Development and Fielding of the Excalibur XM982 Warhead

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Excalibur Team

- Prime Contractor: Raytheon
- BAE Systems Bofors
- GD-OTS
- PM-CAS
XM982 Excalibur

GPS-Guided, Precision Long-Range Artillery Projectile

• Accuracy of Less Than 10M CEP
• Minimizes Collateral Damage
• Employment Flexibility
  - Danger Close
  - Restrictive Environment
  - Limits House Clearing
  - Off-Axis Capable Maneuvering Airframe
• High Impact Angle
  - Ideal For Urban Terrain
  - Optimal Effects
• Increased Effects With Fewer Rounds
• Responsive & Available to the Close-Combat Soldiers/Marines

M109A6 Paladin
  • US Army

M777A2 LW155
  • US Army
  • USMC

Archer

Excalibur is Transforming Cannon Artillery on the Battlefield Today
**Precision Cannon Munition Capability**

**System Description**
- Precision guided, extended range 155mm High Explosive cannon ammunition
- All weather, day/night, fire & forget capability, optimized for urban/complex terrain
- GPS-Inertial Navigation System guidance w/anti-jam technology
- <10 meter CEP Accuracy at all Ranges
- Lethality comparable to M107 HE
- Allows for destruction of high-payoff targets in urban and complex terrain
- Minimizes collateral damage; reduces risk to friendly forces in the close fight
- Responsive; organic to UA & Stryker BCT
- All weather capability
- Fully autonomous; no laser required

**Value to Warfighter**
- Allows for destruction of high-payoff targets in urban and complex terrain
- Minimizes collateral damage; reduces risk to friendly forces in the close fight
- Responsive; organic to UA & Stryker BCT
- All weather capability
- Fully autonomous; no laser required

**Concept**
- Precision Delivery Regardless of Range
- Limits Collateral Damage
- Decreases Volume of Fire Per Engagement
- Enhances Soldier Survivability

**Block Ia-1: Early Fielding**

<table>
<thead>
<tr>
<th>User’s Minimum Capability</th>
<th>Expected Performance</th>
<th>Block Ia-2 Threshold</th>
<th>Block Ia-2 Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy (CEP)</strong></td>
<td>= 20 Meter</td>
<td>= 6 Meter</td>
<td>= 20 Meter</td>
</tr>
<tr>
<td><strong>Effectiveness</strong></td>
<td>= M107 HE</td>
<td>= M107 HE</td>
<td>= M107 HE</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>= 60%</td>
<td>= 74%</td>
<td>= 85%</td>
</tr>
<tr>
<td><strong>Interoperability</strong></td>
<td>All critical top level IERs</td>
<td>All critical top level IERs</td>
<td>All critical top level IERs</td>
</tr>
<tr>
<td>Range</td>
<td>= 24 km</td>
<td>= 24 km</td>
<td>= 30 km</td>
</tr>
<tr>
<td>Concrete Penetration</td>
<td>4”</td>
<td>4”</td>
<td>4”</td>
</tr>
<tr>
<td><strong>Anti-Jam</strong></td>
<td>No</td>
<td>Yes</td>
<td>= 30 Meter</td>
</tr>
</tbody>
</table>

* Key Performance Parameter
** Block Ia-1 Configuration will have Anti-Jam electronics, but will only have limited testing prior to Fielding
Major Components & Functions

- Canard Actuation System - CAS
- Internal Fuze Safe & Arm
- Unitary Warhead
- Spinning Base
- Base Bleed
- GPS Receiver
- Inertial Measurement Unit – IMU
- Height of Burst, Point Detonating & Delay Sensors
- GPS SAASM (Selective Availability-Anti Spoofing Module)
- GPS Antennas
- System & Data Hold Batteries
- EPIAFS - Enhanced Portable Inductive Artillery Fuze Setter
Effectiveness Against Unitary Targets

Infantry Platoon
M549: 25 rounds
M107: 43 rounds
Excalibur: 3 rounds

Command Post
M549: 54 rounds
M107: 78 rounds
Excalibur: 6 rounds

Radar
M549: 10 rounds
M107: 11 rounds
Excalibur: 1 round

Structures
M549: 147 rounds
M107: 110 rounds
Excalibur: 3 rounds

Excalibur is used in a complex target environment!
# Gun Compatibility and Range with Base Bleed

<table>
<thead>
<tr>
<th>Current US 39-caliber systems (M777, M109A6, M198)</th>
<th>40km</th>
<th>MACS-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLOS-C US Army</td>
<td>&gt;36km</td>
<td>MACS-4</td>
</tr>
<tr>
<td>FH77BD* Swedish Army</td>
<td>50km</td>
<td>Swedish Uni-Flex Charge</td>
</tr>
<tr>
<td>* 52 Caliber Howitzers Will Achieve the 50km Range</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**M777 Joint Light Weight Howitzer (LW155)**

**FH77BD “Archer” Howitzer**

**M109A6 Paladin Howitzer and M992A2 FAASV**

**M198 Towed Howitzer**

**Non-Line-of-Sight Cannon (NLOS-C)**
Design Challenges

- Strict IM requirements
- Gun Hardening
- Concrete Penetration
- Evolving Requirements (System Level Trades)
- Long Storage Life
Warhead Development

- SDD Program
  - Trade Studies
    - Explosive Material (Gun Safety, Reliability, IM, and Lethality)
    - Protection of Fuze (Gun Launch and Penetration)
    - IM Liner and Vent Material Study
  - Analysis
    - Finite Element Analysis
    - Hydrocode (Concrete Penetration, BI, FI, and SD)
    - Weapon Effectiveness
  - Testing
    -Insensitive Munitions
    - JMEM Arena Testing
    - Concrete Penetration Testing
    - Proof Load Gun Testing
    - Environmental Testing

- Early Fielding to Fulfill Need for Precision Fire Support (Approx. 800 Warheads Delivered)
Warhead Overview

IM Liner

Booster Cup

Fuzewell

Fuze Liner

Damping Material

Front Retainer

Fuze Retainer Plate

Spin Sensor Cavity

Spacer

IM Vents

Main Charge Explosive (PBXN-9)

Booster (PBXN-9)
Modeling & Simulation
Target Penetration

Correlation of Modeling & Test Results
Impact velocity = 328 m/s (1,076 ft/s)
Angle of obliquity = 0 deg
Angle of attack = 0 deg
Concrete Comp. strength = 4,200 psi
Exit Velocity (Simulation) = 278 m/s
Exit Velocity (Test) = 276 m/s
Modeling & Simulation
Sympathetic Detonation

Prediction: No Detonation of Acceptors
Test Results: Type III (Explosion)

OTI*HULL Hydrocode Results

Sympathetic Detonation Test
# XM982 Warhead Performance

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Requirement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental: Gun Launch</td>
<td>PMP + 5%</td>
<td>Meets Requirements</td>
</tr>
<tr>
<td>Environmental: Hot Gun</td>
<td>Functional After Exposure</td>
<td>Meets Requirements</td>
</tr>
<tr>
<td>Environmental: Life Cycle</td>
<td>20 years</td>
<td>Meets Requirements</td>
</tr>
<tr>
<td>IM: Bullet Impact</td>
<td>$\leq$ Type V</td>
<td>Type V</td>
</tr>
<tr>
<td>IM: Fast Cook-Off</td>
<td>$\leq$ Type V</td>
<td>Type V</td>
</tr>
<tr>
<td>IM: Fragment Impact</td>
<td>$\leq$ Type V</td>
<td>Type V</td>
</tr>
<tr>
<td>IM: Slow Cook-Off</td>
<td>$\leq$ Type V (Objective)</td>
<td>Type III</td>
</tr>
<tr>
<td>IM: Slow Cook-Off</td>
<td>$\leq$ Type II (Threshold)</td>
<td>Type III</td>
</tr>
<tr>
<td>Performance: Lethality</td>
<td>Personnel, Command Post, Air Defense Radar</td>
<td>Meets Requirements</td>
</tr>
<tr>
<td>Performance: Penetration</td>
<td>8&quot; Reinforced Concrete</td>
<td>Exceeds Requirements</td>
</tr>
<tr>
<td>Reliability: Initial</td>
<td>$\geq$ 0.9991</td>
<td>0.9998</td>
</tr>
<tr>
<td>Reliability: Long Term</td>
<td>$\geq$ 0.9990</td>
<td>0.9993</td>
</tr>
</tbody>
</table>
Performance Test Results

Static JMEM Arena Test

Full Scale Penetration Test (Target Exit)

Live Fire Test

Lethality Objectives Achieved
Insensitive Munitions Testing

- Fast Cook-Off Test
- FCO Test (Type V Reaction)
- Bullet Impact Test (Type V Reaction)
- SC0 Test (Type III)
- SD Test (Type III)
- Fl Test (Type V Reaction)
Acknowledgements

- Raytheon Missile Systems
  ↗ Larry Wasielewski
- BAE Systems Bofors
  ↗ Pär Eriksson