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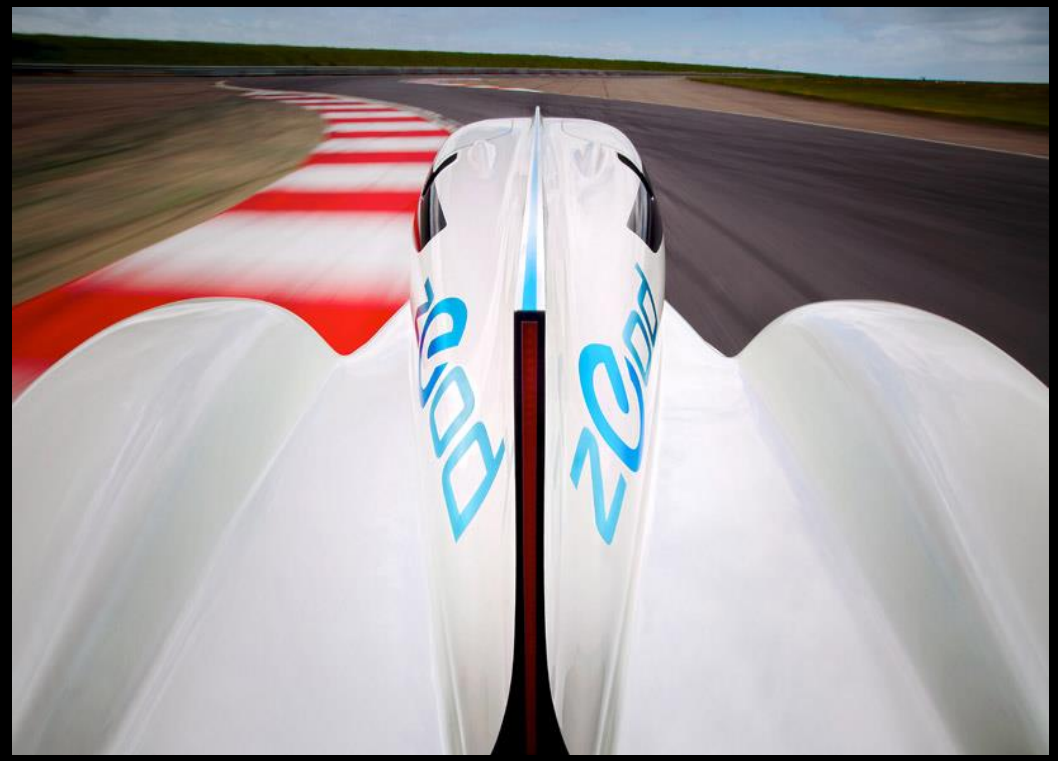

Simon Holloway – Commercial Director

We deliver world-class solutions in motorsport & high-performance engineering

RML Group & Nissan ZEOD - Introduction

- RML Group was founded in 1984 and design, development and manufacture road and race vehicles, advanced engines, EV and Hybrid powertrains
- For the 2014 Le Mans 24hr, RML was commissioned by Nissan to provide a “Garage 56” entry.
- The mission, to demonstrate complete “Zero Emission” laps of the famous circuit. (13.6KM)
- Garage 56 is a separate category at Le Mans primarily to demonstrate new and leading edge technologies, it is not bound by the same regulations, only safety requirements
- Our challenge was to design and develop a vehicle that could lap Le Mans under standard combustion power whilst harvesting energy and then complete whole laps just on Electric power only
- The ICE unit had to be powerful enough to be competitive but light, it was just ballast during the EV lap
- The car had to be low drag to optimise the charge in the battery storage, making packaging a challenge
- Total project (including chassis, aero and Internal combustion engine, EV, EV controls, transmission) designed, built and developed from a clean sheet in 13 months (project kick off May 1, 2013 - car competed at Le Mans June 2014)

RML - ZEOD Le Mans Project 2014 Summary

Nissan ZEOD (Zero Emissions On Demand)

- High technology demonstrator run from ‘Garage 56’ at Le Mans
- Low drag lightweight Hybrid sports car (700kg with fuel, batteries and driver. Note 2015 F1 car weighs 801kg fully fueled)
- Completed the first ever lap of Le Mans in pure electric power (EV) in 4 min 22 seconds (160kph average speed)
- Reached 300kph in the Mulsanne straight in pure EV.
- Combined powertrain (EV and ICE) develops 720BHP (EV power regeneration from braking only)

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RML – ZEOD Vehicle Layout

- Packaging was a major constraint, ICE, Battery, Emotor, Emotor Controller and Gearbox had to fit into limited space for the low drag configuration.

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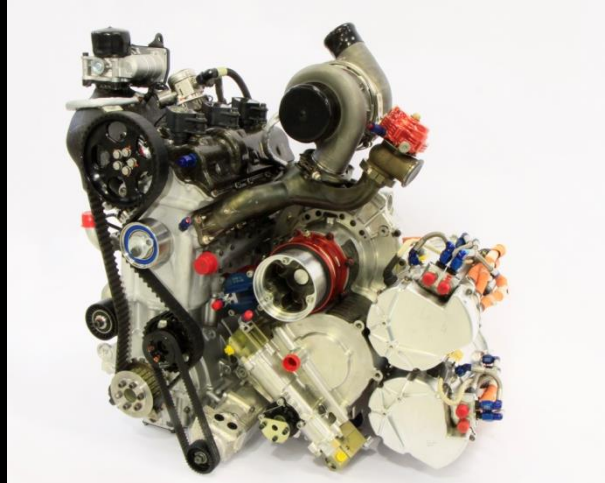
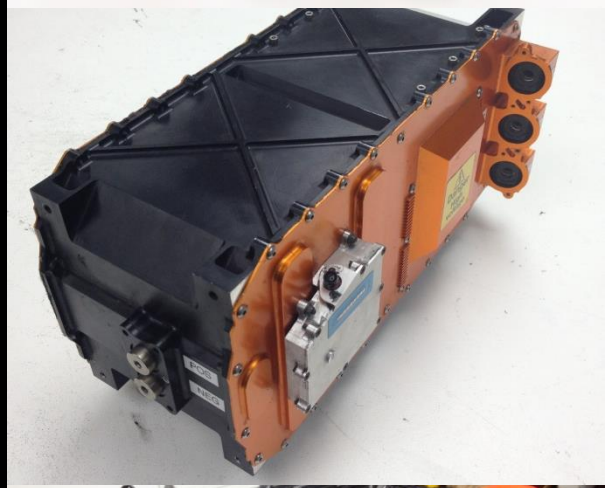
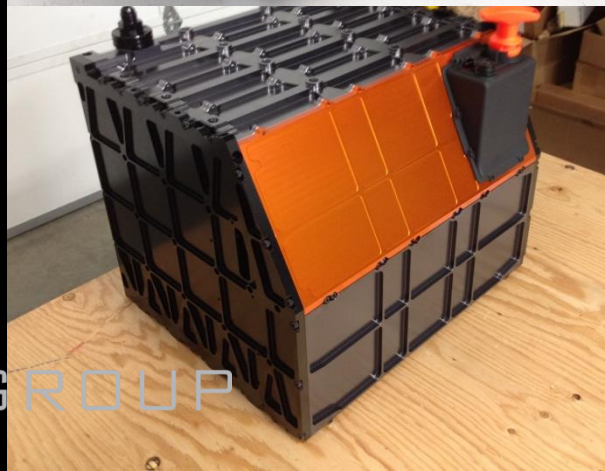
ZEOD Powertrain Components

- Internal combustion engine (ICE)
- Semi-automatic Gearbox
- Hybrid powertrain components:
  - Battery
  - Electric motors: “MGU-K“
  - Electric motor controller







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Internal Combustion Engine

- Characteristics:
  - 3 cylinder Turbo DI
  - 1.5 litre
  - 7500 rpm – low rpm for reduced friction
  - 46kg including exhaust and turbo
  - 400 bhp
  - 380 Nm

- Concepts:
  - Monobloc
  - Use of Carbon
  - Hollow crank
  - No regulations

Monobloc and Carbon Components – Weight Reduction

- Monobloc:
  - Traditional design technique - 1920
  - Allows lightweight due to no cylinder head gasket interface
  - Complex machining through the bore
  - Reduced components improving reliability
  - Thinner wall thickness due to reduced stress in lower part of block, billet machined 3mm thick, optimised via FEA & thermomechanical analysis
- Carbon Components:
  - Carbon used whenever possible to reduce weight
  - Intake Manifold – very short intake port, integrated into plenum
  - Cam Cover – designed to remove as much metal as possible, 1mm thick and also able to holding the DI pump
- Rapid Prototyping:
  - Used for speed of manufacture, flexibility & complexity
  - Electronics interface box

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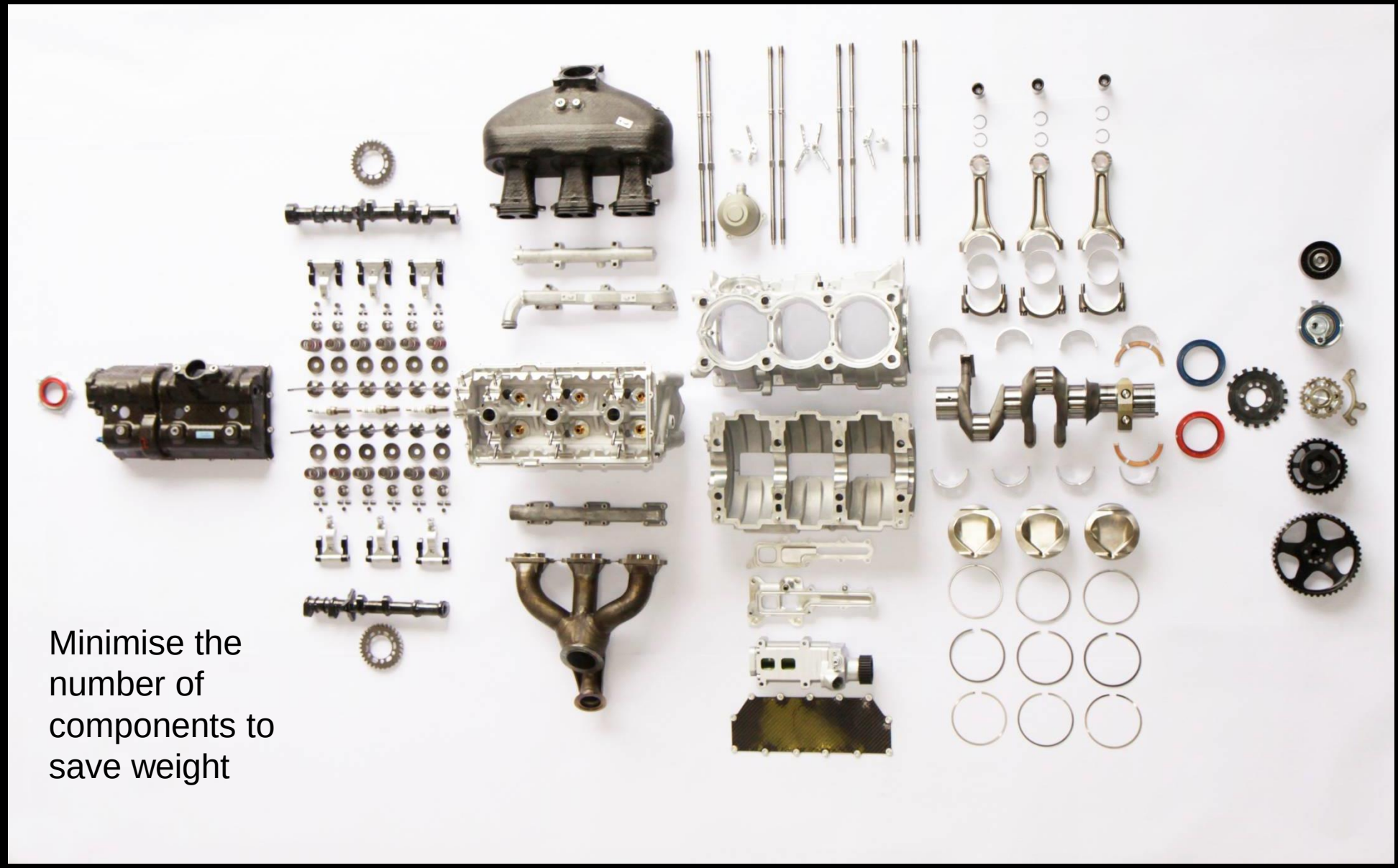
Reduced Bill of Materials - Combining



Minimise the number of components to save weight

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Reduced Weight - Hollow Crank

- Reduction in Crank Mass by hollow crank design
- Accurate design simulation and FEA
- Material specifications and machining capabilities
- Not limited by regulations

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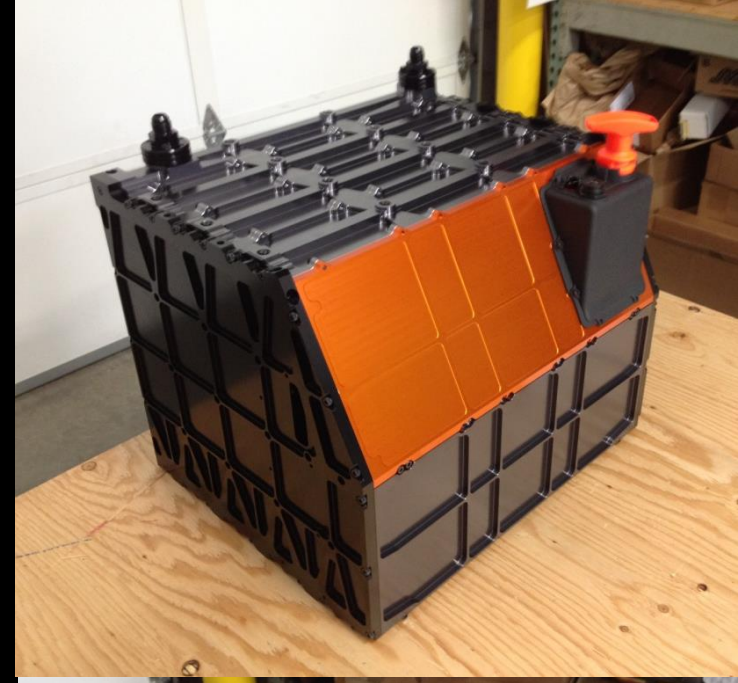
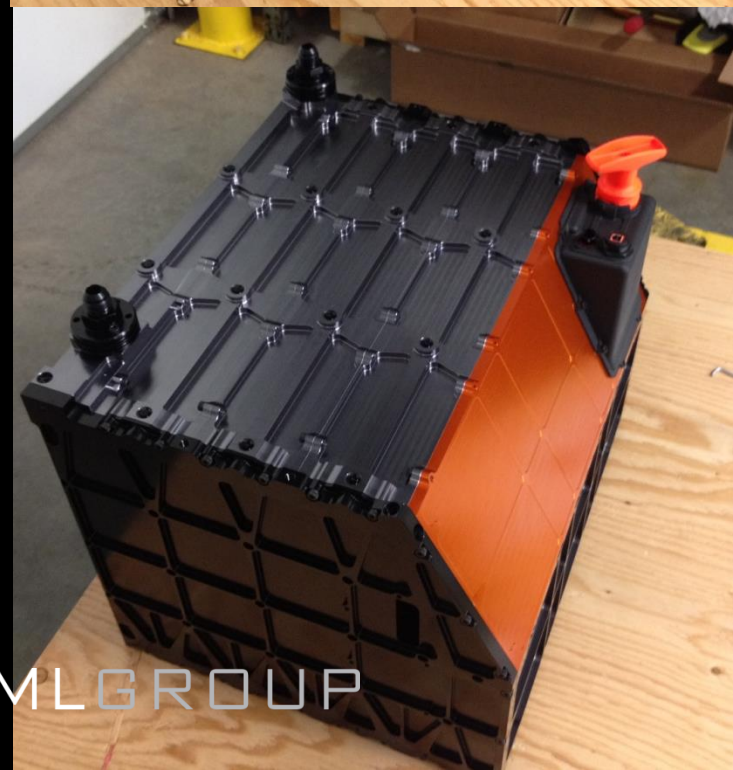
Battery – Heaviest component

- Characteristics
  - 672 Lithium Ion cells
  - Fully BMS controlled and cell balancing
  - 150 kg
  - Dielectric liquid cooled
  - 400 Volt
  - 12 kWh total energy 10kWh useable
  - 280 kW peak power output
- Concept
  - Cells layout: 7P96S and 96S7P
  - Individual cell voltage and temperature management
  - Full in car charge balancing
  - Minimum size
  - Heat rejection
  - FIA safety requirement





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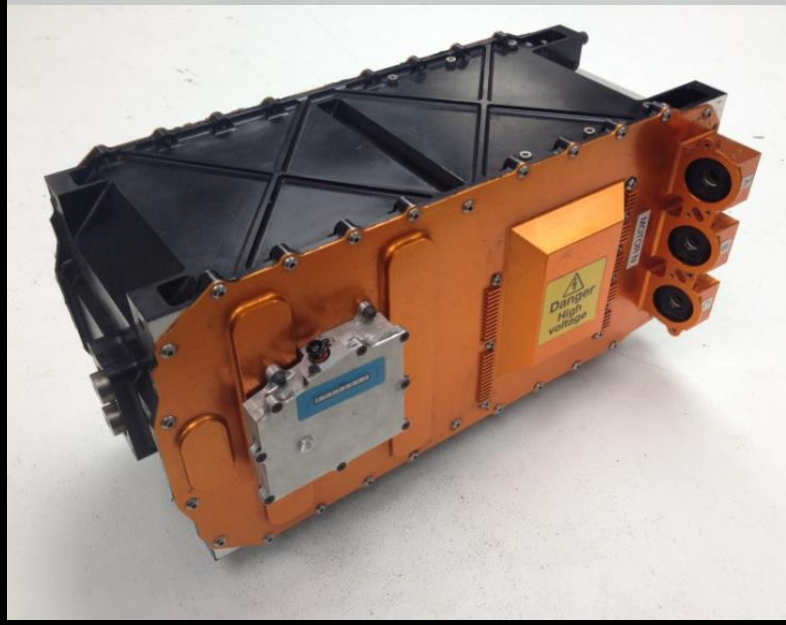
Emotor and emotor controller – Power Density

- Emotor:
  - 40000 rpm e motor
  - 120 kW
  - 12 kg
  - Permanent magnet rotor
- Controller:
  - Combined controller
  - 300 kW potential
  - 14 kg

- Emotor
  - High speed emotor = higher power density X 2
  - Lowest possible inertia
- Controller:
  - Repackaged and lightened 150 kW inverters
  - Bespoke software
  - Skim 93 IGBT technology



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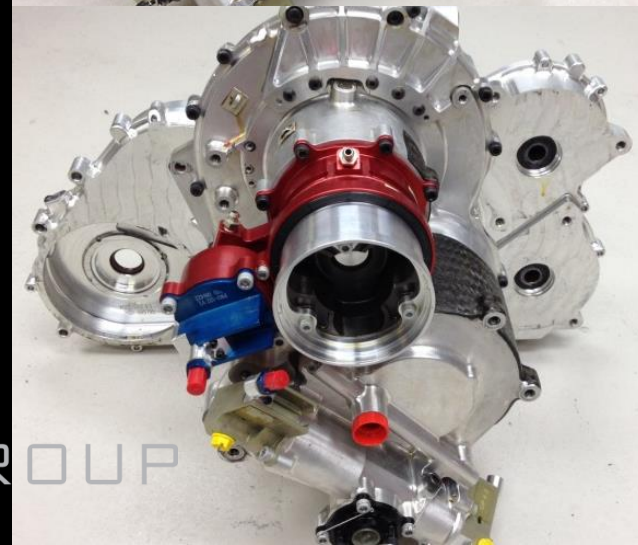
Gearbox - Complexity

- Characteristics
  - Semi automatic
  - 7500 rpm ICE
  - 40000 rpm EV
  - Pneumatic
  - Packaging 40 kg
  - 5 driving gears
  - 6^{th} gear - neutral

- Concept
  - Gear cascade linking ICE and EV into the cluster input shaft
  - Pneumatic locking diff
  - Straight cut gears
  - Gear loss reduction



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Component: Powertrain Control

- Characteristic:
  - Single ECU controls the entire car
  - Over 250,000 + lines of code
  - Motec base ECU
  - In house software
  - In house strategy development

- Concept
  - ICE
  - DRS
  - Brake balance
  - Battery
  - Emotors
  - Gearbox
  - Clutch

RML & Nissan ZEOD Summary

- The Nissan ZEOD was the first ever to complete a competitive electric lap of Le Mans
- A combined powertrain of up to 720bhp for 110kg (plus batteries)
- Knowledge and experience from this project is now being used on road car and motorsport applications
- The ability to produce light-weight powertrains will become increasingly important, especially as range extenders or Hybrid platforms
- Technology and Innovation know how, developed in the UK for motorsport is being transferred into everyday vehicles with assistance from APC, Innovate UK and the Motorsport Industry Association

QUESTIONS?

COME AND SEE US ON THE UK PAVILLION STAND 3320