Advanced Motorsport (MSc)

Group Design Project - Group 5

CFES
Cranfield Formula Electric Series

VOLTA MOTORSPORT

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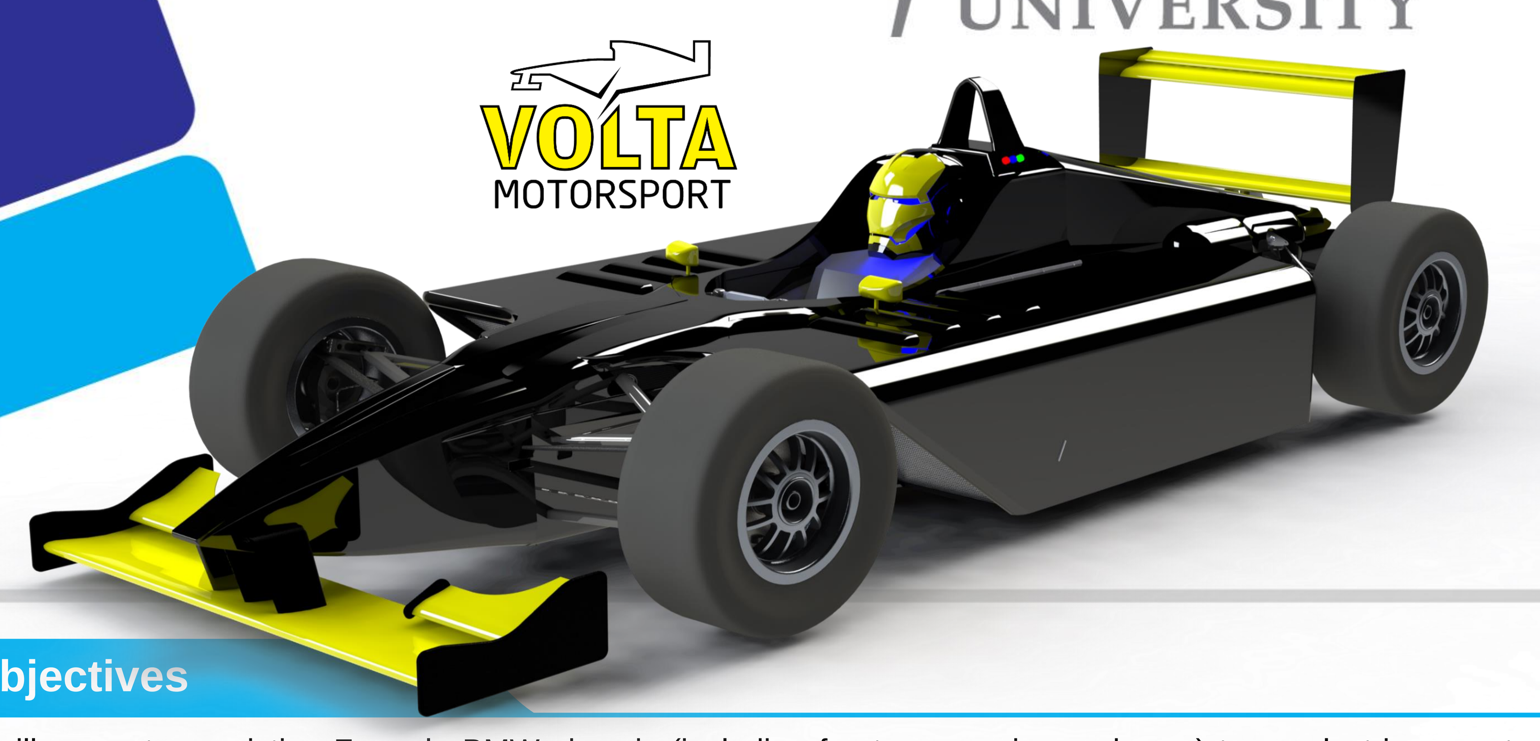


Introduction

The Cranfield Formula Electric Series (CFES) is a new 'one-make' electric motorsport series that is being introduced to serve as a development racing category. The CFES will aid in developing junior drivers for higher categories of electric racing. The CFES season will be 10 race meetings consisting of 15 x 20min races/sessions (5 per day).

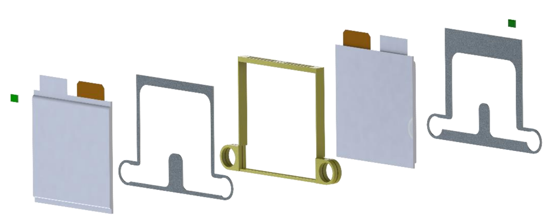
Aim & Objectives

The design will convert an existing Formula BMW chassis (including front suspension and aero) to an electric powertrain formula vehicle. The design must ensure the safety of the users in a variety of operating conditions through the use of efficient & effective crash structures and thermal management systems. The design must be highly energy efficient and cost effective in order to offer performance similar to that of Formula 4.

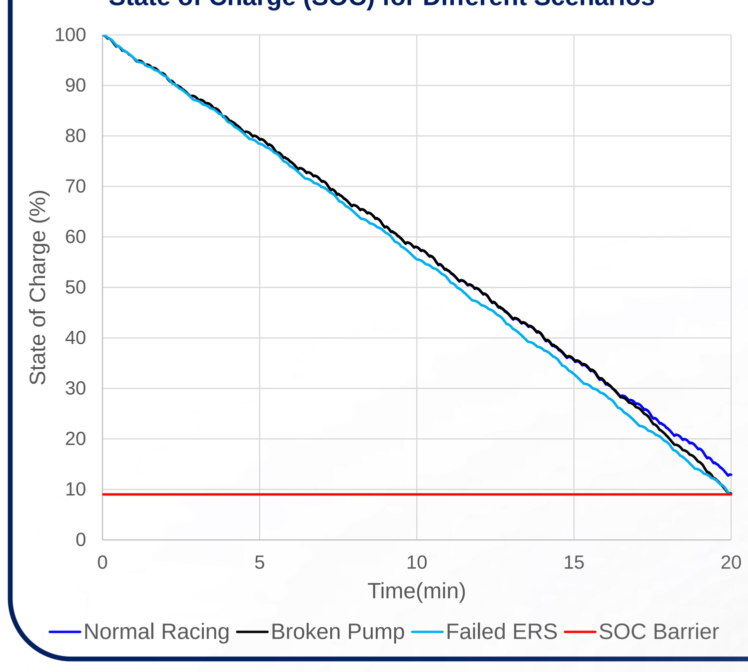
Energy Store

- **288 Cells**
  - **144** cells in Series
  - **2 Strings** in Parallel
- **532.8V** Nominal Open Circuit Voltage
- **329.6kg** Battery Mass
- Semi-submerged Cooling System
  - Quasi-Parallel Cell Cooling
  - Minimised Coolant
  - Controlled Coolant Flow
- Distributed Battery Management System

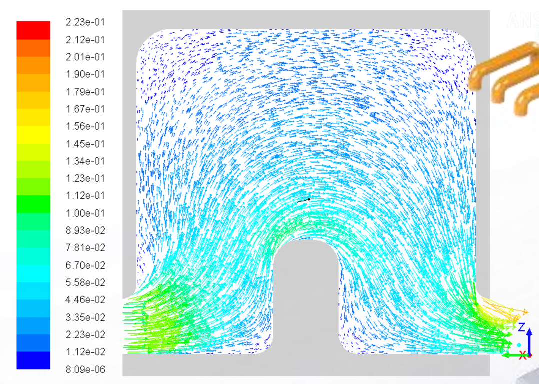
Cell Unit – Exploded View



State of Charge (SOC) for Different Scenarios



Velocity Vector Flow Through Cooling Fin



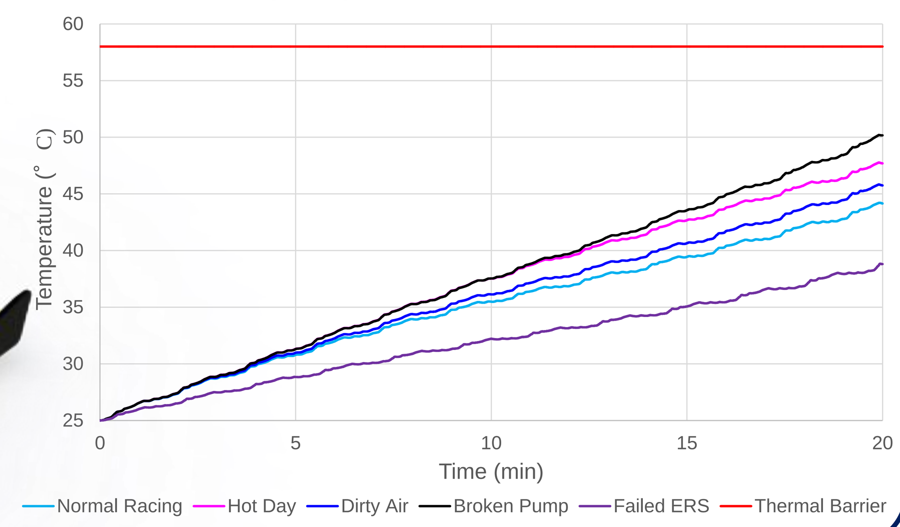
Power Electronics

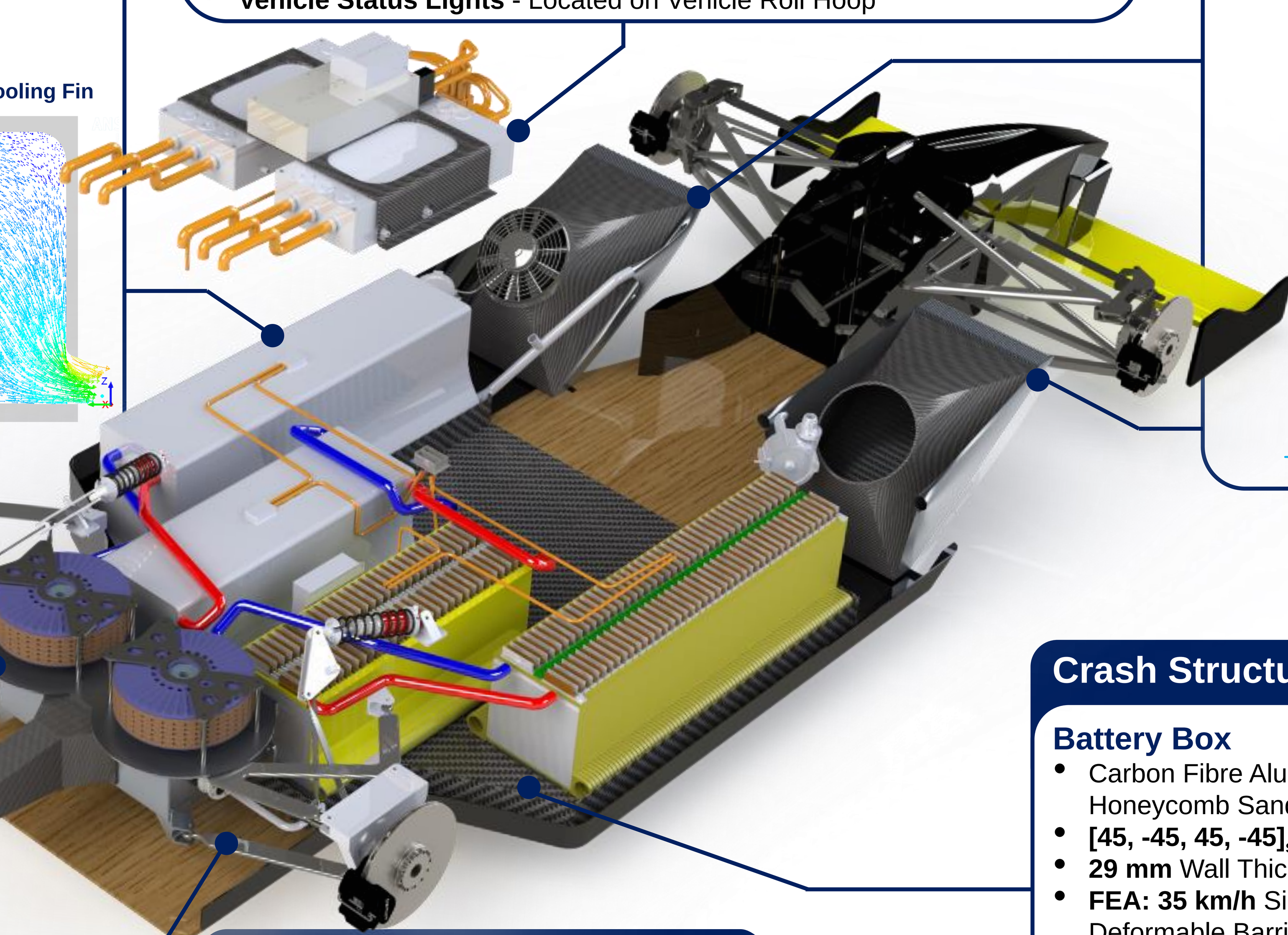
- **2 x Inverter + Motor Controller** Units (Rineheart PM150DZ)
- **High Voltage to 12V** DC-DC Converter (Brusa BSC6)
- **12-24V** DC-DC Converter
- **Autonomous Safety** Protocols via Relays
- **12V Auxiliary Battery** Supply
  - Powers Ignition Control Sequence
  - Powers Data Logging & Cooling System Post HV Battery Emergency Shutdown
- **Vehicle Status Lights** - Located on Vehicle Roll Hoop

Thermal Management

- **2 x Aluminium Plate-Fin** Heat Exchangers – Equal Size
- **NOVEC 7500 Di-electric** Fluid for Energy Store Cooling
- **Glycol:Water (50:50)** Coolant for Motor and Power Electronics Cooling
- **150 L/min** Electric Pump – Battery Circuit
- **15 L/min** Electric Pump – Motor/Electronics Circuit
- **Thermostatically Controlled** Fans and Pumps
- **External Cooling System** for Battery Charging Period

Battery Temperature for Different Scenarios

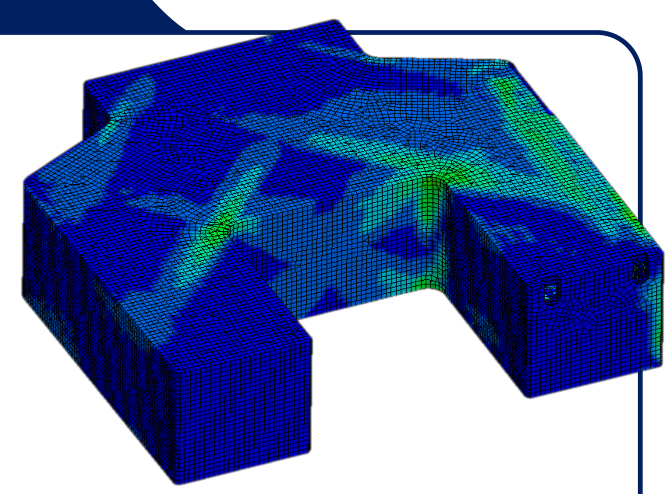




Crash Structures

Battery Box

- Carbon Fibre Aluminium Honeycomb Sandwich
- **[45, -45, 45, -45]$_s$** Layup
- **29 mm** Wall Thickness
- **FEA: 35 km/h** Side Crash into a Deformable Barrier
- Main objective: Protecting cells
- Results:
  - 15mm Max Deflection
  - No Damage to Battery Cells



Rear Crash Structure

- Carbon Fibre
- Exceeds Performance of F-BMW Rear Crash Structure
- FEA crash Tested at 120 km/h

Motor & Transmission

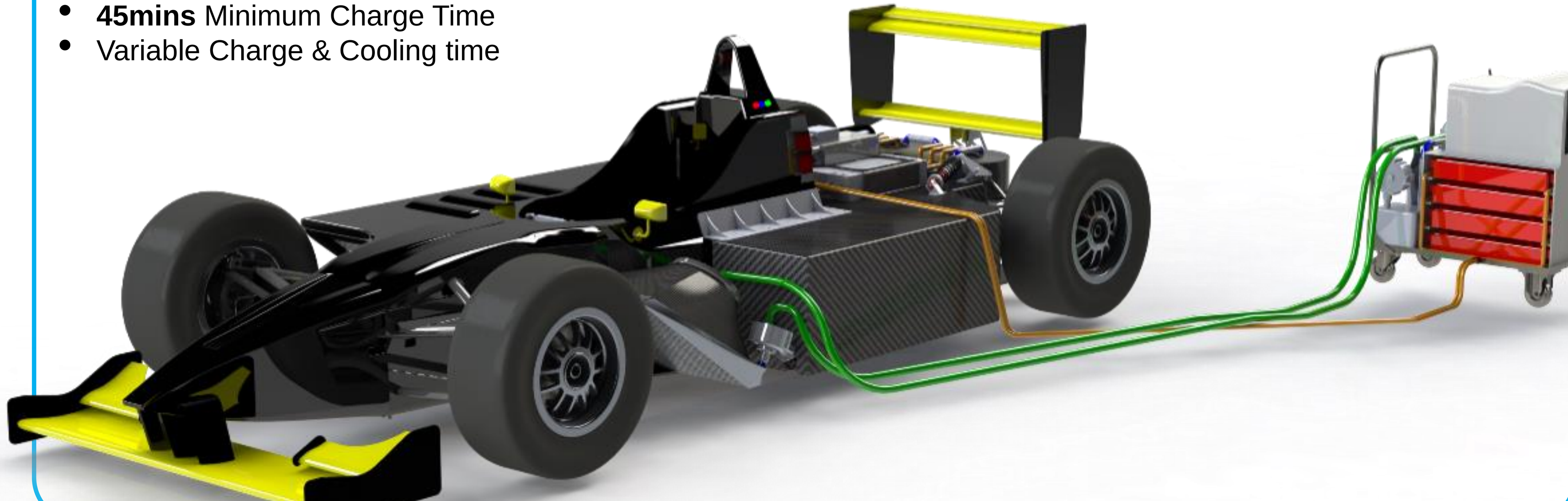
- **2 x Axial Flux** Motors (EMRAX 268)
  - **164 kW** – Race
  - **174 kW** – Qualifying
  - Air & Liquid Cooled
  - Electronic Differential
  - Reversible for Energy Recovery
- **2.28 Final Drive Ratio** – Direct Drive
- Helical Cut Bevel Gearbox
- **Individual Wet-Sump** Lubrication
- **Structural Housing** for Suspension Interface
- Semi-Sealed Motor Cover (Not Pictured)

Vehicle Kinematics

- **800 kg** Total Mass
- **40:60** Weight Distribution F:R (~equal to F-BMW)
- **301mm** CoG height from Ground (~equal to F-BMW)
- Rear Suspension Re-designed to Duplicate F-BMW
- Front Suspension Re-uses Existing F-BMW
- **3.5 Hz** Front Sprung Natural Frequency
- **4.4 Hz** Rear Sprung Natural Frequency
- **392 N/mm** Front Wheel Rate
- **854 N/mm** Rear Wheel Rate
- Re-designed Brake System to Suit Energy Recovery
  - Pressure Reducing Valve

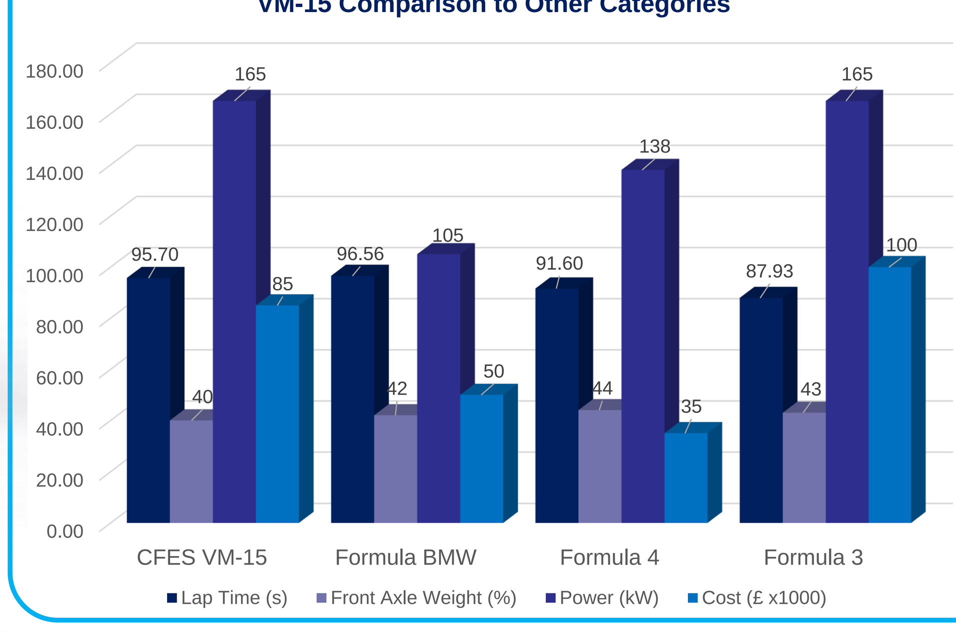
VM-15 Charging & External Cooling

- **Portable** Charging & Cooling Unit
- **4 x 22kW** Chargers at 144A
- **45mins** Minimum Charge Time
- Variable Charge & Cooling time



VM-15 Performance

VM-15 Comparison to Other Categories



The VM-15 was simulated under normal operating conditions as well as a variety of adverse operating conditions to ensure safety (battery core temperature below thermal barrier) and robustness.

The VM-15 was simulated using ChassisSim software where a qualifying and race lap time of **1:35.35** and **1:35.96** were achieved respectively.

During a typical race approximately **7.13MJ** and **2.23MJ** of energy is discharged and recovered each lap respectively.

Utilising existing Formula BMW components has minimised the need for new custom parts, which has aided in minimising costs.

Supported by:

Altair
National College for Motorsport
Racecar engineering
CRANFIELD MOTORSPORT SIMULATION
AVL BOOST
WILLIAMS ADVANCED ENGINEERING
Virgin RACING FORMULA E TEAM
MSA MOTOR SPORTS ASSOCIATION UNITED KINGDOM
MIA MOTORSPORT INDUSTRY ASSOCIATION
ChassisSim The Winner's Edge

Conclusion

The VM-15 was produced using a systematic design approach in which all requirements have been satisfied. The design is cost effective and ensures user safety whilst providing a stable and competitive entry level platform into electric vehicle racing. With more time, the design can be further refined through validating motor, thermal and structural models. This would enable increased performance, however these gains will be minimal. Greater gains can be achieved by designing a chassis and suspension system that integrates more efficiently with the electric powertrain. The design nonetheless meets all design criteria which has yielded a very robust and competitive product.

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