2008 DOE Hydrogen Program

DMFC Prototype Demonstration for Consumer Electronic Applications

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June 13, 2008

Project ID
FC-45

Overview

Timeline

- Project start – Aug ’04
- Funding gap – Jan ’06 – Apr ’07
- Restart program – May ‘07
- Anticipated completion – Dec ‘08
- Percent complete – 70%

Barriers

- Energy/power density
- Cost
- Codes and regulations

Budget

- Total project funding
  - DOE share - $3.0M
  - Contractor - $3.2M
- Funding received in FY07 - .5M
- Funding for FY08 – 1.1 M

Partners

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Methanol Foundation

Gillette/Duracell

Program Objectives

- Benchmark system energy density of 600 Wh/liter
- Demonstrate prototypes
- Develop pathways to low cost for initial market entry
- Demonstrate continual operation of 1,000 hours
- Accelerate codes, standards and regulations to allow shipping and airline passenger cabin usage

Micro DMFC is an early pathway to introduce fuel cell benefits to the public

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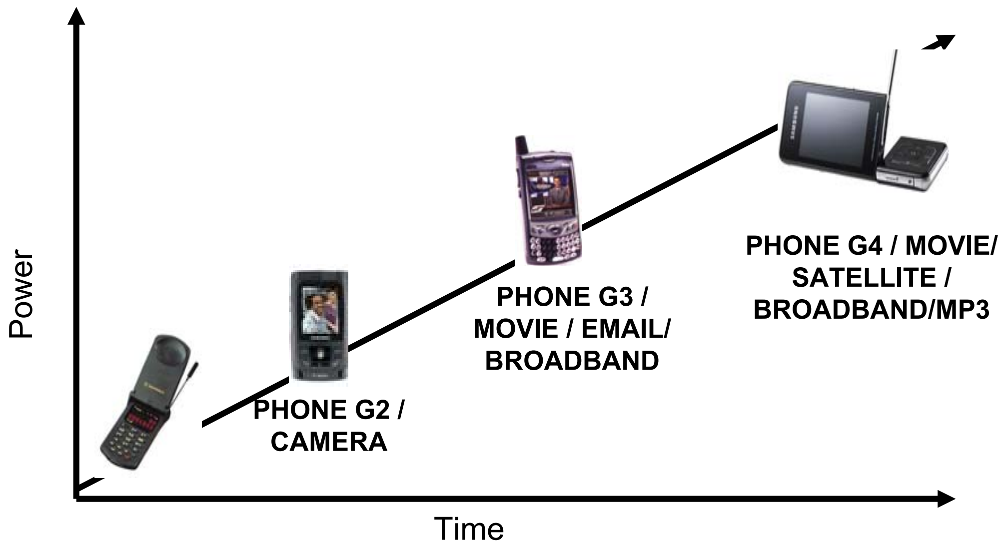
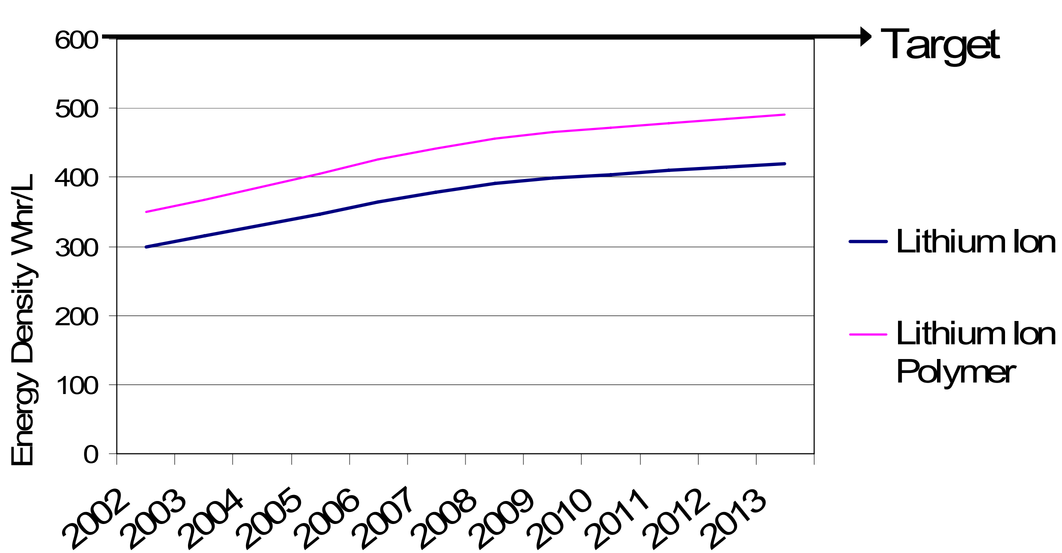
Why Target Consumer Electronics?



Digital convergent devices are taking on more functions demanding more power

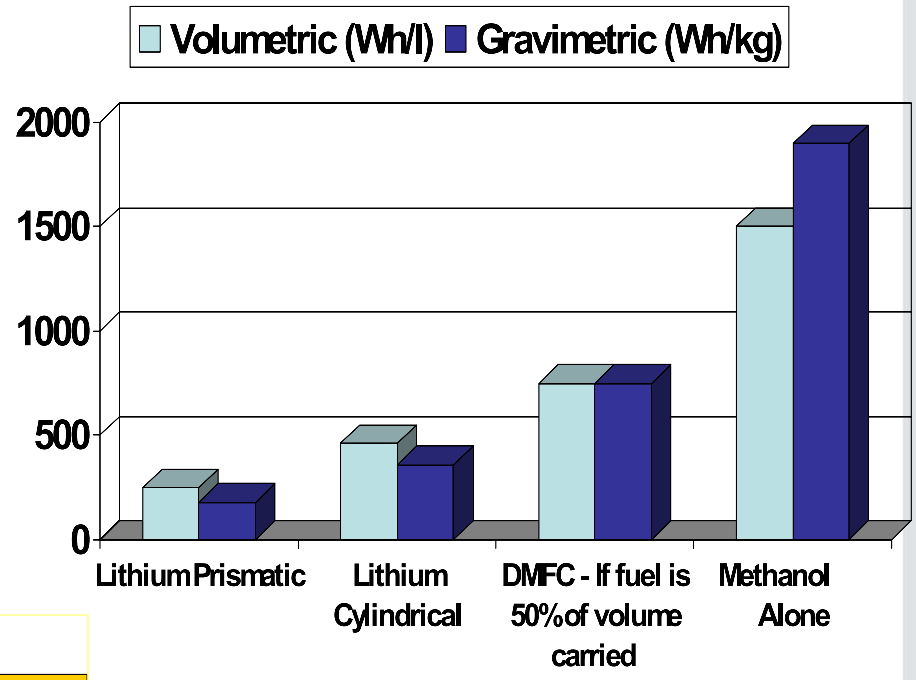


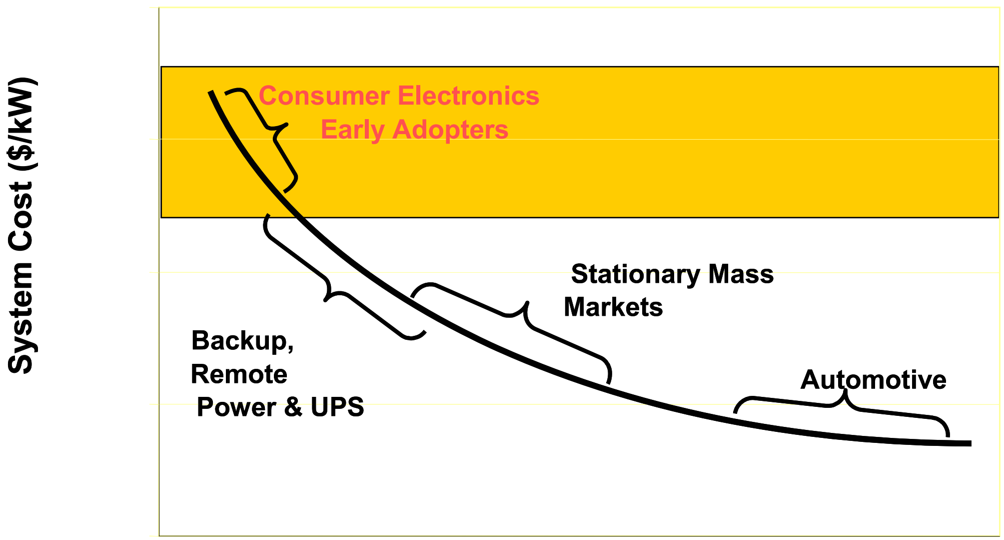
Batteries are not meeting power needs

Advantage of DMFC

<u>DMFC Advantages</u>

- Energy density beats batteries
- Fuel logistics
  - High energy density
  - Simple fueling systems
- Achievable regulatory acceptance





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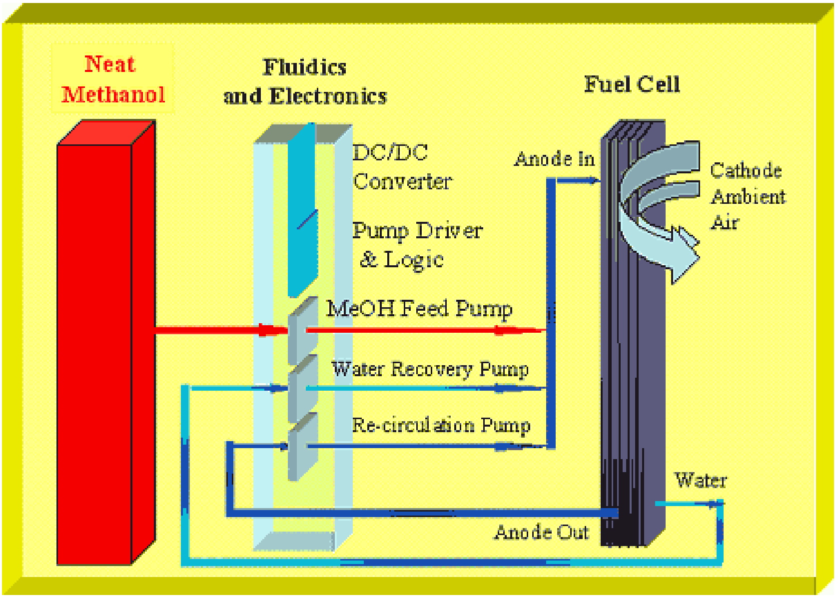
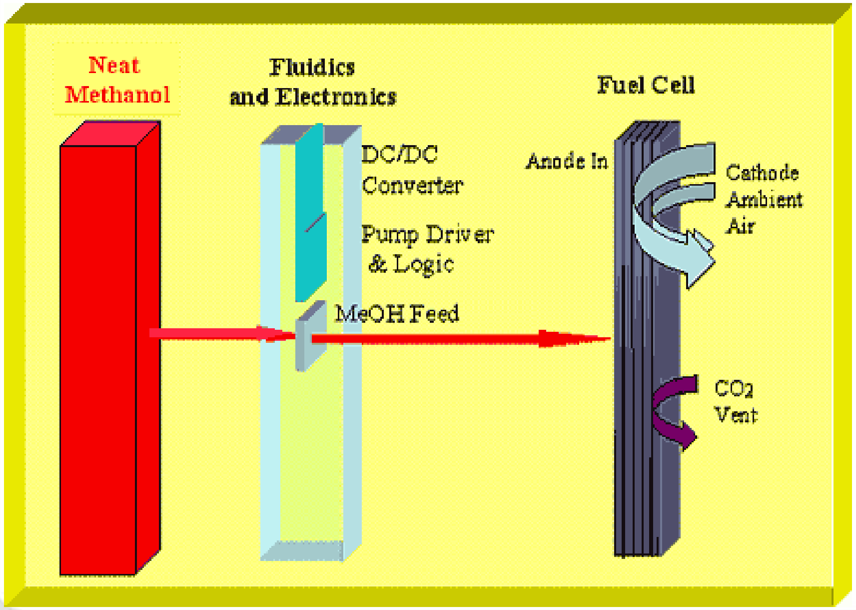
Mobion System Approach
Reduced Complexity

Standard DMFC technology is complex
- Fuel is dilute
- Water is captured
- Pumps move water back to fuel side
- Pumps circulate water on fuel side
- Pumps move fuel into the fuel side

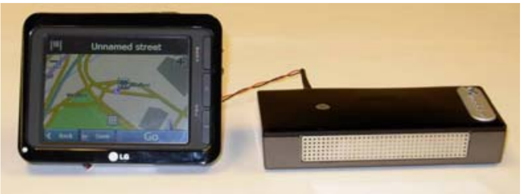




Mobion System Advantage
- Fuel is "neat"
- Water is captured within the membrane
- Structure pushes water back to fuel side
- No pumps move the water on fuel side

Product Integration Approach

Product Option 1
External Accessory



Product Option 2
Base Attachment

Product Option 3
Embedded

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Product Integration Approach

One fuel cell architecture serves multiple products

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External Power Charger Products

Snap-on Attached power Source Products

Embedded Power Source Products

Manufacturing Development Progress

<u>Program technical activities applicable to Hydrogen PEM cells:</u>

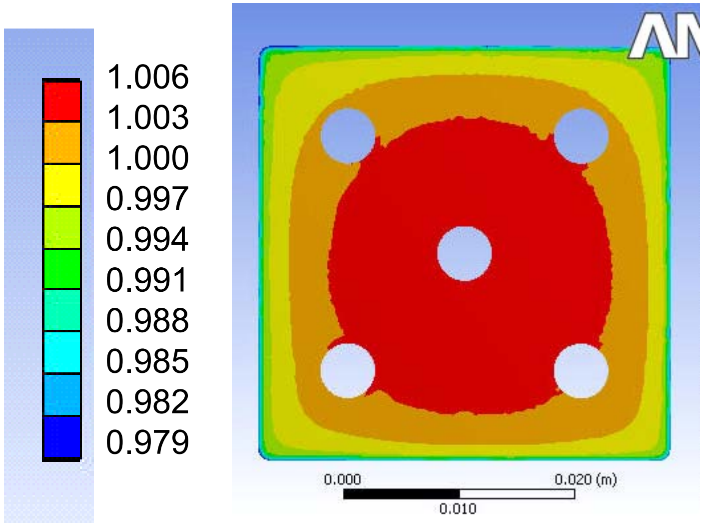
- High volume, low cost, current collector fabrication and coatings
- MEA production development with multiple suppliers
- Molded P2 array process development
  - High yield (no MEA damage)
  - 50mw/cm2 @ 1.4 Wh/cc
- High volume process evaluation for stampings, sealing, bonding, and metal joining

Material Source → Align Assemble and Secure → Molded P2 Arrays → Install into P2 system

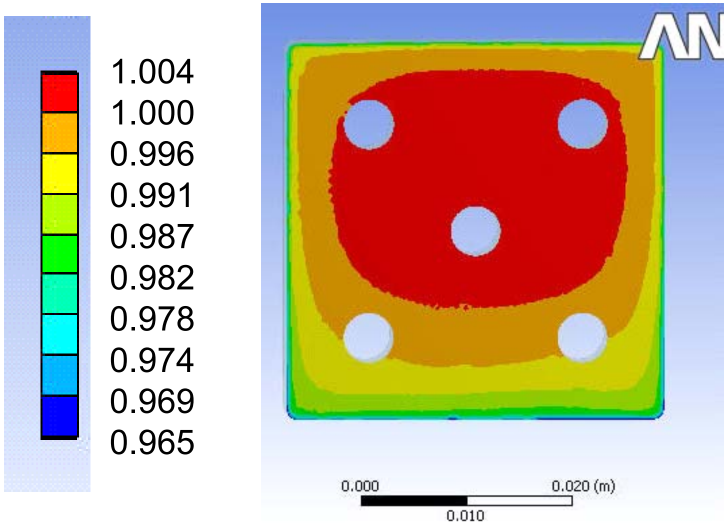
BOP - Thermal Management Progress

- Advanced insulation packages have produce impressive thermal isolation

- Passive variable thermal resistance device maintains constant and uniform MEA temperature over entire temperature range.



Normalized MEA Temperature Profile
at low ambient temperature



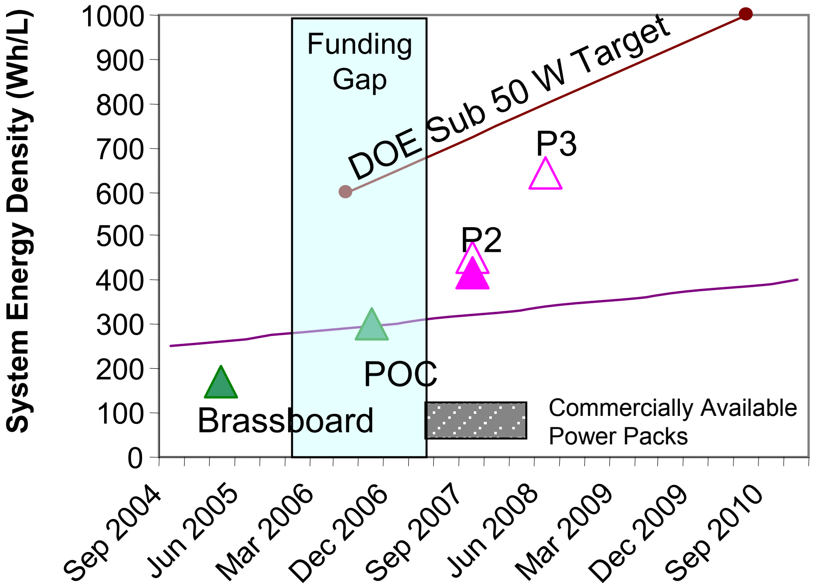
Normalized MEA Temperature Profile
at high ambient temperature

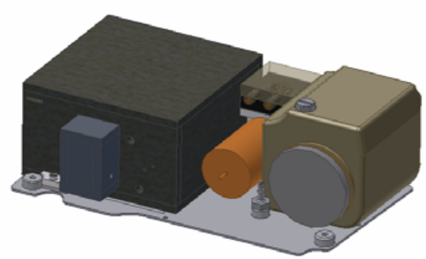
BOP Component Miniaturization Progress

- Fuel pumps are now less than 1 cc
- Fuel feed is tightly integrated to arrays
- Power processing and control electronics are small and highly integrated (electronics use 8 layer board with blind vias & 0201 components)
- Thermal management components are tightly integrated and perform multiple functions
- Higher volumetric power density array decreases thermal loss
- Fuel cartridge & manifold interconnect defined

System Performance Summary

- Brassboard system benchmark in first year of program
- Interim proof of concept (POC) during funding gap used large internal fuel tank
  - Competitive with lithium ion battery energy density
- P2 testing in 2007 uses small internal fuel tank with energy density based on several refills
- 1000 hours run on multiple P2 systems
- P3 System projection based on energy density with several cartridges





2005 Brassboard

2006 POC Prototype

2007 P2 Prototype

Future Component and System Development Work

(Program funding reestablished in May 2007)

FY2008

- Continue to reduce component costs
- Design for high volume manufacturing processes
- Continue to develop supply chain to support high volume capability
- Complete P3 system integration
- Complete MEA, array, and component life testing
- Assemble and test final system prototypes
  - Power and efficiency
  - Life testing
  - Temperature latitude testing

Codes and Standards Progress

- UN established Shipping & Packaging for "fuel cell cartridges containing flammable liquids" (methanol).

- International Electrotechnical Commission (IEC) approved a publicly available specification (PAS) in 2005. IEC standard CDV ("committee draft for vote") was "approved" in 2007

- International Civil Aviation Organization (ICAO) enacted international shipping regulations for fuel cell cartridges; ICAO enacted regulations for methanol, butane and formic acid fuel cell use in airline passenger cabin. (Hydrogen in progress.)

- US DOT enacted passenger exception for fuel cells and fuel cartridges on April 30, 2008.

Goal: Clear regulatory pathway to fuel cartridges available in every store and accepted in every airline passenger cabin

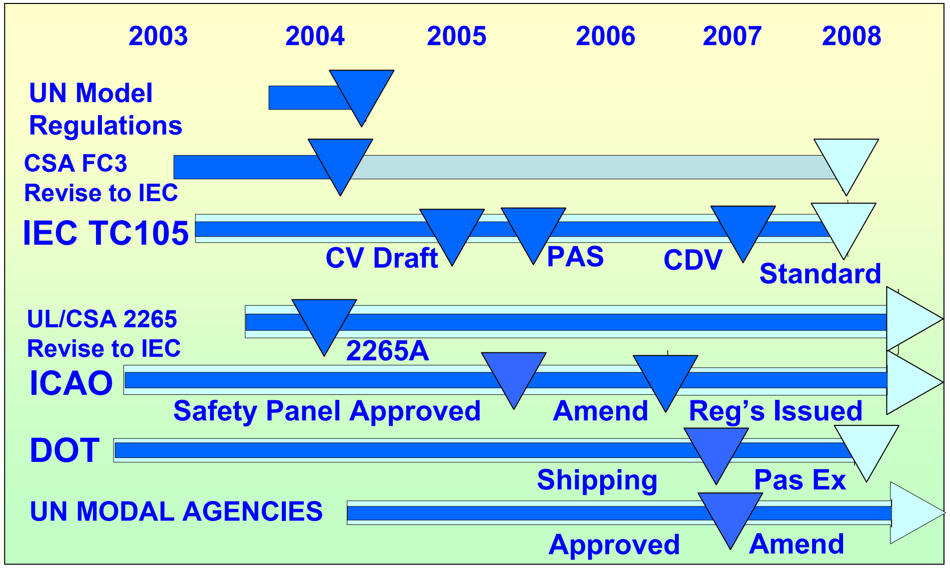
Fuel cell cartridge being designed to meet international transport requirements

Future Codes and Standard Work

- IEC expects to complete work on the 62282-6-1 micro fuel cell safety standard late 2008 (replacing current PAS)
- IEC is developing a common interface standard between micro fuel cell and cartridge
- Develop model for disposal and recycling cartridge and fuel cells

<u>Milestones for 2008</u>

- IEC to issue final Standard 62282-6-1
- UL/CSA revisions follow IEC
- TSA will develop security procedures for fuel cells



Status Against Objectives

- Energy density greater than 600 Wh/L
  - Proof of concept prototype demonstrated 250 Wh/L
  - P2 system test results (several refills) 415 Wh/L
  - P3 performance projected to (several cartridges) 640 Wh/L
- Demonstrate prototypes
  - P2 prototypes (11 units) tested for performance, temperature latitude and life
- Accelerate codes and standards
  - All international standards for shipping and airline passenger transport were in place at start of 2007
  - US DOT enacted passenger exception for fuel cells and fuel cartridges on April 30, 2008
- Demonstrate continual operation to 1000 hours
  - Demonstrated over 1000 hours life testing on multiple P2 systems
  - MEA power and life testing achieving product requirements
- Design and manufacturing pathway to target cost
  - Fuel cell markets for handhelds can be entered at costs significantly above this target – need to modify target for sub-Watt systems

Micro-DMFC Technology Supports US Fuel Cell Programs

- Provides early public exposure and acceptance of fuel cells
- Prepares regulatory environment for other fuel cell technologies
- Maintains important US leadership in portable power
- Suppliers are interested in DMFC as a near term market and path to hydrogen market. Many developments synergistic with hydrogen PEM:
  - Catalyst
  - Membranes
  - GDL
  - Complete MEA
  - Molded frames
  - Seals
  - BOP (pumps, heat rejection, fluid handling)
  - Current collector plates

Summary

Relevance: Open the door to broad public exposure to fuel cells AND develop supplier and large scale manufacturing infrastructure to advance hydrogen fuel cells.

Approach: Develop and miniaturize DMFC technology, find pathways to low cost manufacturing, demonstrate early prototype capabilities.

Technical Accomplishments: Demonstrated prototype energy density on path to system targets. Demonstrate target life at system level. Excellent success on regulatory road map.

Technology Transfer: Continue to develop a broad range of MEA, flow field, current collector and BOP component suppliers.

Propose Future Research: Produce next round of compact fuel cell arrays and test system prototypes. Performance improvements and component miniaturization continues with added effort on manufacturing cost reductions and performance durability.