DARPA's ADVANCED ENERGY TECHNOLOGIES

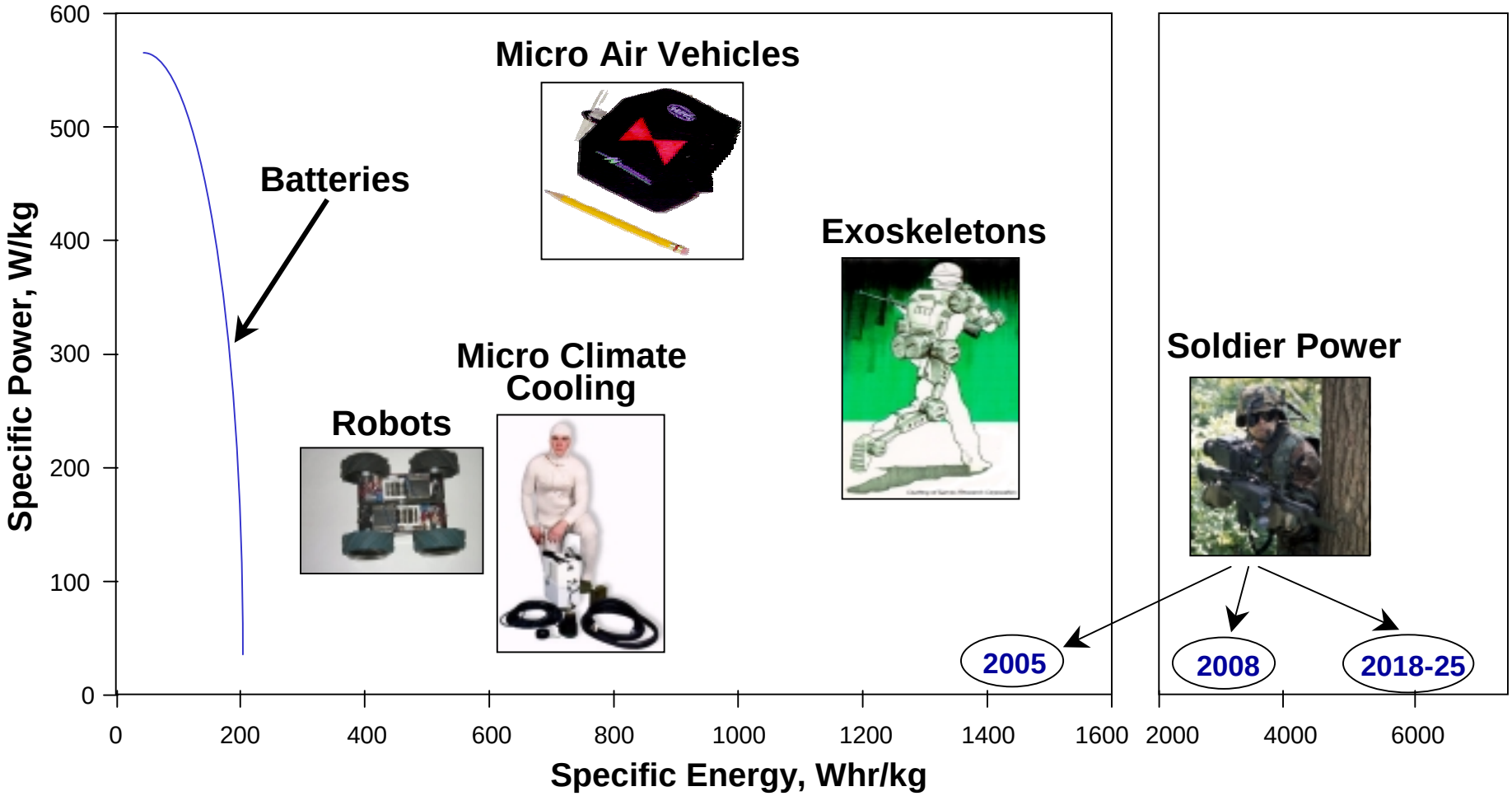
DARPATECH 2000

Dr. Robert J. Nowak
DARPA/DSO
(703) 696-7491 (voice)
(703) 696-3999 (fax)
RNOWAK@darpa.mil

Advanced Energy Technologies Overview

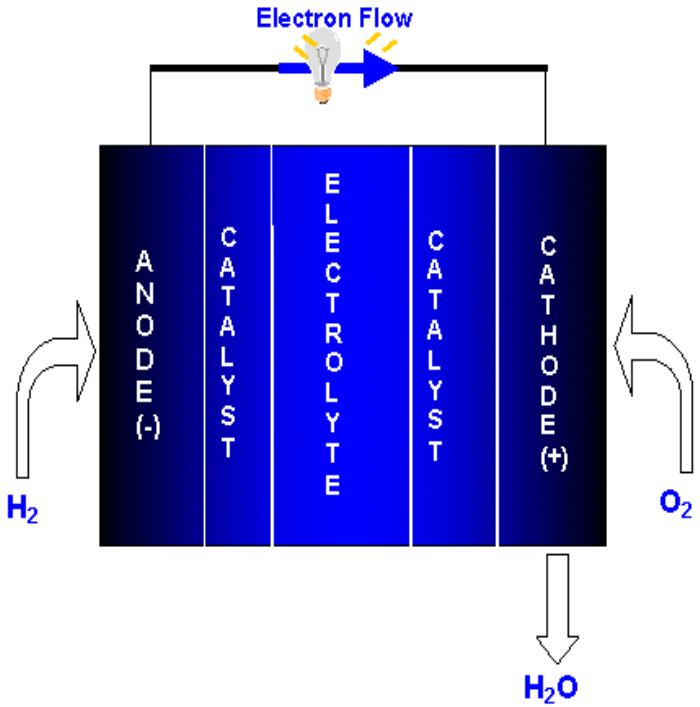
- **Energy Conversion Strategies to Meet Portable Energy Shortfalls**
  - **Near-term Demonstrations**
  - **New Opportunities**
- **Energy Harvesting for Low-Power/ Long-Endurance Missions**
  - **Near-term Demonstrations**
  - **A New Breakthrough - Opportunity**

Performance Shortfall for Today's Power Sources



Energy Conversion Technologies Considered For Portable Power Applications

<u>Electrochemical</u> ε ~ 100 %
- Fuel Cells



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

Dynamic Systems
- Piston
- Turbines
- Stirling

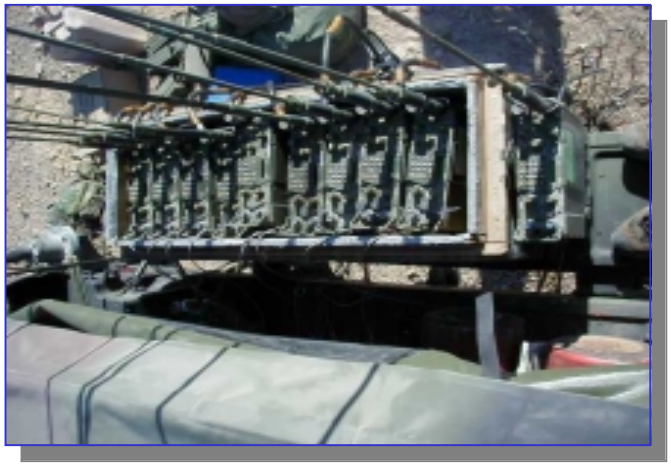
Static Systems
- Thermoelectrics
- Thermionics
- Alkali Metal Thermal to Electric Conversion
- Thermophotovoltaics

Fuel cells promise earliest but not only opportunity

Marine Corps Air Ground Combat Center
29 Palms, CA, Fall 1999

TRAINING

Fuel Cells aboard Humvee



PRC-119 Radios

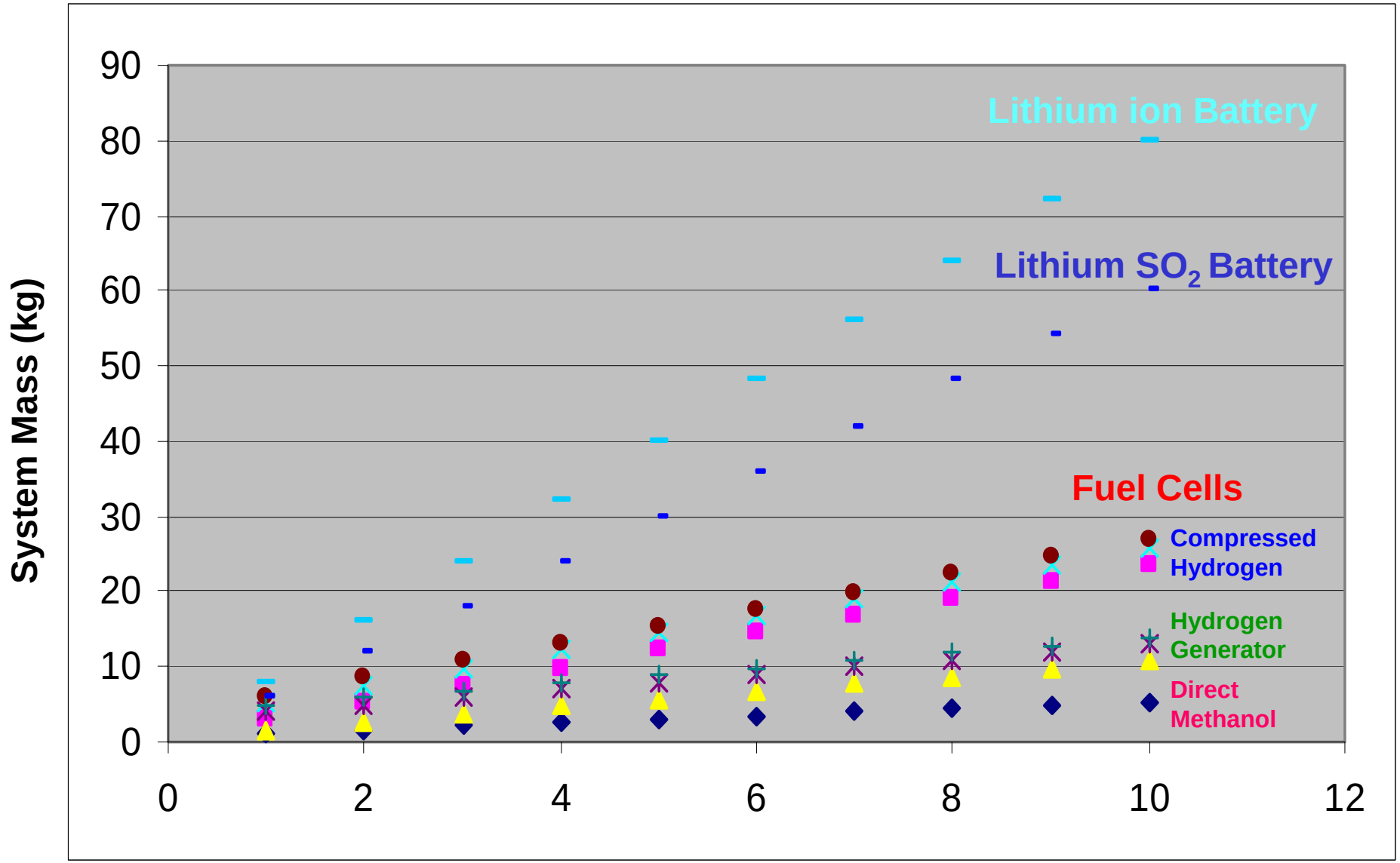
MILITARY EXERCISE

Retransmission Site

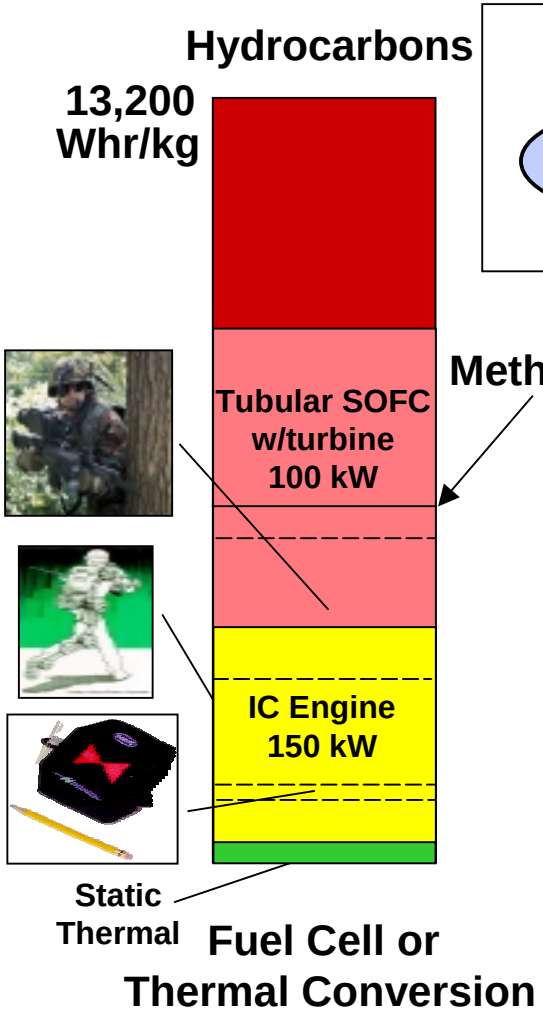
COST ESTIMATE FOR ONE DAY, ONE RETRANS SITE

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

Lithium Battery / Portable Fuel Cell Comparison



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

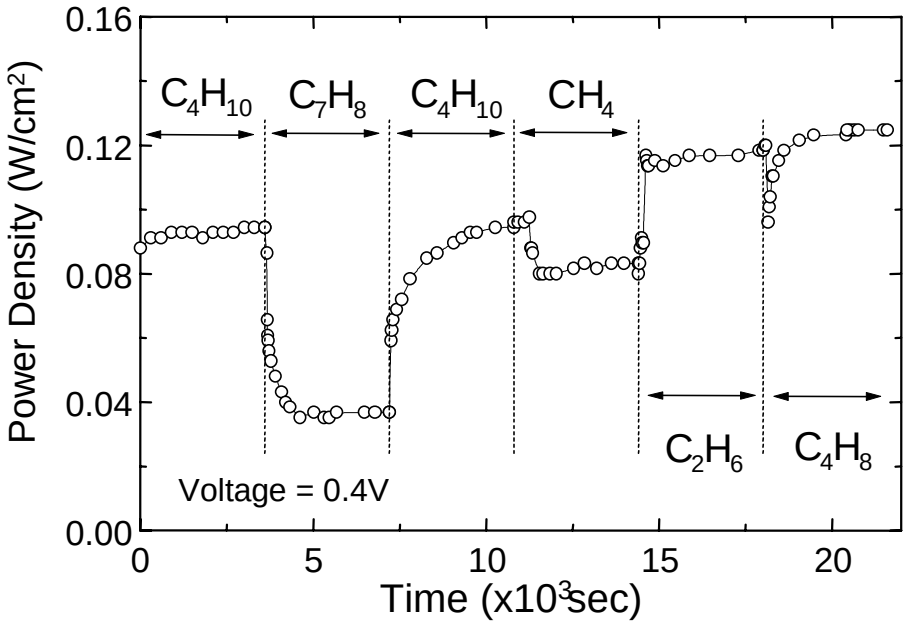


DIRECT OXIDATION

Liquid Fuel → Fuel Cell

CHALLENGES

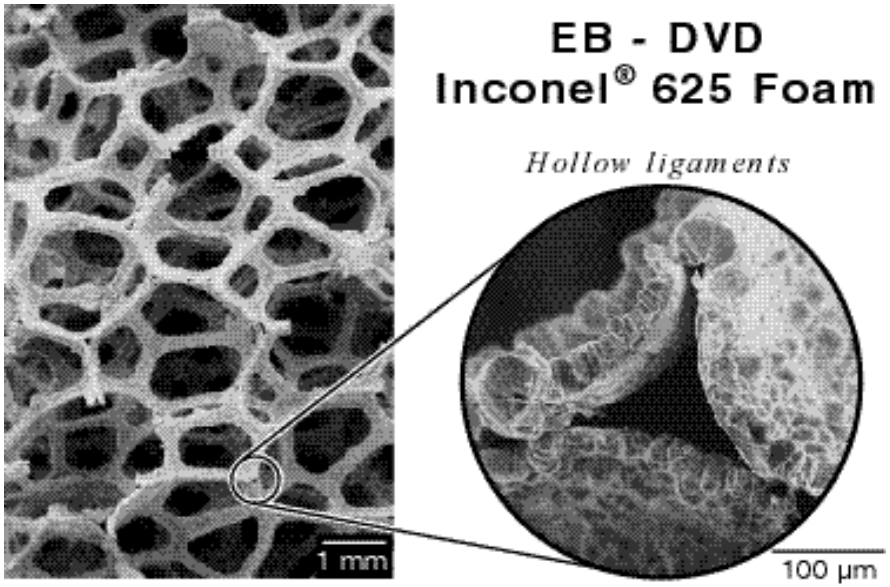
- Increase Performance
  - → Catalysts
- Thermal management
- Liquid Fuels



Gorte, University of Pennsylvania

Thermal Management Opportunities

Superthermal Conductors and Heat Exchangers



Aerogel Insulators

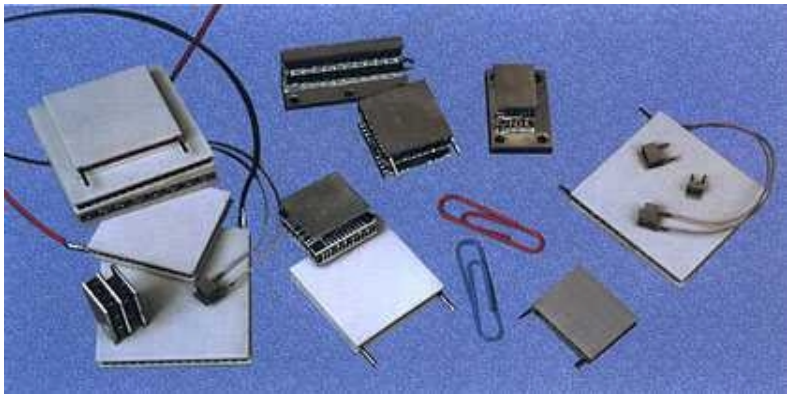
K_{solid} Aerogel = 0.002 W/mK @ 300K
K_{solid} Silica = 1.4 W/mK @ 300K

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

Energy Harvesting for Low-Power/Long-Endurance Missions

Technical Goal

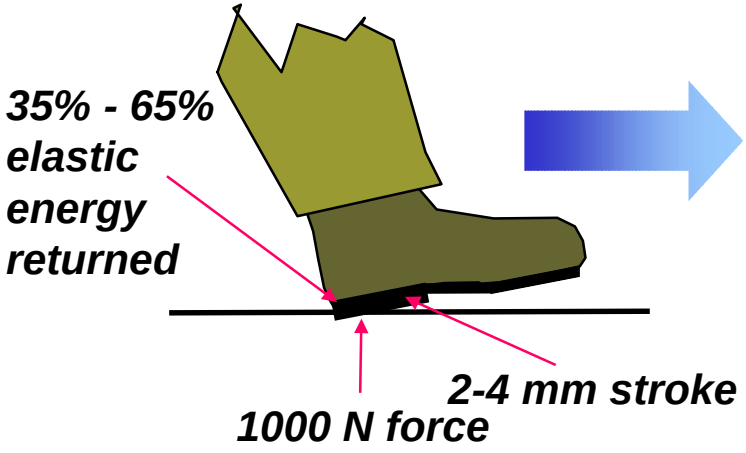
- **Significantly increase mission endurance (>10x) for soldiers and sensors**

Technical Approach

- **Harvest energy and fuel from environmental sources**
- **Integrate harvesting system with devices**

Mechanical to Electrical Energy Conversion

Heel-Strike Generator for Soldiers

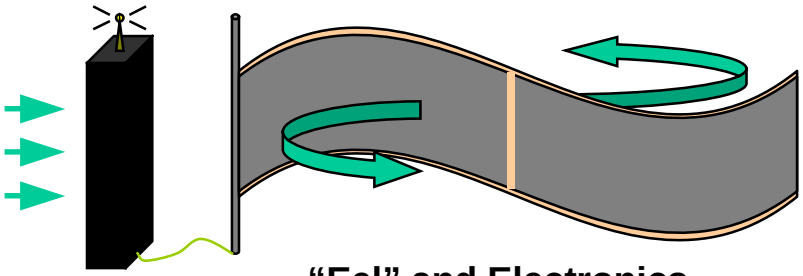


0.7 - 2.6 J available per step

1-2 W Output

Correction factors, e.g., backpack weight, optimized designs, losses such as shoe flexures & conversion losses

Energy Harvesting Eel for Undersea Power Generation

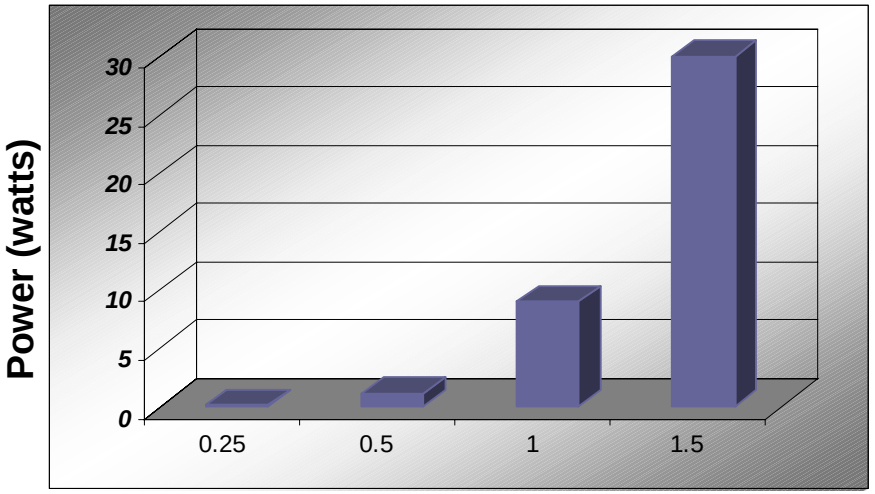


"Eel" and Electronics

Sensor and Acoustic Modem

Ocean Power Technologies, Inc

Output Power



Flow Velocity (meters/second)

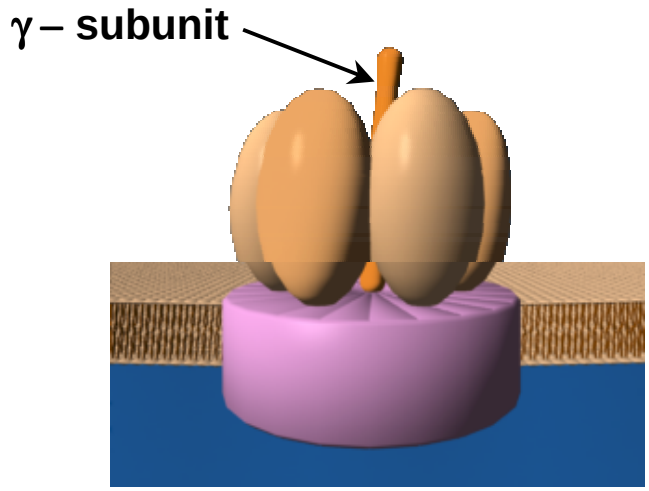
Fundamental Breakthroughs

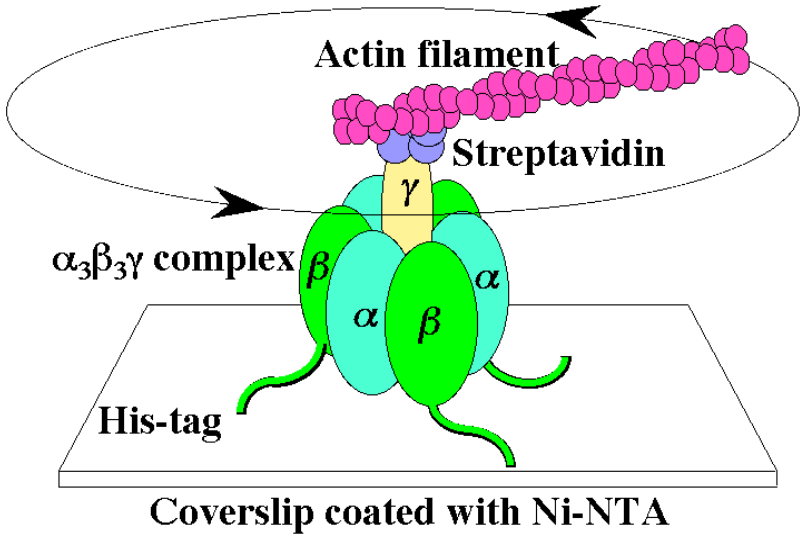
November 1999 Rotary Motor Structure and Architectures

April 2000 Motor Proteins and Motion Systems Structure

F_oF_1-ATPase Biomolecular Motor

Membrane-bound F_o-F_1 ATP Synthase





F_1-ATPase Biomolecular Motor with Actin Filament System (from Noji *et. al.* 1997)

$ATP \rightarrow ADP + Pi \rightarrow AMP + Pi$

- Ubiquitous enzyme
- Synthesize and hydrolyze ATP
- F_1 portion can act independently
- Gamma subunit of F_1 portion rotates (up to 17 r.p.s.)
- F_1 portion can generate up to 100 pN·nm torque

Biomolecular Motors

Technical Issues

- **Determine and Apply Critical Engineering Steps Toward Biomotor Devices**
  - **Spatial and orientational control of motor elements at interfaces**
  - **Systems analysis of force production and work output (ATP in, work out), lifetime and robustness**
- **Design, Build and Test Prototype Devices which utilize the ATP and Biological Motors**
  - **Microvalves, pumps, fluidic movement, sensors and actuators, controlled release devices, robotics, ATP engines**