

E-mobility & SDV: Application to EV Health Monitoring and Predictive Maintenance

E-mobility International Workshop 2026: Challenges & Opportunities

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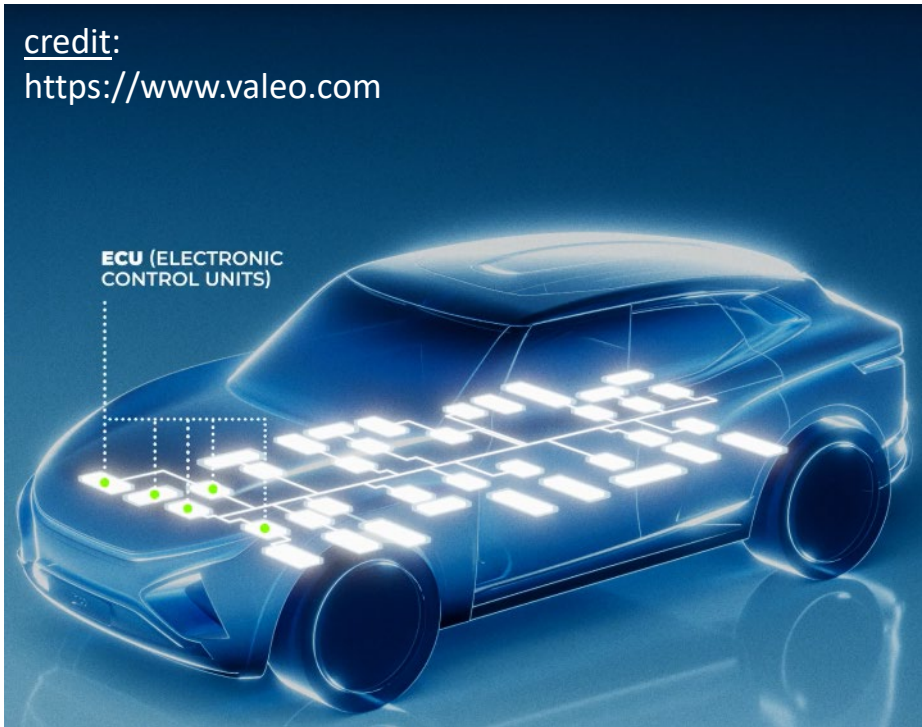


Modern vehicles: a paradigm shift toward software-defined architectures

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Decentralized Architecture

credit:
<https://www.valeo.com>

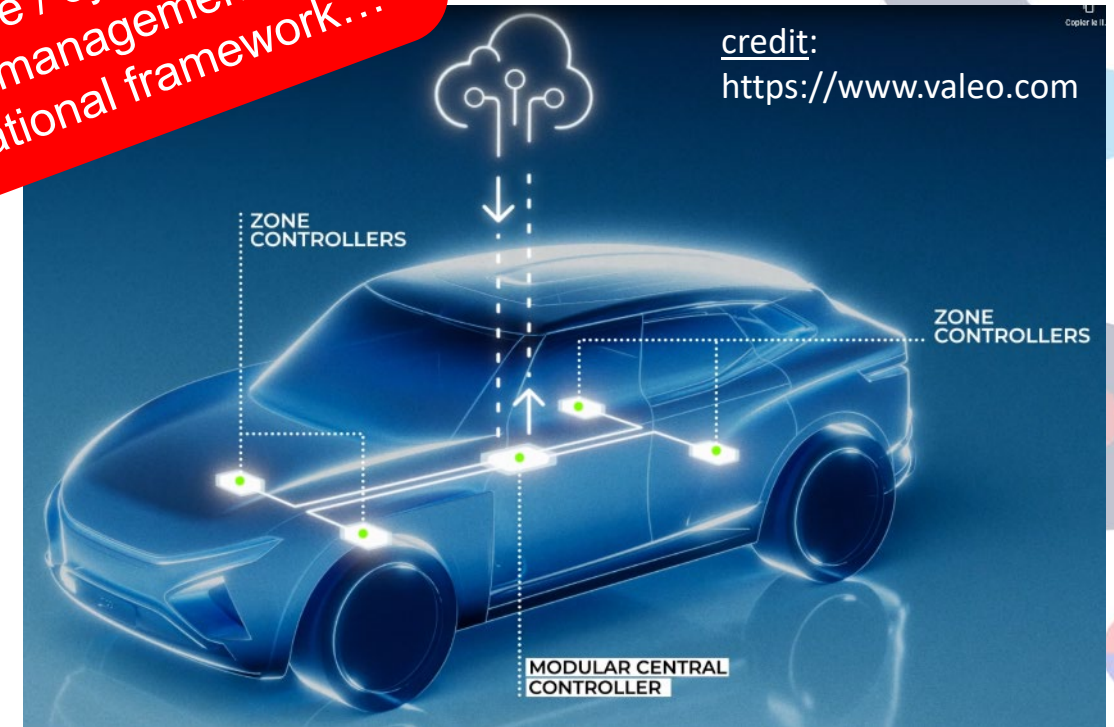


- 1 electronic control units (ECU) per function
 - Nearly 100 ECU distributed across the vehicle
 - Manual updates
 - Cannot be modified after purchase
 - Limited Energy Management

Challenges to tackle: e.g.
architecture / cybersecurity /
data management /
organizational framework...

Centralized Architecture

credit:
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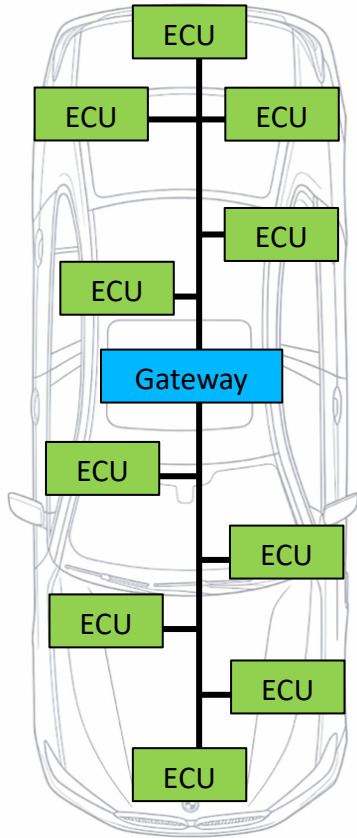


- Centralized compute platform
 - A main control unit manages multiple functions
 - Over-the-Air updates
 - New functionalities post-purchase (soft updates)
 - Adjustment of the Energy Management

Next generation of vehicle: E/E architecture

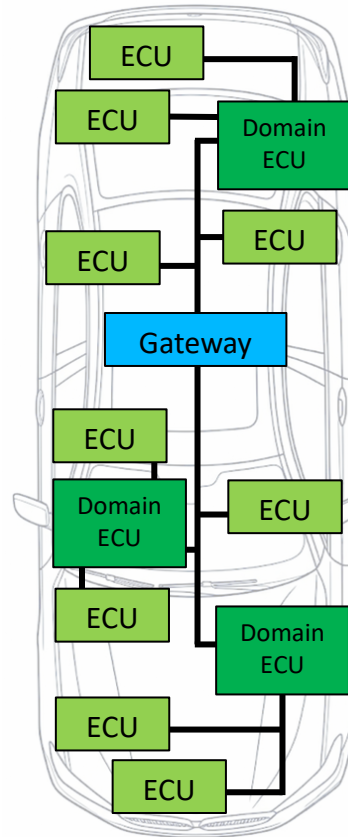
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Distributed architecture
(Older vehicles)



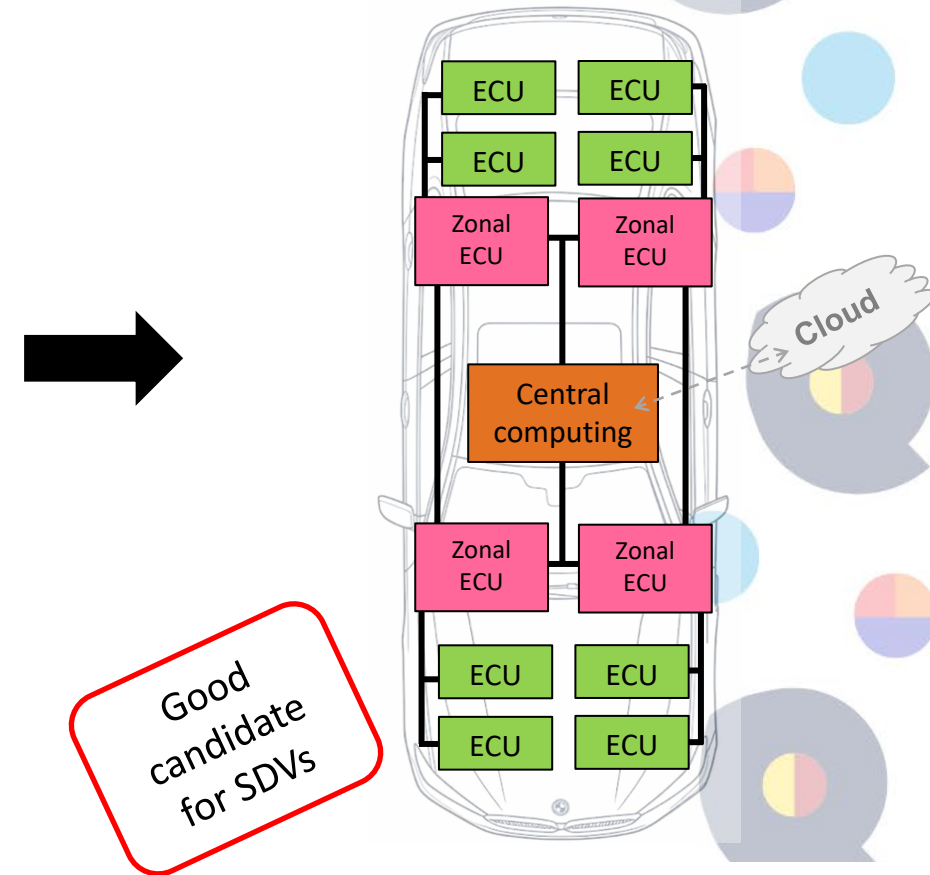
1 function = 1 Elec. Control Unit
(complex and high wiring costs)

Domain centralized architecture
(Today's vehicles)



ECUs grouped by domains
(e.g., powertrain, infotainment)

Zonal centralized architecture
(Tomorrow's vehicles)



ECUs organized by physical
zones (e.g., front, rear)

Outline

1. Horizon Europe CODE4EV Project
2. Application to Use Case II:
Health Monitoring & Predictive Maintenance



Funded by
the European Union



1. Horizon Europe CODE4EV Project

2. Application to Use Case II: Health Monitoring & Predictive Maintenance

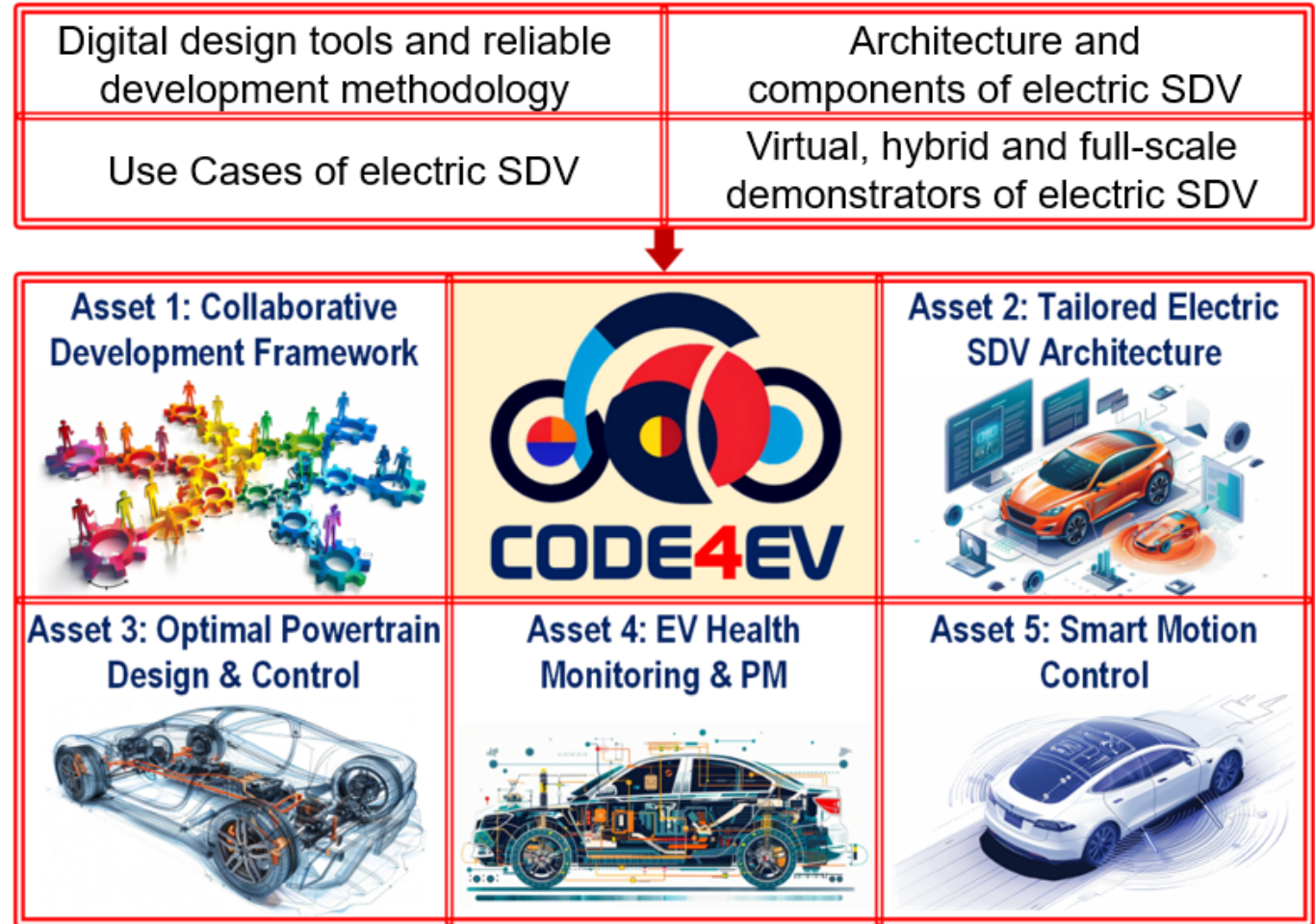


Objective of the project

CODE4EV

COllaborative **D**evelopment
Framework **for** Electric
Software-defined **V**ehicles

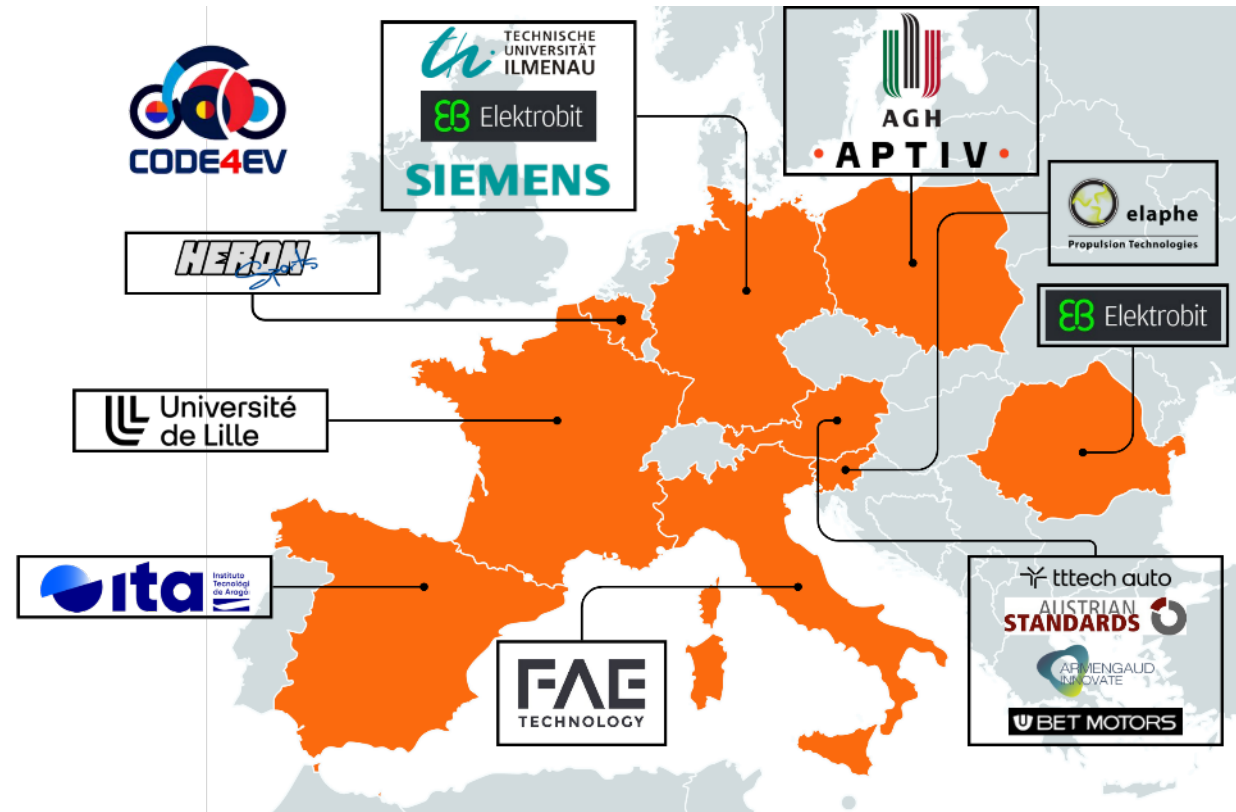
Overall goal: a shared digital
toolset for the design,
production and operation
phases of e-SDVs
→ cross-company
collaboration



5 Assets: resources that contribute to the success and value of the project

Consortium of the project

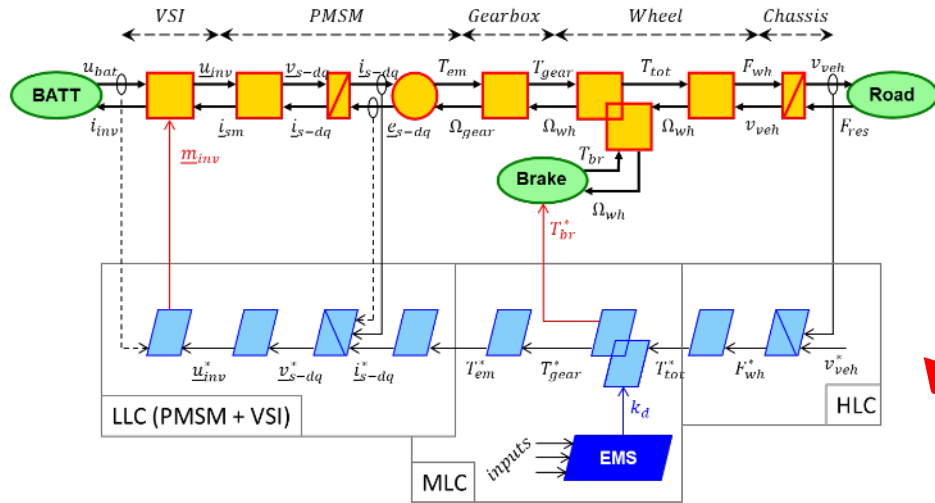
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- Coordinator: Tech. Univ. Ilmenau, Germany
- 15 partners from 9 countries
(Tier suppliers, SW developers,
Large & Small enterprises, Research groups)
- Project duration: 3 years (2025-2027)
- Total cost ~ 5 M 

A collaborative development framework

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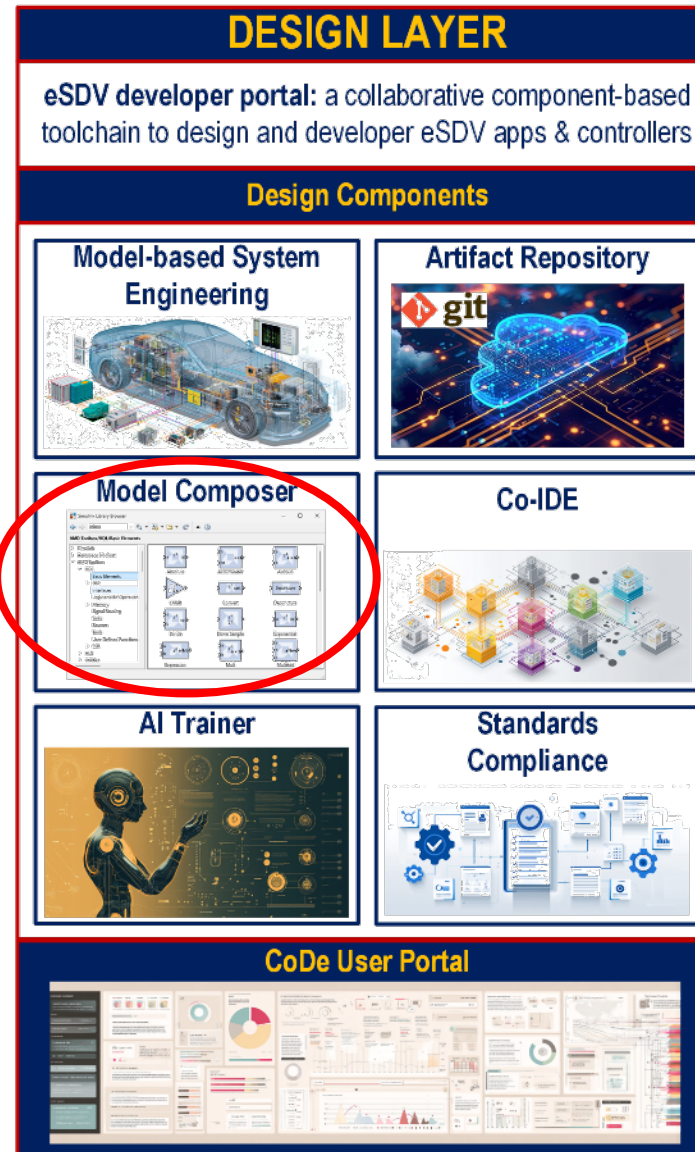
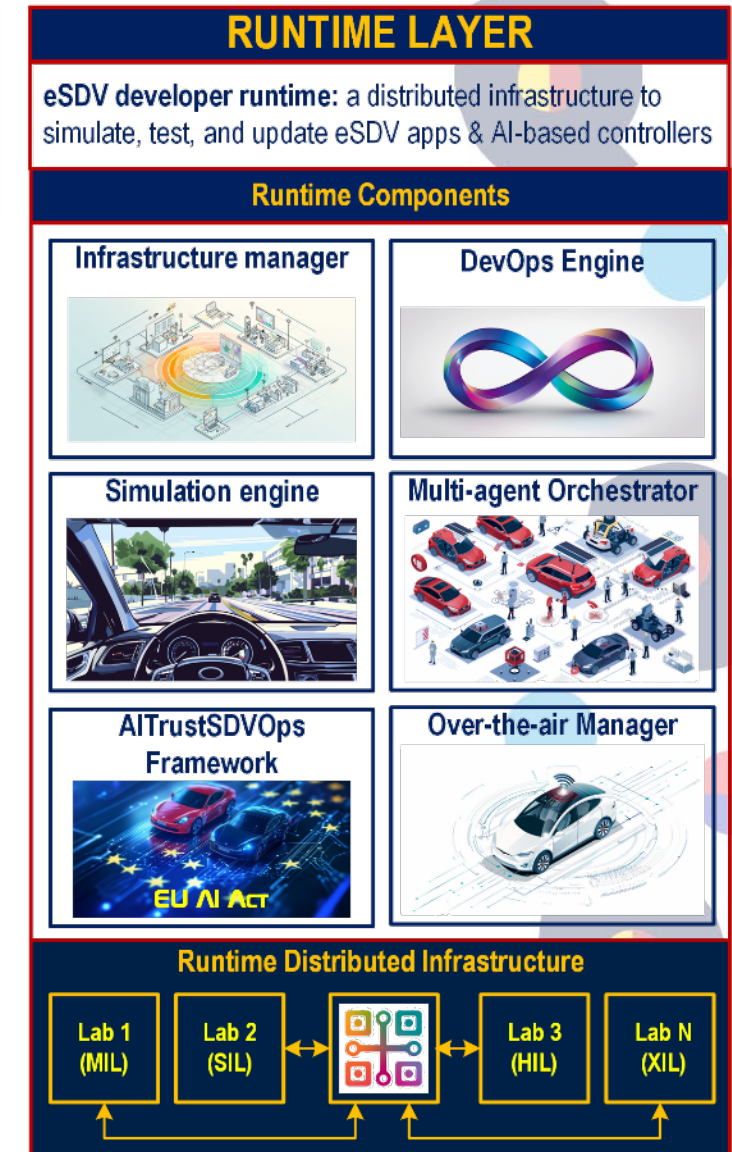
Energetic Macroscopic Representation



From EU project



SDV becomes an engineering framework for continuously optimising both SW and the physical EV



CODE4EV

1. Horizon Europe CODE4EV Project

**2. Application to Use Case II:
Health Monitoring & Predictive Maintenance**



Predictive Maintenance for SDVs

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Corrective

- Fix parts only after they break
- No early costs
- Unplanned downtime / car stops on the road



Scheduled

- Changing parts early
- Early alerts
- Safe



Predictive

- Monitor health & repair just in time
- Early alerts / Planned repairs.
- Saves money and prevent damage.

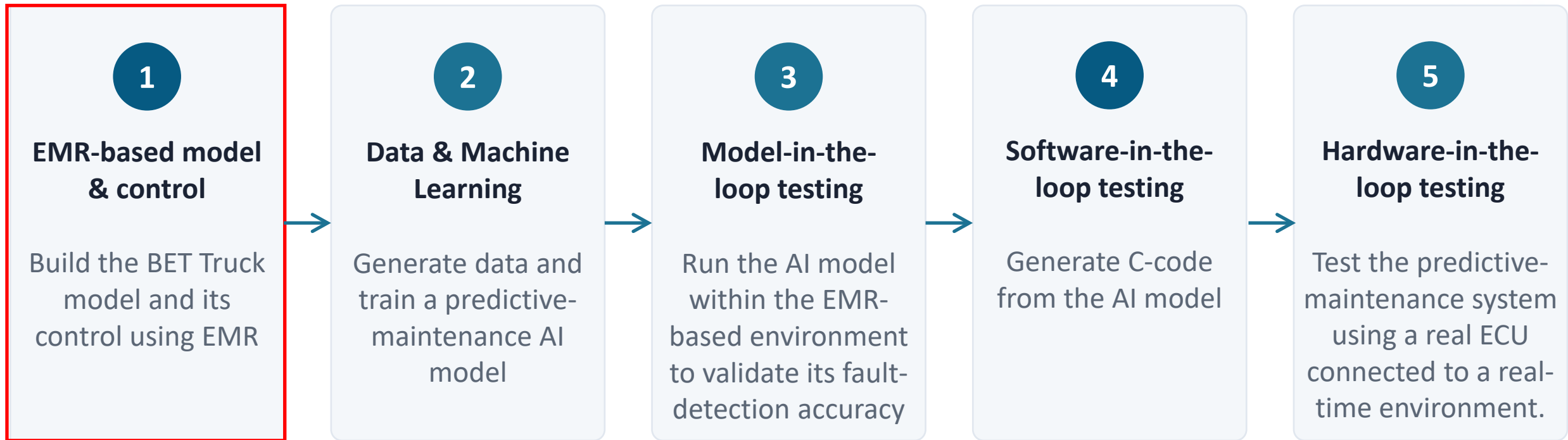
Both the battery and axle-drive units
are key components of electric vehicles

Catch small problems early avoid major breakdowns

SDVs enable real-time predictive maintenance through
continuous ECU and sensor telemetry

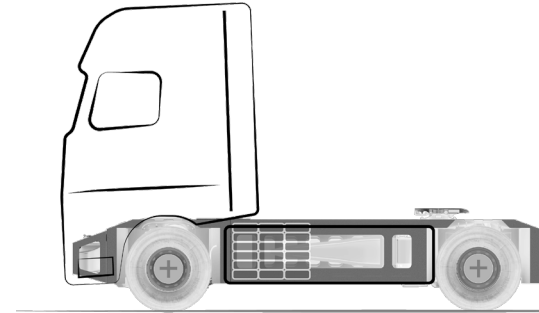
Methodology overview

Five steps take the project from a simulated vehicle model
to a real-time Hardware-in-the-Loop test



Key Assumptions of the Model for UC2

1. Straight-line (longitudinal axis – 1 DoF)
2. Same speed for both axles (no turning)
3. Equivalent front-axle drive unit instead of using two axle drive units



Tractor truck with two axles

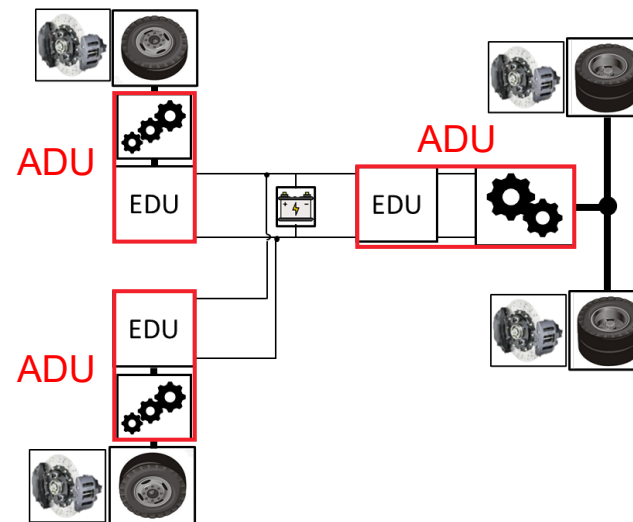
Axle Drive Units – ADU
(Integrated VSI, EM, and gearbox)

 **BET MOTORS**

Front axle:

2 tires

1 ADU per side with
2-speed gearbox per side



Rear axle:

4 tires/twin tires

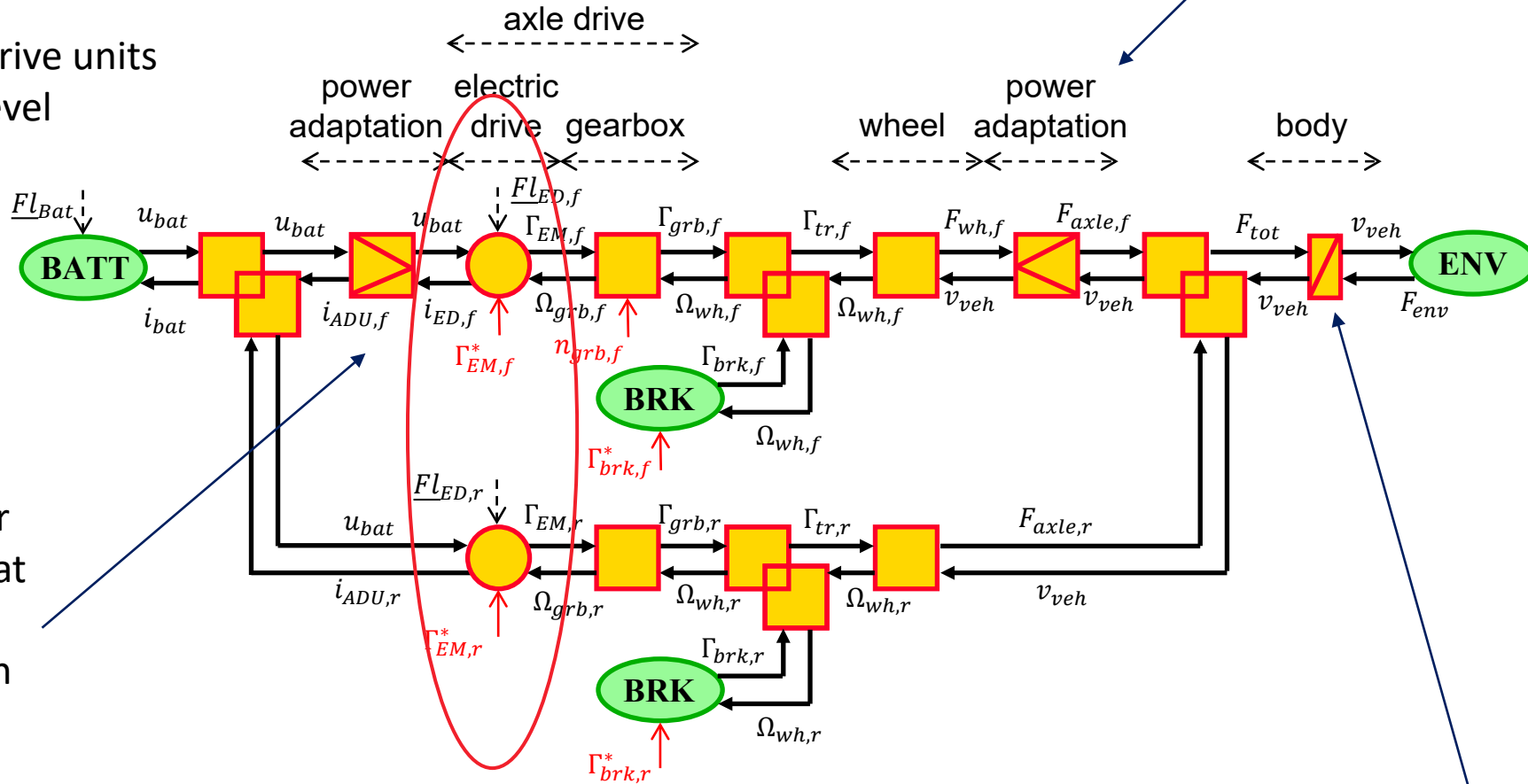
1 ADU with 1-speed gearbox

CODE4EV

EMR-based model of the BET

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Battery and electric drive units
presented at a high level
(single pictograms)



Identical controls for
the axle drive units at
the front axle
→ Power adaptation
elements with a
power factor of 2

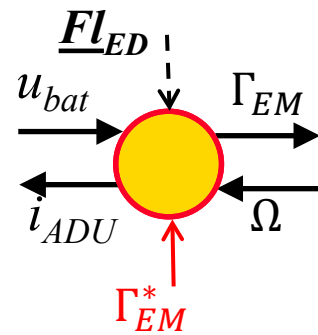
$$\begin{cases} i_{ADU,f} = 2 i_{ED,f} \\ \text{same } u_{bat} \end{cases}$$

$$\begin{cases} F_{axle,f} = 2 F_{wh,f} \\ \text{same } v_{veh} \end{cases}$$

$$v_{veh} = \frac{1}{M_{veh}} \int_0^t (F_{tot} - F_{env}) dt$$

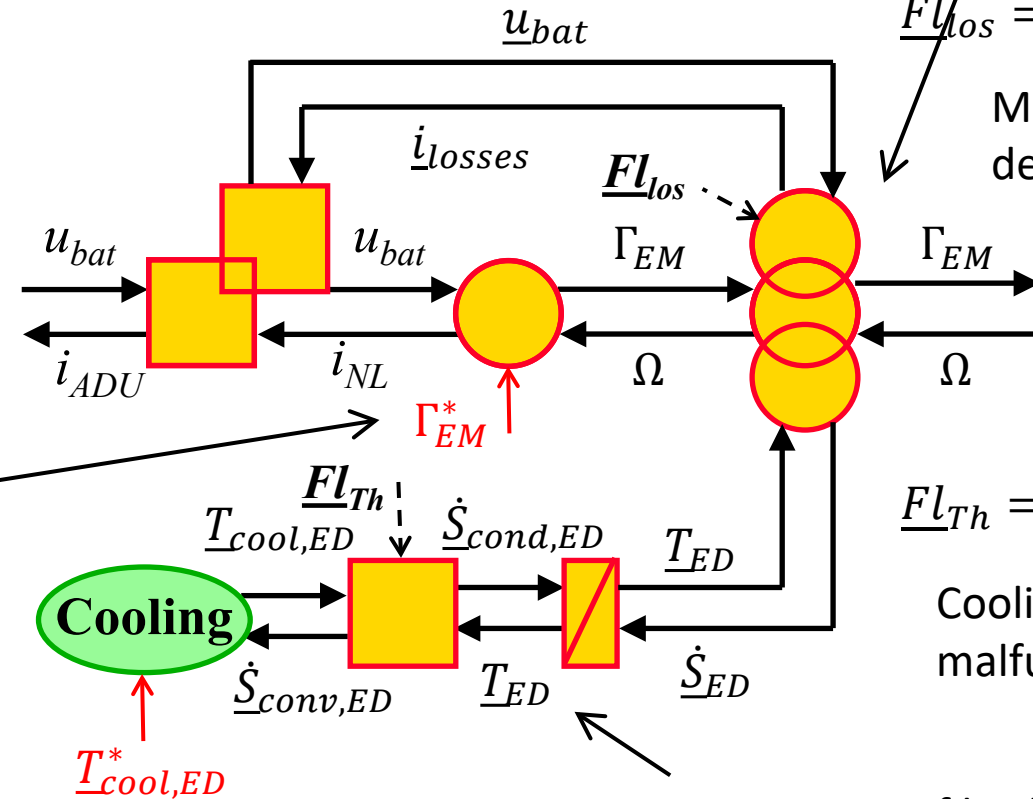
EMR-based model – Electric Drive

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Ideal electric drive
(no losses)

Failure Injections



Temperatures of both inverter
and electrical machine

Losses of both inverter and
electrical machine
function of Γ_{EM} , Ω , u_{bat} and
 $\underline{T}_{ED}$ (T_{EM} and T_{VSI})

$$\underline{Fl}_{los} = \begin{bmatrix} \Delta P_{EM,los} \\ \Delta P_{VSI,los} \end{bmatrix}$$

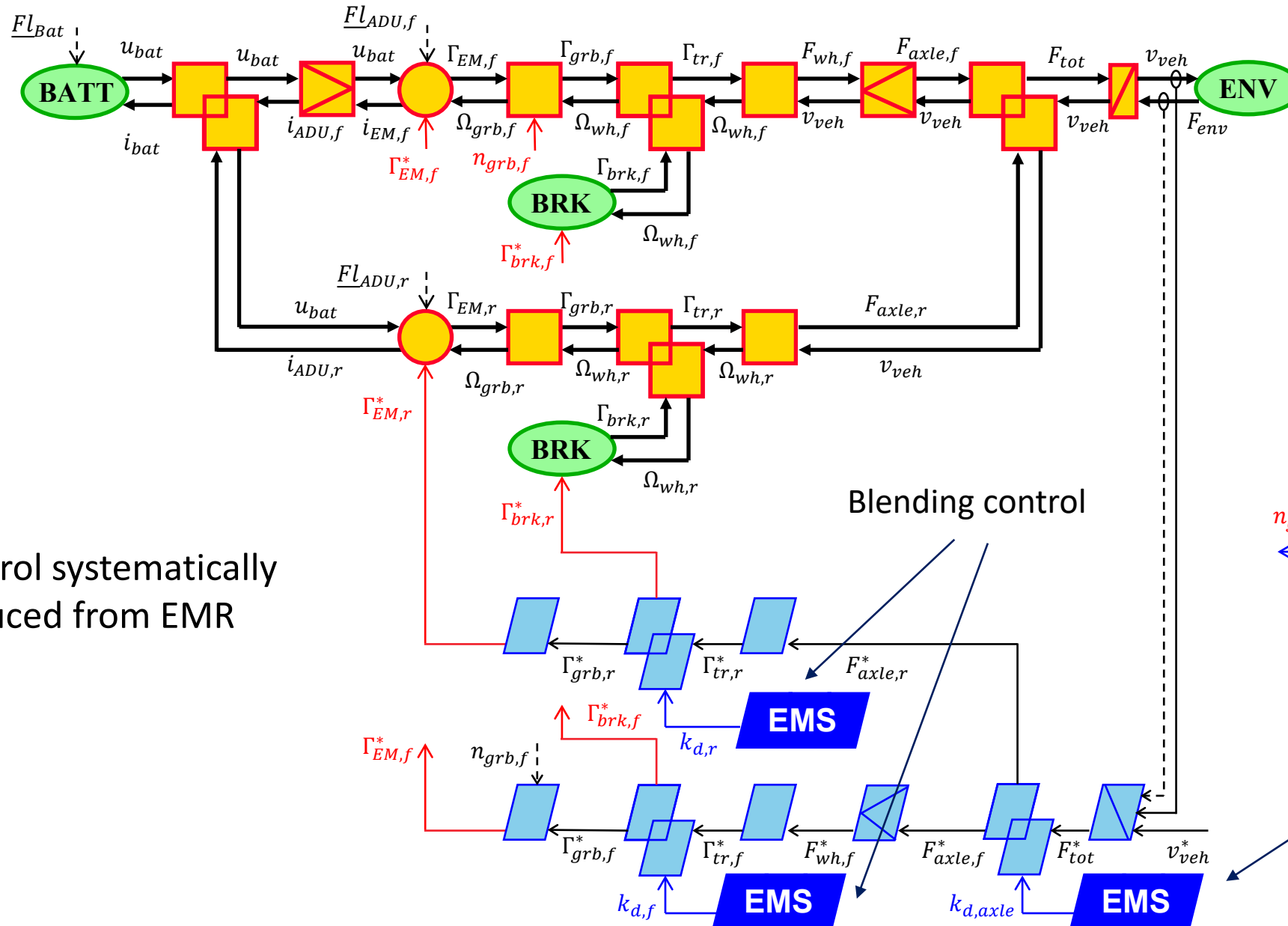
Motor & Inverter
degradation

$$\underline{Fl}_{Th} = \begin{bmatrix} \Delta R_{Th,EM} \\ \Delta R_{Th,VSI} \end{bmatrix}$$

Cooling
malfunction

EMR and inversion-based control of the BET

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Control systematically deduced from EMR

Strategy to select the gear of the 2-speed gearbox

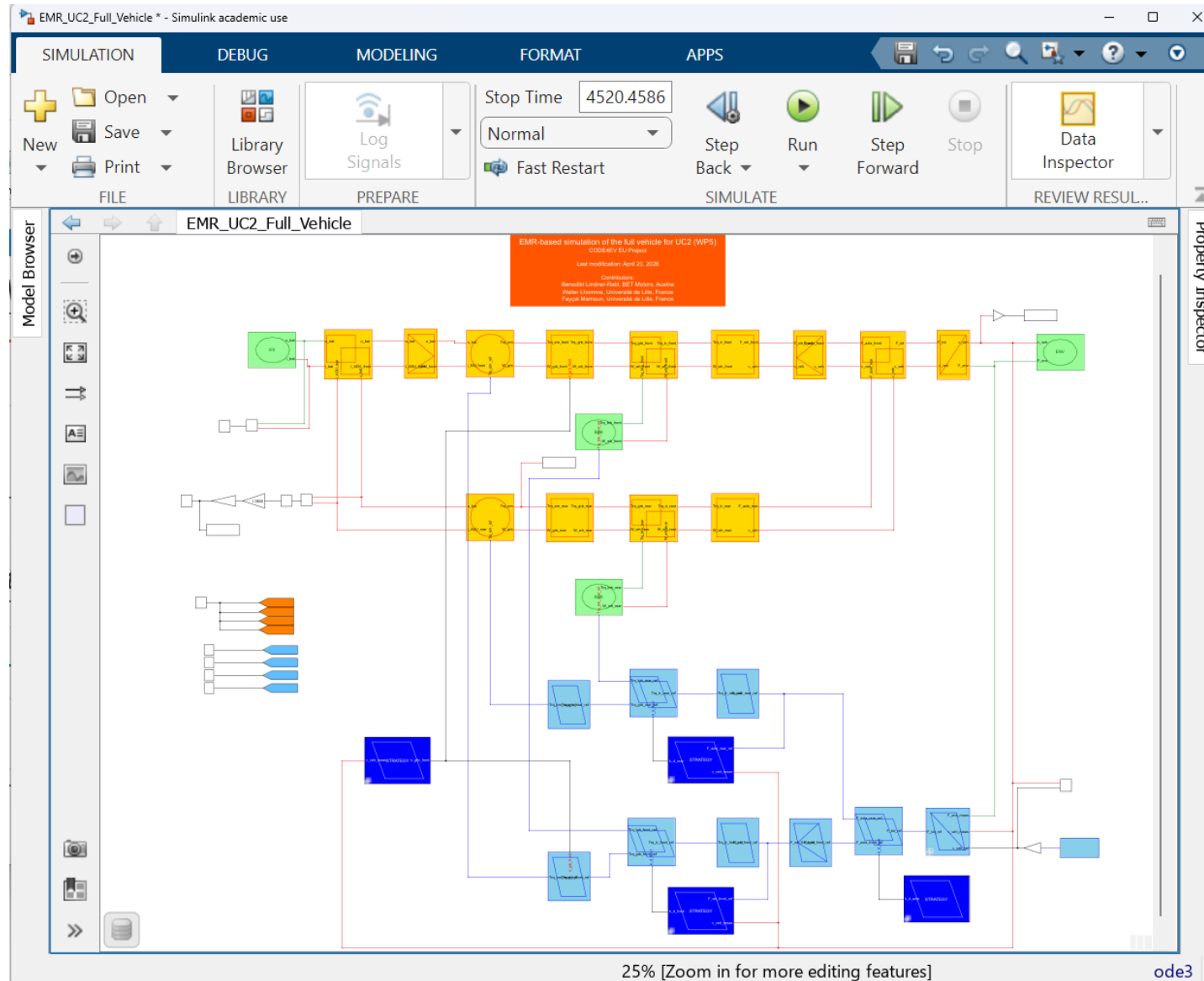
$n_{grb,f}$ **Grb,f**

Power split between front and rear axles

CODE4EV

EMR Implementation in MATLAB-Simulink

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Direct implementation
using the EMR library of
MATLAB-Simulink

Expected impacts of CODE4EV

- **Scientific and technological impact**

- new digital tools for efficient development of complex systems (EMR as methodological model composer)
- new AI-based functionalities of electric vehicles (relevance to powertrain and motion control)
- works for all electric vehicles: from regular cars to trucks and two-wheelers

- **Economic impact**

- reduction (20%) of energy consumption for electric vehicles
- reducing integration efforts (30%), time-to-market (30%), and validation efforts (20%) in the development process of electric vehicles

- **Societal impact**

- reduction of GHG and emissions (better energy management)
- better road safety (smart motion control)



Let's shape the future. Together.



**Funded by
the European Union**



www.code4ev.eu



<https://www.linkedin.com/company/code4ev/>



<https://zenodo.org/communities/code4ev/>

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