Soteria™

Battery Innovation Group

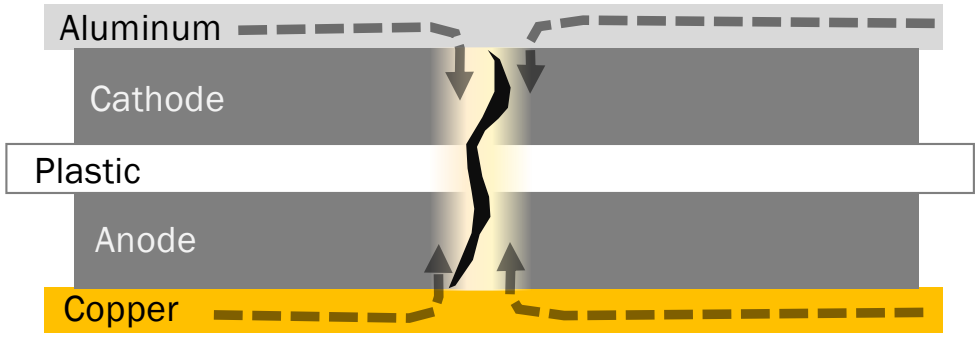
NASA Battery Workshop, 11/17/20.

Post damage cell survival

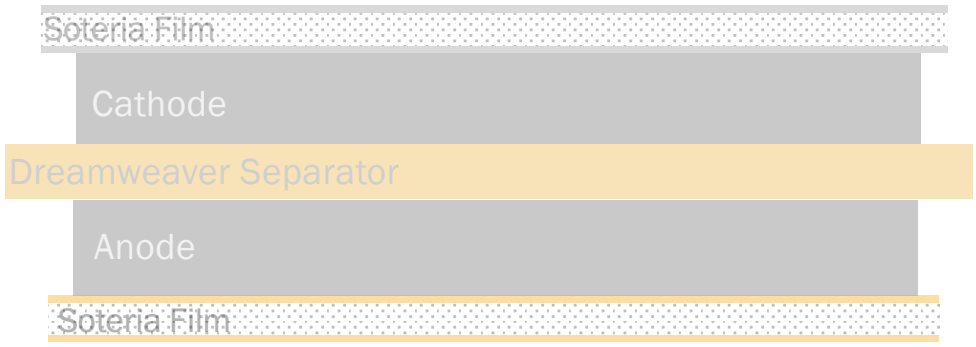
- Latent defects are the cause of many thermal runaway events
- Technologies that are effective at reducing or eliminating the thermal runaway also provide a new thing: A post damage cell that still works
- Soteria has 2 technologies that reduce or eliminate thermal runaway in response to latent defects, a separator and current collector
- Post latent defect cell operation is demonstrated via high load cell capacity discharge in a flying drone.

Inter Layer Short Circuits

Existing Technology



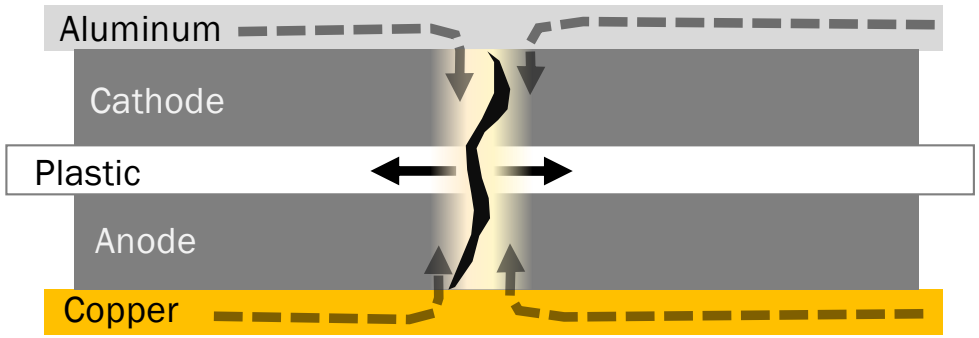
Soteria™ Technology



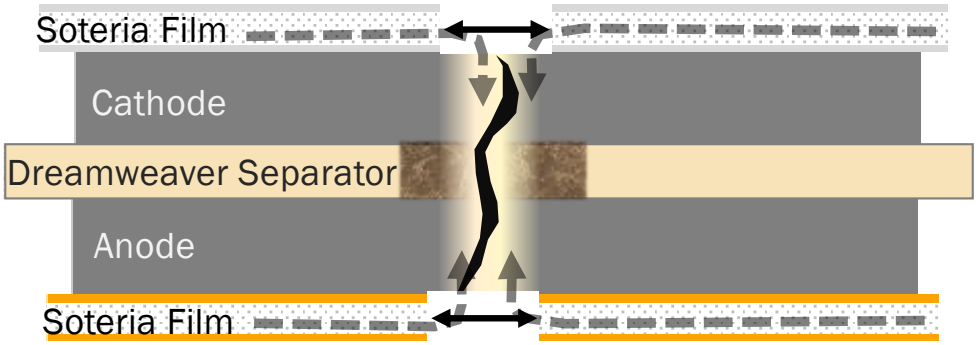
1. Internal short forms
2. High current generates heat
3. Separator retreats
4. Thermal runaway initiates

2 Components Work Together

Existing Technology



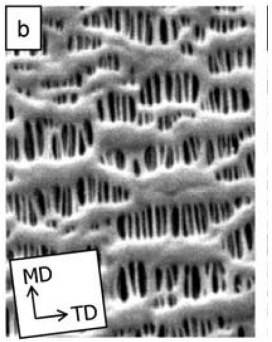
Soteria™ Technology



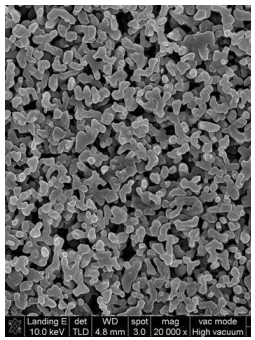
1. Internal short forms
2. High current generates heat
3. Separator retreats
4. Thermal runaway initiates

1. Dreamweaver separator maintains shape
2. Soteria films oxidize, act as internal fuse
3. Energy stops flow
4. Cell continues functioning

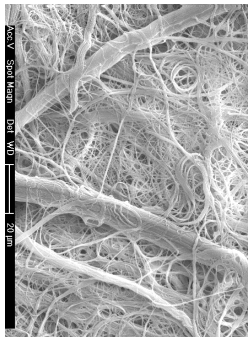
High Temperature Separator



Bare Film

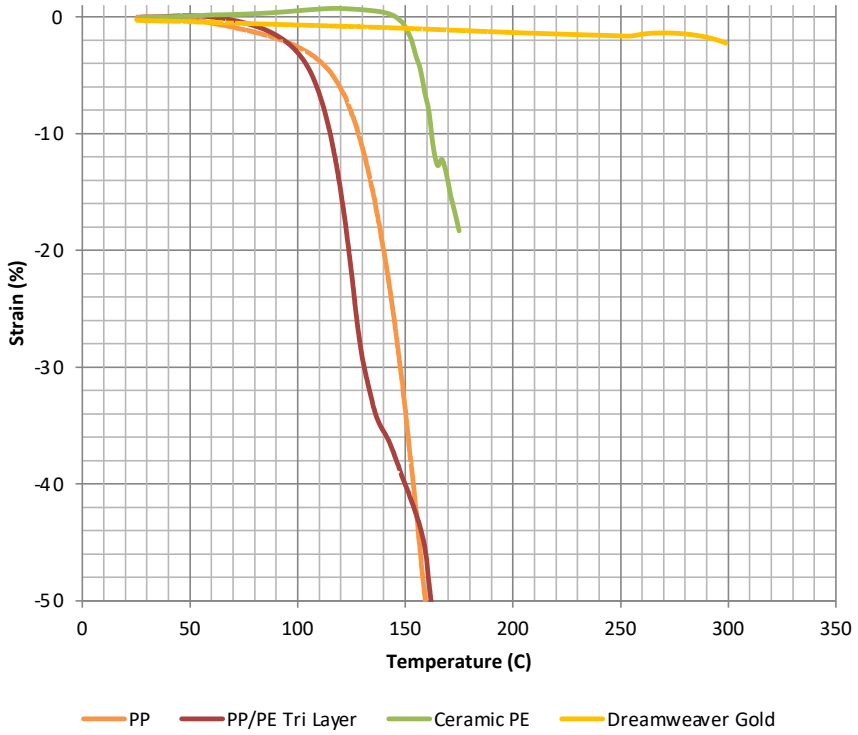


Ceramic Coated



Dreamweaver

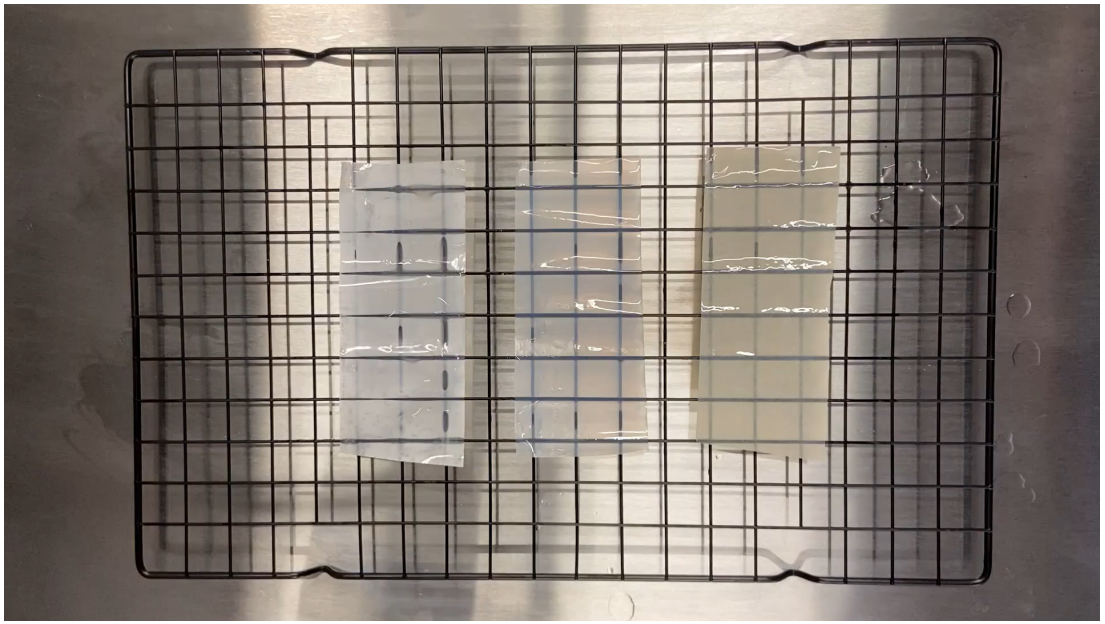
- Bare films shrink between 110—130°C.
- Heavy ceramic coatings improve only 30—40°C.
- Dreamweaver separators are stable to 300°C.
  - Reinforced with aramid fibers, stable to 550°C.



Separator Demo

Uncoated | Ceramic Coated | Dreamweaver Gold

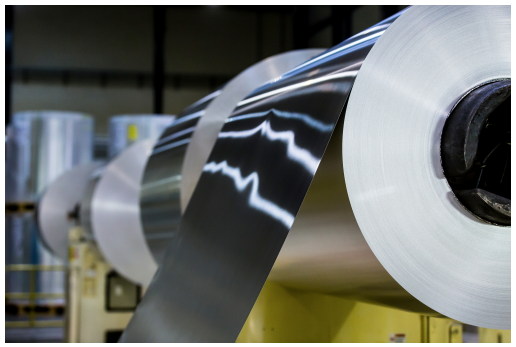
Separators saturated in electrolyte

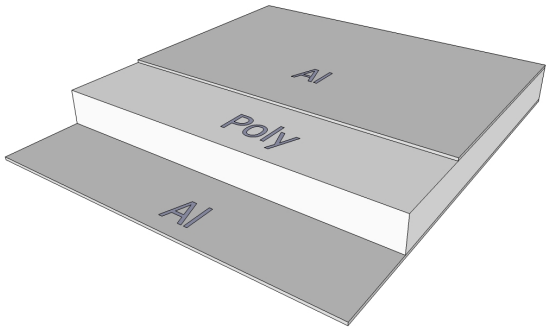


Watch Video:
https://youtu.be/wDsX-h7YqFE

Lighter Metallized Current Collector

	Traditional Copper Foil	Soteria Copper Film	Traditional Aluminum Foil	Soteria Aluminum Film
Thickness	10um	11um	15um	8um
Metal Thickness	10um	0.5 um per side	15um	0.5 um per side
Weight	90 g/m^2	21.5 g/m^2	43 g/m^2	17.9 g/m^2
Tensile	400 N/mm^2	120N/mm^2	150 N/mm^2	160 N/mm^2
Elongation	4%	37%	4%	22%





Test Cell

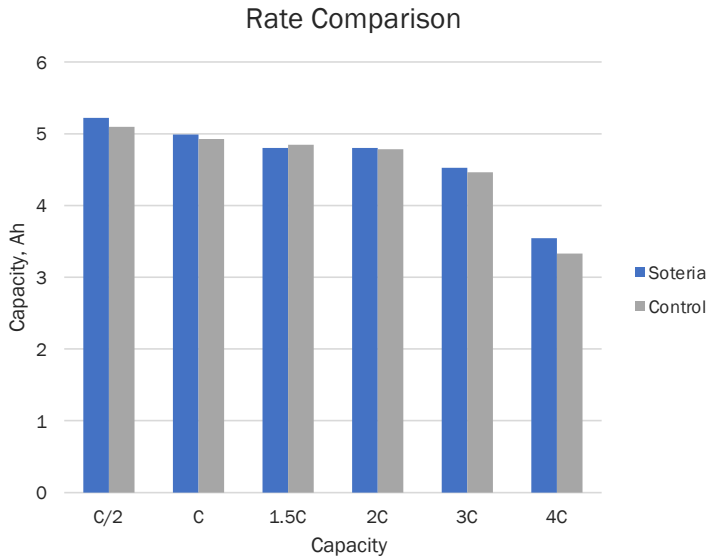
- 5Ah NMC 811 stacked pouch cell
- Uses Soteria AI current collector
- Made in conjunction with control cells of normal materials

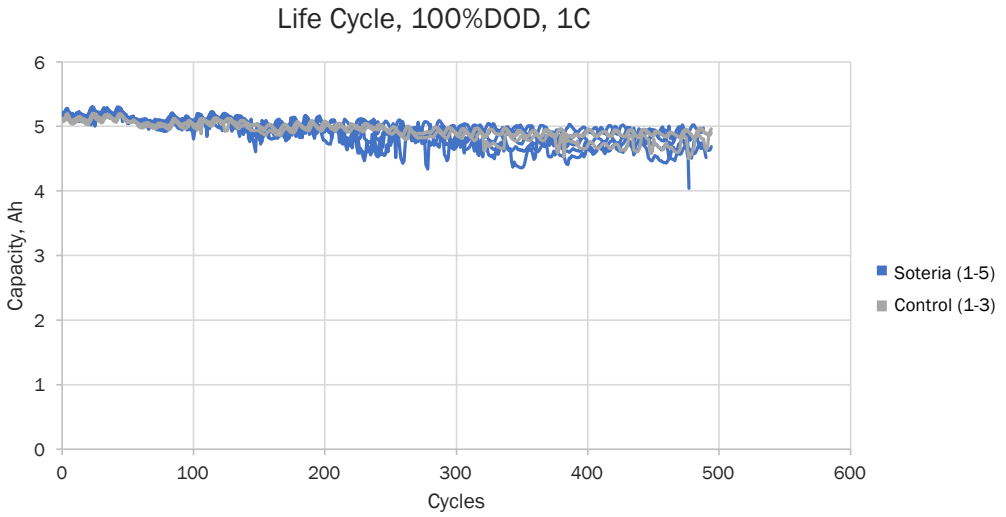
High-Energy Pouch Cell Abuse Testing

(5Ah NMC811-Graphite Pre-production Cells)

Abuse Mode #2: Nail Penetration

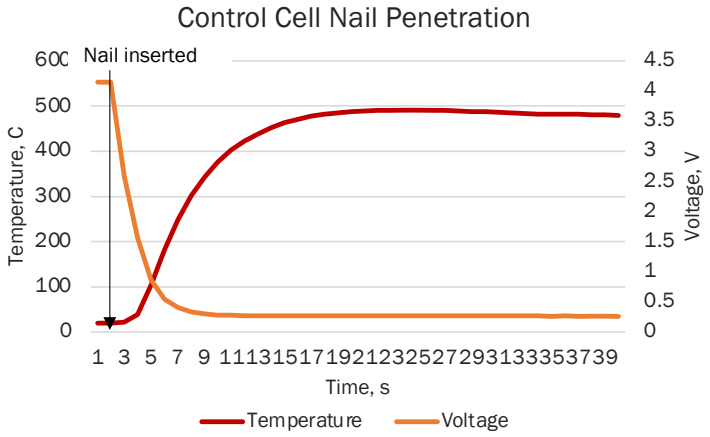
Metallized Films Match Foil Capabilities

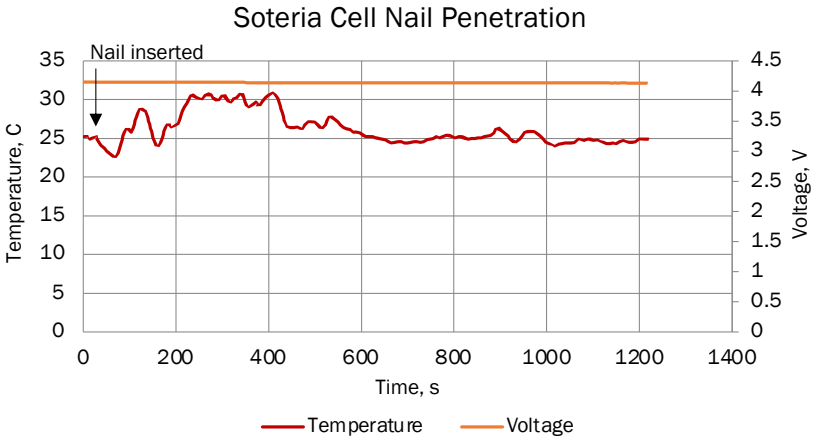


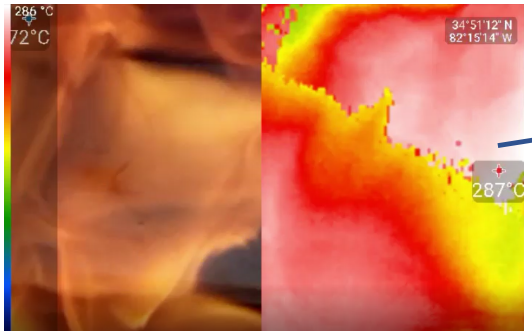


Soteria material cells match capabilities of control cells.

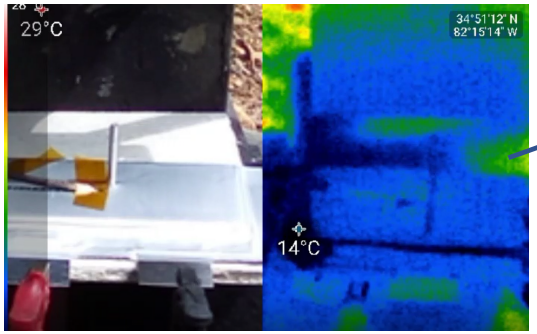
Radically Improved Abuse Performance





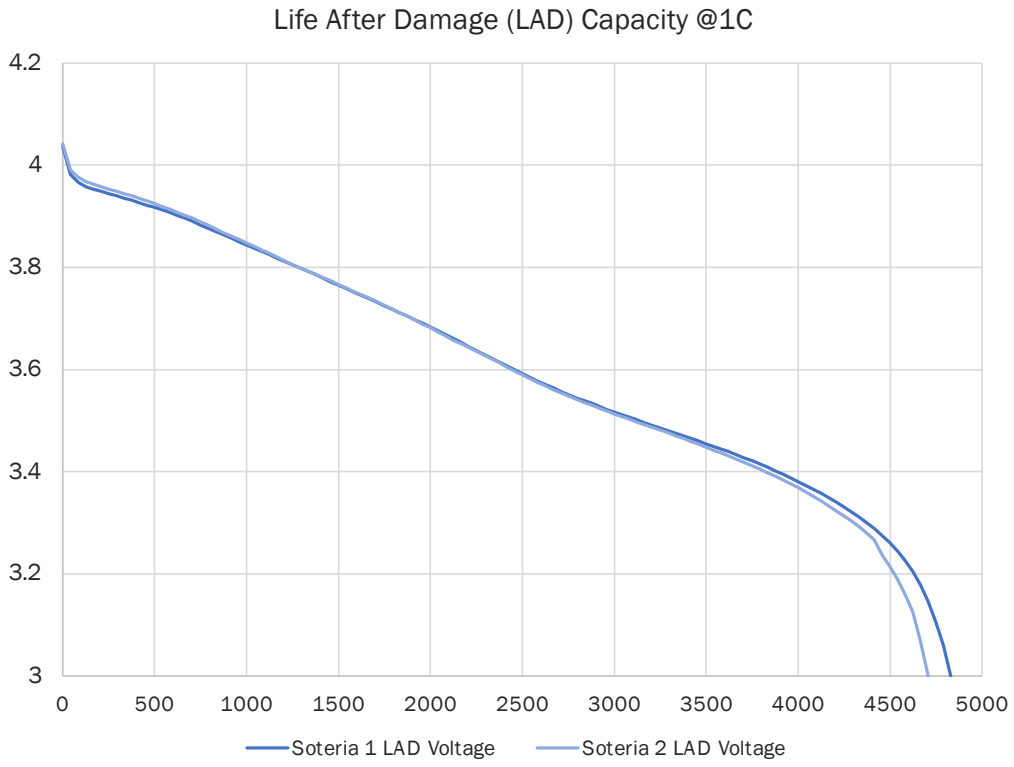


Control cells exhibited typical thermal runaway behavior



Soteria aluminum collector cells maintained voltage, minimal temperature rise

Life After Damage



After penetration test, nail was removed & cell was discharged at C rate.

Cell retained **93%** capacity.

Life After Damage: cell continues to function after defect or damage

Drone

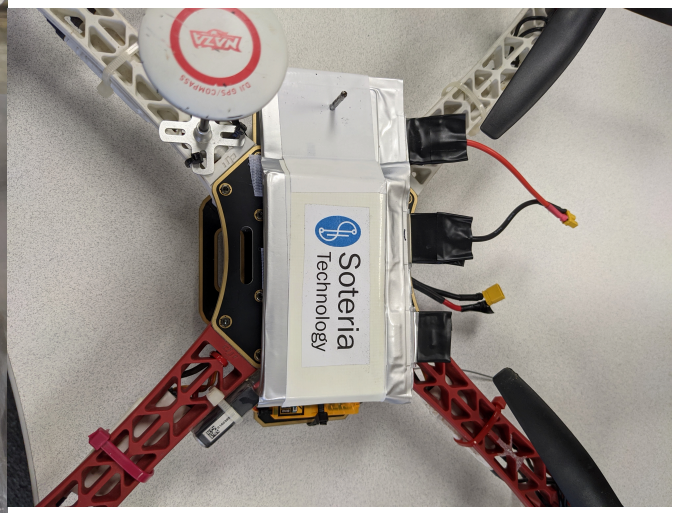
- DJI Flamewheel (450 mm diagonal hub to hub)
- Weight (minus battery) – 796g
  - With production battery (333g) – 1129g
  - With Soteria battery (266g) – 1062g
- Current draw average during flight (hover) – 11-14A
  - Automatic flight control system commanding variation in current for hover

Soteria Drone Battery

- 3S pack
  - 266g
  - 55Wh
  - 207 wh/kg (pack with all components)
- Flight demo preparation
  - 100% SOC (5Ah CC/CV charge to 0.5A cutoff)
  - Nail pen on single cell, nail left in cell
  - Flight until low battery warning

Drone Battery Nail Penetration

- Nail: 3mm diameter, cleaned mild steel
- No observable effects at/after nail insertion
- Pack configured to allow flight worthy balance on drone
- Pack secured to drone with velcro



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Drone Video

Drone Flight Summary

- Undamaged pack flight duration: 22:00
- Soteria nail penetrated pack flight duration: 21:18 (96.81% of undamaged pack)
- Battery start temperature (same as ambient): 21.4C
- Battery surface temp @ touchdown: 35.5C (14.1C rise – same as control)

Post Damage Observations

- Latent Defect Manifestation
  - Conductive particle moves into shorting position
  - Dendrite grows to dangerous position
  - Most likely outcome with Soteria materials is cell capacity reduces
    - Cell behaves like “leaky” cell
    - BMS most likely notes a cell approaching end of life.
      - Possible BMS algorithm modifications to prevent “next flight takeoff”
    - Maintenance event vs. in flight emergency
- Physical Damage
  - Mostly due to accident – crash or structural failure
  - Much improved resistance to thermal runaway – wide range of scenarios possible
    - Some scenarios will allow pack to still provide power. At a minimum, allow BMS to safe the pack.

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Thank You!