

A New Multiphysics Modeling Framework to Simulate Large Battery Packs

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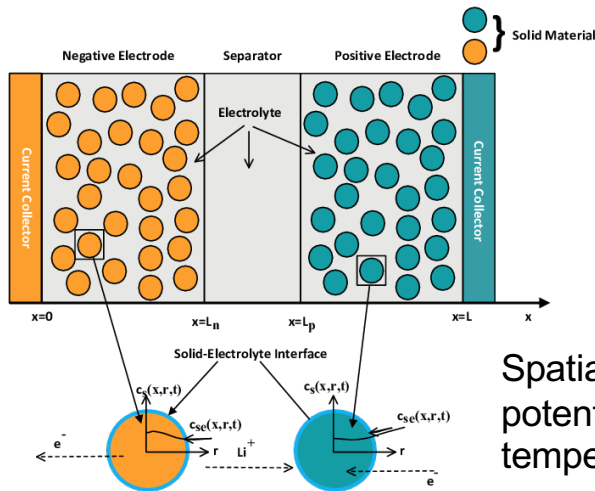
NASA Aerospace Battery Workshop, Huntsville, AL
Nov. 15 – 17, 2022

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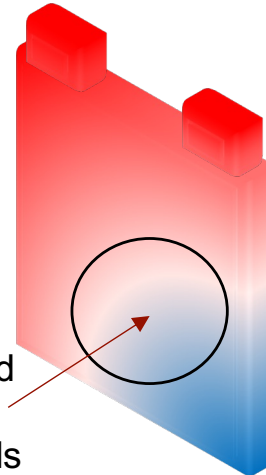


Underlined: Graduate student

Background and Motivation



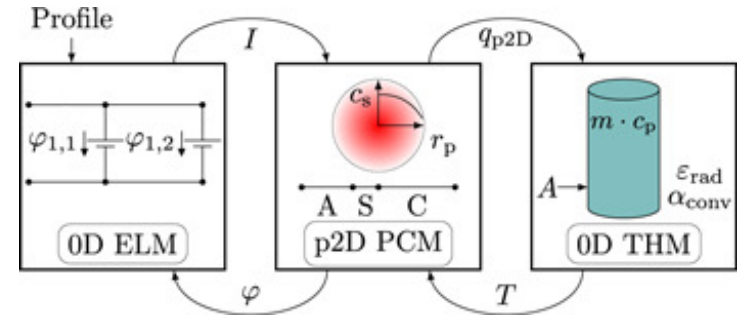
Spatially resolved potential and temperature fields



Microscale, p2D, SPM, etc.

MSMD battery model

Markus Schindler et al 2020 J. Electrochem. Soc. 167 120542



Simplified models or CFD only simulations

Electrode length scale
 $< 1\text{Ahr}$
 $\sim 4\text{V}$

Battery length scale
 $> 1\text{Ahr}$ and $< 100\text{Ahr}$
 $\sim 4\text{V}$

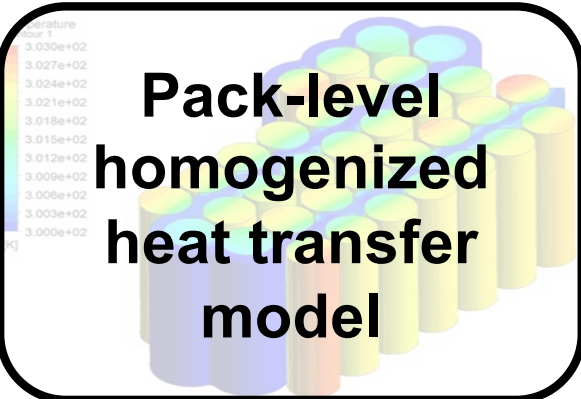
Battery pack length scale
 $> 100\text{Ahr}$
 $> 100\text{V}$

Continuum level physics-based battery models

Battery pack-level modeling framework

**Cell and coolant
temperature**

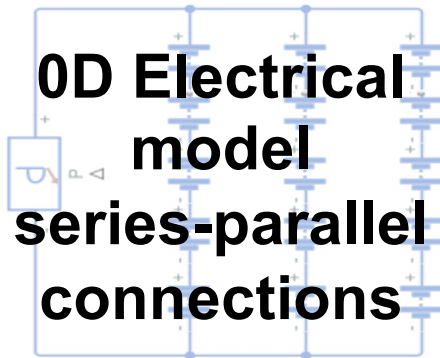
**Pack-level
homogenized
heat transfer
model**



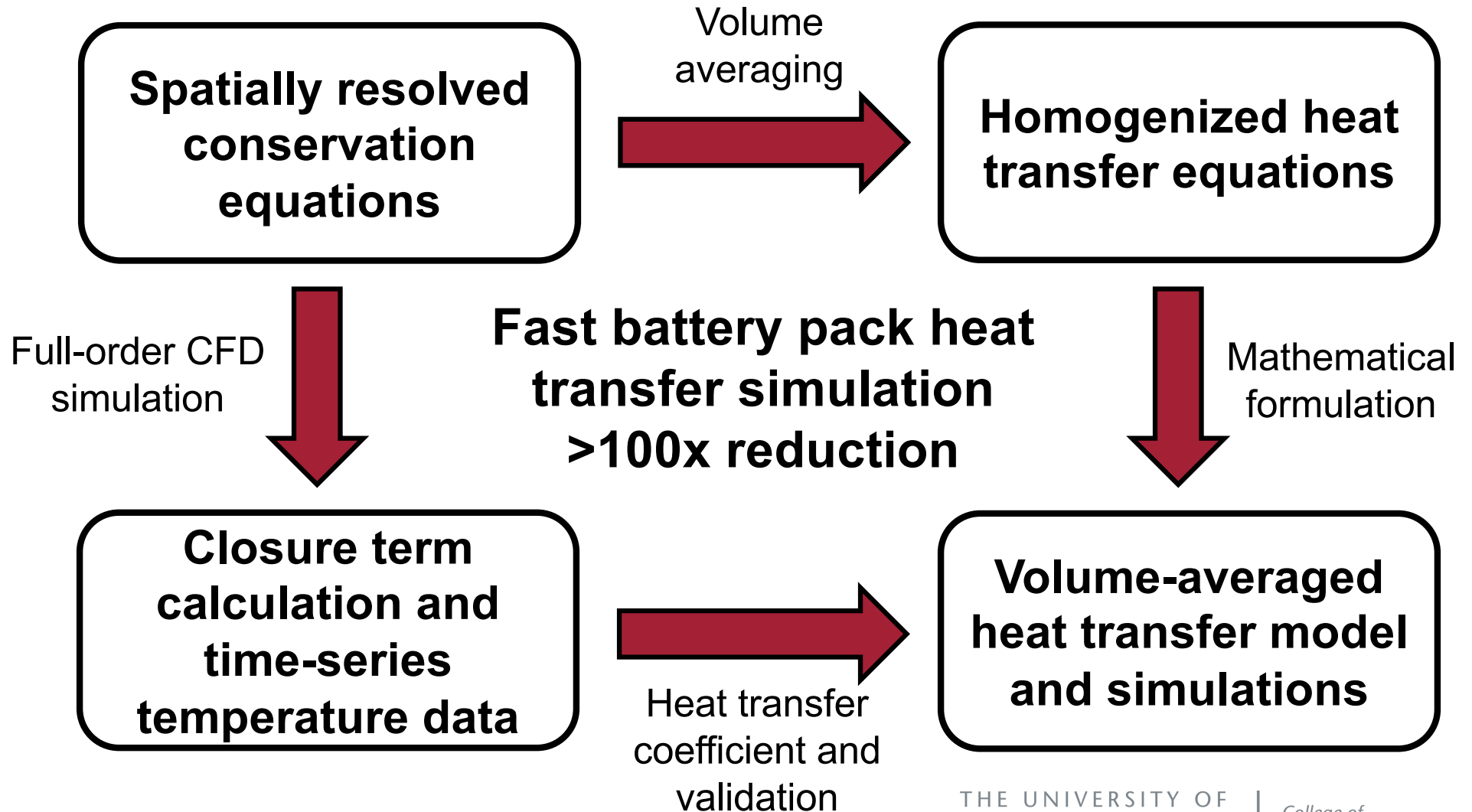
**Electrode-scale
volume-averaged
Tank-in-series
battery model**

Akshay Subramaniam et al 2020 J.
Electrochem. Soc. 167 113506

**0D Electrical
model
series-parallel
connections**

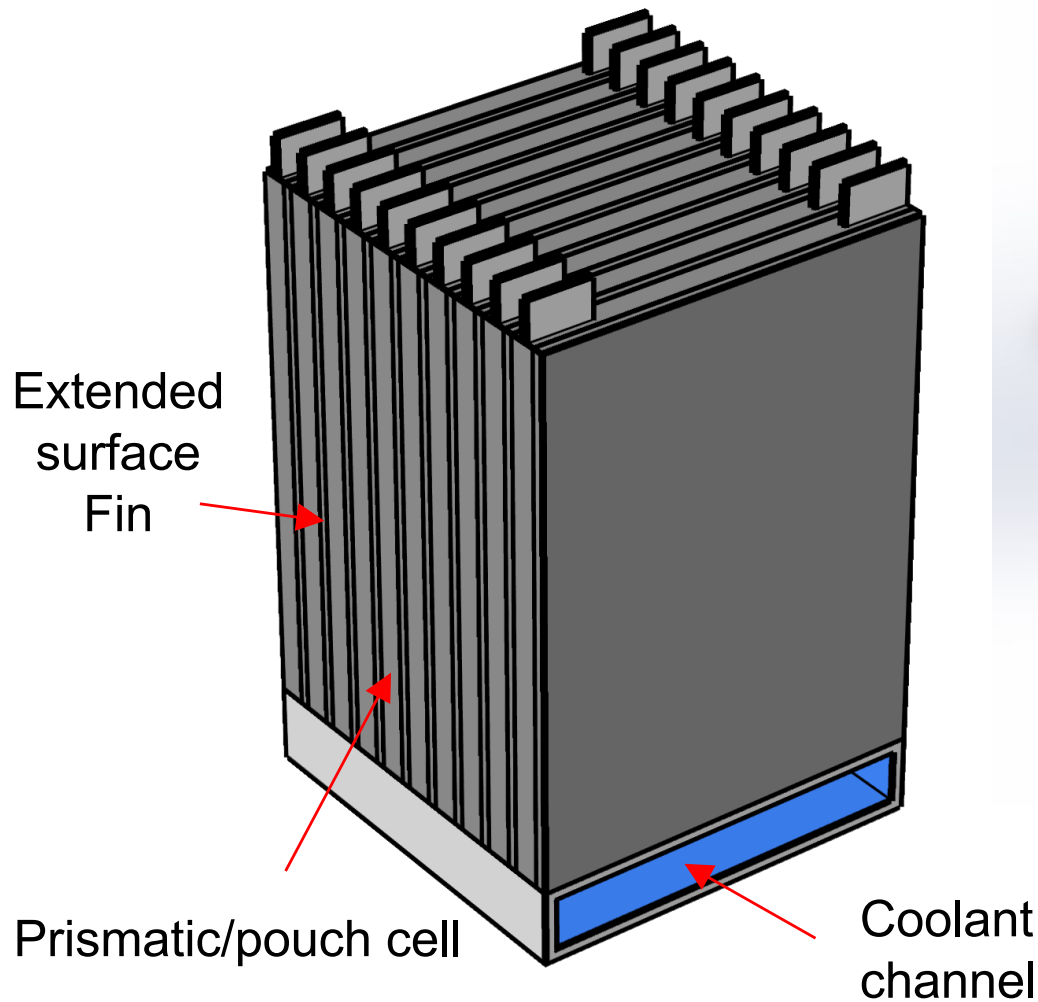


Battery pack-level modeling framework

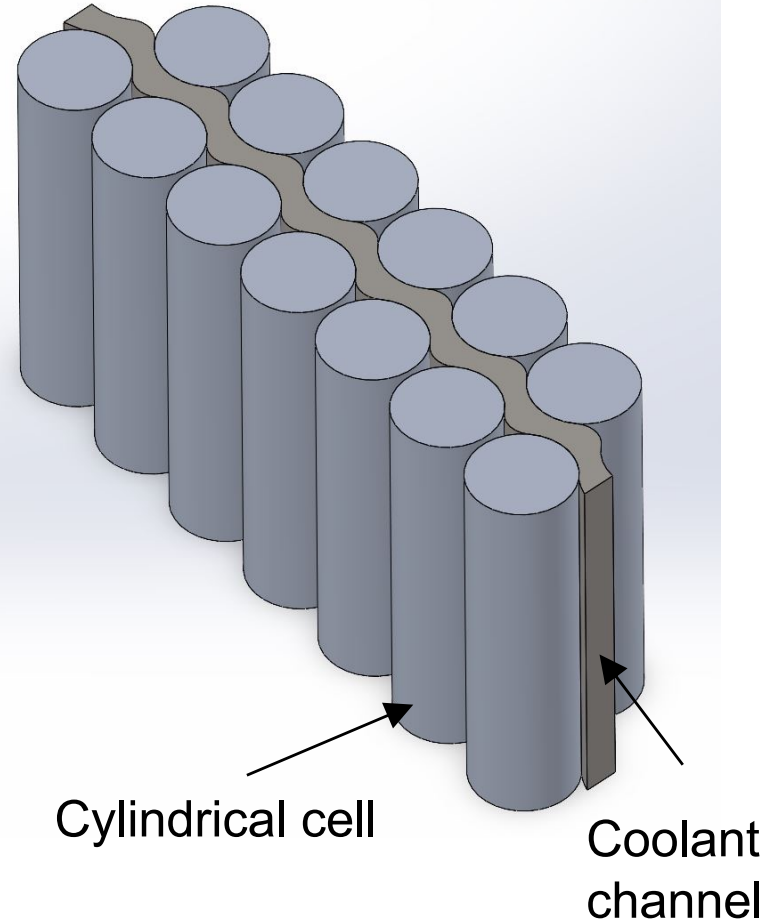


Heat Transfer Model Validation

Pack configuration A



Pack configuration B



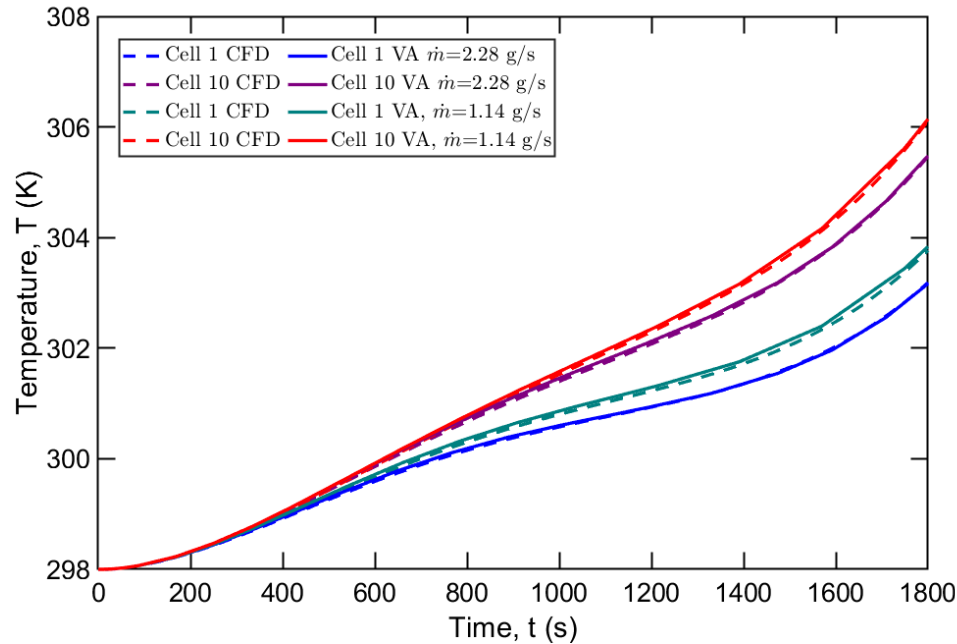
Heat Transfer Model Validation

No electrochemical model

Heat generation vs time data from literature

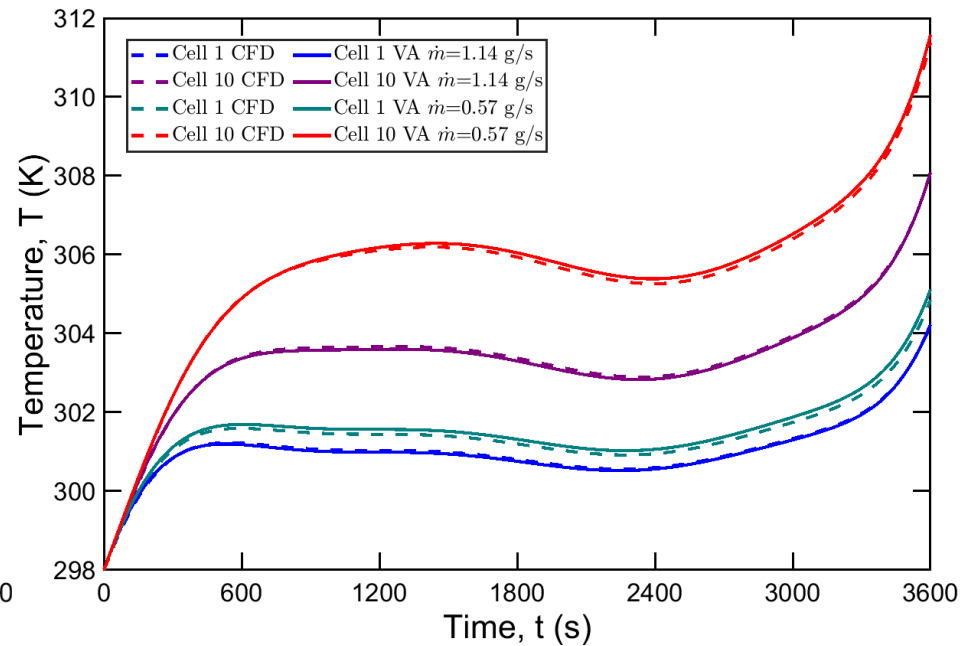
Different discharge and mass flow rates

Pack configuration A



2C discharge rate

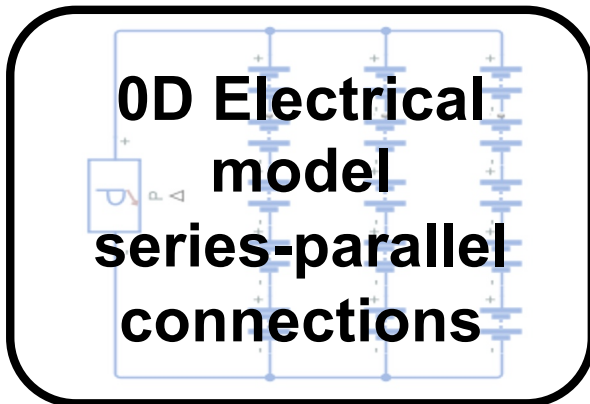
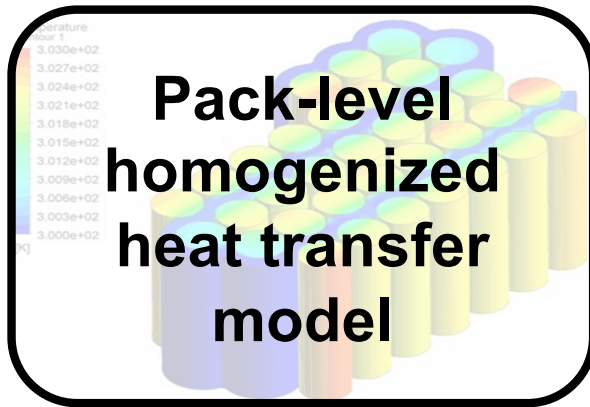
Pack configuration B



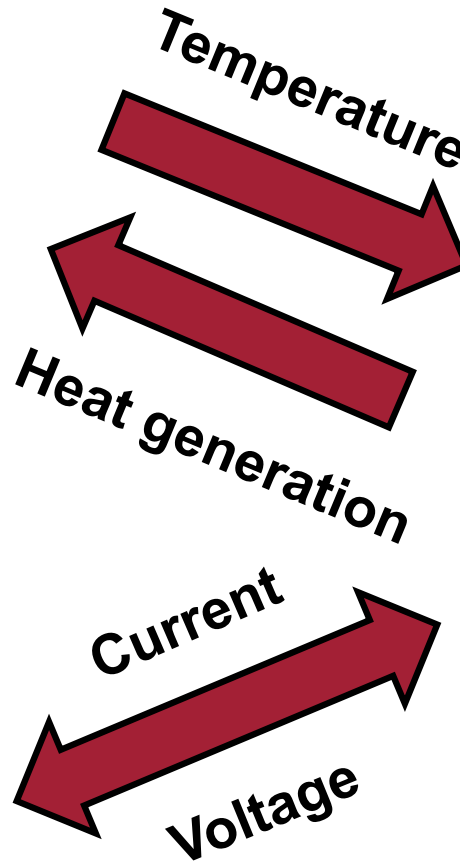
1C discharge rate

Battery pack-level modeling framework

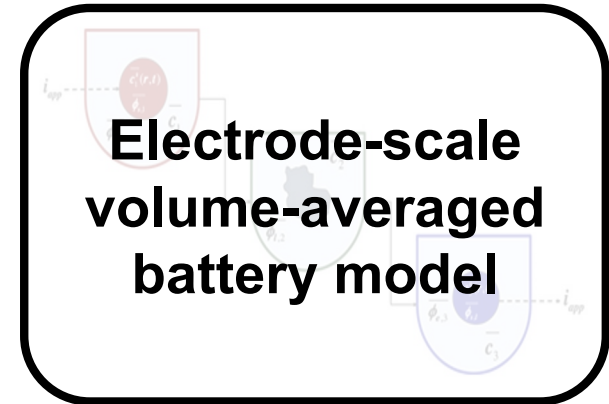
Cell and coolant temperature



Pack voltage and module current



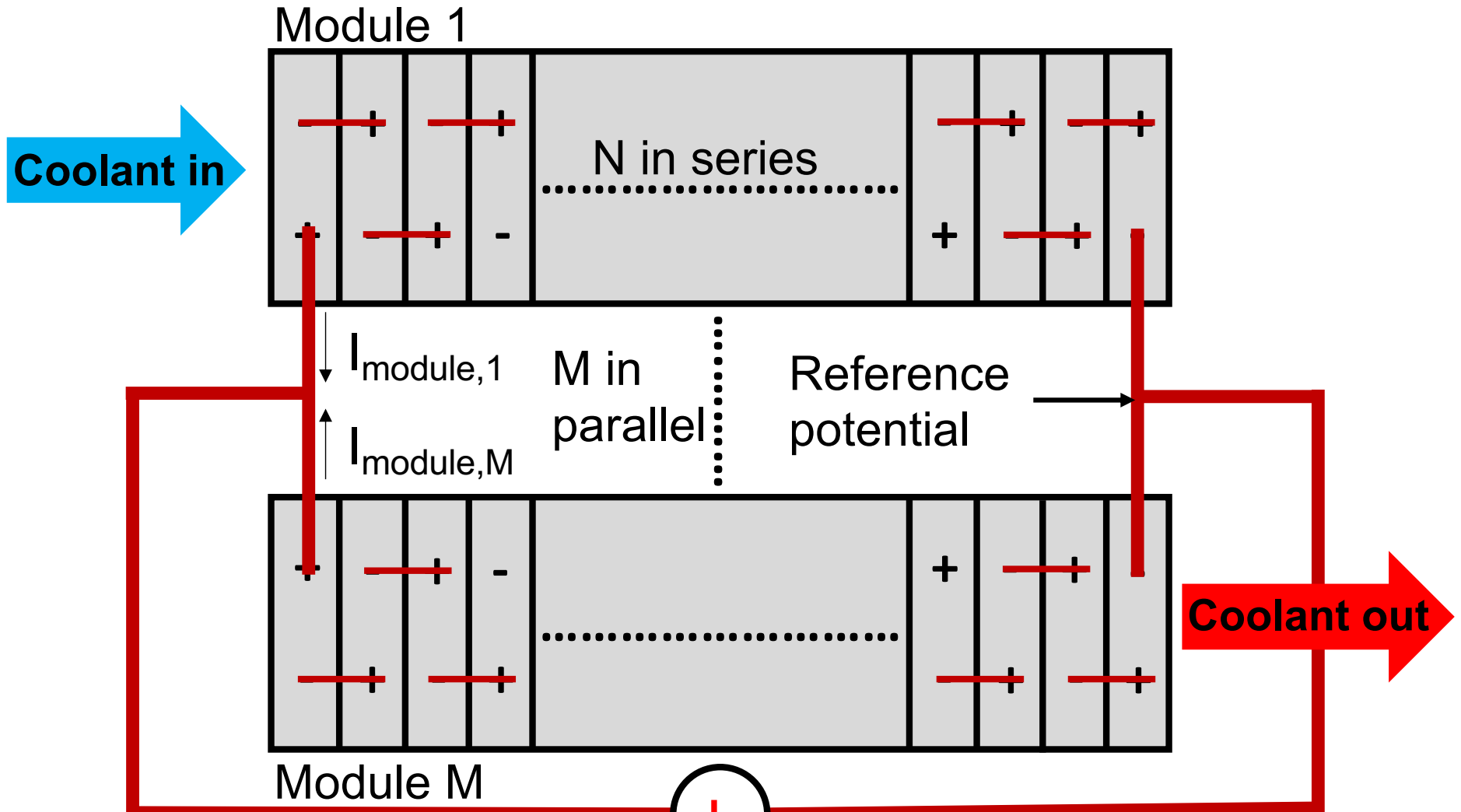
Internal states



Cell terminal voltage

100-300 cells*: ~50-150s for one discharge cycle

Pack level configuration – NsMp



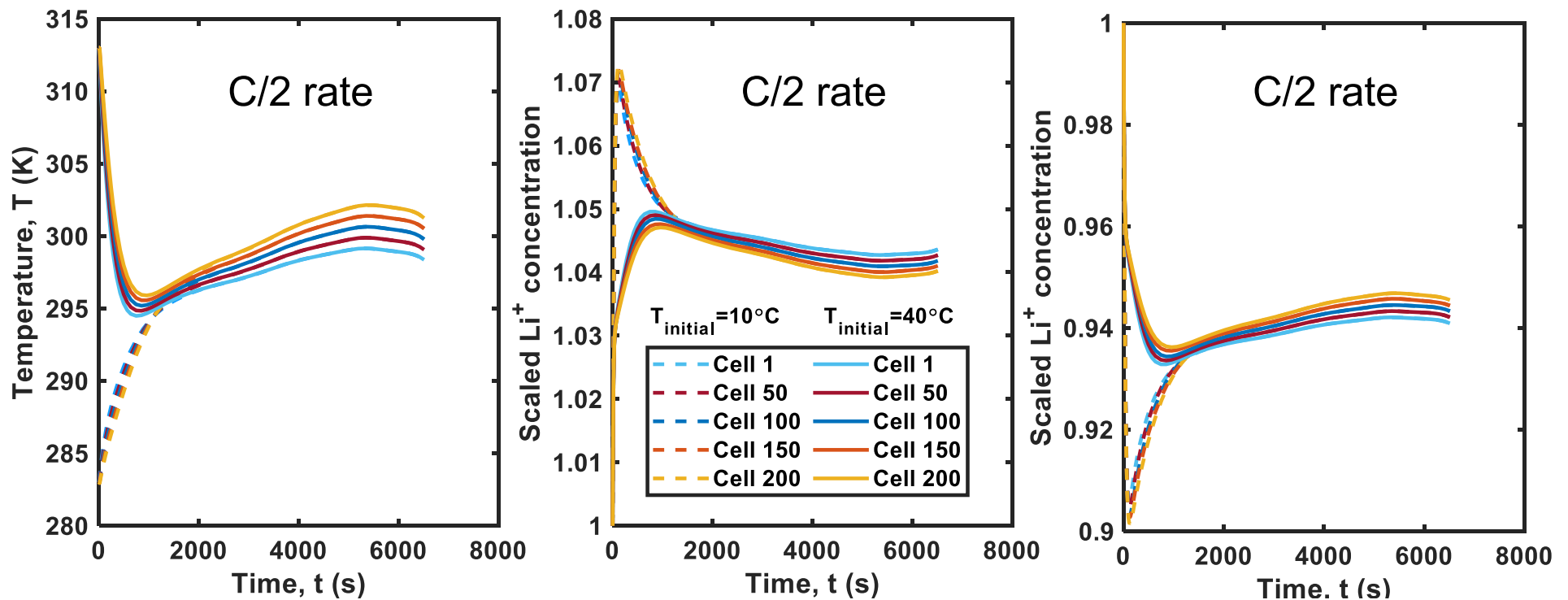
$$I_{\text{pack}} = \sum_{i=1}^M I_{\text{module},i}$$

Pack level simulation results – Effect of initial temperature – 100s2p

Low heat generation rate

Time to cool/warm up the cells much smaller than discharge time

Effect of initial temperature only visible at early times

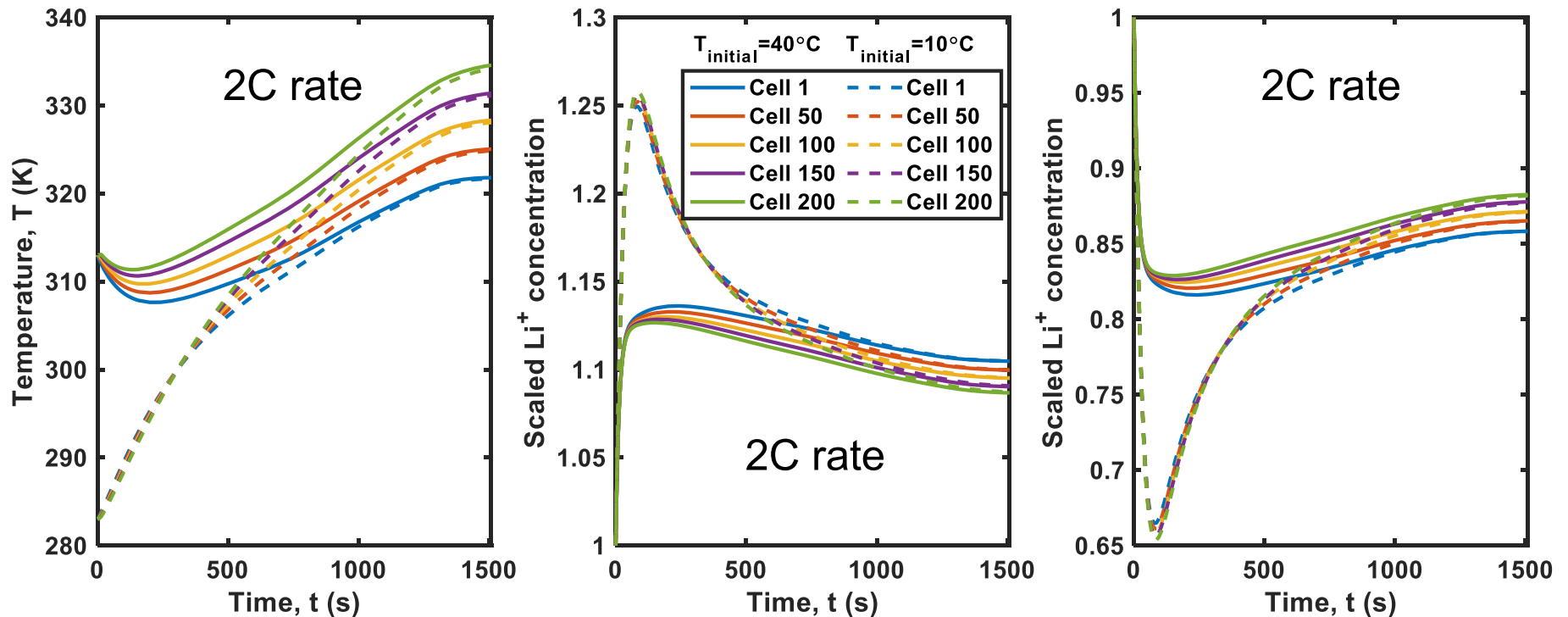


Pack level simulation results – Effect of initial temperature – 100s2p

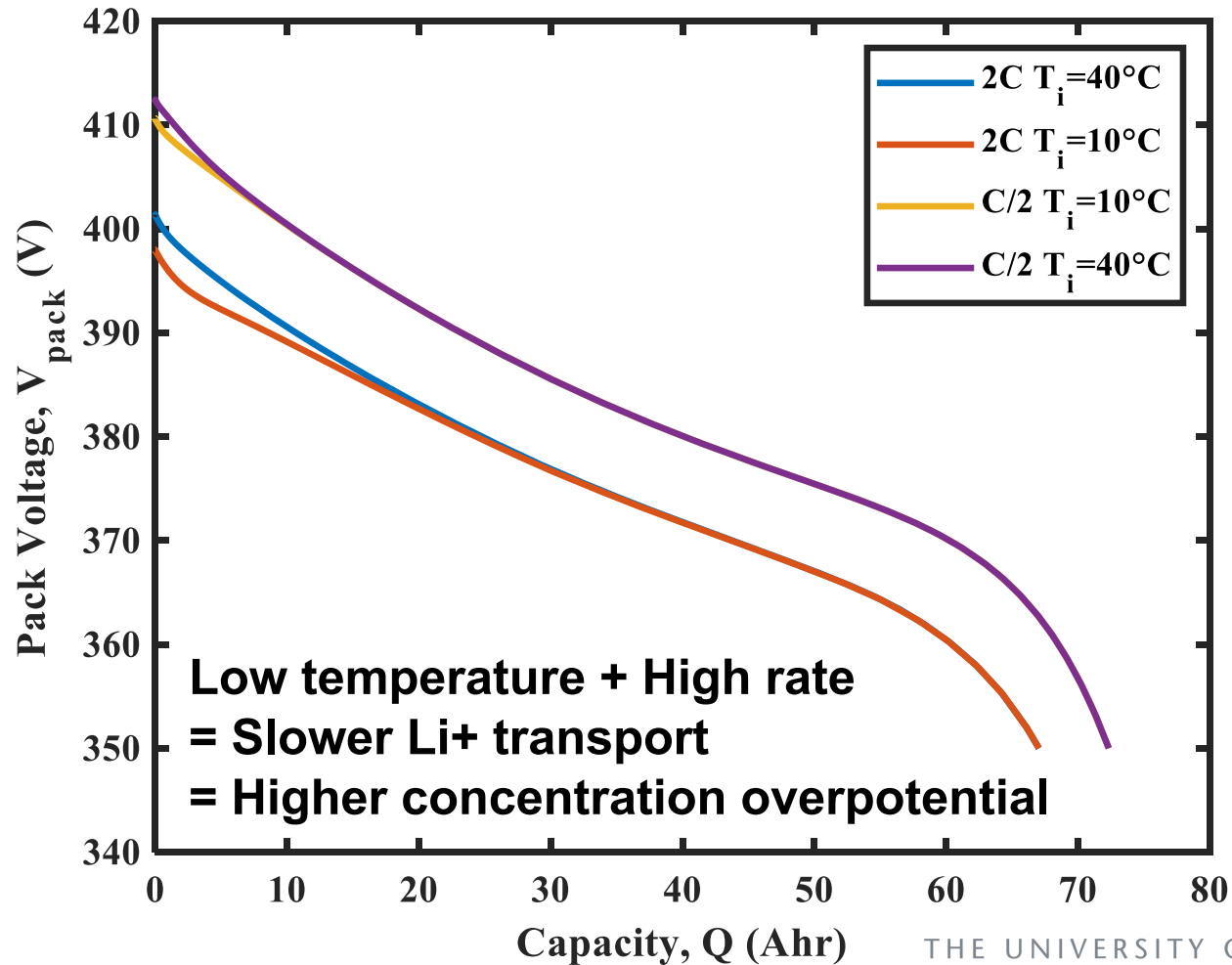
High heat generation rate

Less time for the cells to cool/warm up relative to discharge time

Effect of initial temperature for a significant portion of the discharge



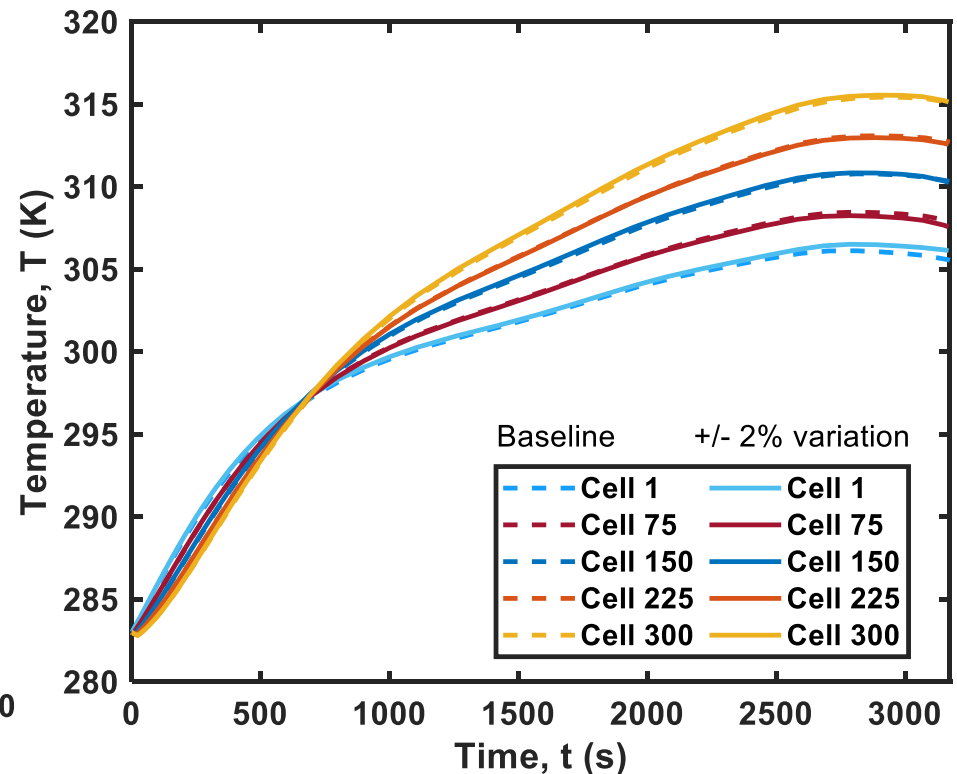
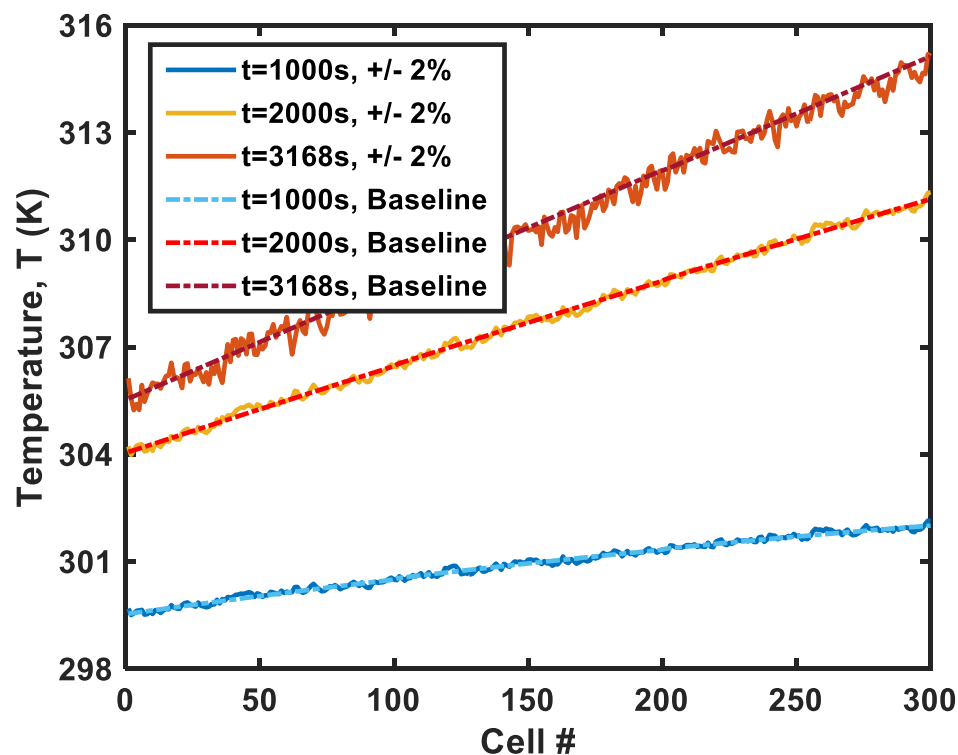
Pack level simulation results – Effect of initial temperature and C-rate – 100s2p



Pack level simulation results – Effect of manufacturing variation – 100s3p

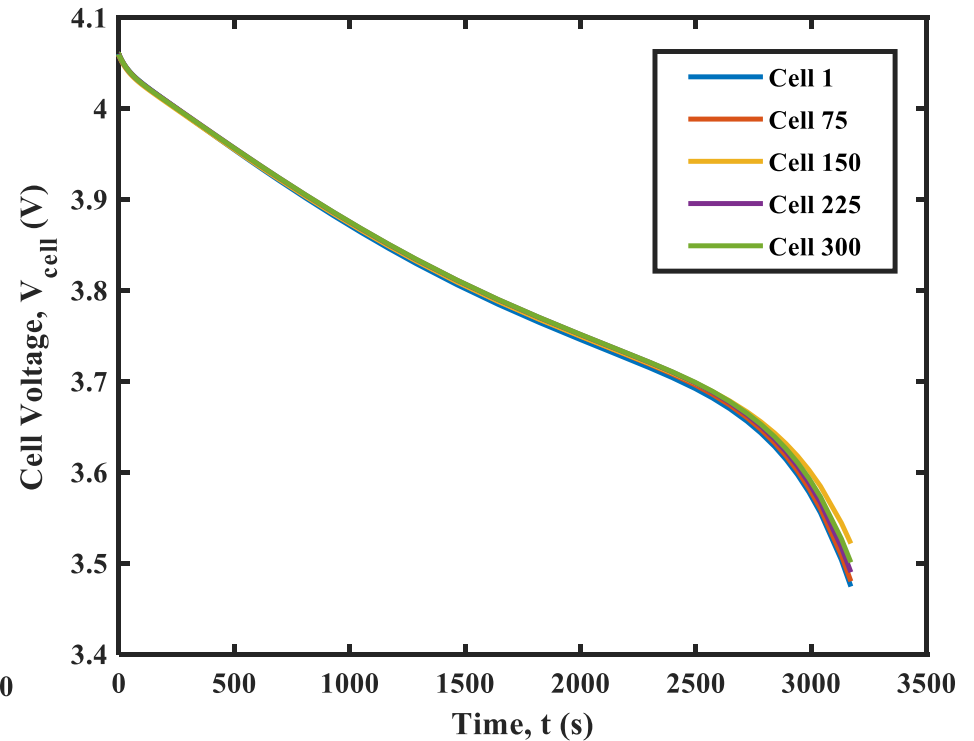
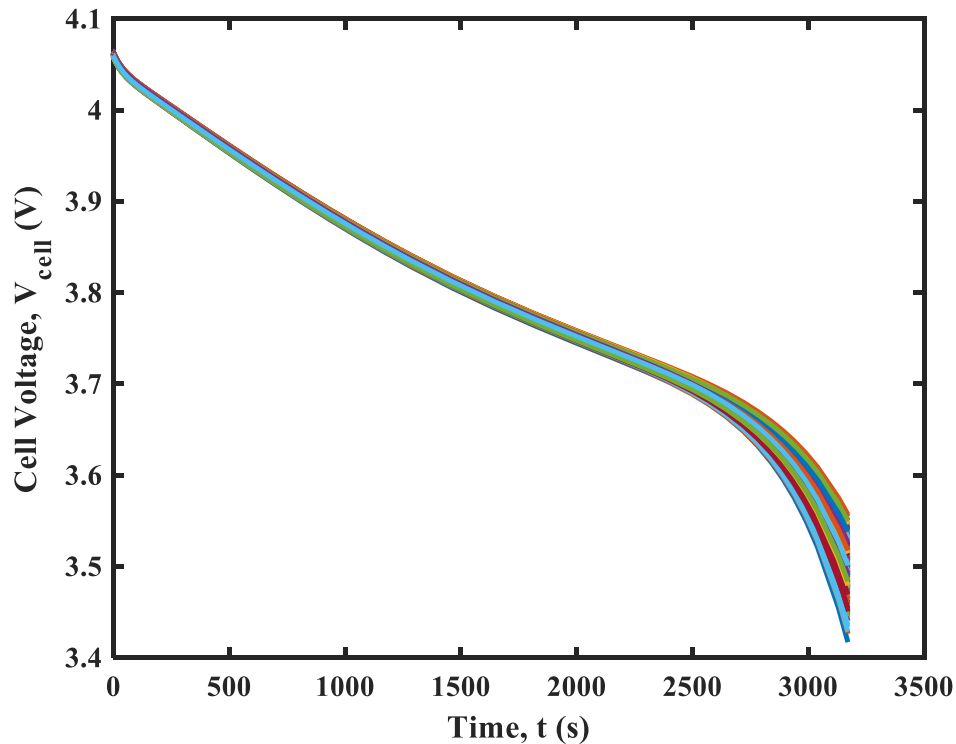
Electrode thickness, porosity, and particle radius randomly varied by +/-2 % across the cells in the pack

Manufacturing variation leads to “noise” in cell-to-cell temperature variation



Pack level simulation results – Effect of manufacturing variation

The cell voltage variation across the pack dictated by manufacturing variation
Effect of pack-level temperature variation appears to be negligible at cycle 0



Summary and future work

- A modeling framework - pack-level heat transfer, voltage and current distribution, and electrode-scale phenomena
- Effect of initial temperature, discharge rate, and manufacturing variation analyzed
- Include charging, cycling, and degradation at the pack level
- Effect of different thermal management approaches
- Study battery pack with different battery chemistry
- Integration with various applications – Space applications, Electric Aircrafts, EVs etc.

Acknowledgements

- Center of Advanced Vehicle Technology
- Alabama Transportation Institute
- Graduate School, University of Alabama
- Department of Mechanical Engineering and
College of Engineering, University of Alabama