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Qualification of COTS Battery Modules Designed for Spacecraft Electrical Power Systems

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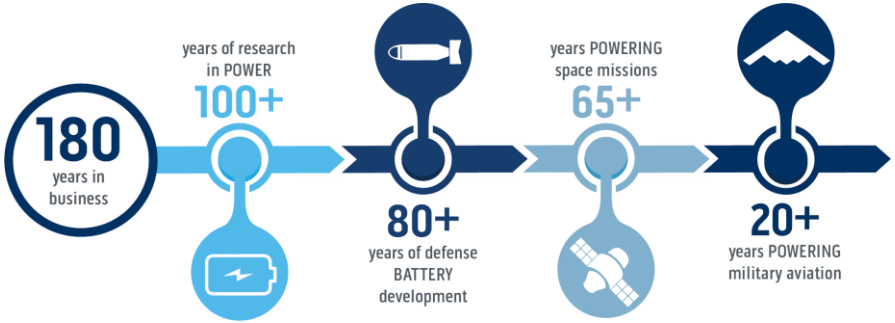
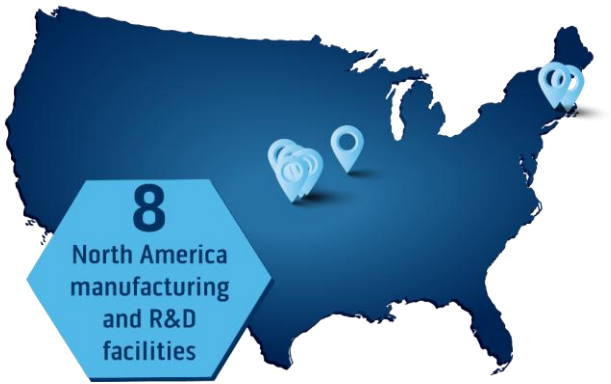
EaglePicher at a Glance



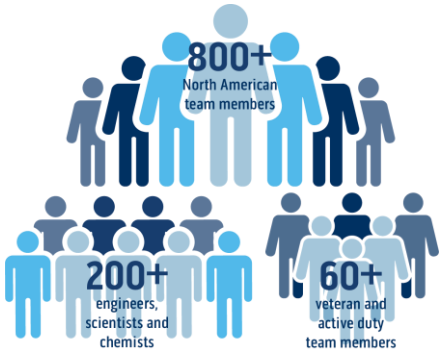


Expertise in More than



Battery Chemistries





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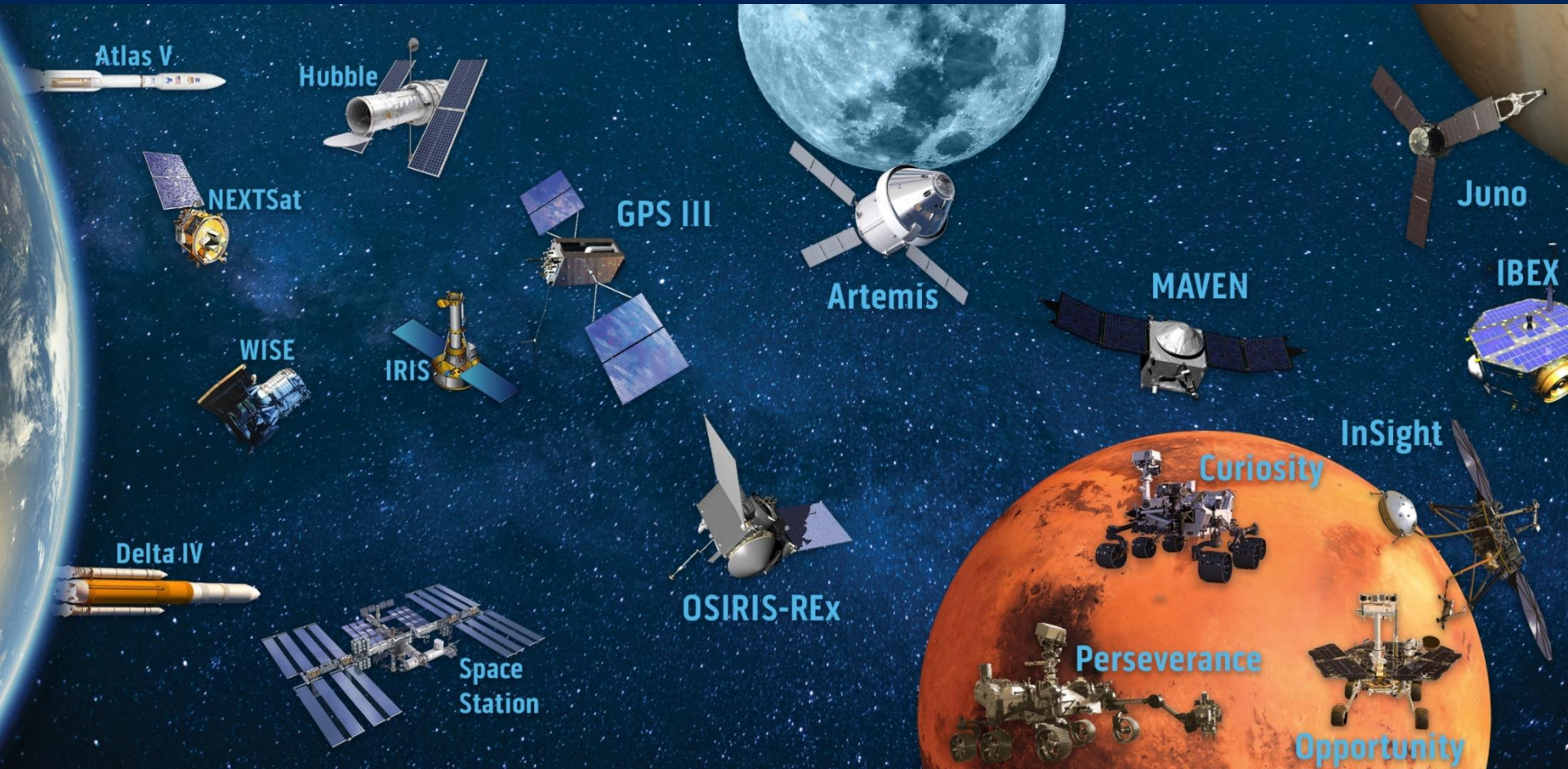
EaglePicher in Space

Space Applications Heritage



Custom Cells and Batteries







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10p8s Battery Design

COTS Battery Overview

- Orion crew module battery design heritage adapted for commercial applications
  - Unmanned
- Cell agnostic
  - Right cell for the right application
  - Power cells typically better suited for high cyclic environment
  - Energy cell typically better suited for low cycle count with high energy requirement
- Supports a range of space missions
  - LEO, GEO, HIEO, MEO
- Can be arranged in parallel or series in EPS to increase capacity or voltage
- Flight units delivered to two customers
- First launch expected Q2 2023

Part Number	Capacity (C)	Configuration	Cell Type
SAR-10241	18.8Ah	8P8S	Power
SAR-10235	23.5Ah	8P8S	Energy
SAR-10243	23.5Ah	10P8S	Power
SAR-10237	29.4Ah	10P8S	Energy
SAR-10245	28.2Ah	12P8S	Power
SAR-10239	35.2Ah	12P8S	Energy



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10p8s Qualification Battery Performance specification

+ 10p8s battery baselined on several programs
+ Qualification testing performed on this configuration

Item	Requirement
Battery capacity @ 20°C	29.4 Ah
Battery energy @ 20°C	845 Wh
Battery nominal voltage @20°C	28V
Maximum continuous discharge current	60 A
Maximum pulse discharge current	80 A, 2s
Battery operating temperature (charging)	0°C to 45°C
Battery operating temperature (discharging)	-10°C to 45°C

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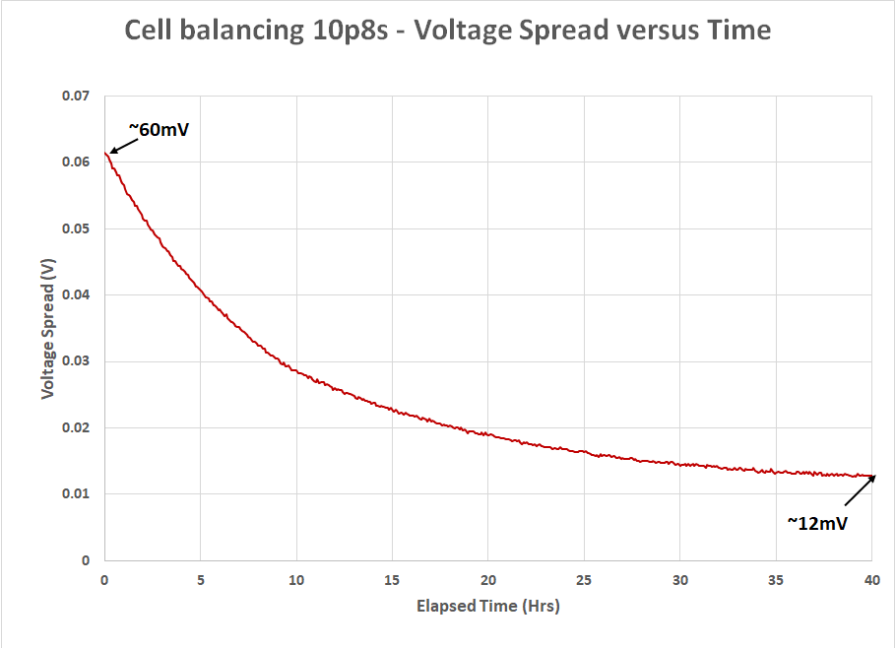
Cell Balancing

- Analog Balancing
- Proportional cell loading based on cell voltage
  - Balancing current up to 600mA
- Autonomous and or externally commanded balancing
- Balancing tested after battery full charge



Cell to cell voltage spread down to ~12mV in 40 hours

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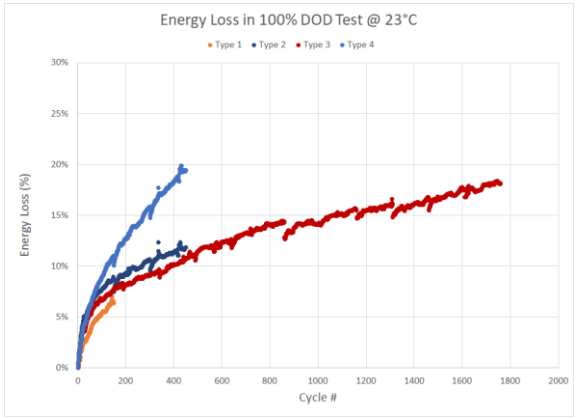
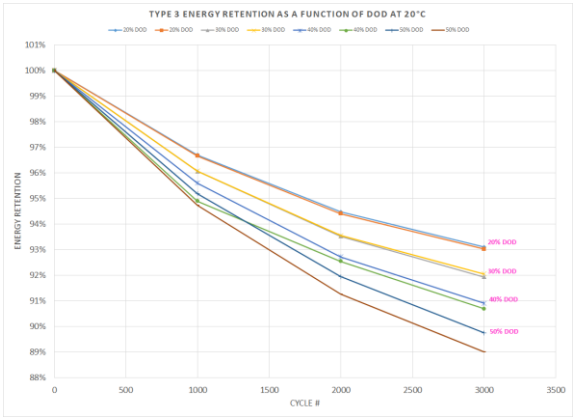
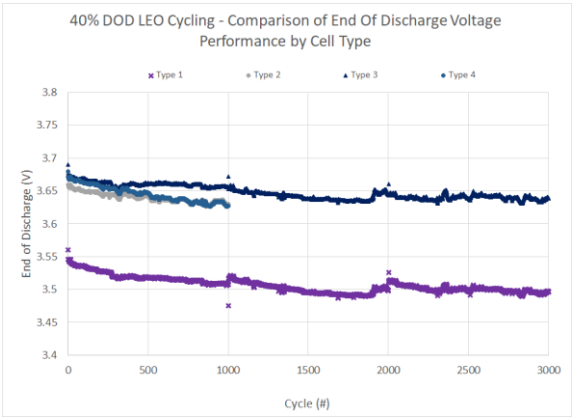
Cell Selection

- EPT has implemented a cell evaluation program
  - Initial characterization to evaluate impact of rates and temperatures on performance
  - Life tests consisting of accelerated and real time (LEO) cycling tests and storage life tests
  - 10 cell types evaluated to date
  - 4 currently in test, 3 more planned to start before YE 2023
- Enables cell selection that best fit mission requirements
- Insurance against eventuality of cell obsolescence







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10p8s Battery Qualification

Qualification Test Suite

- Initial inspection
  - Physical examination
  - Ground bonding
  - Isolation
- Capacity
- QT Sine and Random Vibration
- QT shock testing
- TVAC cycles
- Thermal cycles
- EMI/EMC
- Pulse discharge testing

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Initial inspection

- Physical examination Visual inspection for workmanship, cleanliness, and FOD
  - Battery measured and weighed

Battery length	10.2 in
Battery width	6.8 in
Battery Height	3.5 in
Battery weight	5.6 kgs

- Battery ground bonding and electrical insulation meets specification



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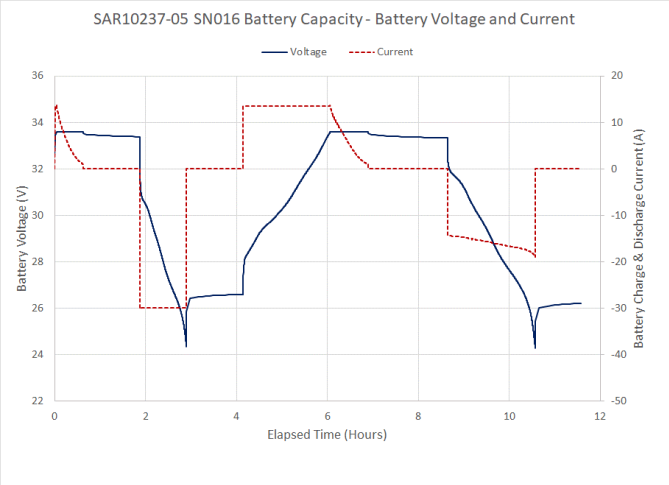
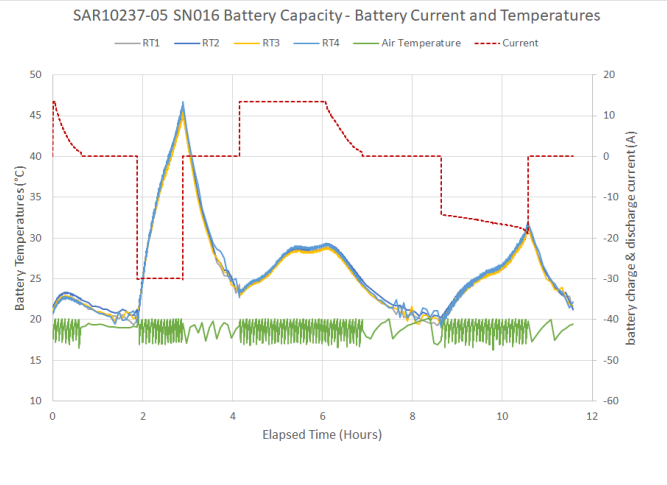
Initial capacity

- Battery capacity measured at 30A and 460W (~16A) at 20°C following CC/CV charge to 4.2V and until first cell hits 3V
- Meets specification requirements for capacity (29.4Ah) and energy (845Wh)

Initial Capacity	Discharge Capacity	Discharge Energy	Average Discharge Voltage	Average Discharge Current
30A discharge	30.5 Ah	856.2 Ah	28.06 V	30 A
460W discharge	30.8 Ah	887.4 Ah	28.82 V	16 A





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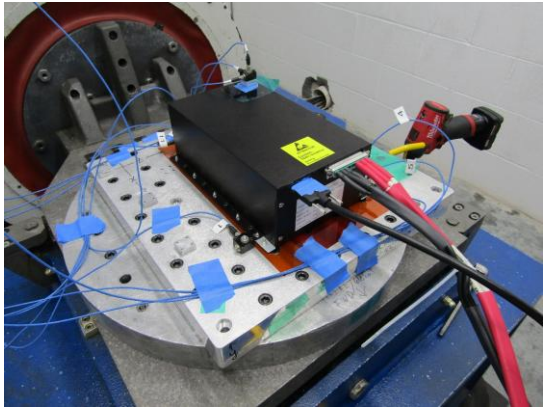
Sine and Random Vibration

- Low level modal sine surveys (5-2000 Hz) performed before and after every run
- Random levels same as NASA GEVS (Random)
- Battery discharged at 5A during vibration
  - No fluctuations in battery voltage, cell voltage, or battery current observed during tests
- Resonant frequencies well above 300Hz
- Frequency shifts <10% for all axes
- No impact on battery capacity and energy

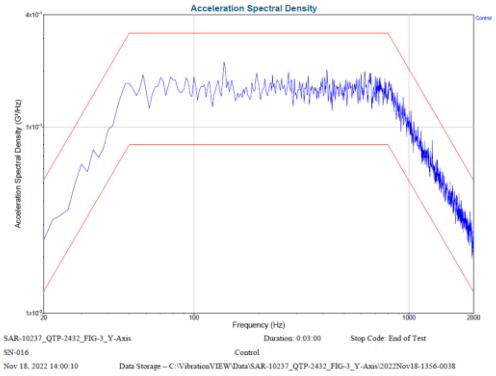


Sine

Frequency (Hz)	Qualification (g)
5.00	1.00
22.00	20.00
100.00	20.00

Random

Frequency (Hz)	PSD (g^2/Hz)
	Qualification
20	0.026
50	0.16
800	0.16
2000	0.026
Overall	14.1Grms, 180 seconds



Resonant Frequencies

	X-axis (Longitudinal)			Y-axis (Normal)			Z-axis (Lateral)		
	Pre-sine	Post-sine Pre-random	Post-random	Pre-sine	Post-sine Pre-random	Post-random	Pre-sine	Post-sine Pre-random	Post-random
Accelerometer 3	361.2 Hz	364.5 Hz	385.8 Hz	766.5 Hz	785.1 Hz	755.1 Hz	379.0 Hz	380.1 Hz	380.1 Hz
Accelerometer 4	363.4 Hz	365.6 Hz	363.4 Hz	917.5 Hz	925.8 Hz	887.7 Hz	353.7 Hz	351.6 Hz	332.1 Hz
Accelerometer 5	599.5 Hz	594.1 Hz	580.0 Hz	614.0 Hz	614.0 Hz	606.7 Hz	349.0 Hz	347.4 Hz	327.2 Hz

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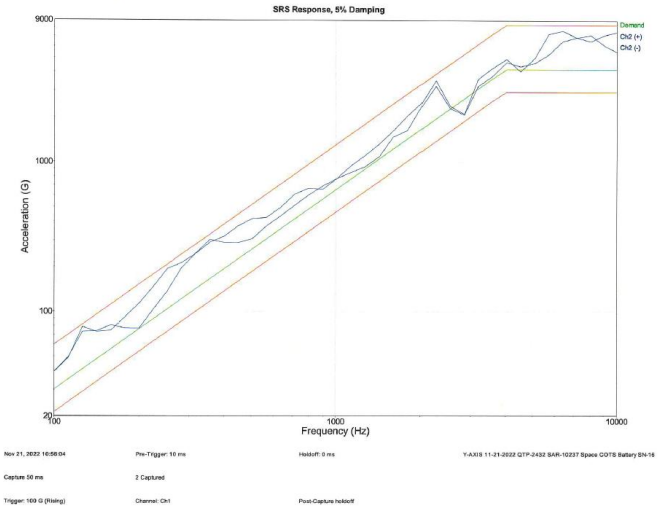
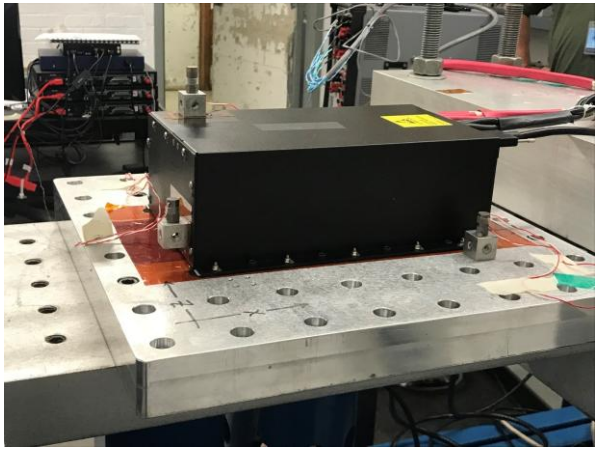
Shock testing

- Battery tested to 2000g
- Battery discharged at 5A during vibration
  - No fluctuations in battery voltage, cell voltage, or battery current observed during tests





Shock levels

Frequency (Hz)	Qualification (g)
100.00	60.00
1000.00	2000.00
10000.00	2000.00

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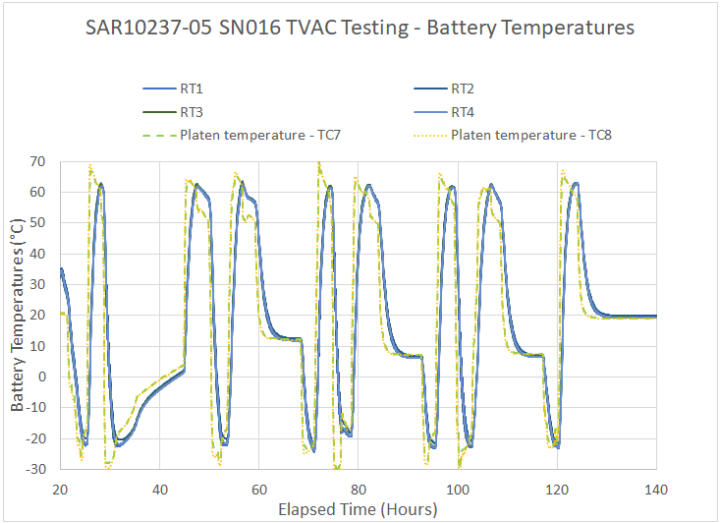
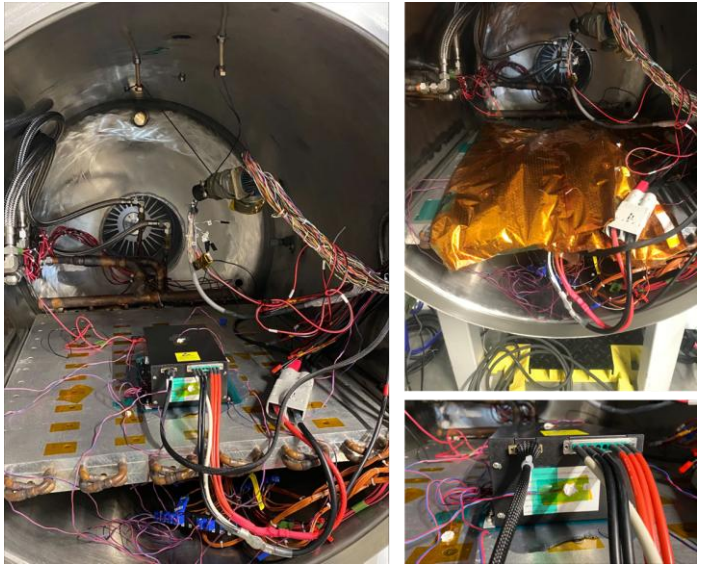
TVAC testing

- 8 cycles between -20°C and 60°C with minimum 1- hour soaks at plateaus
- Battery capacity measured at 20°C in vacuum before and after cycling
- No impact of operating in vacuum at temperature extremes





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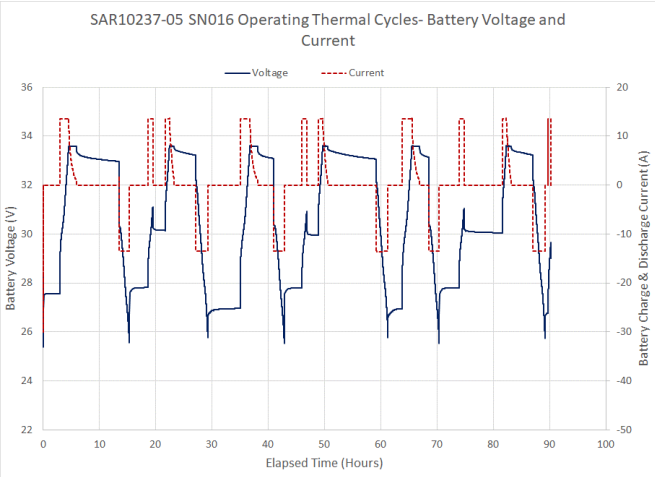
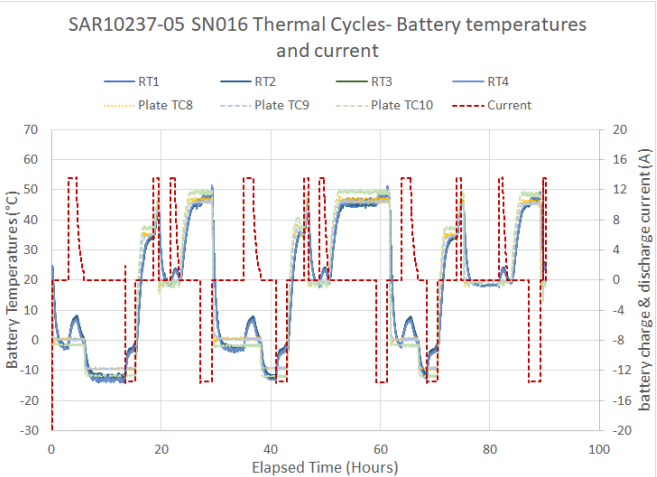
Operating Thermal Cycles (Air)

- 3 cycles performed between -10°C and 45°C with minimum 1-hour soaks prior to discharge
  - 3 full discharges at -10°C
  - 3 full discharges at 45°C
- Battery charging allowed during temperature transition steps
- Demonstrates ability of battery to operate at temperature extremes





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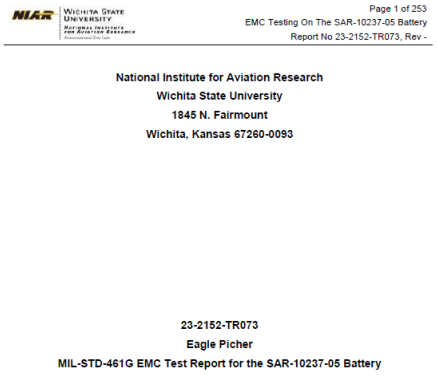
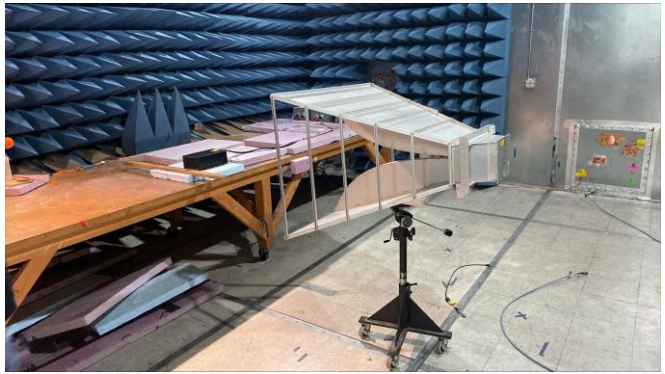
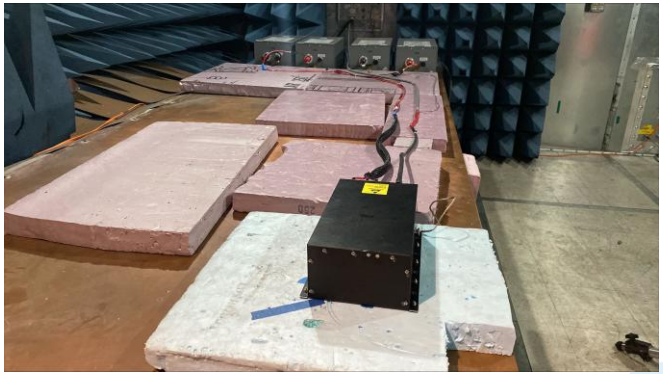
EMI/EMC

- The battery was tested per MIL-STD 461G
- RE102, Radiated Emissions
  - No emissions over limit
- CE102, Conducted Emissions
  - No emissions over limit
- CS118 Electro-Static Discharge
  - No susceptibility observed
- The battery was charged and discharged after testing with no observed issue







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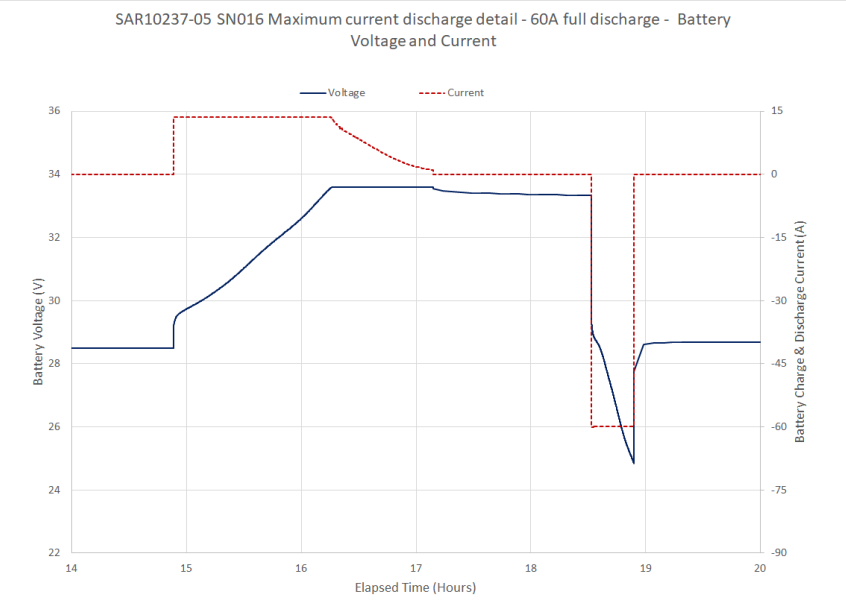
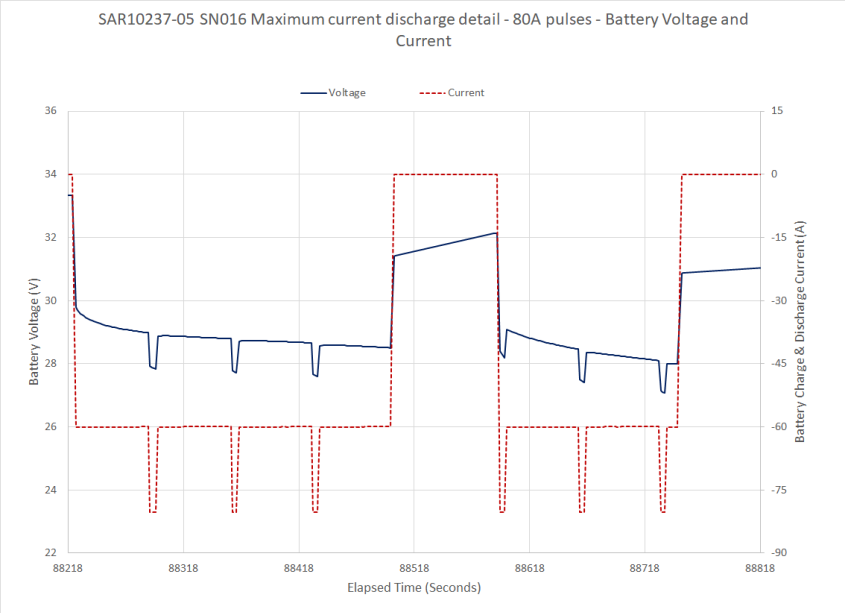
Maximum Continuous and Pulse Discharge Capability

- The battery can be discharged continuously at 60A
- 2s 80A pulse on top of 60A continuous capability demonstrated





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Conclusion/Summary

- EaglePicher has an extensive heritage in space applications
  - Over 3 Billion Cell-hours operating in space, Over 14 years operational on Mars
  - Deep knowledge base on how to design for long endurance, high reliability missions
- EPT developed COTS battery using commercial 18650 format cells has ben qualified
  - Low-cost solution
  - Can be stocked for quick delivery
  - Baselined on several flight programs
- Engineering and Flight units delivered to two different customers
- First launch Q3 2023
- UN/DOT 38.3 completion Q3 2023

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Thank You!

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