U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT, & ENGINEERING CENTER (ARDEC)

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Technology Trends in Fuze and Munitions Power Sources
May 19th 2010

Mr. Oliver Barham

Outline

- ARDEC Fuze Division Introduction
- OSD Joint Fuze Technology Program Introduction
- ARDEC Fuze Capabilities and Technology
  - Micro Electro-Mechanical Systems (MEMS)
  - Proximity Fuzing
  - Electronic Safing and Arming Devices (ESADs)
  - Munition Power Sources

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Fuze Division Mission

- Fuze RD&E Life Cycle
  - – Fuzes
  - – Safe & Arm Devices (Mechanical and Electronic)
  - Related Technologies
    - Advanced Sensors
    - Low Cost, Small, Gun Rugged Electronic and
    - Mechanical Devices (MEMS)
    - Electronic Fuze Setters
  - – E3 Munition Assessments
  - – Munitions Power Sources
- National and International Fuze Related Committees
- Army Fuze Safety Review Board
- DoD + NDIA Fuze Committees

Fuze Division Facilities

- Picatinny Arsenal, NJ
  - Building A (temporary)
    - Office Space for ~70 employees
  - Building B
    - Electronics Laboratory
  - Building C
    - Fuze Development Center
  - Building D
    - Electromagnetic Environmental Effects Test and Evaluation Laboratory
- Co-located with ARL Adelphi Lab Center, MD
  - Office space for ~45 employees
  - Lab facilities
    - RF Proximity, electronic mechanical
    - Prototype machine shop

BRAC Consolidation at Picatinny with $17M state -of- the- art facilities construction

Joint Fuze Technology Program (JFTP)

- **JFTP is an OSD funded 6.2/6.3 national program established (FY10 start) to develop and mature technologies for improving future fuzing performance, survivability, and reliability.**

- **JFTP governance and process is modeled after the Joint Munitions Program (JMP) and the Joint Insensitive Munitions Technology Program (JIMTP).**

- **Program will leverage and be synergistic with projects in JMP, JIMTP and individual Service S&T Programs**

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Joint Fuze Technology Program (JFTP)

OUSD(AT&L)/
PSA/LW&M

Technical Advisory Committee

JOINT FUZE TECH PANEL OVERSIGHT COMMITTEE

PROGRAM MANAGERS
Charles Kelly, Lawrence Fan, Phil Gorman, Tim Tobik

FUZE AREA TECHNOLOGY GROUPS

FATGI – Hard Target / Survivable Fuzing	FATGII – Tailorable Effects	FATGIII – High Reliability Fuzing	FATGIV – Enabling Fuze Technologies
Chair Dr. Howard White (AF)	Chair Gene Henderson (Army)	Chair John Hendershot (Navy)	Chair Chris Janow (Army)
Co-Chairs John Kandell (Navy) Danny Hayles (DTRA) Bill Konick (Army)	Co-Chairs Daniel Lanterman (Navy) Dr. Eric Welle (AF)	Co-Chairs Steve Smith (AF) Tom Crowley (Army) Danny Hayles (DTRA)	Co-Chairs Matt Bridge (AF) Bruce Hornberger (Navy)
SME Participants	SME Participants	SME Participants	SME Participants

Fuze Area Technology Groups

FATG I – Hard Target / Survivable Fuzing	FATG II – Tailorable Effects	FATG III – High Reliability Fuzing	FATG IV – Enabling Fuze Technologies
1.1 Improved M&S 1.2 Fuze Environment 1.3 Next Generation Fuzing Hardware	2.1 Initiation and multi-point technologies 2.2 ESAD Based Multi-point Initiators 2.3 MEMS Based Multi-point Initiators 2.4 Smart Fuzing: Algorithms, fuzing timing and control	3.1 Fuzing Architecture 3.2 Fuzing Components 3.3 UXO reduction features	4.1 Common / Modular Fuze Architecture 4.2 Components Technologies 4.3 Proximity Sensors 4.4 Weapons Effects & Damage Assessment 4.5 Fuzing Power Sources

Micro Electro-Mechanical Systems (MEMS)

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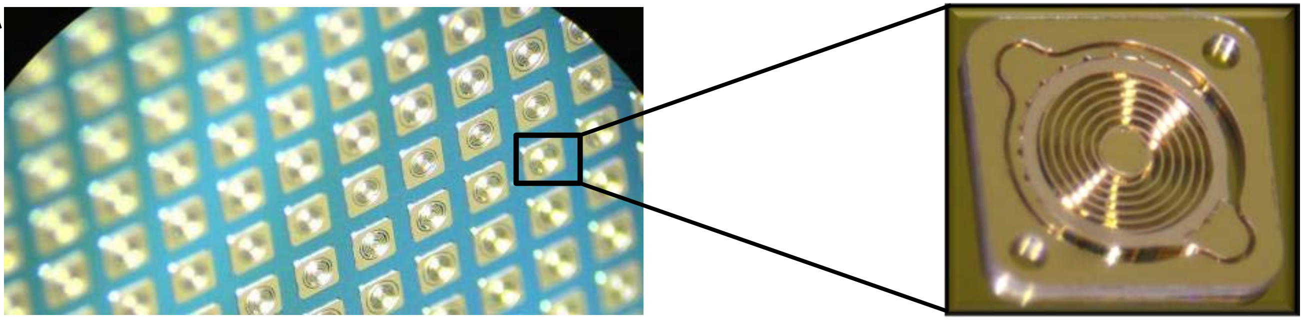
ARDEC S&T Investment: MEMS

2002-2008 S&T Development:

– High-aspect ratio (HAR) *metal* MEMS fabrication*
– MEMS omnidirectional g-switch*
– MEMS S&A and Micro-Scale Firetrain (MSF)
– Explosive inks and direct-write loading of MSF
– Electromagnetic and piezoelectric setback generators

*



40mm HEDP MEMS Program Description

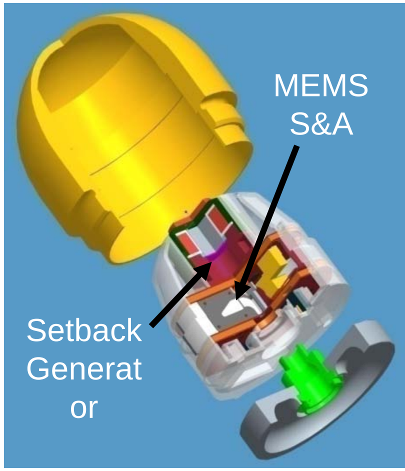
Implement MEMS mechanical S&A device and direct-write explosive ink loading technology to improve the fuzing system & explosive train of the M433 & M430 40mm HEDP cartridges

MEMS = micro-electro-mechanical systems

HEDP = high-explosive, dual-purpose

M430

- New fuze architecture
- Electronic initiation vs. stab detonator
- Command-arm-enable
- Self-destruct capability (reduce UXO)
- More accurate arming distance
- Improved reliability on soft targets & graze
    - MEMS G-switch array
- Drop-in replacement for current fuzes



Program Objectives:

- Demonstrate 40mm MEMS fuze, May 2010
- Fuze & cartridge integration and test, FY10-11
- Cartridge Qualification and TDP, FY12-13

Mk19

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MEMS G-Switch (Impact Sensor)

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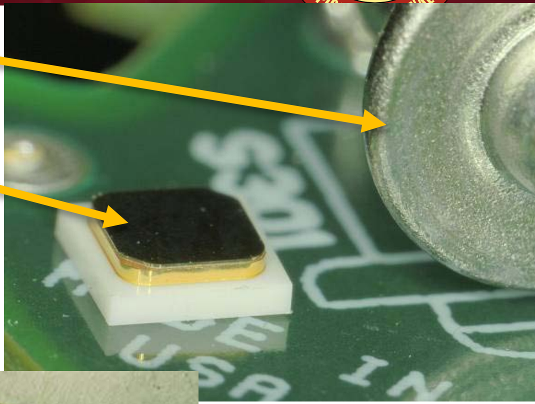
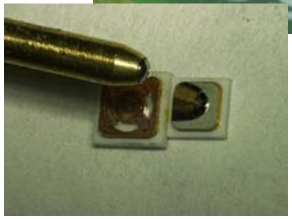
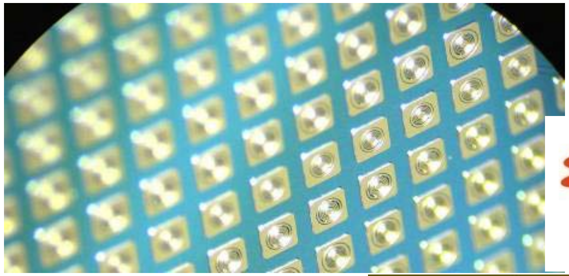
- MEMS Inertial Sensor
  - Surface-mount to standard PCB
  - All metal on ceramic substrate
  - Packaged at the wafer level with hermetic bonds
- Normally-open switch
  - 95% volume reduction from "Lucey" switch
  - Omni-directional sensitivity
    - Independent directional contacts, $\pm$x, $\pm$y, $\pm$z
    - Independent radial spin sensitivity
    - Setback soft/hard impact, spin, graze
    - Robust in overshock
  - 50- to 10,000-Gs range thresholds
  - Tested to 45-kGs at BP, 75-kG at ATK
- Potential for transition to multiple programs
- Customer Interest:
  - ATK, 3800 ea. for XM25,30mm STAR ATO
  - ARDEC 900 ea., MK19 HEPD 40mm- M918







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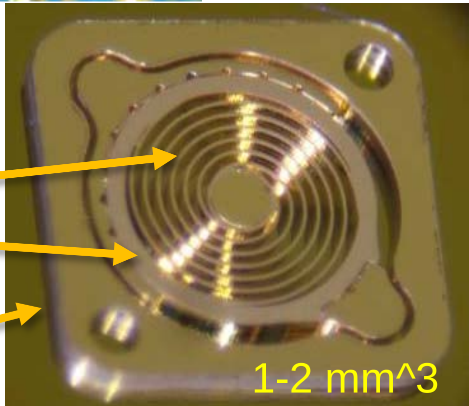

40mm MEMS DEMO – May 2010

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Metal MEMS Device Application Trends

Large- & Med-Cal S&A and Micro-scale Firetrain Integrations

- 105mm and 155mm, ARDEC Fuze & Power ATO
- 50mm, Enhanced Area Protection System
- 40mm, 40mm MEMS Fuze
- 30mm, STAR (scalable technology for adaptive response) ATO
- 25mm

Non-spin S&A Applications

- Hand Grenade, replace M228 fuze
- 50mm, Enhanced Area Protection System

Inertial Mechanical Switches

- Omnidirectional g-switch
- High-current uni-axial g-switch
- Integrating g-switch

New Platforms

- AFRL Cyborg moth project
- Other lightweight/small platform integrations

Proximity Fuzing Technology

JFTP Next Generation Proximity Effort

- Develop a next-generation low cost sensor technology with:
  - Enhanced battlefield performance
  - Improved Electronic Counter-Measure (ECM) resistance
  - Better immunity to reverse engineering

- Use a tri-service Integrated Product Team (IPT) to select the best technology for a wide array of applications
  - Adaptable for a wide array of systems and target types
  - Software defined Height of Burst (HoB)

- Address concerns of the DoD Fuze IPT and Project Manager Combat Ammunition Systems (PM CAS) regarding the existing state of proximity sensor technology

- Maintain the US lead in proximity sensor technology

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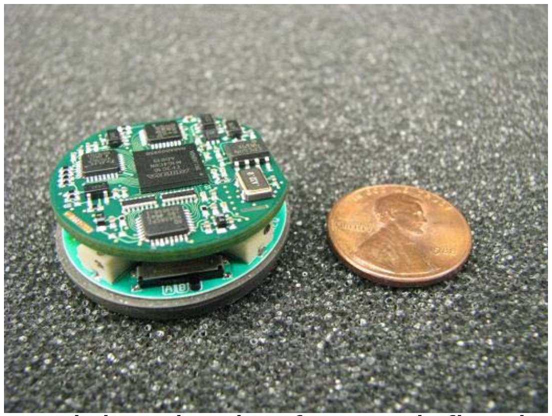
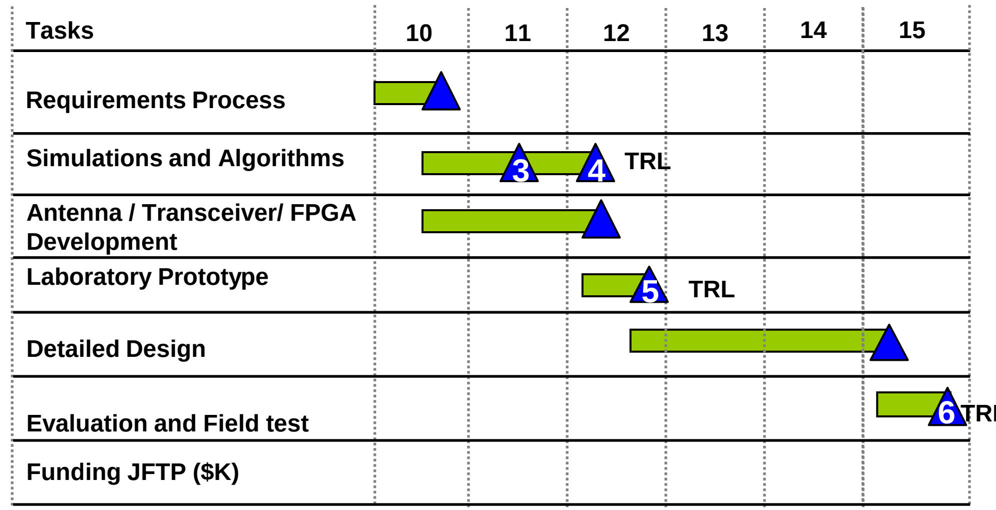
JFTP Next Generation Proximity Effort



Miniaturized software defined proximity sensor

Technology Investment Schedule (FY)



Objective

This program addresses the Department of Defense (DoD) need to develop a next-generation proximity fuze technology to replace the current Frequency Modulated Continuous Wave - Directional Doppler Ratio Ranging (FMCW-DDR) proximity sensors.

Current Year Milestones

- *M1: Joint Proximity Sensor Requirements*
- *M2: QFD Technology Down Select*
- *M3: Refined Task Allocations*
- *M4: Frequency Allocation*

Technical Approach

- *Tri-Service IPT down select to highest payoff technology approach*
- *Advanced antennae, transceivers, and signal processing algorithms capable of frequency agility*
- *Low cost anti-tamper techniques for improved reverse engineering protection*
- *Software defined proximity sensors with selectable standoff and improved electronic countermeasure protection*

Leveraging and Transition Opportunity

- *Technology leveraging from Fuze and Power Army Technology Objective Program*
- *Endorsed by Project Manager for Conventional Ammunition systems (PM CAS)*
- *Potential insertion into XM1156 Precision Guidance Kit (PGK), M782 Multi-Option Fuze for Artillery (MOFA), M734A1 Multi-Option Fuze for Mortars (MOFM)*

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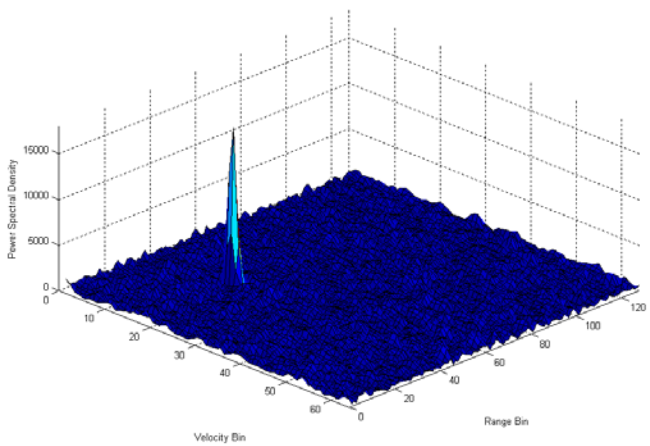
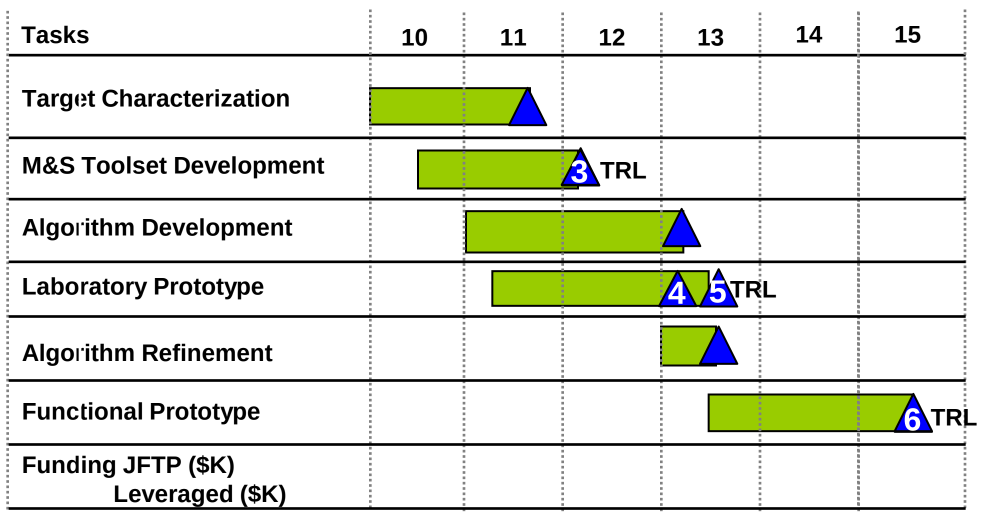
Prox. Sensor for Tailorable Warheads

RANGE - VELOCITY MAP for FMCW Proximity RADAR



Technology Investment Schedule (FY)



Objective

- Develop a sensor system to crudely identify primary features of different target scenes in the end-game encounter
- Provide information to make smart decisions on "how" and "when" to initiate tailorable warheads

Current Year Milestones

- M1: Target Set Selection – Mar10
- M2: Fuze Sensor Data Acquisition System –Jun10
- M3: Baseline Simulation toolset – Oct10

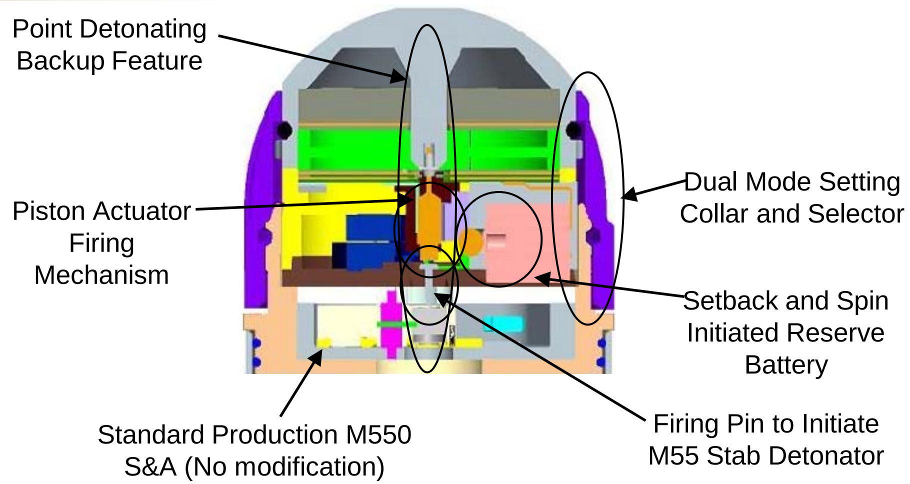
Technical Approach

- Development and validation of M&S toolset to aid in the design of signal processing techniques capable of producing end-game target classification data and accurate standoff measurements
- Design of miniaturized low noise analog, digital, and RF sensor circuitry
- Implementation of advanced DSP algorithms in commercial FPGA/DSP devices

Leveraging and Transition Opportunity

- 105mm Precision Munition (PEO Ammunition)
- Very Affordable Precision Projectile (VAPP)
- Scalable Technology for Adaptive Response ATO
- Sensor, Warhead and fuze Technology Integrated for Combined Effects ATO
- Mortar & Artillery Proximity Fuzes (PM Conventional Ammunition Systems)

Airburst Non-Lethal Munition (ANLM)



- Airburst Non-Lethal Munition (ANLM) is a non-lethal low velocity 40mm grenade fully compatible with existing M203/M320 weapon platforms.

- User settable fuze – two modes: 5m proximity and 5m proximity with delay (room clearing).

- Ability to employ non-lethal effects lasting up to 30 seconds, in a complementary non-lethal manner to enhance combined- arms battlefield effectiveness by minimizing mass physical destruction of people, materiel, infrastructure, and the environment.

- Allow tactical commander the option to tailor a response to situations when a lethal response in not the best option.

30mm Apache Gun System Prox. Fuze

Problem:
M789 HEDP round utilizes an impact mechanism that does not function fast enough when fired at personnel targets in soft or sandy soils. Most of the warhead fragments are absorbed by the ground.

Objective:

Develop a proximity sensor capability confined with the M759 fuze envelope utilizing the existing S&A.

POC: David Errera/Steve Stephey, ARDEC Fuze Division

User/Customer: PM-MAS

Benefits to the Warfighter:
Improve effectiveness of 30mm Apache gun system against personnel targets.

Tasks (FY10/11)

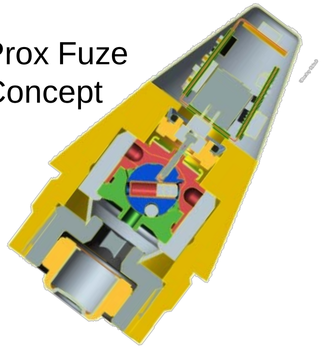
- Evaluate prox sensor using TM projectile.
- Continue tactical fuze design & integration
- Award ATK support contract
- Identify/develop custom components
- Fab, assemble, test sub-assy & demo hardware
- Conduct 30mm demo test

Schedule (FY10/11)

Activity Name	Start Date	Finish Date
Complete Design, Fab & Assembly of TM Demo Hardware	9/1/09	5/28/10
Conduct Live Demo Test w/ 40mm TM Projectile	6/7/10	6/18/10
Review System Requirements	10/5/09	11/6/09
Complete govt fuze design & integration	1/1/10	5/28/10
Design, Fab & Assembly Battery Airgun Hardware	4/19/10	6/18/10
Conduct Battery Airgun Test	6/21/10	7/2/10
ATK Support Contract	6/14/10	5/31/12
Fab & Assemble Explosive Transfer Test Hardware	6/14/10	9/17/10
Conduct Explosive Transfer Tests	9/20/10	10/1/10
Update govt design for packaging & encaspulation	8/2/10	11/19/10
Fab & Assemble airgun test hardware	11/22/10	1/28/11
Conduct Airgun Test	1/31/11	2/11/11
Update Design	2/14/11	4/8/11
Fab, assemble & lab test demo flight test hardware	4/11/11	8/5/11
Conduct 30mm demo flight test	8/8/11	8/25/11
Signal processor dev contract	3/25/10	3/23/11
Battery dev contract	11/1/10	8/26/11

M789 HEDP 30mm round with M759 Fuze

Prox Fuze Concept



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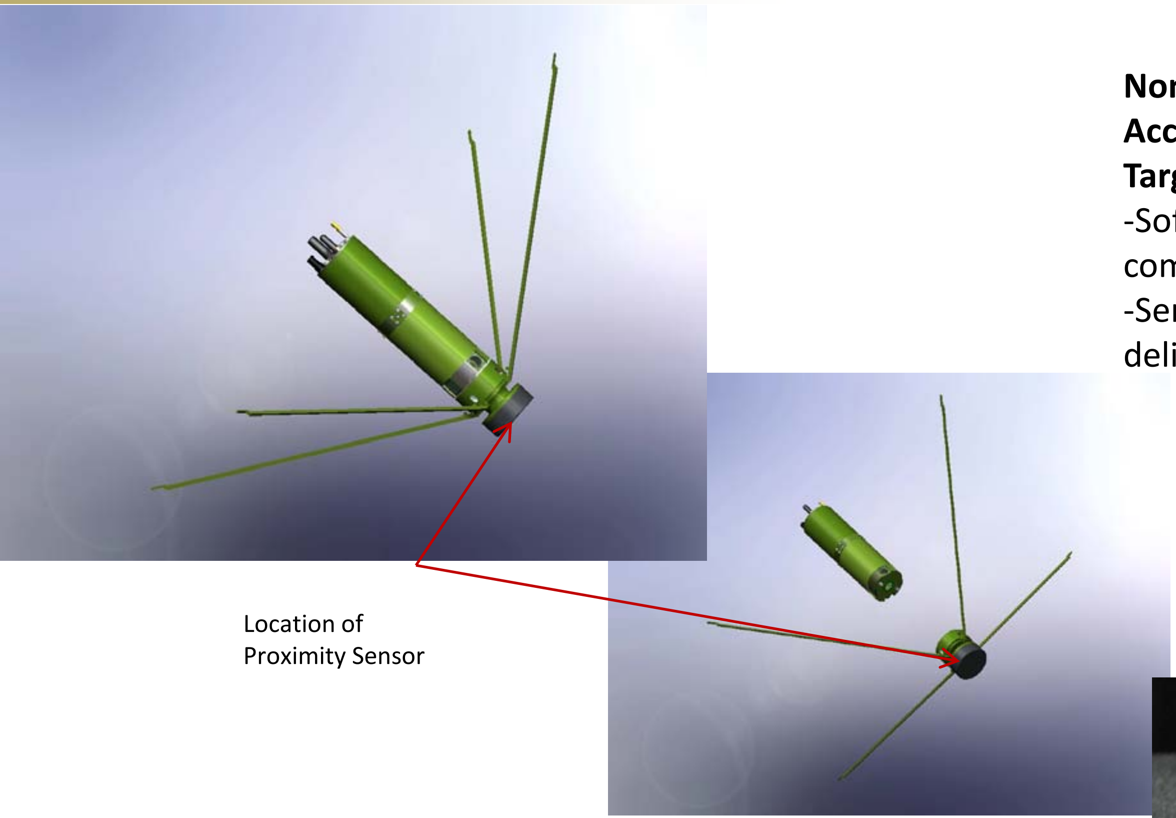
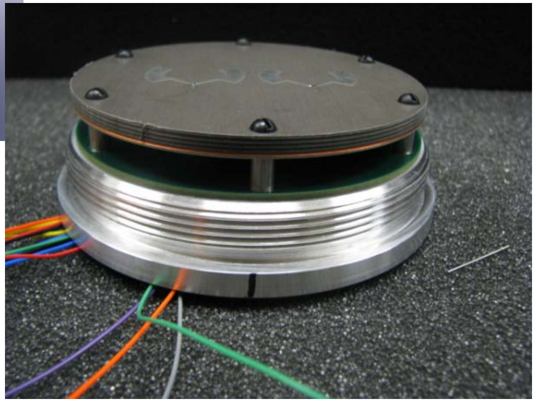
ORIOLE Medium Altitude Prox. Sensor

Nominal Standoff: 150m
Accuracy: +/- 20%
Target Type: HoB on Dense Tree Canopy
-Software defined proximity sensor using commercially available devices
-Sensor output used to deploy parachute for soft delivery of the ORIOLE system





Customer: Army Research Laboratory

Designed, Fabricated, and Characterized in house at ARDEC

Prox. Sensors for UAVs

ARDEC is designing and building proximity hardware for a variety of UAVs and UAV munitions

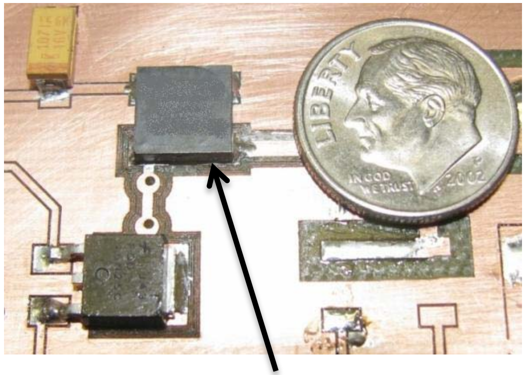
Electronic Safing and Arming Devices
(ESADs)

Electronic Safing and Arming Devices

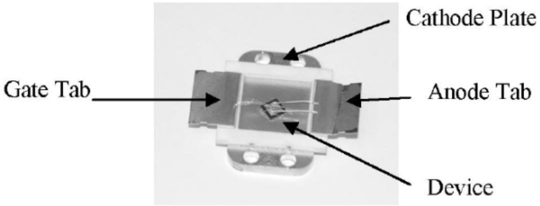
- All Electrical
- No moving parts
- No primary explosives
- High current / voltage devices
- High reliability
- High cost
- Example applications: Rockets, Missiles, Recoverable UAVs

Proposed ESAD Cost/Size Reduction

- JFTP Proposed Program
- Model and analyze transformer loading during setback events. Develop test fixturing to provide alternate mounting configurations for transformers. Develop underfill and assembly methods for mounting transformers to allow survival of artillery setback and prevent the failure of its brittle materials.
- Incorporate SiC switches from multiple manufacturers into ESAD firesets. Work with manufacturers to reduce packaged size for ESADs.
- Low Energy Exploding Foil Initiators (LEEFI) bridge substrates to be developed leveraging previous initiator work. Strict process control to minimize variation of bridge structures is necessary to maintain consistent initiation times



Transformer

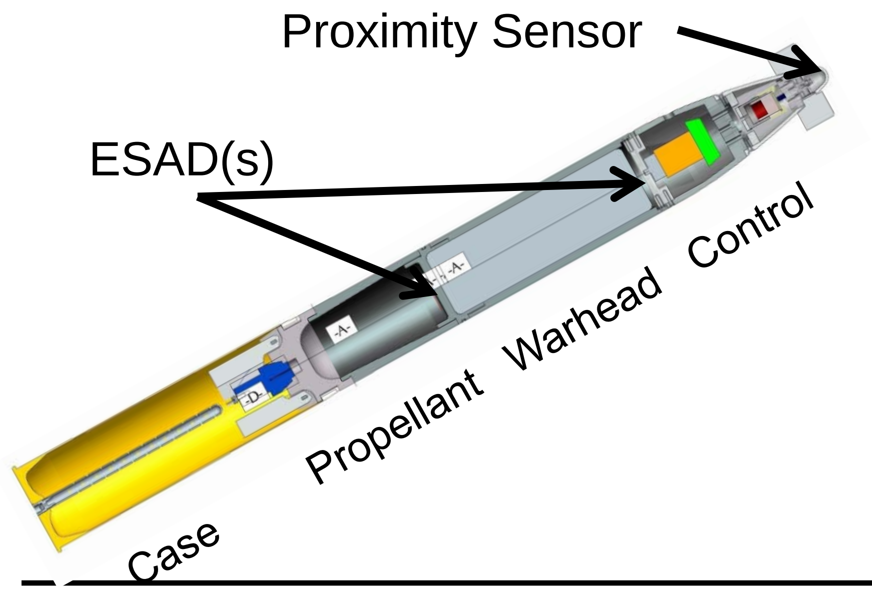


ARL SiC Device

ESAD: Non-Proximity Application

- ARDEC is designing and building ESADs for UAV applications, and others that do not employ proximity sensors

ESAD: STAR ATO 105mm Fuze Development



METC/ARDEC In-House Effort

Height of burst sensor
- System Design
- Schematic Capture / Physical Layout
- Algorithm Architectures
- Firmware Implementations

ESADs
- Safety System Development
- ESAD Laboratory Prototypes
- Firmware Development
- Fireset Design/Development
- Environmental Sensors (Setback Switch / Spin Switches)

Description:

-One of three thrust efforts under STAR ATO
-Increased lethality for Precision 105 mm (VAPP) while minimizing collateral damage
-Efficient thermal battery for Fuze and GNC
-Innovative warhead initiation schemes
-Hardened fuze for penetration
-Optimized HOB sensor for precision engagement

Customer: PM CAS

Requirements: TRADOC PAM 525-66: FOC 05-01, 05-02, 09-01; CNA 08-13 Future Force Capability Gaps Analysis for lethality overmatch; Future Force O&O and FCS ORD

Funding Source: (ASA(ALT)) Core

POC: C. Sanchez, 973-724-5495, camilo.sanchez@us.army.mil

Contracted/OGA Efforts

Electronic Development Corporation (EDC)
- ESAD prototyping
- Electronics integration

U of Florida – Electronics Communications Lab (ECL)
- HOB Sensor Algorithm Support
- HOB Modeling & Simulation

L3-Fuze Ordnance Systems (L3-FOS)
- Setback Sensor Development

ARL - Adelphi, MD
- Environmental Testing

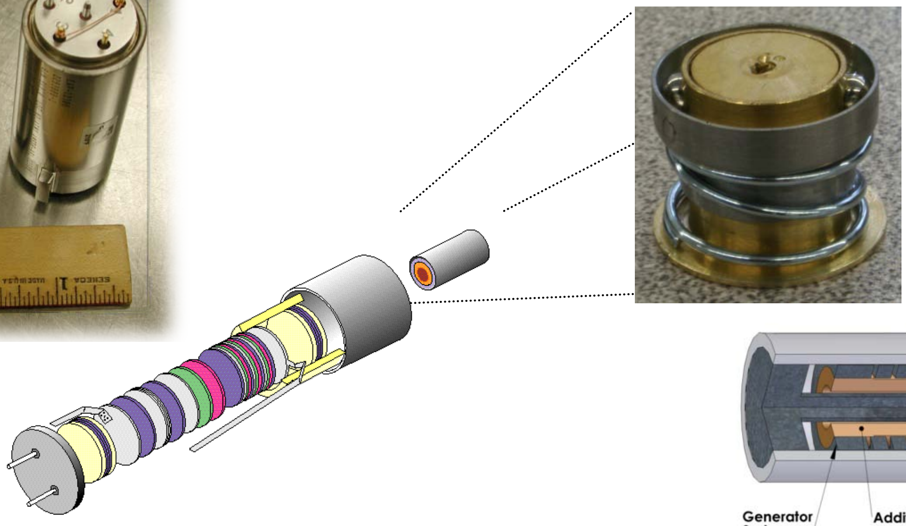
ARL - Blossom Point, MD
- Field Test Support

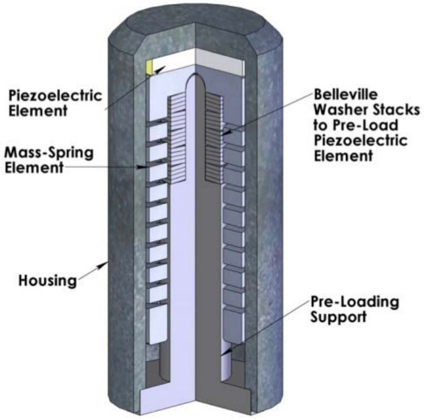
Munitions Power Sources

Munitions Power Sources

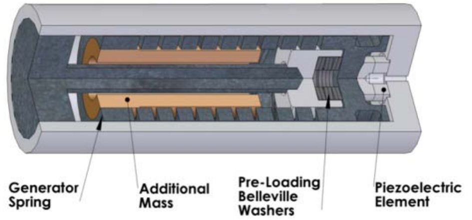
Objective:

To develop advanced, affordable, on-board gun-fired munitions power source technologies with increased energy and power densities, reduced volume and weight, increased mission time & improved extreme temperature performance for a portfolio of munitions.





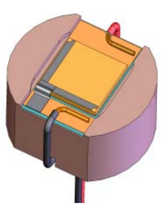
Axial Piezoelectric Harvesters

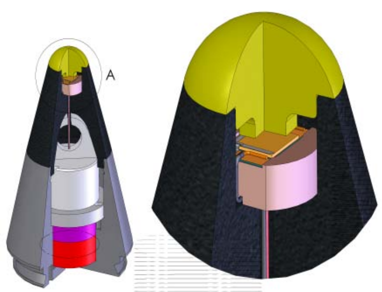


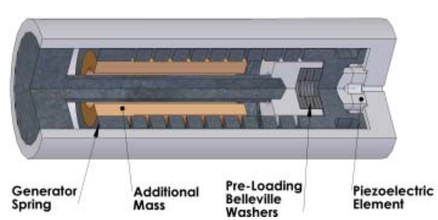
Lateral Piezoelectric Harvesters

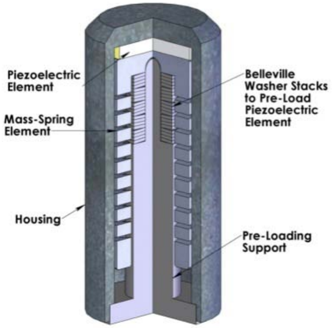
Hybrid Energy Systems *SBIR and Science & Technology Programs*

- Develop new types of energy harvesters to supplement and reduce the dependence on batteries ("Hybrid Energy Systems")
- Convert and combine energy in various forms that is resident in the ballistic environment of gun fired munitions
- Built & tested various types of energy harvesters, several types of designs to be mounted axially and radially for flight tests
    - Piezo-electric based Energy Harvesters
    - Thermophotovoltaic Power Generation for Supersonic Munitions







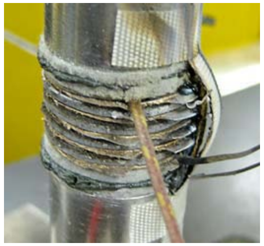


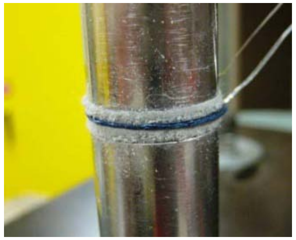
Axial Piezoelectric Harvesters

Thermal Battery Technology

- **Miniature Ignition Systems** *SBIR, Science & Technology Program, Army Commercialization Pilot Program*
  - Develop battery systems with higher energy densities in a smaller volume that meets munitions' performance requirements
  - Increased power source reliability, safety & performance

- **Thin Film Thermal Battery Technology** *SBIR Program*
  - Manufacture geometrically conformal & high performance thermal batteries to provide a more affordable & producible power source also enabling in a higher energy density
- **Nanofoil for Thin Film Thermal Battery** *DoD JFTP Program*
  - Develop a thin film heat source, needed to realize the potential of thin film thermal battery





Liquid Reserve Battery Improvements

Problem:

The liquid reserve battery for the M762A1 electronic time (ET) artillery fuze contains a corrosive, moisture sensitive electrolyte that impacts producibility.

Objective:

As a risk reduction effort, develop a producible and affordable liquid reserve battery for the electronic time (ET) artillery fuze that eliminates the corrosive electrolyte, allows a higher production throughput, maintains performance requirements at low temperature and satisfies a 20 year shelf life.

POC: Karen Amabile, ARDEC Fuze Division

User/Customer: PM-CAS/ PEO-AMMO

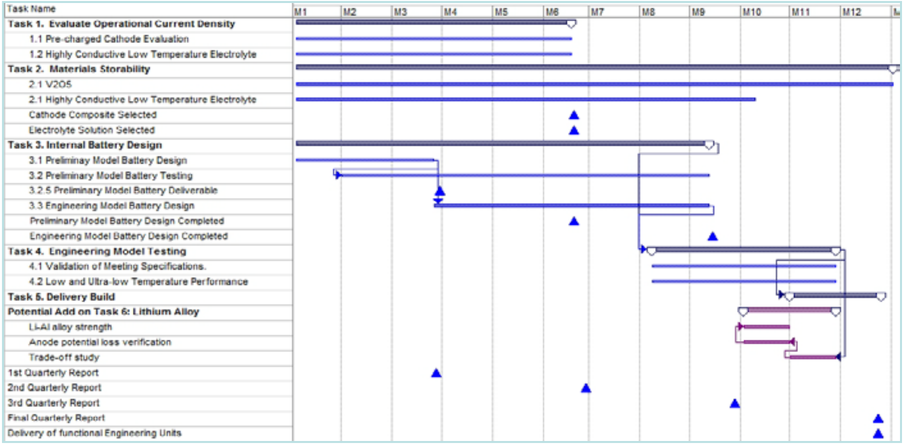
Benefits to the Warfighter:

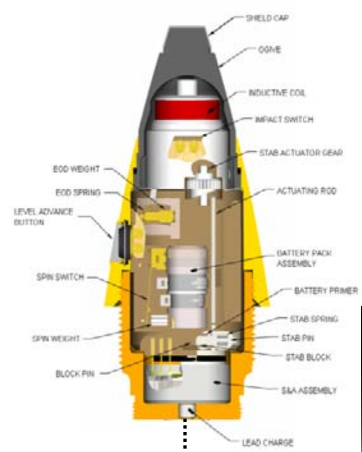
Provides an environmentally friendly and affordable power source for the M762A1 electronic time artillery fuze allowing PEO Ammunition to meet its current production requirements for war reserve quantities as well as future requirements for the M767, M721, M853A1, M816, M819, M930 & M983 mortar rounds.

Tasks (FY10)

- Optimization of baseline cell ($Li/LiBF_4/\gamma$-$BL/DME/V_2O_5$)
- Component stability
- Temperature & performance tests
- Build optimized hardware
- Deliver hardware

FY10 Schedule





XM785

XM784

M762A1 Artillery Fuze

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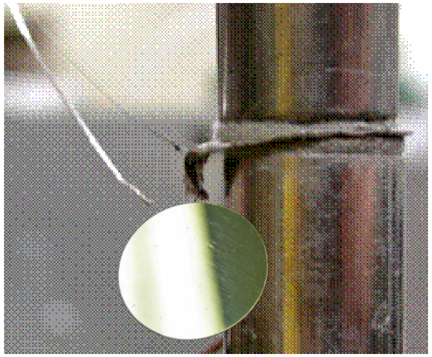
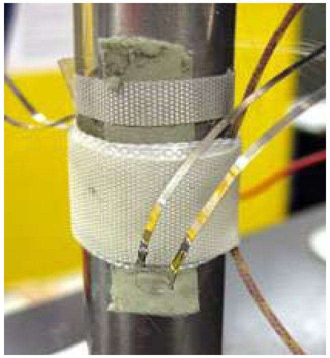
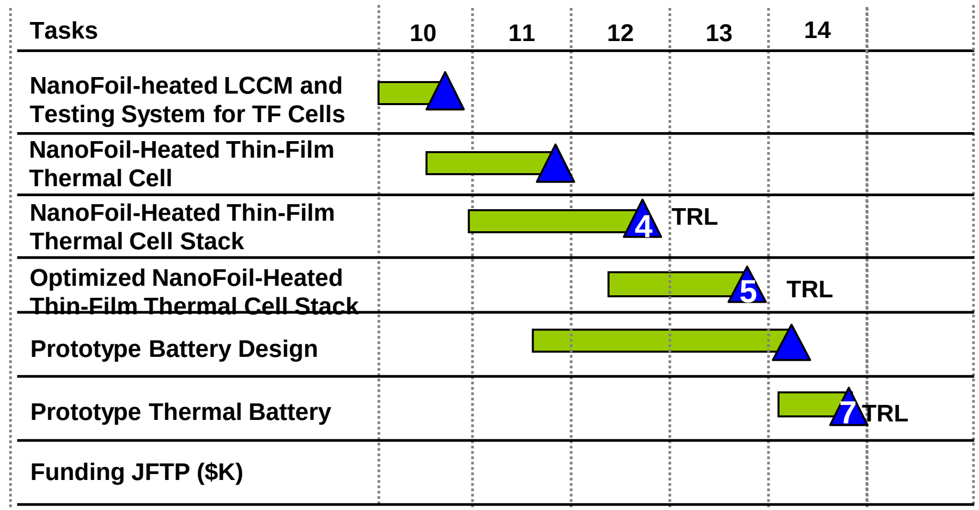
NanoFoil-Heated Thin-Film Battery

A NanoFoil disc for peak temperature test and a NanoFoil-heated pellet-based 4-cell thermal battery stack ready to be initiated and tested

Technology Investment Schedule (FY)



Objective

This project is aimed at producing a prototype NanoFoil-heated thin-film thermal battery made of thin layers of anode, electrolyte, cathode, and heat source components, capable of fast rise, high power and energy, and flexible form factor, and conducive to continuous production.

Current Year Milestones

- *M1: NanoFoil-heated LCCM thermal battery*
- *M2: Test system for thin-film thermal cells and cell stacks*

Technical Approach

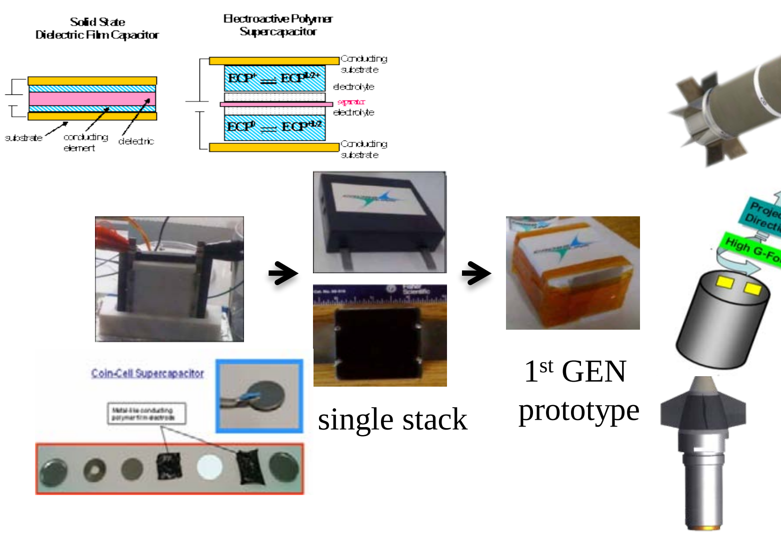
- *NanoFoil will be used as the heat source layer composed of thousands of alternating layers of aluminum and nickel each only a few dozen nanometers thick, made by physical vapor deposition.*
- *Anode, cathode, and electrolyte layers will be produced by commonly available methods such as spray-coating or tape-dipping.*
- *Fast reaction of NanoFoil in combination with the other thin components leading to a fast-rise, high power and energy, and flexible form factor thermal battery.*

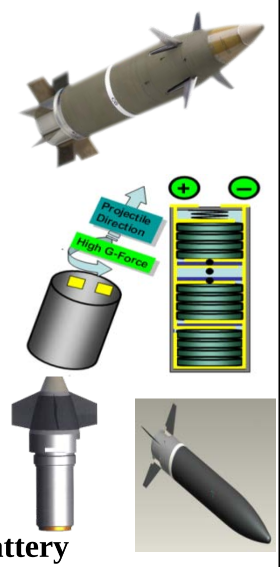
Leveraging and Transition Opportunity

- *Leveraging Sandia National Laboratory's effort on thin-film thermal battery*
- *Leveraging Prior and current ARL-ARDEC efforts on NanoFoil R&D*
- *Leveraging Affordable Precision Components Technology ATO*
- *Potential transition to use in small and medium caliber munitions, artillery and mortar projectiles, rockets, and missiles; the Army's Extended Aerial Protection System; and the Army's PRAXIS; and the Common Smart Sub-munitions Program (CSS)*

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Conductive Polymer-Based Super-Cap





Alternative solution to replace "Data Hold" battery

Customer: Potential customer is PEO-AMMO

- Endorsement by OPM-CAS as of Mar 04, 2010
- Transition potentials:
  - Excalibur, PGK, VAPP(155), STAR(105), APMI, VAPM, and other artillery & mortar rounds
  - potential direct-fired rounds

Leverage:

- DoD-JFTP (6.2 and possible 6.3 follow-on)
- Affordable Precision Component ATO
- Others

Objectives

To advance the development of novel supercapacitor device for fast charging time, function over military temperature range, and high energy/power density needed to extend Army's munitions' capability for current and/or new generation of Munitions and Fuzes.

Challenges

Existing COTS supercapacitor exhibit technological shortfall & gaps :

- Functional over a wide temperature range
- Performance in term of charging time, ESR, energy/power density
- Large scale manufacturing and processing of materials as films for cost effective production
- Extended shelf-life (up to 20 years)

Approaches

- Optimize synthesis of conductive material & film by enhanced functionality of the side chains and dopants.
- Process the conductive polymer systems to create fibers/films that allow highly ordered lamellae and sheet-like structure and enhance performance
- Investigate & develop electrolyte with improved ionic conductivity to satisfy extreme temperature performance and 20 years shelf life
- Mature supercapacitor iteratively throughout R&D cycle

Impacts

- Enhance Warfighter mission flexibility by eliminating the needs to expend the projectile after initialization due to re-usage and effectively infinite operating life of this supercapacitor.
- Ensure availability and technological enabler for alternative, reliable, cost-effective, and common used power source to store mission data
- Potential transition to PM offices for next block upgrade and/or product improvement

APO: Hai-Long Nguyen; 973-724-1543; hailong.nguyen@us.army.mil

Power Sources TCG

- **Power Sources Technical Coordinating Group is a new (2010) DoD/DOE group focused on developing power systems technology to improve munitions and transform national capability through collaborative research**
- **The TCG is implemented to support the Joint Munitions Program (JMP), created by Congress, and managed out of the Office of Land Warfare & Munitions, Office of the Under Secretary of Defense, (Acquisition, Technology and Logistics)**

Questions?