Evaluating Risks in Stationary Storage—Safety Thrust Overview

PRESENTED BY

Summer Ferreira

DOE OE Peer Review 2018

Sept 26 2018

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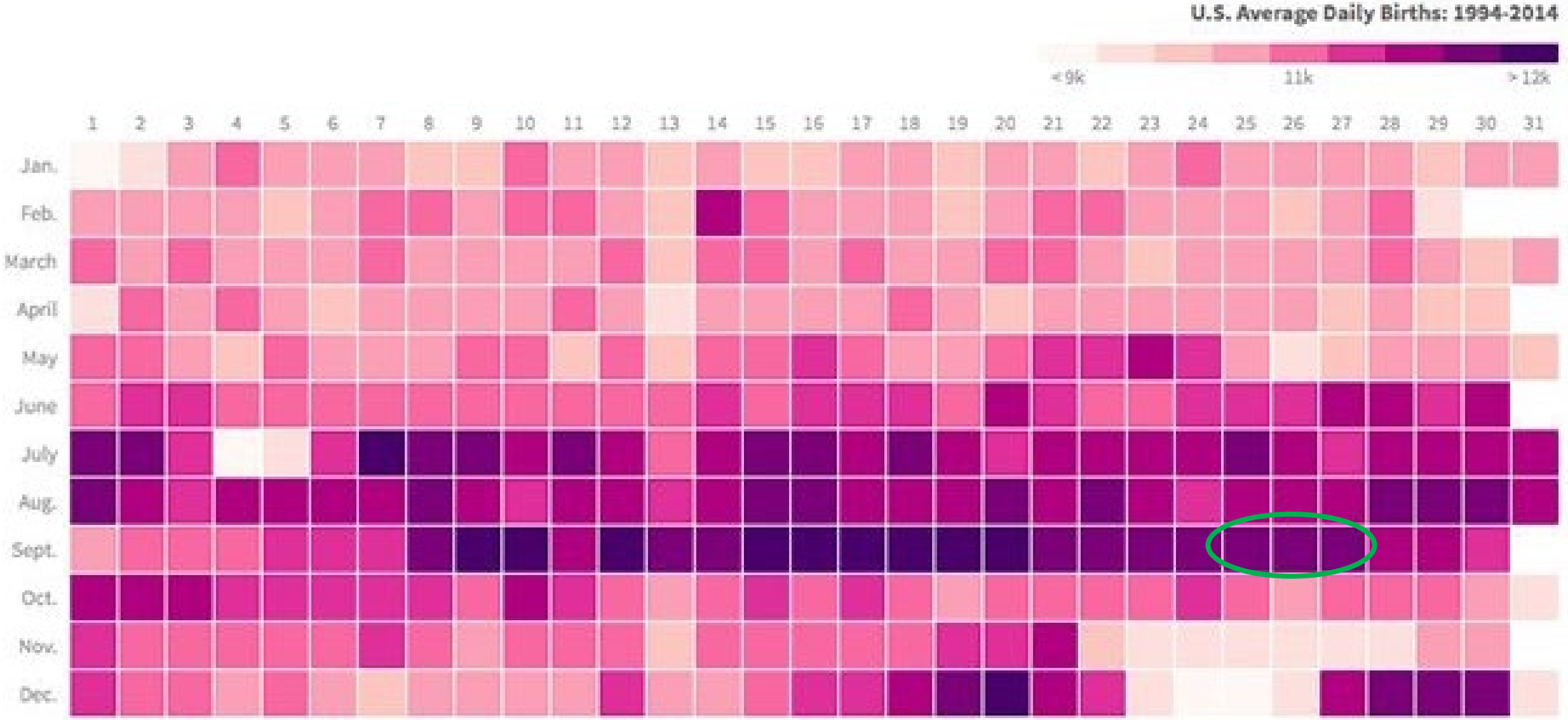

Data: U.S. National Center for Health Statistics (1994-2003); U.S. Social Security Administration (2004-2014) — via FiveThirtyEight

Credit: Matt Stiles/The Daily Viz

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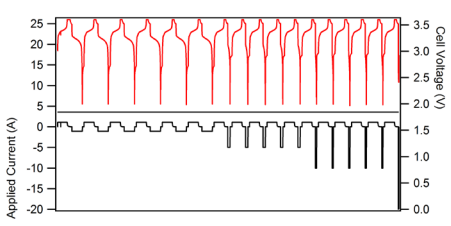

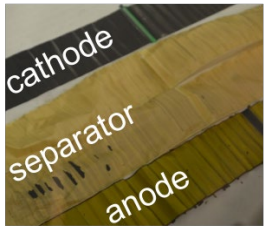

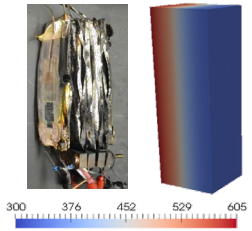

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Materials based modeling

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Venting behavior

Acknowledgements

Battery Safety R&D Program at Sandia
DOE Office of Electricity Dr. Imre Gyuk for supporting energy storage safety work
Office of Vehicle Technologies

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract DE-AC52-06NA25396) and Sandia National Laboratories (Contract DE-AC04-94AL85000).

Sandia National Laboratories

Safety is about reducing risk:

Safety – ‘unlikely to cause danger’

Where risk encompasses consequence and likelihood

Strategy and outreach

2017
- ESS Safety Forum
- Safety Roadmap
- ESS Safety Website Launched

2018
- ESS Safety and Reliability Forum
- Monthly Codes and Standards report
- Bimonthly Newsletter

2019
- ESS Safety and Reliability Forum
- Continued activities to address community safety needs

ENERGY STORAGE SYSTEMS
SAFETY & RELIABILITY FORUM

ES
SAFETY COLLABORATIVE

Sandia National Laboratories

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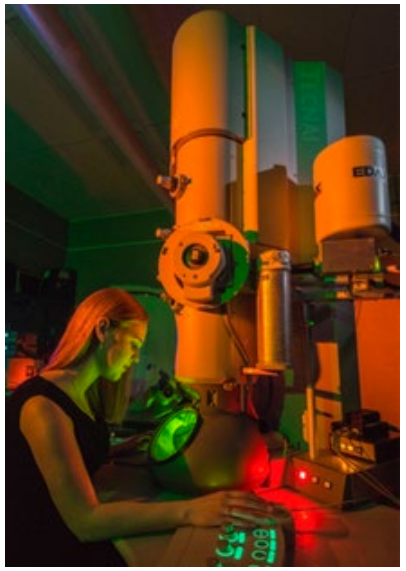
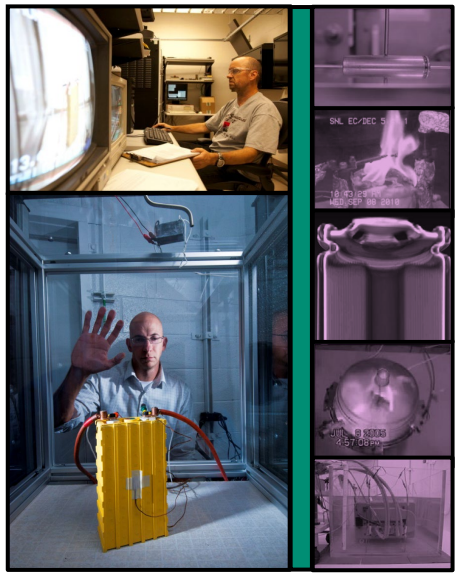
ENERGY STORAGE SYSTEMS

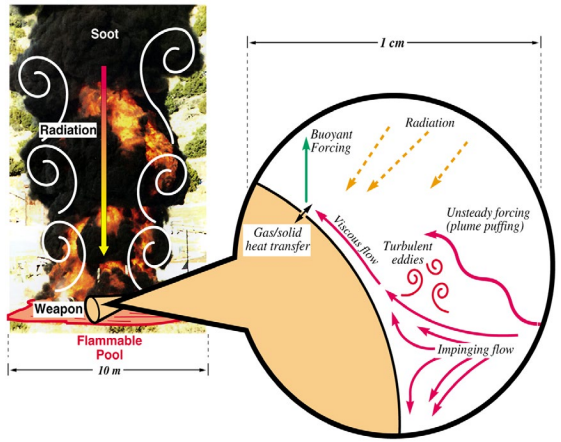
SAFETY & RELIABILITY FORUM

Capabilities for ESS safety R&D at Sandia

- New 5000 Sq Ft facility for analysis within spec
- Center for Integrated Nanotechnology for spectroscopy
- Abuse facilities for failure analysis
- Modeling of high energetic events with Sierra





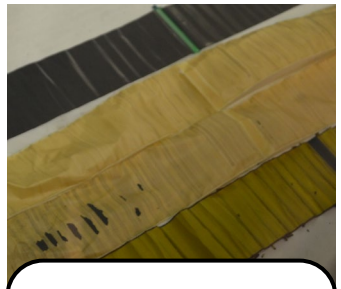


Improving battery failure mitigation

Collaboration: codes, standards, and regulations

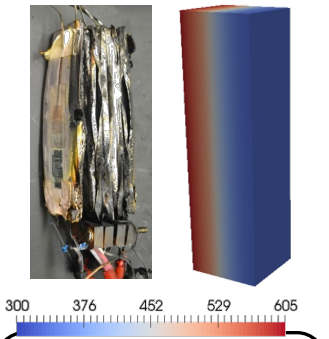
Collaboration: incident response

Baseline electrochemical performance analysis



Materials characterization and thermal stability testing

Electrochemical and whole-cell and string abuse response analysis



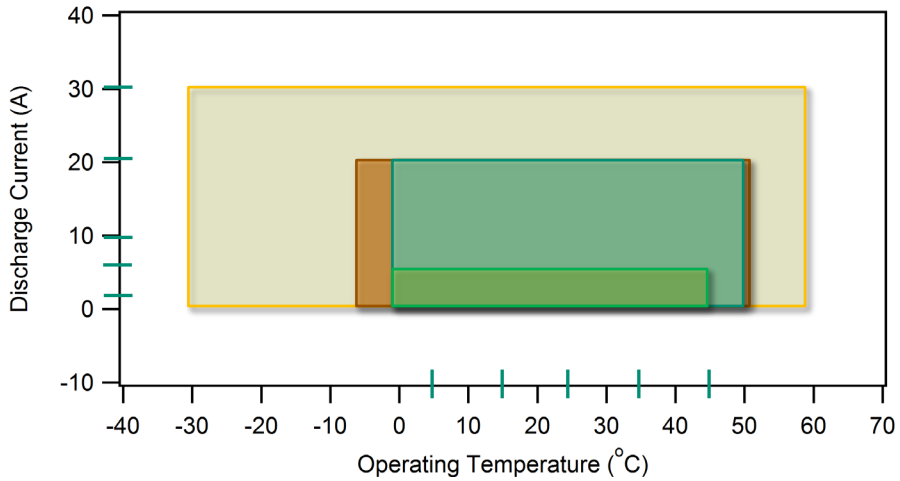
Modeling of thermal propagation

Collaboration: vent plume composition (NM Tech)

Cell operation constraints

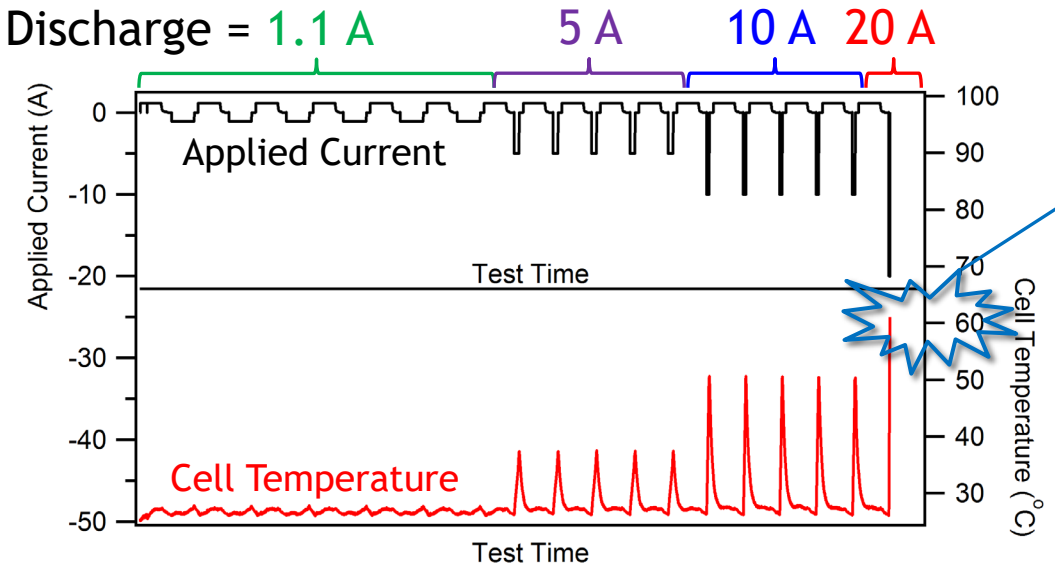
Cathode Chemistry	AKA	Specific Capacity (Ah)	Average Potential (V vs Li°/Li+)	Max Discharge Current	Acceptable Temperature (°C)
$LiCoO_2$	LCO	2.5	3.6	20	0 to 50
$LiFePO_4$	LFP	1.1	3.3	30	-30 to 60
$LiNi_xCo_yAl_{1-x-y}O_2$	NCA	2.9	3.6	6	0 to 45
$LiNi_{0.80}Mn_{0.15}Co_{0.05}O_2$	NMC	3.0	3.6	20	-5 to 50

LCO LFP NCA NMC



Avoiding accelerated aging or abuse

LFP, 25 °C environment



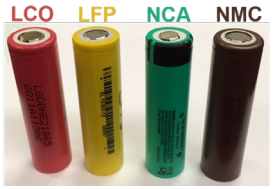
Current = 20 A (max = 30 A)
Environment = 25 °C
Cell skin Temp = 60 °C!!!

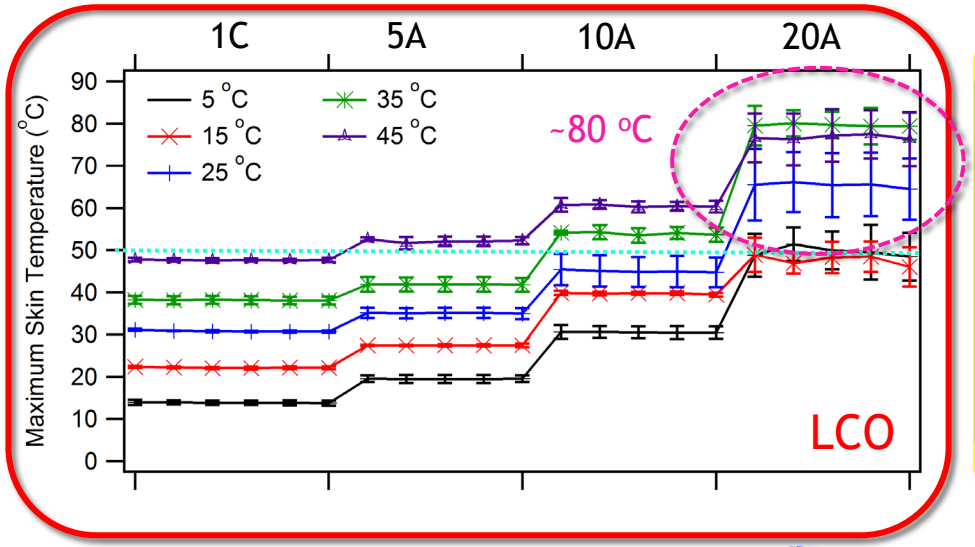
Most packs don't monitor individual cell skin temperatures.
Unintended abuse condition under 'normal' operation.

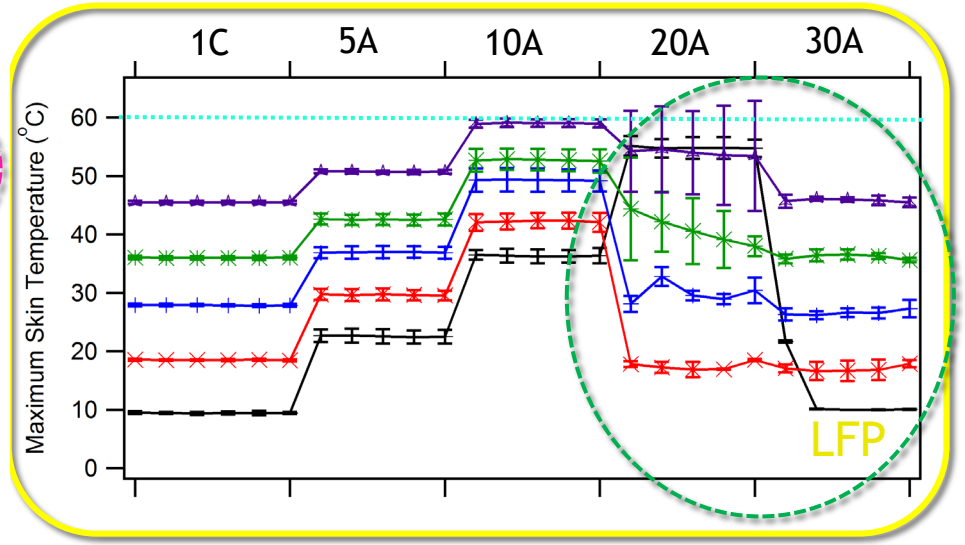
Pristine Cell

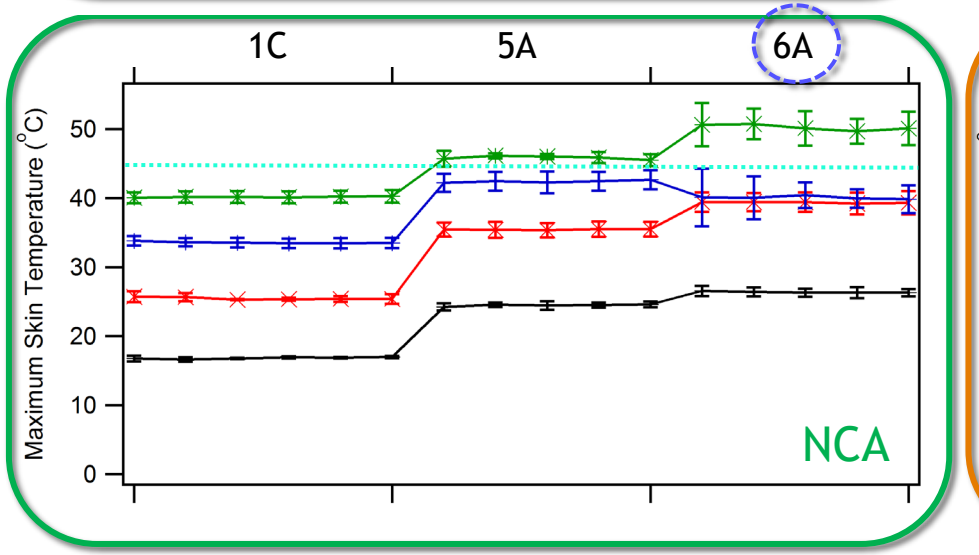
Abused Cell

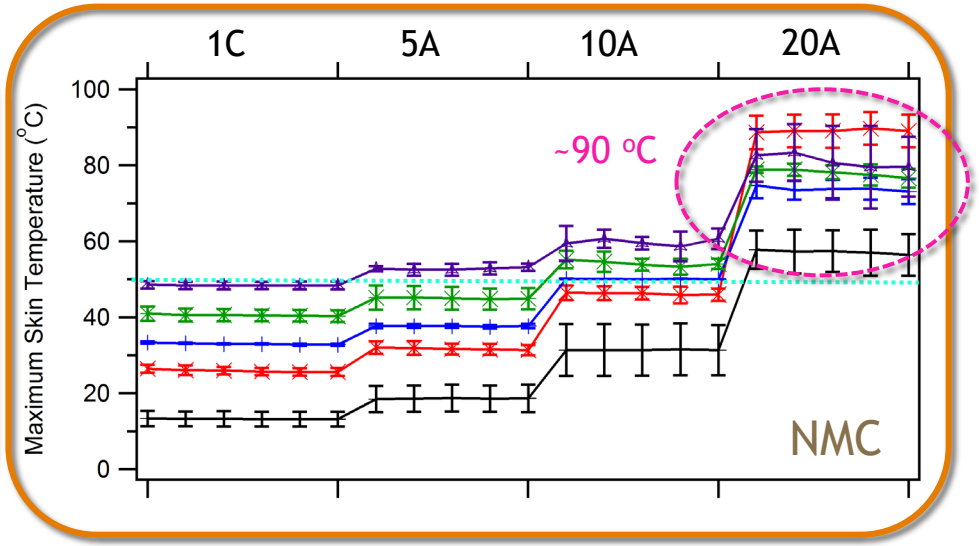
Significant self-heating can occur if cells are unmonitored



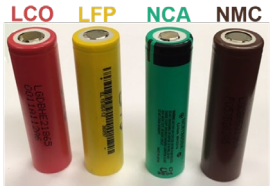


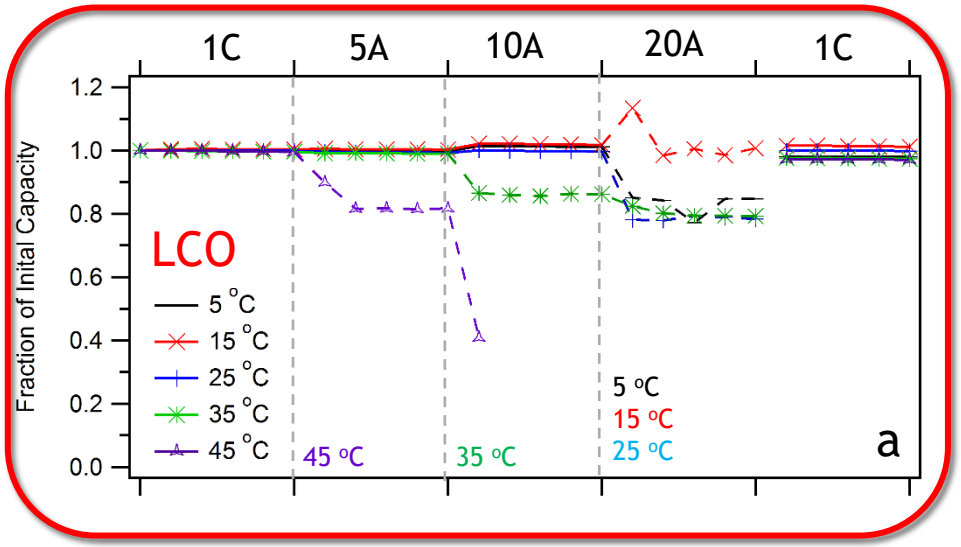


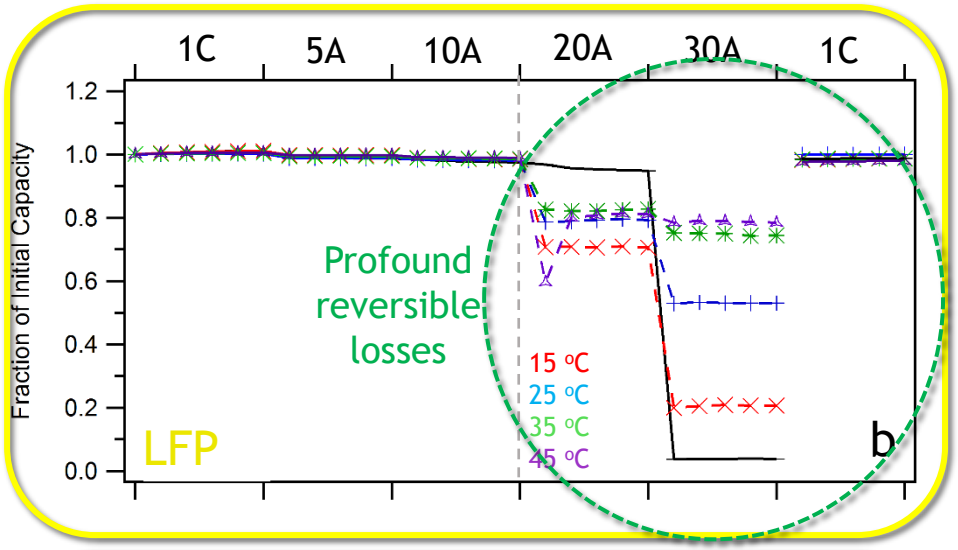


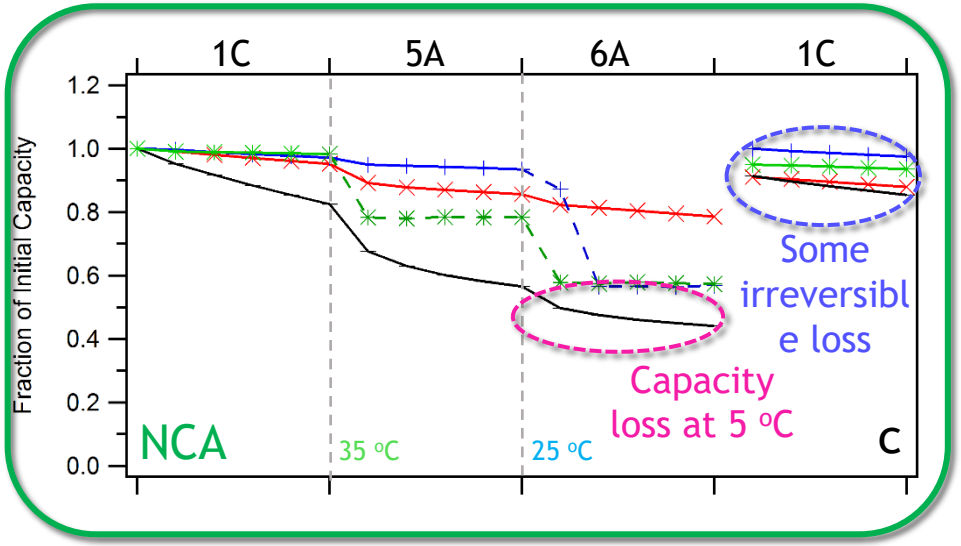


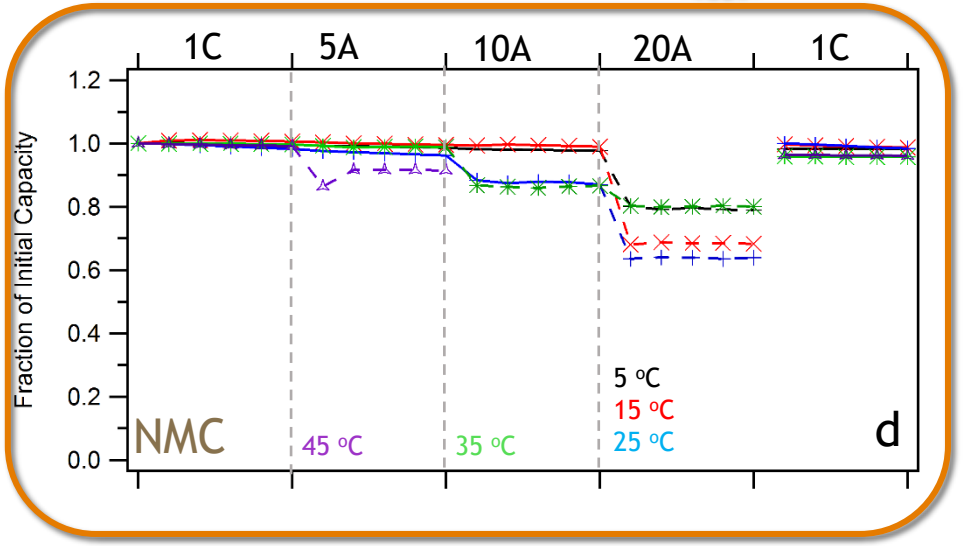
NCA experiences lasting capacity losses after cycling









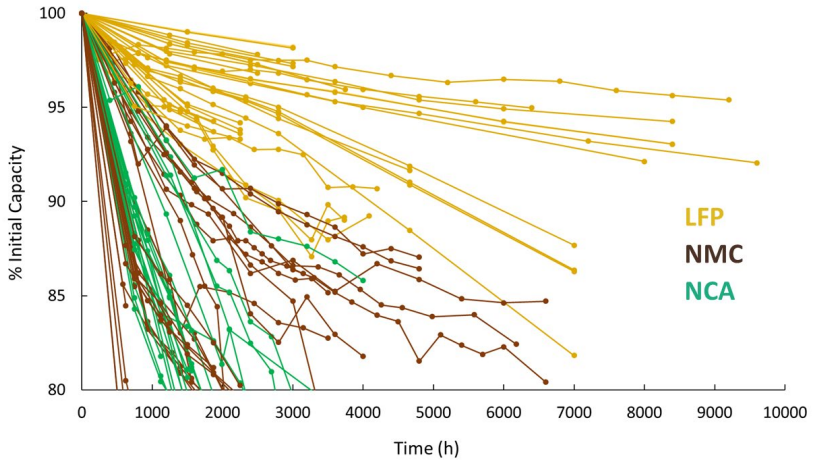


Aging Behavior and Abuse Response of Commercial Lithium-Ion Cells as a Function of Chemistry and Cycling Conditions

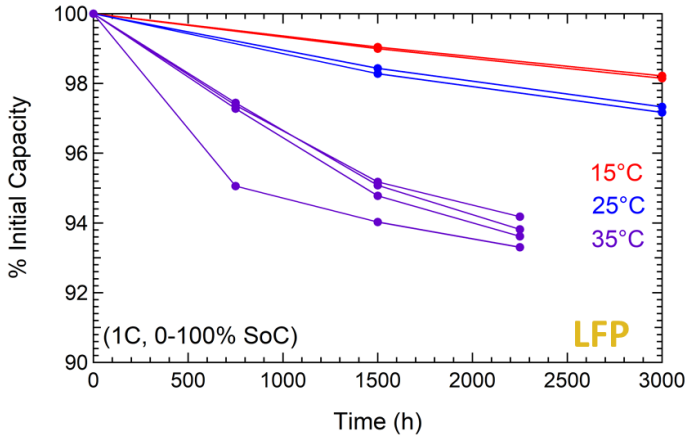
1) Aging Study Design

Variable				
Chemistry	LFP ($LiFePO_4$)	NCA ($Ni_xCo_yAl_{1-x-y}O_2$)	NMC ($LiNi_{0.8}Mn_{0.15}Co_{0.05}O_2$)	
Discharge Rate*	C/2	1C	2C	3C
State of Charge Range	40-60%	20-80%	0-100%	
Environment Temperature	15°C	25°C	35°C	

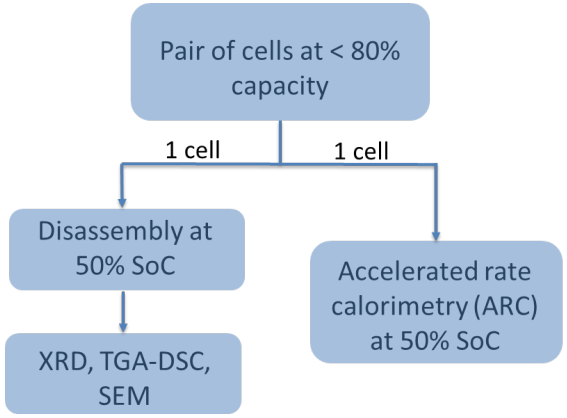
2) Overall Outcomes



3) Influence of Different Variables



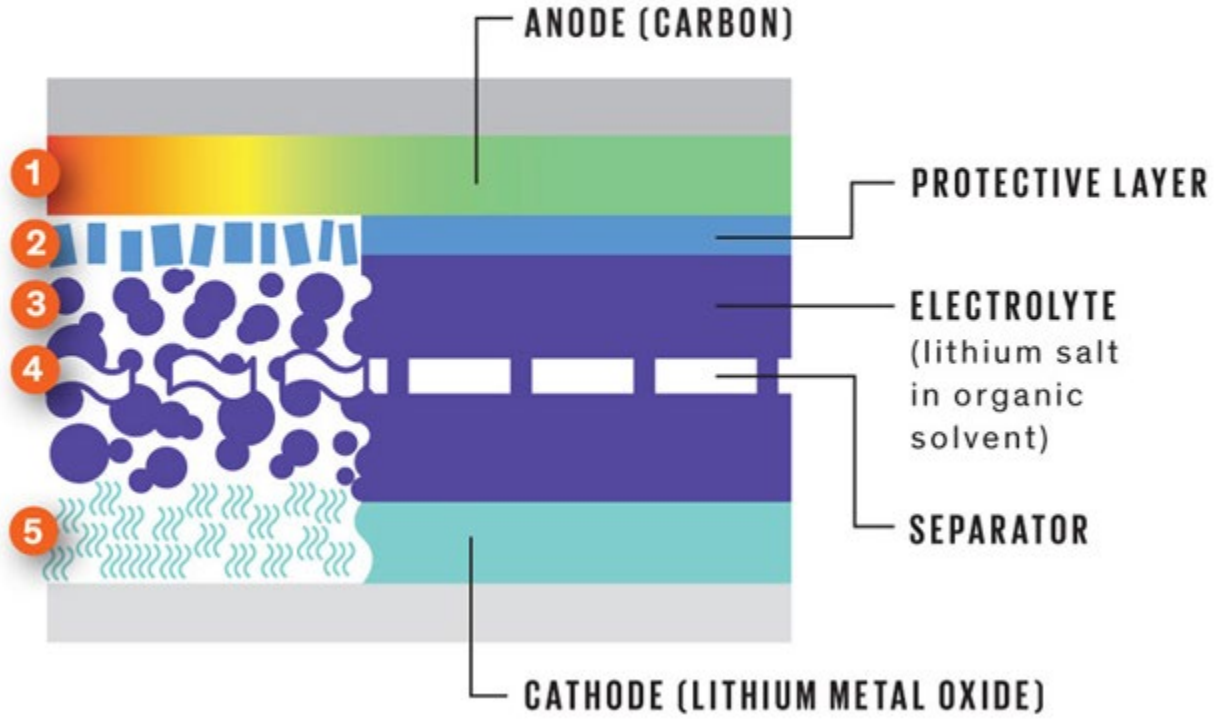
4) Safety of Aged Cells



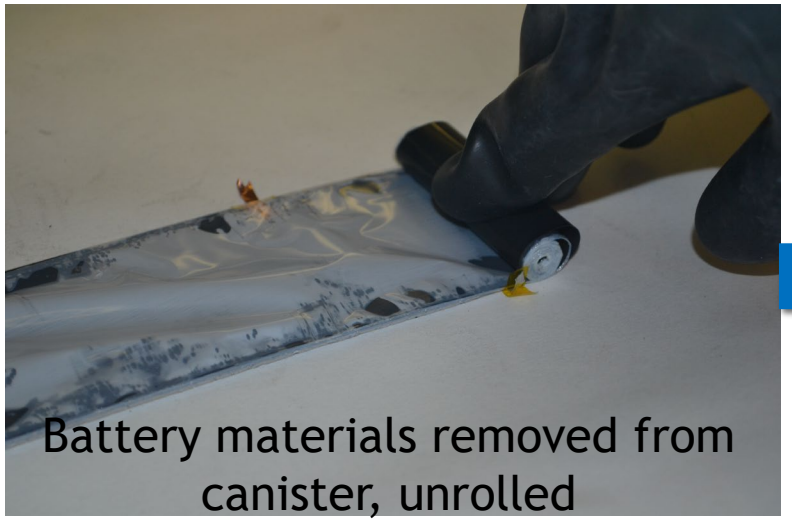
Cell materials are responsible for thermal runaway behaviors

Thermal Runaway in a Lithium-Ion Battery

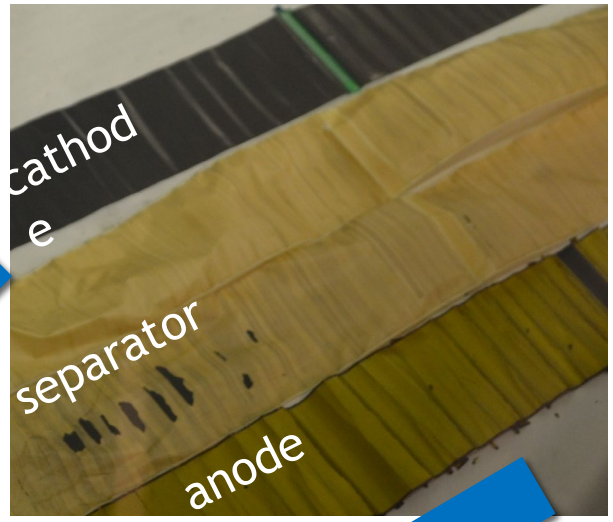
1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.

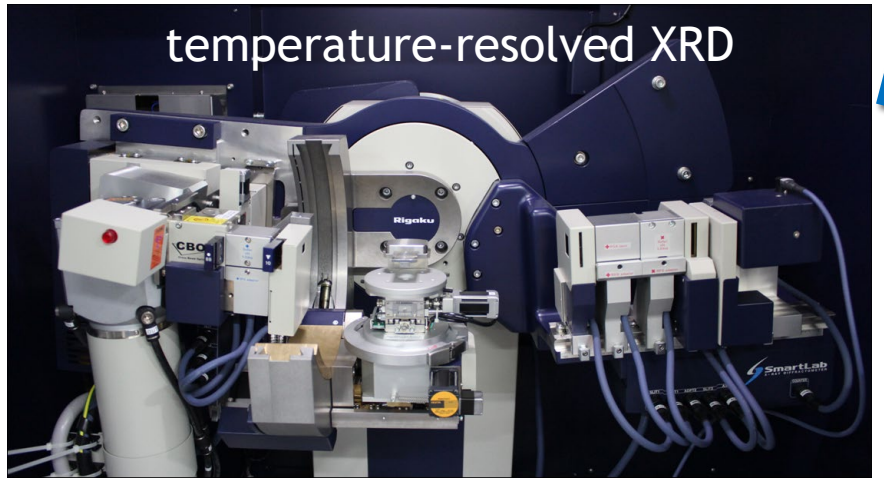


Batteries are disassembled to reveal steps of failure



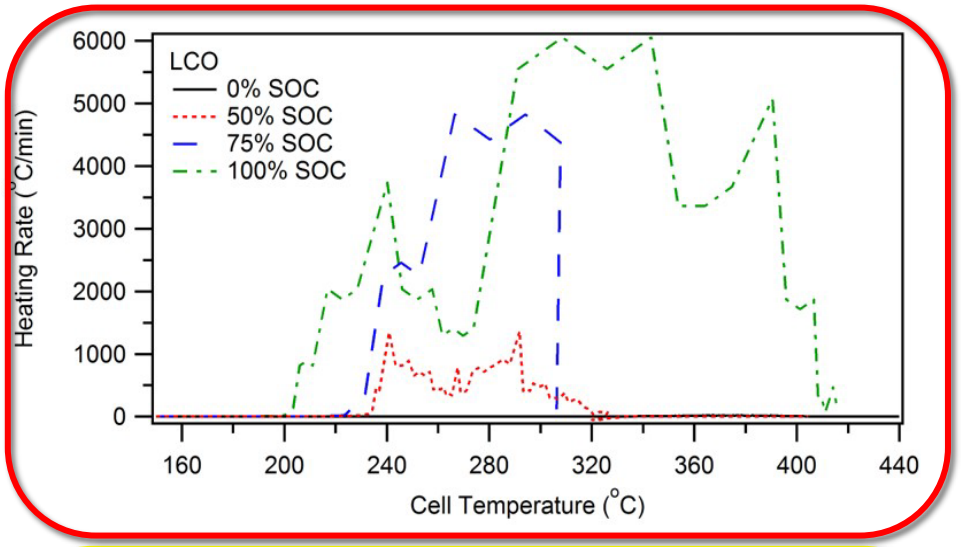
Disassembly

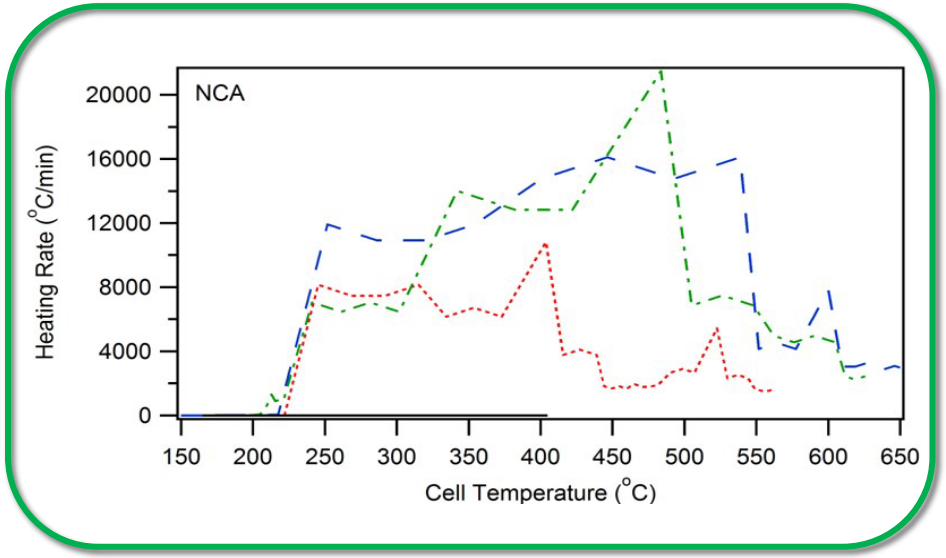


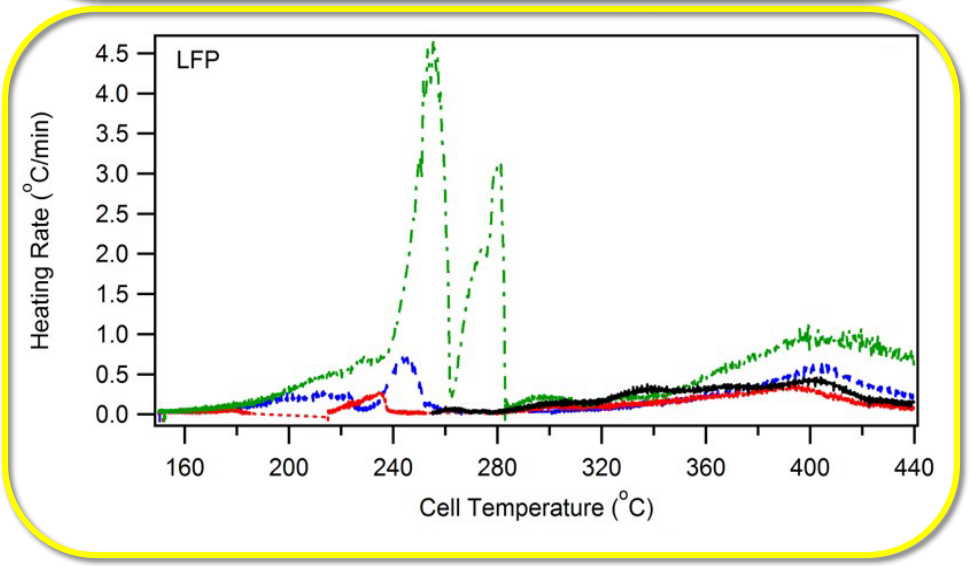


Temperature-resolved XRD shows how the material changes with temperature DSC/TGA, SEM also examined

SOC dependence of heating



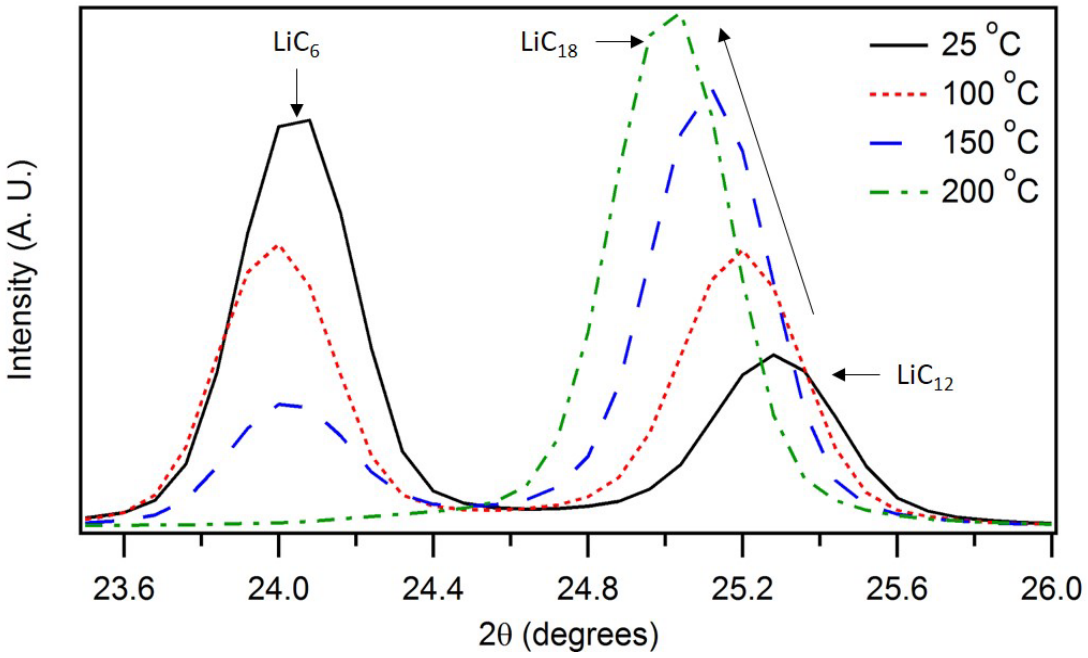


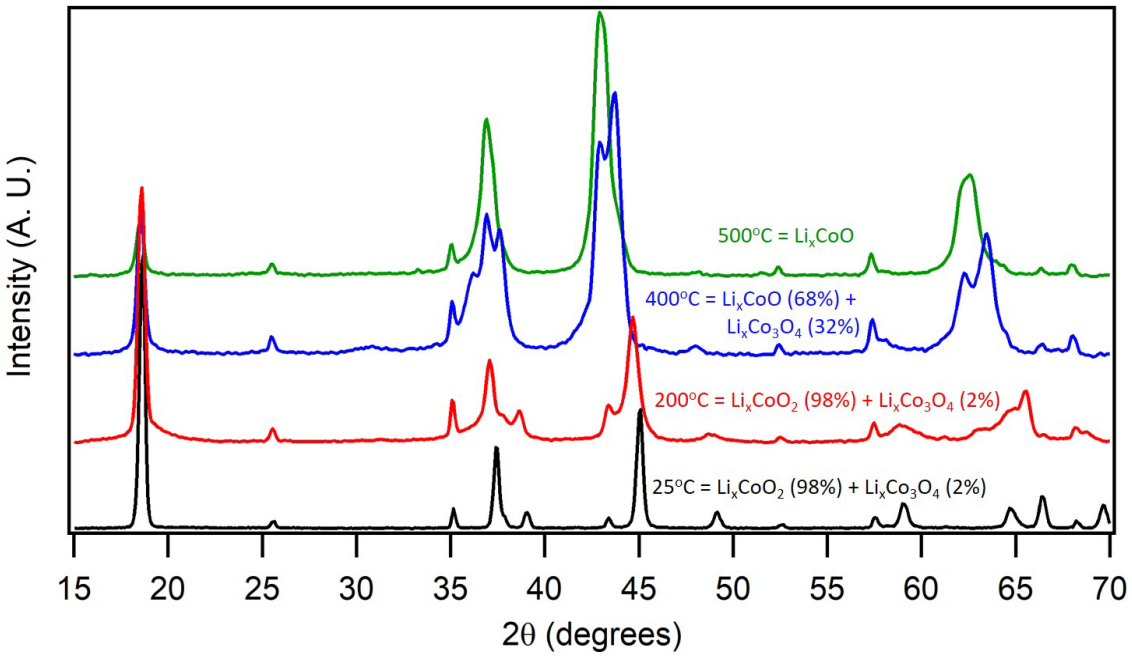


Observations

1) *LFP most stable, but still sensitive to SOC*
2) *LCO onset is SOC dependent*

Lattice changes in anode with heating



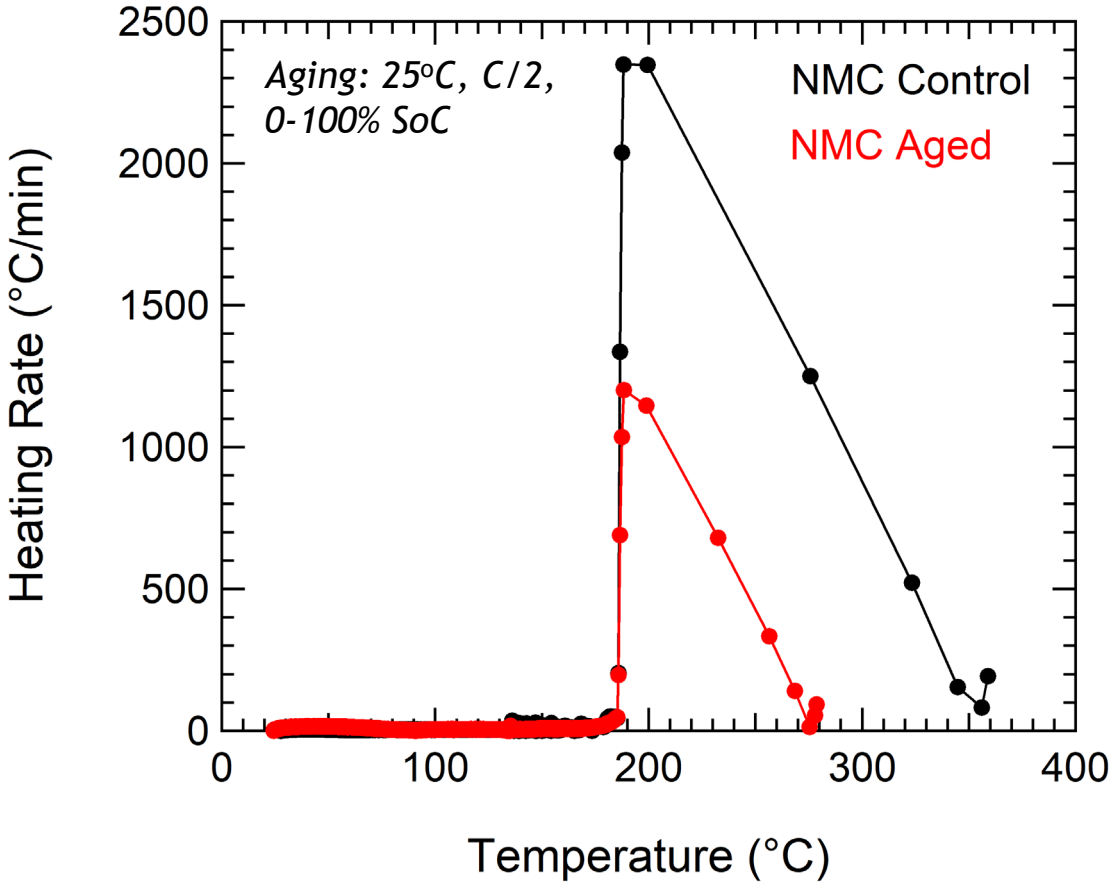


Temperature-resolved XRD pattern of:

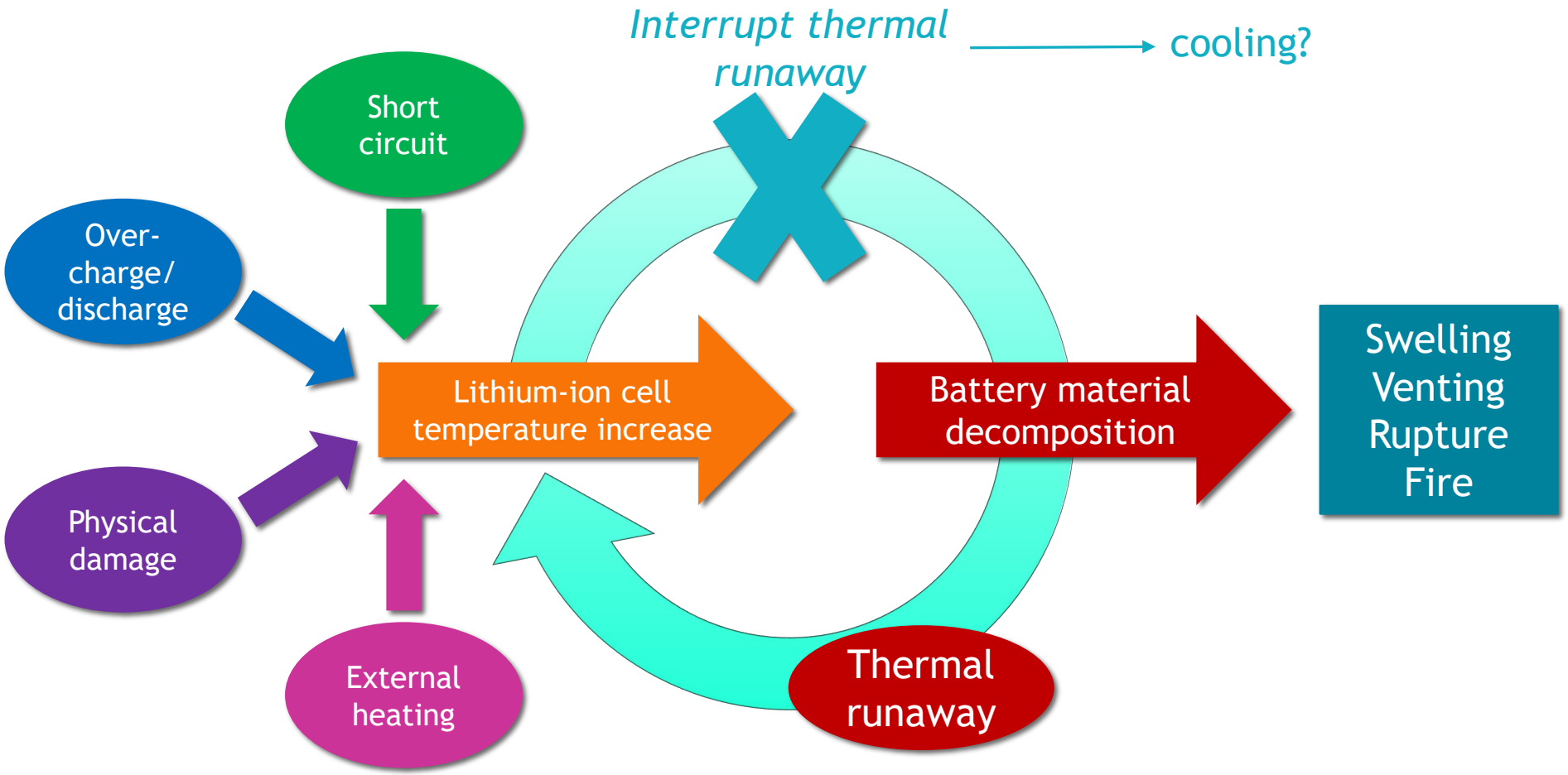
100% SOC LCO anode

100% SOC LCO cathode

Aged cells failed at similar temperature with less heat release



Can we prevent a battery fire?



Summary

Goals:

- Field the most inherently safe chemistries and designs
- **Contain** storage across scales and chemistries
- Effective **suppressants** identification and use
- Appropriate **hardware and software controls** to mitigate failures and propagation of failures

Approach:

- Assess thermal effects and loads during use and as an result of environment
- Testing failure propagation to understanding vulnerabilities

Through integrated R&D into failure behavior and consequences using **experimental** and **modeling** efforts across scale.

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