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AUTOMOTIVE CONFERENCE 2023
Europe

Electrothermal Modeling and Analysis of Battery Packs

Lorenzo Nicoletti, MathWorks

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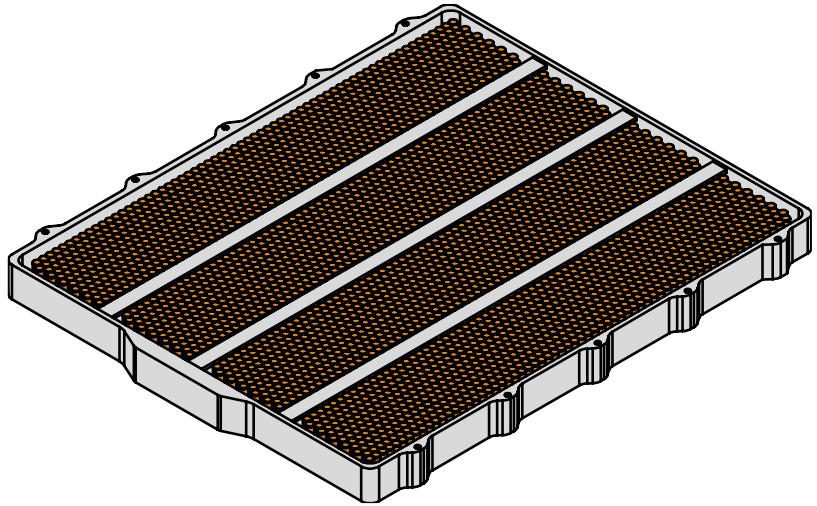
Why Explore Electrothermal Pack Modeling?

The importance of temperature monitoring for Li-Io packs

- Battery Electric Vehicle (BEV) sales are steadily rising
  - BEVs do not have any local CO_2 emissions
- Li-Io battery is the heart of a BEV
  - Energy storage
  - Expensive component
- The Li-Io battery performance is highly influenced by its temperature

Resistance increase
Capacity reduction

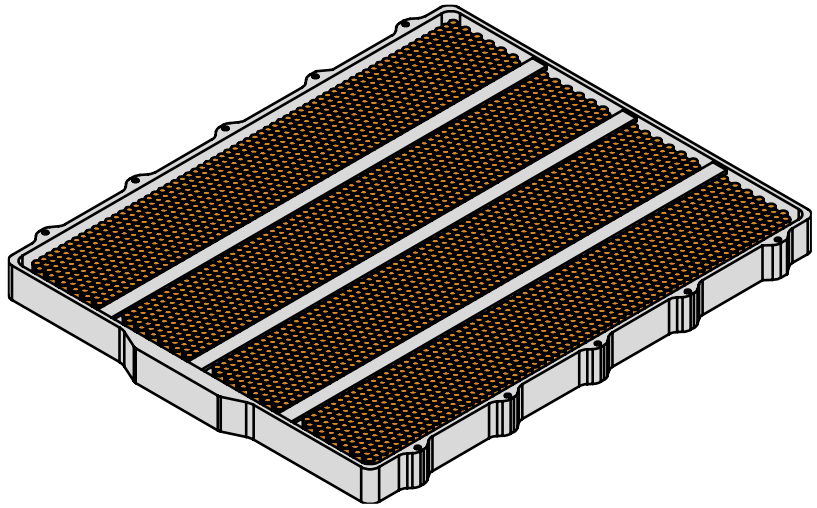


Cell Aging
Thermal Runaway

Why Explore Electrothermal Pack Modeling?

The importance of temperature monitoring for Li-Io packs

Resistance increase
Capacity reduction



Cell Aging
Thermal Runaway

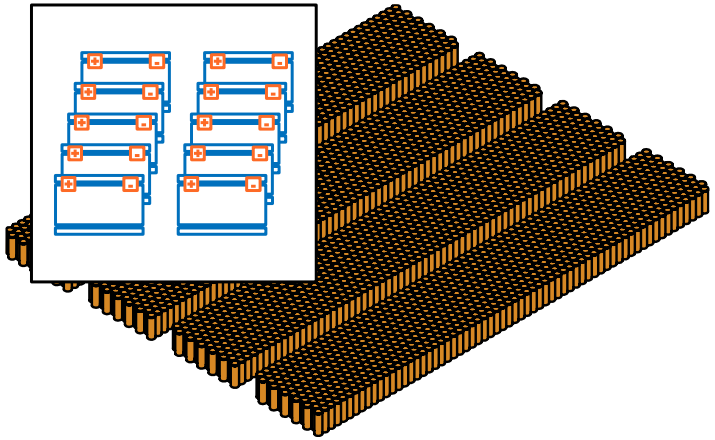
- The BEV thermal management ensures that the battery operates in a safe temperature window
- Electrothermal simulation is a powerful sizing tool for thermal management
- Creating detailed electrothermal models is a challenging task

What Will You Learn Today?

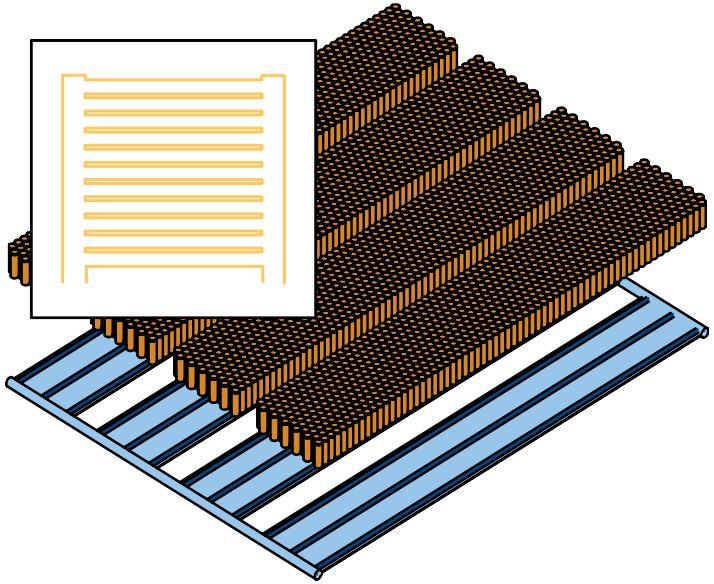
Simulate thermal behavior in fast-charge scenario

Today's aim is to show how you can use Simscape Battery to:

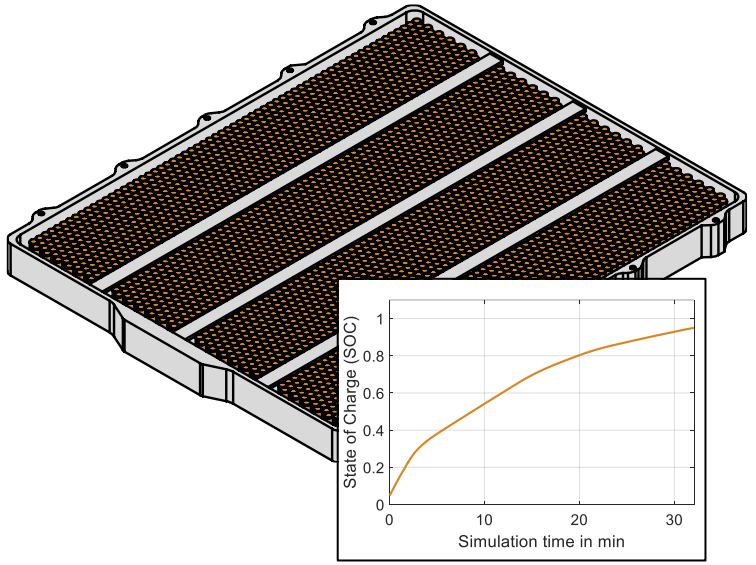
I.
Build an electrothermal pack model



II.
Set up a liquid cooling system



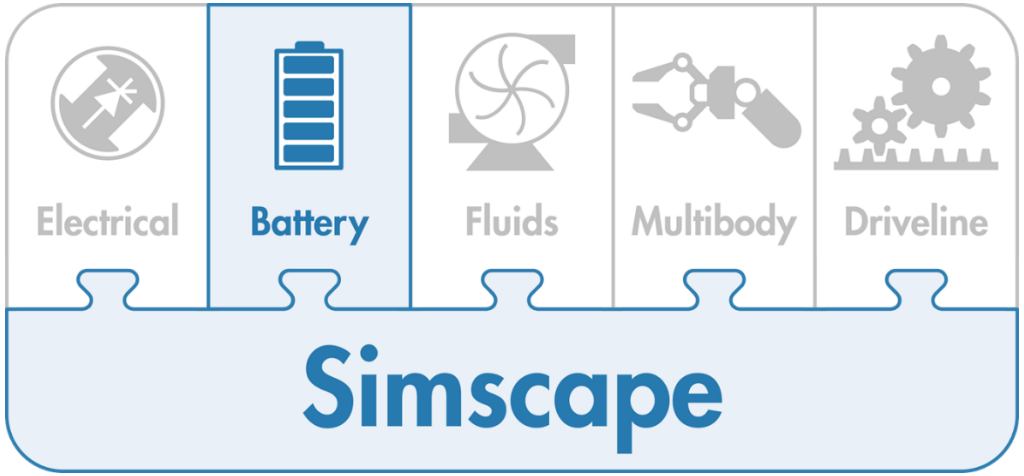
III.
Test pack behavior in a fast-charge scenario

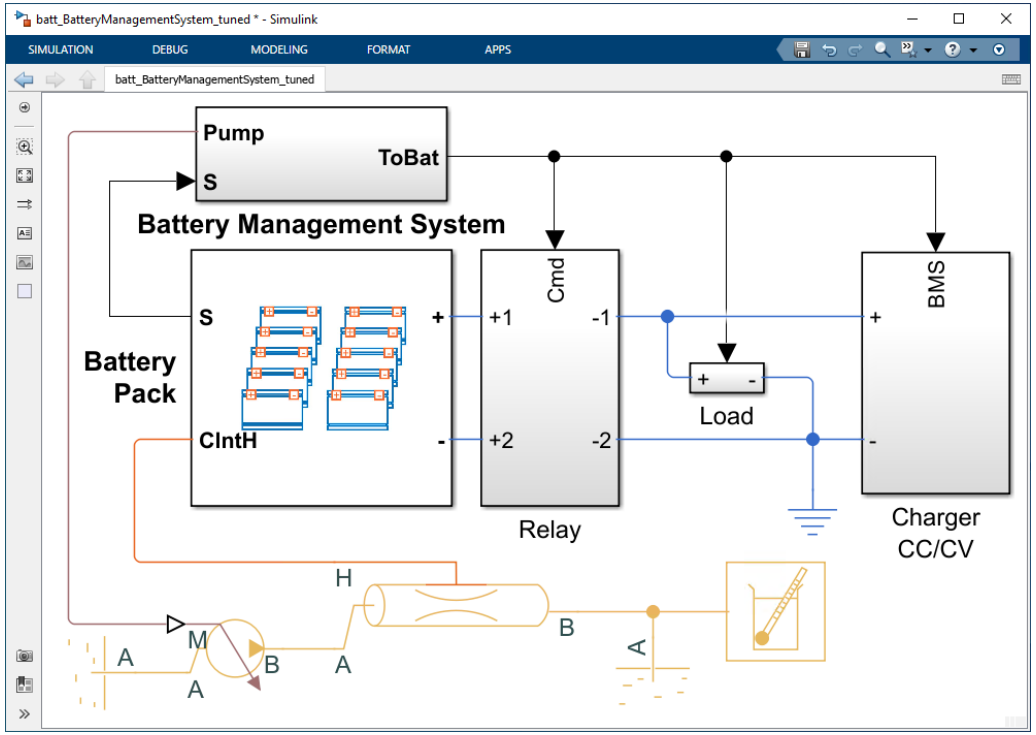


What is Simscape Battery?

Overview

- Add on product of Simscape
- Design and simulate battery and energy storage systems
  - Electrothermal cell behavior
  - Battery pack design
  - Battery management systems (BMS)
- With Simscape Battery you can
  - Test packs for electrical & thermal requirements
  - Test BMS algorithms

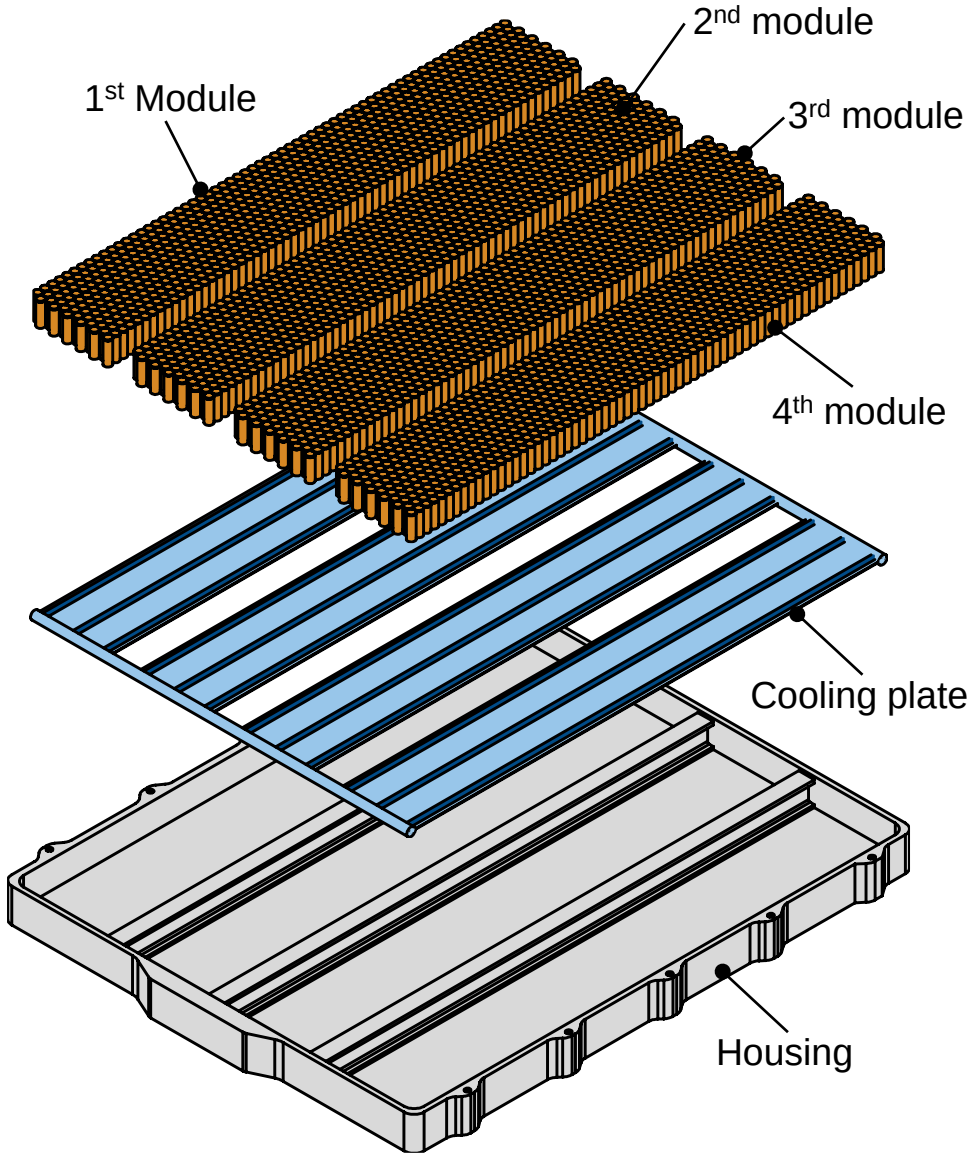




Testing the Limits of a Battery Pack

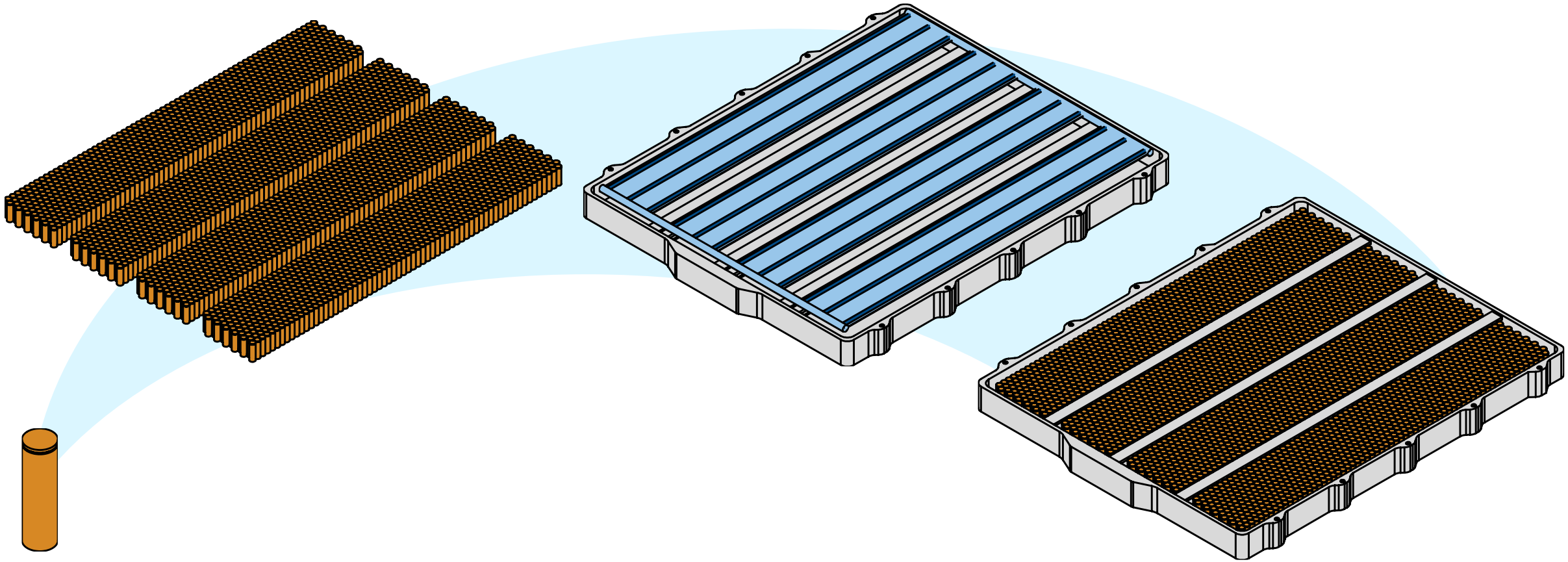
The pack we will use today

- The thermal and electrical modeling will be applied on a previously-sized battery pack
  - 3072 cylindrical cells (21700 format)
  - Electrical scheme 96s32p
  - Cell are disposed in 4 modules
  - Installed energy: 50 kWh
- Generated from an optimization study for a mid-size electric sedan (400 km range)



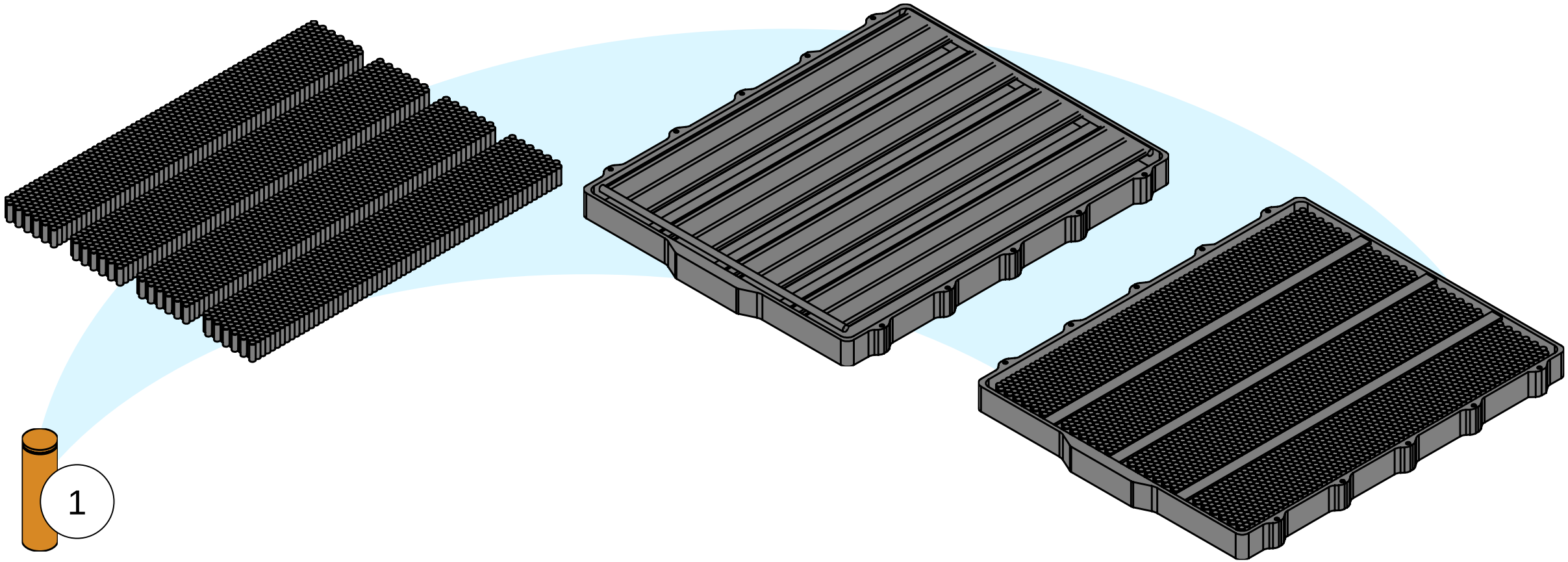
From Cell to Pack: Simulate Behavior in Fast-Charge Scenario

Agenda



From Cell to Pack: Simulate Behavior in Fast-Charge Scenario

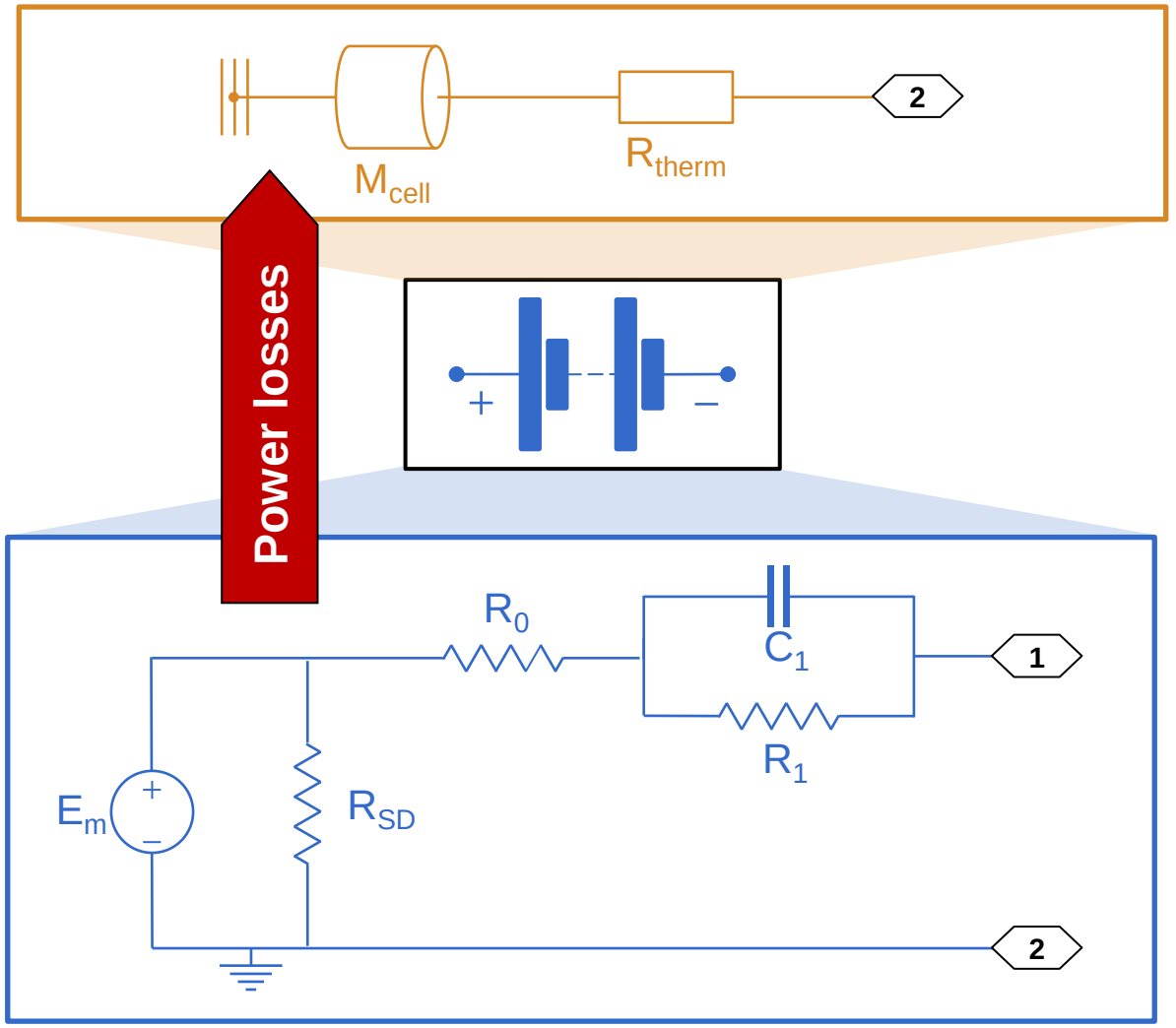
Understanding the cell model



Understanding the Cell Model

Multi-domain physical model

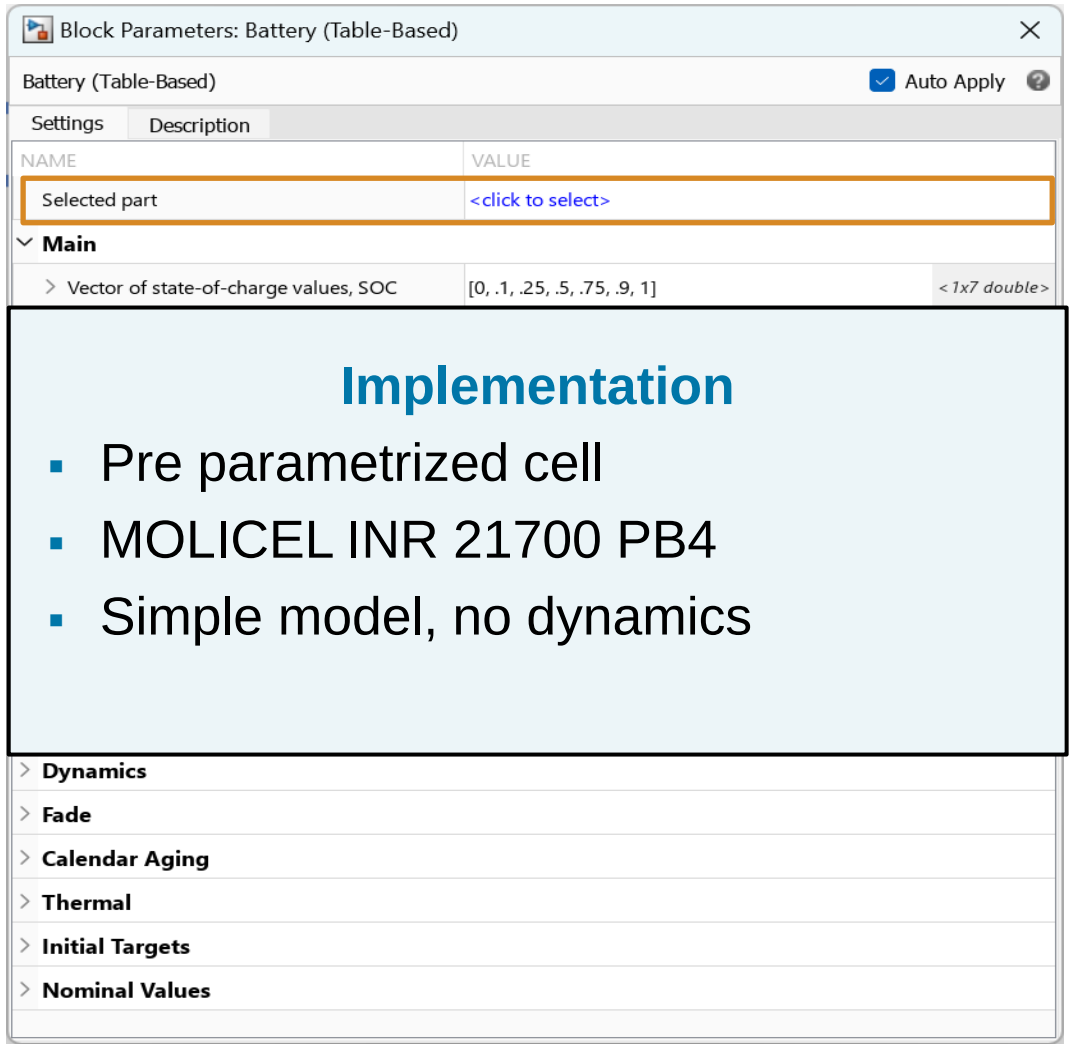
- Multi-domain physical model
- Electrical cell model
  - Cell described with an RC circuit
  - Different levels of detail available
- Thermal lumped cell model
- Power losses calculated from Ohmic losses



» Battery (Table-Based)

Understanding the Cell Model

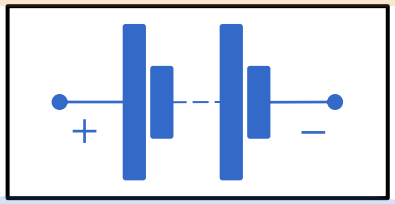
Multi-domain physical model

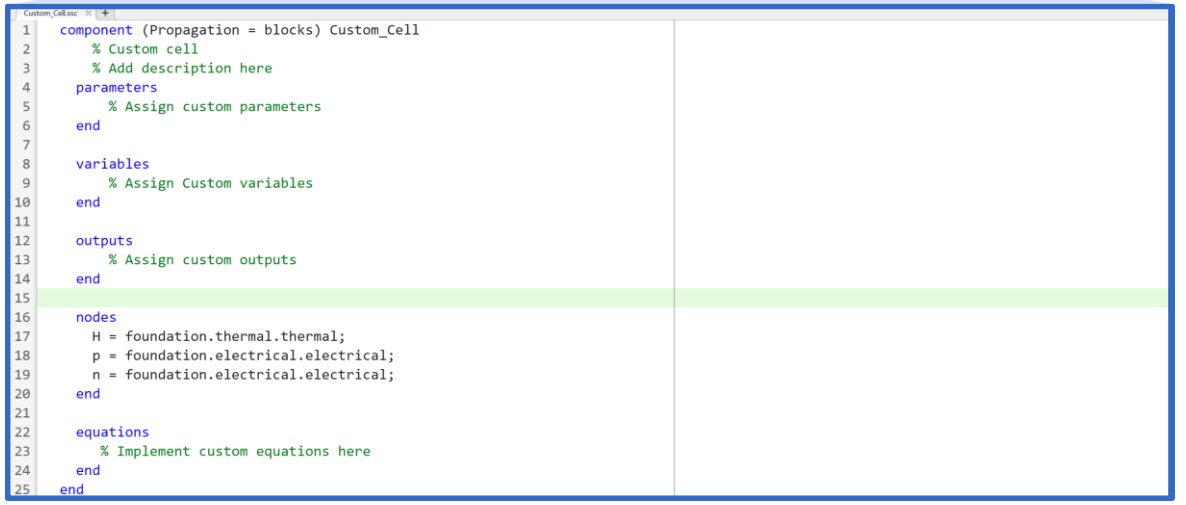


Implementation

- Pre parametrized cell
- MOLICEL INR 21700 PB4
- Simple model, no dynamics

```
    nodes
      H = foundation.thermal.thermal;
      p = foundation.electrical.electrical;
      n = foundation.electrical.electrical;
    end

    equations
       % Implement custom equations here
    end
  end
```



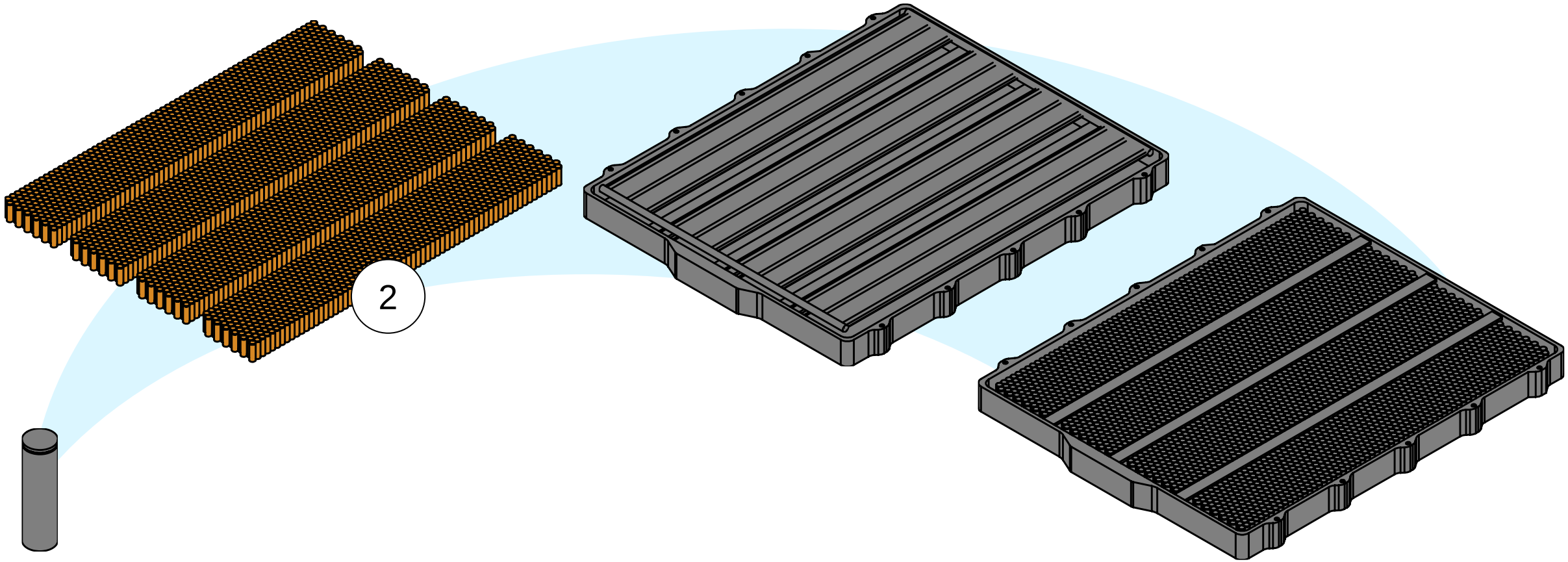


```
component (Propagation = blocks) Custom_Cell
    % Custom cell
    % Add description here
  parameters
      % Assign custom parameters
  end

  variables
      % Assign Custom variables
  end

  outputs
      % Assign custom outputs
  end

  nodes
    H = foundation.thermal.thermal;
    p = foundation.electrical.electrical;
    n = foundation.electrical.electrical;
  end

  equations
     % Implement custom equations here
  end
end
```

» Battery (Table-Based)

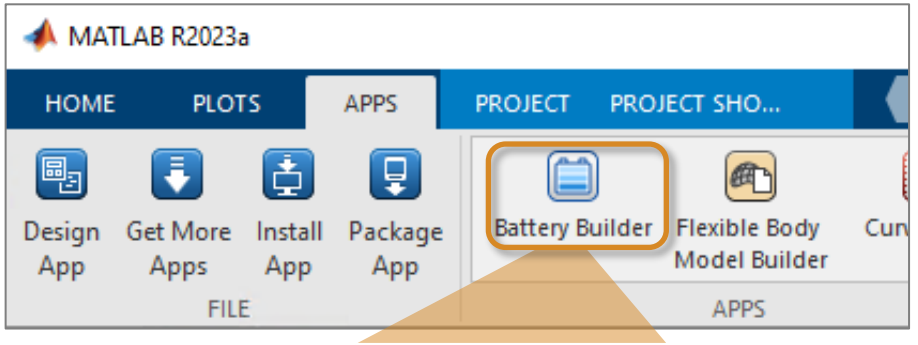
From Cell to Pack: Simulate Behavior in Fast-Charge Scenario

Going from cell to pack



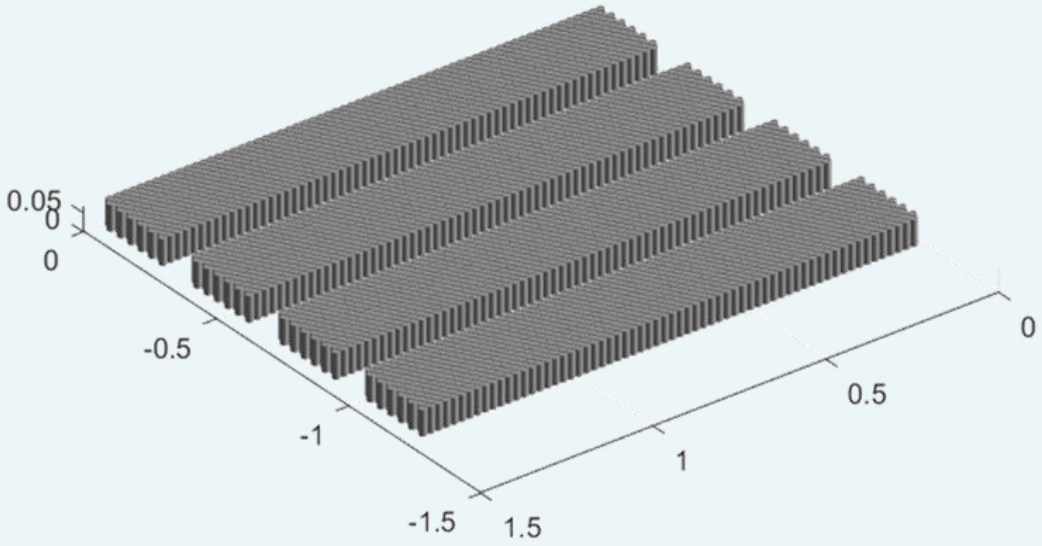
Building a Battery Pack within a Few Minutes

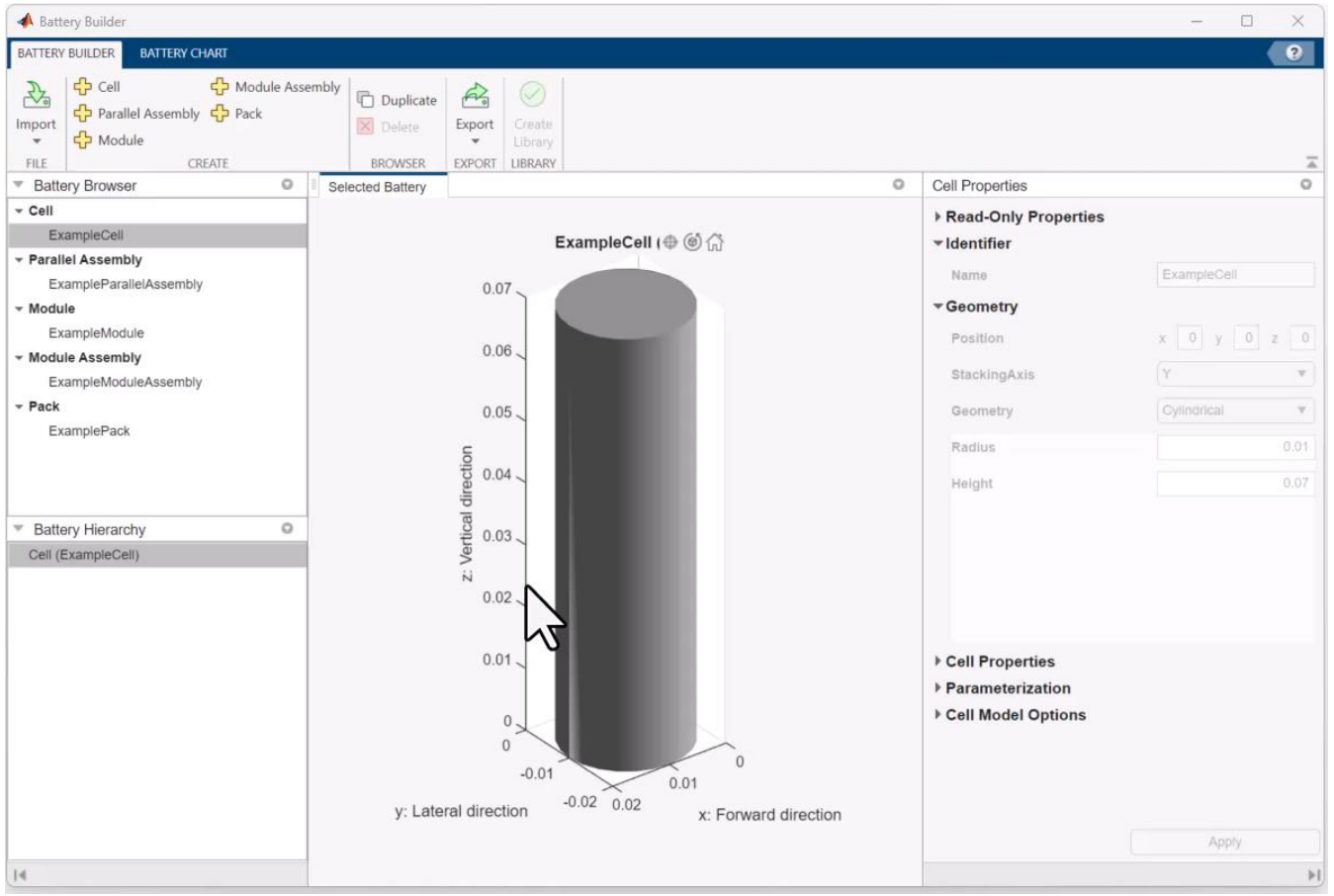
with the Battery Builder App



Implementation

- 3072 cells disposed on four modules
- Electrical scheme 96s32p



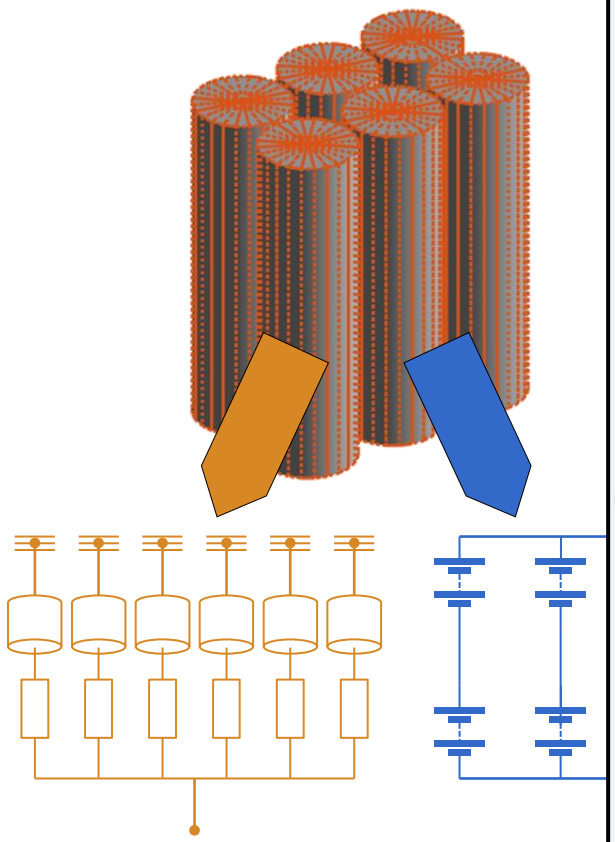


» Battery Builder

Finding the Tradeoff Between Calculation Speed and Precision

Choosing the right model fidelity for the pack

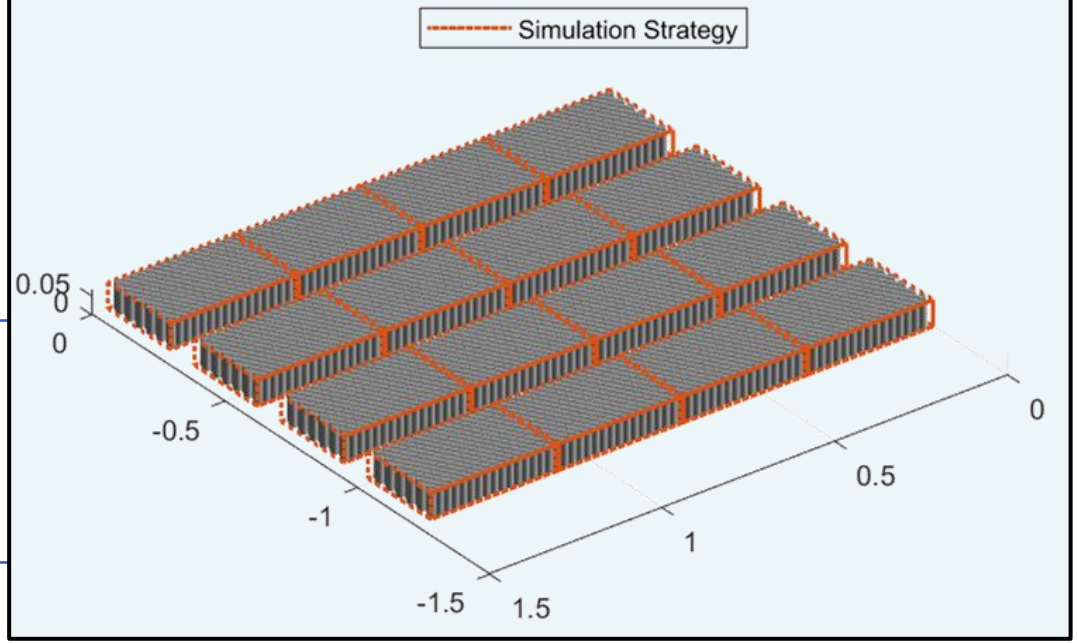
Detailed



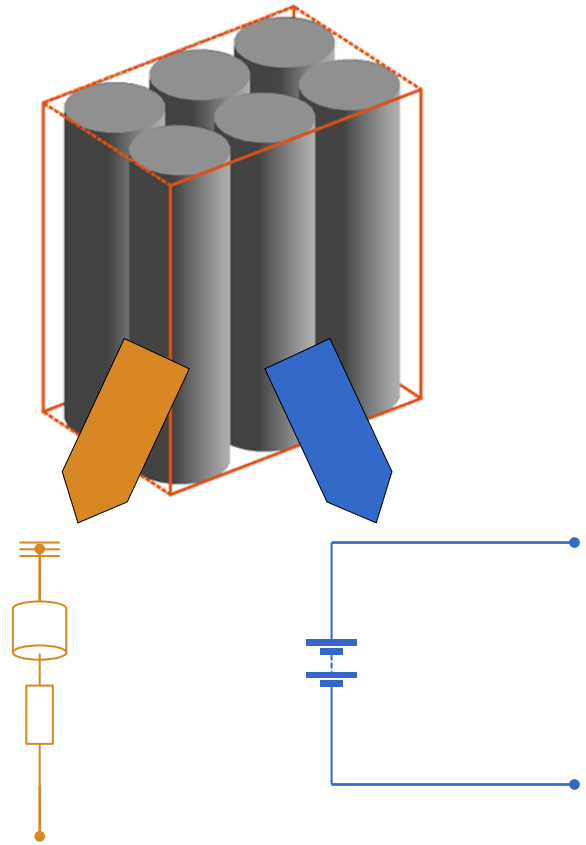
Grouped

Implementation

Selected a *Grouped* model resolution by dividing each module in four cell groups.



Lumped



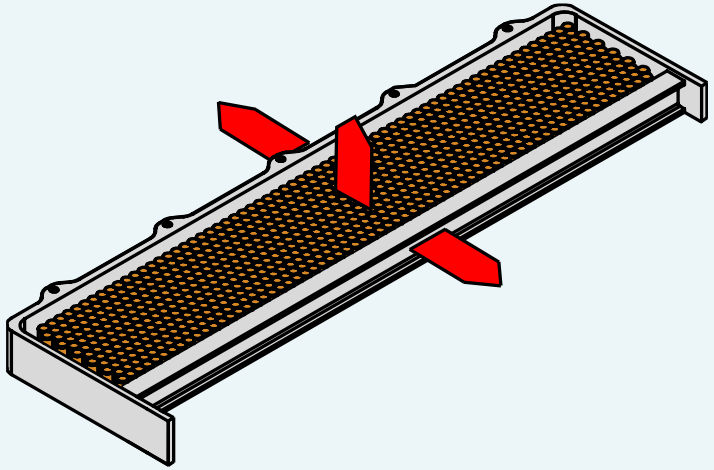
» More to Model Resolution

Modeling the Thermal Behavior of the Battery Pack

Using thermal paths

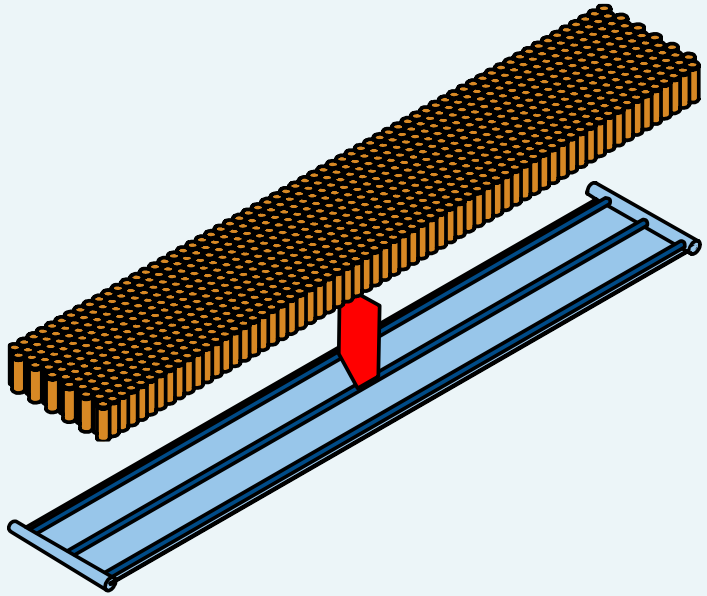
Path to ambient

Implementation

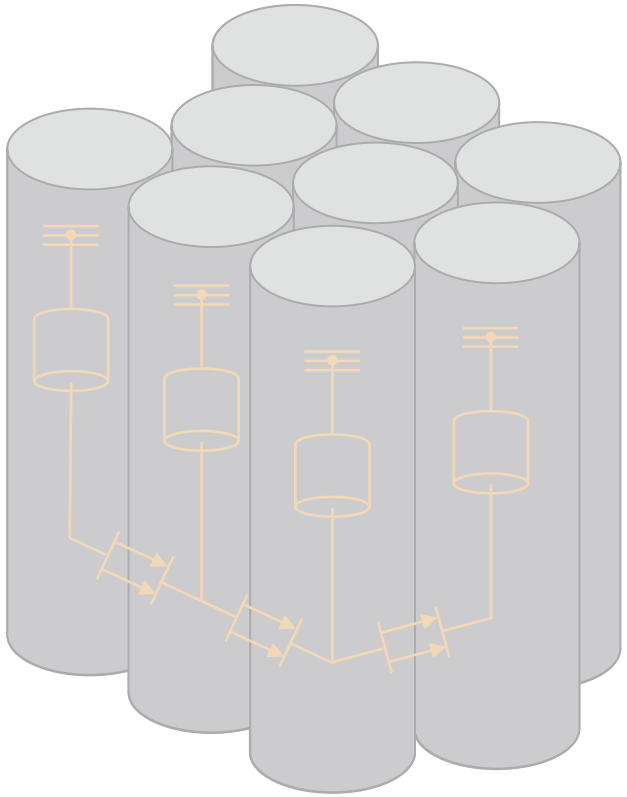


Path to cooling plate

Implementation

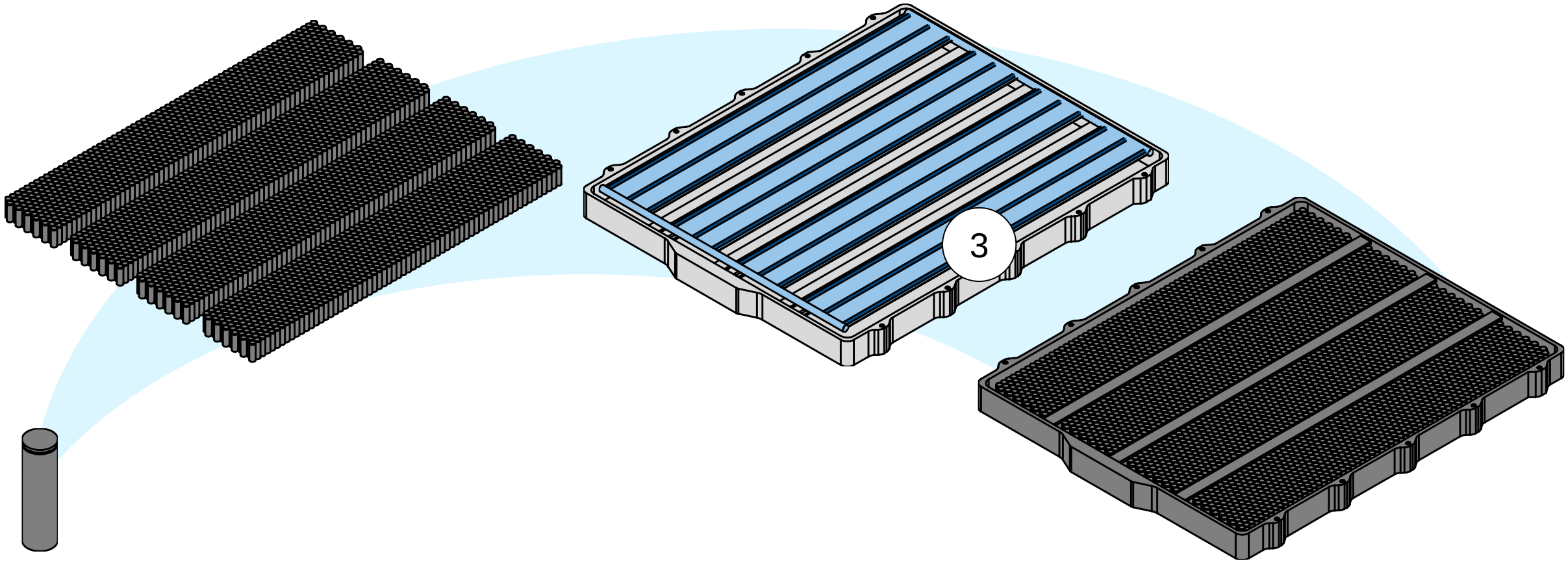


Inter cell path



From Cell to Pack: Simulate Behavior in Fast-Charge Scenario

Sizing the liquid cooling system



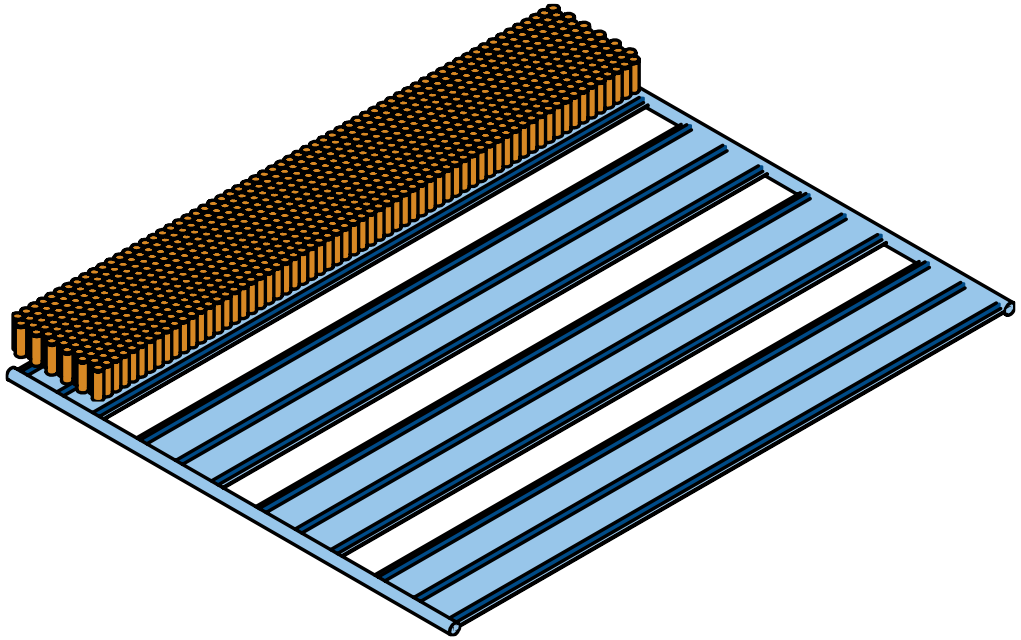
Sizing the Liquid Cooling System

Choosing a cooling plate topology

- The cooling plate blocks model the heat transfer between battery, liquid cooling system, and environment
- Different cooling plate topologies
  - Edge, parallel channel, U-shaped channel
  - Single- and double-sided plates
- Adjust model fidelity

Implementation

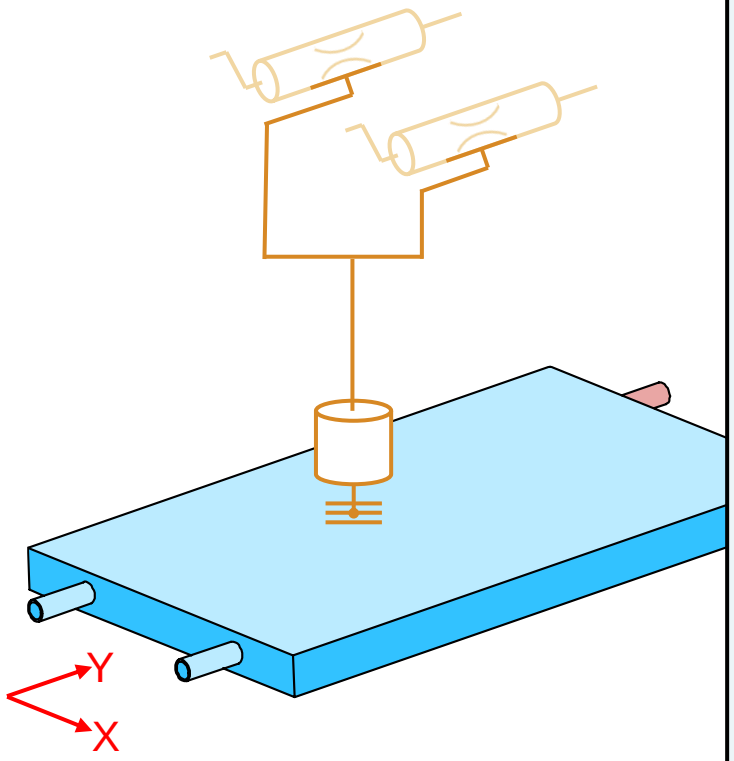
- Parallel channels plate
- Three channels per module (12 total)
- Coolant flow along the module length



Finding the Tradeoff Between Calculation Speed and Precision

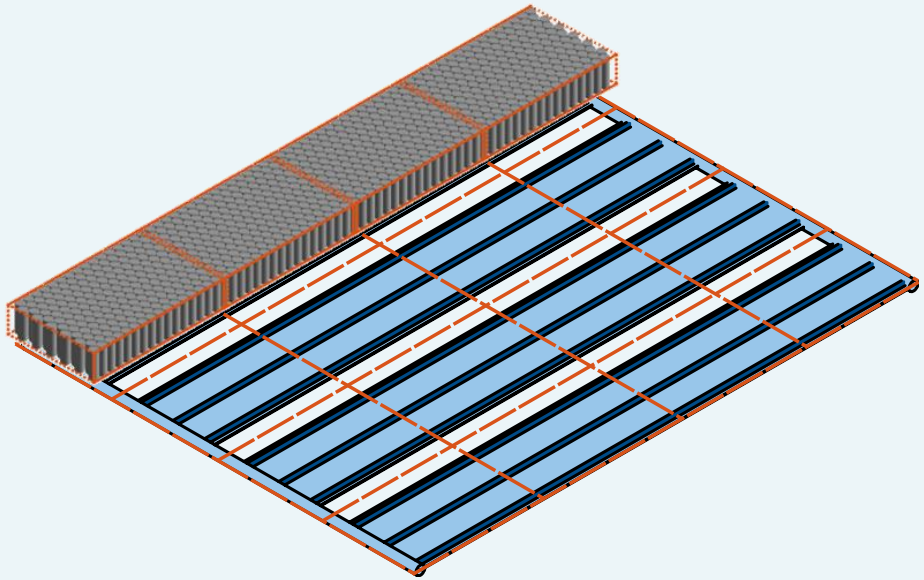
Choosing the right model fidelity for the plate

Lumped plate

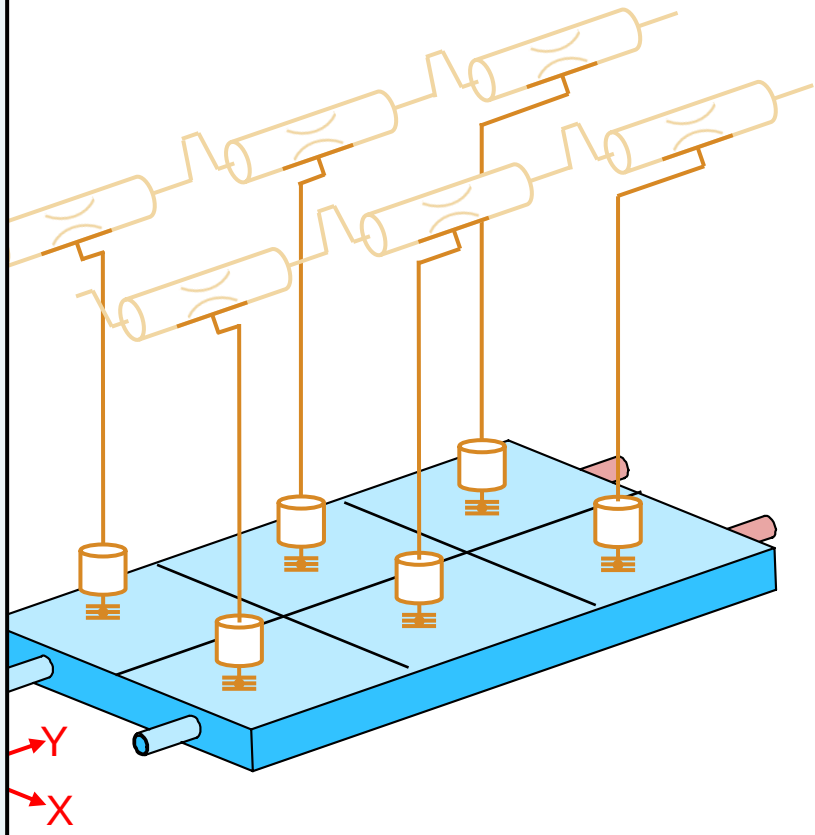


Implementation

The plate was discretized in a 4 by 4 layout as shown below:

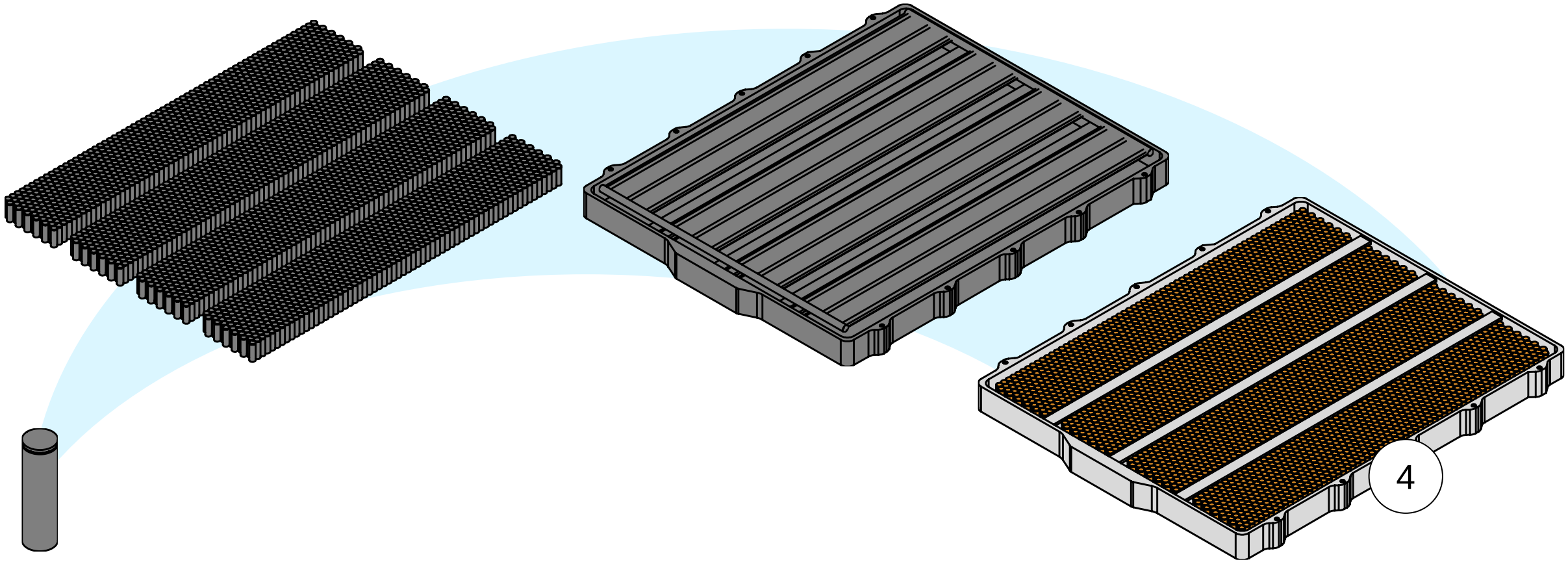


Discretized along X & Y



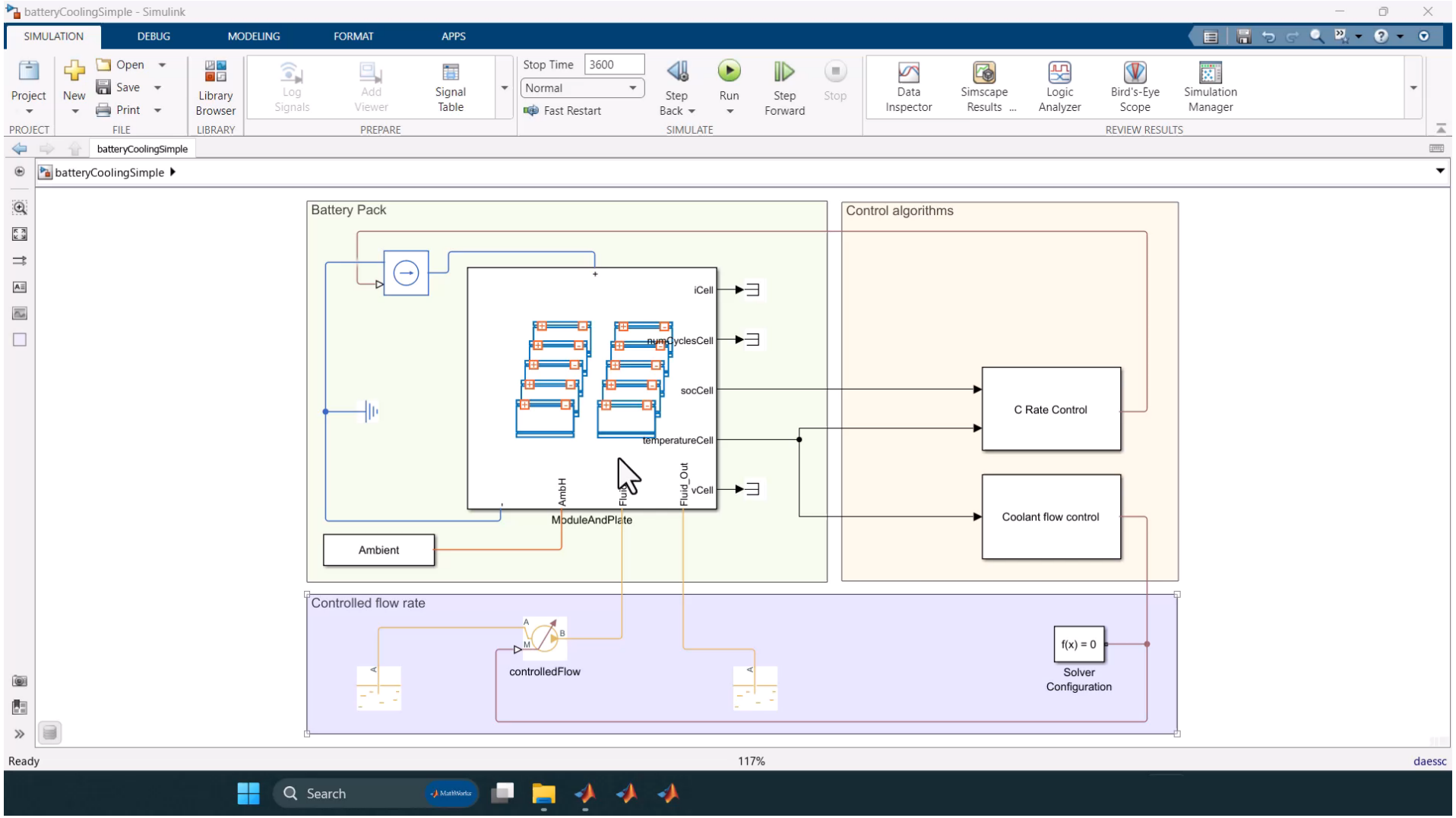
From Cell to Pack: Simulate Behavior in Fast-Charge Scenario

Simulating Fast-Charge behavior



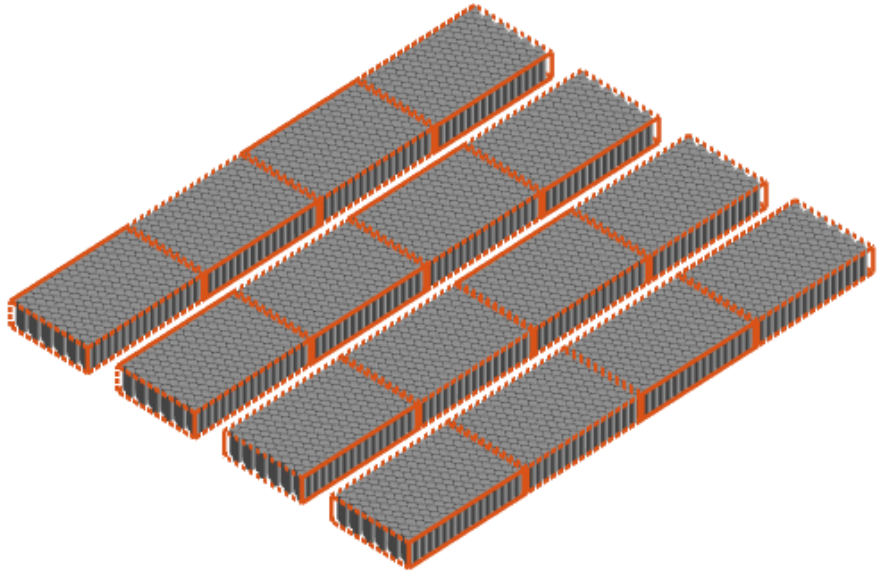
Simulating Fast-Charge Behavior

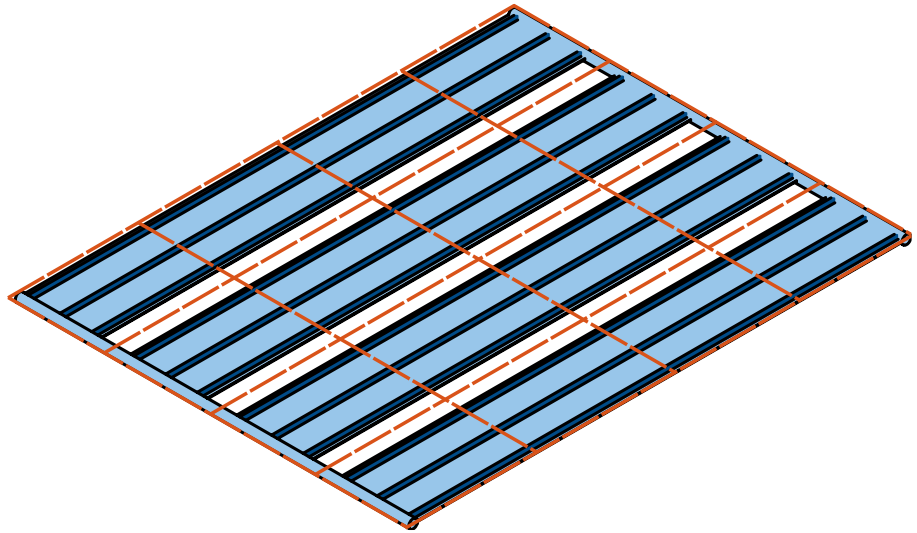
Understanding the model implementation



Simulating Fast-Charge Behavior

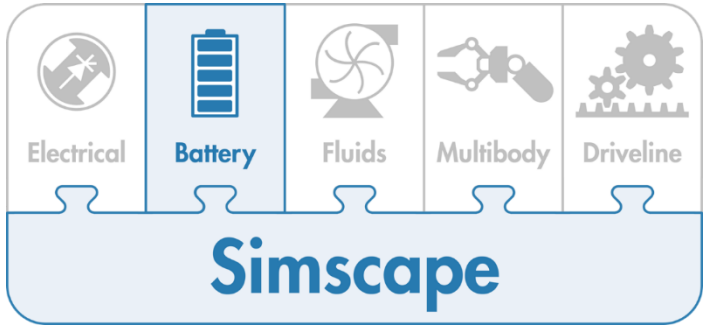
Results





Summary

What did we learn today?



- Key take-away:
  - Simscape Battery is a powerful tool for electrothermal simulation of battery packs.
  - Easily generate battery packs with the Battery Builder
  - Tune model fidelity based on your needs.

- Topics discussed:
  1. Electrothermal modeling of an automotive battery pack
  2. Coupling with a liquid cooling system
  3. Analysis of pack temperature change during a fast-charge scenario

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Thank you