DoD End User Perspective and DARPA Palm Power Program

DOE Fuel Cell Portable Power Workshop
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DoD Compact Fuel Cell Evolution

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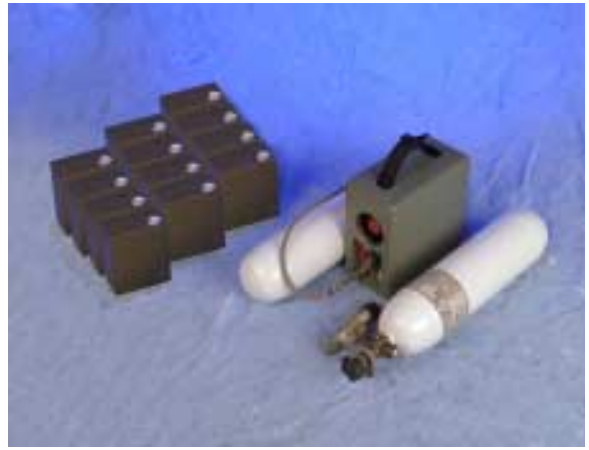
1992 –H_2 Stack
- 15 W; 2.3 kg

1996 - H_2 System (metal hydride)
- 40 W / 90 Wh; 1.6 kg

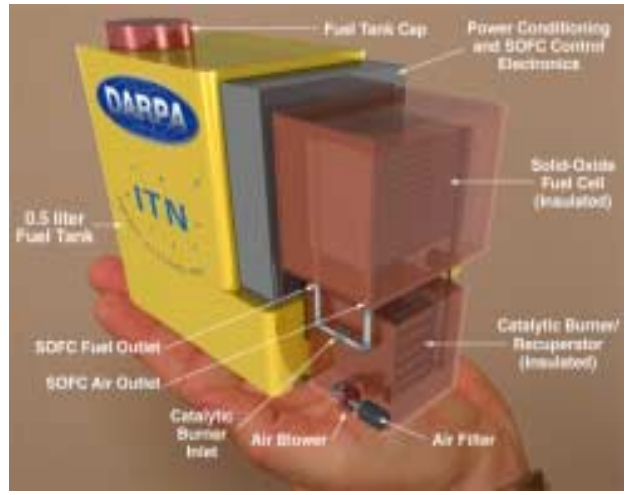


1998 - H_2 System (compressed hydrogen
- 50 W/ 2 kW-hr; 3.4 kg

2001 – DMFC - System
- 60 W; 6.8 kg; 30% efficiency

The Future?

"It's the fuel stupid!"



SOFC –Hydrocarbon – System
- 20 W; 0.72 kg; 28% efficiency (Goals)

Marine Corps Air Ground Combat Center
29 Palms, CA, Fall 1999

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TRAINING

Fuel Cells aboard Humvee

PRC-119 Radios

MILITARY EXERCISE

Retransmission Site

COST ESTIMATE FOR ONE RETRANS SITE

- **BA5590 BATTERIES = $8000**
- **FUEL CELLS = $250**

Ball Aerospace & Technologies Corp and H-Power Corp

Direct Methanol Fuel Cell

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Brassboard

60 Watt Packaged System

- Operates directly on methanol (no fuel processing required)
- Very low temperature operation (case and cooling air is cool to the touch)
- One gallon of methanol (< $0.50) equivalent to 100 lbs. batteries ($4000)
- Technology easily scaled – cellular telephones (1 Watt on up)
- Several distributed units could replace unreliable, noisy generators
- Future technology goal - operate on logistics fuels

LANL and Ball Aerospace & Technologies Corporation

Direct Methanol Fuel Cells for Cellular Phones

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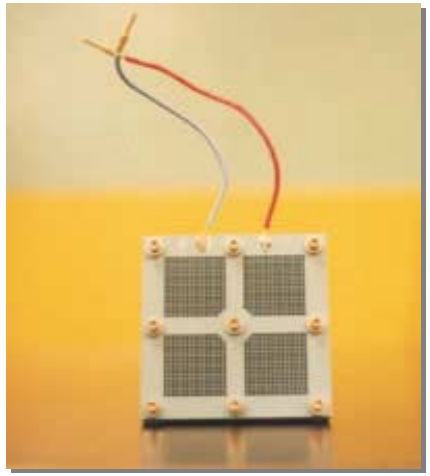
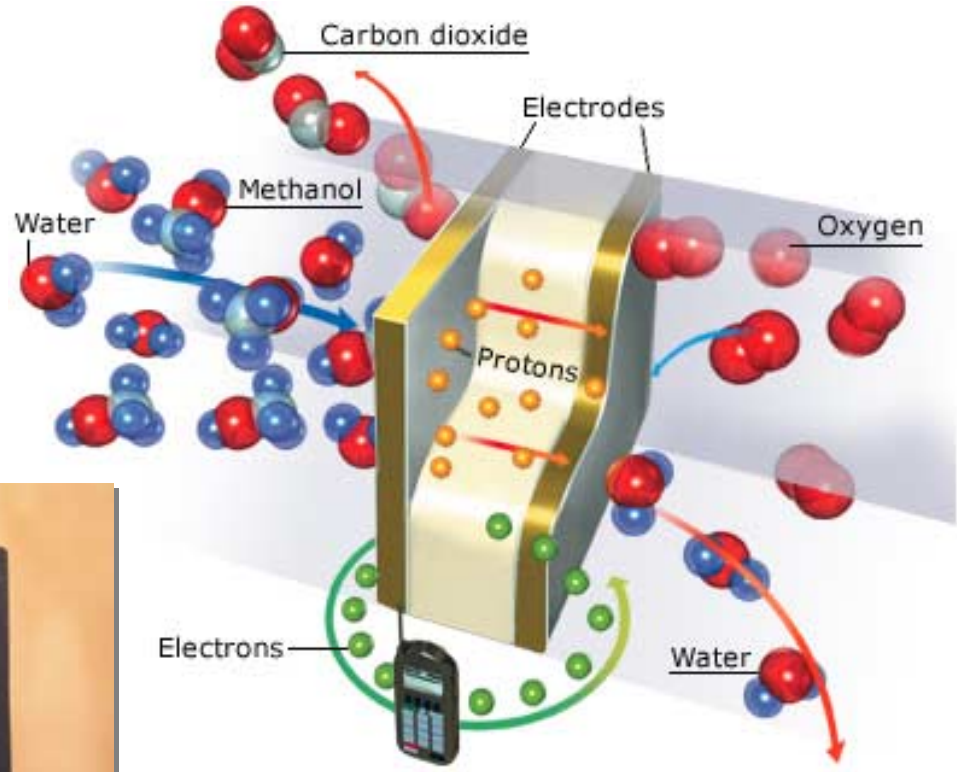
PolyFuel



Motorola

NEC

Manhattan Scientifics



- One Month Operation?
- No Battery Chargers
- Scaleable Technology for More Power Hungry Devices

Performance Shortfall of Today's Portable Power Sources for DoD Applications

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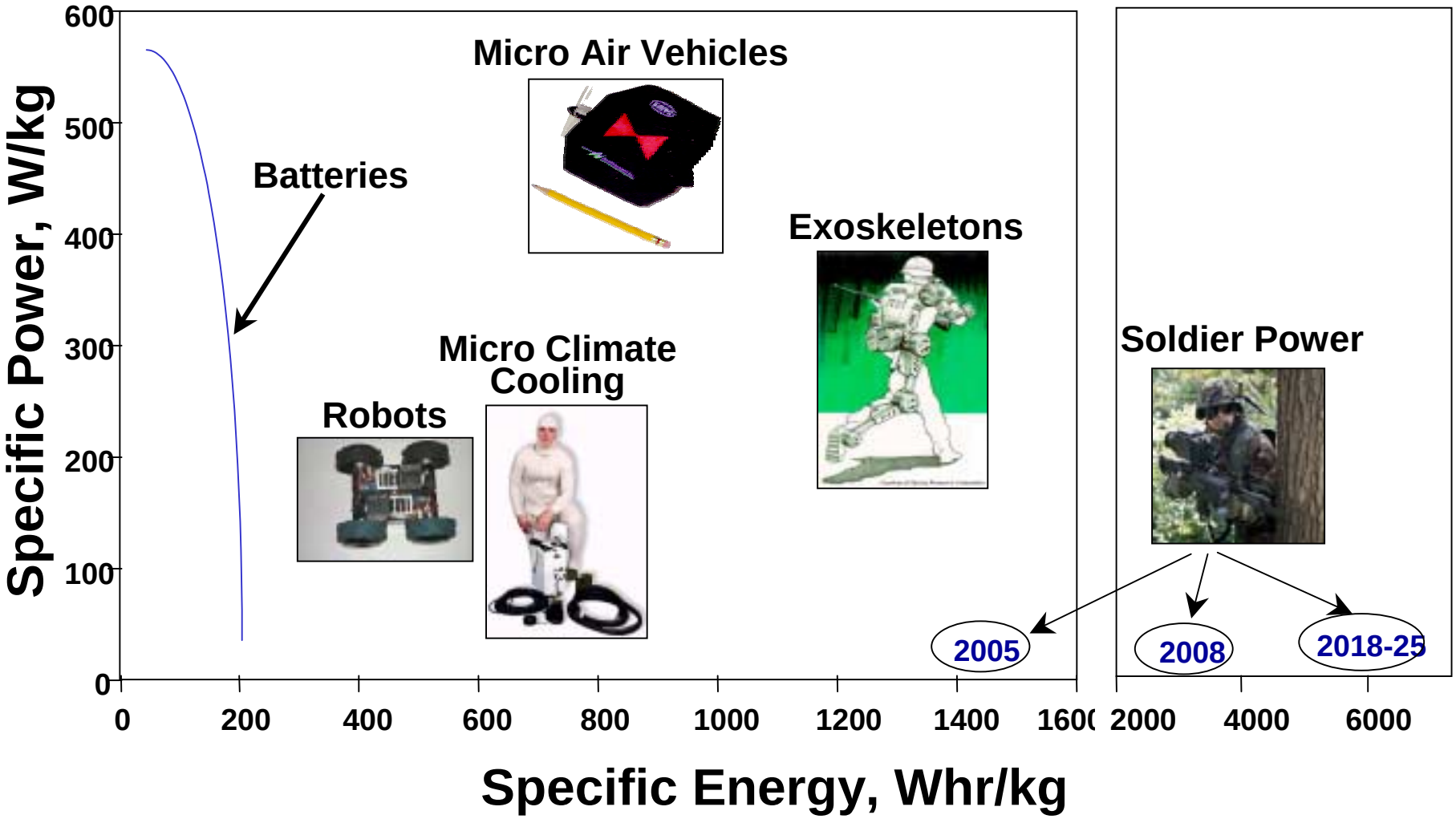

Palm Power

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Idea:

- Develop a 20 W power source in a *hand-held package* having 15 times the energy content of the best battery to meet future power requirements in 2010 and beyond

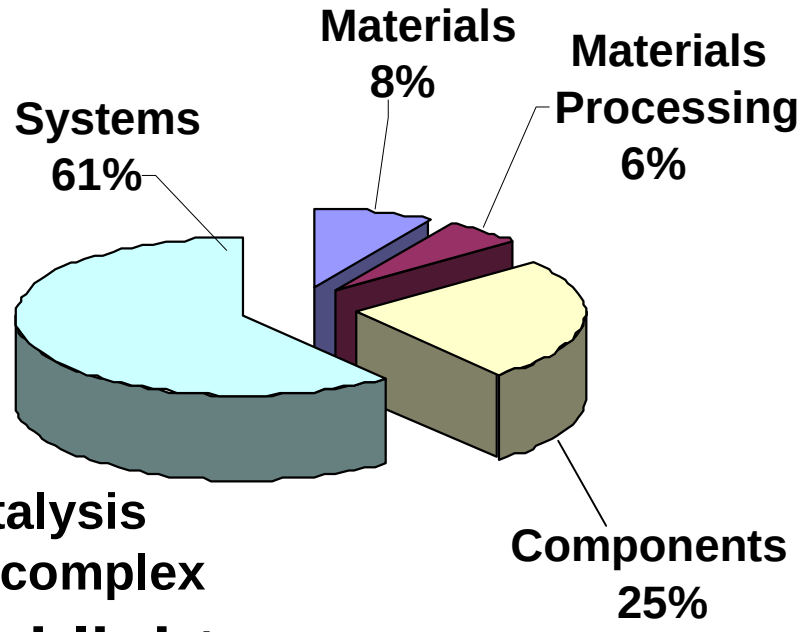
Technical Challenges:

- Highly efficient energy conversion of liquid fuels
- New materials for thermal management, catalysis
- Novel fabrication tools for highly compact, complex systems

Impact:

- *For…*Objective Force Warrior, SOCOM
- *To…*Enable Future Missions
- *via…*Energy Conversion of High Energy Fuels
- Scale Up Option for Cooling, EXO, etc.

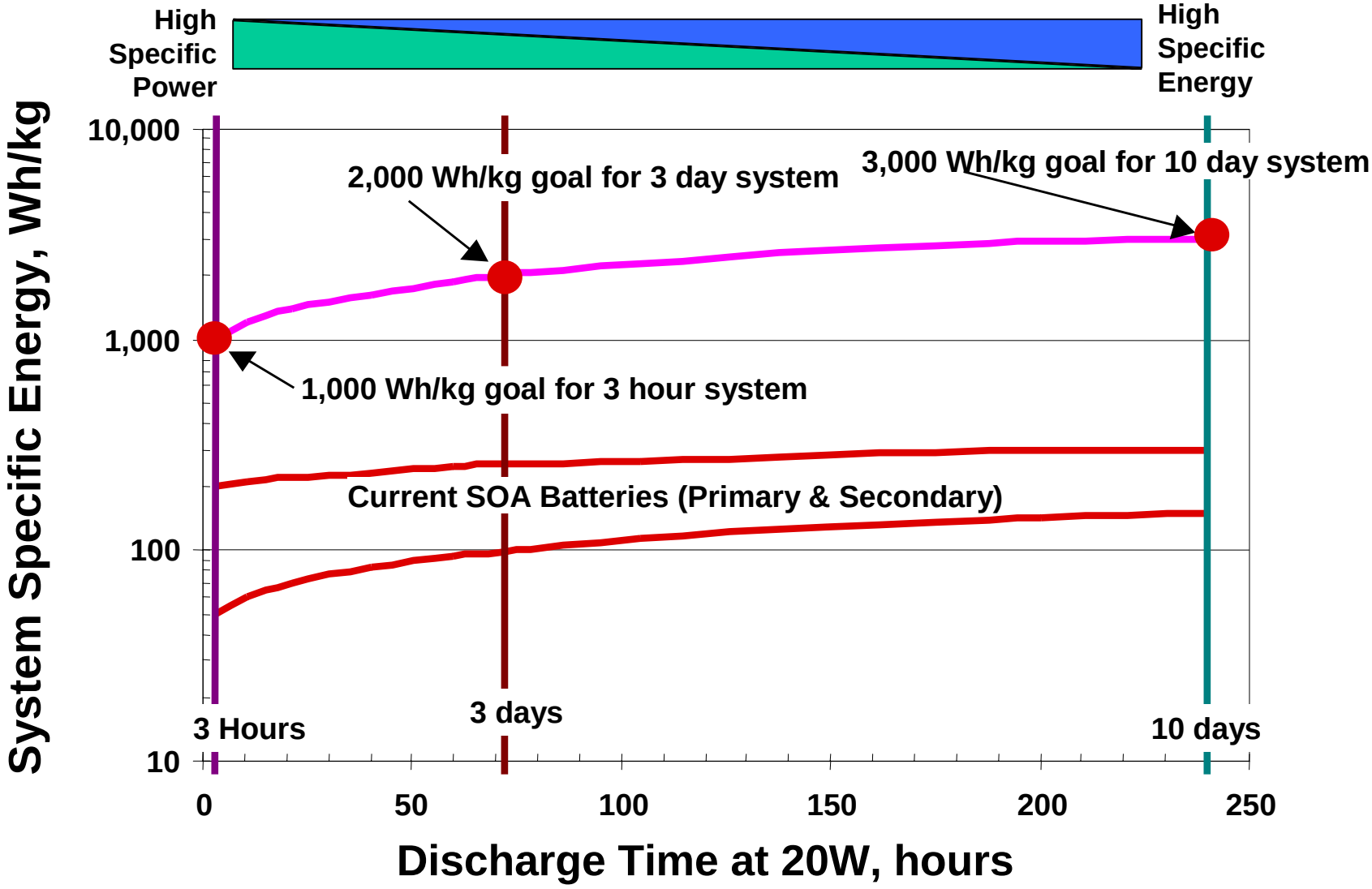
Resource Allocation



Highlights:

- New Start in FY01; Five Year Program. Phase I – 3 Years
- Multidisciplinary teams: Large Corporations, Small Businesses, Universities, Non-profits
- Transition Partners: PM Soldier, Natick, CECOM, SOCOM, Marine Corps, Navy

Mission Energy Goals



Program Structure

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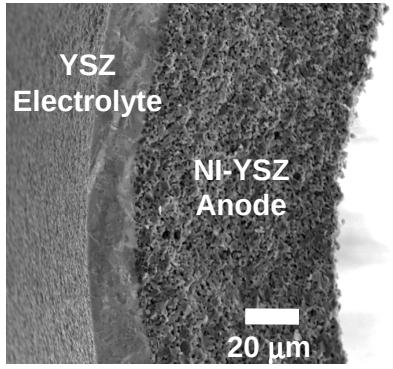
Materials (8%)

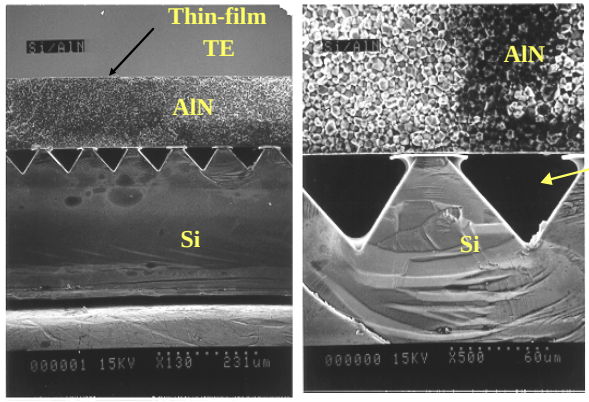
- Membranes
  - U of Colorado
- Electroactive Polymers
  - SRI
- Thermionics
  - Vanderbuilt
  - ENECO
- Thermophotovoltaics
  - Draper Laboratory
- Thermoelectrics
  - RTI

Materials Processing (6%)

- Ceramic Extrusion
  - Georgia Tech
  - Adaptive Materials

Anode Supported Tubule
(SEM Fracture Surface)





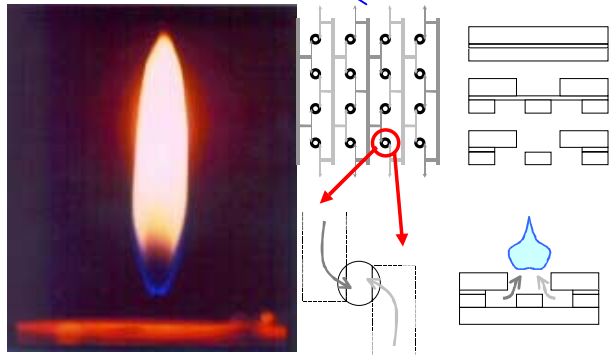
Micro Channels for Heat-Transfer Fluids

Components (25%)

- Small Engine
  - U of Michigan
- AMTEC
  - AMPS
- Micro Fuel Processing
  - RTI
  - Altex

SOFC
- MSRI

Combustion
- Yale U



Integrated Systems (61%)

- DMFC
  - Ball Aerospace
  - Creare
- SOFC
  - ITN Energy Systems
  - Honeywell/General Electric

Program Philosophy

- Multiple Technologies
- Cross-fertilization of Materials and Components
- Flexible Integration Into Systems

Compact Integrated Multi-Fuel Processors

Ashok S. Damle, Research Triangle Institute
Charles J. Call, MesoSystems Technology, Inc.

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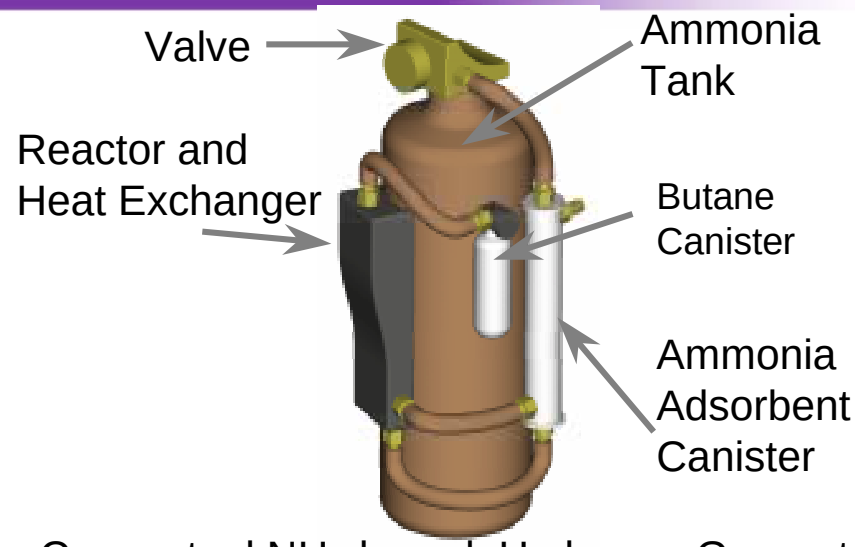
Overall Objective:

- To develop lightweight, fuel processors to convert liquid logistic fuels to high purity on-demand hydrogen

Hydrogen Generator Targets:

- Capacity - 1.5 to 5 kW-hr
- Specific Energy - 2 to 3 kWh/kg



Conceptual NH_3-based Hydrogen Generator

Approach:

- Steam reforming of hydrocarbon fuels and thermal decomposition of ammonia in a H_2 selective membrane reactor
- Integrated micro-channel reactor, auxiliary fuel combustor, H_2 membrane, gas/gas heat exchanger heat recovery, and insulation panels for low heat loss.
- Maximized thermal efficiency and hydrogen yield

Status of Current Technologies:

- Integrated Micro-channel reactor/ combustor for hydrogen generation by thermal decomposition of NH_3
- High-flux, high-selectivity Pd-based composite membranes
- Micro-channel gas/gas heat exchangers for high thermal efficiency
- “Additive” manufacturing for light-weight fuel processor components

Proposed SOFC Palm Power System

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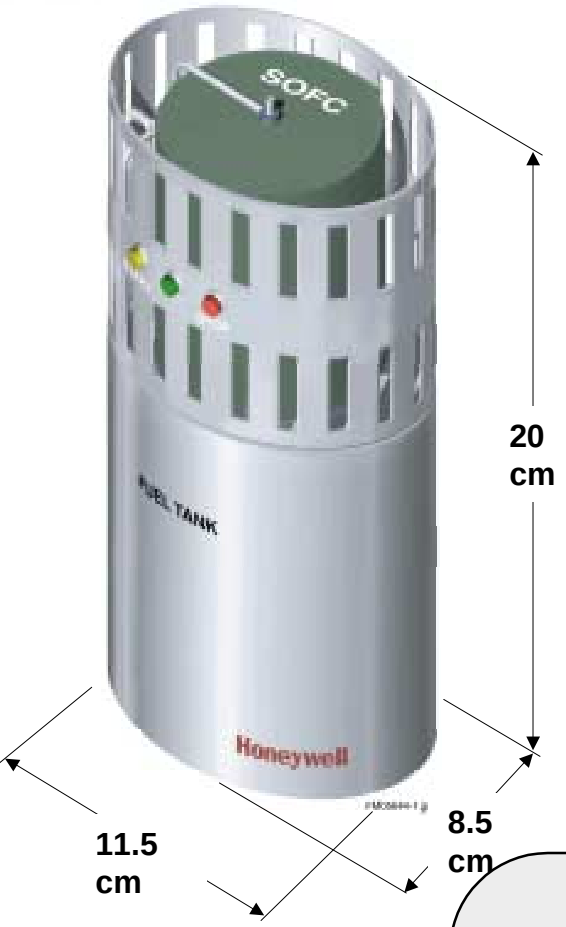
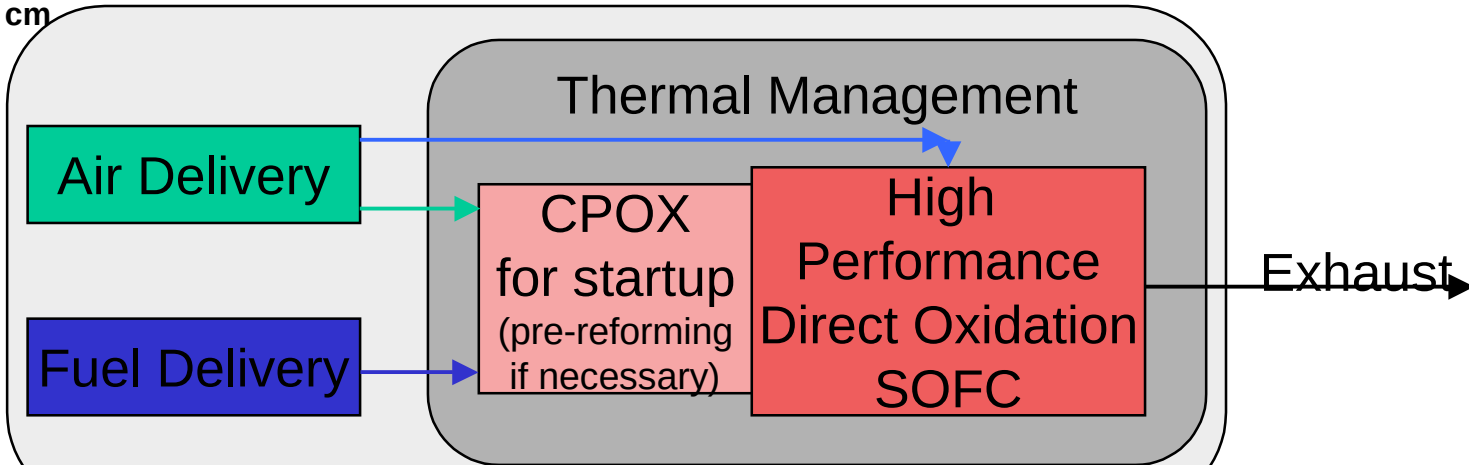


- Power: 20 W, 12 VDC
- Estimated dimension: 8.5 x 11.5 x 20 cm (10-day mission)
- Estimated weight (excluding fuel): 0.5 kg
- Estimated energy density (JP-8 fuel):
  - 2000 Wh/kg (3-day mission)
  - 3700 Wh/kg (10-day mission)
- Fuel: JP-8

Honeywell/GE



Honeywell/GE SOFC Performance

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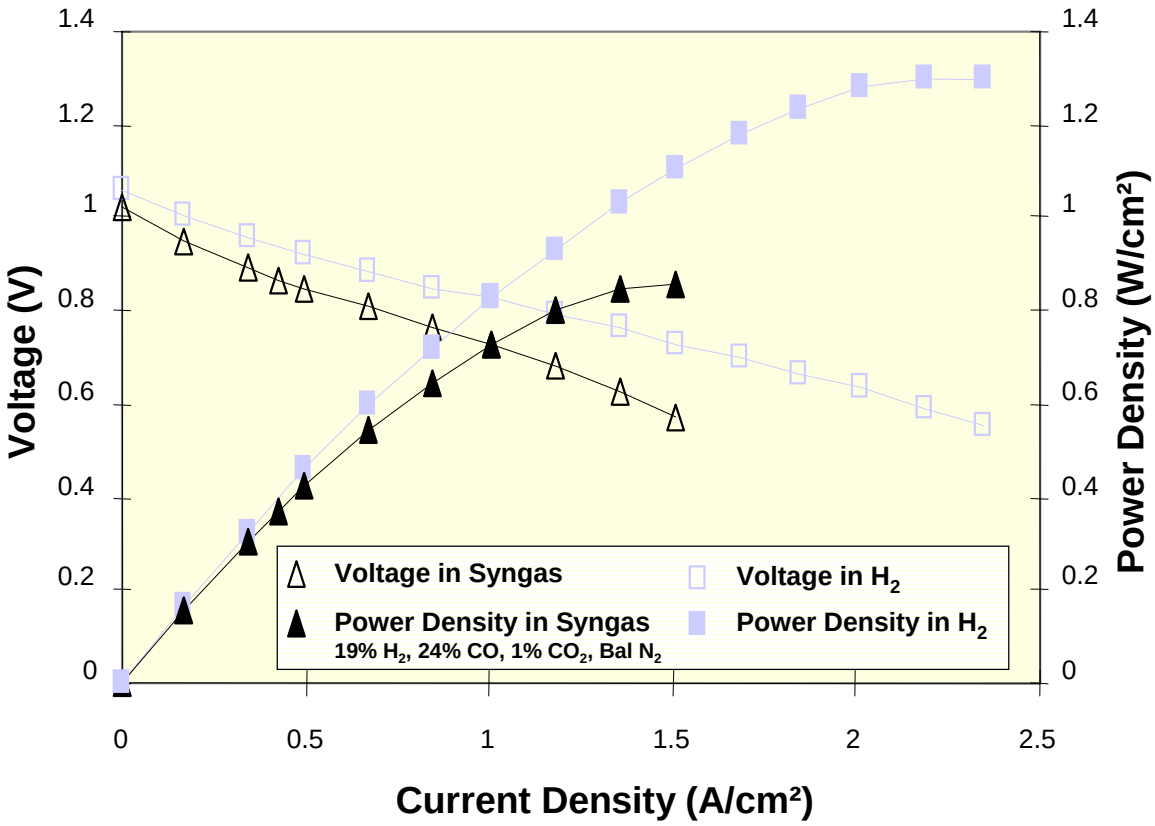

- 800°C operation
- Open circuit voltages in agreement with theoretical values
- Peak power density:
  - **1.3 W/cm² in hydrogen**
  - **0.85 W/cm² in JP-8 syngas**

Direct Oxidation of Liquid Hydrocarbons

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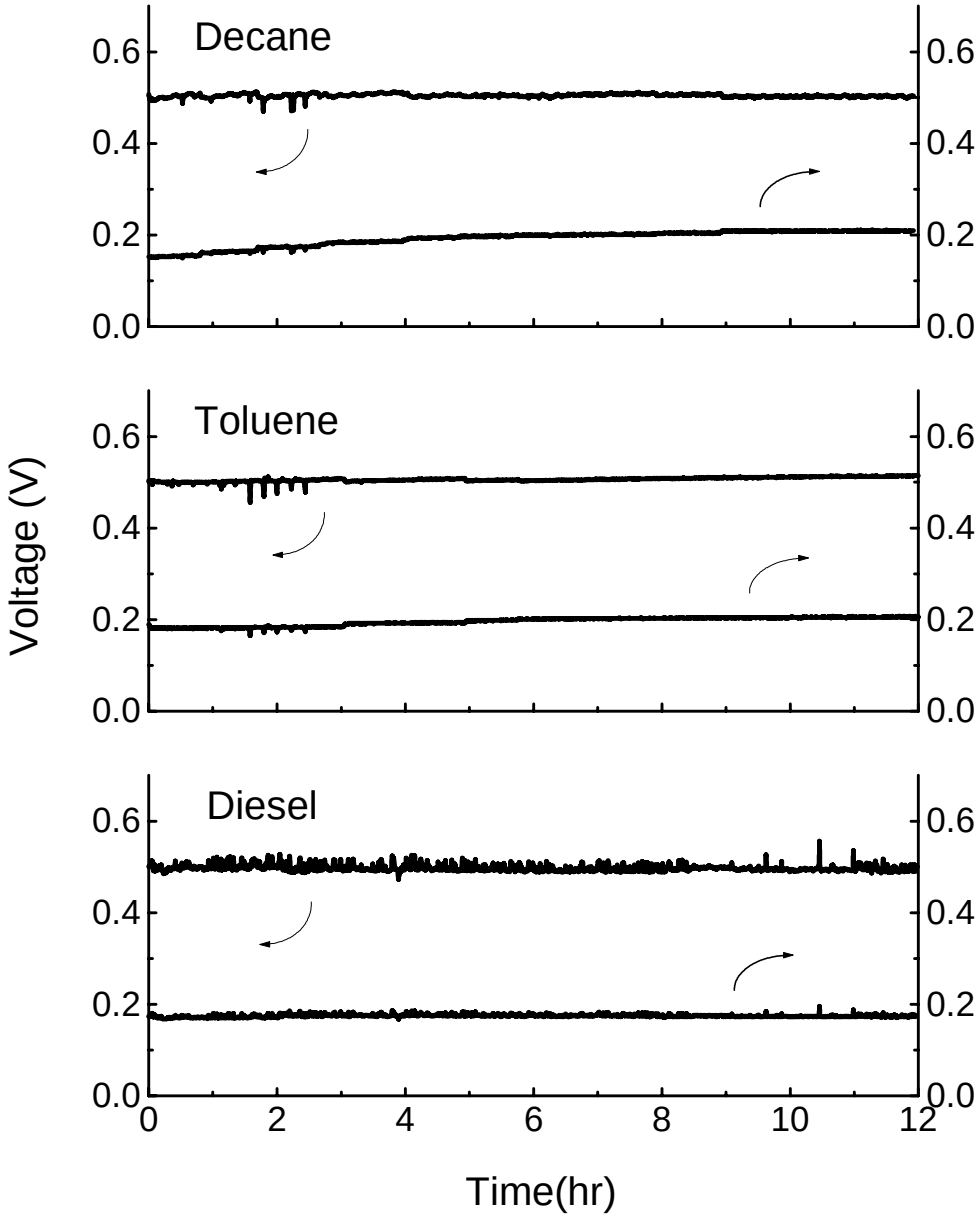

- Performance on liquid hydrocarbon fuels at 700°C
- Stable operation

Penn Engineering

Gorte, Vohs, Worrell

Direct Oxidation of Hydrocarbons in SOFCs

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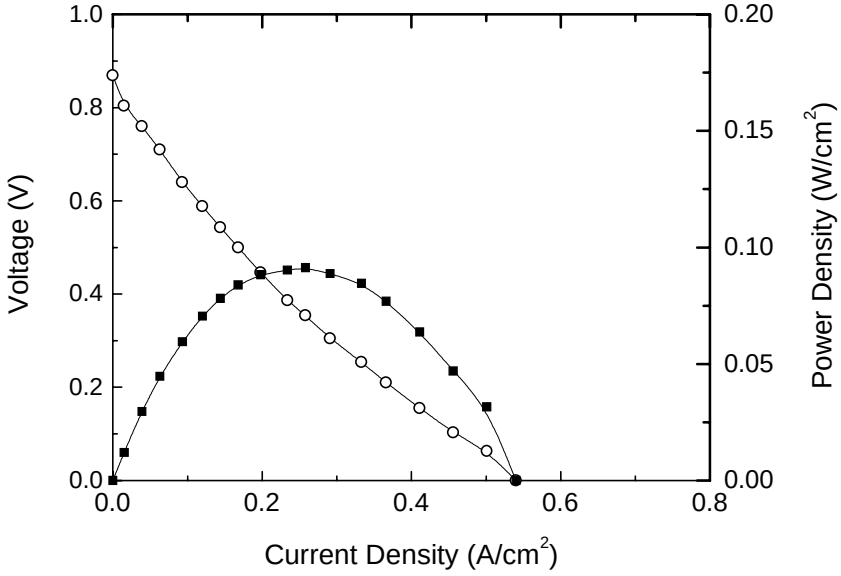
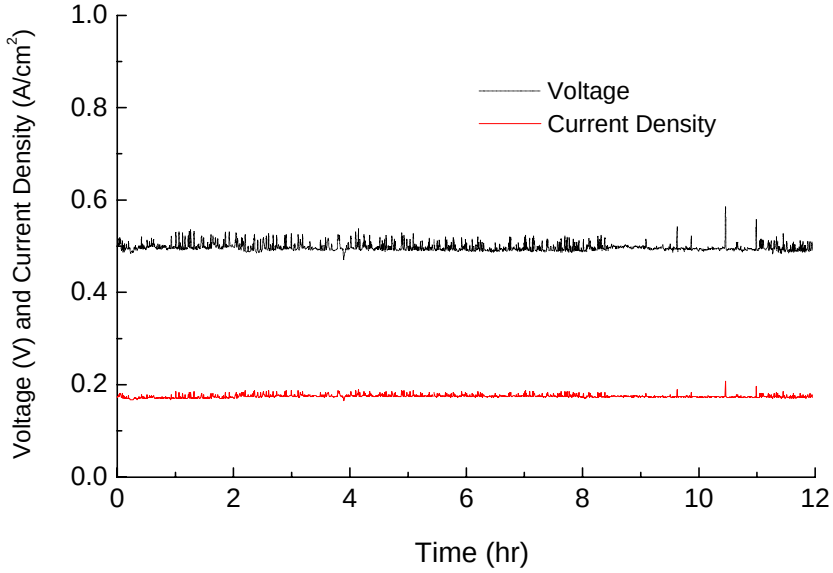
I-V for Diesel Fuel at 700°C



Diesel – Performance vs. Time



Penn Engineering

Gorte, Vohs, Worrell

CPOX for Processing Hydrocarbon Fuels

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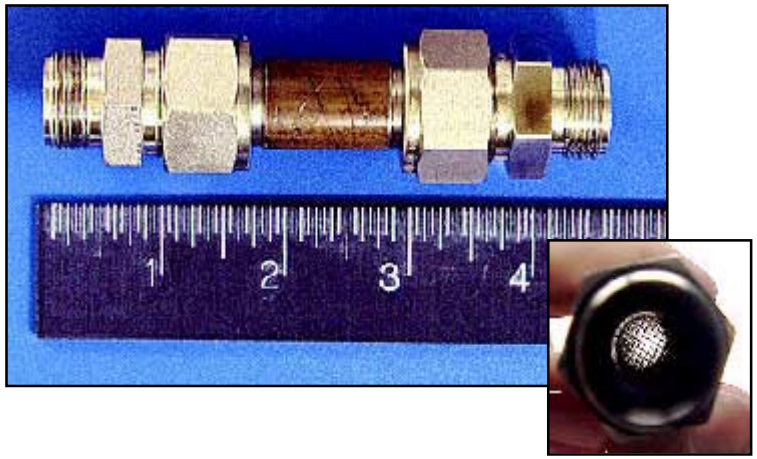

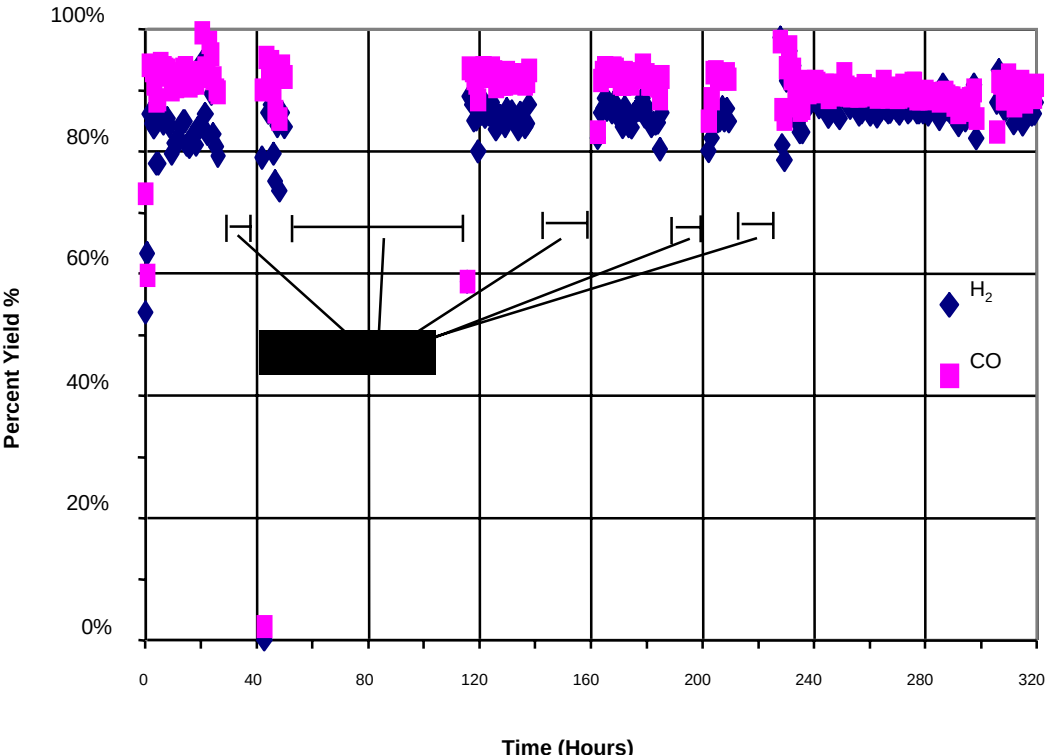

- Fuels: propane, butane, octane, JP-8, and diesel
- Duration: 700 hours to date
- Thermal cycles: 10
- Sulfur tolerance: 1000 ppm dibenzothiophene in JP-8
- Yield: 70-80% of LHV in JP-8

Honeywell/GE

GOAL: 20 W power source in a *hand-held package* having 15 times the energy content of the best battery

http://www.darpa.mil/dso/thrust/md/palmpower/index.html