VDCA Swedish Vehicle Dynamics Competence Area

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/).

VDCA Swedish Vehicle Dynamics Competence Area

a workgroup in

SVEA SWEDISH VEHICULAR ENGINEERING ASSOCIATION

SVERIGES FORDONSTEKNISKA FÖRENING

member of

FISITA

Contents

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	**Coffee and registration**	
09:40-09:50	**Welcome**	Ingemar Johansson (SVEA), Bengt Jacobson (VDCA), Håkan Andersson (AstaZero)
09:50-11:30	**Session 1:** Presentations (20+10 min each):	
	1. Development of frame test rig with MBS simulations	Joakim Eriksson, Scania
	2. Vehicle dynamics testing in a moving-base driving simulator	Sogol Kharrazi, VTI
	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
	Micro presentations of posters (3 min each):	
	Quantify and mimic the feedback through the steering wheel at some driving conditions	Aron Dalemo, Polestar & Chalmers
	Using torque vectoring to improve steering predictability while minimizing energy use in Heavy electric vehicles	Jonas Persson Jonathan Åkesson, Volvo Trucks & Chalmers
11:30-12:30	**Demo tour**	
	4. *AstaZero tracks.* Starts with small presentation, then we join in a bus to go out to the tracks.	Håkan Andersson (AstaZero)
12:30-13:30	**Light lunch** with networking and poster discussion	

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

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 or Bengt Jacobson 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

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

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**

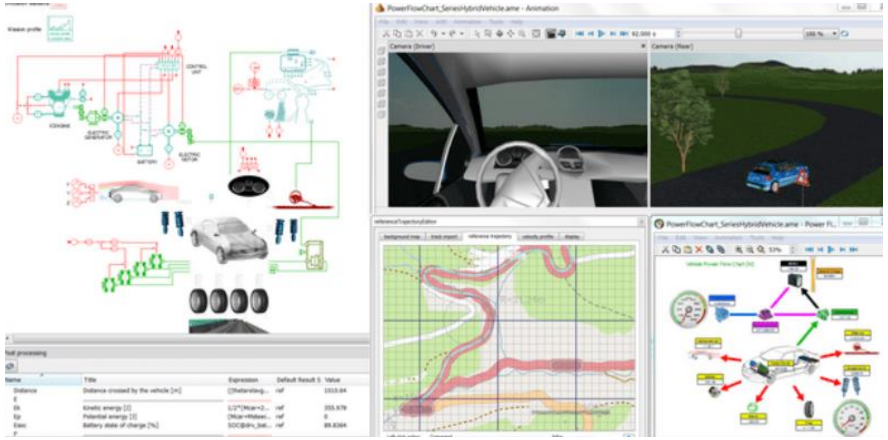
Chair of the Board SVEA

Thank you to AstaZero for hosting the seminar.

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

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**

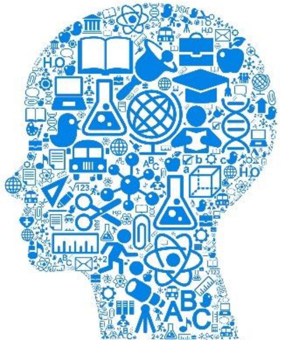


VDCA - Swedish Vehicle Dynamics Competence Area

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

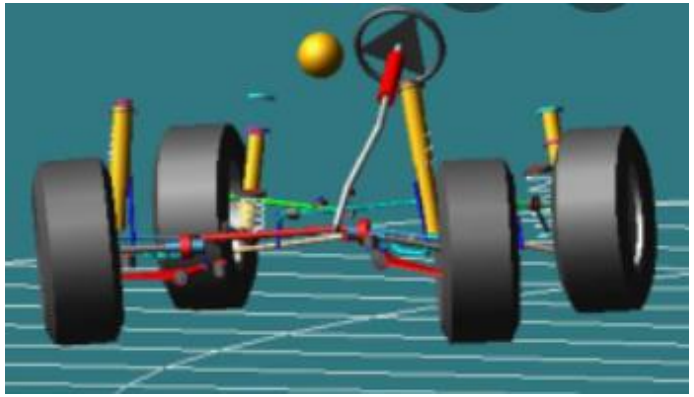
VDCA is since last year a working group within SVEA

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 Bengt Jacobson Håkan Andersson	SVEA VDCA & Chalmers AstaZero
09:50	**11:30**		**Session 1 Presentations (20+10 min each)**		
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 Benjamin Minshaw	Colmis
			Session 1 Posters (3 min each)		
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 Jonathan Åkesson	Volvo Trucks & Chalmers
11:26	11:29				
11:30	**12:30**		**Demo Tour AstaZero test facility**		
		4	AstaZero tracks. Short presentation	Håkan Andersson	AstaZero
			Bus tour test facitility		
12:30	**13:30**		**Light lunch with networking and poster discussion**		

Agenda

13:30	**14:45**		**Session 2: Presentations (20+10 min each)**		
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
			Session 2 Posters (3 min each)		
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 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
14:45	**15:15**		**Coffee with networking and poster discussion**		
15:15	**16:15**		**Session 3: Presentations (20+10 min each)**		
15:15	15:45	7	Tyres and the purposes of models	Edo Drenth 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		
16:15	**16:30**		**Wrap-up**		
			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

Agenda

Introduction

Background

Simulations contribution

Timeline

Result

Summary

Introduction

Name: Joakim Eriksson

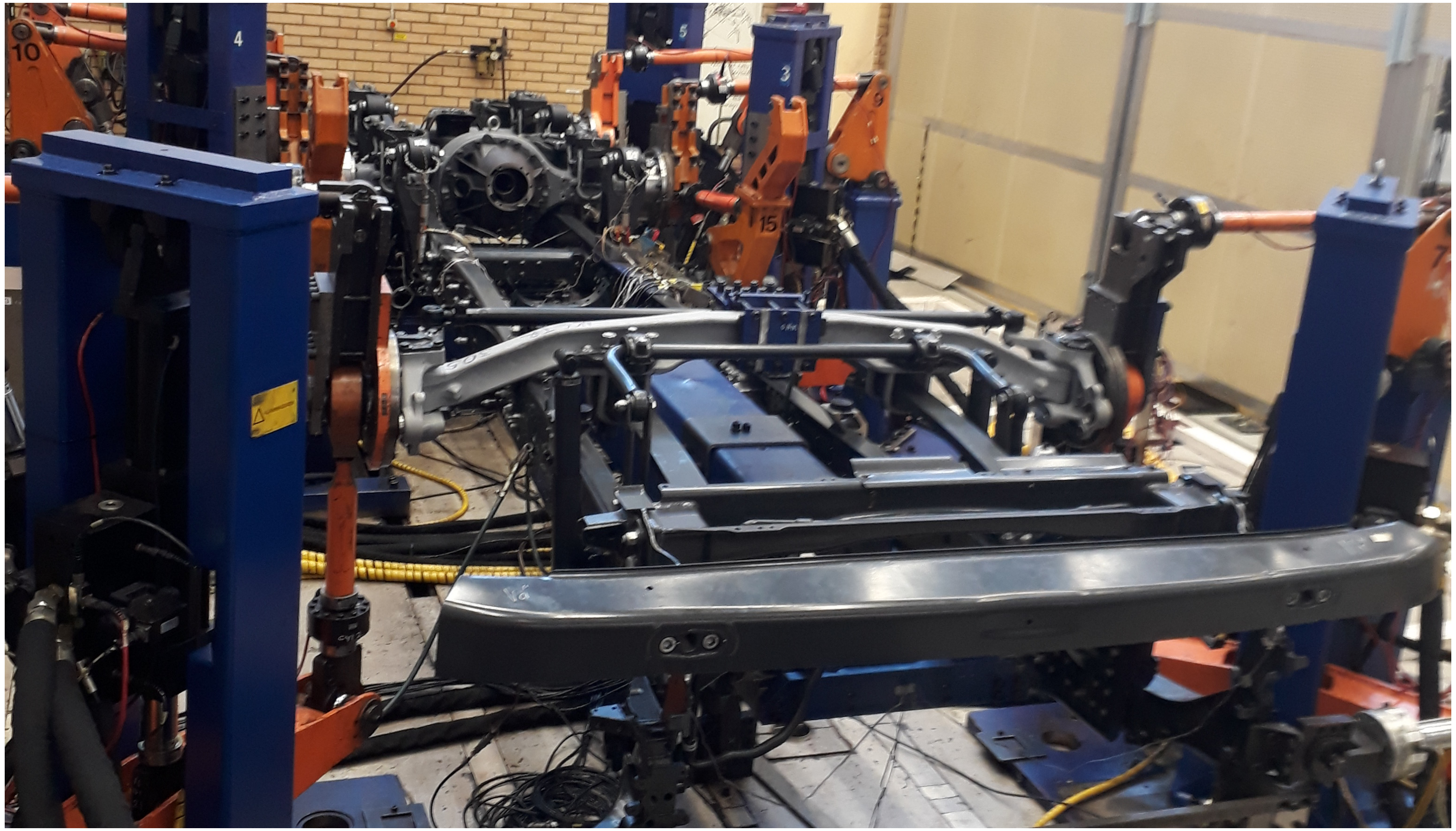
Working experience: 10 years at Scania

Position: Calculation engineer at truck chassis department

Background: Engineering Physics at Umeå University

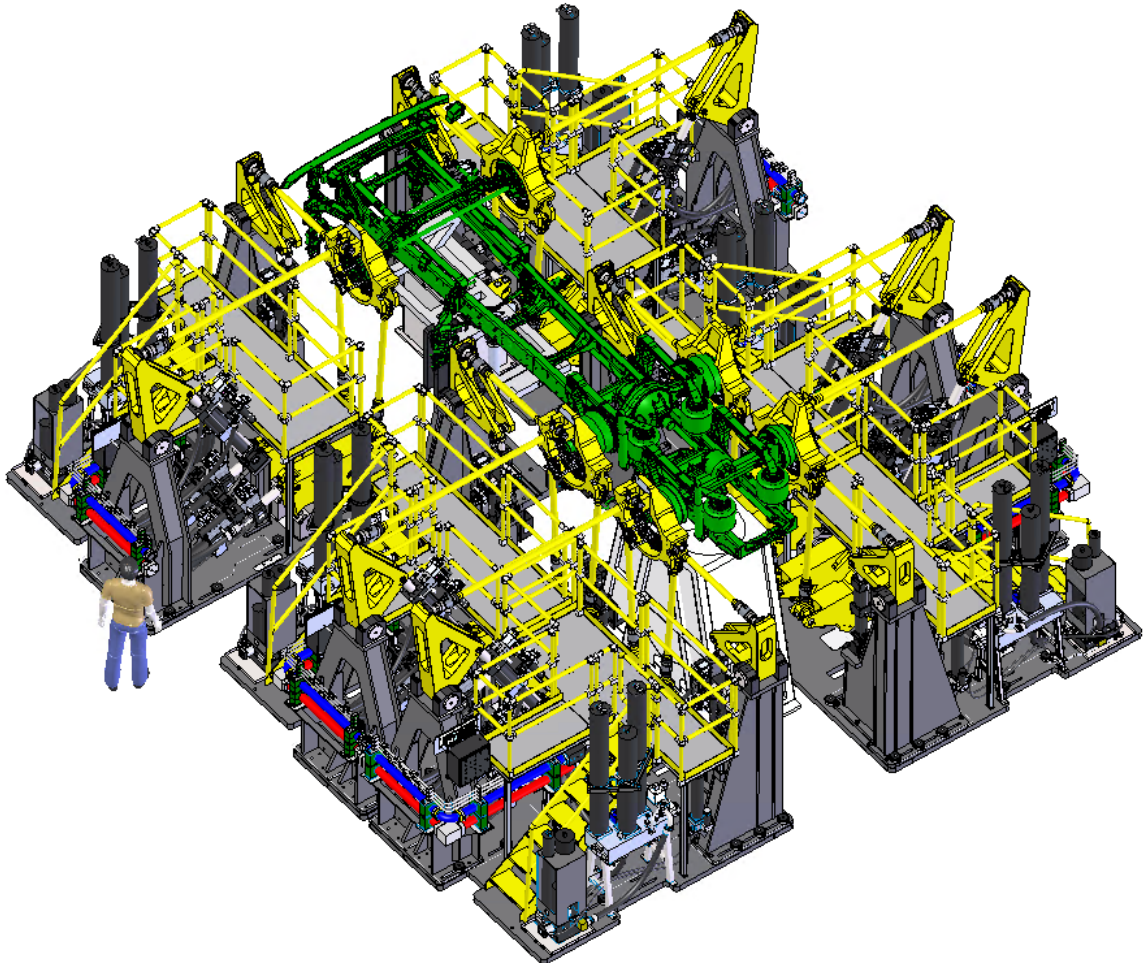
Background

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

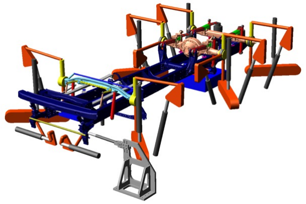


MBS contribution to frame rig development

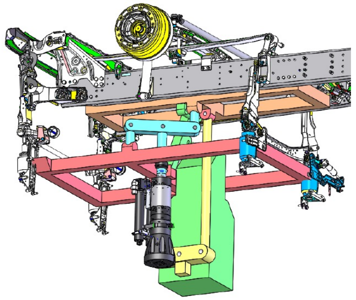
- Obtain loads from full vehicle simulations
- Evaluate and rank different concepts for boundary conditions
- Loads & durability of rig components
- Dimensioning of struts & cylinders
- Geometry assurance
- Strategies for obtaining drive signals & editing test track measurements



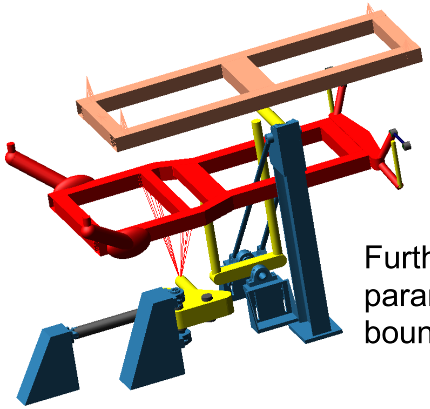
Timeline



Virtual frame rig R25 – verification and method development

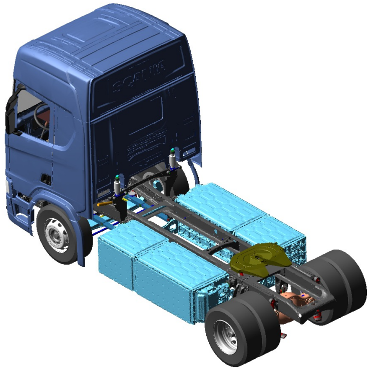


Simulation of initial concept from MTS

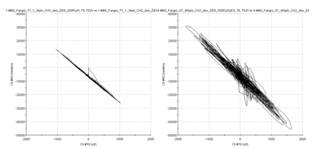


Further development & parameter study of front boundary conditions

Full vehicle simulations with BEV tractor



Virtual strain gauge measurements on BEV components

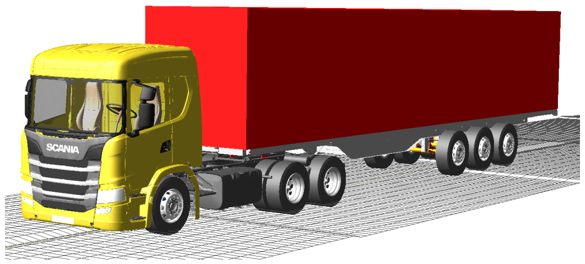


2018

2019

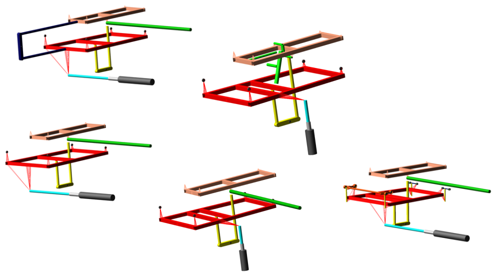
2020

Full vehicle simulations of long haulage test schedule with 6x2 tractor

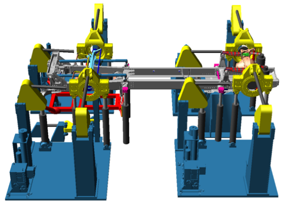


Full vehicle simulations of construction test schedule with 8x4 tipper

8 different concepts for front boundary conditions

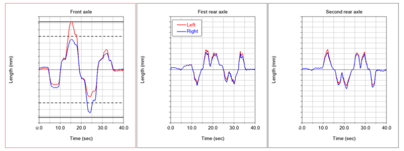


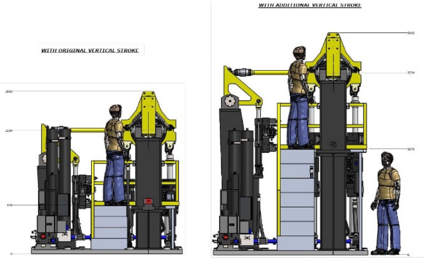
Different concepts for BEV boundary conditions



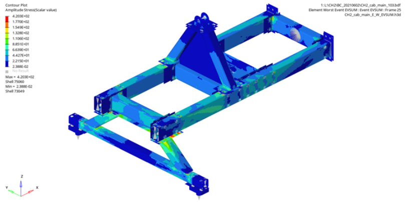
Timeline

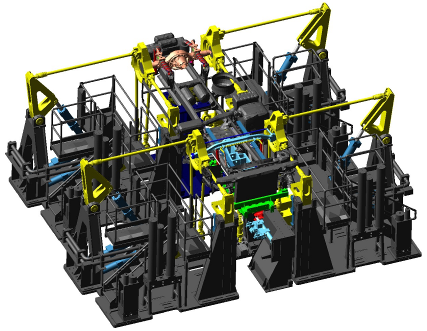
Investigation of increased motion and force demands for construction obstacles

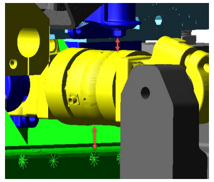




Validation of the boundary conditions together with rig design







Clearance calculations

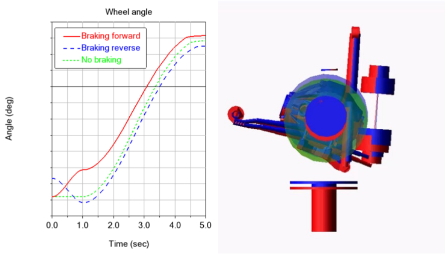
First simulation with measured BEV signals in CH2 ahead of first physical test

2020

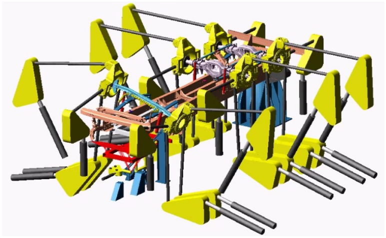
2021

2022

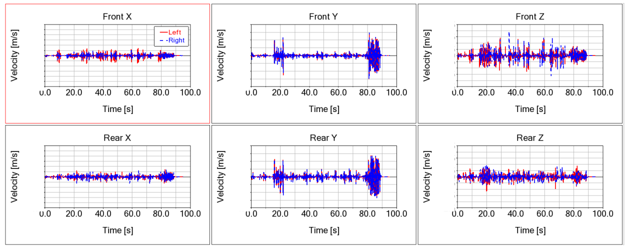
Wheel angle requirements investigation



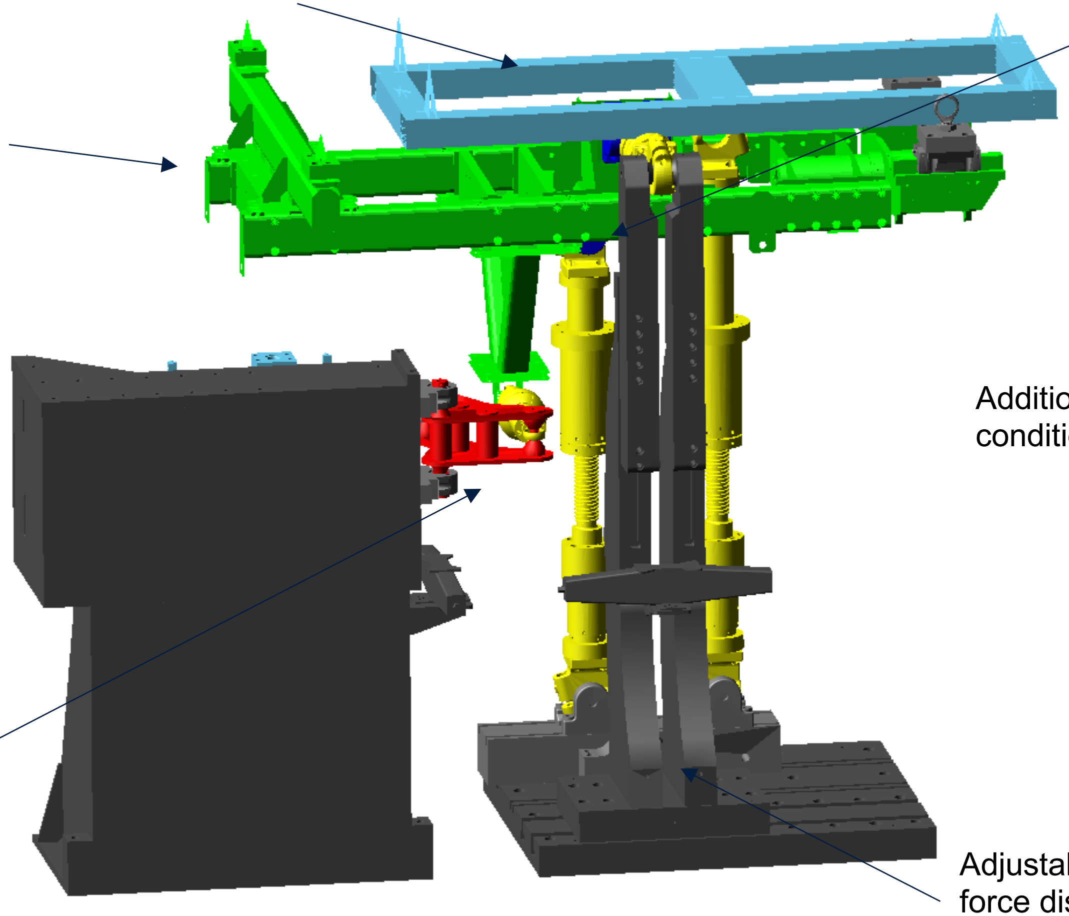
Validation of new corner module concept with increased displacement capabilities

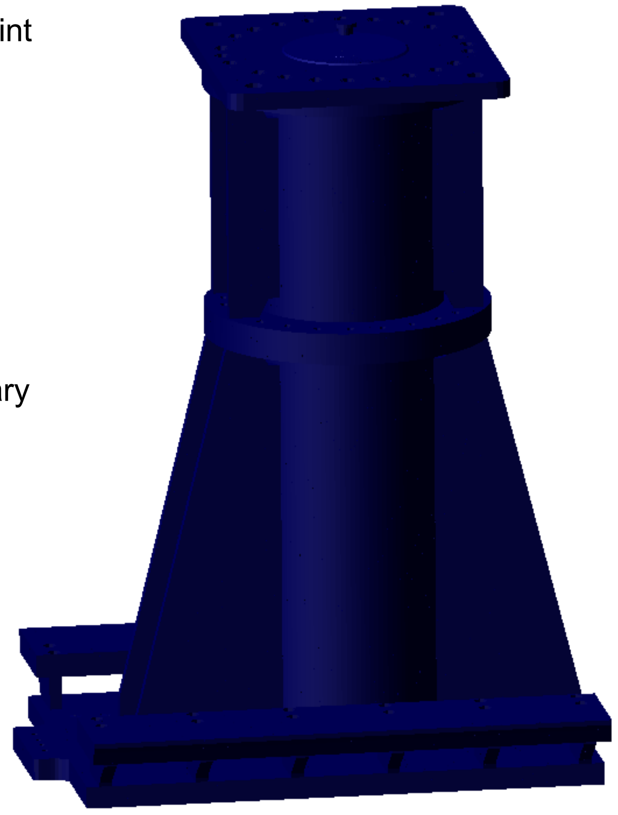


Optimisation of target signal for the physical test



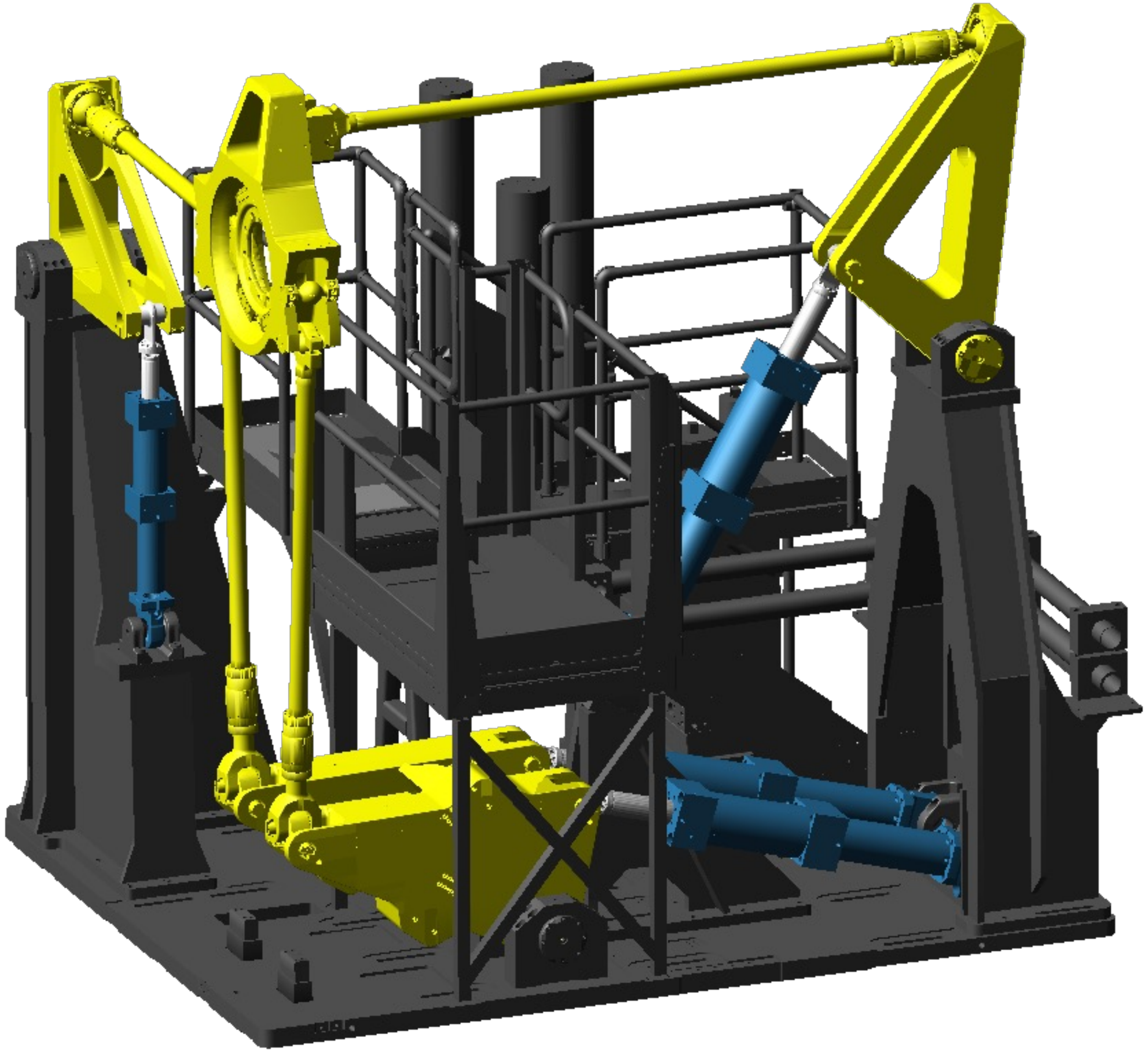
Boundary conditions





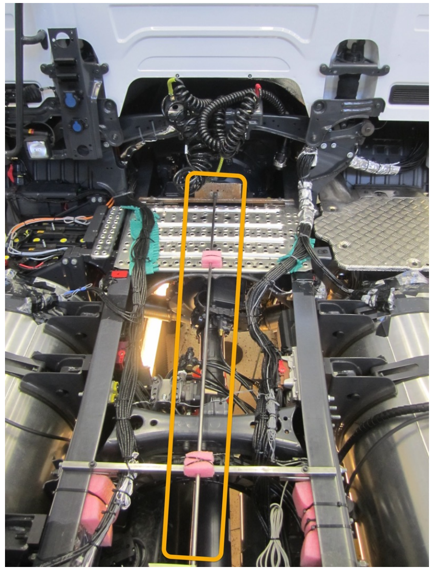
Corner module

- 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

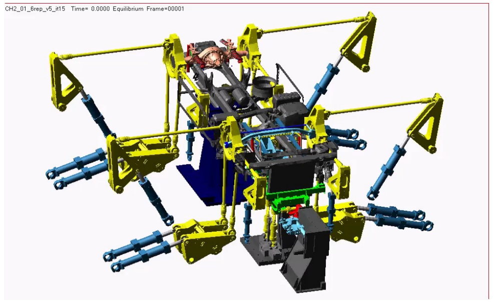
- Wheel force transducers
  - Longitudinal and lateral wheel actuators
  - Braking torque
- Distance axle – frame
  - Vertical wheel actuators (leaf suspension)
- Air spring force (calibrated strain gauges)
  - Vertical wheel actuators (air suspension)
- Frame twist angle
  - Twist input actuator
- Bending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



Rig control method

Test vehicle

Virtual model

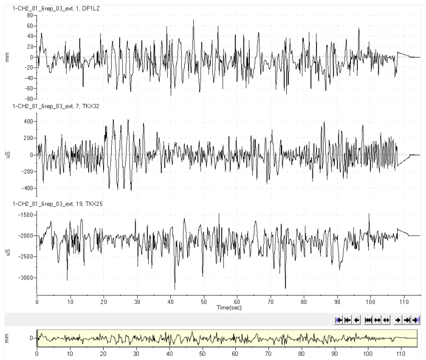


Iterate until

How?

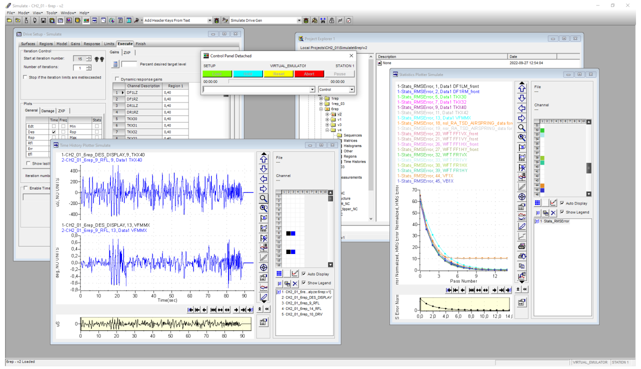
Response

Drive



Measured data

Desired



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
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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

Photo Mark Cruz, Unsplash

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.

vti

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

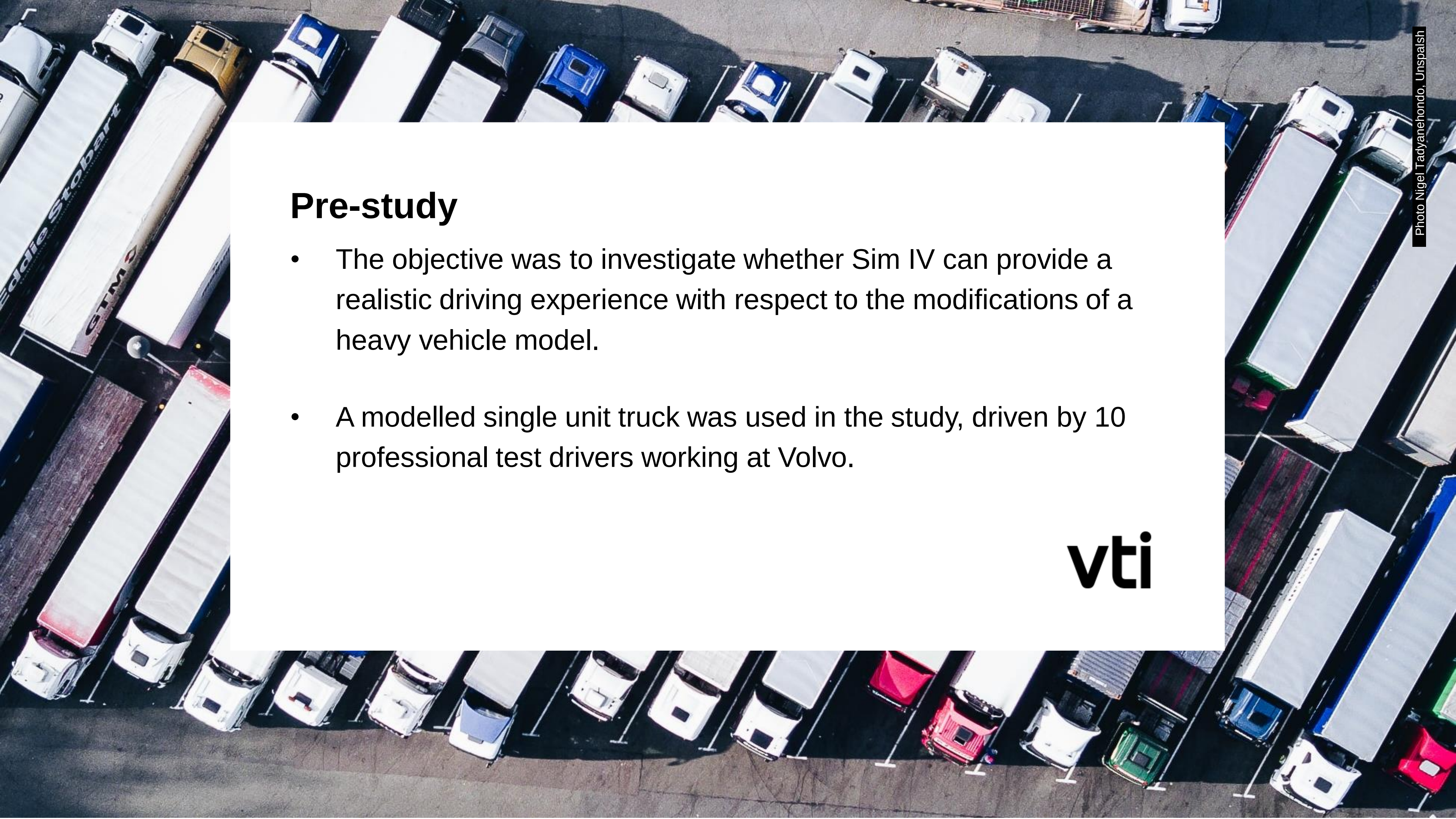


Photo Nigel Tadyanehondo, Unspalsh

Pre-study

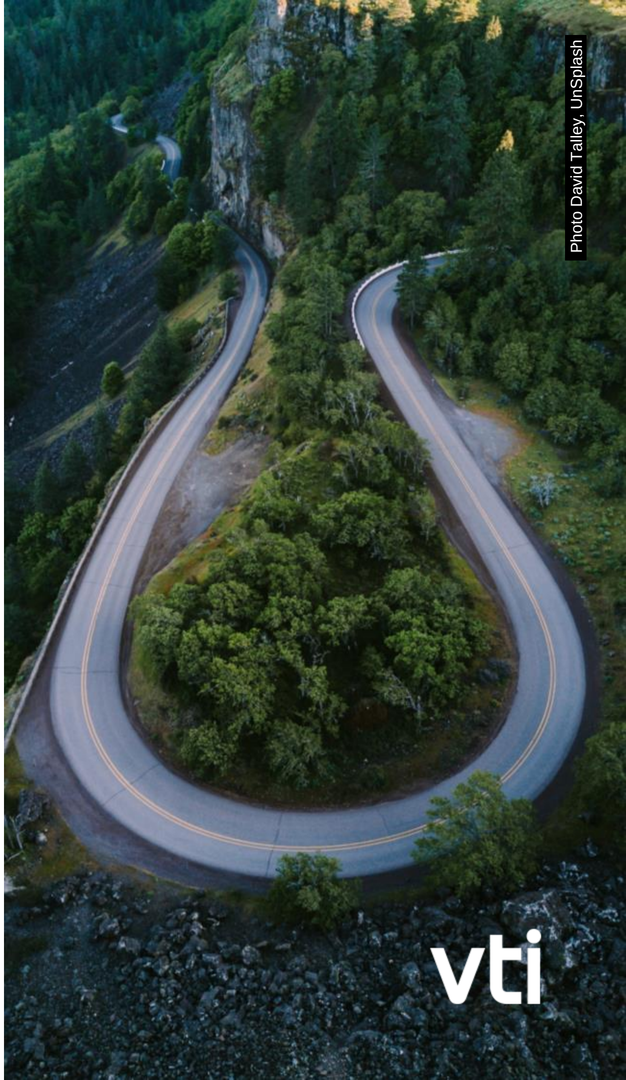
- The objective was to investigate whether Sim IV can provide a realistic driving experience with respect to the modifications of a heavy vehicle model.

- A modelled single unit truck was used in the study, driven by 10 professional test drivers working at Volvo.

Pre-study

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

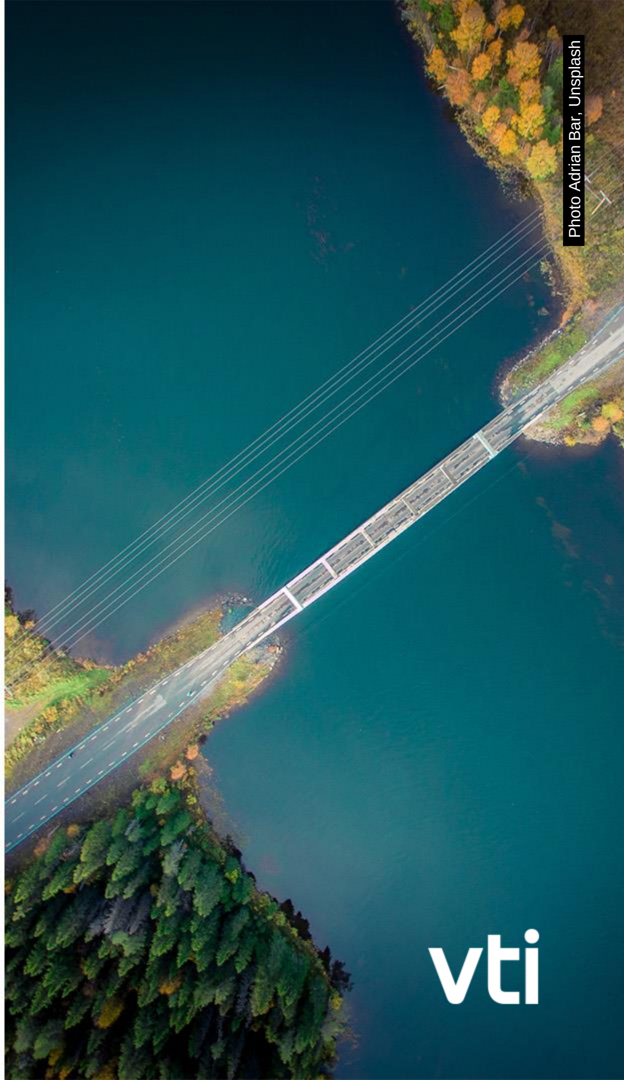
- **Parameter set 1:** Increased roll stiffness: a 100 % and 50% increase of the roll stiffness of the rear and front axles of the truck
- **Parameter set 2:** Decreased roll stiffness: a 40% decrease on the rear axles roll stiffness
- **Parameter set 3:** Softer rear tires: a 25% decrease on the cornering 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

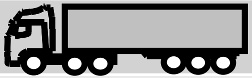
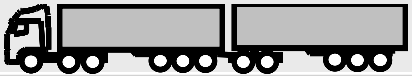
The drivers' deduction of the applied changes on the truck were categorized as **correct**, **quite correct**, or **incorrect**

- 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:

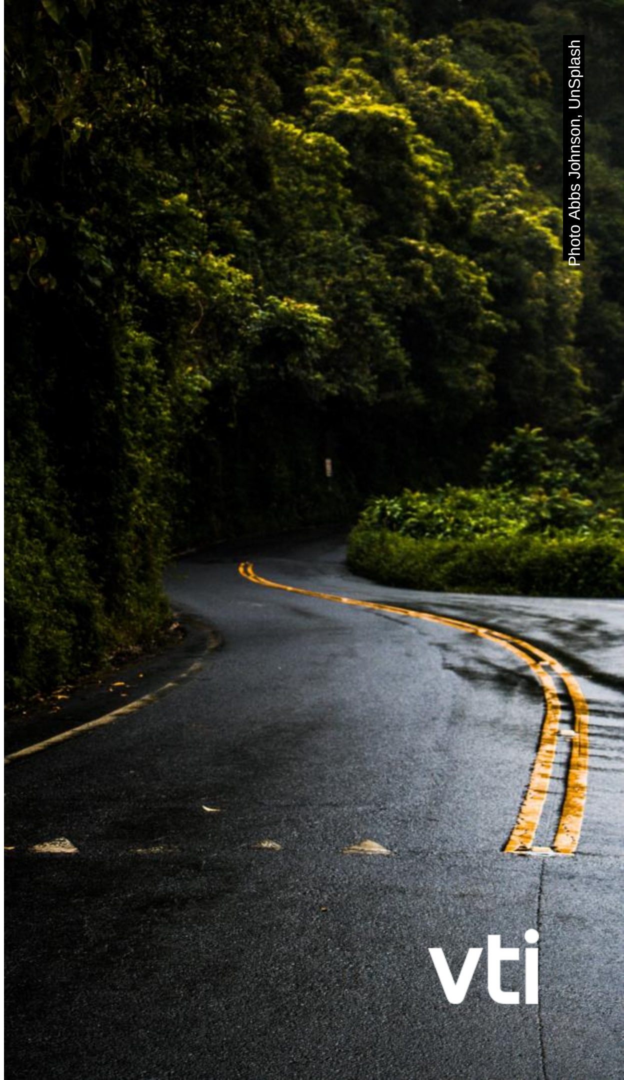
- How easy it is to keep the vehicle on the desired path on the curvy roads
- How they perceive the roll stability of the vehicle on the curvy roads
- How they perceive the trailers, stable or oscillatory, during overtaking and lane changes.
- How easy it is to control the vehicle.

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

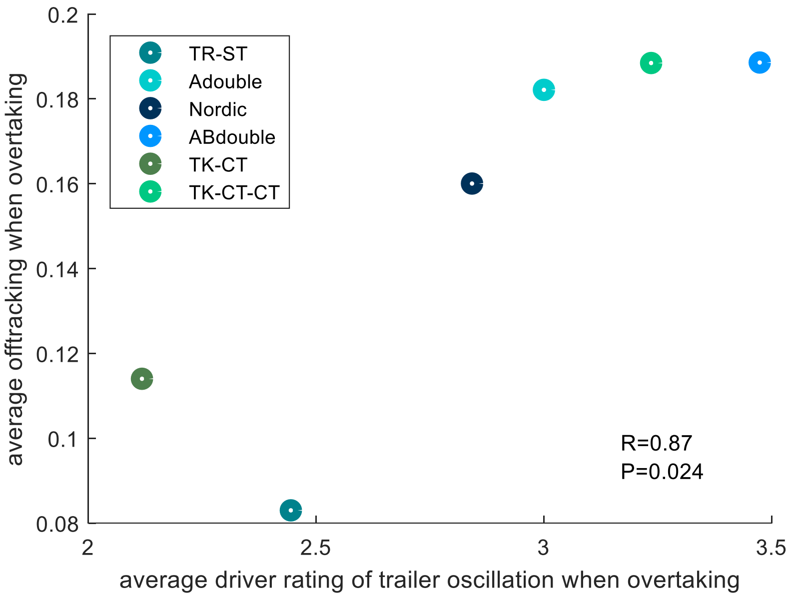
Results, driving experience

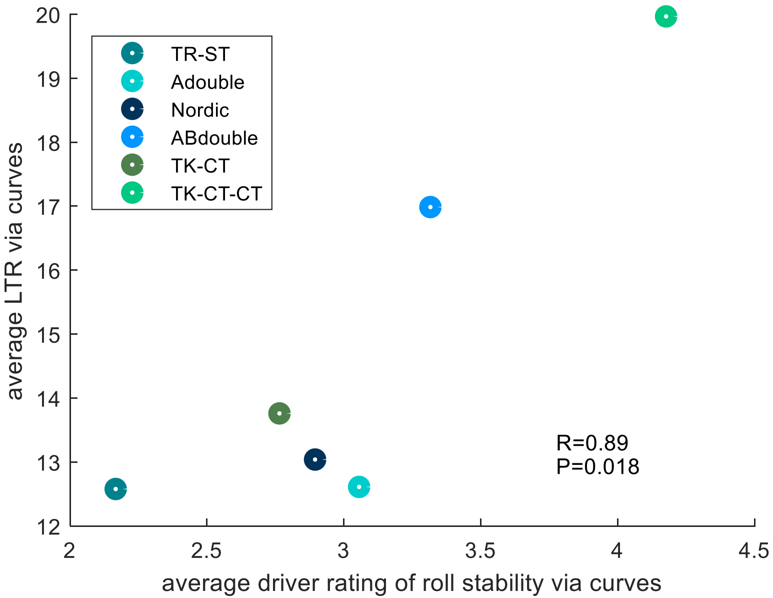
Average ranking of the total driving experience realism was 5.2 out of 7.

	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





vti

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

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.

Foto Geran De Klerk, Unspalsh

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.

Future plans

Driveability assessment in Sim III

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

Scania, VTI, LiU, KTH

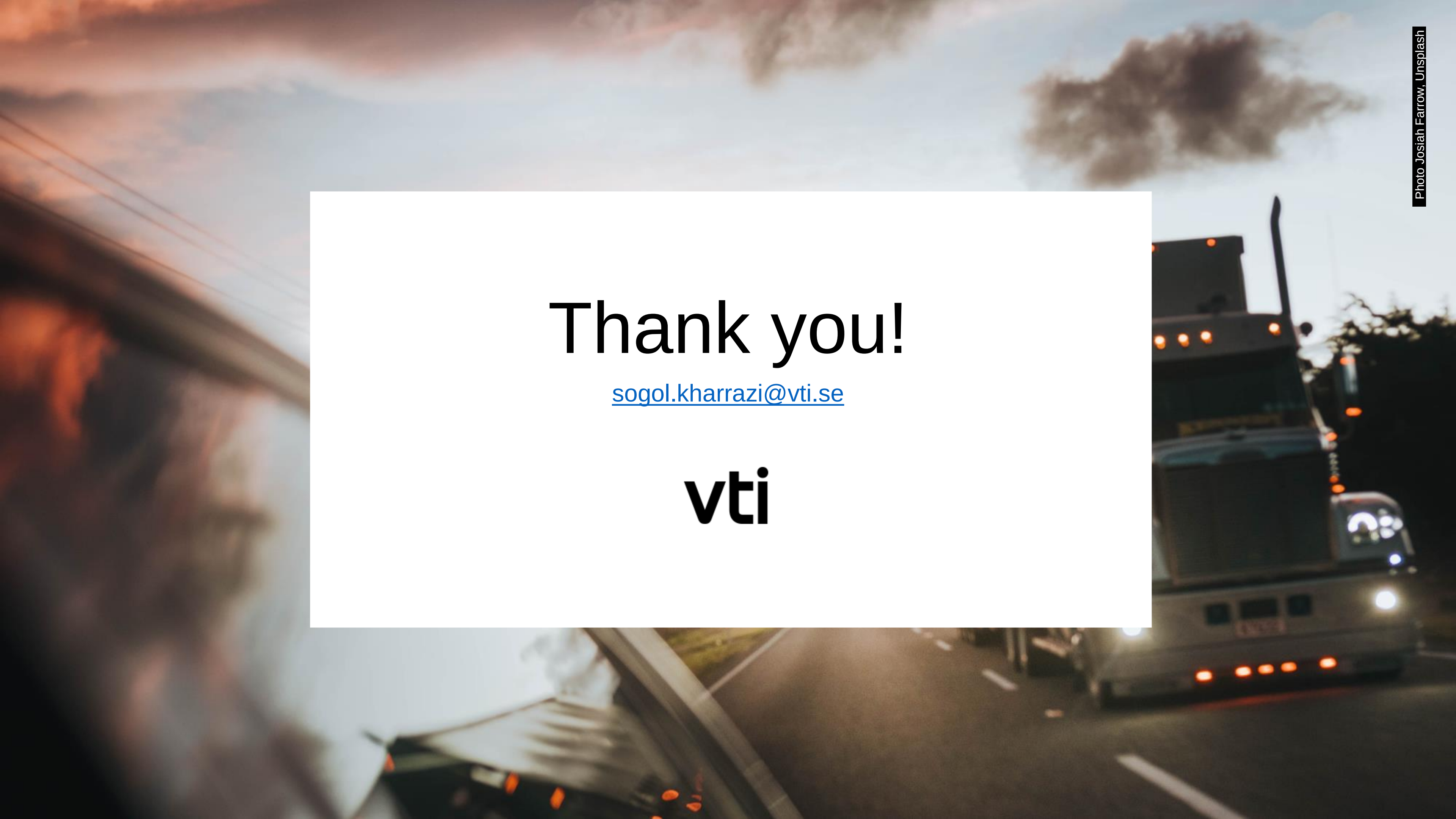


Photo Josiah Farrow, Unsplash

Thank you!

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 24th, 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

This is Colmis.


An open and independent
winter proving ground that serves
the global automotive industry.
2023-05-22
COLMIS

Our story.

1985
Colmis Proving Ground is established.

1987
First electric split-mu track.

1997
SIMLOC Hotel

2007
ISO certifications.

2009
Open Proving Ground.

2013
Rajd & Safety.

2016
ColmisPlus & Driver Training.

2022
New Dynamic Area.


Our purpose.
2023-05-22
COLMIS

Everything you need, in one place.

So that you can focus on the testing.


Our way.
2023-05-22
COLMIS

Not a customer,
a partner.

A customised cold test solution.

Your success is our success.


A team.
Not a single player.

Together we are Colmis.

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

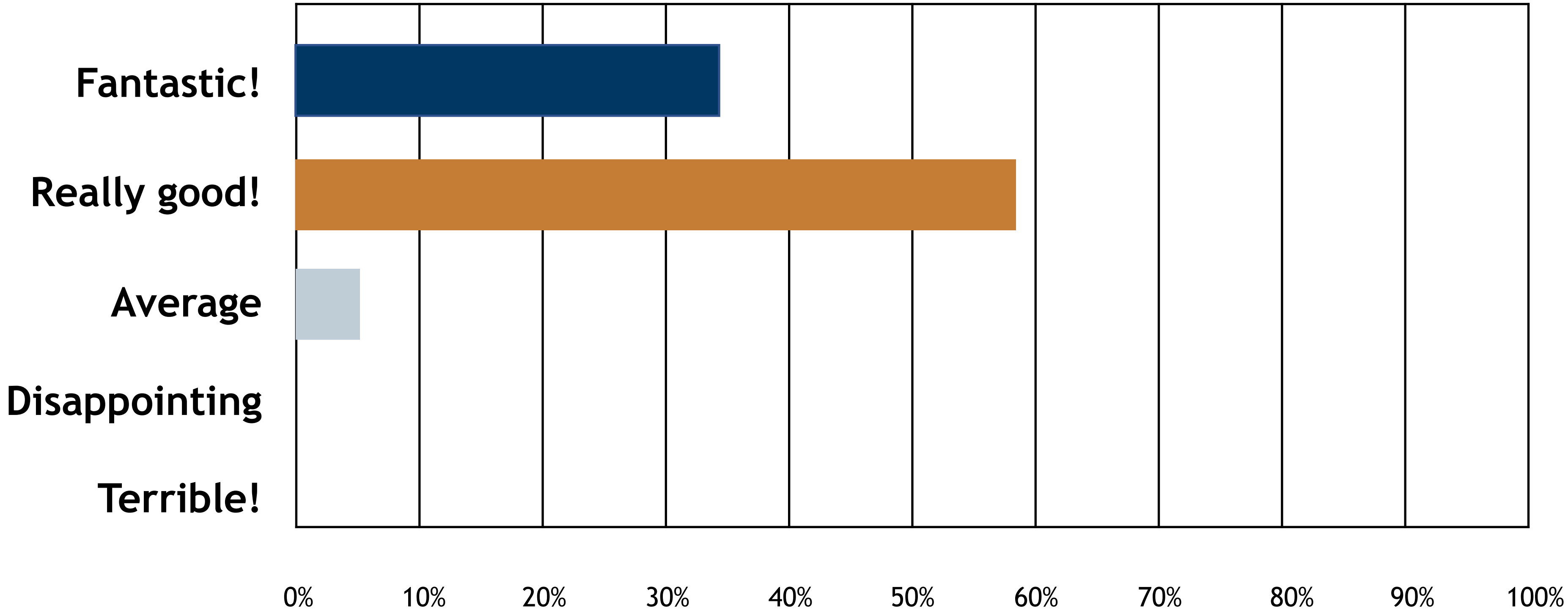
Contract customer -23

”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)?



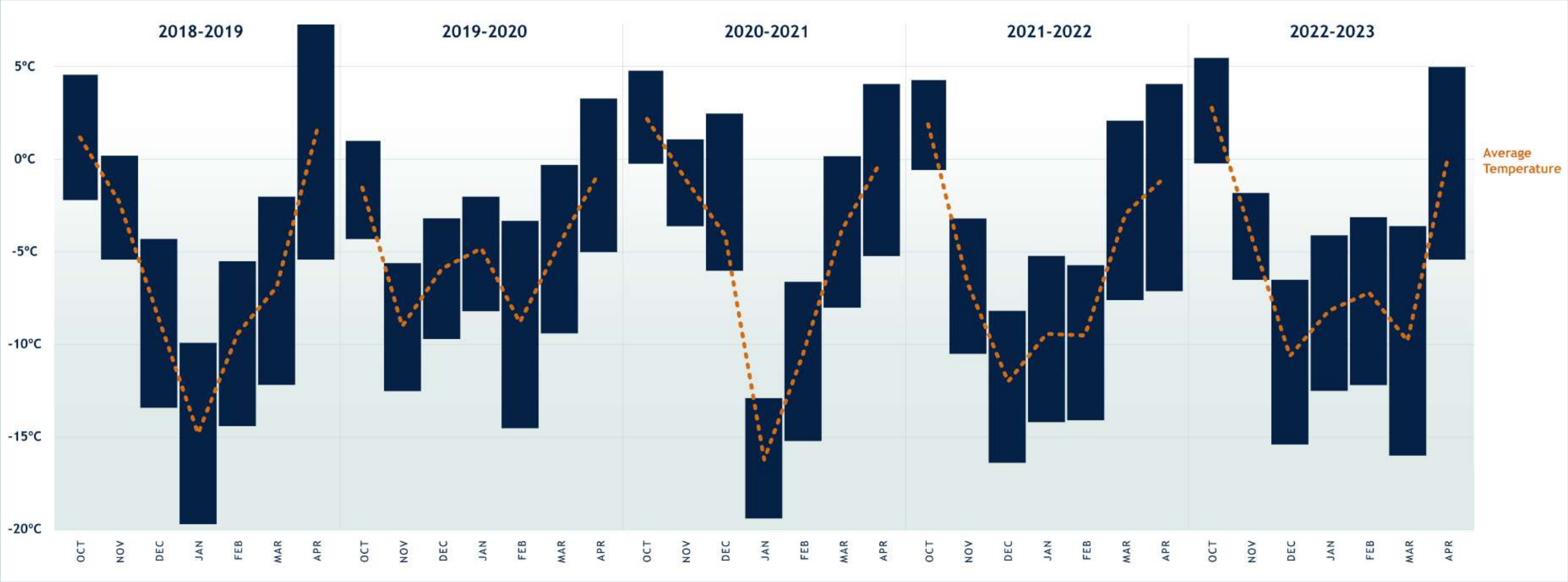
Source: Customer Survey Season 2022/2023

Why Arjeplog.

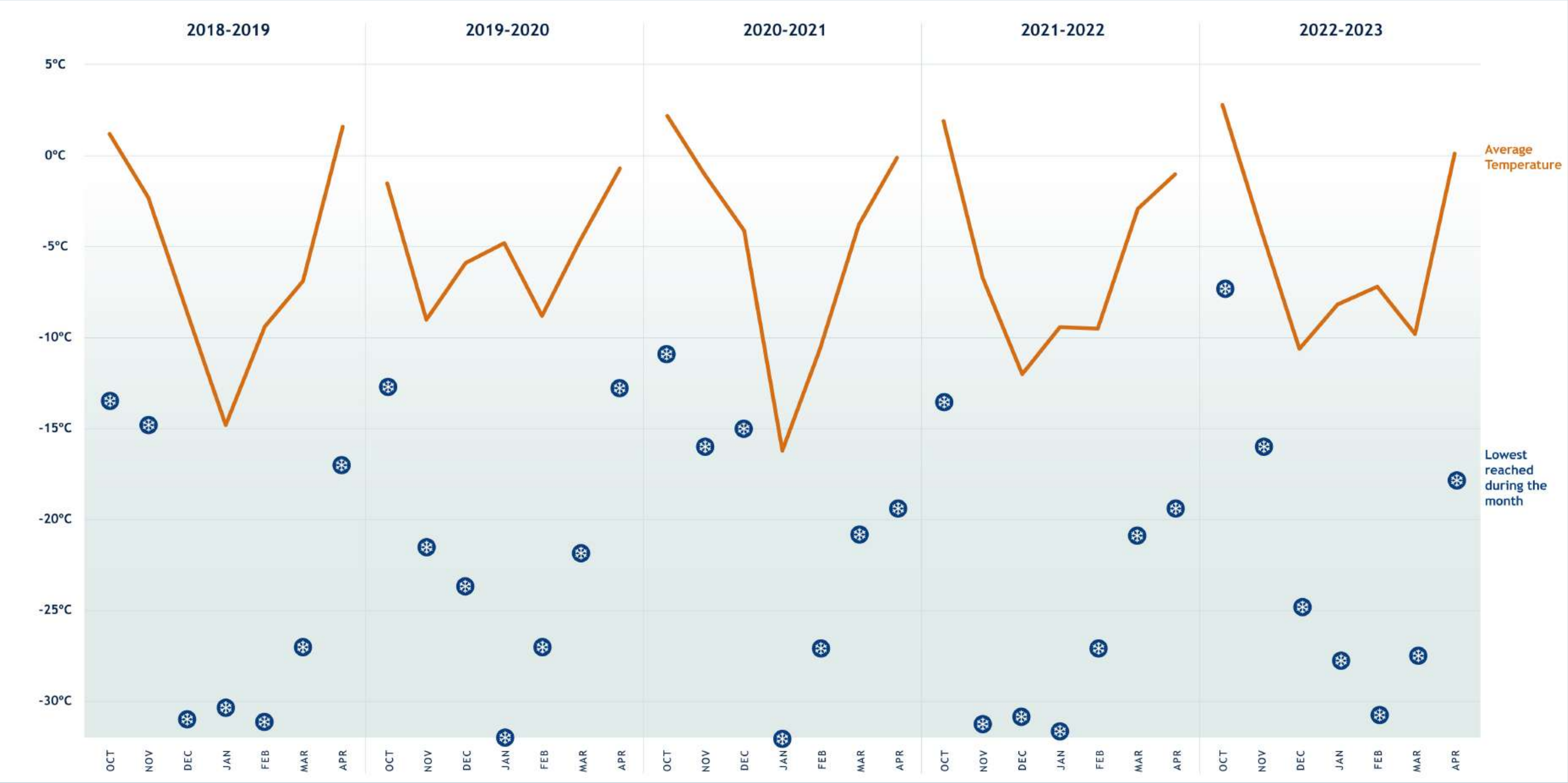
Location.


Canada
ON
WI
QC
Greenland
PA
NL
NS
Iceland
Colmis Proving Ground
Russia
Mongolia
Sweden
Norway
Finland
China
Ireland
Denmark
Kazakhstan
Kyrgyzstan
Germany
France
Austria
Romania
Turkmenistan
JK
PB
UP
Portugal
Italy
Pakistan
India
Greece
Türkiye
TS
GJ
Morocco
Iran
Western Sahara
Tunisia
Syria
Iraq
TN
KL
Algeria
Mauritania
Libya
Egypt
Oman
Saudi Arabia
Mali
Guinea
Burkina Faso
Niger
Yemen
Sudan
Ghana
Chad
Nigeria

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

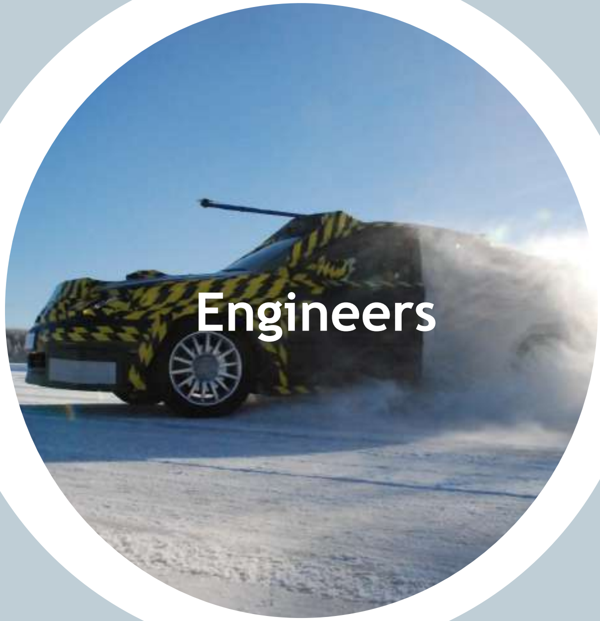
Access: 1h from airport

Why Colmis?

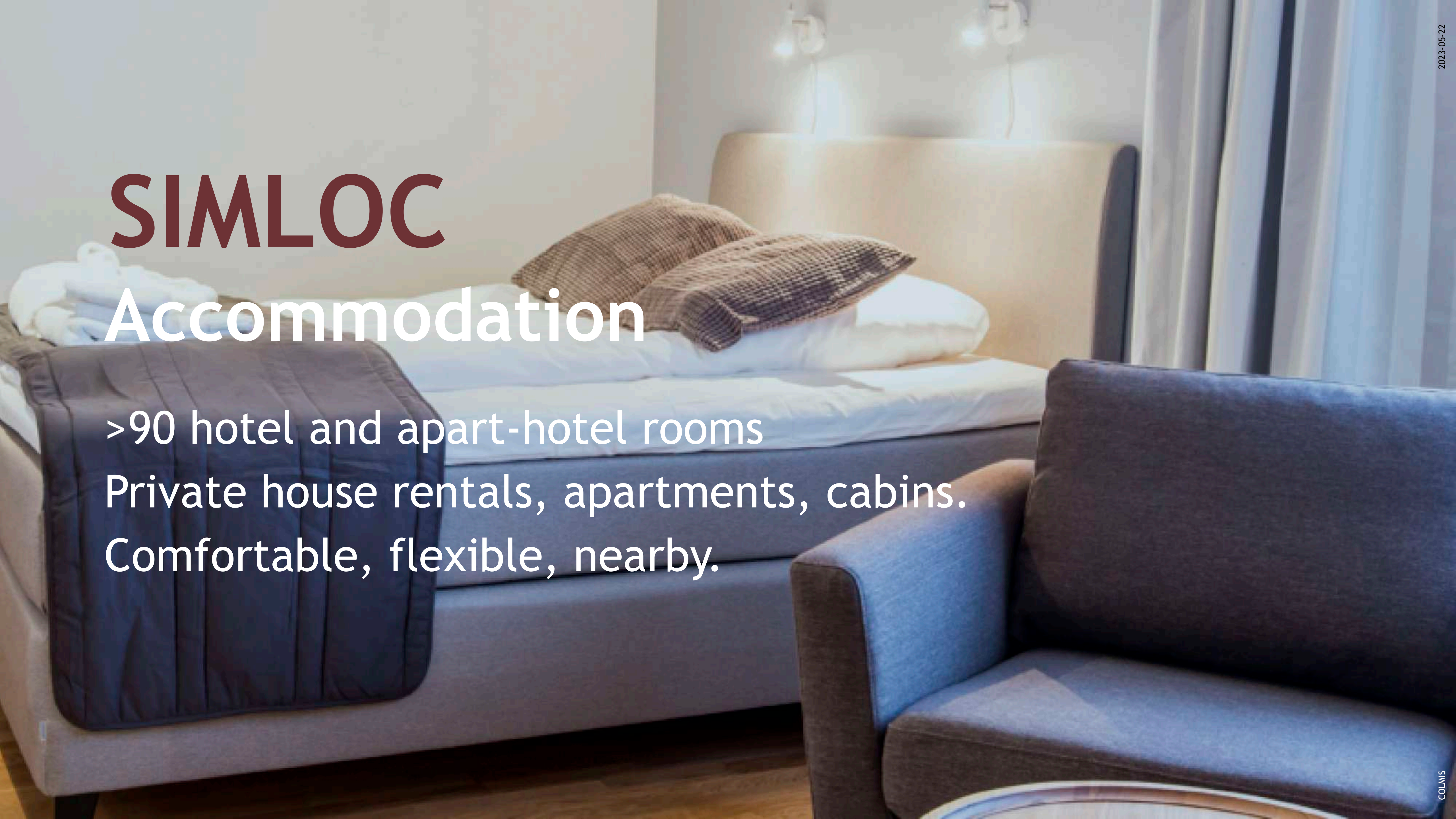
Safety First.

Sustainability & Quality

ColmisPlus Vehicle development support



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^2

Workshops & Office space

>90

Hotel rooms
+ rental of private houses/apartments

2023-05-22

COLMIS

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


Still 84cm today!
2023-05-22
COLMIS

The workshops and offices

EV Charging

Infrastructure.

Cold Chambers.

An open proving ground.

Contract Customers

Spot Customers


What comes
next?
ADAS & Autonomous Driving
More EVs (+ Hybrids) & Hydrogen
New Mobility Trends
Facing Climate Change
2023-05-22
COLMIS


Stay updated.
Follow us @ColmisAB


Questions?

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

COLMIS

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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

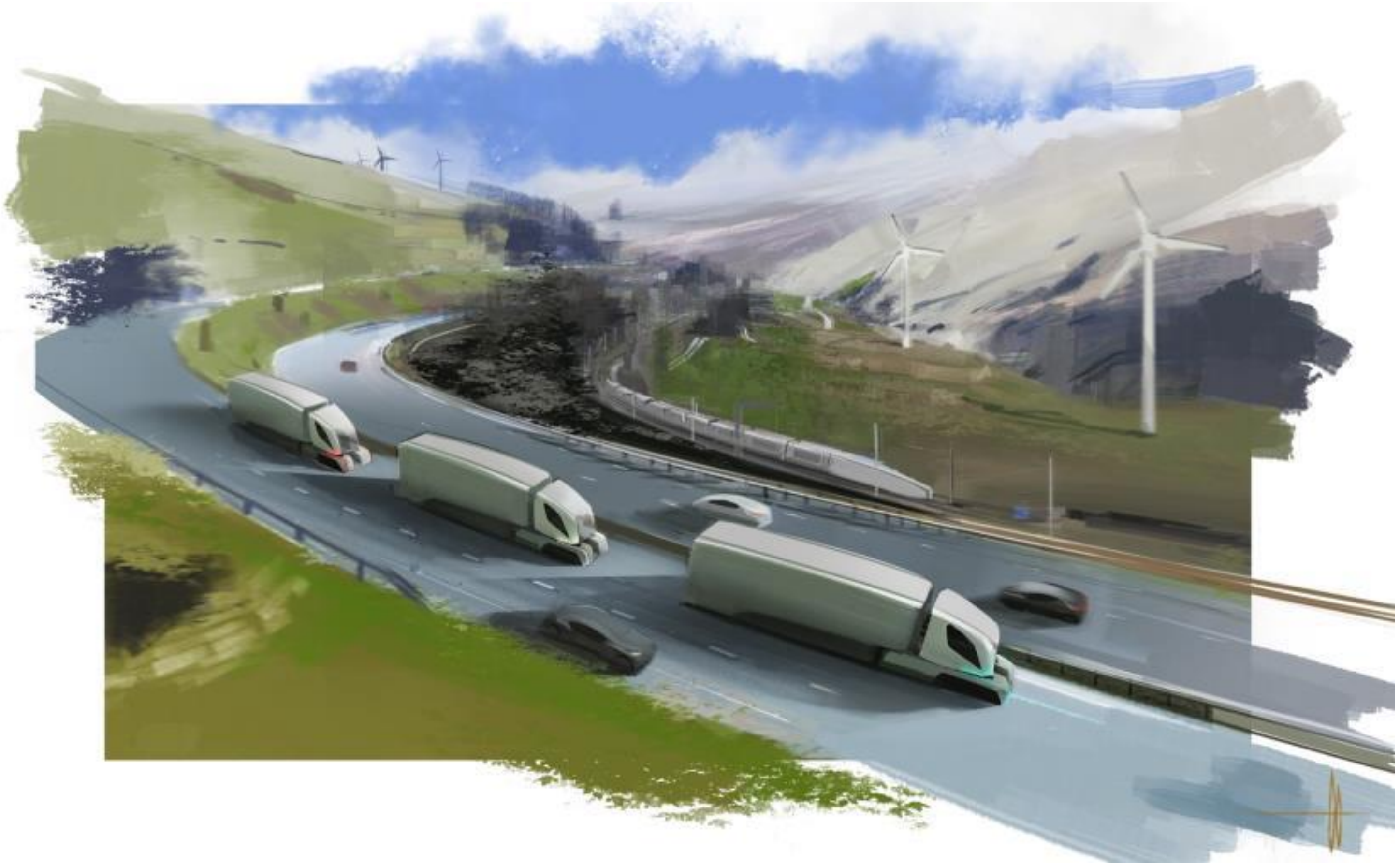
Volvo | Niklas Fröjd / Edo Drenth | Internal

2023-05-23

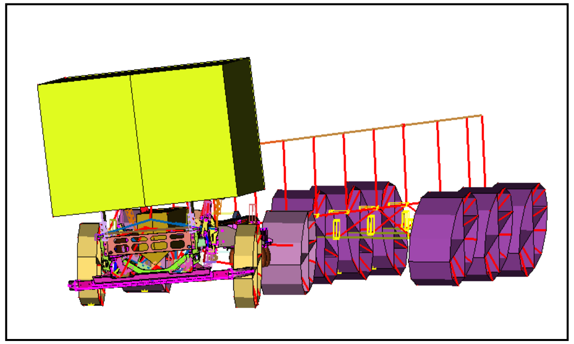
Volvo Group

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

Group Trucks Technology

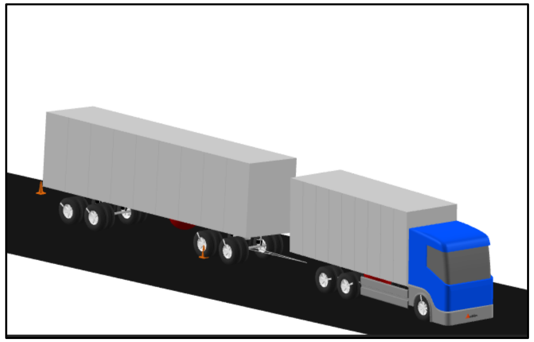


FEM



Semi-detailed 2-track (VTM)

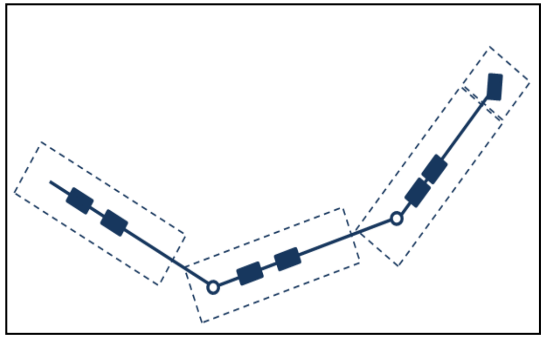
Modelica



MBS

ASM for HIL/SIL/MIL verification

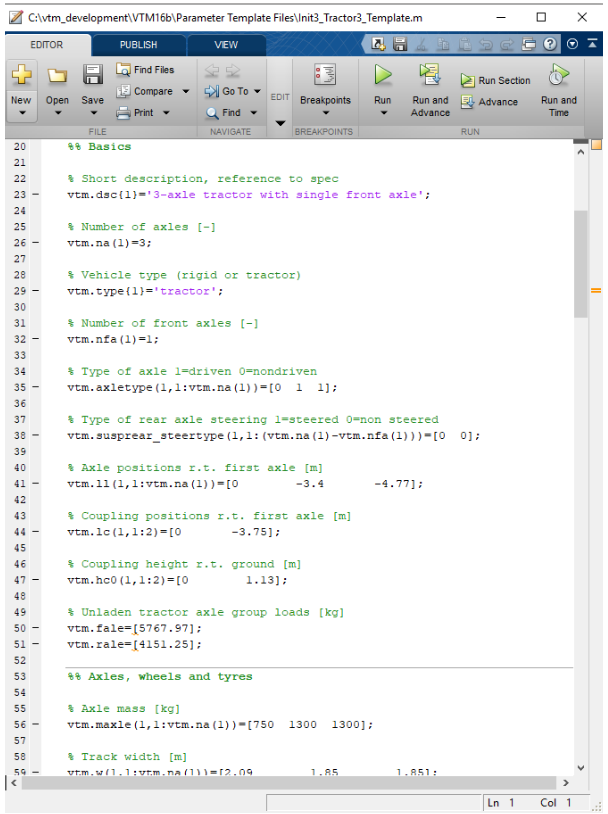
Single-track models for on-line for control design



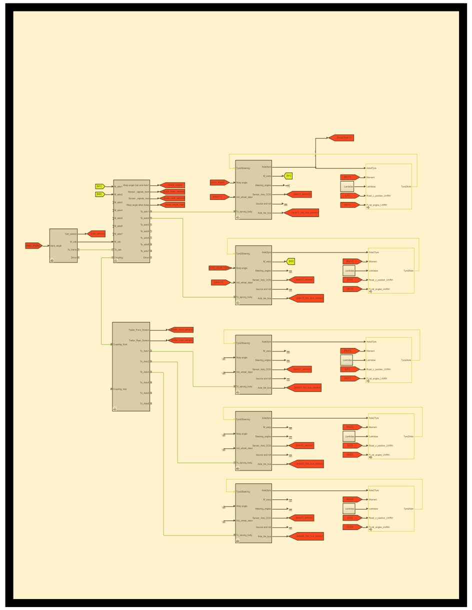
Model data

PDM

Fetch & Create

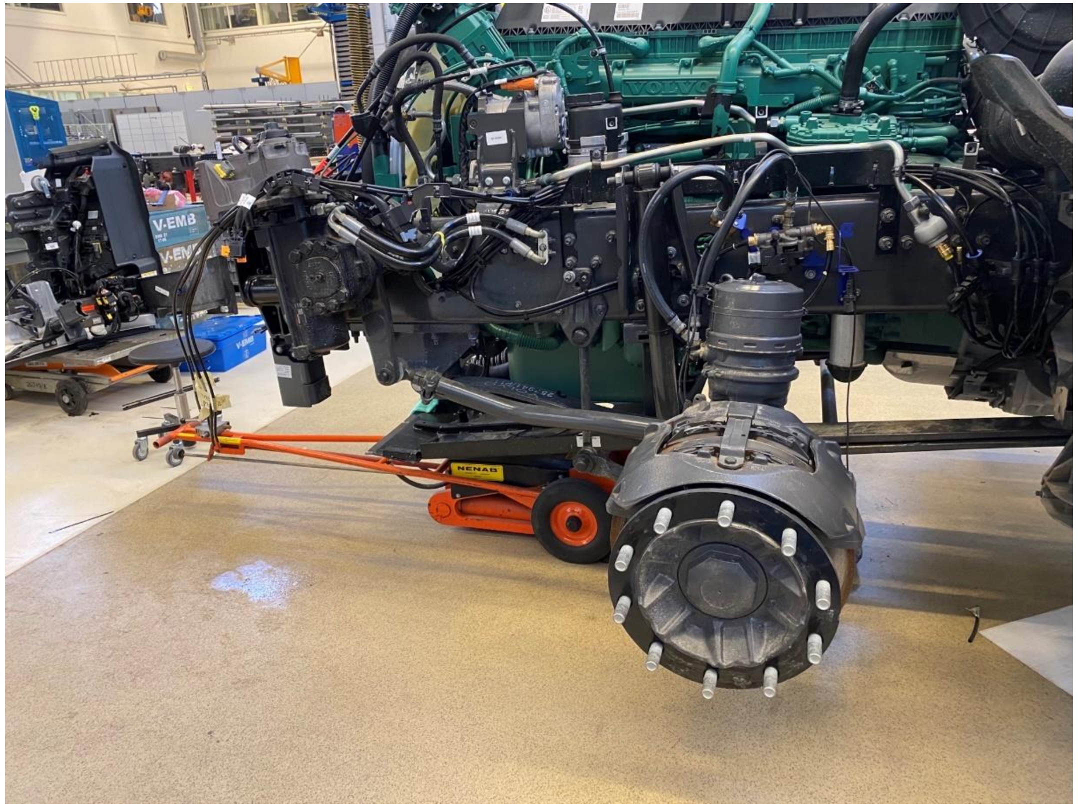


Couple & Load



Executable model

The suspension and steering



The truck frame

The swap-body superstructure

The tipper

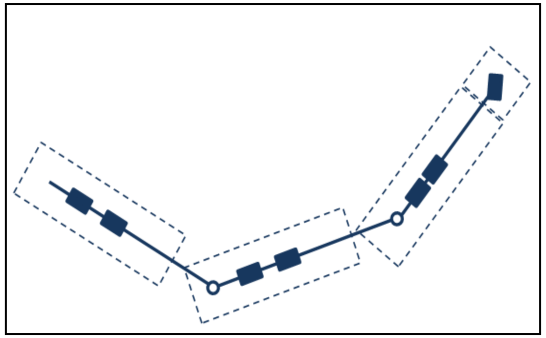
Timber

Tyres

1. Useful linear tyre model for single-track modeling

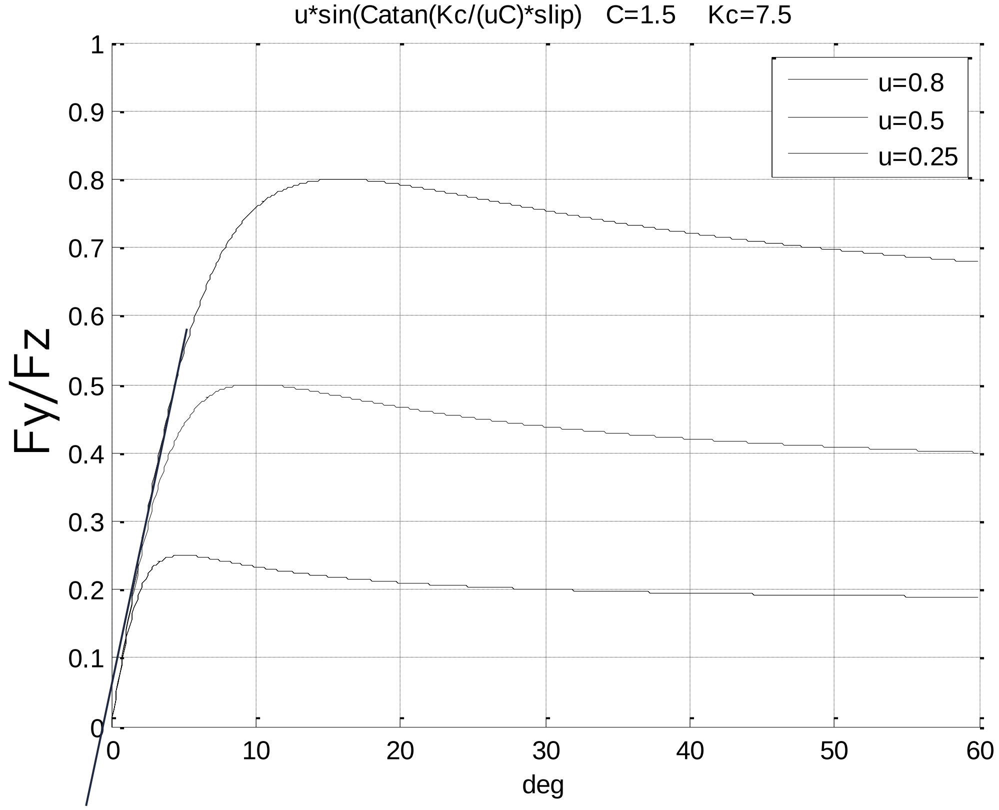
$$F_y = C_\alpha \times \alpha$$

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



C_α:	Cornering stiffness
α:	Lateral slip
K_c:	Cornering coefficient
F_z:	Vertical contact force

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



$$K_c = K_{c0}\left(1 + k\,\frac{F_Z - F_{Z0}}{F_{Z0}}\right)$$

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

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

Modelica Language

fmi Functional Mock-up Interface

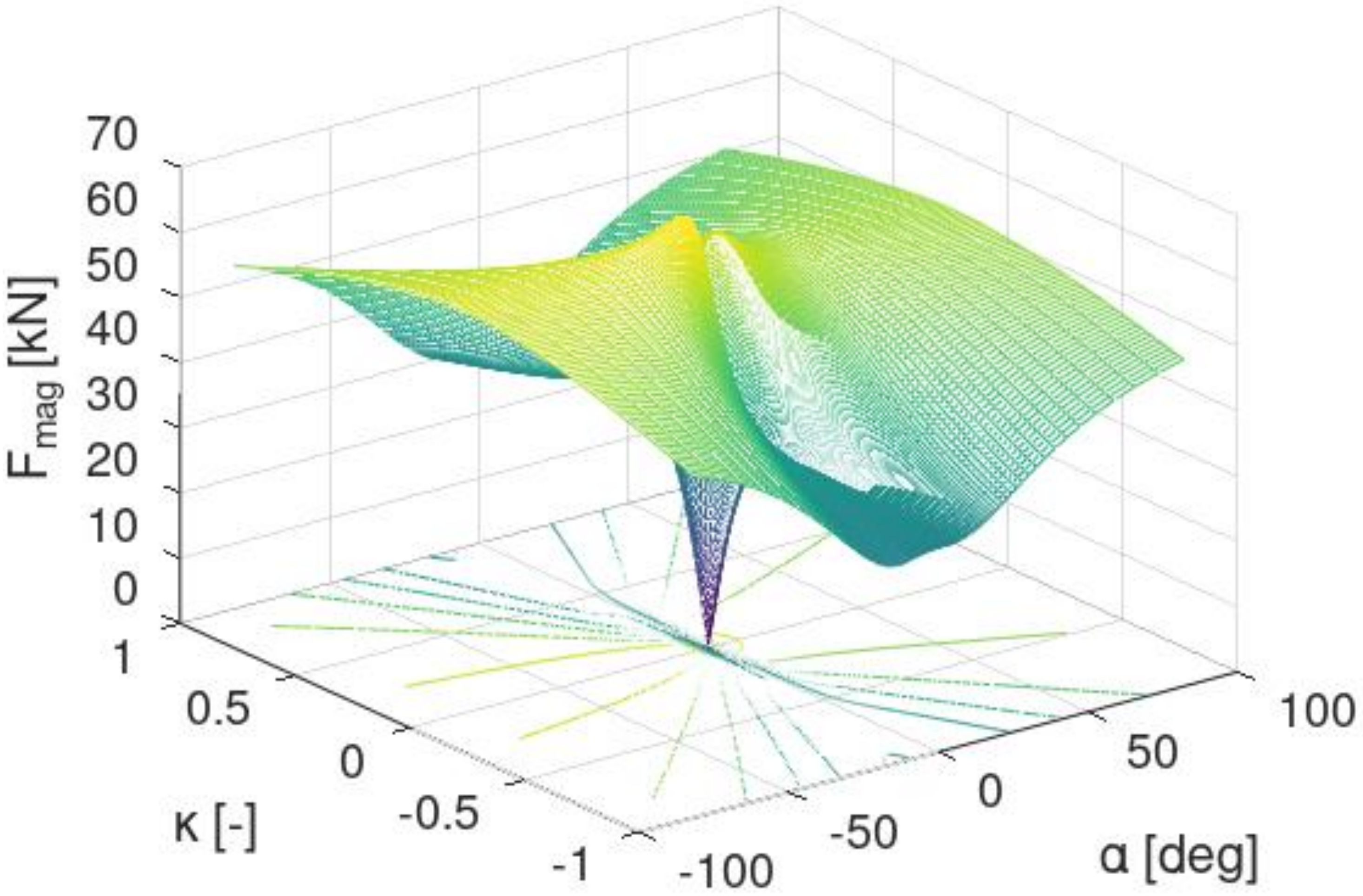
Starting point

445/65 R22.5

Pacejka 2002 – combined slip

Extrapolated parameters from truck tyre parameter sets

The TA15 will be on “rails”

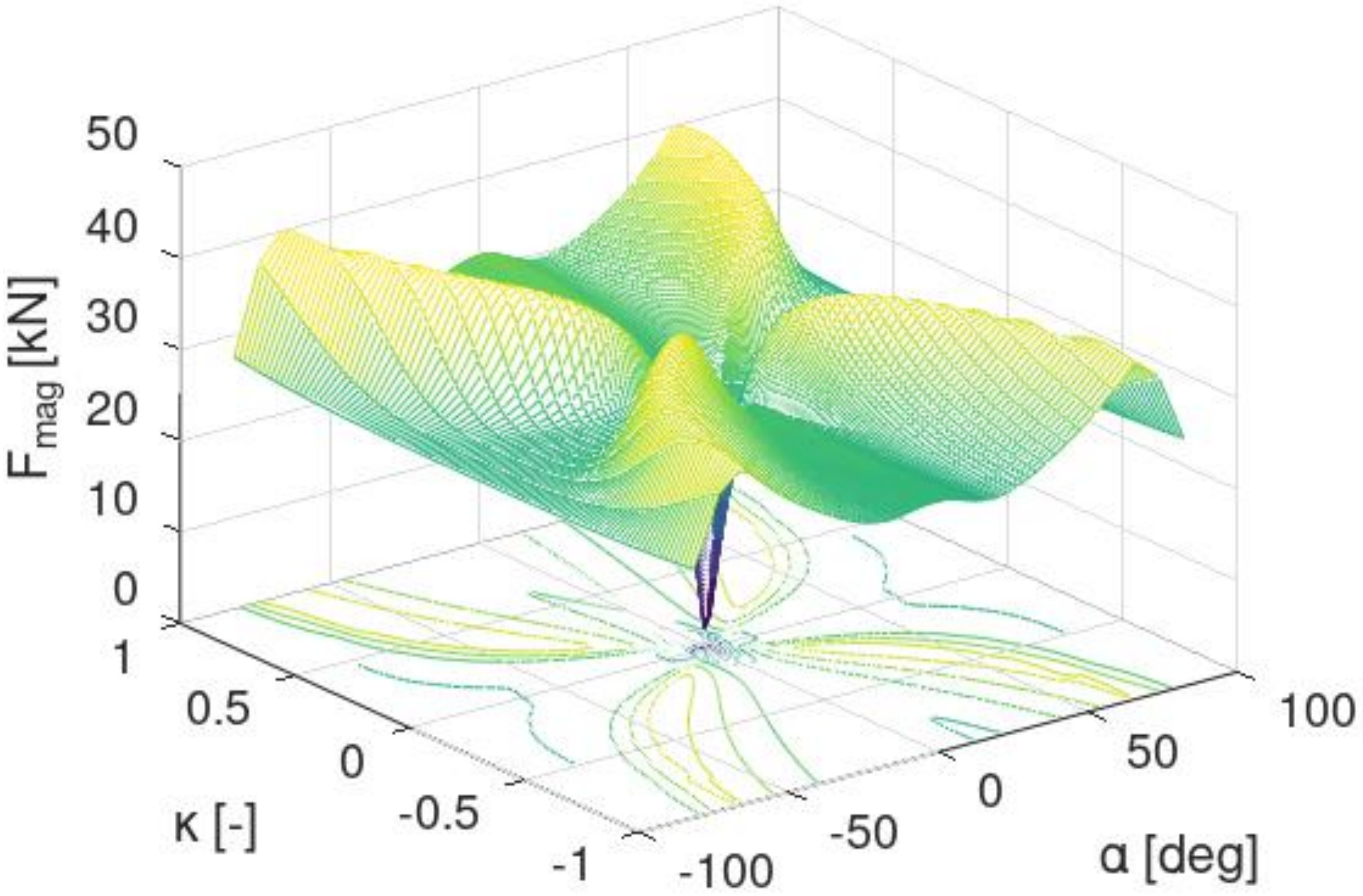


Measured and fitted

Truck tyre

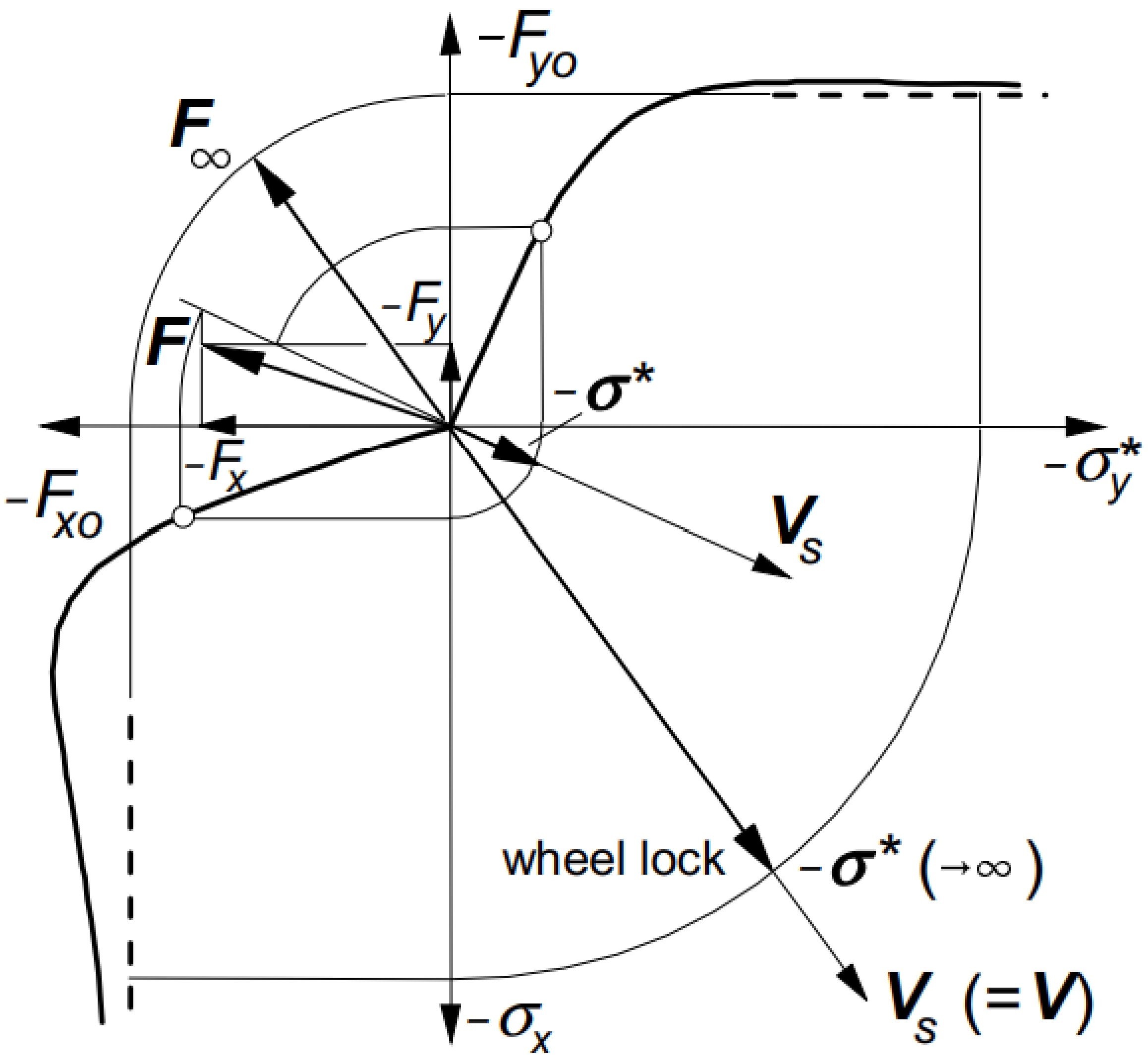
Pacejka 2002 – combined slip

Overfitted within available data?



What do we have?

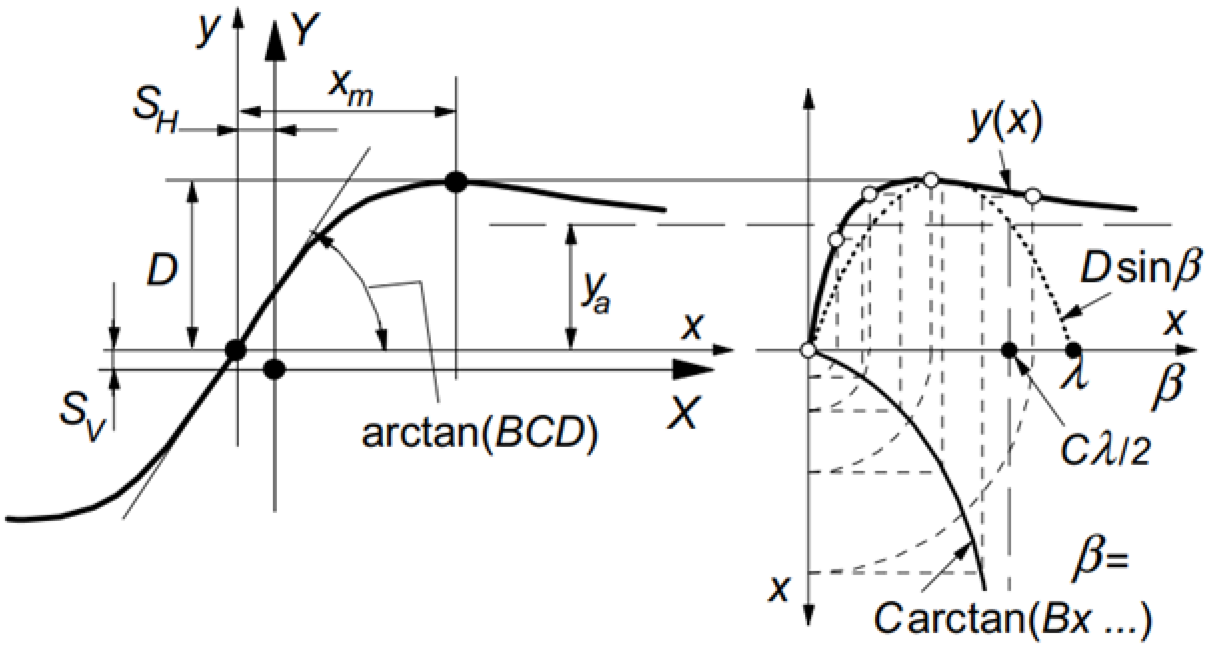
- Basic notion of uniaxial slip characteristics
  - Magic Formula
- Similarity methods
  - Theoretical slips
- Longitudinal slip stiffness
- Cornering stiffness
- Peak friction characteristics
  - Declining with load
  - Asymptotic?
- Identical asymptote for friction?



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

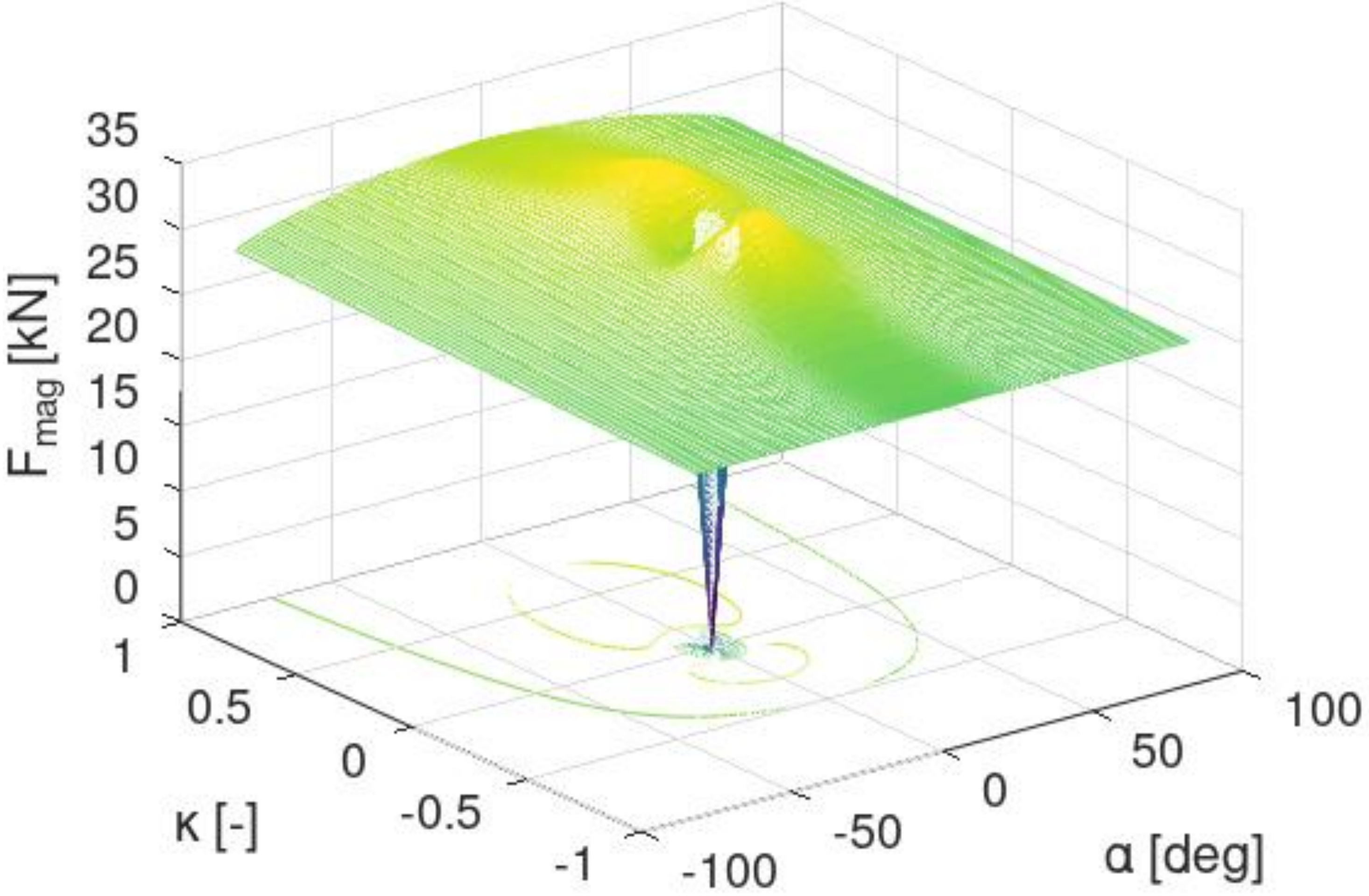
kappaPeak	-0.15
PCX1	1.45
PDX1	0.85
PDX2	-0.05
PDX3	0
PKX1	8.0
PKX2	7.0
PKX3	-0.3
Pure slip lateral	
alphaPeak	17.1887338539 deg
PCY1	1.3
PDY1	0.75
PDY2	-0.05
PDY3	0.2
PKY1	-13.0
PKY2	1.8
PKY3	0.2
Pure slip aligning torque	
QCZ1	1.2
QDZ1	0.1
QDZ2	-0.003
QDZ3	0.0
QDZ4	0.0

Results

445/65 R22.5

VAS22 – combined slip

Minimum set of parameters

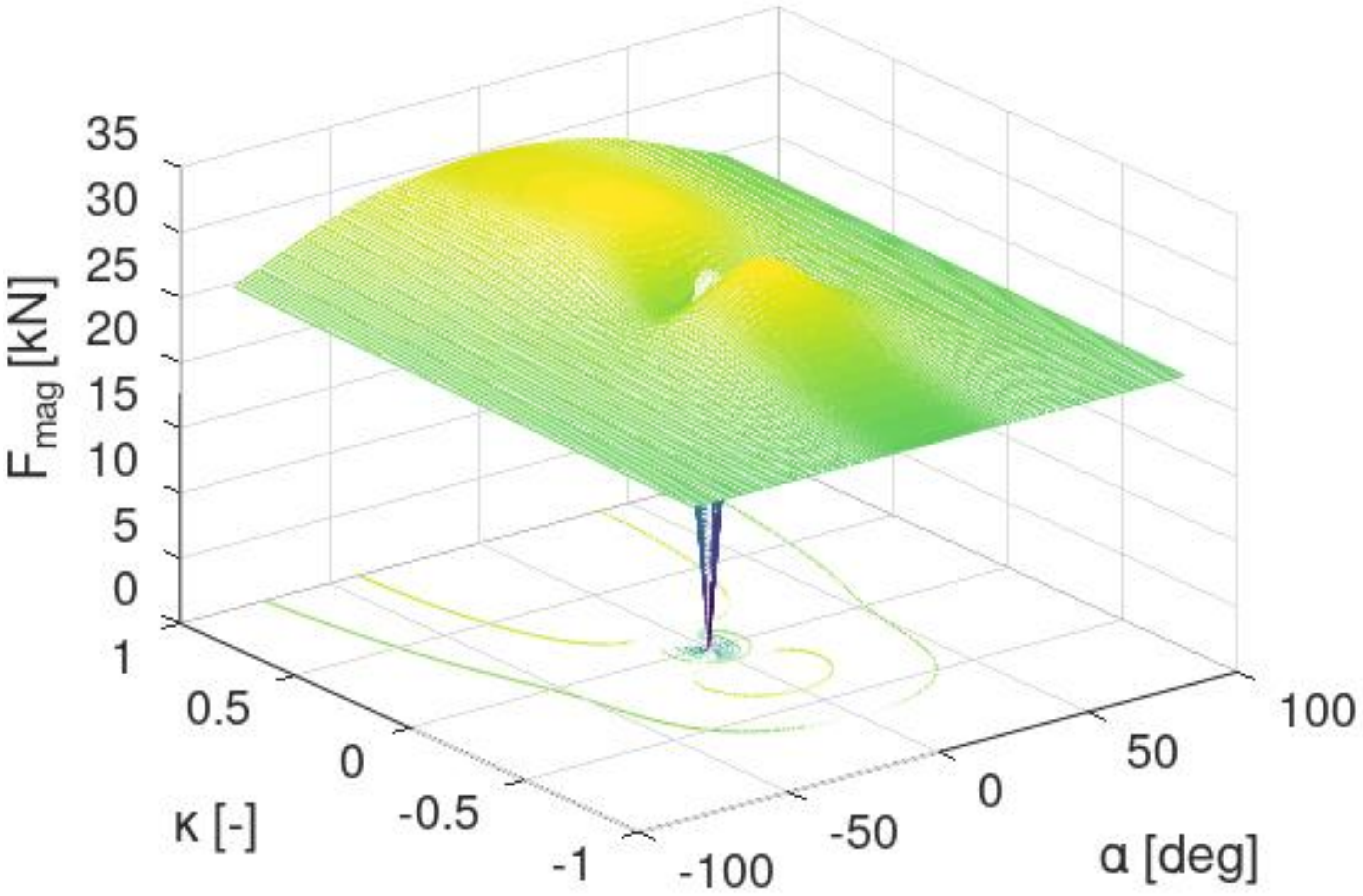


Results

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

VOLVO

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

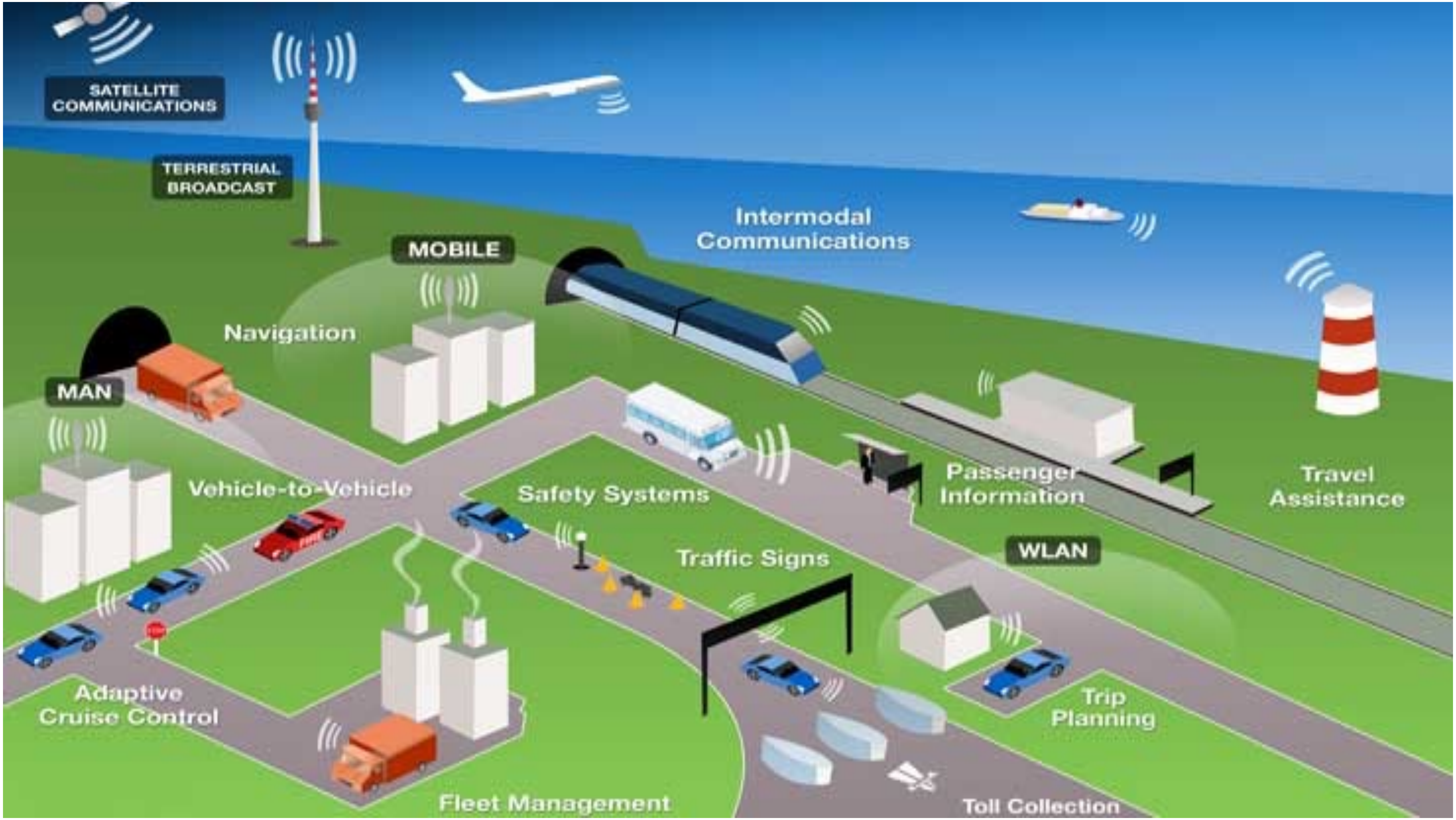
DEVELOP TOMORROW'S MOBILITY SYSTEMS!

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

Dag Bergsjö

dagb@chalmers.se

Program Director MPMOB


SATELLITE COMMUNICATIONS
TERRESTRIAL BROADCAST
MOBILE
Intermodal Communications
Navigation
MAN
Vehicle-to-Vehicle
Safety Systems
Passenger Information
Travel Assistance
Traffic Signs
WLAN
Adaptive Cruise Control
Trip Planning
Fleet Management
Toll Collection

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

CHALMERS

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

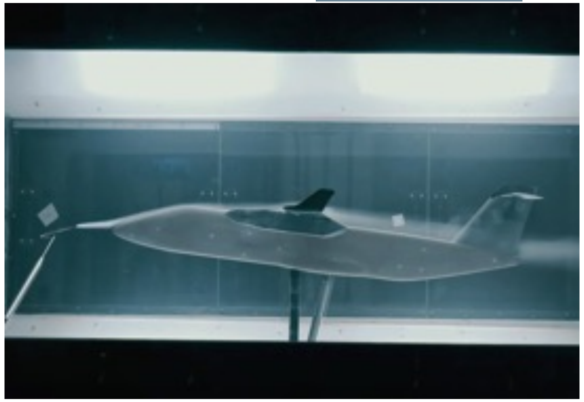
- Aerospace engineering
  - Fluids
  - Structural
  - Artificial intelligence
- Automotive engineering
  - Active and passive safety
  - Powertrain and propulsion systems
  - Vehicle engineering and aerodynamics
- Marine technology and naval architecture
  - Structures
  - Fluid
  - Systems engineering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

CHALMERS

- 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

CHALMERS

CHARMEC

Chalmers Railway Mechanics – a NUTEK/VINNOVA Competence Centre
Chalmers University of Technology

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

CERC

Combustion Engine Research Center

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

Swedish Electromobility Centre

https://emobilitycentre.se/

TechForH2 – Hydrogen Centre

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

LIGHTHOUSE

SWEDISH MARITIME COMPETENCE CENTRE

https://lighthouse.nu/

SAFER

VEHICLE AND TRAFFIC SAFETY CENTRE AT CHALMERS

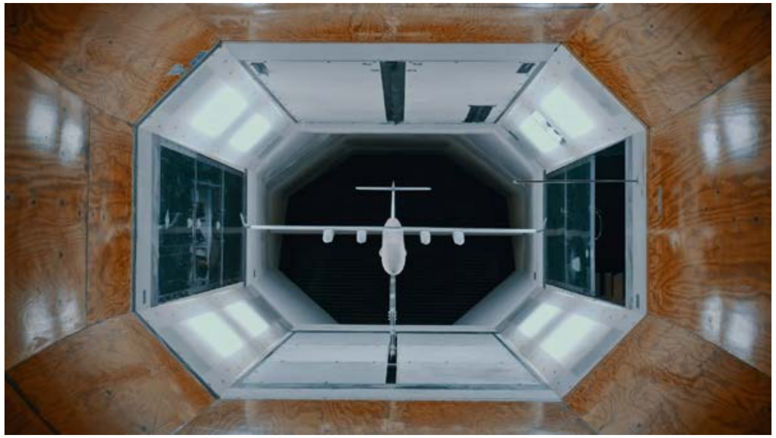
https://www.saferresearch.com/

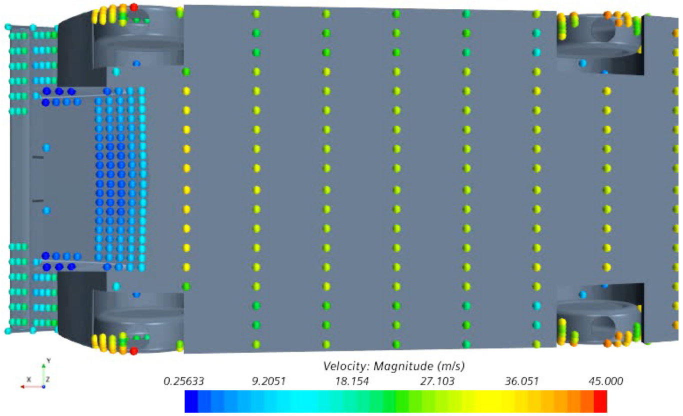
MPMOB: international opportunities

- Double degree with University of Stuttgart (automotive engineering)
- Nordic Master in Maritime engineering, within Nordic Five Tech (marine technology)
- Erasmus exhanges (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)





AVANCEZ

1829

CHALMERS

UNIVERSITY OF TECHNOLOGY

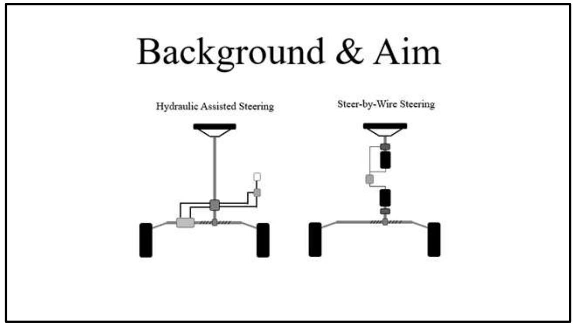
Poster 1:

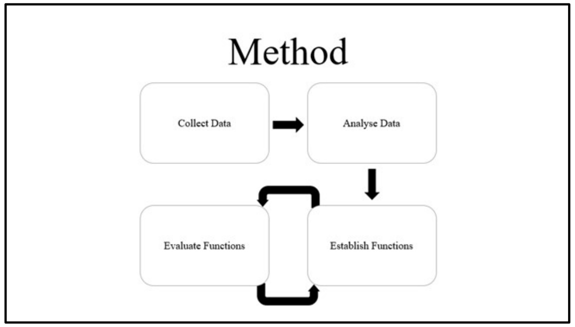
Quantify and mimic the feedback through the steering wheel at some driving conditions

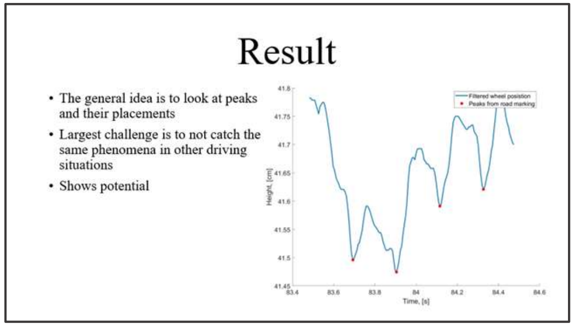
Aron Dalemo, Polestar & Chalmers

Master Thesis Micro Presentation

Aron Dalemo

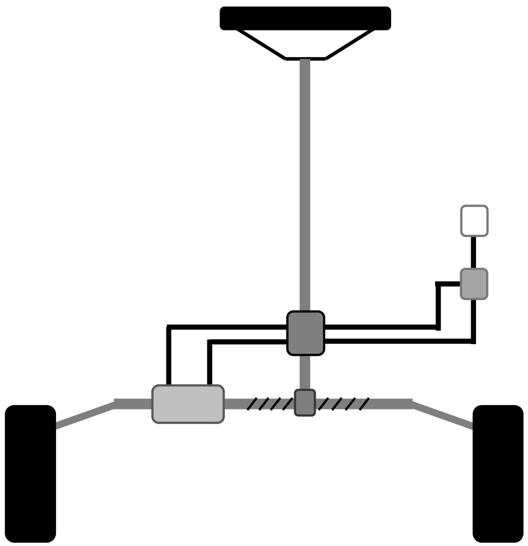

Background & Aim
Hydraulic Assisted Steering
Steer-by-Wire Steering


Method
Collect Data
Analyse Data
Evaluate Functions
Establish Functions

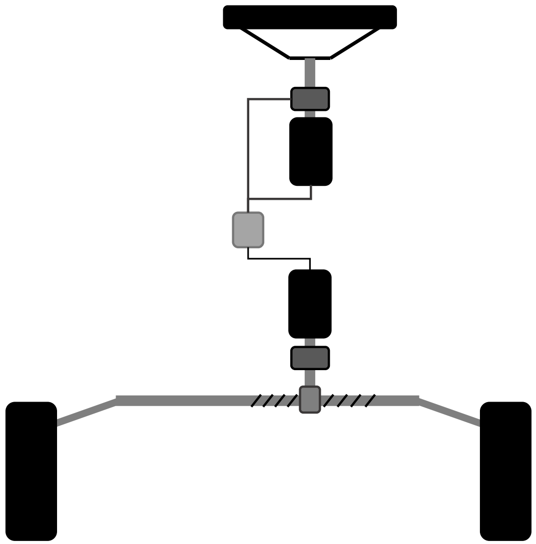

Result
• The general idea is to look at peaks and their placements
• Largest challenge is to not catch the same phenomena in other driving situations
• Shows potential
Filtered wheel position
Peaks from road marking
Height, [cm]
Time, [s]
41.8
41.75
41.7
41.65
41.6
41.55
41.5
41.45
83.4
83.6
83.8
84
84.2
84.4
84.6

Background & Aim

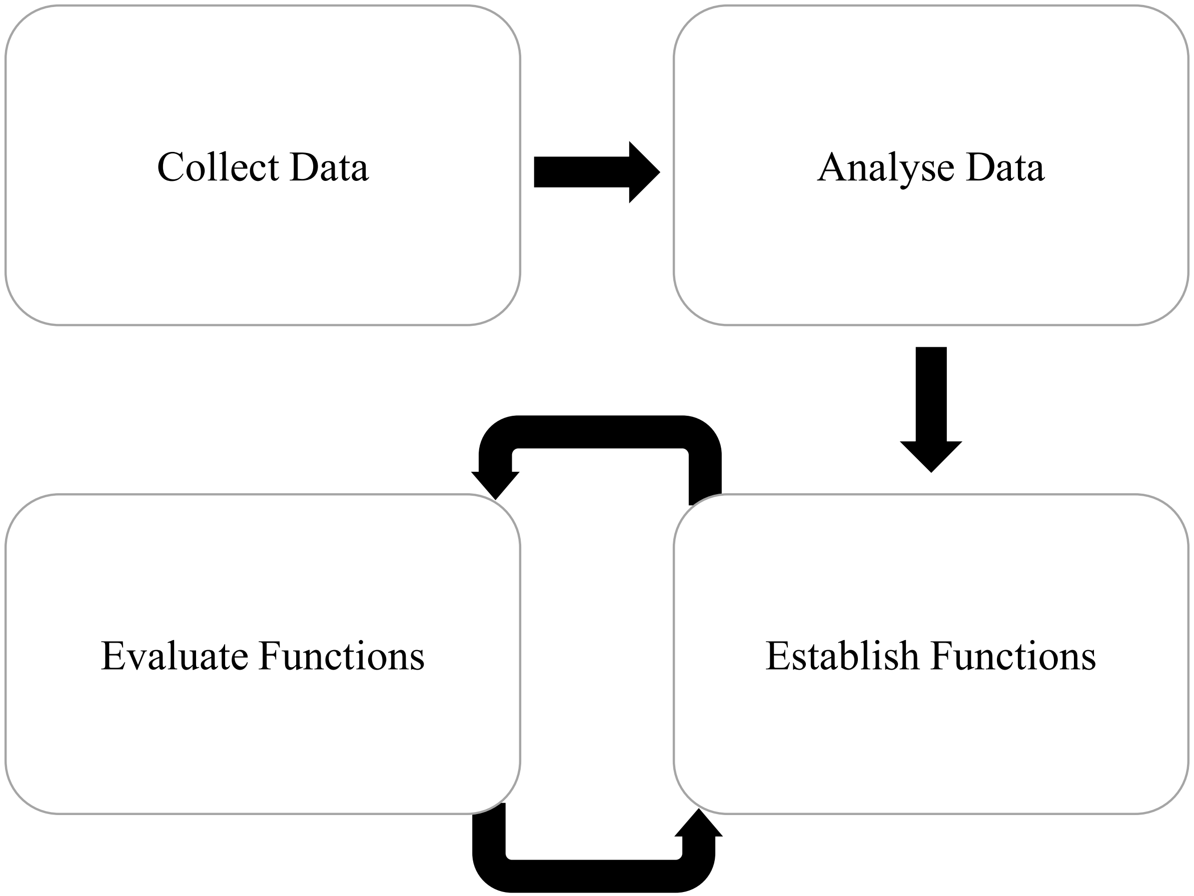
Hydraulic Assisted Steering



Steer-by-Wire Steering

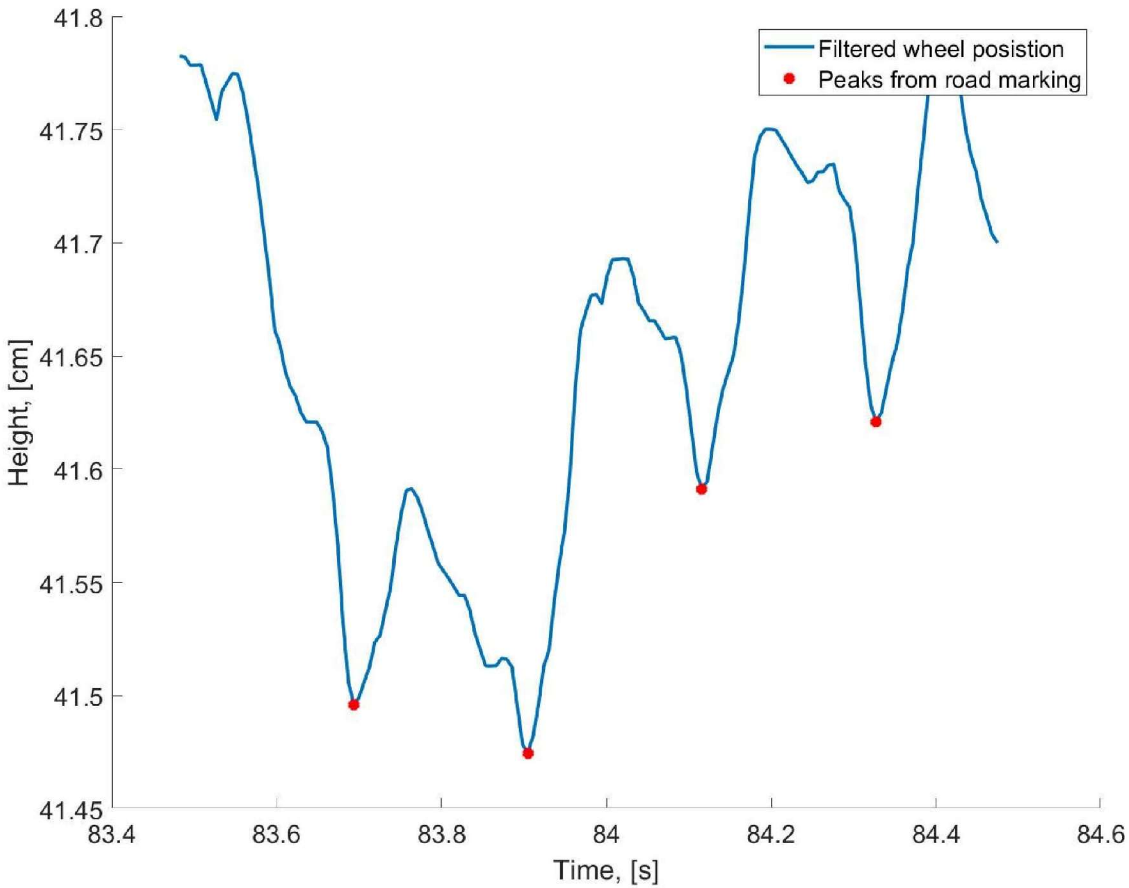


Method


Collect Data
Analyse Data
Establish Functions
Evaluate Functions

Result

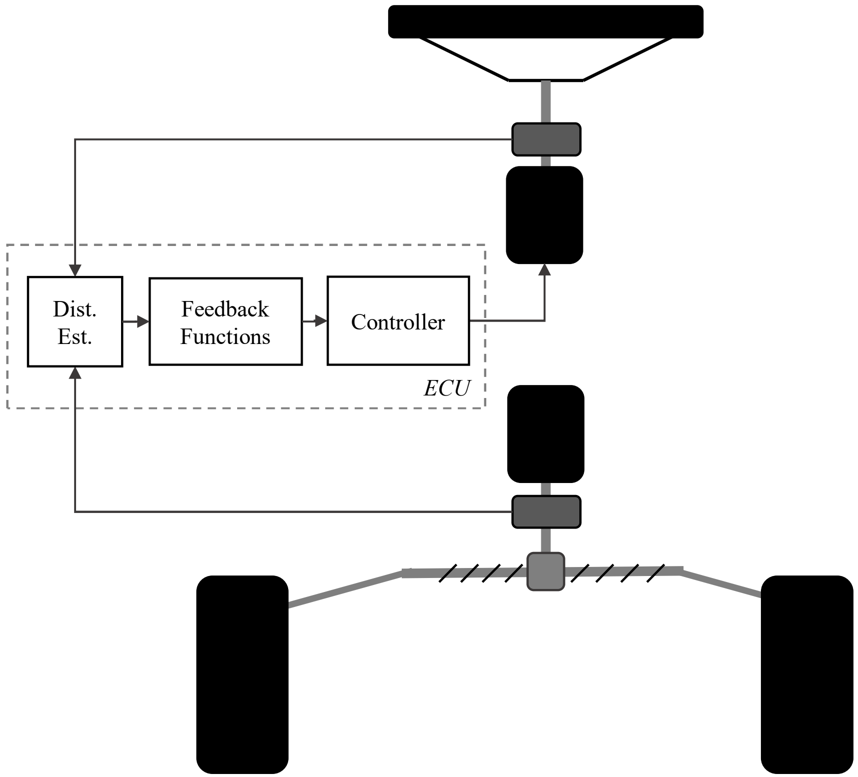
- The general idea is to look at peaks and their placements
- Largest challenge is to not catch the same phenomena in other driving situations
- Shows potential

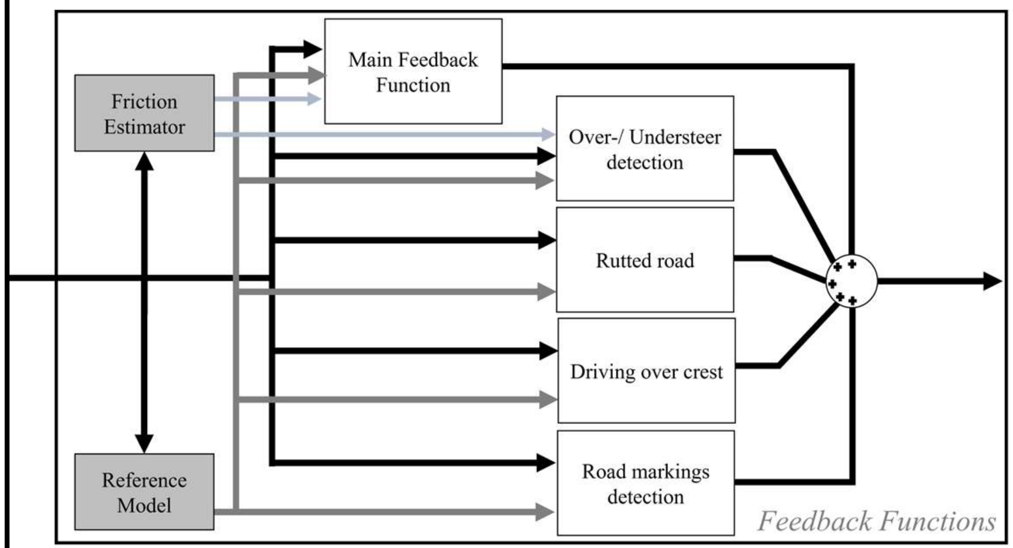


Quantify and mimic the feedback through the steering wheel during some driving condition

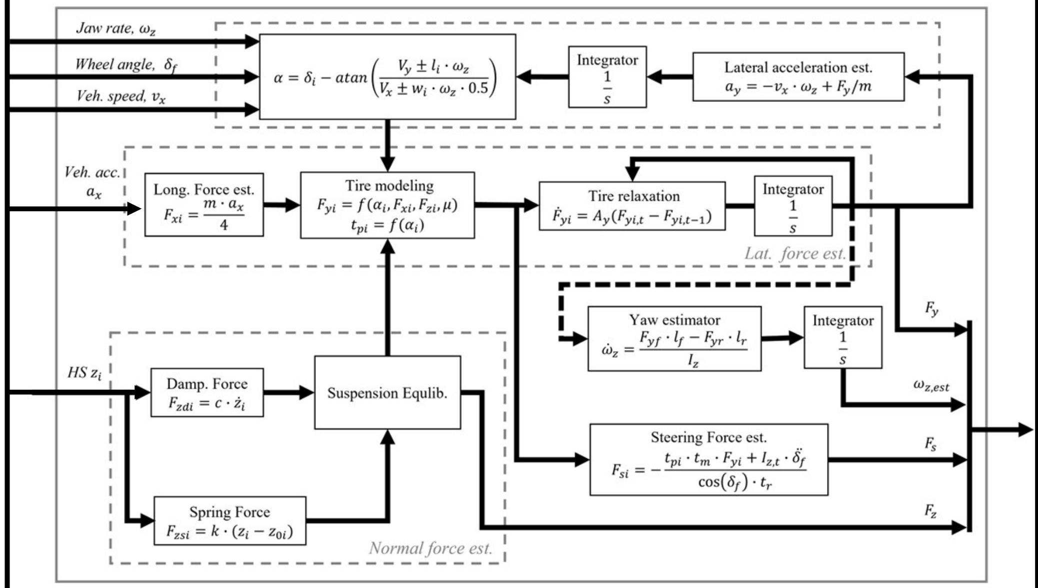
Aron Dalemo

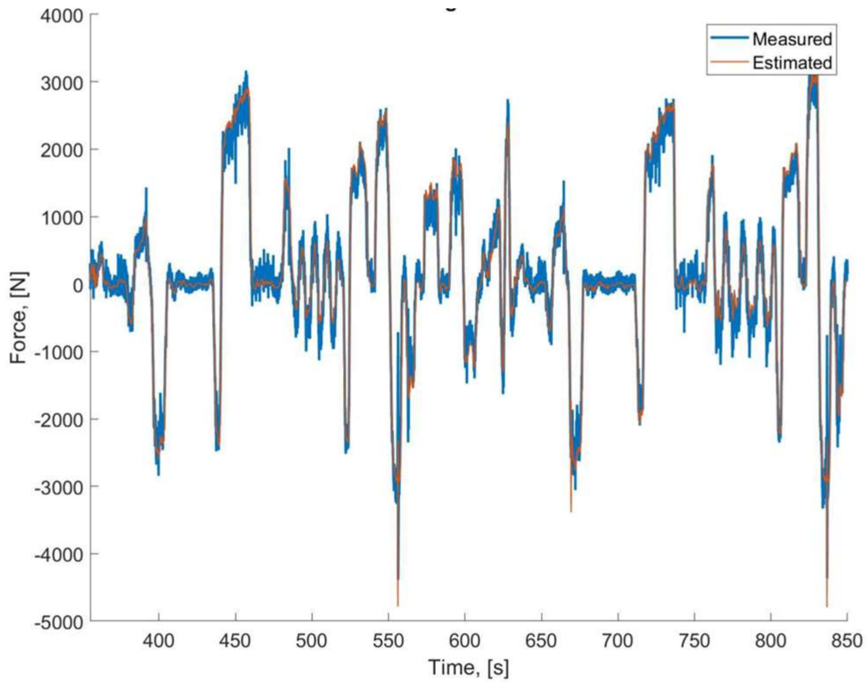
Model





Reference model

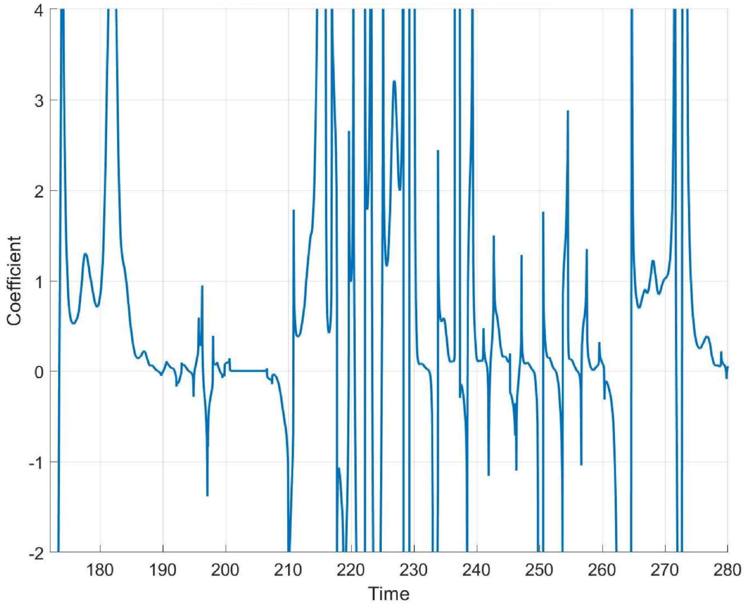




Different scenarios

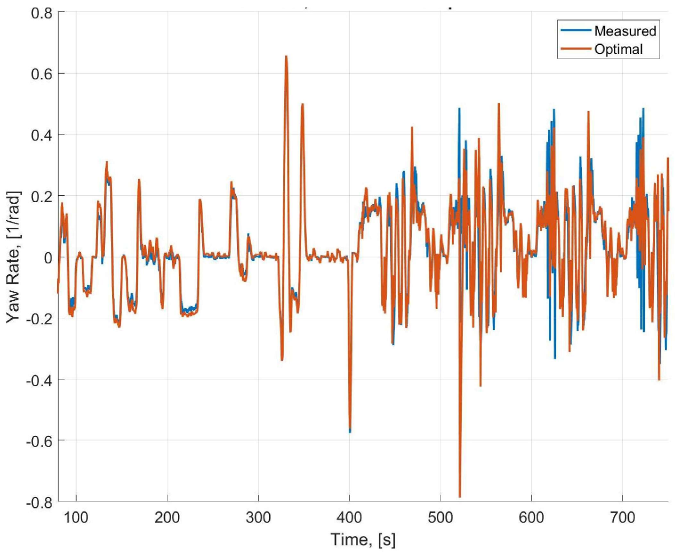
Low friction

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

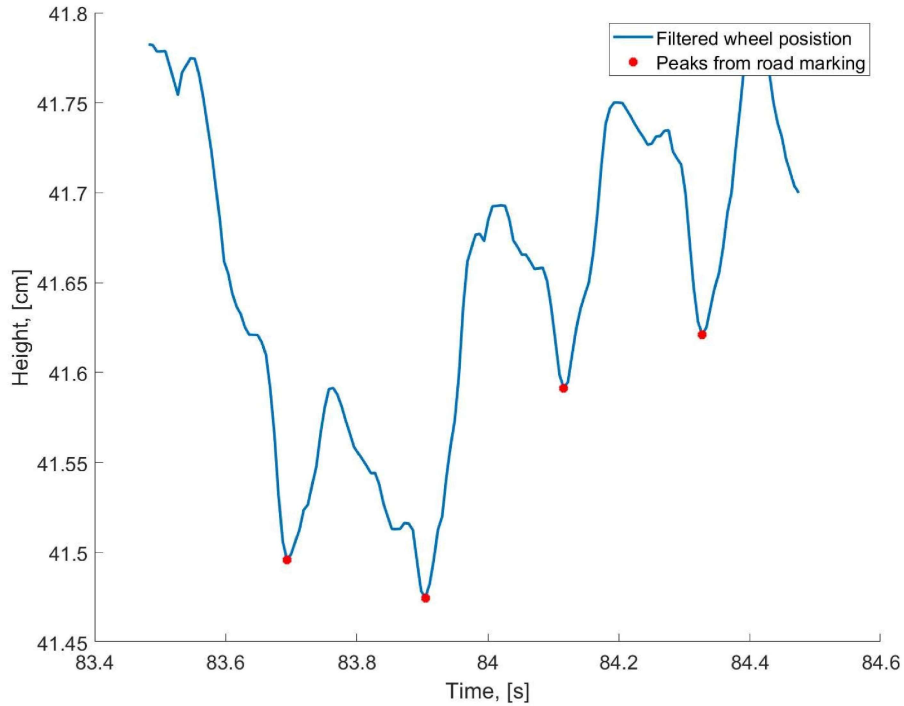


Dashed road markings

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

VOLVO

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

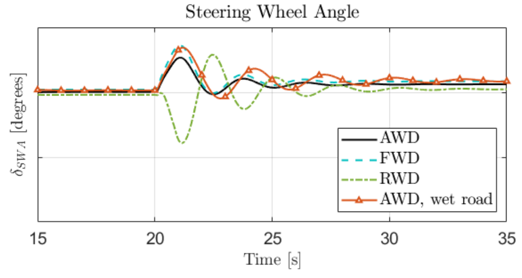
2023-05-22

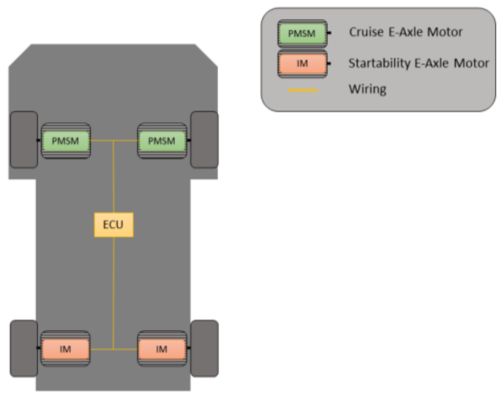
1

VOLVO

Background

- Varying distribution of propulsion between e-axles 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.



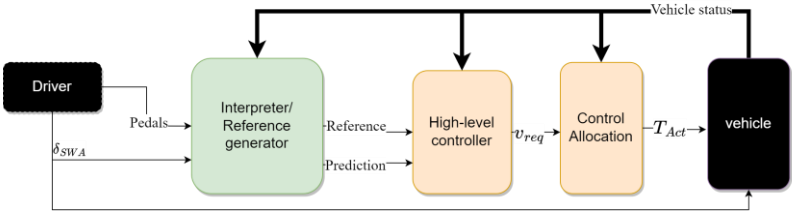


2

VOLVO

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



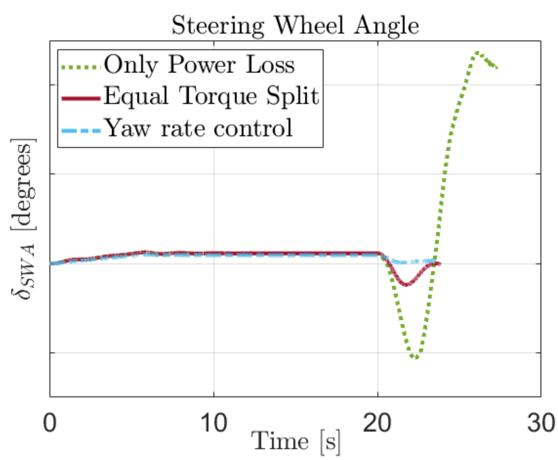
3

VOLVO

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.

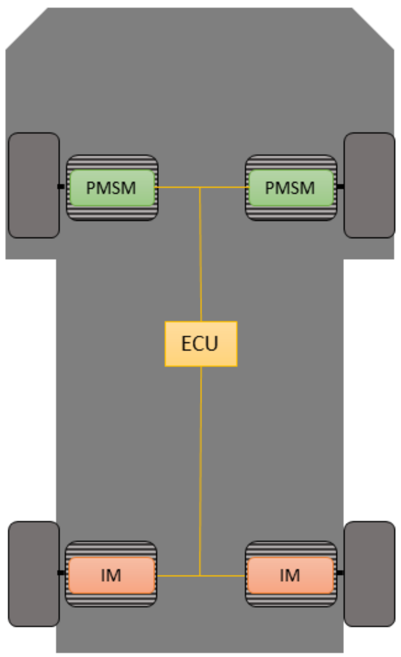


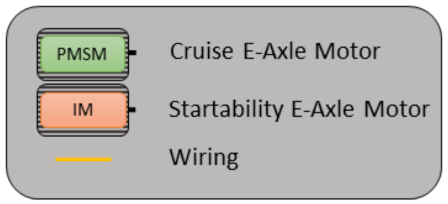
4

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

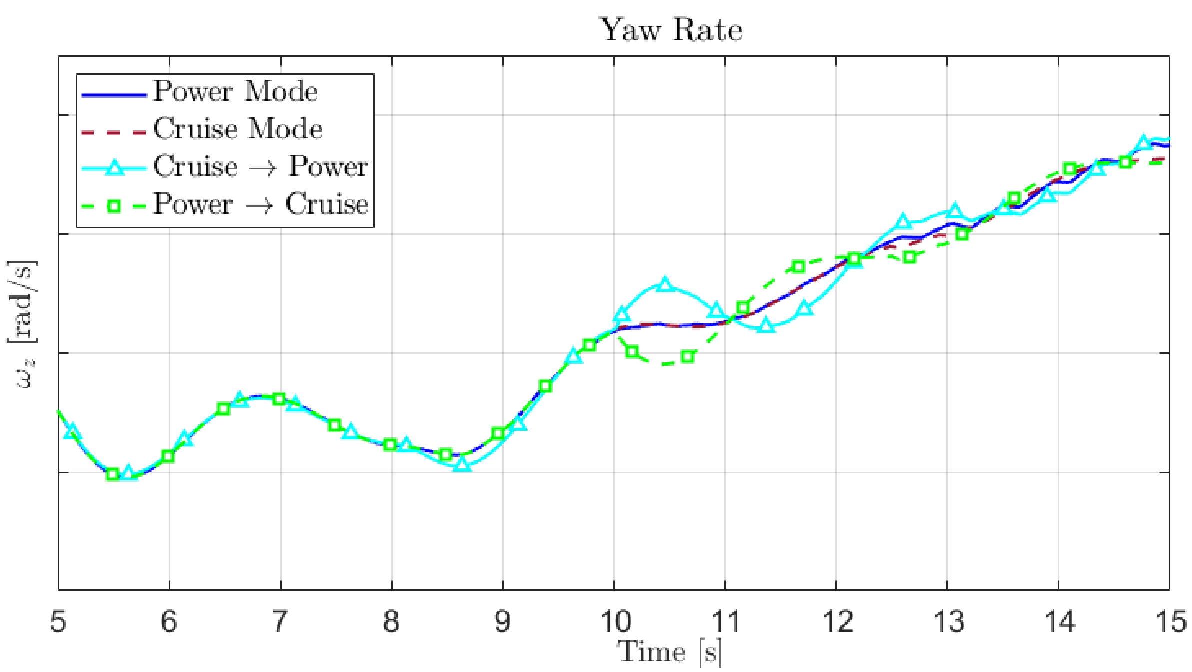
Jonas Persson and Jonathan Åkesson
Department of Mechanics and Maritime Sciences
Chalmers University of Technology

Background

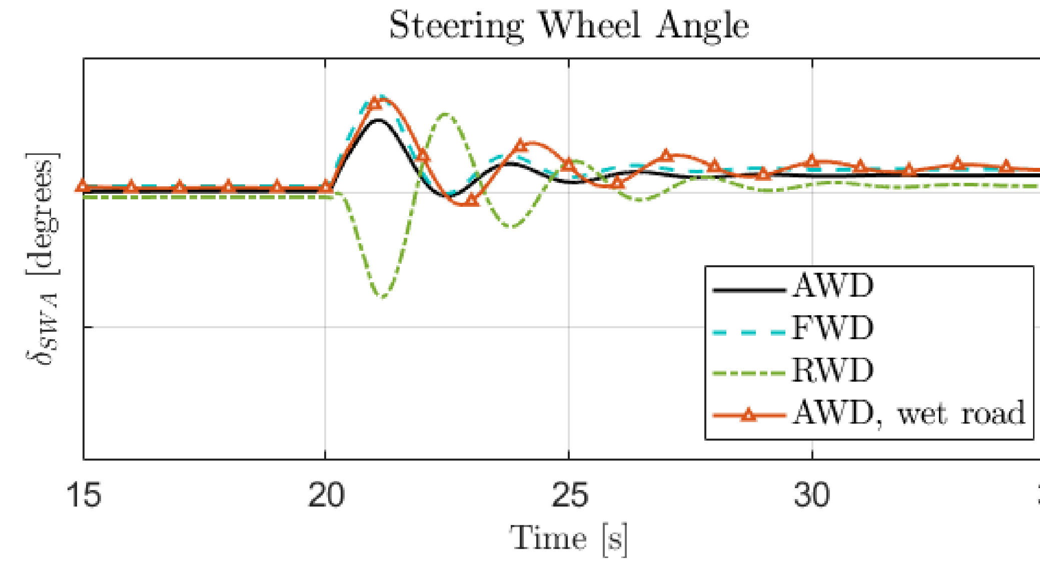




- Varying distribution of propulsion between e-axles will change the handling characteristics, which can make the vehicle unpredictable to steer.
- Separate motors on left and right side allows for micromanaging of lateral dynamics through torque vectoring.

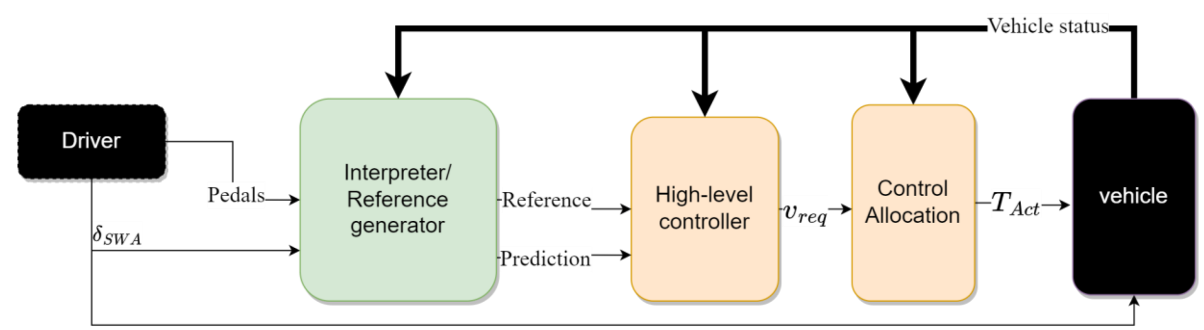


Yaw rate for acceleration during cornering. At 10s, switch in power distribution between e-axles introduce a yaw moment on the vehicle.



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

Jonas Persson and Jonathan Åkesson

VOLVO

Department of Mechanics and Maritime Sciences
Chalmers University of Technology

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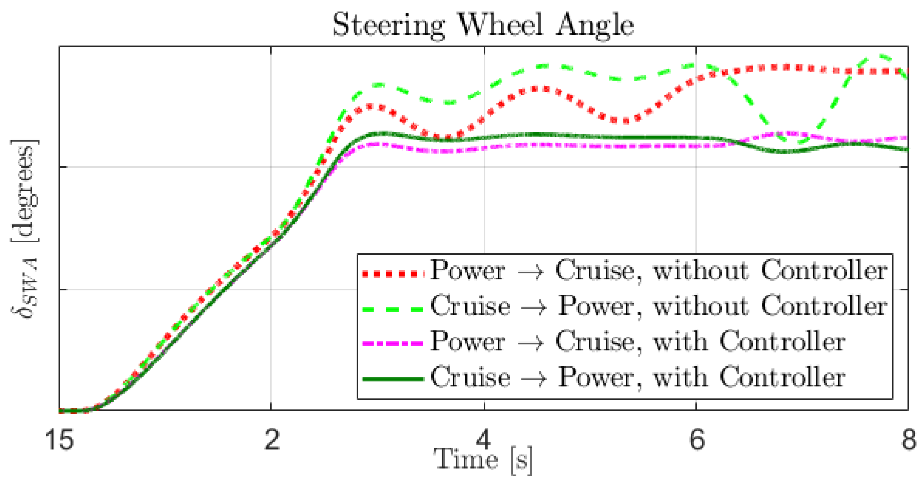
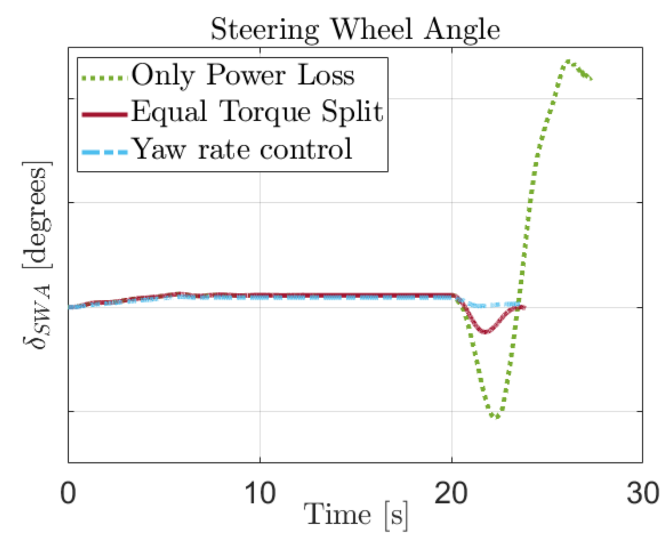
Predictable steering behaviour with Torque Vectoring

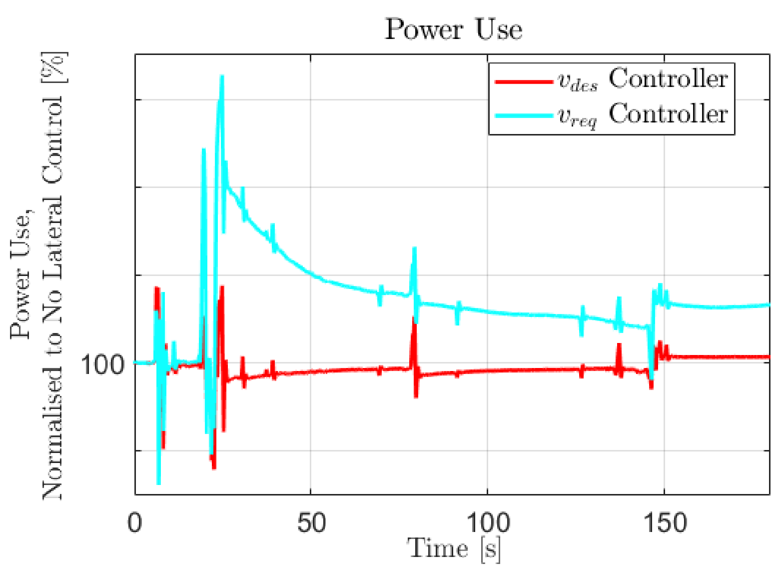


Steering wheel angle for emergency braking during cornering. Yaw rate controller aids in lateral stability, resulting in:

- 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.

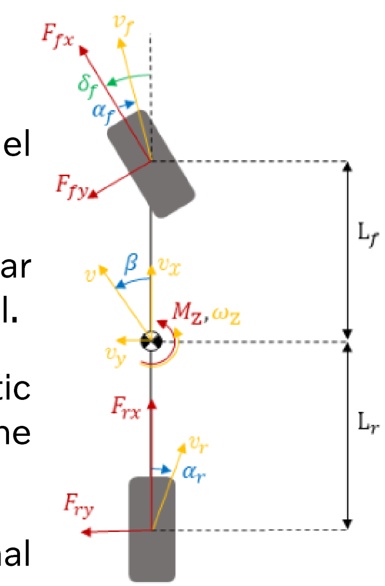
The Model

$$\dot{x} = Ax + Bu + C\delta_f + D$$

$$\min_{z} \quad \frac{1}{2}\mathbf{z}^\top H\mathbf{z} + g^\top \mathbf{z}$$
$$\text{s.t.} \quad A_{eq}\cdot\mathbf{z} = b_{eq}$$
$$A_{in}\cdot\mathbf{z} \leq b_{in}$$

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

- 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

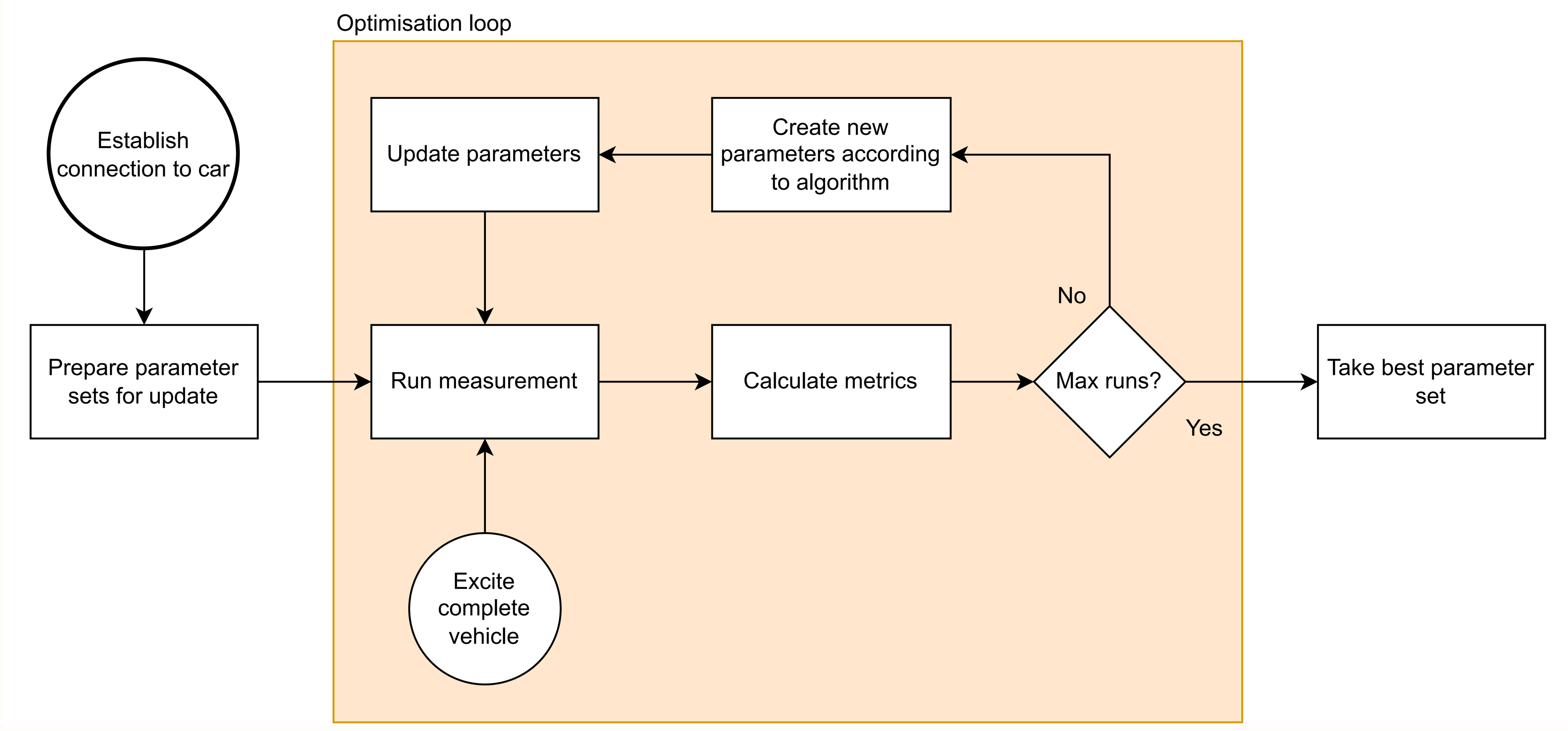


Figure 1: On rig optimisation loop

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

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

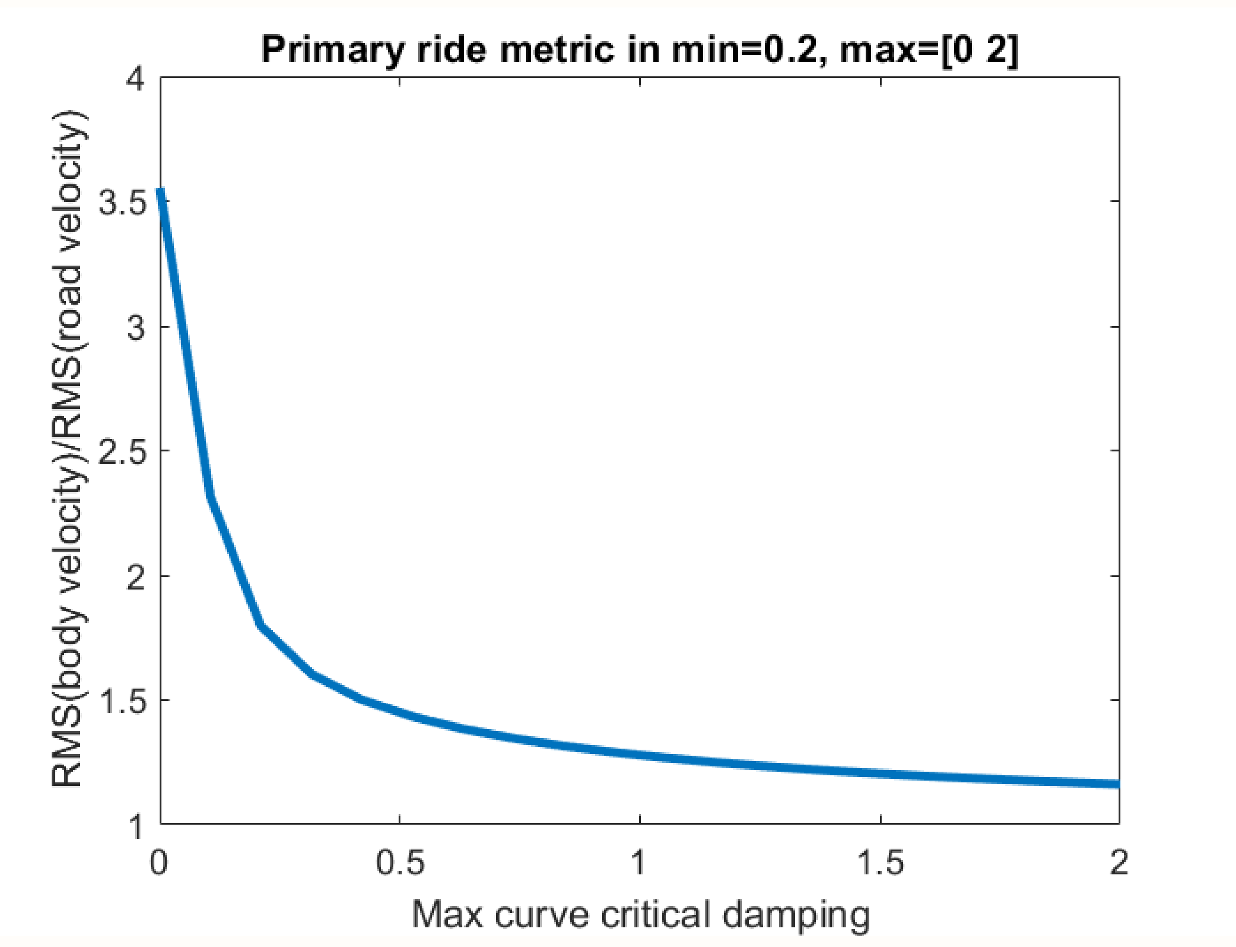


Figure 2: Relation between critical damping and primary ride

- 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

- 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 Primary ride control $= \frac{\mathrm{RMS}(V_{\mathrm{body}})}{\mathrm{RMS}(V_{\mathrm{Road}})}$
- 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

Master thesis at VEAS, Chalmers 2023

Poster 4:

Optimised force distribution algorithm and model

Guglielmo Nappi and Sanjay Banerjee, Scania & KTH

Sanjay & Guglielmo

Optimised force distribution algorithm and model

Model info

23/05/2023

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.

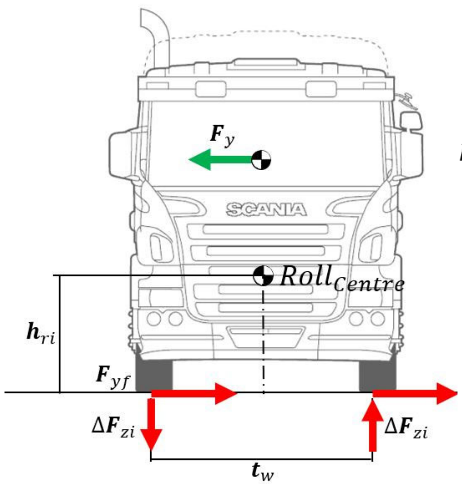
Test Procedure:

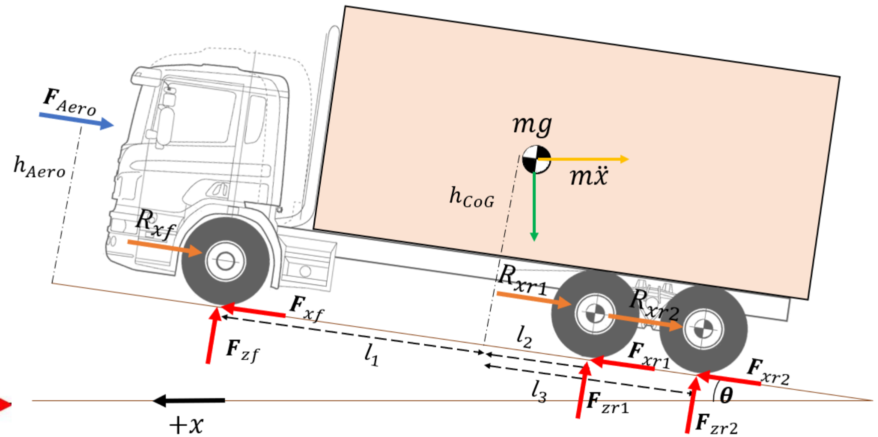
- Isolated **longitudinal** dynamics manoeuvre
- Isolated **lateral** dynamics manoeuvres
- **Combined** longitudinal and lateral dynamics
- Hill climbs

Software used:

Vehicle modelling based on Simulink with MATLAB 2020b scripts.

Truck Code	Gathered info about configurations of the truck.
↓	
Vehicle Model	Vehicle model generation: CG position defined, axle distance from CG, computation of inertia moments.
↓	
Tyre model	Computation of longitudinal and lateral tyre forces at each tyre.
↓	
CG Forces	Computation of the corner forces and overall forces at vehicle's CG.
↓	
Body dynamics	Computation of vehicle body dynamics in 4 DoF and estimation of vehicle states.
↓	
Vehicle states prediction	Predict the vehicle states based on vehicle dynamics output.



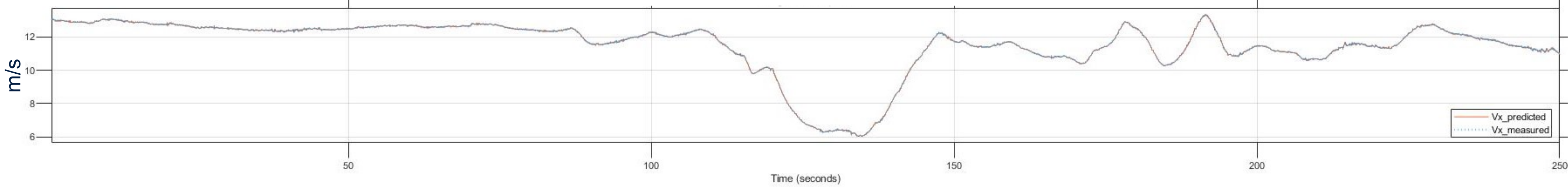


Test procedure and results

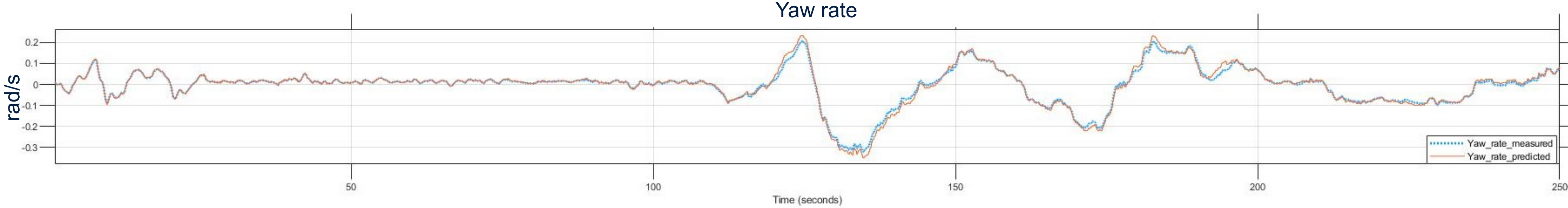
Measured parameter

Estimated parameter

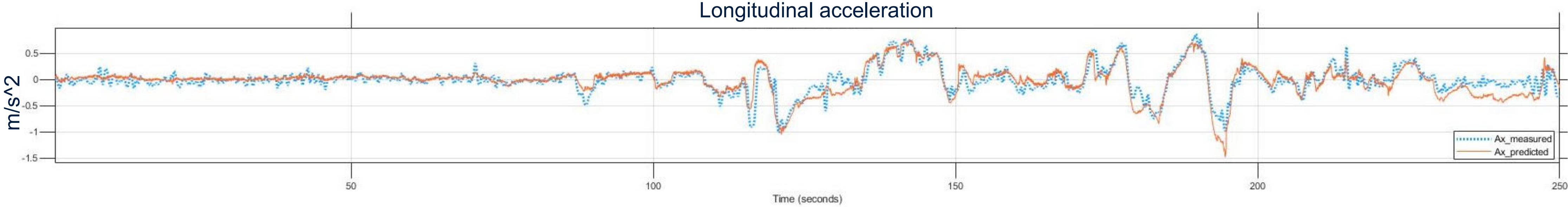
Longitudinal velocity



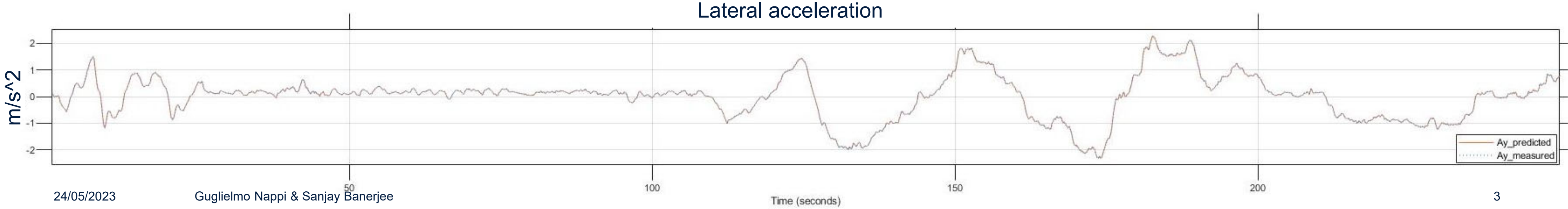
Yaw rate



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

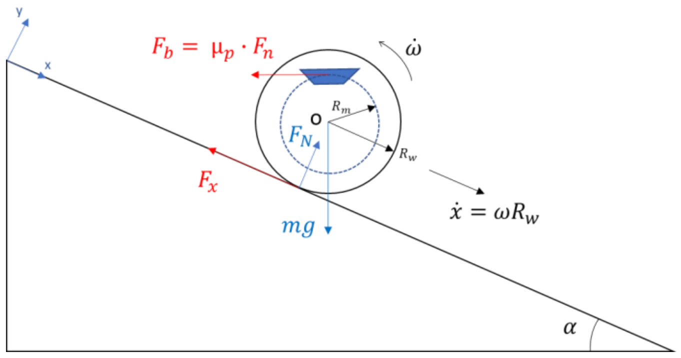
Supervisor: Mats Jonasson, VEAS, M2
Examiner: Petri Piiroinen, Division of Dynamics, M2

Background and problems

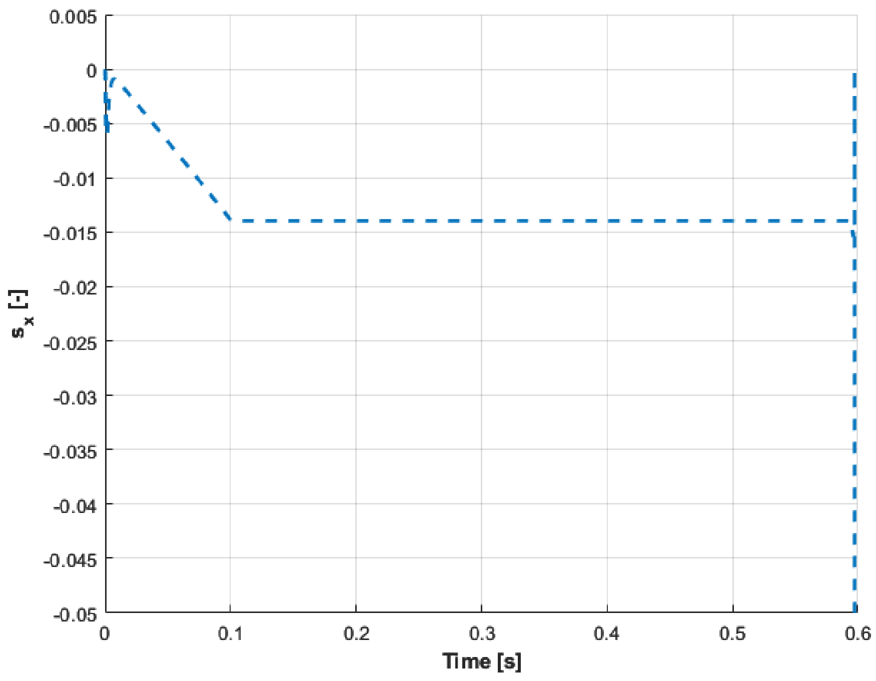
slip variable

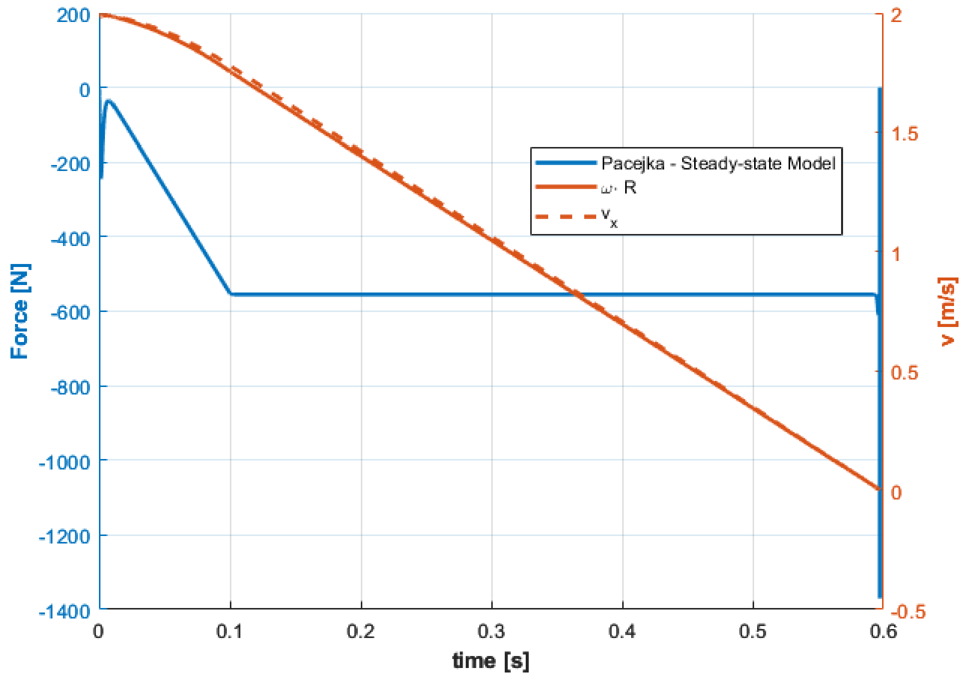
Classic (Pacejka) force models

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

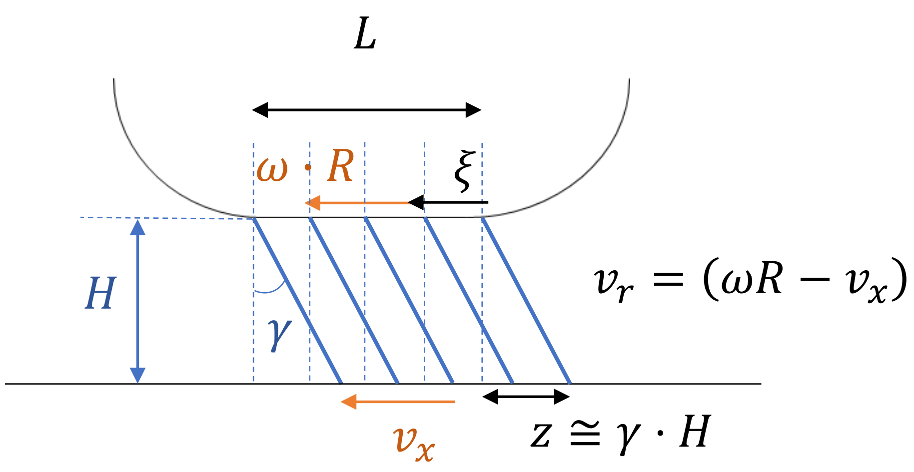


What happen when $\omega \cdot R$ is close to 0?





LuGre Distributed Tyre Model

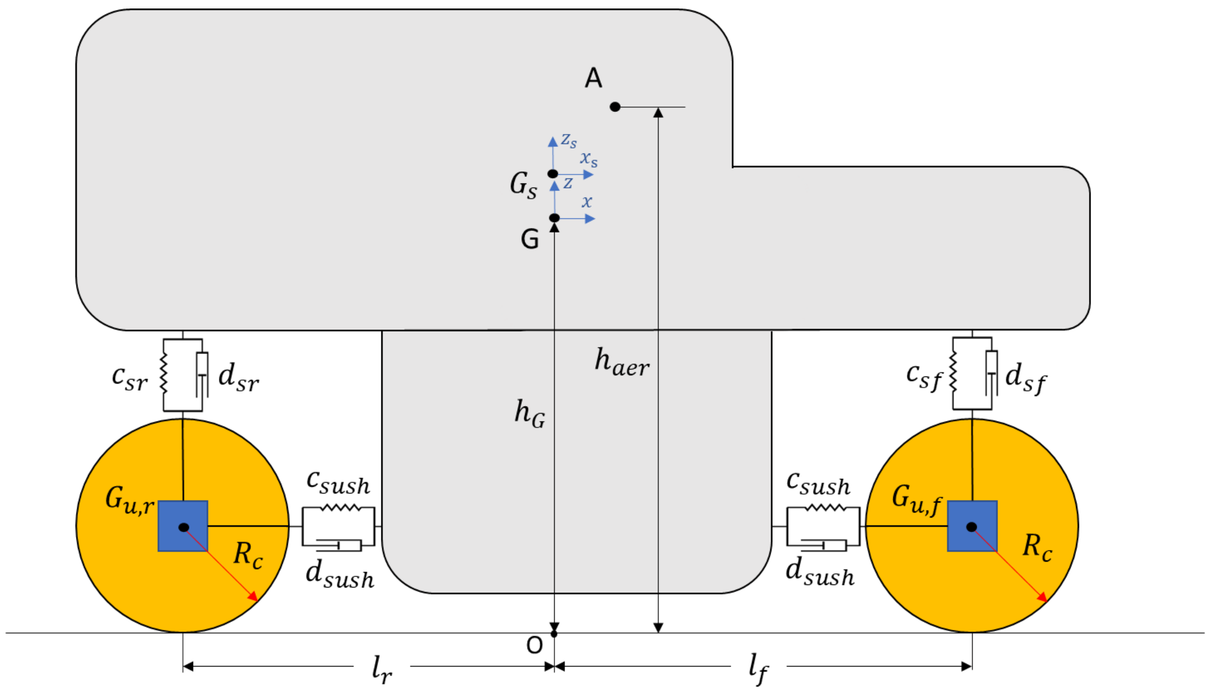


$$F_x = \sum_{i=1}^{N} \mu(v_r(t), N) \cdot p(N) \cdot \Delta\xi$$

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

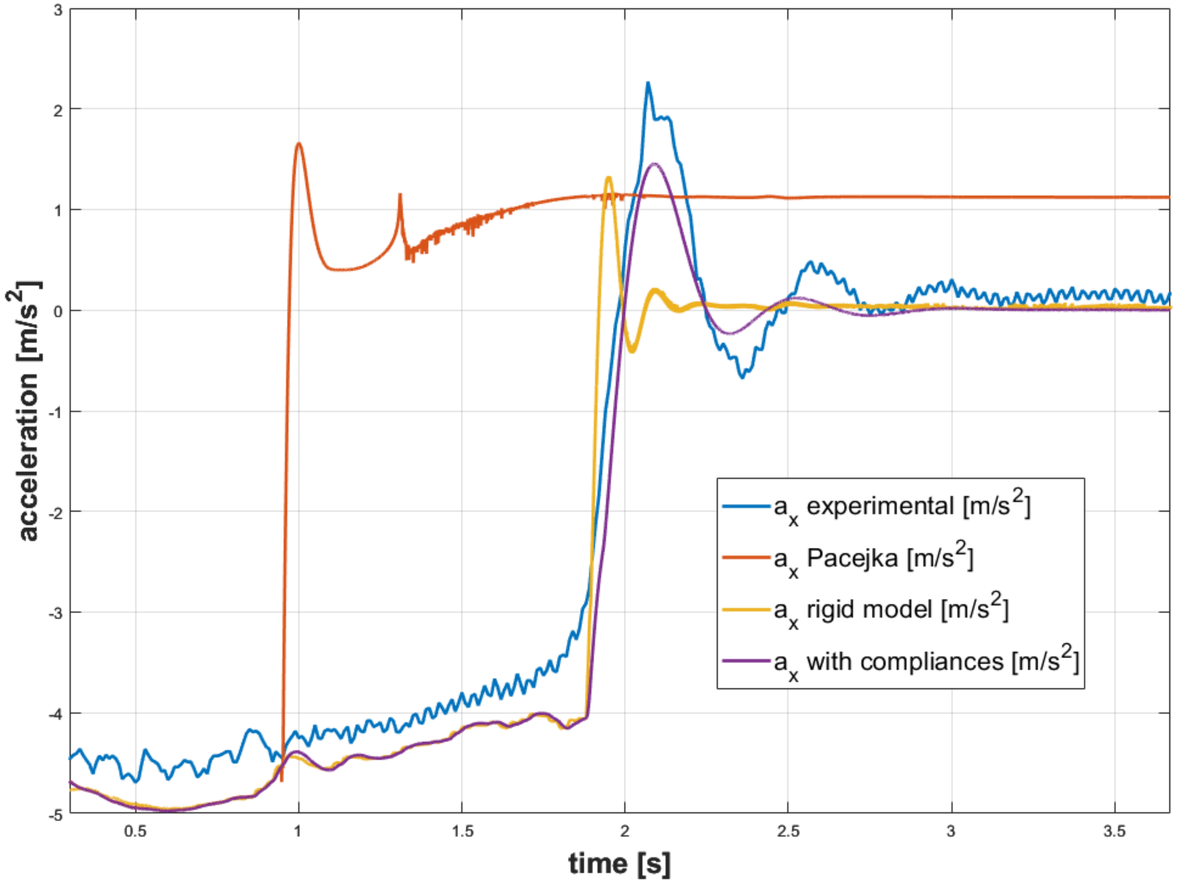
The friction term $\mu(v_r(t), \xi)$ takes into account the bristles deflection behaviour.

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.

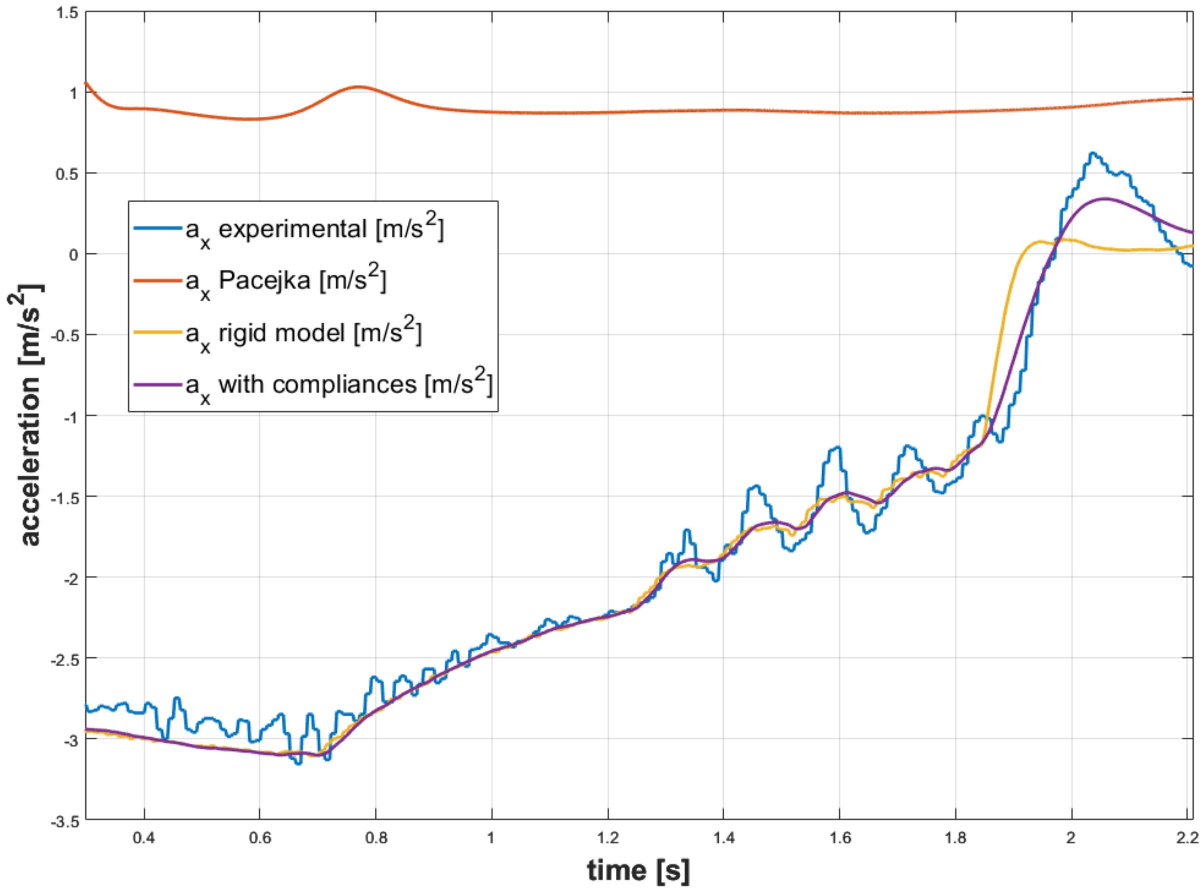


Vehicle model results

Braking on asphalt



Braking on ice



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

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

Thanks for your attention

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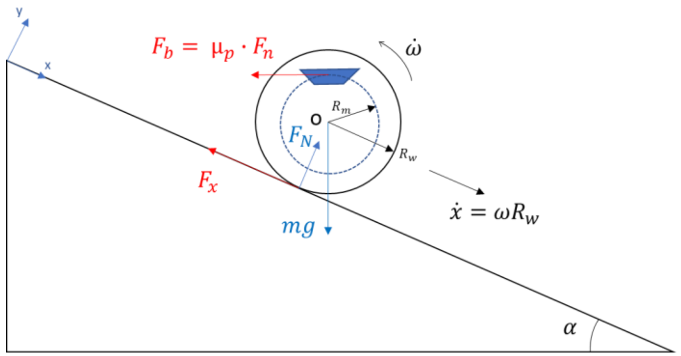

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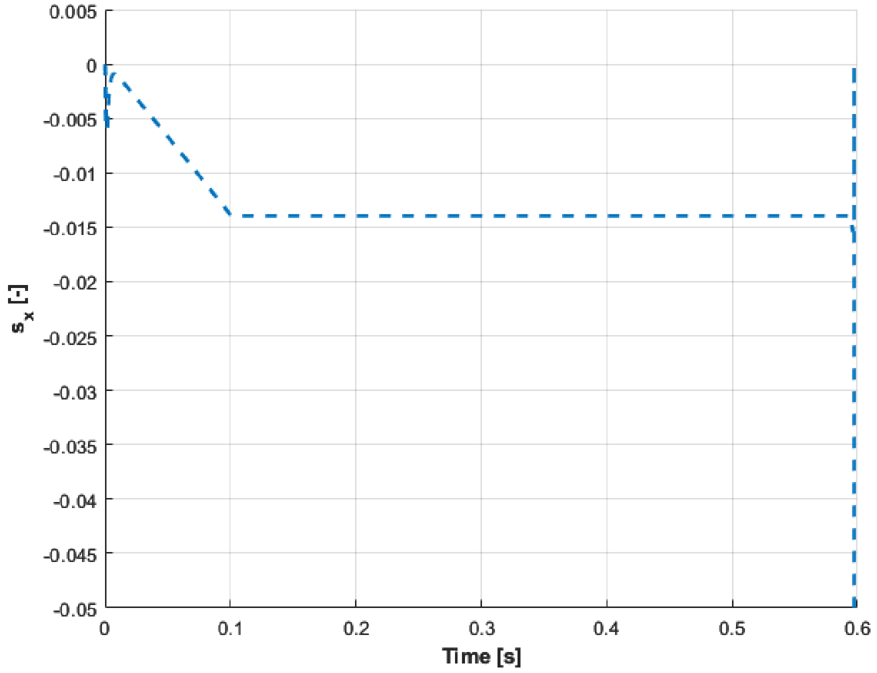

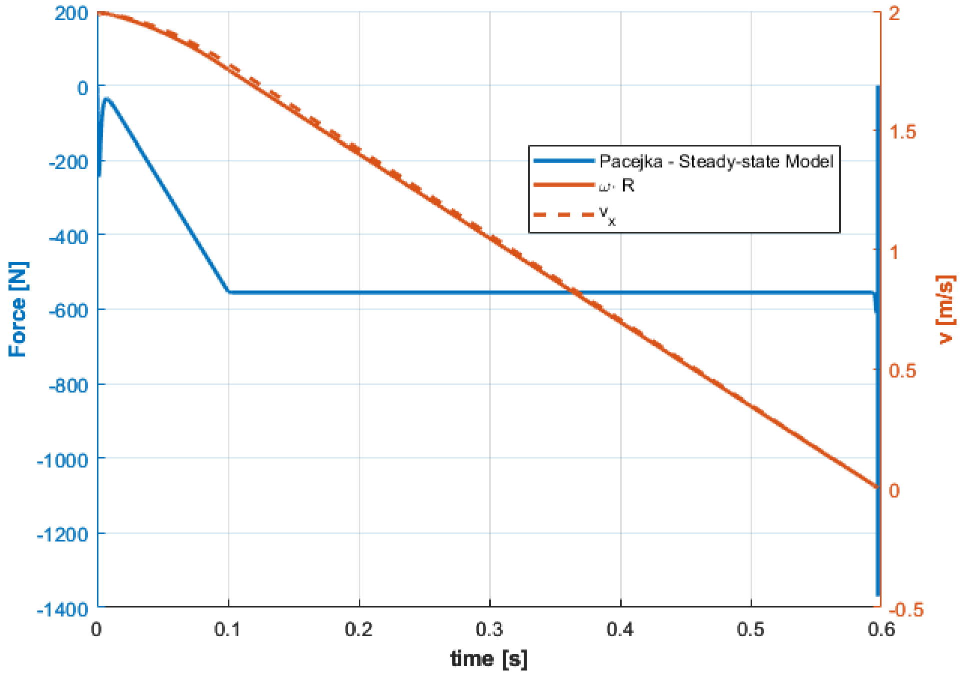

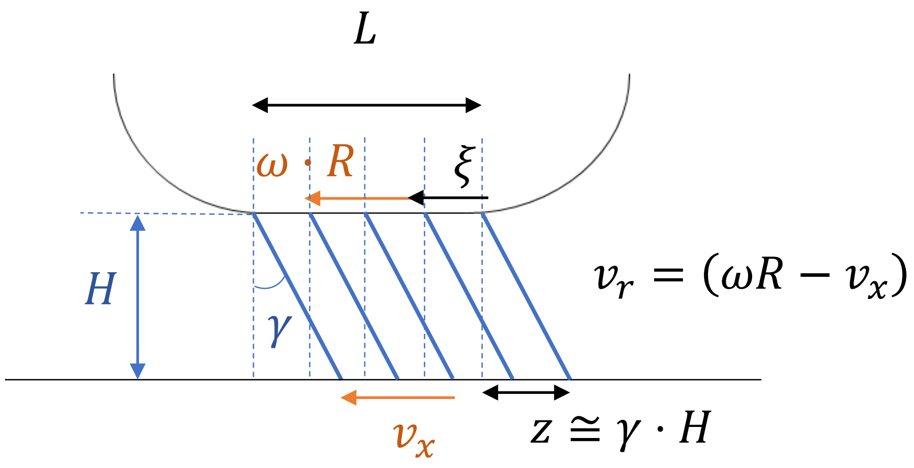

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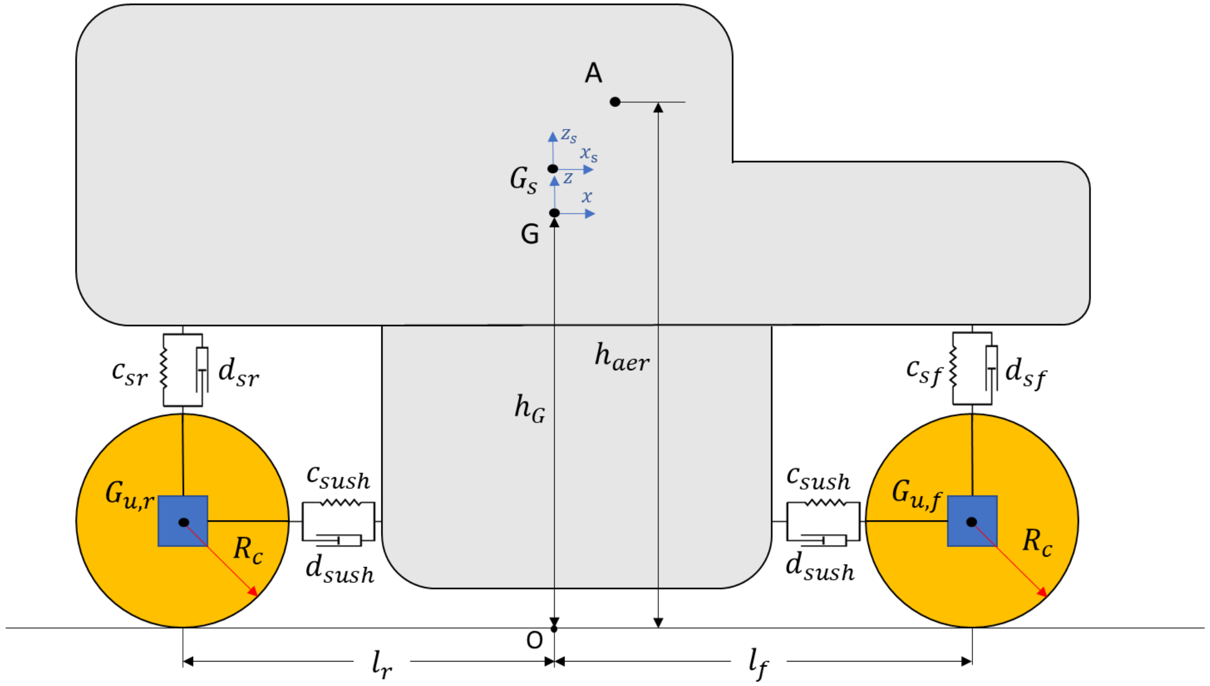

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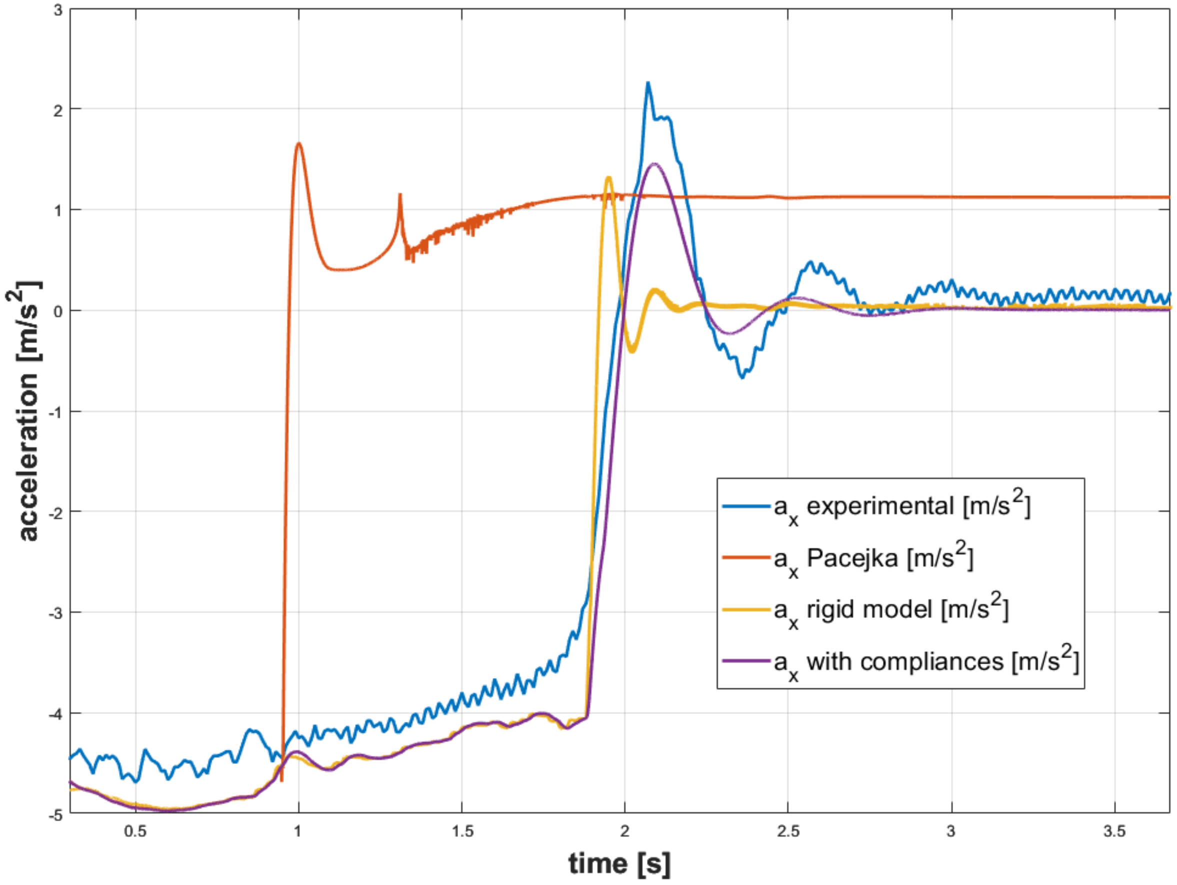
Braking on asphalt



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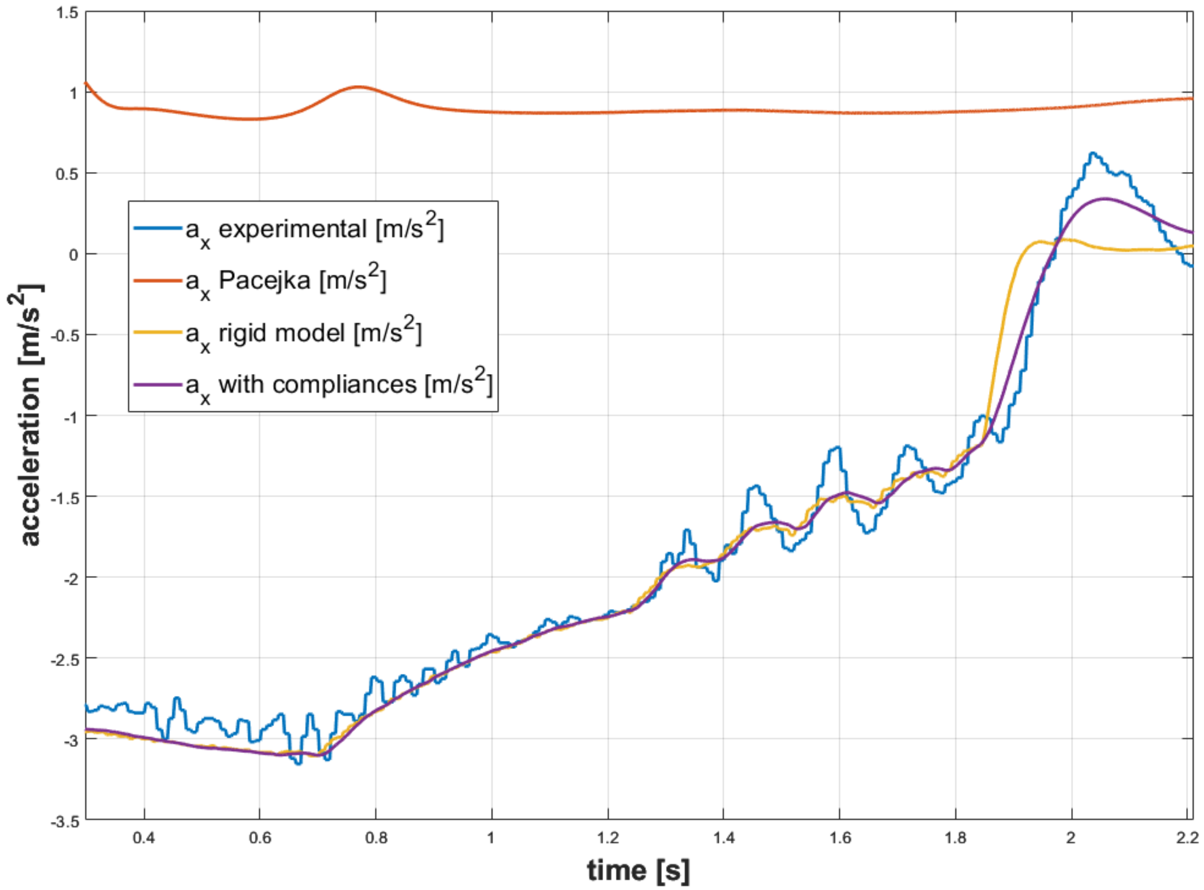

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