U.S. ARMY

DEVCOM C5ISR CENTER

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND C5ISR CENTER

Perspective on Safety Considerations of Next-Generation Batteries for Military Use

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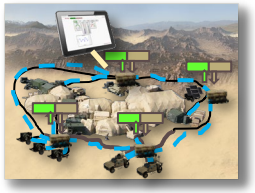
C5ISR CENTER OPERATIONAL ENERGY

Technology Focus Areas


Expeditionary Power Generation & Conversion
Fuel to Electricity, Alternative & Renewable

Advanced Energy Storage
Batteries, Capacitors, etc.

Intelligent Power Management & Distribution

Soldier & Small Unit

Tactical Energy for Soldier Lethality

Increased Soldier Lethality through longer runtimes in distributed operations, with limited resupply

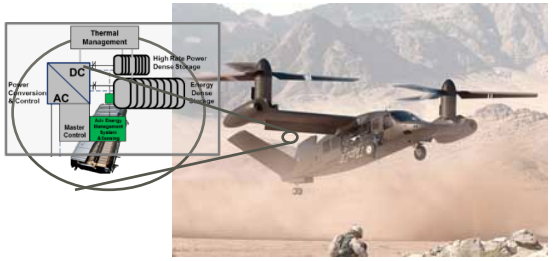
- Energy storage materials for unique battery configurations
- Power generation devices to enable integrated Soldier borne/operated sensors and radios

C5ISR Power & Intelligent Platform Power

Mobile Command Post Power

Reduced Logistics and Increased Flexibility

- Control Standards for Distributed Power Systems
- Energy Predictive Applications for Power Management
- Intelligent Microgrid Demonstrations



Optimized Energy Storage for C5ISR Power

Optimizing platforms to enable C5ISR Dominance

- Pulse Power Energy Storage
- Thermal Analysis & Management
- Control Standards & Distribution

Enabling C5ISR Dominance through Holistic Operational Energy Solutions

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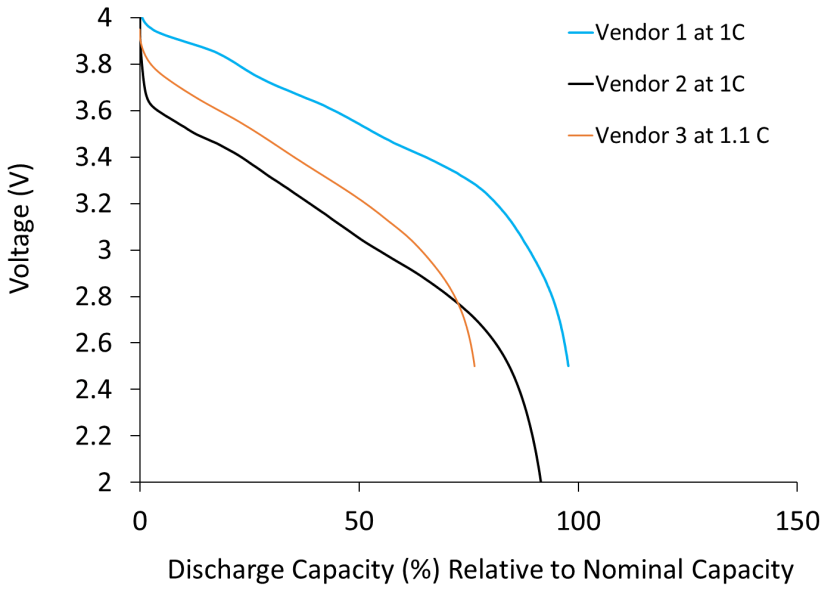
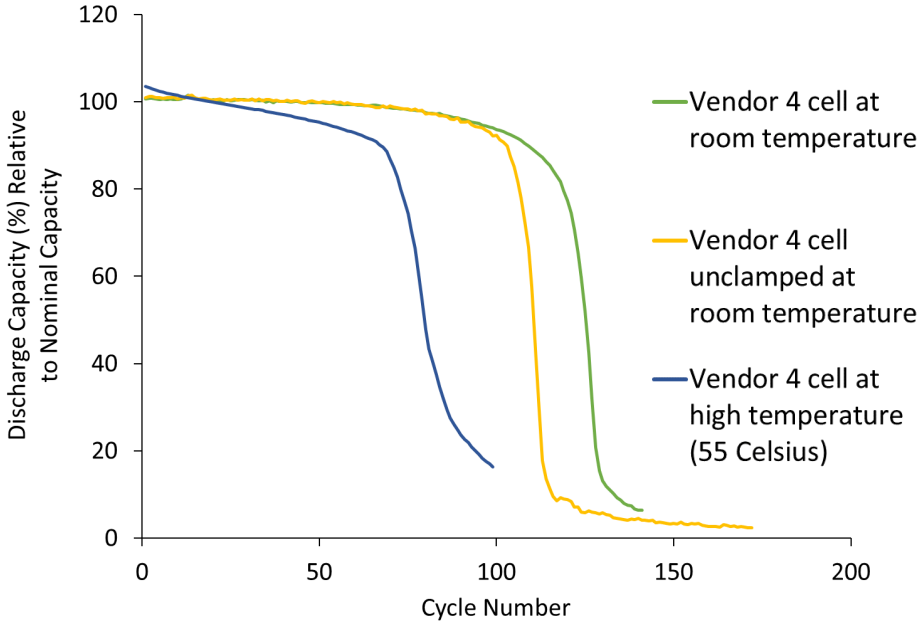
ARMY AREAS OF INTEREST

- **Unmanned Aerial Systems (UAS)**
  - Variability in size, mission profile, weight/size restrictions
  - High energy density requirements
  - High power requirements
  - Relatively less stringent safety requirements due to unmanned nature
- **Conformal Wearable Battery**
  - Primary power source for deployed soldiers
  - Strict volume and weight constraints
  - Safety requirements
- **Future Aviation Battery**
  - Supplement auxiliary power requirements on craft
  - High energy, high power, pulse power requirements
  - Stringent safety requirements for airworthiness
  - Volume/dimensional restrictions

SILICON ANODE

- **Cylindrical Silicon Anode Cells**
  - Vendor 1: COTS 18650 cells with anode containing <25% silicon
  - Vendor 2: Safety material built in to 18650 cylindrical cells with anode containing >25% silicon
  - Vendor 3: 18650 cylindrical cells with anode containing <25% silicon
- **Pouch Silicon Anode Cells**
  - Vendor 4: silicon anode pouch cells
  - Vendor 5: silicon anode pouch cells with inherent safety but lower energy
- **Potential Safety Challenges**
  - High burn temperature of silicon
  - Anode volume expansion
  - Clamping/pressure requirements not feasible for all battery package form factors





SILICON ANODE CELLS AND BATTERIES

- **Cell level**
  - Challenges:
    - Differences between abuse testing of single cell vs multiple cells
  - Assessments:
    - Nail penetration
    - Ballistics characterization
- **Battery package level**
  - Challenges:
    - Heat build up from high current rates
    - Thermal runaway mitigation
  - Assessments:
    - Nail penetration
    - Ballistics characterization

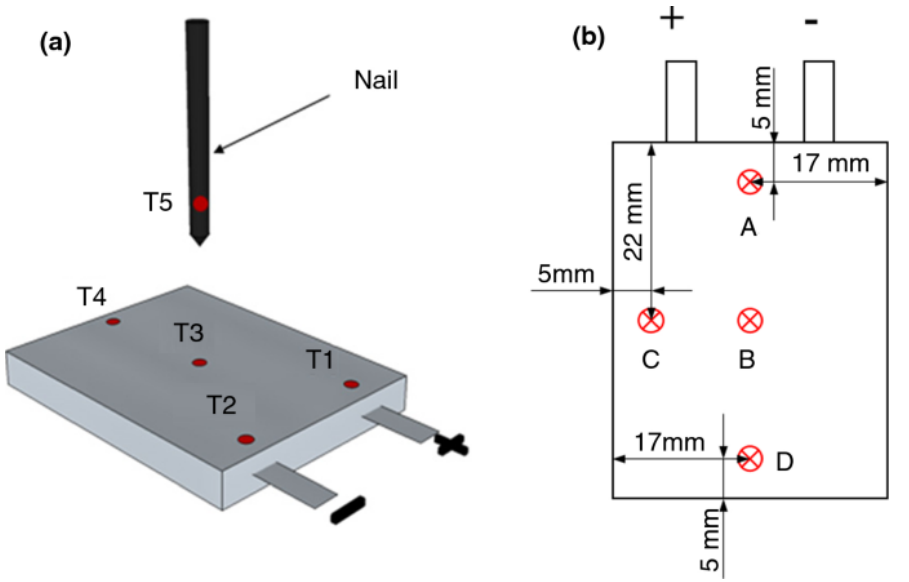
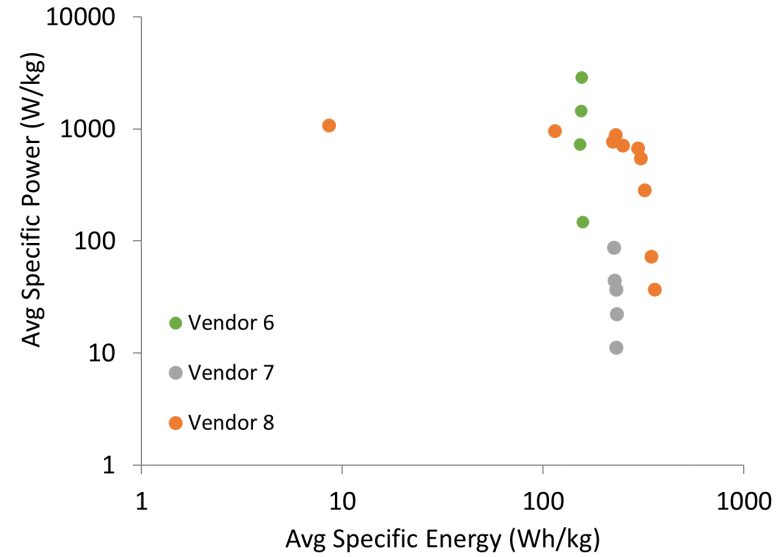
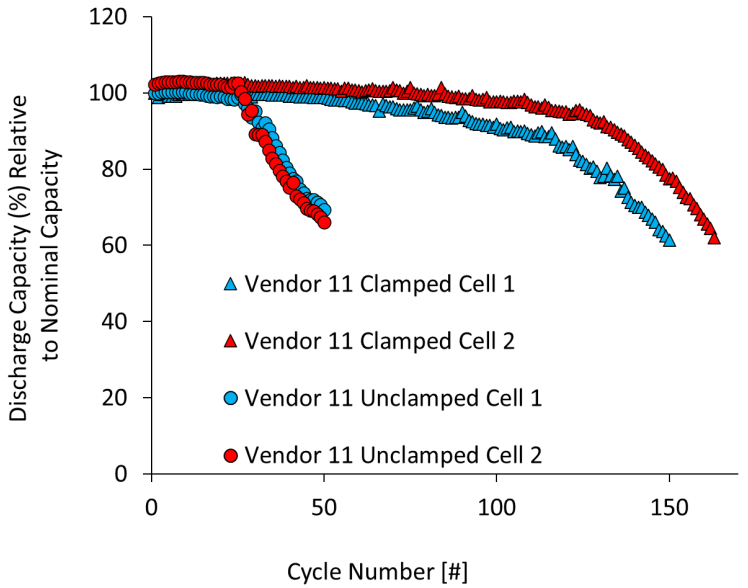


Image from Xu, et al., *J of Thermal Anal Calorim* 144, 273-284 (2021).

LITHIUM METAL ANODE

- **Comparative Testing of Pouch Lithium Metal Anode Cells**
  - Vendor 6: COTS pouch cell, not lithium metal anode
  - Vendor 7: COTS LiPo pouch cell, not lithium metal anode
  - Vendor 8: Lithium metal anode pouch cell, formulated electrolyte
  - Preliminary ballistics testing
- **Additional Lithium Metal Anode Testing**
  - Vendor 9: Single layer pouch cells demonstrate cycle life issues and possible rate limitations
  - Vendor 10: >400 Wh/kg energy density but safety issues arise when cycled unclamped
  - Vendor 11: Lithium metal anode pouch cell performs well clamped
- **Potential Safety Challenges**
  - Clamping/pressure requirements not feasible for all battery package form factors
  - Lithium metal burn temperatures





OTHER TECHNOLOGIES

- **Solid State Electrolytes**
  - Vendor 12: conductive glass electrolyte
  - Vendor 13: solid state garnet electrolyte
  - In general, issues associated with rate limitations
  - Some vendors using catholyte
  - Varying definitions of “solid state electrolytes”

- **Li-S and Li-Se Technologies**
  - Vendor 14: Li-S pouch cell with low energy density, low cycle life, required compression
  - Vendor 15: Li-S pouch cell with low energy, swelling issues
  - Vendor 16: Li-Se pouch cells at low TRL with low energy densities

THANK YOU.

Please reach out with any questions

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