



# KULR TECHNOLOGY GROUP, INC.

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Engineering Technology Roadmap

October 2024 Update

# Our History

**2015**  
KULR Technology Corporation founded in San Diego, CA.

**2017**  
Licensing agreement with NASA – carbon fiber thermal management technology.

**2019**  
Announcement of safe battery design leveraging NASA FTRC data.

**2021**  
Listed on the NYSE American Exchange.

**2023**  
Battery Design and Testing Center of Excellence opened in Webster, TX. Exclusive NASA L-FTRC license.

**2025**  
Launch of the commercialized Space (K1S) and Guardian (K1G) platforms.



2015

2016

2017

2018

2019

2020

2021

2022

2023

2024

2025

2026

**2016**  
Development of thermal runaway shield (TRS) for batteries.

**2018**  
Exclusive licensing agreement with NREL and NASA for ISC-D.

**2019**  
SafeX product line flown to ISS for use in crewed space applications.

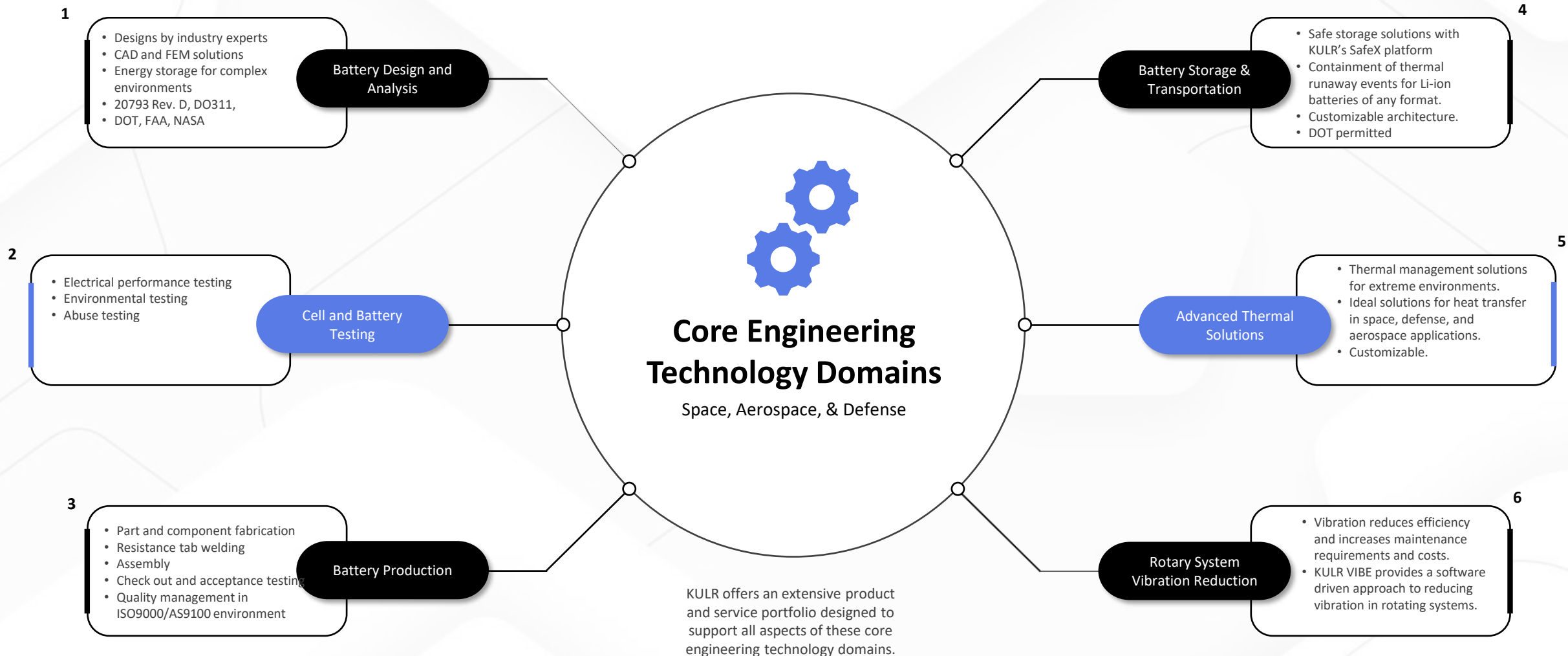
**2021**  
KULR PCM heat sink lands on Mars with Mars Rover Perseverance.

**2022**  
Licensing of small and large FTRC technology from NASA.

**2024**  
Expansion of TX operations and relocation of HQ to TX based offices.

**2025**  
Battery testing services expanded to include environment testing.

# Technology Domains

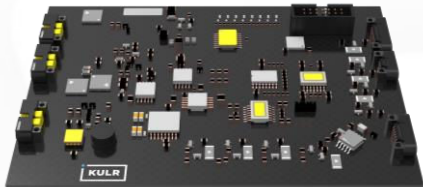


# Battery Design and Analysis

Custom Batteries	KULR ONE	Products	
<p>Industry Experts</p> <ul style="list-style-type: none"> <li>• Designs by engineering team with space flight hardware and BMS dev. experience.</li> <li>• Engineers with backgrounds from NASA, Axiom, commercial battery industry, small-sat industry</li> </ul>	<p>KULR ONE Space</p> <ul style="list-style-type: none"> <li>• 18650/21700 architecture</li> <li>• Thermal runaway safety achieved via passive propagation resistant (PPR) design architecture.</li> <li>• Designed with intent for JSC 20793 Revision D satisfaction.</li> </ul>	<p>Radiation Tolerant Battery Management System (BMS)</p> <ul style="list-style-type: none"> <li>• Designed for 20793 Rev. D battery systems</li> <li>• Off-the-shelf, vacuum tolerant &amp; radiation tolerant, flight ready system.</li> <li>• Ground up safety first architecture.</li> </ul>	<p>Trigger Cells and ISC-Ds</p> <ul style="list-style-type: none"> <li>• Internal short-circuiting device for implant.</li> <li>• Pre-built trigger cells with ISC-D already implanted.</li> <li>• Low temp trigger thermal runaway at 55 °C</li> <li>• High temp trigger thermal runaway at 70 °C</li> </ul>
<p>Computer Aided Design (CAD)</p> <ul style="list-style-type: none"> <li>• Solidworks</li> <li>• Design management w/ Solidworks PDM</li> <li>• Autodesk Fusion 360</li> <li>• Design management with Autodesk Fusion Manage</li> <li>• ISO9000/AS9100 controlled design release processes</li> </ul>	<p>KULR ONE Guardian</p> <ul style="list-style-type: none"> <li>• 18650/21700 architecture</li> <li>• PPR safety strategy.</li> <li>• Robust materials selection for extreme environments.</li> <li>• Designed for DoD applications.</li> <li>• MIL-STD-810H and MIL-PRF.</li> </ul>	<p>CellCheck™</p> <ul style="list-style-type: none"> <li>• Real time monitoring and logistics of battery performance.</li> <li>• Safety and state-of-health monitoring.</li> <li>• Fleet management.</li> </ul>	<p>Thermal Runaway Cell Body Heating Protection</p> <ul style="list-style-type: none"> <li>• Thermal Runaway Shield (TRS) for rapid cooling of conducted thermal runaway heating.</li> <li>• KULR core composite interstitial solution for operation heat management and thermal runaway heat management.</li> </ul>
<p>Finite Element Modeling (FEM) and Analysis</p> <ul style="list-style-type: none"> <li>• ANSYS SpaceClaim &amp; TD Direct</li> <li>• Thermal Desktop</li> <li>• SINDA/FLUINT</li> <li>• GT-SUITemp</li> </ul>	<p>KULR ONE Air</p> <ul style="list-style-type: none"> <li>• Pouch silicon cell architecture</li> <li>• Low mass / low volume structures for aerospace (eVTOL) applications.</li> <li>• Module-to-module propagation resistance strategy.</li> <li>• Consideration given to DO311 requirements.</li> </ul>	<p>WI-37A Screened Cells</p> <ul style="list-style-type: none"> <li>• 18650 format li-ion cells.</li> <li>• Pre-screened to NASA JSC EP-WI37A</li> <li>• Cells arrive to customers pre-matched, screened, and ready to be installed.</li> </ul>	<p>Thermal Runaway Ejecta Mitigation</p> <ul style="list-style-type: none"> <li>• Side wall rupture tubing to protect from potential products expelled through an off-nominal failure.</li> <li>• Burst covers to protect from flowing ejecta.</li> <li>• Fibercore flame arrester to ensure only smoke exits the pack for single cell TR.</li> </ul>



200 Series KULR ONE Space (K1S)



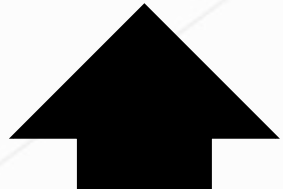
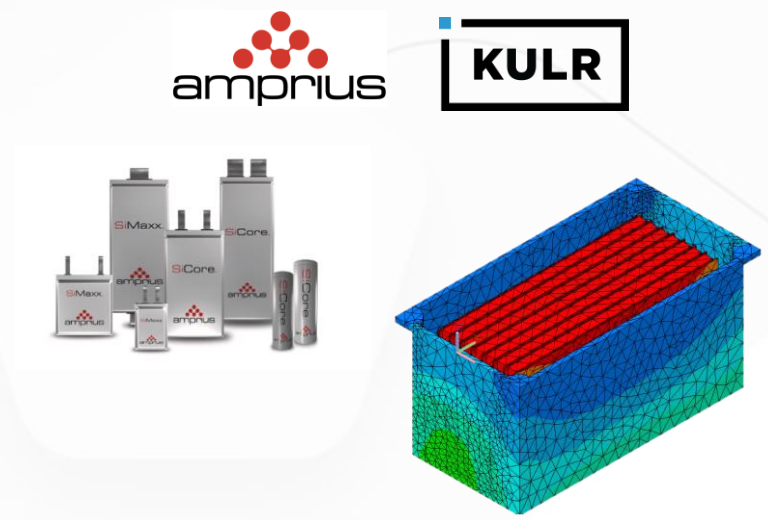
Radiation Tolerant BMS

# Vision to Deliver Leading Energy Storage Solutions

## KULR ONE Space (K1S)

## KULR ONE Guardian (K1G)

## KULR ONE Air (K1A)



## KULR ONE (K1) JOURNEY

2022 to Present

KULR has dedicated the last 24 months to transitioning from a supplier of battery and cell testing and components, to a focus on delivering total energy storage solutions. **KULR ONE** refers to a consistent philosophy across all platforms; safety, reliability, and performance.

CES K1 Prototypes

Early K1G

K1S v2

K1S v4

K1M



# OTS Battery Management Systems (BMS)

## K1S Off-the-Shelf BMS

- Radiation tolerant (75 kRad),
- UART or I2C communications for up to 8 strings.
- Microcontroller based -> endless customization on circuitry.
- Low parasitic drain to support long duration stays in payload bay.
- 10A sustained draw.

## K1G Off-the-Shelf BMS

- ASIC BMS chip with added microcontroller chip.
- 7 to 10 strings in current config, easily modifiable for up to 20 for higher voltage applications.
- 76 A sustained draw; able to increase as needed

### Customizable GUI for monitoring.

The screenshot shows the BMS Utility GUI with the following data:

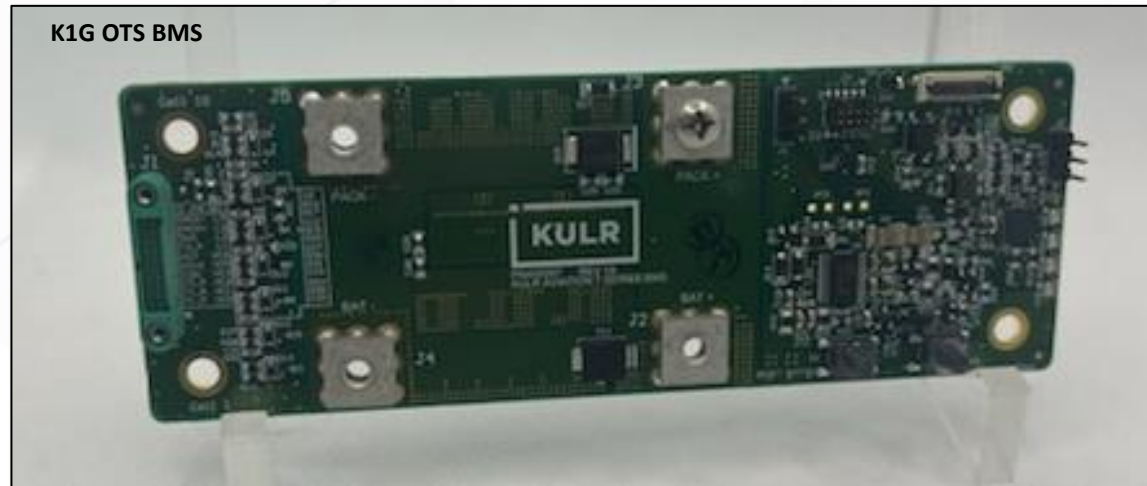
Status		Current settings and Health	
Pack voltage (mV)	23814	OV Trip (mV)	4200
Cell 1 (mV)	3385	UV Trip (mV)	2500
Cell 2 (mV)	3386	OC Trip (A)	72
Cell 3 (mV)	3388	Balance Volt (mV)	4000
Cell 4 (mV)	3388	State of Charge	96
Cell 5 (mV)	3373	State of Health	100
Cell 6 (mV)	3377	Time to discharge (min)	65535
Cell 7 (mV)	3369	OTD Trip (°C)	60
Current (mA)	-33	UTD Trip (°C)	1
Batt Temperature (°C)	26.1	OTC Trip (°C)	60
Die Temperature (°C)	20.1	UTC Trip (°C)	1
Heater trigger (°C)	0	Battery Fault	00
Heater output	OFF	Operation mode	Auto
		Heater control	Disable

Get status option:  One-shot  Periodically (1s)

K1S OTS BMS



K1G OTS BMS



# Cell and Battery Testing

Abuse Testing		Electrical Testing		Environment Testing	
<p><b>Small Fractional Thermal Runaway Calorimetry</b></p> <ul style="list-style-type: none"> <li>Li-ion cells up to 10 Ah</li> <li>Total energy yield,</li> <li>Cell body vs. ejected energy yield</li> <li>Variability characterization vs. trigger method and SOC.</li> <li>Combination synchrotron.</li> </ul>	<p><b>Cell Level Abuse Testing</b></p> <ul style="list-style-type: none"> <li>Temperature measurement</li> <li>Heater, ISC-D, and nail trigger methods</li> <li>4K videography</li> <li>IR video feed</li> <li>Facilitate of online and in-person interaction with customer.</li> </ul>	<p><b>Gas Analysis</b></p> <ul style="list-style-type: none"> <li>Equipped to take samples during testing (vacuum bottle)</li> <li>Submit for 3<sup>rd</sup> party analysis</li> <li>Evaluation of composition of expelled thermal runaway gases.</li> </ul>	<p><b>WI-37A Screening</b></p> <ul style="list-style-type: none"> <li>Mass and dimensional consistencies</li> <li>Capacity retention.</li> <li>DCIR consistency.</li> <li>Visual defect inspection (scratches, dents, corrosion)</li> <li>Matched for pack installation.</li> </ul>	<p><b>Thermal Vacuum (2025 K1-TS Pipeline)</b></p> <ul style="list-style-type: none"> <li>-60 C to +150 C thermal</li> <li>10-6 Torr vacuum pull</li> <li>Can combine with Arbin systems for pack/module cycling.</li> <li>Electronics (BMS) check-out</li> </ul>	
<p><b>Large Fractional Thermal Runaway Calorimetry</b></p> <ul style="list-style-type: none"> <li>Li-ion cells up to 200 Ah</li> <li>Total energy yield,</li> <li>Cell body vs. ejected energy yield</li> <li>Variability characterization vs. trigger method and SOC.</li> </ul>	<p><b>Pack/Module Abuse Testing</b></p> <ul style="list-style-type: none"> <li>Temperature measurement</li> <li>Heater, ISC-D, and nail trigger methods</li> <li>4K videography</li> <li>IR video feed</li> <li>Facilitate of online and in-person interaction with customer.</li> </ul>	<p><b>Particle Size Analysis</b></p> <ul style="list-style-type: none"> <li>Ejecta materials vary in particle size depending on ejection characteristics and level of material decomposition.</li> <li>Microscopic characterization of particle size as a function of grouping.</li> </ul>	<p><b>Cell Cycling</b></p> <ul style="list-style-type: none"> <li>60 A / channel cycling capability w/ Arbin based systems.</li> <li>Cell capacity fade vs. cycle count vs. power profile.</li> <li>Accelerated aging (2025 pipeline).</li> </ul>	<p><b>Thermal &amp; Humidity (2025 K1-TS Pipeline)</b></p> <ul style="list-style-type: none"> <li>-40 to 120 C environment.</li> <li>Up to 100% humidity.</li> <li>Can combine with Arbin systems for pack/module cycling.</li> <li>Electronics (BMS) check-out</li> </ul>	
<p><b>Impingement Zone Mapping</b></p> <ul style="list-style-type: none"> <li>Li-ion cells up to 30 Ah</li> <li>Ejecta impingement region intensity and heat flux characterization.</li> <li>High speed videography and frame by frame analysis of ejecta behavior.</li> <li>Variability characterization vs. trigger method and SOC.</li> </ul>	<p><b>Adiabatic Bomb Calorimetry</b></p> <ul style="list-style-type: none"> <li>Adiabatic calorimetry modes</li> <li>Heat, wait, seek (standard ARC testing)</li> <li>Determination of material decomposition threshold</li> <li>Measurement of thermal runaway onset temperature</li> <li>Characterization of cell body heating rates</li> </ul>	<p><b>Specialized Instrumentation and Set-up (All Methods)</b></p> <ul style="list-style-type: none"> <li>Equipped to provide custom specialized instrumentation and set-up for all testing methods.</li> <li>Ex: In-Situ HF sensors, gas collection systems, customizable NI based DAQ chassis.</li> <li>Controlled atmosphere composition experiments.</li> </ul>	<p><b>Module Cycling</b></p> <ul style="list-style-type: none"> <li>200 A / 200 V channel cycling capability with Arbin based system.</li> <li>Conductive set-up for pack/module electrical and thermal performance characterization.</li> <li>Can combine with abuse testing apparatus upon request.</li> </ul>	<p><b>Vibration (2026 K1-TS Pipeline)</b></p> <ul style="list-style-type: none"> <li>Up to 300 lb payload.</li> <li>SLS, Vulcan Centaur, and GEVS profile compatible.</li> </ul>	

# Bomb Calorimetry

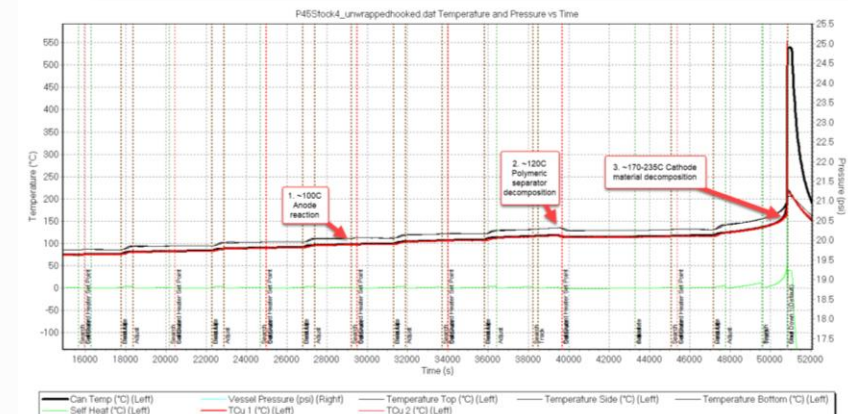
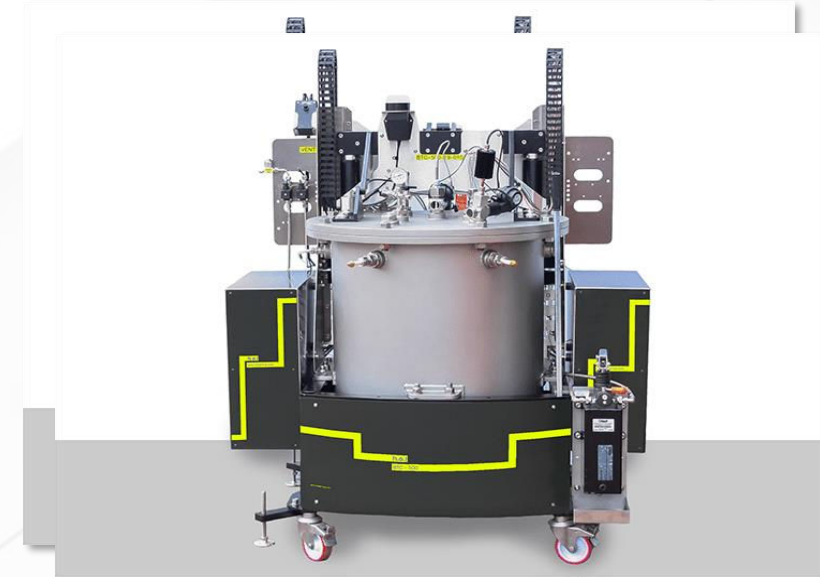
KULR offers extended volume bomb calorimeter services for characterization of material decomposition thresholds of lithium-ion cells. The calorimeter is also useful for determining cell specific heat capacity and can also be used as an adiabatic calorimeter for characterization of cell heating rates as a function of charge and discharge profile.

## Benefits

- Determine temperature thresholds for separator breakdown, anode/SEI decomposition acceleration, and thermal runaway onset temperature.
- Measure total volume of thermal runaway gases generated.
- Approximate gas generation rate.
- Approximate total energy release due to thermal runaway.
- Ease of data comparison by gathering thermal runaway data in a format that is highly referenced in academic literature.

## Key Features

- Industry standard heat-wait-seek methodology.
- Interface for temperature, pressure, and other ancillary sensor measurements.
- Interface for gas sampling.
- In-situ HF, CO, CO<sub>2</sub> sampling (*experimental*)





# Fractional Thermal Runaway Calorimeter

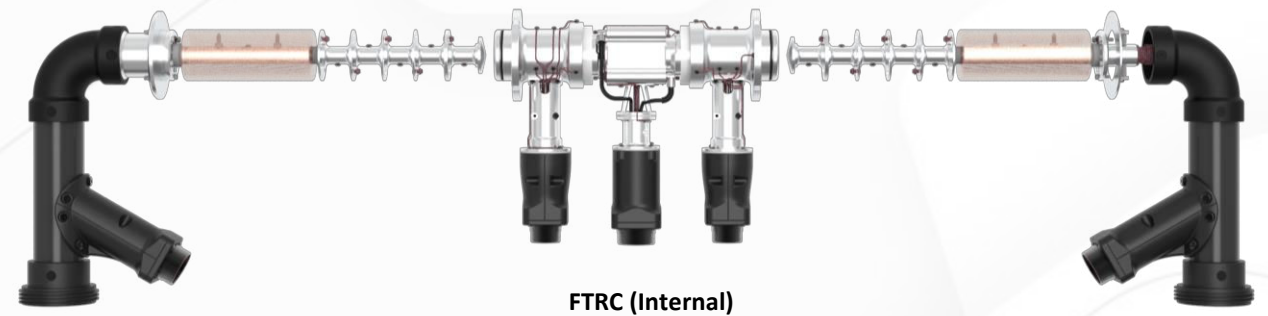
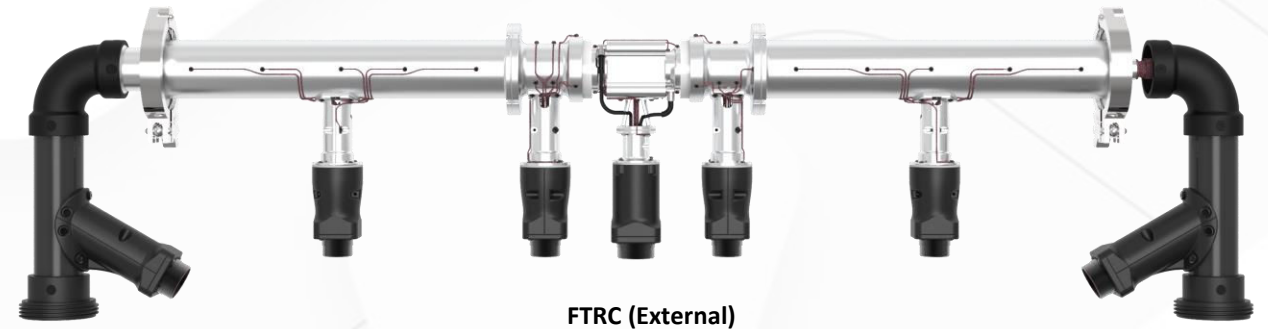
KULR holds commercial license for **NASA's government invention of the year award (IOTYA) winning** small format fractional thermal runaway calorimeter (S-FTRC). FTRC provides calorimetric techniques for evaluating heating response of cell level thermal runaway events.

## Benefits

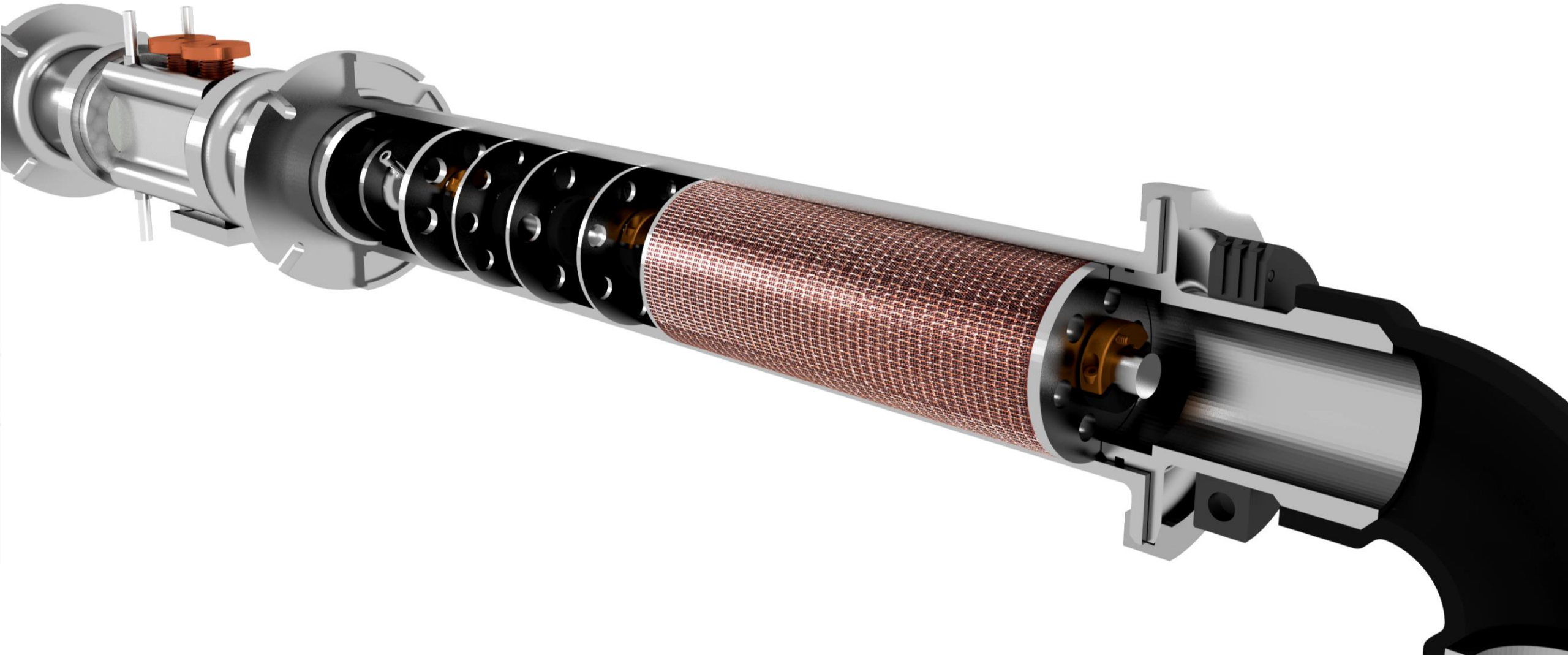
- Measures the total and fractional energy generated due to thermal runaway of a lithium-ion cell.
- Provides insight into the breakdown of energy as it pertains to that released through the cell casing vs. that which is ejected away through the positive and negative ends of the cell.
- Provides critical information for modeling activities that are used to optimize the design of safer batteries.
- Rapid collection of large datasets.
- Design suitable for characterizing thermal runaway variability.

## Key Features

- Determination of total energy (kJ) and fractional energy (kJ) yields.
- Heat rate (W) and heat flux ( $W m^{-2}$ ) analysis.
- Approximation of mass flow rate ( $g s^{-1}$ ).
- Breakdown of remaining cell mass vs. ejected.
- 18650, 21700, cylindrical, prismatic, and custom pouch formats.
- Compatible with heater, nail, and ISC-D trigger methods.



# Fractional Thermal Runaway Calorimeter



# Medium and Large Format FTTC (M-FTTC / L-FTTC)

KULR holds an exclusive licensing agreement for the large format FTTC (L-FTTC) for characterization of fractional energy yield from large format lithium-ion cells when triggered into thermal runaway. A large format cell, with respect to this design, is a cell with capacity greater than 100 Ah. KULR has also modified the L-FTTC with smaller bore apparatus to accommodate “mid” range lithium-ion cell capacities. As such, KULR is the only entity offering comprehensive FTTC testing services for any cell, regardless of capacity.

## Benefits

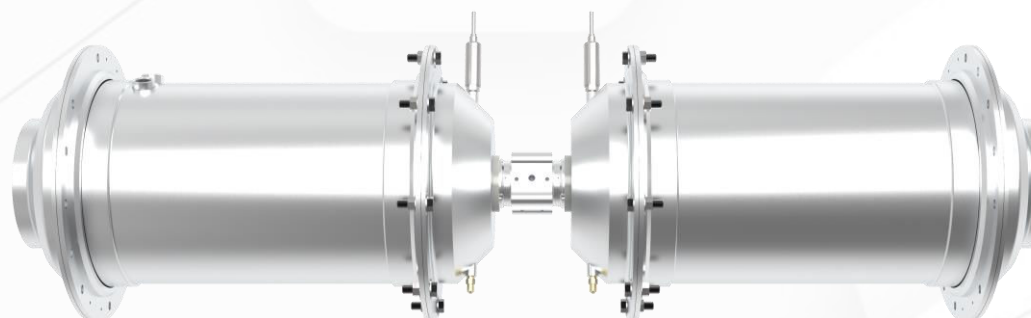
- Measures the total and fractional energy generated due to thermal runaway of a lithium-ion cell.
- Provides insight into the breakdown of energy as it pertains to that released through the cell casing vs. that which is ejected away through the positive and negative ends of the cell.
- Provides critical information for modeling activities that are used to optimize the design of safer batteries.
- Rapid collection of large datasets.
- Design suitable for characterizing thermal runaway variability.

## Key Features

- Determination of total energy (kJ) and fractional energy (kJ) yields.
- Heat rate (W) and heat flux ( $W m^{-2}$ ) analysis.
- Approximation of mass flow rate ( $g s^{-1}$ ).
- Breakdown of remaining cell mass vs. ejected.
- Typically requires custom cell chamber to match customer cell.
- Compatible with heater, nail, and ISC-D trigger methods.



As-Licensed NASA L-FTTC



KULR Developed M-FTTC

# Impingement Zone Mapping

KULR has developed a technique referred to as impingement zone mapping (IZM) to help provide data necessary for designing battery shielding that is used in some of the most vulnerable areas of a battery pack as it pertains to thermal runaway.

## Benefits

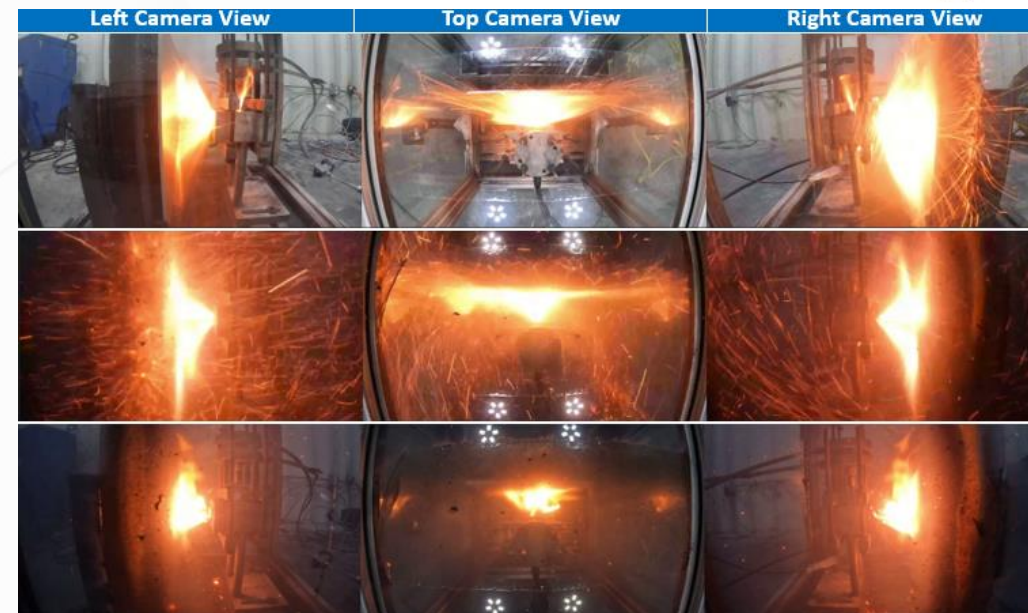
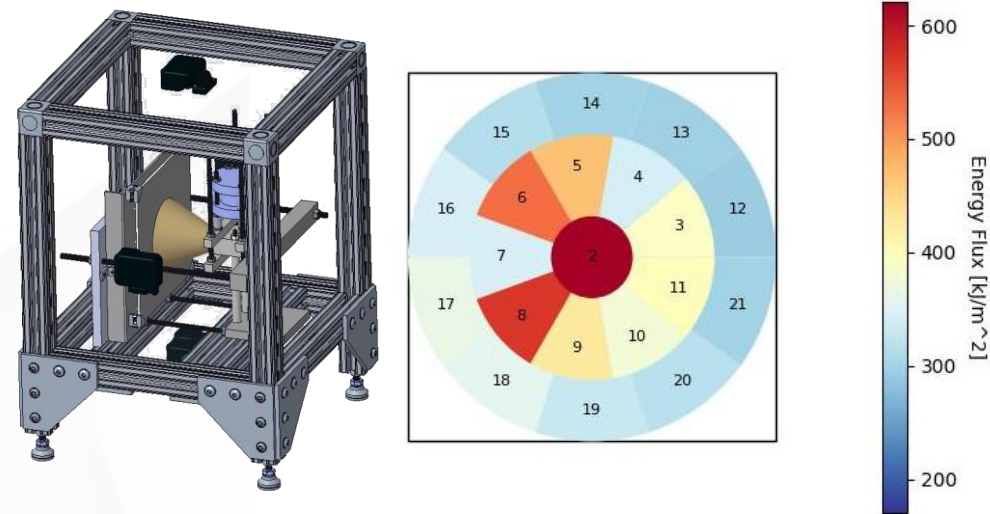
- Characterization of ejecta behavior, including velocity approximation.
- Determination of impingement zone size, shape, and intensity.
- Improved battery safety through understanding of cell behavior.
- Reduced risk by identifying battery enclosure weaknesses.

## Key Features

- 360 view mapping at 240 fps.
- Heat rate (W) and heat flux ( $W\ m^{-2}$ ) analysis.
- 18650, 21700, cylindrical, prismatic, and custom pouch formats.
- Suitable for swap-out of blast plate shielding materials for performance characterization as a function of cell type and trigger method.
- Open cavity testing supports IR camera utilization.

## Impingement Zone Mapping Apparatus Characteristics

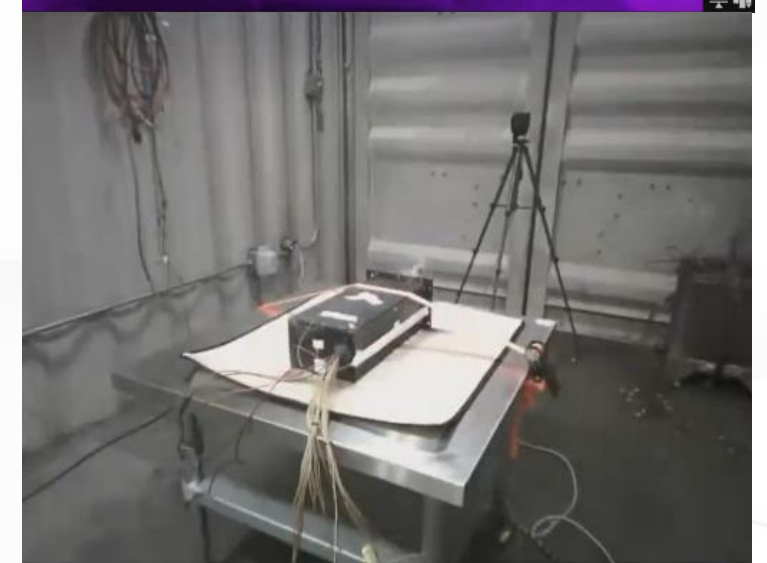
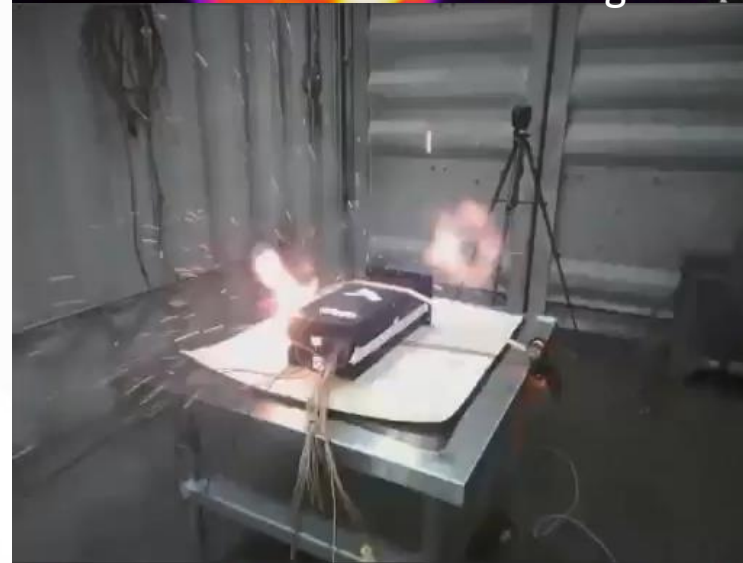
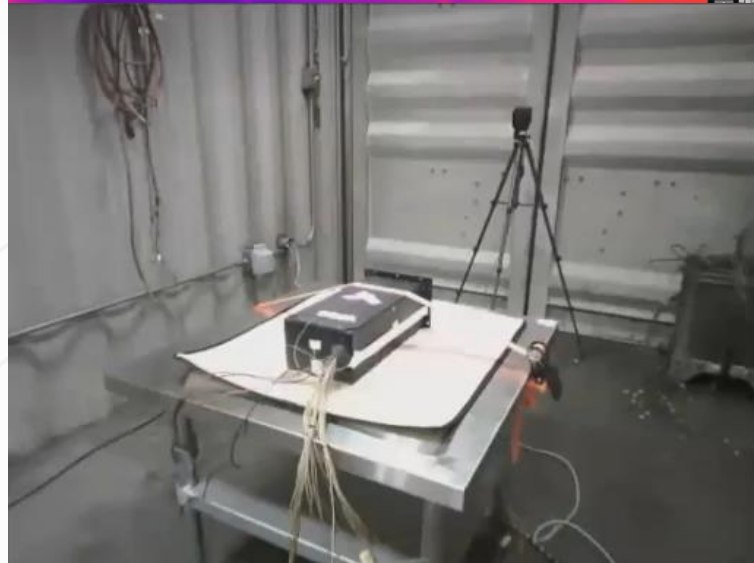
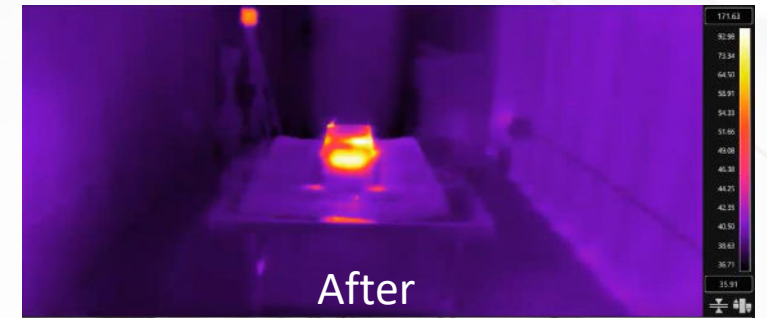
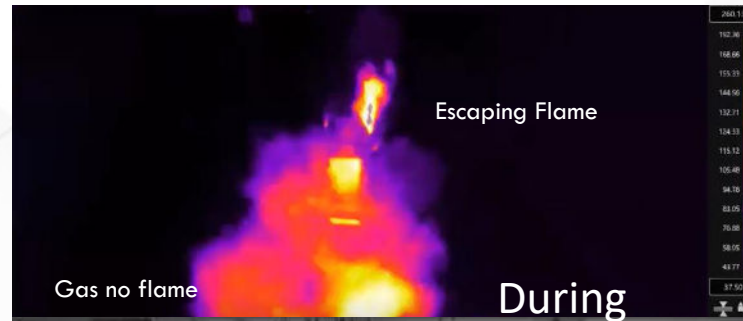
Distance to back-plane (ejecta length)	5mm to 254mm
Back-plane x,y	178mm x 178mm
Max camera frame rate	240 fps
Temperature measurement type	Type K thermocouple
Temperature measurement frequency	90 Hz
Custom post processing algorithm	Python



# Impingement Zone Mapping



# Pack Abuse Testing



# Thermal Runaway Characterization, What's Next?

Thermal runaway is highly variable. Customer datasets are limited to data captured during private testing. **2025 roadmap for testing services will see a re-vamp of how reporting is done by working to automate comparison of customer data to larger available datasets.** The focus will be on increasing the analytics received by the customer for every report.

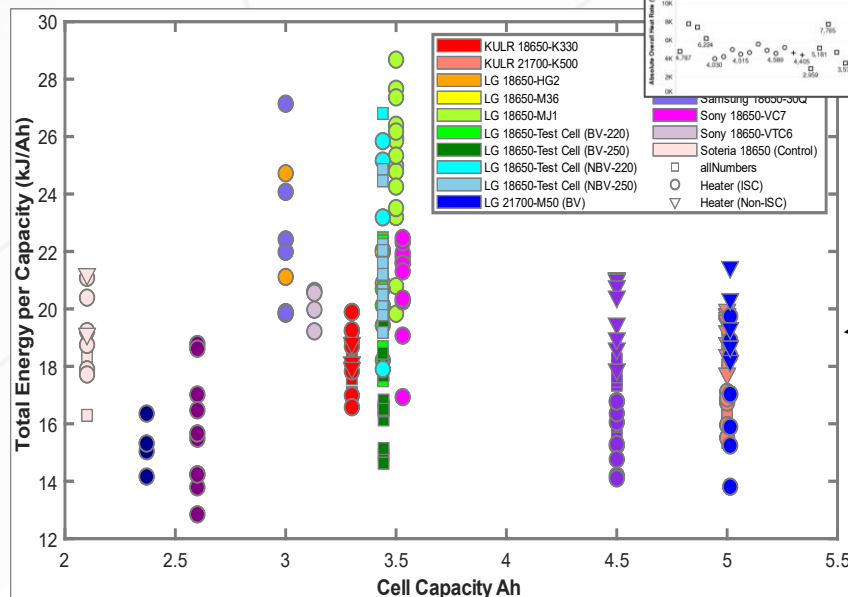
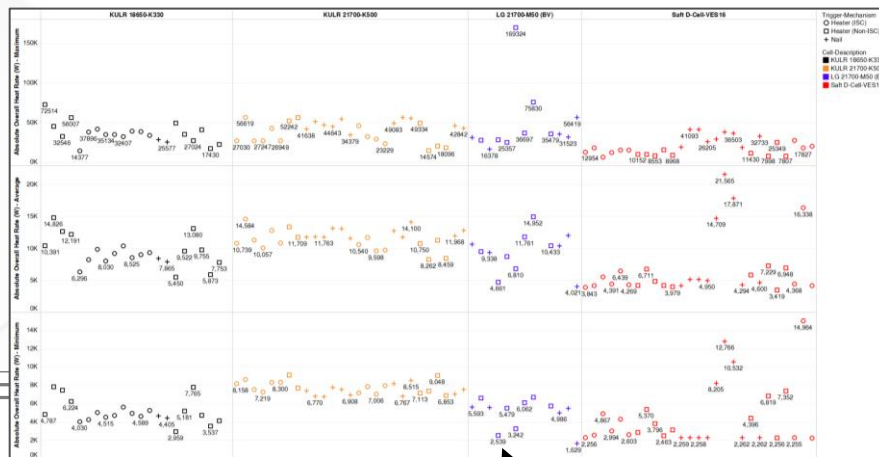
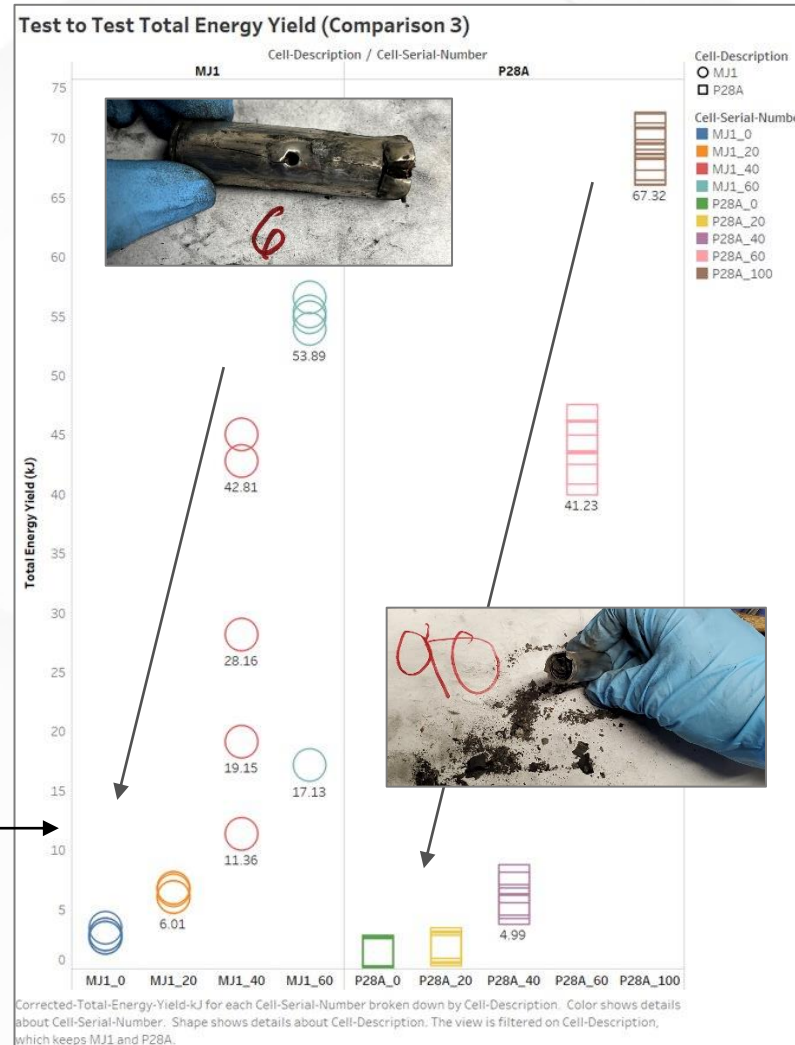


Image Credit: Julia Billman and Donal Finegan, Ph.D. (NREL)

Test to Test Variability in Energy Yield (100% SOC)

Test to Test Variability in Energy Yield (20-100% SOC)



Corrected-Total-Energy-Yield-kJ for each Cell-Serial-Number broken down by Cell-Description. Color shows details about Cell-Serial-Number. Shape shows details about Cell-Description. The view is filtered on Cell-Description, which keeps MJ1 and P28A.

Reference: Walker et. al. "Understanding Thermal Runaway Variability" (2021).

# Cell Screening to JSC EP-WI37A

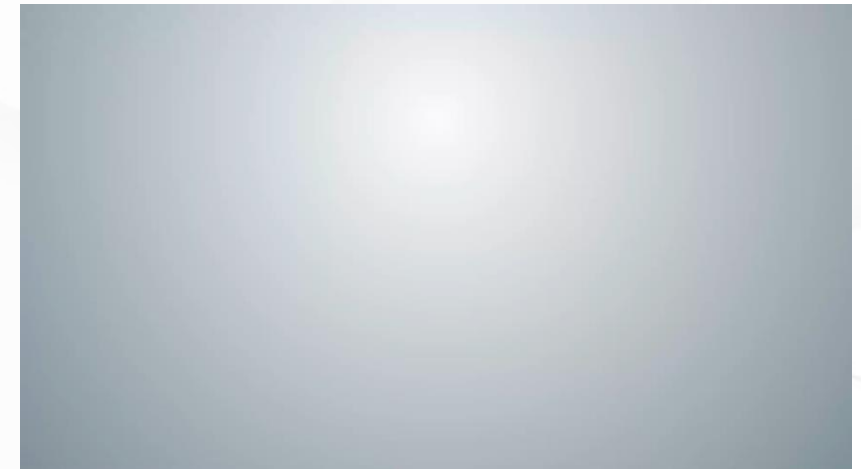
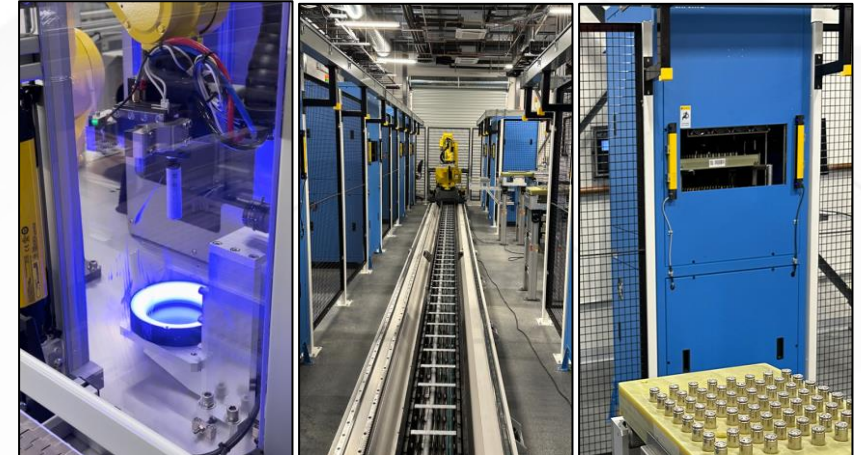
Fully automated approach to quality control screening to the manned spaceflight standard NASA JSC EP-WI-37A which provides checks for cell mass & dimensional consistency, visual defects, and electrical behavior.

## Benefits

- High volume throughput (up to 500K cells per year).
- Ensure only the safest and most reliable cells are used in production batteries.
- Cell level traceability of all measurements.
- Safer and higher reliability battery packs through increased cell quality.

## Key Features

- Compatible with 18650 cells; 21700 coming online Q2 2024.
- Checks for mass and dimensional consistency.
- Visual inspection for physical damage, scratches, dents, and defects.
- Visual inspection for corrosion.
- DCIR measurement and inspection for voltage retention.
- Cell sorting and matching for assembly.





# Battery Production

## Fabrication and Assembly Capabilities

<p><b>Precision Machining</b></p> <ul style="list-style-type: none"> <li>4-Axis CNC capable of regular building materials</li> <li>3-Axis CNC capable of exotic material machining (Yttria, other ceramics, Syntactic foams)</li> <li>Router CNC for organics and light materials</li> </ul>	<p><b>Laser Cutting</b></p> <ul style="list-style-type: none"> <li>CO2 Laser capable of cutting up to 0.5" thick organics and acrylics. Also capable of engraving</li> <li>Fiber Laser capable of cutting nickel and other metals to make battery tabs and components</li> </ul>	<p><b>Clean Room Availability</b></p> <ul style="list-style-type: none"> <li>KULR maintains a clean room for assembly and testing of battery systems</li> <li>900sqft built for ISO 8 certification</li> </ul>
<p><b>3D Printing</b></p> <ul style="list-style-type: none"> <li>Selective laser sintering (SLS) printing capable of nylon 11 and 12, and carbon fiber</li> <li>Regular FDM multi-head printing ability in ABS, PLA, Nylon, and others</li> </ul>	<p><b>Pack/Module Assembly</b></p> <ul style="list-style-type: none"> <li>KULR maintains a prototype assembly lab in addition to the clean room.</li> <li>All required tools including high voltage tooling, plastic manipulation tools and a full electrical bench.</li> </ul>	<p><b>Check-out &amp; Acceptance</b></p> <ul style="list-style-type: none"> <li>Between the clean room and prototype room there are many high-power power supplies, load banks, battery testers and even Arbin Cyclers to perform testing at the cell and pack level.</li> </ul>
<p><b>Standard Machine Shop</b></p> <ul style="list-style-type: none"> <li>Standard hand and power tools</li> <li>Manual Mill</li> <li>Saws, grinders, sanders and polishers</li> </ul>	<p><b>Resistance Tab Welding</b></p> <ul style="list-style-type: none"> <li>Resistance tab welding for battery pack assemblies in-house.</li> <li>High current welding with waveform data monitoring</li> </ul>	<p><b>IS9000/AS9100 QMS and Standards</b></p> <ul style="list-style-type: none"> <li>KULR is certifying its Webster location as an AS9100 certified engineering and manufacturing facility to further serve the aerospace community</li> </ul>



Haas® CNC Mill



Formlabs Fuse1 SLS 3D Printer



Amada Weld Tech Resistance Tab Welder



ISO 9001 Certification

# Battery Storage and Transportation

## SafeX Safe Storage Solutions

### SafeCASE Model G

- Total thermal runaway propagation containment.
- Up to 2.5 kWh payloads



### SafeCASE Model R

- Total thermal runaway propagation containment.
- Up to 2.5 kWh **3.2 kWh** payloads



### SafeCASE Model E

- Total thermal runaway propagation containment.
- Up to 2.5 kWh payloads



### SafeCASE Model 3

- Total thermal runaway propagation containment.
- Up to 2.5 kWh payloads



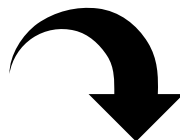
### SafeCASE Model N

- Total thermal runaway propagation containment.
- Up to 2.5 kWh payloads

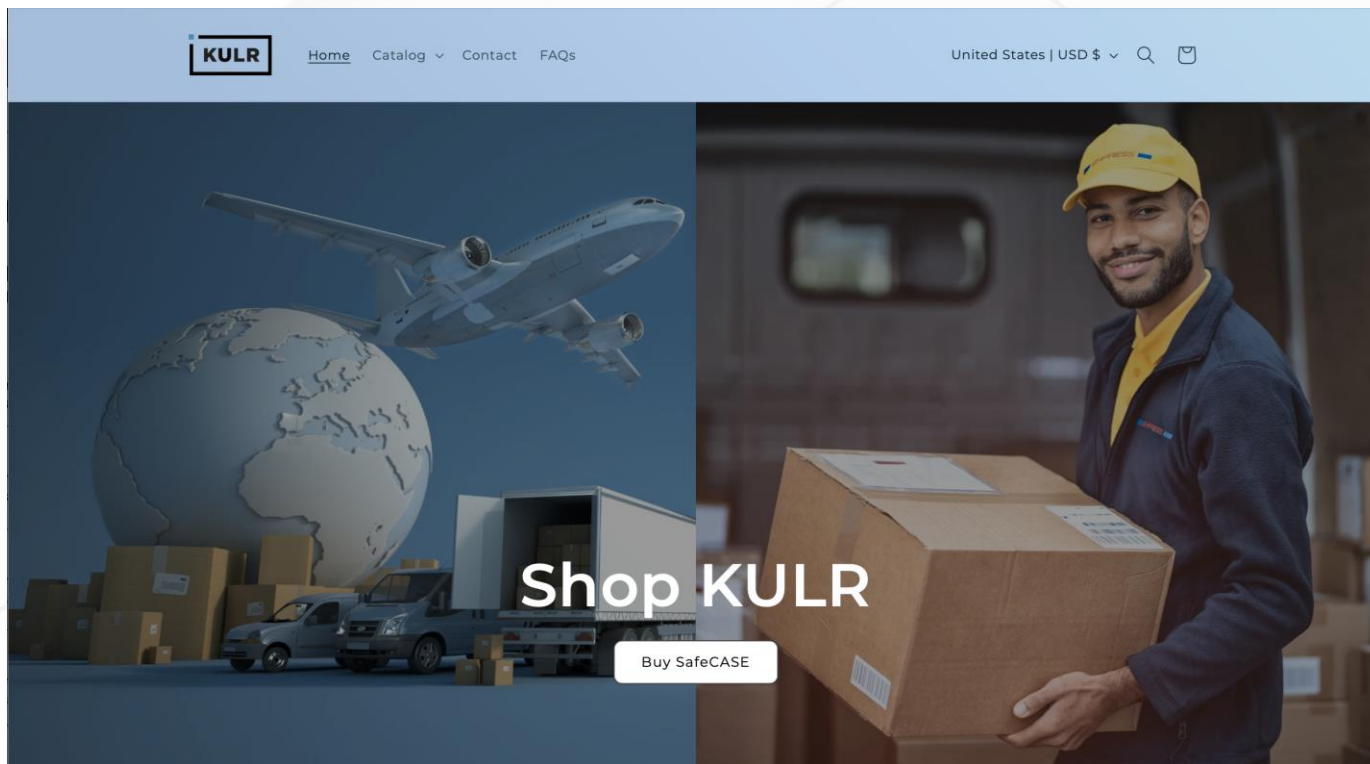


### SafeSLEEVE

- Total thermal runaway propagation containment.
- Up to 300 Wh payloads



[Visit the KULR Marketplace today!](#)



# SafeCASE and SafeSLEEVE

## Safe Transportation and Storage of Lithium-ion Batteries

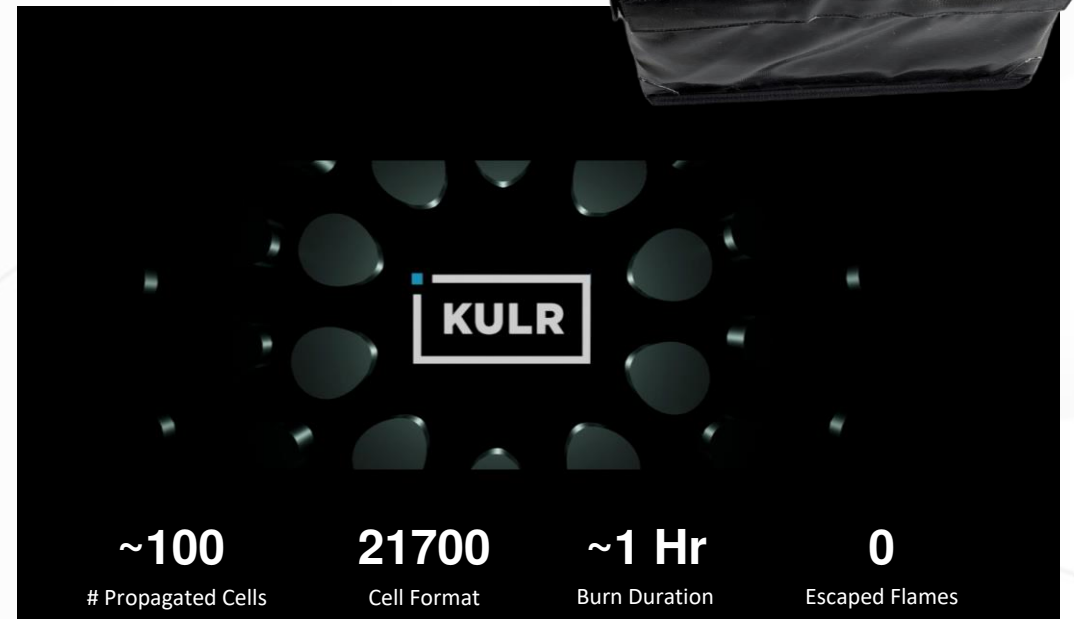
SafeCASE and SafeSLEEVE are the first product line to offer lithium-ion battery shipping coverage up to 2.5 kWh nationwide. Product lines come in customizable formats and sizes and rely on passively propagation resistant (PPR) design features to ensure maximum safety is achieved. Used by NASA in crewed missions since 2019 for laptop batteries.

### Benefits

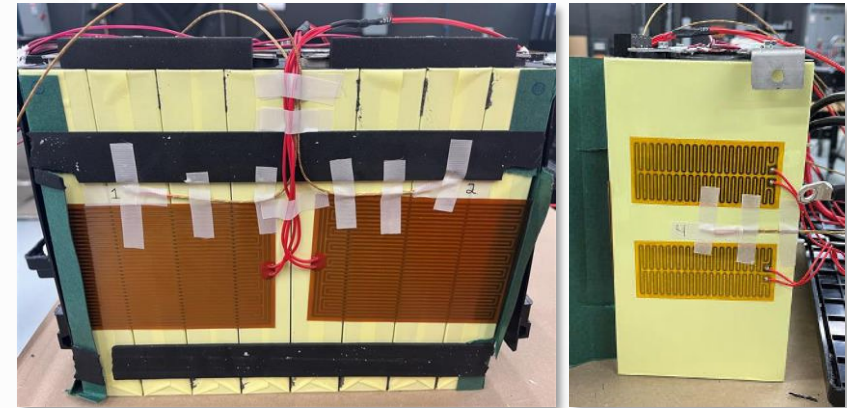
- Nationwide shipping
- Product has been rigorously tested with various batteries constructed from multiple cell formats (including 18650, 21700, and prismatic) to ensure superior safety
- Testing campaigns have included single cells, e-bike batteries, power tool batteries, and large format industrial batteries.
- DOT-permitted customization for secure and personalized transportation.
- Provides certificates of recycling (COR) for precise ESG reporting.
- Swift removal and recycling ensure brand risk management and safety, regardless of battery condition.

### Key Features

- Protection with combination of integrated KULR blast plates, patented thermal runaway shielding, and robust thermal liners.
- Total thermal runaway containment up to 2.5 kWh (SafeCASE) or 300 Wh (SafeSLEEVE)
- Light weight soft goods-based design.
- Re-usable



# SafeCASE Model R Experiment





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