AUV/UUV Advanced Fuel Cell Propulsion Options

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Outline

- Introduction to IdaTech
- Introduction to fuel cell technology
- Propulsion concepts
- Comparison of energy densities
- Potential utility of fuel cell power plants
- Conclusions

About IdaTech

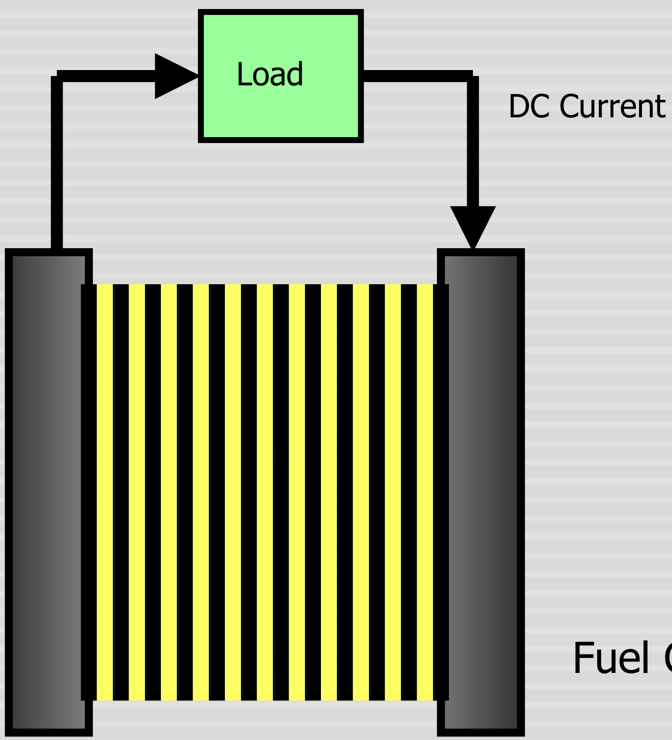
- Founded in 1996
- Approximately 80 employees focused on development of hydrogen generators and fuel cell systems
- Aggressive patenting policy
- Previously worked with Ballard (submarine propulsion); Daimler Benz (automotive propulsion); hydrogen purification (about 40 man-years of experience

Fuel Cell Chemistry

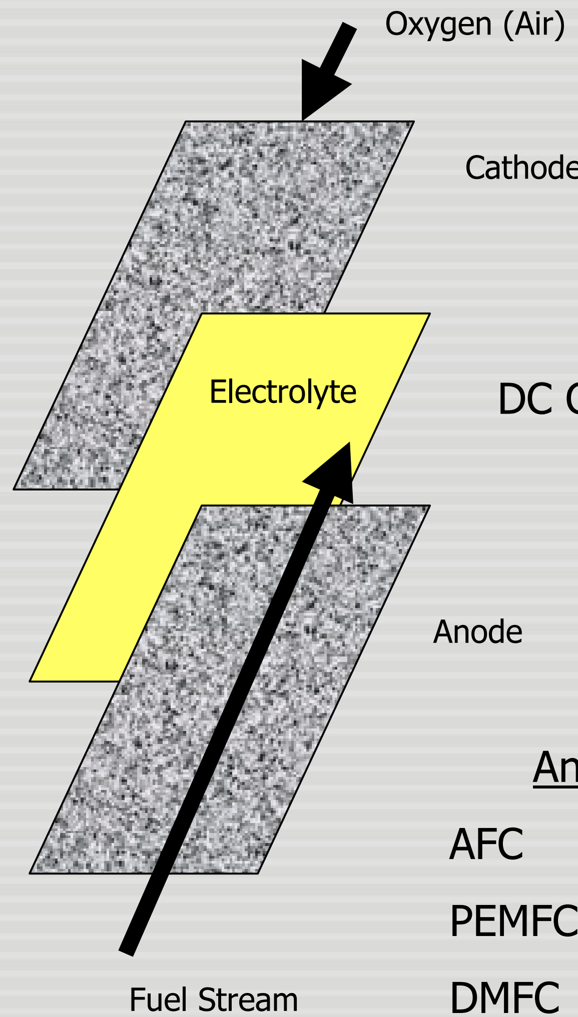
- Electrochemical conversion of fuel/oxidant into electricity and heat
  - Not limited by the Carnot Cycle
  - Generally offers high energy efficiency (>50%)
- Hydrogen is the typical fuel, air the oxidant
- $2\ H_2 + O_2 = 2\ H_2O$ + electricity + heat
  - Anode: $H_2 = 2\ H^+ + 2\ e^-$
  - Cathode: $4\ H^+ + O_2 + 4\ e^- = 2\ H_2O$ + heat

Introduction to Fuel Cells

Primary types: AFC (alkaline); PEMFC (proton-exchange membrane); DMFC (direct methanol)



Fuel Cell Stack



DC Cell Potential

Anode Fuel	
AFC	H2
PEMFC	H2
DMFC	methanol

Low-Temperature Fuel Cells

All offer immediate cold start-up

++	Good
0	Fair
--	Poor

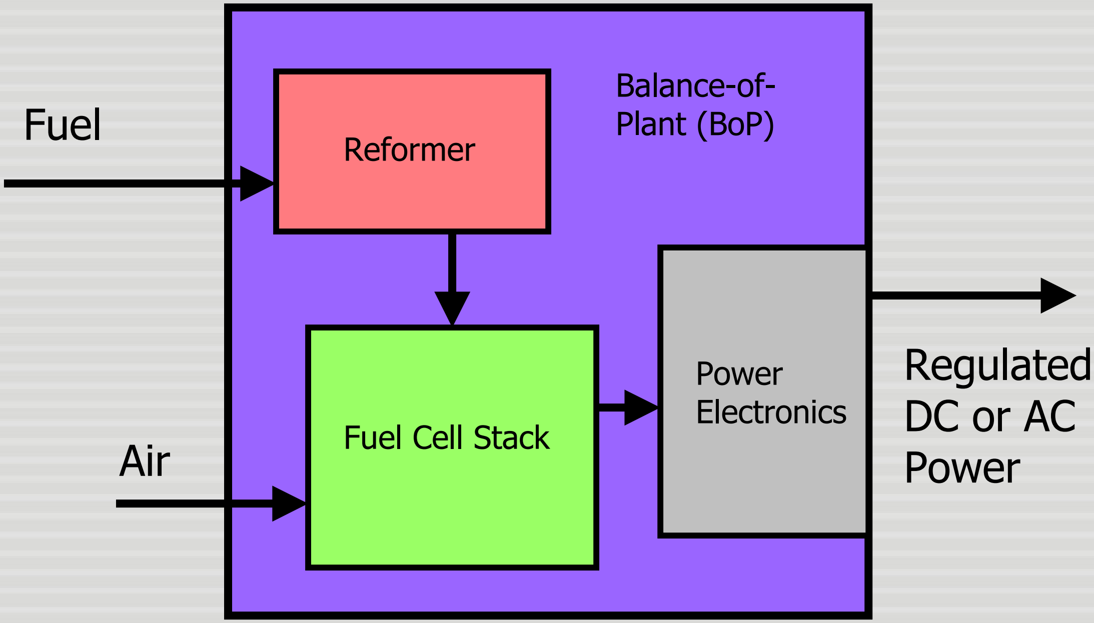
	PEMFC	DMFC	AFC
Degree of Development	++	--	--
Commercialized	0	--	--
Fuel Versatility	++	--	++
Fuel Sensitivity	0 prefers pure H_2	0 fuel must be pure	-- intolerant of CO_2
Comments	relatively mature system designs	low volumetric power density	better system designs needed

Introduction and Definitions

Fuel and Oxidant (air) are stored externally—differing from batteries

Low-temperature fuel cells require H_2 for fuel

H_2 purity is a key issue



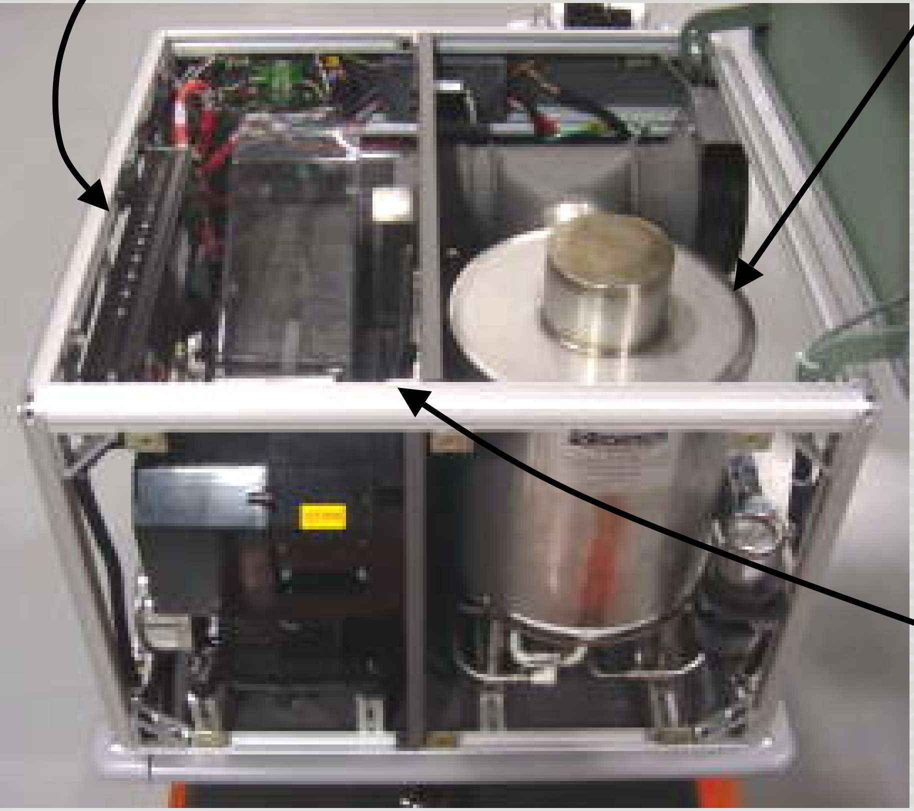
Typical Fuel Cell System

Portable PEMFC System

IdaTech FCS 1200

Fuel Processor
(IdaTech FPM 20)

Power Electronics



Fuel Cell Stack and BoP
(Ballard Nexa™)

Power Electronics

Contents

Sample Fuel Cell Systems

FCS 1200 portable system

1000 W regulated DC power

FCS 5000 stationary system

5 kW combined heat and power

Contents

Fuel Reforming Technology

- Hydrocarbons and alcohols
- Principle methods
  - Steam reforming (SR)
    - $CH_4 + 2\,H_2O \Rightarrow CO_2 + 4\,H_2$
  - Partial oxidation (POX)
    - $CH_4 + O_2 \Rightarrow CO_2 + 2\,H_2$
  - Autothermal reforming (ATR)
  - Thermal anaerobic decomposition (Pyrollisis)
    - $CH_4 \Rightarrow C + 2\,H_2$
  - Plasma assisted ATR or SR

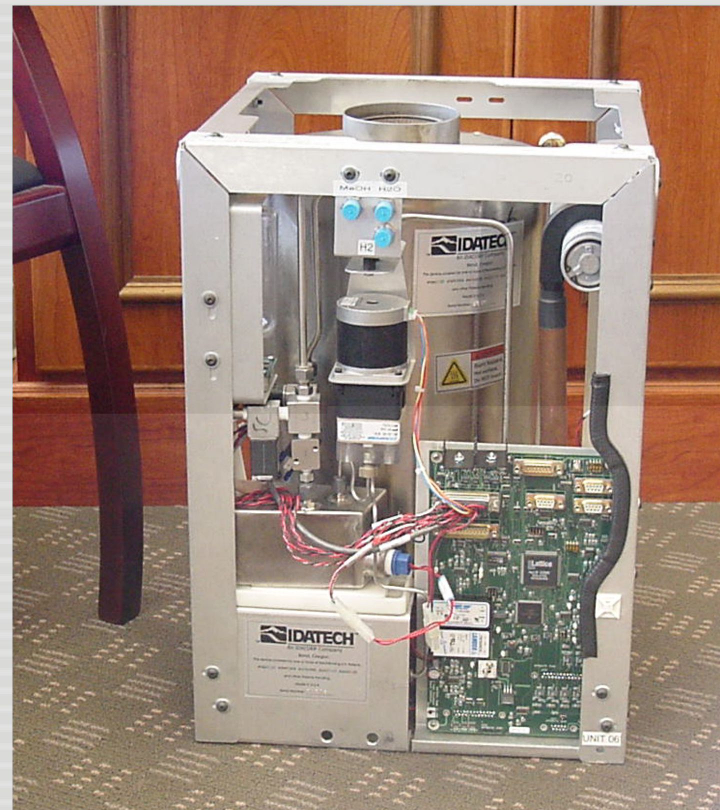
IDATECH
An IDACORP Company
Advanced Fuel Cell Solutions

Commercial Fuel Processor

Fully packaged subsystem

>99.95% H_2 with <3 ppm CO, < 5 ppm CO_2

31 x 37 x 47 cm; 36 kg

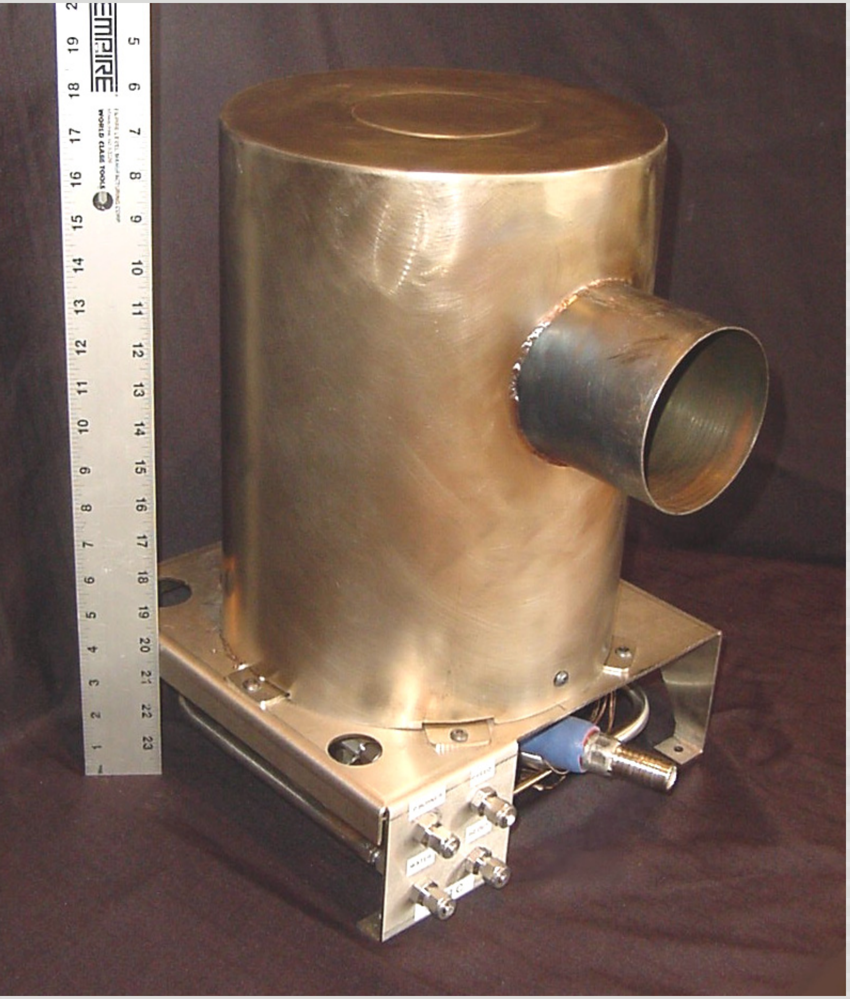


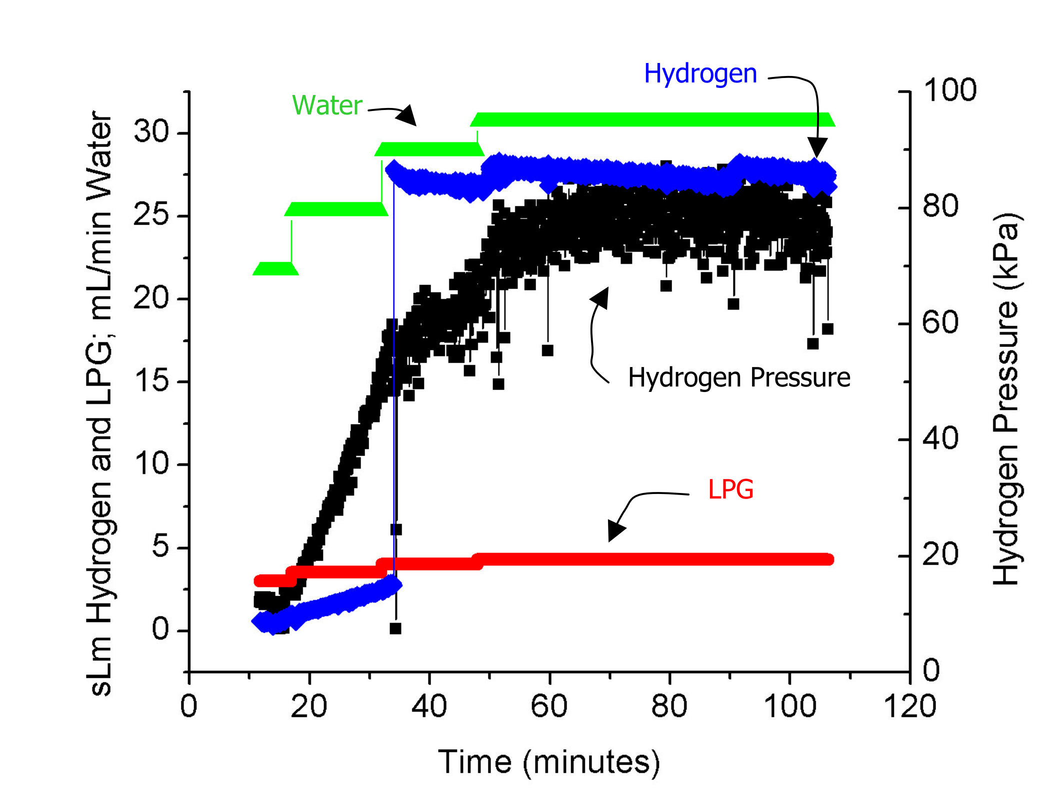
<50 db at 1 m; ready for integration

H_2 (max) >30 sLm (rated at 20 sLm)

RS-485 communication interface

LPG Fuel Processor Development



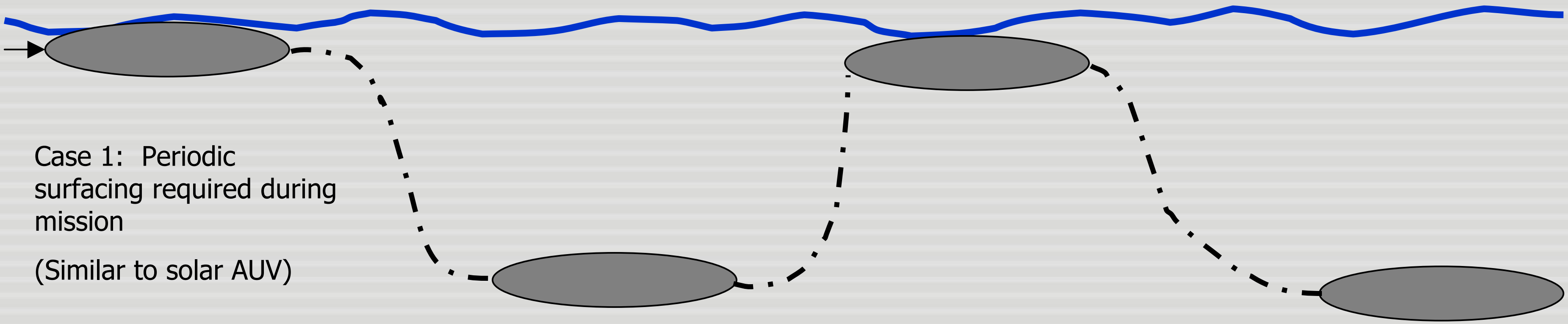


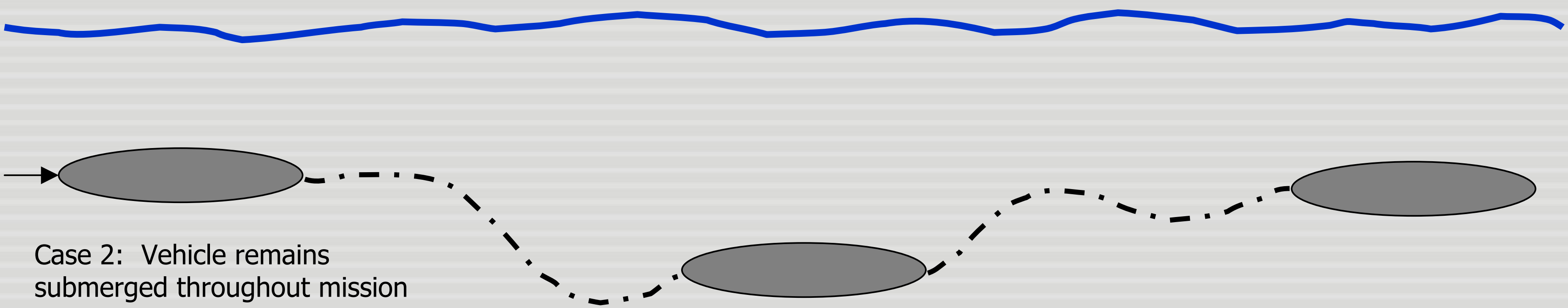
Prototype rated at 25 sLm pure H_2

>99.95% H_2, <3 ppm CO, <5 ppm CO_2

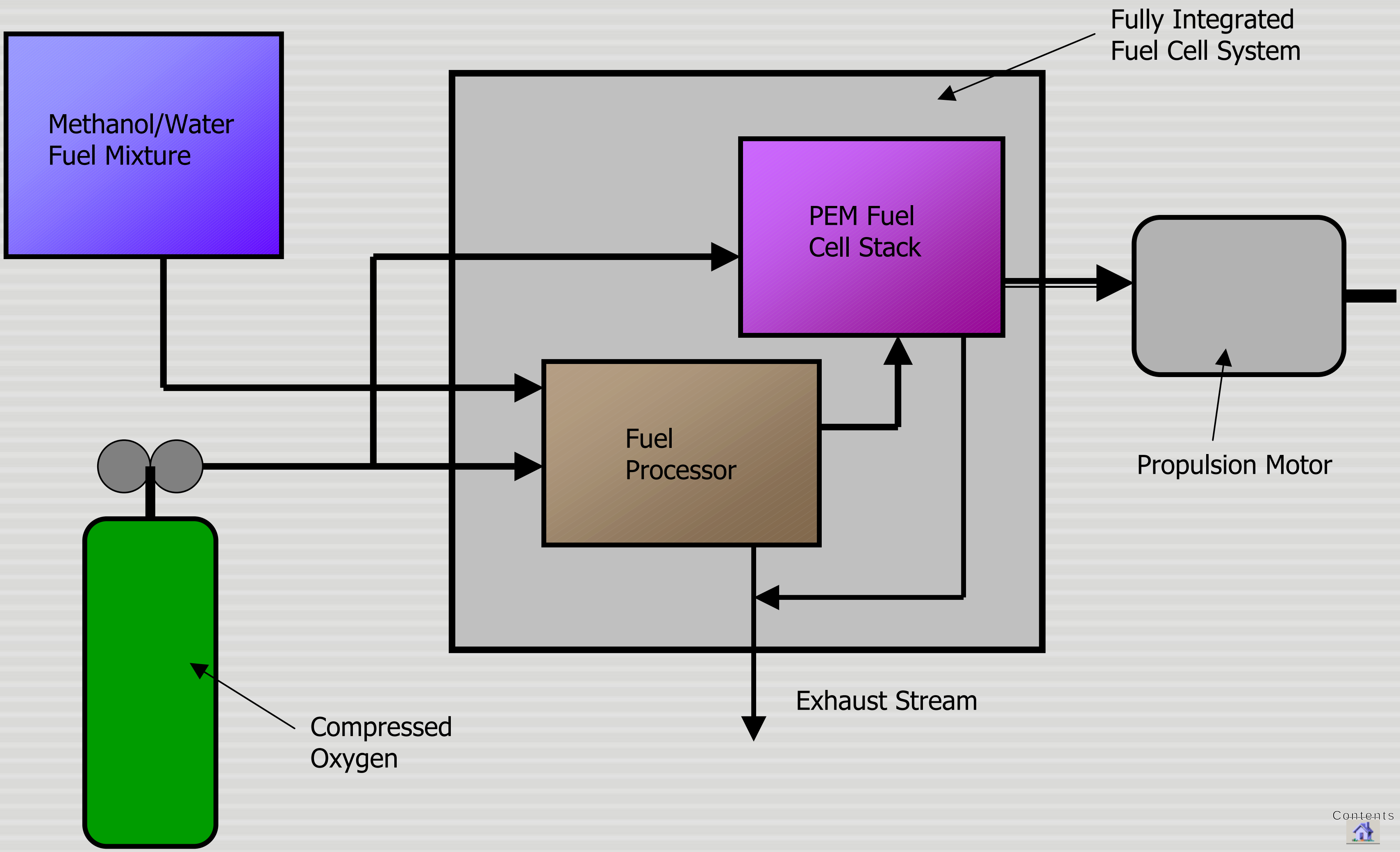
App. 50 cm (H) X 25 cm X 25 cm

Mission Profile

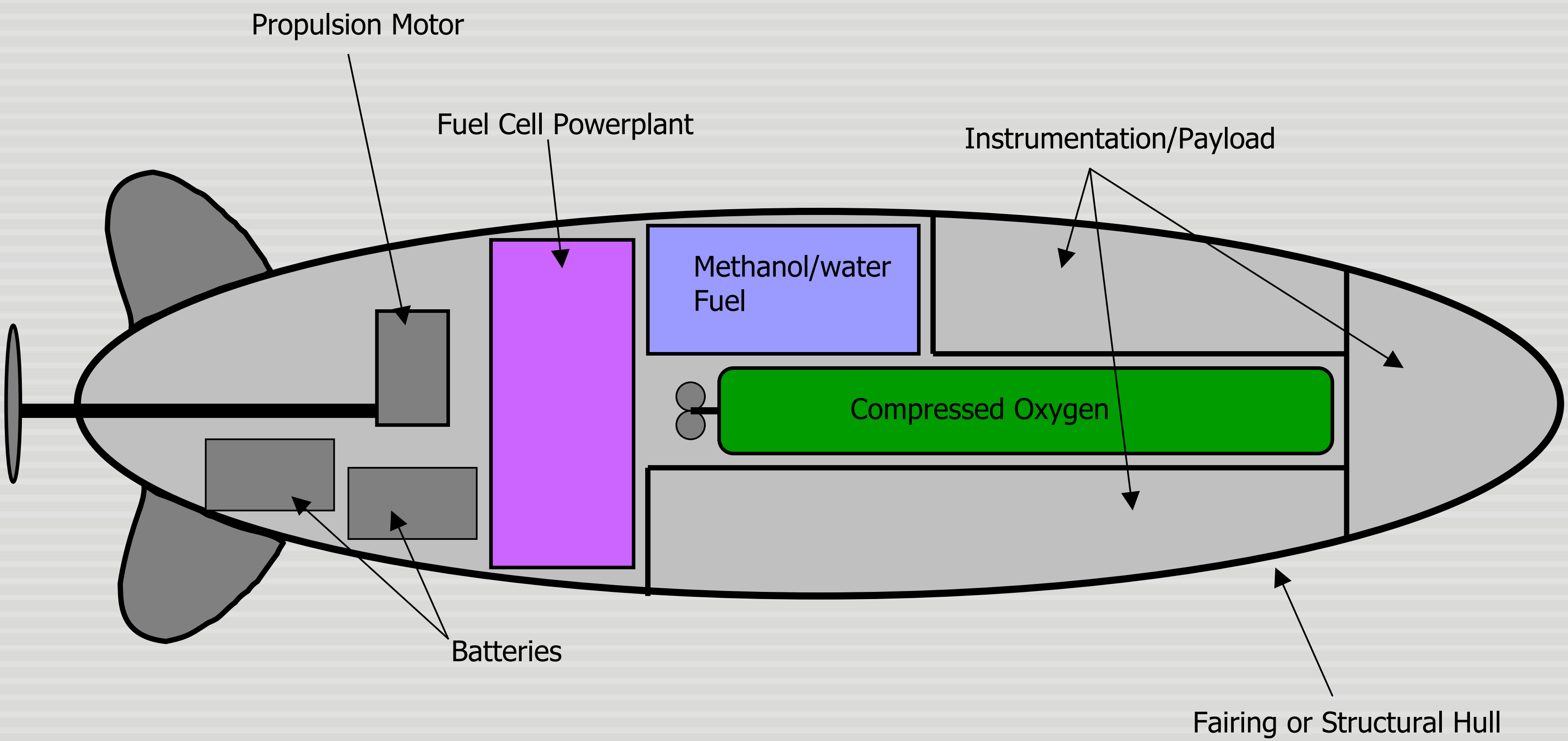




Fuel Cell Powerplant



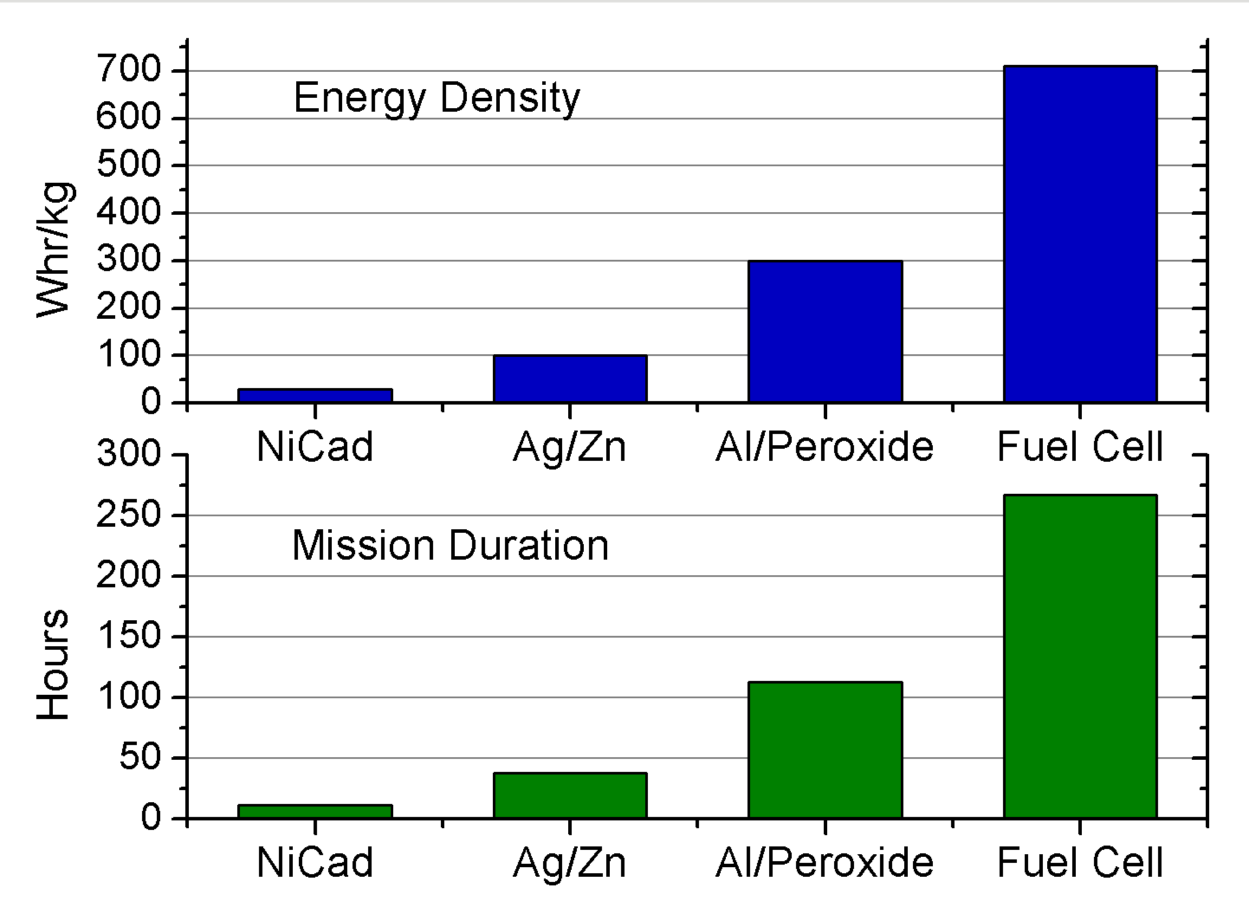
Fuel Cell Propulsion Concept



Exhaust gases from PEMFC = about 7.8 sL/kWhr (electric)

Novel design = no discharge problem

Comparative Energy Densities



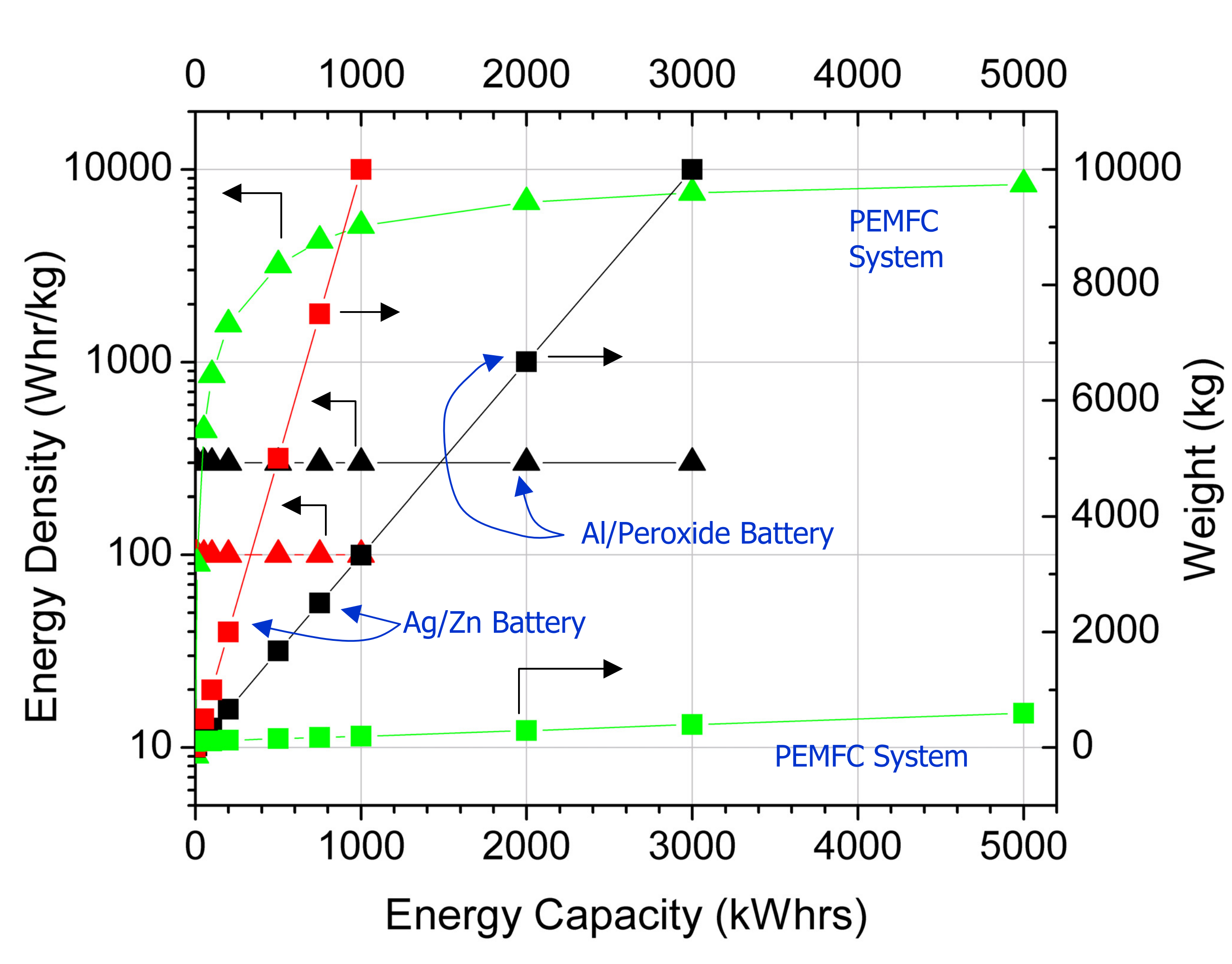
Basis: Batteries/Fuel Cell Weigh 113 kg

Assumes total load is 300W

Fuel Cell System:

- Fully integrated system
- 1.45 L methanol/water fuel
- 573 std. L oxygen
- Total weight = 113 kg

Energy Density vs. Capacity



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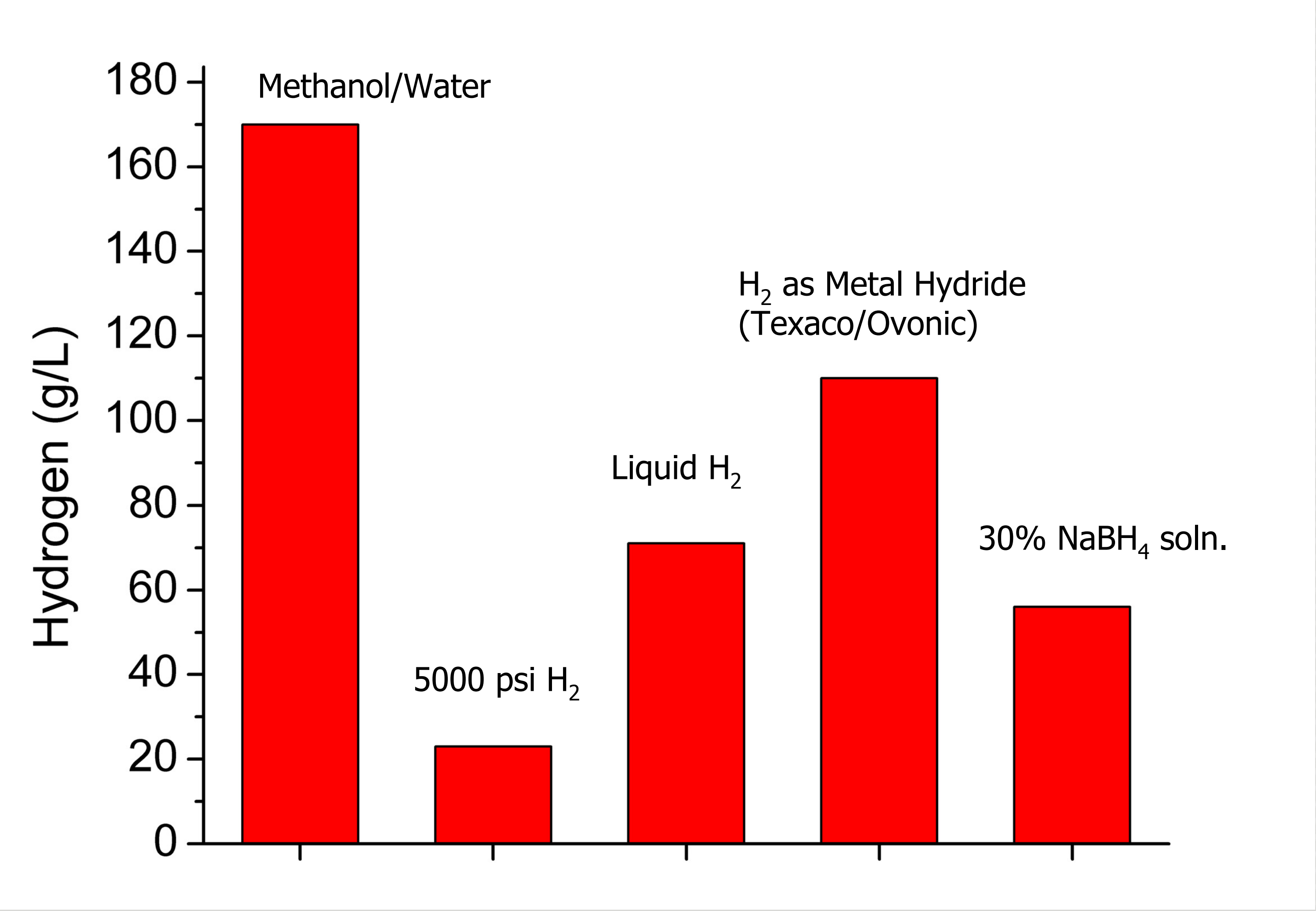
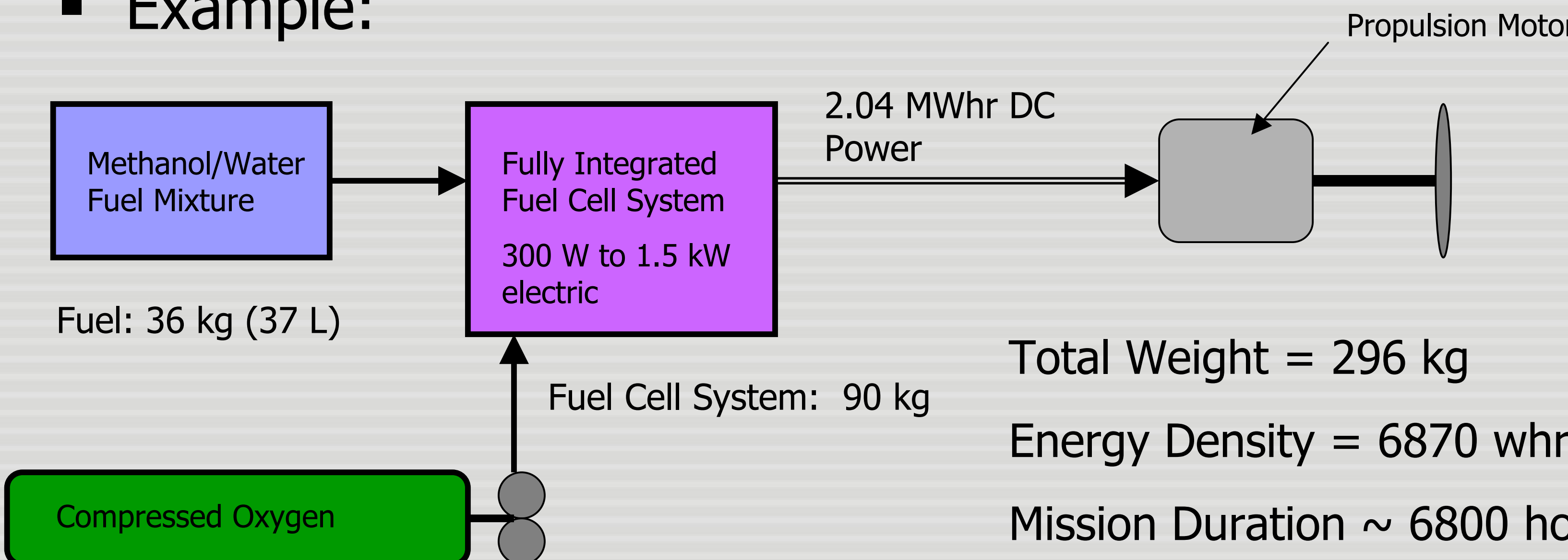
Stored Hydrogen Energy Density



Long-Duration Missions

- Fuel Cells offer advantage over batteries due to high energy density of stored fuel/oxidant
- Example:



Oxygen: 170 kg (27 m^3 in two HC-500 cylinders)

Total Weight = 296 kg

Energy Density = 6870 whr/kg

Mission Duration ~ 6800 hours (@ 300 W: 1360 hours @ 1.5 kW fuel cell output

Potential Utility

- Long-duration mission (possibly weeks or months)
- Could operate in "sleeper" mode
- Fuel cell may be a battery charger/range extender
- Quiet operation