



CAERI

China Automotive Engineering Research Institute Electric Vehicle R&D Progress

China Automotive Engineering Research Institute



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1-CAERI EV R&D Facilities

2-Distributed Driven EV R&D

3-Range Extended EV R&D

4-EV Benchmark

5-Summary



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1-CAERI EV R&D Facilities

2-Distributed Driven EV R&D

3-Range Extended EV R&D

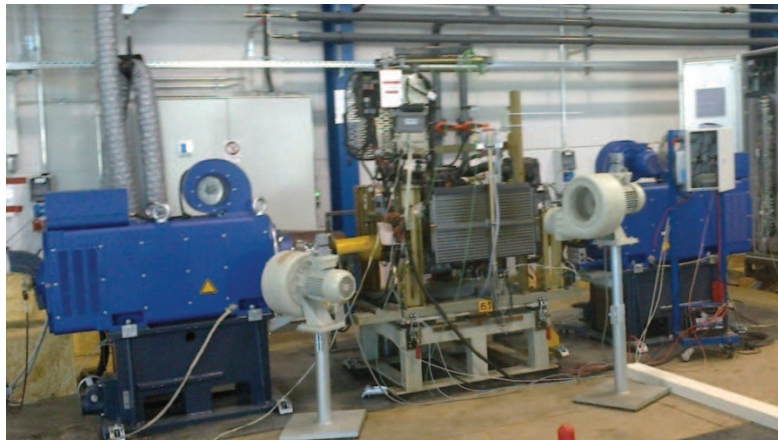
4-EV Benchmark

5-Summary



EV Powertrain Laboratory

Two AVL hybrid powertrain test bench:
Covering powertrains from A0 class vehicle to heavy duty trucks,
hybrid system with engine, transmission, battery and motor.



LD dynamometers of 250kW x2



HD dynamometers of 440kW



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Battery Laboratory

Research and Test Equipments of Battery

Test Equipment of Battery Cell



Arbin and Bitrode
Main Channel: 32
Voltage Range:
0~5V
Current Range:
-100A~100A

Test Equipment of Battery Module



Arbin and Bitrode
Main Channel: 8
Voltage Range:
5~100V
Current Range:
-300A~300A

Test Equipment of Battery System



Digatron
Main Channel: 2
Voltage Range:
-800~800V
Current Range:
-500A~500A

Test Equipment of Safety



Penetration Test



Crush Test



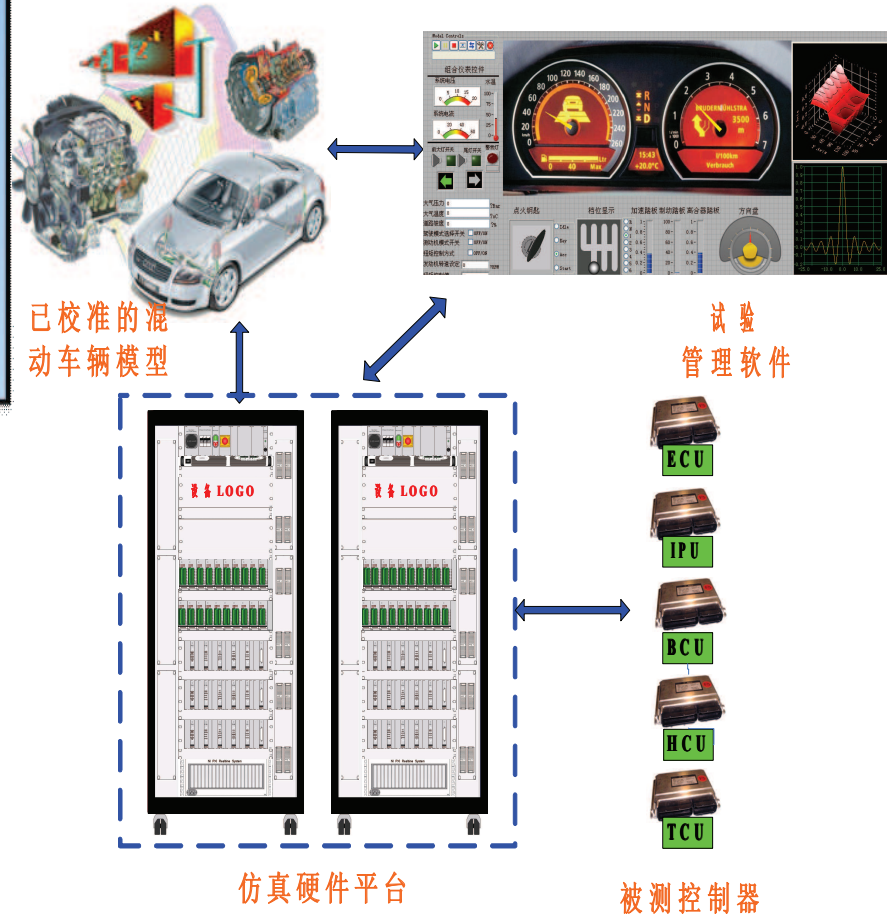
Short Circuit Test



Hardware In the Loop Test Laboratory

CAERI has a full-featured Hardware in loop(HIL) test system for EV controller.

HCU(Hybrid Control Unit), VCU(Vehicle Control unit), ECU(Engine Control Unit), IPU(Integrated Power Unit), BCU(Battery Control Unit), TCU(Transmission Control Unit), CCU(Clutch Control Unit), etc.

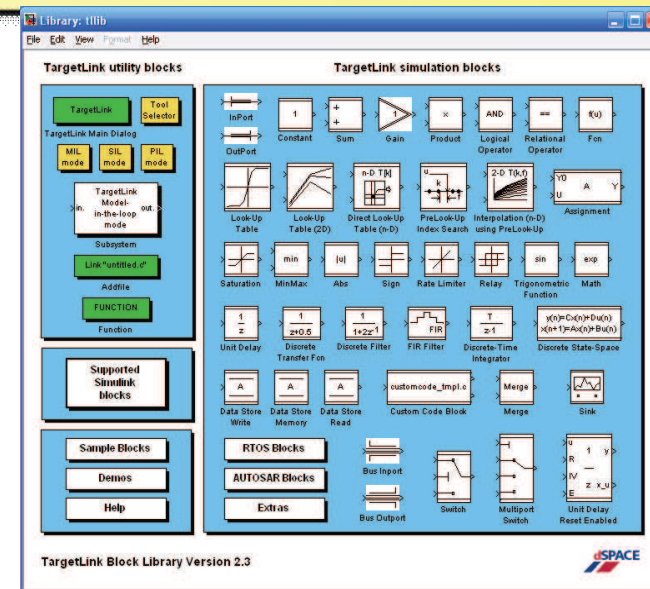




Rapid Control Prototype & Code Generation

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Rapid control prototyping for development of Electric Vehicle Control System
Development : dSpace Mirco AutoBox



Automatic code generation tool —Targetlink
Supporting from the MATLAB / Simulink / Stateflow models to generate
efficient and reliable product code for EV controller

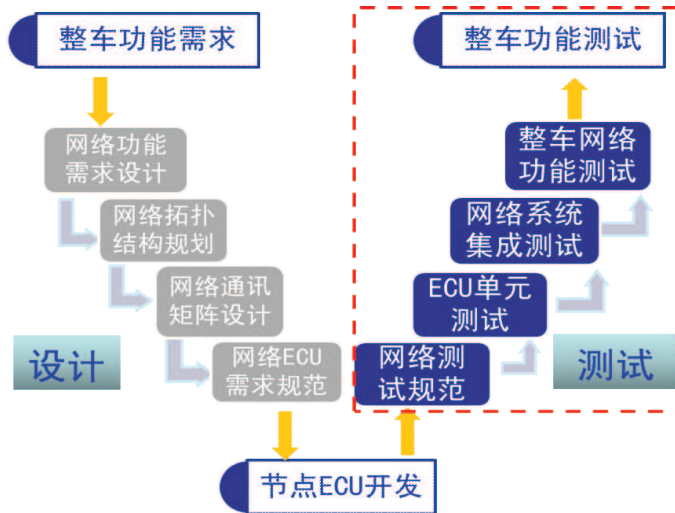
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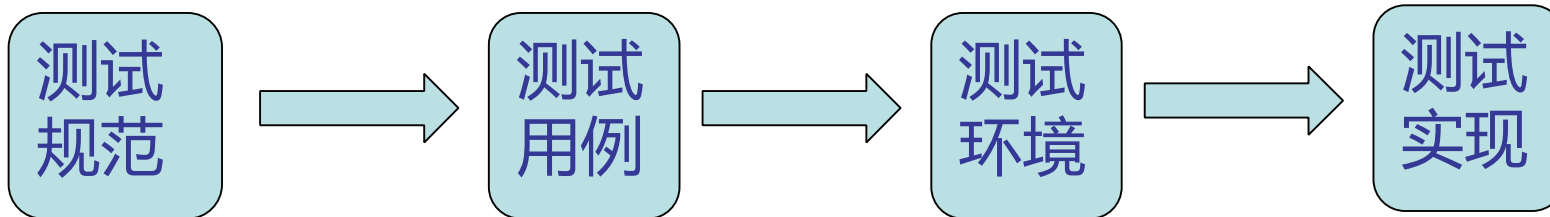
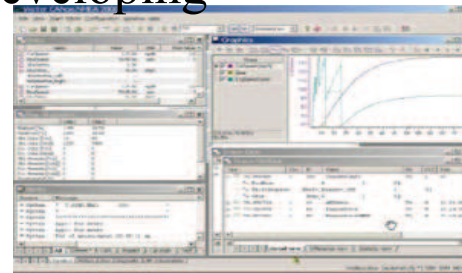
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Network Bus Design and Test

- ✓ 节点与系统通信功能是否符合设计需求
- ✓ 网络的节点与系统通信性能（一致性、完整性、正确性、抗干扰特性、实时性）
- ✓ 整车通信网络功能（容错性、故障诊断、网络管理等）



Automotive bus development tools : CANOe, CANStress, CANScope for automotive bus(CAN, Lin, FlexRay) developing

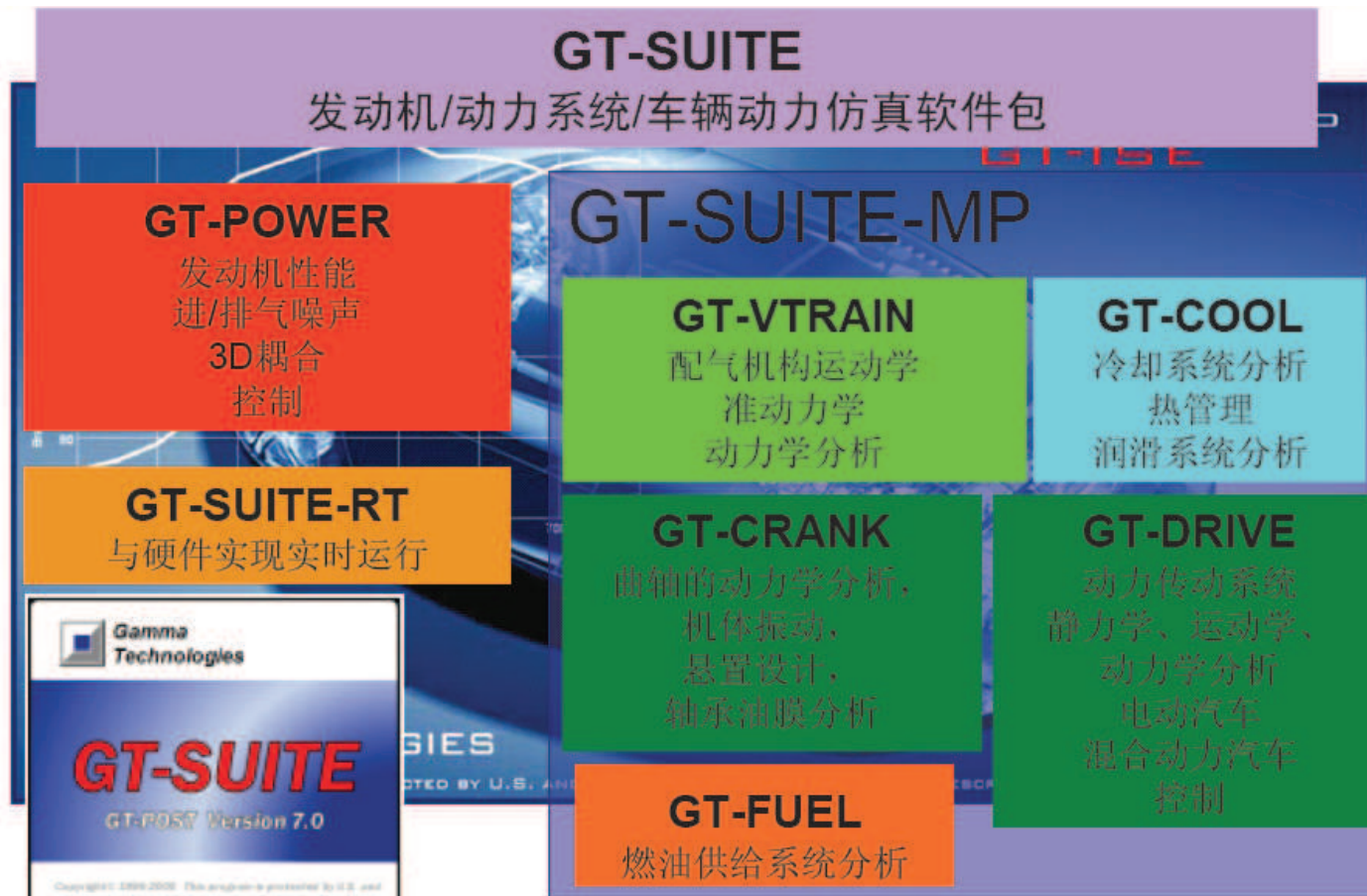




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Vehicle & Powertrain Simulation

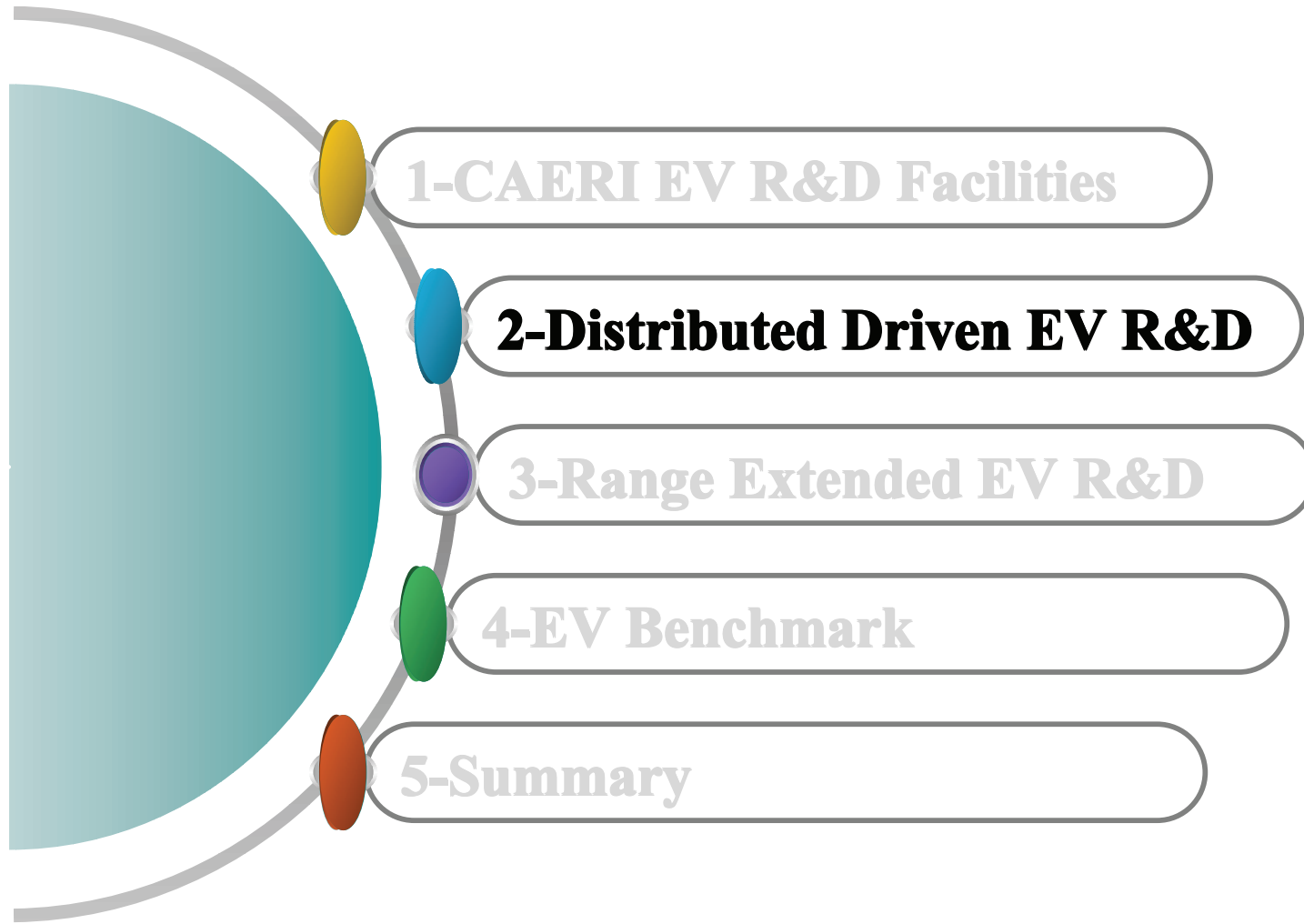
Engine/Powertrain/Vehicle performance simulation



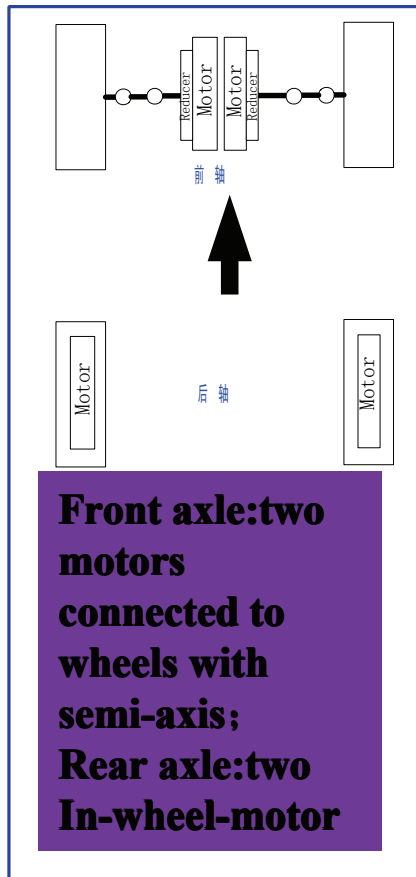
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Prototype Vehicle Configuration



Items	Parameters
Curb Weight/ kg	1252
Battery capacity /kwh	21
Max speed/km/h	>140
Max gradient ability/ %	≥30
Accelaration Time (0-100km/h)	<13
Cruising Range(NEDC Driving Pattern)/km	119
Efficiency of the electric vehicle(NEDC Driving Pattern) /kwh	16.1

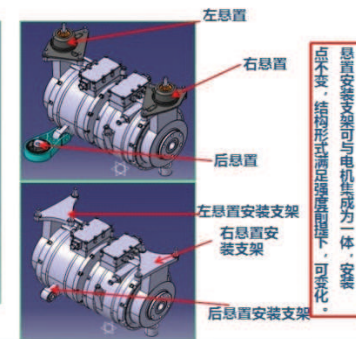
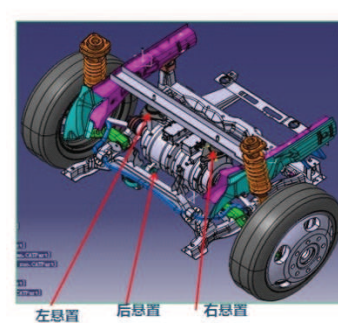
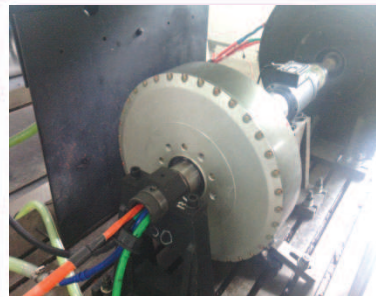
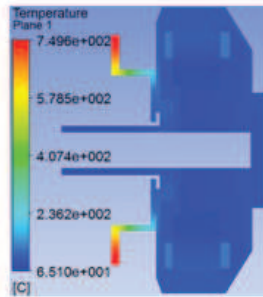


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Specifications of In wheel Motor

Rear motor	
Motor type	PMSM
Rated power (1h)	≥6kW
Peak Power (30s)	≥25kW
Rated torque (1h)	≥65Nm
Peak torque	≥320Nm@600rpm@15s
Rated speed	600r/min
Top speed	1400r/min
Max efficiency	≥92%

Front motor	
Motor type	PMSM
Rated power (1h)	≥10kW
Peak Power (30s)	≥25kW
Rated torque (1h)	≥160Nm
Peak torque	≥320Nm@600rpm@15s
Rated speed	600r/min
Top speed	1400r/min
Max efficiency	≥92%

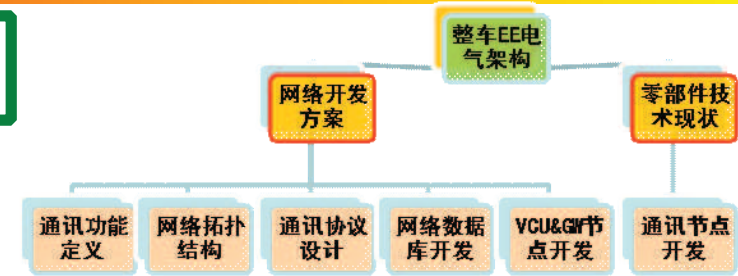




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Flexray/CAN Bus Development

Vehicle communication bus



SignalName	Signal Comment	Signal Min Value (bits)	Signal Max Value (bits)	InValid (hex)	Reso- lution	Offset	Signal Unit	Data Type	Event Command Signal (Yes/No)	Default Value (hex)	Signal Value Description (dec)	
心跳信号		N/A	0	15	N/A	1	0	N/A	unsignd	No	0	N/A
报警		N/A	N/A	N/A	N/A	N/A	N/A	unsignd	No	N/A	N/A	N/A
Motor_FL上下电指令		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	上电 0 下电
Motor_FL反转		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	电机反转 0 电机正转
Motor_FL正反转指令		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	电机反转 0 电机正转
Motor_FL目标运行模式		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	转速有效 0 制动有效
Motor_FL目标转速	电机调速模式	800	800	N/A	0.4	800	rpm	unsignd	No	0	N/A	
Motor_FL目标转速	电机调速模式	0	12000	N/A	3	0	rpm	unsignd	No	0	N/A	
Motor_FR上下电指令		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	上电 0 下电
Motor_FR反转		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	电机反转 0 电机正转
Motor_FR正反转指令		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	电机反转 0 电机正转
Motor_FR目标运行模式		N/A	0	1	N/A	N/A	N/A	unsignd	No	1	1	转速有效 0 制动有效
Motor_FR目标转速	电机调速模式	800	800	N/A	0.4	800	rpm	unsignd	No	0	N/A	
Motor_FR目标转速	电机调速模式	0	12000	N/A	3	0	rpm	unsignd	No	0	N/A	

控制单元
元
传感器

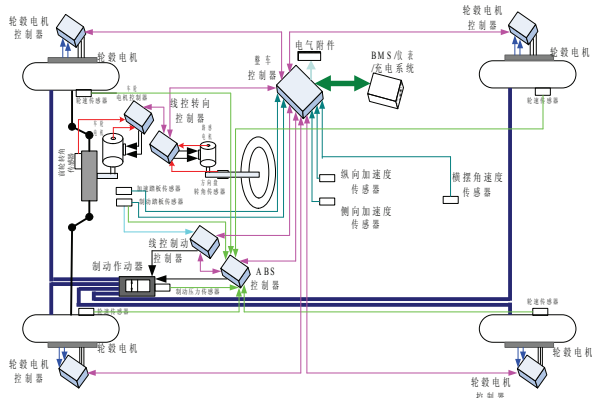
- FlexRay architecture design
- FlexRay Protocol design and test
- gateway design and test



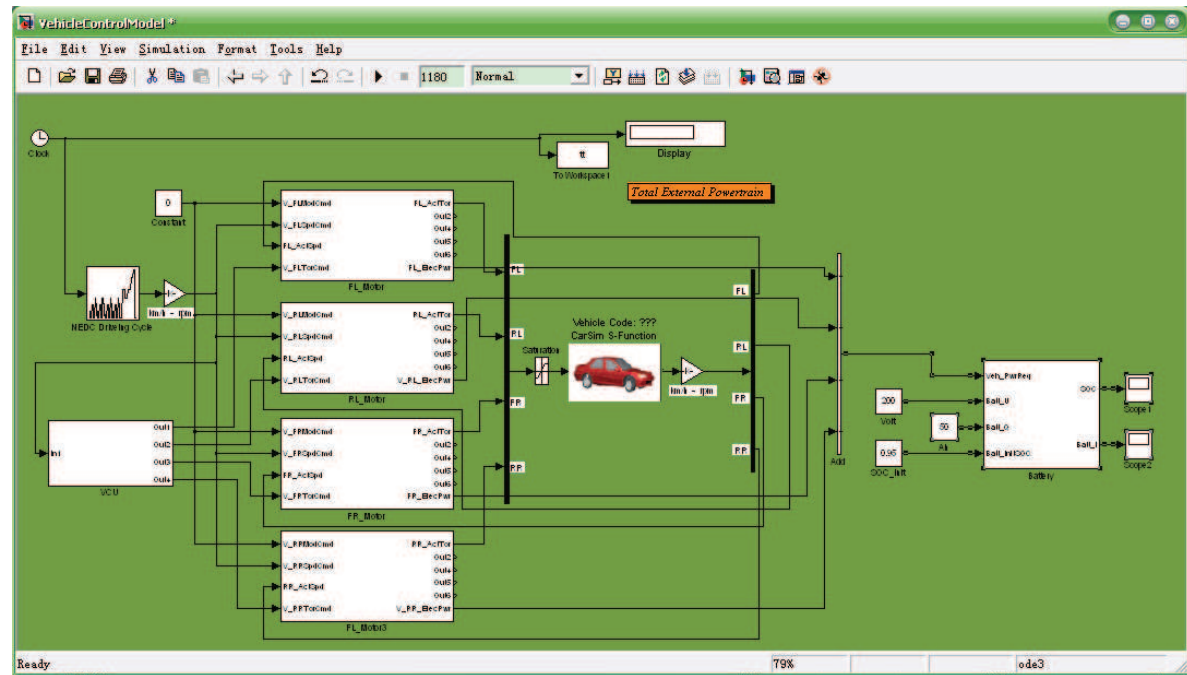
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Vehicle Control System

Simulation platform for VCU



- including :
- Vehicle model
 - Motor model
 - Battery model
 - Driver model
 - VCU software



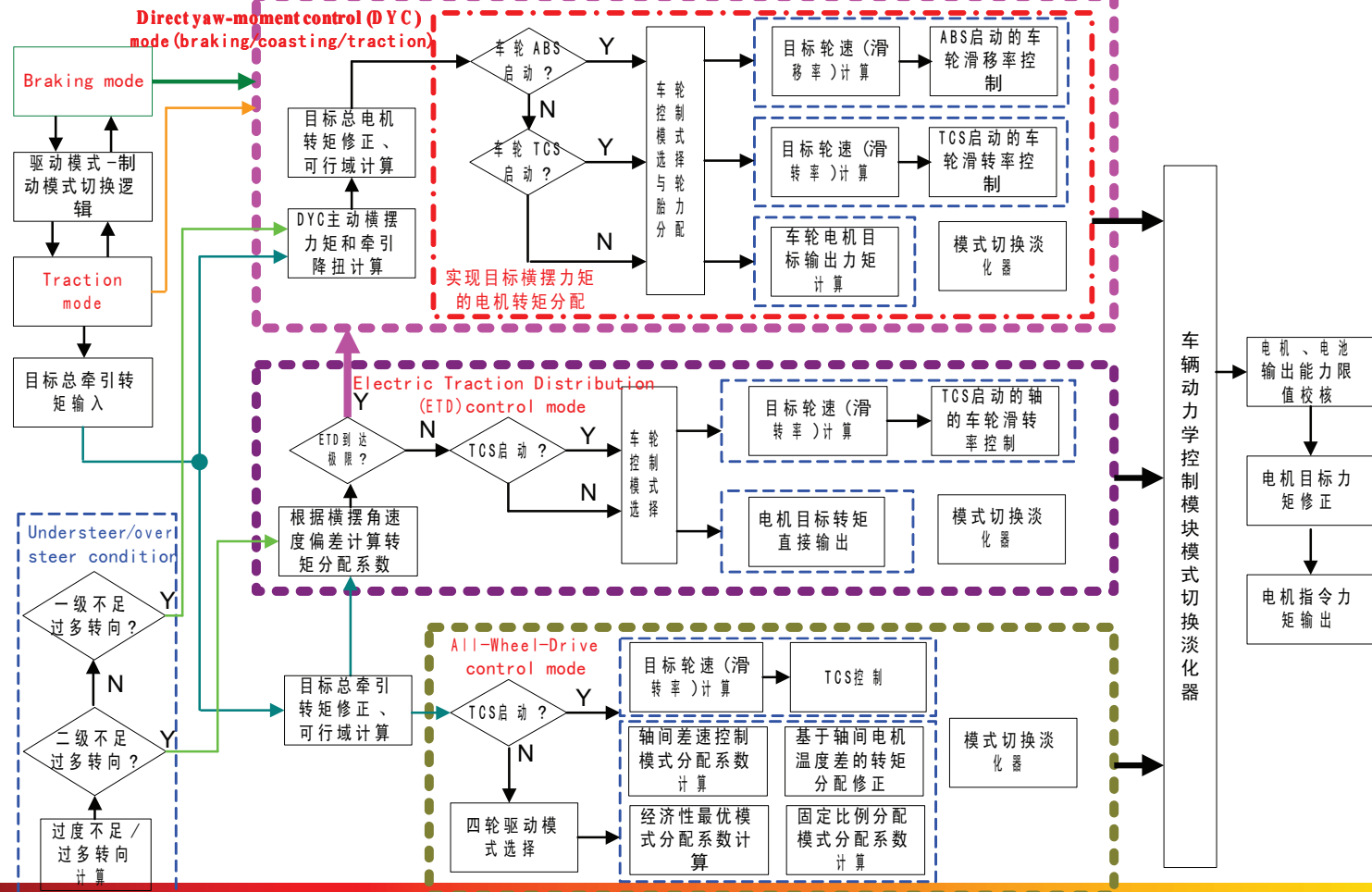
➤ The models used as the platform to test the function of software



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Vehicle Control System

Control SW Architecture



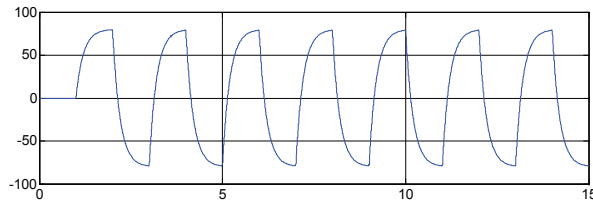


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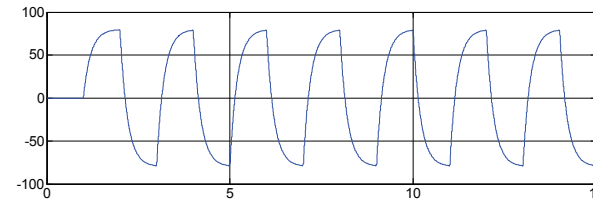
Vehicle Control System

Direct yaw-moment control(DYC)

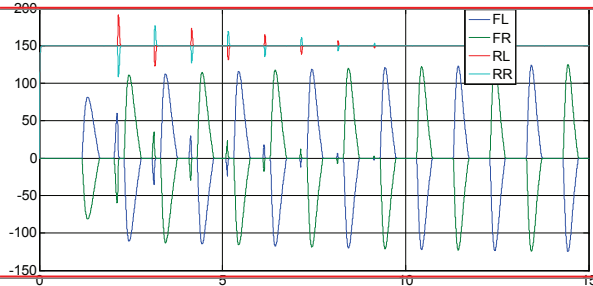
SIL test results



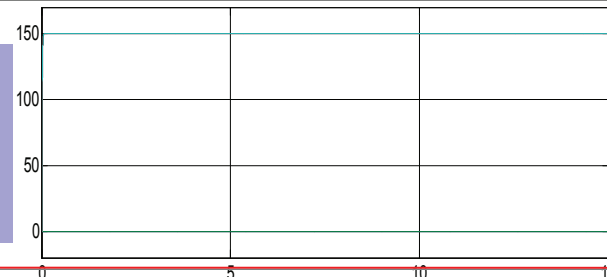
Steering-wheel angle



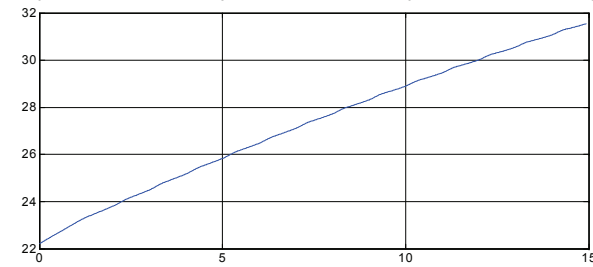
Tire-Road Friction:0.5



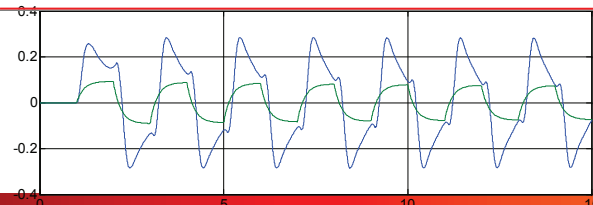
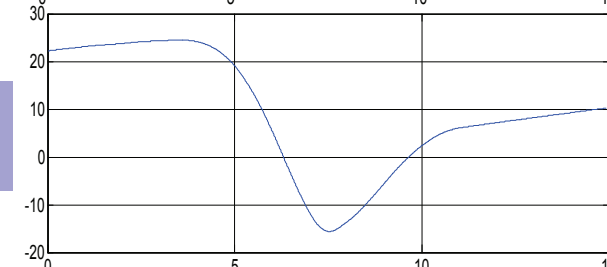
Active torque generated from motors



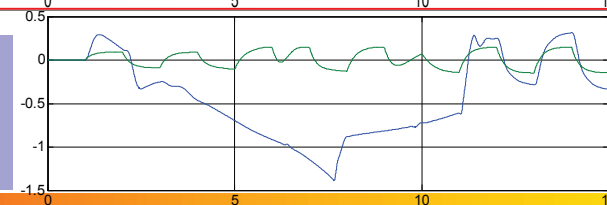
Without DYC



Vehicle speed



measured/desired yaw rate



With DYC



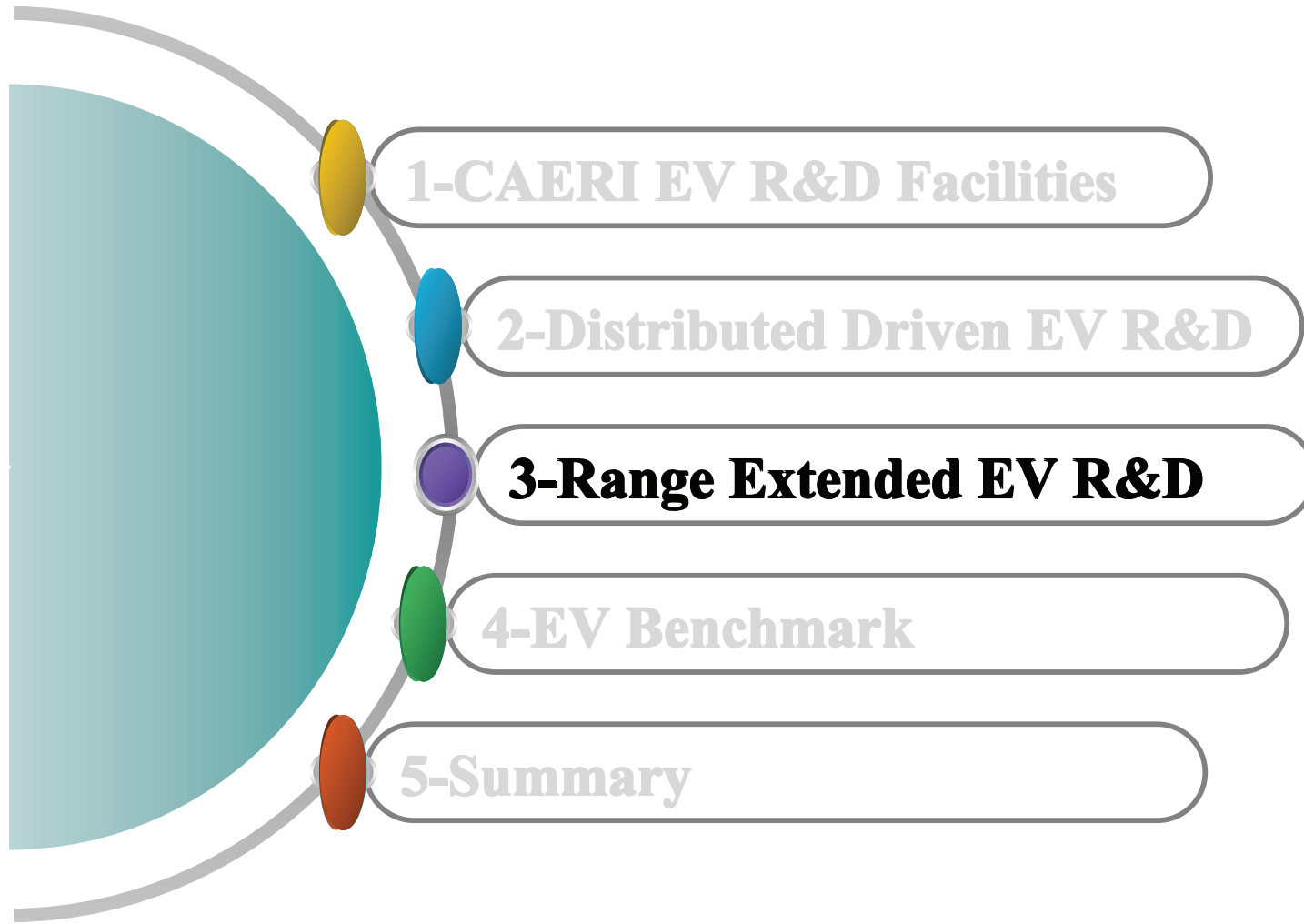
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Vehicle Control System

- Other control functions
 - **Vehicle speed estimation with motor speed**
 - **Estimation of Side Angle with kalman filter**
 - **ESC hydraulic module and its control(under developing)**
 - **Adaptive cruise control(ACC) (under developing)**
 - **Forward collision warning(under developing)**
 - **Driving range estimation(under developing)**



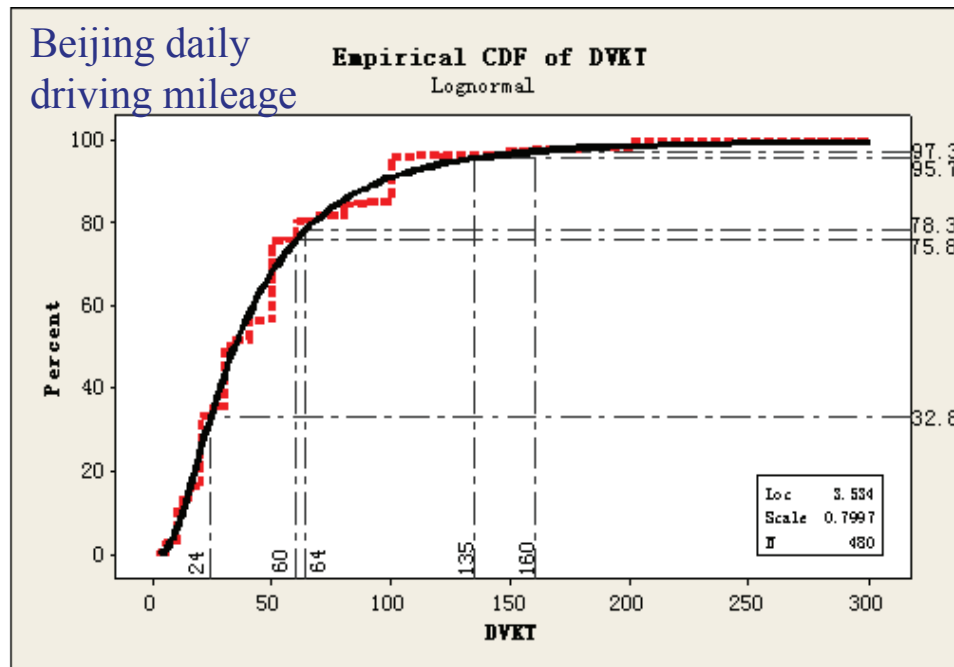
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Vehicle Concept Design



- ① **Features:** High performance for short distance driving, can realize the long distance driving
- ② **The advantage:** reduce battery volume, low cost, low fuel consumption



- **290 days in one year that daily driving mileage less than 60 kilometers**
- **More than 50% of the time daily driving mileage less than 40 kilometers per year**

Reasonable solution:

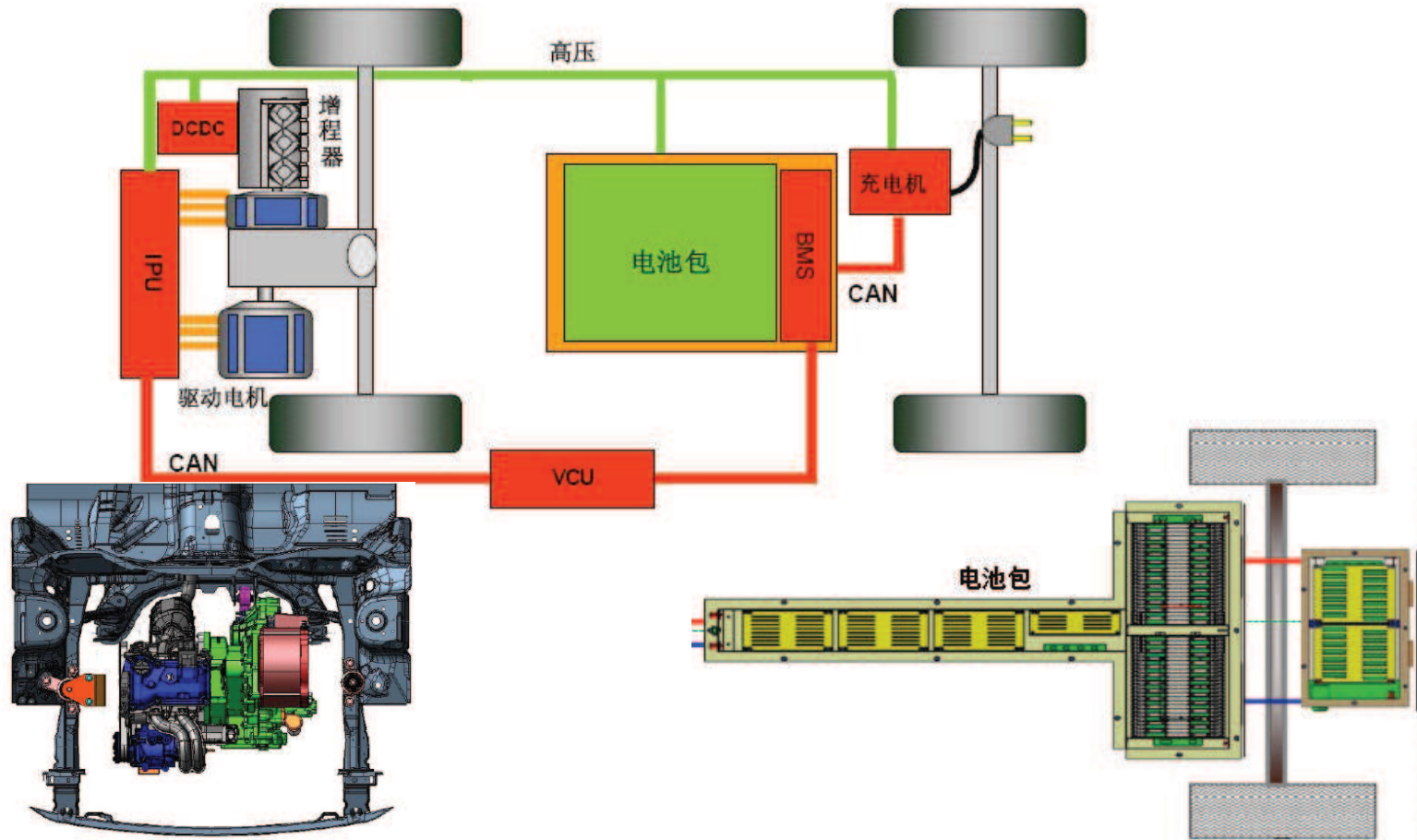
- ① **Maximum mileage under pure electric mileage 40~60km**
- ② **Battery volume: 10~12kWh**



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Development of Range-Extended Electric Vehicle

System Layout

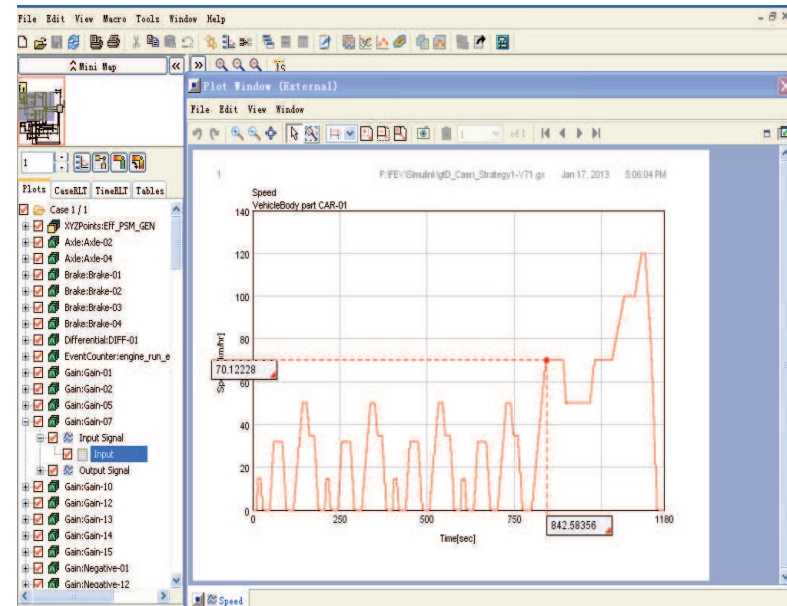
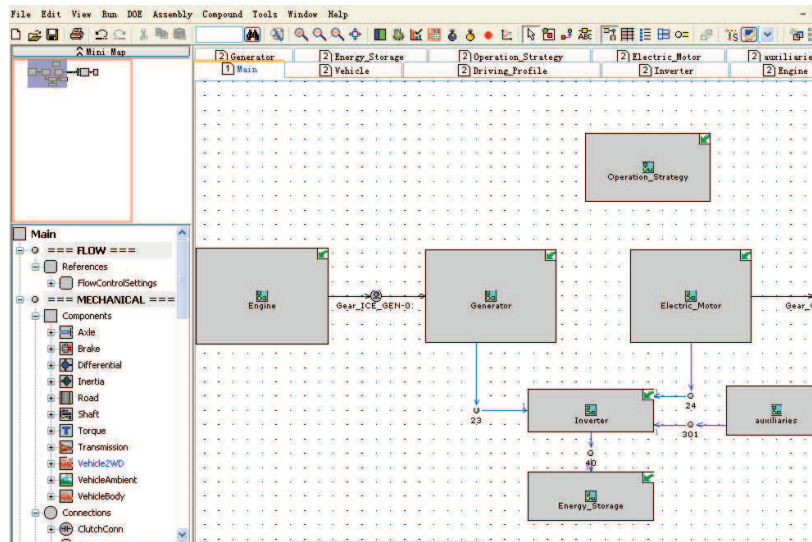




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Vehicle Simulation

According to the Benchmark database, building range-extended powertrain system simulation model (GT - SUITE) to carry out vehicle performance simulation





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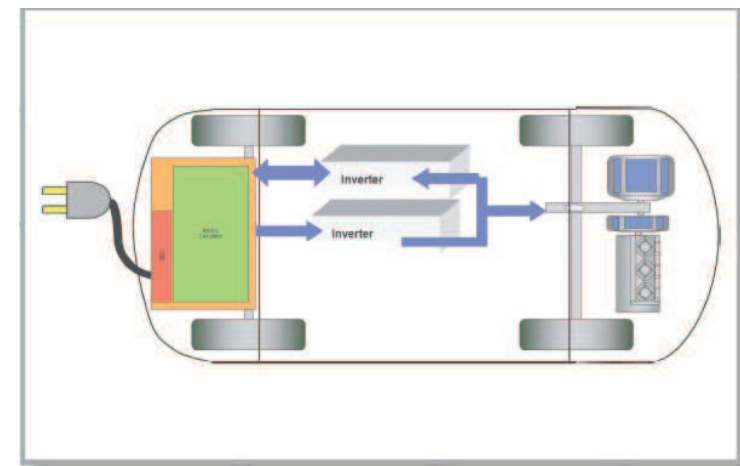
Vehicle Simulation

Target Parameters:

Top-speed	120 km/h
Drive range E/O	50 km/450 km
Fuel /electric consumption	
NEDC	1.14L/100 km 14.4 kWh/100km
Gradability	25%

Parameters Matching

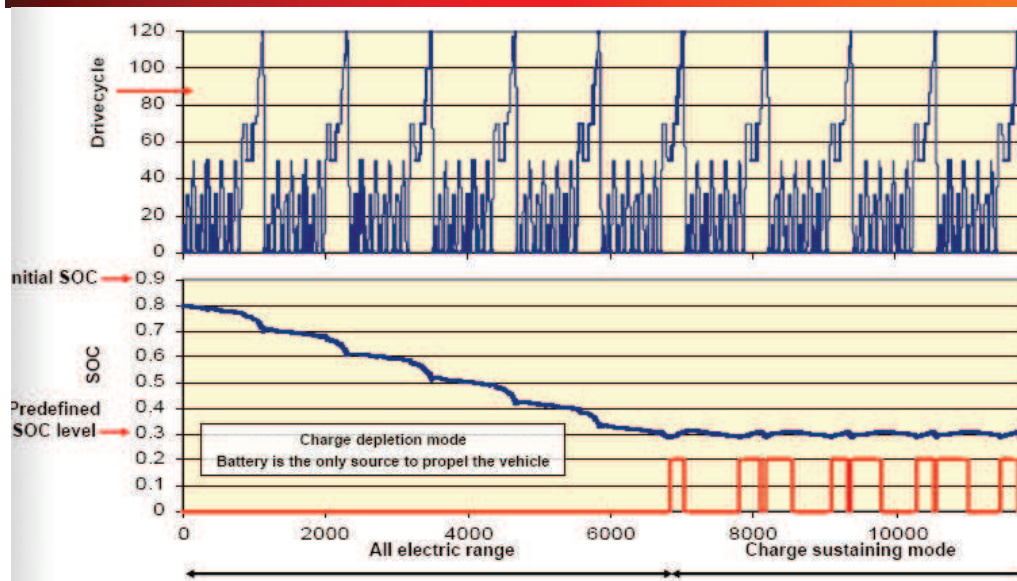
Engine	1L,3cyl naturally aspirated
	13.3 kW@1600 rpm
	24 kW@2800 rpm
Generator	20 kW/105 Nm
E-motor	60 kW/220 Nm
HV-battery	12 kWh/355V/62 kW





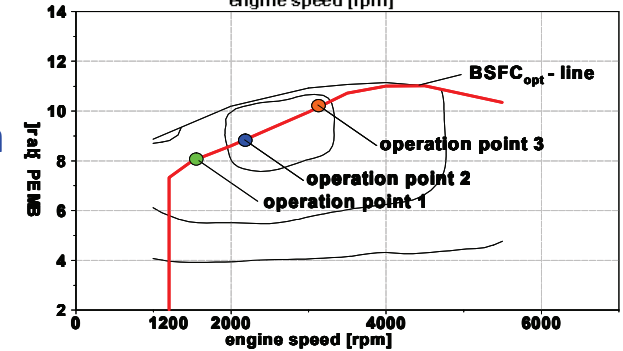
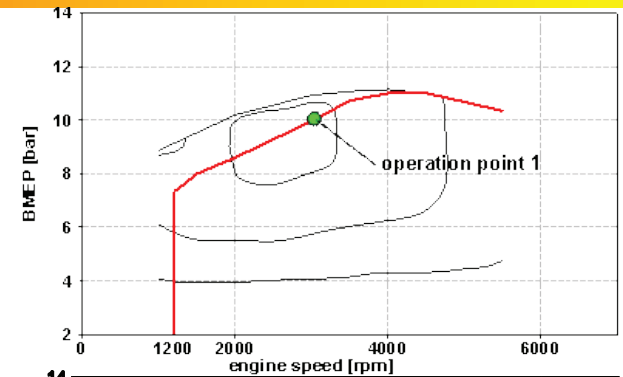
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Vehicle Simulation



One Operation Point

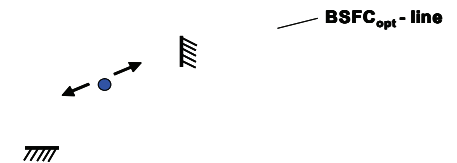
Multiple Operation Points



EREV Work Mode :

- Electric Consumption (pure Electric mode)
- Battery maintenance (RE mode)

along Operation Line

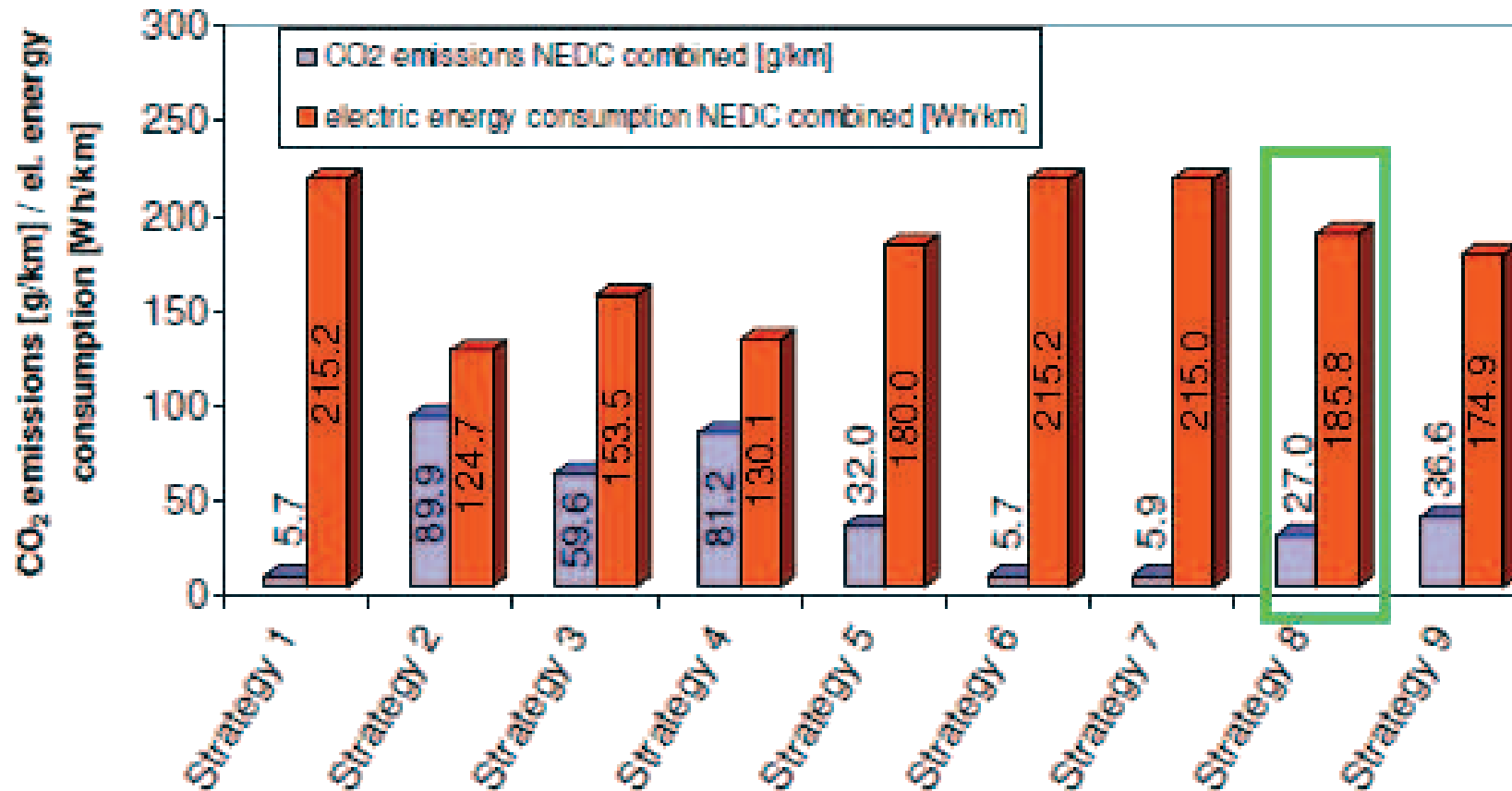




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Vehicle Simulation

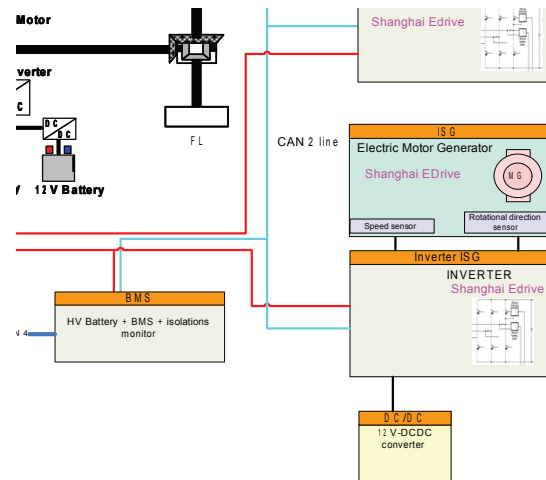
Control strategy simulation





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Vehicle Control System Design



- ◆ The vehicle CAN network topology
- ◆ 5 high-speed CAN → 3 low-speed CAN

Signal Name	Start Bit (LSB)	Length (Bits)	Byte order (Intel, Motorola)	Comment / definition	Receiver
					HCU ISG/PU DCDC Emotor/PU
				Does the message ID means the priority of the message?	
HCU_ISG_Ctrl_cRoll	0	4	Intel	rolling counter	x
StlModeReq	8	4	Intel	requestable state mode of ISG 0x3: Ready 0x5: Service_OffsetCal 0x7: Service_General 0x8: TrqCtrl 0x9: SpeedCtrl 0xE: amDischarge	x
TorgSelP	18	10	Intel	setpoint torque ISG (Not Speed Control??)	x
SpeedSelP	32	8	Intel	speed setpoint for ISG, only with open clutch	x
TqPAMax	40	8	Intel	max limit for positive torque for ISG (motor mode)	x
TqPAMin	48	8	Intel	max negative torque for ISG (generator mode)	x
HCU_ISG_PwrLimit_cRoll	0	4	Intel	rolling counter	x
idclIax	8	11	Intel	max current for motor torque	x
idclIin	19	11	Intel	max current for regenerative torque	x
udclIax	30	10	Intel	max voltage HV	x
udclIin	40	10	Intel	min voltage HV	x

The vehicle CAN network matrix

Msg ID [hex]	Msg ID [dec]	Message Name	Transmitter	DLC	Transmission Type	Cycltime [ms]	busload at 500 kBit/s
							26.42%
132	306	ISG_General	ISG/PU	8	Fixed Periodic	10	2.22%
232	562	ISG_Temp	ISG/PU	8	Fixed Periodic	20	1.11%
134	308	ISG_Limits	ISG/PU	8	Fixed Periodic	10	2.22%
142	322	Emotor_General	Emotor/PU	8	Fixed Periodic	10	2.22%
242	578	Emotor_Temp	Emotor/PU	8	Fixed Periodic	20	1.11%
244	580	Emotor_Limits	Emotor/PU	8	Fixed Periodic	10	2.22%
112	274	HCU_ISG_Ctrl	HCU	8	Fixed Periodic	10	2.22%
114	276	HCU_ISG_PwrLimit	HCU	8	Fixed Periodic	10	2.22%
116	278	HCU_Emotor_Ctrl	HCU	8	Fixed Periodic	10	2.22%
118	280	HCU_Emotor_PwrLimit	HCU	8	Fixed Periodic	10	2.22%
312	786	HCU_LCD	HCU	8	Fixed Periodic	50	0.44%
212	530	HCU_BMS_Ctrl	HCU	8	Fixed Periodic	20	1.11%
122	290	BMS_volCurr	BMS	8	Fixed Periodic	10	2.22%
322	802	BMS_soc	BMS	8	Fixed Periodic	50	0.44%
124	292	BMS_PwrLimit	BMS	8	Fixed Periodic	10	2.22%

The vehicle CAN load rate calculation

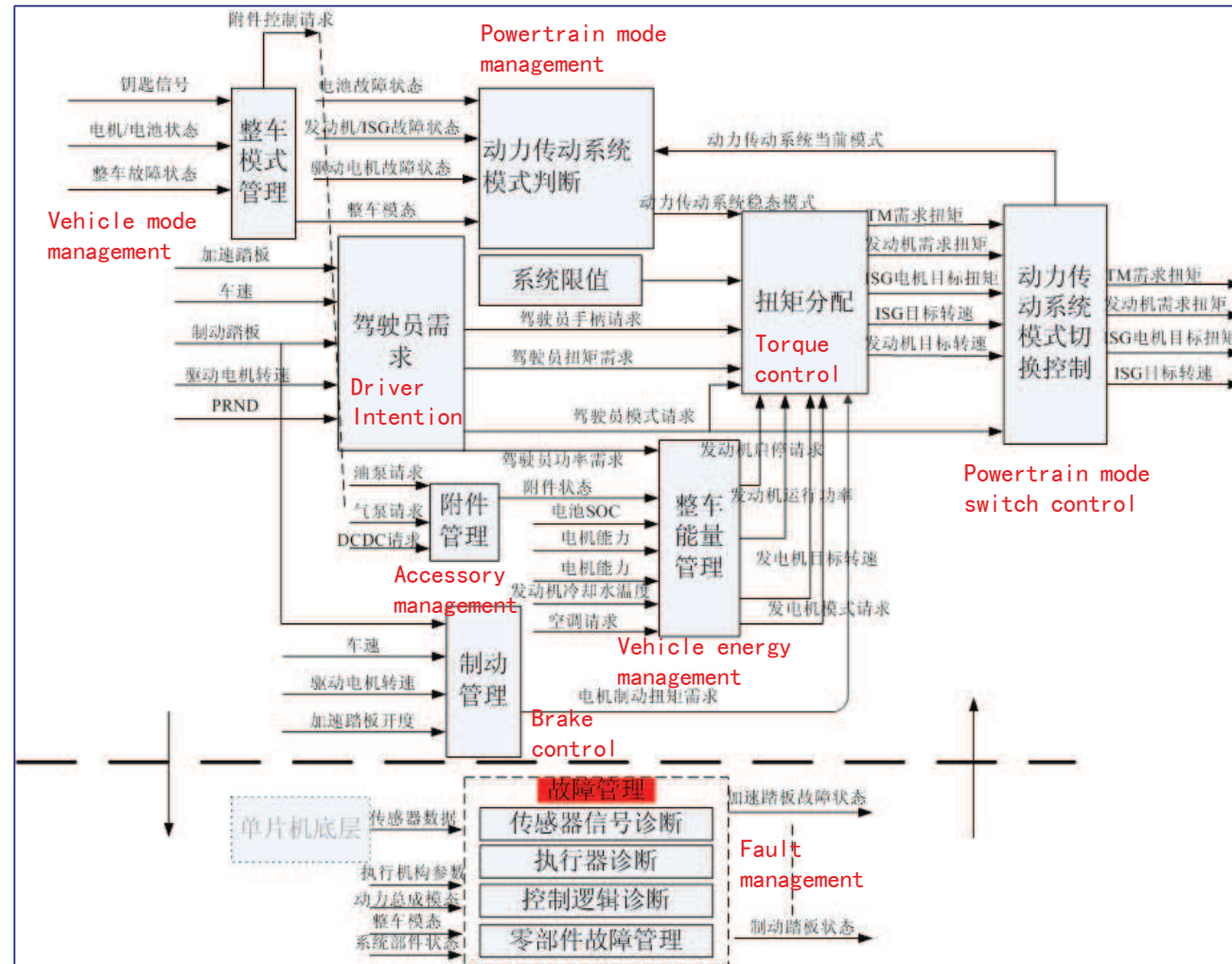
- Design the vehicle CAN network structure and the the vehicle CAN matrix



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The vehicle control system design

Software Architecture



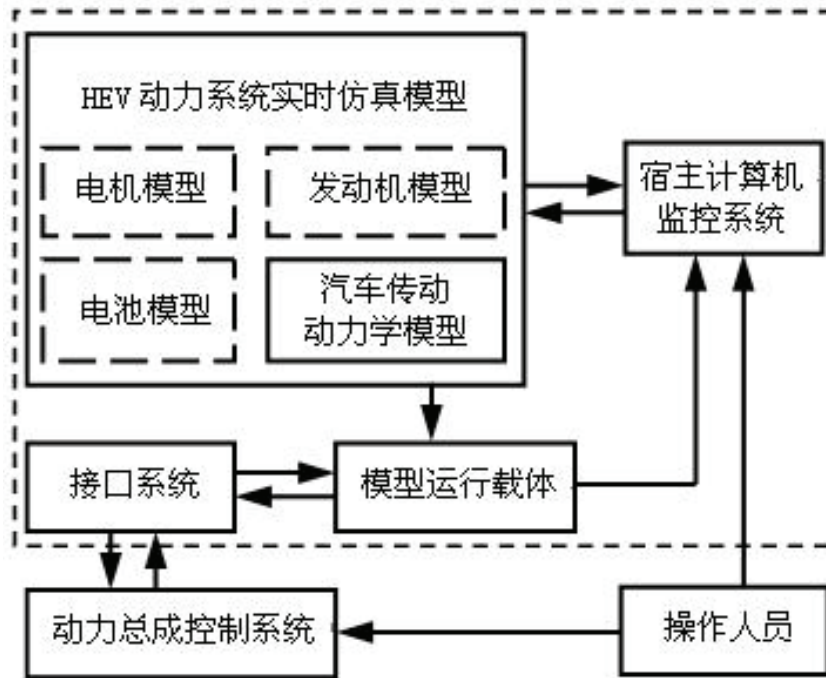


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The vehicle control system design

Hardware in the loop test

The vehicle controller (VCU), motor controller (MCU), battery management system (BMS), engine controller (ECU), and the vehicle network for function testing and diagnostic tests





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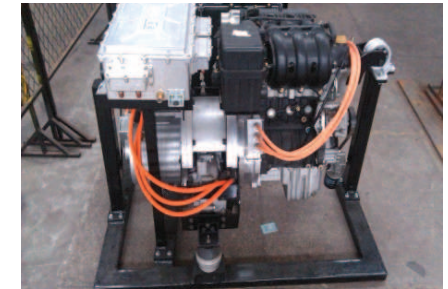
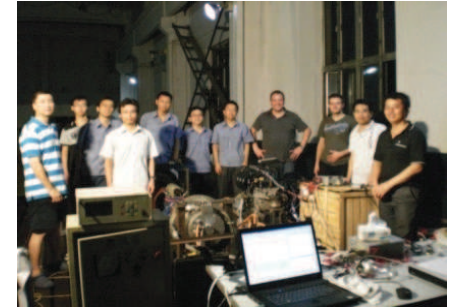
Powertrain Test

□ The Calibration of Range extender

- The engine ignition advance Angle
- Engine torque control
- Range extender speed control

□ System performance test

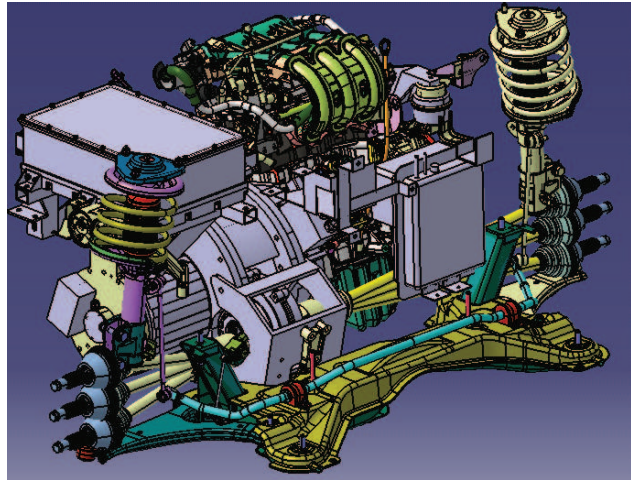
- Range extender efficiency
- Powertrain efficiency
- Range extender power output
- Range extender maximum speed



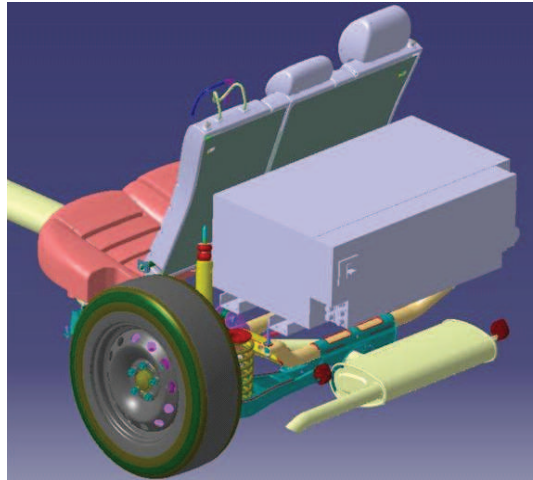


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Vehicle Integration



Powertrain layout



Battery package



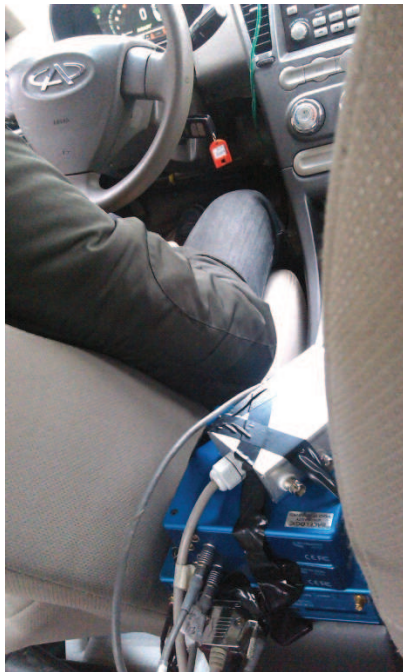
Powertrain cabin



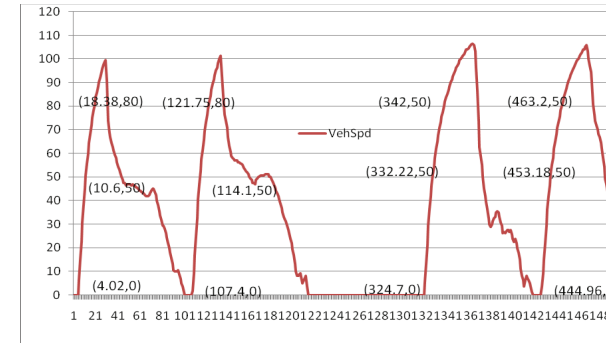
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Vehicle Test

Vehicle dynamic performance test



Proving ground



Acceleration test data

Test item	EV low SOC	EV high SOC	Hybrid low SOC	Hybrid high SOC
0-50km/h acceleration time s	10.1	7.28	10	6.7
50-80km/h acceleration time s	19	8.93	12.1	6.9
Maximum speed km/h	-	-	-	120.8
maximum gradeability %	-	-	-	21%



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Vehicle Test

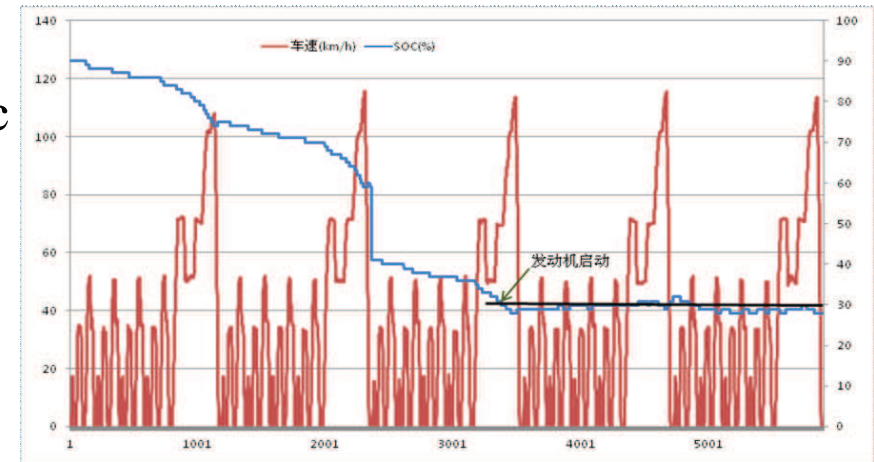
Pure Electric Range

Test based on GB/T 19753 “mild hybrid electric vehicle energy consumption rate test method”

Test results

75%DOD: 40km

100%DOD: 60km

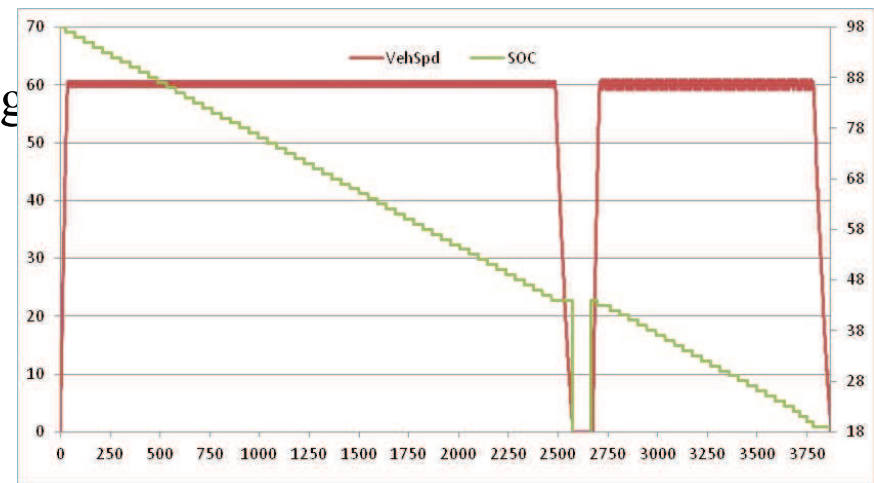


Based on GB/T 18386 “the electric vehicle energy consumption rate and test methods”

Test results

75% DOD: 61.32km

100%DOD: 81.76km





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Vehicle Test

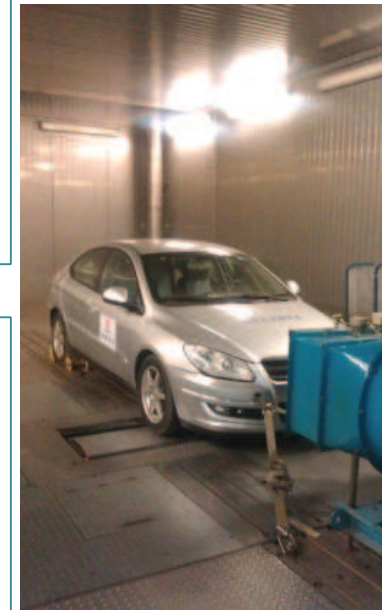
Vehicle energy consumption

Based on GB/T 19753 “mild hybrid electric vehicle energy consumption rate test method”

Electric consumption test	State A	State B
Driving cycle electric consumption kWh/100km	19.48	2.92

Test results

combined electric energy consumption :
12.16 kWh/100km



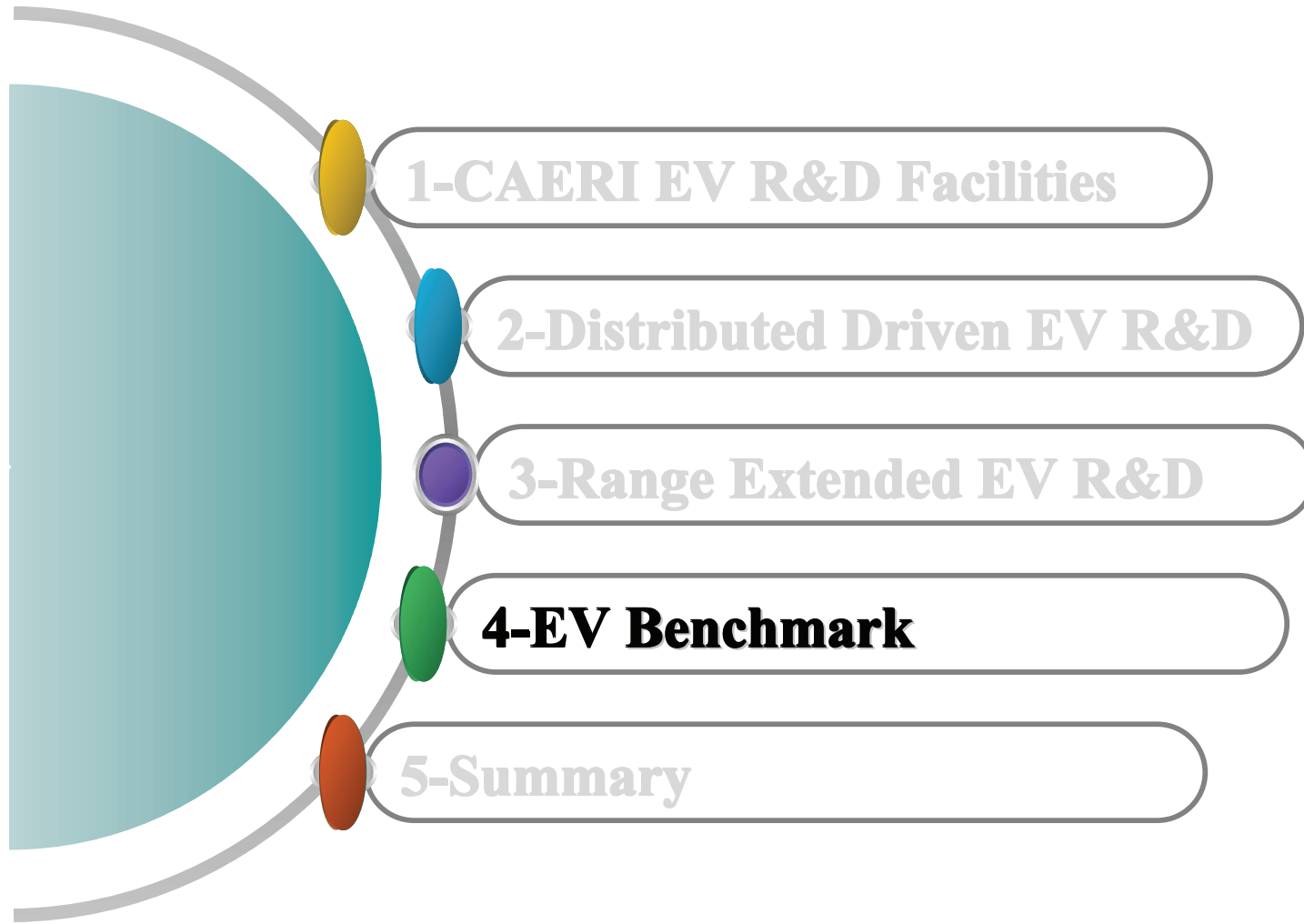
Fuel consumption test	State A	State B
fuel consumption rate L/100km	0.27	6.69
CO2 emissions g/km	6.0	156.7

Test results:

combined fuel consumption : 3.11L/100km
Comprehensive CO2 emissions:
72.63g/km



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National Level Test Center

- 1. National electric vehicle and parts' new-product announcement test center (MIIT)**
- 2. National electric vehicle and key component testing evaluation center (under construction, MOST)**





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Benchmark and evaluation

BEV



Plug-in



REEV



Full Hybrid



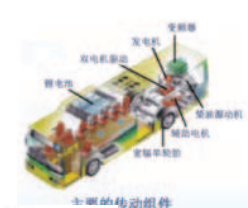
Mild Hybrid



Power train of HDV



Chargers



- Authorized by MOST, inspect and supervise the development of vehicles and parts in 863 program
- Benchmarking more than 12 cars and two powertrain of bus, five chargers

Road Testing & Evaluation

Dynamic test

Brake test

Test report

- Dynamic test includes slide test, accelerate test, top speed test and climbing ability test
- Brake test includes 0type brake test, I-type brake test, ABS invalid brake test, brake force distribution failure brake test, vacuum booster failure brake test, electric regeneration failure brake test, Parking brake test and so on.



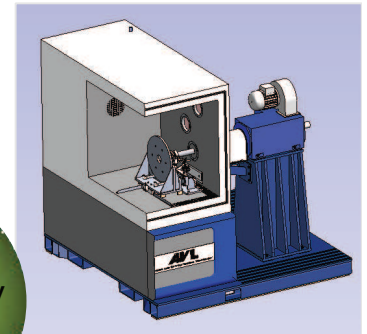


Motor Testing & Evaluation



Reliability

Durability



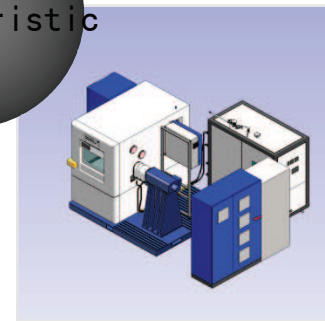
Power density



Dynamic characteristic

Environmental adaptability

Control performance

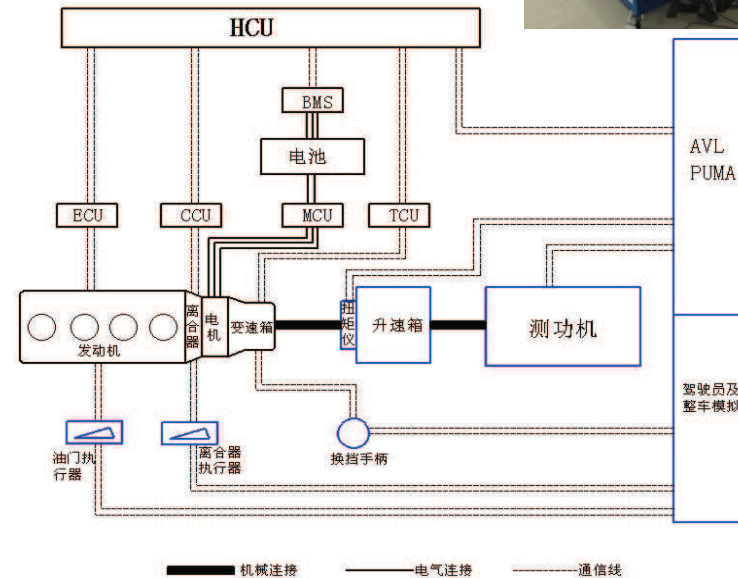
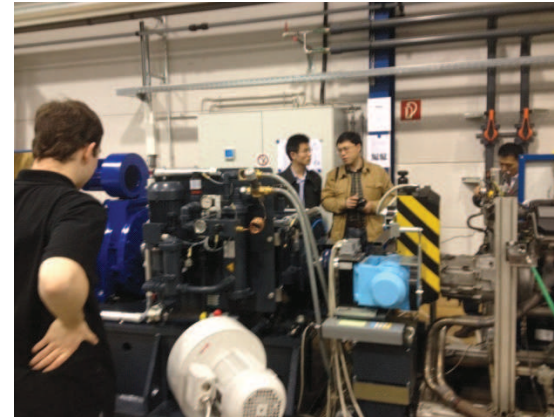




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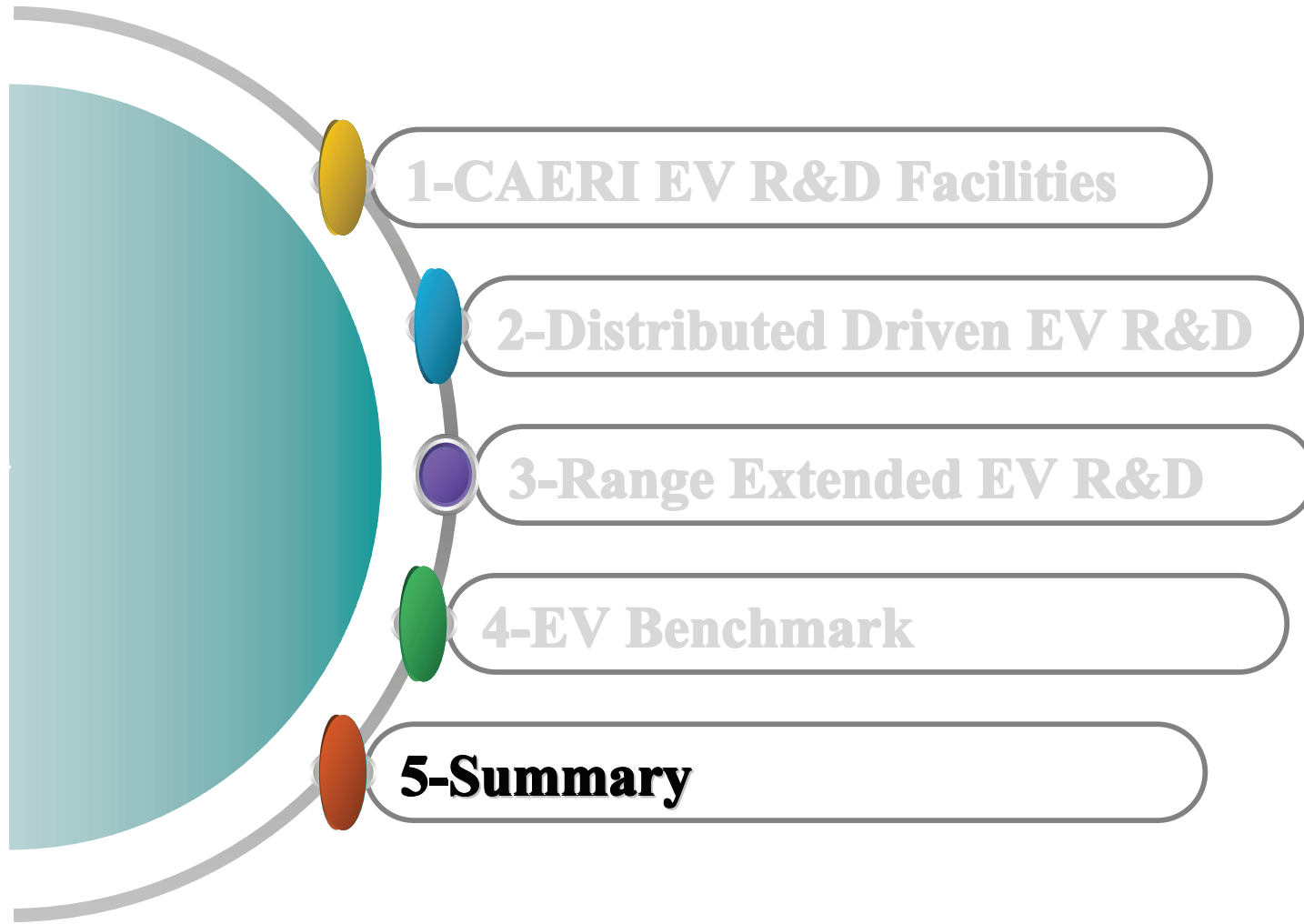
Powertrain testing & evaluation

- Powertrain test including HCU、engine and ECU、clutch、motor and MCU、transmission and TCU、battery and BMS etc
- The test bench simulates vehicles load settings、inertia of the rotating members settings、rolling resistance coefficient settings、frontal area settings、drag coefficient settings、ramp coefficient settings、main reduction ratio settings、tire settings and so on





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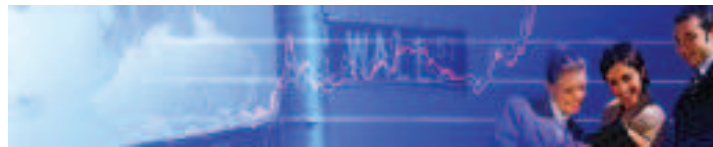
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Summary

- **CAERI has advanced equipments for EV development**
 - Heavy duty&Light Duty powertrain dyno
 - Control system development tools
 - Battery testing equipment
 - NVH, EMC, and crash test
- **CAERI EV R&D focus on**
 - 4 wheel driving EV based on in-wheel motor
 - Range extended vehicle
 - EV and components testing and evaluation



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Thank you



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