

# Power Technology Branch

Army Power Division  
US Army RDECOM CERDEC C2D  
Aberdeen Proving Ground, MD



APPT-TR-07-02

## US Army CERDEC: Fuel Cell Testing Update

Presentation for the 2007 Fuel Cell Seminar  
15-19 October 2007, San Antonio, TX

JJ Kowal

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| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                    |                                             |                                                           | Form Approved<br>OMB No. 0704-0188                               |                                 |
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| 13. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                    |                                             |                                                           |                                                                  |                                 |
| 14. ABSTRACT<br><b>The Army's Communications and Electronics Research, Development and Engineering Center (CERDEC) Fuel Cell Team, located at Fort Belvoir, VA, is actively investigating fuel cell power sources from milliwatt to kilowatt levels to fit the Army's power needs. Currently, many smaller fuel cell programs in progress at CERDEC use a packaged non-logistic fuel. Soldier and Man portable fuel cells combine the portability of batteries with the use of an external energy-dense fuel to fill the gap in power between batteries and generators. For this reason, CERDEC is actively working to assess the state of technology and attempt to field fuel cell power systems with several programs showing promise in providing reliable, small, and lightweight Soldier power solutions. This presentation will focus specifically on the development updates in the Soldier and Man portable power program areas. Over the past year several fuel cell power systems have been tested in CERDEC facilities.</b> |                                    |                                             |                                                           |                                                                  |                                 |
| 15. SUBJECT TERMS<br><b>fuel cell, soldier power</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                    |                                             |                                                           |                                                                  |                                 |
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**RDECOM**



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

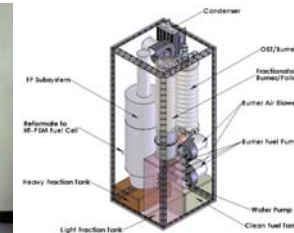
US Army CERDEC: Fuel Cell Testing Update  
2007 Fuel Cell Seminar  
15-19 October 2007, San Antonio, TX

JJ Kowal, Elizabeth Ferry, Jon Cristiani, Terry Dubois, Scott Coombe, Chris Bolton

- Army & CERDEC Fuel Cell Background
  - Current and Future Goals
  - Customers, Partners, Contractors
- CERDEC Fuel Cell Testing
  - Logistic Fuel Processing
  - Soldier Power Systems
  - Solid Oxide Fuel Cells

# Fuel Cell R&D

## *Mission Focus Areas*



**Soldier & Sensor Power  
(1W-100W)**

**Man-Portable Power  
(100W-500W)**

**Auxiliary Power Units  
(500W-10kW)**



**Mission: Rapidly develop and transition suitable fuel cell technologies to applications where they are most needed.**

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

## Soldier & Sensor Power (1W-100W)

### ➤ GOALS:

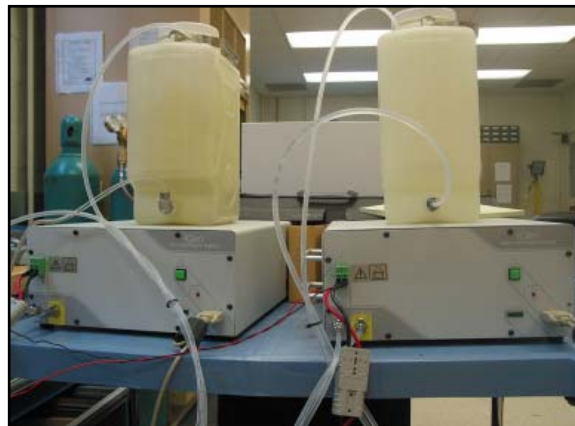
- 20W, package fuel
- 700 Wh/kg (72hr)
- 0.7 kg (dry)
- TRL 6



## Man-Portable Power (100W-500W)

### ➤ GOALS:

- 250W, JP-8
- < 10 kg (dry)
- TRL 5



## Auxiliary Power Units (500W-10kW)

### ➤ GOALS:

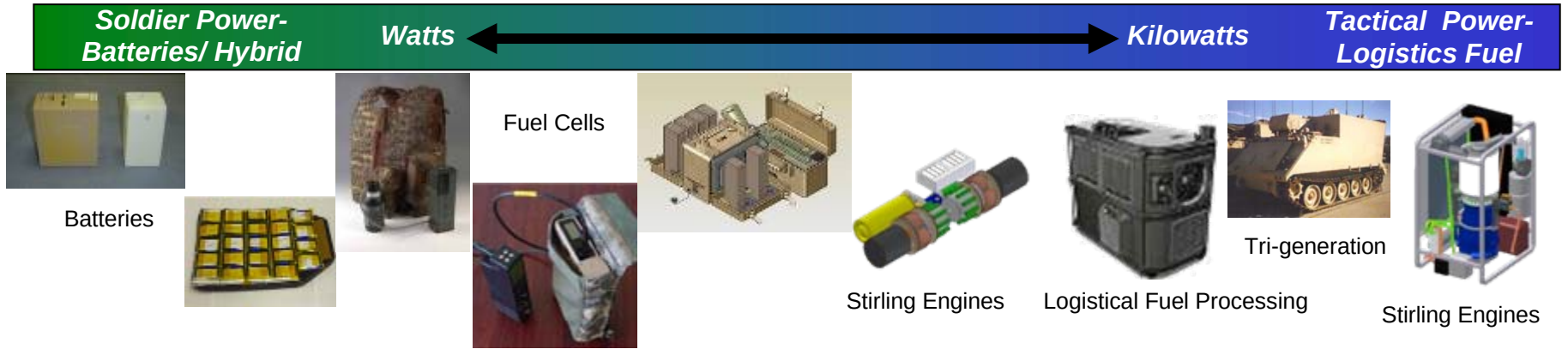
- 2 kW, JP-8
- < 150 kg (dry)
- Noise < 69 dBA
- TRL 5





# Army Power Division

## Mission and Products



### ATO D.CER.2008.08 Power for Dismounted Soldier

- Half-Sized BA5590 Li/CFx Battery
- Half-Sized BA5590 Li-Air Battery
- Soldier Conformal Rechargeable Battery
- Soldier Hybrid Direct Methanol Fuel Cell Power Source
- Soldier Hybrid Fuel Cell Power Source
- Portable Hybrid Power Sources & Chargers, JP-8 fueled

### ATO R.LG.2009.01 Mobile Power

- Transitional Hybrid Power Source, Log-fueled
- Universal Tactical Auxiliary Power Unit
- Co-generation and Tri-generation System

### Technical Objectives

#### • Power for Dismounted Soldier

- |              |           |         |
|--------------|-----------|---------|
| • 1.1lbs     | 400Whr/kg | TRL 4/6 |
| • 1.1lbs     | 600Whr/kg | TRL 3/5 |
| • 3lbs, flat | 140Whr/kg | TRL 4/6 |
| • 25W        | 1.5lbs    | TRL 4/6 |
| • 50-100W    | 3.5lbs    | TRL 4/5 |
| • 150-250W   | 25lbs     | TRL 4/6 |

#### • Mobile Power:

- |              |        |         |
|--------------|--------|---------|
| • 250W-2kW   | 50W/kg | TRL 3/5 |
| • 3-5kW      | 90W/kg | TRL 3/6 |
| • 3kW/18BTUh | 205kg  | TRL 3/5 |

**Army Power Division Mission:** Conduct research, development and system engineering leading to the most cost-effective power, energy, and environmental technologies to support Army's soldier, portable, and mobile applications.

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

## Customers



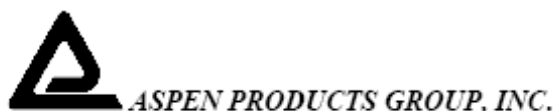
## Partners







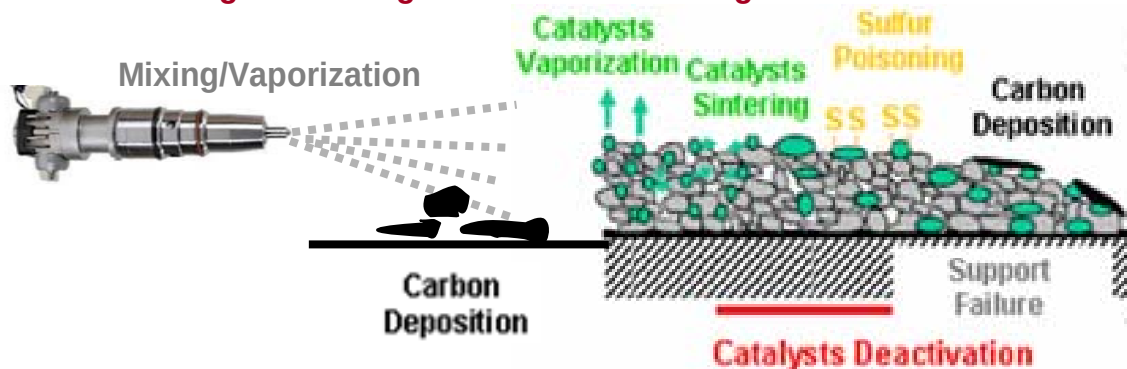
Giner Electrochemical Systems, LLC



Precision Combustion, Inc.



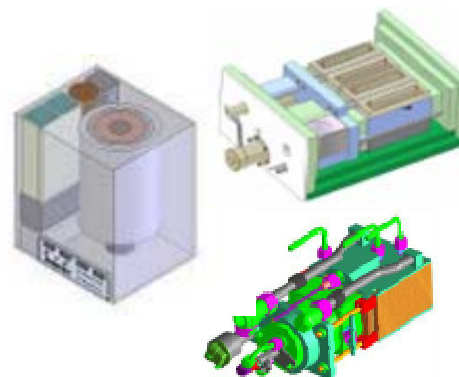
## Technical Challenges with Logistics Fuel Processing



## Logistics Fuel Processing Research

- **Analytical Testing:**
  - Catalyst Evaluation
  - Reformate Composition Analysis
  - Liquid Fuel Analysis
- **Systems Analysis:**
  - Process Modeling
  - Computational Fluid Dynamics

| <b>FY08 Reformation Goals</b>              | <b>2008</b>    |
|--------------------------------------------|----------------|
| System Rated Power (kWe)                   | 0.5 - 5        |
| Fuel (Diesel/JP-8)                         |                |
| Sulfur content (ppm wt%)                   | > 1500         |
| Aromatics (vol %)                          | > 20           |
| Energy Efficiency                          | 70%            |
| Power Density (W/L)                        | 150            |
| Specific Power (W/kg)                      | 170            |
| Start-up                                   |                |
| Cold start (-25degC)                       | < 30 min.      |
| Lab demo (21degC)                          |                |
| Lifetime (w/o replacement)                 | 2000 hrs       |
| Storage Temperature                        | -40 - 52 deg C |
| Maximum H <sub>2</sub> S in Product Stream |                |
| SOFC (mol%)                                | 5 ppm          |
| PEM (mol%)                                 | 50 ppb         |
| Turn Down Ratio                            | > 5 : 1        |
| Acoustic Signature (dBA @ 1m)              | 50             |
| Cost                                       | \$800 / kWe    |



**0.5-5.0 kW<sub>e</sub> Logistics-Fueled Fuel Cell Systems for Auxiliary Power**

## Fuel Cell Auxiliary Power Unit Development

- **Testing & Evaluation:**
  - Prototyping
  - First Article T&E
  - Independent Evaluation
- **Product Development:**
  - Production Engineering
  - Specification Development
  - Life Cycle Cost Analysis



Developed Jointly with CERDEC and DARPA  
 Rated 20W continuous  
 Reformed Methanol Fuel Cell (RMFC)  
 Fuel: 67% Methanol / 33% Water

Dimensions: 9.30" X 5.38" X 1.80"  
 Start Up Time: 23 min. AVG

System Dry Weight: 1.2 kg  
 Fuel Cartridge Weight: 0.35 kg (250 mL)



20W Mission Energy Density:  
 24 hr 210 W-hours/kg  
 72-hr 360 W-hours/kg

Orientation independent except upside down

Started and operated continuous from -5 °C to 45°C

In Development with CERDEC and DARPA  
 Rated 25W continuous  
 Reformed Methanol Fuel Cell (RMFC)  
 Fuel: 67% Methanol / 33% Water

Dimensions: 9.30" X 5.38" X 1.80"  
 Start Up Time: 20 min.

System Dry Weight: 1.2 kg  
 Fuel Cartridge Weight: 0.35 kg (250 mL)

25W Mission Energy Density:  
 24 hr 270 W-hours/kg  
 72-hr 410 W-hours/kg

Orientation independent except upside down





- 10 Rev. A units were taken to the **Joint Readiness Training Center** in Ft. Polk, LA and soldiers were trained on the use of the fuel cell power system
- The JRTC Science and Technology team **keeps soldiers who will soon be deployed informed on new technologies that will be fielded in the near future**



- Soldiers were very pleased with the lighter weight compared to batteries and showed acceptance of the system for certain missions (OP)
- Major issues expressed by soldiers were:
  - Safety
  - High Temp. Operation
  - Integration with Applications



In Development with PM Soldier Warrior and CERDEC

Rated 20W continuous

Direct Methanol Fuel Cell

Fuel: 100% Methanol

Dimensions: 2.31" X 3.06" X 9.75"

Start Up Time: Instant

System Weight: 1.18kg

Fuel Cartridge Weight: 0.47 kg (500 mL)

20W Mission Energy Density:

24 hr 291 W-hours/kg

72-hr 556 W-hours/kg

Orientation dependent



In Development with CERDEC and AFRL  
 Rated 30W continuous  
 PEM Fuel Cell  
 Fuel: Sodium Borohydride ( $\text{NaBH}_4$ )

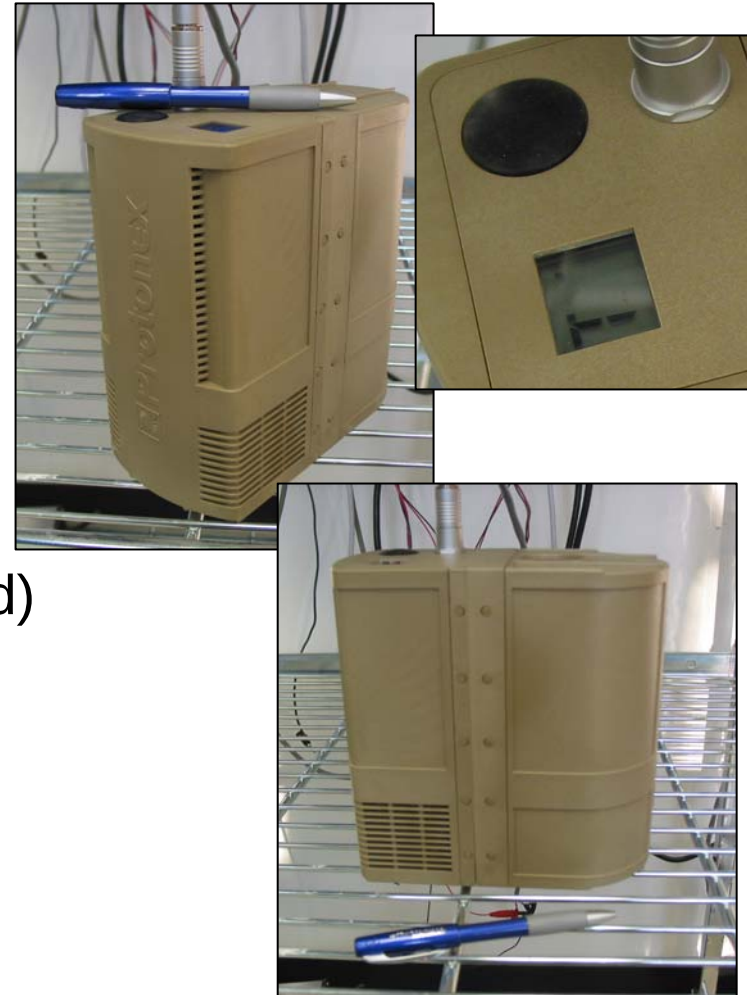
Dimensions: 7.2'' X 7.2'' X 3.6''  
 Start Up Time: <1 min.

System Dry Weight: 0.96 kg  
 Fuel Cartridge Weight: 1.32 kg (hydrated)

20W Mission Energy Density:  
 24 hr 200 W-hours/kg  
 72-hr 350 W-hours/kg

Orientation independent

Operated continuous from -5 °C to 45 °C







In Development with CERDEC and SOCOM

Rated 45-55W continuous (user selectable 24/12 VDC)

PEM Fuel Cell

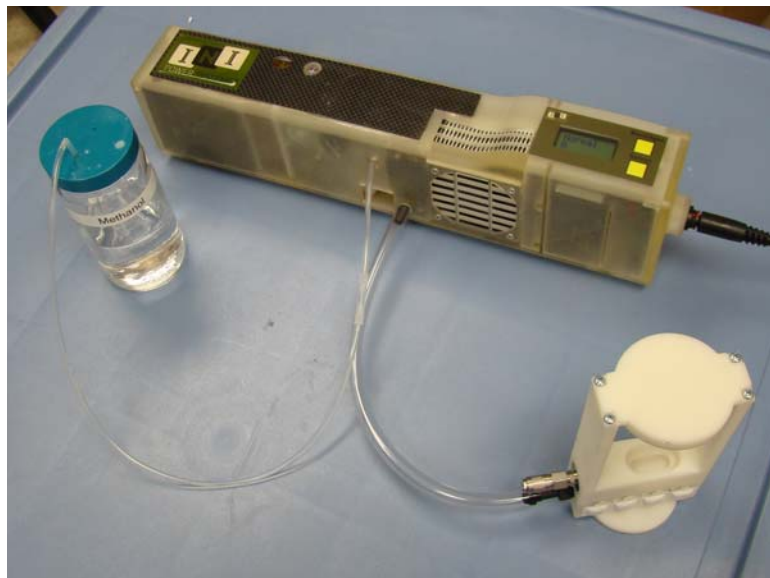
Fuel: Metal Hydride

Dimensions: 11" X 6.4" X 3.5"  
Start Up Time: immediate

System Dry Weight: 2.86 kg  
Fuel Cartridge Weight: 2.30 kg  
System + Fuel Weight: 5.16 kg

Metal hydride is used to fuel this technology demonstrator and is not the final fueling solution

Started and operated from 0 °C to 40 °C



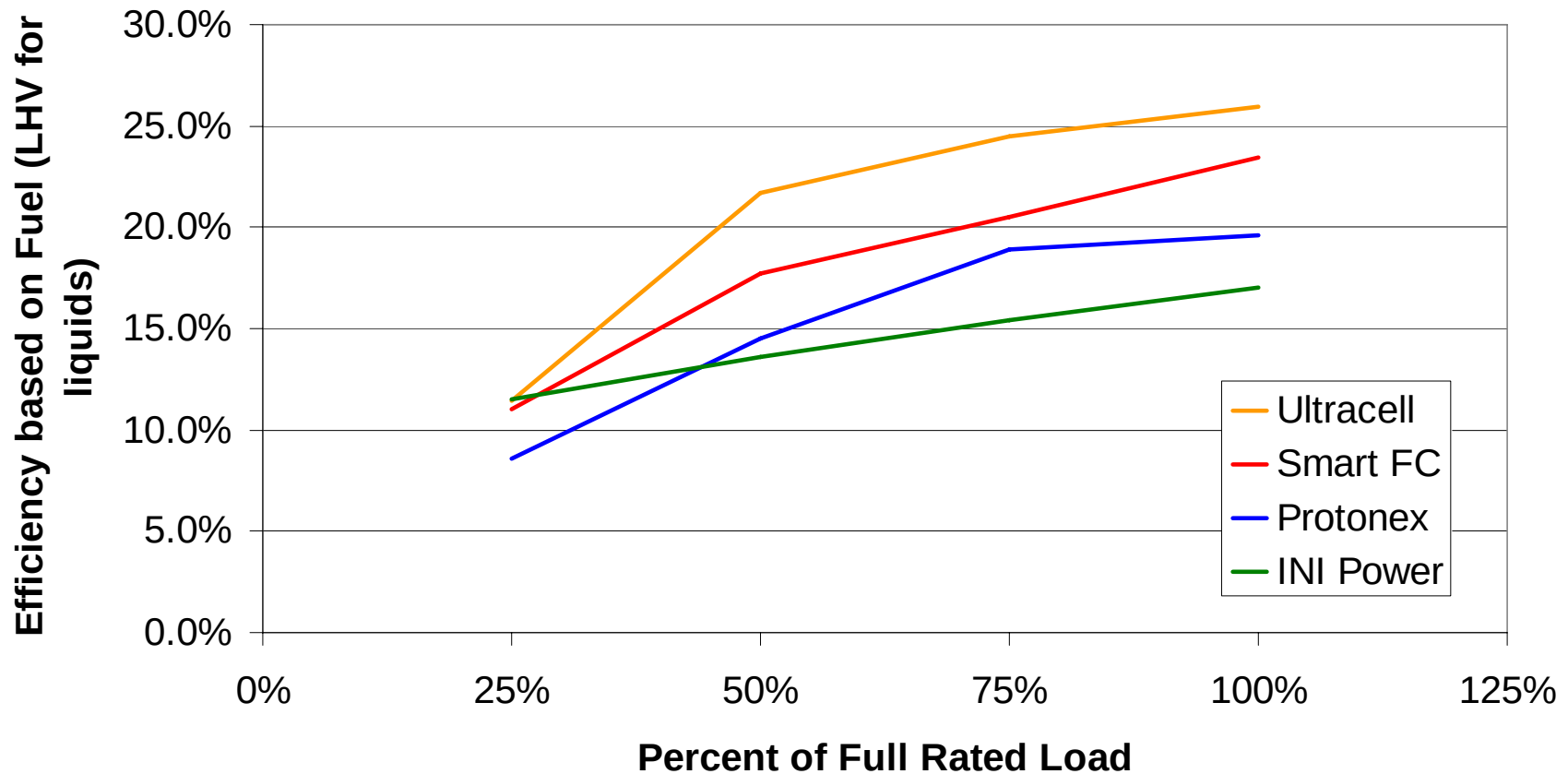
Tested at CERDEC Labs  
Rated 15W continuous  
Direct Methanol Laminar Flow Fuel Cell  
Fuel: 100% Methanol

Start Up Time: instant

System Dry Weight: 1.8 kg

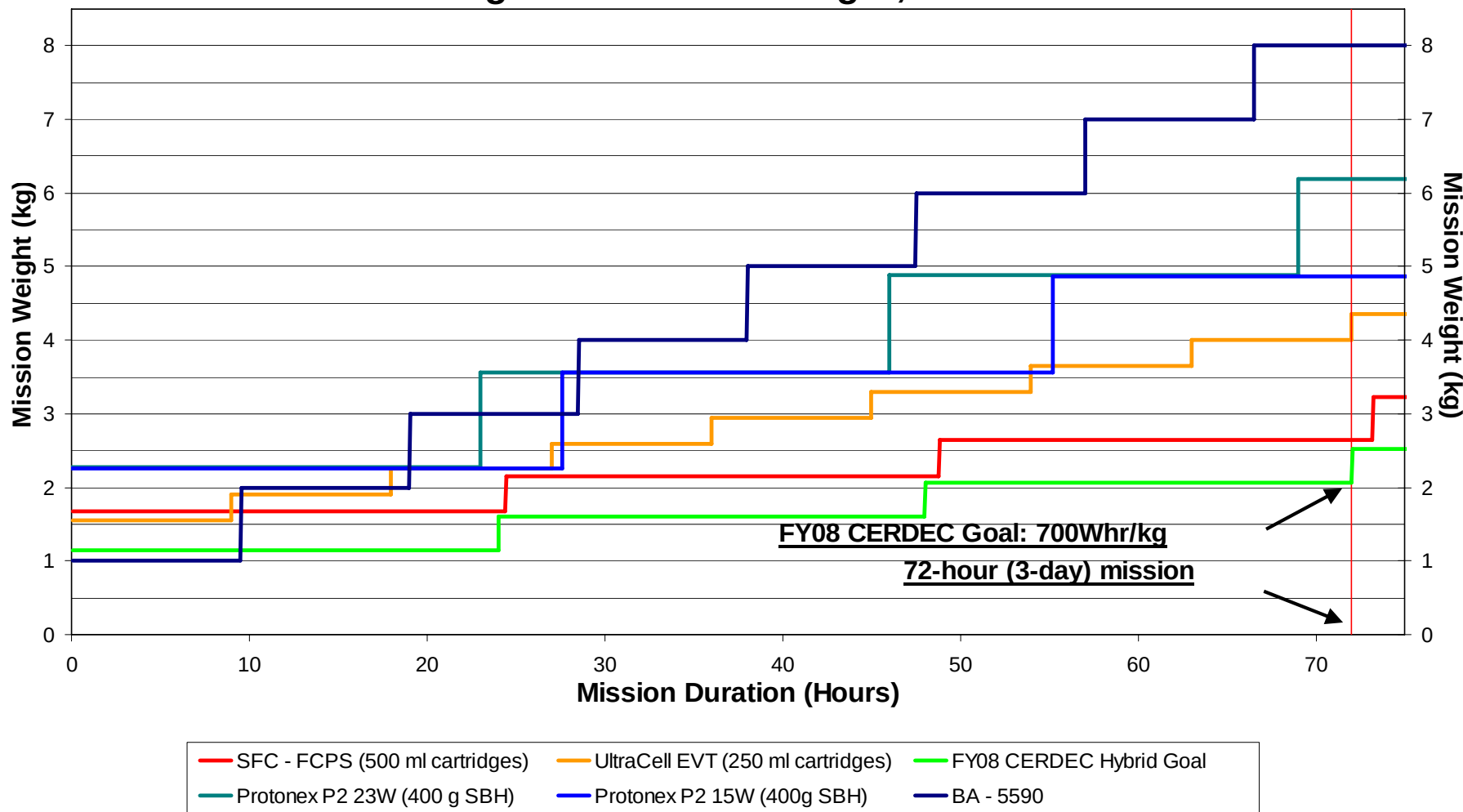
15W Mission Energy Density:  
24 hr 160 W-hours/kg  
72-hr 350 W-hours/kg  
(cartridge weight not included)

## System Efficiency vs Load



**Efficiency is not the whole story...**

## Mission Length vs. Mission Weight, 20W Continuous





| Unit            | Pros                                 | Cons / Issues                                    |
|-----------------|--------------------------------------|--------------------------------------------------|
| INI Power       | Potentially lighter weight           | Orientation, Shock/vibration, Technical Maturity |
| Jadoo           | Reliability, Durability, Orientation | Currently heavy, Supportability                  |
| Protonex        | Durability, Orientation              | Supportability, Reliability                      |
| Smart Fuel Cell | Size, Weight                         | Orientation, Supportability, Reliability         |
| Ultracell       | Supportability, Durability           | Orientation, Emissions, Reliability              |

Issues for all: Safety (disruptive technology), High Temp Operation

Both currently undergoing test plan at CERDEC

## Adaptive Materials Inc. (AMI)

- 50 Watts
- System Weight: 2.3 kg
- Cartridge Weight: 0.4-0.9 kg



## Nanodynamics

- 50 Watts
- System Weight: 4.5 kg
- Cartridge Weight: 0.8 kg



## Advantages

- Higher efficiency
- Potential cost benefits
- Long, continuous run times
- Lighter weight for longer missions (especially over 72 hours)



## Drawbacks

- Air-breathing
- More complex
- \*Cost
- \*Reliability
- \*Robustness



\* High potential for improvement

- The development of fuel cells is promising but there are still technical challenges to solve to **transition from the lab to the battlefield**
- Presently, packaged fuel is acceptable **for units under 500W**
- There is not yet a **clear** technology, fuel strategy, or power level that is most suitable for soldier power applications
- Fuel cells will only be used where appropriate when the technologies are sufficiently developed and **commercially viable**