Advances in Materials and System Technology for Portable Fuel Cells

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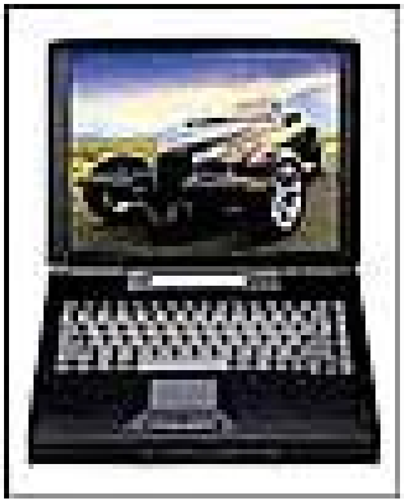
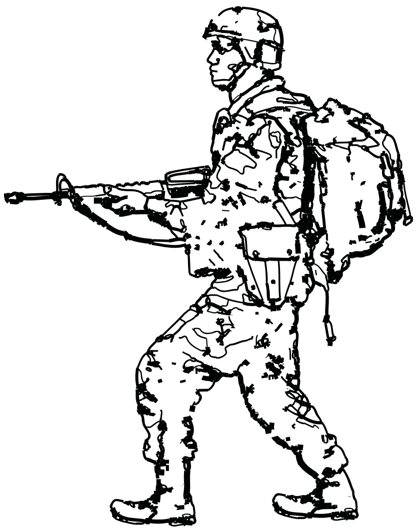
Portable Power

Examples:

2W

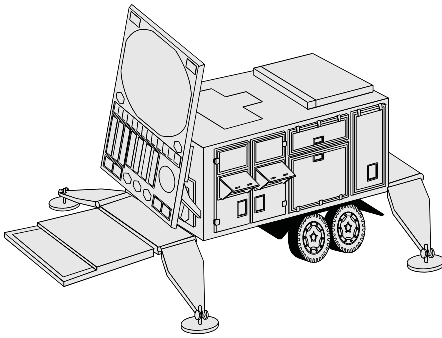


20W



50-100W

500W



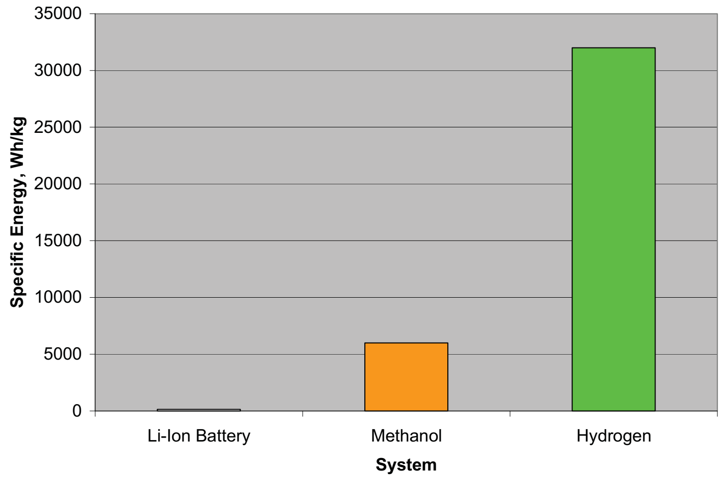
1-5kW

Desirable Characteristics:

- Long operating times (always "ON")
- Zero Recharge time (always "Ready")
- Lightweight (high energy density, >120 Wh/kg)
- "Zero Worry" logistics (battery replacement, inventory, recharging)

Technology Solution

- Li-Ion rechargeable battery : 150 Wh/kg



High Energy Fuels:

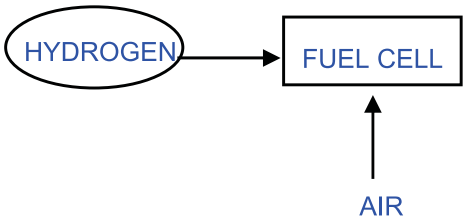
- Methanol, 6000 Wh/kg
- Hydrogen, 32000 Wh/kg

Fuel Cell Technology:

- High-efficiency direct conversion of chemical energy to electrical energy in fuel cells
  - Not limited by Carnot efficiency
- Products are non-polluting; CO_2 and water

Portable Hydrogen Systems

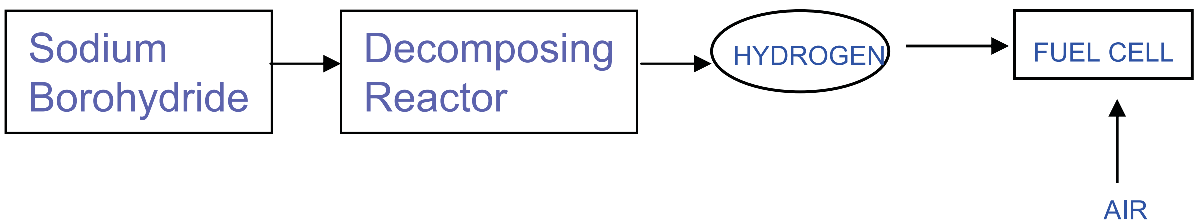
Gaseous Hydrogen Storage (2%) 1998



200 Wh/kg

Ballard 50 W

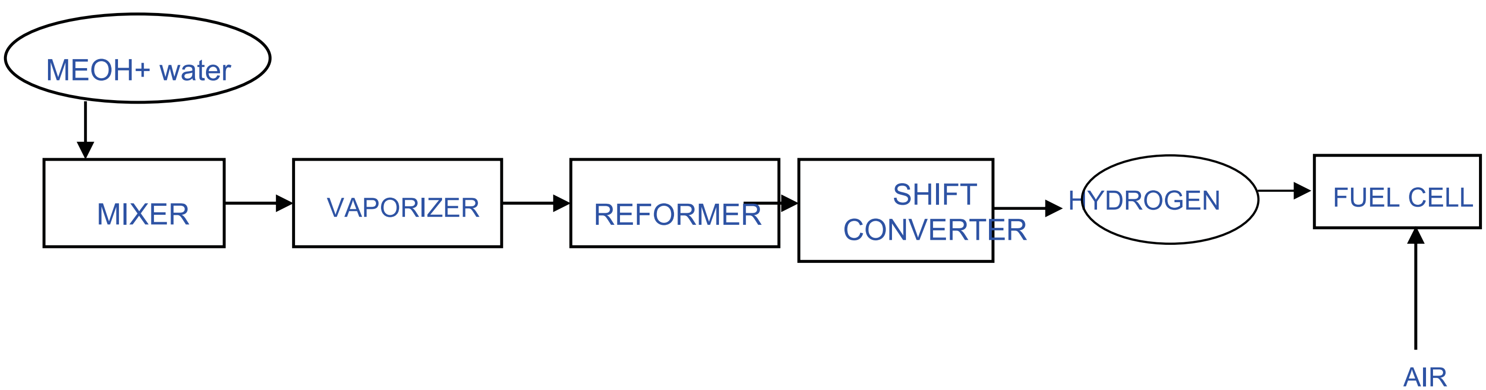
Sodium Borohydride Storage (2-3%) 2005



300 Wh/kg

Protonex 50 W

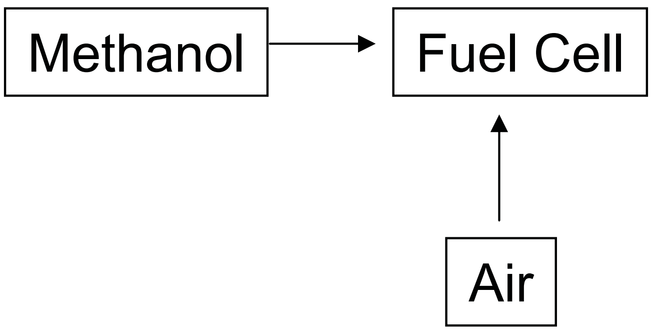
Indirect Methanol Based (5-6%) 2006



330 Wh/kg

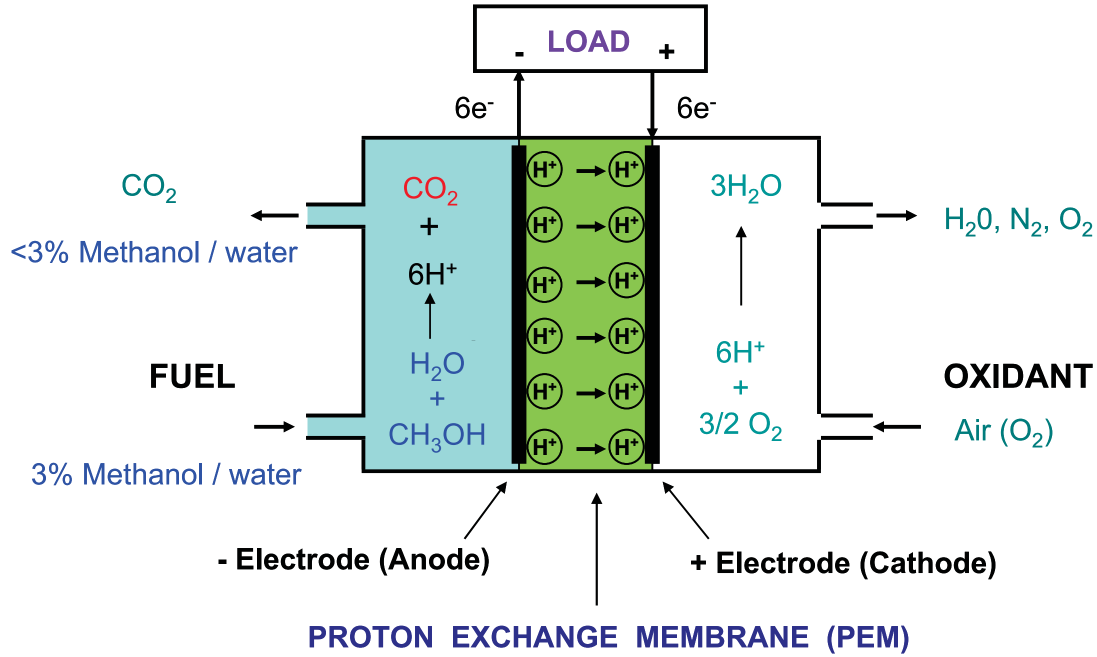
Ultracell 25W

Direct Methanol Fuel Cell



- High Energy Liquid Fuel
- Simple System
- Starts up instantly

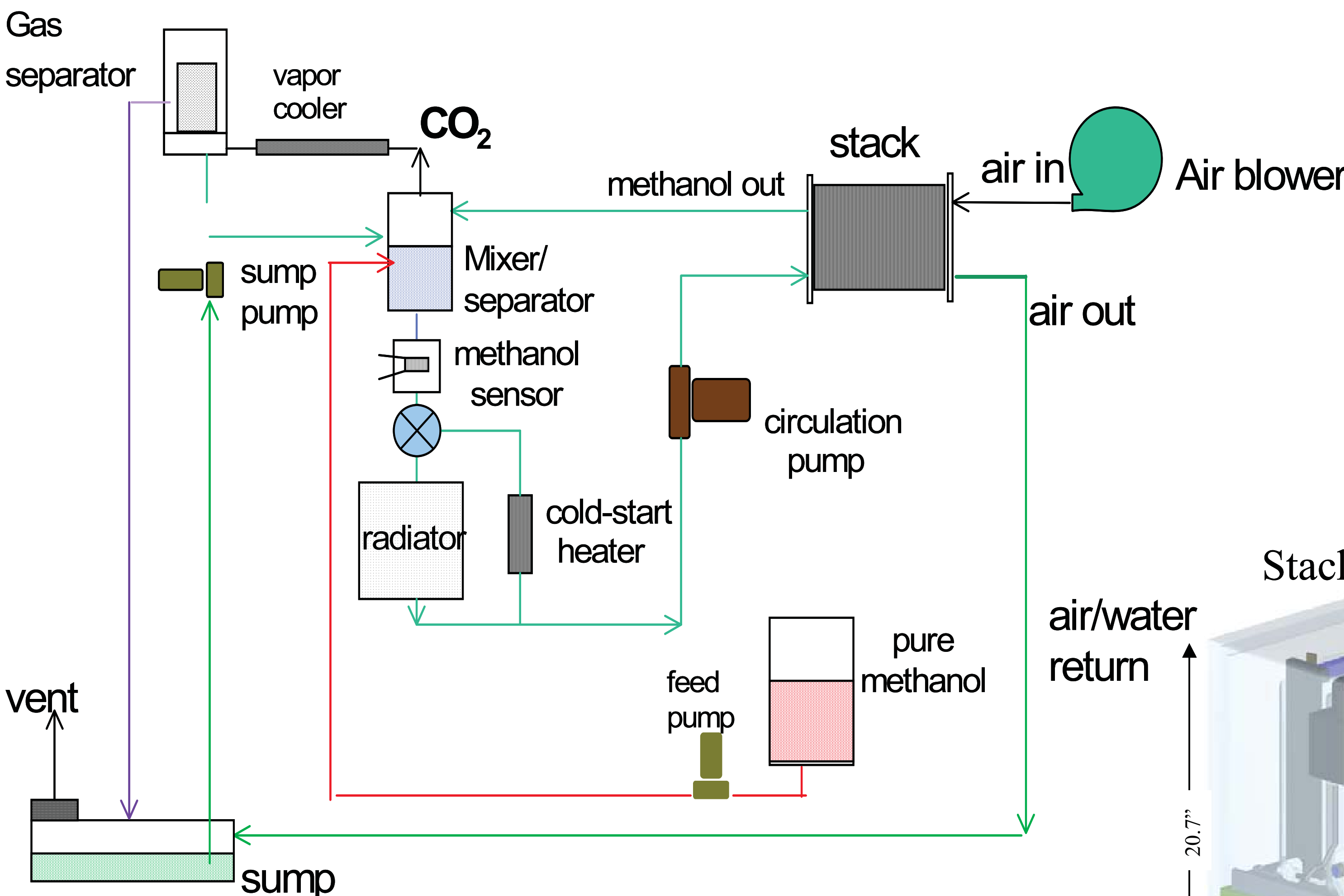
Direct Methanol Fuel Cell

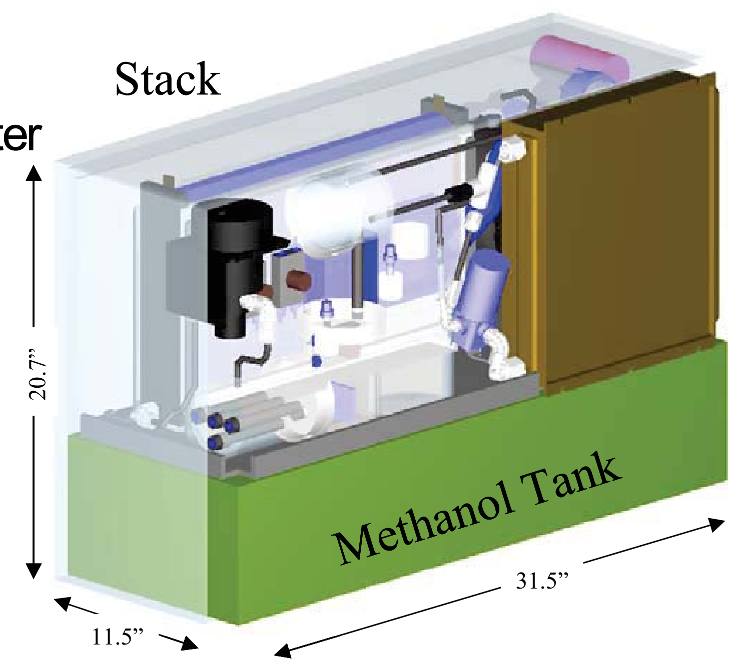


Cell Reaction

$CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O$

Direct Methanol Fuel Cell System Concept





Overview of DMFC R&D at JPL

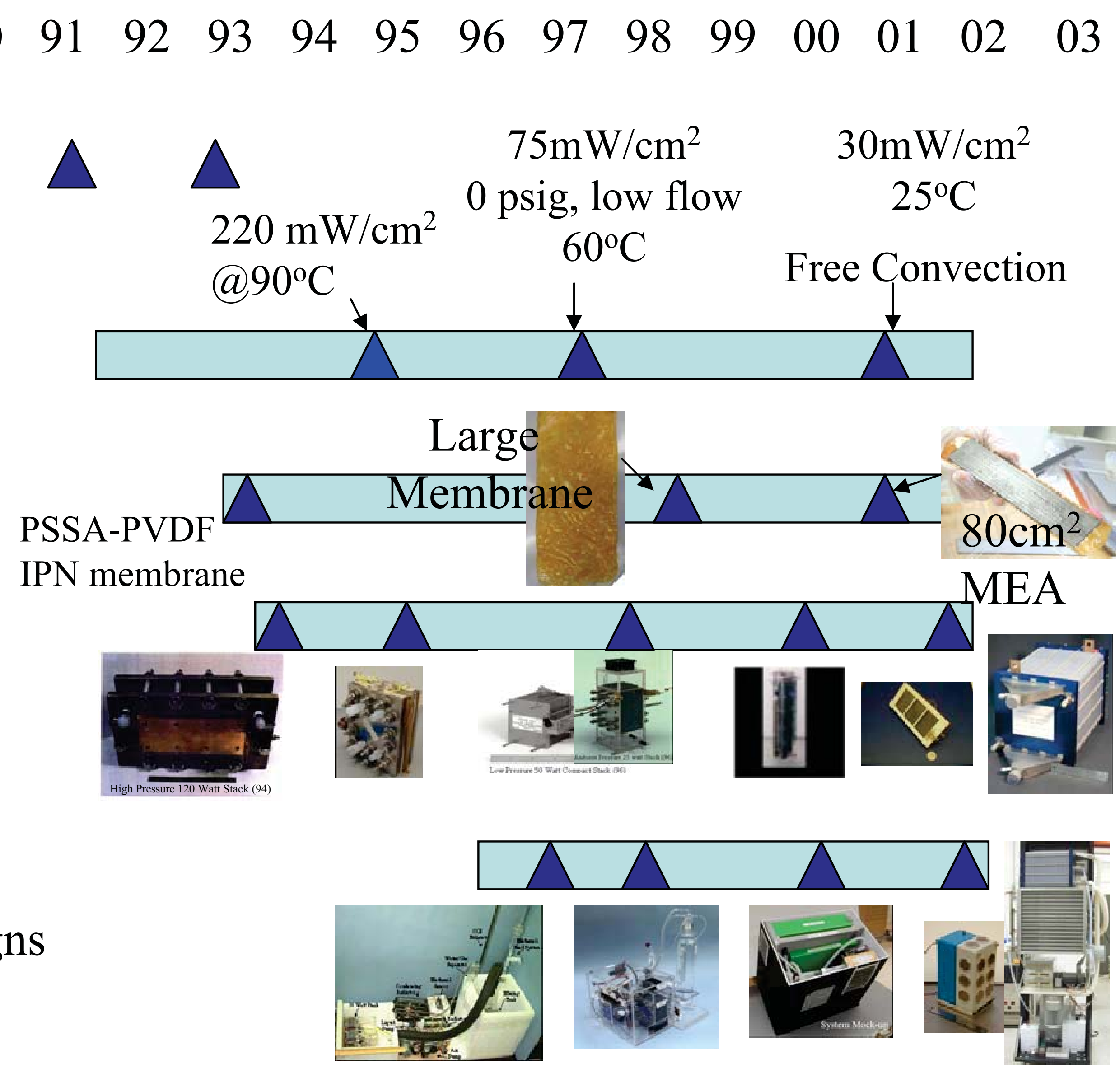
Liquid Feed DMFC
With Polymer Electrolyte

Catalysts, MEA and
Performance Improvements

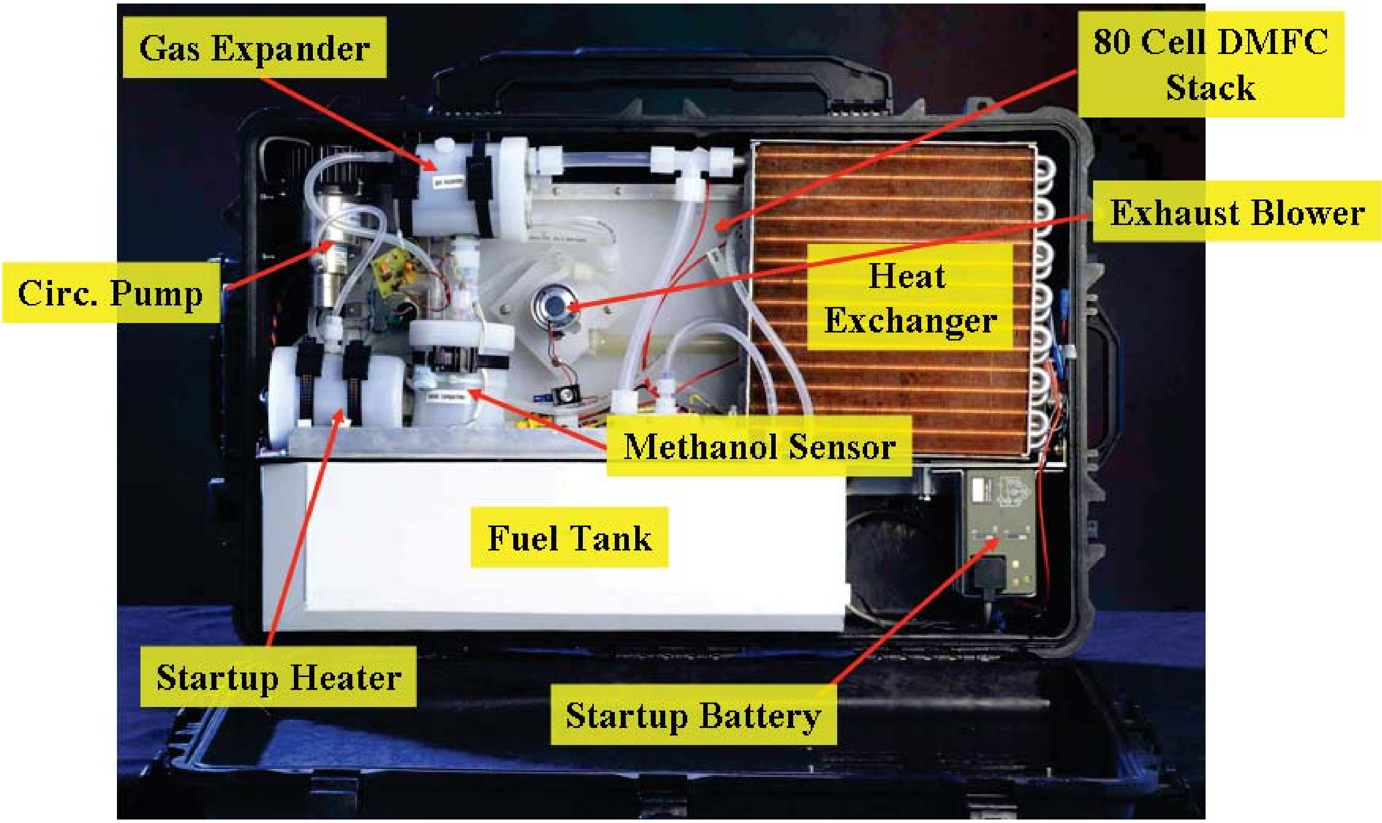
Membranes with reduced crossover
(in collaboration with USC)

1-1000 W Stack Demonstrations
Novel Stack concepts

System Design and Demonstrations
of overall system concept, stack designs
New materials



300-Watt Portable Fuel Cell for Army Applications



High Specific Energy Solution >600 Wh/kg for DoD
Scalable from 50 Watts – 1kW

DMFC units from Smart Fuel Cell Inc, Germany

Use: for charging Pb-Acid Batteries

Dimensions: 13 x15 x 26 cm

Mass: 8 kg

Nominal Power Output: 50 Watts

Specific energy based on methanol fuel: 960 Wh/kg

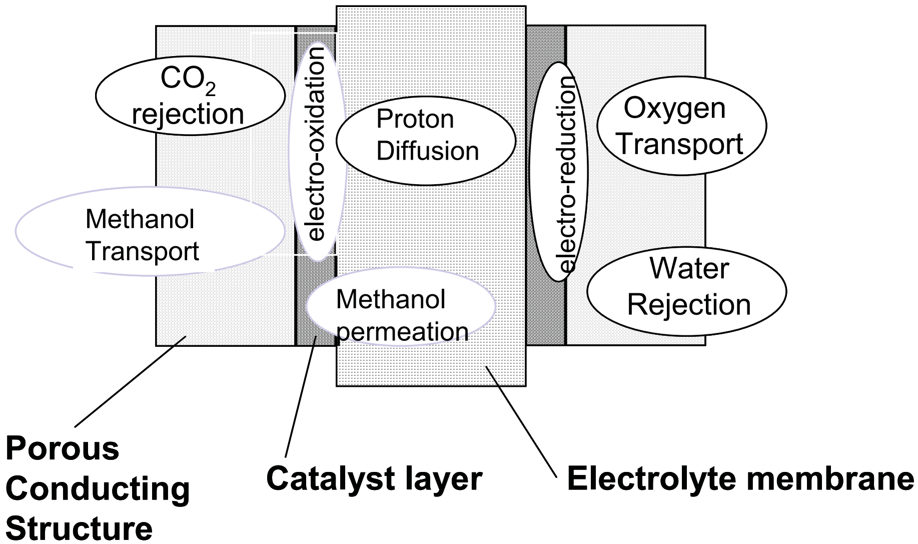
DMFC Status and Prospects

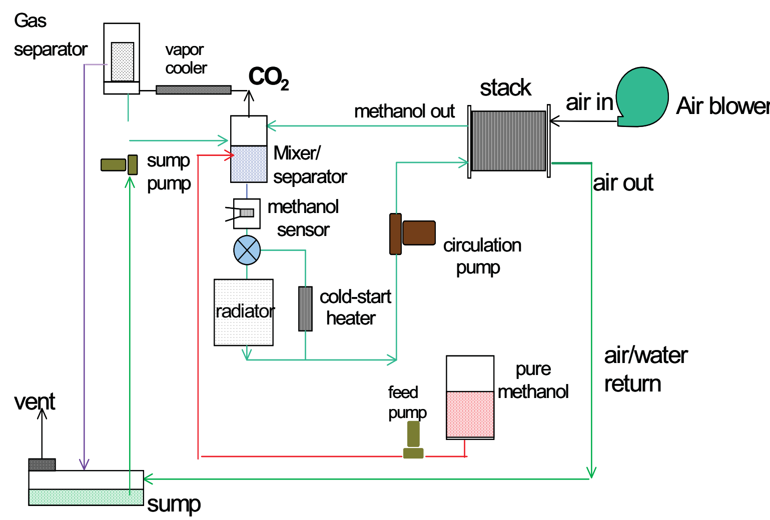
Characteristic	Status	Target	Benefit
Performance *Power Density* *Efficiency*	20 W/kg, 15-20%	100 W/kg 30-35%	Light-weight Compact, high-energy density
Durability	100-500 hours	5000 hours	Meeting lifetime requirements
Cost	$15000/kW	$1000/kW	Increased market potential Reduction in life cycle costs

Challenges

- Electrocatalytic oxidation kinetics
- Polymer Electrolyte Membrane
- Lightweight System Design
- Durability
- Cost reduction

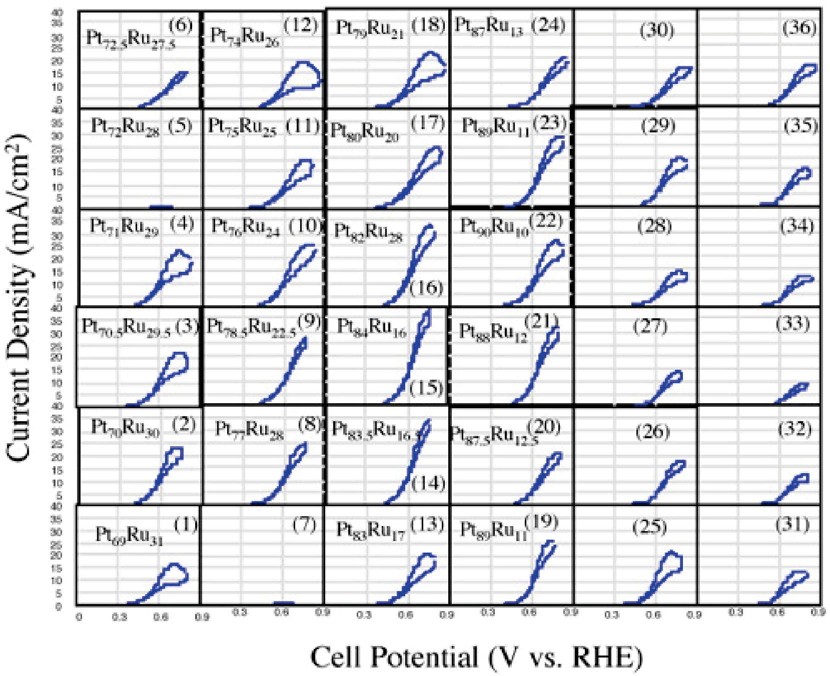
Processes in a Direct Methanol Fuel Cell





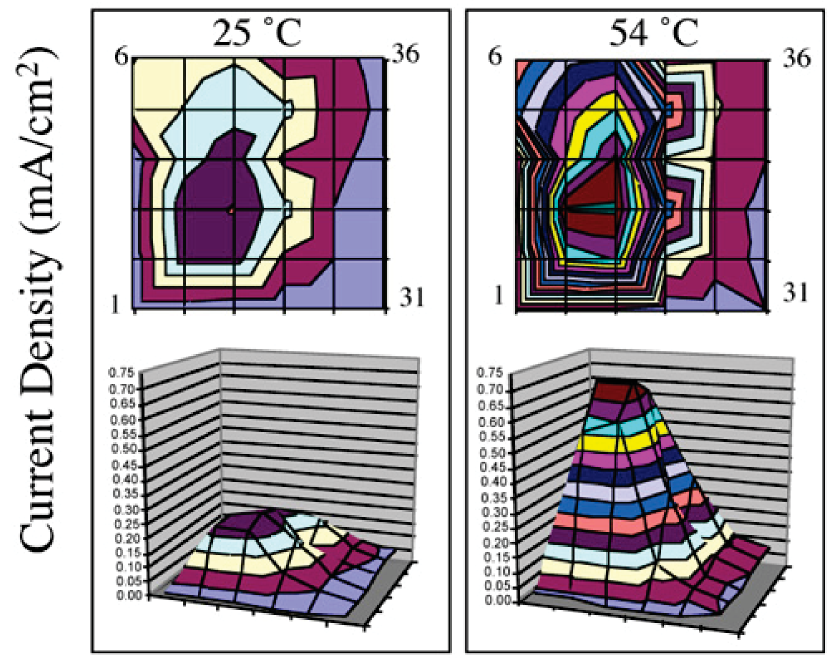
Rapid Screening of Well-Controlled Catalyst Compositions

Multi-Electrode Array Screening



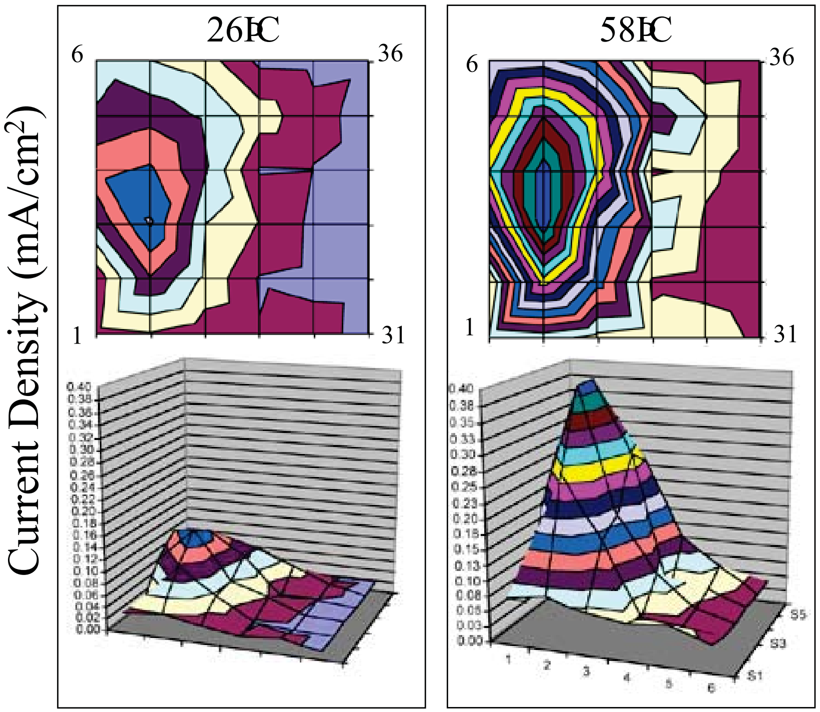
- 60 ˚C, 5 mV/Sec, in 1 M sulfuric/ methanol
- Multiple cycles collected until equilibrium reached
- All current densities **normalized to electrode area**

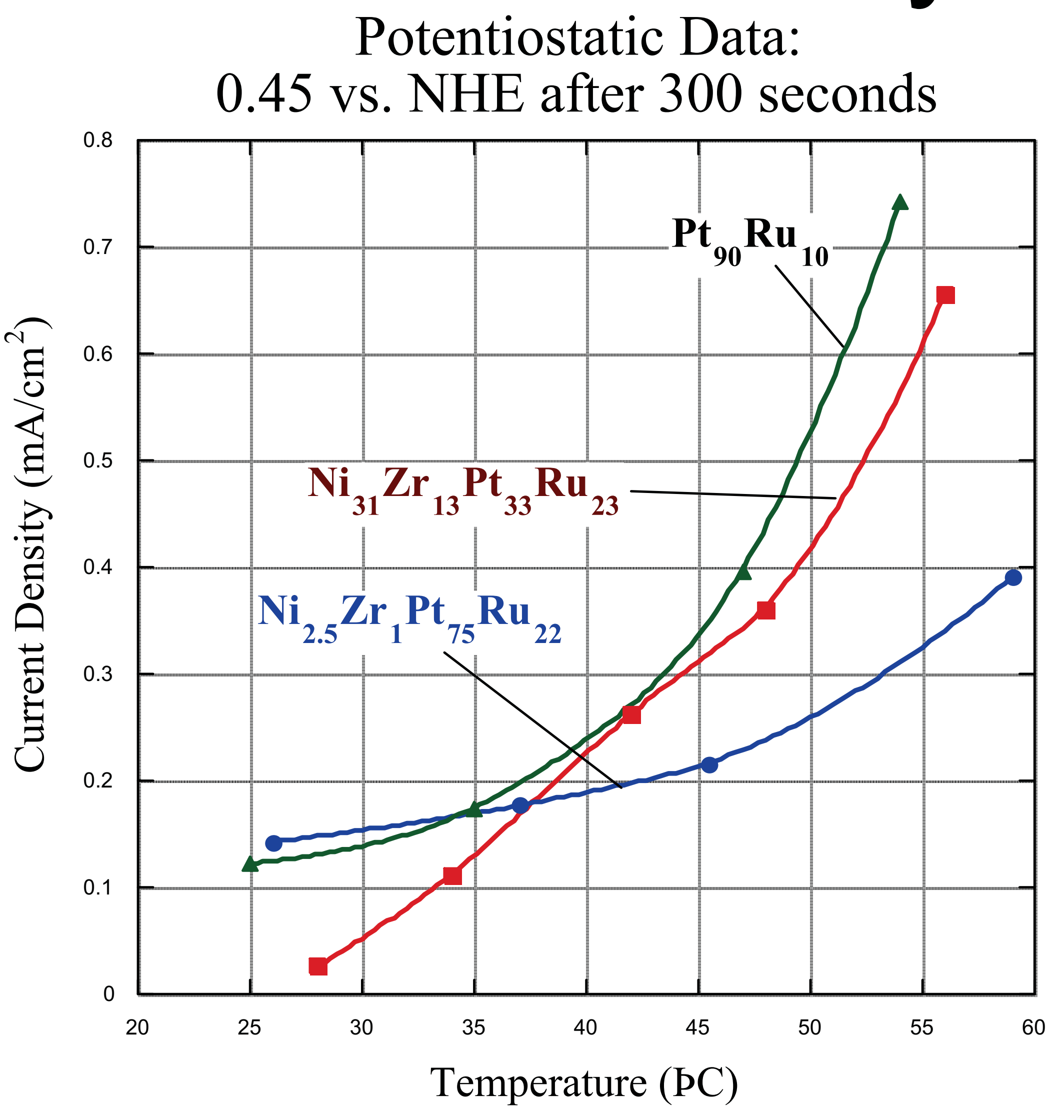
Potentiostatic: Cells held at 0.45 V vs.RHE after 300 seconds



- Smooth profile relating performance to composition
  - Indicative of solid solution,
  - No oxides or phase separation to provide “spikes”
- **Significant performance differential at elevated temperature**

Screening of Ni-Zr-Pt-Ru alloys





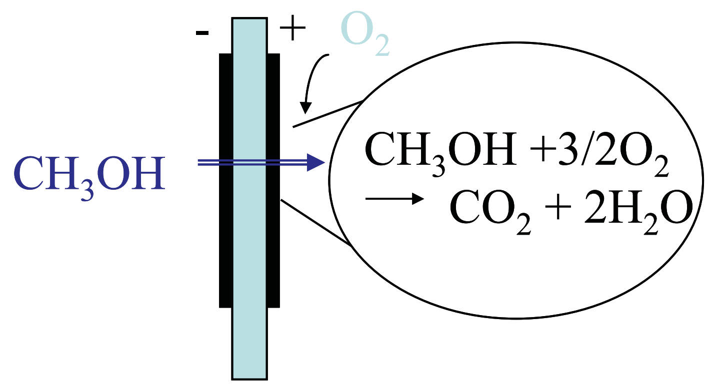
Ni(31)Zr(13)Pt(33)Ru(23) is similar in activity to the best Pt-Ru catalyst

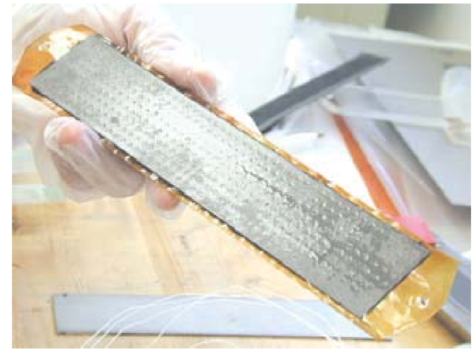
Issues with New Membranes

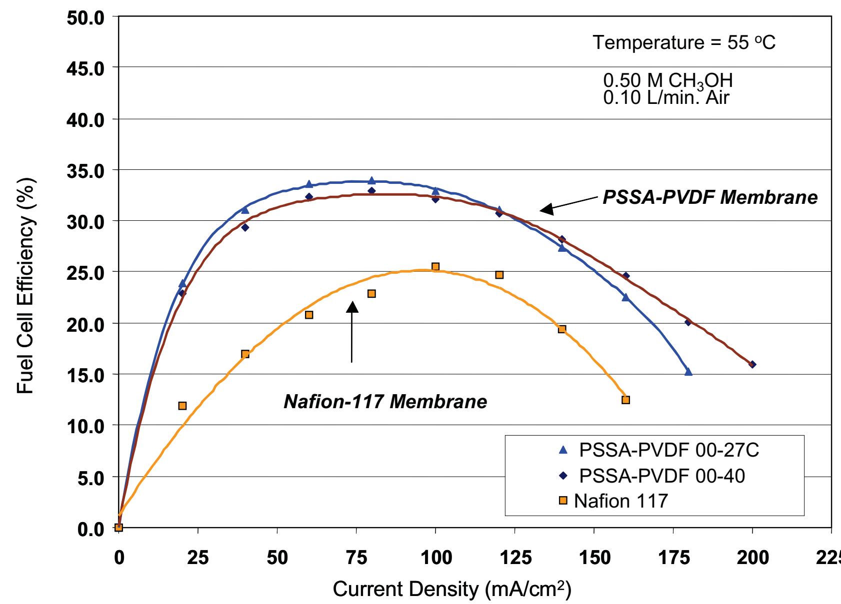
- Compromise of proton conductivity to lower methanol permeability
- Poor mechanical properties in dry state
- Poor membrane-electrode interface properties
- Modest reduction in crossover rate

Membranes With Reduced Methanol Crossover

PSSA-PVDF Membrane







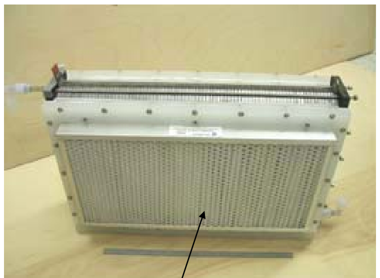
Challenges:

- Compromise of proton conductivity to lower methanol permeability
- Poor mechanical properties in dry state
- Poor membrane-electrode interface properties
- Modest reduction in crossover rate

- Reduces Methanol crossover by 75%
- Inexpensive Membrane Material
- Demonstrated in 80 cm^2 stack

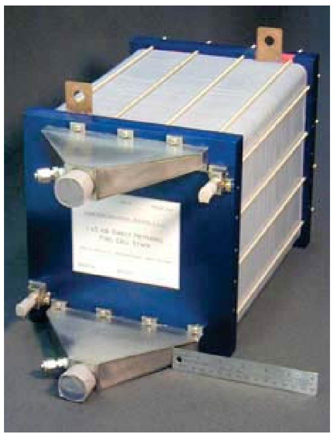
Stacks

Bipolar Designs



Donaldson Air filter

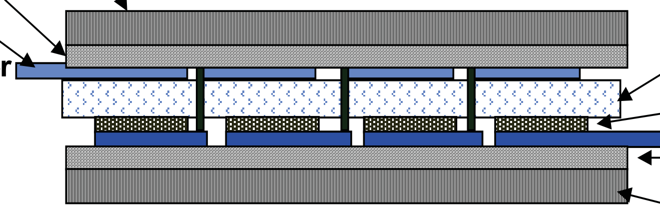
JPL 80-cell
300 Watt



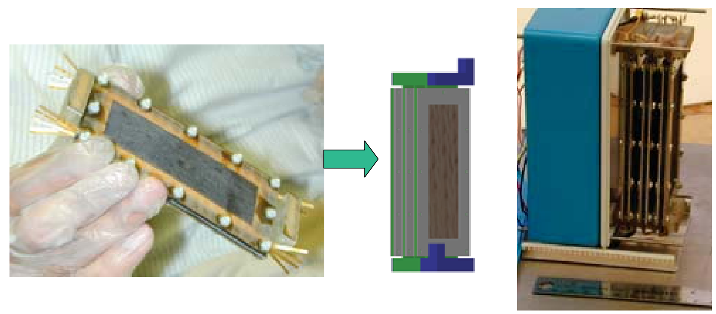
Ambient Pressure 1.4 kW (01)

1.4 kW by Giner Inc.
for JPL.

Monopolar Designs



Monopolar Stack



Lightweight stack operating on natural convection at 50 W/kg at 30°C, 120W/kg at 60°C

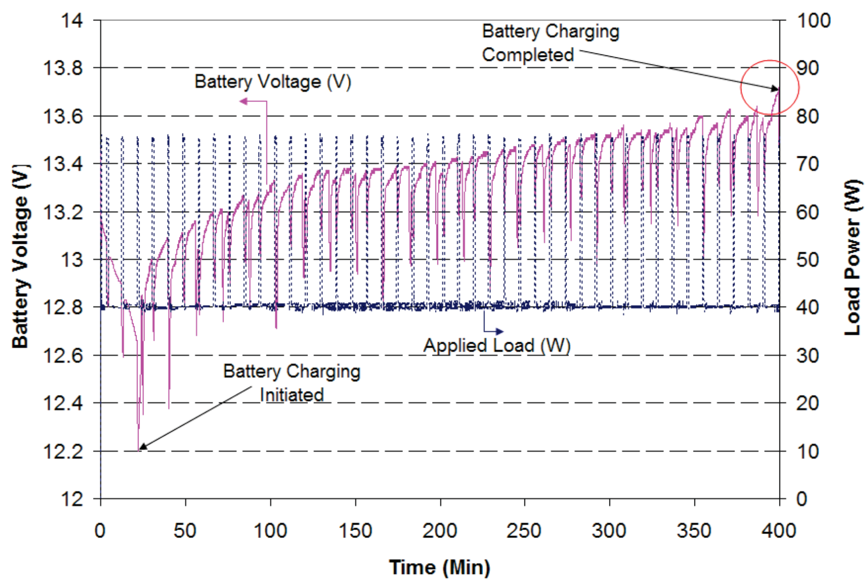
Stack power density is 55- 80 W/kg for operation at 55°-60°C

Stack power density can be enhanced to 120-150 W/kg

Hybrid DMFC System

SFC System

JPL-SFC Hybrid DMFC System



Watts/kg can be significantly improved by hybridizing with batteries

Small Compact Systems

•Controlled delivery of concentrated Methanol

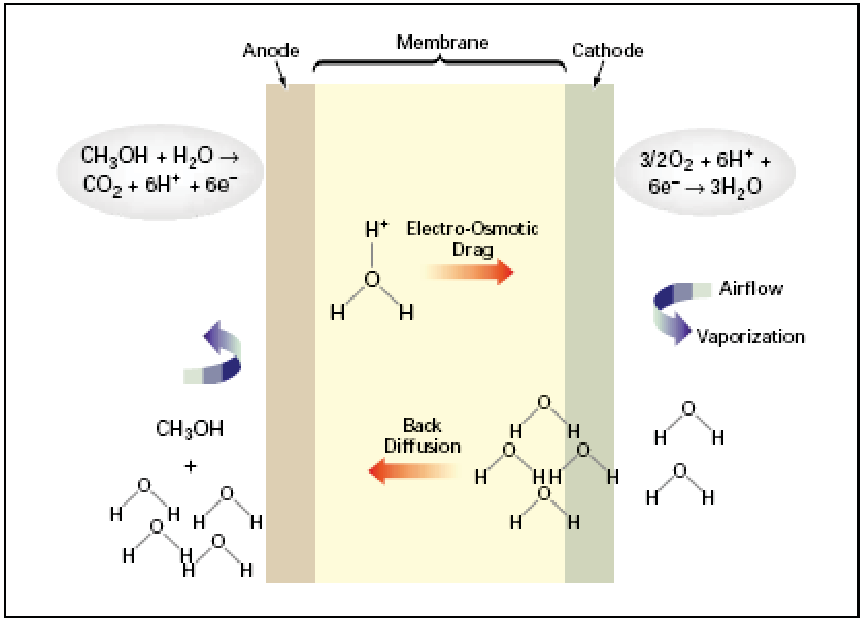
•Relying on Back Diffusion to Supply Water

•Forced Convection at Low Back Pressure

•Higher Power Density of Stack (Anode catalysts)

•Membranes with low methanol crossover for catalyst loading reduction

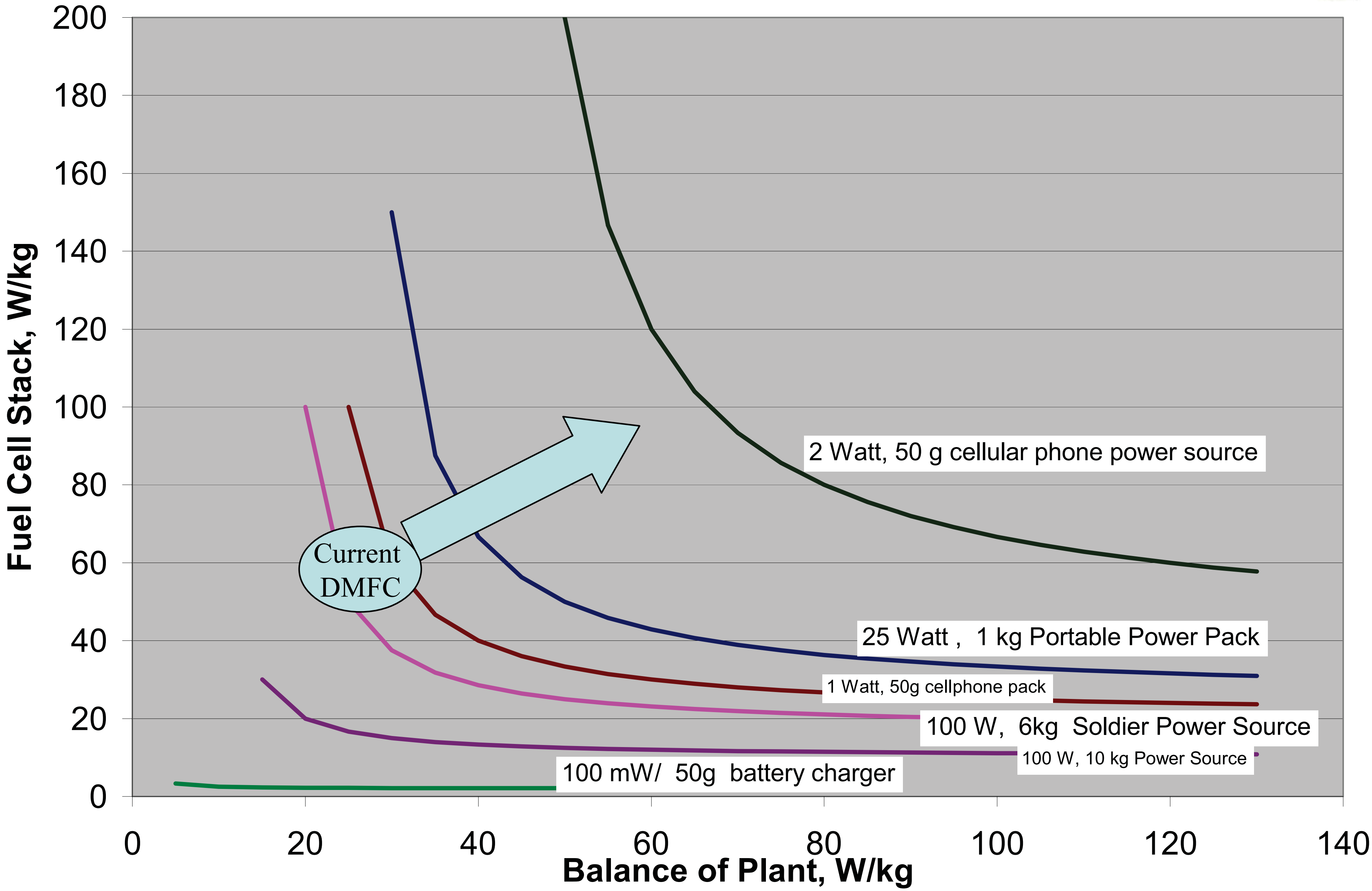
•Integration with High Power Batteries for Load Management



Durability

- Improve inherent instability of catalysts (DuPont MEA, ~2000 hours)
- Prevent loss of hydrophobicity of the cathode
- Accumulation of impurities in the liquid stream
- Reliability of components (pumps, valves)

Stack and System Parameters for Various Applications



Acknowledgements

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