E-Aviation KULR ONE(K1) Air Reference Design with Amprius SiCore^{TM} Technology

Yvonne Diaz (KULR) & Erik Vaknine (Amprius)

KULR Open House

October 23, 2024

Overview: Advanced silicon anode technology meets innovative design approaches

Accelerating the ability to meet electric aviation industry standards

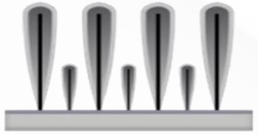
Pushing the boundaries of what’s possible while maintaining safety and performance

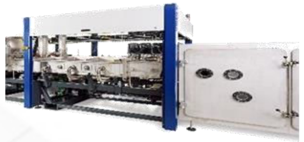
Federal Aviation Administration (FAA)

European Union Aviation Safety Agency (EASA)

Amprius Technologies Inc. (NYSE: AMPX)

Amprius is a pioneer, developer and manufacturer of high energy density silicon anode lithium-ion batteries.


Silicon Anode Design Finalized


kWh Scale Manufacturing


Customer Orders & Commercial Sales


GWh Scale Project Development Initiated


IPO @ NYSE

2008 | 2014 | 2016 | 2018 | 2021 | 2022

PERFORMANCE

High Energy Density: Up to 500 Wh/kg(1) and 1,300 Wh/L(1)(2)

High Power Density: Up to 10C

Fast Charge Rate Capability: 80% charge in <6 minutes (3)

Safety: Passed Military Performance Spec Nail Penetration Test(3)

Wide Operating Temperature: -30°C to 55°C

COMMERCIALIZATION

Production and Sales since 2018: Amprius Batteries are tested and validated by Amprius customers and leading industry partners.

Note: Certain performance metrics are based on specific Amprius products.

(1) At C/10 and 23°C.
(2) Volumetric energy density is calculated using body dimensions at 30% state of charge ("SoC").
(3) With 390 Wh/kg battery, available with SiMaxx™

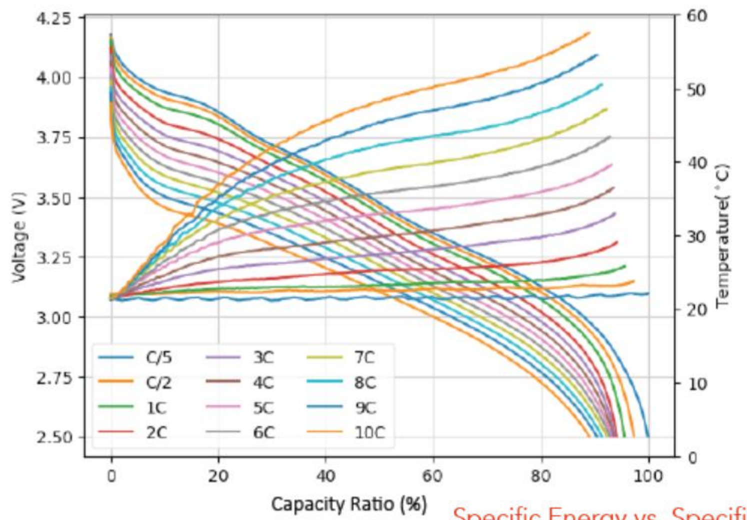
KULR

Amprius Technologies

SA88 SiCore Ultra-High Power Cell

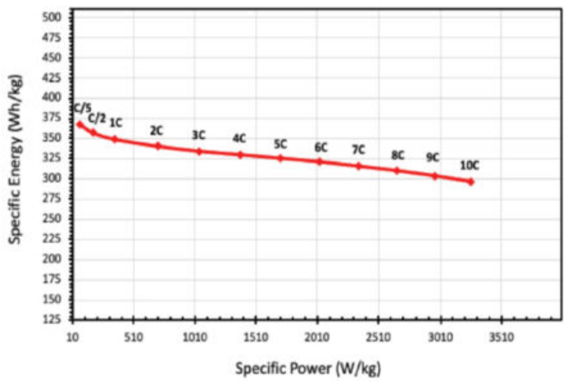
Discharge Rate Capability

At Room Temperature



Specific Energy vs. Specific Power

At Room Temperature

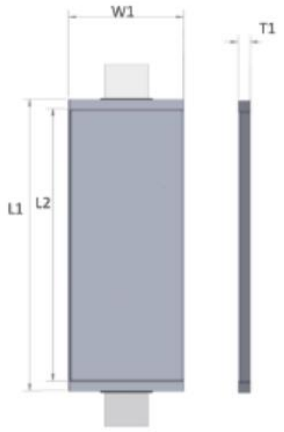


SA88

SiCore™ I Rechargeable Lithium-Ion Cell

amprius PRELIMINARY

10 Ah Ultra-High Power Cell



Specifications

Capacity	Typical @C/5	10000 mAh
		34 Wh
	Minimum	9750 mAh
		33.15 Wh
Cell Voltage	Nominal	3.40 V
	Charge	4.25 V
	Discharge	2.50 V
Discharge Current	Max Continuous	100 A (10C)
	Max Pulse (≤ 10 seconds)	200 A (20C)
Charge Current	Typical	60 A (6C)
	Maximum (0% to 100% SOC)	100 A (10C)
Temperature Range Ambient	Discharge	-20 to 60°C
	Charge	0 to 60°C
	Storage	-20 to 45°C
Internal Resistance	ACIR (1 kHz @ 30% SOC)	≤ 5 mΩ
	DCIR	≤ 7 mΩ
Cycle Life	+1C/-3C, 100% DOD, to 80% SOH	200 cycles
Weight		92 ± 1 g
Packaging		Pouch
Cathode		NMCA
Energy Density Including packaging	Gravimetric	370 Wh/kg
	Volumetric	910 Wh/l
Special Note	Cell requires external clamping of 30 PSI	

Dimensions

Size	L1	135.2 ±0.5 mm
	L1	126.2 ±0.4 mm
	W1	53.1 ±0.2 mm
	T1 (@ 30% SOC)	5.6 ±0.3 mm

Amprius and KULR Partnership

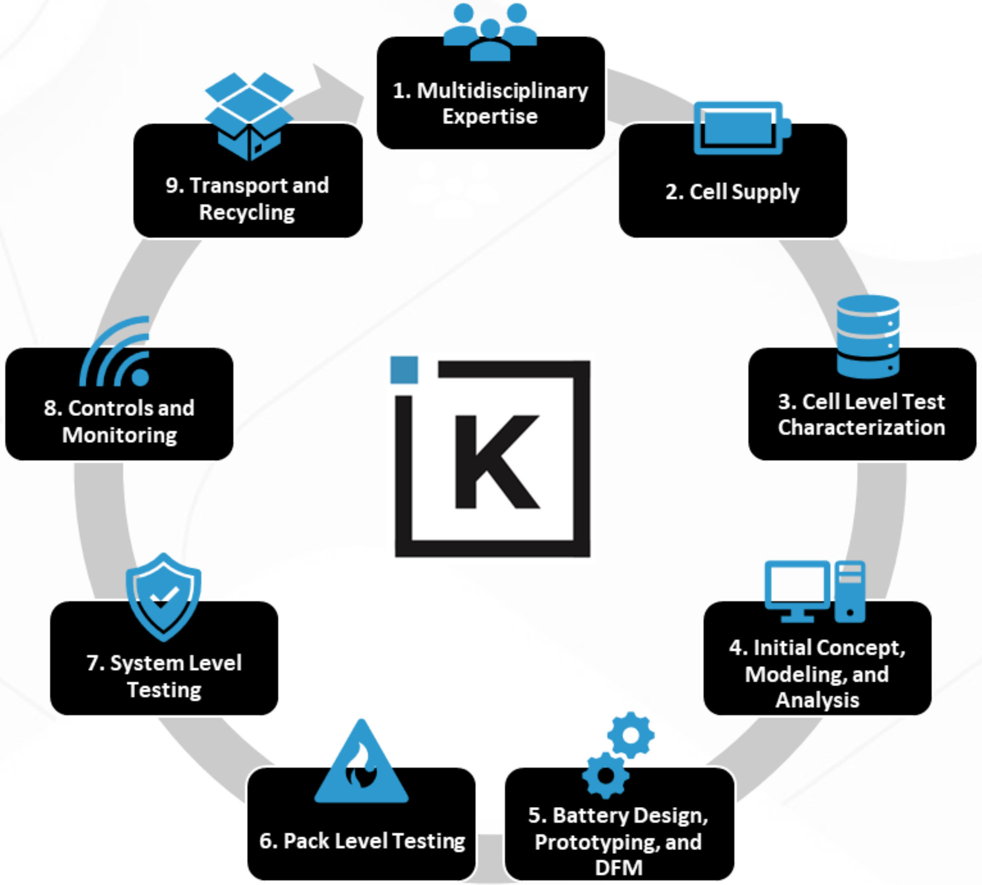
Partnership with KULR to create a mechanical reference design to demonstrate it is possible to integrate high GED pouch cells with Silicon dominant anodes from Amprius that will:

- Pass the Thermal Runaway requirements for cell-to-cell propagation and module containment specified by the FAA and EASA
- Provide the required cell level compression
- Provide passive thermal management to support 10C continuous charge and discharge
- Minimize the GED penalty at the pack level to maintain the Amprius technology advantage versus other traditional technologies.

Reference Design Goal

Provide customers with the building blocks to support the integration of Amprius' high GED pouch cells without overburdening the pack assembly with interstitial material

KULR ONE Design Solutions – A holistic approach for battery design & safety

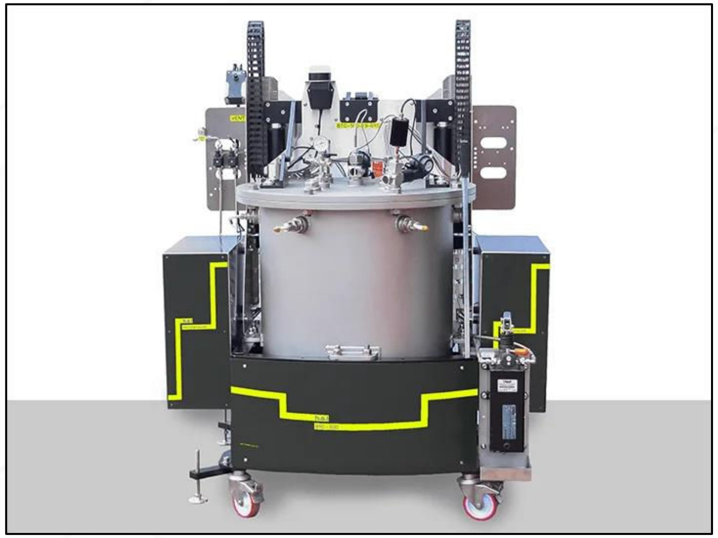


Using advanced designs and innovative cells

To reimagine what's possible

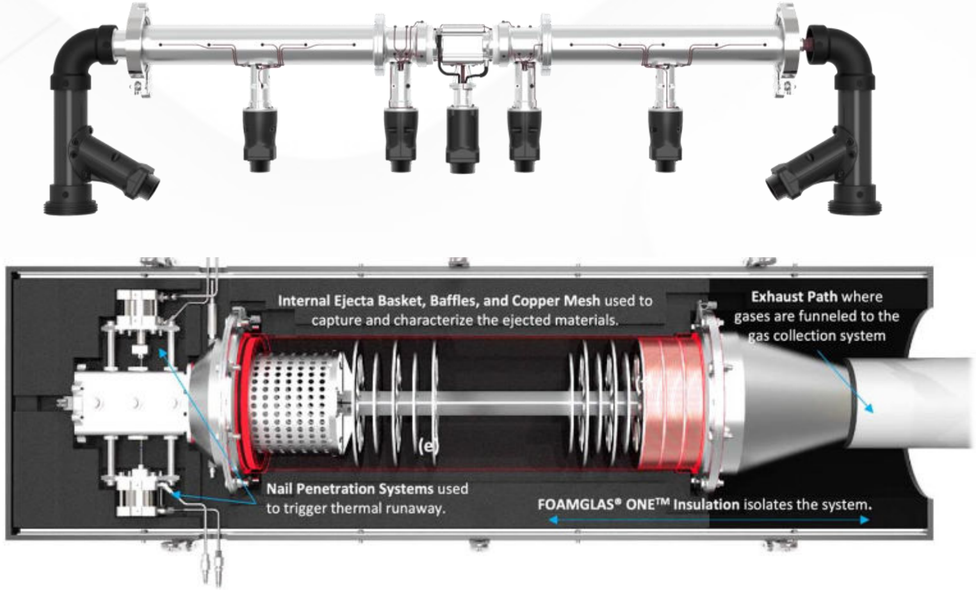
Cell level thermal runaway characterization

Bomb Calorimetry



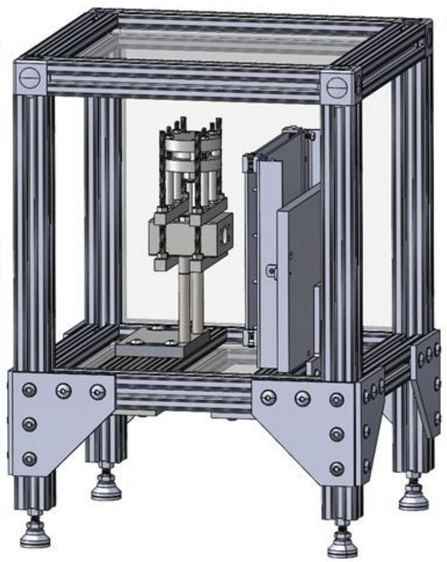
- Determining total heat output
- Precise heat control
- Ease of comparison to literature

Fractional Thermal Runaway Calorimetry (FTRC)



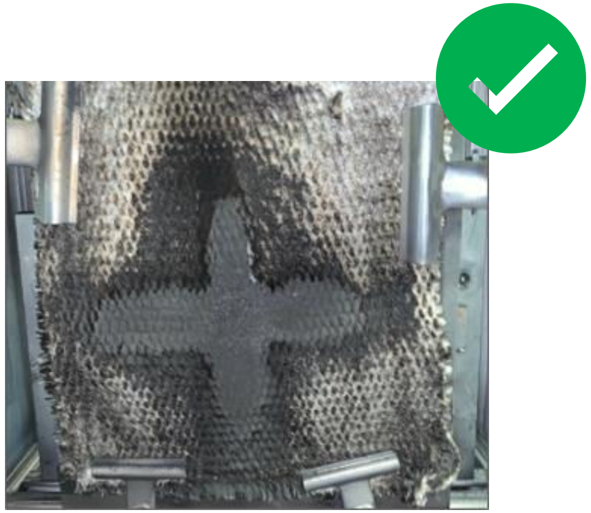
- Measures the total <u>and</u> fractional energy
    - More complete look at heat output
- Breakdown of energy: cell casing vs. ejected through positive/negative ends

Impingement Zone Mapping (IZM)



- Shape, size, temp, and distribution of particles released at TR
- Evaluate barrier materials
- Tailored trigger methods

IZM of Molicel 21700 P45B: An example of the high energy this reference design needs to contain



SafeCASE thermal material

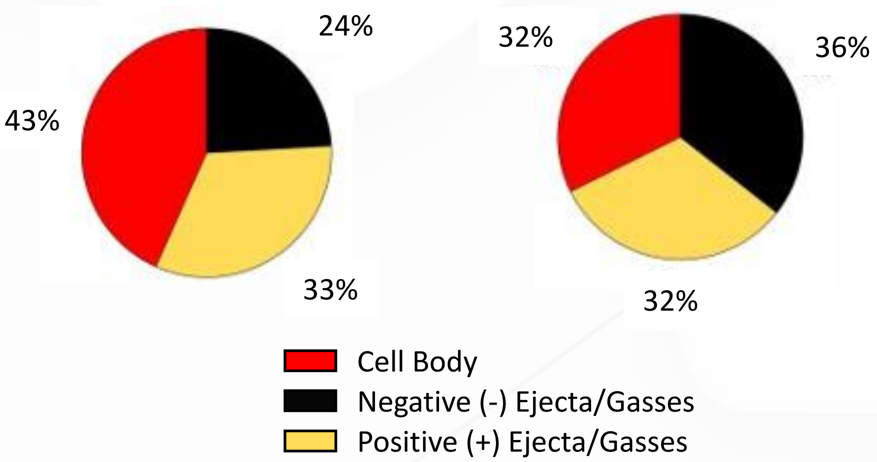
Alternative thermal barrier

Using the KULR suite of testing to fully characterize Amprius SiCore™

Bomb Calorimetry

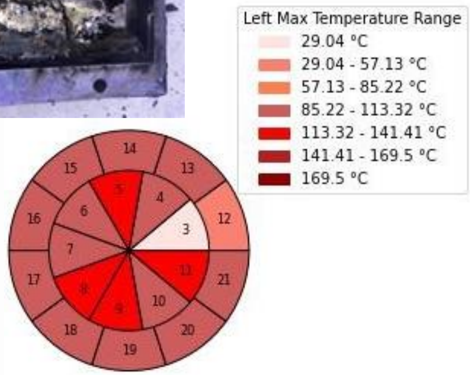
- Cell failure along terminal side edges
- Shows temperature range of when TR occurs
- Range in extent of TR
- Repeat testing is critical to showing variability in TR temps and mode

Fractional Thermal Runaway Calorimetry (FTRC)



- Directional output of energy
- More complete look of total energy
- Repeat testing critical to show variability

Impingement Zone Mapping (IZM)



- Custom cell chamber for SiCore™
- Map of heat ejected
  - Temperature and direction
- Also gathered (not shown)
  - Energy flux ranges
  - Heat flux ranges
  - Total energy yields

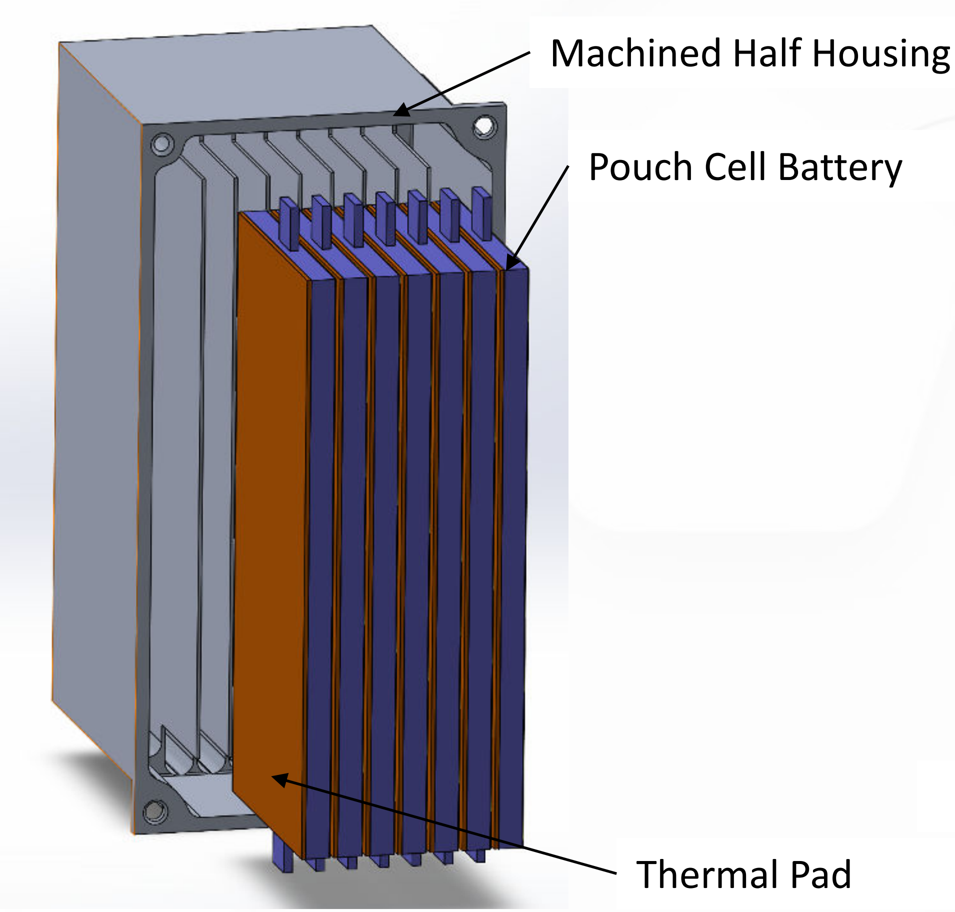
Together these provide critical information for modeling an optimized design

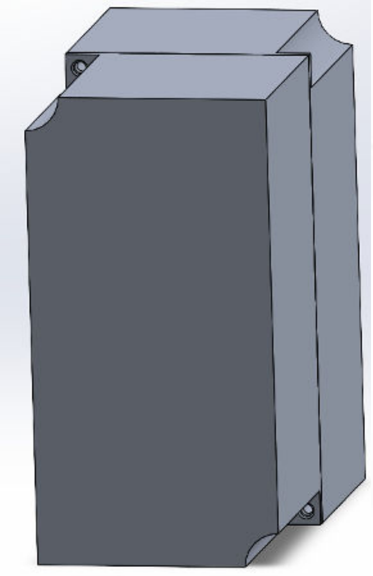
Modeling SiCore^{TM} cells within packs to withstand thermal runaway

Goal: Compact, lightweight 14-cell enclosure with efficient thermal and safety considerations

Initial design concept aims to maximize thermal conductivity, targets gravimetric density ~380Wh/kg & includes:

- **Machined AL housing**
- **Integrated fins**
- **Two ½ housings of 7 each fastened together**
- **Thermal pads for increased heat transfer and thermal isolation**
- **Space to accommodate wiring and protective materials**

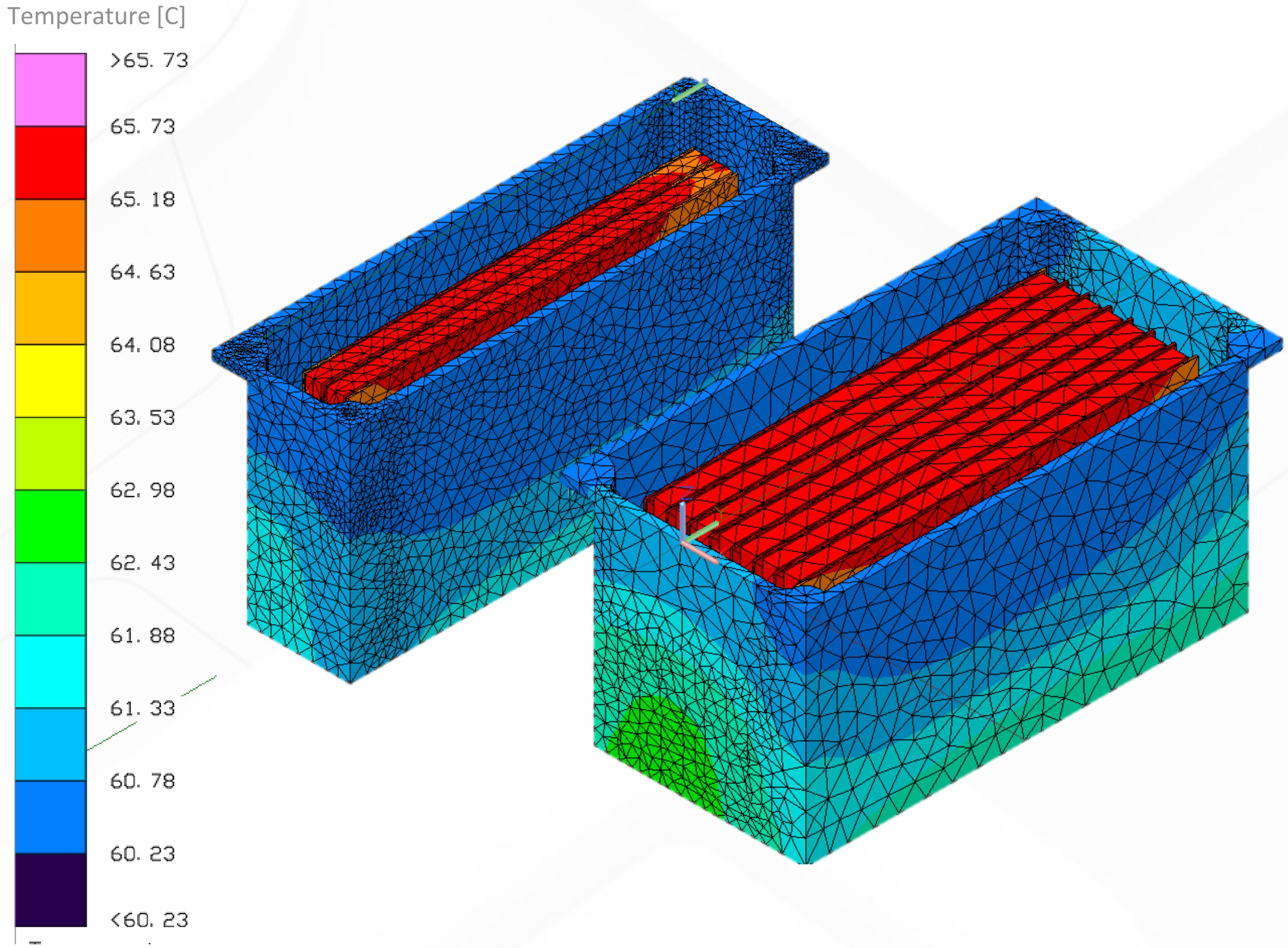




Cell pack (closed)

Initial simulations show promising path forward for reference design

Successful simulations will show cells in thermal runaway (red) while surrounding remain cool (blue)



Simplified 2 and 7 cell system ran for computational speed

Steady state solution solved to anticipate worst-case scenario

No radiation or convention used
Assume uniform heating
Only conductance values included

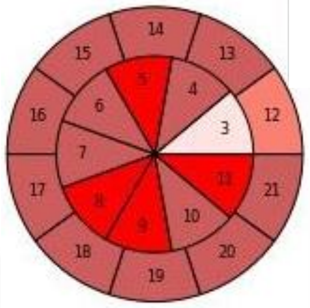
Compared models for various materials

Expanding on initial model and design

Current activities include building on promising results and accounting for main challenges

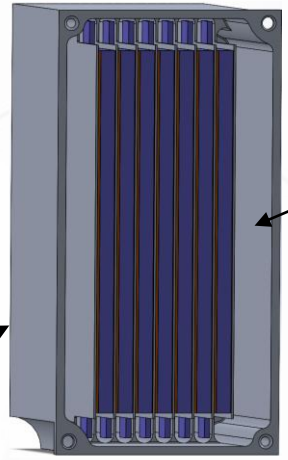
Challenge 1: Containing high heat

- Cell-to-cell propagation limitations by FAA
- Module containment requirements
- Other passive and active cooling considerations



Challenge 2: Meeting high pack energy density requirements

- Low mass ablative shields
- Heat spreaders
- Material type and thickness of base and fins



Challenge 3: Maintain necessary header space to contain gases without over pressurizing

- Optimize header space within size limits
- Cell configuration

Designing a thermally safe module that is tailorable for customer needs

Step 1: Address challenges to obtain a thermally satisfactory design *(Est. Jan 2025)*

- Evaluate optimized cell from Amprius
- Optimize design using thermal modeling
- Additional material testing to ensure compatibility with high energy cells

Step 2: Testing to verify design against thermal FAA/EASA requirements *(Est. March 2025)*

- Build a prototype for testing
- Thermal runaway verification
- Additional regulatory considerations include: UN38.8, DO-311A (FAA), and MOC-3 SC-VTOL (EASA)
- Any necessary re-designs based on application testing learnings

Step 3: Delivery of a tailorable reference design *(Est. June 2025)*

- Available base design of pack integrating Amprius's high GED pouch cells
- Upfront testing and modeling allows for rapid concept generation for alternative customer requirements
    - Exploration of BMS combinations
    - Scaling of design
    - Alternative cells

KULR

cooler · lighter · safer