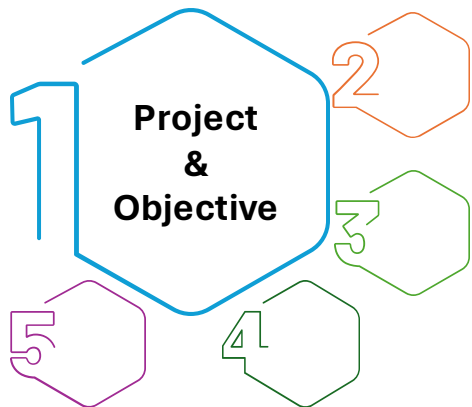




Driving Innovation: Leveraging VI-grade Simulator for Autonomous Perception and Control Optimization



Alberto Lucchini
Tecnologist@PoliMI

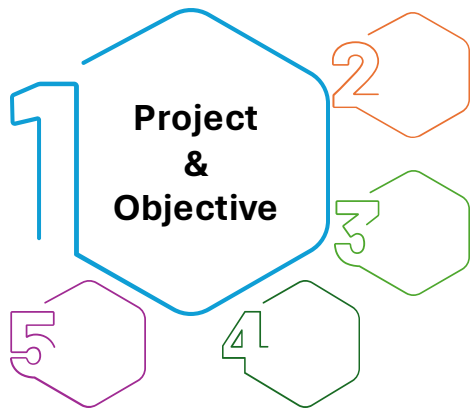


1000 MAD



POLITECNICO
MILANO 1863





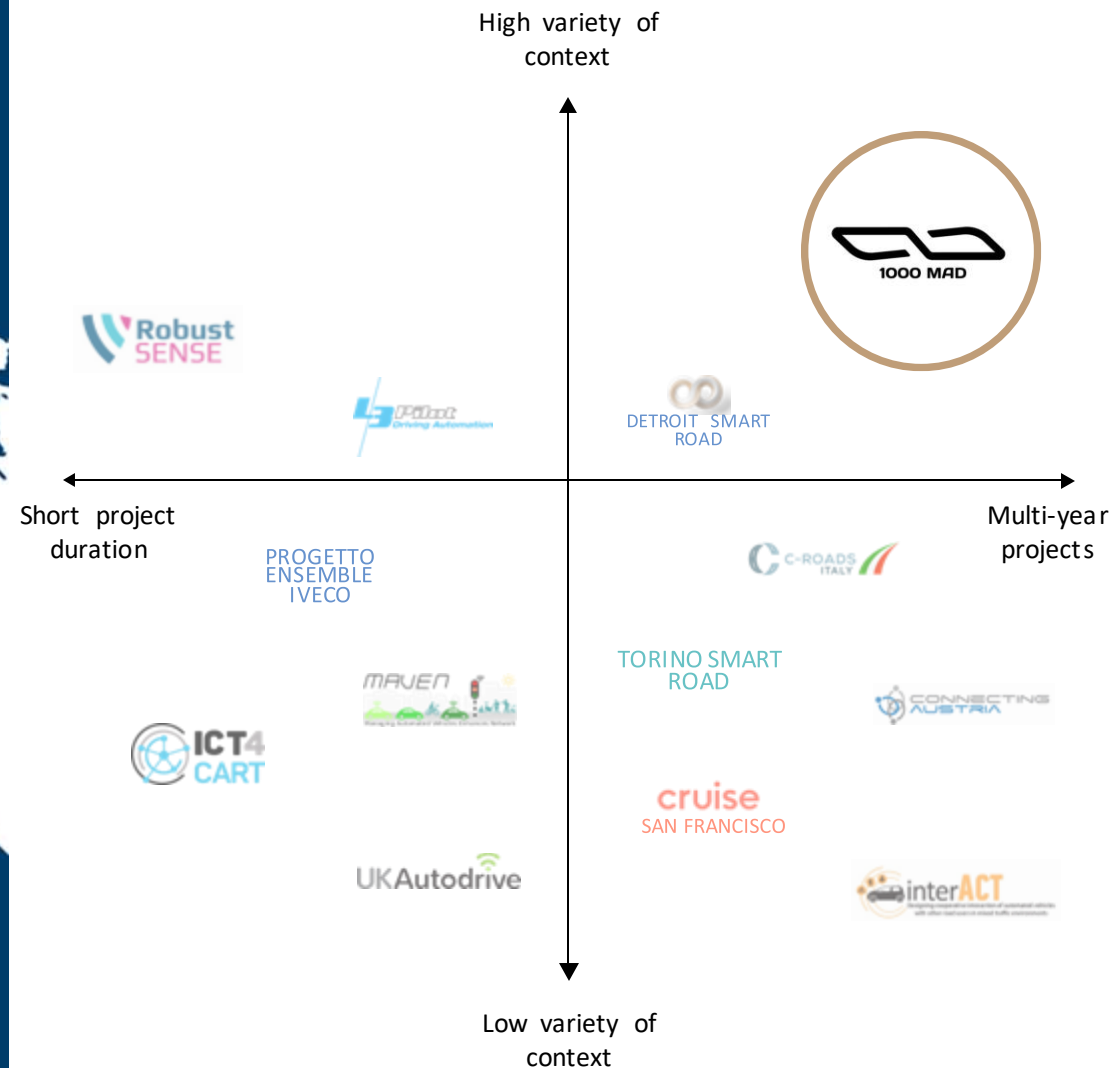
2023 1000Miglia edition

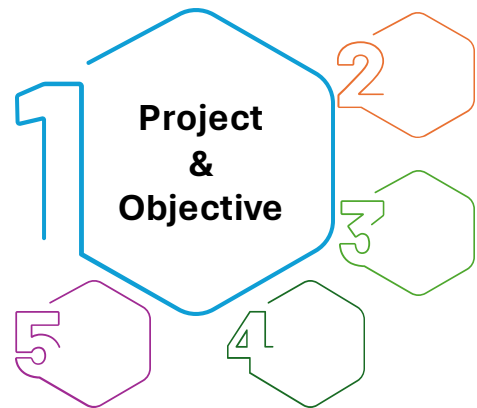


1000Miglia



2023

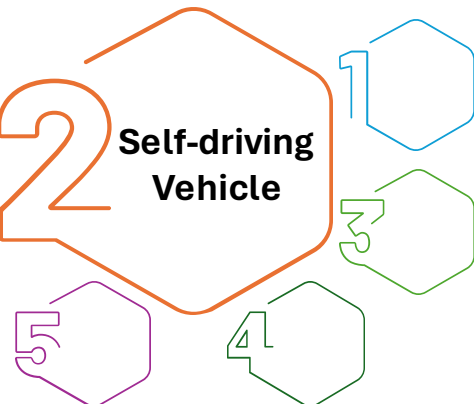




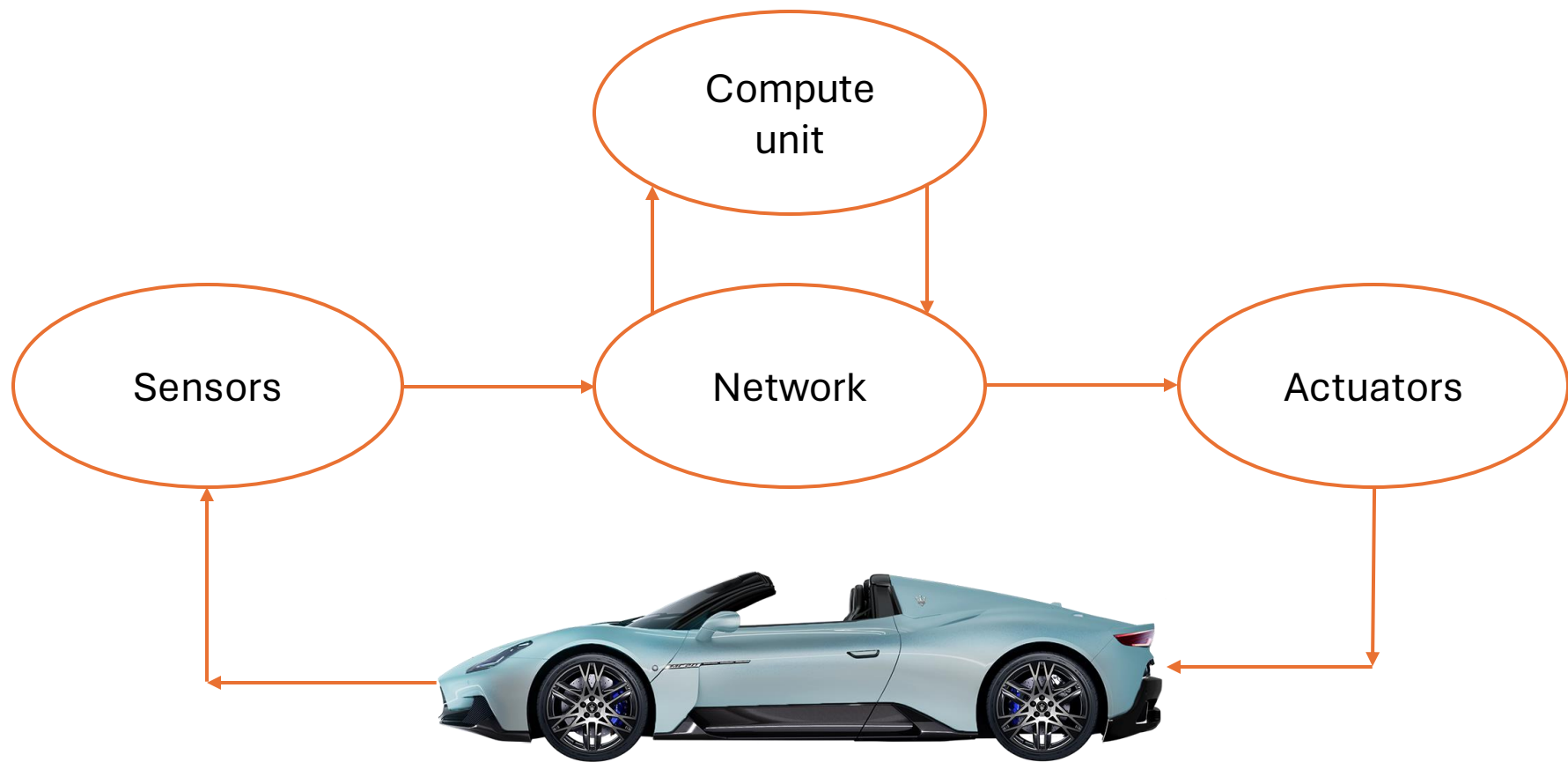
2023 1000Miglia edition

Heritage

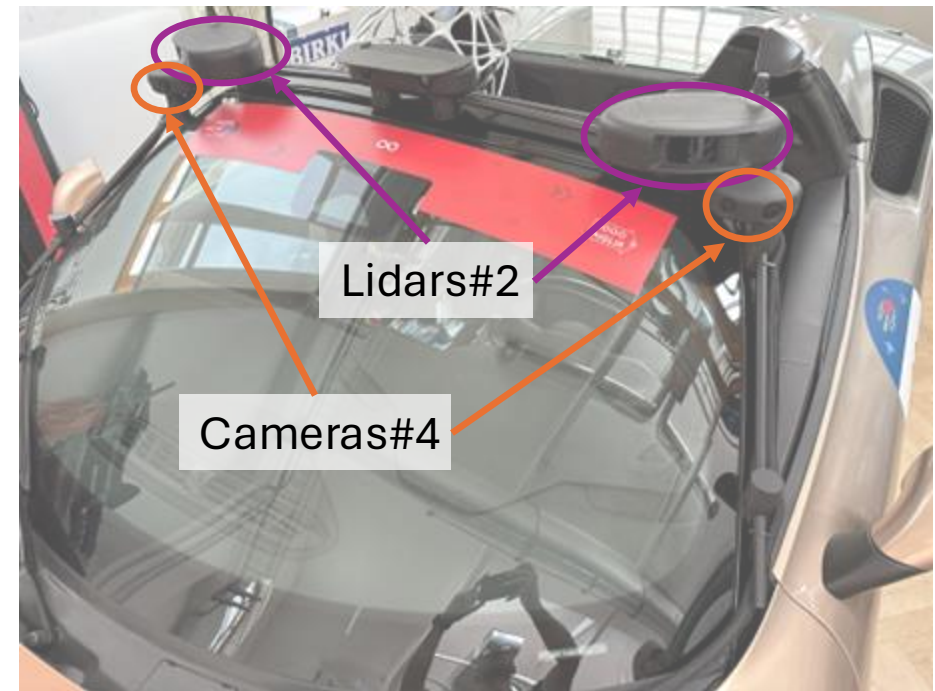
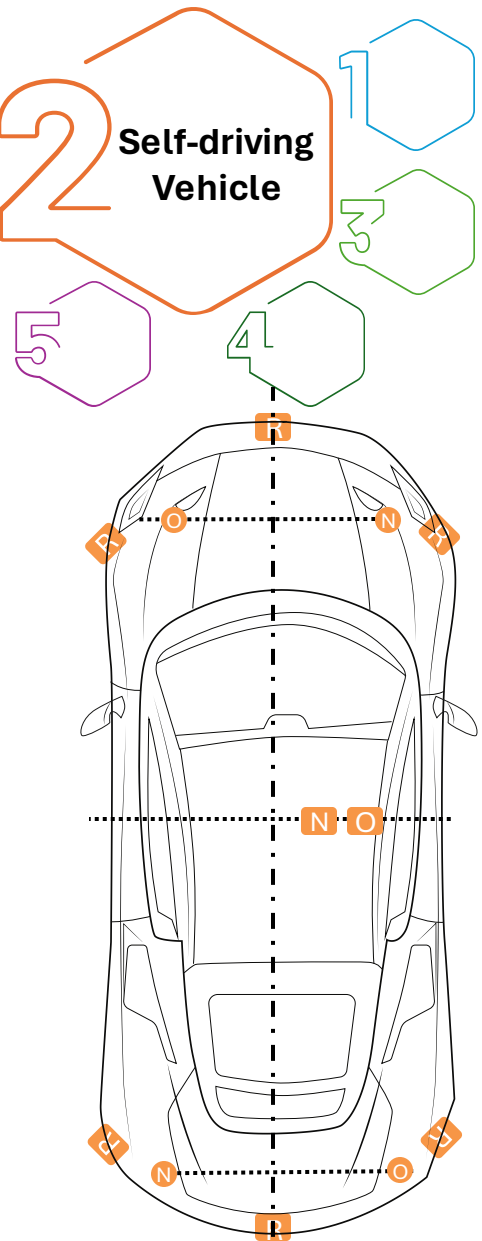




Vehicle Layout



Vehicle Sensors



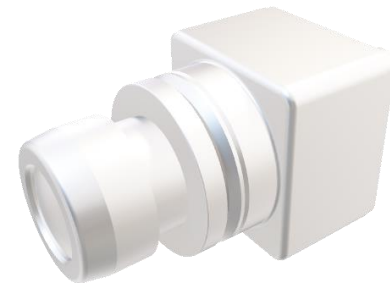
Novatel
PwrPak7D



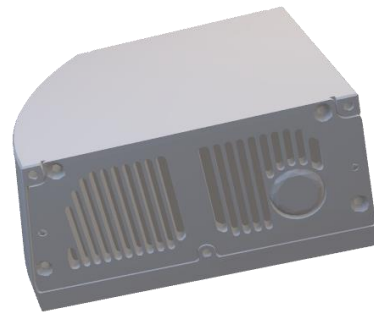
OXTS



CES
ARS450DI



CES
FSC230

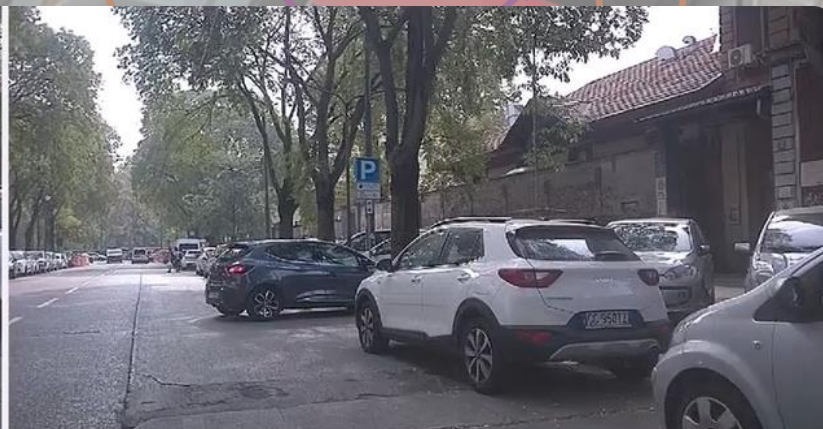


Robosense
M1

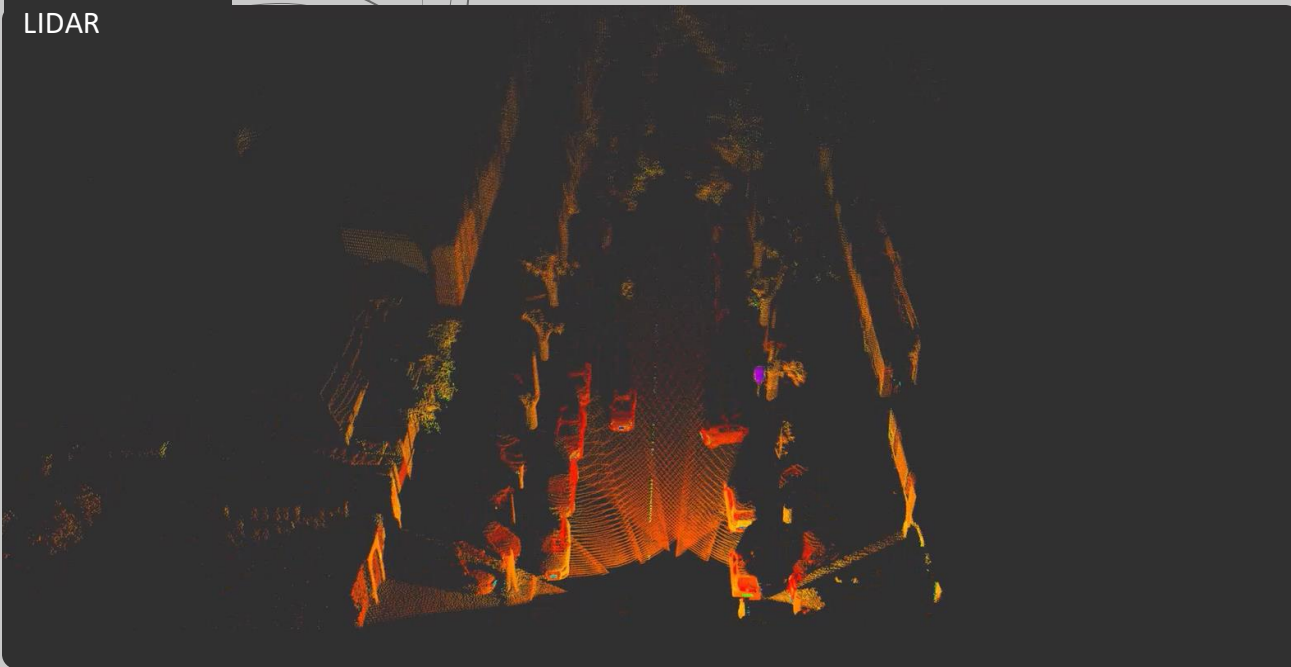
Vehicle

Self-driving
Vehicle

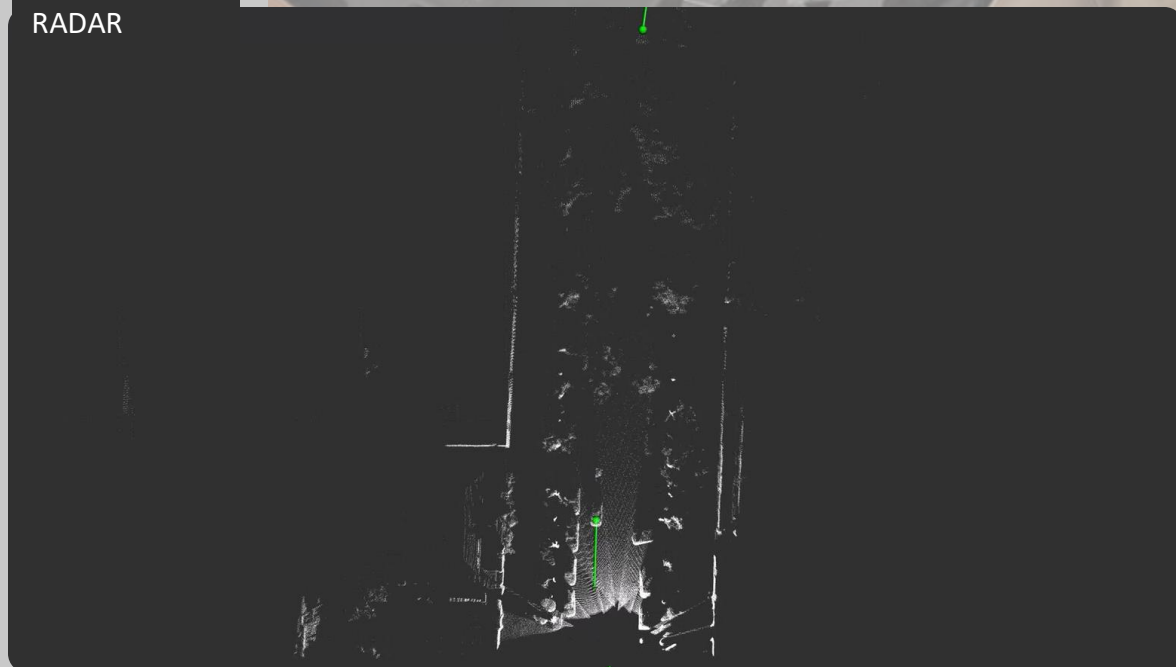
TELECAMERE

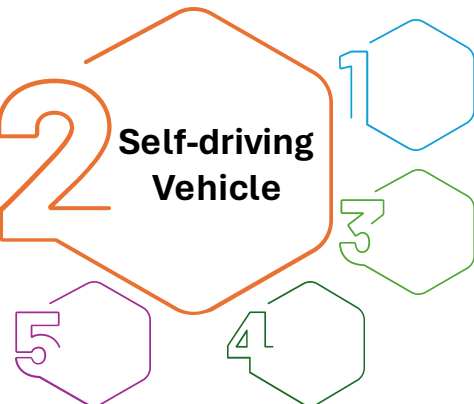


LIDAR

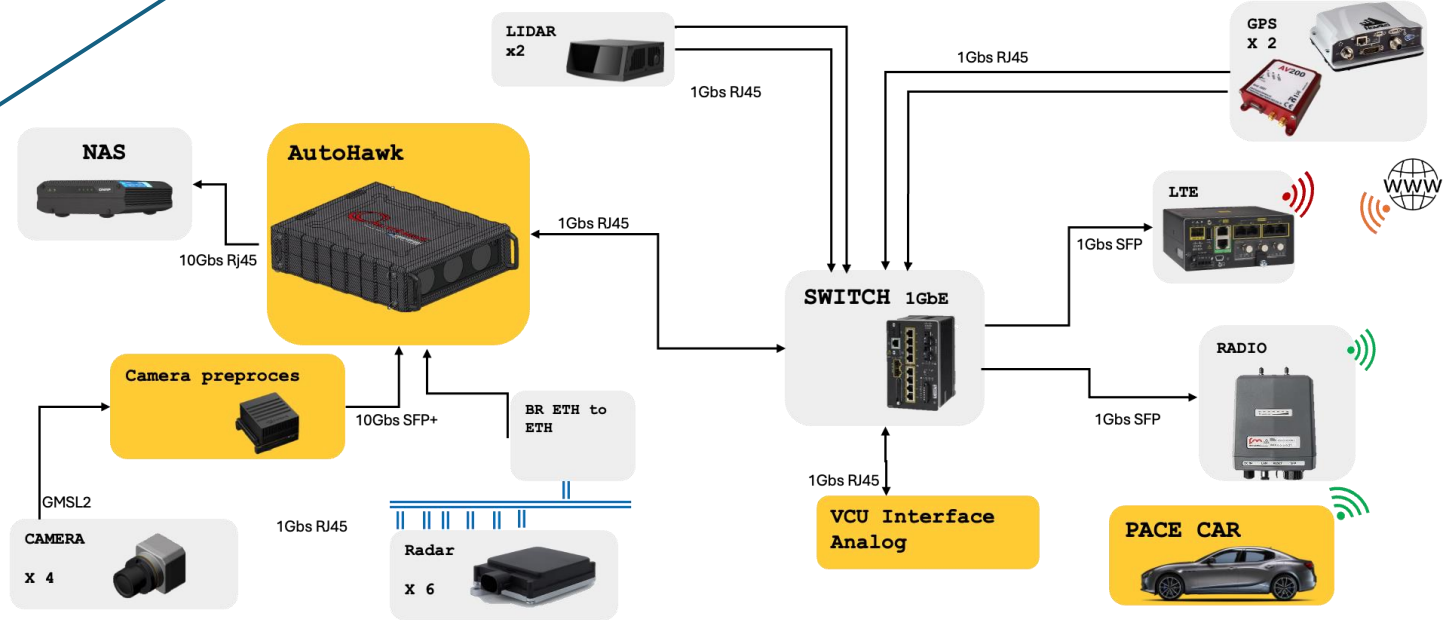
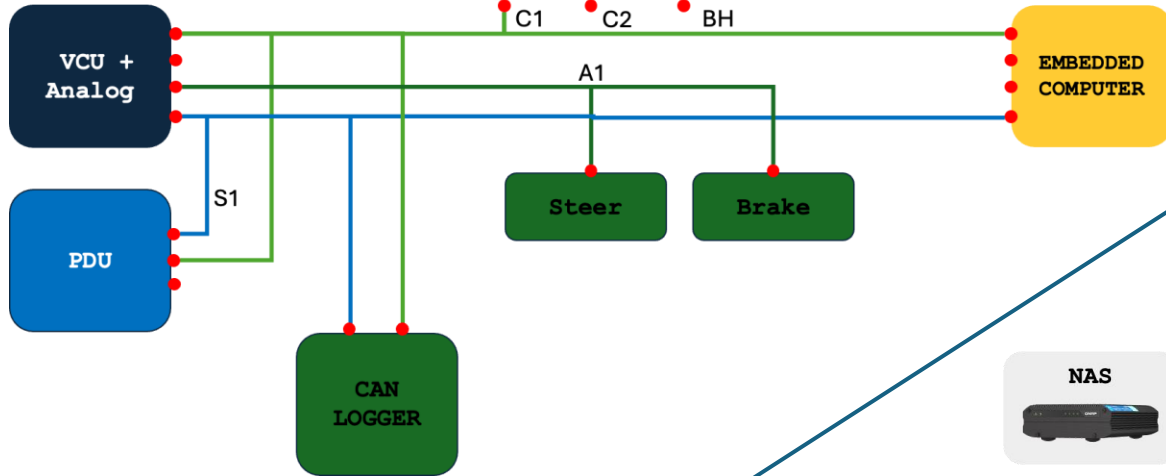


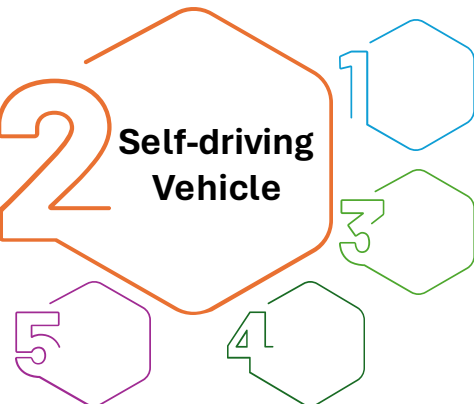
RADAR



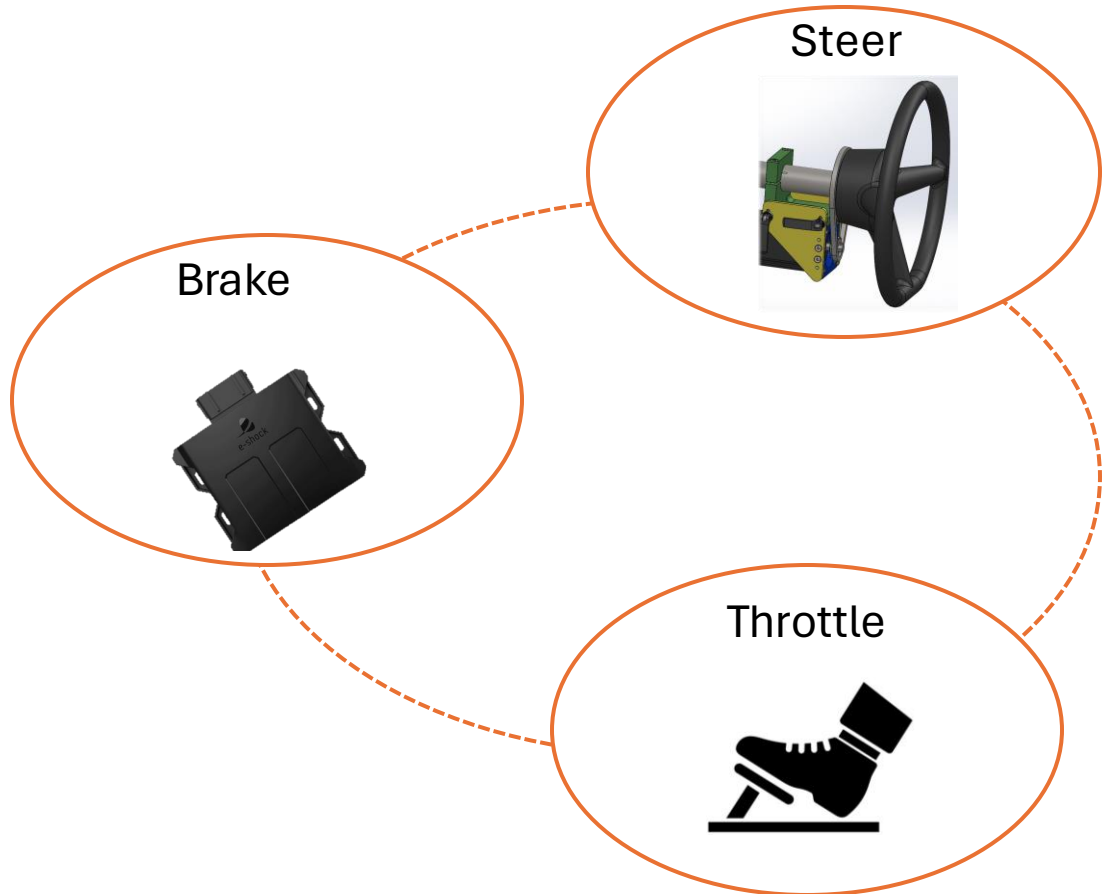


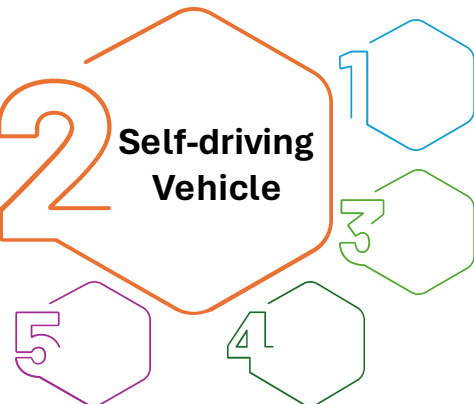
Vehicle Network





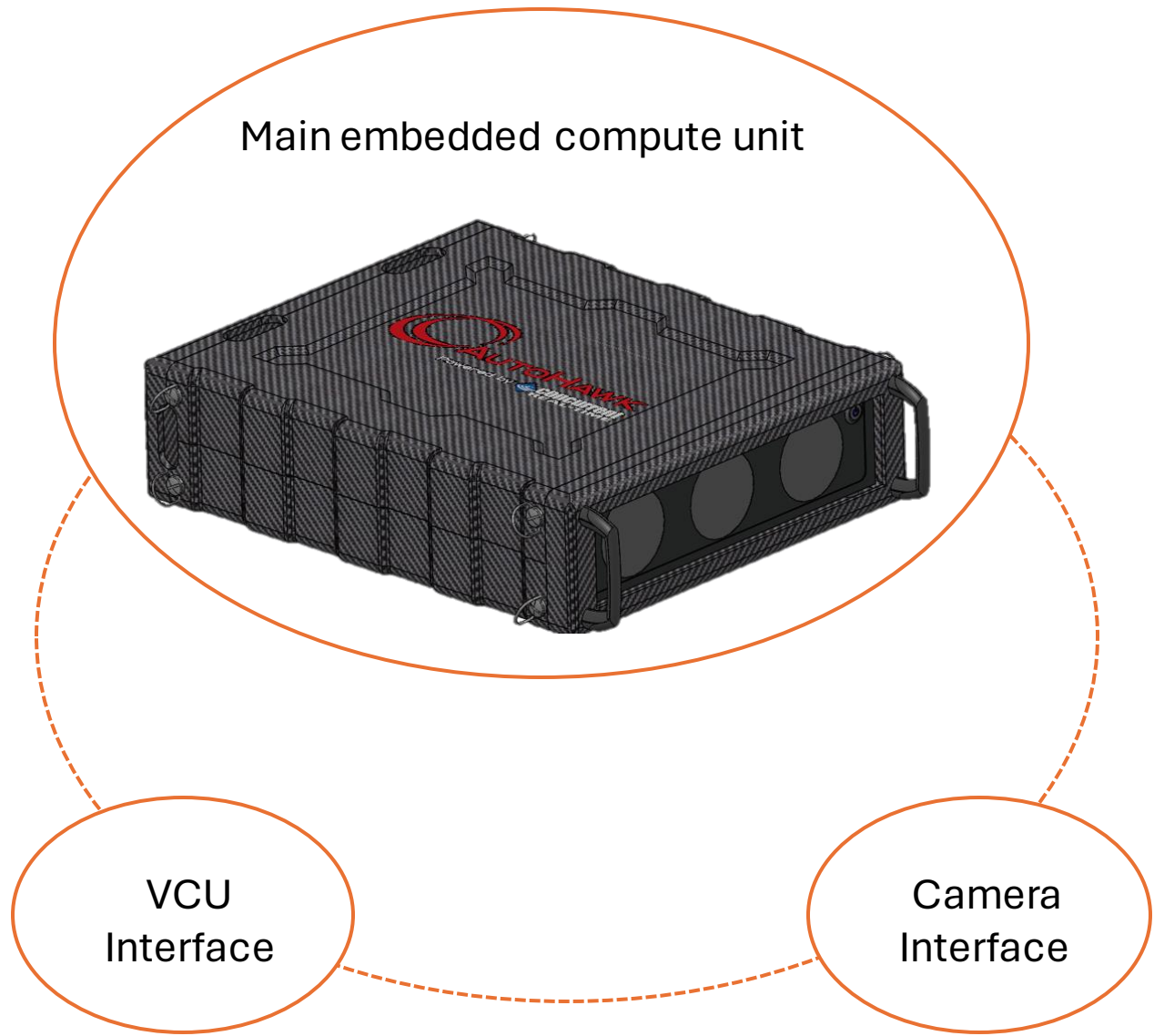
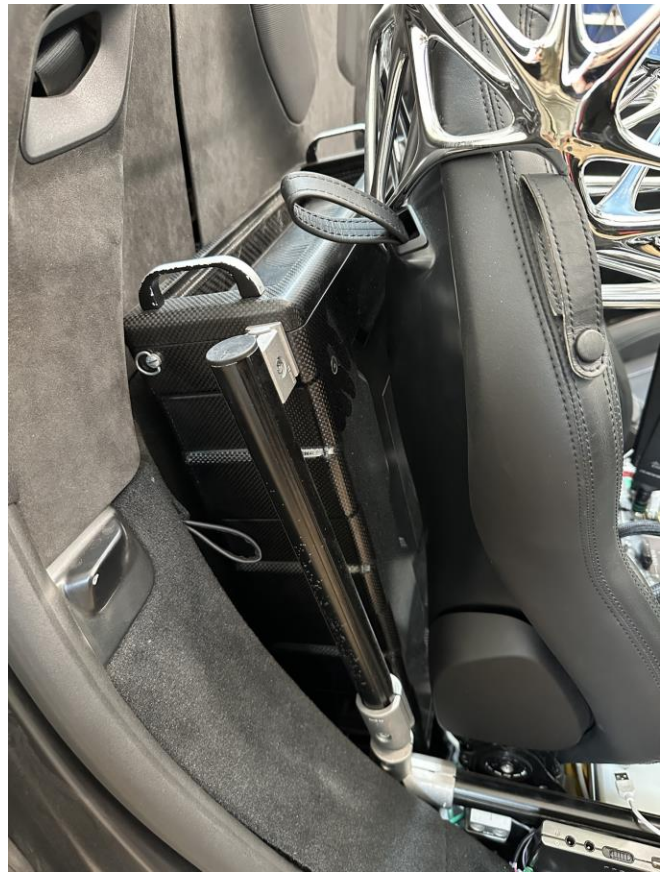
Vehicle Actuators

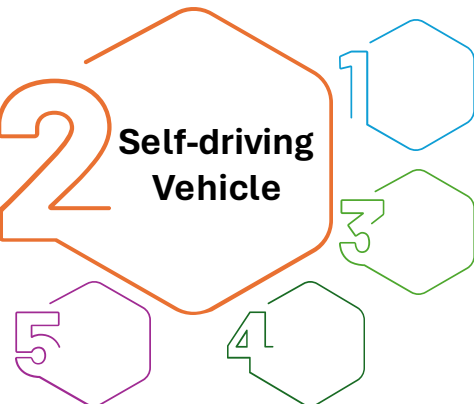




Vehicle

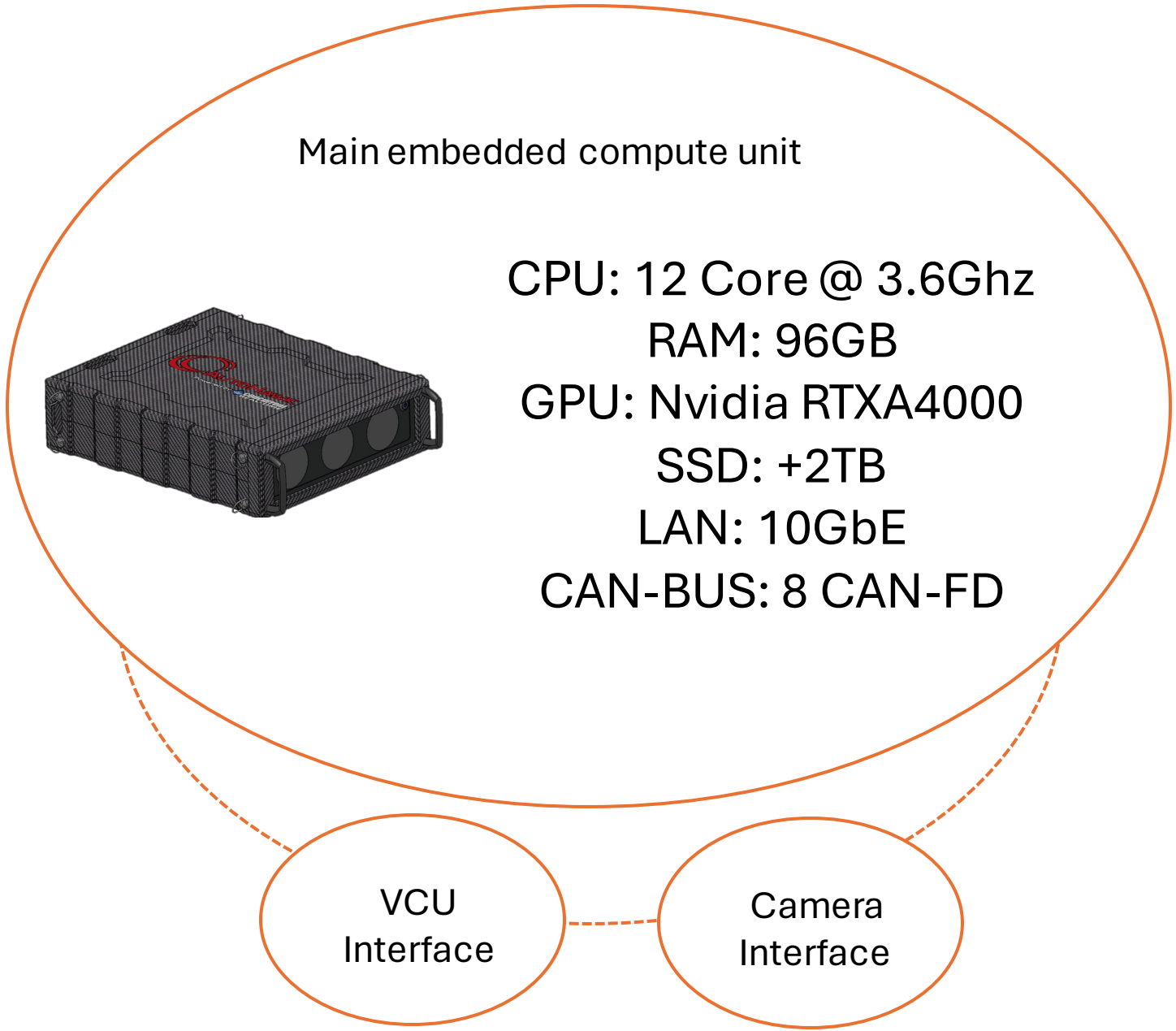
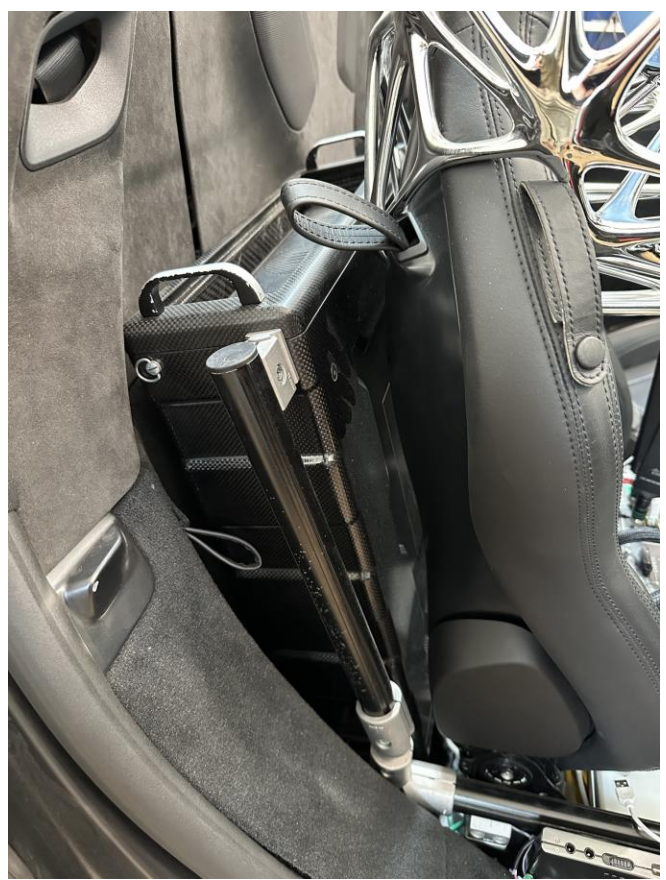
Compute units

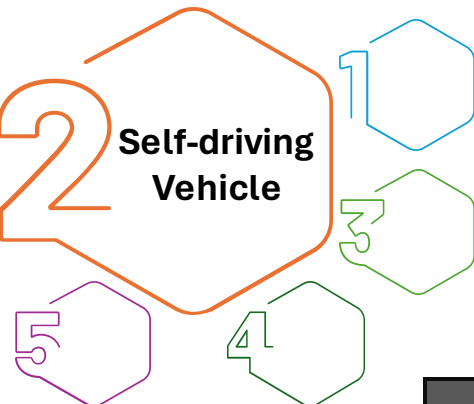




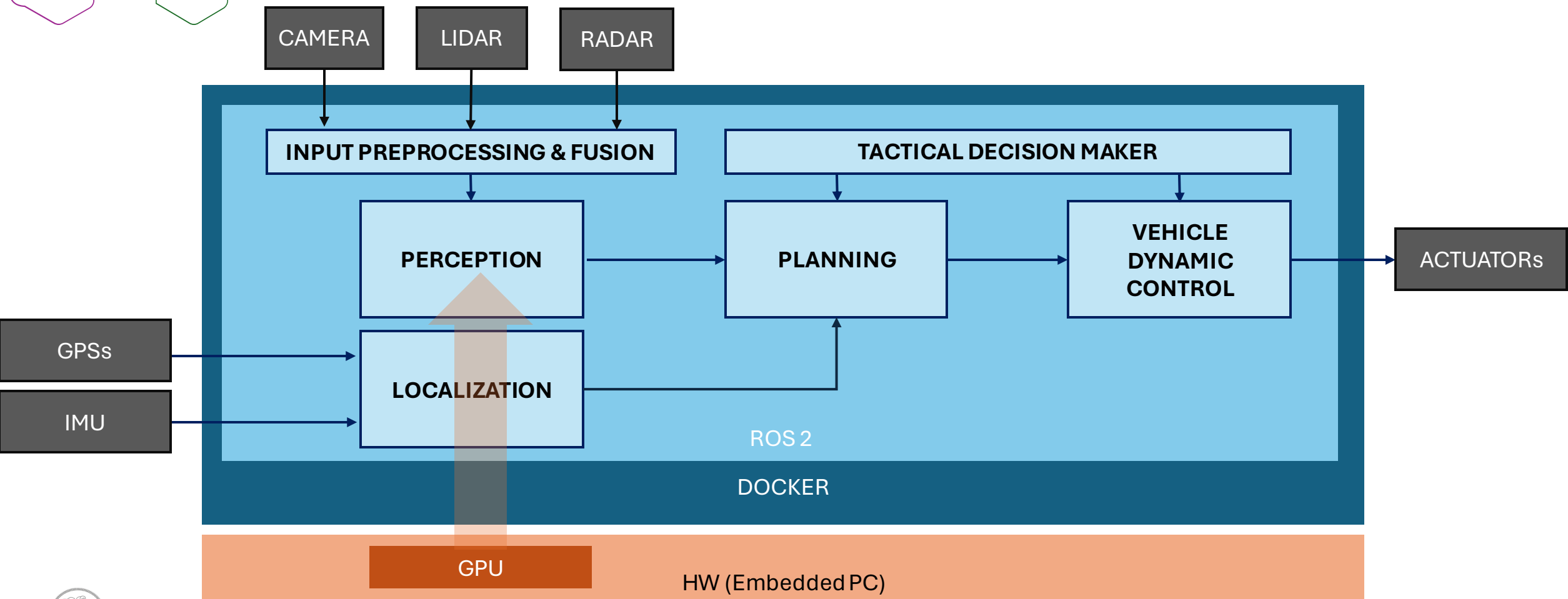
Vehicle

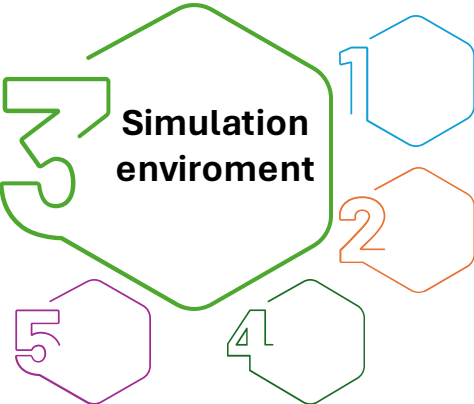
Compute units





Vehicle SW Stack

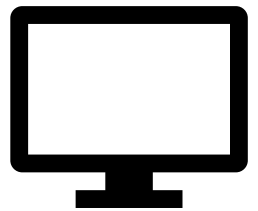




Simulator

Layout

Human driver



Visual render



Main embedded Computer

Self-driving complete stack

Driver request

VI-DriveSim

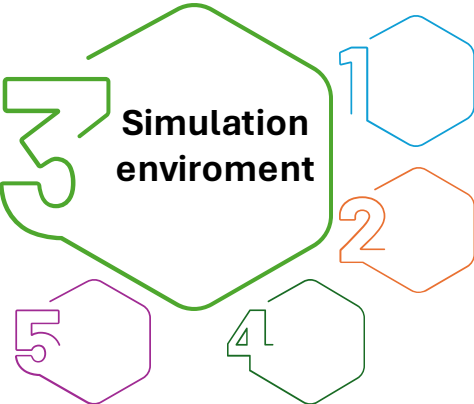


Car state

VI-WorldSim

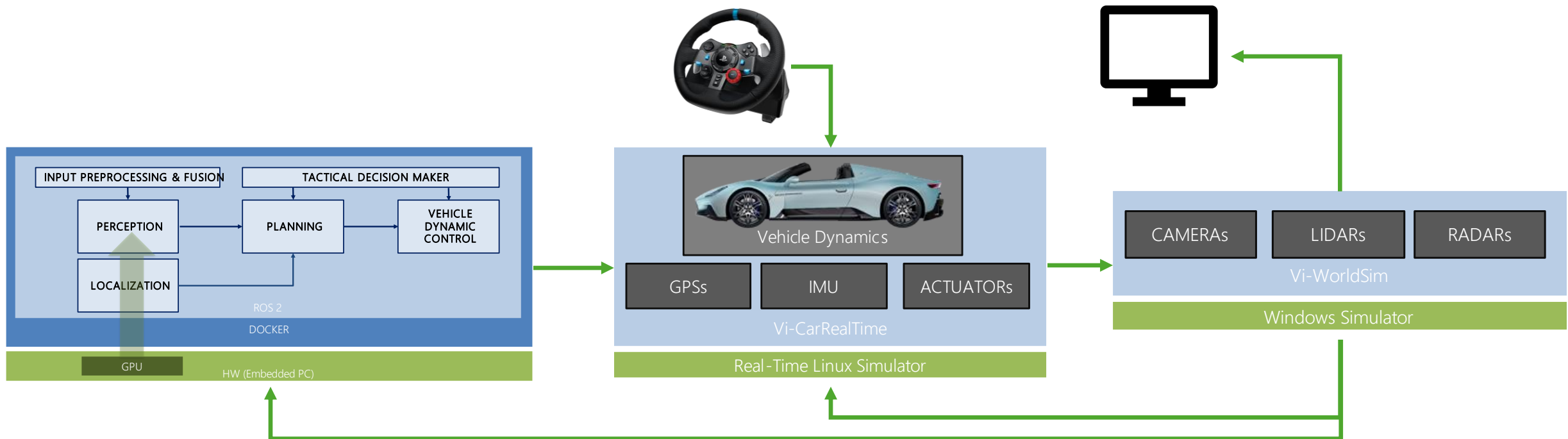


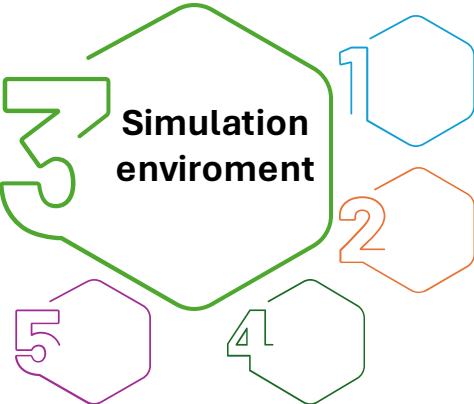
Environmental data



Simulator

SW stack





Simulator

Past experience

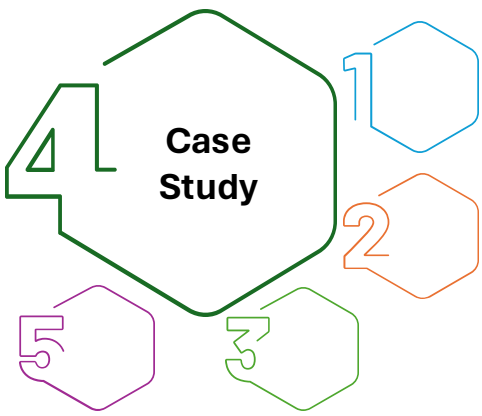
DM70/2018
Certified experience



9000 km of simulation

Full self
driving stack
ACTIVE



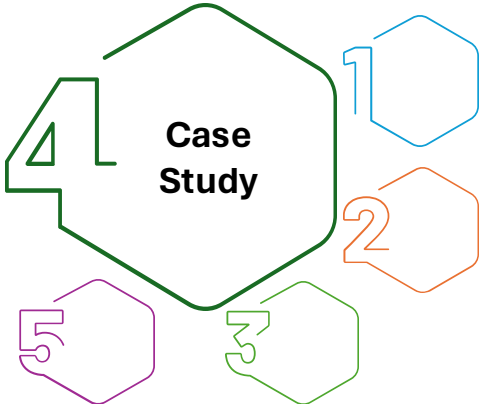


Objective

Leveraging VI-grade Simulator for Autonomous Perception and Control Optimization

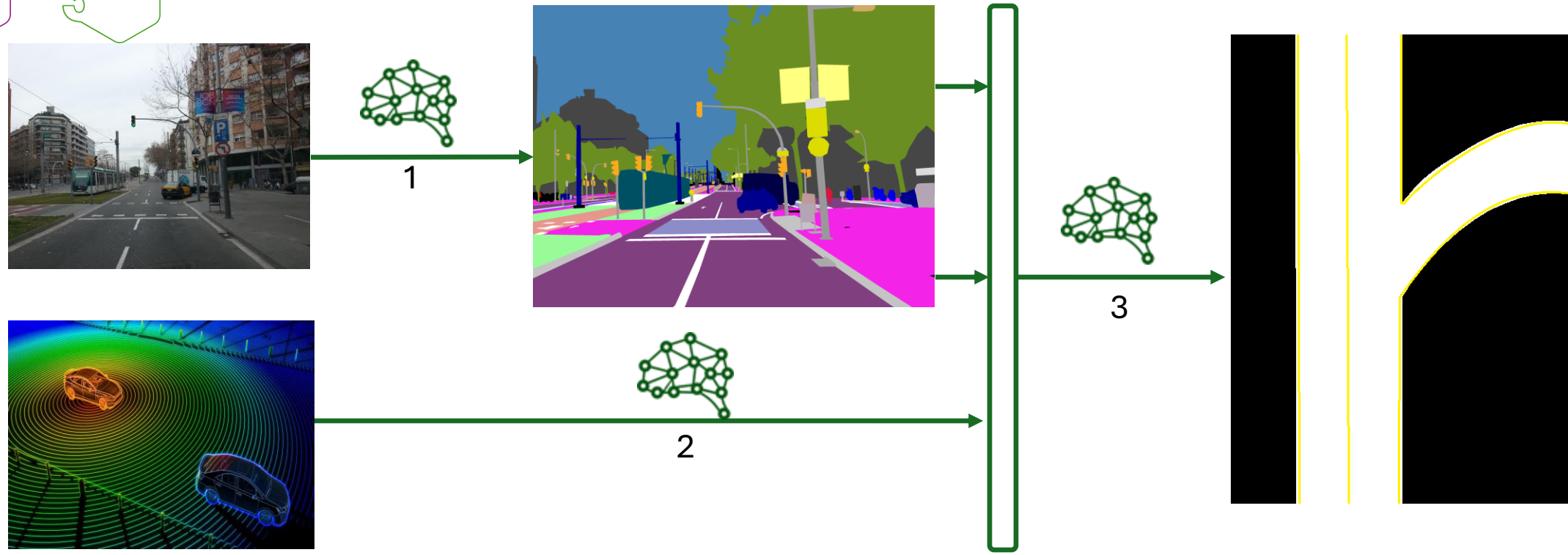
Navigation in open road,
with boundary reconstruction

Twin in the loop simulation



Problem

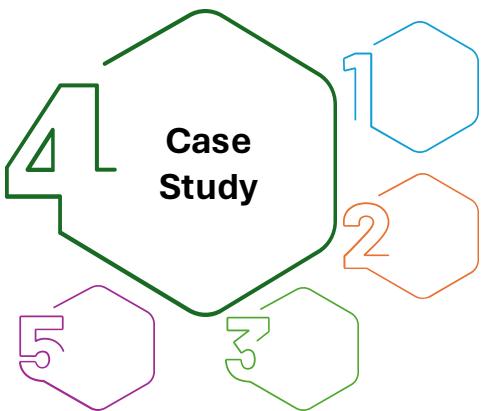
Road reconstruction



Sensors
(image, point cloud)

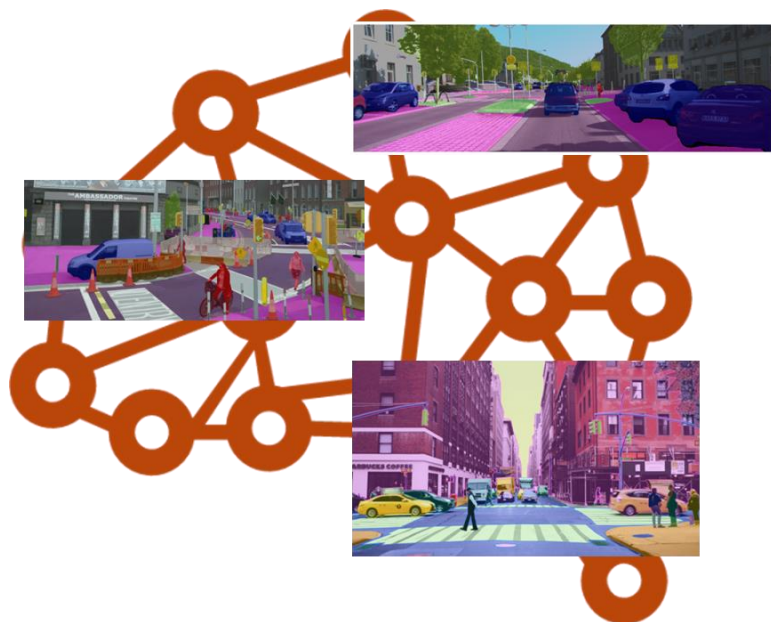
Image semantic
segmentation

Bird eye view
reconstruction



Road Reconstruction

1_Semantic Segmentation



Pre-trained Neural Network



New dataset & training



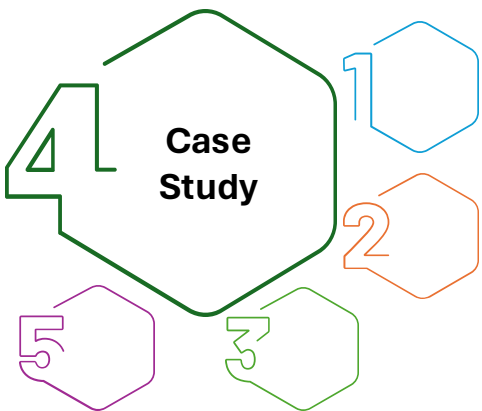
Testing on car



Long process,
Prone to
human error

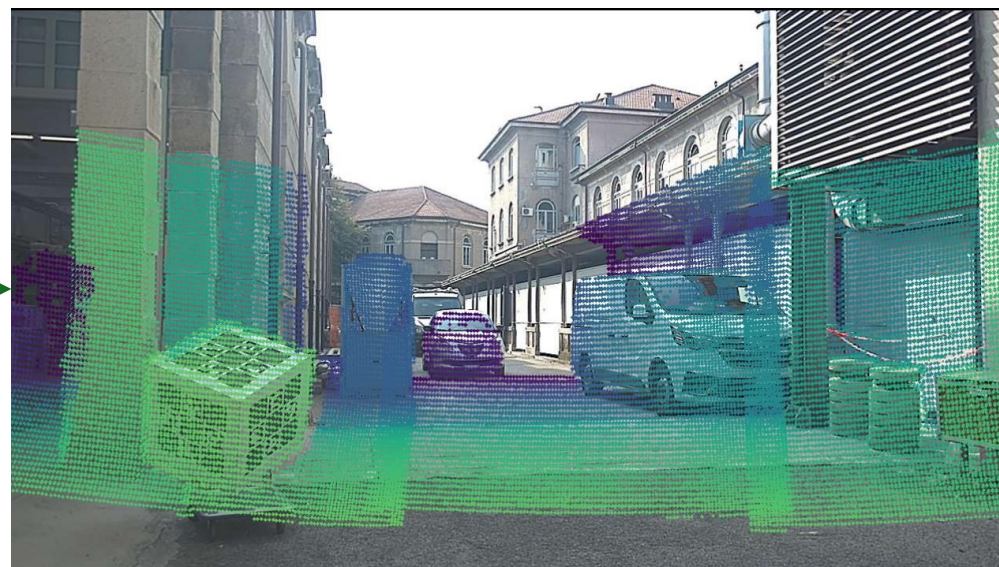
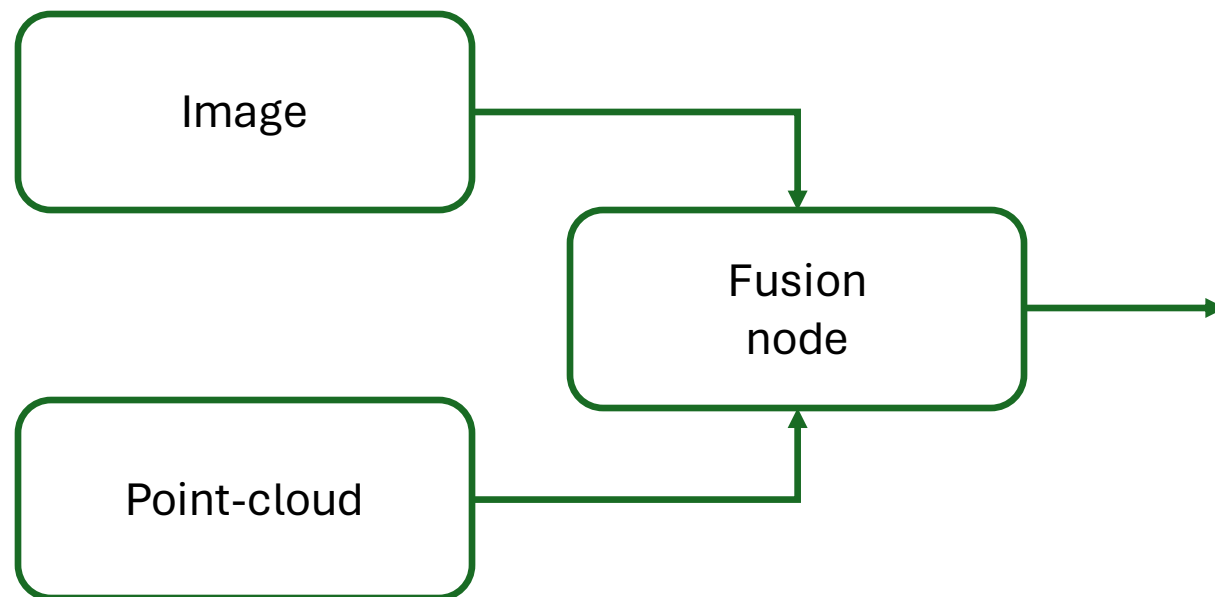


Synthetic data generation using
Vi-Worldsim

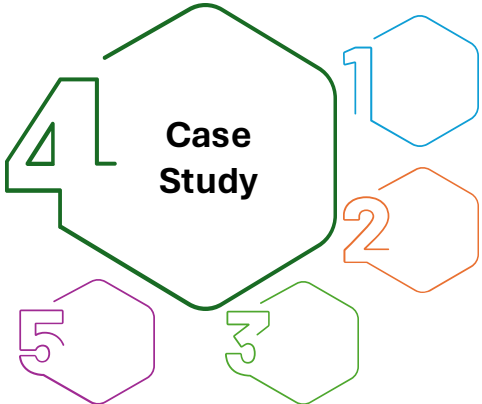


Road Reconstruction

2_RGBD projection



RGBD image



Road Reconstruction

BEV generation

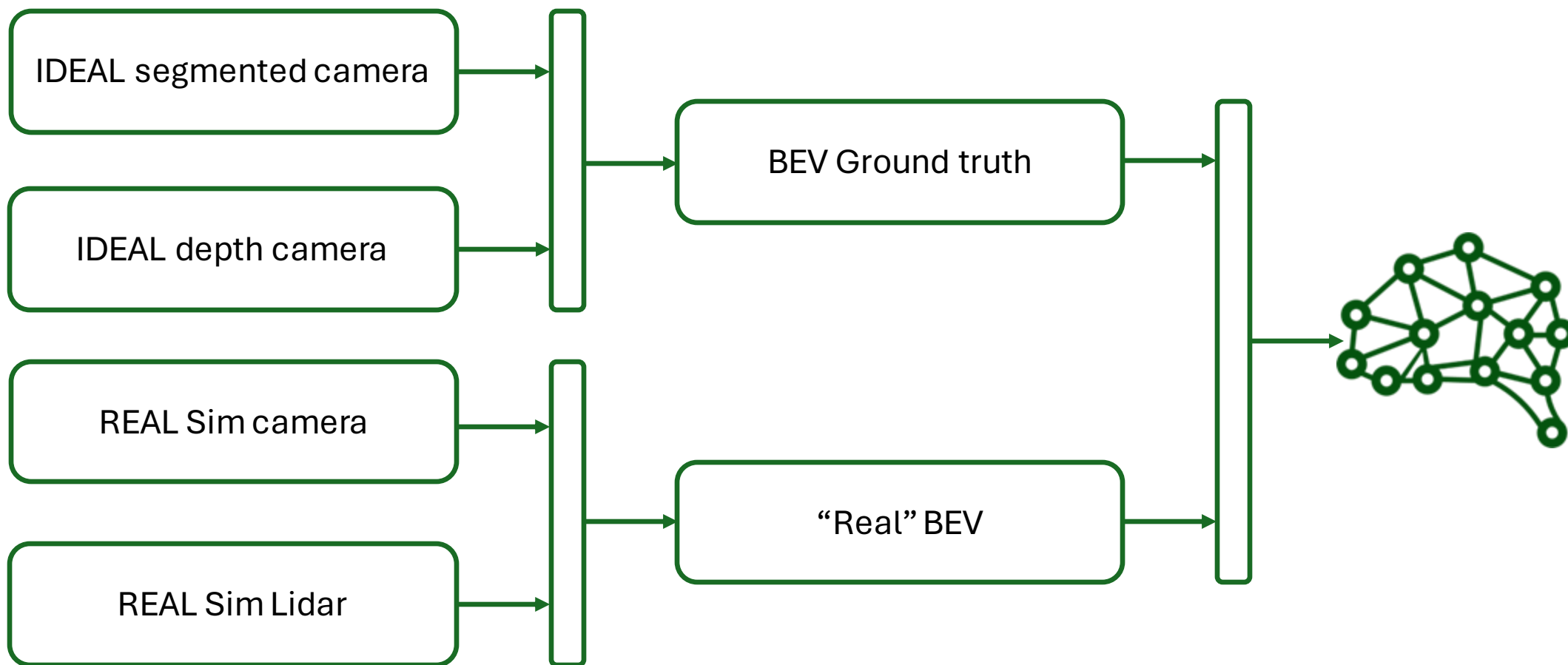


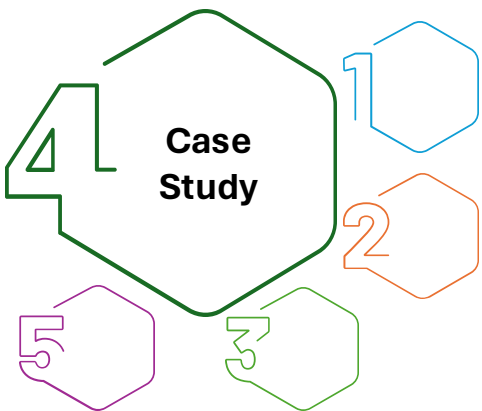
Vi-Worldsim
data generation



Simulator

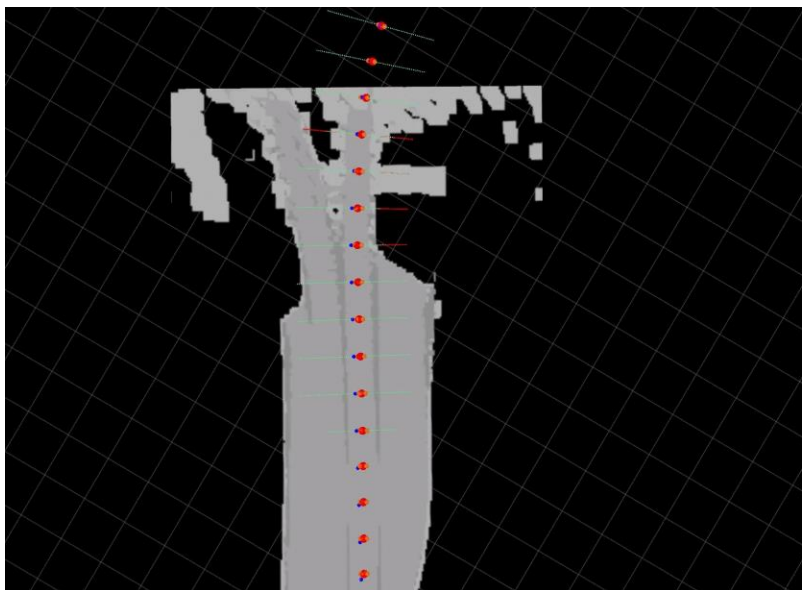
Fusion module training and validation



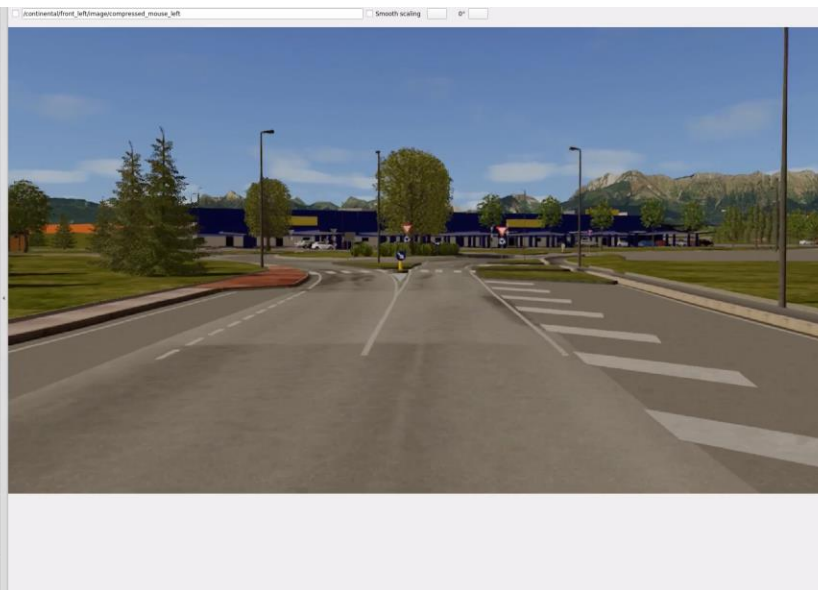


Simulator

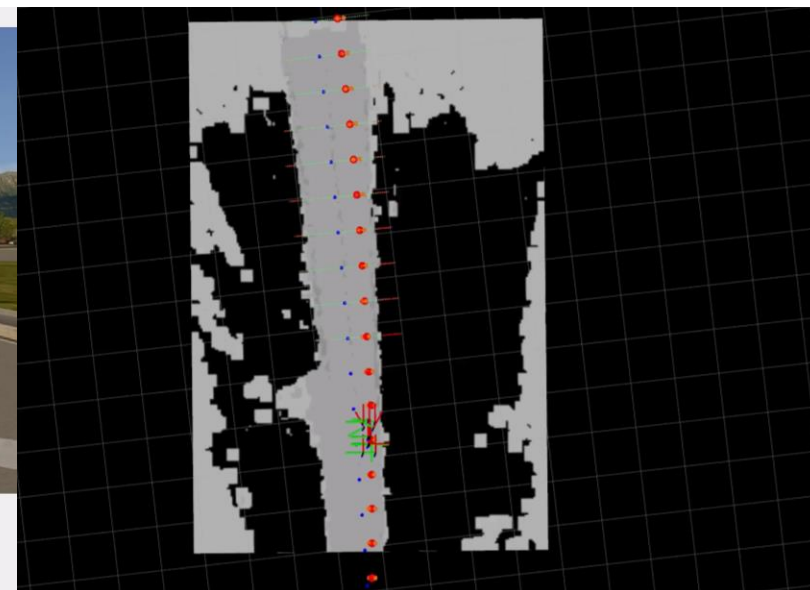
BEV Data generation



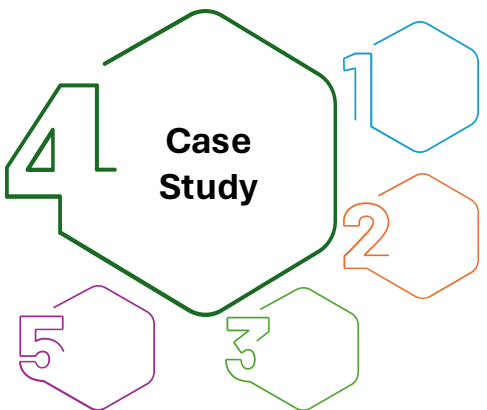
BEV Ground truth



On-board camera

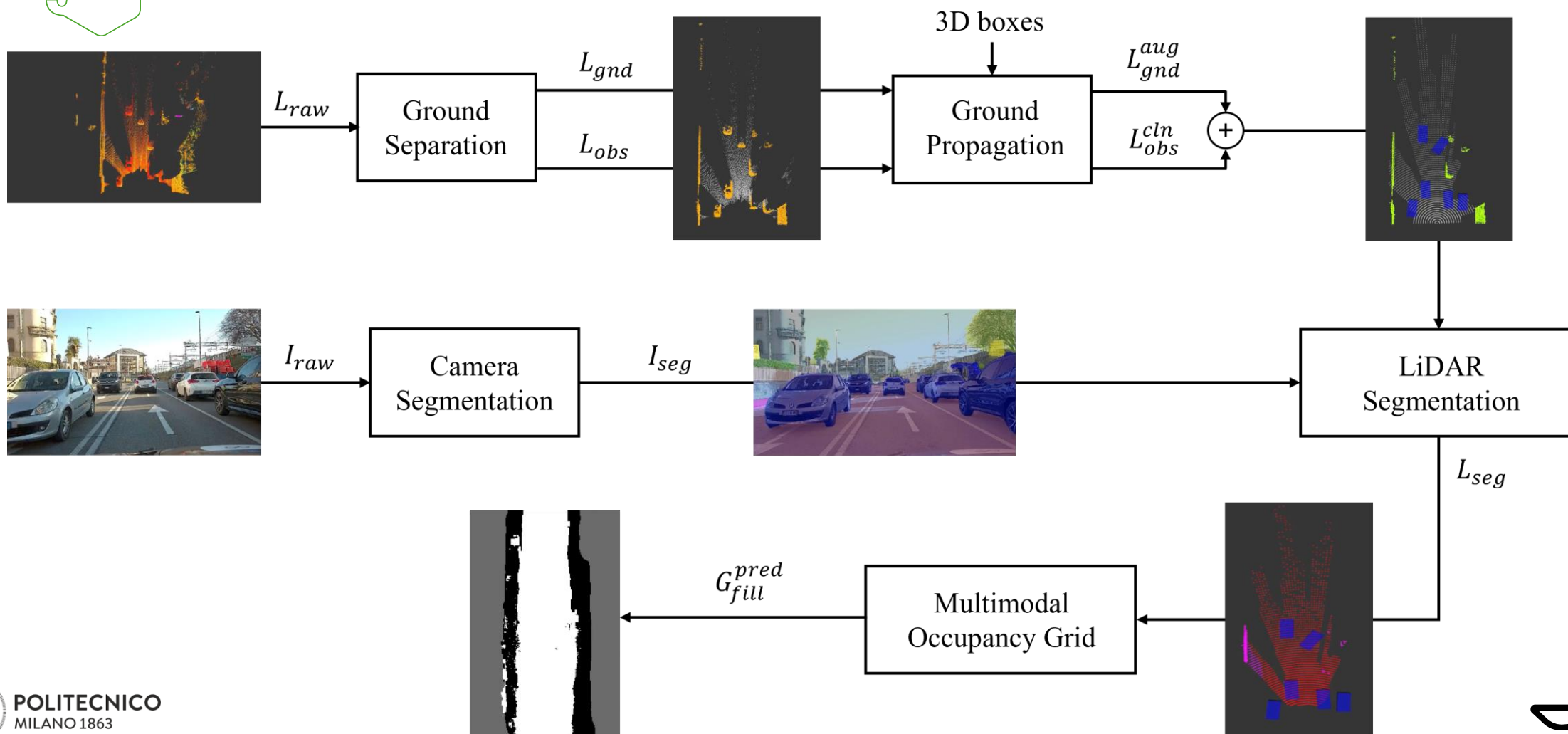


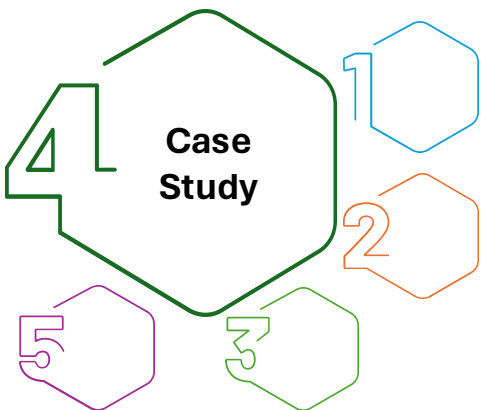
BEV reconstructed



SW Stack

Complete system implementation





SW Stack

Complete system implementation

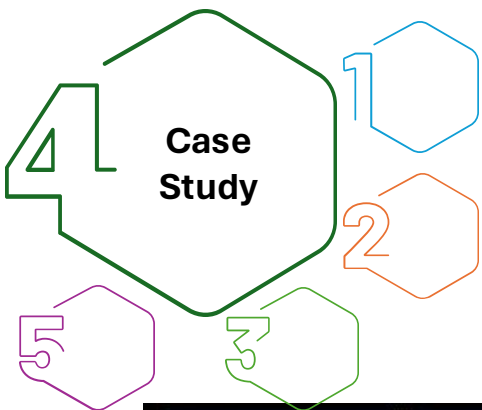
On-line semantic segmentation



On 3 cameras

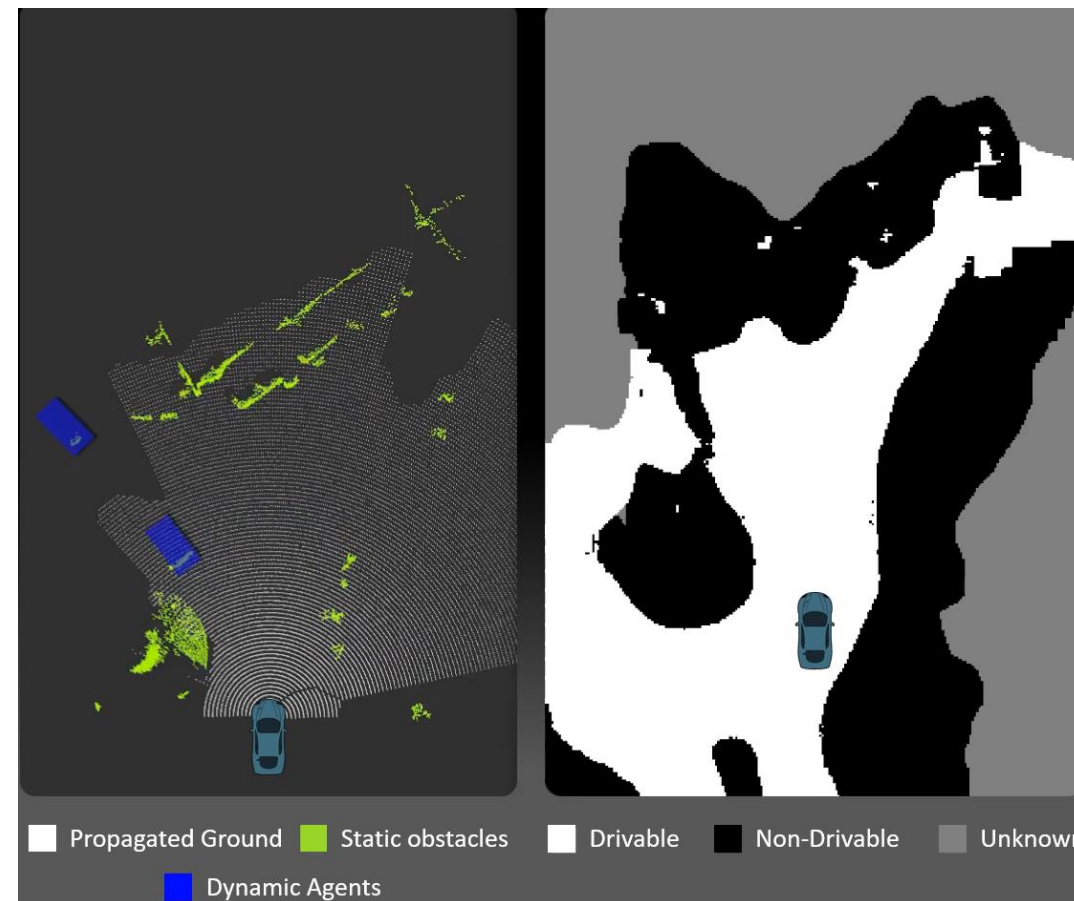


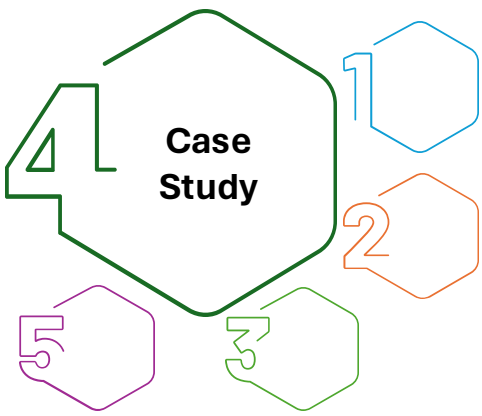
Open roads testing



Open roads testing

Online implementation



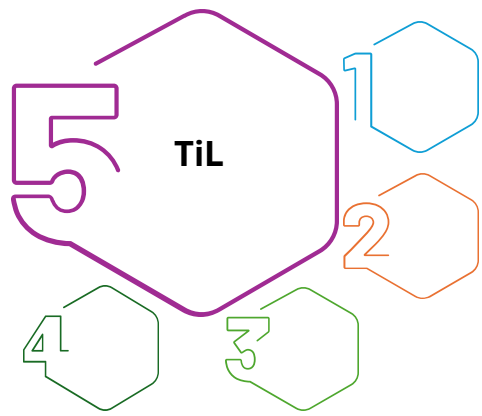


Objective

Leveraging VI-grade Simulator for Autonomous Perception and Control Optimization

Navigation in open road,
with boundary reconstruction

Twin in the loop simulation



Twin in the Loop

Introduction

Research project:

Advances in Twin-in-the-Loop system design

What is the **Twin-in-the-Loop** (TiL) paradigm?



REAL SYSTEM



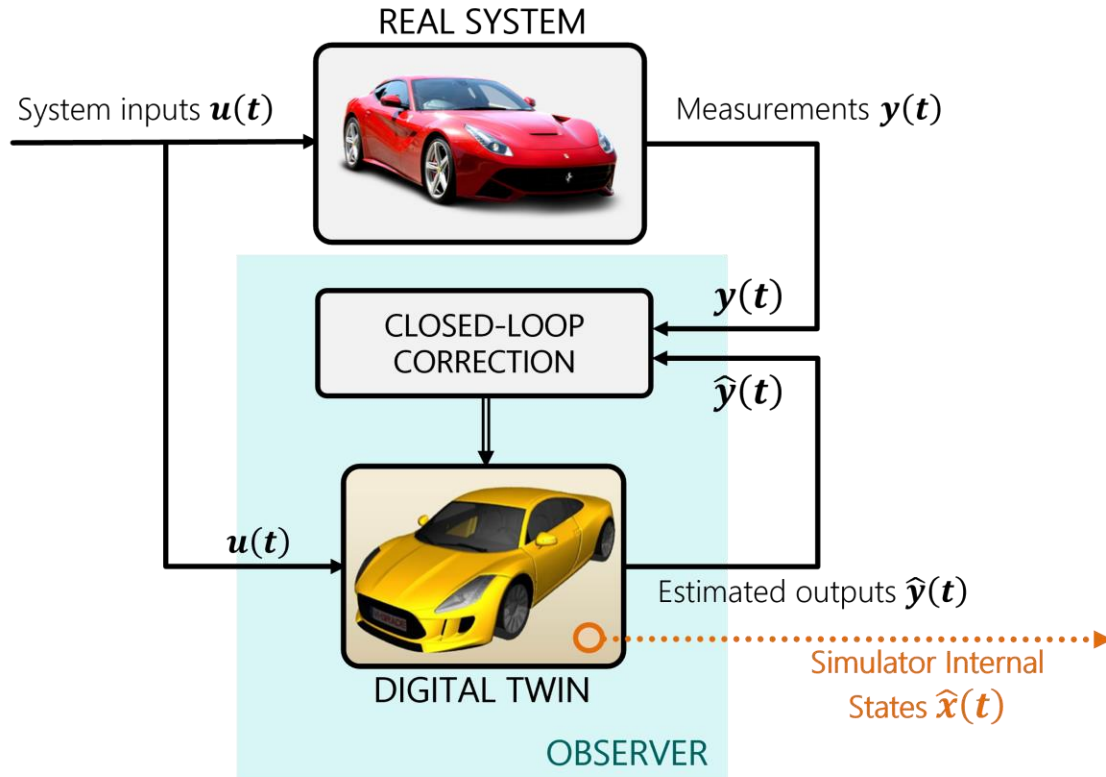
DIGITAL TWIN

$$\begin{cases} \dot{x} = f(x, u) \\ y = h(x, h) \end{cases}$$

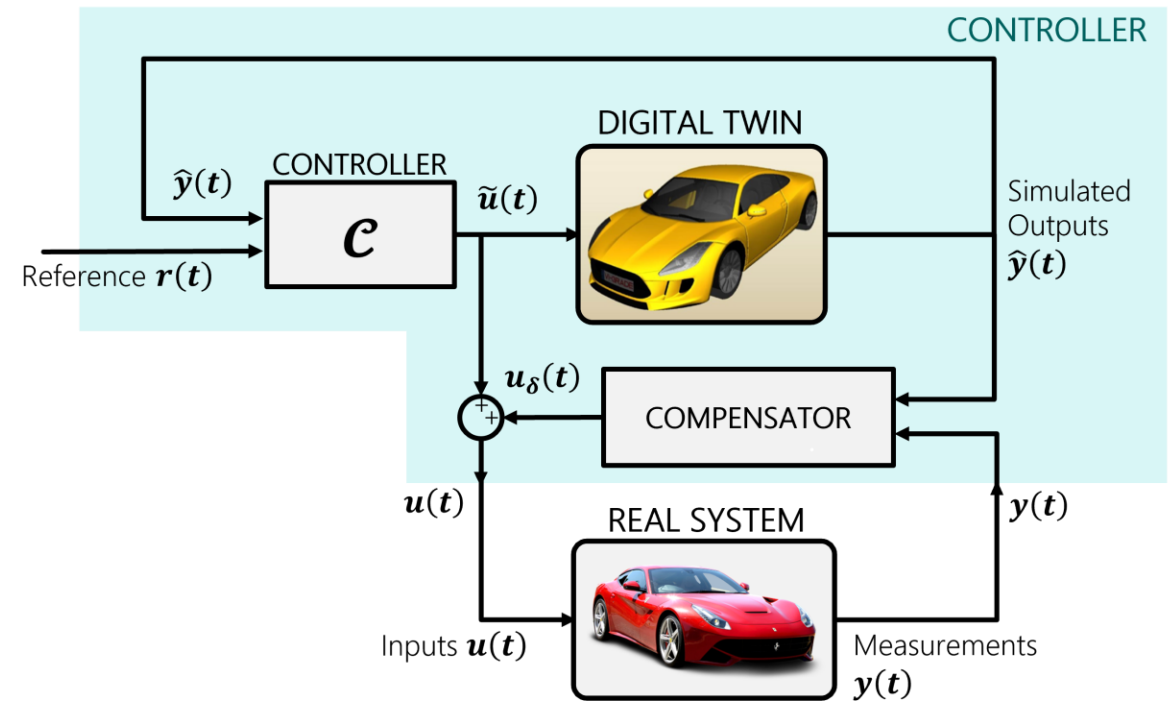
**EXPLICIT
CONTROL-ORIENTED
FORMULATION**

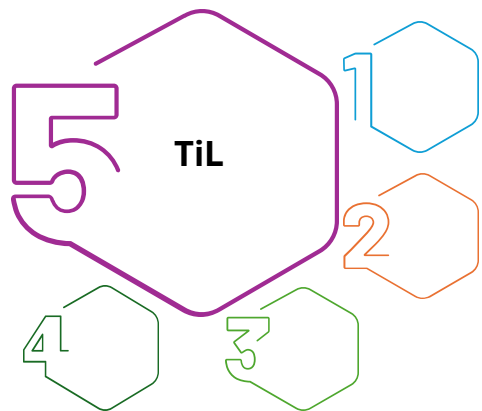


TiL-FILTERING



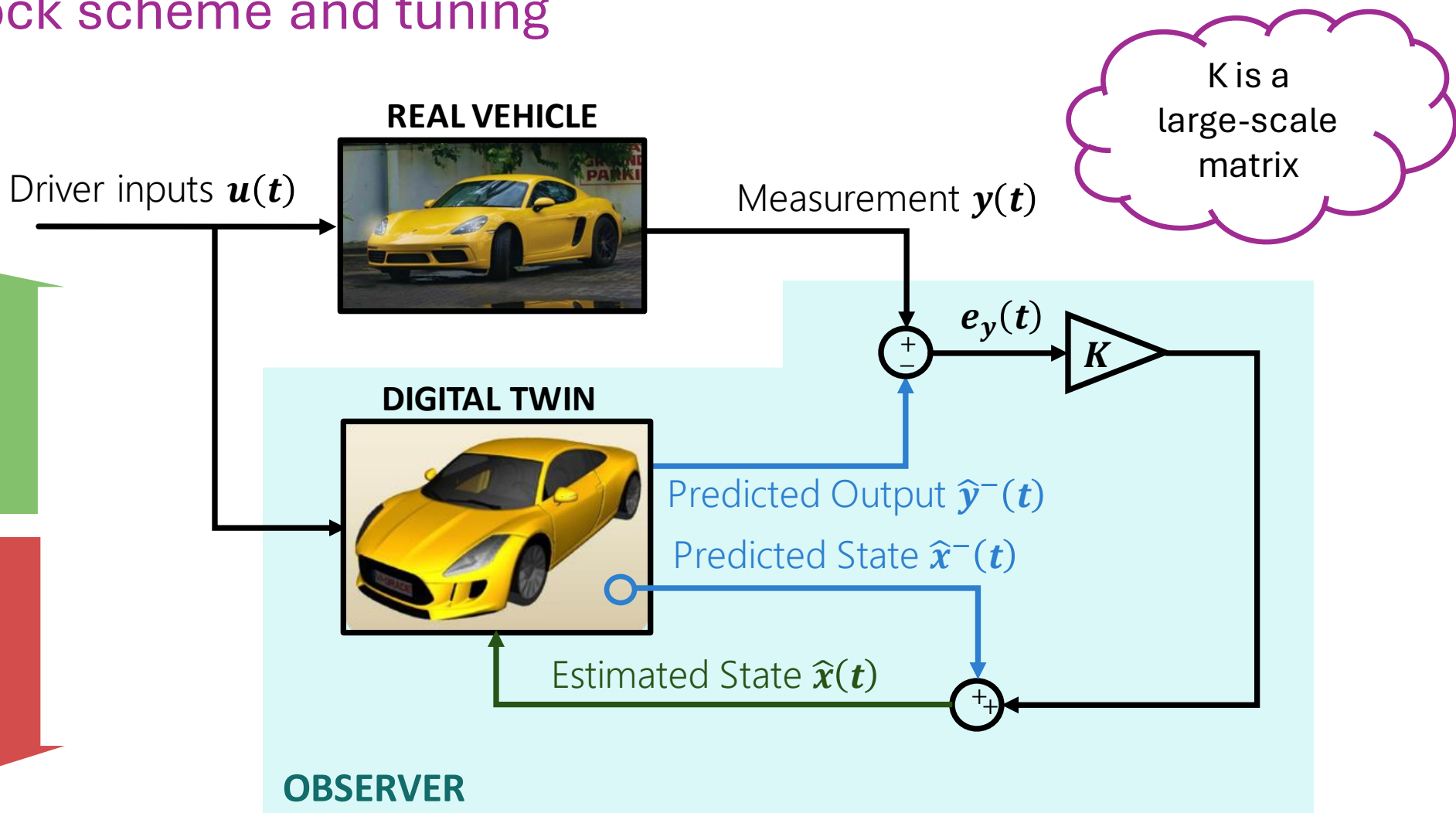
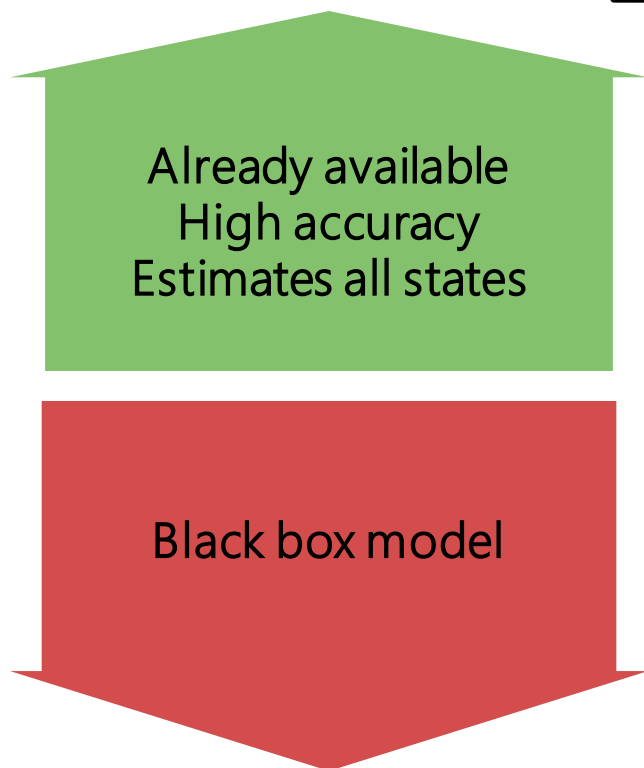
TiL-CONTROL

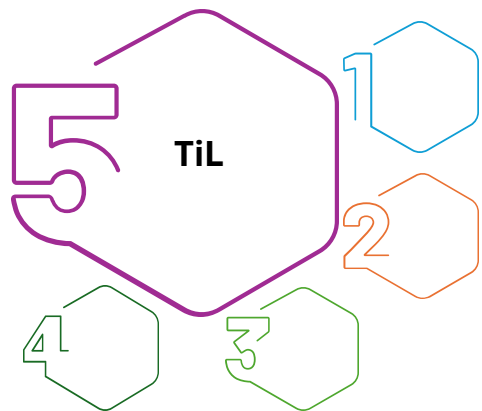




TiL - Filtering

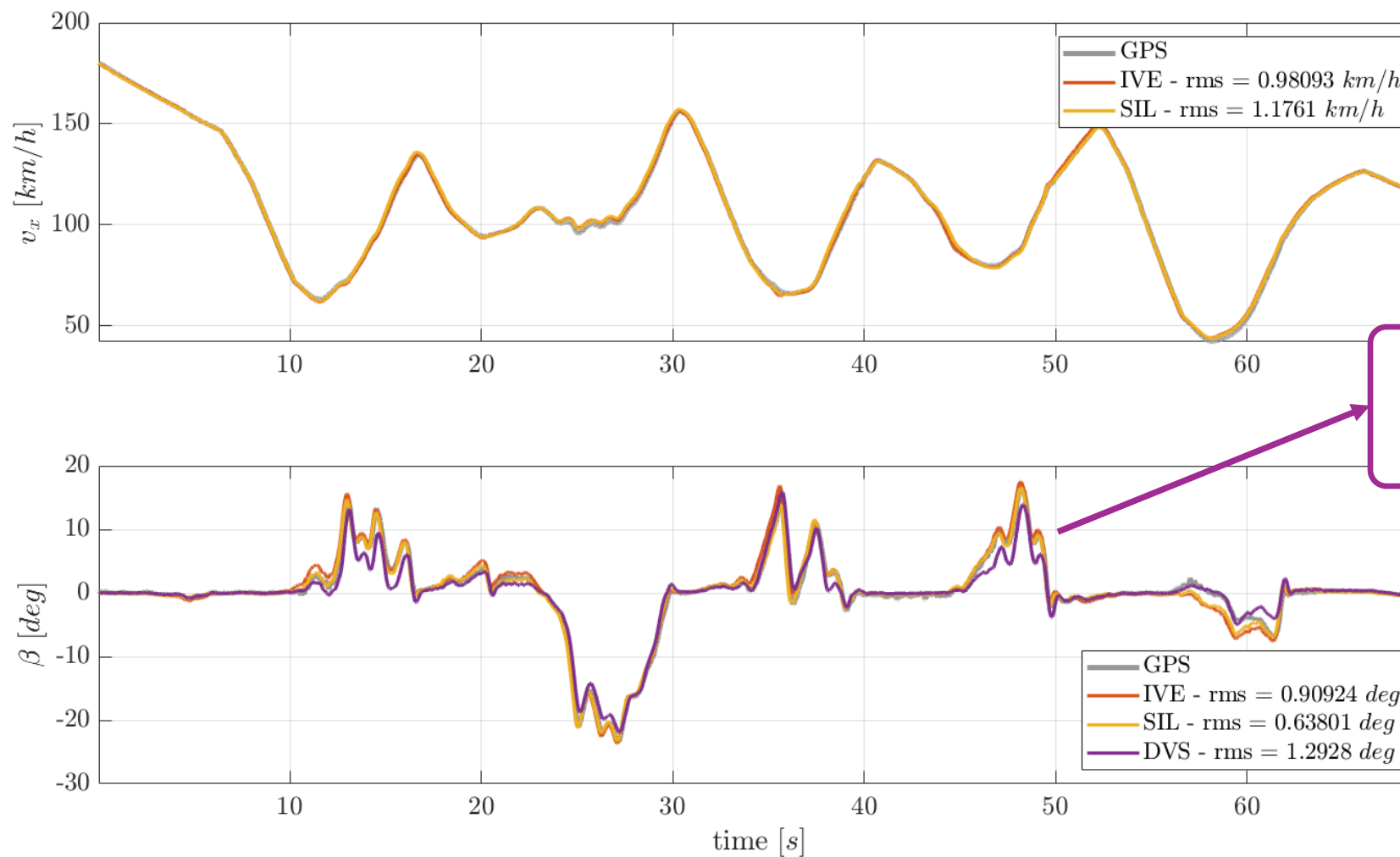
Block scheme and tuning



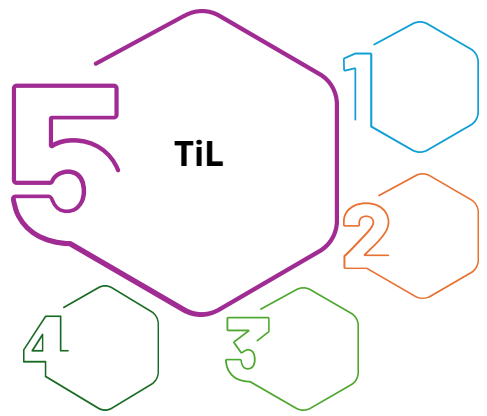


TiL - Filtering

Results

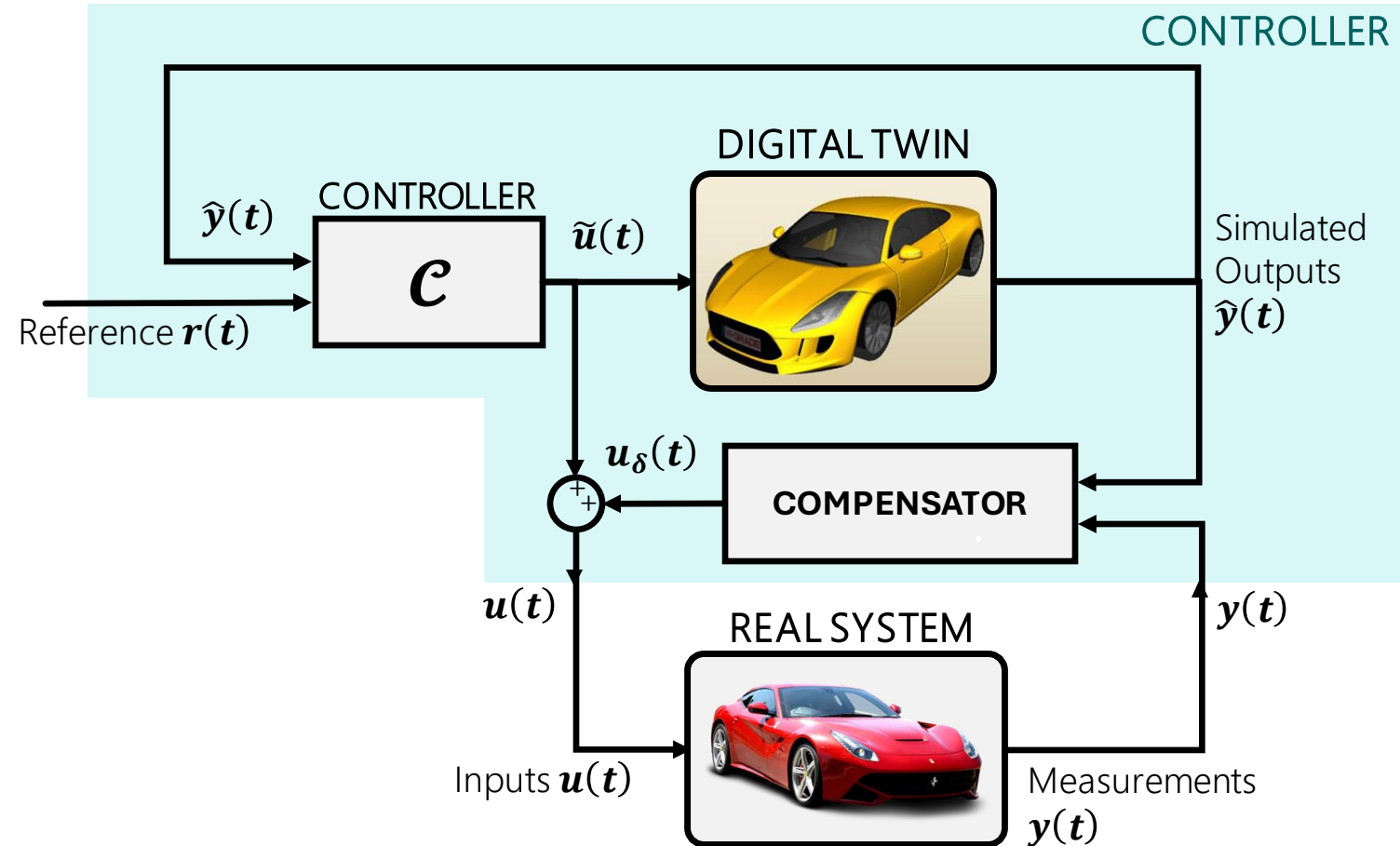
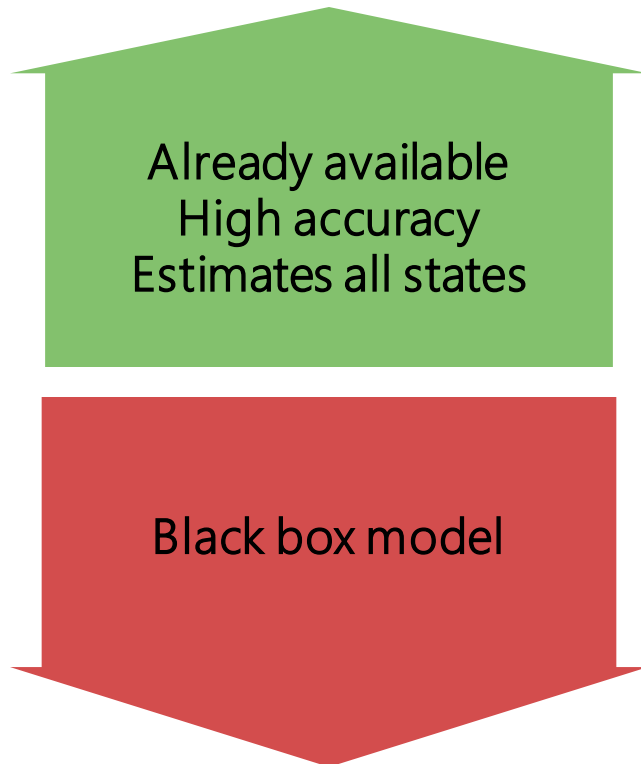


TiL (SIL) Filter outperforms the benchmark!



TiL - Control

Block scheme and tuning

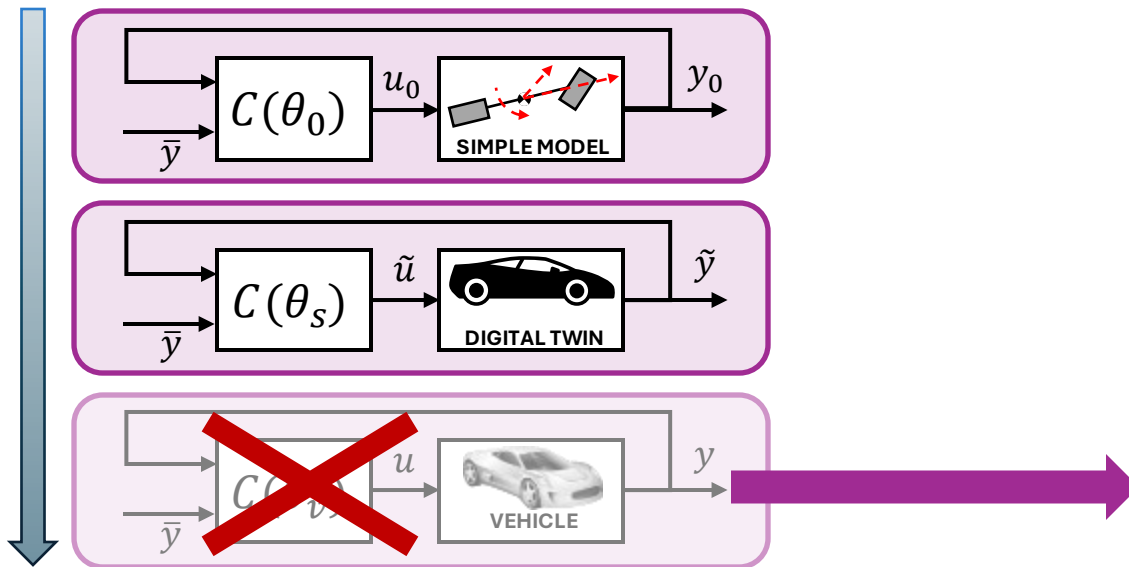


TiL-Control

Control flow design

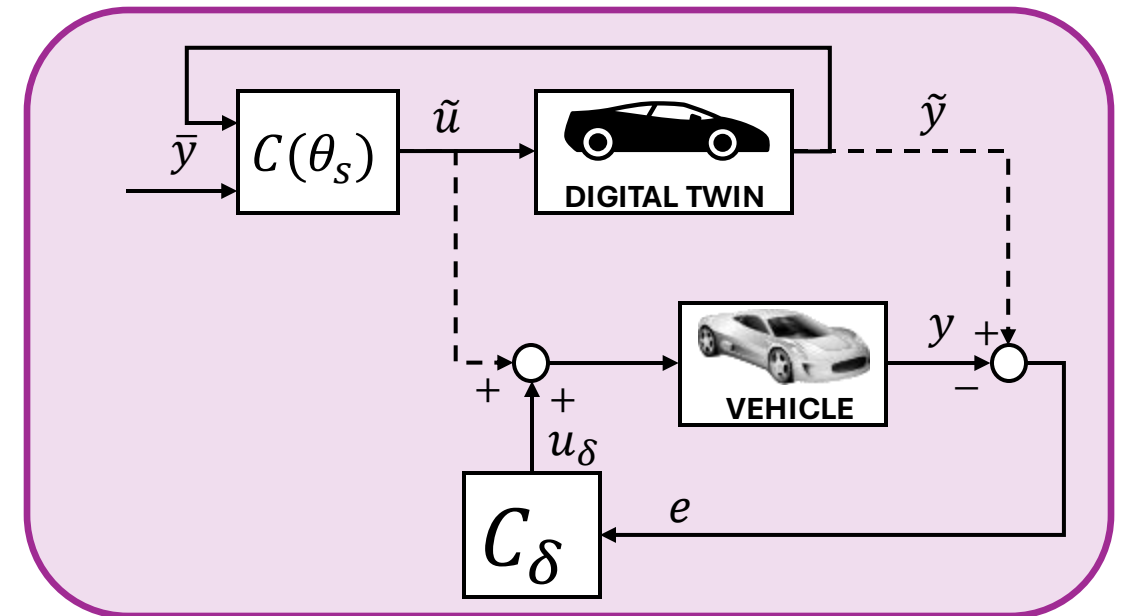
Traditional framework

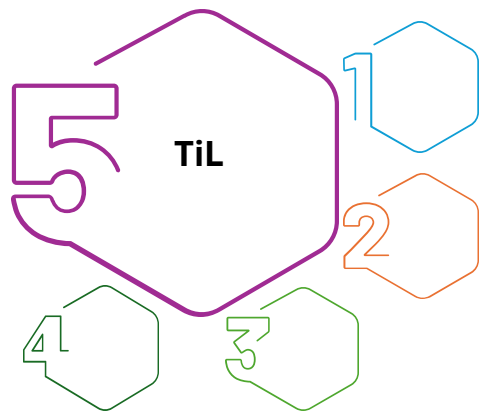
- Vehicle controls development goes through **many steps**
- **Many experiments** to achieve end-of-line tuning



Twin-Loop framework

- **Digital twin directly used on-board** to control the vehicle;
- **Control tuned on the simulator** – simple compensator added.



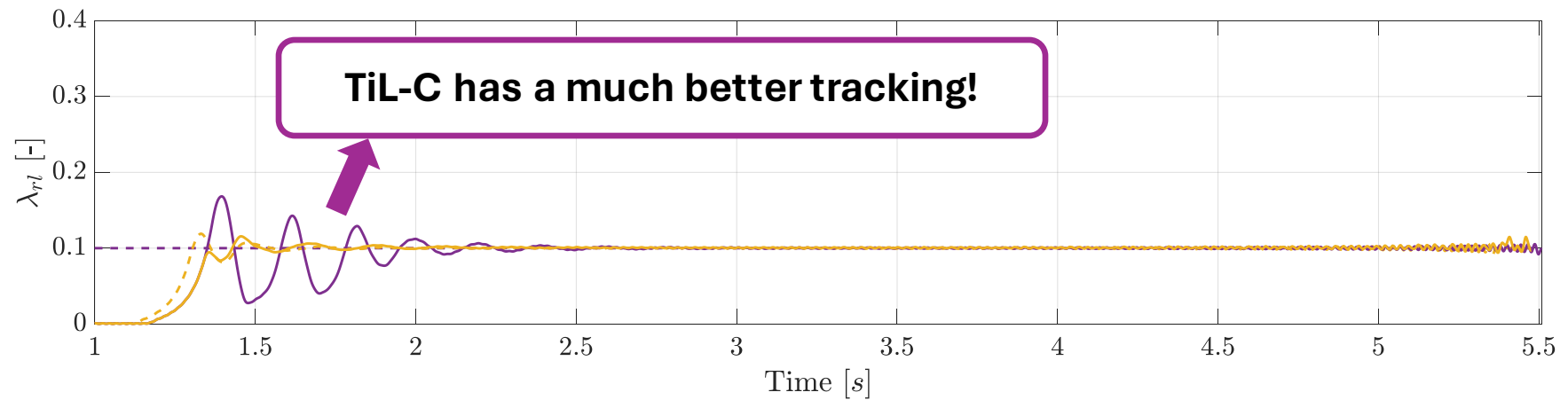
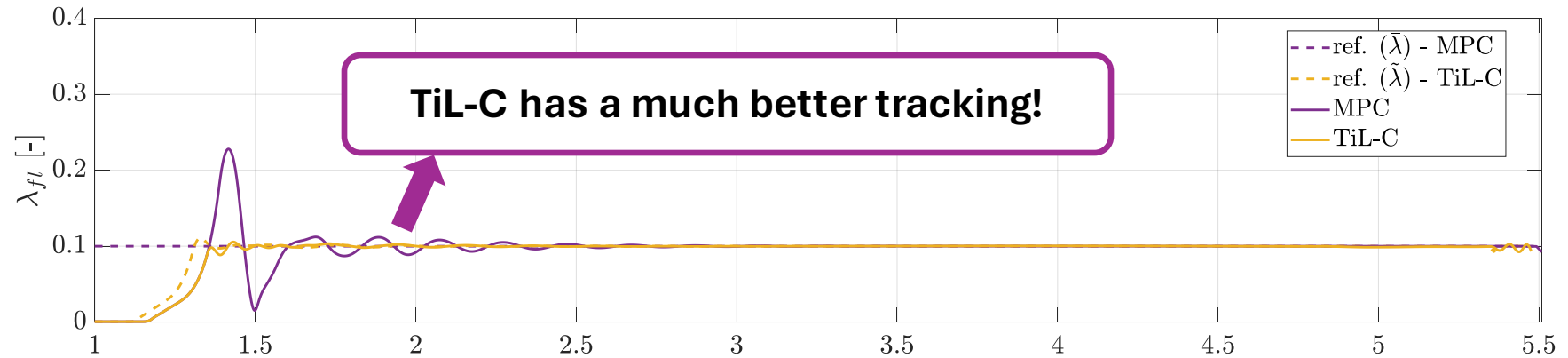


TiL-Control

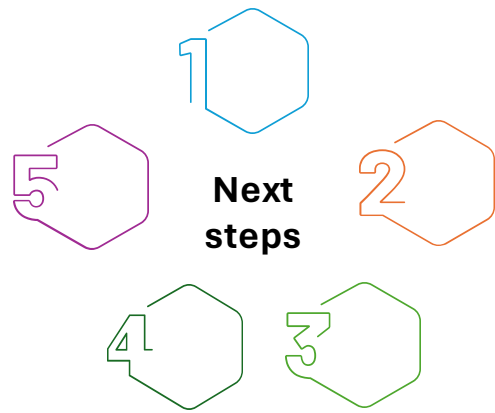
Results

	<i>tracking error [%]</i>
TiL	1.24
Bench	2.44
	+95%

**TiL outperforms
the state-of-the-art
MPC**



Future of mobility



Dynamic simulation



Project start-up



POLITECNICO
MILANO 1863



2022



1000Miglia



12

2023



1000Miglia



20

June-2024



Urban Mobility

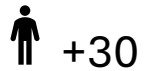


25

Sep-2024



Next challenge



+30

2025

Next challenge

Digital testing

Perception training

Full stack testing





Driving Innovation: Leveraging VI-grade Simulator for Autonomous Perception and Control Optimization



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