SAND2018-3168C

Understanding battery safety through abusive battery testing

PRESENTED BY

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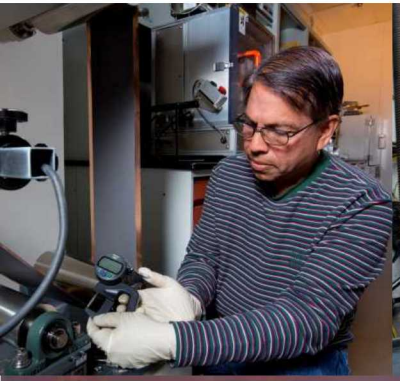
Capabilities and Infrastructure





Battery Abuse Testing Laboratory (BATLab)

Cell Prototype Facility

Battery Calorimetry

Modeling and Simulations

Materials Development R&D

Thermal Test Complex (TTC)

Burn Site, Laurence Canyon

Thermal Test Complex (TTC)

Battery Abuse Testing Laboratory (BATLab)

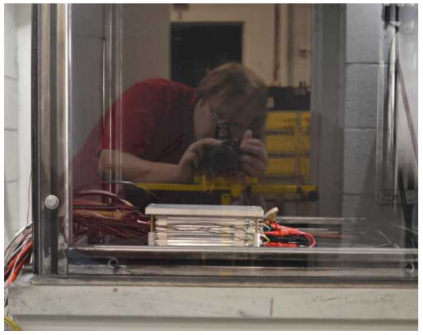
Comprehensive abuse testing platforms for safety and reliability of cells, batteries and systems from mWh to kWh

Cell, module, and battery system hardware deliverables for testing

Mechanical abuse
- Penetration
- Crush
- Impact
- Immersion

Thermal abuse
- Over temperature
- Flammability measurements
- Thermal propagation
- Calorimetry

Electrical abuse
- Overvoltage/overcharge
- Short circuit
- Overdischarge/voltage reversal



Burn Site Test Site

Full Scale Battery Testing Facilities

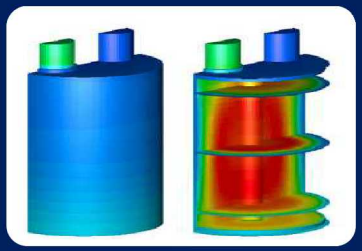
Understanding Battery Failure

Materials R&D

- Non-flammable electrolytes
- Electrolyte salts
- Coated active materials
- Thermally stable materials

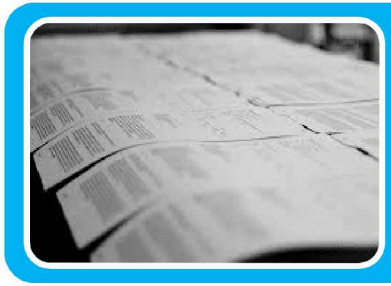
Testing

- Electrical, thermal, mechanical abuse testing
- Failure propagation testing on batteries/systems
- Large scale thermal and fire testing (TTC)
- Development for DOE Vehicle Technologies and USABC



Simulations and Modeling

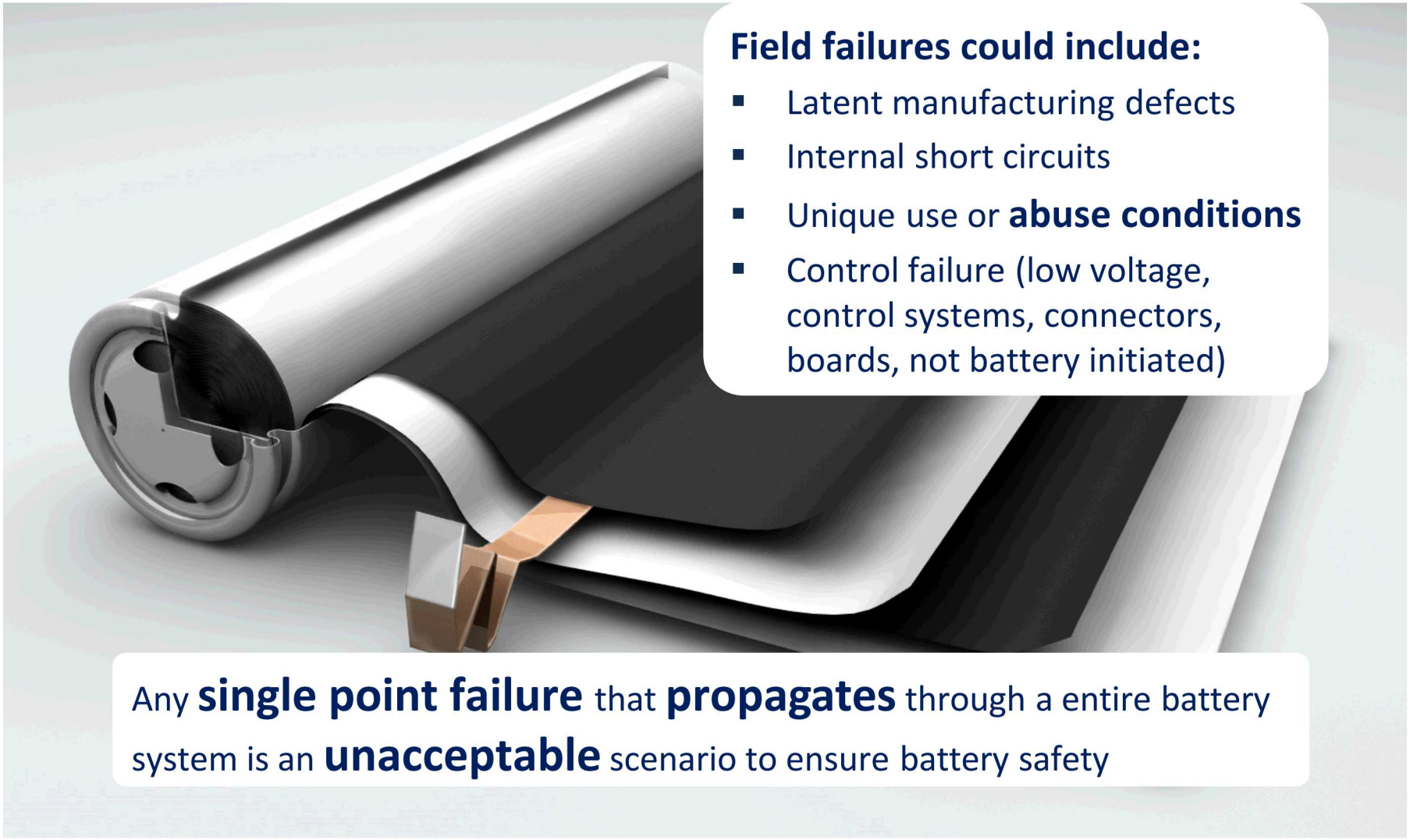
- Multi-scale models for understanding thermal runaway
- Validating vehicle crash and failure propagation models
- Fire Simulations to predict the size, scope, and consequences of battery fires



Procedures, Policy, and Regulation

- USABC Abuse Testing Manual (SAND 2005-3123)
- SAE/UL procedures and standards
- R&D programs with NHTSA/DOT to inform best practices, policies, and requirements

Battery System Field Failures



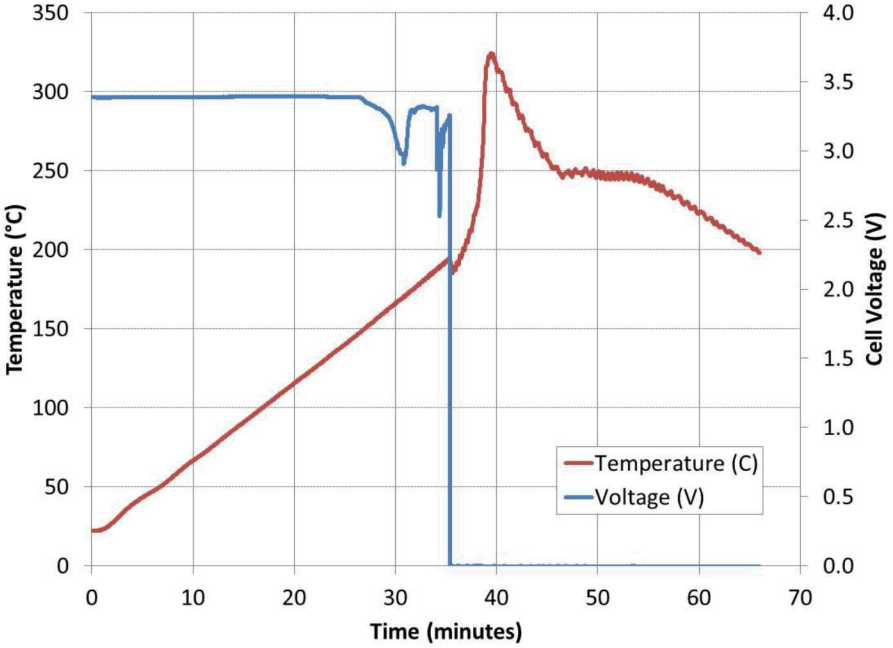
Field failures could include:

- Latent manufacturing defects
- Internal short circuits
- Unique use or **abuse conditions**
- Control failure (low voltage, control systems, connectors, boards, not battery initiated)

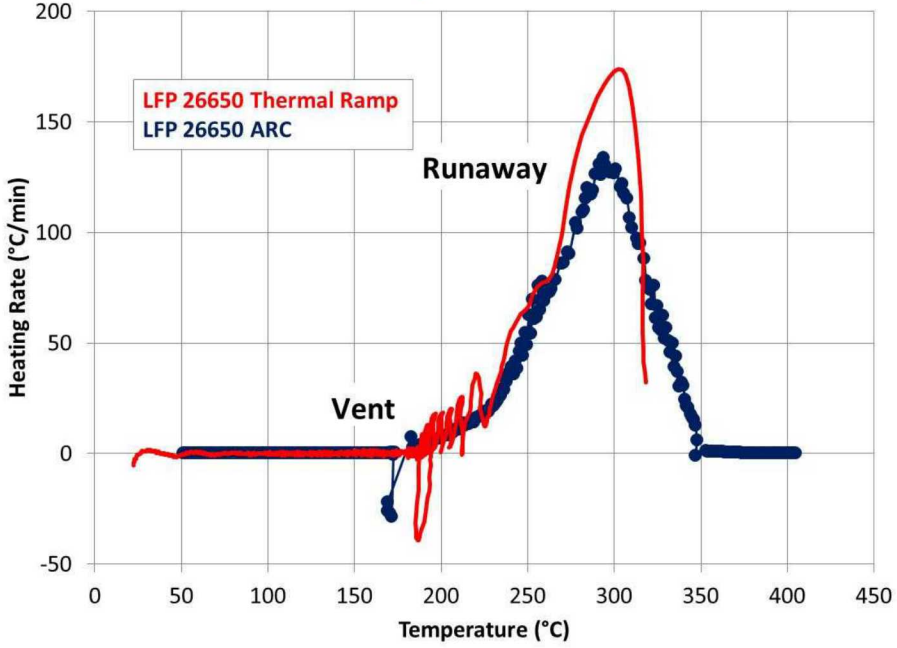
Any **single point failure** that **propagates** through a entire battery system is an **unacceptable** scenario to ensure battery safety

Characterizing Thermal Runaway

Thermal Ramp

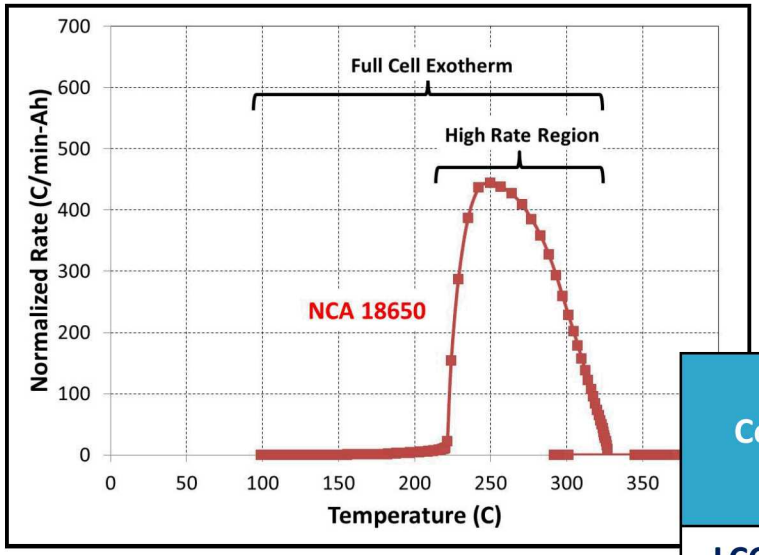


Thermal Ramp + ARC



- ***Consistent cell behavior between thermal abuse and calorimetry experiments***
- ***Greater total temperature rise observed for the ARC experiment because it is in an adiabatic environment***
- ***May be able to use these data to compare results obtained between the two types of experiments***

Characterizing Thermal Runaway



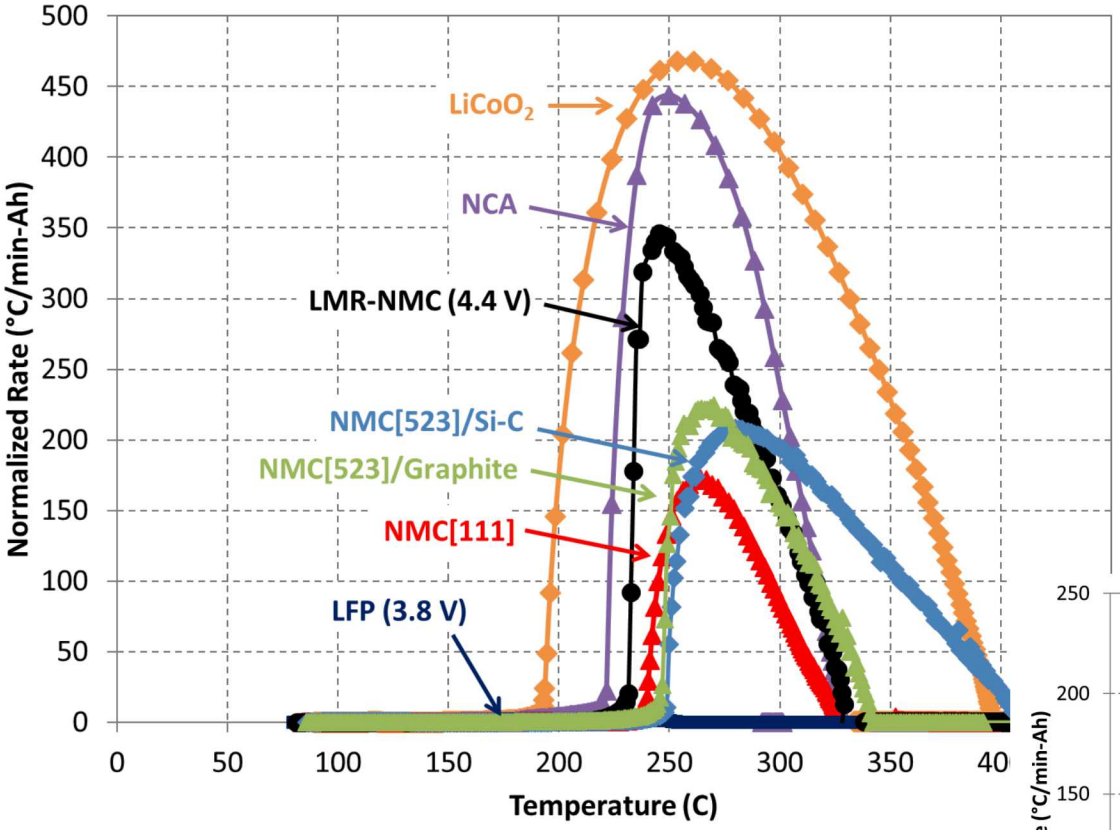
Cell Type	Capacity (Ah)	Runaway Enthalpy (kJ/Ah)		Peak Heating Rate (W/Ah)
		Full Cell	High Rate Region	
LCO 18650*	1.2	28.4	15.9	281
NCA 18650*	1.0	21.6	9.8	266
NMC 18650*	0.95	22.0	8.3	105
LFP 18650*	0.9	18.0	2.4	1
LFP 26650*	2.6	8.2	4.6	65
LFP 26650‡	2.6	8.0	4.5	65

*ΔH based on dT (exotherm)
‡ΔH based on dT/dt (exotherm)

- *Full cell runaway enthalpy shows a significant amount of heat generation from even an LFP 18650 cell*
- *But that heat is generated at much different rates for the different cell types*

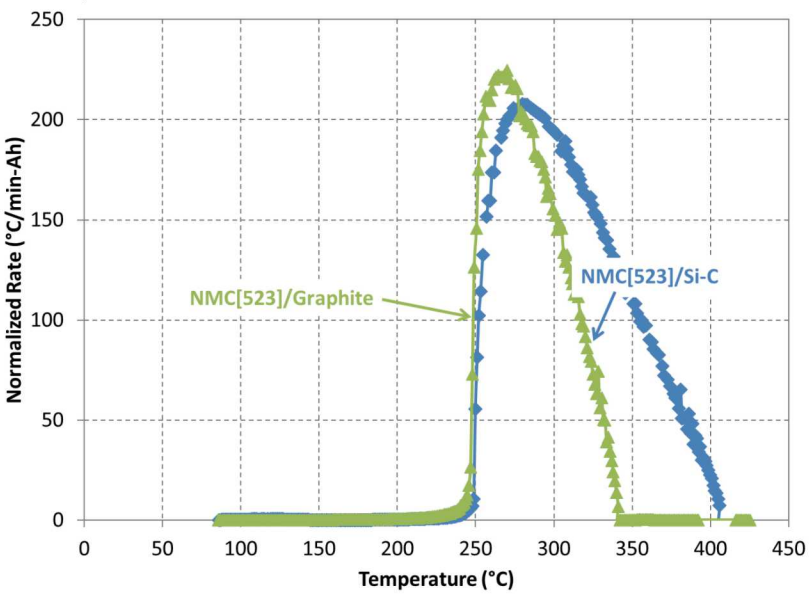
Data provide a quantitative measurement of the runaway enthalpy

Characterizing new materials



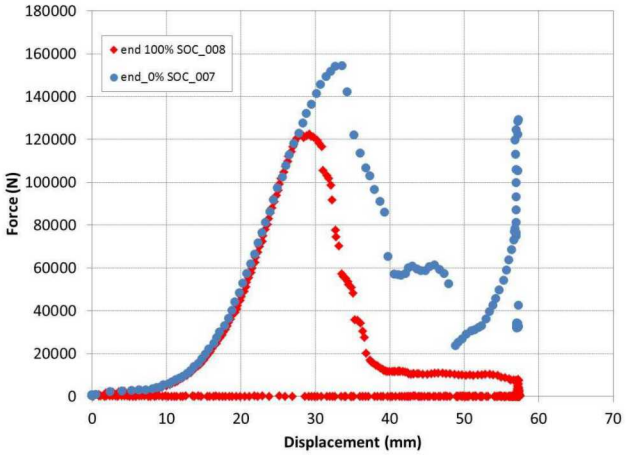
- *Accelerating rate calorimetry shows the behavior of various chemistries*
- *This gives information about peak heating rates and total energy of the thermal runaway*
- *Newer materials such as LFP provide significantly reduced thermal runaway intensities, but have limited energy density*

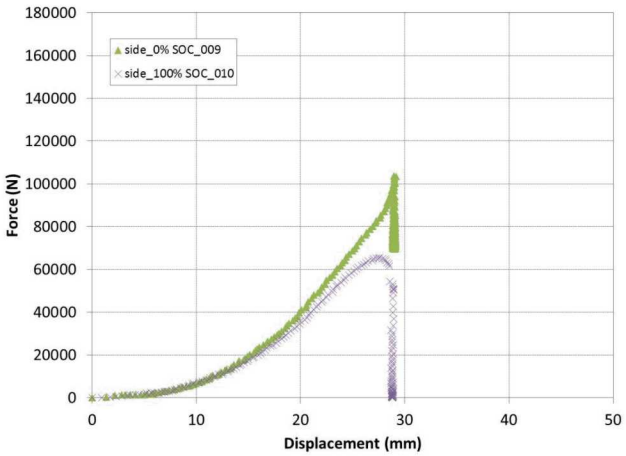
- *New materials can behave in different ways*
- *10-15% Si present in the anode leads to increased runaway energies for a similar cathode material.*



Mechanical Failure Testing

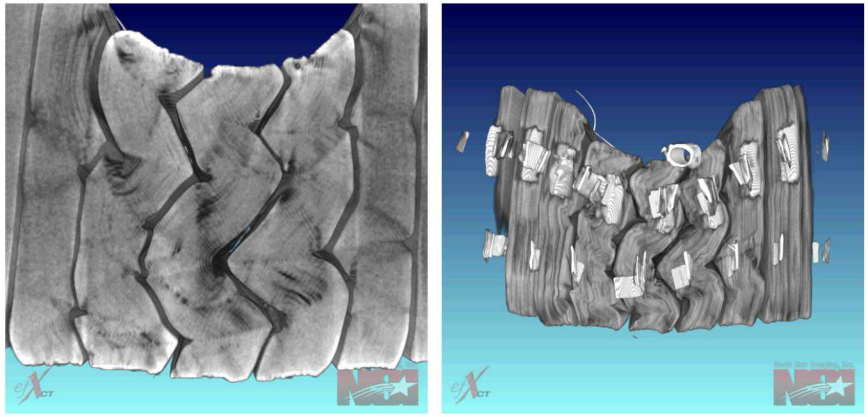
Mechanical behavior under compression





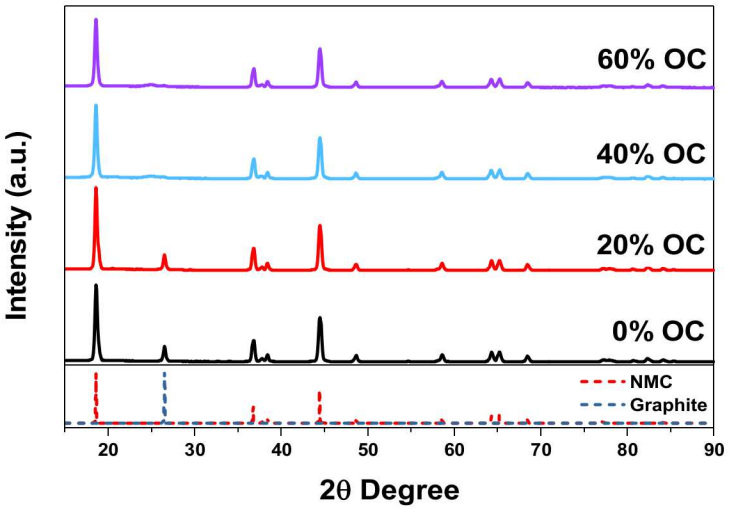
Analog "pole test" of a battery

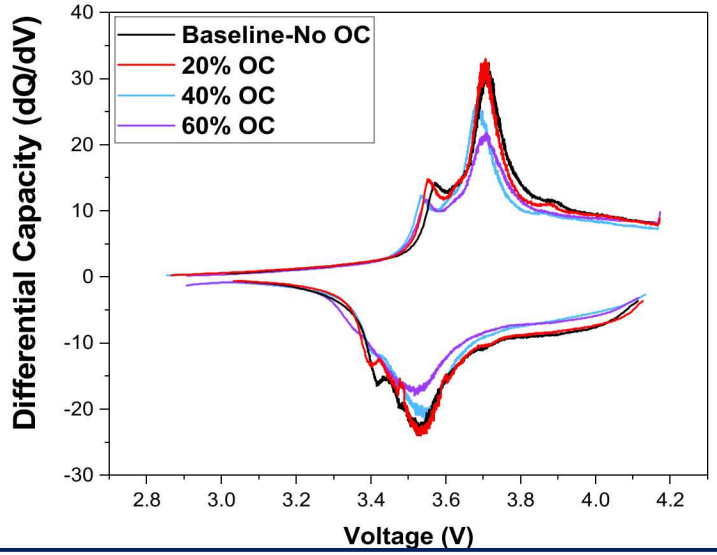
CT analysis to study structural failure modes

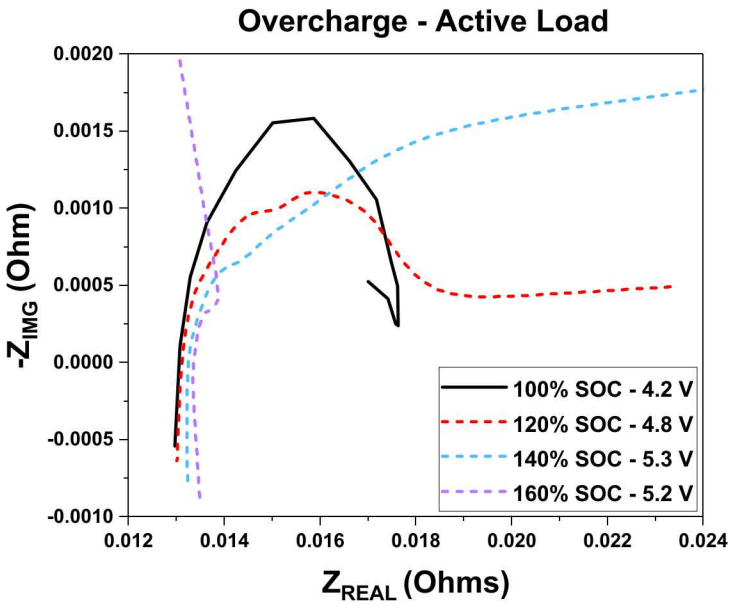


Determining baseline mechanical behavior of batteries during crush/impact testing
Testing support to validate mechanical models for batteries during a crash scenario

Advanced Diagnostics and Analysis



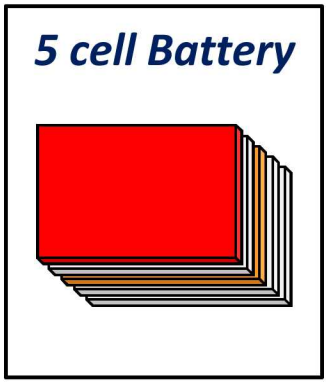


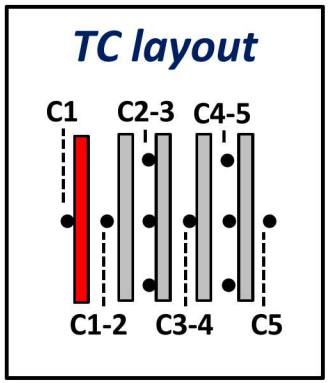


- *Overcharge is applied to 10 AH NMC cells*
- *Fast impedance hardware allows for collection of EIS data while cell is under active load*
- *Cycling performed after overcharge test to observe differential capacity behavior*
- *Anode and Cathode materials harvested post test for materials analysis (Harvested at 0% SOC, cathode results shown)*
- *Coupling electrochemical measurement and materials analysis to create a predictive measurement technique*

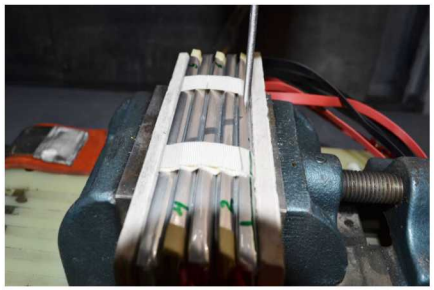
Failure Propagation Testing

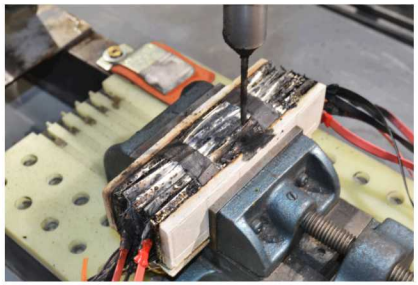
Failures initiated by mechanical insult to edge cell of COTS $LiCoO_2$ packs (3Ah cells)

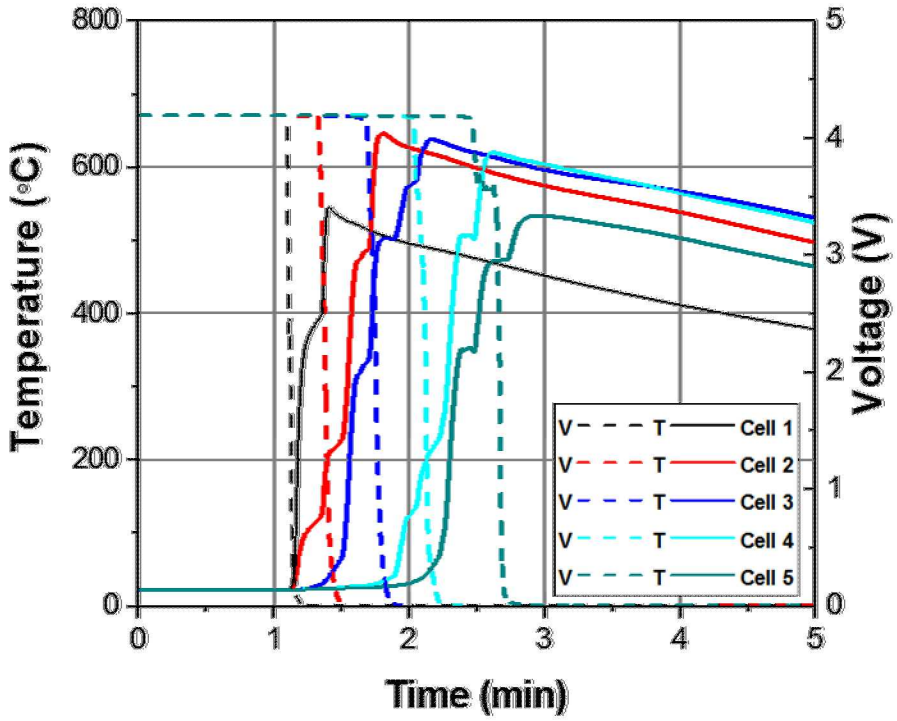




- Successful initiation at Cell #1
- Propagation to adjacent cells
- Cascading failure to entire battery over 60 s



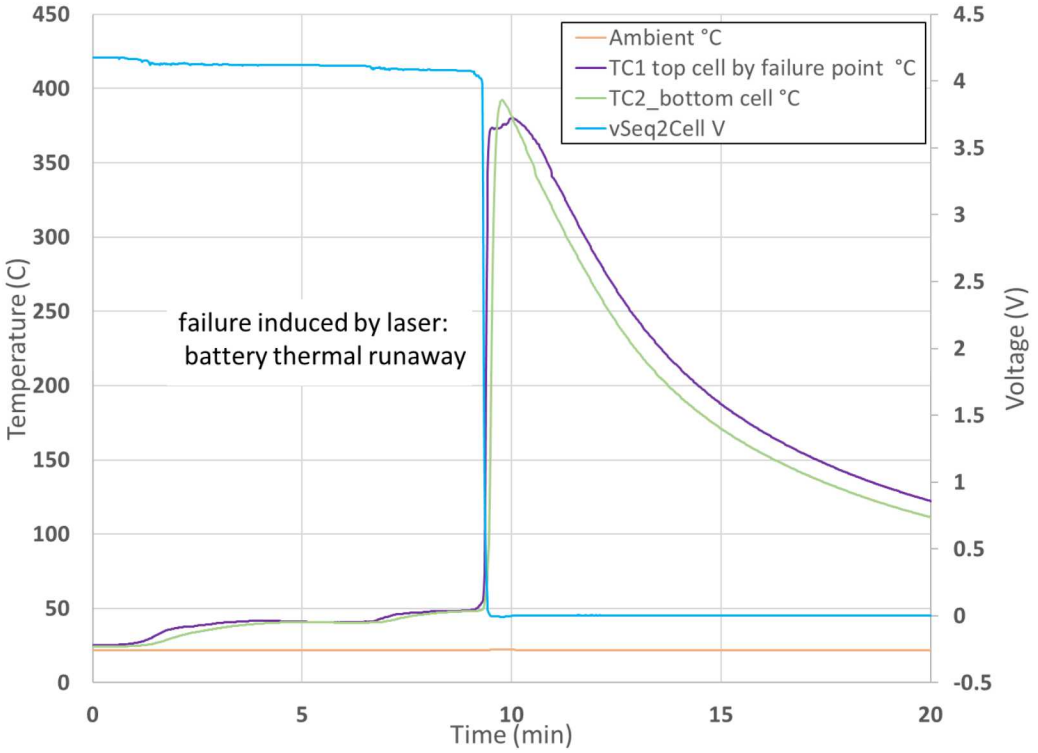


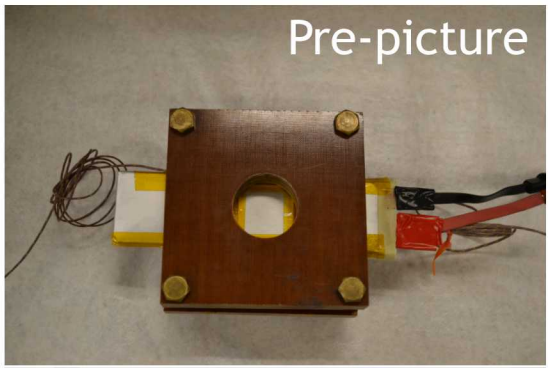


Observed complete propagation when cell are close packed with no thermal management

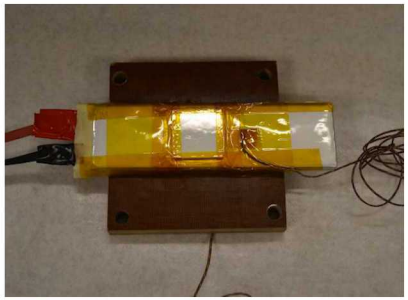
New Test Development

In hopes to reduce the oxygen exposure to hole being produced from laser, an IR transparent slide was used as barrier during testing





- Able to induce failure using laser through silica slide
- Final power setting of 350V, 20ms, 1Hz to induce thermal runaway
  - More energy needed to induce runaway through silica slide
- Maintained seal between silica and pouch cell until full runaway



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Battery Safety R&D Program at Sandia: http://energy.sandia.gov/?page_id=634
ECS Interface Issue on Battery Safety: http://www.electrochem.org/dl/interface/sum/sum12/if_sum12.htm