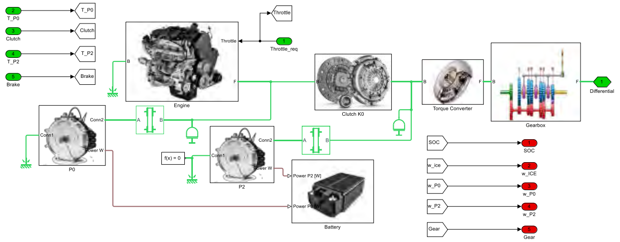
Name	Shailesh HEGDE.
Ph.D in	Mechanical Engineering (XXXV Cycle, First year).
Department	Department of Mechanical Engineering and Aerospace(DIMEAS).
Coordinator	Prof. Luca GOGLIO.
Supervisor	Prof. Nicola AMATI.

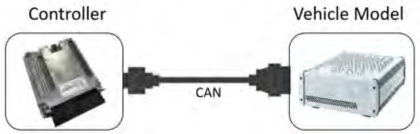
Research area:

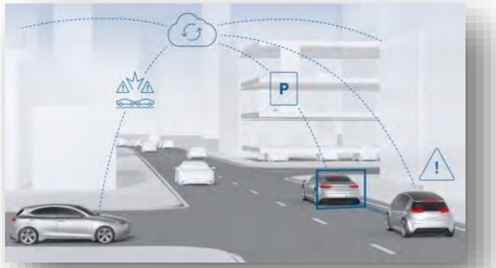
Modeling, control and integration of Mild Hybrid Powertrains *(Dayco Europe S.r.l.).*

The objective of the research work:

1. Vehicle modeling accounting lower level actuator controllers (Throttle, clutch, starter).
2. Design and analysis of Energy management control strategies aimed to understand the benefits of mild hybridization in terms of performance, fuel economy and costs.
3. Deployment of designed control strategies on real time control units (SIL, RCP, HIL and on-vehicle testing).
4. Design of advanced powertrains control strategies based on vehicle connectivity features exploiting data from the cloud and V2x communications.







State of Art

- Nowadays a tremendous effort in the automotive industries is targeted towards the innovation to reduce the CO2 emission in order to overcome the stringent emission regulations around the globe. This resulted in heavy emphasis on hybrid and electric vehicle solutions.

Classification of Hybrid vehicles:

Energy flow :

- **Series,**
- **Parallel**
- **Series-Parallel**

Position of secondary energy source:

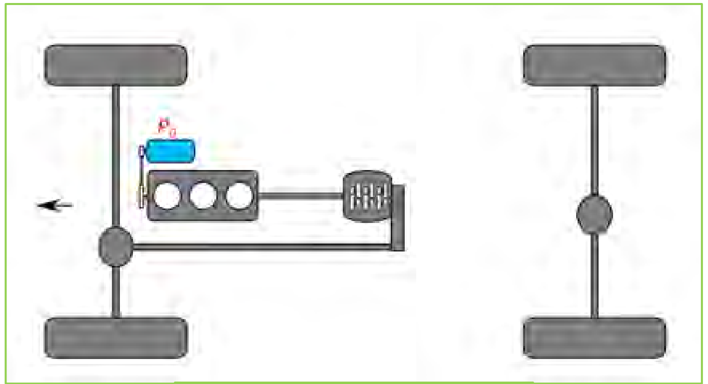
- **P0**
- **P1**
- **P2**
- **P3**
- **P4**

Size of the electric powertrain:

- **Micro,**
- **Mild,**
- **Full**
- **Plug-in**

Controller Classification :

- **Model-based methods**
  - Numerical
  - Dynamic Programming
  - Analytical
    - Pontryagin's Minimum Principle
    - Equivalent Consumption Minimization Strategy
- **Rule-based methods**
  - Charge and Deplete
  - Fuzzy Logic



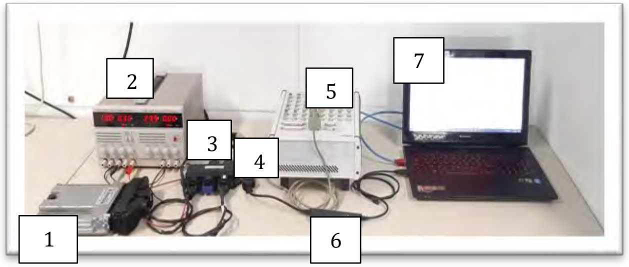
P0 Architecture

Contributions to project

Modeling, control design and Simulation → Controller deployment / Vehicle Emulator → HIL Experimental testbench → On-Vehicle Testing

Vehicle Hybrid architecture : P0
- IC Engine,
- Electric machine,
- Automatic transmission,
- Torque converter.

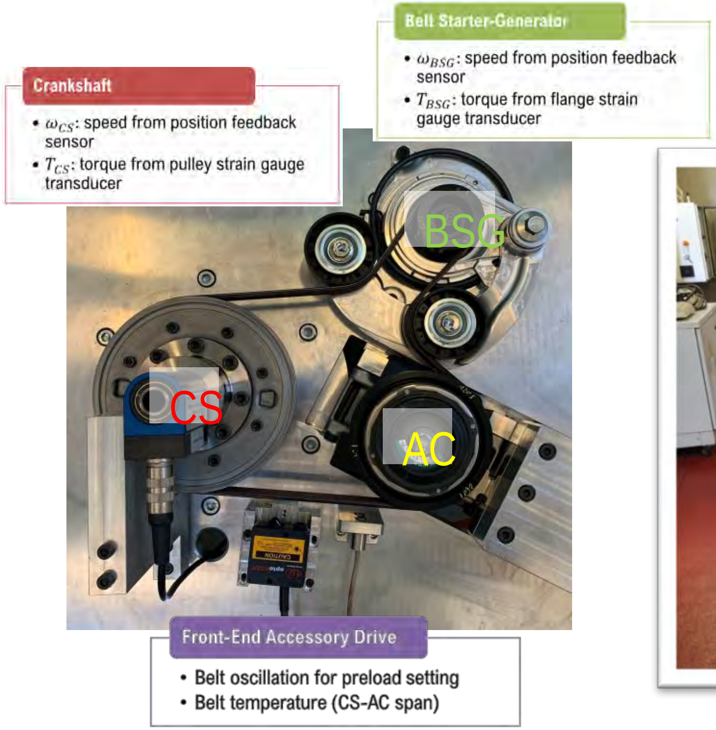
Controller:
ECMS (Equivalent consumption minimization strategy)



(1) ECU Raptor, (2) Power supply, (3) ECU connector, (4) CAN 1 Bus, (5) dSpace MicroLabBox, (6) kvaser USB CAN interface, (7) PC.

Hardware:
- Raptor GCM196 (Controller)
- dSpace MicroLabBox (vehicle Emulator).

Software:
- Controller :
  - Controller code generation : Matlab/Simulink
  - Code deployment and Calibration : Raptor Cal
- Vehicle Emulator :
  - Code generation : Matlab/Simulink
  - Code deployment andCalibration : dSpace Controldesk



Dyno testing at Dayco Europe S.r.l facilities

Controller algorithm and results

ECMS (Equivalent consumption minimization strategy)

Controller

INITIALIZATION
Load ICE map, Load EM map

Driving conditions

Treq > 0 — N → Recuperation mode

Y ↓

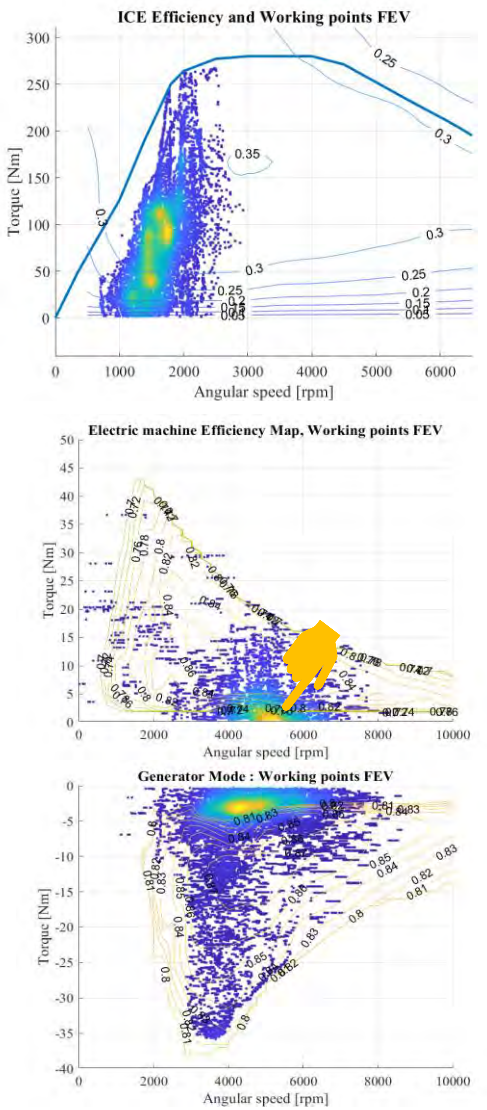
ALGORITHM

(1) CREATE the vector of u possibilities $[u_{min} \dots u_{max}]$
(2) FOR $u = u_{min} : u_{max}$
CALCULATE $\dot{m}_{equivalent}$ vector
END
(3) SELECT the minimum $\dot{m}_{equivalent}(u^*)$
(4) $T_{EM} = u^* \cdot T_{REQ}$ $T_{ICE} = T_{REQ} - T_{EM}$

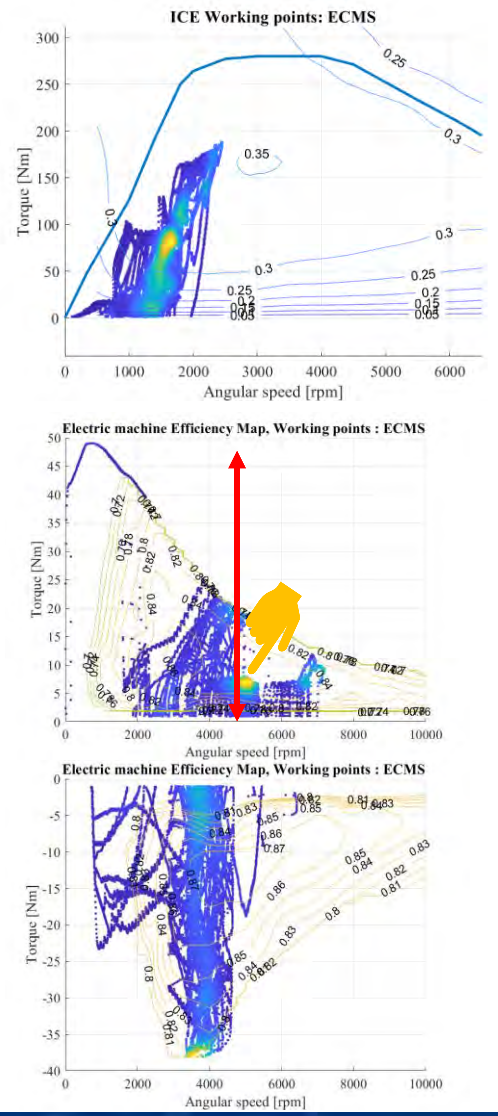
INPUTS

- Requested Torque
- Vehicle speed
- Target and Actual SoC
- Available Motor torque for recuperation, boosting

Existing on-vehicle controller



ECMS controller simulation

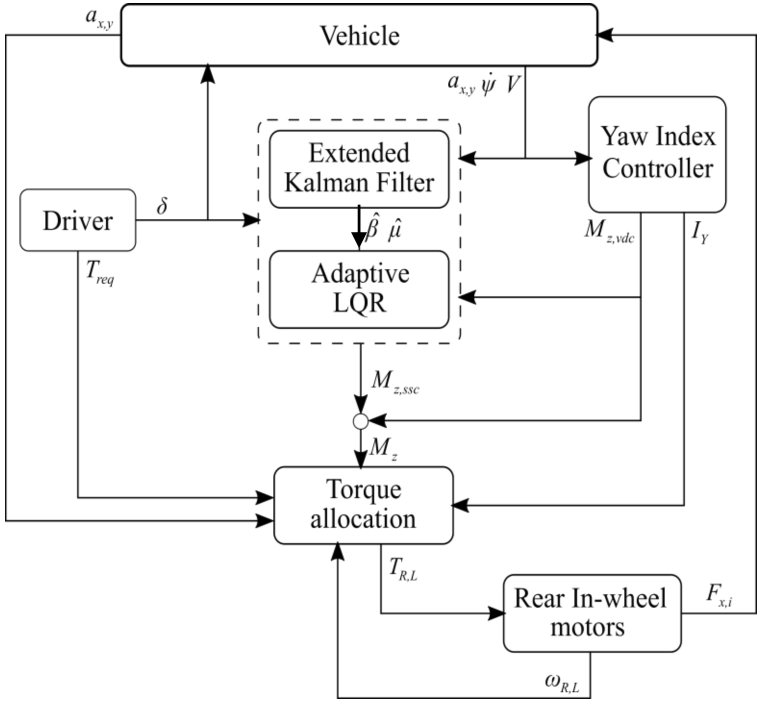


Research collaboration projects:
Torque Vectoring Control for in-wheel motor vehicle (JAC), HiPERFORM project (European Union's Horizon 2020 research and innovation programme), (FCA-CRF).

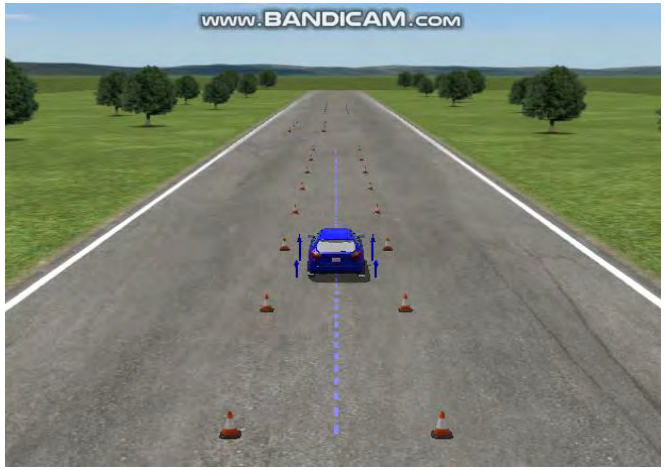
Objectives:

Yaw stability control with active torque distribution in rear axle .
Rapid control prototyping, On-vehicle testing for caliberation.

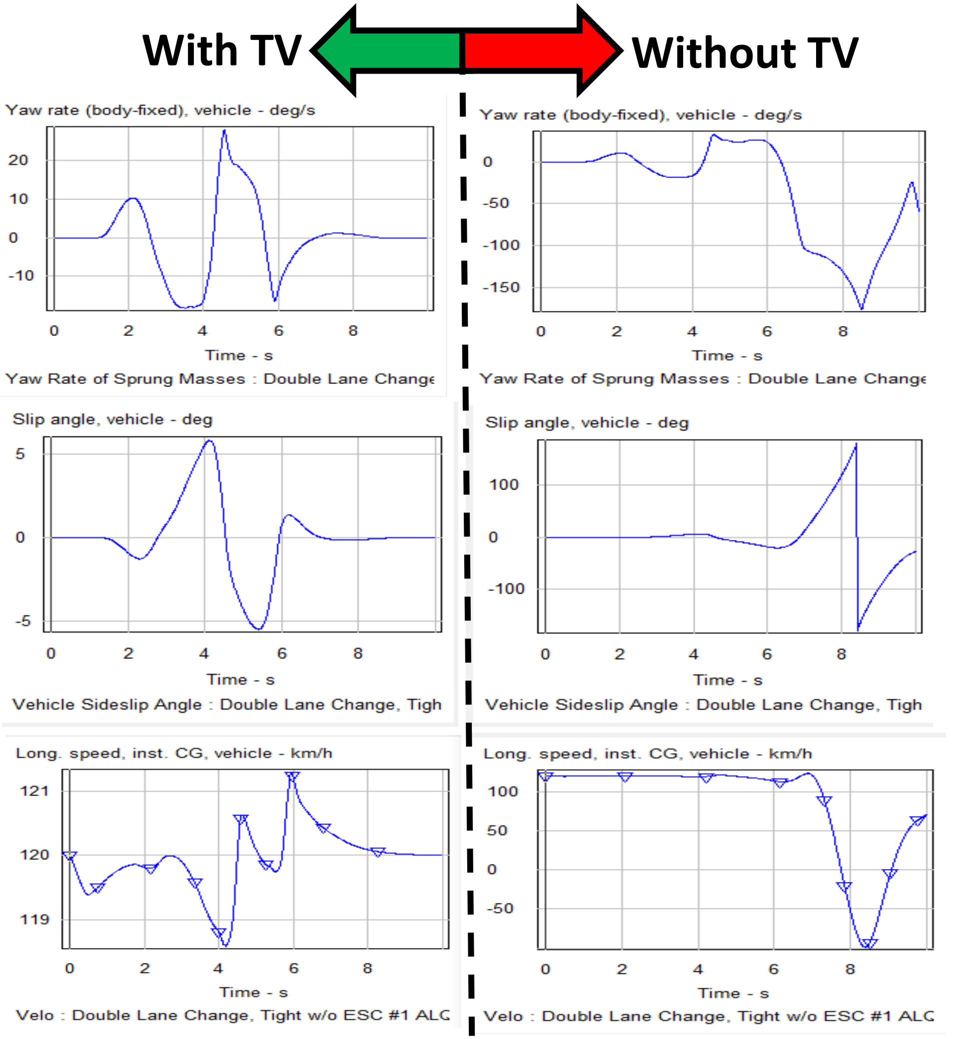
Contol strategy :



Video:



Double Lane Change @120 km/h With TV Without TV



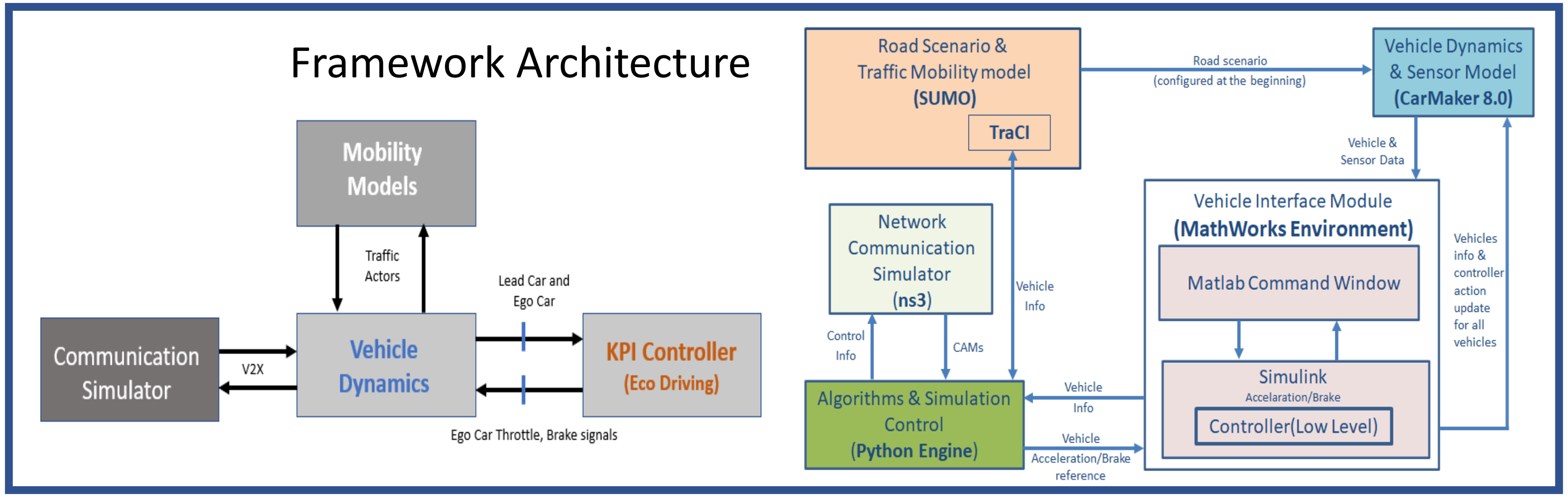
Control strategies of CACC (Cooperative Adaptive Cruise Control), SAVE project (FCA-CRF).

Objectives:

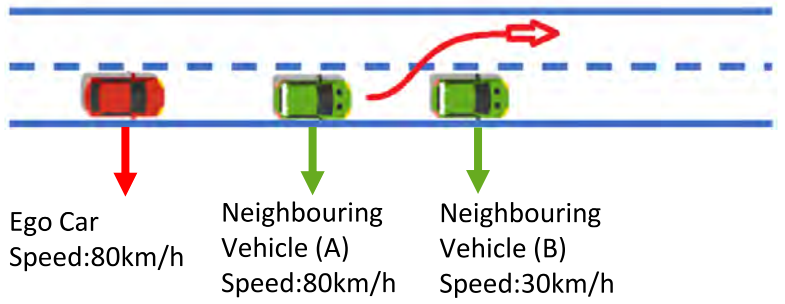
- Create a comprehensive and flexible **simulation framework** that represents all major components of ITS (Intelligent Transport system).
- Design a **Control strategy for CACC** to assess the effectiveness of ITS applications.
- Analyse the impact of connected vehicles (V2x) on passenger **safety and comfort** through relevant use cases.

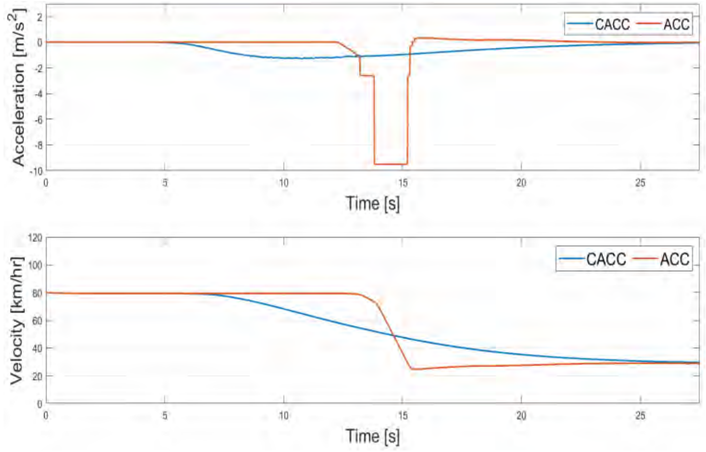
Control Strategy :

- (C)ACC has two cases:
  - Controlling desired **distance** and relative **velocity**
  - Controlling desired **cruise speed**
- CA (Collision avoidance) algorithm **forecasts** potential collision event using **trajectory-based** prediction system.
- Controller with **minimum acceleration** is chosen as desired Ego Car Acceleration.



Scenario 1





Ego Car Acceleration and Velocity trend under ACC and CACC

Foreseen work plan

Modeling, control and integration of Mild Hybrid Powertrains (Dayco Europe S.r.l.).

Equivalent consumption minimization strategy

Design and simulation ⇨ RCP ⇨ HIL testing ⇨ On-vehicle testing

Controller refinement

On vehicle testing:

- Energy management with Static map deployment and calibration (offline).
- Energy management with Realtime optimization by the designed control strategy (Online).

Torque Vectoring Control for in-wheel motor vehicle (JAC), HiPERFORM project (FCA-CRF).

- On-vehicle testing and calibration of Torque Vectoring Controller

Control strategies of CACC (Cooperative Adaptive Cruise Control), SAVE project (FCA-CRF).

- Machine learning techniques to improve the performance of the controller.

List of publications and Courses attended

Publications:

1. Bonfitto, A., Ezemobi, E., Amati, N., Feraco, S., Tonoli, A., & Hegde, S. (2019, July). "State of Health Estimation of Lithium Batteries for Automotive Applications with Artificial Neural Networks." In *2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE)* (pp. 1-5). IEEE.
2. Galluzzi, R., Feraco, S., Zenerino, E. C., Tonoli, A., Bonfitto, A., & Hegde, S. (2020). Fatigue monitoring of climbing ropes. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 1754337120905674.
3. Selvaraj, Dinesh Cyril & Hegde, Shailesh & Chiasserini, Carla Fabiana & Amati, Nicola & Deflorio, Francesco & Zennaro, Giuliana.(2020) A Full-fledge Simulation Framework for the Assessment of Connected Cars. Transportation Research Procedia. (accepted for publication).

Courses attended :

1. 01LCPRV - Experimental modeling: building models from experimental data (33h – hard skills, Politecnico di Torino)
2. 01RGBRV - Optimization methods for engineering problems (30h – hard skills, Politecnico di Torino)
3. 01SFURV - Advanced scientific programming in matlab (28h – hard skills, Politecnico di Torino)
4. 01UJJRO - Automotive transmissions (manual, non-manual and hybrid) (20h – hard skills, Politecnico di Torino)
5. 03OYCIV - Hybrid propulsion systems (15h – hard skills, Politecnico di Torino)
6. Regulation 1151 – WLTC Cycle, Prof. F Cavallino (15h, Online training)
7. Simdrive software training from DAYCO (20h, Online training)

Thank you