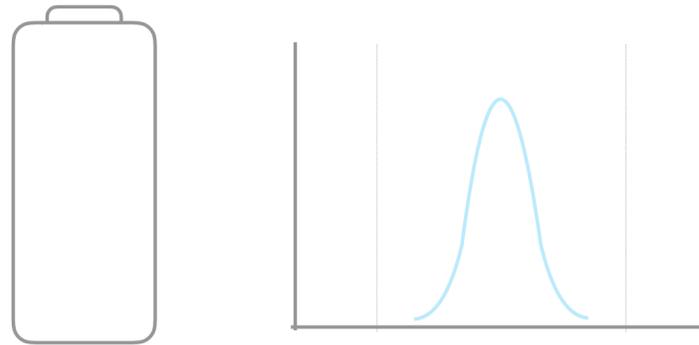


Thermal Safety Testing

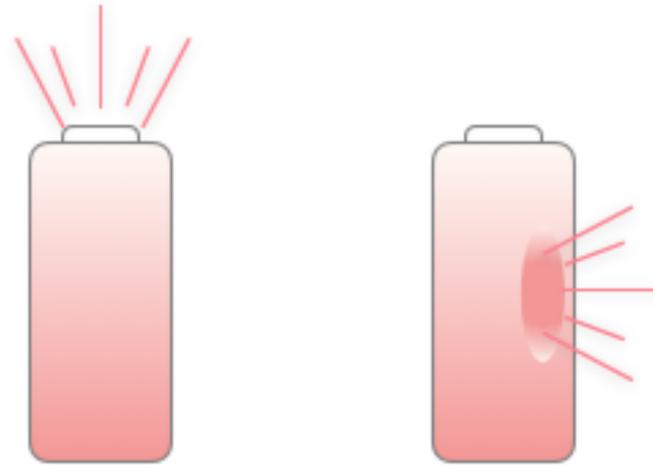
Date - 31 October 2019

Uber

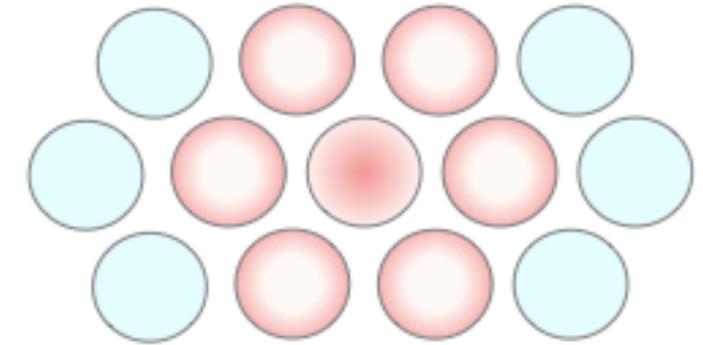
Points of intervention



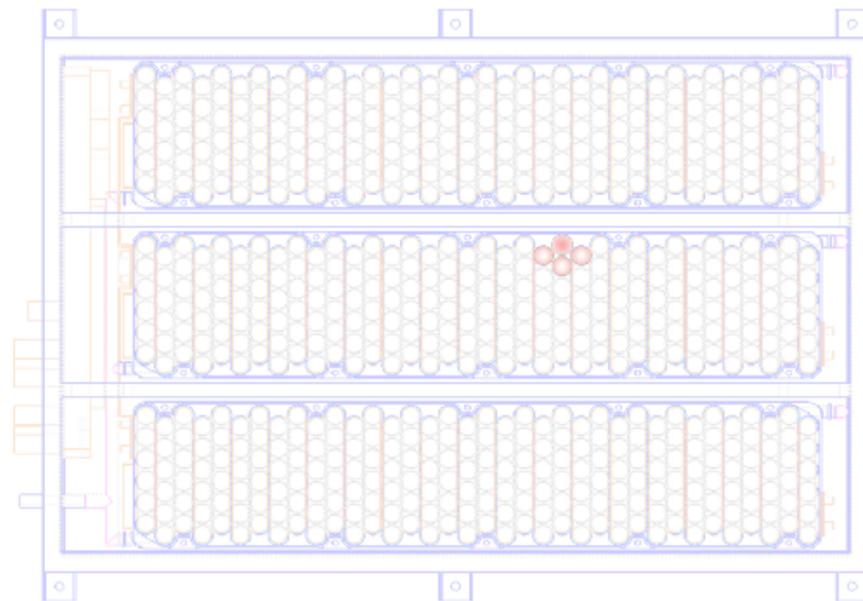
Cell Design and Production Quality



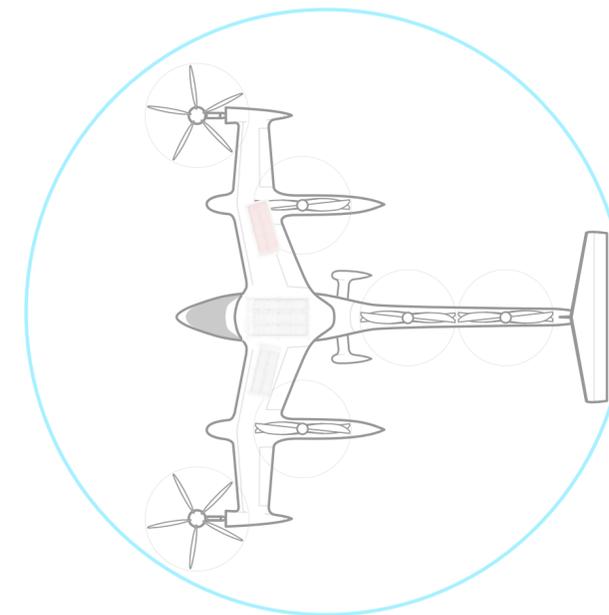
Cell Runaway Characteristics



Cell to Cell Propagation

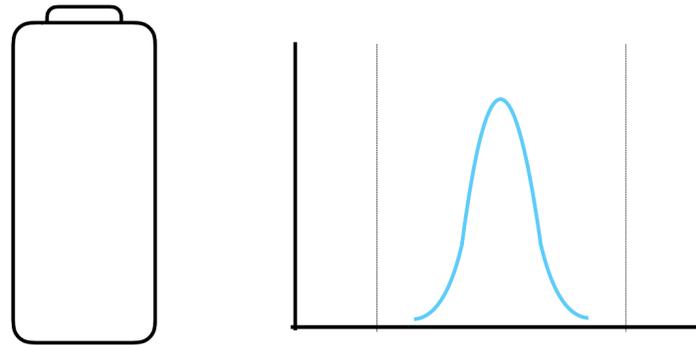


Pack Thermal Event

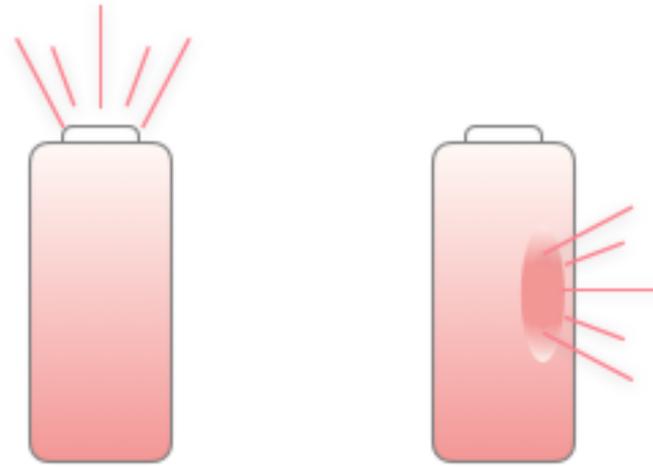


Vehicle Thermal Event

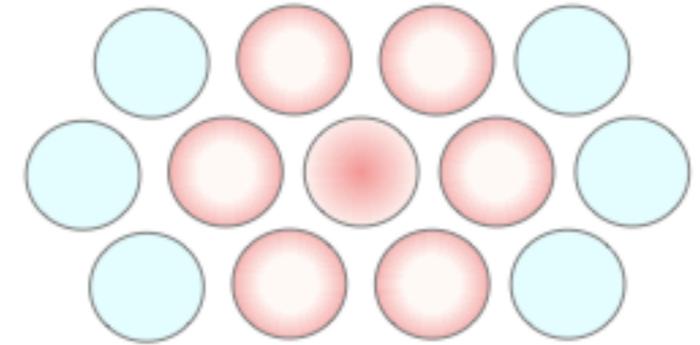
Points of intervention



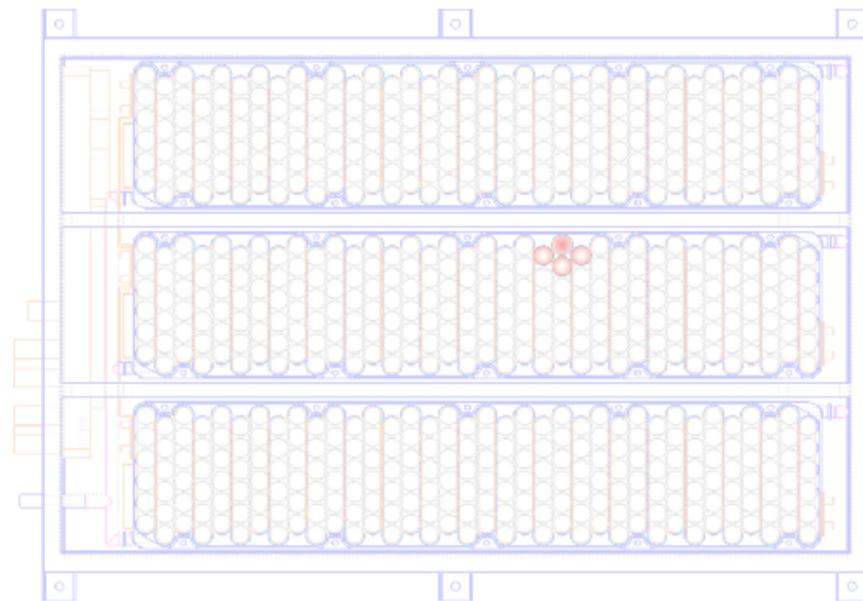
Cell Design and Production Quality



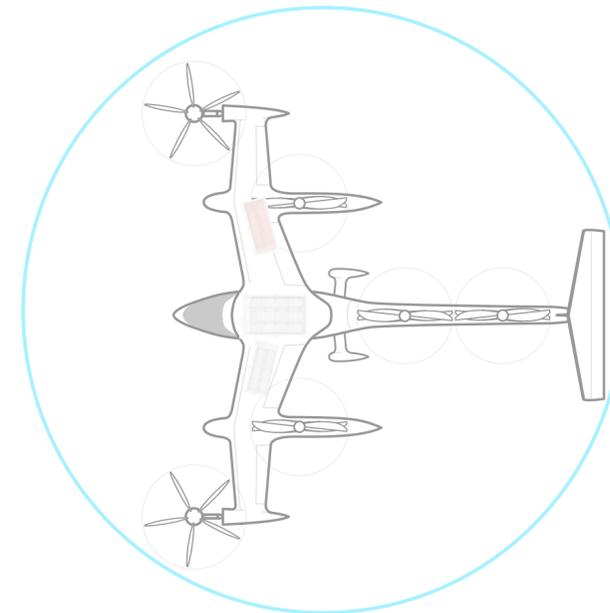
Cell Runaway Characteristics



Cell to Cell Propagation

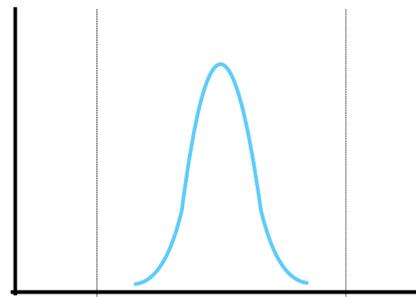
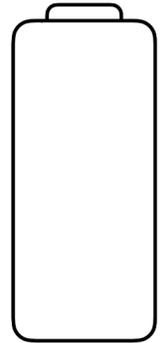


Pack Thermal Event

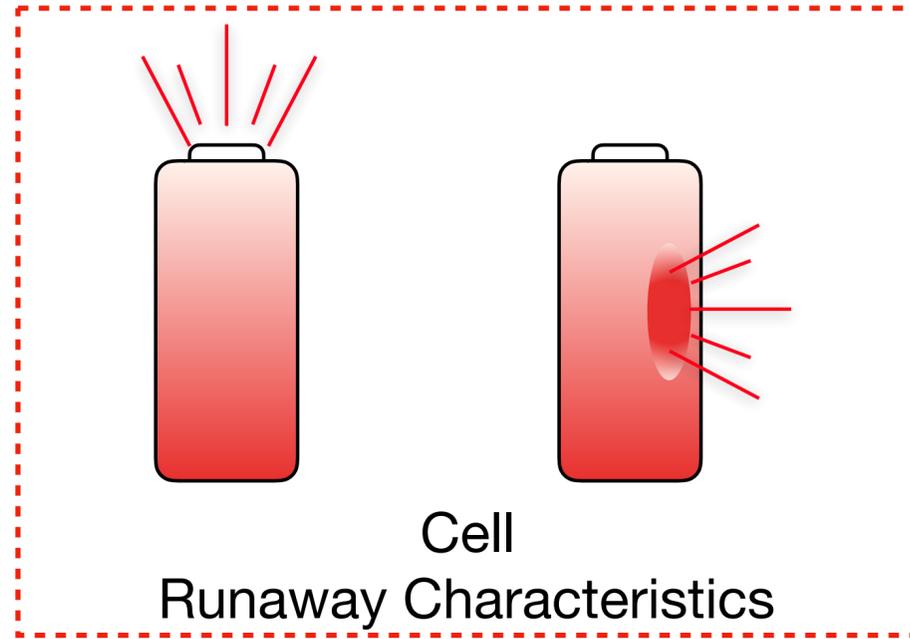


Vehicle Thermal Event

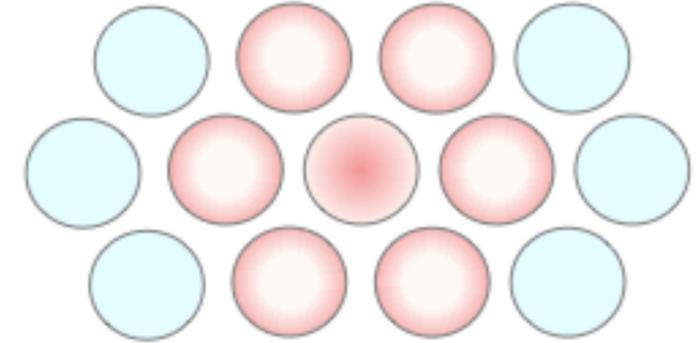
Points of intervention



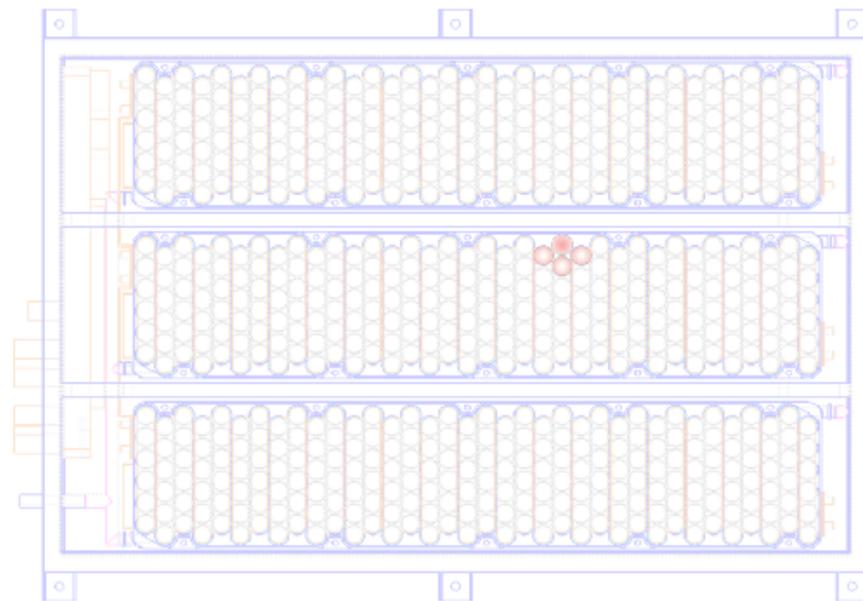
Cell Design and Production Quality



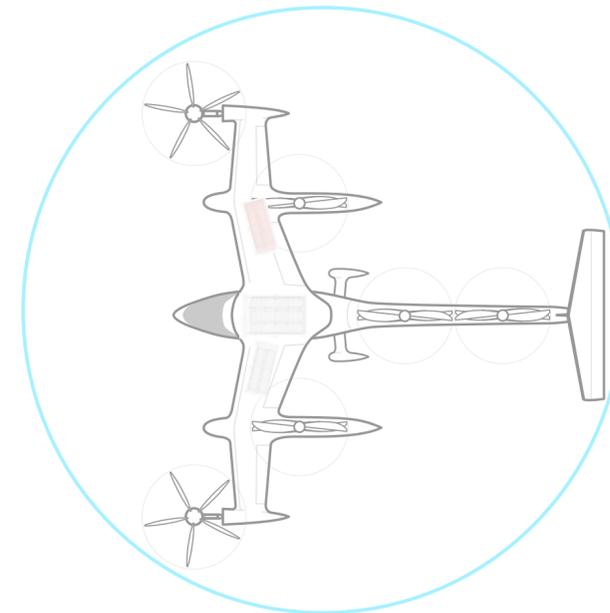
Cell Runaway Characteristics



Cell to Cell Propagation

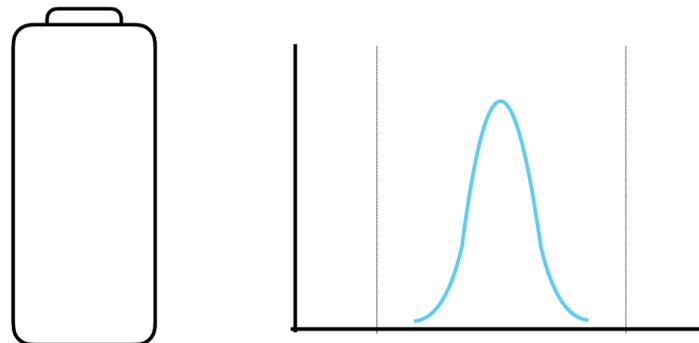


Pack Thermal Event

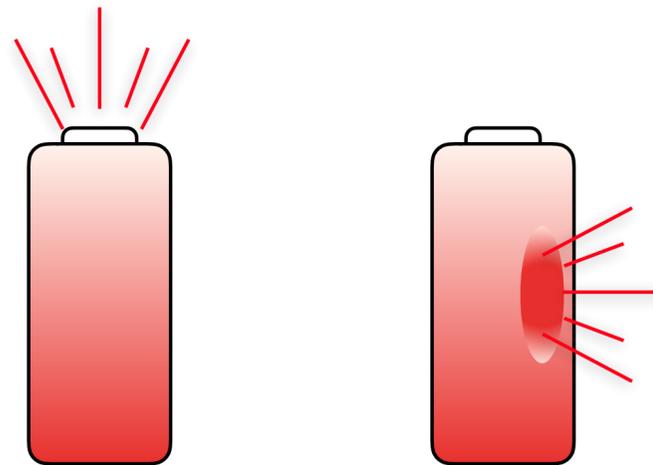


Vehicle Thermal Event

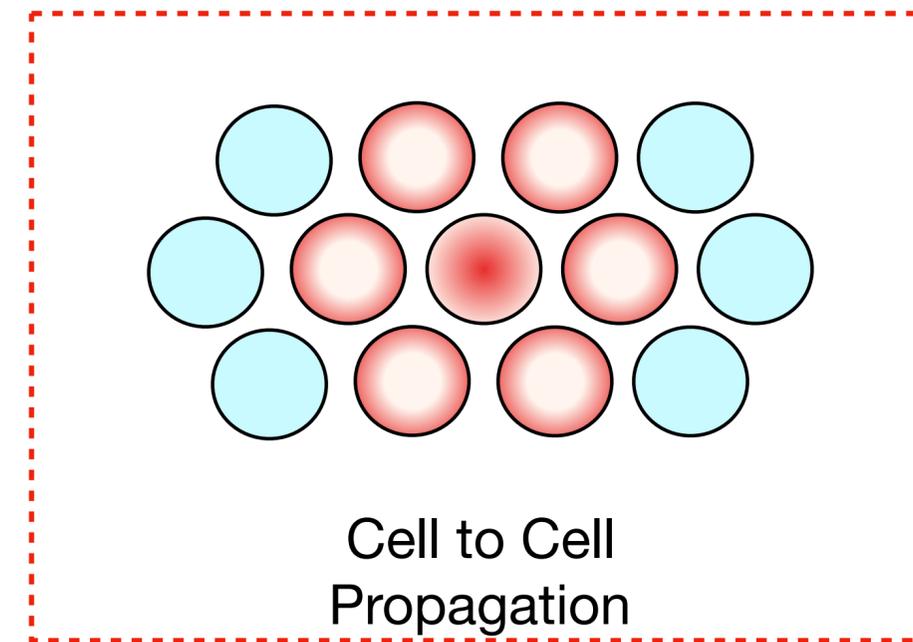
Points of intervention



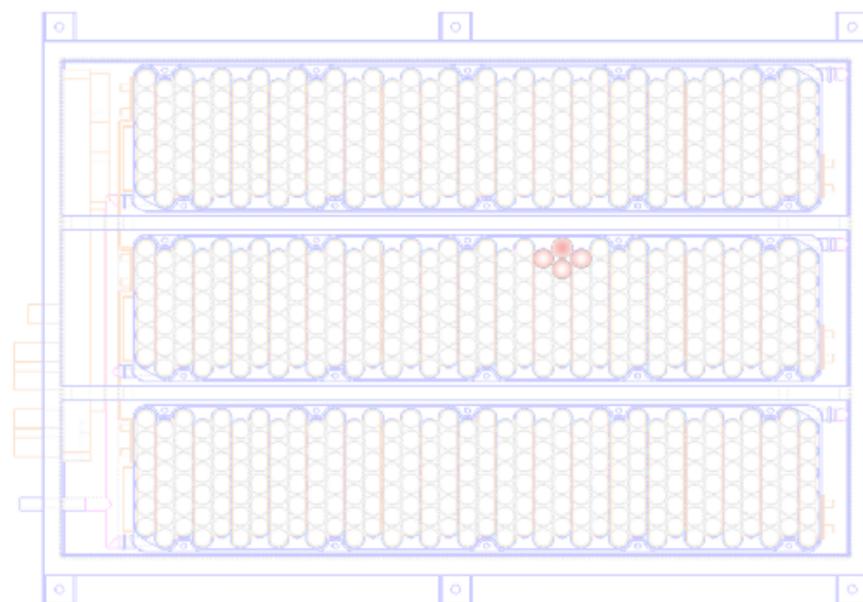
Cell Design and Production Quality



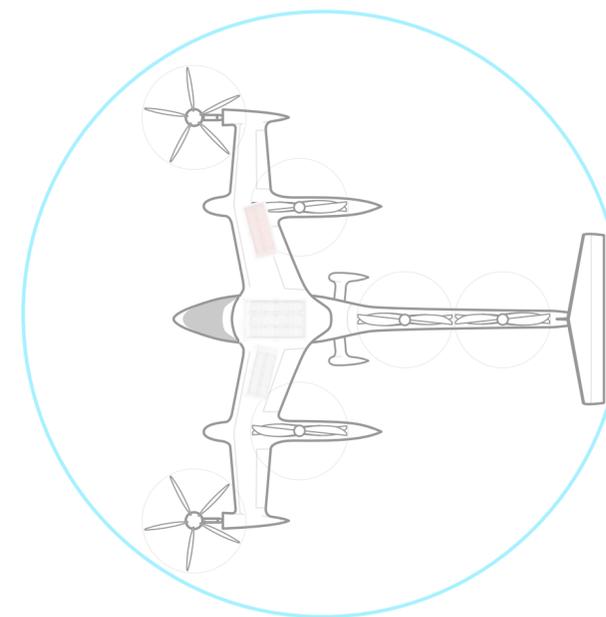
Cell Runaway Characteristics



Cell to Cell Propagation

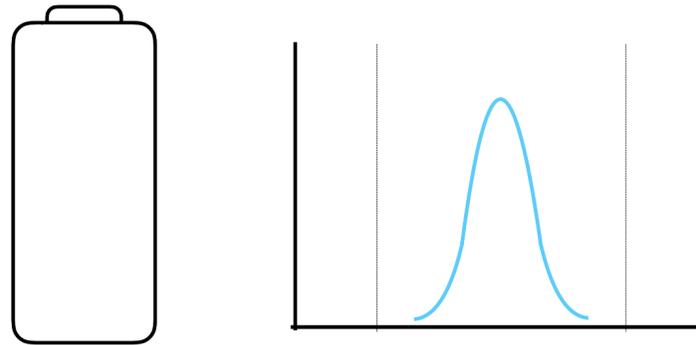


Pack Thermal Event

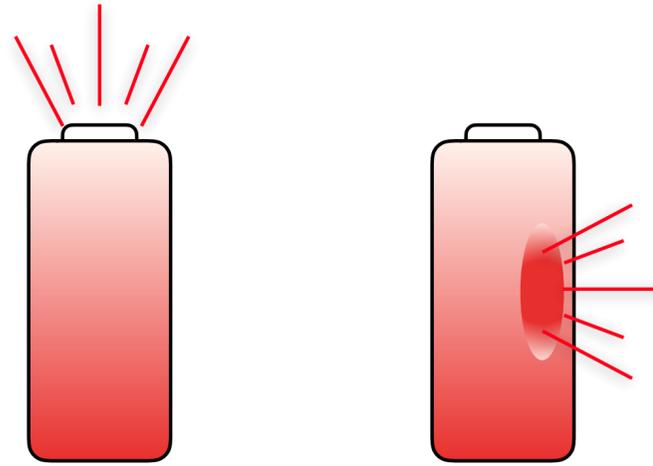


Vehicle Thermal Event

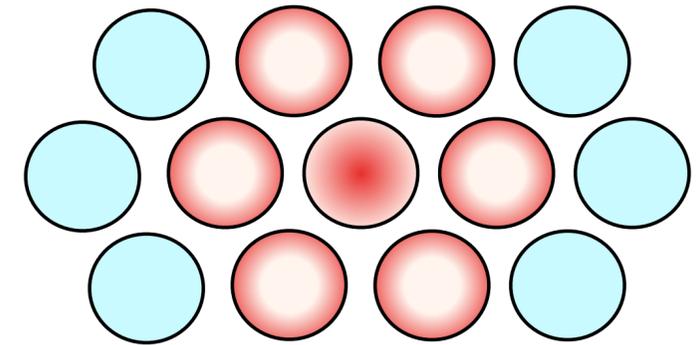
Points of intervention



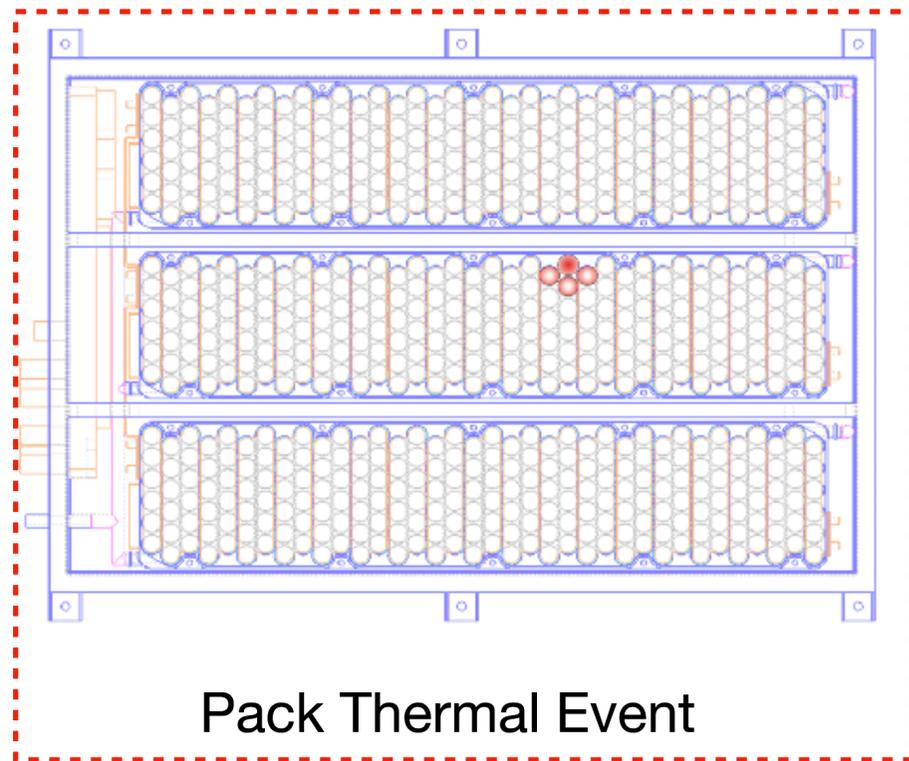
Cell Design and Production Quality



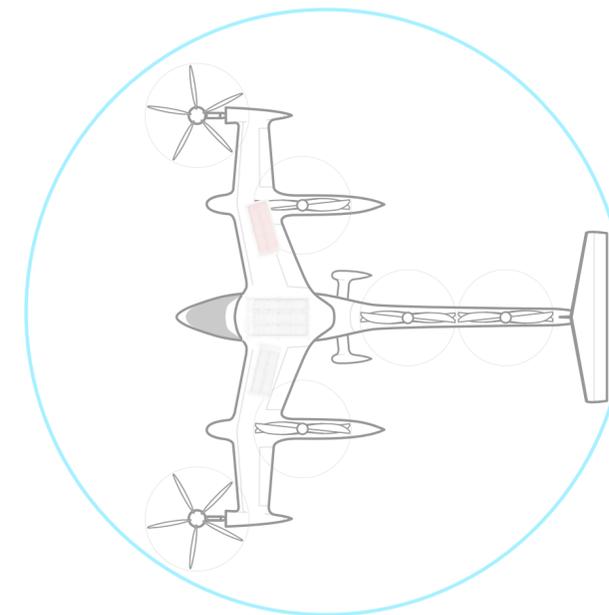
Cell Runaway Characteristics



Cell to Cell Propagation

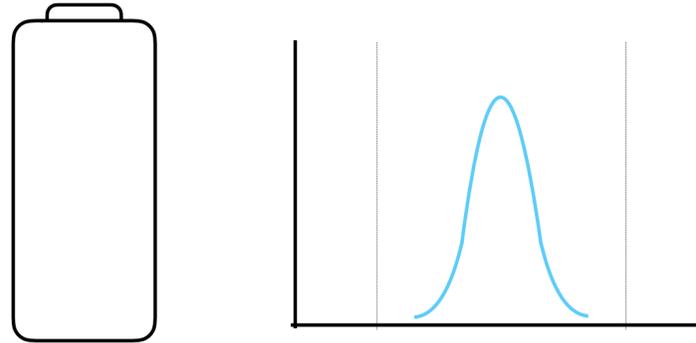


Pack Thermal Event

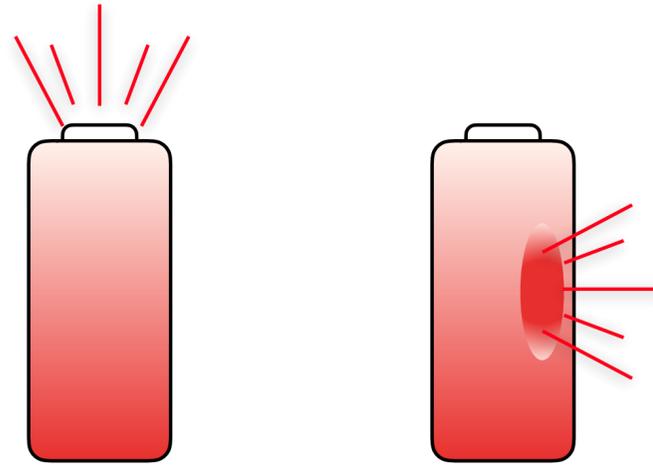


Vehicle Thermal Event

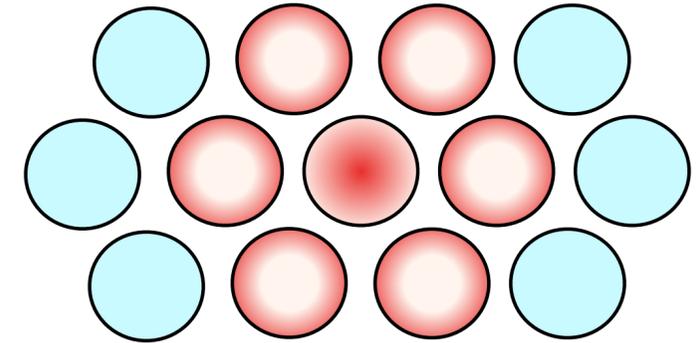
Points of intervention



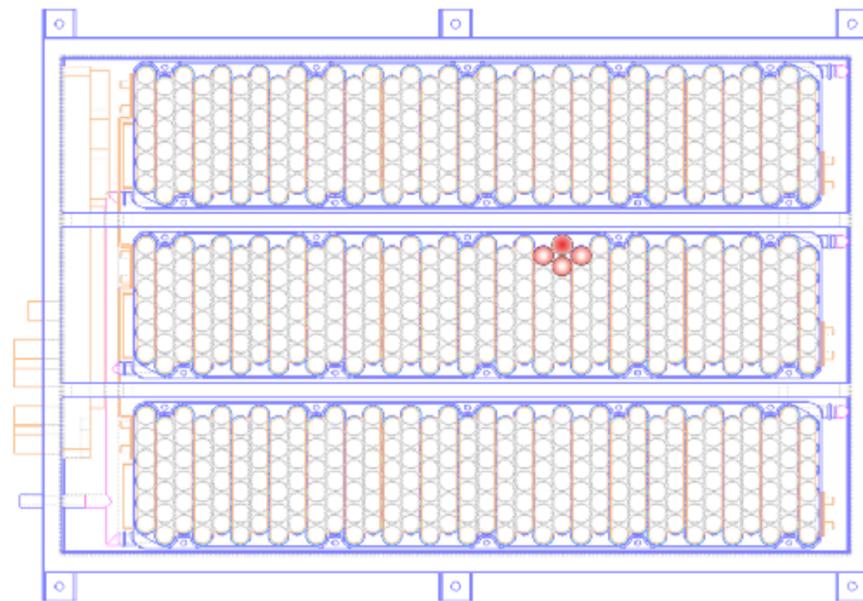
Cell Design and Production Quality



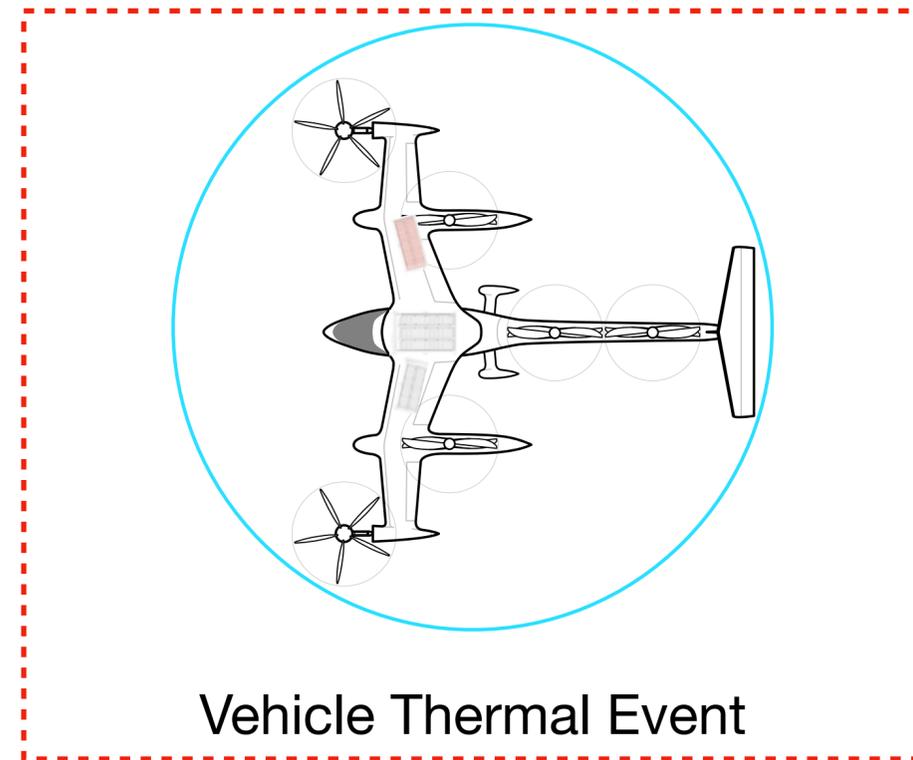
Cell Runaway Characteristics



Cell to Cell Propagation

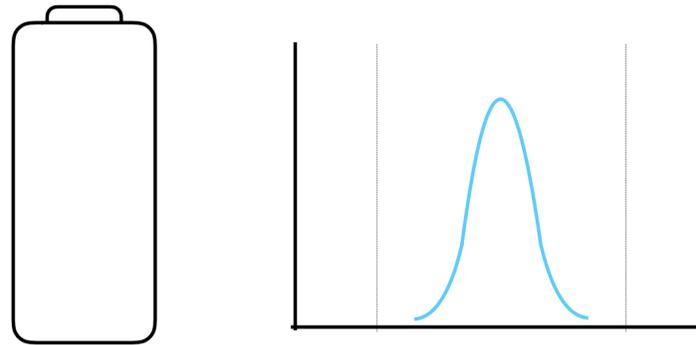


Pack Thermal Event

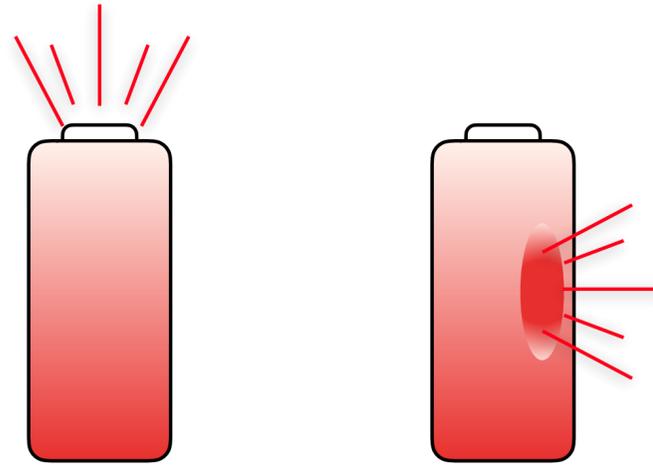


Vehicle Thermal Event

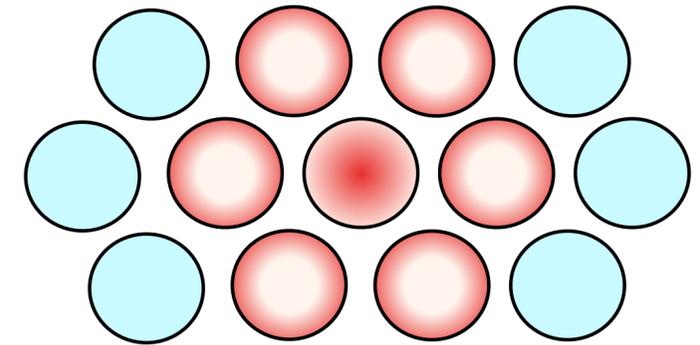
Points of intervention



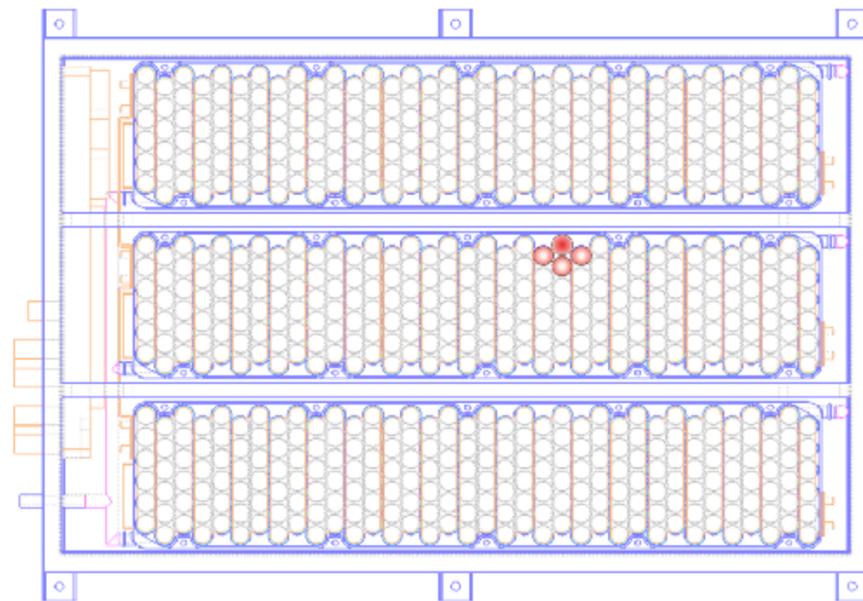
Cell Design and Production Quality



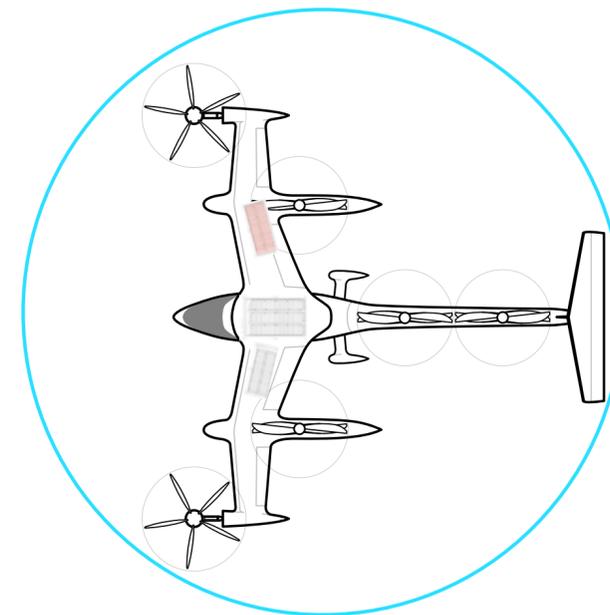
Cell Runaway Characteristics



Cell to Cell Propagation



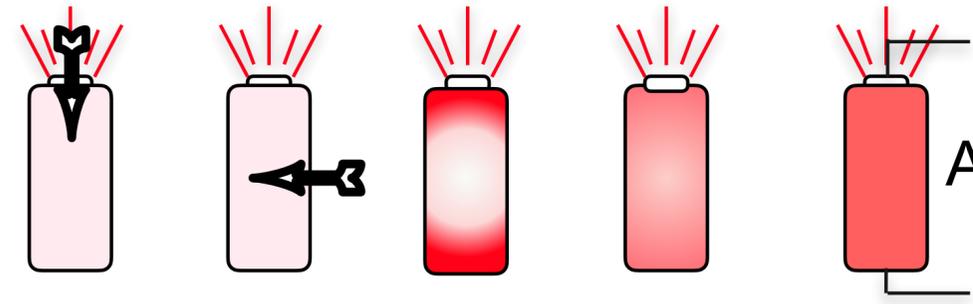
Pack Thermal Event



Vehicle Thermal Event

Single Cell Testing

18650 A

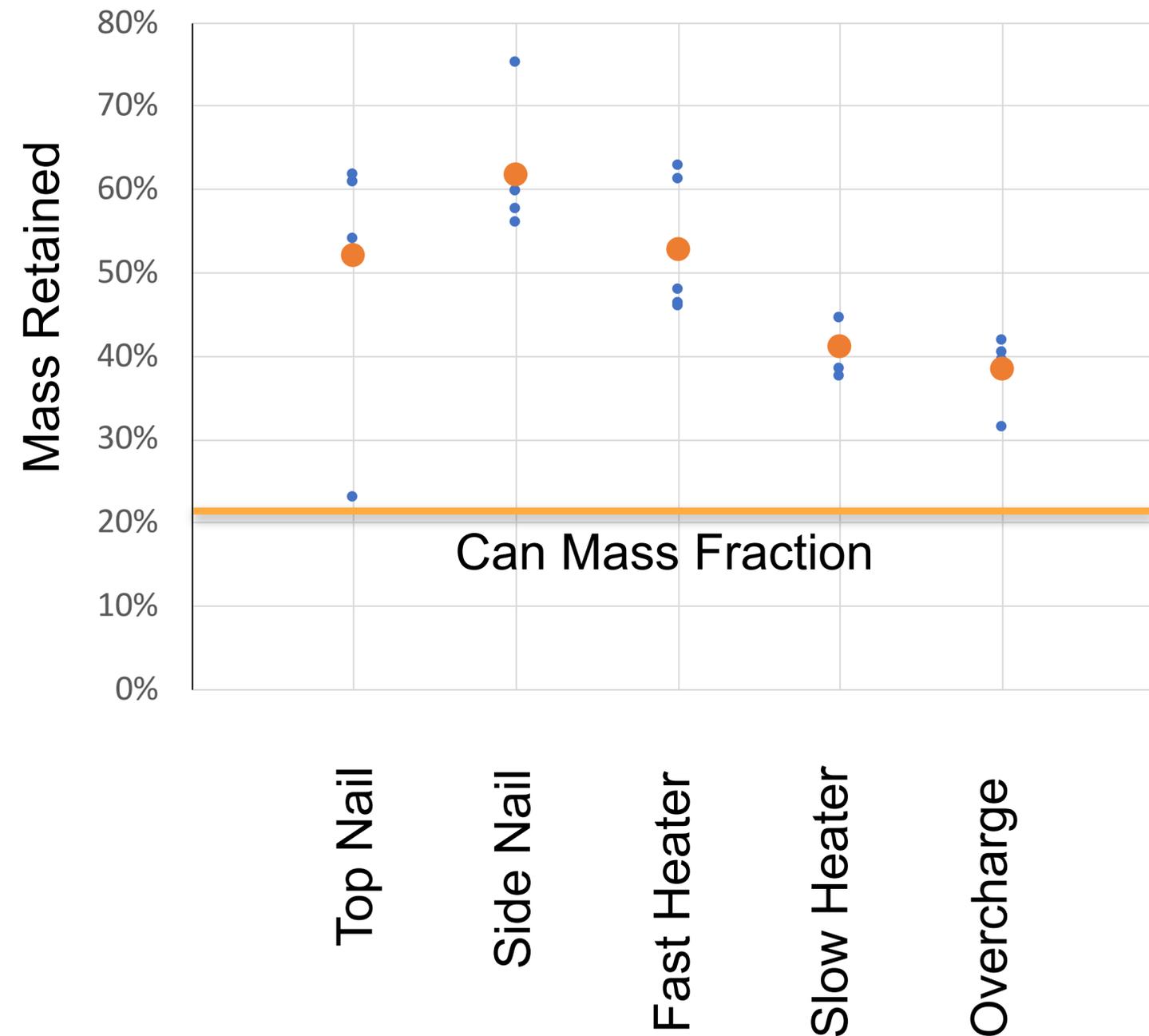


Neighbor Stresses

Energy and Mass retention

Cell Screening

Initiation Mode Selection





45W Heater Causing Can rupture



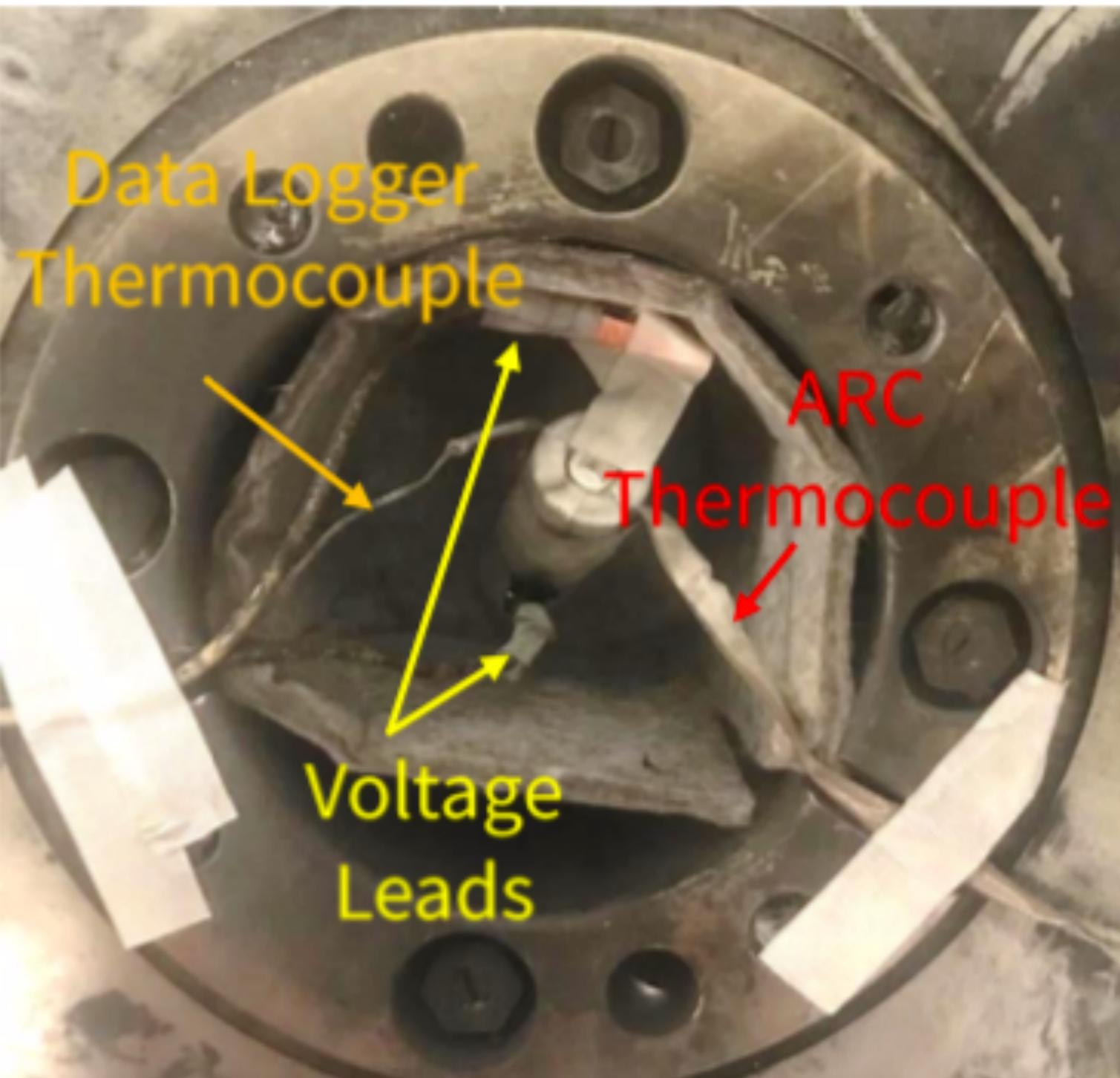
Desirable screening performance



Nail penetration leads to can melt out

Single cell testing highlights failure modes which will make evaluating failure distributions very challenging

Photo of Cell Loaded in ARC



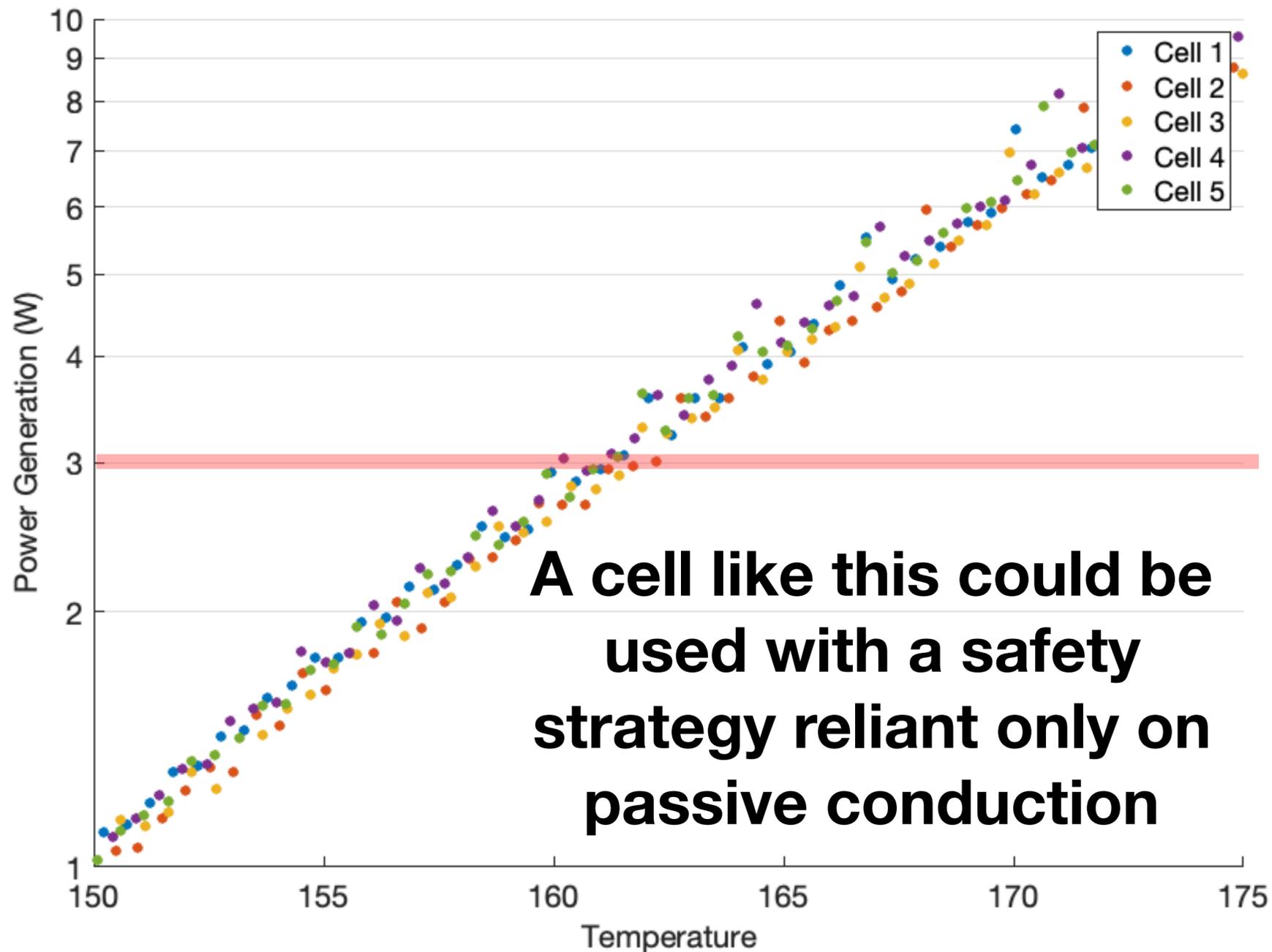
ARC Testing

Failure point in environment

Rate of Reaction vs Temperature

Cell Variation

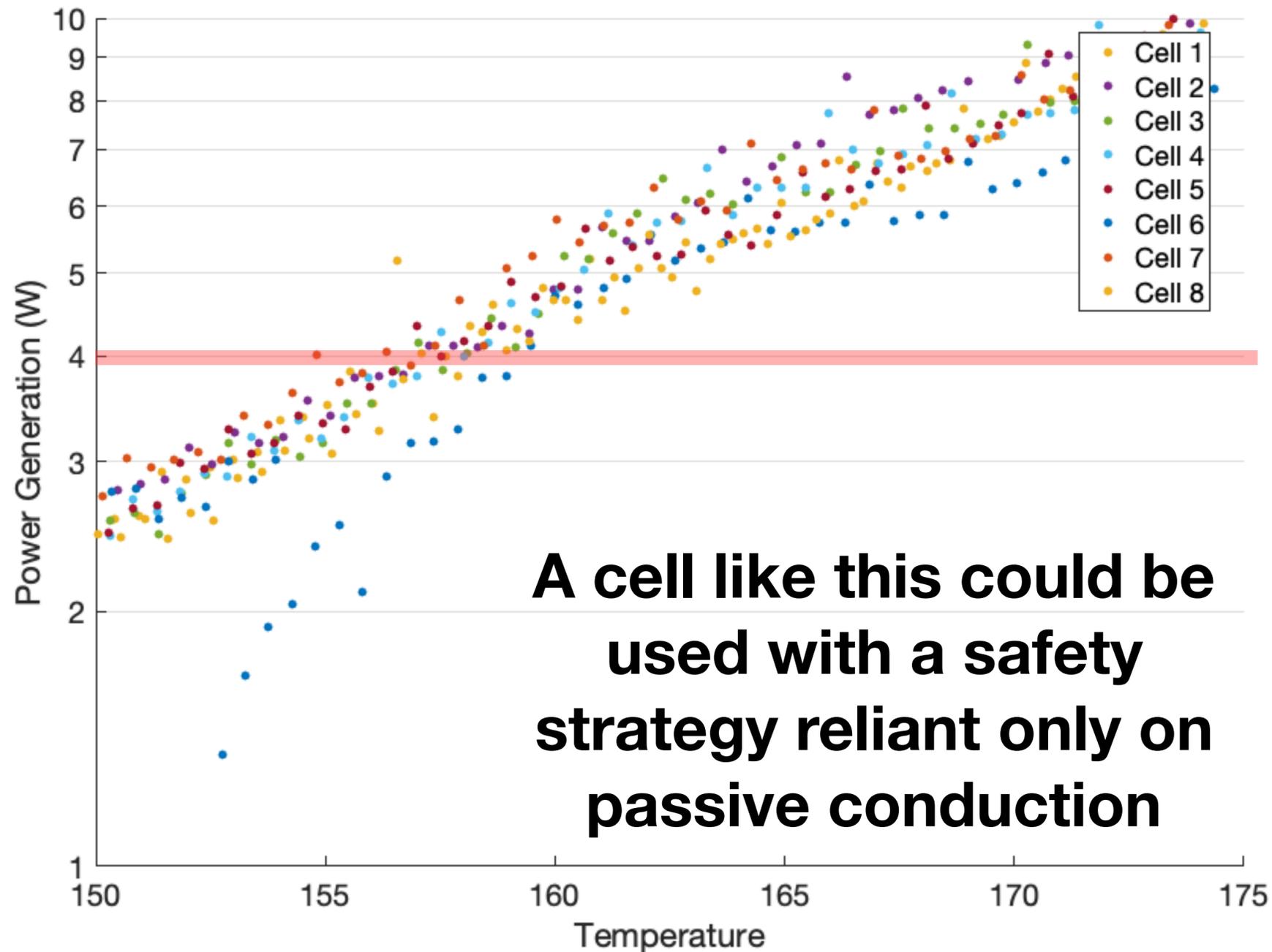
ARC Testing - 18650 A



A cell like this could be used with a safety strategy reliant only on passive conduction

Red line = 3 W
A typical failure point for an 18650 in a passively cooled system

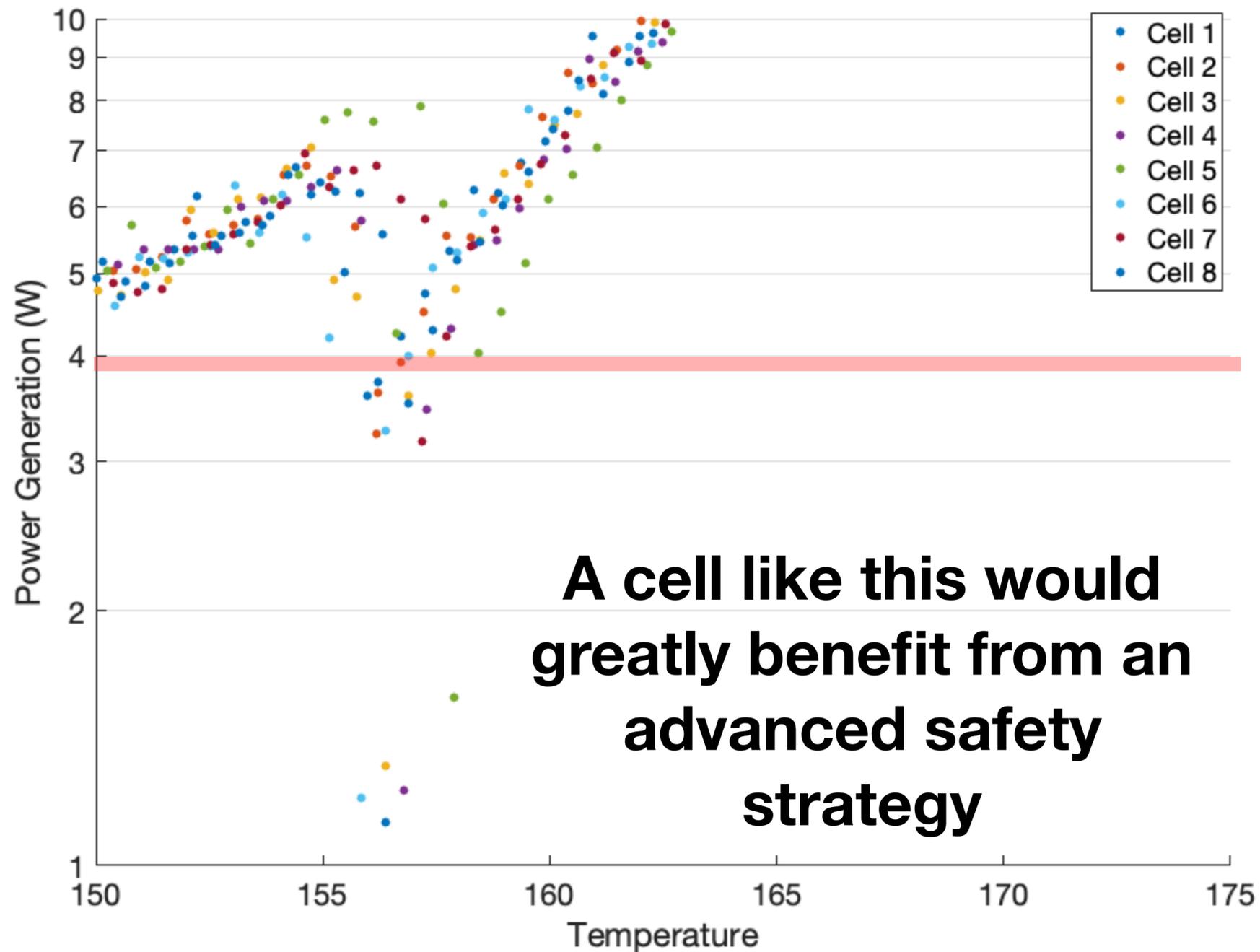
ARC Testing - 2170 A



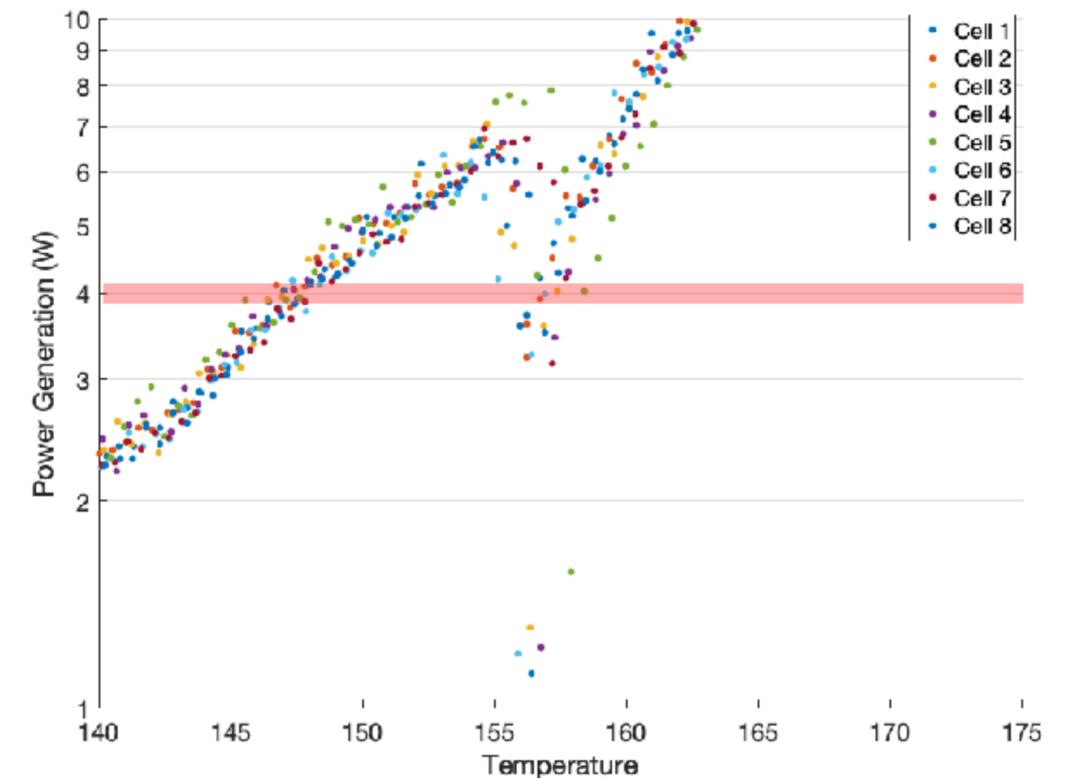
A cell like this could be used with a safety strategy reliant only on passive conduction

**Red line = 4 W
A typical failure point for a 2170 in a passively cooled system**

ARC Testing - 2170 B



Red line = 4 W
A typical failure point for a 2170 in a passively cooled system



ARC Testing - 2170 B

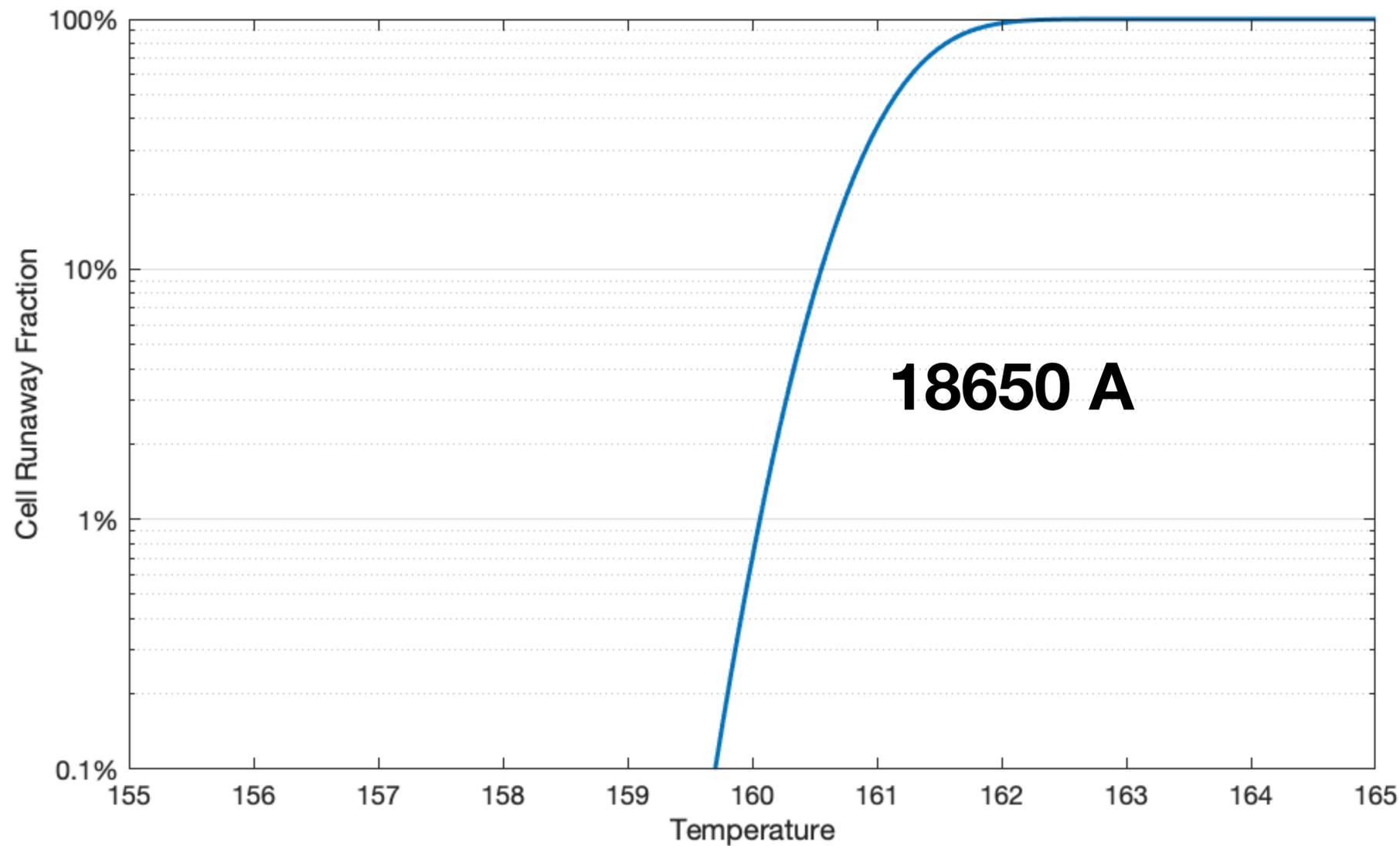
ARC Before Testing



ARC After Testing



ARC Testing - 18650A

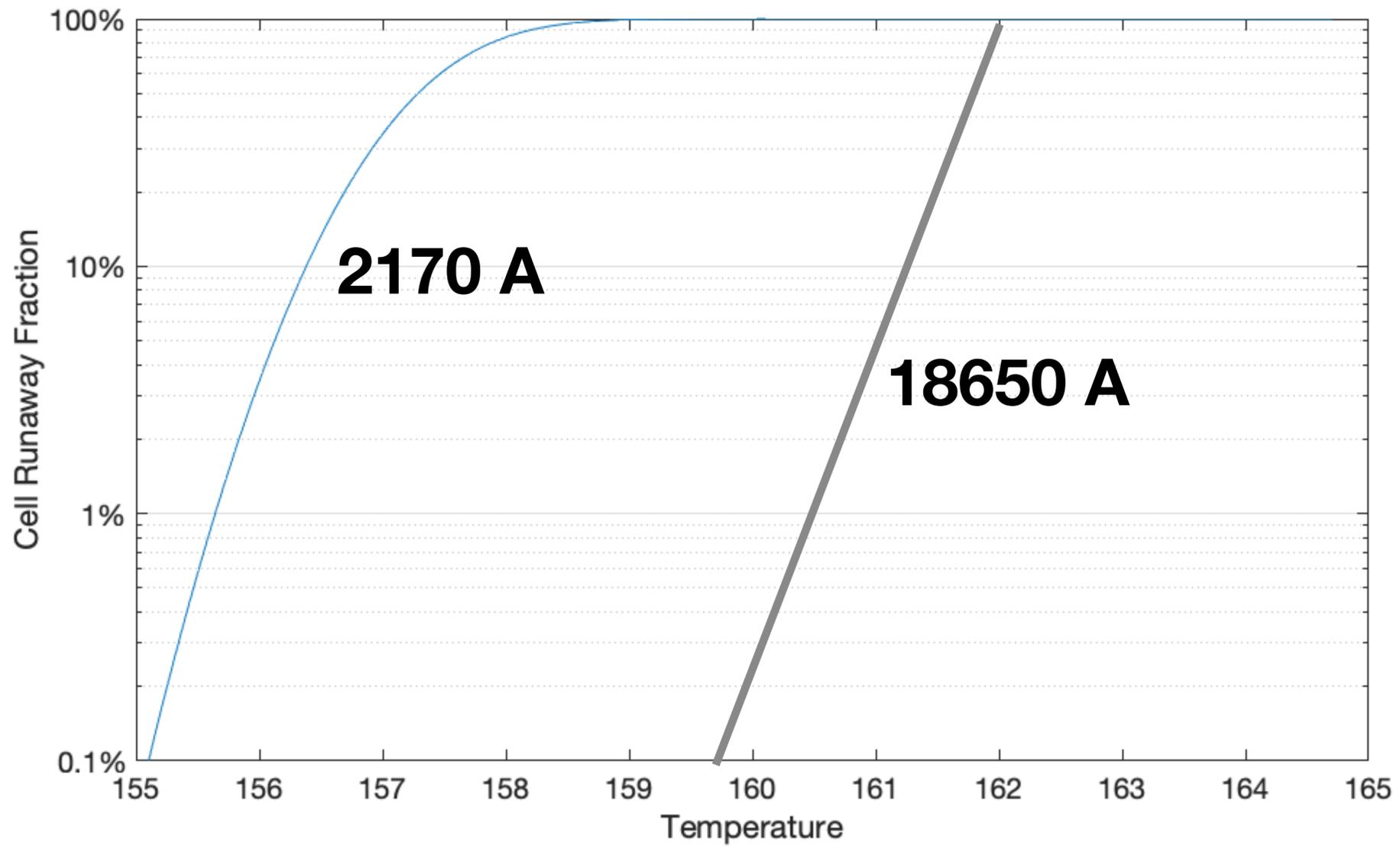


Failure point in environment

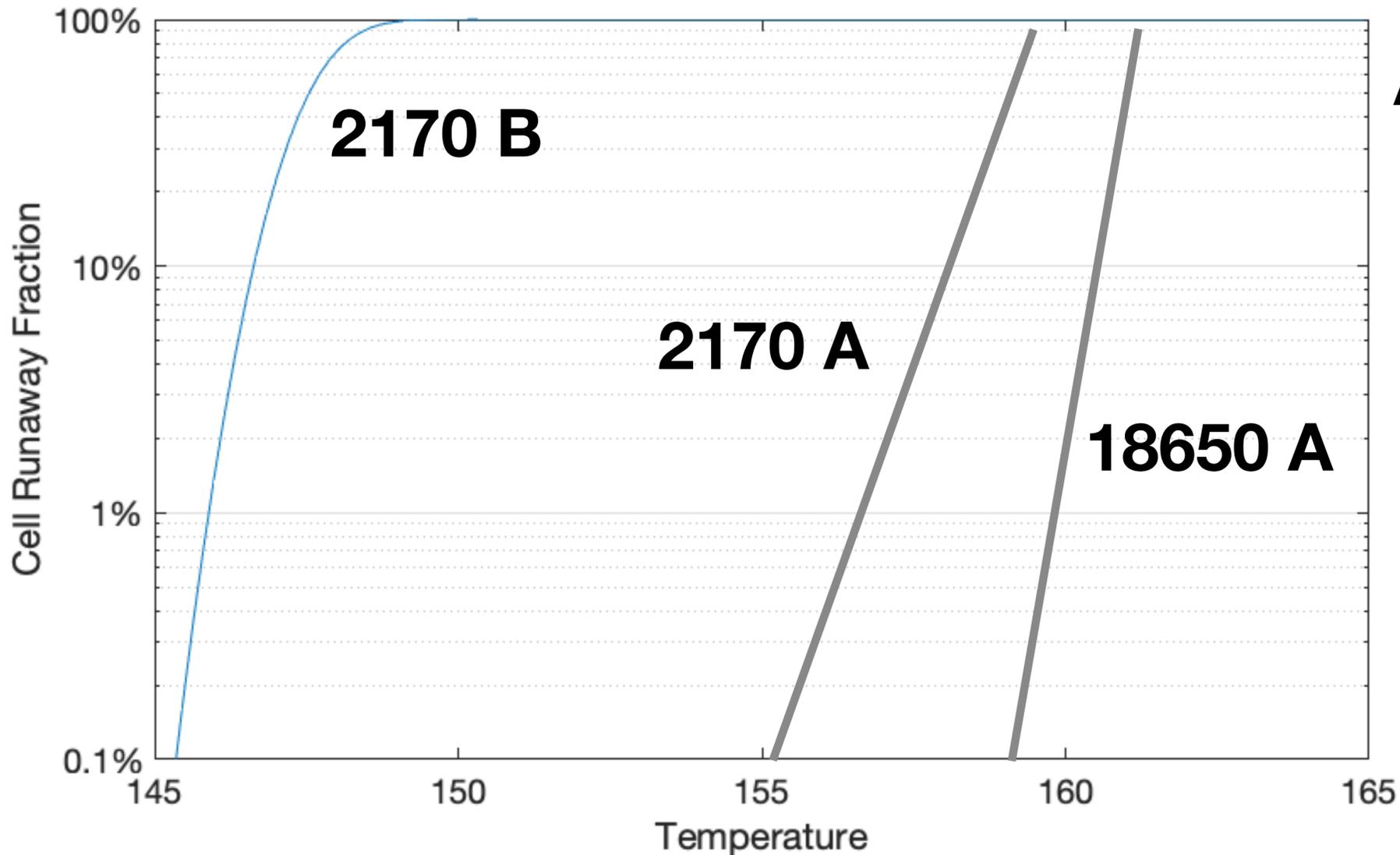
Rate of Reaction vs Temperature

Cell Variation

ARC Testing - 2170 A

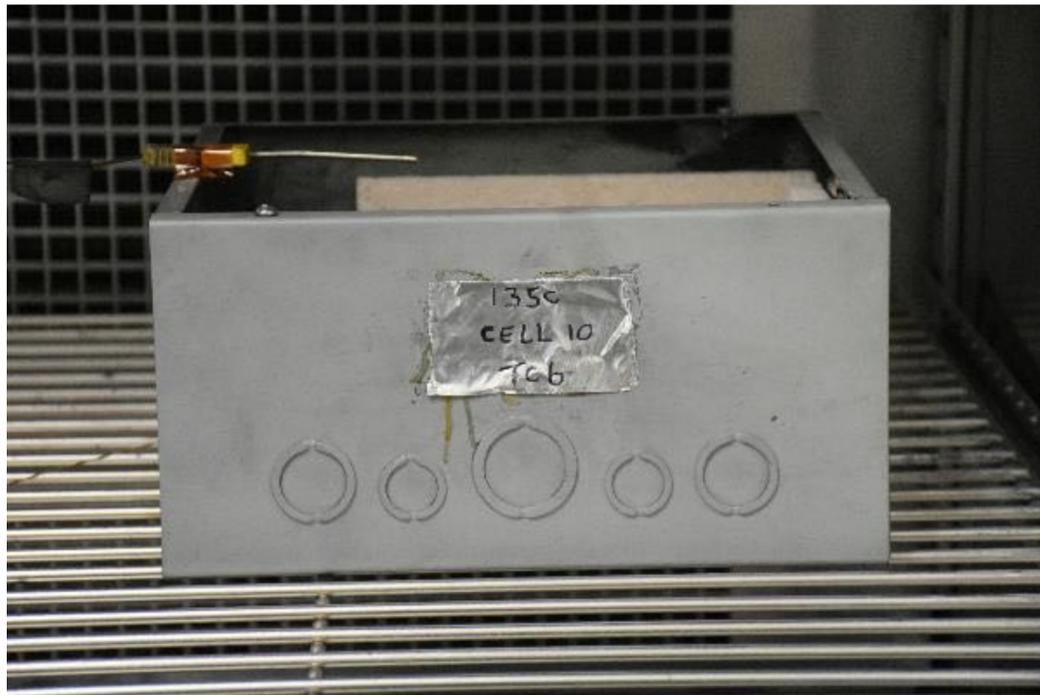
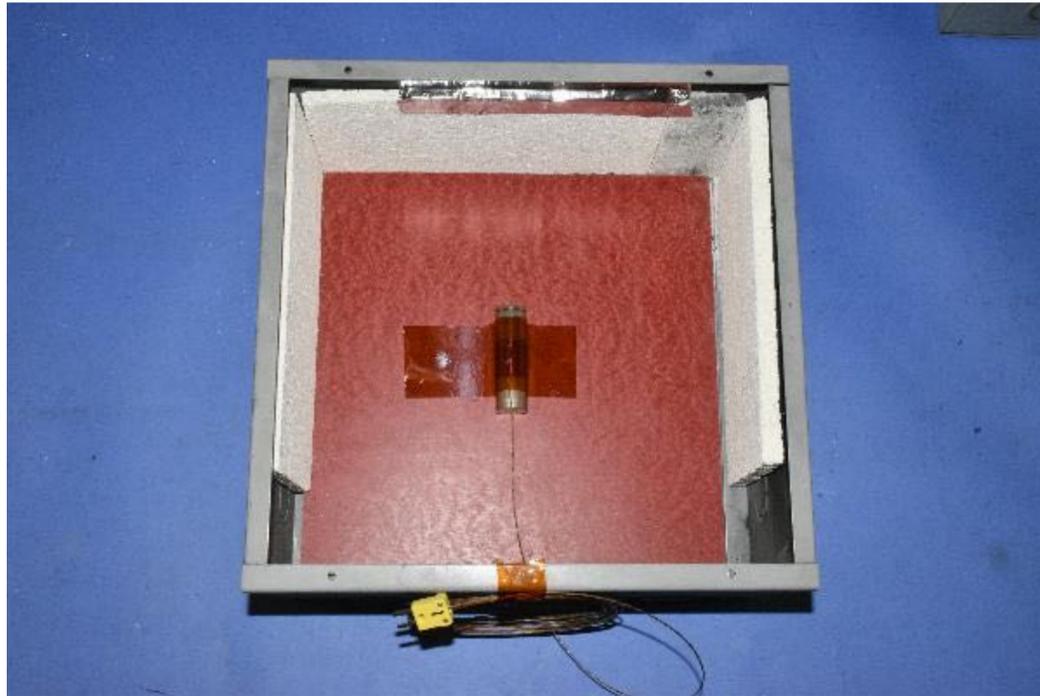


ARC Testing - 2170 B



A pack must implement a safety strategy such that unavoidable failures do not cause cells to exceed these temperatures

T@T Testing



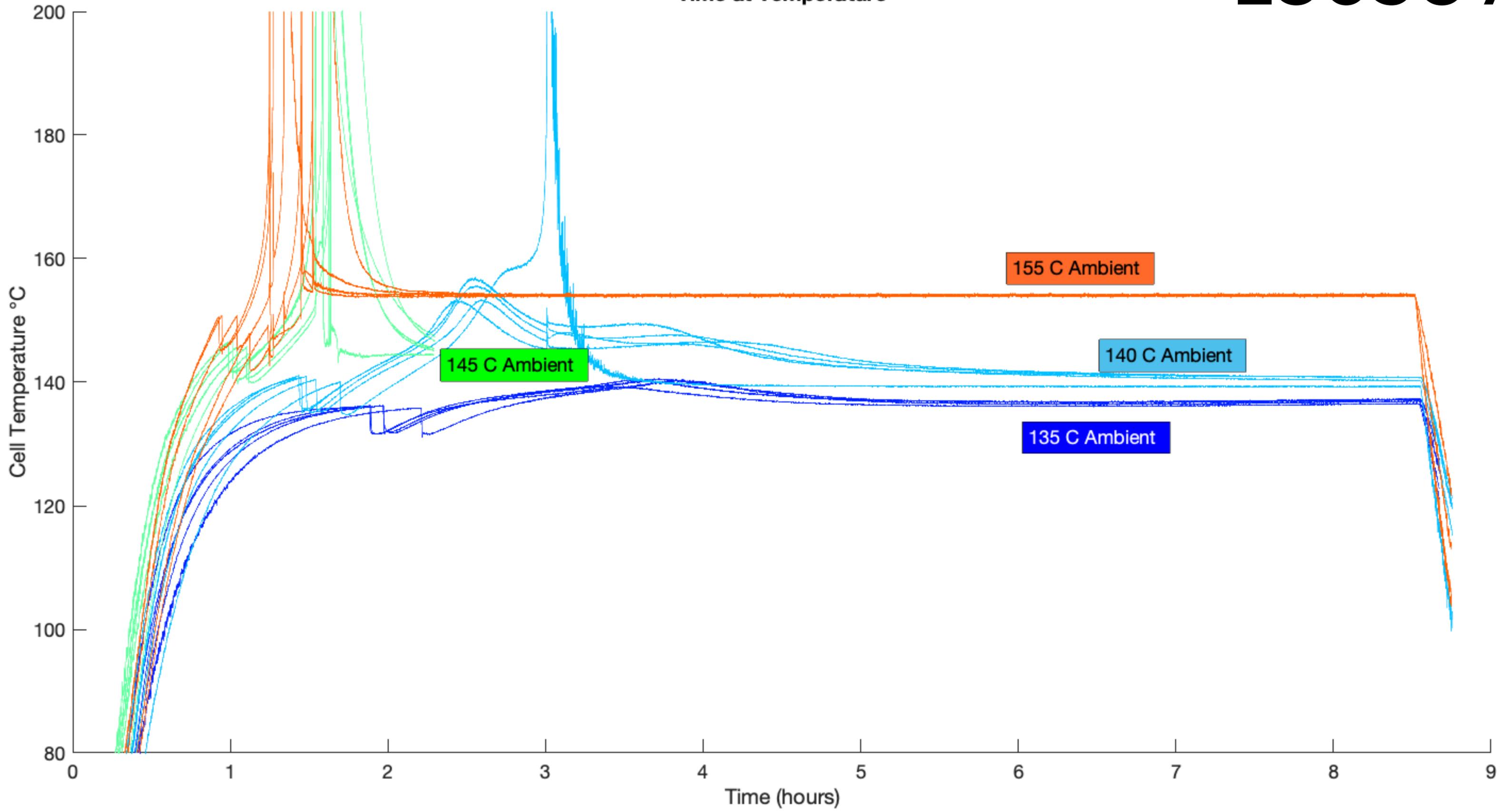
Susceptibility to failure due to accumulation of degradation

Cell Variation

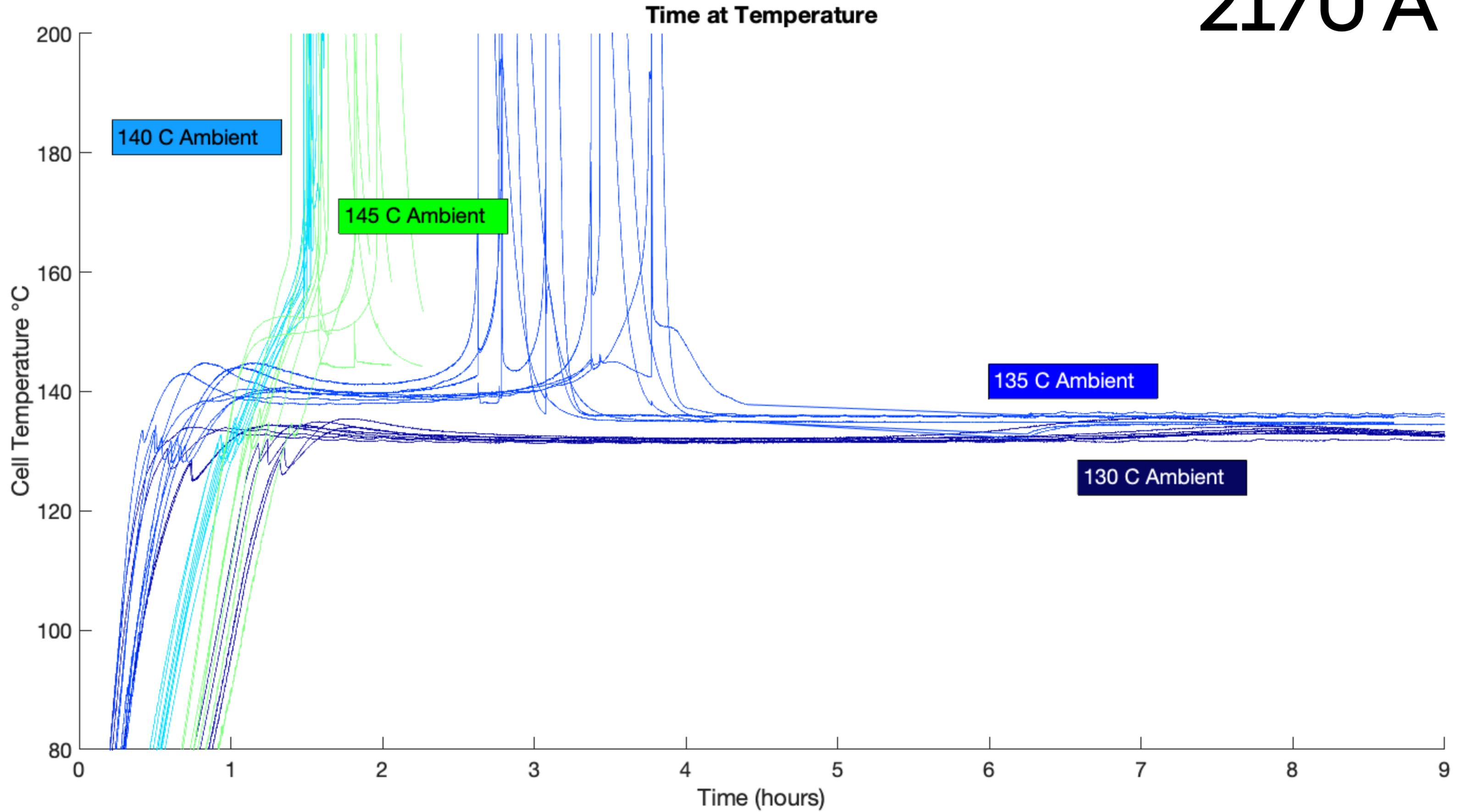
Higher throughput compared to ARC

18650 A

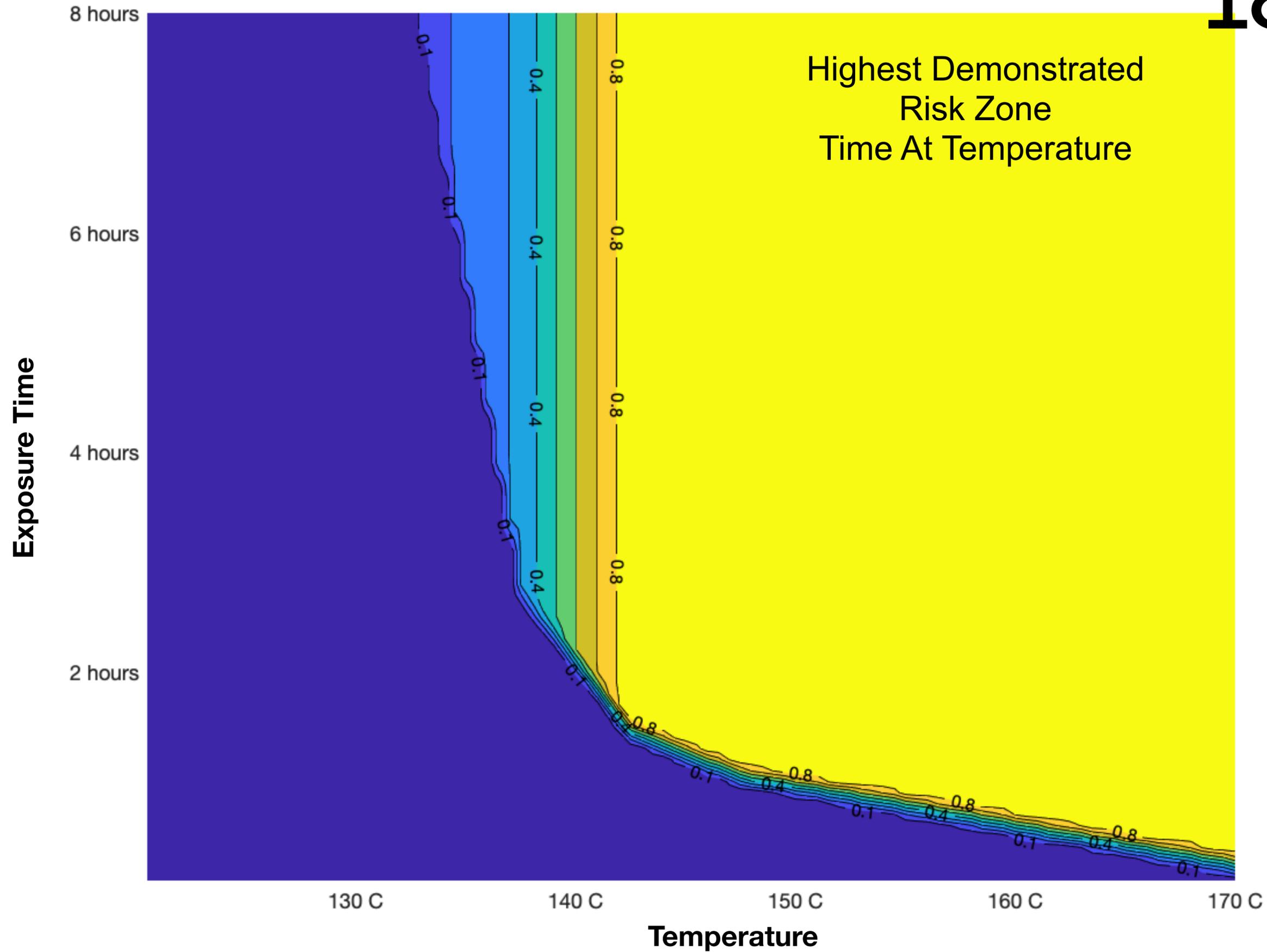
Time at Temperature



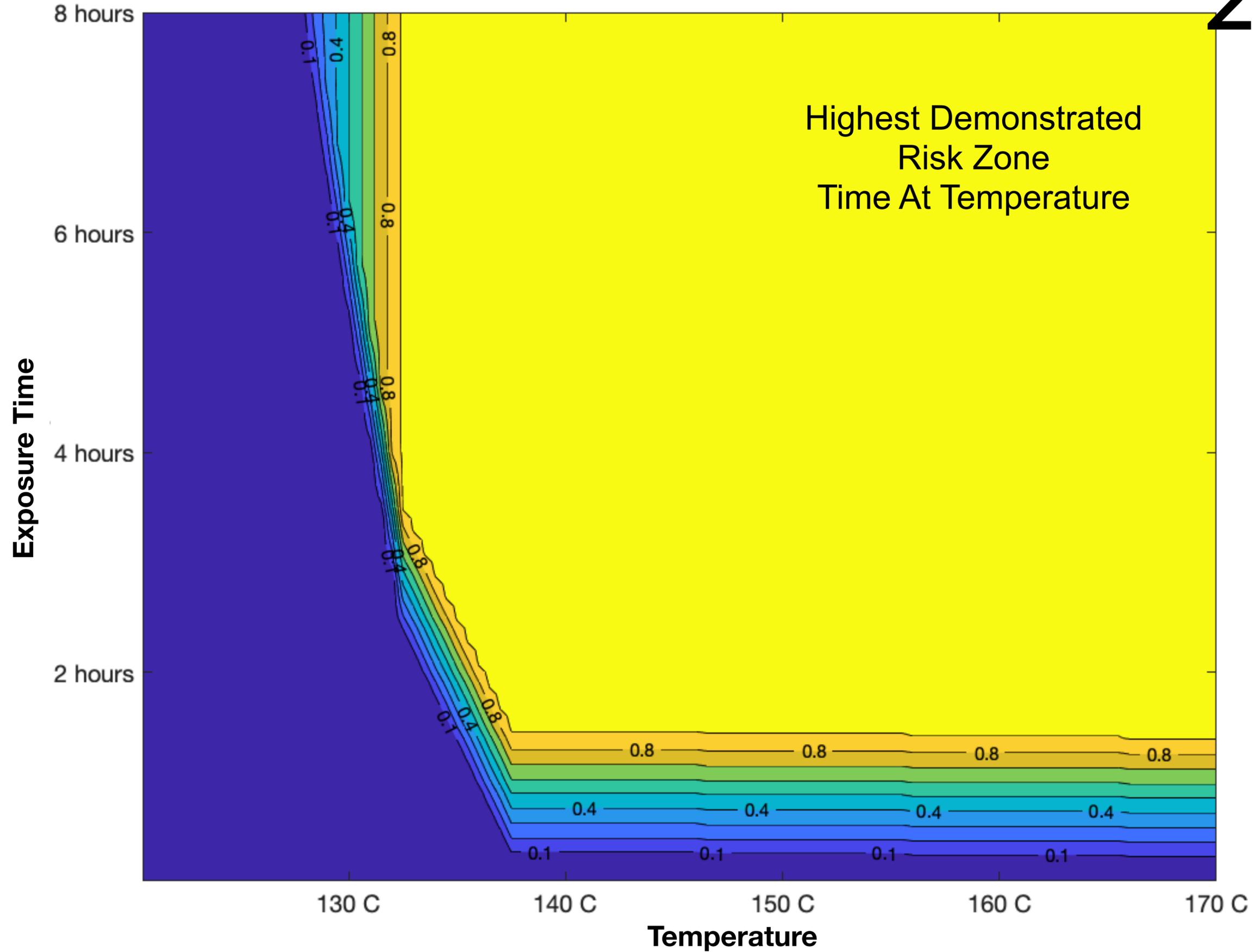
2170 A



18650 A

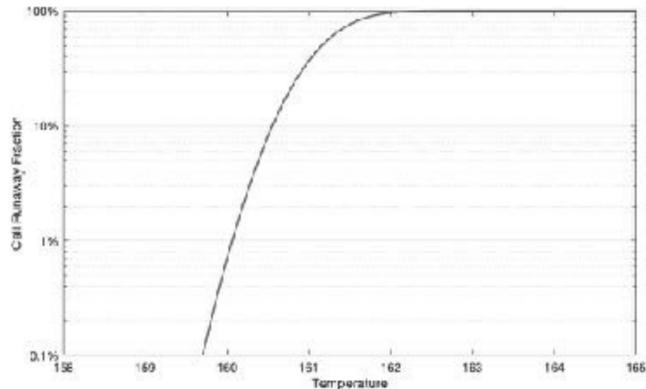


2170 A



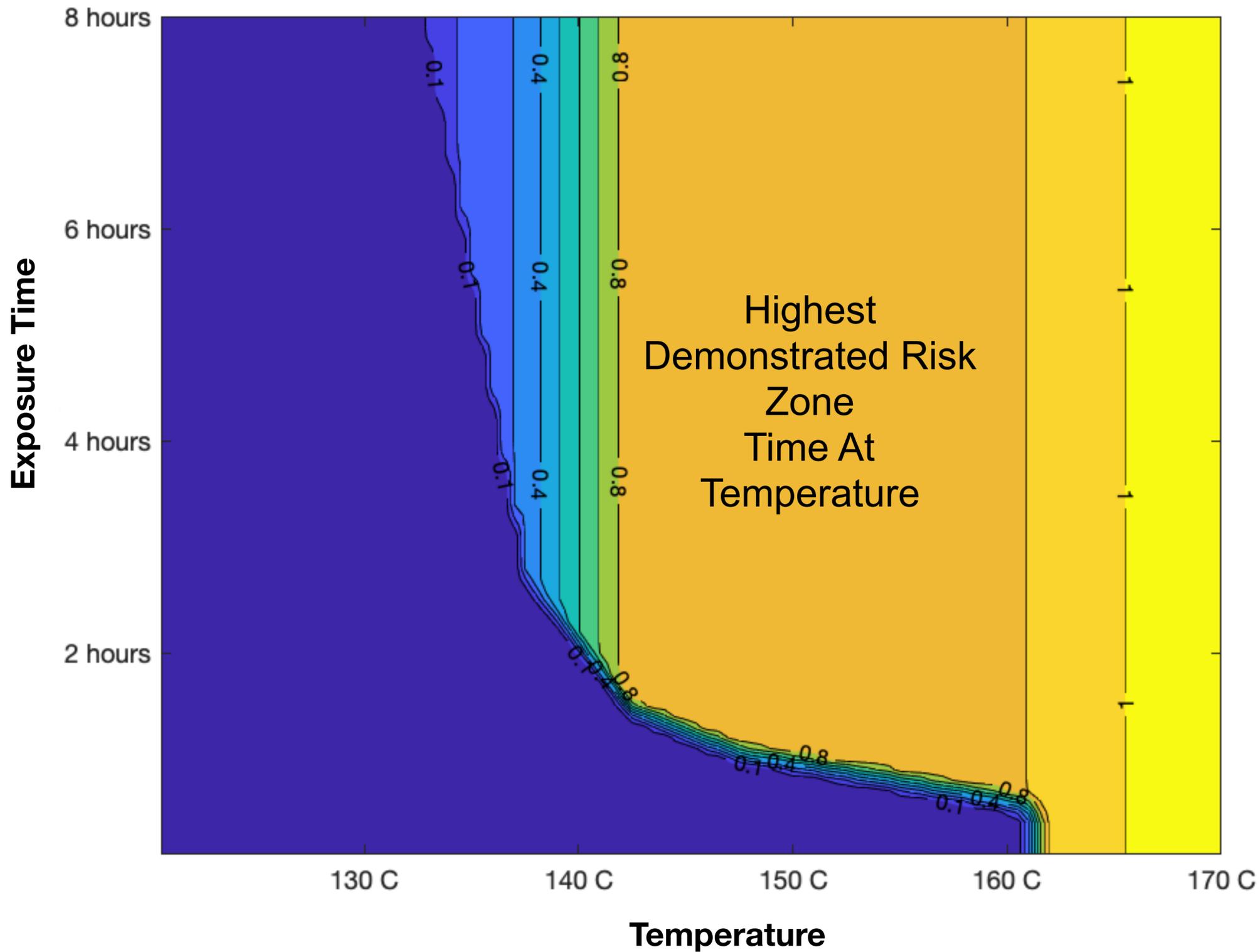
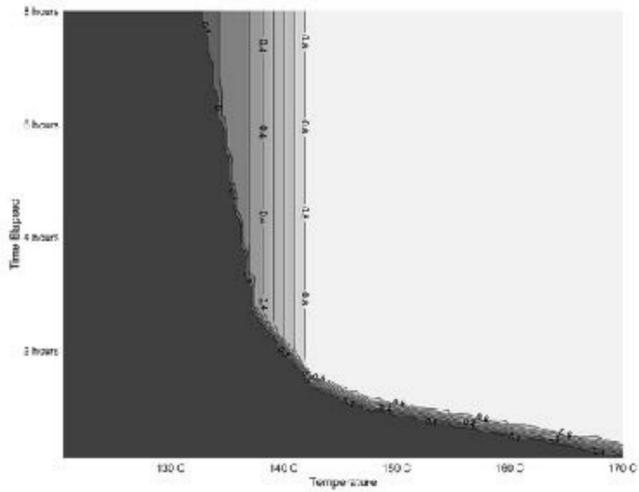
Multi-factor Risk

18650 A



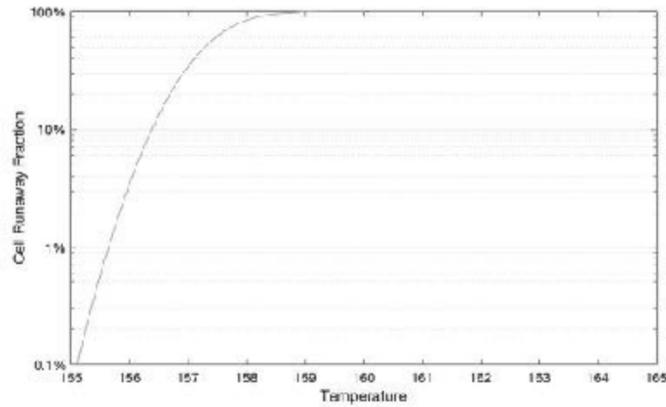
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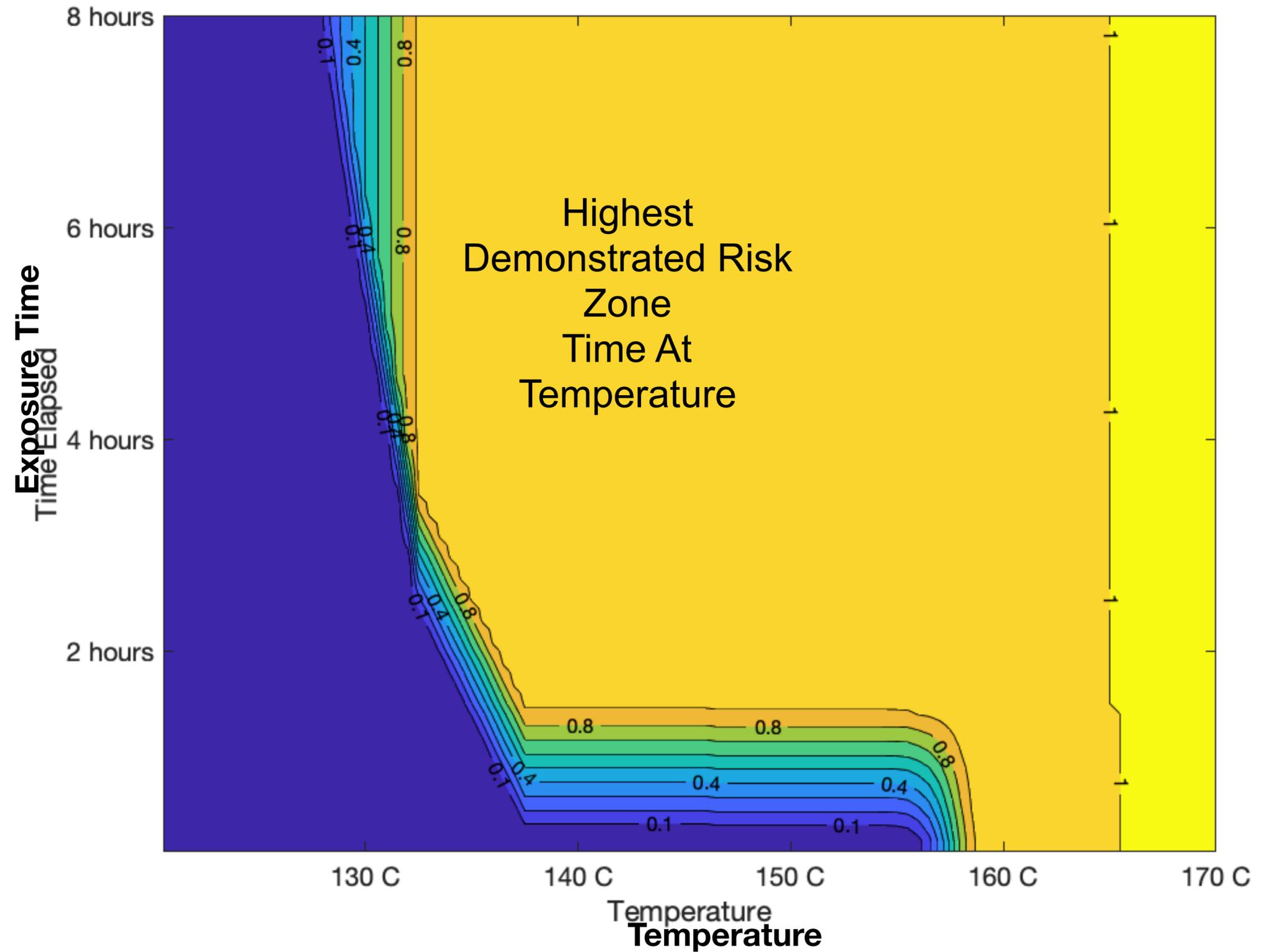
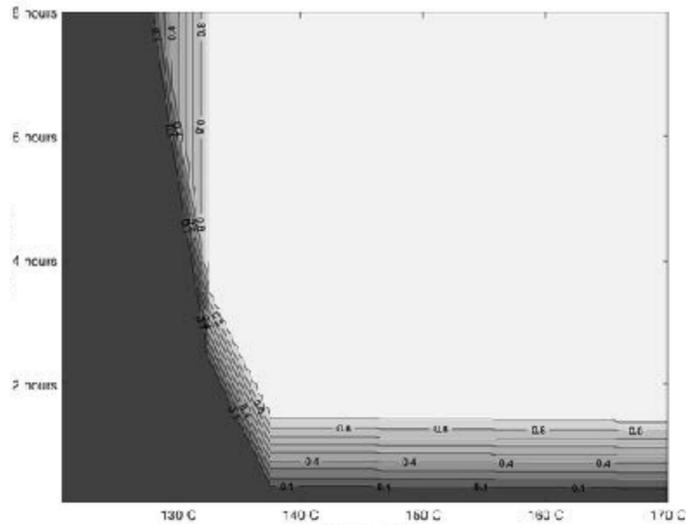
Multi-factor Risk

2170 A

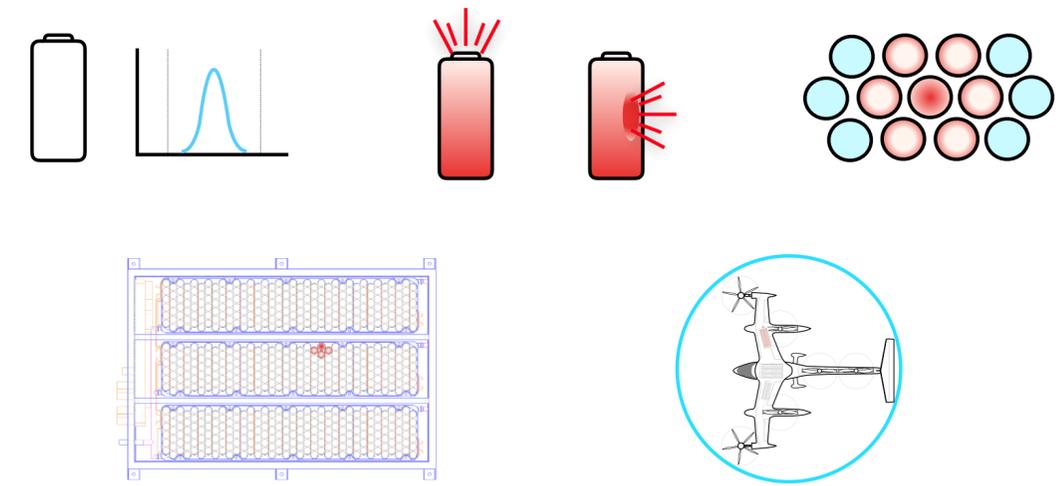


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Uber strategy



Guide and Test Methodology

Uber Elevate intends to develop a guide to instruct aviation battery safety testing, and in parallel publish as standards all the tests it develops.

The guide shall detail a whole system approach to battery safety, and advise on what you need to know about your system before following it.

We intend to develop and conduct tests at most, if not all potential points of intervention, and continually update the guide to reference them as they develop

Once sufficient tests exist and have been published such that a vehicle and battery pack system could pass our safety strategy according to the guide...

- We intend to work alongside TC applicants to utilize the guide as an alternate means of compliance
- We intend to work alongside standards partners like ASTM to codify the guide through the formal ballot process
- We intend to work with the FAA and other CAA's to have the codified guide and supporting tests accepted as a parallel path to that laid out in DO-311A regarding battery propagation safety

Uber