



# Advances in Li/$CF_x$ Non-rechargeable Batteries for Portable Electronic Systems

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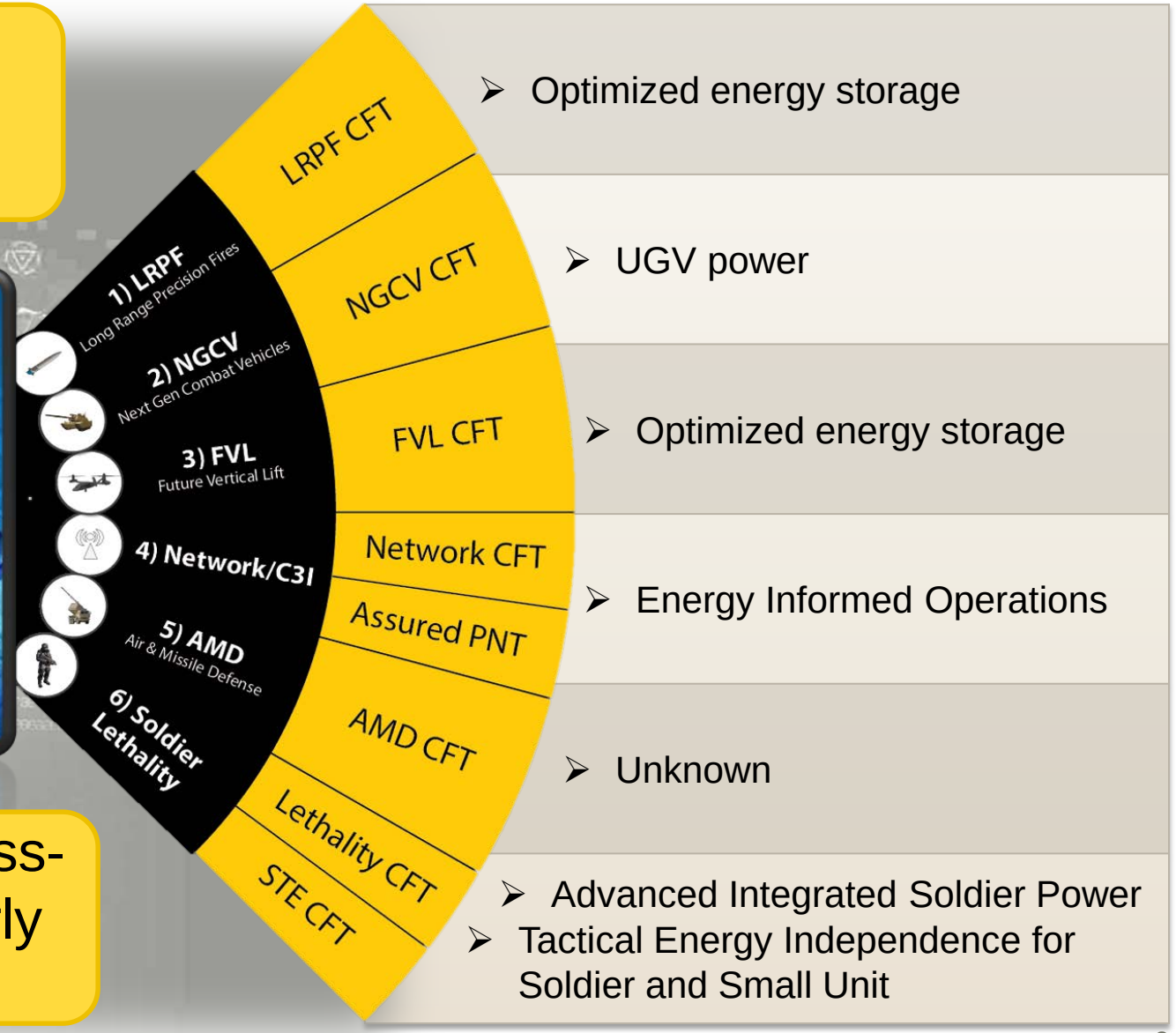
# Introduction: Army's 6 Modernization Priorities

Increasing demand for power and energy as a result of increasing system capabilities.


The power and energy arena is a cross-cutting competency that impacts nearly every CFT.

# Modernization: SL CFT

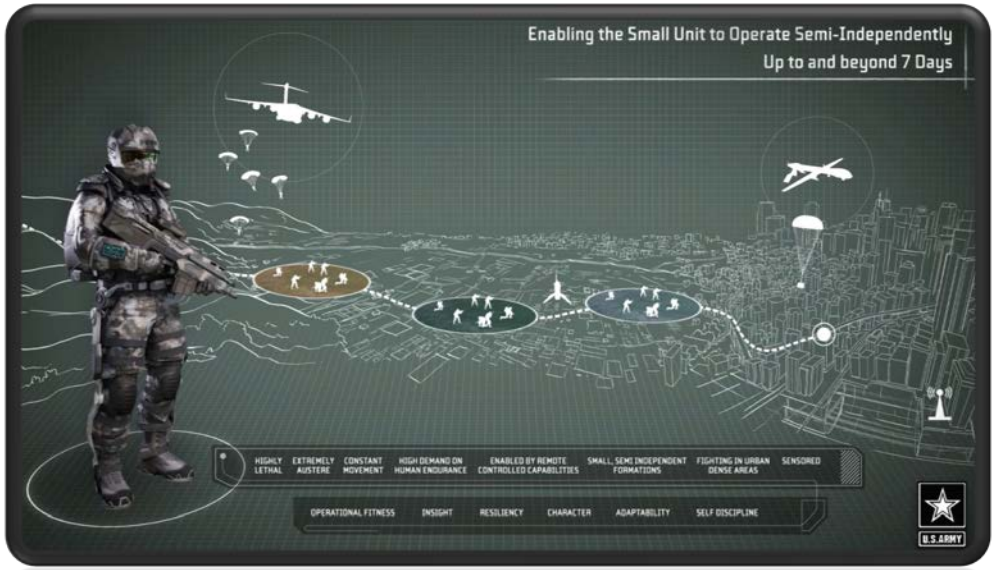
Increasing demand for power and energy as a result of increasing system capabilities.

Increase

- ↑ Power Source duration
- ↑ Energy Storage capacity
- ↑ Sustainable Energy
- ↑ Energy Efficiency
- ↑ Power/Data management & distribution

- ↓ Systems power demand
- ↓ Battery Types
- ↓ Logistical burden
- ↓ Multiple components/systems

Decrease




# SOLDIER LETHALITY CFT E&P CHALLENGE: SUPPORTING A GROWING SOLDIER ENERGY BALANCE

## Energy for Dismounted Soldier Lethality

### Today

- **Rifleman: 8-12 W / SL: 12-15 W**
- **SAPI Conformal & Load Specific Batteries Only**

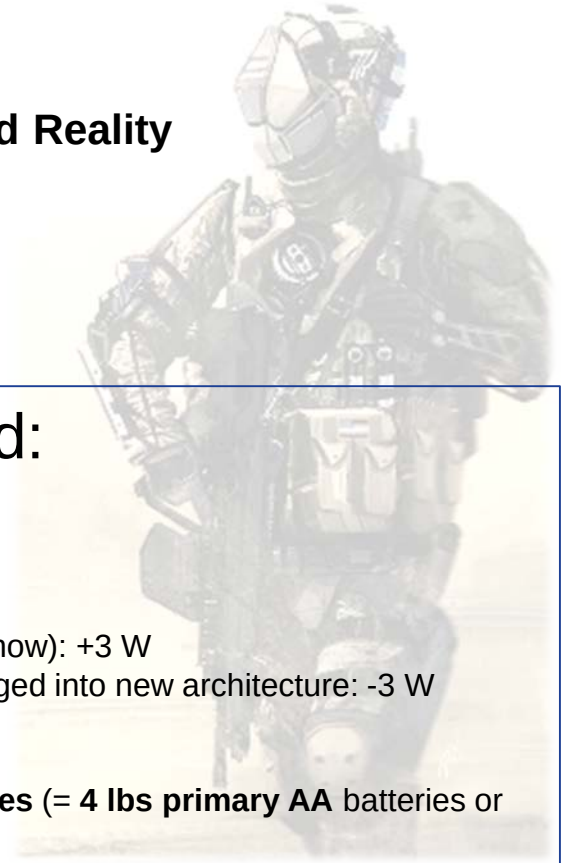
Assume Avg Power Load **~ 12 W**

- 72 hr mission:
  - 864 Whr → 6 ea CWB (150 Whr) → **15 lbs**
    or → 3 ea 2590 (290 Whr) → **9 lbs**
- Reality: The current Networked Soldier carries **20-25 lbs** of batteries for a 72 hour mission

Notes:
a. Values are estimates based on discussions with the Soldier Lethality CFT
b. http://www.energizer.com/batteries/battery-comparison-chart

### 2022-2025 SL CFT added burden

- **New Soldier Lethality CFT gear**
  - o **Powered rifle**
  - o **Heads-Up Data Display and Augmented Reality**
  - o **Adaptive Soldier Architecture**
- **Adds: 10-14 W**[a]
- **Rifleman: 18-26 W / SL: 22-29 W**



Assumed new Avg Power Load:

- 2018 Power load: 12 W
- Add NGSW (powered): **+2-6 W**
- Add HUD with AR: **+8 W**
- Add Adaptive Soldier Architecture (unknown quantity right now): +3 W
- Reductions from present value due to existing devices merged into new architecture: -3 W

- **Total: 22-26W ( > 83% increase)**
- SL CFT EP Workshop analysis: **additional 80+ AA batteries** (= **4 lbs primary AA** batteries or 5.5 lbs Li-ion AA rechargeable batteries)[b]

# SL CFT WORKSHOP
# POWER WORKING GROUP OUTCOMES

**Now**
- Improving requirements language
- Roadmapping

**Near**
- Li/CFx AA or 2/3 A implementation
- Architecture improvements

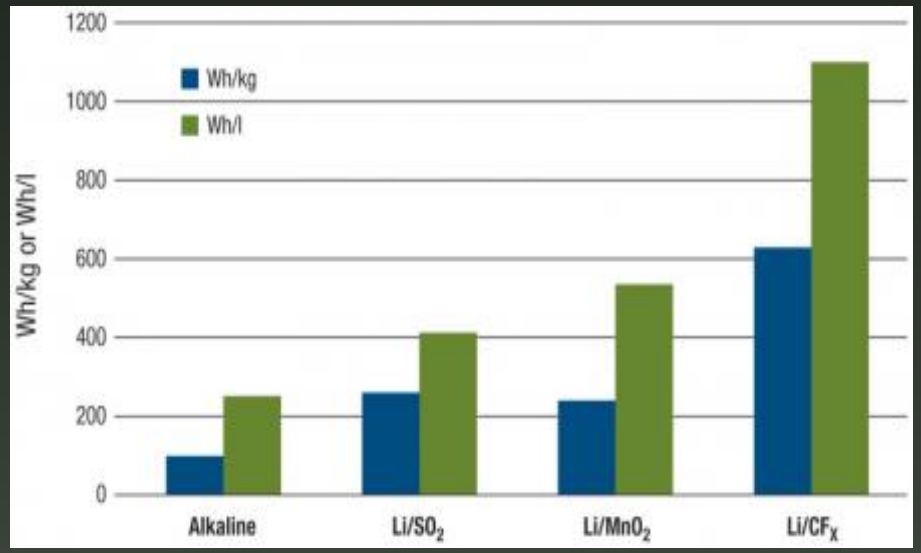
**Mid**
- Requirements language lowering power & energy demand

**Far**
- Replace existing AA with better solution
- Investigate chemistries, alternative sources, and methods

# Background

## $CF_x$ Characteristics

- \+ High energy density
- \+ Wide operating range
- – High heat generation
- – Rate capability
- – Significant initial delay
- – Expensive (due to manufacturing)




http://archive.cotsjournalonline.com/articles/view/101364

## Preparation

- – High temperature reaction of carbon powder and fluorine gas
- – Degree of fluorination is dependent on temperature & pressure
- – Commercially available composition of $CF_x$ is $0.95 < x < 1.15$

## Theoretical performance based on x.

$$CF_x + xLi \rightarrow C + xLiF$$

$$Q_{th} = \frac{xF}{3.6(12 + 19x)}$$

# Hybridization

## $CF_x$ improvement methods

- Carbothermal treatment
- Enhanced surface treatment
- Replacement of graphite to carbon nanostructures

## Hybrid Blends

- Pulse capability
- Can handle wide load distributions
- Advantageous to both chemistries

## $CF_x$-$MnO_2$

+ High energy density
+ Wide temperature range
+ Hybridizing $CF_x$ decreases material costs
+ Better rate capability
+ No voltage drop
+ Better low temp performance
– Energy density lower than $CF_x$
– Thermal output is still high but lower than $CF_x$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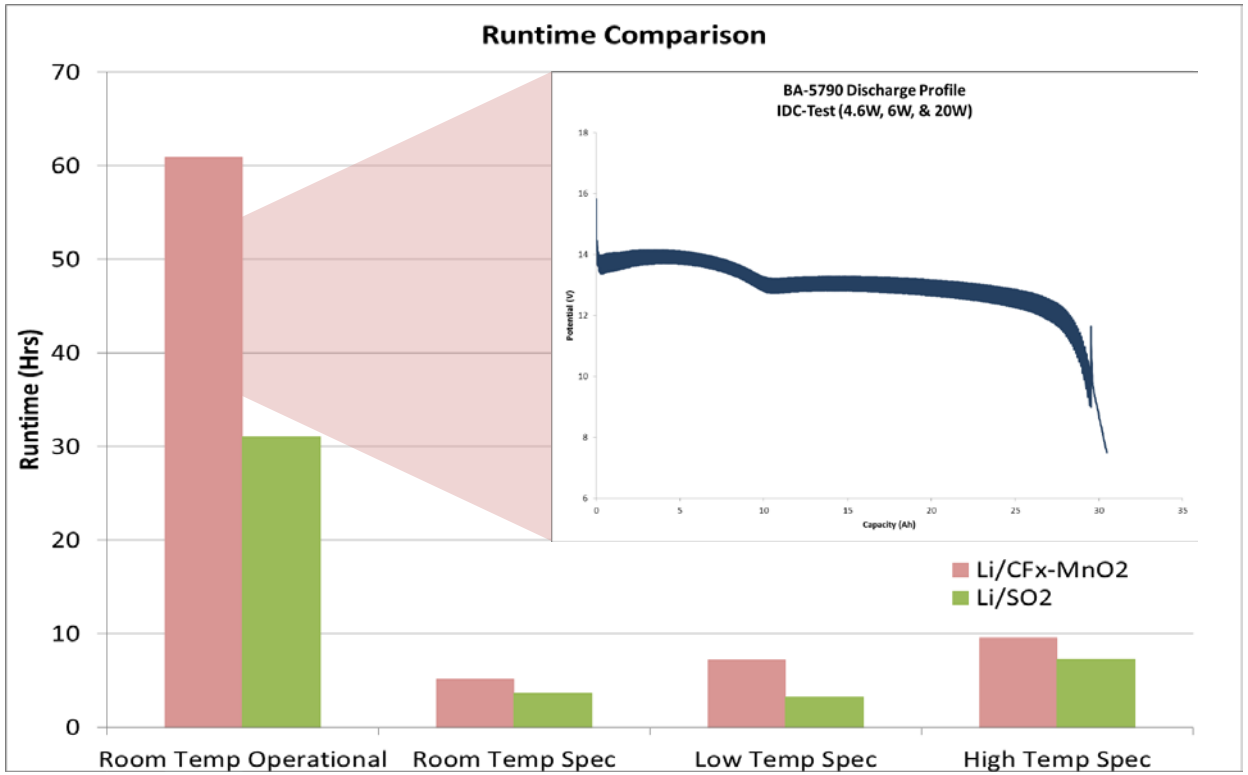
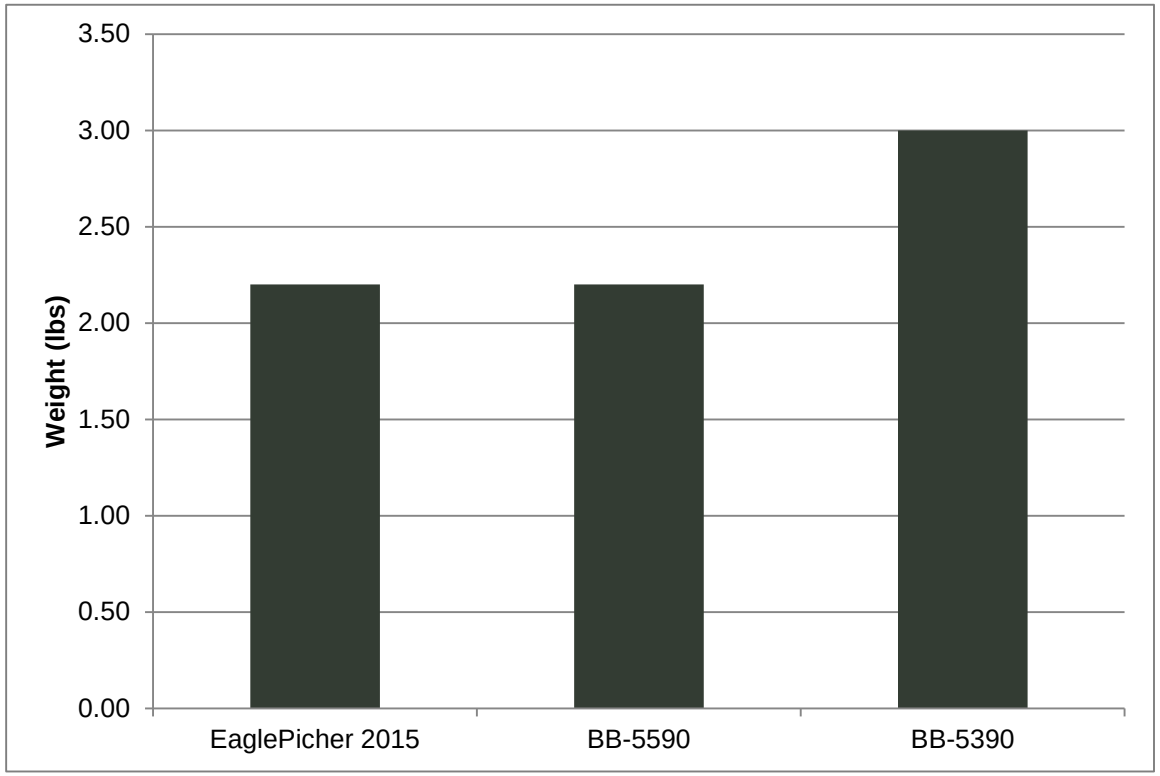
# XX90 BATTERY FAMILY

BA-5790: $Li/CF_x$-$MnO_2$

BA-5590: $Li/SO_2$

BA-5390: $Li/MnO_2$

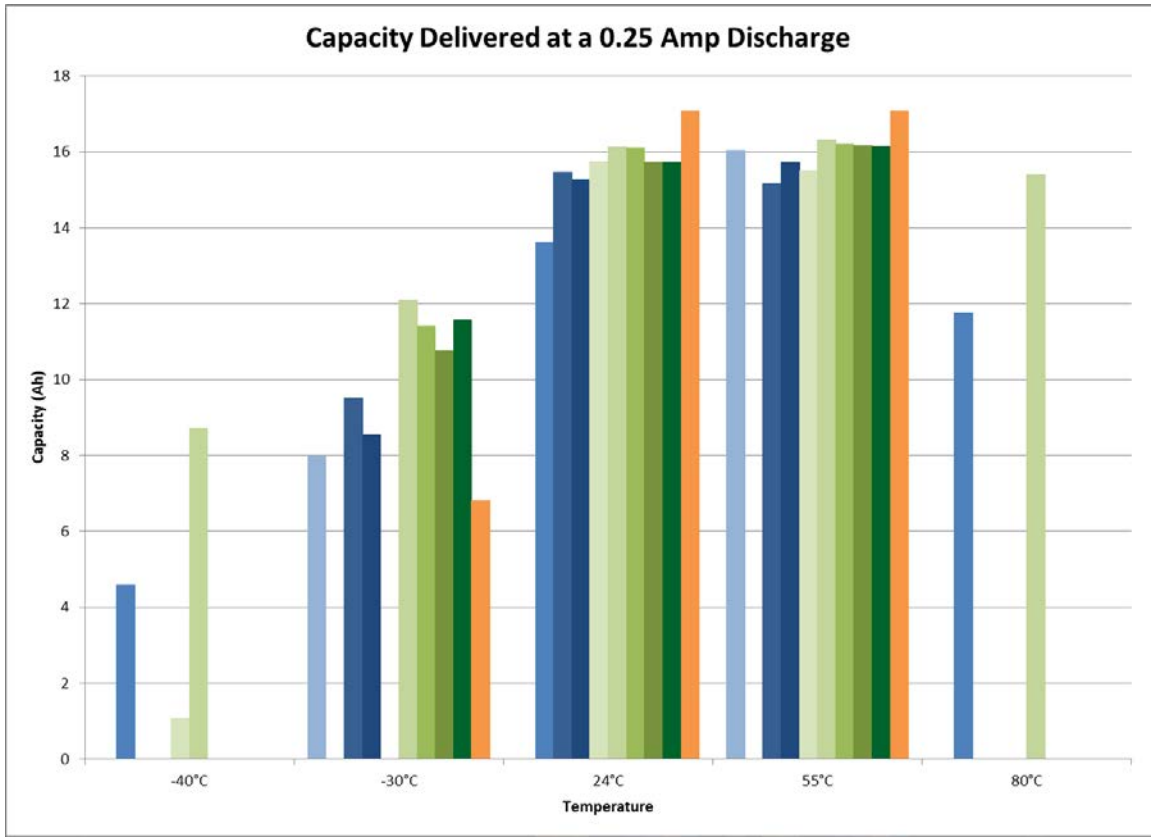


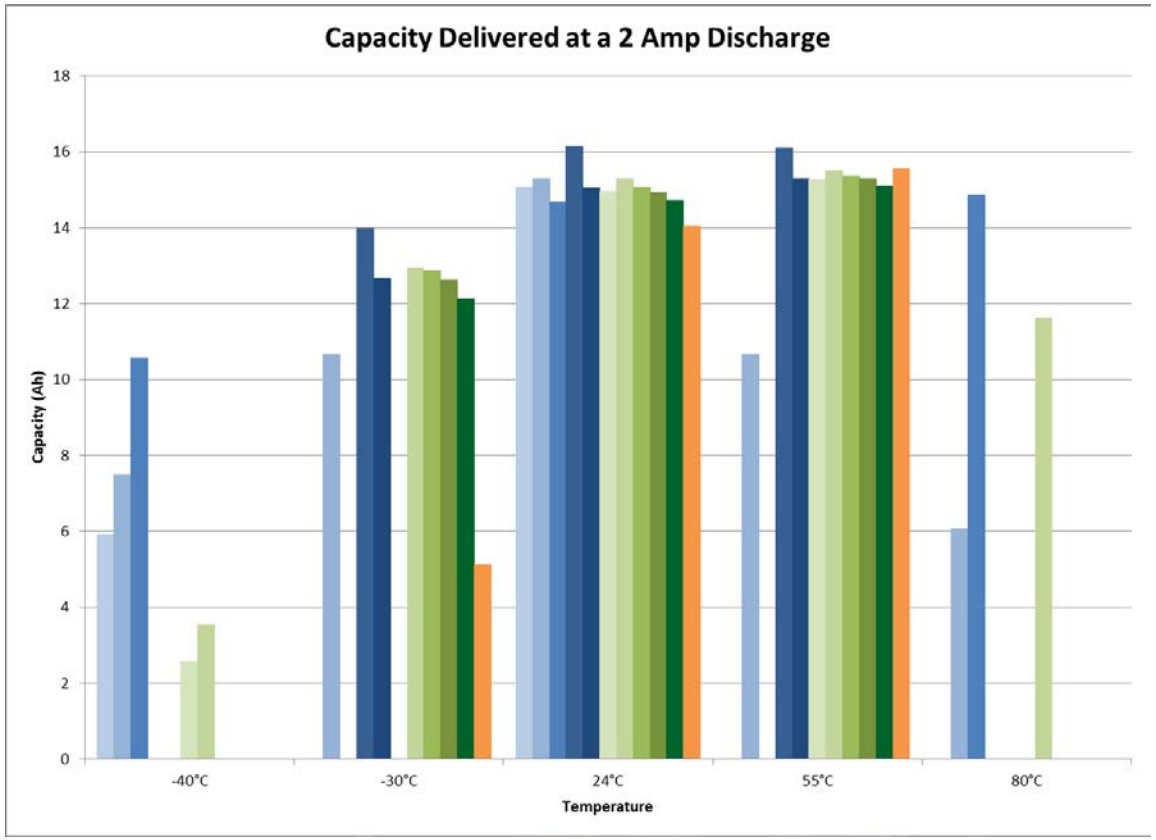



# $Li/CF_X$-$MnO_2$ D CELL DATA

Colors are vendor indicators

Shades of the same color indicate improvements over time

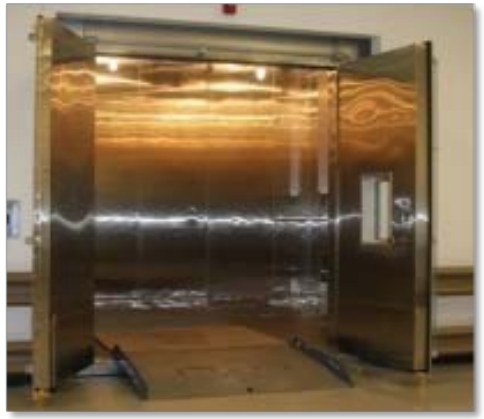


# CAPABILITIES

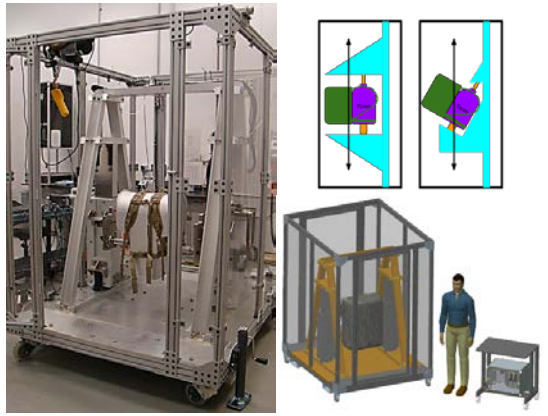
Select CERDEC Power Division laboratory capabilities

Test and Evaluation



Environmental Chambers

Solar Emulator



Warrior Torso Test Stand

| | |
|---|---|
| Modeling, simulation, & prototyping | • SolidWorks, MatLab, LabVIEW, Ansys CFD & Maxwell 3D, Eagle, etc.<br>• PCB printing<br>• 3D printing |
| Test & Evaluation | • Environmental chambers with operating temperature ranges from -50 to +150°C<br>• Hundreds of programmable channels for charging and discharging<br>• Power and Energy evaluation and analysis equipment and software |
| Emulators | • C4ISR load profile emulation<br>• Solar emulator<br>• Torso-wearable energy harvester motion emulator (WATTS) |

# CONCLUSIONS

- SL CFT solutions:
  - Reduce energy demand; add power consumption decision points to acquisition programs
  - Transition away from COTS AA's
- Alternative solutions
  - NGSW & HUD – Li/CFx 2/3 A or other form factor
    - Solar, kinetic, acoustic, wind, and hydro
  - ASA – intelligent power management & e-textiles (technology maturation required)
- Platforms/basing/UxVs:
  - Optimized energy storage, fuel cells, solar, thermoelectric