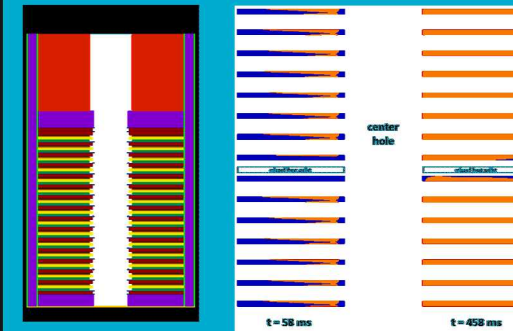


# Observations of Thermal Behavior in a Center-Fired Battery After a Missed Heat Pellet Ignition



PRESENTED BY

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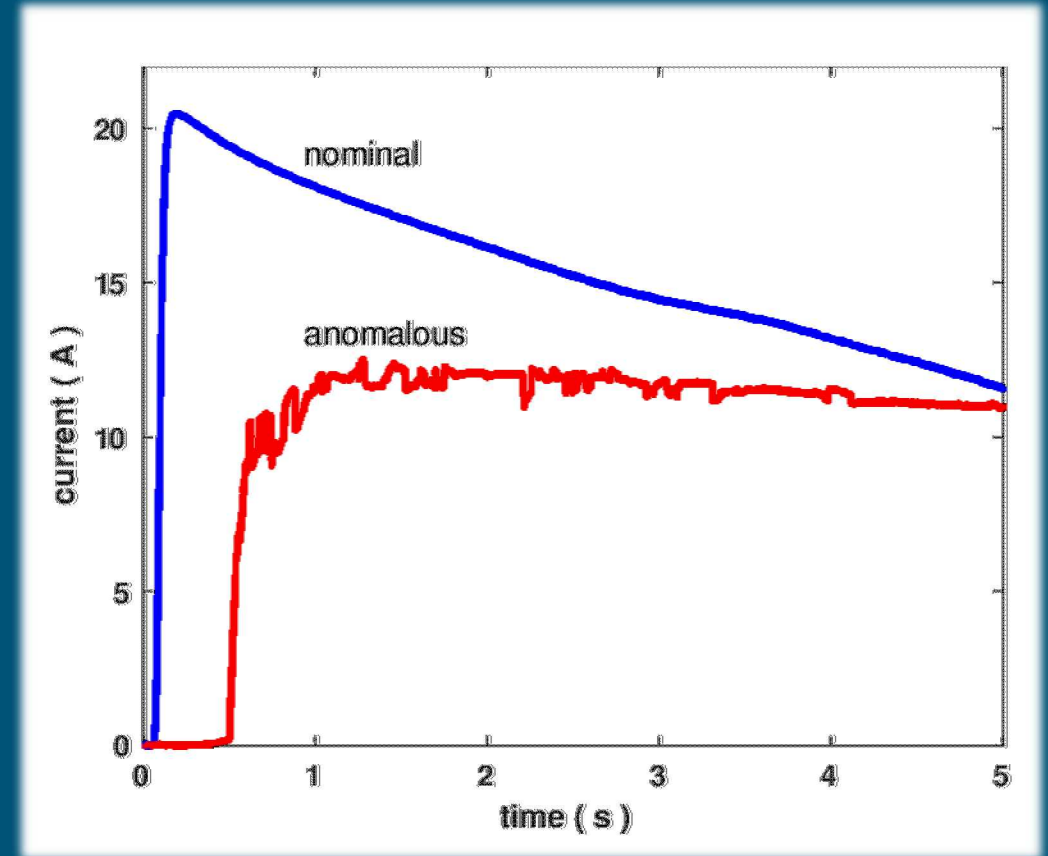
# Observation of Anomalous Behavior in a Real Battery

Battery discharged through a constant resistance

Rise time and current profile differed from previous batteries of the same design

- Nominal rise time: 55 ms
- Anomalous rise time: 492 ms

This work grew from an effort to explain the anomaly



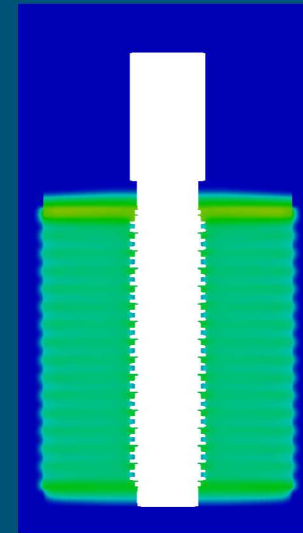
# Ignition in Center-Fired Batteries

No direct contact between pyrotechnic materials

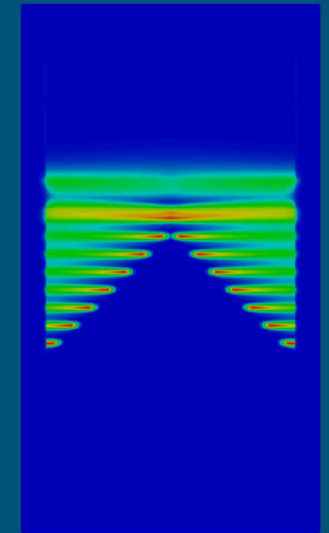
- Relies on gas-phase and particle transport for ignition
- Much faster than heat paper

Missed heat pellet ignition is an acknowledged risk

- Risk increased by:
  - aging
  - stack misalignment



center-fired



side-fired

$t = 125 \text{ ms}$

# Methodology

Initial model built in TABS-Full Battery

- 2D Axisymmetric geometry
- Modified in Cubit to more accurately represent center hole

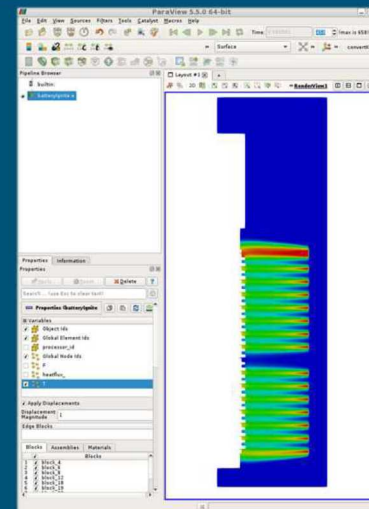
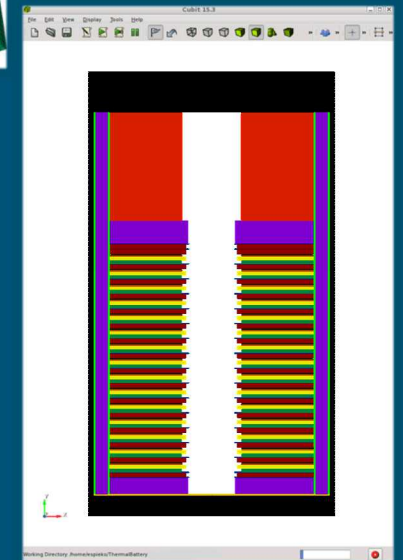
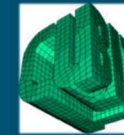
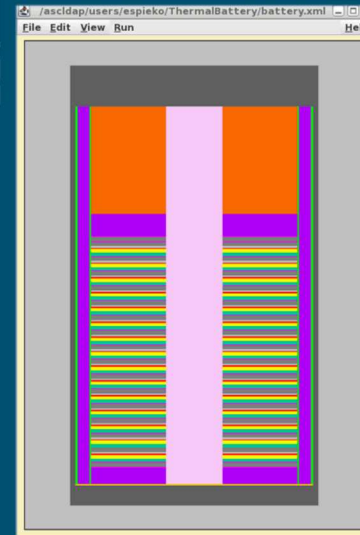
Grid generated in Cubit

- 376,969 quadrilateral elements

Simulations performed in Sierra

- Multimechanics module (Aria)

Visualization / data extraction in ParaView



# Separator Melting

Simulation did not include electrochemistry

- Rise time could not be computed directly

Separator melting was chosen as a surrogate

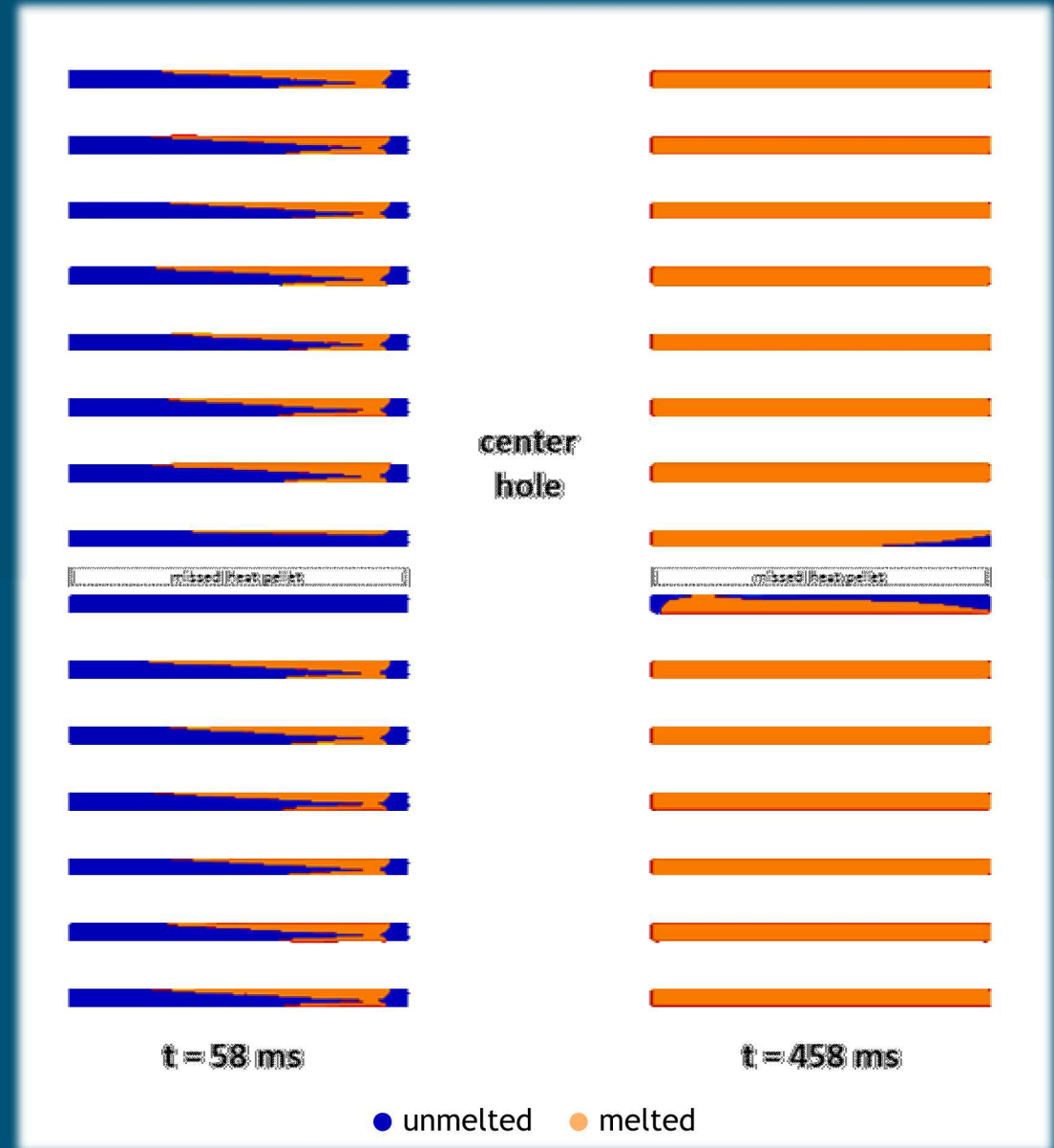
- Rise time related to establishment of a continuous path through melted electrolyte across all separators

At 58 ms, most separators show a melted path

- Compares well with nominal 55 ms rise time

At 458 ms, last separator shows a melted path

- Compares well with anomalous 492 ms rise time



# Sensitivity to Auto-Ignition Temperature

Several values for auto-ignition temperature have been reported

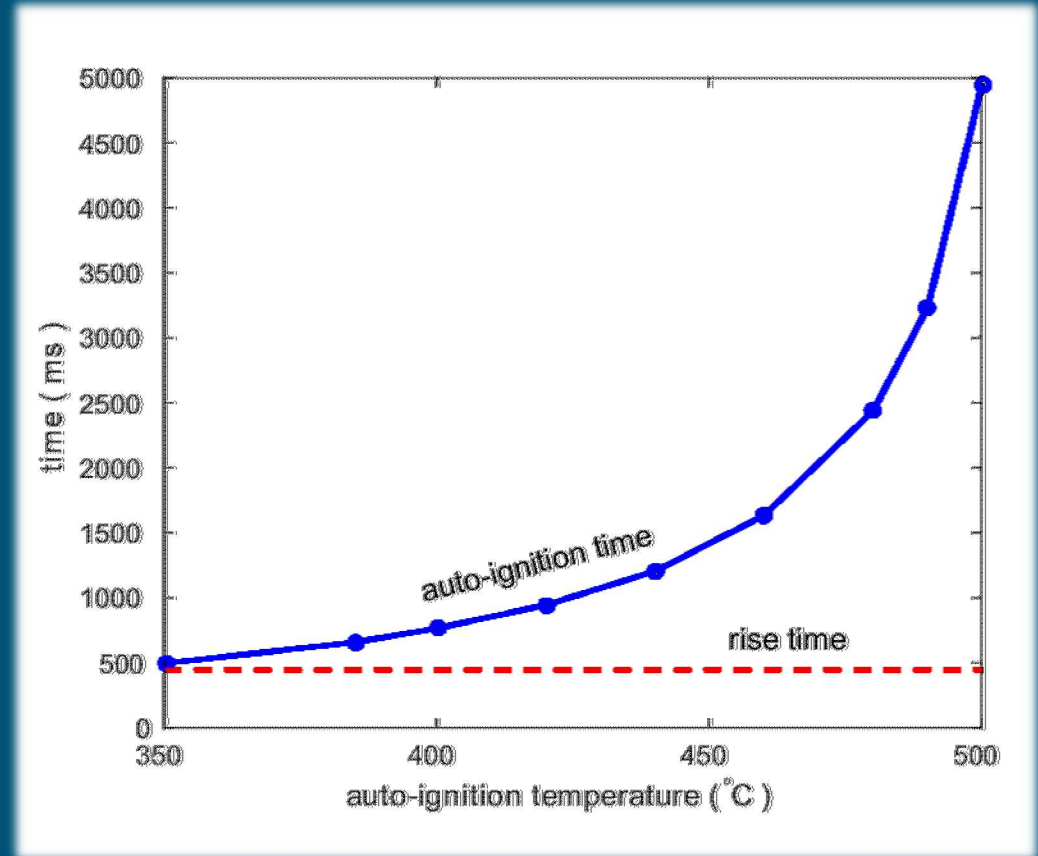
- Likely depends on pellet parameters

Auto-ignition time is strongly dependent on auto-ignition temperature

- Heating of missed heat pellet is a slow process

Rise time is insensitive to auto-ignition temperature

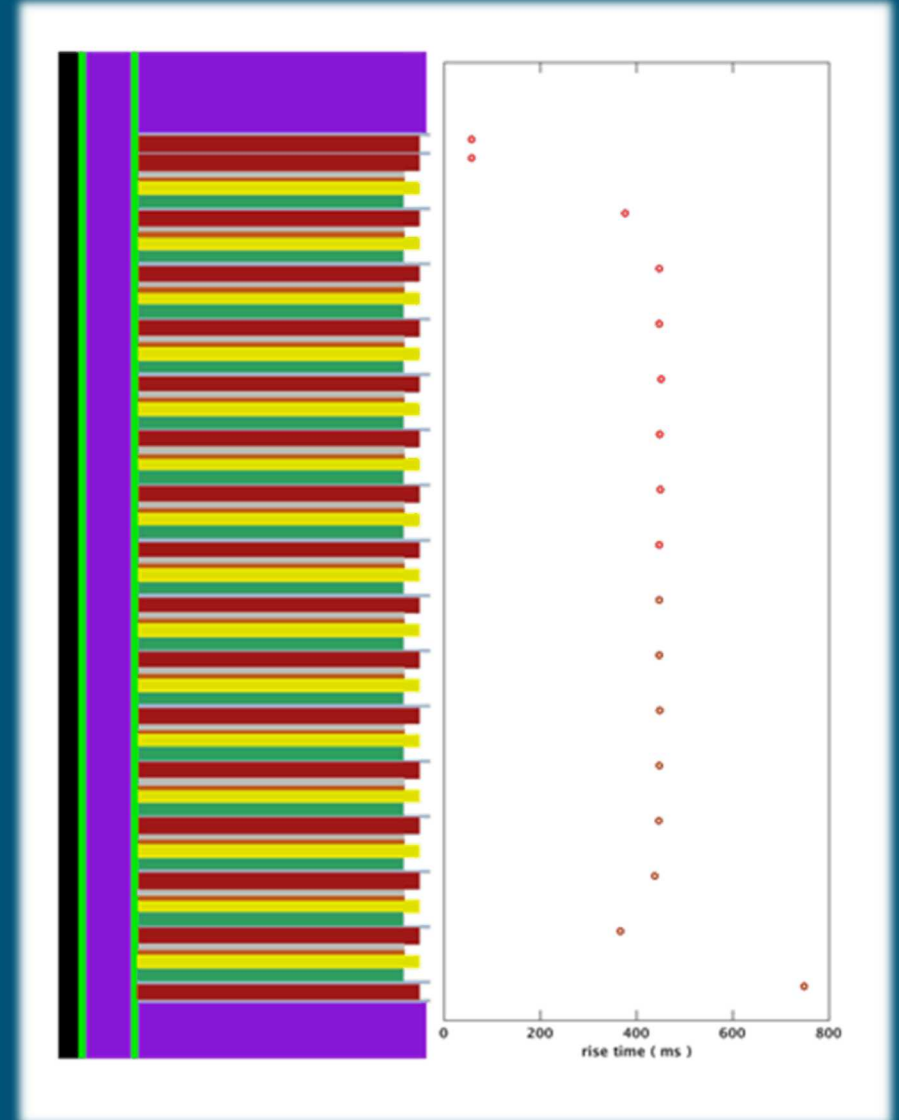
- Last separator melts before last heat pellet ignites because it is closer to a working heat pellet



# Sensitivity to Missed Heat Pellet Position

## Rise time:

- Is insensitive to position near the middle
- Is nearly nominal at the top
  - Almost immediate auto-ignition via adjacent heat pellet
- Increases significantly at the bottom
  - Bottom separator heated from only one side



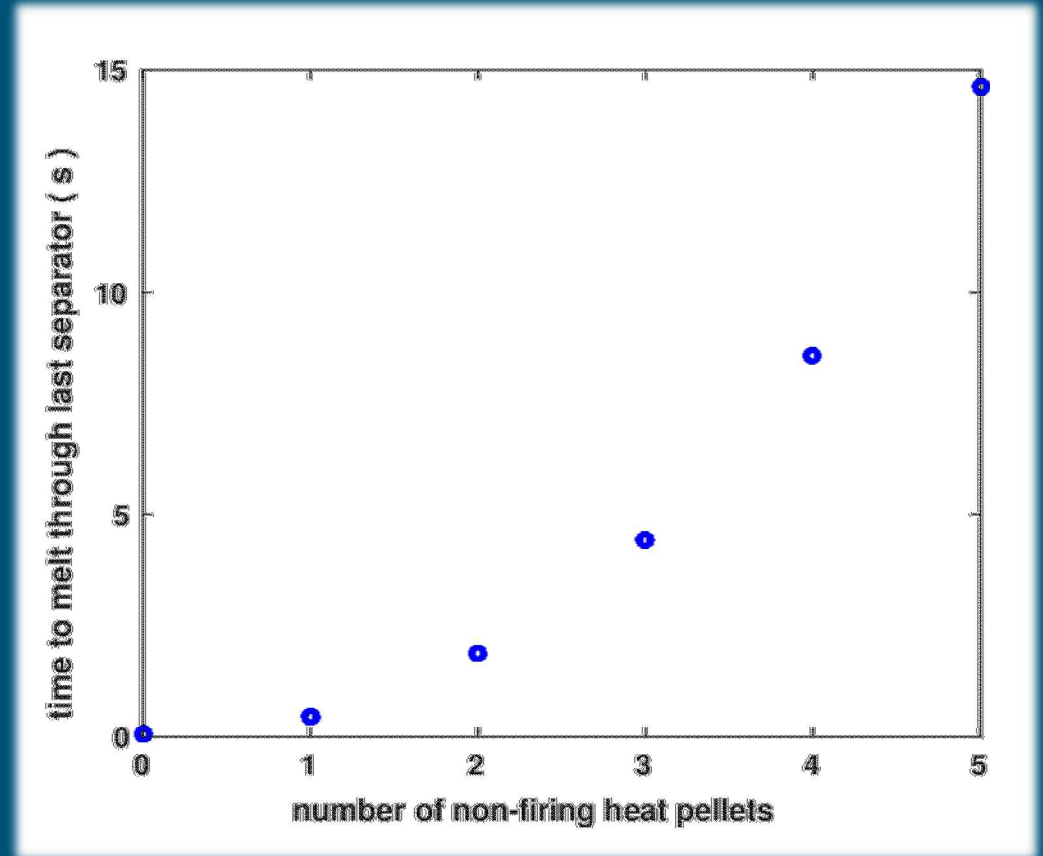
## What If We Miss More Than One?

Rise time increases very quickly as adjacent heat pellets are missed

Non-adjacent heat pellets, if far enough apart, would behave as if one was missed

Based on timing data, anomalous battery had one missed heat pellet

- Perhaps more if well spaced

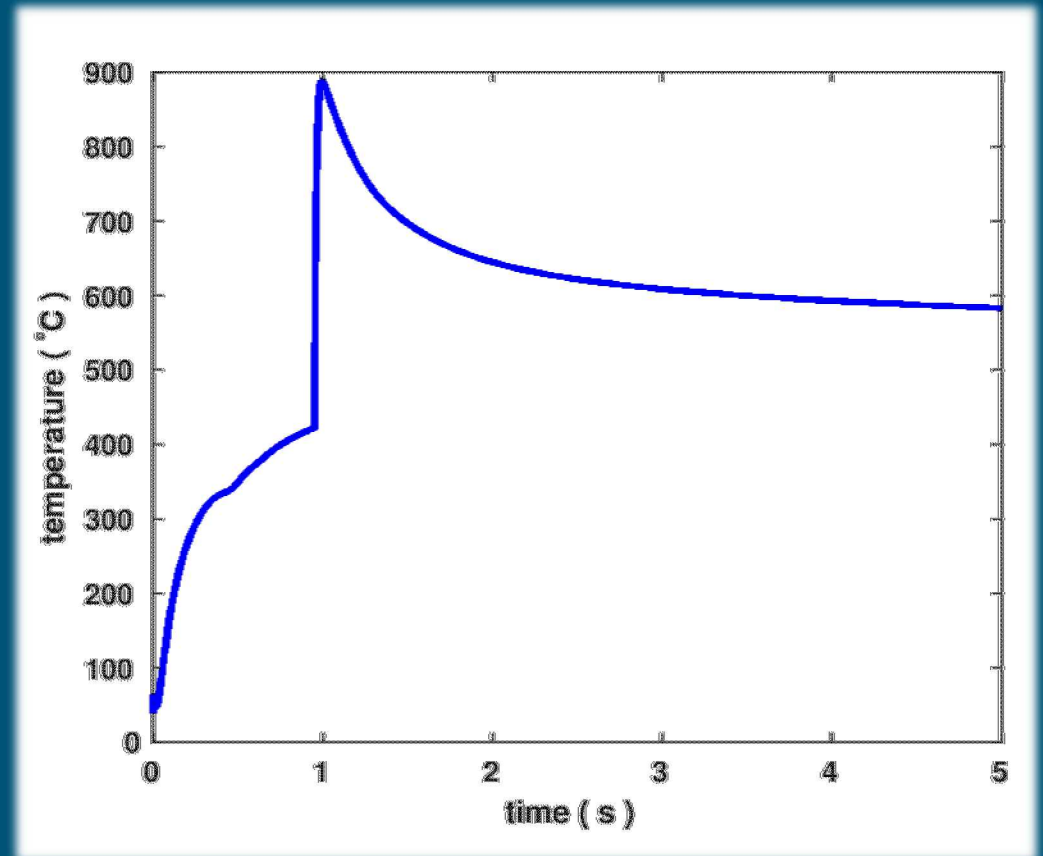


# Late-Firing Heat Pellet Can Trigger Runaway

Due to auto-ignition delay, missed heat pellet fires in an already-hot battery

- Cell materials are exposed to much higher temperatures than expected
- Overheating can cause thermal runaway

Because center-fired batteries are generally short-lived and the missed heat pellet fires late, runaway may not affect application



# Conclusions

Even purely thermal simulations can provide significant insight into battery behavior

- In this case, they were instrumental in determining the cause of an anomalous battery test

Within a simulation, a wide range of scenarios can be explored quickly and inexpensively

- Significant insight was gained regarding sensitivity to various parameters

These simulations showed that a problematic battery could support significant loads before a missed heat pellet auto-ignites

- Performance would be sub-optimal, but perhaps sufficient

The observed behavior is insensitive to missed heat pellet position, except at the ends

The late-firing heat pellet could drive the battery into thermal runaway

- But it may happen too late to affect the application