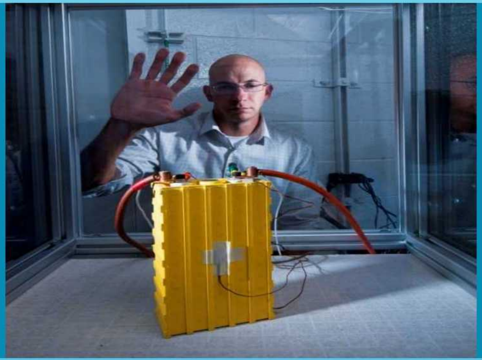
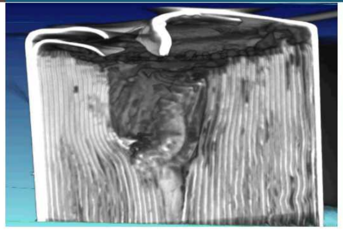
SAND2020-9786C

# Battery Safety Thrust





Joshua Lamb

9/30/2020-10/1/2020

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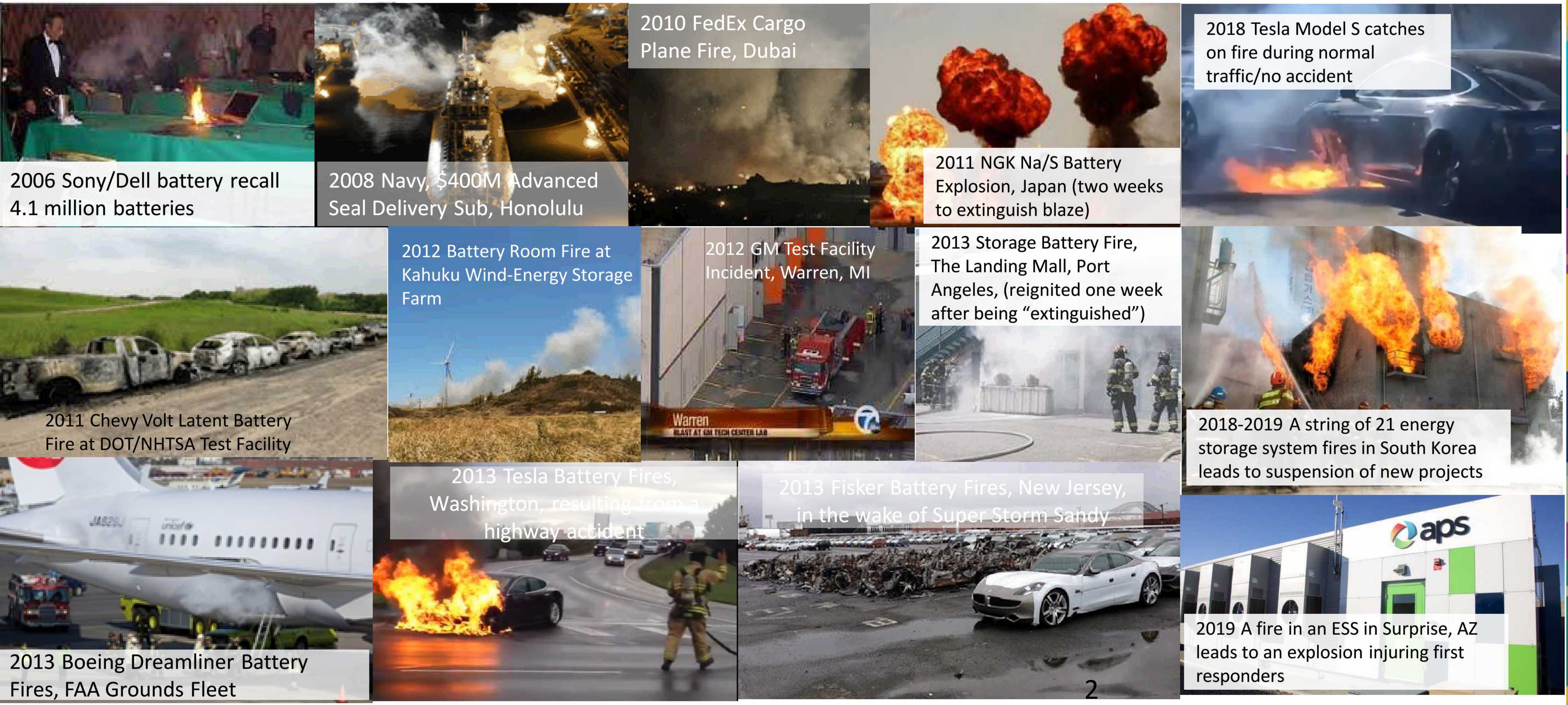
# Grid ESS are the new frontier of battery safety




2006 Sony/Dell battery recall 4.1 million batteries

2008 Navy, $400M Advanced Seal Delivery Sub, Honolulu

2010 FedEx Cargo Plane Fire, Dubai

2011 NGK Na/S Battery Explosion, Japan (two weeks to extinguish blaze)

2018 Tesla Model S catches on fire during normal traffic/no accident

2011 Chevy Volt Latent Battery Fire at DOT/NHTSA Test Facility

2012 Battery Room Fire at Kahuku Wind-Energy Storage Farm

2012 GM Test Facility Incident, Warren, MI

2013 Storage Battery Fire, The Landing Mall, Port Angeles, (reignited one week after being "extinguished")

2018-2019 A string of 21 energy storage system fires in South Korea leads to suspension of new projects

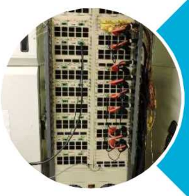
2013 Boeing Dreamliner Battery Fires, FAA Grounds Fleet

2013 Tesla Battery Fires, Washington, resulting from a highway accident

2013 Fisker Battery Fires, New Jersey, in the wake of Super Storm Sandy

2019 A fire in an ESS in Surprise, AZ leads to an explosion injuring first responders

# A collaborative, Multi-lab effort

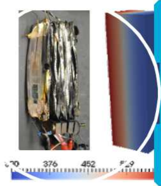


## Battery Reliability

- Yuliya Preger
- Armando Fresquez
- Reed Wittman

## Battery Abuse Testing

Loraine Torres-Castro
Hsin Wang (ORNL)
Michael Hargather (NMT)



## Fire Sciences and Modelling

John Hewson
Matt Paiss (PNNL)
Randy Shurtz
Andrew Kurzawski

## Outreach, codes, and standards

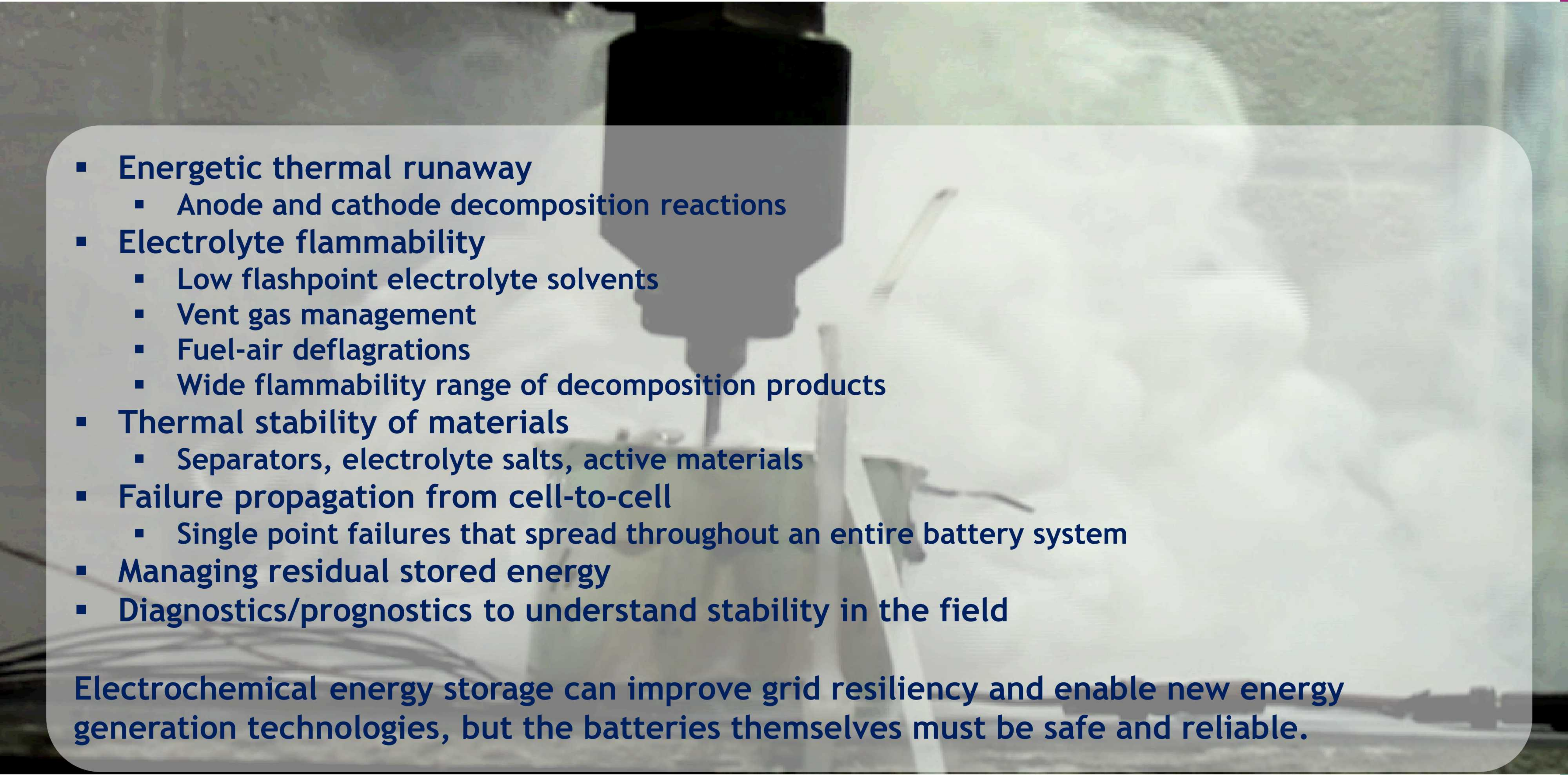
Matt Paiss (PNNL)

Chris Searles

## System design impacts on battery safety

David Rosewater

# Lithium-ion and general battery safety concerns



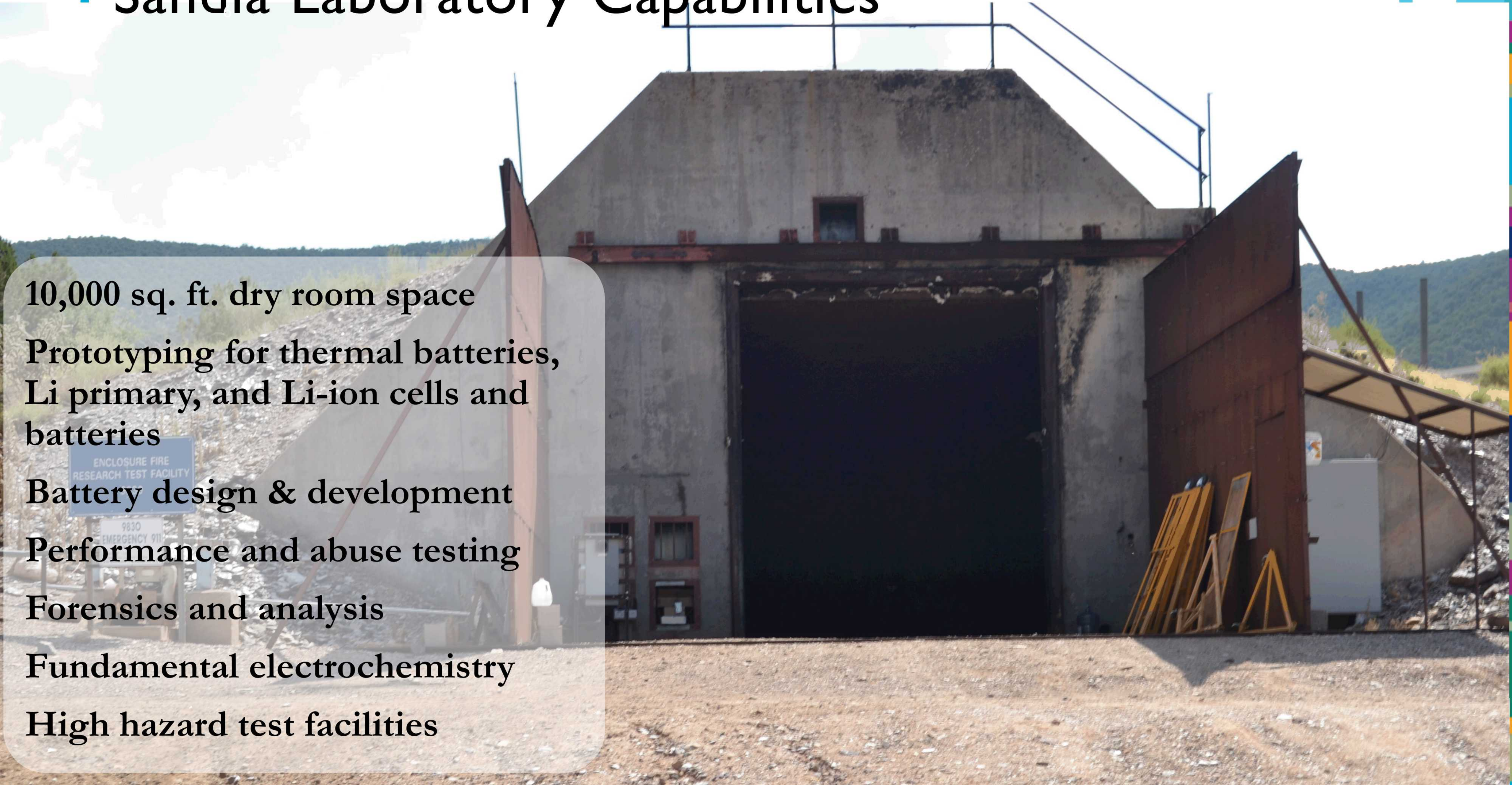
- Energetic thermal runaway
  - Anode and cathode decomposition reactions
- Electrolyte flammability
  - Low flashpoint electrolyte solvents
  - Vent gas management
  - Fuel-air deflagrations
  - Wide flammability range of decomposition products
- Thermal stability of materials
  - Separators, electrolyte salts, active materials
- Failure propagation from cell-to-cell
  - Single point failures that spread throughout an entire battery system
- Managing residual stored energy
- Diagnostics/prognostics to understand stability in the field

**Electrochemical energy storage can improve grid resiliency and enable new energy generation technologies, but the batteries themselves must be safe and reliable.**

# An example of thermal runaway

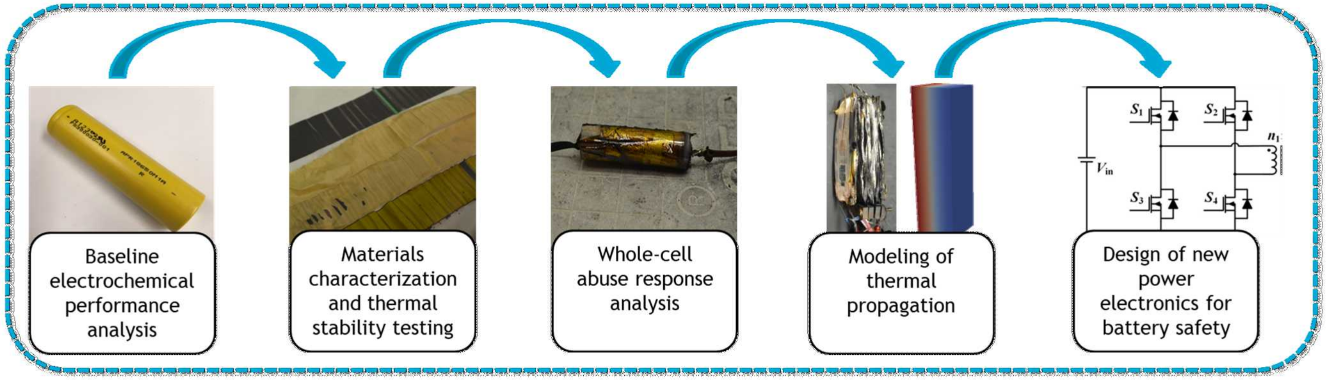

# Sandia Laboratory Capabilities

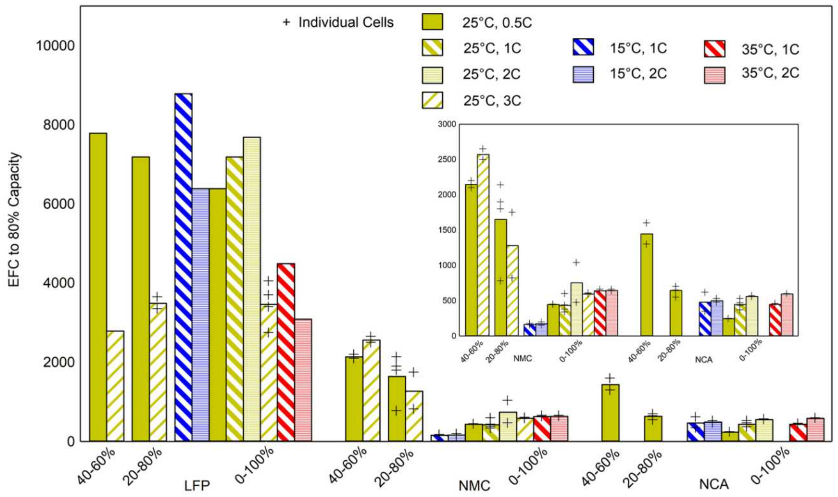
- 10,000 sq. ft. dry room space
- Prototyping for thermal batteries, Li primary, and Li-ion cells and batteries
- Battery design & development
- Performance and abuse testing
- Forensics and analysis
- Fundamental electrochemistry
- High hazard test facilities

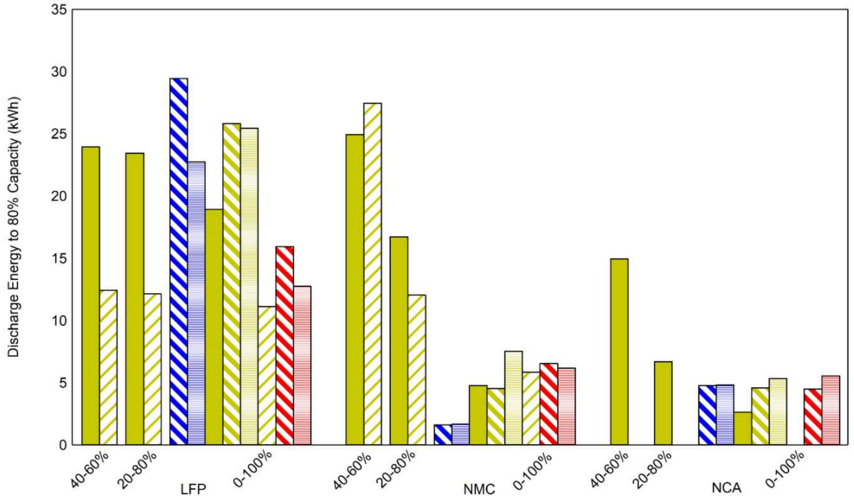


# Long-term safety and reliability

Batteries could be in use for 1000s of cycles, this work looks to develop a better understanding of the reliability and stability of lithium-ion batteries late in their life.



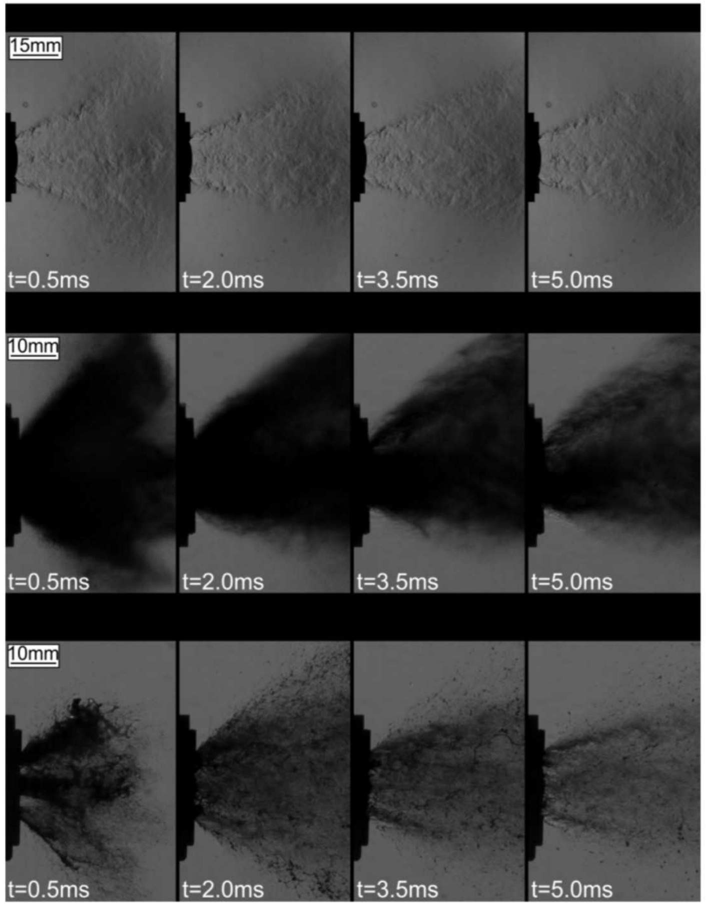




See Poster "Long-term safety and performance of commercial lithium-ion cells" by Y. Preger

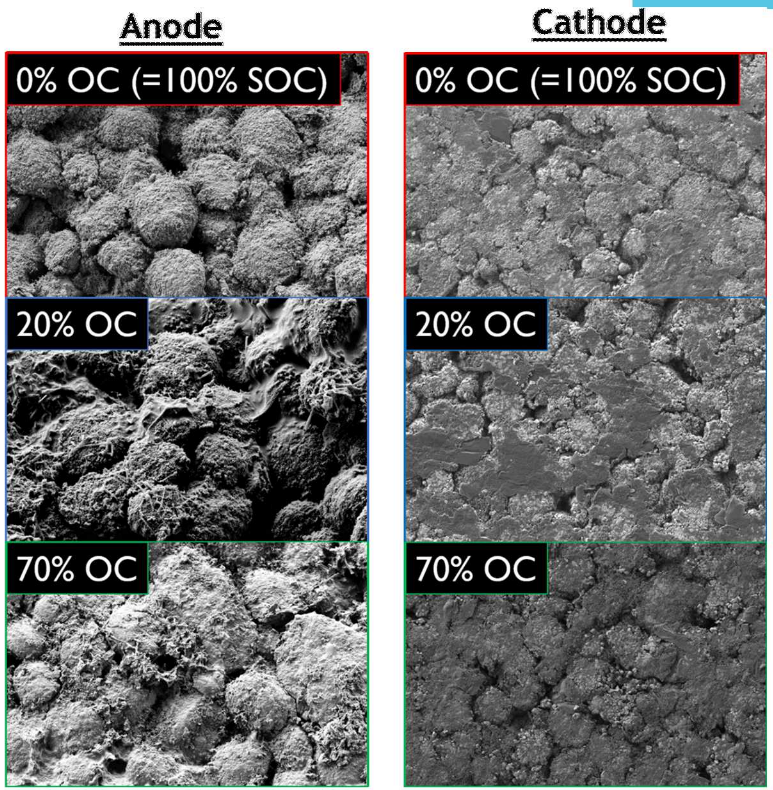
# Battery Abuse Testing

Collaborative evaluation of abuse test results SNL-ORNL
A) Post-test Indenter hole of the 50% SOC cell
B) Side view of cell swelling and seam separation, showing interior contents

More Detail in H. Wang presentation




Electrolyte droplet spray characterization by M. Hargather

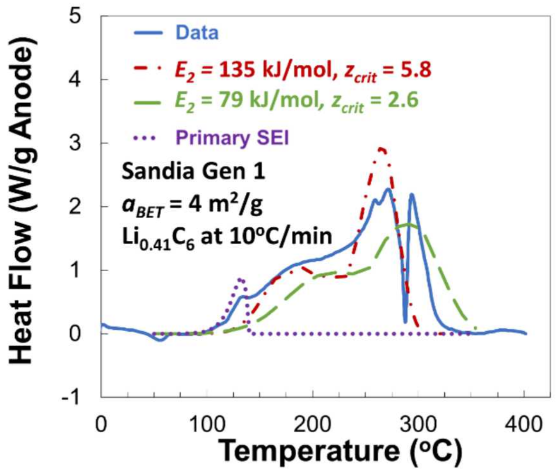


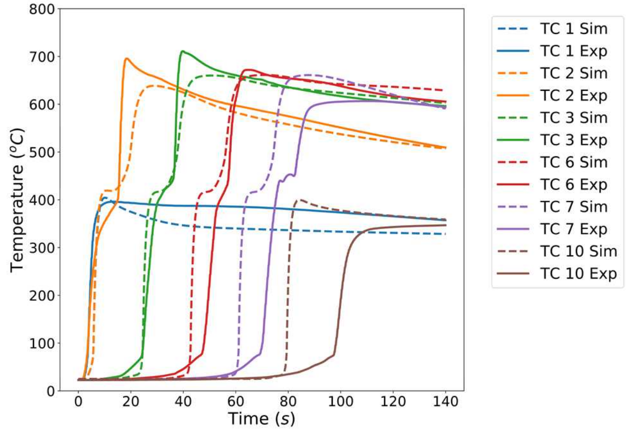

Impacts of overcharge on battery microstructure and materials. See poster “Materials Characterization of Abused Cells” by L. Torres-Castro.

Battery abuse testing presents us with a means to experimentally determine the nature of energetic battery failure and the potential hazards inherent to stored energy.

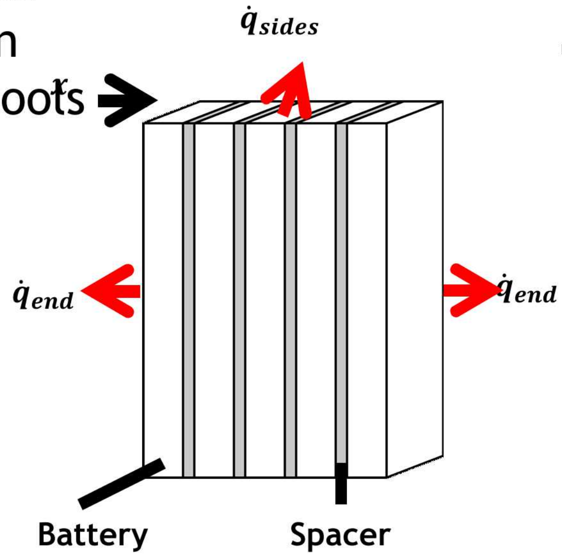
# Fire Sciences and Modeling

- Predict thermal runaway behavior in large systems (multi-cell)
- Develop improved heat-source models for thermal runaway
- Promote effective methods and collaboration in thermal runaway studies
- Finite element modeling of pouch cell stacks



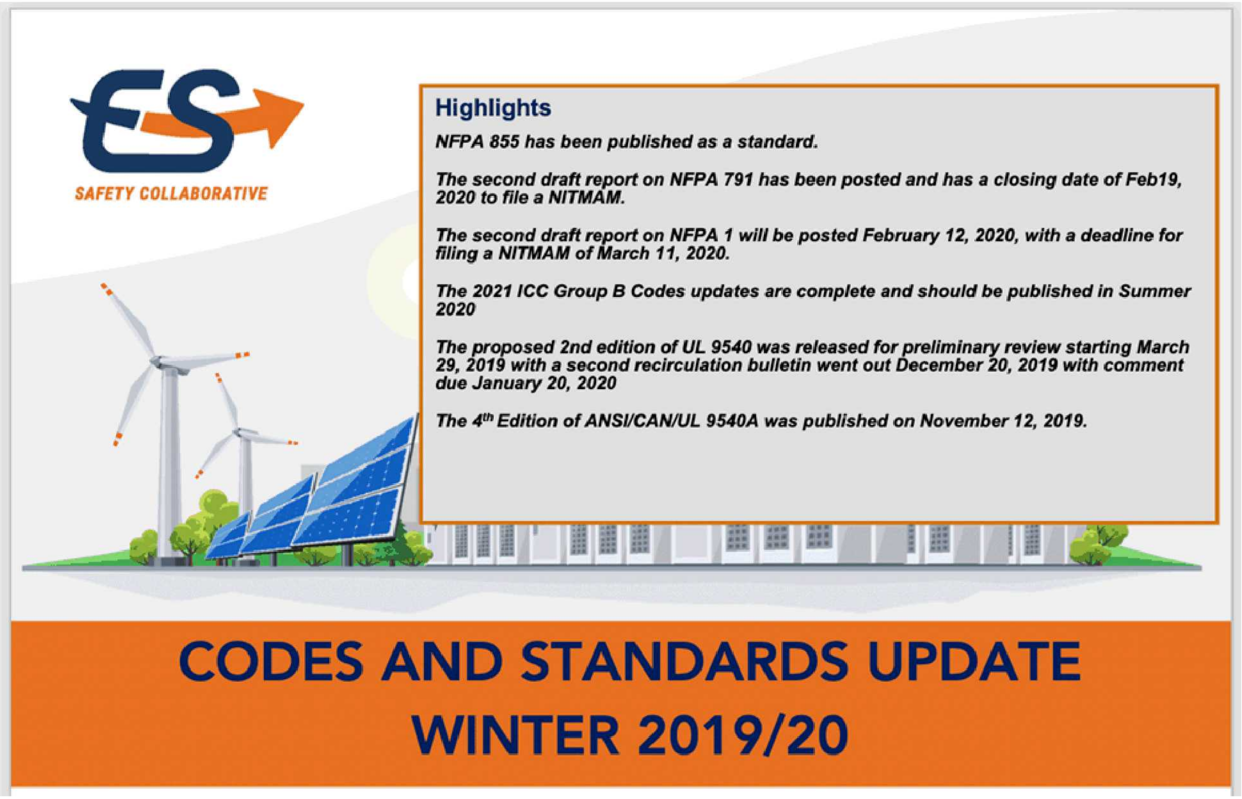

An understanding of the thermodynamics of battery thermal runaway and failure propagation fills in the gaps that testing cannot. This leads to a more reliable design space for large scale systems as better computational tools become available.




See poster by A. Kurzawski for more details.

# Energy Storage Safety Collaborative Reports

**Get the free reports to remain alerted to key ESS Codes & Standards updates!**


ES
SAFETY COLLABORATIVE

**Highlights**

*NFPA 855 has been published as a standard.*

*The second draft report on NFPA 791 has been posted and has a closing date of Feb19, 2020 to file a NITMAM.*

*The second draft report on NFPA 1 will be posted February 12, 2020, with a deadline for filing a NITMAM of March 11, 2020.*

*The 2021 ICC Group B Codes updates are complete and should be published in Summer 2020*

*The proposed 2nd edition of UL 9540 was released for preliminary review starting March 29, 2019 with a second recirculation bulletin went out December 20, 2019 with comment due January 20, 2020*

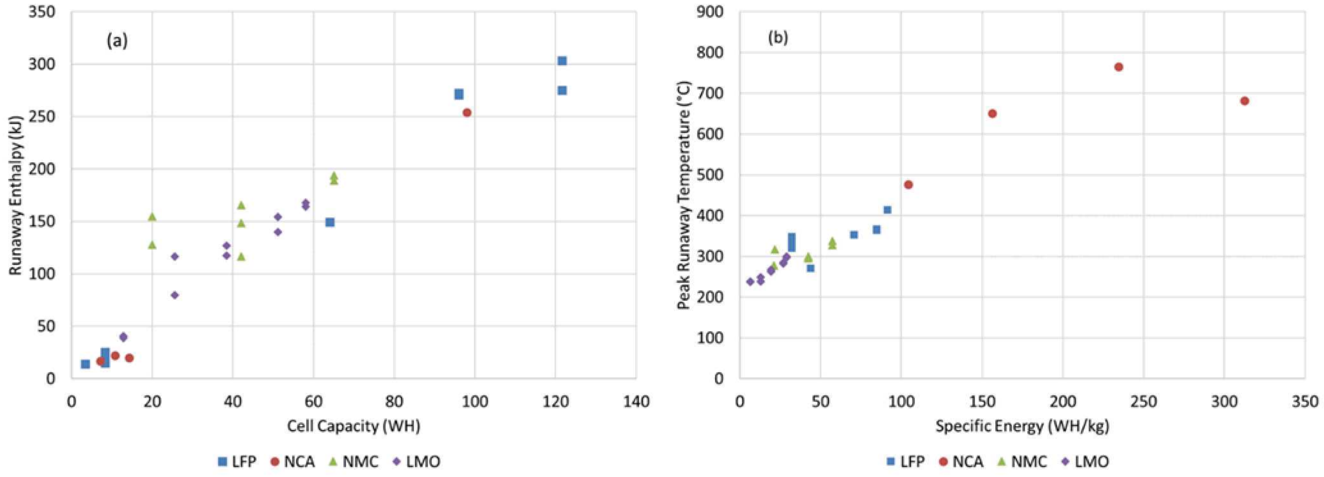
*The 4th Edition of ANSI/CAN/UL 9540A was published on November 12, 2019.*

CODES AND STANDARDS UPDATE
WINTER 2019/20

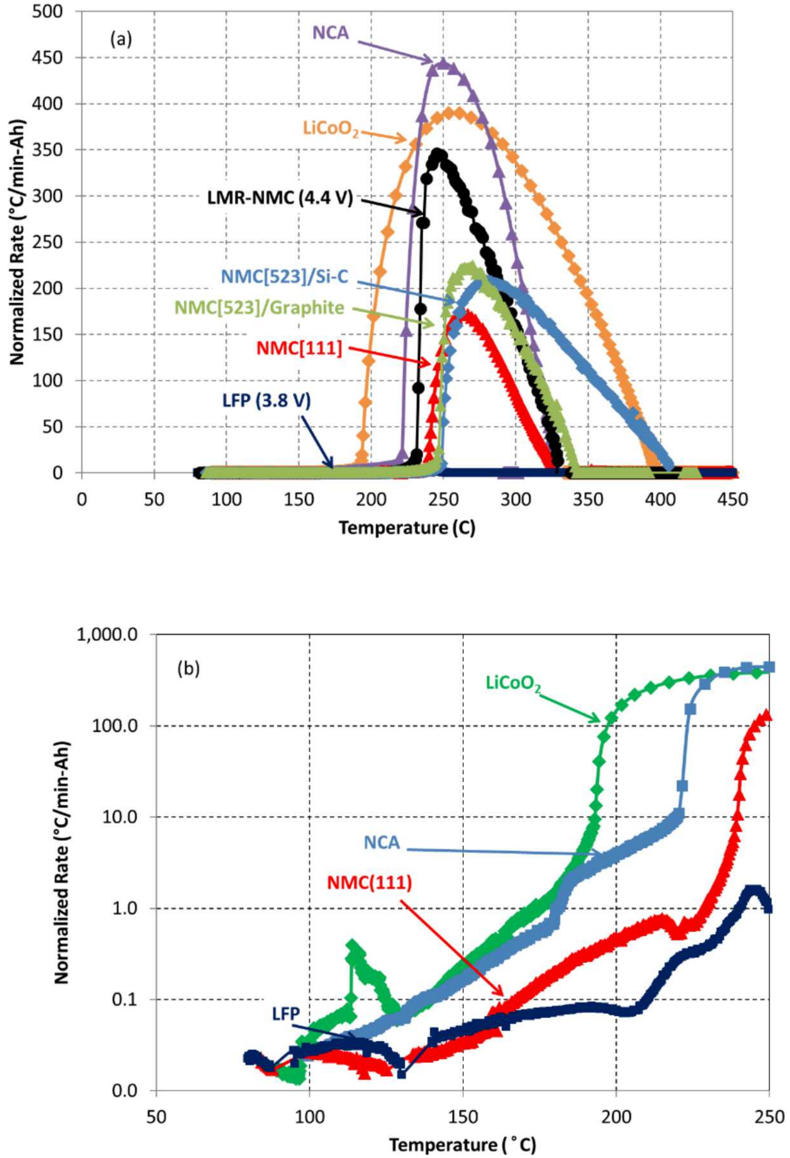
Take photo of code to sign-up to receive quarterly reports

https://public.govdelivery.com/accounts/USDOESNLEC/subscriber/new?topic_id=USDOESNLEC_195

# Accelerating Rate Calorimetry




Compilation of accelerating rate calorimetry data collected at Sandia to better understand the role of energy density in thermal runaway. These plots show how increasing energy densities contribute to higher peak thermal runaway temperatures independent of cathode material.



# Perspective Paper on the need to Study Aqueous Battery Safety

- Motivation:
  - Battery safety focus historically has been on Li-ion systems
  - Aqueous systems have their own potential issues that need to be addressed for them to be commercially adopted quickly
  - Little work has been done to understand the safety aspects of these systems so far
- Primary safety issues in aqueous cells:
  - Gas Evolution
    - Primarily $H_2$
    - Different systems can produce other gasses ($Br_2$ out of Zn-Br and $Cl_2$ out of MA –RFB)
- Thermal Runaway
  - Can occur in any system where an exothermic positive feedback loop is possible (Flooded Pb-acid or Ni-MH)
- Categorized 4 primary pathways cells can degrade to unsafe conditions
  - Electrochemical (Extreme SOC or cycling rate)
  - Chemical (Electrode passivation or separator degradation)
  - Mechanical (Electrode shape change or swelling from gas evolution)
  - Abuse (Extreme temperature or external short)
- Future work focusing on $Cl_2$ out of MA VRFBs

| Degradation Type | Degradation Process | Possible Outcomes of Degradation | Proposed Studies | Measurements |
|---|---|---|---|---|
| Chemical | | | | |
| Membrane | Decomposition by electrolyte<br>Decomposition by impurities | Decreased conductivity<br>Increased charging voltage<br>Active species crossover<br>Gas evolution<br>Enables internal short circuits | Long term chemical stability study in supporting electrolyte at typical operating temperatures<br>Crossover rate at various electrolyte compositions | Rate of crossover<br>Ionic conductivity<br>Mechanical strength<br>Chemical changes in membrane<br>Gas evolution |
| Electrode | Passivation<br>Poisoning by impurity | Increased cell voltage<br>Increased rate of side reactions | Stability in electrolyte<br>Passivation mechanism<br>Effect of different impurities<br>Ability to catalyze reactions in electrolyte | Gas evolution<br>Surface structure changes<br>Electrode voltage |
| Electrolyte | Precipitation of active species<br>Spontaneous reactions | Loss of capacity<br>Loss of electrolyte<br>Self-discharge<br>Increased cell voltage | Pourbaix diagram for all electrolyte conditions<br>Experimental rate of side reactions<br>Influence of species crossover on precipitation and side reactions | Gas evolution<br>Changes to chemical composition<br>Rate of side reactions<br>Changes in capacity |

Part of fig 2 from Reed M. Wittman et al 2020 J. Electrochem. Soc. 167 090545

# Acknowledgements

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