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AUTOMOTIVE
CONFERENCE 2024
Europe

From Electrode to Pack: Simulate and Tune Fast Charge Profiles

Lorenzo Nicoletti, MathWorks

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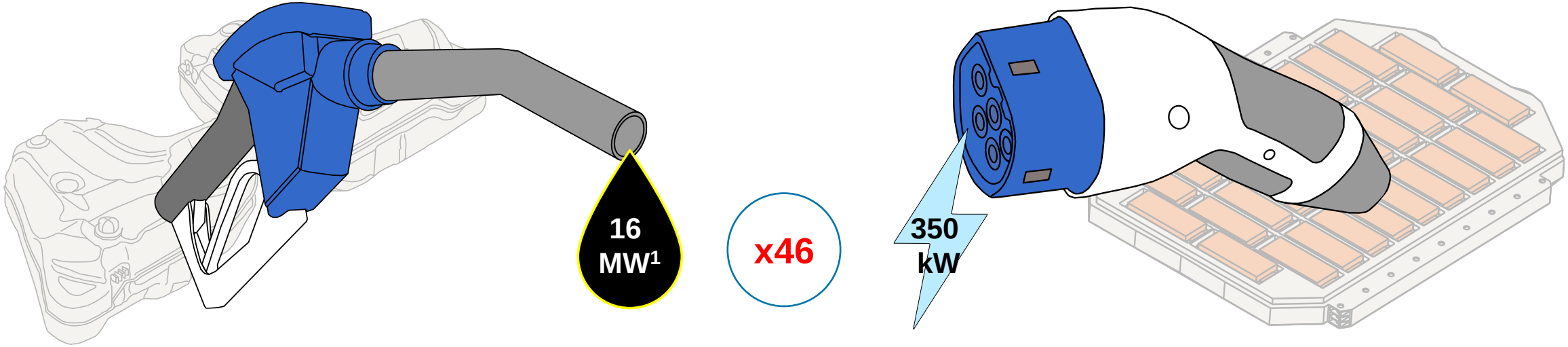
Why Explore Fast Charging?

A comparison with combustion vehicles

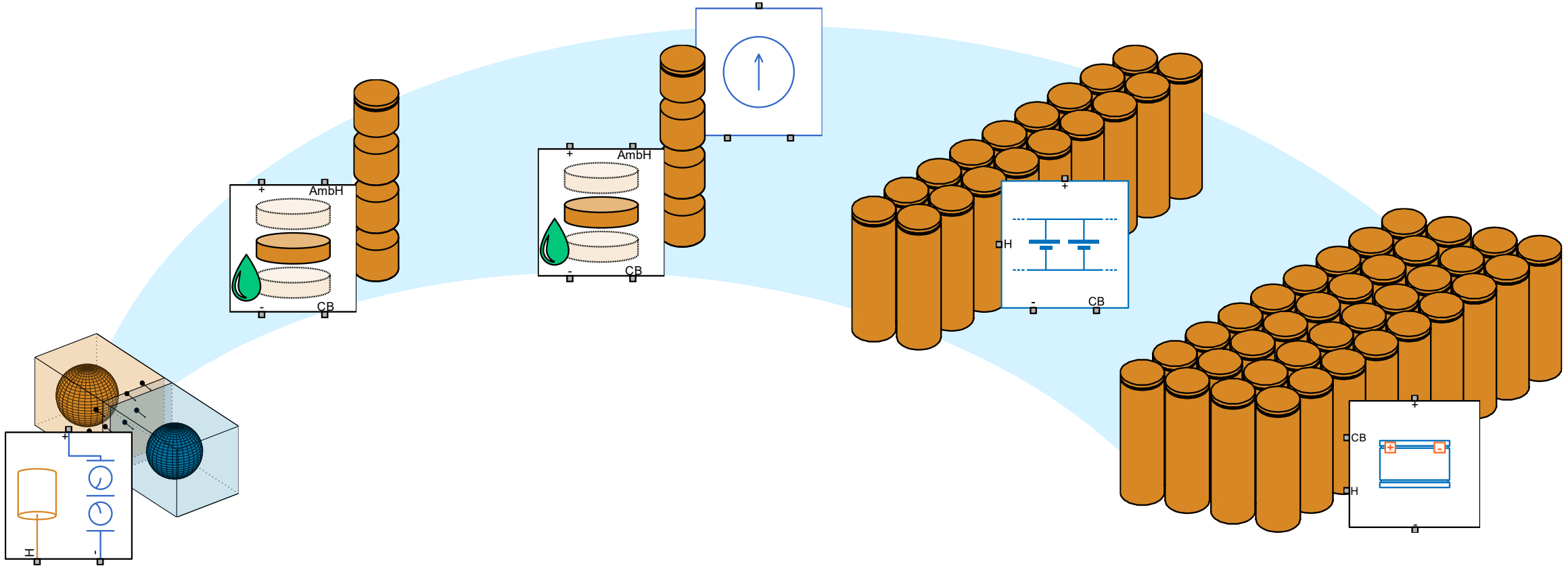


- Mastering fast charging requires a deep knowledge of the cell's behavior
- An improper fast charging strategy accelerates cell aging
- This can be prevented with correct **temperature and current control**
- To succeed in this multidisciplinary field, **simulation models** are required

[1]M. Sterner, I. Stadler, "Energiespeicher: Bedarf, Technologien, Integration", 2014

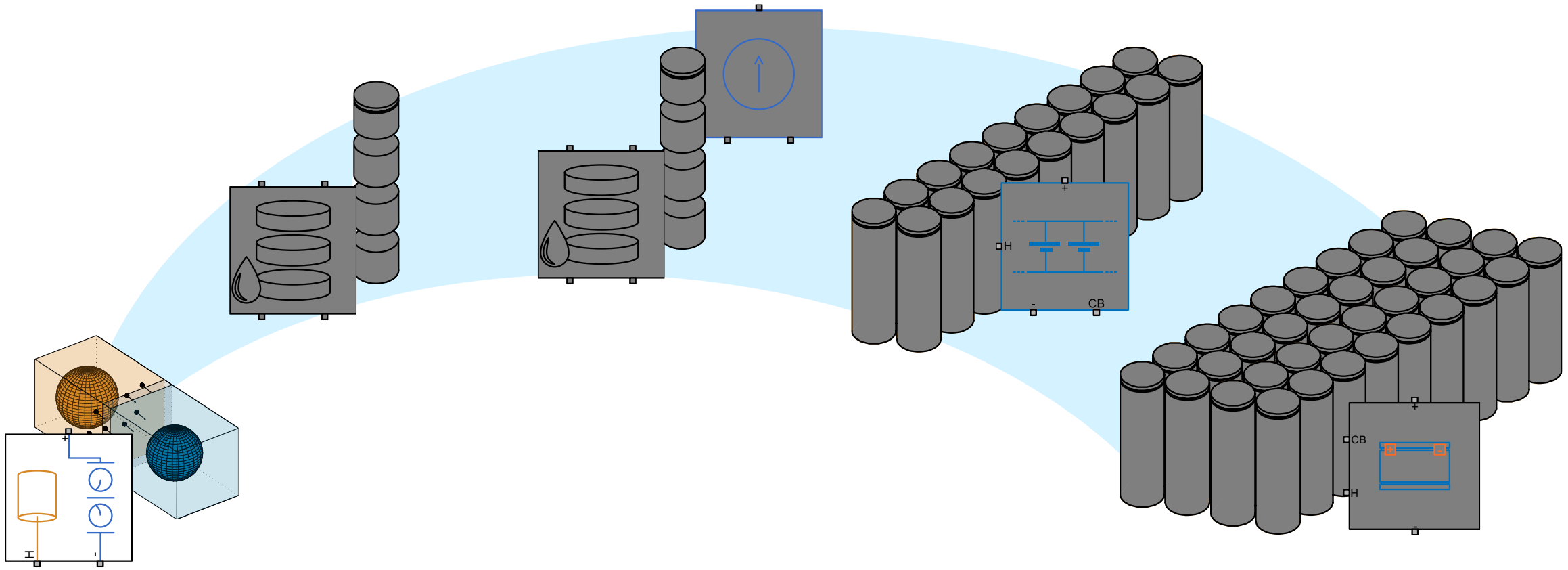
What Will You Learn Today?

Going from Anode to Parallel Assembly



A Journey from Anode to Parallel Assembly

Electrochemical Cell Model

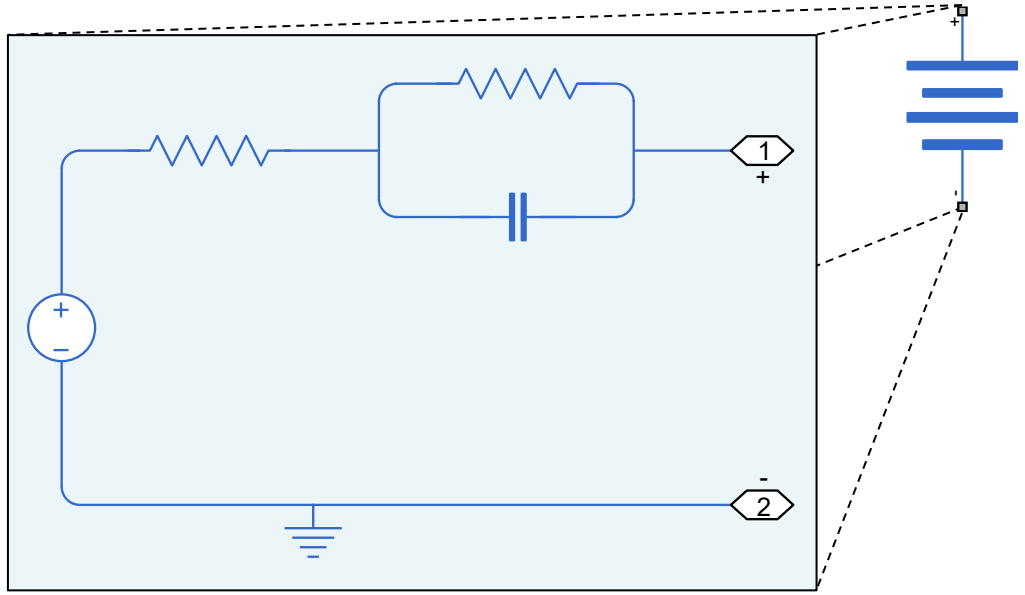


Available Blocks for Cell Modeling

in Simscape™ Battery™

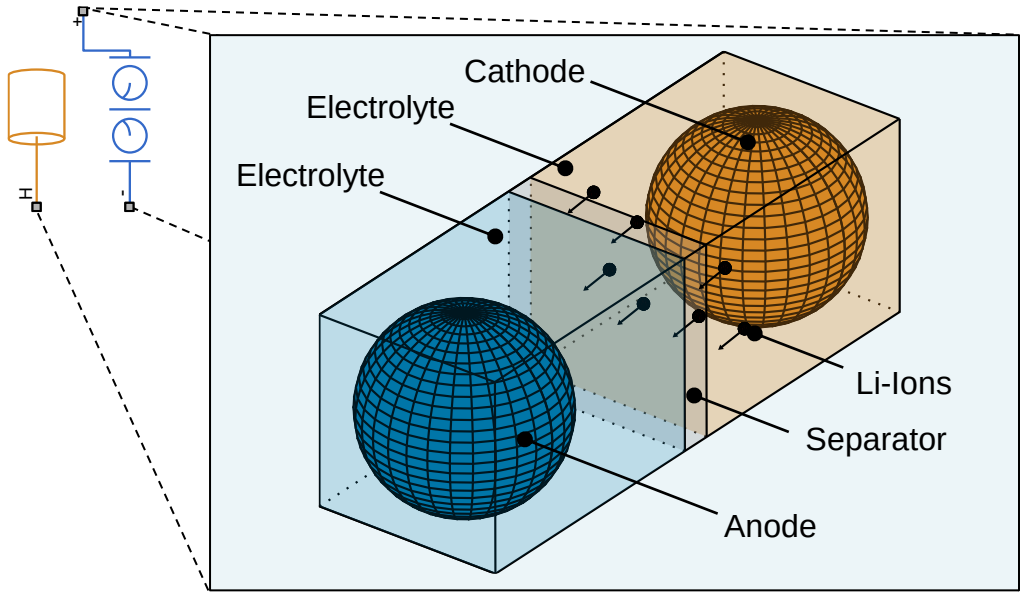
Empirical Model

- Equivalent Circuit Model (ECM)
- Simple to implement and understand
- Limited Accuracy



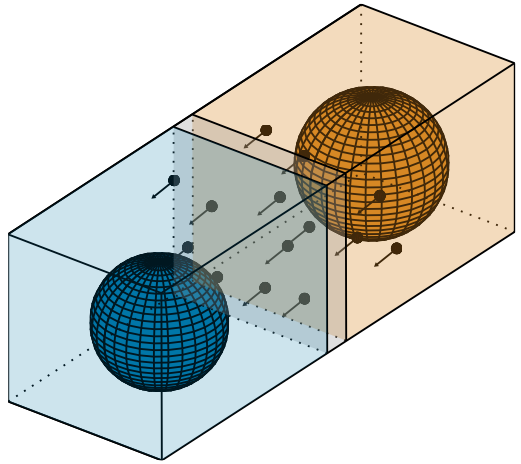
Electrochemical Model

- Single Particle Model (SPM)
- Improved accuracy & balanced complexity
- Requires detailed parameters



Understanding the Electrochemical Model (SPM)

Charging procedure (from 0% to 80% SOC)



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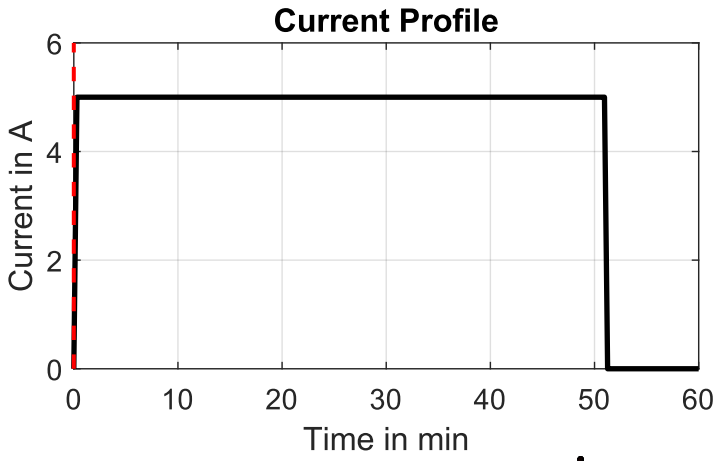

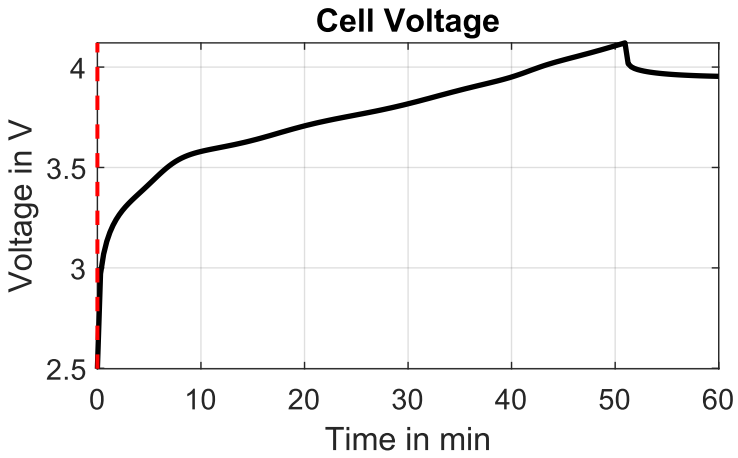

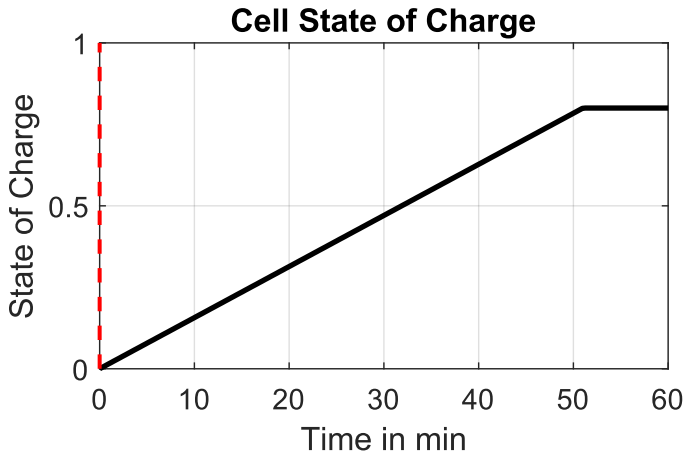

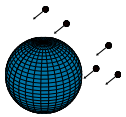

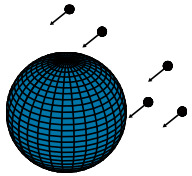

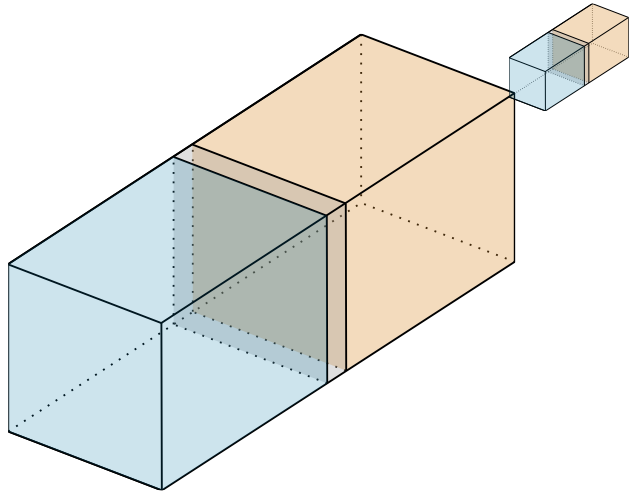

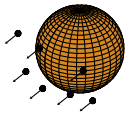

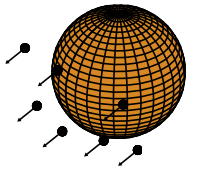

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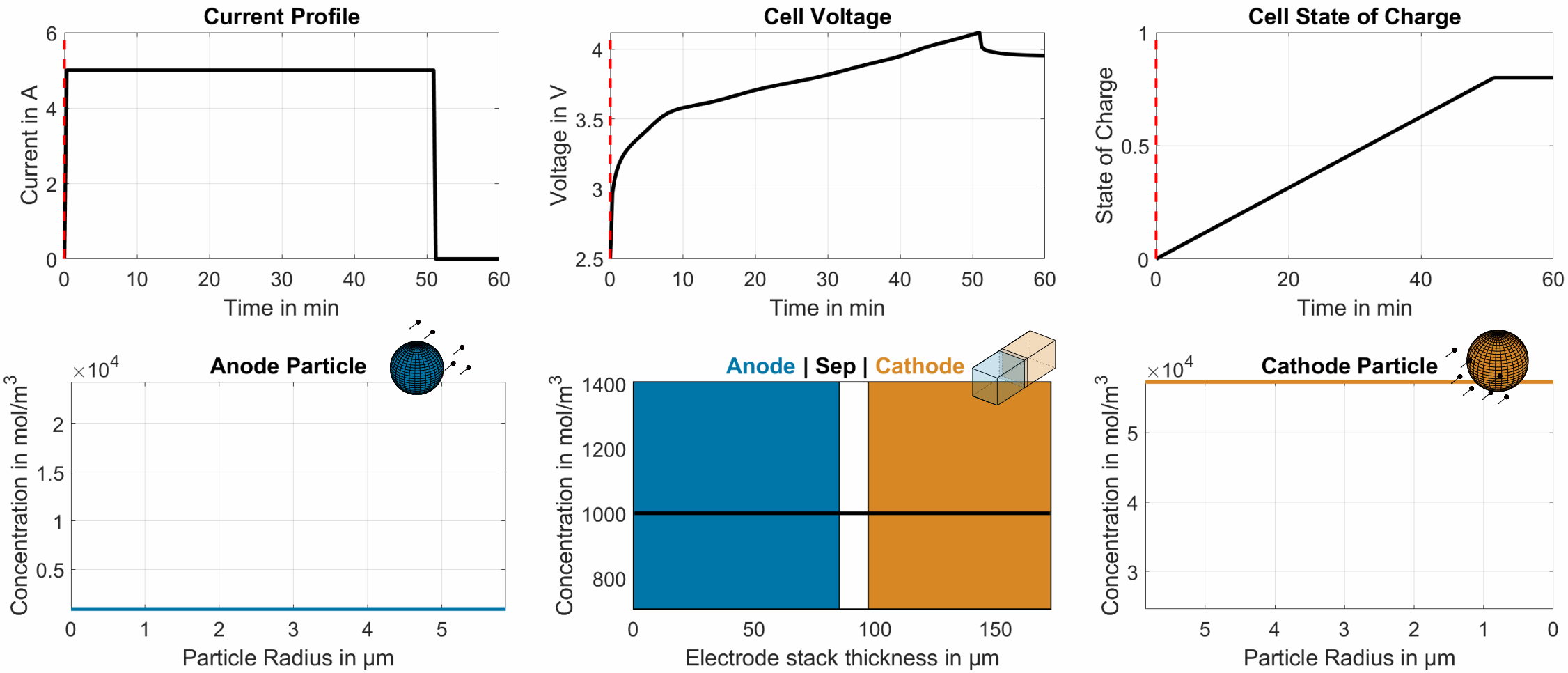
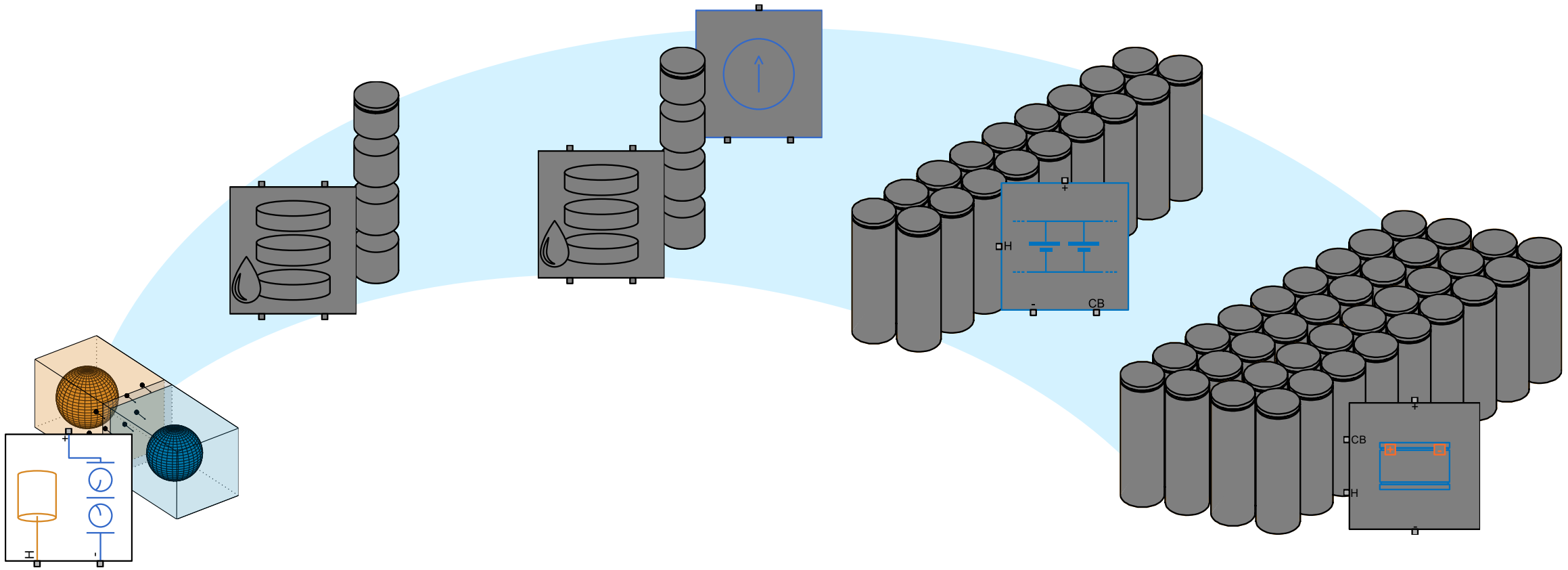


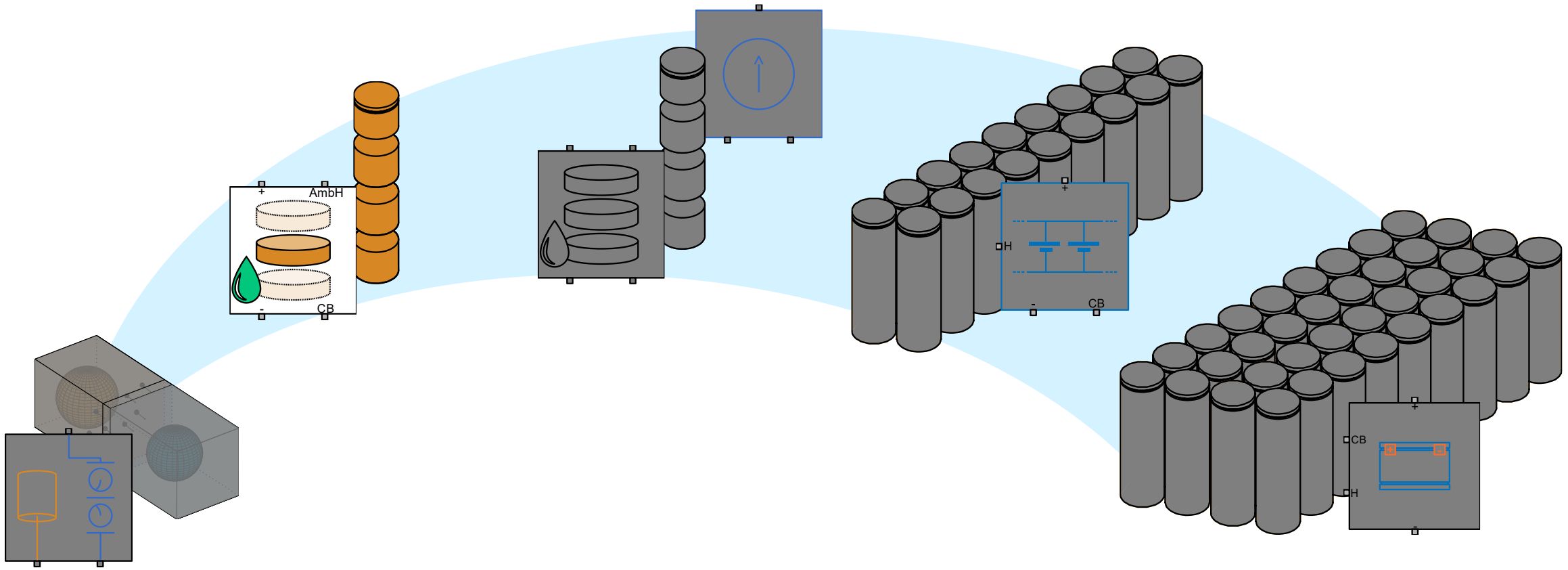
A Journey from Anode to Parallel Assembly

Electrochemical Cell Model



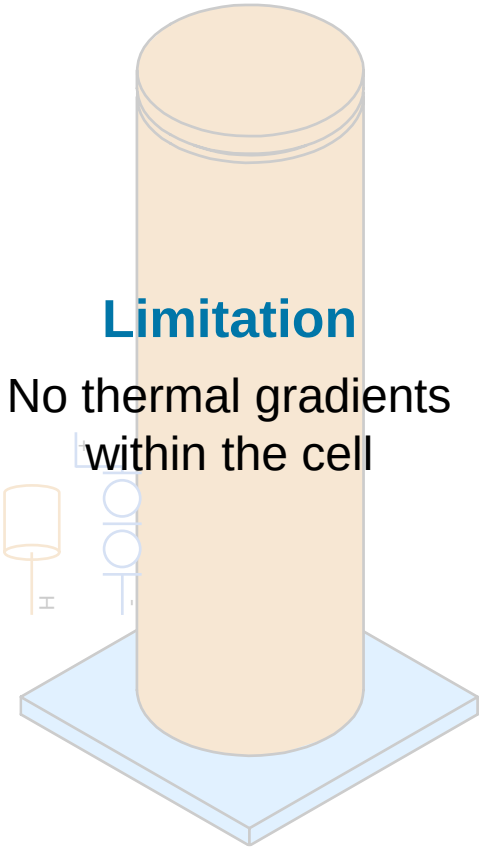
A Journey from Anode to Parallel Assembly

Creating a Spatially Discretized Cell



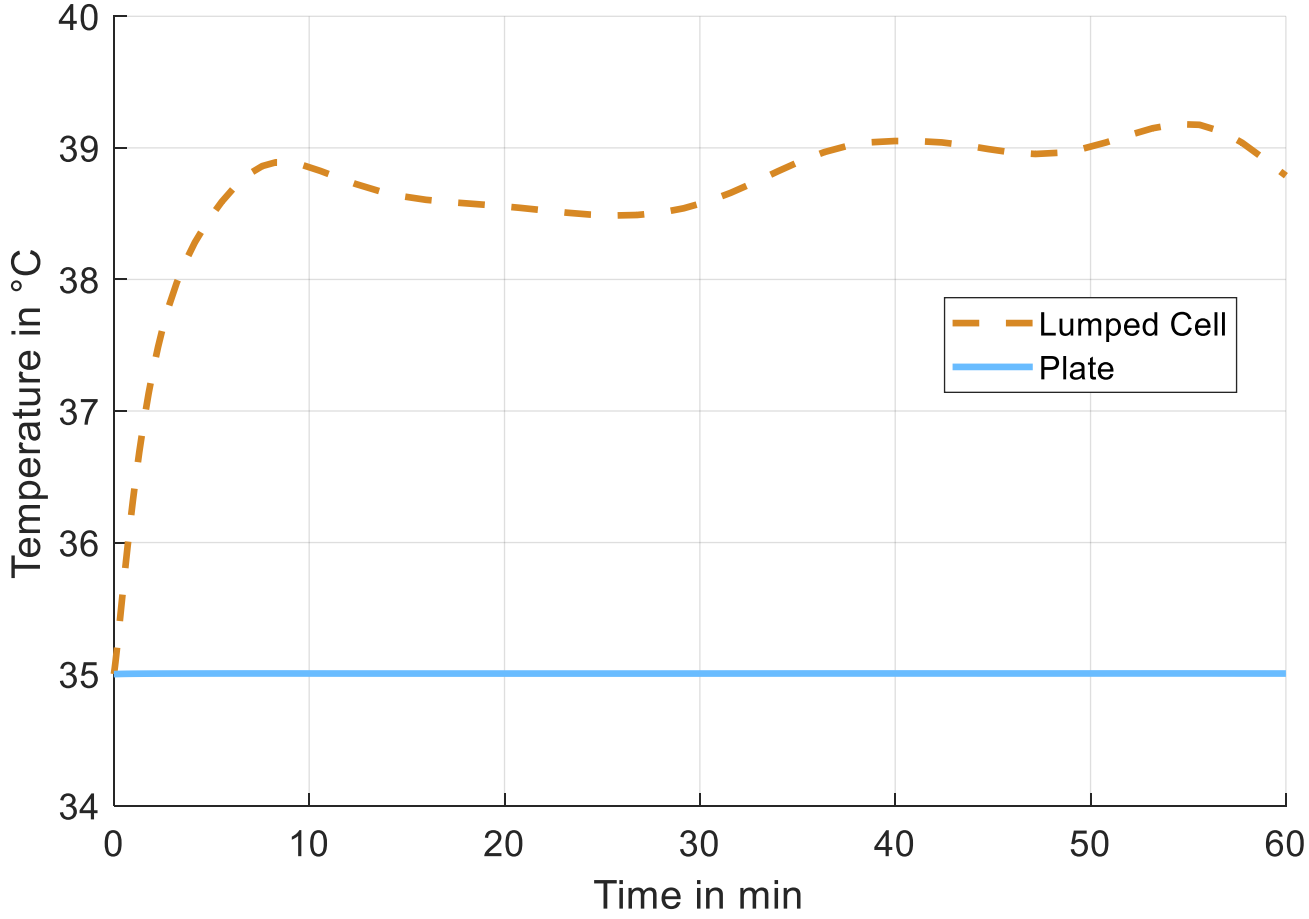
Why Do You Need to Extend the Current Model?

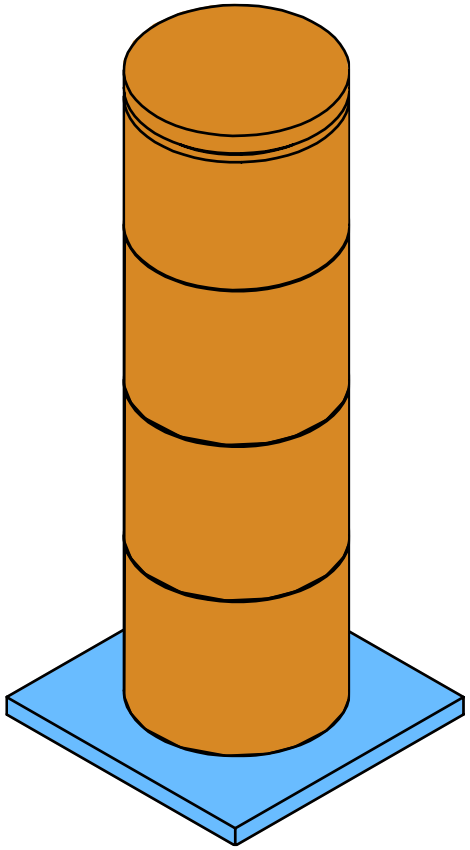
Building a spatially discretized cell



Limitation

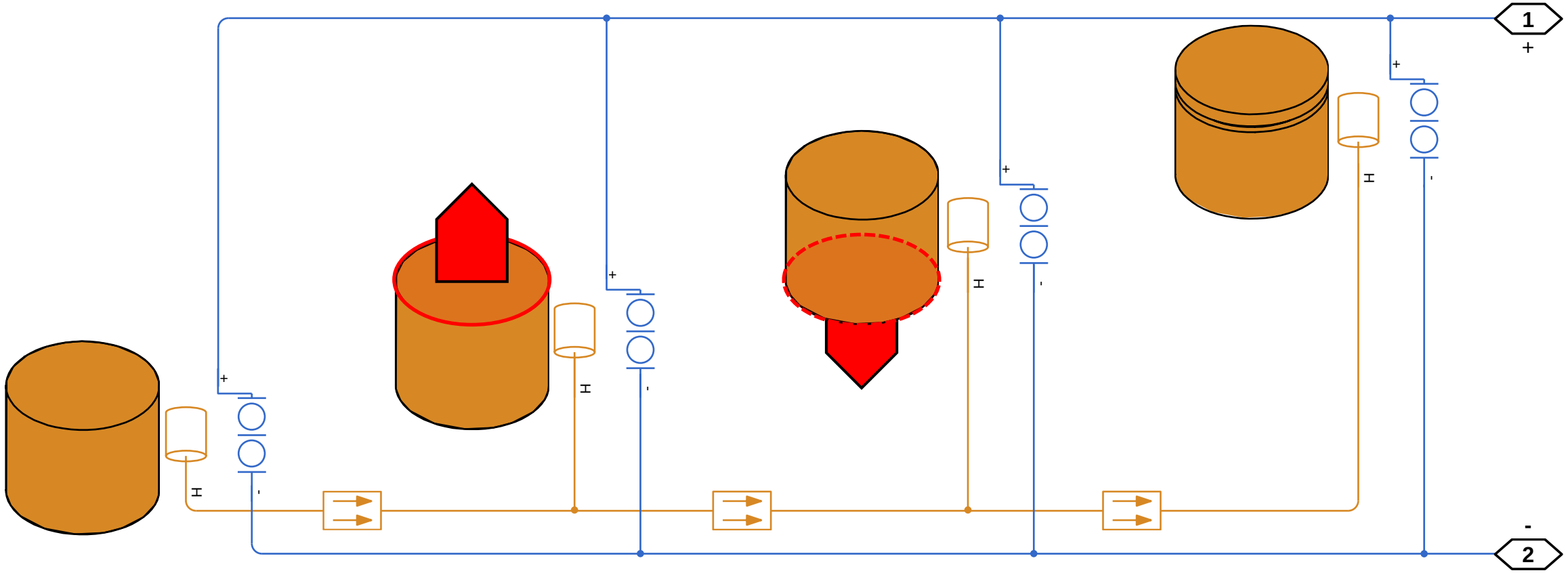
No thermal gradients within the cell





Building a Spatially Discretized Cell

with the SPM Block



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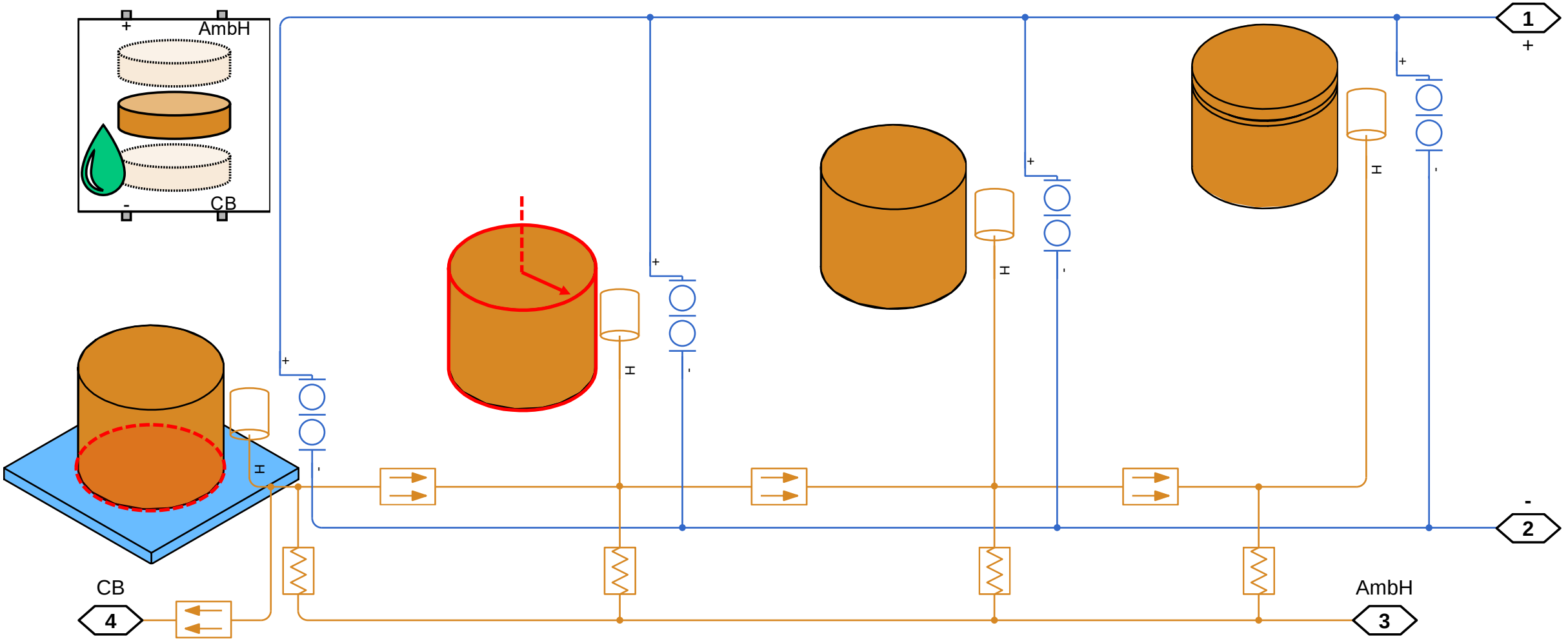
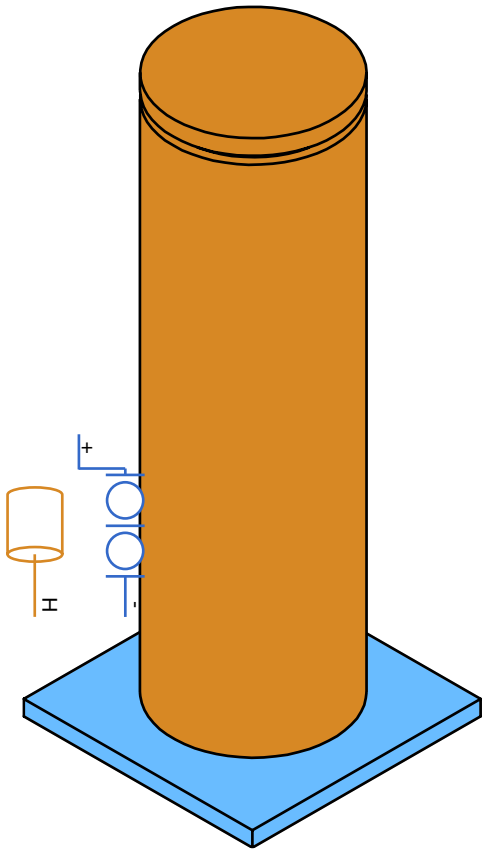
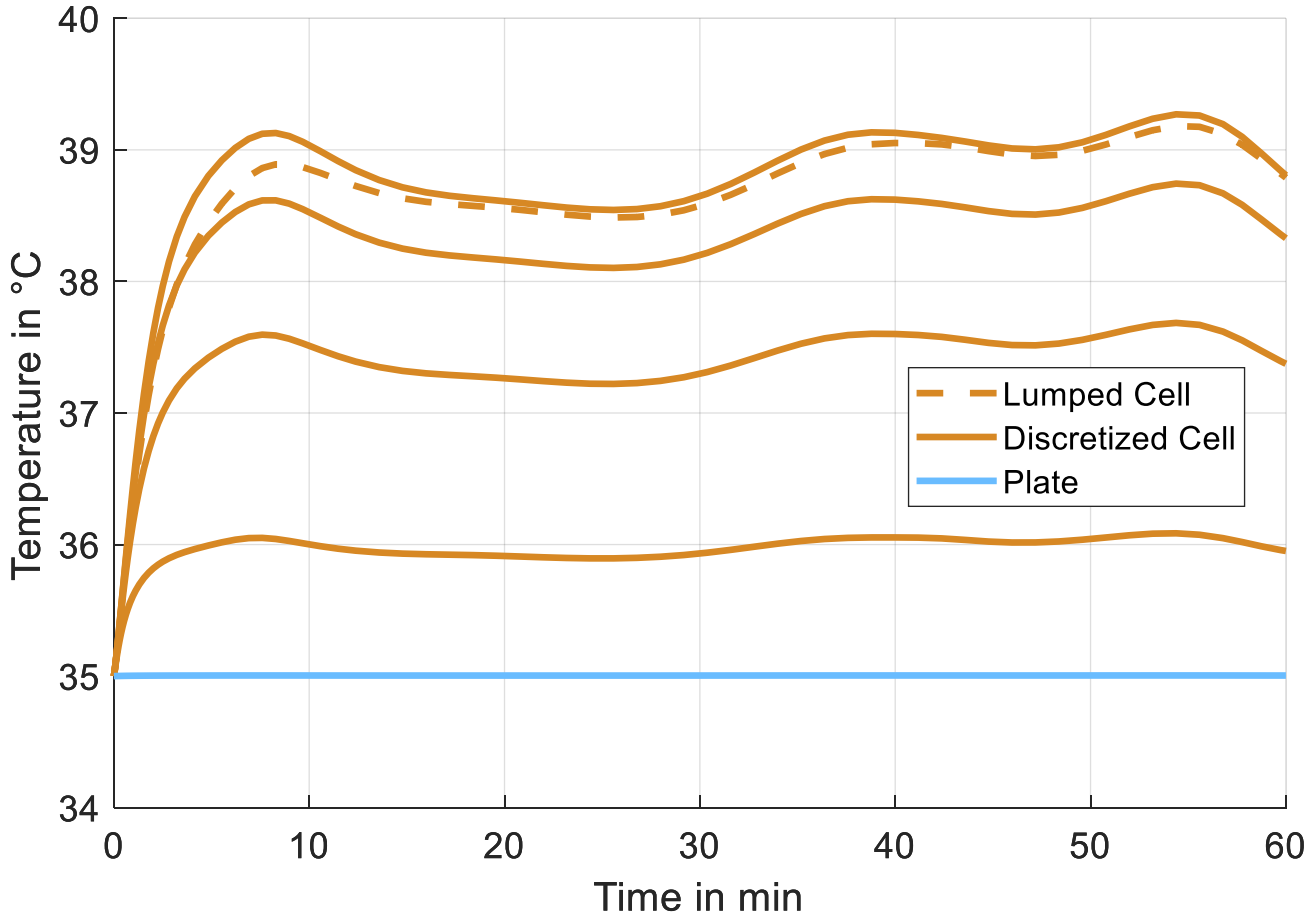


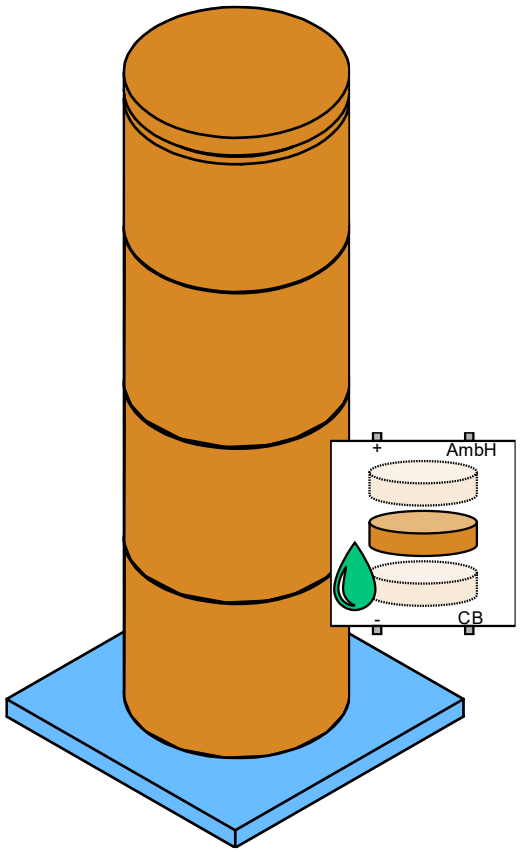
Learn how to automatically generate a Simscape model with `subsystem2ssc`

Building a Spatially Discretized Cell

with the SPM Block

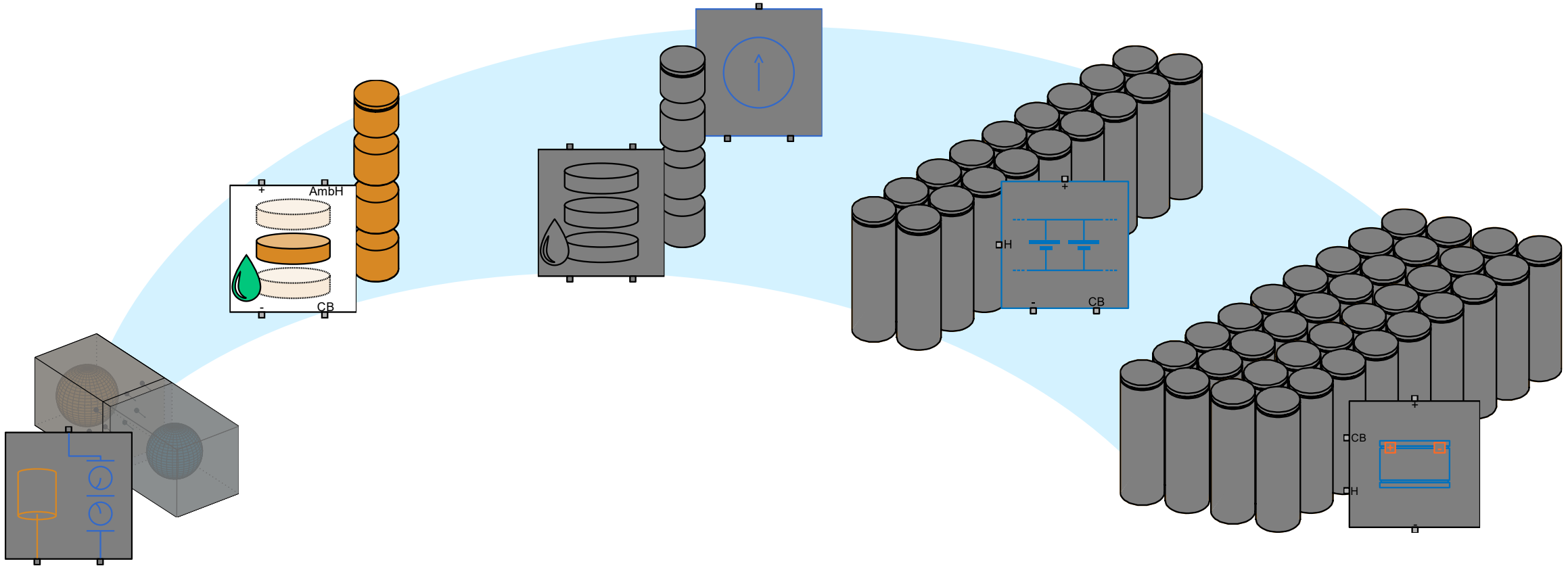






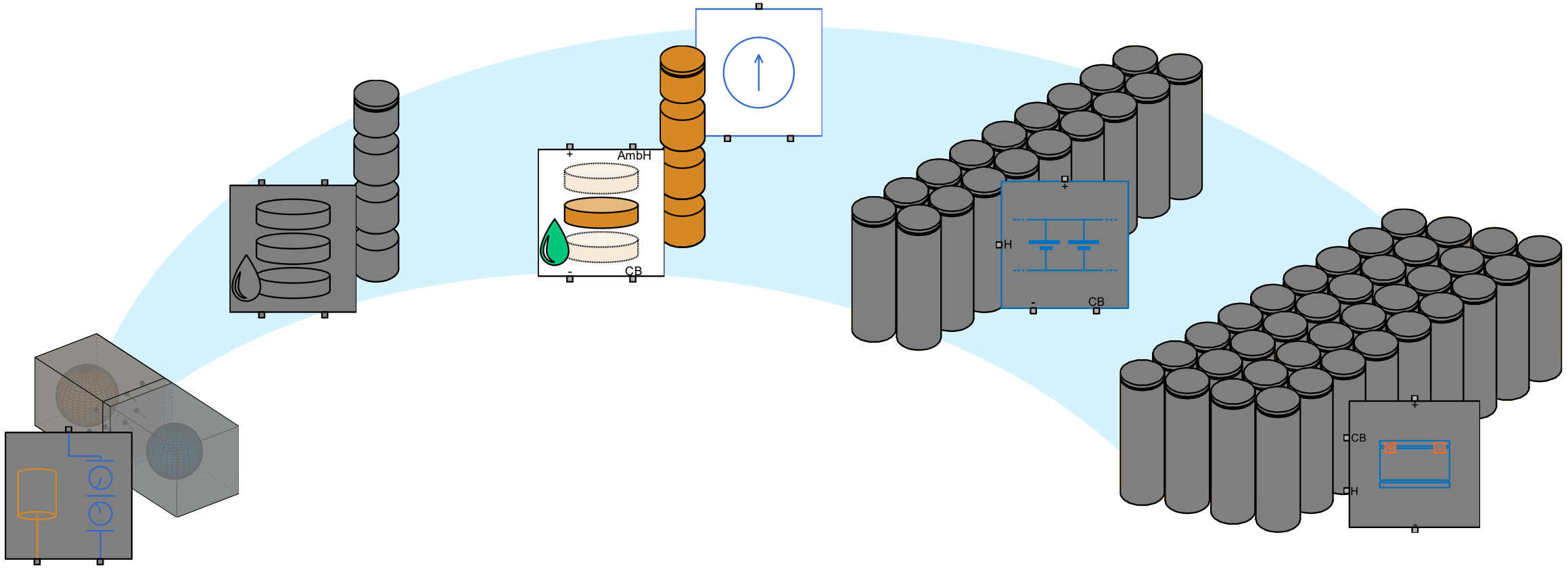
A Journey from Anode to Parallel Assembly

Creating a Spatially Discretized Cell



A Journey from Anode to Parallel Assembly

Cell Characterization

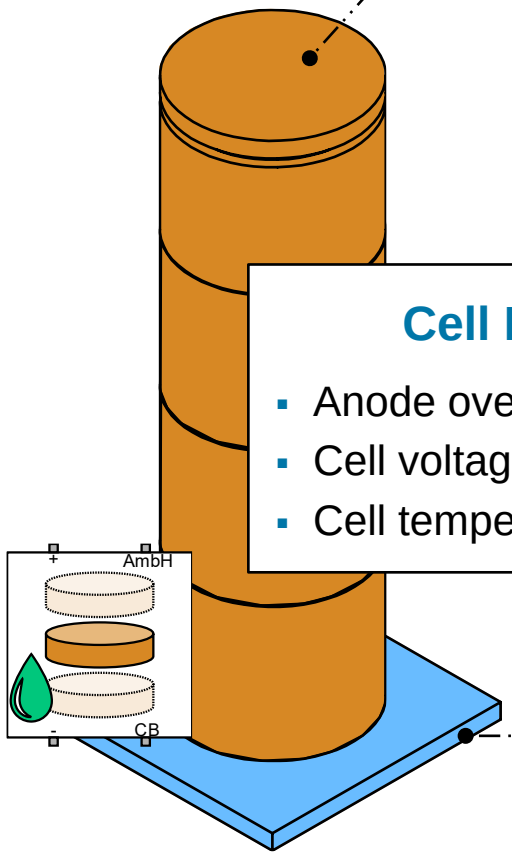


Perform a Cell Characterization through Parameter Sweep

Estimate Current Limits

Initial Conditions

The cell starts at a given SOC and temperature (e.g., 10% and 35°C)



Cell Monitoring

- Anode overpotential* > 20 mV
- Cell voltage < 4.2 V
- Cell temperature < 60°C

Current Derating

Derating based on **Anode overpotential***, cell voltage level, and temperature

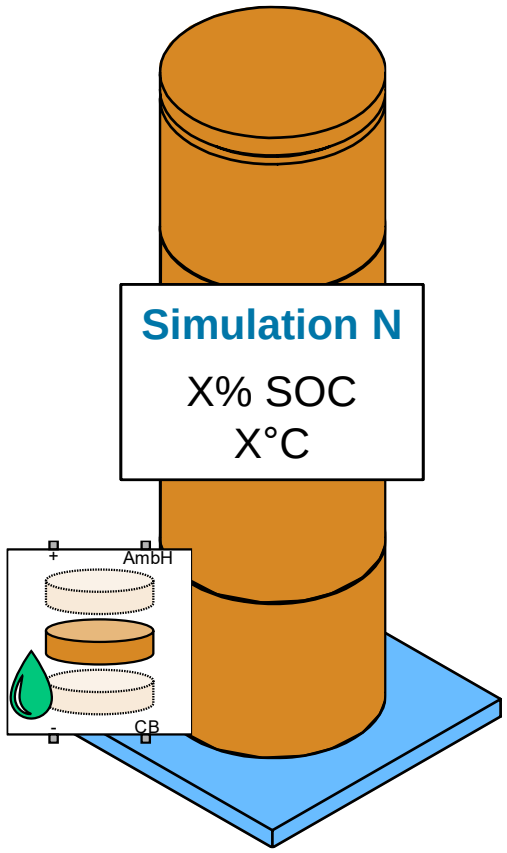
Cell cooling

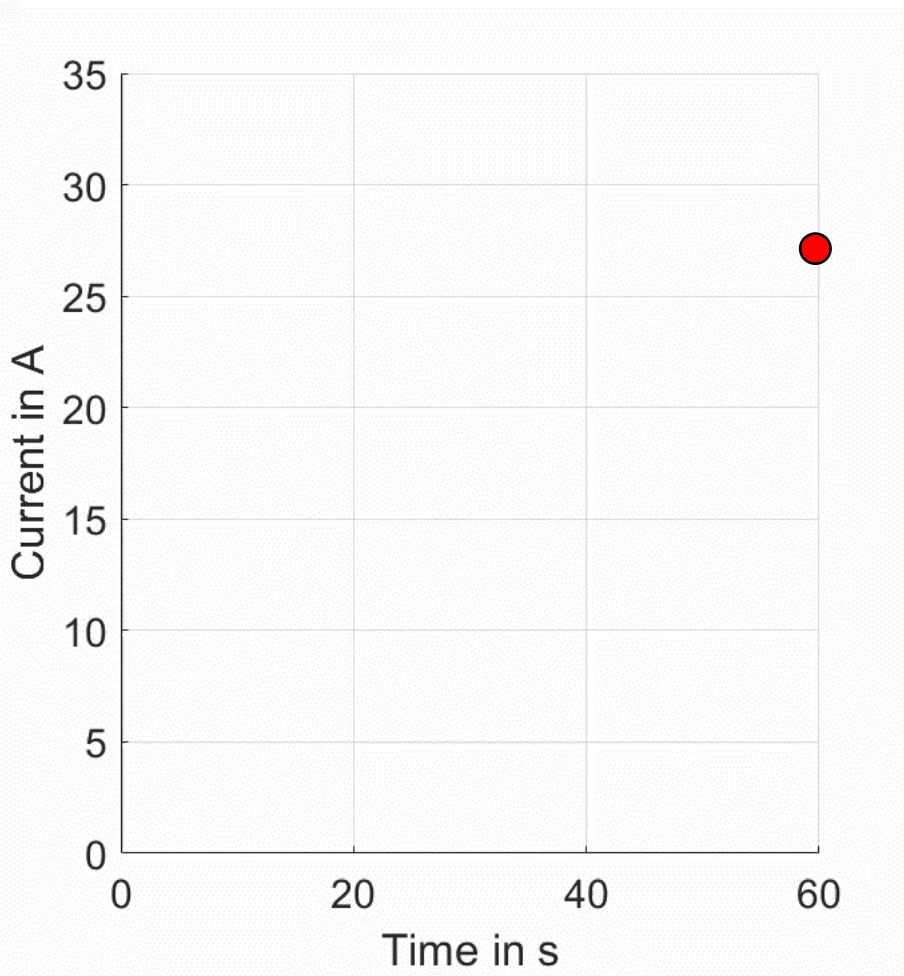
Cooling plate below the cell and heat convection to the environment

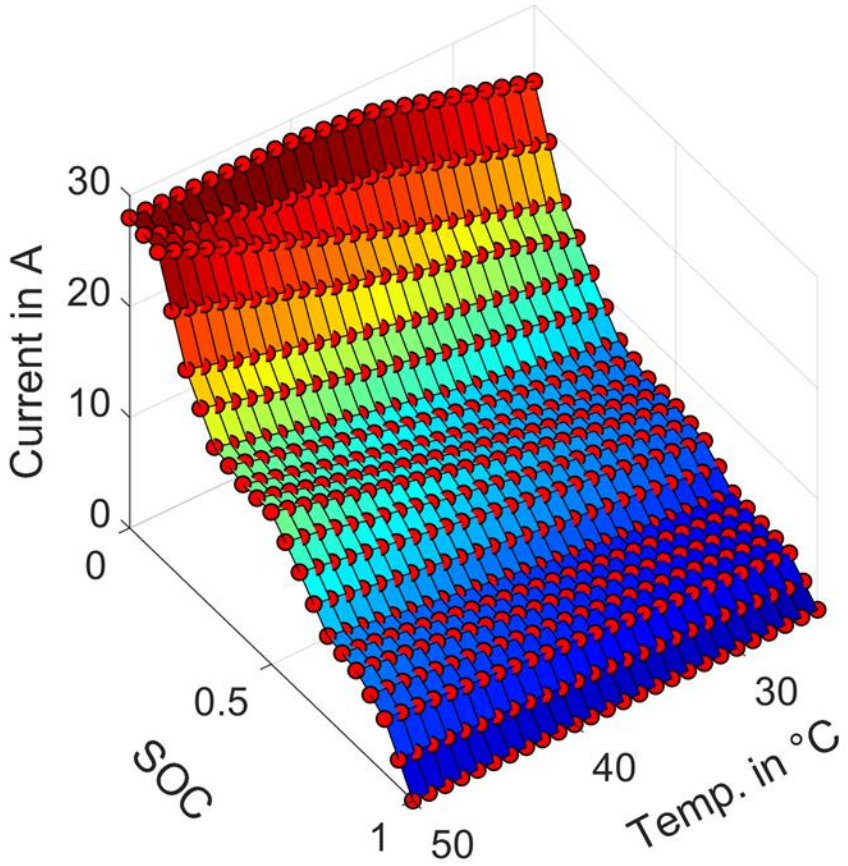
*The anode overpotential is the electrostatic potential vs. the Li reference. It has been implemented by modifying the source code

Perform a Cell Characterization through Parameter Sweep

Estimate Current Limits







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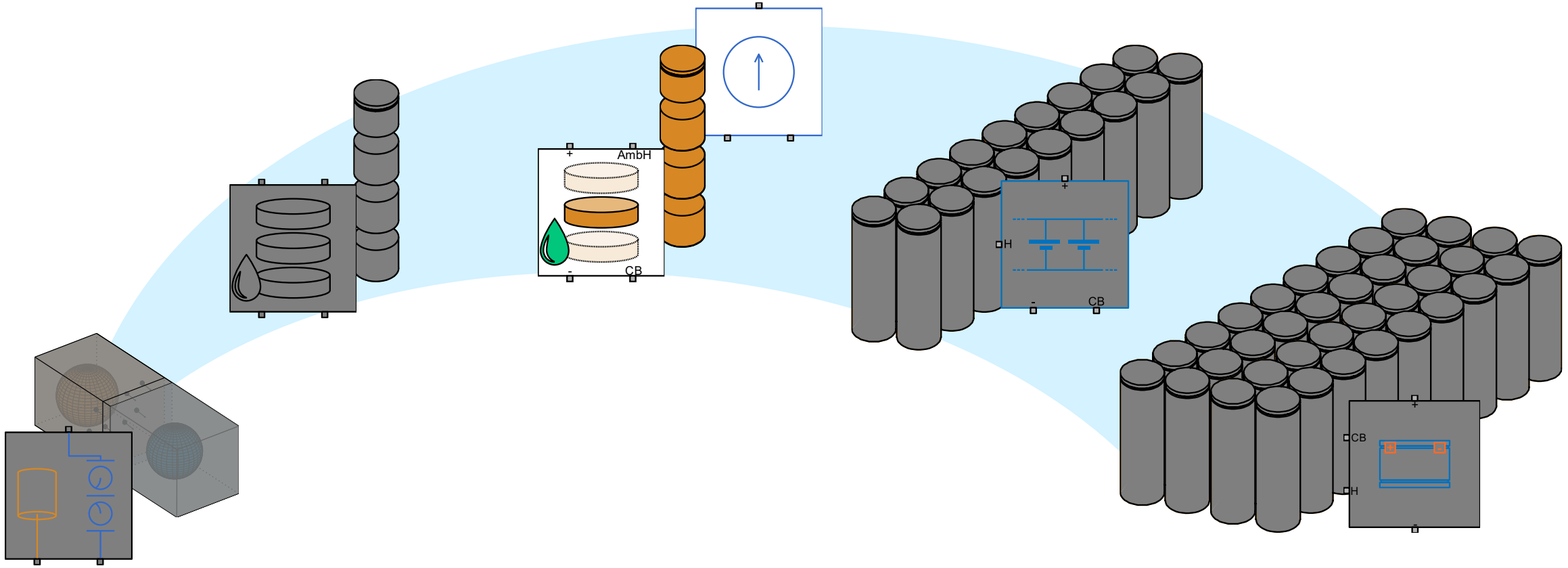
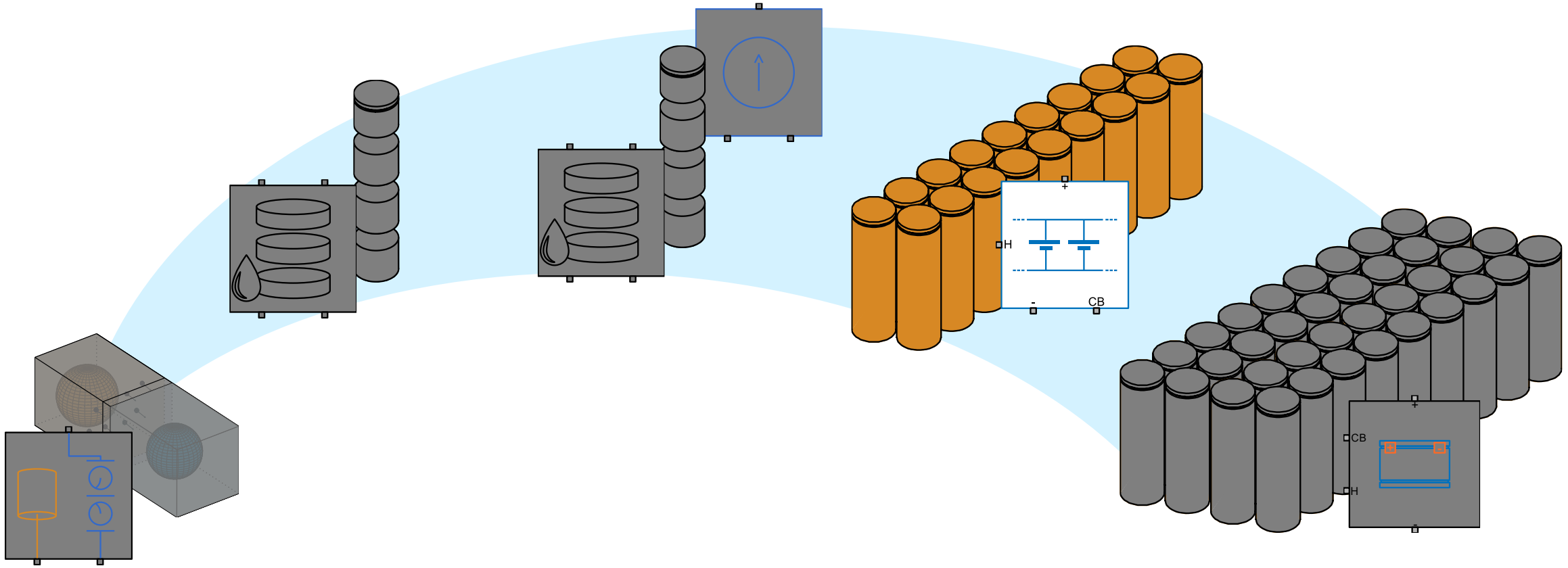


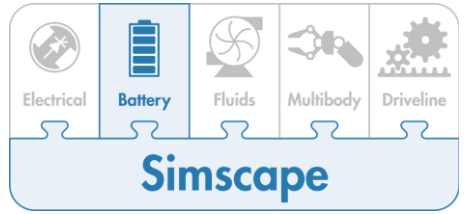
A Journey from Anode to Parallel Assembly

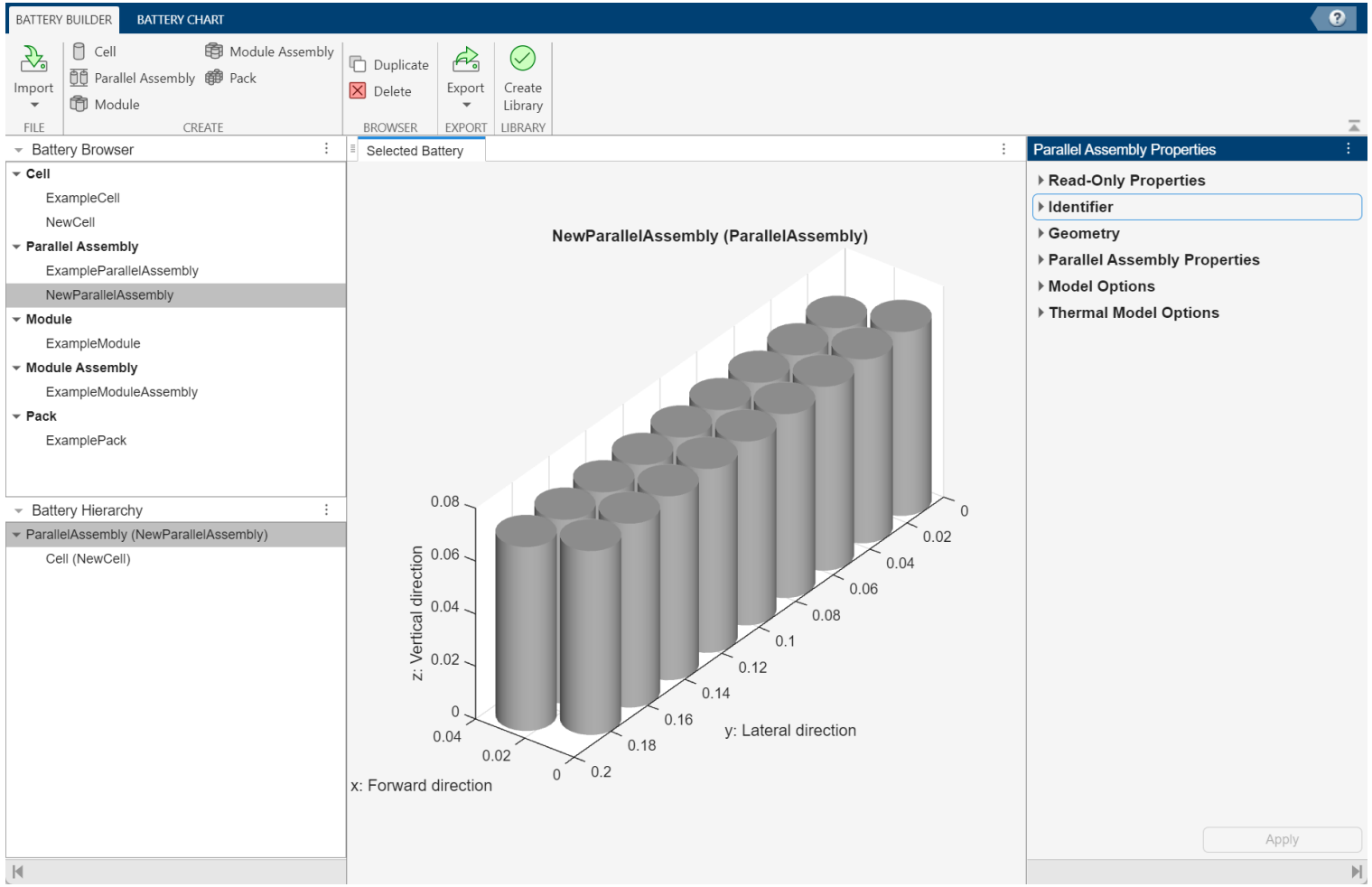
Scale to Parallel Assembly

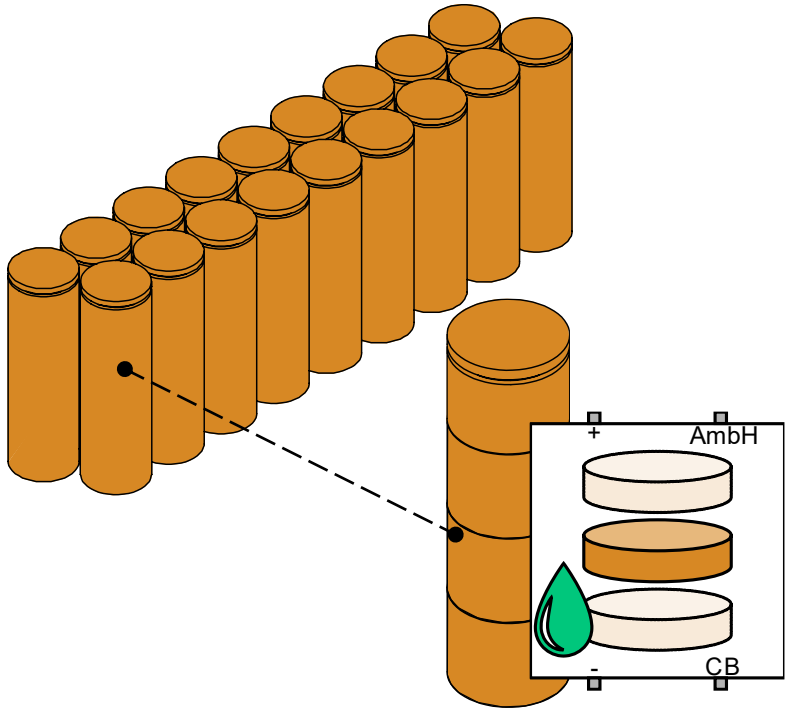


From Cell to Parallel Assembly

with the Simscape Battery Builder App



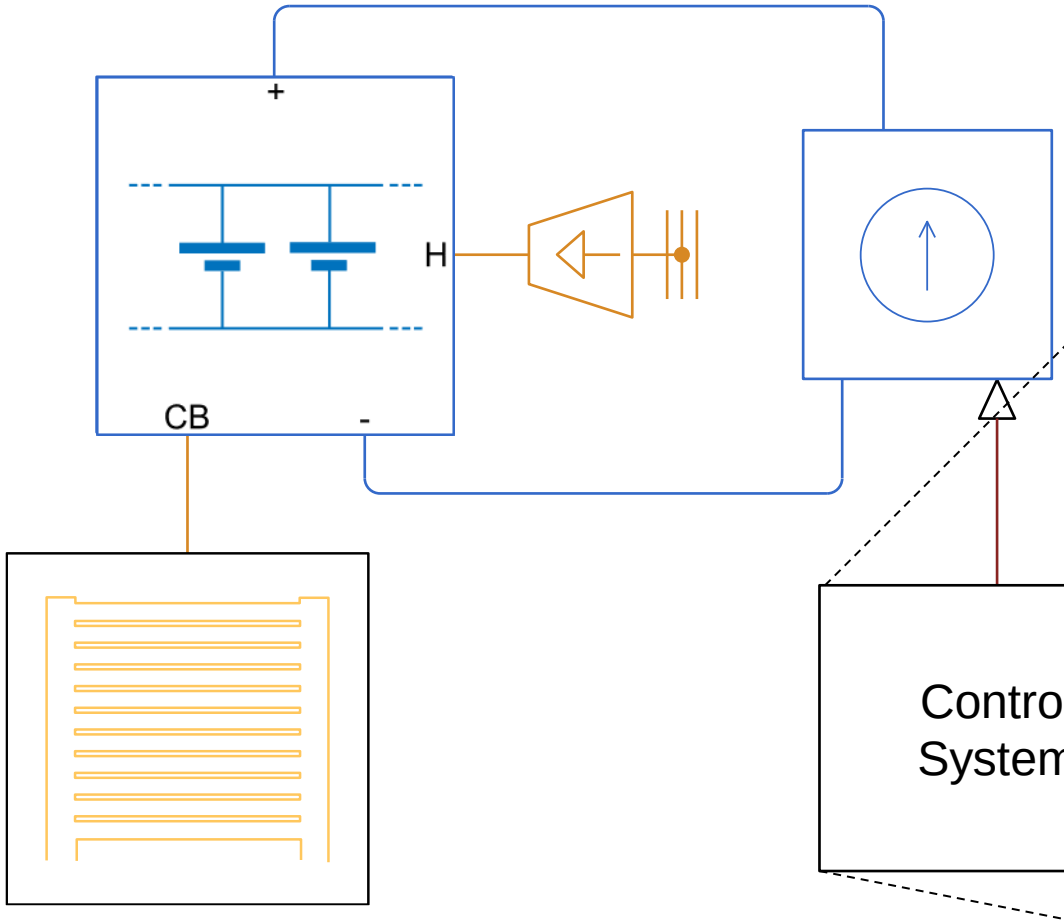




Learn more about the [Battery Builder App]

From Cell to Parallel Assembly

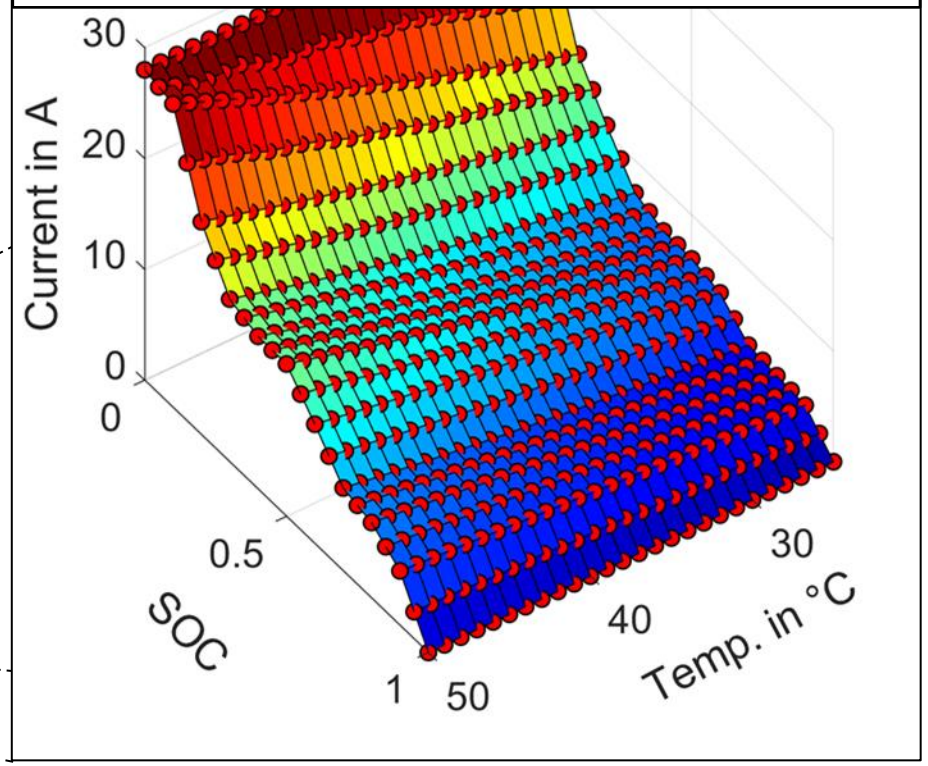
Parallel assembly fast charge



Control System

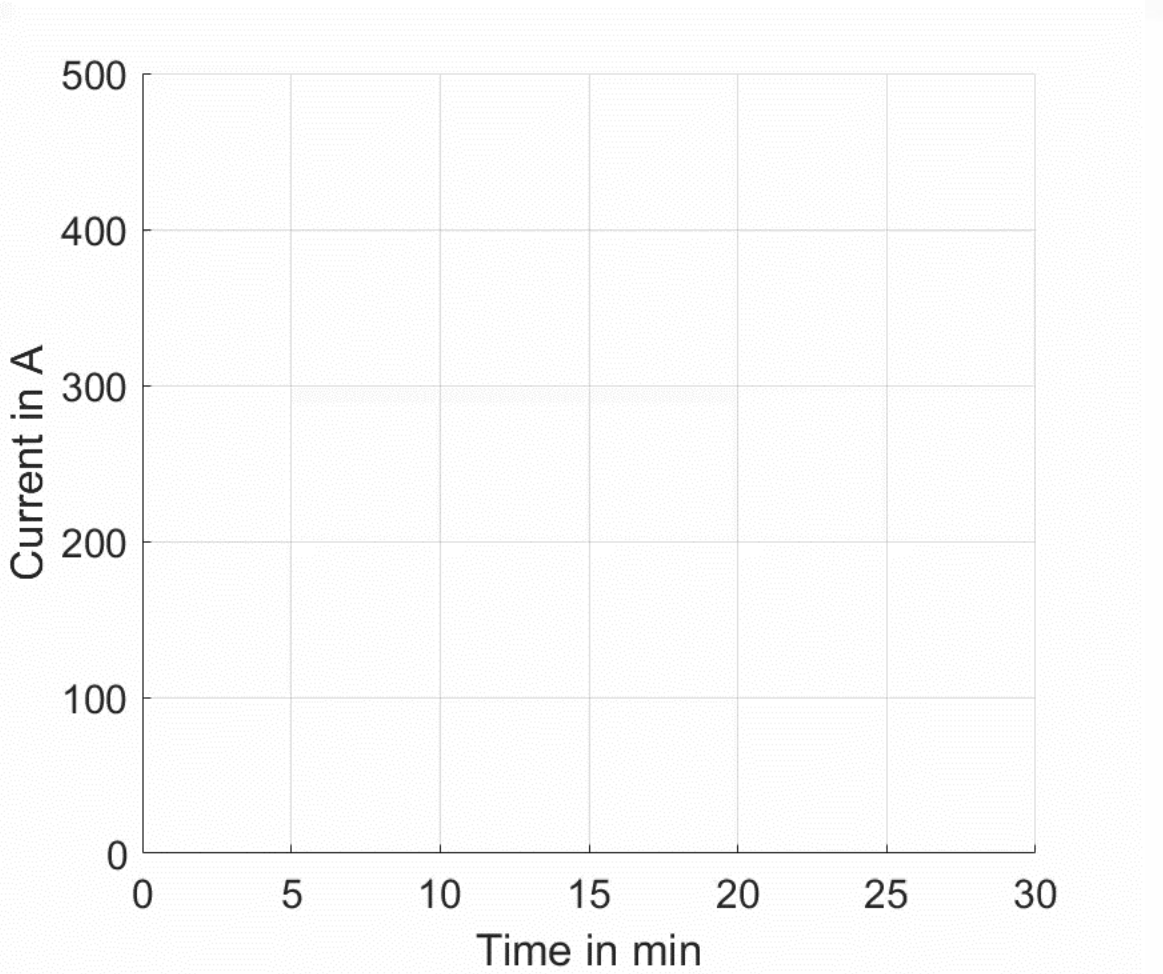
Parallel Assembly Monitoring

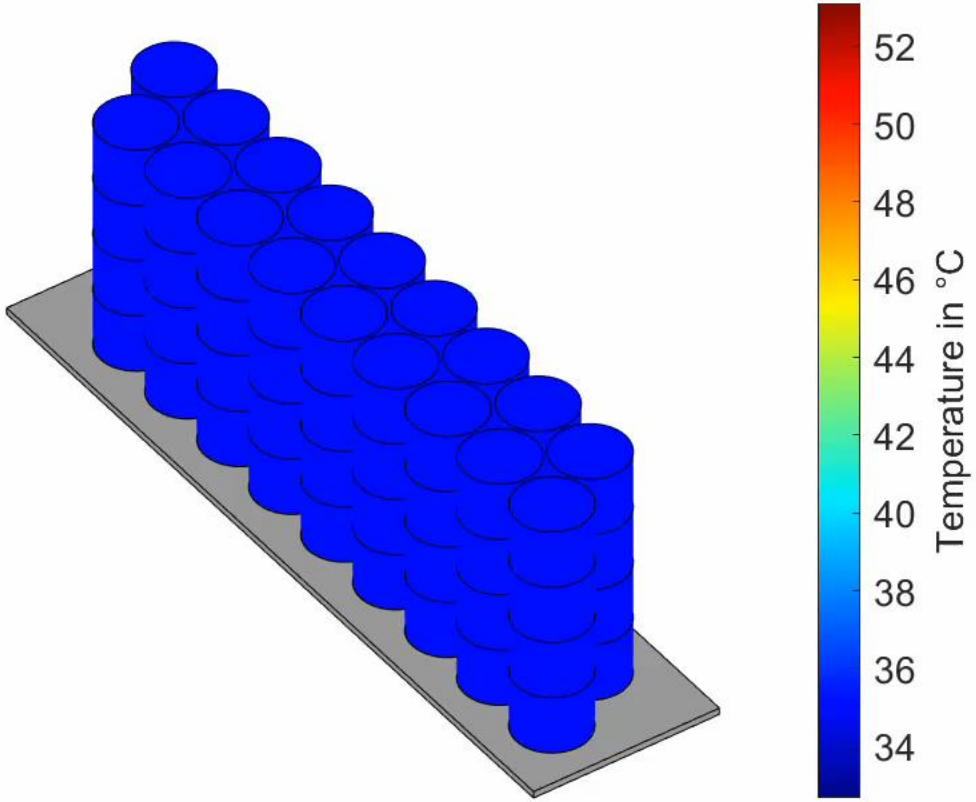
Select the charging current based on the lowest temperature and the highest SOC



From Cell to Parallel Assembly

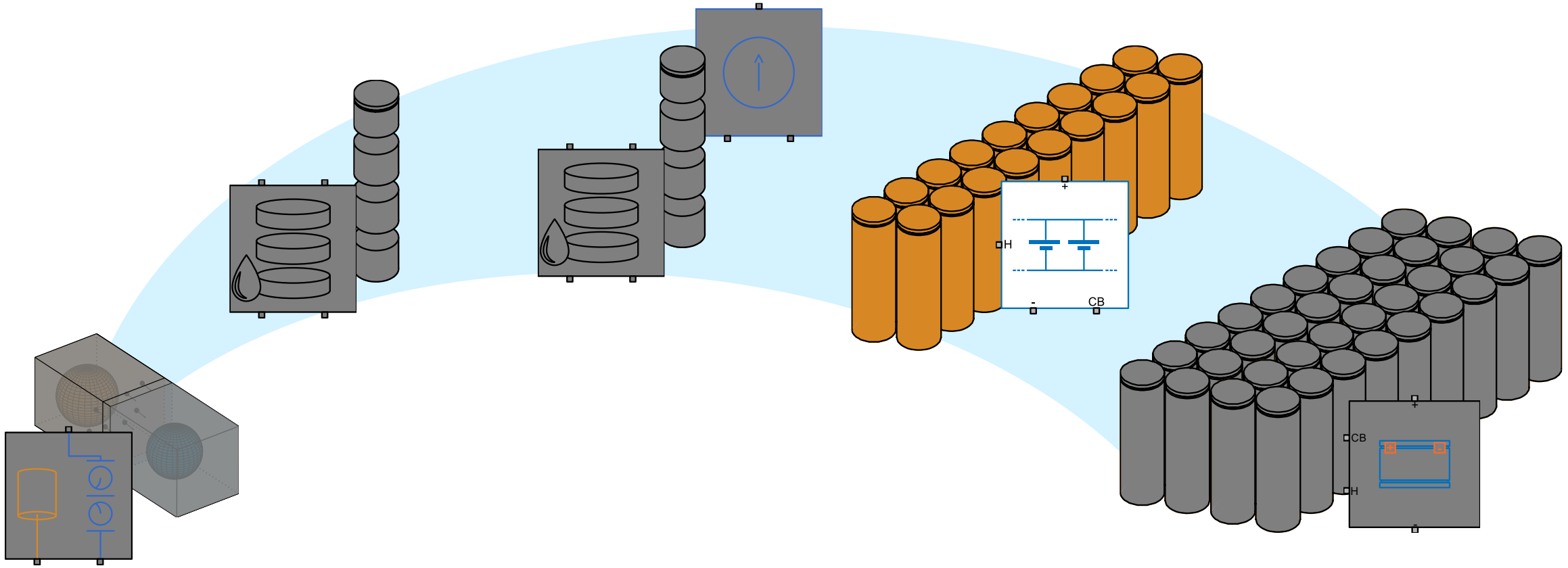
Parallel assembly fast charge





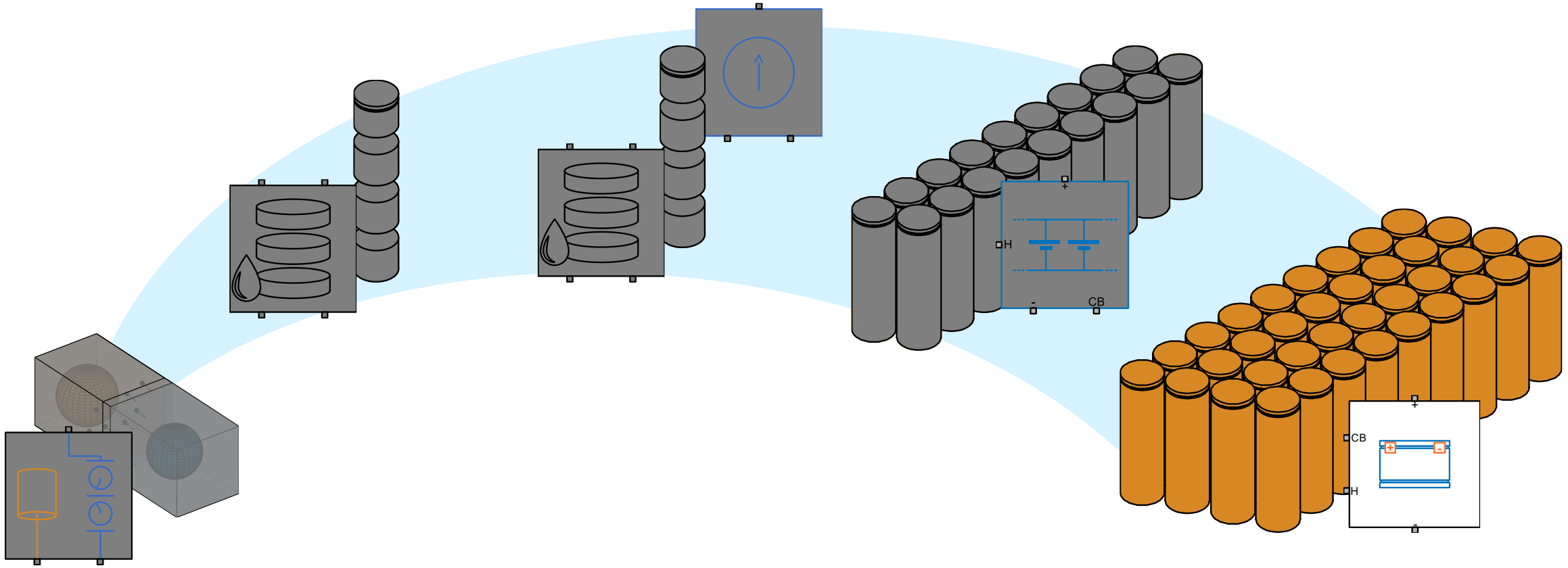
A Journey from Anode to Parallel Assembly

Scale to Parallel Assembly



A Journey from Anode to Parallel Assembly

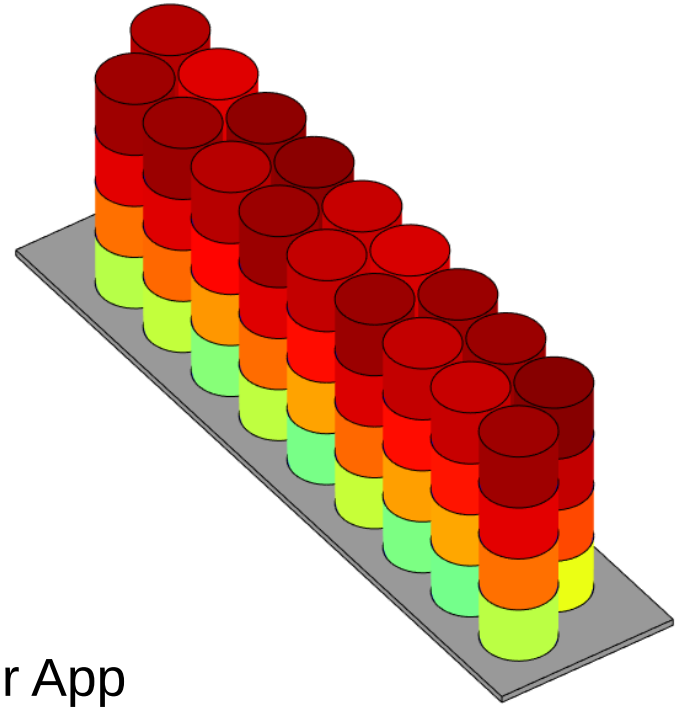
Where to go next?



Summary and Outlook

What did you learn today?

- As the number of cell increases, empirical models can be employed
- Use Simulink® Design Optimization™ to “reduce” your models
- Topics discussed:
  1. Electrochemical cell model (SPM)
  2. Build and characterize a discretized cell
  3. Scale your cell to a parallel assembly
- Key take-away:
  - Simscape Battery now provides electrochemical models
  - You can easily modify and extend the cell models
  - You can integrate your custom models into the Battery Builder App



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Thank you

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