



Designing a Battery System for the VX4

MATLAB EXPO 2024




VERTICAL

Pioneering Electric Aviation

EVTL
LISTED
NYSE





VX 4 Specs

Up to **100**
Miles of Range

0
Emissions in
Operations

10^{-9} ³
1 in a Billion
Catastrophic Failure Rate

1,500¹
Aircraft already
pre-ordered

\$6.0B²
Value of
Pre-order Book

c. 50%⁴
Required Capital
vs Peers

1. Conditional pre-orders
2. Estimated value of the pre-order book
3. EASA MOC SC-VTOL Enhanced Category [\[link\]](#)
4. Based on company estimations





Headquartered in Bristol, UK with over 300 employees



Headquartered in the UK with global suppliers



c.300 engineers in the UK in our design, engineering and testing facilities

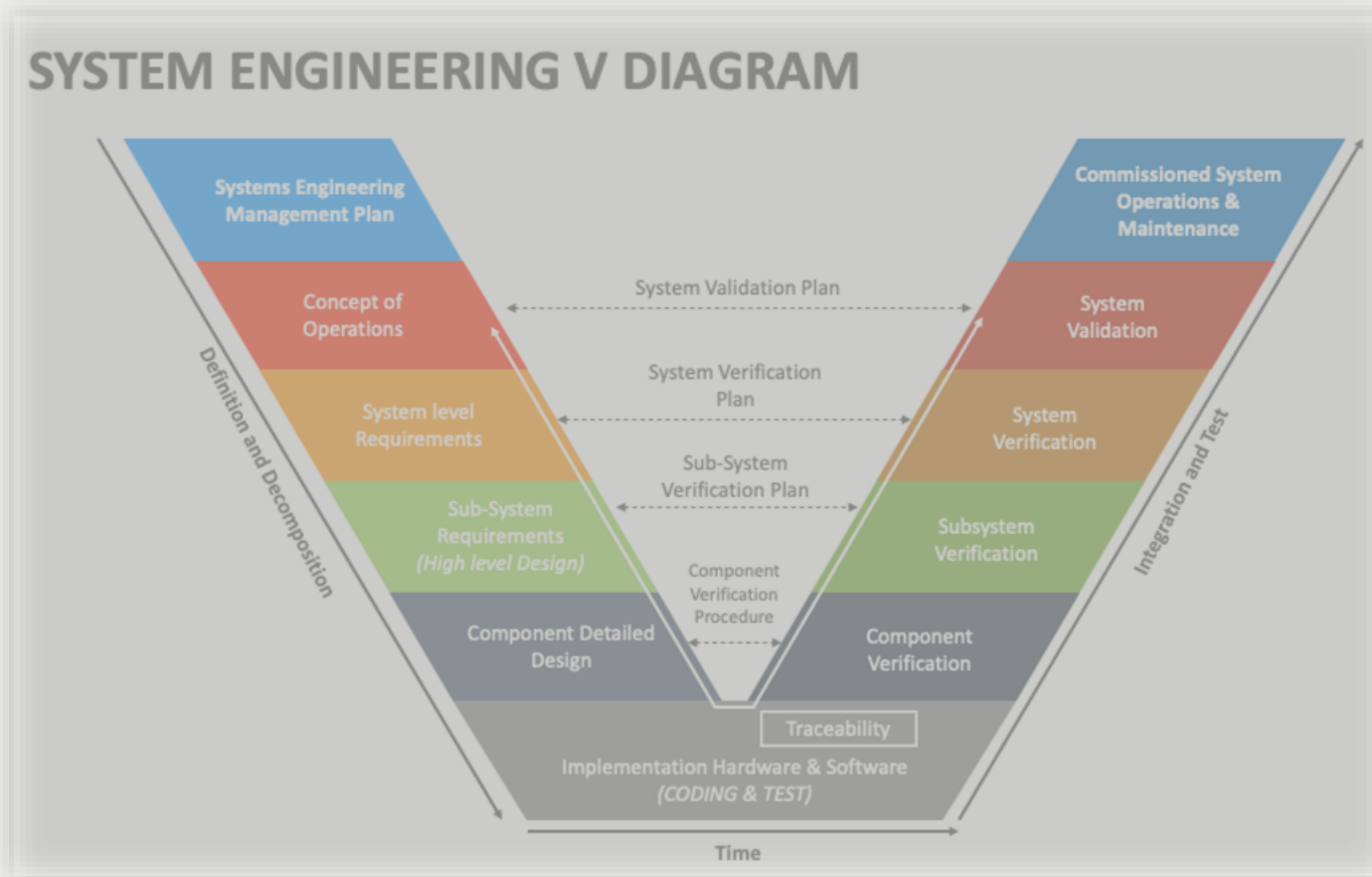


Presenters



Felix Diaz-Maroto Rivas

IPT Lead – Powertrain Modelling and
Simulation

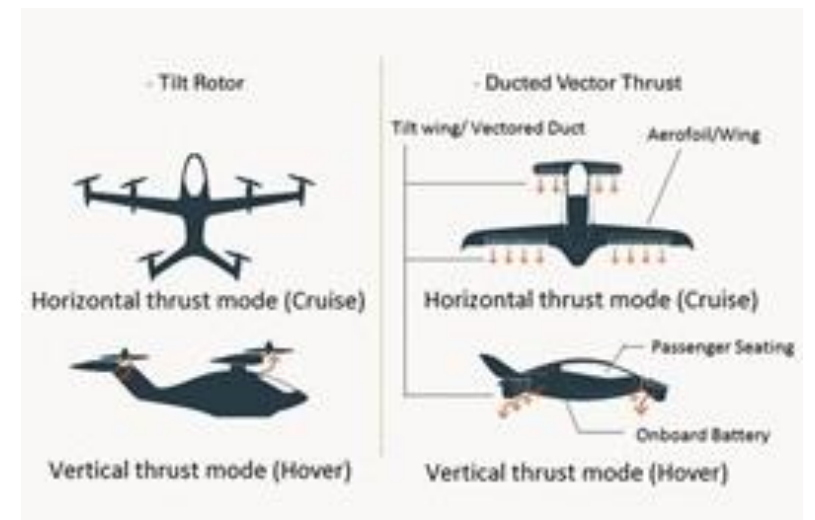
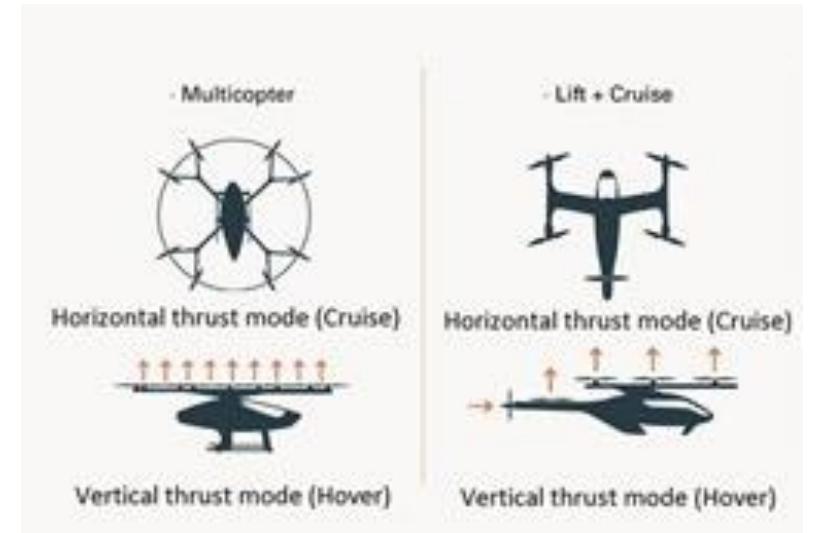
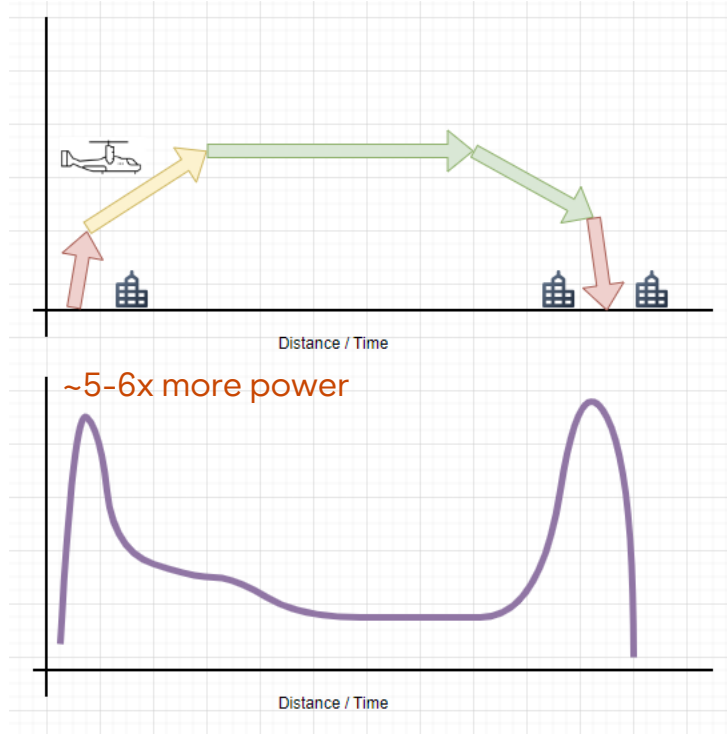


- Introduction
- **Application Background**
- Creating the Models
- Scaling to Battery
- Questions



A Little More About eVTOL

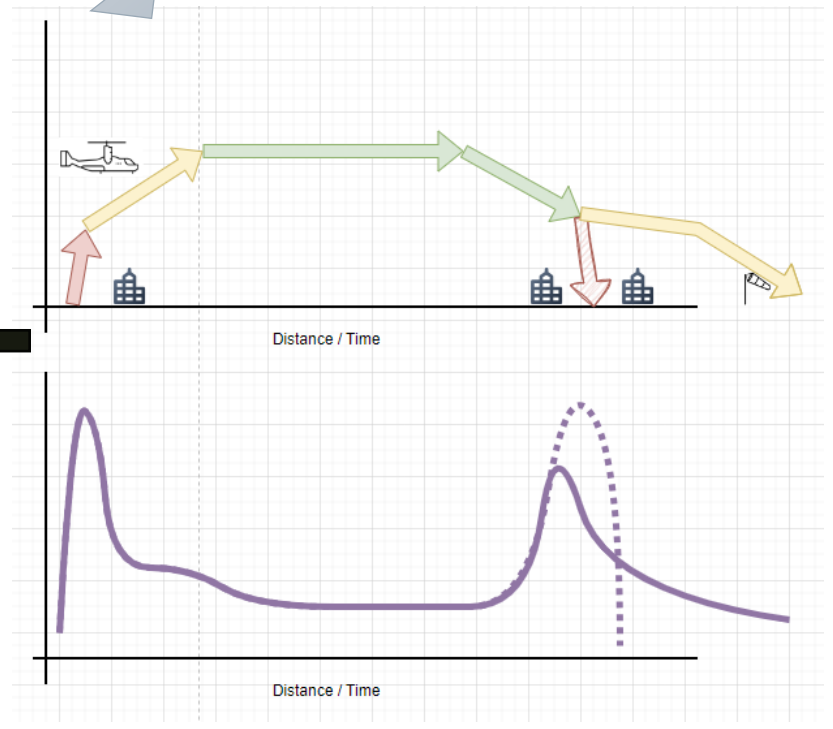
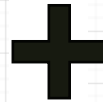
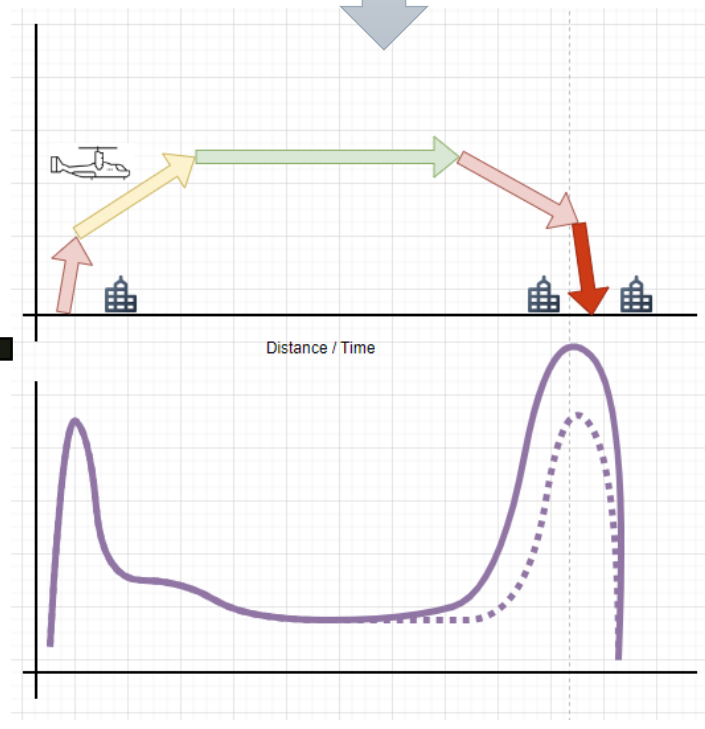
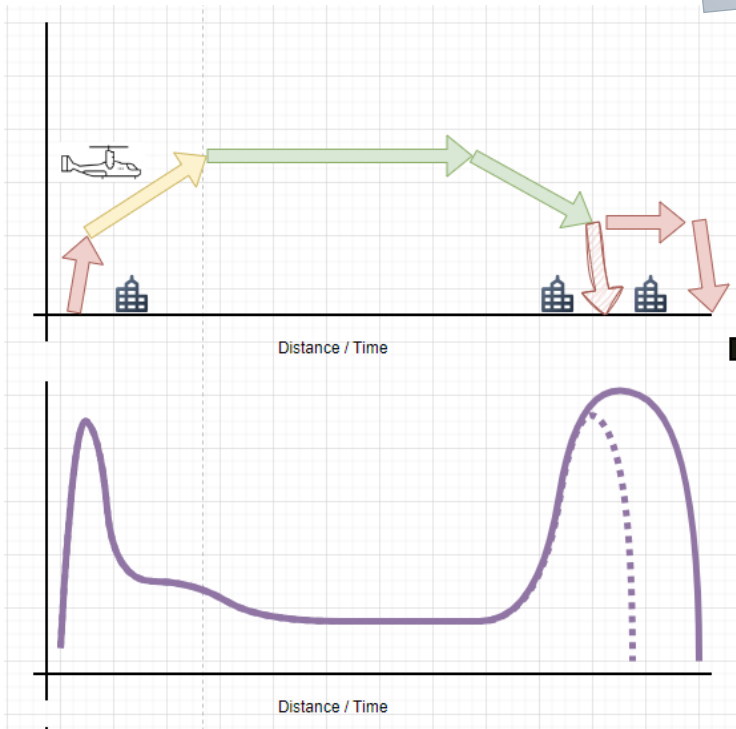
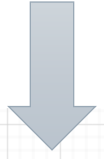
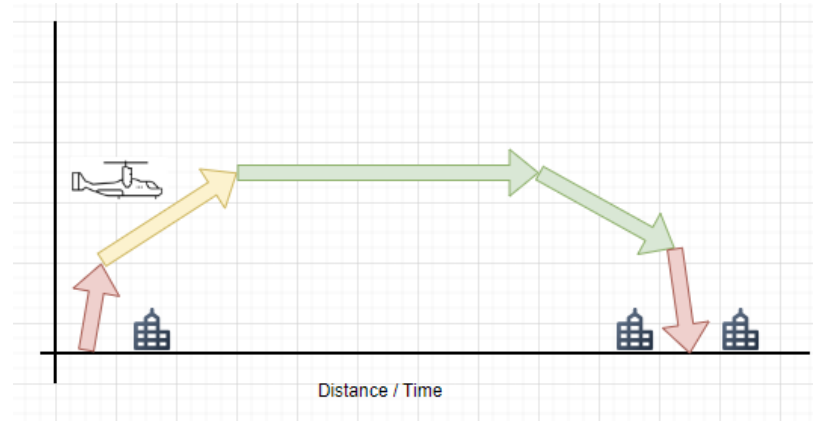
- Hovering is energetically expensive
- Batteries have poor energy capacity vs Fuel
- Transitioning into Wingborne behaviour is key!





Contingencies on Contingencies

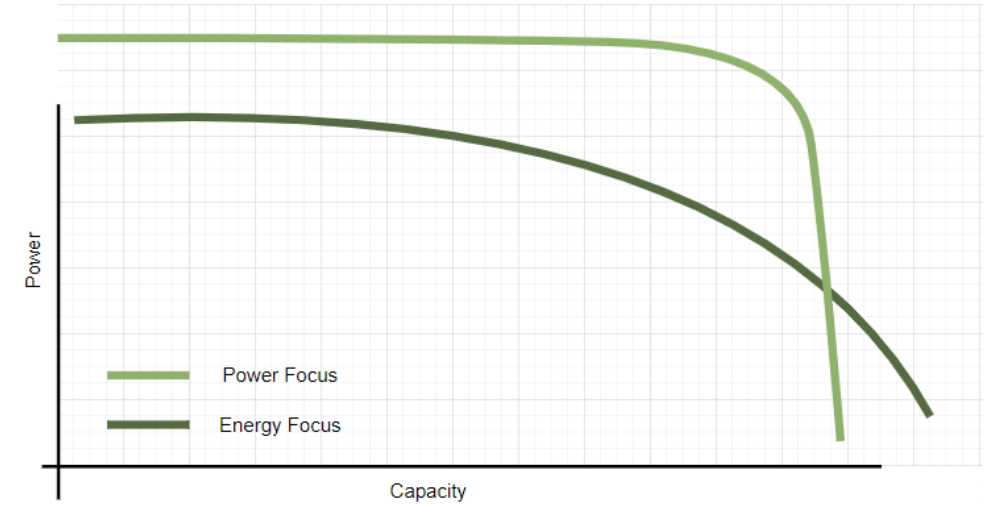
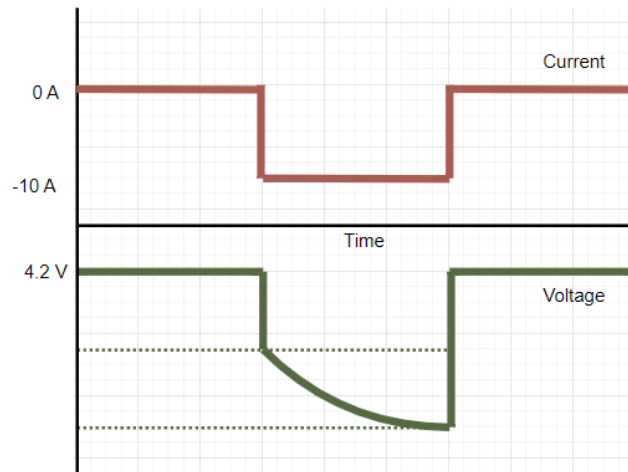
- We can't park anywhere we want
- Countless fault scenarios to analyse





Battery and Lithium Ion Behaviour

- Energy density and Power density are a trade off
- Batteries performance varies with:
 - SoC
 - Frequency



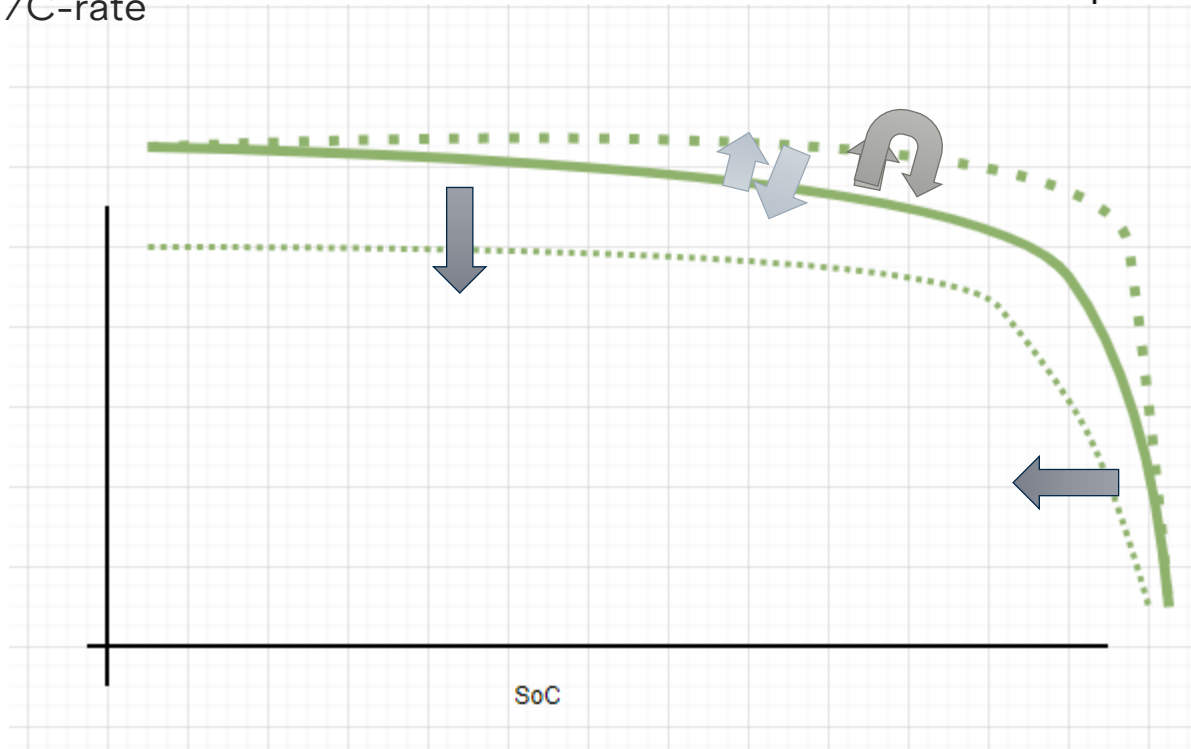
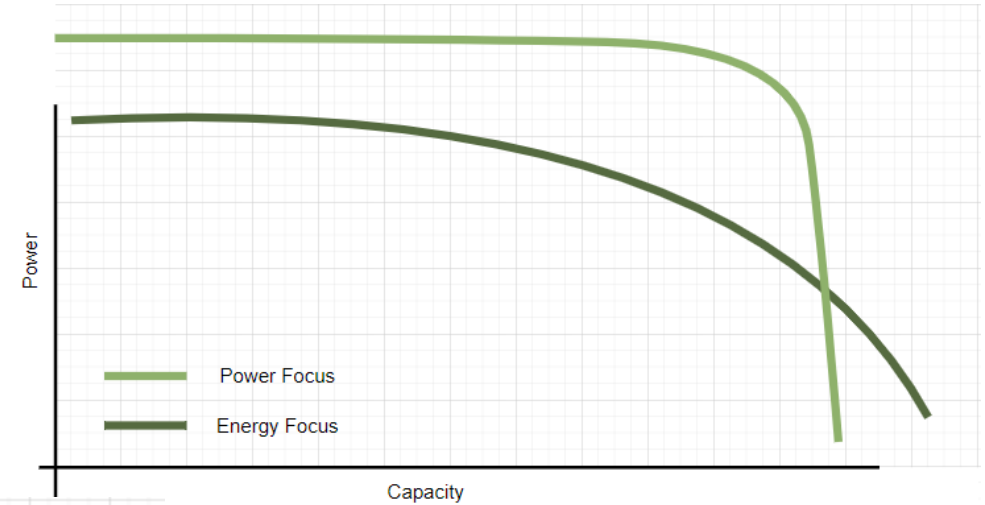
Definitions:

- SoC - State of Charge
 - How much charge/energy is left inside the cell
- C-Rate
 - Measure of current in relation to the cell capacity. 1-C means a current which discharges the cell in one hour. 2-C means it will discharge in half an hour



Battery and Lithium Ion Behaviour

- Energy density and Power density are a trade off
- Batteries performance varies with:
 - SoC
 - Frequency
 - Temperature
 - Current /C-rate
 - Aging



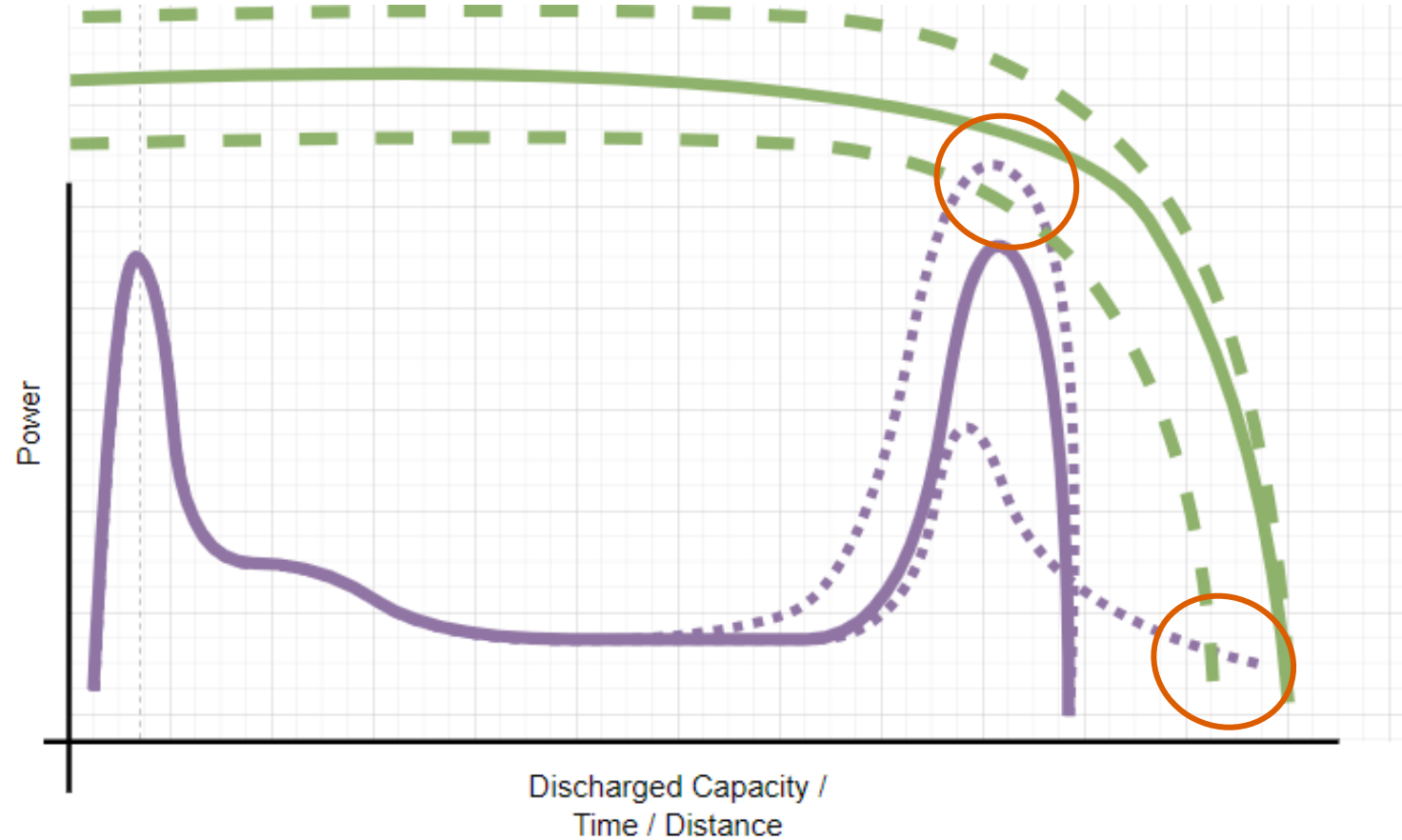
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Battery and Lithium Ion Behaviour

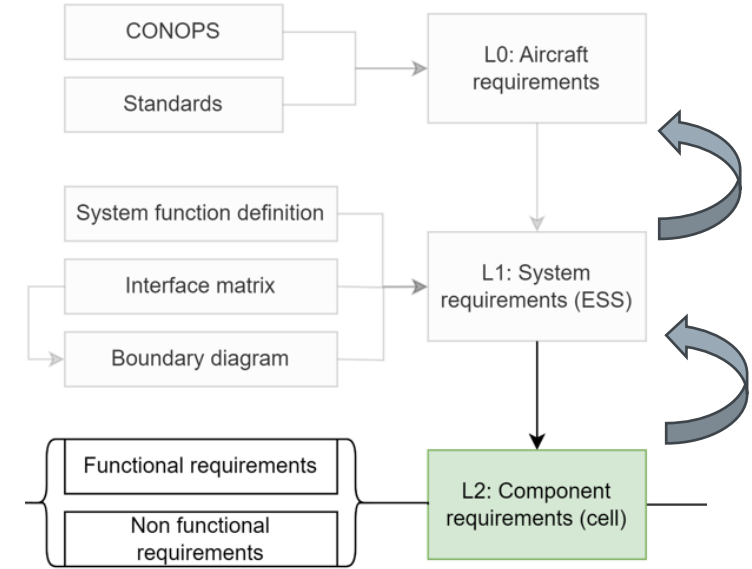
- Power Capability vs Power Demand
- Sensitive to battery conditions
- Critical areas are at the end of profile
- Simulation for Forecasting / Modelling

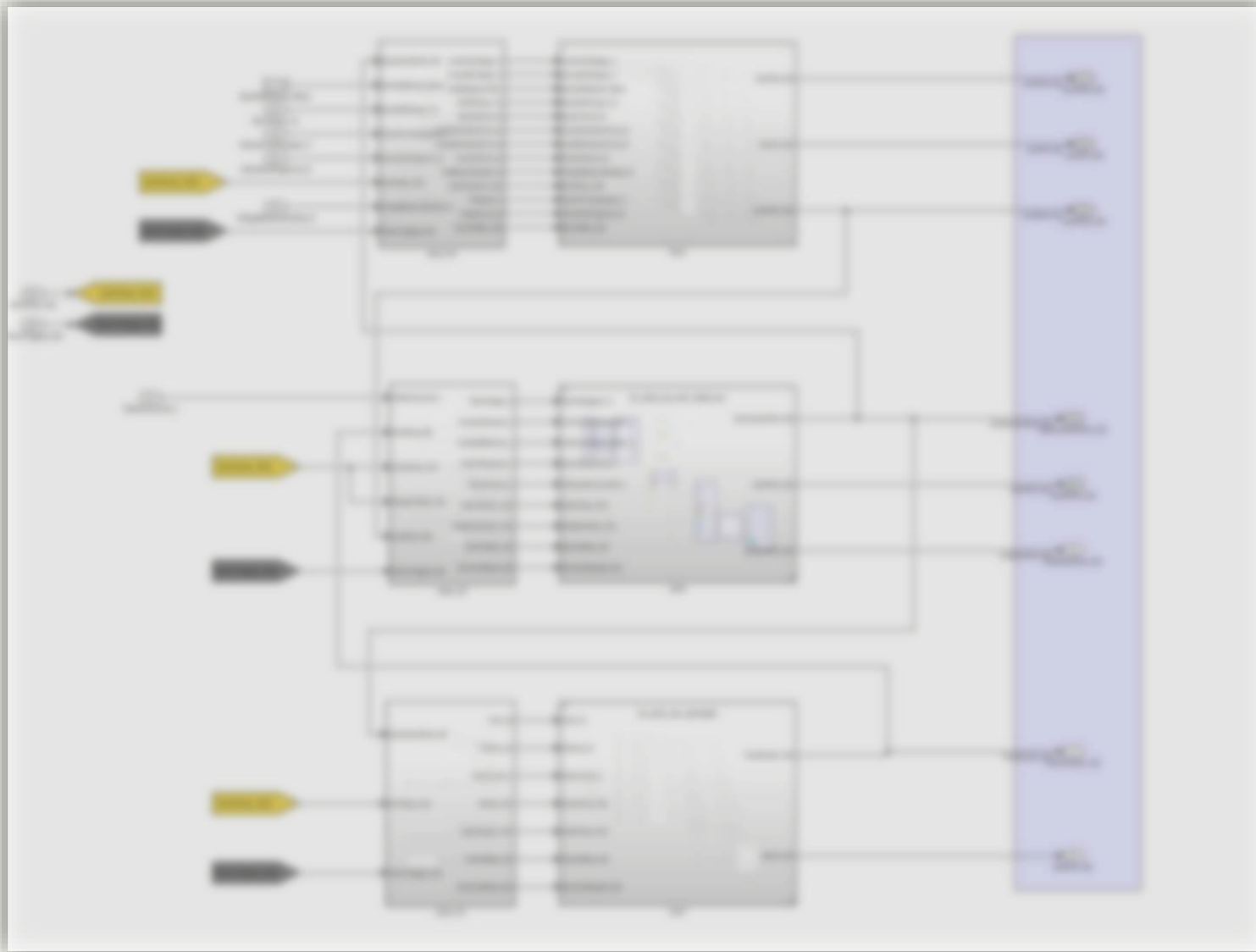




Applying Performance Modelling in the Design Process

- Internal:
 - Requirements
 - Component level testing
 - Battery Algorithms and Pilot HMI
- External:
 - Flight control laws
 - Need to understand battery performance
 - Vehicle level simulation
 - Realistic behaviours



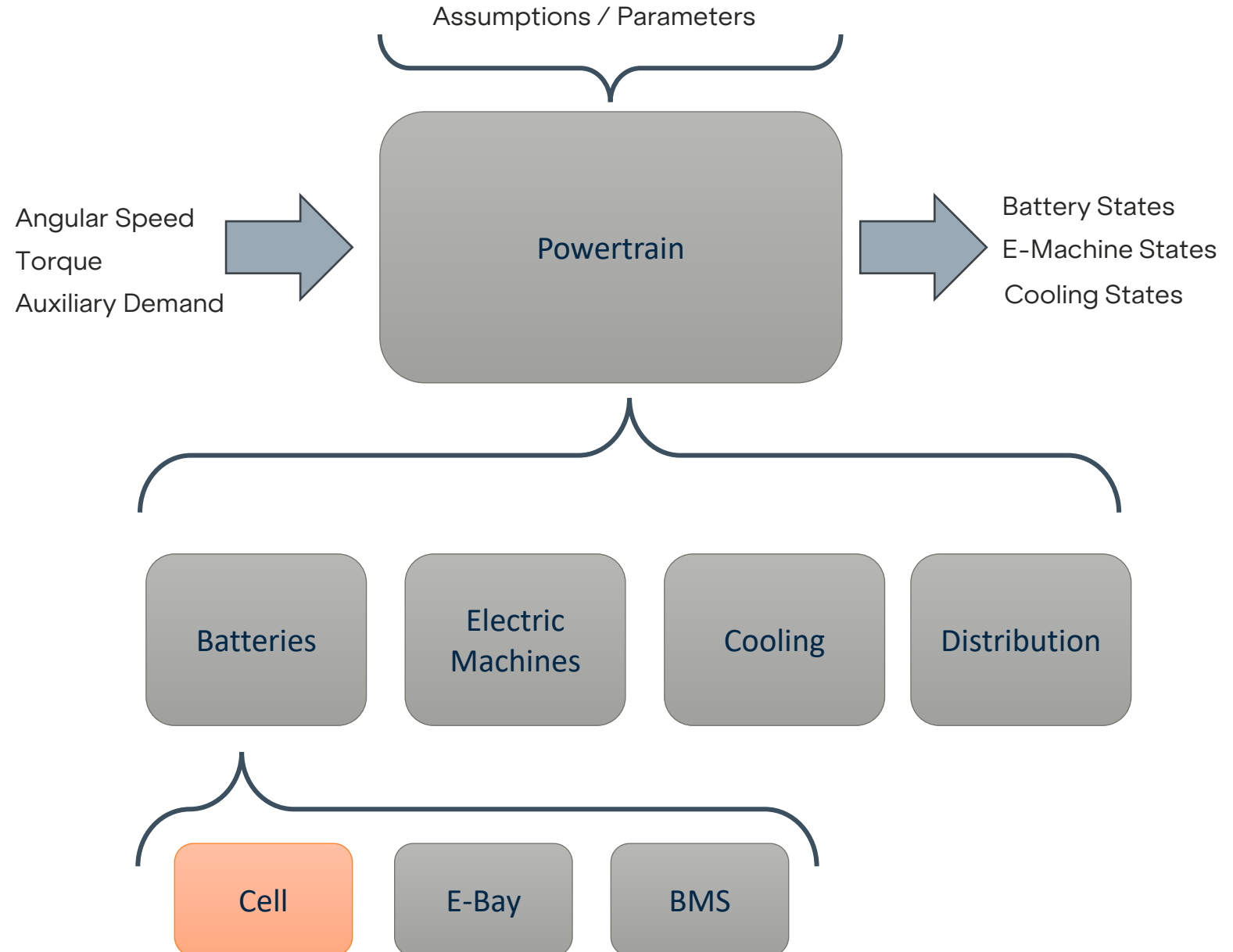
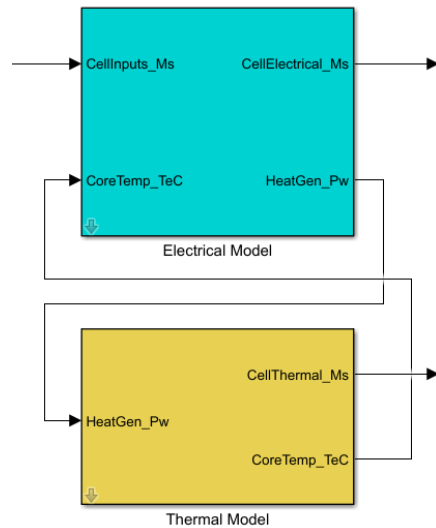


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Tackling the Modelling

- Models are Electro-Thermal
- Cell model is the keystone





Modelling – Make vs Buy

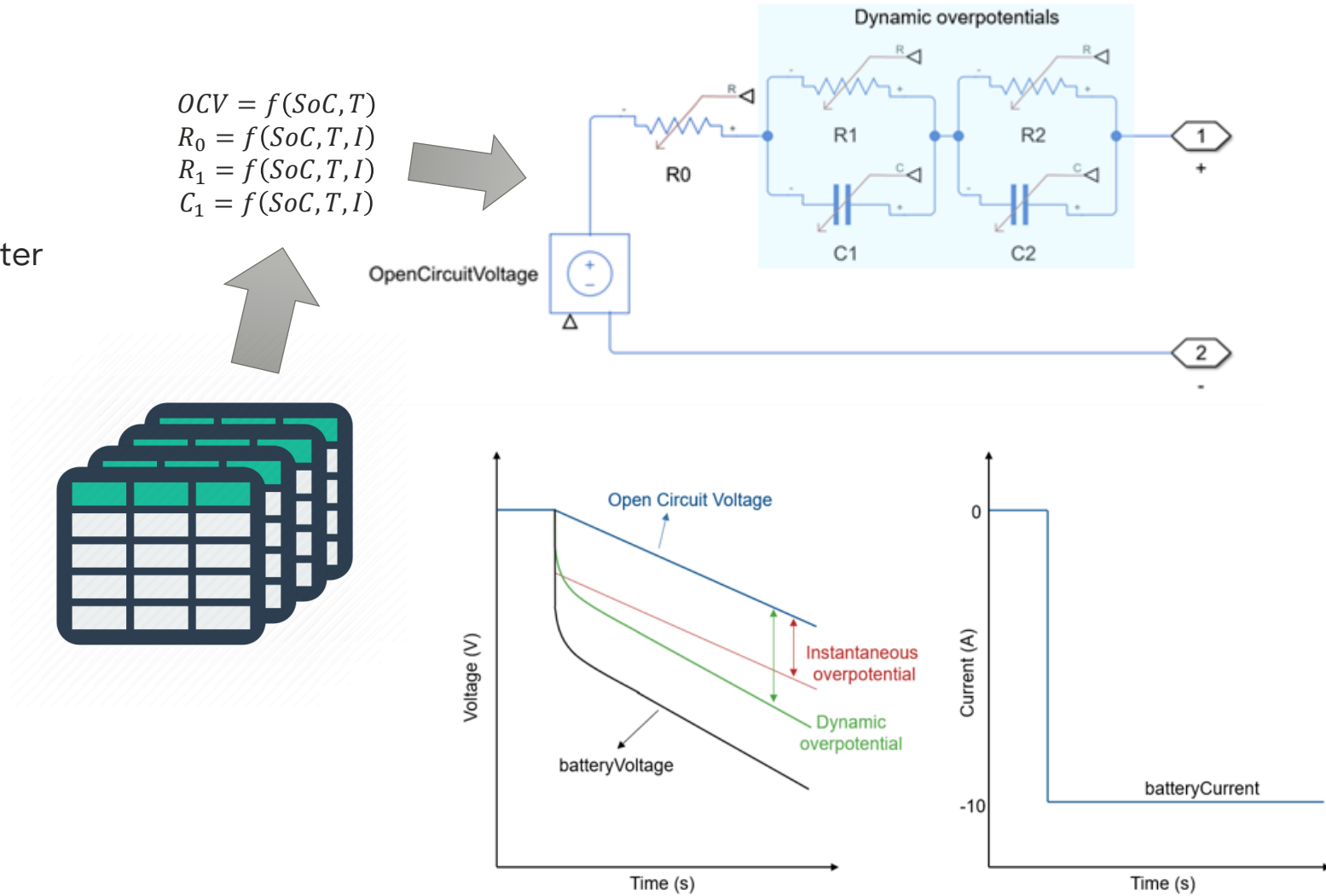
- Making and parameterising a cell model is not trivial!
- Do commercially available models cover the needs?
 - Parametrisation space
 - SoC range
 - Temperature
 - Currents
 - Transparency / Control
 - How the model works?
 - How it was parameterised?
 - Possible to Improve Correlation?
 - Lifetime + other features





Modelling – Modelling Method

- Equivalent Circuit Models
 - Simple
 - Flexible with parameterisation
 - Requires test data to cover all parameter space



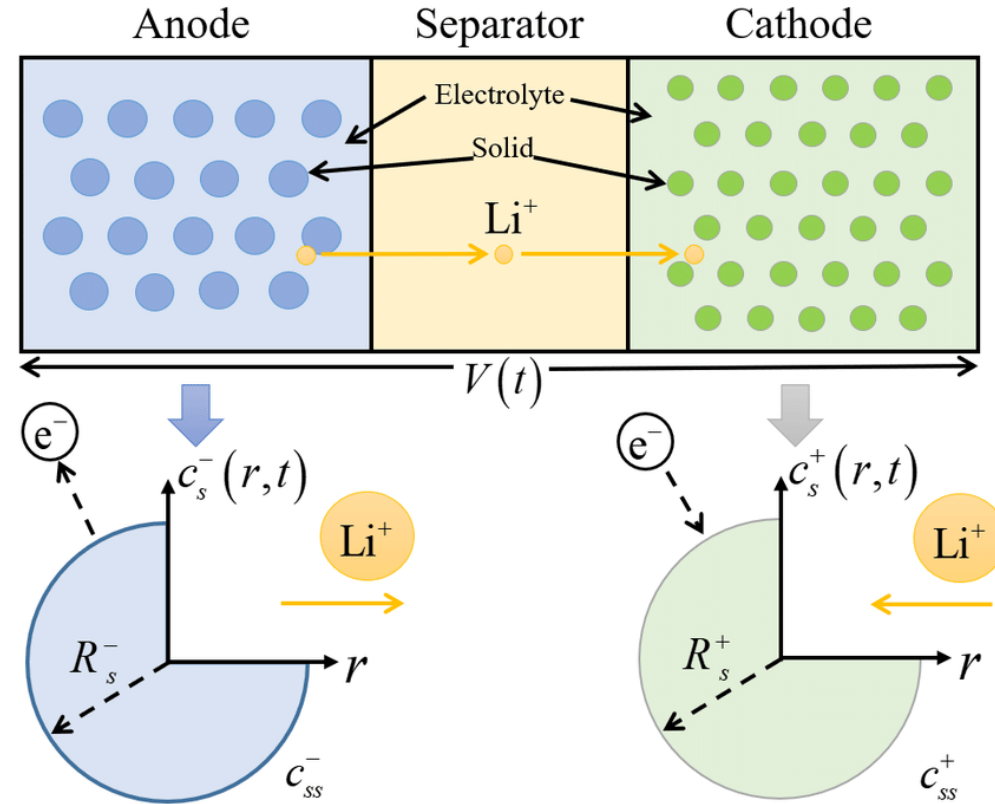


Modelling – Modelling Method

- Equivalent Circuit Models
 - Simple
 - Flexible with parameterisation
 - Requires test data to cover all parameter space

- Physical models – Electrochemical
 - E.g Newman’s Pseudo-2D, Single Particle Model
 - Insight into internal mechanisms
 - Requires detailed knowledge of material and construction

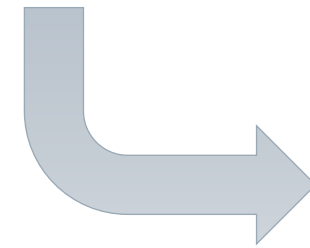
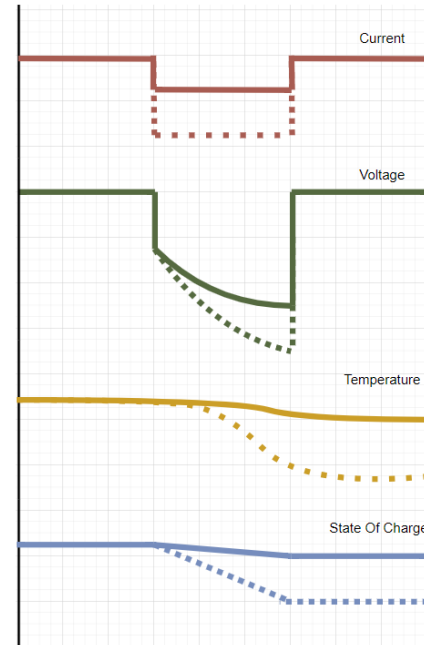
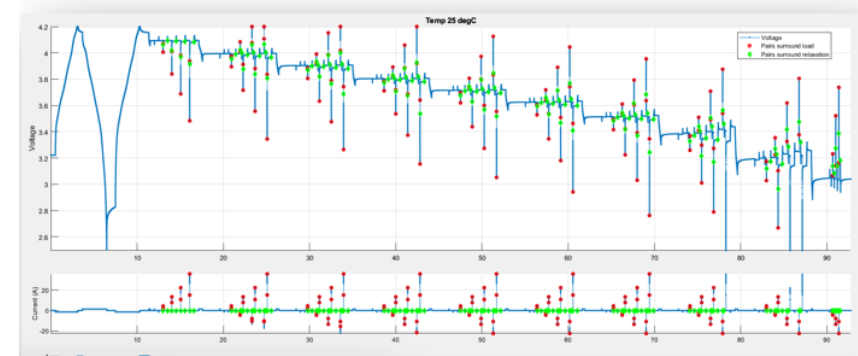
- Equivalent Circuit Models are good for our application for now





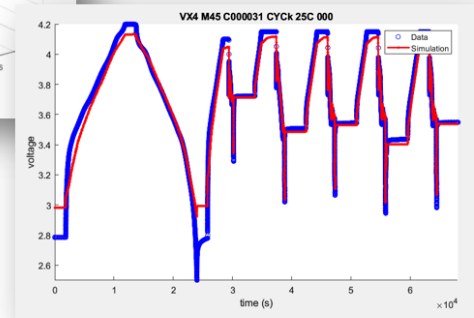
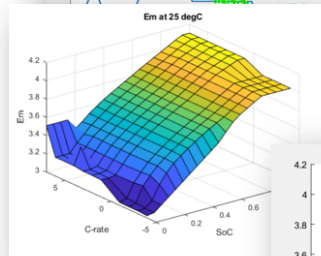
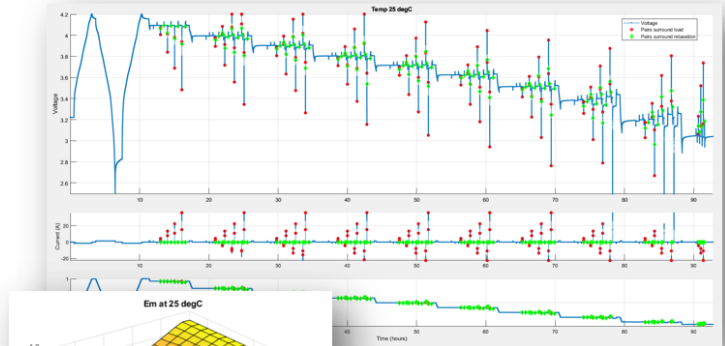
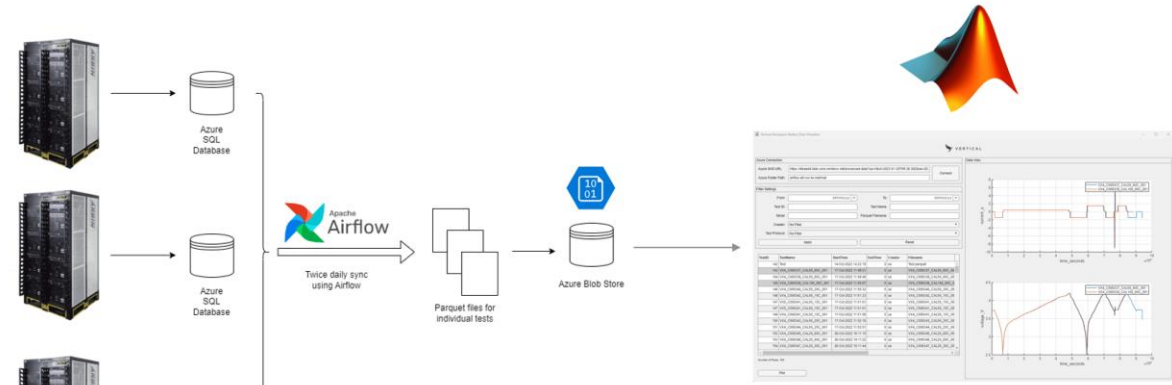
Testing Methodology

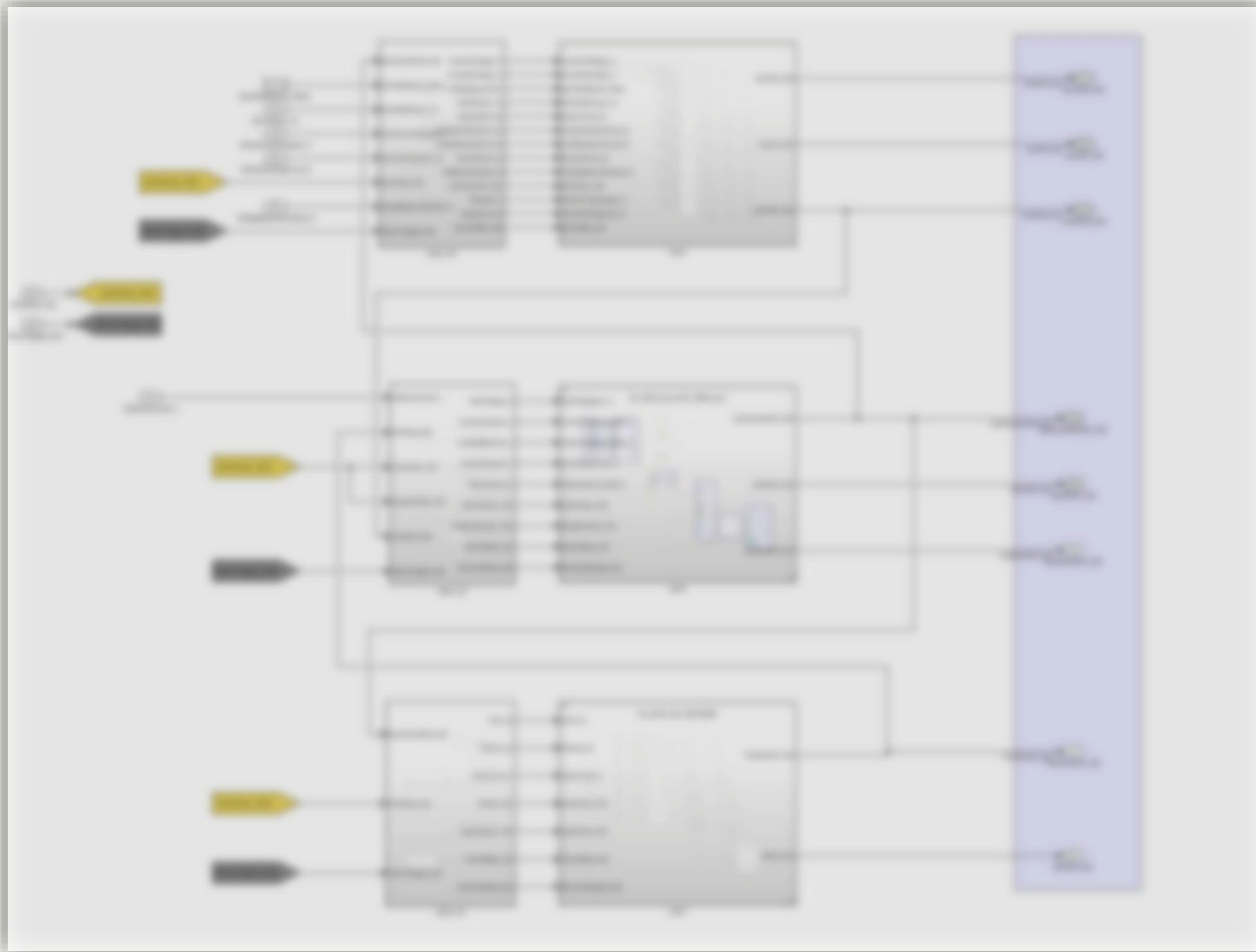
- Parameterising Equivalent Circuit Model by separating components
 - GITT - Galvanostatic Intermittent Titration Technique
 - Small pulses,
 - Measures relaxation and Open Circuit Voltage, among others
 - HPPC / PPC – (Hybrid) Pulse Power Characterisation
 - High Current Pulses
 - Measures dynamic response
 - Has to capture parameterisation space
- Issues:
 - Thermal and SoC assumptions no longer true!





Testing



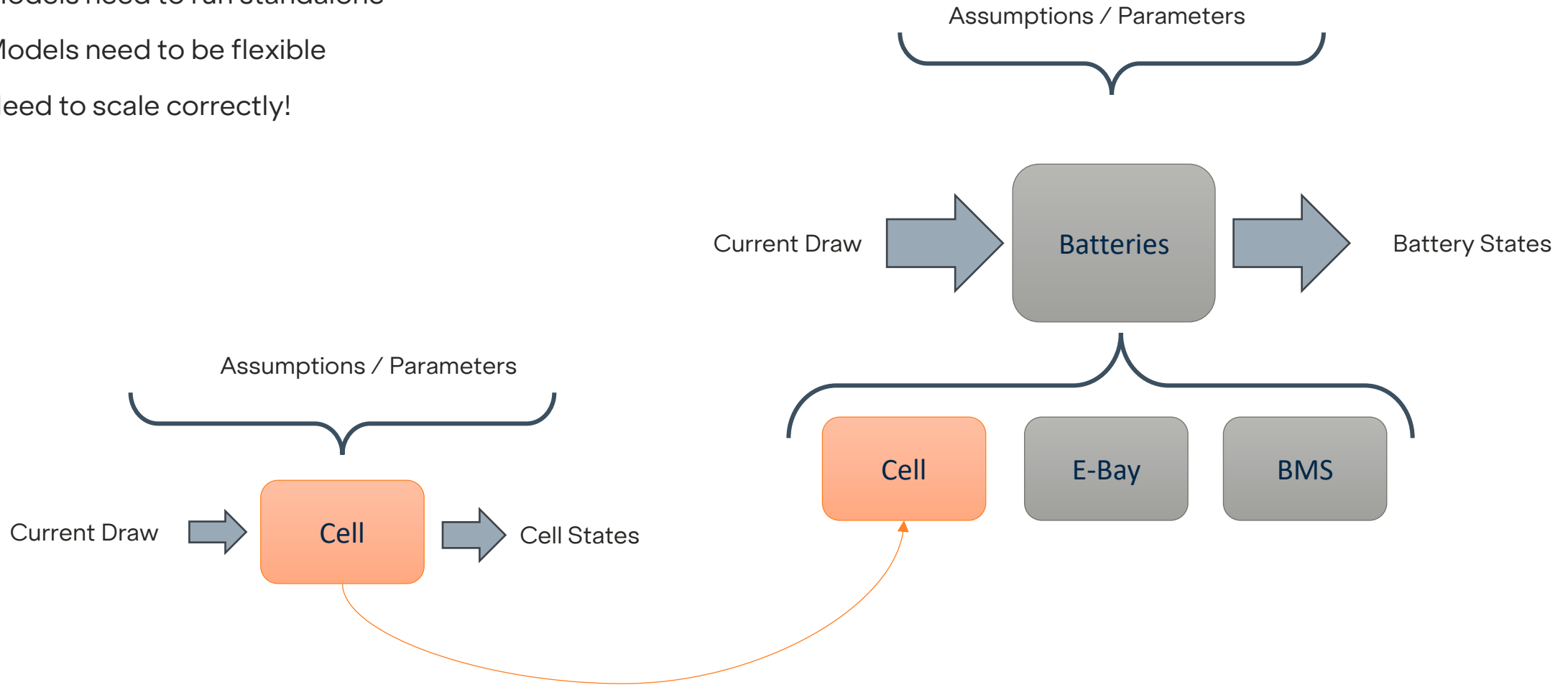


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Scaling Up

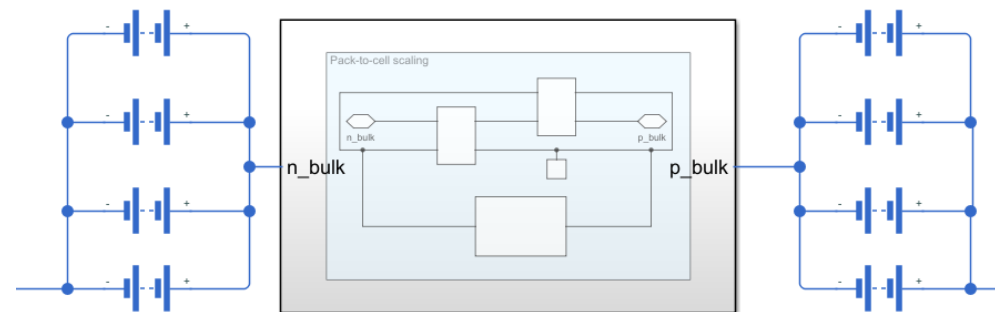
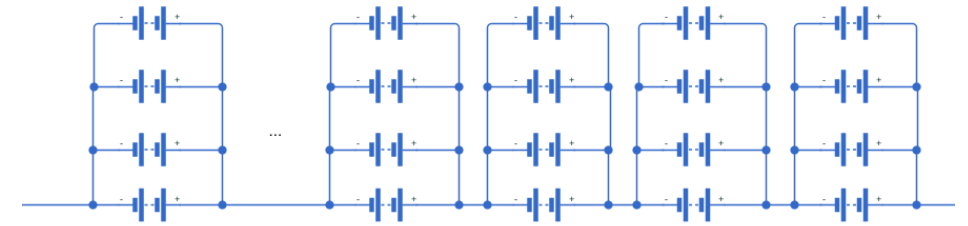
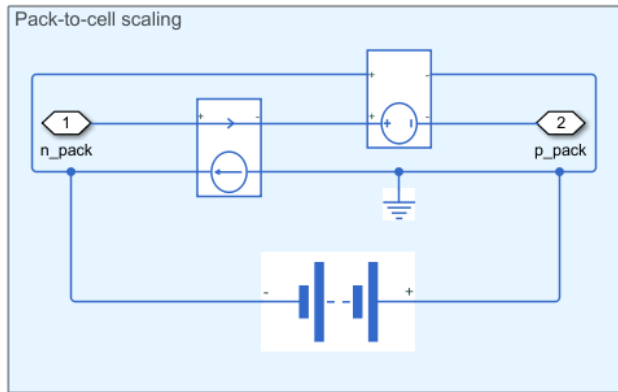
- Models need to run standalone
- Models need to be flexible
- Need to scale correctly!





How to Represent Multiple Cells

- Batteries are made of strings of cells in parallel and series
 - “Supercell”
 - Varying levels of discretisation
 - Fully discretised





Lessons Learned / General Tips

- Use Simscape Battery if you can!
 - Scaling
 - Discretisation
 - Fault injection
- Account for commissioning and difficulties in testing
- Plan the framework / structure ahead of time



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Thank you