

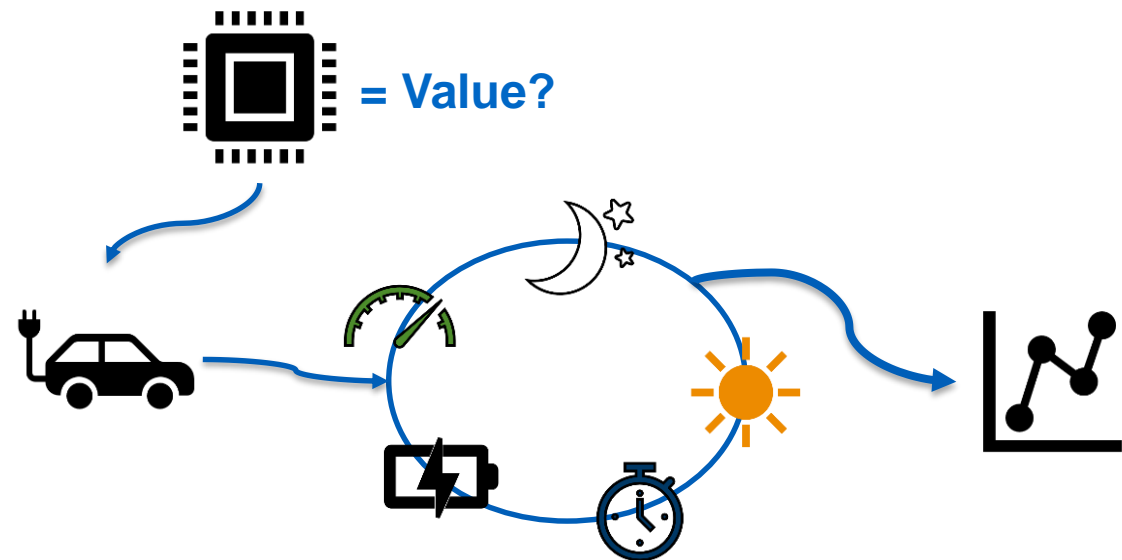
Virtual Electric Vehicle in real-world environment

Jiří Minarik, Petr Liškář

Background

Scope'n'Goal

- Create a **single tool** for quick, efficient and accurate evaluation of a specific product value designed for EVs without being limited
- Built Matlab/Simulink Virtual EV model with High-fidelity features with low computational requirements
 - Twin-track Vehicle Model
 - Traction Drive Model
 - Thermal Management
 - Vehicle Controls



Virtual EV



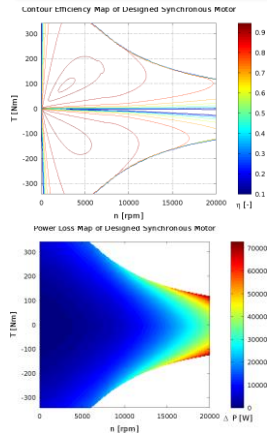
Vehicle models

Single-track model

- 3DOF Single-track model
- 14DOF Twin-track model
- Sedan, SUV, ...
- Configurable chassis and tire model
- Aerodynamic model



Drivetrain

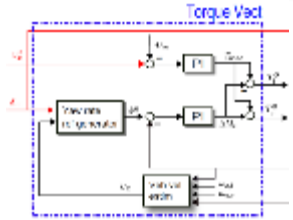


- Multi-motor
- Multi-inverter
- Multi-gearbox
- Library with 5D motor maps
- Library with 5D 800 V inverters

Environment

- Wind, temperature, air pressure
- Altituded, Latitude sensitive
- Wind gust and turbulence model

Controls and monitoring



- Autocruise
- Route speed planning
- GPS data integration
- ABS, ESP, Slip control, Torque vectoring
- Dynamic manoeuvres testing ready

Battery



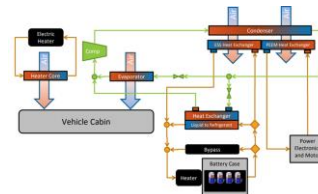
- Calibrated model
- Unique extended Thevenin model developed
- Automated procedure and measurement system

Auxiliary systems

- Vehicle subsystems
- Power steering, lights, other loads

Cooling system

- Simscape model of Vehicle HVAC



Graphical visualisation



Virtual EV - GUI

File Help +

Vehicle

Simulation Settings
Simulation Time:

Car Type
 Sedan VAN
 SUV Pick-Up

Driver Type
 Human Machine

Model Type
 Single-Track Twin-Track

Inertial Loads
Passenger Weight [kg]:
Trunk Weight [kg]:
Overhead weight [kg]:
 Front Left Passenger
 Rear Left Passenger
 Rear Right Passenger
 Front Right Passenger

Vehicle Controllers
Longitudinal Motion
 Traction Control Speed Control
 ABS
Lateral Motion
 Torque Vectoring Lateral Driver
 ESP

Driving Scenario

1-D Motion
Select:

2-D Motion
Double-Lane Change
Initial Speed [km/h]:
Turning Maneuver
Steer Angle [deg]:
Target Speed [km/h]:
Initial Speed [km/h]:
Skid-Pad Test
Pad Radius:
Target Speed [km/h]:

3-D Motion
Select:

Environment
Wind
 Turbulence
 Gust
Gust Start Time [sec]:
Road
Grade [%]:
 Dry Wet
 Snow Ice

Drivetrain

Front Axle
Number of Motors:
Left Wheel
Motor Type:
Inverter Type:
Inverter Switch Freq:
Gear-Box:
Gear-Ratio:
Right Wheel
Motor Type:
Inverter Type:
Inverter Switch Freq:
Gear-Box:
Gear-Ratio:

Rear Axle
Number of Motors:
Left Wheel
Motor Type:
Inverter Type:
Inverter Switch Freq:
Gear-Box:
Gear-Ratio:
Right Wheel
Motor Type:
Inverter Type:
Inverter Switch Freq:
Gear-Box:
Gear-Ratio:

Battery
Type: Capacity [kWh]:


Cooling System

Cabin
Initial Temp [°]:
Target Temp [°]:

Drivetrain
Initial Temp [°]:
Target Temp [°]:

Battery
Initial Temp [°]:
Target Temp [°]:

Advanced Settings OK Plot Cancel Help



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#Real driving, real drivers

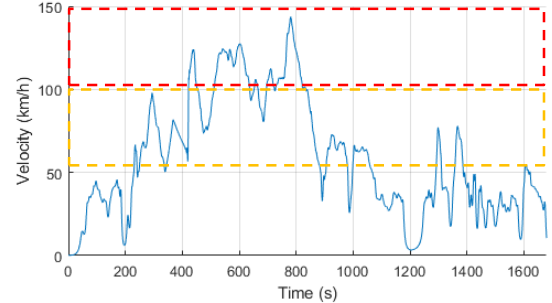
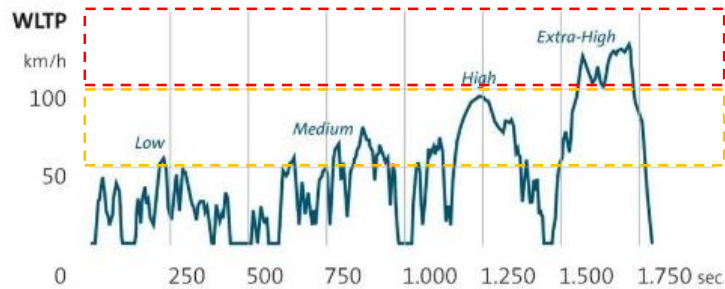
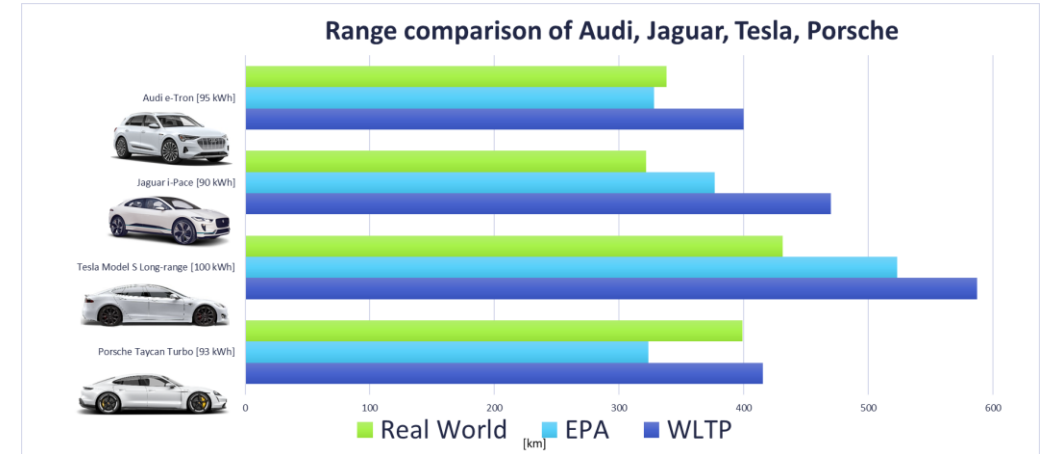
Lab driving



Real driving



Consequences



- Important EVs range discrepancies
- Different operational loads
- Missing key design specifications
- Overall customers dissatisfaction

Out of the lab simulations!

#Real driving!Real drivers!

- Real world planned route
 - Speed profile generation for map given route
- Real drive logs
 - GPS logs processing and re-drive
- All atmospheric phenomenon's
 - Temperature, wind, altitude, air pressure
- Dry, wet, snow, icy roads

- 3D, 2D, 1D environment with countless duty cycles and driving scenarios



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...SO...

...we have the model, right?

...we have the task, right?

...we have all set, right?

Are we ready to go?



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Simulation in “Real-World”

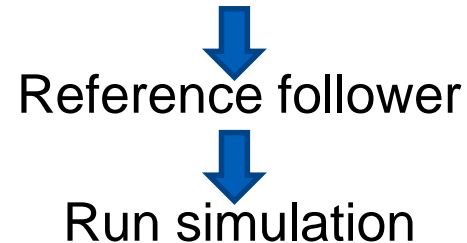
...may have some pitfalls...

Importing the driving data?
Generating data?

Let's Google maps everything!
-> Can we use raw data?

Data?

Data acquisition and preparation



What data?



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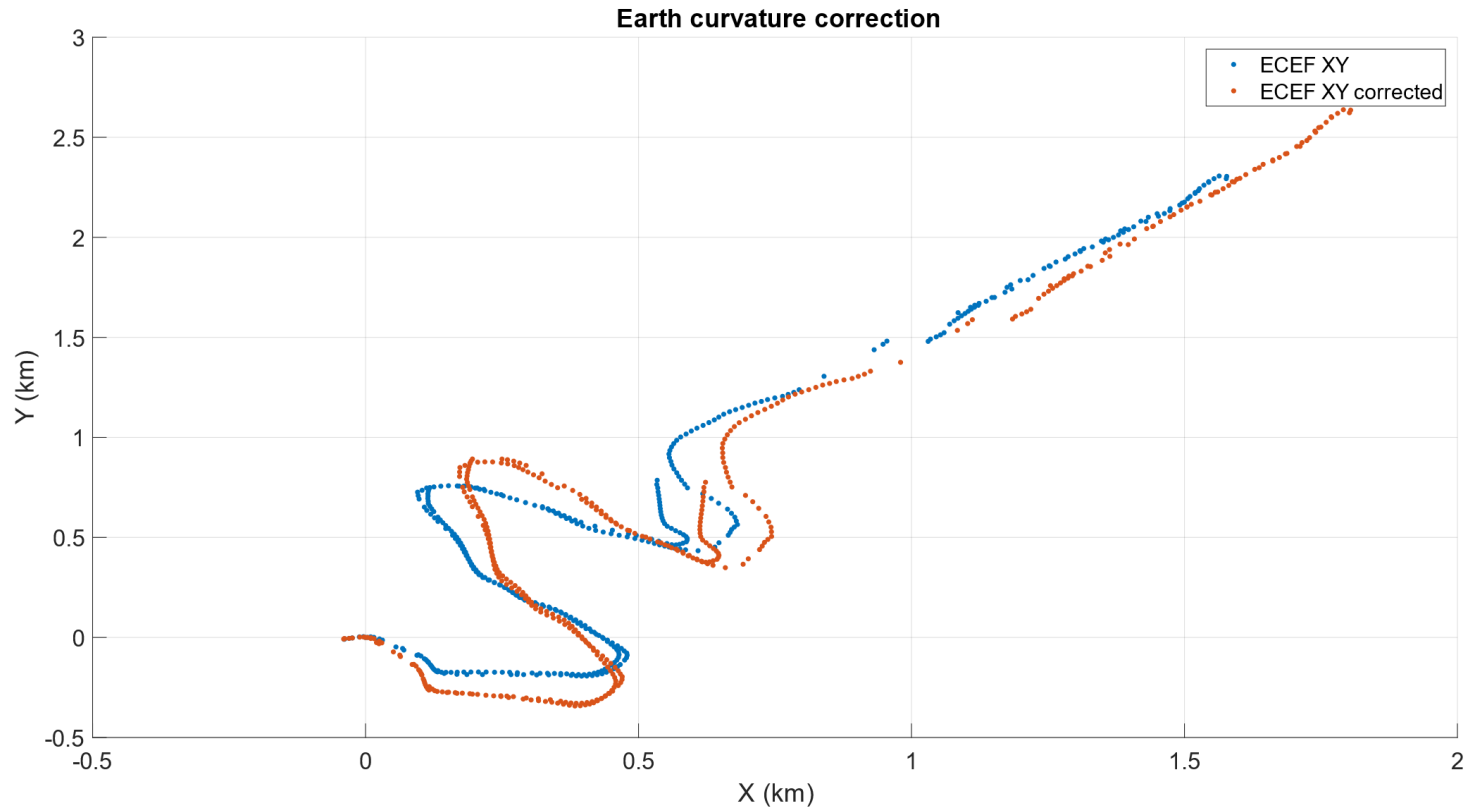
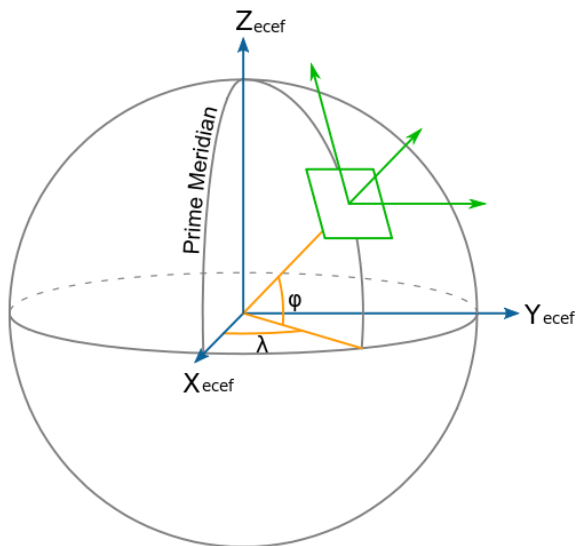
Data acquisition and preparation

- Track approximation => GPX file => XYZ positions

3D LLA to ECEF coordinate XYZ transform



2D projection + road angle



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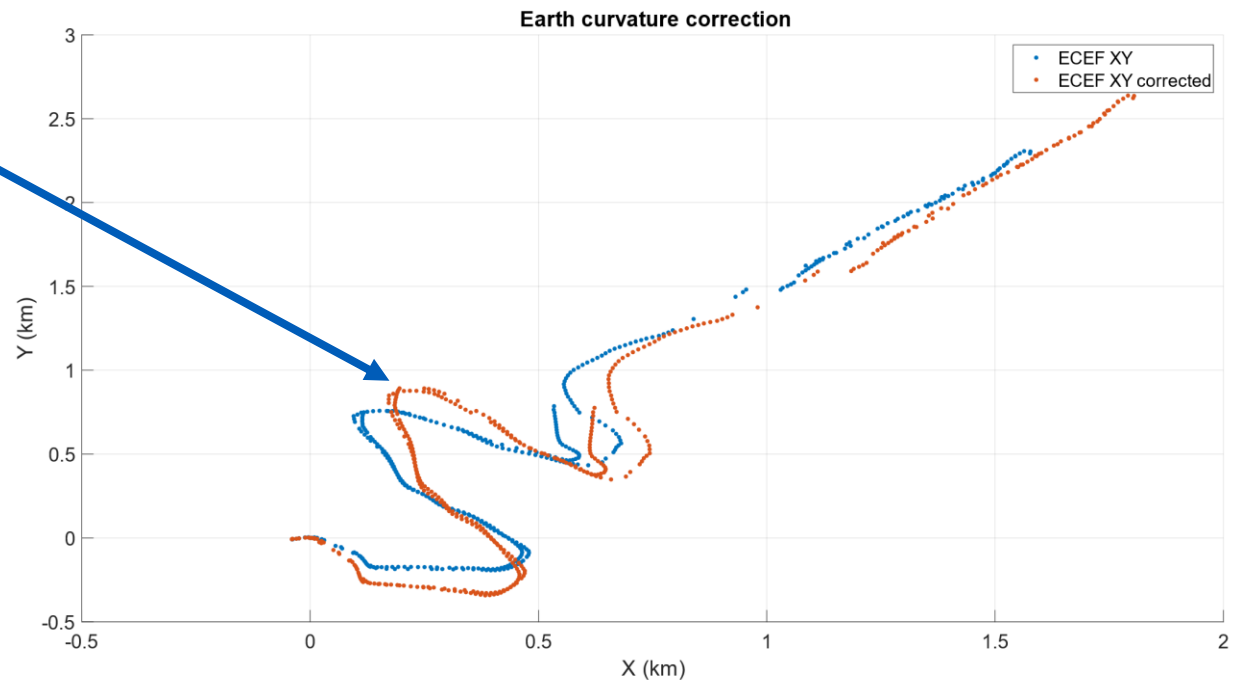
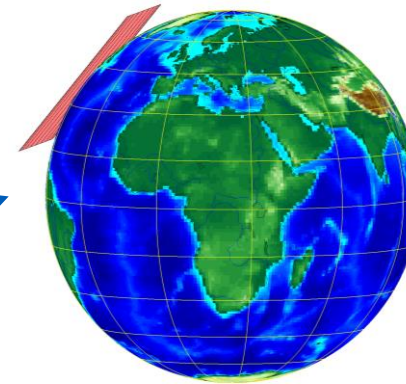
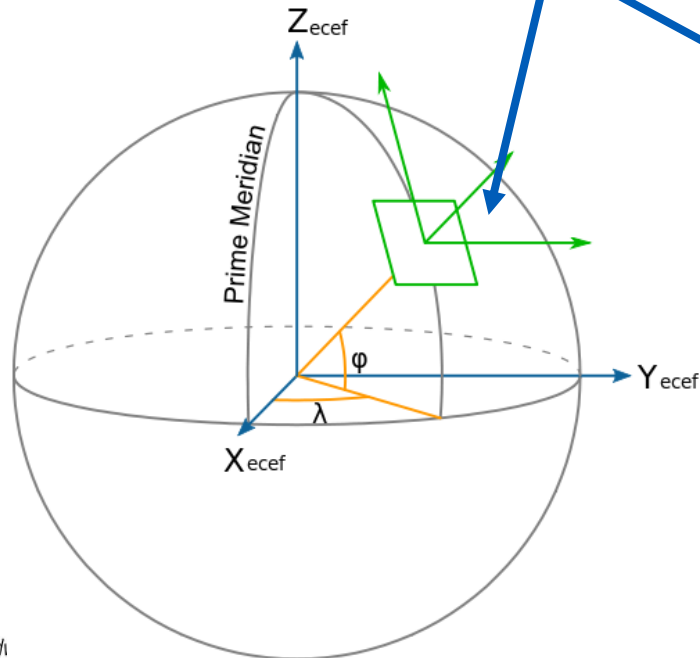
Data acquisition and preparation

- Track approximation => GPX file => XYZ positions

3D LLA to ECEF coordinate XYZ transform



2D projection + road angle



Simulation in Real-World

“Real-world” simulations may have some pitfalls...

Importing the driving data?
Generating data?

Data?

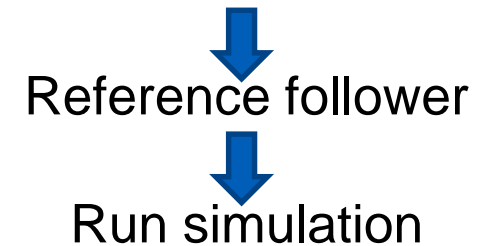
What data?

Let's Google maps everything!

-> Can we use raw data?

-> How do I know how fast should I go?

Data acquisition and preparation





How to generate velocity map?

DieselStation.com



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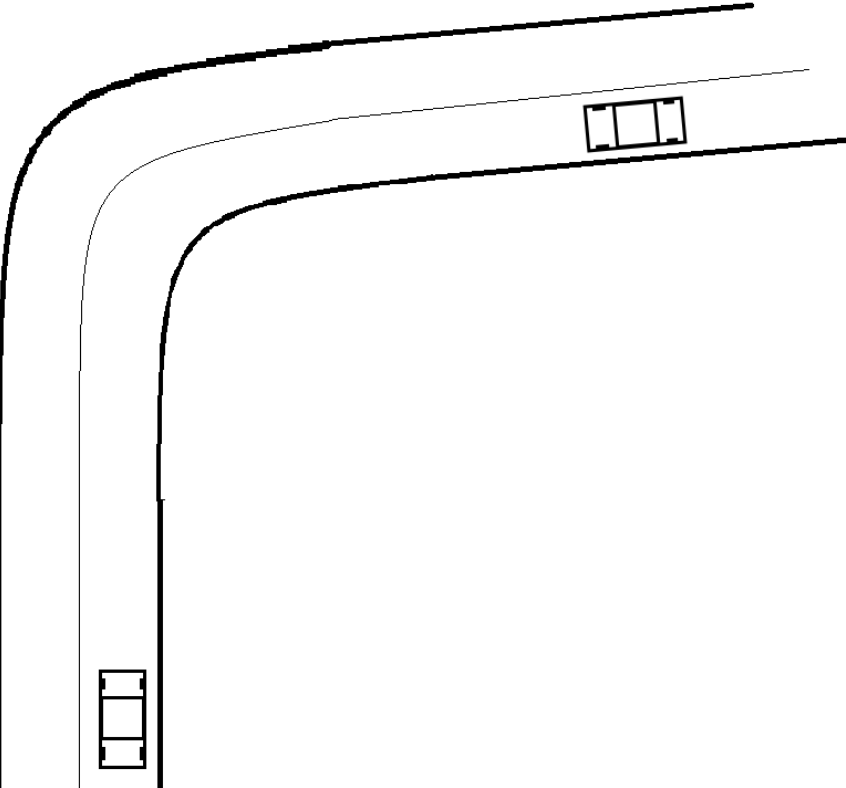
Data acquisition and preparation

- Track approximation => GPX file => XYZ positions
 - XY positions + road grade angle

- **How to generate velocity map?**

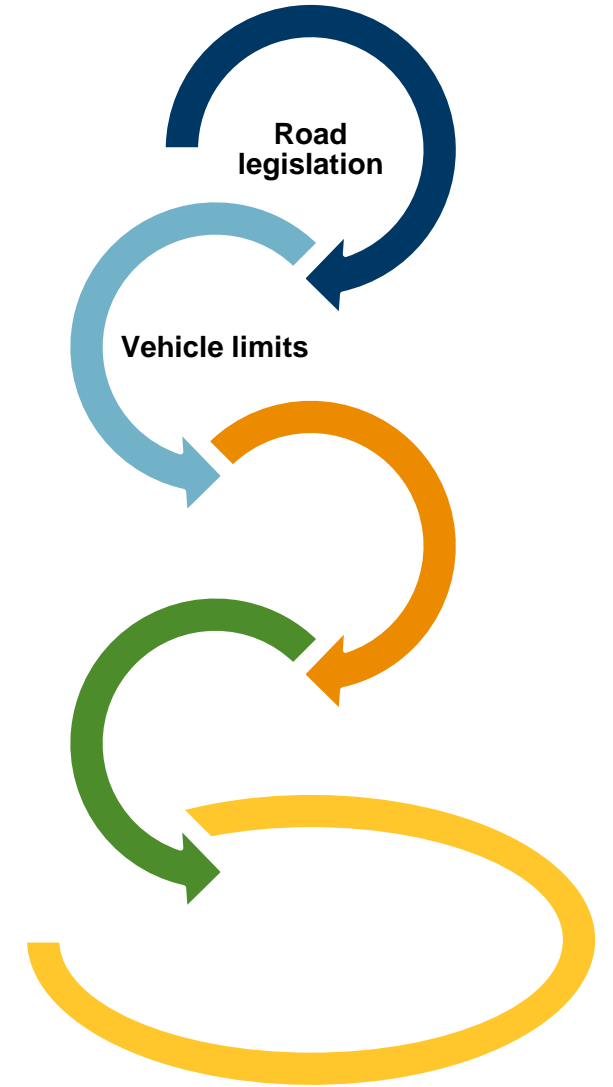
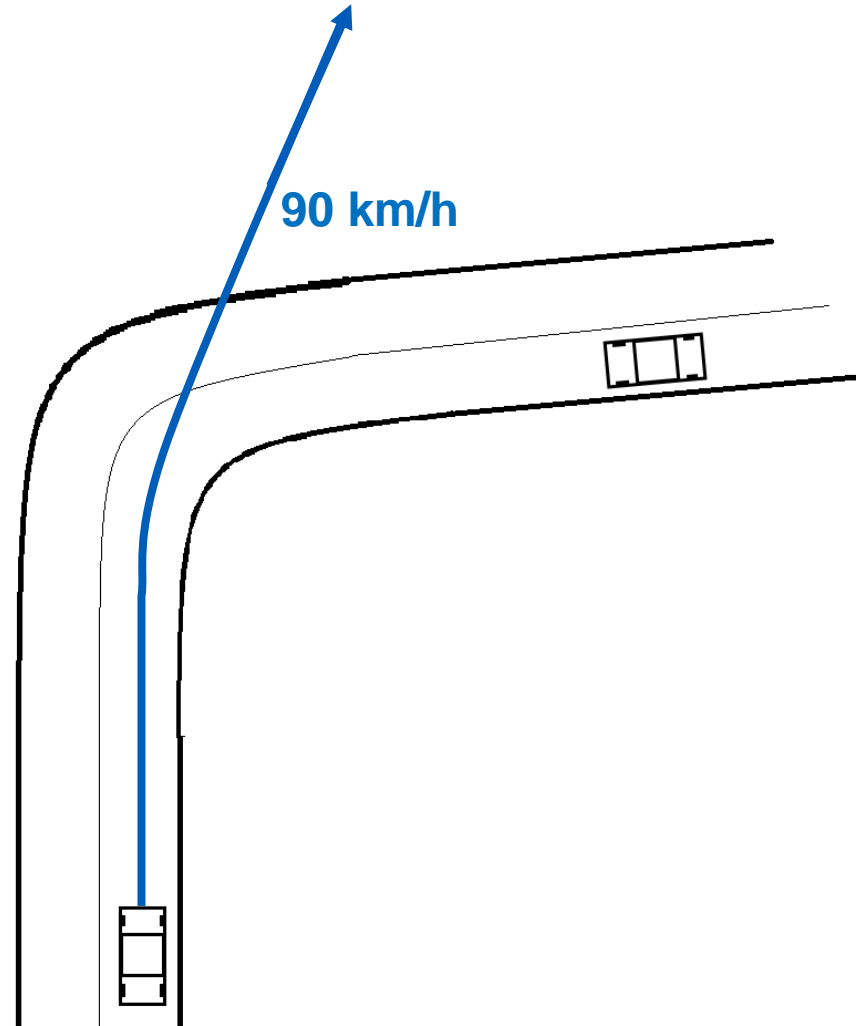
- Measure by GPS
- **Generate data**

Generate data



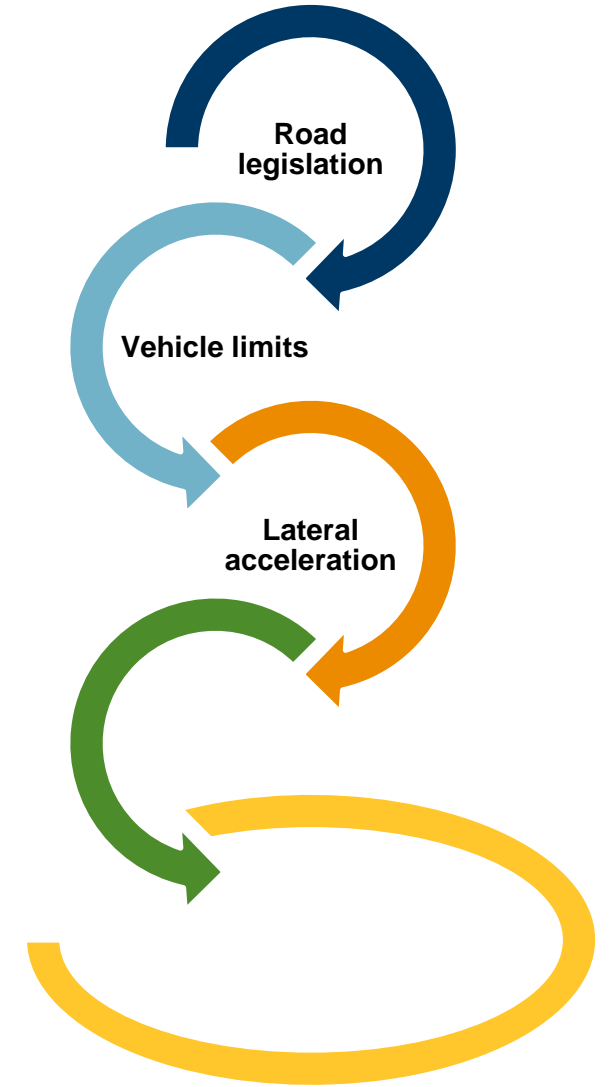
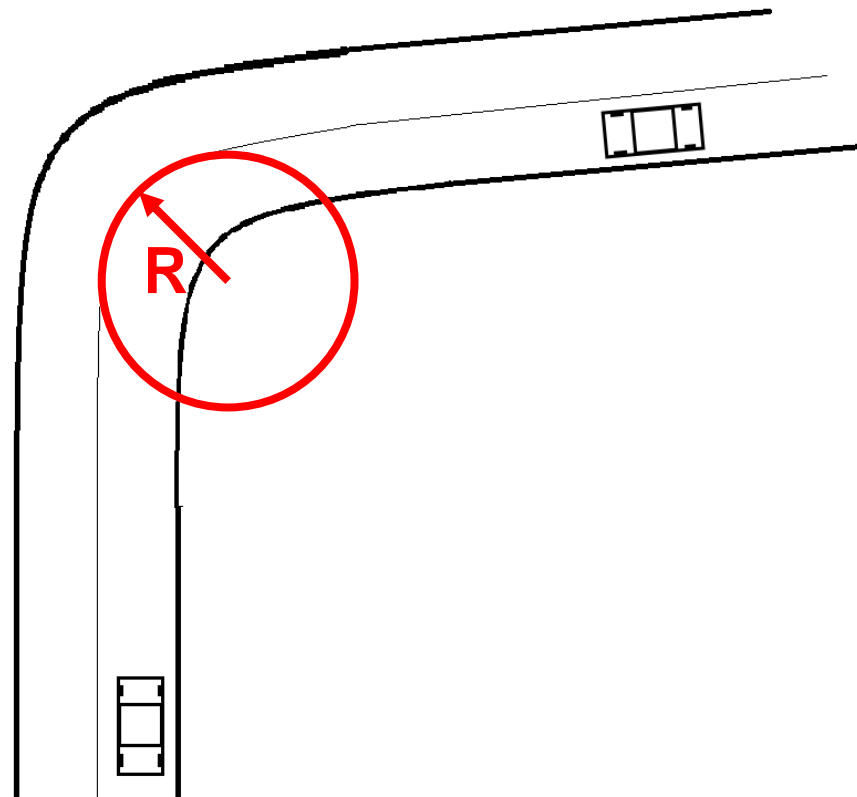
Generate data

- $v_{max} = 90 \text{ km/h}$



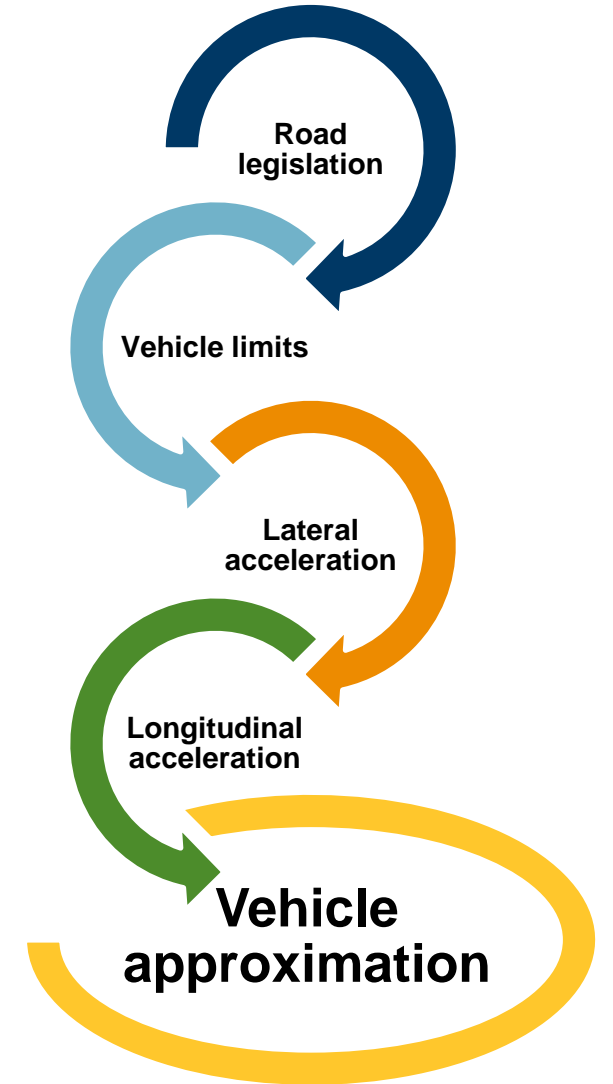
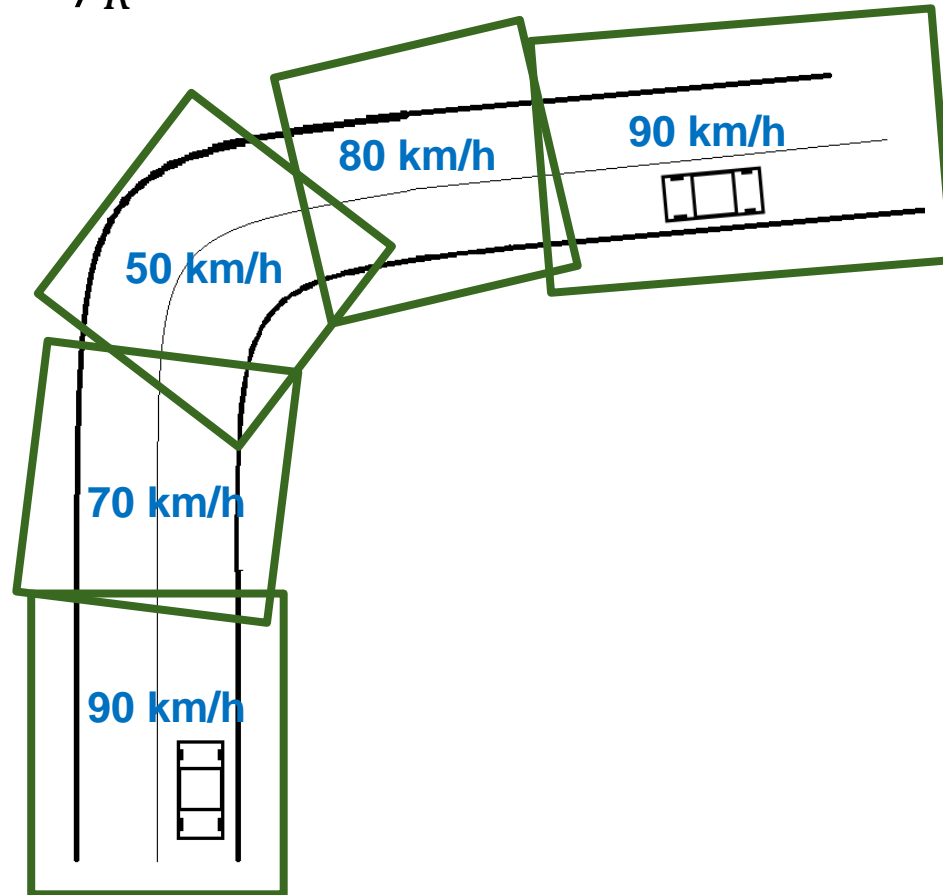
Generate data

- $v_{max} = 90 \text{ km/h}$
- $a_{y,max}$ and Curvature $1/R$



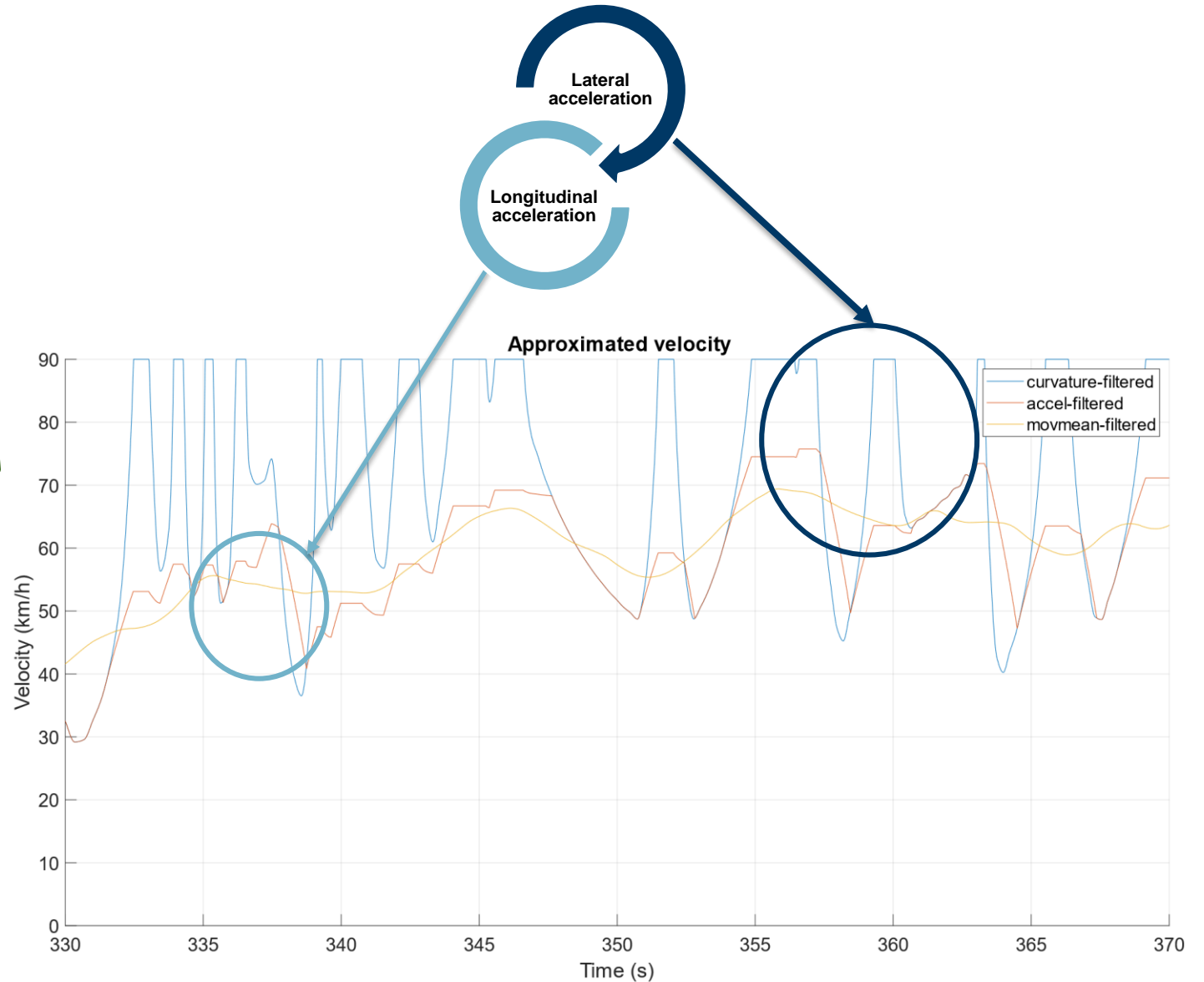
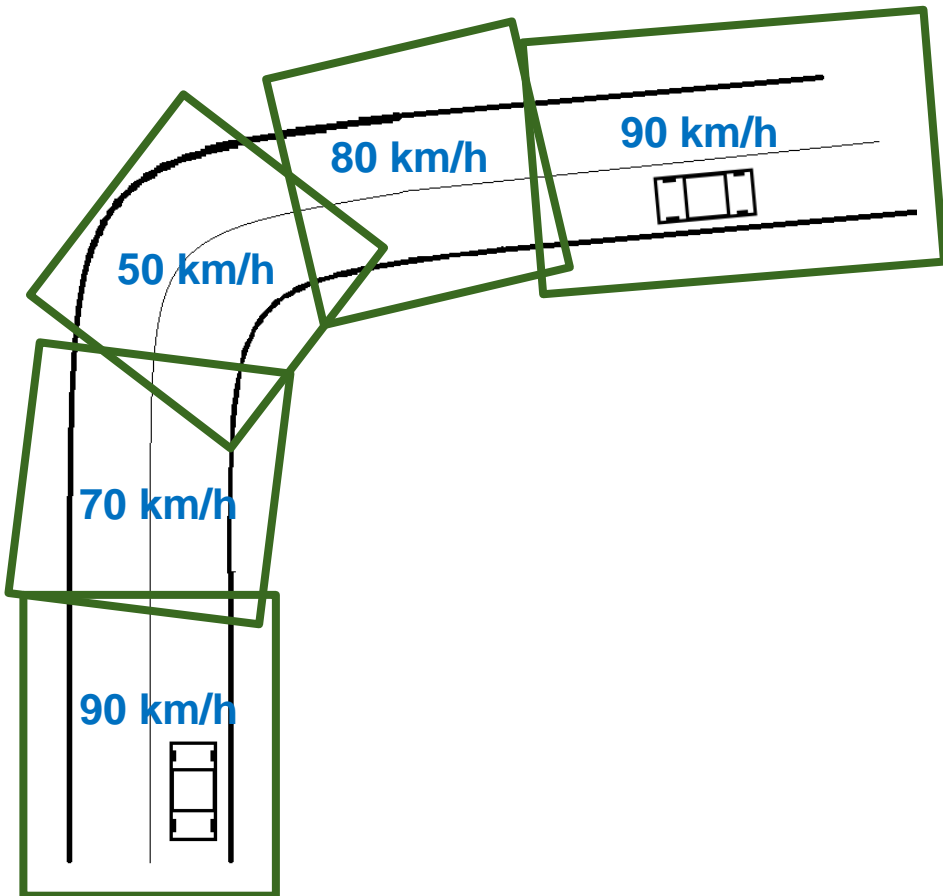
Generate data

- $v_{max} = 90 \text{ km/h}$
- $a_{y,max}$ and Curvature $1/R$
- $a_{x,max}$ and Δs



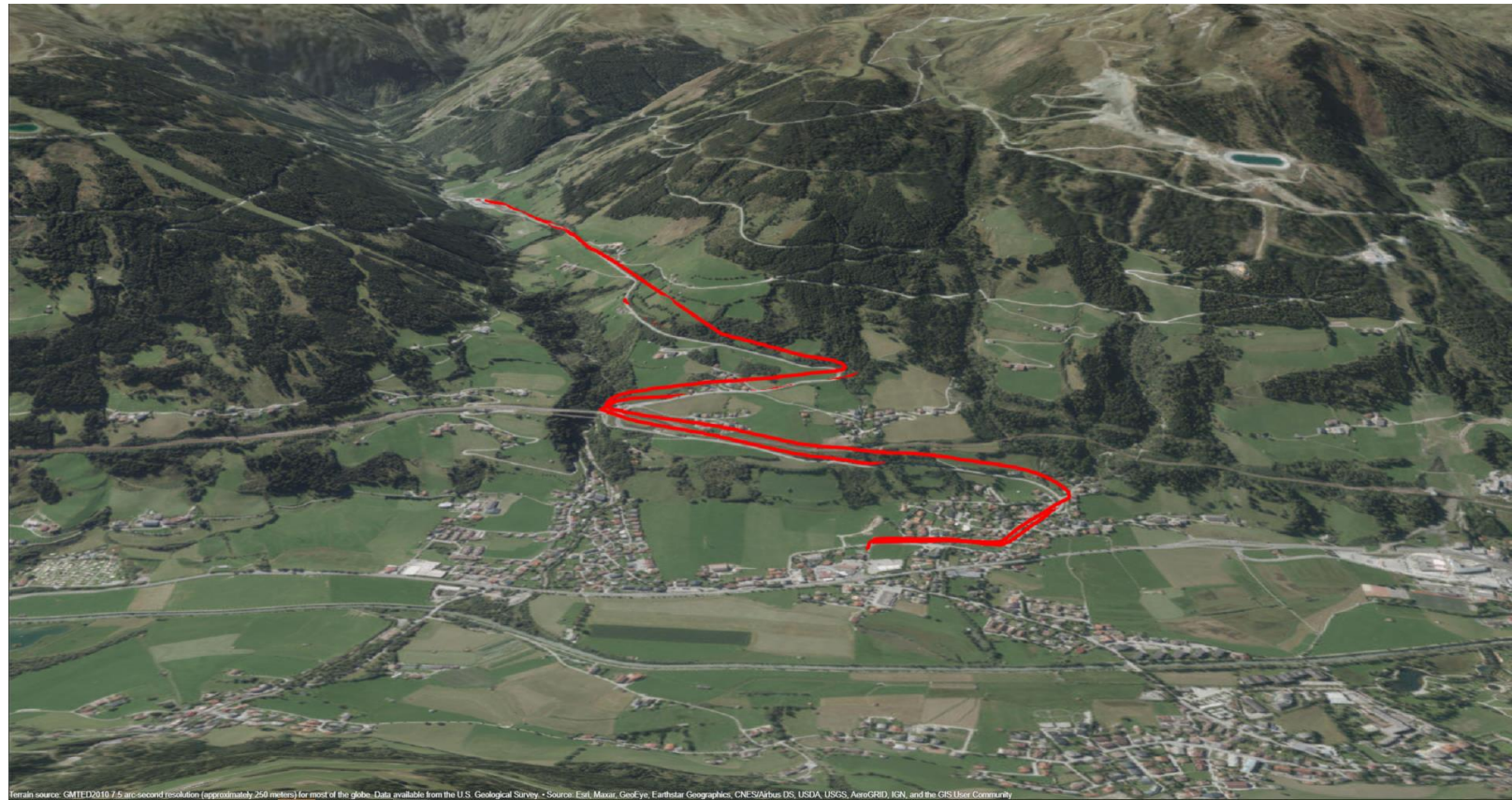
Generate data

- $v_{max} = 90 \text{ km/h}$
- $a_{y,max}$ and Curvature $1/R$
- $a_{x,max}$ and Δs



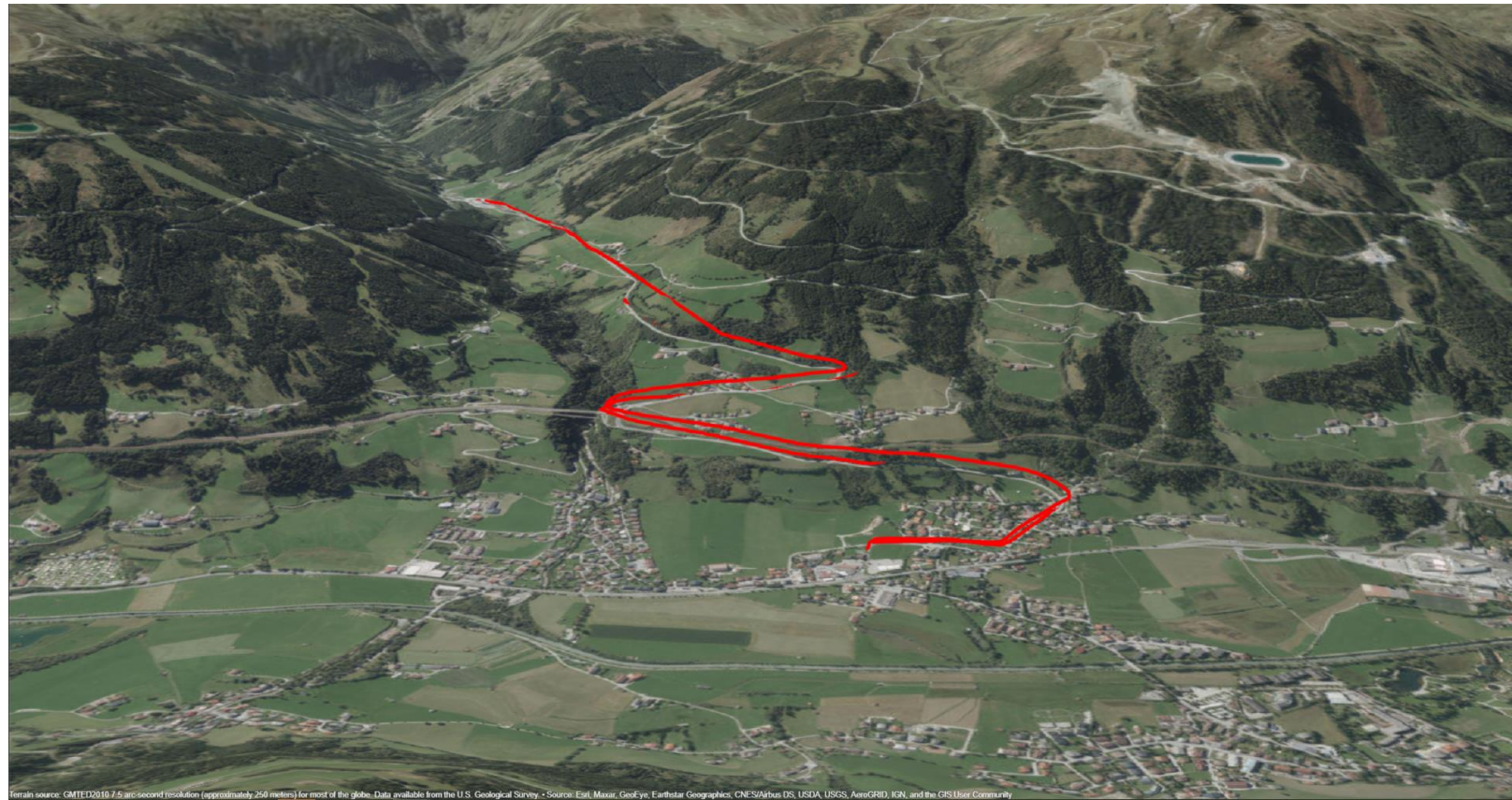
Measure by GPS

- GPS generates:
 - Positions => track formulation
 - Time stamps => velocity calculation



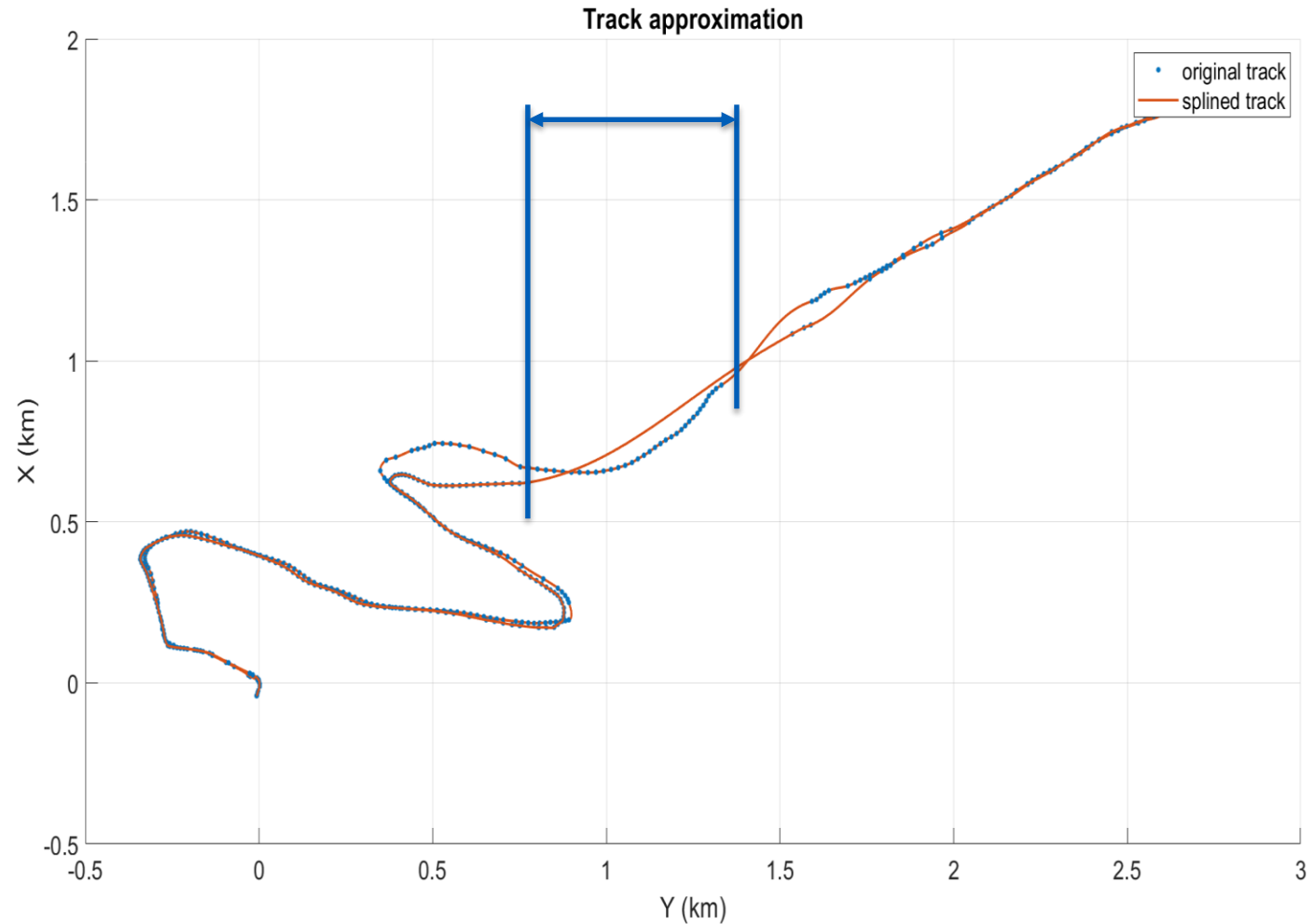
Measure by GPS

- GPS generates:
 - Positions => track formulation
 - Time stamps => velocity calculation
- **GPS accuracy is not guaranteed!**
 - Number of satellites
 - Noise
 - Multipath



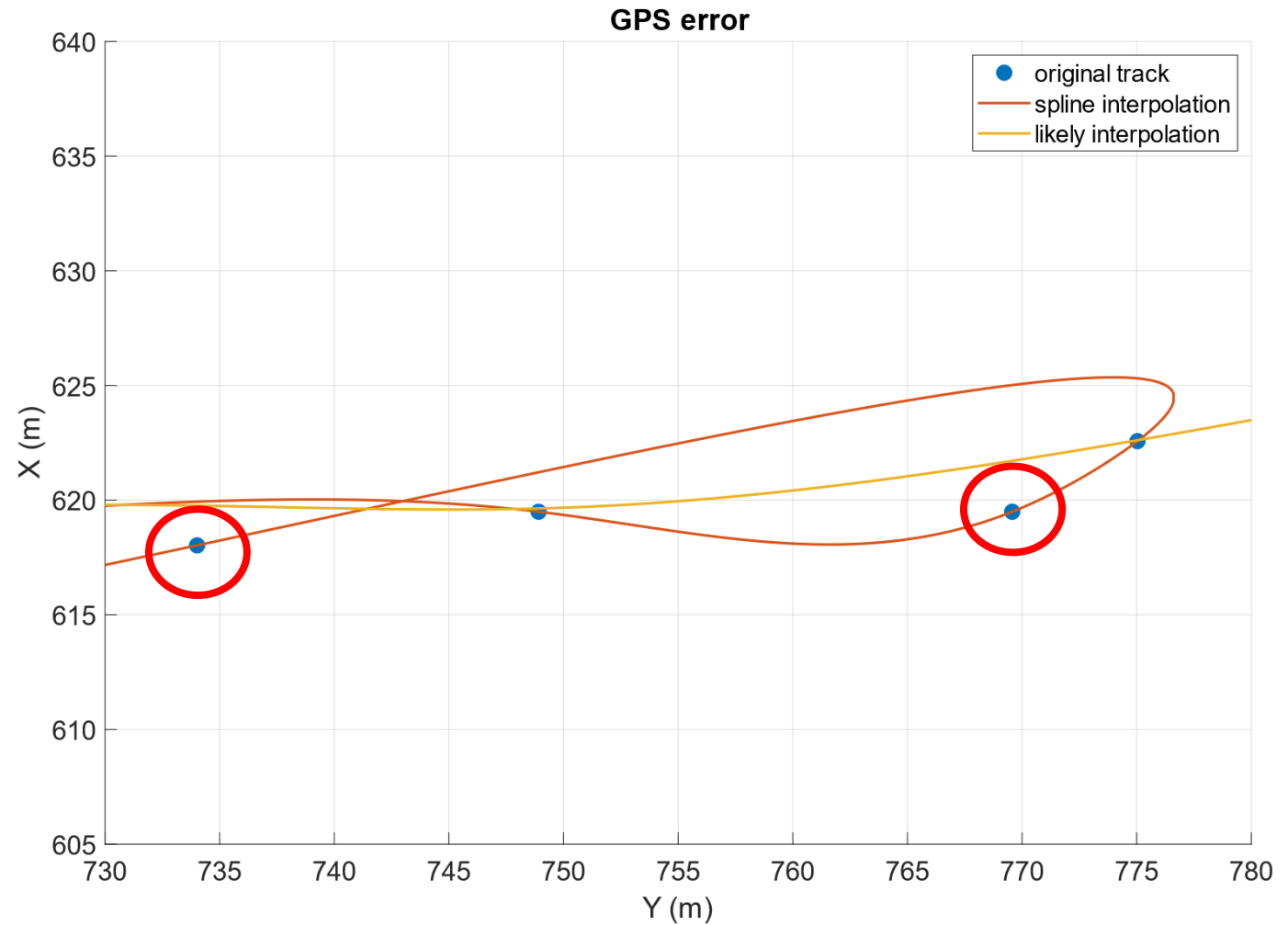
Measure by GPS

GPS data missing!



Measure by GPS

Noisy GPS data!



Simulation in Real-World

“Real-world” simulations may have some pitfalls...

Data acquisition and preparation



Reference follower



Run simulation

Reference follower

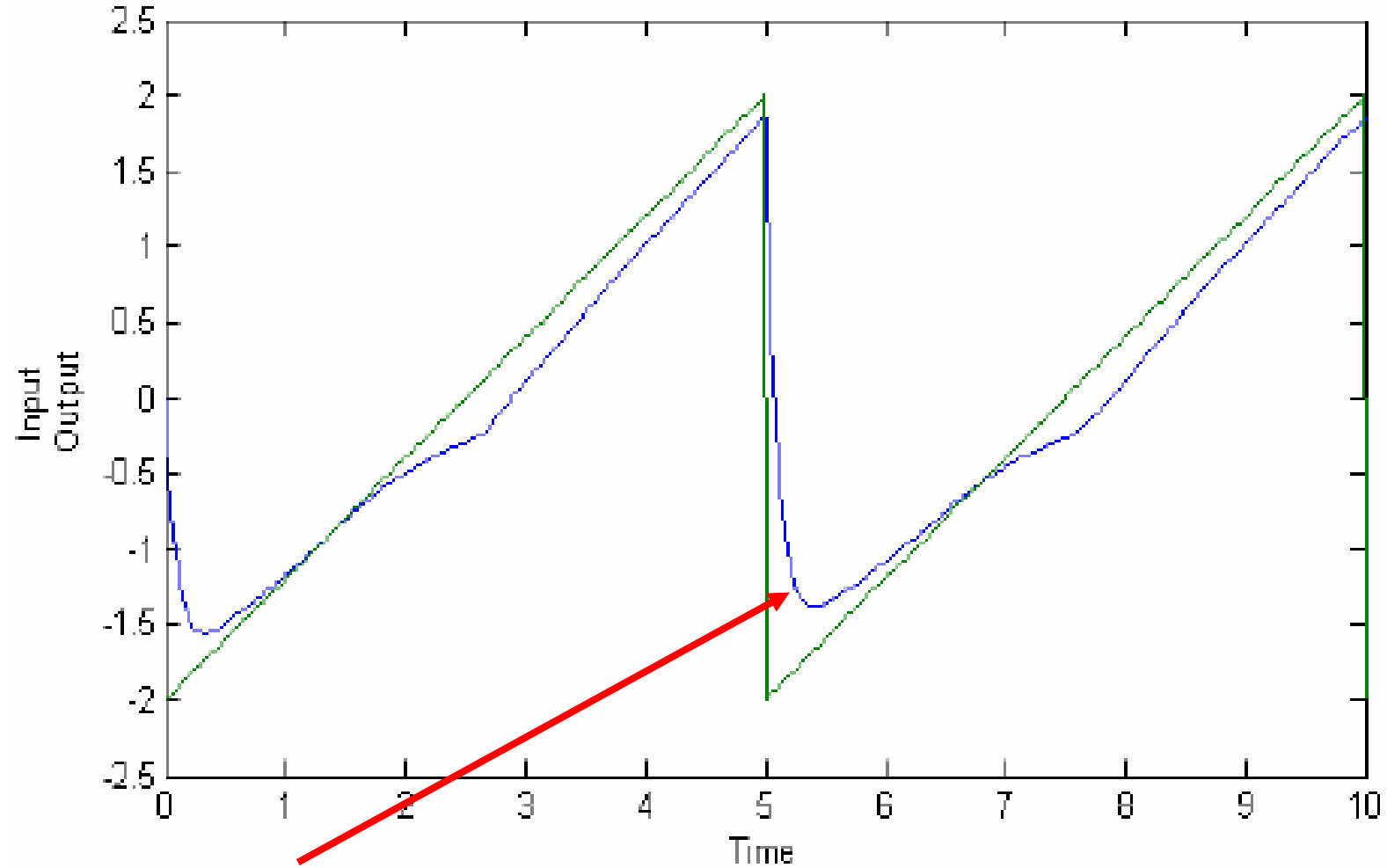
Curvature calculation



Look-ahead path follower



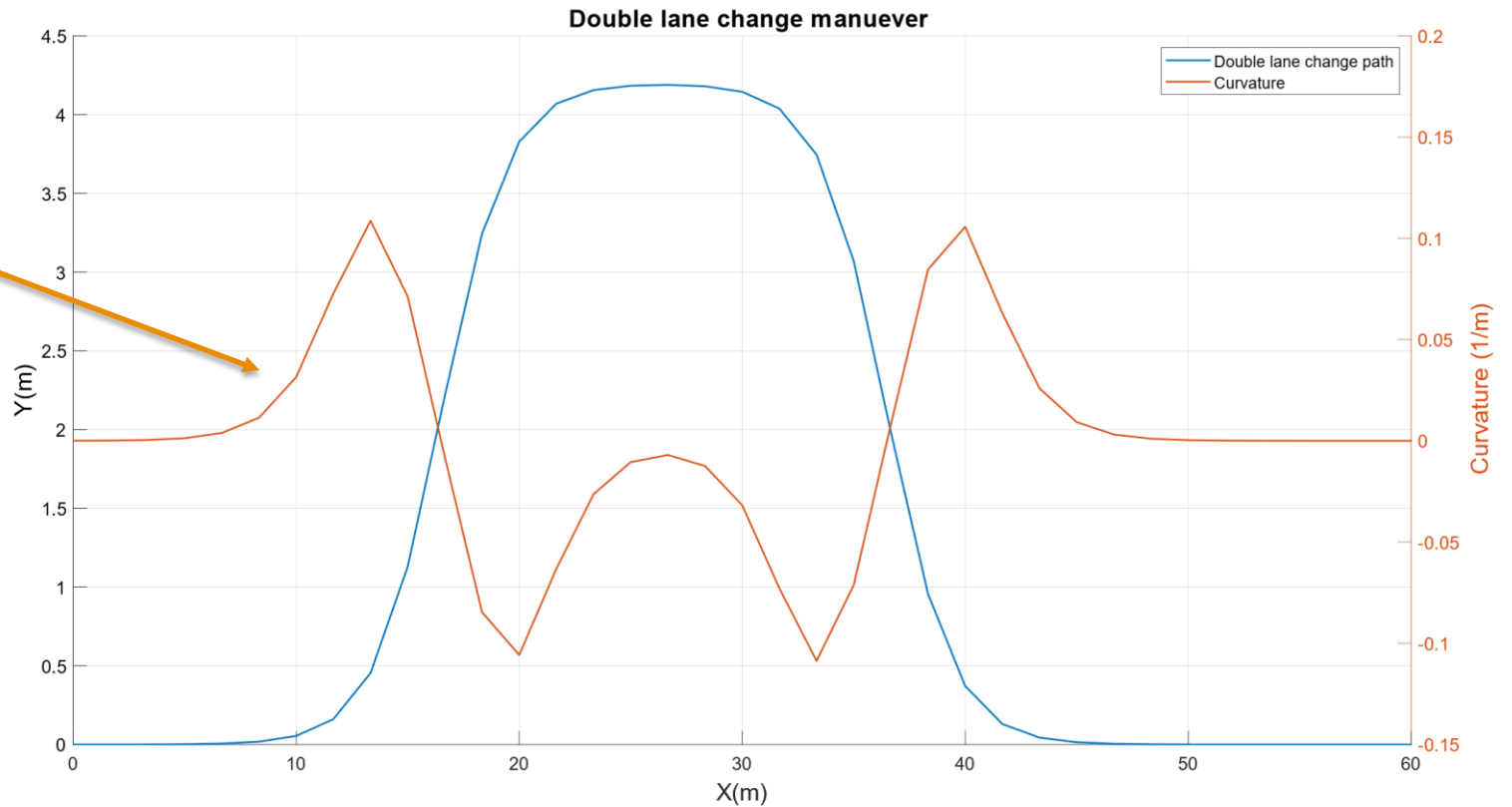
Stability and slip controllers



PID controller response

Reference follower

Curvature calculation
↓
Look-ahead path follower
↓
Stability and slip controller



Reference follower

Curvature calculation

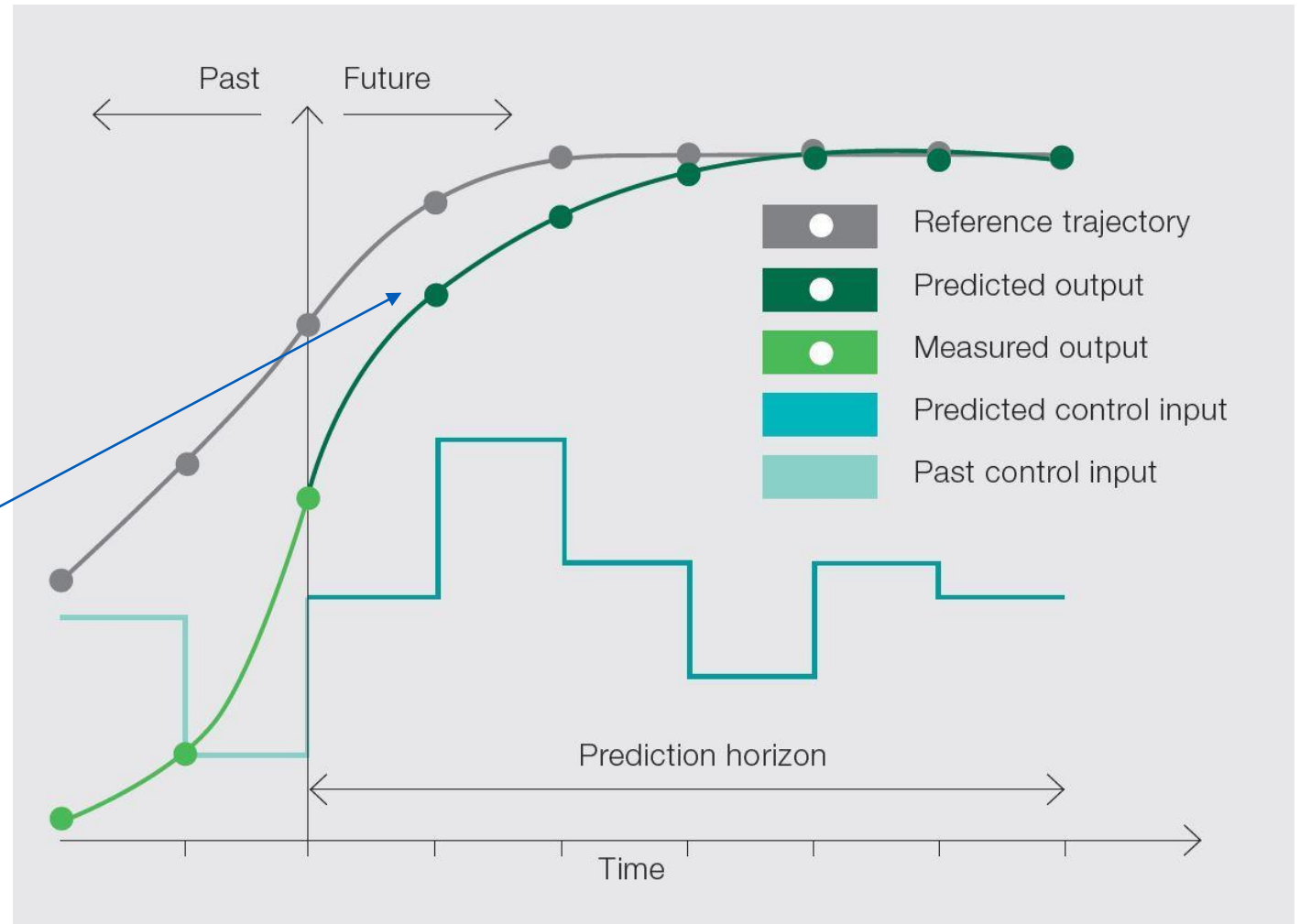


Look-ahead path follower



Stability and slip controllers

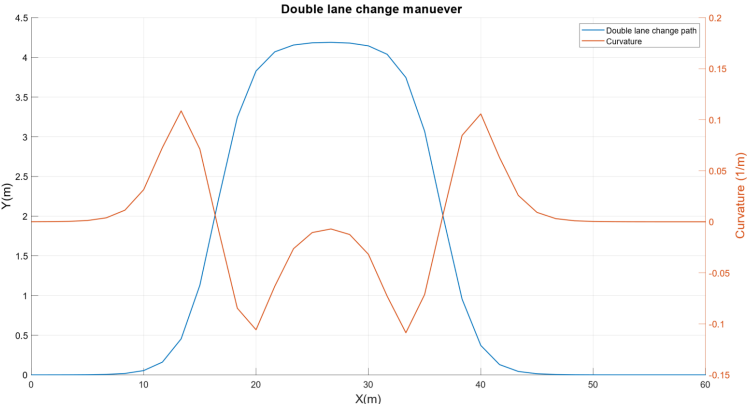
- Model Predictive Control (MPC)
- Stanley



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Reference follower

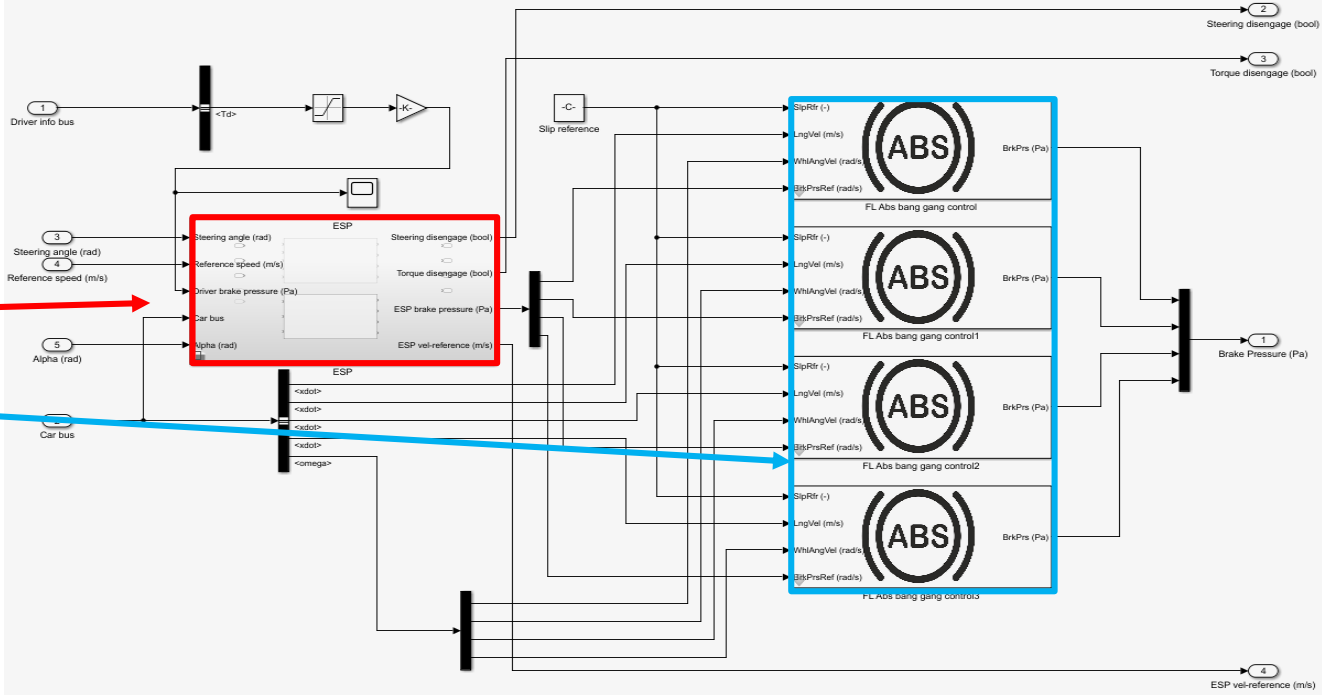
Curvature calculation



Look-ahead path follower

Stability and slip controllers

- MPC
- Stanley
- ESP
- ABS
- TSC



Is that all?



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A man with a beard and short dark hair, wearing a green long-sleeved shirt, is shown from the chest up. He is holding a black pen to his forehead with his right hand, looking slightly to the right with a thoughtful or skeptical expression. The background is a plain, light gray.

Not really...



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Double Lane Change



No stability and slip control



ABS + ESP + TSC

MPC controller + 60 km/h + Wet surface

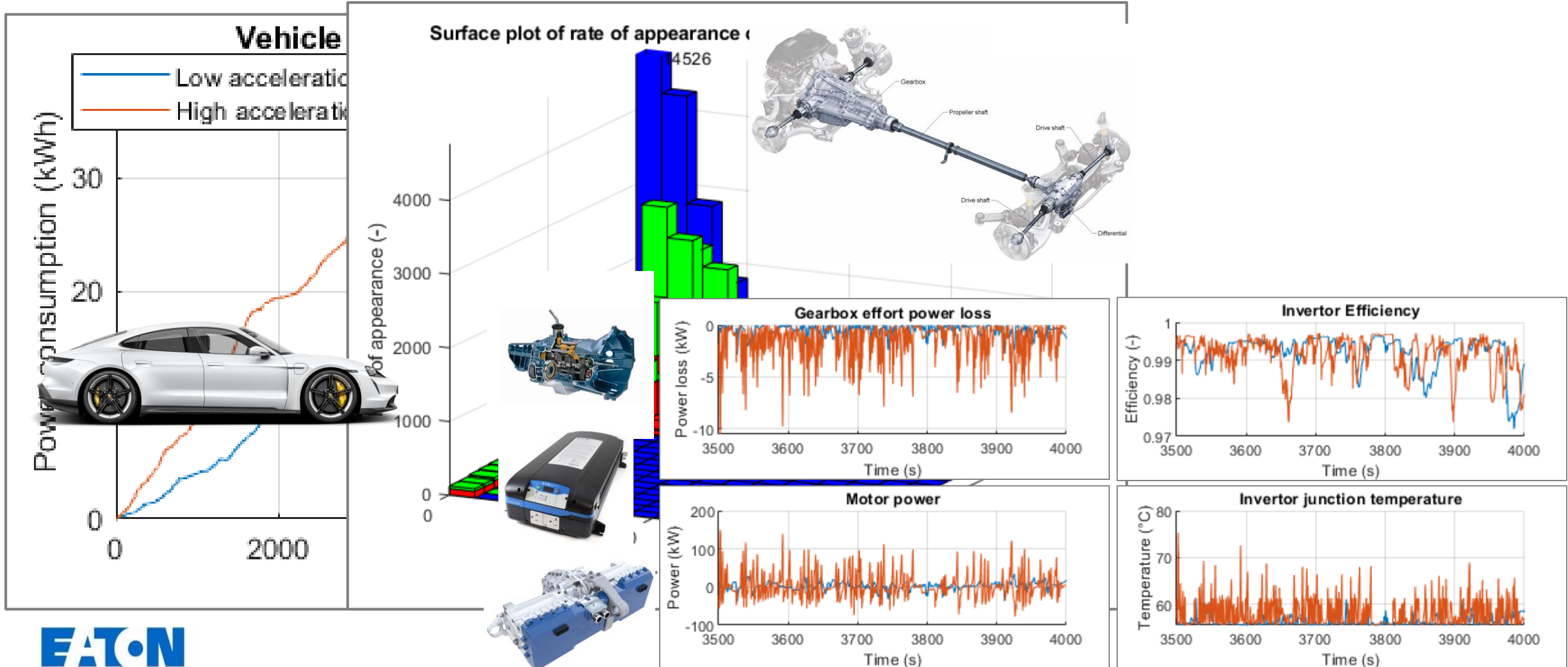
#Real driving!Real drivers!



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#SystemToComponent

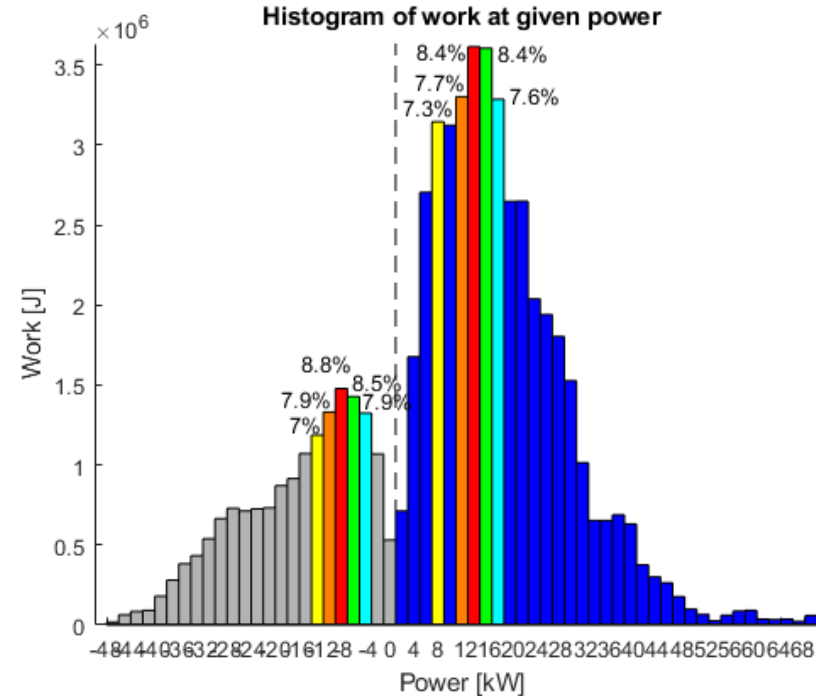
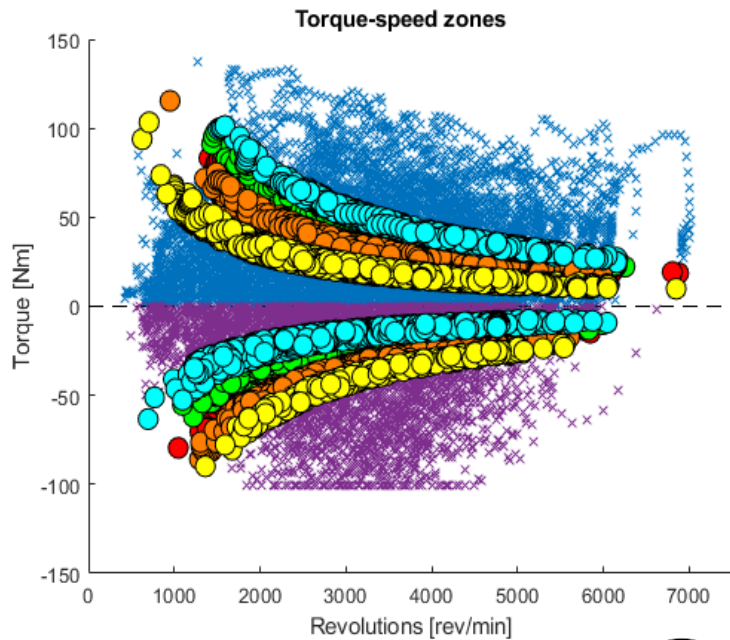
- Asses the entire systems as well as the components performance



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#BoundaryConditions

- Accurate component boundary condition setup



		Fast driver	Gentle driver	delta
Lateral acceleration	m.s ⁻²	5.51	6.09	11%
Longit. acceleration	m.s ⁻²	6.04	3.2	47%
Longit. deceleration	m.s ⁻²	-9.74	-8.45	13%
Peak power	kW	188.8	64.2	66%
Peak recuperation	kW	-77.8	-50.5	35%
Battery current	A	257	87	66%
ESP engagement	-	6	2	67%



• Environment



• Vehicle



• Drivetrain



• Components



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Lessons learned

- High-fidelity single-tool model is feasible (using multilayer 1D models on component level)
- True 3D driving scenarios requires elaborated vehicle controllers
 - Autocruise, Augmented stability program (ABS, ESP, TC,...)
- Accurate battery cell (pack) model is essential for all electric energy consumers within the vehicle grid
- Some batteries behavior is opposed to the common sense
- Regenerative braking should contain an Anti-block function integrated within the Traction Inverter
- Continuous fault detection, maintenance and remediation (on-board or as a cloud function)

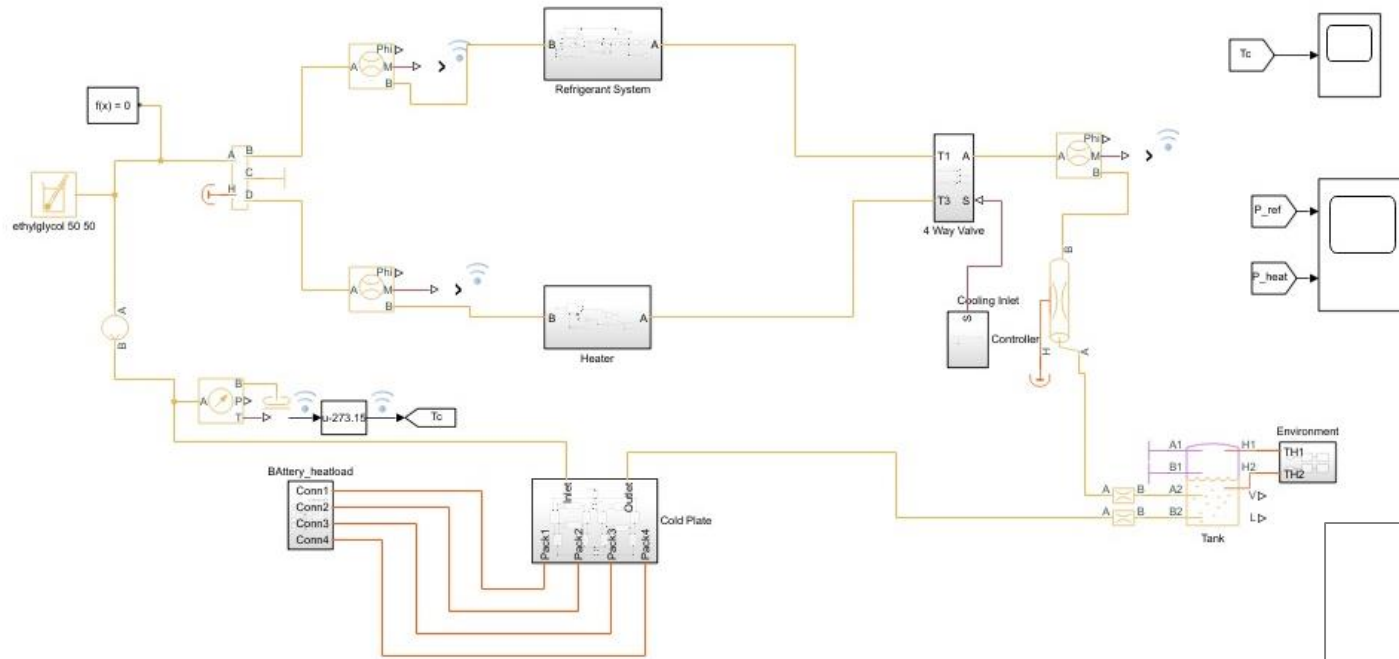


Without learning the whole picture you may pass, but you cannot fit !

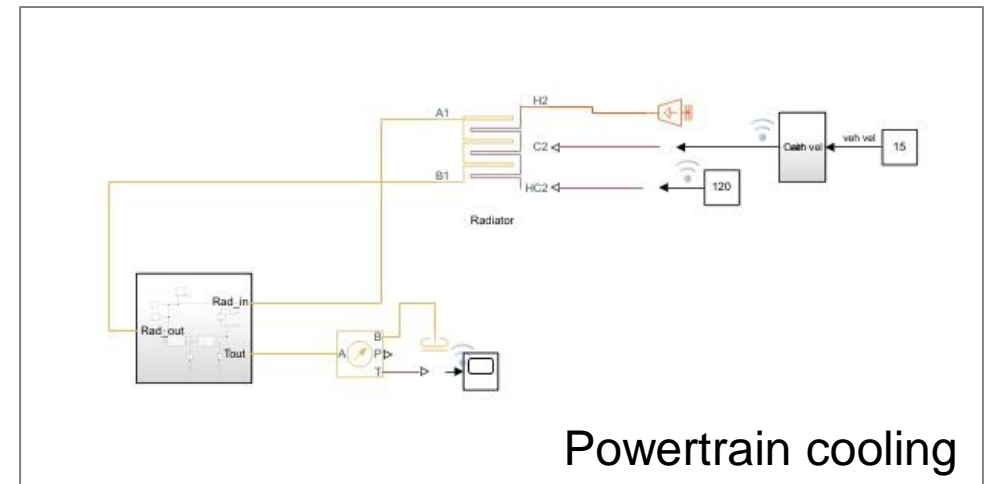
Reference

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<http://www.dirsig.org/docs/new/coordinates.html>
- [2] Comparative Control of a Nonlinear First Order Velocity System by a Neural Network NARMA-L2 Method
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- [3] Model predictive control technology demystified
<https://new.abb.com/control-systems/features/model-predictive-control-mpc>

#StayCool



Battery thermal management



Powertrain cooling