Cloud-based Co-simulation for PHEV Powertrain Development Support

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Agenda

- Motivation
- Introduction to FEV simulation methodology
- Methodology for Powertrain optimization
- Exemplary Use-Cases
- Outlook and conclusions

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- **Motivation**
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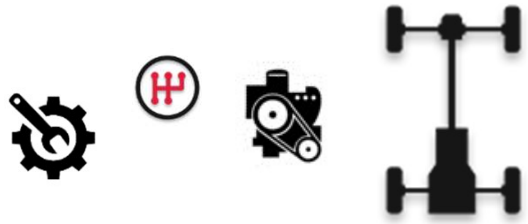
Motivation for virtual engine and vehicle solutions
How to introduce simulation for powertrain calibration?

CHALLENGES

- Increasing complexity of powertrain and engine



- Various environment conditions (high altitude, summer/winter tests) need to be investigated

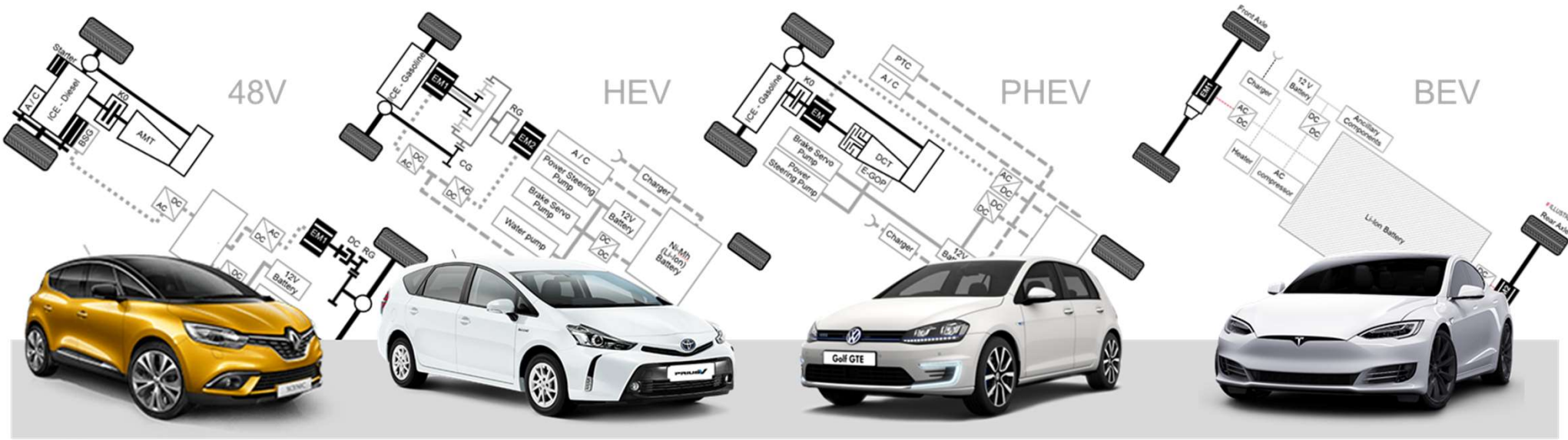
Simulation as a relevant mean for Powertrain development support

- Lack of prototype vehicles/engines and increased text matrix for vehicle/engine derivative validation

- Reduction in calibration effort is needed to get cost efficient products

Motivation for virtual engine and vehicle solutions
System engineering is essential to guarantee the best fitting product

TRENDS SHOW THERE IS NO SINGLE SOLUTION ON THE MARKET. NO SINGLE BEST!



Source: FEV, Pictures from manufacturer websites

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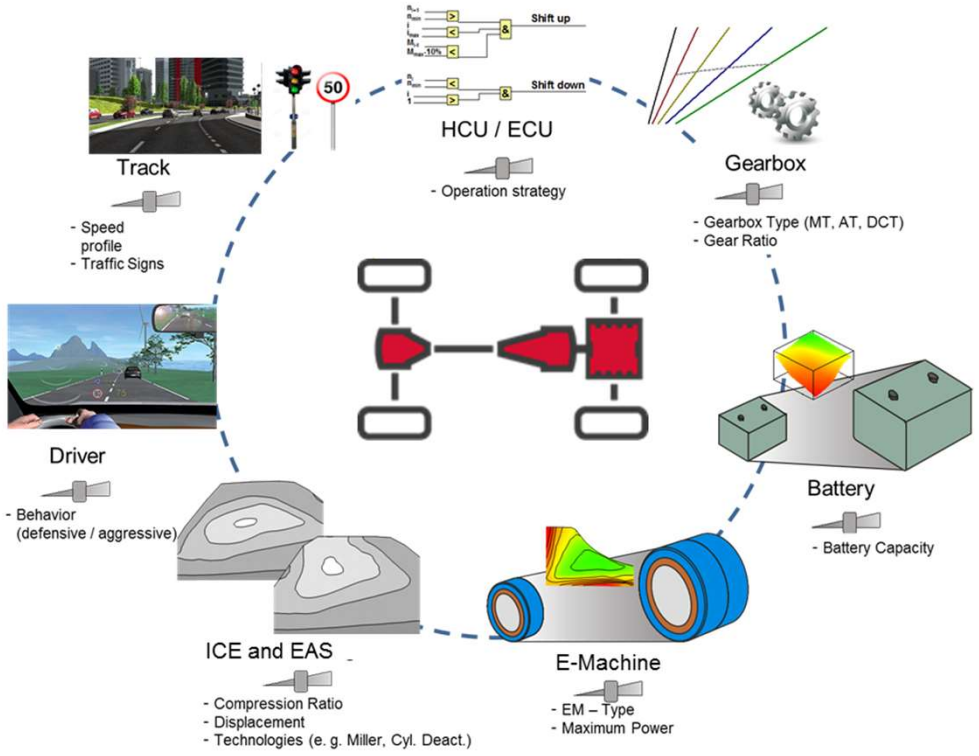
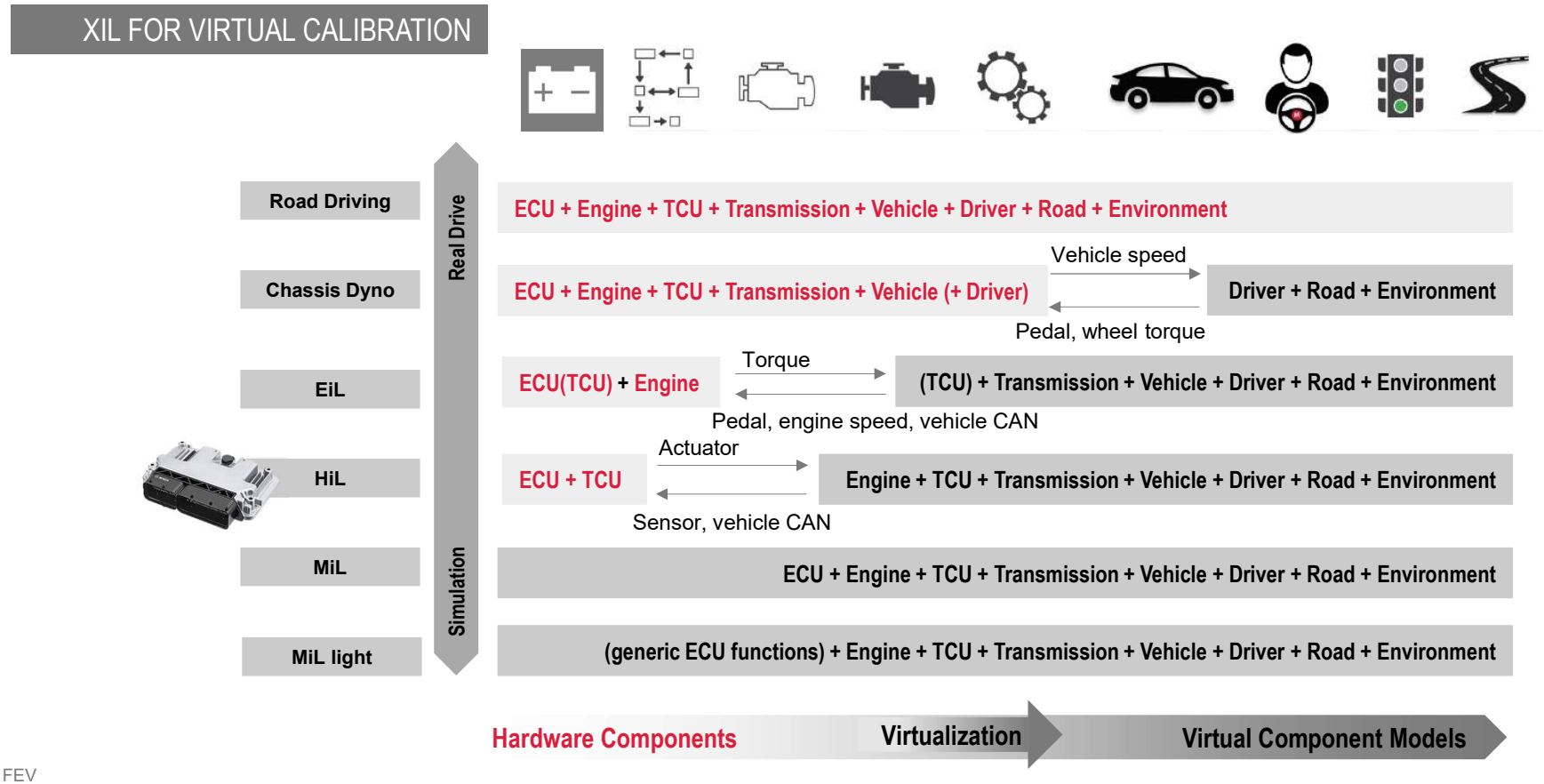
Introduction to FEV simulation methodology
Integrated approach for fuel consumption and performance simulation

UNIQUE PLATFORM SUPPORTING THE COMPLETE POWERTRAIN DEVELOPMENT PROCESS



- For precise fuel consumption simulation, all components and influences have to be modeled and simulated in correct way
- Fully flexible architecture definition (conventional, HEV P0, P1, … , P4, Plug-In) as well as target missions
- Complete, fully Integrated Powertrain Development Methodology supporting the development process:
  1. Targets definition
  2. System definition
  3. System calibration

Introduction to FEV simulation methodology
Level of virtualization



Source: FEV

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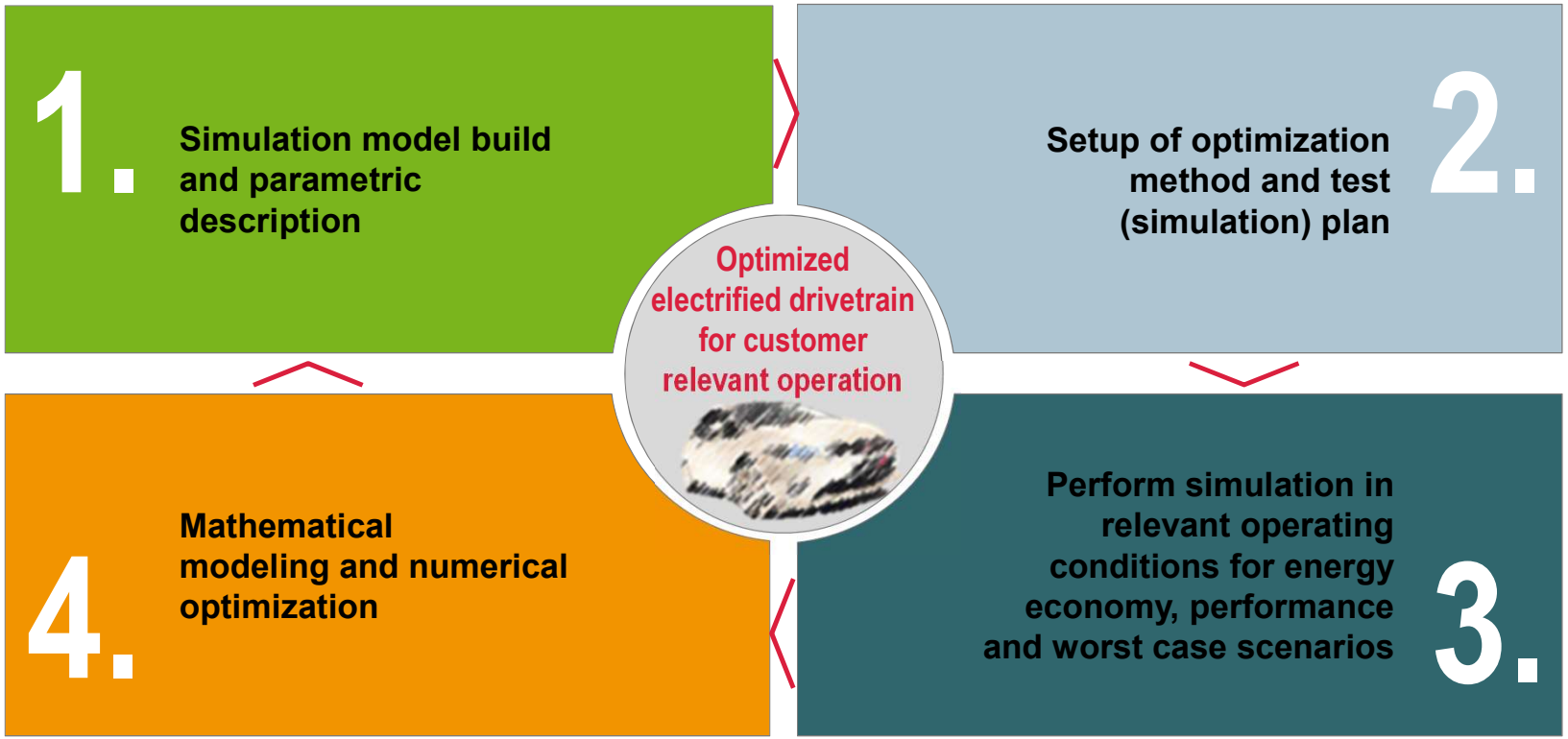
Methodology for Powertrain optimization
FEV's Drivetrain Optimization Tool (DOT) - Approach for Simulation & Optimization

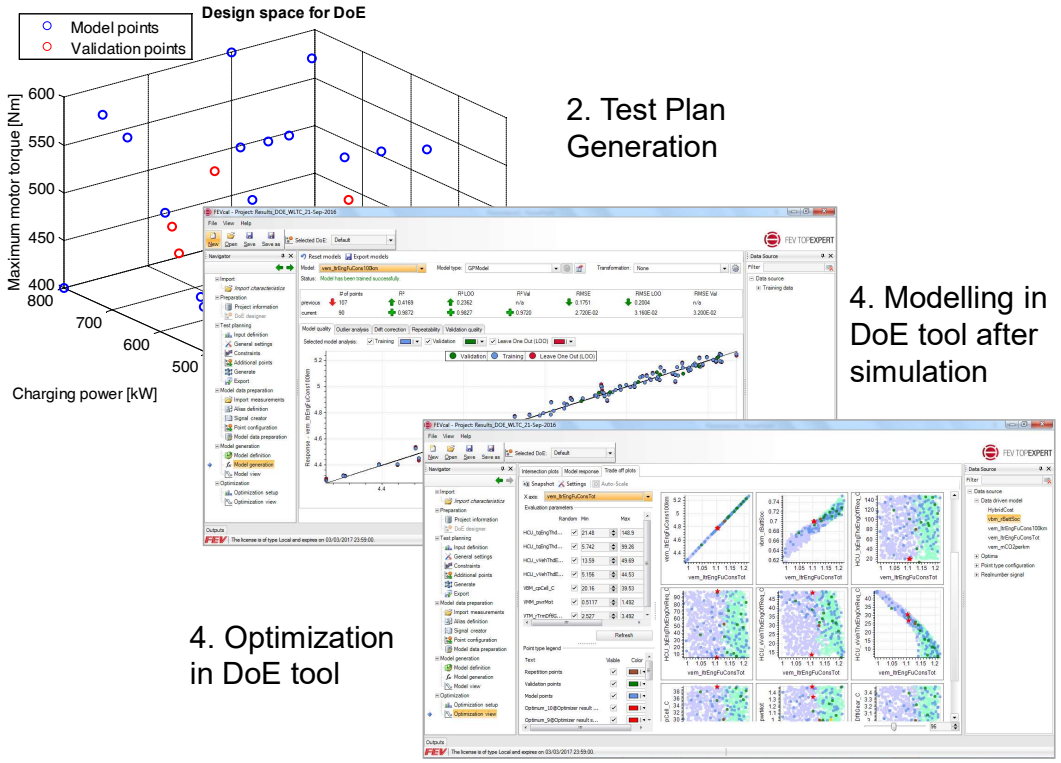
TARGET: OPTIMIZATION OF HYBRID AND ELECTRIC POWERTRAINS FOR CUSTOMER RELEVANT OPERATION



Source: FEV

Methodology for Powertrain optimization
FEV's Drivetrain Optimization Tool (DOT) - Approach for Simulation & Optimization

EXAMPLE: WORK PROCESS USING DOE TOOL AND MATLAB/SIMULINK



4-step approach

- Step 1: model set up
- Step 2: test plan generation
- Step 3: execution of Simulations
- Step 4: modelling and Optimization
  - Modelling in DoE tool* after simulation
  - Optimization in DoE tool
  - Re-run Optima

*FEV applies in-house developed TOPExpert - xCal tool

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  1. Identification of worst case RDE cycle by simulation
  2. PHEV Powertrain Development Support via CRT – FEV MiL cosimulation
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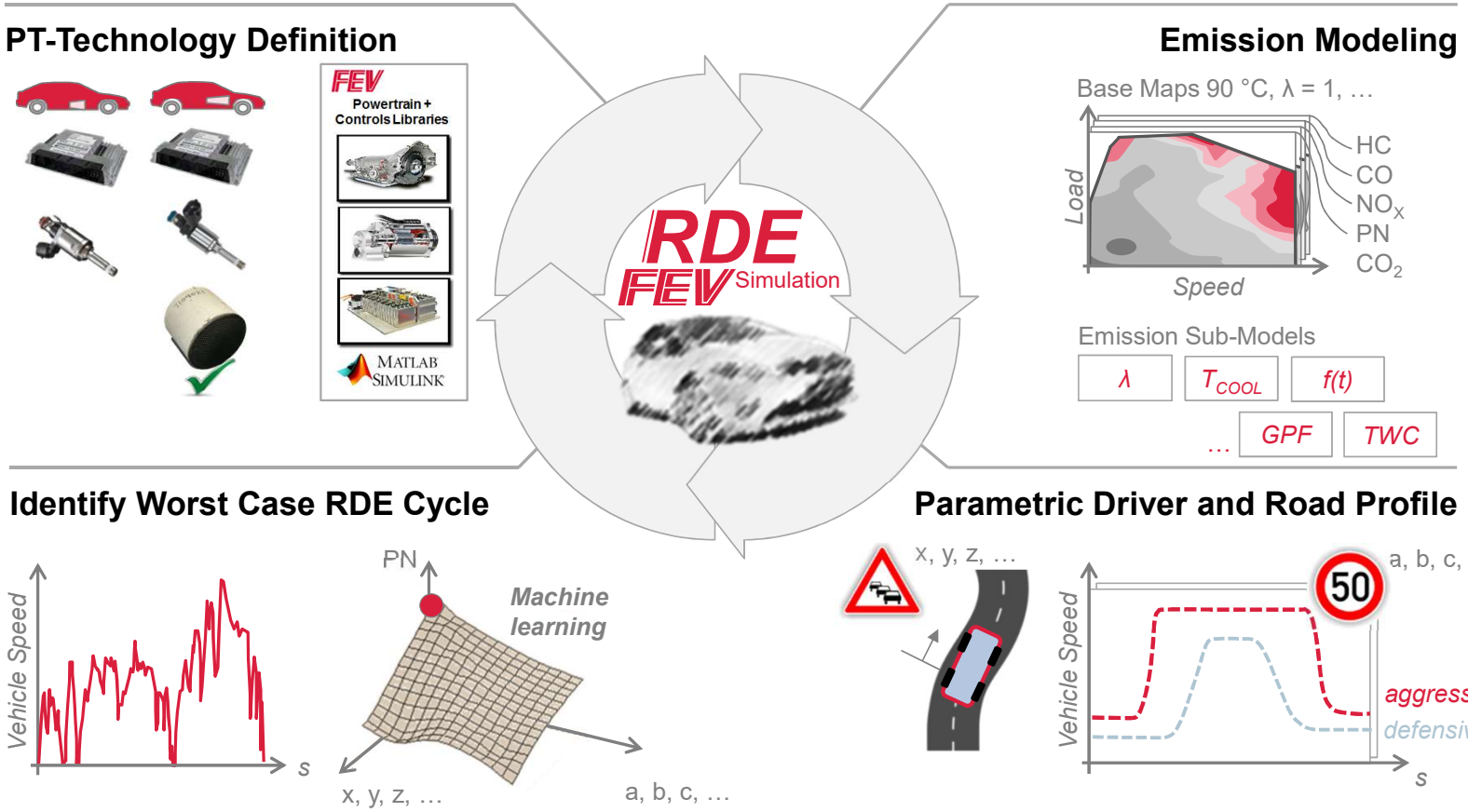
Use-case #1
Identification of worst case RDE cycle by simulation



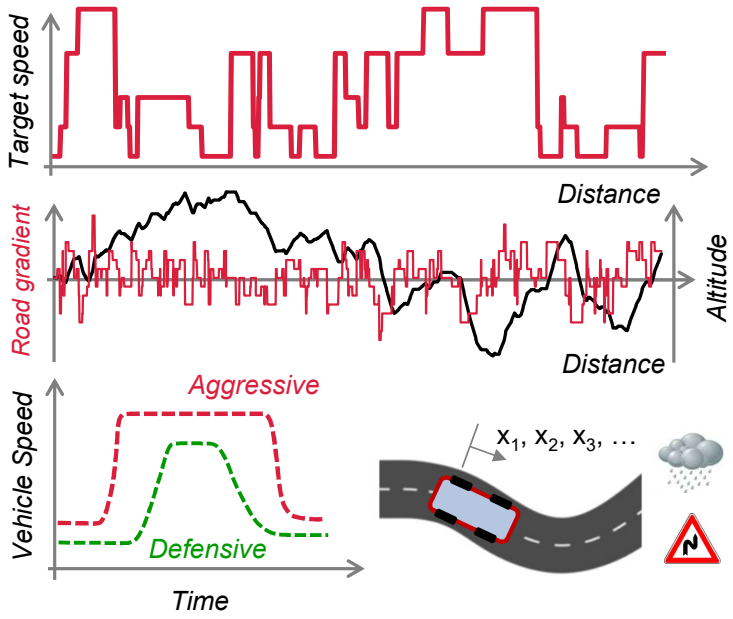
Use-case #1
Parametric Description of Driver, Route and Ambient Conditions

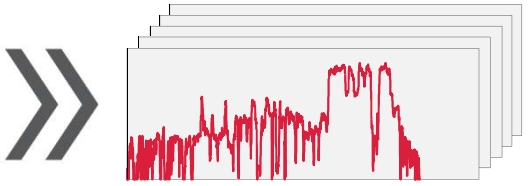
Input parameters:

- Road profile
  - Target speed distribution
    - Probabilities for succeeding speed limit, function of current speed
  - Road gradient
  - Stops in urban, rural, motorway driving
- Driver
  - Aggressiveness
  - Tolerance to speed limit
  - Following behavior
- Others (ambient conditions…)
- In this case example: Σ = 17 parameters

Output:

- Several hundred RDE scenarios incl. simulated tailpipe emissions



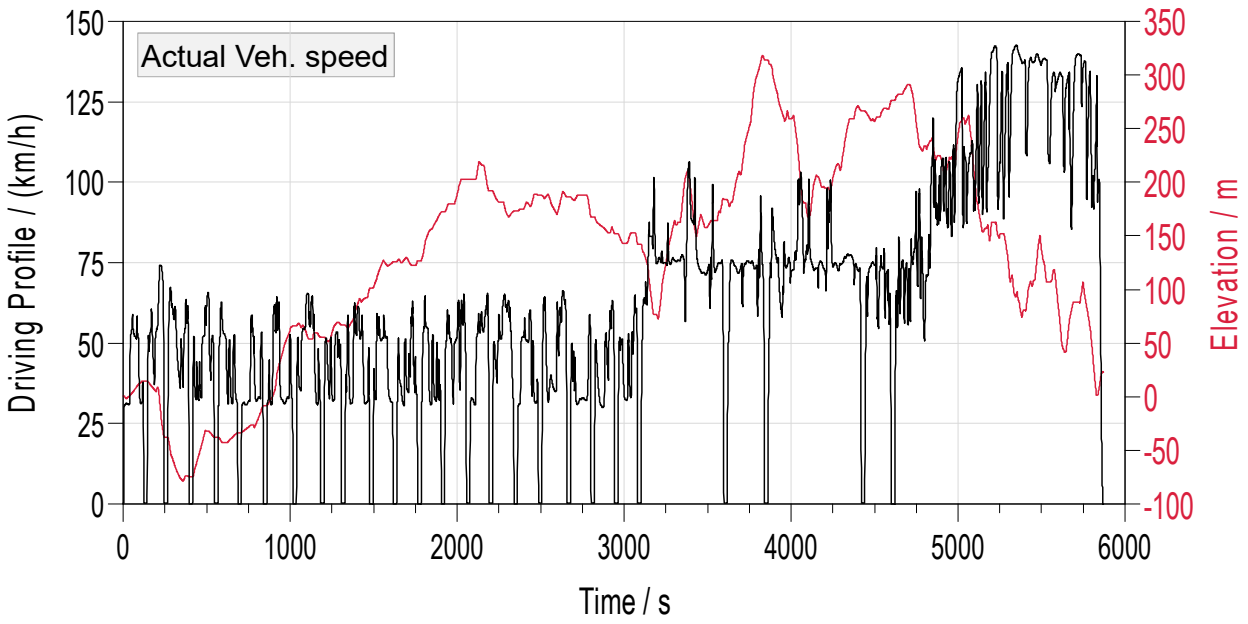


+ Boundary conditions

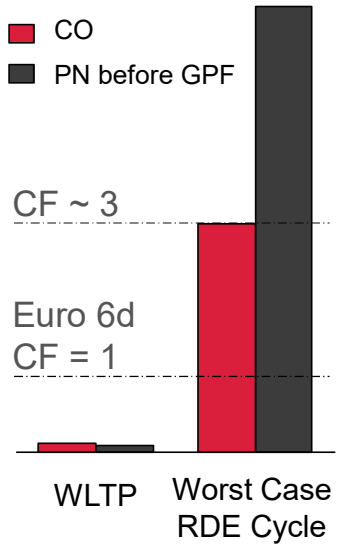
Road gradient source : ECE/TRANS/SC.1/2016/3/Rev.1

Use-case #1
Result of Target speed profile and driver influence

RDE SIMULATION APPROACH – CYCLE GENERATION



- The speed limits together with the vehicle elevation can be varied in a DoE approach in order to investigate the conditions that lead to a worst case cycle



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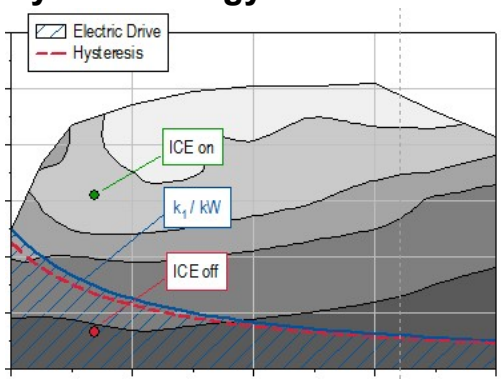
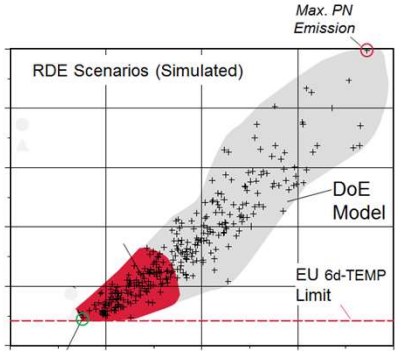
Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

Hybrid strategy Definition



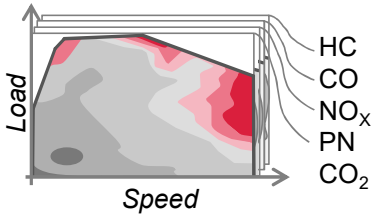
Strategy Impact Evaluation on Emissions and Performances



RDE FEV Simulation

FEV Emission Modelling

Base Maps 'Warm'



Emission Sub-Models

λ | T_{COOL} | … | TWC

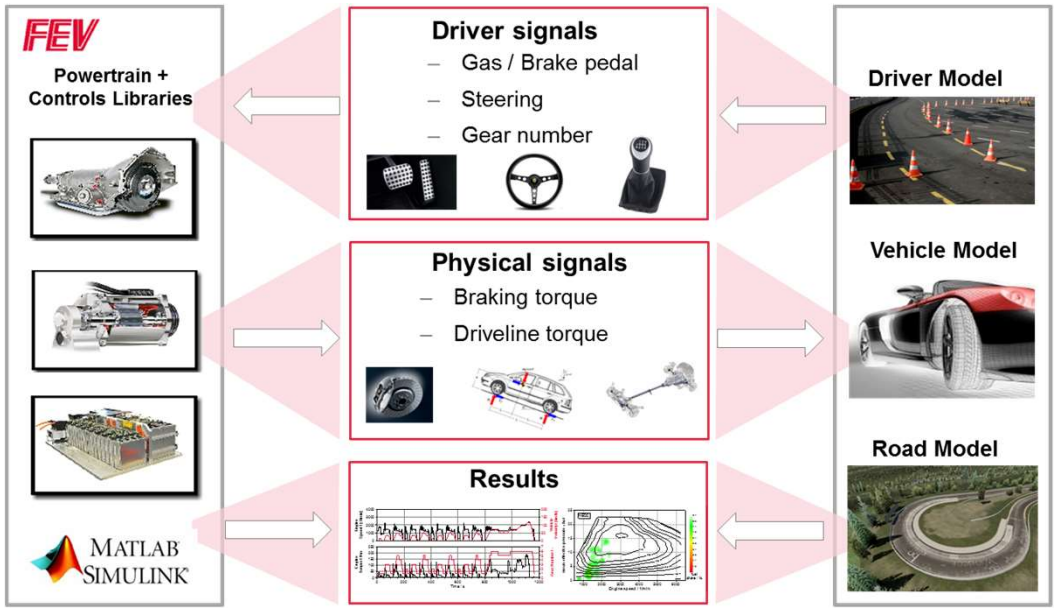
VI-CarRealTime: Vehicle + Driver
SCANeR: Route, Ambient

VI-GRADE

OKTAL >> SIMULATION IN MOTION

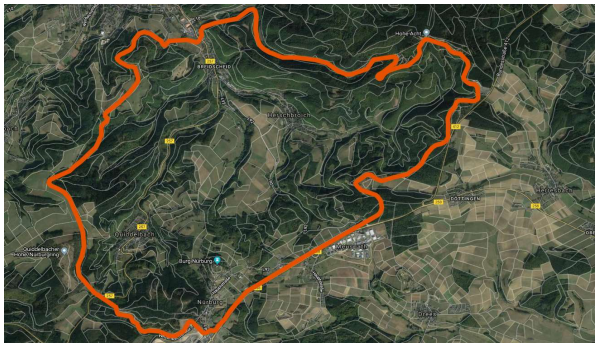
Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

CLOUD-BASED INVESTIGATION (RESCALE) – VEHICLE MODEL (VI-CRT) + MIL POWERTRAIN MODEL (FEV)



- **RDE Bologna → Emissions**

- **Nürburgring Nordschleife → Performance**



Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

CLOUD BASED INVESTIGATION

Investigation Experiment
■ Step 1: Driveline Model Plugin
■ Step 2: Investigation Definition
■ Events
■ Factors
■ Metrics
■ Step 3: Cloud Simulation Job
■ Step 4: Post-processing

Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

CLOUD-BASED VI-CRT – FEV MIL POWERTRAIN MODEL – RDE BOLOGNA

Test Case Data	Length	Duration	Output step
Bologna RDE	84 Km	6400 sec	0.1 sec

Model Parameters	Units	Base	Min	Max
Electric Drive On Minimum SOC Threshold	%	24	20	28
Electric Drive On Minimum Speed Threshold	km/h	122	100	140
Electric Drive Shift On Threshold	%	30	30	90
Initial SOC	%	25	25	25
Electric Drive Performance Mode	-	Off	Off	Off
Front Suspension Camber Angle Variation	deg	-	0.0	0.0
Rear Suspension Camber Angle Variation	deg	-	0.0	0.0
Anti Roll Stiffness Rear/Front Balance	%	75.0%	75.0%	75.0%

Investigation	Investigation Type	Factors	Size
Bologna RDE	Full Factorial	3	180

Cloud Investigation	Value
Hardware Type	Onyx
Number of Cores Per Slot	1
Number of Simultaneous Slots	15
Setup Overhead	8 min
Computation Time	5h 54
Result data size	480Gb

Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

CLOUD-BASED VI-CRT – FEV MIL POWERTRAIN MODEL – NÜRBURGRING NORDSCHELEIFE

Test Case Data	Length	Duration	Output step
Nordscheleife	20.854 Km	485 sec	0.01

Model Parameters	Units	Base	Min	Max
Electric Drive On Minimum SOC Threshold	%	24	24	24
Electric Drive On Minimum Speed Threshold	km/h	122	122	122
Electric Drive Shift On Threshold	%	30	30	90
Initial SOC	%	25	25	75
Electric Drive Performance Mode	-	Off	On	On
Front Suspension Camber Angle Variation	deg	-	-0.5	0.5
Rear Suspension Camber Angle Variation	deg	-	-0.2	0.2
Anti Roll Stiffness Rear/Front Balance	%	75.0%	50.0%	100.0%

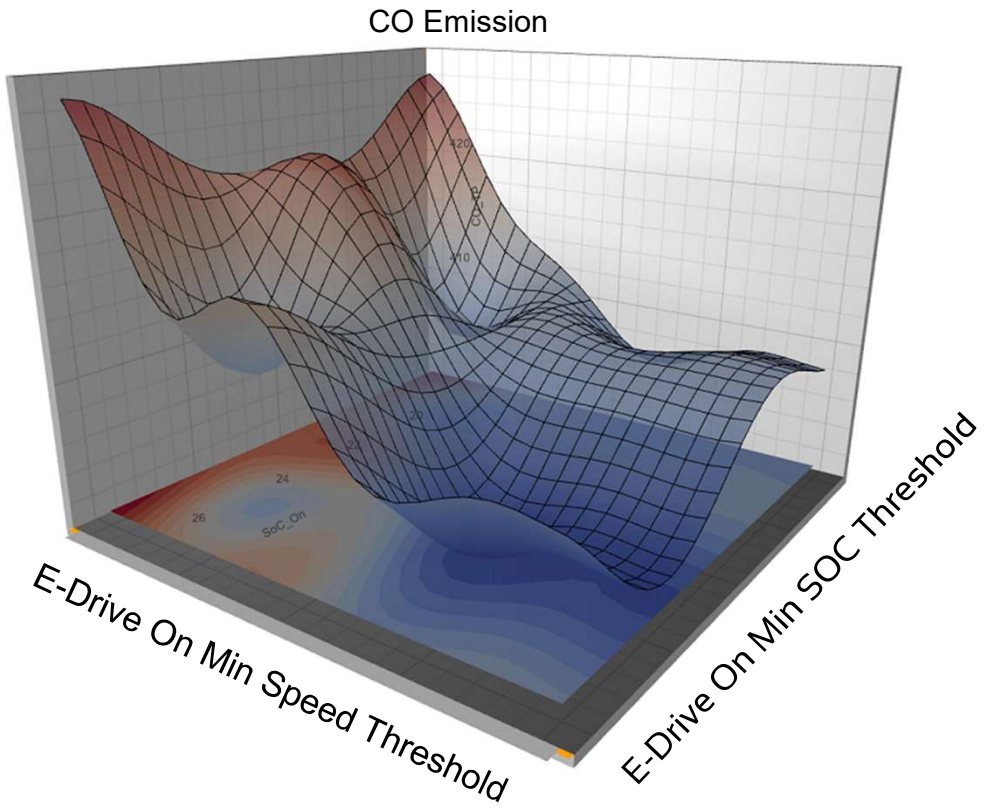
Investigation	Investigation Type	Factors	Size
Nordscheleife	Full Factorial	5	243

Cloud Investigation	Value
Hardware Type	Onyx
Number of Cores Per Slot	1
Number of Simultaneous Slots	15
Setup Overhead	8 min
Computation Time	1h 20min
Result data size	138 Gb

rescale

Use-case #2
Evaluation of hybrid strategy impact on emissions and performance

CLOUD-BASED VI-CRT – FEV MIL POWERTRAIN MODEL – RDE BOLOGNA RESULTS



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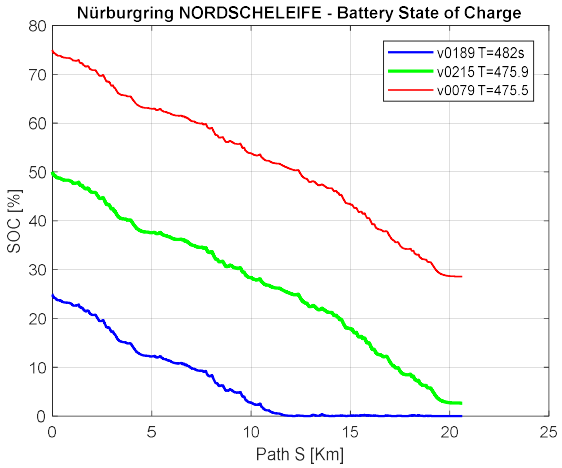
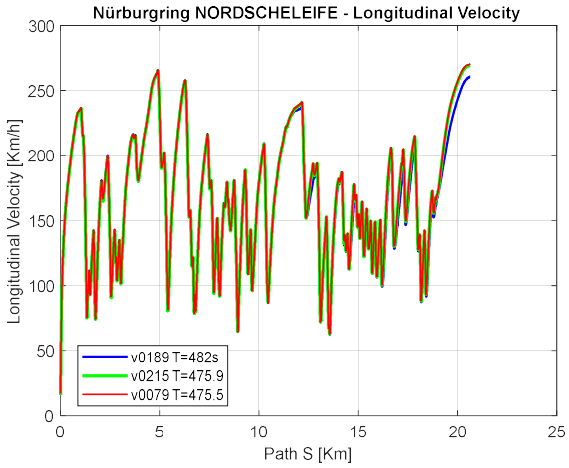
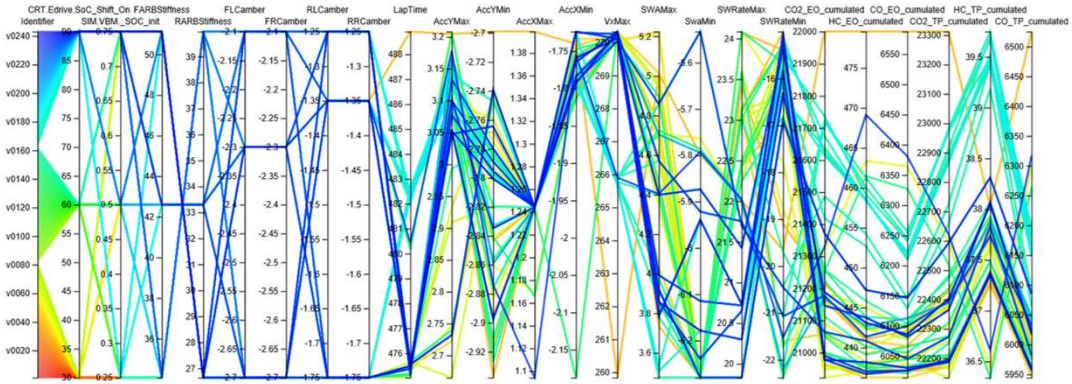
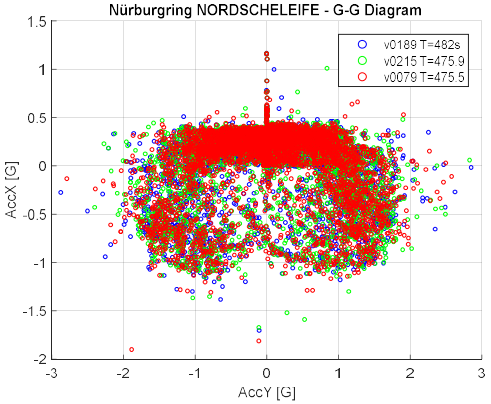
CLOUD-BASED VI-CRT – FEV MIL POWERTRAIN MODEL – NÜRBURGRING NORDSCHELEIFE RESULTS









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Outlook and conclusions

- Nowadays, due to the increasing complexity of powertrain and engine, a **fully Integrated Simulation-based Powertrain Development Methodology** is required to support efficiently the product development process
- A dedicated methodology for Powertrain simulation and optimization has been developed by FEV
- Two alternative exemplary Use-Cases have been presented:
  - Identification of worst case RDE cycle by simulation
  - PHEV Powertrain Development Support via CRT – FEV MiL cosimulation
- Within the second use-case, a Cloud-based investigation using RESCALE platform has been conducted by co-simulating VI-CRT vehicle model + FEV powertrain model
- The presented co-simulation platform allows the investiation of the complete system, providing information in terms of emissions and consumption as well as prediction of the impact of PWT parameters on vehicle perfomances

Thank you for your attention!

Contact details

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