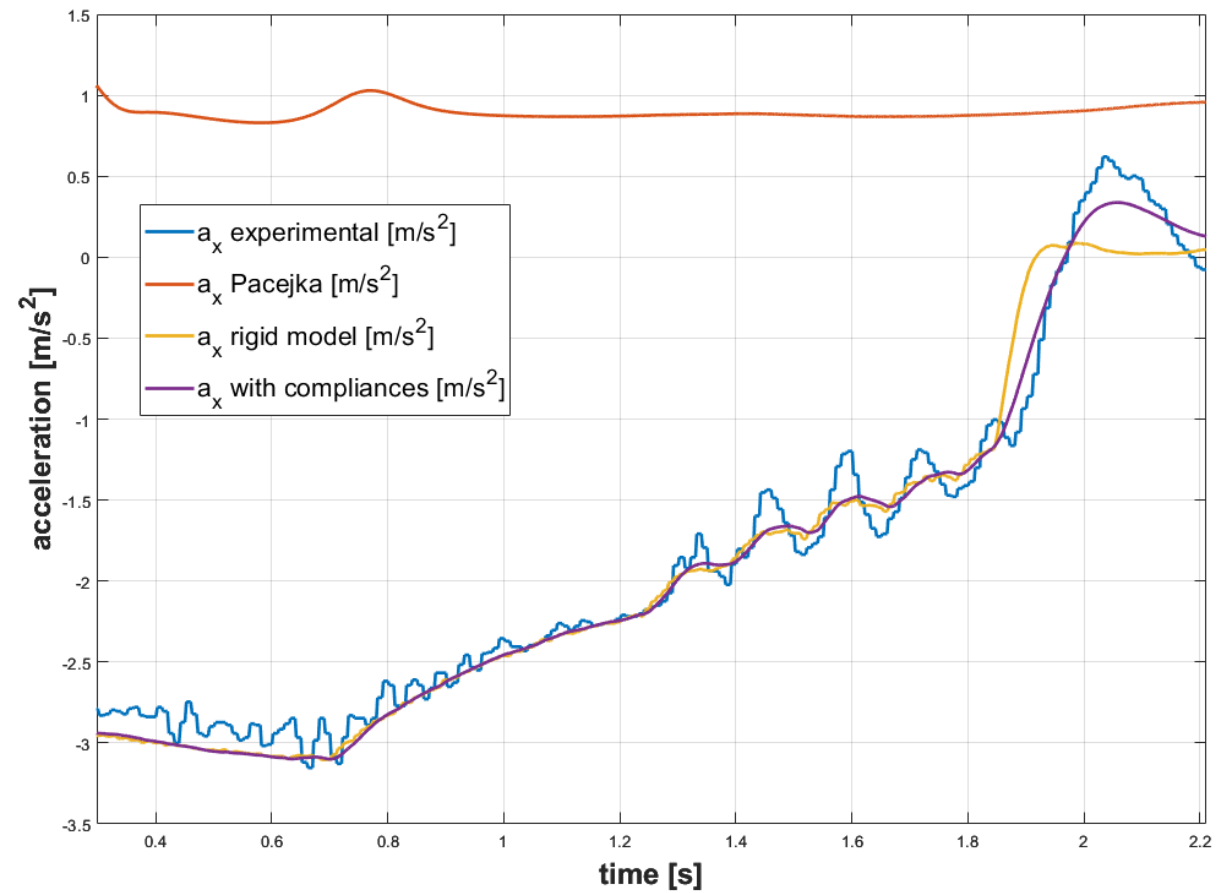


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