virtual vehicle

Accelerating Innovation

INFRAMIX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723016.

Hybrid Testing:

A novel Vehicle-in-the-Loop Testing Method for the Development of Automated Driving Functions in Mixed Traffic Scenarios

Dr. Selim Solmaz

Lead Researcher | Control Systems

GSVF2020 | 01.09.2020

www.v2c2.at

Presentation Outline

- **Inframix project introduction, methods, scenarios & results**
- **Hybrid Testing concept and components**
- **Hybrid Testing experiments description**
- **Result from onramp-merge scenerio**
- **Results from main flow scenrio with IVIM speed advice**
- **KPI Analysis**
- **Conclusions & outloook**

Project Overview: Inframix

INFRAMIX

Duration: 1 June 2017-31 May 2020

EC Funding: 5M €

Coordinator: AustriaTech

Consortium: AustriaTech, ICCS,

Asfinag, Fraunhofer, Siemens Mobility,

Virtual Vehicle, Autopistas,

Enide, Technical University of Crete,

TomTom, BMW

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723016.

Observations & Objectives: Inframix

Avoiding decrease of safety/efficiency by infrastructure support

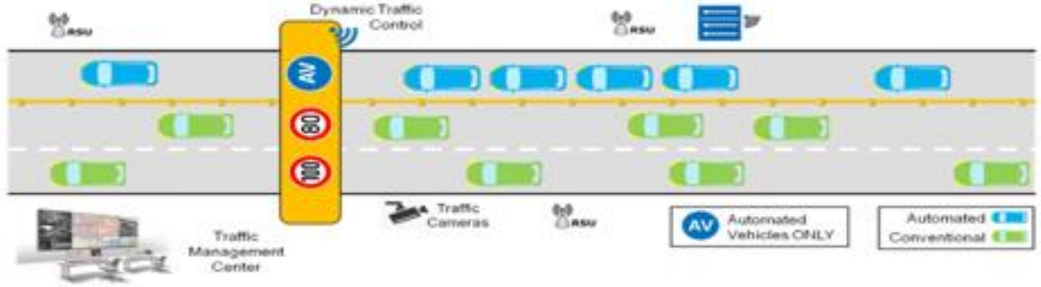
Support from infrastructure at different levels

Support perception capability of AVs	•extend e-horizon (e.g. road works with lane deviations or incidents ahead) including information on detailed lane layout in road work zones
Improve conditions for AV manoeuvres	•Lane change advice before an on-ramp creating more space for merging (automated) vehicles
Support drivers of conv. vehicles	•New lane markings for AD lanes
Improve traffic situation	•Provide recommendations to connected and automated vehicles to increase efficieny (e.g. gap advice in bottlenecks)

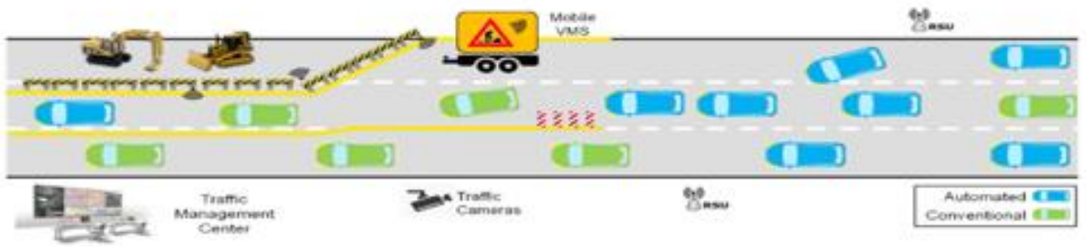
'The main objective of INFRAMIX is to prepare the road infrastructure with specific affordable adaptations and to support it with new models and tools, to accommodate for the step-wise introduction of automated vehicles.'

3 Scenarios – 3 key areas of Inframix

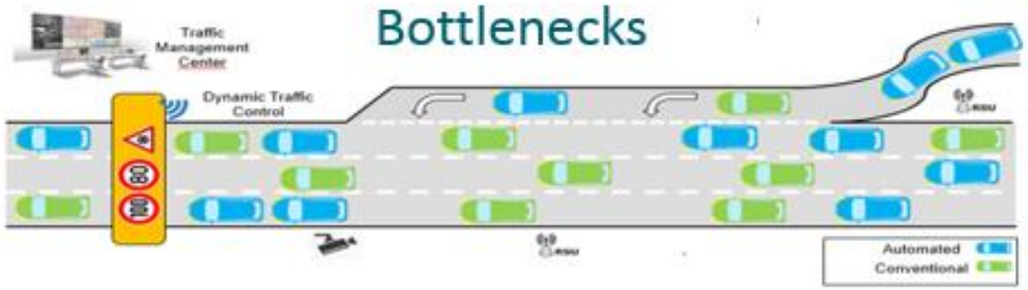
Dynamic lane assignment to automated driving



Roadworks zone

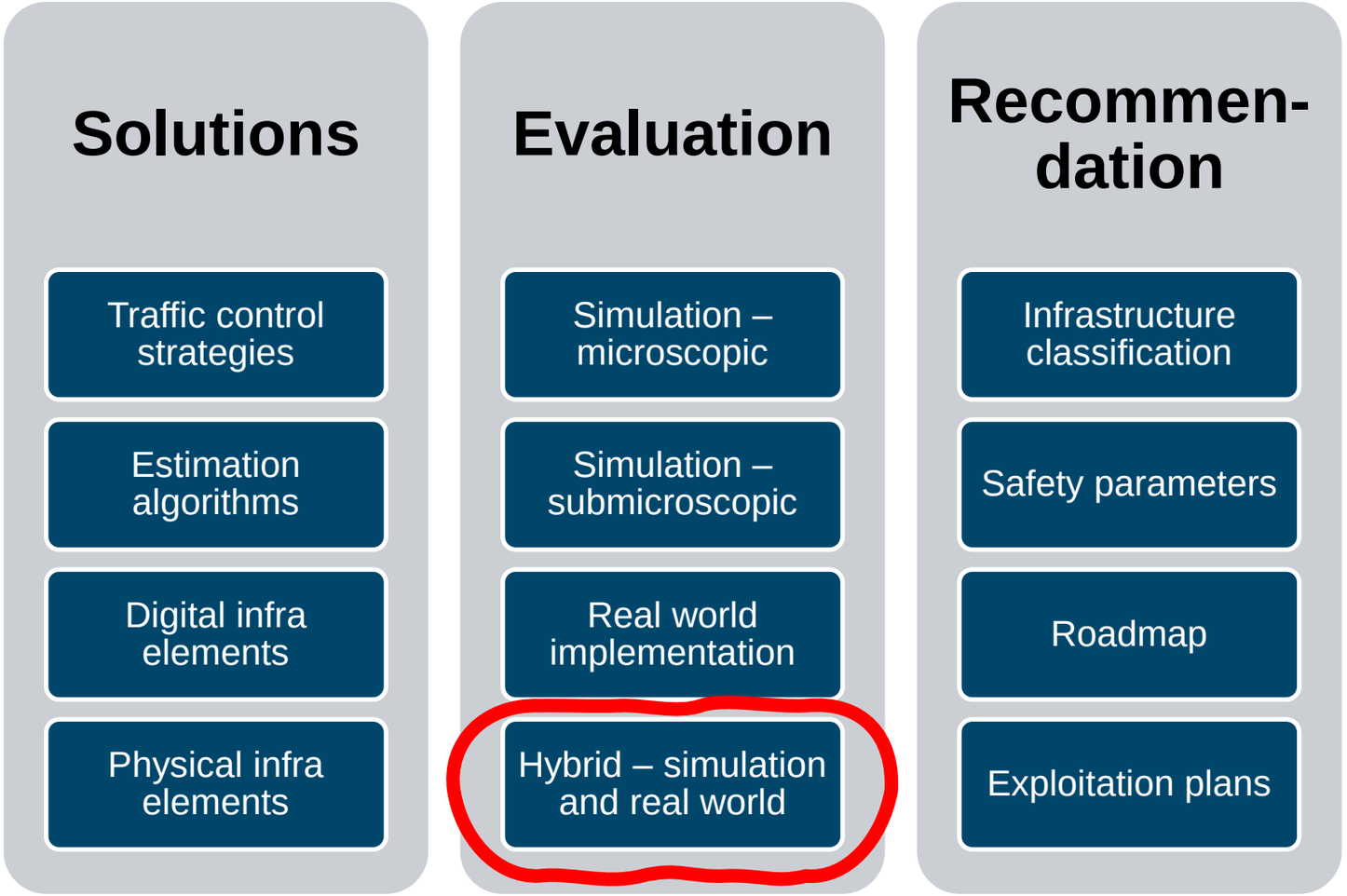


Bottlenecks

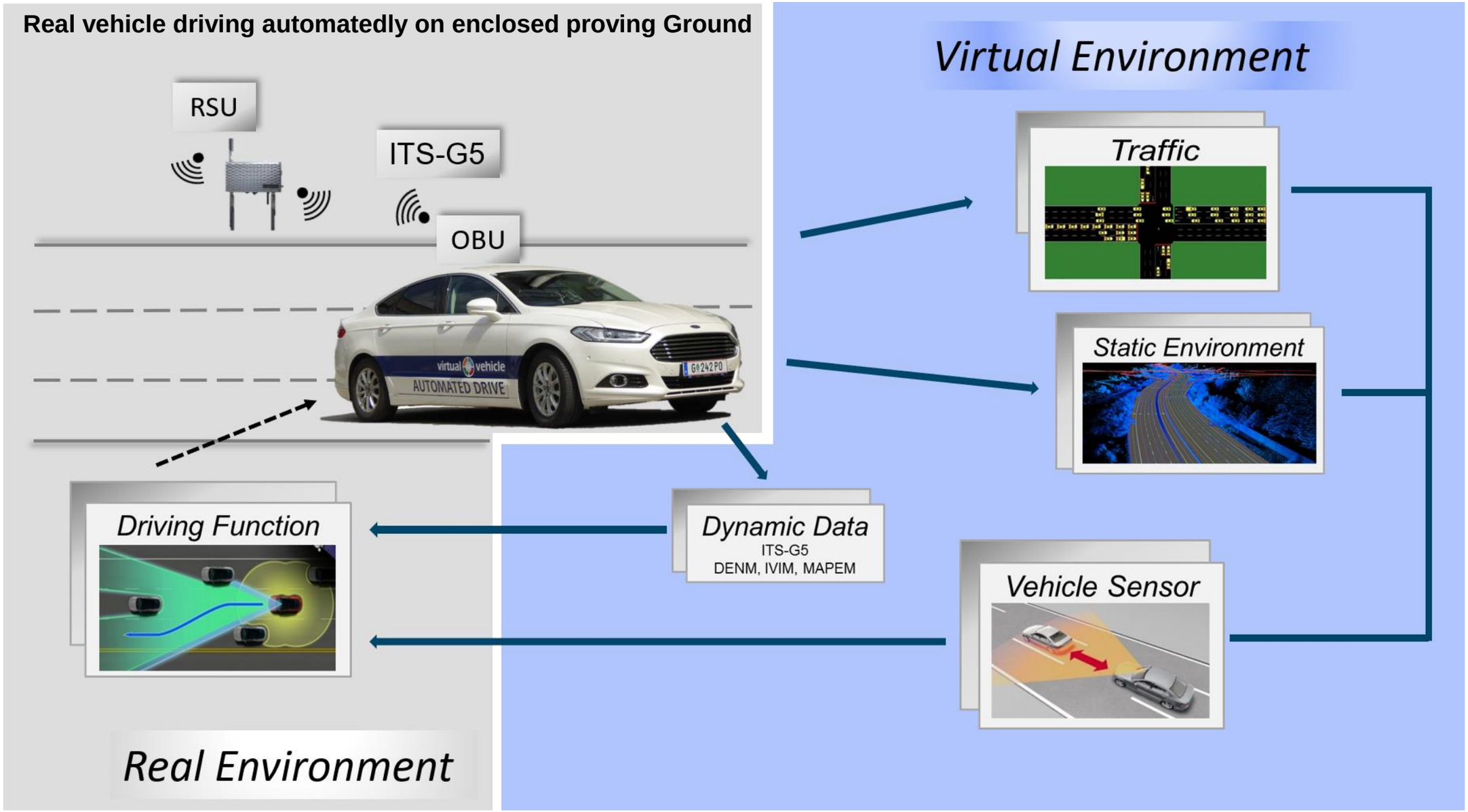


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723016.

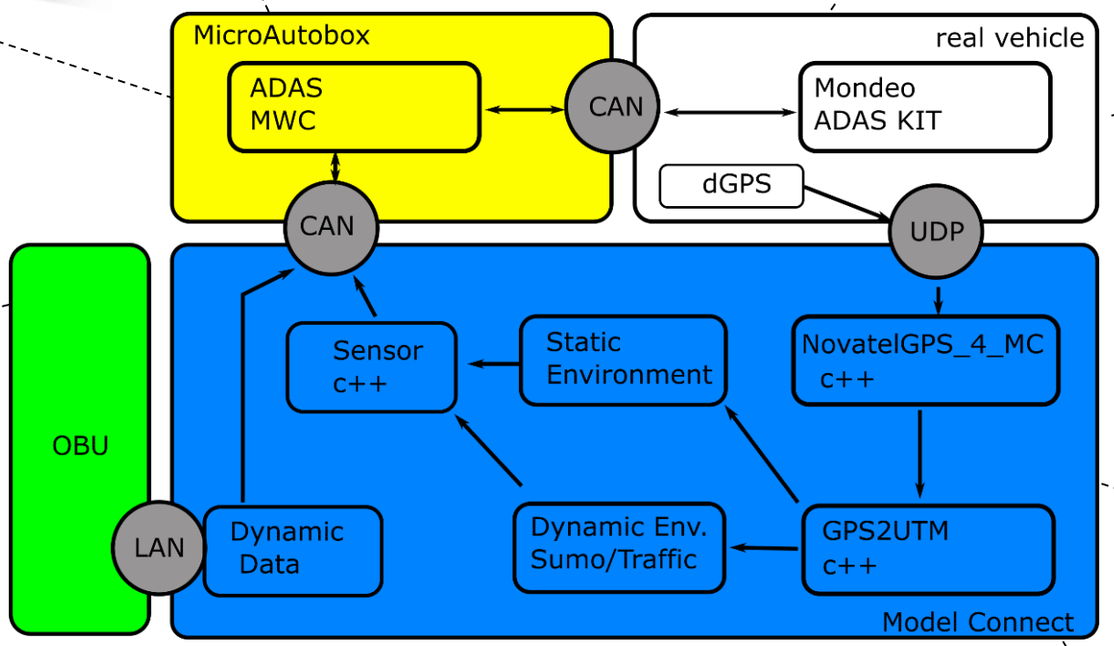
Approach and Highlights: Inframix



Hybrid Testing Concept



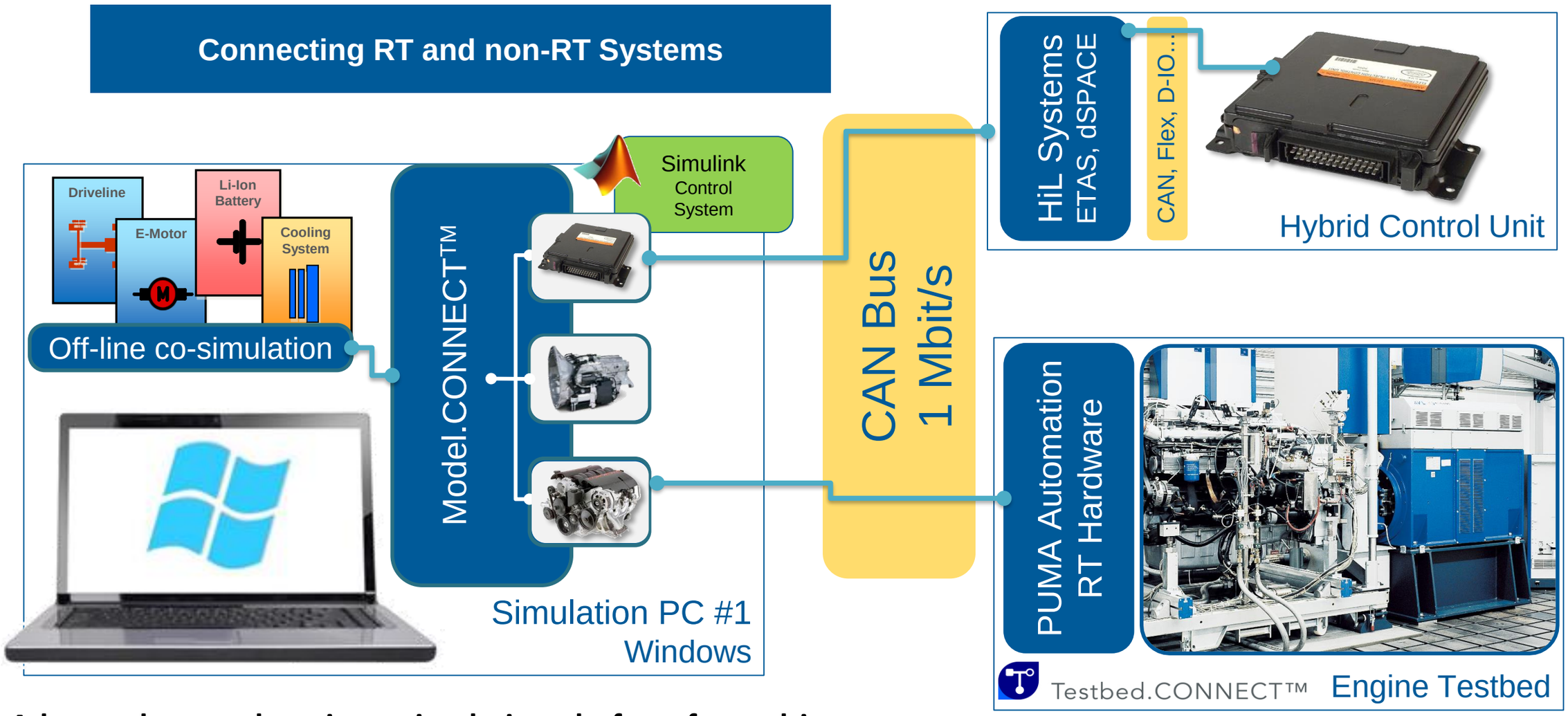
Hardware Components of Hybrid Testing



Co-Simulation Platform

Model.CONNECT™

Connecting RT and non-RT Systems



Advanced, cross-domain co-simulation platform for multi-disciplinary engineering

ViF-Automated Drive (AD) Demonstrator

- ***Drive by wire:***

  DataSpeed ADAS Kit:
  drive, brake, steer, visualize by wire

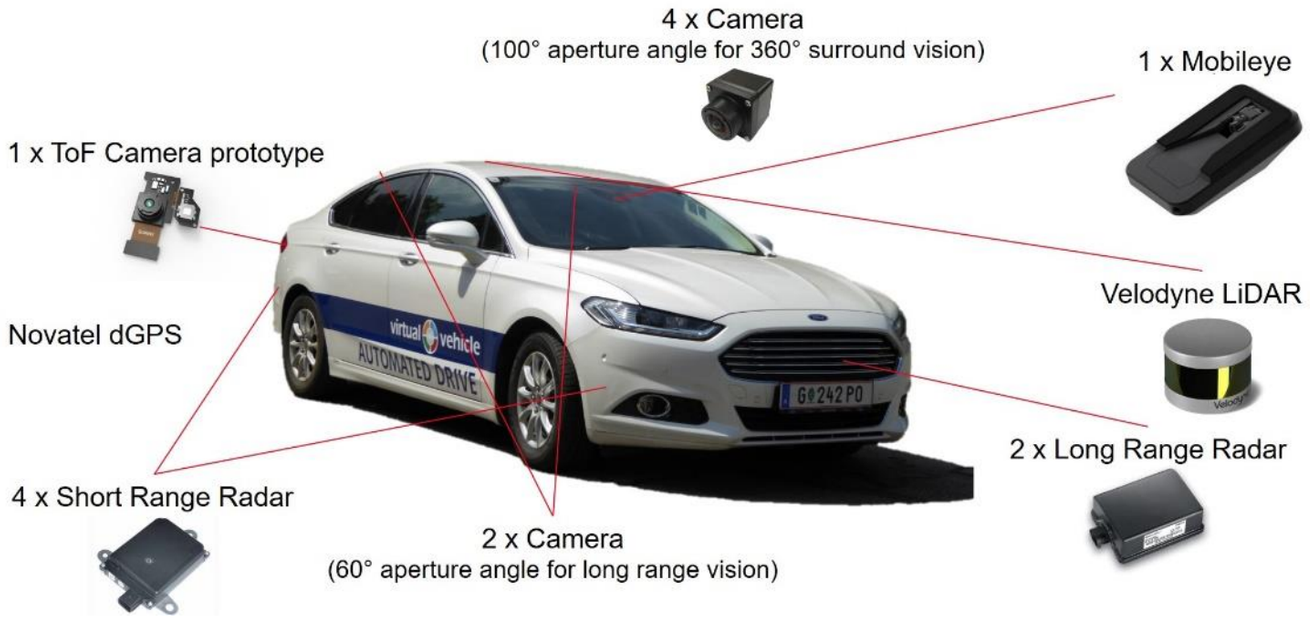
- ***Sensors:***

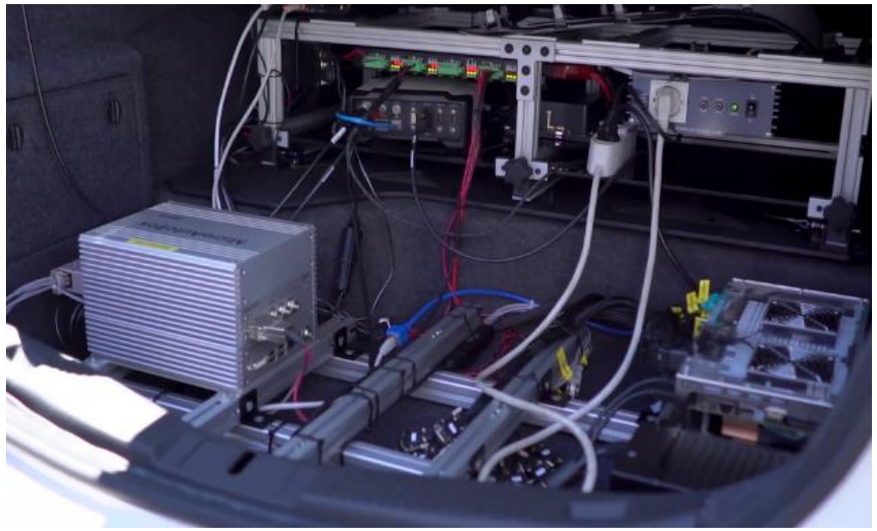
  Cameras, ultrasonic sensors, inertial sensors, GPS, Radars, Lidar(s), ToF…

- ***Interfaces:***

  HMI touch display, CAN,
  ROS (Robot operating System) Kinetic
  Nvidia Drive PX/2 (Ubuntu 16.04)
  dSPACE MicroAutoBox II
  PC (Win/Linux)

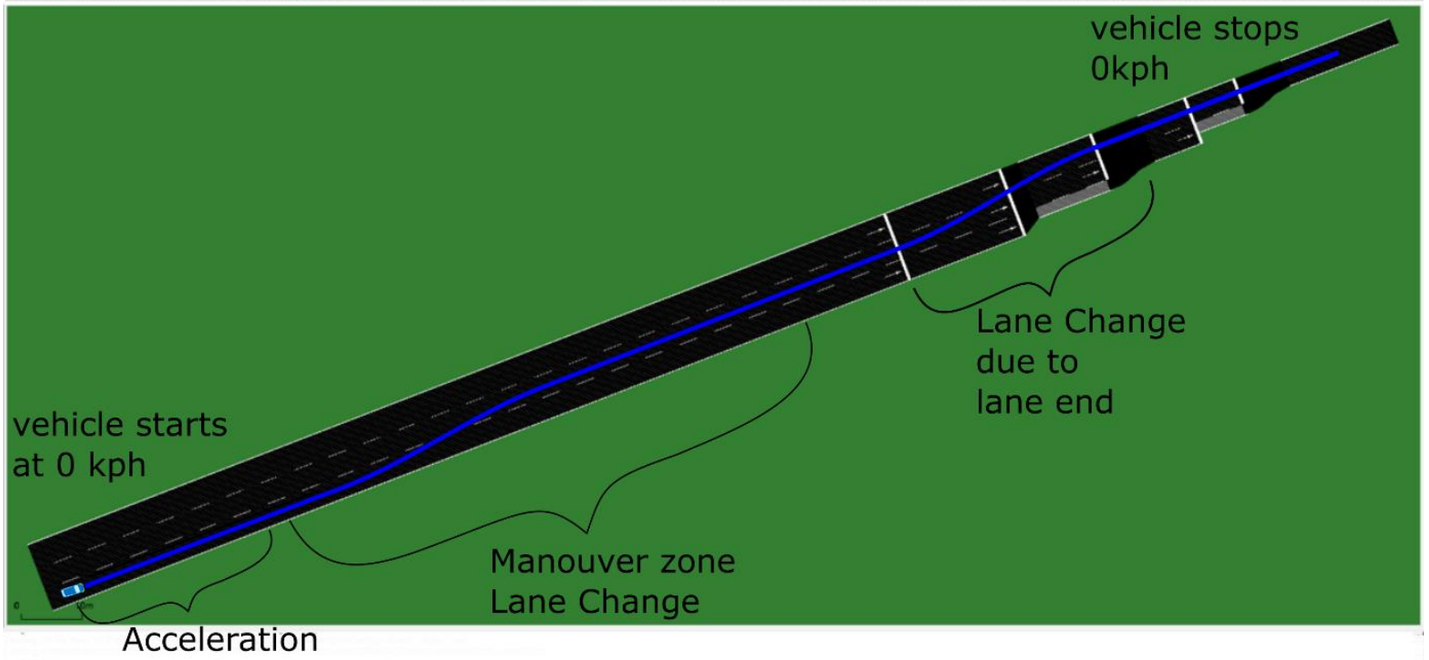
- ***Applications:***
  - ❑ *Measurement (sensor data acquisition, sensor fusion)*
  - ❑ *Development and test (ADAS/AD)*
  - ❑ *Energy management (hybrid car)*
  - ❑ *Proving ground platform*





HD-Map of the Proving Ground

- Open drive map format (.xodr) file of the ÖAMTC Lang-Lebring proving ground near Graz
- A straight road section with approximate usable length of ~250 m and width of at least 10 m across the main testing zone
- 3 virtual lanes with a width of 3.5m each + additional maneuver space as buffer zone



Hybrid Testing Experiments and Scenarios

Experiment Stack-I Onramp – Merge into the main road

- Without traffic
- With low traffic density
- With high traffic density

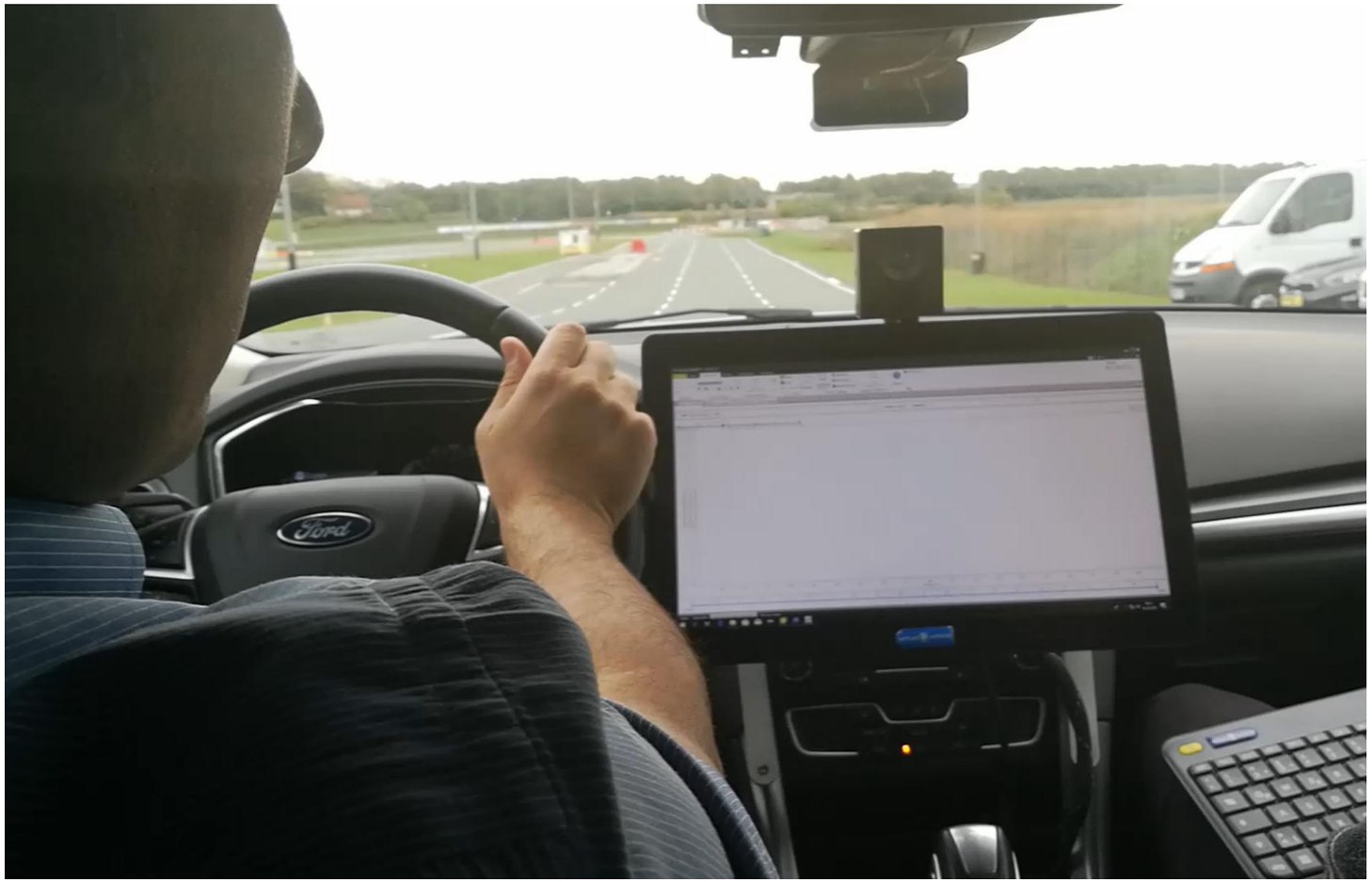
Experiment Stack-II Main road – speed recommendation (IVIM)

- Main road – without traffic
- Main road – without traffic & speed recommendation (IVIM)
- Main road – speed recommendation (IVIM) with vehicle in front & MWC overtakes
- Main road – speed recommendation (IVIM) with vehicle in front MWC adapts speed

Onramp Scenario: Merge into the main road

Merge into main road w/o traffic

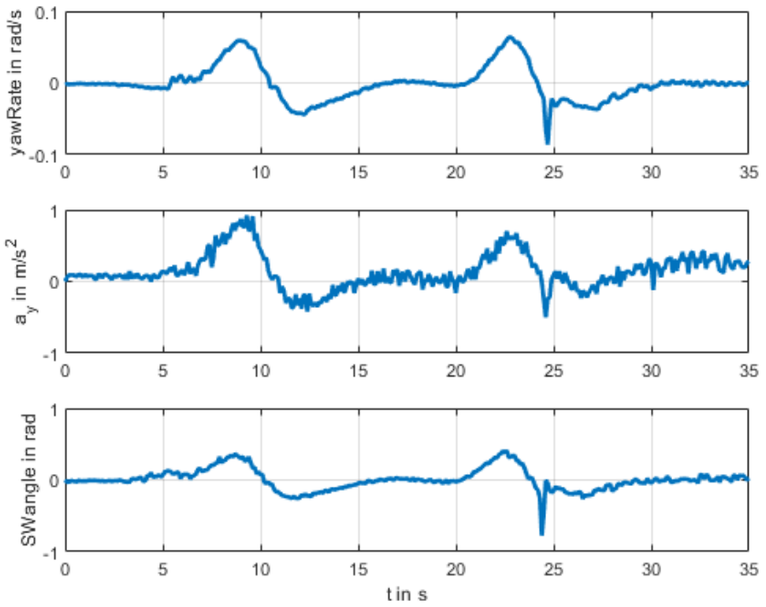
- VuT starts at the rightmost lane & accelerates to 30 km/h
- When the VuT reaches 20 km/h (parameter) it starts the lane change manoeuvre to merge into the main lanes (lane 2 and 3 from the right)
- No interfering traffic

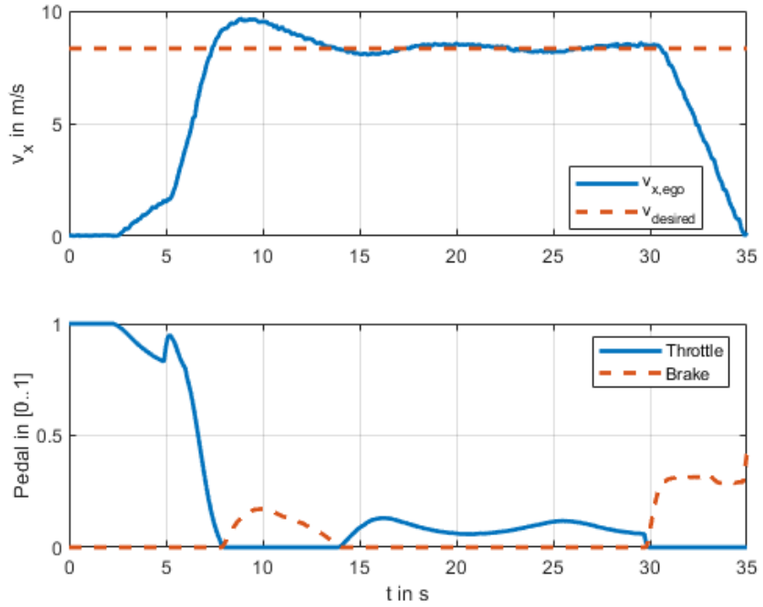


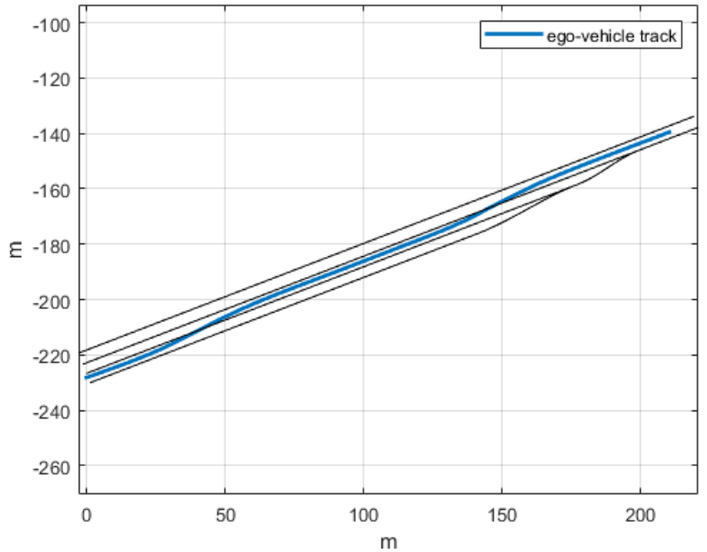
Onramp Scenario: Merge into the main road

Merge into main road w/o traffic

- Data Sample
- Post-Processing
- Longitudinal Dynamics
- Lateral Dynamics
- Ego-vehicle track



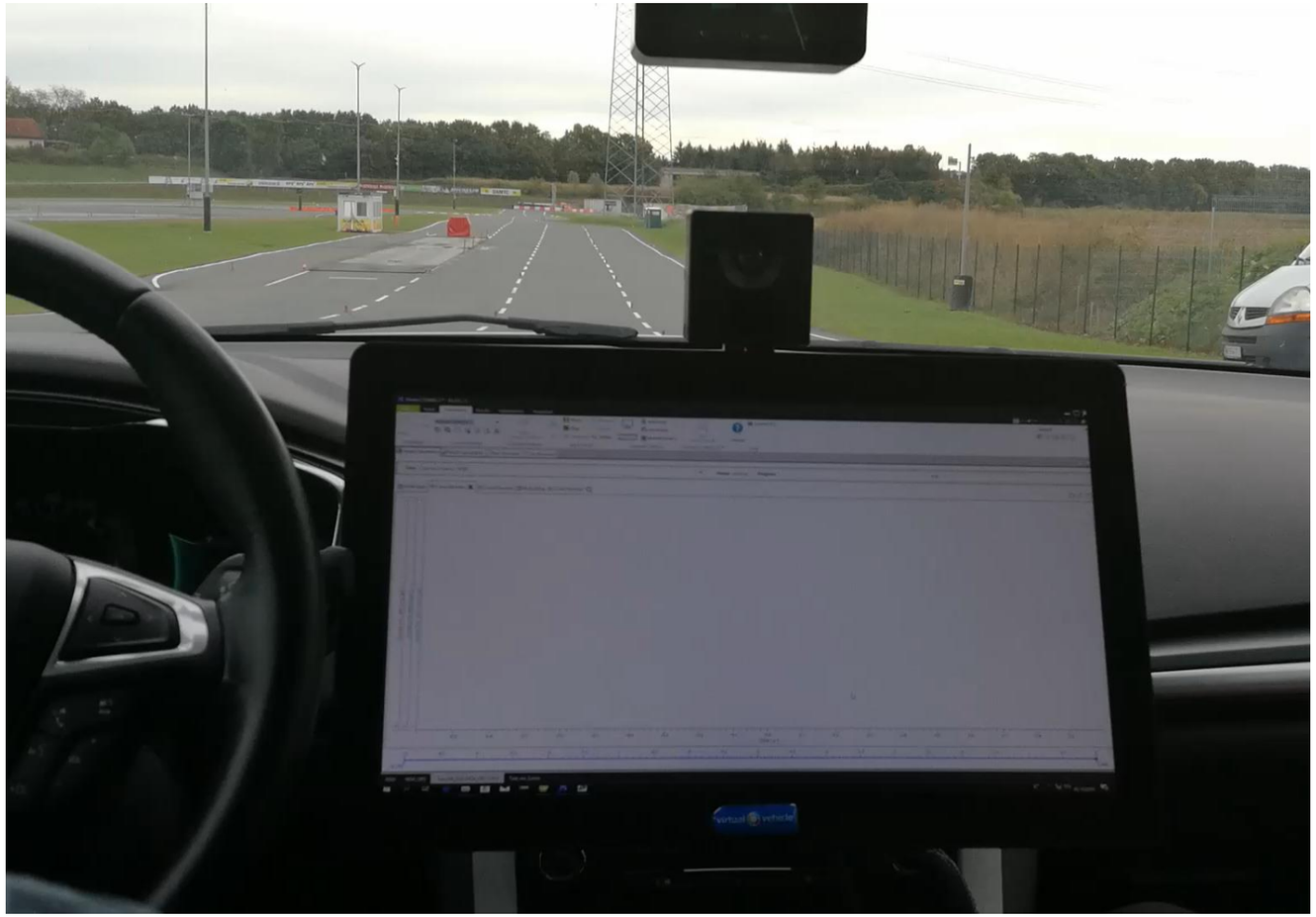




Onramp Scenario: Merge into the main road with Traffic

Merge into main road with low traffic density

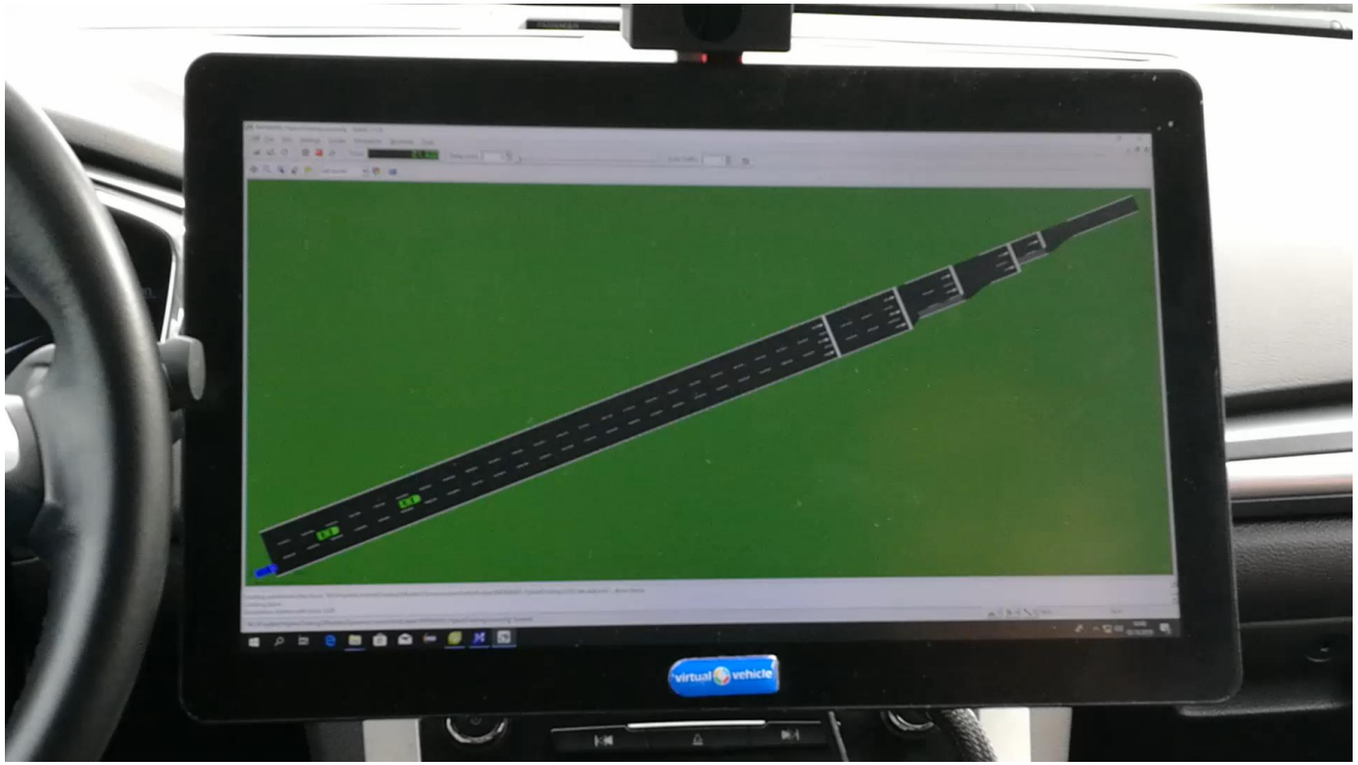
- VuT starts at the rightmost lane & accelerates to 30 km/h
- When the VuT reaches 20 km/h (parameter) it starts the lane change manoeuvre to merge into the main lanes (lane 2 and 3 from the right).
- Three vehicles on the main road



Onramp Scenario: Merge into the main road with Traffic

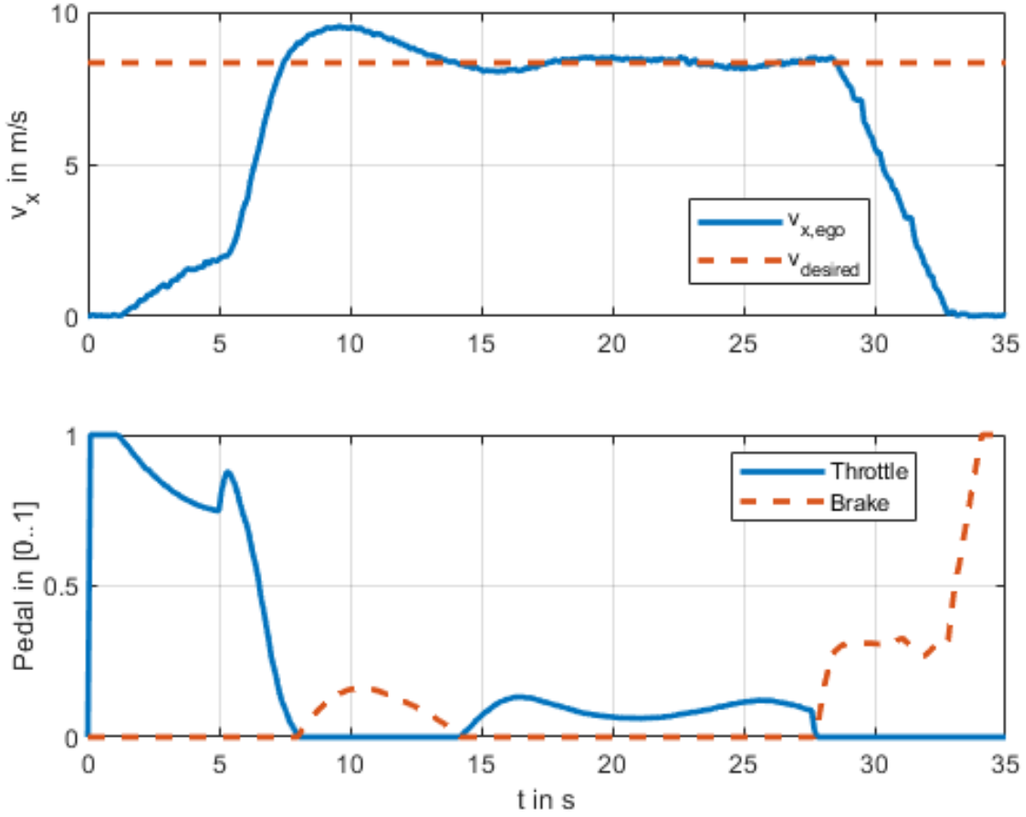
Merge into main road with high traffic density

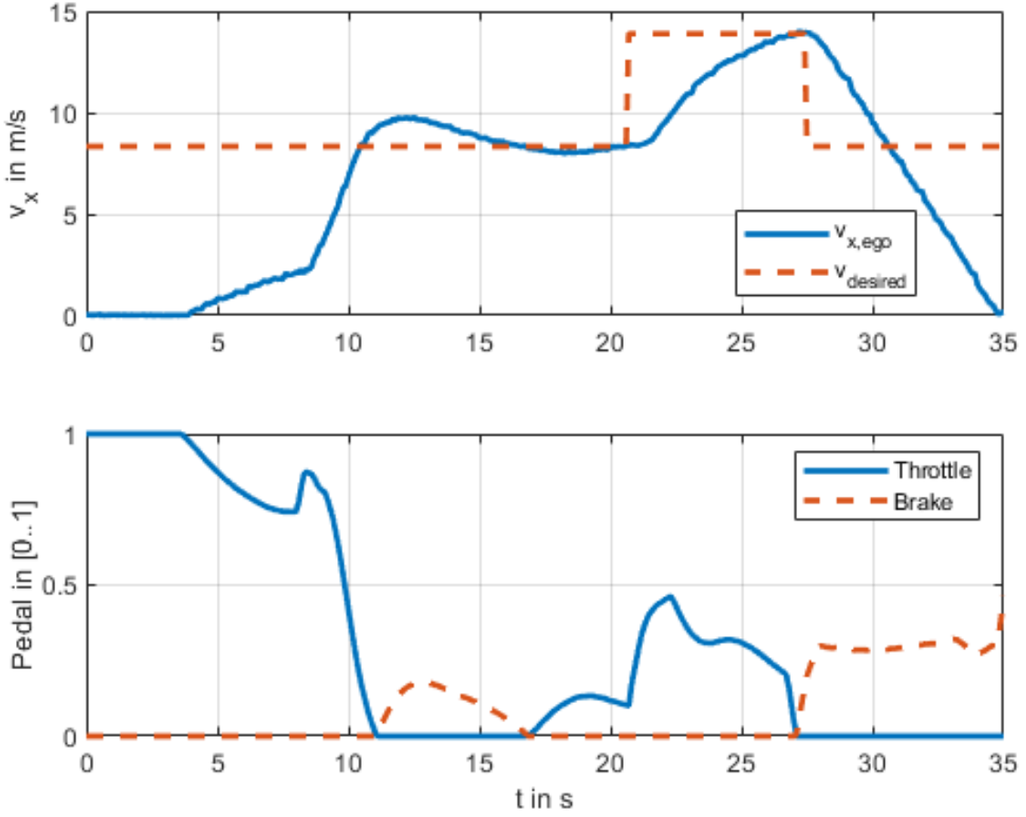
- Lane Change not possible, MWC performs a safety stop



Main road Scenario:
max speed (IVIM) with vehicle in front, MWC adapts speed

- **No Message vs. with ITS-G5 (IVIM) Message**



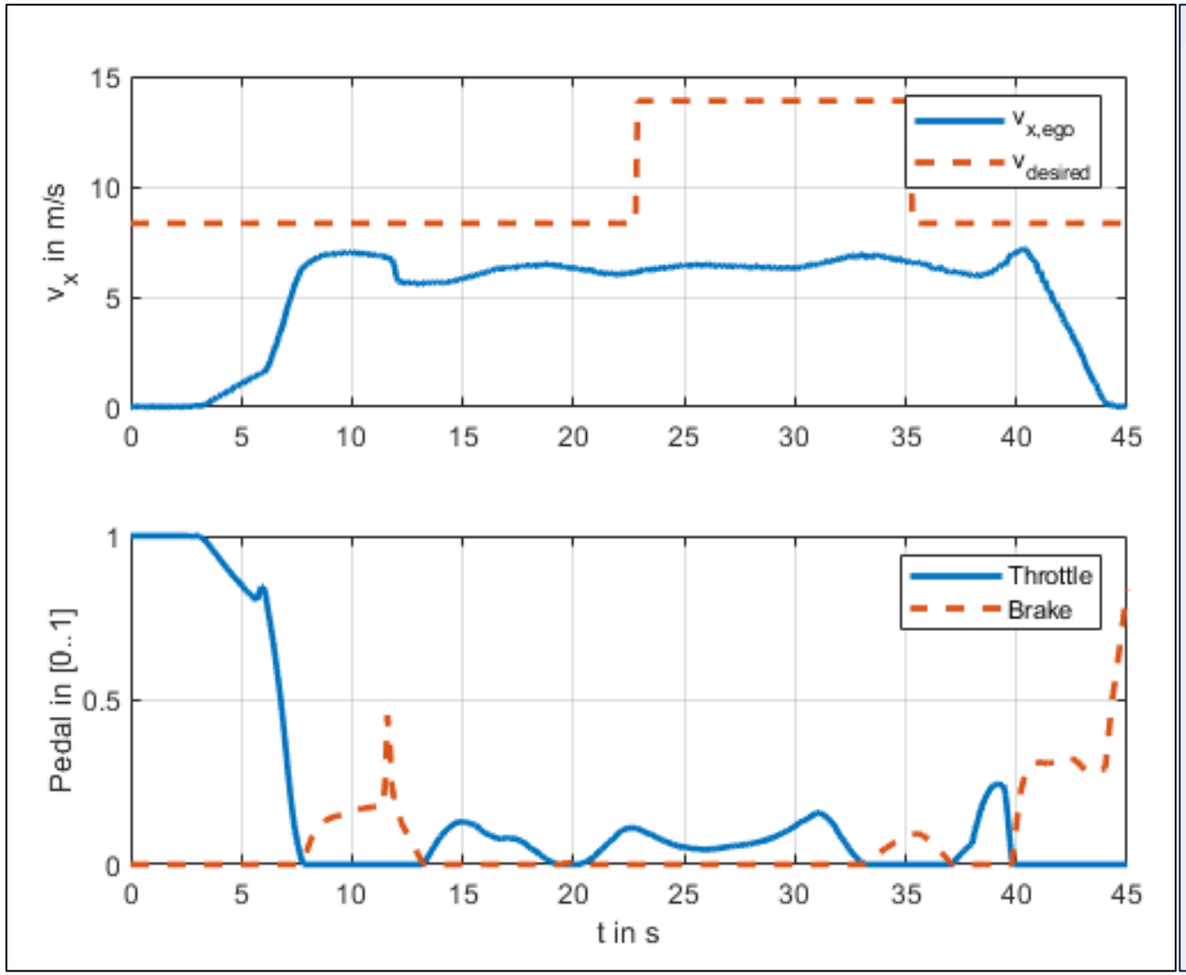


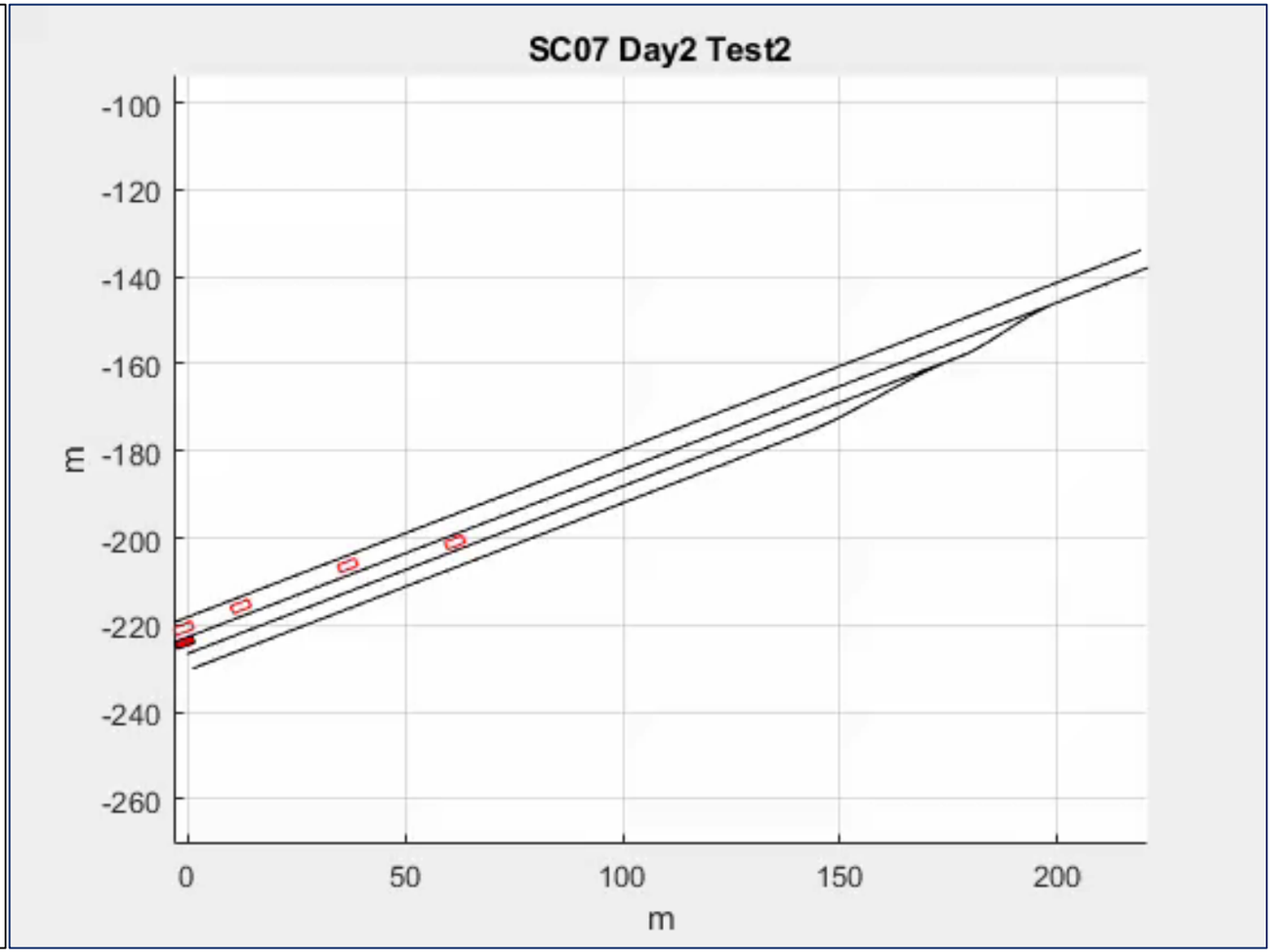
Main road Scenario:
max speed (IVIM) with vehicle in front, MWC adapts speed

With max speed (IVIM), vehicles in front and MWC adapts speed

- The VuT starts on the left side of the track on the middle lane (lane-2), accelerates from stand still to 30 km/h and changes the lane before the lane ends
- After ~100m from the start, the VuT receives an IVIM via its OBU with a new max. speed of 50 km/h and accelerates to this speed
- A slower vehicle in front of the VuT hinders the VuT reaching the new max speed without overtaking forcing the VuT to follow behind it

Main road Scenario:
max speed (IVIM) with vehicle in front, MWC adapts speed





Main road Scenario:
max speed (IVIM) with vehicle in front, MWC overtakes

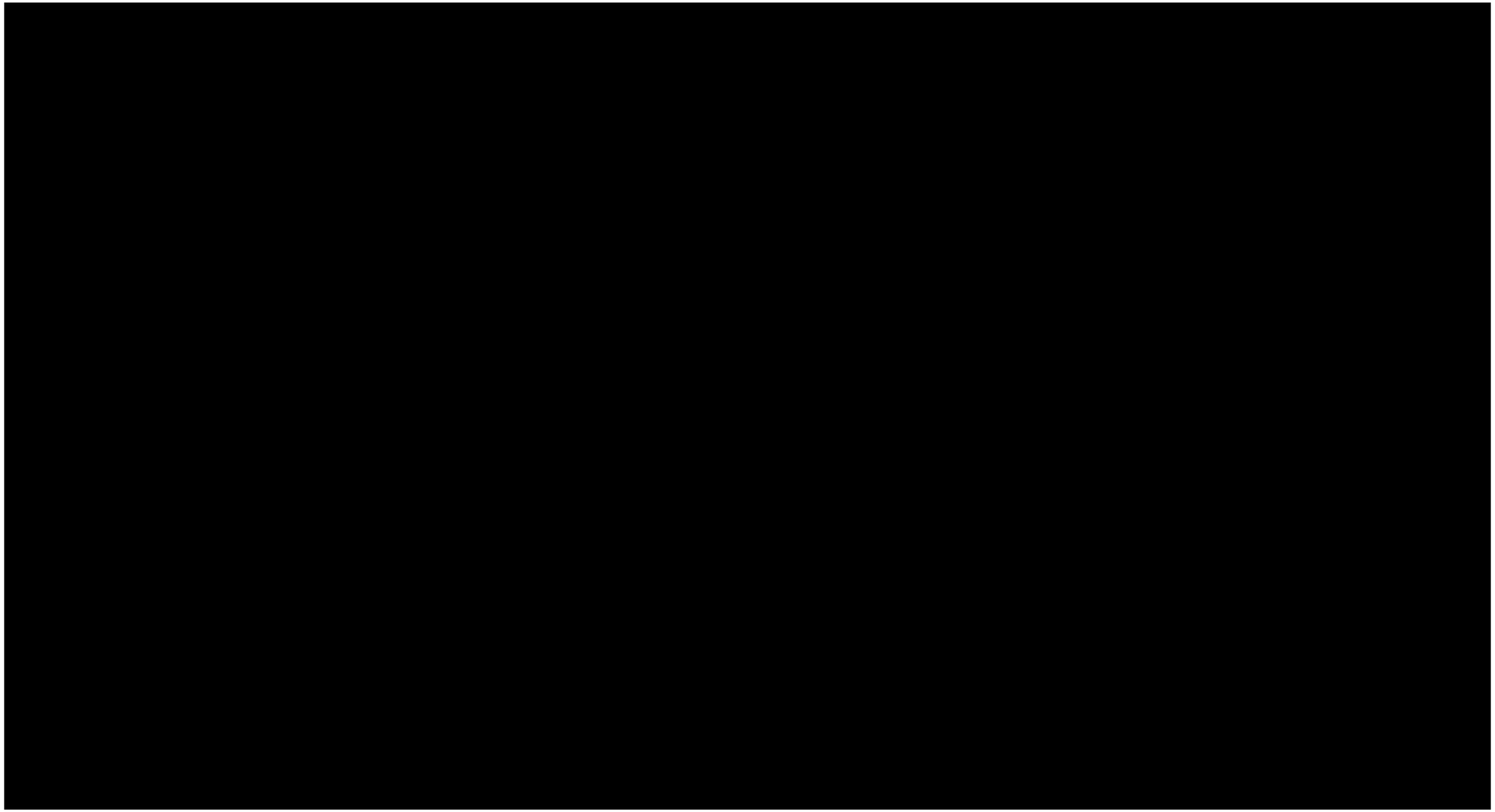
With max speed (IVIM), vehicles in front and MWC overtakes

- The VuT starts on the left of the track on the middle lane (lane-2), accelerates from stand still to 30 km/h and changes to the side lane before the lane ends
- After ~100m from the start, the VuT receives an IVIM via its OBU with a new max. speed of recommendation of 50 km/h and accelerates to this speed but a slower vehicle in front of the VuT hinders the VuT reaching the new max speed without overtaking
- The VuT performs a lane change manoeuvre to overtake

Experiment (Stack-II) KPI Results

Scenario /Testday /Testrun	IVI send	IVI received	IVI Speed	VuT has adapted the speed	mean Speed VuT	mean speed VuT in rel. zone	mean speed all	min dist gap	min time gap	min TTC
-	-	-	km/h	-	km/h	km/h	km/h	m	s	s
4/2/1	no	no	N/A	no	30.7	30.1	30.7	N/A	N/A	N/A
5/2/1	yes	yes	40	yes	34.5	37.7	34.5	N/A	N/A	N/A
5/2/2	yes	yes	50	yes	36.4	41.9	36.4	N/A	N/A	N/A
6/2/1	yes	yes	50	no	34.2	36.1	29.7	11.7	1.17	4.85
6/2/2	yes	yes	50	no	34.2	36.3	29.4	13.82	1.33	5.2
7/2/1	yes	yes	50	no	28.3	27.1	25.1	2.04	0.4	1.36
7/2/2	yes	yes	50	no	23	23.4	19.1	3.34	0.5	3.46

Hybrid Testing Promotion Video



Conclusion & Outlook

- **Repeatable and stable real-world proof of concept runs were demonstrated on the ÖAMTC Lang-Lebring Proving Ground**
- **Data Collected & proof-of-concept shown**
- **Comparison between sub-microscopic simulations were made**
- **Methodology particularly suitable to evaluate ADAS functions in various and randomized traffic scenarios**
- **Another potential utilization is for testing the effect of C-ITS messages on mixed traffic scenarios**
- **Potential extensions are possible and is planned for follow-up research activities:**
  - Sensor modelling
  - 3D visualization integration
  - Integration of vehicular sensors to the co-simulation framework
  - Digital twin calibration

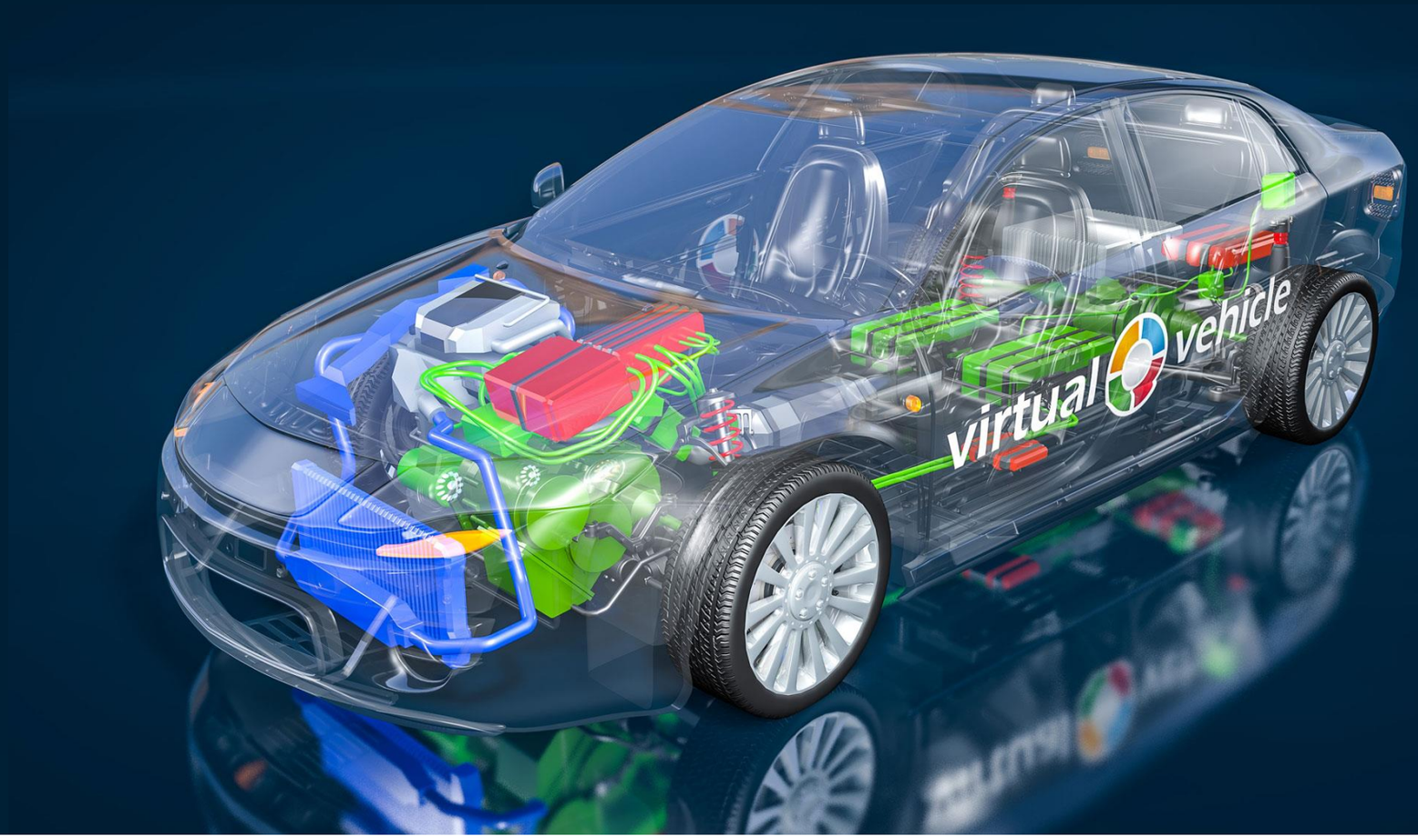
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723016.

virtual vehicle

Accelerating Innovation

THANK YOU

selim.solmaz@v2c2.at



Dr. Selim Solmaz

Lead Researcher | Control Systems

GSVF2020 | 01.09.2020

www.v2c2.at

Virtual Vehicle Research GmbH has received funding within COMET Competence Centers for Excellent Technologies from BMK, BMDW, the Province of Styria (Dept. 12) and the Styrian Business Promotion Agency (SFG). The Austrian Research Promotion Agency (FFG) has been authorised for the programme management.