Fuel Cells for Unmanned Systems Propulsion

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Value Proposition
Fuel Cells for Unmanned Systems

Fuel Cell Power Systems can augment traditional propulsion and auxiliary power systems → Increasing platform performance and utility

• Fuel Cell vs. Battery Systems
  o Fuel cells provide significant improvement in energy density (2-5x LiPO batteries)
  o Extend mission times and provide more data to the user

• Fuel Cell vs. Internal Combustion Engines
  o Fuel cell system provide more reliable performance than ICE (MBTF improvements of >5x)
  o Lower operational costs and better platform reliability

Takeaways:
  o Fuel cells will be instrumental in the second wave of UxV applications
  o Fuel cells can improve:
    • Persistence
    • Operating costs
  o Integration of the power systems is key to maximize results
  o Protonex / Ballard can provide design guidance to full systems manufacturer
    • Includes stacks, fuel subsystems, power electronics and controls
Protonex Unmanned Systems Experience

• Protonex PEMFC systems have strong unmanned system heritage:
  o More than a decade of development
  o Implementation on multiple platforms and customers
  o 100’s of hours of accumulated flight time
  o 3 active UAV power system development projects

• Leverage several key Protonex technologies:
  o Power dense PEM fuel cell stacks
  o High utilization (>99%) H₂
  o Energy dense SBH fuel cartridges
  o Efficient power management electronics
Protonex PEM Fuel Cell Technology

- **Power dense PEM fuel cell stacks**
  - Adhesively bonded construction
  - Rugged and highly durable
  - Liquid cooled, closed cathode design
  - MEA agnostic

- **Specialized stack design for UAV systems**
  - Compact and lightweight
  - Demonstrated designs up to 1.5 kW
  - Up to 100 kW with Ballard technology
  - Specific power > 1,400 W/kg
Complete PEM Fuel Cell Power Systems

- **SBH systems targeted to Group 1 UAS (<20 lb)**
  - Provide 2-3x specific energy of LiPo battery
    - Dramatic improvement in persistence of the platform
  - Single-use fuel cartridges
  - Hybridized with LiPo battery for power bursts

- **Compressed/liquid H₂ systems for Group 2 UAS (21-55 lb)**
  - Low acoustic signature relative to IC engines
  - Exceptional throttle control
  - Reduced maintenance
  - Reduced operational cost

SBH UAV Power System
350 W w/ Peaking Capability

550 W Compressed H₂ UAV Power System
Unmanned Aerial Systems Applications

• **550 W UAV Power System**
  o Designed for compressed/liquid H₂ systems
  o Demonstrated >99% H₂ utilization
  o Total mass = 1 kg (fuel cell, BOP, and electronics)

• **Powers Naval Research Lab (NRL) Ion Tiger platform**
  o 1,100 Wh/kg and 24 hr endurance on compressed H₂
  o 48 hr endurance on liquid H₂

• **Powers NRL Sea Robin/XFC platform**
  o First submarine launched UAV
1.2 kW UAV Fuel Cell Power System Overview

- Targeted for application to Group II UAS (9.5 – 25 kg)
- Designed for operation on compressed/liquid H₂
- >4x energy density of secondary batteries
- System benefits relative to IC engines:
  - Low acoustic signature
  - Exceptional throttle control
  - Reduced maintenance
- Powers Insitu ScanEagle platform
  - Ground testing completed 2016
  - Gaseous/liquid H₂ supply system
  - 8-10 hr target flight time

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Sodium Borohydride Fueling Solutions

- **Safe, low cost chemical hydride**
  - Non-flammable
  - Non-toxic

- **High storage metrics**
  - Aqueous solution, SG = 1.0
  - 0.045-0.064 gH₂/g Solution

- **Hydrogen as needed**
  - Fast start-up
  - Rapid load following
  - Reliable control

**Typical SBH System Flow Diagram**

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800 W UAV Fuel Cell Power System Overview

- Targeted for application to Group I UAS (<9.5 kg)
- Designed for operation on sodium borohydride (SBH) cartridges
- >2x energy density of secondary batteries
- Fully hybridized with LiPo battery for power bursts

- Powers Lockheed Martin Desert Hawk EER platform
  - Hand launchable UAS
  - >6 hr flight time demonstrated

Power Management Scheme

- DC/DC Converter
- Power Combiner
- Battery Interface
- Multiple Power Output Paths
- Fuel Cell
- Secondary Battery

Lockheed Martin
Desert Hawk EER
Air Independent Fuel Cells

- Protonex PEM stacks designed for pure Oxygen
  - Tailored flow channels

- 1 kW Benchtop demonstrator
  - >99% H₂ utilization
  - >99% O₂ utilization

- Protonex has focused on Unmanned Underwater System
  - Leveraging O₂ from hydrogen peroxide (H₂O₂) decomposition
  - Leveraging H₂ from sodium borohydride (SBH) decomposition
  - 2-3x increase over existing systems
  - estimated to provide >350 Wh/L

- Stack and systems suitable for high altitude energy storage

1.5 kW H₂/O₂ Stack

6” x 5” x 4”
15 x 13 x 10 cm
Summary

- Ballard / Protonex has over a decade of UxV experience

- Capability to design and manufacture fuel cell power systems for UxV from 100 W to 100 kW
  - Propulsion, auxiliary power, sensors
  - Hand launched UAVs to commercial APUs

- Takeaways:
  - Fuel cells will be instrumental in the second wave of UxV applications
  - Fuel cells can improve:
    - Persistence
    - Operating costs
  - Integration of the power systems is key to maximize results
  - Protonex / Ballard can provide design guidance to full systems manufacture
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