MATLAB/SIMULINK BASED CROSS DOMAIN VEHICLE SIMULATION FOR EV SYSTEM ANALYSIS AND DEVELOPMENT
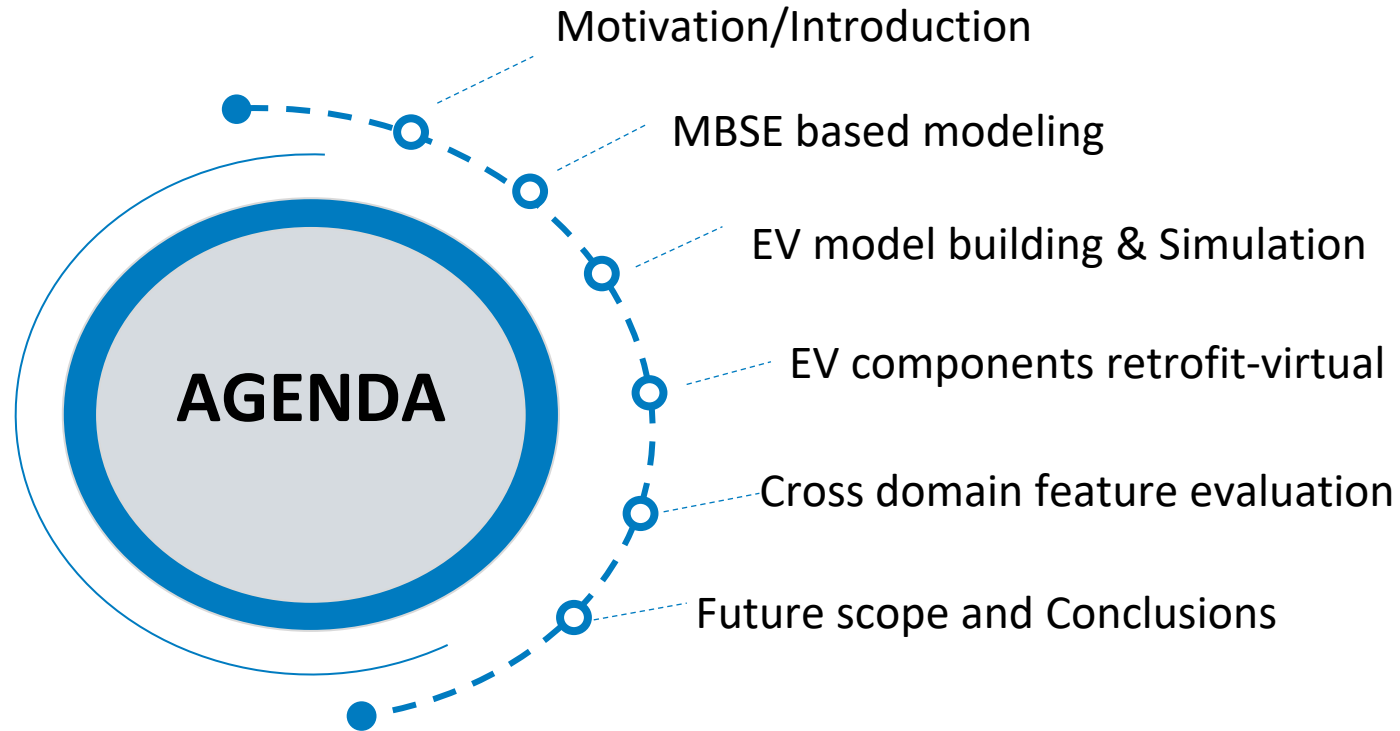
Aurobbindo L (PJ-CSS)

Dibakar M (PJ-CSS)

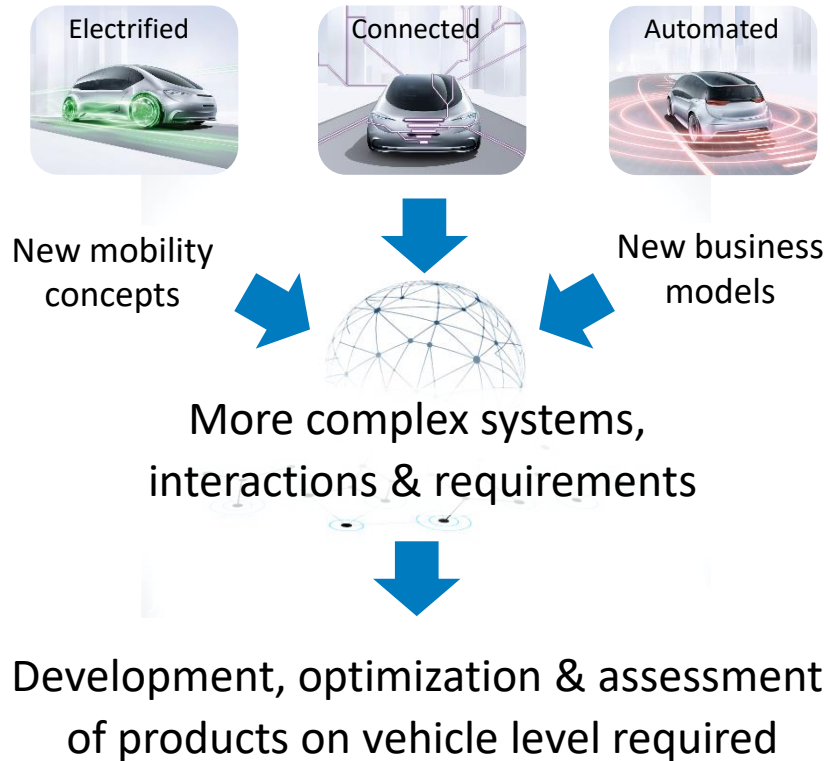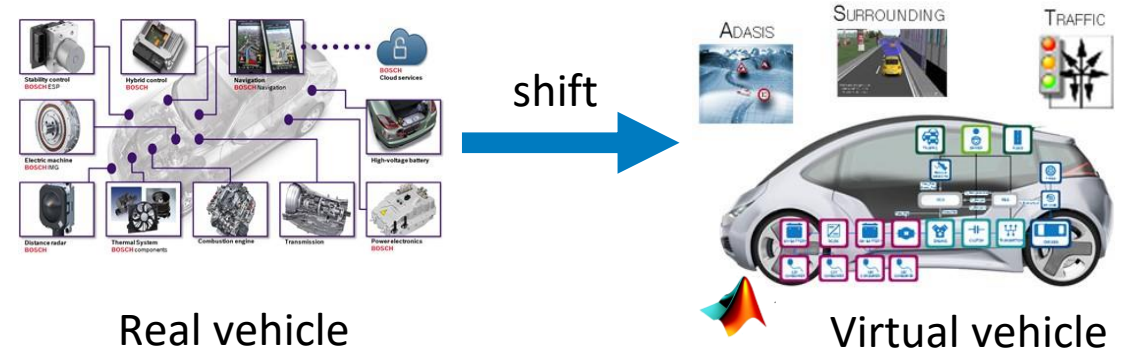**BOSCH**

MATLAB/Simulink based Cross domain vehicle simulation

Agenda

AGENDA

- Motivation/Introduction
- MBSE based modeling
- EV model building & Simulation
- EV components retrofit-virtual
- Cross domain feature evaluation
- Future scope and Conclusions

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Motivation

Challenge	Approach

Challenge

Electrified — New mobility concepts

Connected

Automated — New business models

More complex systems, interactions & requirements

Development, optimization & assessment of products on vehicle level required

Approach

Real vehicle   shift   Virtual vehicle

Benefits

❖ Early system Integration

❖ Cross domain feature evaluation

❖ Vehicle function potential benefit analysis

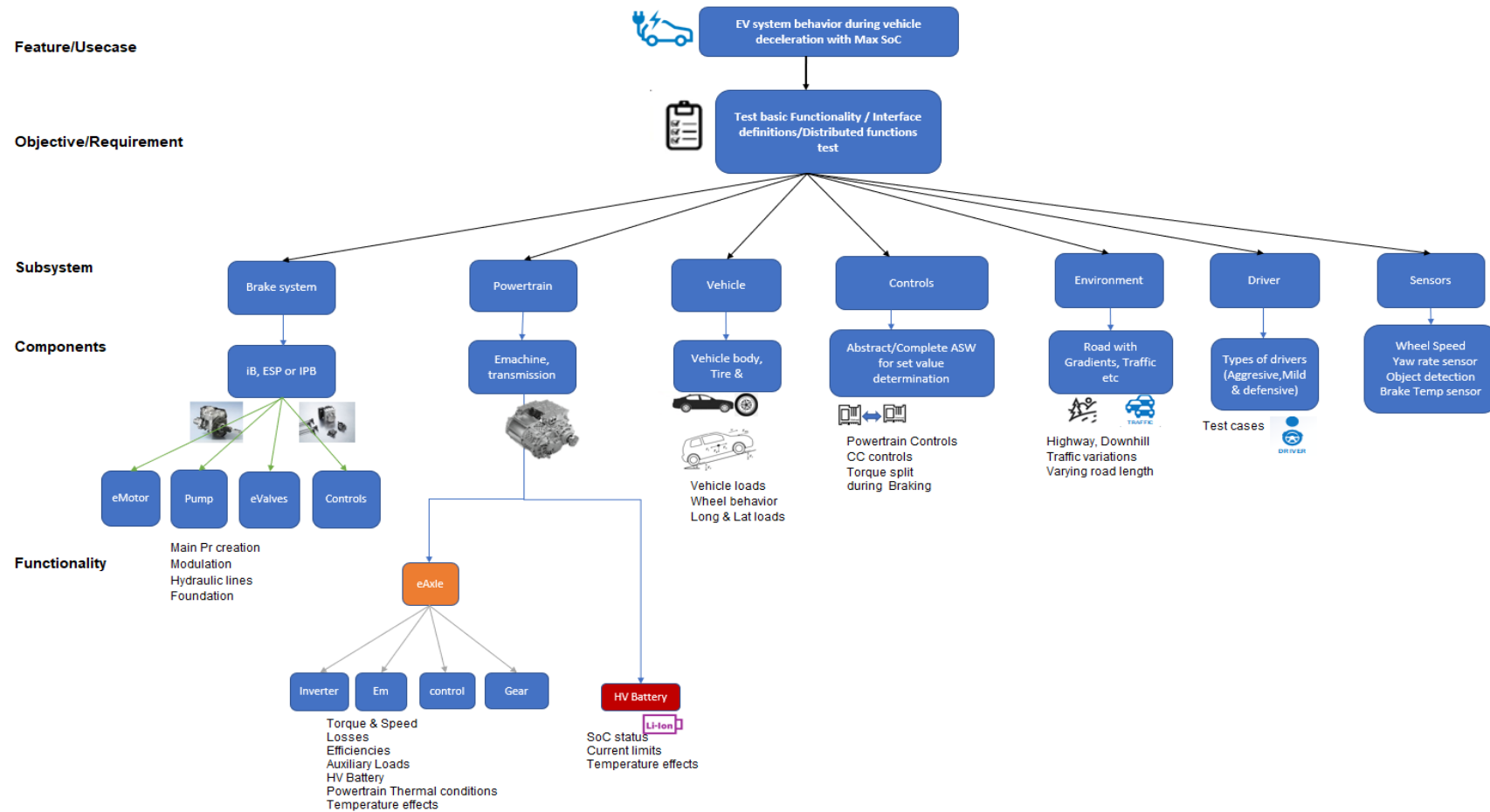❖ Software Defined Vehicle (SDV) development support (S/w enabled features & functionalities)

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MBSE and Simulation – Use Case Oriented Approach

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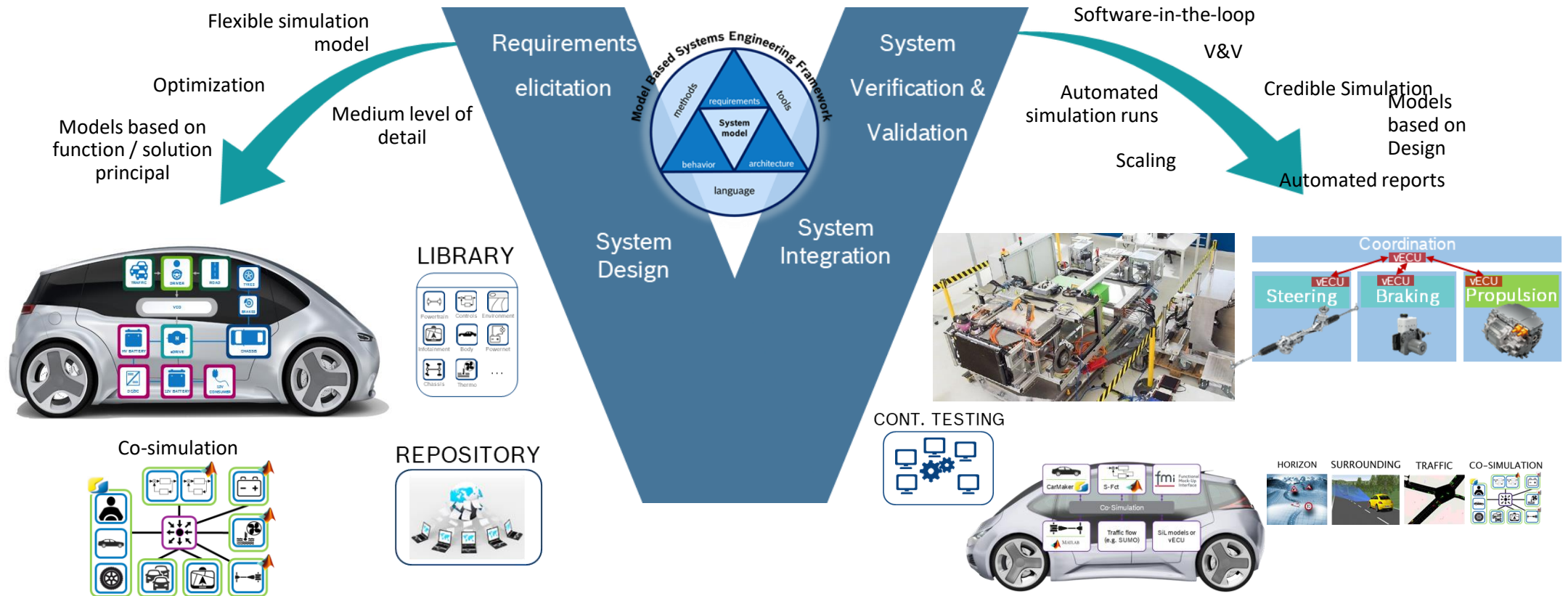
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MBSE based EV Model architecture definition

Consider chain effect of components and be able to provide Optimised system level performance which are easy to integrate in the vehicle

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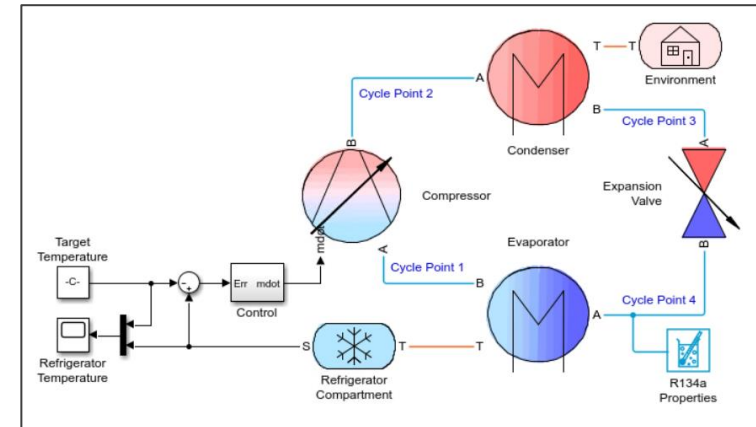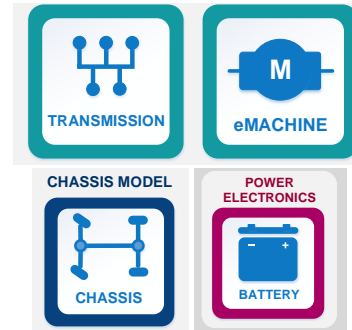# MATLAB/Simulink based Cross domain vehicle simulation

Electric Vehicle Simulation Model in Matlab/Simulink

➢ Domain specific inhouse (Bosch) library models built with component specific data

➢ Matlab/Simulink model for different domains such as:

   o   Powertrain (Ptr),

   o   Powernet (Pnt),

   o   Chassis (Cha)

   o   Thermal system (Ths) and

   o   Controls (Ctrl),
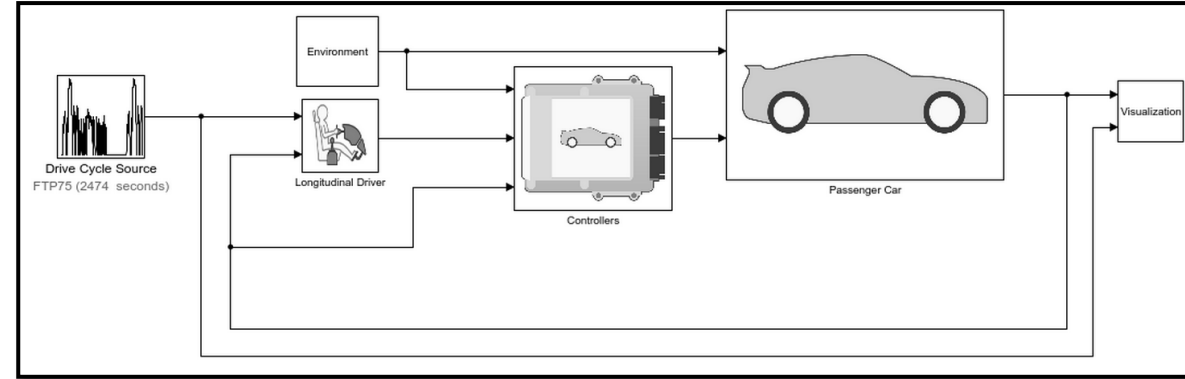
➢ All these libraries are updated with suitable component parameters by updating the object libraries and vehicle related parameters

➢ Library & vehicle model scalable for different class of vehicles

➢ Real road load drive profiles are generated synthetically from the GPS info and create virtual road network

➢ Modular modelling setup for covering various class of vehicles and topologies

➢ Adopt credible methods for reliable simulation results

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EV model building approach & simulation
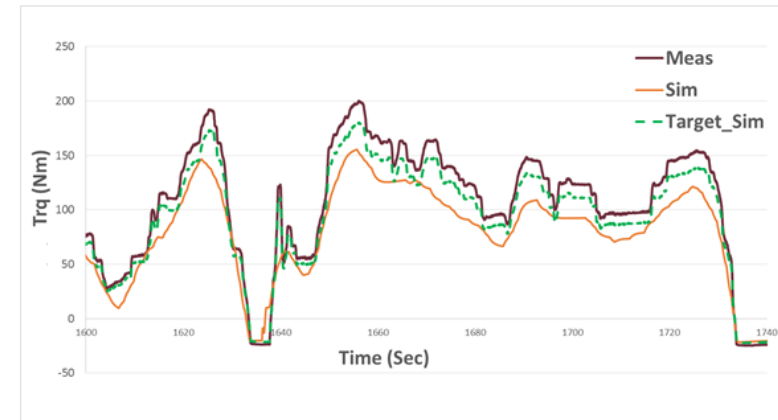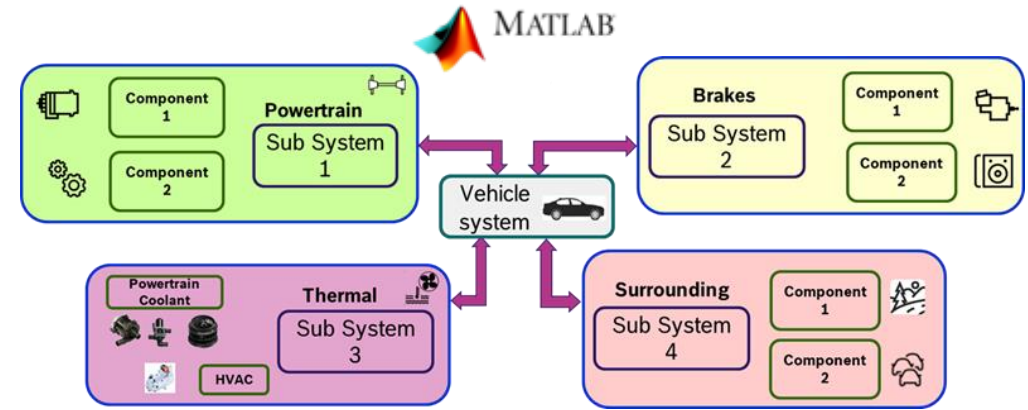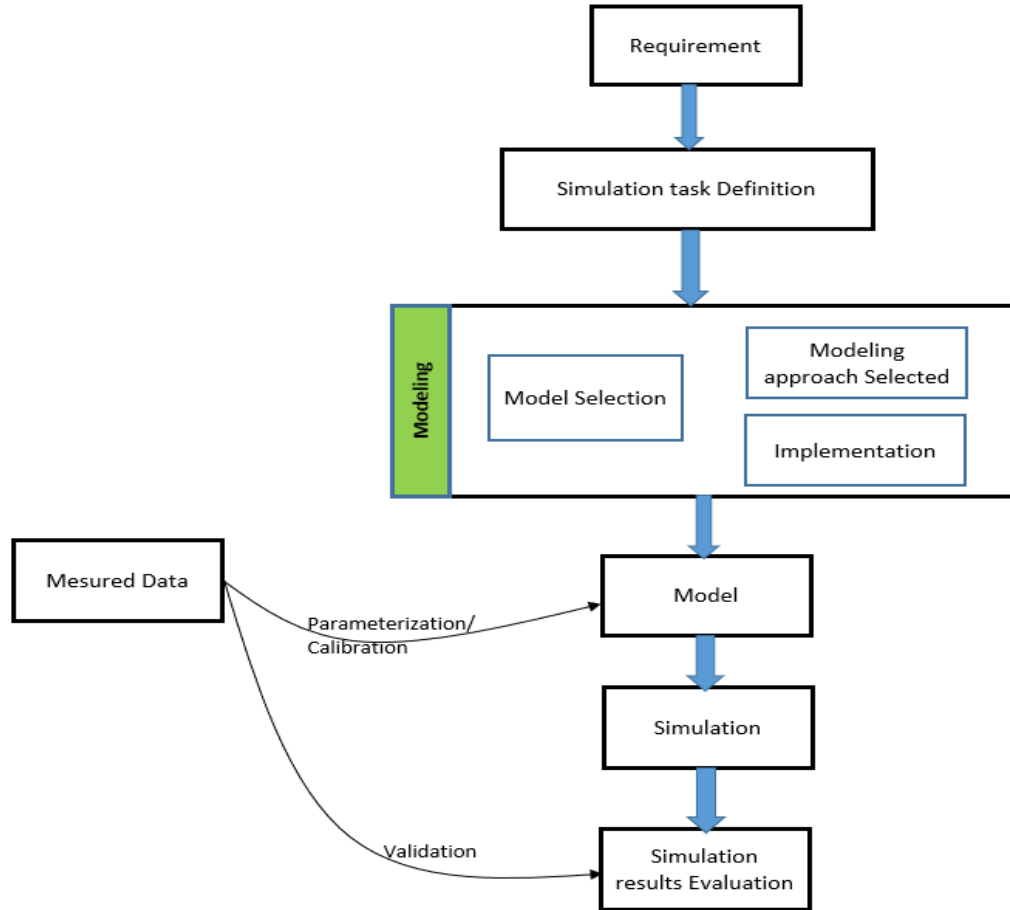
Target is to improve the simulation results with measured data

Use measured & component specific data for model adaptation and carry out credibility assessment

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Baseline EV Model Tuning & Validation

Various maneuvers used for baseline model adaptation and evaluations are:

- ❖ Ideal drive cycle
- ❖ Real drive cycle
- ❖ Acceleration test
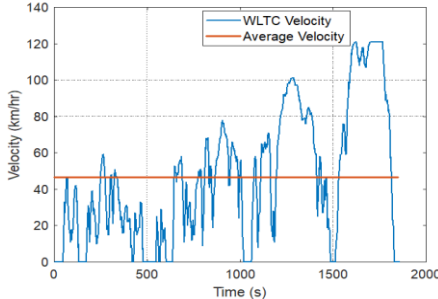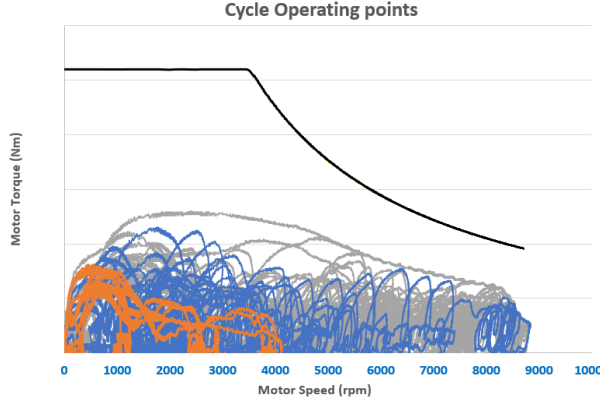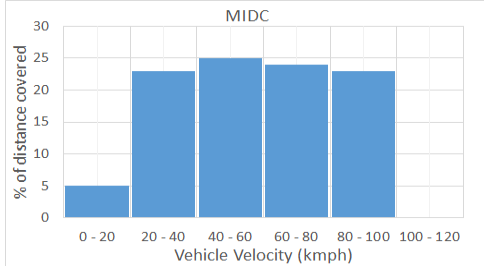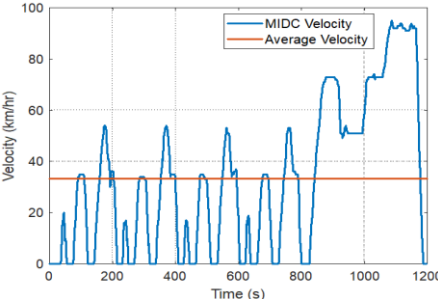- ❖ Gradient test
- ❖ Constant speed
- ❖ HV accessory load influence
- ❖ Thermal derating effects
- ❖ 24hrs drive cycle for HV battery load determinations
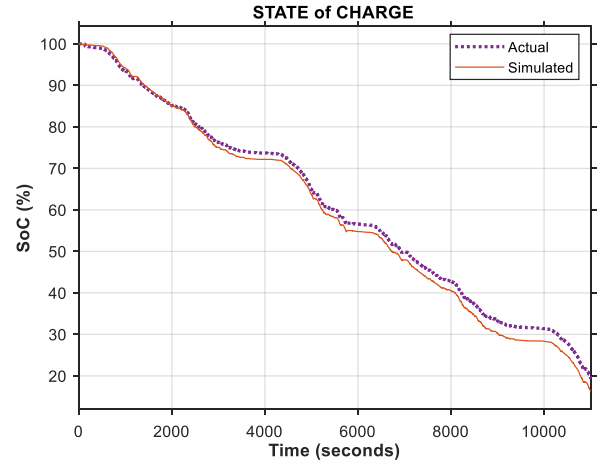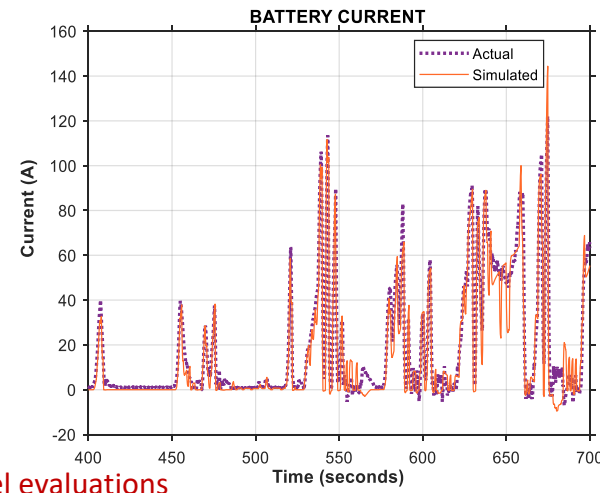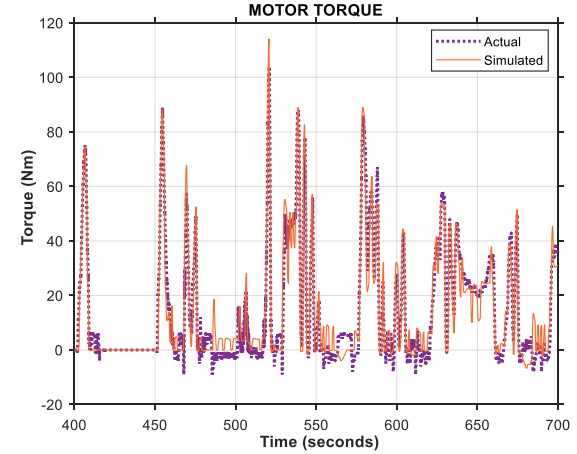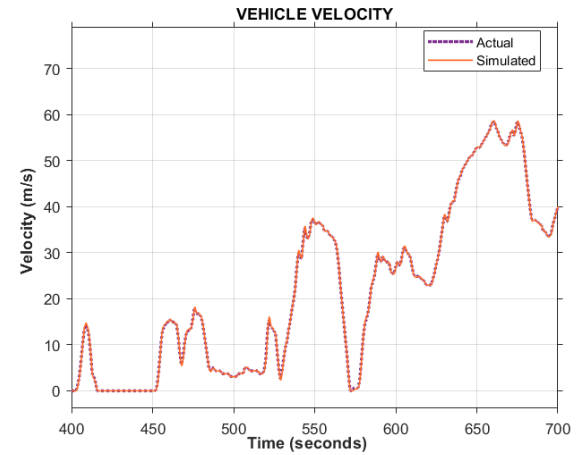
Hatchback class of vehicle used for data gathering and baseline model evaluations

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Performance of EV over Different Drive Cycles

Cycle Operating points
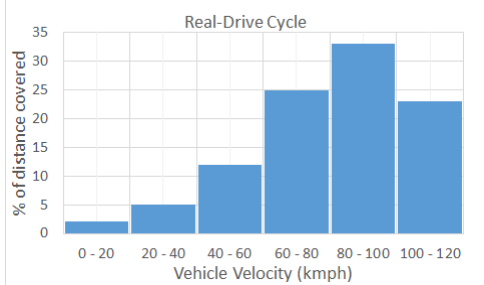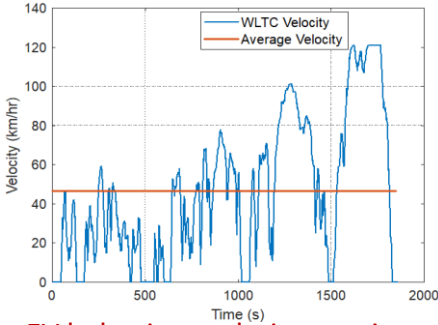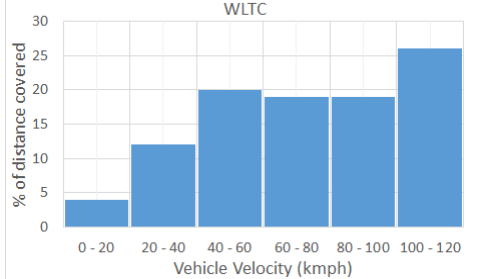
Propulsion & Recuperation Energy Distribution

Test cycle comparison

	MIDC	WLTC	Real-Drive
Engy cons (Wh/km)	104.76	136.24	132.08
Avg Spd (kmph)	33.35	46.74	56.43
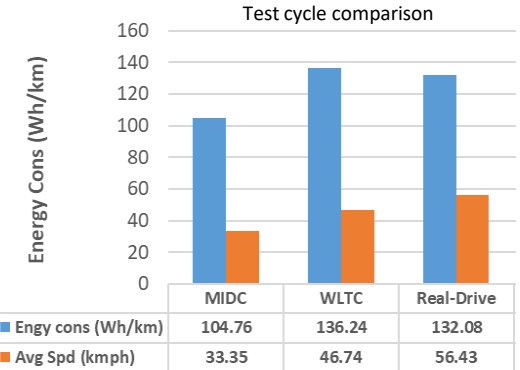
EV behavior analysis at various driving patterns for component to system interactions analysis

Bosch Global Software Technologies Private Limited | 2022-10-15
Mathworks Auromotive Conference 2022

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Performance of EV over Constant Velocities

Energy Consumption (Wh/km)

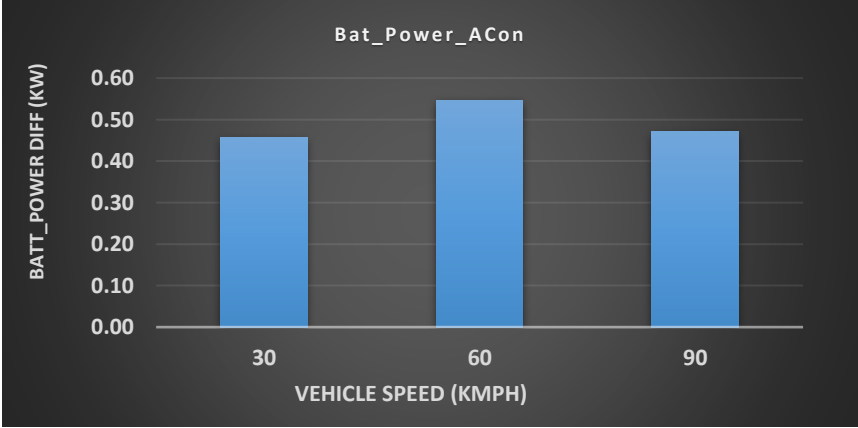|	20.10	24.59	35.22	39.24	44.44	50.41	60.60	70.87	78.65	89.74	100.55	113.69	120.97
Series1	39.89	40.43	45.24	47.95	50.24	57.00	70.98	87.30	105.42	126.58	154.84	180.03	212.77

|	35.00	39.00	44.00	50.00	60.00	70.00	78.00	89.00	100.00	110.95	119.00
Flat Road	523.15	493.65	471.15	415.27	333.46	271.13	224.52	186.99	152.87	131.48	111.25
5% Grad	98.08	96.95	99.00	94.88	92.84	86.17	81.56	75.52	69.08	62.56	59.62
10% Grad	53.97	53.33	53.32	51.92	50.04	49.24	46.34				

Bat_Power_ACon

Baseline model study at various driving maneuvers shows plausible simulation performance

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MATLAB/Simulink based Cross domain vehicle simulation

Thermal system modeling of EV
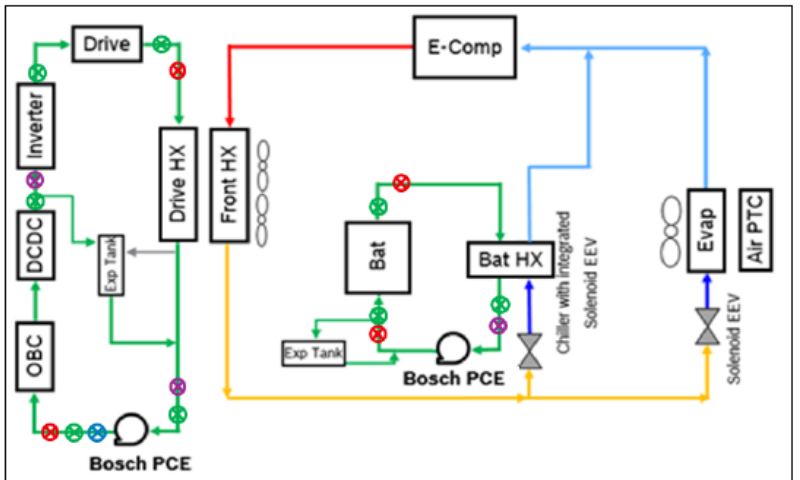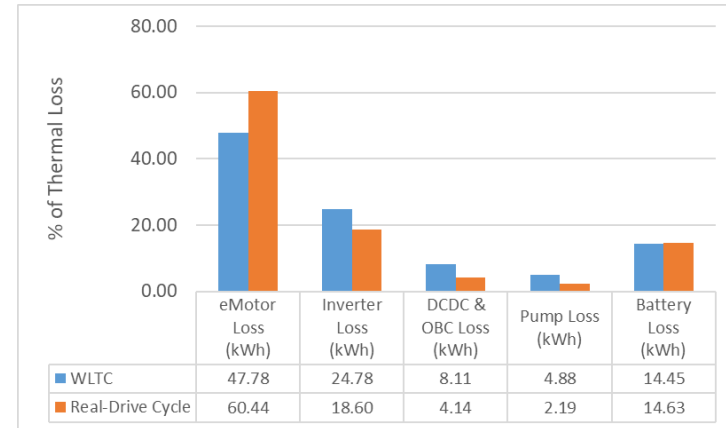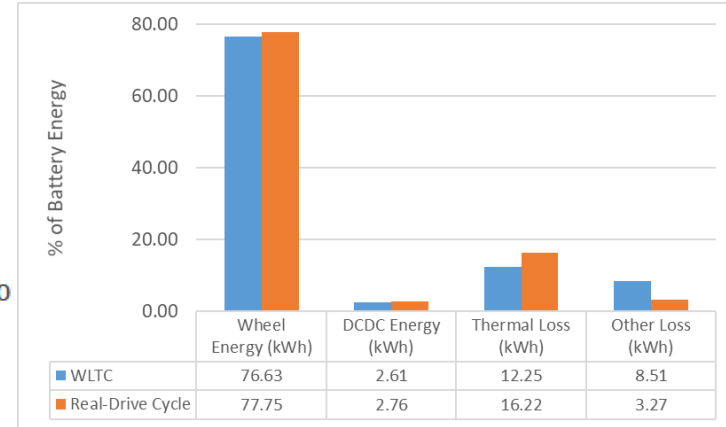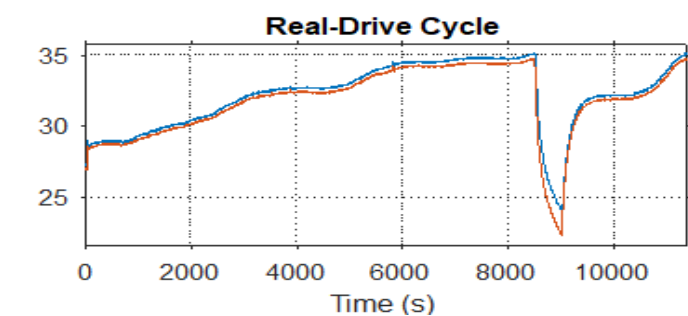

Thermal Management System Layout
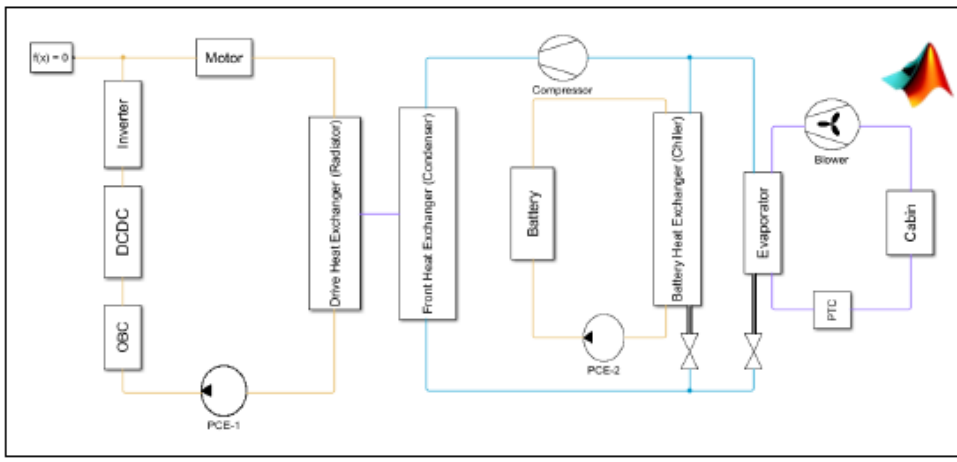
: Revised MATLAB Model for Thermal Management System

- ➢ Thermal architecture is defined, and all the respective components are mapped
- ➢ Heat exchanger data calibrations
- ➢ Interfacing with different coolant loops and various domains (Powertrain, Cabin, HV Battery etc.,)
- ➢ Controller strategy definitions for states and mode control (Heating, Cooling, coolant flow rate control etc.,)
- ➢ Solver optimization for real time simulation behavior
- ➢ Plausible behavior for different test conditions are verified

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Thermal Behavior of EV over Different Drive Cycles

	Wheel Energy (kWh)	DCDC Energy (kWh)	Thermal Loss (kWh)	Other Loss (kWh)
WLTC	76.63	2.61	12.25	8.51
Real-Drive Cycle	77.75	2.76	16.22	3.27

	eMotor Loss (kWh)	Inverter Loss (kWh)	DCDC & OBC Loss (kWh)	Pump Loss (kWh)	Battery Loss (kWh)
WLTC	47.78	24.78	8.11	4.88	14.45
Real-Drive Cycle	60.44	18.60	4.14	2.19	14.63

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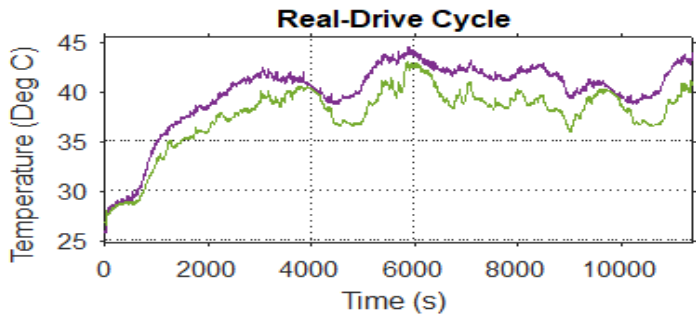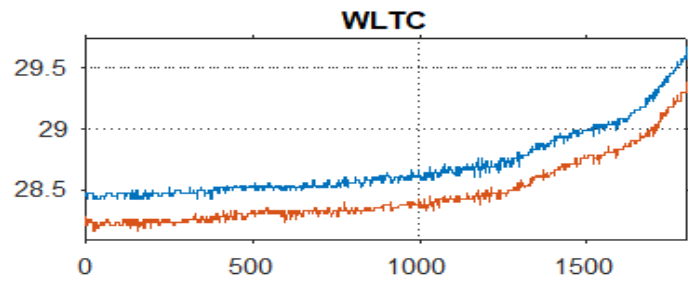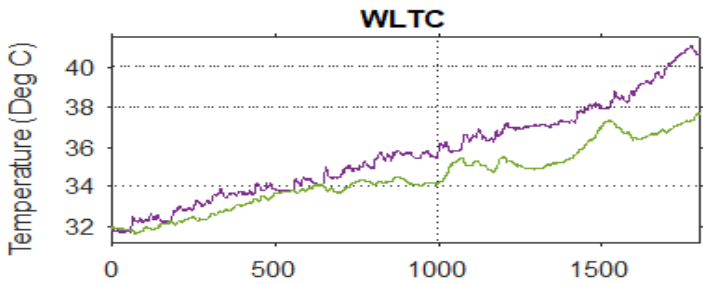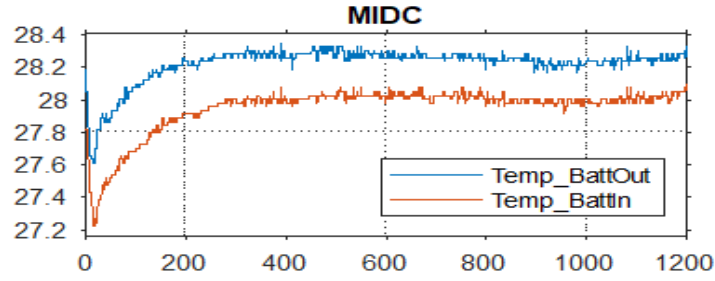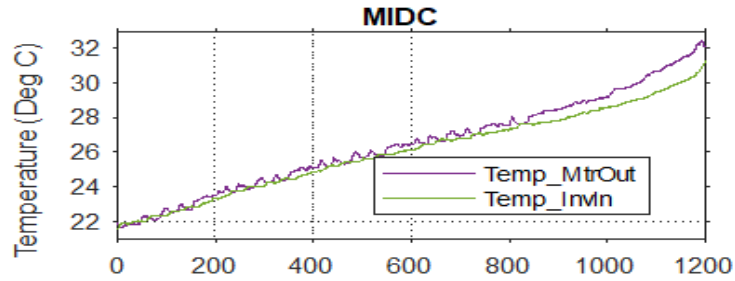
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EV virtual retrofit with competitive components

Component A
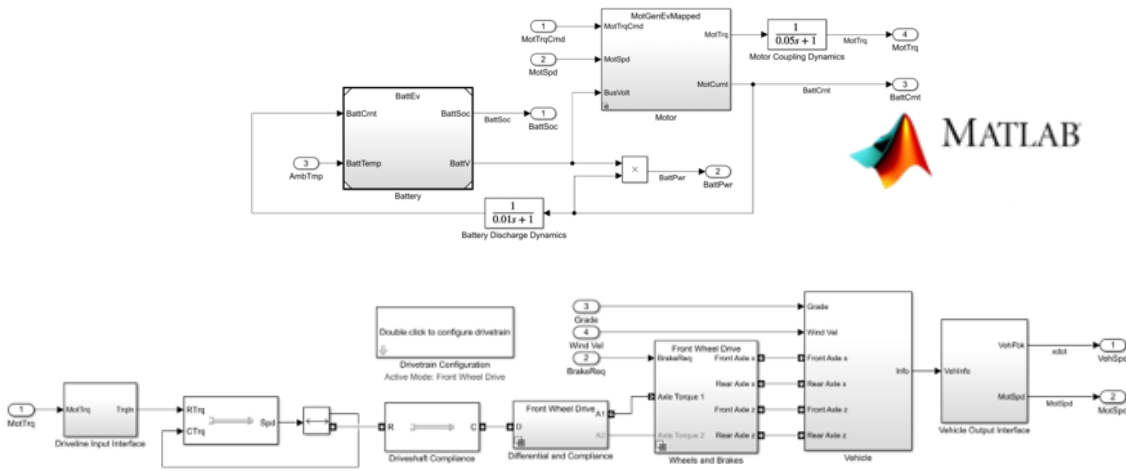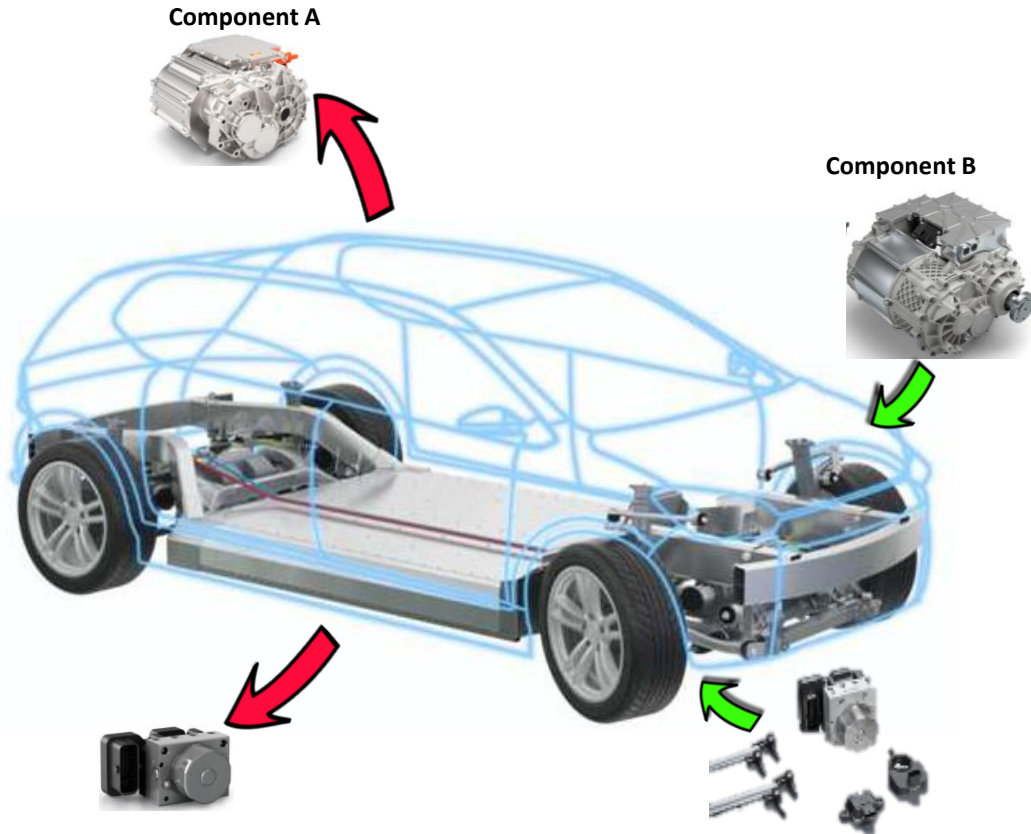
Component B

> Base vehicle model is initially validated for Energy flow, Powertrain & Chassis components and then retrofitted with competitive components data

> Evaluate the performance improvements and range benefits achievable with competitive components

> Potential benefit analysis of Predictive functions like Eco Maneuver- Optimizer (EMO), Thermal control etc.,

Quick & easy retrofit of EV components in virtual supports speedy evaluation at system level

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EV system behavior with competitive components

Comparison of HV Batt Current in MIDC

	MIDC	WLTC	Real-Drive Cycle
eDrive A	238.4	183.66	178.32
eDrive B	279.00	202.28	196.21

	MIDC	WLTC	Real-Drive Cycle
0.1g	238.4	183.66	178.32
0.2g	247.50	193.29	190.45
0.3g	248.43	194.05	190.71

Comparison of HV Batt Energy in MIDC

	MIDC	WLTC	Real-Drive Cycle
eDrive A	238.4	183.66	178.32
eDrive B	279.00	202.28	196.21
eDrive B with 0.2g	289.5	212.32	208.26
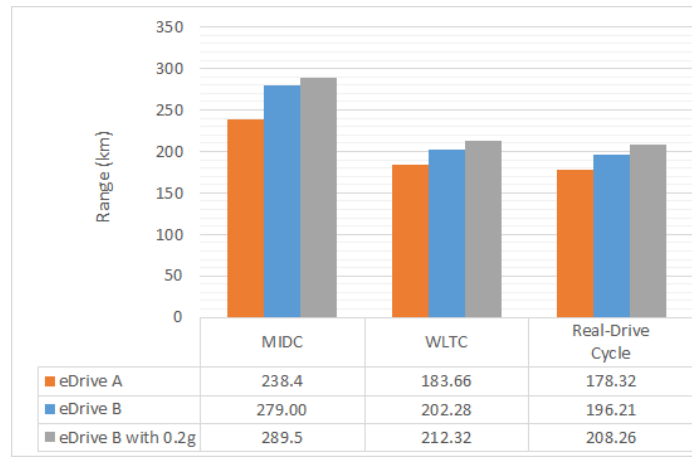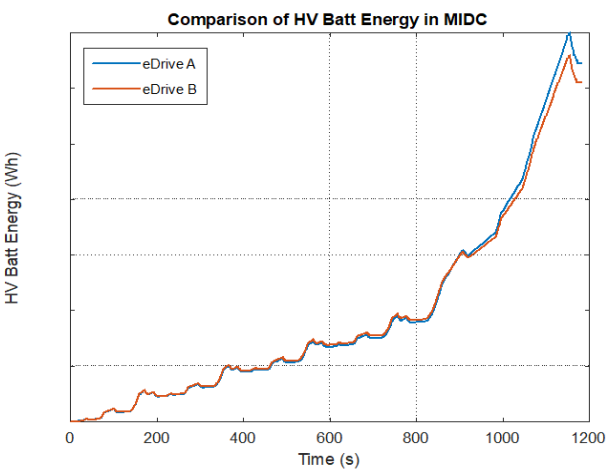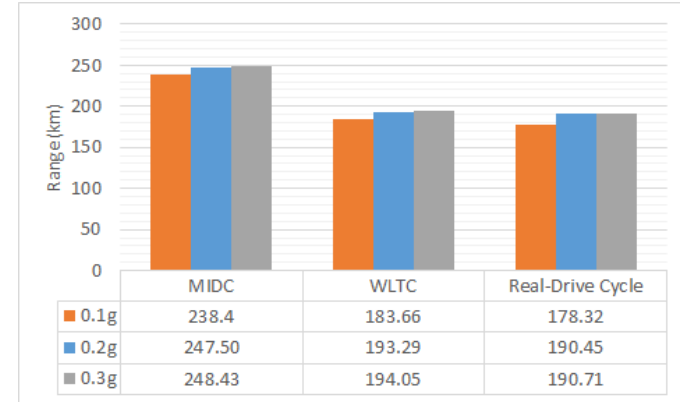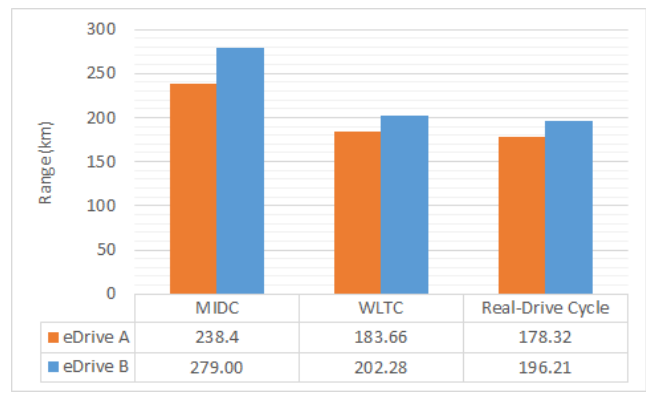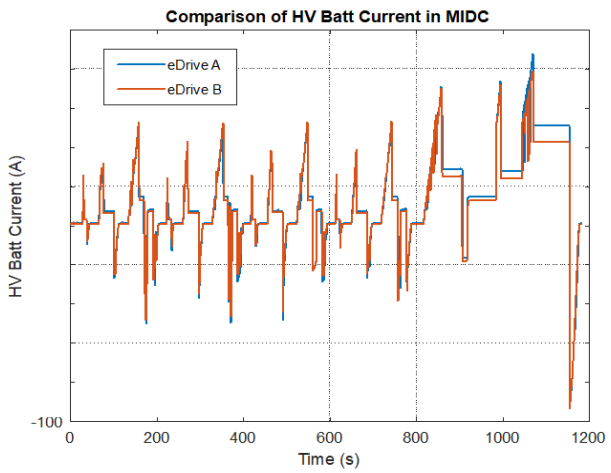
Virtual evaluation of competitive components helps in quicker identification of suitable EV components & features at early development/design phase

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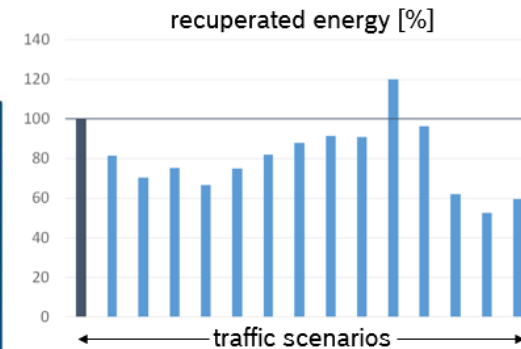
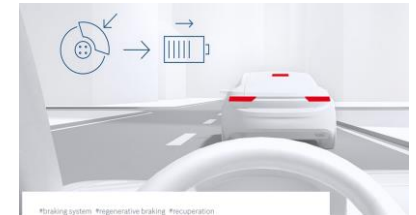## CRB functions potential benefit evaluation

Modeling real vehicle Environment with Vehicle powertrain system

**Real Vehicle in Traffic condition**

Virtual Vehicle in Traffic condition

Interface traffic simulation with vehicle model for creating real road loads and estimate recuperation potential for cross domain functions

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Future scope to be addressed

01   **xDomain models Integration**

Several domain models and library components interfacing in common model – versioning issues, Library support..,
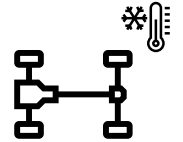
02   **Simulation runtime**

Complex model environments tends to run slower & Numerical issue to be handled

03   **Porting to Cloud**

Create cloud version simulatable models for digital twin application

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Conclusions

> **It is possible to model the various subsystem domain in Matlab/Simulink & handling Simscape library models for component switching**

> **Real test cycle measurements were compared with base simulation & retrofit components**

> **Simulation results show improvement in HV battery energy consumption with competitive components and effect on EV range**

> **With Bosch advanced Braking components having higher deceleration capability it results in more energy recuperated and overall effect on EV range**

> **Simulation provides and initial evaluation platform for deriving KPIs for various solutions and components adaptation to the given vehicle**

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Thank you

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