Advances in Materials and System Technology for Portable Fuel Cells

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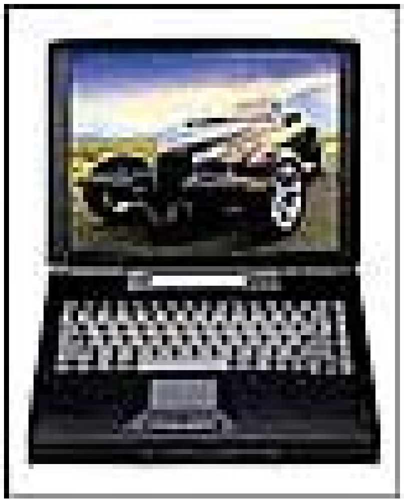
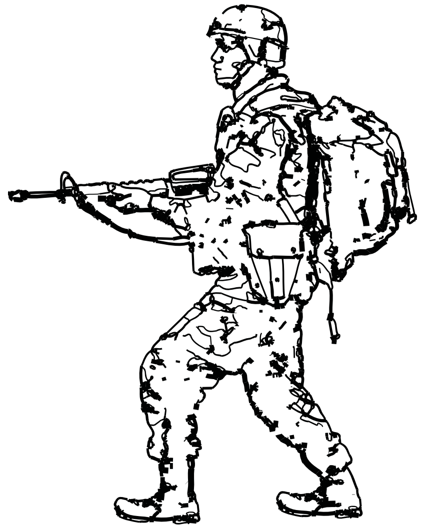
Portable Power

Examples:

2W

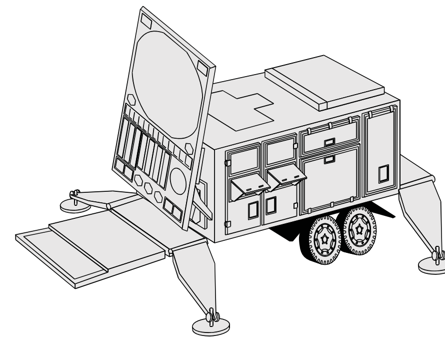


20W



50-100W

500W



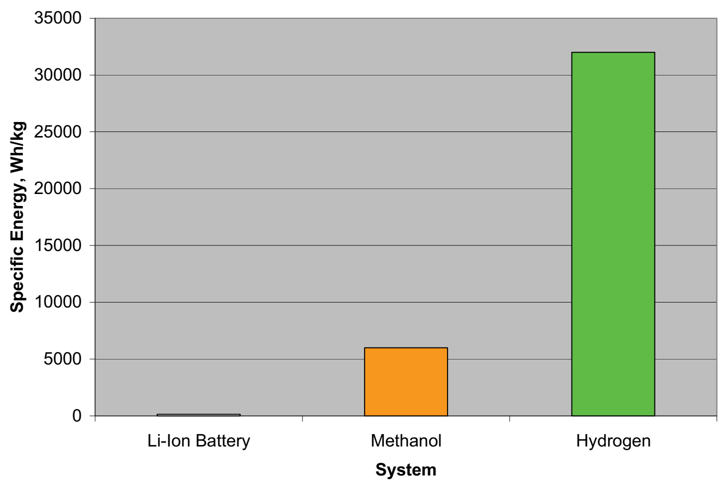
1-5kW

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:

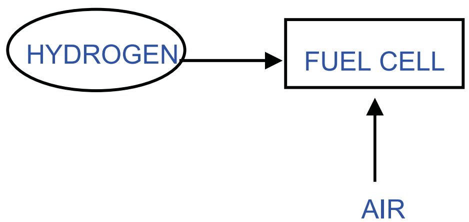
- Methanol, 6000 Wh/kg
- Hydrogen, 32000 Wh/kg

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

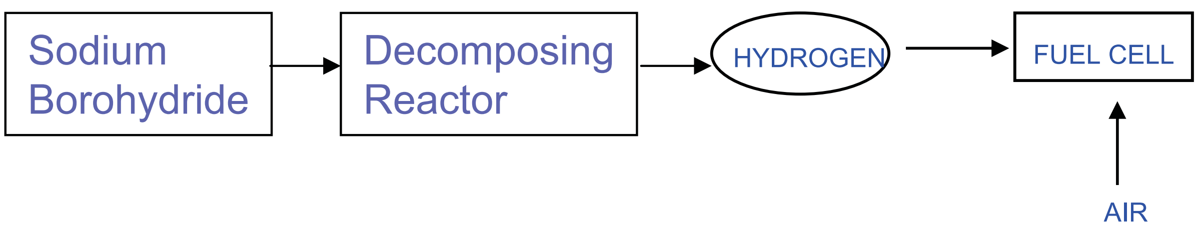
Gaseous Hydrogen Storage (2%) 1998



200 Wh/kg

Ballard 50 W

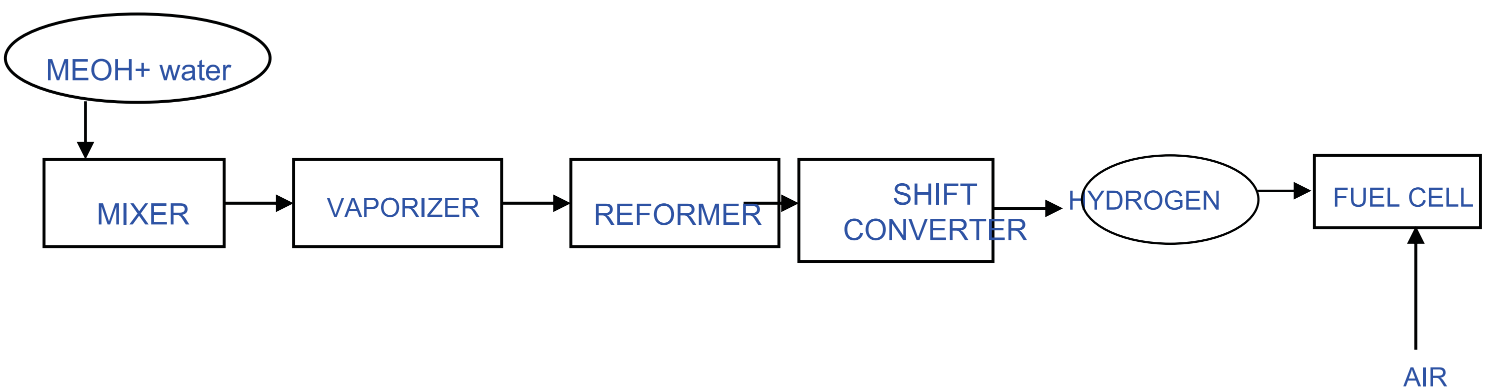
Sodium Borohydride Storage (2-3%) 2005



300 Wh/kg

Protonex 50 W

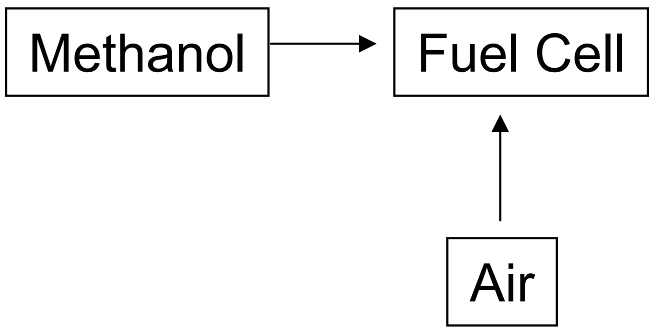
Indirect Methanol Based (5-6%) 2006



330 Wh/kg

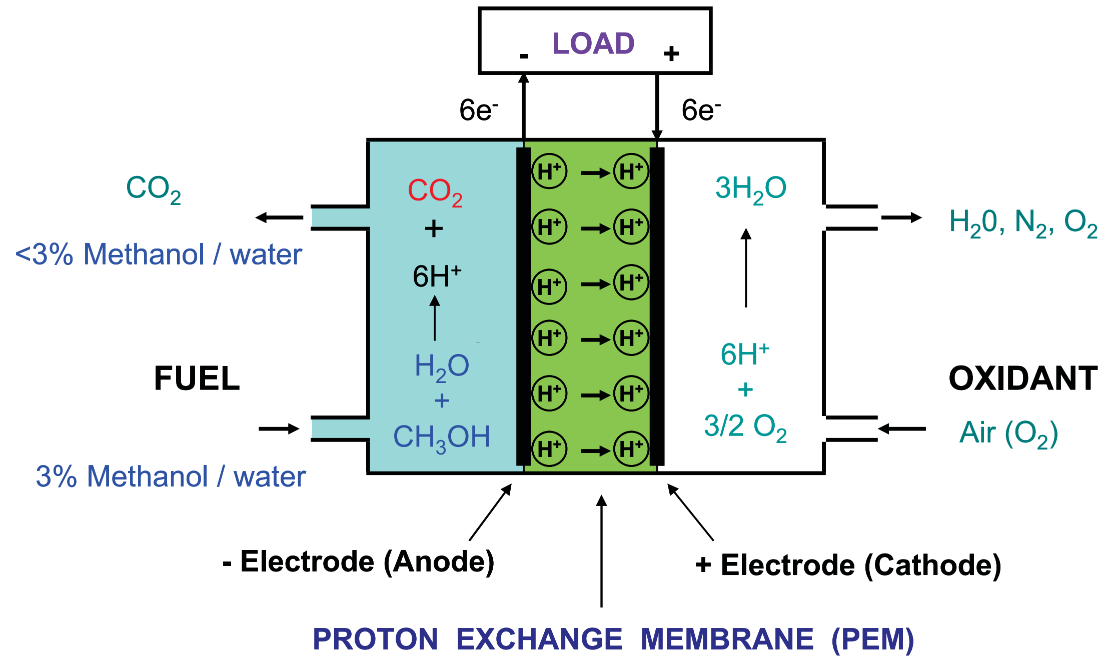
Ultracell 25W

Direct Methanol Fuel Cell



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

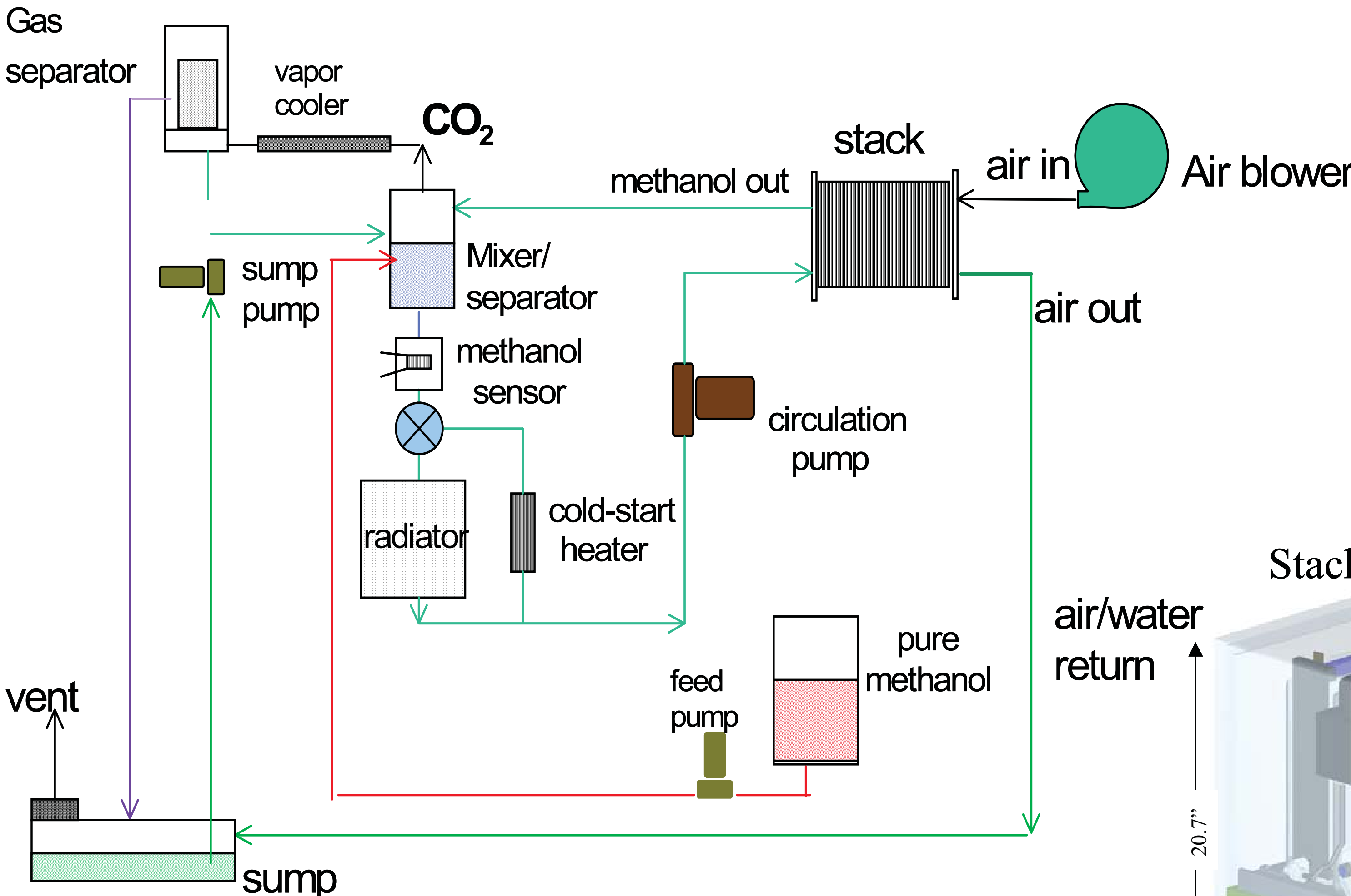
Direct Methanol Fuel Cell

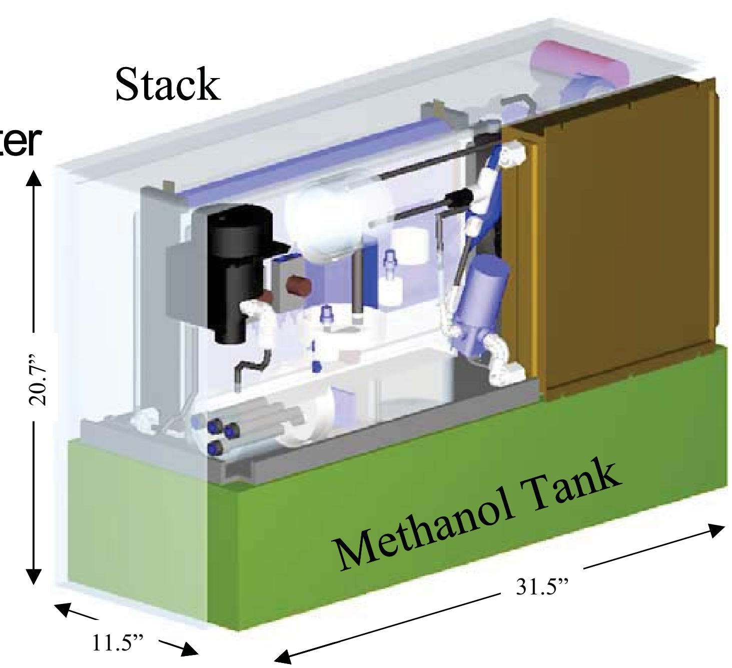


Cell Reaction

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

Direct Methanol Fuel Cell System Concept





Overview of DMFC R&D at JPL

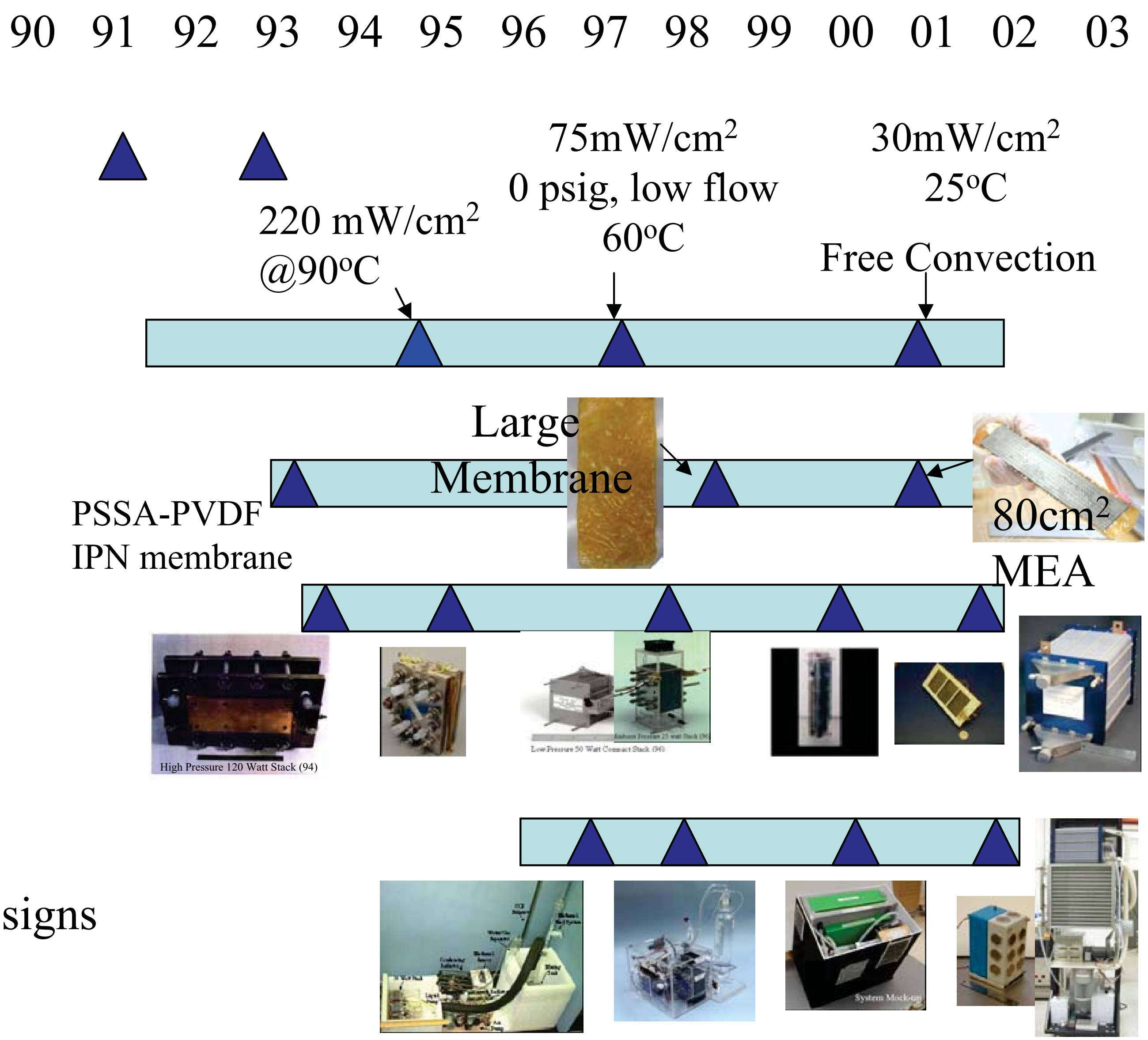
Liquid Feed DMFC
With Polymer Electrolyte

Catalysts, MEA and
Performance Improvements

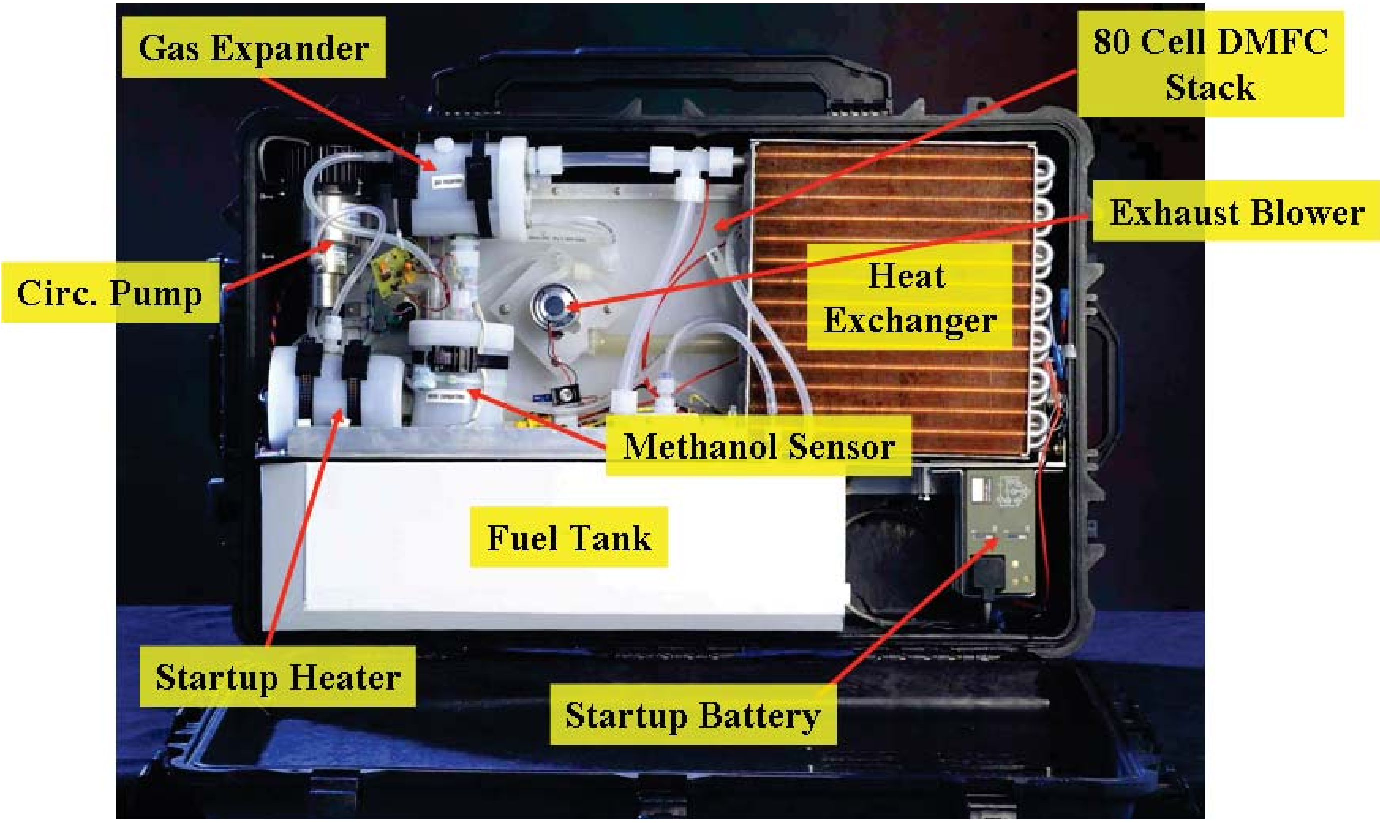
Membranes with reduced crossover
(in collaboration with USC)

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

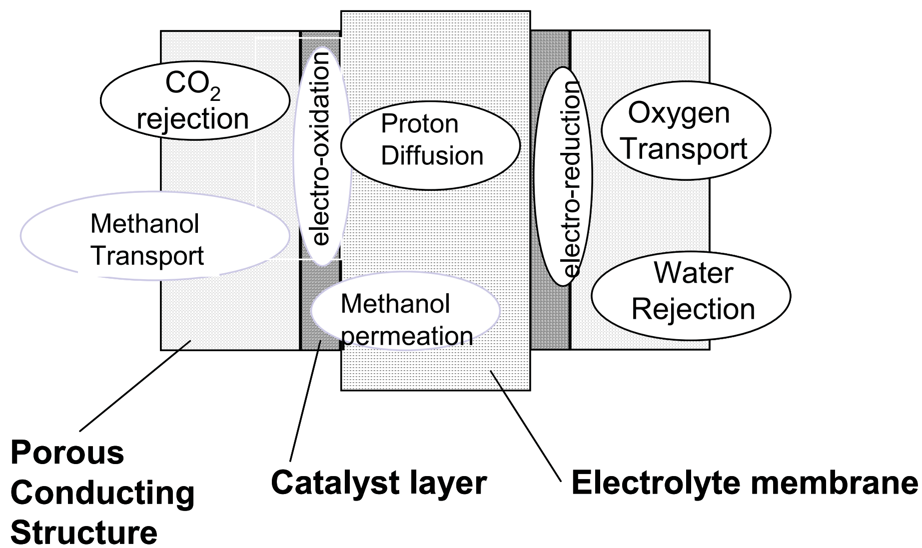
DMFC Status and Prospects

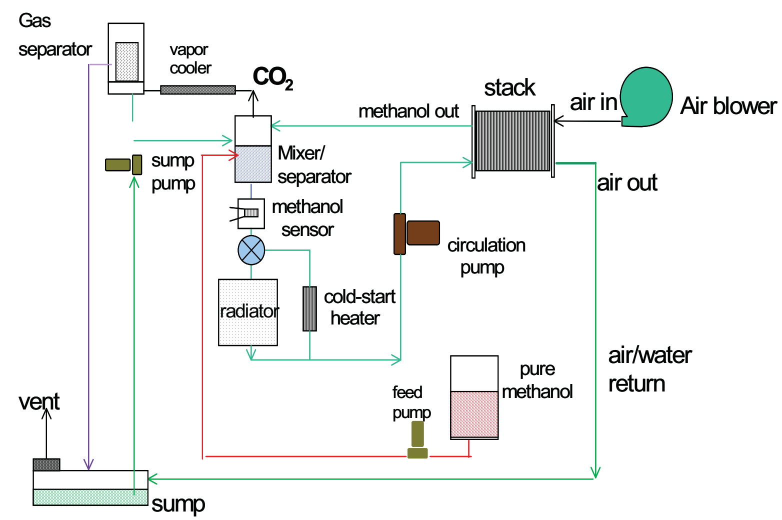
Characteristic	Status	Target	Benefit
Performance *Power Density* *Efficiency*	20 W/kg, 15-20%	100 W/kg 30-35%	Light-weight Compact, high-energy density
Durability	100-500 hours	5000 hours	Meeting lifetime requirements
Cost	$15000/kW	$1000/kW	Increased market potential Reduction in life cycle costs

Challenges

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

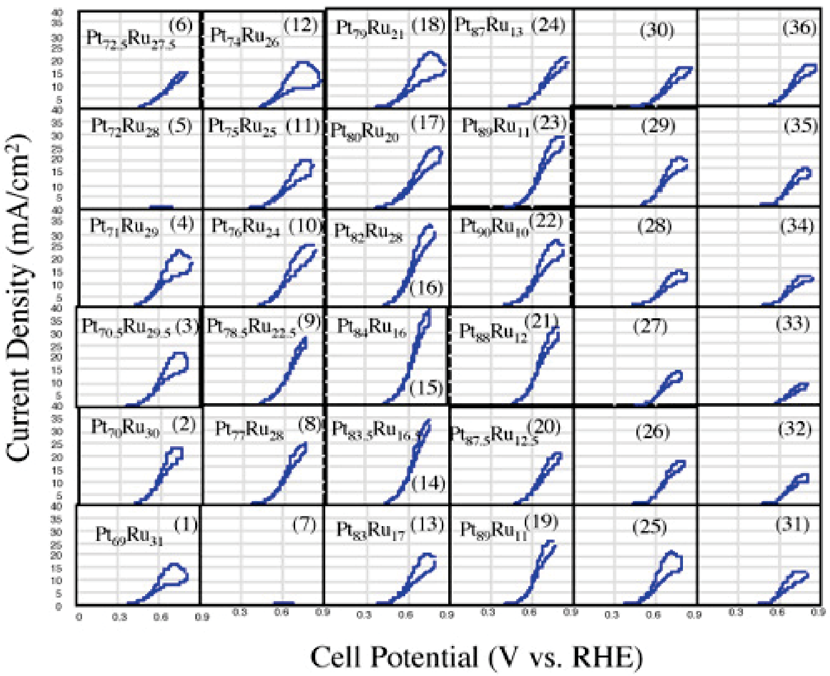
Processes in a Direct Methanol Fuel Cell





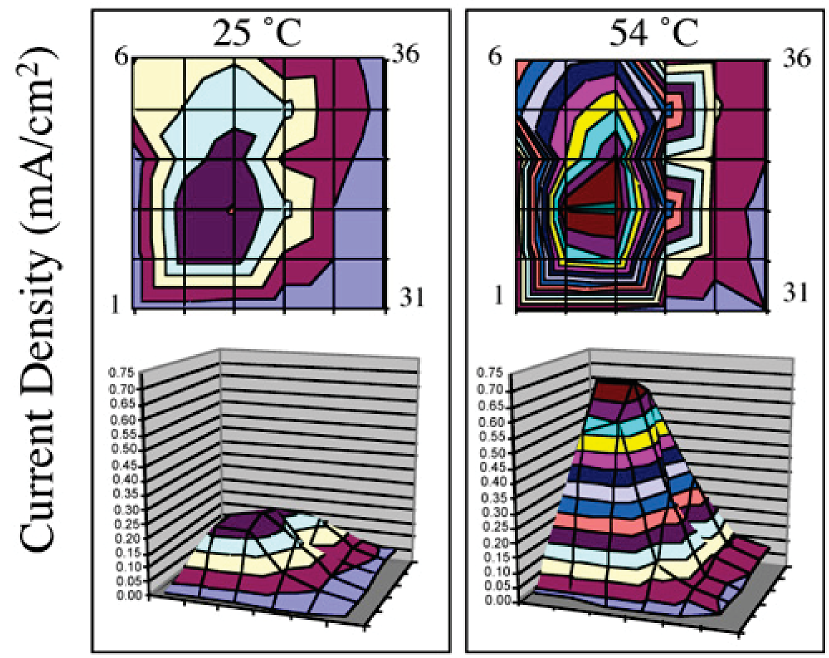
Rapid Screening of Well-Controlled Catalyst Compositions

Multi-Electrode Array Screening



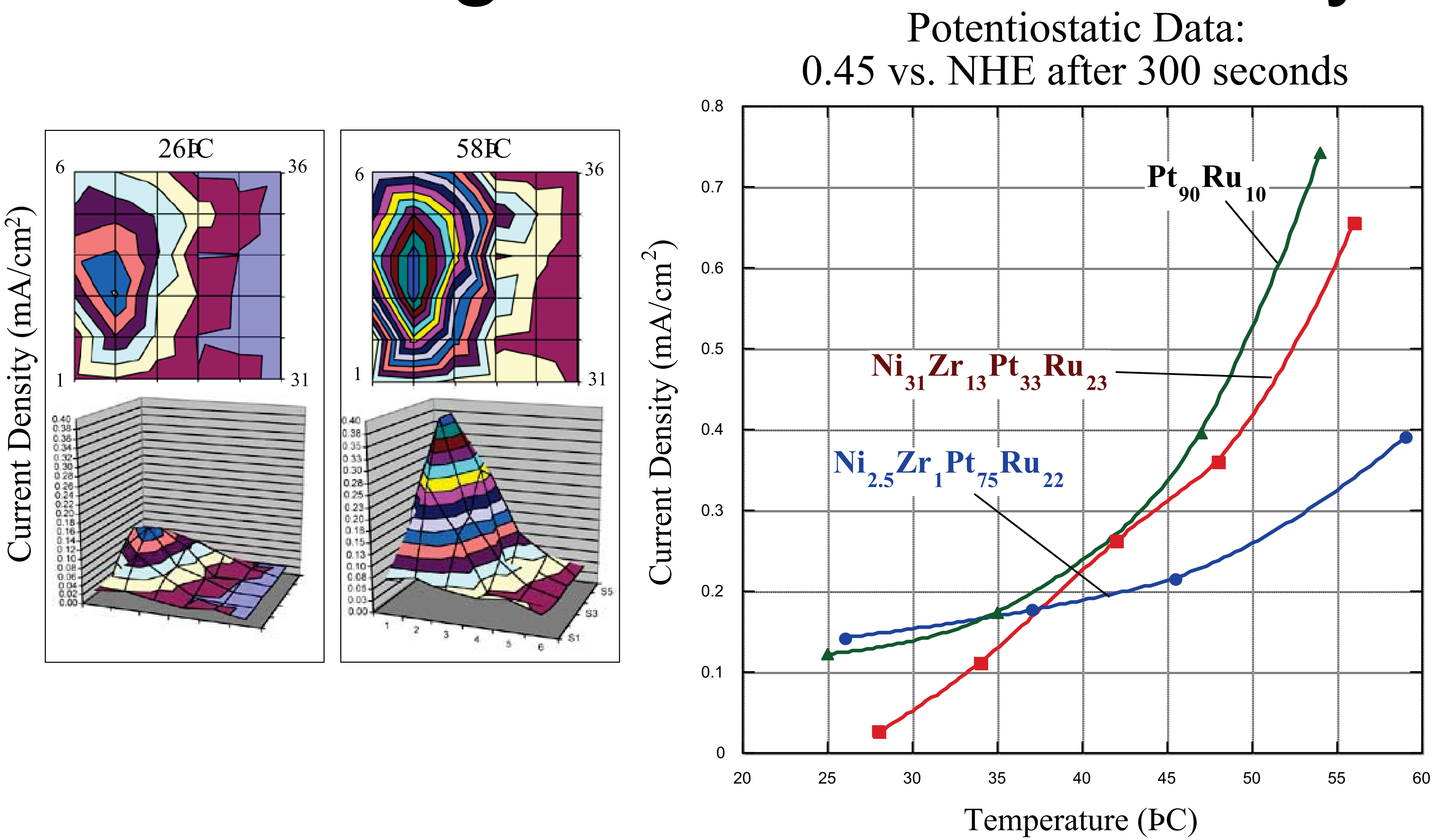
- 60 ˚C, 5 mV/Sec, in 1 M sulfuric/ methanol
- Multiple cycles collected until equilibrium reached
- All current densities **normalized to electrode area**

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



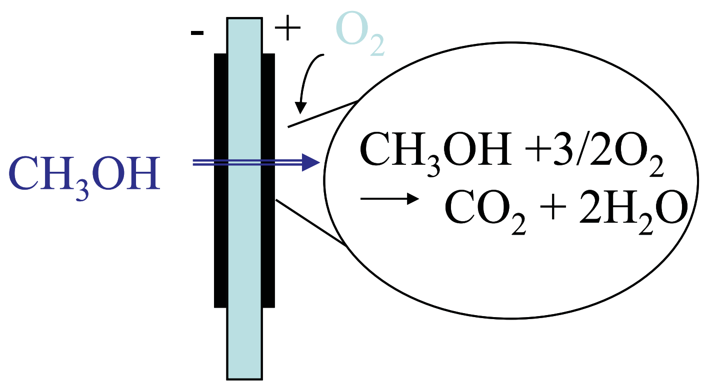
Ni(31)Zr(13)Pt(33)Ru(23) is similar in activity to the best Pt-Ru catalyst

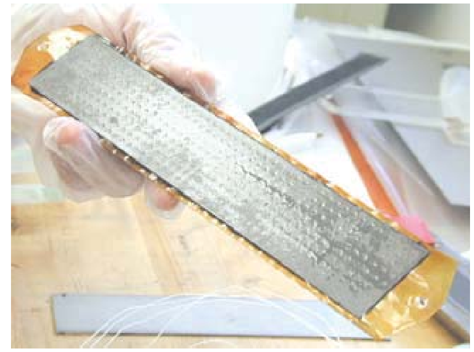
Issues with New Membranes

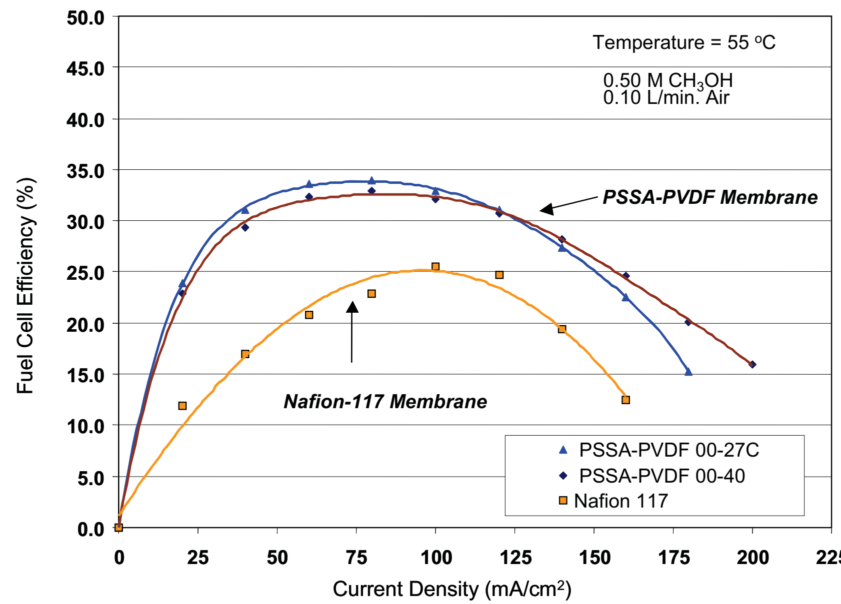
- Compromise of proton conductivity to lower methanol permeability
- Poor mechanical properties in dry state
- Poor membrane-electrode interface properties
- Modest reduction in crossover rate

Membranes With Reduced Methanol Crossover

PSSA-PVDF Membrane







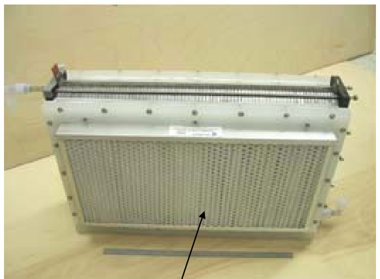
Challenges:

- 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

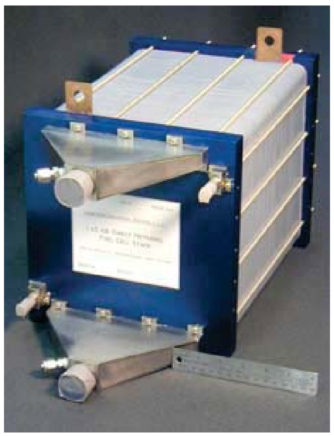
Stacks

Bipolar Designs



Donaldson Air filter

JPL 80-cell
300 Watt

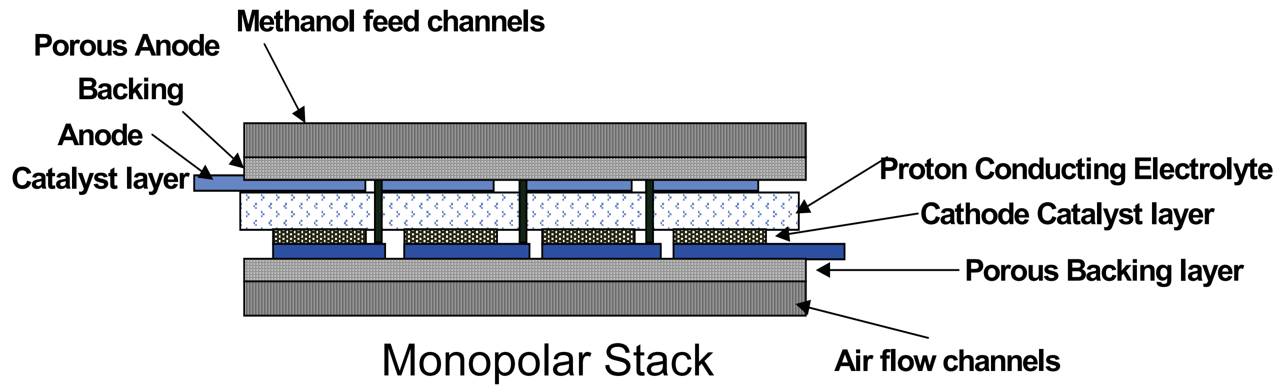


Ambient Pressure 1.4 kW (01)

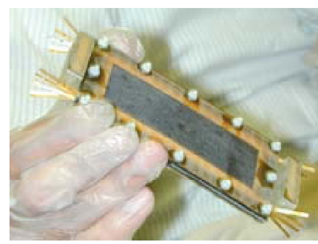
1.4 kW by Giner Inc.
for JPL.

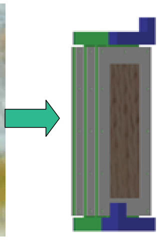
Stack power density is 55- 80 W/kg for operation at 55°-60°C

Monopolar Designs



Monopolar Stack





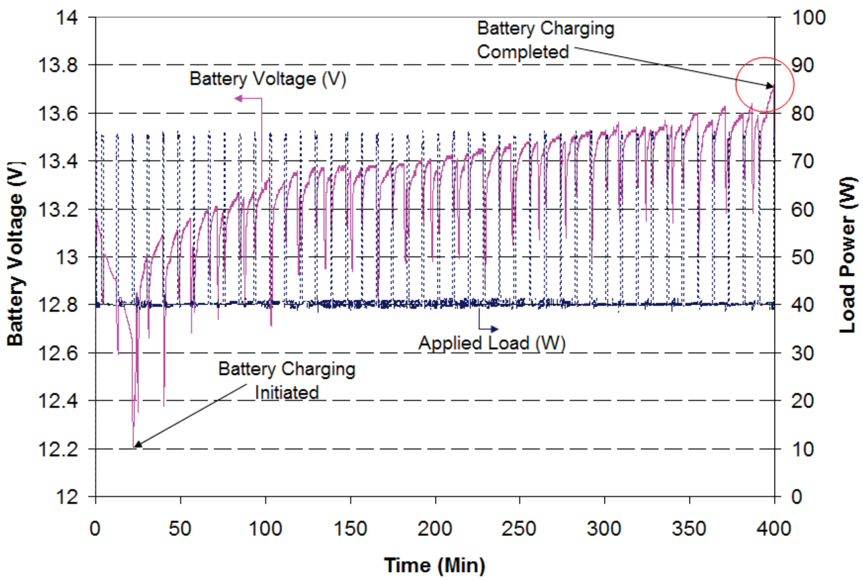
Lightweight stack operating on natural convection at 50 W/kg at 30°C, 120W/kg at 60°C

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

Hybrid DMFC System

SFC System

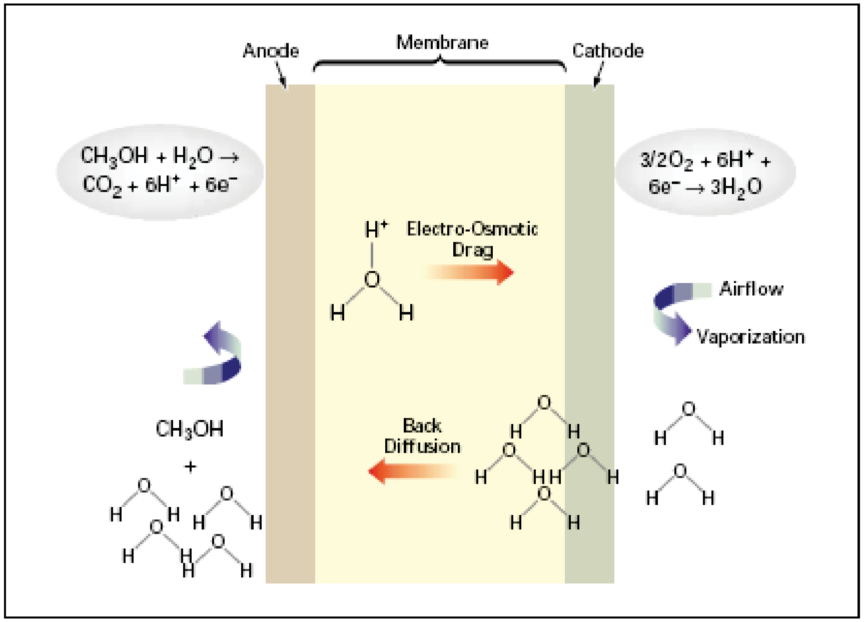
JPL-SFC Hybrid DMFC System



Watts/kg can be significantly improved by hybridizing with batteries

Small Compact Systems

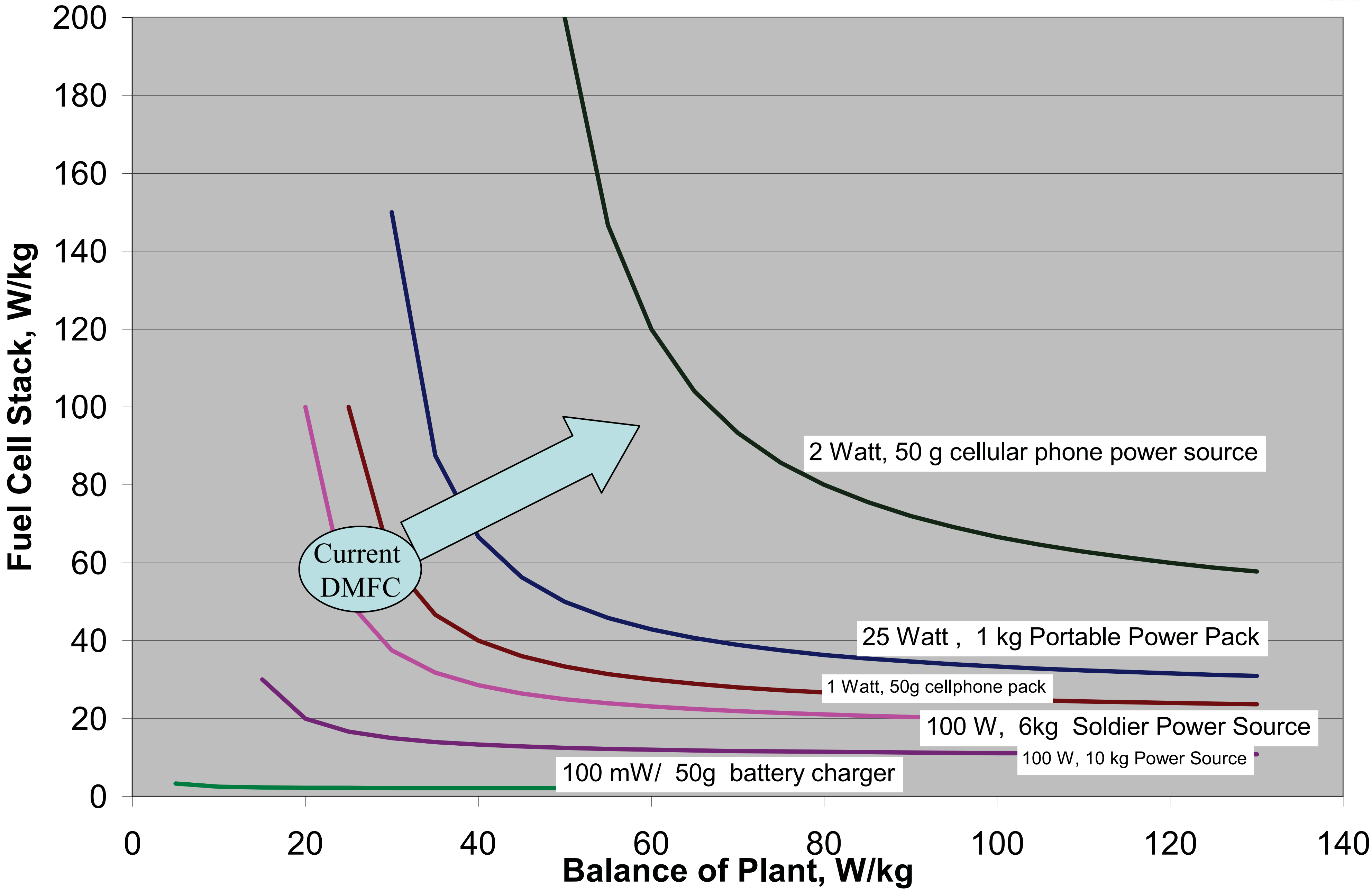
- Controlled delivery of concentrated Methanol
- Relying on Back Diffusion to Supply Water
- Forced Convection at Low Back Pressure
- Higher Power Density of Stack (Anode catalysts)
- Membranes with low methanol crossover for catalyst loading reduction
- Integration with High Power Batteries for Load 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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