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Energetic Materials to Meet Warfighter Requirements: An Overview of Selected US Army RDECOM-ARDEC Energetic Materials Programs

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Presented by:
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Outline

Selected US Army RDECOM-ARDEC Energetic Materials Programs

- Reactive Materials
- Insensitive Munitions Technology
- High Energy/High Blast Explosives
- Nanocrystalline Energetics & Nano Composites
- Summary
Reactive Material Applications

- Demolition Shaped Charge (BAM-BAM)
- Reactive Fragmentation
- EFP RM
- EM Splat
- Reactive IM Liners (PIMS)
- Active Protection System
- Low collateral damage
- Structural energetic
- KE Rod
- IED defeat
- Chemical agent defeat

**Constant Volume Explosion 3cc/gm**

**Constant Volume Explosion 1cc/gm**
Unitary Demolition Reactive Material Warhead

**Barnie SC Concept “The Rubblizer”**

*High-Rate Dynamic Continuum Modeling*

- Incorporates defeat mechanism of a two stage munition into single unitary warhead concept!
- The most effective unitary demolition warhead currently known!

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Scaled up “Bam-Bam” Warhead

**Roadway Cratering Test**

- 8.5 in
- Bam Bam on test stand
- 24 ft wide roadway
- 5’ X 5’ Target
- Bam Bam Crater!!

**PAM Bridge Pier Target Testing**

- 38” Diameter Crater!
- No Barnie
- Barnie!

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**Barnie SC Concept “The Rubblizer”**

- Incorporates defeat mechanism of a two stage munition into single unitary warhead concept!
- The most effective unitary demolition warhead currently known!
REACTIVE MATERIAL
ENHANCED LETHALITY EFP

Explosively formed long penetrator with follow-thru grenade for enhanced behind target effects.
**IM TECHNOLOGY**

- **IM ATO**
  - Warhead Venting
  - Predictive Technology M&S
  - Gun Propellant

- **PEO AMMO IM Energetics Thrusts**
  - Explosives
  - Gun Propellants
  - Warheads

- **Major Customer Program**
  - 155mm Artillery TNT Replacement
  - 120 mm Mortar Composition B Replacement

- **High Performance Computing Software Applications Portfolio**
  - Insensitive Munitions (IM) Modeling & Simulation (M&S)

- **OSD – IM S&T D-Line Program**

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**Six Threats**

- Fast cook-off (FCO)
- Slow cook-off (SCO)
- Bullet impact (BI)
- Fragment impact (FI)
- Sympathetic detonation (SD)
- Shaped Charge Jet Impact (SCJ)
IM ATO provides technology for reducing the vulnerability and hazard of the Army’s future munition portfolio.
IM Warhead Venting for Cook-off Response Mitigation (Tech Base/PEO Ammunition Leveraging)

ARDEC Tech Base Small-Scale 1” Test (In-House)

PEO IM Venting Large-scale 3” test

Vinnting Thrust

Techbase transfer For PEO Demo

Ignition

Tech base ignition and burn modeling:
Predict and design ignition and required venting calibrated using small scale tests

Pressure Transducer Port
Predictive Technology Description
FI/BI/SD IM Warhead Development

NLOS-LS & MRM Impact Modeling

NLOS-LS & MRM SD Modeling

• BI/FI/SD Modeling Results Provide Design Capabilities to Mitigate Responses
• MRM & NLOS-LS: Being Designed to Pass IM Tests!
PEO AMMO IM Propellant Thrust Evaluation of Non-Nitroglycerin Propellants

<table>
<thead>
<tr>
<th>NG Free Propellant</th>
<th>Description</th>
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| ![NG Free Propellant Image](image1) | • Propellant formulations with NG sensitive to ignition from outside stimuli (Poor IM characteristics)  
• Potential of a basic non-NG propellant formulation that can be tailored through changes to grain geometry to work with a wide range of munitions  
• Feasibility study to test and evaluate non-NG extruded propellants for use in DOD munitions items (medium cal and mortar) |

<table>
<thead>
<tr>
<th>Approach</th>
<th>Warfighter Payoff</th>
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</table>
| • Manufacture various candidates  
• IM screening tests  
• Down-select propellants  
• Granulate verification lots  
  • 500 pound lot each for evaluation in 120mm non-NG main charge propellant and for 30mm MK258  
• Ballistic testing  
• IM Testing | • Elimination of NG from propellant formulations will reduce propellant sensitivity to shock  
• Reduced propellant sensitivity to bullet impact and fragment impact  
• Reduced sensitivity will improve propellants response to slow cook-off |
Low Cost Common IM Explosives Program
PEO AMMO / PM-CAS

- Low Cost TNT IM Replacement
  - 11 candidates tested
  - 3 selected candidates showed significant IM improvements and are low cost
  - All Pass SD in current configuration without barrier
  - Team pursuing insertion into M795 production in FY09

- Low Cost COMP B IM Replacement
  - Program on-going
  - Test vehicle is 120mm mortar
  - Multiple candidates under testing

<table>
<thead>
<tr>
<th>155 mm M795</th>
<th>FCO</th>
<th>SCO</th>
<th>BI</th>
<th>FI</th>
<th>SD</th>
<th>SCJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>TBD</td>
<td>IV</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td>TBD</td>
</tr>
<tr>
<td>B</td>
<td>TBD</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td>TBD</td>
</tr>
<tr>
<td>C</td>
<td>TBD</td>
<td>V</td>
<td>IV</td>
<td>V</td>
<td>III</td>
<td>TBD</td>
</tr>
<tr>
<td>TNT</td>
<td>III</td>
<td>III</td>
<td>III</td>
<td>III</td>
<td>I</td>
<td>TBD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detonation / Partial Detonation</th>
<th>Detonation</th>
<th>Deflagration</th>
<th>Burn</th>
<th>No Sustained Reaction (Unofficial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I / II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
<td>VI</td>
</tr>
</tbody>
</table>

Fragment Impact

SD
High Performance Computing Software Applications Portfolio Insensitive Munitions (IM) Modeling & Simulation (M&S)

- ARDEC leading a Tri-Service proposal with National Lab participation (LLNL, SNL, and LANL).
- Focused on improving the state of the art in DOE developed codes for modeling of bullet and fragment impact on rocket motors and confined energetic warheads.
- A 3 year effort that builds upon the previous CHSSI Multiphase Flow and Target response (MFT) effort and leverages numerous DoD/DOE programs such as prior Joint Munitions Planning (JMP) and Technical Coordination Group (TCG) efforts.

BI on Warheads

Fl on Rocket Motors
**JIMTP Structure**

**TECHNICAL ADVISORY COMMITTEE (TAC)**
Tony Melita, LW&M, Chairman

**Joint IM Technology Program (IM D-Line)**

**Joint DoD/DOE Munitions Program (JMP) MOU**

**PEOs Responsible for IM Strategic Plans**

**Senior Level DOD Managers**

**DOE/NNSA/DP JMP TAC Co-chair: Bharat Agrawal and Senior Level DOE Managers**

**DoD IM IPT JSIMTP**

**JIMTP Manager – Pat Baker**

**OSD Manager – Matt Beyard**

**OSD JMP Technical Advisor**
Paul Butler

**Technology Coordinating Groups**

**Work Done by Govt Labs & Industry**

**MATG 1**

**MATG N**

**TCG 1**

**TCG XIV**

**Technology Coordinating Groups**
Work Done by DOE Labs

**- DoD Leads**

**Munition Area Technology Groups Work Done by Govt Labs & Industry**

**- DoD Leads**
OSD D-Line IM Program
A Joint Service Collaboration & Partnership

IM Melt-Cast Explosives

- New IM Melt-Cast explosive compounds
- Synthesize compounds of interest and evaluate safety, toxicity, compatibility & performance at small scale

Measurement of Detonation Velocity

Mortar

155 mm Artillery
OSD D-Line IM Program
A Joint Service Collaboration & Partnership

Development of Halogenated Wax Binder Systems for High Power Explosives

• Press loaded explosive formulations competitive with or exceeding the performance of top explosives (e.g. LX-14), while gaining insensitivity sufficient to achieve IM requirements

• Chlorinated binder systems have shown improvement in IM properties and have helped maintain performance

• BI Test resulted in Type V Reaction - Burn
• LX-14 resulted in Type IV Reaction - Deflagration
High Energy / High Blast Explosives

- High Blast
  - PAX-3 transitioned to BDM and demonstrated in LOS-MP
  - Excellent IM Properties

- High Impulse
  - Several Thermobaric type formulations tested and characterized in coordination with ARL TBX test program and DTRA Test Program

- Combined Effects Explosives - High Energy/High Blast
  - PAX-30
  - PAX-42
Explosive Formulation Development

1987
- PAX-2, 80% HMX IM (25mm)
- PAX-2A, 85% HMX IM (M915, M982, MLRS – Grenade Submunitions)
- PAX-3, HMX/Alum. IM (PAM TC’ed FY99)
- PAX-11, 94% CL-20
- PAX-22, 92% CL-20
- PAX-23, (AX-1) Future Armor Tile for Abrams Tank Systems TC FY99
- PAX-24, TNT Replacement
- PAX-21, Comp B IM Replacement (60mm mortar)
- PAX-12, 90% CL-20 IM (PM SWMO, LSO Warheads)
- PAX-1, 94% CL-20
- PAX-AFX-196 (155MM M107, M795)
- PAX-28, Aluminized Cast (Unitary)
- PAX-31, Improved Comp B Repl (120mm Mortar)
- PAX-41 (SPIDER)

2000
- PAX-XX, (FCS MP-MRM, JCM)

2006
- PAX-2000
PAX 3 Tested in LOS-MP and BDM

- Warhead design and process
  - PAX 3 has excellent loading and machining characteristics
- Integrated PAX 3 warhead fired from M256 gun system at 30,000 g’s
- PAX 3 will not detonate as warhead passes through targets
- PAX 3 warhead performance on target meets exit criteria for LOS-MP ATO
- PAX 3 transitioned to BDM
Twin Screw Extrusion of PAX-3

IN-HOUSE Production Capability “A GO”
High Energy Coupled with High Blast
Increased Blast / Maintained Energy for Combined-Effects Warhead

<table>
<thead>
<tr>
<th>HE</th>
<th>Cost of Explosive Fill ($)/lb.</th>
<th>Metal Pushing/Unit Volume (Experimental)</th>
<th>Blast (Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LX-14 (HMX)</td>
<td>18</td>
<td>0 (Baseline)</td>
<td>0 (Baseline)</td>
</tr>
<tr>
<td>PAX-29c (CL-20)</td>
<td>600</td>
<td>17 %</td>
<td>43 %</td>
</tr>
<tr>
<td>PAX-29n (CL-20)</td>
<td>600</td>
<td>17 %</td>
<td>38 %</td>
</tr>
<tr>
<td>PAX-3 (HMX)</td>
<td>18</td>
<td>-28 %</td>
<td>32 %</td>
</tr>
<tr>
<td>PAX-30 (HMX)</td>
<td>18</td>
<td>6 %</td>
<td>30 %</td>
</tr>
<tr>
<td>PAX-42 (RDX)</td>
<td>7</td>
<td>3 %</td>
<td>24 %</td>
</tr>
</tbody>
</table>

- PAX-30 and PAX-42 maintain metal pushing energy of LX-14 but substantially exceed blast with 18.5% less explosive fill
- Excellent candidates for multi-purpose warhead!
- Excellent Reduced Shock Sensitivity
- Most cost effective
PAX-30 Provides both blast and high penetration

PAX-30 penetration ~10% better than current production with LX-14 in Javelin

‘Stonehenge’ Impulse Test Setup

PAX-30 vs. LX-14 Blast Output

PAX-30 blast outperformed LX-14 in the MRM configuration.
High Blast/Anti-Armor Warheads for Shoulder Fired Munitions

Reduced Solder Burden

CURRENT SOLUTION
1 ARMOR WEAPON
1 BUNKER WEAPON

ONGOING WORK
1 WEAPON FOR ARMOR,
& BUNKER TARGETS

Blast effect for bunker defeat

Jet penetration for armor defeat
**Novel Energetic Materials ATO – Advanced Gun Propellants**

High performance & insensitive propellants
- ETPE layered propellants
- BDNPN, NTO propellants
- High nitrogen propellants

**Enhanced gun performance**
- Tailorable burning rates
- Increased charge weight
- Increased energy density
- Controlled pressurization

**Reduced barrel erosivity**
- Reduced flame T
- Less erosive propellant combustion products

**Reduced sensitivity/vulnerability**
Synthesis Program Target Compounds

High Density High Energy Compounds

ATNI - Amino Trinitroimidazole
Cal. Density 1.92 g/cc
Performance 10% better than HMX and Insensitive due to hydrogen bonding

NATN – Nitramino Trinitroimidazole
Cal. Density 1.96 g/cc
Insensitive due to hydrogen bonding

Insensitive Melt-Cast Materials

DNP - Dinitropyrazole
Density 1.76 g/cc; Performance better than Comp.B Melt cast

MTNI - MethylTrinitroimidazole
Density, 1.79
Detonation velocity better than Comp. B, Melt cast and insensitive

High Energy High Nitrogen Compounds

TTIT - Tris(Trinitroimidazole) Triazine
Cal. Density 2.06 g/cc
Performance 20% better than HMX
Nano-materials / Nano-energetics

On-going Efforts

- Counter Measures
- Igniters
- Green LEI Primers
- Reactive Tungsten Penetrator
- Primers
- Illum Candles
- Dual Use Composites
- Formulation of New Reactive Materials
- Material Fab & Characterization
- MEMs S&A Designs
Production of Nano RDX by RESS

RESS Set-up

- Solvent: Carbon Dioxide
- Saturation P\T: 350 bar\85 °C
- Expansion Pressure: 1 – 60 bar

Current Process Capabilities

- Precise Particle Size Control: 100–500nm
- Production Capacity: 10-12 g/hour
- Continuous Operation: > 10 hours
- Contained Operation with Full Recycle of Solvent (CO₂)

Sensitivity Testing

Impact Test
150 nm RDX Pellet: H₅₀ – 41 cm
150 nm RDX Powder: H₅₀ - >100 cm
Holston C-5 RDX Powder: H₅₀ – 23 cm

Small Scale Gap Test
500 nm RDX in 88/12 wax formulation: Gap₅₀ - 32 kbar
4.8 micron RDX in 88/12 wax formulation: Gap₅₀ - 21 kbar
Nanocomposite Synthesis and Production

- Tunable super-thermites
- Multiple uses, safe to handle

**Burn Rate of Various Materials**

<table>
<thead>
<tr>
<th>Oxidizer Type</th>
<th>Burn Rate (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten Oxide Particles</td>
<td>51</td>
</tr>
<tr>
<td>Molybdenum Oxide Particles</td>
<td>140</td>
</tr>
<tr>
<td>Bismuth Oxide Particles</td>
<td>350</td>
</tr>
<tr>
<td>CuO Nanoparticles</td>
<td>700</td>
</tr>
<tr>
<td>CuO Nanorods</td>
<td>1500</td>
</tr>
<tr>
<td>CuO Nanorods w/ assembly</td>
<td>2200</td>
</tr>
<tr>
<td>CuO Nanowells</td>
<td>2300</td>
</tr>
</tbody>
</table>

**Coated Nanoparticles**

**Patterned Energetics**

**Ordered Energetic Composites**

**Microencapsulation**
Summary

- Army RDECOM-ARDEC Energetic Materials Program focused on meeting goals for transition to Army and Joint Service applications to meet Warfighter needs.
- Reactive materials demonstrated in demolition warheads and as IM liners.
- Actively developing IM Technology for PEO IM Priority Munitions with emphasis on M&S and Partnering in OSD IM S&T D-Line.
- High energy / High blast explosives demonstrated
- Novel Nanocrystalline and Nanocomposite Energetics applications being investigated.