



# A Design Study into Lithium-ion as a Storage Medium for Automotive Applications

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## Introduction

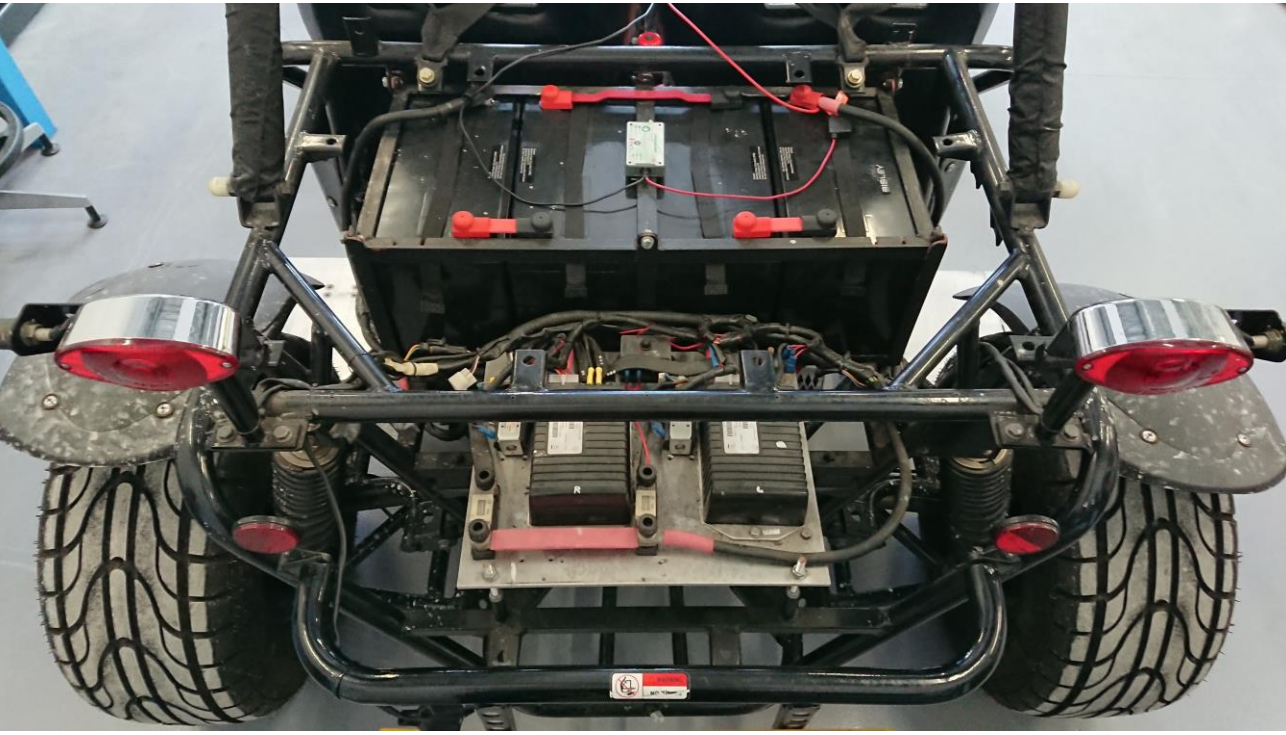
Joyner is an American based firm that produce off-road and UTVs.

The University of Wales has modified their Joyner ATV by removing the ICE and replacing it with two 13kW electric motors. These motors are using four DOD lead acid batteries for energy storage controlled by two Curtis 48V motor controllers.

The total weight of the ATV is 523kg with a front to rear weight ratio of 31/69. To improve the handling of the ATV a new battery pack must be designed.



(Image to show the Joyner ATV)



(Image to show the original lead acid batteries and motor controllers)

## Project Aims

- Research design and safety implications of available battery chemistries.
- Evaluate the best chemistry available for energy storage.
- Test a variety of cells to determine the most suitable.
- Test a variety of materials that can be used as an enclosure for the ESS.
- Design the complete ESS.
- Evaluate the design and weight saving of the ATV.

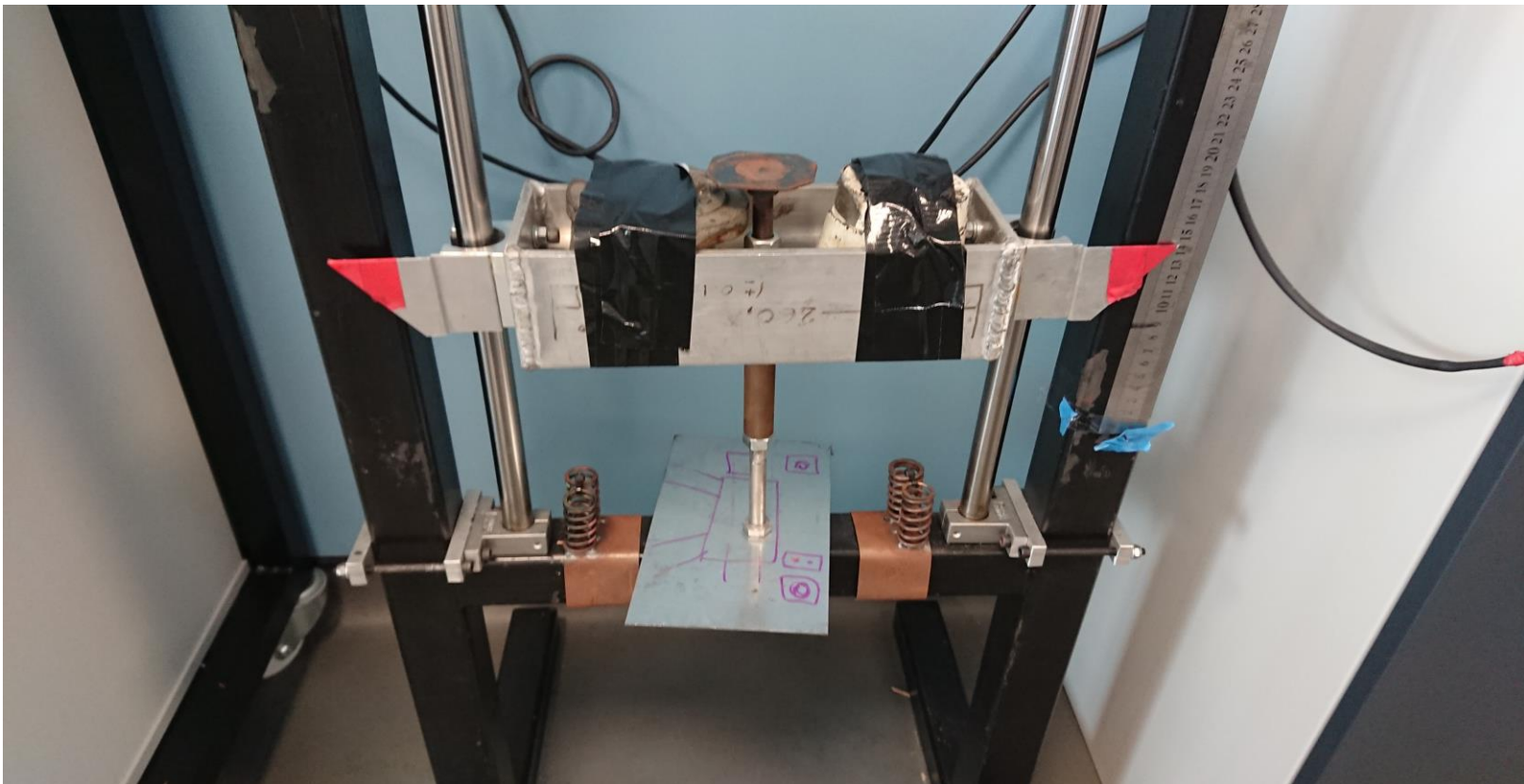
## Methodology

A literature review was conducted to determine the available chemistries used in modern battery cells.

This review also covered the safety implication of these chemistries, ways to mitigate the safety risks using enclosure design, and battery managements systems.

Cells were purchased and their rated capacity was tested using a circuit to draw a constant current, the voltage of the cells were recorded in increments using a multimeter.

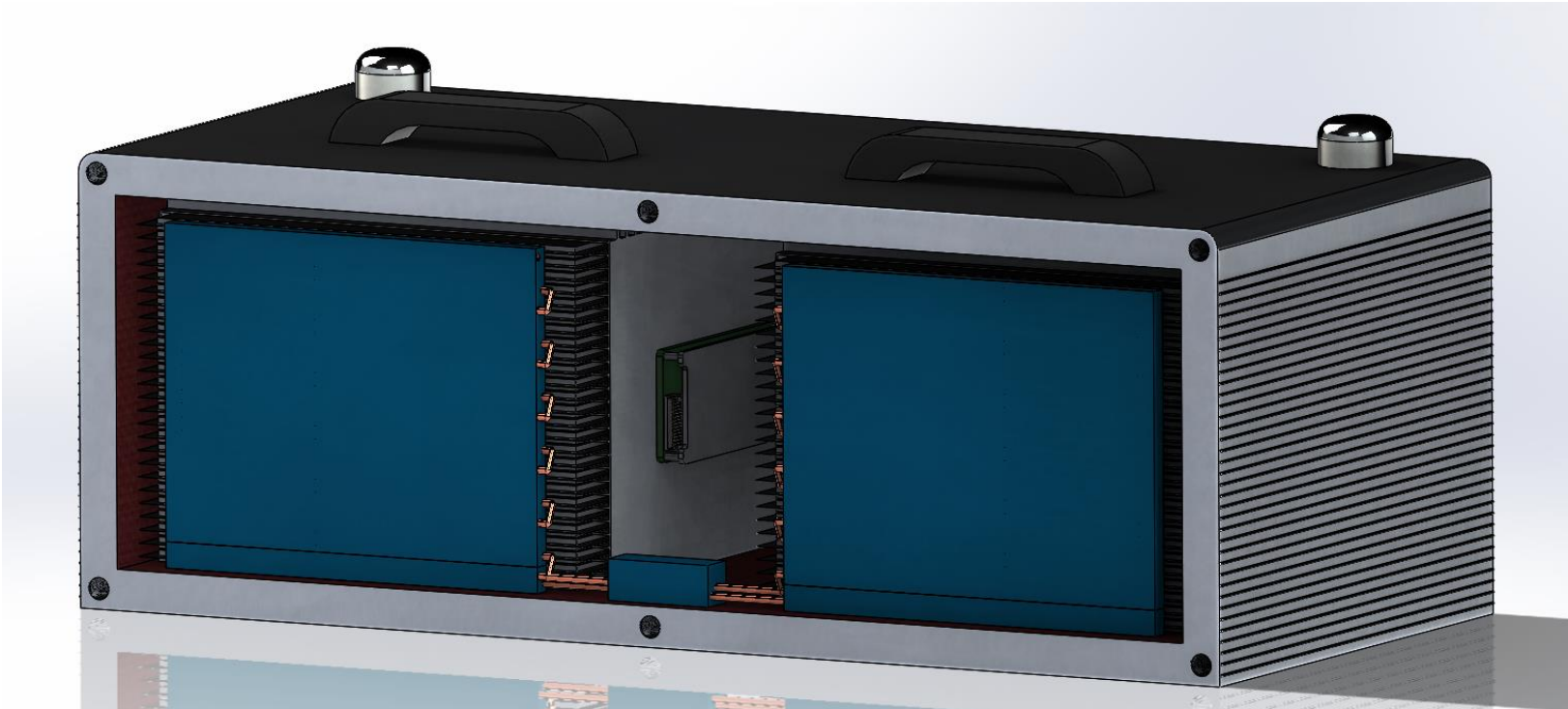
Drop-weight impact testing was performed to establish material strength of an aluminium honeycomb structured specimen and a fibre-reinforced honeycomb structured specimen.



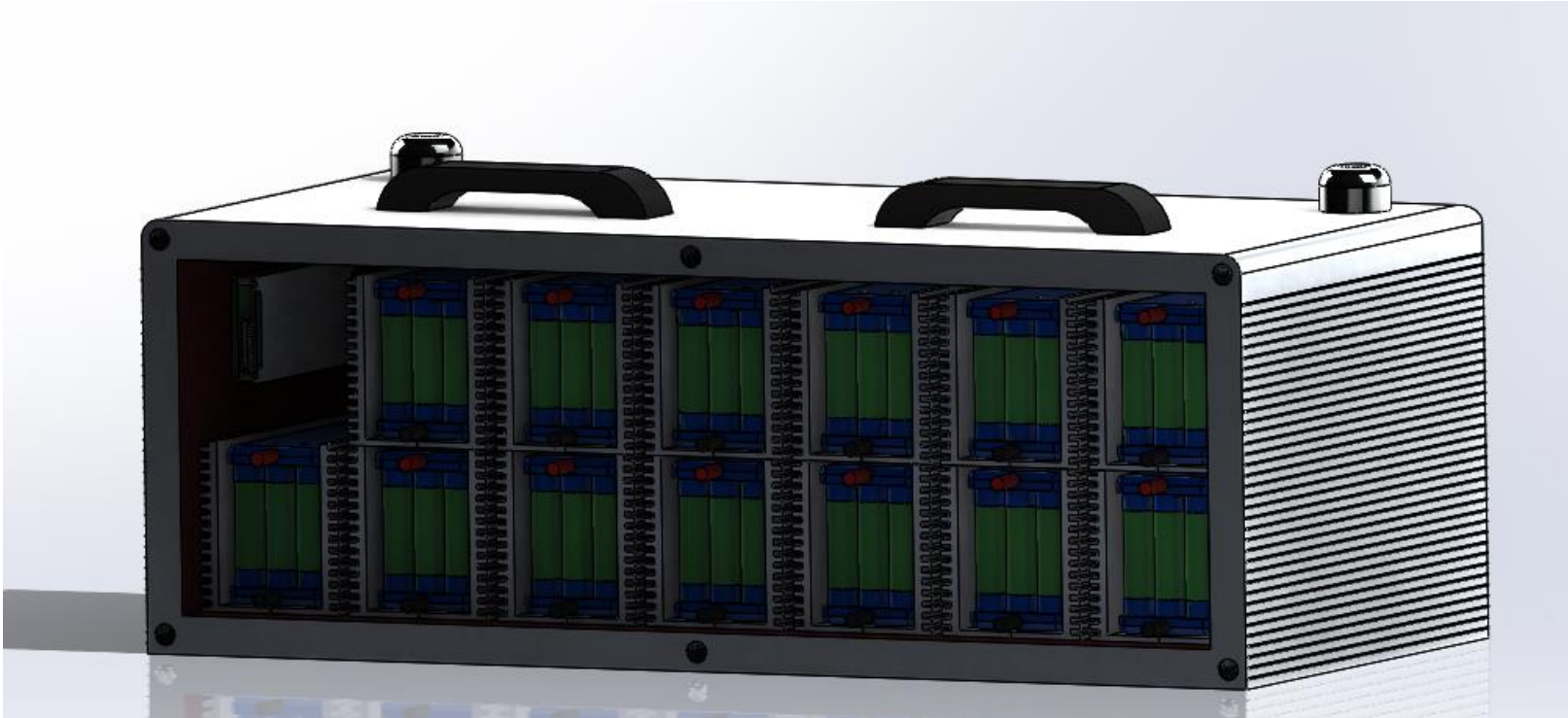
(Image to show the drop-weight impact test equipment)

FEA was performed to verify the drop-weight impact test. The material data for the specimens were not known so using the FEA results it was possible to re-create the materials in Solidworks.

Using Solidworks final designs was created with consideration to the findings of the research, cell testing and the material testing



(Image to show final CAD design using 52 32Ah pouch cells )

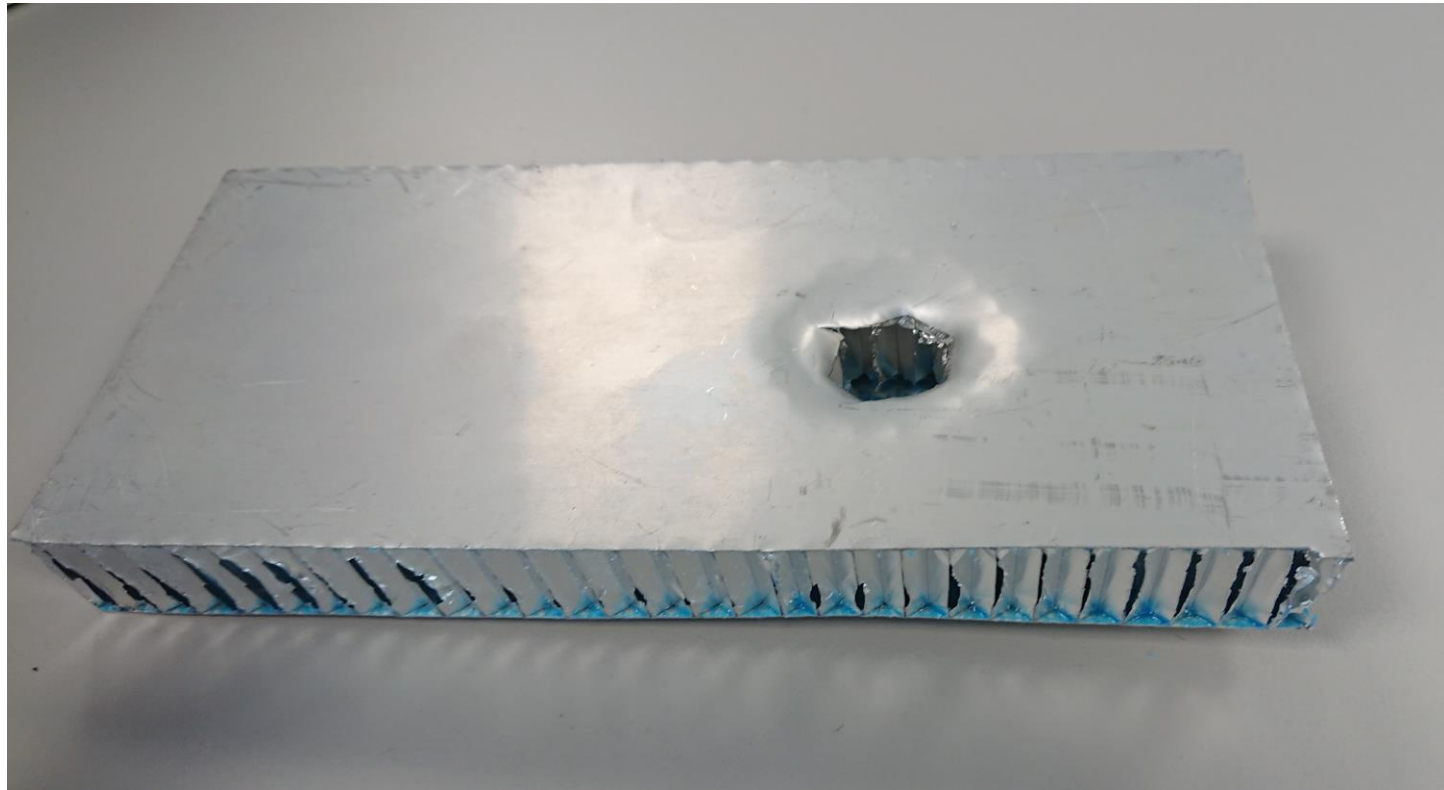


(Image to show final CAD design using 507 3600mAh 18650 cells )

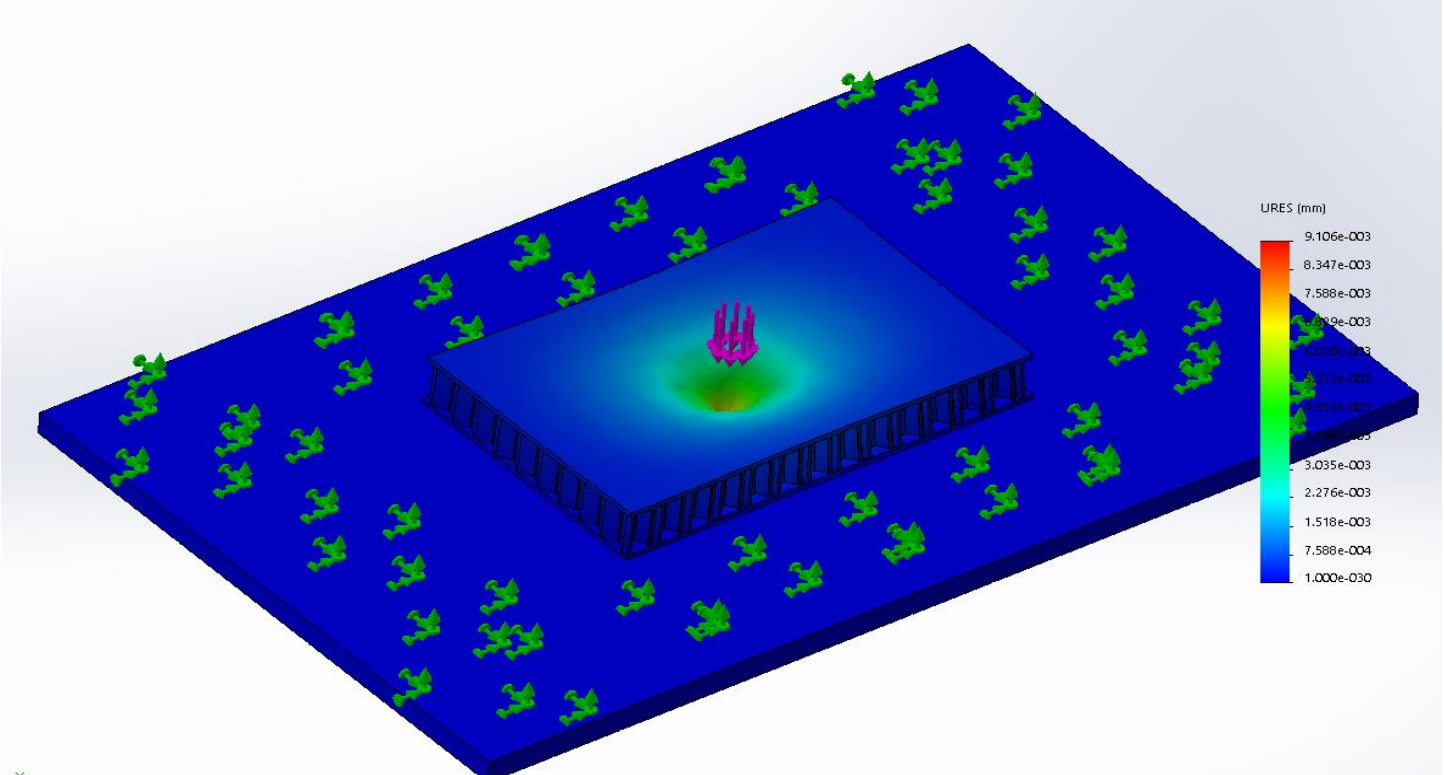
## Results

(Table to show characteristics of the most commonly used battery chemistries, data courtesy of T. Warner)

| Battery Type         | Specific Energy (Wh/kg) | Energy Density (Wh/l) | Specific Power (W/kg) | Cycle Durability |
|----------------------|-------------------------|-----------------------|-----------------------|------------------|
| Lead–Acid            | 33–42                   | 60–110                | 180                   | 500–800          |
| Lithium - ion        | 100–265                 | 250–620               | ~250~340              | 400–1200         |
| Li – ion Polymer     | 100–265                 | 250–730               | ~250~340              | 400–1200         |
| Nickel-Metal Hydride | 60–120                  | 140–300               | 250–1,000             | 500–2000         |
| NiCd                 | 40–60                   | 50–150                | 150                   | 2,000            |



(Image to show the result of drop-weight impact test on an aluminium honeycomb sample)



(Image to show the FEA of the drop-weight impact test on an aluminium honeycomb sample)

## Conclusions

The most suitable material tested was the fibre-reinforced polymer due to its strength and light weight.

Lithium-Ion is the best available chemistry because of its high energy density and life cycle.

The total weight saving of the best design was 64kg changing the front rear weight distribution to 35/65.

Further tests are required to determine the thermal properties of the ESS to ensure safety.

## Acknowledgements

K. Tudor, M. Sandford, M Fall, P. Davis

## References

T. Warner (2015). *The Handbook of Lithium-Ion Battery Pack Design* – p 166-167