CFES

The Cranfield Formula Electric Series

MSc Advanced Motorsport Engineering
Group Design Project – Team 2

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IMPULSE RACING

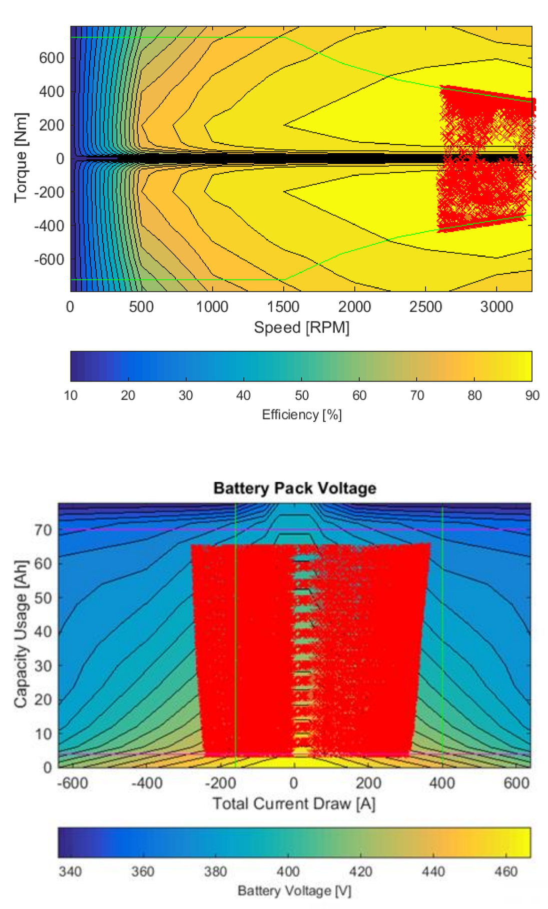
Background

The recent success of electric race cars in championships such as Formula E are a clear demonstration of the potential for electric racing within the motorsport industry. However, the integration of electric technology into the harsh environment of a racecar presents a variety of engineering challenges.

Aims

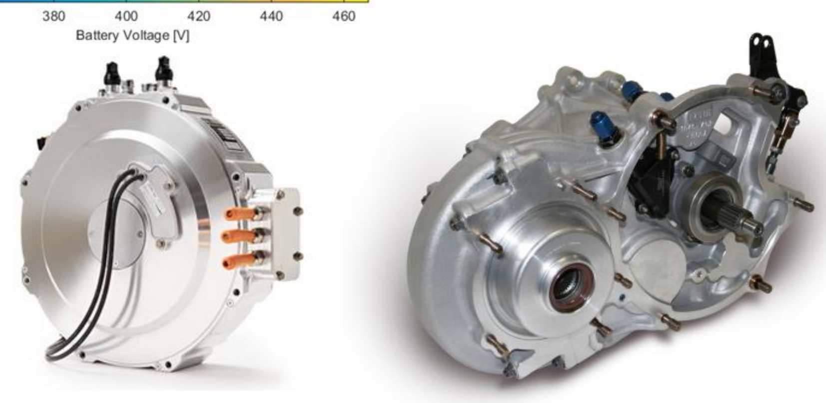
This project aims to pioneer an electric racecar for an entry level single seater feeder series. The design has to ensure that the battery temperature does not exceed 60° C during a 20 minute race around the Donington GP circuit. The proposed battery box has to withstand a side impact crash test simulation to comply with regulations.

Powertrain



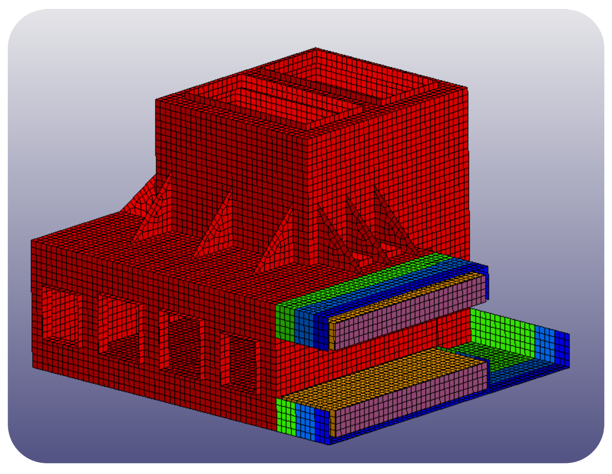
Powertrain optimised to achieve target lap time.

- Motor with 6-speed gearbox combination produced a **92.75%** average efficiency throughout race
- Lap time of **1:32.4** at Donington GP Circuit
- **3.34 MJ** of energy recovered per lap
- Average power of **116 kW** with a peak torque of **450 Nm** (restricted)
- Average motor voltage of **400 V**
- Battery capacity of **66.3 Ah**



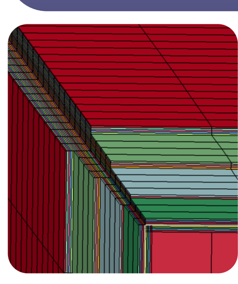
*YASA-750 axial flux motor and Xtrac 1046 gearbox shown, respectively

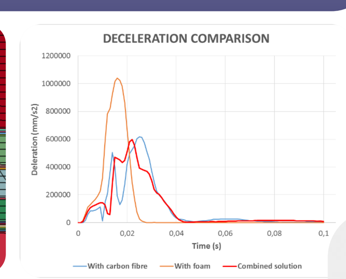
Battery Box



LS DYNA was used to simulate the crash test defined by the regulations. An optimisation process was followed investigating ply count, fibre direction and optimal energy absorbing structure

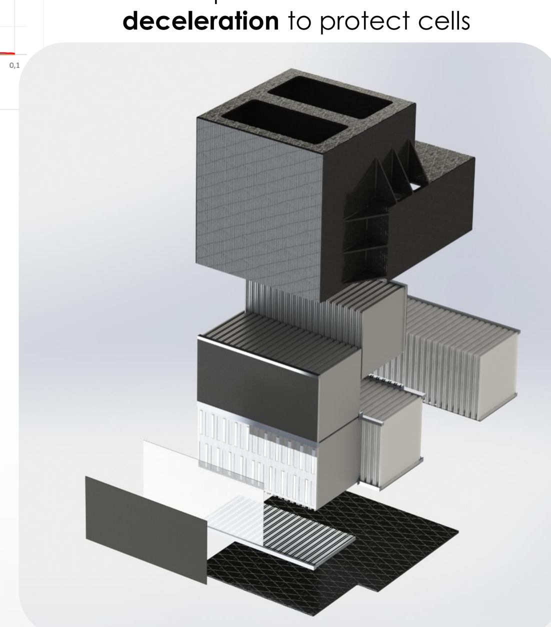
- Full carbon fibre battery box construction
- **22.5 kg** including side crash structures
- Specially designed side "**crush trigger**" structures to absorb energy through stable crushing using varying ply number
- Combined with **Alporas aluminium foam** to aid in energy absorption and stress minimisation
- Final impact structure **minimises deceleration** to protect cells





The battery box assembly designed for air cooling, optimal cell spacing, and efficient packaging

- **228 cells** (114 in series)
- Geometrically defined directional **air flow for cell cooling**
- Aluminium transverse bars maintain cell spacing
- **High dielectric strength** material for secure terminal connections
- **2-piece battery box** design for cell serviceability



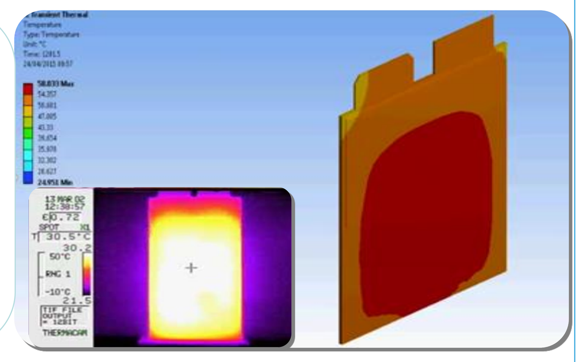
Cooling Systems

Simulnk

Motor-Inverter cooling circuit
- Single original BMW air-liquid heat exchanger, reservoir and **80**W P.D pump
- **Envirotemp FR3** oil used as cooling medium with **25**mm coolant lines.

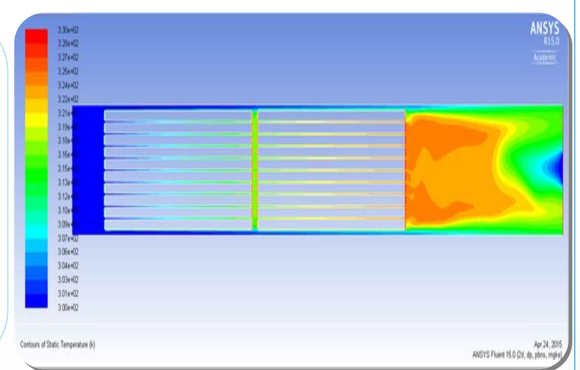
Single cell thermal model.

Air cooled single cell analysis
- Flat plate correlation used for heat transfer coefficient (**30** W/m ^{2} k)
- Similar cell thermal image used for internal cell heating assumption.
- Transient analysis with heat generation for entire race and post race charging cycles.



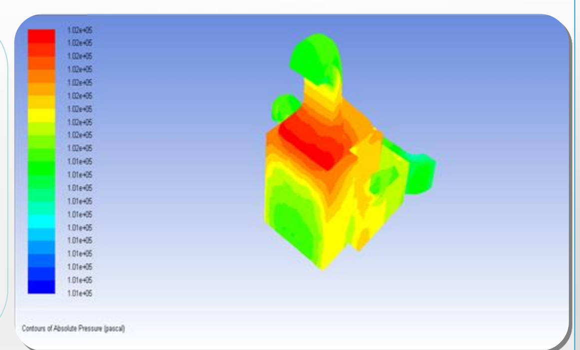
2D Cell spacing thermal &CFD model.

Cell spacing investigation
- Isothermal cell surface **58**° C
- Average race speed used for airflow input.
- Cell spacing value iteration, optimised to **2**mm.
- Results used to re-validate single cell model and battery box design.



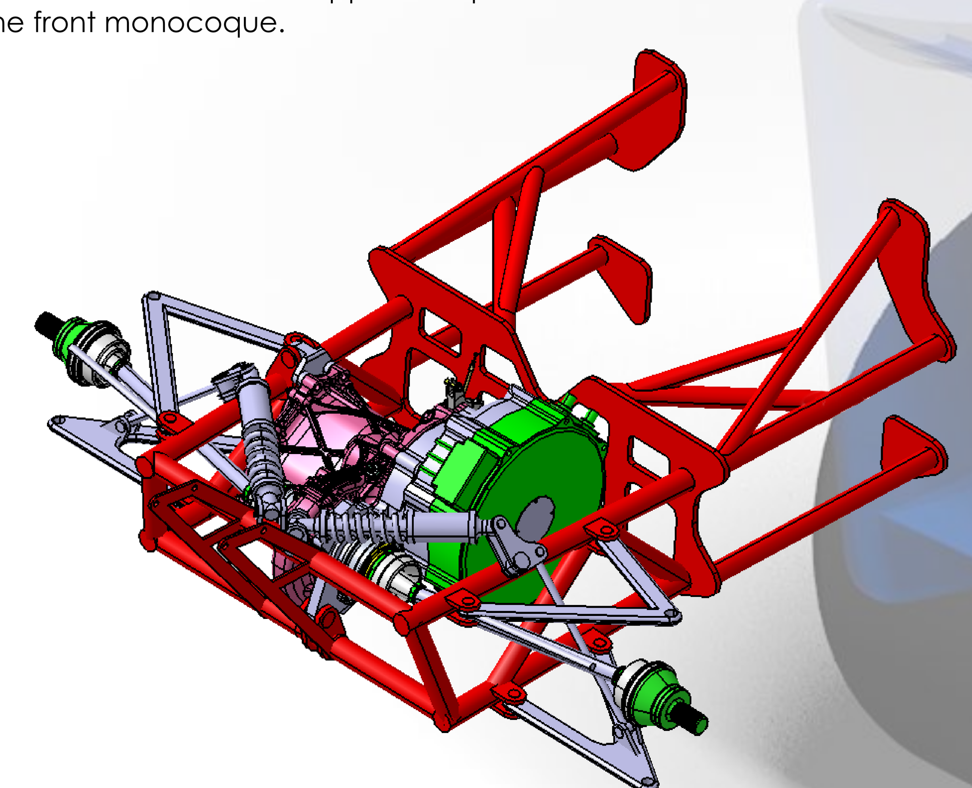
3D Full battery box thermal & CFD model

Battery box design validation
- Volumetric heat generation of cells to match single cell model.(**200,000** W/m^3-k)
- Battery cell temperature **37**° C steady state analysis.
- Ducting and battery box design gave acceptable flow velocities and pressures.

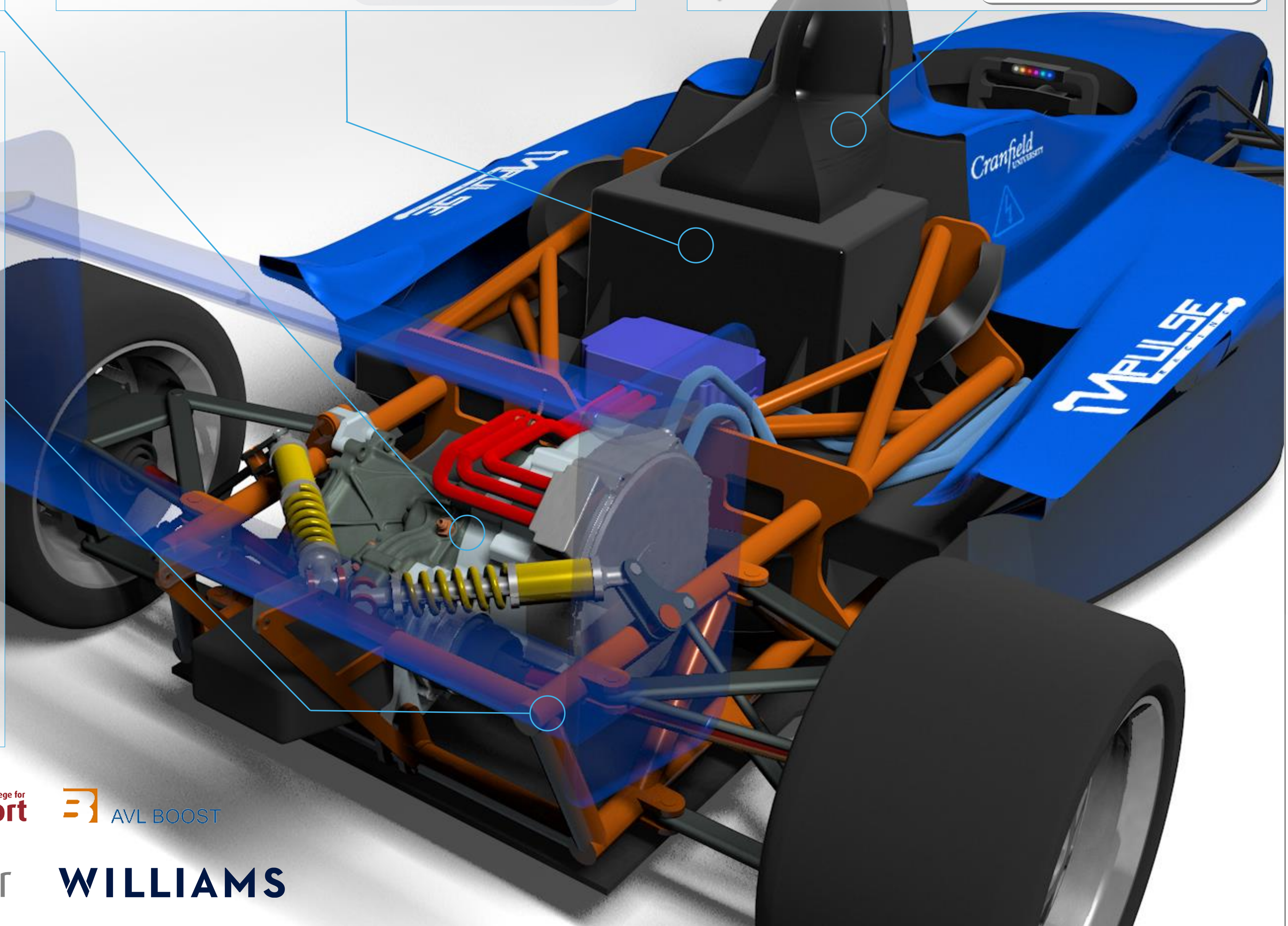


Structural Design

Added rear components were place as far forward in the aim of centralizing mass. The original **bodywork required minimal modification** to accommodate the current layout. A new major component is a rear frame structure which supports all powertrain elements and attaches to the front monocoque.



- **Aerocom 33** tubular steel frame.
- Rear frame structure supports powertrain assembly, suspension pick up points and rear wing fixtures.
- Front frame securely holds battery.
- Redesigned suspension offers the **same kinematic characteristics** despite **50% shorter wishbones.**
- Finalised vehicle is only **48.1 kg above the minimum weight (650 kg).**



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