ADVANCED MUNITION POWER SOURCE TECHNOLOGY

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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MUNITION POWER SOURCE NEEDs

- High G survivability from Gun Launch (5 kGs – 140 kGs)
- 20 Year Shelf Life
- Extreme Temperature performance
  - - 40 F° to +145F° Operating Temperature
  - - 65F° to +165F° Storage Temperatures
- High Power and Energy Density
- High reliability
- Cost effective

Develop affordable munition power supply technologies with increased power and energy densities, that can satisfy tactical munition requirements.

TECHNOLOGY, DEMONSTRATION AND VALIDATION

Initial research conducted under several SBIR programs phase I and II

1.Phase I & II SBIR " Innovative Conformal Power Sources for Advanced Munitions"
2.Phase I & II SBIR "Innovative Optical Based Wireless Communications Technology for Smart Munitions
3.Phase I & II SBIR "Miniature Power Supplies"
4.Phase I & II SBIR "Inertial Ignition Systems"
5.Phase I & II SBIR "Miniature Electrical Ignition Systems"
6.Phase I & II SBIR "Low Cost Improved Thermal Batteries"
7.Phase I & II SBIR "Thin Film Thermal Batteries".

Technologies demonstration and validation

- Supported under ARDEC ATO titled "Fuze and Power for Advanced Munitions"

Additional research development to:

- Optimize power systems volumetric efficiency
- Heat management optimization for thermal reserve power systems
- Scalability across all munition calibers
- Miniaturization, reliability and identification of materials for low cost
- Transitions to acquisition programs

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.

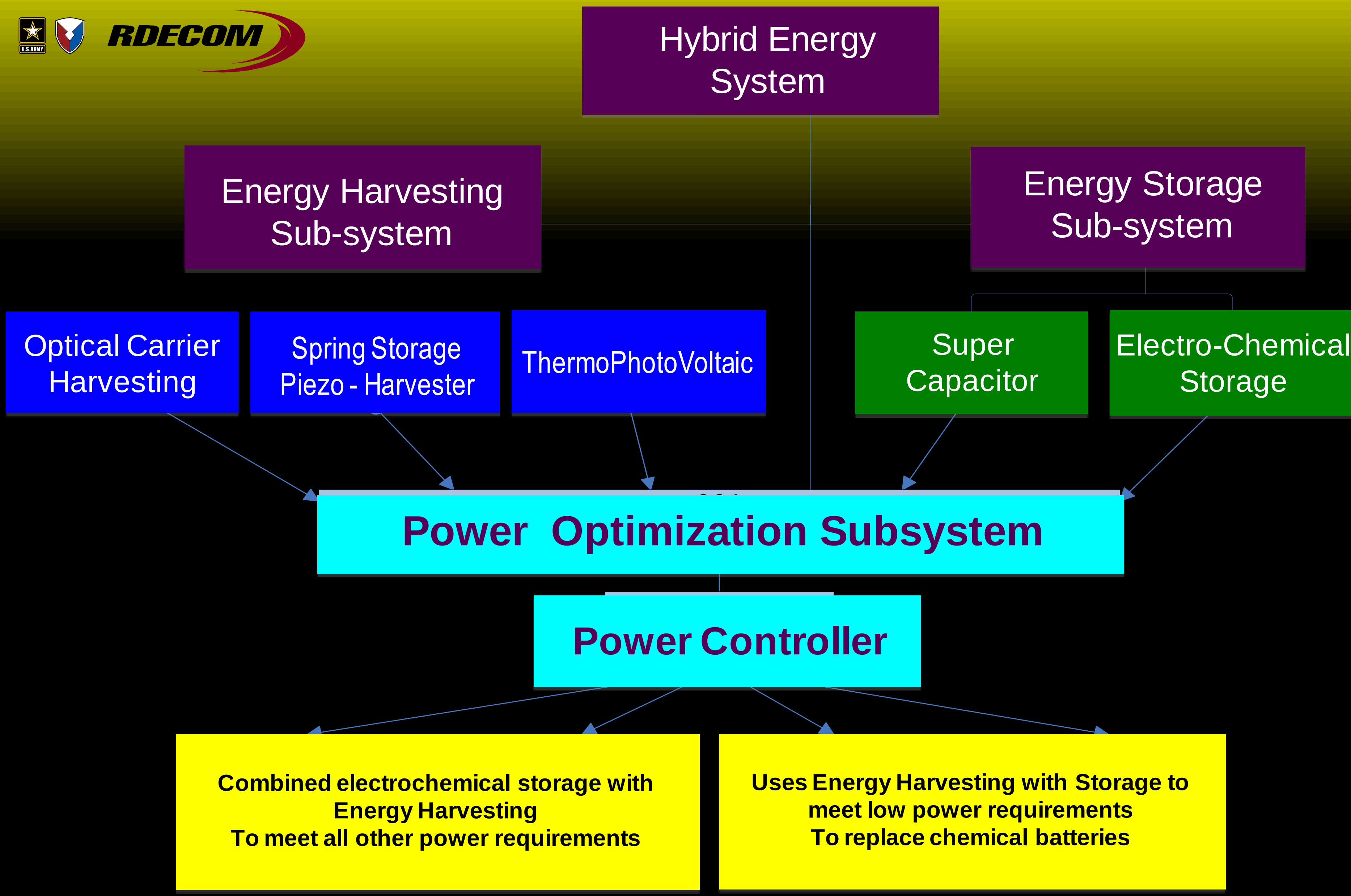
Approach

- 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.

HYBRID ENERGY SYSTEMS FOR GUN FIRED MUNITIONS

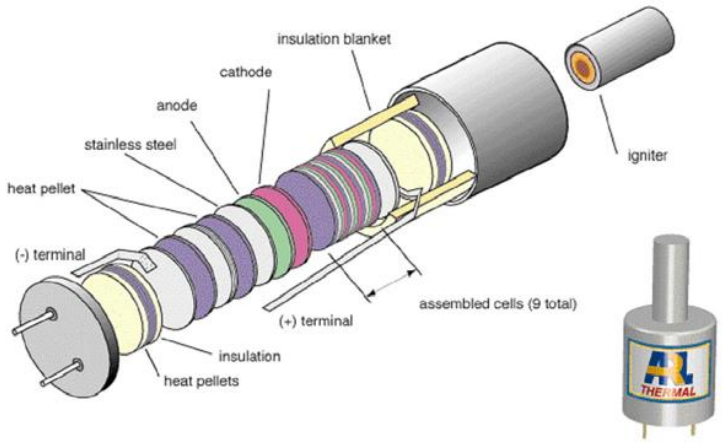


Fast Rise Time Thermal Battery:

- Fast rise time electrochemistry not readily available
  - *Issues with OSHA & EPA regulations*
- Conventional components are thick and brittle
  - *Produced as pressed pellets*
  - *Limited geometry- volume not optimized*
  - *Extra mass to make handling easier – Slows down heat transfer*
- Materials are costly to manufacture
  - *Expensive production equipment & operating costs*
  - *Labor intensive*
- Must survive military environments:
  - *High G-forces from gun launch*
  - *High spin rate (~250-300 rps)*
  - *Minimum 20 year shelf life*
  - *Temperature range of -65 deg F to 160 deg F.*
- Need viable heat source for fast rise time electrochemistry

INERTIAL IGNITERS FOR THERMAL BATTERIES

- Initialize thermal battery
- Inertial activation is preferred
  - No preflight power required
  - Safety mechanism to make go/no-go decision to activate thermal battery
  - Main downfall – size, especially for smaller batteries
  - Significant room for improvement
- Difficult to define requirements up front
  - Systematic process for requirements definition absent
  - Wide variety of munition launch accelerations
- Generate a design which is flexible
  - mass/spring combinations
  - setback / setforward
  - variety of shapes and alternate configuration
- Low G / high G designs



INERTIAL IGNITERS FOR THERMAL BATTERIES (con't)

Objective

Significantly reduce the volume of the inertial igniters to make them suitable for small thermal batteries applications.

- Develop inertial igniters suitable for low to very high-G munitions applications.
- Develop inertial igniters that allow easy integration into all thermal battery designs.

Approach

Development of novel miniature mechanical devices that respond to input impulse with the desired time delay to differentiate firing acceleration profile from accidental events.

- Development of novel single and multi-stage mechanical delay mechanisms that allow for very high delay times in a very small volumes.
- Development of detailed dynamics models, their validation through realistic testing, and optimization of the developed designs.

Payoff for the Army

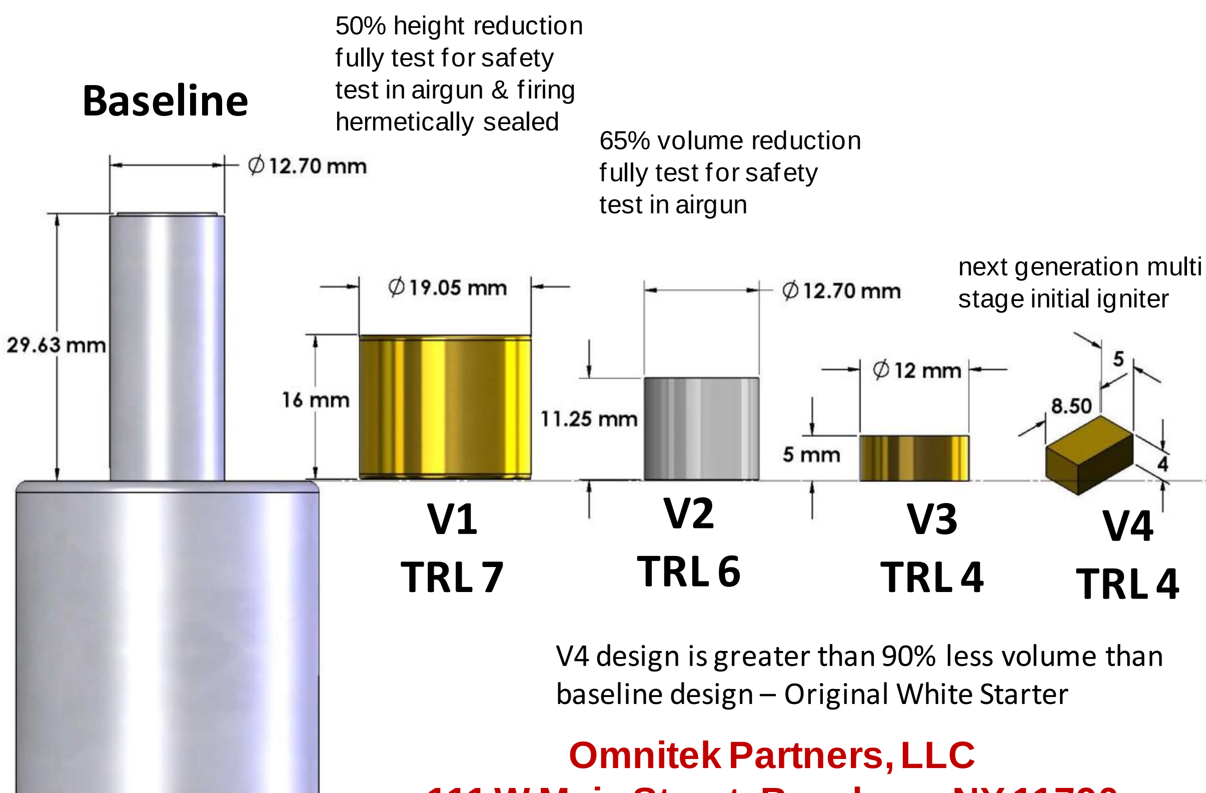
Make inertial igniters available for small thermal batteries to power munitions electronics across all munitions caliber ranges

- Improve reliability, reduce cost, improve safety.

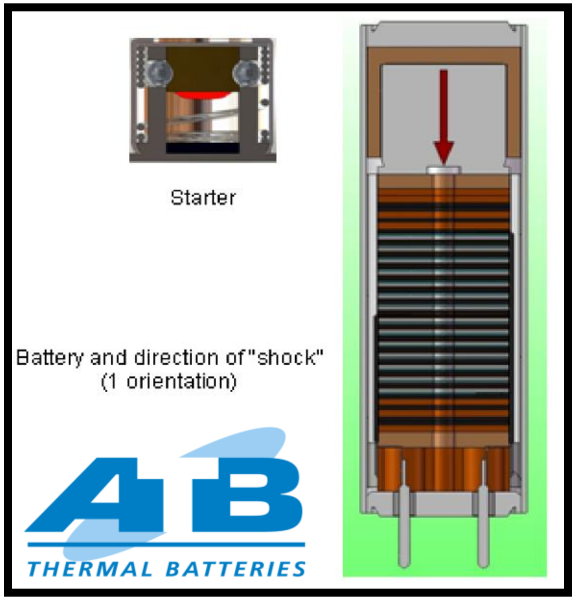
INERTIAL IGNITER for THERMAL BATTERIES (con't)

Thermal Battery Improvements : Miniature Igniter

- Highly miniaturized thermal batteries will require a novel ignition method.
- Various iterations each in different phases.



V4 design is greater than 90% less volume than baseline design – Original White Starter



Omnitek Partners, LLC
111 W Main Street, Bayshore, NY 11790

- Improved integration & cost effective
- Simpler manufacturing process
- Increase industrial base
- Increased battery energy density
- Flexible packaging & manufacturing

INERTIAL IGNITER FOR THERMAL BATTERY (con't) SUMMARY

Families of miniature inertial igniters are under development as part of SBIR Phase II projects with * Omnitek Partners, LLC and are being mature through ATO

- Two generations of igniters have been prototyped and tested for safety (no-fire conditions) and for all-fire ignition in air guns.
- Two generation of igniters have been integrated into thermal batteries and and tested in air-guns (spin and no-spin tests), and one series as integrated into thermal batteries has been tested in an artillery round (fired at YPG on 08/05/2008)
- Currently teaming and collaborating with Advanced Thermal Batteries
- and Omnitek Partners to develop an improved thermal battery.
- Current collaborations with ATB and Omnitek Partners has resulted in integrated improved thermal battery at TRL 6.
- Scheduled to transition to PM and Acquisition Program

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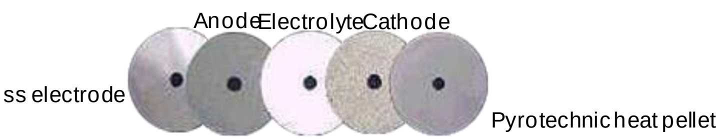
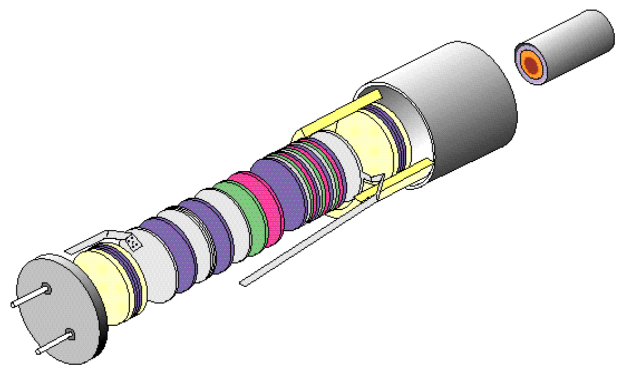
INERTIAL IGNITER FOR THERMAL BATTERY (con't) SUMMARY

Thermal Battery Improvements

- Achieved 30% increase in runtime by implementing an improved heat management:
  - Extra heat end heat pellets
  - Improved insulation material
  - Sidewall heating
- Investigated runtime improvements utilizing metallic gas getters
- Demonstrated in flight test at YPG on 08/05/08





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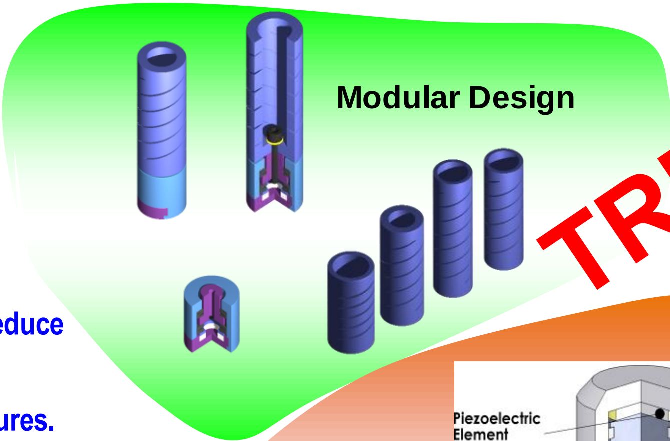
SPRING STORAGE PIEZO ENERGY HARVESTING

Advantages of Using Piezoelectric-Based Energy Harvesting Power Sources in Munitions

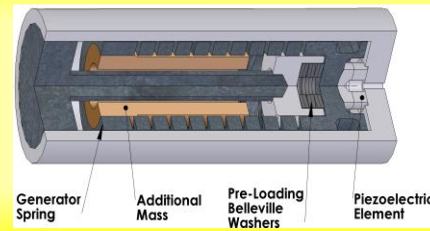
- Safety (no initial power).
- Very long shelf life.
- Relatively small.
- Can replace the onboard battery or reduce size of battery
- Operates in a wide range of temperatures.
- May be integrated into the structure of munitions.
- The level of output voltage provides information about the state of the munitions and can be used as secondary means for fuzing safety and munitions operation.

Axial Piezoelectric Generators



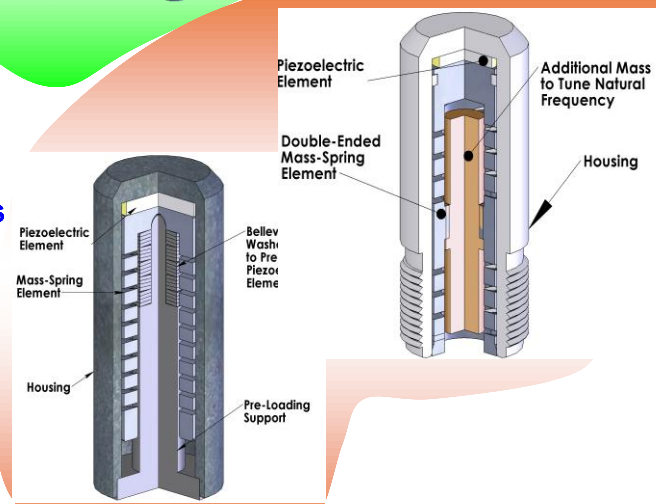
TRL 7

Lateral Piezoelectric Generator



Sources of Energy for Onboard Power Generation

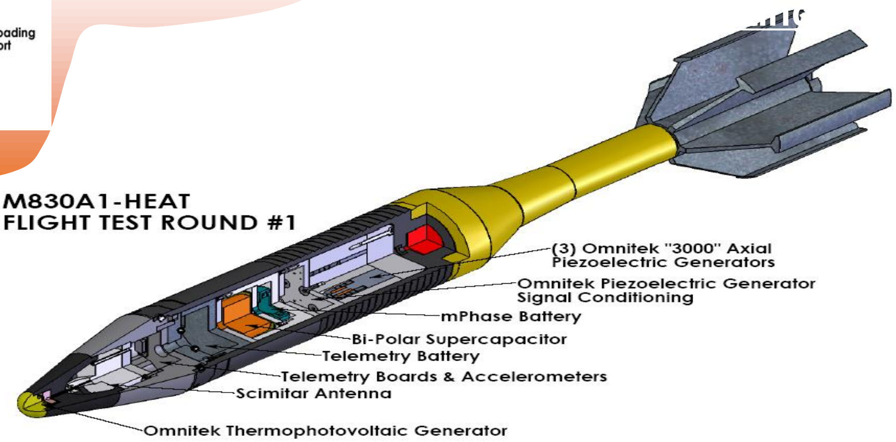
- Firing acceleration.
- Spinning during the flight.
- Drag induced vibration.
- Flow induced heating of leading surfaces during supersonic flight.
- Stored mechanical (potential) energy.



Advantage of Using Spring Storage

For a 1.8 preloading factor, and since only 1/3 of mechanical energy in piezo is electrical energy, the energy converted by the resonating unit is up to (1.8 X 6250 X 3 / 12.5) = 2700 times higher

Flight Test 09/25/07



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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

THERMOPHOTOVOLTAIC (TPV) POWER GENERATION FOR SUPERSONIC MUNITIONS

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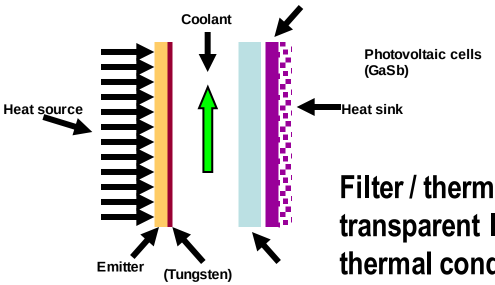
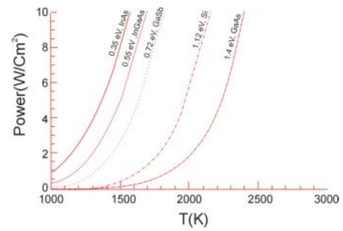
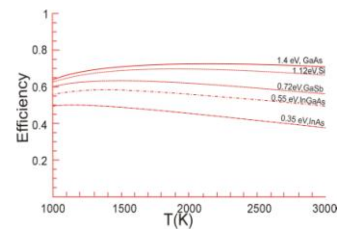
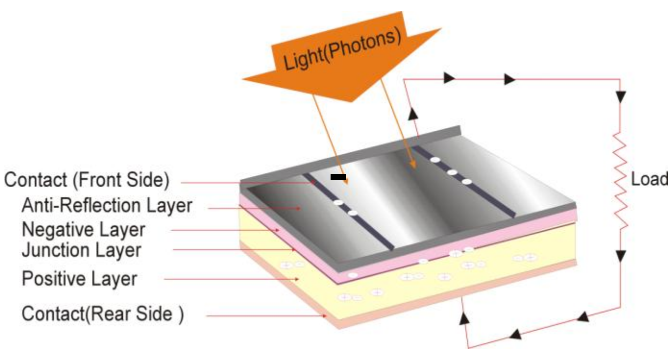
Thermophotovoltaic Materials Based Power Generation – Basic Elements

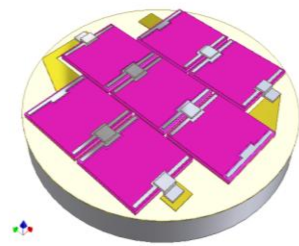


Filter / thermal insulation (a transparent layer with low thermal conductivity, e.g., LiF)





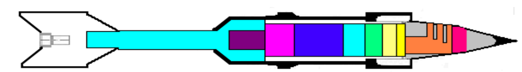




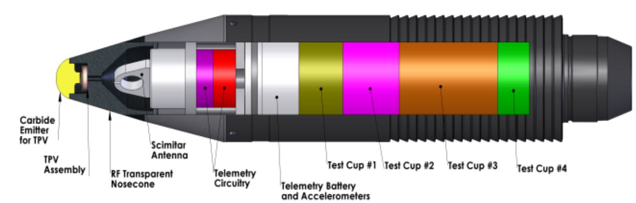
JX Crystals Inc - 3.2 V GaSb IR Circuit - 1 cm x 1 cm

Advantages

- Safety (no initial power).
- Very long shelf life.
- Relatively small.
- Reduces the total onboard battery and/or capacitor volume.
- Can be integrated conformably into the munitions structure.



Flight Test Summer, 2007



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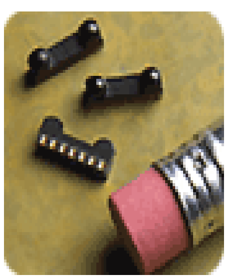
OPTICAL WIRELESS DATA & POWER TRANSFER

Optical Wireless Communications for Munitions

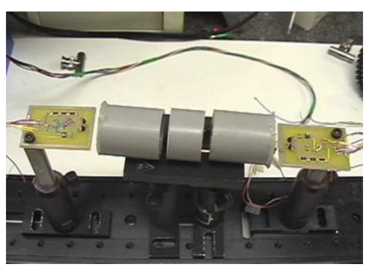
- Potting material utilized as wireless transmission medium (or free space)
- NO Fiber Optics! – optical communication system
- Could be implemented in two ways:
  - Fuze Setter – transfer data (4-16Mb/s) and power preflight (1J less than 0.1s)
  - Wireless communication bus within munition (board to board)
- Demonstrated ½ watt power transmission per cell
- Multiple cells combined for desired power characteristics
- Patented use of “guided” and free space optical communication network in munitions

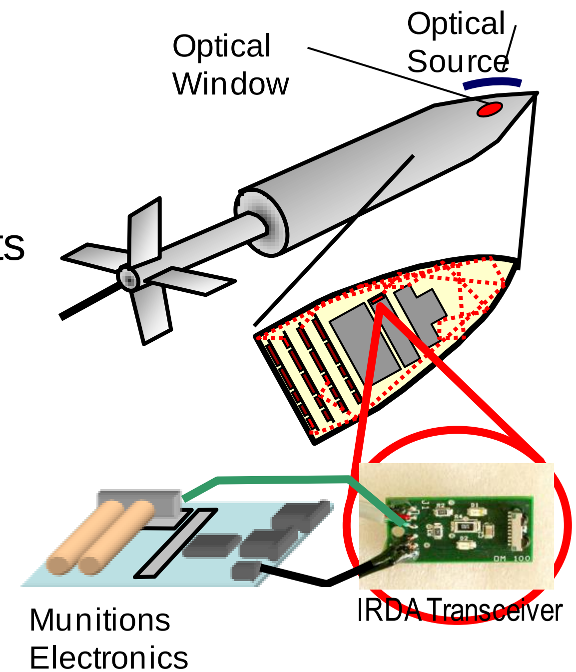
Advantages over wire based systems

- Immune to electromagnetic interference
- Inherently high G tolerant
- Extremely low cost, commercially available components
- Compact and light weight, and low power
- Potential to eliminate umbilical cord or board to board connections



The Smallest IrDA Transceiver

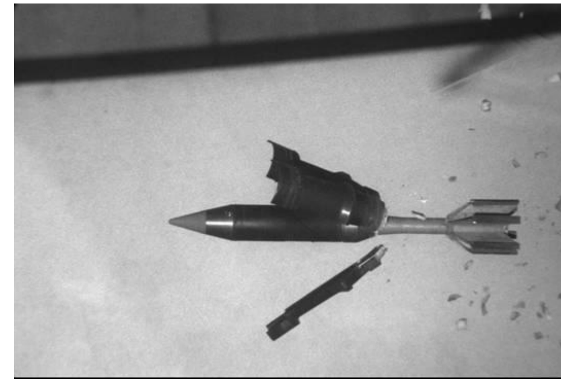




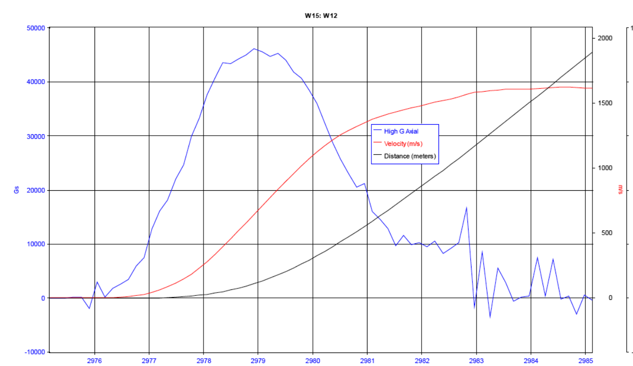
HYBRID ENERGY SYSTEMS SUMMARY

Energy Harvesting technologies are under development as part of SBIR Phase II projects with * Omnitek Partners, LLC and are being mature through ATO

- Built & tested various types of energy harvesters, several types of designs to be mounted axially and radially for flight tests to demonstrate energy harvesting in tri-axial configuration
- First time HES components subjected to gun launched operational environment
- First time converted energy using piezoelectric harvester at over 30% efficiency
- Validated model
- Piezoelectric generators survived 50K G's of setback and produced power to meet ATO objectives
- Excellent quality TM data obtained from flight tests
- Achieved TRL 7



M830A1 tank round upon gun launch



Typical Acceleration Plot for M830A1

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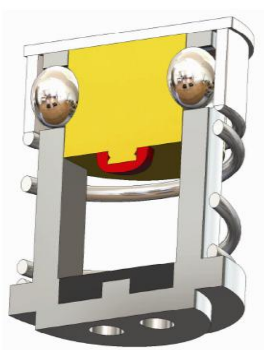
*** Gov't Patent Pending**

BACK UP

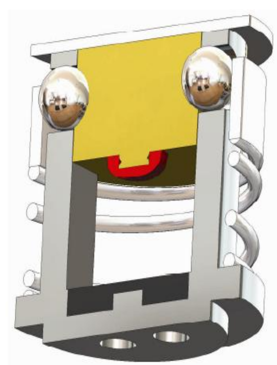
Omnitek inertial igniter and its operation

Fully assembled

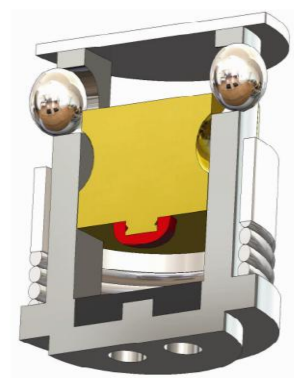
Outer casing removed



At rest (striker locked)



Partial (no-fire) actuation



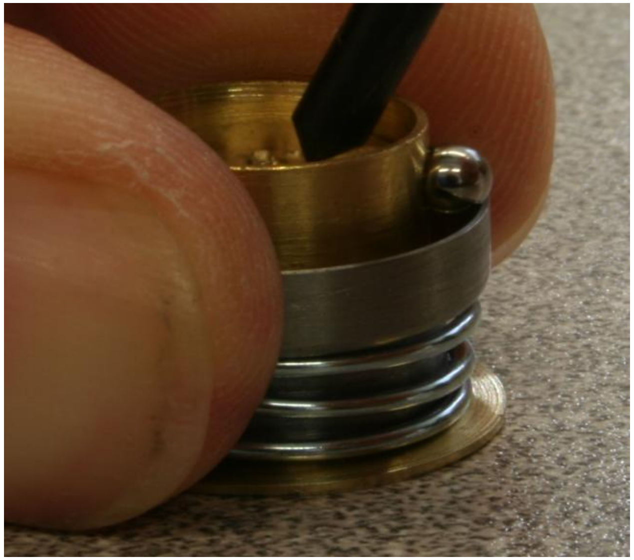
Full (all-fire) actuation (striker released)

Primer based or two part pyrotechnic ignition available

At rest

Operation of the Omnitek "V1" inertial igniter
(Outer casing removed)

Partial actuation



Striker released

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SPRING STORAGE PIEZO ENERGY HARVESTING

$E_{mechanical} = 1 Joule = 1 \frac{w}{\sec}$

$E_{electrical} = 1J * 0.33 = 330\ mjoules$

Power in WATTS is the rate at which energy is used.
and the amount of energy used is measured in JOULES.
Then,
Joules = watts x seconds, therefore watts = joules/seconds.

Then,

$P(watts) = \frac{E}{Time}$

And,

$P(watts) = \frac{(1J)*(0.33)}{0.1\sec} = 3.3 watts$

At V=5 volts; P=3.3watt; $I = \frac{P}{V}$

Then,

$I = \frac{3.3}{5}$; $I = 66$ ma (milliamperes)

- The harvesters are designed as continuous oscillation harvesters coupled to a staked piezo
- Various designs mounted in both axial as well as lateral directions
- Design in flight round stores 1 joule and it is expected to have a 33% efficiency. It is tuned to about 1.2 KHz.
- Depending on the round vibration range, it may produce more or less than 1 joule.
- The axial harvesters are expected to produce at least 1 Joule
- Since this is the first time we are firing these harvesters in a flight round, we will be learning the profile of the vibrational information by means of onboard sensors.

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THERMOPHOTOVOLTAIC (TPV)

Thermophotovoltaic Power Generator Integration into the Nose of a Projectile