Methods for Thermal Runaway Validation of Aviation Batteries

December 2, 2021

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Outline

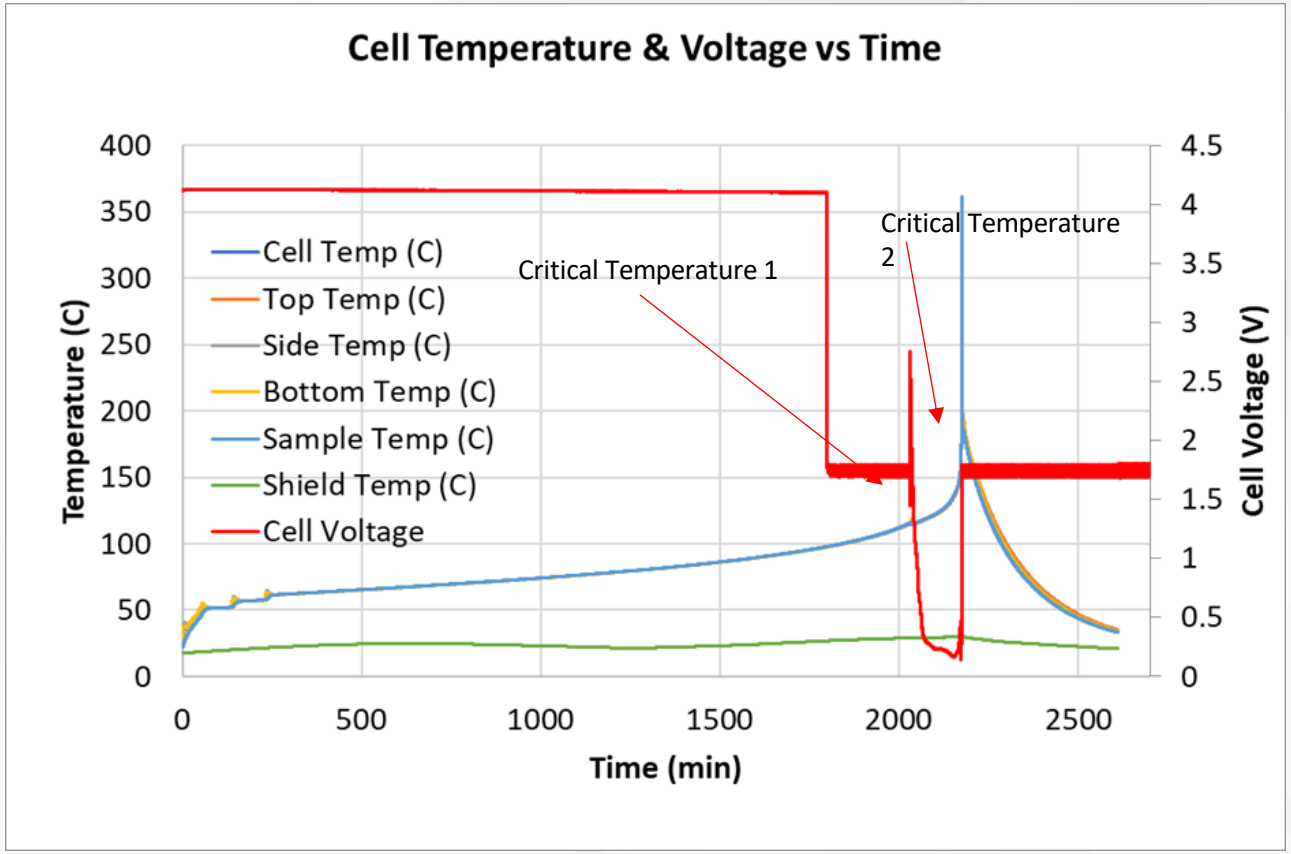
- Introduction to thermal runaway and battery fires
- Thermal Runaway Analysis Methodology
- Samsung 30Q Results
  - Cell
  - Module
- Eagle Picher: Standard Flammability versus Reduced Flammability Electrolyte
  - Cell
  - Module
- Summary

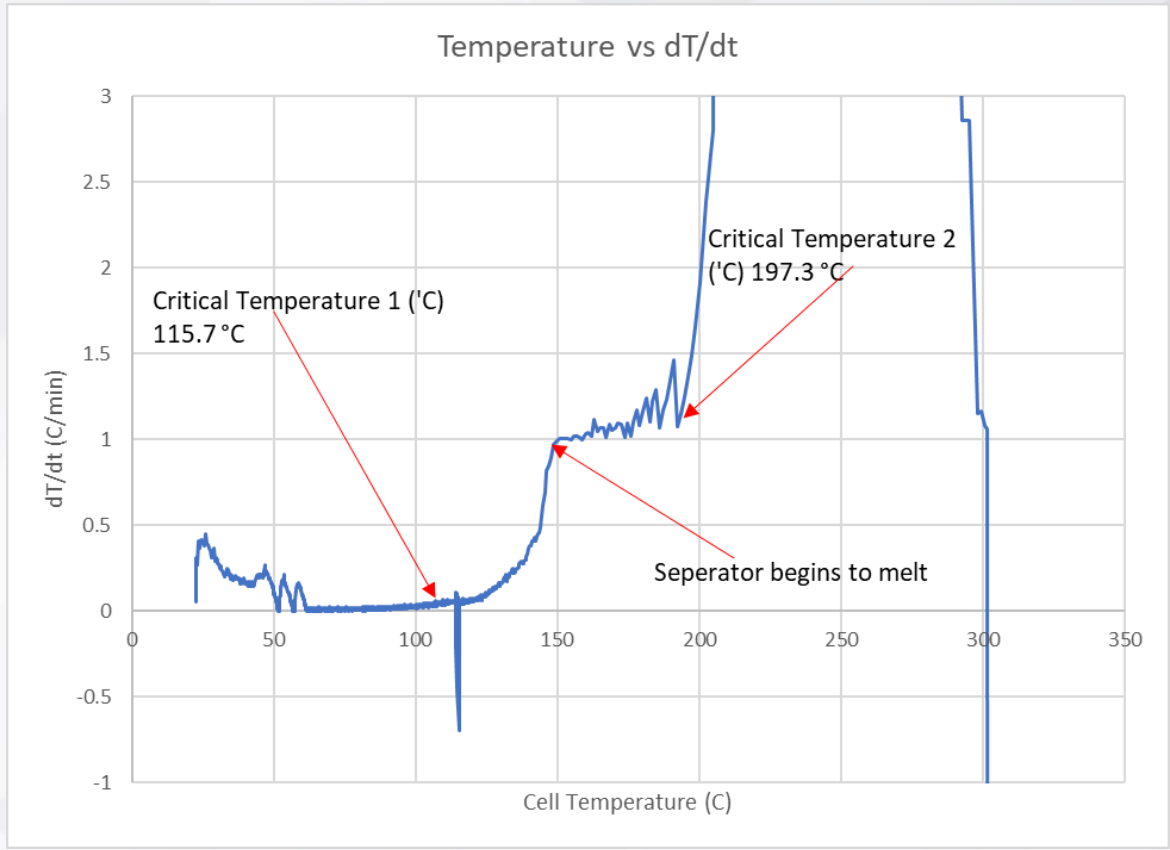
Thermal Runaway Introduction

- Thermal runaway is the point at which heat generated by a battery, either due to charging or discharging, becomes uncontrollable
- Thermal runaway will lead to either permanent battery damage or total cellular destruction and large energy release
- Energy release during thermal runaway includes both the chemical potential of the battery electrolyte and the "joule" heat stored in the cell electrically

Thermal Runaway Introduction

Thermal Runaway Mechanisms





Critical Temp 1: Solid Electrolyte Interface Decomposition

Critical Temp 2: Full Thermal Runaway Event

Samsung Cell Results

- Results from 10- TR test on Samsung 30Q cells

	Maximum Temperature ('C)	Initiation Temperature ('C)	Energy Released (kJ)	Mass Lost (gm)	Jellyroll Ejection
Cell 1	377.3	200.9	14.0	31.8	No
Cell 2	358.0	188.9	13.2	26.4	No
Cell 3	400.5	194.8	30.0	37.0	Yes
Cell 4	302.7	197.3	22.1	37.1	Yes
Cell 5	428.4	194.1	32.2	36.6	Yes
Cell 6	462.7	187.7	34.3	32.4	No
Cell 7	410.1	195.8	30.8	36.8	Yes
Cell 8	325.8	201.4	23.9	33.7	No
Cell 9	325.3	190.3	23.8	25.9	No
Cell 10	355.1	201.9	26.2	33.2	No
Average	374.6	195.3	25.1	33.1	
Standard Dev.	50.8	5.2	7.2	4.2	

- High variability in:
  - Max Temperature, Energy Released, and Mass Lost

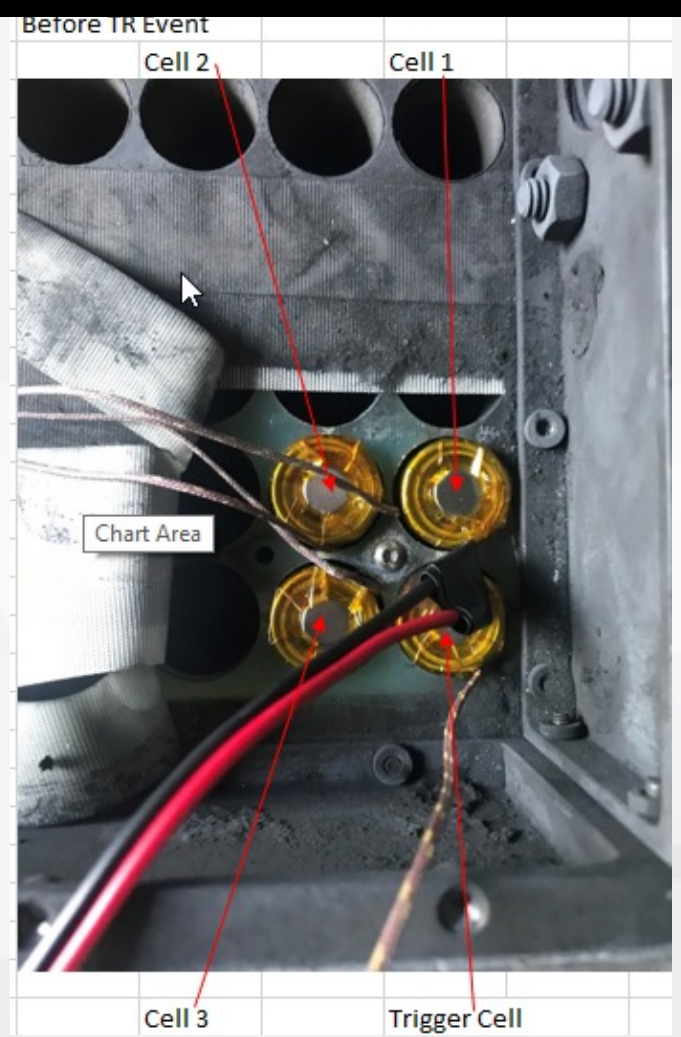
Samsung Cell Results

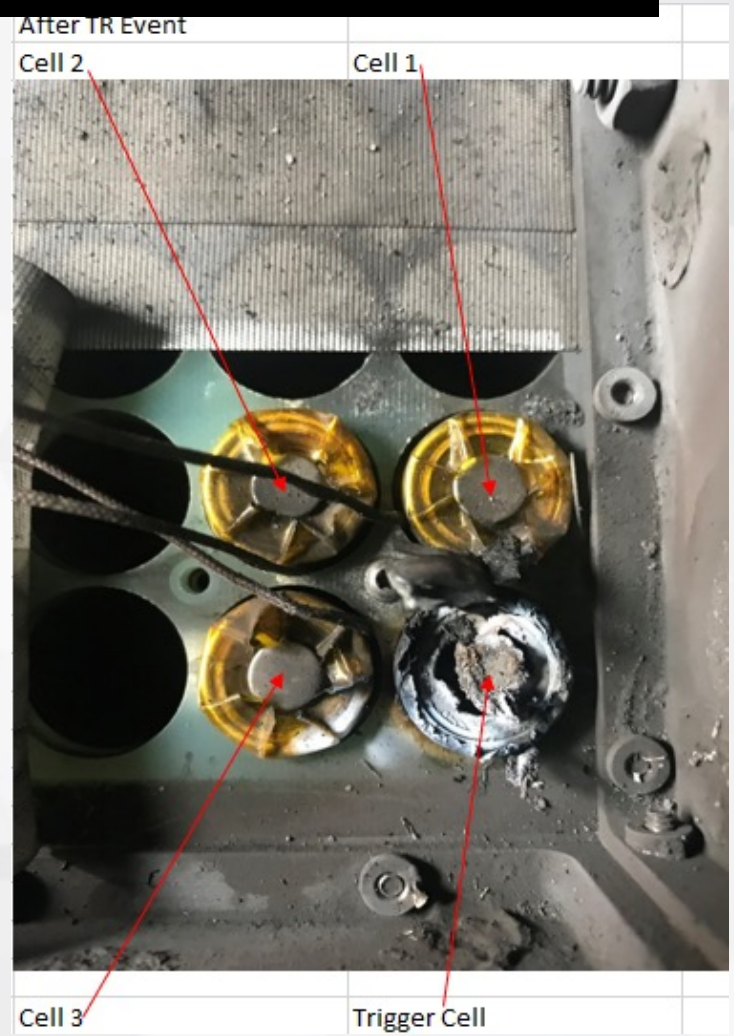
Samsung Cell Results

- Corner

- No cell-to-cell

Propagation Occurred



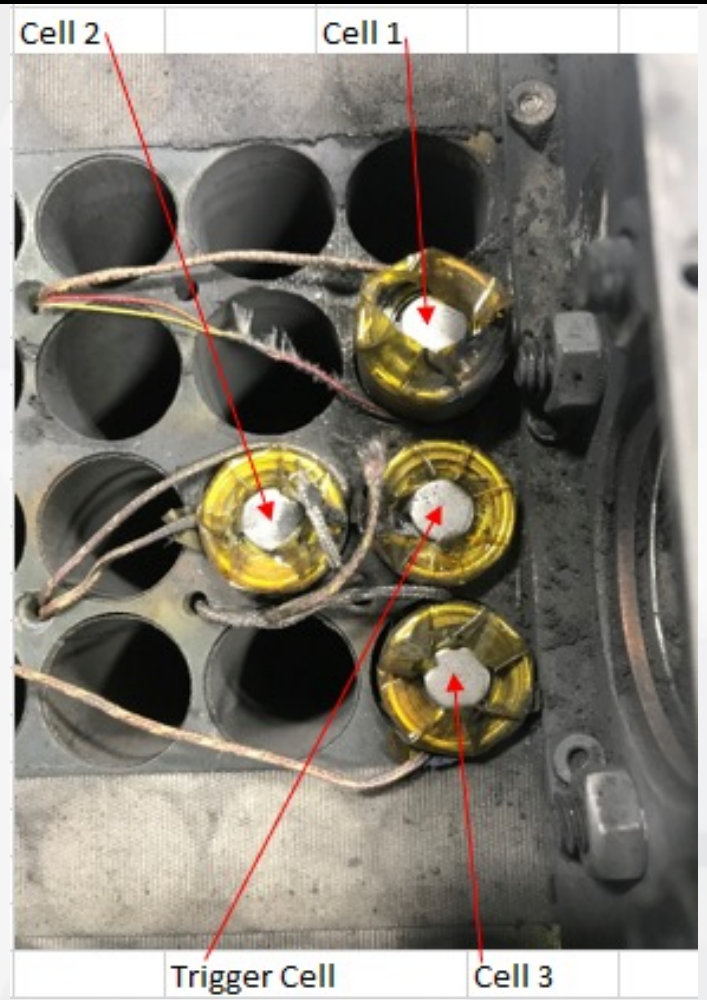


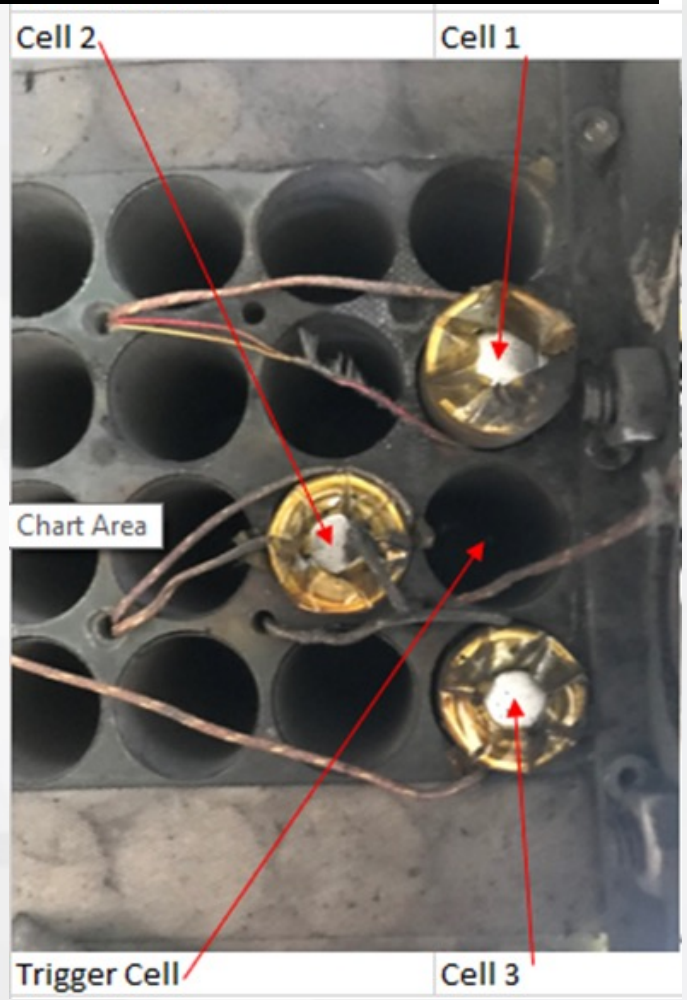
Samsung Cell Results

- Side

- No cell-to-cell Propagation Occurred

- Cell was ejected



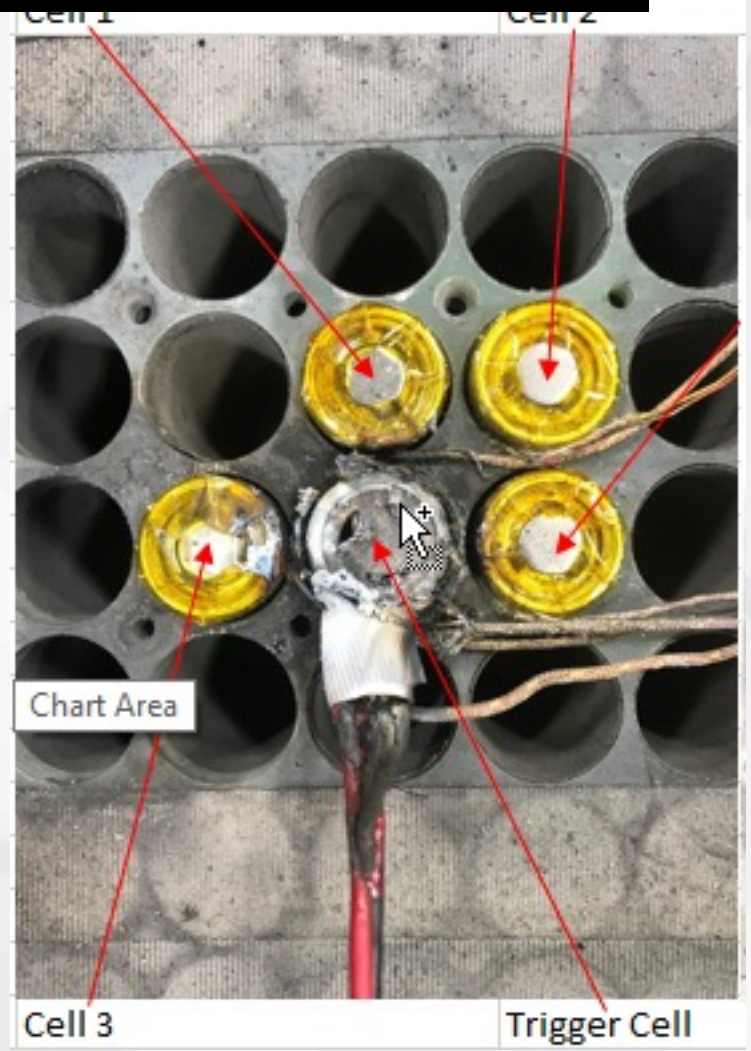


Samsung Cell Results

- Center

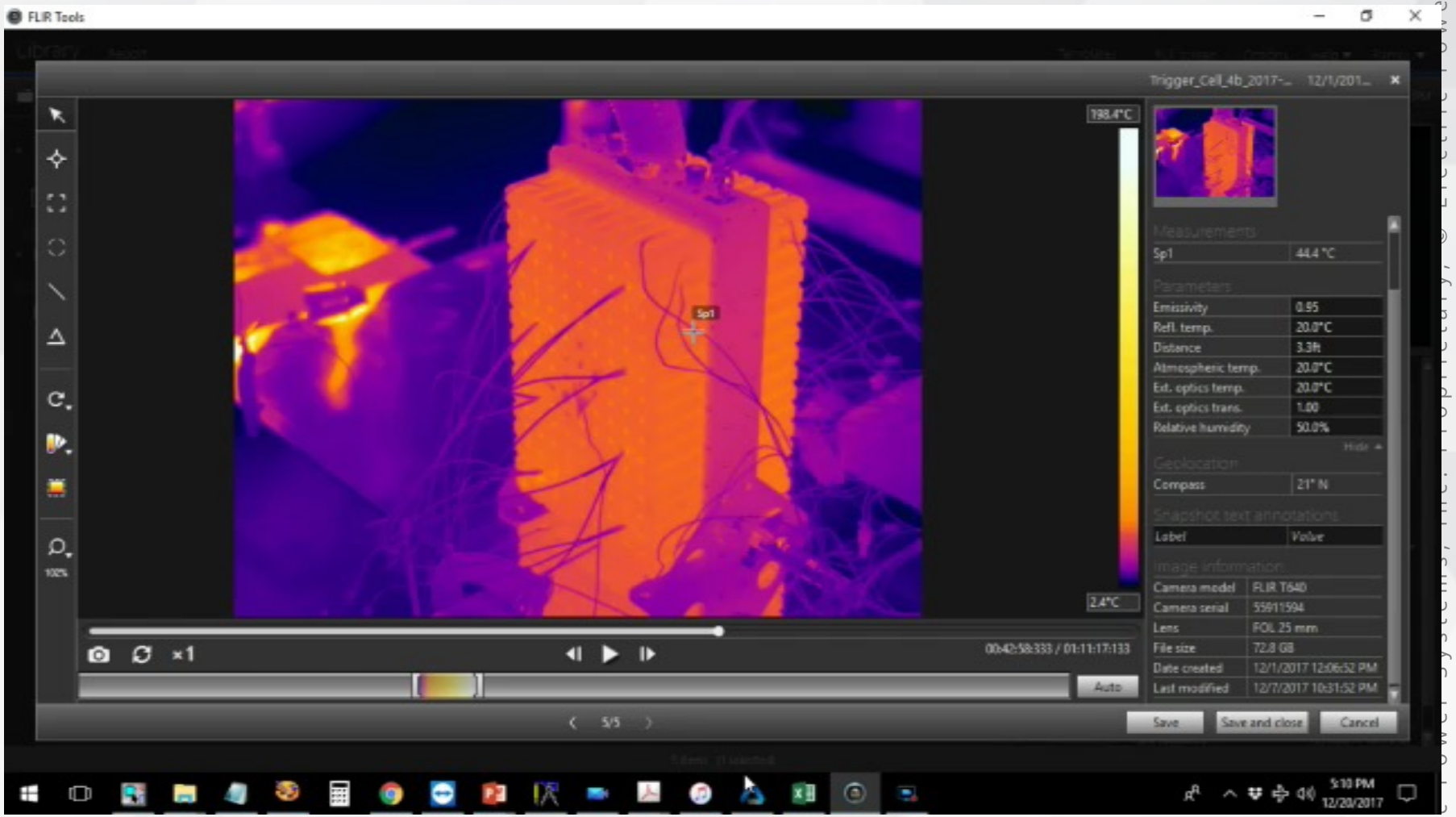
- No cell-to-cell

Propagation Occurred



Module Protection

Past module performance shows containment of TR

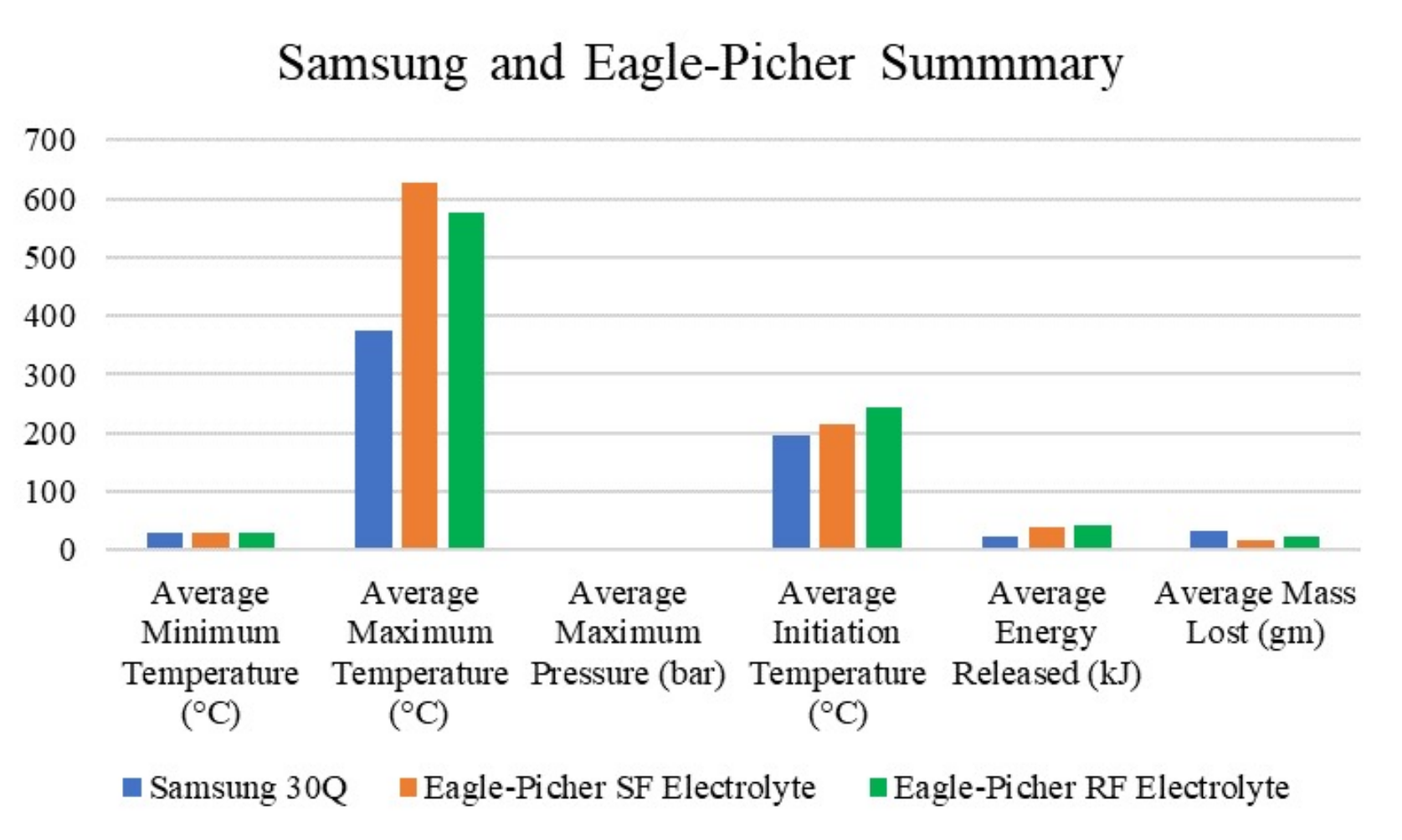


Mitigation Strategies

- **In addition to the Samsung 30Q cells, additional cells from Eagle Picher were also tested for TR response.**
  - Standard Flammability Electrolyte
  - Reduced Flammability Electrotlye

- **These cells followed the same cell and module level testing as the Samsung 30Q cells.**

Reduced Flammability Electrolyte



Reduced Flammability Electrolyte

- On average the RF cells showed ~50°C lower Max TR Temperature versus the SF cells.
- At the module level the RF cells showed ~104°C lower Max TR temperature versus the SF cells.

- Cell TR testing impacts module design
- Module level TR testing impacts system design considerations
- Scale testing is informative at all levels

Acknowledgments

- FAA for the funding
- Alexander Sorensen for the testing work
- Alexander Sorensen and Jennifer Ravenburg for editing

Questions?