Battery Pack Design and Development for First Responder Electric Motorbike

Alistair Farman | MAHLE Powertrain Ltd | 28-Feb-2024

MAHLE Powertrain

This is MAHLE Powertrain

The Knowledge Powering Innovation

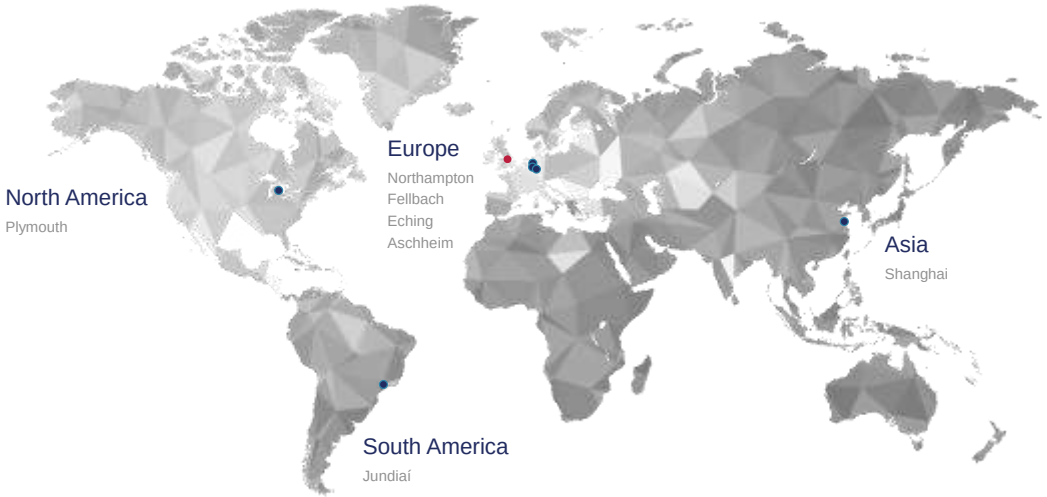
- For over 60 years, MAHLE Powertrain has provided automotive OEMs with the power to solve complex engineering challenges and adapt to the changing demands of the industry
- Support customers with expertise across entire powertrain
- Strength lies in the knowledge and experience of our exceptional people
- Agile and flexible approach, geared around the true needs of the customer
- MAHLE 2030+ strategy focused on
    - **Delivering sustained high performance for EV systems**
    - **Unlocking full potential of IC Engines**
    - **Optimised energy utilisation for total system efficiency**

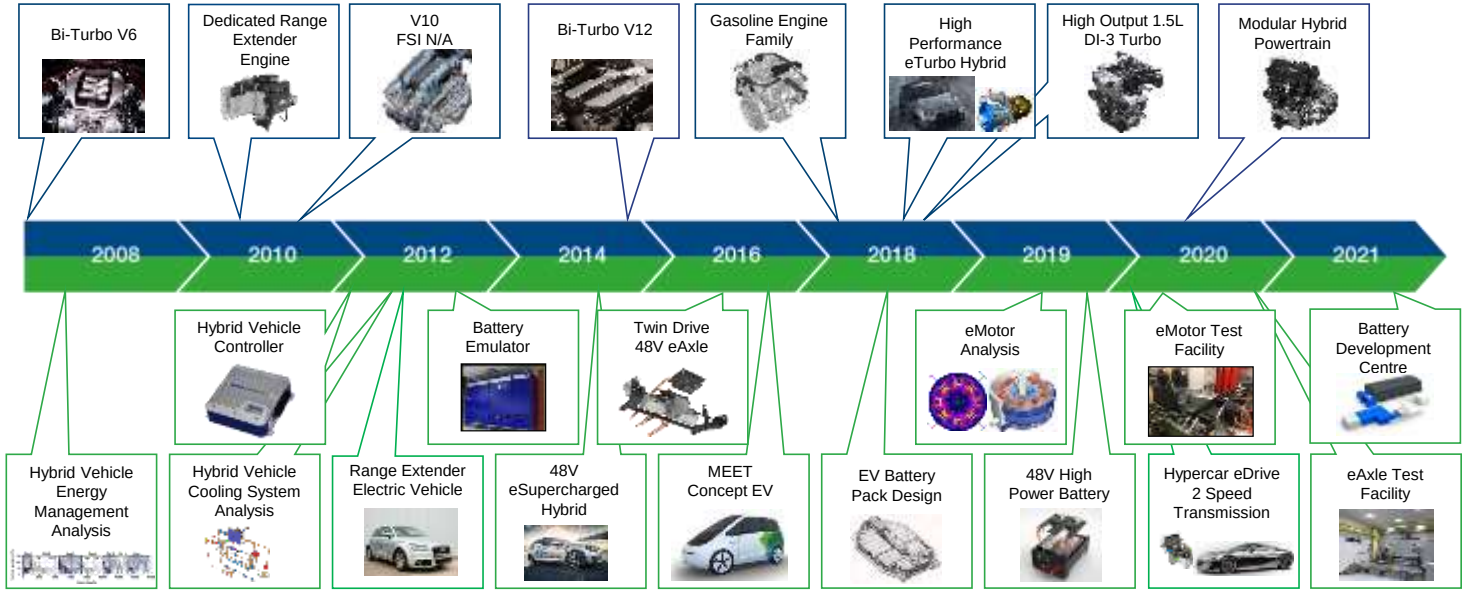
2030+ Strategy

Expertise in electrification

- Expertise in electrification and thermal management built on a rich heritage in ICE
- Our 2030+ strategy actively pursues the continued development of IC engines in tandem with our long-established expertise in the electrification of powertrains

MAHLE 2030+ Strategy





High Level Application

ADVANCED PROPULSION CENTRE UK

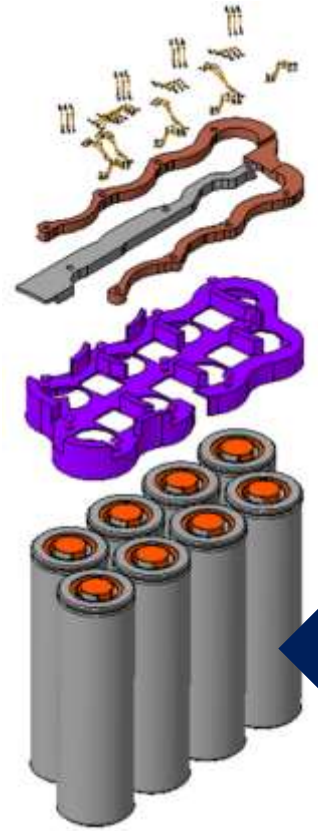
Advanced Route to Market Demonstrator Programme (ARMD2)

Electric First Responder Motorcycle (WMC300E+)

- White Motorcycle Concepts (WMC) and MAHLE Powertrain are working together to develop a proof-of-concept product demonstrator
- BEV three-wheeled motorcycle targeting the police and other emergency first responders
  - Potential entrant to the last-mile delivery fleet market
- Support community policing: increase police visibility
- Classed as a Tricycle but can be ridden on a standard car licence
  - Removes the need for specialist training

High-Level Vehicle and Battery Pack Specifications

Vehicle Parameter	Unit	Target
Range	km	180
Acceleration, 0-100 kmh^{-1}	s	8.6
V_{max}	kmh^{-1}	161
Battery Parameter	**Unit**	**Requirement**
Nominal Voltage (*existing infrastructure compatibility*)	V	324
Power: Continuous	kW	37
Power: Peak	kW	50
10-80% Charge	min	<15



Based on MPT's proprietary M^3x concept

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High-Level Methodology

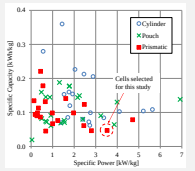
M³x Origins: Ultra-High Performance E-Segment BEV SUV

Vehicle Parameter	Unit	Target
EPA Range (5 cycle)	km	>550
Maximum speed	kmh^{-1}	250
0-100kmh^{-1} acceleration	s	<2.50
Nürburgring lap time, 3-laps, no derate	mm:ss	<8:00
Battery Parameter	**Unit**	**Req't**
Pack mass	Kg	<720
Nominal Voltage	V	800
Electrical layout	S:P	200S33P
Capacity	kWh	144.5
Maximum voltage	V	840
Battery terminal peak power	kW	1122

Cell Testing & Characterisation

- Capacity
- Performance
- Mass
- Dimensions
- Durability (life)
- Safety

Cell Database



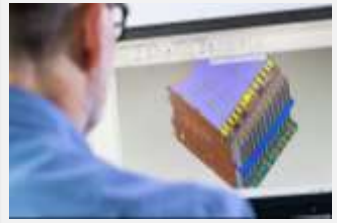
Battery Pack Targets

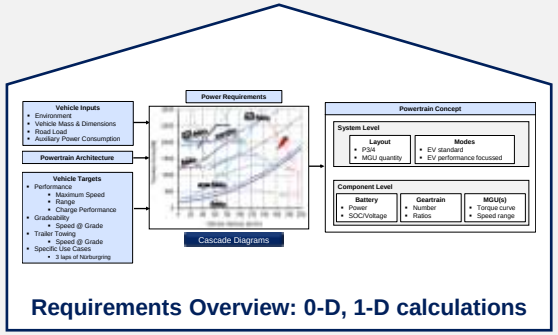
- Capacity
- Performance
- Mass
- Dimensions
- Durability (life)
- Safety

Battery Pack Layouts

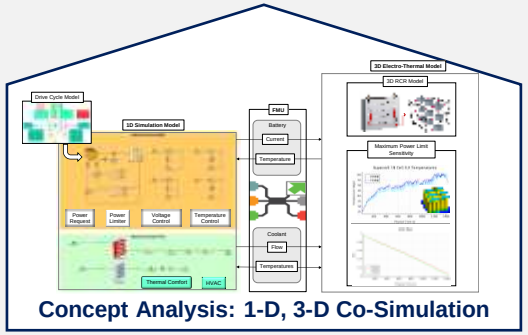
- Potential cell options
  - Pack configuration (S x P)
    - Capacity
    - Performance
    - Mass
    - Dimensions

Battery Pack Design





Requirements Overview: 0-D, 1-D calculations



Concept Analysis: 1-D, 3-D Co-Simulation

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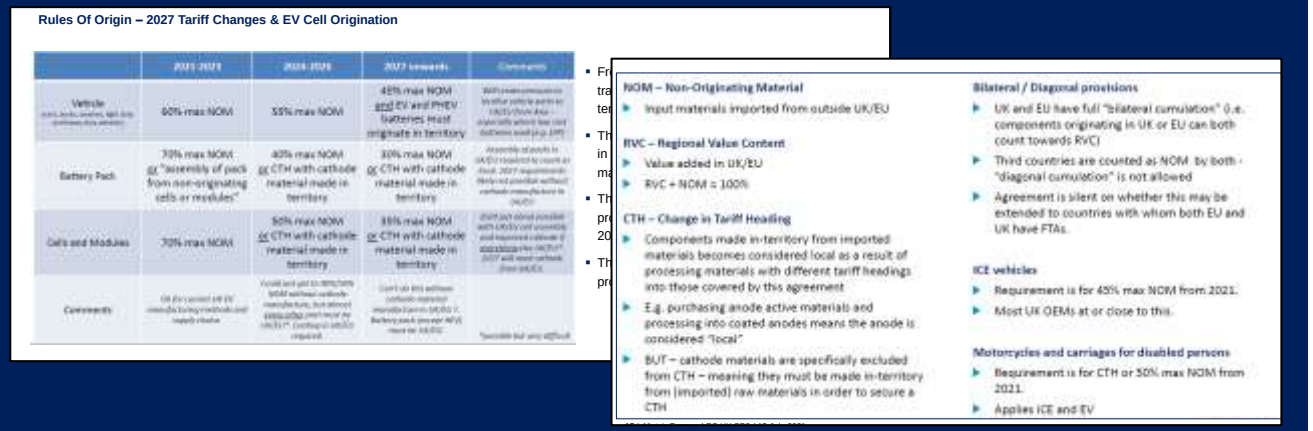
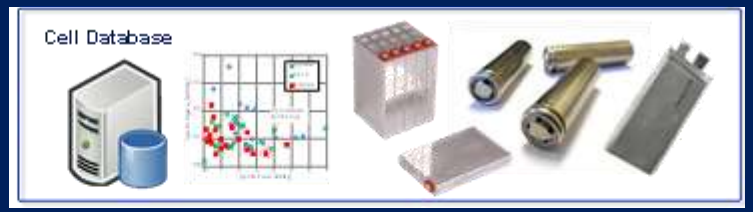
Cell Selection

Market & Commercial Considerations

Rules of Origin:

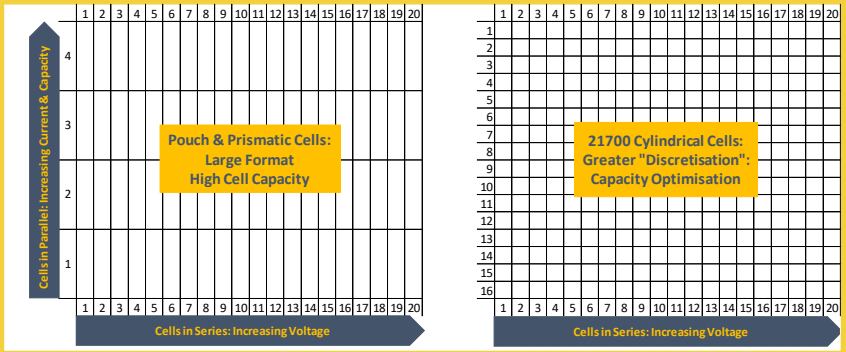


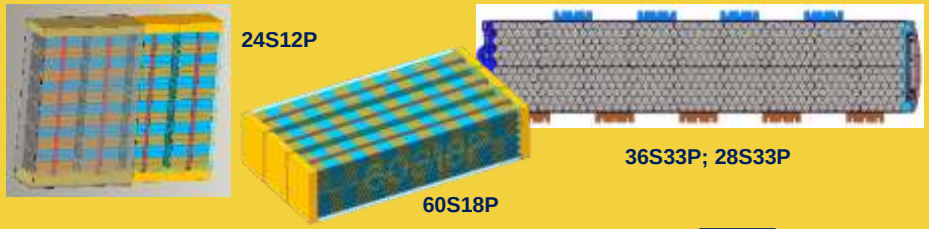
MAHLE Group & MAHLE Powertrain Cell Database:
Cell format availability trends from forthcoming EU and UK Gigafactories



MAHLE Powertrain Technical Requirements for Niche Applications

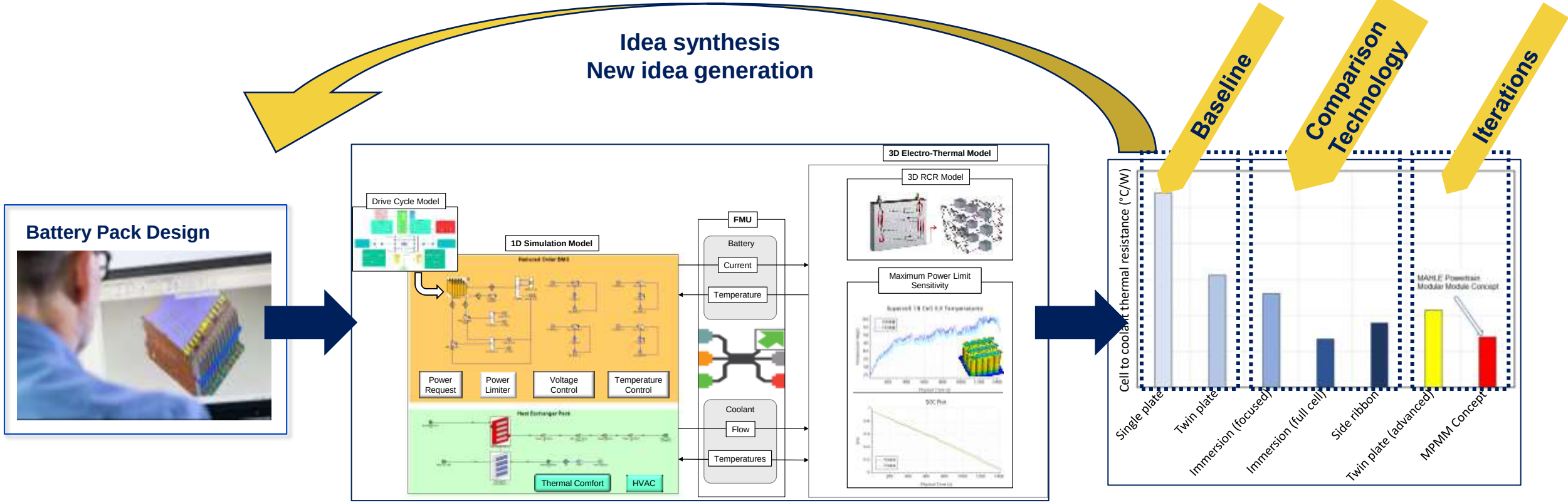
Flexibility and Adaptability





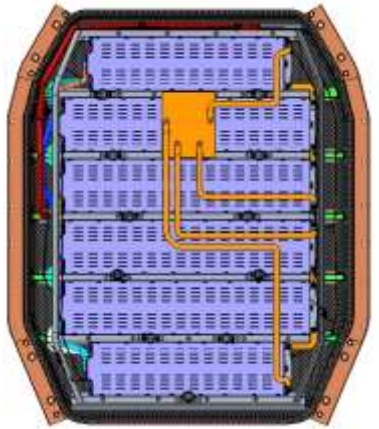
21700-FORMAT CYLINDRICAL CELLS SELECTED

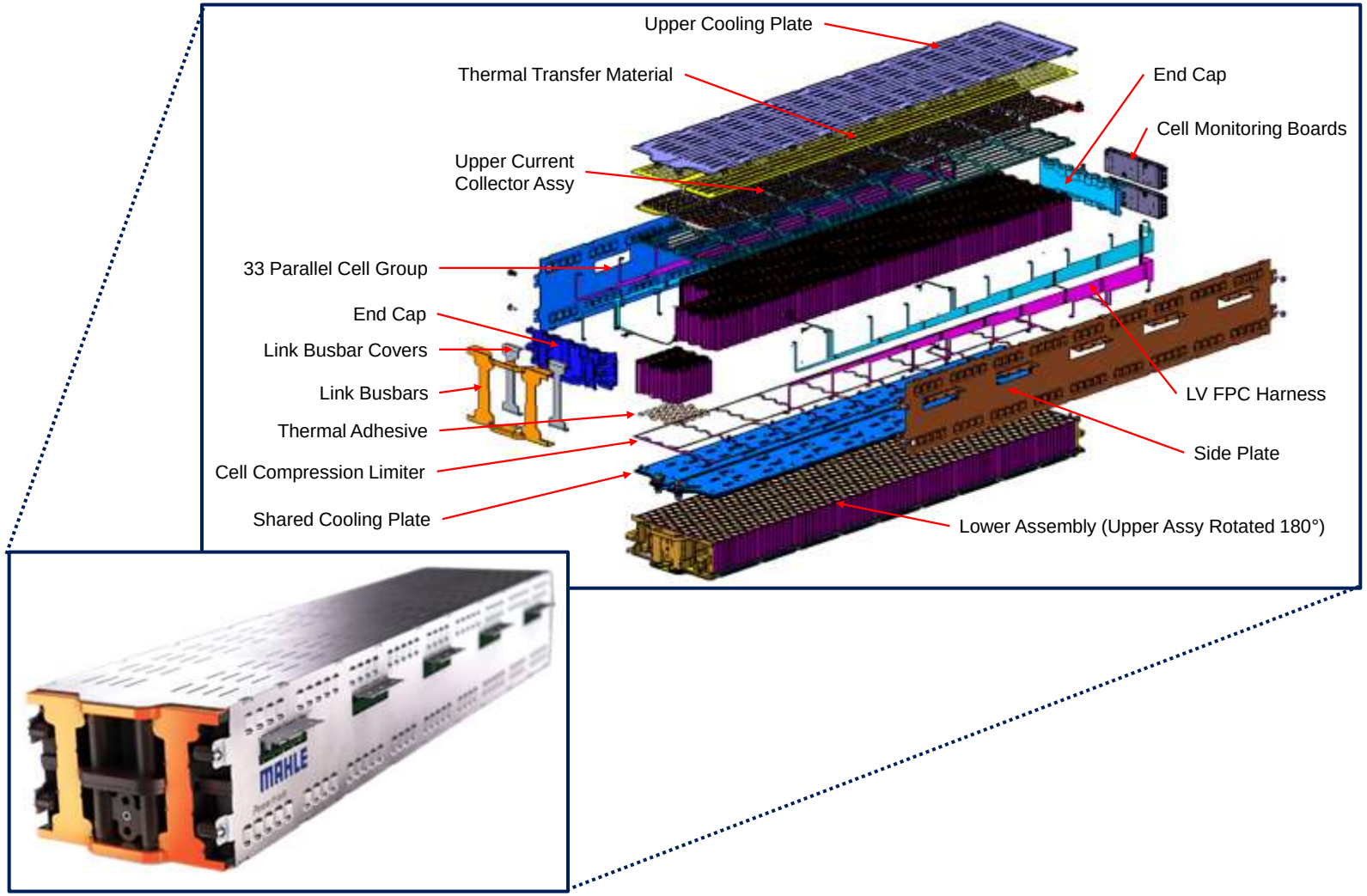
Concept Generation



M³x: a water-glycol cooling concept with performance similar to immersion cooling

M³x “Parent” Concept Overview





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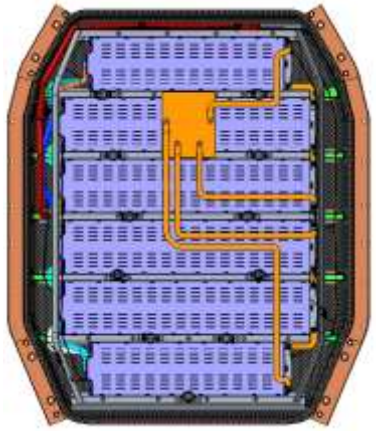
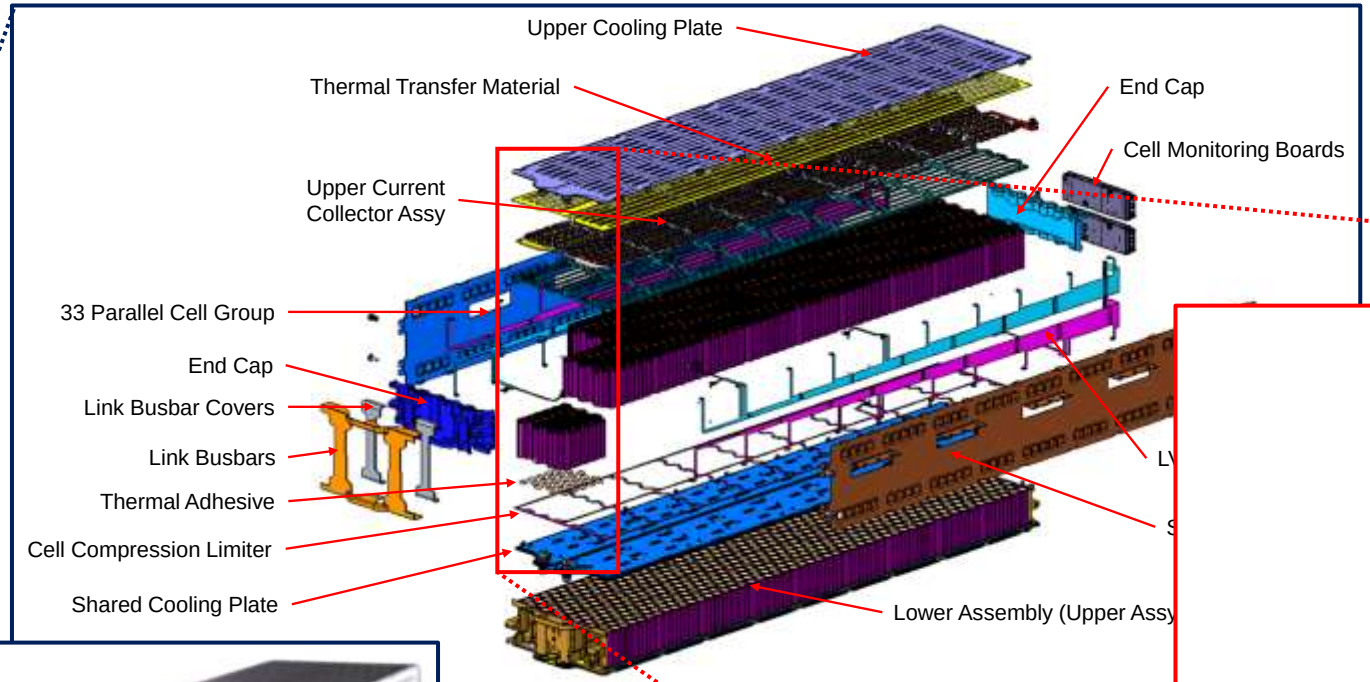
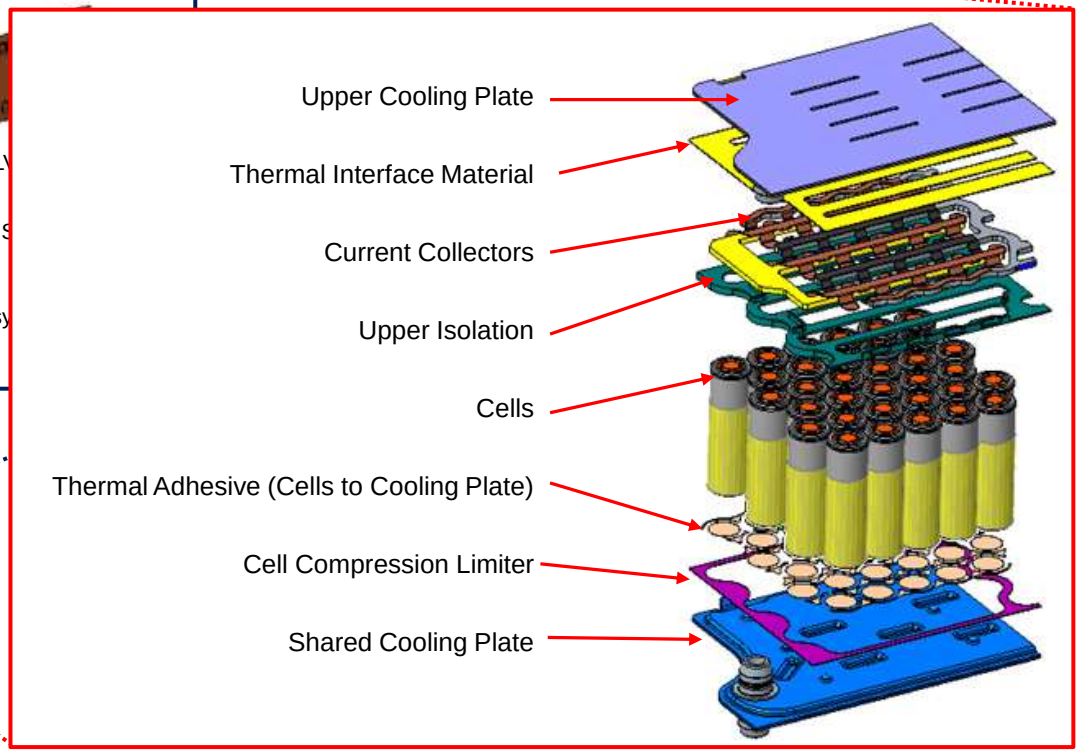




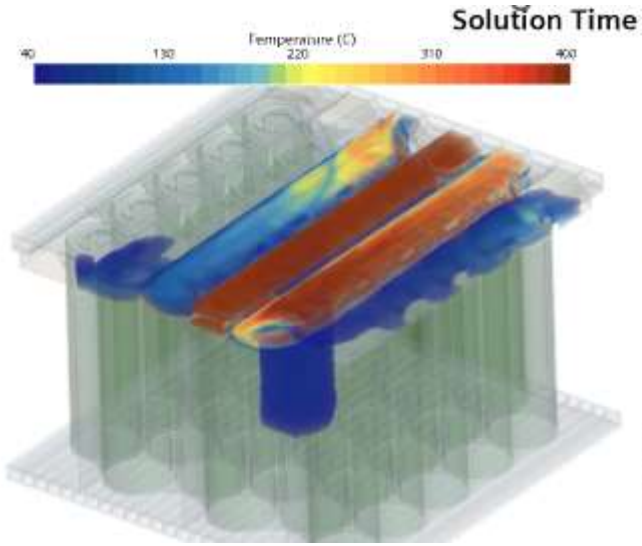


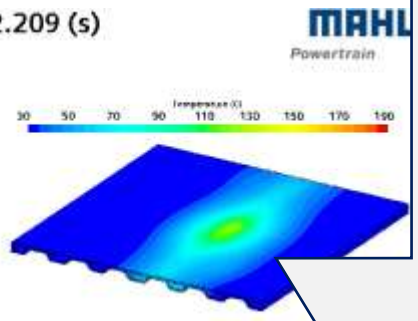
M³x "Parent" Concept Validation Testing

ITEM	TWIN-PLATE RIG	M³x ANALYSIS MODEL	M³x THERMAL RIG
Cell Type	Samsung 48X (*square shoulder facilitates laser welding*)		
+ve Connection	Laser		
-ve Connection	Laser; base of can	Laser; can "shoulder"	
M3x Features	No	Yes	
Elec. Config.	1S12P	2S33P	1S12P
Coolant Flow	2 $lmin^{-1}$	Equiv. to rigs: 11 $lmin^{-1}$	2 $lmin^{-1}$

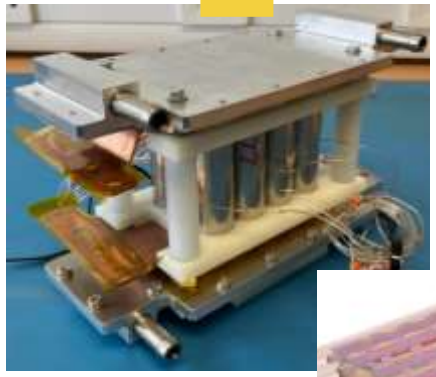
Test Rigs

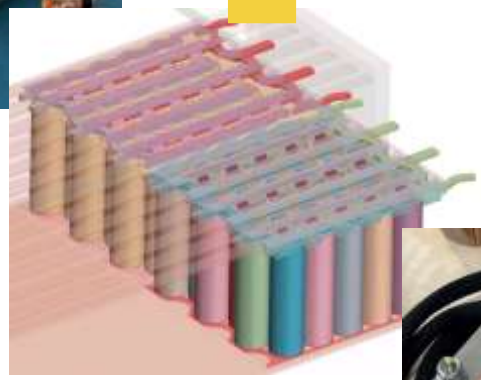
- Basic twin plate thermal rig
- M³x thermal rig: all cooling features
- Thermal runaway: risk to outer cooling plates
  - Single cell
  - Multi-cell tests part of WMC300e pack development





Thermal Runaway Scenario 1
5.5Ah NMC 21700 Cell
Upper Cooling Plate Impingement





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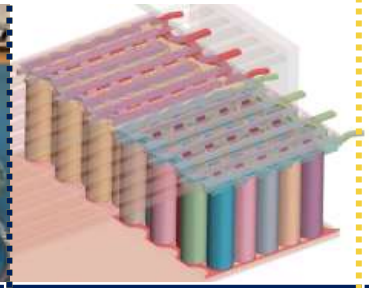
M³x "Parent" Concept Validation Testing



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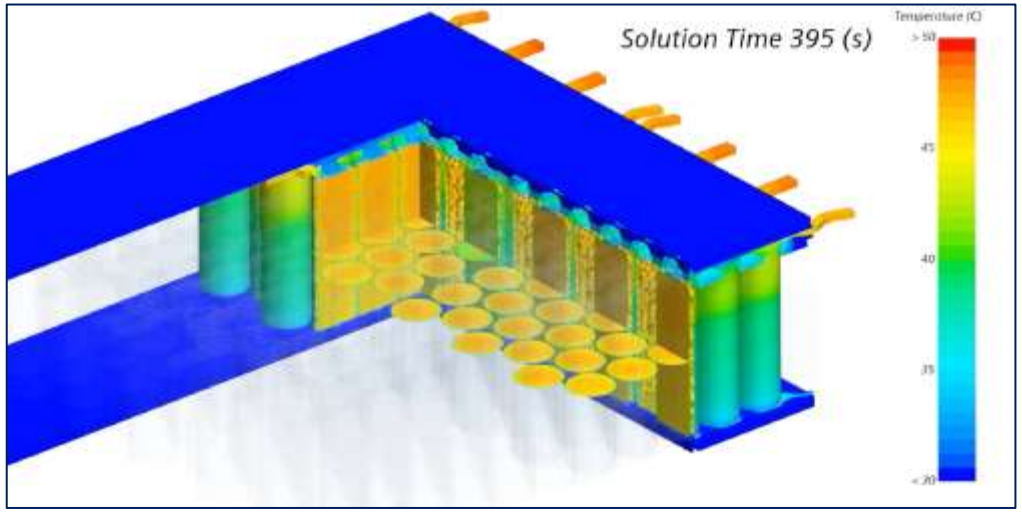
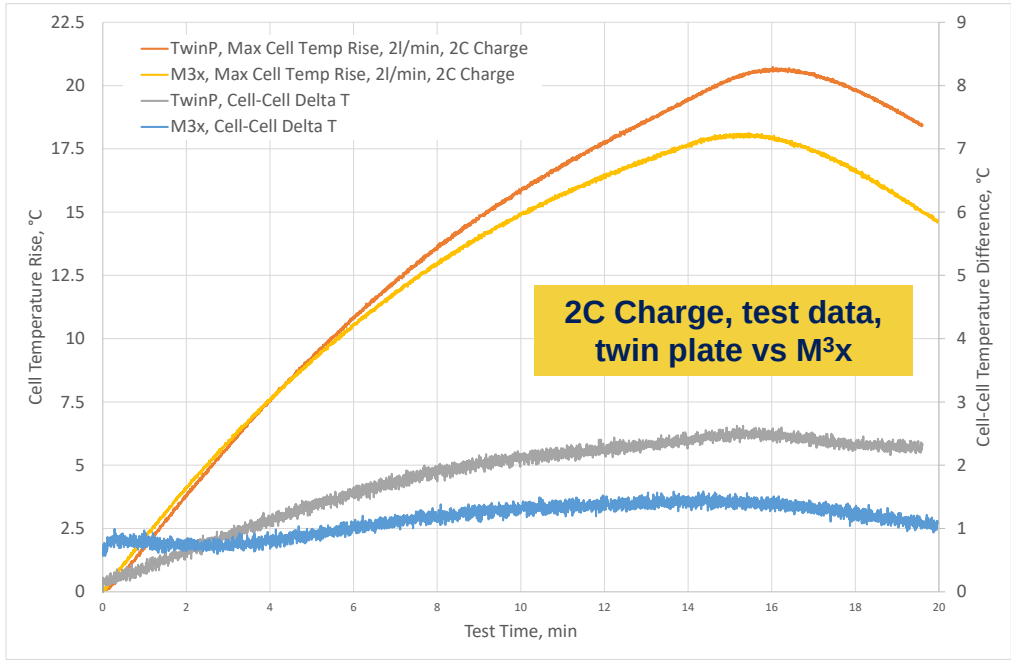
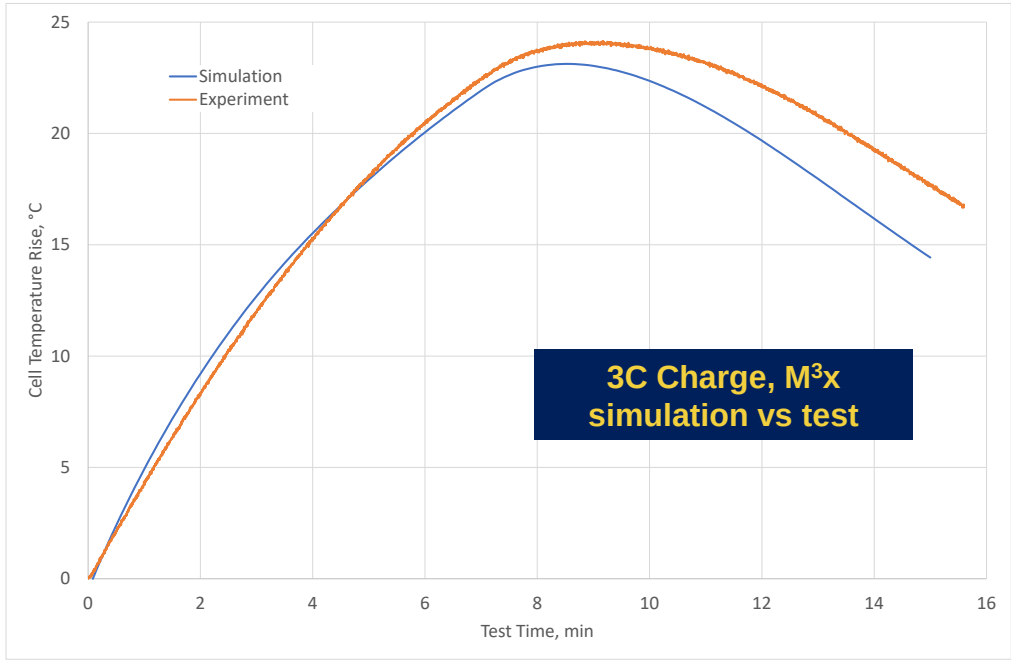
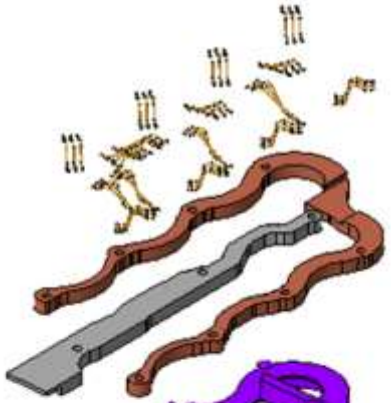






M³x "Child" Application: WMC300e

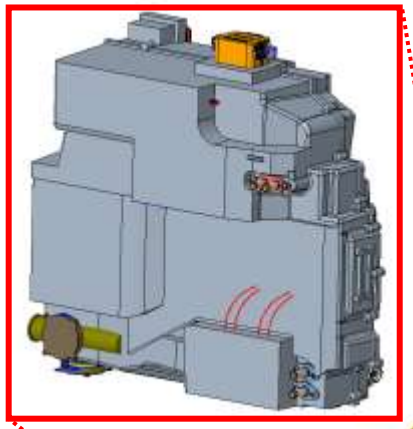


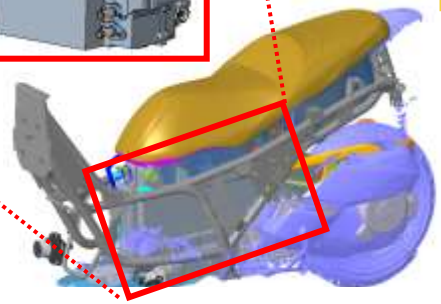
Wire bonding – Aluminium

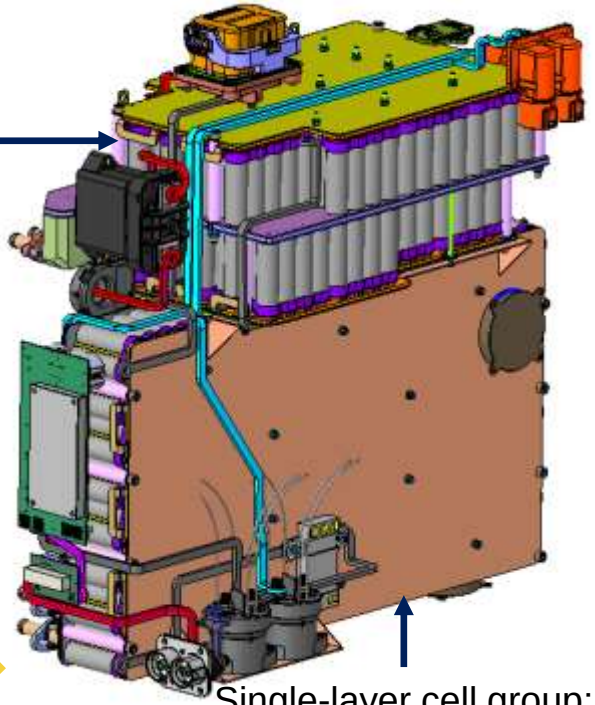
Busbars – Aluminium

Polymer busbar carrier

21700 – P45B CELL

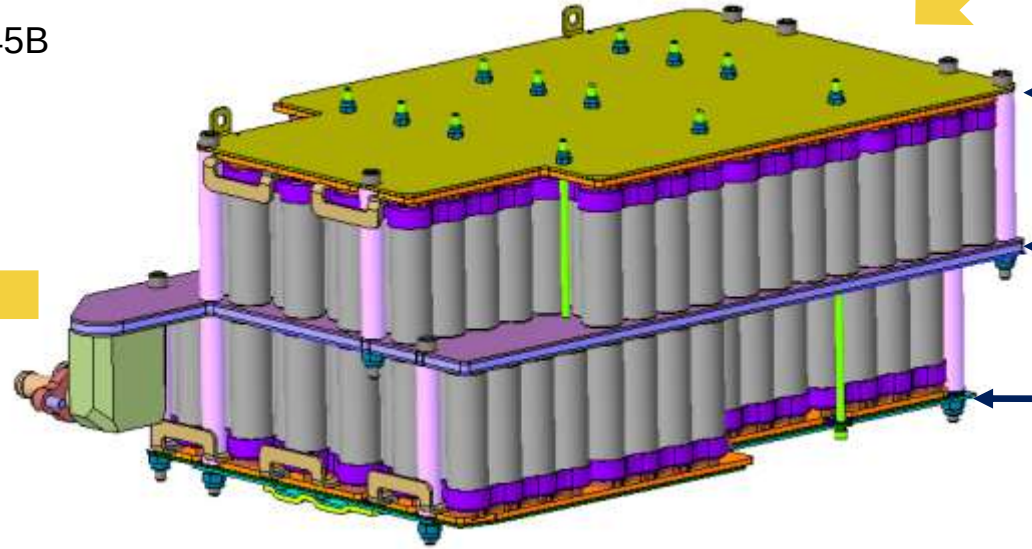






Double-layer cell group; shared cooling plate

Single-layer cell group; single cooling plate



Closing plate with thermal runaway mitigation features

Shared cooling plate

Closing plate with thermal runaway mitigation features

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Development Analysis and Testing: WMC300e “Child” Application

SUPERCELL

Electro-Thermal Performance Rig
Thermal Runaway (nail penetration)
Mechanical (shock, vibration)

ANALYSIS

TEST

Electro-Thermal Performance
Thermal Runaway
Mechanical (shock, vibration)

Wire Bonding Mechanical Integrity
Wire Bonding Electrical & Thermal Resistance

Cycle Life Ageing (drive cycle, high C-rate charge)

SUPERCELL

SUPERCELL GROUPS

Cooling Plate CFD (design optimisation)
Mechanical (shock, vibration)

ANALYSIS

TEST

SUPERCELL GROUPS

PACK

Mechanical (shock, vibration)

ANALYSIS

TEST

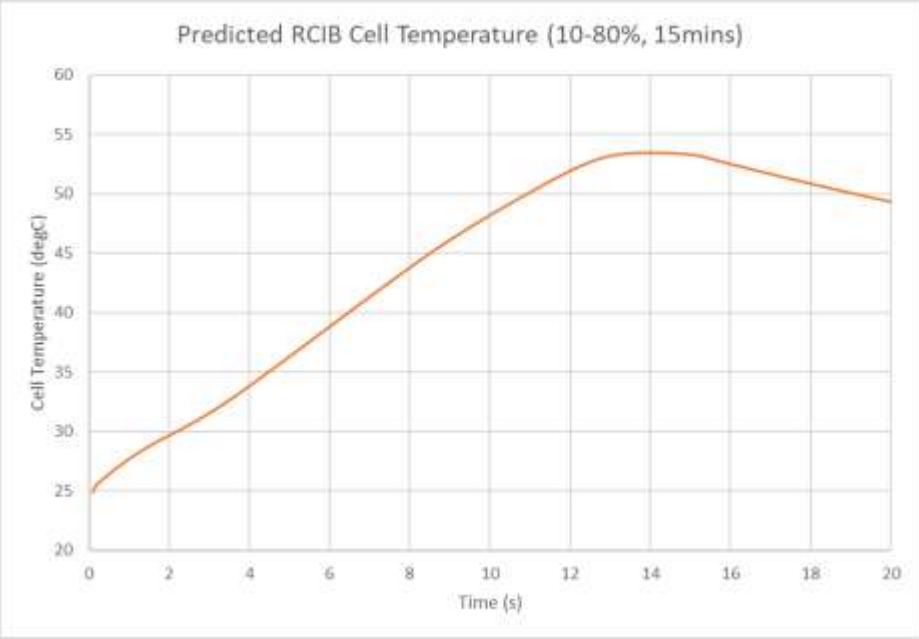
Thermal Performance
Thermal Propagation
Mechanical (shock, vibration)
Ingress Protection

PACK

Development Analysis and Testing: WMC300e “Child” Application

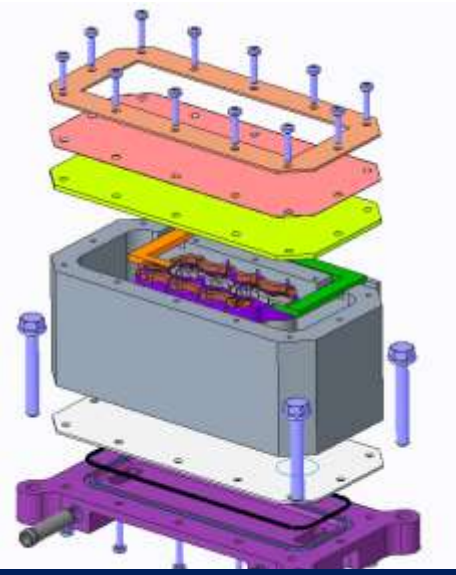
Development Analysis

- MPT has run a full vehicle analysis of the charge process
- Representative battery radiator sizing and coolant flows
- Chosen Molicel P45B cell; ~3C charge



- Plot shows a “deeper” 10-80% charge rather than a 20-80% charge

Molicel P45B Cell Ageing Rig



Supercell Test Rig

Wire Bonding Process Development Rig

Wire Bonding Electro-Thermal Rig

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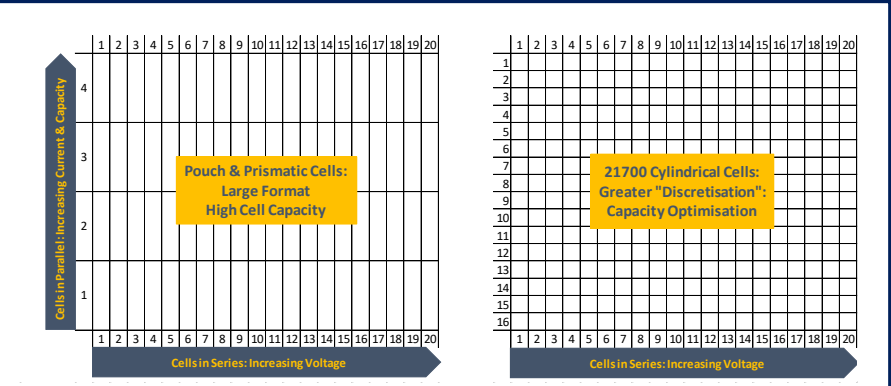
Conclusions

- MAHLE Powertrain has developed a very high performance battery concept with novel enhancements to a water/glycol cooling plate system
  - This allows very low temperature differences within and between cells
  - Strong propagation prevention properties
- 21700 cylindrical cells give a wide range of chemistry options and allow:
  - Finer tailoring of voltage, energy storage and power to suit niche customer requirements
  - Greater packaging flexibility
- Bespoke designs are being developed quickly to suit specific applications



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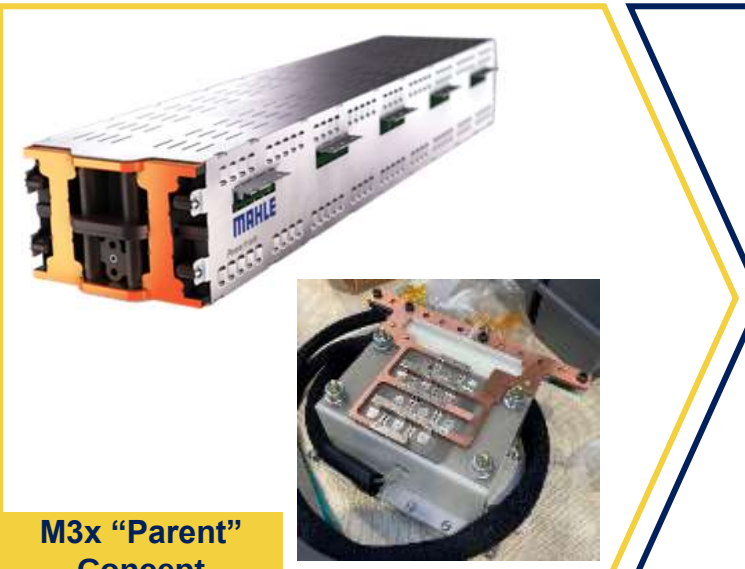
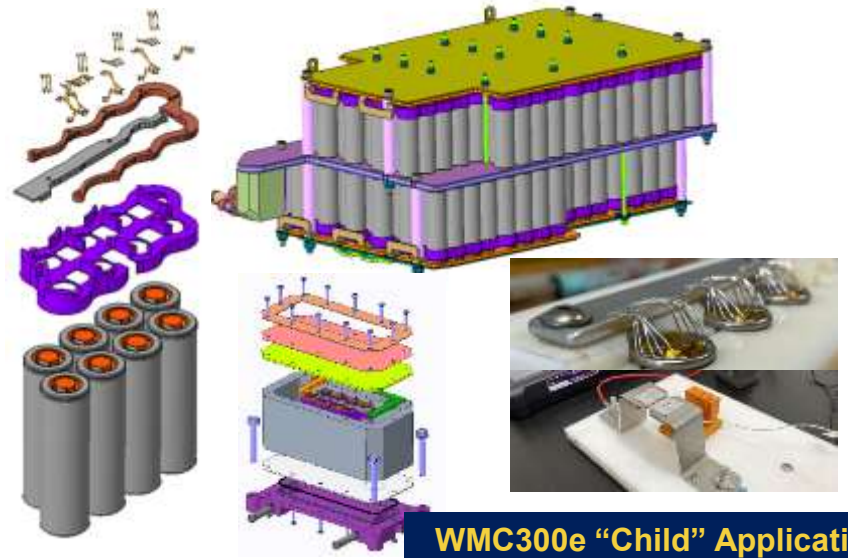
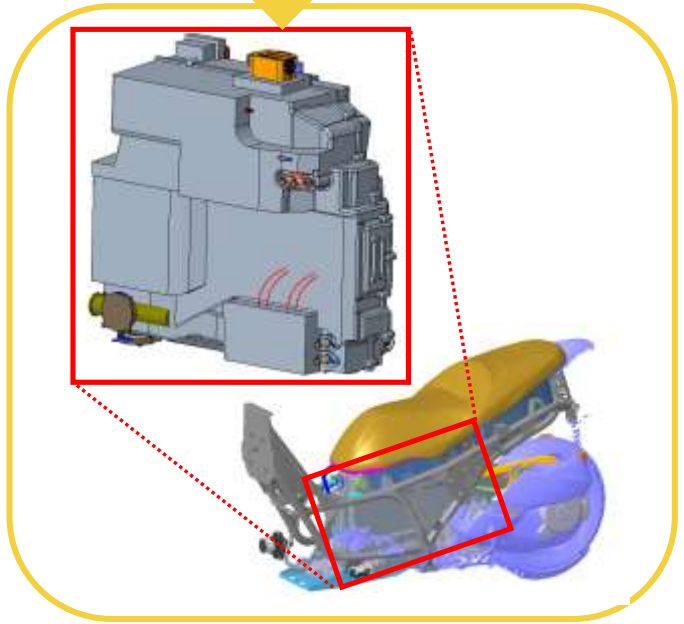


M3x "Parent" Concept



WMC300e "Child" Application



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