Solid Oxide Fuel Cell Power Systems for Small UAVs

2007 Joint Service Power Expo
April 24-26 2007

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Outline

- About Adaptive Materials (AMI)
- AMI Technology & Systems
- Unmanned Aerial Vehicles Power Systems

About AMI

- Ann Arbor, Michigan
- Portable Solid Oxide Fuel Cells
- 25W, 50W and 150W Systems

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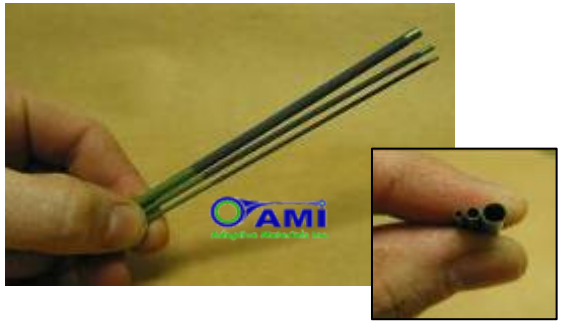
Technology

- Technology originated with large scale power generation
- Low cost ceramic materials
- Real fuel - hydrocarbons

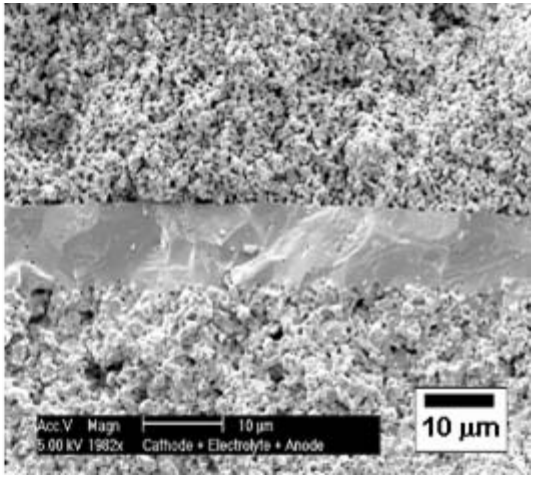
Micro-tubular Fuel Cells



Cathode
$(La_xSr_{1-x})MnO_3$ + YSZ

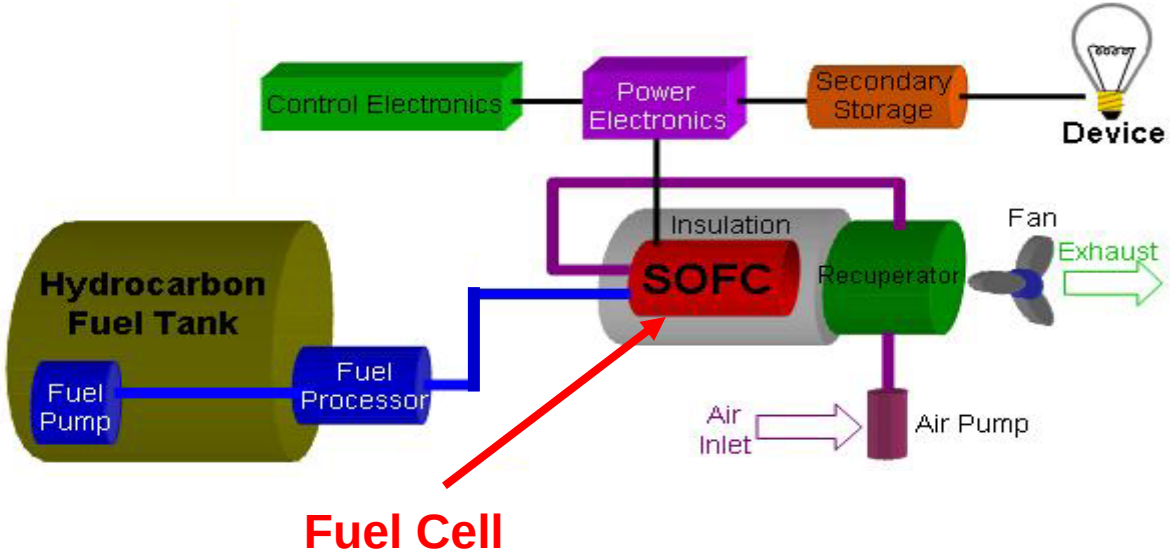
Electrolyte
10µm YSZ

Anode
Ni + YSZ



Technology

- Cells coupled into Stack
- Balance of Plant



Technology

Pilot scale manufacturing facility

- Capacity 100,000 cells per year
- Six Sigma based process improvement

SOFC = Fuel Flexibility

Propane Fuel Tank
9,675 Whr/kg

Global Commodity

- **Maximum Portable Performance**
  - Highest energy density of any packaged fuel
- **100% Consumer Confidence**
  - DOT and UN certified tanks
    - Ground and air shipping
  - Global commodity
    - Existing supply chain and distribution
  - Low Cost
- **You can step outside this room and find fuel for the UAV power system within an hour.**

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- **50 Watt Continuous Power**
  - 12V
  - 100 Watt peak power

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- **System Specifications**
  - Dry system weight, less than 2.25 kg
  - Temperature -20ºC to 50ºC
  - Relative Humidity 5% to 95%
  - 12,500 feet with 0% power degradation
  - Dust and rain to military specification
  - Rapid Start Up < 15 minutes
  - Exhaust temperature <55ºC
  - Multiple fuel compatible

Supply Chain Partners

Parker Hannifin for BOP Assemblies

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50W System

Specifications	
Dry Weight	2.25kg
Volume	4.5
Net System Efficiency	17%

Specific Energy	
3 Day Mission W-hr/kg	**775**
10 Day Mission W-hr/kg	**1200**

End of Life Testing

Goal = 300 Hours
Tested MTBF = 500 Hours

Rapid Start - Stop Testing

Goal = 100 cycles
Avg Cycles = 144 cycles

Why Fuel Cell Powered UAVs?

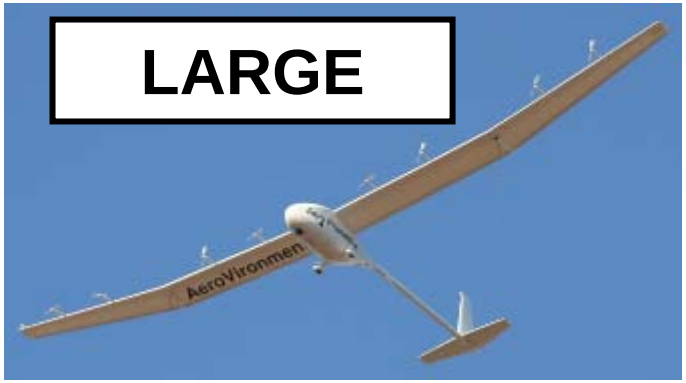
- Quieter than internal combustion engines
- Far more efficient than small fractional horsepower engines
- More range and endurance than batteries
  - Much higher Whr/Kg
- Electric power for payload

Hydrogen Fuel Cell Aircraft In All Sizes

SMALL

- Aerovironment / Lynntech
  - Hornet Micro Air Vehicle 2003
- NRL
  - 2005 - Spider Lion: 100 Watts: PEM : 2 meter span
- California State University, Los Angeles
  - 2006 – 500 Watts: PEM: 5.5 meter span
- Georgia Tech
  - 2006 – 500 Watts: PEM: 6.5 meter span
- Light Human Carrying Aircraft
  - UQM Technologies & BR&TE
- Aerovironment / NASA Dryden
  - Helios
  - HALE

LARGE

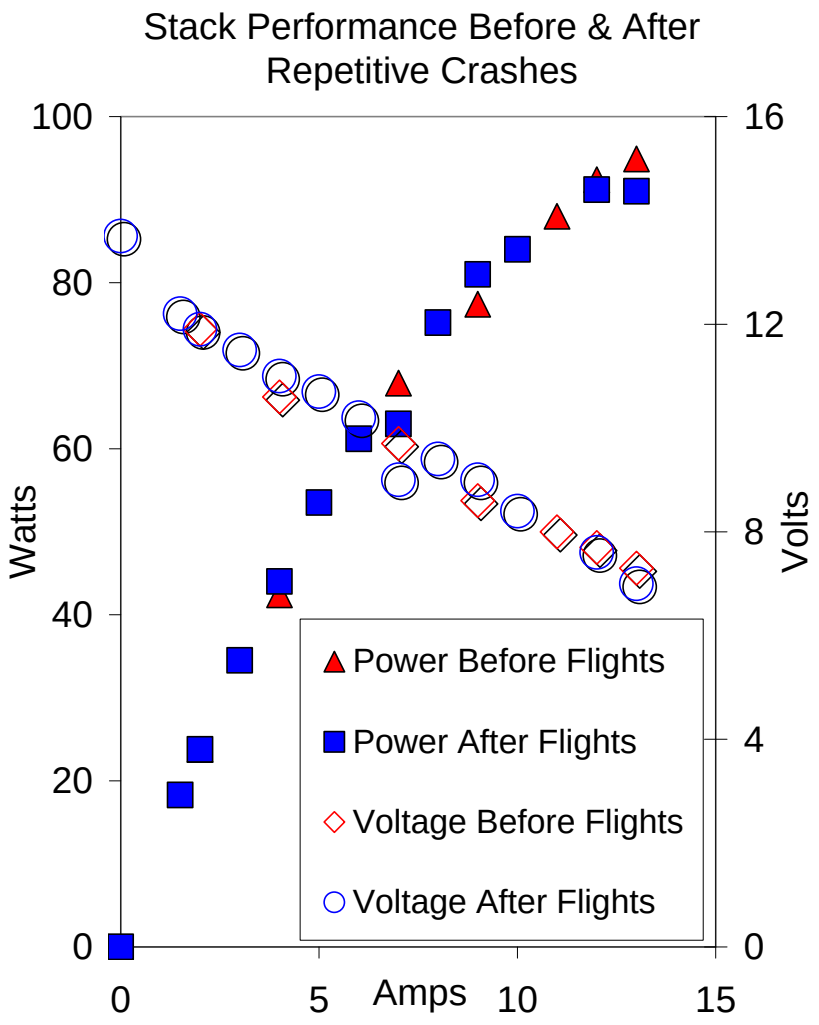


http://www.avinc.com/publish/2006/01/05/1092_GO_Aerial_View2.jpg

SOFC UAV Power Systems are Robust

February 2005

Early Test Flights - Video



Ceramic Not Always = Fragile

Gen One SOFC Powered UAVs

June 2006

UAV Specifications	
Gross UAV Take Off Weight	1.94 kg
SOFC System Dry Weight	0.9 kg
SOFC System Wet Weight	1.06 kg
Cruise Power	~60 Watts
SOFC Dry Specific Power	**72 W/kg**
Flight Specific Energy	**250 Whr/kg**

4 hour 19 minute Flight

- More than 4 hours aloft using a 60 Watt Solid Oxide Fuel Cell system weighing less than 1 kilogram.

Flight and Ground Test Results

Date	Event	Duration (Hrs)	Energy Density (W-hr/kg)
Feb 2005	Flight	0.25	-
Oct 2005	Flight	0.17	-
Jun 2006	Flight	1	60
Jun 2006	Flight	2.3	138
Jun 2006	Flight	4.3	250
Nov 2006	Autonomous Ground Test	11.5	680
Nov 2006	Autonomous Ground Test	8	443
Nov 2006	Autonomous Ground Test	8	440
Nov 2006	Autonomous Ground Test	8	414

Program Highlights

Generation I

250 Whr/kg

Generation II

660 Whr/kg

- Flight tests and bench top endurance runs to prove feasibility of SOFC UAV
- 4:19 flight represents a “world record” in fuel cell powered UAVs

Acknowledgements

- Department of Defense and other agencies
- The AMI team