Call identifier: H2020-GV-03-2016
Grant agreement number: 724095

Bernhard Brandstätter
Virtual Vehicle
## Project Start: April 1st 2017  
## Duration 36 months

### Budget

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Total Costs:</td>
<td>12,694.011 €</td>
</tr>
<tr>
<td>Grant Amount:</td>
<td>9,900,500 €</td>
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</tbody>
</table>

### Administrative Information

<table>
<thead>
<tr>
<th>Participant organisation name</th>
<th>Participant short name</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLVO PERSONVAGNAR AB (Coordinator)</td>
<td>VCC</td>
<td>Sweden</td>
</tr>
<tr>
<td>Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH</td>
<td>VIF</td>
<td>Austria</td>
</tr>
<tr>
<td>Alma Automotive srl</td>
<td>ALMA</td>
<td>Italy</td>
</tr>
<tr>
<td>AVL List GmbH</td>
<td>AVL</td>
<td>Austria</td>
</tr>
<tr>
<td>CENTRO RICERCHE FIAT SCPA</td>
<td>CRF</td>
<td>Italy</td>
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<tr>
<td>CESKE VYSOKÉ UCENI TECHNICKE V PRAZE</td>
<td>CTU</td>
<td>Czech Republic</td>
</tr>
<tr>
<td>FEV GmbH</td>
<td>FEV</td>
<td>Germany</td>
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<tr>
<td>FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV</td>
<td>IMS</td>
<td>Germany</td>
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<tr>
<td>GKN DRIVELINE ZUMAIA SA</td>
<td>GKN</td>
<td>Spain</td>
</tr>
<tr>
<td>GENERAL MOTORS POWERTRAIN - EUROPE SRL</td>
<td>GM</td>
<td>Italy</td>
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<tr>
<td>IDEAS &amp; MOTION SRL</td>
<td>I&amp;M</td>
<td>Italy</td>
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<tr>
<td>IDIADA AUTOMOTIVE TECHNOLOGY SA</td>
<td>IDIADA</td>
<td>Spain</td>
</tr>
<tr>
<td>IESTA - Institut für Innovative Energie- &amp; Stofftauschsysteme</td>
<td>IESTA</td>
<td>Austria</td>
</tr>
<tr>
<td>IFP Energies Nouvelles</td>
<td>IFEN</td>
<td>France</td>
</tr>
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<td>INFINEON TECHNOLOGIES AG</td>
<td>IFAG</td>
<td>Germany</td>
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<td>SIEMENS INDUSTRY SOFTWARE SAS</td>
<td>SIE</td>
<td>France</td>
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<tr>
<td>FUNDACION TECNALIA RESEARCH &amp; INNOVATION</td>
<td>TEC</td>
<td>Spain</td>
</tr>
<tr>
<td>UNIVERSITY OF SURREY</td>
<td>USR</td>
<td>UK</td>
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<tr>
<td>VALEO SYSTEMES DE CONTROLE MOTEUR SAS</td>
<td>VALEO</td>
<td>France</td>
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<tr>
<td>RHEINISCH-WESTFAELISCH TECHNISCHE HOCHSCHULE AACHEN</td>
<td>IKA</td>
<td>Germany</td>
</tr>
<tr>
<td>AVL Schrick GmbH</td>
<td>AVL -S</td>
<td>Germany</td>
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</tbody>
</table>
✓ Objective 1: Cost premium of 5% for mild and full hybrid and 15% for P-HEV compared to best in class non-hybrid diesel vehicles available on the market.

✓ Objective 2: Reduction of fuel consumption on WLTP cycle by 20% and 25% increase in electric driving range for P-HEV, respectively.

✓ Objective 3: Demonstrating the vehicles’ noxious emissions RDE compliance with a 1.5 compliance factor.

✓ Objective 4: Improvement of vehicle performance according to proper performance index and the objective assessment of driveability.

✓ Objective 5: Verification and assessment along 3 vehicle classes and 3 hybrid vehicle architectures.
## IMPACT

### COST

<table>
<thead>
<tr>
<th>Type</th>
<th>Premium to Diesel</th>
<th>Premium to Diesel after ADVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV</td>
<td>75%</td>
<td>22% - 7% long-term</td>
</tr>
<tr>
<td>HEV</td>
<td>30%</td>
<td>5%</td>
</tr>
<tr>
<td>Mild-hybrid</td>
<td>10%</td>
<td>-11%</td>
</tr>
</tbody>
</table>

### Efficiency

<table>
<thead>
<tr>
<th>Measure</th>
<th>Impact on efficiency</th>
</tr>
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<tbody>
<tr>
<td>E-Turbo + ICE downsizing</td>
<td>20%</td>
</tr>
<tr>
<td>Advanced control + Eco Routing/Driving</td>
<td>10-15%</td>
</tr>
<tr>
<td>Optimal torque split</td>
<td>3%</td>
</tr>
<tr>
<td>Comprehensive energy management</td>
<td>1-2%</td>
</tr>
</tbody>
</table>

### Emissions

**measures**

- Simplification + downsizing of engines
- Battery high energy/high power
- Advanced control, ECO-Routing
- Electrically heated catalyst
Battery achievements @ V1

Duration: 36 months
Project Start: 1st April 2017
Project Budget: 12.7 Mio. Euro
Project Funding: 10.0 Mio. Euro

V1 – VCaC
Gasoline HEV with high-power Battery

V2 – CRF
Gasoline PHEV

V3 – GM
Diesel mild-HEV

Optimal Control of HEVs
Advanced Predictive Thermal and Energy Control
economical and ecological routing and speed planning

Innovative Components & Subsystems for HEVs
Enhanced Aftertreatment Systems
Advanced Thermal Management of Components

Independent Validation and Testing / Cost Assessment
Base Vehicles Testing
Demonstrators Validation

Demonstrator 1
Demonstrator 2
Demonstrator 3
High-Performance Hybrid Battery

Module / Pack

Module dimension:
- Length: 635 mm
- Width: 140 mm
- Height: 140 mm
- Weight: < 20 kg

Pack performance (2 modules):
- Capacity: 2 kWh
- Nominal Voltage: 400 V
- Discharge (10s): 100 kW
- Continuous: 60 kW
- Charge (10s): 100 kW

Toshiba high power LTO cells
High-Performance Hybrid Battery

**COOLING DESIGN**

- **Cell amount:** 168 cells serial
- **Cell losses:** 38.4 W
- **Busbar losses:** 0.7 W
  - Losses in battery ($\dot{Q}$): **6.6 kW**
- **Target temp. spread coolant:** $\leq 5.0$ K
- **Specific heat capacity of the coolant** ($c_p$): $3300 \frac{J}{kg*K}$
- **Density of the coolant:** $1073 \frac{kg}{m^3}$
  - Flowrate: **12 l/min**
Achievements @ V2

Duration: 36 months
Project Start: 1st April 2017
Project Budget: 12.7 Mio. Euro
Project Funding: 10.0 Mio. Euro

V1 – VCaC
Gasoline HEV with high-power Battery

V2 – CRF
Gasoline PHEV

V3 – GM
Diesel mild-HEV

Optimal Control of HEVs
Advanced Predictive Thermal and Energy Control
Economical and ecological routing and speed planning

Innovative Components & Subsystems for HEVs
Enhanced Aftertreatment Systems
Advanced Thermal Management of Components

Independent Validation and Testing / Cost Assessment
Base Vehicles Testing
Demonstrators Validation

FCA

Demonstrator 1
Demonstrator 2
Demonstrator 3
Hybrid Battery Solution

- investigating a battery solution for V2 vehicle demonstrator, consisting of high energy modules and high power modules.
- scouting, supply and test bench measurement of post Li-ion lithium-sulfur and solid-state technology cells.
- Commercially available post Li-ion cells did not yet meet energy density levels reported in literature. Cycle life stability for lithium-sulfur was poor, but good for solid-state cells.
- Current NMC-Graphite cell technology will probably prevail in the foreseeable future.

Just for research purposes and not to be implemented in WP5 vehicle demonstrator
Alternative identification and virtual validation of e-4WD architectures

• OBJECTIVES:
  
  • Alternative identification and benchmarking of possible architectures for e-4WD solution.
  • Virtual integration of E/E components (mainly ECUs) for simulation, test and validation

### System Architecture Comparison

<table>
<thead>
<tr>
<th>System Architecture</th>
<th>Topology</th>
<th>Weight Suggestion</th>
<th>Efficiency</th>
<th>Performance</th>
<th>Handling</th>
<th>EV Mode</th>
<th>Cost</th>
<th>Weight</th>
<th>Integration</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sys Arch 0</td>
<td>Base Line, Alfa Romeo Giulia Architecture.</td>
<td>20</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>Sys Arch 1</td>
<td>Hybrid 2F 8 speed gearbox 4WD automatic.</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>Sys Arch 2</td>
<td>Front eTwinster axle capabilities and Torque Vectorsing.</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>Sys Arch 3</td>
<td>Front eAxle dual motors with epicyclic gear.</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Sys Arch 4</td>
<td>Front axle with differential and upper longitudinal.</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>325</td>
<td></td>
</tr>
</tbody>
</table>

**Longitudinal Test**

**Lateral Test**

**Efficiency Test**
Integration and Test rig validation.

- Integration study of the solution and Testing in operational environment: GKN’s test rig with I&M and GKN HW.

  ![Torque Vectoring](image1)
  ![Torque Split](image2)
  ![Brake Blending](image3)
  ![Traction Control](image4)

- Results
  - Lateral acceleration improvement due to torque vectoring algorithms.
  - Longitudinal acceleration improvement with the same traction power.
  - Efficiency improvement due to the regenerative braking.

- Partners
  
  ![Partners Logos](image5)
Achievements @ V3

Duration: 36 months
Project Start: 1st April 2017

Project Budget: 12.7 Mio. Euro
Project Funding: 10.0 Mio. Euro

- V1 – VCaC
  Gasoline HEV with high-power Battery

- V2 – CRF
  Gasoline PHEV

- V3 – GM
  Diesel mild-HEV

Optimal Control of HEVs
- Advanced Predictive Thermal and Energy Control
- economical and ecological routing and speed planning

Innovative Components & Subsystems for HEVs
- Enhanced Aftertreatment Systems
- Advanced Thermal Management of Components

Independent Validation and Testing / Cost Assessment
- Base Vehicles Testing
- Demonstrators Validation

WP7 Project Management, Dissemination, Exploitation

Demonstrator 1

Demonstrator 2

Demonstrator 3
### 15/30 kW Battery System

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Variant I</th>
<th>Variant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack Configuration</td>
<td>-</td>
<td>12S2P (1x12S2P module)</td>
<td>12S4P (2x6S4P modules in series)</td>
</tr>
<tr>
<td>Nominal Voltage</td>
<td>[V]</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Nominal Energy</td>
<td>[kWh]</td>
<td>5.3</td>
<td>10.6</td>
</tr>
<tr>
<td>10s Discharge Current</td>
<td>[A]</td>
<td>600</td>
<td>1.200</td>
</tr>
<tr>
<td>Continuous Discharge Current</td>
<td>[A]</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>10s Charge Current</td>
<td>[A]</td>
<td>225</td>
<td>450</td>
</tr>
<tr>
<td>Continuous Charge Current</td>
<td>[A]</td>
<td>135</td>
<td>270</td>
</tr>
<tr>
<td>Weight</td>
<td>[kg]</td>
<td>42</td>
<td>73</td>
</tr>
<tr>
<td>Dimensions (LxWxH)</td>
<td>[mm]</td>
<td>690 x 387 x 142</td>
<td>932 x 492 x 142</td>
</tr>
</tbody>
</table>

*Indicated values are minimal and based on 50% SOC and 25°C*
V3 - Diesel 48V mild-HEV (GM)

15/30 kW Battery System

VARIANT I
The first **tab (pre-trip)** accesses Eco-Routing functionality. The second one **(in-trip)** presents the output of the Eco-Driving function. Via the **post-trip** tab the user gets a score for his performance based on the energy demand during the trip and on how good the speed advice was followed.
➢ **ECO Routing**: more complex than for ICE or EV due to additional degrees of freedom in the energy management system

➢ **ECO driving**: speed profile

➢ **HMI** providing the driver real time information on the Eco-Routing and Eco-Driving functionalities

➢ Powertrain Energy Management strategy considering input from the optimized predictive control and driver request ➔ reducing energy consumption and emissions production (reducing the AdBlue consumption)

➢ Thermal management including prediction of energy demand by the auxiliaries
Achievements Component Level

- eHC concept definition
- 48V battery development for Opel Insignia
- eHC Driver
- 48V P4 development for Opel Insignia

*All values at 25°C.*
PCM as heat storage

- PCM as heat storage (preconditioned thermal storage for conditioning the engine)

PCM test set-up: copper tubes for separating PCM from coolant and heat transfer

Reducing heat-up time for ICE
Overall ADVICE validation and demonstration concept

Eco Routing/Driving (H1) → Driver

HMI (H1) → for route planning

Thermal/Energy Management (H1, H2)
- e.g. eHC/advanced aftertreatment + other component level innovations

Objectives:
- Fuel efficiency/Emissions
- Cost
- Drivability

Levels for demonstration:
0: Co-Simulation for extrapolation
1: ADVICE
1.5: implementation of some interactions
2: fully integrated (Post-ADVICE)

Hybrid typology: HEV – V1 (VCO)
Hybrid typology: P-HEV – V2 (CRF)
Hybrid typology: HEV – V3 (GM)