

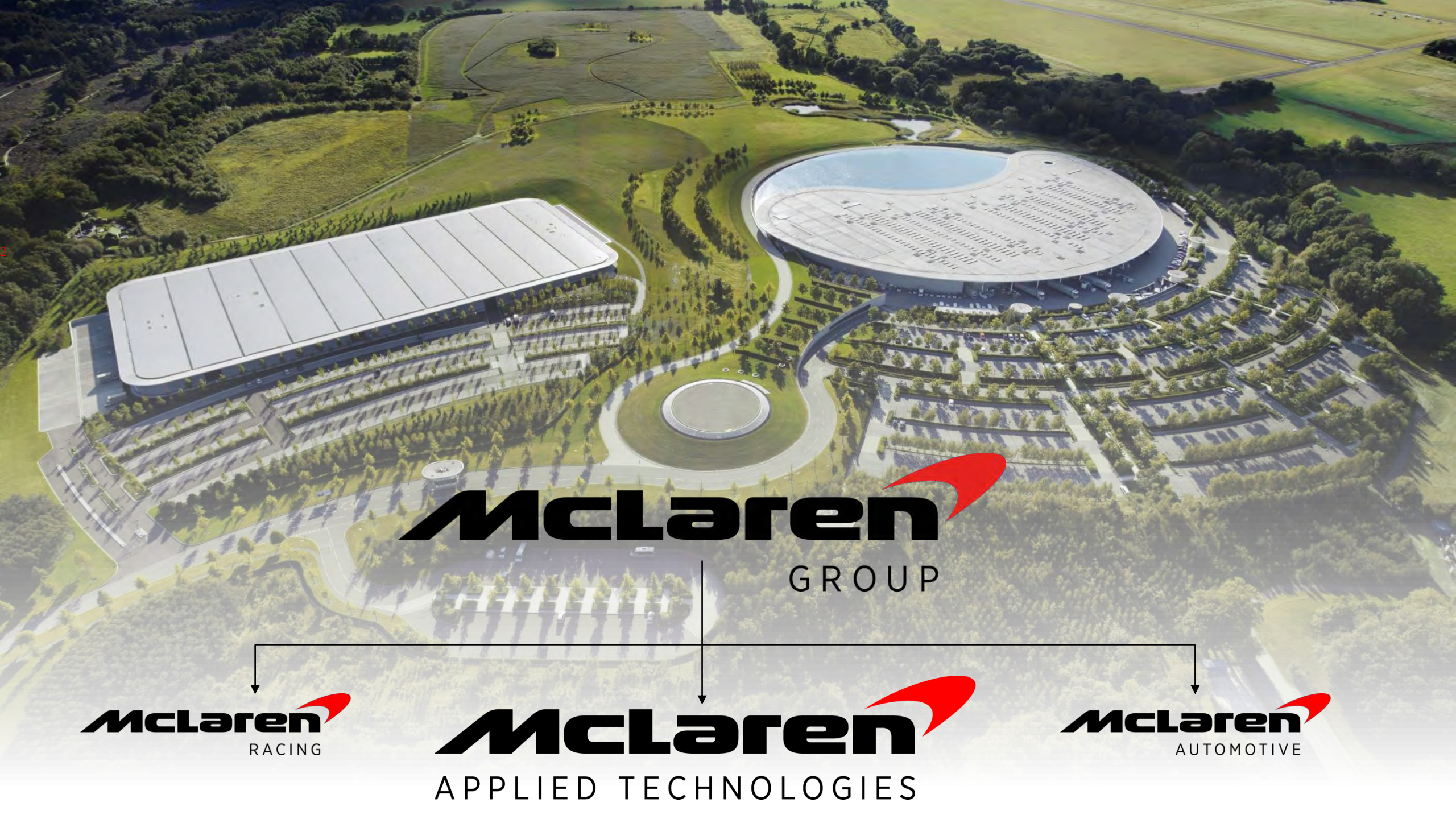


USING MOTORSPORT TO DRIVE BATTERY DEVELOPMENT

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8TH MARCH 2019





McLaren
GROUP

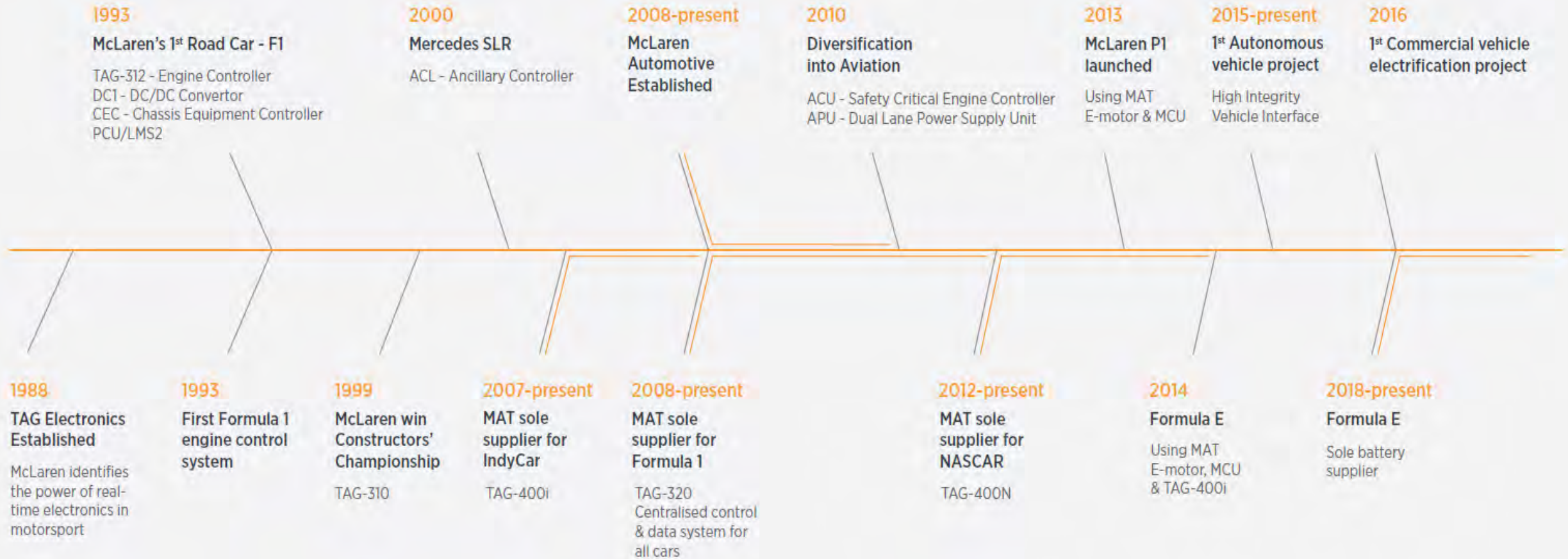
McLaren
RACING

McLaren
APPLIED TECHNOLOGIES

McLaren
AUTOMOTIVE



HISTORY



DATA UNDERPINS EVERYTHING WE DO



11.8BN DATA
POINTS PER
SEASON

MILLIONS OF
SIMULATIONS

10^8 RACE
PERMUTATIONS

1TN DATA
POINTS

DATA FOR
PRODUCT
DESIGN

DATA FOR
BUSINESS
INSIGHT

DATA FOR
BETTER
HUMAN
DECISIONS



McLAREN APPLIED TECHNOLOGIES The Fearless Pursuit of Advantage

MOTORSPORT



Giving drivers, teams and series promoters the performance they need to win

AUTOMOTIVE



Empowering customers to introduce new technologies and drive market differentiation

PUBLIC TRANSPORT



Connecting high speed vehicles, perfecting vehicle availability and unlocking operational capacity

HEALTH



Optimising human performance and driving better clinical outcomes for patients

McLAREN DELOITTE ALLIANCE

Building products that bridge the physical and digital worlds, to help major businesses make better decisions, faster

TECHNOLOGY PLATFORMS



High Integrity Control Systems

- Chassis, Engine & Gearbox Control
- Autonomous Controls Bridge
- Sensing Systems
- Connected Fleet

Vehicle Electrification

- Inverters
- DC/DC Converters
- Combined Traction Unit
- Motor
- Energy Storage

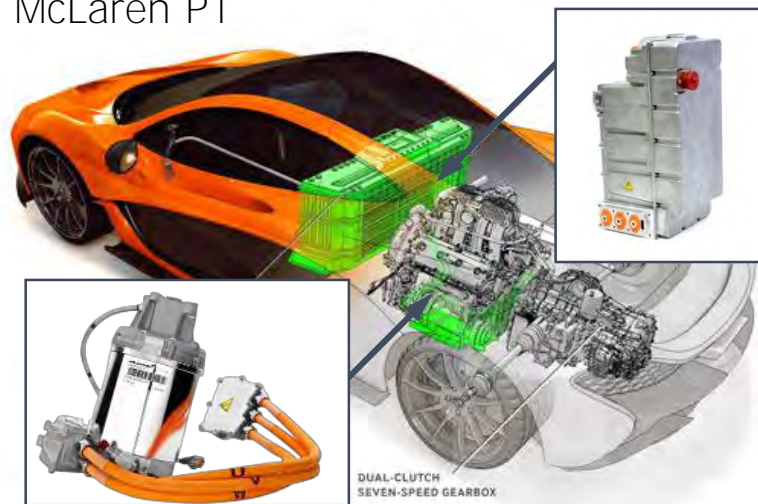
Tools to Support Development

- ATLAS Data Platform
- GDE
- MIDAS / FOCUS
- Driver in the Loop Simulator

TECHNOLOGY PLATFORMS



McLaren P1

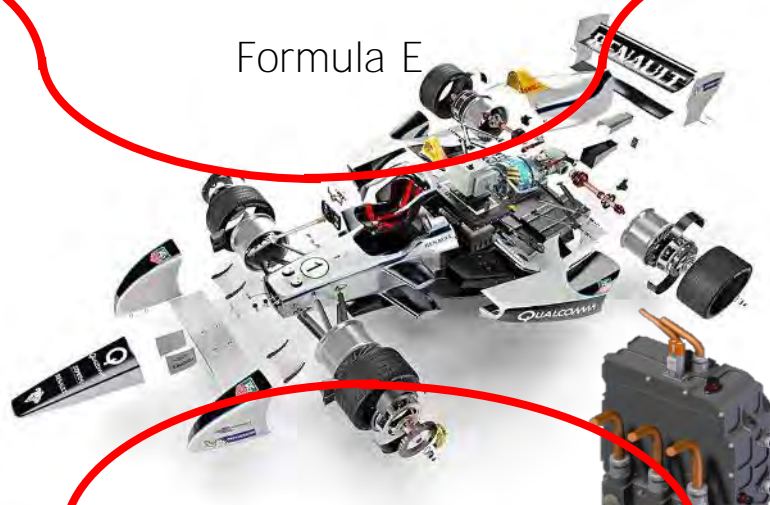


Automotive Robustness

Light Weighting



Formula E



Functional Safety

Formula 1



SiC

Efficiency

Next Generation MPU



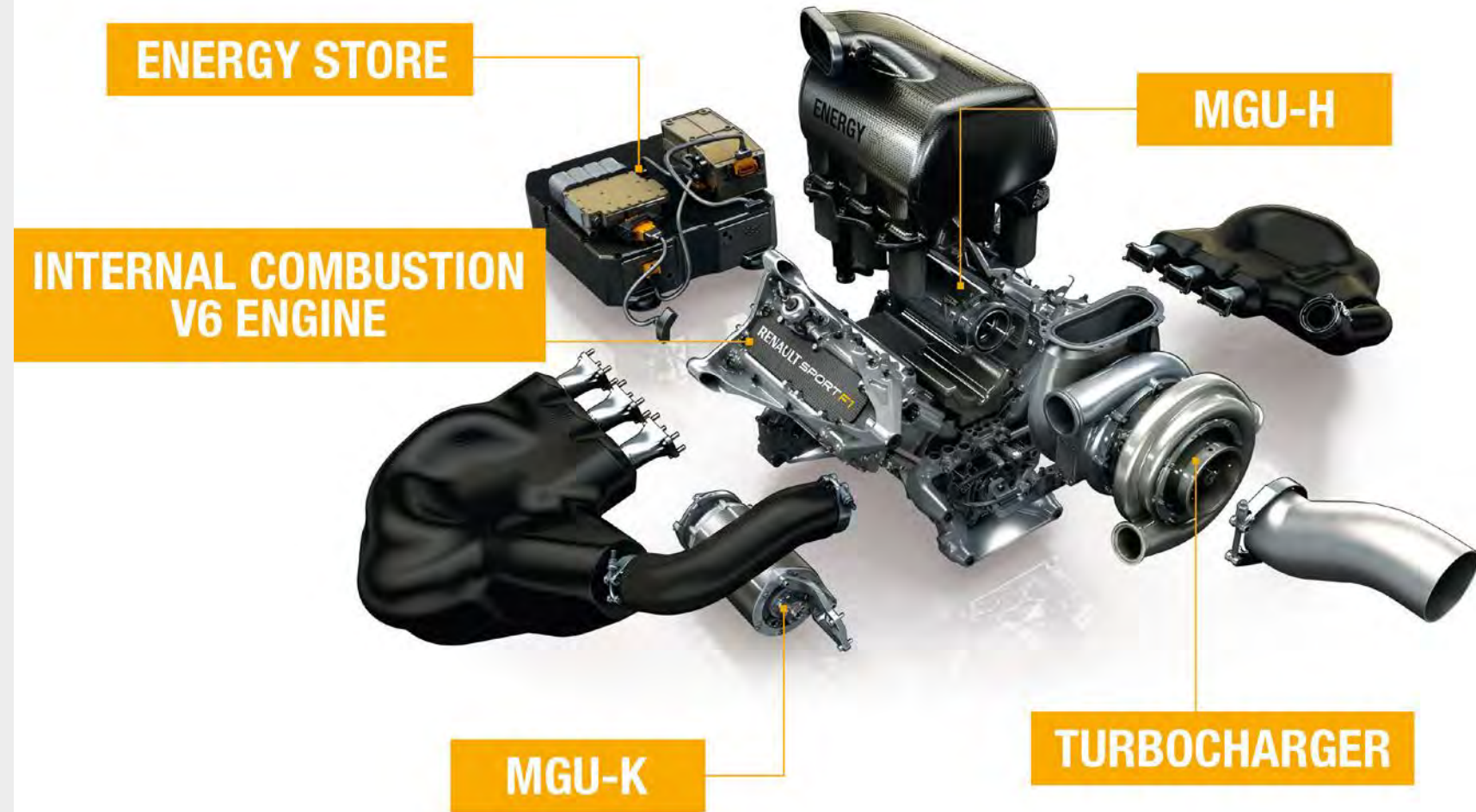


WHAT CAN WE LEARN FROM FORMULA 1

FORMULA 1 ENERGY RECOVERY SYSTEMS



- MAT have provided high performance components into F1 energy recovery systems since 2015
- High levels of integration to ensure highest possible power density
- Automotive specification components to ensure maximum reliability,



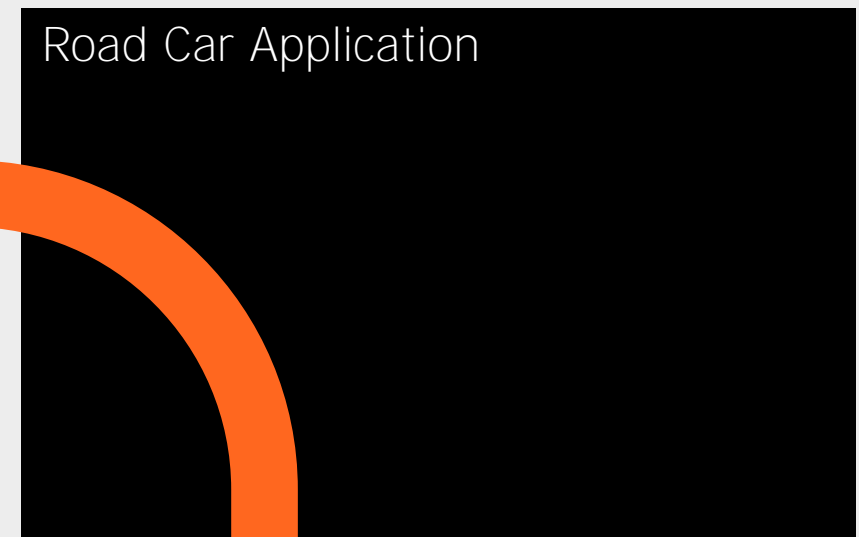
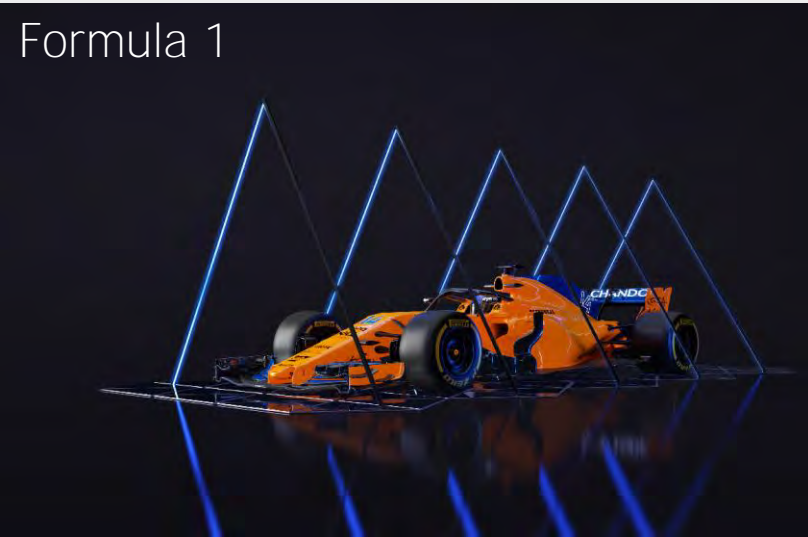
FORMULA 1 ENERGY STORAGE SYSTEM SPECIFICATIONS



- Maximum 4MJ of usable energy (~1.1kWh)
- Approx. 250kW peak power in charge and discharge
- Minimum mass of 20kg for cell + structure (module)
- Gives 12.5kW/kg at module level
- Cell design and pack design fully optimised for application

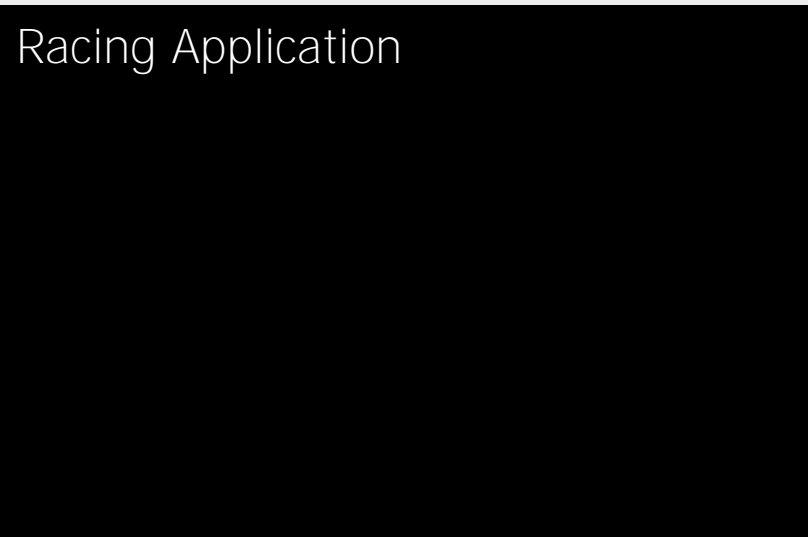


TRANSITION OF FORMULA 1 TECHNOLOGY INTO A HYBRID VEHICLE



Increased Robustness

Reduced Cost and Complexity



Increased Robustness

Reduced Cost and Complexity



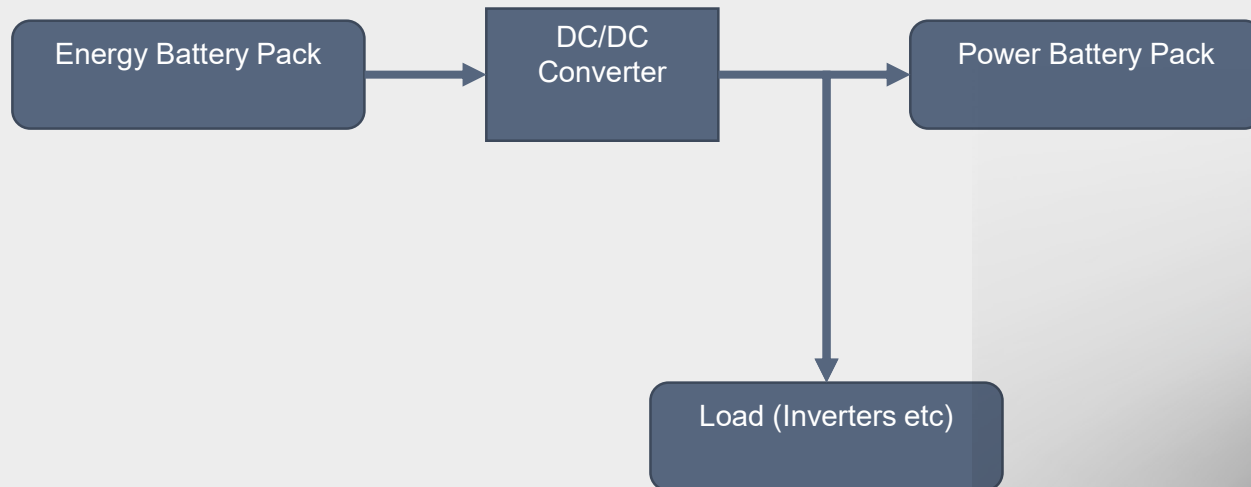


- Tesla sets the bar pretty high for performance EVs
 - **Tesla 'Ludicrous Mode' allows access to full performance of the battery pack at additional cost**
 - Publicity around ludicrous mode feeds into Tesla brand positioning
 - However, this comes at increased risk of battery failure for Tesla
 - Tesla have even been taken to court by their customers over restrictions on its usage
- There is an increasing requirements for other EV manufacturers to compete with the Tesla Ludicrous Mode
 - **However established OEM vehicle platforms and warranty policies won't allow the same approach as Tesla**
- Is there an alternative?
 - What if you could add a Formula 1 battery to an electric vehicle to improve its performance?

HOW WOULD THAT WORK?



- High energy battery pack is connected to high power DC/DC converter
 - DC/DC Converter topology dependant on voltages involved (VCU-200)
- High power battery pack connected to other side of DC/DC converter and loads
 - All transient deployment and regen handled by the power battery
 - Energy battery needs to be sized to meet average power of duty cycle only



A WORKED EXAMPLE



- High energy density cell
 - 250Wh/kg
 - 1.5kW/kg
- At 50% mass overhead and 60kWh usable energy (75kWh total energy)
 - $450\text{kg} - ((60,000 / 0.8) / 250) * 1.5$
 - 450kW – not enough to beat Tesla, need in the region of 600kW
- To achieve 600kW power available, battery mass increases to
 - $600\text{kg} - (600 / 1.5) * 1.5$
 - 80kWh usable energy (100kWh total energy)
- Battery now has the power capability and more energy but at increased cost, mass and volume
 - Is performance estimate still valid with additional 150kg?
 - Can additional battery space be packaged?
 - Is the cost of additional battery viable in business case?

A WORKED EXAMPLE



- Start with the same 60kWh usable energy battery (75kWh total)
 - 450kg
 - 450kW
- Add a high power battery system to provide additional 250kW with 10kW/kg and 100Wh/kg cells
 - 37.5kg battery pack (at 50% mass overhead)
 - 2.5kWh
 - Plus high power DC/DC converter mass – 7kg
- High power battery system adds only 44.5kg to existing 450kg battery
 - Over 100kg mass saving compared to an increase in battery capacity to reach required power
 - Power exceeded by 100kW
 - Reduced load on main energy source as all transient power taken from power battery
 - Cells and cooling designed to provide and accept high power peaks
- Can high power battery cells be affordable in an automotive setting
 - Yes, there are already examples of cells like these coming to the market
 - Charging capability is key



WHAT CAN WE LEARN FROM FORMULA E

FORMULA E

- Blazing a trail in electric vehicle racing
- McLaren Applied Technologies are the Sole Supplier of Formula E Batteries from 2018
- Almost doubling the usable energy to 54kWh
- No need for drivers to swap cars half way through the race
- 200kW during the race
- 250kW during qualifying



HIGH ENERGY DENSITY BATTERY SOLUTIONS



- Formula E will continuously push the boundaries of energy density
 - Formula E will be the modern Formula 1
 - Battery technology in FE is as important as engine technology in F1
- Formula E will become the ultimate testing ground for latest high energy density battery technology
 - Custom cell developments
 - Early testing of technologies
 - Fast recharge times
 - Charging during pit stops?
 - Light weight cooling solutions
 - Off car cooling?
 - Whole vehicle efficiency savings
 - Optimised aero for battery cooling
 - Structural and moulded batteries

A photograph of a modern, curved glass building at night. The building is illuminated from within, showing a multi-level interior with various cars on display. The building's facade is a continuous curve of glass panels. In the foreground, there is a large, dark pool of water with several small, bright lights reflecting on its surface. The sky is dark, and the overall scene is lit with a cool, blueish-white light from the building's interior.

Thank You