



Robust, Zero-Volt-Capable, High-Power Lithium-Ion Batteries for Military Platforms

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Outline

- Introduction to CAMX Power
- CELX-RC[®] Li-ion Technology
- CELX-RC Battery Examples
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Introduction to CAMX Power

CAMX Power's vertically integrated development facility spans the Li-ion value chain.



CAMX Power brings Li-ion battery technologies to market with a record of transitioning innovations to commercial organizations.

CAM-7[®] cathode material platform

- Non-exclusive to BASF and Johnson Matthey (2016)

GEMX[®] cathode material platform

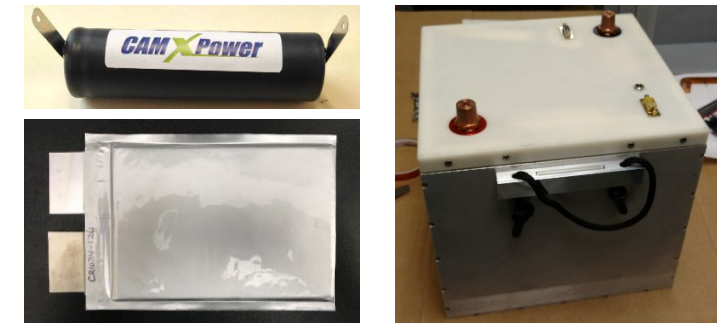
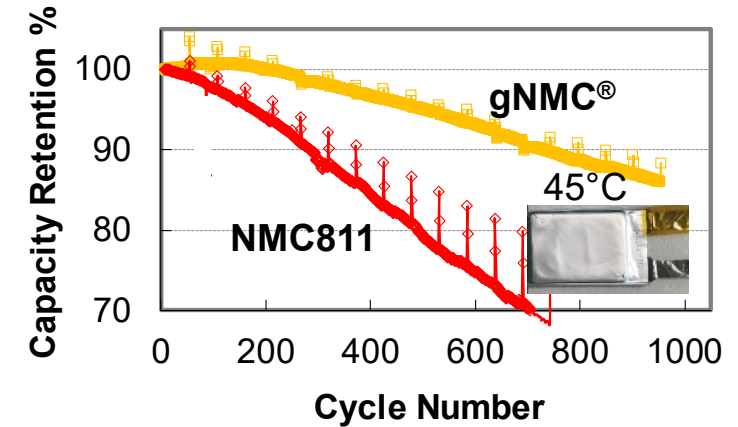
- Non-exclusive license to **EcoPro (2024), Umicore (2023), L&F Co. (2023), LG Energy Solution (2022), Samsung (2020), and Johnson Matthey (2018; sold to EV Metals 2022)**
- Additional license discussions ongoing

Rugged and safe Li-ion battery – CELX-RC[®]

- Limited production and/or licensing for DOD applications

Technologies for detection of internal short circuits in Li-ion batteries

- Cell screening for production QC (screened > 40,000 18650 cells for US Navy and NASA, and sold screening units to NASA)
- In-pack short detection (being adapted for Navy UUVs)



Time for detecting 125kΩ internal short	Std OCV Monitoring	CAMX Technology
	14 days	< 2 hours

CELX-RC[®] Li-ion Technology

CAMX Power has developed CELX-RC[®] Li-ion cell chemistry for specialized applications that require fast charge and discharge capability, low temperature performance, and long life.

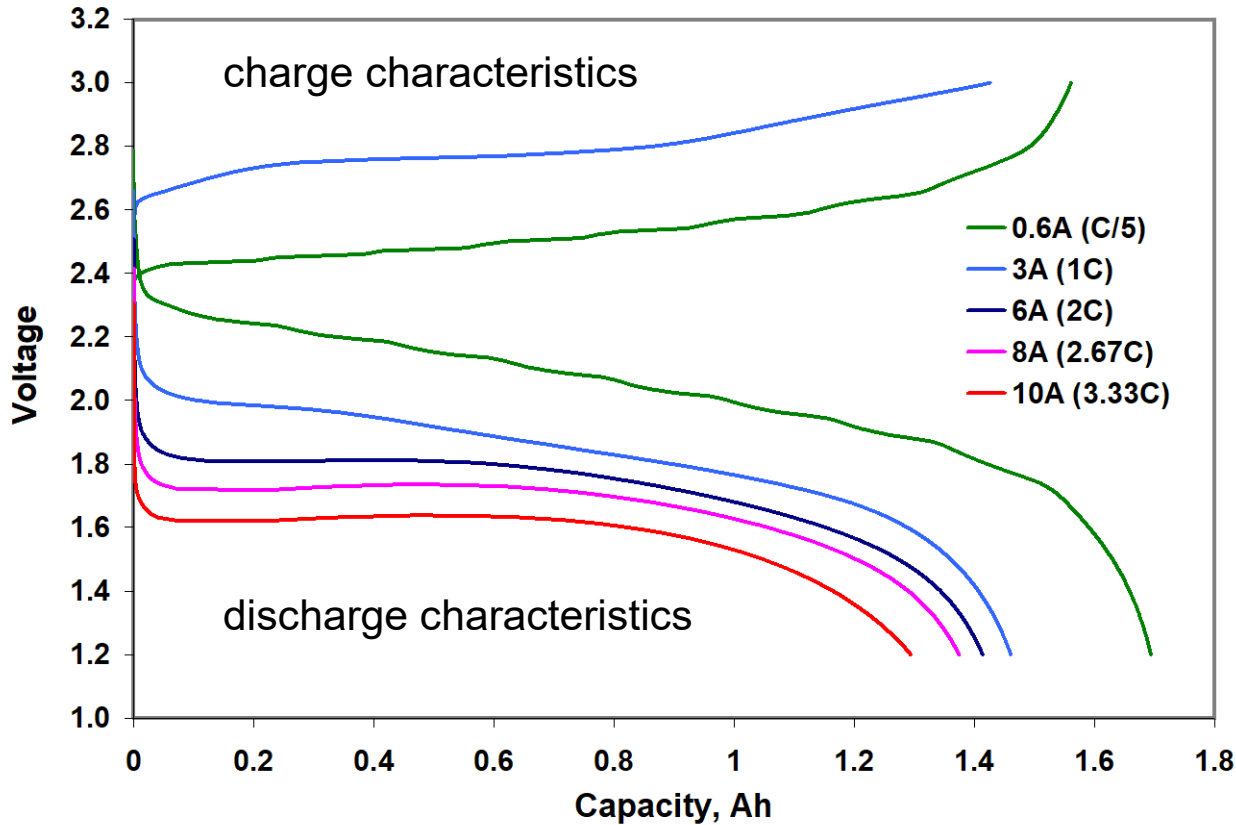
CELX-RC cell chemistry: GEMX high-Nickel cathode material opposite LTO and engineered electrolyte.

Cell format: laminate pouch cells of up to 10 Ah size and 18650 cylindrical cells

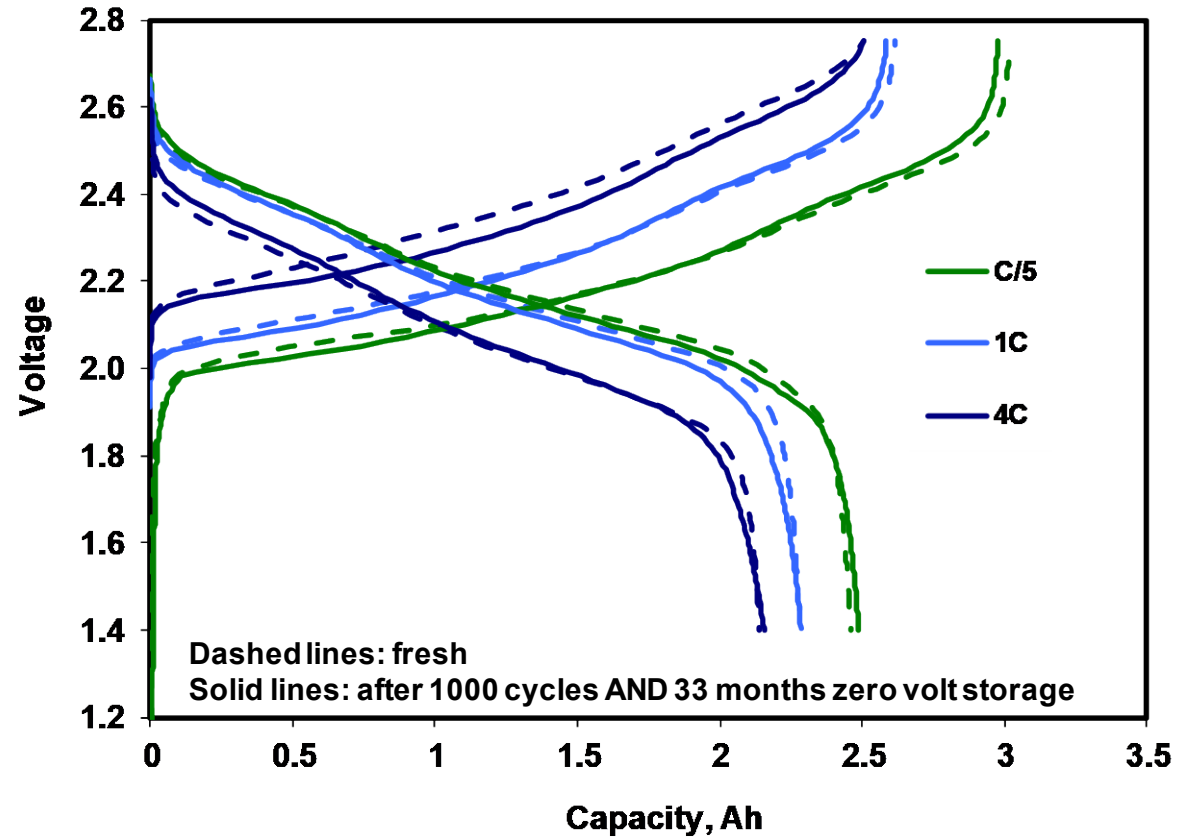
Metric	CELX-RC (GEMX/LTO)	Conventional Li-ion
Cycle and Calendar Life	> 10,000 cycles	ca. 1,000 cycles
Fast Charge	< 10 minutes	> 30 minutes
High Power Discharge	comparable	comparable
Low-Temperature Performance	Charge & discharge	discharge only
Zero Volt Storage/Transportation	possible for years	not possible
Extreme Abuse Tolerance	safe field deployment	not possible
Overcharge Stability without Electronics	robust protection	not possible
Minimal or Optional BMS	radiation tolerant	not possible

CELX-RC cells can operate at extremely low temperature, including ability to be charged quickly, have excellent cycle life, and can be stored at 0V for indefinite time without performance loss.

3 Ah CELX-RC Pouch Cell Charged and Discharged at -50 °C (-58 °F).

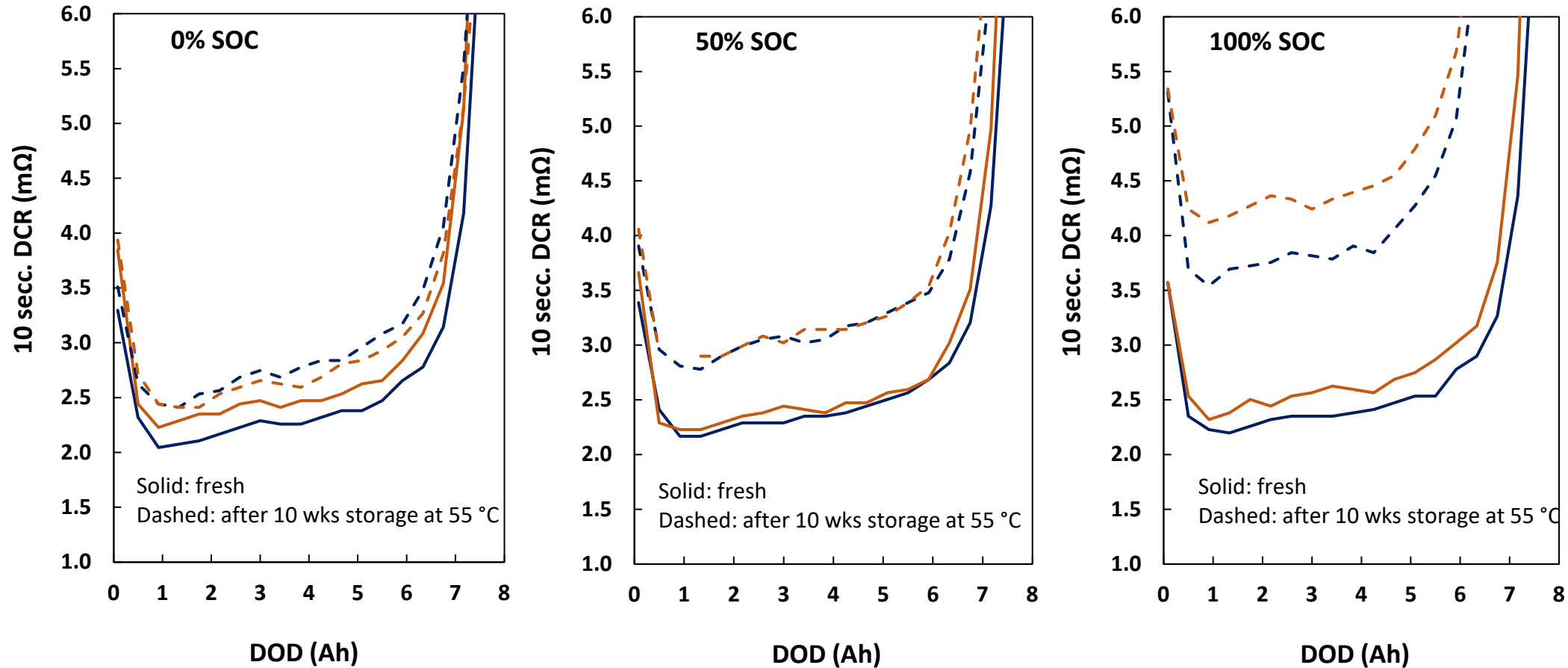


2.5 Ah CELX-RC Pouch Cell Stored at 0V for ~ 3 years & 1000 cycles



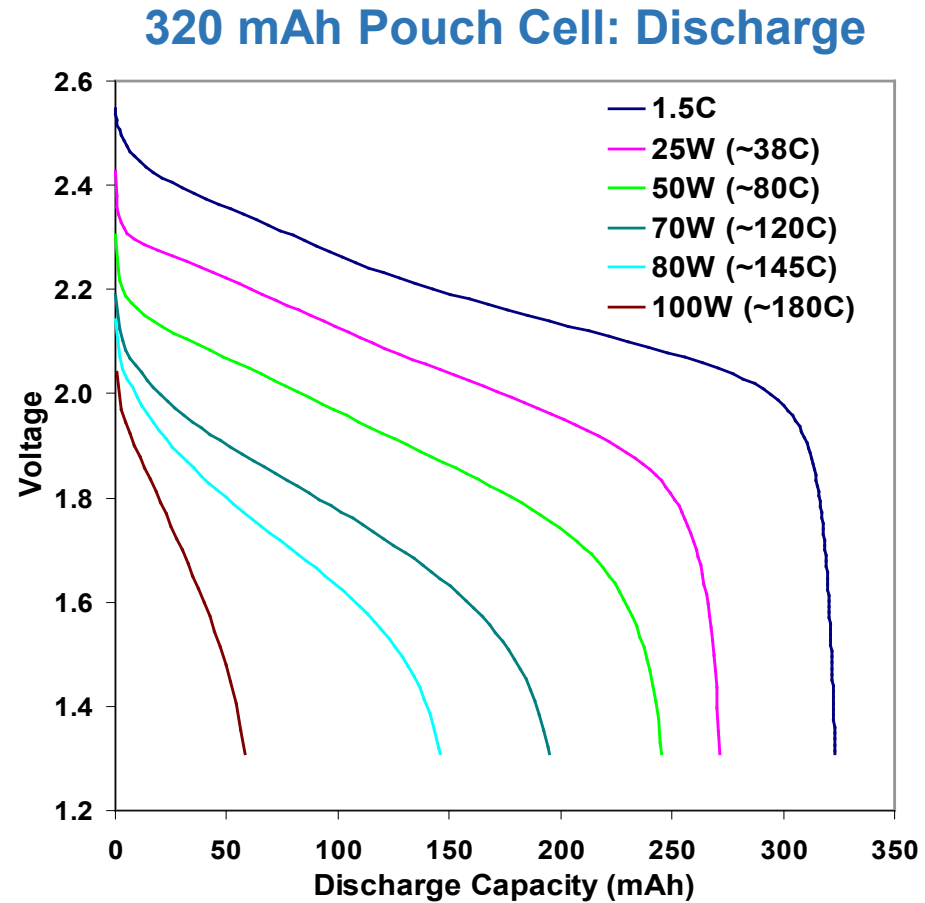
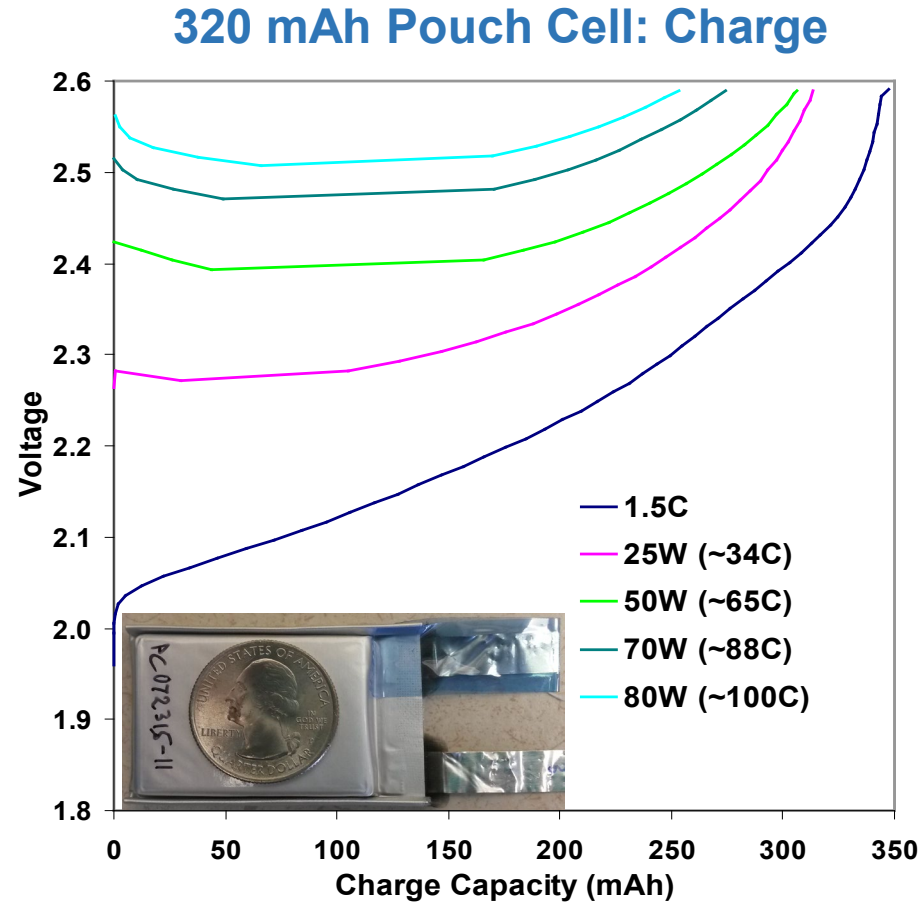
Cells discharged to 0V (0% SOC) and stored at 55 °C for 10 weeks show negligible change in impedance.

8 Ah pouch cells stored at different SOC for 10 weeks at 55 °C and characterized at RT



Solid: Fresh, Dashed: – Stored 10 weeks, Two cells each

CELX-RC cells can achieve ultracapacitor-level performance, supporting continuous 6 kW/kg charge and discharge, in a low electrode loading high power design.



320 mAh, 0.5 mAh/cm², 13.15g, 48mmx30mmx5mm, 52 Wh/kg cell: 2.59V-1.31V unclamped

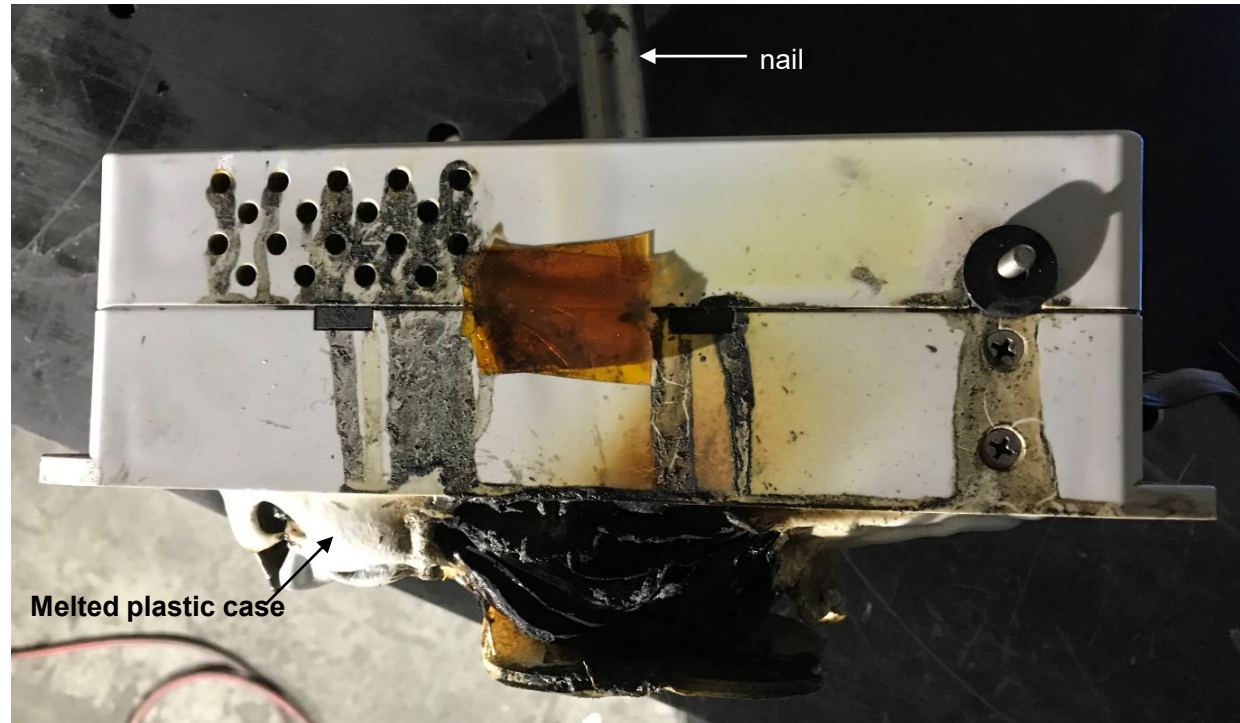
CELX-RC cells have excellent abuse tolerance: pouch cell continued to function after extreme mechanical abuse. CELX-RC module only reached ~ 300°C under the most aggressive abuse conditions.

Mechanical Abuse: 5Ah Cell



Extreme mechanical abuse: cell was penetrated by a nail five times; hammered with a mallet, corner cut with shears. Cell was able to cycle after abuse.

200 Wh Module: 2 cm diameter Nail Penetration



8.5 Ah 11S module charged to 28.5 V nail penetration:

- Shorted with temperature reaching ~300°C; No thermal runaway
- Significant smoke and electrolyte venting; No flames or sparks
- SAE J2464 hazard severity level ≤ 4

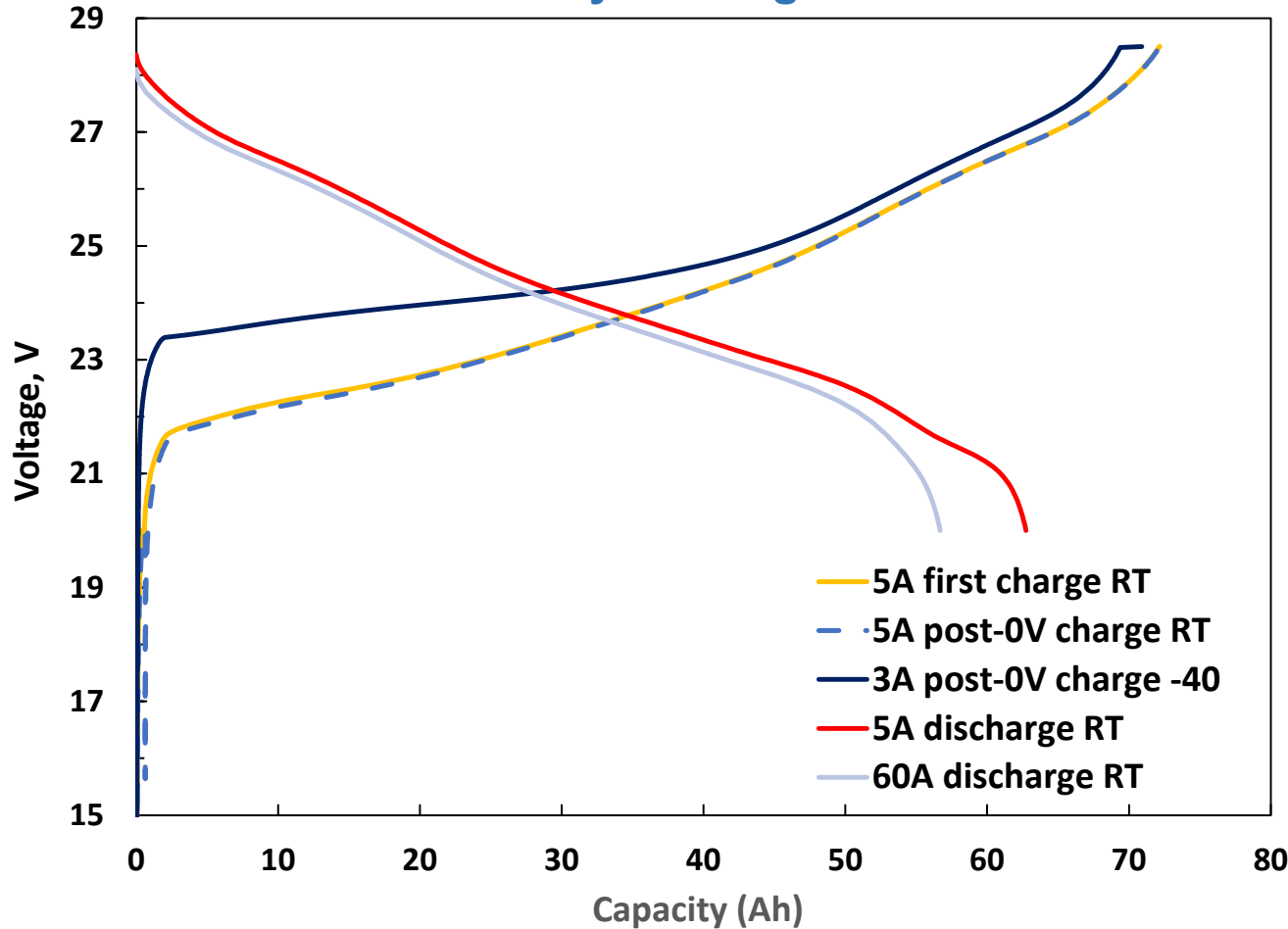
CELX-RC technology can address important military battery concerns and applications.

- Logistically robust batteries (safe, no maintenance in zero-volt condition, fast charging capability)
- Auxiliary and backup batteries (long storage life, reserve capability)
- Replacements for legacy Nickel-Cadmium and Lead-Acid batteries
- Power conditioning and load-leveling batteries
- Extreme low-temperature batteries
- Satellite/space batteries (long life and zero-volt capability provides dead bus event tolerance)
- Radiation-hard batteries (can function without electronic management)
- DEW batteries
- Structurally integrated batteries

0V-Capable 6T Battery Prototype

CELX-RC technology has been demonstrated in a 28V/57Ah 6T prototype with 0V discharge capability for safe, maintenance-free logistical management.

0V discharge returns battery to as-made condition: fully rechargeable at -40 °C



6T Prototype

Construction: 10 Ah pouch cells in 6 parallel strings of 11-series-cell stacks

Weight: 26 kg

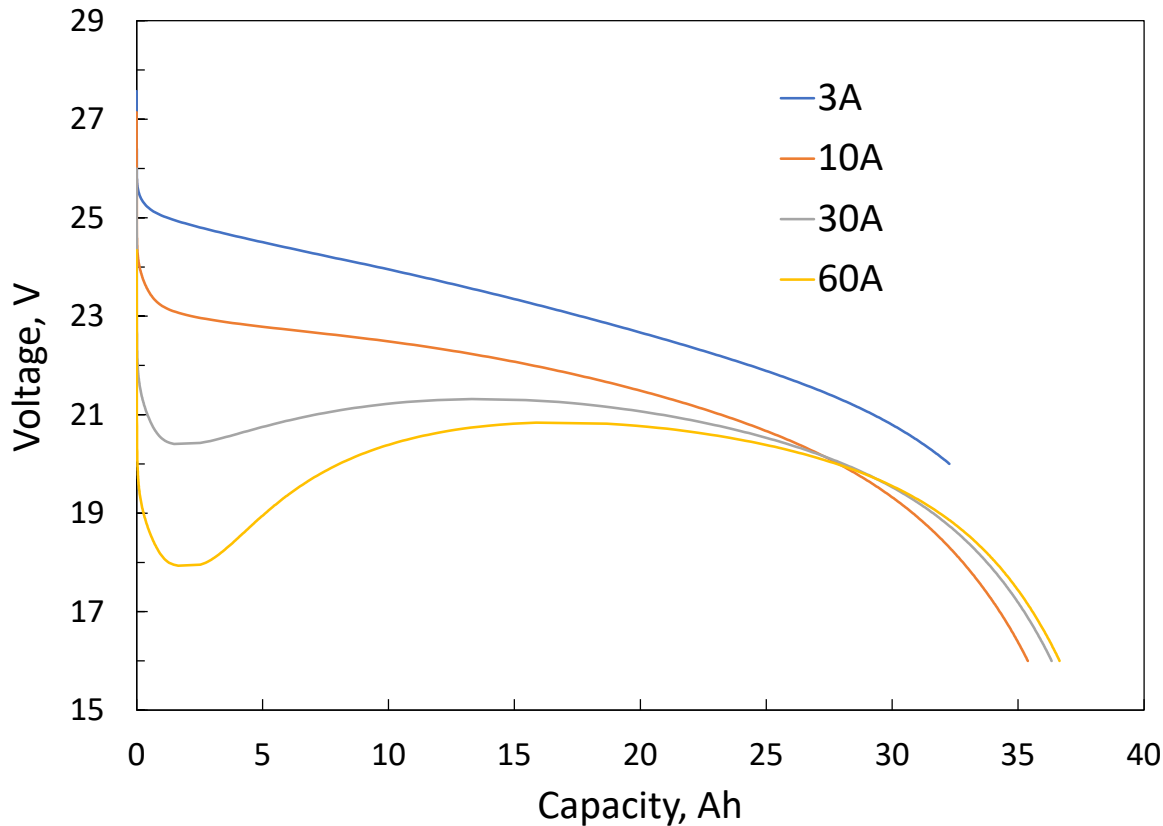
Capacity: 57 Ah (1C rate)

Energy: 1,520 Wh (58.5 Wh/kg)

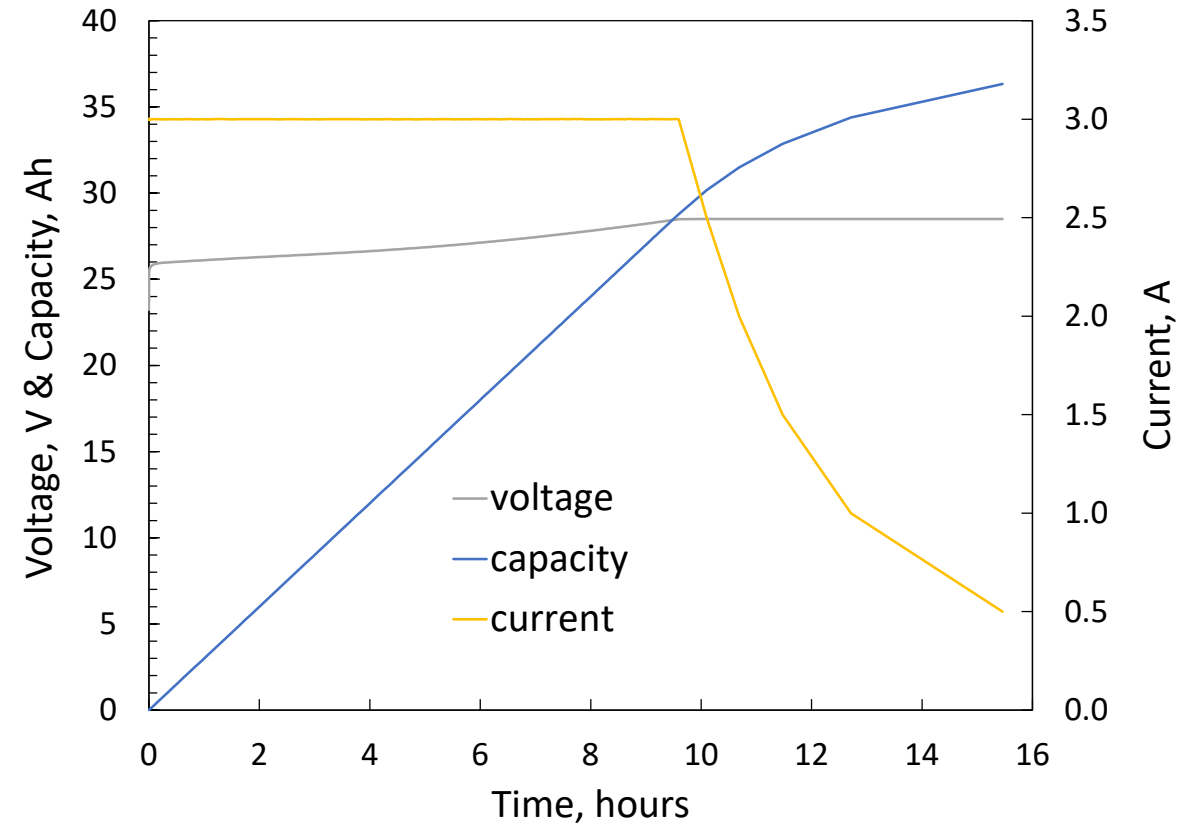


57Ah 6T prototype has outstanding low-temperature properties, with excellent continuous discharge performance and full recharge capability at -60°C.

6T Battery supports continuous discharge at rates up to 1C at -60 °C*



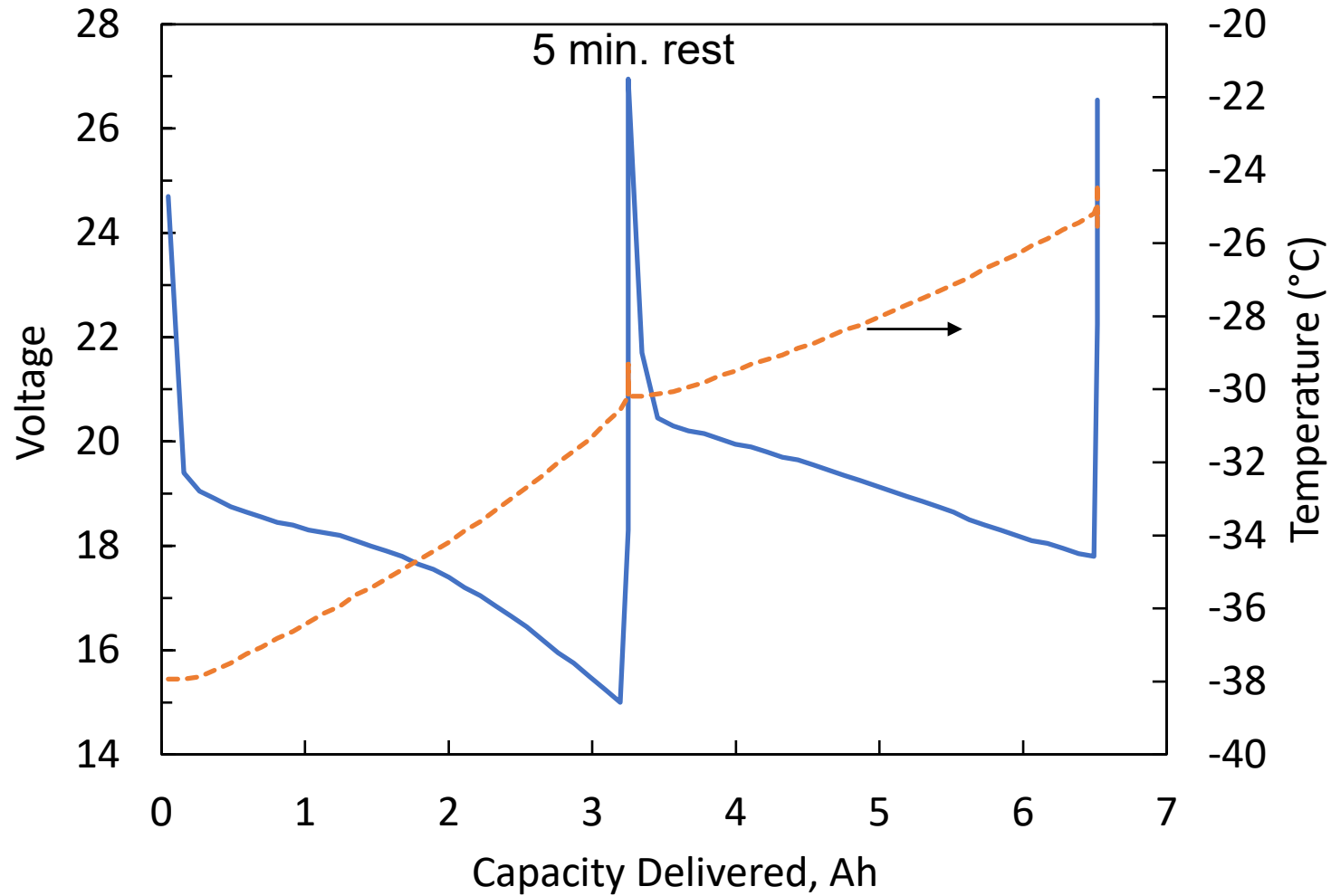
Following discharge at -60 °C, 6T battery can be fully recharged in freezer given enough time



* Battery was fully equilibrated in freezer at -63°C and full SoC prior to discharge

6T battery prototype meets type 1-B55 battery cold-cranking requirements of MIL-PRF-32565C 6T spec.

400 A, 30 sec. pulsing of 6T prototype at -40 °C



High-Power Buffering Module

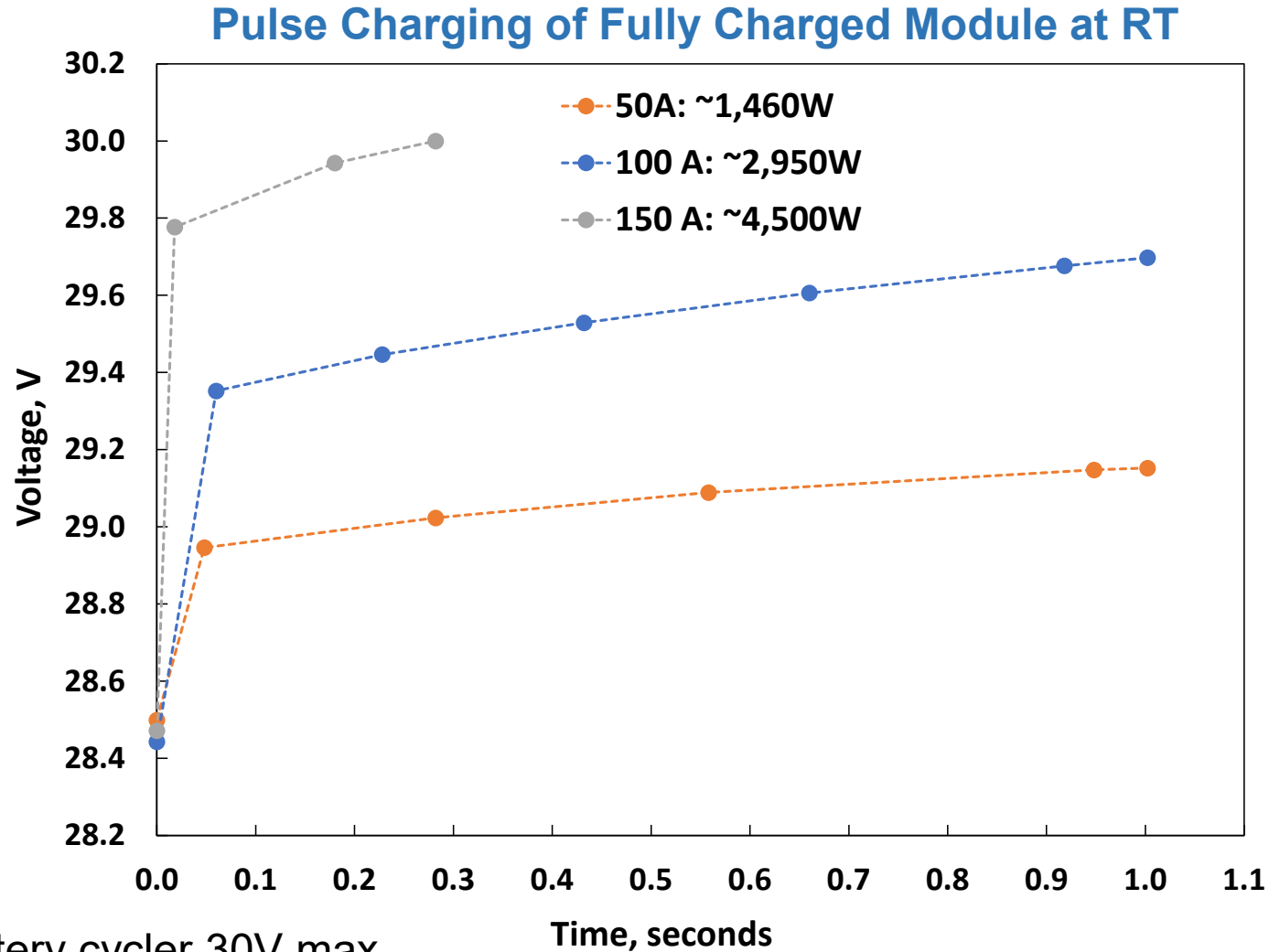
CELX-RC has been demonstrated in an unmanaged 28V/4.3Ah module (2.8L/3.1kg) targeting 4HN battery performance.



Construction: 2 Ah pouch cells in 2-parallel-cell, 12-series-cell array

Parameter	Metric
Capacity	4.3 Ah
Energy	100 Wh
Charge voltage	28.5 V
Maximum 1 sec. charge current at <36 V (from full 28.5 V charge)	600 A
Maximum 30 sec. pulse discharge current at -18 °C (above 14.4 V)	250 A
75 A discharge capacity at -40 °C (above 12 V)	2.3 Ah

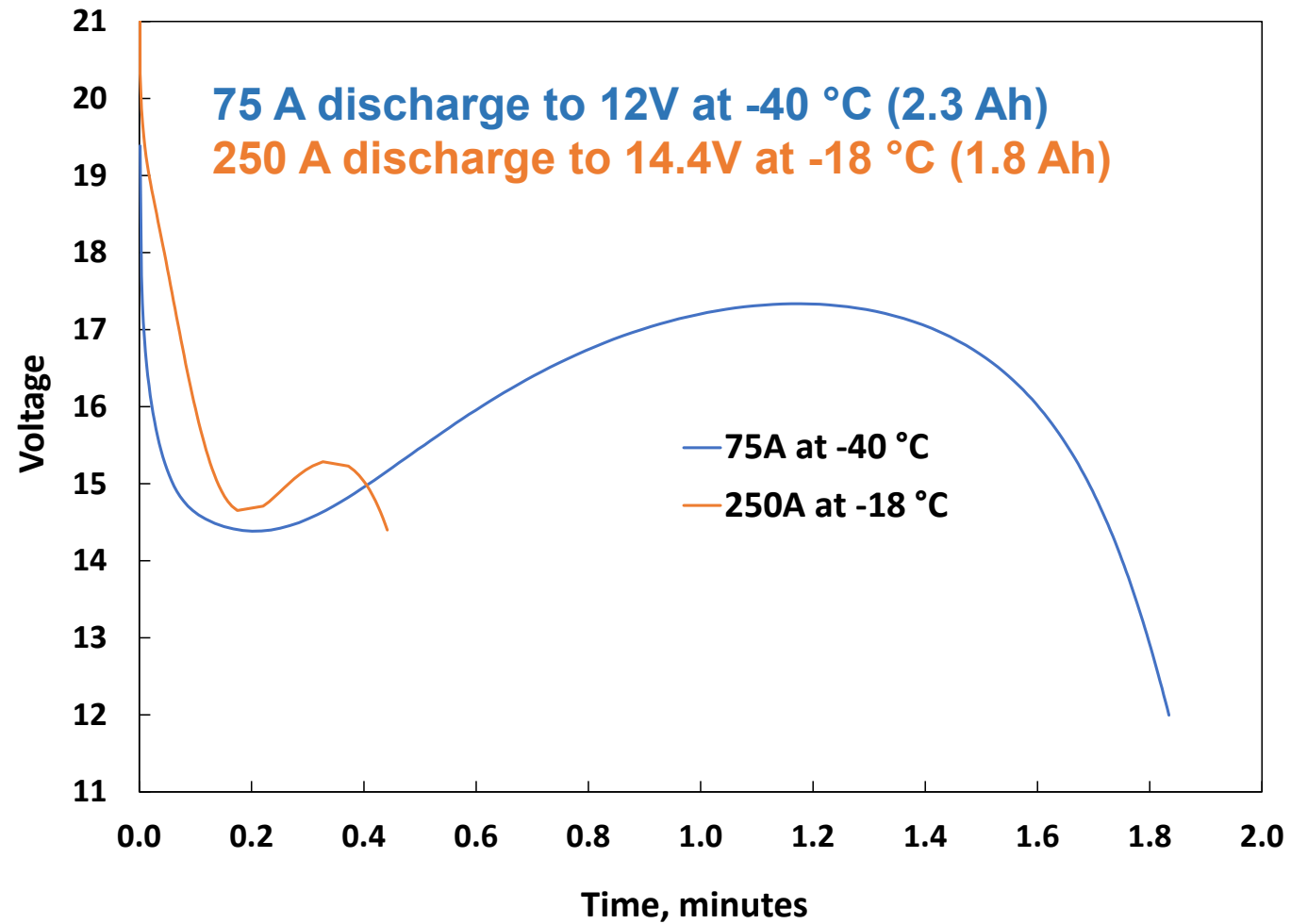
The high-power module is projected* to accept up to 600A charge below 36V for 1s at 28.5V bus voltage.



*Testing limited by battery cycler 30V max.

Module meets MIL-B-11188/2 requirement for 4HN to deliver 75 A above 12V at -40 °C for at least 1.75 min.

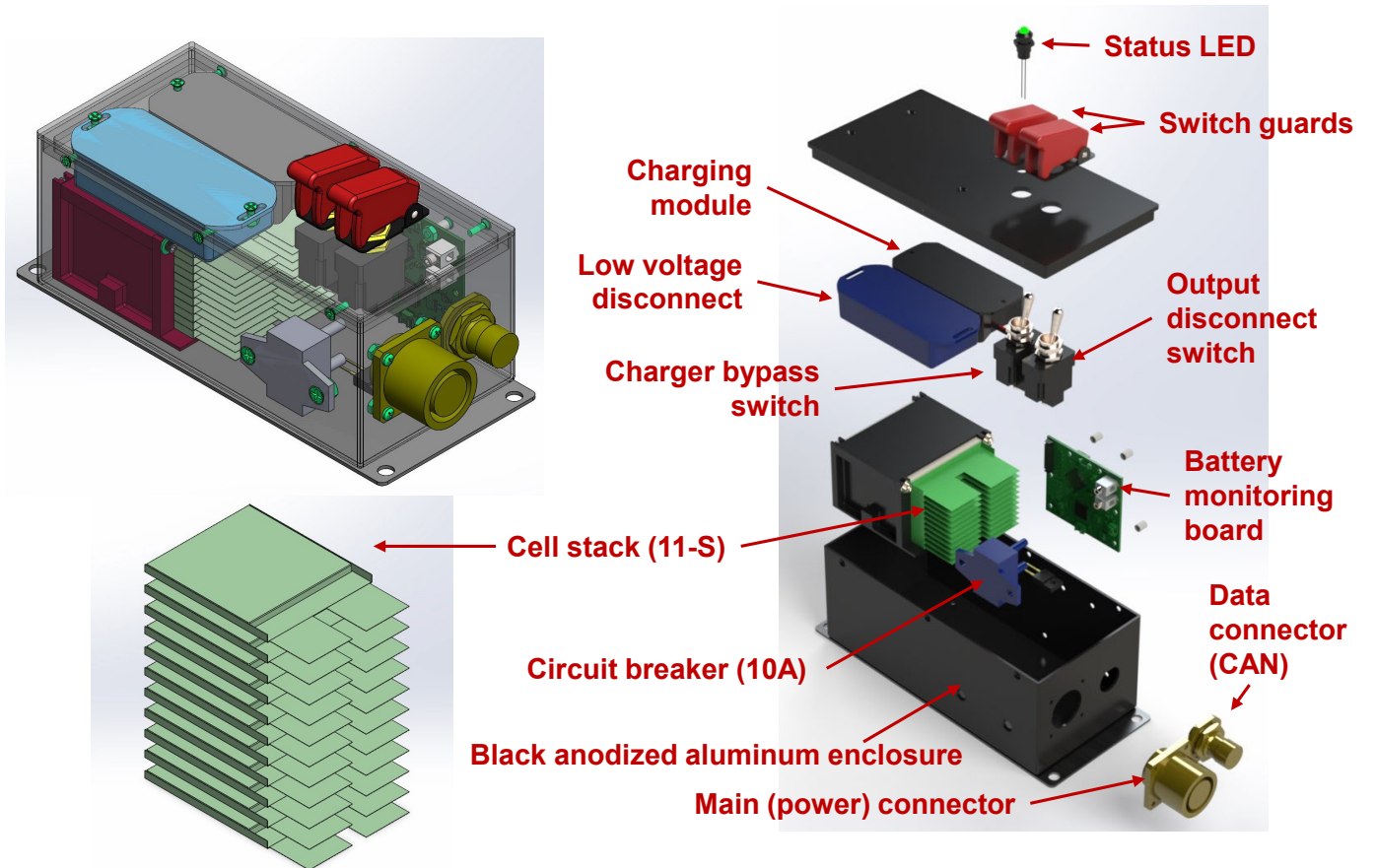
Low Temperature Discharge Performance



**Automatic Fire Extinguishing System
Backup Power Module**

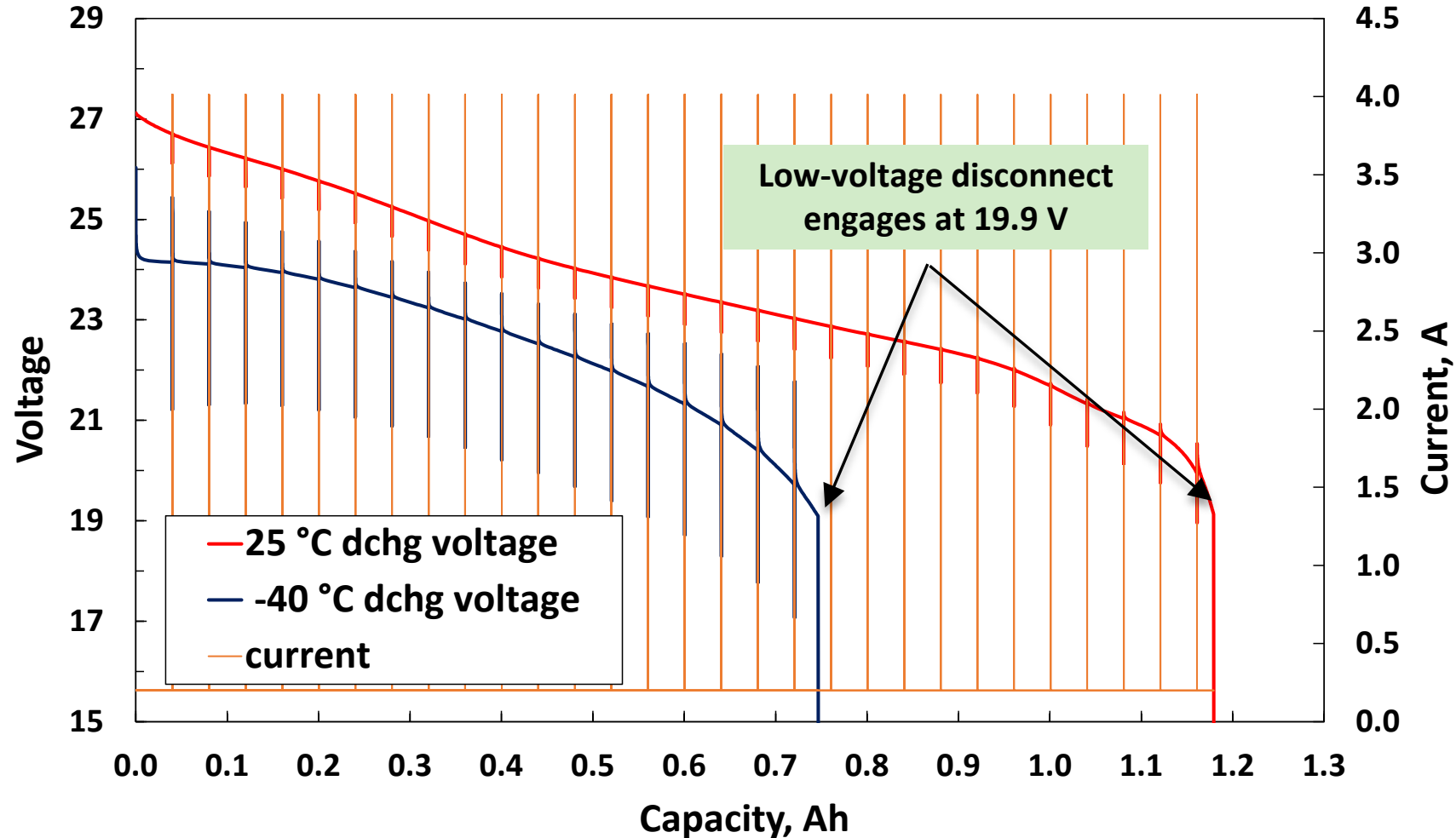
We have demonstrated a monitored but unmanaged 28V/1.2Ah backup power battery for vehicle AFES.

1.2 Ah Pouch Cells in 11-S Array



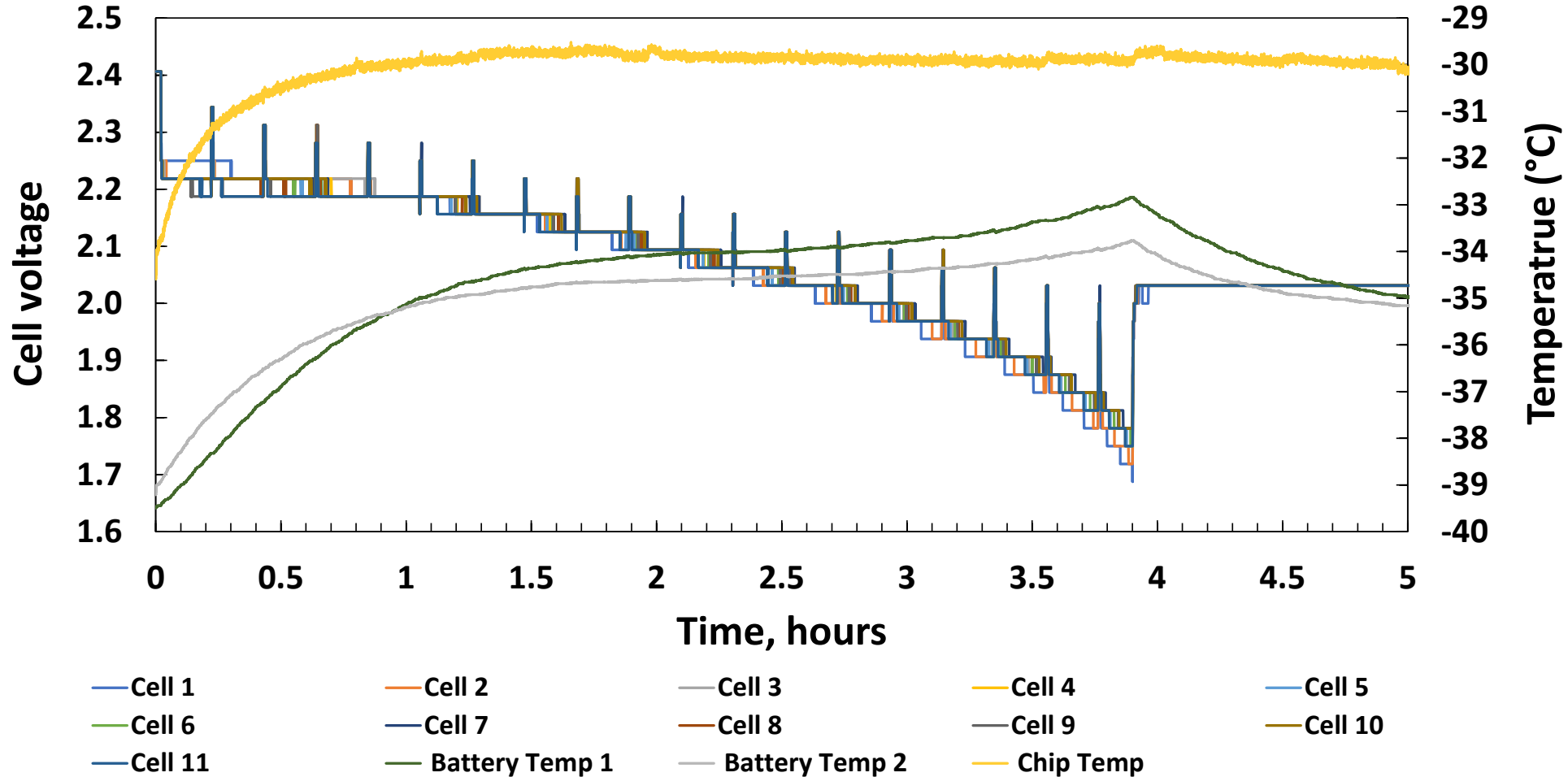
AFES BPM must deliver one 4A pulse within 10 minutes after loss of line voltage. CAMX AFES module sustains 4A pulse current at -40 °C over > 60% depth-of-discharge window.

AFEX Module: repeated 0.2 A/12 min, 4 A/50 ms discharges, 30s rest



AFES module's electronics monitor cell voltages and temperatures and can transmit via CAN.

AFEX Module Monitoring at -40 °C:
Repeated 0.2 A/12 min, 4 A/50 ms discharges, 30s rest



Conclusions

CAMX Power's CELX-RC technology can address several critical DoD battery needs:

- Compatibility with military logistical processes.
- Performance at extreme low temperatures.
- Phasing out of legacy battery technologies that are still mission-critical.
- Lack of domestic sources for lithium-ion batteries.

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