



Optimal Energy Consumption and Recovery  
Based on a system network

Project Status



Joint EC / European Green Cars Initiative Workshop 2013  
Electric Vehicle Systems Architecture and Standardization Needs

2013/10/23 Brussels

Dr. Kosmas Knödler  
Robert Bosch GmbH



# Outline

- ❑ OpEneR project overview
- ❑ Vehicle and subsystem integration
- ❑ Energy management functions
- ❑ From office simulation to testbed
- ❑ Conclusion and outlook
- ❑ OpEneR 3008 4WD performance

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# OpEneR partners and objectives

## Consortium

### Partner

Robert Bosch GmbH  
(Germany, Project Coordinator)



Peugeot Citroën Automobiles S.A.  
(France)



Robert Bosch Car Multimedia GmbH  
(Germany)



AVL List GmbH  
(Austria)



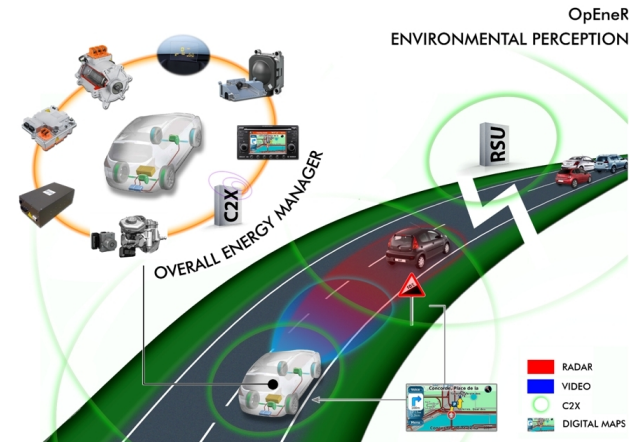
Centro Tecnológico de Automoción de Galicia  
(Spain)



FZI Forschungszentrum Informatik  
(Germany)



- ❑ OpEneR is developing driving strategies & assistance systems, that increase electric vehicle efficiency, driving range & safety.
- ❑ This is achieved by merging data from on-board & off-board sources. A particular focus lies on an optimal cooperation between the electric drivetrain and the regenerative braking system, supported by data from radar, video, satellite navigation, car-to-infrastructure & car-to-car systems.
- ❑ Overall project budget: 7.7 Million €



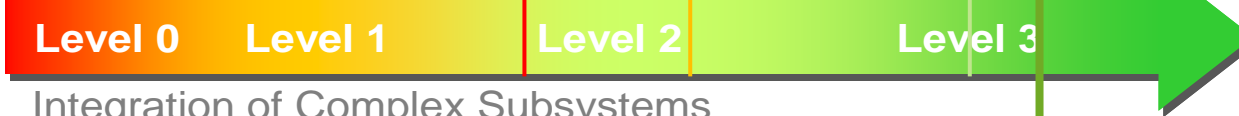
# OpEneR Technology Levels



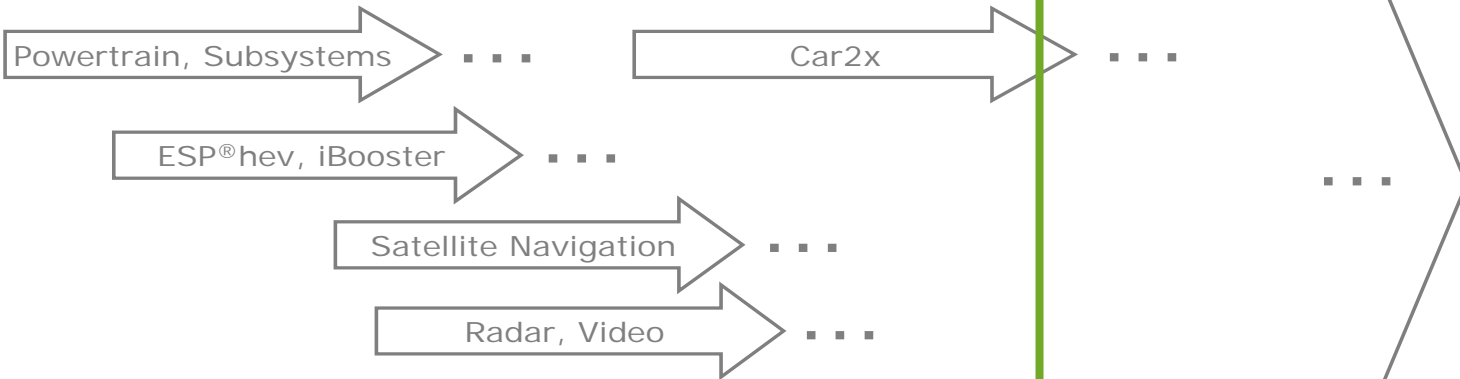
LXA → OpEneR Level X Availability of Vehicle/Hardware  
 LXV → OpEneR Level X Validated OpEneR Technologies  
 LXQ → OpEneR Level X Quantified OpEneR Efficiency

04/2012 L0A 07/2012 L0Q ✓	04/2012 L1A 09/2012 L1V ✓ 12/2012 L1Q	01/2013 L2A 07/2013 L2V ✓ 08/2013 L2Q	09/2013 L3A 01/2014 L3V 04/2014 L3Q
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## Software Development Process – Technology Levels



### Integration of Complex Subsystems



### Sensing Traffic & Environment Conditions



today

OpEneR Vehicle Development

# Test OpEneR prototypes



01/2012 OpEneR prototype n°1 in winter testing



03/2013 OpEneR prototypes n°1 and n°2 in winter testing



06/2013 OpEneR prototype n°1 on 2<sup>nd</sup> Project Review in Boxberg



Initial setup

low- $\mu$  ESP calibration and testing

Function Demonstration

OpEneR Vehicle Development



05/2013 OpEneR prototype in wind channel in Paris

Validation measurements, function validation



12/2012 OpEneR prototype n°1 on Boxberg Test Track

Coasting assist, torque distribution and regenerative braking



04/2013 OpEneR prototype n°1 on Boxberg Test Track

Enhanced coasting assist, torque distribution and regenerative braking

05/2014 Final demonstration event in Vigo, Spain, on public intelligent corridor

Full OpEneR Energy Management Technology demonstrated on public road

Validation measurements, function validation

05/2013 OpEneR prototype n°2 on Graz dynamometer testbed



Functions based on ADAS, ADASIS, c2x



Public Road Release 11/2013



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# Vehicle topology



3008 Hybrid4



**Rear axle**

27 kW/200Nm  
e-machine, HV NiMH  
battery and all-in-one  
DCDC & double inverter



3008 OpEneR



**Front axle**

120 kW/300Nm  
Diesel engine with  
HV Stop/start 8kW  
generator

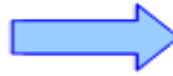




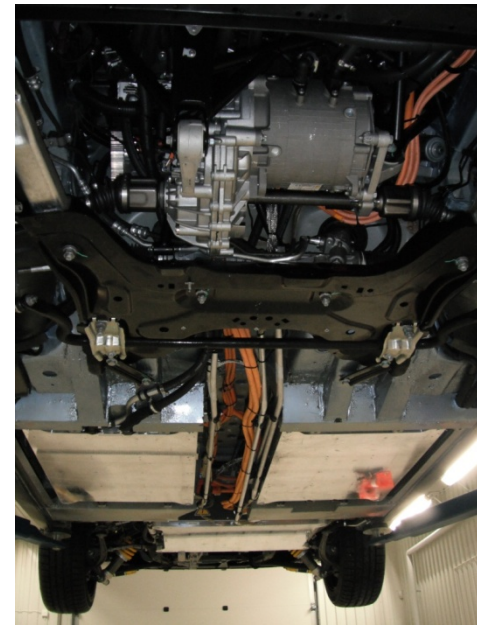
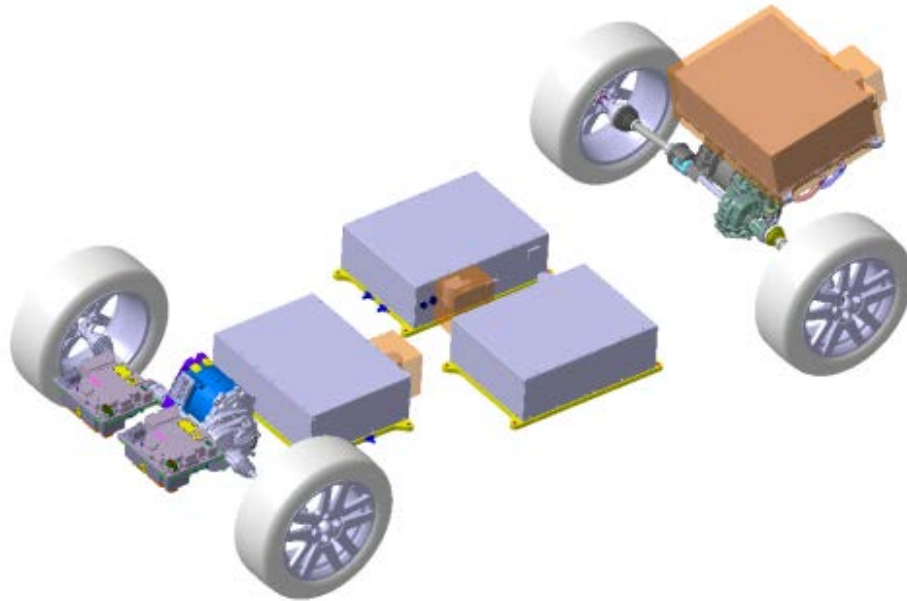
# Vehicle topology



3008 Hybrid4



3008 OpEner



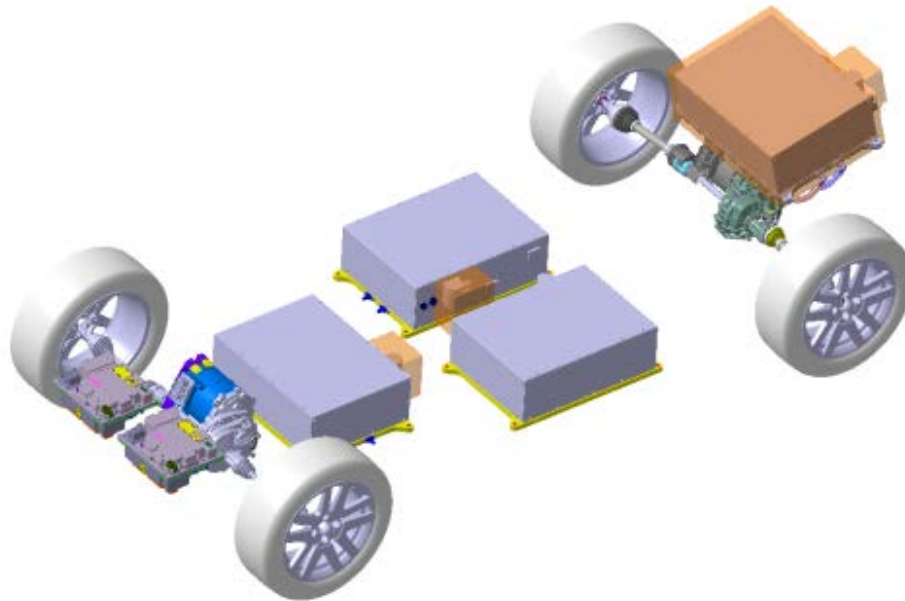
# Vehicle topology



3008 Hybrid4



3008 OpEnerR



- ❑ **2x50kW e-machine**
- ❑ **40kWh battery package**
  - ❑ 4x125kg package in serial connection
  - ❑ FePO4 technology
  - ❑ 36,8 kWh usable capacity (200km range)
  - ❑ 110kW discharge and charge (depending on temp.)
- ❑ **Thermal management**
  - ❑ 2 radiators for inverters/e-machines and battery
  - ❑ Water heating via 2x 6kW CTP (cockpit & battery)
  - ❑ Electric A/C compressor with double circuit (battery & cockpit)
- ❑ **Body & chassis design**
  - ❑ New Body design for battery integration
  - ❑ General behavior similar to 3008 hybrid4 (+200kg)
  - ❑ Body Stiffness same as or better than serial production

# New braking systems

## Components

Brake boost → Vacuum-free & autonomous braking

Vacuum Booster



iBooster



Modulation → Recuperation

ESP®



ESP®hev



OpEneR



iBooster



ESP®hev

## Use cases

Target vehicles

standard vehicle with ICE

ICE vehicle w/ high performance driver assistance (HPDA\*)

Hybrid vehicle (mHEV, sHEV)

PHEV/EV-vehicle or Hybrid with HPDA

\* high performance driver assistance requiring highest pressure dynamics

Setup



## Functions

- Vacuum free braking force amplification
- Support of energy recuperation via two e-machines
- Blending between electric e-machine torque and friction torque
- iBooster for active brake pressure build-up

# New braking systems

## Components

Brake boost → Vacuum-free & autonomous braking

Vacuum Booster



iBooster



Modulation → Recuperation

ESP®



ESP®hev



OpEneR



iBooster



ESP®hev

## Use cases

Target vehicles

standard vehicle with ICE

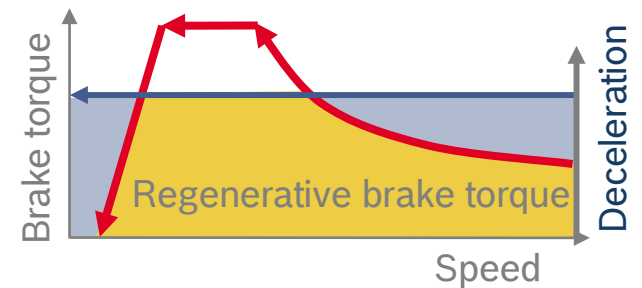
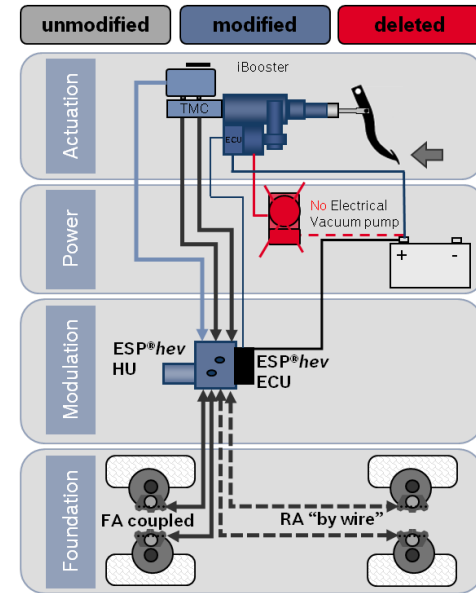
ICE vehicle w/ high performance driver assistance (HPDA\*)

Hybrid vehicle (mHEV, sHEV)

PHEV/EV-vehicle or Hybrid with HPDA

\* high performance driver assistance requiring highest pressure dynamics

Setup



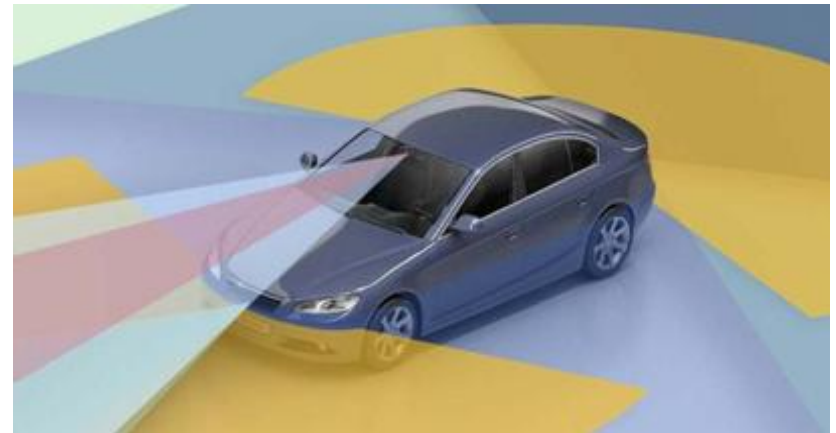
# ADAS in OpEneR



## Components



OpEneR



## Functions

- Traffic Signs, objects, lanes
- Eco ACC w/ Stop & Go
- Blind Spot Detection
- Lane Change Assist
- Rear Cross Traffic Alert

# ADAS in OpEneR



## Components



Ultrasonic sensors



Long range radar



Mid range radar rear



Mid range radar plus



Multi purpose camera



Near Field camera



Night Vision camera



OpEneR



Multi purpose camera



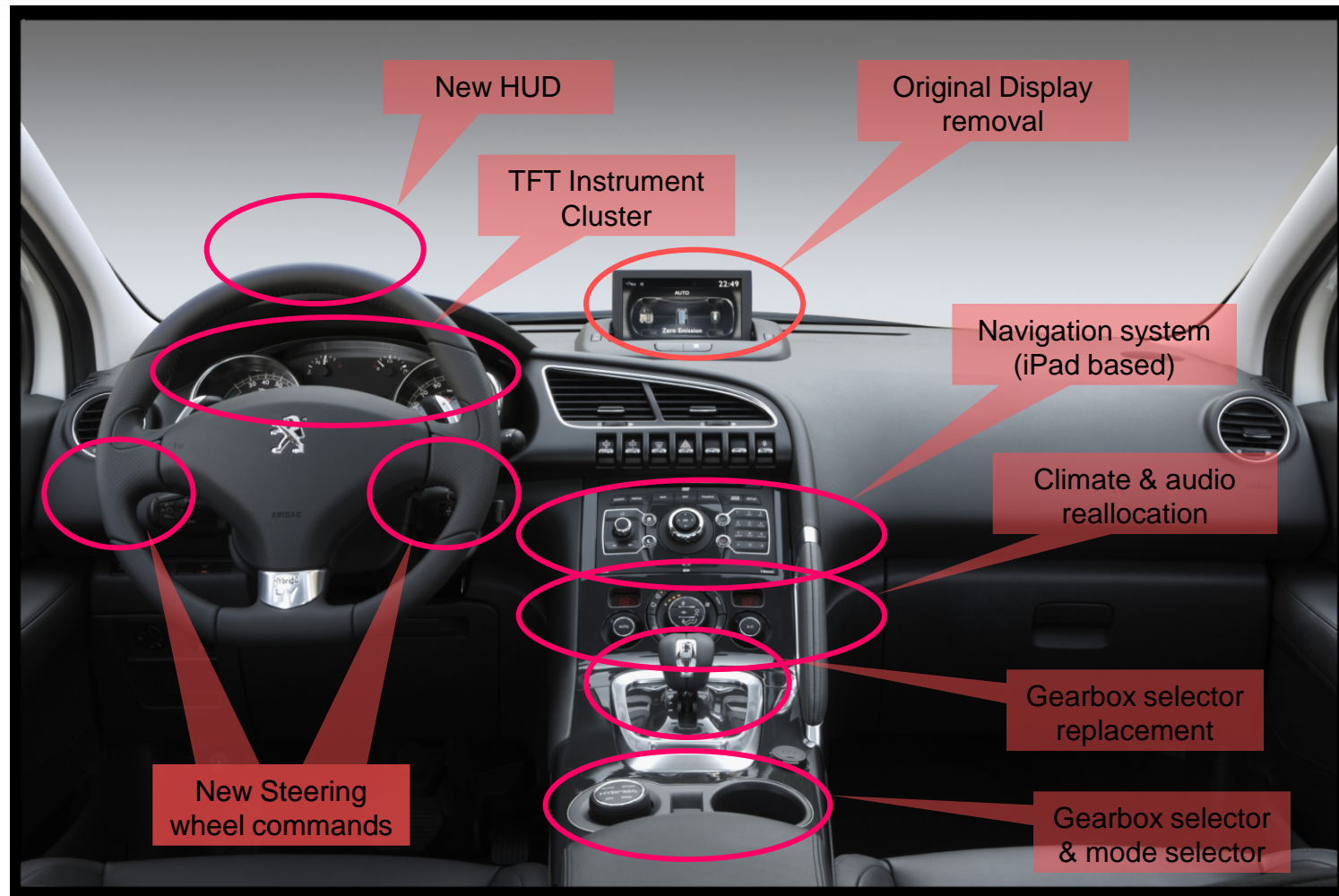
Long range radar



2x Mid range radar rear



# New HMI including SatNav



# New HMI including SatNav





# New HMI including SatNav



# New HMI including SatNav



# Active acceleration pedal



An active pedal supports the driver with **haptic** signals while driving

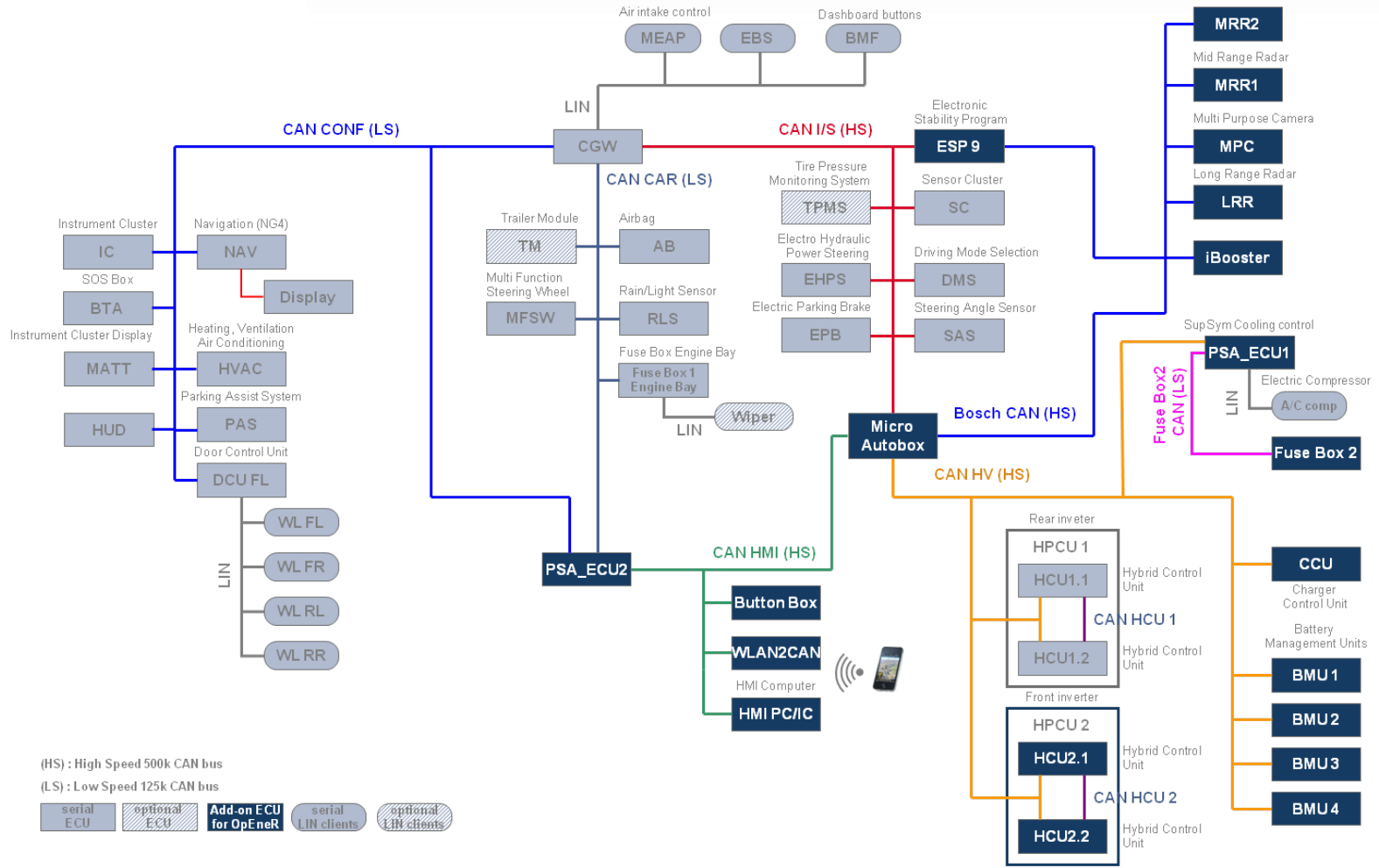
Signals are possible as

- Knocking
- Vibration
- Force feedback
- Variable kick-down
- (Parallel force increase)

Warning signals from **different connected systems** can be sent to the driver



# E/E-architecture



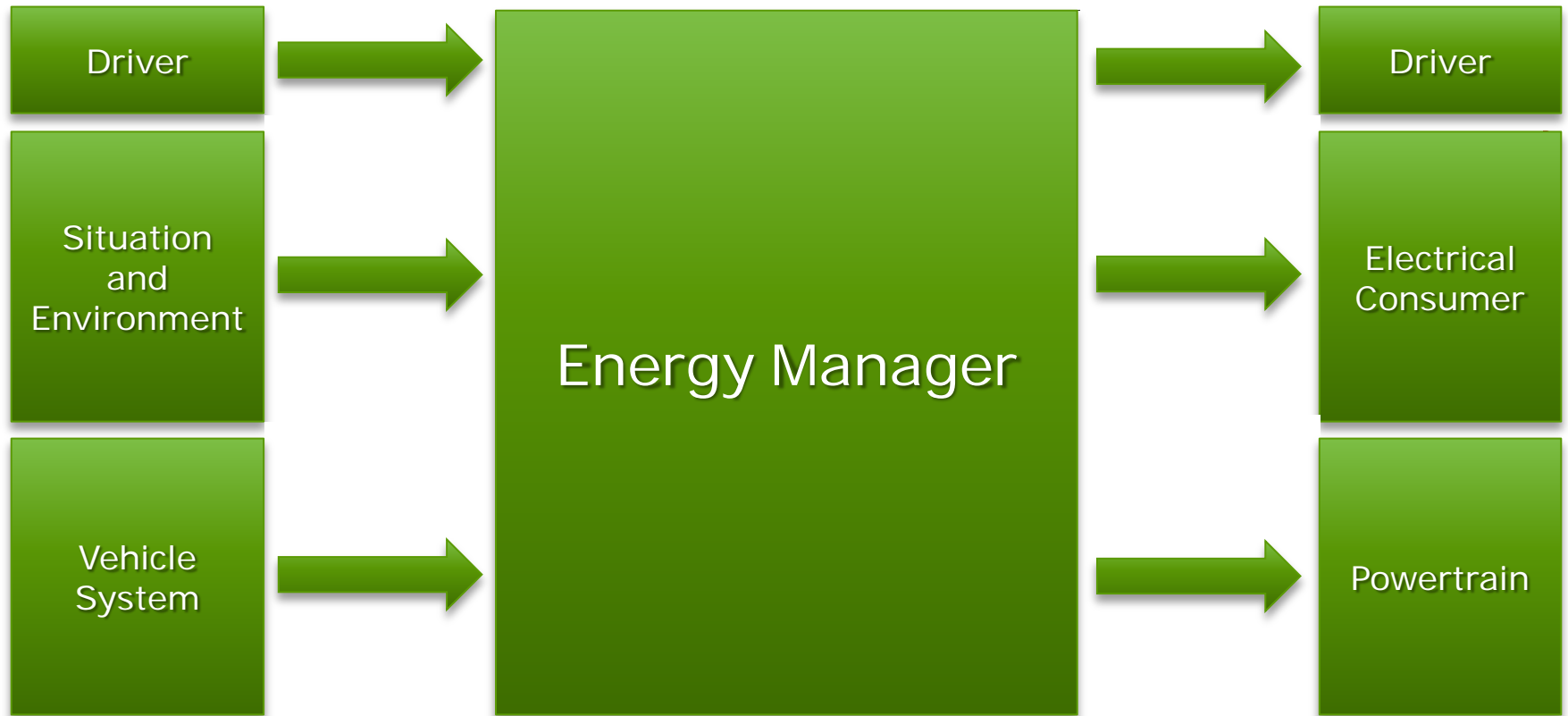
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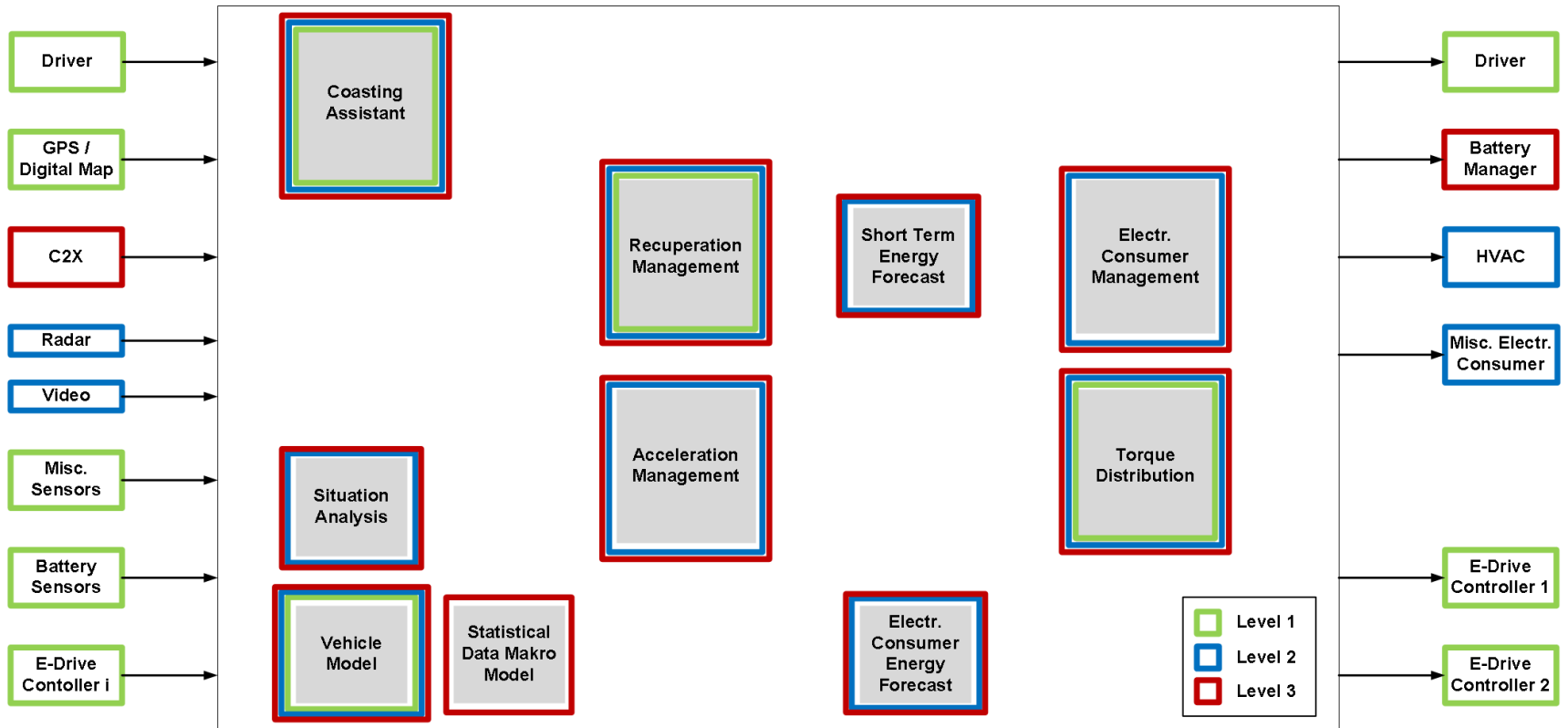
# Energy management functions



# Energy management functions



# Energy management functions





# Energy management functions



- ❑ Energy Efficient Route Calculation
- ❑ ESP<sup>®</sup>*hev*: 2-channel Cooperative Regenerative Braking
- ❑ TCS – Distributed e-Machine Control
- ❑ Torque Distribution
- ❑ Coasting Assistant
- ❑ Energy efficient ACC
- ❑ Acceleration Assistant
- ❑ Energy-efficient auxiliaries

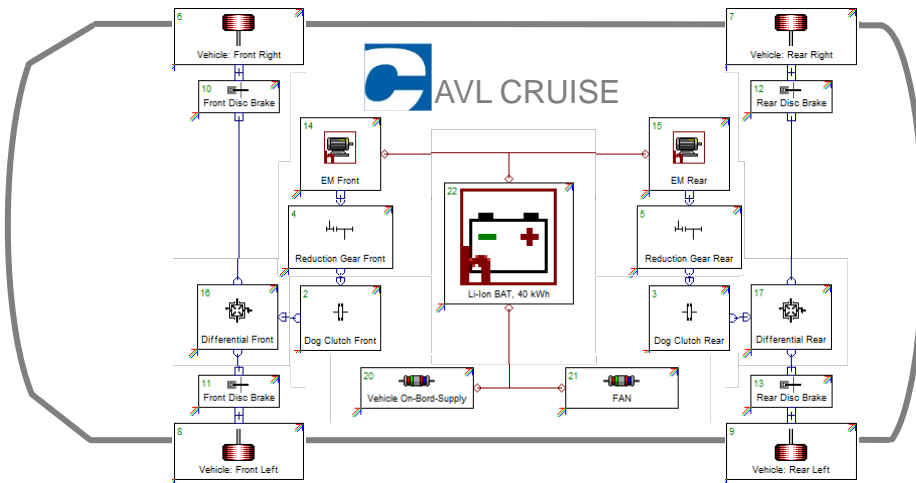
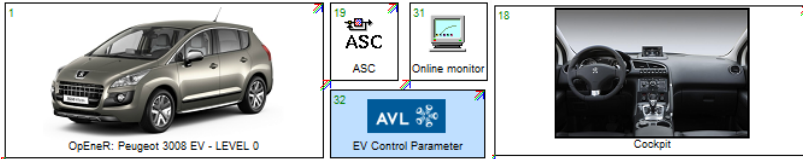
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# From office simulation to testbed



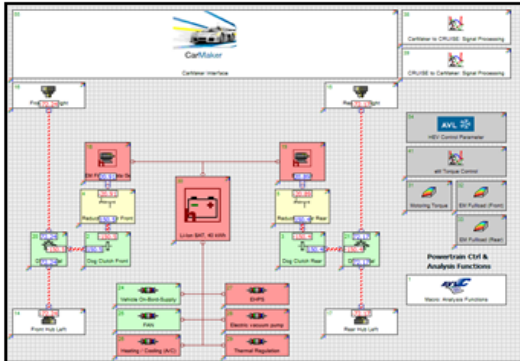
## OpEneR Simulation Toolchain



- ❑ 40kwh battery package (200km range)
- ❑ 110kw discharge and charge (depending on temp.)
- ❑ Front & Rear Axle e-traction i.e. e-4WD
- ❑ Recuperation (e-braking) with ESP<sup>®</sup>hev + iBooster



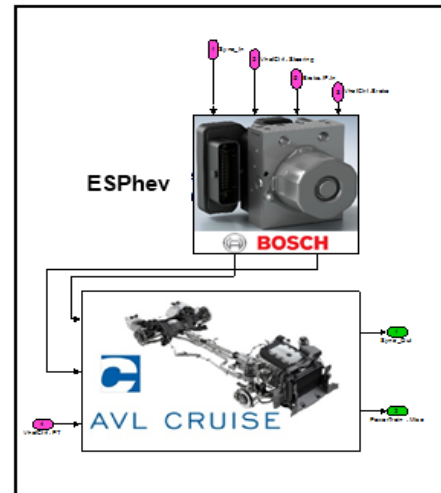
# From office simulation to testbed



OpEneR Powertrain Model



Traffic Scenarios



CarMaker with AVL Cruise



- OpEneR co-simulation environment including the AVL CRUISE powertrain and Bosch ESP<sup>®</sup>hev model

# From office simulation to testbed

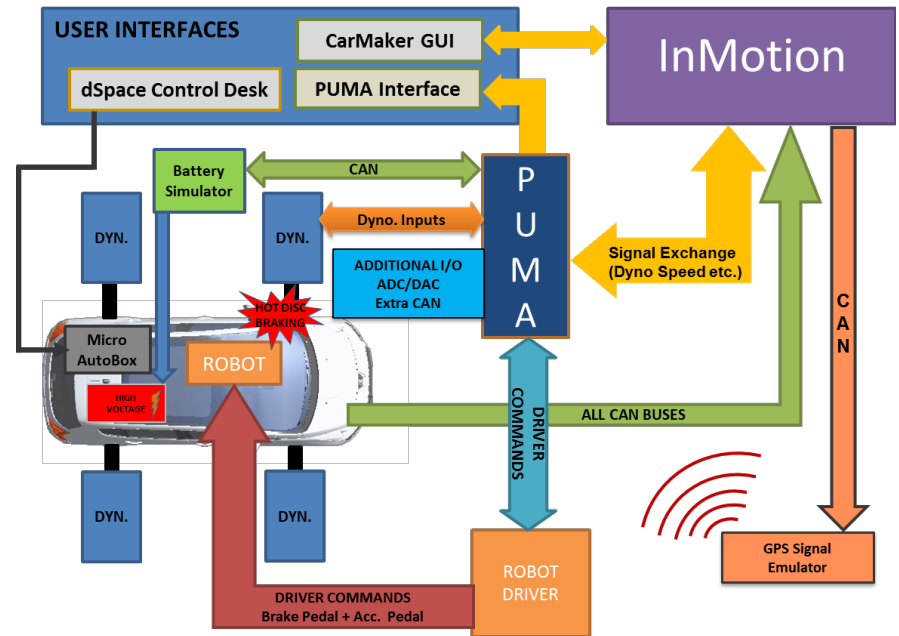
- Simulation toolchain extensively supports development process

Reuse of office simulation environment for AVL InMotion test-bed



## AVL InMotion test-bed

- Fast migration to HiL testing
- Rapid prototype testing
- Realistic real-world conditions
- Complex interface between Unit Under Test, automation and measurement systems



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# Conclusion and outlook



- ❑ Eco ACC function is currently under evaluation
- ❑ OpEneR successfully cooperated eFuture in the field of evaluating eco ADAS functions
- ❑ OpEneR consortium keeps on working on
  - ❑ Architecture, scalability, modularity, and metrics
  - ❑ Energy efficient and safe speed modulation
  - ❑ Energy efficient and safe Torque Split
  - ❑ Energy efficient auxiliary consumers
- ❑ Public road release
- ❑ Afterwards Car-to-X units will be integrated at CTAG
  - ❑ Integration and evaluation of Car-to-X related functions
  - ❑ Final testing and proving during last project review in Vigo, Spain

# Outlook



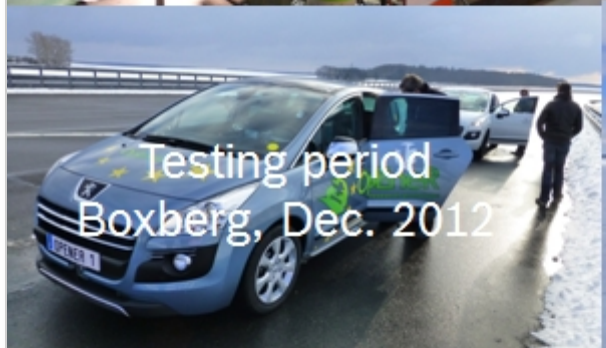
Prototype build-up  
Paris, Dec. 2011



Winter testing  
Arieplog, Jan. 2012



1<sup>st</sup> project review  
Vigo, Jun. 2012



Testing period  
Boxberg, Dec. 2012



Winter testing  
Vaitoudden, Mar. 2013



Wind tunnel  
Paris, Apr. 2013



4-wheel dynamometer  
Graz, May. 2013



2<sup>nd</sup> project review  
Boxberg, Jun. 2013



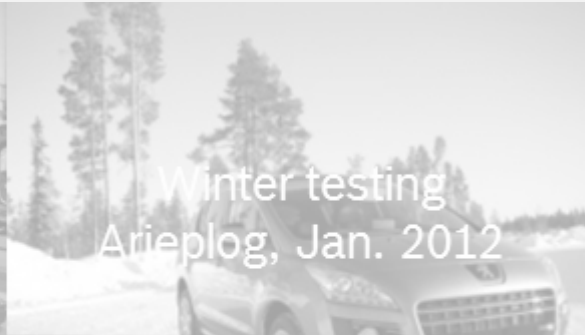
RIVE2013  
Alès, Jul. 2013



# Outlook



Prototype build-up  
Paris, Dec. 2011



Winter testing  
Arieplog, Jan. 2012



1<sup>st</sup> project review  
Vigo, Jun. 2012



Testing period  
Boxberg, Dec. 2012

2013  
Create  
Connect  
Grow  
OpEneR will exhibit  
on Stand 5E13  
Nov. 6th until Nov. 8th



Wind tunnel  
Paris, Apr. 2013



4-wheel dynamometer  
Graz, May. 2013



2<sup>nd</sup> project review  
Boxberg, Jun. 2013



RIVE2013  
Alès, Jul. 2013

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## 3008 4WD performance



OpEneR prototypes proved performance on several events, e.g.

- ❑ Two winter testing periods
- ❑ Testing periods on partner's proving grounds
- ❑ AVL's 4-wheel dynamometer testbed
- ❑ RIVE2013



# Discussion



Thanks for your attention  
Any questions?