42nd Annual Armament Systems: Gun and Missile Systems
Conference & Exhibition

"Meeting Warfighter Needs for the Asymmetric Threat"

23-26 April 2007

Charlotte, North Carolina

Agenda

Tuesday, April 24, 2007

Government Keynote Speaker
MG David Ralston, USA, Commanding General, US Army Field Artillery Center and Fort Sill Commandant, US Army Field Artillery School

* BG Mike Cannon, USA, Program Executive Office for Missiles and Space
* COL Mark Rider, USA, Project Manager for Maneuver Ammunition Systems

Breakout 1 - Effectiveness
* Capabilities of Penetrator with Enhanced Lateral Efficiency (PELE) Medium Caliber Cartridge Versus KE or HE Rounds, Mr. Don Gloude, ATK
* Urban Operation Solutions with Medium & Large Caliber Ammunition, Mr. Jan Hasslid, Nammo

Breakout 1 - Energetics
* ECL - A New Propellant Family for Small and Medium Caliber Applications, Mr. William Worrell, ATK
* Qualification Test Results for the EFSS 120mm Rifled Mortar System, Mr. Joe Buzzett, GD-OTS
* Processing and Sensitivity Testing of theInsensitive TNT Based Explosive - PAX-44, Mr. Duncan Langlois, ATK
* Medium Caliber Lead Free Electric Primer, Ms. Sarah Ford, NAWCWD, China Lake
* Development of Exploding Foil Initiators and Microchip EFI's, Mr. Gert Scholtes, TNO, Netherlands

Breakout 2 - Emerging Technology
* Low Recoil, Heat Transfer Mitigating Rarefaction Wave Gun Engineering, Modeling and Large Caliber System Demonstrator Development, Mr. Kevin Miner, Benet Labs
* Rapid Fire Testing of Advanced Gun Barrel Bore Coatings, Mr. William Vezina, BAE Systems
* T&E of Electromagnetic Railguns, CDR Thomas Boucher, USN, NSWC Dahlgren

Breakout 2 - Direct Fire: EAPS Overview
* Extended Area Protection and Survivability (EAPS), Mr. Phil Brislin, US Army, ARDEC
* Phalanx for Defense Against Rockets, Artillery and Mortar Protection System, Mr. Scott Martin, Raytheon Missile Systems
* Counter Rocket Artillery and Mortar Protection System, Mr. Borje Nyquist, BAE Systems, Sweden

Breakout 2 - Indirect Fire
* Enhanced Lethality with the 105mm XM1025 Performed Fragment Projectile, Mr. George Kurzik, GD-OTS
* 120mm XM325 Mortar, Mr. David Smith, Benet Labs
* 155mm XM324 for NLOS Cannon, Mr. Christopher Aiello, Benet Labs
* 155mm XM1063 Non-Lethal Personnel Suppression Projectile, Ms. Jennifer McCormick, GD-OTS

Wednesday, April 25, 2007
Keynote Speaker  
Mr. David Clagett, Senior Program Analyst, Joint Rapid Acquisition Cell (JRAC), Office of the Under Secretary of Defense (USD), Acquisition, Technology and Logistics (AT&L)

Requirements & Program Trends Session, Mr. Dave Broden, Broden Resource Solutions, LLC & Mr. Bob Glantz, ATK

US Army ARDEC Update, Mr. Antony Sebasto, US Army, ARDEC

Breakout 1 - Armament Subsystems
- M197 Environmental Kit, Mr. Robert Brewer, NAWCWD, China Lake
- M61 Handoff Improvements, Mr. John Fletcher, III, GDATP
- Ultrasonic Temperature and Heat Flux Sensor Technology, Mr. Mark Mutton, Industrial Measurement Systems
- Extended Area Protection & Survivability (EAPS) Gun and Ammunition Design Trade Study, Mr. Daniel Ericson, ASIC

Breakout 1 - Modeling and Simulation
- System Modeling of a 40mm Automatic Grenade Launcher, Dr. Daniel Corriveau, Defense R&D Canada
- A Quest for Practical Design for Six Sigma (DFSS) Tools - PGMM Case Study, Mr. James Kalberer, ATK
- Advanced Engineering Design Modeling and Simulation as a Management Tool, Mr. Steve Liss, US Army, ARDEC

Breakout 2 - Tactical Rockets and Missiles
- Hazard Assessment Testing of the SM-3 Block IA Missile, Mr. Dave Houchins, NSWC Dahlgren
- PRODAS Rocket Artillery in Future Scenarios, First Answer, Dipl. Ing. Harald Wich, Diehl
- The Success of the AMRAAM DBMS/DAS, Mr. John Gerdine, V, Wyle Laboratories

Breakout 2 - Precision Weapons
- 120mm Mid-Range Munition (MRM) Science & Technology Efforts, Mr. Robert Nodarse, US Army, ARDEC
- MRM-KE: A Lethal Solution, Mr. Eric Volkmann, ATK
- 20mm Life Cycle Tests, Mr. Robert Brewer, NAWCWD, China Lake
- Recent Developments in Affordable Laser Guided Precision Weapon Capabilities, Mr. James Franciscovich, BAE Systems
- Trade Space on Appropriate Caliber Ammunition for Terminal Defense Guided Projectile, Mr. Chris Geswender, Raytheon Company

Thursday, April 26, 2007

Breakout 1 - Modeling and Simulation
- Modular Charge Ignition Modeling, Mr. Clive Woodley, QinetiQ, Ltd.

Breakout 2 - Direct Fire
- 120mm Line-of-Sight Multi-Purpose (LOS-MP) Munition Science & Technology Efforts, Mr. Jesse Sunderland, US Army, ARDEC
- Development of the M1040, 105mm Anti-Personnel Round, Mr. Stephen Ginnetto, US Army, ARDEC
- APAM MP-T 120mm XM329 Development Status, Mr. Danny Schirding, Israel Military Industries
- GD-OTS 20mmx120mm Mechanically Fuzed Projectile Program, Mr. Zach Kemp, GD-OTS
- The ATK Air Burst Munitions Program, Mr. Larry Mason, ATK
- 30mm MK46 MOD1 Gun Weapon System (GWS) At-Sea Evaluation, Mr. Andrew Green, NSWC Dahlgren
- M789 LW 30mm HEDP Cartridge In-Bore Detonation Investigation, Mr. John Hirlinger, US Army, ARDEC

Armament Division Overview, Mr. Dave Broden, Broden Resource Solutions, LLC

Telepresent Rapid Aiming Platform (TRAP) - Spiral Development of a Lightweight Remote Weapon System and Integration into a Mobile Sensor-Shooter Network, Mr. Brian McConnell, NSWC Dahlgren

F-22A Lightweight Gun System Comparison, Mr. Peter Wolff, GDATP

Integration of a Remotely Operated, Breach Loaded 120mm Mortar Platform, Mr. Thomas DeVoe, US Army, ARDEC

Shock Aspects of Lightweight Artillery on Mounting Electronics, Mr. William Zepp, US Army, ARDEC
42nd Annual Armament Systems: Gun and Missile Systems Conference & Exhibition

Conference Brochure

“Meeting Warfighter Needs for the Asymmetric Threat”

April 23-26, 2007 Charlotte, NC
Event # 7590

NDIA National Defense Industrial Association
Strength Through Industry & Technology
Monday, April 23, 2007

11:00 am - 6:30 pm
Registration and Exhibit Set-up

5:00 pm - 6:30 pm
Networking Reception in Exhibit Hall

Tuesday, April 24, 2007

7:00 am - 6:30 pm
Registration

7:00 am
Continental Breakfast

8:00 am
Welcome and Introductory Comments
Mr. Sam Campagna, Director, Operations, NDIA
Mr. Mike Till, Head, Gun Systems & Light Weapons Division (G30), NSWC Dahlgren

8:15 am
Industry Keynote Speaker
Mr. Mike O’Brien, Vice President & General Manager, GDATP Gun Systems Strategic Business Unit

8:40 am
Government Keynote Speaker
MG David Ralston, USA, Commanding General, US Army Field Artillery Center and Fort Sill Commandant, US Army Field Artillery School

9:10 am
BG Mike Cannon, USA, Program Executive Office for Missiles and Space

9:35 am
COL Mark Rider, USA, Project Manager for Maneuver Ammunition Systems

9:55 am
Break in Exhibit Hall

10:30 am - 11:25 am
Breakout 1 Breakout 2

Effectiveness
Session Chair:
Mr. Steve French, BAE Systems

Capabilities of Penetrator with Enhanced Lateral Efficiency (PELE) Medium Caliber Cartridge Versus KE or HE Rounds
Mr. Don Gloude, ATK

Urban Operation Solutions with Medium & Large Caliber Ammunition
Mr. Jan Hasslid, Nammo

Emerging Technology
Session Chairs:
Mr. Steve Liss, US Army, ARDEC
Mr. Joe Buzzet, General Dynamics Corporation

Low Recoil, Heat Transfer Mitigating Rarefaction Wave Gun Engineering, Modeling and Large Caliber System Demonstrator Development
Mr. Kevin Miner, Benet Labs

Rapid Fire Testing of Advanced Gun Barrel Bore Coatings
Mr. William Vezina, BAE Systems

Mid Range Munition (MRM)

T&E of Electromagnetic Railguns
CDR Thomas Boucher, USN, NSWC Dahlgren

12:15 pm Lunch in Exhibit Hall Lunch in Exhibit Hall
“The Department of Defense finds this event meets the minimum regulatory standards for attendance by DoD employees. This finding does not constitute a blanket approval or endorsement for attendance. Individual DoD component commands or organizations are responsible for approving attendance of its DoD employees based on mission requirements and DoD regulations.”
Wednesday, April 25, 2007

7:00 am - 5:00 pm
Registration

7:00 am
Continental Breakfast

8:00 am
Opening Remarks
Mr. C.J. Toombs, NAVAIR-WD

8:05 am
Keynote Speaker
Mr. David Clagett, Senior Program Analyst, Joint Rapid Acquisition Cell (JRAC), Office of the Under Secretary of Defense (USD), Acquisition, Technology and Logistics (AT&L)

8:35 am
Requirements & Program Trends Session
Mr. Dave Broden, Broden Resource Solutions, LLC
Mr. Bob Glantz, ATK

8:50 am
US Army ARDEC Update
Mr. Antony Sebasto, US Army, ARDEC

9:15 am
Review of the Most Credible Terrorist Standoff Weapons
Mr. Bernard Halls, MSIOC Belgium

9:40 am Break in Exhibit Hall

10:15 am
Armament Subsystems
Session Chairs:
Mr. Greg Hill, Western Design
Mr. John Resch, US Army, ARDEC

10:20 am
MK44 IPT Update (MK44 Operational Commonality and Airburst)
LtCol Kenny Lewton, USMC, EFV

10:45 am
Weapons Updates: LW25mm, .50 cal Bushmaster
Mr. Rockne Carter, ATK

11:00 am
20mm Linear Linkless Feed System for the AH-1W Cobra Helicopter
Mr. Larry Pollard, Meggitt Western Design

11:35 am
M197 Environmental Kit
Mr. Robert Brewer, NAWCWD, China Lake

12:00 pm
Lunch in Exhibit Hall, Awards Ceremony

Breakout 1

Tactical Rockets and Missiles
Session Chair:
Mr. Edwin DePasqual, Talley Defense Systems

Hazard Assessment Testing of the SM-3 Block IA Missile
Mr. Dave Houchins, NSWC Dahlgren

PRODAS Rocket Simulation Software
Mr. Francis Davis, Talley Defense Systems

PRODAS Rocket Artillery in Future Scenarios, First Answer
Dipl. Ing. Harald Wich, Diehl

The Success of the AMRAAM DBMS/DAS
Mr. John Gerding, V, Wyle Laboratories

Breakout 2

Trifiletti Award Recipient: Mr. Ralph F. Campoli, Consultant, General Dynamics Ordnance and Tactical Systems
Presented by Mr. Joe Buzzett, Director, Technology Programs, General Dynamics Ordnance and Tactical Systems

Military Operations Award Recipient: LtCol Kenny Lewton, USMC, Director of Firepower, Expeditionary Fighting Vehicle, Advanced Amphibious Assault
Presented by Mr. Jim McConkie, Senior Engineer, Gun Weapon Systems Branch, NSWC Dahlgren
<table>
<thead>
<tr>
<th>Time</th>
<th>Breakout 1</th>
<th>Breakout 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:25 pm</td>
<td><strong>Armament Subsystems (Cont.)</strong>  &lt;br&gt;Session Chairs:  &lt;br&gt;<strong>Mr. Greg Hill</strong>, Western Design  &lt;br&gt;<strong>Mr. John Resch</strong>, US Army, ARDEC</td>
<td><strong>Precision Weapons</strong>  &lt;br&gt;Session Chairs:  &lt;br&gt;<strong>Mr. Jim Ripley</strong>, Marine Corps Systems Command  &lt;br&gt;<strong>Mr. Dave Wallestad</strong>, Wallestad &amp; Associates, LLC</td>
</tr>
<tr>
<td>1:30 pm</td>
<td><strong>M61 Handoff Improvements</strong>  &lt;br&gt;<strong>Mr. John Fletcher, III</strong>, GDATP</td>
<td>120mm Mid-Range Munition (MRM) Science &amp; Technology Efforts  &lt;br&gt;<strong>Mr. Robert Nodarse</strong>, US Army, ARDEC</td>
</tr>
<tr>
<td>1:55 pm</td>
<td><strong>Universal Portable Fire Control for US and Allied Conventional and Precision Guided Ammunition</strong>  &lt;br&gt;<strong>Mr. Gregory Schneck</strong>, US Army, ARDEC</td>
<td><strong>MRM-KE: A Lethal Solution</strong>  &lt;br&gt;<strong>Mr. Eric Volkmann</strong>, ATK</td>
</tr>
<tr>
<td>2:20 pm</td>
<td><strong>Ultrasonic Temperature and Heat Flux Sensor Technology</strong>  &lt;br&gt;<strong>Mr. Mark Mutton</strong>, Industrial Measurement Systems</td>
<td><strong>20mm Life Cycle Tests</strong>  &lt;br&gt;<strong>Mr. Robert Brewer</strong>, NAWCWD, China Lake</td>
</tr>
<tr>
<td>2:45 pm</td>
<td><strong>Extended Area Protection &amp; Survivability (EAPS) Gun and Ammunition Design Trade Study</strong>  &lt;br&gt;<strong>Mr. Daniel Ericson</strong>, ASIC</td>
<td><strong>Recent Developments in Affordable Laser Guided Precision Weapon Capabilities</strong>  &lt;br&gt;<strong>Mr. James Franciscovich</strong>, BAE Systems</td>
</tr>
<tr>
<td>3:10 pm</td>
<td><strong>Break in Exhibit Hall</strong></td>
<td><strong>Break in Exhibit Hall</strong></td>
</tr>
<tr>
<td>3:40 pm</td>
<td><strong>Modeling and Simulation</strong>  &lt;br&gt;Session Chair:  &lt;br&gt;<strong>Mr. Al Hathaway</strong>, Arrow Tech Associates, Inc.</td>
<td><strong>Precision Weapons (Cont.)</strong>  &lt;br&gt;Session Chairs:  &lt;br&gt;<strong>Mr. Jim Ripley</strong>, Marine Corps Systems Command  &lt;br&gt;<strong>Mr. Dave Wallestad</strong>, Wallestad &amp; Associates, LLC</td>
</tr>
<tr>
<td>3:45 pm</td>
<td><strong>System Modeling of a 40mm Automatic Grenade Launcher</strong>  &lt;br&gt;<strong>Dr. Daniel Corriveau</strong>, Defense R&amp;D Canada</td>
<td><strong>Swedish Studies of Extreme Long Range Projectiles for Tube Artillery</strong>  &lt;br&gt;<strong>Mr. Borje Nyquist</strong>, BAE Systems, Sweden</td>
</tr>
<tr>
<td>4:10 pm</td>
<td><strong>A Quest for Practical Design for Six Sigma (DFSS) Tools - PGMM Case Study</strong>  &lt;br&gt;<strong>Mr. James Kalberer</strong>, ATK</td>
<td><strong>Trade Space on Appropriate Caliber Ammunition for Terminal Defense Guided Projectile</strong>  &lt;br&gt;<strong>Mr. Chris Geswender</strong>, Raytheon Company</td>
</tr>
<tr>
<td>4:35 pm</td>
<td><strong>Advanced Engineering Design Modeling and Simulation as a Management Tool</strong>  &lt;br&gt;<strong>Mr. Steve Liss</strong>, US Army, ARDEC</td>
<td><strong>Adjourn</strong></td>
</tr>
<tr>
<td>5:00 pm</td>
<td><strong>Adjourn</strong></td>
<td><strong>Adjourn</strong></td>
</tr>
</tbody>
</table>

**Thursday, April 26, 2007**

- 7:00 am - Registration
- 1:25 pm
- 7:00 am - Continental Breakfast
<table>
<thead>
<tr>
<th>Time</th>
<th>Breakout 1</th>
<th>Breakout 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 am</td>
<td><strong>Modeling and Simulation (Cont.)</strong></td>
<td><strong>Direct Fire</strong></td>
</tr>
<tr>
<td></td>
<td>Session Chair: Mr. Al Hathaway, Arrow Tech Associates, Inc.</td>
<td>Session Chair: Mr. Matt Solverson, GD-OTS</td>
</tr>
<tr>
<td>8:05 am</td>
<td>A Guided Projectile Enterprise Modeling and Simulation Environment</td>
<td>120mm Line-of-Sight Multi-Purpose (LOS-MP) Munition Science &amp; Technology Efforts</td>
</tr>
<tr>
<td></td>
<td>Mr. John Kimball, NSWC Dahlgren</td>
<td>Mr. Jesse Sunderland, US Army, ARDEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Eric Scheper, US Army, ARDEC</td>
</tr>
<tr>
<td>8:30 am</td>
<td>Instrumented Ballistic Test Projectile (IBTP)</td>
<td>Development of the M1040, 105mm Anti-Personnel Round</td>
</tr>
<tr>
<td></td>
<td>Mr. Roger St. Ours, US Army, ARDEC</td>
<td>Mr. Stephen Ginetto, US Army, ARDEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LTI Neil Friedberg, USA, ARDEC</td>
</tr>
<tr>
<td>8:55 am</td>
<td>Structural Reliability of Flawed Mortar Bodies</td>
<td>APAM MP-T 120mm XM329 Development Status</td>
</tr>
<tr>
<td></td>
<td>Dr. Jennifer Cordes, US Army, ARDEC</td>
<td>Mr. Danny Schirding, Israel Military Industries</td>
</tr>
<tr>
<td>9:20 am</td>
<td>Simulations of Head Space Case Failure in Medium Caliber Ammunition</td>
<td>GD-OTS 20mmx120mm Mechanically Fuzed Projectile Program</td>
</tr>
<tr>
<td></td>
<td>Dr. Aaron Caba, ATK</td>
<td>Mr. Zach Kemp, GD-OTS</td>
</tr>
<tr>
<td>9:45 am</td>
<td>Internal Ballistic Modeling Using 1-D FNGUN Code</td>
<td>The ATK Air Burst Munitions Program</td>
</tr>
<tr>
<td></td>
<td>Dr. Jang-Horng Yu, ATK</td>
<td>Mr. Larry Mason, ATK</td>
</tr>
<tr>
<td>10:10 am</td>
<td>Modular Charge Ignition Modeling</td>
<td>30mm MK46 MOD1 Gun Weapon System (GWS) At-Sea Evaluation</td>
</tr>
<tr>
<td></td>
<td>Mr. Clive Woodley, QinetiQ, Ltd.</td>
<td>Mr. Andrew Green, NSWC Dahlgren</td>
</tr>
<tr>
<td>10:35 am</td>
<td>Break in Exhibit Hall</td>
<td>Break in Exhibit Hall</td>
</tr>
<tr>
<td>10:50 am</td>
<td><strong>Platform and Weapon System Integration</strong></td>
<td><strong>Direct Fire Session (Cont.)</strong></td>
</tr>
<tr>
<td></td>
<td>Session Chair: Mr. Jim Talley, GDATP</td>
<td>Session Chair: Mr. Matt Solverson, GD-OTS</td>
</tr>
<tr>
<td>10:55 am</td>
<td>Lightweight 30mm Remote Weapon System</td>
<td>M789 LW 30mm HEDP Cartridge In-BoreDetonation Investigation</td>
</tr>
<tr>
<td></td>
<td>Mr. James Lamb, ATK</td>
<td>Mr. John Hirlinger, US Army, ARDEC</td>
</tr>
<tr>
<td>11:20 am</td>
<td>Remote Armaments</td>
<td>M789 LW 30mm HEDP Cartridge In-BoreDetonation Investigation (Cont.)</td>
</tr>
<tr>
<td></td>
<td>Mr. Richard Ciekurs, US Army, ARDEC</td>
<td>Mr. John Hirlinger, US Army, ARDEC</td>
</tr>
<tr>
<td>11:55 am</td>
<td>F-35 Joint Strike Fighter Gun System Update</td>
<td>Lunch in Exhibit Hall</td>
</tr>
<tr>
<td></td>
<td>Mr. David Maher, GDATP</td>
<td>Lunch in Exhibit Hall</td>
</tr>
<tr>
<td>12:20 pm</td>
<td>Lunch in Exhibit Hall</td>
<td>Lunch in Exhibit Hall</td>
</tr>
</tbody>
</table>
Thursday, April 26, 2007 (Cont.)

1:25 pm  Exhibit Hall Closes

1:25 pm  Armament Division Overview
Mr. Dave Broden, Broden Resource Solutions, LLC

1:50 pm  Platform and Weapon System Integration (Cont.)
Session Chair:
Mr. Jim Talley, GDATP

1:55 pm  Telepresent Rapid Aiming Platform (TRAP) - Spiral Development of a Lightweight Remote Weapon System and Integration into a Mobile Sensor-Shooter Network
Mr. Brian McConnell, NSWC Dahlgren

2:20 pm  F-22A Lightweight Gun System Comparison
Mr. Peter Wolff, GDATP

2:45 pm  Integration of a Remotely Operated, Breech Loaded 120mm Mortar Platform
Mr. Thomas DeVoe, US Army, ARDEC

3:10 pm  Shock Aspects of Lightweight Artillery on Mounting Electronics
Mr. William Zepp, JS Army, ARDEC

3:35 pm  Conference Adjourns

THANK YOU FOR ATTENDING
WE’LL SEE YOU NEXT YEAR IN NEW ORLEANS
APRIL 21-24, 2008

Please take a moment to complete the Survey, found in your registration materials. Surveys may be returned to the Registration Desk. Your feedback is greatly appreciated!
Mr. Campoli is recognized world wide as an innovative design expert in the field of ammunition design. His significant contributions have enhanced the performance of US tank kinetic energy ammunition to its recognition today as the most lethal in the world. The dedication to providing our war fighters with only the best was evident during his 38 years of civil service at Picatinny Arsenal and has continued with his consulting efforts for over 25 years in the defense industry. Mr. Campoli is currently a respected design expert with General Dynamics Ordnance and Tactical Systems.

Mr. Campoli is affectionately known around the world as the “Godfather of modern tank KE ammunition.” His contributions to ordnance have not been limited to KE ammunition. The fluted liner designed to enhance performance of HEAT rounds to compensate for projectile spin, sabot design for the current 120mm tank multipurpose round (M830A1), folding fin assembly for high explosive projectiles both tank and artillery, and obturator designs for all US tank ammunition are among Mr. Campoli’s many contributions.

The unique talents of Mr. Campoli have been applied to numerous items which, unfortunately, failed to go to inventory for various reasons. They did, however, demonstrate his gifted design capability. These included XM578 projectile for the 152mm, a target practice round that was range limited by controlled aerodynamic heating, an ultra light aluminum sabots for tank KE projectiles, and improved ignition systems.

Mr. Campoli continues to apply his expertise in evolving technologies. He is currently assisting ARDEC engineers in developing saboted projectile concepts for electromagnetic guns.

Mr. Campoli continues to have a great impact on Army ordnance through his mentoring of R&D personnel. During his career of over 60 years, his insights and knowledge of the industry have been instrumental to the success of many individuals and the programs they have managed.
Military Operations Award Recipient: LtCol Kenny Lewton, USMC
Director of Firepower, Expeditionary Fighting Vehicle, Advanced Amphibious Assault

LtCol Lewton was commissioned as a Second Lieutenant via the Naval Reserve Officer Training Corps Program at Iowa State University in December 1989 with a Bachelor of Arts Degree in Political Science. He reported to The Basic School in March 1990, and upon graduation in August 1990, LtCol Lewton reported to 3rd AA Bn, 1st MARDIV. Nearly all of 3rd AA Bn was deployed to Operation Desert Shield/Desert Storm. LtCol Lewton conducted OJT with the MEU platoon until Basic Amphibious Officer’s Course convened in February 1991.

After graduating from Basic Amphibious Officers Course in April 1991, LtCol Lewton reported to B Co, 3rd AA Bn. He was promoted to First Lieutenant in January 1992. He then deployed to Okinawa as part of the Unit Deployment Program and was attached to 31st MEU. As part of 31st MEU, he deployed to the Republic of Philippines and Hong Kong.

LtCol Lewton elevated to B Co Executive Officer and deployed to Somalia for Operation Restore Hope in December 1992. There, he conducted relief operations as part of the JTF. He redeployed to CONUS in May 1993.

In July 1993, LtCol Lewton transferred to Marine Corps Recruit Depot (MCRD), San Diego, where he served as a Series Commander for L Co, 3rd Recruit Training Bn. He was promoted to Captain on September 1, 1994, and then resigned his commission and left active duty.

During February 1996, LtCol Lewton reassessed to active duty and reported to 3rd AA Bn, 1st MARDIV. He served as Commanding Officer of F Co, 3rd AA Bn from February 1996 to May 1998. Company F deployed to Okinawa as part of the Unit Deployment Program and was retired on May 1, 1998 as part of Marine Corps downsizing.

LtCol Lewton attended the Command and Control Systems Course from August 1998 to May 1999. He then reported to A Co(-), 4th AA Bn as Inspector-Instructor. He served as Company I-I from June 1999 to June 2002 and was promoted to Major in September 1999.

In July 2002, LtCol Lewton was assigned to 2nd Assault Amphibian Battalion, 2nd MARDIV where he served as Operations Officer for 2nd AA Bn and deployed to Operation Iraqi Freedom-1 from January 2003 to May 2003. He completed his tour of duty as OpsO in June 2004. Then, he reported to Direct Reporting Program Manager, Advanced Amphibious Assault (DRPM AAA) in July 2004. Currently, LtCol Lewton serves as Director of Firepower for the Expeditionary Fighting Vehicle. He was promoted to Lieutenant Colonel in September 2005.

LtCol Lewton’s personal awards include: Navy Achievement Medal (2), Navy Commendation Medal (2), Meritorious Service Medal and Combat Action Ribbon (2).
ATK

ATK is a leading provider of advanced weapon and space systems with $3.5 billion in annual sales, approximately 15,500 employees and operations in 21 states.

ATK is the nation’s largest manufacturer of small and medium caliber ammunition. Our ammunition product portfolio spans a broad range, from 5.56mm through .50 caliber rounds for handguns, shotguns and rifles to 20mm, 25mm and 30mm rounds for air, land and sea platforms and large caliber ammunition for main battle tanks. We are developing environmentally friendly training ammunition, enhanced tactical ammunition, next-generation energetic materials and advanced propellants that will increase performance and lethality.

ATK is also a leading producer of Chain-gun® family of medium-caliber gun systems for ground combat, naval and air armament applications. ATK produces the M242 25mm cannon used on Bradley Fighting Vehicles, the MK44 30/40mm cannon for the US Marine Corps’ new Expeditionary Fighting Vehicle and the 30mm M230 cannon for the AH-64 Apache and AH-64D Apache Longbow helicopters.

ATK is the world leader in the design, development and production of solid rocket propulsion systems for space, strategic-missile defense and tactical applications. Our tactical rocket motor portfolio includes propulsion systems for air-to-air, air-to-surface, surface-to-air and surface-to-surface missiles.

Building on the capabilities of our core ammunition and rocket motor businesses, ATK is developing several breakthrough advanced weapon systems, such as the US Navy’s Advanced Anti-Radiation Guided Missile (AARGM) and the US Army’s Precision Guided Mortar Munition (PGMM), Precision Guidance Kit (PGK) and Mid-Range Munition (MRM). Using state-of-the-art guidance, navigation and control systems, targeting systems, high-energy propellants and advanced warheads, ATK is developing weapons that will fly farther and faster and strike their targets with unprecedented precision and lethality.

Additional ATK news and information can be found at www.atk.com.

General Dynamics Armament and Technical Products

General Dynamics Armament and Technical Products (GDATP), an operating unit of the General Dynamics Corporation, is a proven systems integrator of detection, protection and lethality defense products for all branches of the US Department of Defense (DoD) and the Ministries of Defense of more than 30 allied nations.

GDATP provides our customers with advanced capabilities through our Advanced Materials, Detection Systems, Gun Systems and Weapon Systems. GDATP designs, develops and produces high-performance armament systems, a full range of high-performance composite products for the aerospace industry, biological and chemical detection systems, advanced sensor and vision-enhancement systems and mobile shelter systems. GDATP also provides system management for key DoD programs, including the 2.75-inch (70mm) Hydra-70 rocket family.

For more information, please visit www.gdatp.com.
Thank You to our Promotional Partners

Meggitt Defense Systems, Inc. (MDSI)
formerly known as Meggitt Western Design

Specializing in the design, development and production of medium caliber Linear Linkless Ammunition Handling Systems and large caliber Compact Autoloader and Storage Systems, MDSI provides state-of-the-art weapon system capabilities in support of the United States Military and her allies.

MDSI has a solid track record in meeting design-to-production requirements for provision of increased capacity, reliability and volumetric storage efficiency for Ammunition Handling Systems (AHS).

MDSI provides a wide range of medium caliber Linear Linkless Ammunition Handling Systems, all of which have been battle proven. These include the world’s largest, a 3,000-round, 1,800 shot-per-minute 25mm AHS onboard the AC-130U Gunship, a 1,200 round Magazine and a 250 round Combo PAK Magazine providing 30mm ammunition on the Apache Helicopter, two 30mm Magazines (1,200 rounds and 660 rounds) on the Blackhawk Helicopter, a 1,500 round 20mm reload Magazine for Phalanx and a 2,100 round 20mm aircraft reload system called LALS. Additionally, development programs are underway for 30mm, Mk44 Feed Systems for AC-130U and FCS MGV and a 20mm Linkless Magazine to replace the existing Linked system on the Cobra Helicopter.

Our state-of-the-art chain ladder Linkless Feeding Systems allow simultaneous upload and download of rounds and spent cases (where required), providing weapon system efficiency on the battlefield. Linear Linkless Systems are more efficient, weigh less and, most importantly, are more reliable than Linked systems. Our feed and transfer systems maintain complete control of rounds as they are fed directly into the gun system without wasted space. In the end, this means maintaining multi-year reliability records. More importantly, it means that in the heat of combat warfighters don’t have to be concerned with whether or not their ammunition system will jam and fail them.

MDSI has developed large caliber Compact Autoloader and Magazine systems for 105mm, 120mm, 140mm and 155mm. They are electrically or hydraulically-driven, fully automatic systems designed for easy integration to modern combat systems. Patented breakthroughs range from legacy engineering designs for Main Battle Tank test beds to today’s Stryker Mobile Gun System to innovations in robotics for FCS MCS, future main battle tanks and other next-generation combat platforms. Production continues for 105mm Re-supply Magazines on Stryker, and 120mm full scale development is underway for FCS MCS.

As the technology leader in Ammunition Handling and Storage Systems, Meggitt Defense Systems, Inc. is proud to be a sponsor for the NDIA 42nd Annual Armament Systems: Gun and Missile Systems Conference & Exhibition.

For more information, please visit www.wd.com.
Thank You to our Promotional Partners

OSRAM SYLVANIA Global Tungsten & Powders Division

For over 40 years, OSRAM SYLVANIA’s Global Tungsten & Powders Division, located in Towanda, PA, has been designing and manufacturing tungsten and molybdenum powders and parts for defense and aerospace applications. Our facility is the only facility of its kind in North America; vertically integrated from processing the ore into powders to final part production. Additionally, we are the premier recycle point for Tungsten on the continent.

We are ISO 9001:2000 and 14001 compliant and have institutionalized a Six Sigma culture through our “PQI” program. Our state-of-the-art environmental program has garnered us numerous awards for exceeding state and federal environmental safety and stewardship requirements.

SYLVANIA’s Research and Development Department is comprised of dedicated scientists who have helped make us the leading Tungsten technology company in the world. Our facilities are world class, featuring one of the premier inorganic labs in the industry. Our capabilities include: Chemical Analysis, Surface Analysis, Environmental Analysis and Microscopy. SYLVANIA’s R&D prowess has resulted in robust partnerships with the Department of Defense’s most important laboratories, leading prime contractors as well as many of our country’s most prestigious universities and private labs.

We have manufactured products for all Department of Defense Services and key prime contractors. Our defense applications include small, medium and large caliber penetrators, custom powders, fragmenting warheads, canister rounds, shape charges, sheet, plate, wire, ballast, thermal sprays, hard metal tooling and powders for thermal management applications. We are currently in production of a significant array of products supporting critical defense and aerospace functions.

SYLVANIA’s culture fully embraces and supports the necessarily dynamic requirements of today’s defense environment. Whether it is leading edge research for the products of tomorrow or an ongoing enhancement to a dependable legacy system, SYLVANA is the ideal source for your tungsten, molybdenum and other hard material applications.

For more information, please visit www.sylvania.com.
THANK YOU TO OUR PROMOTIONAL PARTNERS

ATK

GENERAL DYNAMICS
Armament and Technical Products

Meggitt Defense Systems
formerly known as
Meggitt Western Design

SYLVANIA
Weapon Systems & Technology Directorate
Benét Laboratories

XM324 Non-Line of Sight Cannon
NLOS-Cannon

Chris Aiello
XM324 NLOS-Cannon

- **Objective:**
  - Design and Develop a lightweight armament for the FCS Non-Line of Sight Cannon (NLOS-Cannon) Platform

**XM324 Cannon - SN001**

XM324 Cannon Installed on BAE System’s Firing Platform
XM324 NLOS-Cannon

• Key Parameters:
  – 155mm, 38 Caliber Lightweight Cannon
    • High Strength Steel Alloy
    • Optimized for Minimum Tube Mass
    • Fires MACS Propellant (Zones 1 through 4)
    • Indexable Tube
  – High Rate of Fire
    • Thermal sensors embedded in the tube wall to monitor real time internal tube temperature
XM324 NLOS-Cannon

• Key Parameters:
  – Lightweight Screw Block Breech
    • High Strength Steel Alloy
    • New 6 Sector Design – Up Swing to Open

M776 Breech Mechanism Assembly
XM324 Breech Mechanism Assembly

“Innovative Armament Solutions for Today and Tomorrow”

Approved for public release; distribution is unlimited. Case GOVT 07-7040. 06 April 2007.
XM324 NLOS-Cannon

- Key Parameters:
  - Minimize System Impulse
    - High Efficiency Multi-Vaned Muzzle Brake
    - ~33% Decrease in Impulse Transmitted to System
XM324 NLOS-Cannon

• **Modeling and Simulation:**
  – Modeling of entire cannon performed with 3D Computer Aided Design Package
  • *Drawings parametrically linked to models and assemblies*
XM324 NLOS-Cannon

- Modeling and Simulation:
  - Extensive use of modern analytical methods utilized during the design cycle
    - *Finite Element Methods – Structural Design*

Comparative Breech Structural Analysis

![Comparative Breech Structural Analysis](image)

M284/M776  M199  XM283  XM324

“Innovative Armament Solutions for Today and Tomorrow”

Approved for public release; distribution is unlimited. Case GOVT 07-7040. 06 April 2007.
XM324 NLOS-Cannon

- Modeling and Simulation:
  - *Finite Element Methods – Dynamic Load Analysis*

Dynamic System Axial Response
XM324 NLOS-Cannon

• Modeling and Simulation:
  • *Computational Fluid Dynamics – Muzzle Brake Optimization*

CFD of Brake During Firing
XM324 NLOS-Cannon

• Testing:
  – Live Firing at Yuma Proving Grounds
    • 44 Rounds Fired to date
    • Test Data indicates performance within expected ranges
  – Fatigue Testing
    • First Breech to begin cycling MAY 07
      – Second planned SEP 07
      – Interim Safe Fatigue Life DEC 07
    • First Tube planned FEB 08
      – Interim Safe Fatigue Life FEB 09
Test and Evaluation of Electromagnetic Railguns

NDIA Gun & Missile Systems
April 23-26, 2007
EM Railgun – Game Changing

Above Sensible Atmosphere
Simplifies deconfliction

Ballistic Trajectory
GPS guidance, navigation & control
500,000 ft

Hypervelocity Electromagnetic Launch (MACH 7.5)
Hypervelocity Impact (MACH 5.0)

Indirect Fire (200+ nm in 6 minutes)
Fixed and Relocatable Targets at Long Range

Direct Fire (Horizon in 6 seconds)

- Long-Range
- Time-Critical
- Persistent
- All-Weather (24/7)
- No Unexploded Ordnance Issues

- Large Capacity Magazines
- No Propellants
- No Explosive Warheads
- Increased Ship Design Options
- Reduced Ship Vulnerability
- Leverages Navy Investment in Integrated Power System

Support for Distributed Ops
How it Works

1. Switch closes, current flows through rails & armature
2. Magnetic field generated around rails as current flows through circuit
3. Magnetic field interacts with armature current generating a Lorentz force
4. Lorentz Force accelerates armature and projectile down barrel

Lorentz Force = 1/2 Inductance Gradient (L') * Current (I)^2

or

Lorentz Force = Current (J) X Magnetic Field (B)
Key Statistics (2007)
- Operating Muzzle Energy: up to 7 MJ
- Terminal Area: 16-MJ Slug
- Gun lines: 1
Current Facility
32-MJ PFN

Fiber Optic Cable

Controls Cabinets

System Controller (Located in Control Van)
Switching and Output Cables

Spark Gap Switch

350-MCM Coaxial Cable
SSG Construction

- Containment Studs
- Safety Shield (capable of stopping broken studs)
- Bore Insulators
- Upper Containment Plate (3 total)
- Side Containment Plate (8 total)
- Lower Containment Plate (3 total)
- Rail Backing Insulators
- Rails
- Launch Package
- Pre-Injector Tube
- Breech Studs
- Containment Studs
Launch Package

- Total Mass = 2.3-3.4 kg
- Aluminum Slug and Armature
- Nylon Bore Riders
- Design based on earlier work at Kirkcudbright and Greenfarm
**Gun - Facility Interfaces**

**Muzzle Chamber**
- 1" Thick A36 Steel Plate
- Bolts Directly to Gun Foundation
- Bolts Directly to Bridge Section
- Adaptable to Variety of Launchers

**Recoil Plates**
- 3" Thick A36 Steel Plate
- Bolt Directly to the Gun Foundation Plates
- Bolt Directly to Underside of SSG
Terminal Area Design

7 Each Bridge Sections
(8’ L x 16’ W x 10’ H x 10” Thick)
Free Standing,
Reinforced Concrete,
Flash X-Ray Cutouts

I-Beam Catch Cart
(8 mini-RR wheels, 12’ long)
Move/Replace first 4 Sand-Filled Steel Boxes

Terminal Pad
(100’ L x 32’ W)
Standard Gage Crane Rails,
3 Rows of Tie Downs every 8’,
2 Instrumentation Troughs

20 Each NRL Shield Blocks –
Double Course
(8’ L x 2.5’ W x 1.5’ Thick)
Interlocking, Reinforced
Concrete

Concrete Blocks
Statically Support last 3
Sand-Filled Steel Boxes

Shot Line
~75” Above the Ground
~66’ to 1st Sand Box

~37 ft Opening

Steel Muzzle
Chamber

7 Each Sand-Filled Steel Boxes
(4’ x 4’ x 3’)
(21’ of Sand Along Line of Fire)
Catch Component

- 7 Each Sand-Filled Steel Boxes, Total of 14 On Hand
  - 4 ft x 4 ft x 3 ft
  - Wt 5740 lbs when Filled
  - 21 ft of Sand along Line of Fire
  - Open Top, Stackable, 4-Way Forklift Entry

- I-Beam Catch Cart
  - Support the First 4 Sand Boxes to Allow Quick Movement & Replacement
  - Runs on Crane Rails Using Mini-Railroad Wheels

- Concrete Blocks
  - Support the Last 3 Sand Boxes
Shot 13 Breech Current and Muzzle Voltage

Slide 13

Breech Current (MA) vs. Time (ms) and Muzzle Voltage (kV) graph.
Muzzle Launch View

- Shot 7
- Muzzle Arc is 500K Amps at 2.3 KV
- 9 PSI Overpressure at 99” from muzzle
Flash X-ray Images

Static X-ray Image  Shot 2 X-ray Image  Shot 4 X-ray Image

Top View

Side View

All images are 3 feet from muzzle
In-Flight Images

Shot 8:

Shot 9:

Shot 10:

Shot 21:

Tue Jan 30 2007 16:00:09.355 793
Target Impact

Shot 1:

Shot 2:

Shot 10:
S&T Technology Challenges

• Launcher
  – Multi-shot barrel life
  – Barrel construction to contain rail repulsive forces
  – Scaling from 8MJ (state of the art) to 32MJ → 64MJ Muzzle Energy
  – Thermal management techniques

• Projectile
  – Gun launch survivability (45 kGee acceleration, Electromagnetic Interference Potential)
  – Hypersonic guided flight for accuracy
  – Lethality mechanics

• Pulsed Power System
  – Energy Density
  – Rep rate operation & thermal management
  – Switching
  – Torque management and multi-machine synchronization (rotating machine)
## ONR I NP Phase I Program

<table>
<thead>
<tr>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Program Initiation</strong></td>
<td><strong>Initial 8MJ Test Capability</strong></td>
<td><strong>Initial 32MJ Test Capability</strong></td>
<td><strong>Go – No Go Decision Point Aug 09</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Exercise Options
- **Concept Design**
- **Technology Development & Preliminary Design**
- **Detail Design & Fabrication**
- **Multiple Awards**

### Executive Steering Committee Conclusion and Recommendation
- **Program Initiation** Aug 05
- **Initial 8MJ Test Capability**
- **Initial 32MJ Test Capability**
- **Go – No Go Decision Point Aug 09**

### Advanced Containment
- **32 MJ LAUNCHER 100 SHOT BORE LIFE DEMO**
- **32 MJ ADVANCED CONTAINMENT DEMO**

### 100MJ Capacitor Bank For Launcher Testing
- **EMLF Test Facility** NSWCDD
- **General Atomics**
- **Boeing**
- **Draper**

### Advanced Capacitor Development
- **33MJ**
- **Rotating Machine Component Development**

### Integrated Launch Package (ILP) Development

### Projectile Trades & Develop 4 Year Plan
Key Statistics (2009)
- Muzzle Operating Energy: 32 MJ
- Terminal Area: 64-MJ Projectile
- Gun lines: 2

- P306 FY09 MILCON ($9.9 M)
- Protected Control Room
- 100+ MJ Pulsed Power System
- Terminal Catch: Up to 16-MJ Slugs
- Ballistic Tunnel
- Terminal Area: 64-MJ Projectiles

2009
Test Results

Video of Test Results
Electromagnetic Launch Facility

TEST SHOT #1
2 October 2006
Electromagnetic Launch Facility Ribbon Cutting

16 Jan 2007
ONR
Dr. Elizabeth D’Andrea (Program Manager)
Office of Naval Research (Code 352)
875 N. Randolph Street
Arlington, VA 22203
703.588.2962

NSWC
Mr. Charles Garnett (Program Manager)
Naval Surface Warfare Center, Dahlgren (Code 308)
6096 Tisdale Road
Dahlgren VA 22448-5156
540.653.3186

Mr. Tom Boucher, P.E. (EMLF Test Director)
Naval Surface Warfare Center, Dahlgren (Code 606)
18236 Thompson Road
Dahlgren VA 22448-5116
540.653.6273
Back-up
Power Ramp Up Testing Plan (2.4kg)

- Velocity – km/s
- Energy – MJ

- 10 KV
- 8.5 KV
- 3.5 MA @ T=0

Banks

Velocity – km/s

Energy – MJ

Banks

0 1 2 3 4 5 6 7 8 9 10
Actual Power Ramp Up Testing

Velocity - km/s

Banks

10 KV
8.5 KV
3.5 MA @ T=0

1098
7
6
1213
14
214
3
5178
11
13
9
151921
10
162022
23

0 1 2 3 4 5 6 7 8

Banks

0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
Velocity - km/s
## Test Results

<table>
<thead>
<tr>
<th>Shot</th>
<th>Mass (KG)</th>
<th>Charge Voltage (KV)</th>
<th>Peak Current (MA)</th>
<th>Muzzle Velocity (m/s)</th>
<th>Muzzle Energy (MJ)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4</td>
<td>8.2</td>
<td>1.7</td>
<td>837</td>
<td>0.841</td>
<td>12.6</td>
</tr>
<tr>
<td>2</td>
<td>2.41</td>
<td>8.18</td>
<td>1.8</td>
<td>1117</td>
<td>1.5</td>
<td>16.9</td>
</tr>
<tr>
<td>3</td>
<td>2.416</td>
<td>7.85</td>
<td>2.35</td>
<td>1560</td>
<td>2.94</td>
<td>24.5</td>
</tr>
<tr>
<td>4</td>
<td>2.456</td>
<td>6.25</td>
<td>2.79</td>
<td>1540</td>
<td>2.91</td>
<td>28.3</td>
</tr>
<tr>
<td>5</td>
<td>2.456</td>
<td>6.85</td>
<td>2.83</td>
<td>1760</td>
<td>3.8</td>
<td>30.7</td>
</tr>
<tr>
<td>6</td>
<td>3.29</td>
<td>6.9</td>
<td>3</td>
<td>1500</td>
<td>3.7</td>
<td>29.4</td>
</tr>
<tr>
<td>7</td>
<td>3.29</td>
<td>7.68</td>
<td>3.13</td>
<td>1680</td>
<td>4.64</td>
<td>29.8</td>
</tr>
<tr>
<td>8</td>
<td>3.288</td>
<td>8.3</td>
<td>3.09</td>
<td>1850</td>
<td>5.63</td>
<td>30.9</td>
</tr>
<tr>
<td>9</td>
<td>3.29</td>
<td>8.6</td>
<td>3.1</td>
<td>1920</td>
<td>6.06</td>
<td>30.9</td>
</tr>
<tr>
<td>10</td>
<td>3.29</td>
<td>8.9</td>
<td>3.09</td>
<td>1990</td>
<td>6.51</td>
<td>31</td>
</tr>
<tr>
<td>11</td>
<td>3.288</td>
<td>9.2</td>
<td>3.1</td>
<td>2070</td>
<td>7.04</td>
<td>31.4</td>
</tr>
<tr>
<td>12</td>
<td>3.346</td>
<td>9.68</td>
<td>3.13</td>
<td>2117</td>
<td>7.5</td>
<td>30.2</td>
</tr>
<tr>
<td>13</td>
<td>3.2</td>
<td>9.65</td>
<td>3.09</td>
<td>2146</td>
<td>7.38</td>
<td>29.8</td>
</tr>
</tbody>
</table>
## Test Results (continued)

<table>
<thead>
<tr>
<th>Shot</th>
<th>Mass (KG)</th>
<th>Charge Voltage (KV)</th>
<th>Peak Current (MA)</th>
<th>Muzzle Velocity (m/s)</th>
<th>Muzzle Energy (MJ)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>2.46</td>
<td>8.2</td>
<td>1.87</td>
<td>1106</td>
<td>1.5</td>
<td>16.9</td>
</tr>
<tr>
<td>15</td>
<td>2.31</td>
<td>8.01</td>
<td>2.46</td>
<td>2005</td>
<td>4.65</td>
<td>27.4</td>
</tr>
<tr>
<td>16</td>
<td>2.89</td>
<td>8.89</td>
<td>2.75</td>
<td>2059</td>
<td>6.13</td>
<td>29.3</td>
</tr>
<tr>
<td>17</td>
<td>3.29</td>
<td>7.8</td>
<td>3.18</td>
<td>1722</td>
<td>4.87</td>
<td>30.3</td>
</tr>
<tr>
<td>18</td>
<td>3.29</td>
<td>7.8</td>
<td>3.18</td>
<td>1717</td>
<td>4.85</td>
<td>30.1</td>
</tr>
<tr>
<td>19</td>
<td>3.402</td>
<td>9.69</td>
<td>2.99</td>
<td>2053</td>
<td>7.17</td>
<td>28.9</td>
</tr>
<tr>
<td>20</td>
<td>2.892</td>
<td>8.9</td>
<td>2.75</td>
<td>2025</td>
<td>5.93</td>
<td>28.3</td>
</tr>
<tr>
<td>21</td>
<td>2.888</td>
<td>8.9</td>
<td>2.75</td>
<td>2019</td>
<td>5.88</td>
<td>28.1</td>
</tr>
<tr>
<td>22</td>
<td>2.89</td>
<td>8.9</td>
<td>2.73</td>
<td>2012</td>
<td>5.85</td>
<td>27.9</td>
</tr>
<tr>
<td>23</td>
<td>2.454</td>
<td>9.49</td>
<td>3.08</td>
<td>2519</td>
<td>7.79</td>
<td>32.7</td>
</tr>
</tbody>
</table>
Launch Package Results

Original Launch Package

Recovered from Shot 1

Recovered from Shot 2
Bore Life
EMLF Testing Concept

<table>
<thead>
<tr>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
</tr>
</thead>
<tbody>
<tr>
<td>8MJ Testing 18 months</td>
<td>2Q/3Q</td>
<td>16-32MJ Testing 18 months</td>
<td>Go No-Go</td>
<td>Order Core 2Q/3Q</td>
</tr>
</tbody>
</table>

**Series A (SSG)**
- Procure parts
- Test
- 20 Shots
- Bore Life

**Series B (SSG)**
- Procure parts
- Test
- 20 Shots

**Series C (SSG)**
- Procure parts
- Test
- 20 Shots

**Series D (LL32)**
- Procure parts
- Test
- 20 Shots

**Series E (LL32)**
- Procure parts
- Test
- 20 Shots

**Series U (LL32)**
- Procure parts
- Test
- 20 Shots

**Series V (LL32)**
- Procure parts
- Test
- 20 Shots

**Series W (LL32)**
- Procure parts
- Test
- 20 Shots

**Series X (LL32)**
- Procure parts
- Test
- 20 Shots

**Series Y (LL32)**
- Procure parts
- Test
- 20 Shots

**Series Z (LL32)**
- Procure parts
- Test
- 20 Shots

**Series ZZ (LL32)**
- Procure parts
- Test
- 40 Shots

**Contractor Tests on Gun-line #2**
- PDR
- BAE Stub Tube
- Test
- Analyze

**GA Adv Containment Launcher**
- Procure parts
- Test
- Analyze

**BAE DEMO - 32MJ**
- 100 Shot Test
- Adv Containment Launcher

**GA DEMO - 32MJ**
- 100 Shot Test
- Adv Containment Launcher

**INP DEMO - 32MJ**
- 100 Shot Test

- 32MJ
- Half mass-full velocity (10kg, 2.5km/sec)
- Full mass-full current-2/3 velocity (20kg, 5.5MA, 1.7 km/sec)

**SSG - Army Single Shot Gun**
**LL32 - 32MJ Lab Launcher**
What is it?
• Gun fired with electricity rather than gunpowder
• Revolutionary 250 mile range in 6 minutes
• Mach 7 launch / Mach 5 hit
• Highly accurate, lethal GPS guided projectile
• Minimum collateral damage

Why is it important?
• Volume & Precision Fires
• Time Critical Strike
• All weather availability
• Variety of payload packages
• Scalable effects
• Deep Magazines
• Non explosive round/No gun propellant
  • Greatly simplified logistics
  • No IM (Insensitive Munitions) Issues
• Missile ranges at bullet prices

Who needs it?
• Marines and Army troops on ground
• Special forces clandestine ops
• GWOT
• Suppress air defenses

When?
• Feasibility Demo 2011
• System Demo 2015
• IOC 2020-2025
Naval Railgun - Key Elements

- **Launcher**
- **Projectile**
- **Pulse Forming Network (PFN)**
- **Ship Integration**

- Capacitors or Rotating Machines
Key Parameters for Sizing a Naval EM Launcher

Pulse Forming Network Size

$$\frac{1}{2} \times \text{Launch Mass} \times \text{Muzzle Velocity}^2$$

Desired Muzzle Energy

Current Profile
- Rail Separation Forces
- Transient Localized Heating

Bore Size & Shape

Barrel Length
- Max Projectile Acceleration
- Bulk Rail Heating

Launcher Efficiency
Risk Matrix Summary

Risk Ranking & Key Impacts

- **Launcher**
  - Failure Impacts Capability
- **Projectile**
- **Rotating Machine PPS**
  - Failure Impacts Volume, Weight & Cost
- **Capacitor PPS**
- **Ship Integration**

Consequence of Failure, $C_F$

Probability of Failure, $P_F$

Failure Impacts

- Capability
- Volume, Weight & Cost

Failure Analysis:
- Bore Life
- Electronics Hardening
- Tactical Containment
- Heat Removal
- Mount Integration
- Launch Survivability
- Recoil
- Cabling & Ring
- Power Generation
- Dynamic Power Management
- Shot Life
- Cabling & Ring
- Auxiliary Cooling
- Rep-rate
- Energy Density
- Switch Recovery
- Rotor Cooling
- ER1
- ER2
- ER3
- ER4
- Muzzle Arc
- Energy Density
- EC1
- EC2
- EC3
- EC4
- EC5
- S1
- S2
- S3
- S4
- S5

Risk Matrix Analysis:
- Probability of Failure
- Consequence of Failure

Slide 38
ONR INP Phase 1 Objectives

- Traceability to 64MJ, 6-10 round / min indirect fire weapon system
- Bore Life
  - 32 Mega-Joule (Muzzle Energy) EM Lab Launcher
  - 10kg launch package; full muzzle velocity of 2.5km/sec
  - 20kg launch package with full current of ~5.5MA
  - Demonstrate more than 100 shot bore life
- Containment
  - 32 Mega-Joule Advanced Containment Launcher
  - 10kg launch package; full muzzle velocity of 2.5km/sec
  - 20kg launch package with full current of ~5.5MA
  - 1000+ round predicted containment structural barrel life
  - Design for thermal management at a rate of 6 round / min
  - Design launcher for minimal round dispersion
  - Transportable on pallets and/or in sea containers,
  - Consider marine environment
Bore Life Consortium

- Spans Basic Research to Full-Scale Demo’s
- Parallel development paths via multiple research sites
- Avoids Duplication
- Efficient use of test resources

- Supports both Navy and Army EM Efforts
- Government purpose data rights to permit competition during the acquisition phase.

Coordinated Development!
Bore Life and Containment

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase of Project</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Conceptual Design Trade Studies</td>
<td>7 mos.</td>
</tr>
<tr>
<td>Army Add</td>
<td>Trade Studies for Army Application</td>
<td>3 mos.</td>
</tr>
<tr>
<td>Option I</td>
<td>Technology Development and Preliminary Design</td>
<td>30 mos.</td>
</tr>
<tr>
<td>Option II</td>
<td>Detailed Design, Fabrication and Demonstration</td>
<td>29 mos.</td>
</tr>
</tbody>
</table>

Lab Launcher - EMTF

- Greenfarm 32MJ PPS
- 32MJ Lab Launcher for Bore Life

Advanced Containment Launcher
## Advanced Containment Launcher

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase of Project</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Conceptual Design Trade Studies</td>
<td>7 mos.</td>
</tr>
<tr>
<td>Army Add</td>
<td>Trade Studies for Army Application</td>
<td>3 mos.</td>
</tr>
<tr>
<td>Option I</td>
<td>Technology Development and Preliminary Design</td>
<td>30 mos.</td>
</tr>
<tr>
<td>Option II</td>
<td>Detailed Design, Fabrication and Demonstration</td>
<td>29 mos.</td>
</tr>
</tbody>
</table>

### General Atomics Team

- **Boeing**
- **L3 Communications**
- **SPARTA**
- **Jackson Engineering**
- **General Atomics**

### Northrop Grumman Team

- **DRAPER Laboratory**
- **CEM**
- **ATK**

### BAE Team

- **IAP**
- **BAE Systems**
- **SAIC**
- **EMD**
Projectile Concept Trades

Description of Effort
• Develop long range projectile concept
  – Lethal
  – Consistent with Navy CONOPS
  – Compatible with any EML gun development
• Identify critical development
  – GN&C
  – Aerobody (drag and thermal protection)
  – Launched survivability
• Produce a development plan

The Boeing AASP Team

Draper Team
Advanced Pulsed Power

• Rotating Machine
  – Watch Army Effort (Demo in FY08)
  – Navy Specific Critical Component Development

• Advanced Capacitor
  – Increased Energy Density
  – Thermal Management for Multi Shot Operation
Steel Muzzle Chamber Component

- Steel Muzzle Chamber
  - Mates to both SSG & Lab Launcher
  - Bolts to 1st Concrete Bridge Section
- Collar Plates Seal Gaps between Launcher & Chamber

Holes to Allow Bolting to Threaded Inserts Cast into Bridge Section (7/8"-9 Thread)

1"-8 UNC Grade 8 Grade 8 Bolts

1" A36 Steel Plate – Custom Made to Adapt to Each Launcher

1" A36 Steel Plate

8" x 6" x 1" Steel Angle
Vans on Van Pad

- Overflow Van
- VIP Van
- Control Van
- Storage Van

Pole with PTZ camera for Range Control
AH-1W M197/M89
ENVIRONMENTAL KIT

NAVAIR Medium Caliber Aircraft Guns
Robert Brewer 760-939-7696
NAWCWD China Lake, CA
OVERVIEW

• Background and Purpose of Kit
• Kit Description and Installation
• BTL Testing
• Flight Test
• Production
• Summary
BACKGROUND

- Dirt and rocks caused high amount of Gun/Feeder stoppages during Desert Storm, Somalia, OEF, and continues to be a problem during OIF.
- Rock/Dirt intrusion remains primary cause of degraded AH-1W Gun Systems in OIF, more than 60% of AH-1W’s have inoperable Gun Systems during Hi-Tempo Operations.
PURPOSE OF KIT

- Prevent rock/dirt/sand intrusion.
- Increase AH-1W Gun System reliability in austere conditions.
- Decrease maintenance man-hours.
- Increase Gun/Feeder service life.
- Regain Aircrew confidence in system.
DESCRIPTION OF KIT

• Covers most open areas on the Gun that are not required for operation.

• Consists of four stainless steel debris shields.
  – Rotor Cover
  – Housing Cover
  – Drive Motor Cover
  – Feeder Cover

• Requires a few consumables for mounting.
DESCRIPTION OF KIT
INSTALLATION

• Installed by O-Level in less than two hours.
• I-level tracking and procurement
• Does not affect current maintenance or operating techniques.
• Used as required in austere environments.
• Blade Tape used to cover remaining critical openings on the Gun and Feeder.
ROTOR COVER

• Rotor Cover mounts in the Main Bearing such that the holes in the cover are aligned with the barrel holes in the Rotor.
• The Cover is attached with 12 Bolts and 12 washers
• The Bolts are torqued to 250 - 300 in-lbs.
HOUSING COVER
HOUSING COVER

- Forward top mounts under Unlocking Cam safety wire.
- Forward sides mount over Gun Housing Bolts, retained by a washer and cotter pin.
- Aft sides are safety wired to aft Gun Housing alignment roll pins.
- Shield is flush with Gun End Plate Clamp.
- Fits all types of Gun Housings.
DRIVE MOTOR COVER

• Mounts under Drive Motor.
• Uses four screws and pre-existing unused threaded holes in Gun Housing.
• Molds against side of Gun Housing.
• Provides half inch of clearance for ejection of brass and live rounds.
FEEDER COVER

• Mounts to the Feeder using forward Mount Pin and Feeder Round Guide screw.
• Covers bottom of Gun Rotor Assembly.
• Extends upward and molded to cover side of Gun Housing.
• Grooved to clear the Feeder Sprocket.
• Does not interfere with ammunition feeding.
M197 BLADE TAPE
M197 BLADE TAPE
**M197 BLADE TAPE**

- Cut pieces to size, cover openings on lower Housing Assembly Elliptical Cam Path.
- Leave gap on bottom Elliptical Cam Path opening to allow lubrication and drainage.
- Cut pieces to size, cover lower Housing Assembly Clearing Cam Path.
- Placed tape over the opening above the main bearing, beneath the electrical contact and other unprotected areas on the upper housing.
- The opening between the feeder shield and the lower housing should be covered with tape.
M89 BLADE TAPE

- Six pieces, cut 1¼ square inch, covers six openings on Feeder Clutch Housing.
- A strip of tape should be placed behind the stripper gear on the clutch.
  - Covers critical Rotating Vane and Clutch Actuator that controls ammunition feeding to the Gun.
- Blade tape should be used on all openings on the back and side of the feeder.
BTL TESTING

• Sand and Dust Testing
  – Mil-Std-810
  – Schmidt 3.5 cu ft Sand Blaster at ~8 ft from Housing
    • >150 µm silica sand blown at 900 cfm with a concentration of up to 50 g/ft^3
    • Sand Blast environment was considered more harsh than reality
  – Dusted by hand prior to firing and from stand during firing
  – Thermocouple data taken
  – 500 baseline rounds, 1100 sand and dust rounds
Sand and Dust Results

- No temperature increase
- Dust related Jams reduced:
  - Single race bearing and seals
  - Additional Blade Tape
BTL TESTING

• Cold Test
  – Mil-Std-810
  – Low Temp Test (-50 deg F)
  – 24 hour soak
  – No adverse effect, 100 rnds fired

• Salt Fog
  – Mil-Std-810
  – 5% Salt Solution for 350 hrs including wet and dry cycles
  – Post rinse with deionized water
  – Minor gun maintenance followed by 100 rnds fired
FLIGHT TEST

• China Lake (VX-9)
  – 2 Flight days attempted firing appx. 180 rounds in dust conditions
  – Gun jammed; unrelated to Kit performance

• Yuma (MAWTS-1)
  – 2 Kits tested (1400 and 1100 Rounds)
  – Daily FARP and Dust conditions
  – Kitted Guns survived Sand Storm (Brown out) that incapacitated non-kitted guns
PRODUCTION

• ECP
  – First Article: 50 Kits, 10 Spares and 5 Trainers
  – Cost: ~$650/Kit
  – Production Drawings

• Manufacturing
  – 304 Stainless Steel Sheet w/ Black Oxide Finish
  – Hydroform For Housing Cover and Motor Cover
  – Stamping for Rotor Cover
  – Bending for Feeder Cover
SUMMARY

• The AH-1W Gun System is the ultimate defense for Aircrew flying combat missions. When operable, the system has multiple uses and is extremely deadly. The Environmental Kit will significantly increase the AH-1W Gun System reliability and reduce maintenance hours by decreasing Gun and Feeder jams caused by rock, dirt and sand intrusion.
QUESTIONS?
20mm LIFE CYCLE TESTS

Robert Brewer – NAWCWD China Lake
Bruce Richards – NSWC Crane
PURPOSE

• Tests were undertaken to simulate the environment seen by ammunition during normal operations in the field
  – Routine ammunition cycling through the LALS-II and M61A2 including upload/download and firing operations
  – Simulate mission sorties to 30,000 feet altitude
  – Ammunition aging

• Observe handling conditions that could potentially result in damaged ammunition and/or compromised seals
PURPOSE (cont’d)

• Investigate the impact of compromised seals on 20mm ammunition performance
• Determine if performance impacts could potentially cause gun system mishaps
• To establish accept/reject criteria for the use of 20mm ammunition under typical life cycle conditions
SCOPE

- External damage described in inspection criteria were addressed with primary interest in:
  - Leaking seals between case neck/projectile
  - Leaking seals between primer and case
  - Scratches and dents to case and/or projectile
  - Excessive wear to Lot identification markings

- Internal damage/deterioration of energetics were address by:
  - Ballistic testing for chamber pressure, action time and velocity
  - Chemical analysis of propellant and primer mix
SCOPE (cont’d)

- Simulate up to 10 upload/download cycles through the LALS-II loading system
- Simulate up to 4 upload/download cycles through the M61A2 gun system
- Simulate the firing cycle through the M61A2 gun system
- Simulate up to 15 mission sortie flights (Temperature, Humidity, Altitude)
- Simulate aging by artificial (accelerated) aging up to 3 months
TEST CONDUCT

- PGU-27A/B ammunition was the primary test ammunition, with M55A2 included for comparison/control purposes
  - 1500 rounds of pristine PGU-27A/B (Condition Code A)
  - 500 rounds of M55A2 (Condition Code C)
- All rounds received were inspected for
  - Dirt or corrosion
  - AUR lot number
  - Gap between nose cap and projectile body
  - Severe gouges, scratches, dents in case
  - Primer Seating
  - Loose projectile or case neck gaps
TEST CONDUCT (cont’d)
Cycle Test

• Rounds were divided into test lots (PGU-27A/B/M55 mix) to include
  – Control lot (Lot A)
  – Temp/Humidity/cycling only (Lot B)
  – LALS-II cycling only (Lot C)
  – LALS-II/gun cycling at 400 spm rate (Lots D-H)
    • Cycle included loading of the LALS-II using hand crank (up to 4X), upload from the LALS-II to the M61A2 at 400 spm, download from the M61A2 into the LALS-II at 400 spm and unloading the LALS-II using the hand crank.
  – LALS-II/gun cycling at 6000 spm rate (Lots I & J)
# PLANNED TEST MATRIX

<table>
<thead>
<tr>
<th>Test Lot</th>
<th>PGU-27A/B</th>
<th>M55A2</th>
<th>Total</th>
<th>Cycled</th>
<th>No. of Cycles</th>
<th>THA Cycled</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>75</td>
<td>25</td>
<td>100</td>
<td>No</td>
<td>0</td>
<td>No</td>
<td>Control</td>
</tr>
<tr>
<td>B</td>
<td>75</td>
<td>25</td>
<td>100</td>
<td>No</td>
<td>0</td>
<td>Yes</td>
<td>Control</td>
</tr>
<tr>
<td>C</td>
<td>1200</td>
<td>400</td>
<td>1600</td>
<td>Yes</td>
<td>-</td>
<td>Yes</td>
<td>LALS-II only</td>
</tr>
<tr>
<td>D</td>
<td>1125</td>
<td>375</td>
<td>1500</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>One Cycle</td>
</tr>
<tr>
<td>E</td>
<td>900</td>
<td>300</td>
<td>1200</td>
<td>Yes</td>
<td>2</td>
<td>Yes</td>
<td>Two Cycle</td>
</tr>
<tr>
<td>F</td>
<td>675</td>
<td>225</td>
<td>900</td>
<td>Yes</td>
<td>3</td>
<td>Yes</td>
<td>Three Cycle</td>
</tr>
<tr>
<td>G</td>
<td>450</td>
<td>150</td>
<td>600</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>Four Cycles</td>
</tr>
<tr>
<td>H</td>
<td>225</td>
<td>75</td>
<td>300</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>Control</td>
</tr>
<tr>
<td>I</td>
<td>75</td>
<td>25</td>
<td>100</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>6000spm clearing cycle</td>
</tr>
<tr>
<td>J</td>
<td>75</td>
<td>25</td>
<td>100</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>6000spm drum only</td>
</tr>
</tbody>
</table>

Note: The table provides a summary of the planned test matrix for different test lots, indicating the number of cycles for each test condition and whether the THA was cycled.
TEST CONDUCT (cont’d)

Cycle Test

• Goal was to cycle rounds in various handling scenarios until seals were compromised (75-80%), as determined through vacuum/water leak tests.

• Rounds completing each phase of cycling were inspected for physical damage, marked with indelible ink and a random sample of 10 rounds were checked for broken seals using the vacuum/water test chamber.
VACUUM LEAK TEST CHAMBER
LALS-II LOADING TRANSFER UNIT
LALS-II LOADING TRAY
LALS-II
M61A2 WITH LALS-II ATTACHED
M61A2/LALS-II CYCLING
RESULTS OF CYCLE TESTS

• After cycling through the LALS-II and the M61A2 gun at 400 spm rate up to 4 cycles (Lots C-H)
  – 0 to 20% Leakers only
  – No Loose Projectiles were detected by hand twisting
  – Minor scratches and dents were present
  – Many AUR Lot Numbers were illegible after only 3 cycles
RESULT OF CYCLE TESTS (cont’d)

• Test Plan was modified to increase the number of test rounds used for 6000 spm cycle tests. Increased the total rounds for Lots “I” & “J” to 200 PGU-27A/U and 70 M55A2 each.
  - Lot “I” - added 125 PGU-27A/U from Lots “D” & “E”
    - added 45 M55A2 from Lots “D” & “E”
  - Lot “J” - added 125 PGU-27A/U from Lot “D”
    - added 45 M55A2 from Lot “D”
RESULT OF CYCLE TESTS (cont’d)

• Lot “I” (cycled through gun clearing cycle) at 6000 spm-
  - 60% loose projectiles (hand twist) plus scratches and dents

• Lot “J” (cycled through magazine drum and chuting only) at 6000 spm–
  - No loose projectiles with minor scratches and dents
HAND TWIST NOT A RELIABLE TEST FOR FINDING LEAKING PROJECTILE SEAL

• Lot “I” – Random sample of 10 PGU-27A/B = 100% leakers by vacuum/water test method also indicated 100% loose projectiles by hand twist method.

• Lot “J” – Random sample of 10 PGU27A/B = 20-50% leakers by vacuum/water test method but checked O.K. by hand twist method.
RESULT OF CYCLE TESTS (cont’d)

• Very few leakers (<20%) observed (at 400 SPM rate) after:
  -11+ cycles through LALS-II
  -4 cycles through M61A2 gun
• 540 rounds cycled through gun and/or drum at 6100 SPM rate
  -All rounds that went through the gun had broken seals
  -Some (20 to 50%) that went through the drum only, had broken seals.
1.5 METER DROP TEST (PGU-27A/B)

• Dropped nose down
  – 7 out of 10 had projectile/case neck leaks as indicated by vacuum/water test method.

• Dropped 45° nose down
  – 10 out of 10 had projectile/case neck leaks as indicated by vacuum/water test method.
AGGRESSIVE LALS-II DOWNLOADING

- 100 rounds of PGU-27A/B with intact projectile seals (vacuum/water leak checked) were subjected to aggressive downloading by rapid hand cranking of the LALS-II and letting the ammunition fall into ammunition cans on the floor.
- After one cycle – 7% were leakers by vacuum/water test
- After two cycles – 25% were leakers by vacuum/water test
AGGRESSIVE LALS-II DOWNLOADING

LALS II REPLENISHER DOWNLOAD
CONCLUSIONS (Cycling Tests)

- Loading and downloading using a properly functioning LALS-II does not break case neck seals
- Cycling through the drum magazine at rate may break seals
- Cycling through the gun at rate does break seals
- Dropping ammunition does breaks seals
- Aggressive downloading can break seals
TEST CONDUCT (cont’d)
THA Testing

• After all cycling through the LALS-II/M61A2 gun were complete, the test ammunition was shipped to the test contractor for temperature, humidity, altitude cycling.

• THA cycling was conducted at National Technical Systems, Camden, Arkansas
AMMUNITION IN ALTITUDE CHAMBER
TEST CONDUCT (cont’d)
THA Testing

• THA conditioning of three test groups
  – Test Group #1 – 5 altitude cycles
  – Test Group #2 – 10 altitude cycles
  – Test Group #3 – 15 altitude cycles

• Temperature cycled from 90º F and 85% Humidity at ambient pressure to-
  • -37º F at simulated 30,000 feet altitude

• Two hour ramp up time
• Two hour dwell at set conditions
TEST CONDUCT (cont’d)
Artificial Aging

• After completion of THA cycling, the test ammunition was shipped to NSWC, Crane, for artificial aging, chemical analysis and ballistic testing.

• The purpose was to investigate the impact of THA cycling combined with Artificial Aging on rounds with compromised seals for ammunition performance degradation.
ACCELERATED AGING

• 160° F Storage for the following periods:
  - 2 days, 1 week, 2 weeks, 1 month,
    2 months, 3 months
• Sample rounds were inserted into aging chamber at appropriate staggered intervals in order to remove all rounds at once for chemical analysis and ballistic testing.
TEST FLOW FOR ROUNDS WITH BROKEN SEALS
CHEMICAL ANALYSIS

• Heat Flow Micro-Calorimetry
  – Shelf life comparison between control lot and broken seal lot

• High Performance Liquid Chromatography/Gel Permeation Chromatography
  – Propellant condition/degradation

• Karl Fischer
  – Moisture content of propellant and primer mix

• Differential Scanning Microscopy
  – Degradation in primer output
BALLISTIC TESTING

• Single shot Mann Barrel testing for:
  - Peak case mouth pressure
  - Velocity
  - Action time
Develop and Demonstrate Critical Technologies for Bridging the Gap Between the Initial C-RAM Capability and the Objective EAADS Capability for Providing Mobile, 360-Degree Hemispherical Extended Area Protection from RAM Threats
Defeat RAM Aerial Threat Targets

- Small Presented Areas
- Low RCSs
- Thick, Hard Warhead Cases
- Short Times of Flight
- High Rates of Fire
- Dual Purpose Improved Conventional Munitions (DPICMs)

Target List

- Mortars: 60 mm – 120 mm
- Rockets: 107 mm-240 mm
- Artillery: 122 mm-152 mm
EAPS Baseline Concept

- 50mm Bushmaster Cannon
- RF Data Link
- Radar Track
- 10 Round Burst
- Forward Fragmentation Warhead Detonation
- Mid-Flight Course Correction
- 50mm Course Corrected Projectile
Goals and Objectives

By the end of FY08 Demonstrate:

- EAPS 50mm Automatic Cannon on Hardstand Mount
- 50mm Lethality Round
- 50mm Course Correction Round
- ATS Radar Integration for Tracking and RF Communication
- Component Level Tests to Demonstrate Fuzing, Warhead Lethality, Course Correction and Engagement Accuracy Against Static Targets

Continued Systems Analysis to Validate the System Level Effectiveness

Transition to Follow-On System Integration Development
The Gun as Part of a Gun/Missile Solution

- Short Range Lethality
- Fast Reaction Time
- Low Cost per Kill
- Engagement of “Leakers”
- Advanced Ammunition Tailored To the Threat

Cannons Complement Missiles Well in Terms of Range, Reaction Time and Cost per Kill - Complementary Solution may be Best
50mm Bushmaster Cannon

- Hybrid Bushmaster Cannon
- Accommodates EAPS 50mm Caliber Cartridge Length
- No New Development Required
- Twin Guns in Common Turret

50mm Bushmaster Specs
- Caliber: 50mm
- Cartridge Length: 538mm (21”)
- Firing Rate: SS/200 spm
- Weight: 510 lbs
- Recoil Force: 14,000 lb
- Power Req’d: 3 HP
- Manufacturer: ATK MCS, Mesa

BMIV AFT RECEIVER with BMIII BREECH & FWD RECEIVER

Twin 50mm Cannons in EAPS Turret
• Truth Radar for C-RAM
• Very, Very Accurate
• Can Provide Tracking and Communication for Divert, Detonate and Telemetry
• Transceiver can Miniaturized for 50mm EAPS Projectile
• Tracks Multiple Incoming Targets and Outgoing Interceptor Munitions Simultaneously
Tactical Configuration

- Primer
- Black Powder
- Tail Fins
- Propellant
- Electrical connector
- Battery
- Control Electronics
- Thruster Port
- Thruster Propellant
- Projectile case
- Rotating band
- Cartridge case
- Explosive
- Forward Fragmenting Warhead
- Antenna
Baseline Design:

- **Multiple Explosively Formed Penetrator (MEFP) Warhead**
  - Use of existing technology
  - Form a low weight frag with high expulsion velocity
  - Single or Multiple Warhead Liners
  - Design EFPs to have a fixed dispersion pattern size

Alternative Design:

- **Directional Fragmenting (DiFrag) Warhead**
  - Leverage off the 120mm LOS-MP Warhead Technology
  - Release a low weight Pre-form frag with high expulsion velocity
  - Array of high-density tungsten frags in a matrix material
  - Design Warhead to have a fixed dispersion pattern size

- **Potential Upgrade to enhance lethality**
  - Use of **Reactive Materials**
  - Encapsulate into a hollow Tungsten-preform
  - Adds Chemical Energy to propagate deflagration of Threat
Advanced Technology Demonstrator (ATD) Program (FY09-FY10)

• Planned Activities
  - Integrate Course Correction and Warhead into a single EAPS Projectile
    • Introduce a electronic self-destruct capability to the EAPS Projectile
  - Develop a Prototype Autonomous Turret
    • Turret and Weapon elevation Drives
    • Link-less Feed System
  - Integrate the ATS Radar and Weapon Fire Control
  - Demonstrate a functional weapon system on an existing platform (LAV, BFV, or MLRS) against a dynamic RAM Target

Twin 50mm Cannons in EAPS Turret
Summary

• EAPS is a Challenging Program
• Offers High Payoff
• Best “Team” Formed
  – Joint Government/Industry IPT
    • ATK Advanced Weapon Systems
    • ATK Medium Caliber Systems
    • ATK Launch Systems
    • Arrowtech
    • Technovative Applications
• Course Correction and “in-Flight” ATS Radar Data Link are “Break-through” Technologies
• If We are Successful, a Follow-on Integration Development Effort for FY09-FY10 is Likely
Notational EAPS Weapon Platform
Gun and Missile Systems

National Defense Industrial Association (NDIA)

Armament Division

2007 Division Status

23-26 April 2007
The Links – Who, What, Why

National

- All services
- Industry
- Jointness
- International

Defense

- Worldwide Threats
- Homeland Defense
- Readiness
- Technology and Operational Superiority

Industrial

- Industry Organization
- Spokesman for Industry
- Resources
- Capability/Readiness

Association

- Visions
- Innovative Solution
- Communication
- Sharing
- Jointness
- Linking Government and Industry

An Organization Ensuring Strength Through Industry and Technology
NDIA Missions

• **Advocate**: Cutting Edge Technologies, Superior Weapons, Equipment, Training, and Support for America’s 3 and First Responders

• **Promote**: Responsive and Vigorous Government-Industry National Security Team.


**Organization Objective**: Provide “Value Added” Symposiums and Activities Ensuring Mission Objectives
NDIA Focus → Responsive to Industry/DoD Community → Ensures Relevance

Addressing Issues Critical to Guns and Ammunition, Missiles and Rockets Systems

Armament Division Focus—“Value Added” Activity
• Expanded participation
• Resource for government and industry
• Linked to key DOD and service strategies
• Capture “lessons learned” → ensure readiness → shape future
• Encouraging leverage of complementary systems
• Effective use of exhibits, demonstrations, and tours

Establishing Vision for 21st Century Relevance

Addressing Transformation—Ensuring Readiness
Objective: Coordinated Focus and Vision for Armament Systems

Armaments Division

- Small Arms Systems
  - Brian Berger

- Gun and Missiles
  - Mike Till

- Future
  - TBD

Committees

Responsive Organization – Ensures Relevance
Scope – Area of Interest – Responsibility Definition Clarity
Establishing and Ensuring Strategic Focus

Themes, areas discussed; no specific action
Symposium Attendance Realizing Growth

• Gun and Missile Systems
  Attendance---350-500 in last 5 years

• Small Arms Systems
  Attendance—400-550 in last 5 years

  Expanded Participation

  Strategic Focus

  New Attendees and repeat attendees

  Growth of Exhibits

  Continued International participation

  • Interest and Activity Strategically Focused
  • Armament Division meets Needs of Government and Industry
## Committee Scope

### Small Arms Systems
- Individual weapon(s)
- Crew served weapon(s) (e.g., ≤ 40mm)
- Lightweight Systems
- Ammunition
  - Enhanced/lightweight
  - "Green"
- Full life cycle management
- Supportability
  - Training
  - Logistics
- Target Acquisition/Fire Control System (TA/FCS)
- Remote Stabilized Turret System
- System Integration
- Networked capabilities
- Non lethal
- Homeland Defense systems

### Gun and Missile Systems

#### Guns and Ammunition
- Medium caliber systems
- Tank systems
- Mortar systems
- Artillery systems
- Naval gun systems
- Aircraft/helicopter systems
- Precision systems
- Platform Integration
- Manned/robotic applications
- System integration
- TA/FCS
- Supportability
- Life cycle management
- Stabilized Turret System

#### Missiles and Rockets
- Tactical missiles and rockets
- Shoulder Fired Systems
- Ground launched
- Aircraft/helicopter launched
- Precision Systems
- System Integration
- Manned/robotic applications
- Life cycle management

### Links to Other Committees
- Common Enabling Technologies, Modeling/Simulation, Man-Tech

### Synergism ➔ Commonality
2007 Symposium

Meeting Warfighter Needs for the Asymmetric Threat

Addressing the Theme!

- Joint Capability
- Joint Requirements
- Readiness Capability

Applying Common Advanced Technologies and Integrated Systems

- Capability focused complementary integrated systems
- Strengthening Legacy Systems while evolving “new”
- Address key force multipliers
  - Precision
  - Mobility
  - Communication
- Planning and implementing Spiral Development
- Building on “lessons learned” for future readiness
  - Priority to supporting the Warfighter
- Ensuring responsive industrial base capability
- Attention to life cycle management

Enabling an Integrated and Responsive Joint Force Capability
Meeting Warfighter Needs for the Asymmetric Threat

- Understanding the Need
- Joint Requirement(s)
- Requirements Pull
- Technology Push
- Readiness/Capability/Responsiveness
- Direct Integration
- System Integration Adaptations
- Spiral Development
- Supportability

- Threat Specific Solutions vs. Capability Driven and Adaptable
- Operational Flexibility and Responsiveness
- Industrial Base Readiness
- Spiral Development

Response to Symposium Theme
- Adaptable, Innovative, Visionary, Capability Focused
Vision: Readiness for Today and the Future

Joint Services: Defining and Executing the Change
Industry: Ensuring Technology and Product Availability – Evolution

Asymmetric Threats

Joint Operations

Joint Requirements

Transformation Initiative

Simultaneously
Changing the Force
Responsiveness – Technology – Capability
and
Maintaining Readiness of Existing Forces

Readiness

Industry Responding to Joint Force Needs
Meeting the Needs of Our Joint Ground Forces in the Fight Against Terrorism

Address and Focus on the Theme

DoD and Homeland Defense Capabilities

- Joint Force operations and capability
- Response to asymmetric threats
- Adapt systems and technology for operational flexibility — Jointness
  - Responsiveness
- Push technology envelope(s)
- Push integration efficiencies
- Add functional capabilities
- Introduce new systems
- Ensure readiness and capability

“Lessons Learned” — Readiness/Capability — Responsive Force — Jointness — Technology Change

Shape the Future — Enable the Force
Armament Division Success

Guns and Ammunition/Missiles and Rockets

Value Added Has Been Demonstrated

Leadership to Strengthen the Armament Community

Challenge: Applying Technology, Systems for Future Force

Ensuring Readiness . . . . Responding to the Challenge Advancing Superior Capability

Symposium Benefits Confirmed

“Value Added” – Strategic Focus
2007 Armament Division Highlights

- Symposium Attendance Strong and Growing
- Symposium Exhibits Effective and Quality Enhanced
- Attention to Strategic Focus Topics Enhances Effectiveness
- Executive Committee activity strengthened an increased
- Government and Industry Partnership in Division leadership demonstrated

Armament Division leadership strength enables strategic focus to address current and future needs
Armament Division Strategic Focus

- Strategic Focus Request from NDIA Board of Directors

- Strategic Focus Purpose--- Ensure NDIA Missions are Achieved
  - Advocate
  - Promote
  - Provide

- Strategic Focus Armament Division Response ---
  - Input from each Committee
  - Topics Addressing Armament Division Effectiveness Submitted

- Strategic Focus Benefits—
  - Committee Action to Implement Changes –
  - Committee Mission Focused to Specific Actions for Armament Community
NDIA Missions

• NDIA Missions Shape the Strategic Actions of All Divisions

• Mission Statements

  – **Advocate**: --Cutting Edge Technologies, superior weapons, equipment, training, and support for America’s Warfighter and First Responders.

  – **Promote**: --Responsive and Vigorous Government—Industry National Security Team

  – **Provide**: --Forums for Exchange of Information Between Government and Industry on Matters of National Security
Armament Division

• **Strategic Focus Topics Addressing Armament Division**
  – Relevance to Current and Future Capability
  – Strengthening the Industrial Base
  – Building a Team—Government and Industry
  – Promoting Communication with “Value Added”

• **Linked to NDIA Mission Statements**
  – Advocate
  – Promote
  – Provide
Armament Division

• **Focus Area/Objective:** Establish a Mentor/Protégé relationship throughout the Armament Division --- Industry and Government to ensure succession planning and technology/experience transfer in all aspects of defense business and in conduct of NDIA committee operations.

• **Narrative:** There has been much discussion regarding the decline of the workforce and the emerging shortage of technical staff. One component of this consideration is the mentoring of the new to ensure transfer of technology and experience thus supporting succession planning. The committees Executive Committees can be used as a resource for mentor/protégé of the NDIA--enabling an effective transition of the organization. This should be structured with the thought of moving the process into the industry members and later into the government agencies.
Strategic Focus Topics

1. Ensure Understanding of **NDIA Role, Mission, and Benefits**

2. Establish **Mentor Protégé** Relationships

3. Ensure **Symposium Theme** flows throughout the Program

4. Address Symposium Content which will **“Impact”** Programs, Technology, and Approaches

5. Increase **Industry Leadership** in Symposium Presentations

   *Increase Industry Communication of Innovation etc.*

6. Enhance **Symposium Quality** Thru Innovation and Intra-Divisional

   Teams—Sharing Ideas and Approach
7. Establish Executive Committee **Focus Subcommittees** for Selected Technologies/Systems or Priority Topics.

8. Address **Industrial Base Readiness** for Transition to Reduced Level of Activity—And Readiness for the Next Event

9. Expand **Emphasis of Platforms, Systems Integration and Enabling Technologies** in the Armament Division Programs

10. **Other Topics** to be Addressed by Executive Committee
    - Executive Committee Initiatives
    - Symposium Attendee Initiatives/Suggestions
    - Requests from NDIA
    - Requests from DOD/Agencies
Executive Committee Improvement Topics

1. Clarify **Caliber and System Responsibility** of Gun and Missile Committee vs. Small Arms Committee

2. Address **Integration of Precision Strike** Component of NDIA

3. Increase **User Community** Involvement

4. Address Symposium **Presentation Quality**

5. Address **Symposium Presentation Mix** – Industry vs. Government and type of Presentations—Requirements, Acquisition, Platforms, Systems, Technology, Industrial Base etc.

6. Improve “Value Added” of **Keynote Speakers**
7. Include **Requirements Segment** in All Symposium Programs

8. Capture and Address **Attendee Suggestions/Recommendations**

9. Expand Use of **Panel Discussions**

10. Utilize **New Formats** for Presentations and Consider “Kiosk” Approach for Additional Papers.

11. Link **Exhibits** to Theme – (If practical and Affordable)

12. **Executive Committee** Structure and Operation

13. Conduct **Special Studies**

14. Add **New Committee** (e.g. Integration Focus, Precision etc.)
Armament Division Strategic Initiatives

1. Armament Division— **Strategic Focus** based on Committee Input

2. Monthly **Division Chairman Telecoms**—Plan Improvement

3. **Executive Committees** Identifying and Addressing Focus Areas
   - Strategic Focus Topics
   - Committee Initiatives
   - Symposium Input and “Lessons Learned’
   - Response to DOD or Agency Requests

4. Requesting Symposium **Attendees Communicate/Share Ideas**, Suggestions, Concerns, Topics etc.

5. Goal to Not be Static Organization— **Change to Address Relevant Topics and Interests.**
1. **Ensuring Capability** for the Warfighter
   - Current Systems
   - Refurbishment/Repair – Industry and Depot Responsiveness
   - Expendables
2. Responding to **Urgent Technology/System Needs**
   - “Lesson Learned” Responses
   - Adapting to Asymmetric New Threats and Conditions
3. Maintaining and Adapting the **Industrial Base**
   - DOD Organic Base
   - Industrial Base
4. Establishing and Transitioning **New Technology and Systems**
   - Requirement Process Effectiveness
   - Program Decision Milestones
   - Schedules/Spiral development and Technology Insertion
   - Funding
5. **Understanding** Budgets and Funding  
   Shaping Development Plans leading to New Systems  
   Maintaining Production to ensure Readiness  
6. **Addressing** Acquisition Change Considerations  
7. Transitioning the Workforce  
   Attention to DOD Technical Manpower Study  
   Mentoring effectively  
   Enabling the entry Workforce  
8. Evolving New Technology To Readiness for System Applications  
   Understanding the Need  
   Technology Insertion — Insertion Before the Next Technology  
   “Maintaining Innovation” thru effective Industry and Government investments  
9. Maintaining Technical Data Packages (TDP’s) vs. Performance Spec and consideration of Intellectual Property etc.
2007 Top Defense Issues

- Issue 1: Maintain Integrity---Responsiveness of Acquisition Process
- Issue 2: Promote Defense Workforce Sustainability
- Issue 3: Invest in Defense Industrial Base Technology to Support Warfighter and Maintain Readiness
- Issue 4: Improve Small Business Utilization
- Issue 5: Preparing for Transformation
- Issue 6: Ensure International Competitiveness of US Industry

NDIA Board of Directors Approved Focus
NDIA Focus Issues to Congress
Objective: International cooperation and integration of symposiums benefiting industry and Department of Defense to encourage partnerships for development, production, and interoperability

Approach:
- Coordination of NDIA Armament Division programs with “Symposium at Shrivenham” The Royal Military College of Science
- Common presentations and panel participants is a strong “open door” resource

European Small Arms and Cannon Symposium
August 2007
NDIA Communications

• National Defense Magazine
  – Emphasis on relevant and timely topics
  – Frequently source of media, DoD, and Congressional reference

• Website
  – Symposium presentations available — attendee access
  – Complementary information
  – Full list of activity

• Top public policy issues — prioritized — addressed to Congress — strengthen the community
Armament Division 2007 Challenges

• Ensuring Focus on NDIA Mission Statement

• Addressing Armament Division Strategic Focus Topics
  • Enhancing Membership “Value Added”

• Capturing Symposium Attendee and Membership Topics of Interest in Programs and Activities

• Ensure Membership Awareness of Top NDIA Congressional Issues and Impact

• Seek Symposium and Related Activity which Impact Capability and Responsiveness
Take-Away Thoughts

• NDIA is strong and valuable
  – Resource use enables timely/responsive solutions
• Armament Division has Strategic Focus — Implementing Objectives
• Multi-discipline capability links NDIA Divisions
• Listen to “lessons learned” and jointly enable readiness capability
• Commitment to “value added” changes
  – Strategic Focus Initiatives
  – Understanding of Responsiveness Issues
  – Emerging Changes in Acquisition
  – Attention to Industrial Base Readiness Needs
• Attendee participation/input strengthens organization

Executive Committees Impacting Activity
Strategic Focus Changes
Ensuring “Value Added”
Strategic Focus Emphasis

• Effective **Communications and Links** Across Government and Industry

• Ensuring **Innovation** in Technology and Systems

• Strengthening the **Industrial Base** —Recognizing the Need

• Building an **Integrated Team** —Industry and Government

• Promoting Communication with **“Value Added”** Content
Leadership Vision

NDIA Armament Division Is:

• A relevant voice and forum
• Meeting NDIA Mission Statements with Strategic Focus
• Responsive to DoD community and industry challenges
• A forum for DoD/industry interaction discussion of “lessons learned” and needs
• Supporting national defense through people resources, networking, and symposiums
• Transforming to ensure relevance to changing military, geopolitical environments, technology, and industrial base resources

The NDIA Community is the Resource of Choice For Excellence in National Defense Topics/Communications
NDIA Division Focus Areas
For 2007
Armament Division

12 March 2007

Prepared by:
Dave Broden
Division Chairman

Contributors: Mike Till—Guns and Missiles
Brian Berger—Small Arms
Committees

1. Guns and Missiles --- Mike Till  Chairman

2. Small Arms Systems --- Brian Berger  Chairman
• **Focus Area/Objective:** NDIA Division Executive Committee understanding of NDIA Mission and Purpose

• **Narrative:** Division/Committee Executive Committee Members do not have a clear understanding of the mission, purpose and objectives of NDIA. As a result the committee activities are not consistent with the Advocate, Promote, Provide themes. As a result the committees provide programs only without the thought of impact to the industrial base and/or providing capability to the warfighter. Armament Division is seek to discuss this at each committee meeting. Executive Committee members must become more than meeting planners they must be ambassadors for the NDIA and its mission in all respects.
Focus Area/Objective: Ensure Symposium theme is reflected in the program content.

Narrative: Many Symposium reflect the mission of the Committee but not the theme established by the committee. This is often driven by the “call for papers” process which identifies papers which are very general. A more disciplined process linked to the theme and requiring that the executive committee members “force” the issue to the theme is under discussion. Committee must become leaders and trend setters not just planners.
• **Focus Area/Objective:** Include Symposium Content that will “Impact” Programs, Capability, Resources not only Report Status.

• **Narrative:** Symposium often focus on reporting what has been going on or what is going on rather than making statements or presentations which offer change or capability which will impact how programs or capability is achieved. NDIA is the key format to have this “open” dialogue of what is needed to “impact” program etc. We are discussing how to effectively include this element of program content.
• **Focus Area/Objective:** Ensure Armament Division Symposium have a Strong Industry and Industrial Base content vs. focus on government activity

• **Narrative:** Armament Division Symposium have seem a decrease in industry focus and presentation participation while government papers are increasing. As the “I” in NDIA states the organization is to promote the Industrial Base—a plan and thrust to return to communicating the innovative and resource readiness activity of industry is evolving.
• Focus Area/Objective: Symposium Content and Quality Enhancement thru Intra-Divisional Innovation Teams

• Narrative: The two committees of the Armament Division—Small Arms and Guns and Missiles have agreed to for cross committee working groups of 2-5 Executive Committee personnel to address topics with objectives to address improvement or changes in the format and content of the Division Symposia. This is underway.
Focus Area/Objective: Executive Committee Focus Subcommittees to ensure in-depth presentations on priority topics

Narrative: There is a recognized need for the Executive Committees to seek and obtain presentations for symposiums on high priority topics and trends. To address this executive committee subcommittees of 3-5 members will focus on a particular technology, system, or topic and ensure in-depth symposium content.
Armament Division

• **Focus Area/Objective:** Armament Division Industrial Base Readiness for transition from war to peace capability—discussion of what should be the industry response.

• **Narrative:** The products, technology, and systems of the Armament Division are uniquely sensitive to volume capability. There is a need to provide a forum addressing the downturn and how Industry should prepare for it and when. This NDIA activity should reach across multiple divisions.
• **Focus Area/Objective:** Including System Integration and Enabling Technologies in the Armament Division Symposia is often overlooked—expanded emphasis is a focus need.

• **Narrative:** Armament Systems require attention to System Integration (platforms, fire control, feed and storage, logistics etc.) and also specific enabling technologies. Industry has significant technology and innovation to support this system focus. The Executive Committee is seeking to strengthen the links to these areas in Executive committee membership, presentations, and participation.
• **Focus Area/Objective:**

• **Narrative:**
Symposium Observations

Linking NDIA and DoD Realized

• Improved links to DoD and service thrusts and initiatives
• Interest in “after action reports” — “lessons learned” → industry responsiveness → addressing challenges

Symposium Quality and Communication Demonstrated

• Presentation quality improvements and “So What” benefit messages have added value
• Focused interest in systems level presentation vs. technology unless technology offers payoff vision
• Industry adjusted to intellectual property concerns and expanded participation positively
  – Industry worked with vision
Ensuring Relevance

- Evolve executive committees
  - Integrate relevant organization(s) for future
    - Industry
    - Government
- Improve division charters to ensure relevance/clarity
- Symposium themes
  - Future “vision” focus
  - Emphasize Readiness topics
- Symposium content
  - Focus on “Value Added” for attendees
  - Emerging technology and capability
  - Panels
  - Interactive format
- Attendees
  - Participation is growing resource

Armament Division is Key to Current and Future Force Capability
1. Focus on relevant and “value added” topics
2. Solid links to Transformation and future topics
3. “Lessons learned” and “after action reports” input shapes the future
4. Recognition of need to address industrial base readiness — capability — responsiveness—capability today and the future
5. Executive committees focused to objectives
6. National Small Arms Center established/operational
   – 50+ companies
   – Program planning addressing GAPs in-process
   – Procurement activity realized
     Budget process moving forward effectively
7. Continued panel discussions focus to key interest topics
8. Recognized forum for business/technology “networking”
2007 Armament Division Highlights

• Leadership for National Small Arms Consortium and Center Executive Committee
  Research Committee and Subcommittees
• Participation in Industrial Base Status and Needs Briefings
  Communication of Situations, Changes and Actions
• Armament Division Executive Committees demonstrated Leadership
  Multiple Meetings
  Expanded Participation
  Shaping the Future
• NDIA Armament Division Contacted by Government and Industry for expertise to address specific needs---
  Talent and Experience benefited specific activity
Committee Structure

**Gun and Missile Systems**

- **Guns/Ammunition Focus Subcommittee**
- **Missiles and Rockets Focus Subcommittee**

Chairman, Mike Till

*May be 1 or 2 subcommittees

Organization Focuses on **Commonality** and **Synergism** and Provides **Links** to the Two Components
Committees were

Guns and Ammunition

Missiles and Rockets

Committee is

Guns and Ammunition, Gun and Missile Systems

Benefits Realized

1. Commonality NDIA membership
2. Leverages convergency of technology and systems
3. Stimulates discussions — dialogue
4. Symposium attendance efficiency (one vs. two meetings)
5. Brings separate communities together for common purpose

Symposium Interest, Attendance, and Dynamics Enhanced
2006 Top Defense Issues

• Issue 1: Sustain the Defense Industrial Base
• Issue 2: Sustain Overall Military Readiness While Continuing the Global War on Terrorism and Preparing for Future Defense Transformation
• Issue 3: Improve the Integrity and Responsiveness of the Acquisition Base
• Issue 4: Improve Small Business Opportunities
• Issue 5: Strengthening the National Security Workforce

NDIA Board of Directors Approved Focus
Established by Government Policy Advisory Committee
Look to Web Site for Full Details
These Issues are NDIA Membership Voice to Congress
Guns and Missile Symposium
2007
23-26 April 2007

Requirements and Trends
Observations
For
Consideration
• Presentation Content and Comments are the Opinions of the Presenters: Dave Broden and Bob Glantz

• The Opinions Expressed do not Represent the Position of NDIA, any Company, or any DOD component.

• This Presentation is Intended to Stimulate Discussion of How Programs and Technology are evolving to Ensure Superior Capability to the US and Allied Armed Forces.
  • Program Structure—Roles--Responsibility
  • Program Schedule
  • Acquisition Management Approach
    Contract Type
    Risk Management Responsibility
Trends Requirements & Contract Reform

• Requirement Approach Shifted in 1980’s thru early 2000’s:
  – from Detailed Specific Design and TDP focus
    - Wills and Shalls
    - Build to print
  – to Performance Specifications and Criteria
    - Key Performance Perimeters
    - Threshold and Goals
• Both Contractor and Government Gain by Using Performance Specifications which allow Rigorous Trade-Off of Design and Performance—
  • Requirements viewed as Thresholds and Goals
  • Allows for Best Value
  • Allows for Spiral Development, Technology Insertion, and Pre-Planned
System Management Trends

• Requirement Approach Shifted in 1980’s thru early 2000’s:
  – From: Government as System Integration Manager with
    - One Major integration contractor
    - Government Providing Major Sub Systems as GFE/GFM
    - Government conducting Sub System and System Testing
  – To: One Face to the Government Program Office
    - Corporate Contracts
    - Lead Systems Integrator
    - Ship Yard Manager
    - Contractor providing Certification
    - Purchase of Off the Shelf Items against Performance Specifications
What did not change

• Laws established by Congress after World War II
  – 2 page letter contract for Liberty Ships
  – Support the Depot System
  – And Others

• Federal Acquisition Regulations (FAR’s)

• Department Of Defense Acquisition Regulations (DAR’s)

• Individual Service Supply & Support Directives and Requirements
Current Trends

- Recent trends seem to be moving:
  - Away from:
    - Performance Specifications
    - Lead Systems Integrators
  - Back toward:
    - Technical Data Packages procurements
    - Requiring a complete set of drawings.
    - Service Unique Technical Manuals
Issues

• Requirements Definition
  – Clarity
  – Creep
  – Responsive to Rapid Response Needs
  – Intellectual Property

• Technology Change Rate Before Product Completion
  – “Moores Law”---How can a Product be Realized –Timely

• Contracting Structure

• Contracting Type

• Funding Anticipated Decline

• Risk Responsibility—Industry vs. Government vs. Shared
• Establish Acquisition Management Focused to “Results” with a Rigorous “Process”
  • Timely Integration of New Technology and Systems

• Ensure Utilization of “Lessons Learned”
  • Subject Matter Experts
  • Prior Program Life Cycle (Pros—Cons)
  • Acquisition Process Changes

• Maintain Performance Specification Concept and Incentives
  • Ensure joint Government and Industry SME’s

• Maximize Incremental Performance Growth —Threshold, Goals, Spiral Development, etc. ----Minimize time to Deploy

• Maximize “Best Value” thru Shared Risk Management
END
Trend Topics

• Ability to Respond to the Rapid Changing Needs of Asymmetric Warfare.

• Meeting the Reset, Refurbishment, and Inventory Challenges

• Recognizing and planning to Ensure Industrial Base Readiness for Future Conflicts

• Evolving “New” Capability while “Reset etc.” Proceeds and Budgets are Constrained

• Ensuring Depth of Subject Matter Experts in Government and Industry
Qualification of 120mm Rifled Ammunition in Support of the Expeditionary Fire Support System (EFSS)

42nd Annual Armament Systems: Guns and Missile Systems Conference & Exhibition

April 23-26, 2007
Charlotte, NC

Approved for public release by MARCORSYSCOM on 4/19/07
EFSS Program Overview

Expeditionary Fire Support System is a U.S. Marine requirement for a weapon system that must be:

- All weather
- Ground Based
- Close supporting
- Accurate
- Immediate Response
- Lethal indirect fire
EFSS System Description

An EFSS system consists of:

- Two Prime Movers
- Ammunition Trailer
- 120mm Rifled Mortar
- Full Suite of 120mm Rifled Ammunition
Mortar and Ammunition Background

TDA (a subsidiary of Thales) developed 120mm Rifled Mortar and Ammunition
- Developed in the early 1970s
- In service with 24 countries, including 4 NATO armies and Japan.
- Over 500,000 rounds fired with no issues.
- Rifled barrel provides a spin stabilized projectile.
- Maximum range of standard rifled ammunition is 8.1km
- GD-OTS teamed with TDA to bring rifled mortar capability to EFSS platform
Standard 120mm Rifled Ammunition

TDA’s 120mm Standard Ammunition Suite

- High Explosive (HE) – 4.2 kg of TNT
- Practice – 0.5 kg of black powder for spotting
- Illumination – 1.9 kg flare
- Obscurant/Incendiary (Smoke) – 2.8 kg of White Phosphorous

All four types of ammunition share the same Tail Charge Assembly.
USMC funded GD-OTS to upgrade the ammunition to meet qualification requirements of the USN for EFSS

- Insensitive Munitions (IM)
- Environmental and Durability
- Hazard Classification
- Fuze Safety
- Performance Oriented Packaging (POP)
- Electro-static Discharge
EFSS HE Ammunition Upgrade

Modifications to HE Projectile
- Replace TNT fill with PBXW-128 (HMX based)
- Equip with an M767A1 fuze utilizing a PBXN-5 booster
- Add a fuze venting liner between the projectile body and the fuze

Design Constraint
- Maintain equivalent lethality
- Similar ballistics
EFSS Practice Ammunition Upgrade

Modifications to Practice Projectile
- Equip with an M767A1 fuze utilizing a PBXN-5 booster
- Add a fuze venting liner between the projectile body and the fuze

Design Constraint
- Maintain spotting ability
- Same ballistic to EFSS HE
Modifications to Illumination Projectile
- Equip with an M762A1 fuze

Design Constraint
- Maintain flare ability
- Similar ballistics
EFSS Smoke Ammunition Upgrade

Modifications to Smoke Projectile
- Equip with an M767A1 fuze utilizing a PBXN-5 booster
- Replace Comp B igniter with PBXN-9

Design Constraint
- Maintain obscurant ability
- Similar ballistics
EFSS Container Assembly Upgrade

PA117 Vented Container Assembly for HE, Practice, and Illumination rounds
- Blow out panels allow pressure release
- Foam packaging separates and returns to resin form when heated
- Fuze has room to completely detach from projectile with heat and pressure

Blowout Panels allow pressure release from inside the container
Foam cushions and sleeves melt and separate to prevent insulation of heat
EFSS Container Assembly Upgrade

PA103A2 Container Assembly for Smoke only

- Blow out panel allow pressure release from the bottom of the container
- Foam packaging separates and returns to resin form when heated
- Smoke projectiles are stored and transported vertically to prevent air gaps in the white phosphorous resulting in poor ballistic performance

A Blowout Panel in the bottom of the container allows pressure release
Environmental/Durability Qualification Test Plan

45 EFSS rounds of each ammunition type were tested (including vibration and drop testing)

- High Temp (+160F)
- Low Temp (-65 F)
- Low Pressure Altitude
- Temperature Shock

Test facilities included
- NSWC Dahlgren
- NSWC Crane
- Hawthorne
Hazard Assessment/Classification Qualification Test Plan

54 EFSS rounds of each ammunition type were tested

Testing required to meet MIL-STD-2105C, Hazard Assessment Tests for Non-Nuclear Munitions

Hazard Assessment/Classification Testing (54)

- 28 Day Temp. & Humidity (12)
- Inspect, X-ray & Fire (3)

- Transportation Vibration [-65F] (3)
- Transportation Vibration [+70F] (3)
- Transportation Vibration [+160F] (3)

- Shipboard Vibration [-65F] (3)
- Shipboard Vibration [+70F] (3)
- Shipboard Vibration [+160F] (3)

- 4 Day Temp. & Humidity (6)
- Inspect, X-ray & Fire (3)

- 40Ft Drop (3)
- Inspect, X-ray & Fire (3)

- Combined Fast Cook-off/External Fire (25)
- Combined Sympathetic Detonation/Stack Test (8)
- Shaped Charge Jet (2)
- Fragment Impact (2)
- Bullet Impact (2)
- Slow Cook-off (2)

- Thermal Stability (1)
IMRB reviewed the EFSS ammunition qualification results

- Testing reviewed and results officially scored
- Approved for submission for final qualifications

### EFSS AMMUNITION QUALIFICATION STATUS April 16th, 2007

<table>
<thead>
<tr>
<th>EFSS Round Types</th>
<th>Slow Cook-Off</th>
<th>Fast Cook-Off</th>
<th>Fragment Impact</th>
<th>Bullet Impact</th>
<th>Sympathetic Detonation Confined</th>
<th>Sympathetic Detonation Unconfined</th>
<th>Shape Charge Jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE</td>
<td>V</td>
<td>IV</td>
<td>III</td>
<td>V</td>
<td>Pass</td>
<td>Pass</td>
<td>I</td>
</tr>
<tr>
<td>Illumination</td>
<td>V</td>
<td>IV</td>
<td>III</td>
<td>IV</td>
<td>Pass</td>
<td>Pass</td>
<td>Not scheduled</td>
</tr>
<tr>
<td>Smoke Projectile</td>
<td>III</td>
<td>III (Mixed Pallet)</td>
<td>III</td>
<td>IV</td>
<td>Pass (Mixed pallet)</td>
<td>Pass (Mixed pallet)</td>
<td>Not scheduled</td>
</tr>
<tr>
<td>Smoke Tail Charge Assembly</td>
<td>IV</td>
<td>III</td>
<td>III</td>
<td>IV</td>
<td>Pass (Mixed pallet)</td>
<td>Pass (Mixed pallet)</td>
<td>Not scheduled</td>
</tr>
<tr>
<td>Practice</td>
<td>V</td>
<td>IV</td>
<td>III</td>
<td>IV</td>
<td>Pass</td>
<td>Pass</td>
<td>Not scheduled</td>
</tr>
</tbody>
</table>
EFSS Qualification Conclusion

- All qualification testing in accordance with the basic test plan have been completed

- Testing conducted at the following locations:
  - NSWC Dahlgren
  - NSWC Crane
  - NSWC Indian Head
  - Hawthorne
  - Eglin AFB

- Strategic plan for future improvements being evaluated

- IOC scheduled for late September of 2007
The Declining Missile Business Base, Are We Taking Too Much Risk?

Presented to
42nd Annual Armament Systems:
Gun and Missile Systems
Conference and Exhibition

Presented by
BG Mike Cannon
Program Executive Officer,
Missiles and Space

24 April 2007

Approved for Public Release; Distribution Unlimited
THE ERODING ADVANTAGE
U.S. ARMY TACTICAL MISSILE SYSTEMS

- Existing Capability Gaps Are Not Being Met
- Performance Gap Closing Between Existing U.S. and Foreign Systems
- Targets and Threats are Evolving and Presenting Greater Challenges
- U.S. Science and Technology No Longer Leads World in Many Missile-Relevant Categories
- No New Development of ‘Next Generation’ Tactical Missiles
  - No New Systems Since Inception of Javelin
  - Lack of Any New 6.3 Level Missile Technology Demonstrations
  - Budgetary Constraints Resulting in Handful of Existing Projects Being Cancelled or at Risk

ANY SOLDIER - ANYWHERE - ALL THE TIME...
Foreign systems continue to improve and challenge our systems in performance.

ANY SOLDIER - ANYWHERE - ALL THE TIME...
Direct Fire and Air to Ground Targets-Threats

- Much More Than Just Tanks-Vehicles, Structures, Dismounts…
  *BUT must account for…*
- Evolving Base Armor and Explosive Reactive Armor Becoming More Efficient
- 2ND Generation Thermal Optics: Detection Up to 5km
- Increased Use and Integration of Soft and Hard-Kill Active Protection Systems

Air to Ground and NLOS/BLOS Targets-Threats

*Direct fire concerns +*

- Development of Modernized Air Defense Systems Such As Skyshield Which Can Shoot Down MLRS, ATACMS, Hellfire
- Global Positioning System Jamming

ANY SOLDIER - ANYWHERE - ALL THE TIME...
FUTURE WARFARE TRENDS
THREAT AND TARGET TRENDS

Ground to Air Targets - Threats

- UAV Proliferation, Miniaturization and Weaponization
- Large Caliber Rocket Proliferation and Accuracy Improvement
- Cruise Missile Proliferation With Reduced Signatures and On Board Electro-optical Countermeasures
- Maneuvering Reentry Vehicles
Missile Tech Base FY07-13
Based on FY08 POM Position

FY08-11 6.3 Increase due to Smaller Lighter Cheaper
88% in 3 Missiles—PAM, JCM, and PAC-3 / Missile Segment Enhancement
No Investment in Direct Fire Missiles
Many Technologies Critical to DoD Systems are Not Readily Obtained Through Traditional Education Paths or Have Limited Commercial Markets

Slow-Down / Cancellation of Missile System Programs Will Leave Critical National Technology Areas at Risk Through Loss of Well Trained Scientists and Engineers in the Government and Industry (Aging Workforce, BRAC, No New Development)

Missile Technology Areas

| Seeker Technologies  | 63 |
| Propulsion           | 38 |
| Modeling/Simulation  | 33 |
| Aerodynamics / Controls | 32 |

Erosion Of This Base Will Be Unrecoverable

ANY SOLDIER - ANYWHERE - ALL THE TIME
• Close Combat / Direct Fire Tactical Missile Development is a Very High Priority
• Cruise Missile Defense Efforts Deserve High Priority and Must Include Low Cost Counters to Large Caliber Rockets
• Develop Cost-Effective Counter to UAV Threat
• Must Fund Robust Stockpile Reliability Program to Preserve Existing Capability
• Reverse Downturn in Tech Base Funding

Without Investment in These Capability Areas, May Lose the Human Capability to Address these Areas
The Challenge We Face

Smother Innovation

Resist Change

RISK

SPEED

Embrace Status Quo

Rapid Acquisition

Meeting Immediate Warfighter Needs
Challenge of Differing Expectations

- Future Focused
- Very Structured Process
- Evolved Requirements
- Analysis of Alternatives
- Lengthy Development
- High Visibility on Program
- Large Investment

Now focused
- More ad hoc process
- Broad requirement
- Quick assessment of alternatives
- Limited development
- High visibility on results
- Limited investment

MEETING IMMEDIATE WARFIGHTER NEEDS

May 2, 2007

Joint Rapid Acquisition Cell
The Department has numerous existing authorities across several functional areas:

- Funding
- Requirements
- Acquisition
- Procurement
- Test & Evaluation
- Communications
Joint IED Defeat Organization (JIEDDO) is the focal point for all efforts in the Department of Defense to defeat Improvised Explosive Device (IEDs)

Services use various methods to meet Title 10 responsibilities and shorten acquisition timelines for < ACAT I to meet urgent and compelling needs

- USAF – Combat Capability Document
  - < 60 days from authorization
  - Air Staff authorization < 16 days from receipt from MAJCOM
- USA – Operational Need Statement (ONS)
  - < 120 days from authorization, but “do it now” approach post 9-11
- USMC – Urgent Universal Need Statement (UUNS)
  - < 60 days from authorization
- USN – Rapid Deployment Capability (RDC) and Abbreviated Acquisition Program (AAP)
  - < 160 days from authorization
- SOCOM – Combat-Mission Need Statement (CMNS)
• Problem: Despite existing authorities to deliver equipment / services to the warfighter, the process is still restrictive and inefficient.

• Solution: Establish the OSD Joint Rapid Acquisition Cell (JRAC)
  – Responsible to the Secretary of Defense through Under Secretaries of Defense for Acquisition, Technology & Logistics and Comptroller.
  – Monitors, coordinates, and facilitates meeting Combatant Commanders’ Immediate Warfighting Needs.
• DEPSECDEF Memo of 3 Sep 04 established JRAC.

• Each COCOM / Service nominated a Flag Officer Level JRAC point of contact.

• USD (AT&L) / USD (Comptroller) memo of 10 September appointed a JRAC Director and Deputy Director.

• DEPSECDEF Memo of 15 Nov 04 established procedures.
JRAC Core & Advisory Groups

JRAC CORE GROUP
- OSD Comptroller
- General Counsel
- Joint Staff
- Acquisition, Technology & Logistics (AT&L)
- Defense Procurement & Acquisition Policy
- Combating Terrorism Technology Task Force (CTTTF)

JRAC ADVISORY GROUP 1
- Operational Test & Evaluation
- Other AT&L Offices
- National Assessment Group
- Combatant Commands
- Army
- Navy
- Air Force
- Marines
- SOCOM

1 COCOMs and Military Services have FO/GO representatives

Army Rapid Equipping Forces/ Operational needs Statements
Navy Capability Rapid Deployments
USAF Combat Capability Document
USMC Urgent Universal Needs Statements
SOCOM Combat Mission Needs Statement

May 2, 2007

MEETING IMMEDIATE WARFIGHTER NEEDS
Joint Rapid Acquisition Cell
JRAC Focus

- What is best for the warfighter?
- Near-term acquisition, materiel, and logistics solutions
  - capability needed must be quickly fieldable, supportable in place, affordable, and of acceptable risk
  - level of performance necessary to satisfy needs of COCOM
- OIF, OEF, GWOT
- Long-term plan to resolve systemic problems
• **Joint Urgent Operational Need (JUON)**
a COCOM-certified and prioritized urgent operational need, outside DoD 5000/Military processes, requiring a DOTMLPF solution that, if left unfulfilled, will seriously endanger personnel and/or pose a major threat to ongoing operations.

• **Immediate Warfighter Need (IWN)**
a JUON requiring a timely (Goal 120 days to 2 years) materiel, services, and/or logistics solution that, if left unfulfilled, will seriously endanger personnel and/or pose a major threat to ongoing operations.

• **Resolved IWN**
the delivery of the required capability has commenced.
• OEF/OIF/GWOT originator recommends JUON & obtains approval of first GO in chain-of-command.

• JUON (that cannot be satisfied in an appropriate time-frame by an existing Military Service / Defense Agency process) submitted to COCOM for certification / prioritization.

• COCOM rejects or certifies / prioritizes JUON and submits to Joint Staff / JRAC simultaneously.

• With Joint Staff recommendation, JRAC designates or declines JUON as IWN within 14 days of submission to JRAC.

• JRAC tracks IWN and facilitates its resolution, if counter-IED, forwards to JIEDDO for action.

GOALS: 48 hrs from receipt to designation as IWN.

IWN resolved ASAP (GOAL: 120 Days – 2 years).
JRAC Process Flow

OIF / OEF / GWOT Originates JUON

COCOM / Services Execute Solution

Direction to execute

IWN solution presented to leadership

JRAC tracks and facilitates solution 120 days – 2yrs

C-IED

JIEDDO

MEETING IMMEDIATE WARFIGHTER NEEDS
MATERIEL SOLUTIONS

- Improved command and control capabilities for NORAD planes over U.S. cities
- First use of Rapid Acquisition Authority to acquire Counter Remotely-controlled-IED Electronic Warfare (CREW) devices - on contract < 12 days
- Cougar – Facilitated rapid, sole-source acquisition of EOD Vehicle - 120 by Feb 06
- Assisted in foreign sources approval for ballistic glass in vehicle up-armoring
- Facilitated funding for additional Counter Rocket, Artillery and Mortar intercept
- Coordinated among CENTCOM, JCS and Services on UAV improvements and resolution of interoperability issues
- Facilitated funding and contracting activities for acquisition, testing and deployment with dismounted CREW capability
- Supported analysis of technology and production constraints that limit CREW-2 schedules and the equipping of warfighters with improved capability
Overview of Activity

- MATERIEL SOLUTIONS (continued)
  - Full-Spectrum Effects Platform – Validation of IWN and funding of prototypes for an operational concept development capability
  - Recommended accelerating technology on Malodorous Agents
  - Improved funding and schedule for the High Intensity Directed Acoustics (HIDA) Program
  - Facilitated funding for Joint IED Neutralizer prototypes, testing and operational assessment
  - Expedited funding for Iraqi document exploitation
  - Provided rapid funding of critical communication equipment for coalition forces
  - Obtained funding for biometrics initiatives in Iraq and Afghanistan
  - Assessing flexible SIGINT capability for GWOT use, worldwide
  - Funded Full Motion Video Receiver Solution
  - Coordinated Air Force funding for Joint Precision Airdrop System
  - Successfully secured funding for coalition jammers
  - Provided urgently required funding to facilitate completion of construction of a compound protecting US Forces.
Overview of Activity

• EQUIPMENT MAINTENANCE, SUPPORT AND TRAINING ISSUES
  – Recommended solutions for maintenance and readiness on WARLOCK jammers
  – Provided recommendations on management and transfer of Stay Behind Equipment
  – Supported TSUNAMI relief, researching C-130 parts availability and contracting
  – Facilitated additional funding and contracting of Iraqi cultural and civic advisors
Overview of Activity

- **JRAC OUTREACH TO WARFIGHTERS**
  - Participated in JCS/COCOM-sponsored HUB TRIPS and visited CENTCOM & SOCOM
  - Conducted secure VTCs w/ deployed unit commanders
  - JRAC sponsored Joint Rapid Acquisition Conference scheduled 20-21 Jun 06

- **JRAC / JIEDDO Initiatives**
  - Planned initial CREW Strategy
  - Membership on JSIB, JRAB, JIPT and SRSG
  - Providing support as Mitigate Sub-IPT Chair

- **ACQUISITION POLICY IMPACTS**
  - Included JRAC processes in DoD-level Stability Operations Directive
  - Revised 5000-series directives and assisted with CJCSI 3470.01
  - First use of SecDef Rapid Acquisition Authority – April 05

- **OFFICE OF MILITARY COOPERATION-AFGHANISTAN (OMC-A) AND AFGHANISTAN NATIONAL ARMY ASSISTANCE**
  - Supported solicitation and source selection for Medium Tactical Vehicles
  - Contract competitively awarded in 2.5 months vs. typically > 6 months
Programmatic Actions

Level of Funding Impact upon Programs with JRAC Involvement

≈ $600M or more *

* Based upon contract awards, initiatives, and projects in which the JRAC has facilitated solutions or provided programmatic/contracting assistance
• Policy Changes Impacting JUONs and IWNs
  – Rapid Validation and Resourcing of Joint Urgent Operational Needs (JUONS) in the Year of Execution, Chairman Joint Chiefs of Staff Instruction (JCSI 3470.1) Currently under revision
  – Secretary of Defense’s Rapid Acquisition Authority
Making Capabilities Process Agile: Faster and More Flexible

Issue – Current Process inflexible and slow

- CJCSI 3470.01 provides framework for integration, acceleration
  - DOTMLPF broad perspective on solution alternatives
  - Improved integration of CONOPS/technology providers
  - Reach to employ diversity of funding & technology programs
  - Joint perspective from solution inception

Joint Rapid Agile Acquisition Process

- DOTMLPF Solution
- DARPA Developmental technology
- QRSP/TTI Accelerated lab products
- ACTD/JCTD Innovative demos
- DAC/FCT Test to procure

Urgent CoCom Need
- Emergent Needs
  - CBRN interdiction
  - Surface moving target engagement

Joint Rapid Agile Acquisition Cell

OSD/JS Partnership

FCB Facilitates Non-Acq Options and Evaluates Acq Options
- Ku band lease (CENTCOM)

JERIC FACILITATES ACQ OPTIONS

3470.01 FCB Look

Accelerate PORs

Services

CBRN interdiction

Surface moving target engagement

OSD/JS Partnership

Me: 049
Rapid Acquisition Authority

  - Waive statutes and regulations for testing and procurements – short of criminal statutes
  - $100 million in authority, per fiscal year, to move funding regardless of “color”
  - Notify Congress within 15 days of action
  - Provides valuable flexibility for quick response to Immediate Warfighter Needs in response to combat fatality
• Background
  – VCJCS questions, April 2006, resulted in Rapid Fielding Study
  – Joint Rapid Acquisition Workshop, June 2006, reviewed results and current state of OSD and Joint guidance

• Current effort focuses upon key areas
  – Improving visibility and transparency of Rapid Fielding Initiatives
  – Development and implementation of process standards
  – Determination of an information sharing approach

• Next JRA Workshop scheduled for 19 – 20 June in Tampa, FL
• SbPRNet Sites
  – Joint Rapid Acquisition Cell (JRAC) Website
    ▪ http://www.acqs.osd.pentagon.smil.mil/jrac
  – JRAC JUON Tracking Tool
  – JCS Knowledge Management/Decision Support
    ▪ https://jrockmds1.js.smil.mil/guestjrcz/gBase.homepage – search on “JUON”
  – CENTCOM Requirements Information Management
    ▪ http://hqsweb03.centcom.smil.mil/cpim/files/requirements_org_chart_files/slide1529.htm
    ▪ http://hqsweb03.centcom.smil.mil/cpim/req_needs_introduction.asp
• NIPRNet Websites
  – Joint Rapid Acquisition Community of Interest -- https://acc.dau.mil/jra
System Modeling of a 40mm Automatic Grenade Launcher

Dr. Daniel Corriveau and Mr. Alain Dupuis
Flight Mechanics Group, Precision Weapons Section

42nd Gun and Missile Systems Conference & Exhibition
April 23-26, 2007
Presentation Overview

- Objectives
- Background
- Aerodynamics of a 40 mm HV grenade
- Error budget development
- Weapon system simulation results
- Conclusions
Objectives

• Develop an aerodynamics model for a generic 40 mm HV grenade

• Develop an error budget model for the MK19 AGL
  • Drag/Mass error (%)
  • Round-to-round muzzle velocity error (m/s)
  • Gun dispersion (mils)
  • Ammunition dispersion (mils)

• Establish the specification requirements for a new AGL gun system
Background

- CASW (Company Area Suppression Weapon) is a high priority procurement project for the CF

- 40 mm grenade launcher for various rounds:
  - HEDP
  - Airbursting

- DRDC tasked to compare the various contenders:
  - FCS
  - Aero and flight dynamics of rounds
  - $P_{hit}$ and lethality
  - Direct and indirect fire capability
Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero

Round Characteristics at time of burst or detonation:
- Dispersion
- Probability of hit
- Remaining Speed
- Remaining Spin
- Angle of descent (AOD)
- Time of Flight

Weapon System representation

MET data

Defence R&D Canada • R & D pour la défense Canada
Ammo model development
A/B range trial

• Complete ammo aero model
Ammo model development
Shadowgraphs

- Instrumented length: 220 m
- Section: 6 m x 6 m
- 54 Stations: Indirect orthogonal shadowgraphs
- 4 Schlieren stations

Defence R&D Canada • R & D pour la défense Canada
Ammo model development

Projectile motion

6DOF CALCULATED
• EXPERIMENTAL DATA POINTS

X (m)

Y (m)

Psi (deg)

Theta (deg)
Ammo model development

Aerodynamic model
Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero

Weapon System representation

Round Characteristics at time of burst or detonation:
- Dispersion
- Probability of hit
- Remaining Speed
- Remaining Spin
- Angle of descent (AOD)
- Time of Flight

MET data

Defence R&D Canada • R & D pour la défense Canada
Weapon system model development

- Weapon system representation:
  - Error budget model
  - Dispersion analysis

\[
\begin{align*}
S_{DX_{TOTAL}}^2 &= S_{DV_x}^2 + S_{GD_x}^2 + S_{AD_x}^2 \\
S_{DY_{TOTAL}}^2 &= S_{DV_y}^2 + S_{GD_y}^2 + S_{AD_y}^2
\end{align*}
\]
Error budget development

<table>
<thead>
<tr>
<th>MODEL</th>
<th>B1</th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>Measured</td>
<td>LOW LEVEL</td>
</tr>
<tr>
<td>Drag/Mass (%)</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>$V_M$ – round to round (m/s)</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>$V_M$ – lot to lot (m/s)</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Wind Std (m/s)</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Pressure Std (mbars)</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Air Temp (°C) Std Dev</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Vert. Bore sight alignment (mils)</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Horz. Bore sight alignment (mils)</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Target range Error (m)</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Gun dispersion (mils)</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Ammunition Dispersion (mils)</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Fuze Error (% of time)</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

• Required as input to Prodas:
  • Estimated based on literature and user experience
  • Determined accurately through an accuracy trial
Error budget development
Muzzle velocity error

- Determined using Radar measurements
- Data processed using Radar2000

<table>
<thead>
<tr>
<th>SHOT NUMBER</th>
<th>$V_{MUZ}$ (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01</td>
<td>240.91</td>
</tr>
<tr>
<td>B02</td>
<td>242.73</td>
</tr>
<tr>
<td>B03</td>
<td>238.67</td>
</tr>
<tr>
<td>B04</td>
<td>242.81</td>
</tr>
<tr>
<td>B05</td>
<td>243.31</td>
</tr>
<tr>
<td>B06</td>
<td>242.33</td>
</tr>
<tr>
<td>B07</td>
<td>243.63</td>
</tr>
<tr>
<td>B08</td>
<td>243.66</td>
</tr>
<tr>
<td>B09</td>
<td>240.14</td>
</tr>
<tr>
<td>B10</td>
<td>242.12</td>
</tr>
<tr>
<td>Mean</td>
<td>242.03</td>
</tr>
<tr>
<td>Std Deviation</td>
<td>1.55</td>
</tr>
<tr>
<td>Std Deviation (%)</td>
<td>0.64</td>
</tr>
</tbody>
</table>
Error budget development

Drag/Mass error

<table>
<thead>
<tr>
<th>SHOT NUMBER</th>
<th>Mass (gm)</th>
<th>$C_{X0}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01</td>
<td>239.64</td>
<td>0.16120</td>
</tr>
<tr>
<td>B02</td>
<td>240.56</td>
<td>0.16028</td>
</tr>
<tr>
<td>B03</td>
<td>240.03</td>
<td>0.16167</td>
</tr>
<tr>
<td>B04</td>
<td>242.10</td>
<td>0.17356</td>
</tr>
<tr>
<td>B05</td>
<td>240.75</td>
<td>0.16238</td>
</tr>
<tr>
<td>B06</td>
<td>241.54</td>
<td>0.16434</td>
</tr>
<tr>
<td>B07</td>
<td>240.36</td>
<td>0.15635</td>
</tr>
<tr>
<td>B08</td>
<td>242.16</td>
<td>0.15558</td>
</tr>
<tr>
<td>B09</td>
<td>241.11</td>
<td>0.15850</td>
</tr>
<tr>
<td>B10</td>
<td>240.82</td>
<td>0.15936</td>
</tr>
<tr>
<td>Mean</td>
<td>241.26</td>
<td>0.154</td>
</tr>
<tr>
<td>Std Deviation</td>
<td>0.7336</td>
<td>0.002</td>
</tr>
<tr>
<td>Std Deviation (%)</td>
<td>0.30</td>
<td>1.30</td>
</tr>
</tbody>
</table>

- Variation in $C_{X0}$ due to non-uniform band engraving
- Variation in mass due to quality control

$$\sigma\left(\frac{C_{X0}}{M}\right) = \frac{\sigma_{C_{X0}}}{M} - \frac{C_{X0}}{M^2} \sigma_M = 1.0$$
Error budget development
Ammunition dispersion (aerodynamic jump)

• Due Mainly to Initial Yaw Rate
  • In bore Balloting
  • CG Offset

• Theory States
  - If initial yaw rate, $q_0$, is known
  - with aerodynamic package and physical properties
  - can calculate ammunition disp.
Error budget development

Ammunition dispersion (aerodynamic jump)

Angle of Attack – Extrapolated to Muzzle with A/B Range Data

<table>
<thead>
<tr>
<th>SHOT NUMBER</th>
<th>1st Max Yaw (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01</td>
<td>2.87</td>
</tr>
<tr>
<td>B02</td>
<td>1.55</td>
</tr>
<tr>
<td>B03</td>
<td>2.85</td>
</tr>
<tr>
<td>B04</td>
<td>2.90</td>
</tr>
<tr>
<td>B05</td>
<td>1.74</td>
</tr>
<tr>
<td>B06</td>
<td>2.71</td>
</tr>
<tr>
<td>B07</td>
<td>2.46</td>
</tr>
<tr>
<td>B08</td>
<td>2.10</td>
</tr>
<tr>
<td>B09</td>
<td>2.73</td>
</tr>
<tr>
<td>B10</td>
<td>1.31</td>
</tr>
<tr>
<td>Mean</td>
<td>2.323</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>0.601</td>
</tr>
</tbody>
</table>
Error budget development
Ammunition dispersion (aerodynamic jump)

\[
q_0 = \frac{\phi_F - \phi_S}{2} \alpha_{\text{max}}
\]

\[
\theta_{\text{aero}} = \frac{(C_{N\alpha} - C_X)d}{C_{m\alpha}V_0} \left( \frac{I_yq_0}{md^2} \right)
\]

First Max Yaw Average (deg): 2.32
Standard Deviation: 0.6 deg

\( S_{\text{ADx}} = 0.40 \) mils
\( S_{\text{ADy}} = 0.40 \) mils
Error budget development

Gun dispersion: drop and lateral analyses

\[ S^2_{DY_{TOTAL}} = S^2_{D_{Vy}} + S^2_{G_{Dy}} + S^2_{A_{Dy}} \]

\[ S^2_{DX_{TOTAL}} = S^2_{D_{Vx}} + S^2_{G_{Dx}} + S^2_{A_{Dx}} \]

- Total
- Observed
- Due to Gravity drop \((V_{MUZ}, \text{mass}, C_{X0})\)
- Ammunition Dispersion
- Gun Dispersion
Error budget development
Gun dispersion: total dispersion

Accuracy trial:
• NATO StanAg procedure
Error budget development

Gun dispersion: drop analysis

\[ S_{Dx_{TOTAL}}^2 = S_{Dv_x}^2 + S_{GDx}^2 + S_{ADx}^2 \]

- Total Observed: 0.640
- Due to Gravity drop (\(V_{MUZ}, \text{mass}, C_{x0}\)): 0.353
- Gun Dispersion: 0.400

Defence R&D Canada  •  R & D pour la défense Canada
Error budget development

Gun dispersion: lateral analysis

\[ S_{DY_{TOTAL}}^2 = S_{D_{Vy}}^2 + S_{GDy}^2 + S_{ADy}^2 \]

- Total Observed
- Due to Gravity drop \((V_{MUZ}, \text{mass}, C_{x0})\)
- Gun Dispersion
- Ammunition Dispersion

\[ S_{D_{Vy}} = 0.00 \, \text{m} \]
\[ S_{GDy} = 0.84 \, \text{m} \]
\[ S_{ADy} = 0.400 \, \text{m} \]
## Error budget development

### Error budget model

<table>
<thead>
<tr>
<th>Errors</th>
<th>SERIES D</th>
<th>PROPOSED ERROR BUDGET For LETHALITY Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tripod w/o sand bag, natural ground</td>
<td>LOW</td>
</tr>
<tr>
<td>Drag/Mass (%)</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>$V_M$ – round to round (m/s)</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>$V_M$ – lot to lot (m/s)</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Wind Std(m/s)</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Pressure Std (mbars)</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Air Temp (C) Std Dev</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Bore sight alignment (mils)</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Target range Error (m)</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Gun dispersion (mils)</td>
<td>H: 0.84</td>
<td>H: 0.42</td>
</tr>
<tr>
<td></td>
<td>V: 0.35</td>
<td>V: 0.18</td>
</tr>
<tr>
<td></td>
<td>A: 0.60</td>
<td>A: 0.50</td>
</tr>
<tr>
<td>Ammunition Dispersion (mils)</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>Fuze Error (% of time)</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero

Weapon System representation

Round Characteristics at time of burst or detonation:
- Dispersion
- Probability of hit
- Remaining Speed
- Remaining Spin
- Angle of descent (AOD)
- Time of Flight

MET data

Defence R&D Canada • R & D pour la défense Canada
Monte-Carlo Based Weapon System Simulations

• Performed using the Ground-to-Ground module of PRODAS
• 2 DOF fly-out routine
• Hundreds of fly-out simulation with randomly varied system errors
• Yield dispersion at target and probability of hit
• Enables one to perform or determine:
  • Scenario/Mission simulations
  • Weapon system specifications
  • Weapon system weaknesses
Scenario/Mission Simulations

1 box of ammo: 32x

5 standard NATO targets: 2.3m high X 4.6m wide
Scenario/Mission Simulations

Assuming a $P_{\text{HIT}}^* = 90\%$ to be considered a good hit by the gunner then:

\[
N = \frac{\ln(1-P_{\text{HIT}}^*)}{\ln(1-P_{\text{HIT}}^{1S})}
\]

<table>
<thead>
<tr>
<th>RANGE</th>
<th>$P_{\text{HIT}}^{1S}$</th>
<th>$N$</th>
<th>Number of individual shots required obtain 90% mission success</th>
<th>Cumulative number of individual shots required obtain 90% mission success</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1.000</td>
<td>0.00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>400</td>
<td>1.000</td>
<td>0.00</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>700</td>
<td>0.876</td>
<td>1.10</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1000</td>
<td>0.532</td>
<td>3.03</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>1400</td>
<td>0.142</td>
<td>15.03</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>

Mission success: 100\%
Weapon System Specifications: FCS

Cant angle error

- Standard vertical NATO targets: 2.3m high X 4.6m wide
Weapon System Specifications: FCS

Range error

- Standard vertical NATO targets: 2.3m high X 4.6m wide
Weapon System Specifications: FCS

Boresight error

- Standard vertical NATO targets: 2.3m high X 4.6m wide
Weapon System Specifications: Ammo

Time fuze error

- Ground target
Weapon System Specifications: Ammo

Muzzle velocity error

- Standard vertical NATO targets: 2.3m high X 4.6m wide
Conclusion

- An aerodynamic model was developed for a 40 mm HV grenade
- An error budget model was developed for the MK19 AGL
- These models were used successfully to perform system simulations of 40mm AGL
Contact Information:

Dr. Daniel Corriveau
Phone: 418-844-4000 Ext. 4156
Defence R&D Canada – Valcartier
E-mail: daniel.corriveau@drdc-rddc.gc.ca
Integration of a Remotely Operated, Breech Loaded 120 mm Mortar Platform

BRIEFING FOR THE GUNS & MISSILES SYMPOSIUM - 26 APRIL 2007

Providing America Advanced Armaments for Peace and War

Thomas J. DeVoe
INTRODUCTION

Generate Technology Concepts
Execute Life Cycle R&D
Partner with OGA, Industry & Academia

Indirect Fire Systems Division
Objective NLOS-M Technology ATO
Laser Ignition for Cannon Artillery
Artillery & Mortar Systems
Remotely Operated 120 mm Mortar Technology
PROJECT OVERVIEW

- 120 mm Automated Mortar
- Breech Loaded
- In-line Autoloader/46 Round Magazine
- Integrated Titanium Turret and Cradle

14 rpm Maximum Rate of Fire

Live Fire Demonstrations from Hardstand and M113 Armored Personnel Carrier

120 MM TURRETED MORTAR CAN BE MOUNTED ON A VARIETY OF FIXED OR MOBILE PLATFORMS
Remotely Operated 120 mm Mortar Technology

BACKGROUND

• **Trade-offs**
  – Elevating Turret vs. Elevating Gun
  – Smooth Bore vs. Rifled Bore

• **Design**
  – ARDEC: Cannon, Recoil Mechanism, Turret, Fire Control
  – Western Design: Ammunition Handling Design and Fabrication
  – General Atomics: Turret Structural Design

• **Fabrication**
  – ARDEC: Titanium Turret
  – Watervliet Arsenal: Cannon Tube and Breech
  – Rock Island Arsenal: Recoil Mechanism

• **Integration** - ARDEC
Remotely Operated 120 mm Mortar Technology

TURRET

Azimuth, Elevation and Breech Control

Fire Control

Breech & Cam Plate

Magazine

Communications

Power Distribution

Autoloader Control
Remotely Operated 120 mm Mortar Technology
ARMAMENT

- Cannon Design Features (XM325)
  - Screw Block Breech
  - 3 Meter, Smooth Bore Mortar Tube
  - Round Positioning and Retention Features
  - Anti Fall-Back Latch
  - Solenoid Actuated Firing Mechanism
  - Breech Open Via Cam Plate
- Gun Mount
  - Independent Recoil and Recouperator Modules
  - Cradle Integral with Turret
Remotely Operated 120 mm Mortar Technology

AMMUNITION HANDLING

Bridge Assembly

Clamp Assembly

46 Magazine Canisters

Rammer Assembly/Load Tray
Remotely Operated 120 mm Mortar Technology
FIRE CONTROL

Mortar Fire Control System (MFCS)

CROW – MS Windows based processor

- Gun as FDC
- Network Fires
- Remotes Fires
- Autonomous Operations

SINGARS   PLGR    TALIN INU
Remotely Operated 120 mm Mortar Technology
TESTING

Mount Checkout and Proof Test - Picatinny Gun Shed

15 Rounds Fired
Charge 0 – Charge 4+
Proofed Cannon
19,700 psi
Remoteley Operated 120 mm Mortar Technology TESTING

Aberdeen Test Center Live Fire Demonstration
177 Rounds
Charge 1 – Charge 4
30° QE
Automated Multi-Round Missions
14 rpm Rate of Fire
Ballistic, Recoil and Thermal Data Acquisition
Remotely Operated 120 mm Mortar Technology
ROWST Mortar

Aberdeen Test Center Live Fire Demonstration

- 30 Rounds
- Charges 2 and 4
- 0° and 30° QE
Remotely Operated 120 mm Mortar Technology
ROWST Mortar

Mortar Turret

5 Tons
191” x 98” x 36.5”
Remotely Operable

Turret on M113 A2

17 Tons
222” x 100” x 108”
C130 Compatible

Turret on LAV-25

15 Tons
253” x 99” x 114”
C130 Compatible with Modification

Turret on Stryker

23 Tons
275” x 105” x 116”
C130 Compatible with Modification
Extended Area Protection & Survivability (EAPS) Gun and Ammunition Design Trade Study

Presented By: Dan Ericson
April 2007
NDIA Guns & Missiles Symposium

Distribution A: Approved For Public Release.
**Mission:**
10-1: Serve as TACOM-ARDEC Systems Analysis organization—provide analytical services to all operating segments

**Vision:**
Our Systems properly represented in the M&S Environment
-- Complete knowledge and understanding

**Team:**
- 29 Personnel
- Almost all S&Es, Multidisciplinary
- Engineers, Physical Scientists, Computer Scientists, Physicists, Mathematicians
Hierarchy of Modeling & Simulation

M&S Hierarchy

Tools used by Projects are defined by the Simulation Support Matrix!
Initial (3/2005) Concept Of EAPS Requirements

- Notional Requirements:
  - Targets: Mortars, Cannon Artillery, Rockets
  - Engage All Threats Within A Ground Protection Radius Prior To Coming Within Specified Distance From Ground
  - Defeat Single / Multiple Threats
    - High/Low Order Detonation Of Payload (Primary)
    - Detonation or Destruction of Fuze (Secondary)
    - Destabilization of the Round; Damage To The Flight Body (Tertiary)
  - Quick Response Time
  - Improved Logistics and Cost
  - Low Collateral Damage
  - Mobile / Transportable

Study Objective: To Determine The Feasibility Of Meeting EAPS Requirements And (If Possible) To ID a Gun / Ammo Solution
Basic Approach To The Problem

1. Use brainstorming and QFD to develop the range of gun systems and munitions likely to address the threat and customer needs.
2. Determine details of the threat and weapon systems sufficient to allow a detailed analysis to be conducted.
3. Develop a computer simulation which models the EAPS environment with sufficient accuracy to compare system alternatives.
4. Run the simulation for all system alternatives.
5. Evaluate results and make recommendations.
Initial SME Selections: Most Promising Options (5/13/05)

- Early detection: Acoustics (*needs prove out of utility*).
- Acquisition and Tracking Radars: **PTS**, Phalanx, etc. (*compare to each other*).
- Guidance: Unguided, **Command Guidance**, Lock on Before Launch, Autonomous (*needs Phit analysis*).
- Fuzing: Proximity – RF or Optical/ IR, Time, **Command Detonate**, Direct Hit KE.
- Warhead: **multi-EFP**, Canister with Multi-KE Rods or Tungsten Balls, Focused, **Preformed Fragments**, KE bullets, frangible KE (*needs lethality, fragment size, weight, velocity tradeoff study*).
- Weapon systems: 20mm (Phalanx-type), **50mm** (Bush III, Skyshield types), 70mm, 82mm Scorpion.
Basic Idea Is To Model The Event Timeline, Accuracy, & Lethality In Explicit Detail

1975 US Standard Atmosphere
3-DOF Trajectory Engine

Threat Round
Mass
Diameter
Drag
Muzzle Velocity

Search & Track Radar
Accuracy
Range

Interceptor
Smart
Conventional

Protected Area

Simulation Models A One (Or Many) On One Engagement Of Incoming Threat Round With EAPS Gun (Acoustics, Radar, Fire Control, Gun, Bullet)
Flow of EAPS Gun Mission

Threat Launch

Search Radar
Detect
Criteria:
- Target < Search Range
- M Samples
- Delay 500ms

Tracker Detect
& Estimate
Criteria:
- Search Detects
- Target < Track Range
- Warhead Lethal
- N Samples
- Delay 250ms + Time For Target To Come In Range

Fire Control
Calculation
Criteria:
- Track Established
- Lead Within Limits
- Slew Rate Within Limits
- Threat Impact In Protected Area
- Delay 250ms (Includes Final Gun Slew)

Note: All Delay Times Are Examples; What Is Ultimately Used Will Depend On System Architecture
Target Parameters

- Target is described by the following data set:
  - Aerodynamic drag data
  - Associated Mach numbers
  - Radius of round (m)
  - Weight of round (lbs)
  - Launch velocity (mps): Number of zones, velocity for every zone
  - Location of launcher (m)
  - Length of warhead
  - Explosive fill
  - Thickness of casing (mm)
  - RCS (DBSM)

- Trajectory data to insure flight characteristics match other models.

Example: Mortar round
Engagement Options

Rapid Fire- Hit to Kill
- C-RAM Type Engagement
- 20-30mm Caliber
- High Rate of Fire
- KE or HEPD Kill
- Lowest Cost Ammo
- High Expenditure Rate
- Issues: Collateral Damage and Cost

Precision Fire- Burst to Kill
- 35-82mm Caliber
- Low- Mod Rate of Fire
- Advanced Warhead
- Prox/Advanced Fuzing
- Moderate Cost Ammo
- Issues: Adequate Ph and Lethality

Precision Fire- Guide to Hit
- 30-35mm Caliber
- Low- Moderate Rate of Fire
- Command Guided Course Correction
- KE Kill
- No Warhead, Fuze or S&A
- High Cost Ammo
- Issues: Burst Size, Cost and SD

Precision Fire- Guide to Burst
- 50-82mm Caliber
- Low Rate of Fire
- Command Guided Course Correction
- Advanced Warhead
- Prox/Advanced Fuzing
- High Cost Ammo
- Issues: Cost, Complexity, Size

All Engagement Options Evaluated
Kill Mechanism/ Fuzing Options

KE/ Shaped Charge w/ Impact Fuze
- C-RAM Type Engagement
- 20mm or Larger
- Hit to Kill
- For KE Kill:
  - >50 gm, 1800 mps to get High Order?
  - >24 gm, 800 mps to get Breakup?
- Min Size Shaped Charge?
- Must Include Self Destruct

KE Preforms w/ Time Fuze
- Burst to Kill Engagement
- Probably Addressing Breakup Kill
- Preformed Tungsten Cylinders or Spheres
- Large Frags Required (10-20 gm?)
- Focused Forward Cone
- Minimum Caliber: 35 or 50 mm?

Blast Frag w/ Proximity Fuze
- Burst to Kill Engagement
- High Order Det or Breakup Kill?
- Prescored or Preformed Frags?
- MEFP or Mult SC Concepts?
- Large Frags Required (10-20 gm?)
- Spherical vs Focused Pattern?
- Forward Frag or Side Frag Pattern?

All Warhead and Fuzing Options Evaluated
# Gun System Candidates

<table>
<thead>
<tr>
<th>System</th>
<th>Cal (mm)</th>
<th>Firing Rate (spm)</th>
<th>Muzzle Vel (mps)</th>
<th>Projectile Mass (gm)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phalanx</td>
<td>20</td>
<td>4500</td>
<td>1030</td>
<td>99</td>
<td>C-RAM System</td>
</tr>
<tr>
<td>GAU-12</td>
<td>25</td>
<td>4200</td>
<td>1097</td>
<td>186</td>
<td>25mm Gatling Gun</td>
</tr>
<tr>
<td>Goalkeeper</td>
<td>30</td>
<td>4200</td>
<td>1080</td>
<td>362</td>
<td>Production CIWS System</td>
</tr>
<tr>
<td>Mk44</td>
<td>30/40</td>
<td>200</td>
<td>1020 (1000)</td>
<td>378 (740)</td>
<td>30/40mm Precision Gun</td>
</tr>
<tr>
<td>Bush III</td>
<td>35/50</td>
<td>250</td>
<td>1050 (1375)</td>
<td>750 (1051)</td>
<td>35/50mm Precision Gun</td>
</tr>
<tr>
<td>Skyshield</td>
<td>35</td>
<td>1000</td>
<td>1050</td>
<td>750</td>
<td>Production Air Defense Sys</td>
</tr>
<tr>
<td>Bush IV</td>
<td>40 Bofors</td>
<td>160</td>
<td>1100</td>
<td>975</td>
<td>Bigger 40 than Super 40</td>
</tr>
<tr>
<td>Bofors 57</td>
<td>57</td>
<td>220</td>
<td>1030</td>
<td>2400</td>
<td>Naval Gun System</td>
</tr>
<tr>
<td>XM274</td>
<td>75</td>
<td>70</td>
<td>1100</td>
<td>5220</td>
<td>Army Developed Gun System</td>
</tr>
<tr>
<td>Scorpion</td>
<td>82</td>
<td>120</td>
<td>277</td>
<td>3230</td>
<td>Foreign Mortar System</td>
</tr>
</tbody>
</table>
### Trade Study Results - Req PR: Characterization of Trade Space

<table>
<thead>
<tr>
<th>Warhead</th>
<th>Guidance</th>
<th>20mm 100% lbs.</th>
<th>25mm 101% lbs.</th>
<th>35mm 730% lbs.</th>
<th>50mm 1020% lbs.</th>
<th>75mm 5061% lbs.</th>
<th>82mm 6893% lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE-Sabot</td>
<td>No</td>
<td>PR~30% 100% Shots</td>
<td>PR~40% 35% Shots</td>
<td>ROF Too Low</td>
<td>Similar To Smaller Calibers</td>
<td>ROF Too Low</td>
<td>Velocity Too Low</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>Too Small</td>
<td></td>
<td></td>
<td></td>
<td>PR ~60% 5-9% Shots</td>
<td>ROF Issues</td>
</tr>
<tr>
<td>HE-Nat</td>
<td>No</td>
<td>PR~30% 100% Shots</td>
<td>Not Done</td>
<td>Not Done – Appears to Have Low Promise</td>
<td>Results Similar to KE Sabot</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>Too Small</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HE-PFF</td>
<td>No</td>
<td>Too Small</td>
<td></td>
<td>Not Done</td>
<td>PR &gt;100% ~1.5% Shots</td>
<td>PR~10% 1% Shots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td></td>
<td></td>
<td>Not Done</td>
<td>PR&gt;100% ~0.75% Shots</td>
<td></td>
<td>Not Done</td>
</tr>
<tr>
<td>CE-Unitary</td>
<td>No</td>
<td>Not Done – Appears to Have Low Promise</td>
<td>Results should be similar to KE Sabot</td>
<td>Too Slow Likely To Be Ineffective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HE-EFP</td>
<td>No</td>
<td>Too Small</td>
<td></td>
<td>Not Done</td>
<td>PR&gt;100% ~1.5% Shots</td>
<td>PR~10% 1% Shots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td></td>
<td></td>
<td>Not Done</td>
<td>PR&gt;100% ~0.75% Shots</td>
<td></td>
<td>Not Done</td>
</tr>
<tr>
<td>KE-Subs</td>
<td>No</td>
<td>Approach</td>
<td></td>
<td>PR~20% 10-15% Shots</td>
<td>PR~60% 7% Shots</td>
<td>PR~60% 2% Shots</td>
<td>Too Slow Likely To Be Ineffective</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>Cost/Kill: &lt;66%</td>
<td>Weight/Kill: 28.3%</td>
<td>Time/Kill: ~40%</td>
<td>PR~100% 1% Shots</td>
<td>PR~90% ~2% Shots</td>
<td>Logistic Burden Too High</td>
</tr>
<tr>
<td>CE-Subs</td>
<td>No</td>
<td>Not Done – Appears To Be Too Small (Insufficient Number Of Submunitions)</td>
<td>Not Done</td>
<td>May Have Some Promise In Larger Calibers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cost, Weight and Time Analysis: 50mm FF Guided vs 82mm Mortar

System Meets All Objectives: Performance, Cost, Weight, and Mission Time Are Improvements Over Requirements
Cost, Weight and Time Analysis: 75mm FF Guided vs 82mm Mortar

Relative Performance

Relative Cost

Relative Weight

Relative Mission Time

System Meets Almost All Objectives: Performance (Out to 90% Of Threat Impact Range), Cost, Weight, and Mission Time Are Improvements Over Requirements

Borderline Performance At longer ranges
• Recommended Development of A Demonstrator Incorporating:
  – External Surveillance Radar With At Least Phalanx Range Capability
  – PTS/ATS Fire Control Radar For Tracking And Communication Link
  – 50mm Bushmaster III/IV Gun Capable of Achieving High Muzzle Velocity
  – Interceptor Using Course Correction Technology From MAST STO (Single Thruster, Guidance Instruments)
  – Transceiver Compatible With PTS/ATS Radar
  – Command Fuzed Forward Fragmenting Warhead Using Multiple EFP (or, Back Ups, Reactive Fragments or Preformed Tungsten Fragments with Boost)

Launched EAPS Gun and Interceptor Development Using These Rough Guidelines As Most Likely Technical Approach To Meet C-RAM Intercept Needs
EAPS Gun Architecture

- Networked Search Sensor
- Networked Tracking Sensor
- Gateway Allowing Link Between Networked Tracker & EAPS Gun
- Gateway Linking Networked Search & Track Functions
- EAPS Gun
  - Fire Control Computer
  - ATS Tracking / Communications Sensor
  - Gun Autoloader & Servos
- Interceptor Flight
- Interceptor Thrust
- Interceptor Detonation
- Monitors Flight Communicates
- Commands Communications
Probability of Mission Success Versus Mortar Threat

Exceeds ATO Performance Threshold With 1.25% Shots Out To 140%
### Gun System Requirements (ATO Objectives)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>EAPS ATO</th>
<th>Approach To EAPS Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pk</td>
<td>$\geq RPK$</td>
<td>$&gt;RPK$ Vs Threats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.25 to 2.5% Shots (MEFP Design)</td>
</tr>
<tr>
<td>Kill Range</td>
<td>$\geq 100%$</td>
<td>$&gt;120%$ Ground Range</td>
</tr>
<tr>
<td>Stowed Kills</td>
<td>$X$</td>
<td>1X to 2X</td>
</tr>
<tr>
<td>Cost/ Kill</td>
<td>$&lt;$T$</td>
<td>45% to 90%K of T Based On DTUPC</td>
</tr>
<tr>
<td>Multiple Near Simultaneous Threats</td>
<td>$-$</td>
<td>Up to 8 Targets Within One Quadrant</td>
</tr>
<tr>
<td>Fratricide/ Collateral Damage</td>
<td>Minimize Potential</td>
<td>Probability of Collateral Hit Low</td>
</tr>
<tr>
<td>Transportability</td>
<td>TBD</td>
<td>C5A, C17</td>
</tr>
<tr>
<td>Mobility</td>
<td>Mobile, 360 Hemispherical</td>
<td>Meets With 20-Ton Class Vehicle</td>
</tr>
</tbody>
</table>

Meets All Specified Goals For EAPS Gun
42nd NDIA Gun & Ammunition Symposium

M61 Handoff Improvements

presented by:  John Fletcher III
Agenda

- Aircraft Overview
- Gun System
- Changes Made
- Summary
T/A-50 Golden Eagle

- Advanced Trainer & Light Attack Aircraft for ROKAF & International Markets
- KAI-LM Aero Co-Development Program (Technical Support by LM Aero)
- T-50 International (TFI) for International Marketing
- Performance: F-16 > T-50 > Hawk/F-5
- Demonstrator aircraft flying
- Production to start in 2009
- 82 fighters on order thus far
T/A-50 Characteristics

- MTOGW: 26,400 lb
- Empty Weight: 14,200 lb
- Max Thrust: 17,700 lb
  - Engine: F404-GE-102
- Performance:
  - Max Speed: Mach 1.4
  - Service Ceiling: 48,000 ft
  - G-Limit: -3/+8 g

Dimensions:
- Length: 43.1 ft
- Width: 30.1 ft
- Height: 16.1 ft
## Gun System Characteristics

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun</td>
<td>3-Barrel Externally Powered 20mm Gatling</td>
</tr>
<tr>
<td>Firing Rate</td>
<td>3,000 Shots per Minute</td>
</tr>
<tr>
<td>Ammo Handling System</td>
<td>Closed Loop Linear Linkless</td>
</tr>
<tr>
<td>Ammo Capacity</td>
<td>204 Rounds</td>
</tr>
<tr>
<td>Drive System</td>
<td>Hydraulic-Mechanical</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>28VDC, 30 Amps Max.</td>
</tr>
<tr>
<td></td>
<td>115VAC, 400 Hz (Firing Circuit)</td>
</tr>
<tr>
<td>Hydraulic Power</td>
<td>3,000 psi Static</td>
</tr>
<tr>
<td></td>
<td>20 gpm Max. Flow @ 2,400 psid</td>
</tr>
<tr>
<td>Dispersion</td>
<td>8 Milliradians (80% Circle)</td>
</tr>
<tr>
<td>System Weight (Empty)</td>
<td>295 Pounds</td>
</tr>
</tbody>
</table>
A-50 Gun System

System includes Gun Control Unit (GCU)

Ammunition Container
Loading Access
Interface Unit
Main Drive Gearbox
Hydraulic Drive
Ammunition Chutes
Transfer Unit

3-Barrel 20mm Gun
Transfer Unit Roundpath

- **Feed side**
  - Rounds enter via conveyor belt
  - Extracted by feed sprocket at min velocity
  - Fed into gun bolt at max velocity

- **Unload side**
  - Spent cases or unfired rounds extracted from gun bolt by unload sprocket at max velocity
  - Deposited into conveyor belt at min velocity
Non-Circular Gearing

Feed Sprocket Shaft (600 RPM Avg)

Aft

Cluster Gear - 4-Lobe Non-Circular (750 RPM Avg)

5-Lobe Gear on Turnaround Shaft (600 RPM)

4-Lobe Idler Gear (750 RPM Avg)
Gun Heritage

- The gun was developed from the M61A2 20 mm gun
  - Three barrels removed
  - Firing rate reduced to match barrel count
- Modifications made to improve round/case handoffs
  - Gun housing
    - Clearance openings for load and unload sprockets extended
  - Bolt guide track
    - Two clearance chamfers added to center track
    - One clearance chamfer added to left forward track
Handoff Comparison

Increased diameter sprockets = improved round control at handoff
Summary

- These minor modifications to the gun allow much better round and case control during handoff
- Resulting in:
  - Less case neck denting by unload sprocket
  - Decreased likelihood of jam at round handoff
- As proven by:
  - No stoppages in the gun or transfer unit during qualification test
  - 43,000+ rounds fired on ground and in air to date by A-50 with no system chargeable stoppage
Contact Information

- John G. Fletcher III
- General Dynamics Armament and Technical Products
- 128 Lakeside Avenue
- Burlington, VT 05401
- 802-657-6358 phone
Lead Free Electric Primers
(Project Number 1331)

2007 NDIA Gun and Missile Systems Conference and Exhibition

Sarah A. Ford

23 April – 26 April

Approved for public release; distribution is unlimited
The Objective of the SERDP Lead-Free Electric Primer (LFEP) Program is to Demonstrate the Feasibility of Substituting Metastable Interstitial Composite (MIC) Materials for the Lead Styphnate... Leading to the Development of a Safe, Reliable & Effective Lead Free Electric Primer (LFEP) for Use in Medium Caliber Ammunition
Electrically Initiated Ammunition In-Service:

20mm Ammunition

USN / USMC / USAF / NATO / FMS

Historically Over 1 Million Rounds per Year

(Peace Time Records)

30mm Ammunition – USA

Annual Production / Utilization

Lead Styphnate – 1700 Pounds

Barium Nitrate – 2000 Pounds

Environmental / Health Hazards Well Known / Documented
TECHNICAL APPROACH

Chemistry Focus

Material Characterization
Optimal Fuel/Oxidizer Ratio (Heat Treated MoO$_3$)
Material Mixing Processes - Solvent, Performance
Environmental Issues (Nano Particulate By-Products)

Primer Reliability

Material Instability
  Stability of MIC/Oxidizer + Additives
MIC Primer Fabrication
  Wet-Loading/Consolidation Process
Aging
TECHNICAL APPROACH

Safety Issues

Primer Mixing Formulation and Processing Hazards
HBSES, ESD, BAM
Production Line ‘Desensitization’

Manufacturing / Producibility Issues

Scalability
Safety
Cost
Reliability / Reproducibility
All-Up Round Performance

Primer Composite
- Aluminum - Particle Size (Nano)
- Oxidizer - MoO$_3$, Bi$_2$O$_3$
- Mixing Process - Sonification
- Additives - Carbon/Binder/Gas Generator

Reproducibility
- MIC Materials
- Mixing Conditions
- Composition
- Consolidation Process
# ACCOMPLISHMENTS

## Chemistry Focus

<table>
<thead>
<tr>
<th>Nanocomposite Ingredients</th>
<th>Size</th>
<th>Active Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Powder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technanogy</td>
<td>33 nm</td>
<td>48.8% (TGA @CL)</td>
</tr>
<tr>
<td>Technanogy</td>
<td>50 nm</td>
<td>64.8% (TGA @CL)</td>
</tr>
<tr>
<td>Nanotechnology</td>
<td>80 nm (116 nm)</td>
<td>82.7% (TGA @CL)</td>
</tr>
<tr>
<td>China Lake</td>
<td>208 nm</td>
<td>86.0% (TGA @CL)</td>
</tr>
<tr>
<td>Molybdenum Trioxide</td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Climax</td>
<td>40 nm (BET @CL)</td>
<td></td>
</tr>
<tr>
<td>Aldrich</td>
<td>1.6 μm (BET @CL)</td>
<td></td>
</tr>
<tr>
<td>Bismuth Oxide</td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Aldrich</td>
<td>320 nm (BET @ CL)</td>
<td></td>
</tr>
<tr>
<td>Skylighter</td>
<td>1-3 μm (BET @ LANL)</td>
<td></td>
</tr>
<tr>
<td>Sigma-Aldrich</td>
<td>&lt; 10 μm</td>
<td></td>
</tr>
</tbody>
</table>
ACCOMPLISHMENTS

Chemistry Focus

LFEP Materials Summary

Binder
- Improved Pressed Pellet Integrity
- Improved Ignition Reliability
- Improved Handling Safety

Carbon
- Reliable Electric Ignition

Gas Generant
- Reduced All-Up Round Action Time
- Optimal Amount

Multi-Vendor Al/MoO$_3$ Source Demonstration

All-Up Round Action Times
Technanogy, NSWCIH, NAWCWD
An obvious change occurs in the “as received” MoO₃ from the manufacturer, Climax. Freshly prepared samples of MoO₃ are white and have large surface areas (~ 45 m²/g) as measured by BET. However, exposure to air over time results in a significant decrease in surface area (~ 20 m²/g) and leads to a lime green coloration.
Chemistry Focus

Heat Treatment of MoO₃

Untreated MoO₃ After 24 Days in Air

MoO₃ Heated to 500°C for 15 Minutes

MoO₃ Heated to 400°C for 15 Minutes

MoO₃ Heated to 400°C for 180 Minutes
MoO₃ Heat Treatment Study Analysis

- Determine Optimal Time and Temperature for Conversion
  - Total Orthorhombic Phase Conversion
  - Minimal Particle Size Growth
- X-Ray Diffraction To Determine Material Phase
- SEM To Determine Particle Size and Morphology
Determine Aging vs Different Mix Processes

Dry Mixing – Mechanical Shaker for 2 Minutes

Ultrasonic Bath

Sonicate Al/MoO₃ for 15 Minutes

Sonicate Mixture for 1 Hour

Ultrasonic Horn (100W, 400W)

Sonicate Mixture for 0.5 to 2 min.

Mixing Process Monitoring

TGA of MIC
ACCOMPLISHMENTS

Chemistry Focus

Solvent Effect in Mixing
Hexane Versus i-PrOH

Hexane

Poorer Mixing

i-PrOH
### Chemistry Focus

**400W Sonic Mixing**  
75% Amplitude 0.5s pulse, 1 min.

#### Molybdenum Trioxide MoO₃

<table>
<thead>
<tr>
<th>Aluminum Powder</th>
<th>Climax 40 nm</th>
<th>Aldrich 1.6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hexane</td>
<td>i-PrOH</td>
</tr>
<tr>
<td>Al (35 nm)</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Al (50 nm)</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Al (80 nm)</td>
<td>Good</td>
<td></td>
</tr>
</tbody>
</table>

#### Bismuth Trioxide Bi₂O₃

<table>
<thead>
<tr>
<th>Aluminum Powder</th>
<th>Aldrich 320 nm</th>
<th>Skylighter 1-3 mm</th>
<th>Sigma-Aldrich &lt; 10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hexane</td>
<td>i-PrOH</td>
<td>Hexane</td>
</tr>
<tr>
<td>Al (35 nm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al (50 nm)</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Al (80 nm)</td>
<td>Good</td>
<td>Poor</td>
<td>Very Good</td>
</tr>
<tr>
<td>Al (208 nm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al (5 mm)</td>
<td>Good</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Poor** – Material Separation (Al from Oxidizer) Was Observed  
**Good** – Little or No Material Separation  
**Very Good** – No Material Separation, Rapid Precipitation, Easy Isolation (Filtration)
Chemistry Focus

Pan Test
50-55 mg of Al/Bi$_2$O$_3$
Optimization results were similar for both methods. Optimal performance achieved at a 2.5 Al/MoO$_3$ ratio. Best performance for fuel rich composites.

2 Al + MoO$_3$ $\rightarrow$ Al$_2$O$_3$ + Mo
Stoichiometric at 2:1

Pan Deflection Test is a rapid screening tool for MIC performance
ACCOMPLISHMENTS

MIC Performance Testing As Measured By Al Pan Dent Deflection

Al(50 nm)/MoO₃(44nm)
400 W Ultrasonic Horn
2 minute @ 75% Ampl
Pulse Length = 0.5 sec

Performance using FC-77 as a solvent exceeds hexane by > 20%

Cause under investigation
Safety Status:

Standard Handling Safety Tests Completed

MIC/BTATZ/Kel-F/C Composition Has Reduced Sensitivity

ESD/Friction/Impact Effects Moderated Formulation by Kel-F Binder

Conduct Safety Tests on Altered Primer Formulation

Al/Bi₂O₃/BTATZ/Kel-F/C Composition

Determine if Mix Sensitivity Moderated by Kel-F Binder

Develop Formulation Process – Reduce Hazardous Operation

Focus on Handling, Processing and Desensitization
Handling and Safety Concerns

**Issue:** ESD and friction sensitivity of MIC materials, particularly Bi$_2$O$_3$, has raised concerns in handling safety.

**Approach:** Utilize safety tests for ESD and friction that are sensitive enough to rank primer formulations for handling.

Establish “wet” loading procedures that minimize handling and reduce sensitivity during processing.
**Electrostatic Discharge (ESD) Sensitivity**

Power Supply = 0-5KV

Capacitance = Variable
0.02, 0.04, 0.22 μF

Energy Range =
2.75 to < 0.001 Joules

Variable Electrode Gap
ACCOMPLISHMENTS

Safety Status:

Friction Sensitivity Data Al Composites

<table>
<thead>
<tr>
<th>Mixture</th>
<th>6/6 NF @ Low Fire Point</th>
<th>Sample Size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETN</td>
<td>42N</td>
<td>~35mg</td>
<td>Burn Mark and NOx Generation</td>
</tr>
<tr>
<td>M-52 Primer Mix</td>
<td>4N</td>
<td>~2 mg</td>
<td>Moderate snap, spark</td>
</tr>
<tr>
<td>Al(80)/Moly/ BTATZ/KelF</td>
<td>9N</td>
<td>~2 mg</td>
<td>Moderate snap, spark</td>
</tr>
<tr>
<td>Al(80)/Moly/KelF</td>
<td>0.05N</td>
<td>~2 mg</td>
<td>Extremely loud snap, spark</td>
</tr>
<tr>
<td>Al(80)/Moly</td>
<td>0.05N</td>
<td>~2 mg</td>
<td>Extremely loud snap, spark</td>
</tr>
<tr>
<td>Al(80)/BiO</td>
<td>0.05N</td>
<td>~2 mg</td>
<td>Extremely loud snap, spark</td>
</tr>
<tr>
<td>Al(80)/AgIO3/KelF</td>
<td>0.05N</td>
<td>~2 mg</td>
<td>Extremely loud snap, spark</td>
</tr>
<tr>
<td>Al(80)/AgIO3</td>
<td>0.05N</td>
<td>~2 mg</td>
<td>Extremely loud snap, spark</td>
</tr>
</tbody>
</table>

BAM Friction Tester
Relative friction sensitivity of energetic materials generated by mechanically rubbing between roughened surfaces

Range = 0.05N to 10N on small BAM
5.0N to 360N on standard BAM
ACCOMPLISHMENTS

**Primer Reliability**

- Chemical Instability
  - Stability of MIC (Al/MoO$_3$)
  - Material Aging (H$_2$O) – atmospheric, chemical, contamination

- MIC Mixing Process – Ultrasonic Mixing

- Loading and Pressing
  - Density
  - Electrical Properties (C)
  - Physical Integrity (Binder)
Both LFEP Loading Procedures Utilize MIC Pastes that are Loaded and Pre-Consolidated (Incrementally), Dried and Given Final Consolidation After Drying.

**Solvent-Based Primer Loading Process**
MIC Formulation and Hexane (1:1 by weight)

**Water-Based Primer Loading Process**
Nano Al Treated with Methyltrichlorosilane
Heat Treatment of the MoO$_3$

**Issue** - Treatment of MIC Materials to Enhance Handling Safety May Adversely Affect Primer Performance
ACCOMPLISHMENTS

Al (80 nm) 0.163g  
NH₄H₂PO₄ 0.042g  
Bi₂O₃ (320 nm) 0.963g  
Gum Arabic 0.059g  
Water 25 ml

Al and NH₄H₂PO₄ in 10 ml of H₂O sonicated for 30 s
Bi₂O₃ and Gum Arabic in 15 ml of H₂O sonicated for 30 s
2 Components mixed and sonicated for 1 minute
Transferred into an Petri dish and air dried.

Result: Separation of Al and Bi₂O₃ during drying process
Conclusion: Phase separation will lead to highly variable primer performance
ACCOMPLISHMENTS

All-Up Round (AUR)

Primer Electrical Resistance Measurement & Test Firing Fixture
Issue: Primer performance may vary depending on environmental conditions found in storage and operation.

Approach: Promising primer formulations are verified by loading in AUR’s and conducting PVAT testing at ambient and cold temperatures that would be most detrimental to performance.
All-Up Round (AUR)  

Cold Temp AUR Test Conditions
• All Rounds Cold Conditioned
• Liquid Nitrogen Used To Cool Breech and Barrel within Shroud
• Dry Air Used to Remove Moisture around Breech

Cold Temp Test Setup
## ACCOMPLISHMENTS

### All-Up Round (AUR)

<table>
<thead>
<tr>
<th>Formulation Identity</th>
<th>Firing Test Date</th>
<th>Initial Temperature (°F) of Primer</th>
<th>Primer Test Temperature (°F)</th>
<th>Action Time (msec)</th>
<th>Chamber Pressure (ksi)</th>
<th>Velocity (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTHU-22</td>
<td>2 Mar 05</td>
<td>Ambient</td>
<td>Ambient</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHU-22</td>
<td>4 Apr 05</td>
<td>Ambient</td>
<td>Ambient</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHU-47</td>
<td>23 Jun 05</td>
<td>Ambient</td>
<td>Ambient</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHU-53</td>
<td>23 Jun 05</td>
<td>Ambient</td>
<td>Ambient</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHU-57</td>
<td>27 Sept 05</td>
<td>Ambient</td>
<td>Ambient</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHU-22</td>
<td>20 Oct 05</td>
<td>Cold Temperatures</td>
<td>Cold Temperatures</td>
<td>Within Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
<tr>
<td>KTHW-24</td>
<td>24 Oct 05</td>
<td>Cold Temperatures</td>
<td>Cold Temperatures</td>
<td>Exceed Spec</td>
<td>Within Spec</td>
<td>Within Spec</td>
</tr>
</tbody>
</table>
ACCOMPLISHMENTS

Manufacturing/Producibility:

Coordinated efforts with the Army’s ammunition procurement office, Joint Munitions Command, and the Navy’s medium caliber ammunition program office, PMA-242, to begin the technology transition process.

Scalability
Handling Safety
Cost
Reliability/Reproducibility
PARTNERING

• MIC Joint Service Working Group-Government
  Los Alamos National Laboratory
  Lawrence Livermore National Laboratory
  Sandia National Laboratory
  Eglin Air Force Base
  NAWCWD-China Lake
  NSWC-Indian Head

• MIC Joint Service Working Group-Industry
  GDOTS Canada Inc
  ATK
  Novacentrix
Following Successful Development & Demonstration of a Medium Caliber LFEP the Navy, & Likely the Army, will Pursue the Follow-On Development, Qualification & Production of Environmentally Favorable Primers for Military Ammo Applications.

ESTCP began FY07 and partnering with: Primer and Ammunition Manufacturers-Lake City Ammunition and Armament Plant and GDOTS Canada Inc. Materials Manufacturers-Novacentrix

Production and handling studies will be the focus of the first year of ESTCP. Investigators will work with industry to ensure a cost effective, viable production method for mass production of Lead-Free Electric Primers.

The qualification process will include industry buy in and Low Rate Initial Production. The LRIP lot will be thoroughly evaluated.
Questions?
NDIA 42\textsuperscript{nd} Annual Armament Systems: Gun and Missile Systems

April 25, 2007

Recent Developments in Affordable Laser Guided Precision Weapons Capabilities

Jim Franciscovich
Electronics and Integrated Solutions Inc.
Sensor Systems
Driven by Changes

The Precision War = Dynamic Missions/Threats
- Target Sets Requiring Better than GPS Accuracy
  - Tank (T-80), SA-6, SA-8, Guns, Self Propelled AAA, APC, Bunker doors, small revetments, pickup trucks, SUV’s etc
- Real Time Reactive Targeting – Dynamic Mobile Targets
- Fighting in Close without Boundaries- Distributive Operations
- Restricted Rules of Engagement
- Minimize Collateral Damage - Preservation of the Infrastructure
- Minimize Potential for Fratricide

Affordability
- Low Unit Cost – Shortened Development Timelines
- Use of Qualified & In Inventory Assets
- One Weapon One Kill
- Minimize Platform Integration Costs
- Minimize Training & Logistics Burdens

Enabled by Technology

Focus on the Future = Low Cost Precision Effects

Approved for Public Release
Advanced Precision Kill Weapon System (APKWS™)
AVIATION OPERATIONAL NEED

Limited Weapon Options For Soft Targets

**Employment Concepts**

- Precision Strikes on Soft/Light Armor Point Targets
- Increases Platform Stowed Kills
- Close Aerial Fire Support
- Urban Terrain Employment
- Remote Designation of Targets
- Complement to HELLFIRE and Unguided Rockets
- Reduced collateral damage
- Mission Description:
  - SASO – Enhanced Aircraft Performance and Duration
  - LIC – Enhanced Effectiveness for Scout/Reconnaissance
  - MIC – Provide Significant Capability vs Multiple Point Targets
  - HIC – Complement Deep Strike and Anti-Armor

**Hydra-70 Rocket (1 - 6 Km)**
- Short effective range
- Poor accuracy (Area Weapon)
  - High cost/soft kill at 6 Km
  - High collateral damage
  - Fratricide potential
  - Low stowed kills at 6 Km
- High transportation cost

**HELLFIRE (1 - 8 Km)**
- High cost/soft kill at 6 Km
- Weapon Over-match

**Unguided 2.75” Rocket (Area Suppression)**

**Guided 2.75” Rocket**

(Soft & Lightly Armored Point Targets)

• More Accurate Than Unguided 2.75” Rocket – Essential Anti-Terror Weapon
• Less Costly Than HELLFIRE and allows for more Stowed Kills
• Reduced collateral damage

Approved for Public Release
APKWS™
CONCEPT OF OPERATIONS

CONOPS
• Suppression
• Self Designate
• Cooperative Engagement

Approved for Public Release
APKWS™ Components

Mid-body Design is **Supportable**
- No field modifications required
- No changes to weapons loading
- Limited training required for pilots

Mid-body Design is **Reliable**
- Optics protected prior to launch from adjacent firings, sand, moisture, etc.
- Wide FOV for broader capture area

Mark 66 Mod 4 2.75” Rocket Motor

**M151 Unitary Warhead & M423 Fuse**

No Impact on Warhead Effectiveness
- Warhead does not “fire through” guidance unit

**Table:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Current Wt per Unit (lbs)</th>
<th>Length (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidance &amp; Control</td>
<td>8.9</td>
<td>18.5</td>
</tr>
<tr>
<td>Motor</td>
<td>13.7</td>
<td>41.8</td>
</tr>
<tr>
<td>Payload &amp; Fuse</td>
<td>9.2</td>
<td>13.5</td>
</tr>
<tr>
<td>All Up Round</td>
<td>31.8</td>
<td>73.8</td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
<td><strong>35</strong></td>
<td><strong>75</strong></td>
</tr>
</tbody>
</table>

Approved for Public Release
Mid-Body Seeker

Compatible with legacy Hydra components

Guidance Section protected inside the launcher

Deployment Flexibility

Stowed and sealed optics provide full lifecycle environmental protection

Simple Guidance Section Assembly Into an All Up Round

MK66 MOD 4 Solid Rocket Motor

APKWS II Guidance Section

M151 Warhead

M423 Fuze

Approved for Public Release
Proven Performance

Tested throughout the full environmental spectrum

- Vibration
- Shock
- Environmental Testing
- HWIL, ALSPES, at Temp Facility, Outdoor Range Testing

Approved for Public Release
Flight Test Success
APKWS™ Advantages

**Increased Accuracy**
- 20-100m
- <2m
- Low cost conversion
- 1.5km to 5km range
- Area Suppression becomes Precision Strike

**Reduced Logistics Burden**
- 12 to 1 reduction in transport load outs for same combat effectiveness

**> Stowed Kills per Sortie**
- Hydra 70
- Guided APKWS

**< Cost for Stowed Kills per Sortie**

- AMRDEC/DCD analysis in support of LCPK ATD

Approved for Public Release
XM 395 PGMM
Precision Guided Mortar Munition

XM 395 PGMM Satisfies the need for responsive, precision munition that reduces collateral damage

- BAE Systems Wide FOV Distributed Aperture Semi-Active Laser Seeker “DASALS™”
  - Delivered > 50 Seekers
  - Demonstrated Mortar Launch Hardness
    - Rail Gun & Guided Flight
  - Demonstrated Hit
    - ATK scored a hit after firing PGMM from a standard 120mm mortar at Yuma Proving Grounds.

- Target set includes enemy personnel protected by brick over block walls, lightly armored vehicles (LAV), and an earth & timber bunkers

Laser-guided 120mm mortar
Max-range 7.2km
Deployed similar to conventional mortars
Compatible with all current smooth bore 120mm mortar weapons

Approved for Public Release
Flight Test Success
Optically Designated Attack Munitions (ODAM)

60 mm fuze / guidance

60mm Mortar Launcher

1000m Slant Range Acquisition

2) Trajectory Estimated

3) Apogee Sensed

4) Mortar Roll Angle = 0°

5) Spot Acquired

6) Aero Corrections

≤ 4m CEP

≥ 100m Steering Radius

≥ 300m Designation Range

1200m – 3000 Launch Ranges

ODAM will change the Paradigm of Indirect Fires!
Why ODAM?

• Drives precision down to infantry company level
  • First-shot kills, avoid collateral damage
  • Enable reliable indirect / long-range fires
• Dramatically accelerates the infantry battle
  • ~5X more kills / mortar platoon, ~10X faster
• Low cost – not silver bullet – use as either guided or unguided round, as tactics dictate
  • Train as you would fight

• If proven successful – disruptive technology
  • ~1/20 recurring cost of other precision rounds
  • Adds only 1 lb / round, 4 in to length (3.7 to 4.7 lb, 15 to 19 in)
Flight Test Success
Summary

- **Affordable Precision Benefits the Warfighter**
  - Fills the Requirements for Responsive, Precision Munitions that Reduce Collateral Damage
  - Demonstrated Progress & Increased Technology Readiness Levels
  - Improves the ability to Train as you would Fight
- **First-shot kills accelerates the battle in a distributed operational environment**
  - Potential exist to drive precision down to Infantry Company level
  - Allows for Affordable Real Time Reactive Targeting addressing Dynamic Mobile Targets

Approved for Public Release
The Success of the AMRAAM DBMS/DAS

John Gerdine
Wyle Laboratories Inc.
Niceville Florida 32579 U.S.A.
Overview

• Asymmetric Threat
• AMRAAM Development
• Test and Evaluation (T&E) History
• Current AMRAAM Production
• Test and Evaluation Program
• AMRAAM DBMS/DAS Development
• DBMS/DAS Design and Operation
• Resource for Detailed Analysis and Improvement
• Summary
Asymmetric Threat

• United States must expect to face asymmetric threats within the air battle space
• In the future, the US cannot expect an enemy to present the kind of target set that it has seen in years past
• Technology and techniques are always being developed to neutralize the power of the US
AMRAAM Development

- The AIM-120 AMRAAM was developed jointly by the Air Force and the Navy
- The main purpose of AMRAAM was to maintain air superiority
  - All weather radar guided missile
  - Multiple target engagement capability
  - Counter electronic warfare
  - Launch and leave
AMRAAM T&E History

• Full Scale Development (FSD) testing began in 1984
  – Ground tests
  – AMRAAM Captive Equipment (ACE) flight tests
  – Hardware-In-Loop (HIL) Simulations
  – Digital Simulations
  – Pre-programmed flight tests
  – 100 guided missile flight tests
AMRAAM T&E History

• AMRAAM was flight tested and evaluated by the Operational Test and Evaluation organizations to confirm performance with an emphasis on effectiveness and suitability
• Pre-Planned Product Improvement P³I Programs
• Over the last 10 years, AMRAAM continues to be evaluated in the Weapon System Evaluation Program (WSEP)
Current AMRAAM Production

• As of the 6th of October 2006, Raytheon Company received its first production award for the AIM-120D configuration of AMRAAM.
  – Production and delivery will support the U.S. Air Force, Navy and Army.
• The AIM-120D is an enhanced capability missile
• Changing technology and battle space requirements of the warfighter.
• AMRAAM is the most carried air-to-air missile in the U.S. arsenal and is deployed in 32 countries.

(Source Aerospace & Defense News Headlines: Raytheon)
Test & Evaluation Program

• The development process for the AMRAAM weapon system involved a robust Test & Evaluation program
  – Well planned
  – Definitive road map that adhered to the requirements
  – AMRAAM developed in stages
  – The T&E program ultimately proved AMRAAM capability and performance
AMRAAM Telemetry

• The AMRAAM is fully instrumented
• All subsystems and phases of flight are monitored
• The telemetry is recorded at the test ranges and delivered to Wyle for processing and analysis
Time, Space, Position Information (TSPI)

- TSPI is available on DoD test ranges and is used by analysts as a reference datum or ‘truth data’ in order to quantify weapon system performance.
- Measurements on the launch aircraft, the missile and each target are merged into a common coordinate system.
- TSPI is processed for AMRAAM analysis in the same coordinate system.
- Direct comparison
- Global Positioning System (GPS) at all major DoD test ranges.
AMRAAM DBMS/DAS Development

• AMRAAM Joint Systems Program Office (JSPO) developed the AMRAAM Data Base Management System and Data Analysis Software (DBMS/DAS)

• Primary requirements
  – Maintain all data relevant to T&E flight tests
  – Analyze AMRAAM total weapon system performance

• Every AMRAAM launched over the past twenty three years (1984 – present) is maintained in the DBMS and the DAS has been used to evaluate performance.
Data Base Management System (DBMS)

- Evaluate total weapon systems performance
- Support government milestone reviews
- Validate the AMRAAM simulations
- Perform special studies and produce white papers
- Support system upgrades
- Throughout several improvement phases, the task of validating improvements was accomplished using flight test data maintained in the DBMS.
Data Analysis Software (DAS)

- Predefined core set of automated software routines (contexts)
- User Defined Contexts
- DAS streamlines the task of total weapon system analysis.
  - AMRAAM weapon system complexity and the quantity of data transmitted in telemetry
  - Valuable asset during anomaly investigations
DBMS/DAS Operation

- AMRAAM telemetry and TSPI is loaded into the DBMS immediately after a mission
- Data is cataloged with information that pertains to the missile, launch aircraft and targets
- Contexts are run in a batch processing mode to produce data products
DBMS/DAS Operation

• The data products are reviewed, analyzed and inserted directly into the Quicklook report as an appendix
• Contexts are run on a repetitive basis for every AMRAAM mission
• Specialized contexts for anomalies
Weapon System Analysis

• Flight test objectives and requirements.
  – Data analysis and reporting
  – Anomaly Investigations
  – Simulation Validation
  – Special Studies
  – AMRAAM Product Improvement Programs
  – FMS Support
Anomaly Investigations

• The DBMS/DAS is used for anomaly investigations to determine the root cause of anomalies.

• Point anomaly
• Trend analysis
Simulations Validation

• AMRAAM HIL and digital simulations
• DBMS is the primary source of actual flight test data used to validate simulations
• Validation process
Special Studies

• The data contained in the DBMS has been used to perform special studies, produce white papers and develop performance evaluation summaries

• Special contexts

• To date, there are over 45 special studies and white papers produced by the Wyle analysis team
AMRAAM Upgrades

• Since AMRAAM was fielded, there have been many requirements for missile improvements.
• Broad spectrum of scenarios and electronic warfare.
• Validating improvements
• Validate the improvements as they are integrated into the simulation.
Foreign Military Sales (FMS) Support

• The DBMS maintains mission data from AMRAAM flight tests programs conducted by foreign countries to support aircraft integration and In-Service firings.
• FMS countries conduct flight tests in CONUS and OCONUS
• Foreign countries employ AMRAAM from US and foreign aircraft
Summary

• The success of the AMRAAM DBMS/DAS can be measured by its contribution to developing AMRAAM as a world air superiority weapon system.
• Valuable asset to AMRAAM for twenty three years and is still used today
• The Acquisition process for developing a weapon system must include a robust Test & Evaluation program and a DBMS/DAS to maintain and analyze data
Air Force Material Command News
Service 10/2/2006

- The need for change is one reason Gen. Bruce Carlson, AFMC commander, chose the test and evaluation enterprise as one of his four AFMC strategic areas under Air Force Smart Operations for the 21st century.
- AFSO 21 serves as an overarching program guiding continuous process improvement throughout the Air Force.
- "AFMC needs a test and evaluation presence at the early stages of an acquisition program in order to help build testability into the program from the outset," said Dr. Jerome, who also is the deputy director of Air, Space and Information Operations at Headquarters AFMC.
- "Involving the testing community earlier in the program development would help to better define test and evaluation strategies for acquisition programs."
- This will benefit future acquisition efforts by having the right test capabilities -- defined as infrastructure, process and people -- in place to plan and execute developmental and operational testing more effectively and efficiently than we do today," Dr. Jerome said. "Ultimately, it will deliver effective and suitable weapon systems on time and on cost."
Questions?
Presentation to 42nd Annual Gun and Missiles Conference

Trade Space on Appropriate Caliber Ammunition for Terminal Defense Guided Projectile

Advanced Programs
Chris E Geswender
cegeswender@raytheon.com
Andrew Hinsdale
Andrew_j_hinsdale@raytheon.com

April 23, 2007
Traditional Threats

- Large capital platforms
- Large, highly capable weapons
- Low engagement rates
- Relatively long reaction times
- Usually engaged by a large, high performance missile
- Gunfire used only as last ditch defense against “leakers”
- “Cost Effectiveness” equation based on cost to kill ~ cost of threat

Main Defensive weapons designed against these threats
New Asymmetric Platform Threats

- With loss of “active” peer threats, lower capability countries dominant threat
- Weapons used by these countries are usually militarized commercial products
- GPS or GPS/INS permits easy weaponization of UAV or USV platforms
- Terrorists can also use same technology as effectively as the U.S.
- Threats likely to employ multiple units and surprise to ensure mission success with low reaction times
- Guns are appropriate as primary engagement weapon
- “Cost Effectiveness” equation requires cost to kill ~ “political” cost of failure

Newer threats, secondary weapons being designed to handle
New Non-Traditional Threats

- New generation of low volume, GPS or SAL guidance applied to unguided munitions
- These weapons will result in simultaneous attacks in large numbers
- Low reaction times due to short ranges and large numbers
- Gunfire only practical means to respond to these threats in high engagement rates
- Target “hardness” ranges from hard to very hard, a major technical challenge

- Equally available to terrorists and even the smallest of nation states
- “Cost Effectiveness” equation should be cost per kill ~ “political” cost of failure

A new problem, requiring new solutions
## Not All Functions Drive Trade Space

<table>
<thead>
<tr>
<th>Function</th>
<th>Projectile Caliber Influence</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection</td>
<td>Weak</td>
<td>Primarily a function of the search sensor</td>
</tr>
<tr>
<td>Classification</td>
<td>Weak</td>
<td>Determines if signal represents a threat</td>
</tr>
<tr>
<td>Engagement Planning</td>
<td>Strong</td>
<td>Determines order of engagement, how many projectiles per target to fire (projectile lethality used in calculations)</td>
</tr>
<tr>
<td>Fire Control System (FCS)</td>
<td>Weak</td>
<td>Coordinates target state, sensor pointing and gun pointing to begin engagement</td>
</tr>
<tr>
<td>Weapon Initialization</td>
<td>Medium</td>
<td>Smaller calibers cannot be guided but would have smart-fuzing larger calibers that may require additional states to support guidance</td>
</tr>
<tr>
<td>Weapon Deployment</td>
<td>Strong</td>
<td>Gun carriage and auto-loader characteristics strongly determined by caliber of projectile fired</td>
</tr>
<tr>
<td>Weapon Control System (WCS)</td>
<td>Medium</td>
<td>Smaller caliber may have fuze aiding and larger caliber may require additional transmitted states for guidance (lethal radius influences accuracy required)</td>
</tr>
<tr>
<td>Terminal Effects</td>
<td>Strong</td>
<td>Caliber size determines both lethal radius and per-shot-lethality of projectile</td>
</tr>
</tbody>
</table>

**NOTE** – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues
Newest Threats are Hardest to Defeat

- Small radar cross section
- Very hard shell body
- Small vulnerable area
- Small reaction times
- Likely to have large number of simultaneous threats
- Requires K-kill to not revisit (soft kill is a dud but not known until impact)

These threats drive the requirements for a self defense projectile

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues
### Side by Side Analysis

<table>
<thead>
<tr>
<th>Caliber</th>
<th>US DoD</th>
<th>Other</th>
<th>In Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mm</td>
<td>USAF</td>
<td>Aircraft Guns</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vulcan ADU</td>
<td></td>
</tr>
<tr>
<td>25 mm</td>
<td>M2A1 Bushmaster</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>30 mm</td>
<td>USAF, USM</td>
<td>FRG-ABM</td>
<td>Yes</td>
</tr>
<tr>
<td>35 mm</td>
<td>N/A</td>
<td>Skyguard</td>
<td>Yes</td>
</tr>
<tr>
<td>40 mm</td>
<td>USAF</td>
<td>BOFORS</td>
<td>Yes</td>
</tr>
<tr>
<td>57 mm</td>
<td>USN LCS, DDX</td>
<td>BOFORS</td>
<td>Yes</td>
</tr>
<tr>
<td>60 mm</td>
<td>N/A</td>
<td>X-WP</td>
<td>No</td>
</tr>
<tr>
<td>76 mm</td>
<td>USN FFG, USCG</td>
<td>NATO FFG</td>
<td>Yes</td>
</tr>
<tr>
<td>90 mm</td>
<td>N/A</td>
<td>Unknown</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Selection is available from a large range of operational calibers**

*NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues*
Combat Proven Answer to New and Non-Traditional Threats

- Exists and fielded
- Proven lethality
- Low per engagement cost
- RF primary sensor
  - IIR capability
- Engages low elevation targets
- Engages high elevation targets
- Multiple projectiles
  - HE
  - Incendiary
  - Tracer
  - Self destruct
- Support leveraged by large installed base

http://www.raytheon.com/products

Test and combat video available at
http://www.videotiger.com/vids/amazingmilitarydefensiveweapon.wmv

Proven highly effective in ship-board and static-land scenarios

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues
30 mm/35 mm Operational

- AHEAD technology, developed by Oerlikon Contraves, improves the capability of air defense guns to engage and destroy aerial targets from large aircraft to small targets like missiles or PGMs.

- The gun fires short, 24 round burst of high velocity AHEAD rounds aimed at the target's intercept point to activate and separate the projectile into 152 heavy tungsten metal spin-stabilized sub-projectiles (3.3 grams each), forming a lethal cone shaped metal cloud, placed ahead of the target in its flight path.

- 35 mm AHEAD is designed to fit existing Skyguard air defense systems.

- The 30 mm AirBurst Munition (ABM) is currently being qualified for the German Army for deployment with the MK 30-2 ABM cannon mounted on the Puma AIFV.

- A 35 mm version optimized for ground-to-ground effect is being qualified for the Bushmaster III chain gun mounted on the new CV9035 IFV of the Royal Dutch Army. Denmark has also selected the ABM capability for its CV9035.

- The ABM concept is also highly suitable as a Counter-Rockets, Mortars and Artillery (C-RAM).

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues.
40 mm/57 mm Cannons Operational

- The 57 mm MK 3 provides unmatched lethality with multiple 57 mm ammunition options available from the weapon's twin compartment magazine that can shift between round types instantly. Bofors 57 mm 3P all-target programmable ammunition allows three proximity fuzing options as well as settings for time, impact and armor-piercing functions. With a range of 17 kilometers, Bofors 57 mm HCER surface target ammunition provides reach and explosive effect comparable to larger caliber guns.

![Image of cannons and a littoral combat ship]

http://www.uniteddefense.com/prod/ngun_mk3.htm

<table>
<thead>
<tr>
<th>Cartridge Weight</th>
<th>Gun</th>
<th>Cartridge Weight</th>
<th>Cartridge Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>955 G</td>
<td>57mm L60 40x311R</td>
<td>2,230</td>
<td>57mm m/47 57x230R</td>
</tr>
<tr>
<td>870 G</td>
<td>40mm L/70 40x364R</td>
<td>2,400</td>
<td>57mm L60-70 57x438R</td>
</tr>
</tbody>
</table>

Littoral combat ship using the larger rounds as primary batteries

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues.
76 mm Cannons Operational and New Solutions are in Work

Naval Applications

Advanced Projectiles

Potential Land Based Applications

High speed 76 mm compatible for naval and land combat employment

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues
### DOES NOT INCLUDE 2 + 1 Firing Protocol

<table>
<thead>
<tr>
<th>Calibre cm</th>
<th>Weight kg</th>
<th>Volume cm³</th>
<th>load per 5T truck</th>
<th>fired per kill &amp;</th>
<th>intercepts per truck</th>
<th>trucks per K intercept</th>
<th>gun firing rate</th>
<th>Firing Time to Time to Max Eff</th>
<th>1st Engage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3</td>
<td>1</td>
<td>105</td>
<td>889</td>
<td>4267</td>
<td>20</td>
<td>213</td>
<td>5</td>
<td>600</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>2.1</td>
<td>574</td>
<td>423</td>
<td>2032</td>
<td>10</td>
<td>203</td>
<td>5</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>5.7</td>
<td>4</td>
<td>1,749</td>
<td>222</td>
<td>1067</td>
<td>3</td>
<td>356</td>
<td>3</td>
<td>150</td>
<td>20</td>
</tr>
<tr>
<td>7.6</td>
<td>10</td>
<td>3,455</td>
<td>89</td>
<td>427</td>
<td>2</td>
<td>213</td>
<td>5</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>5,814</td>
<td>59</td>
<td>284</td>
<td>1</td>
<td>284</td>
<td>4</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>10.5</td>
<td>17.8</td>
<td>8,573</td>
<td>30</td>
<td>240</td>
<td>1</td>
<td>240</td>
<td>5</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td>27.6</td>
<td>11,198</td>
<td>32</td>
<td>155</td>
<td>1</td>
<td>155</td>
<td>7</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>15.5</td>
<td>52</td>
<td>26,630</td>
<td>17</td>
<td>82</td>
<td>1</td>
<td>82</td>
<td>13</td>
<td>4</td>
<td>60</td>
</tr>
</tbody>
</table>

@ Assume one AD vehicle - ignoring azimuth training time
# Assume 3 AD vehicles with overlapping azimuths - ignoring azimuth training time
& Assumed to be required to effect a K kill

### INCLUDES 2 + 1 Firing Protocol

<table>
<thead>
<tr>
<th>Calibre cm</th>
<th>Weight kg</th>
<th>Volume cm³</th>
<th>load per 5T truck</th>
<th>fired per kill &amp;</th>
<th>intercepts per truck</th>
<th>trucks per K intercept</th>
<th>gun firing rate</th>
<th>Firing Time to Time to Max Eff</th>
<th>1st Engage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3</td>
<td>1</td>
<td>105</td>
<td>889</td>
<td>4267</td>
<td>20</td>
<td>213</td>
<td>5</td>
<td>600</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>2.1</td>
<td>574</td>
<td>423</td>
<td>2032</td>
<td>10</td>
<td>203</td>
<td>5</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>5.7</td>
<td>4</td>
<td>1,749</td>
<td>222</td>
<td>1067</td>
<td>3</td>
<td>356</td>
<td>3</td>
<td>150</td>
<td>20</td>
</tr>
<tr>
<td>7.6</td>
<td>10</td>
<td>3,455</td>
<td>89</td>
<td>427</td>
<td>2</td>
<td>213</td>
<td>5</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>5,814</td>
<td>59</td>
<td>284</td>
<td>1</td>
<td>284</td>
<td>4</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>10.5</td>
<td>17.8</td>
<td>8,573</td>
<td>30</td>
<td>240</td>
<td>1</td>
<td>240</td>
<td>5</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td>27.6</td>
<td>11,198</td>
<td>32</td>
<td>155</td>
<td>1</td>
<td>155</td>
<td>7</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>15.5</td>
<td>52</td>
<td>26,630</td>
<td>17</td>
<td>82</td>
<td>1</td>
<td>82</td>
<td>13</td>
<td>4</td>
<td>60</td>
</tr>
</tbody>
</table>

@ Assume one AD vehicle - ignoring azimuth training time
# Assume 3 AD vehicles with overlapping azimuths - ignoring azimuth training time
& Assumed to be required to effect a K kill

57 mm and 76 mm appear best for intermediate range intercept
Payload Lethality Inputs  
(All Data from Open Sources)

**Joules required to Damage Target**

<table>
<thead>
<tr>
<th>Target</th>
<th>Light Damage</th>
<th>Moderate Damage</th>
<th>Heavy Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>0.1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Aircraft</td>
<td>4</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Armor</td>
<td>10</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

\[ J = \text{Kg} \times (\text{m/s})^2 \]

**Probability of Kill**

\[ N_{\text{hits}} = A\left( N_{o}/4\pi R^2 \right) \]

where:
- \( N_{\text{hits}} \) is the expected number of fragments hitting;
- \( N_{o} \) is the initial number of fragments from the warhead;
- \( A \) is the frontal area of the target presented to the warhead;
- \( R \) is the range of the target to the warhead.

For multiple hits the overall \( P_k \) is found from

\[ P_k = 1 - (1-P_{k_{\text{hit}}})^{N_{\text{hits}}} \text{, if } N_{\text{hits}} > 1 \text{, or} \]

**Initial Fragment Velocity**

The theoretical result for fragment velocity using the Gurney constant \((2\Delta E)\) for TNT is 2328 m/s:

\[ v = \sqrt{2\Delta E} \sqrt{\frac{C}{M}} \sqrt{1 + \frac{K(C/M)}{1}} \]

where:
- \( C/M \) is the charge-to-metal ratio
- \( K \) depends on the configuration:
  - Flat plate: \( K = 1/3 \)
  - Cylinder: \( K = 1/2 \)
  - Sphere: \( K = 3/5 \)

**Fragment Velocity at Range**

\[ V(s) = V_o \times e^{-\rho C_d A_s/2M} \]

- \( \rho \) = The density of air. Normally 1.2 Kg/m3
- \( V_o \) = The fragment velocity
- \( C_d \) = The coefficient of drag. Depends on the shape of the fragment and to some extent, the velocity
- \( A \) = The cross-sectional area of the fragment
- \( M \) = Mass of fragment
- \( s \) = Distance traveled

*NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues*
Projectile Must Match Warhead Size to Miss Distance Performance

Projectile Data Derived from Jane’s Ammunition Handbook

<table>
<thead>
<tr>
<th>Dia</th>
<th>Length</th>
<th>C/M</th>
<th>No</th>
<th>Vo</th>
<th>Jo</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>110</td>
<td>0.1</td>
<td>600</td>
<td>600</td>
<td>12</td>
</tr>
<tr>
<td>30</td>
<td>110</td>
<td>0.15</td>
<td>900</td>
<td>1100</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>210</td>
<td>0.13</td>
<td>2300</td>
<td>1000</td>
<td>30</td>
</tr>
<tr>
<td>57</td>
<td>340</td>
<td>0.19</td>
<td>5400</td>
<td>1200</td>
<td>68</td>
</tr>
<tr>
<td>76</td>
<td>375</td>
<td>0.10</td>
<td>7900</td>
<td>900</td>
<td>51</td>
</tr>
</tbody>
</table>

PROJECTILE HIT TO KILL (HTK)

A hit is when the miss is less than 80% of the sum of the weapon diameters

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues

All payloads require hit to kill or very high precision guidance
Gun Accuracy Implies Different Solution for Different Engagement Ranges

- Longer Range First Engagement
  - Guided Missile
  - Long Range First Engagement Guided Projectile
- Short Range First Engagement
  - Unguided Blast Frag Projectile
- Point Defense
  - Unguided KE Projectile
  - Or DEW

All solutions require hit to kill or very high precision.
Conceptual Volume Allocation

~ 340 mm

Payload

Guidance And Control

Volume Allocation Based on 57 mm Projectile

Recent miniaturization allows guidance in 76 mm and 57 mm projectiles and moving towards 40 mm

NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues
Summary

- Depending on desired operational flexibility and cost sensitivity, there are a number of potential solutions
  - Targets come in radical size differences
  - Targets come in radical differences in “hardness”
- Cost/performance standard set by trailer mounted PHALANX system
- For higher mobility, the candidate calibers are between 20 mm – 155 mm
- Projectiles calibers of 20 mm, 30 mm, 40 mm would likely be unguided
  - Insufficient volume for payload/guidance/power
- Guidance can be realistically considered for 57 mm and 76 mm projectiles
  - Both gun sizes can be mounted in AFV chassis
  - Guided 76 mm projectiles in advanced development
  - Projectile volumes sufficient for GNC/power considerations
- Implementation of actuation and power source are the technical challenges in smaller calibers
- For any caliber, due to wide variations in target size/hardness, it may take different warhead families to best cover threats
2007 NDIA
42nd Annual Armament Systems:
Gun and Missile Systems Symposium
23 – 26 April 2007

Capabilities of Penetrator with Enhanced Lateral Efficiency (PELE®)
Medium Caliber Cartridge vs. KE or HE Ammunition

Don Gloude, 20mm Design Engineer
ATK Medium Caliber Systems

Mark Weron, 20mm Program Engineer
Hill AFB
• Cartridge Concept Overview
• OT&E Ground-to Ground Test Plan
• Test Performance
• Conclusion
• Acknowledgements/Contacts
• Questions & Answers
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 – 2001</td>
<td>Technology Transfer to 20 mm x 102 mm PELE® and Target Effect Evaluation specified by MoD</td>
</tr>
<tr>
<td>2002</td>
<td>German MoD decision for 27 mm x 145 mm PELE® FSD</td>
</tr>
<tr>
<td>2003</td>
<td>In-House Technical Evaluation of 20 mm x 102 mm PELE® by Diehl</td>
</tr>
<tr>
<td>2004</td>
<td>In-House Technical Evaluation of 27 mm x 145 mm PELE® by Diehl</td>
</tr>
<tr>
<td>2005</td>
<td>USAF Decision to select 20 mm x 102 mm PELE® for OT&amp;E (Operational Test and Evaluation) as potential replacement for PGU-28/B</td>
</tr>
<tr>
<td>2006</td>
<td>OT&amp;E testing began at Eglin AFB</td>
</tr>
</tbody>
</table>
Ammunition
20 mm x 102 mm
PELE®

PELE® Cartridge & Projectile Assembly

PELE
PGU-28
## 20 mm PELE® Design Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (max)</td>
<td>168 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>264 g</td>
</tr>
<tr>
<td>Projectile Mass</td>
<td>100 g</td>
</tr>
<tr>
<td>Muzzle Velocity</td>
<td>3410 f/s</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Average Mean Radius = 15 in. at 500 yds</td>
</tr>
<tr>
<td>Penetration</td>
<td>Ballistic limit &lt; 2750 f/s against 0.375 in. (9.5mm) armor at 0°</td>
</tr>
<tr>
<td>Ballistics</td>
<td>Comparable to PGU 28A/B or PGU 27A/B</td>
</tr>
<tr>
<td>Design</td>
<td>Low drag version</td>
</tr>
</tbody>
</table>
Key Features of PELE® Cartridge

• Compatible with all 20mm M39A2, M61, M197, M621 and ATK Viper chain gun systems

• Inert Projectile has no Explosives or Fuze

• Multi-role Ammunition
  ➢ Air-to-Air
  ➢ Air-to-Ground
  ➢ Ground-to-Ground
  ➢ Ground-to-Air

• Enhanced Performance
  ➢ Fragmentation (w/o HE)
  ➢ Penetration (like SAPHEI)
  ➢ Can be tailored to customer objectives

• Dual Purpose for Combat and Training

• Reduced Cost and Logistics

• High Reliability
Principles of PELE® Function

Projectile Body: High density material (steel or tungsten)

Inner Core: Low density material (plastic or aluminum)

Steel or tungsten penetrates the target

Plastic or aluminum does not penetrate the target

Simple Design …
Principles of PELE® Function

- Density differences between inner core and projectile body
- Upon target impact, projectile body penetrates target; interior core does not penetrate
- Impact generates an extremely high pressure in the inner core causing the projectile body to fragment as it exits the target

… Yet Effective.
Fragmentation of PELE® Projectile

Target: 2 mm Al / 0° NATO
Impact Velocity: 750 m/s

Target: 2 mm Al / 80° NATO
Impact Velocity: 750 m/s

X-ray images of function
PELE® Multi-Plate Array Test Set-up

FIXED WING EQUIVALENT TARGET S1

- Function point - Projectile fragments
- Maximum fragmentation effect
- Nearly no fragments leave the target - all energy stays in the target
PELE® Delivers More Energy in the Target Compared to Other Tactical Ammunition
**PELE® Performance on Multi-Plate Array**

An advanced weapon and space systems company

<table>
<thead>
<tr>
<th>plate 1</th>
<th>plate 2</th>
<th>plate 3</th>
<th>plate 4</th>
<th>plate 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="plate1.png" alt="Image" /></td>
<td><img src="plate2.png" alt="Image" /></td>
<td><img src="plate3.png" alt="Image" /></td>
<td><img src="plate4.png" alt="Image" /></td>
<td><img src="plate5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>plate 6</th>
<th>plate 7</th>
<th>plate 8</th>
<th>plate 9</th>
<th>plate 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="plate6.png" alt="Image" /></td>
<td><img src="plate7.png" alt="Image" /></td>
<td><img src="plate8.png" alt="Image" /></td>
<td><img src="plate9.png" alt="Image" /></td>
<td><img src="plate10.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Fixed Wing Equivalent Target S1 – 2mm Al Spaced at 300mm**

Few fragments leave the target – all the energy stays in the target.
PELE® Penetration Performance

PELE® able to penetrate 10 mm Rolled Homogeneous Armor (RHA)
Less than 0.5 mil difference out to 4000m range.
TARGETS
• Cessna Cardinal (light aircraft)
• F-16/C-130 Wing Sections
• F-16 Tail Section
• M577 Armored Personnel Carrier (APC)
• M577 APC Rear Hatch
• Light Utility Trucks
  (each test set-up included dummies)

TEST SET-UP
• Air/ground (A/G) engagements converted to ground-to-ground (G/G) using PRODAS® software
• Ballistic trajectories simulated for both A/G and G/G engagements
• Impact velocities matched to position targets
# Cessna Cardinal Test Set-up

| Target Set | 1 Cessna Cardinal  
1 Pilot / 1 Co-pilot  
2 Passengers |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)</td>
<td>3444.9 / 3169.23</td>
</tr>
<tr>
<td>PRODAS Ground-Ground Target Location (ft)</td>
<td>535</td>
</tr>
</tbody>
</table>
Cessna Cardinal Test Damage

Entrance Hole

09/28/2006

REAR

09/28/2006

REAR

REAR

REAR

An advanced weapon and space systems company
Cessna Cardinal Test Damage

ENGINE DAMAGE

ENGINE DAMAGE
### F-16/C-130 Wing Section Test Set-up

| Target Set                          | 1 F-16 Wing w/ 1 dummy  
1 C-130 Wing w/ 2 dummies |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)</td>
<td>3444.9 / 3130.77</td>
</tr>
<tr>
<td>PRODAS Ground-Ground Target Location (ft)</td>
<td>610</td>
</tr>
</tbody>
</table>
F-16 Wing / ‘Troop’ Damage

An advanced weapon and space systems company

Images showing damage to the wing of an F-16 aircraft, marked with arrows. The date 09/28/2006 is visible on the images.
C-130 Wing / ‘Troop’ Damage

Residual Fuel in Wing Foam Burning
**F-16 Tail Section Test**

<table>
<thead>
<tr>
<th>Target Set</th>
<th>1 F-16 Tail w/ 3 dummies</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)</td>
<td>3444.9 / 2978.13</td>
</tr>
<tr>
<td>PRODAS Ground-Ground Target Location (ft)</td>
<td>915</td>
</tr>
</tbody>
</table>

Significant damage to exit surface with composite skins.
F-16 Tail Section Test

Test Set-up

'Troop' Damage
### M577 APC Test Set-ups

| Target Set          | 1 M577 APC w/ 5 passengers  
6 dummies in hasty cover |
|---------------------|-------------------------------------------------|
| PRODAS Muzzle / Impact Velocity (ft/s) | 3444.9 / 2808.94  
2460.36 |
| PRODAS Ground-Ground Target Location (ft) | 1210  
2000 |
20mm PELE® is effective against light armor.
M577 APC Test Damage

Penetrated 8” Reinforced CMU Wall

‘Troop’ damage inside APC

Did not penetrate APC at extended range (5000 ft) in all shots
# M577 APC Rear Hatch Test

<table>
<thead>
<tr>
<th>Projectile Type</th>
<th>Muzzle Velocity (ft/s)</th>
<th>Impact Velocity (ft/s)</th>
<th>Impact Range (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PELE®</td>
<td>3388.406</td>
<td>2472.430</td>
<td>1966.881</td>
</tr>
<tr>
<td></td>
<td>3429.776</td>
<td>2505.556</td>
<td>1968.057</td>
</tr>
<tr>
<td>PGU-27A/B</td>
<td>3405.015</td>
<td>2432.786</td>
<td>1968.880</td>
</tr>
<tr>
<td></td>
<td>3402.988</td>
<td>2405.282</td>
<td>2021.135</td>
</tr>
<tr>
<td></td>
<td>3424.768</td>
<td>2347.559</td>
<td>2212.883</td>
</tr>
<tr>
<td></td>
<td>3412.408</td>
<td>2253.949</td>
<td>2359.837</td>
</tr>
<tr>
<td></td>
<td>3418.592</td>
<td>2435.984</td>
<td>1965.469</td>
</tr>
<tr>
<td></td>
<td>3415.898</td>
<td>2426.698</td>
<td>1972.231</td>
</tr>
</tbody>
</table>

PELE® penetrates vs PGU-27
## Light Truck Test Set-ups

<table>
<thead>
<tr>
<th>Target Set</th>
<th>2 Light Utility trucks w/ passengers 6 dummies in hasty cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)</td>
<td>3444.9 / 2460.36 1262.07</td>
</tr>
<tr>
<td>PRODAS Ground-Ground Target Location (ft)</td>
<td>2000 5000</td>
</tr>
</tbody>
</table>
Light Truck Test ‘Troop’ Damage
Light Truck Test Damage

Fire in 5 gal. Diesel Fuel Can Hit by PELE®

Engine Damage
Test Summary

• All targets were incapacitated except the APC at 5000 ft ground-to-ground.

• PELE® ignited residual fuel in AC-130 wing foam and diesel fuel in 5-gallon fuel can.

• ‘The round met or exceeded performance projections.’ – Air Force assessor.

• Air Force down-selected to the PELE® round because Qualification Testing showed it to be as good or better than the PGU-28/B, especially if you factor in the life cycle cost savings.
20 mm x 102 mm PELE® cartridge offers:

- Combined HE and KE performance characteristics
- 100% safe – No reactive materials and no fuze
- High reliability and long shelf life
- Low cost – standard materials, simple manufacturing, short lead times
- “One round for all” – combat and training round (reduced logistic burden)
- Can be optimized for individual customer’s requirements
- Ready for service – ballistic match to PGU-27 and PGU-28/B, existing ignition system and no impact to aircraft operating systems (e.g. software) or handling equipment

PELE® is an ideal form-fit-function tactical solution.
Acknowledgements

• Diehl BGT Defence GmbH & Co.
• Mr. Mark Weron, Hill AFB
• Mr. Larry Douma, ATK Medium Caliber Systems
• Mr. Dan Delaney, ATK Medium Caliber Systems
• Mr. Duane Bjorlin, ATK Medium Caliber Systems
Contacts

Bob Schmitz (ATK 20mm Program Manager)
(763) 712-7724
Bob.schmitz@atk.com

Don Gloude (ATK 20mm Design Engineer)
(763) 712-7710
don.gloude@atk.com

Rodney Ward (ATK Medium Caliber Systems Business Development)
(480) 324-8608
Rodney.ward@atk.com

Mark Weron (Program Engineer - Hill AFB)
(801) 777-7803
Mark.Weron@Hill.af.mil
MK 46 Mod 1 At-Sea Evaluation

A Overview of Live-Fire Test Events Conducted Onboard the LPD 17
August 2006

Prepared for:
NDIA 42nd Annual Gun and Missiles Systems Conference

By:
Andrew Green
NSWC Dahlgren Division

23-26 April 2007
Outline

• Background
• Collaborative Effort
• The Test Platform
• Test Setup
• Ammunition
• Targets
• Test Objectives
• Constraints/Issues
• Test Evolution
• Types of Data Collected
• Summary
Background

- Combat System Ship Qualification Trial (CSSQT) required of all new ships as part of Post-Delivery Test and Trials (PDT&T) phase
  - Emphasis on gun system as this will be a new system on the lead ship of a new ship class

**LPD 17 CSSQT Air & Surface Events**
- Objective: Conduct live-fire exercises to collect data to verify if ship’s force can safely and effectively operate GWS in its assigned mission and to verify safe operation of GWS itself

- Questions raised regarding accuracy of various ammunition types (armor-piercing (AP) and high-explosive (HE))
  - Is AP ammo more accurate and is it worth the additional cost?

**LPD 17 AP vs. HE Ammunition Comparison Test**
- Objective: Conduct live-fire exercise to collect % hit versus range data

- Questions regarding the effectiveness of the MK 46 Mod 1 GWS
  - Is its performance as indicated by M&S Tools during trade-off studies?

**MK 46 Mod 1 GWS At-Sea Risk Reduction Test for LHA 6**
- Objective: Conduct live-fire exercise to collect engagement data
**Collaborative Effort**

**NAVSEA – Warfare Centers**

<table>
<thead>
<tr>
<th>NAVSEA</th>
<th>NAVSEA</th>
<th>NAVSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• PM4 (under PEO IWS3C) – Conventional Ammunition Manager</td>
<td>• Code W22 – WSEM for LHA(R) Program</td>
<td>• LPD 17 CSSQT Project Office</td>
</tr>
<tr>
<td>• Code 40 - ISEA for MK 46 (PMS 317)</td>
<td>• Code G32 – Lead Gun Systems Engineer, LHA 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Code G61 – Provided Photo Documentation and Instrumentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Gun Tech Warrant Holder (plus A&amp;A Ships CS TWH in SEA06)</td>
<td></td>
</tr>
</tbody>
</table>

**NAVSEA – PEOs**

<table>
<thead>
<tr>
<th>PEO</th>
<th>PEO</th>
<th>PEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>• PMS 317 – Provided Platform (LPD 17) and Range Time (VACAPES OPAREA) during CSSQT at-sea period</td>
<td>• PMS 495 – Provided APFSDS-T ammunition assets to all parties under MoA</td>
<td>• IWS1 – Provided input to LHA(R) test events</td>
</tr>
<tr>
<td>• PMS 377 – Provided funding and ammunition for LHA(R) events</td>
<td></td>
<td>• IWS3C – Provided input to LHA(R) test events and oversaw ammunition allocation (3C/PM4)</td>
</tr>
</tbody>
</table>

**Outside of NAVSEA**

<table>
<thead>
<tr>
<th>NAV</th>
<th>NAV</th>
<th>NAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ONI/SABER &amp; SWDG (OPNAV N72) – Provided input &amp; concurrence for LHA(R) test event scenarios</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• NAVAIR NAWC Aircraft &amp; Weapons Divisions – provided targets &amp; targets support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• DRPM AAA &amp; GDAMS – Provided support for MK 46 GWS</td>
<td></td>
</tr>
</tbody>
</table>
Collaborative Effort (Cont.)

• 2 separate Memorandums of Agreement – Involving 3 separate Program Executive Offices, 4 Program Management Offices, and two Surface Warfare Center Divisions (Dahlgren and Crane Divisions)
  – 2-Party MoA between PMS 317 (LPD 17) & PMS 377 (LHA(R))
    • Use of LPD 17 as test platform for LHA 6 RRT

  – 4-Party MoA between PEO Ships/PMS 317 & PMS 377, PEO IWS3C/PM4 (NSWC Crane by extension), and PEO LMW/PMS495 (NSWC DD by extension)
    • Provision of 1440 MK 258 Mod 1 APFSDS-T hydro-ballistic rounds for all planned at-sea test events
Collaborative Effort (Cont.)

• Three overarching test plan documents
  – PMS 317 Sponsored Test Events
    • LPD 17 CSSQT Plan, Vols. 1 & 2
    • 30-Millimeter x 173 Armor-Piercing and High-Explosive Ammunition Comparison Test Plan (NSWCDD/MP-06/76)
  – PMS 377 Sponsored Test Events
    • MK 46 Mod 1 Gun Weapon System (GWS) At-Sea Risk Reduction Test For The Amphibious Assault Ship (LHA) 6 (NSWCDD/MP-06/35)
The Test Platform
USS San Antonio (LPD 17)

“Never Retreat…Never Surrender”

- Built by Northrop Grumman Ship Systems, Commissioned 14 January 2006
- 684 feet OAL, 105 ft beam, 23 ft draft, 24,900 ton displacement (full load)
- 363 Crew, 699 Troops, Surge capacity of +101 (800 total)
- Intended to replace older LPD 4 and LSD 36 classes
- Designed to carry and launch the EFV (14 vehicles) and the LCAC (2 in well deck)
- Can operate 2 MV-22 Osprey tilt-rotors or 4 CH-46 Sea Knight helicopters simultaneously
- MK31 Mod 1 RAM Guided Missile System (2 launchers), 30mm MK 46 Mod 1 Gun Weapon System (2 systems), .50 cal M2HBs (single and twin mounts)
Test Setup – LPD 17

Live Fire Target Approach Sector for MT 32

SHROS

Target C2 Comms

MT32

SHROS Data Van & Target C2 Station

Live Fire Target Approach Sector for MT31

MT31
Test Setup – Photo/Instrumentation

• Shipboard High Resolution Optical System (SHROS)
  – Operated by NSWCDD personnel
  – Provides day video, infrared video, and radar data
  – Independent sensor system not coupled to the weapon system
  – Mounted on edge of flight deck
  – Controlled from command and control (C2) Data Van located in hangar bay

• Documentary video recording
  – MK 46 battle-sight display video, interior and exterior views, roving documentary video and still photography
  – Command and Control and other activities for investigation into Human Systems Integration (HSI) issues

SHROS Mount

SHROS Sensor Package
**Test Setup – Target C2**

- Remote targets command and control operations
  - Remote Control Operators (RCO) C2 station located in the hangar bay
  - C2 antennae located on flight deck for clear line of sight (LOS) to targets
- Targets operated using either the Portable Command and Control Unit (PCCU) or radio control
- Operated by NAVAIR NAWC Aircraft and Weapon Divisions
### Ammunition

**MK 239 Mod 0 TP-T, PGU-15/B TP**
- NALC AA65
- 1850 Rounds

**MK 258 Mod 1 APFSDS-T**
- NALC AA71 Substitute
- 1440 Rounds

**MK 266 Mod 2 HEI-T, MK 264 Mod 0 MPLD-T**
- NALC AA89
- 1600 Rounds

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>NALC</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>APFSDS-T</td>
<td>Armor-Piercing, Fin-Stabilized, Discarding Sabot, Traced</td>
<td>NALC</td>
<td>TP</td>
</tr>
<tr>
<td>HEI-T</td>
<td>High-Explosive (HE) Incendiary, Traced</td>
<td>TP</td>
<td>TP-T</td>
</tr>
<tr>
<td>MPLD-T</td>
<td>Multi-Purpose, Low Drag, Traced</td>
<td>Target Practice</td>
<td>Target Practice, Traced</td>
</tr>
</tbody>
</table>

**Approved for Public Release; Distribution is Unlimited**
Target Set

HSMST

Steel Mesh Billboard  Plywood Billboard

QST-33 SEPTAR

Over 22 total targets made available for the various test events

Vindicator UAV

Towed Sled Billboard

SDST (Jet-ski)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED
Test Objectives

• CSSQT Events
  – Can ship’s force operate the MK 46 Mod 1 safely and effectively in its assigned mission on the LPD 17?

• AP vs. HE Ammunition Comparison Test (AP/HE Comparison)
  – Collect % hit vs. range for APFSDS-T and HEI-T/MPLD-T ammunition types on stationary billboard targets for various ranges

• LHA 6 Risk Reduction Test (RRT)
  – Collect kill assessment, engagement timeline, and % hit vs. range, target position data
• Minimize Combat System/Crew impact on successful conduct of the test
  – Established ROE (Detect & ID established prior to engagement with MK46)
  – Simplified engagements without sacrificing potential realism
• MT31 vs. MT32
  – MT32 provided more deck space near mount for SHROS and target C2 packages
  – Arc of fire over port-quarter allowed for minimal ship structure influence on test events
• Potential Unexploded Ordnance
  – Several firing events called for the use of AA89 ammunition (MK 266 Mod 1 HEI-T/MK 264 Mod 0 MPLD-T linked 1:1) against Fleet standard High Speed Maneuvering Surface Targets, or HSMSTs. These craft were based on RHIB hulls which were very rugged and fairly unsinkable
  – Nature of 30mm point-detonating HE ammunition may lead to potential unexploded ordnance situation (plan for worst case)
  – Test plans changed to accommodate this reality
    • Only inert ammunition would be fired at HSMST targets and wood/foam billboards
    • Any target engaged with HE had to be disposed of at-sea
  – Other targets reconfigured or designed for use with AA89 ammunition
    • De-foamed QST-33 SEPTAR
    • Steel mesh billboards built as targets for AA89 ammunition during AP-HE Comparison Test
  – **Bottom line:** any target engaged with HE ammunition would have to be sunk post-event
LPD 17 Test Evolution & Events

- LPD 17 CSSQT
  - Surface Events vs. MT32 and MT31
  - Air Event vs. MT32
  - Sled Event vs. MT32 (not executed)
- Ammunition Comparison Test
  - Firing Runs vs. MT32 covering 3 Range Bands
- LHA 6 Risk Reduction Test
  - 4 Firing Runs vs. MT32
- 9 total gun firing events planned
  - All gun firing events had to be completed in a 5 day window
  - All gun test events competed with ship drills, inspections, and other test events with respect to time and ship’s force availability
Awaiting Their Fate…
Launching a QST-33 SEPTAR off LPD 17’s Stern Ramp
Test Environment

• Test environment ranged from calm seas and little wind to 15+ knot winds and large swells and whitecaps

• Environment varied over test evolution from rough seas to clam and back again

• Boat targets airborne at times in rough seas

• Screen captures from SHROS covering live-fire events
Types of Data Collected

• Video
  – Battle-sight (MK 46), SHROS (Color, FLIR), Roving/Documentary (including video/audio covering activity involving HSI issues)

• Timeline
  – IRIG-B

• Target Behavior Information
  – Speed, Heading, Location

• Photographic
  – Target Damage Assessments
  – Test Setup & Execution
Types of Data Collected (cont.)

GPS Plots and Timeline Information of Target Path for Event Reconstruction

Target Speed Plots
Summary

- Given a new ship, new gun system, and inexperienced crew...
- LPD 17 CSSQT
  - Ship’s force operated MK 46 Mod 1 safely and effectively
  - Ship qualified for SuW mission
  - Results documented in “USS San Antonio (LPD 17) CSSQT Summary Report, 22 January 2007”
- AP vs. HE Ammunition Comparison Test
  - All requisite data collected
  - Results documented in NSWCDD/MP-07/21, “30-Millimeter Armor-Piercing Versus High Explosive Ammunition Comparison Test Report”
- LHA 6 Risk Reduction Test
  - All requisite data collected
- 1 firing event out of 9 not executed (CSSQT Sled Event)
- Several valuable lessons learned from planning through execution to be applied to follow-on at-sea tests
- Entire test evolution was a success
QUESTIONS?

For technical information, please contact:

Naval Surface Warfare Center, Dahlgren Division

Mr. Andrew Green, Code G32

Telephone: (540) 653-8868
E-mail: dlgr_nswc_g32@navy.mil
-“Urban Operation Solutions with Medium & Large Caliber Ammunition”

Presented at
42nd International Guns & Missiles Conference
Charlotte, NC, USA

by
Jan G. Hasslid
Vice President/Marketing
Medium & Large Caliber Ammunition
Nammo MLCD
Norway
2007-04-24
Contents

• Definitions
• Challenges
• Solutions to Support the Warfighter needs
• Recommendations
# Nammo’s Business Units

<table>
<thead>
<tr>
<th>Small Caliber</th>
<th>Medium &amp; Large Caliber</th>
<th>Missile Products</th>
<th>Demil</th>
<th>Talley Defense Systems</th>
</tr>
</thead>
</table>

- **Small Caliber**
- **Medium & Large Caliber**
- **Missile Products**
- **Demil**
- **Talley Defense Systems**
#1 Challenge for Nammo Technology & Products
-Customer wants more out of less types of ammunition

- MP-MultiPurpose
- AB- Air Burst
- APFSDS-T
- Nammo plastic training & short range
#2 Challenge for Nammo Special Products
- Customer want’s a complete solution for the operational needs

Urban Warfare Solutions

- Vehicle ammunition
  - Artillery & Mortars
- Aircraft ammunition
  - Navy ammunition
- Training

Target distance

Target hardness
Definition of Business Development Areas
MLCD\textsuperscript{[2007]}

- **Urban Warfare**: 40%
- **Vehicle Ammunition**: 20%
- **Artillery & Mortars**: 15%
- **Aircraft Ammunition**: 15%
- **Navy Ammunition**: 5%
- **Life Cycle Management**: 5%
- **Order intake**:
Warfighter Ammunition Solutions
-Trends with Asymmetric threat

Sales 2002-2006

Performance Index

Year

Ref.
URBAN WARFARE SOLUTIONS
-Meeting the Warfighters needs
Urban Warfare Solutions

• 12,7mm as the true MultiPurpose Ammunition
• 40mmX51 AGL Programmable Ammunition
• M72 Shoulder Launched Missile
• Training & Short Range Ammunition
12.7 mm MP Family (0.50cal)

- Multipurpose Warshots
  - MP [NM 140, MK211]
  - MP-T [NM160, MK300]
  - MP-DT [Dim Trace]
  - AP-S [NM 173]
  - Training ammunition
  - SG [Ballistic match]
  - SG-T [Ballistic match]
  - RR [Reduced range]
  - PSRTA-T [Short range]
  - Blanks [Plastic]

SDZ Reduction!!
12.7 MP-DT for Night Operations

Dim Tracer at target

Standard Tracer at target

Qualified with:
- 5.56mm
- 7.62mm
12,7mm MULTIPURPOSE, MP

V0=910m/s

0.50 Cal. MK211 by ATK/Nammo
40mmX53 Ammunition Solutions for 40mm Automatic Grenade Launchers

- New Ammunition – Programmable Air-Burst
  - 40mmX51 PPHE MK285
  - 40mmX51 IHV-HEDP M430PIP by N2 Defence (NICO & Nammo)
  - 40mmX51 PPHE-RF

- New AGL systems developed during the last 10 years
  - Mk47 Striker by GD-ATP
  - GMG by Heckler & Koch, H&K

- Mk 19 Legacy
40mm x 51 Nose Fuzed HE Round
The Solution for Urban Operations

Fragments distributed:
- Sideways
- Backwards

Highly effective against hidden targets e.g. on rooftops, behind corners, inside buildings, in trenches etc., targets you don’t normally take out with direct fire.
Fragmentation of HE Warhead

Distance from detonating point:

- 3 m
- 5 m
- 7.5 m
- 10 m

Penetrations / m^2

Sector (degrees)

EAGLE kill 40mm MK285 warhead
40mmX51 PPHE Ammunition (US MK 285)

- Electronic programmable Time Fuze (US MK 438)
  - Point Detonating (mechanical)
  - Self-Destruct (electronic)
  - Mechanical Safe & Arm (US MK91)
- Prefragmented Shell
- IM Properties (use of PBXN 5 & 9)
- Improved Propulsion (NICO)
  - V0=240m/s
  - Very small V0 variation with temperature
40mmX53 IHV-HEDP M430 PIP

- M430 (HEDP) Improved High Velocity Program
  - Key improvements:
    - PD/SD function implemented
    - New Propulsion Unit (NICO)
    - IM properties with PBXN-11
    - After Armour Effect (Incendiary)
    - Penetration++
    - Reduced safety zone (Back-plug)
- P-Programmable version optional
**40mmX51 PPHE-RF (Radio Frequency)**

**New Air-Burst technology**

- Developed as a co-operation between NAMMO and FFI (Norwegian Defence Research Establishment)
- The principle can be used on all systems which requires the advantage of Air-Burst capability
- External add-on solution
  - We only need Fire Control with Range Finder & Ballistic Computer
- Radio Signals sent from transmitter to reciever built-in in the fuze
M72 LIGHT ANTI-ARMOUR WEAPON

M72 LAW

IMPROVEMENTS/NEW VERSIONS

M72 EC-LAW      M72 ASM-VERSIONS
(EC = ENHANCED CAPACITY)  (ASM = ANTI STRUCTURE MUNITION)

M72 by Nammo Group(Talley Defence Systems/Nammo MLCD)
M72

Launcher Improvements for the User

- Increased hit probability – on-axis trigger operation
- Reduced weight – Carbon composite fiber inner tube
- Improved human factors – grip tape and self-folding sights
- Available for all M72 product improvements
M72 ASM-RC

RC- Reduced Caliber WARHEAD:

- Penetrates building structures such as
  - Double brick Walls
  - Clay Walls
  - Timber and Sand Bags Bunker
- 400 g explosives of type DPX-6
- Multiphase blast effect
- Composite warhead shell body
- Low Collateral Damage Warhead
M72 ASM-RC

FUZE:

- Single mode – long delay (20 ms)
- Dual mode
  - Long (20ms) or short delay (2 ms)
- Graze function
M72 ASM-RC
FIRING DEMONSTRATION
FIRING AGAINST URBAN STRUCTURE. FUZE WITH LONG DELAY

- **PLYWOOD 14mm AND CRUSHED STONE 300mm**
- **WINDOW 500x500mm**
- **WOODEN FRAME WORK 2” x 6” CENTER TO CENTER 300mm**
- **WOODEN DOOR SIZE 2000x1000mm. STEELPLATE 2mm**
- **SOFT CONCRETE (LECA) BRICKS. THICKNESS 150mm.**
- **WOODEN FRAME WORK 2” x 4” CENTER TO CENTER 600mm**
- **CHIPBOARD 12mm INSIDE/OUTSIDE. STEELPLATE 0,7mm INSIDE**
- **SANDBAGS TWO LAYER**
- **STEELPLATE 0,7mm INSIDE AS A WITNESSPLATE**
Vehicle Ammunition
-New products suitable for asymmetric warfare

- 25mm
- 30mm
- 120mm

Key elements
- Precision strike
- Insensitive Munitions
- Low Collateral damage
- Short range training
- Air Burst capability
Rapid development and qualification of State-of-the-Art Ammunition! (example 30mmX173)

- **Warshots**
  - MP-T/SD   MK 264 mod 0   NM 222
  - TP-T      MK 270 mod 0   NM 219
  - APFSDS-T  MK 258 mod 0   NM 225
  - APFSDS-S  MK 258 mod 1   “Swimmer”

- **Training**
  - TPDS-T    [Qualified May 2007]
  - TP-T RRR  Reduced Ricochet Risk
  - P-SRTA    Plastic Short Range

- **Blanks**

  ”-We have been supported by our Home Market CV90’s and US NAVY/USMC-EFV”
Range Reduction by 30mmX173 TPDS-T
-Ballistic match with APFSDS-T

Height

1500m

8000m

Range

37000m

APFSDS-T

TP-T template
120mm Ammunition

Product & Development Programs

- HE-T MK I
- IMHE-T
- TP-T (spotting)
- TP-I (Inert)
- KE-TP
- APFSDS-T

120mm cooperation GD-OTS/Nexter/Nammo
120 mm IMHE-T Tank Ammunition

- $V_0 = 744\text{m/s} \rightarrow 1030\text{m/s}$
- Improved accuracy to $<0.2\text{mils @ 2000m}$
- Increased explosive charge weight ($2.7 \rightarrow 3.2\text{kg}$)
- Increased penetration
- Dual mode Fuze
- Maintaining fuze function at low graze angles
- Qualify the round according to the new NATO STANAG for operational and storage temperatures [-54--+71\text{C}]
120 MM IMHE-T AMMUNITION

Project plan:

- IM testing of the explosive and propellant will be completed in June 2007
- Firing demo is planned for July. 2007 US/GD-OTS
- Development finalized by Dec. 2007
- Ammunition qualified in Sept. 2008
Aircraft Ammunition

• Expanding the MP capabilities by APEX ammunition in 25, 27 and 30mm applications
User Requirements Solved by APEX

Air to Air
“MP” functionality inside light skinned targets
- Fragmentation
- Blast
- Fire starting capability

Improved capability

Close Air Support
Heavy ground targets
- Penetration of armor
- Penetrating Fragments
Recommendation...
(Examples)

- Urban Warfare Solutions
  - 12.7mm
  - 30mmX173
  - 40mmX51 MK 285 & IHV-HEDP
  - M72 Shoulder Launched Weapon
  - 120mm HE-T Mk I

- Rapid Developments (2007)
  - 12.7 Dim Trace (IR)
  - 30mm TPDS-T
  - M72 ASM-RC
  - 120mm IMHE-T

- Development Programs
  - APEX
  - Air Burst (30-120mm)
Questions?
Jan G. Hasslid
Vice President/Marketing
Medium & Large Caliber Division
Nammo Raufoss AS
P.O. Box 162
NO-2831 Raufoss
Norway
Tel: +47 61 15 25 33
Fax: +47 61 15 22 50
Mob: +47 46 42 03 88
jan.hasslid@nammo.com
www.nammo.com
M789 LW 30mm HEDP Cartridge In-Bore Detonation Investigation

Presented By
Mr. John Hirlinger, ARDEC
&
Dr. Scott Kukuck, ARL

26 April 2007
Agenda

• 30mm Inbore/Hangfire Investigation
  – Apache M230 Weapon System Basic Information
  – Reported Problems
    • Total Incident Types / #’s & Groupings
    • Resultant Damage Examples
  – Investigation Team
  – Methodology Employed
  – Most Likely Causes & Actions Taken
  – Additional Recommendations
  – Summary
Apache M230 Weapon System

- Aircraft System
  - Turret Mounted Weapon
  - Closed Loop Linkless Feed System
  - Weapon Mounted Uploader/Downloader; ‘D’ Model Aircraft have Additional Ammunition Sideloader
  - First In/Last Out Ladder/Rail Magazine

- M230 Weapon
  - Externally Powered w/Electric Drive Motor
  - Single Barrel, Chain Driven Automatic Cannon
  - 625 ± 25 Shots per Minute Firing Rate

- M789 High Explosive Dual Purpose Cartridge
  - Aluminum Cartridge Case w/Electric Primer, IB52 Booster System & Double Base WC855 Ball® Powder
  - High Strength 4130 Steel Projectile w/PBXN-5 Explosive Fill
  - Spin Compensated Shaped Charge Liner
  - Point Initiating, Base Detonating Nose Mounted Fuze
Original Incident Classifications

- **Hangfire** – Ballistic functioning of the cartridge occurs outside of the dwell time of the weapon. Operating group & sometimes receiver damaged.
  - 23 Incidents since Aug 97

- **Inbore Detonation** – Premature initiation in the barrel under the barrel support shroud. Barrel bulges, sometimes ruptures.
  - 21 Incidents since Aug 97

- **Severed Barrel** – Premature initiation in the barrel near the muzzle. Muzzle is completely lost.
  - 2 Incidents Since Aug 97
Typical Damage
“Minor Event” - Hangfire
Typical Damage
“Severe Event” - Hangfire
Typical Damage
Inbore Detonation

- Damage Similar to or Identical to Severe Hangfire/High Pressure Plus Barrel Cracking & Muzzle Break Impacts by Fragments
Typical Damage
Bullet on Bullet

Severed Barrel

Severed & Ruptured Barrel
In-Bore/Hang-fire Investigation Team Participation

In-Bore/Hang-fire Investigation Team Encompasses Elements From Across Area Weapon System, and is a Total System Approach to Solving LW30mm Field Issues
IHIT Methodology

- Team Used A System Engineering And Six Sigma Approach
  - Interviews w/Field Units (Shooters, Ground Crews, Supply)
  - Re-work Previous Root Cause Analysis for Inbore Detonations
  - Use Failure Mode Effects Analysis (FMEA) Process
  - Collect Data (Modeling, Simulation, Testing) To Fill Data Gaps & Populate Fault Tree For Each Failure Mode
  - Conduct Design Of Experiments (DOE) And Verification Testing
  - Incorporate Changes Into TDP
• No Incident Resulted from the 1st Round Fired
• Ammo Usually Stays in A/C Until Scheduled Phase Maintenance - Some Units Reloaded in Reverse Order of Download
• Manual Mode for Sideloader & Uploader/Downloader are Still Used Infrequently
• Feed System Jams While Uploading are Still Occurring Resulting in Punctured Cartridge Cases
A Total System Approach

Cannon, Handling System & Aircraft Systems
121 Potential Causes

Ammunition Handling & Storage
3 Potential Causes

Ammo Metal Parts Manufacture
55 Potential Causes

215 Total Potential Failure Modes Identified

Six Sigma Tools:
- Continuous Black Belt Consultation
- Failure Modes Effect Analysis
- Fault Tree Analysis
- Design of Experiments

Identified Three Major Root Causes

- Cross Functional/Cross Organizational IPT
- Co-Leaders from PM-MAS & PM-Apache
- User Involvement & Feedback
- Systems Engineering
Hangfire/High Pressure
## Ignition System DOE Phase I

The table below summarizes the control factors and their levels for the experiment:

<table>
<thead>
<tr>
<th>Control Factors</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booster Mix</td>
<td>100%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Primary Charge</td>
<td>With</td>
<td>Without</td>
<td></td>
</tr>
<tr>
<td>Flashtube Pellets</td>
<td>Pellet</td>
<td>Powder</td>
<td></td>
</tr>
<tr>
<td>Propellant Level</td>
<td>100%</td>
<td>50%</td>
<td>25%</td>
</tr>
</tbody>
</table>

The Pareto chart illustrates the standardized effects of various factors. The chart highlights the following:

- **Propellant**
- **Booster**
- **Primary**
- **Booster & Propellant Interaction**

The Mann Barrel test is also mentioned in the document.
Damaged IB52 Pellets/Flash Tube

Open Air High-Speed Video of Flash Tube Venting

Normal Shot #1 Breech
Normal Shot #2 Breech
Normal Shot #2 Projectile
Normal Cold Breech
Normal Cold Projectile
Normal Hot Breech
Normal Hot Projectile
Normal IB52

Live Propellant 30-mm Gun Simulator

WC855 in Flash Tube has Given Greater Than 40 ms Ignition Delay

Some Damage IB52 Pellets

Broken Lacquer Seal with WC855 in Tube

Gas Velocity From Flash Tube

Normal IB52

Gas Velocity From Flash Tube

WC855 in Tube

Some Damage IB52 Pellets

Broken Lacquer Seal with WC855 in Tube

Gas Velocity From Flash Tube

WC855 in Tube

Some Damage IB52 Pellets

Broken Lacquer Seal with WC855 in Tube

Gas Velocity From Flash Tube
Hot Temperature Storage Led to DPA Depletion

- Over time, the original stabilizer, DPA, depletes and converts to daughter products – 2NDPA, NNODPA; DPA reaction rate increases as temperature increases

**Lot 1995 Aged at 71°C**

<table>
<thead>
<tr>
<th>Lot 1995 @ 71°C</th>
<th>Pull 1 - Day 4</th>
<th>Pull 2 - Day 8</th>
<th>Pull 3 - Day 13</th>
<th>Pull 4 - Day 15</th>
<th>Pull 5 - Day 19</th>
<th>Pull 6 - Day 22</th>
<th>Pull 7 - Day 25</th>
<th>Pull 8 - Day 27</th>
<th>Pull 9 - Day 29</th>
<th>Pull 10 - Day 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>% DPA</td>
<td>% EC</td>
<td>% NNODPA</td>
<td>% 2NDPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lot 2006 Aged at 60°C**

<table>
<thead>
<tr>
<th>Lot 2006 @ 60°C</th>
<th>Pull 1 - Day 4</th>
<th>Pull 2 - Day 8</th>
<th>Pull 3 - Day 13</th>
<th>Pull 4 - Day 15</th>
<th>Pull 5 - Day 19</th>
<th>Pull 6 - Day 22</th>
<th>Pull 7 - Day 25</th>
<th>Pull 8 - Day 27</th>
<th>Pull 9 - Day 29</th>
<th>Pull 10 - Day 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>% DPA</td>
<td>% EC</td>
<td>% NNODPA</td>
<td>% 2NDPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lot 2006 @ 71°C**

<table>
<thead>
<tr>
<th>Lot 2006 @ 71°C</th>
<th>Pull 1 - Day 4</th>
<th>Pull 2 - Day 8</th>
<th>Pull 3 - Day 13</th>
<th>Pull 4 - Day 15</th>
<th>Pull 5 - Day 19</th>
<th>Pull 6 - Day 22</th>
<th>Pull 7 - Day 25</th>
<th>Pull 8 - Day 27</th>
<th>Pull 9 - Day 29</th>
<th>Pull 10 - Day 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>% DPA</td>
<td>% EC</td>
<td>% NNODPA</td>
<td>% 2NDPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• DPA concentration of the 1995 Lot had depleted to half the concentration of the 2006 Lot at time = 0

• AT 71°C, DPA concentration depleted to 0 within 22 days of storage
Ballistic Pressure Increases With Days Aged

- Within 10 days of aging a new propellant lot at 71°C, the measured pressure was in excess of the upper specification limit of 335 MPa.

Ballistic testing conducted at ambient. All data corrected with reference ammunition. Data is the average of 5 shots.

Variation in pressure performance attributed to migration of DBP deterrent.
Casemouth Pressure vs Days Aged - 2006 Propellant Lots Conditioned at 71 deg C
(Test RFAAP 07-004 & 005)
IHIT Propellant Aging Study - Ballistic Testing at Radford 4-5 January 2007

\[ y = 4.8286x + 288.65 \]
\[ R^2 = 0.8304 \]

- Test Firing order randomized for 55 cartridges in test group
- Data corrected to reference rounds
- Data sorted by Age - 0 to 33 days
- Error bars represent +/- 1 SD

Based on data from Test 2430, estimated Casemouth and Chamber Pressure for charge weight of 51.5 grams at 20 days at 71 deg C (Propellant conditioned in drum not cartridge for Test 2430. Recommend subjecting sufficient qty of this aged WC-855 to extended conditioning at 71C at ATPG to attain Chamber Pressure in range of “On” setting for DOE Factor 6 (470-490 MPa). Based on the propellant aging study data shown here, expect to get to desired pressure in <10 days.

2006 Propellant Lot aged @ 71°C

Estimated Casemouth Pressure at 51.5 grams based on fit at 3 charge weights from Test 2430 (Y = 14.718x - 338.55)

SOW - LSL for 470-490 MPa Chamber Pressure (“On” Setting DOE Factor 6)

SOW - USL for 470-490 MPa Chamber Pressure (“On” Setting DOE Factor 6)

Estimated Chamber Pressure at 51.5 grams based on fit at 3 charge weights from Test 2430 (Y = 15.045x - 336.07)

2006 Propellant @ 71C - Avg Peak CM Pressure by Age Group

Linear (2006 Propellant Lot aged @ 71°C)
### Headspace DOE

#### Phase I Test Matrix

<table>
<thead>
<tr>
<th>Firing Order of Rounds</th>
<th>No. of Rounds</th>
<th>High Pressure (approx 500 Mpa)</th>
<th>Nominal Pressure</th>
<th>Nominal Headspace</th>
<th>Headspace 0.025&quot;</th>
<th>Headspace 0.031&quot;</th>
<th>Hot Barrel (180°F)</th>
<th>Ambient Barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

- **Tested ok**: Incident 1
- **Incident 1**: Incident 2

#### Phase II Test Matrix

<table>
<thead>
<tr>
<th>Firing Order of Rounds</th>
<th>No. of Rounds</th>
<th>High Pressure (approx 415 Mpa)</th>
<th>Nominal Headspace (.022&quot;)</th>
<th>Maximum Headspace (.031&quot;)</th>
<th>Ambient Barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
• Hangfire signature has been replicated without an actual hangfire event.
  Excessive headspace
  Elevated pressure (~ 500 Mpa)
  Hot barrel

• Propellant gases vented from the chamber area can damage the operating group and receiver.

• Damage created similar to that seen in HE-Inbore events, except no barrel bulge and generally no Blast Suppressor damage.

• Not all “hangfires signatures” are necessarily actual hangfires.
Hangfire/High Pressure

• Most Likely Causes
  ★ Extended Vibration Damages Cartridge Ignition System (Replicated)
    - No Rounds Showed Physical Damage After 144 Hours
    - 30% Showed Some Damage After 192 Hours
  ★ Extended High Temperature Exposure Changes Propellant Characteristics (Replicated)
    - Significant Pressures Measured after 432 Hours @ 71° C (160° F)
  ★ Cartridge Cases are Punctured and Propellant is Lost or Contaminated (Replicated)

• Actions Taken to Date to Reduce/Eliminate Issues
  – 1980s Production Placed into Condition Code ‘N’
    • Removed to Strategic Reserve in Kuwait, Planned for Demilitarization When Stockpile has been Replenished
  – Aviation Safety Action Message (ASAM) and AIN issued
    • Requires Download and Inspection of Ammo at Aircraft Regularly Scheduled Maintenance
    • Requires Rotation of Ammo When Reloaded into Aircraft to Minimize Prolonged Exposure to Vibration and Extreme Temperatures
  – Initiated Design Improvement Program to Improve Robustness of the Ignition Train
Inbore Detonation
Explosive Reaction and Response

Low Order Time Lines

35 μs  55 μs  75 μs  100 μs

Barrel from Arizona Incident

Data from Incidents, Experiment and Modeling

Signature matches an initiation at rear of warhead
Dynamic Signature Replication
Bullet-on-Bullet

Violence and location reveal that bullet on bullet scenario not likely scenario for bulge...

Tests conducted:
- HE round → HE round (3 times)
- HE round → HE round (dummy fuze)
- HE round → TP round

Implies rear bullet initiation

Follow-on shot with solid fuze result was an in-bore with incorrect signature
Dynamic Signature Replication Set Forward

Result is g-load on order of $10^3$-$10^5$ with no reaction of projectile (Fuze ripped off body)

**Liner / Retainer gaps**
- Gap > 0.032 in (from x-ray)
- Defuzed
- 8 shots, no in-bores

**Fuzed**
- No defects as determined from x-ray
- Standard, fuzed rounds
- 5 shots, no in-bores

Exuded explosive in threads
Gap between retainer and liner
Dynamic Signature Replication High Pressure (Body Failure)

Rationale
- Structural analysis found weak area in rear
- Bullet-on-bullet tests at APG:
  - 4 out of 4 shots went low order
  - Initiation from rear of projectile

Procedure
- Single projectile of increased mass
- Replace fuse with tungsten weight
- Provide data for fracture model

Mass taken to over double (2.25x) of projectile with subsequent increase of base pressure – NO initiation of explosive
Dynamic Signature Replication Foreign Material (aka Putty)

M789 LW30mm HEDP round

Shot 1

Bulged barrel centered at < 8 inches from breech

Dummy fuze replaces live fuze (with putty to match mass)
Foreign Material in Liner Cavity

<table>
<thead>
<tr>
<th>Sample AA</th>
<th>Fragment</th>
<th>Mass (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>51.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>311</td>
<td></td>
</tr>
</tbody>
</table>

P-t Curves from Test 2410

1st in-bore

6 loose fragments at 71C: 2/2 in-bores
All other conditions: 0 / 33

Notes:
- Testing at ATPG 5/2/06
- Casemouth pressure measured (trace#2); chamber pressure port (trace#3) n/a for this test series
- Pressure values corrected based on calibration of transducer #C14607 from ATPG test data sheet.

Top View

X-section

Fragments

X-ray

Location of In-Bore
Test vs. Field Incidents - Profile

Reference Line approx. 9.5" from end of barrel

- Test 2410
- Ft. Rucker Barrel
- Arizona Barrel

Relative Diameter vs. Relative Position (inch)

- Black: Fragments
- Red: Ft Rucker
- Blue: Arizona
Fault Tree Probabilities for In-Bore DOE Factors

<table>
<thead>
<tr>
<th>Block</th>
<th>Reliability</th>
<th>Prob. of Failure</th>
<th>Final Probability</th>
<th>Priority Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>#504 Setback initiation due to debris in cavity</td>
<td>1</td>
<td>1.0005E-05</td>
<td>A1.11</td>
<td>1.0005E-05</td>
</tr>
<tr>
<td>#65 Thin sidewall body fails on setback</td>
<td>1</td>
<td>7.8400E-07</td>
<td>A1.12</td>
<td>7.8399E-07</td>
</tr>
<tr>
<td>#502 Particles embedded in HE cause HE to initiate at setback</td>
<td>1</td>
<td>5.0000E-07</td>
<td>A1.15</td>
<td>4.9999E-07</td>
</tr>
<tr>
<td>Normal projectile 7</td>
<td>0.9914</td>
<td>9.9137E-01</td>
<td>A2.1</td>
<td>4.5107E-08</td>
</tr>
<tr>
<td>#504 Setback initiation due to debris in cavity</td>
<td>0.9999</td>
<td>1.0000E-04</td>
<td>A2.11</td>
<td>1.6300E-09</td>
</tr>
<tr>
<td>#1 Thin BCP flange fails on setback</td>
<td>1</td>
<td>1.0000E-09</td>
<td>A1.17</td>
<td>1.0000E-09</td>
</tr>
<tr>
<td>#307 Projectile Base deformed by propulsion gases</td>
<td>1</td>
<td>6.6700E-10</td>
<td>A1.17</td>
<td>6.6699E-10</td>
</tr>
<tr>
<td>#303 Baseplug Vibrate loose</td>
<td>1</td>
<td>3.3400E-10</td>
<td>A1.2</td>
<td>3.3399E-10</td>
</tr>
<tr>
<td>#80 Cut Cartridge Case</td>
<td>1</td>
<td>1.0000E-10</td>
<td>A1.3</td>
<td>9.9998E-11</td>
</tr>
<tr>
<td>Improperly secured HE moves back and detonates at setback</td>
<td>1</td>
<td>2.0000E-11</td>
<td>A1.16</td>
<td>2.0000E-11</td>
</tr>
<tr>
<td>PBXN-5 Develops cracks in storage #51</td>
<td>1</td>
<td>1.0001E-11</td>
<td>C1.1</td>
<td>1.0001E-11</td>
</tr>
<tr>
<td>Voids in explosive pellet #52</td>
<td>1</td>
<td>1.0000E-11</td>
<td>C1.3</td>
<td>1.0000E-11</td>
</tr>
</tbody>
</table>

DOE Factor
Special Purpose Test
Redundant with a Prior Element Being Tested

In spec Ballistic Event 1.6345E-05 9.9998E-01 A1.1
#303 High pressure event 0.9227 1.630000E-05 G2
#503 Maximum pressure event 0.9985 4.550000E-08 G1

In-bore demonstrated in Test 2410
1 Factor 4
2 Cu shaving test at High P in DOE SOW
3
4
5 Factor 2
6 Factor 3
7 Factor 1
8
9
10
11
12 Factor 5
13

Propellant High Pressure (Factor 6)
Thin Dome (Factor 3)
Thin Flange on Fuze Base Closing Plug (Factor 1)
Cut Case (Factor 5)
Thin Sidewall due to Eccentric Cavity at Crimp Grooves (Factor 4)
Loose Base Closing Plug in Fuze (Factor 1)
## Main In-bore DOE

<table>
<thead>
<tr>
<th>Factor</th>
<th>Example of “On” Factor Setting</th>
<th>Example of “Off” Factor Setting</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shots “on”</td>
</tr>
<tr>
<td>Loose BCP</td>
<td>~1/2 Thread Engagement</td>
<td>Full Thread Engagement</td>
<td>80</td>
</tr>
<tr>
<td>Thin BCP Flange</td>
<td>~ .015” Flange Thickness</td>
<td>~ .044” Flange Thickness</td>
<td>5</td>
</tr>
<tr>
<td>Thin Dome</td>
<td>~ .05” Dome Thickness</td>
<td>~ .125” Dome Thickness</td>
<td>80</td>
</tr>
<tr>
<td>Eccentric Cavity</td>
<td>Max Eccentricity (~ .020&quot;)</td>
<td>Nominal Eccentricity (~ .008&quot;)</td>
<td>80</td>
</tr>
<tr>
<td>Cut Cart. Case</td>
<td>Cut through case to proj. body</td>
<td>No Cut</td>
<td>80</td>
</tr>
<tr>
<td>High Pressure</td>
<td>~405 MPa Chamber</td>
<td>~480 MPa Chamber</td>
<td>81*</td>
</tr>
</tbody>
</table>

* 1 shot included thin BCP Flange
Test In-bore Comparisons

Barrel Diameter (inches)

Distance from End of Barrel (inches)

- Foreign Material
- Thin Flange
P-t Curves from DOE In-bores (Thin Flange)

- **No In-bore**
- **In-bore #1**
- **In-bore #2**
- **In-bore #3 (High Pressure)**
Inbore Detonation

• Most Likely Causes
  ⭐⭐ Foreign Material from Manufacturing Process in Liner Cavity (Replicated)
  ⭐ Thin Flange/Spitback Crimp (Replicated)

• Actions Taken to Date to Reduce/Eliminate Issue
  – 1980s Production Placed into Condition Code ‘N’
    • Removed to Strategic Reserve in Kuwait Planned for Demilitarization When Stockpile has been Replenished
  – 1990+ Production
    • Thin Flange on Base Closing Plug Identified as a Critical Defect
      – Additional Testing Added to Verify Design Margin
      – Double Automated Inspections Added to Manufacturing Line
    • Affected Lots (Prior Inbore Detonations) Restricted from Use Until Screened
    • X-Ray Screening to Remove Defective Rounds Being Initiated
    • Manufacturing Process has been Modified to Eliminate Source of Foreign Material
  – AIN & ASAM Issued to Minimize Ammo Exposure to Extreme Temperatures
Bullet on Bullet
Bullet on Bullet

A loss of propellant due to punctured case caused:
1. Increased Action Time (5 to 24 ms)
2. Decreased Range
3. Projectiles stuck beyond origin of rifling at ~15% propellant load
4. Projectiles stuck at origin of rifling or failed to debullet at 5-10% propellant load.
Bullet on Bullet

• **Most Likely Causes**
  - ★ Cartridge Cases are Punctured and Propellant is Lost
    - Efficiency Loss to a Level of 10-15% (Replicated)

• **Actions Taken to Reduce/Eliminate Issue**
  - ASAM #AH-64-07-ASAM-13 Issued
    - Emphasizes Use of “Auto” Mode for D Model Apache Sideloader which Minimizes Risk of Creating and Firing Punctured Cases
    - Requires Download and Inspection of Ammunition at Aircraft Regularly Scheduled Maintenance
    - Re-emphasizes the Need for Caution Uploading/Downloading the Aircraft to Avoid Punctured Cartridge Cases
Summary

• Investigation is Completed
• Final Reports are Being Written for Individual as well as Combined Efforts
• Investigation Results are Being Formulated into:
  – Design Changes
  – Manufacturing Process Changes
  – Stockpile, Manual and/or Procedural Changes, as Applicable
Hazard Assessment Testing of the SM-3 Block IA Missile

Presentation for the NDIA Gun and Missile Systems Conference

25 April 2007

Dave Houchins
Dahlgren Division, Naval Surface Warfare Center
Test & Evaluation Division (Code G60)
Hazard Assessment Testing of the SM-3 Block IA Missile

Outline

• Description of SM-3 Block IA missile
• Hazard Assessment Test Program
• Test methodologies
• Summary of results
• Lessons-learned
SM-3 Block IA Missile

• Sea-based component of the Ballistic Missile Defense system
• Launched from Vertical Launching System of DDG-class ships
  – Approximately 22 ft length x 13.5 in diameter
    • MK 72 booster ~21 in diameter
  – Contains ~2065 lbm propellant
  – Designed for MK 21 MOD 2 VLS canister
    • Total mass of all-up round ~6300 lbm (i.e., missile and canister)
• Exo-atmospheric intercept using Kinetic Warhead
Environmental Tests (encanistered missile)

- 28-Day Temperature & Humidity
- Transportation Vibration
- Shipboard Vibration
- Launch Shock
- 4-Day Temperature & Humidity
- 40-ft Drop
  - Aft-end down

Insensitive Munitions Tests (individual sections)

- Fast Cook-off
  - Third Stage Rocket Motor
  - Kinetic Warhead
- Slow Cook-off
  - Third Stage Rocket Motor
  - Kinetic Warhead
- Bullet Impact
  - Third Stage Rocket Motor
  - Kinetic Warhead
- Fragment Impact
  - Third Stage Rocket Motor
  - Kinetic Warhead
- Fast Cook-off
  - Third Stage Rocket Motor
Hazard Assessment Testing of the SM-3 Block IA Missile

28-Day / 4-Day Temperature and Humidity (T&H) Test Method

- Encanistered missile cycled between hot/humid and cold environments
  - Conditions based on environmental profile for logistics life-cycle
    - +130°F with 95% RH for hot/humid environment
    - -20°F for cold environment
      - 1 cycle includes 24-hr (min) exposure to each environment
- Tests conducted using programmable environmental chamber
- Test methods identical except for duration
  - 14 cycles for 28-day T&H; 2 cycles for 4-day T&H

![Diagram showing temperature and relative humidity changes over time](image-url)
Transportation Vibration Test Method

- Encanistered missile subjected to random vibration IAW MIL-STD-810
  - Simulate transportation by truck over improved roads
  - Input applied through 3 orthogonal axes; 1 axis at a time
  - 3 hr/axis duration to simulate 3000 miles over-the-road transport
- 2 hydraulic actuators used to provide input at each PHS&T skid
Hazard Assessment Testing of the SM-3 Block IA Missile

Transportation Vibration Input Profile

- **Vertical Axis**
- **Transverse Axis**
- **Longitudinal Axis**

Power Spectral Density $g^2/Hz$ vs. Frequency (Hz)
Shipboard Vibration Test Method

- Encanistered missile subjected to random vibration to simulate shipboard environment
  - Input profile and duration based on shipboard measurements in VLS cells
    - 4 – 200 Hz frequency range
    - Input spectrum encompasses full range of ship speeds and sea states
    - 39-hr/axis to simulate anticipated deployment durations
  - Input applied through 3 orthogonal axes; 1 axis at a time
- System-specific tailored test requiring approval from NAVSEA 05T
  - Most systems tested IAW MIL-STD-167
    - Sinusoidal vibration across 5 – 50 Hz frequency range
- Accomplished using UD-4000 electrodynamic shaker
  - Special fixtures used to provide input at correct interfaces with canister
Shipboard Vibration Input Spectrum

<table>
<thead>
<tr>
<th>Spectrum Breakpoints</th>
<th>Frequency (Hz)</th>
<th>PSD (g^2/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.0</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>13.5</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>13.5</td>
<td>0.006800</td>
</tr>
<tr>
<td></td>
<td>14.5</td>
<td>0.006800</td>
</tr>
<tr>
<td></td>
<td>14.5</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>27.0</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>27.0</td>
<td>0.001566</td>
</tr>
<tr>
<td></td>
<td>29.0</td>
<td>0.001566</td>
</tr>
<tr>
<td></td>
<td>29.0</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>35.0</td>
<td>0.000135</td>
</tr>
<tr>
<td></td>
<td>200.0</td>
<td>0.000054</td>
</tr>
</tbody>
</table>
Shipboard Vibration Test Setup (Transverse Axis)

- Transverse Shipboard Vibration Fixture
- All-Up Missile in MK-21 Canister
- UD 4000 Shaker
- Hydraulic Bearings
- VLS Dog-Down Fixture
- Deck Interface Fixture
Shipboard Vibration Test Setup (Longitudinal Axis)
Near Miss Shock Test Method

- Accomplished using DS-3 Shock Machine
  - Large-displacement, pendulum-type impact shock machine
  - Highly-tunable design
    - Continuously adjustable pendulum impact velocity
    - Unique adjustable fixture permits input through 3 principal axes of item
- System-specific tailored test requiring approval from NAVSEA 05P3
  - Alternative to Heavyweight Test (i.e., “Barge Test”) of MIL-S-901
  - Input levels tuned to actual field measurements
Hazard Assessment Testing of the SM-3 Block IA Missile

Near Miss Shock Test Setup
Tuning of Input for Near Miss Shock Test

Pendulum drop height – peak velocity
Programmer pad thickness – initial acceleration
Brakes & Springs – initial pulse duration; magnitude of neg. velocity
Obliquity/clocking – Longitudinal and Transverse components
Hazard Assessment Testing of the SM-3 Block IA Missile

Representative Response Data

![Graph showing velocity over time for different accelerometers and a requirement line.](image)
Hazard Assessment Testing of the SM-3 Block IA Missile

**Configuration of Kinetic Warhead**

- 3 propellant grains in Solid Divert and Attitude Control System (SDACS)
  - Pulse 1 grain is TP-H-3510 propellant
  - Pulse 2 grain is TP-H-3511 propellant
  - Sustain grain is TP-H-3512 propellant
- SDACS case is graphite-epoxy composite
Hazard Assessment Testing of the SM-3 Block IA Missile

Configuration of Kinetic Warhead for Insensitive Munitions Tests

• Kinetic Warhead assembled to simulated Guidance Section shroud
  – 13.625-in OD annular aluminum cylinder with ½-in thick aluminum closure plate
  – Guidance Unit simulated using high-fidelity mass model
  – Cryogenic gas bottle present and fully-charged
• Block IA Nosecone installed over Kinetic Warhead
  – Secured to simulated Guidance Section shroud in same manner as tactical missile
  – All Nosecone explosive components present
Hazard Assessment Testing of the SM-3 Block IA Missile

General Configuration of Third Stage Rocket Motor

- 2 propellant grains
  - Pulse 1 grain is TP-H-3518A propellant
  - Pulse 2 grain is TP-H-3518B propellant
- Case sidewall is filament-wound graphite-epoxy composite
- Toroidal cold gas bottle contains pressurized nitrogen
Configuration of Third Stage Rocket Motor for Insensitive Munitions Tests

- TSRM assembled with end caps to simulate adjoining missile sections
  - Each end cap is 13.72-in OD annular aluminum cylinder with ½-in thick closure plate
  - Aft end cap secured using 4 explosive bolts
    - Replicate configuration of tactical missile
Bullet Impact Test Method

• Item impacted by three (max) 0.50-cal AP projectiles
  – Velocity of 2800 ± 200 ft/s
  – Bullets fired at 50 ms intervals using three 50-cal Mann barrels
• Trajectory of bullets perpendicular to longitudinal axis of test item
  – Bullets aimed to pass through center of SDACS propellant in KW
  – Bullets aimed to pass through Pulse II grain and ignition tube in TSRM
• Instrumentation and data collection IAW MIL-STD-2105B
  – Gun firing times
  – Bullet velocities
  – Air shock
  – High-speed video record of events
  – Post-test recovery and characterization of remains
Bullet Impact Test Setup
Fragment Impact Test Method

• Item impacted by three ½-in mild-steel cubes
  – Velocity of 6000 ± 200 ft/s
  – Cubes launched using 60mm smoothbore gun and unique FRP sabot
• Trajectory of cubes perpendicular to longitudinal axis of test item
  – Aimed to pass through center of SDACS propellant in KW
  – Aimed to pass through Pulse II grain and ignition tube in TSRM
• Instrumentation and data collection IAW MIL-STD-2105B
  – Cube velocities
  – Air shock
  – High-speed video record of events
  – Post-test recovery and characterization of remains
Hazard Assessment Testing of the SM-3 Block IA Missile

Fragment Impact Test Setup

- 60mm Gun
- Fragment Shield
- Pressure Gauges 1, 2, 3, 4, 5, 6
- 22'-7' Forward End
- Velocity Screens (3)
- Test Item (assembled in test fixture)

Plan View
Fast Cook-Off Test Method

- Item suspended above pool of burning JP-5 aviation fuel
  - Average flame temperature >1600°F
  - 30-ft x 30-ft fuel basin used to ensure complete immersion within flame
- Instrumentation and data collection IAW MIL-STD-2105B
  - Flame temperature
  - Air shock
  - Video record of events
  - Post-test recovery and characterization of remains
- Pretest modeling to predict time to reaction
  - 1-D model to examine radial heat transfer through case sidewall
  - Examined two bounding flame temperature conditions
    - 1600°F average flame temperature
    - 2000°F average flame temperature
Hazard Assessment Testing of the SM-3 Block IA Missile

Fast Cook-Off Test Setup
Hazard Assessment Testing of the SM-3 Block IA Missile

Predicted Temperature at Liner/Propellant Interface During TSRM Fast Cook-Off

- 1600°F Avg Flame Temp
- 2000°F Avg Flame Temp

Time (minutes)

Temperature (deg F)

Fire Build-Up
Ablative Burn-Off
Predicted Time of Propellant Ignition

Reactions Observed

### Summary of Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-Day Temperature &amp; Humidity</td>
<td>No safety-related anomalies</td>
</tr>
<tr>
<td>Transportation Vibration</td>
<td>No safety-related anomalies</td>
</tr>
<tr>
<td>Shipboard Vibration</td>
<td>No safety-related anomalies</td>
</tr>
<tr>
<td>4-Day Temperature &amp; Humidity</td>
<td>No safety-related anomalies</td>
</tr>
<tr>
<td>Near Miss Shock</td>
<td>No safety-related anomalies</td>
</tr>
<tr>
<td>Bullet Impact</td>
<td>Kinetic Warhead: Type IV reaction (deflagration)</td>
</tr>
<tr>
<td></td>
<td>Third Stage Rocket Motor: Type III reaction (explosion)</td>
</tr>
<tr>
<td>Fragment Impact</td>
<td>Kinetic Warhead: Type IV reaction (deflagration)</td>
</tr>
<tr>
<td></td>
<td>Third Stage Rocket Motor: Type III reaction (explosion)</td>
</tr>
<tr>
<td>Fast Cook-Off</td>
<td>Third Stage Rocket Motor: Type IV reaction (deflagration)</td>
</tr>
</tbody>
</table>
Lessons Learned

• Multi-shaker setup used for Transportation Vibration test introduces additional issues related to phase control
  – Currently not explicitly addressed in MIL-STD-810
  – Accepted / best practices still evolving
• Not possible to achieve same input levels at both ends of canister in Shipboard Vibration test due to fixture dynamics
  – Fact-of-life constraint for single-shaker setup using large, complex fixture
  – Problem most pronounced at higher frequencies
  – New state-of-the-art facility at NSWC/Dahlgren will enable multi-shaker testing in vertical orientation
• Near Miss Shock test demonstrated capability to replicate real-world triaxial shock input to large encanistered missile using pendulum-type shock machine
  – Potential alternative to “Barge Test” for some systems
    • Subject to approval by NAVSEA 05P5 on case-by-case basis
    • May reduce system design risks
More Info

- Test program documented in two NSWCDD technical reports
  - NSWCDD/TR-06/47, Standard Missile - 3 Block IA Hazard Assessment Test Results
    - Draft currently in final review
  - NSWCDD/TR-06/48, Standard Missile-3 Block IA Near Miss Shock Qualification Test Report
The Quest for Practical DFSS (Design-for-Six-Sigma) Tools

PGMM Case Study

James Kalberer and Doug Storsved
ATK Advanced Weapons Division

NDIA Gun and Missile Systems Conference
25 April 2007
Charlotte, North Carolina
XM395 PGMM
Precision Guided Mortar Munition

- **Swift, ballistic flight to target** – no midcourse guidance – laser guidance in terminal phase
- **Few moving parts** – high reliability in high-G gun environment
- **Accurate** – simple, responsive thruster control
- **Lethal** – large warhead overmatches all PGMM targets
PGMM Operational Elements

PGMM Overview

An advanced weapon and space systems company

Ballistic Flight to Target Acquisition

Guided Flight to Hit Designated Target

Forward Observer Paints Target (Laser On)

FO-Target Line

Gun-Target Line

Destroy Target

PGMM Incapacitates Personnel Protected by:
Masonry Structures, Earth/Timber Bunkers, or Light Armor Vehicles

Simple Mission Setting

Fire Support Element (FSE)

Forward Observer

Mortar Squad

Fire PGMM

Heavy Mechanized M1064

Fire Direction Center (FDC)

M577

Fire Support Fleet (FSE)
PGMM Cartridge – Simple, Rugged, and Precise

- Modular Design
- Simple Interconnect
- Few Moving Parts
- Mature Subsystems

PGMM Overview

An advanced weapon and space systems company
Six Sigma & Lean Enterprise Model for PGMM

An advanced weapon and space systems company

**Project Overview**

**DFSS, CDOV**
- Robust Design
- Requirements Flowdown
- First Time Quality

**VOC**
- Minimize Parts
- Simplify Design
- Poka Yoke (Error Proof)

**Lean Design, DFA**
- Error Free Processes
- Improve Yields
- Reduce Variability

**Customer Satisfaction**
- Identify Value Stream
- Improve Processes
- Eliminate Waste
- Error Free Processes

**Lean Manufacture**
- Improve Efficiency
- Improve Effectiveness

**Avoid Problems**
- Fix Problems

**Six Sigma, DMAIC**

DFSS: Design For Six Sigma
DFA: Design for Assembly
CDOV: Conceive, Design, Optimize, Verify
VOC: Voice of the Customer
DMAIC: Define, Measure, Analyze, Improve, Control
**Objectives**

1. Vigorously apply several DFSS tools to the PGMM (Precision Guided Mortar Munition) program
2. Refine and evaluate the tools (benchmark, provide lessons learned, resource planning guides)
3. Support timely execution of major PGMM program milestones (SRR, SDR, PDR, CDR)

<table>
<thead>
<tr>
<th>DFSS Tool</th>
<th>Status</th>
<th>ATK Technical Excellence Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder Analysis</td>
<td>Complete</td>
<td>2. Data Based Decision Making</td>
</tr>
<tr>
<td>Operational Crosswalk</td>
<td>Complete</td>
<td>3. Consideration of System-Level Issues and Interactions</td>
</tr>
<tr>
<td>Requirements Development and Mgmt</td>
<td>Complete</td>
<td>1. Requirements Defined and Tracked</td>
</tr>
<tr>
<td>QFD (Quality Functional Deployment)</td>
<td>Complete</td>
<td>3. Consideration of System-Level Issues and Interactions</td>
</tr>
<tr>
<td>FMEA (Failure Modes Effects Analysis)</td>
<td>Complete</td>
<td>3. Consideration of System-Level Issues and Interactions</td>
</tr>
<tr>
<td>System-Wide Defects Tracking</td>
<td>Complete</td>
<td>2. Data Based Decision Making</td>
</tr>
<tr>
<td>Productibility Scorecard</td>
<td>Complete</td>
<td>7. World Class Process Control at ATK and our Suppliers</td>
</tr>
</tbody>
</table>
Traditional Approach to Product Development

An advanced weapon and space systems company

Project Overview

Studies at TRW:
- 54% of all defects are detected after development testing
- 45% of these defects are requirement defects

Recent Program at ATK
- 44% of defects were detected after subsystem testing
- 62% of all defects were requirement defects

Latent Requirement Defects Are Costly

Design for Competitiveness, Advance copy by Bart Huthwaite
New Approach to Product Development

DFSS/Lean Six Sigma Initiatives/Project

Requirements Discovery Process

Customer Requirements

Stakeholder Analysis

Operational Crosswalks

Requirements Development & Mgmt

Quality Functional Deployment

Correct Requirements
Complete Requirements
Consistent Requirements
Necessary Requirements
Testable Requirements
Unambiguous Requirements
Traceable Requirements
Modifiable Requirements

Identify Design Trade Space (CAIV)
Identify Potential Requirement Change
Introduce Requirements Tracking Metrics

Project Start

Contractor Requirements

SRR

SDR

Preliminary Design

PDR

Manage Requirements

Continue Design Development Process

ATK Technical Standard
Requirements Defined and Tracked
Stakeholder Analysis

An advanced weapon and space systems company

Results

- This tool has utility for Program Managers, Business Development teams, and Engineering leadership
- Database protects against knowledge base turnover
- Helps to ensure that no stakeholder’s interest is ignored – develops complete set of stakeholders
Operational Crosswalks

Light Forces

- MFCS – Mortar Fire Control System
- MMS - Mortar Mission Setter
- Mortar Extraction Tool
- LRRS - Loose Round Restraint System
- Helicopter Transport
- Vehicle Weapon Racks
- Autoloaders/Breechloaders

Heavy Mechanized Forces

- FCS NLOS-M (Future)
- Stryker BCT-MC Soltam Vb (Current)
- M1064A3 Mortar Carrier
- M121 Mortar (Current)

ATK Technical Standard
System-Level Interactions
Requirements Development and Management

An advanced weapon and space systems company

Requirements Development and Management

CUSTOMER REQUIREMENTS

STAKEHOLDER ANALYSIS

OPERATIONAL CROSSWALKS

REQUIREMENTS DEVELOPMENT & MGMT

QUALITY FUNCTIONAL DEPLOYMENT

Requirements Development and Management

DFSS/Lean Six Sigma
Initiatives/Project

REQUIREMENTS DISCOVERY PROCESS

CORRECT REQUIREMENTS
COMPLETE REQUIREMENTS
CONSISTENT REQUIREMENTS
NECESSARY REQUIREMENTS
TESTABLE REQUIREMENTS
UNAMBIGUOUS REQUIREMENTS
TRACEABLE REQUIREMENTS
MODIFIABLE REQUIREMENTS

IDENTIFY DESIGN TRADE SPACE (CAIV)
IDENTIFY POTENTIAL REQUIREMENT CHANGE
INTRODUCE REQUIREMENTS TRACKING METRICS

IDENTIFY STAKEHOLDER ANALYSIS

IDENTIFY OPERATIONAL CROSSWALKS

IDENTIFY REQUIREMENTS DEVELOPMENT & MGMT

IDENTIFY QUALITY FUNCTIONAL DEPLOYMENT

Project Start

CONTRACTOR REQUIREMENTS

SRR

SDR

PRELIMINARY DESIGN

PDR

MANAGE REQUIREMENTS

CONTINUE DESIGN DEVELOPMENT PROCESS

CONTINUE DESIGN DEVELOPMENT PROCESS

ATK Technical Standard

Requirements Defined and Tracked

Slide 11
### 3.3.5.2 KPP 2 - Lethality

**REFERENCE:** System Performance Specification  Draft 31-Jan-03

**OWNER:** USAIC

<table>
<thead>
<tr>
<th>EVALUATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCOMPLETE</td>
</tr>
<tr>
<td>INCONSISTENT</td>
</tr>
<tr>
<td>INCORRECT</td>
</tr>
<tr>
<td>INFEASIBLE</td>
</tr>
<tr>
<td>UNMODIFIABLE</td>
</tr>
<tr>
<td>UNNECESSARY</td>
</tr>
<tr>
<td>UNTESTABLE</td>
</tr>
<tr>
<td>UNTRACEABLE</td>
</tr>
<tr>
<td>AMBIGUOUS</td>
</tr>
</tbody>
</table>

**DESCRIPTION:**
3.3.5.2 KPP 2 – Lethality. The XM395 cartridge SHALL have the ability to incapacitate or fractionally casualitize personnel protected within and by point...

**CROSS-REFERENCE:** CTP 9. Draft ORD Para. 4.1.1.1.1, 4.1.1.1.2

**PRIORITY:**

- MISSION/SAFETY CRITICAL
- USEFUL
- DESIRABLE

- NON-NEGOTIABLE (CAIV)
- FLEXIBLE
- UNLIKELY TO CHANGE
- MAY CHANGE
- MOST LIKELY TO CHANGE

**SOURCE:** ORD

**RATIONALE:**
The user wants to envision how many rounds they will need to kill a target (hence two rounds specified).

**METHOD OF VERIFICATION:**

4.3.5.2 Lethality. To be verified via analysis and test of XM395 subsystem and system flight hardware against all targets specified in section...

**Note:** Since we are verifying performance through modeling, we are most interested in validating our models. Further discussion needed.

**ISSUE:**
Why two rounds or less? Why not specify single round, when we are assuming (in evaluation) independence in probability? How do we assign how the laser designator operation influences lethality? How do we model delivery errors?

**CORRECTIVE ACTION:**
Probability of collapse is now also included for the Earth & Timber bunker. We would like to have guidance on how to constrain or define the operational conditions and “real world” error sources under which we are to perform. Can we refer to an error budget within the spec (Section 4)?

---

Verbatim from Customer Performance Specification
### 3.3.5.2 KPP 2 - Lethality

**REFERENCE:** System Performance Specification Draft 31-Jan-03

**DESCRIPTION:**
3.3.5.2 KPP 2 – Lethality. The XM395 cartridge SHALL have the ability to incapacitate or fractionally casualitize personnel protected within and by point...

**EVALUATION:**
- INCOMPLETE
- INCONSISTENT
- INCORRECT
- INFEASIBLE
- UNMODIFIABLE
- UNTESTABLE
- UNNECESSARY
- AMBIGUOUS

**ISSUE:**
Why two rounds or less? Why not specify single round, when we are assuming (in evaluation) independence in probability? How do we assign how the laser designator operation influences lethality? How do we model delivery errors?

**CORRECTIVE ACTION:**
Probability of collapse is now also included for the Earth & Timber bunker. We would like to have guidance on how to constrain or define the operational conditions and 
*real world* error sources under which we are to perform. Can we refer to an error budget within the spec (Section 4)?

**METHOD OF VERIFICATION:**
4.3.5.2 Lethality. To be verified via analysis and test of XM395 subsystem and system flight hardware against all targets specified in section...

*Note:* Since we are verifying performance through modeling, we are most interested in validating our models. Further discussion needed.
### 3.3.5.2 KPP 2 - Lethality

**REFERENCE:** System Performance Specification  Draft 31-Jan-03

**DESCRIPTION:** 3.3.5.2 KPP 2 – Lethality. The XM395 cartridge SHALL have the ability to incapacitate or fractionally casualitize personnel protected within and by point...

**OWNER:** USAIC

**EVALUATION:**
- [X] INCOMPLETE
- [ ] INCONSISTENT
- [ ] INCORRECT
- [ ] INFEASIBLE
- [ ] UNMODIFIABLE
- [ ] UNTESTABLE
- [ ] UNTRACEABLE
- [ ] UNNECESSARY
- [ ] AMBIGUOUS

**ISSUE:**
Why two rounds or less? Why not specify single round, when we are assuming (in evaluation) independence in probability? How do we assign how the laser designator operation influences lethality? How do we model delivery errors?

**CORRECTIVE ACTION:**
Probability of collapse is now also included for the Earth & Timber bunker. We would like to have guidance on how to constrain or define the operational conditions and “real world” error sources under which we are to perform. Can we refer to an error budget within the spec (Section 4)?

**METHOD OF VERIFICATION:**
4.3.5.2 Lethality. To be verified via analysis and test of XM395 subsystem and system flight hardware against all targets specified in section...

*Note: Since we are verifying performance through modeling, we are most interested in validating our models. Further discussion needed.*
### Requirements Walkthrough Statistics

#### Requirements Development

<table>
<thead>
<tr>
<th>Customer Priorities</th>
<th>129 Non-ENV REQ</th>
<th>70 ENV REQ</th>
<th>199 Total REQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission/Safety Critical</td>
<td>39</td>
<td>52</td>
<td>91</td>
</tr>
<tr>
<td>Useful</td>
<td>85</td>
<td>18</td>
<td>103</td>
</tr>
<tr>
<td>Desireable</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Non-Negotiable</td>
<td>89</td>
<td>68</td>
<td>157</td>
</tr>
<tr>
<td>Negotiable</td>
<td>39</td>
<td>2</td>
<td>41</td>
</tr>
<tr>
<td>Flexible</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Unlikely to Change</td>
<td>118</td>
<td>72</td>
<td>190</td>
</tr>
<tr>
<td>May Change</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Most Likely to Change</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

#### Criticality
- 2/3 Non-Critical
- 74% 129 Non-Environmental Requirements
- 26% 70 Environmental Requirements
- 46% 199 Total Requirements

#### Tradeoffs
- 3/10 Negotiable
- 69% 129 Non-Environmental Requirements
- 30% 70 Environmental Requirements
- 21% 199 Total Requirements

#### Stability
- 8% May Change
- 92% 129 Non-Environmental Requirements
- 100% 70 Environmental Requirements
- 95% 199 Total Requirements

### Contractor Feedback (64 Issues)

- Ambiguous: 15
- Unnecessary: 8
- Infeasible: 8
- Incomplete: 8
- Inconsistent: 6
- Incorrect: 2
- Miscellaneous: 17

- The PGMM Performance Specification was very well written by OP-Mortars, USAIC, and ARDEC
- Only 64 issues (32% of 199 requirements)
- The 64 issues spawned 58 Actions (9 of which were critical).
Reduced Customer Requirements

- 199 “SHALL” requirements in US Army SPS (System Performance Specification)
- Deleted 17 requirements (8.5%)
- Relaxed another 5 requirements (2.5%)

Significance

Eliminated requirement to meet safety and reliability performance for one environmental requirement (unnecessary)

- Avoided fuze redesign cost of ~$300K to safely reset after exposure to the second environment

Relaxed a second environmental requirement to be met in an in-package, un-powered condition rather than in an un-packaged, powered condition

- Avoided special testing at government facility to verify redesign
PGMM Requirements Audit and Defect Tracking

Requirements Management

An advanced weapon and space systems company

---

**Process**

- Requirements Discovery
- SRR
- SDR
- PDR
- Track Defects

---

**Results**

- 946 System and subsystem requirements audited
- 46% had at least 1 potential defect
- 87% of potential defects realized a change to the requirement

---

**Requirement Defects**

<table>
<thead>
<tr>
<th>Requirement Defects</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incorrect Information</strong></td>
<td>Incorrect Test Standard</td>
</tr>
<tr>
<td></td>
<td>Incorrect Paragraph Reference</td>
</tr>
<tr>
<td></td>
<td>Incorrect Environmental Levels</td>
</tr>
<tr>
<td><strong>Omissions</strong></td>
<td>Missing Test Standard</td>
</tr>
<tr>
<td></td>
<td>Missing Requirement</td>
</tr>
<tr>
<td></td>
<td>Missing Verification</td>
</tr>
<tr>
<td><strong>Ambiguities</strong></td>
<td>More Than One Interpretation</td>
</tr>
<tr>
<td><strong>Poorly Written</strong></td>
<td>Multiple “Shalls” In One Requirement</td>
</tr>
<tr>
<td></td>
<td>Spelling and Grammar</td>
</tr>
<tr>
<td></td>
<td>Requirement Not Clear</td>
</tr>
<tr>
<td><strong>Misplaced</strong></td>
<td>Requirement in Wrong Section</td>
</tr>
<tr>
<td></td>
<td>Requirement Applied to Wrong Subsystem</td>
</tr>
</tbody>
</table>

---

*ATK Technical Standard*

*Early elimination of deficiencies*
Quality Functional Deployment

Customer Requirements

Stakeholder Analysis

Operational Crosswalks

Requirements Development & Mgmt

Quality Functional Deployment

Requirements Defined and Tracked

ATK Technical Standard

DFSS/Lean Six Sigma Initiatives/Project

Requirements Discovery Process

Correct Requirements
Complete Requirements
Consistent Requirements
 Necessary Requirements
 Testable Requirements
 Unambiguous Requirements
 Traceable Requirements
 Modifiable Requirements

Identify Design Trade Space (CAIV)
Identify Potential Requirement Change
Introduce Requirements Tracking Metrics

Manage Requirements

Continue Design Development Process

ATK Technical Standard
Requirements Defined and Tracked

Slide 18
Quality Functional Deployment (QFD)

QFD characterized nose protector as a net liability in meeting requirements.

Finally, optical window testing at supplier characterized SAL sensor performance with smears and scratches typical of handling – confirmed low risk in elimination.

Cost Avoidance: Aerodynamic flight testing at Yuma to confirm separation ~$100K
An advanced weapon and space systems company

Quality Functional Deployment (QFD) - Results

Completed 27 Jan 2005

Key Subsystems

- Fuze, WIM = Safety Critical
- Monopack = Environmental Protection
- CTM, SAL, GNC, Warhead = Mission Critical
- Battery & PC = Reliability Critical
- Propelling Charge, Ignition Cartridge = Range Critical

Quality Functional Deployment (QFD)
Completed 27 Jan 2005
Project Objectives Met

✔ **Vigorously Applied DFSS to PGMM:** Tools successfully applied to the Precision Guided Mortar Munition Program

✔ **Refined and Evaluated Tools:** Provided benchmarks, lessons learned, resource planning guides

✔ **Major PGMM Program Milestones Met:** SRR, SDR, PDR and CDR were held on schedule, within budget, and with high quality

Additional Benefits

✔ **Simplification Achieved:** Eliminated or relaxed 11% of US Army system performance requirements; cost avoidance well over $450K

✔ **Forced Strong Customer Relationship:** DFSS Tool application facilitated communication across the design team
James Kalberer
ATK Advanced Weapons Division
4700 Nathan Lane North
Plymouth, MN 55442
763-744-5406
james.kalberer@atk.com
GENERAL DYNAMICS
Ordnance and Tactical Systems

42nd Annual Armament Systems: Gun and Missile Systems Conference & Exhibition
Event #7590
April 23 - 26, 2007
Charlotte, North Carolina

“Meeting Warfighter Needs for the Asymmetric Threat”

GD-OTS 20mmx102mm Mechanically Fuzed Projectile Program
Introduction:
GD-OTS 20mm Fuzed Cartridge Alternative

• For the last several years, GD-OTS has invested funds into the development of a mechanically fuzed variant to the 20mm PGU-28A/B.

• GD-OTS has made a conscious effort to make safety a number one priority during the development process.

• Fuze has been designed to operate with delay or point detonating mode.

• Fuze has capabilities in calibers other than 20mm.

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Cartridge Safety and Performance Requirements

• Configuration Requirements
  – Fully compliant with current PGU-28A/B Cartridge envelope.
  – Ballistic match with current 20mm PGU family of ammunition.
Performance Requirements

- **Design Requirements (Delay Fuze) per AS6120**
  - Function after impact with .063 inch aluminum plate at 200 yards
  - Function delay of 400-800 microseconds after impact with .080 inch aluminum plate at 200 yards
  - Function after impact with .080 inch aluminum plate @ 75° NATO at 200 yards
  - Produce a low order reaction of the body explosive after initiation
  - Defeat 3/8 inch RHA @ 45° obliquity with a probable ballistic limit velocity of 2786 ft/sec

- **Design Requirements (Point Detonating)**
  - Function after impact with .063 inch aluminum plate at 200 yards
  - Function after impact with .080 inch aluminum plate @ 75° NATO at 200 yards
  - Produce a high order reaction of the body explosive after initiation
  - Defeat 3/8 inch RHA @ 45° obliquity with a probable ballistic limit velocity of 2786 ft/sec

*APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07*
Identify Fuze Requirements

- Must fit within PGU 28A/B Nose envelope.
- Must be within reasonable range of current PGU 28A/B pyrotechnic nose mass.
- Must be able to function across all temperature extremes.
- Must be able to defeat light skin targets at both low and high graze angles.

Safety

- Survive acceleration at high temperature and pressure launch
- Fully compliant with Mil-Std-1316
- Fully compliant with Mil-Std-331 and Mil-Std-810 cartridge safety and environmental requirements
- Fully compliant with Mil-Std-1751
Approach

- Identify Fuze Requirements
- Conduct Market Survey
  - Conduct Risk Assessment.
  - Key parameters:
    - Method of initiation
    - S&A type
    - Firing train
    - Fuze interface with projectile body
    - Maximum commonality to existing 20mm
- Other Factors
  - Performance history
  - Minimize fuze design changes to interface with existing 20mm projectile configuration
  - Ease of qualification
- Acquire Test Hardware
- Conduct Design Demonstration Testing
Cartridge Description

The General Dynamics-OTS solution utilizes the following:

- A ball rotor approach fuze similar to the M505 that employs dual independent safeties and can function in either the delay or point-detonating mode.
- Ballistic match to the 20mm PGU family of ammunition.
- Meets the 20mmx102mm Cartridge envelope.
- Utilizes components common to the 20mm PGU family of ammunition.

GD-OTS developed a cartridge to meet the requirements of the USAF and leverage commonality with existing technology and manufacturing processes.
Cartridge Description

- Cartridges utilize same propellant and LAP facility.
PGU-28A/B, 20mm Mechanically Fuzed Variant
Trajectory Comparisons

Trajectory Conditions:
- Aircraft Altitude: 6,000 ft ASL
- Aircraft Airspeed: 450 knots
- Muzzle Velocity: 3440 ft/sec
- Standard Atmospheric Conditions

Projectile Velocity At Slant Range

Slant Range - Feet
Velocity - Feet / Second

- 20mm SAPHEI PGU-28A/B
- 20mm LD w/MECHANICAL FUZE
PGU-28A/B, 20mm Mechanically Fuzed Variant Trajectory Comparisons

Trajectory Conditions:
- Aircraft Altitude: 6,000 ft ASL
- Aircraft Airspeed: 450 knots
- Muzzle Velocity: 3440 ft/sec
- Standard Atmospheric Conditions

[Graph showing projectile time of flight at slant range with graphs for 20mm SAPHEI PGU-28A/B and 20mm LD w/MECHANICAL FUZE]
PGU-28A/B, 20mm Mechanically Fuzed Variant Trajectory Comparisons

Projectile Drop at Slant Range

Trajectory Conditions:

- Aircraft Altitude: 6,000 ft ASL
- Aircraft Airspeed: 450 knots
- Muzzle Velocity: 3440 ft/sec
- Standard Atmospheric Conditions
Hand Safety Testing

Primary Component
Safety Test Set Up from
Mil-Std-331

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Hand Safety Testing

Final Configuration

Design passes the D1 “Out of Line” safety test per Mil-STD-331

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Detonation Delay/Point Detonating Test Set-Up Description

Target Array

Gun and Mount

Witness Panels 4’ and 6’ Behind Trigger Plate

630 ft
Pictures from Demonstration Testing

Impact with .080"
Aluminum at 200 yards

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Pictures from Demonstration Testing

Ø of hole is approximately 60mm

.080" Aluminum trigger plate for point detonating test

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Pictures from Demonstration Testing

.080” Aluminum Trigger plate (75 degrees) for Graze Sensitivity Test, 100% Function

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Pictures from Demonstration Testing

Witness Panel 4’ behind trigger plate for Graze Sensitivity Test

APPROVED BY THE USAF FOR PUBLIC RELEASE, 4/17/07
Summary of Results

<table>
<thead>
<tr>
<th>Verification Tests</th>
<th>Delay Function</th>
<th>Point Detonating Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Booster Testing</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Booster Material Ballistic Evaluation</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Low Drag Shape Concept</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Explosive Train Development</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Explosive Train Down Select</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Detonation Delay</td>
<td>Demonstrated</td>
<td>N/A</td>
</tr>
<tr>
<td>Armor Penetration</td>
<td>Met Requirement</td>
<td>Expected to meet requirement per AS6120</td>
</tr>
<tr>
<td>Projectile Sensitivity</td>
<td>Demonstrated</td>
<td>Demonstrated</td>
</tr>
<tr>
<td>Point Detonating Function</td>
<td>N/A</td>
<td>Demonstrated</td>
</tr>
<tr>
<td>Fragmentation</td>
<td>Test Not Performed, witness panel comparison to PGU 28-A/B yields better fragmentation</td>
<td>Test Not Performed</td>
</tr>
<tr>
<td>Graze Sensitivity (75 Degrees)</td>
<td>Demonstrated</td>
<td>Demonstrated</td>
</tr>
<tr>
<td>Function and Casualty</td>
<td>Test Not Performed</td>
<td>Test Not Performed</td>
</tr>
<tr>
<td>Safety Tests</td>
<td>Passed Mil-Std-331 D1</td>
<td>Passed Mil-Std-331 D1</td>
</tr>
<tr>
<td>No-Arm (3 meters against .040&quot; Al)</td>
<td>Passed</td>
<td>Passed</td>
</tr>
</tbody>
</table>

**GD-OTS has performed testing against all of the key baseline performance requirements to ensure future success**
Summary

• GD-OTS has developed and successfully demonstrated a Mil-STD-1316 compliant, mechanically fuzed variant, both point detonating and delay, to the 20mm PGU 28 A/B Cartridge.

• Fuze has been proven to function across temperature extremes.

GD-OTS has completed significant testing and investment on a 20mm fuzed cartridge and is prepared to move forward.
Questions?
XM1131 105mm High Explosive Pre-Formed Fragmentation (PFF) Cartridge

Guns and Missiles Conference

April 23 - 26, 2007
Agenda

- Overview
- 105mm PFF
  - Background
  - Characteristics
  - Performance
  - Type Classification Plan
- Summary
Why 105mm and PFF?

• With current 105mm ammunition the warfighter is at a disadvantage by the lack of range and lethal performance

• The ACA²P 105mm PFF projectile has given the light warfighter expanded capabilities in lethality

• The lightweight mobility of 105mm weapons, coupled with 155mm level lethality, means that the light forces are not hindered by weight restrictions

• Having an entire suite of 105mm ammunition with the same ballistic solution, provides the warfighter with a complete tool kit to accomplish the mission successfully
ACA²P 105mm Family

- Visible Illumination
- IR Illumination
- Bi-spectral screening smoke
- RP Incendiary
- HE Practice
- VLAP - Velocity Enhanced Long-Range Artillery Projectile
105mm PFF Background

• In 2002, the Advanced Cannon Artillery Ammunition Program (ACA²P) was created to help modernize conventional artillery ammo

• Need for high effectiveness against soft targets without the use of DPICM’s

• Several successful static tests conducted both at Picatinny Arsenal and at Ft. Sill confirmed the very high effectiveness

• Army’s priority is 105mm Base Bleed IM HE-PFF
System Description
XM1131 105mm IM HE PFF

*Assumptions based on artillery usage: Basebleed could provide better stand-off, accuracy, and tracer capability, if desired.
System Characteristics
XM1131 105mm IM HE PFF

- Type – HE w/ Pre-Formed fragments
- Weight – 34.8lbs (16kg)
- Length – 21.6in (551mm) (fuzed)
- Projectile Body – High fragmentation steel with inner lining of > 9,000 ~3mm tungsten balls
- IM Explosive Fill – 4.1lbs (1.8 kg) of PBX blend (80% RDX)
- Max. Ranges –
  M119A2 105mm howitzer
  M67 11.5km BT - 13.7 km Base Bleed
  M200 13.9km BT - 18.1km Base Bleed
X-Ray View of the XM1131

Tungsten matrices
PFF Test – Ft. Sill - 2005

Legend:
R₁ = 5 meters
R₂ = 10 meters
R₃ = 15 meters
Greater Lethality versus Personnel and Soft Skinned Targets

105mm PFF HE strikes

155mm M107 strikes
Increased Ground Operational Reach

105mm Range Comparison

M119A2

Current Operational Limits

- 11.5 Km M1 HE
- 14 Km M760 HE

Extended Operational Reach

- 15 Km XM1131
- 18.1 Km XM1130

ACA²P
105mm Lethality Comparison

- PFF has 2 - 4X improvement in lethality compared to current M1(HF) against select targets
- Improved first shot $P_{kill}$
- Reduction in collateral damage
- Growth to precision accuracy
Reduced Vulnerability

IM Accomplishments – 1st Qtr

- IM Tests conducted at Denel in March, unpackaged:
  - Bullet Impact: Pass Type IV*
  - Fragment Impact: Pass Type IV*
  - Sympathetic Det: Pass Type III (12mm HDPE)
  - Fast Cook-Off: Pass Type IV*
  - Slow Cook-Off: Pass Type IV*
  - 12 Meter Drop: Pass Type V

* Base ejection safe distance exceeded, no deflagration or burn

- U.S. Army moving ahead with pressed warhead
- Passed all but one IM test
IM Compliance

Bullet Impact

Fragment Impact

Sympathetic Detonation

Fast Cook-off
XM1131 TC Path for Army

- IM Board Review Complete
- Packaging Confirmation Test Complete
- Explosives Task Order Complete
- TC Hardware Delivery Complete
- Explosives Qual Test Start Complete
- Qualification Tests Complete
- CPD Approval Apr 07
- TC Documentation Jun 07
- TC Standard Jul 07
- Initial Fielding Aug 08
AC-130 PFF Application

#1- Increased lethality from
  • PFF Warhead

#2- Improved survivability
  • IM Warhead
  • Greater Stand-off

#3 -Reduced Co-lateral Damage
  • Reduced danger area
  • Improved Accuracy
ACA²P Technologies Demonstrated

- Base bleed
- Boat tail
- BI-spectral smoke
- IR illumination
- Phosphorus
- PFF

Bi-spectral smoke

IR illumination
Army currently evaluating XM350 HYBRID propellant for 105mm Pff to replace both the M67 and M200 zoned ranges with single charge system.

- Performance Improvements:
  - Enhanced Ballistic Efficiency
    - Uses a burn rate modifier
    - Improved geometry
  - Reduced barrel wear, erosion, and gun-flash
  - Superior IM performance improves aircraft survivability
  - Affordable replacement to M1
  - Potential to reduce gun recoil
  - Eliminates dependence on foreign nitro-guanidine
Processing and Sensitivity Testing of the Insensitive TNT Based Explosive – PAX-44

National Defense Industry Association
Gun and Missile Systems Conference & Exhibition
Event #7590
April 23-26, 2007
Charlotte, NC

G. Duncan Langlois
Energetic Materials Technology Group
ATK – Energetic Systems Division
Radford Army Ammunition Plant
Overview

• ATK Strategy for IM Replacement Energetics
• M795 Energetic Replacement Project
• PAX-44 – Basic Information
• Processing Experiments and Demonstrations
  • LAP Study
  • Finishing Study
• IM Experiments and Demonstrations
  • BI Test series
  • Cook Off Testing
  • Sympathetic Detonation Testing
• Conclusions
• **Overarching Goal:**
  
  • Provide MIL-STD 2105C Compliant Energetic Solutions based on Low-Cost Proven Technologies to drive Low Life-Cycle Cost Growth and meet Warfighter Demands

• Comply with system specific Threat Hazard Assessments with the target goals of full 2105C compliance

• Utilize proven basic technologies to minimize implementation upsets with a focused Design For Six Sigma driven approach

• Plan for Low Life-Cycle Cost Growth
  
  • Break the standard cycle of high cost IM energetics
  
  • Provide cost effective solutions without passing the costs up the supply chain
  
  • Maximize fielding amounts of needed munitions on a fixed POM budget
M795 Energetic Replacement Project

- IM Improvement for Legacy GP Artillery Rounds
- 155mm M795 HE used as test bed
- Culmination of a multi-year multi source competition
- ATK was a primary stakeholder as the provider of legacy energetics

- Competitive test covered all aspects of supply chain and munitions life-cycle
- Testing was conducted as head-to-head sensitivity and performance testing with consideration for life-cycle cost impact
• TNT Based IM energetic

• 80/20 TNT / Performance Desensitizing Additive (PDA)

• PDA was an engineered, oxygen carrying, density matched, organic fuel that serves as an inert additive to dilute threat stimuli but contributes near-equivalent energy in the detonation regime

• Formulation allows all the benefits of TNT
  • Easy melt casting
  • Flaking
  • Low-toxicity
  • Excellent storage characteristics

• PDA is designed to provides advantages to shock mitigation (BI, FI, SD, SCJ) and benefits to Cook-off thermal stability
LAP Study

- Iowa Army Ammunition Plant – Indirect Fire Business Unit
  - Full Scale Pour of 45 Projectiles using production equipment
  - Screening experiment to determine if x-ray acceptable rounds could be cast with PAX-44 using the current range of process controls (TNT -> Comp-B)
  - Follow on testing to determine effect of feather and process additives

- Army ARDEC Bldg. 810 Process Optimization Experiments
  - Belt Flaking PAX-44 for feather material
  - Optimized Model Based Controller cooling profiles
  - On-site test articles for ARDEC IM testing
Pour Quality Progression
Finishing Study

• ATK – Energetic Systems Division
  – NTIB TNT Facility

• Supplier of TNT for M795 LAP operations

• Only domestic manufacturer of TNT

• GOAL
  – Use standard finishing process and production equipment to make PAX-44 flakes conforming to the same military quality standard as Type I Flake TNT
  – Demonstrate path for low impact facilitization of PAX-44 if needed to support major testing or classification operations
• IM Experimentation and Demonstrations
  • Bullet Impact Testing
    – 9 PAX-44 tests (NTS-Camden, ATK-LS, ARDEC)
  • Cook-off Testing
    – Fast Cook-off (NTS-Camden)
  • Sympathetic Detonation Testing
    – Duplicate testing (NTS-Camden)
PAX- 44 BI Testing – Phase 1

- Initial Testing Conducted with Projectiles from first casting at IAAAP
- (2) Tests – STANAG 4241
- Repeated Type III Reaction
- Sensitivity linked to cast quality
PAX- 44 BI Testing – Phase 2

• Efforts to improve casting quality (Feathering, Process Additives, MBC Cooling)
• Consistent Improvement of Bullet Impact Response over range of cast-qualities
PAX- 44 BI Testing – “No Reactions”

- Rounds with excellent cast quality repeatedly demonstrated “No Reaction” aka Type VI reaction to Bullet Impact Testing
Unresolved Issues in BI Testing

• Unfortunately, Cast quality is not the only driver of Bullet Impact Response
  • 3 Tests (above) all conducted using X-Ray Approved munitions
    – Passed MIL-P 63252 rev A and MIL-STD 453 Criteria for TNT loaded projectiles
  • Reactions ranged from Type III Explosion to “No Reaction”
  • As yet an unresolved issue
Cook Off Testing

• Energetic and System level Improvements to M795 Cook Off response showed incremental improvement, but did not meet program goals

• Why is cook off so tough?

  • Logistical Configuration
    – Large Explosive/Case mass ratio
    – Vertical Orientation
  • Energetic Issues
    – Foaming TNT provides infinite path flame front
    – Work underway to provide additional Cook-off Response mitigation
Sympathetic Detonation Testing

- Initial indications showed that shock propagation was likely at expected separation distances
- Testing conducted for information purposes and to provide baseline data for improvement projects
Conclusions

• PAX-44 has demonstrated capabilities
  
  • Processing
    – High TNT percentage allows it to be processed in a manner consistent with TNT and Comp-B
    – Relative low additive percentage allows it to be drum-flaked and meet TNT spec for flake character
    – Builds on TNT strengths of long-term stability and low chemical reactivity
  
  • Sensitivity
    – IM testing of PAX-44 loaded munitions show improved response to impact based testing
    – PAX-44 shows incremental improvement with respect to SD testing and Cook Off
  
  • Cost
    – Using proven low-cost materials the cost impact to making an energetic fill less sensitive can be minimized
HS-Digital Footage

An advanced weapon and space systems company
Phalanx CIWS For Defense Against Rockets, Artillery, and Mortars

Presenter: Scott G. Martin
High Value Site Defense Program Manager
Date: 25 April 2007
The Current Tactical Situation…

Requires The Capability To Defeat …

- Cruise Missiles
- Various Military Aircraft
- UAVs
- Slow Civilian Aircraft
- Helicopters
- Lightly Armored Vehicles
- Small Boats With Weapons

AND Rockets, Artillery, and Mortars!!

Expanding The Role Of A High Value Site Defense System Can Signal A Revolution In War-fighting By Defeating Enemy Rockets, Artillery And Mortars BEFORE They Impact The Ground
Characteristics of a High Value Site Defense System

- Positive Command & Control
- Positive Target Identification
- Quick Response
- Capability Against a Large Target Set
  - Both Air and Surface Threats
- Programmable & Dynamic No-Engage Sectors
- Limit Collateral Damage

Demands a System Which Can Neutralize Multiple Threats & Types In a Single Engagement
Primary Mission:
Terminal Defense Against ASCM threat and High Speed Aircraft Penetrating Other Fleet Defensive Envelopes

Added Missions:
• Surface Mode
  - Counter Small, Fast Surface Craft and Slow Flying Helicopters and Aircraft
• Sensor Support For Close-in Missile Engagements
• High Value Site Defense

Benefits:
• Supports Multiple Roles In Ships Self Defense
• Man-in-the-Loop, Autonomous or Integrated Operation
• Fast Reaction
Phalanx CIWS AAW Operational Sequence

ENGGAGEMENT STATUS
1. Search
2. Assign
3. Track
4. Recommend Fire
5. Gun Fire
6. Kill Assessment

Target Detection
Track Acquisition
Open Fire
First Potential Intercept
First Corrected Round
Cease Fire
Angular Miss
Continuous Aim Correction
Target
Search
Threat Assessment

1 2 3 4 5 6
Proven Against Threats in Both Anti-Air and Surface Mode

SeaSkimming ASM

Subsonic Tactical ASCM
Mach 2+ ASCM Test Targets
High G Maneuvering ASCM
High Diving ASCM
155 mm Shells
Mortars/Rockets
Mine Simulators
Jetski
18 & 35 ft Boats
C12 & S3 Jet Aircraft
Mirage, F-18 & A4 Jet Aircraft
SH-60, HH-1N, Cobra Helos
Man-in-Water (Swimmer)
50 & 80 knot Boats

Diving ASM

Cobra Helo w/Flares

A4 Jet Aircraft

UAV

155mm

Small Boat Engagement

Rigid Inflatable Boat

Boghammar

Track Only Op
Today’s HVSD Solution: Land-Based Phalanx Weapon System (LPWS)

LPWS Mission
- Terminal Defense Against Mortars and Rockets
- Sensor Support For Close-in Engagements
- Search Radar Provides Low False Alarm Rate Target Detect
- Track Radar Provides Accurate Target Track Information
- Accurate Point of Impact Prediction
- Man-in-the-loop, Autonomous Or Integrated Operation
- Improved Gun Mounting Optimized Gun Barrels (OGB)
- M-940 High Explosive Incendiary Traced Self-Destruct (HEIT-SD) Ammunition

Standard Mk-149 (Penetrator) Ammunition Could Be Lethal
M-940 Ammunition Eliminates Collateral Damage
Strategic Placement Provides for Overlapping Protection

- 2 Weapon Systems (Minimum) Per Site Provides 360 Degree Coverage
- Proper placement would Allow Both Systems to Engage
- Provides Surveillance/Control for Road/Water Route Access Routes
Self-Contained Lowboy Trailer Design Raytheon

- Tool Box
- Chiller
- COTS Portable Structure
- Generators
- Manual Jacks
LPWS
Site Hardware Arrangement

• “Movable” Installation
  – Self Contained
    • Power
    • Cooling
    • Operator Station
  – Trailer Mounted
    • Commercial Chiller
    • Jacks Provide Stability

• Ethernet Fiber-optic Based Interfaces
  – Allow Several Km Distances Between Protected Areas And Site Control
  – Portable Remote Control Unit Can Be Placed At Centralized Control Location

• Remote Equipment Monitoring Facilitated By “On-trailer” Automatic Maintenance & Operational Data Collection

• Phalanx Gun Mount Hardware Is 99.9% Common With Existing USN Block 1B Systems
Concept of Operation

• HVSD System Receives External Target Cue
  – Air Or Surface Search Radars
• OR, HVSD System Autonomously
  – Detects, Acquires, Tracks, And Engages Inflight Targets That Can Intercept Defended Area
• Self-destruct Ammunition
  – Destroys Incoming Target Given A Hit
  – Self-destructs If No Target Impact Eliminating “Fall Of Shot”
  – Compatible With Existing Weapons Systems And Logistics Requirements
• Rapid Reload Using Deckloader System
Conclusions

- Phalanx Block 1B Has Demonstrated Capability to Defeat a Wide Range of Air and Surface Threats to High Value Sites
  - Positive Threat Identification
    - Radar to Detect Incoming Targets
    - FLIR For Visual Target ID
  - Defense Against Air Threats
    - Rockets, Artillery, Mortars
    - Cruise Missiles
    - Low Slow Aircraft
  - Defense Against Surface Threats
  - Lowboy Trailer Configuration Provides Ability to Move System to High Threat Area
  - Self-Destruct Ammunition Reduces Collateral Damage From Fall of Shot

Phalanx Can Play a Significant Role in High Value Site Defense
The Land-based Phalanx Weapon System

Proven In Testing…
Currently Deployed…
Proven In Battle…
Saving Lives Today!
30mm x 173mm Air Burst Munition

Applications for Ground and Sea Platforms

NDIA

24 April 2007
This briefing will discuss:

- ATK Air Burst Munitions Evolution

- System Overview

- Air Burst Munition Test Shots and Video
Air Burst Ammo Target Set

- Lightly Fortified Infantry Emplacement (LFIE)
- ATGM Crew
- Troops in squad
- Watercraft
- BTR Lightly Armored Vehicles
ATK Experience

- Objective Individual Combat Weapon (OICW)
- XM25 Weapon System
- ALACV - Super 40mm Air Burst round
- Medium Caliber Ammunition
  - 20mm
  - 25mm
  - 30mm
- Gun Designer and Producer
  - Bushmaster Family
  - MK44
  - LW25
- Designer and Producer of Inductive Setting Systems
ATK Air Bursting Munitions Evolution

1999 2001 2002 2003 2004 2005 2006

Shoulder Fire
- OICW 20mm Ammo
- 20mm Firing

Cannon Caliber
- 30mm ABM Nose Fuze
- 30mm Firing Demonstrations
  Dec 2001
  May 2002
  Nov 2002
- MK44 30/40mm Cannon
- Super 40mm Development ALACV
- 30mm ABM Base Fuze
- 30mm ABM Base Fuze Firing

Approved for Public Release 06-S-1905 dated July 10, 2006
System Applications

• Bursting munition applications must be **system integration focused**
  – Open architecture — system of systems

• Bursting munition effectiveness is centered on error budget management
  – Interfaces must be in place “now” for later integration

• Platform integration and interfaces are critical

• Bursting munitions is a **system** not just fuze or ammunition
  – Fuze — Fire control interface
  – Setter — Human interface
  – Gun
ATK Air Burst System Overview

Key Components

- MK44 Chain Gun
- Gun Control Unit (GCU) with Inductive Fuze Setter
- Fire Control System
- ATK ABM Projectile
- Target Set

- Expeditionary Fighting Vehicle (EFV)
- Other MK44 platforms include: LPD-17, Bradley Fighting Vehicle & FCS

Approved for Public Release 06-S-1905 dated July 10, 2006
MK44 Inductive Setting: System Configuration

Gun Control Assembly (GCU)

- **ATK Fuze**
- **Setter Module**
- **GCU Electronics**

**MK44 Feeder**

- **Set Coil**

**MK44 Chain Gun**

**Vehicle Fire Control Unit**

- **User Interface**
- **Laser Range Finder**
- **Sensors Air, Tilt**

= ATK addition
### Physical Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartridge Length</td>
<td>290mm</td>
</tr>
<tr>
<td>Cartridge Weight</td>
<td>728g</td>
</tr>
<tr>
<td>Projectile Weight</td>
<td>423g</td>
</tr>
<tr>
<td>Propellant Type</td>
<td>Single Base</td>
</tr>
<tr>
<td>Cartridge Case Length</td>
<td>173mm</td>
</tr>
<tr>
<td>Cartridge Case Material</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Primer</td>
<td>M36A2 Percussion</td>
</tr>
<tr>
<td>Fuze</td>
<td>ATK Turns/Time</td>
</tr>
</tbody>
</table>

### Performance Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muzzle Velocity</td>
<td>980m/s</td>
</tr>
<tr>
<td>Chamber Pressure (ambient)</td>
<td>360MPa</td>
</tr>
<tr>
<td>Dispersion</td>
<td>0.5mr</td>
</tr>
<tr>
<td>Penetration</td>
<td>TBD</td>
</tr>
<tr>
<td>Trace Time</td>
<td>2 sec min, 5-6 sec typical</td>
</tr>
</tbody>
</table>
Shot 2 – 500m Air Burst Sequence  Highspeed

Approved for Public Release 06-S-1905 dated July 10, 2006
Shot 3 – 500m Air Burst

Down Range Views

Side View

Approved for Public Release 06-S-1905 dated July 10, 2006
ABM Test Video
Telepresent Rapid Aiming Platform (TRAP)

Spiral Development of a Lightweight Remote Weapon System and Integration Into a Mobile Sensor-Shooter Network
• TRAP T-250D MK IV Hardware Overview
• Cameras
• User Interface
• Tactical Display
• SLAM-R Laser Unit
• Counter Sniper Vehicle
• Image Stabilization
• Quad-X Portable Security Unit
• T250-FS: Facility Security Model
• SWORDS UGV
• EOD applications
• TRAP T360: Moving Forward
• Points of Contact / Questions?
Cameras

- Color - Sony FCB-980S camera + US Optics booster lens; 19° – 1.2° HFOV; 3.75 lbs
- I² - XR/MEGA-10LC tube, Sony XX285 CCD, CAT lens; 12°, 6°, 3° HFOV (digital zoom); 2.7 lbs
- Thermal – L3 320 x 240 core; 12°, 6° HFOV (digital zoom); 1.7 lbs
User Interface

Selector
Arming
Power
Camera Control
Motion
Fire (top + bottom)
Multi-function Buttons
6.5” LCD

Multi-function Buttons

Motion

Fire (top + bottom)

Camera Control

Selector
Arming
Power
Tactical Display

Position

Range

360 Position

Laser Aim

Weapon Aim

Heading

AZIMUTH: 4721 m110
Sensor/Laser Aiming Module – Remote (SLAM-R)

- Uses modified STORM optical bench
- Remote operable RS-232 interface
- MILES and Digital Compass removed
- Modular IR illuminator spot/flood
- Accepts MIL-STD-1275B host power
- 6” x 1.75” x 4.75” (incl. illum. pod)

- High / Low power lockout switch
- Class 1 LRF, +/- 1.5m to 4,500m +
- Visible aiming laser, Class 3b / 3a
- IR aiming laser, Class 3b / 1
- IR illuminator (30 mW), Class 3b / 3a
  - Expandable to 100 mW
CSV concept to combine emerging / COTS technologies in a light weight, low-cost package to counter the ongoing sniper threat in Iraq and Afghanistan

- Initiated by USMC 1MEF at Camp Pendleton
- Prototype tested March 2006 at Twenty Nine Palms, CA
Counter Sniper Vehicle

- Third-Party software maps vector and GPS location of incoming rounds, slews TRAP to target bearing for manual engagement via TRAP interface
- GPS coordinates stored – can be used for squad deployment, call for fire, or GPS-guided ordnance

- System can store video/stills for analysis
- Current controller may be replaced with the system in use on Gunslinger and the Full Spectrum Effects Platform (FSEP)
- In-theater testing Summer ‘07
Image Stabilization
Uses Ovation Systems “Stable Eyes” module by QinetiQ Technology

<table>
<thead>
<tr>
<th>Stabilized</th>
<th>Un-Stabilized</th>
</tr>
</thead>
</table>

Video recorded from moving CSV – system has detected a shot and is orienting TRAP towards the shooter
Quad-X: Portable Security Network

• Network up to four (4) TRAP systems
• Master operator/supervisor
• Video outputs for additional displays or recording devices
• Programmable security sweeps
• Linux-based, fully upgradeable
Facility Security Model

- In use at the Prairie Island Nuclear Power Station and Kirtland Underground Munitions Security
- Designed for elevated locations (0-60° depression, 190° traverse)
- Motorized enclosure provides weapon security, environmental and small-arms fire protection
- Fiber optic network – can integrate with existing perimeter sensors and surveillance systems
SWORDS
Special Weapons Observation Remote reconnaissance Direct action System
U.S. Army’s first Safety Confirmed Armed Unmanned Ground Vehicle!

- Weaponized Foster Miller Talon 3B robot
- Missions:
  - Over Watch / Recon
  - Security
  - First In / Room Clearing
  - Offensive

- Range: 1,000m LOS, 200m NLOS
- Speed: Up to 5 mph
- Weapons: M249, M240, M107, M203, 12 gauge, AT-4, and SMAW
- Sensors: Microphone, LRF, pan/tilt/zoom camera, wide area camera, weapon sight camera (day + IR), front and rear driving cameras
Joint EOD TechDiv
I-SCS: Improved Submunition Clearance System

Allows EOD Technicians to locate, identify, and engage explosive ordnance items from inside armored vehicles – improved safety and accuracy with less operator fatigue.

**Identify / Engage:**

**Threshold**
- BLU-61 at 50 m
- 155mm rounds at 500 m
- MK84 bomb at 1,000 m

**Objective**
- M42 at 50 m
- 130mm rounds at 500 m
- MK82 bomb at 1,000 m

Range: 50 m (actual screen shot)
TRAP T360

• Incorporating the spiral improvements from the past 5 years
• 400 round 7.62mm
• Brushless motors
• Anti-slip brake system

• Integrated 360 drive
• Closed-loop feedback
• Better environmental resistance
• Mechanical stabilization
• Prototype testing July ‘07
Points of Contact

- Presenter – Brian McConnell, NSWC Dahlgren
  – brian.mcconnell@navy.mil (540) 653-8316

- USMC & CSV – Captain R.M. Vorgang, MCWL GCE
  – roland.vorgang@usmc.mil (703) 432-0450

- EOD – Jean Nelson, Joint EODTechDiv
  – jean.nelson@navy.mil (301) 744-6358 x253

- SWORDS – Dave Platt, ARDEC/USSOCOM
  – sfcplatt@earthlink.net (973) 876-3122

- SLAM-R – Bill Lindsay, Insight Technology Inc.
  – wlindsay@insight-tek.com (603) 626-4800

- TRAP – Greg McNamer, Precision Remotes Inc.
  – greg.mcnamer@precisionremotes.com (510) 215-6474 x232

- Thermal Optics – Chris Canter, EMX Inc.
  – chris@emx-inc.com (321) 751-0111 x105

- I² Optics – Mike Buchin, Stanford Photonics Inc.
  – mbuchin@stanfordphotonics.com (650) 969-5991
National Defense Industrial Association
42nd Annual Armament Systems:
Gun and Missile Systems Conference & Exhibition

155mm XM1063
Non-Lethal Personnel Suppression Projectile

April 23-26, 2007
Charlotte Convention Center – Charlotte, North Carolina
XM1063 - Outline

- Introduction
- Why Non-Line of Sight Non-Lethal?
- XM1063 Design
- Program Timeline
- Program Successes
- Upcoming Program Events
- Summary/Conclusions
- Acknowledgments
XM1063 - Introduction

- XM1063 Provides Non-Line of Sight Non-Lethal Capability to the US Army
- US Army ARDEC Leads the IPT That is Developing the XM1063
  - GD-OTS focuses on payload submunition development and production of test hardware
  - Many contractors and other government agencies have contributed to the IPT’s success
- Program Is In the Third and Final Year of an Advanced Technology Objective Development Effort
- Progress Made in First Year of Effort Was Presented at Last Year’s Conference
- This Presentation Will Update Progress To Date
XM1063 – Why Non Line of Sight Non-Lethal?

- XM1063 Intended to Provide a New Capability
  - Non Line of Sight Non-lethal
    - Separate combatants from non-combatants
    - Suppress, disperse or engage personnel
    - Deny personnel access to, use of, or movement through a particular area, point or facility

- Addresses Need for Non-Lethal Options That Is Highlighted by Current Conflicts in Iraq and Afghanistan
  - Minimizes collateral damage, fatalities and permanent injury
XM1063 Design

Utilizes Type Classified M864 DPICM Projectile Body, Base Burner, Fuze, Expulsion Charge

Non-Lethal Submunitions Replace DPICM Payload

Submunitions Dispense Non-Lethal Personnel Suppression Agent Without Detonators or Explosives
XM1063 – Program Timeline

<table>
<thead>
<tr>
<th>Test Series</th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopter Drop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KE Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expulsion/Struc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Tunnel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Month Demo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NLOS-C Comp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FinalExpul/Struc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helicopter Drop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ballistic Flight Test Demo (TRL 5)**
- Component and Sub-System
- NL PS payload simulant delivery

**Full Up System Demo (TRL 6)**
- Max Range Live Firing
- KE Mitigated Sub-munition for NL PS from a 155mm Projectile Cargo Rd
XM1063 Program Successes

- All Up Round Testing
  - Successful Test Firings Demonstrating TRL 5+
    - Standard 39 Caliber Gun
      - June 2005, MACS Zone 4 (original submunition design)
      - July 2006, MACS Zone 5 (updated submunition design)
      - February 2007, MACS Zone 4 (further updated submunition design)
    - Prototype FCS NLOS-C
      - July 2005, MACS Zone 3 (original submunition design)
XM1063 Program Successes

- Component Level Testing
  - Submunition Static Dissemination Testing
    - October 2005 (various submunition configurations)
    - September 2006 (various submunition configurations)
  - Helicopter Drop Testing
    - December 2005 (updated submunition drag device design)
  - Wind Tunnel Testing
    - June 2005 (original submunition drag device design)
    - October 2006 (further updated submunition drag device design)
  - Non-Lethal Payload Clinical Trials
  - Frangible Case Design Development
    - Ongoing
  - Submunition Structural Testing
    - October 2006
XM1063 Upcoming Program Events

- Milestone B – Transition to PM
  - TRL 6 Demonstration Test Firing scheduled for 4QTR FY07
    - Minimum and Maximum Range
    - Flight Stability
    - Structural Integrity
    - Target Effectiveness
    - Area Coverage
XM1063 – Summary/Conclusions

- Continued Program Success Since Beginning of Program
- Provides Non Line of Sight Non-Lethal Capability
- Utilizes Type Classified M864 Components for Easy Integration Into Inventory
- Demonstrated Using Standard 39 Caliber and Prototype FCS NLOS-C (TRL 5)
- Transition to PM at the End of FY07
XM1063 - Acknowledgements

I’d like to acknowledge and thank the entire XM1063 IPT. The contributions of each IPT Team member and member organization has allowed for continued program success.
XM1063 POC Information

**Speaker:**
- Jennifer McCormick
- General Dynamics OTS
- (425) 216-7341
- jennifer.mccormick@red.gd-ots.com

**Co-author:**
- Robert Lee
- US Army ARDEC
- (973) 724-4134
- robert.lee10@us.army.mil
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

BRIEFING FOR THE NDIA GUNS AND MISSILE SYSTEMS CONFERENCE - APRIL 23 – 26, 2007
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION
WAVE GUN ENGINEERING, MODELING AND LARGE
CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- SONIC RAREFACTION WAVE GUN TECHNOLOGY
- ENGINEERING DEVELOPMENT
  - MODELING & SIMULATION
  - DESIGN & ENGINEERING
  - PERFORMANCE TESTING
- TRANSITION
- SUMMARY
Sonic RAREFACTION WAVE GUN (RAVEN) is a Projectile Launch Method that achieves:

- Unprecedented Reductions in Recoil Impulse
- Significant Reductions in Gun Barrel Heating
- Muzzle Blast Reduction

While Maintaining the Efficiency & High Projectile Velocity of Conventional Guns (No Loss in Projectile Velocity)

RAVEN was Invented at Benet Laboratories, US Army, Oct 2002 by Dr. Eric Kathe (Patent: 6,460,446)
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION
WAVE GUN ENGINEERING, MODELING AND LARGE
CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

Ignition

Breech Vent Opens
While Projectile is
Still In-Bore

Sonic Rarefaction
Wave Catches
Projectile At the
Gun Muzzle

No Velocity
Loss

“Innovative Armament Solutions for Today and Tomorrow”
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION
WAVE GUN ENGINEERING, MODELING AND LARGE
CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- 50% - 100% Recoil Reduction for No Velocity Loss
  - High Velocity Guns Can Be Nearly Recoilless
  - High Efficiency Recoilless Operation Obtainable
  - Can Maintain High Lethality on a Lighter Platform

![Graph showing relation between Recoil Momentum and Gross Vehicle Mass](image)

- M551: 116% OSL
- M1A1: 49% OSL
- M8 AGS: 128% OSL
- M60A1: 43% OSL
- 105mm RAVEN: 54% OSL

Ogorkiewicz Stability Limit (OSL)

“Innovative Armament Solutions for Today and Tomorrow”
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION
WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- Approximately 50% Reduction in Barrel Heating
  - Enables Lightweight Gun Barrel Technology
  - Allows Increased Firing Rate
  - Mitigates Need for Erosion Protective Coatings
  - May Use More Energetic Propellants

- Approximately 2/3 Reduction in Muzzle Blast
  - Lower Vision Obscuration
  - Lower Overpressure on Front of Vehicle/Platform

- Control of Muzzle Velocity via Rarefaction Wave (ex.: artillery zoning)
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- **35mm Rarefaction Wave Gun Demonstration**
  - Inertial Breech Vent
  - External Breech Guide
  - Thrust Generating Exhaust Nozzle

35mm Proof-of-Principle RAVEN Cannon

- 61% Recoil Reduction
- 41% Heat Transfer Reduction
- No Loss of Muzzle Velocity

“*Innovative Armament Solutions for Today and Tomorrow*”
**LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT**

**ENGINEERING DEVELOPMENT & DEMONSTRATION**

- **ARDEC Technology Base Program Objectives**
  - Advance Sonic Rarefaction Wave gun (RAVEN) technology (from TRL 4) Enabling
    - Lightweight Cannons & Firing Platforms
    - Reduced Heat Transfer / Higher Rates of Fire
  - Demonstrate TRL 5 for large caliber RAVEN Cannon (Direct & Indirect Fire)
  - Integrate State-of-the-Art materials and processing technology for minimum system weight and maximum performance
  - Transition technology into a solution for Army and other Defense/Commercial needs

|---------------------------------------|-----------------------------------|------------------------------|---------------------------------------------|

“**Innovative Armament Solutions for Today and Tomorrow**”
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- **Direct Fire RAVEN Demonstrator** (FY06 Design, FY07 Build & Test)
  - Based on 105mm FCS MRAAS Direct & Indirect Fire Cannon
  - Swing Chamber Allows Rear Venting & Rapid Fire
  - Rear Venting Cased Telescoped Ammunition (Slug Projectile)
  - Inertial Breech Vent to Expansion Nozzle (Thrust Generated)
  - Split Nozzle (Inertial Breech Cast Steel Outer Nozzle Slides Over Composite/Steel Fixed Inner Gun Nozzle)

- **Next Generation RAVEN Demonstrator** (FY07 Design, FY08 Build & Test)
  - Design for Minimum Weight – Advanced Materials
  - Alternative & More Efficient Vent Methods
• **Modeling & Simulation**

New 1-D Finite Volume Interior Ballistics & Dynamics RAVEN Gun Design Tool
- Validated with 35mm RAVEN Closed Breech & Vented Firing Data
- Includes Recoil Brake, Muzzle Brake, Thrust, Heat Transfer Models

Computational Fluid Dynamics _Fluent, GTBL, NGEN_

- 2-D Axis-Symmetric Fixed and MDM Modeling of Vent Gas flow
- Thrust, Heat Transfer & Shock Structure Analysis
- NGEN/CFD _Fluent Coupling (ARL/ARDEC FY07– 08)_
- Erosion Modeling (ARDEC FY07 – FY08)
- Blast Field Modeling (SEA, Inc. FY08)
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

105mm RAVEN Prototype Demonstrate Components

- Breech Ring
- Cannon Tube
- Swing Chamber
- Trunnion
- Hydraulic Recoil Cyl. (4)
- Gas Recuperator Cyl. (2)
- Composite Gun Nozzle
- Cast Steel Inertial Breech Nozzle
- Breech Nozzle Support Vanes

<table>
<thead>
<tr>
<th>System</th>
<th>Trunnion Impulse</th>
<th>Muzzle Energy*</th>
<th>Energy/Impulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>105mm M68/M900</td>
<td>19,100 NS</td>
<td>7.86 MJ</td>
<td>412</td>
</tr>
<tr>
<td>105mm MRAAS/Slug</td>
<td>23,580 NS</td>
<td>8.97 MJ</td>
<td>380</td>
</tr>
<tr>
<td>120mm M256/M829A3</td>
<td>29,400 NS</td>
<td>11.7 MJ</td>
<td>398</td>
</tr>
<tr>
<td>105mm RAVEN</td>
<td>9,852 NS</td>
<td>8.76 MJ</td>
<td>889</td>
</tr>
</tbody>
</table>

58% Recoil Reduction Over RAVEN Closed Breech & FCS MRAAS Baseline

“Innovative Armament Solutions for Today and Tomorrow”
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

• Performance Testing
  • Hardstand Testing _ M&S Validation
    • Interior Ballistics Engineering Data
    • Recoil Dynamics Engineering Data
    • Thermal Measurements
    • Blast Field Characterization
  • Light Weight Vehicle Platform Testing
    • Stability Analysis
    • Blast Field Characterization
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVES
ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

<table>
<thead>
<tr>
<th>CURRENT STATE</th>
<th>TECHNOLOGY DEVELOPMENT &amp; DEMONSTRATION</th>
<th>ENDSTATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FY07</td>
<td>FY08</td>
</tr>
<tr>
<td></td>
<td>Spiral Development – Medium &amp; Large Caliber Technology Demonstrators</td>
<td></td>
</tr>
<tr>
<td>M&amp;S Tools Prepared</td>
<td></td>
<td></td>
</tr>
<tr>
<td>105mm Direct Fire Designed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>105mm Direct Fire Fabricated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>155mm In-Direct Fire Concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gun &amp; Ammo Engr. Solutions Applying RAVEN Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeling &amp; Simulation Validated with Test Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Materials &amp; Processes Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Weight Direct &amp; Indirect Fire RAVEN Launchers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solutions Enabling Increased Lethality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solutions Enabling Lightweight Gun Platforms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Innovative Armament Solutions for Today and Tomorrow”
LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

SUMMARY

• State-of-the-Art Design, Analysis, M&S and Fabrication
  ▪ Designed Utilizing State-of-the-Art Modeling & Simulation and Design Tools
  ▪ Maximum Use of Advanced Materials & Manufacturing Processes

• RAVEN is a Breakthrough Generic Gun Technology that will Lighten the Force & Pave the Way for Next Generation High Mobility Projectile Launcher Systems
  ▪ Light Weight Direct & Indirect Fire Systems Gun Systems
  ▪ Mounted & Robotic Ground Platforms or Individual Weapons
  ▪ Ground, Aerial, Naval or Amphibious Platforms

Contact: kminer@pica.army.mil

“Innovative Armament Solutions for Today and Tomorrow”
Problem Statement

- Auto ignition or “cook-off” is one of the most serious safety concerns when firing large caliber guns.
- Researchers inability to perform measurements at locations where they are needed
Measurement Concept Temperature

- Precise Timing Measurements to Measure Temperature & Erosion

Determining Inner Chamber Surface Temperature

\[
\text{Change of Echo Separation} = (\text{Velocity Temperature Coefficient}) \times (\text{Echo Separation})
\]
Mark 45 MOD 4 Live Fire Trials

Multiple Successful Live Fire Trials

NETS (NON-Intrusive Erosion and Temperature Sensor) prototype installed on the MK45 MOD 4 Gun at NSWCDD for several live fire experiments in 2005-2006

• Accurate Internal Temperature Measurement
• Transient Temperature Measurement
• Off-line Heat Flux Calculations
Precise Internal Temperature Measurement

Ultrasonic Temperature for Three Firings of Mark 45 Mod 4 Normalized to 70 degrees Fahrenheit.
(Black Squares are Thermocouple based modeled data provided by NSWCDD)
Transient Temperature Measurement

Technology offers the potential for temperature measurement on a microsecond timeframe.

(Ultrasonic Temperature data collect every 200 usec.)
Measurement Concept for Heat Flux:

Inverse Solution

1. Forward Conduction Solution
2. Temperature Distribution
3. Predict Ultrasonic Time of Flight
4. Compare Predicted with Real
5. Does Approx Boundary Condition Work?
   - Yes: Correct Temperature Distribution
   - No: Adjust Boundary Condition

Approximate Boundary Condition

- Adjust Boundary Condition
Off-line Heat Flux Calculations

Ultrasonic based Heat Flux determination at the Gun Bore Interface over a period of 1.5 seconds
Measurement Possibilities for the *Ultrasonic Temperature and Heat Flux Sensor*

### Features, Advantages, and Benefit of the Ultrasonic Technology

<table>
<thead>
<tr>
<th>Features</th>
<th>Advantages</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun Temperature</td>
<td>Non-Intrusive Direct Measurement</td>
<td>Increased Gun Safety</td>
</tr>
<tr>
<td>Gun Erosion</td>
<td>At Sea Measurement Continuously Monitor</td>
<td>Tactical and Safety</td>
</tr>
<tr>
<td>Transient Temperature</td>
<td>Non-Intrusive High Speed Measurements</td>
<td>Barrel Coatings/Propellants Combustion Instability</td>
</tr>
<tr>
<td>Heat Flux</td>
<td>Non-Intrusive High Speed Response</td>
<td>Barrel Coatings/Propellants Gun Research</td>
</tr>
</tbody>
</table>
Opportunities for the *Ultrasonic Temperature and Heat Flux Sensor*

**Gun Safety**
- 5”/62 MK 45 MOD 4 gun
- BOFORS MK 110 57mm gun US Coast Guard & Navy
- Lightweight Howitzer (JLWH) 155mm Program

**Research**
- 155mm Advanced Gun System for DD(X)
- US Army Benet Laboratory Gun
- Barrel Coating & Munitions Research
- Combustion Chamber Instabilities
- Insulating And Metallic Aeroshells
State of Development for the *Ultrasonic Temperature and Heat Flux Sensor*

**ACCOMPLISHMENTS:**
- DEVELOPED concept of a sound sensor for temperature and heat flux algorithms
- IMPLEMENTED in both lab and live fire environments
- DISCOVERED transient temperature/heat flux measurements
- INCORPORATED PXI Platform for real-time system
- ACCELERATED development to capitalize on field testing

**NEXT STEP:**
- Ruggedness for safety application
- Explore transient measurement applications
- Partner for combustion engine and aerospace
- Field Testing Field
The Great American “sound and temperature” Road Show

Deploy solutions at various research facilities

Success in these ventures will give us a good baseline to build a market as well as validate our technology.

We are very confident in our technology, but have limited contacts to deploy and test.

Non-destructive nature of the measurements allows for easy implementation without disruption to ongoing tests.
Thanks For Listening!

Force Modulator Test In 300-Ton Clearing Press

Pressure vs. Stroke (inches)

0 500 1000 1500 2000 2500 3000 3500 4000 4500

0 1 2 3 4 5 6 7 8 9 10

Stroke (inches)

High Pressure (Psi)

Cylinder #1 High Pressure Chamber

Cylinder #2 High Pressure Chamber

Slide Contacts Binder Ring (Aerodynamic Cylinder)

Press Bottom Dead Center, Return Delay Predetermined By Customer

6.3 5.5 4.0 5.0 4.7

Tonnage

Tighter Mfg. Tolerance Will Reduce Fluctuation

Initial Slide Shock Absorbed

Ultrasonic Temperature and Heat Flux Sensor Technology

Mark J. Mutton BSEE
R & D Engineer
MMutton@imsysinc.com

Industrial Measurement Systems, Inc.
2760 Beverly Dr.
Aurora, IL 60504
120mm Mid Range Munition (MRM)

ARDEC S&T Effort

Presented at:
42nd Annual Armament Systems: Guns & Missile Systems Conference & Exhibition
25 April 2007

Robert Nodarse
RDECOM-ARDEC
(973)-724-3813

Providing America Advanced Armaments for Peace and War
Outline

• Program Overview
  – Background/History

• MRM Technology Development
  – Airframe
  – Lethality
  – GNC/Seeker

• MRM Integrated TRL6 Demonstrations
  – Autonomous
  – Semi-Active Laser (SAL)
  – Dual Mode

• Summary
What is MRM???
FCS MCS Mid-Range-Munition (MRM)

Objective: Provide the FCS Mounted Combat System (MCS) with a precision munition capable of defeating LOS/BLOS threats out to 12km.

Goal: Develop and integrate the necessary technologies to demonstrate a TRL 6 precision munition, ready for Milestone B and System Development & Demonstration (SDD) Phase.

SYSTEM CHARACTERISTICS:
• Precision Munition for FCS MCS Vehicle
• Designed to Defeat High Pay-Off
• Fleeting Targets (MBTs with ERA, APCs, Artillery, etc.)
• Incorporates Autonomous and Designated Seeker Modes
• Operates in Line-of-Sight or Beyond Line-of-Sight from 2km to 12Km

Extended the Capability to Defeat Heavy Armor out to 12Km
BLOS Operational Modes

MRM provides an extended range (BLOS) precision kill capability to the FCS Mounted Combat System enhancing the lethality and survivability of the system.

- **Autonomous**
  - Munition Searches & Engages Target

- **Designate**
  - Munition Searches for Laser Spot on Target and Engages
  - Terminal Phase – Munition Conducts Aim Point Refinement to Maximize Lethality
  - Reverts to Autonomous Mode if Spot is Lost or not Found

- **Designate Only**
  - Same as Designate Except if Laser Spot is Lost or not Found – Munition Does not Revert to Autonomous Mode
  - Enables Added Control Under Highly Restrictive ROE

Robust Design Maximizes Operational Flexibility and Lethality
MRM - System Video
BLOS Engagement

SCOUT POSITIONED 3 KM IN FRONT OF TANK FORCE
Mid-Range Munition Concepts

Program has Achieved Autonomous, SAL, and Dual Mode TRL 6!

MRM-KE

- **Target Types**
  - Main Battle Tanks (MBT) w/ ERA
  - Light Armor (BMP)
  - Self Propelled Artillery (SPH)/(MRL)
  - Air Defense Artillery (ZSU)
  - Bunkers (Earth & Timber)

- **Attributes**
  - Fleeting High Payoff Targets
  - Single Point Defeat
  - Stationary or Moving (Fleeting)

MRM-CE

- Dual Mode Seeker
- Uncooled IIR & SAL

Target Types:

- Main Battle Tanks (MBT) w/ ERA
- Light Armor (BMP)
- Self Propelled Artillery (SPH)/(MRL)
- Air Defense Artillery (ZSU)
- Bunkers (Earth & Timber)

Attributes:

- Fleeting High Payoff Targets
- Single Point Defeat
- Stationary or Moving (Fleeting)
MRM Program Approach

- Mid Range Munition
  - Cartridge
    - Projectile
      - Warhead
      - Air Frame/Structure
      - Guidance and Control
      - Seeker
    - Gun Propulsion System
      - Propellant
      - Ignition System
      - Cartridge Case
  - Packaging

Recommended Critical Technologies

- Bring all Critical Technologies to TRL 6
- Develop two concepts in parallel to reduce program risk
- Team with PEO-AMMO (PM-MAS) to facilitate/accelerate transition to SDD
MRM
Warhead Subsystem

- Technology:
  - MRM- KE: Kinetic Energy warhead with rocket motor boost to kill velocity
  - MRM-CE: Shaped Charge warhead penetrates the target’s main armor to provide high overall lethality.
- Achieved: TRL 6
- Basis for Assessment:
  - Verified LOS and BLOS lethality by HARP gun and static fire tests against the threat range targets (including ERA)
  - Demonstrated Lethality on Heavy Armor and Non-Heavy target (Bunker)
    - Defeats ERA and APS with high delta velocity prior to impact
  - Pk Analysis from ARL indicates excellent System Performance

[Images of warheads and tests]
Air Frame Subsystem

- **Technology:**
  - Robust and maneuverable airframe for BLOS range
  - Deployable Fins
- **Achieved: TRL 6**
- **Basis for Assessment:**
  - Conducted Wind tunnel testing and 6-DOF Aero. Model
  - Demonstrated Airframe structure integrity and BLOS flight at tactical velocities
  - Verified max. range capability
  - Demonstrated rocket motor boost to kill velocity
  - Demonstrated performance across temp. range
  - Validated in GTH testing

MRM-KE

MRM-CE
MRM
Guidance and Control

- Technology:
  - Thrusters, Canards, IMU
- Achieved: TRL 6
- Basis for Assessment:
  - Verification of designs was completed through Finite element modeling, rail gun testing, bench testing and ballistic testing.
  - Demonstrated pre programmed maneuver projectiles fired from 120mm gun – all survived setback
    - All projectiles performed requisite maneuver commands
  - Tactical maneuver authority was demonstrated
  - Software verified through IFS, PIL and HIL
  - Validated in GTH testing
MRM
Seeker Subsystem

- Technology:
  - Un-cooled IIR and SAL sensor
  - MMW and SAL sensor
- Achieved: TRL 6
- Basis for Assessment:
  - Performed extensive rail and gun testing of the Seeker Assembly to ensure Hi G survivability.
  - Extensive CFT testing/demonstrated Pacq and tracking capability
  - Software verified through IFS, PIL and HIL
  - GTH demo’s validated integrated system
MRM Accomplishments

✅ Autonomous GTH Demo - 2004
  Stationary target at 5.2 Km

✅ SAL GTH Demo - 2006
  Moving target at 8.7 Km

✅ DMS GTH Demo - 2007
  Stationary target at 5.2 Km
  Off set designation

Program has achieved Autonomous, SAL and Dual Mode TRL 6
MRM TRL6 Demonstrations
Summary

• MRM is an integral part of the ARDEC’s 120mm MCS and Abrams Ammunition System Technologies (MAAST) ATO

• Industry Partners - ATK & Raytheon

• MRM has demonstrated TRL6 for:
  - All major Subsystems
  - Integrated Autonomous Seeker Guide to Hit - 2004
  - Integrated SAL Seeker (Designate) Guide to Hit - 2006
Our Vision
ABRAHAM

System Design

- Rolling Airframe
- HF-pulsed LADAR
- Signal-processing
- Fire Control
- Advanced Warhead

Calibre: 120 mm
Length: 1600 mm
Weight: < 25 kg
Primary Targets

Tomahawk

Exocet

HARM
Additional Targets
Secondary Targets
Other targets
System Components

- Surveillance RADAR
- C²
- Fire Control
- Firing Units
ABRAHAM System

The Unit is thought to be a part in a system by system approach
The Unit should be possible to operate remotely
Equipped with a radar site complex firing tasks could be accomplished

- Maximum Intercept range should be ~3000 m from each unit
- Flight out time to ~3000m will be ~5s
- Maximum target speed 1000 m/s.
- Launch should be done when target a a distance of ~8km
- A ~15 km detection capability of the Surveillance radar

A firing unit consist of:
- Gun
- Radar site (option)
- Rocket in ready to launch tube
ABRAHAM - Sensor
Sensor -- Principal

- Six laser range-finders; three per helix
  - Laser transmitter
  - Laser receiver
  - Software
- Target Detection Software
Sensor -- Principal

• Rotating directional warhead
• Rotating sensor
• Two helixes
  • Distance
  • Angle

Laser range-finder
Sensor in rotations apparatus
Sensor trial – Shot no.1
ABRAHAM - Warhead
Warhead Design

METAL MATRIX AIRFRAME BODY
- Tungsten Pre-Formed Fragments

ADVANCED SHAPE
Simultaneously
- Long Range
- Short Range

Rolling Airframe

Foot-print of 1m² @ 50m
Warhead Rotation Trial

A: Warhead with rotation device.
B: Target setup with dural aluminum sheets (20 with 2,5 cm spacing)
C: High speed video.
D: Camera for surveillance of safety- and arming functions.
Warhead Impact with rotation
Penetration Capability

20 mm STEEL at ~2.5m
120mm Mortar Rounds

The long distance mode impacts with approx 110 TM-balls.

The explosives was brought to detonation by chock initiation.

Close range mode impacted with approx 20 TM-balls.

The explosive was brought to deflagration.
ABRAHAM
Launch and Propulsion
Launch Trial
Fin Deployment Test

- Picture at top: projectile closes in on whiteness paper
- Picture in middle: Hood is ejected
- Lower pictures: Projectile has flown through paper with fins deployed
ABRAHAM

ABRAHAM from a Launch and Propulsion perspective:

- A “recoilless” launch gives the rocket $\sim v_0$ 250 m/s
- A rocket motor accelerates the rocket to a maximum of 1000 m/s
- Tilted fins gives a stable flight and a rotation of approx. 12 - 15000 rpms
TWO WAYS TO GO

Phase 2

ABRAHAM
System X
ABRAHAM Light

Rak
Art
Grk
Pvrb
Rpg
+ "MultiRole"

Xrb
Smrb
Arb
UAV
UCAV
Fpl
(Hkp)
(Rak)
System Development Philosophy

**Sub-systems**
- Warhead
- Fuze
- SAU
- Propulsion
- Guidance and Control
- Power
- Airframe
- Aerodynamics
- Launcher/Mount
- Launch Tubes(s)
- Fire Control
- Eject Motor
- Interface
- IFF
- Safety
- Sub-Systems

**Philosophy**
- Low risk
- Low cost
- Modular approach

**Systems**
System Development Philosophy

- Ability to offer modules for different applications (pick and mix)
- New technology for low Unit Cost/Price
- Develop new weapon systems (Technology for next generation weapon systems)
- Ability for rapid exploitation of technology to new systems
- No need to develop costly single use weapons as in the past

Warhead
Fuse
SAU
Propulsion
Guidance and Control
Power
Airframe
Aerodynamics
Launcher/Mount
Launch Tubes
Fire Control
Eject Motor
Interface
IFF
Safety
Sub-Systems
Objects that needs Protection

- Escort under preparations, munitions handling and evacuation.
- Recon party driving on road and off road. Destroyed vehicle.

The object various in:
- size
- mobility
- passive protection levels
Terrorist Threat

Iraq rebel with American 60 mm mortar.

QUASSAM 2, improvised rocket.

The most common targets are small and many are hard.

RPG can be used for indirect fires. The grenades AD-function after approx. 900 m of flight has been used to obtain airburst.
ABRAHAM Light

Has a multifaceted shaped warhead and increased numbers of laser designators.

The increased numbers of laser designators detects targets in the forward helix and another in the back helix.

The rocket now weighs well under 20 kg.

It will also be slightly shorter than the original version.
ABRAHAM

Potential Applications of ABRAHAM Technology

- **Future Ground Based Air Defence Adjunct**
- **Low Cost Naval Point Defence**
- **Naval Anti-Surface - Counter Attack Craft**
- **Counter Mortar Point Defence System**
- **Direct Battlefield Engagement (soft skinned)**
- **120 mm Smooth Bore/Interim Rifled**
- **Future Rapid Effects System (FRES) Weapon**
- **Indirect Battlefield Artillery Warhead/Payload**
- **Loitering Munition Payload**
- **Replacement of current payloads**
NDIA Gun and Missile Systems Conference

April 24, 2007
Current Environment

✓ US Army FM 3.0 – Operations
✓ Offense Operations
✓ Defensive Operations
✓ Stability Operations

• “Army forces are trained, equipped, and organized to control land, populations, and situations for extended periods”

• “These occur during combat operations and throughout the post-conflict period”

• Apply force selectively and discriminately....precision munitions and non-lethal assets are vital.
Precision Munitions

• Supports COIN Ops
• Must have precision targeting
• Minimizes collateral damage
• 24/7, All weather

For the first time, the ground commander now has dedicated precision munitions that he can employ quickly and efficiently.
Precision Munitions

• Rockets & Missiles
  - Guided MLRS - Unitary
  - ATACMS Unitary
  - Precision Attack Munition

• 155 mm
  - Excalibur
  - Precision Guidance Kit

• Future Possibility - Precision 105mm
Rockets and Missiles

Guided MLRS Unitary

Combat Proven!

- Range: 15-70+ Km
- Multi-Mode Fuze (PD, Delay, Proximity)

Non-Line of Sight Launch System (NLOS-LS)

- Range: .5-40+ Km
- Grid Atk, SAL & Uncooled IR
- 12-Pound Warhead
- Attacks Stationary/Moving Tgts
Precision Munitions
GMLRS Unitary
Precision Munitions
GMLRS Unitary in Iraq
Precision Munitions

Excalibur Characteristics & Capabilities

• Range
  – 7.5 km min range
  – Early fielding, 24km
• Near vertical terminal angle
  – Approximately 80-85 degrees
• 10m CEP at all ranges
• GPS guided, IMU backup
• 3 Fuze setting:
  – PD
  – Delay – up to 8 inches of reinforced concrete
  – Proximity HOB
Precision Munitions
Excalibur
# Precision Munitions

## Precision Guidance Kit (PGK)

### Mission

To enhance the accuracy of current and future 105mm & 155mm artillery projectiles.

### Characteristics

- Backwards compatible with current munitions
- GPS ‘guided’ which provides location
- Cost effective by reducing delivery errors

### Requirements

- CEP of less than 50m (T) and 10m (O).
- Four operational modes: super quick, delay, proximity, and electronic time
- Apr 06 – PM award Technology Development contracts
- 27 Mar- 6 Apr 07 – Shoot off and Contract Award
**PGK Operational Concept**

**What it is:**
- Low cost, fuze-sized module intended to replace a "NATO standard" fuze
- Used on conventional ammunition

**What it does:**
- Reduces delivery errors by improving projectile accuracy with the aid of guidance

**How it does it:**
- GPS provides location and time during flight
- Inertial Navigation System determines trajectory and makes corrections
- Includes fuzing function

**Benefits of Reduced Dispersion**
- Increases Effectiveness – Kills targets quicker
- Reduces Collateral Damage
- Reduces Logistics Burden
- Allows closer support of friendly troops

**Precision Munitions**

**Actual Trajectory Determination And Correction Calculated**

**Trajectory Adjustment Applied**

**Unguided Trajectory**

**Dispersion Area of Corrected Round**

**Dispersion Area of Uncorrected Round**

- "Grid" Fin Canards
  - Provide High Lift without Stall
- Internal Magnetometer and Roll Rate Sensors
- GPS Antenna (2)
- Roll Brake Coils
- COTS Batteries (CR2) & Drive Motor
- Standard MOFA Radar and Setter Coils
- Standard Primer and S&A
- Standard MOFA Radar and Setter Coils
Accurate Targeting

Joint Effects Targeting System

- “Born Joint” requirement
- Requirement of 10M TLE at 10KM
- Modular components

Light Weight Locator Designator Rangefinder

- Very large modular force requirement
- 40M TLE at 10KM
- Weight – 35 lbs

Fire Support Sensor System

- Our mounted answer
- 17M TLE at 10KM
- Converting to ASV
- Working BFIST integration
- Stabilized with CRS3
Precision Strike Suite
Special Operating Forces (PSS-SOF)
Non-lethal

- Must maintain a full spectrum focus
- Beyond just delivery systems/munitions
- IO and EW key assets
- Includes full range of lethal and non-lethal assets
Non-lethal

• Information Operations (IO):
  • The employment of the core capabilities of Electronic Warfare, Computer Network Operations, Psychological Operations, Military Deception, and Operations Security, in Concert with Specified Supporting and related Capabilities, to affect or defend Information Systems, and to influence decision making. (FM 3-13, Information Operations Doctrine, TTP)

• Field Artillery Role
  • Designated Lead for Tactical IO
  • Tactical IO Course – Now taught at Field Artillery School
Non-lethal

• Electronic Warfare (EW) / Electronic Attack (EA)
  • Any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. The three major subdivisions within electronic warfare are:
    • Electronic Attack
    • Electronic Protection
    • Electronic Warfare Support
  • (Joint Publication 3-51, Joint Doctrine for Electronic Warfare)

• Field Artillery Role
  • Designated as the U.S. Army EA Specified Lead for Corps and Below Army wide EA Requirements
  • Army Operational Electronic Warfare – Now taught at Field Artillery School
Expeditionary Units with Campaign Capabilities

✓ Smaller, more capable units led by competent leaders
  • Mix of delivery systems with access to full suite of sensors and munitions
  • Systems designed to deploy and fight off the ramp
  • Migrate tactical and technical fire direction to the lowest possible level with maximum feasible centralized control
  • Develop multifaceted observers in appropriate numbers with technical enhancements
  • Smaller, lighter systems and units capable of integrating and operating with maneuver units without loss of capability

✓ Increased survivability and system reliability
  • Enhanced vehicle and crew protection – auto reload under armor
  • Same mobility and vehicle signature as supported maneuver
  • On-board Prognostics, early fault warning and troubleshooting

✓ Organized for sustained operations
  • Fires Brigades and BCT Fires Battalions operate for up to 72 hours without resupply
Expeditionary Units with Campaign Capabilities

High Mobility Artillery Rocket System (HIMARS)
NLOS-Cannon

**Characteristics**
- MRSI And Direct Fire Capable
- Precision Munitions Capable
- Integrated Projectile Tracking System
- 2-man Crew, 2 in Ammo Carrier
- 24 Projectiles And 72 Propellant Increments Capacity (155mm)

**Requirements**
- Maximum Range: 30 km (26km w M549, 32km w/ Excalibur)
- Minimum Range: 4 km
- Rate of Fire: 6 Rnds/Min (Sustained)
- Main Armament: Zone 4 - 38 Calibers Long 155mm
- Rearm: 15 min
- Munitions: All current and developmental munitions of it’s caliber
- Responsiveness: Emplaced-20 sec; Moving-30 sec.
- Deployability: C-130 Emergency Only (One NLOS-C)
NLOS-Cannon

Non Line of Sight - Cannon
Fully Networked Battle Command

✔ Joint network connectivity from space to mud
  • Robust, multi-form communications with routine network linkage
  • Network-based point and click targeting

✔ A single battle command system
  • Seamless exchange of information via common software
  • Universal user access to system capabilities
  • Point and click interface with embedded help and training

✔ Enhanced situational awareness
  • Every Soldier and platform integrated into a tailorable common operating picture at every echelon
  • Identification of friendly, enemy and non-combatants
  • Unified fires deconfliction process
Network determines optimum solution for second HPT to be a combination of NLOS-C and Mortars.

Network computes optimal solution to engage the most dangerous target (Attack Aviation).

Network tasks sensor to conduct BDA – reattack as required.

Attack Aviation identifies multiple HPTs and provides target description and location data to network.
C-RAM

- **Counter-Rocket Artillery Mortar**
  - System of systems to counter the indirect fire threat
- **7 Pillars**
  - Shape, Sense, Warn, Protect, Intercept, C2, Respond
- **Successful in Theater and at NTC**
Direct Fire Ammunition: “Meeting Warfighter Needs for the Asymmetric Threat”

COL Mark Rider
24 APR 07
Take Aways

- Significant Production Ramp Up of Direct Fire Ammunition Has Met Our Warfighters’ Needs
- Substantial New Capabilities Provided in Theater for use Against Asymmetric Threats
- Future Direct Fire Products Will Provide Even Greater Capabilities
- Direct Fire Ammunition Information to Support our Warfighters in the Asymmetric Fight

Quantity, Capabilities, & Information to Support Warfighters’ Needs
MISSION: PM MAS Provides Direct Fire Combat And Training Ammunition Capabilities To All Warfighters (Army, Navy, Air Force, Marines)
Significant Direct Fire Production Ramp Up

Small Caliber Deliveries

All Services, All sources

40MM Deliveries

Deliveries Nearly Quadruple

Dollars Increased Substantially (Army Only)

All Services, All sources

4.4M 4.7M 5.1M 7.7M 12.4M 15.6M

FY02 FY03 FY04 FY05 FY06 FY07

CTG 40MM PRACTICE M781 CTG 40MM WHITE STAR PARA M583
CTG 40MM HEDP M430 F/MK19 MG CTG 40MM HEDP M433
CTG 40MM TP M918 LINKED F/MK19 MG
CTG 40MM PRACTICE M385A1
CTG 40MM WHITE STAR CLUSTER M585

Use or Disclosure of Data Contained on the Page is Subject to Restrictions on Title Page
Significant Direct Fire Production Ramp Up

Medium Cannon Caliber Deliveries

Large Caliber Deliveries

Increasing Deliveries

Consistent, Significant Deliveries

DISTRIBUTION STATEMENT A: Use or Disclosure of Data Contained on the Page is Subject to Restrictions on Title Page
New Capabilities in Theater
MGS and 105mm Ammunition

- **Wall-Breaching Cartridge for Stryker Mobile Gun System (MGS)**
  - Requirement: Create 30”x 50” Hole In Double Reinforced Concrete Wall, Defeat Bunkers & Dismounted Infantry
  - Full Rate Production

- **Anti Personnel Cartridge (APERS) for Stryker Mobile Gun System (MGS)**
  - Requirement: Defeat Dismounted Infantry Squad In The Open From 50-500m
  - >2000 Tungsten Balls
  - Full Rate Production
New Capabilities in Theater
MGS and 105mm Ammunition

Capabilities for the Warfighter in the Asymmetrical Fight

M393A3 HEP

M1040 APERS
New Capabilities in Theater
120mm Ammunition

- Anti Personnel Cartridge for Abrams
- Requirement: Defeat Dismounted Infantry Squad In the Open From 200 to 500M
- Demonstrated Effectiveness Against Alternate Targets
  - Light Skinned Vehicles
  - Concrete Block Walls
  - Concertina Wire
- ~1100 Tungsten Balls
- Full Rate Production
New Capabilities in Theater
120MM Ammunition

M1028 Anti-Personnel Cartridge

**Capabilities for the Warfighter in the Asymmetrical Fight**
Future Capabilities
120MM Ammunition

Advanced Multi-Purpose

PRESENT: 4 ROUNDS

TARGET SET

FUTURE: 1 ROUND

Combines capabilities of M1028, M830A1, M908 and M830 into ONE Round

Providing the Warfighter Improved Lethality and Operational Flexibility
Future Capabilities
120MM Ammunition

Mid Range Munition (MRM)

System Characteristics:
- 120mm Precision Tank Cartridge For FCS Vehicle MCS
- Designed To Defeat High Value Fleeting Targets (Tanks, APCs, Artillery, Etc.)
- Incorporates MMW And/Or I2R Seekers and Laser Seeker
- Operates In Line-of-Sight Or Beyond Line-of-Sight Modes
- Operates Autonomously And/Or With Designation
Warfighter Ammunition Information Program (WAIP)

Problem Statement
Users Not Aware of Specific Ammunition Capabilities

Objective
Develop Program to Address Ammunition Informational Gaps

- Direct Fire Ammunition Operational Focus
  • Classes / Forum Established
  • Train the Trainer Approach

- Several Units Instructed on Small, Medium, and Large Caliber Direct Fire Ammunition
  – 25th ID, 3rd ID, 82 ABN, 11th ACR, 3rd ACR
  – Marines, National Guard, Master Gunner Classes, SMA Classes, Warrant Officer Classes, etc..

- Links All Soldiers to Ammunition Experts Within the Government & Industry

- POC: Mr. Steve D’Ostroph, WAIP Team Leader, PM MAS, steven.dostroph@benning.army.mil

Assists Warfighters in Understanding Operational Capabilities of Their Ammunition Against Asymmetric Threats
Summary

- Significant Production Ramp Up of Direct Fire Ammunition Has Met Our Warfighters’ Needs
- Substantial New Capabilities Have Been Provided in Theater for use Against Asymmetric Threats
- Future Direct Fire Products Will Provide Even Greater Capabilities
- Direct Fire Ammunition Information to Support our Warfighters in the Asymmetric Fight

Quantity, Capabilities, & Information to Support Warfighters’ Needs
APAM-MP-T 120mm , XM329
(Anti-Personnel / Anti-Materiel – Multi Purpose Tank Round)

Danny Schirding
Chief Systems Engineer & Sr. PM
Tank Ammunition Directorate

National Defense Industrial Association
42nd Annual Armament Systems: G&M Systems
Charlotte, NC
April 23-26, 2007

Israel Military Industries Ltd. (IMI)
P.O. Box 1044
Ramat Hasharon 47100, ISRAEL
dschirding@imi-israel.com
APAM 120
MISSION STATEMENT

To provide the best round for Main Battle Tanks (MBTs) against targets other than tanks:

- To provide rapid and lethal direct fires in support of assaulting infantry
- To incapacitate infantry, especially AT squads (Ambush)
- To penetrate bunkers and buildings with maximum resulting damage
- To breach walls, allowing passage of friendly troops
- To destroy light armored vehicles (LAV’s)
- To be effective in Military Operation in Urban Terrain (MOUT)
- To deter/destroy helicopters (Self Defense)
APAM 120
XM329

- Multi – Purpose Tank round
- Used with all NATO 120 mm smooth-bore guns
- Compliant with:
  - STANAG 4385 & AEP 26
  - STANAG 4493
  - STANAG 4369 & AOP 22
  - STANAG 4157
  - MIL-STD-810
  - MIL-STD-1316 & 331
  - ITOP and others
  - IDF specifications and requirements
APAM 120
Anti-Personnel/Anti-Materiel Round

- Cartridge length: 984 mm
- Cartridge weight: 27 Kg
- Projectile weight: 17 Kg
- Projectile Length: 750 mm
- Muzzle velocity: 900 m/sec
- Chamber pressure: 3,400 bar
- Accuracy (SD): 0.3 mil
- Temperature limit - Storage: -40 °C to 63 °C
- Temperature limit - Firing: -40 °C to 52 °C

(*) - Programmable Electronic Fuze System
APAM 120mm – Warhead

- Three independent safety mechanisms according MIL-STD-1316
  - centrifugal
  - set-back (pin)
  - body caging
- Neutralization pin for safety improvement
- Twin sliders for redundancy
- Reliability of operation > 97% (warhead)
- Hazardous duds < 0.1%
- Designed for optimal fragmentation performance and high lethality
APAM 120
Modes of Operation

1) Ejection of 6 warheads at the set range -
   - Anti - Personnel [AP]
   - Anti Helicopter [AH]

2) Impact W/Delay [Delay = f (range)]

3) Impact - Super Quick [S.Q.]

4) Air-burst at the set range [unitary warhead]

   “Extra” features –
   - Air-Burst functioning as Back-up to Ejection Mode
   - Grazing functioning
   - Impact as default set
APAM 120
Ammunition Data Link/Fuze Setting
Round in Gun

120mm smoothbore NATO gun

Junction Box

Trigger

FCS (Bi-Directional Date Link)

- **Round ID** –
  Type, Muzzle Velocity, Temp.

- **Talk forward** (Data Link to Round in Gun) –
  Mode of operation, Range, Power, Continuous Programming up date

- **Talk-back** message (from the Round) -
  Data Linked, Errors.

Inductive Setting - Fuze Setter (in emergency)
Program Integration Management Chart & Main Milestones

Israel Military Industries Ltd. (IMI)

Cartridge & Data Link

Reshef Technologies Ltd.

Fuze System

Integration Tests & CDR

Safety Tests

Operational Trials

Qualification Tests

PRR

I-MOD: System Integration

IMI & IDF

Approval

IDF

IDF

IMI

Elbit Systems Ltd.

FCS & Data Link

PRODUCTION

I-Mod: System Integration

Operational Trials

Quality Tests

PRR
**APAM 120**

Development Program – Main WBS

- Warhead
- Projectile
- Data Link
- Primer
- Fuze System

Integration → CDR → Qualification → Certification

Serial Production
APAM – AP mode on the Battlefield

Length of beaten area compensates for inaccurate ranging.
APAM 120
High Stability at Long Ranges – Excellent Accuracy
APAM 120
Warhead Separation and radial dispersion
AM MODE (IMPACT)

- Projectile will -
  - Penetrate LAV’s
  - Penetrate bunkers
  - Breach walls
- High density of lethal fragments inside
APAM 120
Primer and Ammunition Data Link

- The Data Link current doesn’t pass through the primer igniter
- MIL-STD 1512
- MIL-I-23659C
- All Fire $> 2.1A$
- No Fire $< 1.0A$
- Safety: $\infty$ db

No need to change/modify the Breech Block
APAM 120
Special Firing Box & Data Setting
Used During FSD

- Data Link or
- Inductive settings
APAM

UPGRADE YOUR FIRE POWER

THE AMMUNITION OF TOMORROW
TODAY FROM IMI
Development of Exploding Foil Initiators and Micro Chip EFIs

Gert Scholtes and Wim Prinse
Overview

• Introduction
• Why EFI systems
• Exploding Foil Initiator Research
• Research on Explosives
• Conclusions
Introduction
Exploding Foil Initiator Research

- Exploding foil
- Electrical circuit
- Velocity of the flyer
- Driver Explosive
- Secondary flyer
- Acceptor explosive
Shock initiation research at TNO: 
Mega Ampere Pulsar and Flyer Impact

Wim Prinse

~4 feet
Why an EFI system

• An EFI is intrinsically safer than standard initiators (no primary explosive)
• More reliable (so hardly no UXO’s)
• Works much faster < microseconds
• Can be smaller (near future)
• Is compliant with new STANAG (4560) regulations
• New opportunities (tandem charges, aimable warheads)

• Disadvantage : More expensive (at the moment)

• Future: Micro Chip EFI (McEFI) → inexpensive
Exploding foil

- Dimension of the foil (length, width, thickness, form, material)
- Shockwave impedance of the tamper
- Thickness and material of the flyer
- Length and width of the barrel

![Diagram of exploding foil components: barrel, flyer, tamper, Kapton, copper](image-url)
Electrical circuit

- Optimisation of the circuit
  - low loss capacitor
  - Switch (solid state)
  - transmission line
- Development of measuring techniques (current, voltage, velocity of the flyer)
- 90 % efficiency of energy deposited in the exploding foil (50 % other circuits)
Fabry-Perot system

laser-light

Fabry-Perot etalon

fibre

lens A

lens B

slit in coating

lens C

streak camera

Grin-lens

Moving Flyer
Fabry-Perot system

- Laser-light
- Fabry-Perot etalon
- Slit in coating
- Streak camera
- Lens A
- Lens B
- Lens C
- Fibre
- Grin-lens
- Moving Flyer
Flyer velocity measurement by F-P Interferometer

- Acceleration of the flyer influenced by:
  - thickness and material
  - exploding foil dimensions and material
  - shockwave impedance of the tamper
- Integrity of the flyer during acceleration
- Determination of optimum barrel length

4 km/s in 80 ns (2.5 mi/s)
Research on Explosives I

- Recrystallisation of HNS II to HNS IV
- The crystals are more uniform (smaller distribution)
- The length to width to thickness is 10:3:2
- A further increase in specific surface area is possible
Initiation behaviour of different explosives

- Different types of explosives
  - HNS IV several brands
  - TATB several grades
  - New explosives
- Initiation energy depends on flyer thickness and velocity
Initiation of 5 x 5 mm HNS IV pellet

Voltage < 1300 Volt

Transmission line
Numerical simulations of flyer impact

- Lee-Tarver model modified with visco-plastic pore collapse model
- Qualitatively the simulations can explain the experiments

Reacted fraction of HNS IV after initiation by 5.4 mm/μs flyer
Secondary flyer acceleration

- Driver explosive (HNS IV), confined
- Secondary flyer material:
  - aluminium
  - stainless steel
  - kapton
  - mylar
- Important properties:
  - spall strength (attenuator)
  - shockwave impedance
  - size and thickness
- Velocity of flyer measured with Fabry-Perot Velocity Interferometer System
Secondary flyer impact

Acceleration of a 0.25 mm stainless steel flyer by HNS IV
Successful initiation of TATB and RDX by
• 0.15 mm SS steel flyer
• 0.35 mm mylar flyer
• 0.3 - 0.5 mm Al flyer
Development of mini EFI and developer platform for Micro Chip EFI (McEFI)

- Efficient Transmission line with exploding bridge
- Pressed HNS IV
- Electronic component of the shelf (capacitor, HV unit, solid state switch and some standard electronic components)
- Knowledge/experience

- Mini-EFI and developer platform for McEFI
Conclusions

• A very efficient electrical circuit ($\eta = 90\%$)
• Mini-EFI Works at Voltage lower than 1300 Volt (Solid state switch)
• With “of the shelf components” small IM compliant EFI-detonators can be build (8cm$^3$ including High Voltage-supply)
• The use of secondary flyers makes the detonation train more reliable (in case of set-back)
• Combining the EFI with the ESAD with Micro Chip technology can make a small and cost effective unit

Gert Scholtes: Gert.Scholtes@tno.nl
Wim Prinse: Wim.Prinse@tno.nl
U.S. Army Armament Research, Development, and Engineering Center (ARDEC) Update

Presented to

NDIA 42nd Annual Armament Systems: Guns and Missile Systems Conference

25 April 2007

Anthony J. Sebasto
U.S. Army Armament Research, Development, and Engineering Center (ARDEC)
asebasto@pica.army.mil
973-724-6198
ARDEC Mission
Life Cycle Engineering & Support

Lightweight Dismounted Mortar
Plasma Arc Furnace
Supercritical Water Oxidation

R&D
DEML
PROD
FIELD SUPPORT

Excalibur
Lightweight Handheld Mortar Ballistic Computer, XM32
Lake City Army Ammunition Plant

M240B 7.62MM Machine Gun
40mm Multi-Shot Launcher

Lake City Army Ammunition Plant
5.56/7.62

...Providing Over 90% of the Army’s Lethality
Established “Center of Mass” for Armament Systems and Munitions for Joint Services

- Proven track-record supporting transition of technologies to the field; since early FY 05.....
  - >28 Material Releases (MR) (>40 since early FY03)
  - >34 Urgent MR (>50 since early FY03)

- ARDEC Personnel ~ 3000; ~900 new hires since FY99
- >$100M invested in “World Class” experimental R&D facilities since mid-90’s; Additional $75M planned
- Strong partnerships with Industry, Academia, and other Government agencies.
- In-house rapid prototyping initiatives demonstrating new desired capabilities, supporting production prove-out and initial fielding demands
- >$125M Tech Base portfolio addressing Joint needs

2004 & 2006 Army Large R&D Lab of the Year
R&D and Experimentation Facilities

Major Examples

**Davidson Advanced Warhead Development Facility**
- Opened 1996
- $11.7M
- Maximum 50 TNT equivalent capability
- 100m indoor warhead test range

**Precision Armaments Lab**
- Opened 2000
- $8.8M
- 2 Lab grade elevators for sensor dev
- 3 Target locations; 150m, 400m, & 1500m

**Armament Technology Facility**
- Opened 2003
- $8.4M
- 2nd 100m range opening FY09
- 100 & 300m indoor ranges
- Environmental chambers

**Armament Software Engineering Cntr**
- Opened 2005
- $15.5M
- Level 5 CMMI Certified
- Integrated S/W & H/W development/integration
- Multi-platform SOSI highbay capability
New Facilities Under Construction

Breaking “Old” Grounds

Soft Recovery System (SRS)
$9.0M
- High-g test Munition/Components to 20K g’s
- 155mm capability (current); Only one in existence
- Navy 5”, 120mm mortar, and EM Gun planned

High Energy Propellant Formulation Facility
$17.7M
- 45,000 ft² Propellant Pilot Plant
- Characterization Laboratories
- Magazine Storage / Offices

Pyrotechnic Research & Technology Complex
$9.9M
- 33,000 ft² Engineering Offices & Laboratories
- Pilot manufacturing facility
- Energetic stowage

Explosives R&D Loading Facility
$8.0M
- 28,000 ft² Melt Pour Operations & Engineering
- Climate Controlling Machining
- Explosive Pressing, Cast Cure, & X-Ray

Opening
- May FY07
- FY08
- FY09

$9.0M
$17.7M
$9.9M
$8.0M
### Materiel Release Items
- Receiver, Radio Firing Device: M17 (Remote Activation Munitions System (RAMS))
- M1028 120mm Tungsten Canister Cartridge
- M278 2.75-inch IR Rocket with Mk66 Mod 4 Rocket Motor
- M232A1 Modular Artillery Charge System (MACS) 155mm Propelling Charge
- M777A1 155mm Medium Towed Howitzer
- M1040 105mm Canister Cartridge
- M782 Multi-Option Fuze Artillery (MOFA)
- Mk7 Mod 2 Anti-Personnel Obstacle Breaching System (APOBS), Tactical
- Mk7 Mod 2 APOBS, Training Aid
- M264 2.75-inch Red Phosphorous Smoke Screening Rocket with Mk66 Mod 3 Rocket Motor
- M720A1 60mm HE Mortar Cartridge with M734A1 Multi-Option Fuze
- M768 60mm HE Mortar Cartridge with M783 PD/DLY Fuze
- Mk243 Mod 0 9mm Jacketed Hollow-Point (JHP) Cartridge
- M255A1 2.75 inch Rocket Flechette Warhead with M439 RS Fuze and Mk66 Mod 4 Rocket Motor
- M111 Improved Position and Azimuth Determining System (IPADS)
- M107 Long Range Sniper Rifle

### Urgent MR Items
- XM110 Semi-Automatic Sniper System
- Enhanced M113A2 Rapid Entry Vehicle, Spirals 1 and 2
- USMC GG04 Rubber Ball Grenade (Army XM104)
- Advanced Combat Optical Gunsight (ACOG), Model TA31F (to USASOC, USAREUR, NGB, FORSCOM)
- Mk108 Mod 1 Signal Illumination Kit, Green Star – Pen Flare (30,000 to ARCENT-CFLCC)
- Mk135 Mod 1 Signal Illumination Kit, Various Color – Pen Flare (9,700 to ARCENT-CFLCC)
- Advanced Combat Optical Gunsight (ACOG), Model TA31RCO-M4 with LFU/ARD (to USASOC, USARPAC, NGB, FORSCOM, EUSA)
- M32 Lightweight Handheld Mortar Ballistic Computer (LHMBC) Version 2.1
- M927 105mm High Explosive Rocket Assist (HERA) Cartridge
- M100 Grenade, Rifle Entry Munition (GREM)
- M101 Grenade, Rifle Entry Munition – Target Practice (GREM-TP)
- Mk108 Mod 1 Signal Illumination Kit, Green Star – Pen Flare
- Mk142 Mod 0 Signal Illumination Kit, White Star – Pen Flare
- M1028 120mm Tungsten Canister Cartridge (to FORSCOM)
- XM328 40mm Multi-shot Grenade Launcher (MGL) (89 to ARCENT-CFLCC)
- Enhanced M113 – Rapid Entry Vehicle
Materiel Release Items – Con’t…

- MK281 Mod 0 40mm Practice Cartridge
- M879 81mm Full Range Practice Mortar Cartridge
- M21 Modernized Demolition Initiator (MDI), Cap, Blasting, Non-Electric
- M192 Lightweight Ground Mount (LWGM)
- Paladin Digital Fire Control System (PDFCS)
- M240H 7.62mm Aviation Machine Gun
- M393A3 High Explosive Plastic with Tracer (HEP-T) 105mm Cartridge
- M467A1 Target Practice with Tracer (TP-T) 105mm Cartridge
- Paladin Software Version 7 for the M109A6 Howitzer Automatic Fire Control System (AFCS)
- M2 Vehicle Light-Weight Arresting Device (VLAD)
- M85 Trainer, Receiver, Radio Firing Device: M85 (Remote Activation Munitions System (RAMS) Trainer)

Urgent MR Items – Con’t…

- XM1092 12 Gauge Extended Range Non-Lethal Marking Munition (ERNLMMs)
- XM1091 40mm Extended Range Non-Lethal Marking Munition (ERNLMMs)
- X26E Tasers, A.T. XP Air Cartridges and Digital Power Magazines
- Mk79 Mod 2 Signal Kit, Personnel Distress: Red Color – Pen Flare
- BBU-35/B Impulse Cartridge
- FN303 Less Lethal Launcher and Associated Equipment
- XM101 Common Remotely Operated Weapon Stations (CROWS)
- M930E1 120mm Illuminating Mortar Cartridge
- M278 2.75-inch IR Rocket with Mk66 Mod 4 Rocket Motor
- Matrix System plus spares
- Platoon-Size Non-Lethal Capabilities Set
- X26E Advanced Taser Weapon and Associated Equipment
- Heckler & Koch MP5-A5 and MP5K-PDW 9mm Submachine Guns
- M107 Long Range Sniper Rifle
- M203 Grenade Launcher Day Night Sight (DNS), Model 1800 Black with Tritium Sights
- Vehicle Lightweight Arresting Device
- Bradley Reactive Armor Tiles “A2” Vehicle Sets to ARCENT
- A2 Bradley Fighting Vehicle System Armor Tile Sets
Urgent Material Releases
Some Recent Examples

**M1028 120mm Canister Cartridge**
- New Anti-Personnel capabilities for Abrams Tank out to 500m+
- >15,000 rounds fielded to Army/Marines.

**M100 Rifle Launched Grenade Munition**
- Door Breaching Munition fired from M16A2 and M4 with standard 5.56mm M855 rounds.
- 300 tactical/1250 training rounds fielded

**M113A2 Rapid Entry Vehicle (REV)**
- Non-lethal response under armor with
  - 4 modified M870 shotguns
  - 6 Modular Crowd Control Munitions
- 4 vehicles fielded

**M927 105mm High Explosive Rocket Assist (HERA) Cartridge**
- Extended range capability to 16km+ to meet critical mission need
- Combination new production and M913 conversion yielded ~3600 cartridges
- ~700 cartridges fielded
Rapid Prototyping Initiatives
Examples of “Tech Push” for Early User Demo’s AND Support to Production Requirements

Gunner’s Protection Kits (GPKs)

**M114 Objective GPK (O-GPK)**
- Concept Demo in 6 Months
- ARDEC Level III TDP
- Depot Production for >15K GPKs

**RG31 GPK**
- Modified O-GPK
- ARDEC LRIP underway

**SOCOM GPK**
- Expanded Requirements
- ARDEC LRIP underway

**Sculpted Transparent Armor**
- Curved Transparent Armor
- Enhanced Situational Awareness
- Concept demo planned May 07

**Stryker Cupula Shield**
- PM Request
- Concept Demo in 90 days
- ARDEC LRIP to OIF (7 Brigades)

**MAJOR DESIGN GOALS**
- Maximize protection level & area
- Minimize weight
- Maintain situational awareness
- Use existing attachment points
- Utilize proven ballistic materials
- Minimize number of components
- Interface with standard weapon mounts
- Modularity

Close Coordination with Customers Key to an Integrated Solution for Survivability, Lethality, and Situational Awareness
Remote Armament for Unmanned Platforms

Rapid Prototyping Initiatives
Examples of “Tech Push” for Early User Demo’s AND Support to Production/Fielding Requirements

**Key Design Challenges:**
- Weight/Cube/Power
- Weapon Re-arm/Automation
- Integration on COTS platforms
- Communications
- Roof and internal structures
- No fire zones / motion inhibits
- Vehicle dynamics
- EMI

**Remote Armament Sys Tech**
- Weapon designs specifically for unmanned platforms
- Ease of integration/functionality
- Concept demos FY08/09

**Picatinny LtWt Mount on TAGS**
- ARDEC in-house developed mount
- <200lb weight class with M240/M249
- 3 mounts supporting customer demos

**Obj NLOS Mortar Technology**
- Elevating automated turret concept
- Demo on surrogate platforms FY07-09

**Special Weapon Observation-Reconnaissance Direct Action System (SWORDS)**
- Safety Confirmation Jun 06
- 3 Deployed to 3rd ID for Training
- Urgent Material Release expected

**“I’m ready to deploy with this unit and SWORDS”**
- SGT, 1-3 Cavalry, 3BDE/3ID

Valuable Lessons Learned on Design and Safety Considerations to Apply to Remote Armament Programs

Initial Production Prove-Out and Fielding Support
Evaluation of Acoustic Sniper Detection Systems

• PURPOSE: Validate accuracy of vehicle mounted gunfire detection systems, both statically and on the move against vendor stated performance specifications
  • Verify performance of system's ability to detect/locate sniper fire under various conditions
  • Verify system robustness to false alarms

• Three-Phase Test at APG:
  • Stationary – Open Field (Completed)
  • On the Move – Open Field (Completed)
  • Stationary – Urban Environment (May - Jun)

• Emerging Results:
  • System tested provide varying degrees of detect and locate capabilities
  • In general, discrepancies exist between vendor claimed performance specifications and test results

• Specific platform testing requested by customers underway

Testing Critical for Requirements Generation and Establishing TTPs
Recent Tech Base Transitions
Major Examples-Weapons

LtWt 81mm Dismounted Mortar

- Joint Army/Navy Funded
- ~30% weight reduction (to <70lbs)
- New Inconnel Tube Mat’l & Process
- Simpler, More Ergonomic Bi-Pod
- ~50% UPC reduction
- Transitioning to Prod ECP FY07

XM325 120mm Mortar Cannon

- 3 meter tube with screw block breech
- 8 km range with M900 series ammo
- Demonstrated 12 rpm firing rate (FCS Threshold Requirement)
- Transitioned to FCS Program at TRL 6
Recent Tech Base Transitions

Major Example-Ammunition

Line-of-Sight-Multi-Purpose (LOS-MP)

Current

Future- 1 Round

• Enhanced Lethality with One-Round against:
  • Concrete Wall
  • Earth and Timber Bunker
  • Lt Armor
  • Personnel

• LOS-MP TRL6 Exit Criteria met:
  • Defeated Double reinforced concrete wall with Hole size 30”x50” in <3 shots
  • Demonstrated greater than threshold range (700m) with potential to meet objective capabilities (40-2000m)

• Transitioned to PM-MAS

30 Man Platoon Defeated > 1000m

1-Shot T-55 Defeat

2 Shots- Defeat DRC

1 Shot Bunker Defeat
 LOS-MP Design Process

- Initial conceptualization to meet requirements
- Definition of high risk process and long lead items
- Define shortfalls of M&S: Fill gaps with test, experience

Enabled TRL 6 Demo in 2 Years

Modeling/Configuration Pro Engineer/Intralink

IB Simulation IBHVG2
Structural analysis FBD/ANSYS
Target penetration CTH

Failure in any model reiterates design process

No iteration of design during testing!

Lethality Models CASRED/MPR3D/AJEM/MUVES

Flight Performance

Fragmentation

Verify Models

3D numerical control Pro Manufacture

Flight performance PRODAS

DR concrete wall

Modeling and Simulation Saved $6.8M and 27 Months
ARDEC Tech Base Investments
Some Examples w/ Joint Service Applications

**Hardened Combined Effects Penetrator Warheads (FY04-08)**
- Single warhead to defeat armor, bunkers, personnel, UAVs with capability to bash-through and detonate within urban structures and clear re-bar.
- Broad applications across guns and missiles

~$38M

**LtWt Small Arms Technologies (FY05-08)**
- Technologies to reduce weight, increase reliability, and decrease training burden
- Plastic cased and caseless ammo under evaluation
- 35-45% total weapon/ammo weight reduction in 5.56mm achievable (Baseline: M249)

~$35M

**Electromagnetic Gun (FY04-08+)**
- Subsystem technology maturation focus
- Enables next level of mission area analysis to support Army program path forward decisions
- Broad weapon mission applications across Services
- Army/Navy collaboration

$85M+

**Common Smart Submunition (FY04-09)**
- Next generation smart submunition
- High kill probability against threat spectrum incl APS
- Application across munitions/missiles(≥120mm) & UAVs
- Supports Air Force “Area Dominance” via MOA

$60M
Application of World-Class M&S Tools is Dramatically Enhancing the Way We Design and Assess Products/Processes
In Summary....ARDEC/Picatinny...

- Established “Center of Mass” for Armament Systems and Munitions for Joint Services
- Proven track record of rapid transition of technology to the field
- Modernizing R&D facilities maintaining world-class capabilities
- Developing new concepts/technologies to enhance warfighter capabilities
- Demonstrating future warfighting capabilities today!

ARDEC/Picatinny……..

Products, people, and processes enabling our ultimate customer, the soldier, to “take care of business” throughout the spectrum of conflict!
120 MM XM325 OBJECTIVE NON-LINE-OF-SIGHT MORTAR CANNON TECHNOLOGY (ON-MT) PROGRAM

BRIEFING FOR THE GUNS & MISSILES SYMPOSIUM - 23 APRIL 2007

Providing America Advanced Armaments for Peace and War

DAVID C. SMITH, P.E.
ON-MT MORTAR CANNON OVERVIEW

• BACKGROUND: IN 2001, ARDEC TECHNOLOGY BASE DEVELOPED A PROGRAM TO DEMONSTRATE KEY 120 MM BREECH LOADED MORTAR TECHNOLOGIES, INCLUDING A CANNON, AUTOLOADER, FIRE CONTROL AND THE INTEGRATION OF THESE ITEMS. FOCUS HERE IS CANNON.

• SEPARATE BRIEFING ON INTEGRATION
  – SYSTEM INTEGRATION SESSION, THOMAS DEVOE

• GOALS & OBJECTIVES: DEVELOP A LIGHTWEIGHT 120MM MORTAR CANNON FOR USE ON A 20 TON VEHICLE
  – WEIGHT: < 800 POUNDS
  – BREECH LOADED
  – RETAIN MORTAR ROUND AT ALL ELEVATIONS
  – HIGH RATE OF FIRE
  – NO ALTERATION TO EXISTING AMMUNITION
  – NO EXPENDABLE DEVICES (STUBCASE, CLIPS, ETC)
  – IGNITION TRAIN RELIABLE & SAFE
ON-MT MORTAR CANNON FEATURES

- CANNON DESIGN FEATURES:
  - SCREW BLOCK BREECH – LIGHTWEIGHT + RELIABLE
  - MORTAR TUBE THICKER & LONGER THAN 120 MM M121
    - HIGH RATE OF SUSTAINED FIRE (SIMILAR TO DROP FIRE)
    - LONGER TRAVEL FOR INCREASED RANGE
    - INCREASED STIFFNESS FOR DIRECT FIRE
  - ROUND RETENTION FEATURES
  - CARTRIDGE FALL BACK FEATURES
  - UNIQUE IGNITION SUB-SYSTEM
  - COUNTER RECOIL BREECH OPENING VIA CAM PLATE
- CANNON RECEIVED TYPE DESIGNATION XM325 IN 2004
ON-MT MORTAR CANNON
FEATURES

- CAM PLATE & ELECTRIC ACTUATOR
- SCREW BLOCK BREECH
- DEBANGE OBTURATOR (SPINDLE NOT SHOWN)
ON-MT MORTAR CANNON
MORTAR BOMB RETENTION SHOE

SPECIAL RETENTION SHOE & SOLENOID HOLDS THE BOMB IN POSITION
ON-MT MORTAR CANNON
VACUUM - BOMB POSITIONING DEVICES

CUSTOM DESIGN
VACUUM VALVE
ASSEMBLY

MECHANICAL
FALL BACK
LATCH
ON-MT MORTAR CANNON
IGNITION SYSTEM

FIRING PIN ROTATES TO FIRE POSITION AFTER BREECH CLOSURE

RELIABLE SPINDLE & DEGANGE OBURATOR

CAM PLATE COUNTER RECOIL BREECH OPENING

SOLENOID ACTUATES FIRING PIN
FINITE ELEMENT ANALYSIS OF DEBANGE SEAL
CONDUCTED TO ASSESS:
• ROBUST OPERATION WITH CLOSURE PRE-LOAD
• MIN & MAX MATERIAL CONDITIONS
• EFFECTS OF THERMAL EXPANSION (RATE-OF-FIRE)
• ADEQUATE SEAL ACROSS ALL ZONES
ON-MT MORTAR CANNON
COMPONENT ANALYSIS - MECHANISM

• EXTENSIVE TESTING OF BREECH MECHANISM WAS CONDUCTED TO ASSESS RELIABILITY & FUNCTION:
  – ALL ELEVATIONS
  – WORN SPRINGS
  – POOR LUBRICATION
  – TEMPERATURE EXTREMES
ON-MT MORTAR CANNON DEVELOPMENT SCHEDULE

• Design – Benét Labs October 2003 May 2004
• Fabrication – Watervliet Arsenal & Benét Labs – May – August 2004
• Developmental Testing (Benét Firing Facility – Malta, NY):
  – Firing Test: 08 September - 18 November 2004
  – Total Shots Fired: 192
• Disassembly – Rework - Ship: November 2004 – December 2004
ON-MT MORTAR CANNON DEVELOPMENT TESTING

XM325 CANNON S/N 1 IN PROOF FIRING
WRIGHT MALTA TEST STATION
SEPTEMBER 2004
ON-MT MORTAR CANNON
DEVELOPMENT SCHEDULE (cont’d)

• Systems Integration & Autoloader Tests (Picatinny Arsenal Firing Range)
  – Cannon shipped 02 March 05
  – Integration Complete 15 May 05
  – Firing Test 16 May – 14 June 2005
  – Total Shots Fired: 15 (including Proof Rounds)

• Elevation and High Rate-Of-Fire Testing – Aberdeen Test Center
  – Firing Test: July – August 2005
  – Total Shots Fired: 174 rounds
  – Demonstrated 12 round per minute
ON-MT MORTAR CANNON
SYSTEM INTEGRATION & TESTING

SEPARATE BRIEFING COVERING THE OTHER SUBSYSTEMS AND SYSTEM INTEGRATION – SYSTEM INTEGRATION SESSION

“Innovative Armament Solutions for Today and Tomorrow”
ON-MT MORTAR CANNON
SUMMARY

• XM325 CANNON:
  – ALLOWS LOADING OF ALL CURRENT 120 MM MORTAR AMMO WITHOUT MODIFICATION
  – PROVIDES ROUND POSITIONING AND FALBack PREVENTION
  – HAS A SAFE, RELIABLE ROBUST IGNITION SYSTEM
  – FEATURES A CAM PLATE FOR COUNTER RECOIL OPENING
  – HAS BEEN TESTED WITH ELECTRICAL ACTUATOR
  – HAS BEEN DESIGNED AND TESTED FOR HIGH RATES OF FIRE
XM325 MORTAR CANNON AND THE ON-MT SYSTEM HAVE BEEN DEMONSTRATED TO MEET ALL FUTURE COMBAT SYSTEM REQUIREMENTS FOR A NON-LINE-OF-SIGHT MORTAR!!

THE XM325 CANNON HAS BEEN SELECTED BY BAE AND FCS LEAD SYSTEM INTEGRATOR TO BE THE PRIMARY WEAPON OF THE NLOS-M MORTAR VEHICLE!!
120mm Line-of-Sight Multi-Purpose (LOS-MP) Munition S&T Efforts

Guns and Missiles Conference April 25th 2007

Presented by
Jesse Sunderland LOS MP Engineer, RDECOM ARDEC
Outline

• **Program Overview**
  – Exit Criteria

• **XM1069 Design**
  – Process
  – Cartridge
  – Warhead
  – Fuze (XM1157)
  – Data Link

  \{ \text{Modeling & Simulation} \}

• **XM1069 Testing**
  – Warhead
  – Structural
  – Concrete Wall
  – Anti-Personnel

  \{ \text{Test & Evaluation} \}

• **Conclusion**
Program Overview

• **Subset of 120mm MCS and Abrams Ammunition System Technologies (MAAST) ATO**

• **LOS-MP TRL6 Exit Criteria**
  - Double reinforced concrete wall
    - Hole size 30”x50” in 3 shots or less
  - Anti-Personnel:
    - 200-700 meters Threshold
    - 40-2000 meters Objective

• **Industry Partners**
  - GD-OTS, ATK, L3

All technical data Government generated & owned
Line Of Sight Multi-Purpose (LOS-MP)

Present: 4 Rounds
- M908
- M830A1
- M830
- M1028

Target Set
- Anti-Personnel
- Concrete Walls
- Bunkers
- Light Armor

Future: 1 Round
- XM1069

Improved Lethality with Reduced Logistic Burden

The LOS-MP combines capabilities of M1028, M830A1, M908 and M830 into ONE Round
Initial conceptualization to meet requirements
Definition of high risk process and long lead items
Define shortfalls of M&S: Fill gaps with test, experience

**LOS-MP Design Process**

- **Modeling/Configuration**: Pro Engineer/Intralink
- **IB Simulation**: IBHVG2
- **Structural analysis**: FBD/ANSYS
- **Target penetration**: CTH
- **Fragmentation**: CALE/PAFRAG

**M&S Savings**: $6.8 mil/27 months

- **Flight Performance**: PRODAS
- **Fragmentation**: CASRED/MPR3D/AJEM/MUVES
- **Lethality Models**: DR concrete wall

**Decrease design time and tests**

Failure in any model reiterates design process

No iteration of design during testing!
Practical Application of New Technology
XM1069 Warhead Design

- **Blast fragmenting target penetrating**
  - Iteration of CTH/CALE-PA FRAG modeling
  - Structural integrity for:
    - Concrete Wall
    - Earth and Timber Bunker
  - Delivers intact warhead and fuze to target sweet spot
  - IM design

Fragmentation:
- ~24000 fragments

**Survivable & Lethal**

Four ARDEC Patents Pending

- CALE/PAFRAG predictions
- X-ray after DRC
XM1069 Fuze Design

- **Multimode Programmable Base Detonating (XM1157)**
  - 5 modes: 4-Point Detonate, Timed airburst
  - Dual safe: Setback, commit to launch
    - 3 leaf mechanism
    - Electronically controlled piston actuator
  - Power, function mode and time sent via data link
  - S&A
    - No rotating contacts
    - 90 degree rotor
  - Electronics
    - Dual Micro-controller
    - Enhanced Capabilities

ARDEC Patent Pending

Preliminary AFSRB approval
Munition Data-Link

• **Provides ability to:**
  – Power fuze
  – Set function mode & time
  – Verify data and munition status

• **Primer ignition isolated from data transmission**

• **Common Data Link for Abrams and MCS vehicles**

Utilizes production primer and case base
Warhead Testing: Frag Recovery

• **Fragment Recovery**
  – Fragment recovery determines efficiency of warhead to produce desired fragment size and number
  – Fragmentation recovery results validate and refine PAFRAG/CALE modeling data

93% fragment mass recovery was achieved
Fragment Recovery Data
Experimental vs CALE/PAFRAG Analysis

Body Fragment # vs Mass

Nose Fragment # vs Mass

Simulation predicted experimentation
Warhead Testing: Frag Velocity

- **Fragment Velocity**
  - Determines static detonation fragment velocity
  - Fragmentation velocity results validate and refine PAFRAG/CALE modeling data

Nose Fragment Velocity Test: 0.740 mm/µs
Predicted: 0.750 mm/µs

Body Fragment Velocity Test: 1.360 mm/µs
Predicted: 1.200 mm/µs
**XM1069 Structural Testing**

- Validate Propulsion models
- Validate FEA models
- Validate CTH model
- Evaluate target deceleration (for fuze programming)
  - Concrete/Double Reinforced Concrete: Equal difficulty
  - E&T Bunker hardest on airframe

**DR Concrete Wall**

Energy Decrease: 32KJ
Velocity Decrease: 60 m/s

**E&T Bunker**

Energy Decrease: 210KJ
Velocity Decrease: 162 m/s
TRL6: Concrete Wall Test

- Demonstrated XM1069 integrated with XM1157 fuze & data link
- Defeated target in 2 shots

Warhead integrated with fuze defeats target

MOOUT standard 8” double reinforced wall
TRL6: Anti-Personnel Test

- Demonstrated airburst performance between threshold and objective ranges

- 29 - 40' by 40' tarps to capture fragment spread

- Fired from Abrams SEP Tank with Data link

- Demonstrated performance at 1000 meters

Sample silhouette from test:
- Large Dots: Body frag hits
- Small Dots: Nose frag hits
XM1069 Test Successes

- Bunker defeat 1 shot
- 2 shots defeat DRC
- Simulated ATGM defeat 1000m
- T-55 defeat 1 shot
- 30 man platoon defeated past 1000m
THE U.S. ARMY

ARMAMENT RESEARCH,
DEVELOPMENT, &
ENGINEERING CENTER

PRESENTS
Conclusion

- **LOS-MP TRL6 Exit Criteria has been met**
  - Double reinforced concrete wall
    - Hole size 30”x50” in 3 shots or less
  - Anti-Personnel:
    - 200-700 meters Threshold
    - 40-2000 meters Objective
- M&S reduced time and risk
- Testing validated and refined M&S
- LOS-MP technology ready for transition to PM-Maneuver Ammunition Systems for Advanced Multi-Purpose SDD
Energetic Materials to Meet Warfighter Requirements: An Overview of Selected US Army RDECOM-ARDEC Energetic Materials Programs

Mr. Steven Nicolich
Chief, Energetics & Warheads Division
US ARMY RDECOM-ARDEC
Picatinny Arsenal, NJ
(973)-724-3016
steven.nicolich@us.army.mil

Presented by:
Dr. Rao Surapaneni
US ARMY RDECOM-ARDEC
Picatinny Arsenal, NJ
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
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!

Scaled up “Bam-Bam” Warhead

Roadway Cratering Test

- Barnie on test stand
- 81mm
- 38” Diameter Crater!
- No Barnie
- Barnie!

PAM Bridge Pier Target Testing

- 8.5 in
- Bam Bam on test stand
- 24 ft wide roadway
- 5’ X 5’ Target
- Bam Bam Crater!!
REACTIVE MATERIAL
ENHANCED LETHALITY EFP

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

Design 2 (25 cm)
S1 @ 160 µs
S2 @ 430 µs
S3 @ 800 µs
S4 @ 2290 µs

Design 3 (14.6 cm)
S1 @ 100 µs
S2 @ 300 µs
S3 @ 500 µs
S4 @ 700 µs
S5 @ 1170 µs
**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**
IV. WE 2005.03 IM Technologies for Guns, Missiles, and Warheads

IM technology will enhance survivability and performance requirements while providing life-cycle cost savings to the Army and providing improved safety. Currently, transitionable technology does not enable IM compliant munitions to be developed/fielded in timeframes consistent with requirements. New technologies, both energetics and system level mitigation, will provide solutions for designing munitions to (1) maintain/improve survivability at reduced/constant platform and packaging weight, (2) obtain cost and logistics benefits through reduced hazard class and improved safety, and (3) address the need for technology development to support the threat to munitions. FY05. Determine through experimentation the fragment impact failure threshold for a given propulsion charge. Simulate benchmark experiments to identify key predictive deficiencies (TRL 4). FY06. Apply/demonstrate venting design capability to laboratory hardware. Demonstrate IM potential of a new high-energy propellant (TRL 4). FY07. Demonstrate: (a) with the addition of barriers and container venting MIL-STD-2105C compliance, (b) a new high-energy propellant provides IM/performance potential equivalent to or better than current propellant, (c) near tactical design of warhead venting (TRL 5). FY08. Apply venting design to full-scale prototype warhead using reactive liner materials. Demonstrate slow cook-off burning response (TRL 5). FY09. Demonstrate IM compliance through testing using barriers, venting and a high-energy IM missile and gun propellant. Demonstrate that prediction methodology using advanced numerical tools can predict fragment impact and slow-cookoff response for a prototype munition (TRL 6).

SUPPORTS: PEO Missiles and Space, UAMBL, MRM, MAST STO, PEO Ammo, PM-FCS, PM ARMS, LOS-MP, APKWS, JCM, NLOS-LS, PGMM, PAC-3 MSE, GMLRS.

IM ATO PROVIDES TECHNOLOGY TO THE ARMY’S MUNITION PORTFOLIO

<table>
<thead>
<tr>
<th>Example Munition Response Profile</th>
<th>FCO</th>
<th>SCO</th>
<th>BI</th>
<th>FI</th>
<th>SD</th>
<th>SCJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/II DETONATION/PARTIAL DETONATION</td>
<td>VI</td>
<td>V</td>
<td>IV</td>
<td>III</td>
<td>II</td>
<td>I</td>
</tr>
<tr>
<td>III EXPLOSION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV DEFLAGRATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V BURNING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI NO SUSTAINED REACTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**

- **Pressure Transducer Port**
- **Venting Thrust**
- **Techbase transfer**
  For PEO Demo

**Tech base ignition and burn modeling:**
Predict and design ignition and required venting calibrated using small scale tests
Predictive Technology Description
FI/BI/SD IM Warhead Development

NLOS-LS & MRM Impact Modeling

NLOS-LS & MRM SD Modeling

Max Pressure Histories

Peak Pressures
Adjacent: 17Kbar
Diagonal: 7Kbar

• BI/FI/SD Modeling Results Provide Design Capabilities to Mitigate Responses
• MRM & NLOS-LS: Being Designed to Pass IM Tests!
<table>
<thead>
<tr>
<th>NG Free Propellant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Propellant formulations with NG sensitive to ignition from outside stimuli (Poor IM characteristics)</td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
<tr>
<td>• Feasibility study to test and evaluate non-NG extruded propellants for use in DOD munitions items (medium cal and mortar)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approach</th>
<th>Warfighter Payoff</th>
</tr>
</thead>
</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>

- Detonation / Partial Detonation
- III Detonation
- IV Deflagration
- V Burn
- VI No Sustained Reaction (Unofficial)

Fragment Impact

- SD

Bullet Impact
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.
**JIMTP Structure**

- **DoD IM IPT**
  - JSIMTP

- **JIMTP Manager** – Pat Baker
  - OSD Manager – Matt Beyard

- **PEOs Responsible for IM Strategic Plans**

- **Senior Level DOD Managers**

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

- **DoD IM IPT**
  - JSIMTP

- **MATG 1**
  - Munition Area Technology Groups
  - Work Done by Govt Labs & Industry
  - DoD Leads

- **MATG N**

- **TCG I**
  - Technology Coordinating Groups
  - Work Done by DOE Labs
  - DoD Leads

- **TCG XIV**
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)

1997
- PAX-11, 94% CL-20
  - PAX-3, HMX/Alum. IM (PAM TC’ed FY99)
  - PAX-2A, 85% HMX IM (M915, M982, MLRS – Grenade Submunitions)

2000
- PAX-21, Comp B IM Replacement (60mm mortar)
- PAX-23, (AX-1) Future Armor Tile for Abrams Tank Systems TC FY99
- PAX-12, 90% CL-20 IM (PM SWMO, LSO Warheads)
- PAX-24, TNT Replacement

2006
- PAX-XX, (FCS MP-MRM, JCM)
  - PAX-41 (SPIDER)
  - PAX-AFX-196 (155MM M107, M795)
  - PAX-28, Aluminized Cast (Unitary)
  - PAX-31, Improved Comp B Repl (120mm Mortar)
  - PAX-22, 92% CL-20

2006
- PAX-AX (155MM M107, M795)
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

Extruded PAX-3

Final End Product PAX-3

Granulated 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 - Methyl Trinitroimidazole
  - 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**

- **Counter Measures**
- **Igniters**
- **Primers**
- **Illum Candles**
- **Dual Use Composites**

**On-going Efforts**

- **Green LEI Primers**
- **Reactive Tungsten Penetrator**

**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: 100–500 nm
- 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: \( H_{50} – 41 \) cm
150 nm RDX Powder: \( H_{50} – >100 \) cm
Holston C-5 RDX Powder: \( H_{50} – 23 \) cm

Small Scale Gap Test

500 nm RDX in 88/12 wax formulation: \( \text{Gap}_{50} - 32 \) kbar
4.8 micron RDX in 88/12 wax formulation: \( \text{Gap}_{50} - 21 \) kbar

SEM Image of Nano RDX
Nanocomposite Synthesis and Production

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

Coated Nanoparticles

Patterned Energetics

Ordered Energetic Composites

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>
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.
Advanced Gun Barrel Technologies (AGBT)

76mm Rapid Fire Testing

NDIA Gun and Missile Systems Conference, 2007

Bill Vezina
BAE Systems Land & Armaments
(763) 572-4898
william.vezina@baesystems.com
Agenda

• AGBT Program Background and status
  – Screening Methodology
  – Current Status
• 76mm Test Planning
• 76mm Rapid Fire Testing
• 76mm Test Results
• AGBT Path Forward
• Questions
Objectives

- Identify & develop Gun Barrel Technologies that enable upgrades to existing barrel capabilities for Naval gun propulsion missions
  - Increased Gun Barrel Erosion & Fatigue Life
  - Improved Gun Barrel Thermal and Ballistic Performance
  - Reduced Life Cycle Cost

Payoffs

- Increased Gun System Availability
- Improved Ballistic Capability (Higher KE for increased range)
- Lower Life Cycle Cost

Transition

- Develop/Demonstrate Improved Barrel Life and Ballistic performance over AGS Baseline for Transition into Future DD(X) Flights
• Gun firing thermal loads generate heat check cracks
• Chrome plating is thermally and chemically attacked until it strips off and exposes the substrate
• Heat check cracks expose steel substrate to chemical attack from combustion gases
• Substrate steel is thermally altered by extreme high temperature spike from gun firing
• Steel substrate is rapidly eroded from aggressive chemical attack at high temperature

**Borescope view of heat checks at origin of rifling**

**Microscopic view of bore surface after electro-chemical removal of chrome plate**

**AGBT Program Background**

**Root Problem: Chrome Plated Barrel Wear and Erosion**
Technical Approach

Advanced Gun Barrel Technology Detailed Approach

- Application to small sample
- Low cost gun firing test
- Proof of concept demo

Technology Assessment

<table>
<thead>
<tr>
<th>Electroless Nickel-Boron</th>
<th>Sputtering</th>
<th>Explosive Cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CED</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPVD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Free Form Fabrication</td>
</tr>
</tbody>
</table>

45mm Screening Evaluations

- 45mm Laboratory Gun Fixture
  - Six technologies evaluated
  - Hand loaded lab fixture
  - Single shot testing

Technologies Evaluated:

- Explosive Cladding
- EPVD Coating
- Chrome Plating

Subscale Competition/Demo

- 76mm Gun Tests
- MK75 76mm Naval Gun
  - Two technologies evaluated
  - Fielded gun mount
  - Chrome baseline comparison

- 155mm Prototype Demonstration Advanced Gun System (AGS)
  - Down select Winner

- Application in full scale
- Most difficult application
- Most expensive testing platform
- Production quality process
- Transition requirements demo

- Two technologies evaluated
- Fielded gun mount
- Chrome baseline comparison

- One technology transitioned

<table>
<thead>
<tr>
<th>FY03</th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
</tr>
</thead>
</table>

76mm Test Planning

Test Approach:

• Test philosophy is to maintain traceability to the objective AGS gun barrel High Rate of Fire environment.

• Parameters of the objective environment to be matched:
  – Thermal profile through coating and near bore
    • Best match of temperature effects and thermal stress
  – Chemical environment of propellant with bore
    • Best match of chemical attack on bore surface
  – Mechanical stresses
    • Best match of stresses in coating and at interface

• 76mm Test barrel liners produced at BAE Systems OEM barrel production facility in Louisville, KY.
76mm Test Planning

- 76mm platform selected for close match to the AGS environment
- Advanced technology prototype gun barrel assemblies will be fired at high rates to determine robustness of bore surface
- Historical 76mm service records indicated that measurable wear and erosion would occur within 400 rounds fired.
- Adhesion of bore surface material and erosion resistance will be recorded using laser bore mapping technology
- A chrome plated barrel liner will be subjected to the same test protocol to establish a baseline with existing technology
76mm Rapid Fire Testing

- 80 shots fired through each liner between inspections
  - Two 40 round bursts separated with 15 minute cool-down.
  - Burst duration chosen for best match to AGS thermal profile, and to minimize impact of potential stoppages.
- Minimal stoppages were incurred
  - Gun maintainers on hand to keep mount working smoothly
- 400 rounds total fired through each liner.
76mm Rapid Fire Test Results

- Rapid fire testing of competing technologies will be complete this summer
- The following results will examine the performance of the Chrome Baseline liner only.
76mm Rapid Fire Test Results

- Liners were inspected after every 80 rounds.
- Liners were thoroughly cleaned, and laser bore mapped.
- The most notable erosion/wear was at the shot start region.
• Chrome liner, Proof shots only
76mm Rapid Fire Test Results

- Chrome liner, after 80 shots

Chrome Wear and Erosion Progression
• Chrome liner, after 160 shots

Chrome Wear and Erosion Progression
76mm Rapid Fire Test Results

- Chrome liner, after 240 shots

Chrome Wear and Erosion Progression

Axial Location (BFR) inch

Diameter inch
• Chrome liner, after 320 shots
• Chrome liner, after 400 shots
76mm Rapid Fire Test Results

- Laser Bore Mapping images of Chrome liner new, and after 400 rounds.
  - Note, depth of lands has progressed deeper than grooves.
76mm Rapid Fire Test Results

• Micrographic analysis.
  – Surface and axial section view of chrome loss transition area in forcing cone region.
76mm Rapid Fire Test Results

• Noteworthy observation
  – Effect of projectile induced mechanical loads

Similar thermal and chemical environment between these two areas. But the mechanical environment is dramatically different. The area to the right was subject to the physical impact of the projectiles, as well as the additional radial strain caused by the engraving of the rotating band.
• 76mm HRF Testing of Competing Technologies will be completed summer 2007.
• Winning technology will be selected for development into 155mm AGS barrel design.
• 155mm AGS barrel will be tested to demonstrate compliance with AGS transition requirements
  – 50% improvement in life
  – Reduction in life cycle cost
• If compliant with transition criteria, the Advanced Gun Barrel Technology will transition to the acquisition program for insertion into DDG 1000
Questions
MRM-KE: A Lethal Solution

Eric Volkmann
Alliant Techsystems (ATK)
4700 Nathan Lane
Plymouth, MN  55442
763-744-5110
Eric.Volkmann@atk.com

42nd Annual Armament Systems: Gun and Missile Systems
Conference & Exhibition
Charlotte, North Carolina, 23 -26 April 2007
Acknowledgements

• PM-MAS, Picatinny NJ
• ARDEC, Picatinny NJ
• Army Research Laboratory, Aberdeen MD
• Alan Gauzens – ATK TERM-KE/MRM Program Manager
• Barry Lindblom – ATK TERM-KE/MRM Technical Lead
• Many other contributors to this program’s success…. 
What is MRM-KE?

- Mid-Range Munition-Kinetic Energy (MRM-KE)
- Next generation Beyond Line Of Sight (BLOS) tank ammunition
  - Fire-and-forget from 120mm smooth bore cannon
  - 2 to 12 km Range
- Under development via ARDECs MAAST ATO
- MRM Program Transitions to SDD in GFY 08
Platforms and Targets

Potential Platform

M1A2 Abrams

Planned MRM Platform

FCS Mounted Combat System Concept

Primary Target

Secondary Targets
Basic Design

• Evolution of XM1007 Tank Extended Range Munition (TERM-KE) into MRM-KE

   - High Strength Composite Case For Launch Loads
   - Fold Out Fins For Stabilization
   - Rocket Motor For Terminal Velocity Boost
   - Long Rod For Deep Penetration Large Diameter Hole
   - Maneuver Mechanism For Steering
   - Guidance Electronics For Accurate Target Hit
   - High Density Battery For Power
   - Dual Mode Semi Active Laser MMW Sensor All Weather

Total Projectile used in Target Defeat
Speed Kills – MRM-KE Advantage

- Accuracy from Dual Mode all-weather Millimeter Wave and Semi Active Laser sensors with maneuver mechanism
- Hard Target Lethality from terminal velocity boost & large diameter penetration hole

Autonomous un-aided BLOS Target Hit in 2004!

VIDEO
Terminal Ballistics Modeling and Test

- Terminal ballistics modeled using 3D EPIC Lagrangian computer code
  - 3D, multi-processor simulations
  - Complex target interaction
- Testing at Army Research Lab, Aberdeen MD
  - 7” diameter, experimental HARP gun tube

HARP (High Altitude Research Project) = High Velocity

Experimental Gun

Simulation Example

Test Round in Sabot
Proven Performance

- Testing has shown MRM-KE effective against modern tanks protected by explosive reactive armor
- MRM-KE Impacts with > 2.5x the energy of 120mm KE bullet
- MRM-KE also effective against secondary targets

MRM-KE delivers bunker buster/soft target defeat
Summary

• ATK’s MRM-KE is Beyond Line Of Sight, Fire-And-Forget 120mm “tank” ammunition round

• MRM-KE is Lethal against main battle tanks and softer, secondary targets
  – Dual-mode, all weather Millimeter Wave and SAL sensors with accurate guidance system
  – Terminal rocket motor velocity boost → Speed Kills

• Currently in ARDECs MAAST ATO S & T Phase
  – MRM SDD award planned for Summer/Fall 2007
Rocket Artillery in Future Scenarios, First Answer

GMLRS-SMArt

42nd Annual Armament Systems: Gun and Missile Systems Conference

Ing. grad. Harald Wich
Diehl BGT Defence
Head of Product Management Artillery Rocket Systems
Harald.Wich@diehl-bgt-defence.de
Outline

- Who we Are
- The Past
- The Future
- Options

A Solution
  - Concept
  - Benefits
  - Performance
  - Programme Timeline

Summary/Conclusions
Who we Are in a nutshell

- Diehl BGT Defence is a System House and Technology Company in the Areas of Defence and Security 1630 Employees $550 m Sales
- Member of the privately owned Diehl Group
- Historically a direct Fire Company started “Indirect Fire” Activities
  - 1982 Development Sensor Fuzed Munitions → SMArt® 155 developed and manufactured under GIWS JV with Rheinmetall
  - 1983 Demonstration of First guided Mortar Round “Bussard”
  - 1983 MLRS Final Integrator for Rockets and RPC´s
  - 1985 Studies and Demonstrators on Guided 155 mm
  - 1997 First guided MLRS Flight “NAW”
  - 2005 Development of GMLRS-SMArt
This is not our only target!
The Future

- NBC
- DPICM
- Artillery Fragments (all around)
- RPGs (Front Sector)
- Medium Calibre Machine-gun (Front Sector)
- Heavy Machine-gun (all around)
- Directed Anti Personnel Mine
- Anti Tank Mine Under Wheel and under Hull
Options

- **DPICM**, (Dual Purpose Improved Conventional Munition)
  - small Fragments
  - shaped Charge
  - Anti Personnel/(Material)
  - Anti Armor/Material

- **Unitary**, (a single HE filled Effector in a Carrier)
  - Fragments
  - Penetrator
  - Anti Personnel/Material
  - Anti Infrastructure

- **SFM**, (Sensor Fuzed Munition)
  - Designed to fight hard and semi-hard Targets

SFM´s are perfect to fight all protected Targets!
A Solution

GMLRS M30 Rocket

SMArt® DM 702

No Payload

4 SMArt® Sub-Munitions

G- SMArt Rocket
SMArt®

Characteristics

- **Tri mode**
  - passive Infrared (IR)
  - passive 94 GHz Millimetre Wave (Radiometer)
  - active 94 GHz Millimetre Wave (Radar)
- High sophisticated Sensor Fusion
- High Performance **Tantalum Liner Warhead**
- IR/mmW Sensor, bore sighted with Warhead (apart from small lead angle)
- **Single (first) pass Detection** and Warhead Initiation
- **Redundant** built-in **Self-Destruct** Function
  - Altitude (Slant Range) commanded through Radar Channel
  - Battery burn-out initiates Self-Destruct

More than 20,000 SMArt® Sub-Munitions produced up to now!
SMArt Principle of Function

**SMArt`s Sensors are simple and the kill Mechanism is very robust!**

**TARGET SEARCH DURING STABLE DESCENT**

- Starting Height: 150 m AGL
- Very short Detection Range (SLR)
- Immune to adverse Weather
- Very large Scan Area enclosed: \( \leq 35,000 \text{ m}^2 \)
- High Probability of target in Footprint
- Top Attack: most vulnerable Area on Target
- Sub-Munition Descent... at low Speed
- Immune to DAS...
- SFF Attack: immune to ERA and other Type of Protection

**MAIN PERFORMANCE DATA**

- Target detection and tracking
- Operational mode: automatic
- Engagement envelope:

Angled linters and blast skirts resist RPG & IED attacks.
SMArt Adaptation to GMLRS

Change Spin released Battery Activation to Rocket Control

No Change on Sub-Munition Descent, Search and Detect and Self Forging Fragment Function

Change Spin opened Ballute to high Speed Drag Chute

Change Acceleration Environmental Criteria of S&A to Rocket ESAD Control

Minor Modifications only to SMArt Sub-Munition!
G-SMArt Sub-Munition Dispense

- **GMLRS Rocket**
  - **down Sub-Munition**
    - Drag Chute Opening Time = T1 - ΔT
  - **up Sub-Munition**
    - Drag Chute Opening Time = T1 + ΔT

- **Free Flight**
  - programmable

- **Drag Chute**
  - fixed
  - until detect
  - or Selfdestruck

- **Spin Chute**

- **t₀ - x**: - Payload Activation

- **t₀**: Warhead Event
  - 4 Sub-Munitions ejected
    - at the same Time
    - into 4 Quadrants

- **left/right Sub-Munitions**
  - Drag-Chute Opening Time = T1

- ΔX
- ΔY
G-SMArt Sub-Munition Function

Free Flight, Drag Chute Flight and Spin Chute Flight, some Hit Examples
Programme Timeline and Growth Potential

- **SMArt® 155 (Anti Tank)**
  - Insensitive HE

- **G-SMArt Adaptation**

- **G-SMArt Serial Production**
  - Insensitive RM
  - Increased Range

- **SMArt® Anti Material**
  - Multi Mode

Leveraging form both GMLRS and SMArt® Improvements
G-SMArt will always be up-to-date
Performance Prediction

Command Posts

Air Defence Systems

Mechanized Infantry

Artillery

Number of Rockets

MBT

APC

SPG

ADA

Point

Area

MRL

ADU

SMArt

DPICM

UNITARY
G-SMArt Summary

- Quick Solution based on “In Production” SMArt® and GMLRS
  - low Cost/low Risk
- Effective against **hard**, **semi-hard** and **protected** Targets
  - robust to passive Protection and reactive Armor
  - robust to DAS Countermeasures
- Wide Attack Footprint
- Close Combat Capability
- Minimal Collateral Damage
- Clean battlefield operation due to redundant self-destruct

G-SMArt will take care of all future needs attacking protected Targets!
Thank you for your Attention!

Any Questions?

Lance Corporal Klöbke is currently our only operational Rocket Launcher Colonel!
F-22A Lightweight Gun System Comparison

NDIA Gun and Missile Systems Conference & Exhibition

Peter C. Wolff
Project Engineer
Phone: 802-657-6198
Email: pwolff@gdatp.com

April 26, 2007
Agenda

- Overview of the F-22A Gun System
- Comparison to Legacy Gun Systems
- Application of Composite Materials
- Lightweight Composite Conveyor Element
Background Information

- Developed for Lockheed Martin during the mid-1990s.
  - Low weight and tight envelope requirements
  - High stiffness requirement – container supported at the ends
- Incorporated new technologies
  - Extensive use of composite materials
  - Semi-flexible recoil track; single conveyor stores & transfers ammunition to/from the gun
  - Lightweight composite conveyor element
M61A2 20mm Gun and F-22A Lightweight Linear Linkless Ammunition Handling System

- M61A2 Gun
- Ammunition Transfer Unit
- Recoil Track Assembly
- Linear Linkless Ammunition Container

GENERAL DYNAMICS
Armament and Technical Products
LLAHS Overall Size

99.8” (2,534.9mm)

9.1” (232.2mm)

73.1” (1,856.7mm)

44” (1,117.6mm)

9.3” (236.7mm)
F-15E, F-16, and F/A-18 E/F Gun Systems

F-15E
Linear Linkless, Closed Loop Ammunition Handling System
Mainly Metallic Construction

F-16
Rotary Linkless, Closed Loop Ammunition Handling System
Mainly Metallic Construction

F-16 & F/A-18 E/F

F/A-18 E/F
## Specifications and Weight Comparisons of 20mm Aircraft Gun Systems

<table>
<thead>
<tr>
<th>SYSTEM DESIGNATION:</th>
<th>F-22A</th>
<th>F-15E</th>
<th>F-16</th>
<th>F/A-18 E/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed System Type (closed loop)</td>
<td>Linear Linkless</td>
<td>Linear Linkless</td>
<td>Rotary Linkless</td>
<td>Rotary Linkless</td>
</tr>
<tr>
<td>Ammunition Capacity</td>
<td>480</td>
<td>500</td>
<td>511</td>
<td>412</td>
</tr>
<tr>
<td>Gun Type</td>
<td>M61A2</td>
<td>M61A1</td>
<td>M61A1</td>
<td>M61A2</td>
</tr>
<tr>
<td>Firing Rate (shots/minute)</td>
<td>6000</td>
<td>4000/6000</td>
<td>6000</td>
<td>4000/6000</td>
</tr>
<tr>
<td>Empty System Weight (pounds)</td>
<td>378</td>
<td>484</td>
<td>506</td>
<td>451</td>
</tr>
<tr>
<td>Gun Weight</td>
<td>202</td>
<td>248</td>
<td>248</td>
<td>202</td>
</tr>
<tr>
<td>Feed System Weight (pounds)</td>
<td>176</td>
<td>236</td>
<td>258</td>
<td>249</td>
</tr>
<tr>
<td>Feed System Weight Delta from F-15E (pounds)</td>
<td>-60</td>
<td>0</td>
<td>+22</td>
<td>+13</td>
</tr>
<tr>
<td>System Specific Capacity (lbs/rd)</td>
<td>0.79</td>
<td>0.97</td>
<td>0.99</td>
<td>1.09</td>
</tr>
</tbody>
</table>
F-22A Ammunition Container Assembly Line Replaceable Unit (LRU) Makes Extensive Use of Composites

- Semi-Flexible Recoil Track Assembly Allows Conveyor Belt to Recoil with the Gun
- Compression Molded Lytex™ 4149 Turnaround Guides and Edge Closeouts Bonded to Panels
- Top and Bottom Covers and Side Panels Constructed of Glass/Carbon/Epoxy Face Sheets with Aluminum Honeycomb Core
Hydraulic Drive, Container Drive Shaft, and Transfer Unit LRUs

These LRUs Use Conventional Metal Construction

Hydraulic Drive Assembly

Transfer Unit Assembly
Container Drive Shaft
Compression molded Lytex™ 4149 Edge Closeouts Form Panel Perimeter

Compression Molded Lytex™ 4149 Edge Closeouts

Glass/Carbon/Epoxy face sheets are pre-cured and secondarily bonded to edge closeouts and honeycomb core
View Inside Showing Ammunition Container Side Panel with Serpentine Path

Compression Molded Lytex™ 4149 Turnaround Guide is Bonded to a Composite Track Panel

Glass/Graphite/Epoxy Track Panel

Glass/Graphite/Epoxy Face Sheets

Lytex™ 4149 Edge Closeout

CROSS SECTION OF TRACK PANEL

Aluminum Honeycomb Core

Lytex™ 4149 Edge Closeout
Ammunition Storage and Transfer Schematic

- A continuous conveyor belt with 473 conveyor elements transfers ammunition to the gun and transfers fired cases back to the ammunition container.
- The recoil track allows the conveyor belt to recoil with the gun during firing and permits container installation & removal.
Recoil Track Collapses onto Container to allow Installation and Removal
Injection Molded Conveyor Elements
PEEK™ with 30% Carbon Reinforcement
View of top row of conveyor belt in ammunition container with cartridges
Key Suppliers of Composite Components

- Quantum Composites – Bay City, MI
  - Supplier of Lytect™ 4149 material
- Parkway Products Inc. – Erlanger, KY
  - Lytect™ 4149 compression molded parts
- Midwest Plastic Components – Minneapolis, MN
  - PEEK™ with 30% carbon fiber injection molded conveyor elements
- Neptune Precision Composites – Jacksonville, FLA
  - Fabrication of composite panel assemblies
- GDATP – Saco, ME
  - Structural and final assembly
Modelling the Ignition of Modular Charges

Clive Woodley & Steve Fuller

A presentation to: 42nd Guns & Missiles Conference

April 2007
Contents

01 Background
02 Validation
03 Simulations
04 Conclusions & future work
01
Background
01 Charge design – why UPCS?

Existing inventory replaced with 1 module
01 Charge design – advantages of UPCS

- **Current charges**
  - Not fully IM compliant
  - Not cleared for A1/C2 climatic conditions
  - Wasteful – decremental system
  - Costly & L10 can’t routinely be used for training
  - Often remain in WMR until they ‘life out’

- **With UPCS**
  - Same charges are used in training as are deployed for war fighting
  - Training simplified/more realistic
  - Substantial cost savings can be achieved through incremental system
  - Logistic burden reduced
  - Autoloader compatible
01 Modular charges – the problem being addressed

Safety & performance are important requirements – linked to ignition

• Pressure waves eliminated or minimised and consistent
• Simultaneous ignition along length of charge
• Combustible cartridge cases present barrier to flamespread along the propellant bed
• Modules act as projectiles!

![Graph showing pressure difference over time](image)

![Diagram of modular charges structure](image)
01 Modelling approach - QIMIBS

2D mortar code

- Developed initially with MOD funding
- Developed further using QinetiQ funding
- Details presented at 22nd International Symposium on Ballistics
- Ability to represent internal solid boundaries
Validation
02 Primer only – single module – initial geometry
02 Primer only – single module

1.43g black powder
Max velocity measured: 1.5m/s
Max velocity predicted: 3.2m/s

1.25g NC
Max velocity measured: 2.0m/s
Max velocity predicted: 5.0m/s

Correct trend predicted for pressure and module velocity
Module velocities overpredicted but no account taken of sliding resistance
02 5 modules - flamespread

![Graph showing time of first visible light vs distance from breech (m), with lines for Test 1, Test 2, and Simulation.](image)
03 Simulations
03 Simulations

- Single module
  - Igniter mass & location
  - Flash tube diameter & vent hole size

- Three modules
- Five modules
03 Single module – igniter mass (5g top, 15g bottom)

0.5ms

1.0ms
03 Single module – igniter mass (5g top, 15g bottom)

1.5ms

2.0ms
03 Single module – igniter mass (5g top, 15g bottom)

2.5ms

3.0ms
03 Single module – igniter mass (5g top, 15g bottom)

3.5ms

4.0ms
03 Single module – igniter mass (5g top, 15g bottom)

4.5ms

5.0ms
03 Single module – igniter mass (5g top, 15g bottom)

5.5ms

6.0ms
03 Single module – igniter mass (5g top, 15g bottom)

6.5ms

7.0ms
03 Single module – igniter mass
03 Single module – effect of igniter position

Outside = outside module but inside flash tube
Inside = inside module but outside flash tube

Modelling indicates better ignition if igniter material is both sides of the flash tube
03 Single module – effect of flash tube diameter

Modelling indicates better ignition for 26mm flash tube diameter
03 Single module – effect of flash tube hole size

Modelling indicates better ignition for 6mm flash tube holes
03 Three modules – initial geometry
03 Three modules – 10g black powder per module

Taking 600K as the propellant ignition temperature, propellant in 2nd & 3rd modules ignited 0.8ms & 1.7ms after the 1st module

Use another internal ballistics code to predict pressure waves
03 Five modules – initial geometry
Five – 10g black powder per module

Igniter in last module not ignited

Module 2 might ignite first

Taking 600K as the propellant ignition temperature, propellant in 2nd, 3rd & 4th modules ignited 1ms, 2ms & 5ms after the 1st module – use another internal ballistics code for $\Delta P$
Conclusions & future work
Conclusions & further work

- QIMIBS has much of the functionality required to model MCS
- Validated for two primers for 1 & 5 modules
- Parameter studies showed
  - 5g black powder per module not likely to ignite
  - Best position of igniter is both sides of flash tube
  - 26mm diameter flash tube better than 52mm and 20mm
  - Reducing flash tube vent area predicted to produce better ignition
- Predictions for 5 modules show
  - Primer and igniter insufficient to ignite (5th) module adjacent to the projectile
  - Module 2 might ignite before module 1
  - Possibility of significant ignition delay for 4th module
- 155mm gun firings planned & further modelling
- Conclusions likely to be very dependent on primers and geometries used in this study
ECL® – A New Propellant Family for Small and Medium Caliber Applications

42nd Gun and Missile Conference
April 23 – 26, 2007
Charlotte, North Carolina

B. Vogelsanger, Nitrochemie
W.J. Worrell, ATK Radford
Jim Wedwick, ATK Radford
Please contact one of the individuals below for a copy of the presentation

- Name: Beat Vogelsanger
  - Phone: +41 (0) 33 228 12 01
  - Company: Nitrochemie Wimmis AG
  - Email Address: Vogelsanger@Nitrochemie.com

- Name: W.J. Worrell
  - Phone: (540)639-7798
  - Company: ATK
  - Email Address: WJ.Worrell@ATK.com

- Name: Jim Wedwick
  - Phone: (540)639-7876
  - Company: ATK
  - Email Address: Jim.Wedwick@ATK.com
Shock Aspects of Lightweight Artillery on Mounting Electronics

William T. Zepp
Primary Electronic Systems Applied to Artillery

• Computer
  – Data Input
  – Digital Communications
  – Ballistic Computation
  – Peripheral Control
  – Data Display(s)
  – Mission Processing

• Sensors
  – Inertial Navigation and Weapon Pointing Unit

• Power Supplies
General Firing Environment

- QE/Charge combination
  - Low QE/high charge
  - High QE/High charge

- Excitation short duration

- Recoiling mass acceleration
  - Longitudinal dominant
  - Primary low frequency

- Weapon Structure
  - Deflection stores and releases energy
  - Low to high frequency
  - Low to high accelerations
General Towing Environment

• Towing configuration
  – Folded
  – Unfolded

• Road Condition
  – Paved
  – Unimproved
  – Cross country

• Excitation over long duration
Requirement During Weapon Development

- Shock/Vibration Environment Electronics subjected to part of trade-off matrix
- Built into system
- Example M777A1 155mm Towed Howitzer
Retrofit Existing System

- Existing shock/vibration environment on weapon a given
- Little if any modification to function, structure, or loadings
- Built onto system
- Example: L118 105mm Towed Howitzer
Retrofit on US M119A2 105mm Howitzer

• Desire Digital Fire Control capability
• Compatible for full range of operation under normal and emergency conditions
• Structure / function “it is what it is”
M119A2 Howitzer Firing

300 mils

800 mils

1244 mils
Shock Levels (G’s)

(Longitudinal / Transverse / Vertical)
Power Density Levels (G^2/Hz)

( Longitudinal / Transverse / Vertical )
Electronics Options For Retrofit Applications

• Subsystem/Component Isolation
  – Alignment maintenance
  – Size/Weight implications
  – Non-interference of weapon controls/operation

• Component hardening
Summary

• New Weapon Development
  – Must be part of trade-off mix
  – Limits/drives structure and material selection
  – Limited opportunities

• Retrofit to Existing Weapon
  – Base Weapon largely “is what it is”
  – Limited parameters to adjust for compatibility
  – Greatest number of opportunities
Brief Info

• Abstract Ref # - 4559
• Author/Presenter: William T. Zepp
• William.t.zepp@us.army.mil
TITLE:
Shock Aspects of Lightweight Artillery on Mounting Electronics

AUTHOR/PRODUCER (S):
William T. Zepp

OFFICE SYMBOL: AMSRD-AAR-AEW-S(D)
PHONE/BLDG #: 973-724-4516 BLDG 61N

AUTHOR/PRODUCER (S):  

ADDRESS (IF APPLICABLE):

COMPANY ADDRESS:

COMPANY PHONE:

PURPOSE OF RELEASE:  
Presentation ☒ Publication ☐ Abstract ☐ News Release ☐ Other ☐

MEETING TITLE (If presentation, speech or conference paper): 42nd Gun & Missile Systems Conference (NDIA)
PLACE: Charlotte, NC  
DATE(S): 23-27 April 2007  
DoD Sponsored: ☐ Yes ☒ No

PUBLICATION (Magazine, journal, newspaper, proceeding): Proceedings  
Solicited ☒ Yes ☐ No

CERTIFICATION: I certify that this material has not been copied substantially without written permission from the author/producer and does not contain any sensitive, potentially controversial, FOOU or classified information.

William T. Zepp  
Author's/Producer's Signature

REQUIRED APPROVALS: Signatures below certify that this material was reviewed for technical accuracy, classified information, security implications, proprietary information, competition-sensitive information and policy guidelines; that inventions have been previously submitted for patent review, and that the subject matter does not fall under the Militarily Critical Technology List.

SIGNATURE (Division level)  
Type: Charles Widmer  
Approve ☒ Yes ☐ No  
Date: 3/26/07  
Remarks:
Recommend Distribution: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ F

SIGNATURE (Center/Directorate/PM level)  
Type: Mark A. Ford  
Approve ☒ Yes ☐ No  
Date: 27 Mar 07  
Remarks:
Recommend Distribution: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ F

SIGNATURE (OPSEC)  
Type: Robert E. Souders  
Approve ☒ Yes ☐ No  
Date: 27 Mar 07  
Remarks:
Recommend Distribution: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ F

SIGNATURE (Patent/Legal)  
Type:  
Approve ☒ Yes ☐ No  
Date: 28 March 07  
Remarks:
Recommend Distribution: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ F

SIGNATURE (Contracting Officer, if appropriate)  
Type:  
Approve ☒ Yes ☐ No  
Date:  
Remarks:
Recommend Distribution: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ F

DISPOSITION: BASED ON RECOMMENDATIONS PROVIDED ABOVE, CLEARANCE IS GRANTED FOR PUBLIC RELEASE BASED ON THE APPROVED DISTRIBUTION CIRCLED BELOW

Tara J. Buss  
Pica/Ord Public Affairs Office  
Date: 3/26/07

U.S. Army  
Armament Research & Development Command

A ☒ (Unlimited)  D ☐ (DOD & DOD Contractors only)
B ☐ (U.S. Govt only)  E ☐ (DOD Components only)
C ☐ (U.S. Govt & Contractor only)  F ☐ (As directed by or higher authority)