"A DARPA Perspective on Small Fuel Cells for the Military"

Defense Sciences Office

Presented at the

SOLID STATE ENERGY CONVERSION ALLIANCE (SECA) WORKSHOP

Arlington, VA
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Performance Shortfall for Today's Power Sources

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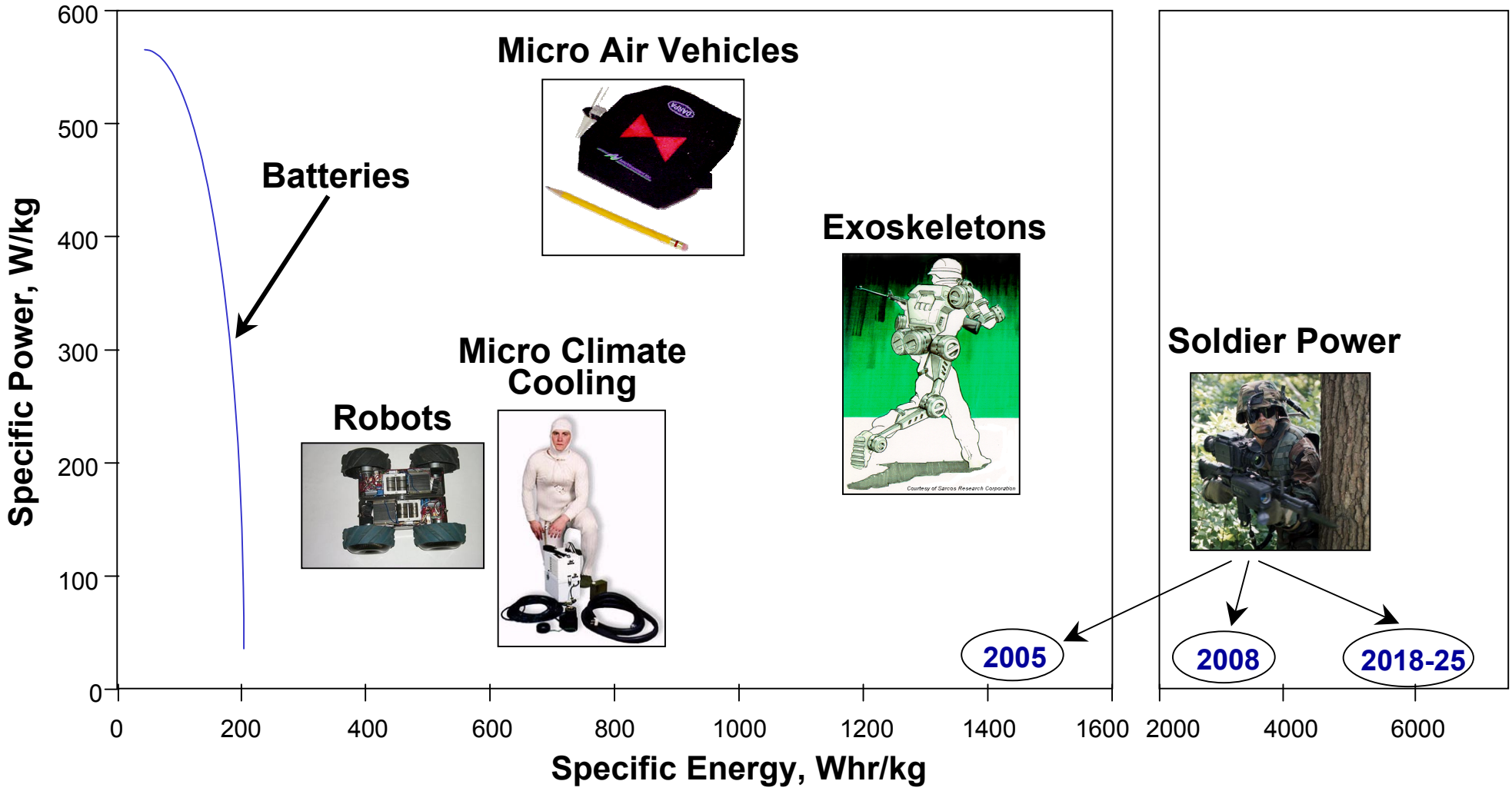

Energy Conversion Technologies Considered For Portable Power Applications

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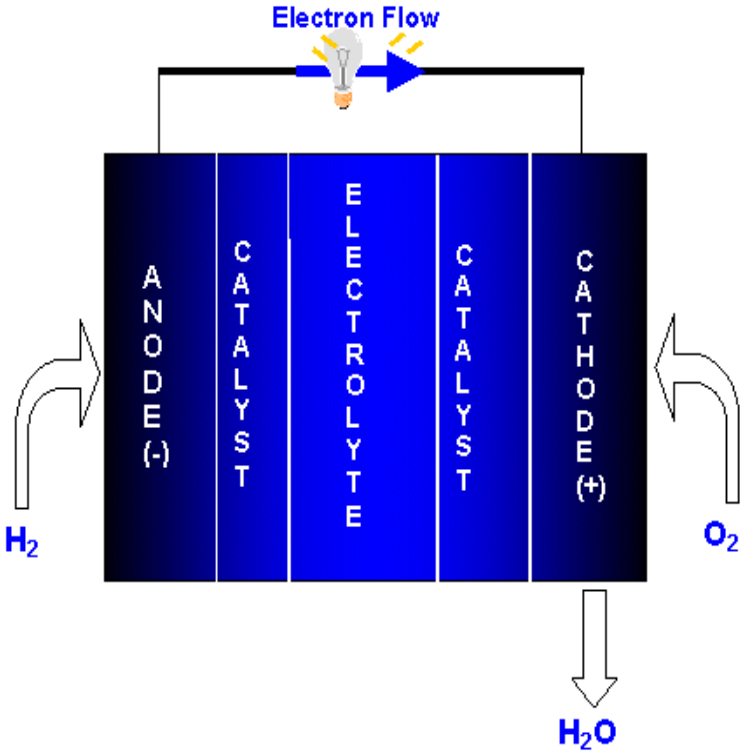
<u>Electrochemical</u> ε ~ 100 %

- Fuel Cells



<u>Heat Engines</u> ε = [(1 -T_L/T_H) * 100] %

Dynamic Systems

- Piston
- Turbines
- Stirling

Static Systems

- Thermoelectrics
- Thermionics
- Alkali Metal Thermal to Electric Conversion
- Thermophotovoltaics

Fuel cells promise earliest but not only opportunity

DoD Compact Fuel Cell Evolution

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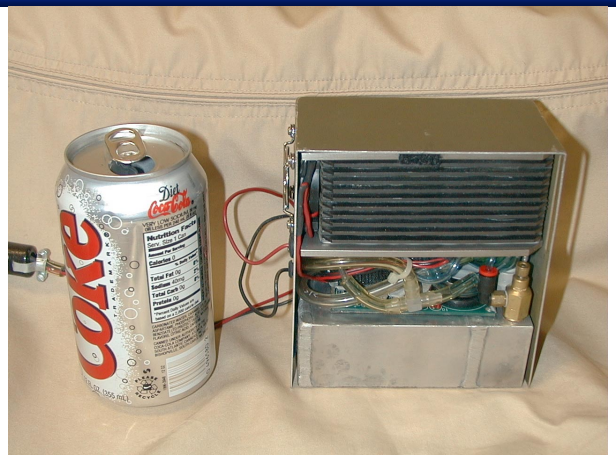
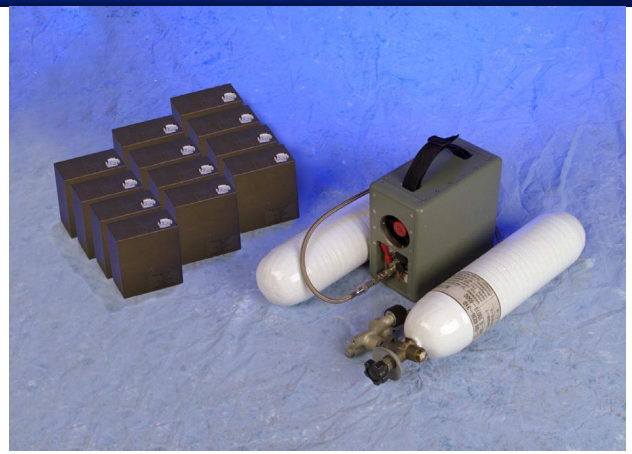
1992 –H_2 Stack

- 15 W
- 5 pounds



1996 - H_2 System

- 40 W / 90 Wh
- 3.5 pounds
- Metal Hydride



1998 - H_2 System

- 50 W/ 2 Kw-hr
- 7.5 lbs
- Compressed Hydrogen

2000 – DMFC Stack (2001 - System)

- 70 W
- 2.2lbs (goal)

Future - SOFC

The Fuel is ***the*** Issue

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 DAY, ONE RETRANS SITE

- **BA5590 BATTERIES = $900**
- **FUEL CELLS = $26**

Operation Strong Angel - Humanitarian Exercise
11-15 June 2000, Parker Ranch, HI

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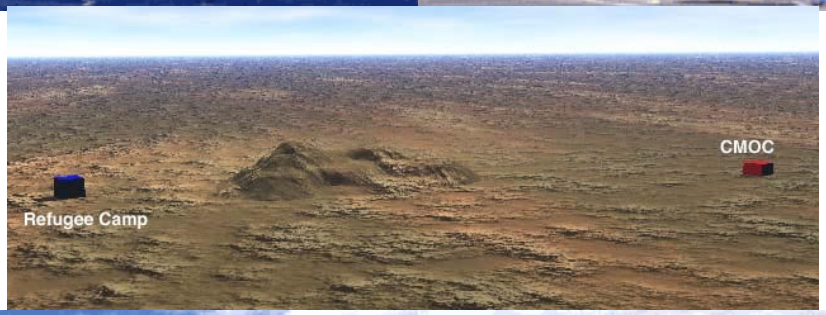

UNITED NATIONS
HIGH COMMISSIONER FOR REFUGEES

unicef

Welcome to the
World Food Programme
The food aid organization of the United Nations

American Red Cross

Operation Strong Angel

Parker Ranch, HI, 11-15 June 2000

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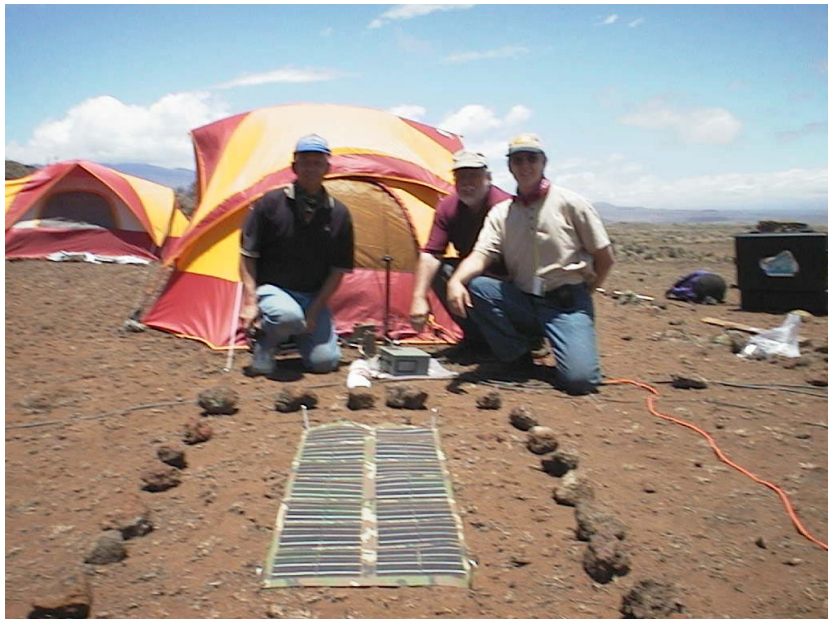
Fuel cells operating laptop Computers, battery chargers In the CMOC area



Hybrid Fuel Cell, photovoltaic, Battery system operating a Ham Radio at the refugee camp

Hydrogen Sources Comparison For Portable PEM Fuel Cells

50 W
PEM Fuel Cell
(2.7 kg)

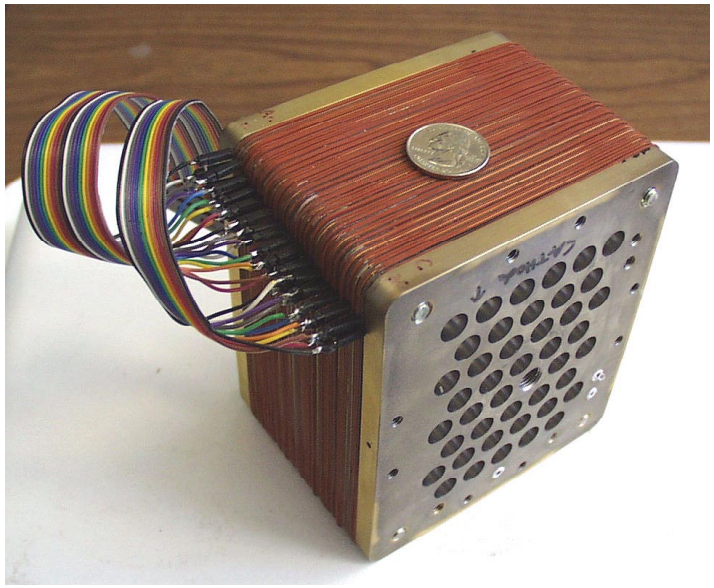
4500 psi H_2
289 Wh/kg
1.7% Storage

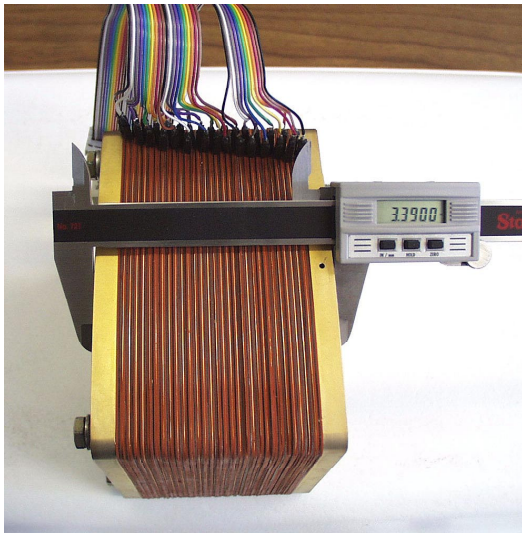
$NH_3 + LiAlH_4 \rightarrow H_2$ + Solid Products
1000 Wh/kg
6% Storage

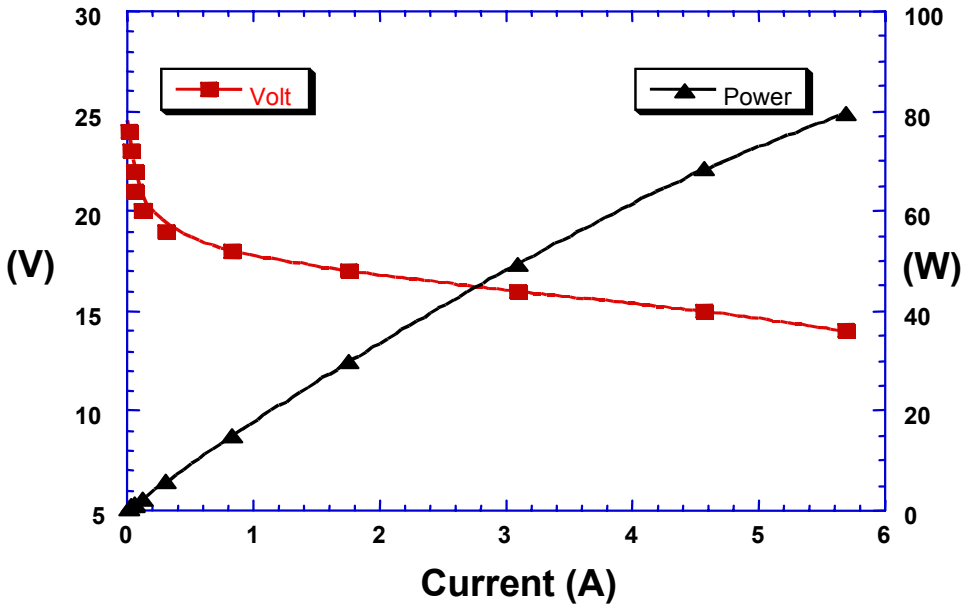
30-Cell Direct Methanol Fuel Cell Stack

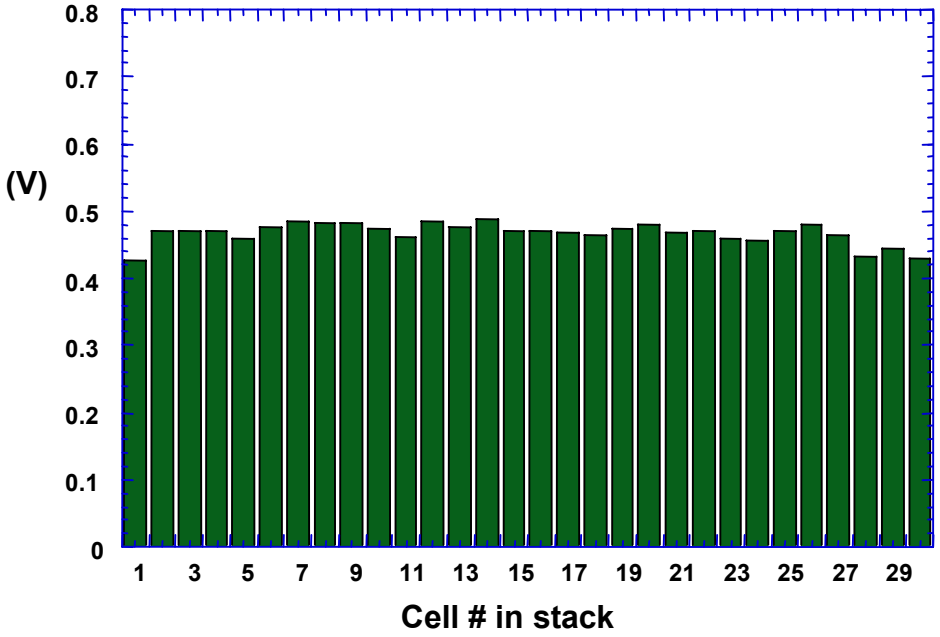
Los Alamos National Laboratory

Defense Sciences Office









Lithium Battery / Fuel Cell Comparison

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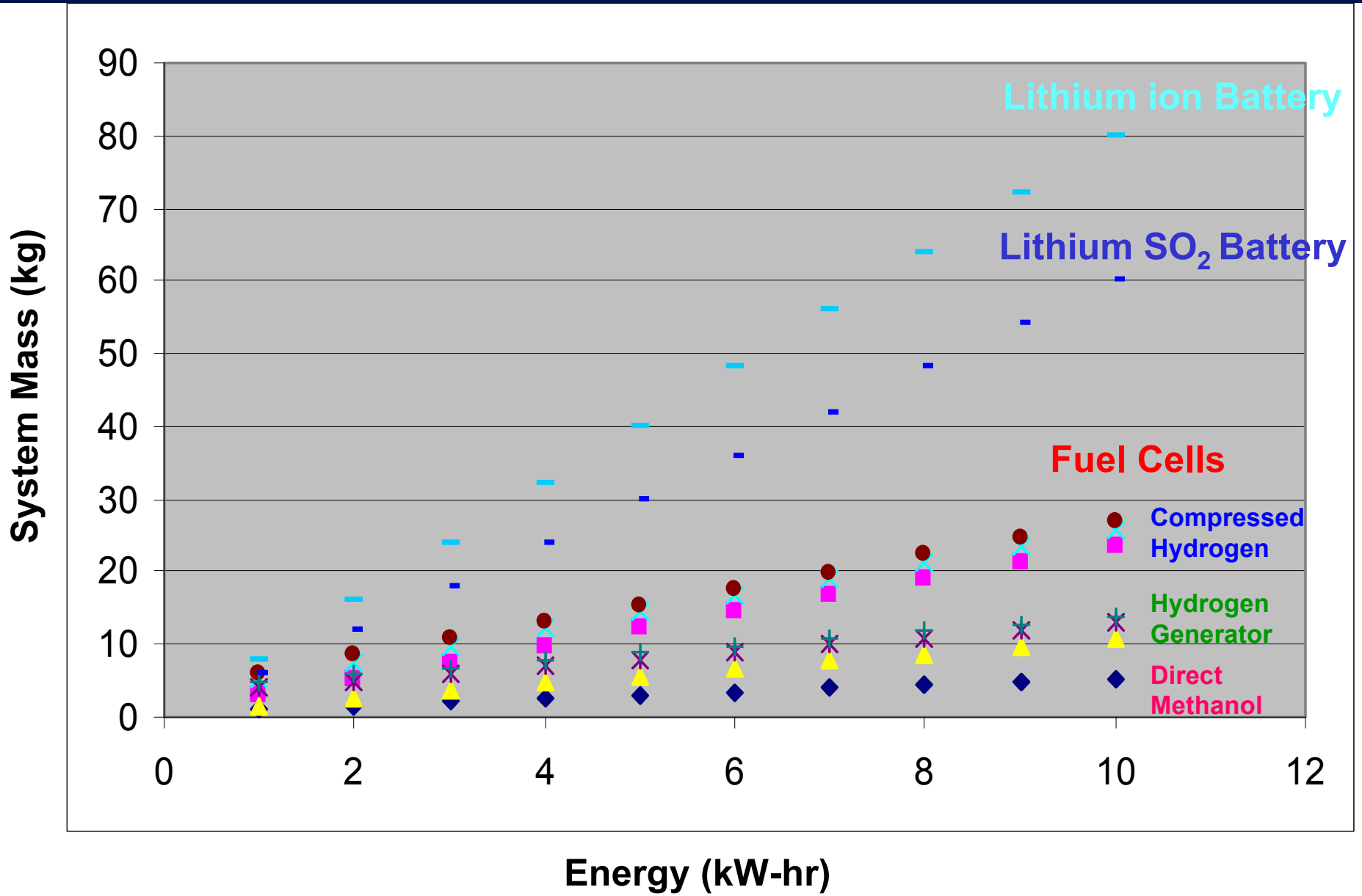

Palm Power Program

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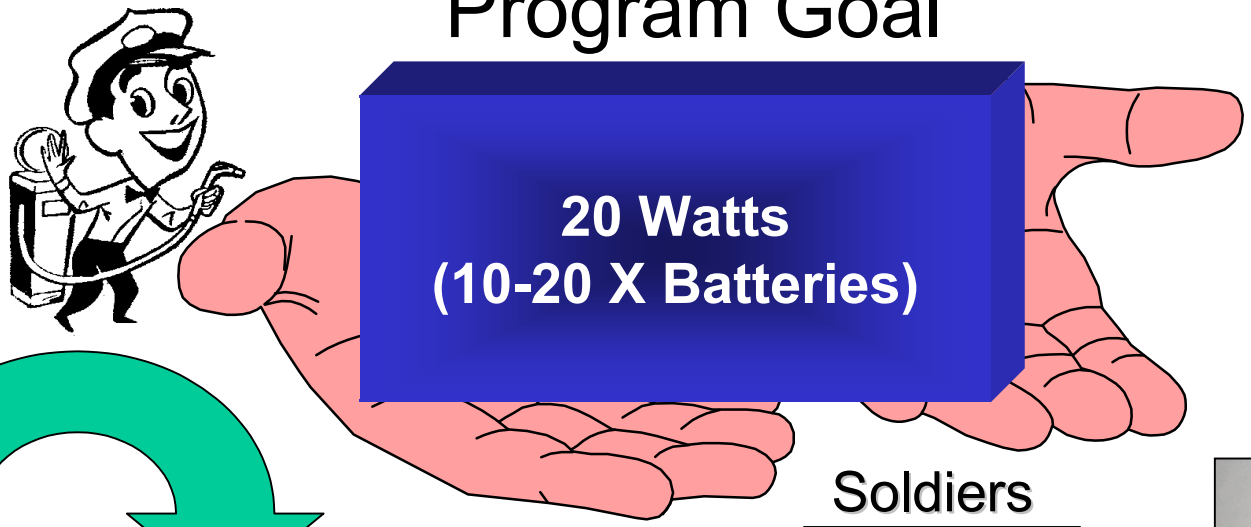
Program Goal

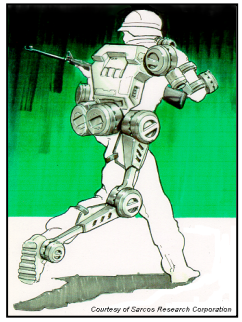


High Energy Content Fuel

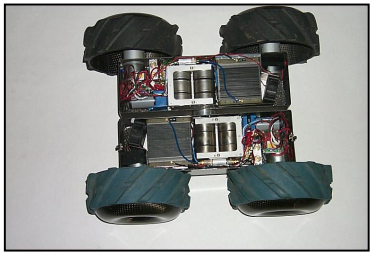
Electric Power

Soldiers

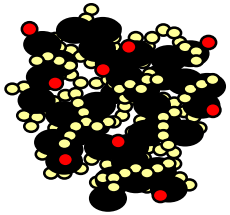
Exoskeletons

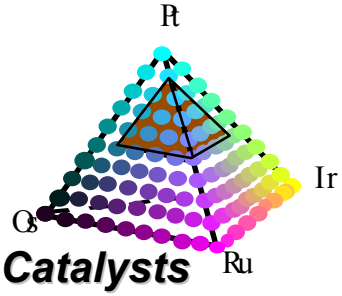


Robots



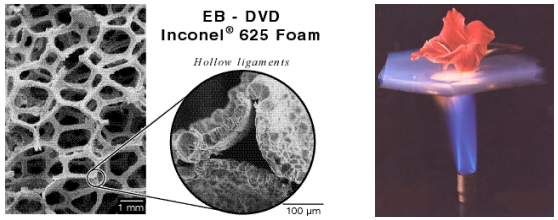
Materials Development





Catalysts

Thermal Management



Thermal Conductors…and Insulators

System Integration

- **Fabrication**
- **Cascading Systems**

High T ***Low T***

The Holy Grail? - *Direct* Conversion of Hydrocarbon Fuels

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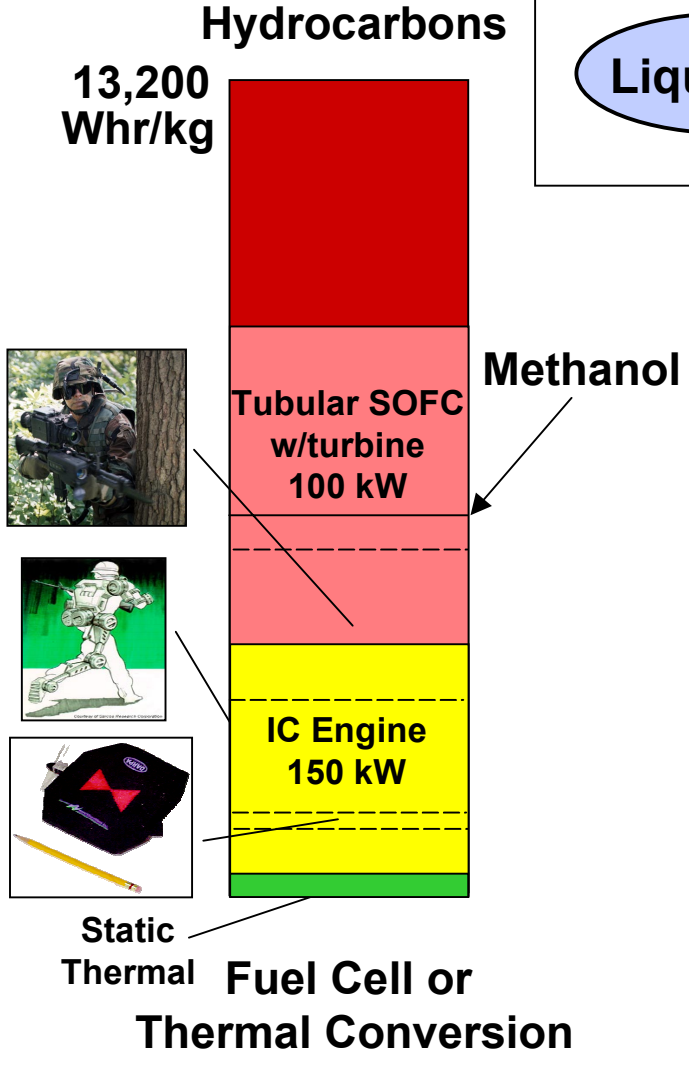


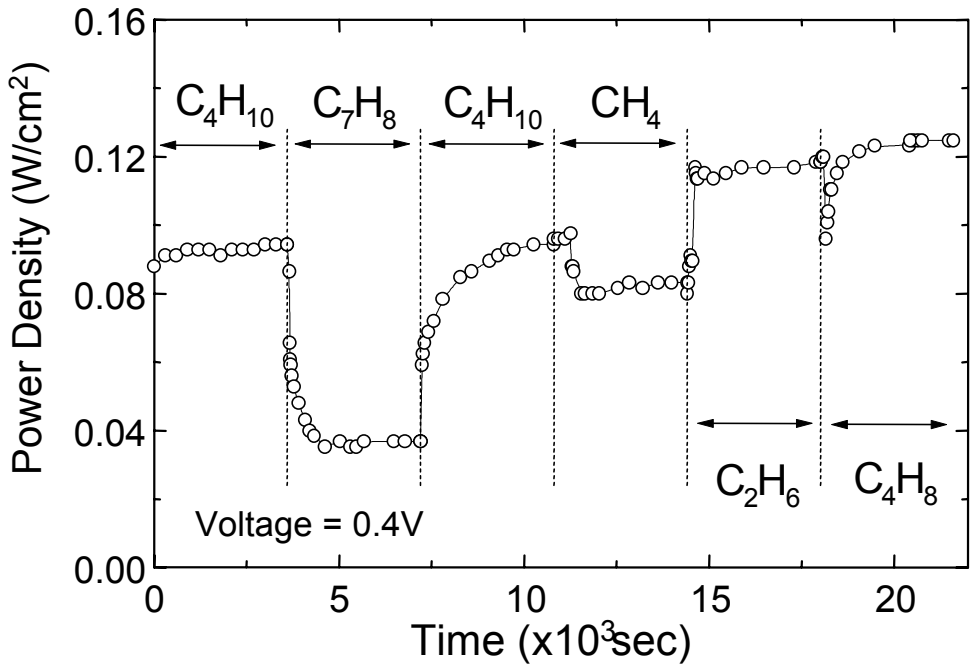
DIRECT OXIDATION

Liquid Fuel → Fuel Cell

CHALLENGES

- Increase Performance
  - → Catalysts
- Thermal management
- Liquid Fuels

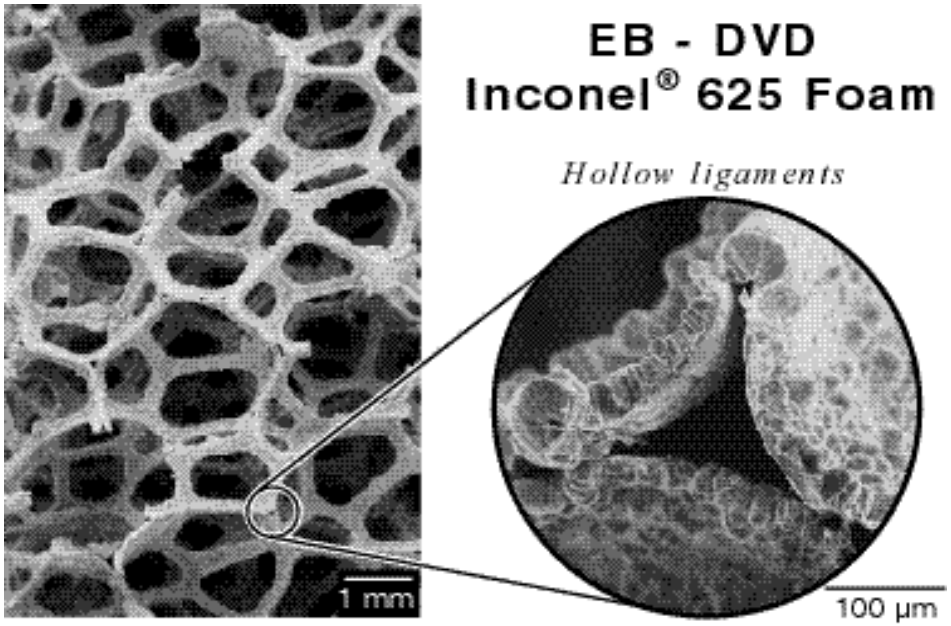
Recent work:



S. Park, J. M. Vohs, and R. J. Gorte, Nature, 404 (2000) 265.

Thermal Management Opportunities

Superthermal Conductors and Heat Exchangers



Aerogel Insulators

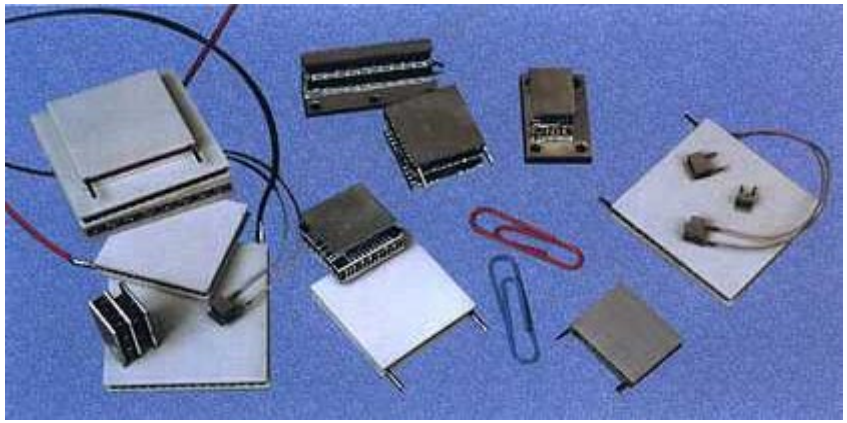
K_{solid} Aerogel = 0.002 W/mK @ 300K
K_{solid} Silica = 1.4 W/mK @ 300K

Thermal Integration Opportunities

Cascading Systems

- **Thermally integrate multiple technologies**
  - ✓ **Design**
  - ✓ **Fabrication**

+



SOLID OXIDE FUEL CELL
1000 - 650 C

THERMOELECTRICS
1000 - 100 C

Integrated Efficiency >> Σ Individual Efficiencies

Palm Power Goals

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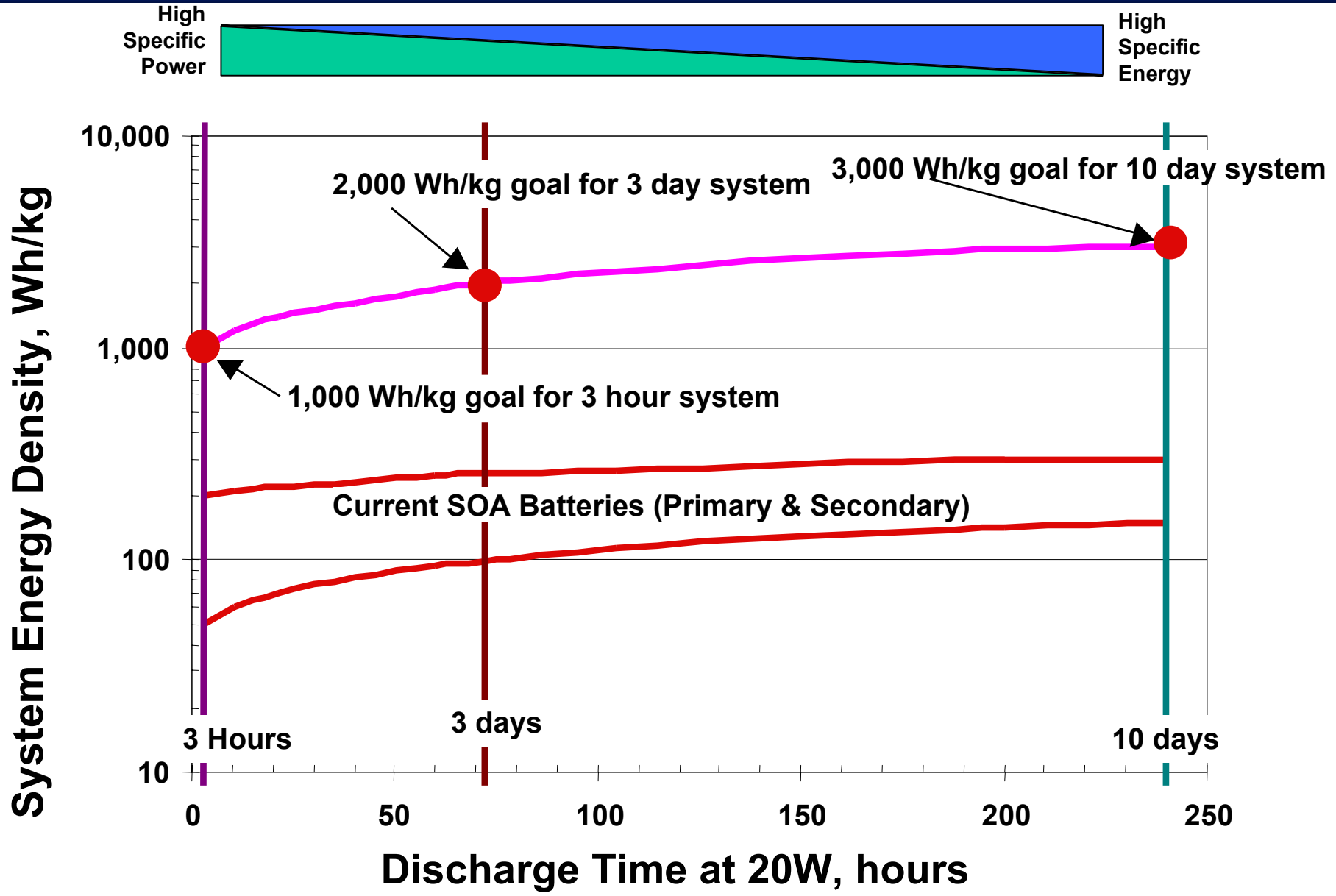

http://www.darpa.mil/dso/thrust/md/palmpower/index.html

Power Driven Technology Revolutions

Period	Technology	Specific Power	Revolution
Early 1700's	Steam engines	0.005 W/g	'Industrial'
1890-1960	Steam turbines	0.05-1.0 W/g	
'Transportation'			
	IC engines		
1950-2000	Turbojets	10 W/g	'Aviation'
	Turbofans		
2000-?	Microcombustors	100 W/g	Use imagination

Information from Prof Alessandro Gomez, Yale University

The Bottom Line

Photo by Sarah Underhill