Virtual Electric Vehicle in real–world environment

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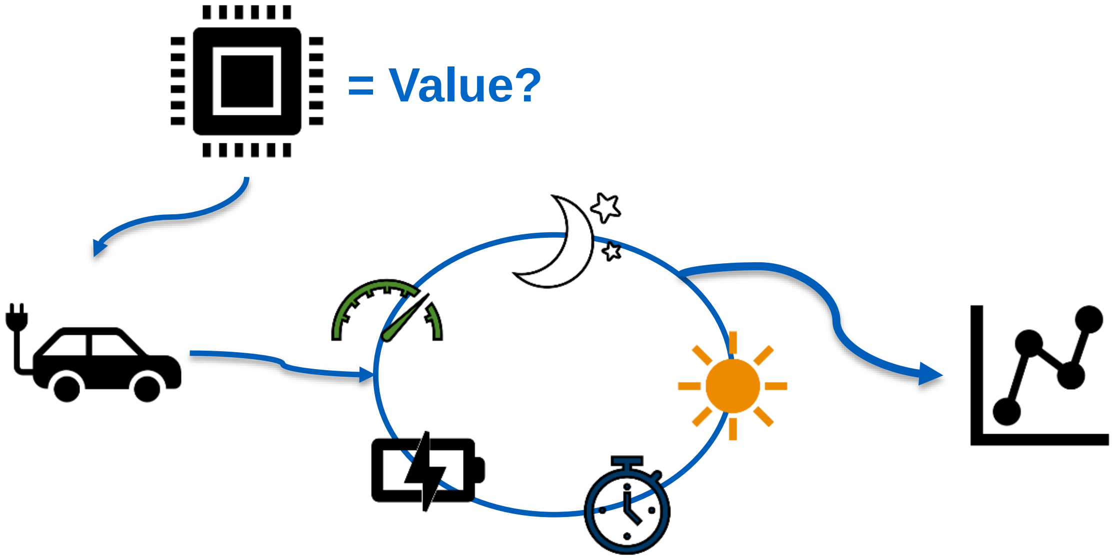
Background

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



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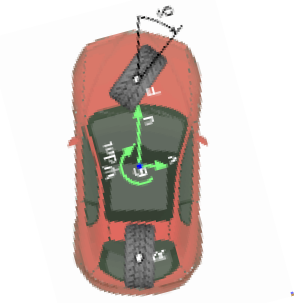
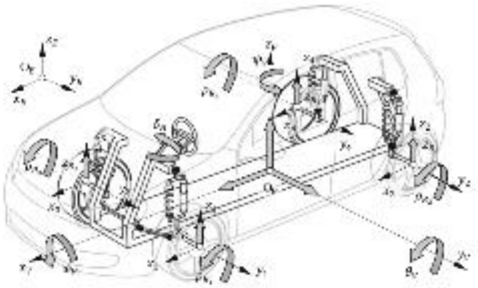
Virtual EV

Vehicle models

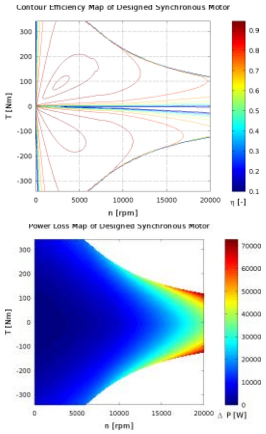
Single-track model

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





Drivetrain

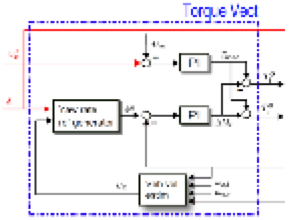


- Multi-motor
- Multi-inverter
- Multi-gearbox
- Library with 5D motor maps
- Library with 5D 800 V inverters

Environment

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

Controls and monitoring



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

Battery

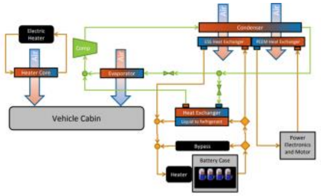
- Calibrated model
- Unique extended Thevenin model developed
- Automated procedure and measurement system

Auxiliary systems

- Vehicle subsystems
- Power steering, lights, other loads

Cooling system

- Simscape model of Vehicle HVAC



Graphical visualisation

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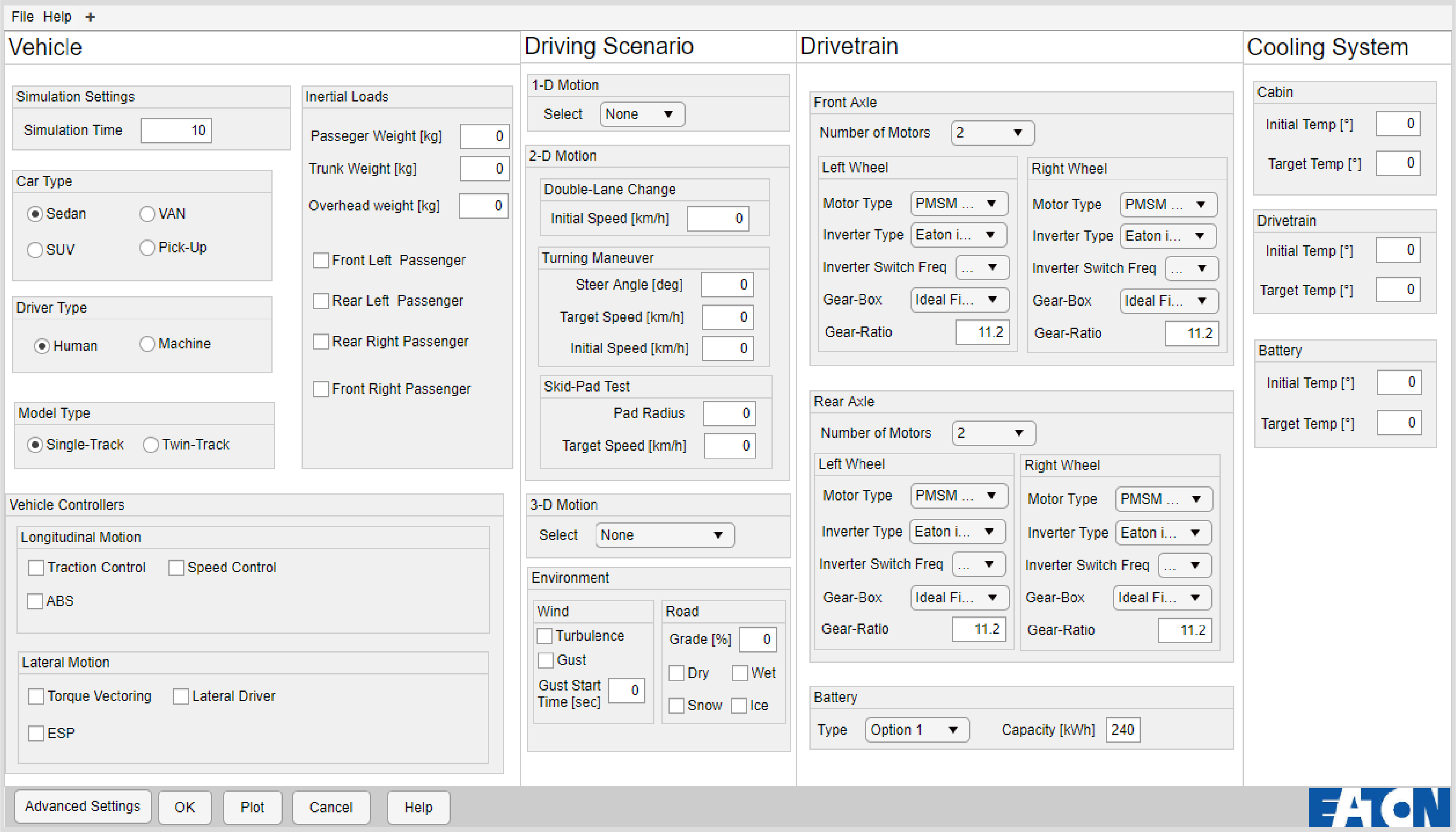
Virtual EV - GUI



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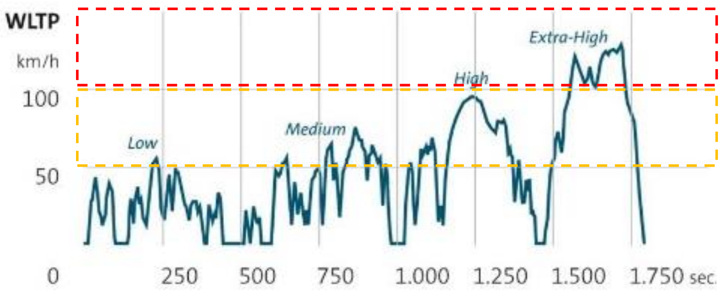
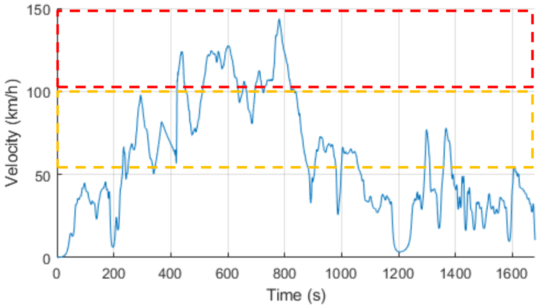
#Real driving, real drivers

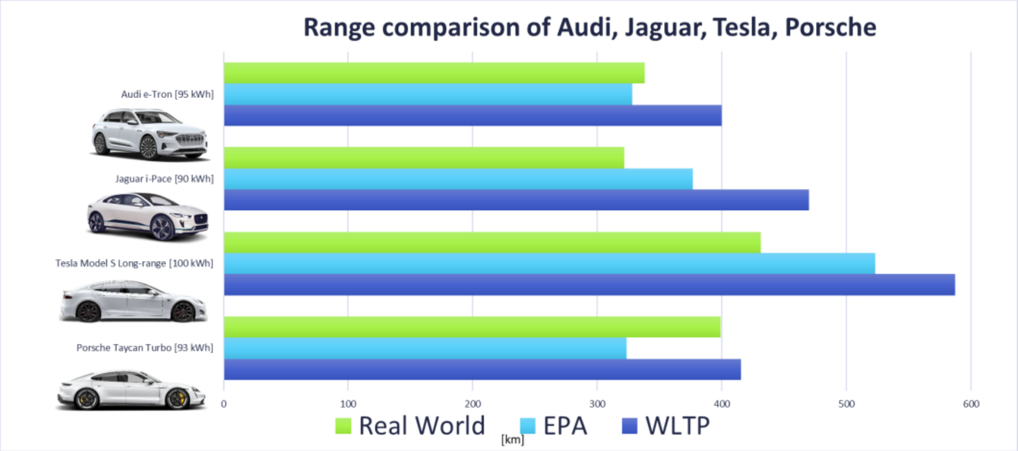
Lab driving



Real driving



Consequences



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

Out of the lab simulations!

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#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

…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?

<u>Data acquisition and preparation</u>

↓

Reference follower

↓

Run simulation

What data?

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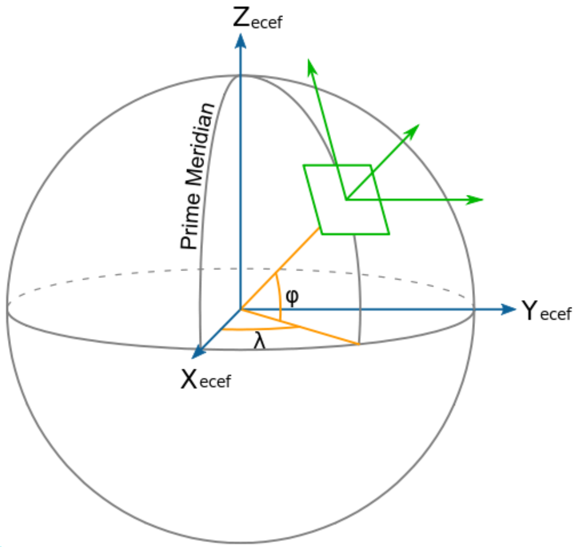
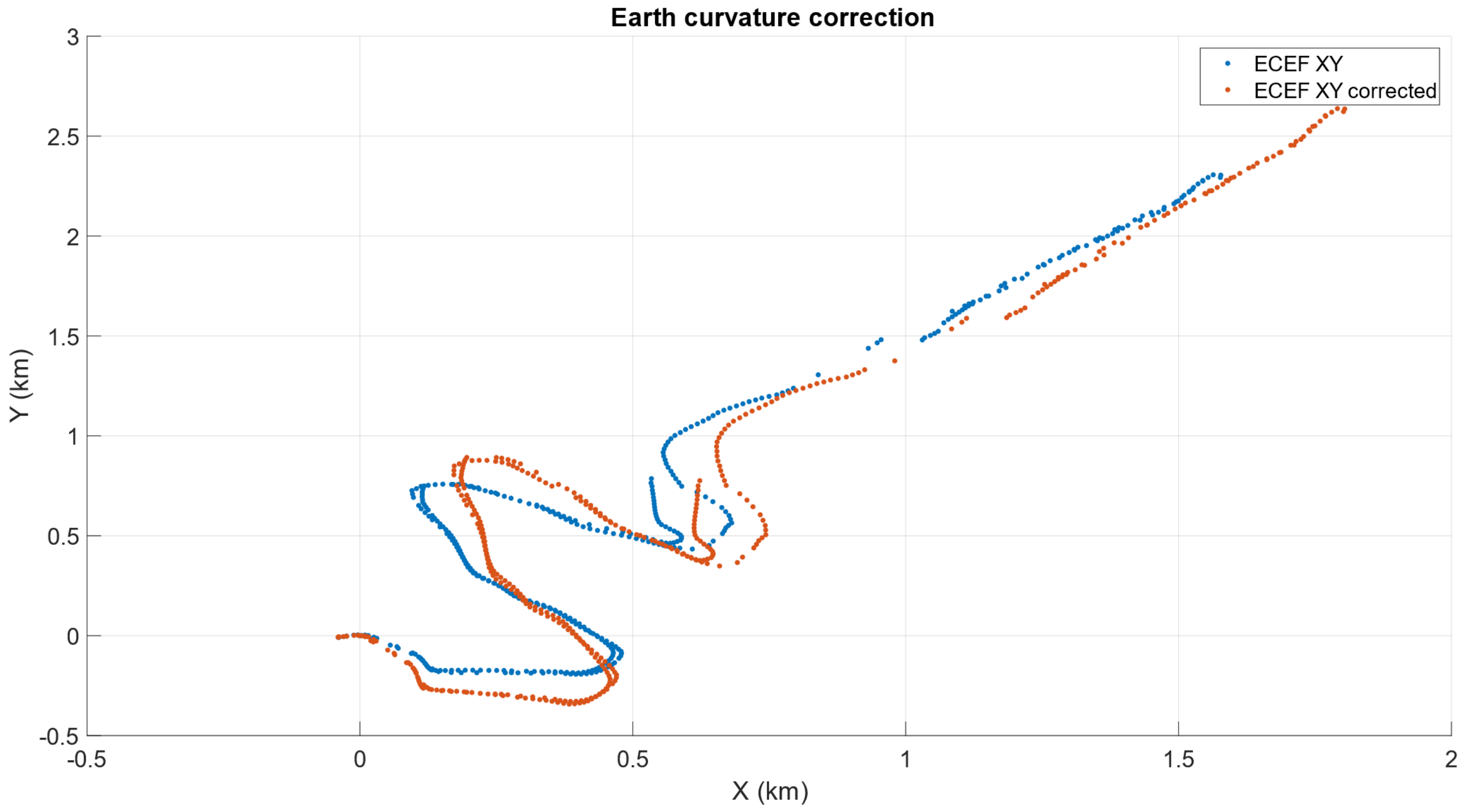
Data acquisition and preparation

- Track approximation => GPX file => XYZ positions

3D LLA to ECEF coordinate XYZ transform

2D projection + road angle





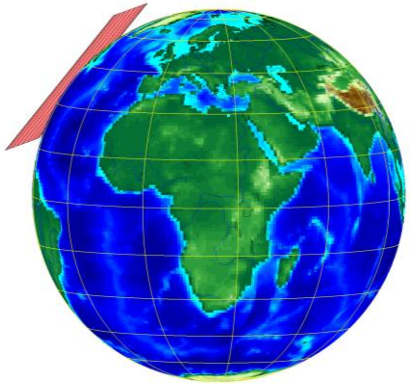
[1] Coordinate Systems

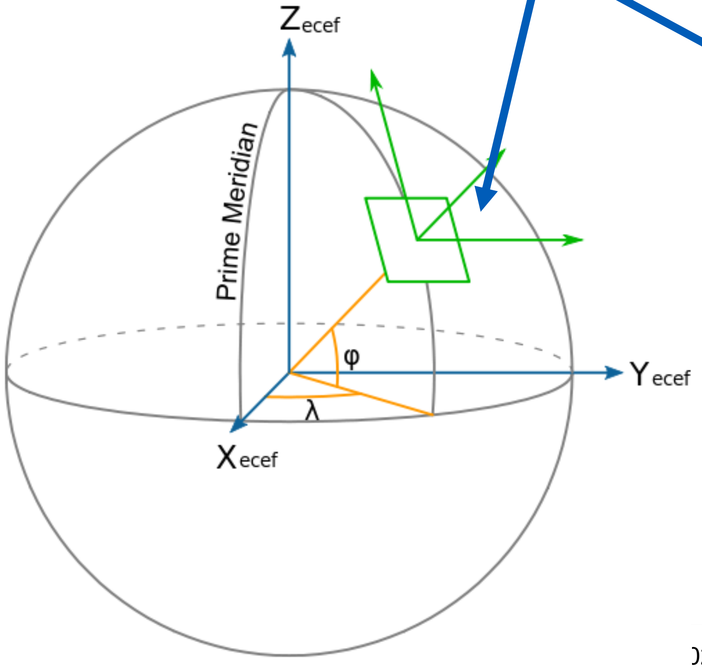
Data acquisition and preparation

- Track approximation => GPX file => XYZ positions

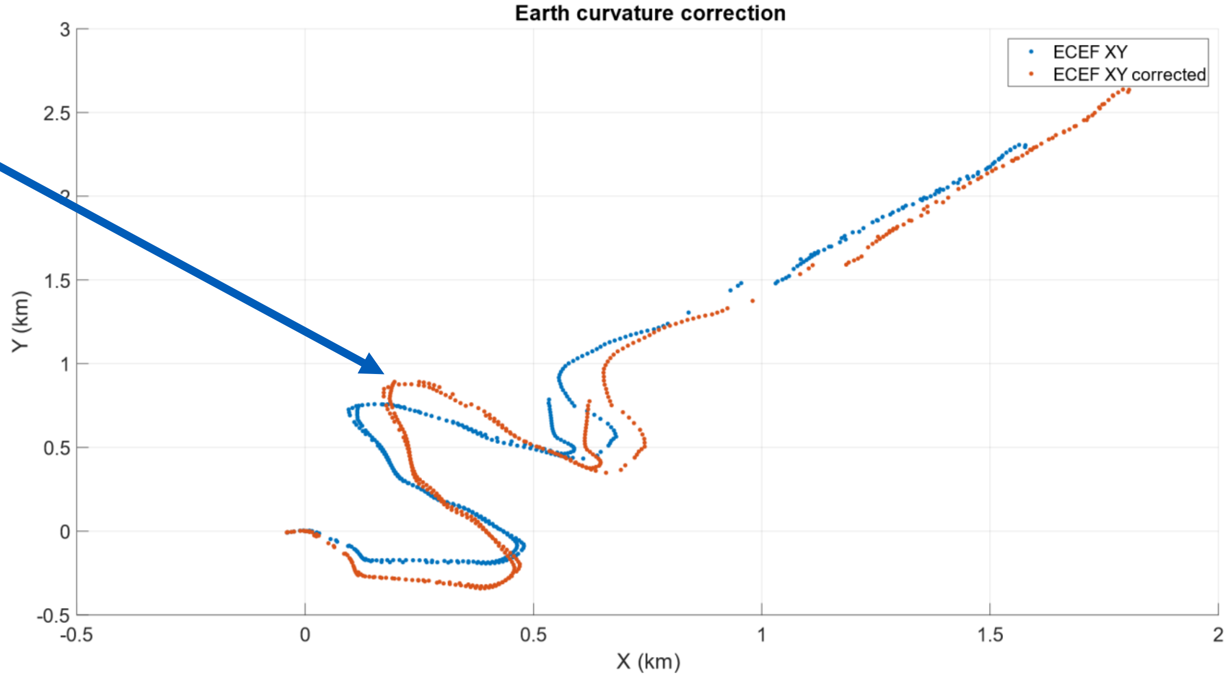
3D LLA to ECEF coordinate XYZ transform

2D projection + road angle





[1] Coordinate Systems



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

Reference follower

Run simulation

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How to generate velocity map?

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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

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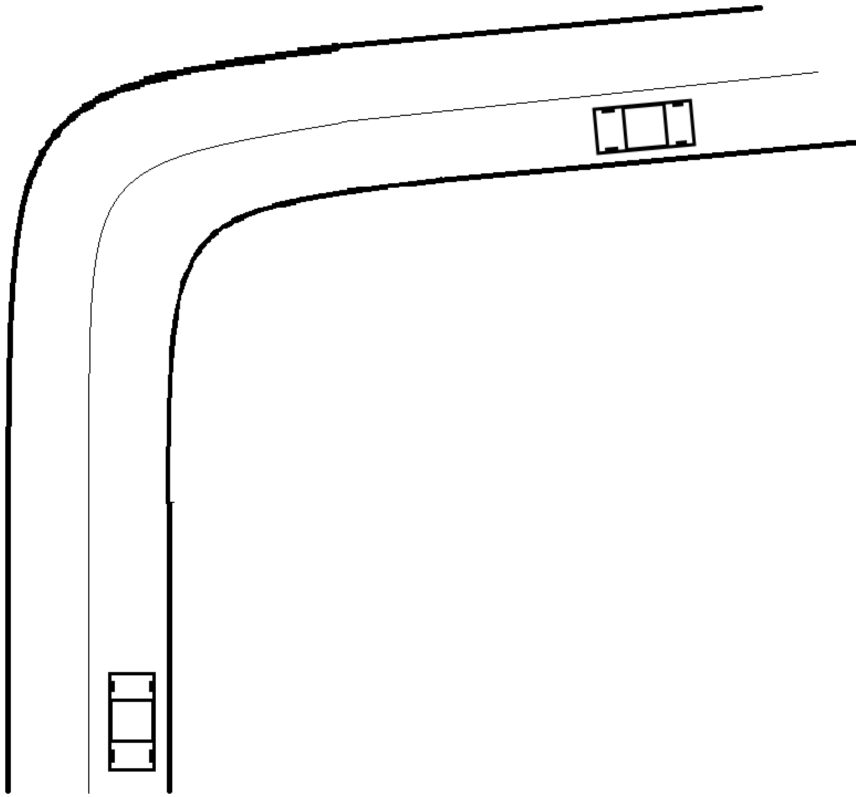
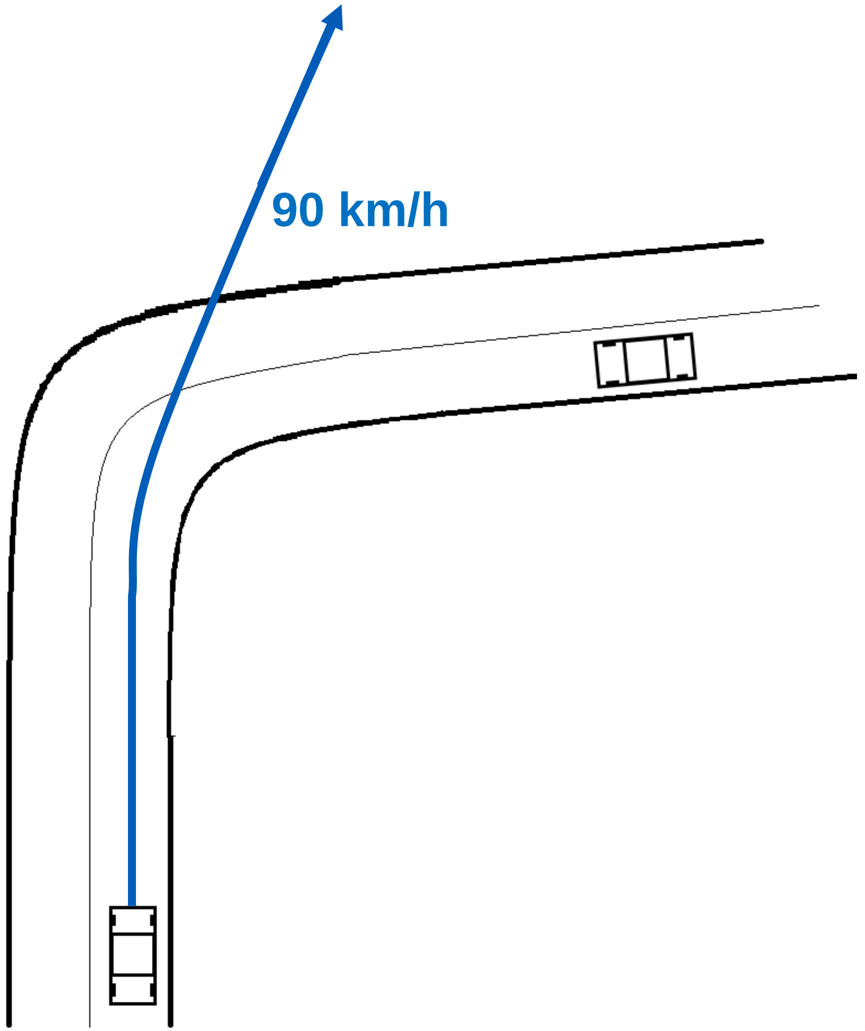
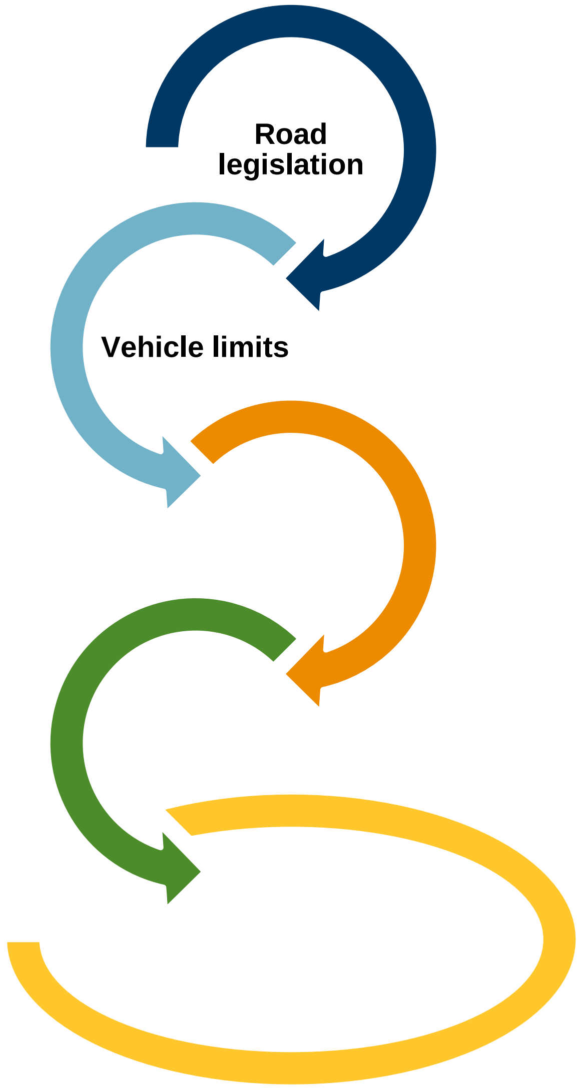
Generate data



Generate data

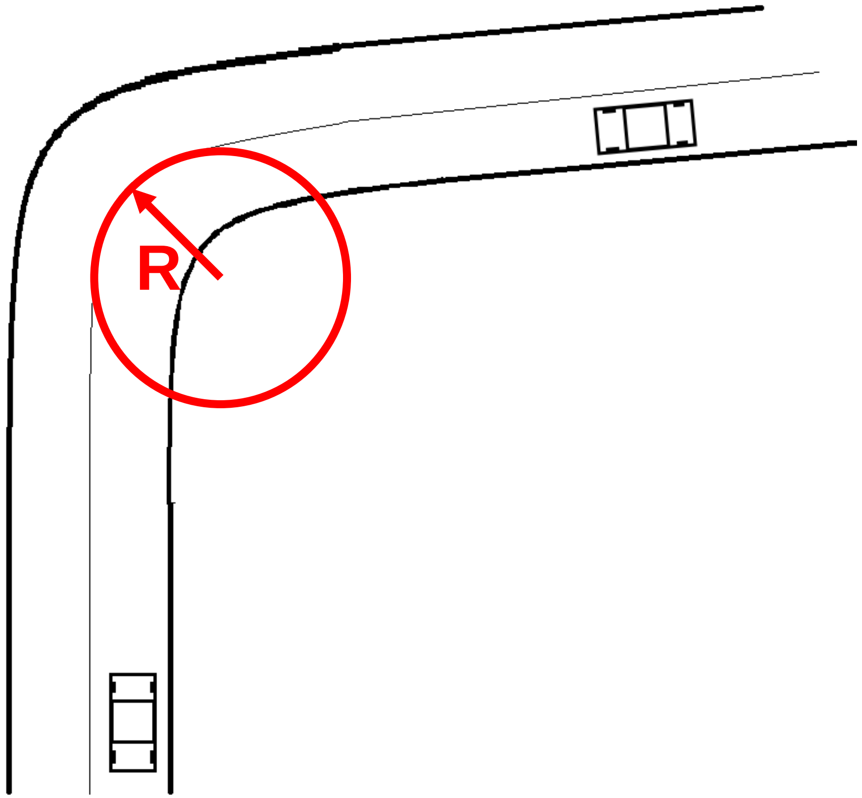
- $v_{max} = 90\ km/h$

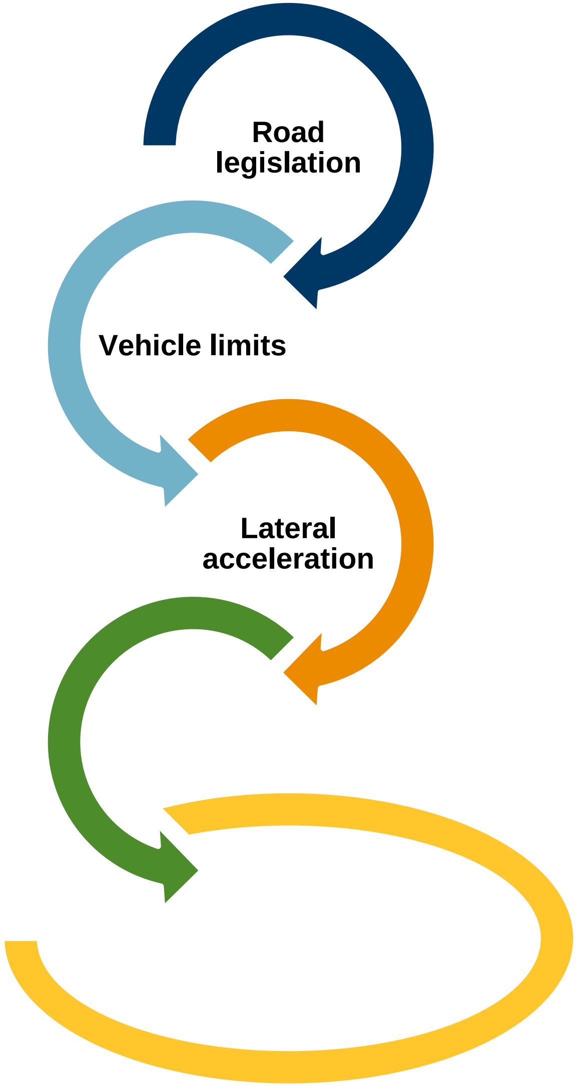




Generate data

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





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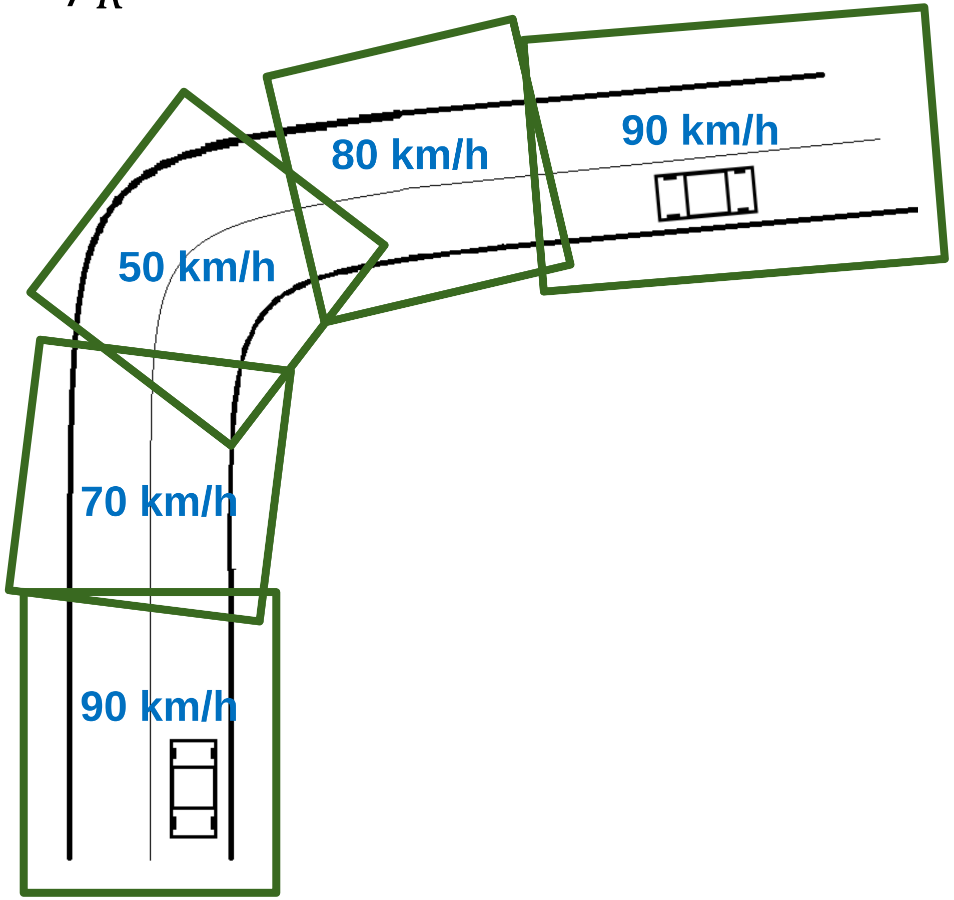
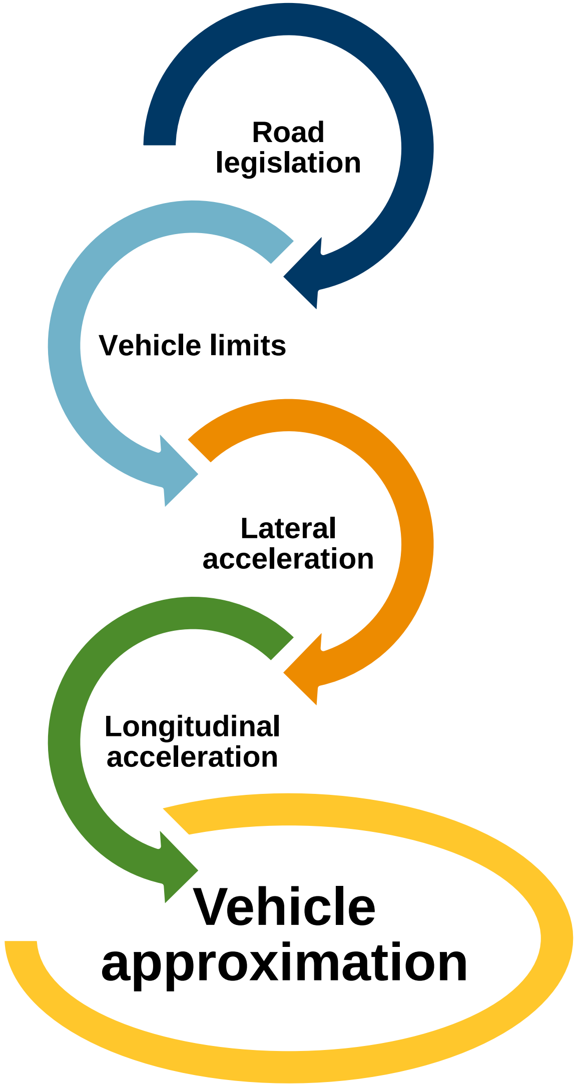
Generate data

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





Generate data

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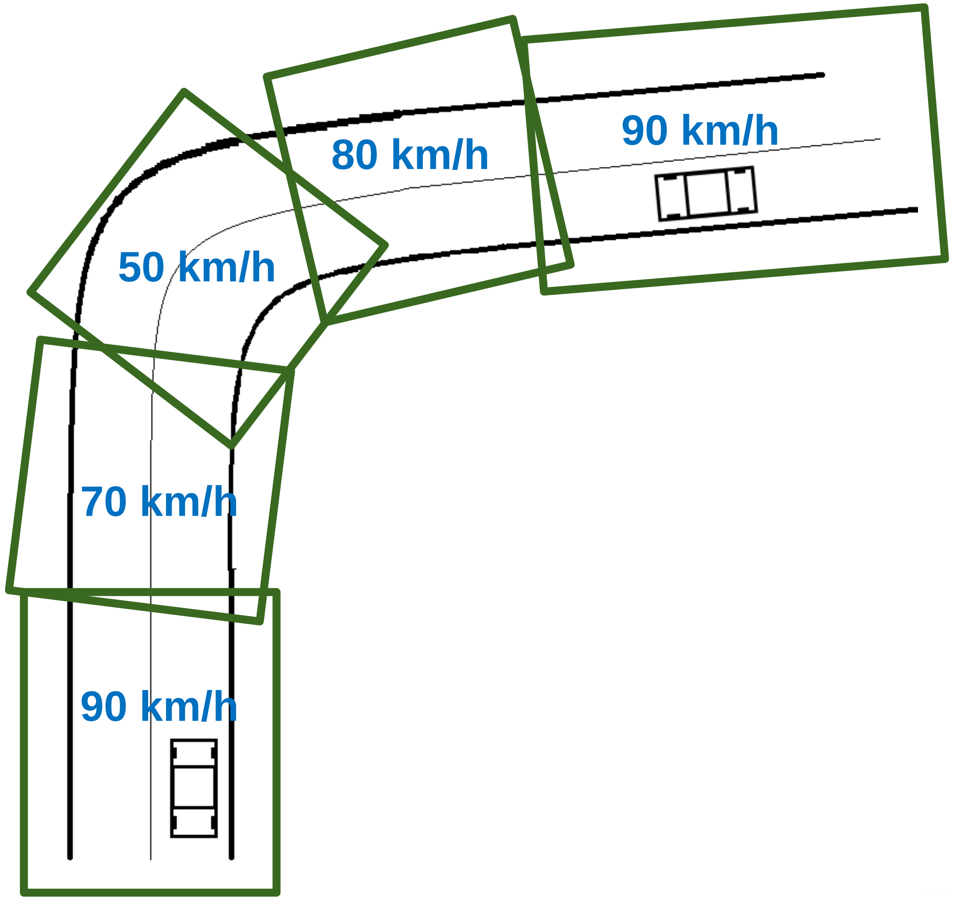
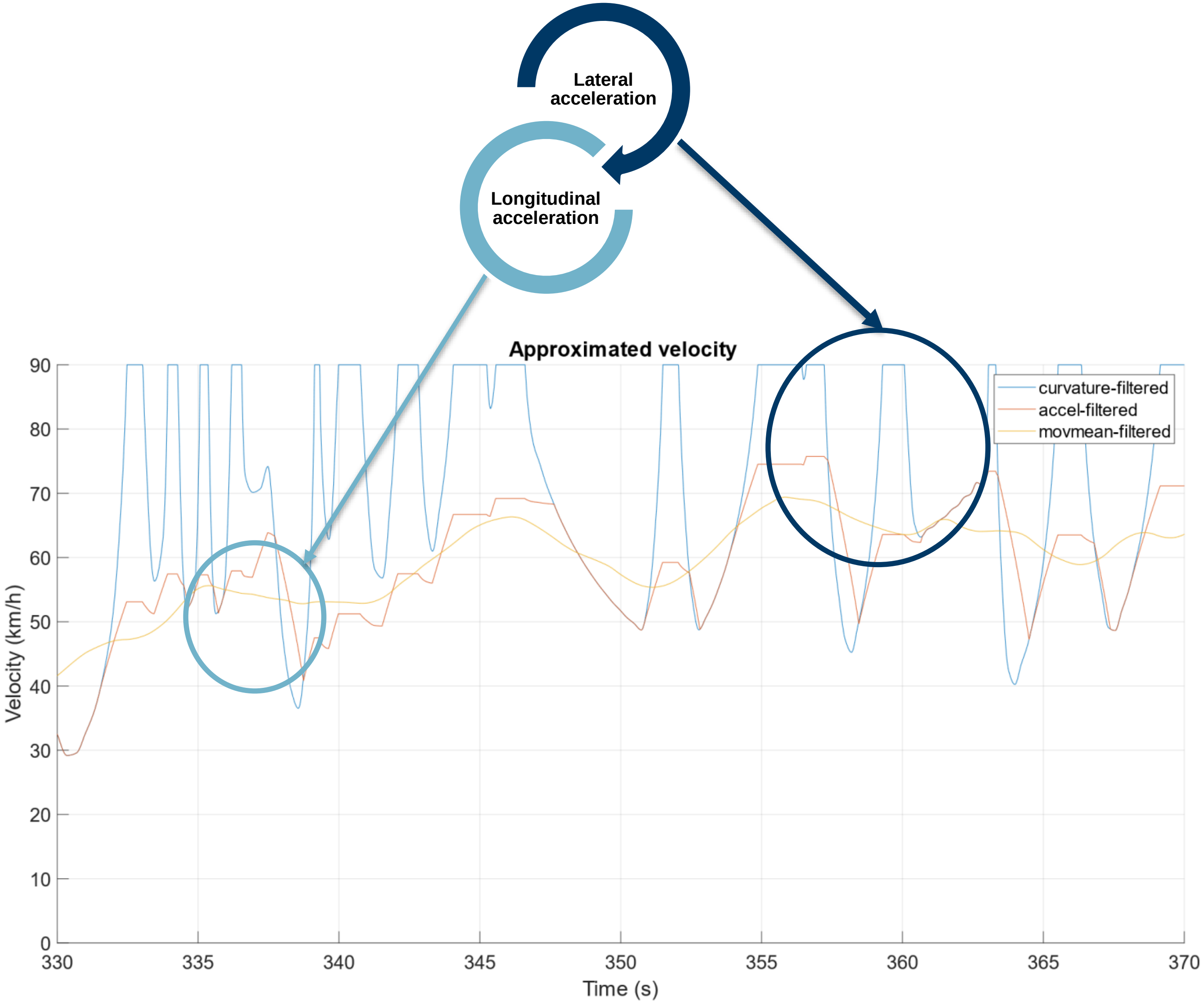
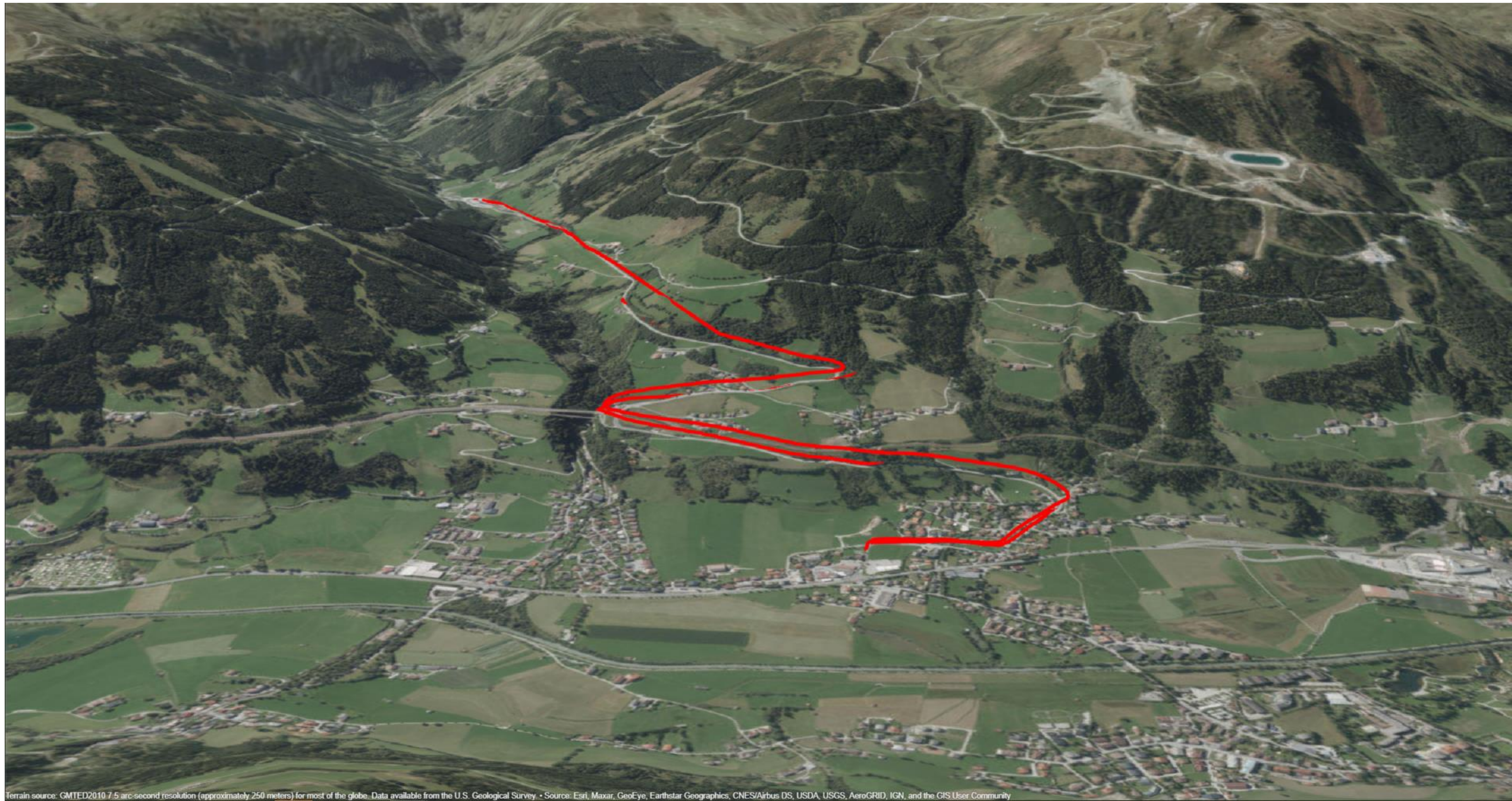




Measure by GPS

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



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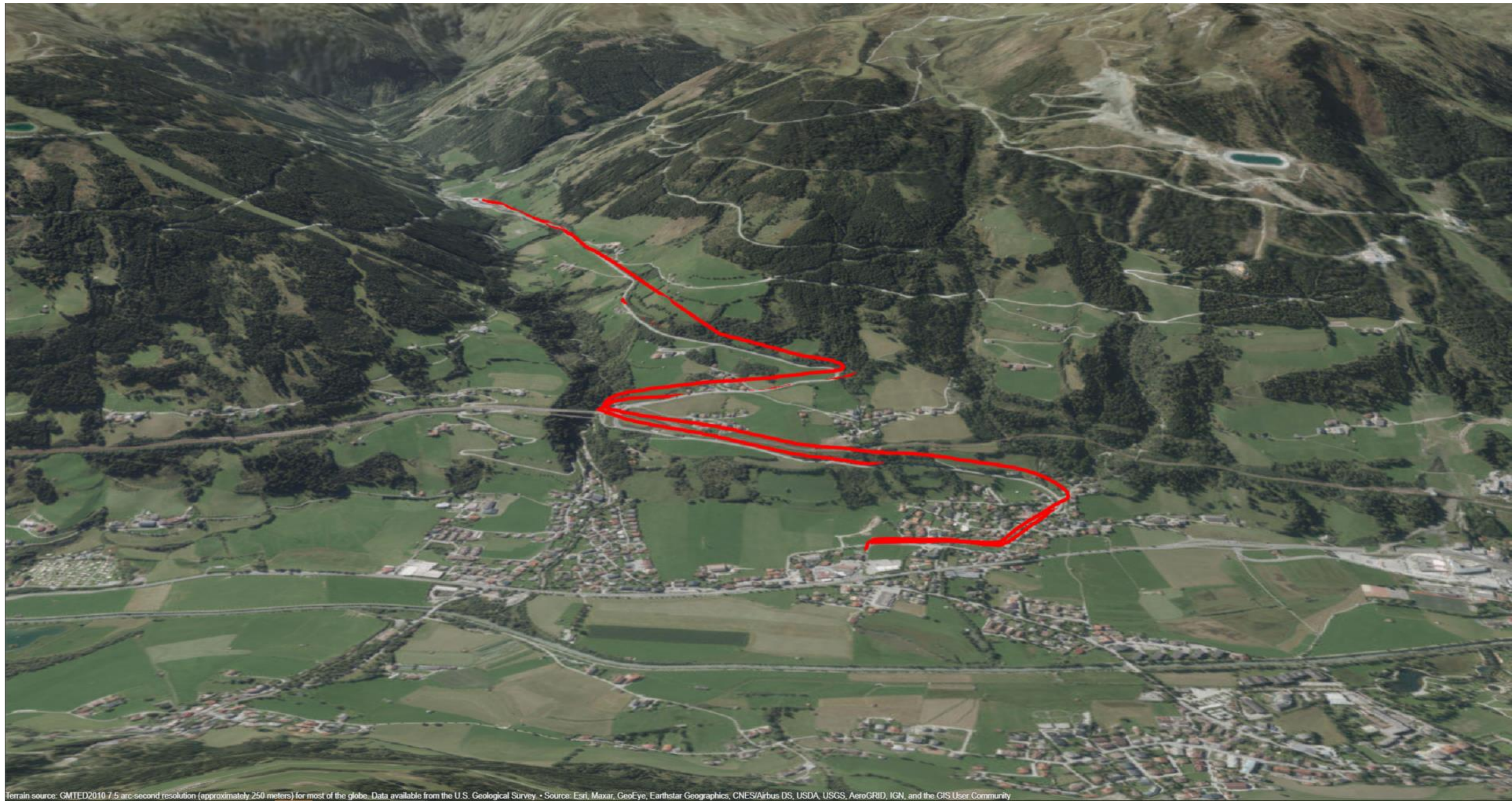
Measure by GPS

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



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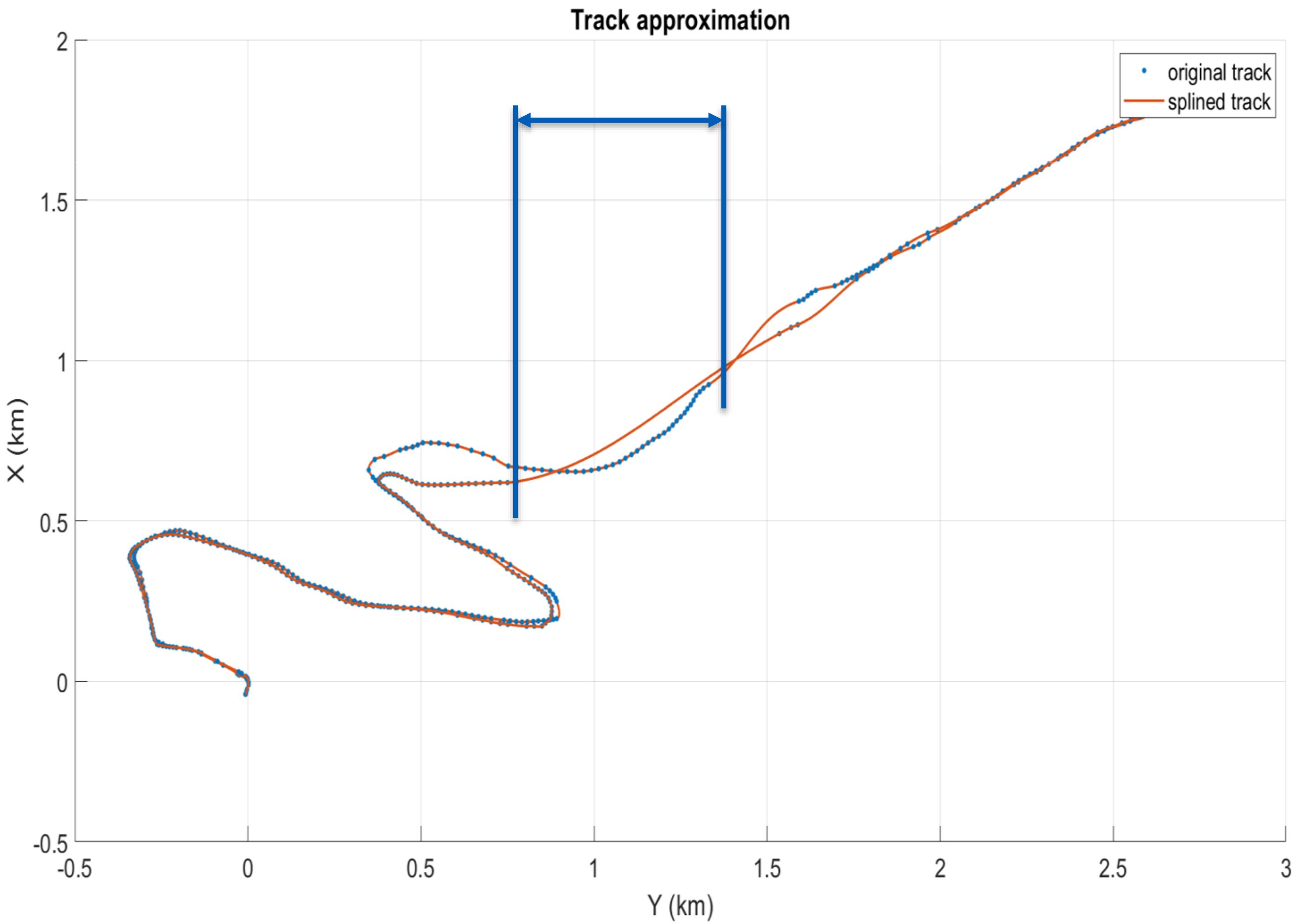
Measure by GPS

GPS data missing!



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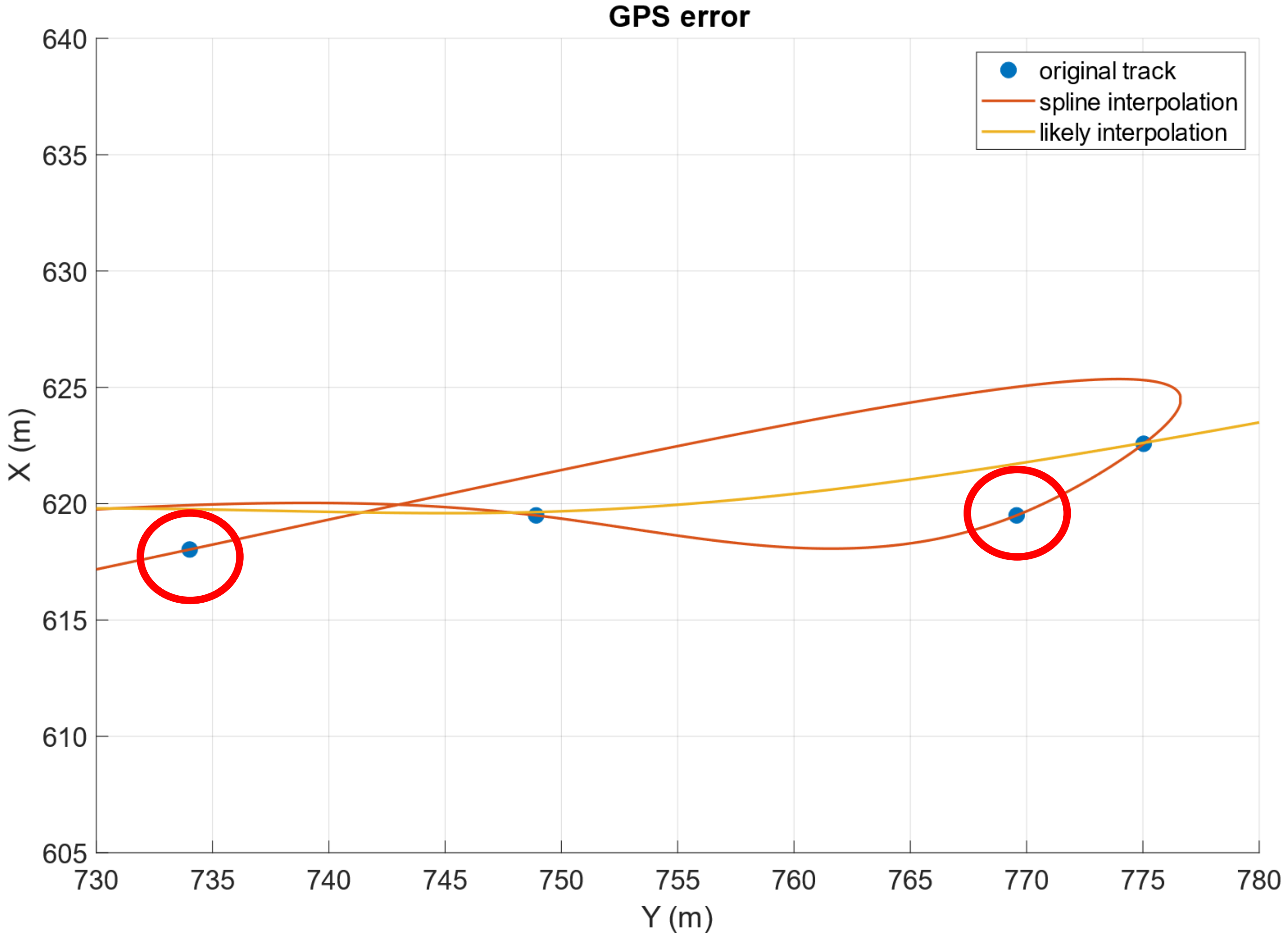
Measure by GPS

Noisy GPS data!



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Simulation in Real-World

“Real-world” simulations may have some pitfalls…

Data acquisition and preparation

↓

<u>Reference follower</u>

↓

Run simulation

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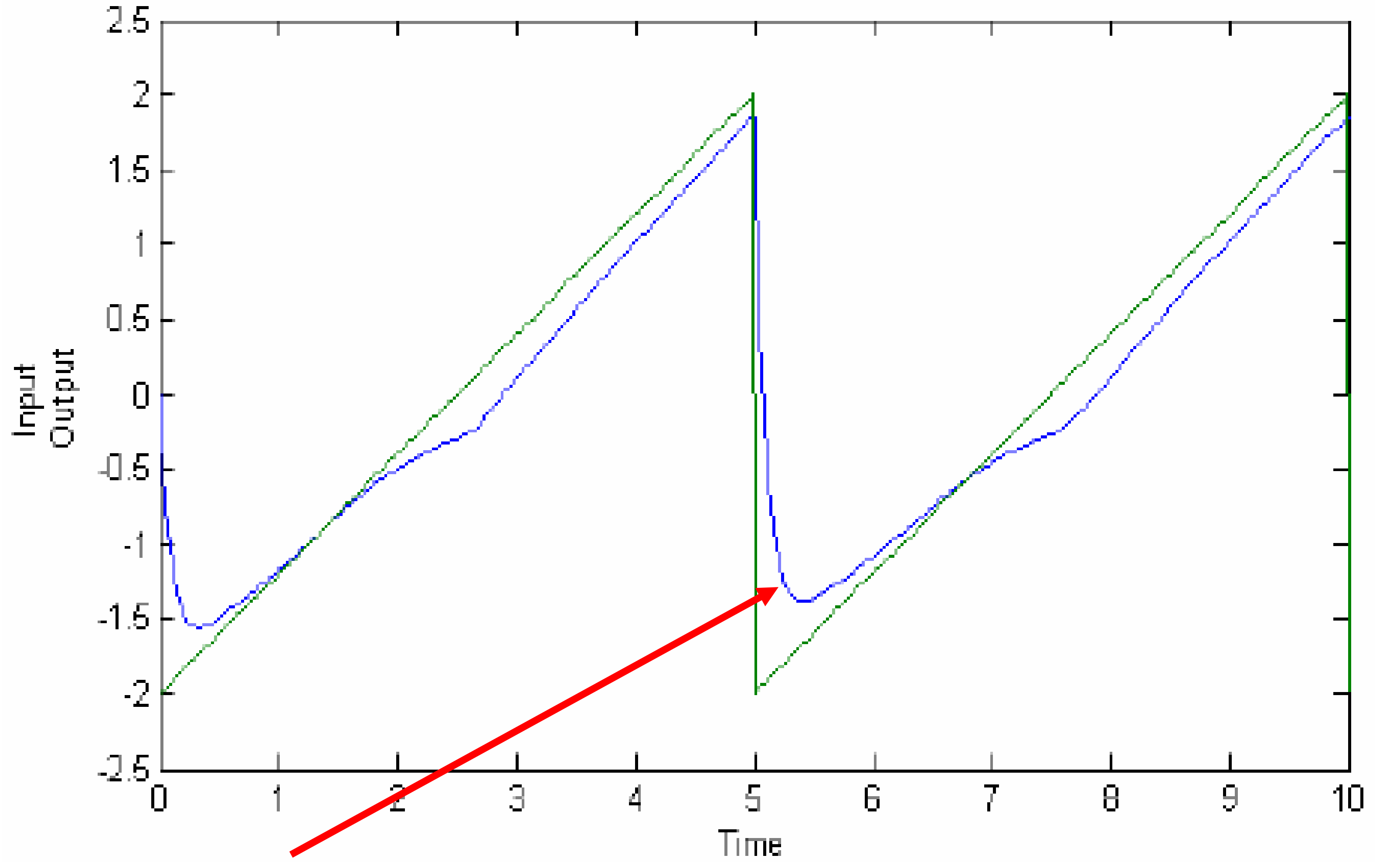
Reference follower

Curvature calculation

Look-ahead path follower

Stability and slip controllers



PID controller response

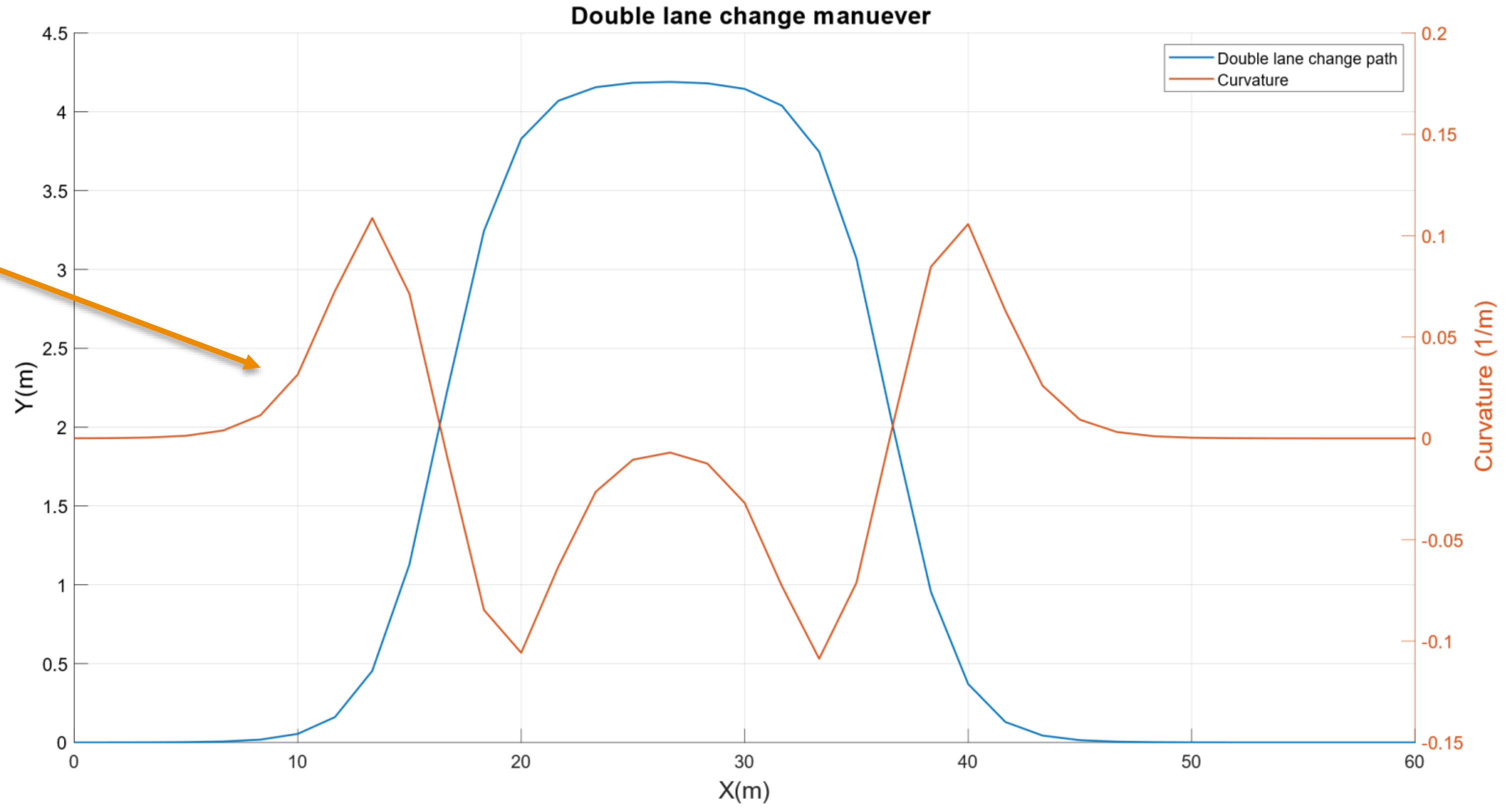
[2] Comparative Control of a Nonlinear First Order Velocity Sy

Reference follower

Curvature calculation

Look-ahead path follower

Stability and slip controller



[2] Comparative Control of a Nonlinear First Order Velocity Sy

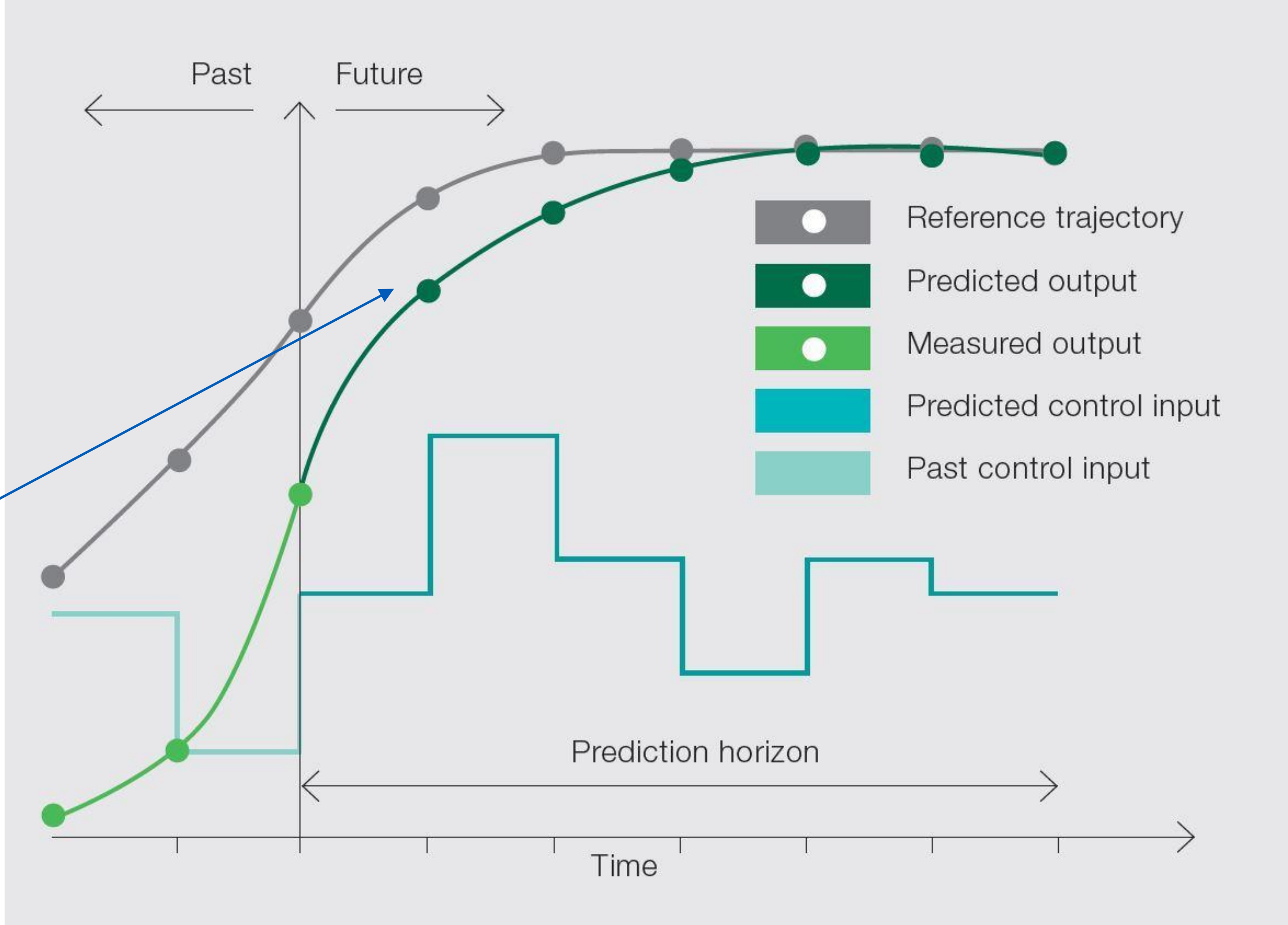
Reference follower

Curvature calculation

Look-ahead path follower

Stability and slip controllers

- Model Predictive Control (MPC)
- Stanley



[3] Model predictive control technology demystifie

Reference follower

Curvature calculation

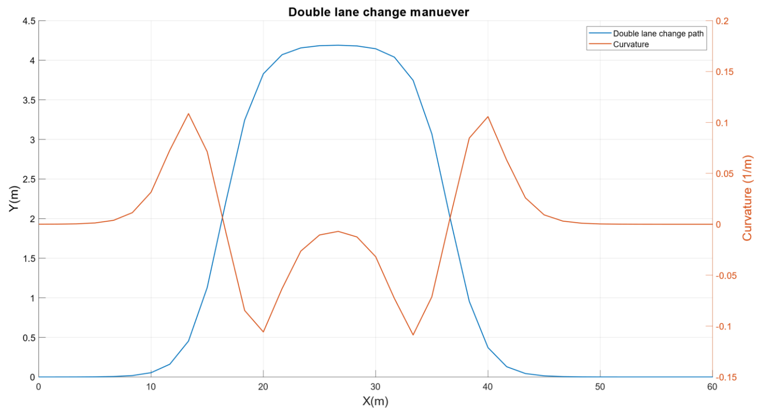
Look-ahead path follower

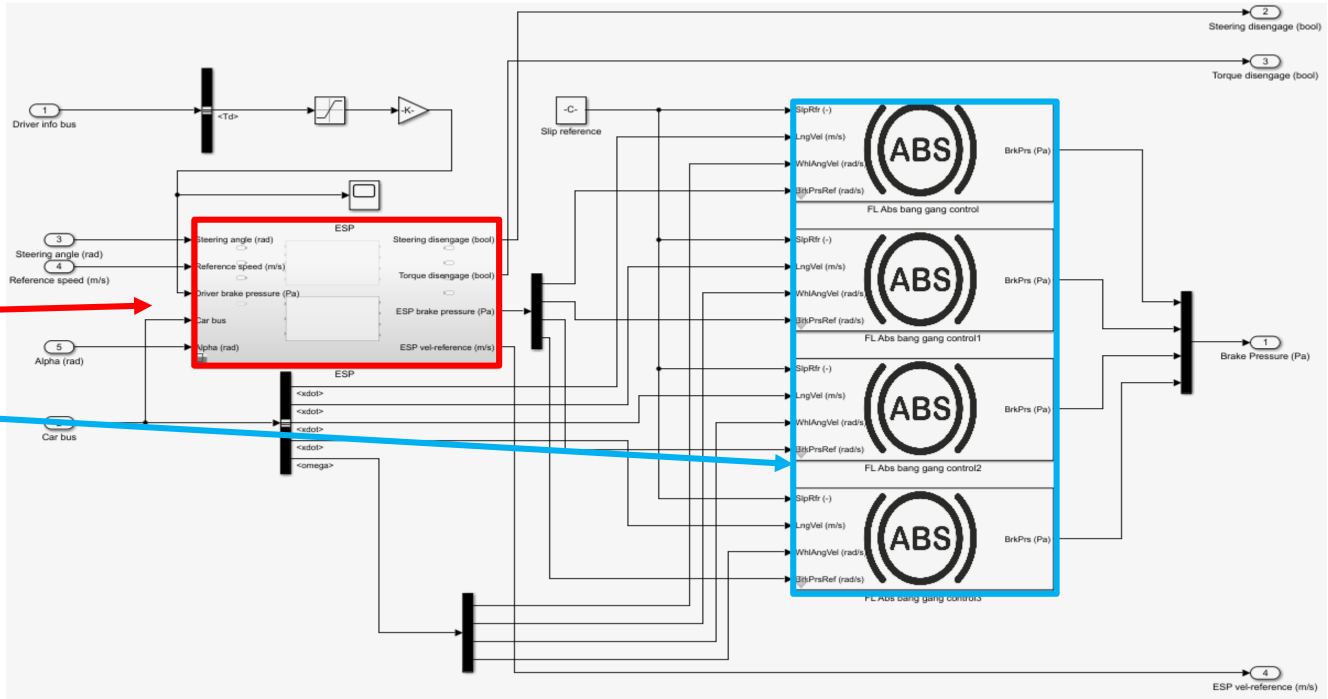
Stability and slip controllers

- MPC
- Stanley

+

- ESP
- ABS
- TSC





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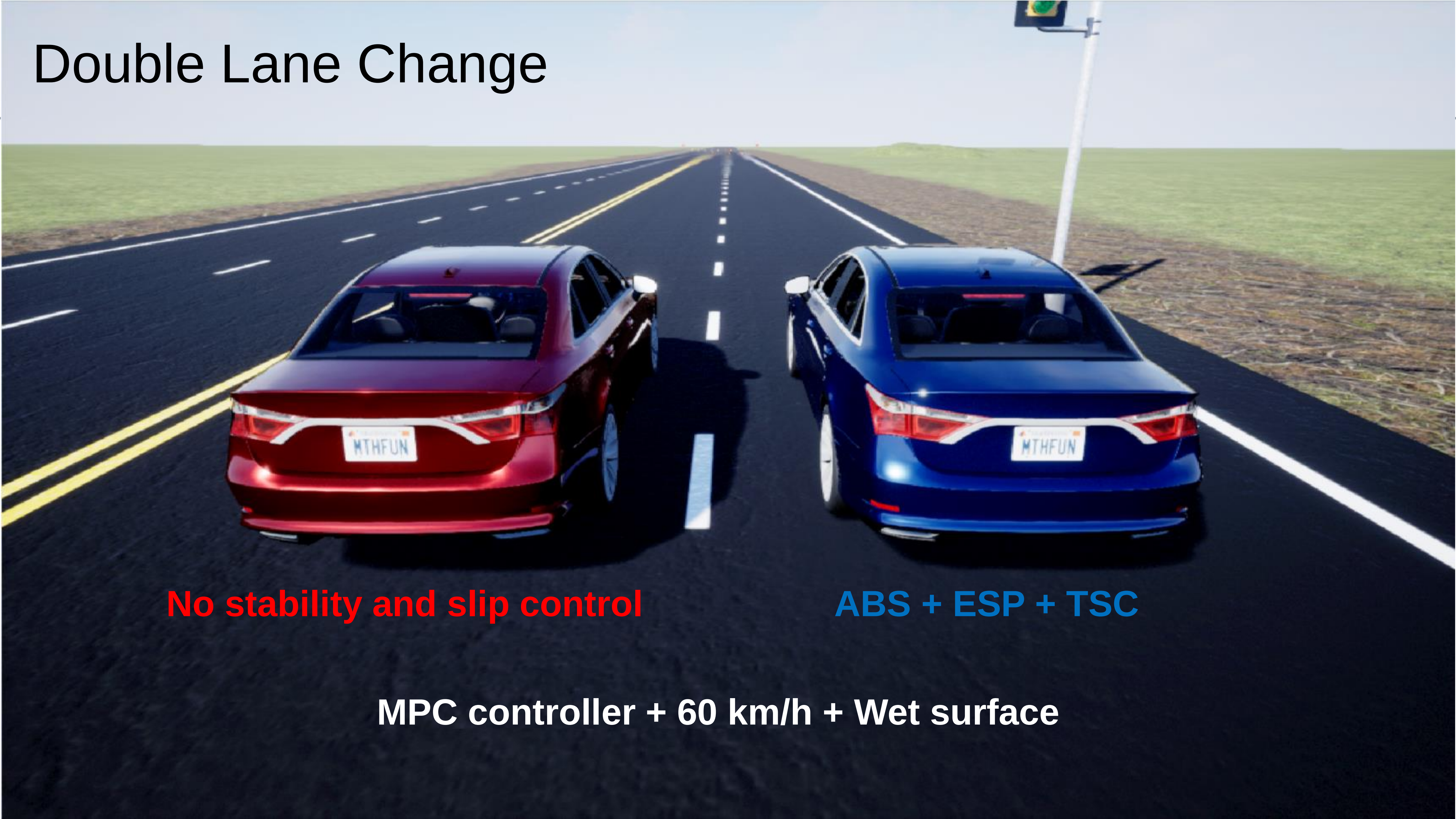
Is that all?

Not really…

Double Lane Change



#Real driving!Real drivers!

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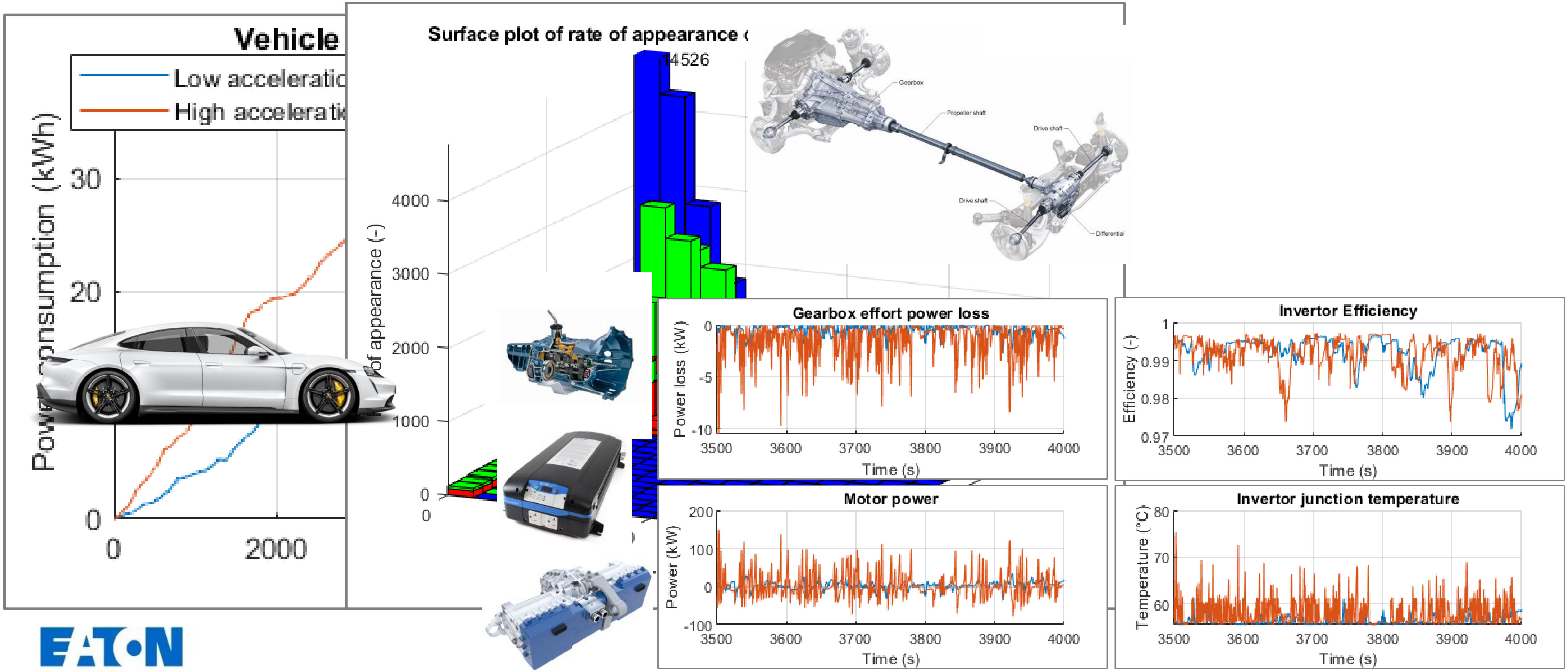
#SystemToComponent

- Asses the entire systems as well as the components performance



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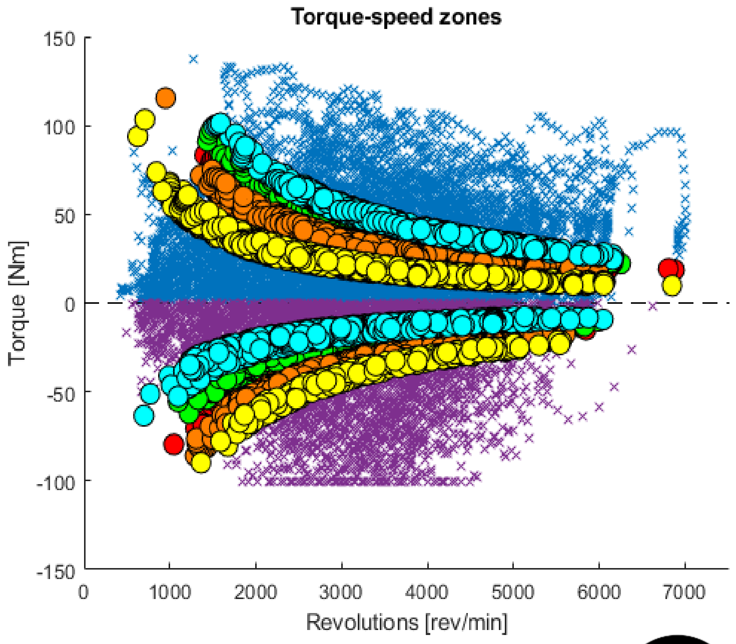
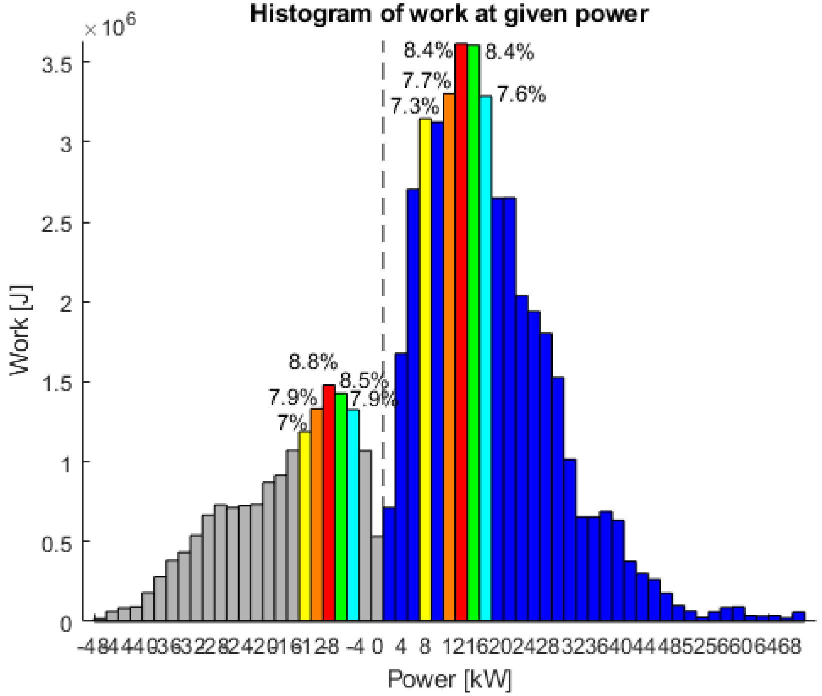
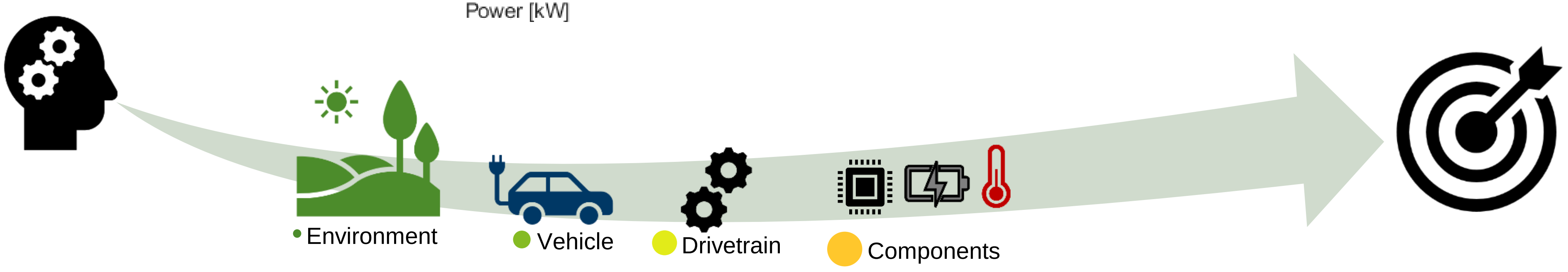
#BoundaryConditions

- 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%**



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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 !

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Reference

- [1] Coordinate Systems
  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
  https://www.researchgate.net/publication/251843836_Comparative_Control_of_a_Nonlinear_First_Order_Velocity_System_by_a_Neural_Network_NARMA-L2_Method
- [3] Model predictive control technology demystified
  https://new.abb.com/control-systems/features/model-predictive-control-mpc

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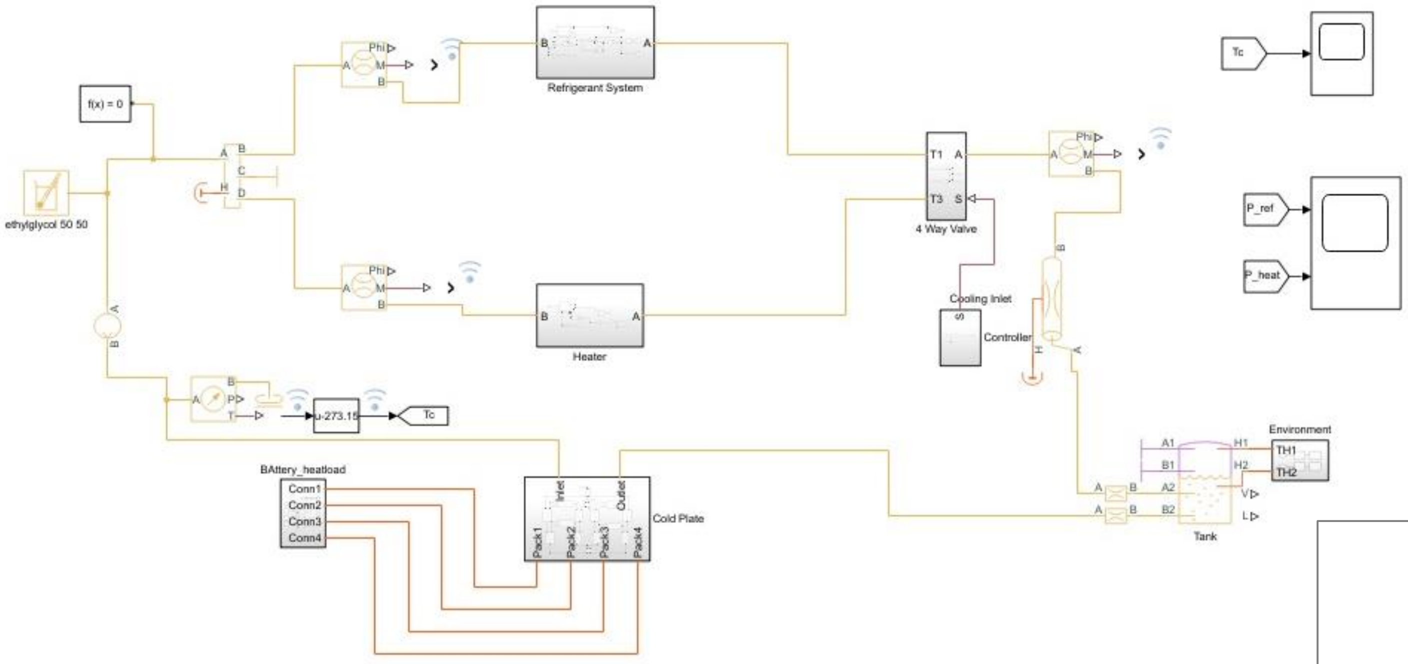
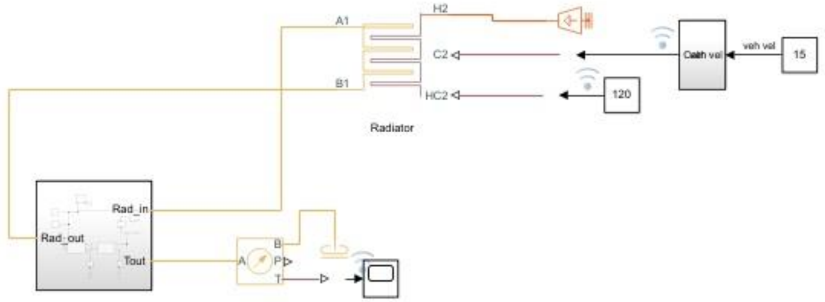
#StayCool



Battery thermal management



Powertrain cooling