

## DISRUPTING THE BATTERY DEVELOPMENT PROCESS WITH AN INTELLIGENT DIGITAL TWIN

Alex Gregory, Senior Project Engineer, Altair  
David White, Battery Engineering Leader, Danecca  
20<sup>th</sup> April 2023

# Leading Convergence of Computational Science and AI in Engineering

Altair is at the forefront of the evolution toward a smarter, more connected world.

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Helping companies use digital twins, intelligent models, and the convergence of simulation, HPC, and AI to predict and optimize system outcomes.



# 74 Offices in 27 Countries



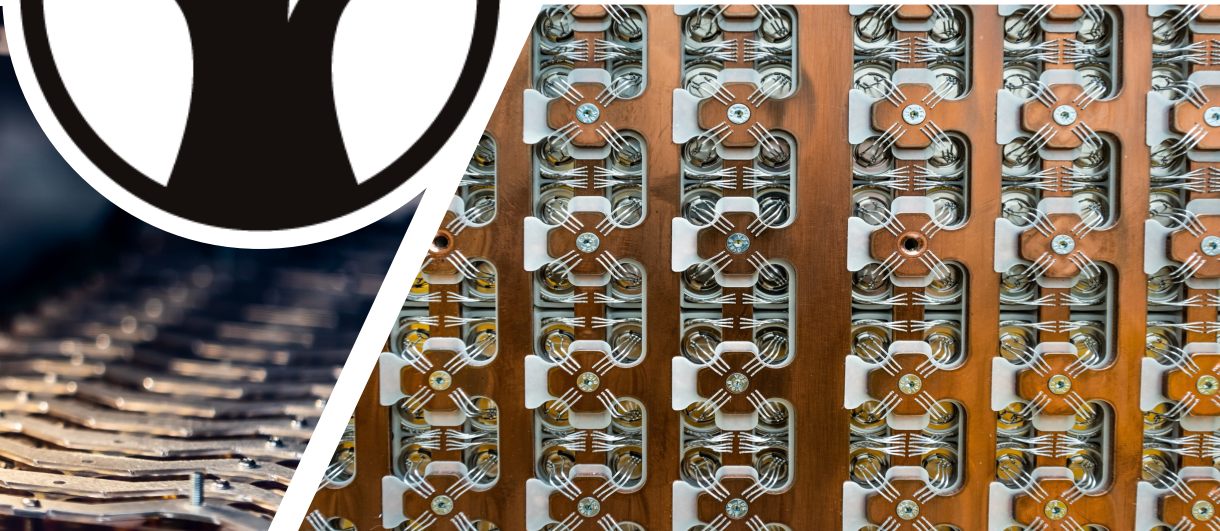


Danecca break down the barriers to electrification from our HQ at Silverstone, UK

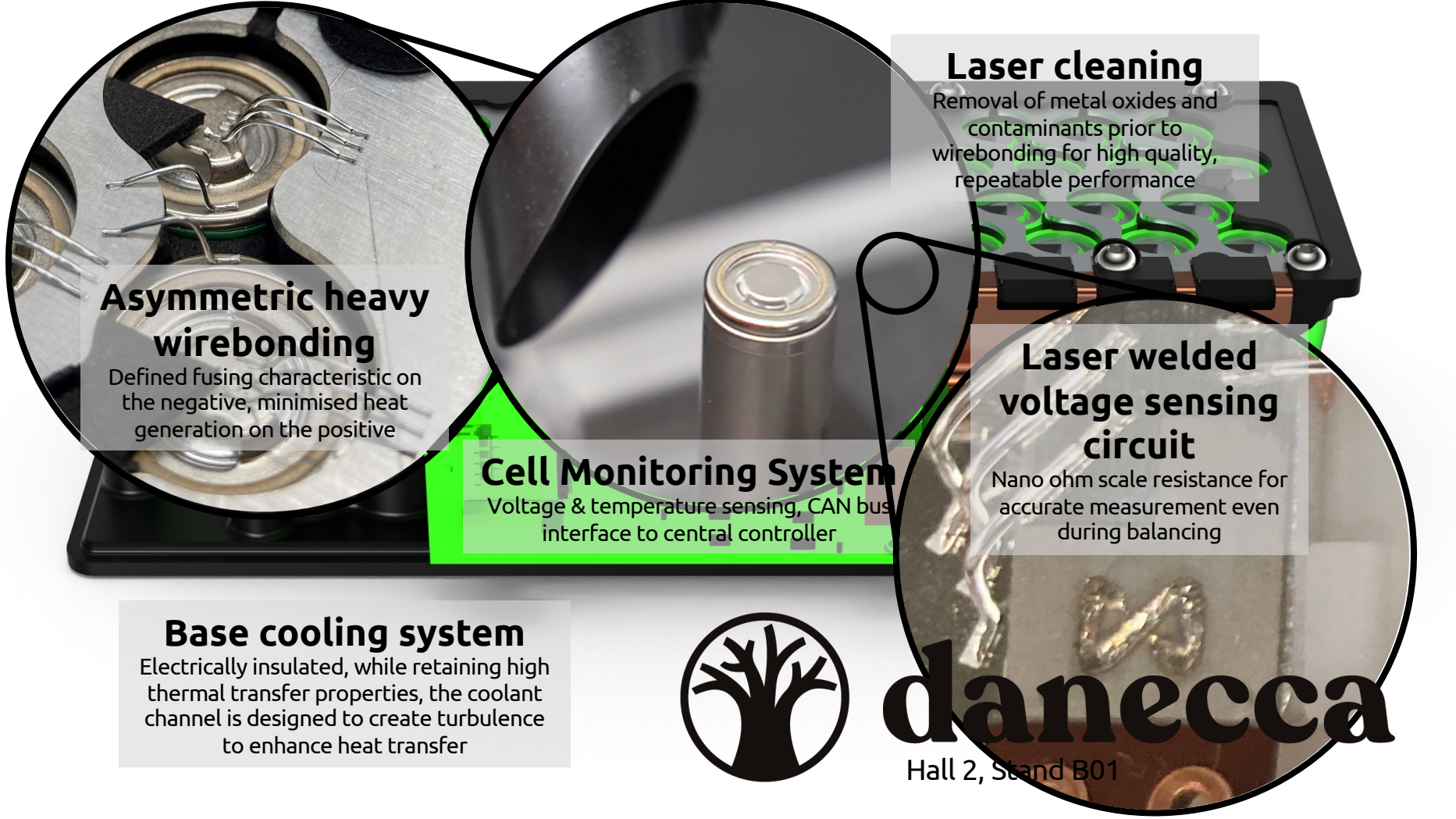
Design | Build | Test | Intelligence | Factory



Megan Carlisle @ Danecca Ltd



Frank Clarke for Danecca Ltd



### **Asymmetric heavy wirebonding**

Defined fusing characteristic on the negative, minimised heat generation on the positive

### **Laser cleaning**

Removal of metal oxides and contaminants prior to wirebonding for high quality, repeatable performance

### **Laser welded voltage sensing circuit**

Nano ohm scale resistance for accurate measurement even during balancing

### **Cell Monitoring System**

Voltage & temperature sensing, CAN bus interface to central controller

### **Base cooling system**

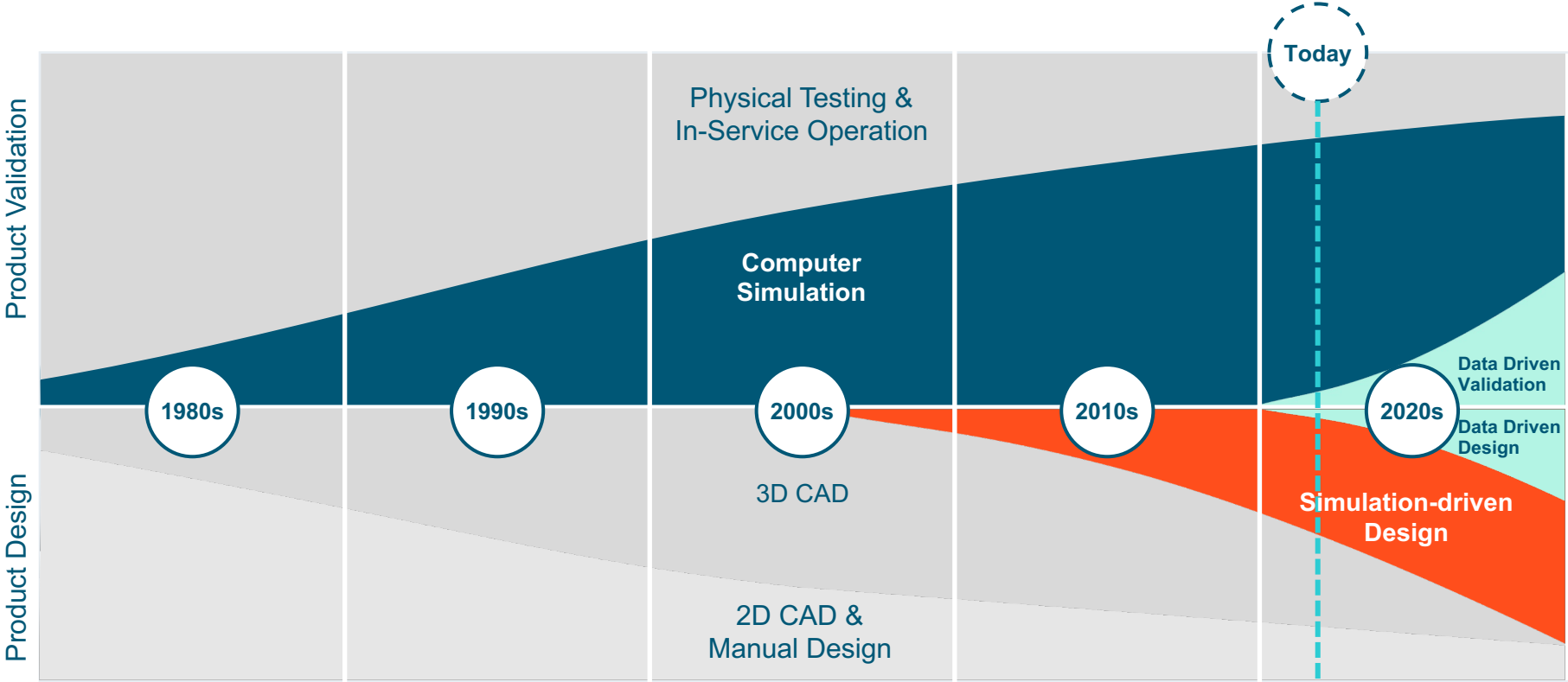
Electrically insulated, while retaining high thermal transfer properties, the coolant channel is designed to create turbulence to enhance heat transfer



# **danecca**

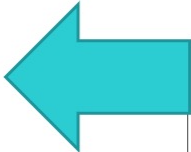
Hall 2, Stand B01

# The Digital Twin - Evolution of Simulation and Data



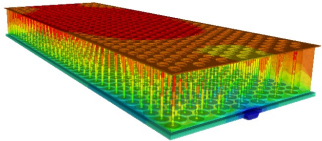
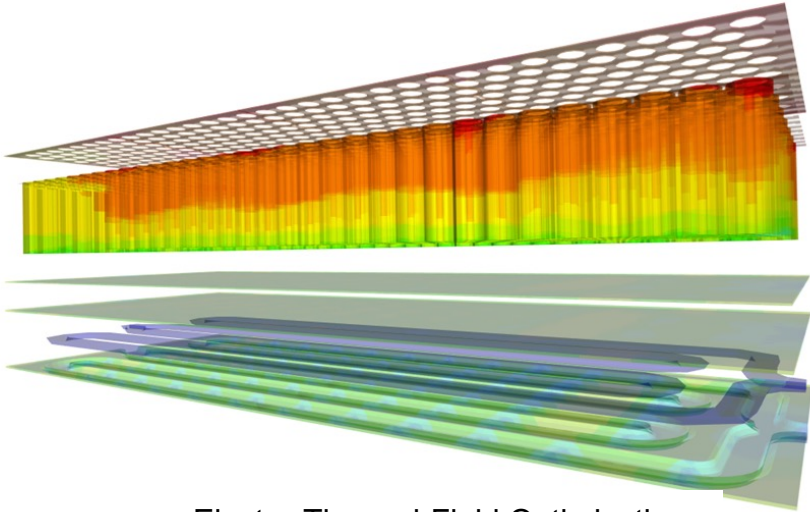
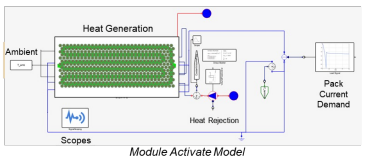
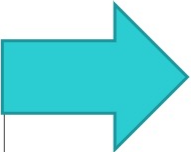
# BATTERY SIMULATION TECHNOLOGY

# Battery Simulation Capabilities



Increased speed  
Low fidelity OS model

Increased predictability  
Improved physics of OS model



System Modelling Tools  
Module / Pack Layout

Electro-Thermal-Fluid Optimization  
Design & Verification

CFD  
Verification



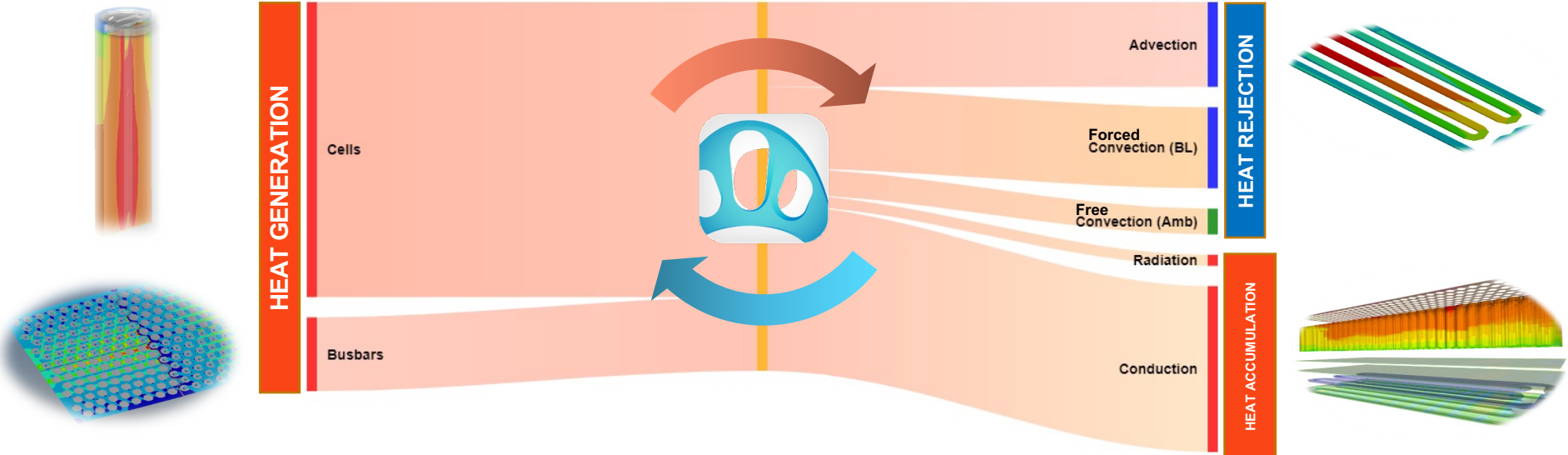
Altair OptiStruct®





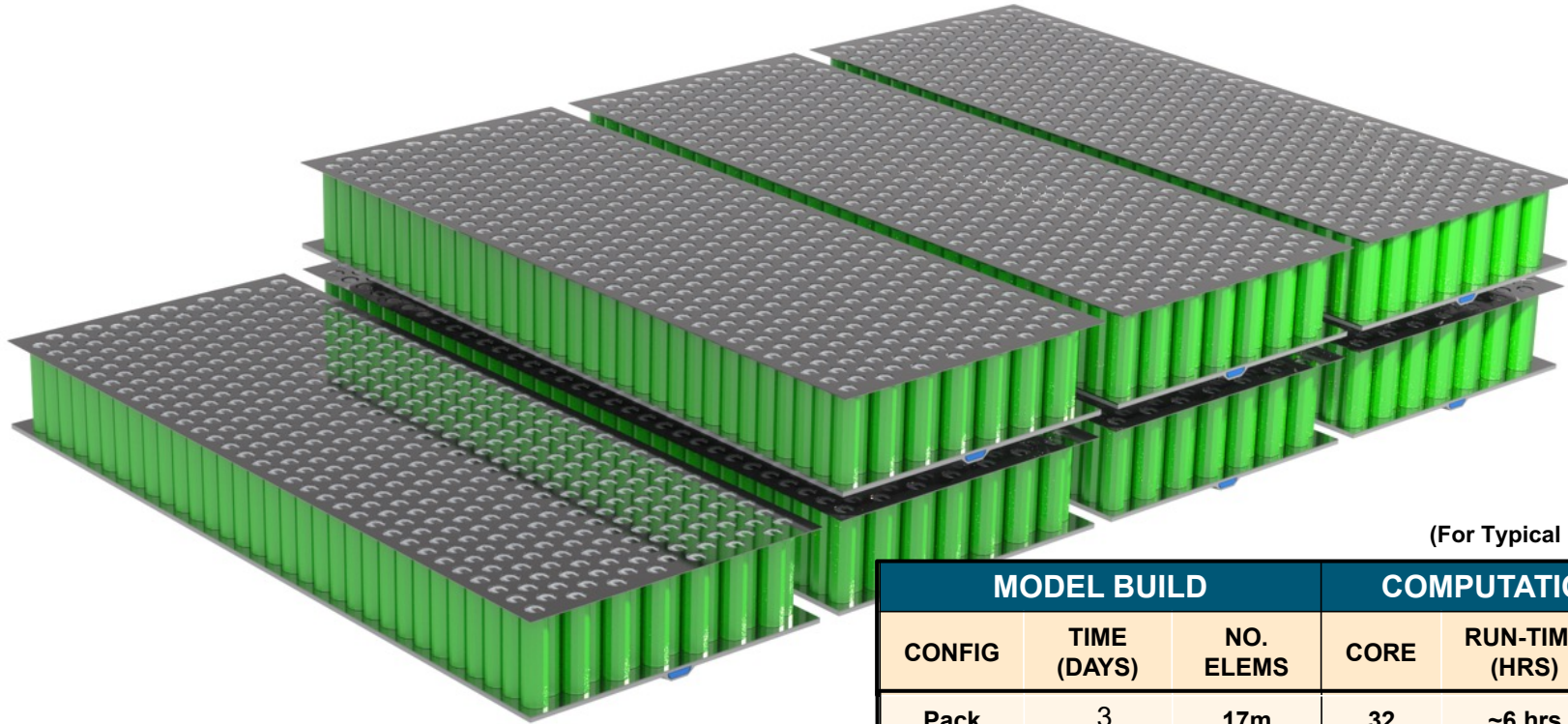
# Predictive : Multi-Physics Capture

## Electro-Thermal Analysis



# Productivity – Speed & Scale

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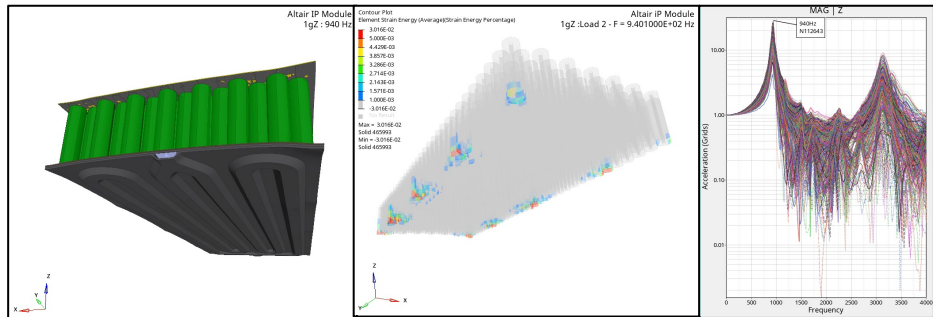
(For Typical Duty Cycle 600s)

MODEL BUILD			COMPUTATION COST		
CONFIG	TIME (DAYS)	NO. ELEMS	CORE	RUN-TIME (HRS)	MEMORY
Pack	3	17m	32	~6 hrs	~150Gb

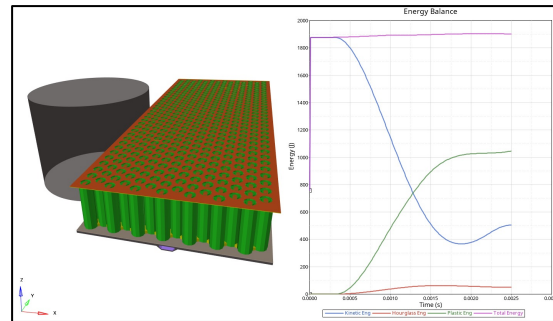
# Productivity- Single Finite Element Model

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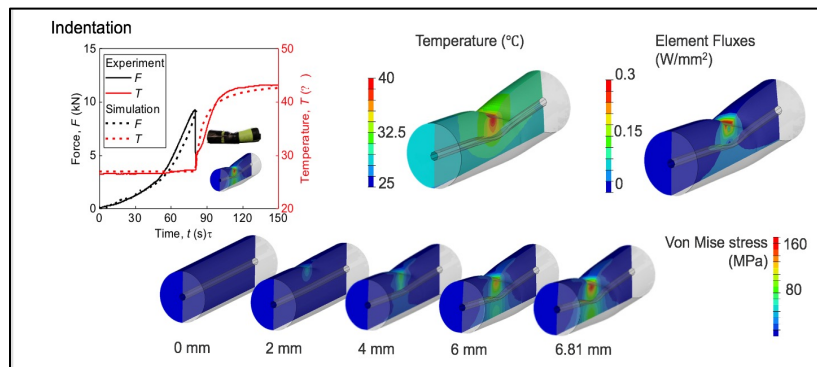
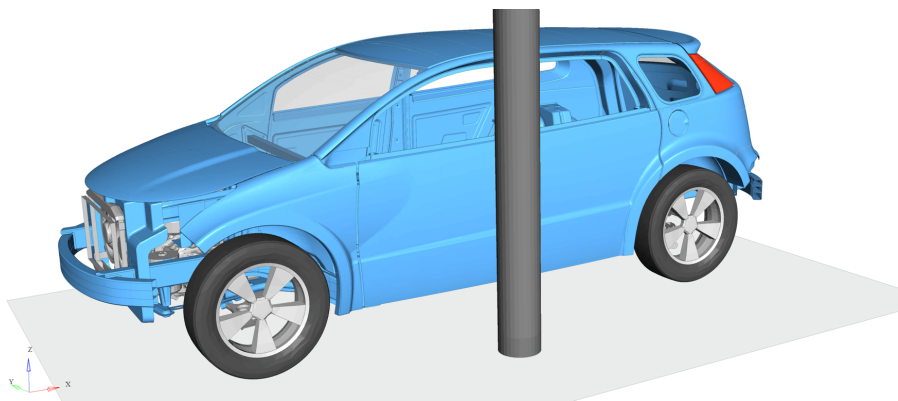
## Multi Attribute Evaluation



NVH, Durability



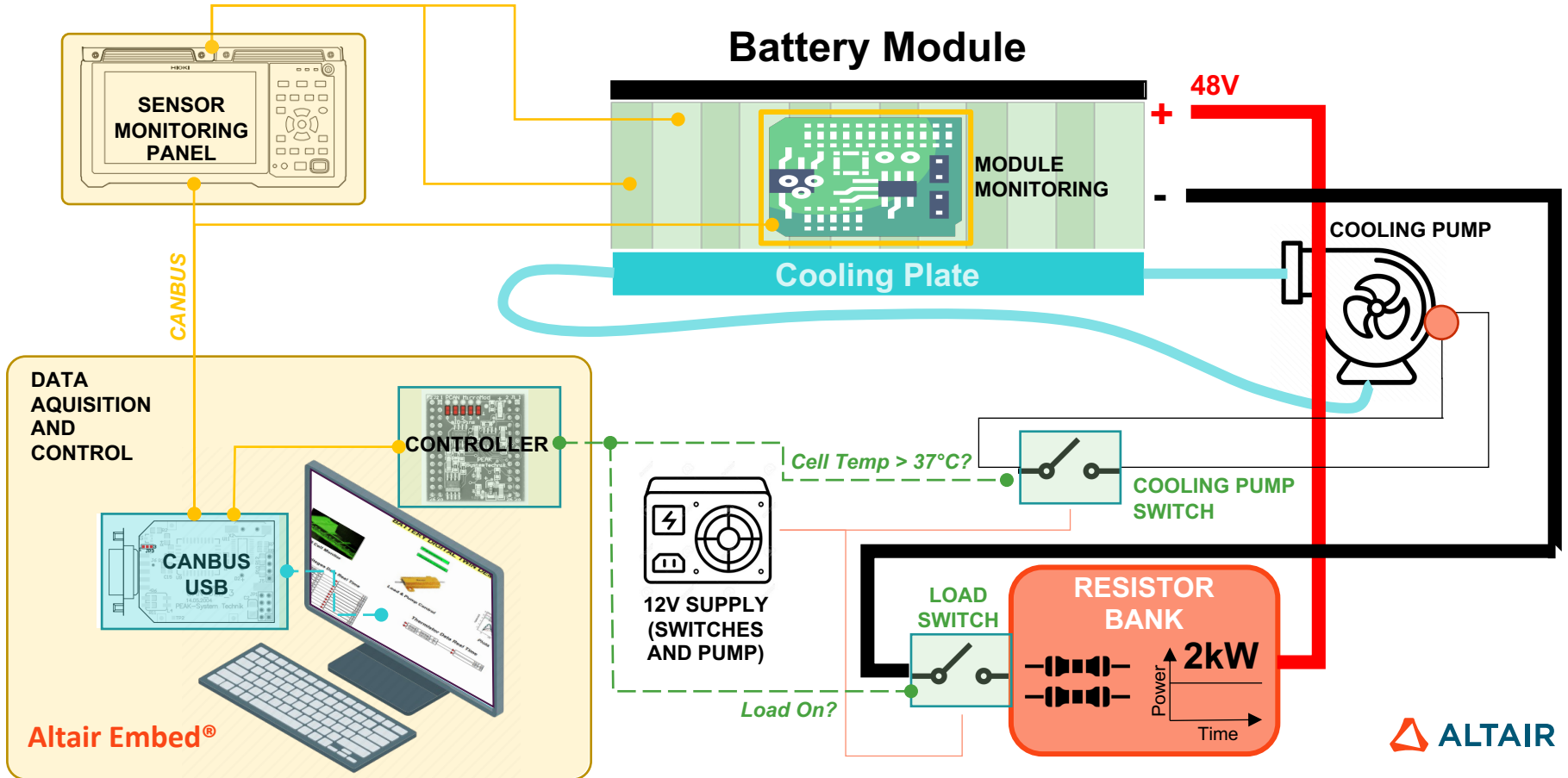
Impact



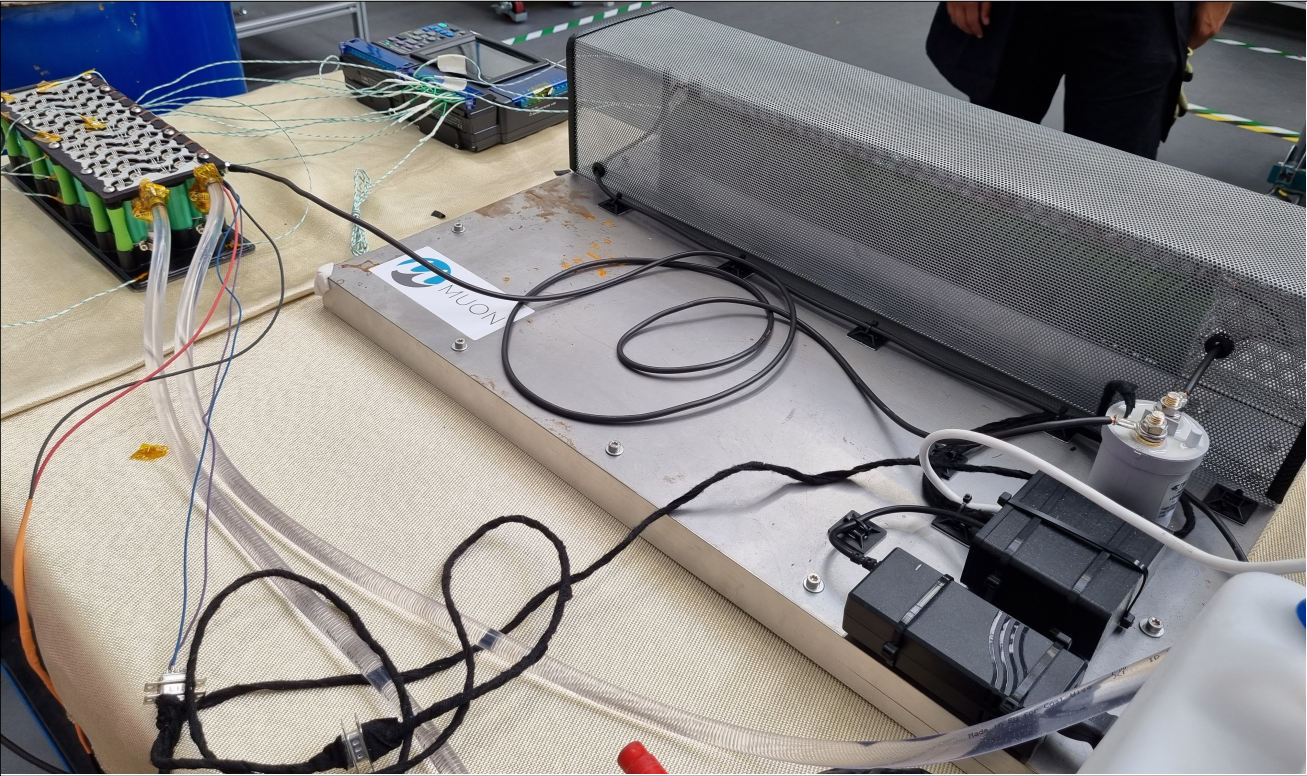
Thermal Runaway

# DIGITAL TWIN DEMONSTRATOR

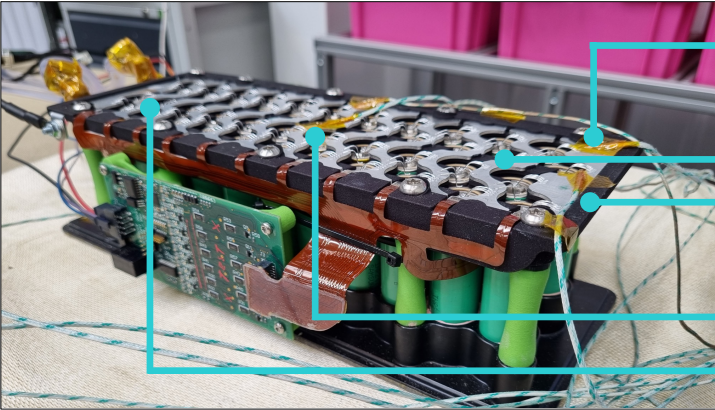
# Demonstrator System Schematic



# System



# Nervous System – Thermocouple Sensors (Sixteen Measurements)



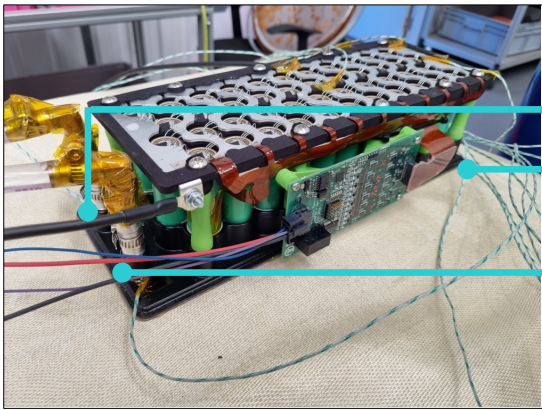
+ve Terminal

S10P3

BB1

BB6

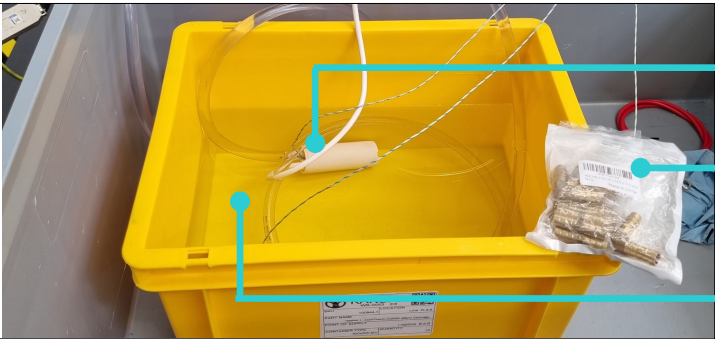
S2P2



Inlet Plate

Divider

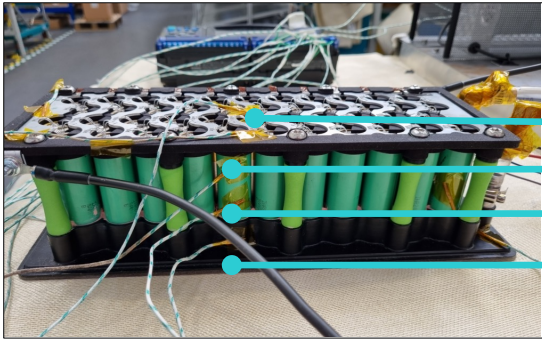
Outlet Plate



Inlet Pipe

Outlet Pipe

Coolant



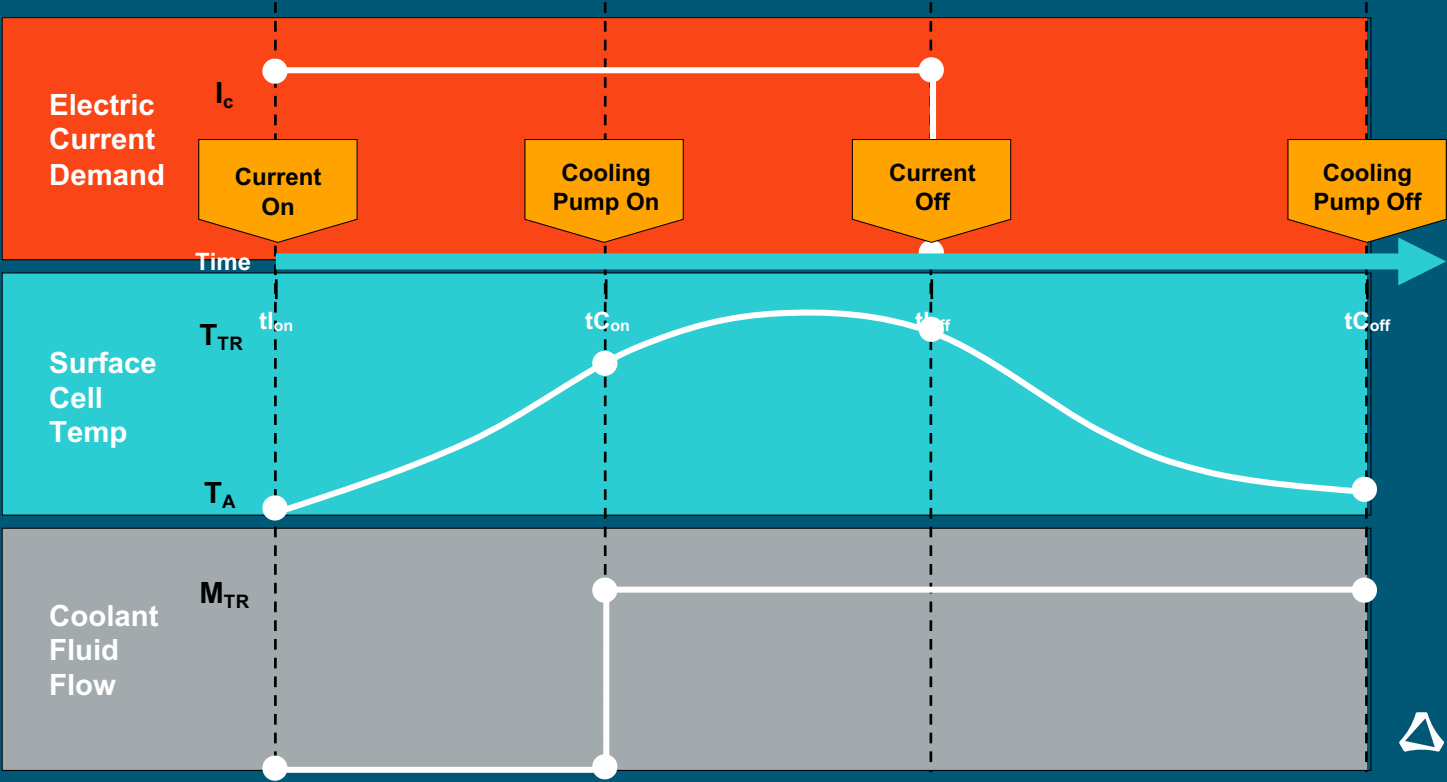
S7P4(1)

S7P4(2)

S7P4(3)

S7P4(4)

# The Brain - Event Modelling

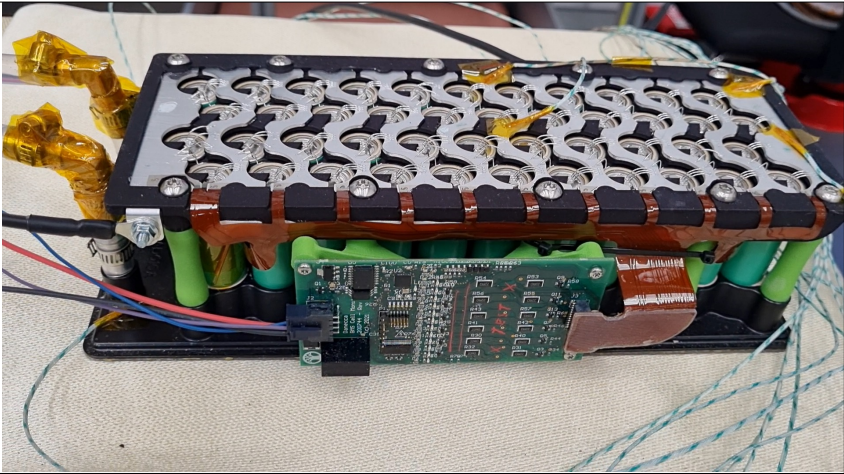




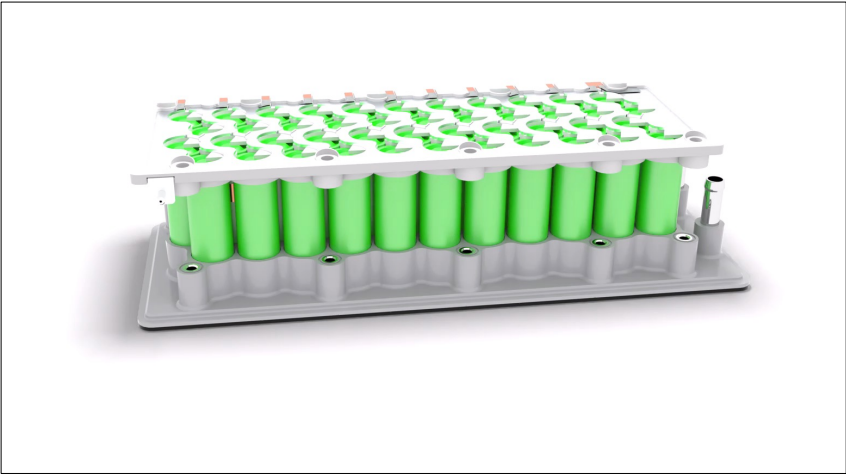
# INTRODUCING THE TWINS

## Battery Module

# Introducing the 'Digital Twins'



Physical Twin

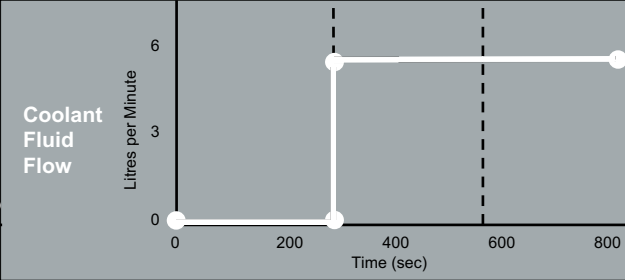
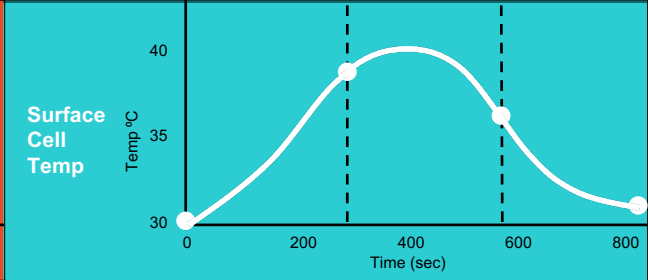
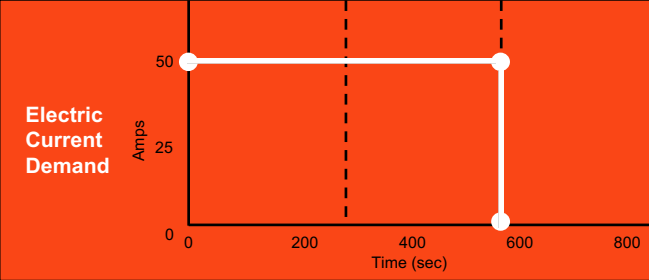
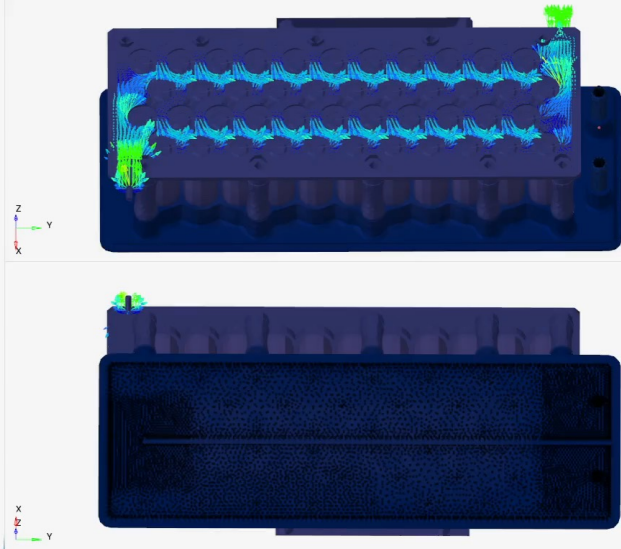
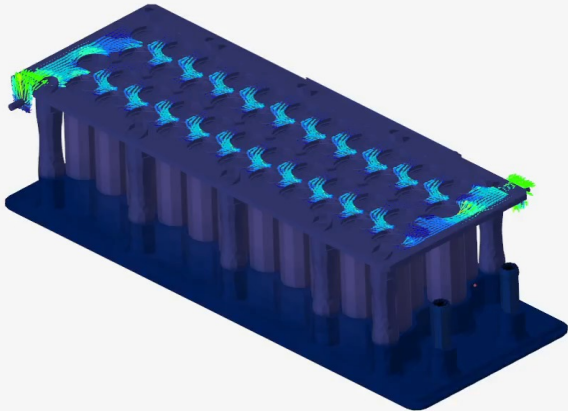


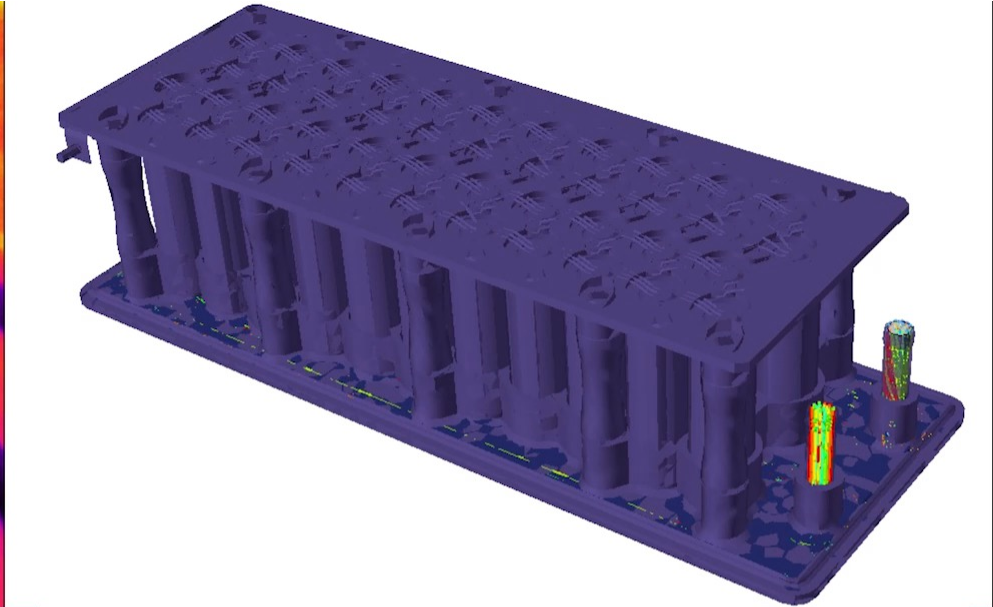
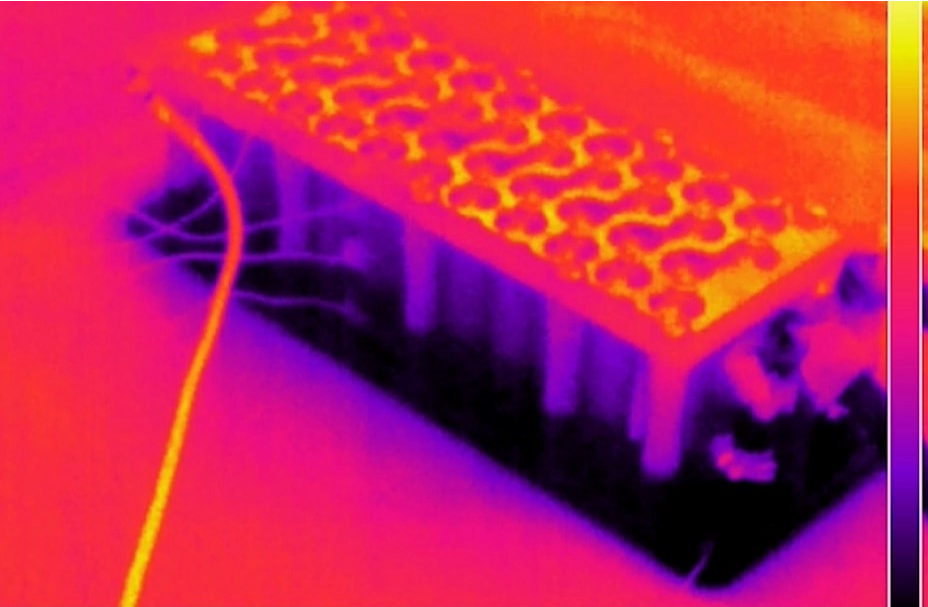
Digital Twin

# CORRELATION EXERCISE

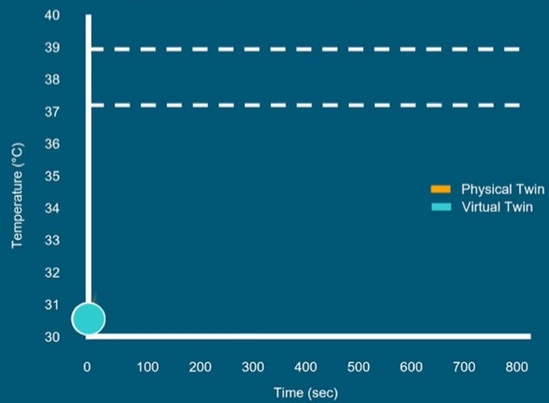
“The Twins Teach One Another”

# Digital Twin Multiphysics Results Display

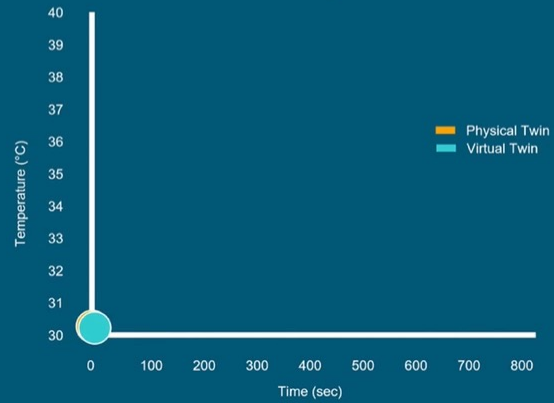




Battery Cell Surface Temperature S7P4(2)



Busbar Temperature BB1

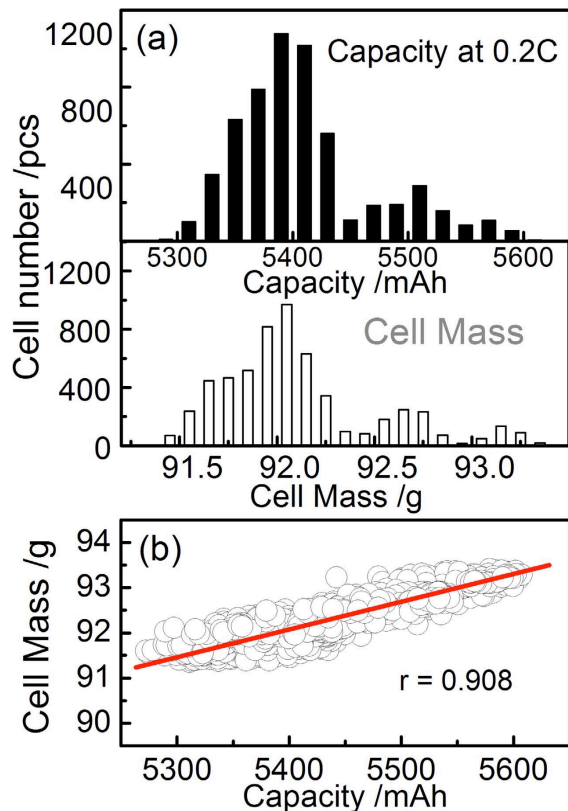


# DIGITAL TWIN

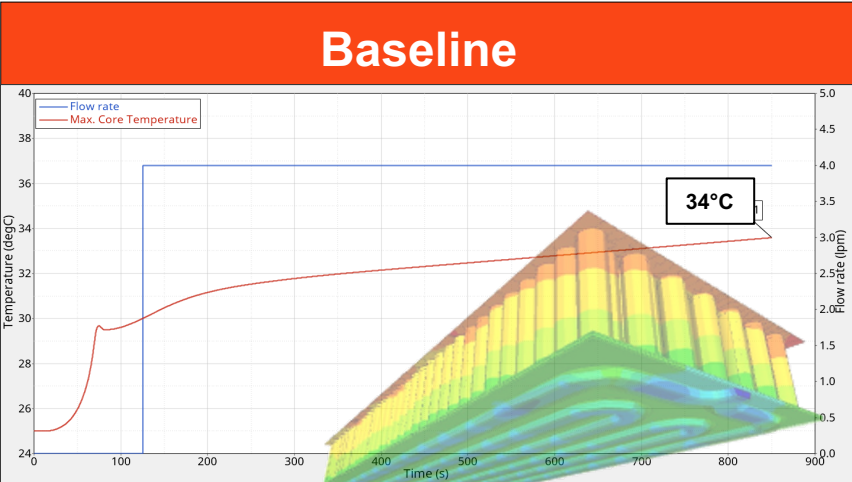
Unleash the Power with Optimization Technology

# Fast & Efficient Design Studies

- **‘What-if’**
  - Tool is flexible and efficient
    - Component Thickness (e.g. Cooling Plate, Thermal Mats etc.)
    - Busbar Sizing – Busbar Joule Heating
    - Cooling Channel Profiles, Flow Rates, Chiller Temps, Pump Size
    - Cell Wiring Configurations – Current Imbalance
- **Optimization**
  - Understanding system sensitivity and optimization
    - Objective : Minimise Mass
    - Constraints :  $\leq$  Battery Temp of Individual Cell or Cell Variation within a Group
    - Variables : Component Thickness, Cooling Profiles / Parameters
- **Robustness – Big Data**
  - Cell Variation (Mass, Geometry, internal resistance), Localised Busbar Connections



# Typical OptiStruct Range Optimization Study



Cooling Pump Switched on at 30°C  
Maximum Cell Temperature 34°C  
Cooling Pump Duration 85% of the cycle



Minimise Cooling Pump Duration  
Switch Cooling Pump On/Off (Cell  $\Delta T$  Gradient)  
Maximum Allowable Cell Temperature 37°C

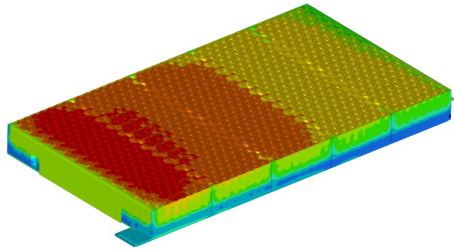
**60%** Reduction in Cooling Duration Time | **8** Pump On/Off Cycles Determined | **5 Miles** Range increase



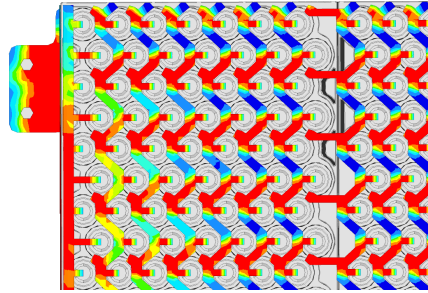
# Typical Battery Pack Attribute Evaluation

## THERMO-ELECTRICAL

Grid Temperature

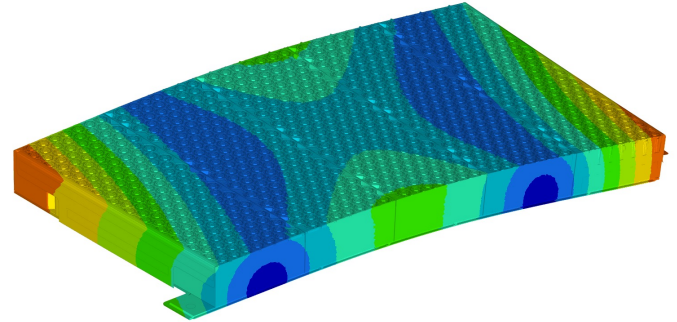


Current Density 2D



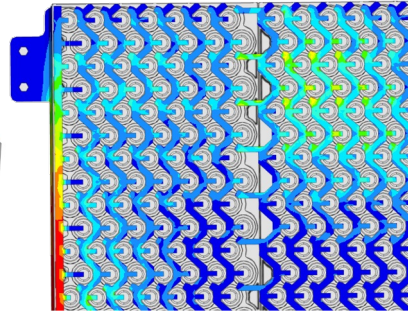
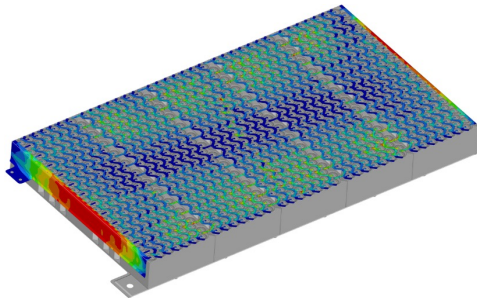
## NORMAL MODES

Eigen Modes



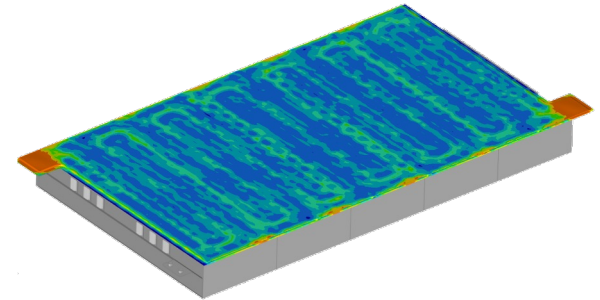
## PSD

RMS Element Stresses (Segalman Von Mises Stress)

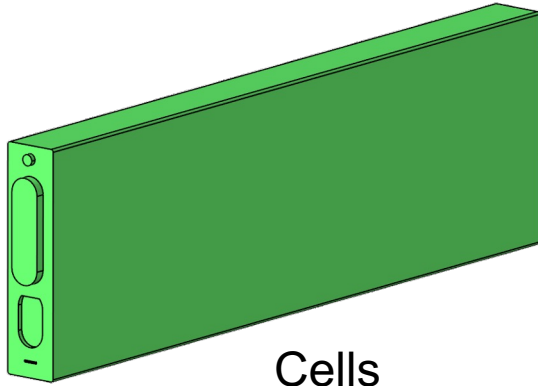


## STRUCTURAL – Fluid Pressure

Element Stresses

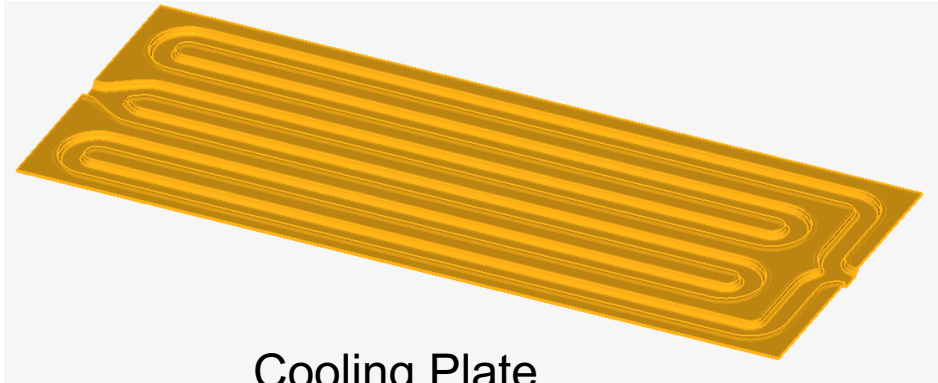


# Typical Design Variables



Cells

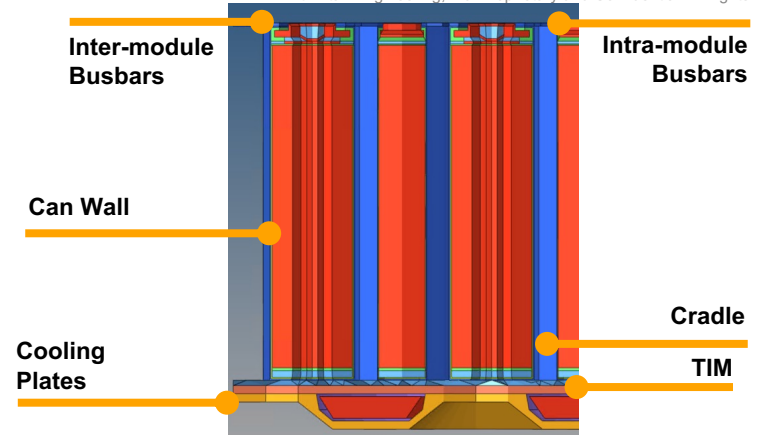
(Height, Casing Thickness, Internal Void, Orientation etc.)



Cooling Plate

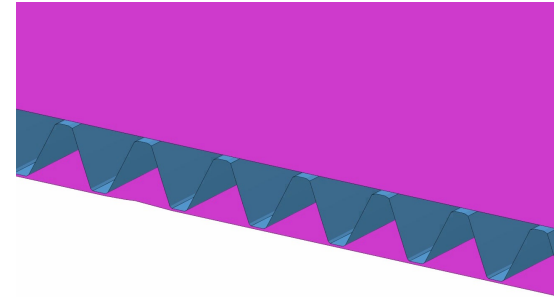
Structural Gauges

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Module

Multiple Component Gauges

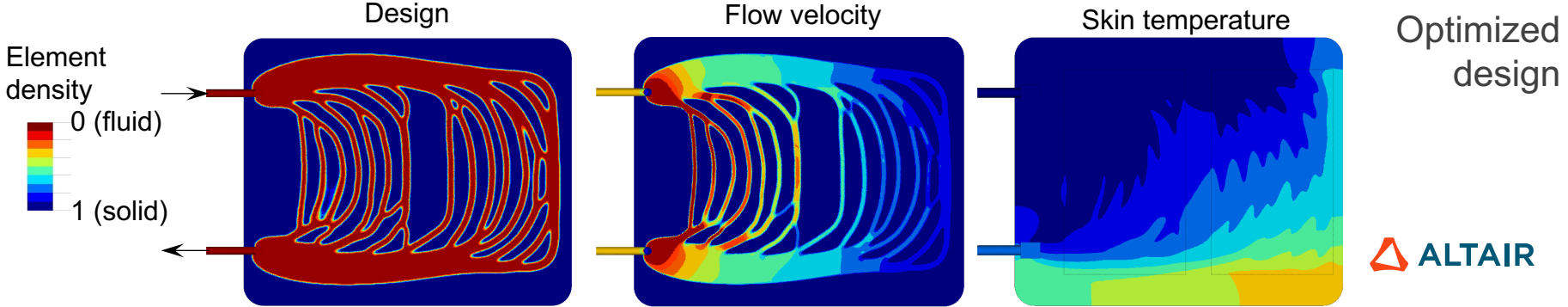
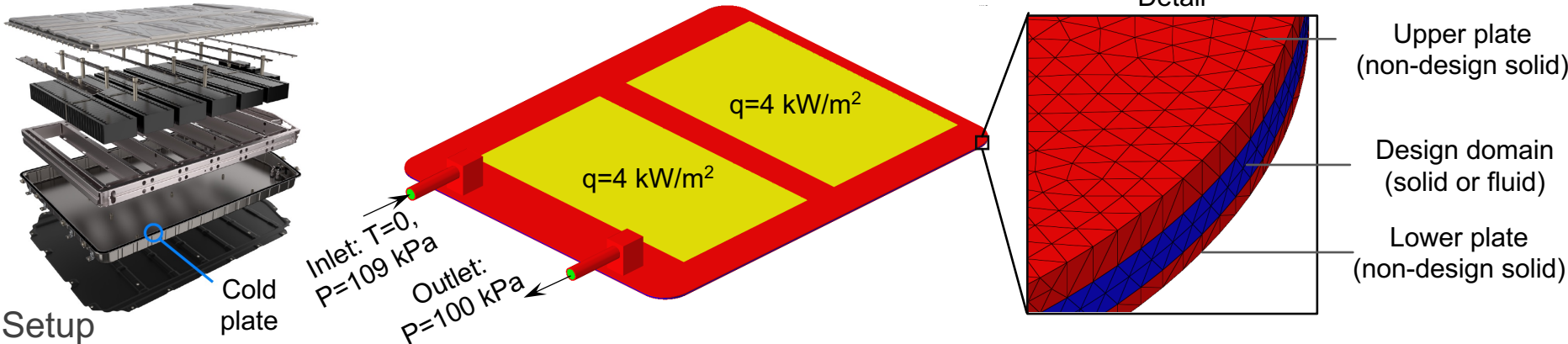


Cooling Plate Layout

Height Variation (e.g.  $\pm 15\%$ ), Profile

# Battery Pack Cooling: Cold Plate Topology Optimization

Cooling channel design by topology optimization to improve combination of conduction and forced convection based on design dependent flow.



# Project Gamma

- Faraday Battery Challenge UKRI funded project
- The project focuses on developing an integrated structural battery pack and wireless communicating battery cells to allow increased efficiency, reliability, and sustainability of automotive batteries.
- It aims to support the growth of UK manufacturers of automotive battery components and products.
- Consortia members:
  - Altair Engineering Limited
  - Jaguar Land Rover Limited
  - Danecca Ltd

[ukri.org/news/delivering-the-future-of-battery-technology/](https://ukri.org/news/delivering-the-future-of-battery-technology/)



# SUMMARY

# Summary

- Agile Development – Physical & Virtual – ‘Pack Development in a Month’ Partner
  
- Rapid Simulation Tool
  - Verification – Complex Multi-Physics, Control logic Integration
  - Design – Productivity (Multi-Attribute Model Evaluation, Speed), Intelligence
  - Optimization – Control logic, multi-physics, multi-attribute
  
- Emergence of 3D Digital Twins to Impact Design



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