



# Renewable Power and Energy Systems for Defense Needs



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**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

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## POWER & ENERGY CAPACITY REQUIREMENTS

**1 - 100 mW    1 W    1 KW    10 KW    100 KW    1 MW    10 MW    2TW**

Mechanical  
Energy  
Harvesting  
( Flight /  
Impact  
Flywheel )

Thermo  
PhotoVoltaic  
Emission  
Harvesting  
&  
Thermo  
electric

Aerodynamic  
Forces  
Flow  
Based

High efficiency  
Switching  
& Regulation  
  
Electrical  
Storage  
Materials

EM Wave  
Harvesting  
  
(Optical / RF  
Photovoltaics)

Modeling  
and  
Simulation

Green /  
Eco- Friendly  
&  
Radioisotope  
Energy Sources

Novel  
Electrode  
Materials  
&  
Manufacturin  
g

Raw Fuels  
Fuel Cells  
&  
Energetic  
Materials

## NOVEL POWER, ENERGY & INTEGRATED SYSTEMS

### FUZES / PRECISION / SMART MUNITIONS



### ARMAMENT SYSTEMS



ADS



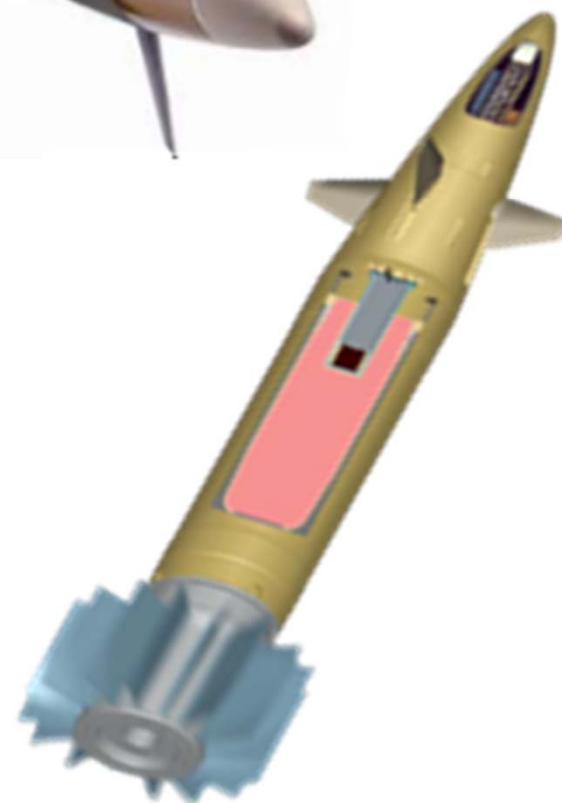
HPM



M150



M119





# A SYSTEMS APPROACH FOR GUN FIRED MUNITIONS



## OBJECTIVE

- ❑ Bring a systems approach to the management of power requirements throughout the mission profile of smart and guided munitions across all caliber ranges.
- ❑ Develop technologies that free up lethality volume, by reducing the size of power sources
- ❑ Reduce munitions power to a single battery or eliminate battery altogether in some applications.

## APPROACH

- ❑ Harvest energy from the vibrational environment of munitions systems
- ❑ Optimize the conversion of energy, store in a capacitor medium
- ❑ Combine harvested/stored energy with optimized electrochemical stored energy

## PAYOFF FOR THE ARMY

- ❑ Improve reliability, reduce cost, improve safety, temperature performance and producibility.
- ❑ Improve scalability of power systems across all munition caliber ranges.

## PRE-LAUNCH

- ❑ Optical Power Transfer.
- ❑ Inductive Power transfer
- ❑ Contact.



### Advantages:

- No need to initiate reserve batteries
- Transfers power and information to the round before firing
- Same method used for maintenance and health of rounds.

## LAUNCH - PERIOD

### Harvesting:

- ❑ Stored mech. energy.
- ❑ Firing acceleration.
- ❑ Spinning.



### Advantages:

- Safety (no initial power).
- Replaces onboard battery
- Wide temp. performance
- Conformable
- Capability to survive entire launch range.  
(10 Kg's – 250 Kg's)

## FLIGHT

### Harvesting:

- ❑ Thermophotovoltaic
- ❑ Piezo/spring storage
- ❑ Spinning

### Reserve Cells:

- Improved Thermals
- Liquid reserves



### Advantages:

- Meets wide ranges of munitions power requirements.
- Meets fast power risetime needs.
- Meets power needs in high spin.
- Meets launch / flight survivability and shelf life requirements

## MAINTENANCE & HEALTH

- ❑ Simple / **safe** method to wake up round, transfer power and data.
- ❑ Uses small optical window on round



### Advantages:

- No need to initiate reserve batteries
- **Safe, secure**, can be automated.



### Power Energy Systems

#### Energy Harvesting Sub-system

Optical Carrier  
Harvesting

Spring Storage  
Piezo - Harvester

ThermoPhotoVoltaic

#### Energy Storage Sub-system

Super  
Capacitor

Electro-Chemical  
Storage

#### Power Optimization Subsystem

#### Power Controller

Combines electrochemical storage  
with Energy Harvesting  
and its scalable  
to meet a wide range of  
munitions power requirements

Uses Energy Harvesting  
To meet low power requirements  
To replace chemical batteries

**Munitions & Fuzes**

- Batteries
  - Liquid Reserve
  - Thermal
- Capacitors
- Piezo-Electric Crystals
- Energy Harvesters

**Armaments**

- Pulse Power Supply
- Pulse Forming Networks
- Capacitors
- Switches
- Generators
- Batteries

**Technical Challenges****Increased ENERGY / POWER Density****Reduced Volume / Weight**

- G-Hardening (80,000 G' s)
- Cold Temp Performance(-45F)
- Shelf Life ( $\geq 20$  years)

- High Rep Rate
- Peak Power vs. Avg Power
- Fast Rise Times
- Waveform Variability

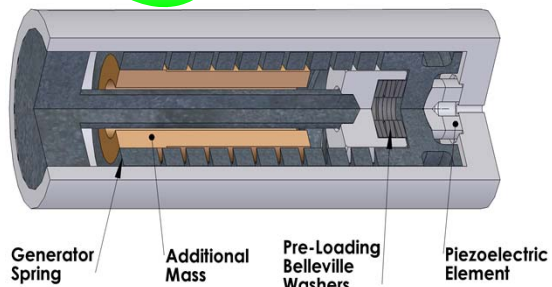
**Hybrid Energy System prototypes that provide required power for guided missiles and projectiles thru integrated functionality**

## Axial Piezoelectric Generators

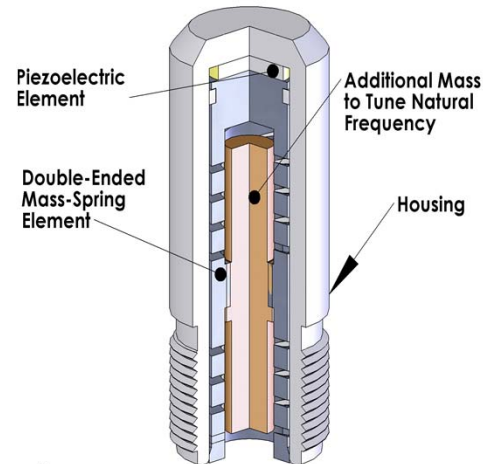
## Hybrid Energy System: Piezoelectric Harvesters

### Modular Design

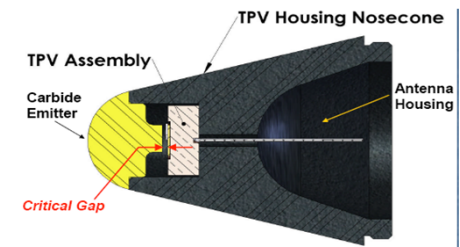
## Axial Piezoelectric Generator



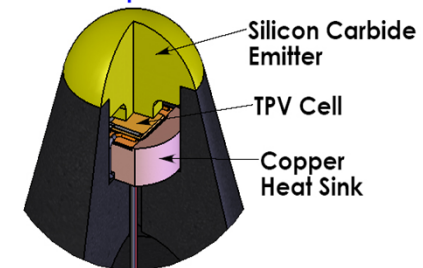
## Lateral Piezoelectric Generator



## Hybrid Energy System: Thermophotovoltaic



### Thermophotovoltaic

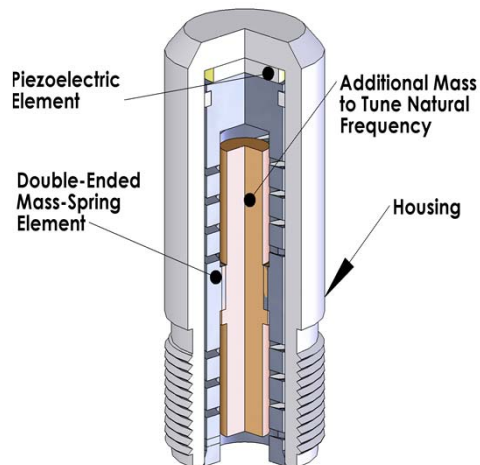




## ***Energy Harvesting from Armament Systems by Collecting Waste Energy During Operation.***

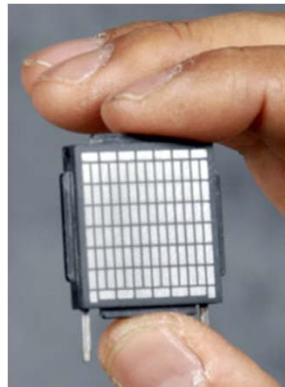
### **Gun and Vehicle Shock (Vibration)**

#### **Axial Piezoelectric Generator**



### **Gun Tube Heat (Thermal)**

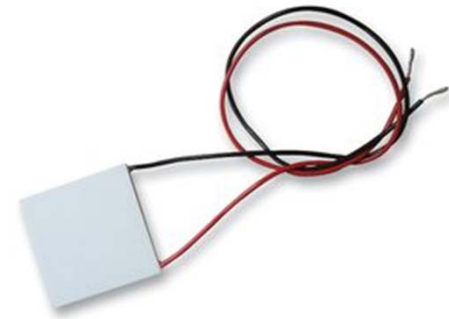
#### **Thermo PhotoVoltaic**



*In this July 31, 2008, photo released by General Motors, a module for a thermoelectric generator is shown in Warren, Mich. The generator, which converts exhaust heat to electricity, could improve fuel economy. (General Motors, Lee Short/Associated Press)*

### **Component Cooling (Peltier Cooler)**

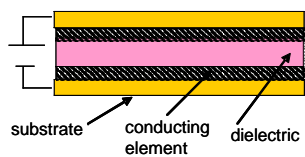
#### **Semi Conductor (p & n-type)**



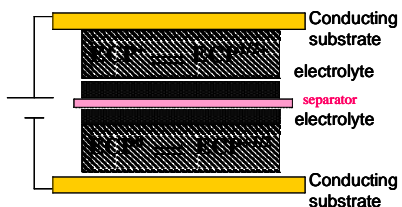
*Image found at [www.newark.com](http://www.newark.com)*

## Ultra-capacitors

**Solid State Dielectric Film Capacitor**

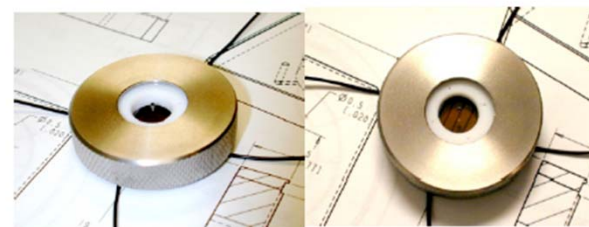


**Electroactive Polymer Supercapacitor**

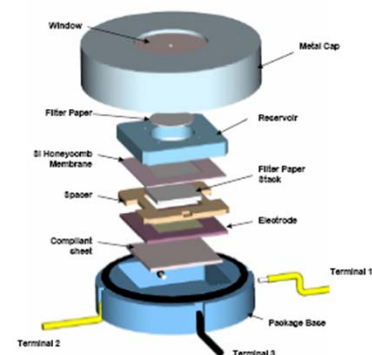


## Nano Reserve Battery

Micro-battery Prototype Package

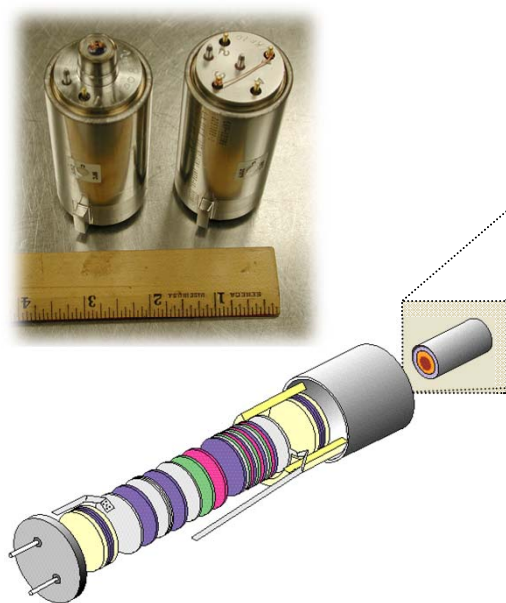


A Micro-battery Prototype Package

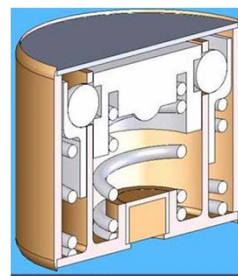


***Scalable and flexible architectures that will meet increasing power requirements***

## Thermal Battery: Higher Energy Density

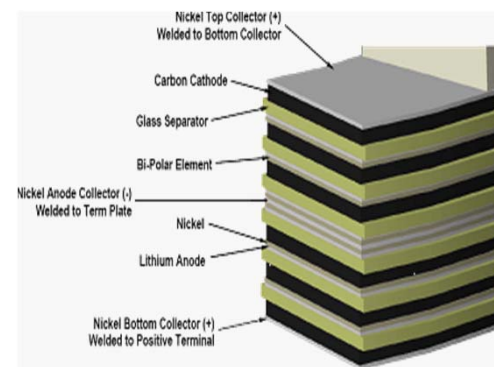


## Thermal Battery Igniter: Volume Reduction



## Liquid Reserve Batteries: Novel Organic Electrolytes

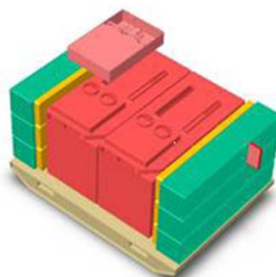
**Increased Producibility**



## Pulse Power Supply



## Pulse Power Supply for High Energy



## Solid State Switch for Field and Load

- Si SGTO
- SiC Thyristor

## New Battery Chemistries (3Ah/3V ; 12Ah/48V)



## Solid State Switches



## Capacitors for DE Weapons

