Common Low-cost Explosive Insensitive Munitions Program
Phase 2: Explosive Replacement for Comp B

2009 Insensitive Munitions and Energetic Materials Technology Symposium
May 12, 2009
Philip Samuels
PM-CAS/US Army ARDEC
Philip.samuels@us.army.mil

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.
• Baseline Explosive Fills
  – TNT (Melt-pour)
    • Baseline for all 105/155mm Artillery
  – Comp-B (Melt-pour)
    • Baseline for all 60/81/120mm Mortar
      – Also allowed for Artillery’s 105mm M1 and 155mm M107

• Efforts Prior to FY07 for IM Explosive Fills
  – 60mm Mortar
    • PAX-21 (Melt-pour) --- Type-Classified & Fielded
  – 81mm Mortar
    • T.B.D. --- leveraging 60mm & 120mm Mortar efforts
  – 120mm Mortar
    • HBU-88B (Cast-cure) --- Type-Classified
  – 105mm Artillery
    • T.B.D. --- no active program
  – 155mm Artillery
    • PAX-196 (Melt-pour)
• IMX-101 passed all Engineering IM Tests in the 155mm M795 Artillery Projectile  
  – Met TNT lethality in M795

• IMX-101 was loaded in the 120mm M934A1 Mortar for IM and Lethality testing as part of the Common Fill evaluation  
  – Performance tests proved that IMX-101 does not have enough energy to compete with Comp B in the 120mm Mortar
Common Low-cost IM Explosive Program

- New IM Explosive for Artillery and Mortar applications that are:
  - Effective
    - Maintain Lethality with minimal or no degradation
  - Less Sensitive
    - If not fully compliant, must show improvement over Baseline explosive
  - Affordable
    - Artillery Cost Drivers = Steel Body Material & Explosive Fill
    - Mortar Cost Drivers = Steel Body Material, Fuze & Propelling Charges
  - Producible within the National Technology and Industrial Base (NTIB)
    - Infrastructure
    - Raw Ingredients
    - Explosive formulation
    - Projectile Load, Assemble & Pack (LAP)
  - Other Considerations
    - Intellectual Property Rights
    - Demilitarization
    - Environmental

Program initiated in FY07

Primary Objective is to provide a Common IM Fill — or —

one common TNT replacement (Artillery)...

...and one common Comp-B replacement (Mortars)
### IM Test Results

**Mortar Baseline**

<table>
<thead>
<tr>
<th>IM Test:</th>
<th>FCO</th>
<th>SCO</th>
<th>BI</th>
<th>FI</th>
<th>SD</th>
<th>SCJI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passing Criteria</strong></td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td>III</td>
</tr>
<tr>
<td><strong>60mm (Comp-B/PAX-21)</strong></td>
<td>II</td>
<td>V**</td>
<td>III</td>
<td>II**</td>
<td>V</td>
<td>III*</td>
</tr>
<tr>
<td><strong>81mm (Comp-B)</strong></td>
<td>(II)*</td>
<td>(II)*</td>
<td>(III)*</td>
<td>(III)*</td>
<td>(I)*</td>
<td>(I)*</td>
</tr>
<tr>
<td><strong>120mm (Comp-B)</strong></td>
<td>II</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>(I)*</td>
</tr>
</tbody>
</table>

**Reactions:**
- **VI**: No Sustained Reaction
- **V**: Burn
- **IV**: Deflagration
- **III**: Explosion
- **II**: Partial Detonation
- **I**: Detonation

**60mm**
- HF1 Steel w/ PAX-21
- 0.8 lb Explosive Fill
  - [Comp-B: free]
  - [PAX-21: ~$15/lb]

**81mm**
- Steel Body
- HF1 Steel w/ “A1”
- 2.0 lb Explosive Fill
  - [Comp-B: free]

**120mm**
- Steel Body
- 6.6 lb Explosive Fill
  - [Comp-B: free]

**Notes:**
- **( )** Assessment – not tested
- **( )** with PAX-21 and Intumescent Coating

---

**Technology Driven. Warfighter Focused.**
Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---

Common Low-cost IM Explosive Program

- “Funnel” framework to progressively screen candidates

**Filter 1 -- Safety & Performance**
- Pass / Fail

**Filter 2 -- In sensitive Munitions**
- Must Show Improvement

**Business Case Analysis (BCA)**
- Utility
- Life-cycle Costs
- Risk Analysis

**IM Explosive Fill**
for 120mm and/or 155mm

**Filter 1 Criteria**
- Cheetah Calculations
- Standard Safety Tests
- Electrostatic
- Friction Impact Sensitivity
- Vacuum Thermal Stability
- Differential scanning
- Critical Diameter

**Filter 2 Criteria**
- Tier 1 IM Tests (BI, FI, SCO, SD)
- Tier 2 IM Tests (FCO, SCJI)

**BCA Criteria**
- IM Tests, Lethality, Logistics, Safety, Platform
- Performance of the alternatives against weighted factors
- Risk analysis
- Comparable cost analysis
- Sensitivity Analysis

**Arena Test & Qualification**

---
Sources:

- Historical / Government / Industry / Foreign
- QFD conducted by ARDEC
- PEO-AMMO IM Thrust Programs
- Navy and Air Force Explosives
- Industry efforts
- Phase I CLIMEX Program
Candidate Explosive Fills

– Melt-pour
  • Traditional Ingredients
    – RDX
    – HMX
  • Less Sensitive Explosive Filler
    – NTO
    – NQ
  • Less Sensitive Energetic binder
    – DNAN
    – Nitrate Salts
  • Reduced Nitramines (Aluminized)

– Cast-cure
  • Inert binder
    – RDX
    – IRDX
    – Rounded RDX

– Press-fill
  • Inert binder with RDX (Redesign of metal parts – Not Evaluated)
IM Test Matrix

Tier I Testing

1st test Type I, II, III

STOP

BI

1st test Type I, II, III

STOP

FI

1st test Type I, II, III

STOP

SCO

Type IV, V

Detonation Calibration

Type IV, V

SD w/o barrier

1st test Type I, II

STOP

Data Evaluation

Type III, IV, V

Tier II Testing

SCJI

FCO

Protocol Considerations:
- Cost of Test
- Ease of Setup
- Threats for Comparison to Baseline
- Reaction Level for proceeding
Test Configuration

- IM Test Configuration for Comp-B Replacement (Mortars)
  - 120mm established as test vehicle
    - M934A1 Mortar Round with Standard Steel
    - No container for FI, BI, SCO
    - M734A1 MOFM Live Fuze
      - Reduced-thread Steel Fuze Adapter
      - PBXW-14 Booster Pellet to initiate IM fills
    - Replace CH6 Booster Pellet with PBXW-14 (if necessary)
  - Palletization configuration for SD
    - 2 rounds per PA154 Metal Container
    - One Round Up, One Round Down in Fiber Tubes
    - Wood (6 x 8)
Bullet Impact Test

MIL-STD-2105C / 7.62mm AP Bullet / Witness Plate & Pressure Gage

Results varied from Type III to Type V
Fragment Impact Test

MIL-STD-2105C / 6,000 ft/s Fragment / Witness Plate & Pressure Gage

Results varied from Type IV to Type V.
Slow Cook-off Test

MIL-STD-2105C / 50F/hr / Precondition 145F / Witness Plate & Pressure Gage

Results varied from Type I to Type V
Sympathetic Detonation Test

MIL-STD-2105C, PA154 Configuration, Witness Plate & Pressure Gages

PA154 w/o Barrier

Results varied from Type I to Type III
IM Test Results

<table>
<thead>
<tr>
<th>IM Test:</th>
<th>FCO</th>
<th>SCO</th>
<th>BI</th>
<th>FI</th>
<th>SD</th>
<th>SCJI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing Criteria</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td>III</td>
</tr>
<tr>
<td>120mm Baseline (Comp B)</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>(I)*</td>
<td>(I)*</td>
</tr>
<tr>
<td>HBU88B (Cast-Cure)</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>III</td>
<td>I</td>
</tr>
<tr>
<td>IMX-104 (Melt Cast)</td>
<td>V</td>
<td>IV</td>
<td>V</td>
<td>V</td>
<td>III</td>
<td></td>
</tr>
</tbody>
</table>

- Engineering IM Tests in the M934A1 120mm Mortar with IMX-104 show vast improvement over baseline Comp B
Fragmentation Analysis

ARL Water Pit Test

– Static detonation of M934A1 Mortars loaded with IM formulations and Comp B Baseline
– Soft Recovery of Fragments
– Fragmentation Analysis

IMX-104 fill meets Comp B fragmentation performance
Summary

- IMX-104 down-selected as best candidate based on IM, Lethality, Life Cycle Cost, and Production Readiness

- IMX-104 qualification:
  - 81mm M821A2 Mortar for FY11
  - 60mm & 120mm Mortars in FY12