ESRIUM

SAFE AND EFFICIENT ROADS

ESRIUM has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004181.

virtual vehicle

ENABLING **FUTURE VEHICLE** TECHNOLOGIES

Real-life Implementation and Comparison of Authenticated Path Following for Automated Vehicles based on Galileo OSNMA Localization

S. Solmaz, G. Nestlinger, K. Lambauer, R. Lesjak, S. Schweitzer, and J. Garcia

www.v2c2.at

Assoc. Prof. Dr. Selim Solmaz
Control Systems Group Leader

IEEE-IAVVC, 16-18 Oct, 2023

17/10/2023

EU Project ESRIUM

EGNSS-enabled Smart Road Infrastructure Usage and Maintenance for increased energy efficiency and safety on European road networks

Our challenge

ESRIUM is an international project fostering safer and more efficient roads towards a smarter, safer, greener transport system. The key innovation will be an EGNSS-based digital map of road surface damage and road wear. The road wear map will contain unique information for the road operators to enhance road maintenance planning and to provide route recommendations to automated vehicles.

Our solution

The imbalanced usage of the road surface contributes to its degradation, leading to safety risks especially for connected and automated vehicles. The problem becomes even worse with harsh weather conditions. Our solution consists of an EGNSS-based digital map of road damages and safety risks that will allow for route adjustments through I2V communication free of charge. These recommendations will lead to a more balanced use of the road surface and to a longer lifetime of the road infrastructure.

ESRIUM regularly captures the status of the road surface through a sensors, cameras and EGNSS-based localisation devices to send them to the platform operator.

The data platform operator extracts relevant information from the raw data, integrates it into the digital map and automatically generates safety warnings.

Road operators can communicate route recommendations to CAV drivers and truck fleet operators to better manage traffic and avoid safety risks, while optimising road maintenance planning.

Our team

Esrium_H2020

Esrium group

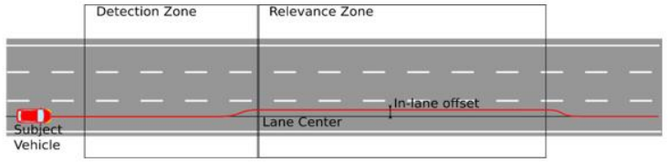
www.esrium.eu

ESRIUM has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004181.

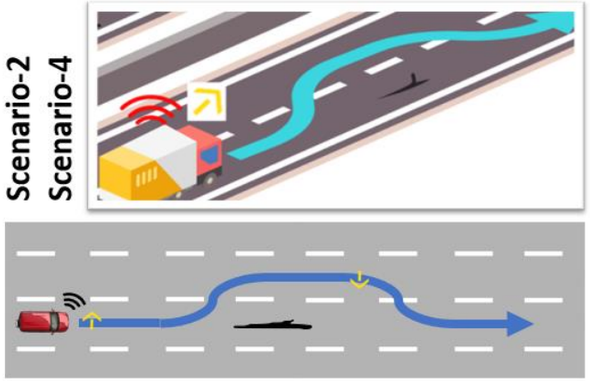
ESRIUM Use Case 2 (EUC-002)

Routing Recommendations within and between lanes based on the road wear map, provided via C-ITS messages

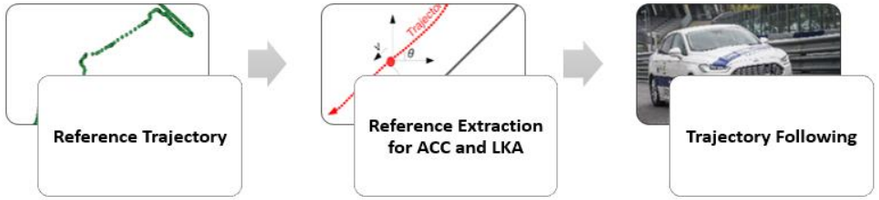
Scenario-1

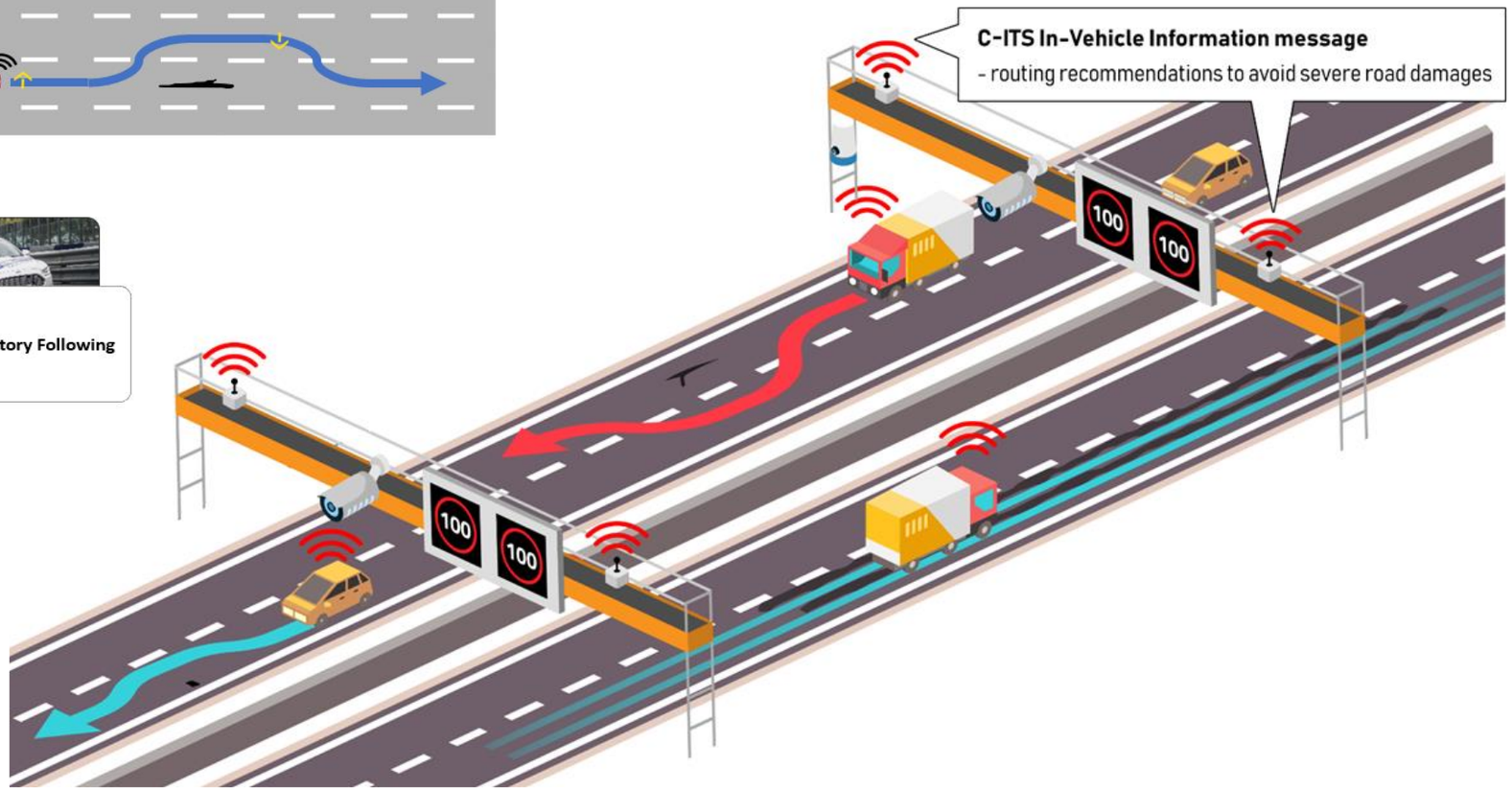


Scenario-2
Scenario-4



Scenario-3



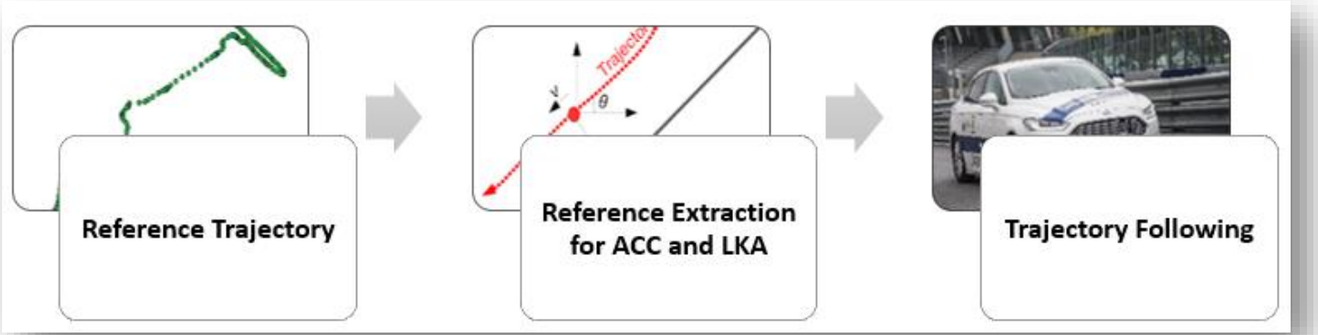


ESRIUM EUC-002 (Test Scenario-3)

Path-tracking use case to analyze the effect of OSNMA authentication on positioning accuracy.

Two scenarios:

- open-sky (left)
- urban location (right)



Automated Driving Test Vehicle

Vehicle Interface (Dataspeed Inc.):

- Drive, brake, steer by wire
- Vehicle data

Processing Plattforms:

- dSpace Microautobox II
- PC (Win/Linux)

Localization:

- Novatel RTK-DGPS / ProPak6 / RTK
- Septentrio Mosaic-H5 RTK-EGNSS / EPOSA-RTK
- Positioning < 5cm, 100Hz via TCP/IP

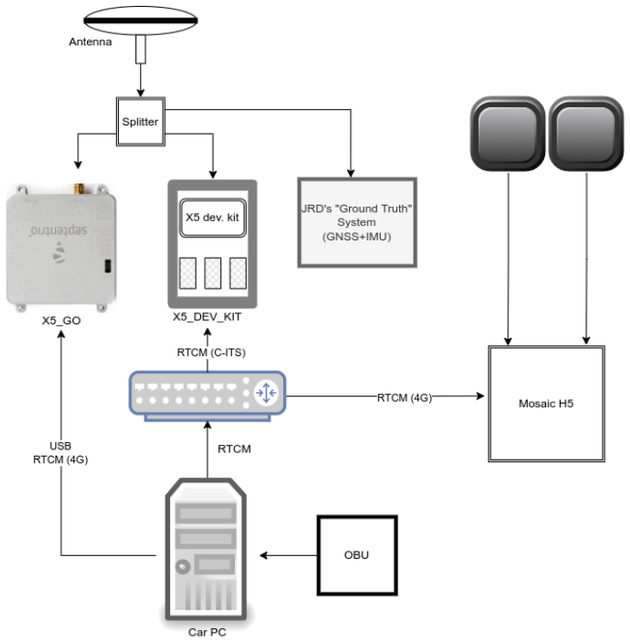
Other Sensors:

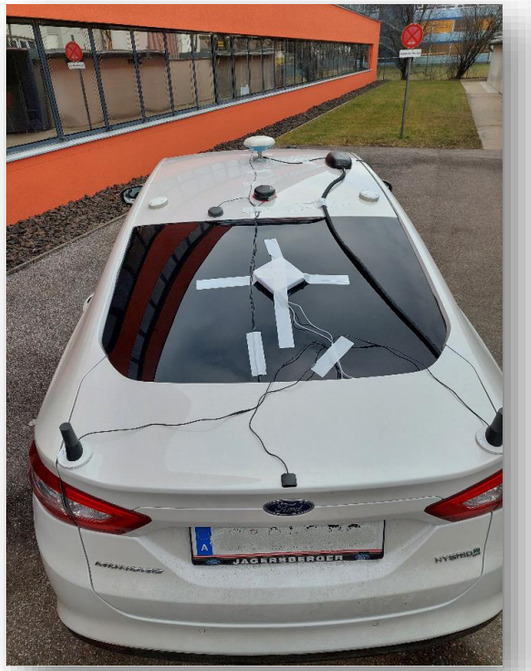
- Radar(s), Camera(s), Lidar(s)
- ToF (Time-of-Flight) Camera(s), Ultrasonic sensors

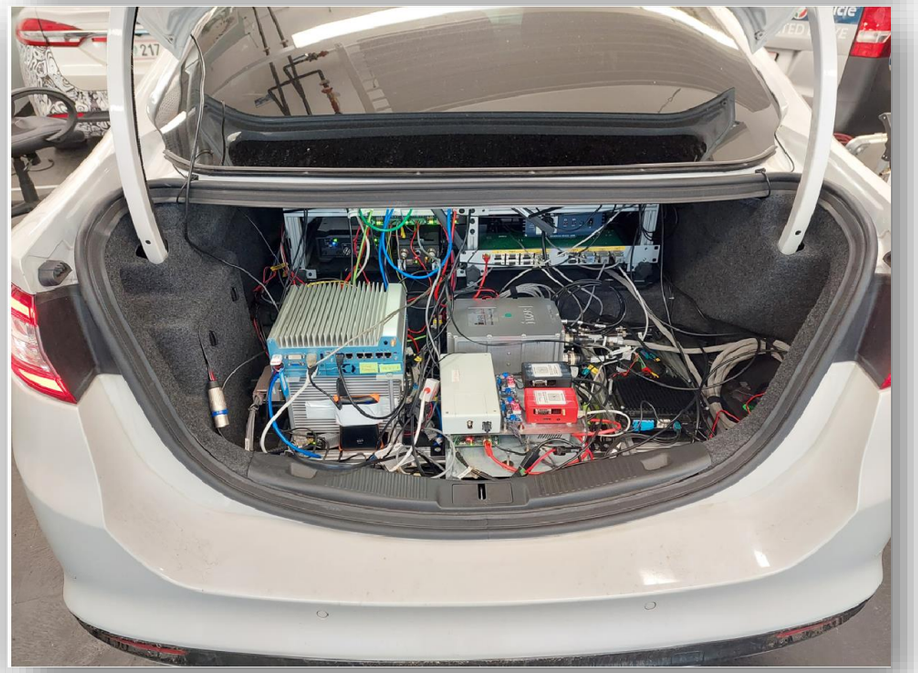
Feature	Ford Fusion
Platform	FORD CD4
Initial release date	Oct 2015
Throttle control frequency	50 Hz
Brake control frequency	50 Hz
Steering control frequency	100 Hz
Steering angle control	Yes
Steering torque control	No
Gear shift control (PRNDL)	Yes[1]
Turn signal control	Yes
ULC (speed control)	Yes
Individual wheel speeds	100 Hz
3-Axis accelerometer	100 Hz
Roll and yaw rate gyro	100 Hz
Parking SONAR sensors	5 Hz
Tire pressures	2 Hz
GPS	100 Hz

Automated Driving Test Vehicle

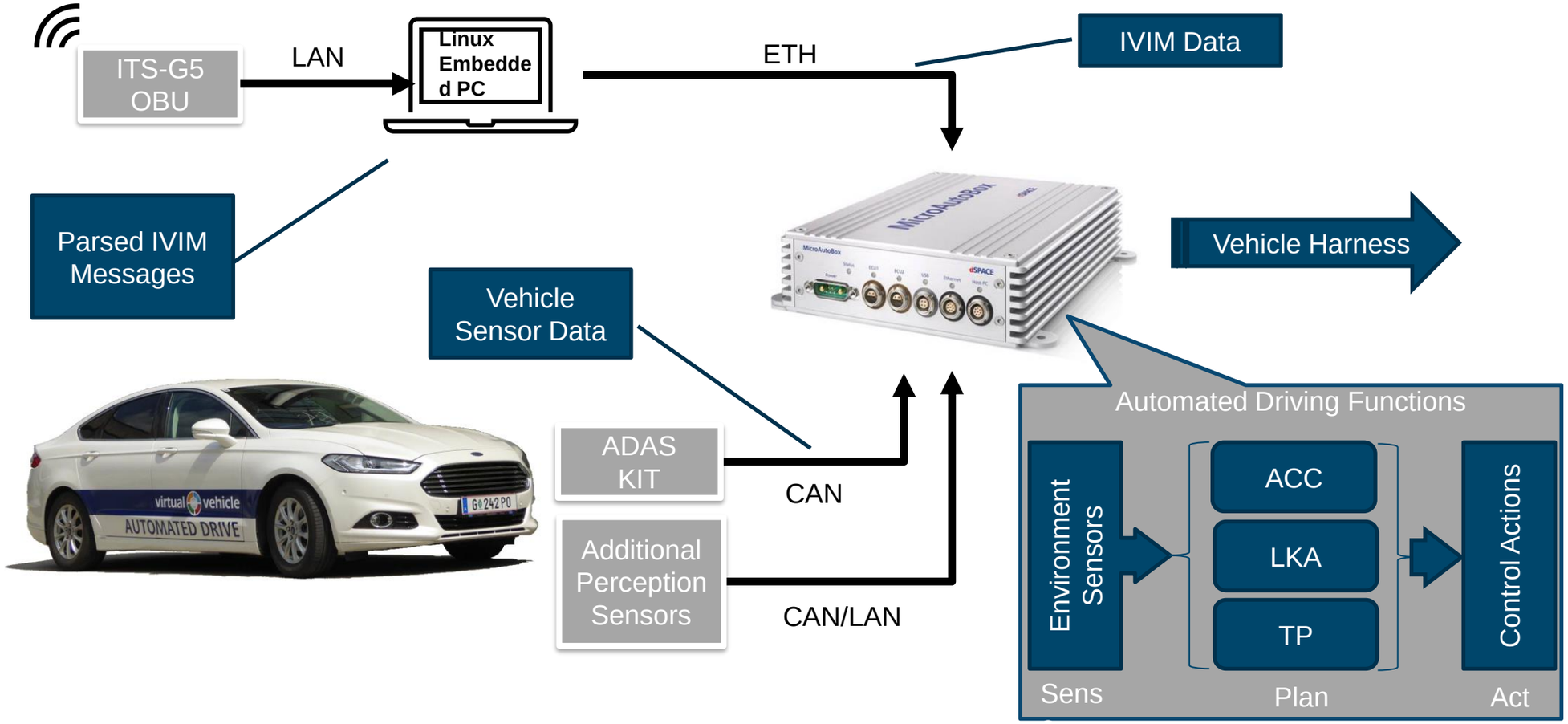
- Ford Mondeo Hybrid
- Vehicle state is accessible via CAN bus
- Drive-by-wire via desired steering wheel and brake/throttle commands
- Closed-loop path following:
  Septentrio mosaic-H5 dual-antenna EGNSS receiver
- dSPACE MicroAutoBox II to run the developed algorithms



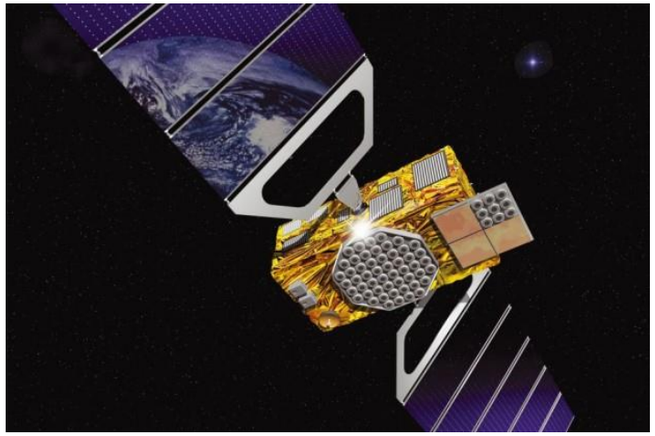




Test Vehicle HW-Setup and Interfaces



ESRIUM OSNMA Performance Tests

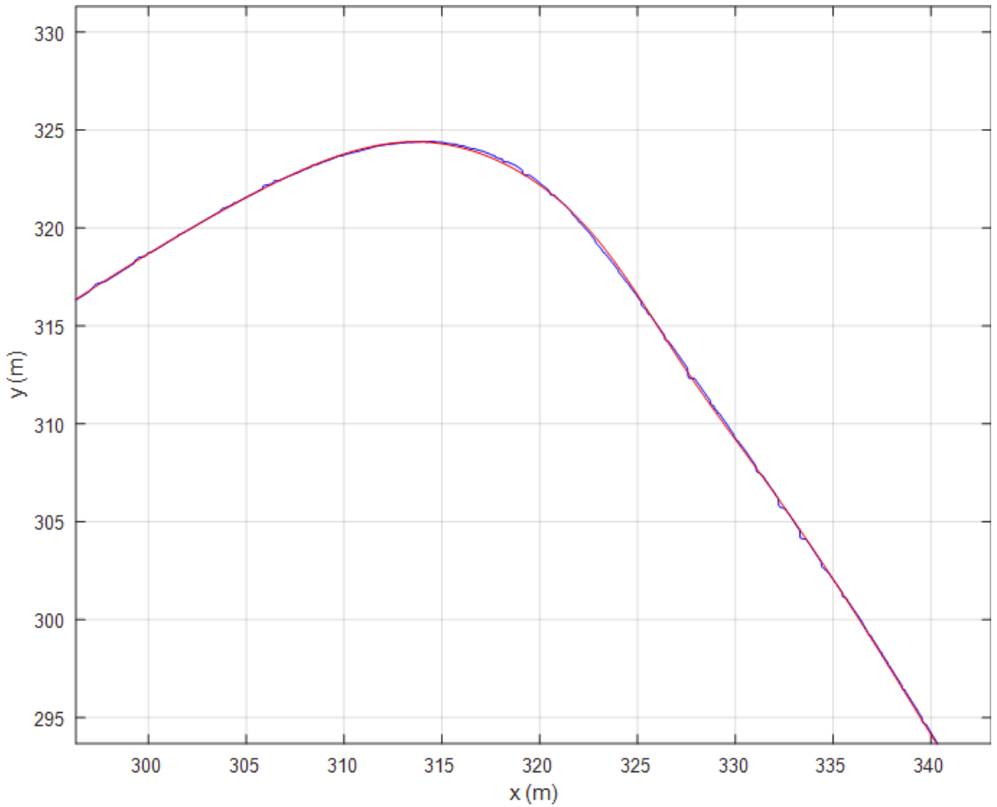


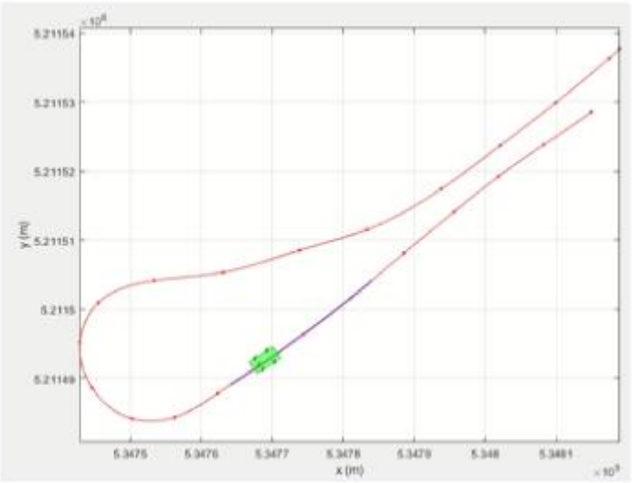
- Open Service Navigation Message Authentication (OSNMA) is a data authentication function for the Galileo Open Service worldwide users, freely accessible to all. Currently in a deployment testing phase.
- OSNMA allows the detection of GNSS spoofing attacks by an authentication mechanism that allows users to verify the authenticity of GNSS information, making sure that the data they receive is indeed from Galileo and has not been modified in any way.
- OSNMA performance assessment combined with localization and trajectory following tests in Graz on 15.02.2023.
- Different OSNMA modes (strict, loose, off) for localization were compared
- Performance under different operational environments (motorway, urban areas, buildings, trees, different elevations) was tested.
- In our paper the focus is performance assessment of OSNMA-assisted localization for automated driving systems
- Trajectory following under full-open sky and multi-path signal reflection areas with/without OSNMA were tested.

Trajectory following (EUC-002)

Aim: Follow the path of a pre-recorded trajectory

The reference path is stored as a spline ⇒ smooth heading and curvature





Driving Function Overview

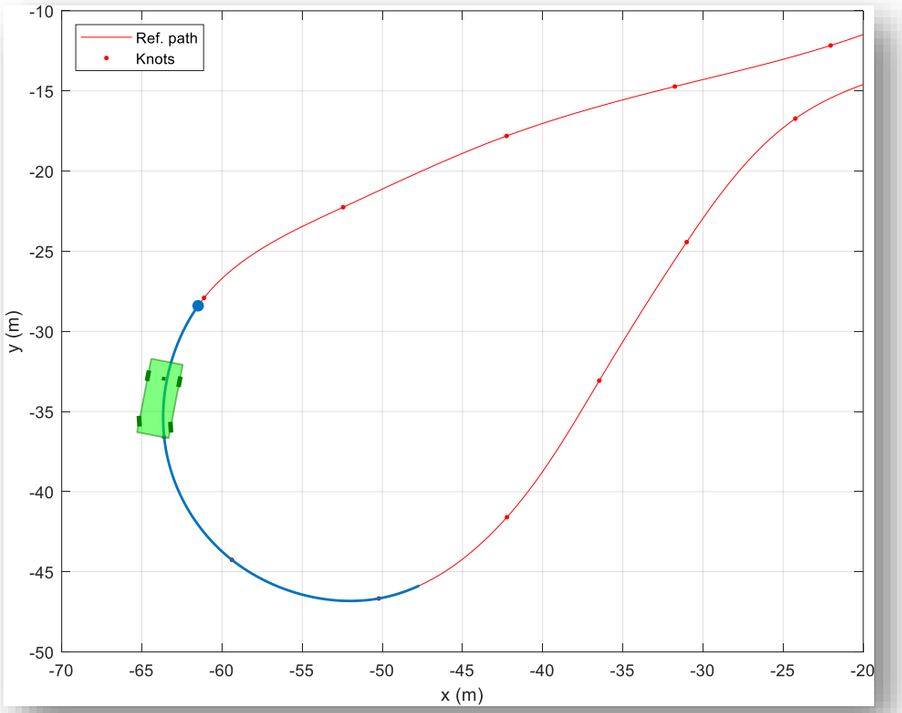
- Path follower: Finds the section (blue) of the parametric reference path $\boldsymbol{\Gamma}(\tau)$ related to the current vehicle position $\boldsymbol{p}$
  1. Find τ^* so that $\langle \boldsymbol{\Gamma}'(\tau^*) | \boldsymbol{p} - \boldsymbol{\Gamma}'(\tau^*) \rangle = 0$
  2. Restrict $\boldsymbol{\Gamma}$ to the domain $\tau^* - a \leq \tau \leq \tau^* + b$

- Speed controller: Calculates a desired acceleration

$$v_{\max} = \sqrt{\frac{a_{y,\max}}{\kappa_{\max}}} \;\Rightarrow\; a_{\text{set}} = k_{\text{P}} \left(\min\{v_{\text{set}}, v_{\max}\} - v \right)$$

- Lateral controller: Calculates the desired steering wheel angle
  -> state-feedback based on single-track model and lateral/angular path tracking error

- Longitudinal controller: Calculates the brake/throttle commands
  -> standard PI controller with anti-windup



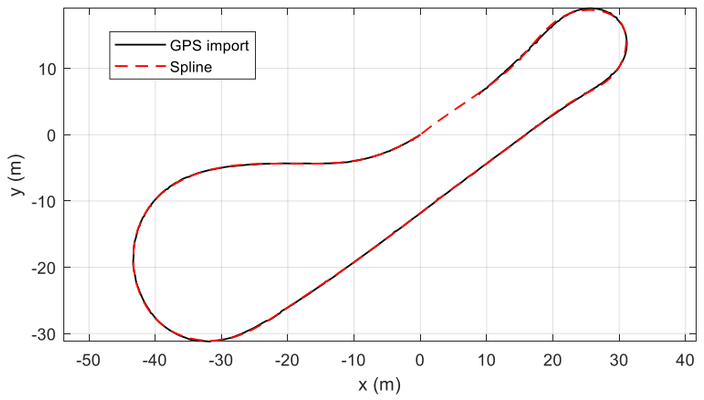
Reference path?

Reference Path

Requirements:

I. Closed path
Do multiple uninterrupted rounds -> obtain „steady state“ results despite imperfect starting position/orientation

II. „Smooth“ path
Avoid discontinuities in the path’s derivatives, i.e., heading & curvature -> Utilized by path tracking controller

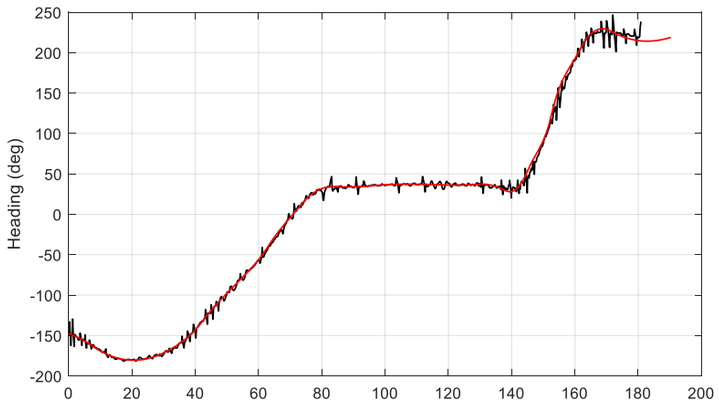


Approach:

1. Log a manually driven trajectory
2. Extract the section of interest -> list of waypoints
3. Apply spline approximation algorithm

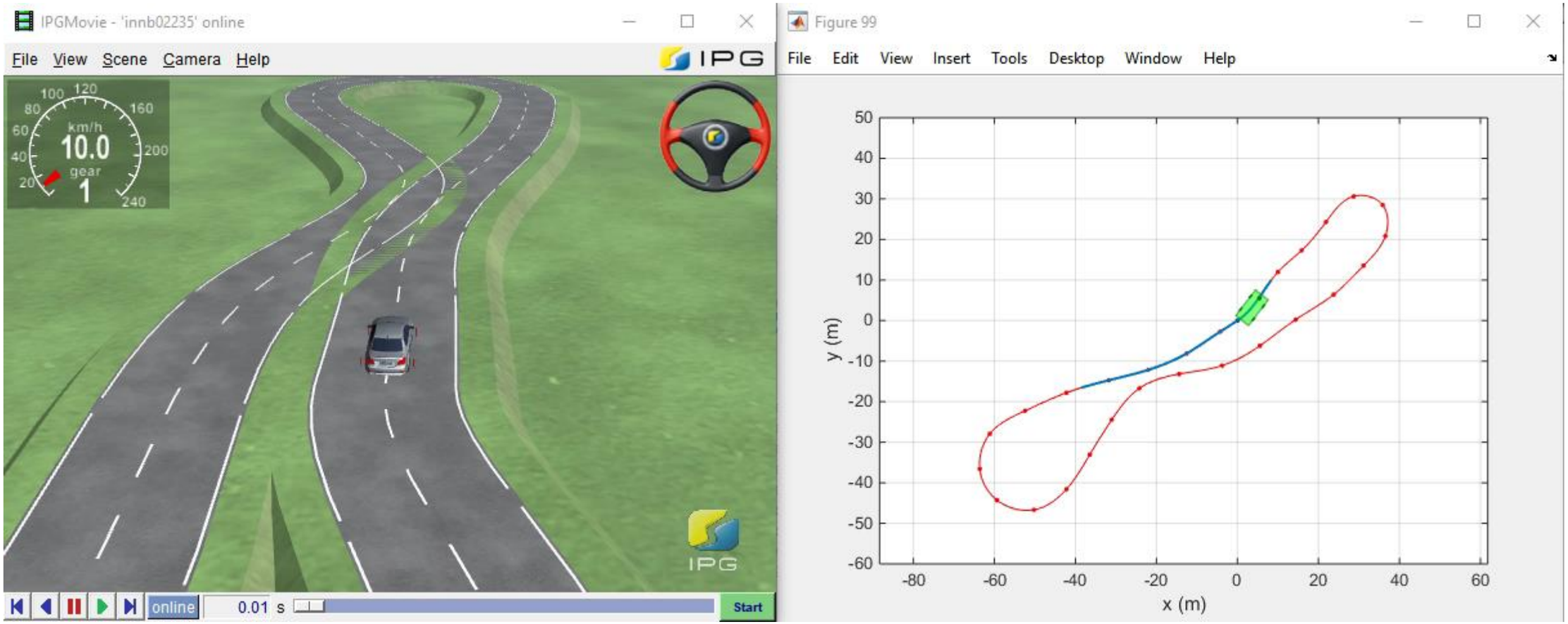
Respective boundary conditions fulfill requirement I.

A polynomial degree of 3 and continuity conditions at spline knots satisfy requirement II.



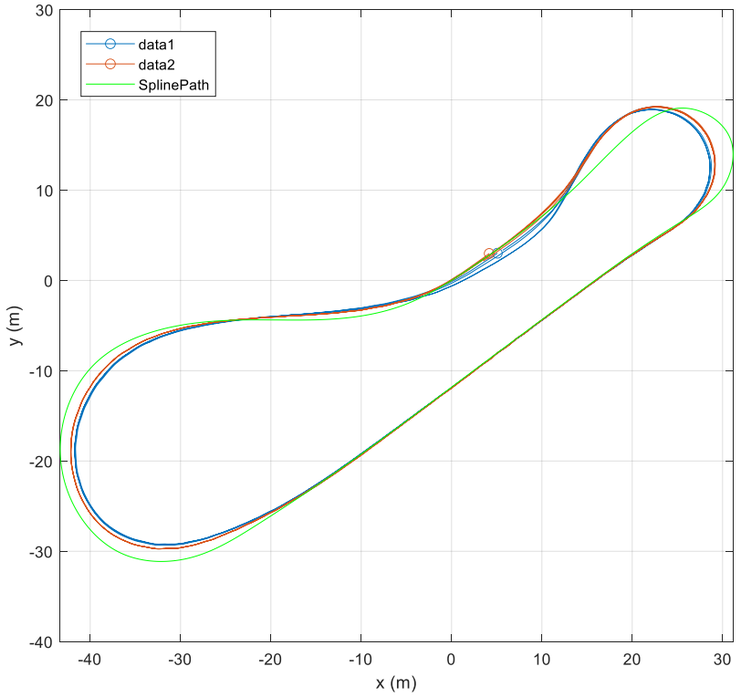
Development in Simulation

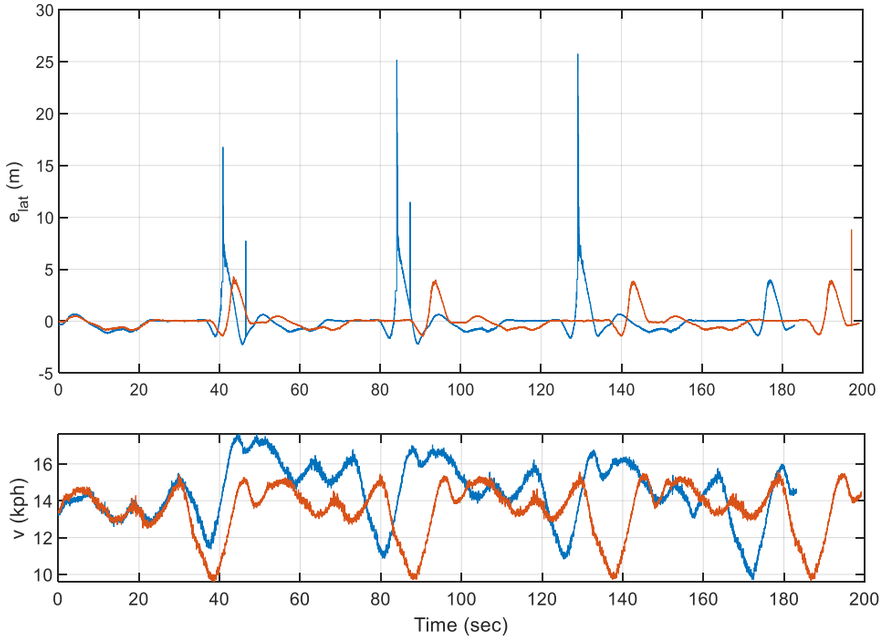
- Current position and heading from EGNSS + correction data
- Current path section is extracted from reference path -> passed to path tracking controller
- Pre-development of the ADAS function and control algorithm in IPG-Carmaker/Matlab simulation environment



Results – Open sky scenario

OSNMA OFF (blue) and ON (red) along with reference path (green)





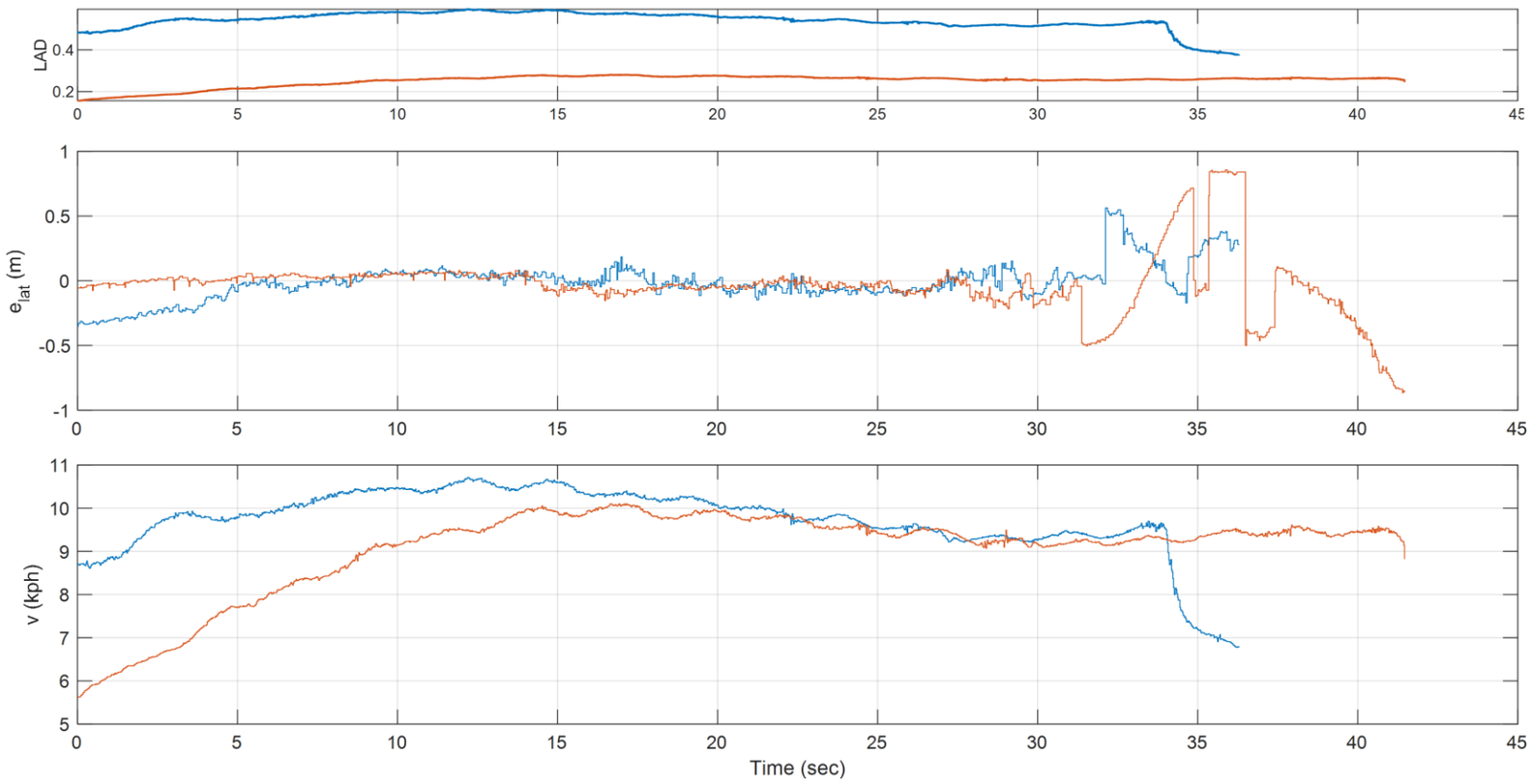
Almost identical results, despite a small time shift due to slightly different velocities/IC.

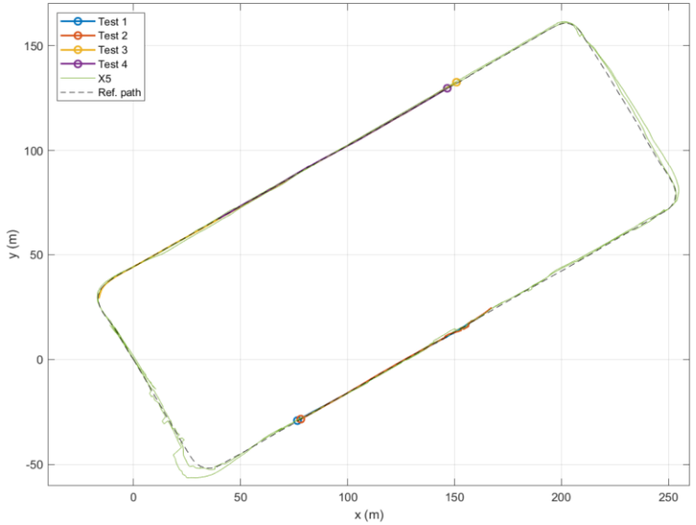
⇒ OSNMA-based trajectory following is feasible!

though more satellites supporting the service are needed

Results – Urban scenario

- Degraded the GNSS location solution
- No RTK-assisted solution with OSNMA on





- General observation: path following is not reliable due to the changing RTK localization types due to multi-path signals

On-road test results

Conclusions & Outlook

- In this work, we have implemented a path-tracking controller for an automated driving demonstrator vehicle to test the effect of OSNMA authentication service in the context of automated vehicle localization. The experiments indicated that the use of OSNMA under open-sky conditions is feasible with limitations. Even with OSNMA turned off, sub-meter deviations can lead to control performance issues of the automated vehicle. This can be attributed to the very low number of OSNMA-enabled EGNSS satellites as well as the instantaneous changeability of the RTK solution method.

- Particularly for urban settings, multi-path effects can lead to severe degradation in localization solutions, which exacerbates accuracy and tracking performance. In our experiments, the OSNMA strict setting was unusable in urban settings for accurate or improved localization and OSNMA-off was marginally usable but definitely not acceptable for stable path tracking purposes.

- Since it is not possible with active OSNMA authentication to spoof position information, it brings some security assurance factors to satellite-based localization. However, the stable operation requires sufficient coverage and a clear line of sight with the sky. These factors severely limit the utility of GNSS-based localization systems for safety-related applications in automated driving solutions. For autonomous driving, OSNMA helps only marginally with the problem, though further testing needs to be done in more representative motorway conditions and with the presence of more supporting satellites.

ESRIUM

SAFE AND EFFICIENT ROADS

ESRIUM has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004181.

EUSPA European Union Agency for the Space Programme

virtual vehicle

ENABLING **FUTURE VEHICLE** TECHNOLOGIES

THANK YOU!

Assoc. Prof. Dr. Selim Solmaz
Group Leader Control Systems

www.v2c2.at

Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
Bundesministerium Arbeit und Wirtschaft
FFG Promoting Innovation.
Das Land Steiermark Wirtschaft, Tourismus, Wissenschaft und Forschung
SFG

Virtual Vehicle Research GmbH wird im Rahmen von COMET Competence Centers for Excellent Technologies durch BMK, BMAW, Land Steiermark und Steirische Wirtschaftsförderung (SFG) gefördert. Das Programm wird durch die FFG abgewickelt.