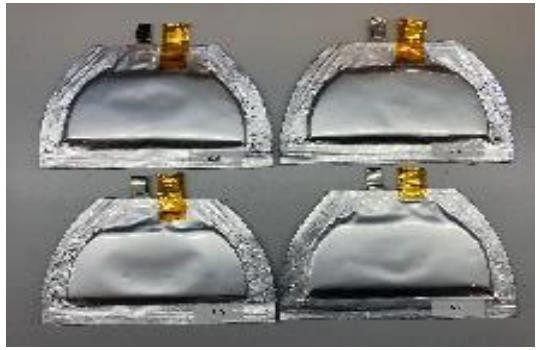
Safe, Wide-temperature Range, Long Life 0V Storage-capable Batteries for DoD Applications

James Dong, Ph.D., Sayangdev Naha, Ph.D., Russell Farmer
ADA Technologies, Inc. - Englewood, CO



Manufacturing Innovative Products for Advanced Markets

ADA Technologies, Inc. Overview

ABOUT

ADA is a manufacturing company that specializes in meeting mission critical performance requirements for DOD advanced energy storage applications through innovations and development in:

- Rapidly configurable cell shapes due to die-less electrode cutting through programmable laser cutter
- Custom-built automation equipment for flexible cell manufacturing
- **Automated Laser Electrode Cutting (ALEC)** - fabricate any size/shape of cell – minimized up-front tooling NRE – enables novel electrode enhancements

ADA MISSION

Providing a range of products by leveraging unique capabilities:

- Advanced, high-performing electrochemistries
- Conformal battery and ultracapacitors development tailored to mission requirements
- Agile manufacturing platform enables rapid development, flexible production commonality and optimum SWaP-C

- **Small business founded in 1985 (veteran owned and managed)**
- **Commercialization success**
  - 30+ patents
  - 8 spinout companies
- **Manufacturing Division**
  - 32,000 ft^2 facility; 1,600 ft^2 dry room
- **ISO 9001:2015** certified
  - Multi-year manufacturing contracts
- **Established DoD contractor**
  - DCAA Approved Accounting System
  - CMMC Level 2.0 Compliant

ADA Technologies, Inc.

ADA Advanced Energy Storage

ADA specializes in meeting mission critical performance requirements for DOD advanced energy storage applications

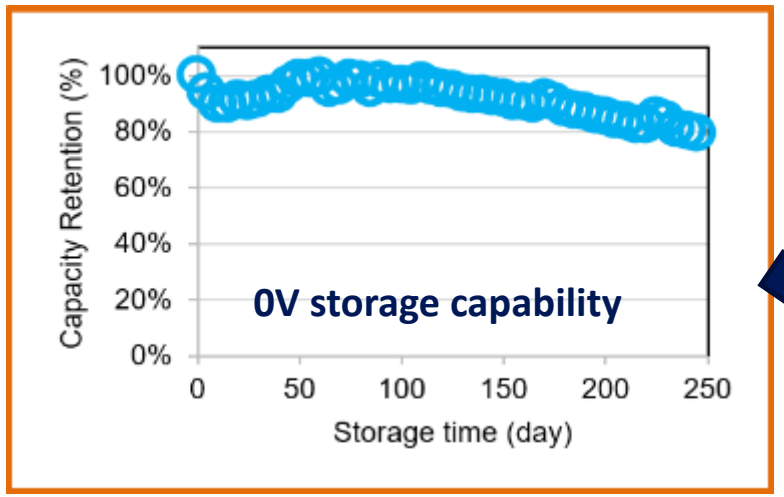
Able to enhance system performance through improvements in:

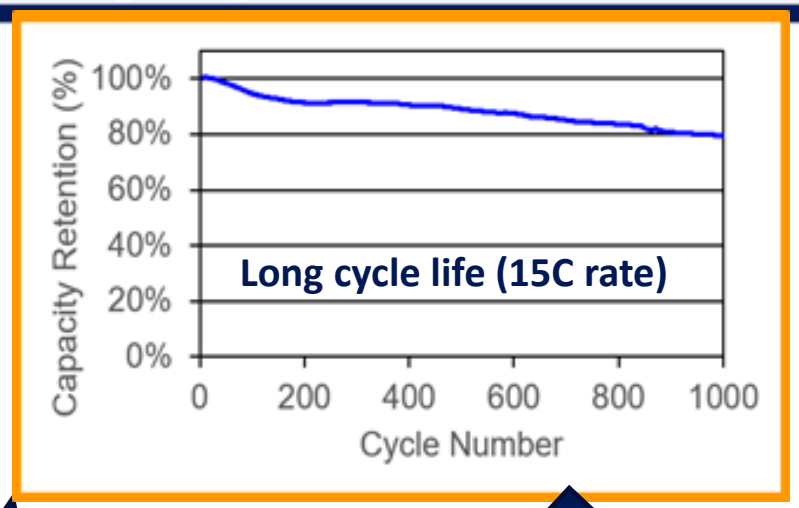
- Energy (>50% increase)
- Power (5X)
- Weight (40 – 50% reduction)
- Volume (40 – 50% reduction)
- Safety (0V storage and improved electrolytes)
- Domestic production and supply chain (where possible)

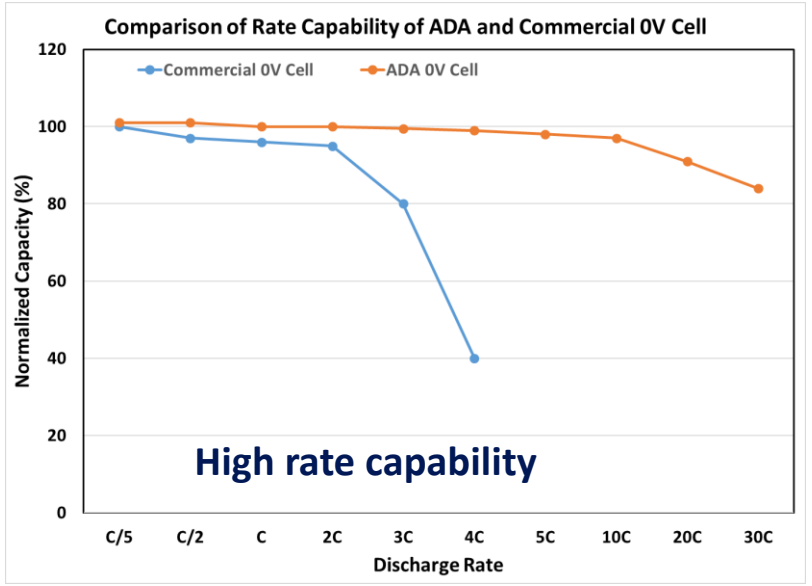
ADA Advanced Energy Storage Technologies Value Proposition

ADA AES Products & Solutions	Status (TRL/MRL); Attributes	Applications/ Customers/ Future & Current Stakeholders
Ultracapacitor (product)  Capacitance: 13F Voltage: 2.7 VDC ESR DC (mΩ): 185 0.2" x 1.25" x 1.0"	**MRL-9 (Ready Now Solutions)** **Attributes:** • >80% capacity retention for 500k cycles • Operational temperature range **-40°C to 70°C** • **Hermetically sealed** metal case • Shock: up to **60,000g** • Storage: **-40°C to +85°C**	**Current customer: Leading OEM munitions guidance kit power source supply contract in place** **Other applications** • SmallSat/CubeSat power source for power bus surge prevention • Synthetic aperture radar (SAR) payload power source **Other possible stakeholders –** • **AFLCMC/EB; Army AvMC** – munitions applications • **USSF/NASA:** satellite applications
0V Safe Li-Ion™ battery (patented) Capacity: 2.5- 10Ah Energy Density : up to 108 Wh/kg, 270 Wh/L Nominal voltage 2.2-3.2V	**TRL-6/MRL -5 (Near-Term Solutions)** **Attributes:** • Safe, high-rate chemistry • Capable of extended, safe storage and transport at 0V • Excellent replacement candidate for **obsolete NiCd batteries** for **high power density** DoD applications, where **extended safe storage & transport** are required	**Current contract:** • **DLA/NAVSEA SBIR Phase II**: NiCd battery replacement program • **AFNWC SBIR D2P2**: Back-up/emergency power supply – Minuteman III • **Army GVSC Phase I**: Backup power and ECU battery replacement for old AGM and NiCd batteries; modernization of JLTVs and tanks • **Other applications** • Legacy & future aircraft engine and APU starter motor NiCd battery replacement **Other possible stakeholders –** • **AFLCMC/WB:** Ni-Cd replacement for legacy platforms with APUs which do not use JFS – e.g. C130, KC-135, B1, B2, B52. • **NAVAIR:** CASES Aviation Batteries • **Army PEO AVN:** Hybrid UAS applications (powering VTOL functions)

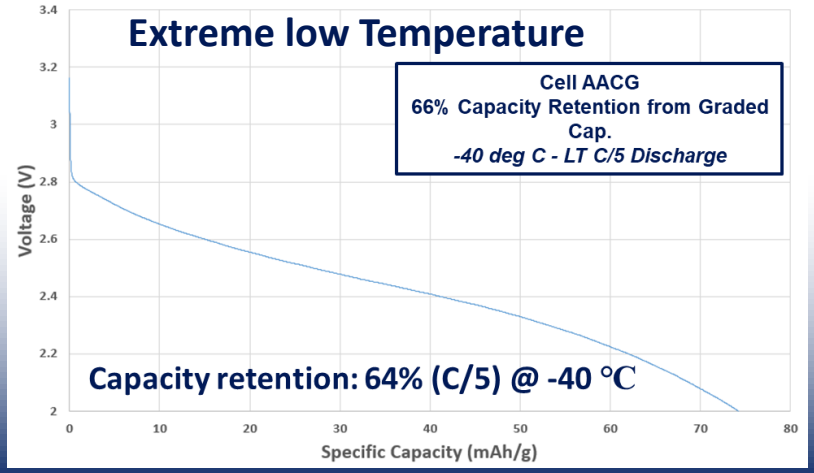
Safe Li-Ion™ – Performance Highlights – SWaP-C, and Abuse Tolerance



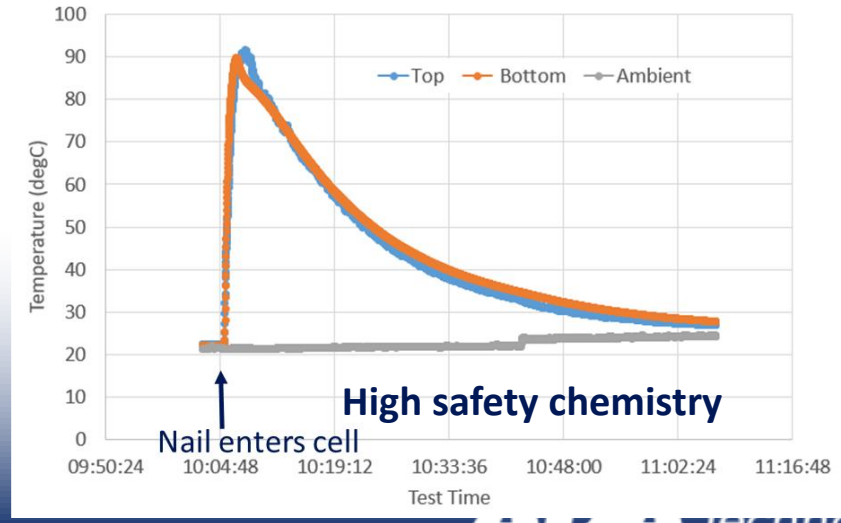




Safe Li-ion™ Cell

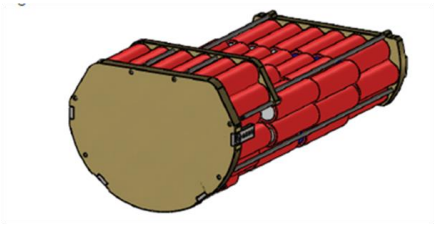


Nail Penetration of 5 Ah 0V cell charged to 3.5V

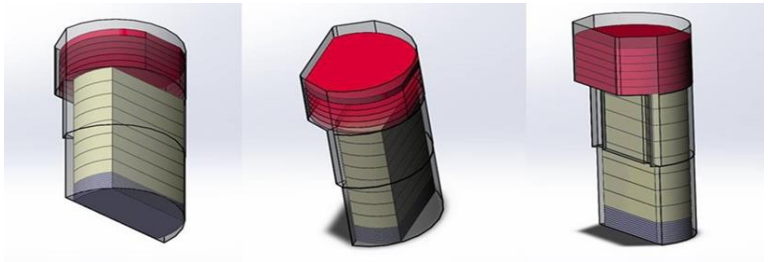


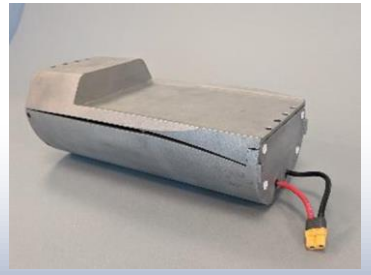
Safe Li-Ion™ Battery – Size, Weight, Power, and Cost (SWaP-C)

Pack Level ⟸ Cell Level ⟸ Electrode Level

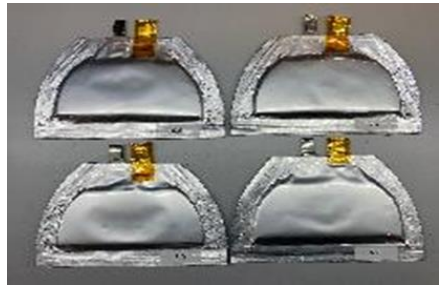


COTS 18650 Battery Pack

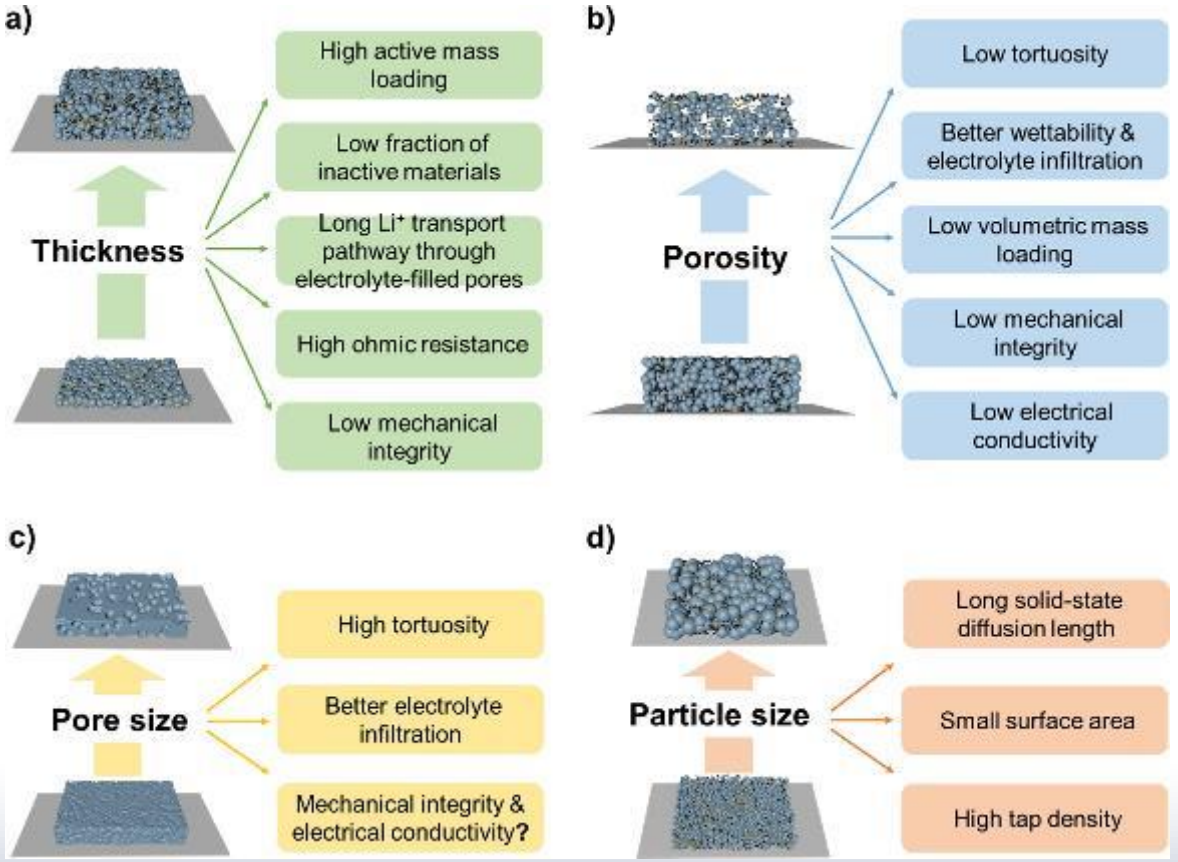




Drop-in replacement with alternative pouch cell format



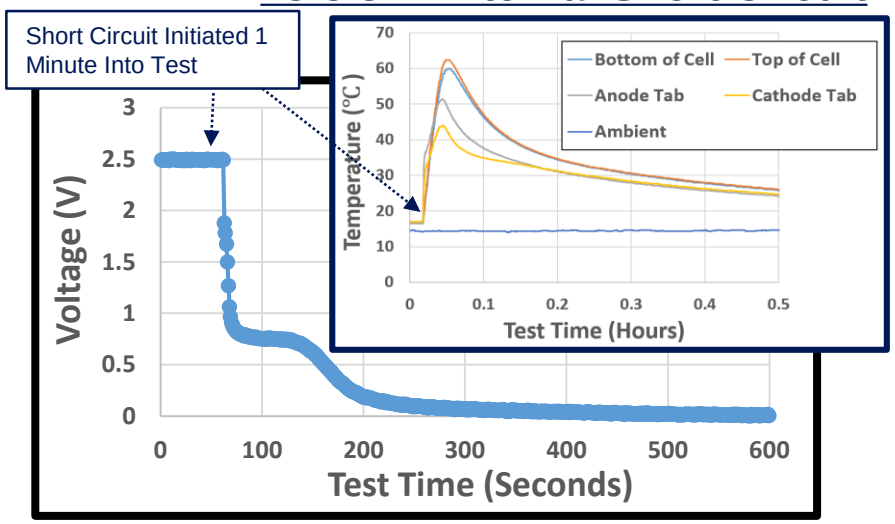
Conformable shape and size



Cell chemistry selection and electrode architecture design

Abuse Tolerance: Cell Level (3.5Ah) S9310 Safety Testing

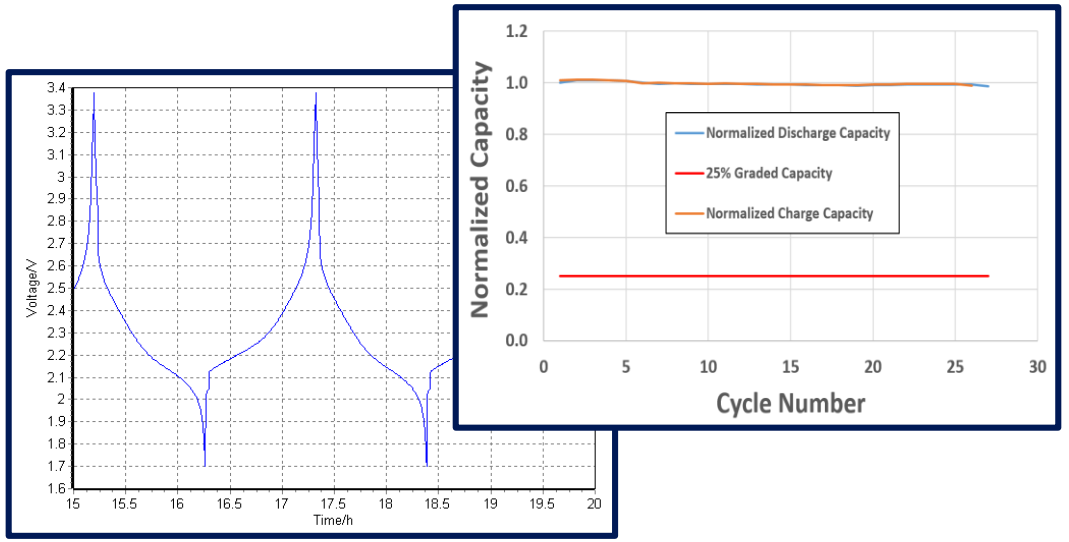
13-3.8.1 External Short Circuit



Per S9310: Short circuit fully charged unit with appropriate load (typically 0.02 ohm or less)

Maximum temperature reached was 62℃ (48℃ above ambient)

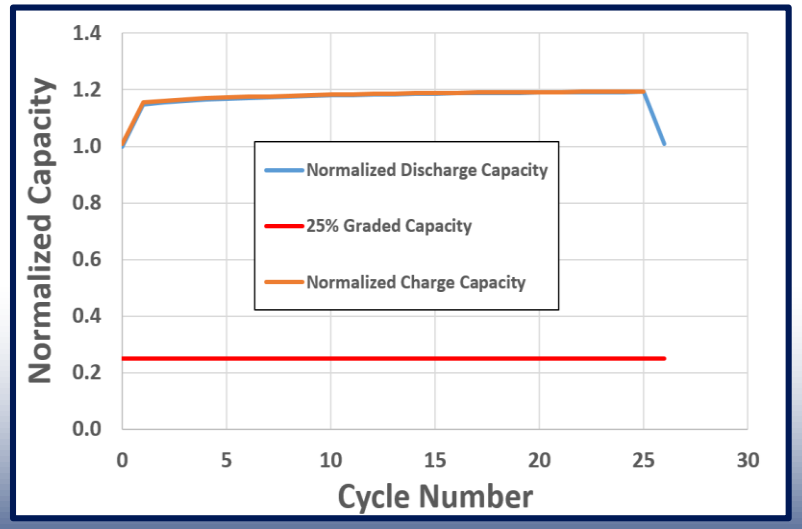
13-3.8.2 Overcharge/discharge



Per S9310: Charge cell to 1.25x of upper cutoff voltage. Minimum of 20 cycles and must deliver > 25% rated capacity on discharge

Overcharging the cell to 1.25x of the standard cutoff voltage shows no negative effects on cell performance

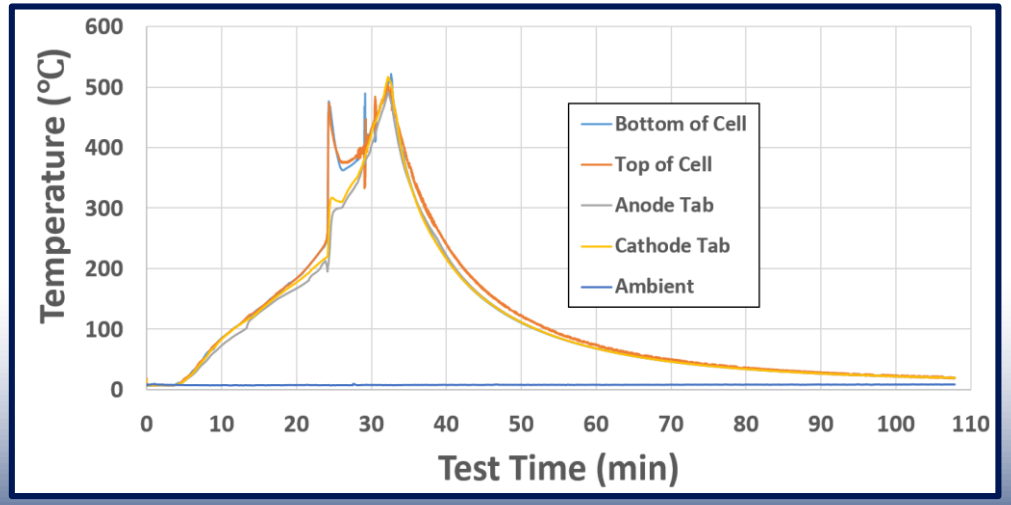
13-3.8.3 Charge/Over-discharge



Per S9310: Discharge cell 1.25x longer than required for published capacity. Minimum of 20 cycles and must deliver > 25% rated capacity on discharge

Over-discharging the cell yielded ~20% extra capacity from the rated capacity over 25 cycles, with no irreversible capacity loss afterwards

13-3.8.4 High-Temperature Test



Per S9310: Increase cell temperature by 10℃ per minute until reaching 500℃ or reactions stop

Traditional cells trigger thermal events ~150℃. **ADA's cells do not experience an event until 240℃**

ADA Technologies, Inc.

Defining Cell Level S9310 Pass / Fail

Passing Criteria by Platform

Cell level S9310 safety testing

- Key factors that determine this are:
  1) If a flame is generated
  2) If gas is generated / vented
  3) If the cell failure would result in structural damage to the battery case (likely from explosion)
- Ultimately, the *entire battery pack* needs to pass the criteria included on the chart to the right

Safe Li-Ion™ cell passed NAVSEA S9310 safety criteria at the highest level!

Table 13-1. Passing Criteria for Test Units by Platform

Platform	Passing Criteria
Submarines	Complete containment of all gaseous/liquid/solid material and flames from an MCE with temperatures measured below 100 °C and internal pressure below 50 percent of any venting mechanism (if present) or rupture condition is a passing condition. All other results need to be assessed under the conditions of use for risk mitigation and threat to the platform and personnel.
Aircraft[1/]	Venting of gaseous and liquid material is permitted. Venting of solid material and flames outside of the test unit is not permitted. Structural failure resulting in rupture of the test unit is not permitted. The peak pressure remains equal to or below 50 percent of the yield pressure of the unit in any test. Operation of a safety mechanism designed to release pressure is permitted. All other results need to be assessed under the conditions of use for risk mitigation and threat to the platform and personnel. (1)
Ships	Complete containment of all flames from an MCE and peak pressure below 50 percent of any venting mechanism (if present) or rupture condition is a passing condition. Venting of gaseous, liquid, and solid material is permitted. Structural failure resulting in rupture of the test unit is not permitted. All other results would need to be assessed under the conditions of use for risk mitigation and threat to the platform and personnel.
Land	Venting of gaseous, liquid, and solid material and flames is permitted. Structural failure resulting in rupture of the test unit is not permitted. The peak pressure remains equal to or below 50 percent of the yield pressure of the unit in any test. Operation of a safety mechanism designed to release pressure is permitted.
Naval R&D & Test Facilities	Venting or rupture of the test unit and release of toxic, flammable, or explosive gases and materials, projectiles, and fire jets is permitted. Non-expendable equipment and facility damage is maintained below the reportable threshold of MIL-STD-882 and supporting personnel are not injured.

NOTE:

1/ The location of the cell or battery in the aircraft will be closely scrutinized, especially regarding the possibility of toxic, corrosive gases affecting crew members, passengers, or high-priority equipment or systems.

Abuse Tolerance: Cell Level (3.5Ah) Wide Temperature Performance

	Low Temperature Storage (-54℃)	High Temperature Storage (66℃)
Cell Capacity Retention	101%	98%
Change to 100% SOC DCR	9% Decrease	13% Decrease

	Low Temperature Charge (-18℃)	High Temperature Charge (46℃)
Capacity Retention	96%	99%
C- Rate	C/20	C/5

	Low Temperature Discharge (-40℃)	High Temperature Discharge (60℃)
Capacity Retention	63%	107%
C- Rate	C/20	C/5

Challenges and Possible Solutions

- **Challenge 1**: Lots of interest from different programs across the DoD, however, acquisition interests as well as maturation/TRL-MRL investments are limited or not well understood

  Possible Solutions:

  – Qualify more battery providers
    - Reserve components for demand surge
    - Facilitate company capital investment decision and cost analysis
  – Flexible on cell format if no performance to be comprise

- **Challenge 2**: Raw Materials Cost and Availability from Domestic Supply

  Possible Solutions:

  – Government subsides for purchase but not only for produce
  – Horizontal collaboration to increase purchase power
    - more effectively utilize existing space, equipment and people

Conclusions

- **ADA specializes in meeting mission critical performance requirements for DOD advanced energy storage applications**
  - Advanced, high-performing electrochemistry
  - Agile manufacturing platform enables rapid development, flexible production commonality and optimum SWaP-C

- **ADA Safe Li-Ion™ battery is currently transitioning to manufacturing**
  - Safe, high-rate chemistry – passing NAVSEA S9310 safety criteria at the highest level
  - Capable of extended, safe storage and transport at 0V
  - Extremely wide operational and non-operational temperature window (-40 ^{o}C to +60 ^{o}C for discharge – validated)
  - Ultra-high power capability (discharge rate up to 30C)
  - Excellent replacement candidate for **obsolete NiCd batteries** for **high power density** DoD applications

Contact Information

James Dong, Ph.D.
Director, Advanced Energy Storage
jamesd@adatech.com

Russ Farmer
President, CEO
russf@adatech.com

Sayan Naha, Ph.D.
VP, Business Development
SayanN@adatech.com

ADA AES Value Proposition (Contd.)

ADA AES Products & Solutions	Status (TRL/MRL); Attributes	Applications/ Customers/ Future & Current Stakeholders
Lithium Sulfur (LiS) – 5 Ah Li-S pouch cells capable of 300 cycles >200 Wh/kg	**TRL-4/MRL-4 (Near Term Solutions)** **Attributes:** • LiS batteries do not contain Co/Ni, thereby alleviating supply chain concerns • ADA's LiS demonstrates > 200Wh/kg & > 300 cycle life at single cell level • Higher TRL/MRL compared to SOTA	**Applications -** • Enhanced duty cycle of SmallSats by attaining ~3X capacity compared to conventional Li ion batteries • Dismounted soldier power **Other Possible Stakeholders -** • **USSF; SSC/BZ – Space Systems Integration Office (SSIO):** higher duty cycle spacecraft; backup power for LEO missions • **DEVCOM Soldier Center –** Lightweight, safe and higher duty cycle batteries for soldier power
Hybrid Energy Storage Devices 	**TRL-4/MRL-4 (Near Term Solutions)** **Attributes:** • Enables high power and high energy density driven applications for **DoD & Commercial** platforms without unnecessarily stressing or oversizing the power source • **Combines high power NMC with high energy CFx technologies** through advanced BMS	**Applications –** • Commercial eVTOL & eSTOL interest; AF Agility Prime and ARPA-E funded Electrified Aircraft program airframe manufacturers **Possible stakeholders -** • **PEO AVN (Army) –** eVTOL, hybrid VTOL UAS platforms • **Special Operations Forces (SOF) AT&L** – UAS power sources requiring high power and high energy density mission needs in a single platform **– Group 2/3/4 UAS**