FUEL CELL POWER SYSTEMS FOR EXTENDED DURATION UAV AND UGV SYSTEMS

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THE NEXT GENERATION OF PORTABLE POWER™
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AGENDA

- Company Overview

- Technology and Products

- Markets

- Ultra High Performance Power Systems
  - UAV Power Systems
  - UGV Power Systems

- Summary
PROTONEX OVERVIEW

- Leading provider of 10 - 1000 watt fuel cell based power solutions
  - Portable, remote and mobile power
  - Targeting applications underserved by batteries and small generators

- Strong traction to date with US Government agencies
  - Over $35m* in program value with Air Force, Army, Navy, SOCOM, DARPA, DOE, NASA…

- Well positioned to deliver product for military and commercial applications
  - Offering PEM and SOFC products to meet diverse application needs
  - Capable of high performance and low cost

- Key strategic partnerships in place
  - Parker Hannifin, Cummins, Raytheon, CBC, Northrop Grumman, US Military

- Headquartered in Southborough, Massachusetts
  - Over 90 employees today and growing

- Publicly traded on the AIM market of the LSE - symbols: PTX and PTXU

* Includes contracts awarded to Mesoscopic Devices before acquisition in April 2007
FUEL CELL SYSTEMS

Fuel cell based power systems provide many advantages over existing technologies

VS. ADVANCED BATTERIES
- Reduced weight
- Extended run times
- Reduced size
- Lower life cycle cost
- Enables new applications

VS. ICE GENERATORS
- Greater efficiency
- Reduced emissions
- Lower noise level
- Lower heat signatures
- Lower life cycle cost
TWO TECHNOLOGY PLATFORMS AT PROTONEX

- **Proton Exchange Membrane (PEM)**
  - Fuels
    - Methanol
    - Chemical Hydride
    - Hydrogen
  - Operating temperature: 50°C – 75°C
  - Readiness: now

- **Solid Oxide Fuel Cell (SOFC)**
  - Fuels
    - Propane
    - Gasoline, Diesel and JP-8
    - Biofuels
  - Operating temperature: 650°C - 750°C
  - Readiness: 1-2 years

Fuel flexibility to address multiple applications
Strong overlap between PEM and SOFC
CURRENT PRODUCTS IN DEVELOPMENT

- Fully integrated power systems - fuel in, power out
- PEM or SOFC core technology
  - Similar control and power management components
  - Hybridized with batteries to “drop into” existing apps
- Supporting multiple fuel types
  - Hydrogen, chemical hydrides, methanol, propane – **today**
  - Gasoline, kerosene, diesel, JP8, biofuels – **future**
- Strong and expanding IP base
  - 43 patents issued/pending
TARGETING A BROAD RANGE OF POWER APPLICATIONS

<table>
<thead>
<tr>
<th>MILITARY</th>
<th>GOVERNMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field and portable generator</td>
<td>Field and portable generator</td>
</tr>
<tr>
<td>Vehicle auxiliary power units</td>
<td>Emergency backup systems</td>
</tr>
<tr>
<td>Squad battery charger</td>
<td>First responder equipment</td>
</tr>
<tr>
<td>UAV and UGV propulsion</td>
<td>Vehicle auxiliary power units</td>
</tr>
<tr>
<td>Soldier or remote power source</td>
<td>Persistent surveillance</td>
</tr>
<tr>
<td>Power management devices</td>
<td></td>
</tr>
<tr>
<td>Pulse™ M250, J500</td>
<td>Quantum™ M250, D500</td>
</tr>
<tr>
<td>Pulse™ UAV, UGV</td>
<td>ProCore™ M250</td>
</tr>
<tr>
<td>Pulse™ P125</td>
<td>Procore™ UAV</td>
</tr>
<tr>
<td></td>
<td>Xtend™ M250, M500, M1000</td>
</tr>
</tbody>
</table>

Protonex products are “horizontal” in nature, addressing many diverse applications currently using batteries or generators.
MAJOR SEGMENTS AND APPLICATIONS – Non Military

DC Backup Power
- Telecom Wireless
- Telecom Wireline
- Traffic Systems
- Broadband / CATV
- Critical Systems
- Security Systems

Emergency
- Homeowner Emergency
- Battery Chargers
- Communications Equipment
- Emergency Response
- Security Systems
- Traffic Control Systems

Recreation
- Portable Power
- RV Power
- Marine Power
- Campsite Power
- Remote Cabins
- Expeditions

Professional
- Scientific Equipment
- Power Tools
- Battery Charging
- Communication Systems
- Security Systems
- Video Equipment

Mobile
- Electric Motorbikes
- Personal Mobility
- Vehicle APUs
- Golf / Utility Carts
- Mobile Signage
- Commercial Robots

Renewable
- Solar Power Systems
- Wind Power Systems
- Remote Monitoring
- Remote Signaling
- Off-Grid Homes
ULTRA HIGH PERFORMANCE POWER SYSTEMS
Air Force and Navy Programs
- Significantly extended mission time
- 2-4 times the energy density of batteries
- Equivalent performance (power)

- Broadens mission capabilities
- Ability to carry greater payload
- Silent, reliable power
<table>
<thead>
<tr>
<th>Propulsion System</th>
<th>Flight Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical battery solution</td>
<td>1 - 2 hours</td>
</tr>
<tr>
<td>Protonex fuel cell system with available compressed hydrogen tank</td>
<td>3 hour 19 min.</td>
</tr>
<tr>
<td>Protonex fuel cell system with compressed hydrogen tank built in</td>
<td>6-24 hours</td>
</tr>
</tbody>
</table>

300W net power @ <1kg
CHEMICAL HYDRIDE FUEL CARTRIDGE
SODIUM BOROHYDRIDE [NaBH₄]

- Simple design
- High storage metrics
- Cartridge system
- Hydrogen as needed
- Non-flammable
- Non-toxic
- Wide temperature range
- Low cost materials
FIELD WATER FOR CARTRIDGE HYDRATION

- Chemical hydride system can use a wide variety of field waters

- Shown to be robust to contamination from:
  - Tap water
  - Fresh water (lake, stream)

- Waste waters, such as grey water or bodily fluids may be used with filtration

- Advantage: Warfighter may carry lighter, dry cartridge into field and use available water for power
HAND LAUNCHABLE UAV POWER SYSTEMS

- Chemical hydride fueled [NaBH₄]
- Fuel cell system 100-200W

Flight time targets:
- Current battery systems
  - 2-4 hrs
- FY07 – 6+ hrs
- FY08 – 10+ hrs

Demonstrate fuel cells in currently fielded UAVs
- PUMA selected for initial integration
- Minimal changes to existing plane

Air Force Research Laboratory
FA8650-06-C-2677
Early flight results (5/4/07)

- 4 hr 53 min flight
- Wind conditions (3-10 m/s)
- Average power >150W with higher winds (>7 m/s)
- 55 min. additional airtime remaining in cartridge
UAV ENDURANCE PROGRESS

ENDURANCE HOURS

DATE OF FLIGHT

Jun-05 Dec-05 Jun-06 Dec-06 Jun-07 Dec-07 Jun-08

9:05h TRL 7 12/6/07
## UAV SIZE & CLASS

<table>
<thead>
<tr>
<th>UAV Name</th>
<th>Manufacturer</th>
<th>Power Plant</th>
<th>Weight</th>
<th>Wingspan</th>
<th>Endurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAVEN B</td>
<td>Aerovironment</td>
<td>Electric Motor</td>
<td>4.2 lbs</td>
<td>53”</td>
<td>90 min</td>
</tr>
<tr>
<td>PUMA</td>
<td>Aerovironment</td>
<td>Electric Motor</td>
<td>13 lbs</td>
<td>102”</td>
<td>150 min</td>
</tr>
<tr>
<td>STALKER</td>
<td>Lockheed Martin</td>
<td>Electric Motor</td>
<td>14 lbs</td>
<td>120”</td>
<td>120 min</td>
</tr>
<tr>
<td>DESERT HAWK III</td>
<td>Lockheed Martin</td>
<td>Electric Motor</td>
<td>6.5 lbs</td>
<td>54”</td>
<td>90 min</td>
</tr>
<tr>
<td>SILVER FOX</td>
<td>Advanced Ceramics Research</td>
<td>Gas Engine</td>
<td>26.2 lbs</td>
<td>94”</td>
<td>600 min</td>
</tr>
<tr>
<td>SCAN EAGLE</td>
<td>Boeing</td>
<td>Gas Engine</td>
<td>39.6 lbs</td>
<td>120”</td>
<td>900 min</td>
</tr>
</tbody>
</table>
HYBRID POWER SYSTEM FOR TALON ROBOT

High Specific Energy
Fuel Cell

High Specific Power
Hybrid battery

Fuel cell power

Time

Power to TALON

Time
ENERGY STORAGE COMPARISON

Greater than 2X more energy storage compared to advanced batteries
Endurance Testing
Conducted at Foster Miller, 14AUG08

Average power required is lower than fuel cell average power (upward trend in voltage)

Full speed dash power required is greater than 180W original

45 km!
# Fuel Cell Power System - Talon Performance Summary

<table>
<thead>
<tr>
<th></th>
<th>Target Performance</th>
<th>Demonstrated System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total energy capacity</strong></td>
<td>750 W·hr</td>
<td>1396 W·hr</td>
</tr>
<tr>
<td><strong>Continuous average power capability</strong></td>
<td>180 W</td>
<td>210 W</td>
</tr>
<tr>
<td><strong>Peak power capability</strong></td>
<td>1260 W</td>
<td>1305 W</td>
</tr>
<tr>
<td><strong>Voltage limits</strong></td>
<td>42-32</td>
<td>43.5V-35V</td>
</tr>
<tr>
<td><strong>Peak current delivery</strong></td>
<td>30A</td>
<td>30A</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>16 lbs</td>
<td>14 lbs</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>Fits within existing Talon Battery Space</td>
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</tbody>
</table>
POTENTIAL MISSIONS FOR LONG DURATION ROBOTS

- Border / perimeter patrol
- Identification / clearing of land mines
- Material transport at the squad level
- Surveillance, long term recon
- Combat engagement
WHY PROTONEX?

- Fuel cell team with pragmatic strategies
  - Portable sub-kilowatt focus - best fuel cell opportunity
  - Securing world-class commercial partners
  - Company delivering on commitments

- Protonex is well-positioned to capitalize on the global demand for environmentally friendly and energy efficient power

WHY FUEL CELLS FOR UAVS / UGVs?

- Hybrid power systems with 2-4x energy of best battery

- More mission capability:
  - More time on station
  - More data
  - More functionality

Not just another fuel cell company…