Future Trends and Thrusts for Army Manportable Power Sources

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US Army RDECOM CERDEC
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AGENDA

• Soldier Power Requirements
• Science & Technology Programs
• Solutions Available Today
• What’s Next
  - High Energy Batteries
  - Hybrid Power Sources
  - Fuel Cells
  - Stirling Engine
• Summary
Our Challenge

...Lighten Their Load
**Future Warriors**

- **System Run Time**
  - **24 hrs**
  - **72 hrs**
  - **96 hrs**

**System Power Draw**

- **Batteries**
  - Li-MnO2
  - Li-Ion
  - Zn-Air

- **Fueled Power Sources**
  - MeOH Fuel cells
  - Stirling Engines

**Hybrid Power Systems**

- Log Fuel Cell (SOFC)
- Log Stirling
- Li-Air

**Legend**:

- **Electronic Devices**
- **Power Source Technologies**
- **System Developers MUST Make This Happen!**

**Power Management Can Help Bridge This Gap**

**MORE POWER ...... ...... LESS WEIGHT**
**Purpose:**
Develop component technologies for power systems for increased mission duration while decreasing logistics burden

**Products:**
- **Soldier**
  - <500 Watt Man-portable field battery charger and improved rechargeable batteries
  - Hybrid power source (fuel cell & battery)
  - Li-Air battery and improved photovoltaics

**Payoff:**
- Provides savings by reducing number of batteries required for soldiers. Increased power/energy adds mission capability.
- **Transitions:**
  - Hybrid demonstrators to PM-Soldier in FY06; improved technology for Ground Soldier System in FY08
Purpose: To provide the Warfighter with small lightweight power sources that maximize specific energy for core Soldiers, integrated Soldier systems and sensors.

Products:
- Prototype Half-size/2X energy primary C4ISR batteries
- Conformal rechargeable Soldier system batteries
- Soldier mission extending hybrid fuel cell system
- Logistic fuel (JP8) powered Soldier portable power source to enable tactical battery recharging

Payoffs:
- Reduction in Soldier weight load
- Extended mission times in Soldier and sensor applications
- Battlefield energy independence; reduced logistics
- Increased Soldier mobility, sustainability, survivability and deployability by providing higher energy sources
- Power sources and charging technologies that meet Soldier-as-a-System requirements
Solutions Available Today

**Batteries With State-Of-Charge-Indicators**

- Instantly Indicates Remaining Capacity in BA-5590A and BA-5390A
- Adds No Additional Weight to Battery
- BA-5590A/U (Li/SO₂)
  - All Production Converted to SOCI
- BA-5390A/U (Li/MnO₂)
  - In Stock & Available Now

**High Energy Rechargeable Li-Ion Batteries**

BB-590 Nicad, BB-390 NMH, BB-2590, BB-X590 Batteries and Primary BA-5590 Discharge at 2A

![Graph showing voltage and capacity](image)

- BB-2590 Li ion Fielding 2002
- BA-5590
- BBX590 Polymer Prototype

BB-590 Nicad in Army for 20 years
BB-390 NMH Fielded in 1995

**Li-Ion Rechargeable Batteries**
Solutions Available Today (cont)

**AA 8 - PACK SCAVENGER**

Portable Fast Battery Charger for AA-size Cells

- **8 - PACK SCAVENGER**
- **Any 12 VDC source**

### Charging Sources

<table>
<thead>
<tr>
<th>Charging Sources</th>
<th># of AA-cells Charged</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA-8180</td>
<td>128</td>
</tr>
<tr>
<td>BA-8150</td>
<td>80</td>
</tr>
<tr>
<td>BA-8140</td>
<td>64</td>
</tr>
<tr>
<td>BA-5590</td>
<td>24</td>
</tr>
<tr>
<td>BA-5390</td>
<td>32</td>
</tr>
<tr>
<td>BB-390</td>
<td>20</td>
</tr>
<tr>
<td>BB-2590</td>
<td>24</td>
</tr>
<tr>
<td>SP4-solar panel</td>
<td>∞</td>
</tr>
<tr>
<td>Vehicle Adapters</td>
<td>∞</td>
</tr>
</tbody>
</table>

- Recharges commercial AA cells
- Charges 8 cells in 100 minutes
- Scavenges un-used energy from Military power sources
- Saves 25lbs per Platoon over 5 days

5 oz.  <$200
55 W Solar Charger - Soldier

- Charges two 6.2Ah BB-2590 Li-Ion batteries in ~5-6 hrs
- Flexible Panel Design
- Anti-Glint, Inlaid Cammo

<table>
<thead>
<tr>
<th>Maximum Power (Watts)</th>
<th>Nominal Voltage (Volts)</th>
<th>Maximum Current (Amperes)</th>
<th>Weight (lbs.)</th>
<th>Deployed Area length x width (in.)</th>
<th>Packed Volume length x width x height (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.0</td>
<td>16</td>
<td>2.8</td>
<td>4.4</td>
<td>55 x 32</td>
<td>11 x 9 x 1.3</td>
</tr>
</tbody>
</table>

Renewable Energy – Lighten Soldier Loads, Reduce Logistics, Lower Costs
AA-Cell Solar Charger - Soldier

- Charges four 2.3Ah AA NiMH batteries in ~4 hrs
- Flexible Panel Design
- Anti-Glint

- 9” x 5” x 2” folded
- 9” x 25”, deployed w/shade
- 0.87 lbs without batteries

Renewable Energy – Lighten Soldier Loads, Reduce Logistics, Lower Costs
Rucksack Portable Power System - Soldier

- DC/AC power output and Charger for military batteries.
- In field use for unattended ground sensors (UGS) and surveillance systems.

Soldier Feedback:
“I wanted to thank you again for everything. The camera system [using a REPPS system for 24 hour operation] has been a huge success thus far and I believe has saved lives by keeping our soldiers out of harms way.”
SPC Fiorino, David G.

Renewable Energy – Lighten Soldier Loads, Reduce Logistics, Lower Costs
Extended Run-Time
Lithium Carbon Monofluoride (Li/CFx) Batteries

Objective
The development of high energy density Li/CFx batteries allow for:
- A BA-5590 replacement with twice the run time at equivalent weight and volume
- A half-sized BA-5590 with equivalent run time at half the weight and volume

Technology

<table>
<thead>
<tr>
<th>Disposable Battery</th>
<th>Chemistry</th>
<th>Weight (lbs)</th>
<th>Energy (Wh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA-5590</td>
<td>Li/SO2</td>
<td>2.16</td>
<td>200</td>
</tr>
<tr>
<td>BA-5390</td>
<td>Li/MnO2</td>
<td>2.94</td>
<td>300</td>
</tr>
<tr>
<td>BA-XX90</td>
<td>Li/CFx</td>
<td>2.2</td>
<td>400</td>
</tr>
</tbody>
</table>

Twice the Mission Runtime at same weight versus the BA-5590

Participants
- Sponsor (s): U.S. Army RDECOM CERDEC
- Gov’t Contributors: PM JTRS Ground Domain HMS, USAIC
- Industry: Five Known Interested Parties
## What’s Next – Hybrid Power Sources

### Hybrid Power Mission Extender

<table>
<thead>
<tr>
<th>Case Study:</th>
<th>For a 72hr Mission How many batteries/hybrids do we need to support the Land Warrior System?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Weight</th>
<th>Volume</th>
<th>Energy (available)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-145 Lithium Ion (Baseline)</td>
<td>13.2 lbs</td>
<td>216 in³</td>
<td>870 Wh</td>
</tr>
<tr>
<td>Gen 4 Zinc-Air/Li-145 Hybrid</td>
<td>9.4 lbs</td>
<td>218 in³</td>
<td>1145 Wh</td>
</tr>
<tr>
<td>UltraCell Fuel Cell Li-145 Hybrid</td>
<td>6.1 lbs</td>
<td>94 in³</td>
<td>895 Wh</td>
</tr>
</tbody>
</table>
What’s Next - Hybrid Power Sources

- Extends Mission Runtimes
- Reduces the Battery Weight and Volume Required for Multiple Day Operation
- Reduces Logistics Costs

Hybrid Power Sources

- Interface Electronics
- High Energy Density Component (refillable at low cost)
- High Power Density Component (rechargeable with high cycle life)
- Pulse or Intermittent Power Load
- Sealed Pb-Acid / Zinc-Air Battery/Battery Hybrid for SATCOM Radios
- Lithium Ion / Zinc-Air Battery/Battery Hybrid for UGS
- Lithium –ion Battery / Solar Panel Hybrid for UGS
- Zinc-Air Battery / Capacitor Hybrid for Javlin
What’s Next - Hybrid Power Sources

Battery Hybrid Power Source - Soldier

Zinc-Air Battery
- Nominal potential: 14 V
- Nominal rating: 15 Ah
- Weight: 900 g
- 42- Cell “AA” Design:
- 14S3P cell configuration

Li-Ion Battery
- Nominal potential: 15.2 V
- Nominal rating: 7.2 Ah
- Weight: 882 g (1.94 lbs)
- 16 18650G 2 Ah cells
- 4S4P cell configuration

200 Wh/kg

Provides 1/3 Weight Reduction Over Rechargeable Alone for 24 Hours
What’s Next - Fuel Cells

20W DMFC - Soldier

- Dimensions: 9.75” x 2.31” x 3.06”
- System Dry weight: 1.18 kg
- Fuel cartridge: 500 ml / 0.47 kg
- 24 hr mission weight: 1.6 kg
- 72 hr mission weight: 2.6 kg
- Efficiency: 22.4%
- Fuel Cartridge Duration: 24 hours
- Fuel is 100% methanol at low temp; water/methanol mix at high temp >40ºC
- 72 hour mission energy density 554 W-hr/kg

Mission Extender Power Source, Battery Charging
What’s Next - Fuel Cells

25W RMFC - Soldier

CERDEC collaboration with DARPA

Dimensions: 9.3” X 5.38” X 1.8”
System Dry Weight: 1.2 kg
Fuel Cartridge Weight: 0.325 - 0.350 kg

24 hr mission weight: 2.25 kg
72 hr mission weight: 4.23 kg

Efficiency: 23.8% @ 20 watts
Fuel Cartridge Duration: 9 hours

72 hr mission energy density: 340 Wh/kg
20 W Solid Oxide Fuel Cell - Portable

CERDEC collaboration with DARPA and SOCOM

- Power: 20 W
- Start Up Time: 20 minutes
- Dimensions: 11.6” X 3.7” X 5.11”
- System Weight: 1.55kg
- Fuel Cartridge Weight: 0.406kg (propane/butane)

- 24 hr mission weight: 1.95 kg @ 20 Watts
- 72 hr mission weight: 2.77 kg @ 20 Watts

- Fuel Cartridge Duration: 25 hours @ 20 Watts
- Energy Density: 520 W-hours/kg
  (72 hrs@ 20 watts)
Developing a 250 W portable fuel cell system operating on de-sulfured JP-8 fuel.

Current system uses Propane/Butane fuel.

Partial Oxidation (POX) reformer design for JP-8. Air oxidation, smaller reactor

<10kg target for 250 W.
What’s Next - Stirling Engine - Portable

CERDEC collaboration with DARPA

• Air cooled design
• Propane (FY06)
• JP-8 fuel (FY08)

Projected JP-8 160\textsubscript{We} Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-end Temperature</td>
<td>650 °C</td>
</tr>
<tr>
<td>Cold-end Temperature</td>
<td>70 °C</td>
</tr>
<tr>
<td>Nominal Operating Frequency</td>
<td>102 Hz</td>
</tr>
<tr>
<td>Nominal Voltage</td>
<td>28 V\textsubscript{DC}</td>
</tr>
<tr>
<td>Nominal Engine/ Alternator Output Power</td>
<td>160 W\textsubscript{e}</td>
</tr>
<tr>
<td>Fuel</td>
<td>JP-8</td>
</tr>
<tr>
<td>Engine/ Alternator Efficiency</td>
<td>36 %</td>
</tr>
<tr>
<td>Generator System Efficiency (without parasitics)</td>
<td>24 %</td>
</tr>
<tr>
<td>Net System Efficiency</td>
<td>20 %</td>
</tr>
<tr>
<td>System Weight</td>
<td>&lt;10kgs</td>
</tr>
</tbody>
</table>

Platoon Level Portable Power Source, Battery Charging – JP-8 Target Fuel
• Power Source Technologies continue to improve.

• Power Sources will always be seen as a weight/volume/logistic burden unless taken in as part of the equipment system level designs, which must include power management.

• Power Management of the Systems to a Fixed Power Budget will reduce the weight, volume, and logistic costs for power and energy.