DEVELOPMENT AND OPTIMIZATION OF AN ELECTRIC HYPERCAR POWERTRAIN

Gerhard Vosloo, Rimac Automobili d.o.o.
IPG Apply & Innovate 2020
AGENDA

- Introduction
- Background and motivation
- Development process
- Targets
- Use case: longitudinal performance
- Use case: track performance
- Use case: range and efficiency
- Correlation and validation
WHO WE ARE

- Founded: 2009 (first employees in April 2011)
- Team today: 700+ people (400+ in R&D)
- Completed B2B projects: 30+
- Developed, produced and delivered world's fastest electric supercar
- Tier 1 supplier to 10 Global OEMs
- Total investment so far: ~€140M
- Deloitte technology fast 50: 10th place
  4 consecutive years amongst top 100
- Awarded as the best employer in Croatia
- European Business Award

2008
- Rimac Automobili is founded in Sveta Nedelja, Croatia.

2009
- Mate Rimac converts his BMW E30 into an electric race car and the idea is born

2010
- Mate Rimac breaks 5 Guinness and FIA World records for the fastest accelerating electric car.

2011
- Rimac completes its first B2B project for IDIADA. First revenues.
- First OEM projects
- First profitable year

2012
- World Premiere of the Concept_One, world's first all-electric supercar
- 10 employees

2013
- First car delivered
- Intense development and testing of Rimac All Wheel Torque Vectoring System.
- The Concept_One becomes FIA Formula E's official Race Director car
- First production vehicle contract
- A-round completed

2014
- Rimac builds Nobuhiro Monster Tajima's race car for the Pikes Peak International Hill Climb.
- 100 employees

2015
- The Concept_One becomes FIA Formula E's official Race Director car
- Significant expansion of facilities

2016
- Rimac builds Nobuhiro Monster Tajima's race car for the Pikes Peak International Hill Climb.
- World Premiere of the Concept_One
- 10 employees
- Significant expansion of facilities

2017
- Rimac builds Nobuhiro Monster Tajima's race car for the Pikes Peak International Hill Climb.
- 100 employees
- Significant expansion of facilities

2018
- Rimac builds Nobuhiro Monster Tajima's race car for the Pikes Peak International Hill Climb.
- 250 employees
- World premiere of Rimac's next generation hypercar, the C_Two
- Porsche becomes a shareholder
- 400+ employees
- Further expansion of production facilities
- Opening of offices in Split and Osijek
- Launch of the Xianyang JV location

2019
- Joint Venture in China signed
- Dealer network expansion in three continents – North America, Europe and Asia
- 250 employees
- Hyundai Motor Group becomes a shareholder
- 500+ employees
- Further expansion of production facilities
- Opening of offices in Split and Osijek
- Launch of the Xianyang JV location

2020
- Testing and development of the C_Two continues
- More than 700 employees
**Development and production** of the Aston Martin Red Bull Valkyrie supercar hybrid battery system, infotainment and connectivity system.

**HYUNDAI MOTOR GROUP**
Development of an electric version of Hyundai Motor's N brand midship sports car and a high-performance fuel cell electric vehicle.

**Koenigsegg**
Development and manufacturing batteries and power distribution units for the Koenigsegg Regera hypercar.

**CUPRA**
Development of an full EV system for CUPRA (SEAT) e-racer prototype.

**JAGUAR**
Developed an electric version of the iconic Jaguar E-Type, which was used as the groom and bride car for the Meghan Markle and Prince Harry's royal wedding.

**AUTOMOBILI PININFARINA BATHTISTA**
Development of an powertrain system and electronics of Automobili Pininfarina Battista electric hypercar.

**OEM PROJECTS**

Development of an electric version of Hyundai Motor's N brand midship sports car and a high-performance fuel cell electric vehicle.
HYPERCARS

A new approach to high performance through technology and innovation

TECHNOLOGY

Technology developed from the ground up, driving the electric revolution
Debuted at the 2011 Frankfurt International Auto Show

2.5 sec 14 sec 1224 hp 355 km/h 1600 Nm 350 km
0-100km/h 0-300km/h 900 kW Electrically limited From 0 to 6500rpm On a single charge

14 sec 0-300km/h

From 0 to 6500rpm
On a single charge

1600 Nm
350 km

Electrically limited
From 0 to 6500rpm
On a single charge
HYPERCAR

1.85* sec
0-100 km/h

1914 hp
1400 kW

412 km/h
Electrically limited

2300 Nm
From 0 to 6500 rpm

550 km
On a single charge
C_TWO

- Globally homologated
- 4 independently controlled electric motors power each wheel
- Rimac all-wheel torque vectoring
- Full carbon fibre monocoque with structurally integrated battery pack
- Active Aerodynamics
- Autonomous driving capabilities
- Driving Coach
OUR SERVICES

BATTERY PACKS

INFOTAINMENT

DRIVETRAIN

ELECTRONICS

ADAS

CONNECTIVITY
BACKGROUND & MOTIVATION

- Hypercar EV segment
  - Low volume
  - Less cost conscious
  - Incorporates latest and most advanced EV technology

- Electric vehicles (EV) are undergoing exponential growth and development
  - Electric motors
  - Inverters
  - Battery Cells
  - Battery pack design and cooling
  - Architecture

DEVELOPMENT AND OPTIMIZATION OF AN ELECTRIC HYPERCAR POWERTRAIN
THE CHALLENGE FOR EV HYPERCARS

Rapid prototyping and flexibility to adapt and include latest EV technology
... or risk being left behind by competitors!

“If you aren’t first you’re last” – Ricky Bobby
THE DEVELOPMENT PROCESS

Targets

Performance status

Component level test data
Subsystem (e.g. front powertrain)
Vehicle level test data

IPG CarMaker

Design iteration

Powertrain

Battery
Inverters
Motors

Overall vehicle Layout & other Parameters

DEVELOPMENT AND OPTIMIZATION OF AN ELECTRIC HYPERCAR POWERTRAIN
**TARGETS**

*Targets listed does not represent actual targets of the Rimac C_Two*

- **Performance:**
  - Longitudinal
    e.g. 10 x 0-100-0 km/h without overheating/de-rating
  - Track
    e.g. 1 lap of Nürburgring, Nordschleife without any power de-rating

- **Range:**
  e.g. 550+km on WLTP
LONGITUDINAL PERFORMANCE

Performance analysis at lower SoC

NOTE: Results are given as an example, data is not representative of current, nor previous status.
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ELIMINATE BOTTLENECKS FOR A HOLISTIC DESIGN

- Improved cooling performance
- Higher sustained power output from battery
- Improved cell chemistry/design
- Higher demand on rest of powertrain
- Increased thermal and durability requirements
Consumption and identifying losses

### WLTC consumption, range and losses

<table>
<thead>
<tr>
<th>Consumption</th>
<th>XXX.X Wh/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>XXX.X km</td>
</tr>
</tbody>
</table>

#### Contribution of Losses

<table>
<thead>
<tr>
<th>Losses</th>
<th>Front</th>
<th>Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Powertrain Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td>1.5%</td>
<td></td>
</tr>
<tr>
<td>Inverters</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Motors</td>
<td>13.5%</td>
<td></td>
</tr>
<tr>
<td>Gearbox</td>
<td>6.8%</td>
<td></td>
</tr>
<tr>
<td><strong>Friction Brakes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tyre Rolling Resistance</strong></td>
<td>31.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Auxiliary</strong></td>
<td>8.3%</td>
<td></td>
</tr>
</tbody>
</table>

### Powertrain efficiency based on WLTC cycle

<table>
<thead>
<tr>
<th>Component</th>
<th>Front</th>
<th>Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>92.0%</td>
<td>91.0%</td>
</tr>
<tr>
<td>Inverter</td>
<td>96.0%</td>
<td>95.0%</td>
</tr>
<tr>
<td>Gearbox</td>
<td>97.6%</td>
<td>97.5%</td>
</tr>
</tbody>
</table>

**NOTE:** Results are given as an example, data is not representative of current, nor previous status.
COMPONENT LEVEL
- Battery
- Motor & Inverter
- Gearbox

SYSTEM LEVEL
- Front and/or Rear Axle
- Controlled operating conditions
- Controlled cooling environment

VEHICLE LEVEL
- Full system integration with all control systems
- Variable operating conditions
- Driver in the loop
- Limited control

CORRELATION AND VALIDATION OF SIMULATIONS

Increased variables and complexity
For any additional information you might need, feel free to contact me.

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