

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 Offi ce 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

- Energetic Materials to Meet Warfighter Requirements: An Overview of the US Army- REDCOM-ARCEC Energetic Materials Program, Dr. Rao Surapaneni, US Army, ARDEC
- 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 the Insensitive 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), Offi ce 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 Ginetto, 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-BoreDetonation 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, Breech 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

Agenda

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

	Breakout 1	Breakout 2
10:30 am	**Effectiveness** Session Chair: ***Mr. Steve French,*** BAE Systems	**Emerging Technology** Session Chairs: ***Mr. Steve Liss,*** US Army, ARDEC ***Mr. Joe Buzzet,*** General Dynamics Corporation
10:35 am	Capabilities of Penetrator with Enhanced Lateral Efficiency (PELE) Medium Caliber Cartridge Versus KE or HE Rounds ***Mr. Don Gloude,*** ATK	Low Recoil, Heat Transfer Mitigating Rarefaction Wave Gun Engineering, Modeling and Large Caliber System Demonstrator Development ***Mr. Kevin Miner,*** Benet Labs
11:00 am		Rapid Fire Testing of Advanced Gun Barrel Bore Coatings ***Mr. William Vezina,*** BAE Systems
11:25 am	Urban Operation Solutions with Medium & Large Caliber Ammunition ***Mr. Jan Hasslid,*** Nammo	Mid Range Munition (MRM) ***LTC(P) Kenneth Tarcza, USA,*** PEO Ammunition
11:50 am		T&E of Electromagnetic Railguns ***CDR Thomas Boucher, USN,*** NSWC Dahlgren
12:15 pm	Lunch in Exhibit Hall	Lunch in Exhibit Hall

Tuesday, April 24, 2007 (Cont.)

	Breakout 1	Breakout 2
1:25 pm	**Energetics** Session Chair: ***Mr. Brian Tasson,*** ATK	**Direct Fire: EAPS Overview** Session Chair: ***Mr. Matt Solverson,*** GD-OTS
1:30 pm	Energetic Materials to Meet Warfighter Requirements: An Overview of the US Army-REDCOM-ARCEC Energetic Materials Program ***Dr. Rao Surapaneni,*** US Army, ARDEC	Extended Area Protection and Survivability (EAPS) ***Mr. Phil Brislin,*** US Army, ARDEC
1:55 pm	ECL - A New Propellant Family for Small and Medium Caliber Applications ***Mr. William Worrell,*** ATK	Phalanx for Defense Against Rockets, Artillery and Mortar Protection System ***Mr. Scott Martin,*** Raytheon Missile Systems
2:20 pm	Qualification Test Results for the EFSS 120mm Rifled Mortar System ***Mr. Joe Buzzett,*** GD-OTS	Counter Rocket Artillery and Mortar Protection System ***Mr. Borje Nyquist,*** BAE Systems, Sweden
2:45 pm	Break in Exhibit Hall	Break in Exhibit Hall
3:15 pm	**Energetics (Cont.)** Session Chair: ***Mr. Brian Tasson,*** ATK	**Indirect Fire** Session Chair: ***Dr. Steve Piper,*** Piper Pacific International
3:20 pm	Processing and Sensitivity Testing of the Insensitive TNT Based Explosive - PAX-44 ***Mr. Duncan Langlois,*** ATK	Enhanced Lethality with the 105mm XM1025 Performed Fragment Projectile ***Mr. George Kurzik,*** GD-OTS
3:45 pm	Medium Caliber Lead Free Electric Primer ***Ms. Sarah Ford,*** NAWCWD, China Lake	120mm XM325 Mortar ***Mr. David Smith,*** Benet Labs
4:10 pm	Environmentally Friendly Medium Caliber Percussion Primers ***Dr. Rao Yalamanchili,*** US Army, ARDEC	155mm XM324 for NLOS Cannon ***Mr. Christopher Aiello,*** Benet Labs
4:35 pm	Development of Exploding Foil Initiators and Microchip EFI's ***Mr. Gert Scholtes,*** TNO, Netherlands	155mm XM1063 Non-Lethal Personnel Suppression Projectile ***Ms. Jennifer McCormick,*** GD-OTS
5:00 pm - 6:30 pm	Reception in Exhibit Hall	Reception 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

	Breakout 1	*Breakout 2*
10:15 am	**Armament Subsystems** Session Chairs: ***Mr. Greg Hill,*** Western Design ***Mr. John Resch,*** US Army, ARDEC	**Tactical Rockets and Missiles** Session Chair: ***Mr. Edwin DePasqual,*** Talley Defense Systems
10:20 am	MK44 IPT Update (MK44 Operational Commonality and Airburst) ***LtCol Kenny Lewton, USMC,*** EFV	Hazard Assessment Testing of the SM-3 Block IA Missile ***Mr. Dave Houchins,*** NSWC Dahlgren
10:45 am	Weapons Updates: LW25mm, .50 cal Bushmaster ***Mr. Rockne Carter,*** ATK	PRODAS Rocket Simulation Software ***Mr. Francis Davis,*** Talley Defense Systems
11:10 am	20mm Linear Linkless Feed System for the AH-1W Cobra Helicopter ***Mr. Larry Pollard,*** Meggitt Western Design	PRODAS Rocket Artillery in Future Scenarios, First Answer ***Dipl. Ing. Harald Wich,*** Diehl
11:35 am	M197 Environmental Kit ***Mr. Robert Brewer,*** NAWCWD, China Lake	The Success of the AMRAAM DBMS/DAS ***Mr. John Gerdine, V,*** Wyle Laboratories
12:00 pm	Lunch in Exhibit Hall, Awards Ceremony	Lunch in Exhibit Hall, Awards Ceremony

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

Wednesday, April 25, 2007 (Cont.)

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

Thursday, April 26, 2007

7:00 am - 1:25 pm Registration

7:00 am Continental Breakfast

Thursday, April 26, 2007 (Cont.)

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

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,*** US 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!

Trifiletti Award Recipient: Mr. Ralph F. Campoli
Consultant, General Dynamics Ordnance and Tactical Systems

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).

Thank You to our Promotional Partners

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 then 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.

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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.

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ATK

GENERAL DYNAMICS
Armament and Technical Products

Meggitt Defense Systems
formerly known as
Meggitt Western Design

SYLVANIA

Weapon Systems & Technology Directorate
Benét Laboratories

ISO 9001 Certified
FS15149

XM324 Non-Line of Sight Cannon
NLOS-Cannon

Chris Aiello

ARDEC

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

XM324 NLOS-Cannon

ISO 9001 Certified
FS15149

- **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

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XM324 NLOS-Cannon

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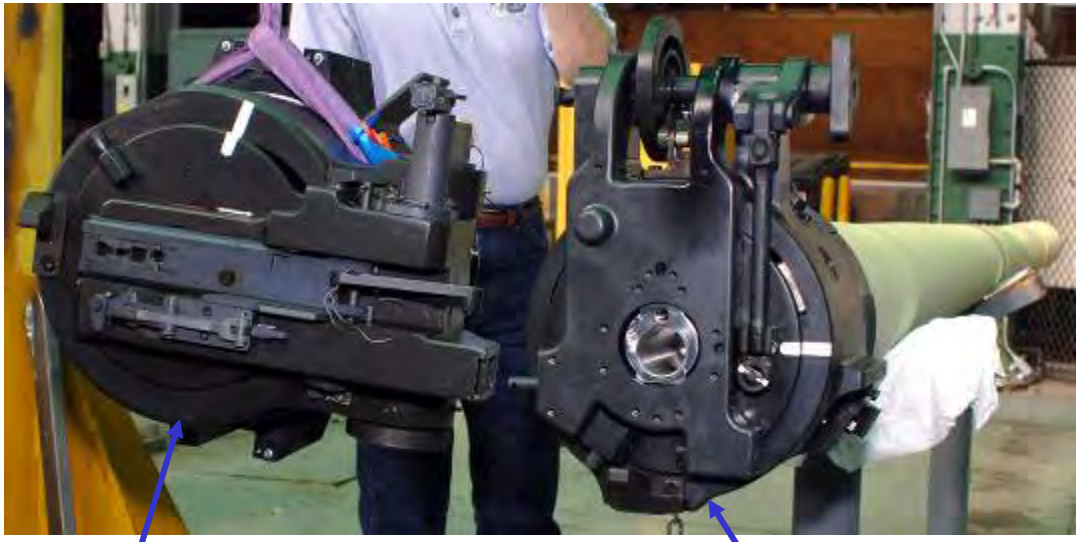
- **Key Parameters:**
  - **155mm, 38 Caliber Lightweight Cannon**
    - ***High Strength Steel Alloy***
    - ***Optimized for Minimum Tube Mass***
    - ***Fires MACS Propellant (Zones 1 through 4)***
    - ***Indexable Tube***
  - **High Rate of Fire**
    - ***Thermal sensors embedded in the tube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

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XM324 NLOS-Cannon

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- **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

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XM324 NLOS-Cannon

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



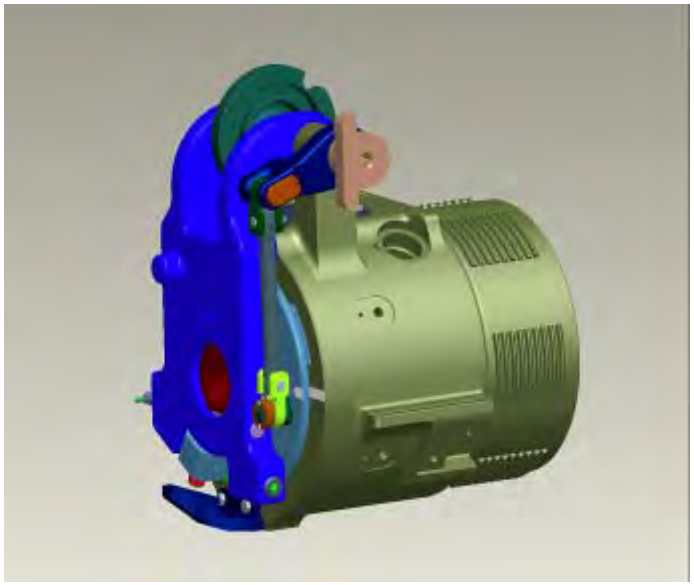


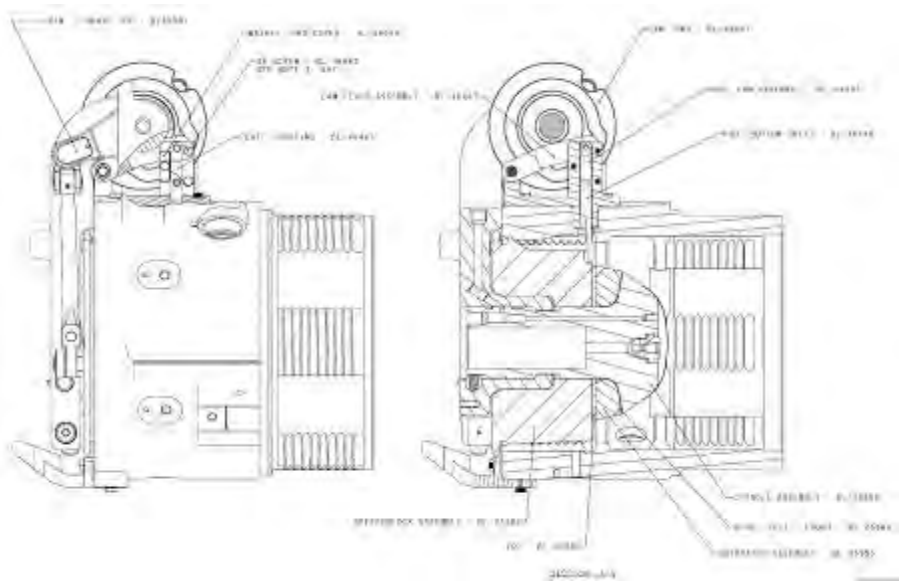
Approved for public release; distribution is unlimited. Case GOVT 07-7040. 06 April 2007.

XM324 NLOS-Cannon

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





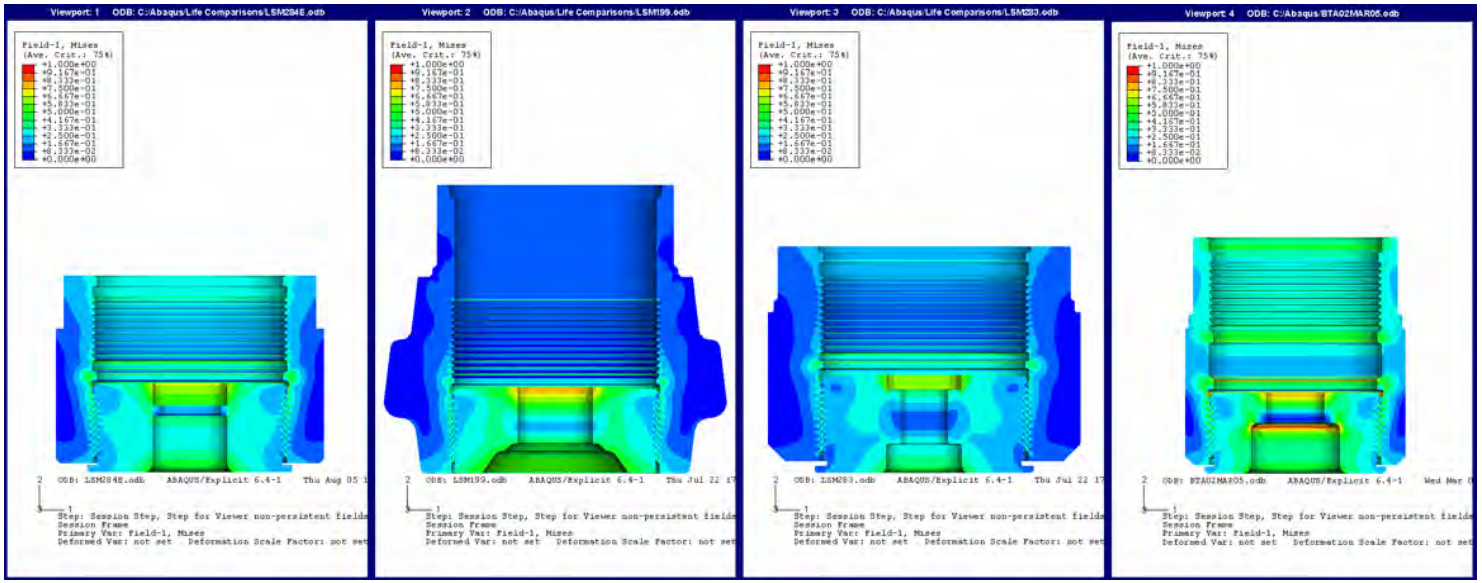
Approved for public release; distribution is unlimited. Case GOVT 07-7040. 06 April 2007.

XM324 NLOS-Cannon

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

Comparative Breech Structural Analysis



M284/M776 **M199** **XM283** **XM324**

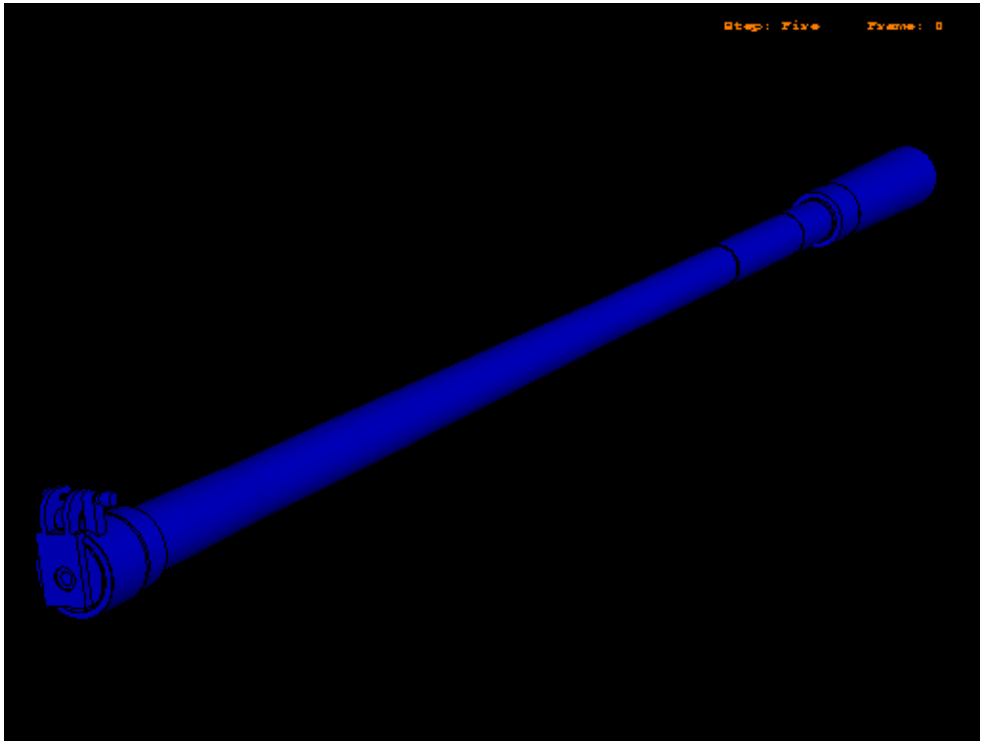
Approved for public release; distribution is unlimited. Case GOVT 07-7040. 06 April 2007.

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

Dynamic System Axial Response



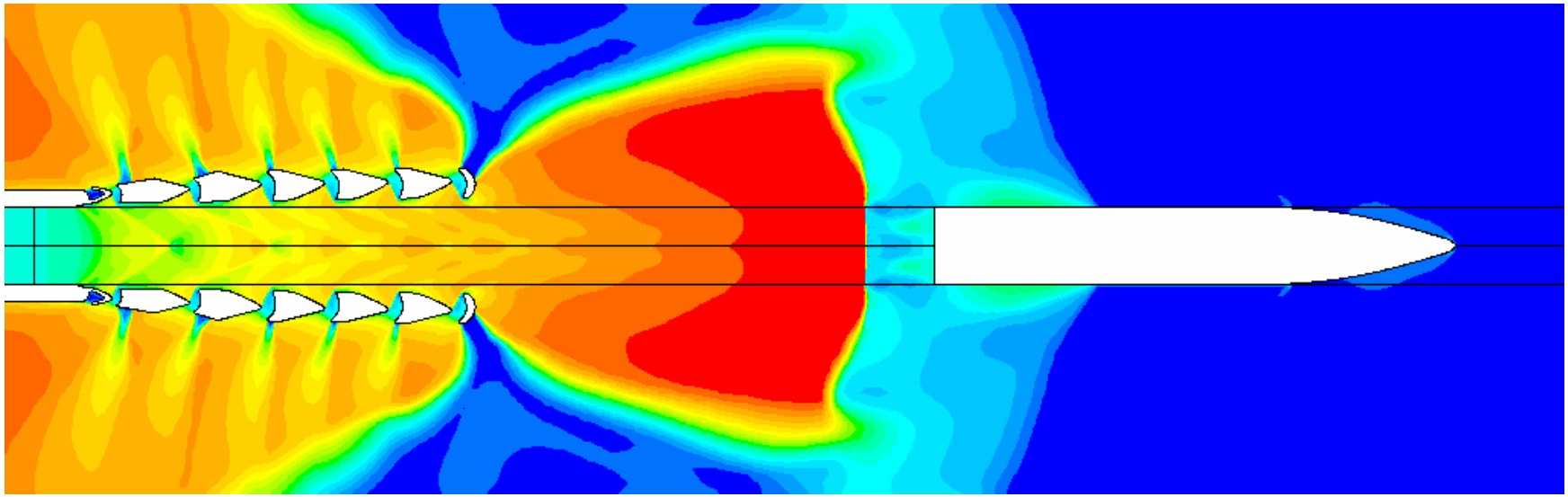
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XM324 NLOS-Cannon

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

CFD of Brake During Firing

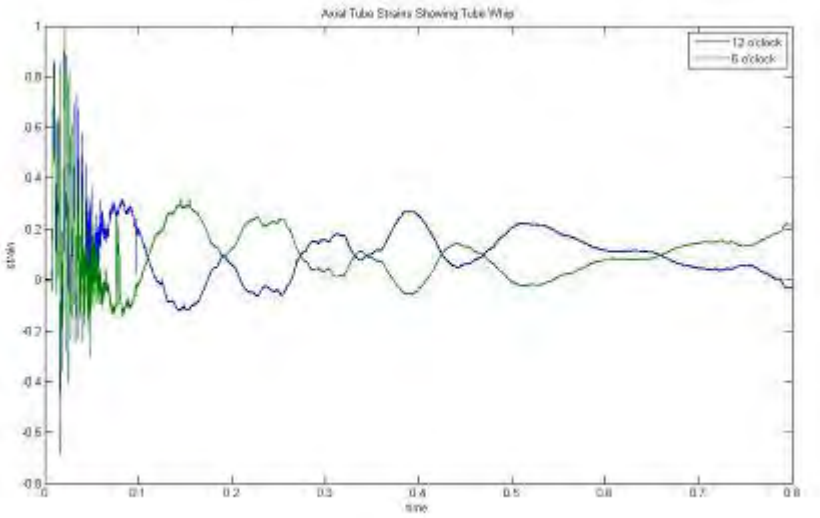


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XM324 NLOS-Cannon

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- **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***



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Revolutionary Research . . . Relevant Results

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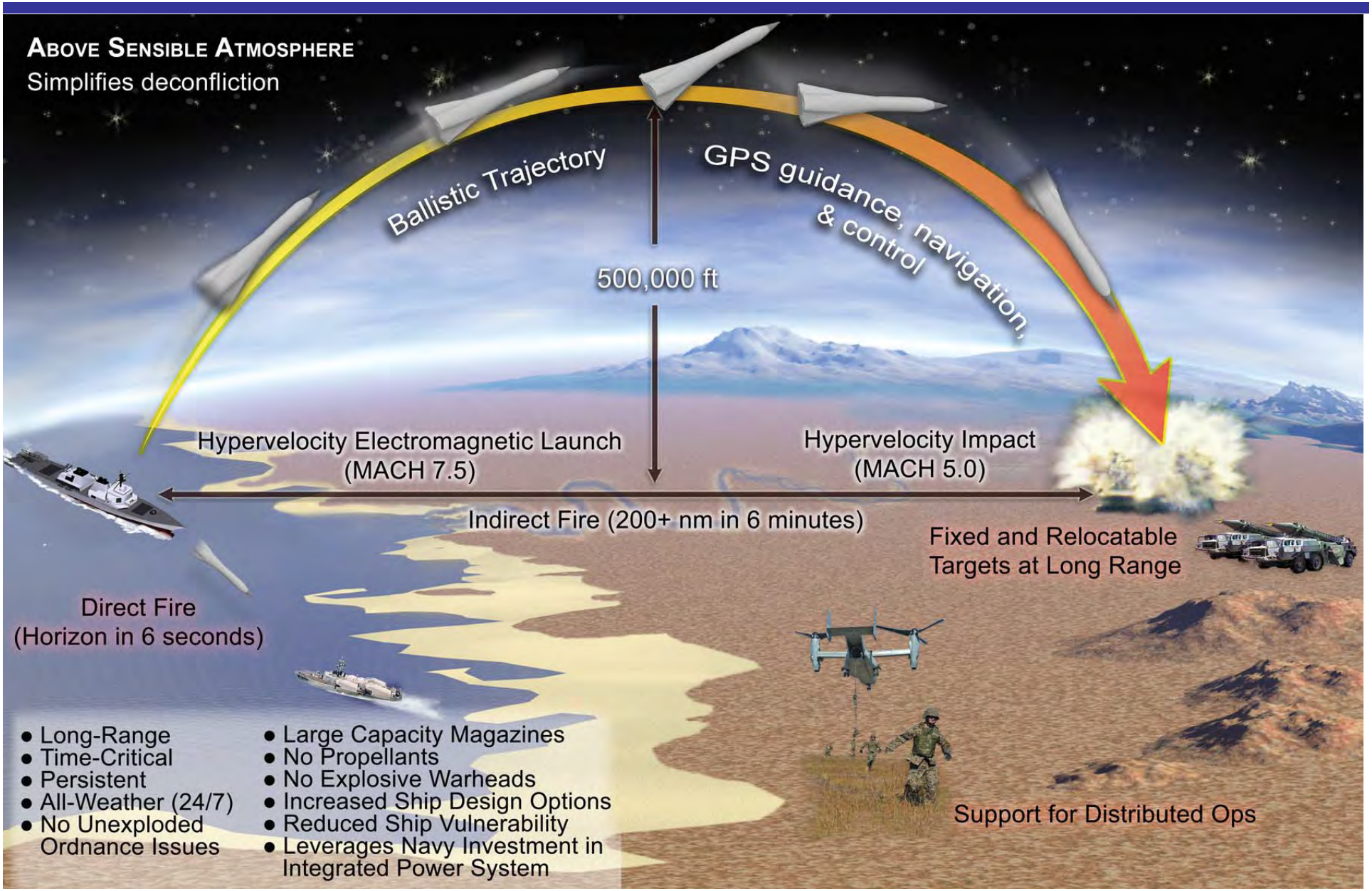
Test and Evaluation of Electromagnetic Railguns

NDIA Gun & Missile Systems
April 23-26, 2007

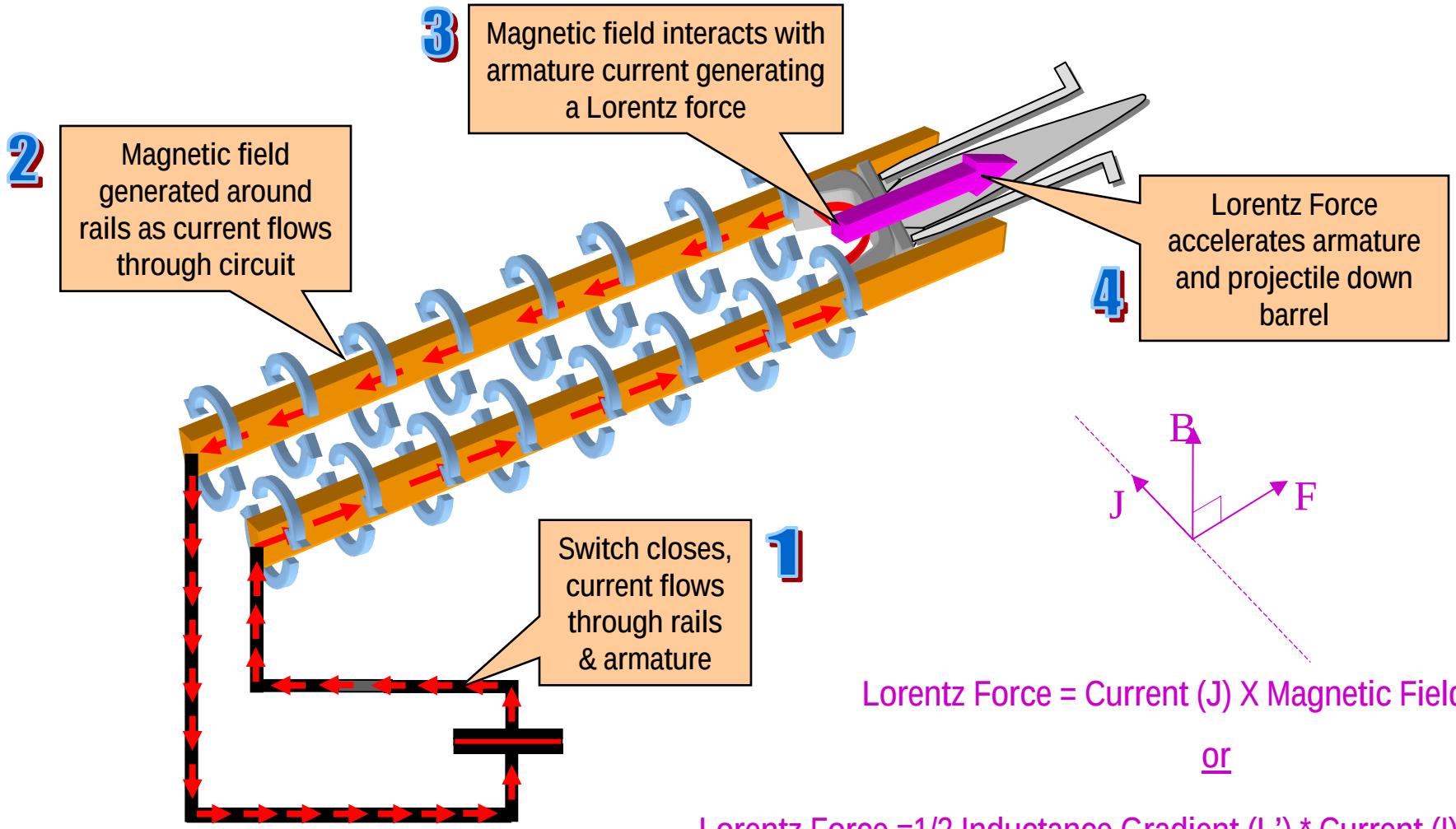


DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited

EM Railgun – Game Changing



How it Works

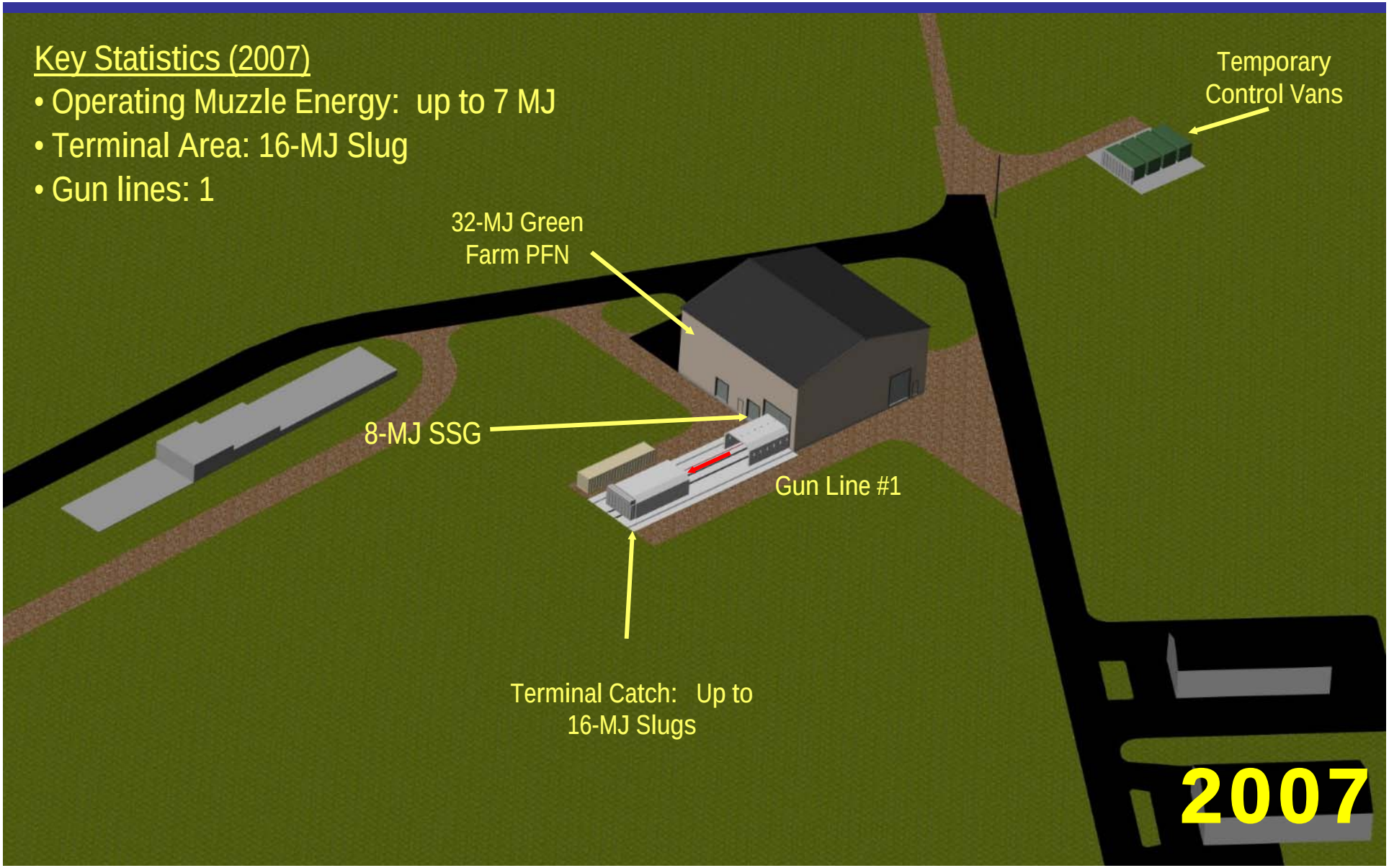


Lorentz Force = Current (J) X Magnetic Field (B)

or

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

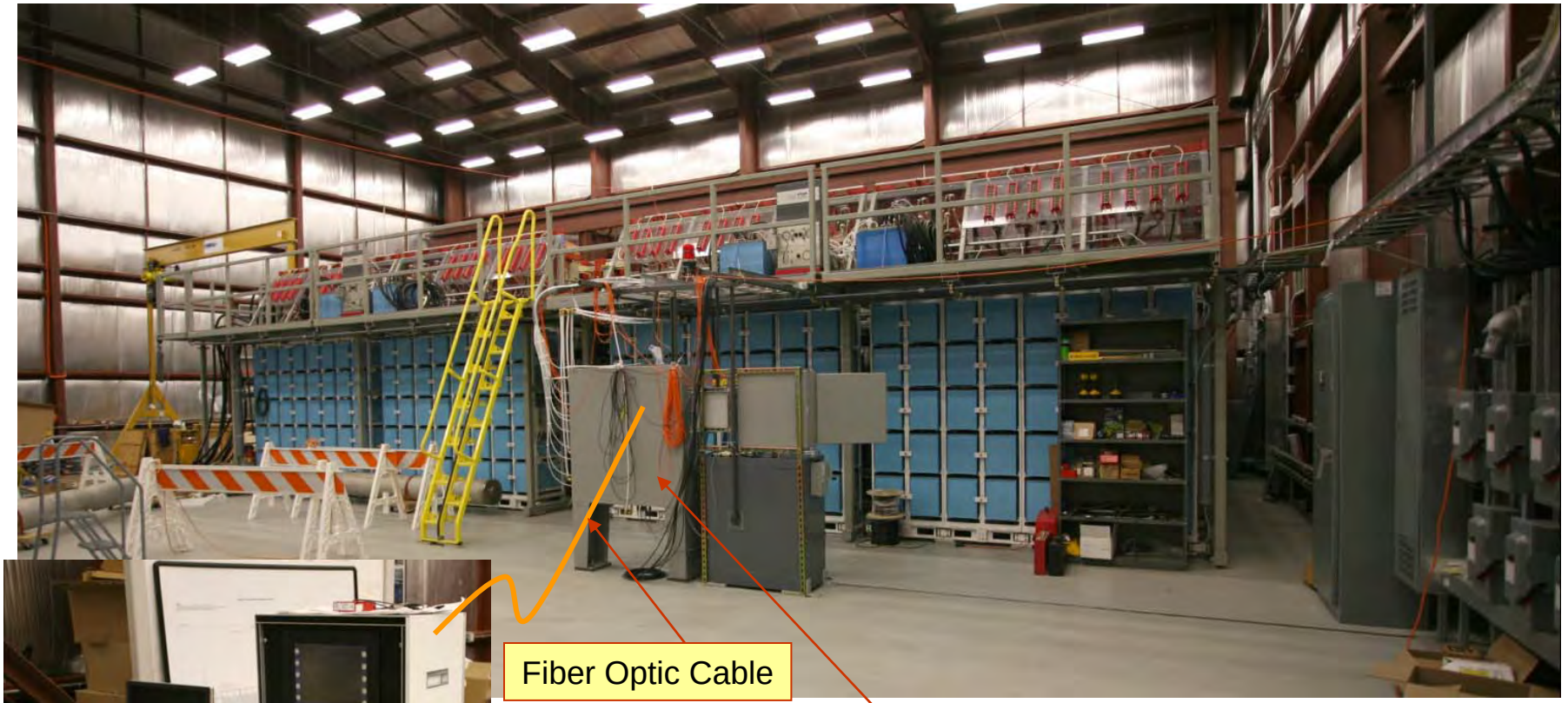
Current Facility



Current Facility



32-MJ PFN





Fiber Optic Cable

Controls Cabinets

System Controller
(Located in Control Van)

Switching and Output Cables



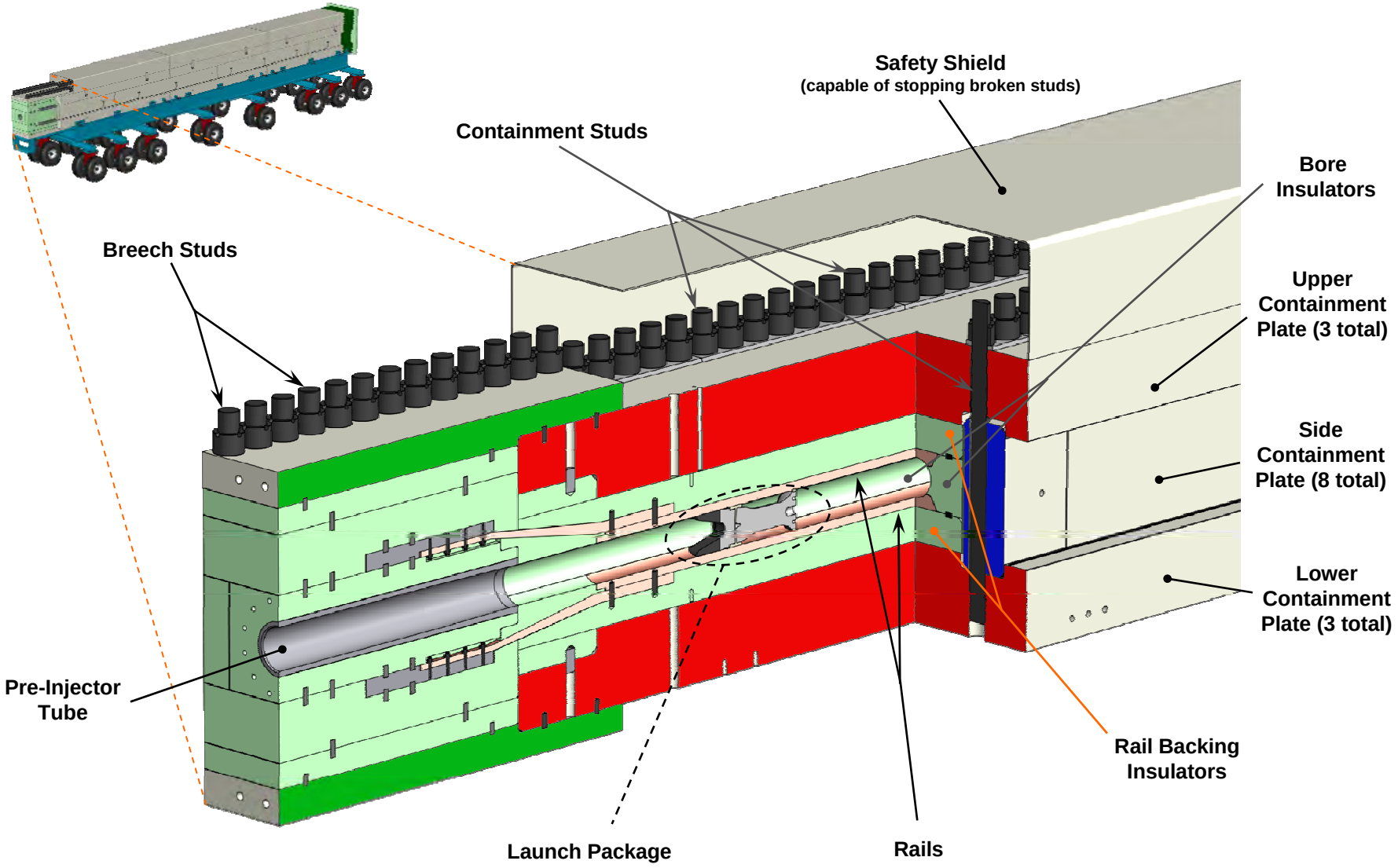




350-MCM Coaxial Cable

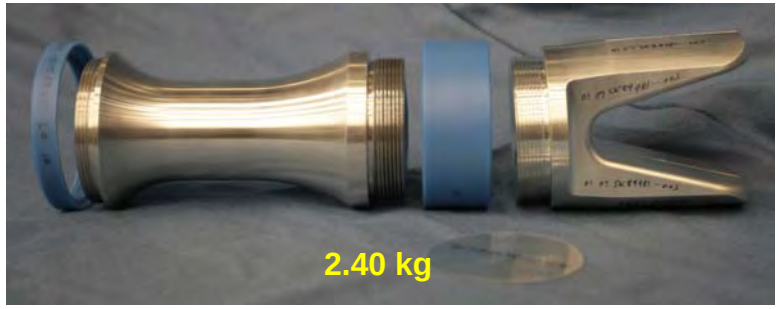
Spark Gap Switch

SSG Construction

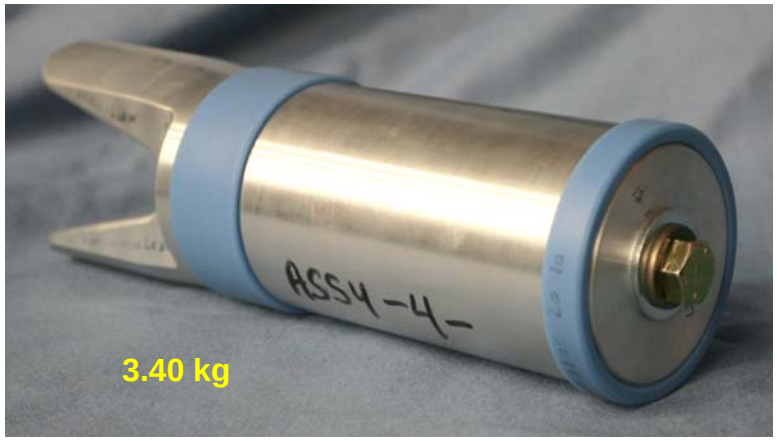


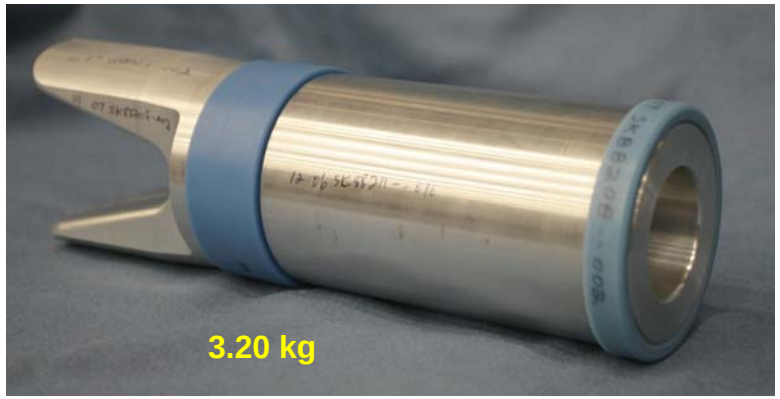
Launch Package

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



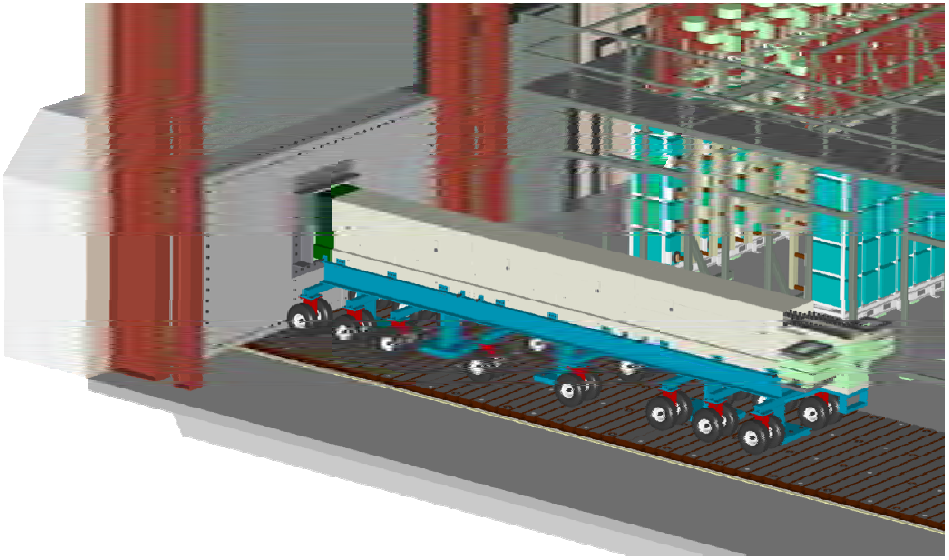




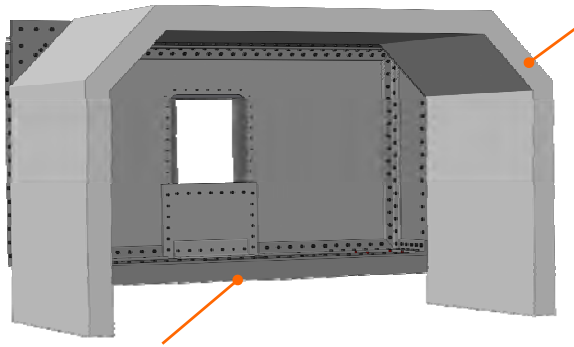


Gun - Facility Interfaces





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 Sand-Filled Steel Boxes
(4’ x 4’ x 3’)
(21' of Sand Along Line of Fire)

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

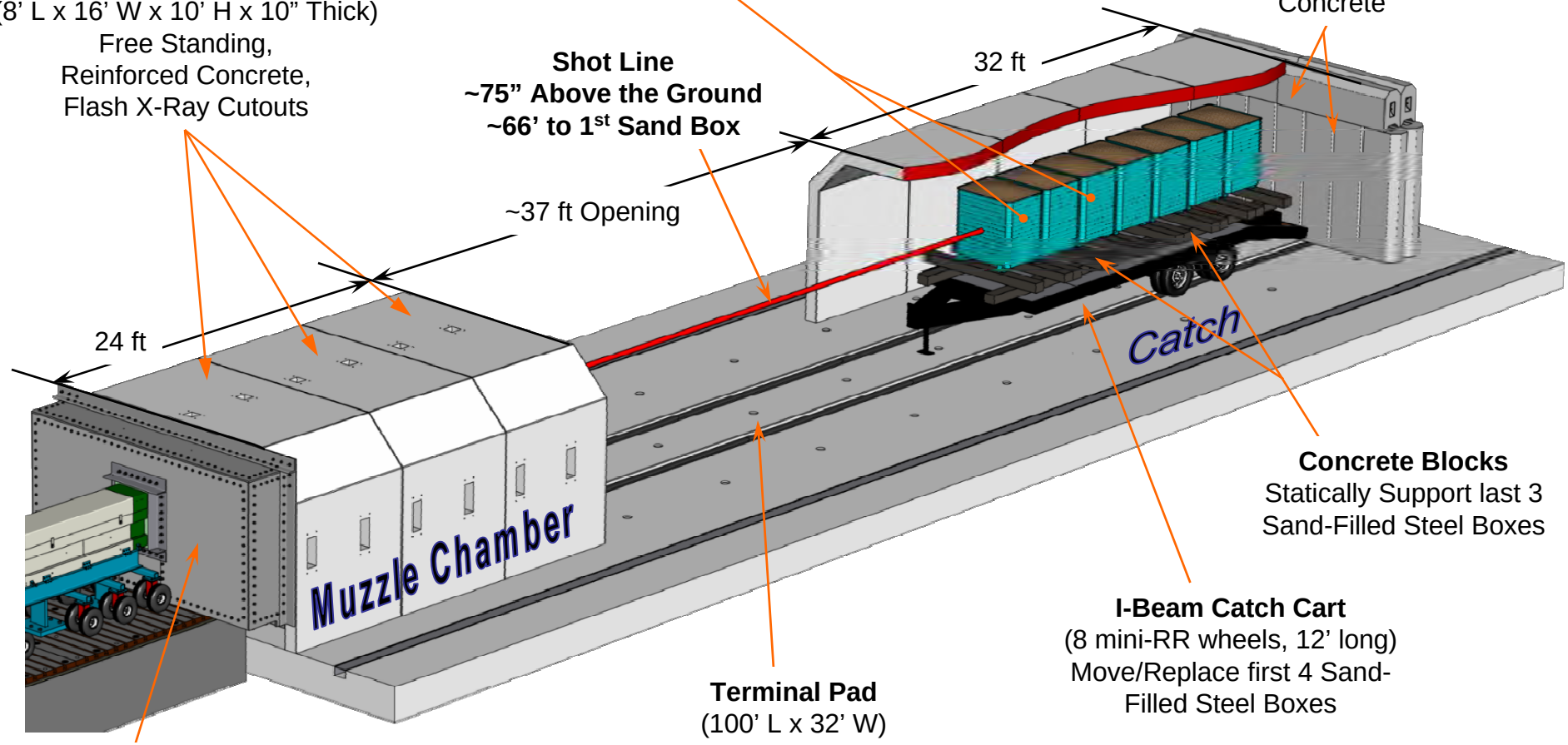
7 Each Bridge Sections
(8’ L x 16’ W x 10’ H x 10” Thick)
Free Standing,
Reinforced Concrete,
Flash X-Ray Cutouts

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

32 ft

~37 ft Opening

24 ft



Concrete Blocks
Statically Support last 3
Sand-Filled Steel Boxes

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

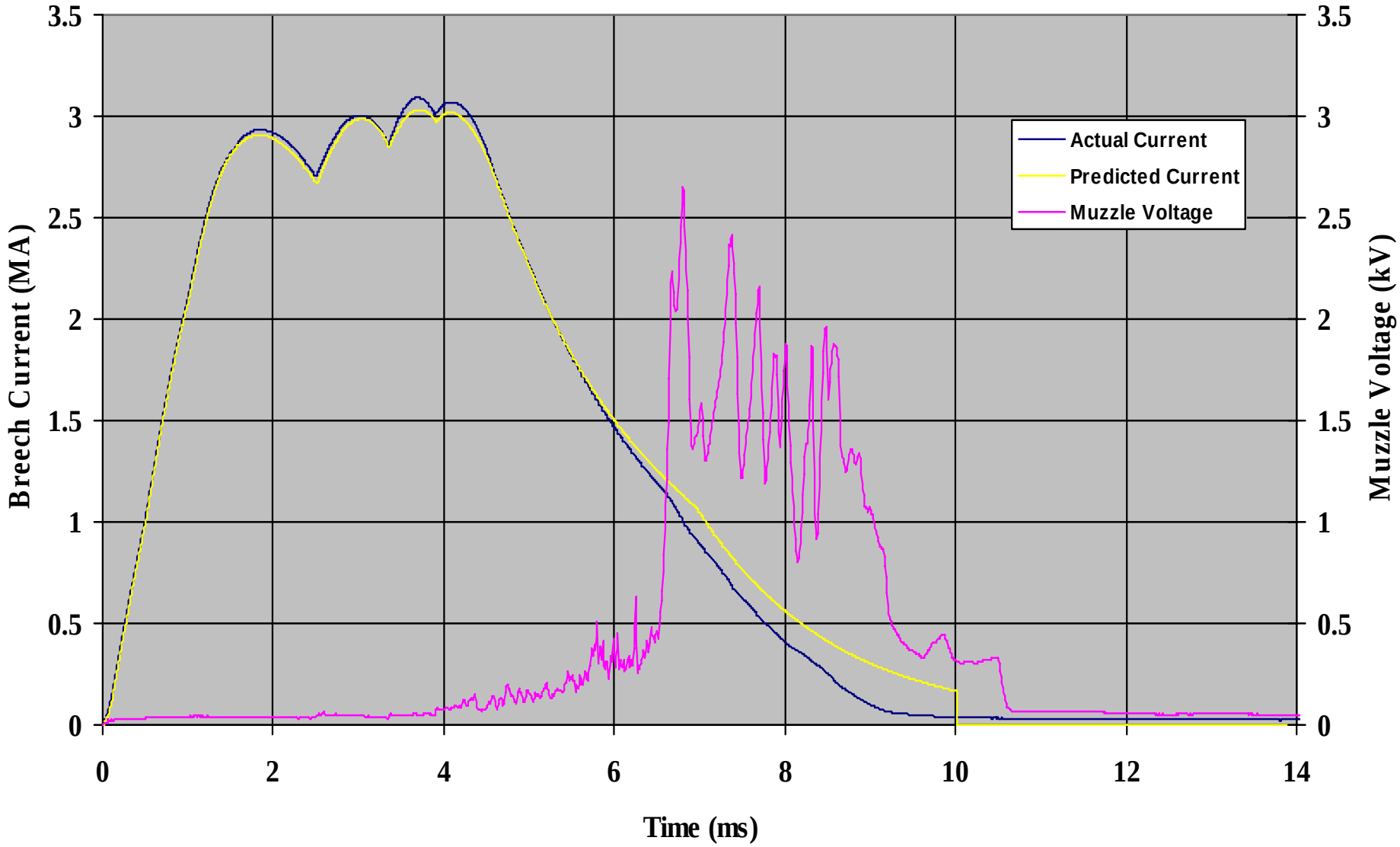
Steel Muzzle Chamber

Catch Component

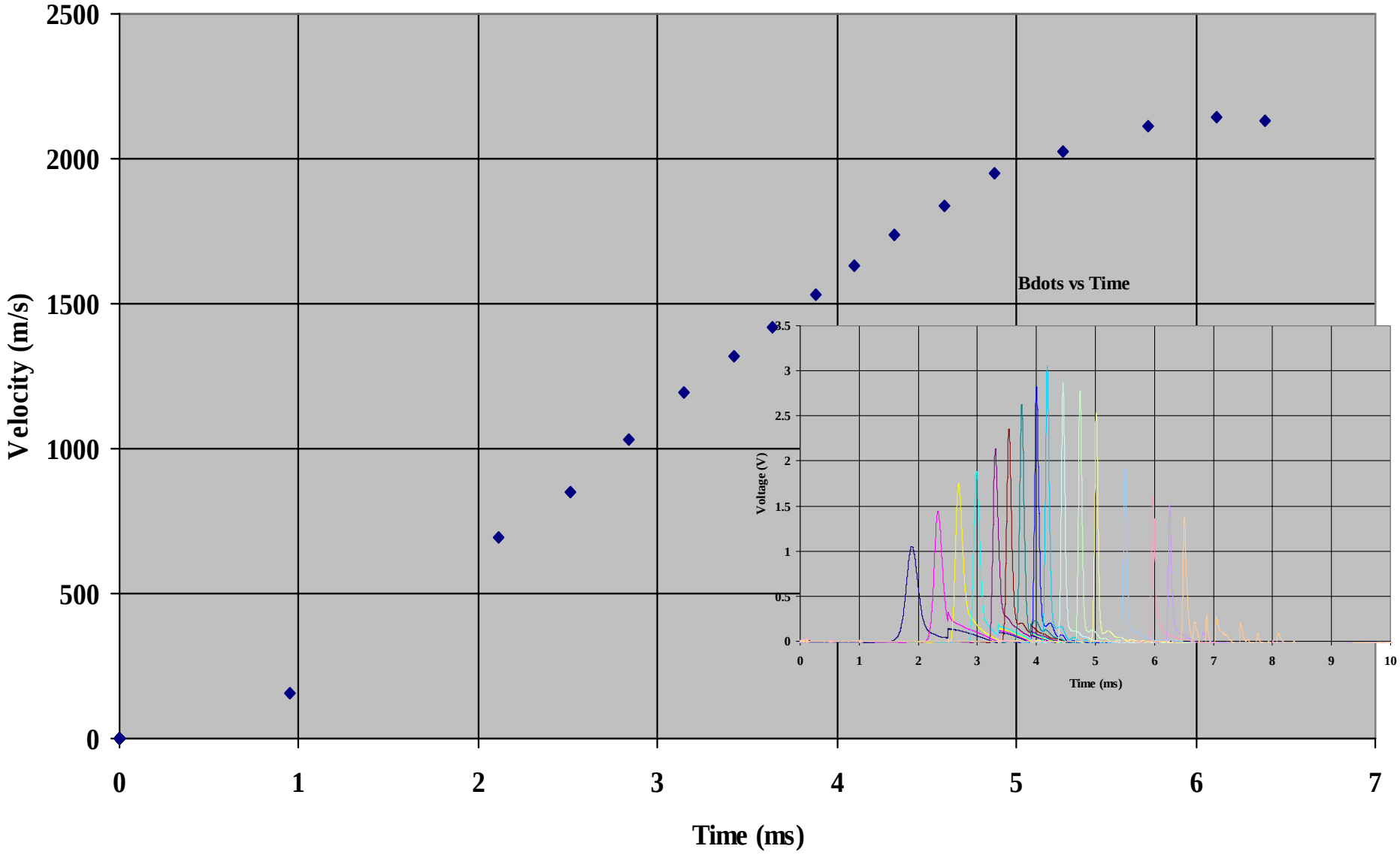
- 7 Each Sand-Filled Steel Boxes, Total of 14 On Hand
  - 4 ft x 4 ft x 3 ft
  - Wt 5740 lbs when Filled
  - 21 ft of Sand along Line of Fire
  - Open Top, Stackable, 4-Way Forklift Entry
- I-Beam Catch Cart
  - Support the First 4 Sand Boxes to Allow Quick Movement & Replacement
  - Runs on Crane Rails Using Mini-Railroad Wheels
- Concrete Blocks
  - Support the Last 3 Sand Boxes



Shot 13 Breech Current and Muzzle Voltage

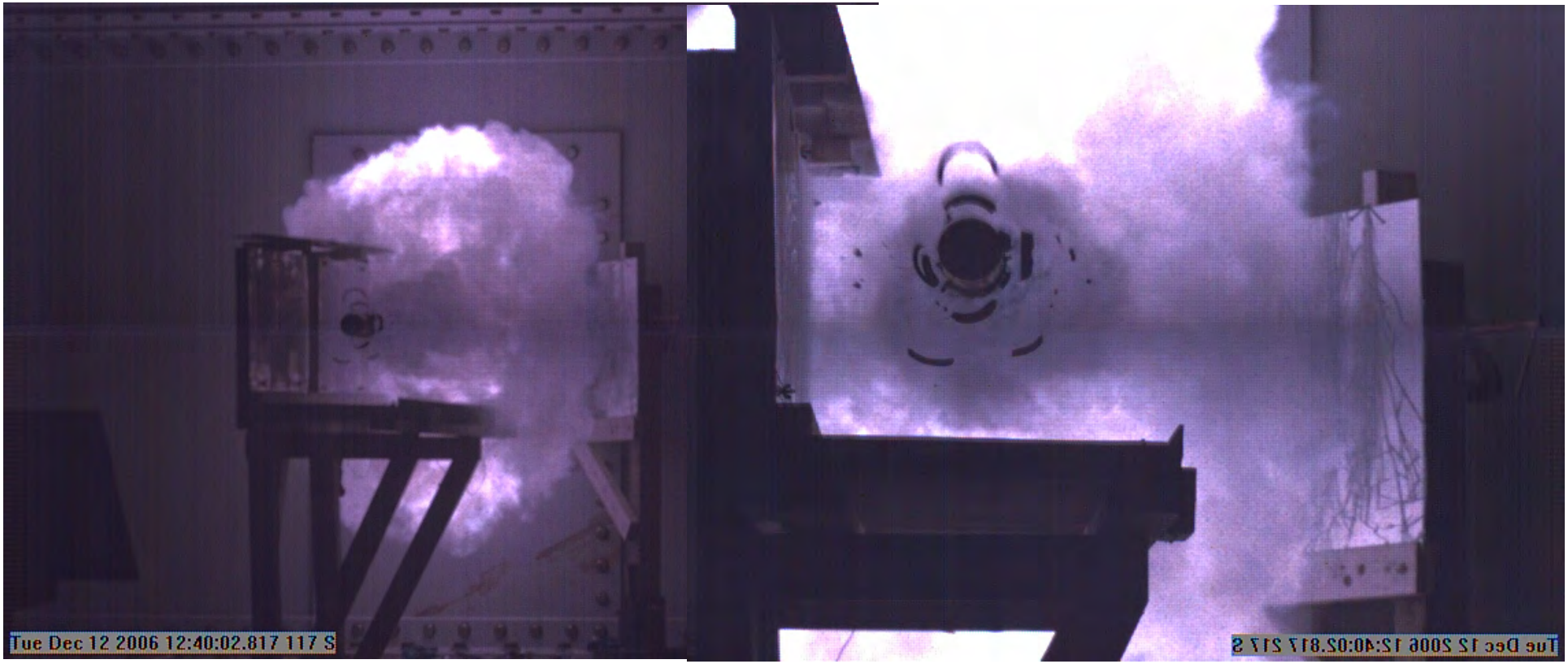


Shot 13 Velocity

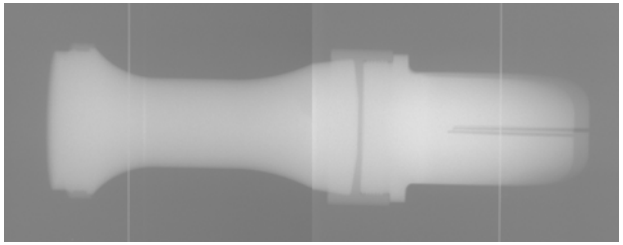
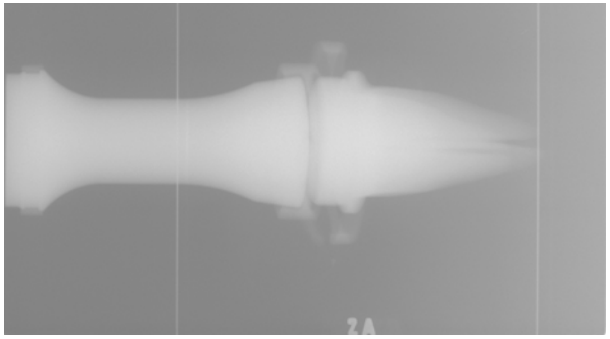
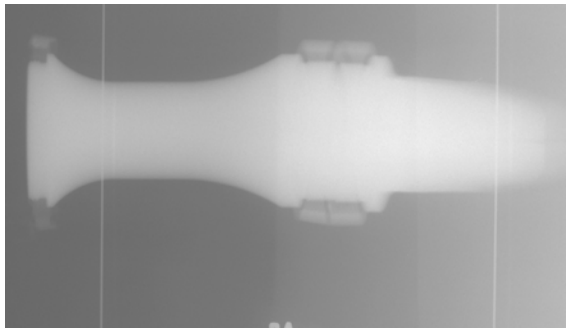
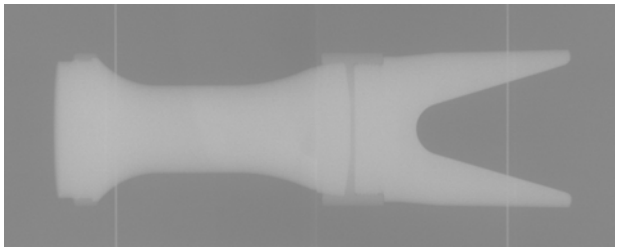
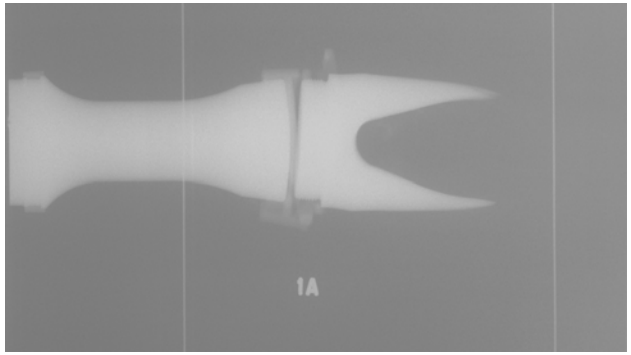
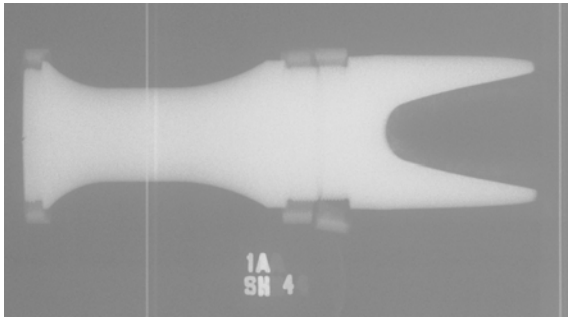


Muzzle Launch View

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



Flash X-ray Images

	Static Xray Image	Shot 2 Xray Image	Shot 4 Xray Image
Top View			
Side View			

All images are 3 feet from muzzle

In-Flight Images

Shot 8:

Shot 9:

Shot 10:

Shot 21:



Target Impact

Revolutionary Research . . . Relevant Results

NAVSEA WARFARE CENTERS DAHLGREN

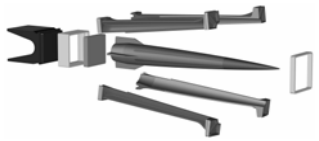


S&T Technology Challenges

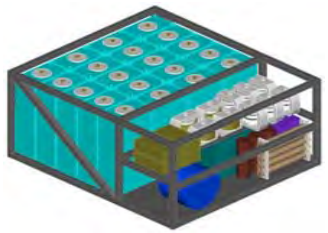
- Launcher
  - Multi-shot barrel life
  - Barrel construction to contain rail repulsive forces
  - Scaling from 8MJ (state of the art) to 32MJ → 64MJ Muzzle Energy
  - Thermal management techniques



- 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 INP Phase I Program

Revolutionary Research . . . Relevant Results

NAVSEA WARFARE CENTERS DAHLGREN

FY05	FY06	FY07	FY08	FY09	FY10	FY11

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



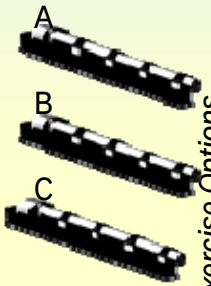
BAE

32MJ Lab Gun For Bore Life Development

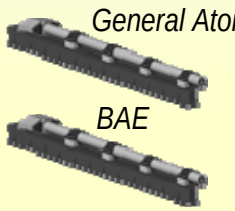
Launcher Bore Life Development



32 MJ LAUNCHER 100 SHOT BORE LIFE DEMO



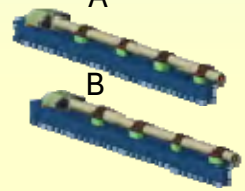
Exercise Options



General Atomics

BAE

Advanced Containment



Concept Design

Technology Development & Preliminary Design

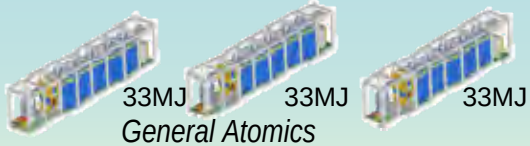
Detail Design & Fabrication

32 MJ ADVANCED CONTAINMENT DEMO



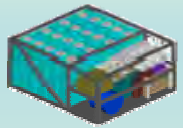
EMLF Test Facility NSWCDD

100MJ Capacitor Bank For Launcher Testing

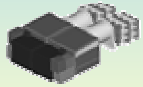


33MJ 33MJ 33MJ

General Atomics



Advanced Capacitor Development



Rotating Machine Component Development

Multiple Awards



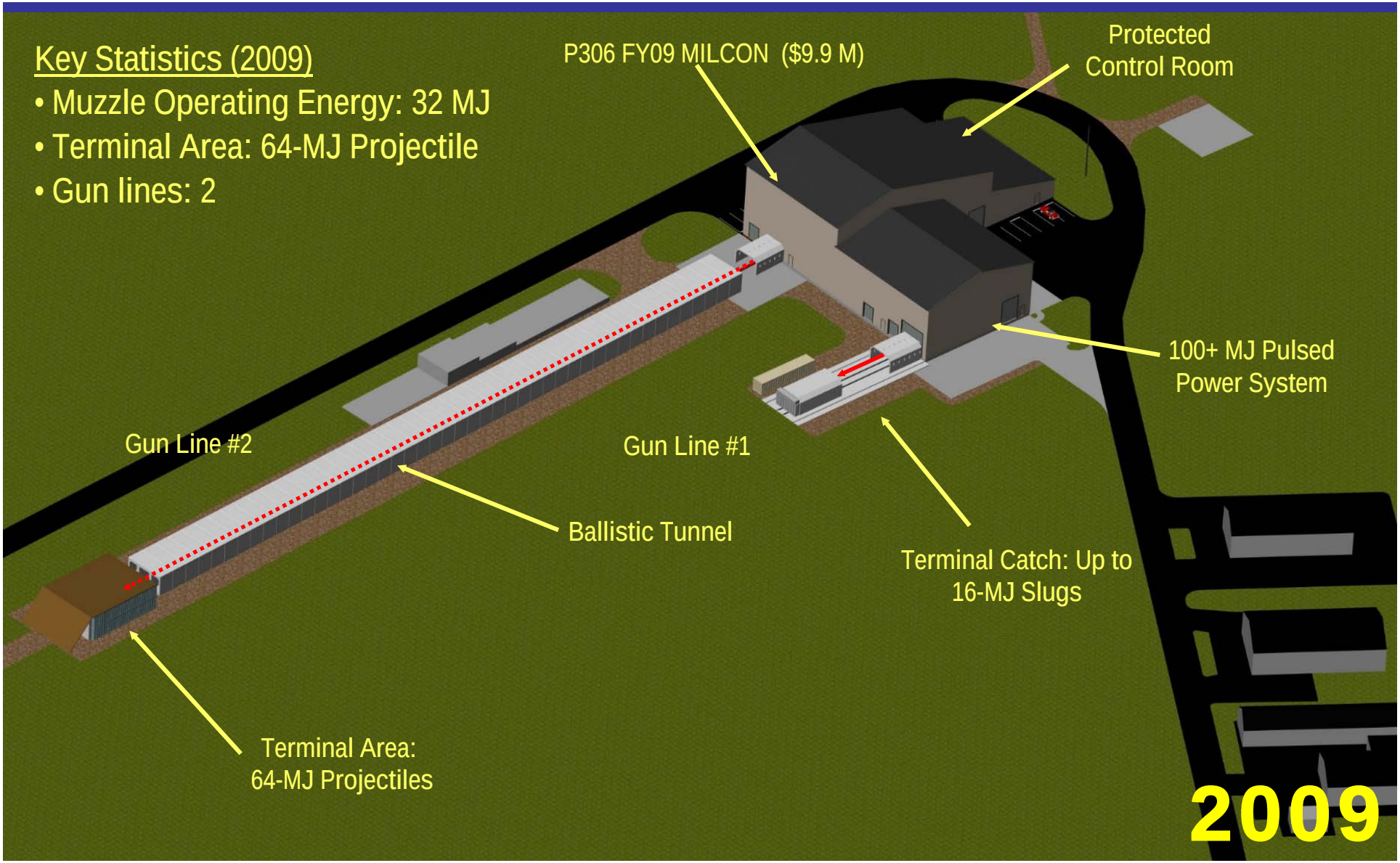
Boeing

Draper

Projectile Trades & Develop 4 Year Plan

Integrated Launch Package (ILP) Development

Milcon Addition



Test Results

Video of Test Results

Electromagnetic Launch Facility



TEST SHOT #1

2 October 2006




Tue Dec 12 2006 12:40:02.815 617 S

Electromagnetic Launch Facility Ribbon Cutting

16 Jan 2007





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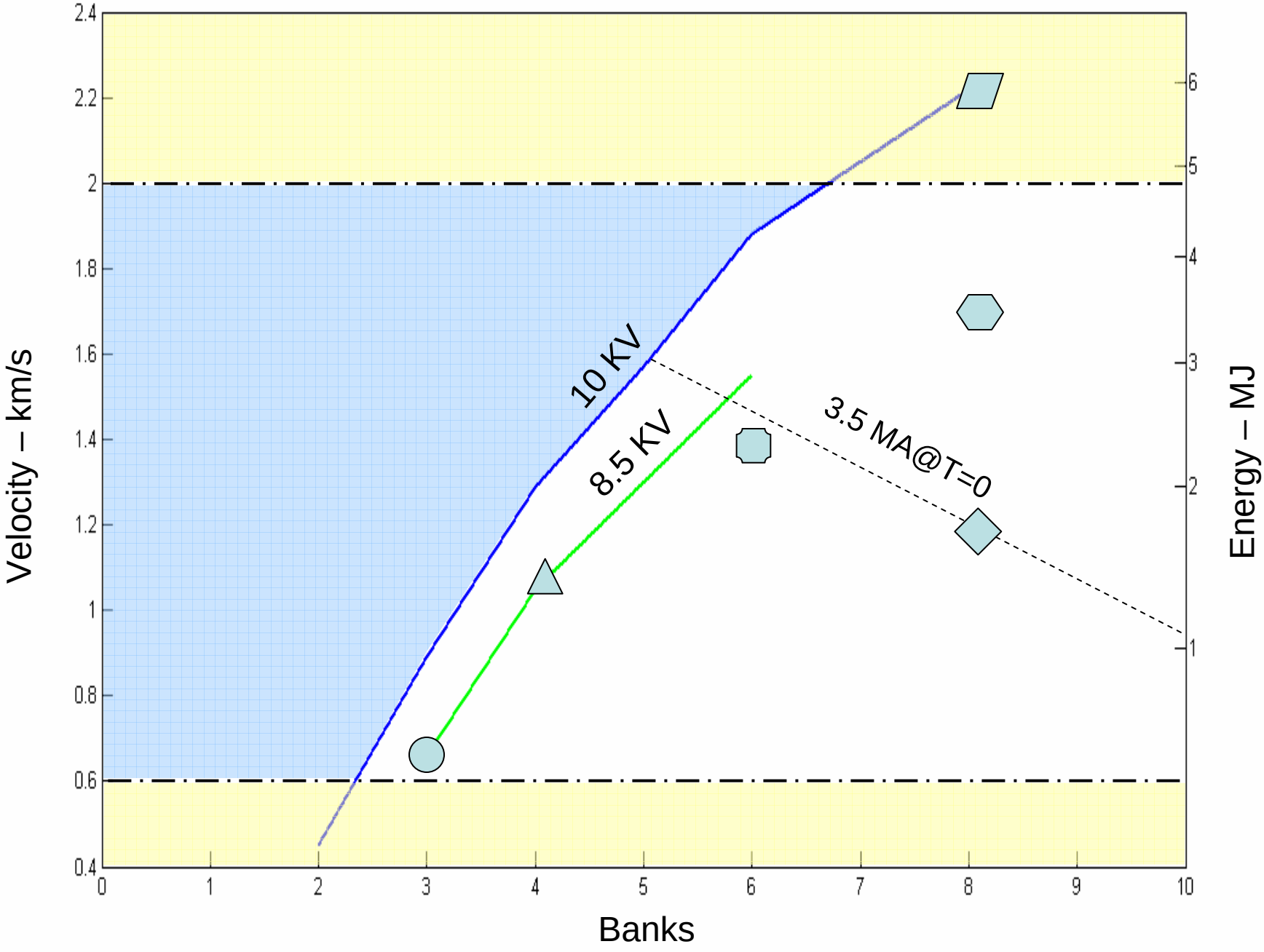
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ONR
Revolutionary Research . . . Relevant Results

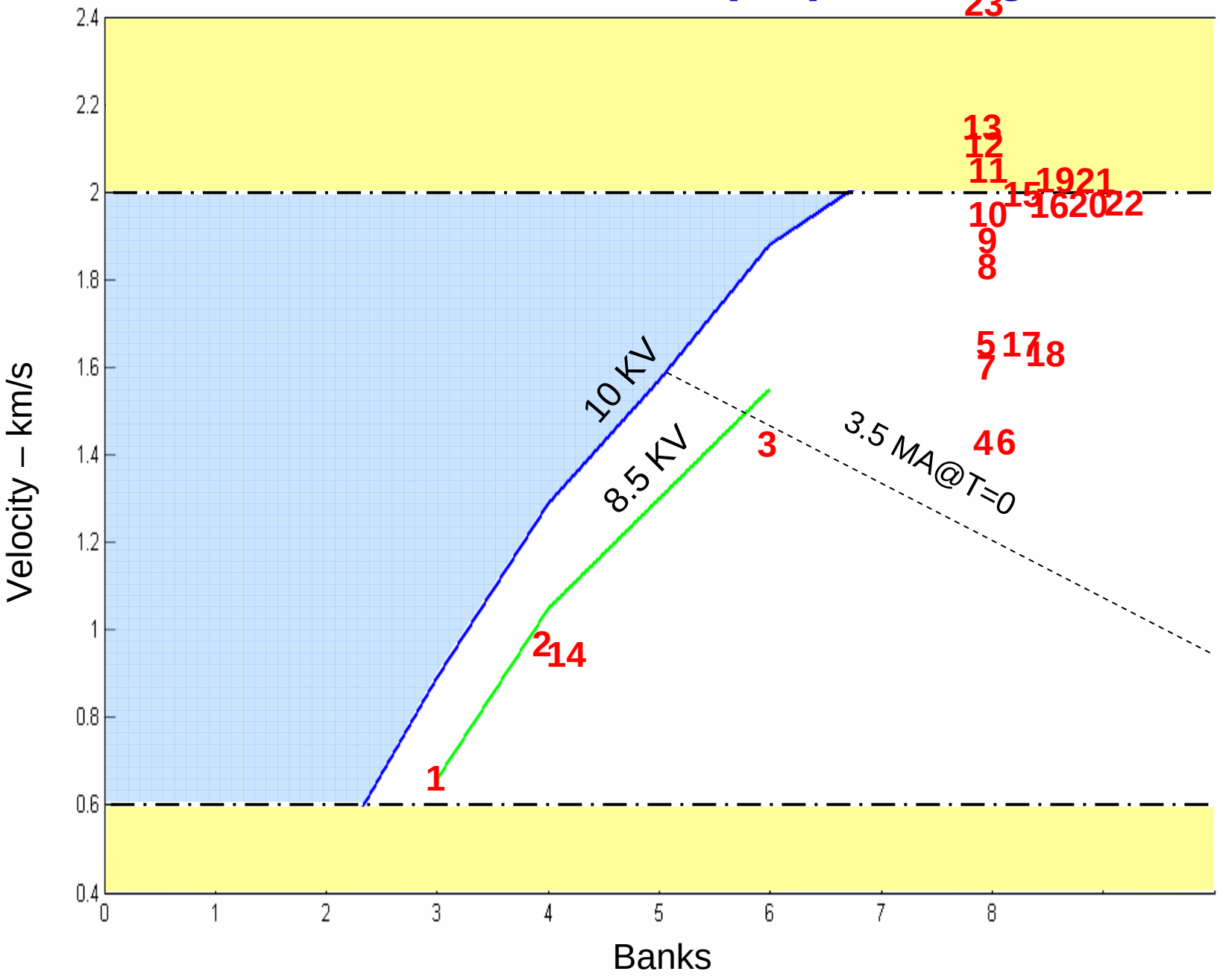

NAVSEA
WARFARE CENTERS
DAHLGREN

Back-up

Power Ramp Up Testing Plan (2.4kg)



Actual Power Ramp Up Testing



Test Results

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

Test Results (continued)

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

Launch Package Results

Original Launch Package



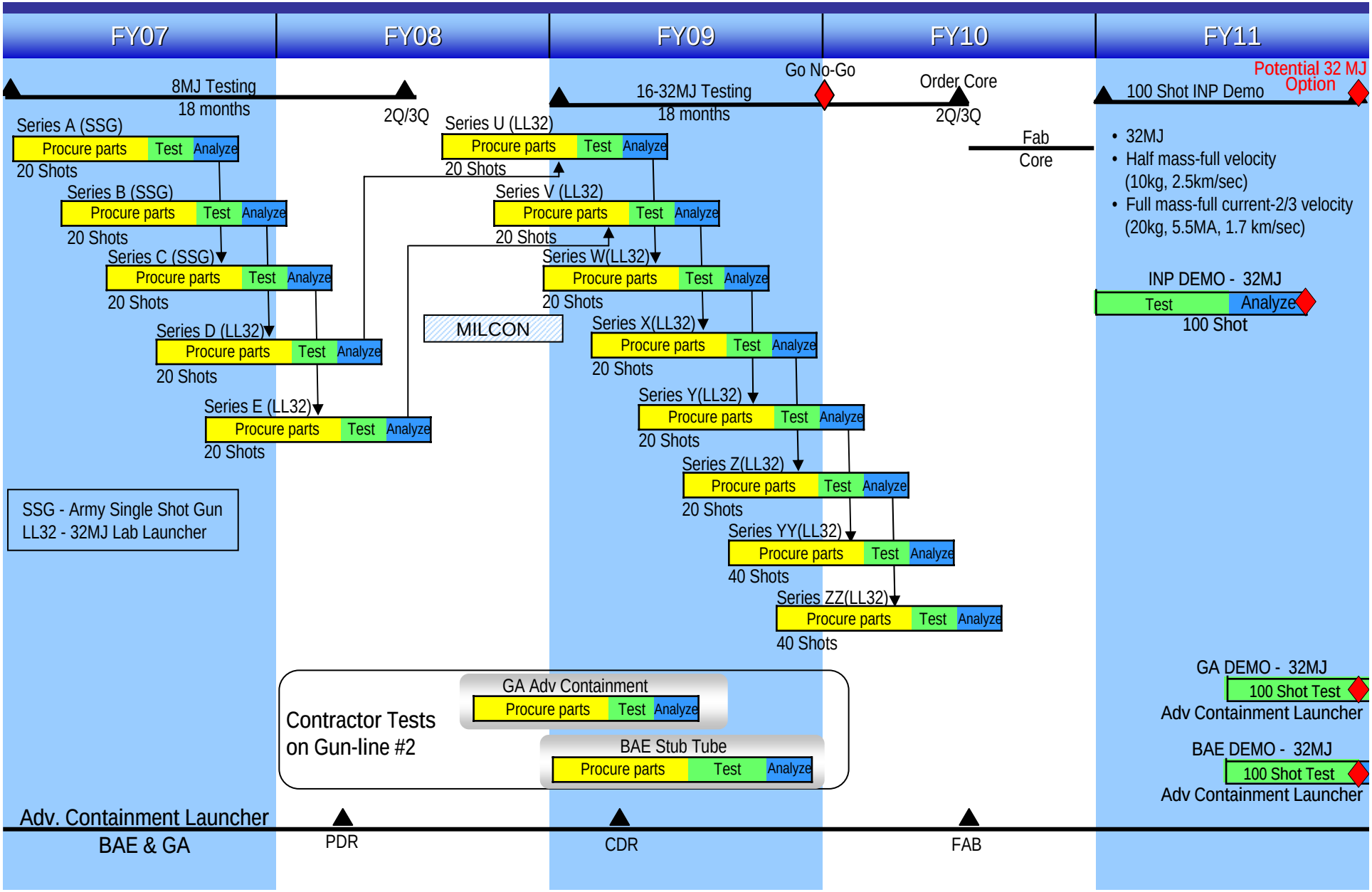
Recovered from Shot 1



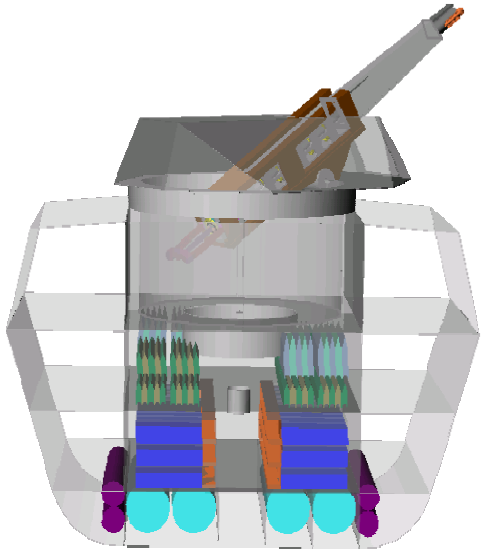
Recovered from Shot 2



Bore Life
EMLF Testing Concept



Navy Electromagnetic Railgun



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

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

Who needs it?

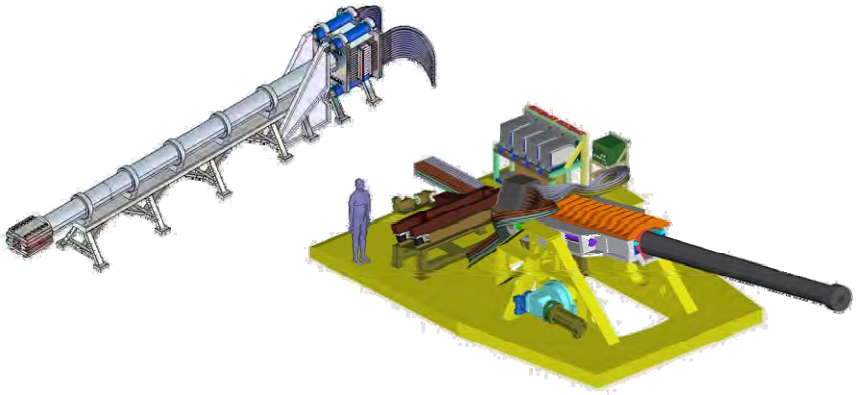
- Marines and Army troops on ground
- Special forces clandestine ops
- GWOT
- Suppress air defenses

When?

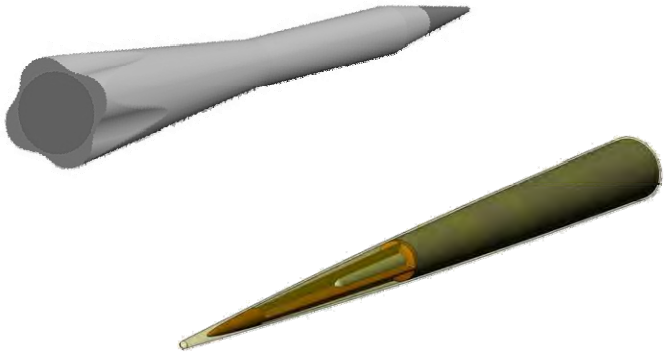
- Feasibility Demo 2011
- System Demo 2015
- IOC 2020-2025

Naval Railgun – Key Elements

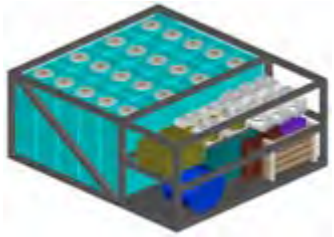
Launcher

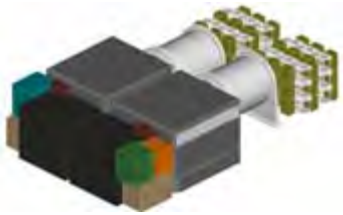


Projectile



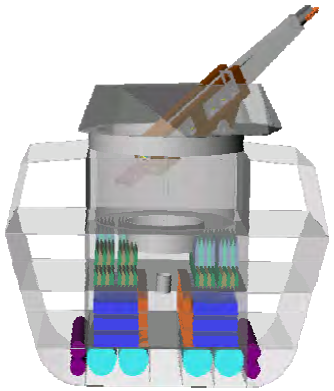
Pulse Forming Network (PFN)





Capacitors or Rotating Machines

Ship Integration



Key Parameters for Sizing a Naval EM Launcher

Pulse Forming Network Size

½ * Launch Mass * Muzzle Velocity^2

Desired Muzzle Energy



Current Profile

- Rail Separation Forces
- Transient Localized Heating

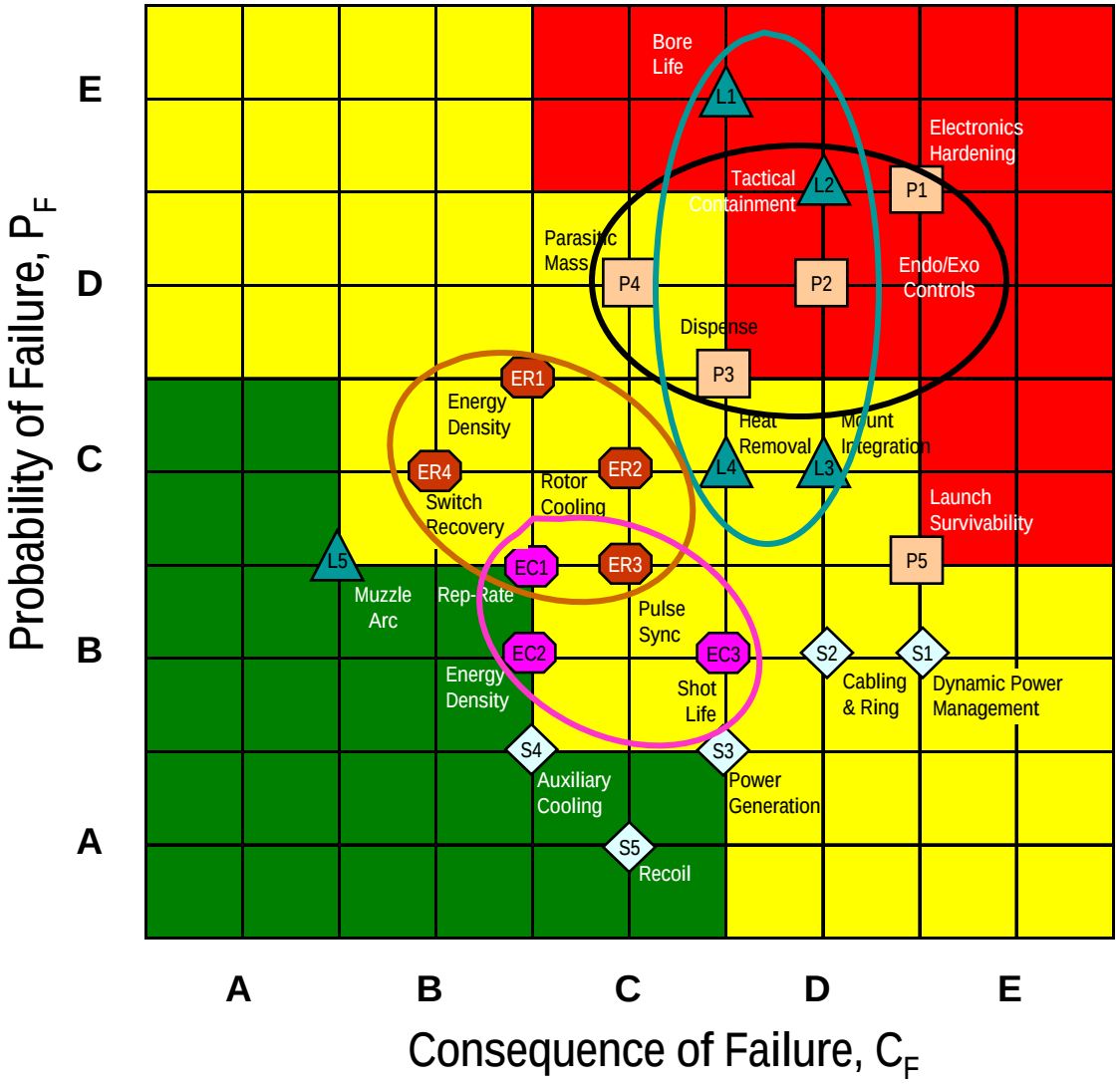
Bore Size & Shape

Launcher Efficiency

Barrel Length

- Max Projectile Acceleration
- Bulk Rail Heating

Risk Matrix Summary



Risk Ranking & Key Impacts

- L — Launcher
- P — Projectile

Failure Impacts Capability

- ER — Rotating Machine PPS
- EC — Capacitor PPS
- S — Ship Integration

Failure Impacts Volume, Weight & Cost

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

Integrated System Demo Strategy

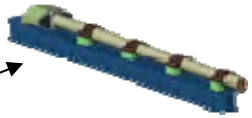
INP I 2005-2011

INP II 2011 - 2015

EM Lab Gun for Bore Life Development



INP Phase I EM Railgun Demonstration Launcher





Launcher Technology Dev.



Launcher Trades & Concept Dev.

INP Phase II EM Railgun Demonstration Launcher



INP Phase II Long Range Integrated System Demo





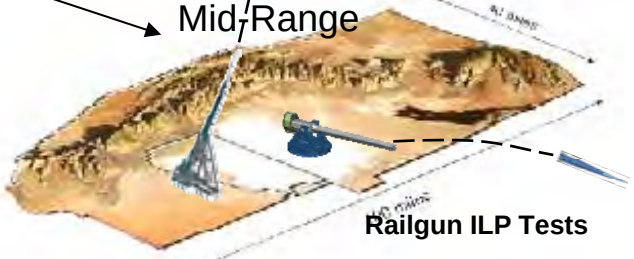
Projectile Trades & Concept Dev.



ILP Interface in bore dynamics

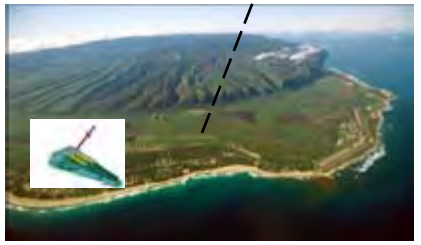
Endo-Exo Testing

Mid-Range



Railgun ILP Tests

Long-Range



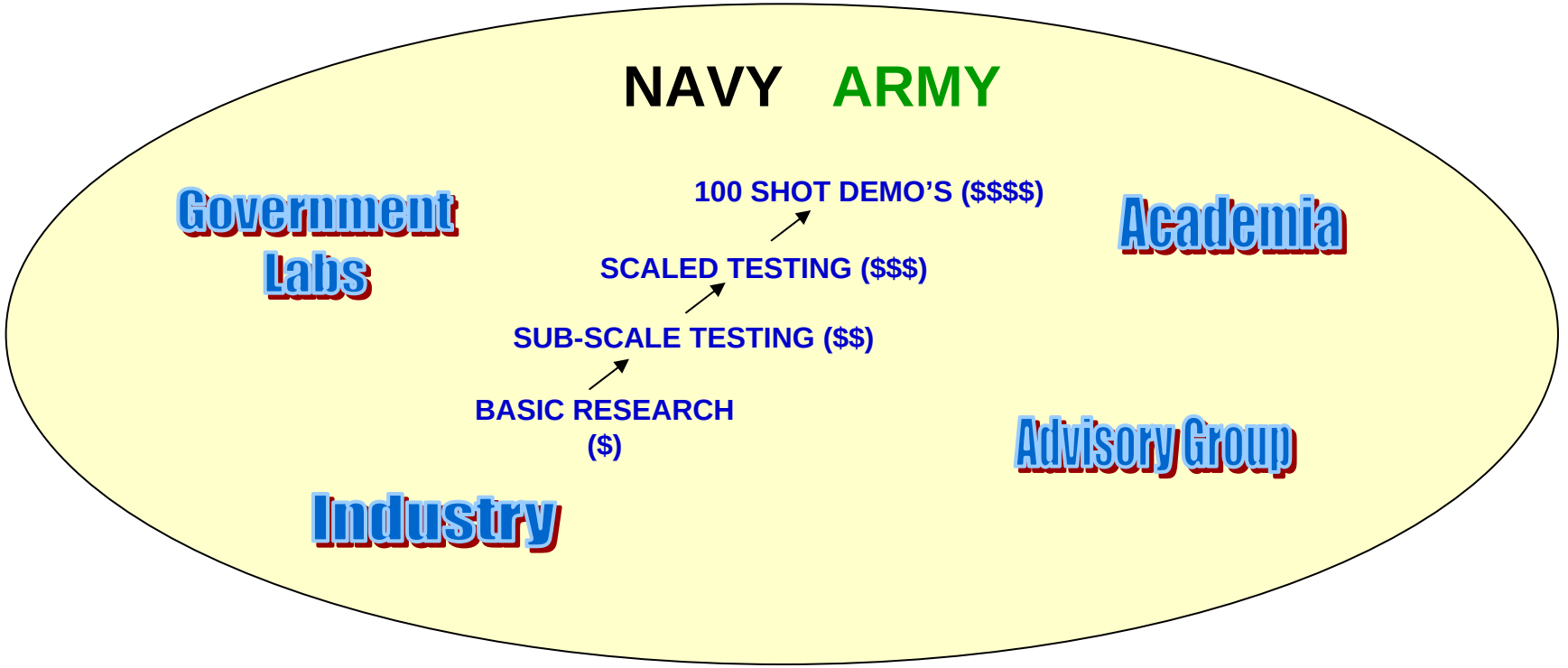
Electromagnetic Test Facility





Terminal High Velocity Powder Gun

Bore Life Consortium

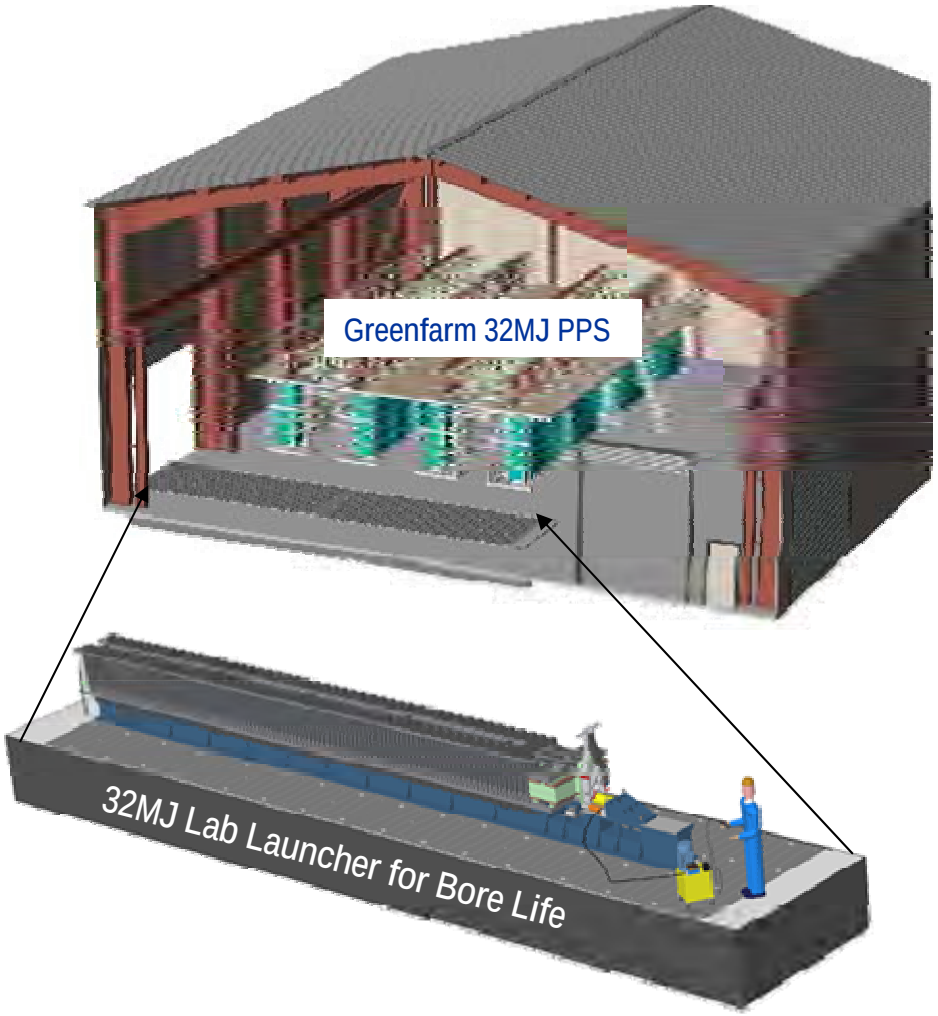


- Spans Basic Research to Full-Scale Demo's
- Parallel development paths via multiple research sites
- Avoids Duplication
- Efficient use of test resources
- Supports both Navy and Army EM Efforts
- Government purpose data rights to permit competition during the acquisition phase.

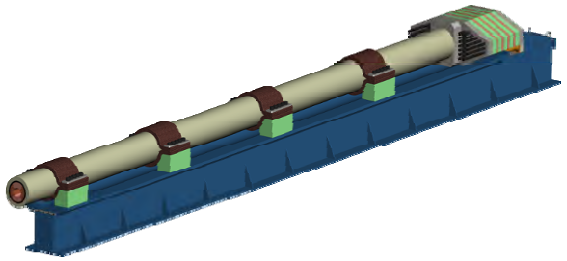
Coordinated Development!

Bore Life and Containment

Lab Launcher - EMTF



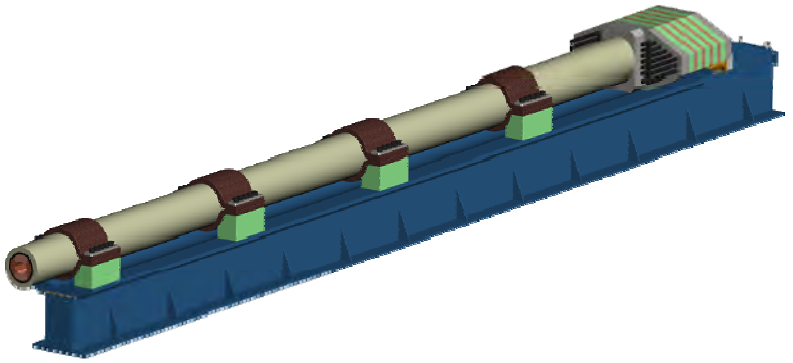
Advanced Containment Launcher



Phase	Phase of Project	Period
Basic	Conceptual Design Trade Studies	7 mos.
Army Add	Trade Studies for Army Application	3 mos.
Option I	Technology Development and Preliminary Design	30 mos.
Option II	Detailed Design, Fabrication and Demonstration	29 mos.

Advanced Containment Launcher

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General Atomics Team

BOEING

L3 communications Applied Technologies Pulse Sciences

GENERAL ATOMICS

SPARTA

Jackson Engineering
Engineering Technology and Development

Northrop Grumman Team

NORTHROP GRUMMAN

DRAPER LABORATORY

CEM

ATK ALLIANT TECHSYSTEMS

BAE Team

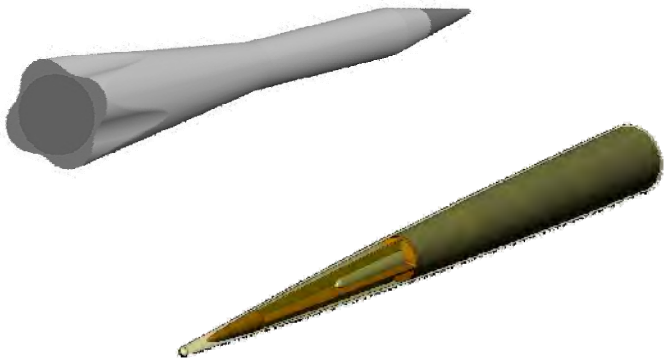
IAP

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

General Atomics, Honeywell, ARA, Boeing, ARL, Rockwell Collins, simulations

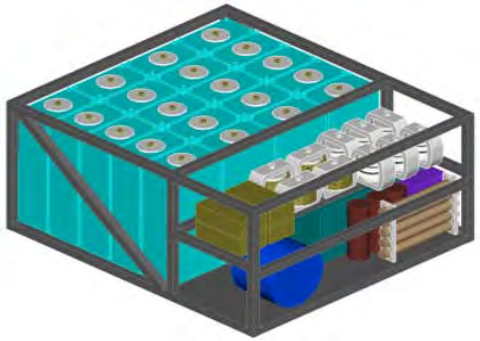
Draper Team

Draper Laboratory, TEXTRON Systems, ATK Alliant Techsystems, Mayflower Communications™

Advanced Pulsed Power

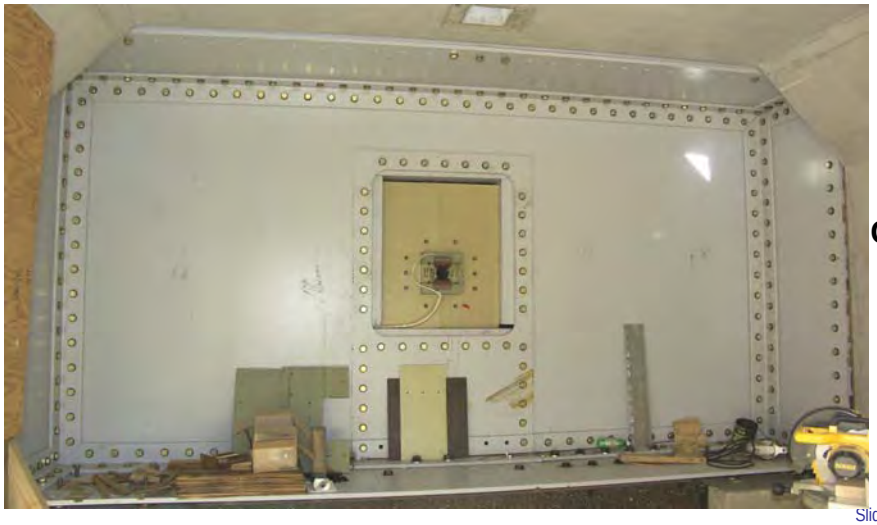
- Rotating Machine
  - Watch Army Effort (Demo in FY08)
  - Navy Specific Critical Component Development
- Advanced Capacitor
  - Increased Energy Density
  - Thermal Management for Multi Shot Operation

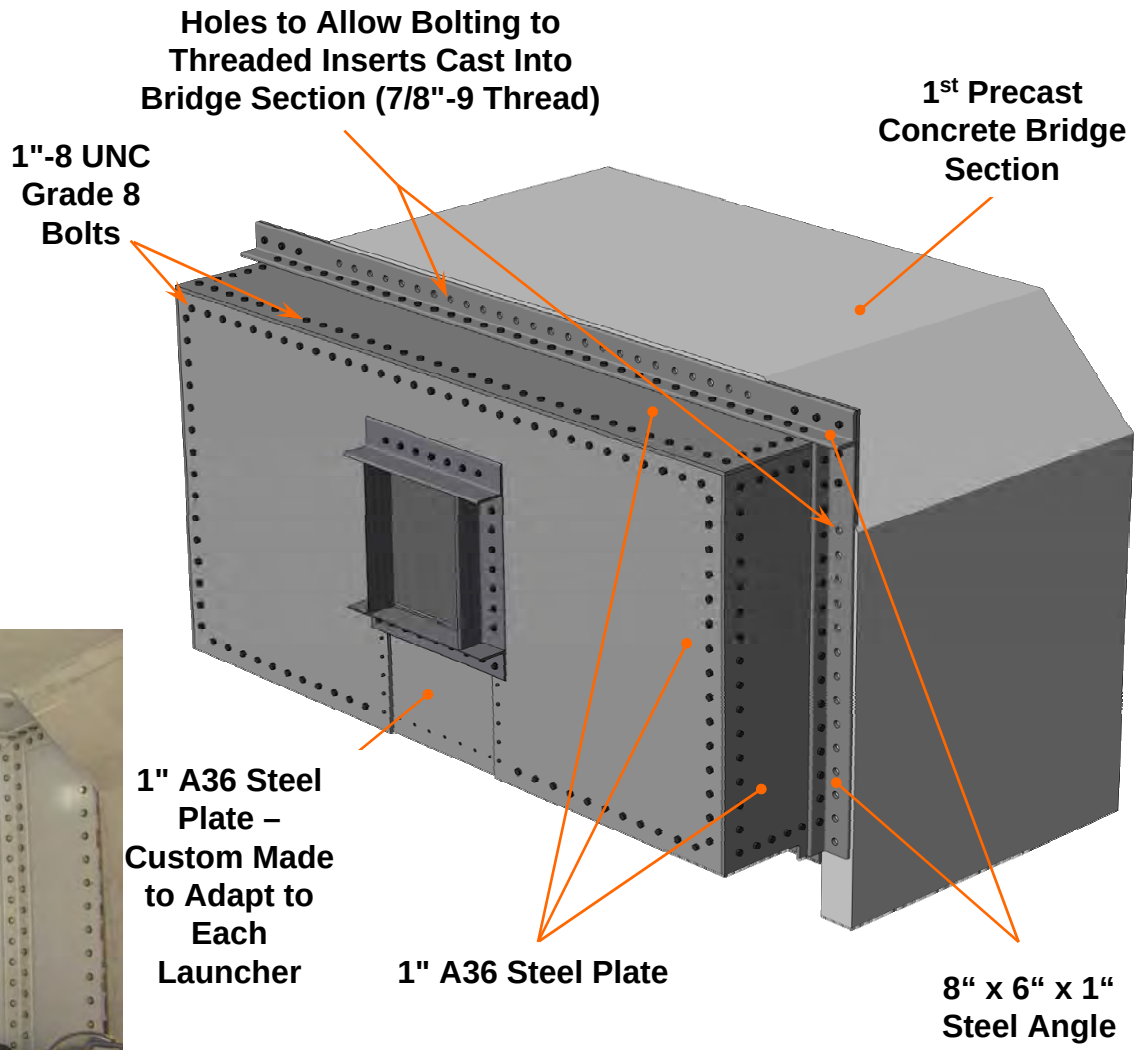




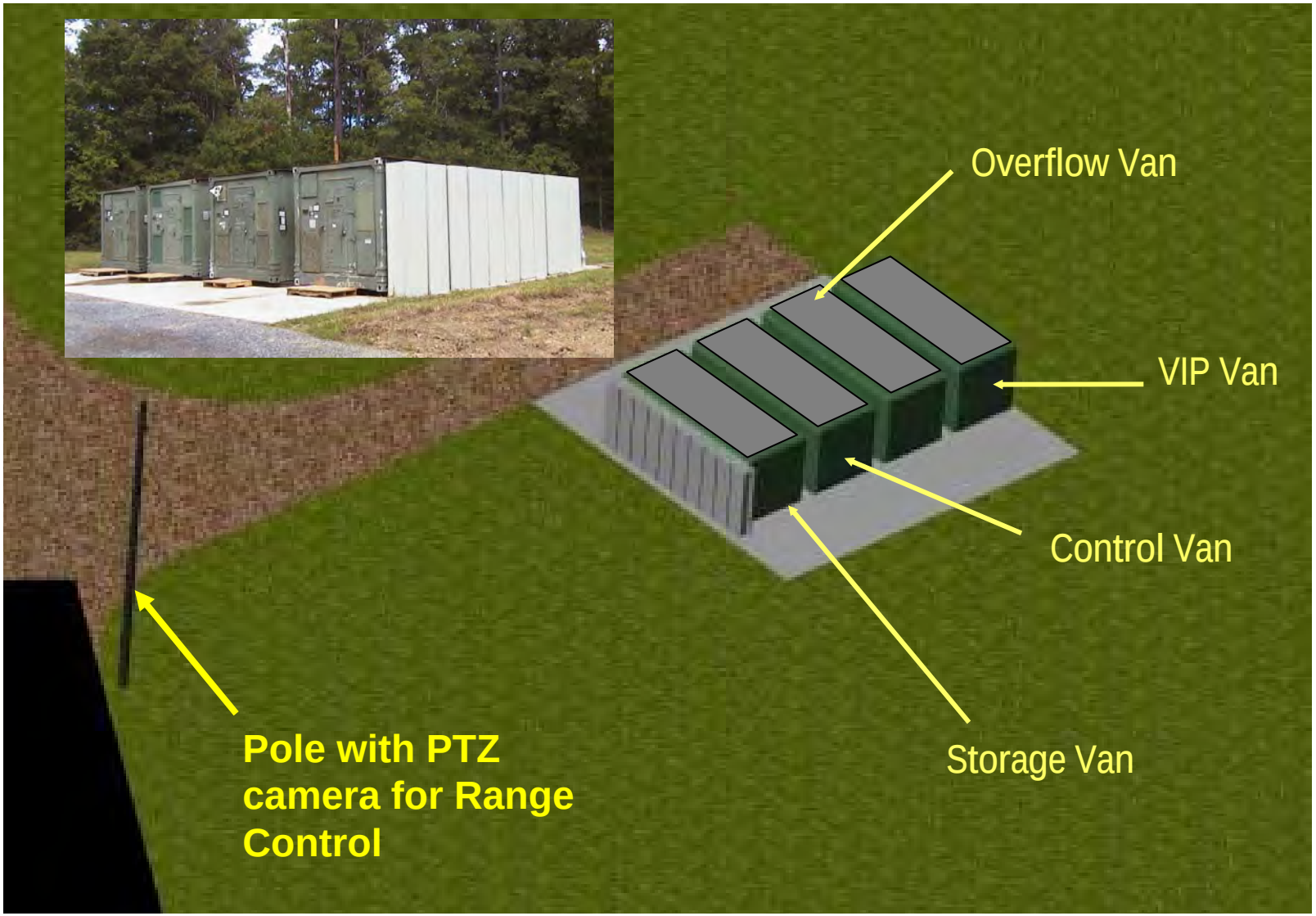
Steel Muzzle Chamber Component

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





Vans on Van Pad



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

CL Med Cal ISE



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.

NAVAIR

CL Med Cal ISE

ROTOR COVER



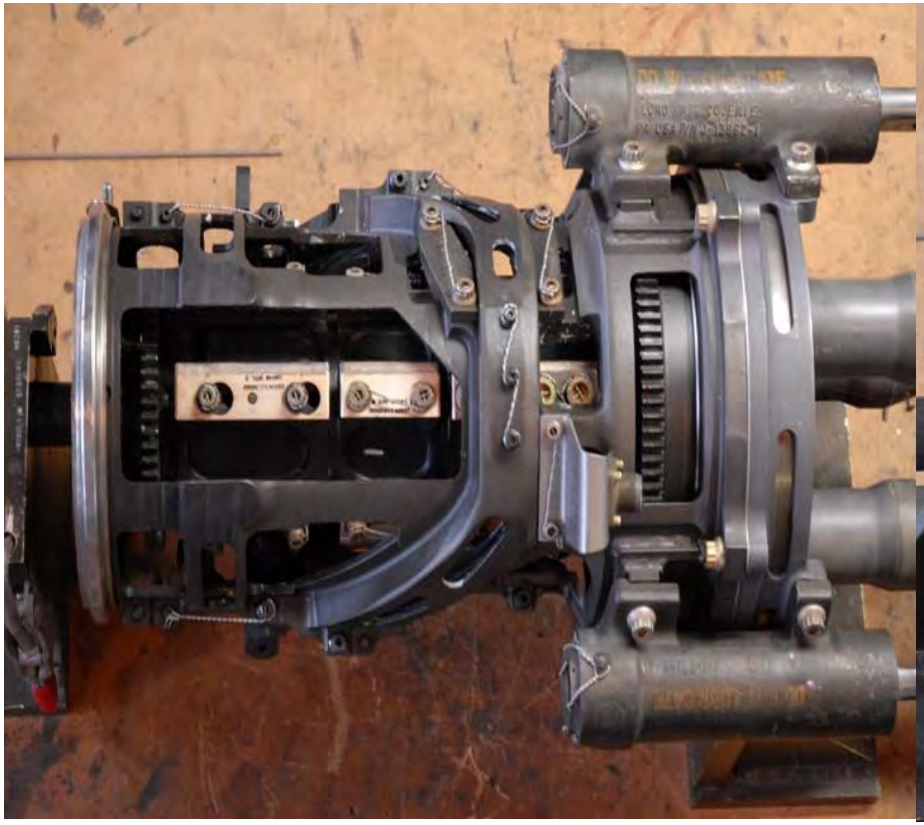


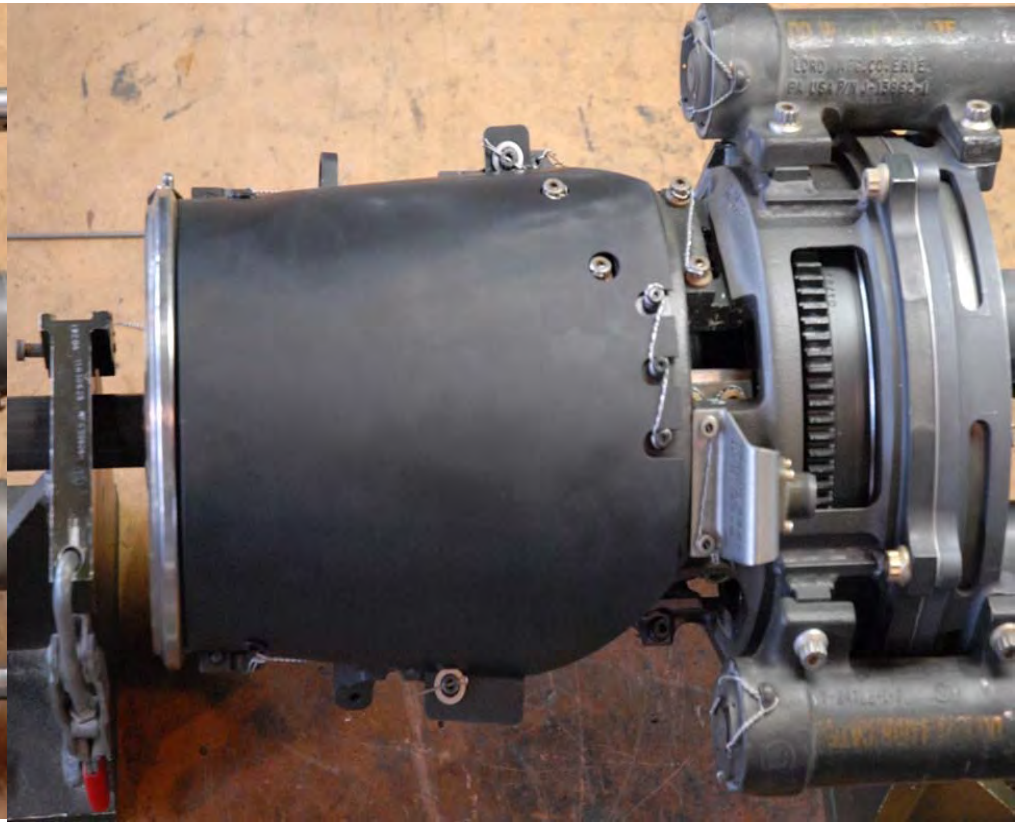
ROTOR COVER

- 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

CL Med Cal ISE





HOUSING COVER

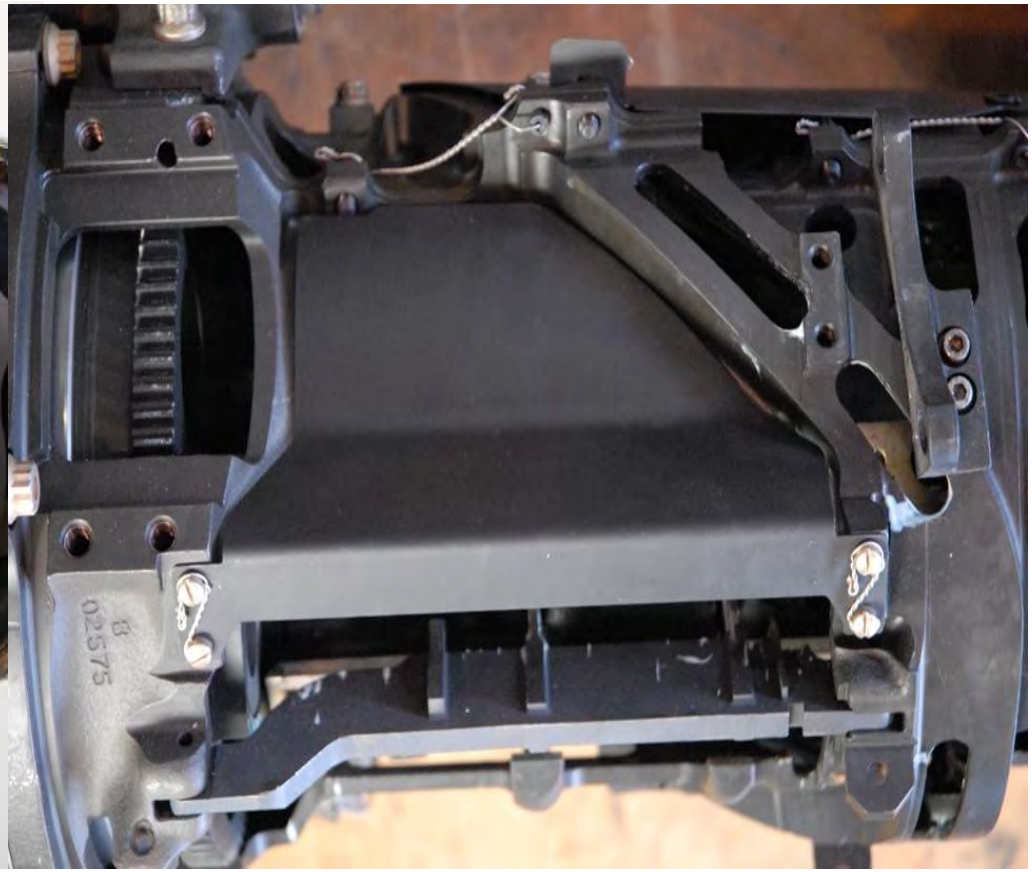


- Forward top mounts under Unlocking Cam safety wire.
- Forward sides mount over Gun Housing Bolts, retained by a washer and cotter pin.
- Aft sides are safety wired to aft Gun Housing alignment roll pins.
- Shield is flush with Gun End Plate Clamp.
- Fits all types of Gun Housings.

DRIVE MOTOR COVER

CL Med Cal ISE





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.

NAVAIR

CL Med Cal ISE

FEEDER COVER



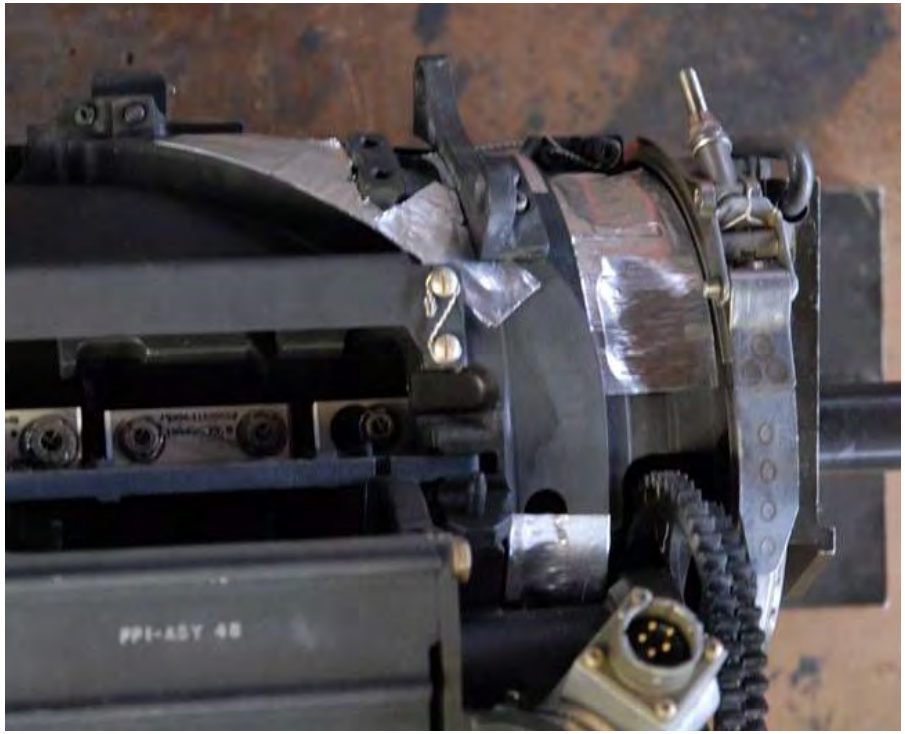


FEEDER COVER

- 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

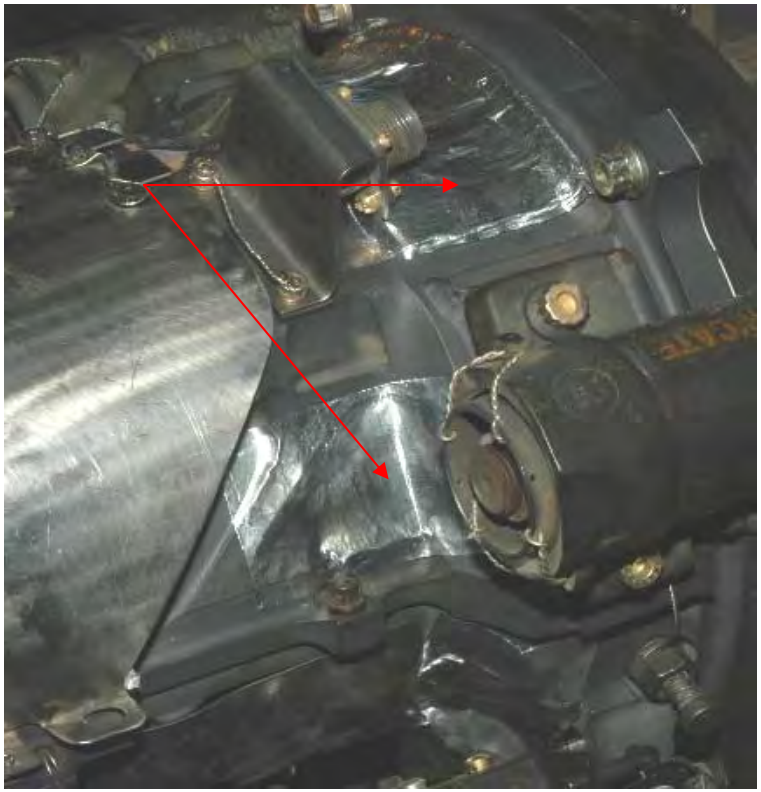
CL Med Cal ISE

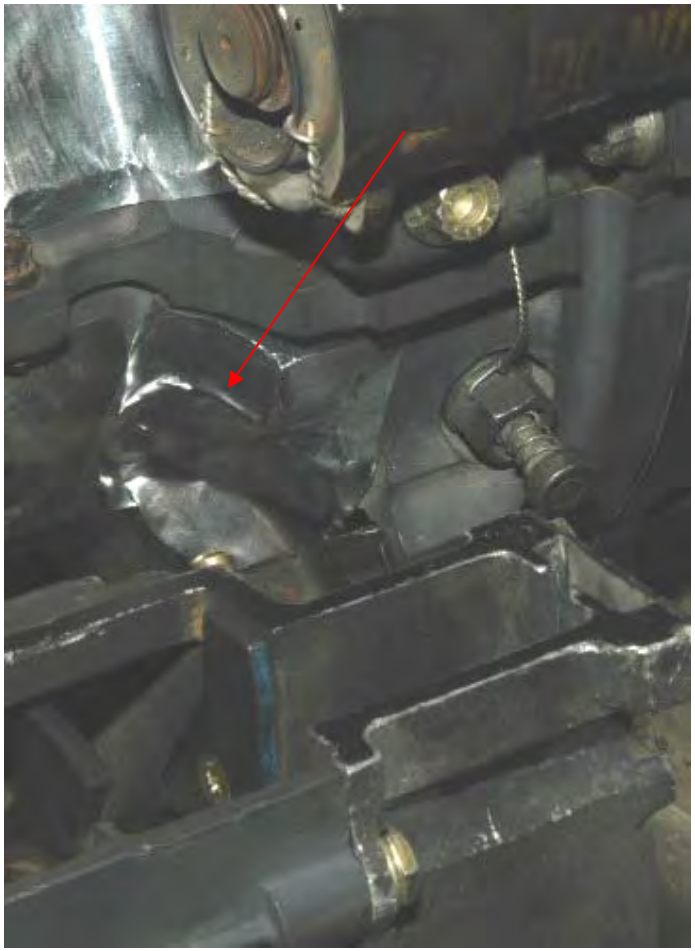




M197 BLADE TAPE

CL Med Cal ISE







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.

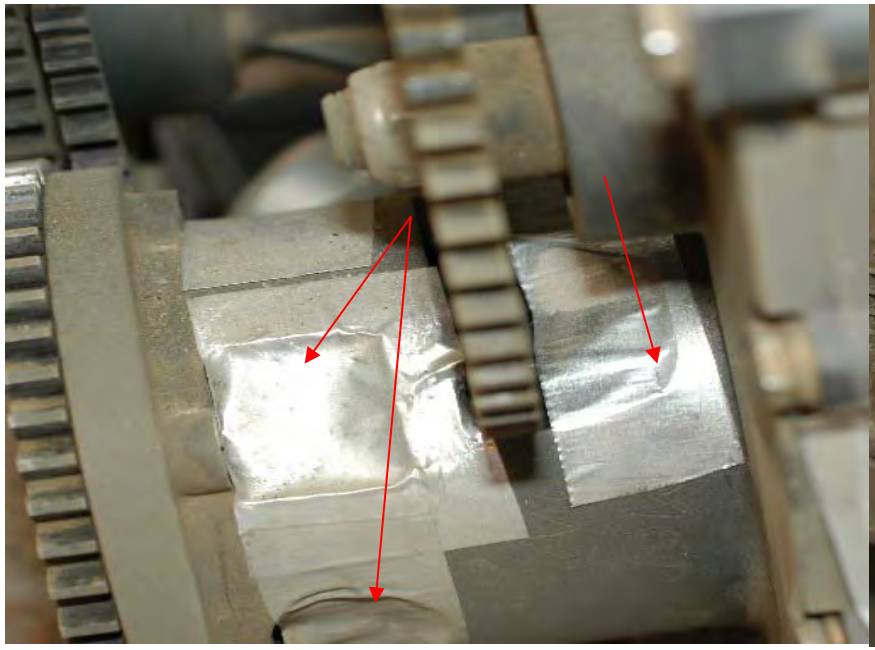
M89 BLADE TAPE

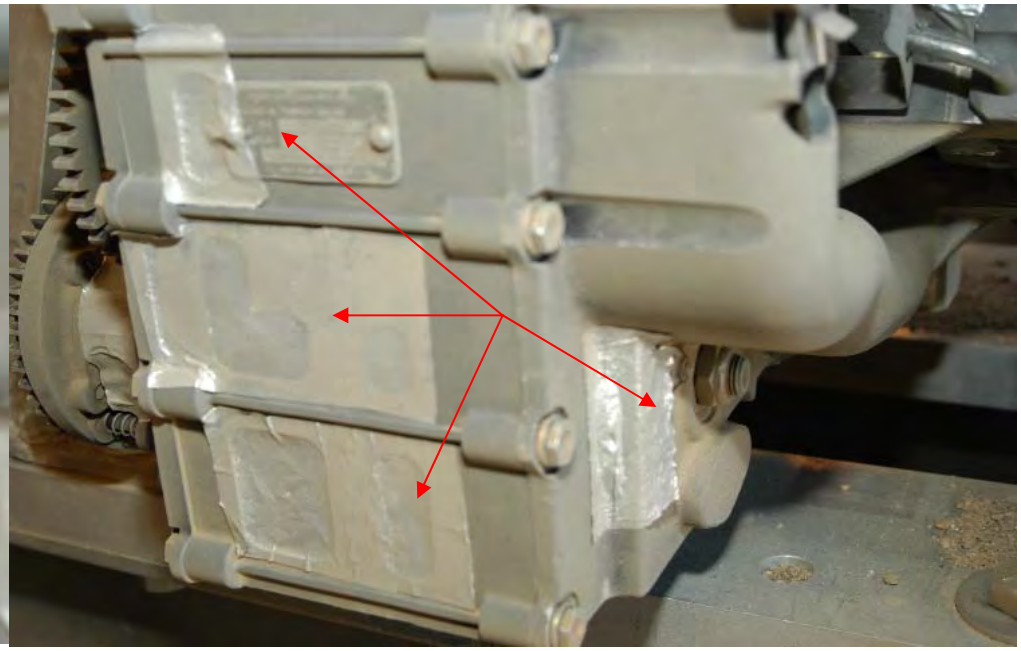
CL Med Cal ISE





M89 BLADE 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





BTL TESTING

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



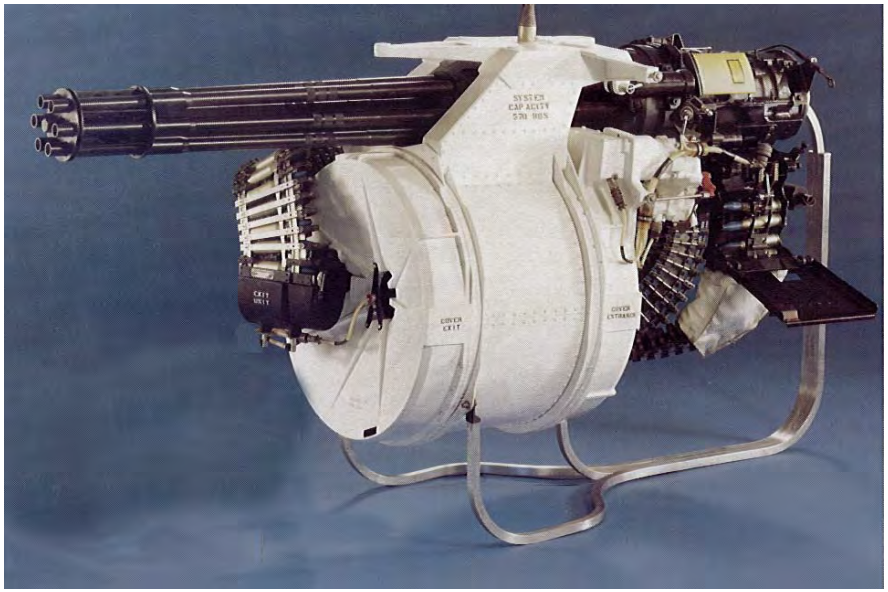
- The AH-1W Gun System is the ultimate defense for Aircrew flying combat missions. When operable, the system has multiple uses and is extremely deadly. The Environmental Kit will significantly increase the AH-1W Gun System reliability and reduce maintenance hours by decreasing Gun and Feeder jams caused 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

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

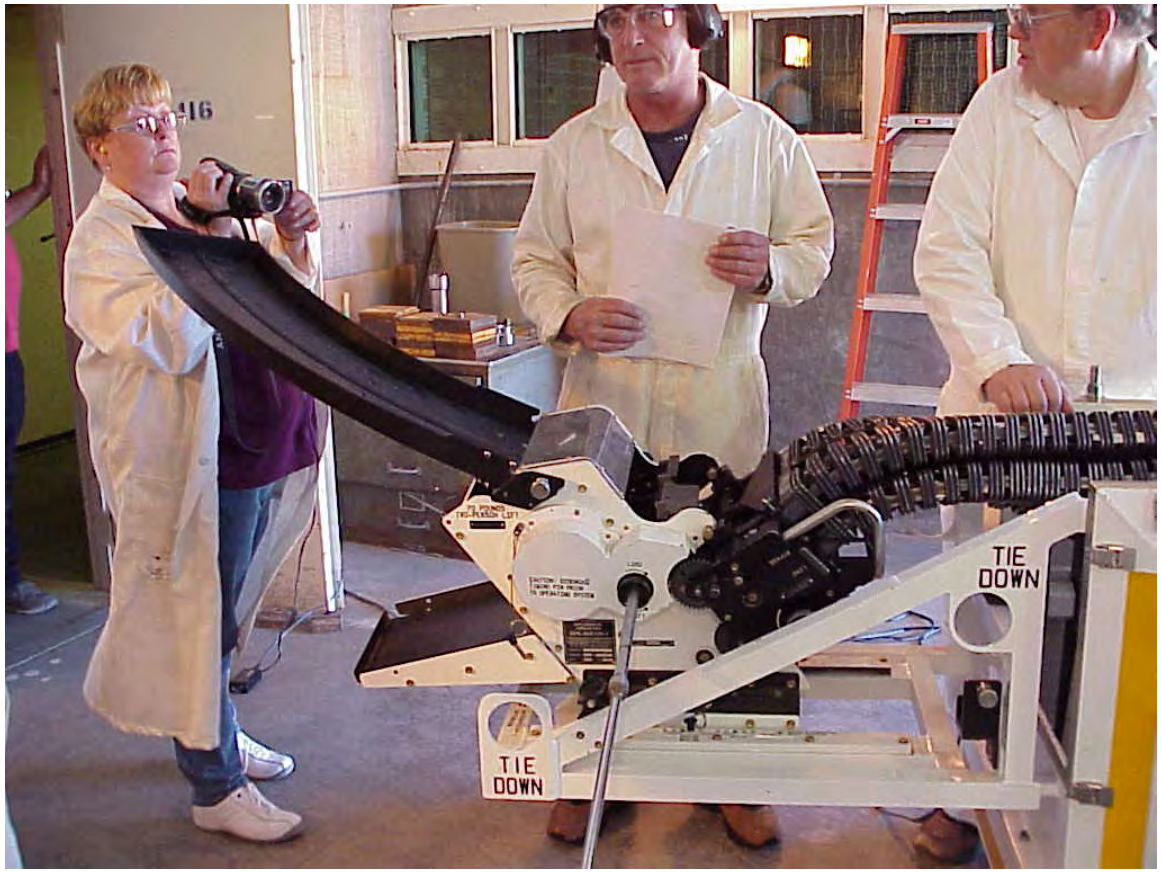
TEST CONDUCT (cont'd)
Cycle Test

- **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.**

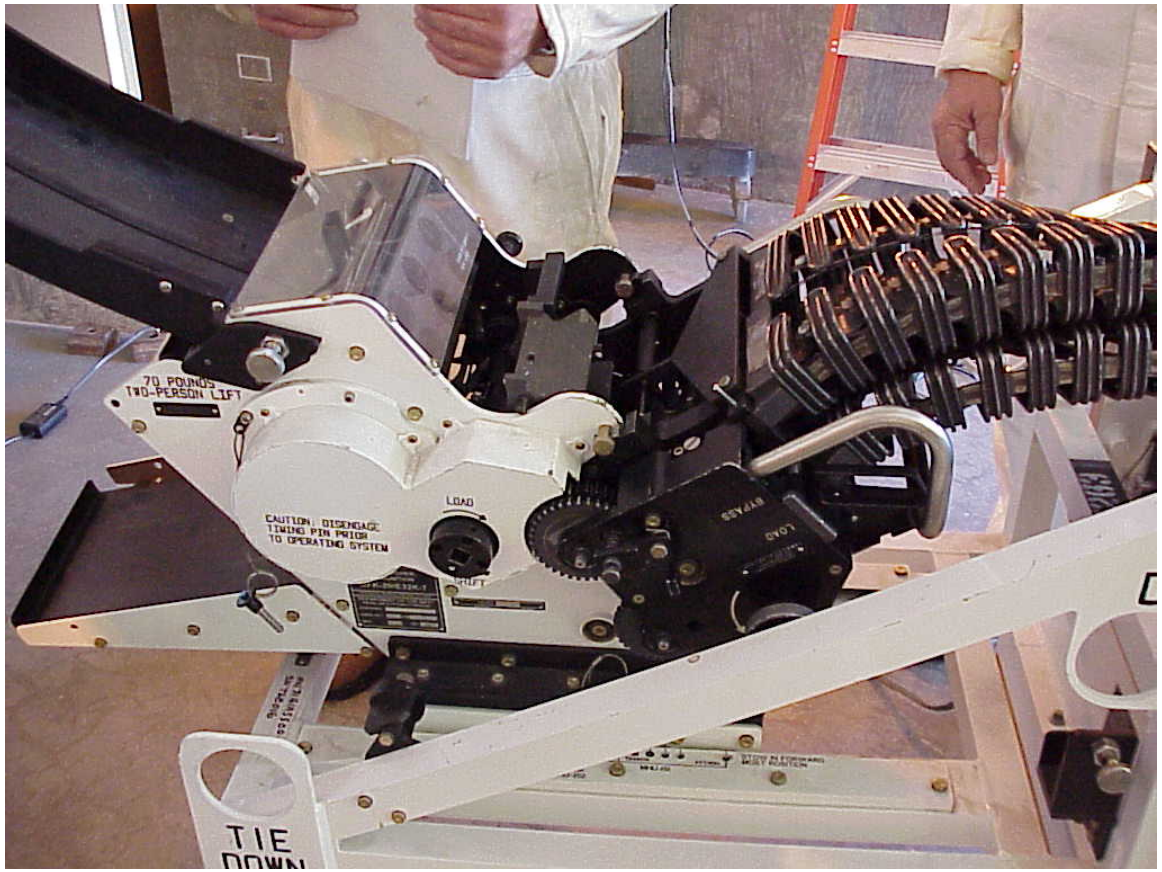
VACUUM LEAK TEST CHAMBER



LALS-II LOADING TRANSFER UNIT



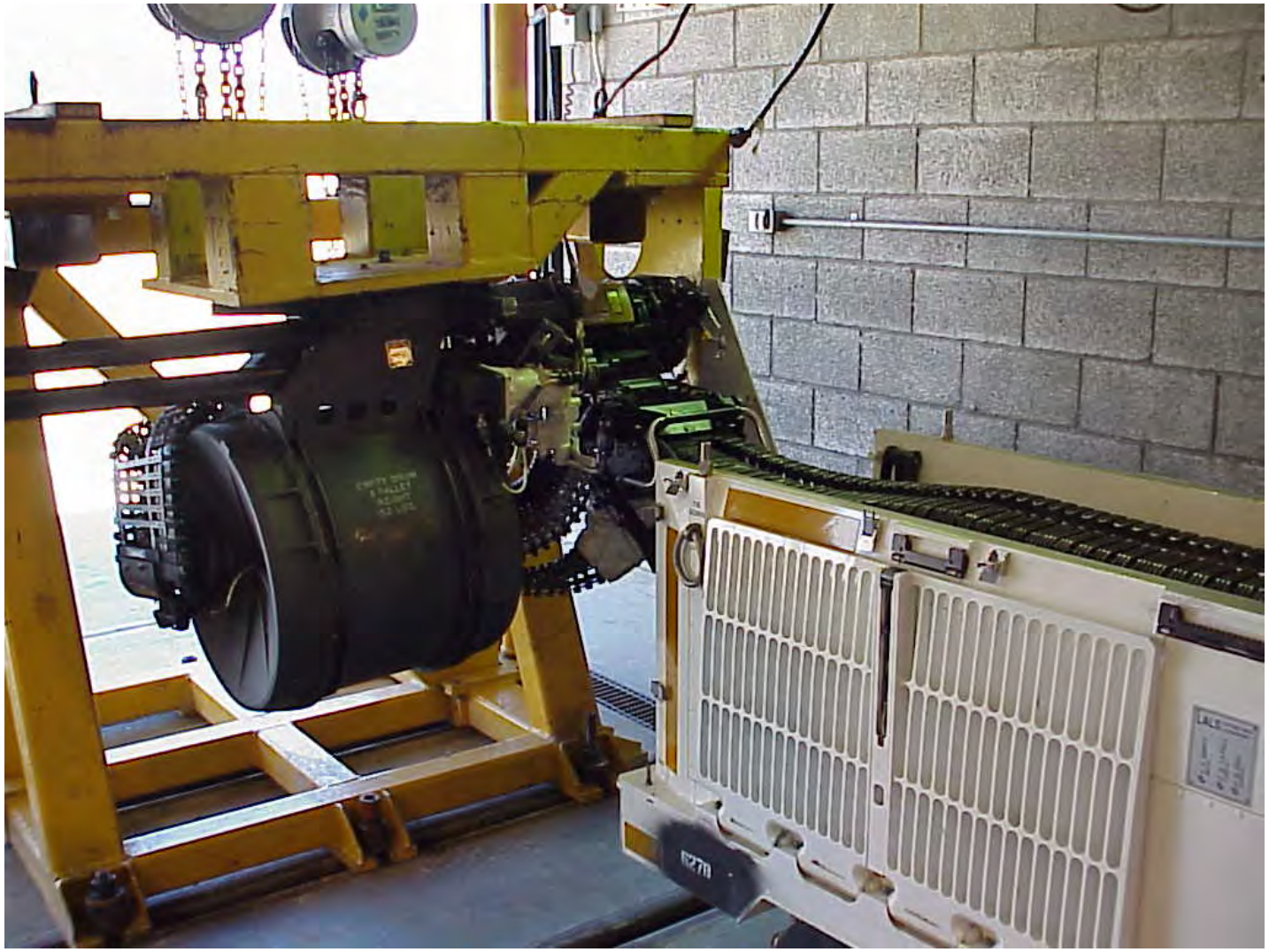
LALS-II LOADING TRAY



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**

  -<u>All</u> 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



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 <u>may</u> break seals**
- **Cycling through the gun at rate <u>does</u> break seals**
- **Dropping ammunition <u>does</u> 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



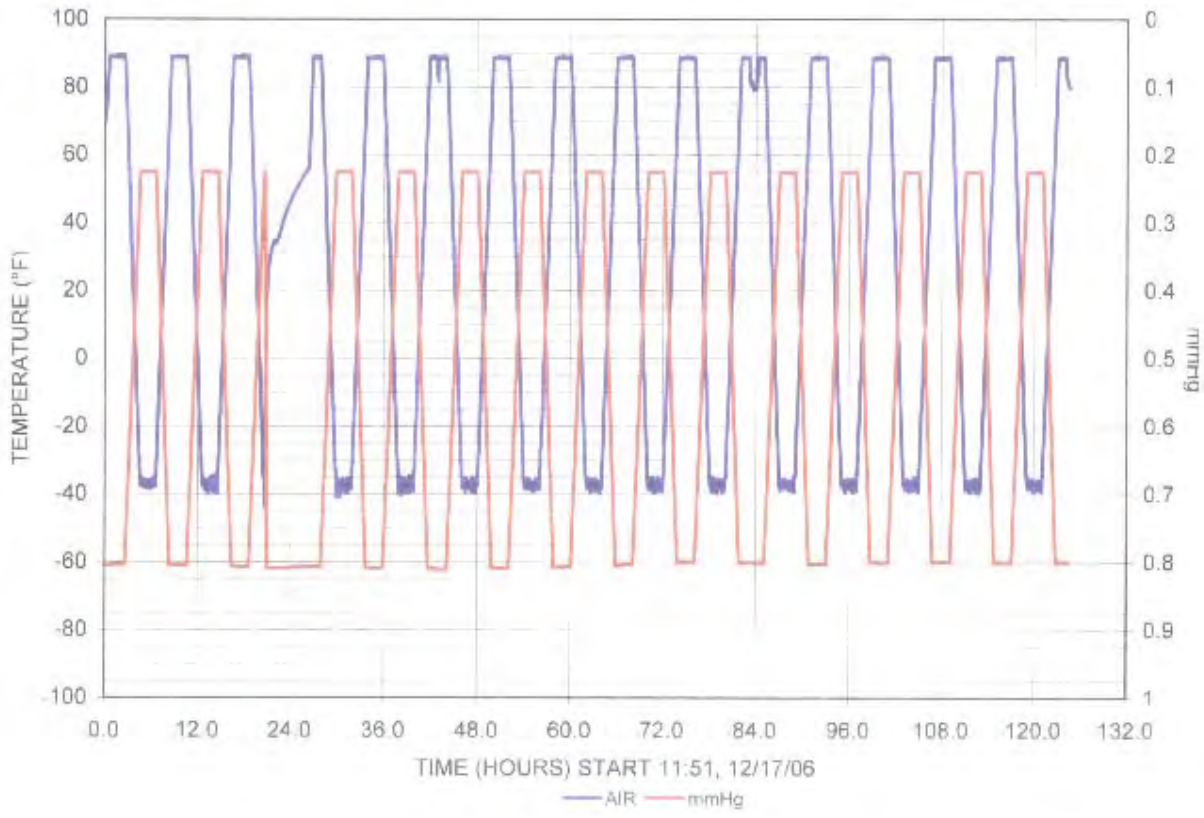
TEST CONDUCT (cont'd)
THA Testing

- **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**

NAVAIR

NAWC
TEMPERATURE HUMIDITY ALTITUDE

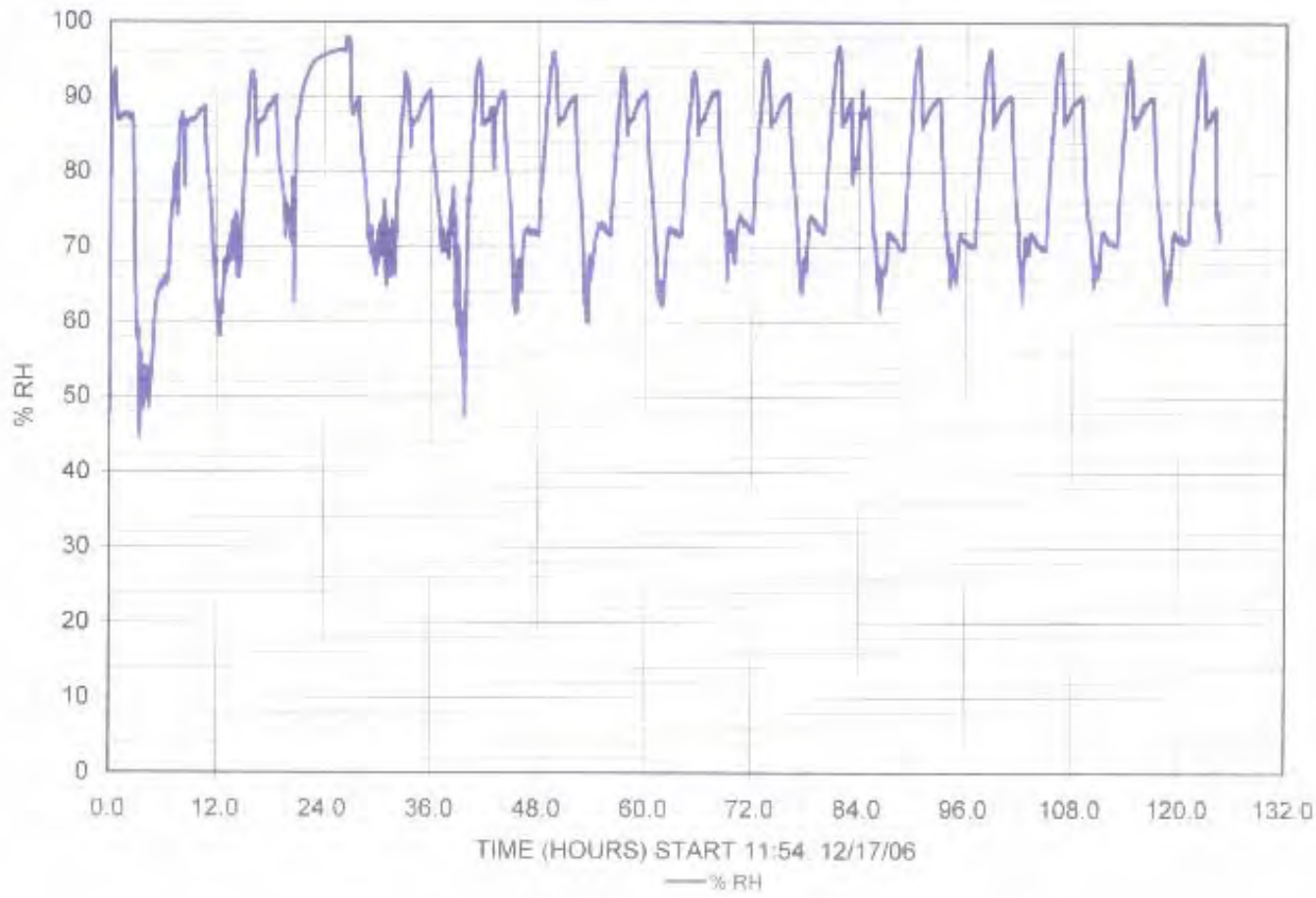
MJO: N001762A



NAVAIR

NAWC
TEMPERATURE HUMIDITY ALTITUDE

MJO: N001762A



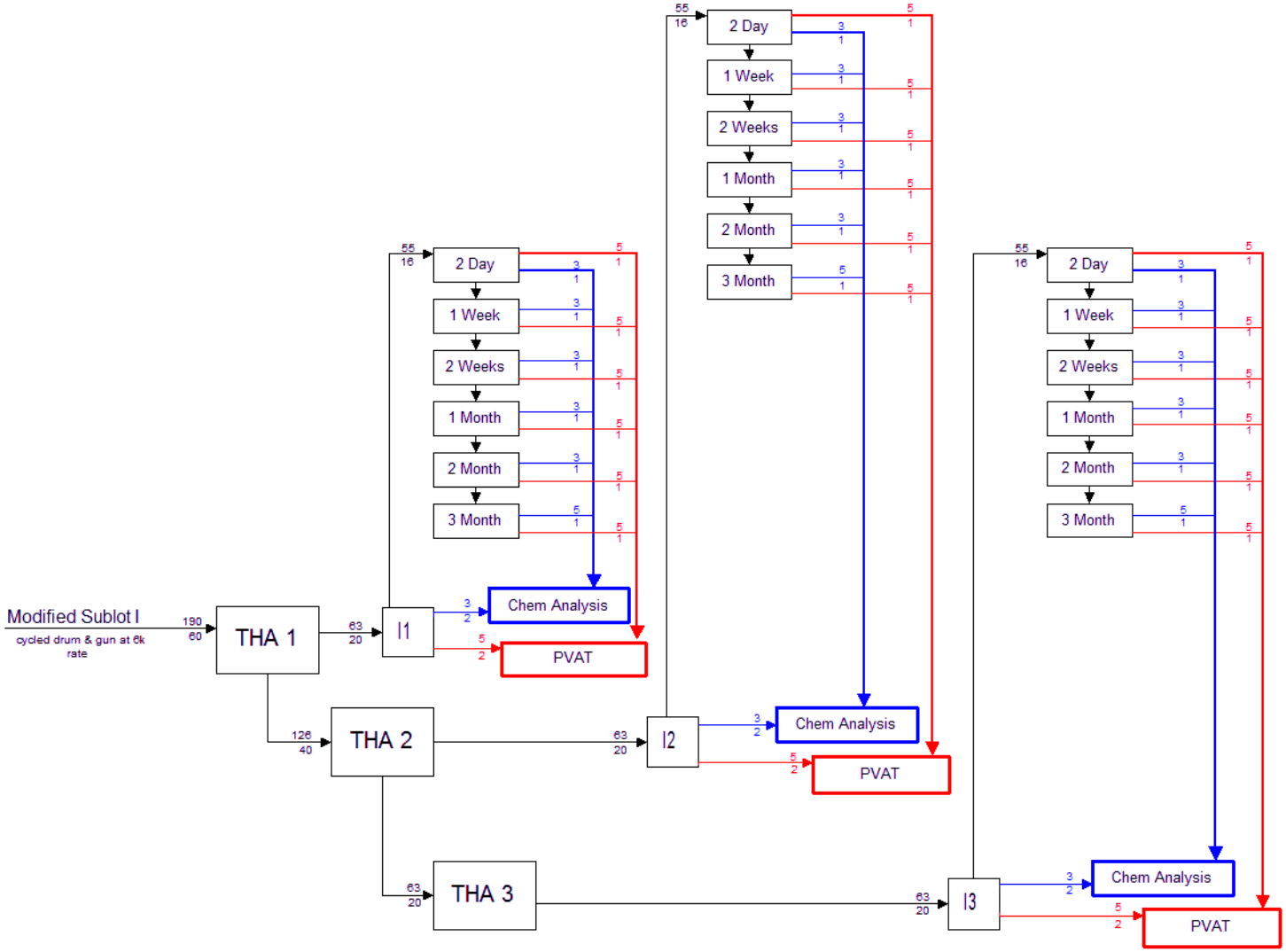
TEST CONDUCT (cont'd)
Artificial Aging

- **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

- **160º 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



NDIA

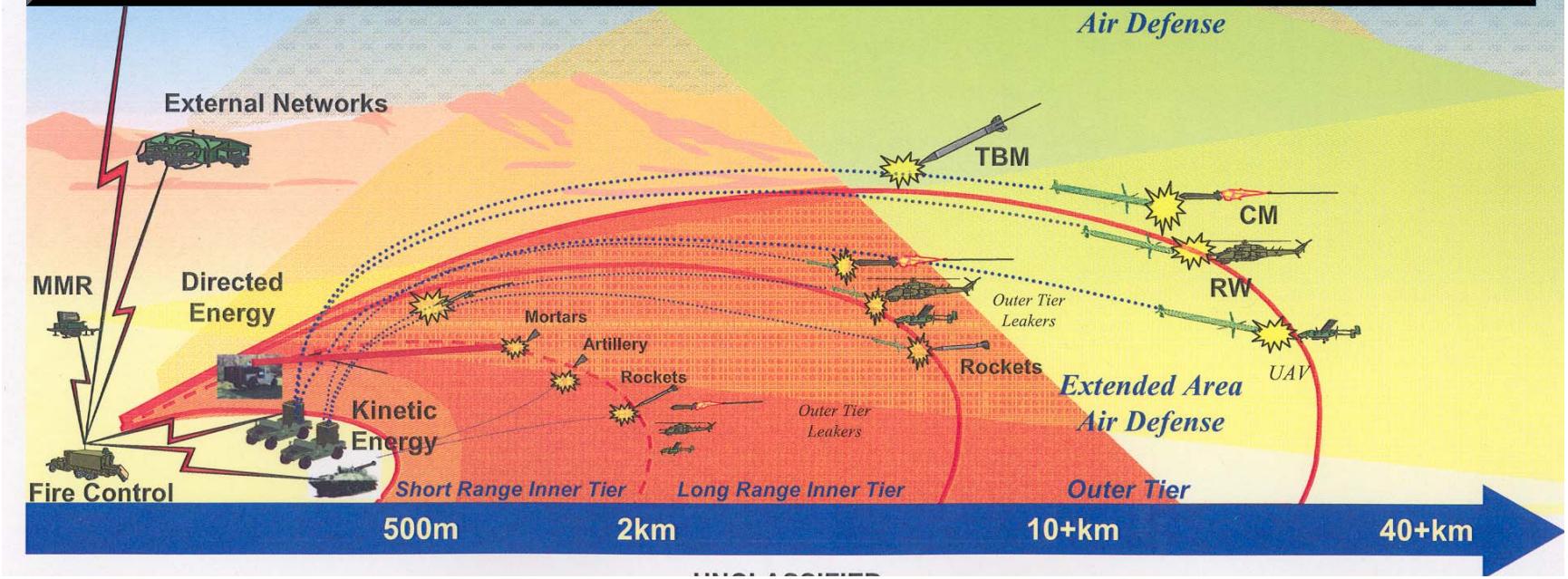
42nd Annual Armament Systems Gun & Missile Systems Conference

April 23-26, 2007

Presented by;
Phil Brislin
RDECOM-ARDEC

EAPS Goal and Battle Space

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



Program Requirements

Defeat RAM Aerial Threat Targets

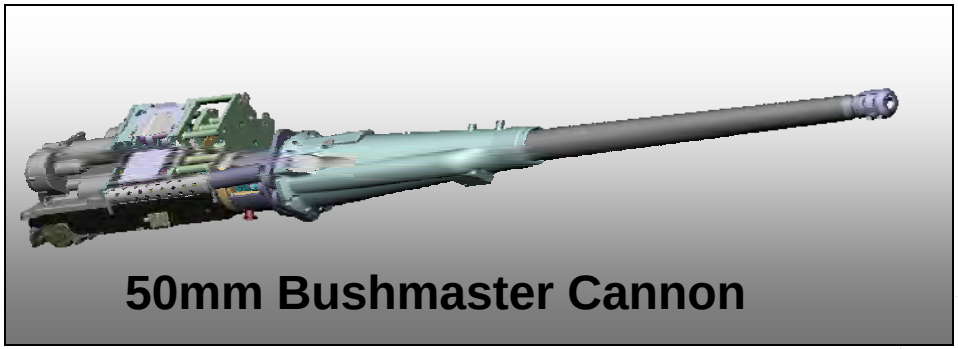
- Small Presented Areas
- Low RCSs
- Thick, Hard Warhead Cases
- Short Times of Flight
- High Rates of Fire
- Dual Purpose Improved Conventional Munitions (DPICMs)



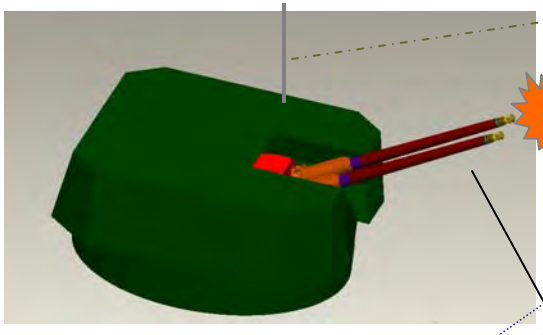
Target List

- **Mortars: 60 mm – 120 mm**
- **Rockets: 107 mm-240 mm**
- **Artillery: 122 mm-152 mm**

EAPS Baseline Concept



50mm Bushmaster Cannon



RF Data Link

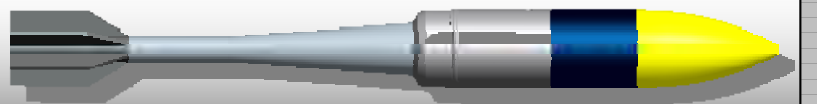
Radar Track

Forward Fragmentation Warhead Detonation

Mid-Flight Course Correction

10 Round Burst





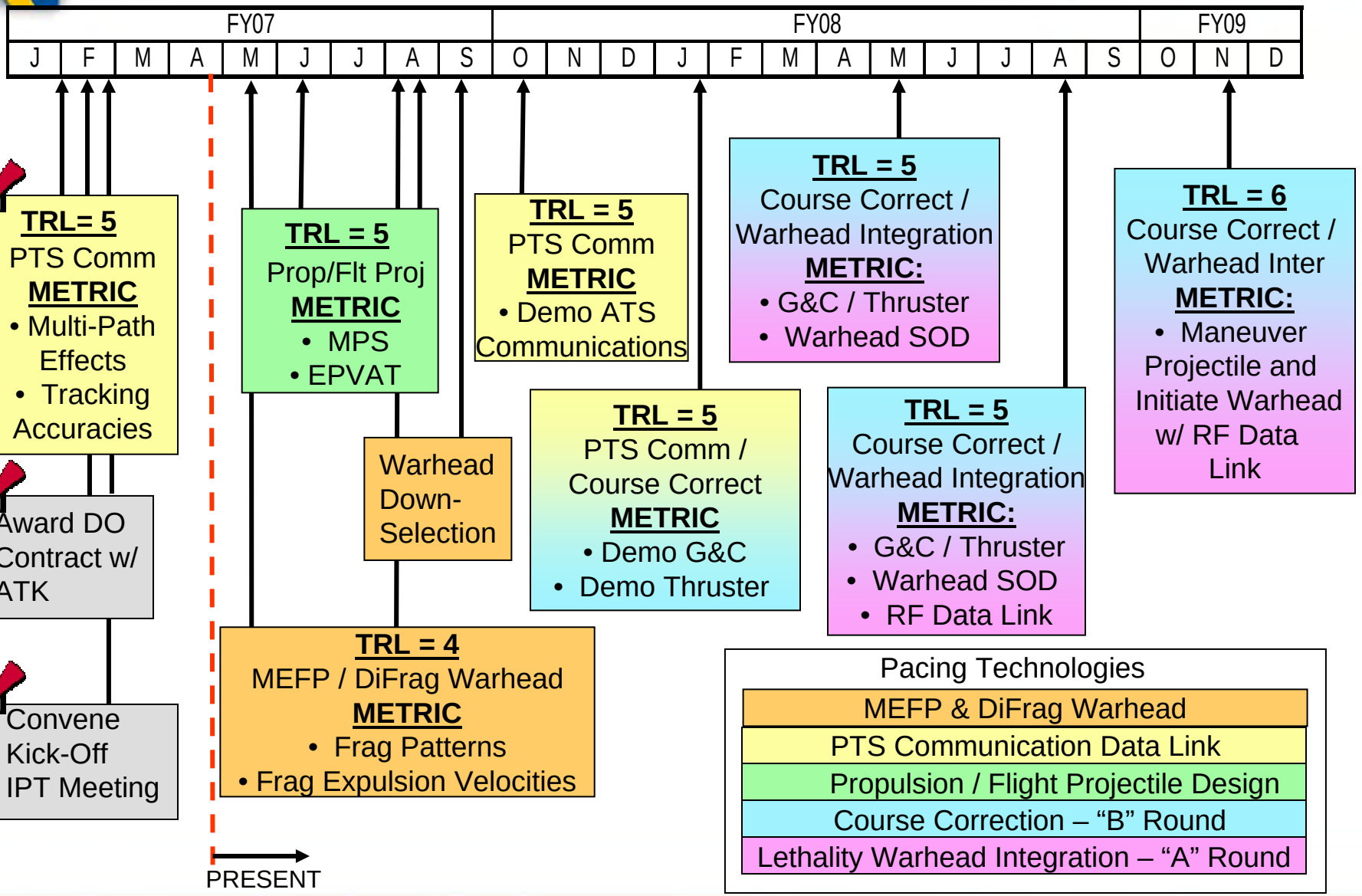
50mm Course Corrected Projectile

Goals and Objectives

- By the end of FY08 Demonstrate:
  - EAPS 50mm Automatic Cannon on Hardstand Mount
  - 50mm Lethality Round
  - 50mm Course Correction Round

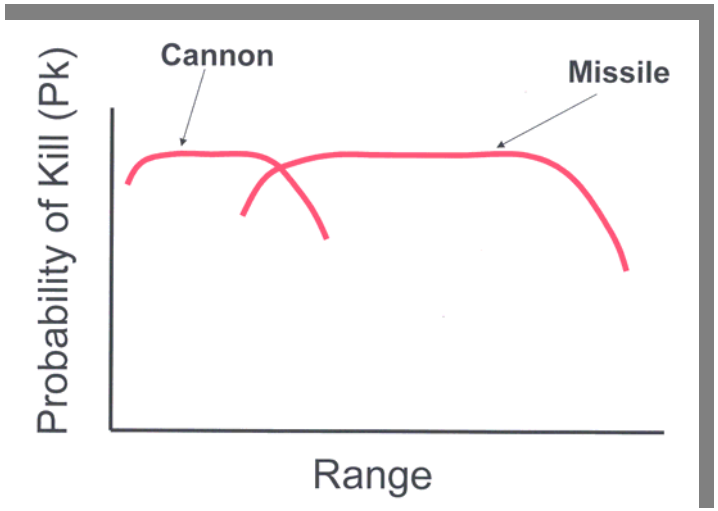
  Common Projectile Carrier Demonstrated Separately
  - ATS Radar Integration for Tracking and RF Communication
  - Component Level Tests to Demonstrate Fuzing, Warhead Lethality, Course Correction and Engagement Accuracy Against Static Targets
- Continued Systems Analysis to Validate the System Level Effectiveness
- Transition to Follow-On System Integration Development

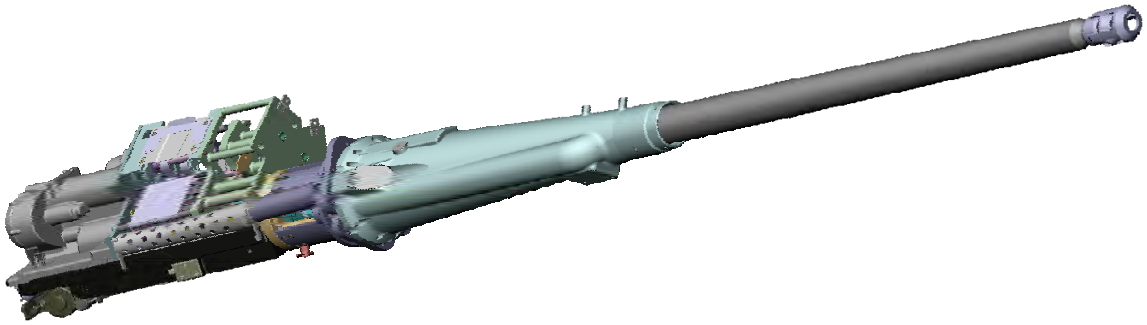
Program Milestones



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

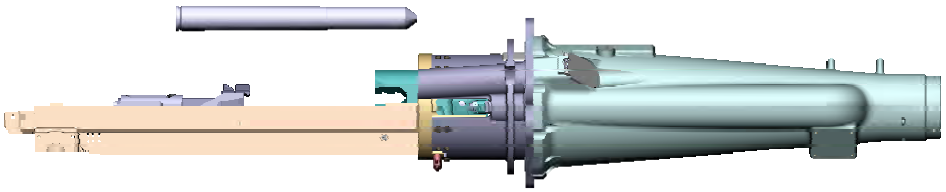


- Hybrid Bushmaster Cannon
- Accommodates EAPS 50mm Caliber Cartridge Length
- No New Development Required
- Twin Guns in Common Turret

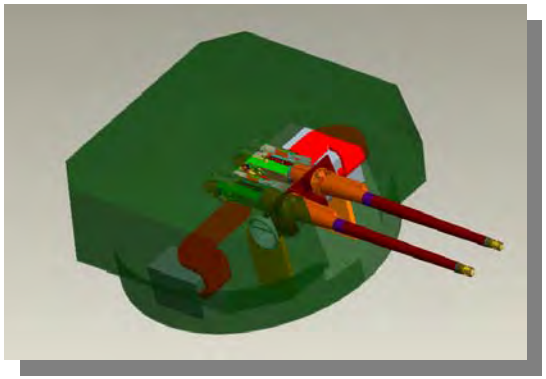
50mm Bushmaster Specs

- **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

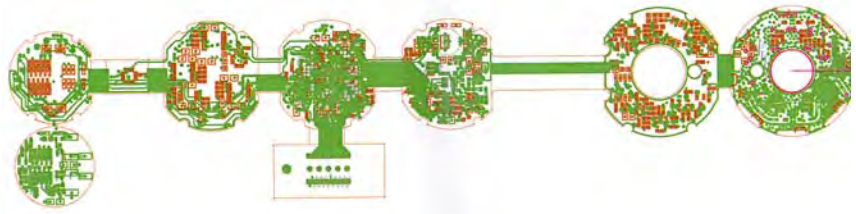


Twin 50mm Cannons in EAPS Turret

ATS Radar Communication Data Link

- 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

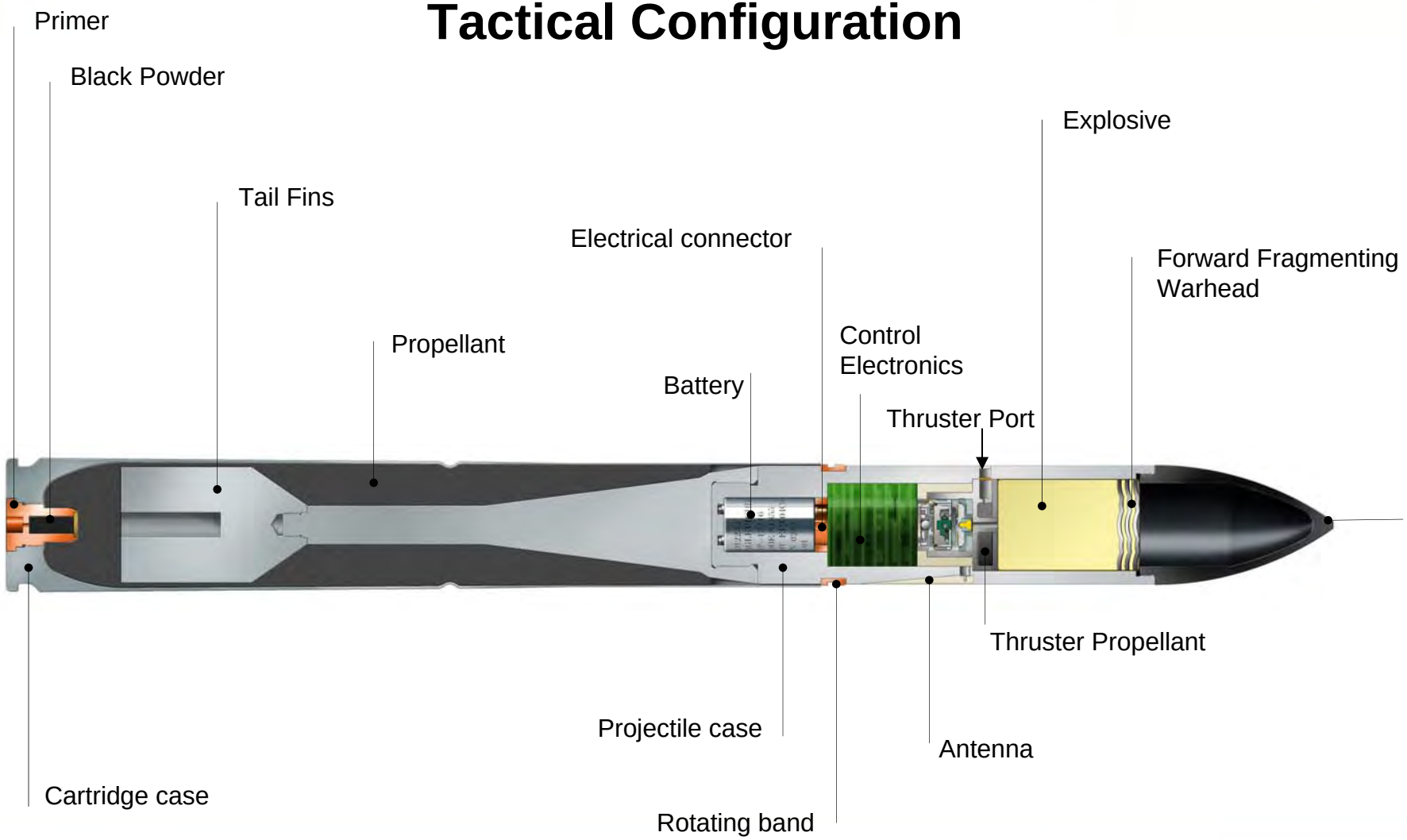




Miniaturized Transceiver

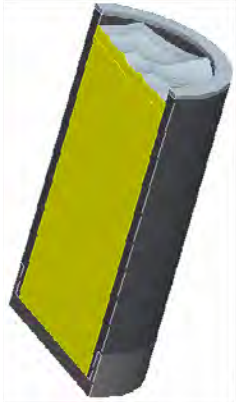
Current Baseline EAPS Projectile

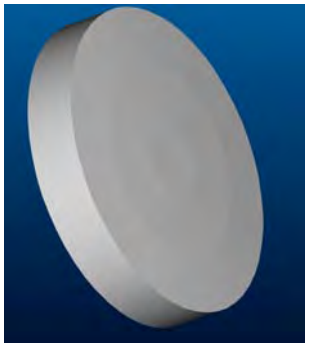
Tactical Configuration



Dual Warhead Development Paths

- Baseline Design :
  - *Multiple Explosively Formed Penetrator (MEFP) Warhead*
    - Use of a 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

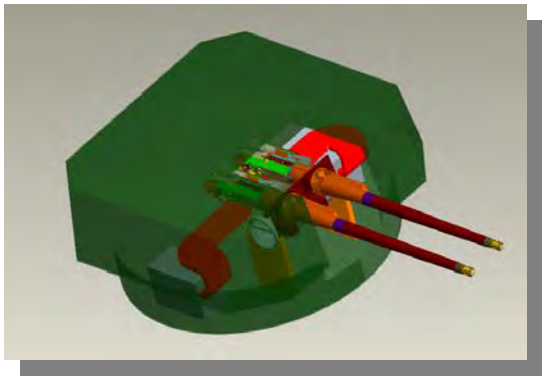




Proposed Follow-On Program

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.**

- **Provide: Forums for the Exchange of Information between Government and Industry on Matters of National Security.**

Organization Objective: ***Provide "Value Added" Symposiums and Activities Ensuring Mission Objectives***

Bottom Line

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

Leadership

Objective: Coordinated Focus and Vision for Armament Systems

Armaments Division

Dave Broden

Committees

- Small Arms Systems — Brian Berger
- Gun And Missiles — Mike Till
  - Guns/Ammunition
  - Rockets/Missiles
- Future TBD — TBD

Themes, areas discussed; no specific action

Responsive Organization – Ensures Relevance

Scope – Area of Interest – Responsibility Definition Clarity

Establishing and Ensuring Strategic Focus

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

Gun and Missile Systems

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

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

Synergism → Commonality

Common Enabling Technologies, Modeling/Simulation, Man-Tech

Links to Other Committees

2007 Symposium

Guns and Ammunition

Rockets and Missiles

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
  - Situation awareness
  - Lethality
- 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

Linking to Theme

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

Readiness

Simultaneously

Changing the Force

Responsiveness – Technology – Capability
and

Maintaining Readiness

of
Existing Forces

Industry Responding to Joint Force Needs

Small Arms Systems

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

Small Arms Committee

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**

Strategic Focus Topics (Continued)

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**

Executive Committee Improvement Topics

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.

Armament Division Focus Topics

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

Armament Division Focus Topics (continued)

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

NDIA International Symposium Links

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

NDIA Messages and Content Has Impact

and

Website Used Extensively as Resource

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

Armament Division

Committees

1. Guns and Missiles ---Mike Till Chairman

2. Small Arms Systems --- Brian Berger Chairman

Armament Division

• **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.

Armament Division

- **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.

Armament Division

• **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.

Armament Division

• **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.

Armament Division

- **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 Symposiums. This is underway.

Armament Division

- **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.

Armament Division

- **Focus Area/Objective: Including System Integration and Enabling Technologies in the Armament Division Symposiums 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.**

Armament Division

- **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

Armament Division 2007

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

Armament Division 20067 Highlights

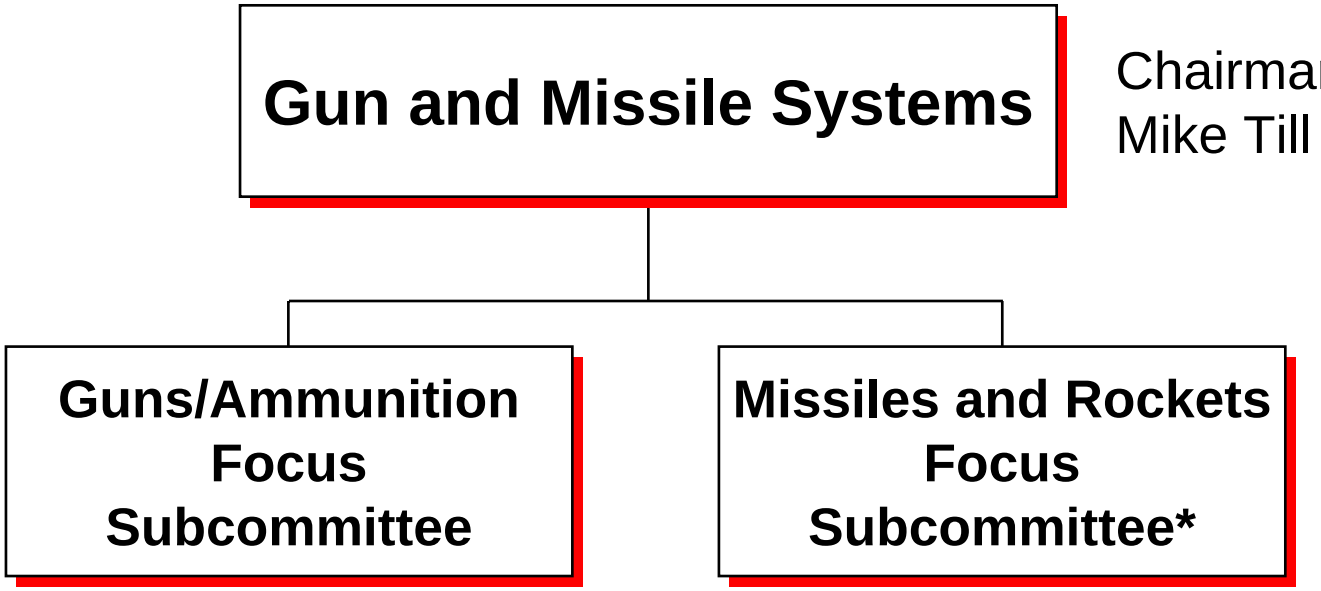
1. Focus on relevant and "value added" topics
2. Solid links to Transformation and future topics
3. "Lessons learned" and "after action reports" input shapes the future
4. Recognition of need to address industrial base readiness — capability — responsiveness---capability today and the future
5. Executive 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



*May be 1 or 2 subcommittees

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

Guns, Ammunition, Rockets, Missiles Section/Committee---Gun and Missile Systems

Committees were	Committee is
Guns and Ammunition	, Gun and Missile Systems
Missiles and Rockets	

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 Disclaimer

- **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 <u>is Intended to Stimulate Discussion</u> 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**

Requirements and Trends Recommendations

- **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







Approved for Release by TDA

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

Approved for Release by TDA

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



Approved for Release by TDA

120mm Rifled Ammunition for USMC



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

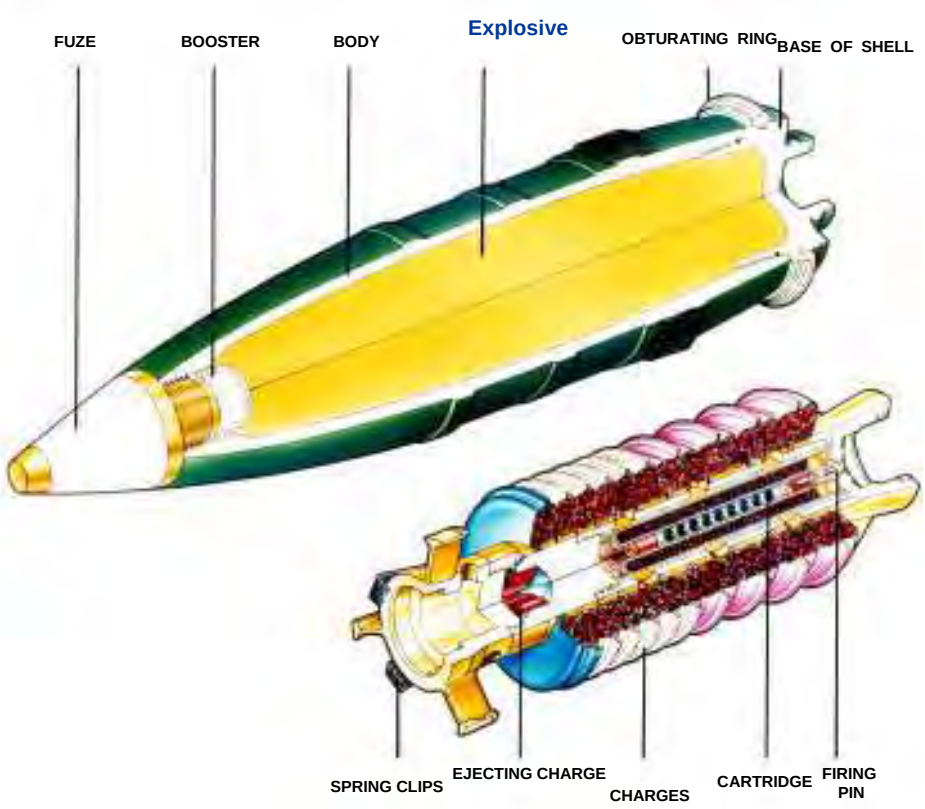
EFSS HE Ammunition Upgrade

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



Approved for Release by TDA

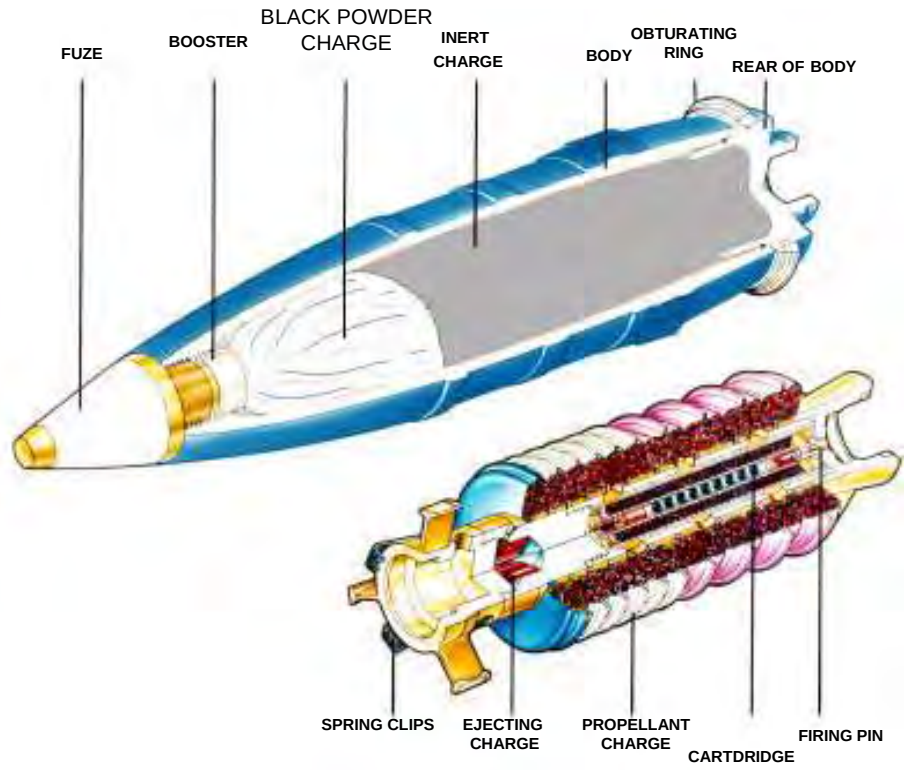
EFSS Practice Ammunition Upgrade

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



Approved for Release by TDA

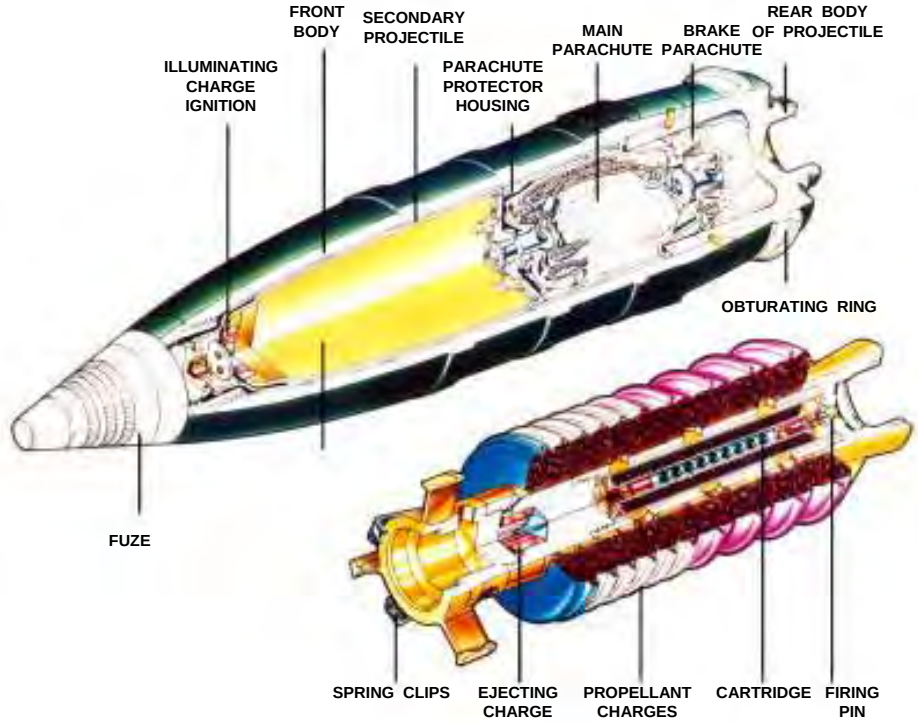
EFSS Illumination Ammunition Upgrade

Modifications to Illumination Projectile

- Equip with an M762A1 fuze

Design Constraint

- Maintain flare ability
- Similar ballistics



Approved for Release by TDA

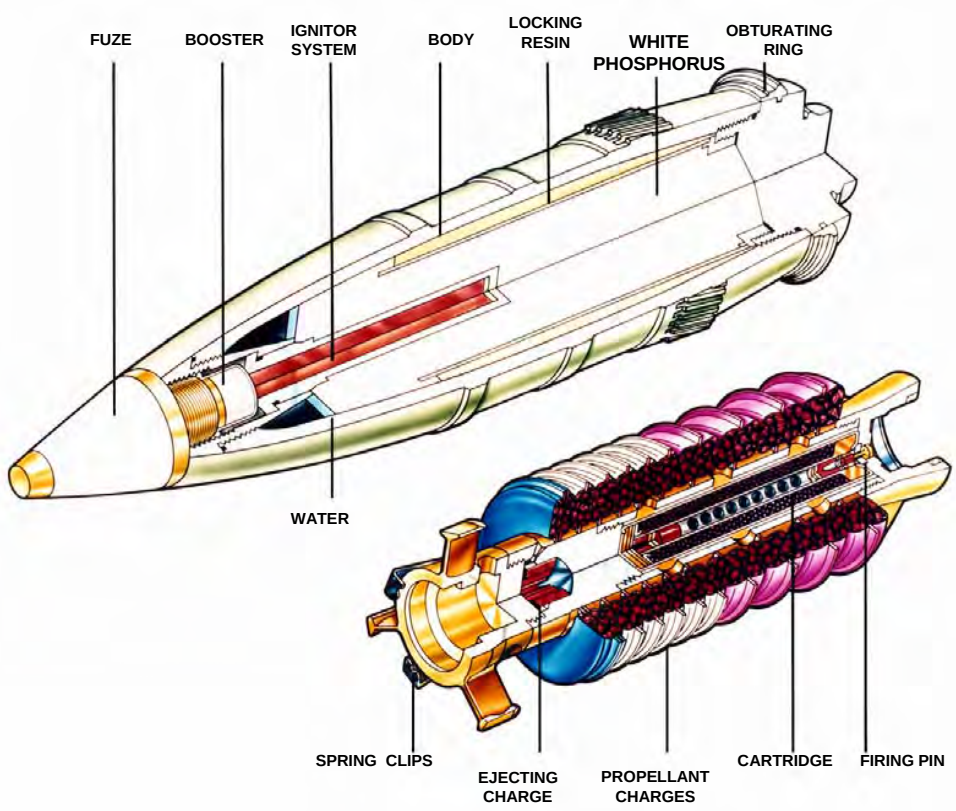
EFSS Smoke Ammunition Upgrade

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

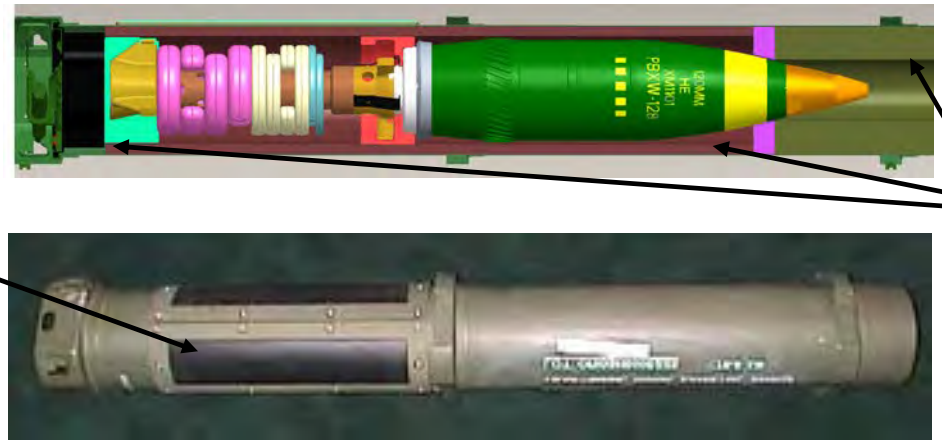


Approved for Release by TDA

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



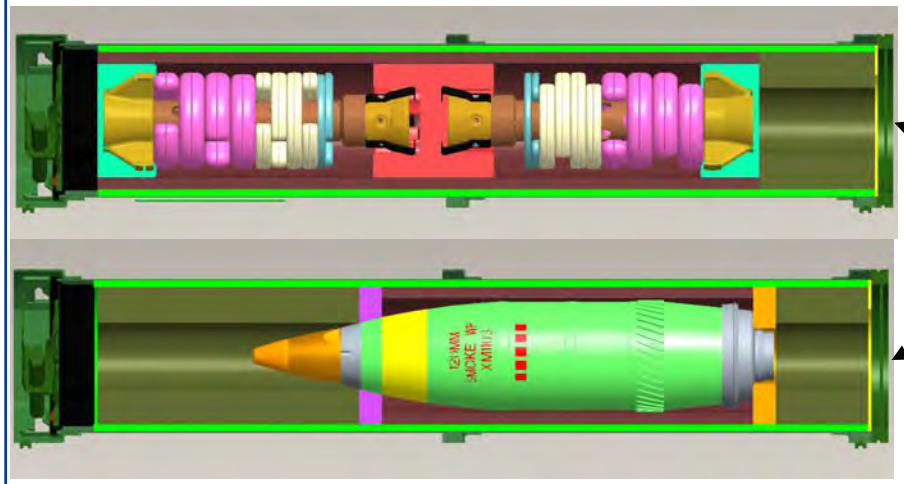
Blowout Panels allow pressure release from inside the container

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

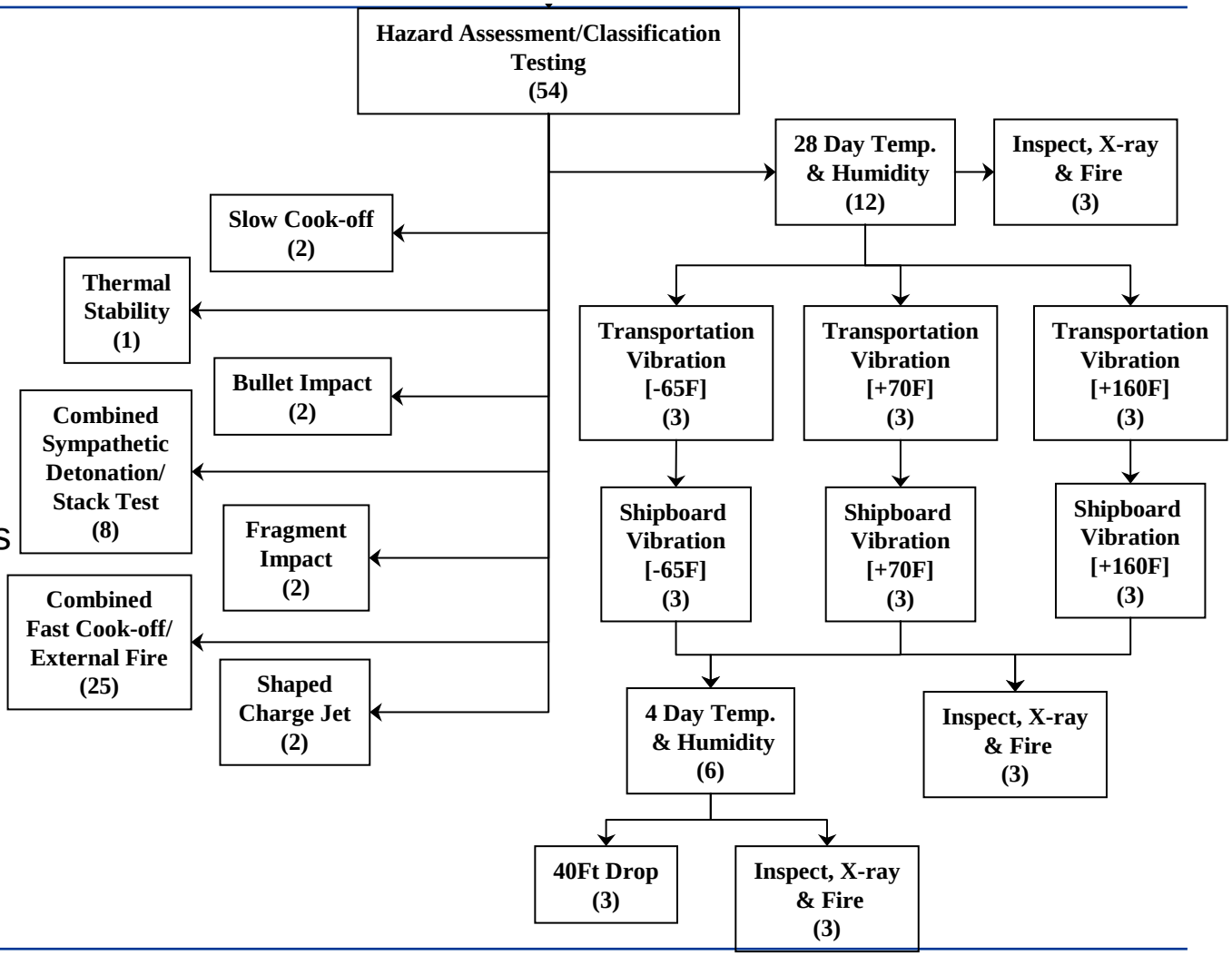
Test facilities included

- 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



EFSS Qualification Results



EFSS AMMUNITION QUALIFICATION STATUS April 16th, 2007							
	IM TESTS						
EFSS Round Types	**Slow Cook-Off**	**Fast Cook-Off**	**Fragment Impact**	**Bullet Impact**	**Sympathetic Detonation Confined**	**Sympathetic Detonation Unconfined**	**Shape Charge Jet**
HE	V	IV	III	V	Pass	Pass	I
Illumination	V	IV	III	IV	Pass	Pass	Not scheduled
Smoke Projectile	III	III (Mixed Pallet)	III	IV	Pass (Mixed pallet)	Pass (Mixed pallet)	Not scheduled
Smoke Tail Charge Assembly	IV		III	IV			Not scheduled
Practice	V	IV	III	IV	Pass	Pass	Not scheduled

IMRB reviewed the EFSS ammunition qualification results

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

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

PROGRAM EXECUTIVE OFFICE MISSILES AND SPACE

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

ANY SOLDIER - ANYWHERE - ALL THE TIME...

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

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PROGRAM EXECUTIVE OFFICE
MISSILES AND SPACE

PERFORMANCE GAP IS CLOSING









Foreign systems continue to improve and challenge our systems in performance









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FUTURE WARFARE TRENDS
THREAT AND TARGET TRENDS

- **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

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PROGRAM EXECUTIVE OFFICE MISSILES AND SPACE

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**

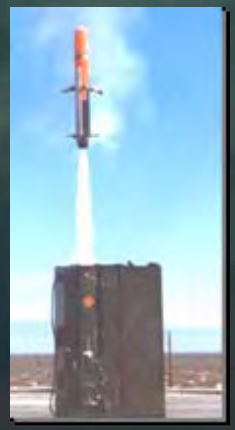
PROGRAM EXECUTIVE OFFICE
MISSILES AND SPACE

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THE ERODING BUSINESS BASE

Programs In Development

Precision Attack Munition





Joint Common Missile (JCM) /
Joint Air to Ground Missile (JAGM)

PAC-3 Missile
Segment Enhancement



Programs Transitioning from Tech Base FY08-13

0

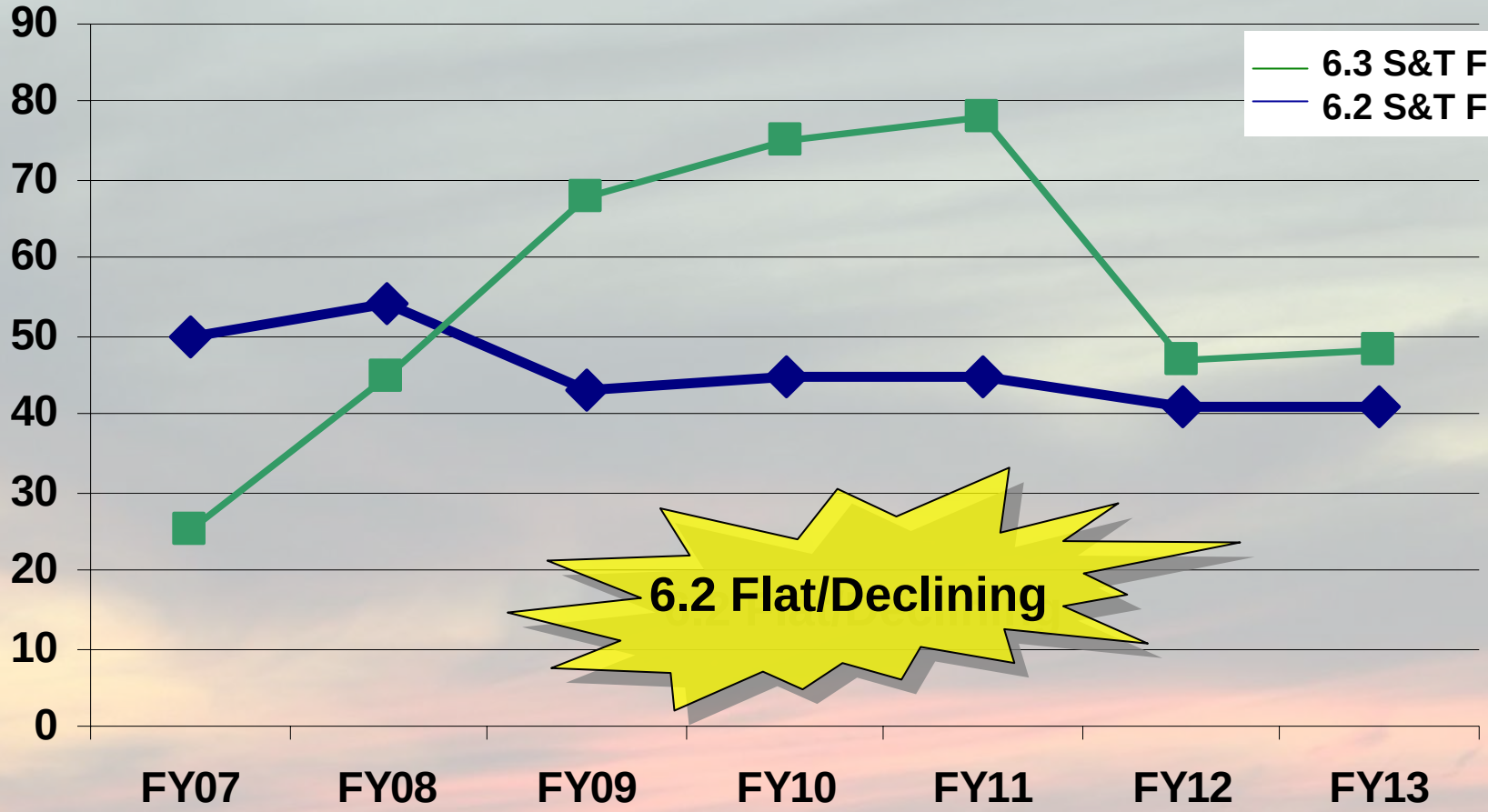
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PROGRAM EXECUTIVE OFFICE
MISSILES AND SPACE

Missile Science & Technology

Missile Tech Base FY07-13

Based on FY08 POM Position



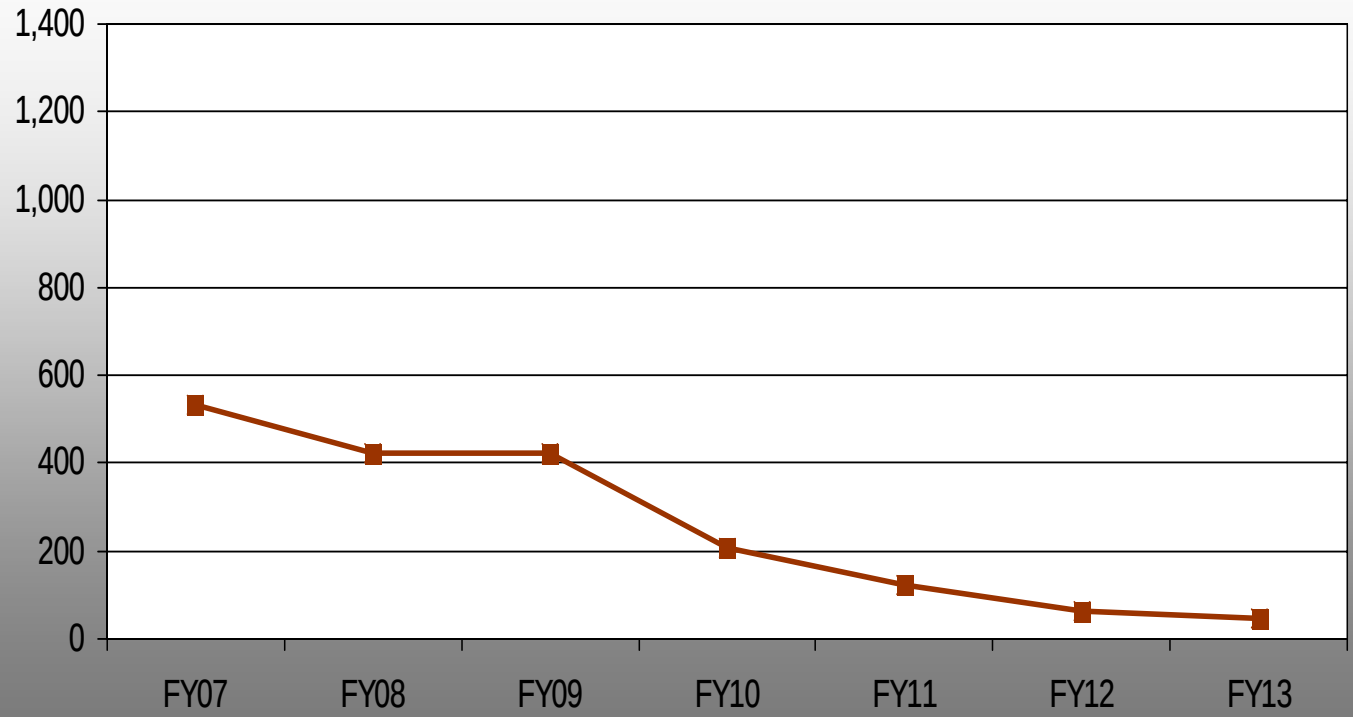
FY08-11 6.3 Increase due to Smaller Lighter Cheaper

MISSILE RDT&E

POM BES FY08

RDT&E Budget ($M) Missiles Only

TOW 2A
TOW 2B
TOW 2B AERO Variants
TOW Bunker Buster (BB)
Javelin
Javelin Block I
NLOS PAM
BASIC and ER MLRS
GMLRS (XM30 / XM31)
GMLRS ALT WHD
GMLRS P3I
ATACMS Variants (BLK I, IA, II)
ATACMS Unitary Variants
Hellfire Variants (AGM-114A-N)
Hellfire (AGM 114P+)
Joint Common Missile (JCM)
APKWS II
Hydra 70
Hydra 70 Flechette (M255A1)
Hydra 70 HE/PD (M151 / M423)
Viper Strike
Stinger Block I
PAC-2
GEM Variants
PAC-3
MSE



Funded Missiles Shown in Red

*88% in 3 Missiles—PAM, JCM, and PAC-3 / **Missile Segment Enhancement***
No Investment in Direct Fire Missiles

MILITARILY – SIGNIFICANT CRITICAL TECHNOLOGY ATROPHY









- **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	% Loss of Base
Seeker Technologies	63
Propulsion	38
Modeling/Simulation	33
Aerodynamics / Controls	32

Erosion Of This Base Will Be Unrecoverable

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PROGRAM EXECUTIVE OFFICE MISSILES AND SPACE

PATH FORWARD

- 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

PROGRAM EXECUTIVE OFFICE
MISSILES AND SPACE

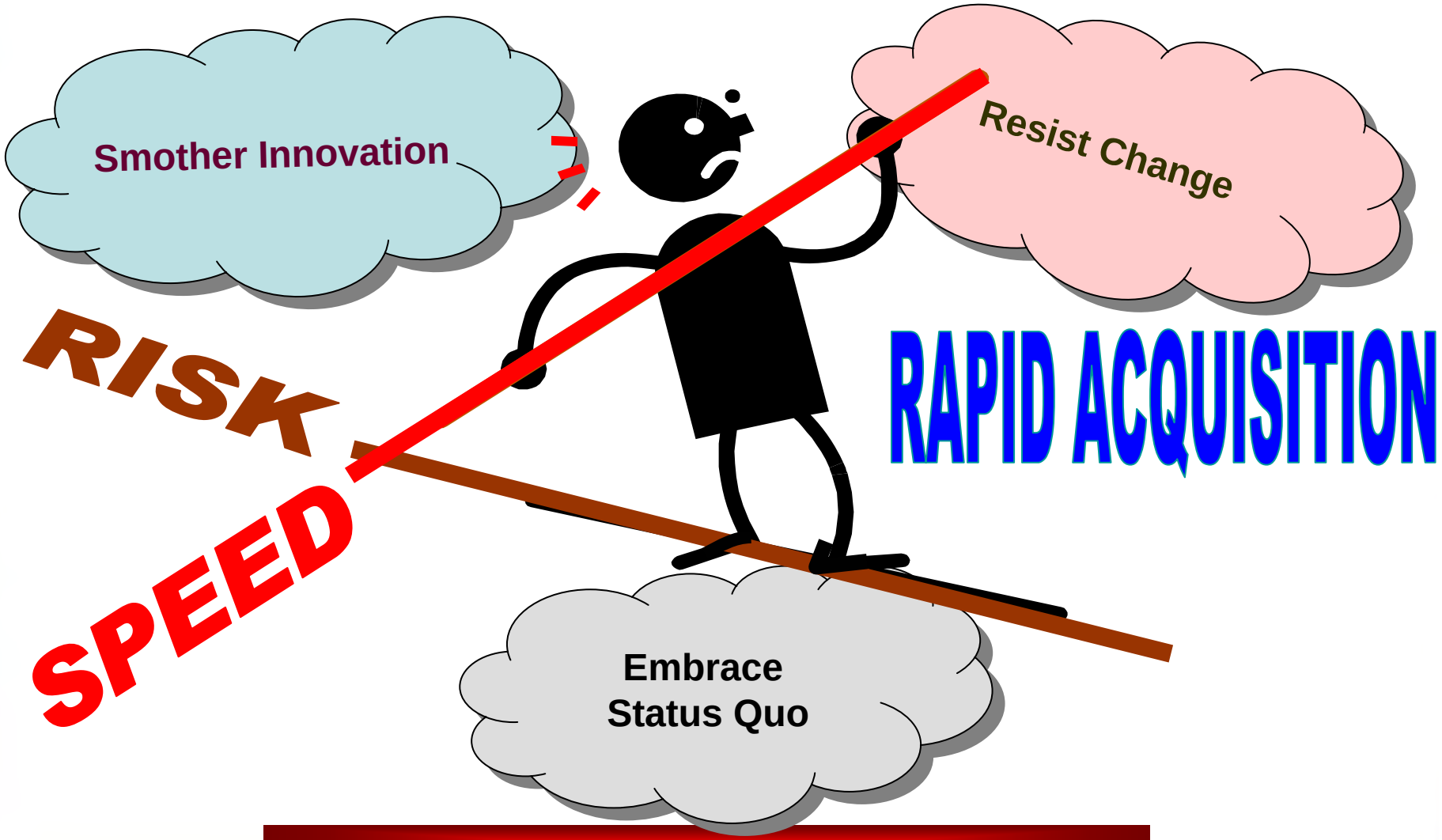
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JOINT RAPID ACQUISITION CELL

NDIA Gun and Missile Systems
Conference & Exhibition
"Meeting Warfighter Needs for the Asymmetric Threat"
25 April 2007

The Challenge We Face



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

Big A

little a

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



MEETING IMMEDIATE WARFIGHTER NEEDS

Existing Authorities

- **The Department has numerous existing authorities across several functional areas:**
  - **Funding**
  - **Requirements**
  - **Acquisition**
  - **Procurement**
  - **Test & Evaluation**
  - **Communications**

MEETING IMMEDIATE WARFIGHTER NEEDS

DoD / Service Processes

- **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)**

MEETING IMMEDIATE WARFIGHTER NEEDS

The JRAC Solution

- **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.**

MEETING IMMEDIATE WARFIGHTER NEEDS

JRAC Stand-up

- **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.**

MEETING IMMEDIATE WARFIGHTER NEEDS

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

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

1 COCOMS and Military Services have FO/GO representatives

MEETING IMMEDIATE WARFIGHTER NEEDS

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**

MEETING IMMEDIATE WARFIGHTER NEEDS

JRAC Definitions

- **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.

MEETING IMMEDIATE WARFIGHTER NEEDS

JRAC Procedures

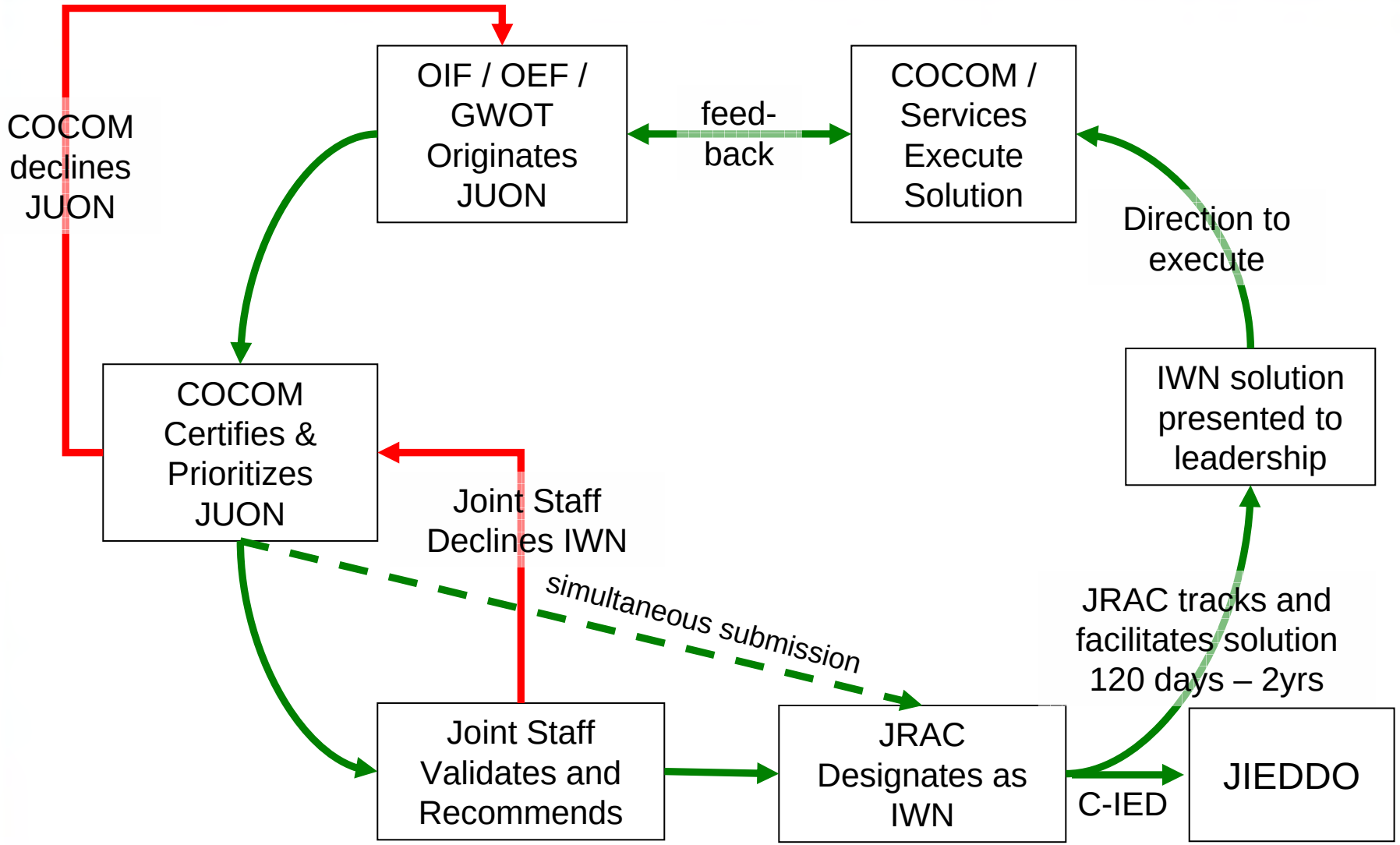
- **OEF/OIF/GWOT originator recommends JUON & obtains approval of first GO in chain-of-command.**
- **JUON (that cannot be satisfied in an appropriate time-frame by an existing Military Service / Defense Agency process) submitted to COCOM for certification / prioritization.**
- **COCOM rejects or certifies / 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).

MEETING IMMEDIATE WARFIGHTER NEEDS

JRAC Process Flow



MEETING IMMEDIATE WARFIGHTER NEEDS

Overview of Activity

- **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

MEETING IMMEDIATE WARFIGHTER NEEDS

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.**

MEETING IMMEDIATE WARFIGHTER NEEDS

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**

MEETING IMMEDIATE WARFIGHTER NEEDS

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**
  - Assisted in the drafting of JIEDDO DoD Directive 2000.19
  - 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

MEETING IMMEDIATE WARFIGHTER NEEDS

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*

MEETING IMMEDIATE WARFIGHTER NEEDS

Joint Staff / JRAC

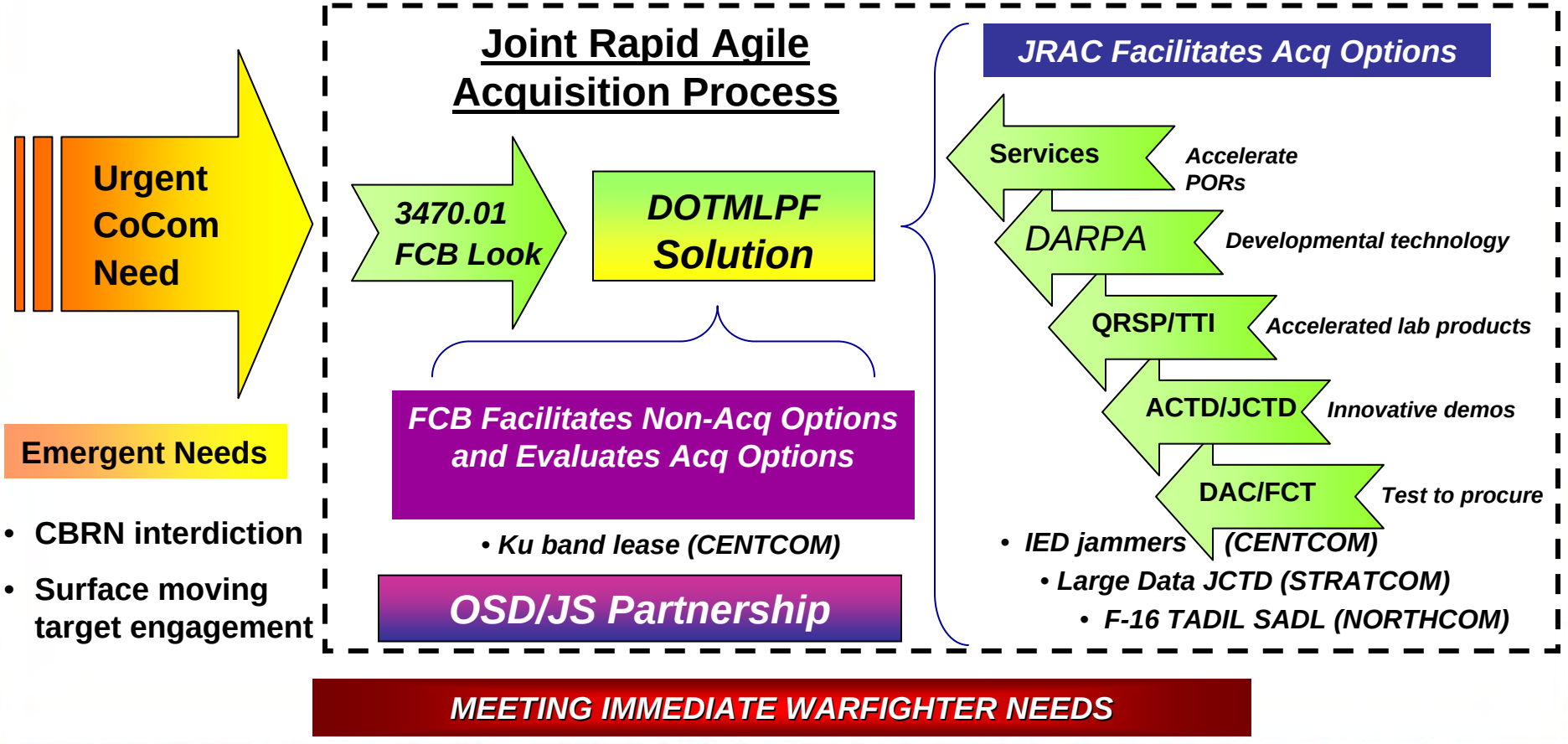
- **Policy Changes Impacting JUONs and IWNs**
  - **Rapid Validation and Resourcing of Joint Urgent Operational Needs (JUONS) in the Year of Execution, Chairman Joint Chiefs of Staff Instruction (JCSI 3470.1) Currently under revision**
  - **Secretary of Defense's Rapid Acquisition Authority**

MEETING IMMEDIATE WARFIGHTER NEEDS

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**



Rapid Acquisition Authority

- **SECDEF granted special authority in Bob Stump National Defense Act for Fiscal Year 2003 as amended by the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005**
  - **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**

MEETING IMMEDIATE WARFIGHTER NEEDS

Joint Rapid Acquisition Improvement Initiative

- **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**

MEETING IMMEDIATE WARFIGHTER NEEDS

JRAC Websites

- **SIPRNet Sites**
  - **Joint Rapid Acquisition Cell (JRAC) Website**
    - **http://www.acqs.osd.pentagon.smil.mil/jrac**
  - **JRAC JUON Tracking Tool**
    - **https://leo.acqs.osd.pentagon.smil.mil/jrac.nsf – userid & password required**
  - **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**
    - **Joint Rapid Acquisition Workshop Summary -- https://acc.dau.mil/CommunityBrowser.aspx?id=105736**
  - **U.S. Army Rapid Equipping Force -- http://www.ref.army.mil/**
  - **Air Force Warfighter Rapid Acquisition Process -- https://www.safaq.hq.af.mil/mil/wrap/index.html**

MEETING IMMEDIATE WARFIGHTER NEEDS

DEFENCE R&D DÉFENSE

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

Defence Research and Development Canada
Recherche et développement pour la défense Canada
Canada

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


GDATP Mk47 *Striker*40 AGL

- 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

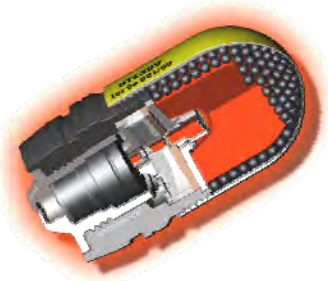

Denel (Vektor) Y3 40mm AGL

Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero





Weapon System representation



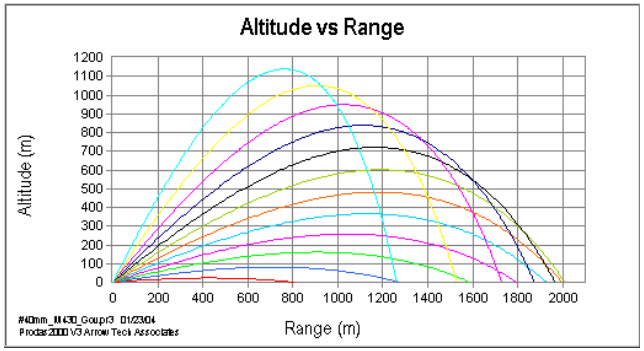
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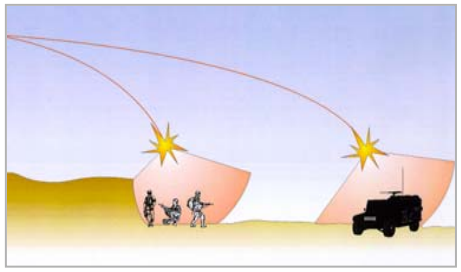


PRODAS

Round Characteristics at time of burst or detonation:

- Dispersion
- Probability of hit
- Remaining Speed
- Remaining Spin
- Angle of descent (AOD)
- Time of Flight



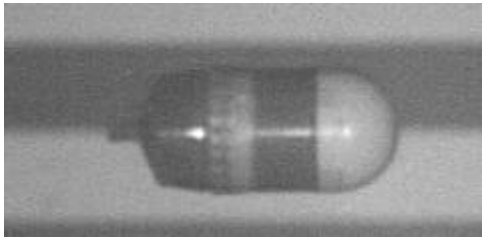


Ammo model development

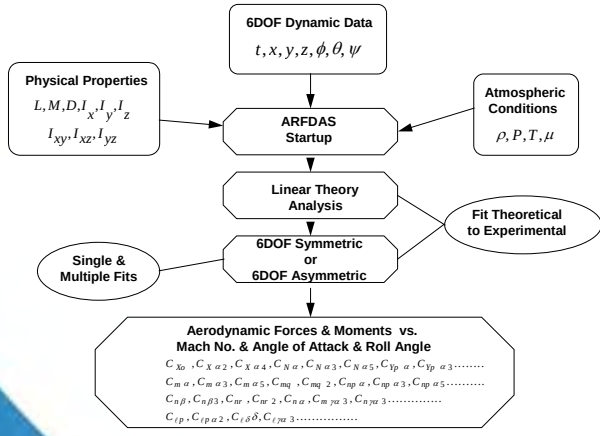
A/B range trial







ARFDAS - ***Aeroballistic Range Facility Data Analysis***

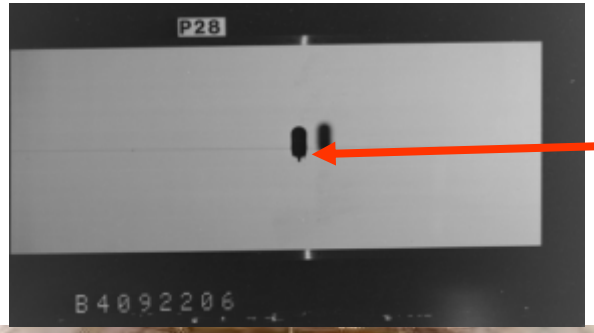


- Complete ammo aero model

Ammo model development

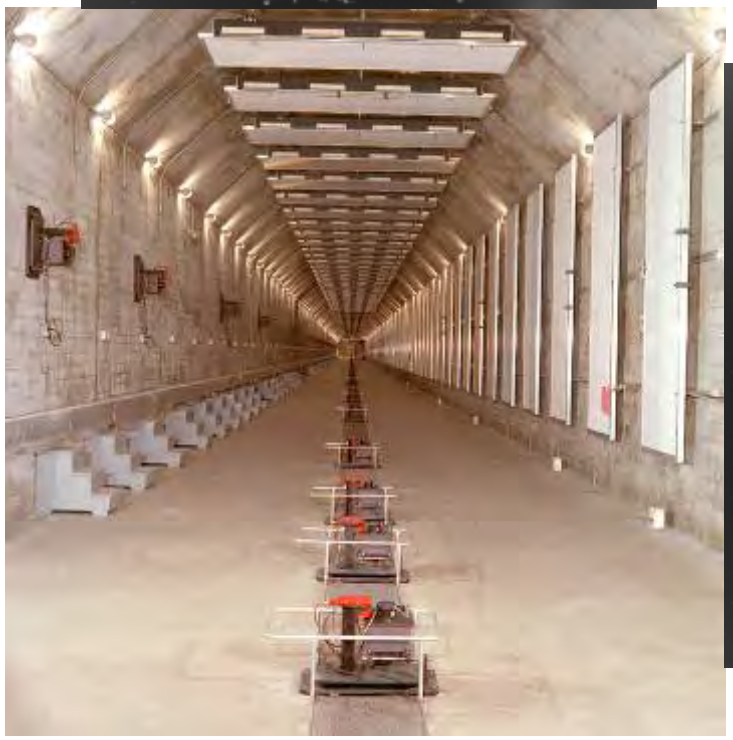
Shadowgraphs

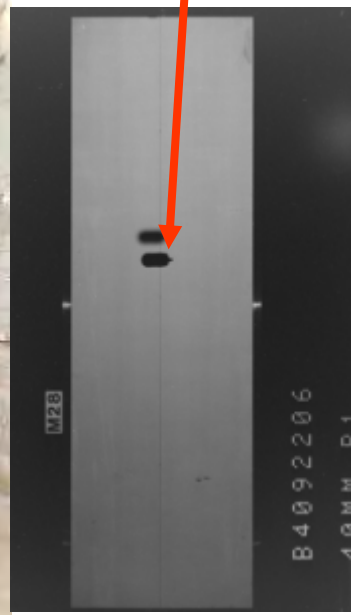
- Instrumented length: 220 m
- Section: 6 m x 6 m
- 54 Stations:
  Indirect orthogonal shadowgraphs
- 4 Schlieren stations



Pit View

Shadow

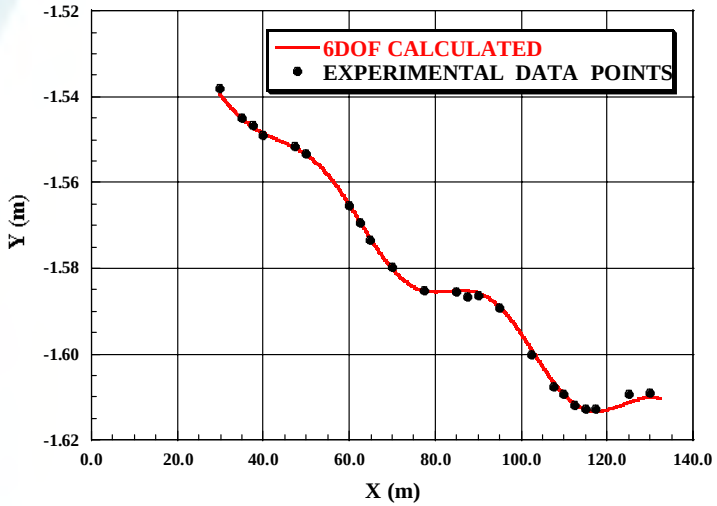


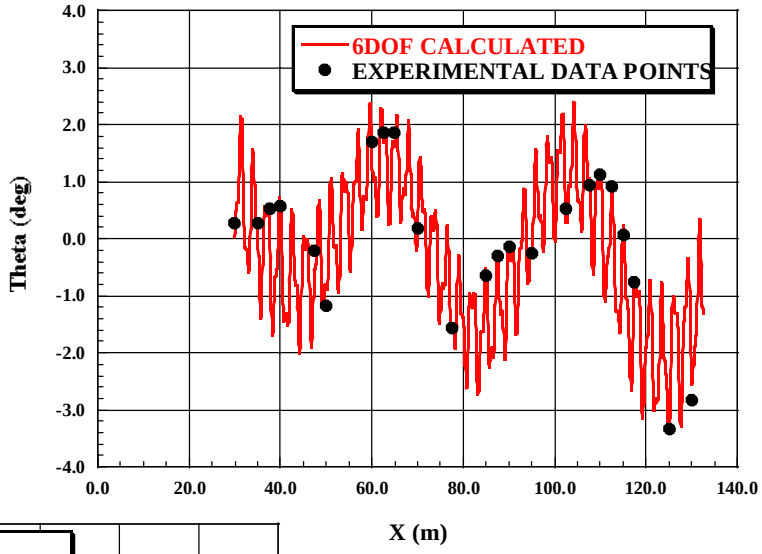


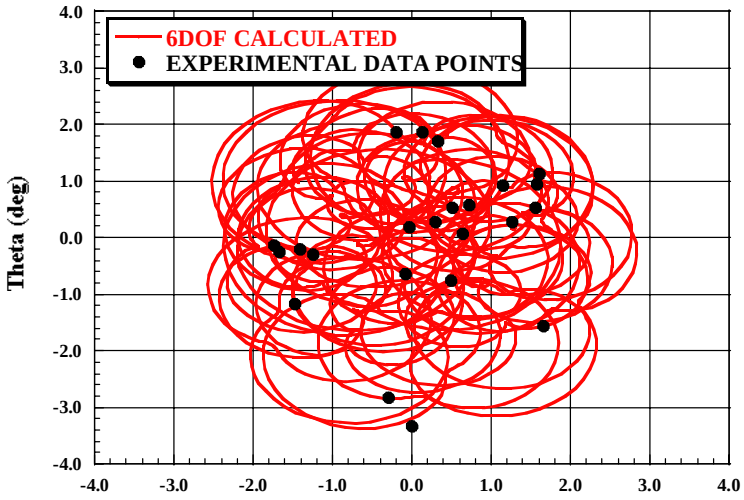
Wall View

Ammo model development

Projectile motion

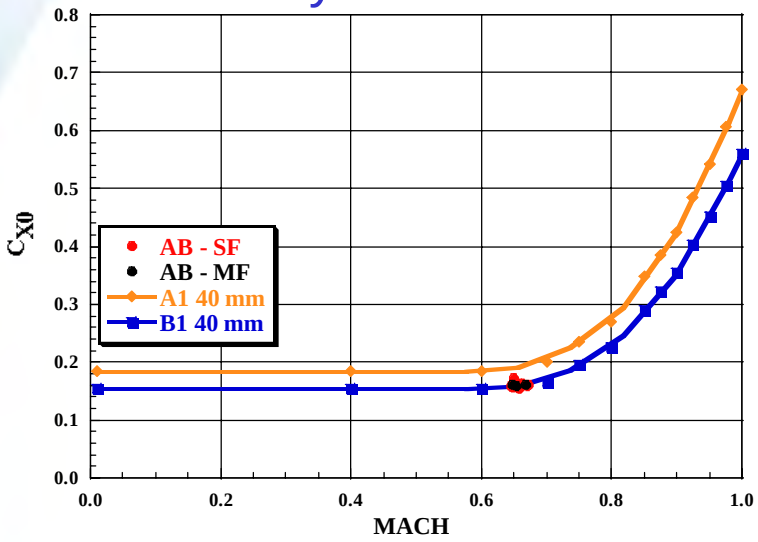


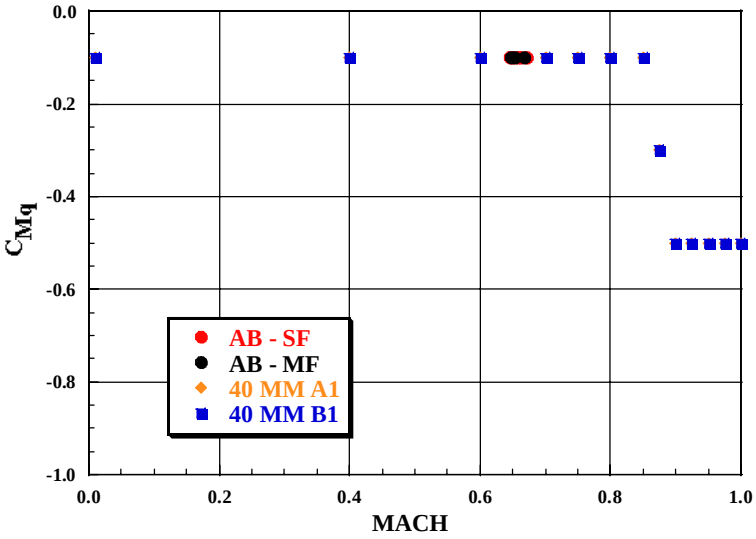




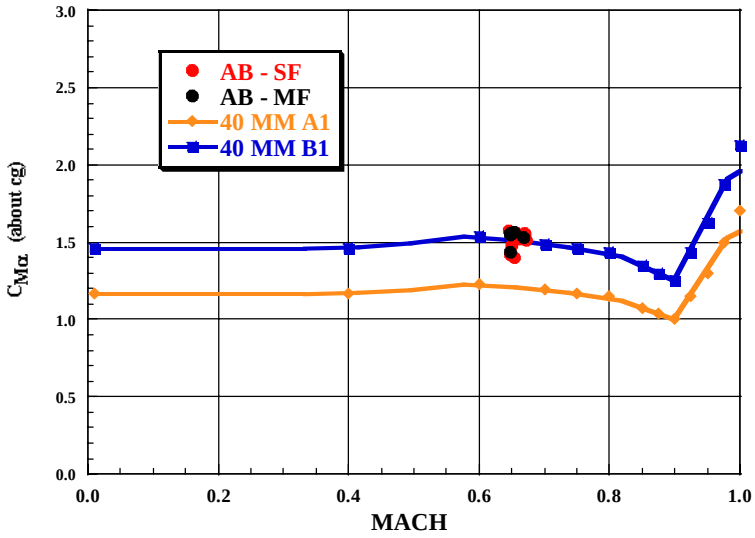
Ammo model development

Aerodynamic model







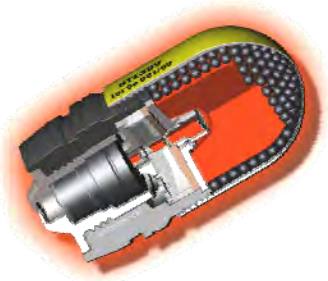


Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero





Weapon System representation



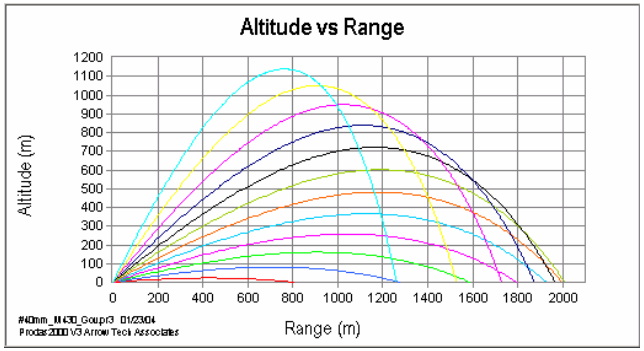
MET data

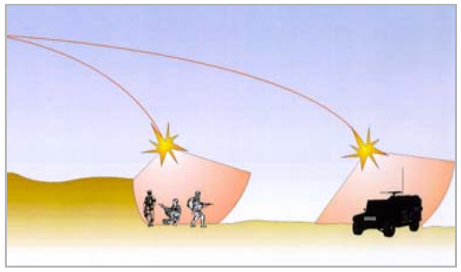


PRODAS

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 model development

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

$$S^2_{DX_{TOTAL}} = S^2_{DVx} + S^2_{GDx} + S^2_{ADx}$$

$$S^2_{DY_{TOTAL}} = S^2_{DVy} + S^2_{GDy} + S^2_{ADy}$$





Error budget development

MODEL	B1	A1		
Errors	Measured	LOW LEVEL	MEDIUM LEVEL	HIGH LEVEL
Drag/Mass (%)		1.0	3.0	5.0
V_M – round to round (m/s)		0.5	1.5	4.0
V_M – lot to lot (m/s)		0.5	1.5	4.0
Wind Std(m/s)		1.0	3.0	5.0
Pressure Std (mbars)		1.0	2.0	4.0
Air Temp (C) Std Dev		1.0	3.0	5.0
Vert. Bore sight alignment (mils)		1.0	2.0	3.0
Horz. Bore sight alignment (mils)		1.0	2.0	3.0
Target range Error (m)		1.0	2.0	4.0
Gun dispersion (mils)		0.6	1.2	4.0
Ammunition Dispersion (mils)		0.5	1.5	3.0
Fuze Error (% of time)		1.0	3.0	4.0

- 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



SHOT NUMBER	V_{MUZ} (m/s)
B01	240.91
B02	242.73
B03	238.67
B04	242.81
B05	243.31
B06	242.33
B07	243.63
B08	243.66
B09	240.14
B10	242.12
Mean	242.03
Std Deviation	1.55
Std Deviation (%)	0.64

Error budget development

Drag/Mass error

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

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

$$\sigma\left(\frac{\overline{C_{X0}}}{\overline{M}}\right) = \frac{\sigma_{\overline{C_{X0}}}}{\overline{M}} - \frac{\overline{C_{X0}}}{\overline{M}^2}\,\sigma_{\overline{M}} = 1.0$$

Error budget development

Ammunition dispersion (aerodynamic jump)

- **Due Mainly to Initial Yaw Rate**
  - **In bore Balloting**
  - **CG Offset**

- **Theory States** ⇒

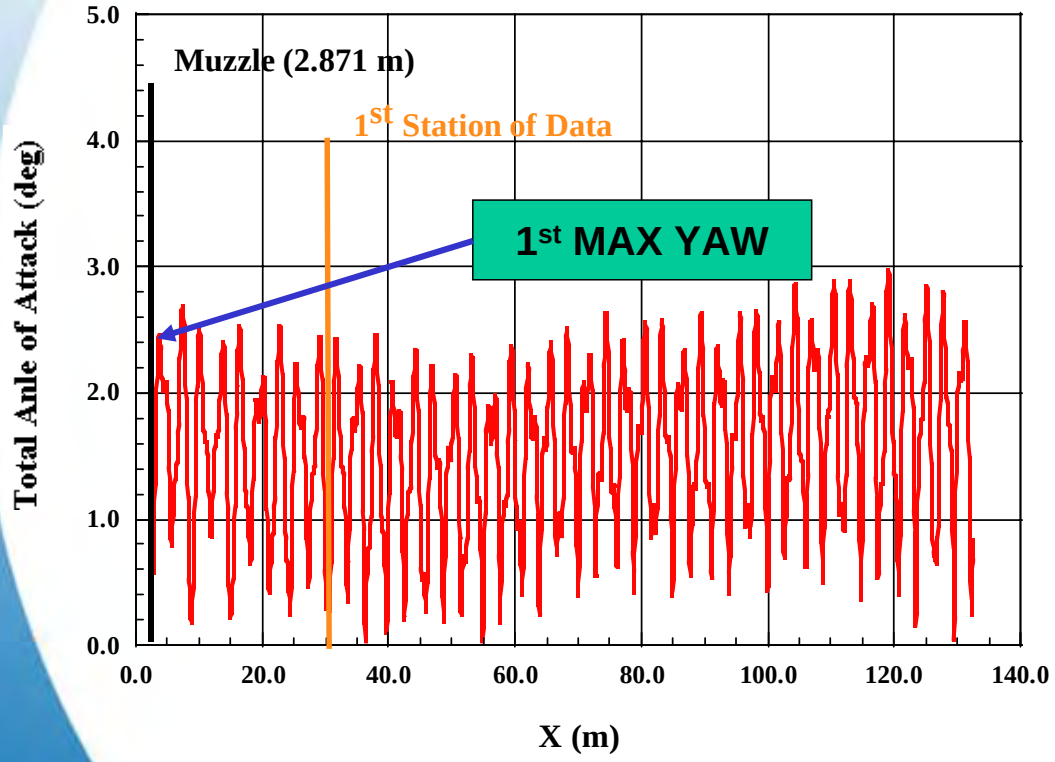
- If initial yaw rate, q_0 , is known
- with aerodynamic package and physical properties

- can calculate ammunition disp.

Error budget development

Ammunition dispersion (aerodynamic jump)

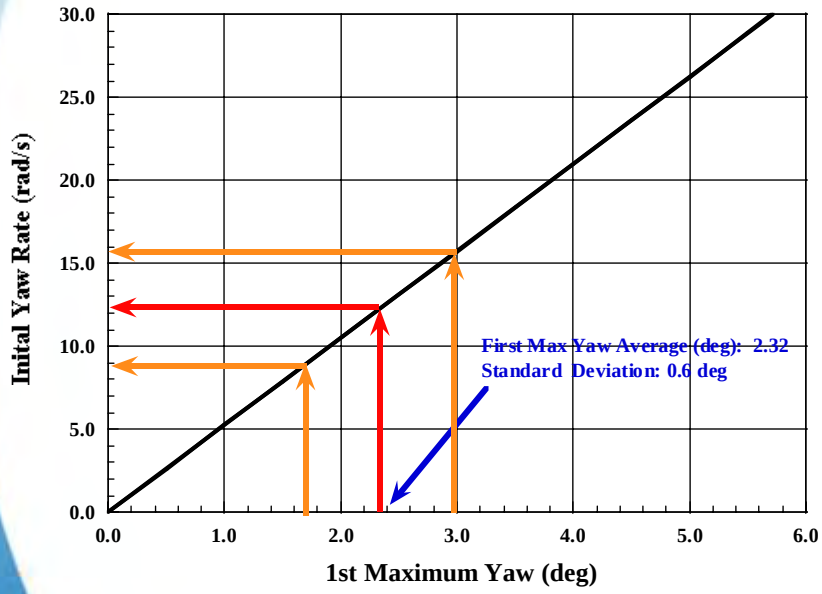
Angle of Attack – Extrapolated to Muzzle with A/B Range Data

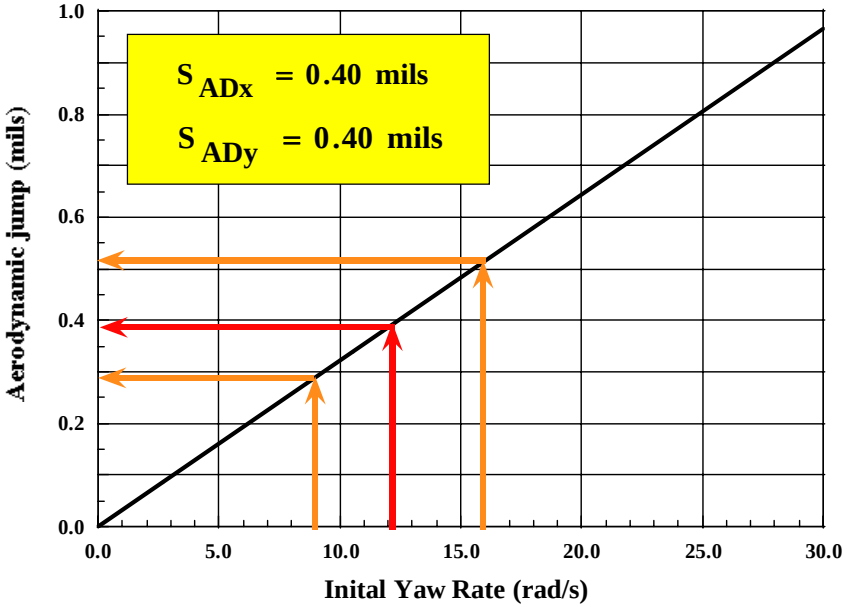


SHOT NUMBER	1st Max Yaw (deg)
B01	2.87
B02	1.55
B03	2.85
B04	2.90
B05	1.74
B06	2.71
B07	2.46
B08	2.10
B09	2.73
B10	1.31
Mean	2.323
STD. DEV.	0.601

Error budget development

Ammunition dispersion (aerodynamic jump)





$$q_0 = \frac{\left(\dot{\phi}_F - \dot{\phi}_S\right)}{2}\overline{\alpha}_{\max}$$

$$\theta_{aero} = \frac{\left(C_{N\alpha} - C_X\right)d}{C_{m\alpha}V_0}\left(\frac{I_y q_0}{md^2}\right)$$

Error budget development

Gun dispersion: drop and lateral analyses

$$S^2_{DY\,TOTAL} = S^2_{D\,Vy} + S^2_{GDy} + S^2_{ADy}$$

$$S^2_{DX\,TOTAL} = S^2_{D\,Vx} + S^2_{GDx} + S^2_{ADx}$$

Total Observed

Due to Gravity drop (V_{MUZ}, mass, C_{X0})

Gun Dispersion

Ammunition Dispersion

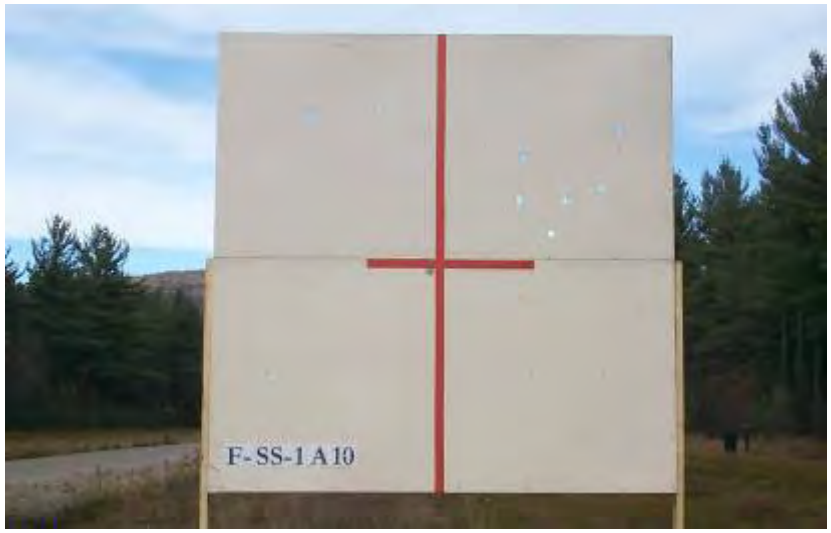
Error budget development

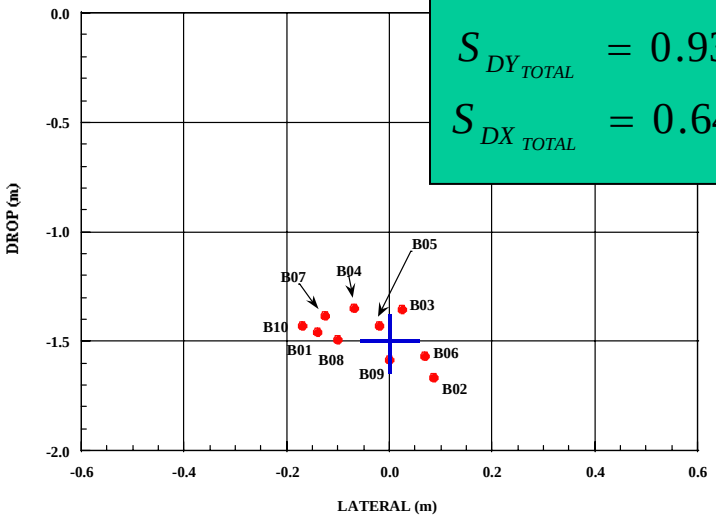
Gun dispersion: total dispersion

Measured

$S_{DY_{TOTAL}} = 0.93 \ mils$

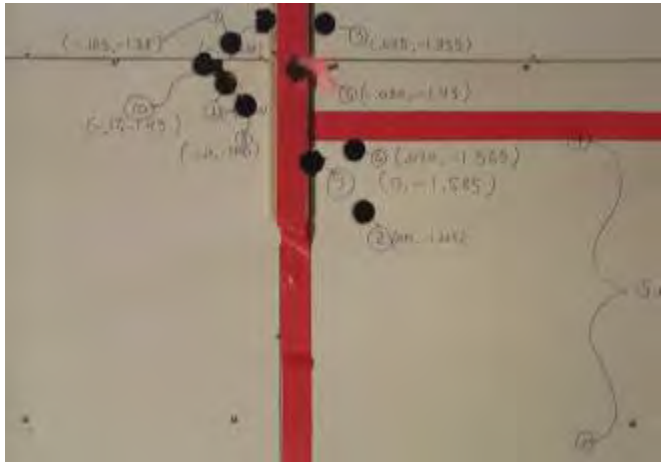
$S_{DX_{TOTAL}} = 0.64 \ mils$





Accuracy trial:

- NATO StanAg procedure



Error budget development

Gun dispersion: drop analysis

$$S^2_{DX_{TOTAL}} = S^2_{D_{Vx}} + S^2_{GDx} + S^2_{ADx}$$

Total Observed

$S_{DX_{TOTAL}}$

0.640 mil

Due to Gravity drop (V_{MUZ}, mass, C_{X0})

$S_{D_{Vx}}$

0.353 mil

Gun Dispersion

=

Ammunition Dispersion

S_{ADx}

mil

0.400 mil

Error budget development

Gun dispersion: lateral analysis

$$S^2_{DY_{TOTAL}} = S^2_{D_{Vy}} + S^2_{GDy} + S^2_{ADy}$$

Total Observed

$S_{DY_{TOTAL}}$

0.930 m

Due to Gravity drop (V_{MUZ}, mass, C_{X0})

$S_{D_{Vy}}$

0.00 m

Gun Dispersion

$S_{GDy} = 0.84$ m

Ammunition Dispersion

S_{ADy}

0.400 m

Error budget development

Error budget model

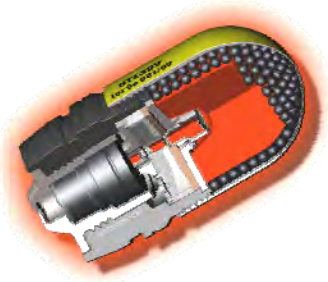
Errors	SERIES D	PROPOSED ERROR BUDGET For LETHALITY Study		
	Tripod w/o sand bag, natural ground	LOW	LOW IDEAL	HIGH
Drag/Mass (%)	1.00	1.0	1.0	1.5
V_M – round to round (m/s)	1.6	0.8	0.8	2.0
V_M – lot to lot (m/s)		0.8		2.0
Wind Std(m/s)		0.5		1.0
Pressure Std (mbars)		1.0		2.0
Air Temp (C) Std Dev		0.5		1.5
Bore sight alignment (mils)		0.5		1.25
Target range Error (m)		1.0		2.0
Gun dispersion (mils)	H: 0.84 V: 0.35 A: 0.60	H: 0.42 V: 0.18 A: 0.50	H: 0.42 V: 0.18 A: 0.50	H: 1.05 V: 0.44 A: 1.0
Ammunition Dispersion (mils)	0.40	0.30	0.30	0.50
Fuze Error (% of time)		0.5		3.0

Background

Weapon system modeling

Ammo: mass, CP, CG, shape, aero





Weapon System representation



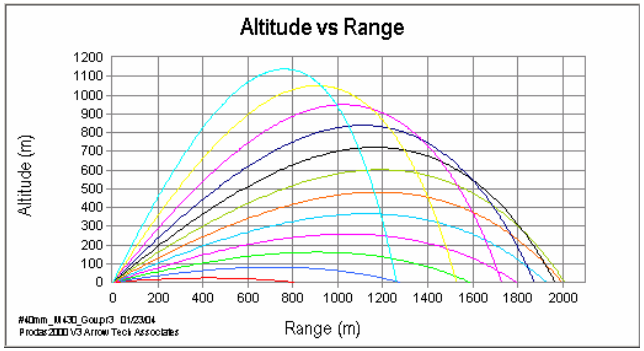
MET data

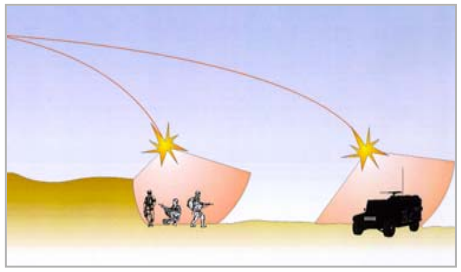


PRODAS

Round Characteristics at time of burst or detonation:

- Dispersion
- Probability of hit
- Remaining Speed
- Remaining Spin
- Angle of descent (AOD)
- Time of Flight

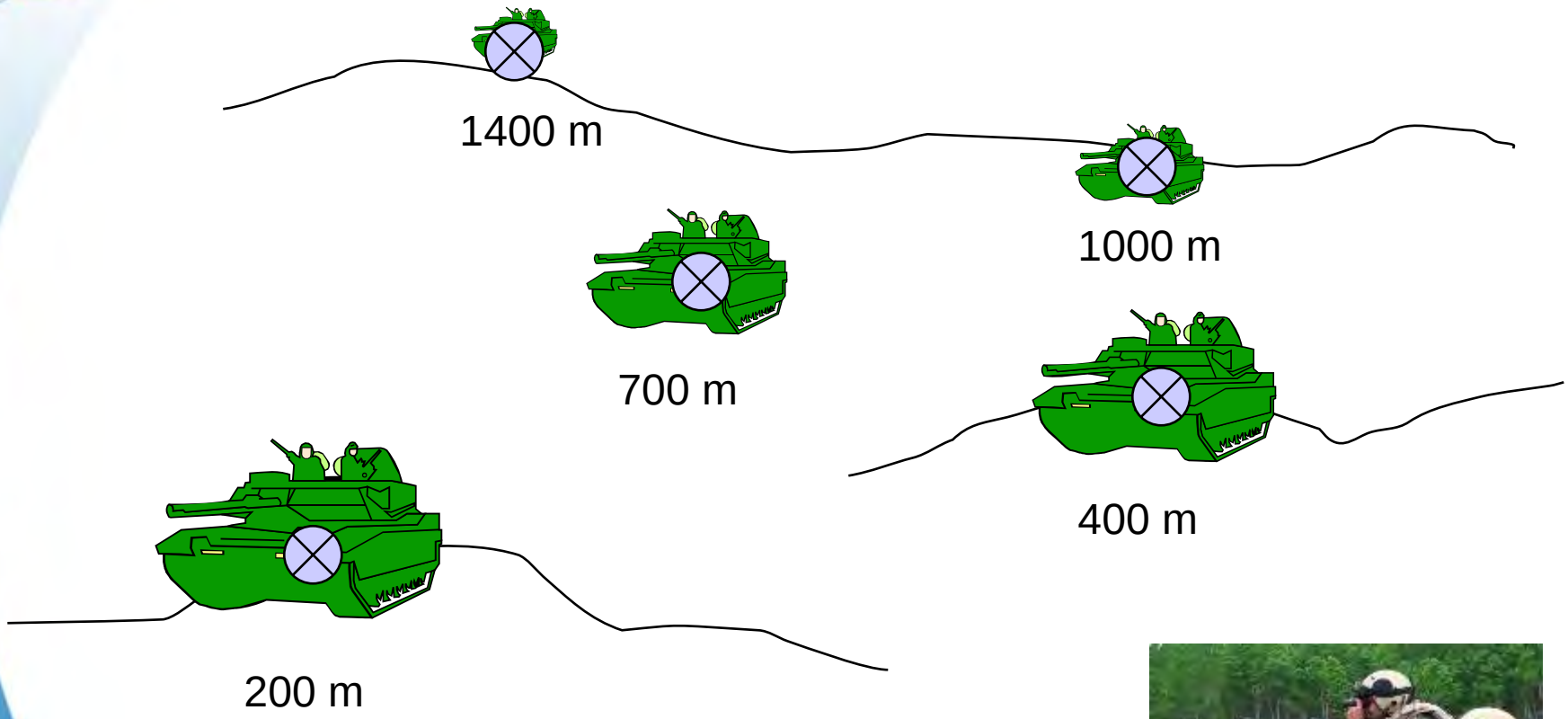




Monte-Carlo Based Weapon System Simulations

- 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



5 standard NATO targets: 2.3m high X 4.6m wide

1 box of ammo: 32x





Scenario/Mission Simulations

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

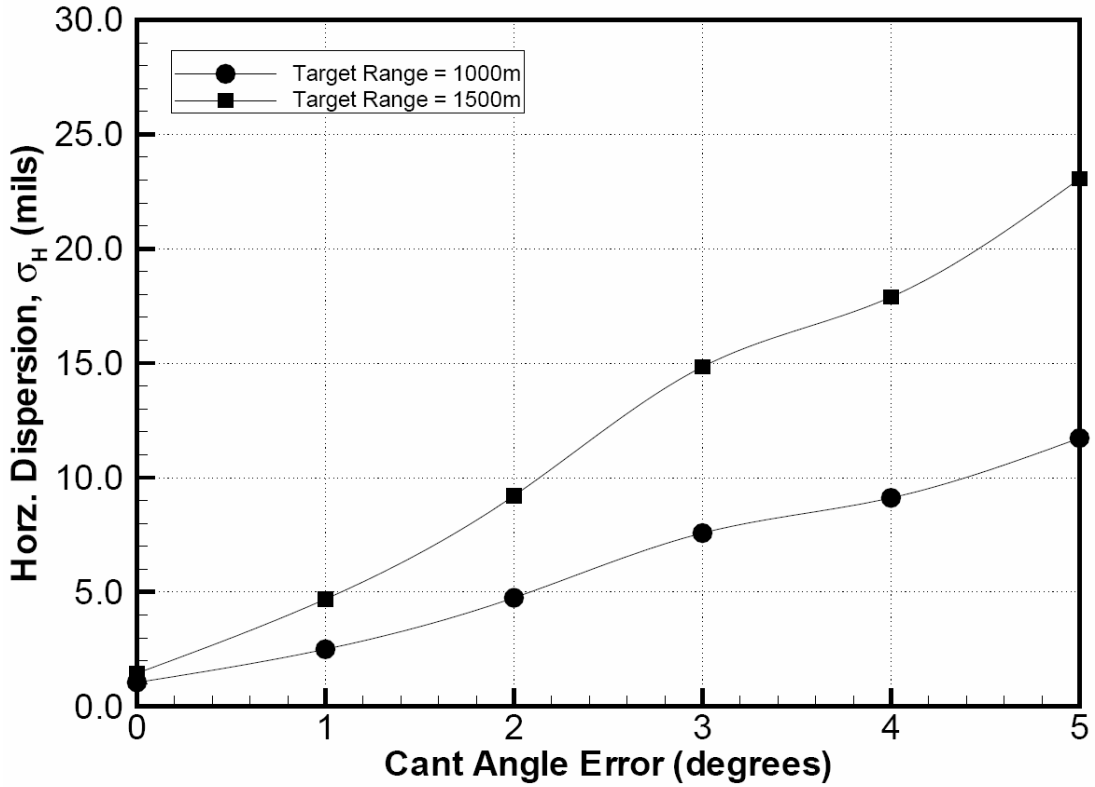
RANGE	P^{1S}_{HIT}	N	Number of individual shots required obtain 90% mission success	Cummulative number of individual shots required obtain 90% mission success
200	1.000	0.00	1	1
400	1.000	0.00	1	2
700	0.876	1.10	2	4
1000	0.532	3.03	4	8
1400	0.142	15.03	16	24
Mission success:			100%	

where $$N = \frac{\ln(1 - P^{*}_{HIT})}{\ln(1 - P^{1S}_{HIT})}$$

Weapon System Specifications: FCS

Cant angle error

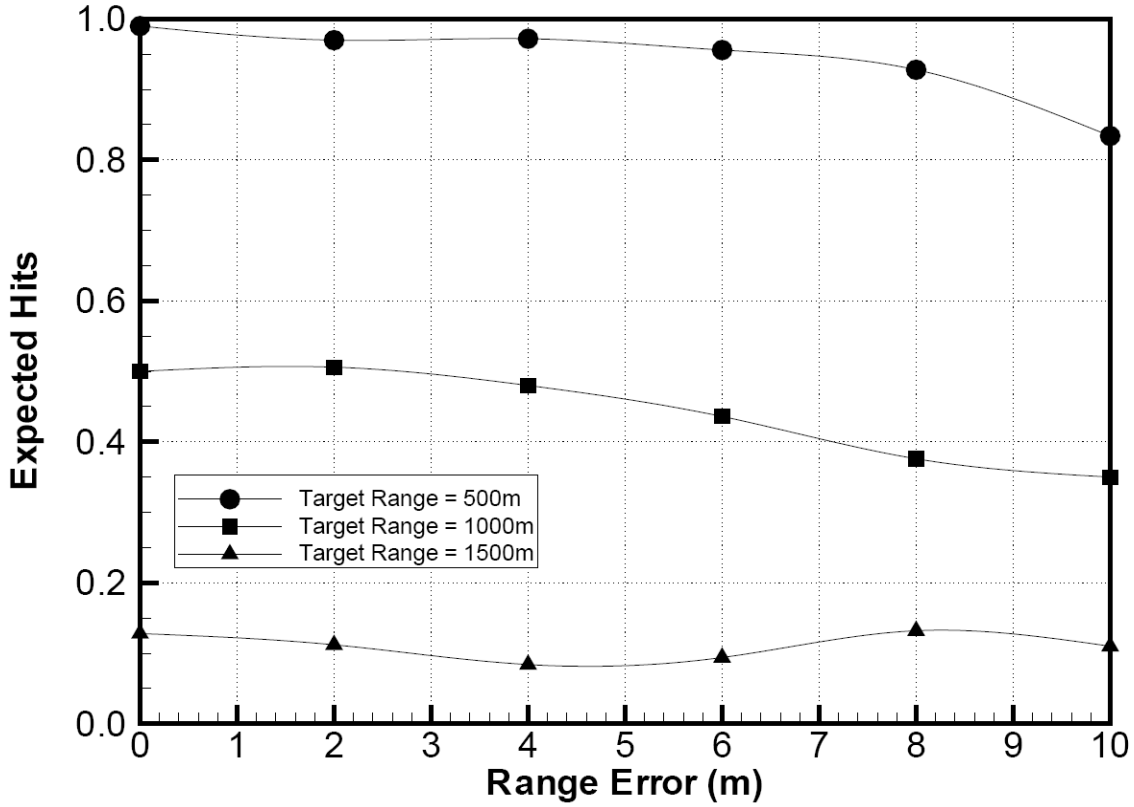
- Standard vertical NATO targets: 2.3m high X 4.6m wide



Weapon System Specifications: FCS

Range error

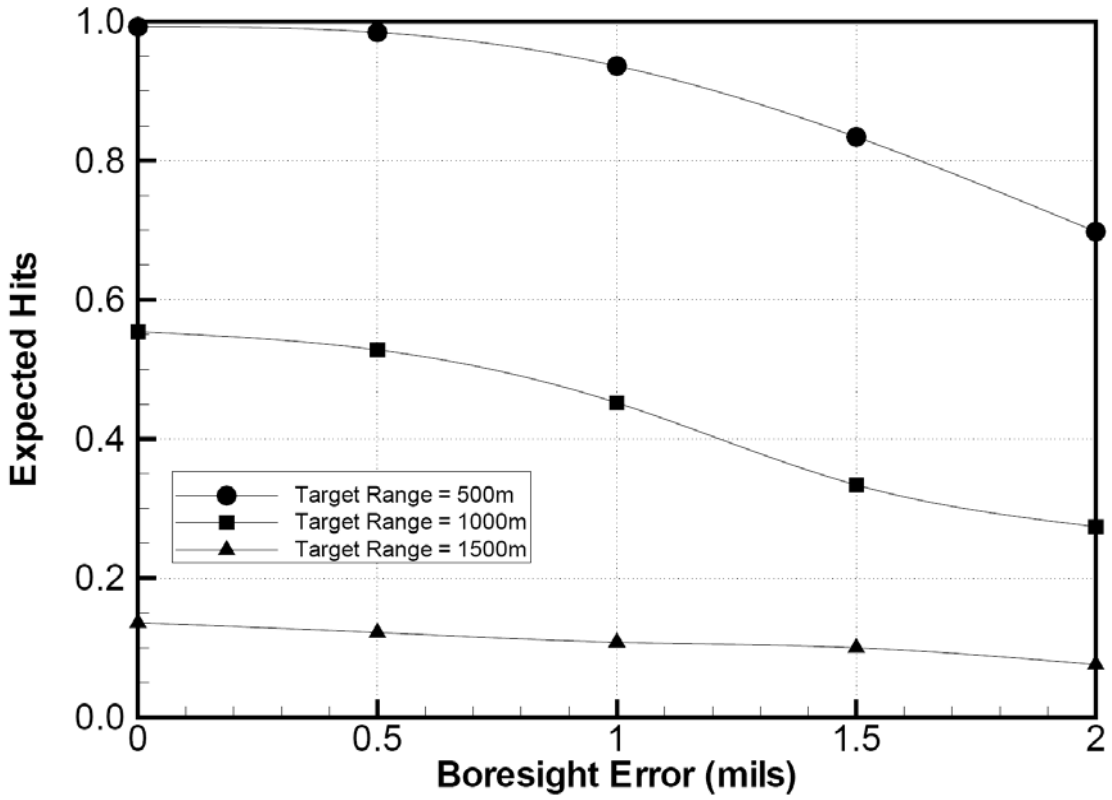
- Standard vertical NATO targets: 2.3m high X 4.6m wide



Weapon System Specifications: FCS

Boresight error

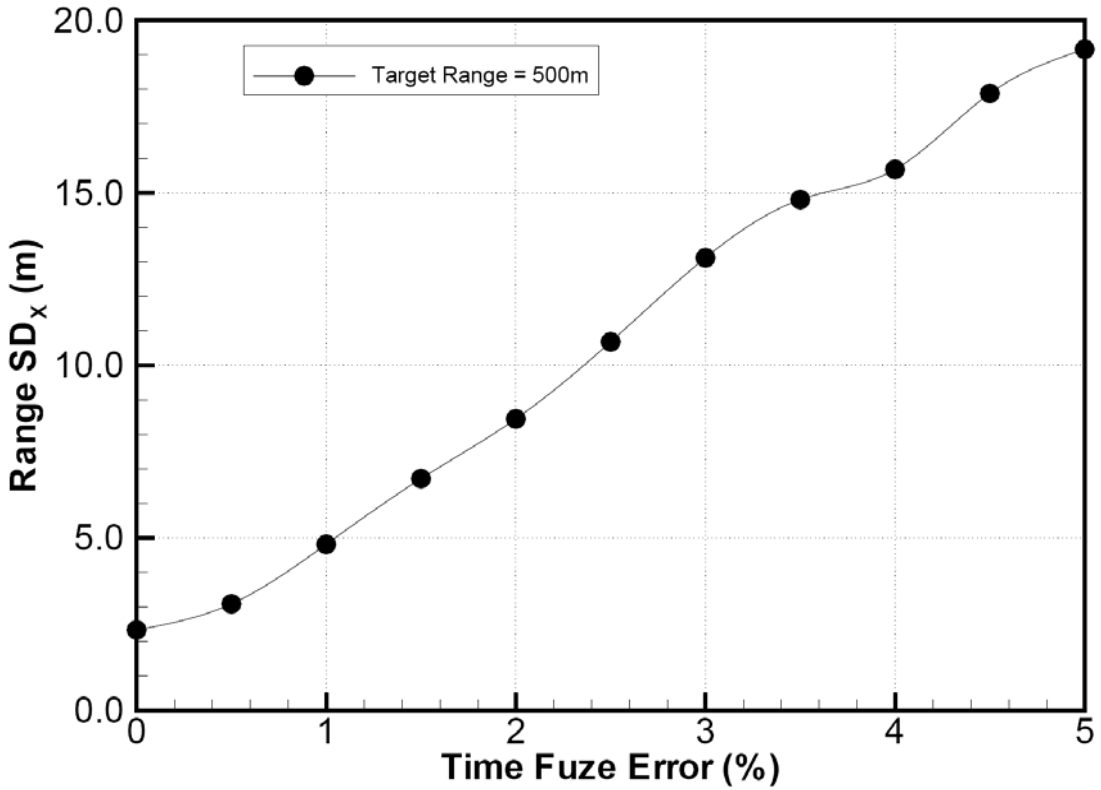
- Standard vertical NATO targets: 2.3m high X 4.6m wide



Weapon System Specifications: Ammo

Time fuze error

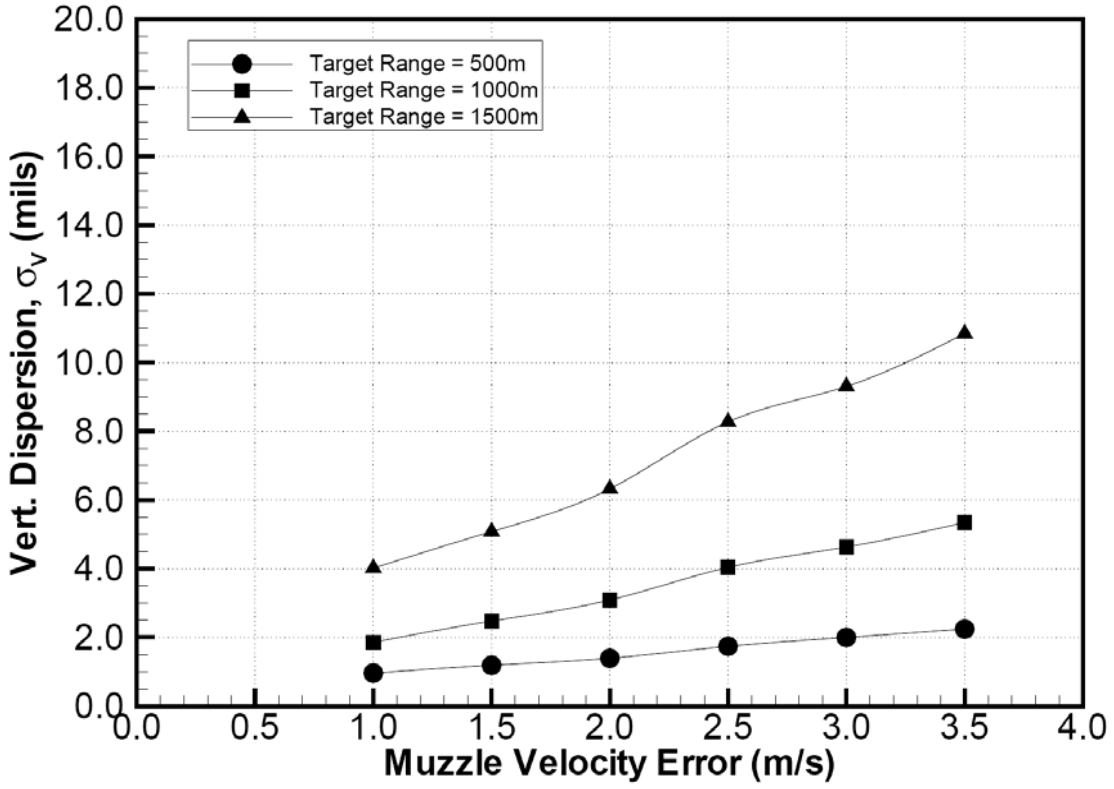
- Ground target



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


DEFENCE
R&D
DÉFENSE

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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

Remotely Operated 120 mm Mortar Technology
INTRODUCTION

US ARMY RDECOM-ARDEC
Weapon Systems & Technology Directorate

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



Indirect Fire Systems Division

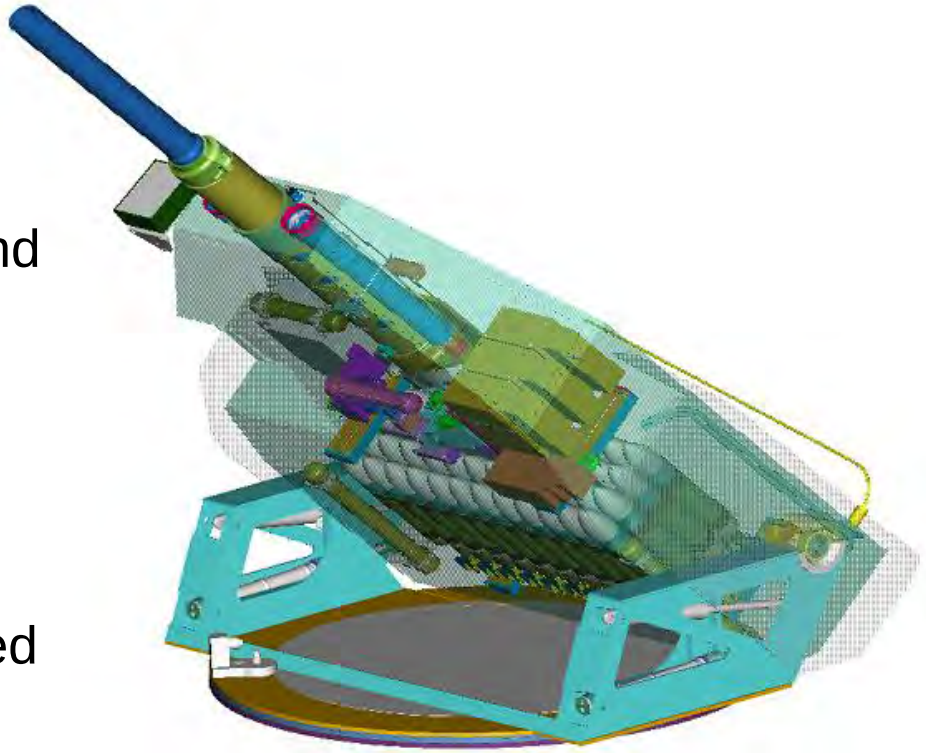
Objective NLOS-M Technology ATO
Laser Ignition for Cannon Artillery
Artillery & Mortar Systems

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

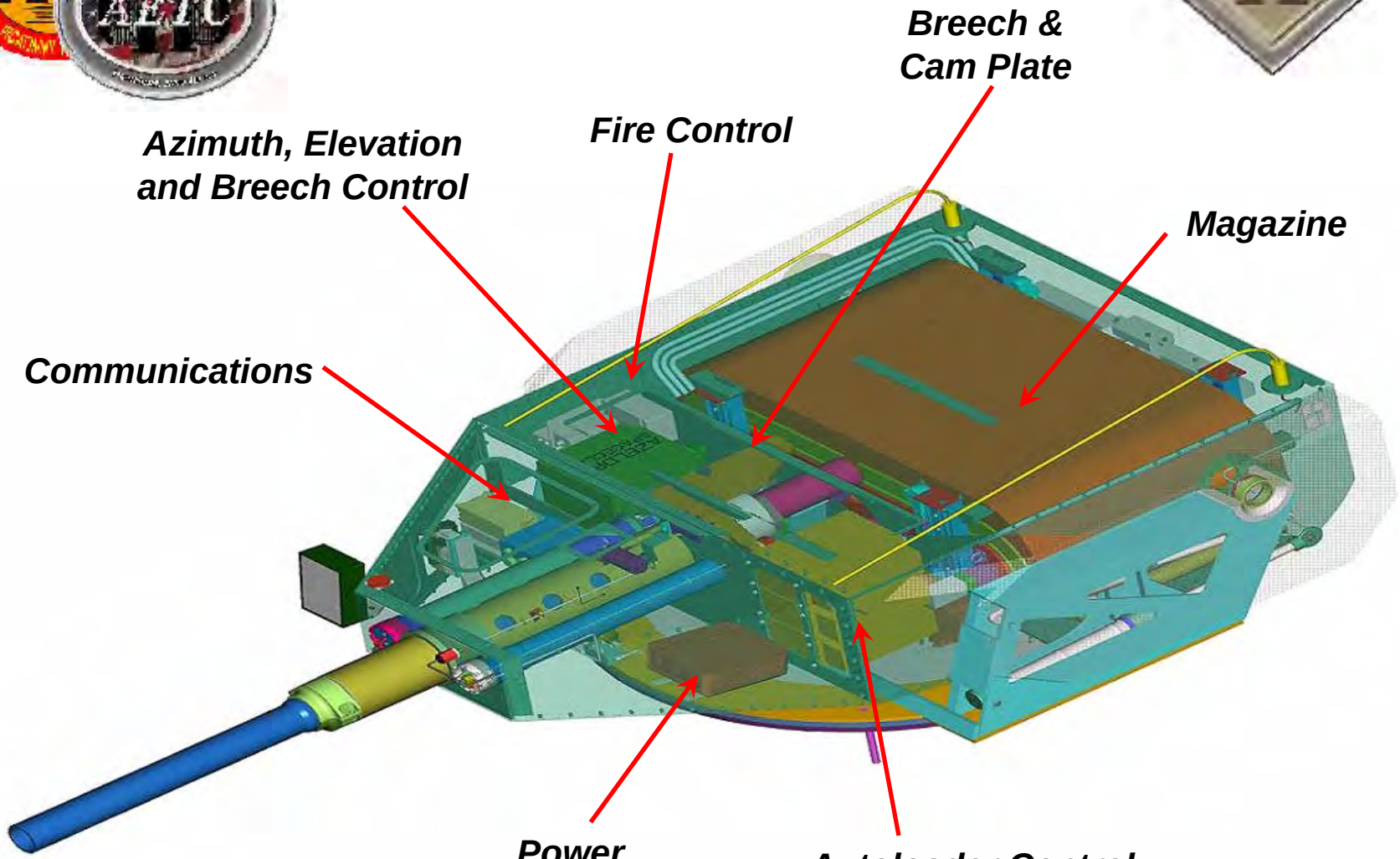


120 MM TURRETED MORTAR CAN BE MOUNTED ON A VARIETY OF FIXED OR MOBILE PLATFORMS

Remotely Operated 120 mm Mortar Technology
BACKGROUND

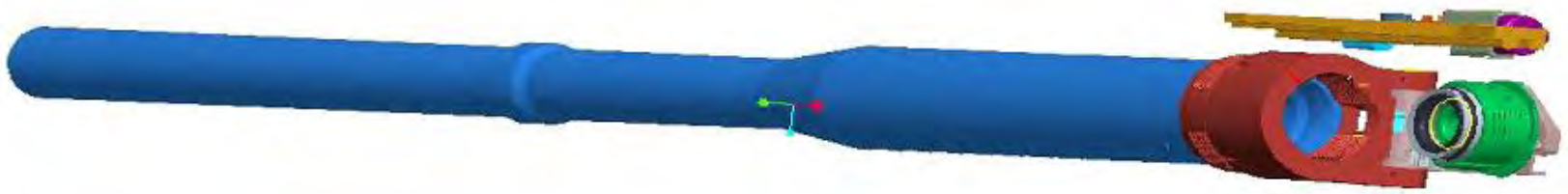
- **Trade-offs**
  - Elevating Turret vs. Elevating Gun
  - Smooth Bore vs. Rifled Bore
- **Design**
  - ARDEC: Cannon, Recoil Mechanism, Turret, Fire Control
  - Western Design: Ammunition Handling Design and Fabrication
  - General Atomics: Turret Structural Design
- **Fabrication**
  - ARDEC: Titanium Turret
  - Watervliet Arsenal: Cannon Tube and Breech
  - Rock Island Arsenal: Recoil Mechanism
- **Integration** - ARDEC

Remotely Operated 120 mm Mortar Technology
TURRET

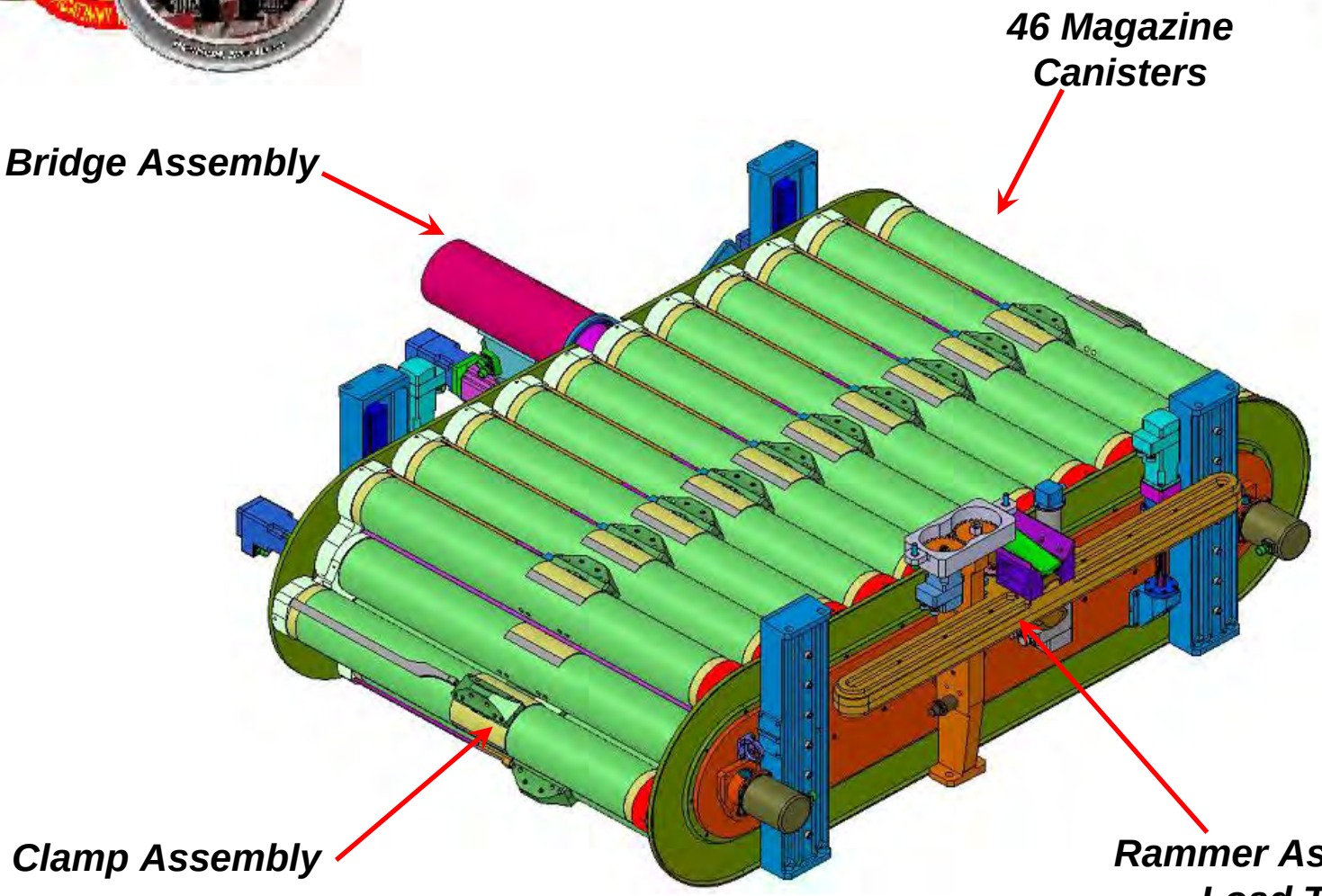


Remotely Operated 120 mm Mortar Technology
ARMAMENT

- 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



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

Remotely Operated 120 mm Mortar Technology
TESTING



Aberdeen Test Center Live Fire Demonstration

177 Rounds
Charge 1 – Charge 4
30º 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



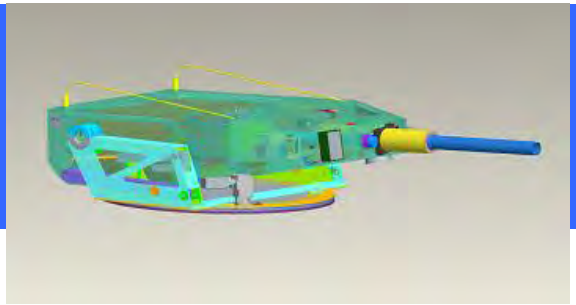
Remotely Operated 120 mm Mortar Technology
ROWST Mortar

Mortar Turret

5 Tons

191” x 98” x 36.5”

Remotely Operable

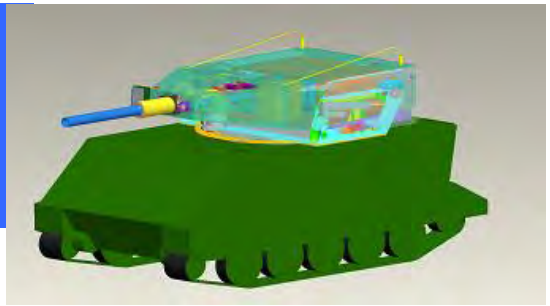


Turret on M113 A2

17 Tons

222” x 100” x 108”

C130 Compatible



Turret on LAV-25

15 Tons

253” x 99” x 114”

C130 Compatible with Modification

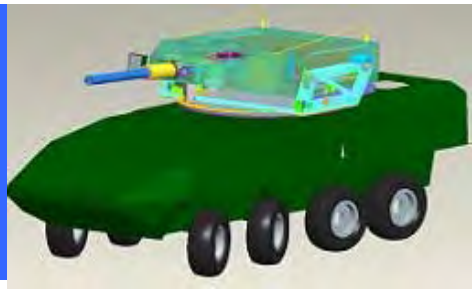


Turret on Stryker

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.

System Analysis Division

Mission:

10-1: Serve as TACOM-ARDEC Systems Analysis organization-provide analytical services to all operating segments

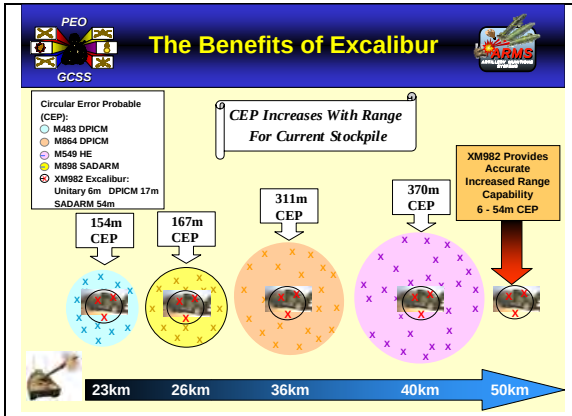
Vision:

***Our* Systems properly represented in the M&S Environment**

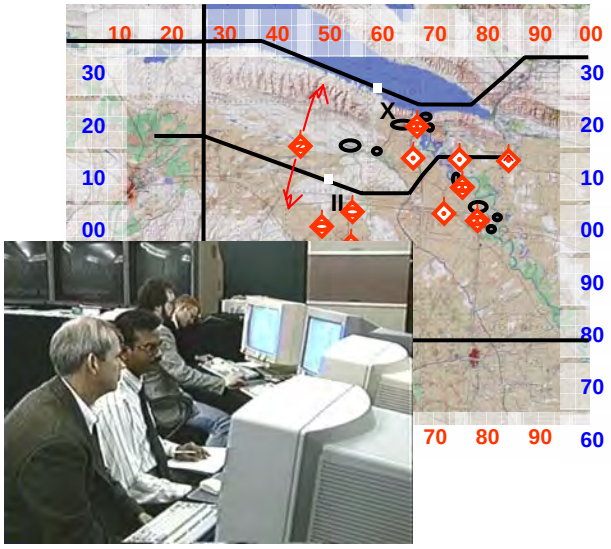
-- *Complete knowledge and understanding*

Team:

- **29 Personnel**
- **Almost all S&Es, Multidisciplinary**
- **Engineers, Physical Scientists, Computer Scientists, Physicists, Mathematicians**

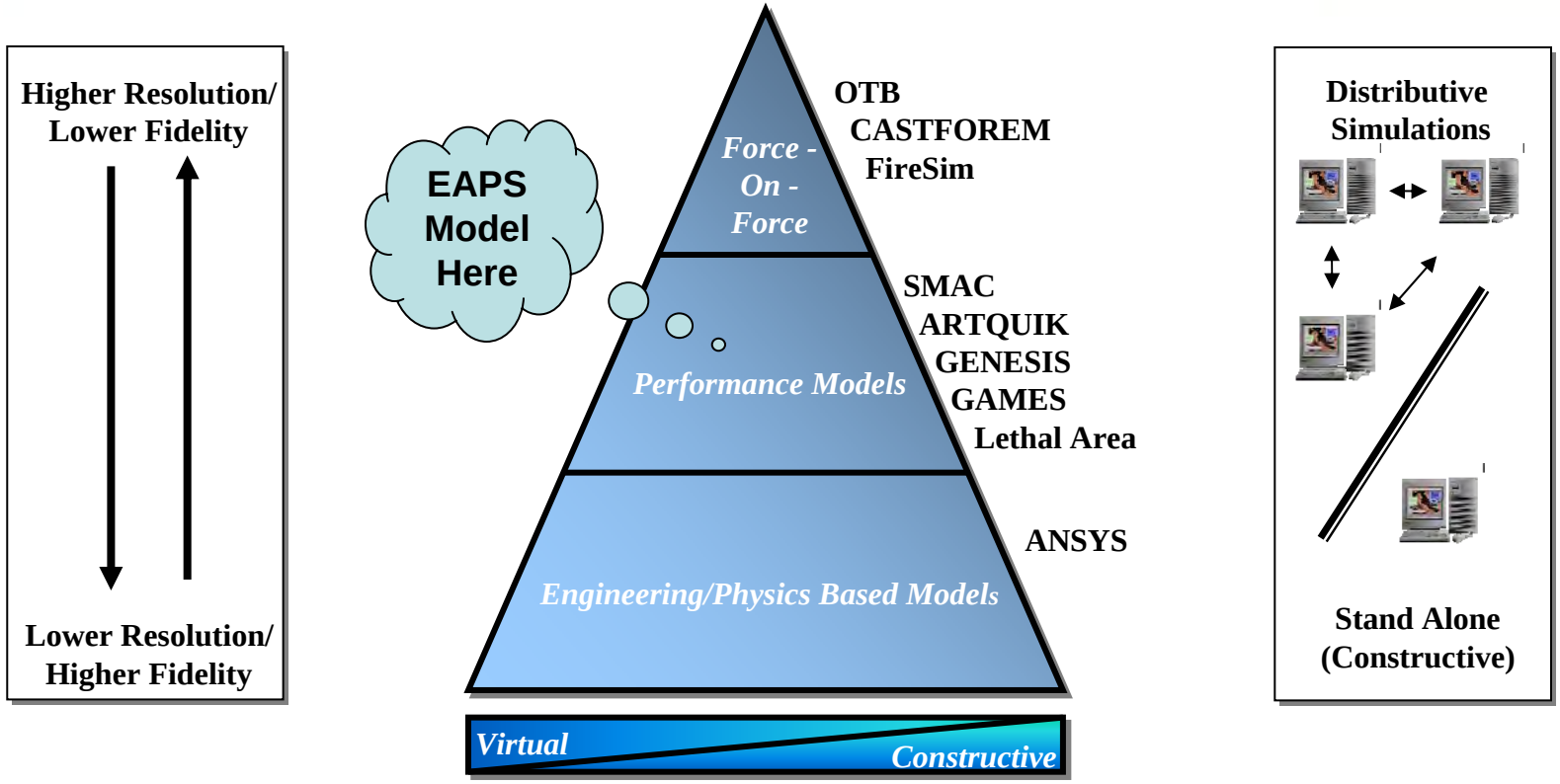


Effectiveness Analysis



Distributive/Live/Virtual Exercises

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

EAPS System Analysis
Evaluation Method

Basic Approach To The Problem

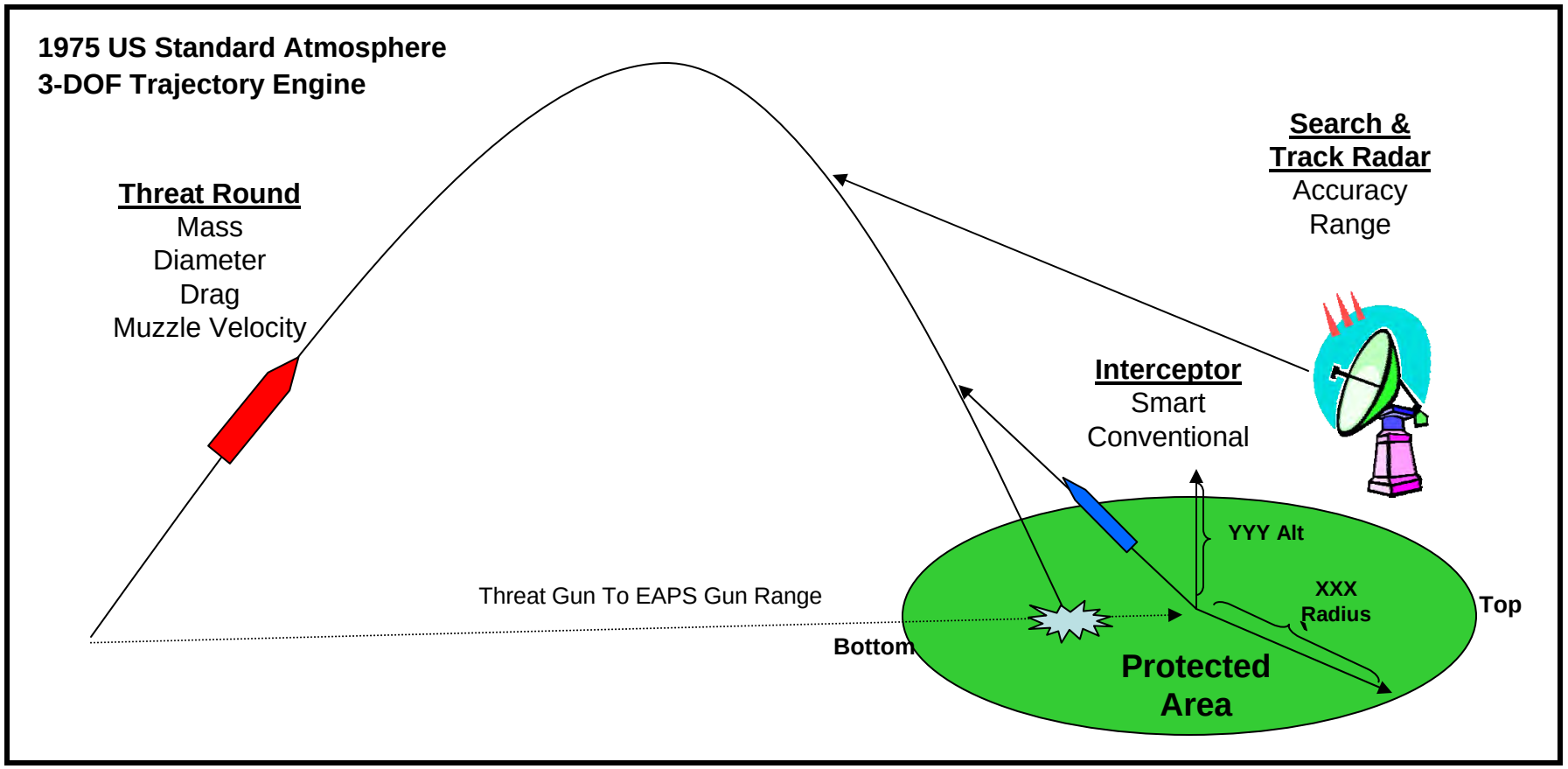
1. Use brainstorming and QFD to develop the range of gun systems and munitions likely to address the threat and customer needs.
2. Determine details of the threat and weapon systems sufficient to allow a detailed analysis to be conducted.
3. Develop a computer simulation which models the EAPS environment 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.

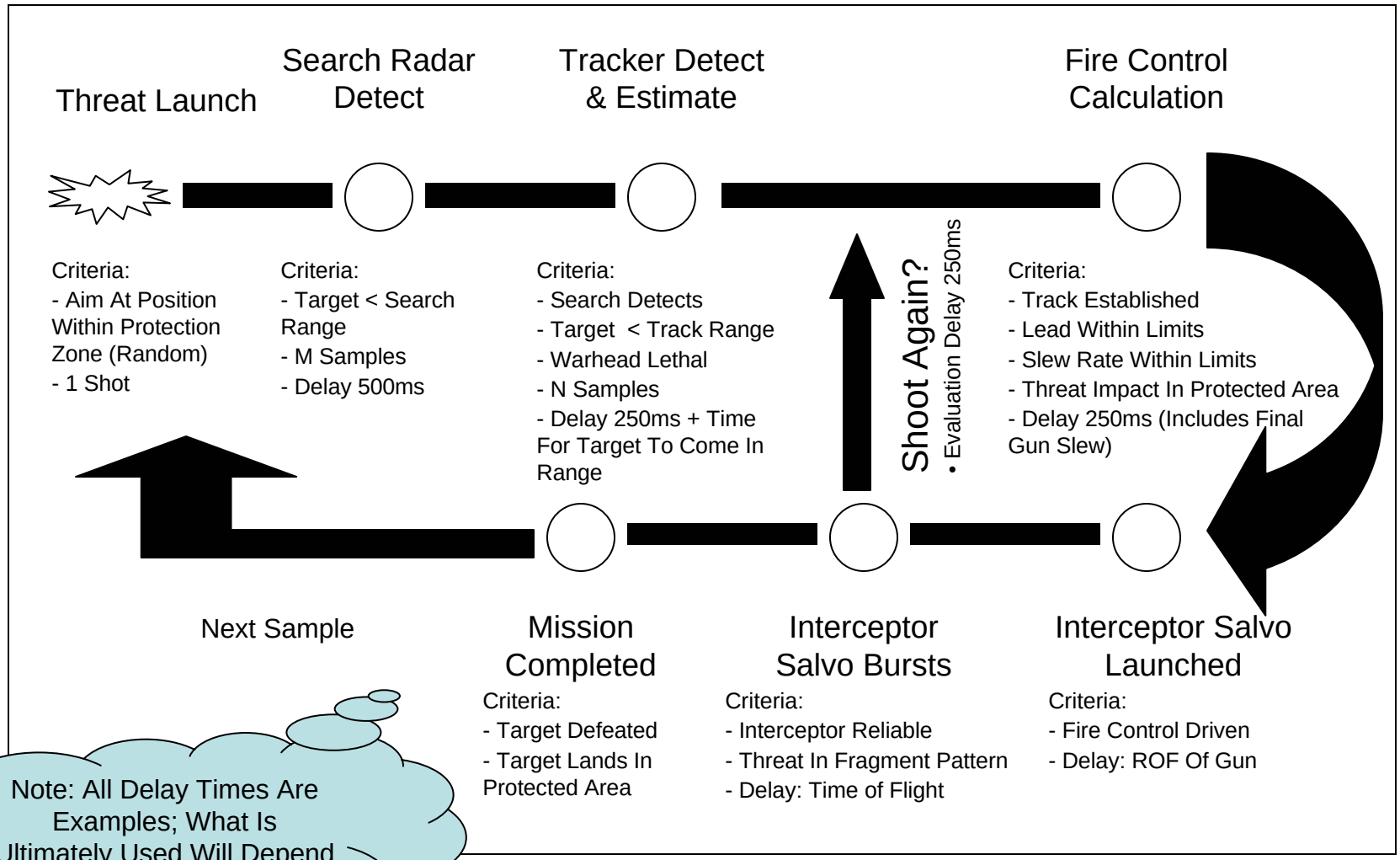
EAPS.F FORTRAN Gun Simulation

Basic Idea Is To Model The Event Timeline, Accuracy, & Lethality In Explicit Detail



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

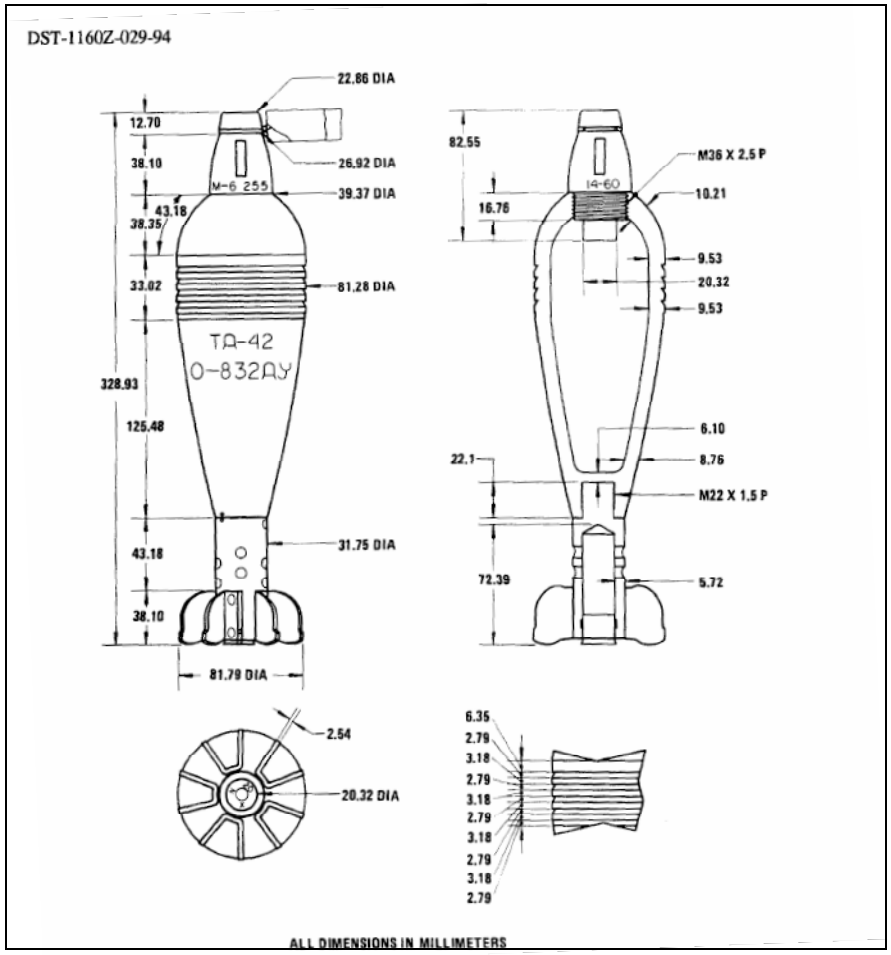


Note: All Delay Times Are Examples; What Is Ultimately Used Will Depend On System Architecture

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 1



- 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 2



- 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 3

- 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





Course Corrected Ammunition

Precision Fire- Guide to Burst 4

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



Course Corrected Ammunition



All Engagement Options Evaluated

Kill Mechanism/ Fuzing Options

KE/ Shaped Charge w/ Impact Fuze 1

- 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 2

- 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 3

- 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

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

Trade Study Results - Req PR:
Characterization of Trade Space

Warhead	Guidance	20mm 100% lbs.	25mm 101% lbs.	35mm 730% lbs.	50mm 1020% lbs.	75mm 5061% lbs	82mm 6893% lbs
KE-Sabot	No	PR~30% 100% Shots	PR~40% 35% Shots	ROF Too Low	Similar To Smaller Calibers ROF Too Low		Velocity Too Low
	Yes	Too Small		PR ~60% 5-9% Shots	ROF Issues		
HE-Nat	No	PR~30% 100% Shots	Not Done	Not Done – Appears to Have Low Promise Results Similar to KE Sabot			
	Yes	Too Small					
HE-PFF	No	Too Small			Not Done	PR >100% ~1.5% Shots	PR~10% 1% Shots
	Yes				Not Done	PR>100% ~0.75% Shots	Not Done
CE-Unitary	No	Not Done – Appears to Have Low Promise Results should be similar to KE Sabot					Too Slow Likely To Be Ineffective
	Yes						
HE-EFP	No	Too Small			Not Done – Appears to Have Moderate Promise Results Should Be Similar To HE-PFF		
	Yes						
KE-Subs	No	Too Small		PR~20% 10-15% Shots	PR~60% ~7% Shots	PR~60% ~2% Shots	Too Slow Likely To Be Ineffective
	Yes			Too Small	PR~100% ~2.5% Shots	PR~90% ~2% Shots	
CE-Subs	No	Not Done – Appears To Be Too Small (Insufficient Number Of Submunitions)				Not Done – May Have Some Promise In Larger Calibers	
	Yes						

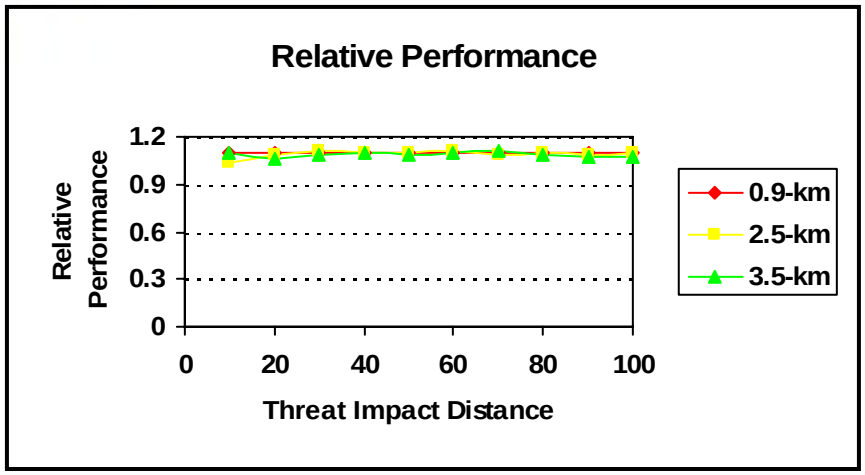
What Works
100% PR

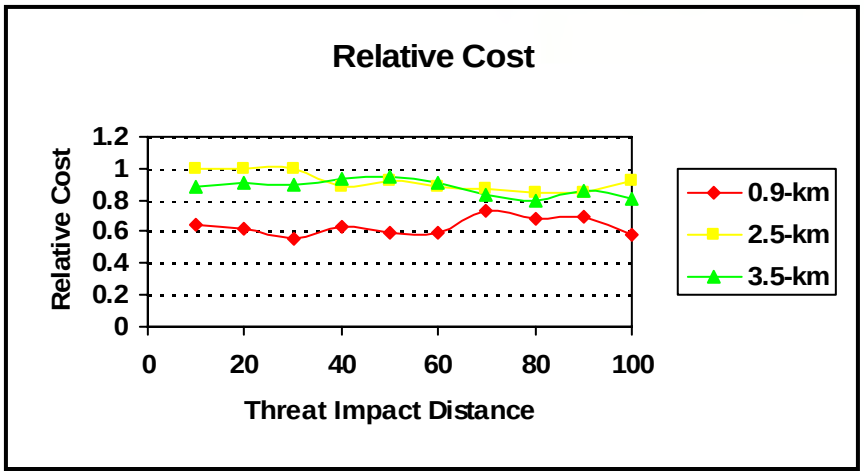
Approach
Cost/Kill: <66%
Weight/Kill: 28.3%
Time/Kill: ~40%

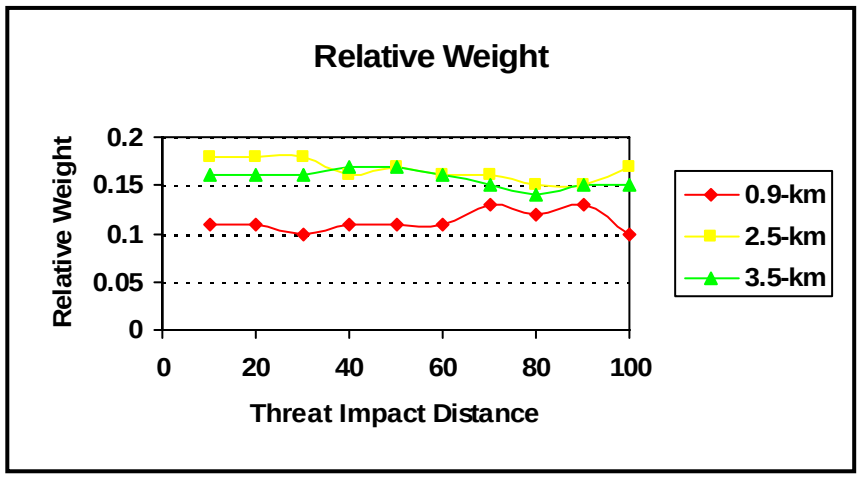
Fuze Risk Too High

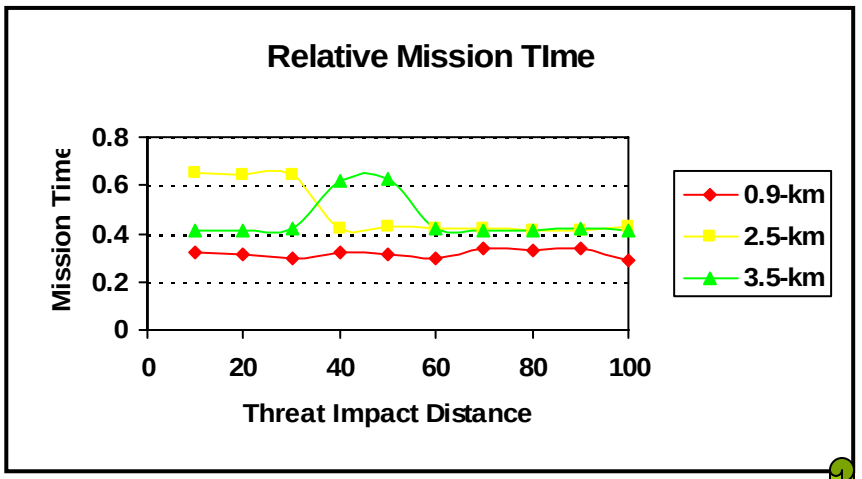
Logistic Burden Too High

Cost, Weight and Time Analysis: 50mm FF Guided vs 82mm Mortar



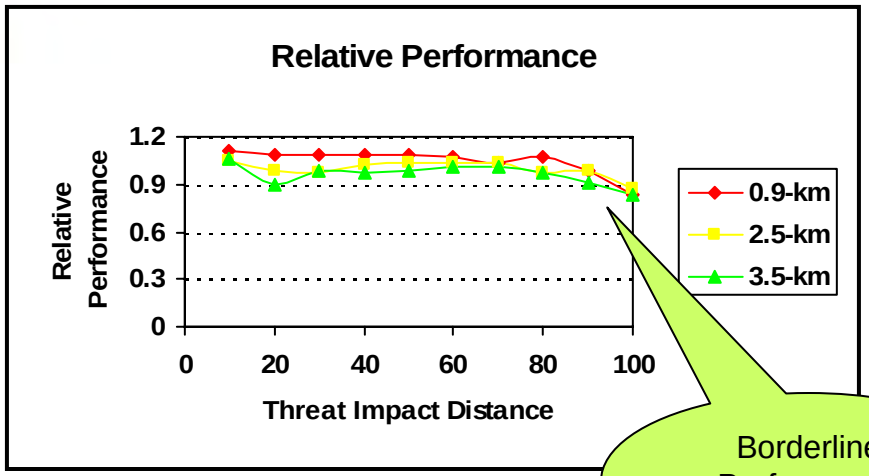


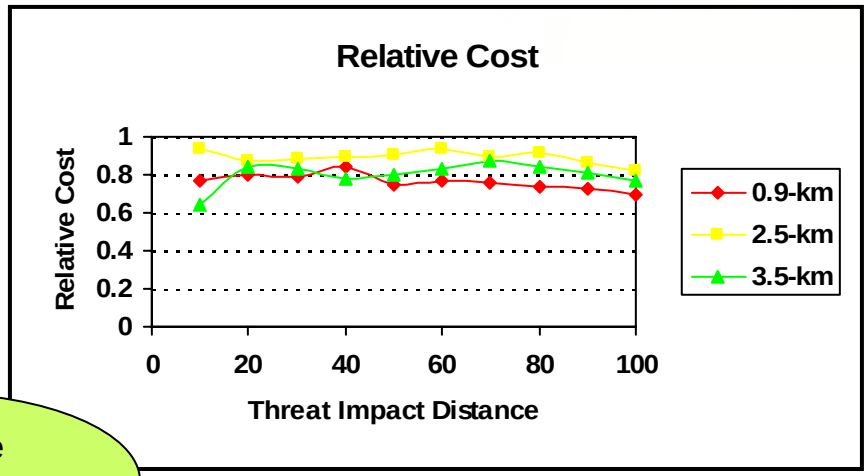




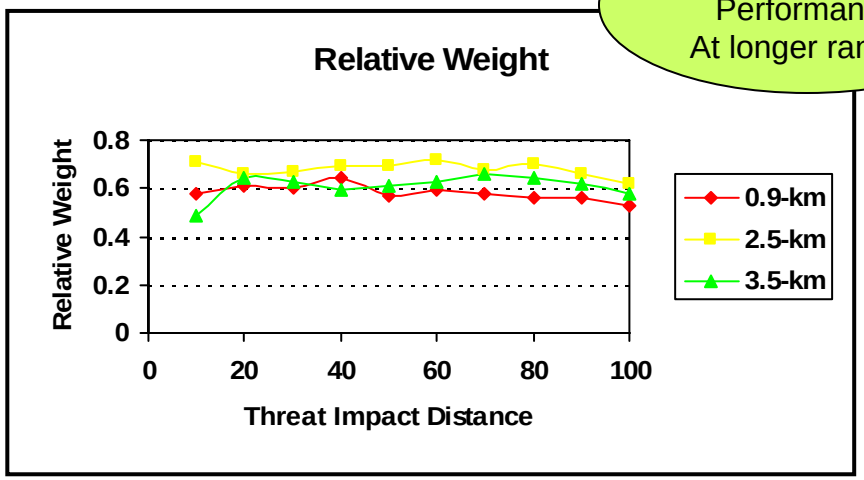
System Meets All Objectives: Performance, Cost, Weight, and Mission Time Are Improvements Over Requirements

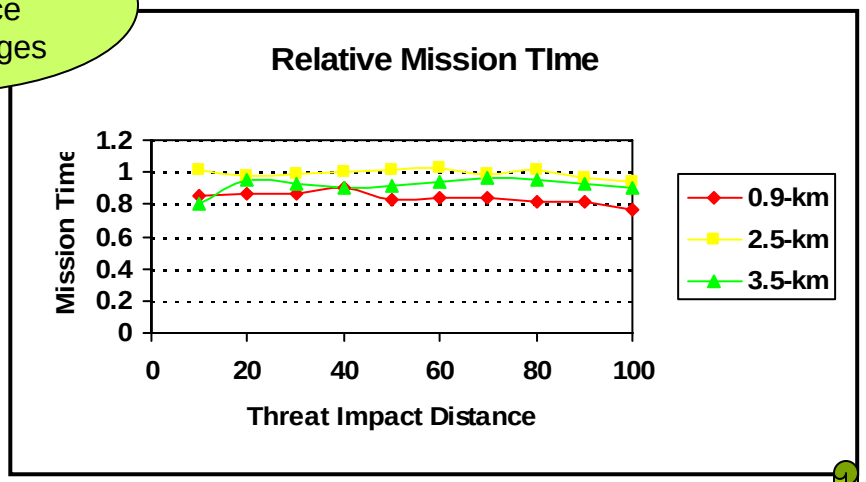
Cost, Weight and Time Analysis: 75mm FF Guided vs 82mm Mortar





Borderline Performance At longer ranges





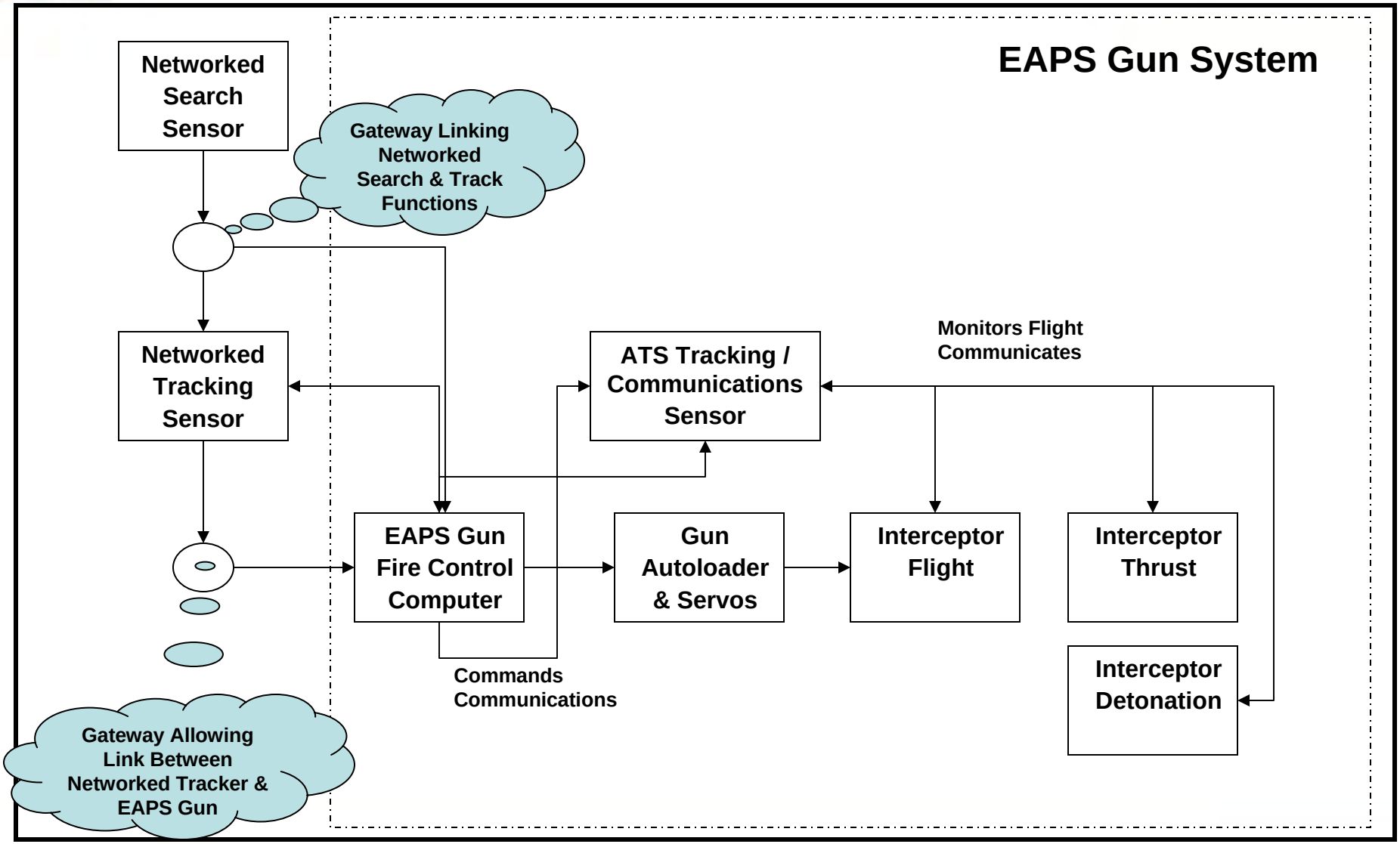
System Meets Almost All Objectives: Performance (Out to 90% Of Threat Impact Range), Cost, Weight, and Mission Time Are Improvements Over Requirements

Used M&S To Determine Technical Approach To EAPS

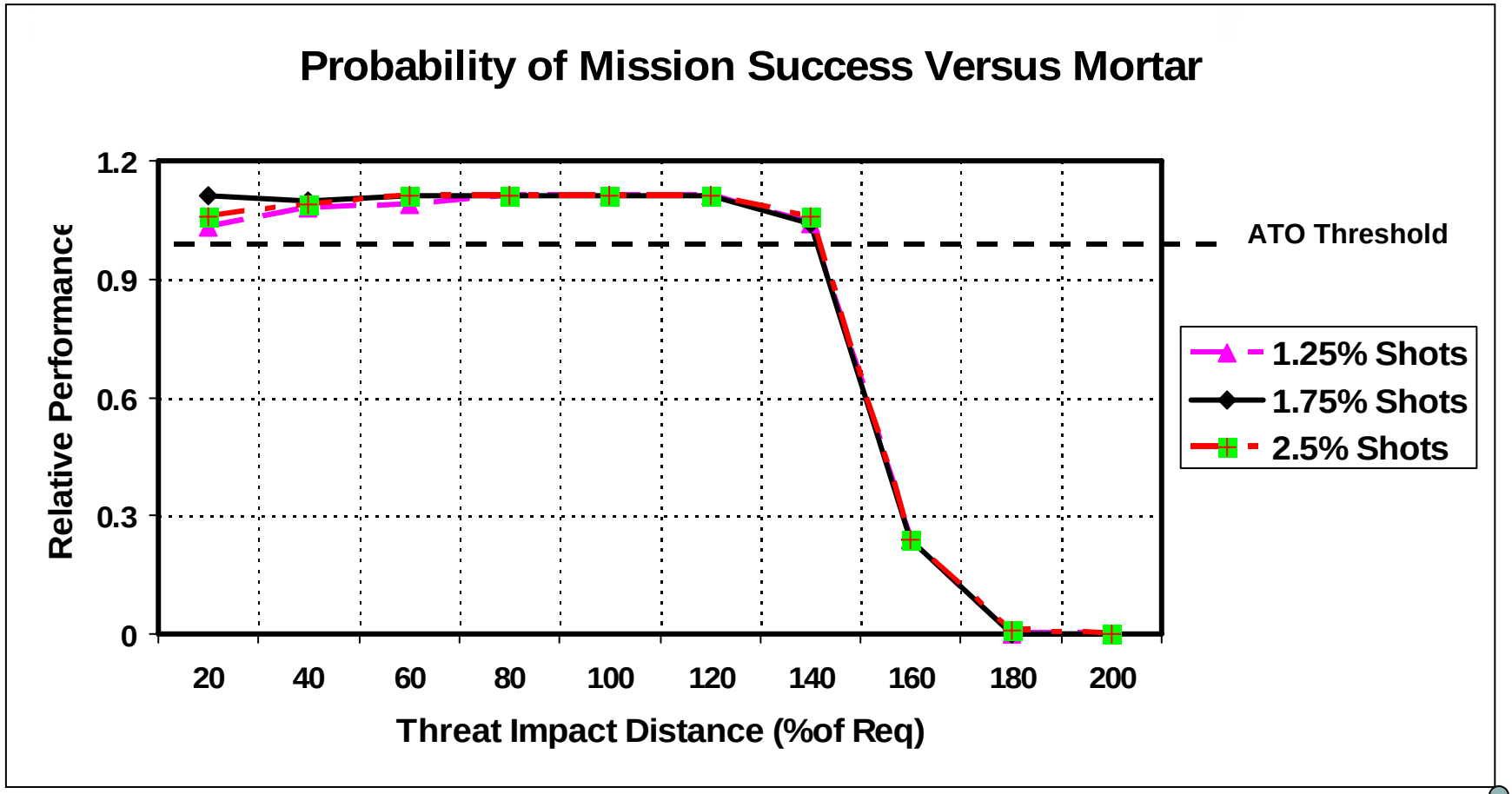
- Recommended Development of A Demonstrator Incorporating:
  - External Surveillance Radar With At Least Phalanx Range Capability
  - PTS/ATS Fire Control Radar For Tracking And Communication Link
  - 50mm Bushmaster III/IV Gun Capable of Achieving High Muzzle Velocity
  - Interceptor Using Course Correction 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



Probability of Mission Success Versus Mortar Threat



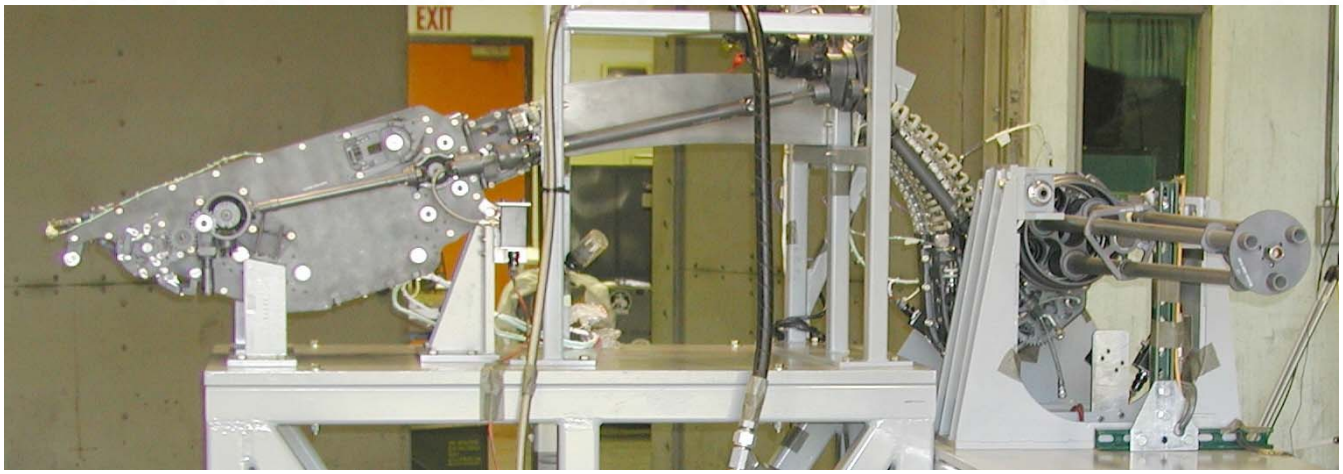
Exceeds ATO Performance Threshold With 1.25% Shots Out To 140%

Gun System Requirements (ATO Objectives)

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

Meets All Specified Goals For EAPS Gun

GENERAL DYNAMICS
Armament and Technical Products



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

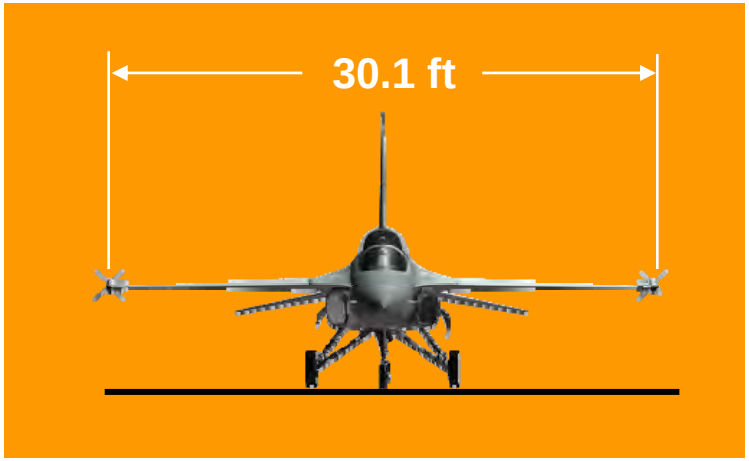


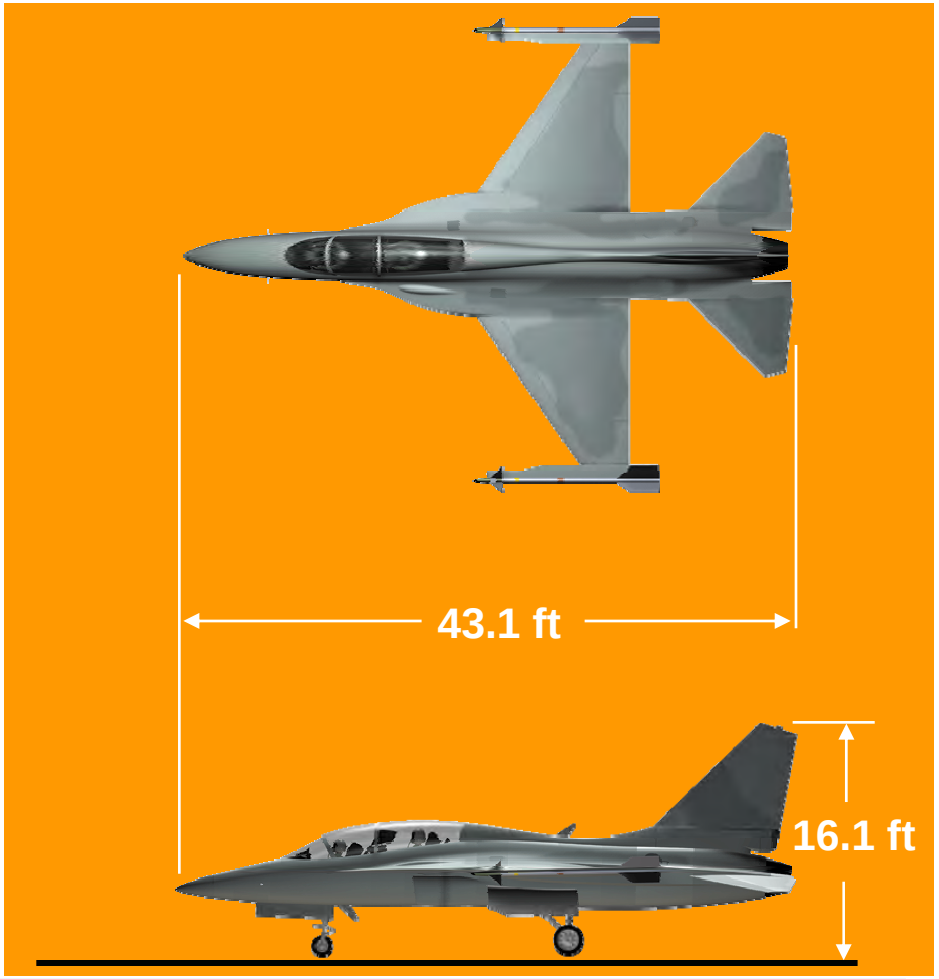


- Advanced Trainer & Light Attack Aircraft for ROKAF & International Markets
- KAI-LM Aero Co-Development Program (Technical Support by LM Aero)
- T-50 International (TFI) for International Marketing
- Performance: F-16 > T-50 > Hawk/F-5
- Demonstrator aircraft flying
- Production to start in 2009
-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

T/A-50 Characteristics

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

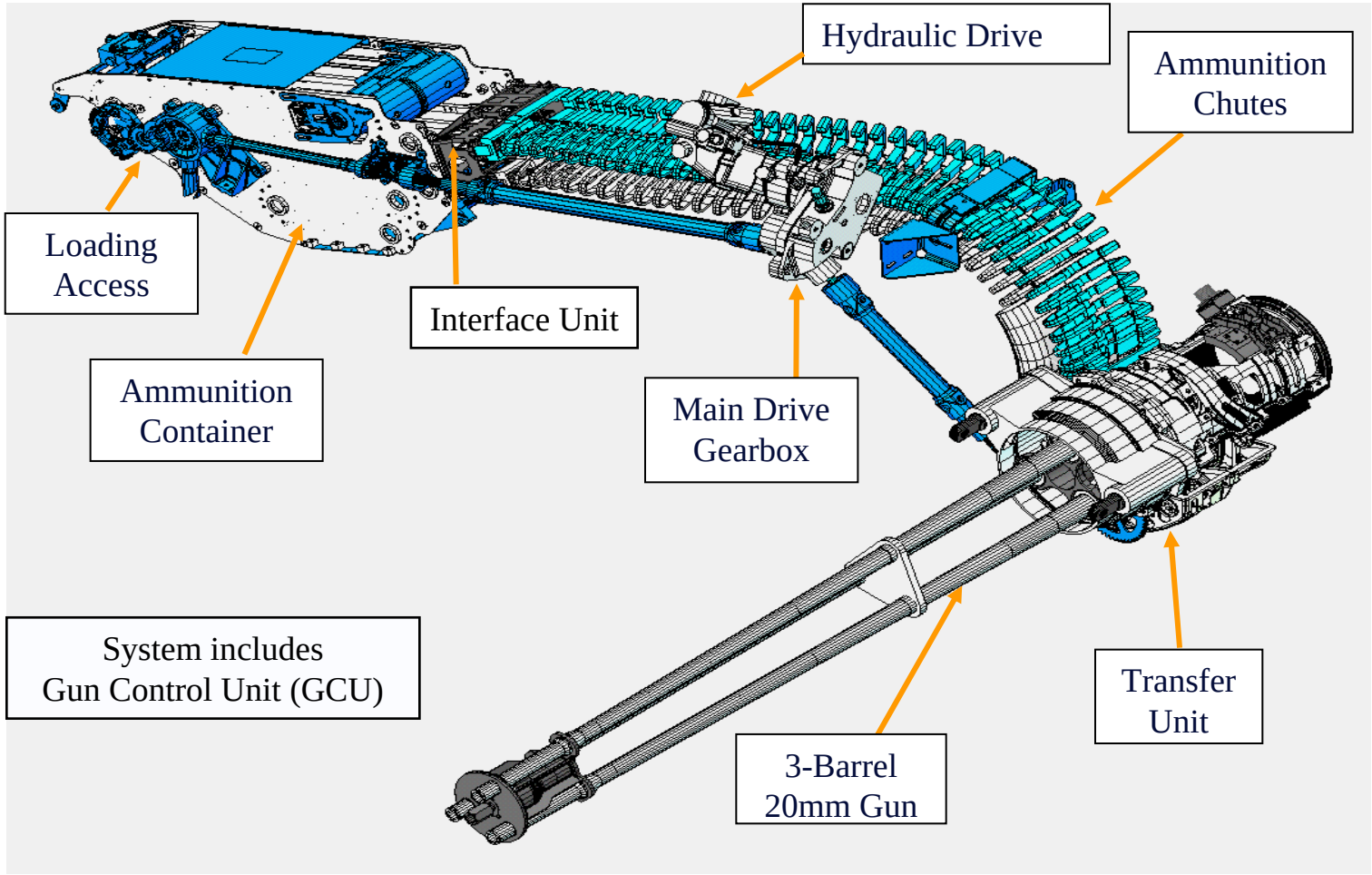




Gun System Characteristics

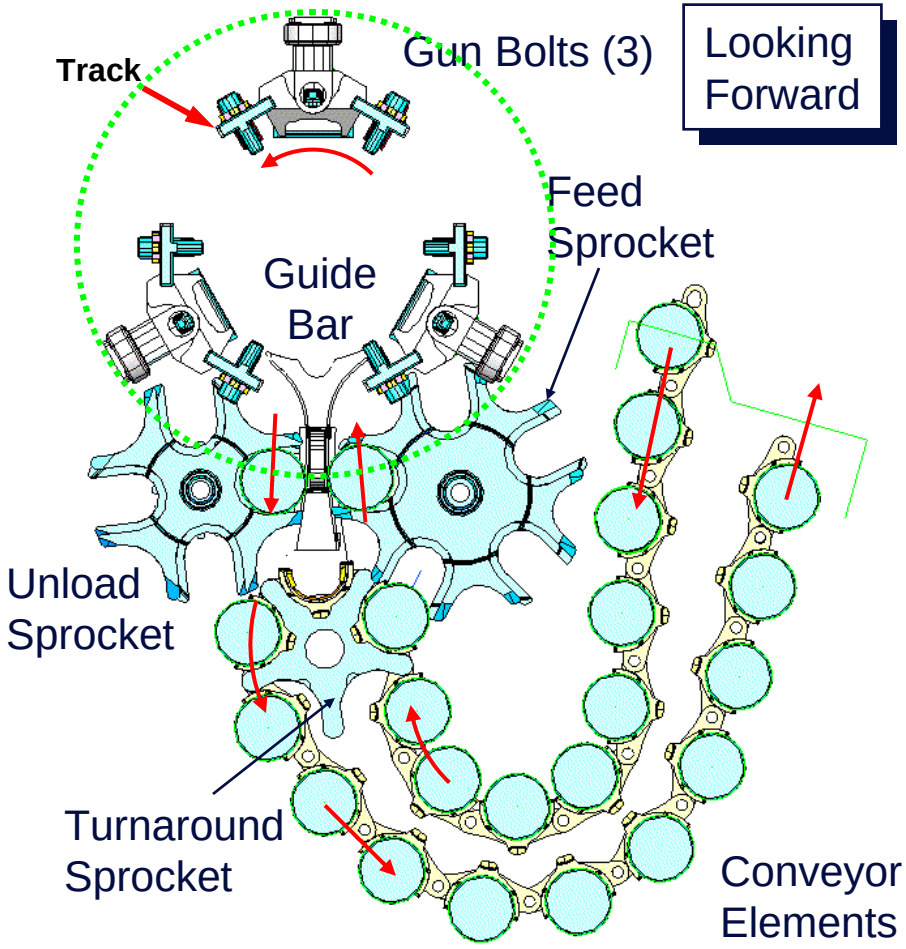
Gun	3-Barrel Externally Powered 20mm Gatling
Firing Rate	3,000 Shots per Minute
Ammo Handling System	Closed Loop Linear Linkless
Ammo Capacity	204 Rounds
Drive System	Hydraulic-Mechanical
Electrical Power	28VDC, 30 Amps Max. 115VAC, 400 Hz (Firing Circuit)
Hydraulic Power	3,000 psi Static 20 gpm Max.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

A-50 Gun System

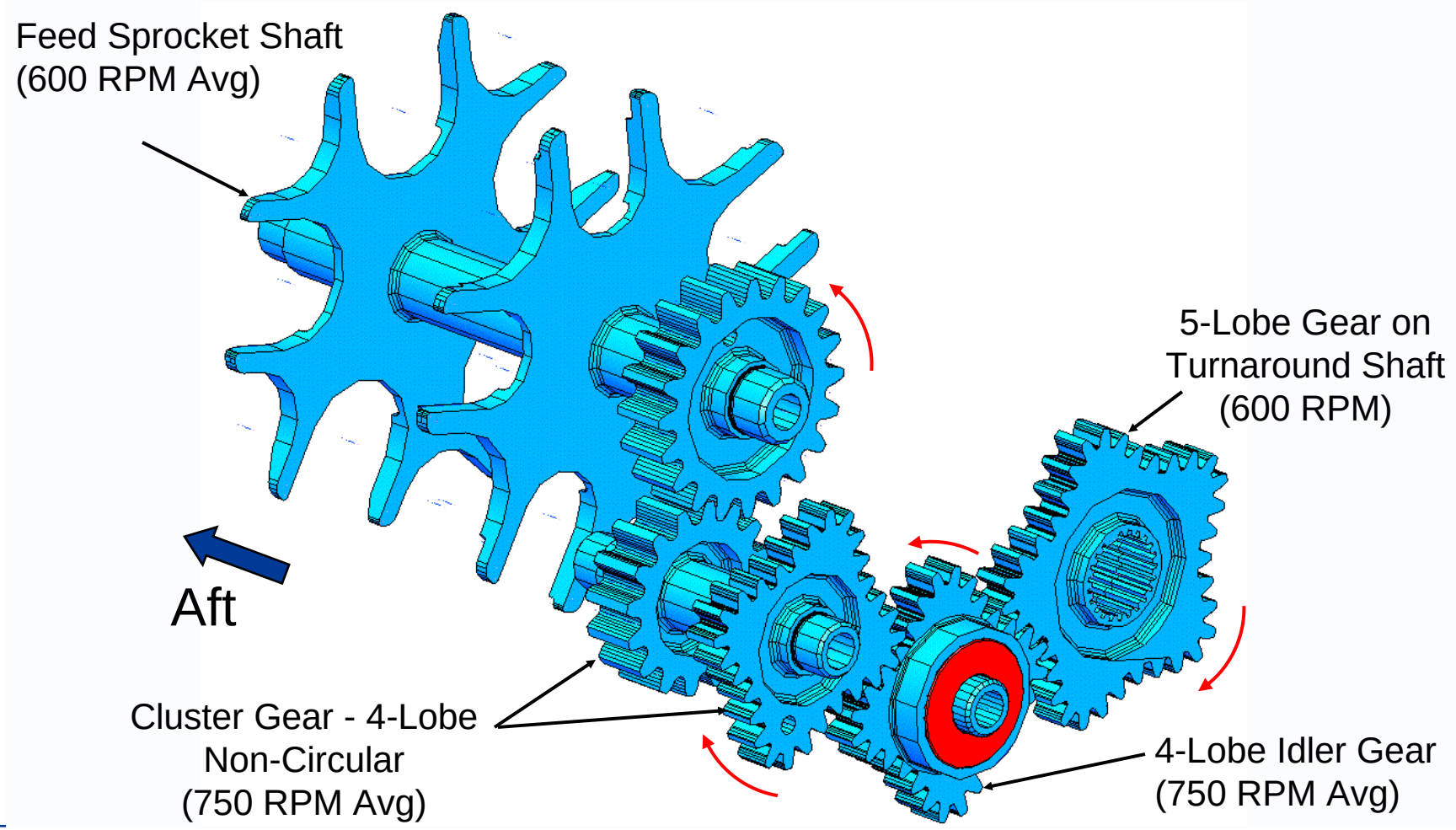


Transfer Unit Roundpath

- 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



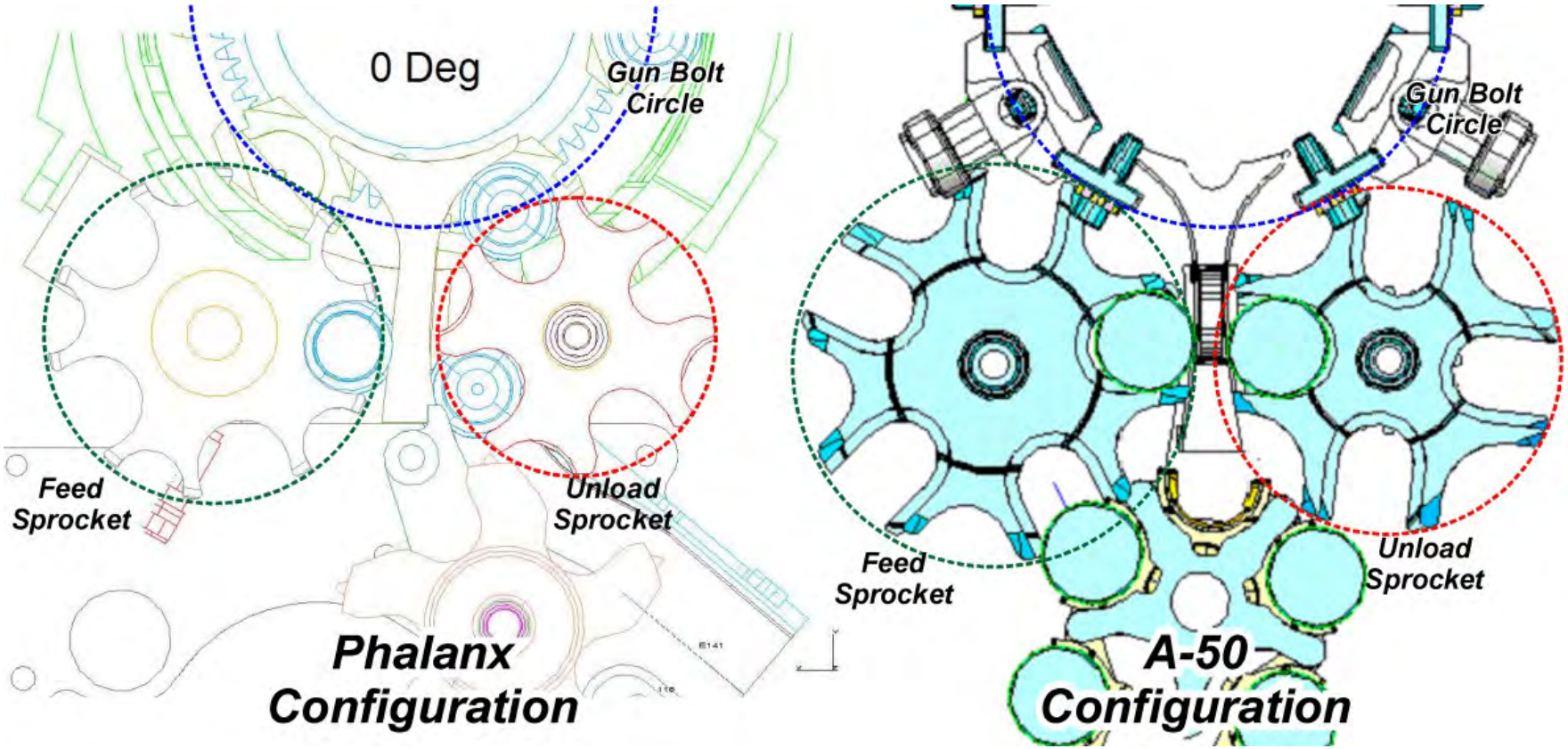
Non-Circular Gearing



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

GENERAL DYNAMICS

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

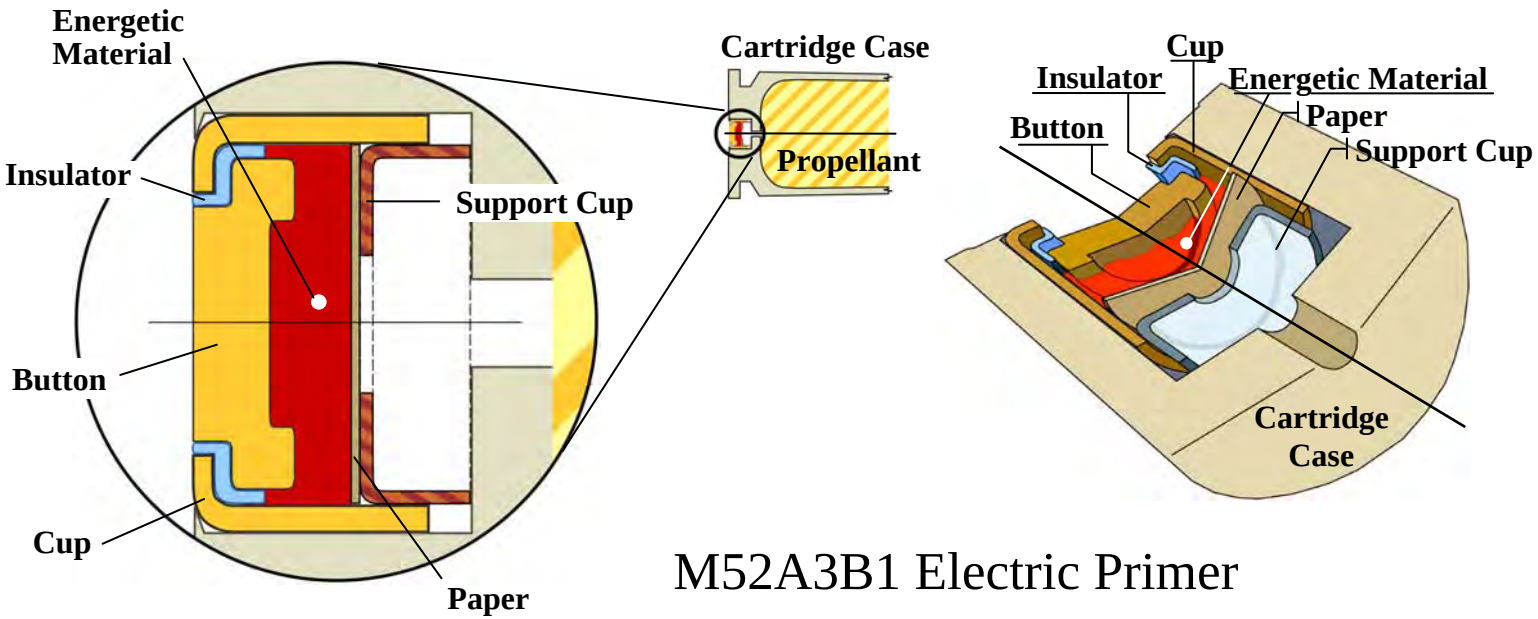
Sarah A. Ford

23 April – 26 April

Approved for public release; distribution is unlimited

PROGRAM OBJECTIVE

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



M52A3B1 Electric Primer

BACKGROUND / NEED

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

TECHNICAL APPROACH

All-Up Round Performance

Primer Composite

- Aluminum - Particle Size (Nano)
- Oxidizer - MoO_3, Bi_2O_3
- Mixing Process - Sonification
- Additives - Carbon/Binder/Gas Generator

Reproducibility

- MIC Materials
- Mixing Conditions
- Composition

Consolidation Process

ACCOMPLISHMENTS

Chemistry Focus

Nanocomposite Ingredients

Aluminum Powder	Size	Active Al
Technanogy	33 nm	48.8% (TGA @CL)
Technanogy	50 nm	64.8% (TGA @CL)
Nanotechnology	80 nm (116 nm)	82.7% (TGA @CL)
China Lake	208 nm	86.0% (TGA @CL)

Molybdenum Trioxide	Size
Climax	40 nm (BET @CL)
Aldrich	1.6 μm (BET @CL)

Bismuth Oxide	Size
Aldrich	320 nm (BET @ CL)
Skylighter	1-3 μm (BET @ LANL)
Sigma-Aldrich	< 10 μm

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

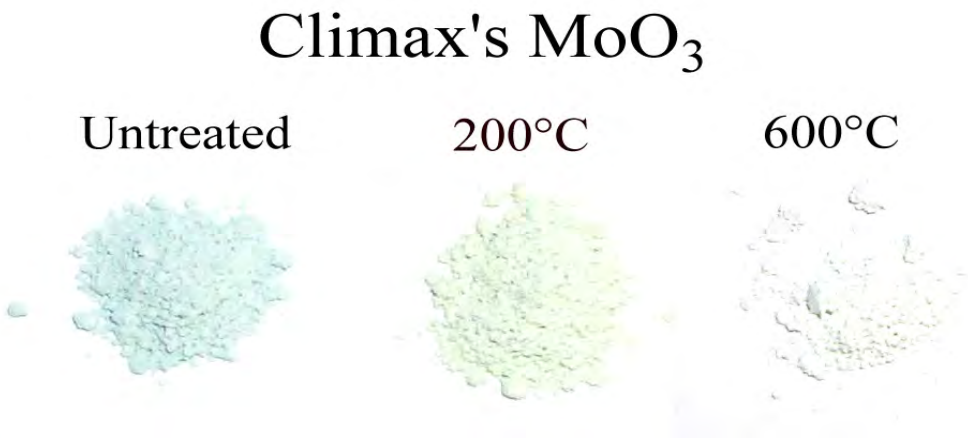
Multi-Vendor Al/MoO_3 Source Demonstration

All-Up Round Action Times
Technanogy, NSWCIH, NAWCWD

ACCOMPLISHMENTS

Chemistry Focus

Aging of the Oxidizer

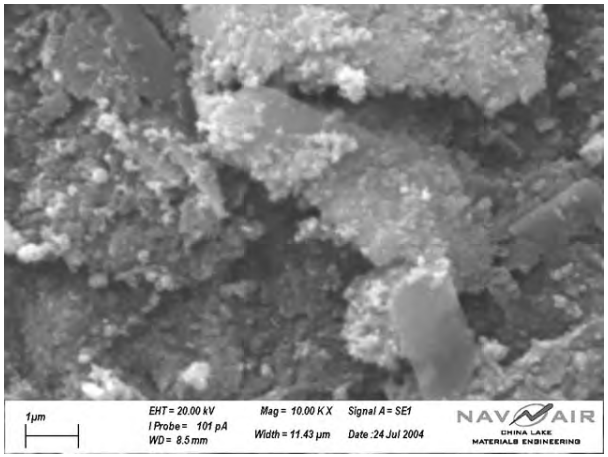


An obvious change occurs in the "as received" MoO_3 from the manufacturer, Climax. Freshly prepared samples of MoO_3 are white and have large surface areas (~ 45 m^2/g) as measured by BET. However, exposure to air over time results in a significant decrease in surface area (~ 20 m^2/g) and leads to a lime green coloration.

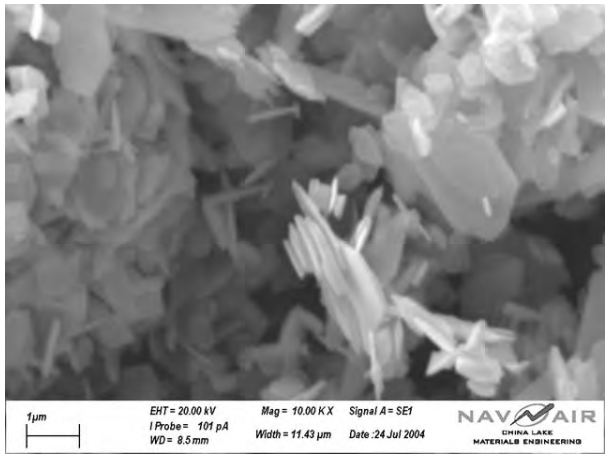
ACCOMPLISHMENTS

Chemistry Focus

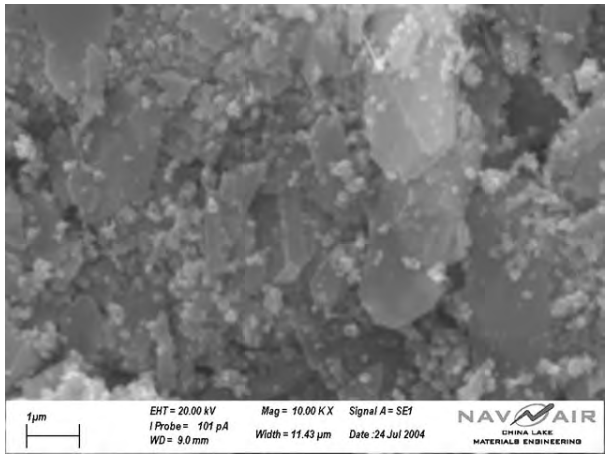
Heat Treatment of MoO_3



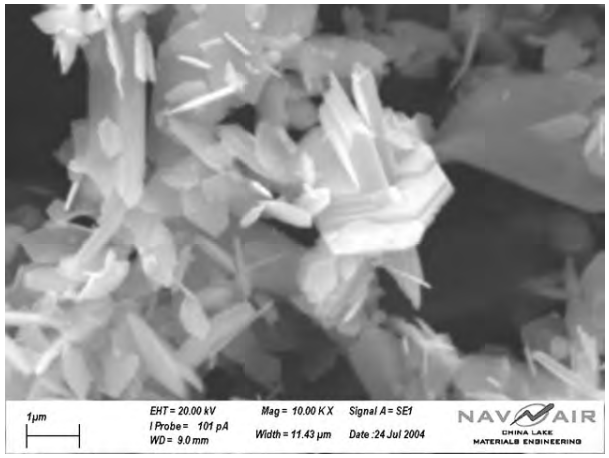
Untreated MoO_3 After 24 Days in Air



MoO_3 Heated to 500°C for 15 Minutes



MoO_3 Heated to 400°C for 15 Minutes



MoO_3 Heated to 400°C for 180 Minutes

ACCOMPLISHMENTS

Chemistry Focus

Heat Treatment of MoO_3

	Heat Treat Temperature					
	400 Degrees Centigrade		443 Degrees Centigrade		500 Degrees Centigrade	
Time (Minutes)	Morphology	Size (nm)	Morphology	Size (nm)	Morphology	Size (nm)
15					Orth (100%)	220
22			Orth (100%)			
30	Mono / Ortho				Orth (100%)	
60	Mono / Ortho					
120	Orth (100%)					
180	Orth (100%)	198			Orth (100%)	

MoO_3 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

ACCOMPLISHMENTS

Chemistry Focus

Ultrasonic Mixing

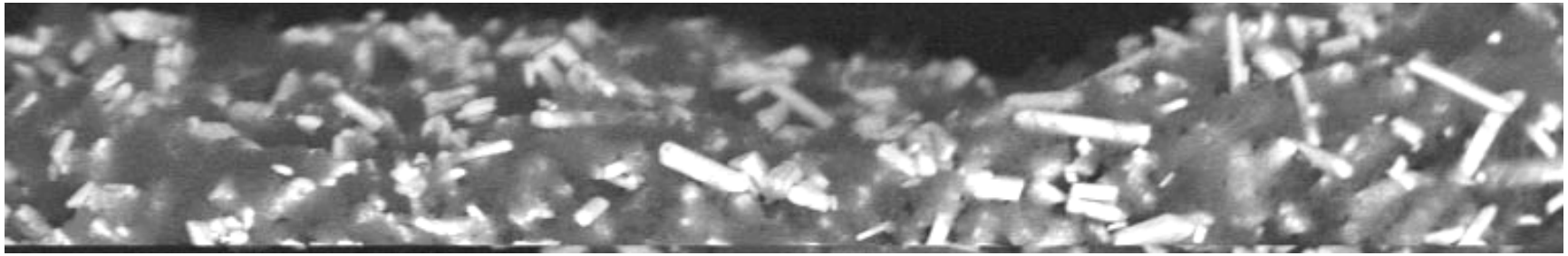
Determine Aging vs Different Mix Processes

- Dry Mixing – Mechanical Shaker for 2 Minutes
- Ultrasonic Bath
  - Sonicate Al/MoO_3 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

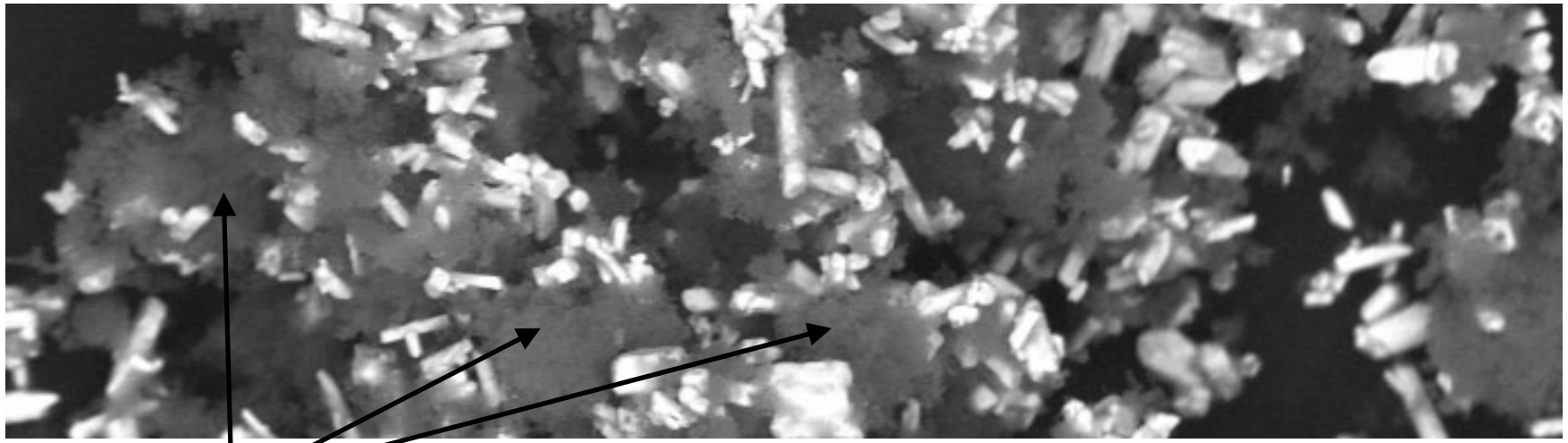
ACCOMPLISHMENTS

Chemistry Focus

Solvent Effect in Mixing Hexane Versus i-PrOH



Hexane



Poorer Mixing

i-PrOH

ACCOMPLISHMENTS

Chemistry Focus

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

	Molybdenum Trioxide MoO_3			
Aluminum Powder	Climax 40 nm		Aldrich 1.6 mm	
	Hexane	i-PrOH	Hexane	i-PrOH
Al (35 nm)	Good			
Al (50 nm)	Good		Good	
Al (80 nm)	Good		Good	

	Bismuth Trioxide Bi_2O_3					
Aluminum Powder	Aldrich 320 nm		Skylighter 1-3 mm		Sigma-Aldrich < 10 mm	
	Hexane	i-PrOH	Hexane	i-PrOH	Hexane	i-PrOH
Al (35 nm)				Poor		
Al (50 nm)	Good	Poor		Poor	Good	Very Poor
Al (80 nm)	Good	Poor	Very Good	Good	Good	
Al (208 nm)					Good	
Al (5 mm)	Good					

Poor – Material Separation (Al from Oxidizer) Was Observed

Good – Little or No Material Separation

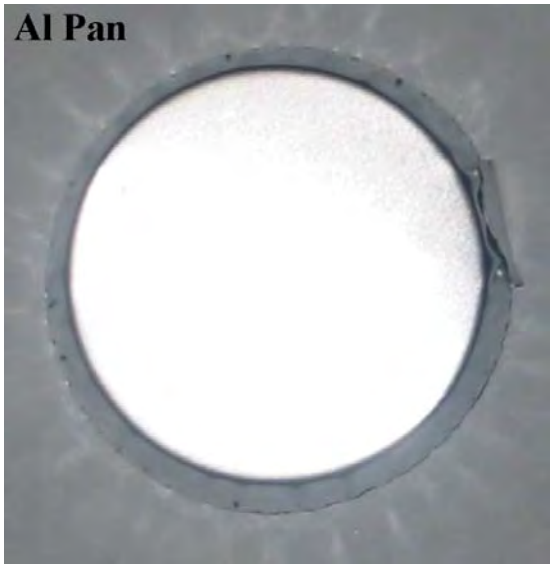
Very Good – No Material Separation, Rapid Precipitation, Easy Isolation (Filtration)

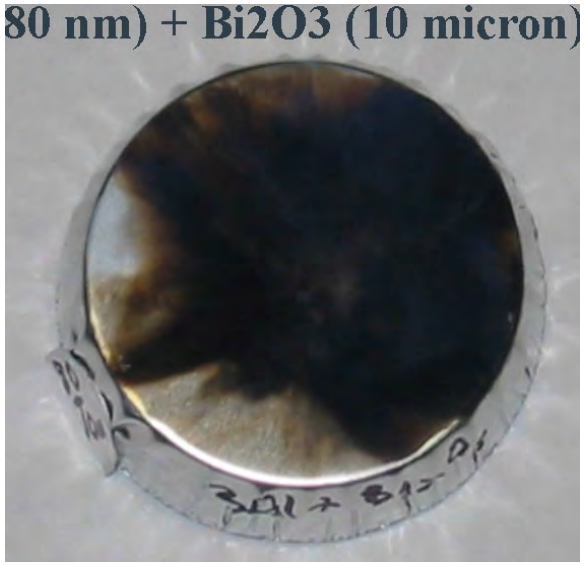
ACCOMPLISHMENTS

Chemistry Focus

Pan Test

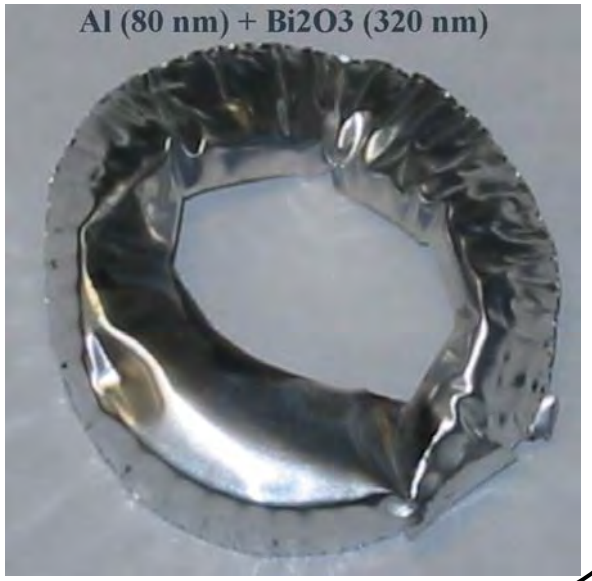
50-55 mg of Al/Bi_2O_3





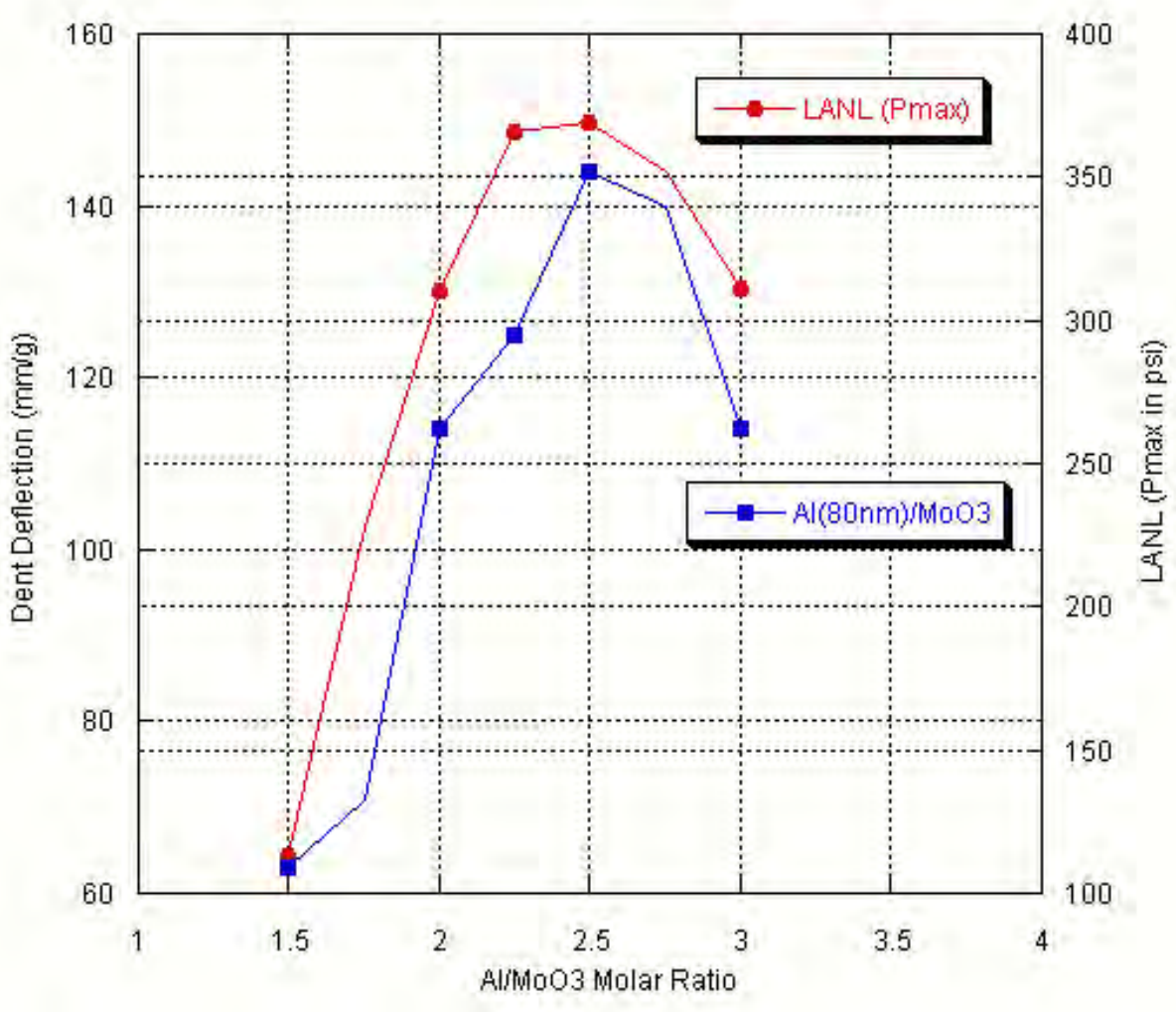






ACCOMPLISHMENTS

Optimization of Al(80nm)/MoO_3 (Cl) by LANL Pressure Cell Versus Pan Deflection



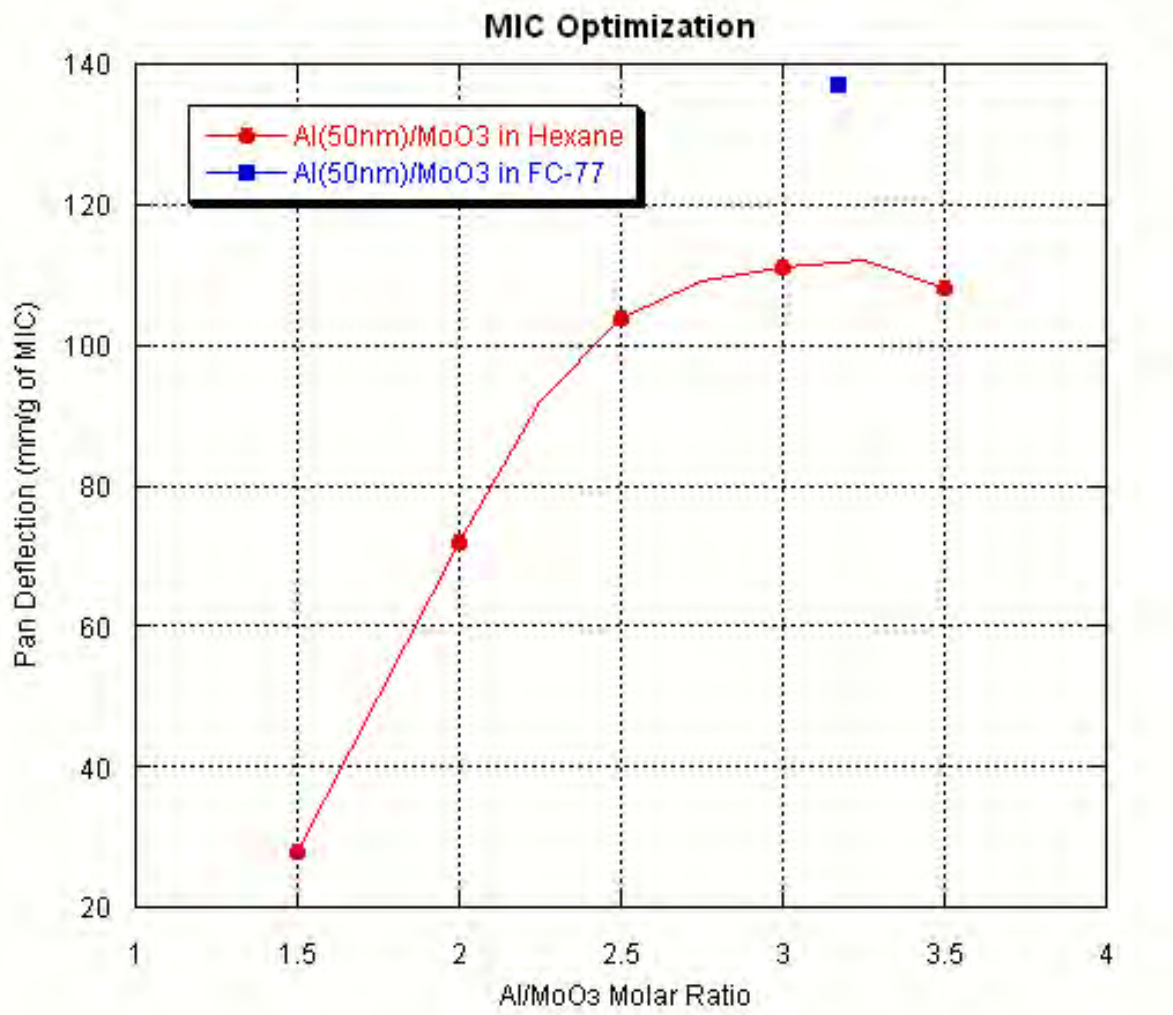
Optimization results were similar for both methods. Optimal performance achieved at a 2.5 Al/MoO_3 ratio. Best performance for fuel rich composites.

2 Al + MoO_3 → Al_2O_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)/MoO_3(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

ACCOMPLISHMENTS

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/Bi_2O_3/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

ACCOMPLISHMENTS

Safety Status:

Handling and Safety Concerns

Issue: ESD and friction sensitivity of MIC materials, particularly Bi_2O_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.

Safety Status:

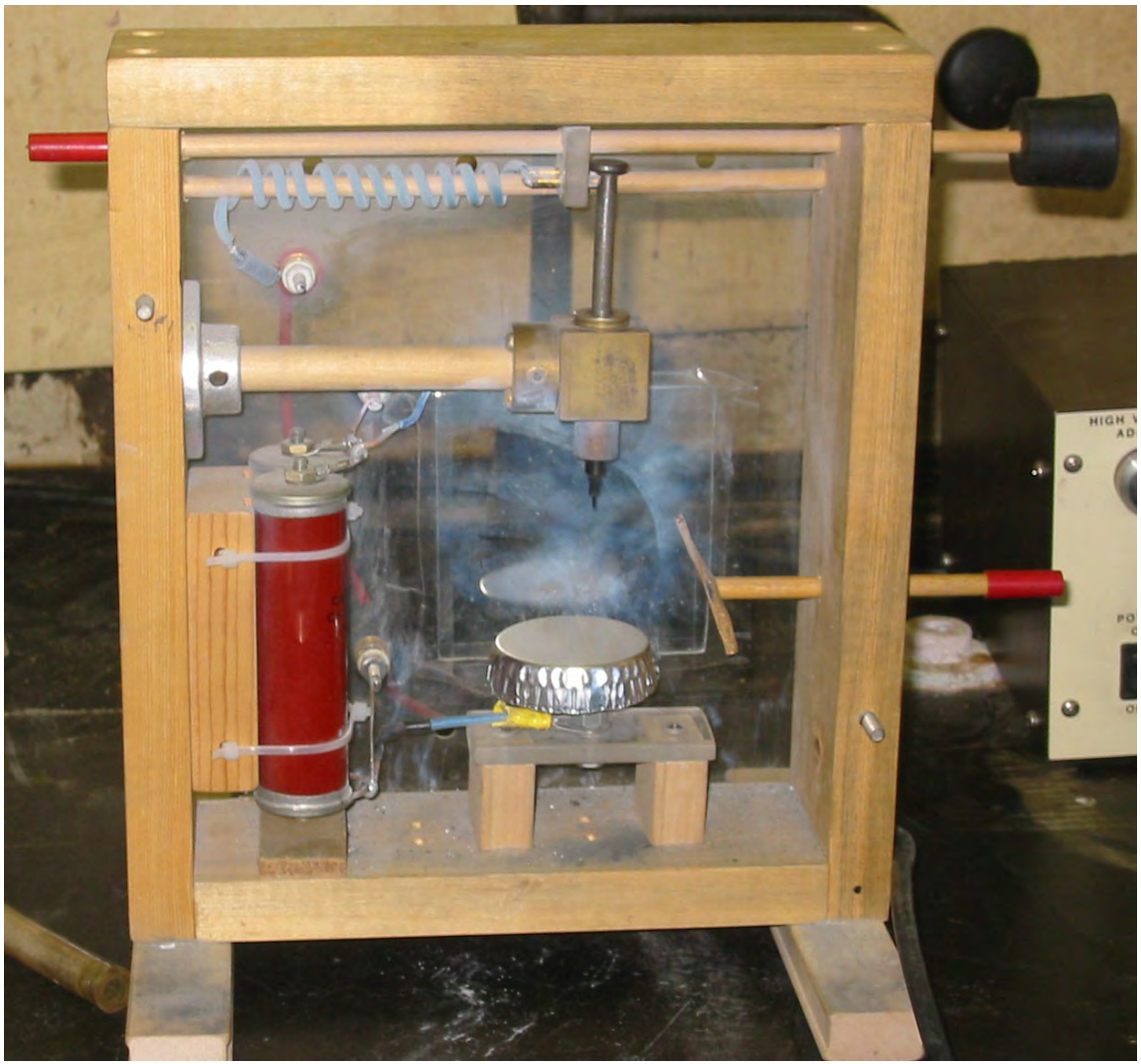
Electrostatic Discharge (ESD) Sensitivity

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

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

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



Primer Reliability

Chemical Instability

- Stability of MIC (Al/MoO_3)
- Material Aging (H_2O) – atmospheric, chemical, contamination

MIC Mixing Process – Ultrasonic Mixing

Loading and Pressing

- Density
- Electrical Properties (C)
- Physical Integrity (Binder)

ACCOMPLISHMENTS

Primer Reliability

Loading Procedures

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
$NH_4H_2PO_4$	0.042g
Bi_2O_3 (320 nm)	0.963g
Gum Arabic	0.059g
Water	25 ml

Al and $NH_4H_2PO_4$ in 10 ml of H_2O sonicated for 30 s
Bi_2O_3 and Gum Arabic in 15 ml of H_2O 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 Bi_2O_3 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

ACCOMPLISHMENTS

All-Up Round (AUR)

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.

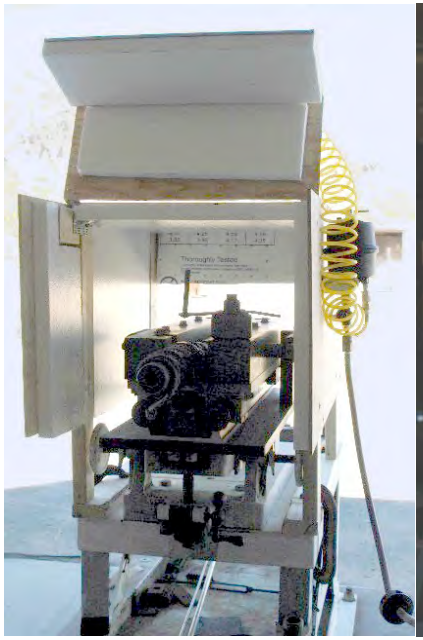
ACCOMPLISHMENTS

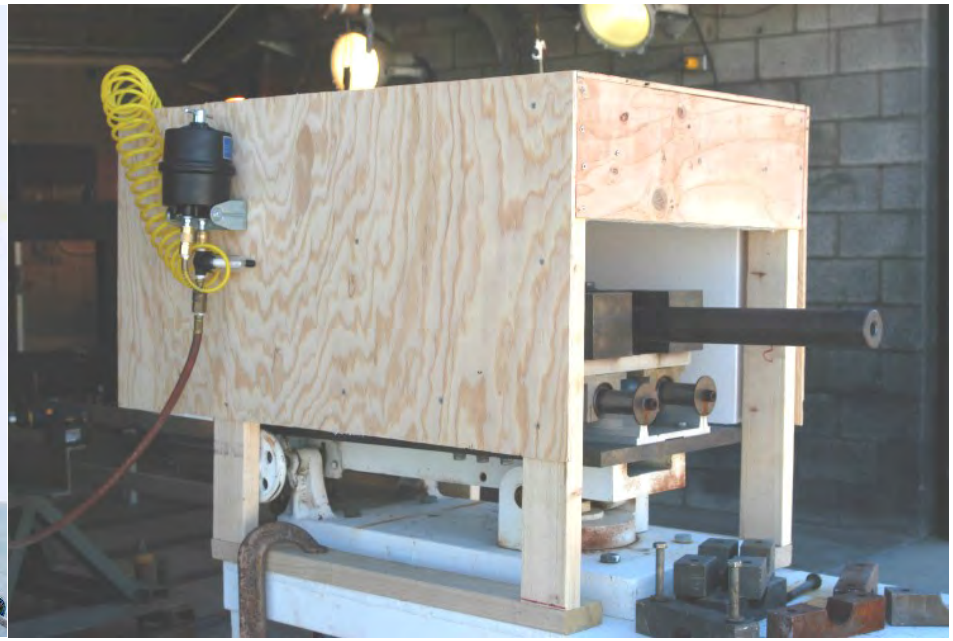
All-Up Round (AUR)

Cold Temp Test Setup

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





ACCOMPLISHMENTS

All-Up Round (AUR)

Formulation Identity	Firing Test Date	Initial Temperature (ºF) of Primer	Primer Test Temperature (ºF)	Action Time (msec)	Chamber Pressure (ksi)	Velocity (fps)
KTHU-22	2 Mar 05	Ambient	Ambient	Within Spec	Within Spec	Within Spec
KTHU-22	4 Apr 05	Ambient	Ambient	Within Spec	Within Spec	Within Spec
KTHU-47	23 Jun 05	Ambient	Ambient	Within Spec	Within Spec	Within Spec
KTHU-53	23 Jun 05	Ambient	Ambient	Within Spec	Within Spec	Within Spec
KTHU-57	27 Sept 05	Ambient	Ambient	Within Spec	Within Spec	Within Spec
KTHU-22	20 Oct 05	Cold Temperatures	Cold Temperatures	Within Spec	Within Spec	Within Spec
KTHW-24	24 Oct 05	Cold Temperatures	Cold Temperaures	Exceed Spec	Within Spec	Within Spec

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

TRANSITION PLAN

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?

BAE SYSTEMS

PRECISION TARGETING

NDIA 42nd 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



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Affordable Tactical Seekers

BAE SYSTEMS

PRECISION TARGETING

➢ 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

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Advanced Precision Kill Weapon System (APKWS™)

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BAE SYSTEMS

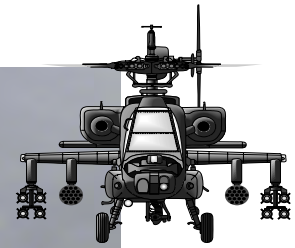
AVIATION OPERATIONAL NEED

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





Platforms:
Cobra
Apache
Kiowa
ARH
UAV's…..



Does not meet Accuracy

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



Does not meet low Cost

~ Weapons Gap ~

Guided 2.75" Rocket (Soft & Lightly Armored Point Targets)

Unguided 2.75" Rocket (Area Suppression)

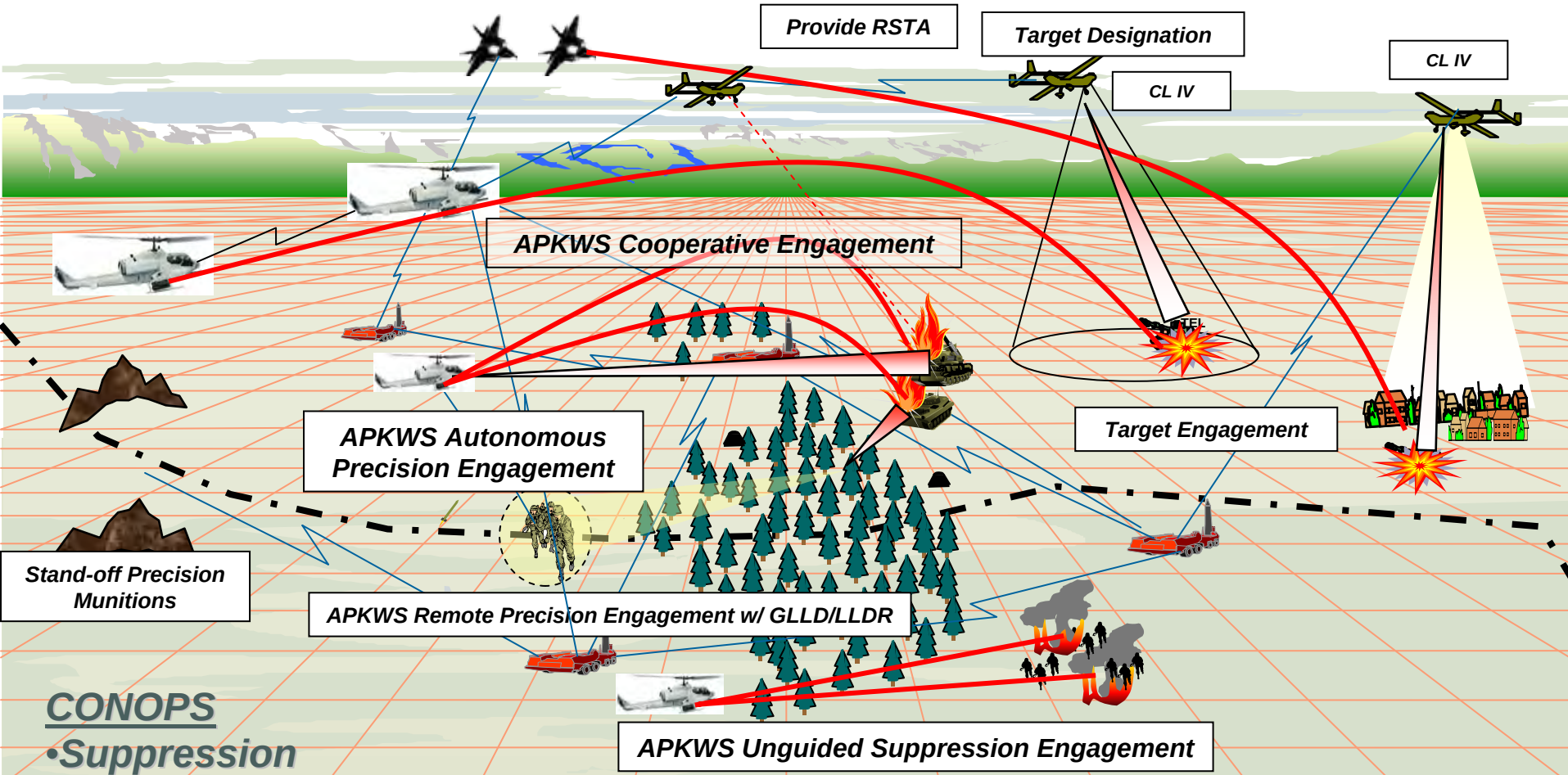
AGM-114 Hellfire (Anti-Armor)

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

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APKWS™

CONCEPT OF OPERATIONS



CONOPS

- ***Suppression***
- ***Self Designate***
- ***Cooperative Engagement***

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APKWS™ Components

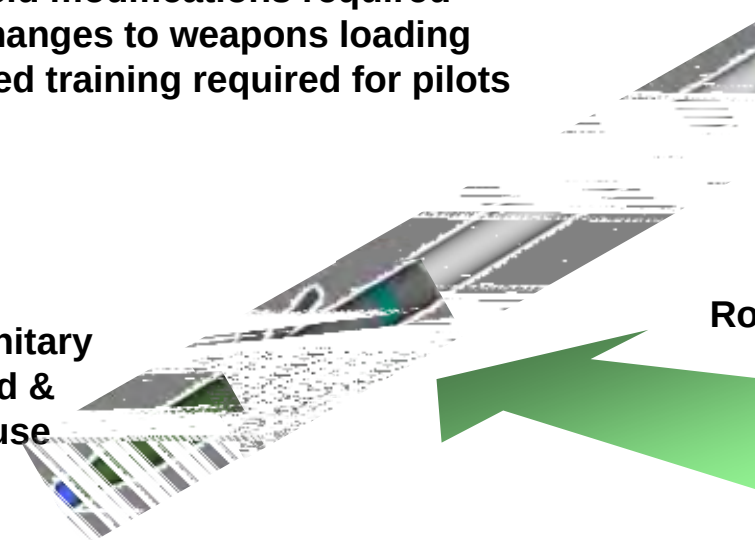
BAE SYSTEMS
PRECISION TARGETING

Mid-body Design is *Supportable*

- No field modifications required
- No changes to weapons loading
- Limited training required for pilots

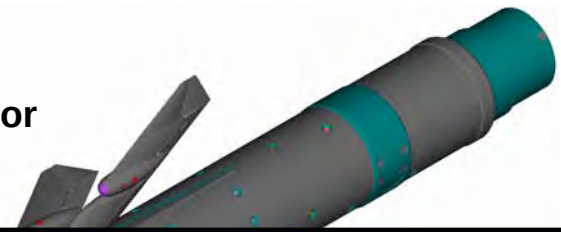
Mid-body Design is *Reliable*

- Optics protected prior to launch from adjacent firings, sand, moisture, etc.
- Wide FOV for broader capture area



M151 Unitary Warhead & M423 Fuse

Mark 66 Mod 4 2.75" Rocket Motor



Description	Current Wt per Unit (lbs)	Length (inches)
Guidance & Control	8.9	18.5
Motor	13.7	41.8
Payload & Fuse	9.2	13.5
All Up Round	31.8	73.8
Requirement	*35*	*75*

No Impact on Warhead Effectiveness

- Warhead does not "fire through" guidance unit

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Mid-Body Seeker

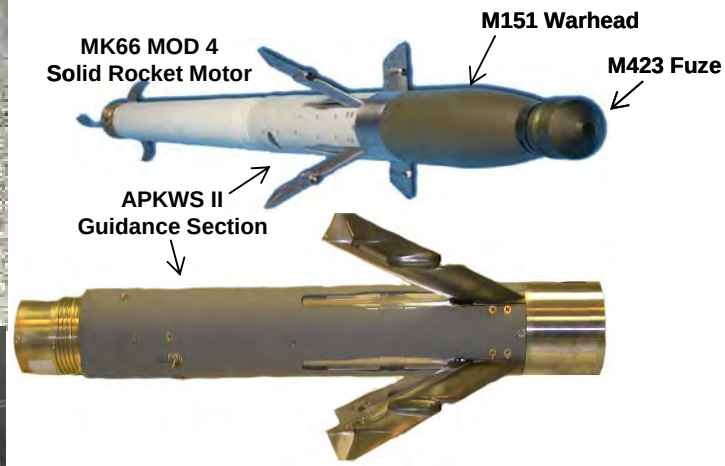
BAE SYSTEMS

PRECISION TARGETING

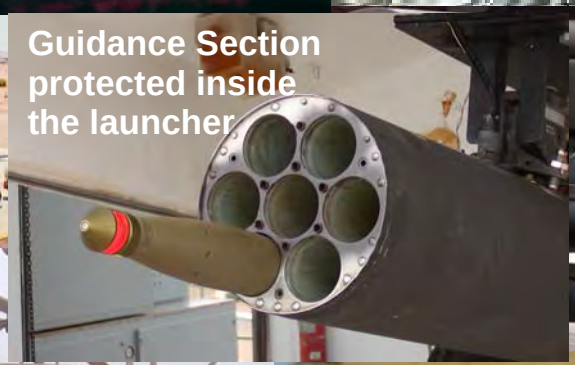


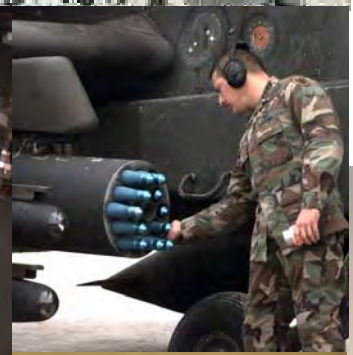


Simple Guidance Section Assembly Into an All Up Round















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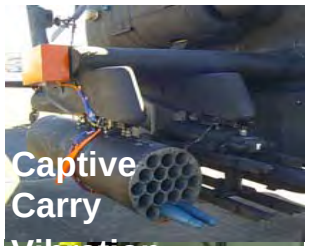
Proven Performance

BAE SYSTEMS

PRECISION TARGETING

Tested throughout the full environmental spectrum

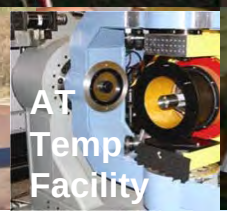
- Vibration
- Shock
- Environmental Testing
- HWIL, ALSPES, at Temp Facility, Outdoor Range Testing

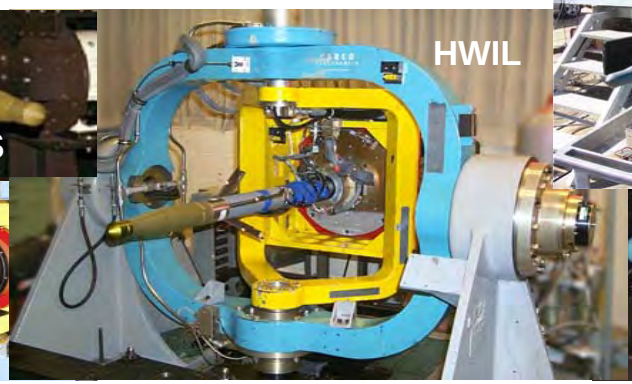




















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Flight Test Success

BAE SYSTEMS

PRECISION TARGETING



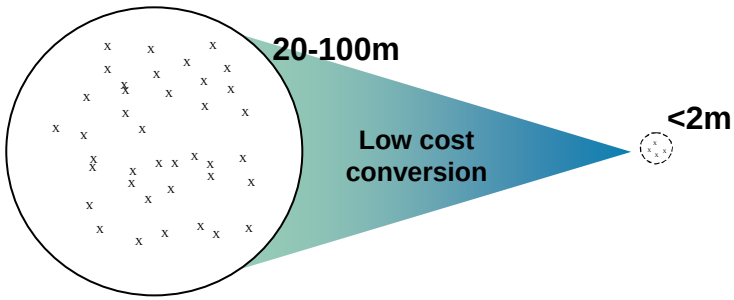
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APKWS™ Advantages

BAE SYSTEMS

PRECISION TARGETING

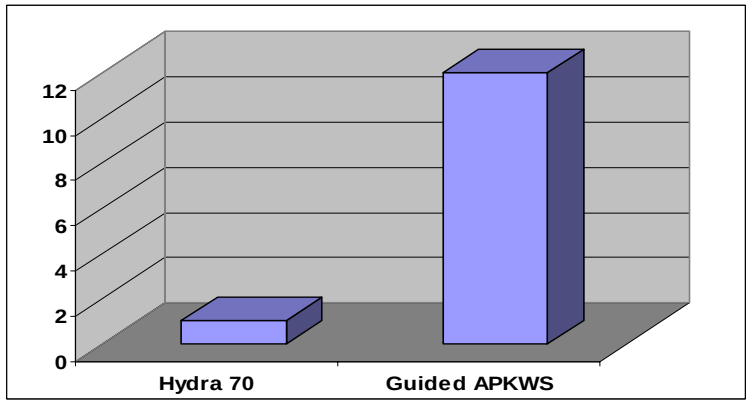
Increased Accuracy



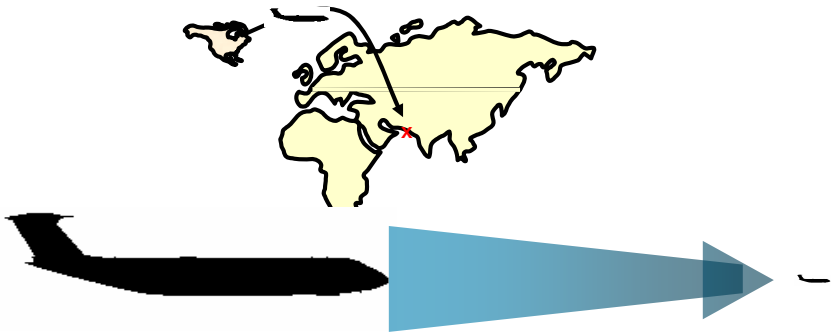
1.5km to 5km range

Area Suppression becomes Precision Strike

> Stowed Kills per Sortie

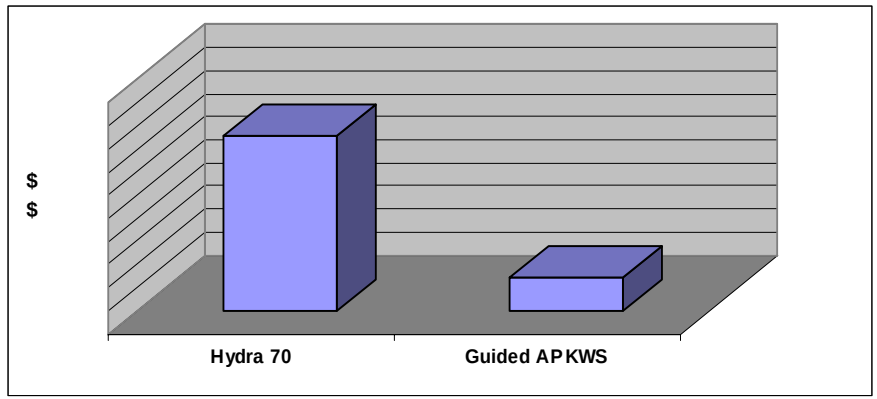


Reduced Logistics Burden



12 to 1 reduction in transport load outs for same combat effectiveness

< Cost for Stowed Kills per Sortie



• AMRDEC/DCD analysis in support of LCPK ATD

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XM 395 PGMM
Precision Guided Mortar Munition

BAE SYSTEMS

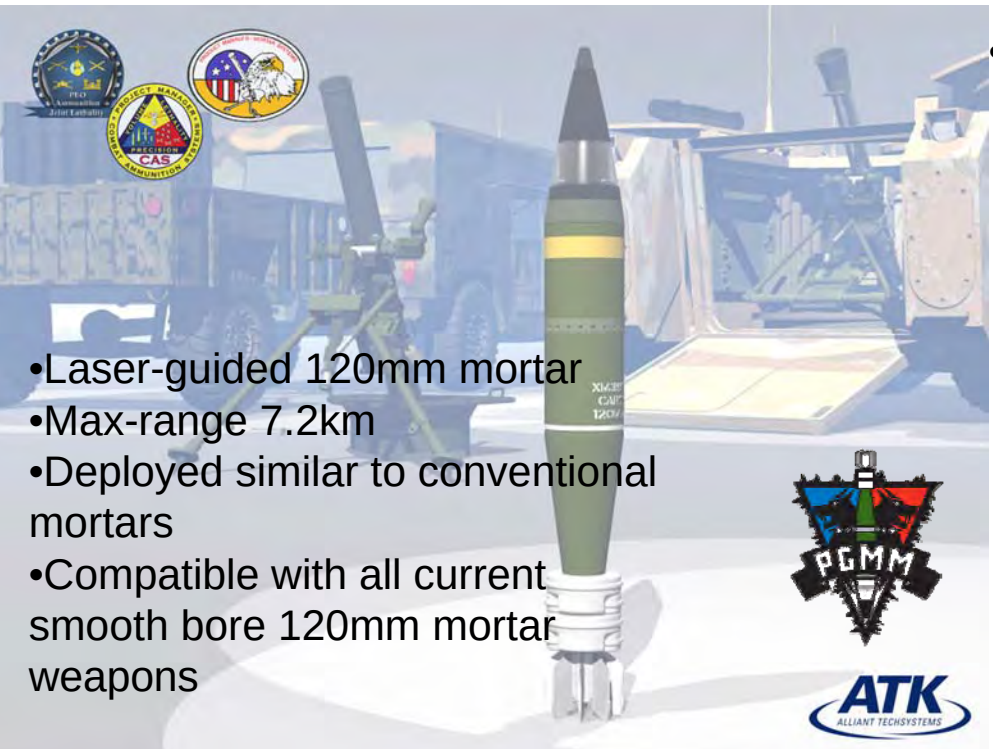
ATK ALLIANT TECHSYSTEMS

PRECISION TARGETING

PGMM

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





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

- 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.
    - The round flew approximately 2.5 miles to target and maneuvered to a precision strike

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Flight Test Success



BAE SYSTEMS

ATK
ALLIANT TECHSYSTEMS

PRECISION TARGETING

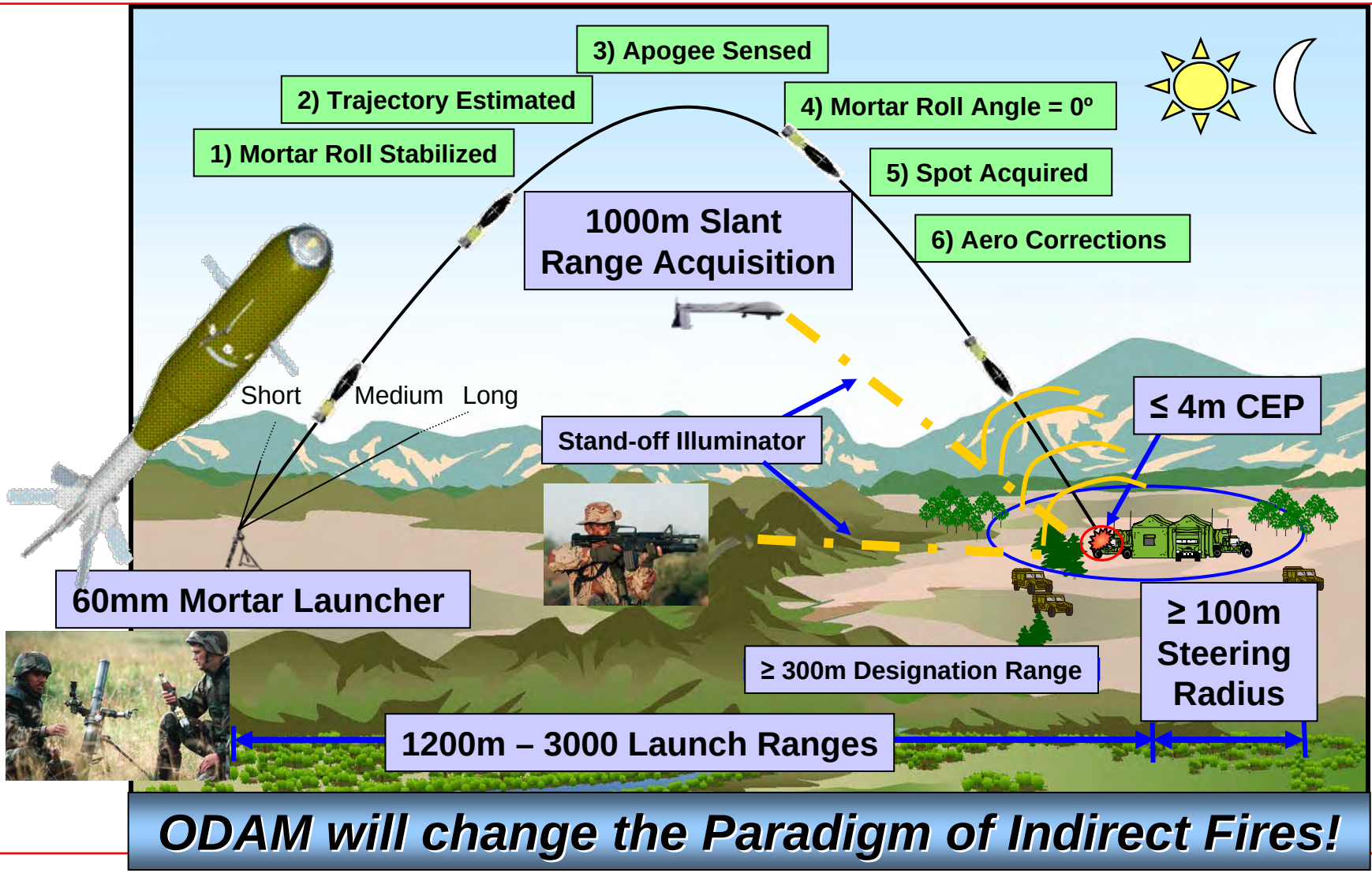
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Optically Designated Attack Munitions (ODAM)

60 mm fuze / guidance

BAE SYSTEMS

PRECISION TARGETING



ODAM will change the Paradigm of Indirect Fires!

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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 – <u>disruptive technology</u>
  - ~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)



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Flight Test Success

BAE SYSTEMS

PRECISION TARGETING



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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

BAE SYSTEMS





The Success of the AMRAAM DBMS/DAS

John Gerdine

Wyle Laboratories Inc.

Niceville Florida 32579 U.S.A.

wyle laboratories

Public Release Approval
AAC/PA #03-28-07-217

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

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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

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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

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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

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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 P^3I Programs
- Over the last 10 years, AMRAAM continues to be evaluated in the Weapon System Evaluation Program (WSEP)

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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)

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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

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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

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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.

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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.

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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.

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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

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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

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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

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Weapon System Analysis

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

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Anomaly Investigations

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

- Point anomaly
- Trend analysis

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Simulations Validation

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

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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

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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.

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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

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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

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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."

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Questions?

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Raytheon

Customer Success Is Our Mission

Presentation to 42nd Annual Gun and Missiles Conference

Trade Space on Appropriate Caliber Ammunition for Terminal Defense Guided Projectile

Advanced Programs

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April 23, 2007

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

Traditional Threats

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Missile Systems

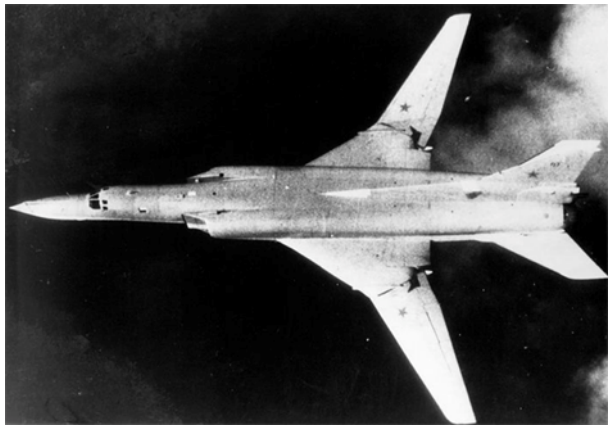
- Large capital platforms
- Large, highly capable weapons
- Low engagement rates
- Relatively long reaction times
- Usually engaged by a large, high performance missile
- Gunfire used only as last ditch defense against “leakers”
- “Cost Effectiveness” equation based on cost to kill ~ cost of threat











Main Defensive weapons designed against these threats

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Missile Systems

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

Cigar Boat Threat (BOGHAMMER)



Jet Ski



RPG threat



Micro UAV



Large UAV



Mini UAV



Newer threats, secondary weapons being designed to handle

New Non-Traditional Threats

Raytheon
Missile Systems

- 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

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Missile Systems

Not All Functions Drive Trade Space

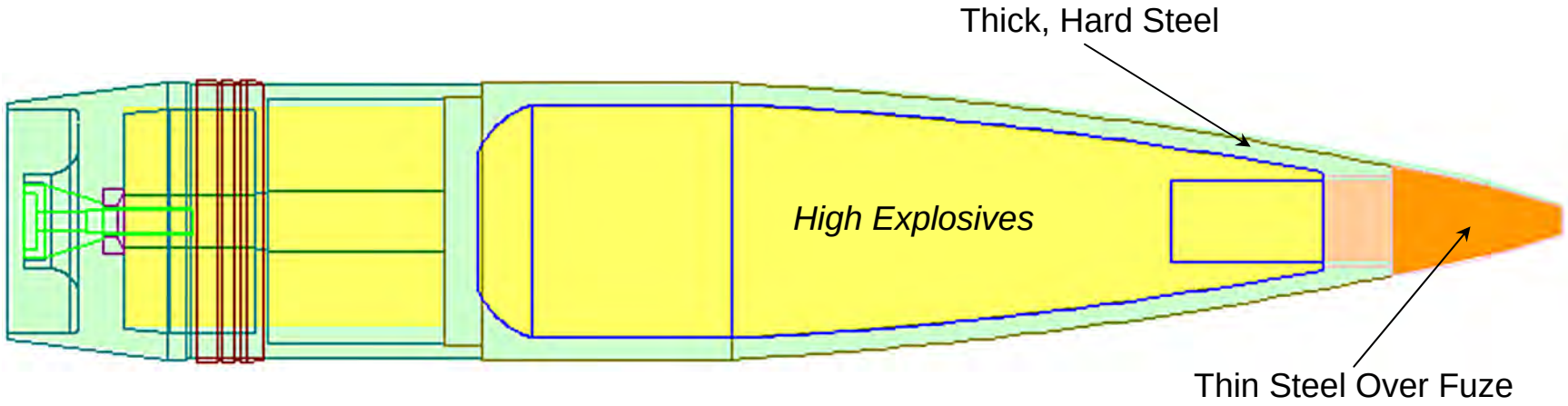
Function	Projectile Caliber Influence	Comments
Detection	Weak	Primarily a function of the search sensor
Classification	Weak	Determines if signal represents a threat
Engagement Planning	Strong	Determines order of engagement, how many projectiles per target to fire (projectile lethality used in calculations)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

Projectile, gun, and fire control must be solved holistically

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

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Missile Systems



- 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

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Missile Systems

Side by Side Analysis

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

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

Raytheon Missile Systems

- 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



Scale UAV



Personal Watercraft



Small Boat Threat



Surface Mine

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

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Missile Systems

- 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)





http://www.defense-update.com/products/a/ahead.htm

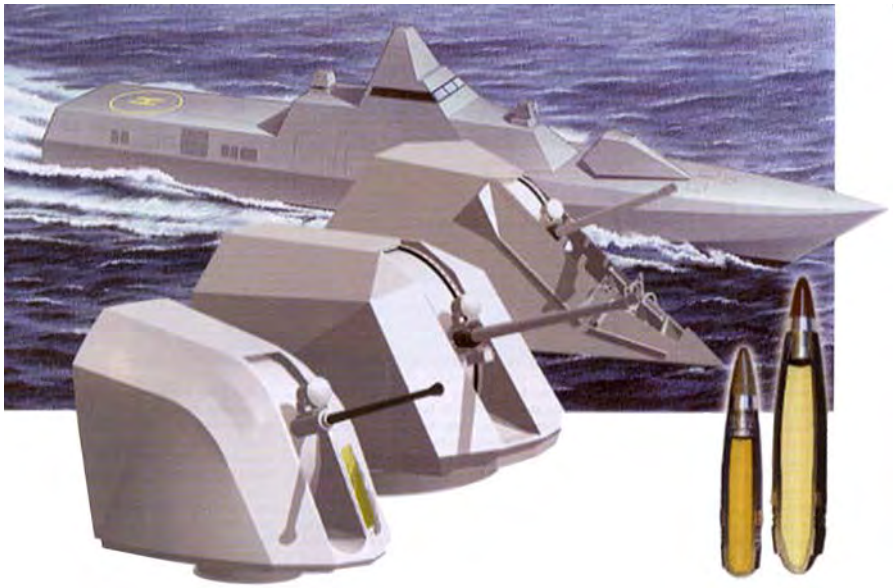
“Cargo-based” KE rounds exist for point defense

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

Raytheon
Missile Systems

- 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



Cartridge Weight		Velocity	Energy
Gun	G	Meters per Second	Joules
40mm L/60 40x311R	955	850 – 900	345,000 – 387,000
40mm L/70 40x364R	870	1,030	461,000
57mm m/47 57x230R	2,230	744	617,000
57mm L60-70 57x438R	2,400	1,020	1,250,000

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

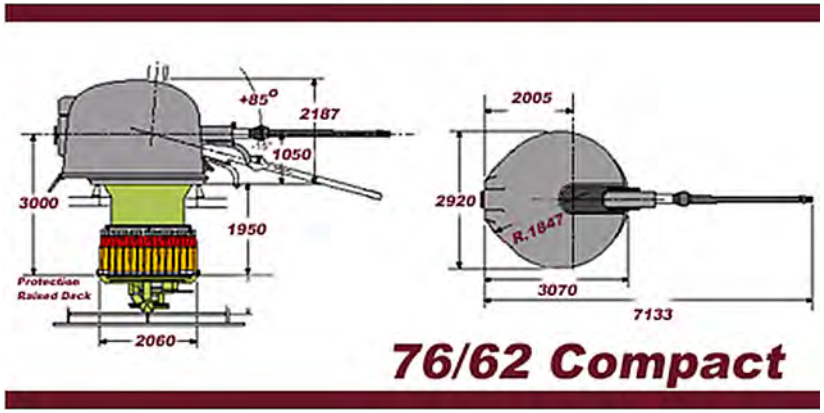
Littoral combat ship using the larger rounds as primary batteries

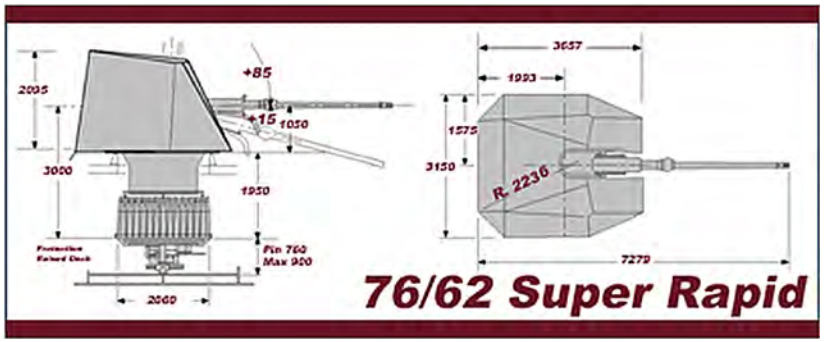
NOTE – All equations, weapon descriptions, and equipment specific material from open sources, usually the internet to avoid ITARS or classification issues

76 mm Cannons Operational and New Solutions are in Work

Raytheon Missile Systems

Naval Applications

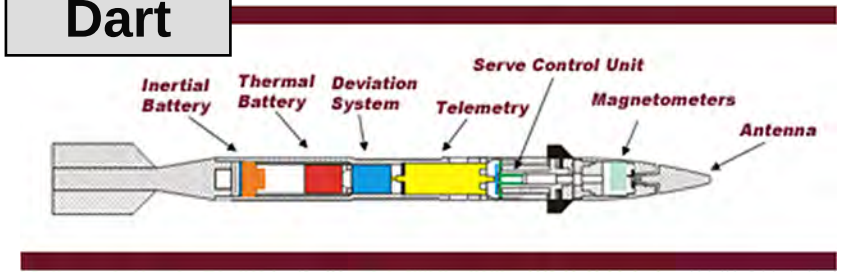




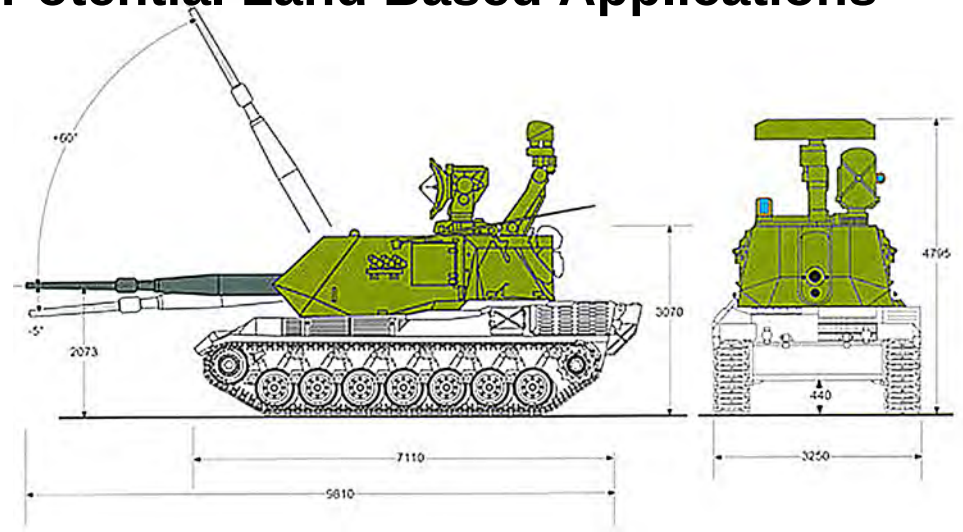
http://www.finmec.com

Advanced Projectiles

Dart



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

Caliber Trade – Army Application

Moderate Engagement Rate

Raytheon Missile Systems

DOES NOT INCLUDE 2 + 1 Firing Protocol

Calibre cm	Weight kg	Volume cm^3	number per ton	load per 5T truck	fired per kill &	intercepts per truck	trucks per K intercept	gun firing rate	Firing Vehicle WT	Time to engage @	Time to engage #	Max Eff Range	1st Engage Range
2.3	1	105	889	4267	*20*	213	5	600	20	48	16	5,000	16,800
4	2.1	574	423	2032	*10*	203	5	300	20	48	16	11,000	16,800
5.7	4	1,749	222	1067	*3*	356	3	150	20	29	10	14,000	10,080
7.6	10	3,455	89	427	*2*	213	5	120	40	24	8	18,000	8,400
9	15	5,814	59	284	*1*	284	4	20	40	72	24	18,000	25,200
10.5	17.8	8,573	50	240	*1*	240	5	10	40	144	48	18,000	50,400
12	27.6	11,198	32	155	*1*	155	7	6	60	240	80	20,000	84,000
15.5	52	26,630	17	82	*1*	82	13	4	60	360	120	30,000	126,000
								rpm	ton	sec	sec	meter	meter

@ 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

Calibre cm	Weight kg	Volume cm^3	number per ton	load per 5T truck	fired per kill &	intercepts per truck	trucks per K intercept	gun firing rate	Firing Vehicle WT	Time to engage @	Time to engage #	Max Eff Range	1st Engage Range
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5.7	4	1,749	222	1067	*4*	267	4	150	20	38	13	14,000	13,440
7.6	10	3,455	89	427	*3*	142	8	120	40	36	12	18,000	12,600
9	15	5,814	59	284	*2*	142	8	20	40	144	48	18,000	50,400
10.5	17.8	8,573	50	240	*2*	120	9	10	40	288	96	18,000	100,800
12	27.6	11,198	32	155	*2*	77	13	6	60	480	160	20,000	168,000
15.5	52	26,630	17	82	*2*	41	25	4	60	720	240	30,000	252,000
								rpm	ton	sec	sec	meter	meter

@ 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)

Raytheon Missile Systems

Joules required to Damage Target

Target	Light Damage	Moderate Damage	Heavy Damage
Personnel	0.1	1	4
Aircraft	4	10	20
Armor	10	500	1000

$J = Kg*(m/s)^2$

Probability of Kill

$N_{hits} = A(N_o/4\pi R^2)$

where:

N_{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

$P_k = 1 - (1-P_K|_{hit})^{Nhits}$, if $N_{hits} > 1$, or

Initial Fragment Velocity

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

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

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

$V(s) = V_o * e^{-\rho C_d A s/2M}$

ρ = 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

Raytheon Missile Systems

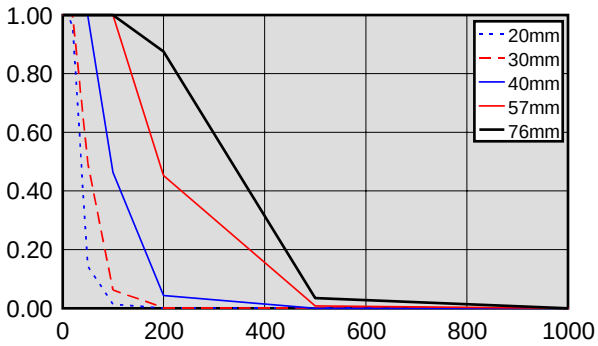
Projectile Data Derived from Jane's Ammunition Handbook

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

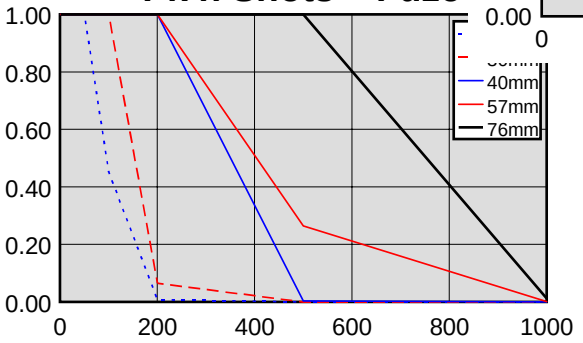
Blast

Fragment

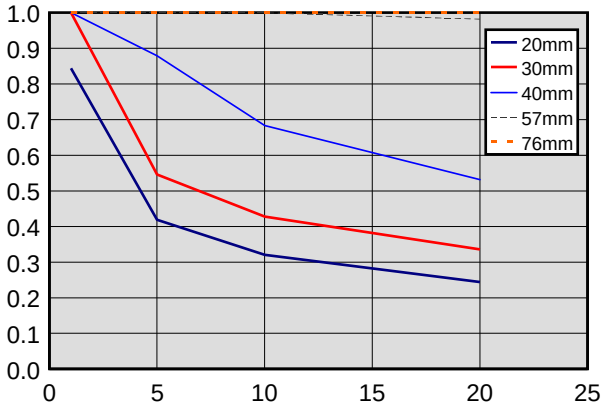
Pk n Shots – Shell



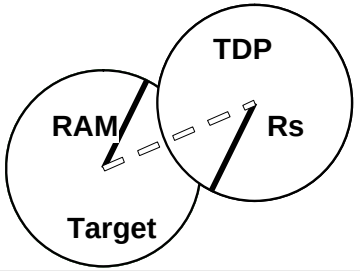
Pk n Shots – Fuze



KE Submunitions (HTK)



Projectile Hit to Kill (HTK)



RAM Target Type	Required Miss (mm)
280 mm Rocket	220
155mm Artillery	122
81 mm Mortar	92.4

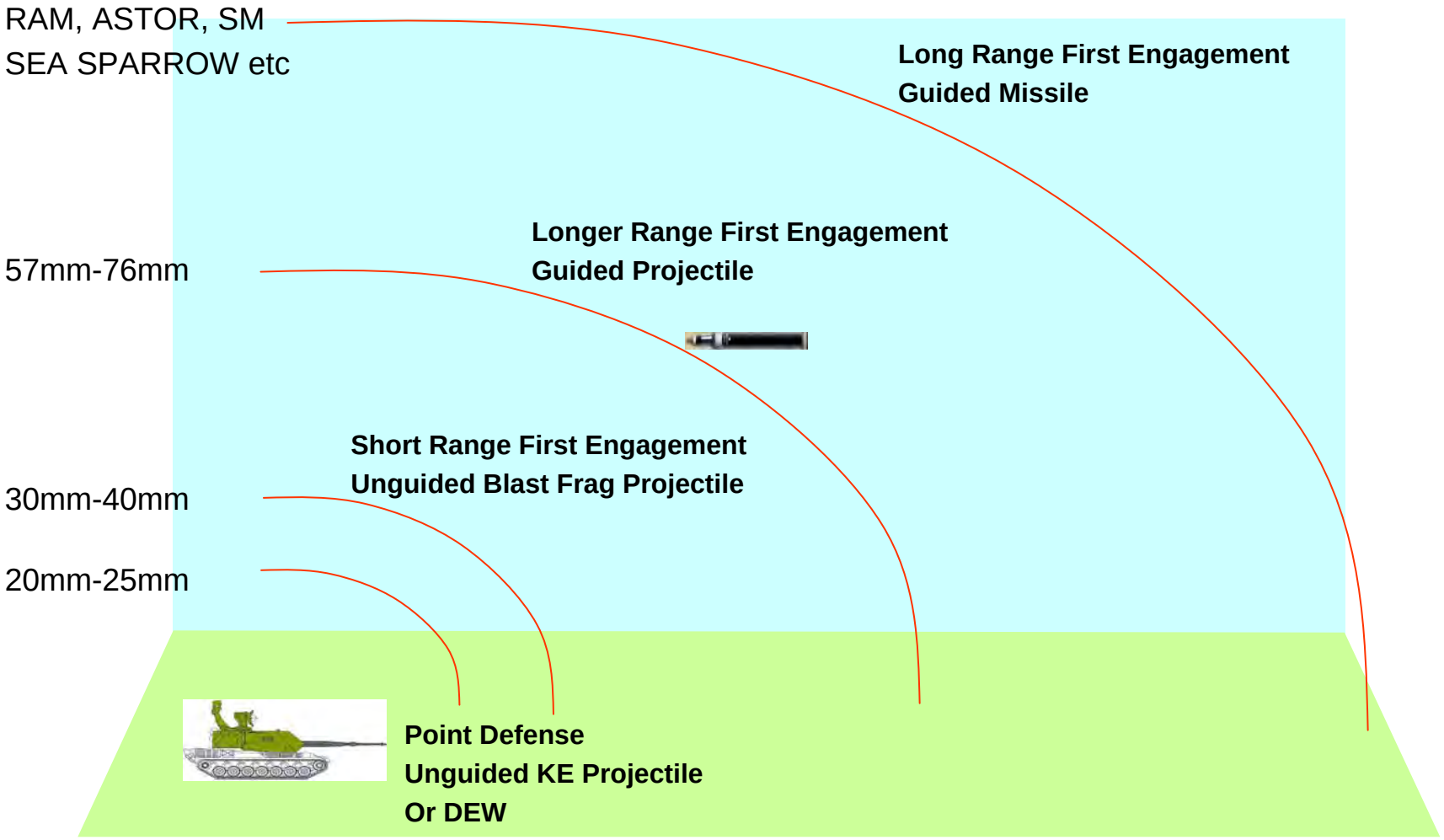
A hit is when the miss is less than 80% of the sum of the weapon diameters

All payloads require hit to kill or very high precision guidance

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

Gun Accuracy Implies Different Solution for Different Engagement Ranges

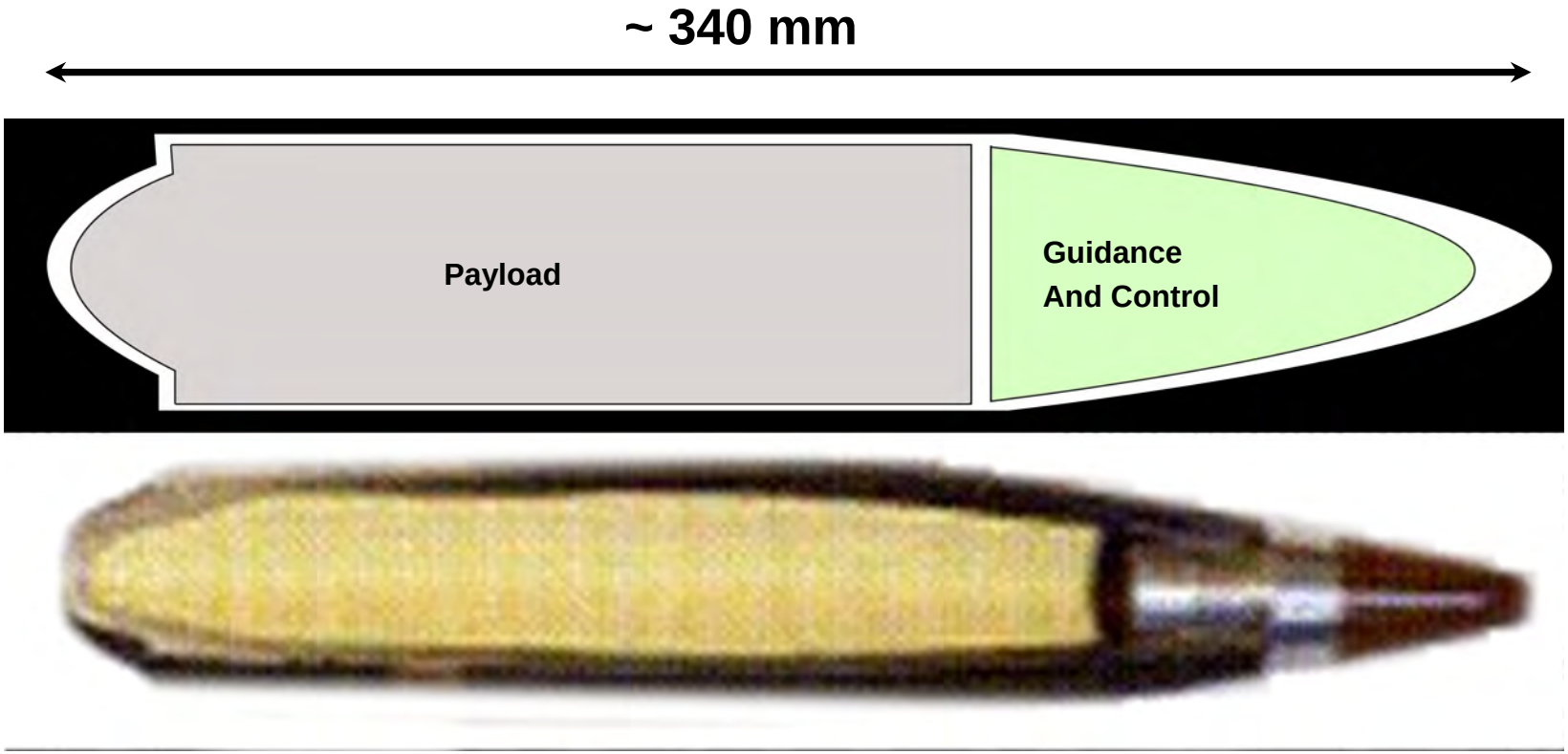
Raytheon Missile Systems



All solutions require hit to kill or very high precision

Conceptual Volume Allocation

Raytheon
Missile Systems



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

Raytheon
Missile Systems

- 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

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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



PELE® Cartridge - Outline

- Cartridge Concept Overview
- OT&E Ground-to Ground Test Plan
- Test Performance
- Conclusion
- Acknowledgements/Contacts
- Questions & Answers

PELE® Development History

1997 – 1999	**Feasibility Studies and Proof of Principle of PELE® Technology**
2000 – 2001	**Technology Transfer to 20 mm x 102 mm PELE® and Target Effect Evaluation specified by MoD**
2002	**German MoD decision for 27 mm x 145 mm PELE® FSD**
2003	**In-House Technical Evaluation of 20 mm x 102 mm PELE® by Diehl**
2004	**In-House Technical Evaluation of 27 mm x 145 mm PELE® by Diehl**
2005	**USAF Decision to select 20 mm x 102 mm PELE® for OT&E (Operational Test and Evaluation) as potential replacement for PGU-28/B**
2006	**OT&E testing began at Eglin AFB**

PELE® Cartridge & Projectile Assembly

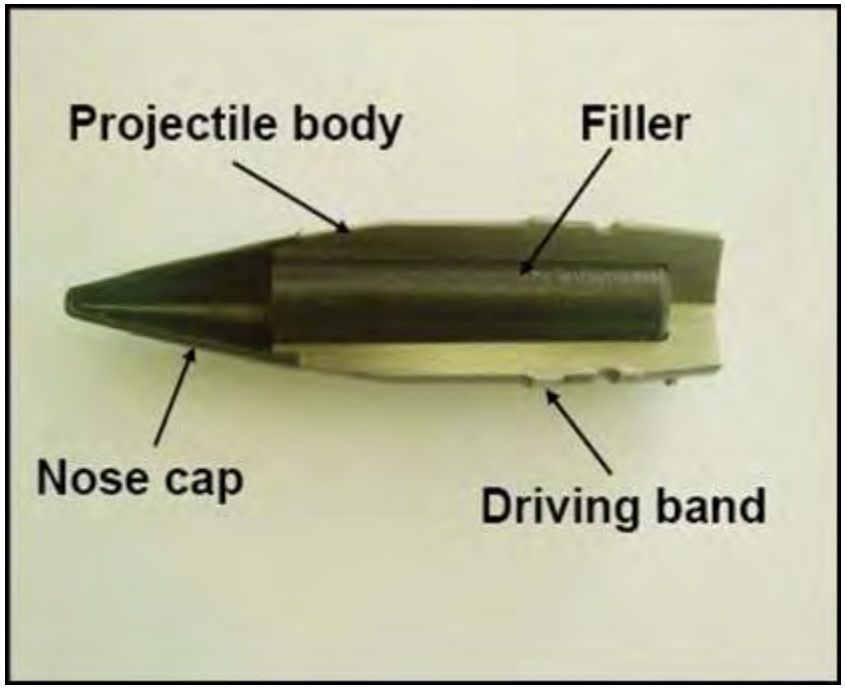
Ammunition
20 mm x 102 mm
PELE®



PELE



PGU-28



20 mm PELE® Design Characteristics

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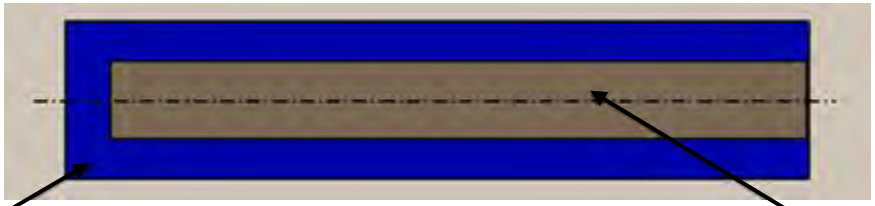


Length (max):	**168 mm**
Weight:	**264 g**
Projectile Mass:	**100 g**
Muzzle Velocity:	**3410 f/s**
Accuracy:	**Average Mean Radius = 15 in. at 500 yds**
Penetration:	**Ballistic limit < 2750 f/s against 0.375 in. (9.5mm) armor at 0°**
Ballistics:	**Comparable to PGU 28A/B or PGU 27A/B**
Design:	**Low drag version**

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

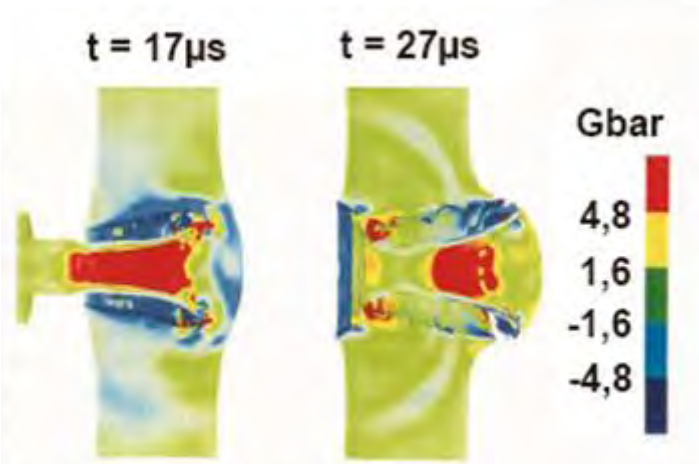


Projectile Body: High density material (steel or tungsten)

Inner Core: Low density material (plastic or aluminum)

Steel or tungsten penetrates the target

Plastic or aluminum does not penetrate the target

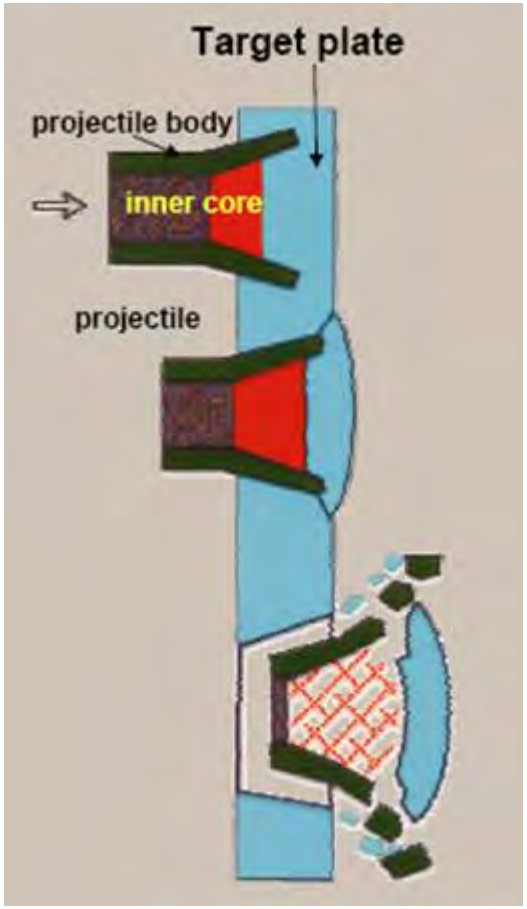


Pressure distribution on penetrator

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.

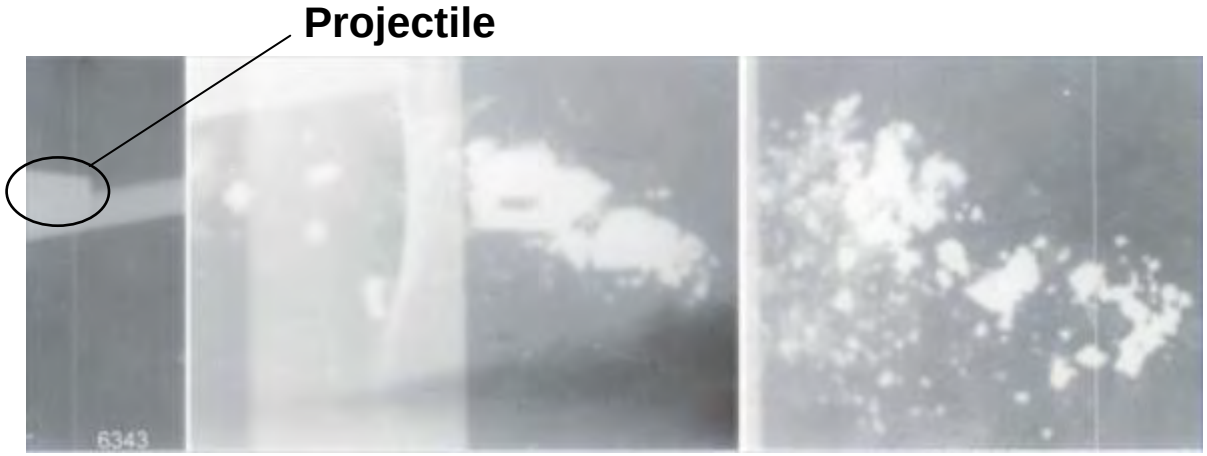
Fragmentation of PELE® Projectile

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Target: 2 mm Al / 0° NATO

Impact Velocity: 750 m/s



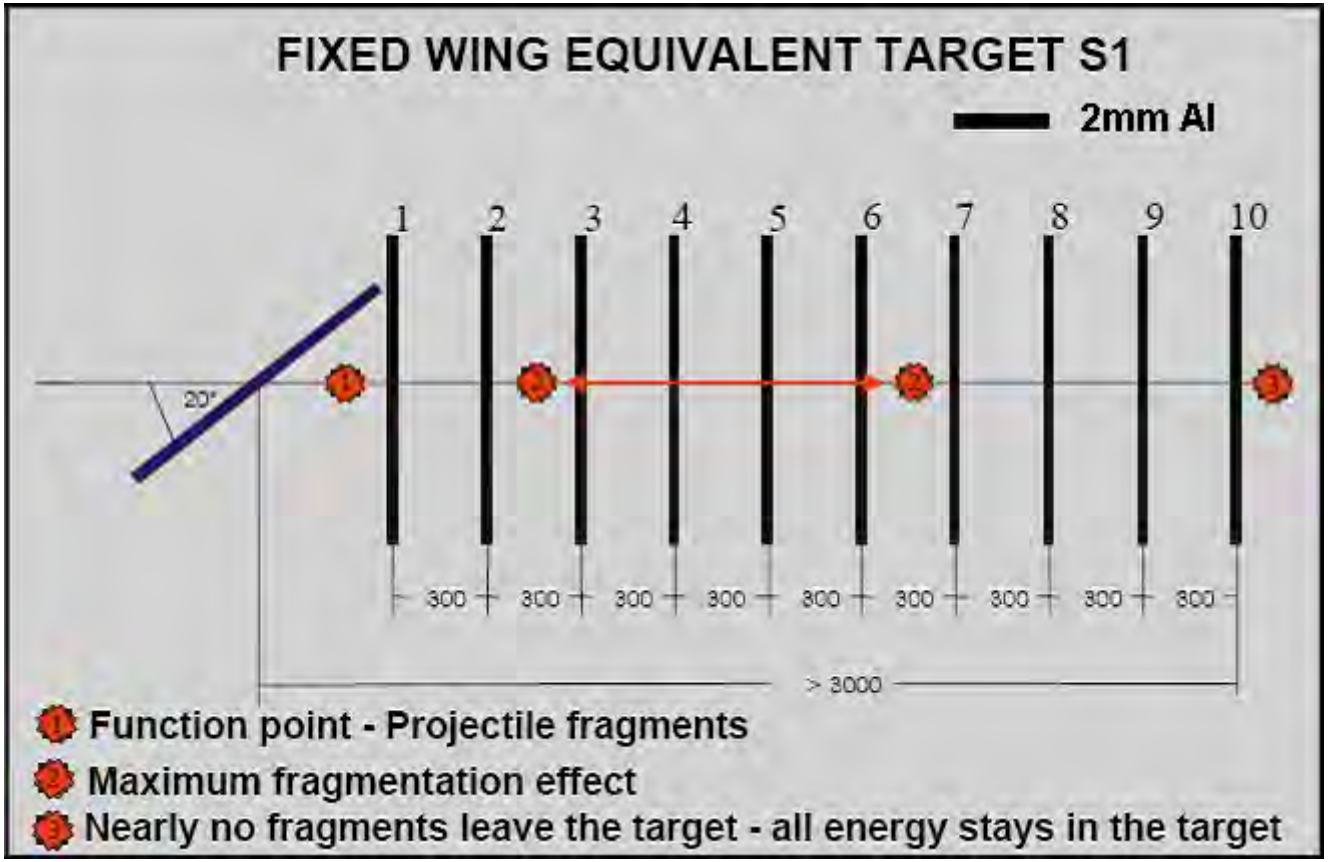
Target: 2 mm Al / 80° NATO

Impact Velocity: 750 m/s

X-ray images of function

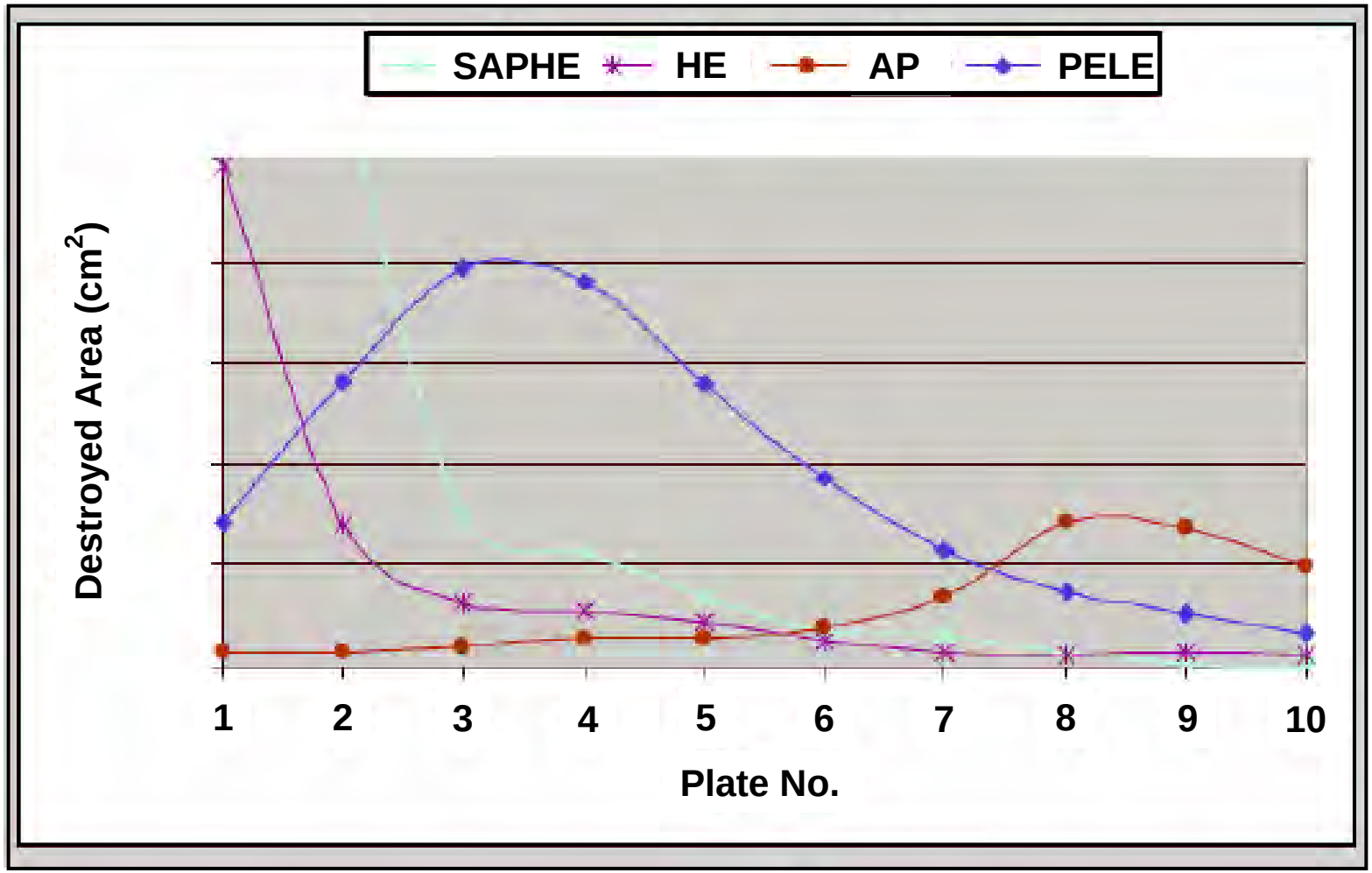
PELE® Multi-Plate Array Test Set-up

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PELE® Performance vs Other Combat Ammo

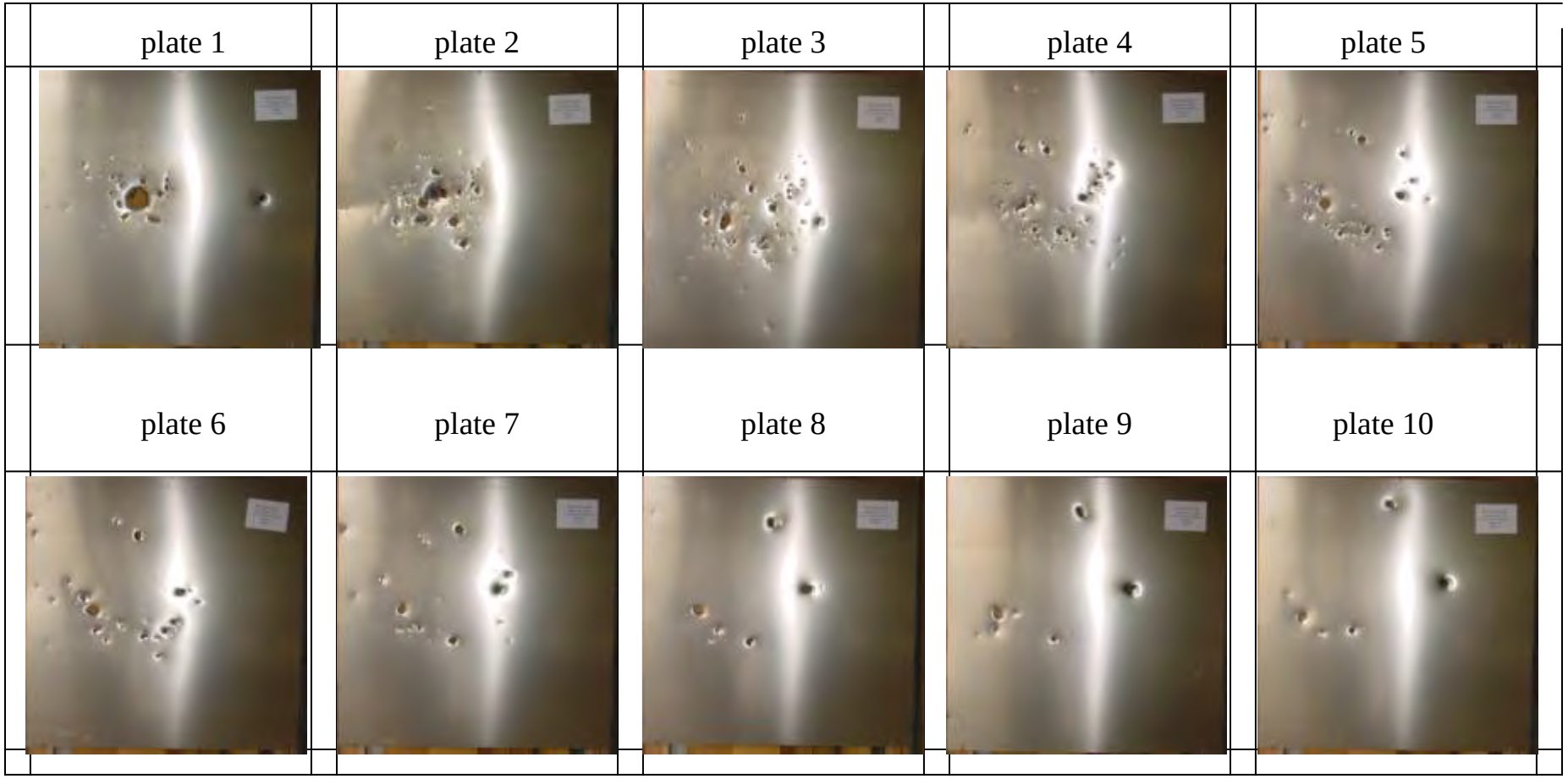
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PELE® Delivers More Energy in the Target Compared to Other Tactical Ammunition

PELE® Performance on Multi-Plate Array

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

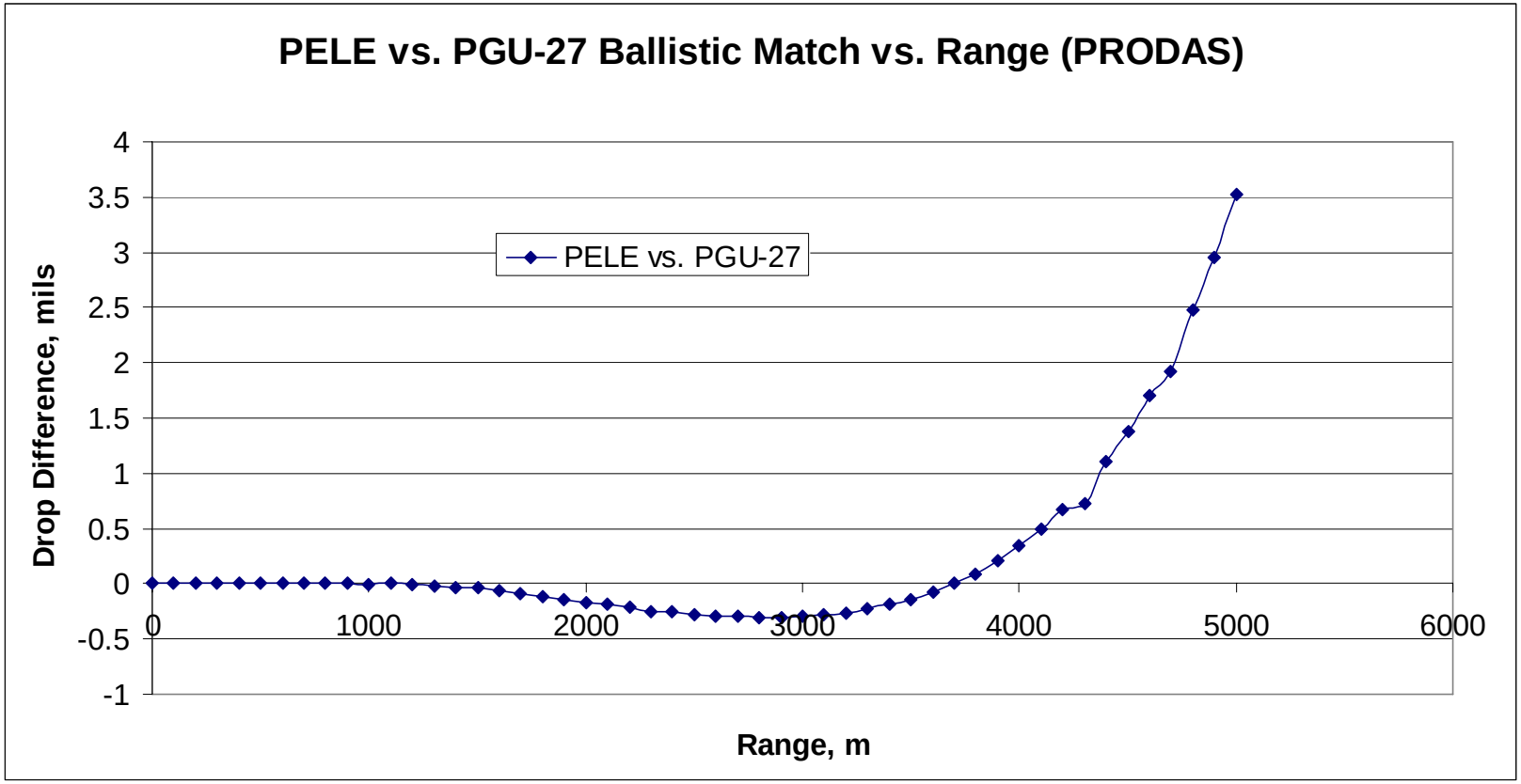
Few fragments leave the target – all the energy stays in the target.

PELE® Penetration Performance



PELE® able to penetrate 10 mm Rolled Homogeneous Armor (RHA)

PELE® vs PGU-27 Ballistic Match



Less than 0.5 mil difference out to 4000m range.

USAF OT&E Test Plan

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**
PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)	**3444.9 / 3169.23**
PRODAS Ground-Ground Target Location (ft)	**535**

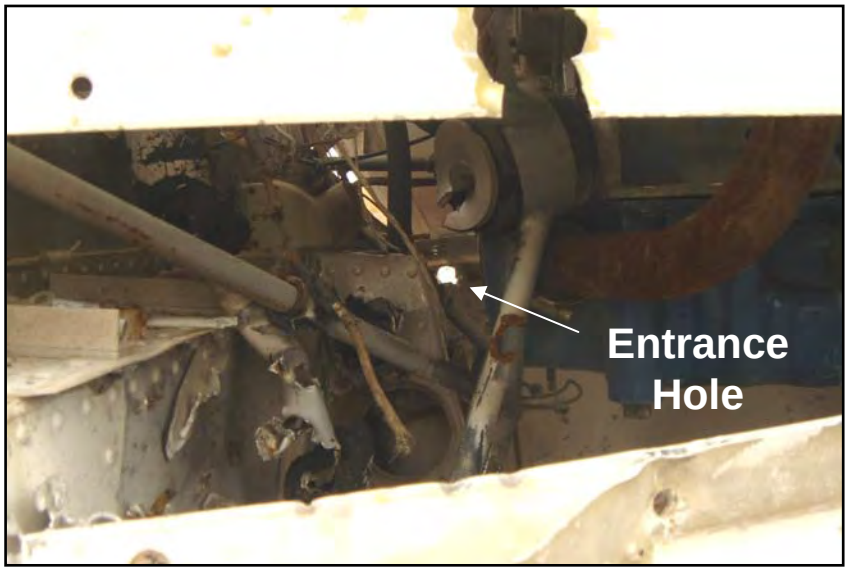




Cessna Cardinal Test Damage

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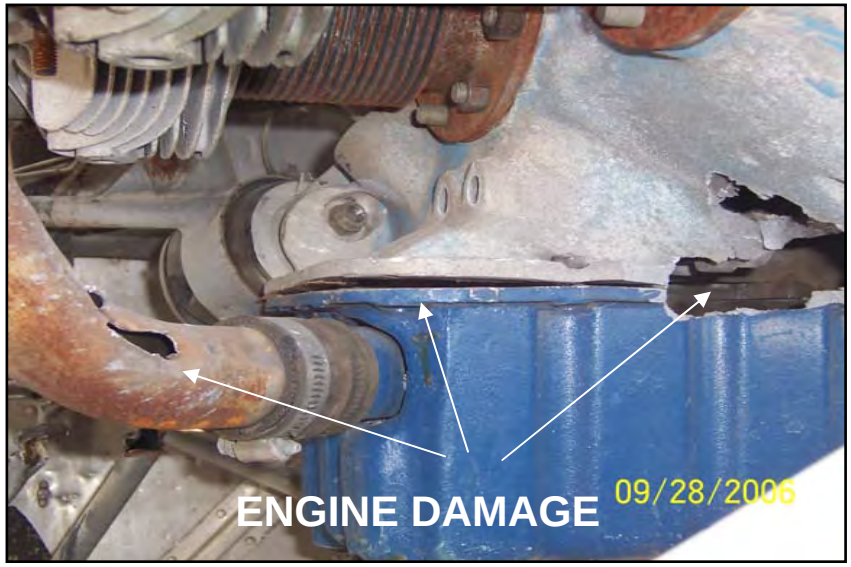
Cessna Cardinal Test Damage

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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**
PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)	**3444.9 / 3130.77**
PRODAS Ground-Ground Target Location (ft)	**610**





F-16 Wing / ‘Troop’ Damage

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C-130 Wing / ‘Troop’ Damage

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Residual Fuel in Wing Foam Burning





F-16 Tail Section Test

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Target Set	**1 F-16 Tail w/ 3 dummies**
PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)	**3444.9 / 2978.13**
PRODAS Ground-Ground Target Location (ft)	**915**





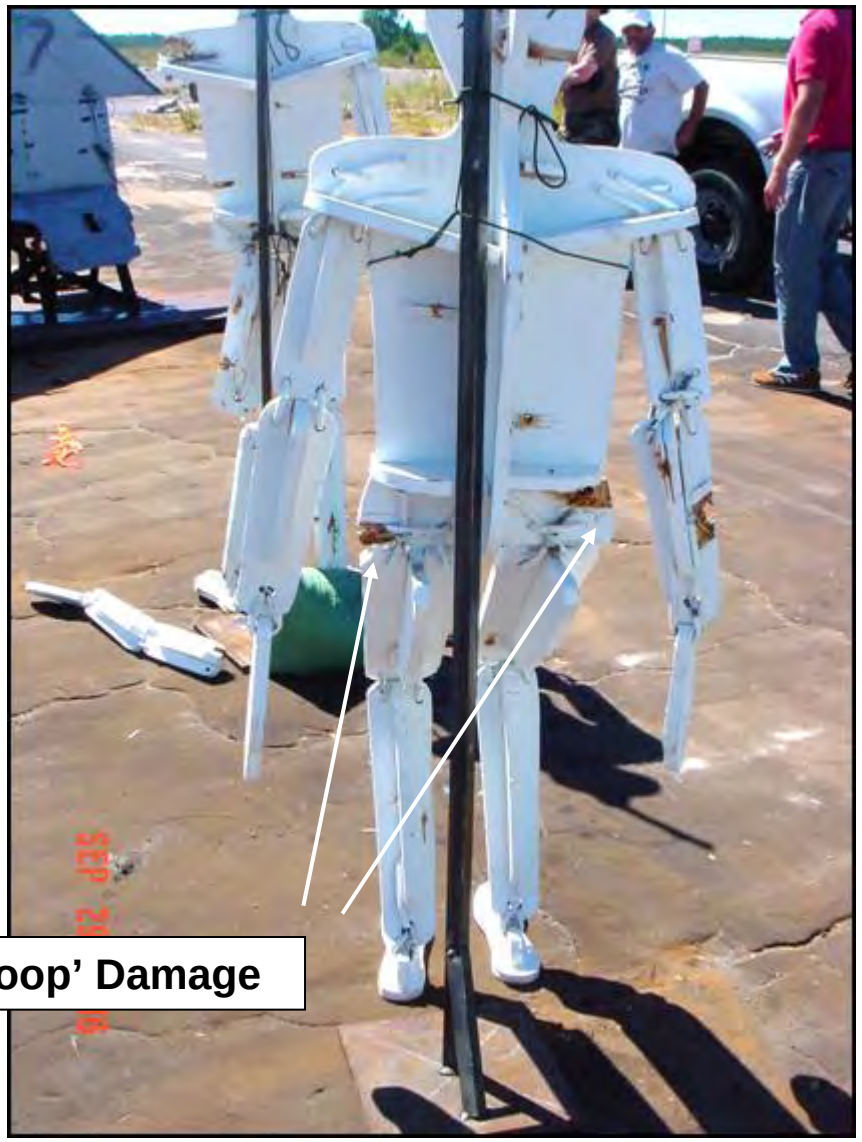
Significant damage to exit surface with composite skins.

F-16 Tail Section Test

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‘Troop’ Damage

M577 APC Test Set-ups

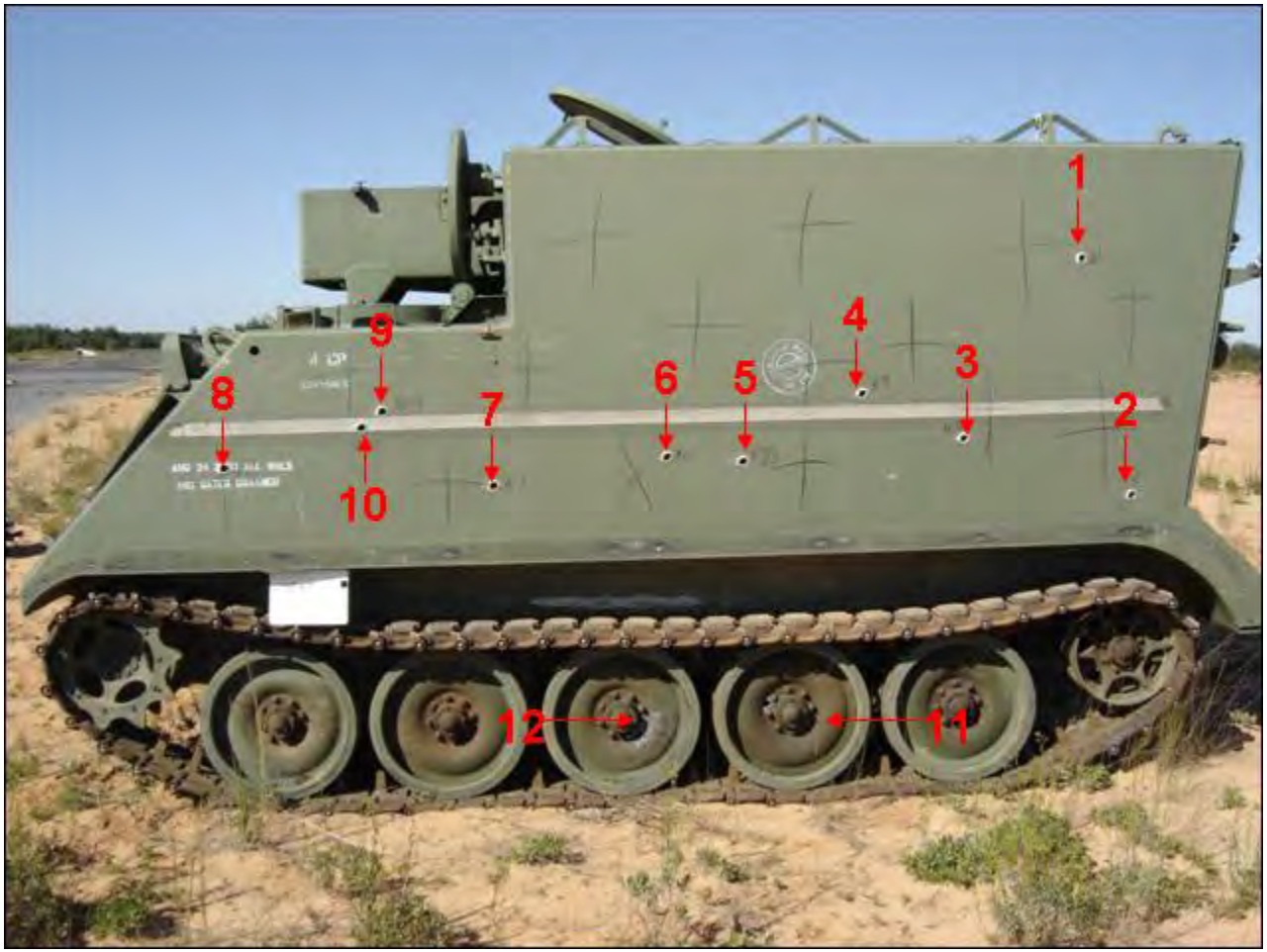
Target Set	**1 M577 APC w/ 5 passengers 6 dummies in hasty cover**
PRODAS Muzzle / Impact Velocity (ft/s)	**3444.9 / 2808.94 2460.36**
PRODAS Ground-Ground Target Location (ft)	**1210 2000**





M577 APC Test Damage

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20mm PELE® is effective against light armor.

M577 APC Test Damage

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‘Troop’ damage inside APC





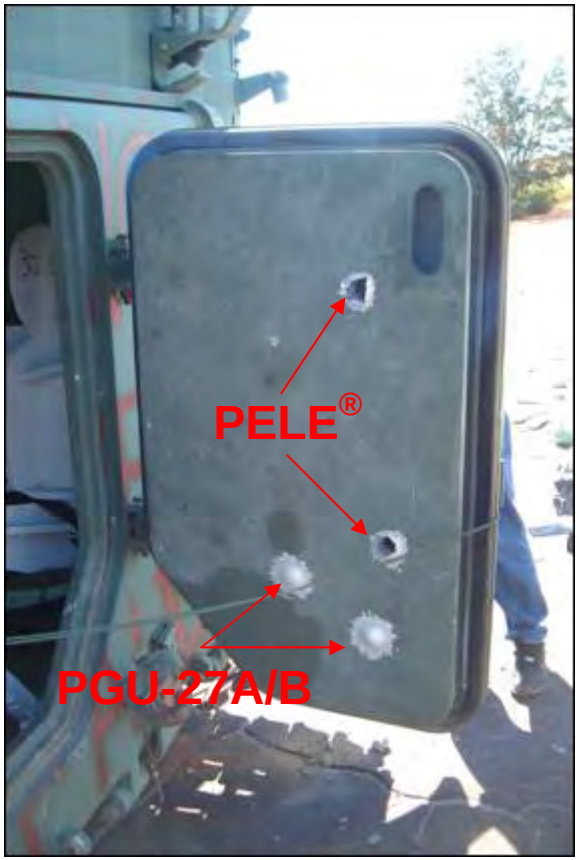
Penetrated 8” Reinforced CMU Wall



Did not penetrate APC at extended range (5000 ft) in all shots

M577 APC Rear Hatch Test

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



PELE® penetrates vs PGU-27

Light Truck Test Set-ups

Target Set	**2 Light Utility trucks w/ passengers 6 dummies in hasty cover**
PRODAS Muzzle / Impact Velocity @ 1000 ft SR (ft/s)	**3444.9 / 2460.36 1262.07**
PRODAS Ground-Ground Target Location (ft)	**2000 5000**





Light Truck Test ‘Troop’ Damage

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Light Truck Test Damage

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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.**

Conclusion

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

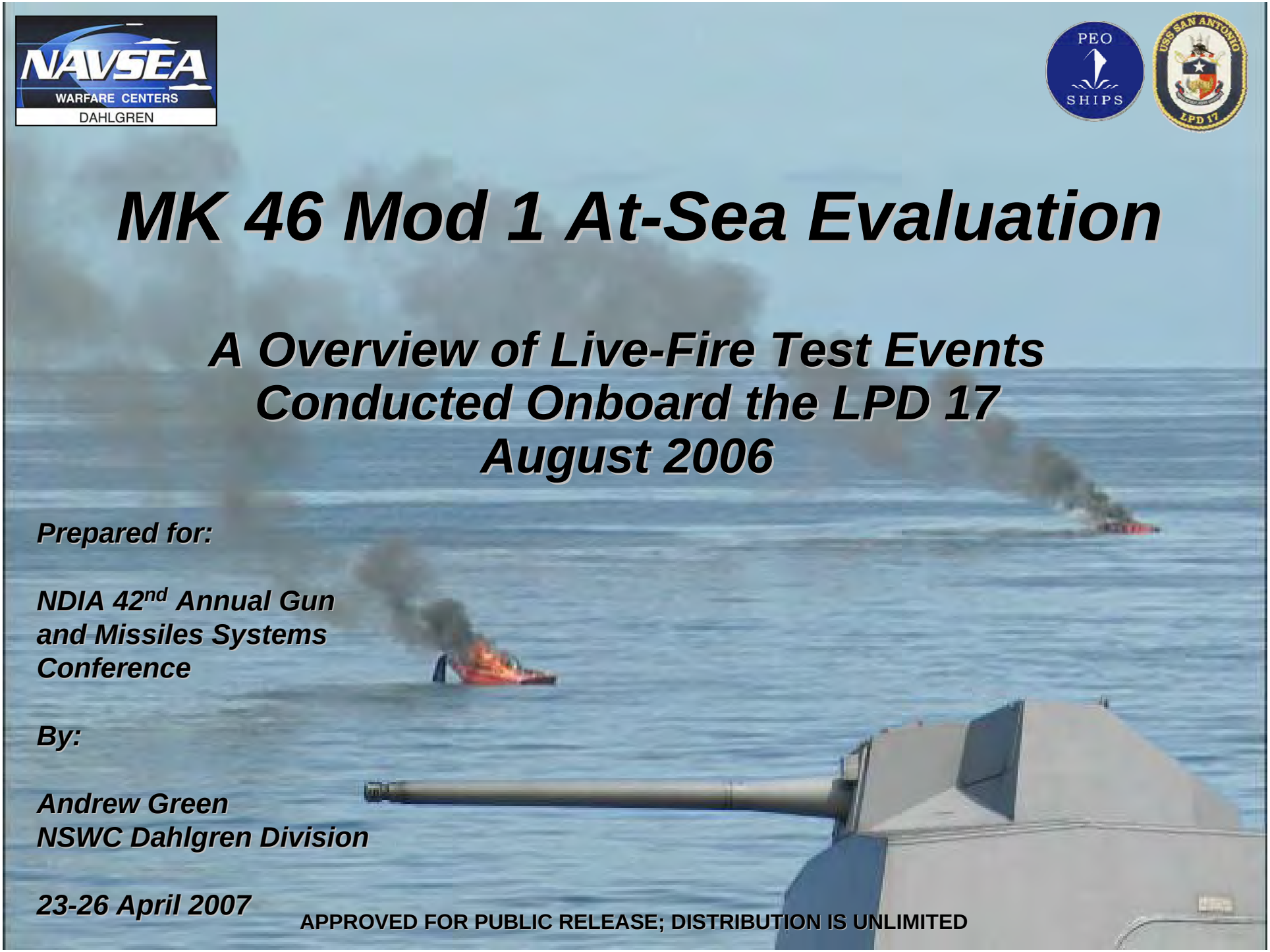
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MK 46 Mod 1 At-Sea Evaluation

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

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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

NAVSEA WARFARE CENTERS CRANE

- PM4 (under PEO IWS3C) – Conventional Ammunition Manager
- Code 40 - ISEA for MK 46 (PMS 317)

NAVSEA WARFARE CENTERS DAHLGREN

- Code W22 – WSEM for LHA(R) Program
- Code G32 – Lead Gun Systems Engineer, LHA 6
- Code G61 – Provided Photo Documentation and Instrumentation
- Gun Tech Warrant Holder (plus A&A Ships CS TWH in SEA06)

NAVSEA WARFARE CENTERS PORT HUENEME

- LPD 17 CSSQT Project Office

NAVSEA – PEOs

- PMS 317 – Provided Platform (LPD 17) and Range Time (VACAPES OPAREA) during CSSQT at-sea period
- PMS 377 – Provided funding and ammunition for LHA(R) events

- PMS 495 – Provided APFSDS-T ammunition assets to all parties under MoA

- IWS1 – Provided input to LHA(R) test events
- IWS3C – Provided input to LHA(R) test events and oversaw ammunition allocation (3C/PM4)

Outside of NAVSEA

- ONI/SABER & SWDG (OPNAV N72) – Provided input & concurrence for LHA(R) test event scenarios
- NAVAIR NAWC Aircraft & Weapons Divisions – provided targets & targets support
- DRPM AAA & GDAMS – Provided support for MK 46 GWS

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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









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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)

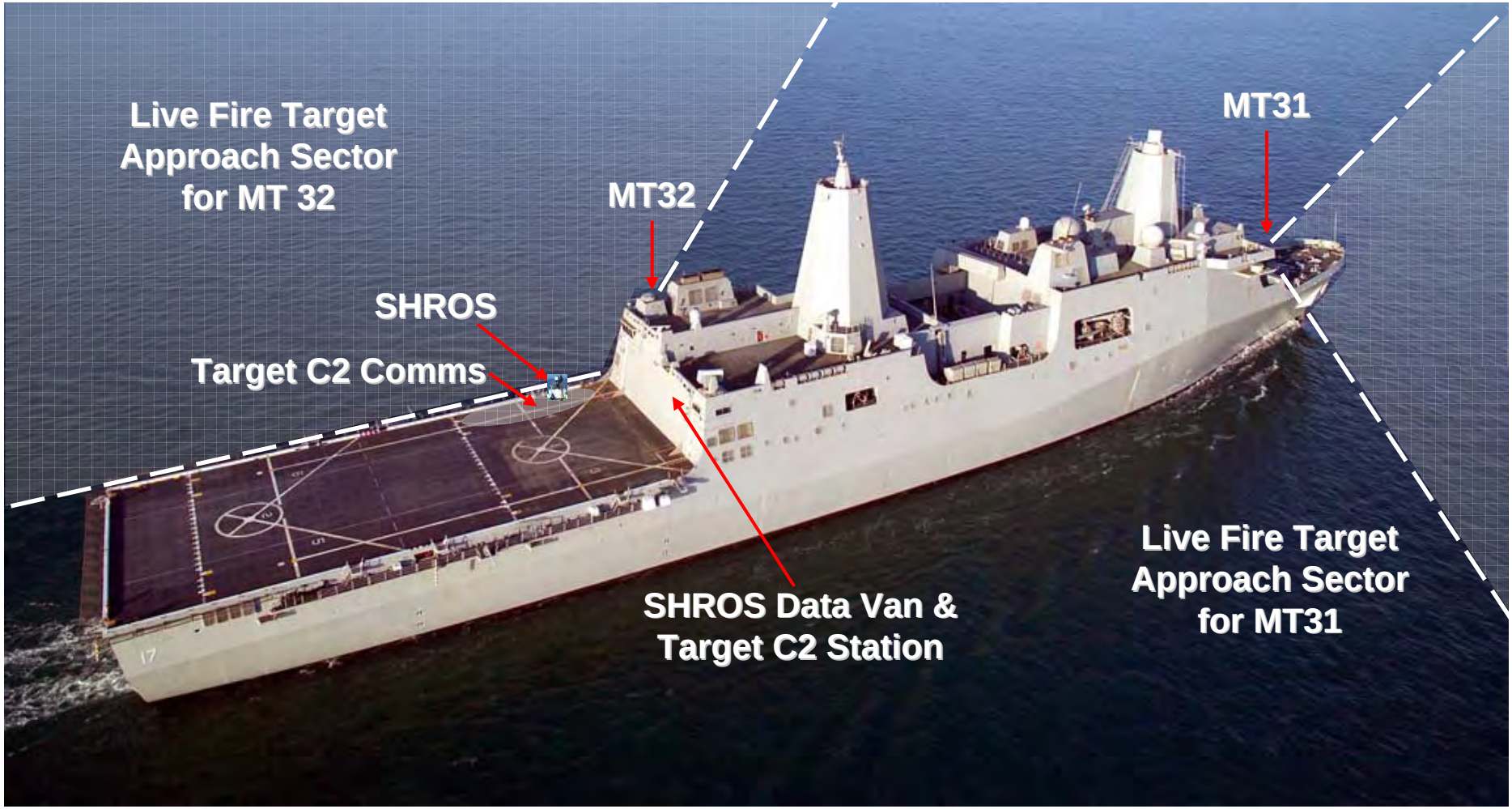
The Test Platform
USS San Antonio (LPD 17)



- 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)

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Test Setup – LPD 17

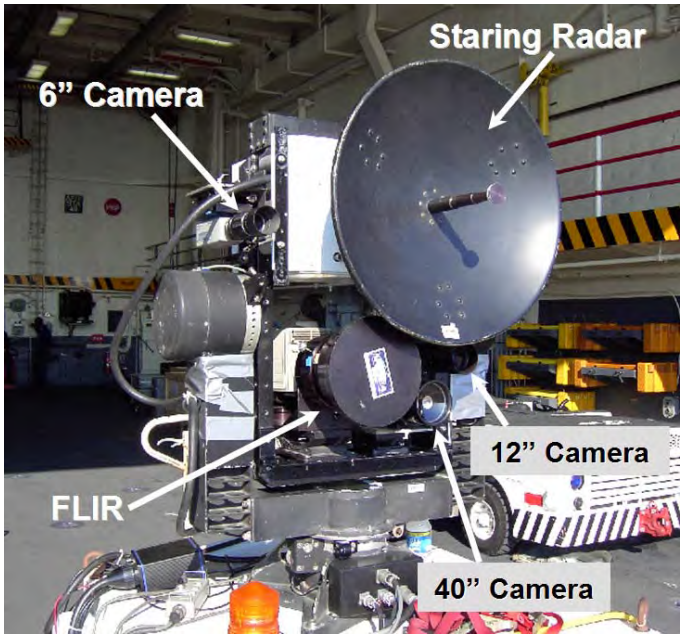


Test Setup – Photo/Instrumentation

- 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

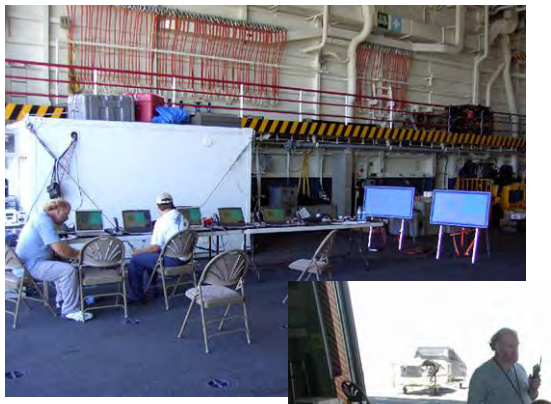


SHROS Mount



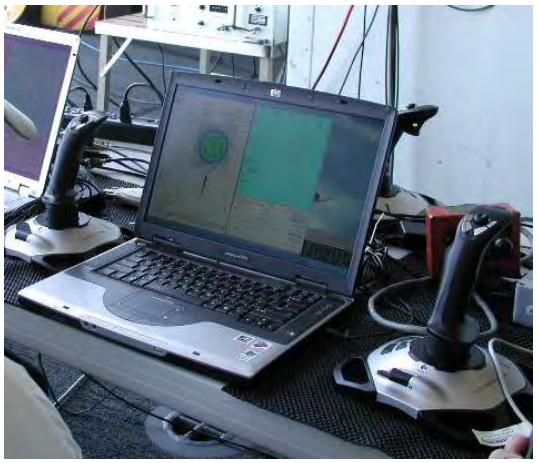
SHROS Sensor Package

Test Setup – Target C2



RCO Station





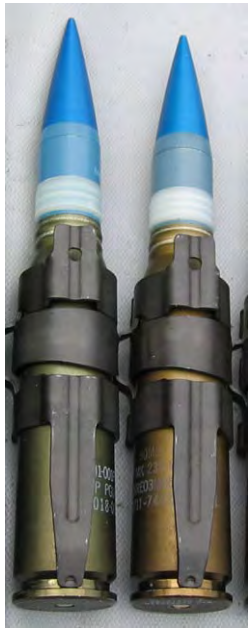
PCCU system

C2 antennae



- 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	MK 258 Mod 1 APFSDS-T	MK 266 Mod 2 HEI-T, MK 264 Mod 0 MPLD-T
NALC AA65	NALC AA71 Substitute	NALC AA89
1850 Rounds	1440 Rounds	1600 Rounds

APFSDS-T	Armor-Piercing, Fin-Stabilized, Discarding Sabot, Traced	**NALC**	Naval Ammunition Logistics Code
HEI-T	High-Explosive (HE) Incendiary, Traced	**TP**	Target Practice
MPLD-T	Multi-Purpose, Low Drag, Traced	**TP-T**	Target Practice, Traced

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Target Set



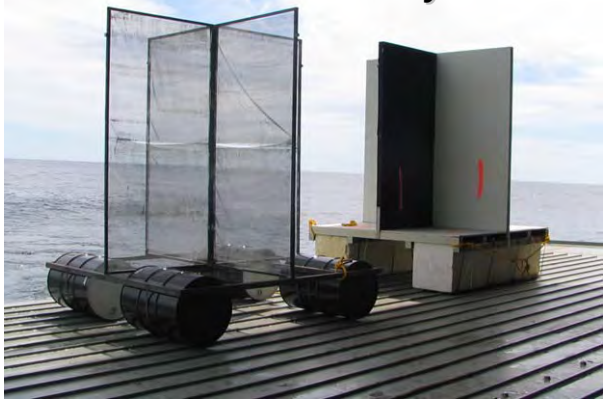
HSMST



QST-33 SEPTAR

Steel Mesh Billboard

Plywood Billboard



Over 22 total targets made available for the various test events





SDST (Jet-ski)

Towed Sled Billboard



Vindicator UAV



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

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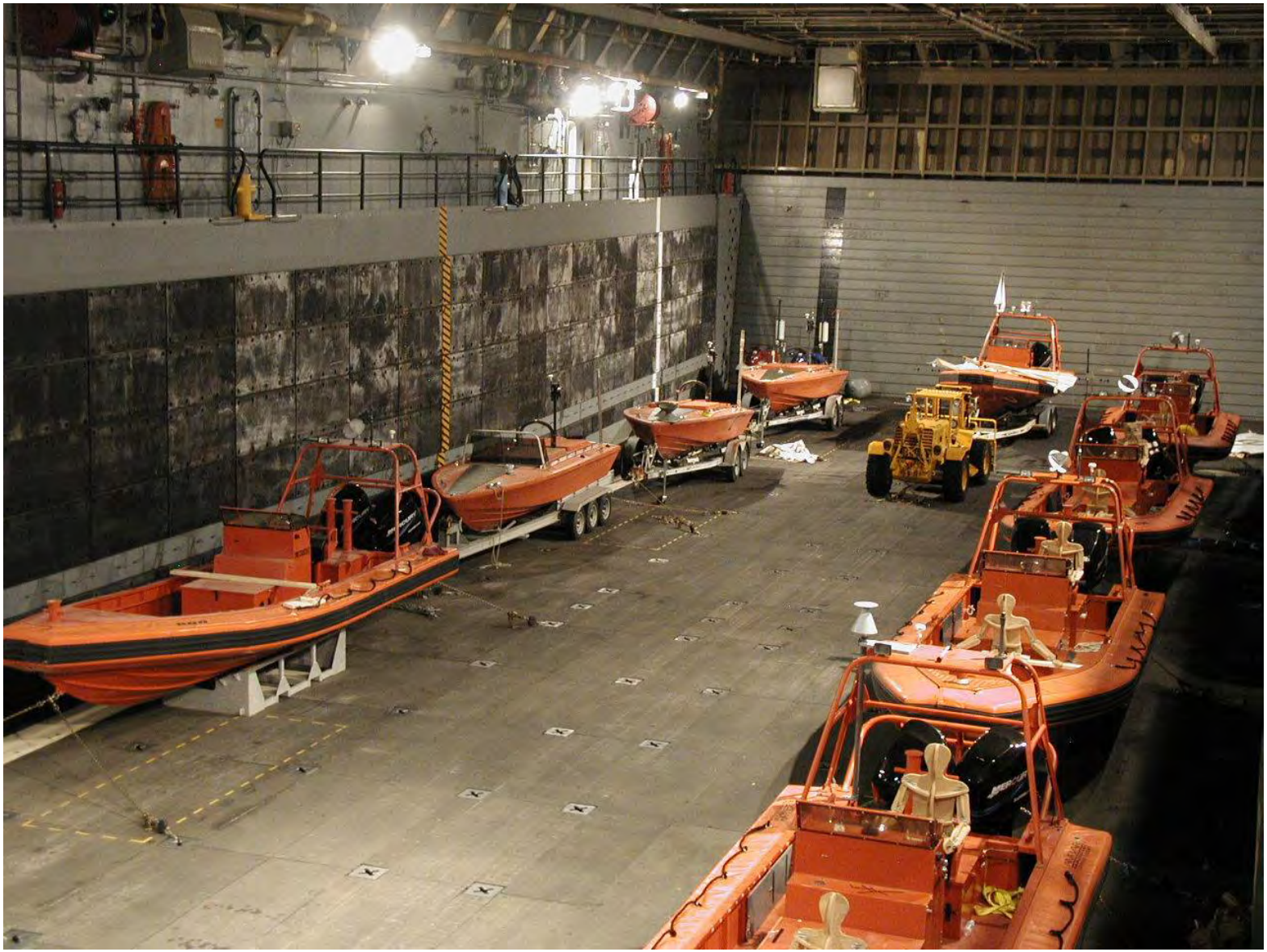
Constraints/Issues

- 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**

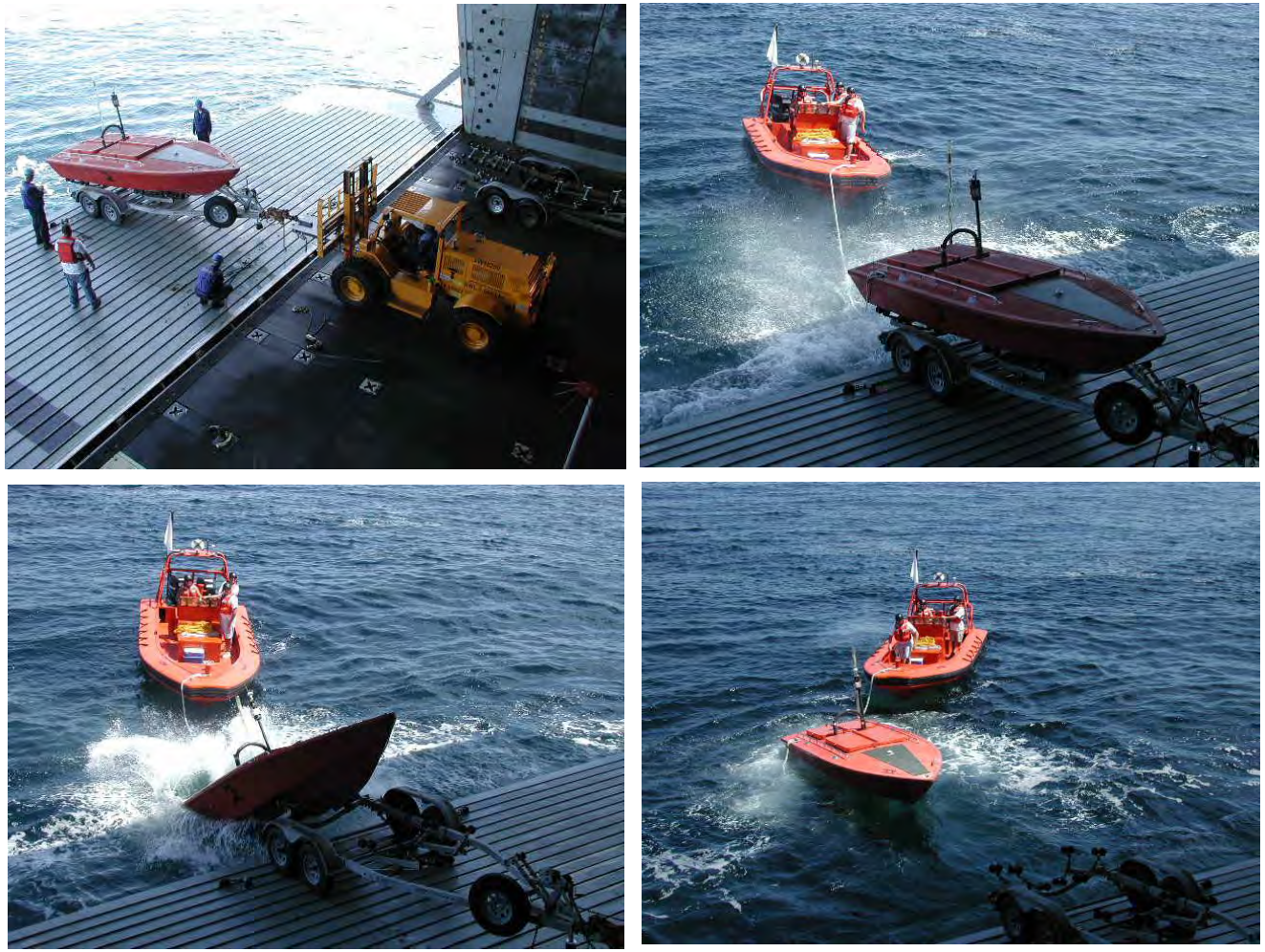
LPD 17 Test Evolution & Events

- 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…



…Kick 'em Out!



Launching a QST-33 SEPTAR off LPD 17's Stern Ramp

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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











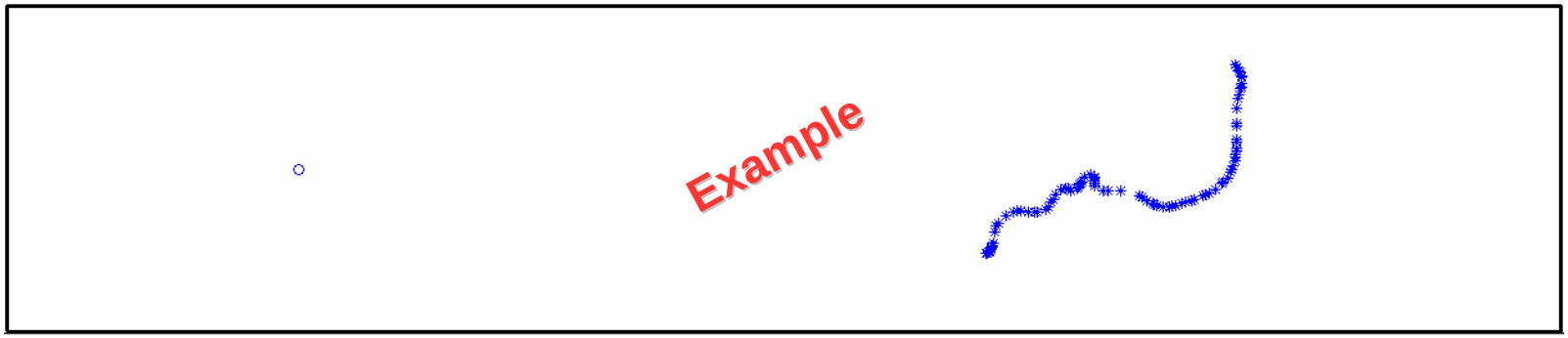


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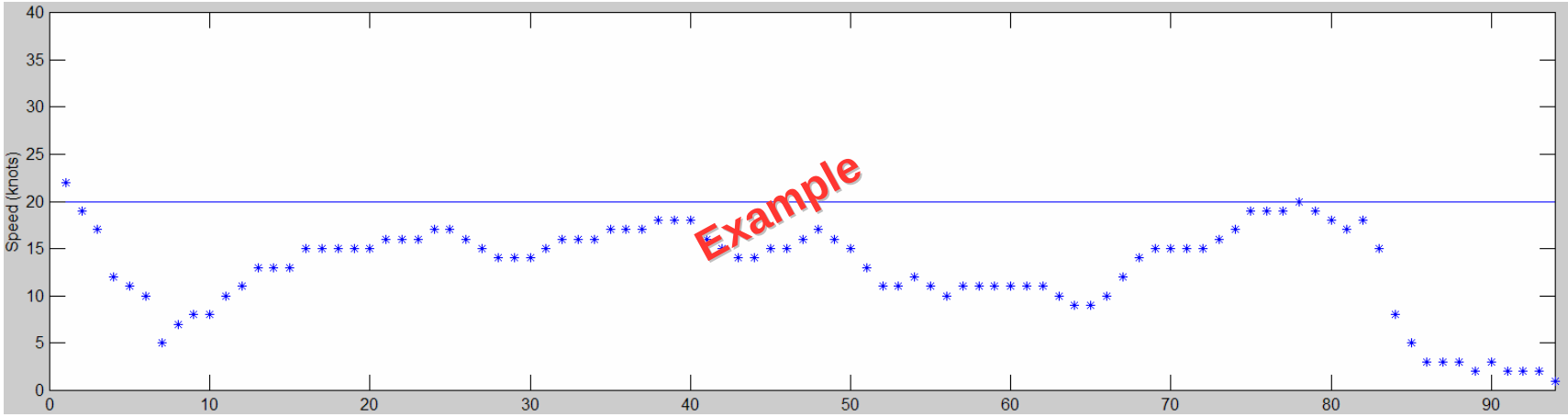
Types of Data Collected

- 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.)



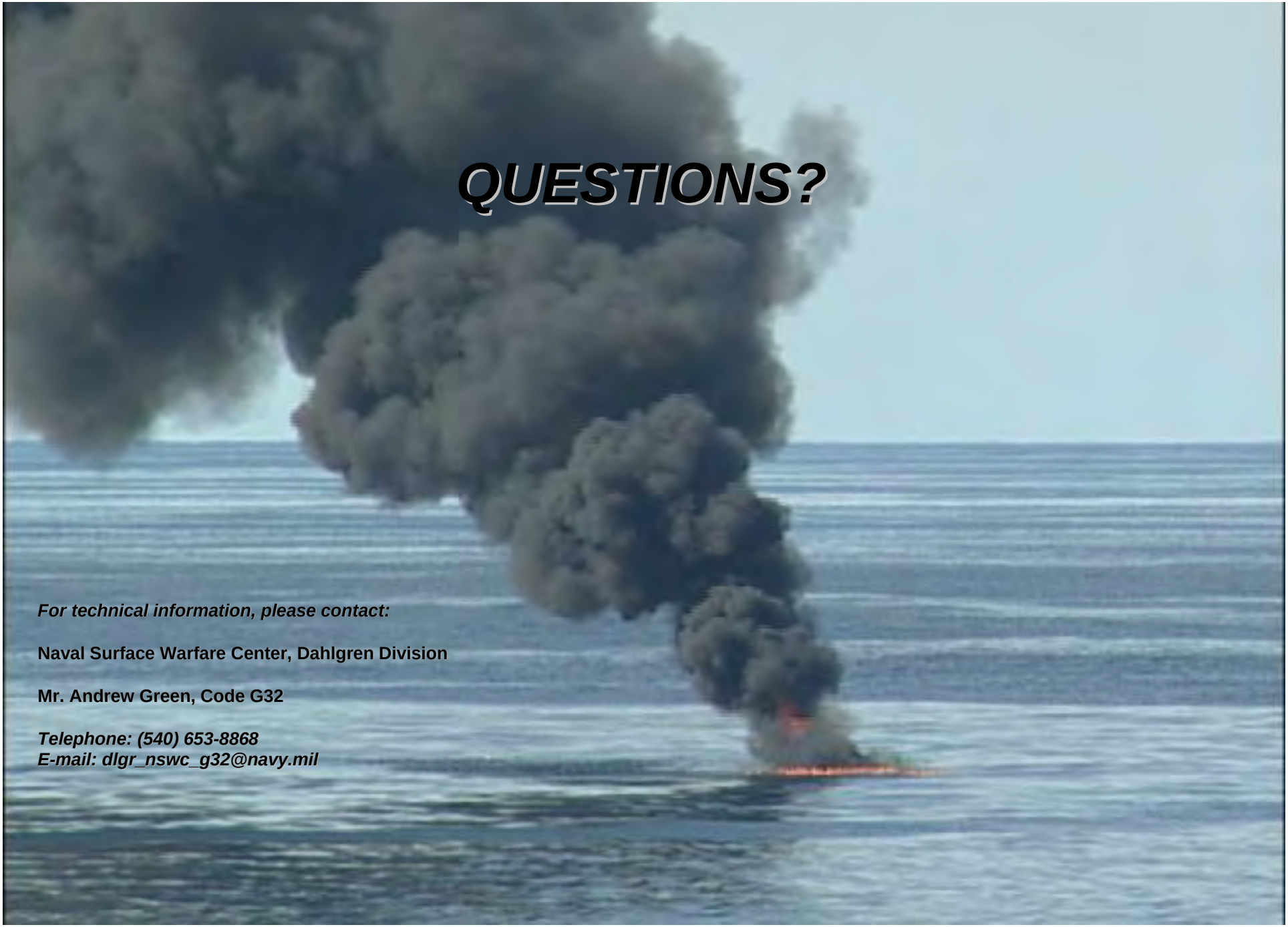
GPS Plots and Timeline Information of Target Path for Event Reconstruction



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
  - Results documented in NSWCDD/MP-07/15, "*MK 46 MOD 1 Gun Weapon System At-Sea Risk Reduction Test For The Amphibious Assault Ship (LHA) 6 Test Report*"
- 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



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

Small Caliber	Medium & Large Caliber	Missile Products	Demil	Talley Defense Systems











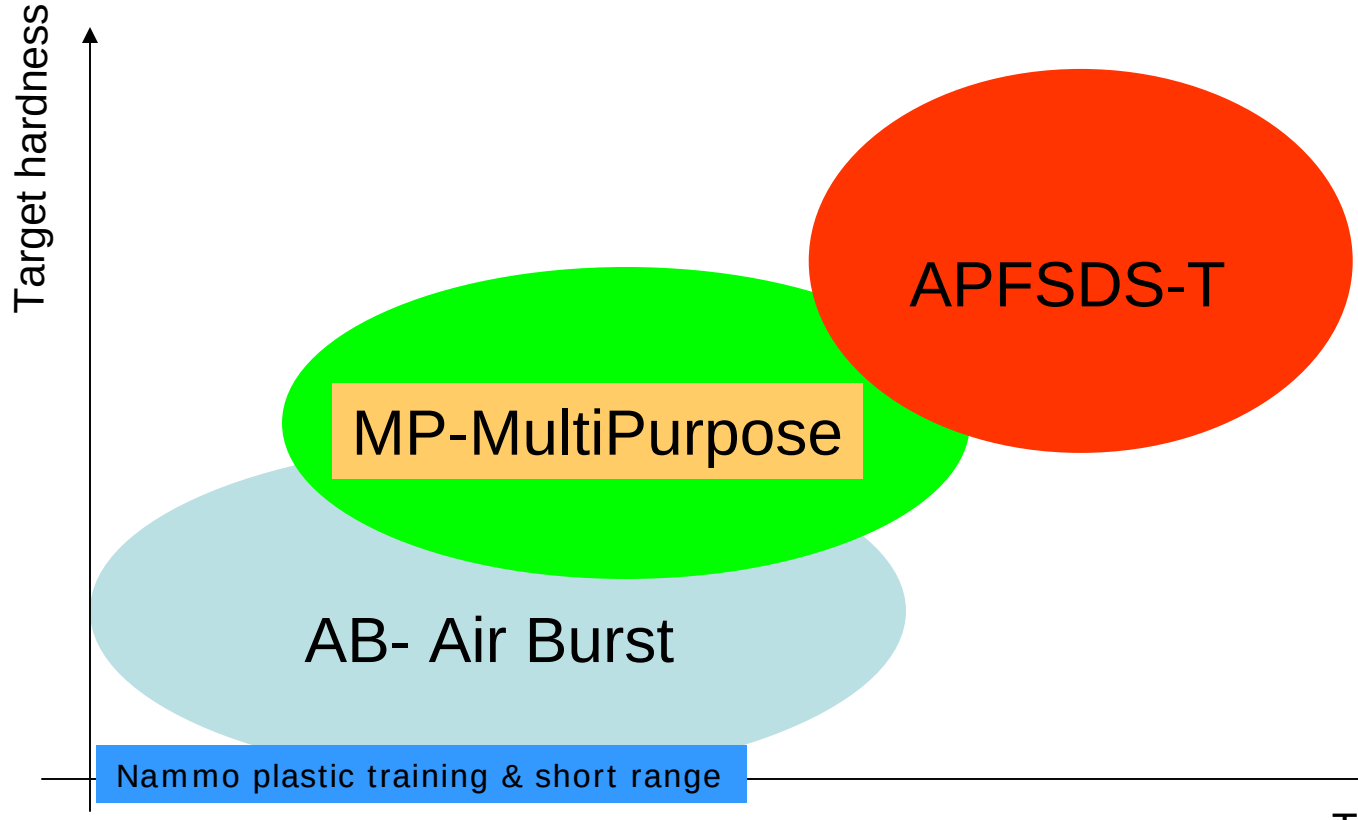




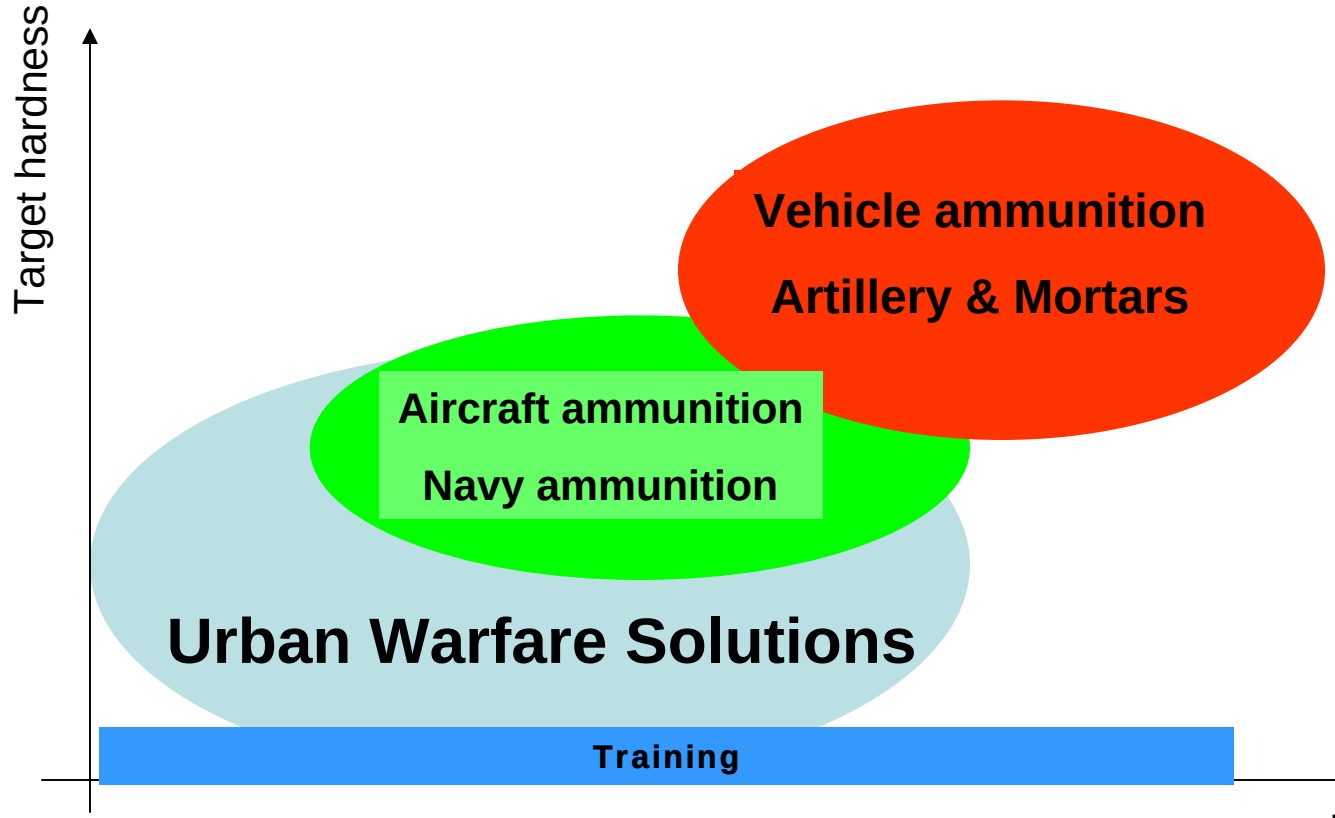




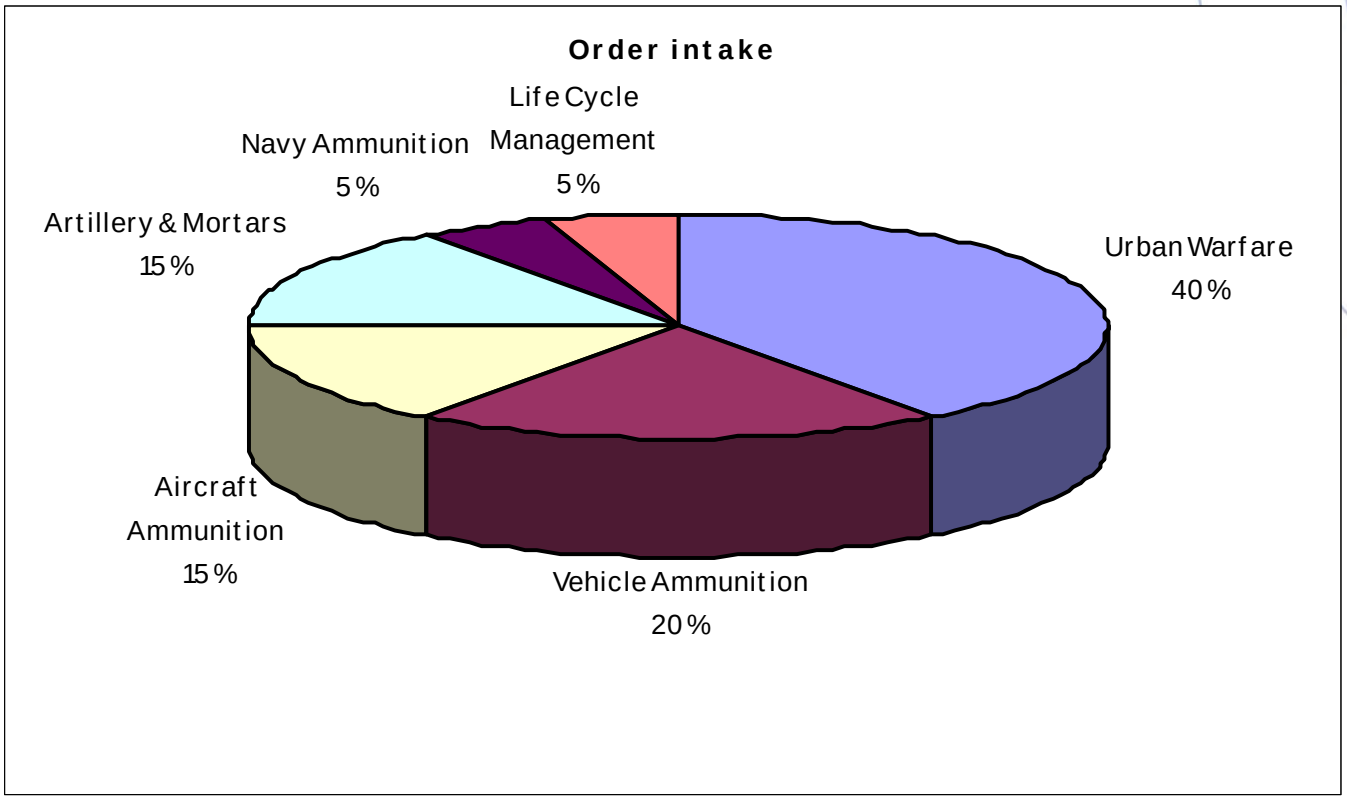
#1 Challenge for Nammo Technology & Products -Customer want's more out of less types of ammunition



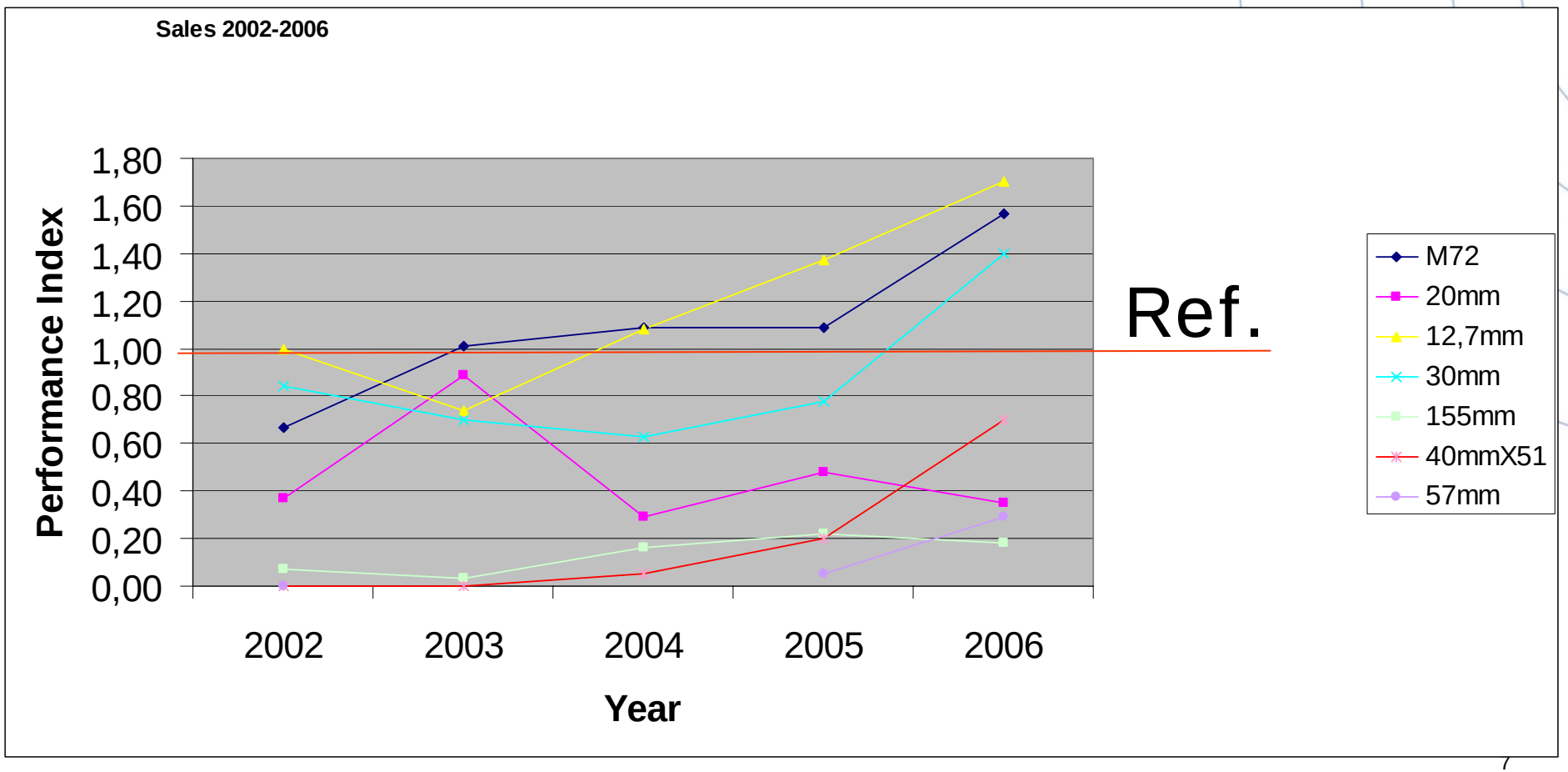
#2 Challenge for Nammo Special Products -Customer want's a complete solution for the operational needs



Definition of Business Development Areas MLCD[2007]



Warfighter Ammunition Solutions -Trends with Asymmetric threat



URBAN WARFARE SOLUTIONS

-Meeting the Warfighters needs

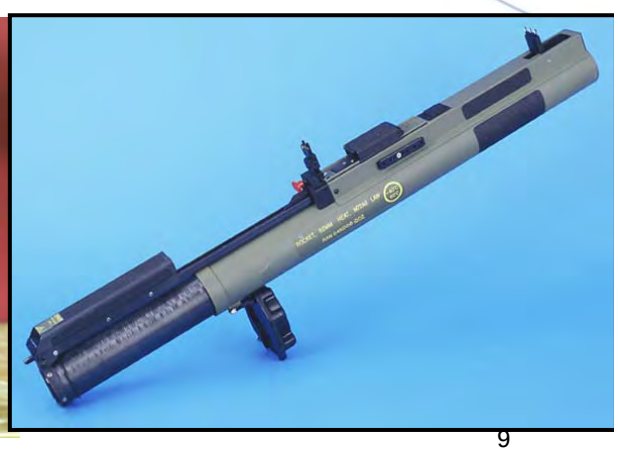


Urban Warfare Solutions

- 12,7mm as the true MultiPurpose Ammunition
- 40mmX51 AGL Programmable Ammunition
- M72 Shoulder Launched Missile
- Training & Short Range Ammunition

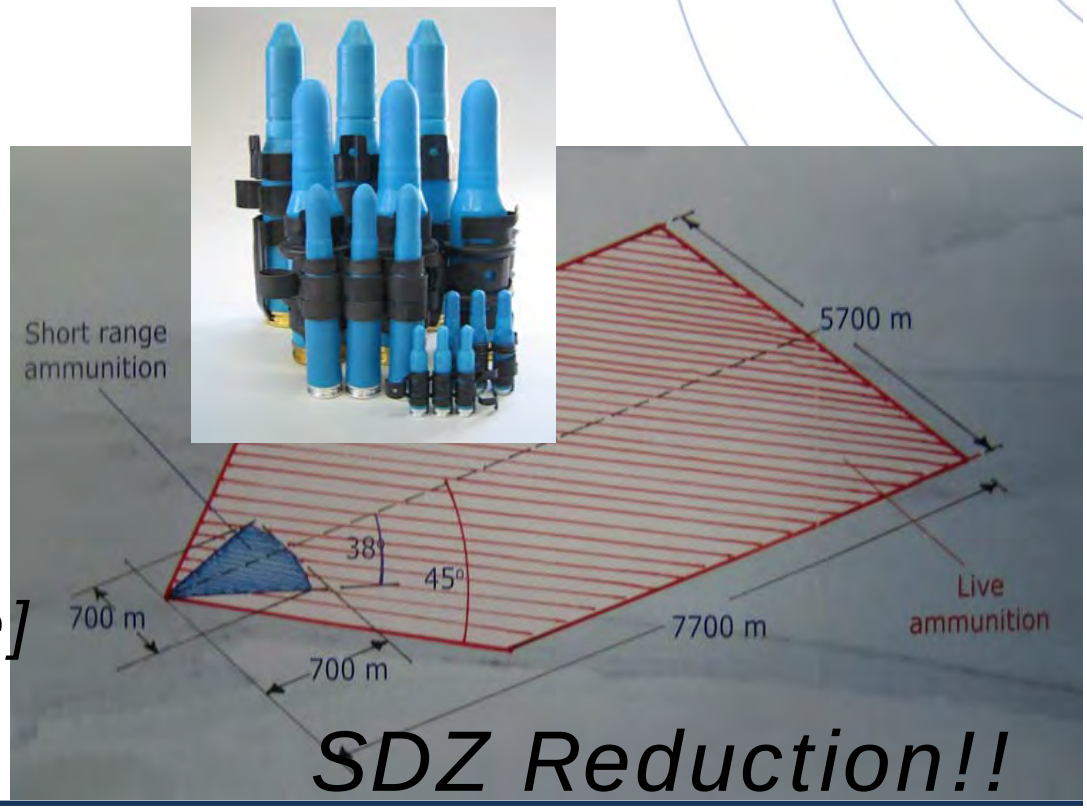






12,7 mm MP Family(0.50cal)

- 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]

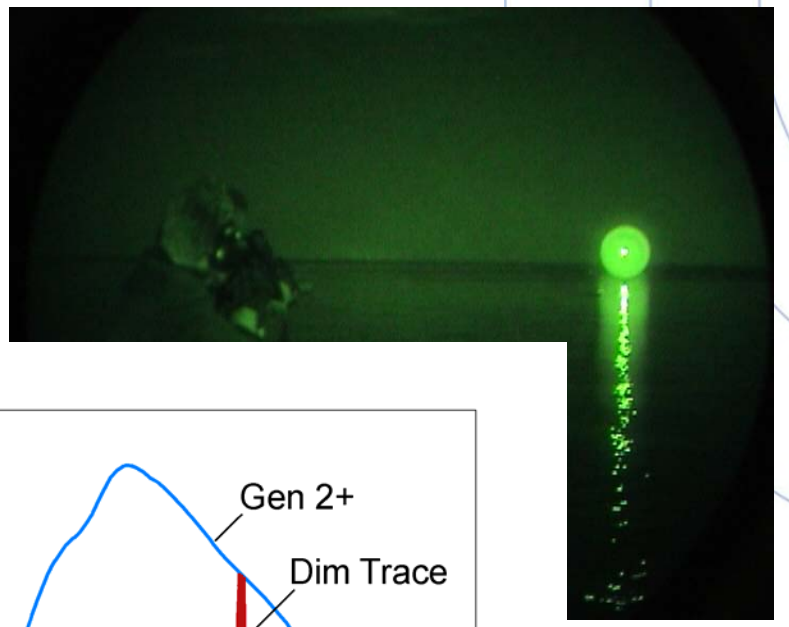


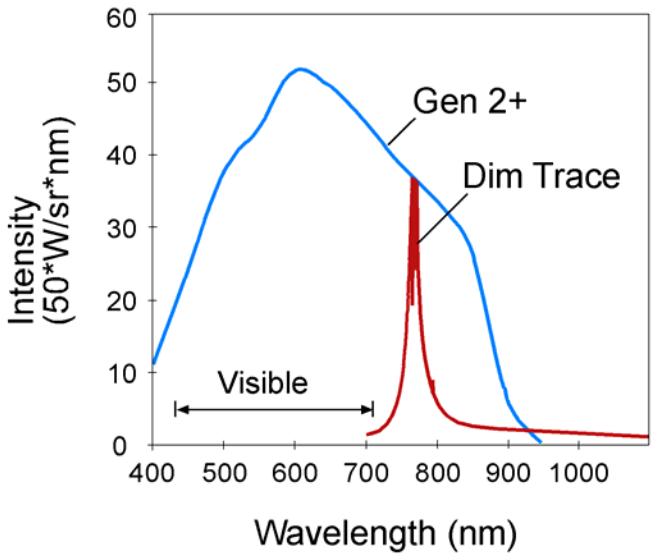
12,7 MP-DT for Night Operations

Dim Tracer at target



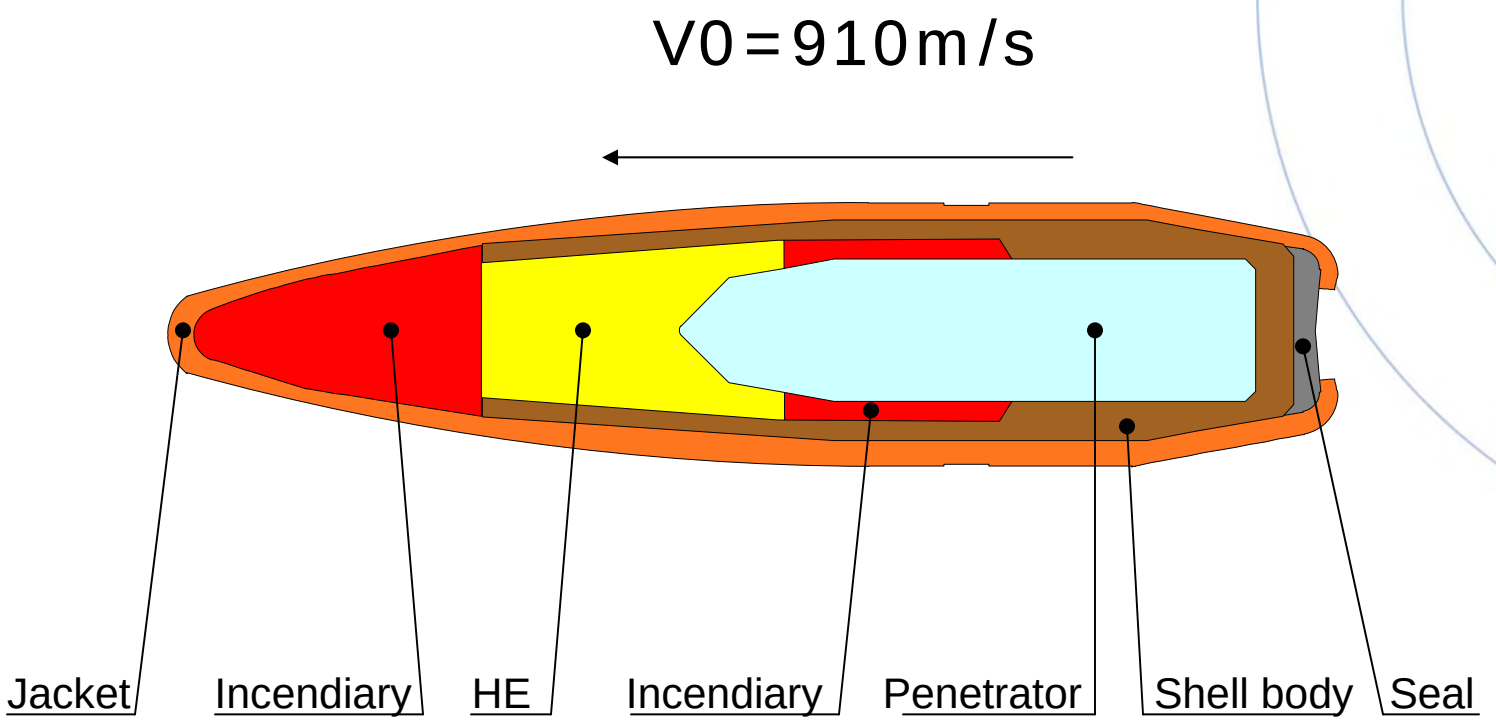
Standard Tracer at target





Qualified with:
-5,56mm
-7,62mm

12,7mm MULTIPURPOSE, MP



0.50 Cal. MK211 by ATK/Nammo

40mmX53 Ammunition Solutions for 40mm Automatic Grenade Launchers

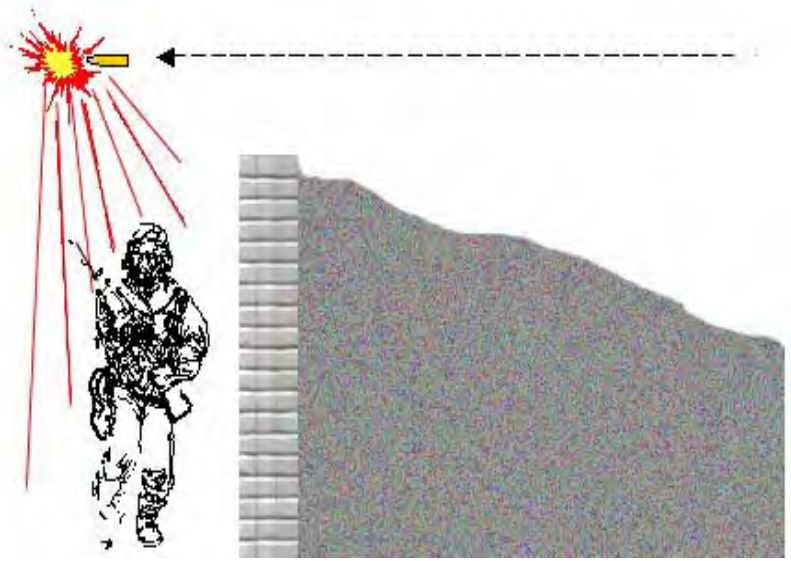
- New Ammunition – <u>Programmable Air-Burst</u>
  - 40mmX51 PPHE MK285
  - 40mmX51 IHV-HEDP M430PIP by N2 Defence(NICO&Nammo)
  - 40mmX51 PPHE-RF
- New AGL systems developed during the last 10 years
  - Mk47 Striker by GD-ATP
  - GMG by Heckler&Koch,H&K
- Mk 19 Legacy





40mm x 51 Nose Fuzed HE Round
The Solution for Urban Operations

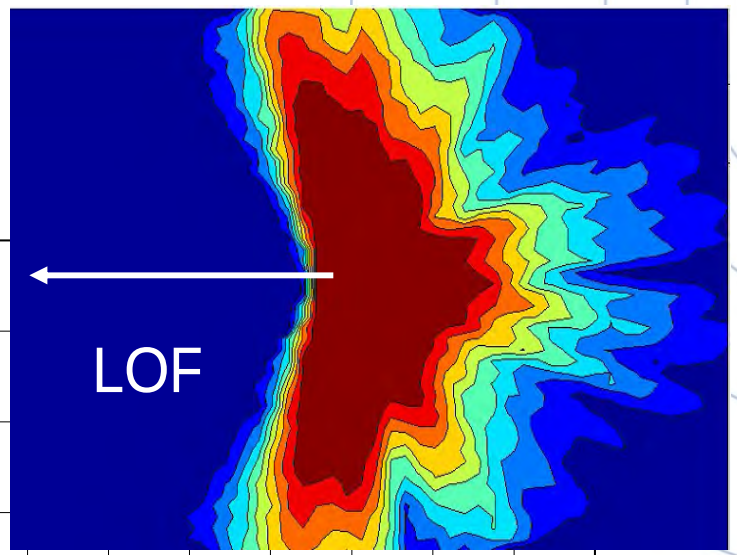
Fragments distributed:
- Sideways
- Backwards

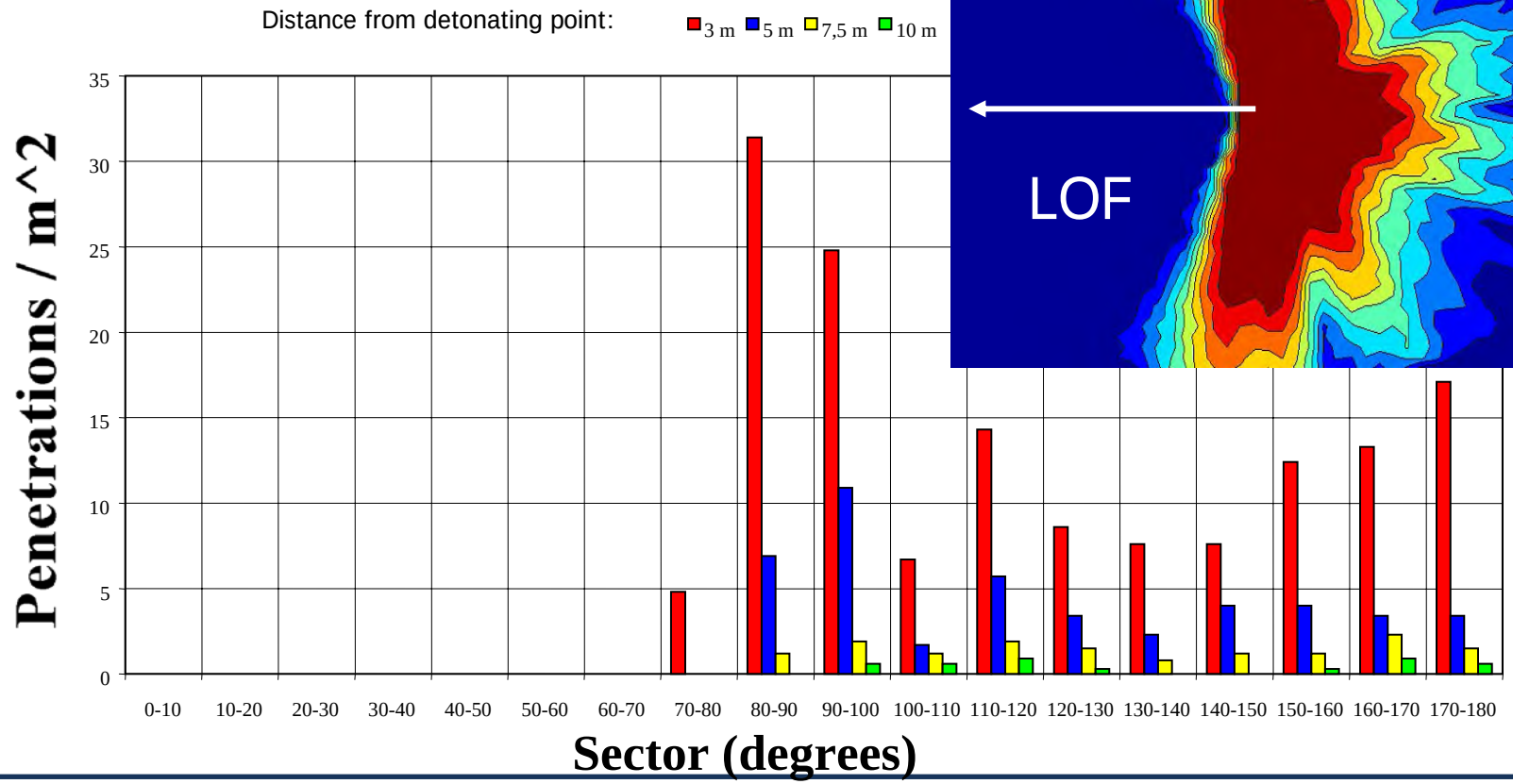


Highly effective against hidden targets e.g. on rooftops, behind corners, inside buildings, in trenches etc.,
targets you don't normally take out with direct fire

Fragmentation of HE Warhead

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

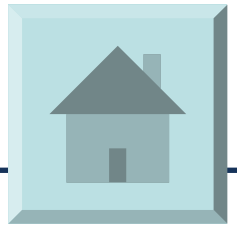
- M430 (HEDP) Improved High Velocity Program
  - Key improvements:
    - PD/SD function implemented
    - New Propulsion Unit (NICO)
    - IM properties with PBXN-11
    - After Armour Effect (Incendiary)
    - Penetration++
    - Reduced safety zone (Back-plug)
- P-Programmable version optional



N2 Defence
by Nammo/RWM

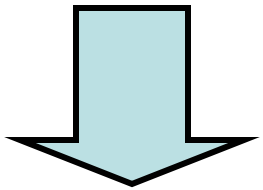
40mmX51 PPHE-RF (Radio Frequency) New Air-Burst technology

- 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

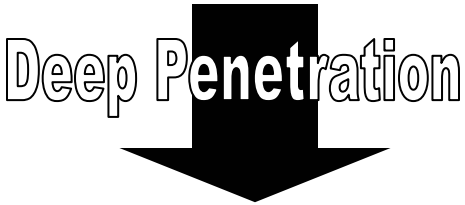


M72 LIGHT ANTI-ARMOUR WEAPON

M72 LAW



IMPROVEMENTS / NEW VERSIONS





M72 EC-LAW

(EC = ENHANCED CAPACITY)

M72 ASM-VERSIONS

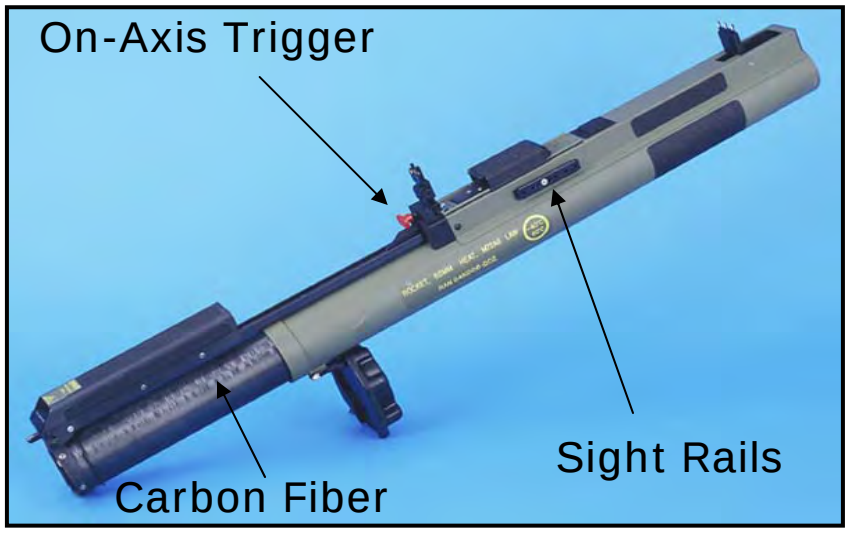
(ASM = ANTI STRUCTURE MUNITION)

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

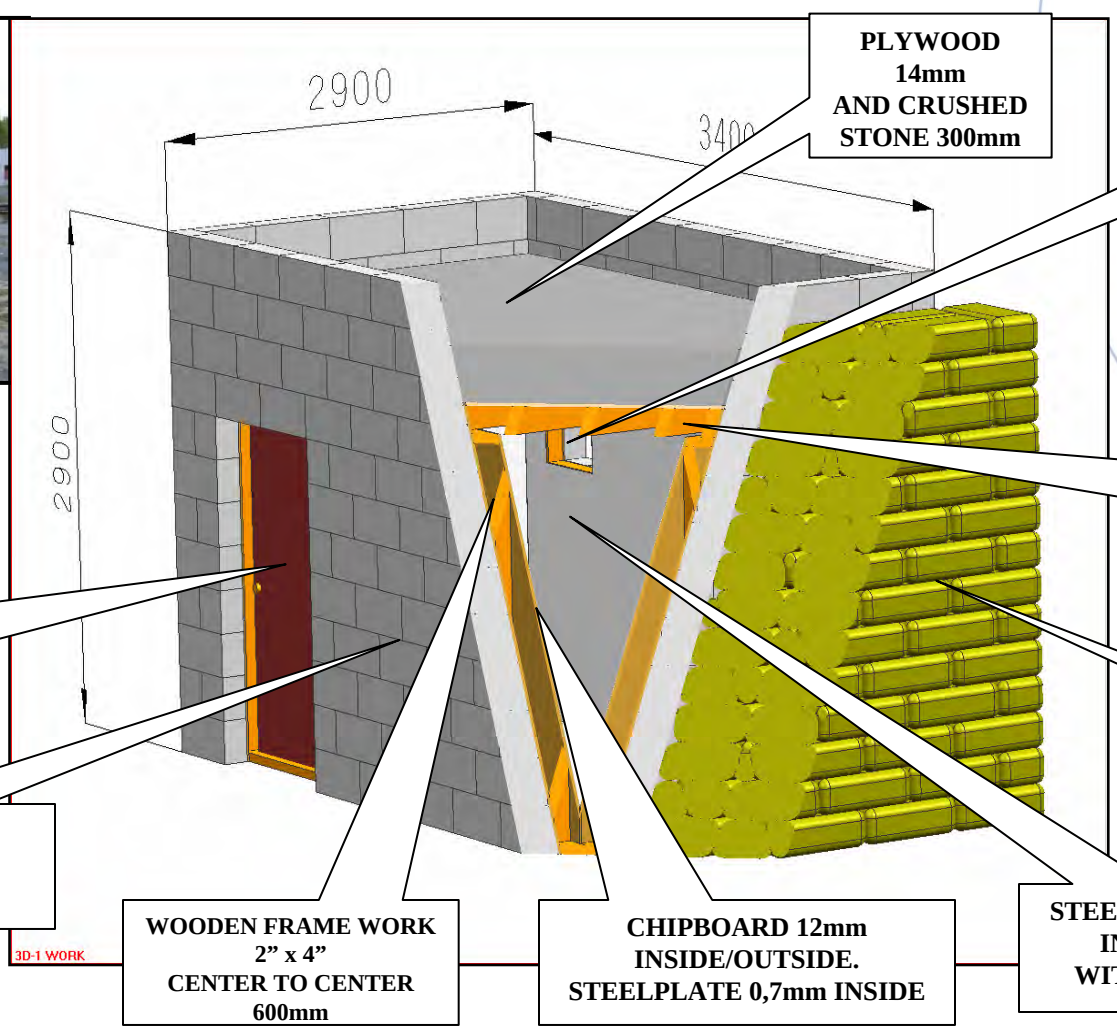
M72 ASM-RC

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

SANDBAGS
TWO LAYER

SOFT CONCRETE
(LECA) BRICKS.
THICKNESS 150mm.

WOODEN FRAME WORK
2" x 4"
CENTER TO CENTER
600mm

CHIPBOARD 12mm
INSIDE/OUTSIDE.
STEELPLATE 0,7mm INSIDE

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

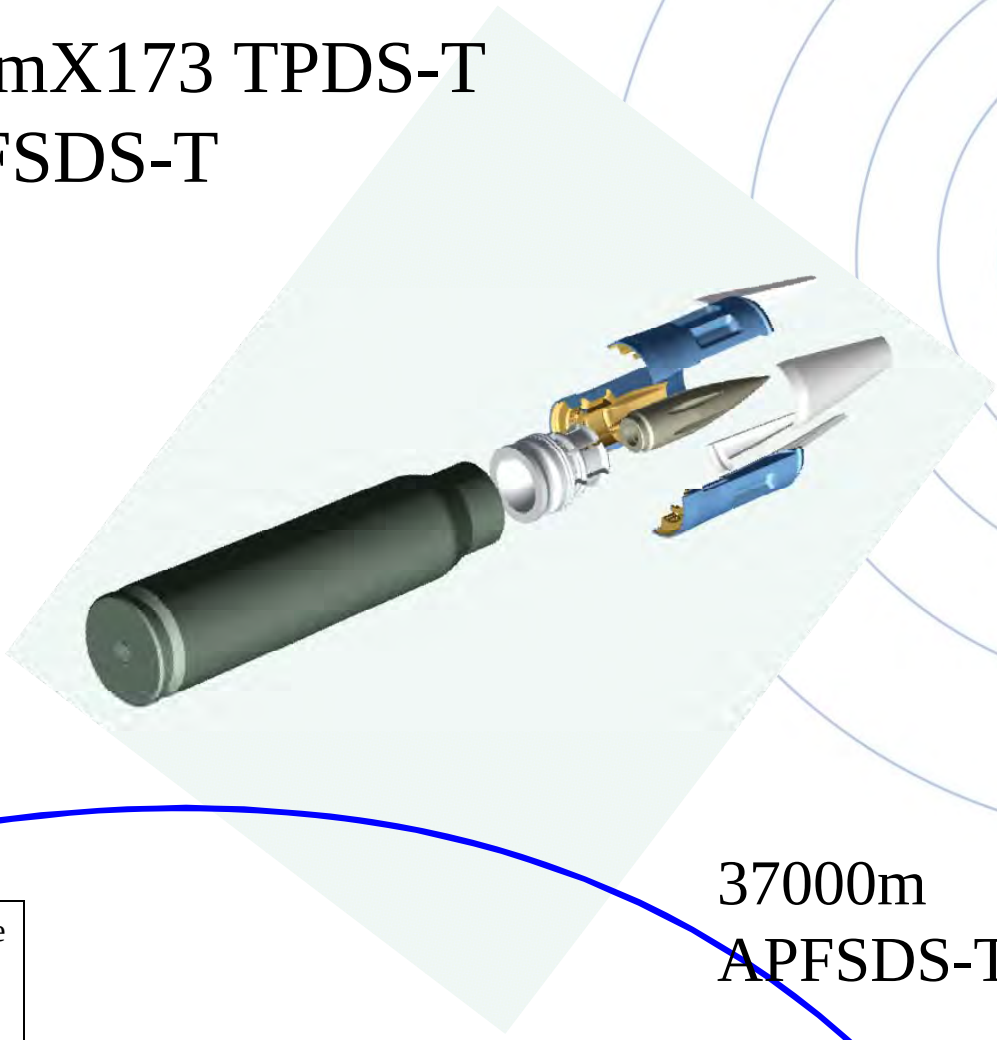


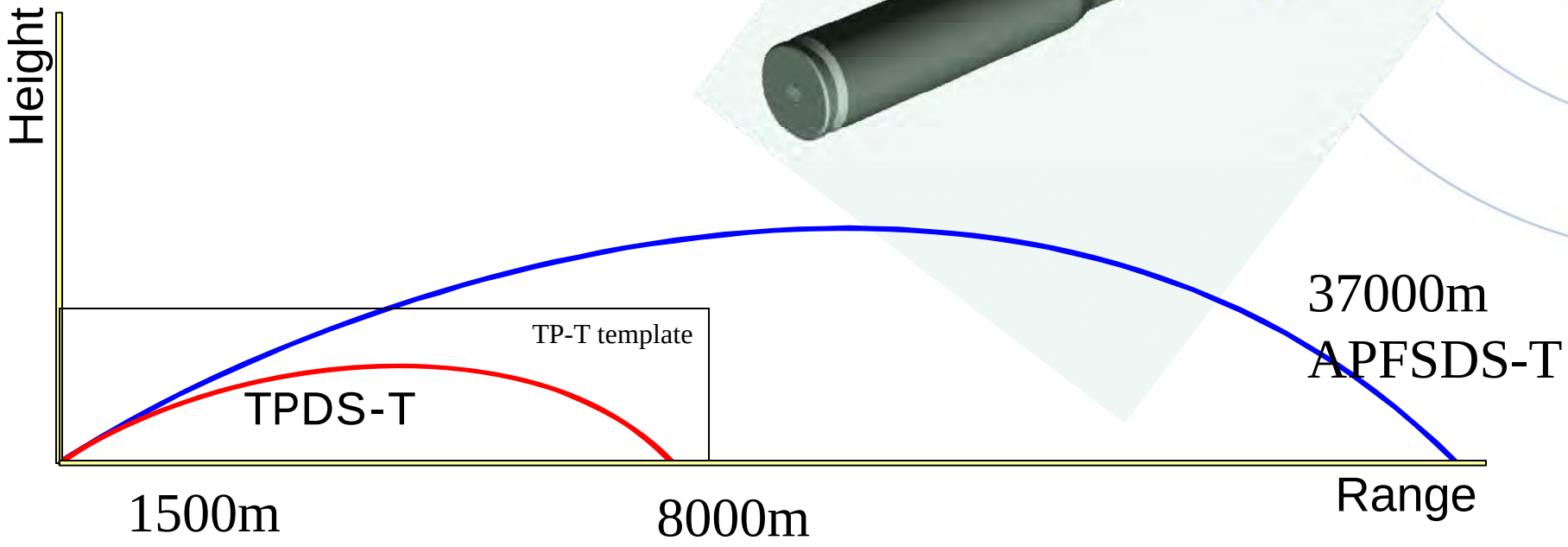
Rapid development and qualification of State-of-the-Art Ammunition! (example 30mmX173)

- 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

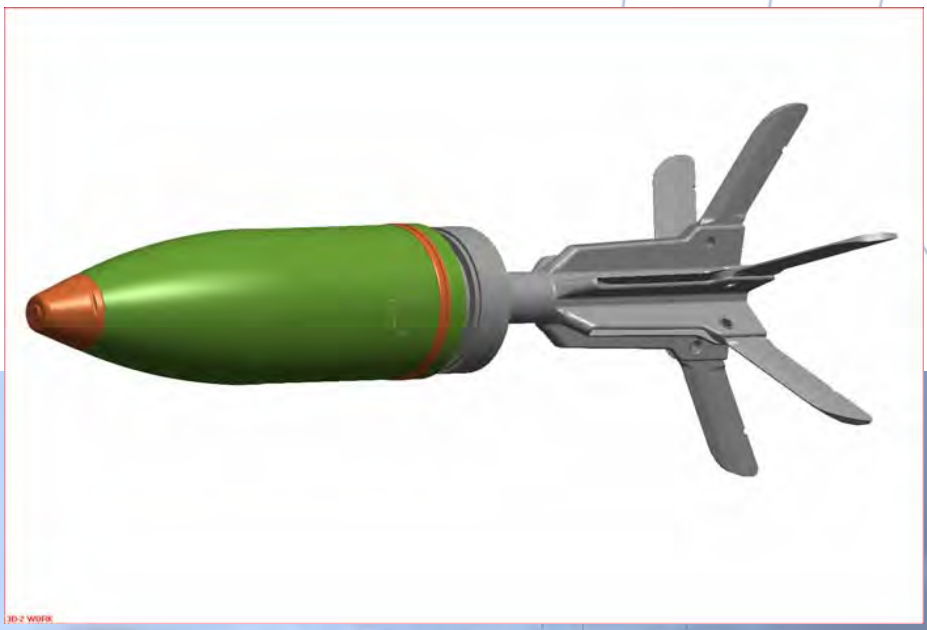




120mm Ammunition

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

- V0=744m/s →1030m/s
- Improved accuracy to <0,2mils @2000m)
- Increased explosive charge weight (2,7→3,2kg)
- 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--+71C]

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

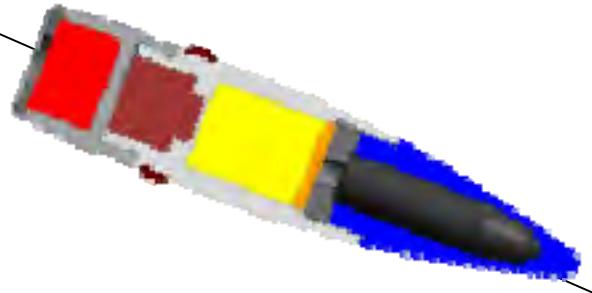


Air to Air

"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

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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

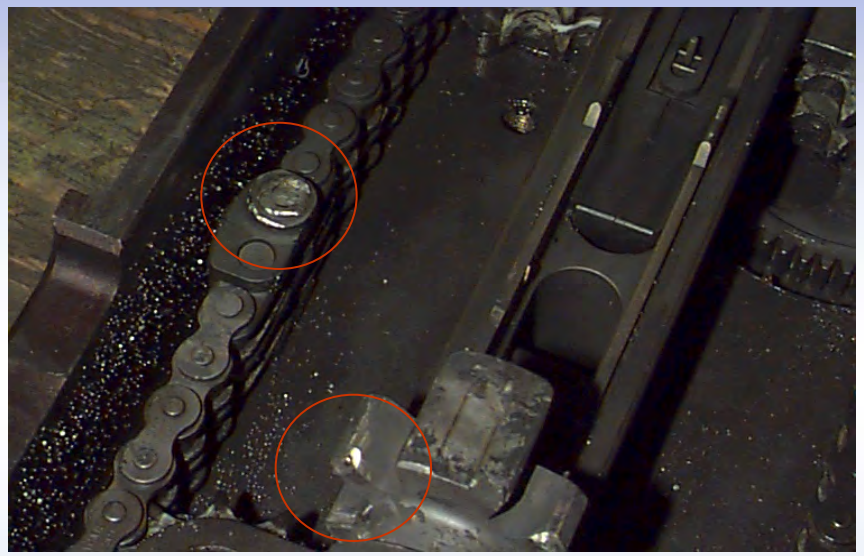








Typical Damage
"Severe Event"- Hangfire



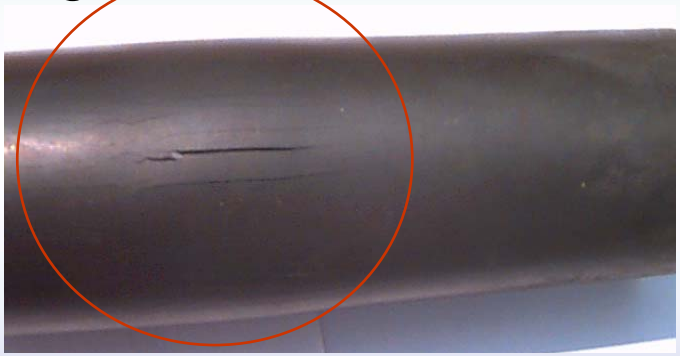






Typical Damage Inbore Detonation

- Damage Similar to or Identical to Severe Hangfire/High Pressure Plus Barrel Cracking & Muzzle Break Impacts by Fragments



Typical



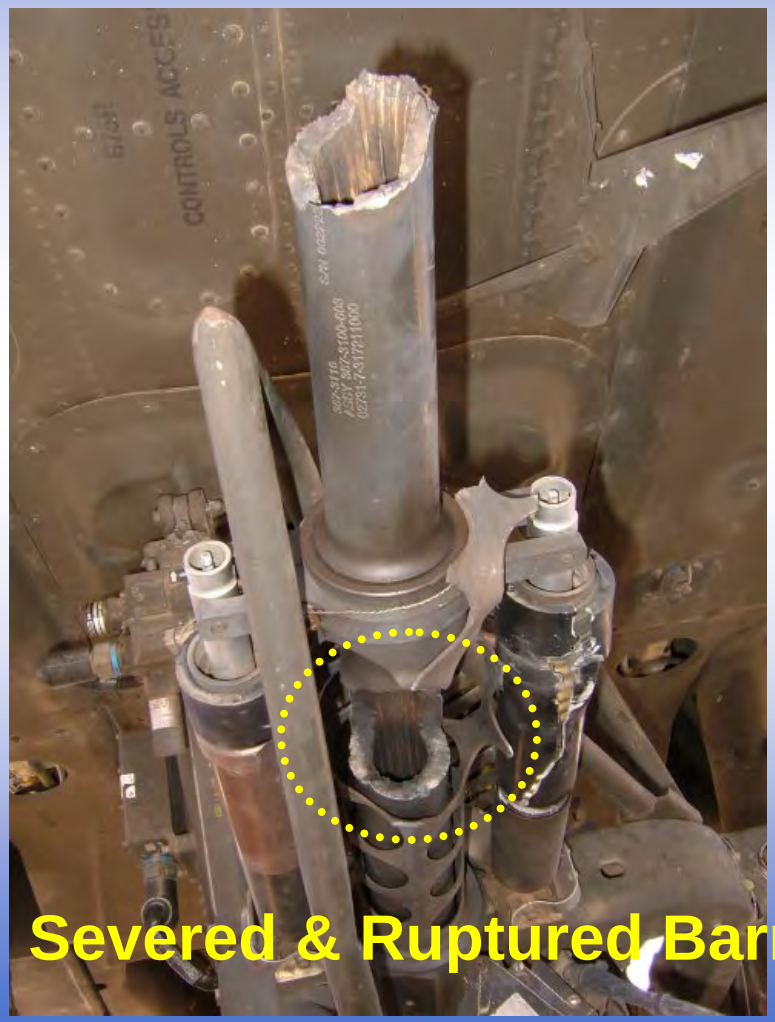
Extreme



Typical Damage
Bullet on Bullet



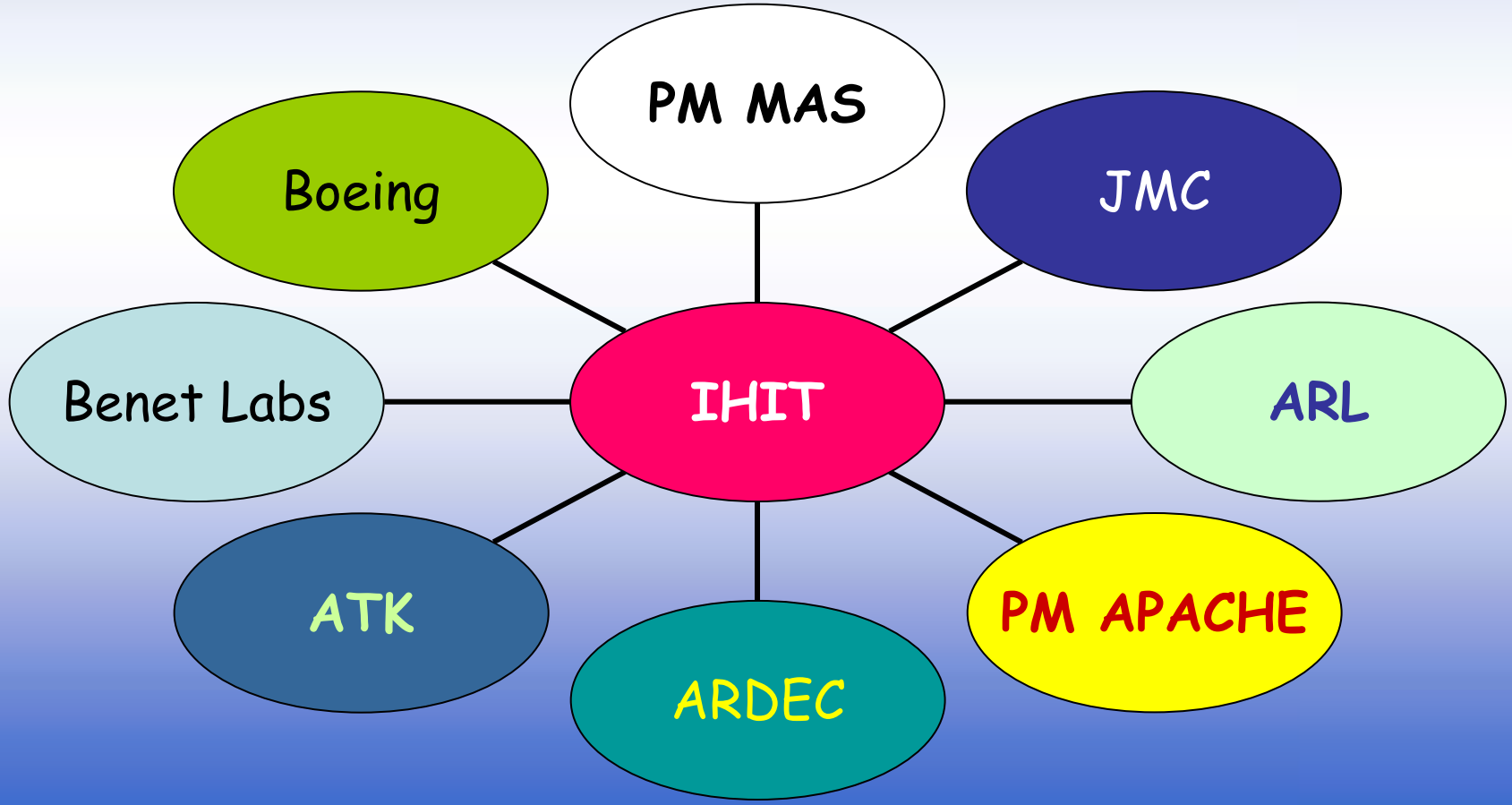
1/130th



2/101st

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

UNIT VISIT & INCIDENT KEY INFORMATION

- 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

- Cross Functional/Cross Organizational IPT
- Co-Leaders from PM-MAS & PM-Apache
- User Involvement & Feedback
- Systems Engineering

Cannon, Handling System & Aircraft Systems

121 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

Ammunition Handling & Storage

3 Potential Causes



Ammo Metal Parts Manufacture

55 Potential Causes



Ammunition LAP

36 Potential Causes



Identified Three Major Root Causes

Hangfire/High Pressure

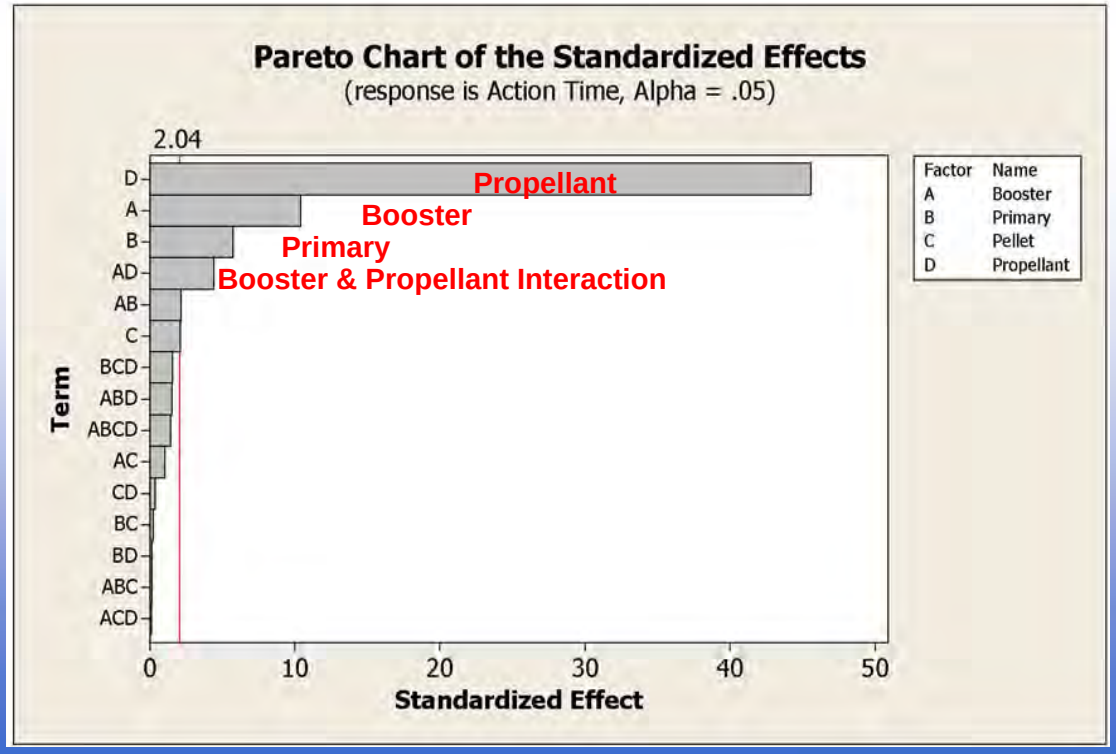
Ignition System DOE Phase I

Control Factors	Level 1	Level 2	Level 3
Booster Mix	100%	50%	
Primary Charge	With	Without	
Flashtube Pellets	Pellet	Powder	
Propellant Level	100%	50%	25%

MANN BARREL TEST







Damaged IB52 Pellets/Flash Tube

Open Air High-Speed Video of Flash Tube Venting

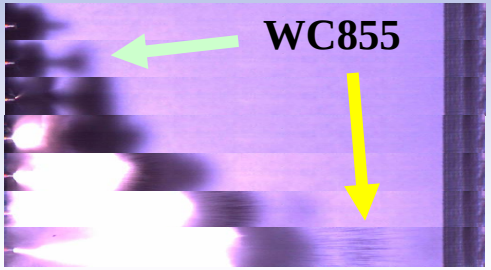
Normal Flash Tube

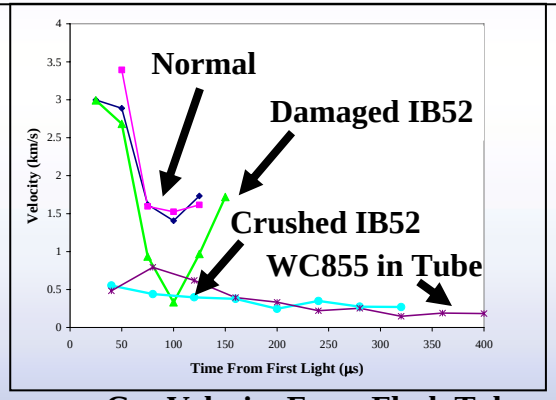


Damaged IB52



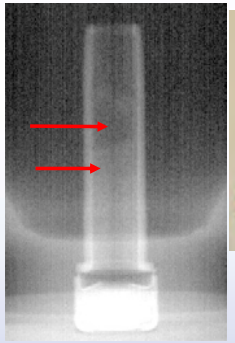
WC855 in Tube





Gas Velocity From Flash Tube

Radiograph Damaged Flash Tube in M789





Some Damage IB52 Pellets

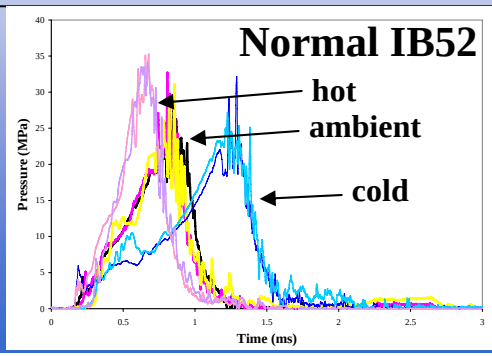


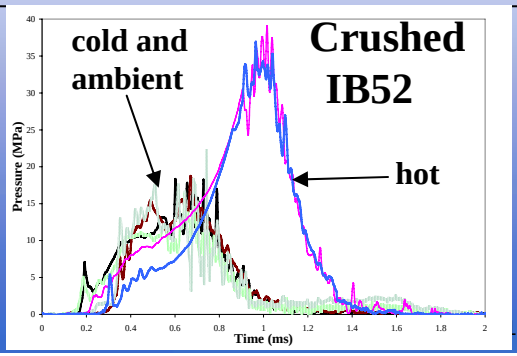
Broken Lacquer Seal with WC855 in Tube

Live Propellant 30-mm Gun Simulator



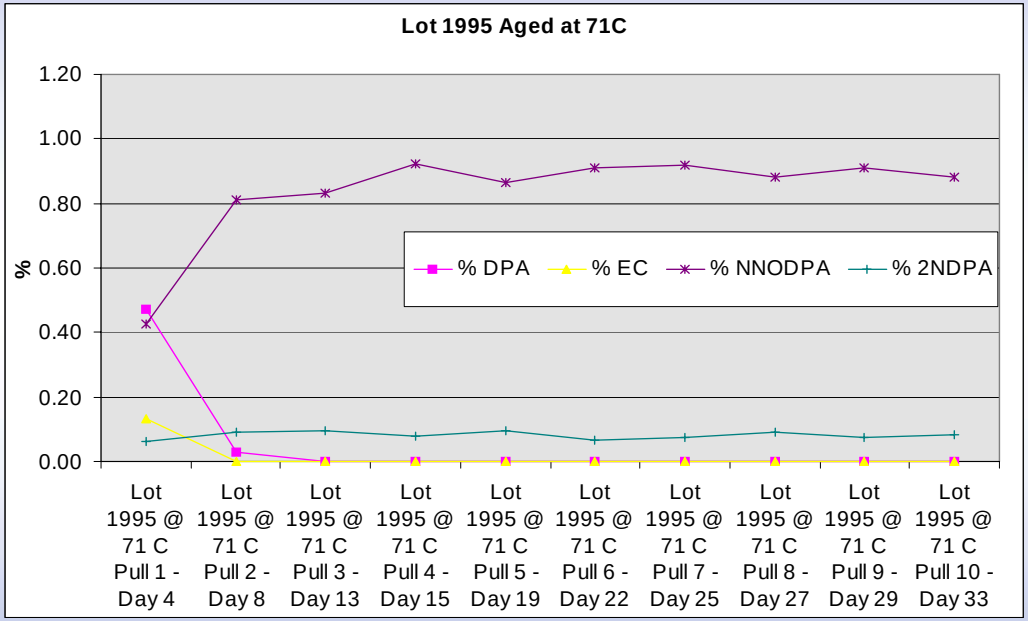
WC855 in Flash Tube has Given Greater Than 40 ms Ignition Delay

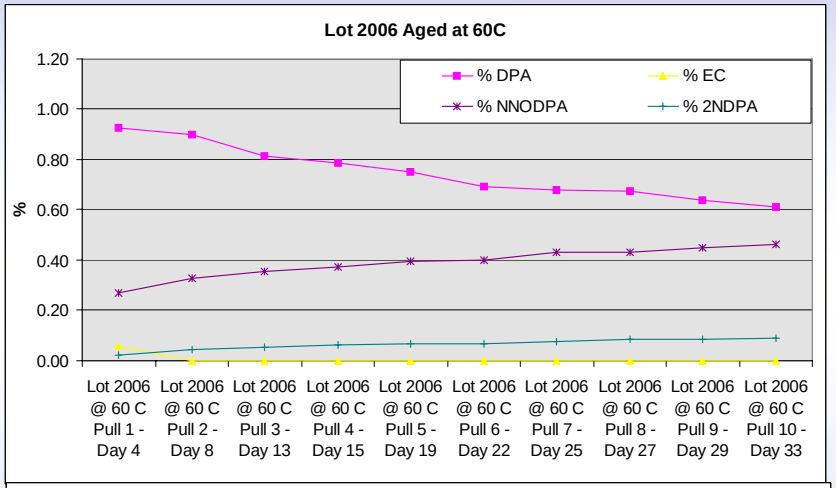


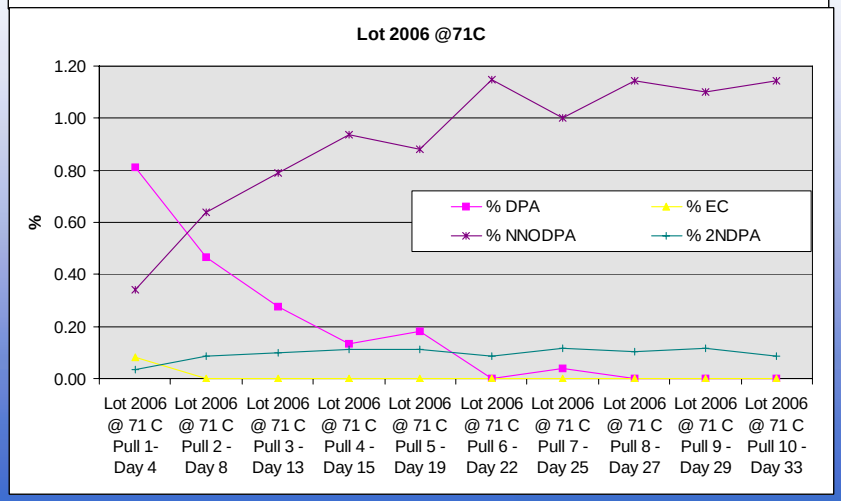


Hot Temperature Storage Led to DPA Depletion

- Over time, the original stabilizer, DPA, depletes and converts to daughter products – 2NDPA, NNODPA ; DPA reaction rate increases as temperature increases





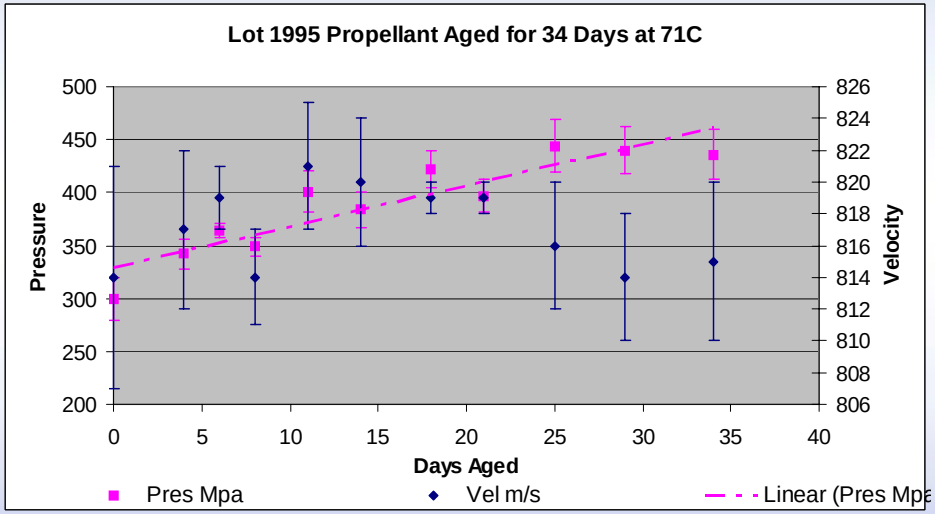


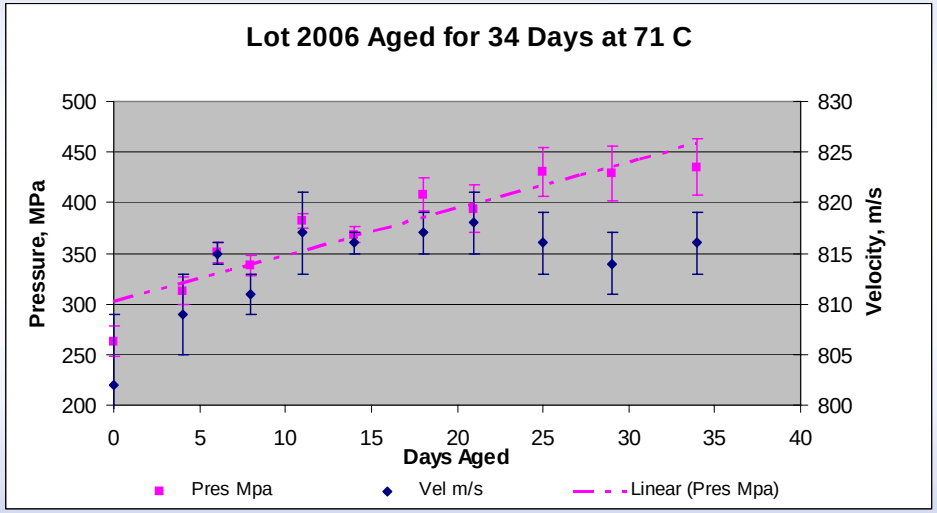
•DPA concentration of the 1995 Lot had depleted to half the concentration of the 2006 Lot at time = 0

•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**



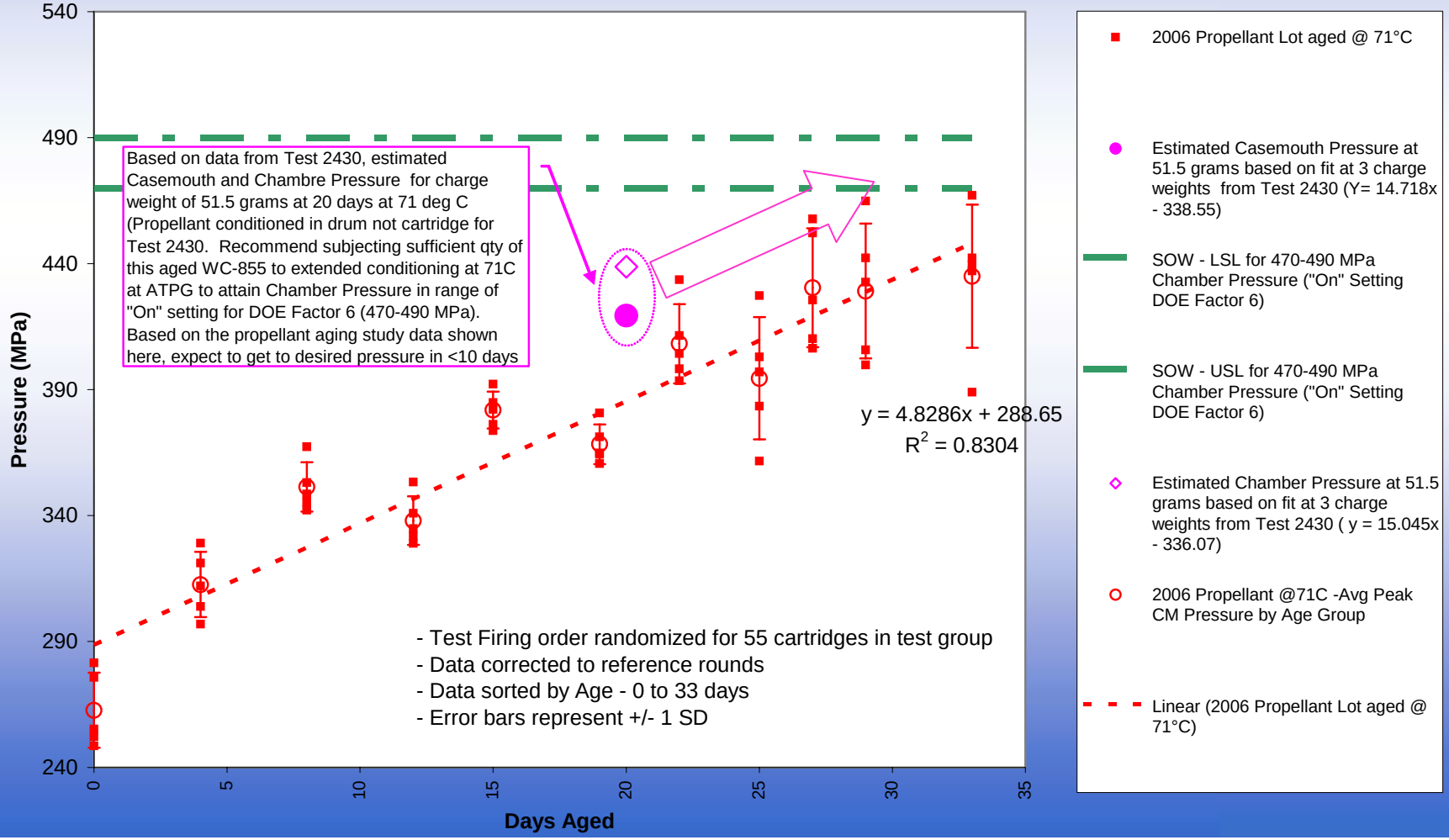


- Ballistic testing conducted at ambient. All data corrected with reference ammunition. Data is the average of 5 shots.

- Variation in pressure performance attributed to migration of DBP deterrent

Aged WC-855 for DOE Factor 6

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



Headspace DOE

Phase I Test Matrix

Firing Order of Rounds	No. of Rounds	High Pressure (approx 500 Mpa)	Nominal Pressure	Nominal Headspace	Headspace 0.025”	Headspace 0.031”	Hot Barrel (180ºF)	Ambient Barrel
1	5		X	X				X
2	5	X		X				X
3	5	X			X			X
4	5	X				X		X
5	5		X		X		X	
6	5		X			X	X	
7	5	X			X		X	
8	5	X				X	X	

Tested ok

Incident 1

Incident 2

Phase II Test Matrix

Firing Order of Rounds	No. of Rounds	High Pressure (approx 415 Mpa)	Nominal Headspace (.022”)	Maximum Headspace (0.031”)	Ambient Barrel
1	5	X	X		X
2	5	X		X	X

Headspace DOE

- **Hangfire signature has been replicated <u>without</u> 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

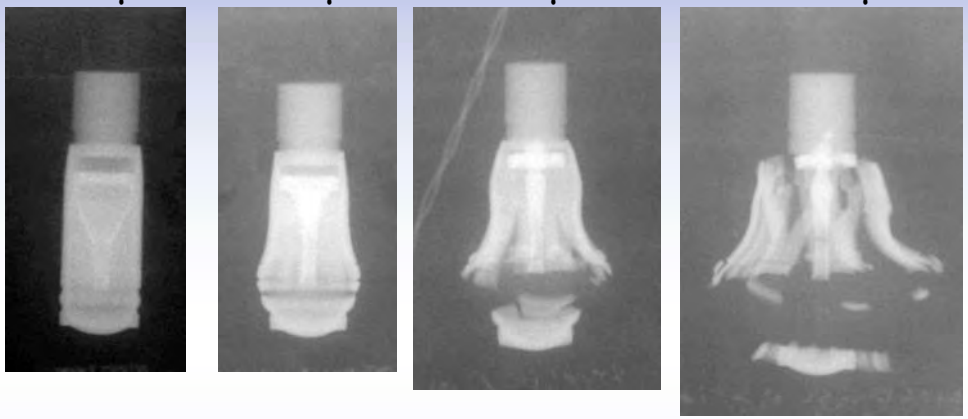
- Most Likely Causes
  - Extended Vibration Damages Cartridge Ignition System (Replicated)
    - No Rounds Showed Physical Damage After 144 Hours
    - 30% Showed Some Damage After 192 Hours
  - Extended High Temperature Exposure Changes Propellant Characteristics (Replicated)
    - Significant Pressures Measured after 432 Hours @ 71º C (160º 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

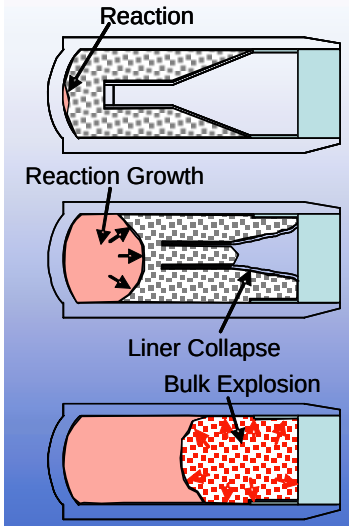
Inbore Detonation

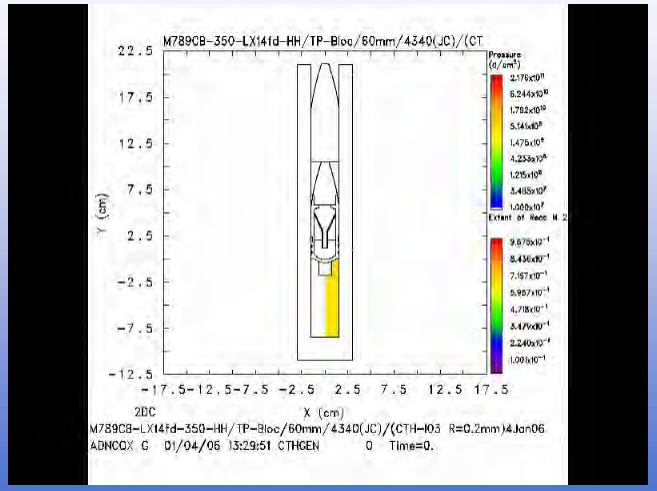
Explosive Reaction and Response

Low Order Time Lines

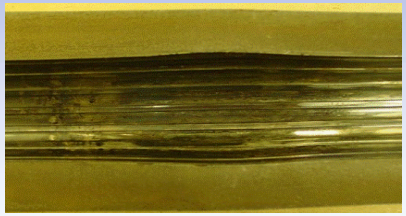
35 µs 55 µs 75 µs 100 µs



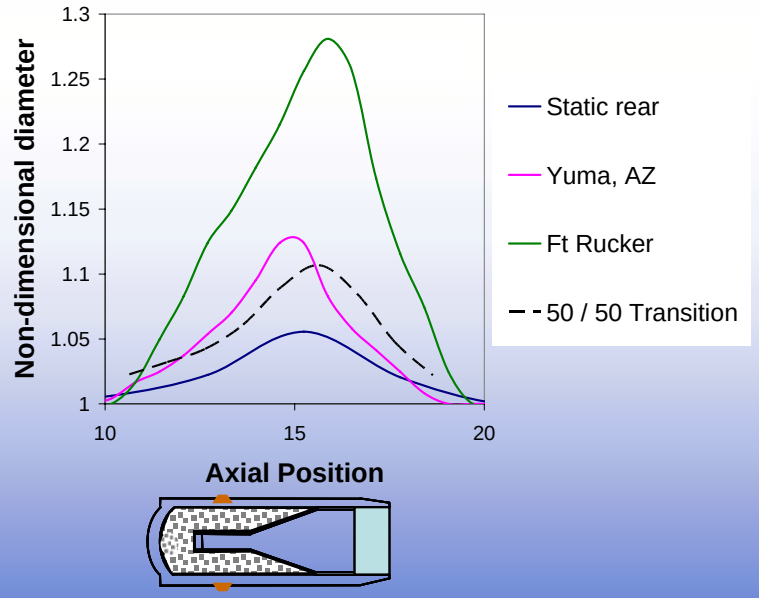




Barrel from Arizona Incident

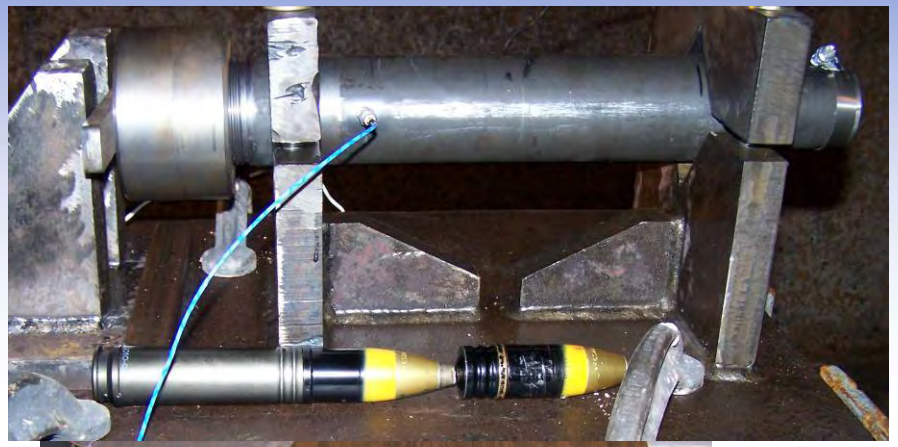


Data from Incidents, Experiment and Modeling



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

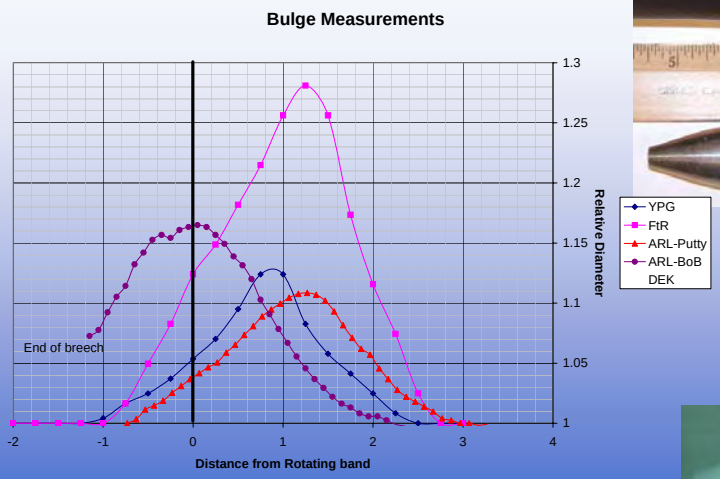
Implies rear bullet initiation









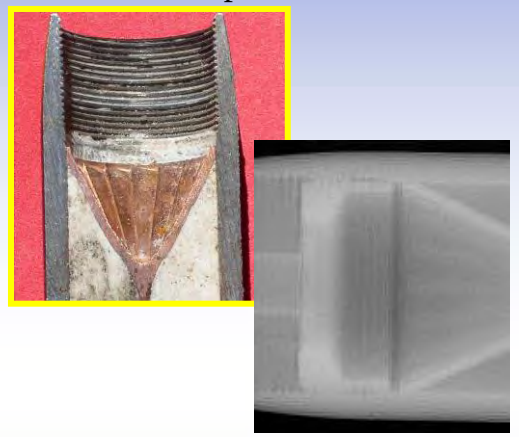


Follow-on shot with solid fuze result was an in-bore with incorrect signature

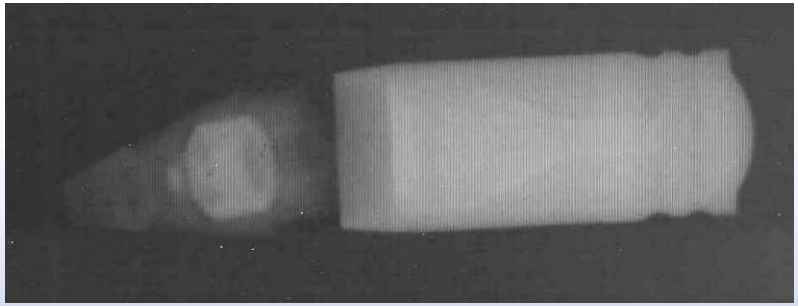
Dynamic Signature Replication Set Forward



Exuded explosive in threads



Gap between retainer and liner



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

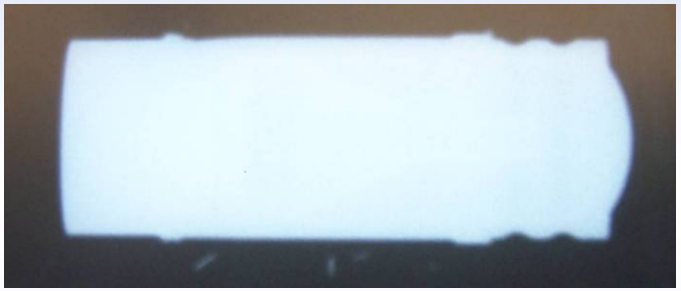
Fuzed

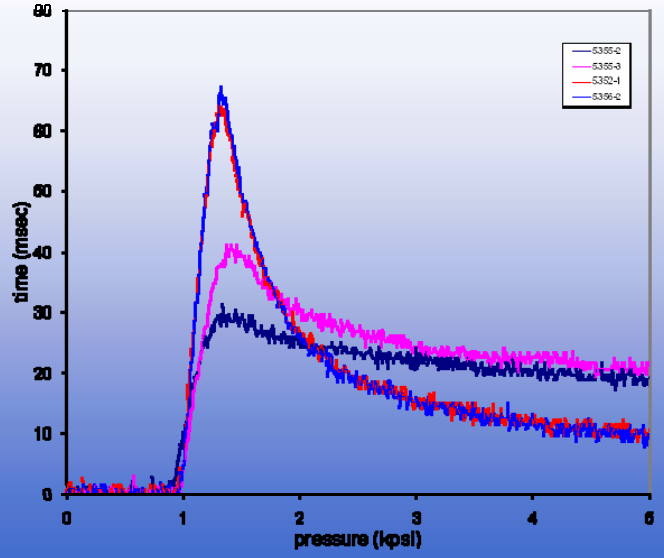
- No defects as determined from x-ray
- Standard, fuzed rounds
- 5 shots, no in-bores

Dynamic Signature Replication High Pressure (Body Failure)

2.00 x







Rationale

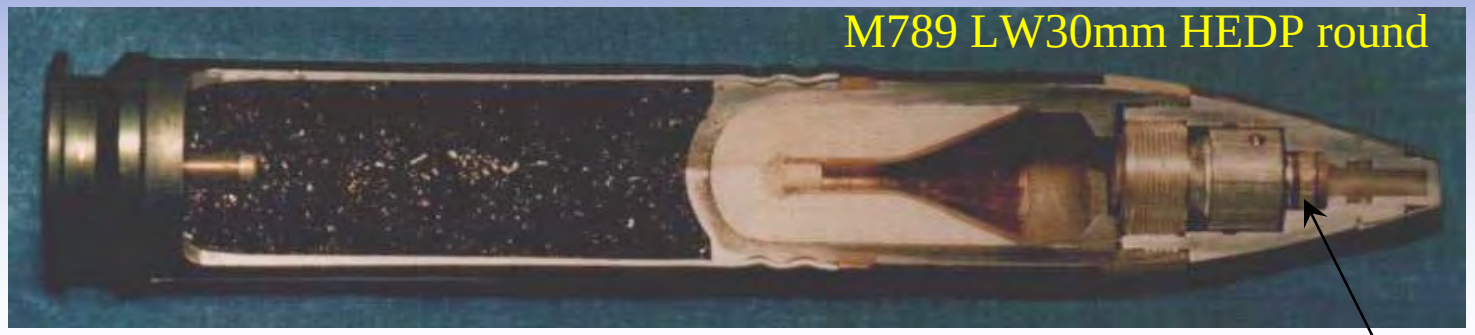
- Structural analysis found weak area in rear
- Bullet-on-bullet tests at APG:
  - 4 out of 4 shots went low order
  - Initiation from rear of projectile

Procedure

- Single projectile of increased mass
- Replace fuse with tungsten weight
- Provide data for fracture model

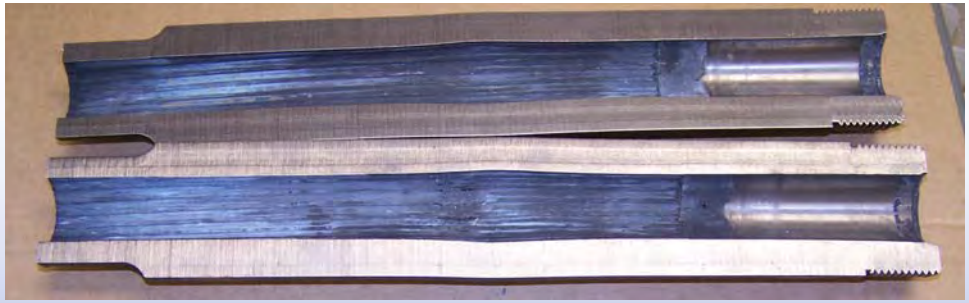
Mass taken to over double (2.25x) of projectile with subsequent increase of base pressure – NO initiation of explosive

Dynamic Signature Replication Foreign Material (aka Putty)



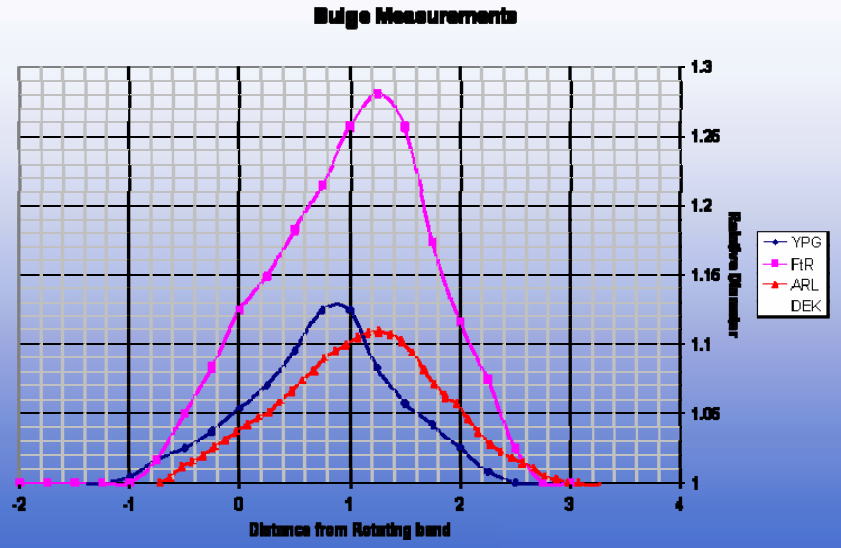
Dummy fuze replaces live fuze
(with putty to match mass)

Shot 1

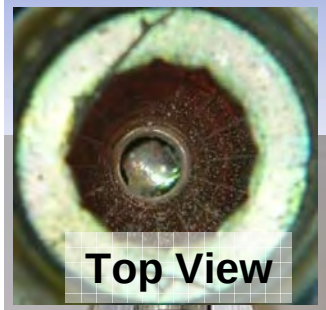


Bulged barrel centered at < 8 inches from breech

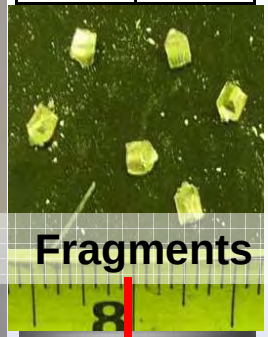




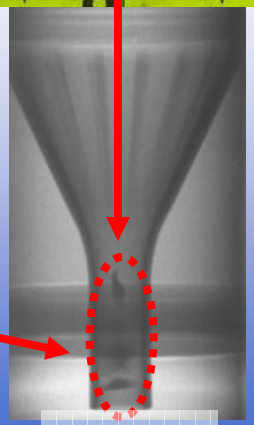
Foreign Material in Liner Cavity

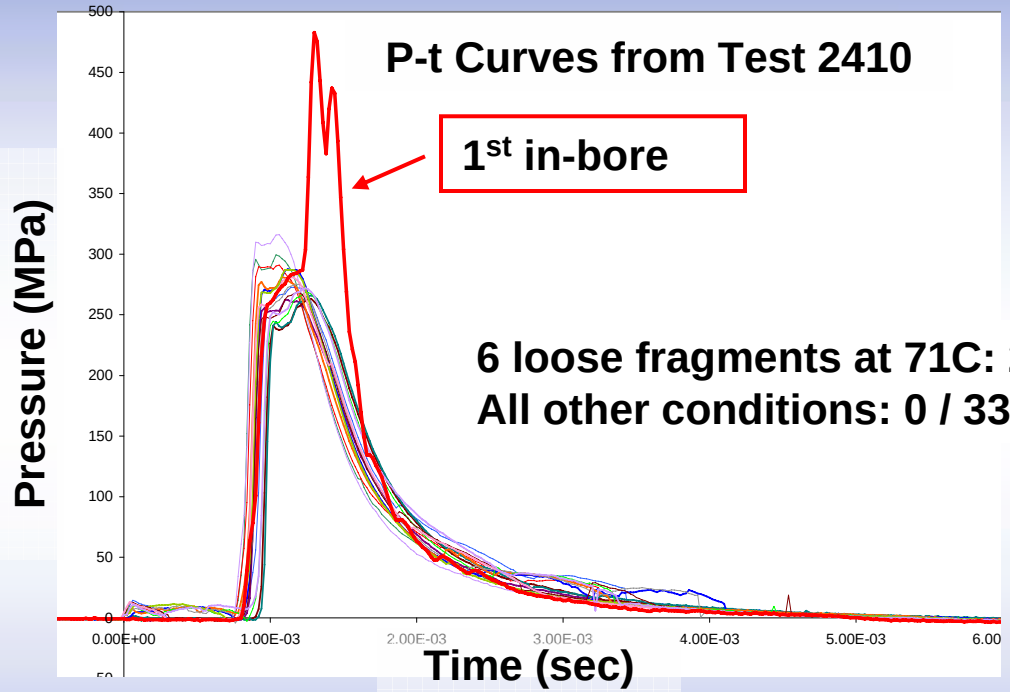


Sample AA	
Fragment	Mass (mg)
1	48
2	51
3	53
4	54
5	53
6	52
Average	51.8
Total	311





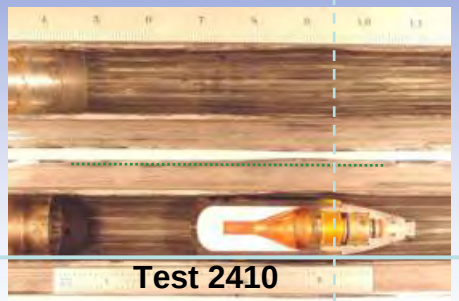




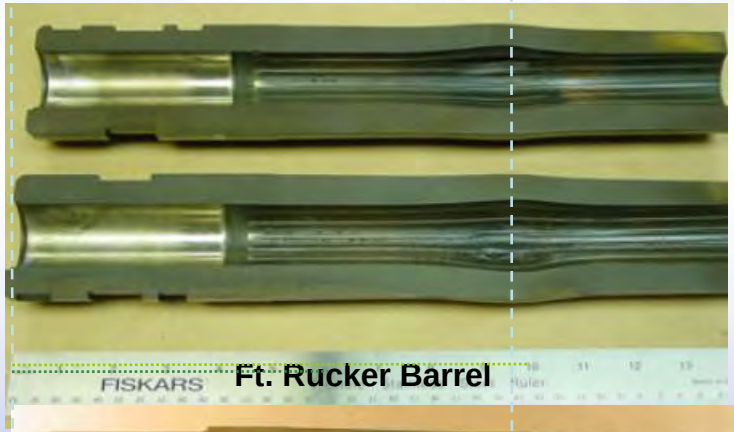
6 loose fragments at 71C: 2/2 in-bores
All other conditions: 0 / 33



Test vs. Field Incidents - Profile



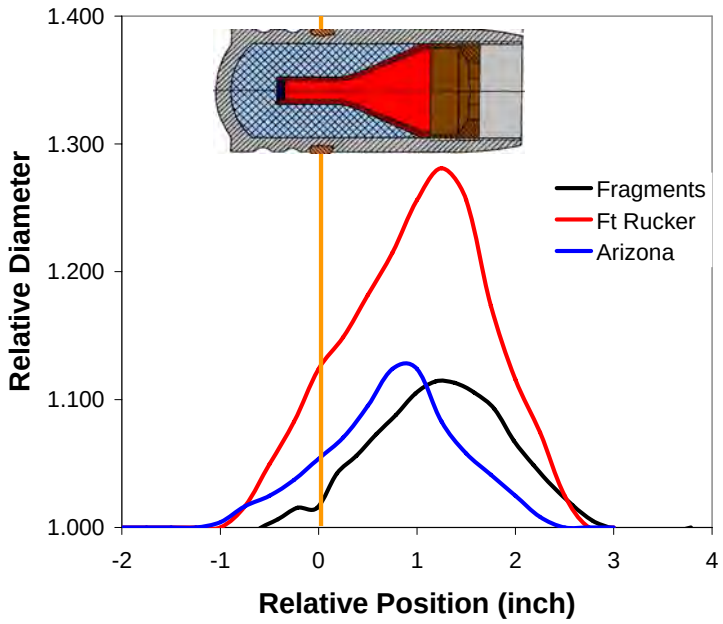
Test 2410



Ft. Rucker Barrel



Arizona Barrel



Reference Line approx. 9.5” from end of barrel

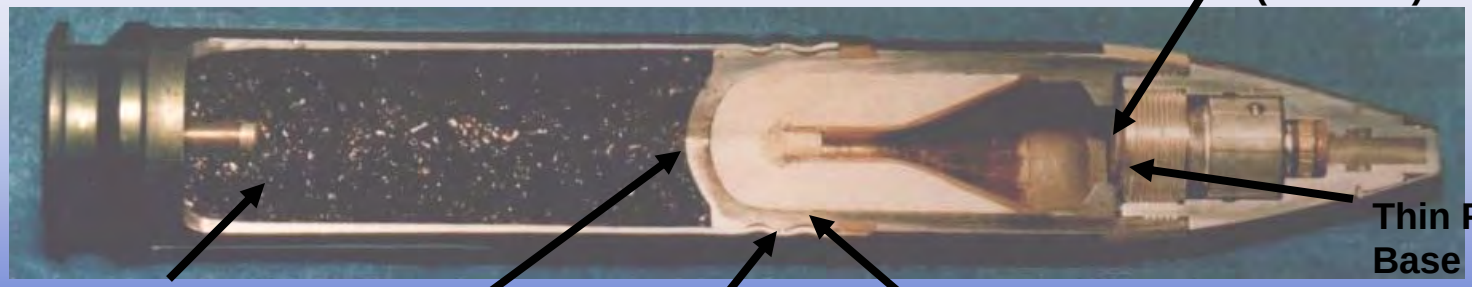
Fault Tree Probabilities for In-Bore DOE Factors

Block	Reliability	Prob. of Failure		Final Probability	Priority Ranking	
#504 Setback initiation due to debris in cavity	1	1.0005E-05	A1.11	1.0005E-05		In-bore demonstrated in Test 2410
#65 Thin sidewall body fails on setback	1	7.8400E-07	A1.12	7.8399E-07	1	Factor 4
#502 Particles embedded in HE cause HE to iniiate at setback	1	5.0000E-07	A1.15	4.9999E-07	2	Cu shaving test at High P in DOE SOW
Normal projectile ?	0.9914	9.9137E-01	A2.1	4.5107E-08	3	
#504 Setback initiation due to debris in cavity	0.9999	1.0000E-04	A2.11	1.6300E-09	4	
#1 Thin BCP flange fails on setback	1	1.1000E-09	A1.17	1.1000E-09	5	Factor 2
#307 Projectile Base deformed by propulsion gases	1	6.6700E-10	A1.9	6.6699E-10	6	Factor 3
#303 baseplug Vibrates loose	1	3.3400E-10	A1.2	3.3399E-10	7	Factor 1
#80 Cut Cartridge Case	1	1.0000E-10	A1.3	9.9998E-11	8	Factor 5
#502 Particles embedded in HE cause HE to initiate at setback	1	5.0000E-06	A2.15	8.1500E-11	9	
Improperly secured HE moves back and detonates at setback	1	2.0000E-11	A1.16	2.0000E-11	10	
#65 Thin sidewall body fails on setback	1	6.4000E-07	A2.12	1.0432E-11	11	
PBXN-5 Develops cracks in storage #51	1	1.0001E-11	C1.1	1.0001E-11	12	
Voids in explosive pellet #52	1	1.0000E-11	C1.3	1.0000E-11	13	

Factor 6 – Chamber Pressure G1 and G2

DOE Factor
Special Purpose Test
Redundant with a Prior Element Being Testing

In spec Ballistic Event	1.6345E-05	9.9998E-01	A1.1
#503 High pressure event	0.9227	1.63000E-05	G2
#503 Maximum pressure event	0.9985	4.55000E-08	G1



Loose Base Closing Plug in Fuze (Factor 1)

Thin Flange on Fuze Base Closing Plug (Factor 2)

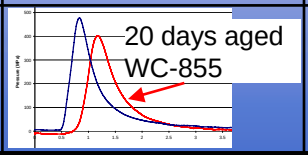
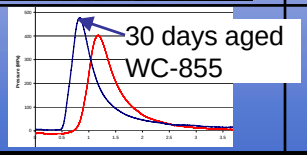
Propellant High Pressure (Factor 6)

Thin Dome (Factor 3)

Cut Case (Factor 5)

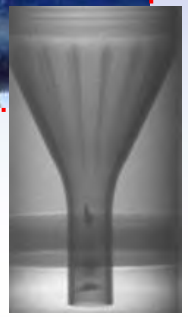
Thin Sidewall due to Eccentric Cavity at Crimp Grooves (Factor 4)

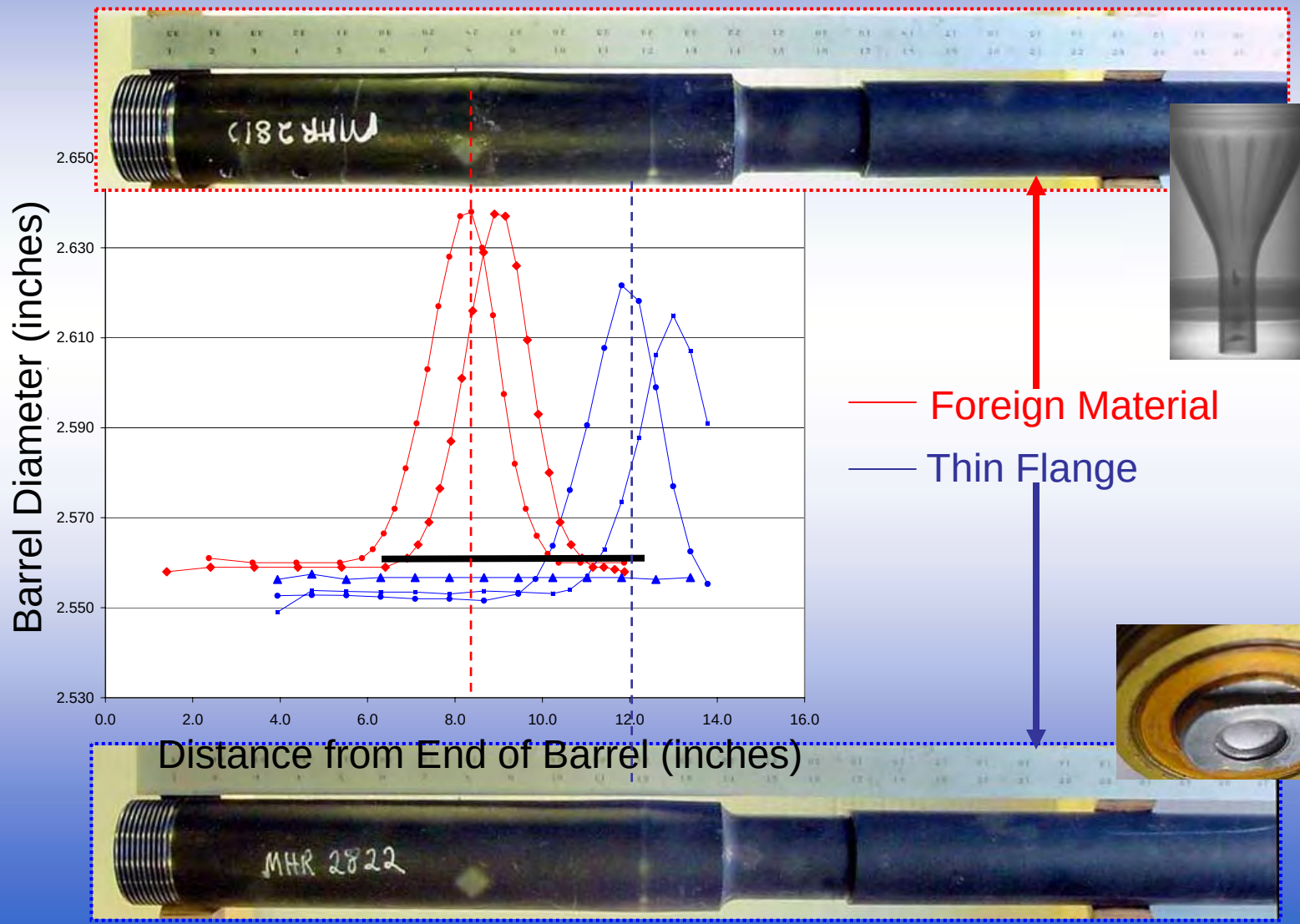
Main In-bore DOE

Factor	Example of "On" Factor Setting		Example of "Off" Factor Setting		Test Results	
					Shots "on"	In-bores
Loose BCP		~1/2 Thread Engagement		Full Thread Engagement	80	0
Thin BCP Flange		~ .015" Flange Thickness		~ .044" Flange Thickness	5	3
Thin Dome		~.05" Dome Thickness		~.125" Dome Thickness	80	0
Eccentric Cavity		Max Eccentricty (~.020")		Nominal Eccentricty (~.008")	80	0
Cut Cart. Case		Cut through case to proj. body		No Cut	80	0
High Pressure		~405 MPa Chamber		~480 MPa Chamber	81*	1

* 1 shot included thin BCP Flange

Test In-bore Comparisons

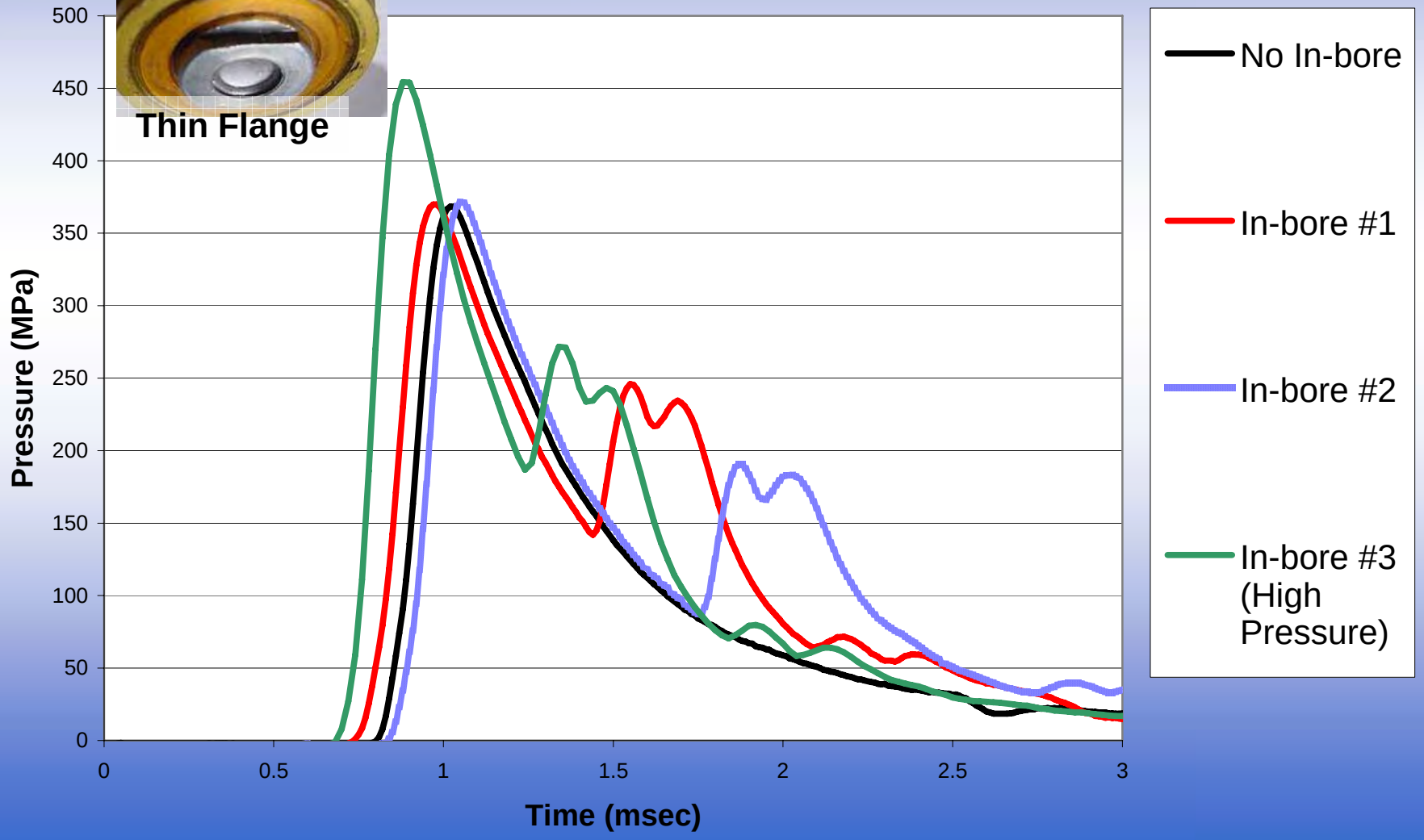






P-t Curves from DOE In-bores (Thin Flange)





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

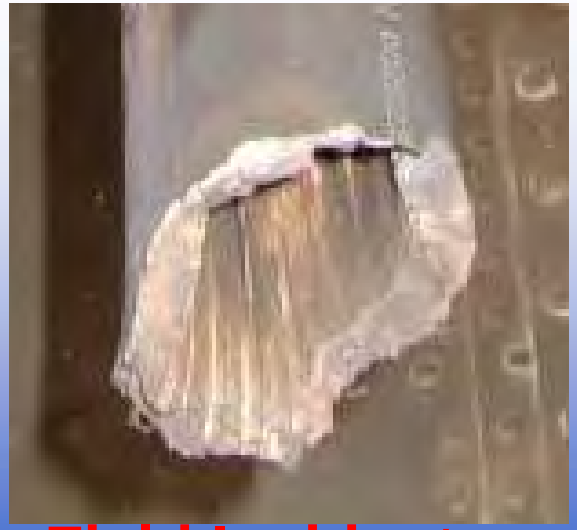
Bullet on Bullet

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.



Field Incident



Stuck Projectile Test

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

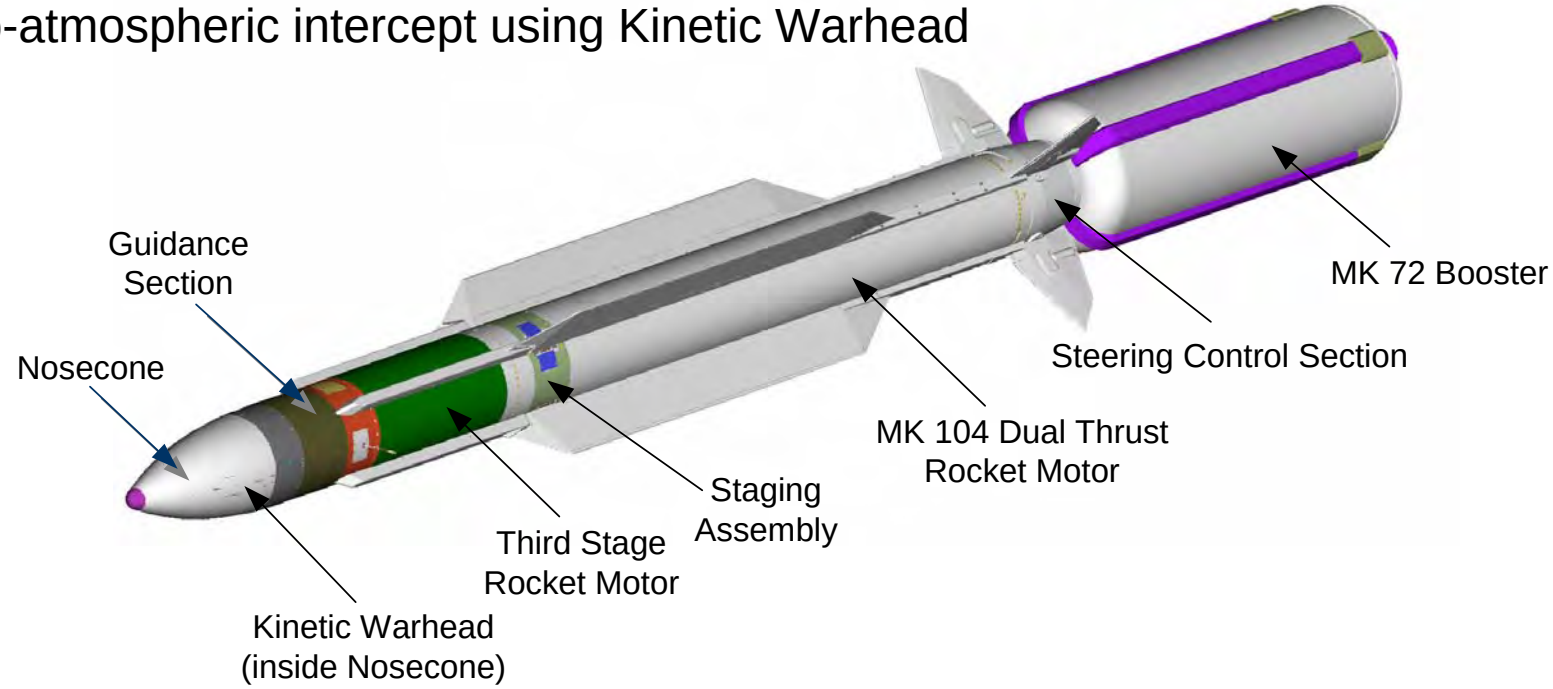
Dave Houchins
Dahlgren Division, Naval Surface Warfare Center
Test & Evaluation Division (Code G60)

Outline

- Description of SM-3 Block IA missile
- Hazard Assessment Test Program
- Test methodologies
- Summary of results
- Lessons-learned

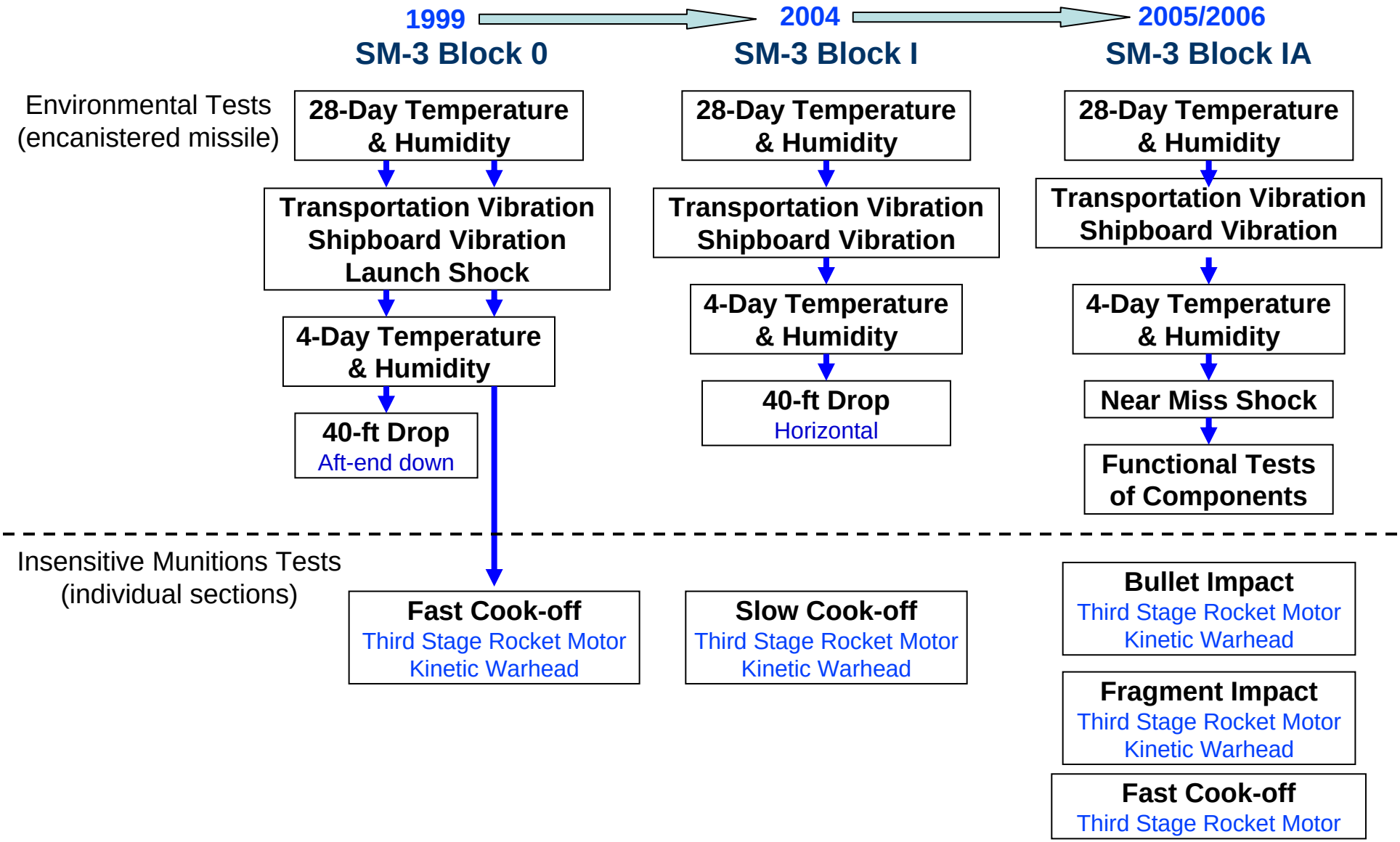
SM-3 Block IA Missile

- 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



Hazard Assessment Testing of the SM-3 Block IA Missile

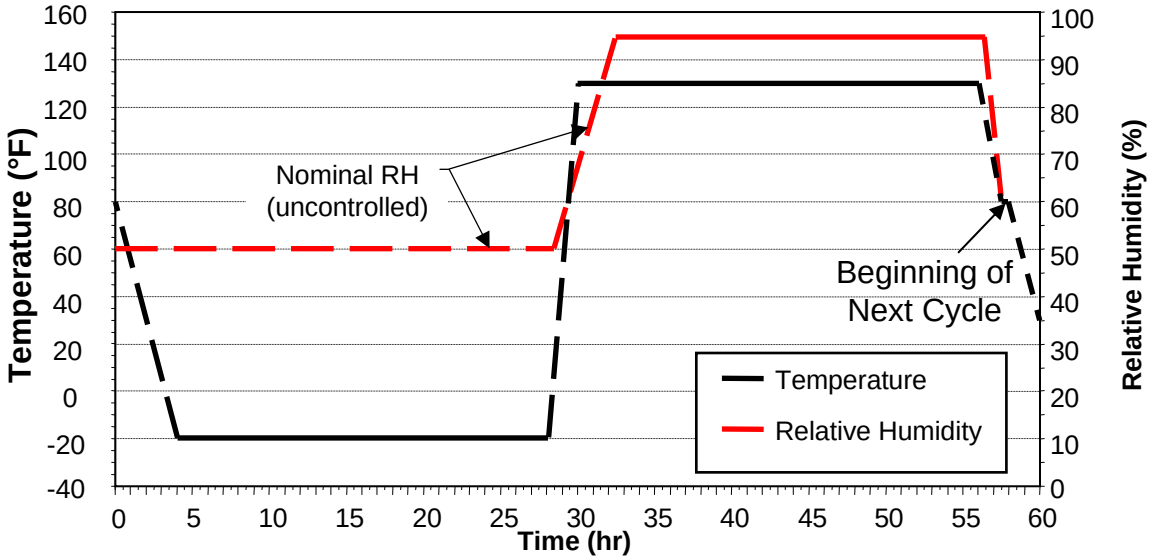
Hazard Assessment Test Program for SM-3



28-Day / 4-Day Temperature and Humidity (T&H) Test Method

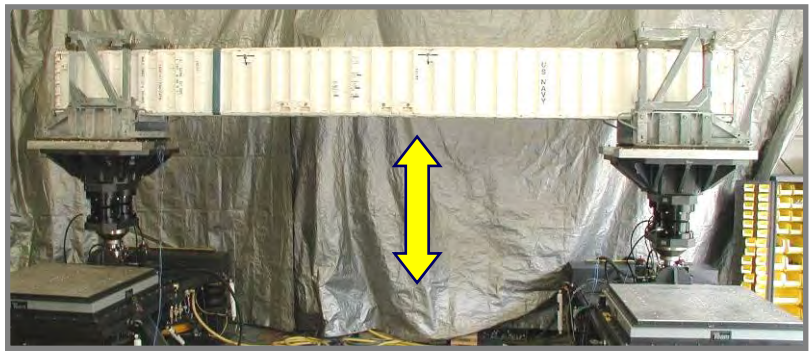
- Encanistered missile cycled between hot/humid and cold environments
  - Conditions based on environmental profile for logistics life-cycle
    - +130F with 95% RH for hot/humid environment
    - -20F for cold environment
  - 1 cycle includes 24-hr (min) exposure to each environment
- Tests conducted using programmable environmental chamber
- Test methods identical except for duration
  - 14 cycles for 28-day T&H; 2 cycles for 4-day T&H



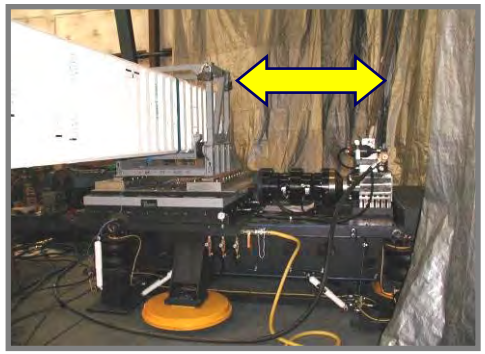


Transportation Vibration Test Method

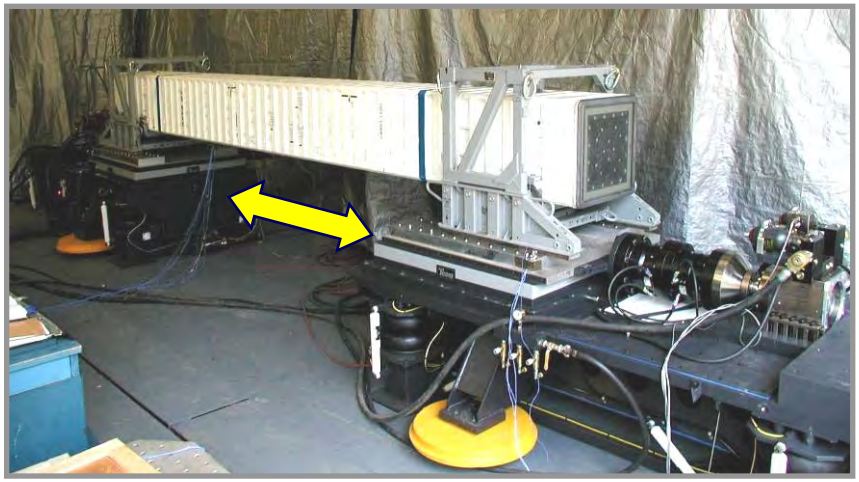
- Encanistered missile subjected to random vibration IAW MIL-STD-810
  - Simulate transportation by truck over improved roads
  - Input applied through 3 orthogonal axes; 1 axis at a time
  - 3 hr/axis duration to simulate 3000 miles over-the-road transport
- 2 hydraulic actuators used to provide input at each PHS&T skid



Vertical Axis

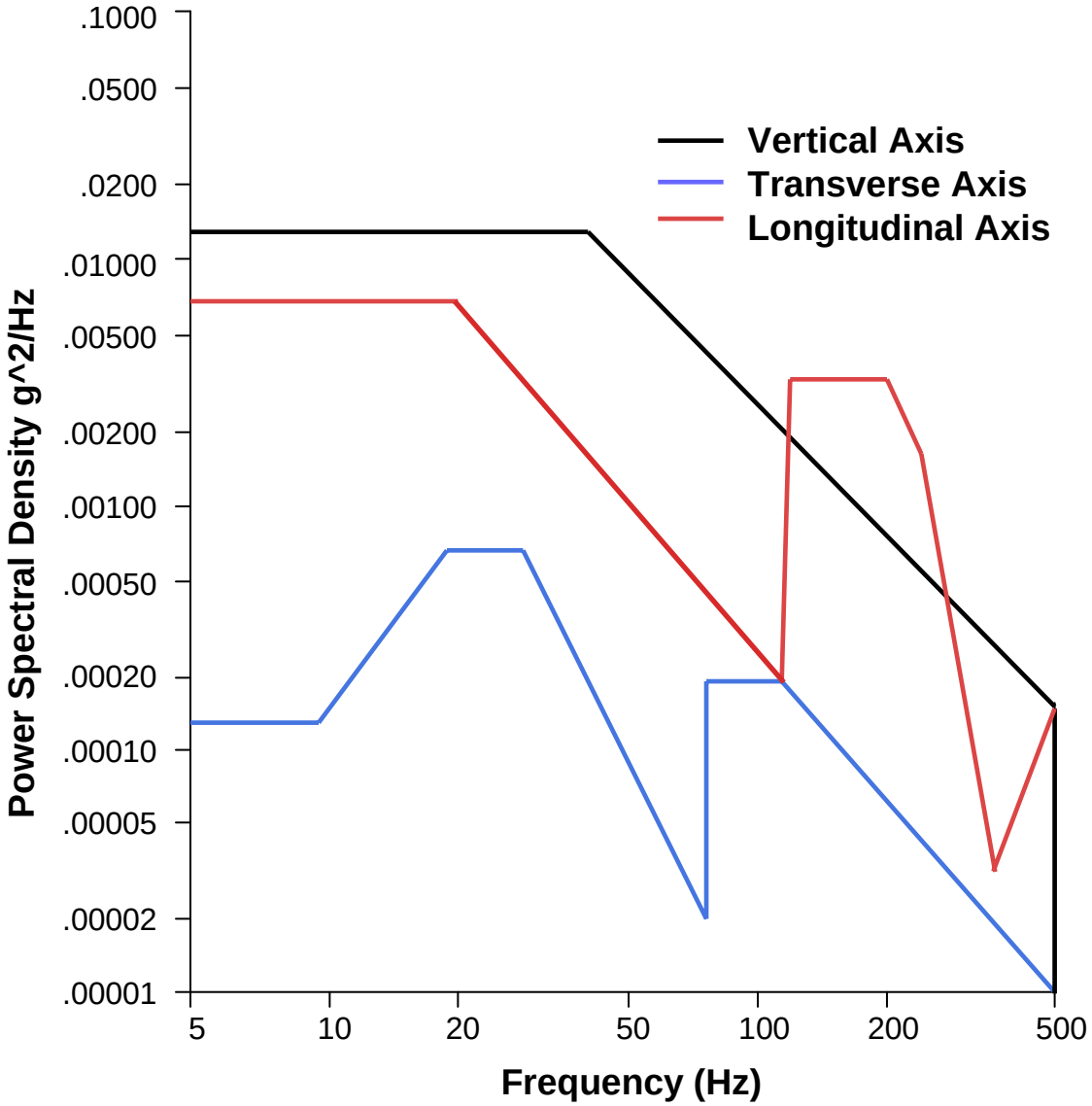


Transverse Axis



Longitudinal Axis

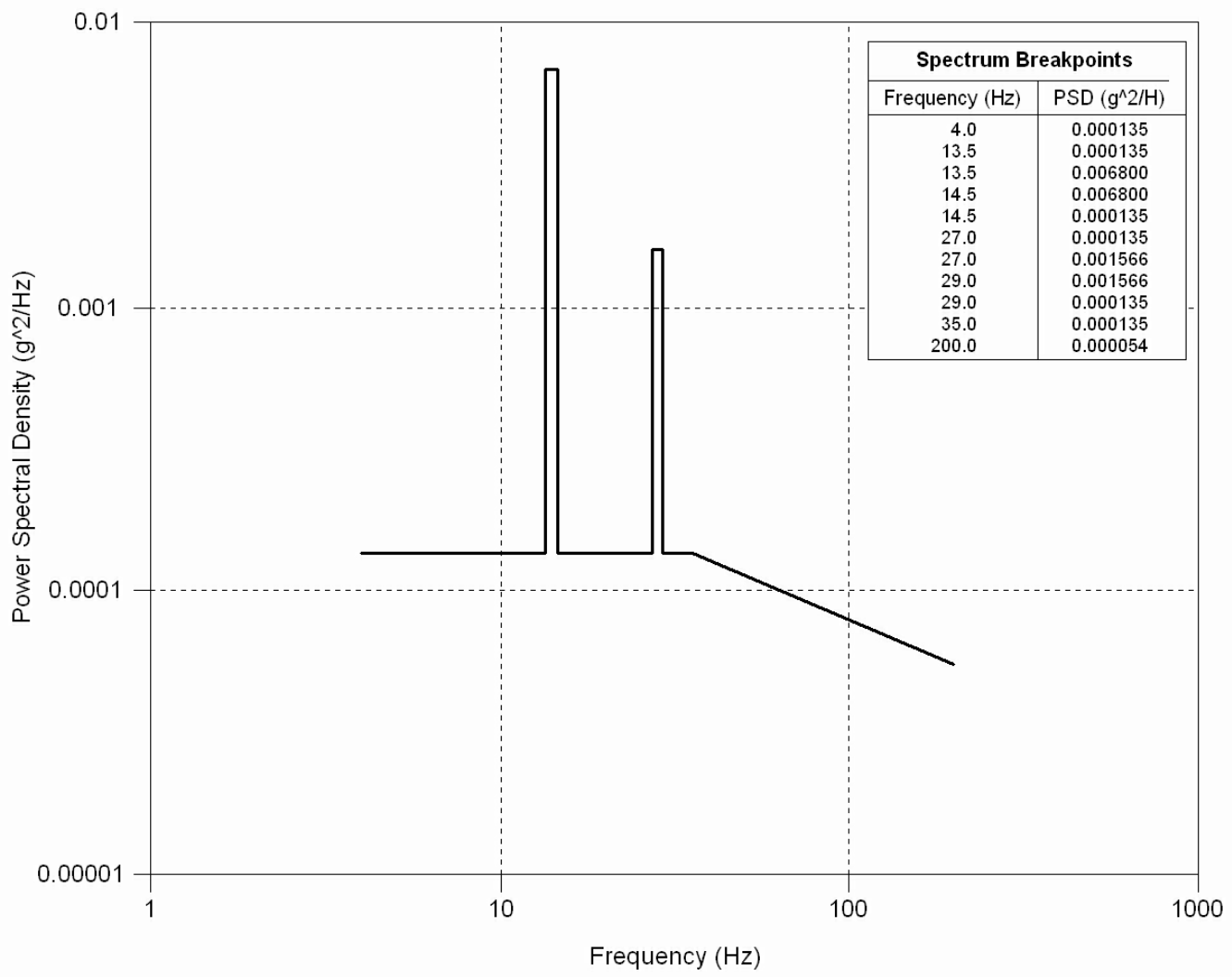
Transportation Vibration Input Profile



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

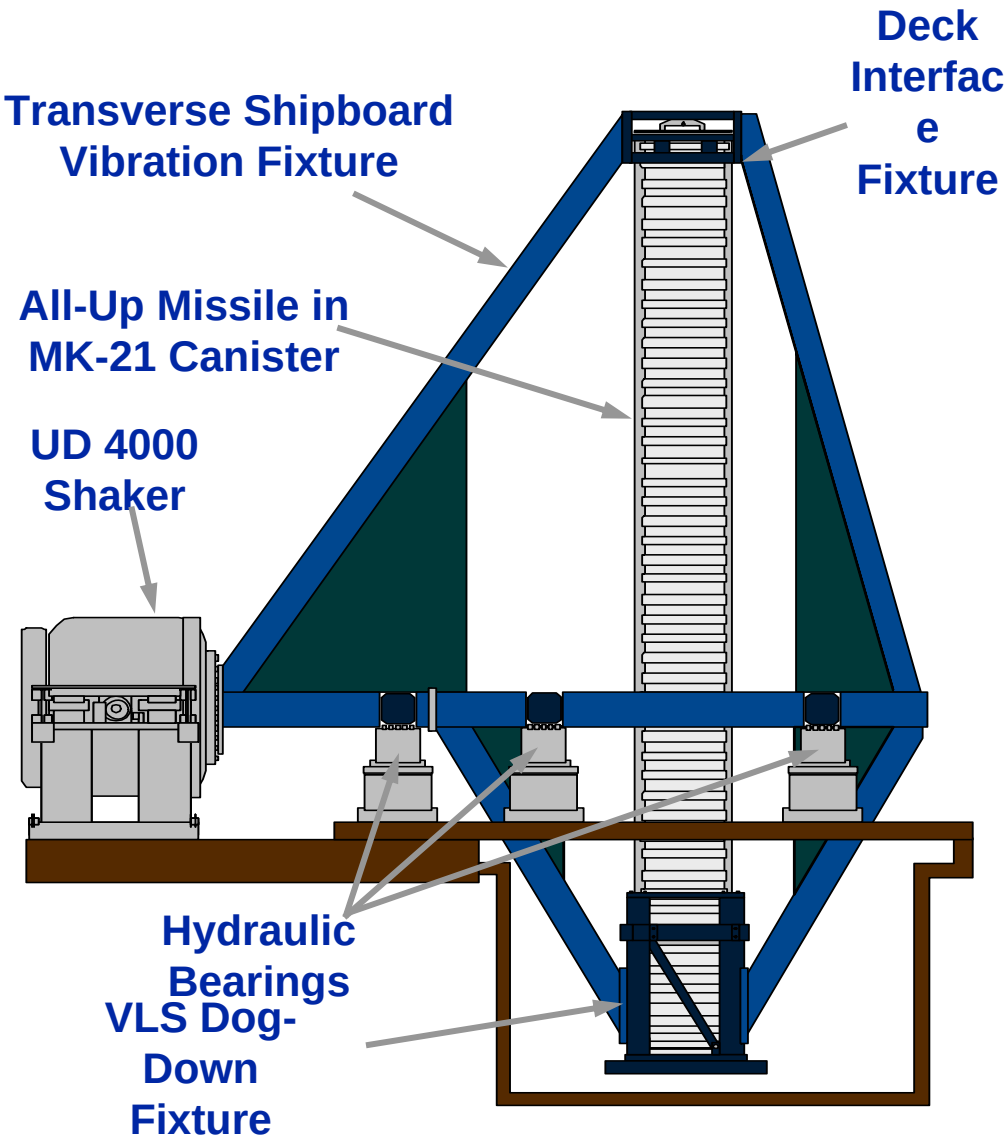


Spectrum Breakpoints

Frequency (Hz)	PSD (g^2/H)
4.0	0.000135
13.5	0.000135
13.5	0.006800
14.5	0.006800
14.5	0.000135
27.0	0.000135
27.0	0.001566
29.0	0.001566
29.0	0.000135
35.0	0.000135
200.0	0.000054

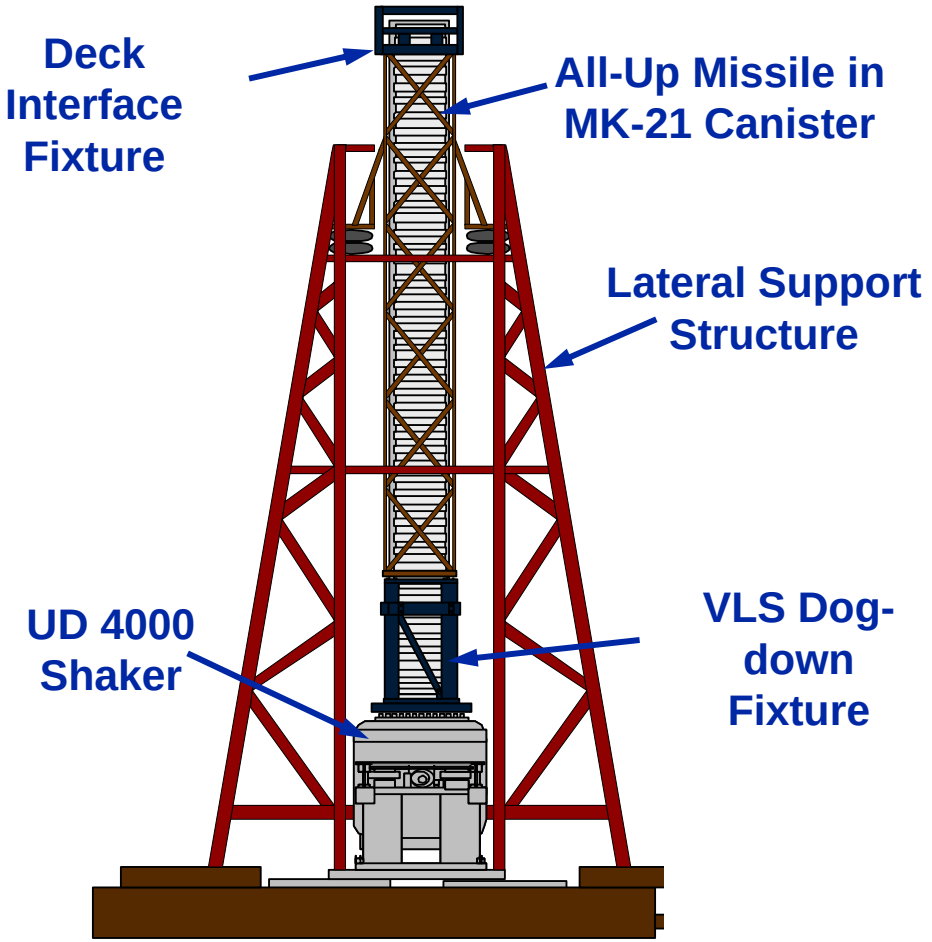
Shipboard Vibration Test Setup (Transverse Axis)





Shipboard Vibration Test Setup (Longitudinal Axis)

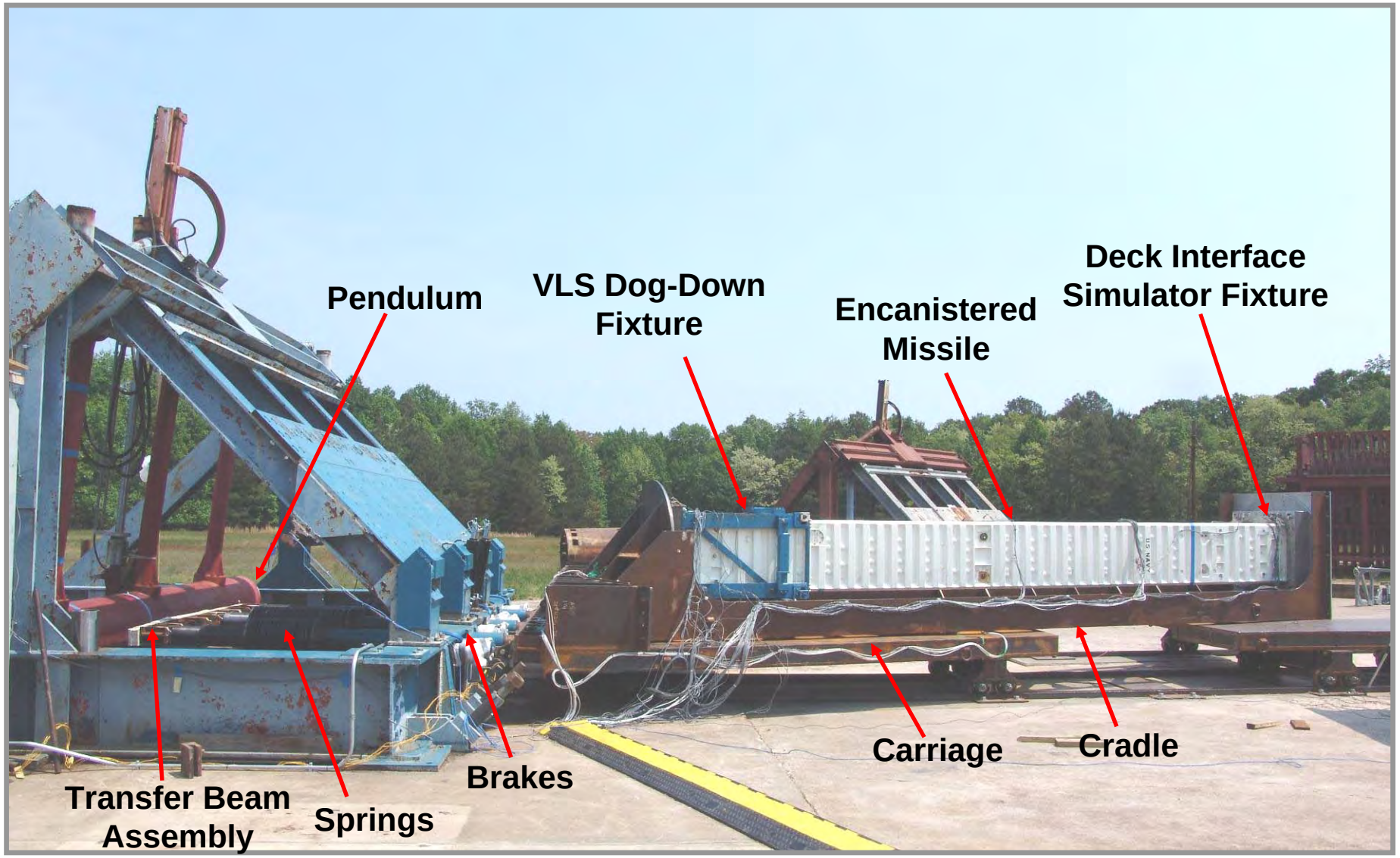




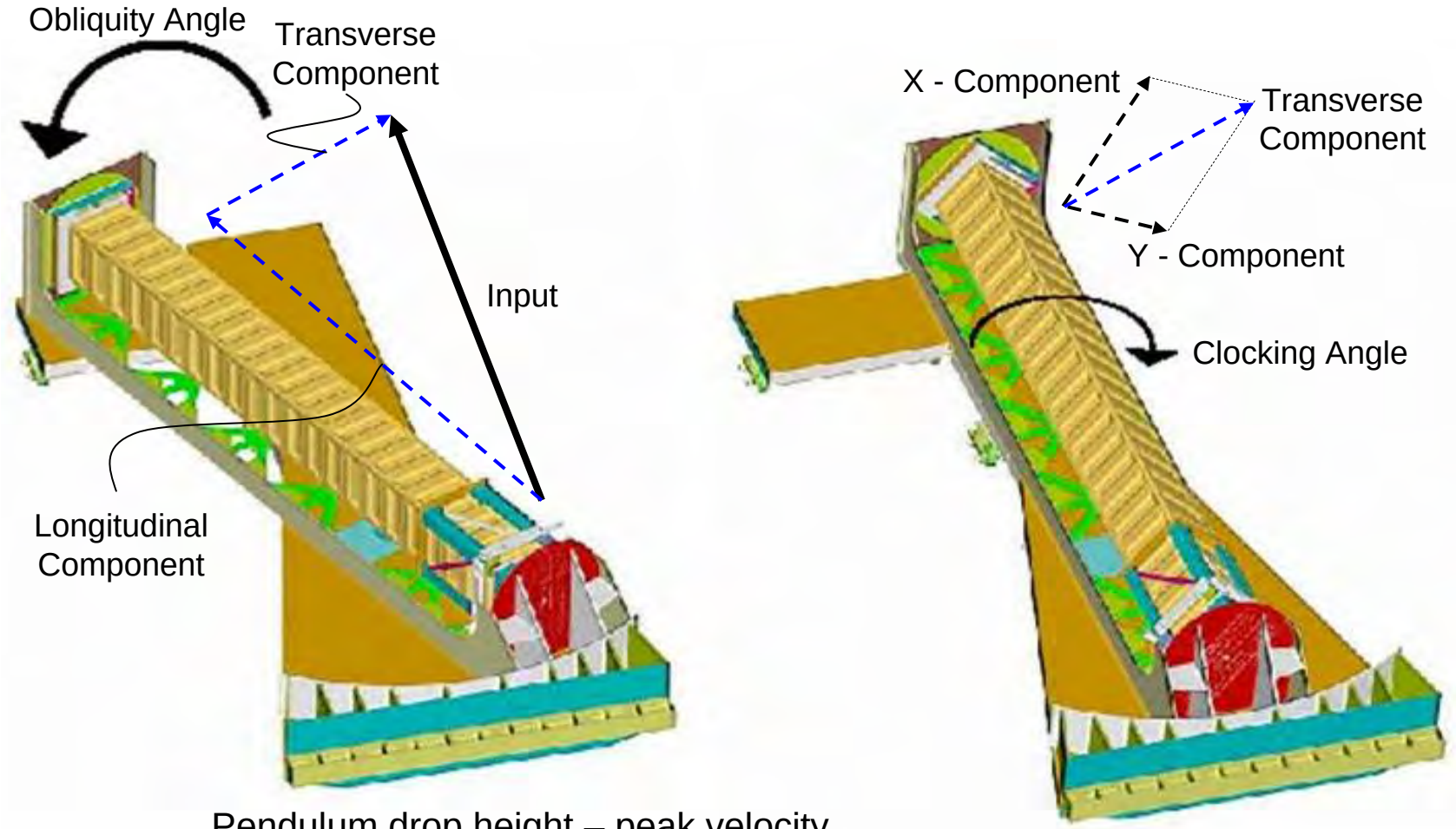
Near Miss Shock Test Method

- 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

Near Miss Shock Test Setup

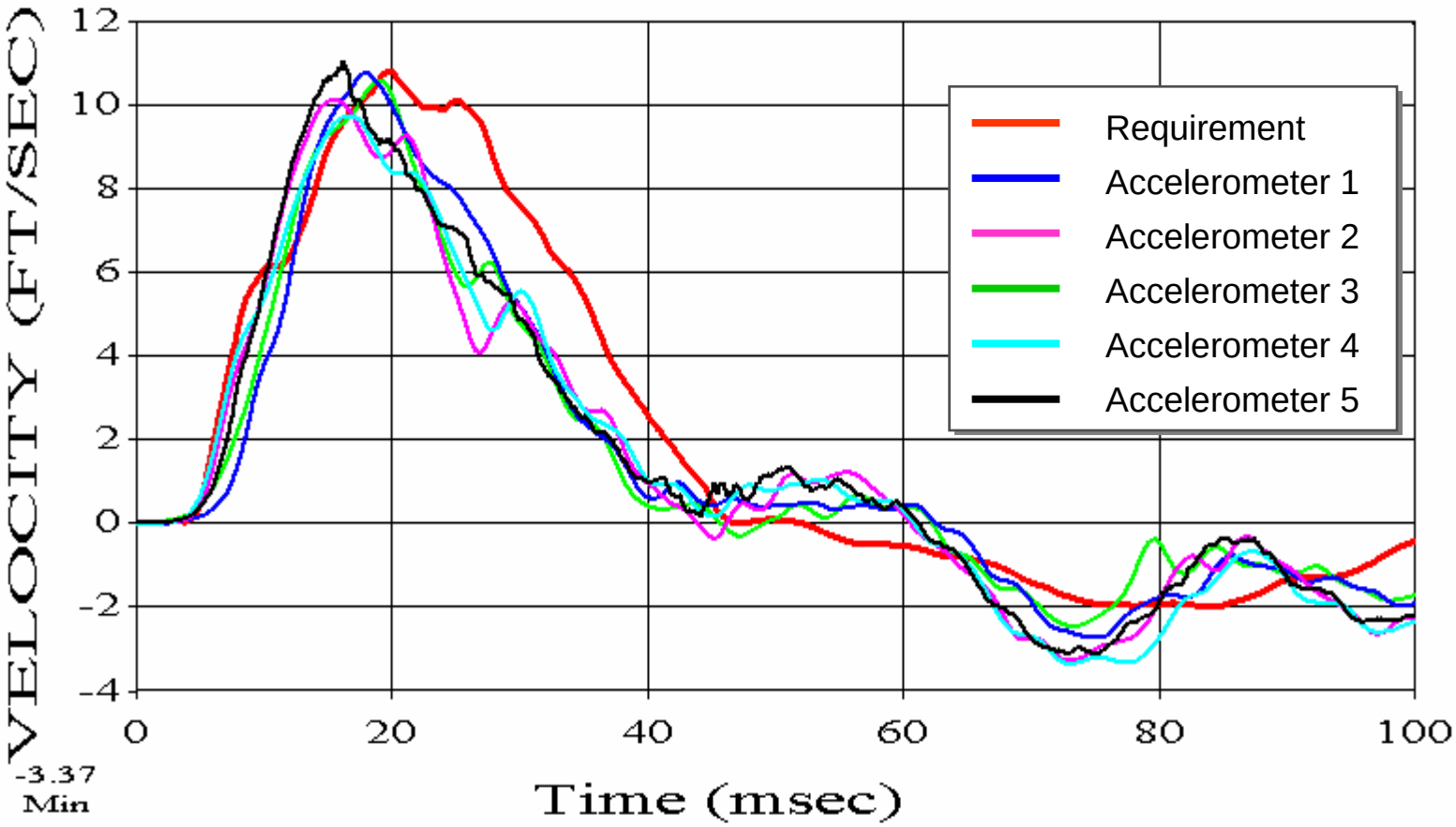


Tuning of Input for Near Miss Shock Test

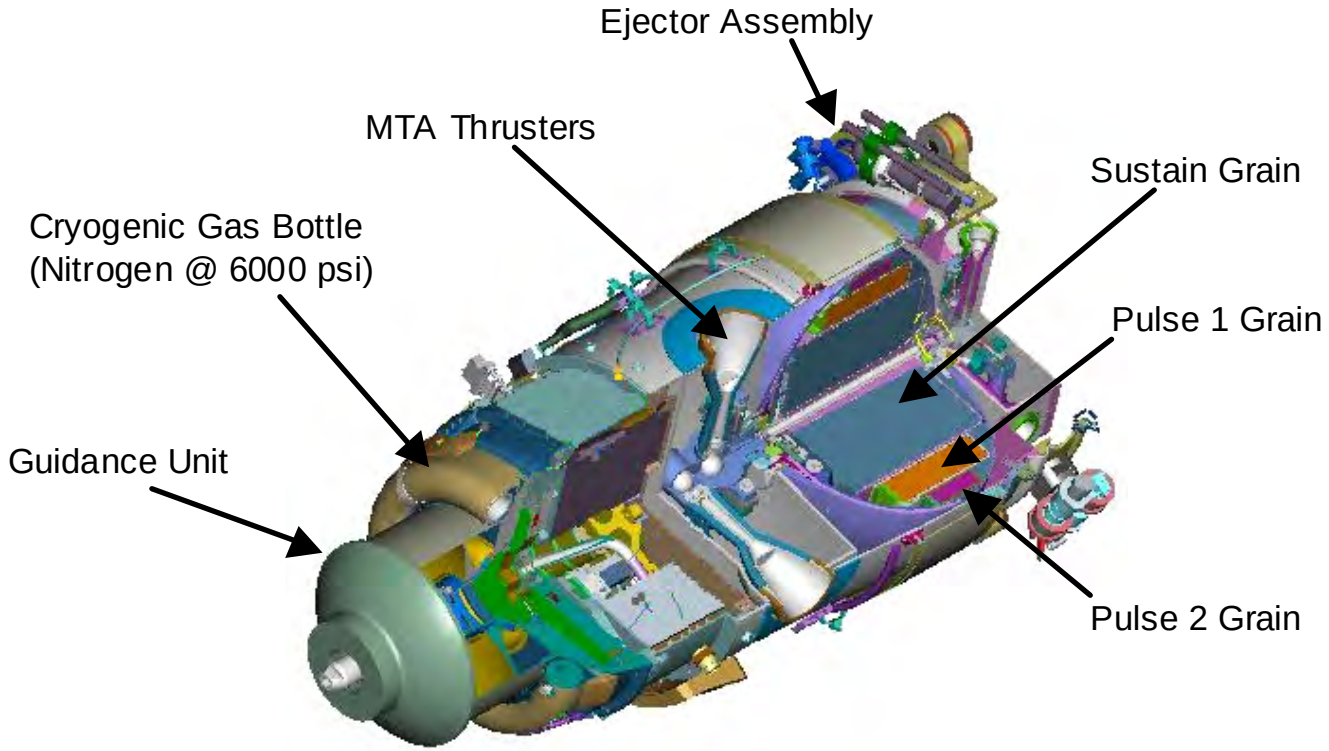


Pendulum drop height – peak velocity
Programmer pad thickness – initial acceleration
Brakes & Springs – initial pulse duration; magnitude of neg. velocity
Obliquity/clocking – Longitudinal and Transverse components

Representative Response Data

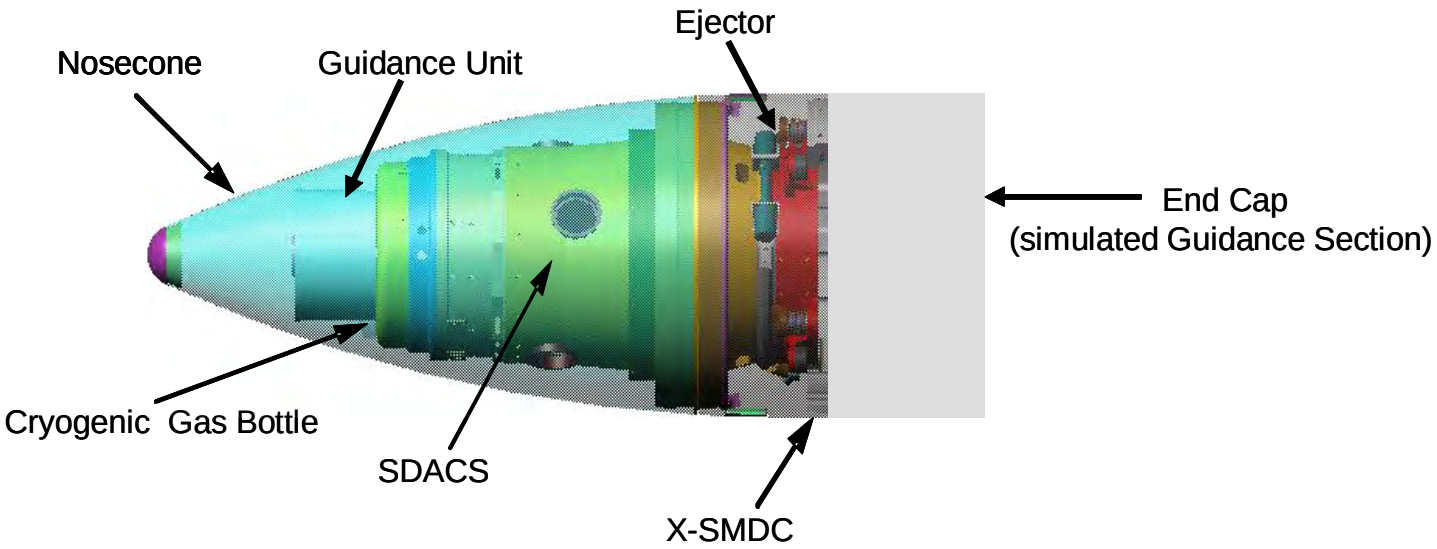


Configuration of Kinetic Warhead



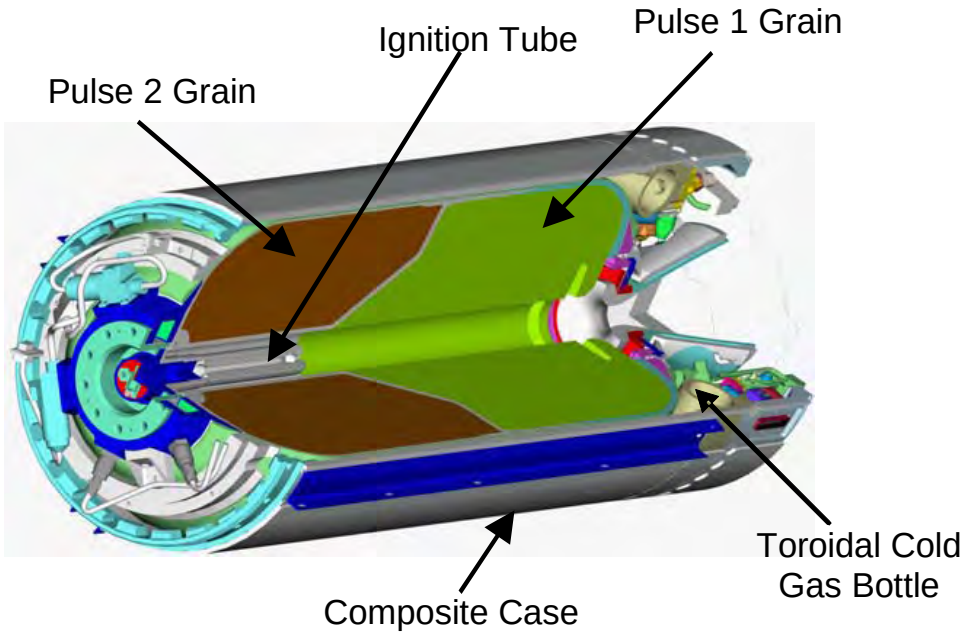
- 3 propellant grains in Solid Divert and Attitude Control System (SDACS)
  - Pulse I grain is TP-H-3510 propellant
  - Pulse 2 grain is TP-H-3511 propellant
  - Sustain grain is TP-H-3512 propellant
- SDACS case is graphite-epoxy composite

Configuration of Kinetic Warhead for Insensitive Munitions Tests



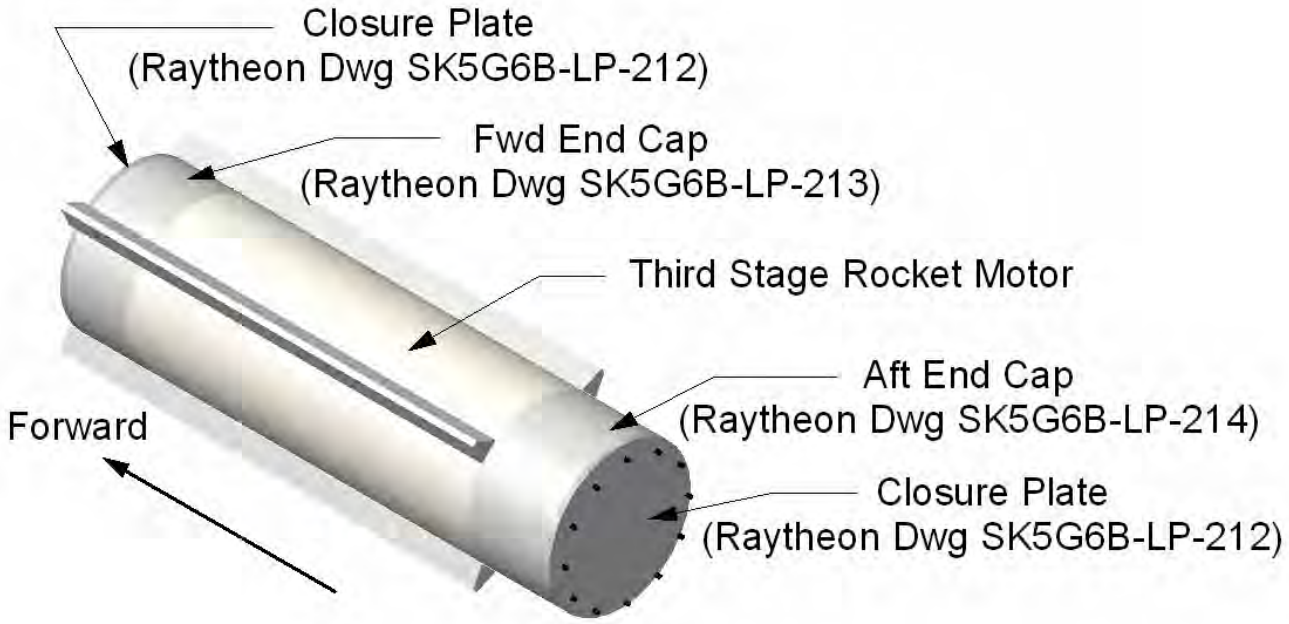
- Kinetic Warhead assembled to simulated Guidance Section shroud
  - 13.625-in OD annular aluminum cylinder with ½-in thick aluminum closure plate
  - Guidance Unit simulated using high-fidelity mass model
  - Cryogenic gas bottle present and fully-charged
- Block IA Nosecone installed over Kinetic Warhead
  - Secured to simulated Guidance Section shroud in same manner as tactical missile
  - All Nosecone explosive components present

General Configuration of Third Stage Rocket Motor



- 2 propellant grains
  - Pulse I 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

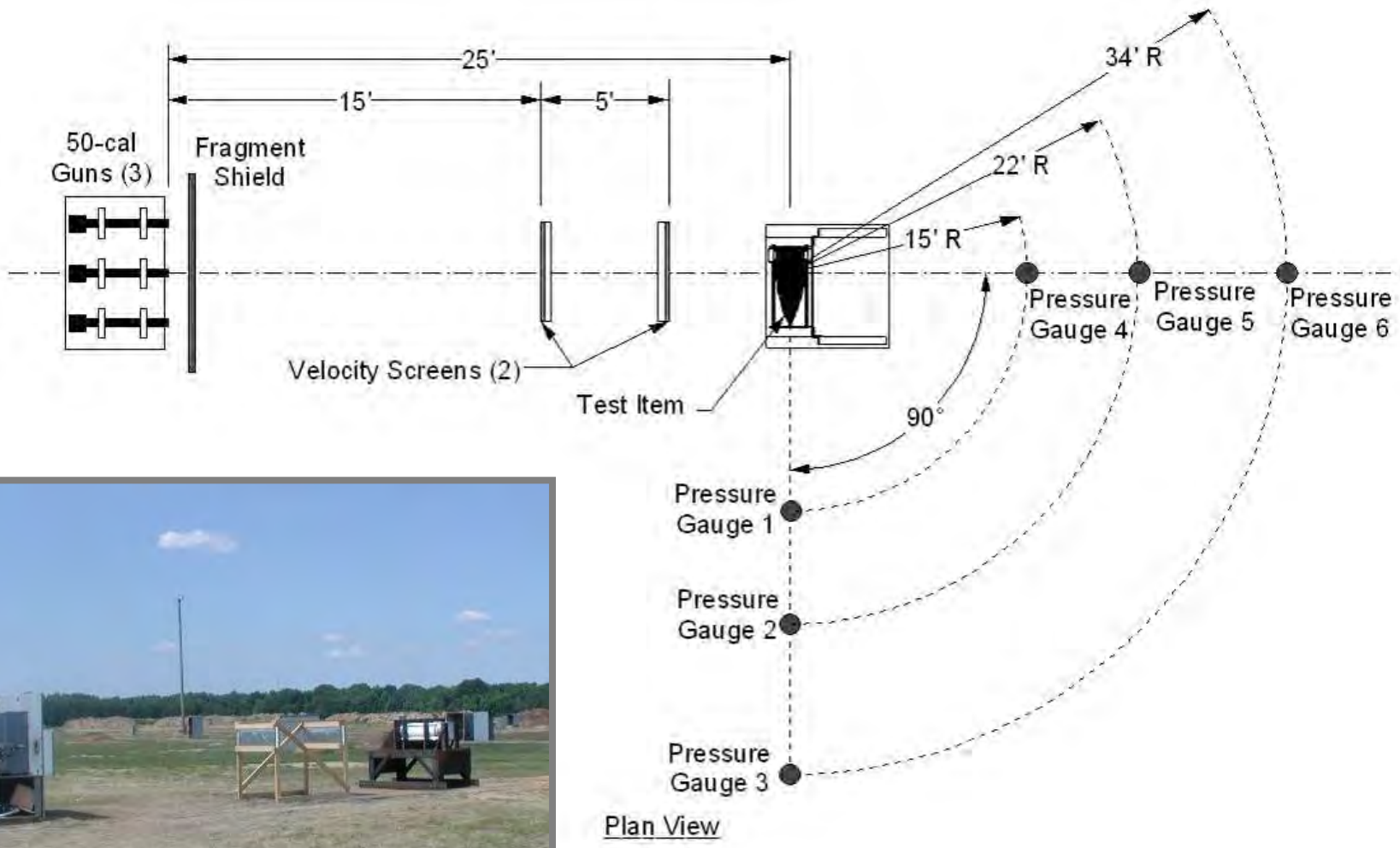


- TSRM assembled with end caps to simulate adjoining missile sections
  - Each end cap is 13.72-in OD annular aluminum cylinder with ½-in thick closure plate
  - Aft end cap secured using 4 explosive bolts
    - Replicate configuration of tactical missile

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



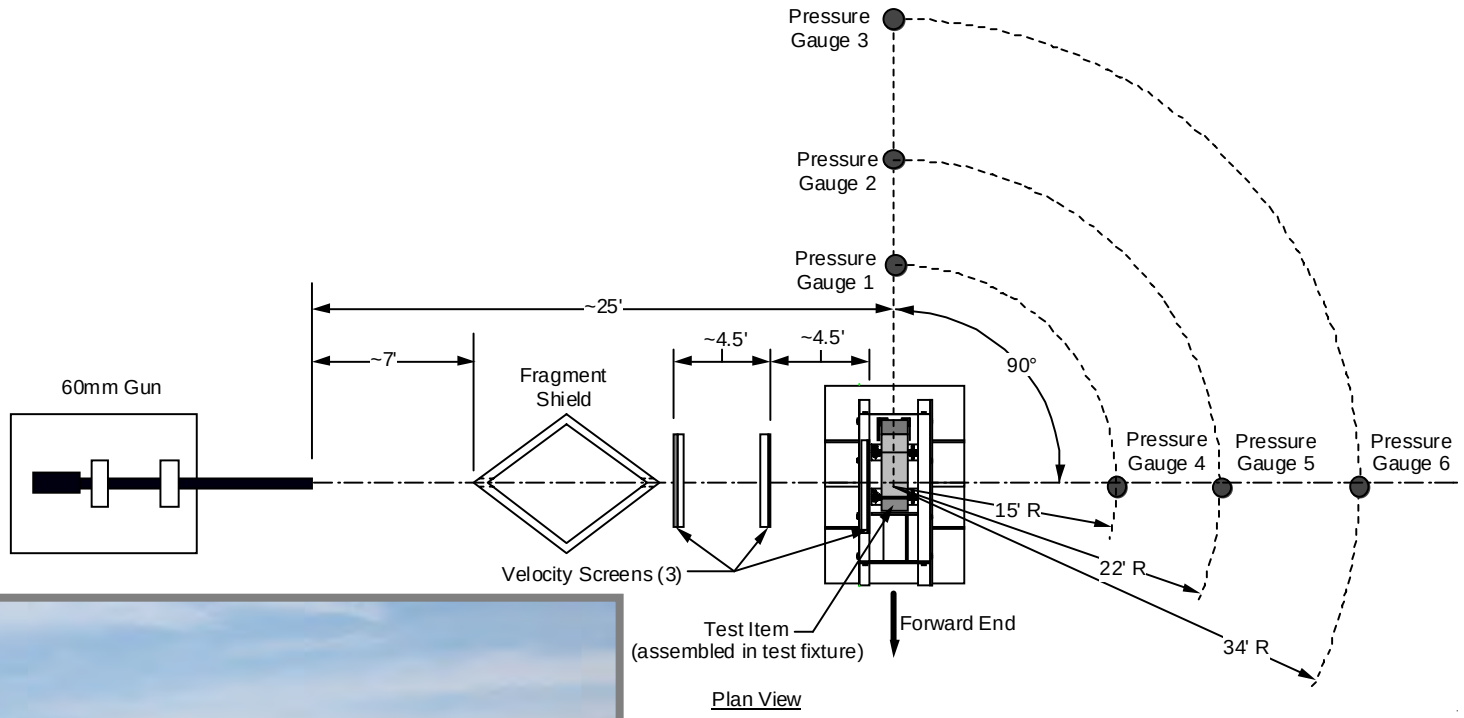


Fragment Impact Test Method

- 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

Fragment Impact Test Setup





Plan View

Fast Cook-Off Test Method

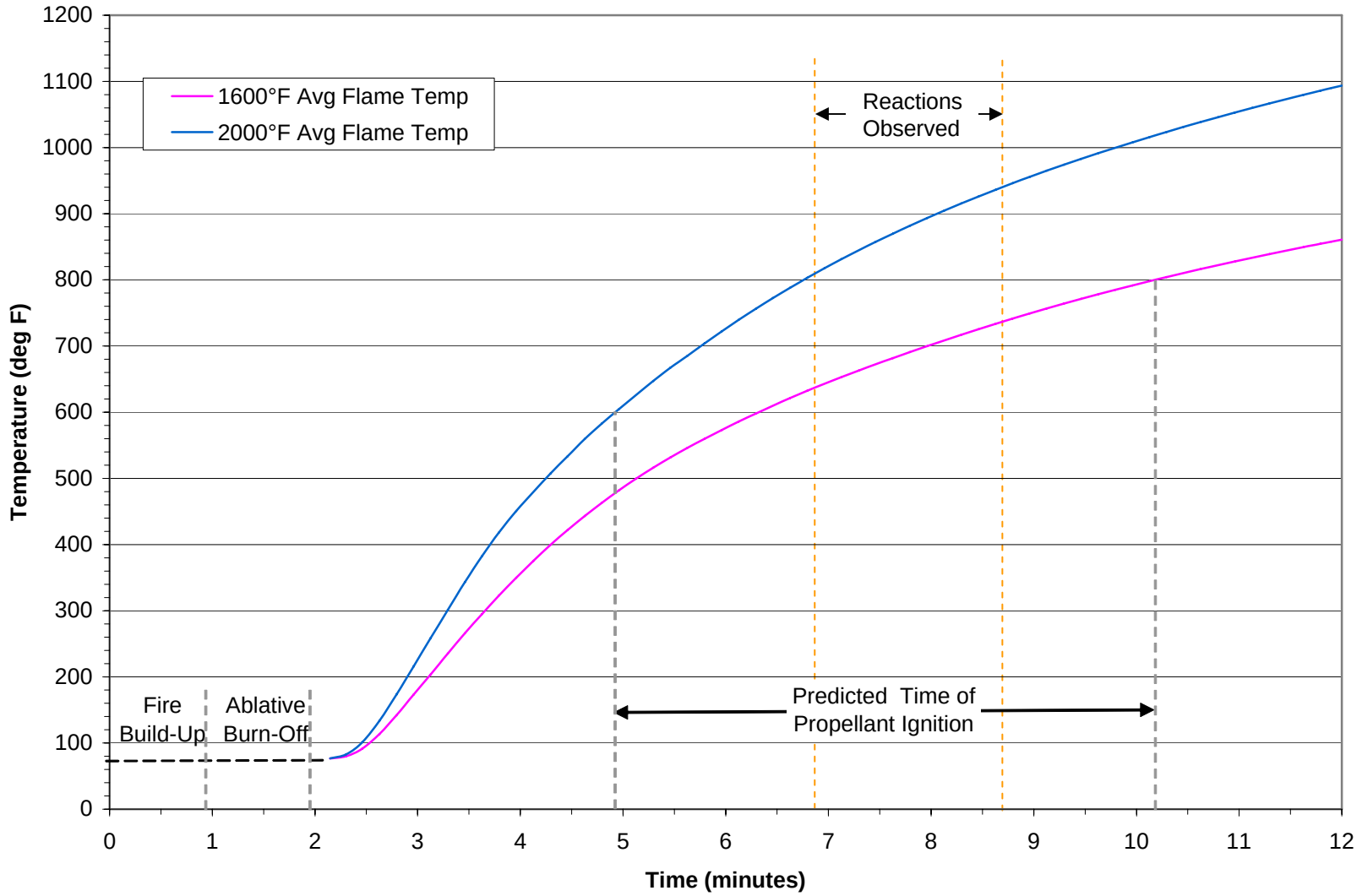
- Item suspended above pool of burning JP-5 aviation fuel
  - Average flame temperature >1600F
  - 30-ft x 30-ft fuel basin used to ensure complete immersion within flame
- Instrumentation and data collection IAW MIL-STD-2105B
  - Flame temperature
  - Air shock
  - Video record of events
  - Post-test 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

Fast Cook-Off Test Setup





Predicted Temperature at Liner/Propellant Interface During TSRM Fast Cook-Off



Summary of Test Results

Test	Result
28-Day Temperature & Humidity	No safety-related anomalies
Transportation Vibration	No safety-related anomalies
Shipboard Vibration	No safety-related anomalies
4-Day Temperature & Humidity	No safety-related anomalies
Near Miss Shock	No safety-related anomalies
Bullet Impact	Kinetic Warhead: Type IV reaction (deflagration) Third Stage Rocket Motor: Type III reaction (explosion)
Fragment Impact	Kinetic Warhead: Type IV reaction (deflagration) Third Stage Rocket Motor: Type III reaction (explosion)
Fast Cook-Off	Third Stage Rocket Motor: Type IV reaction (deflagration)

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

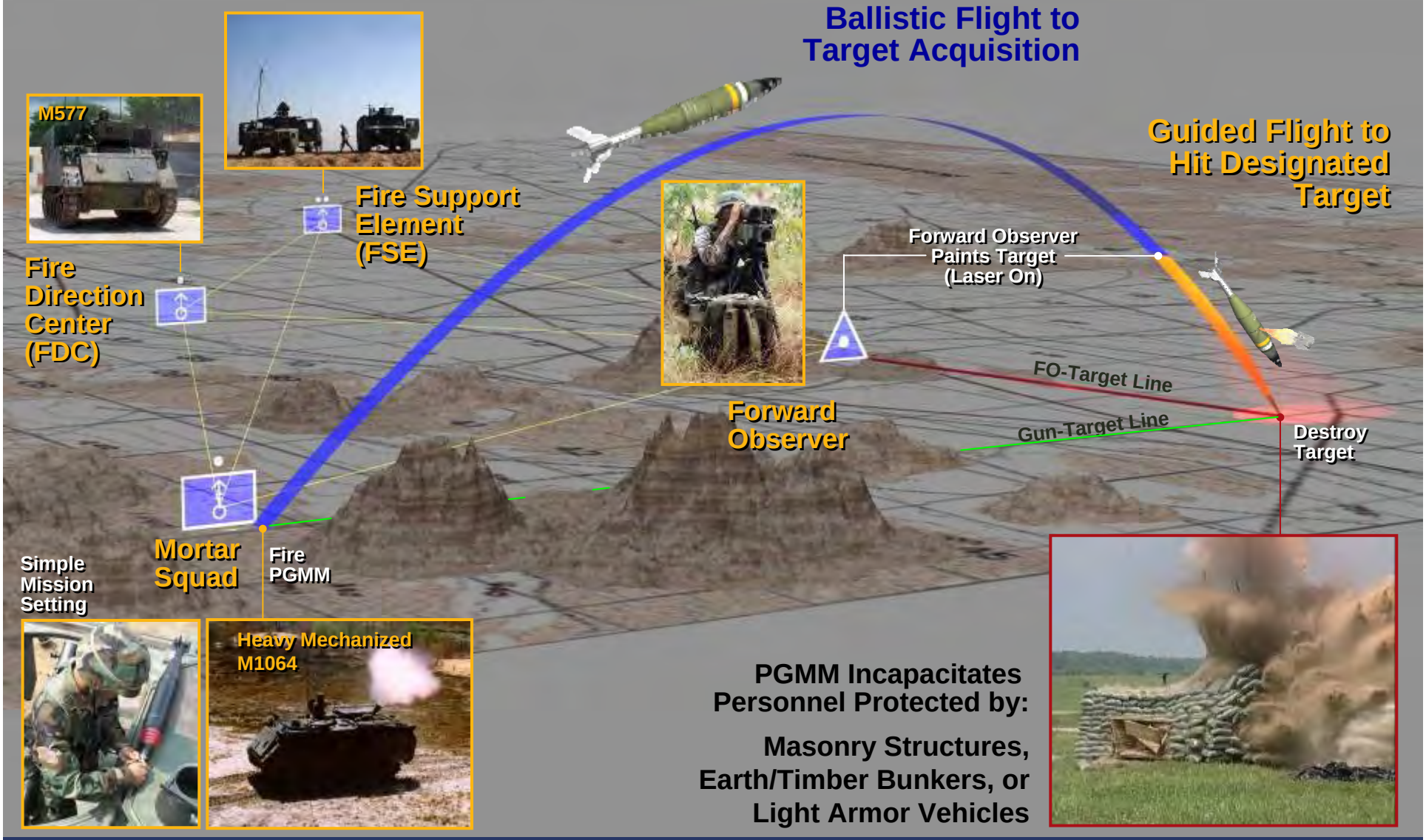
XM395 PGMM

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

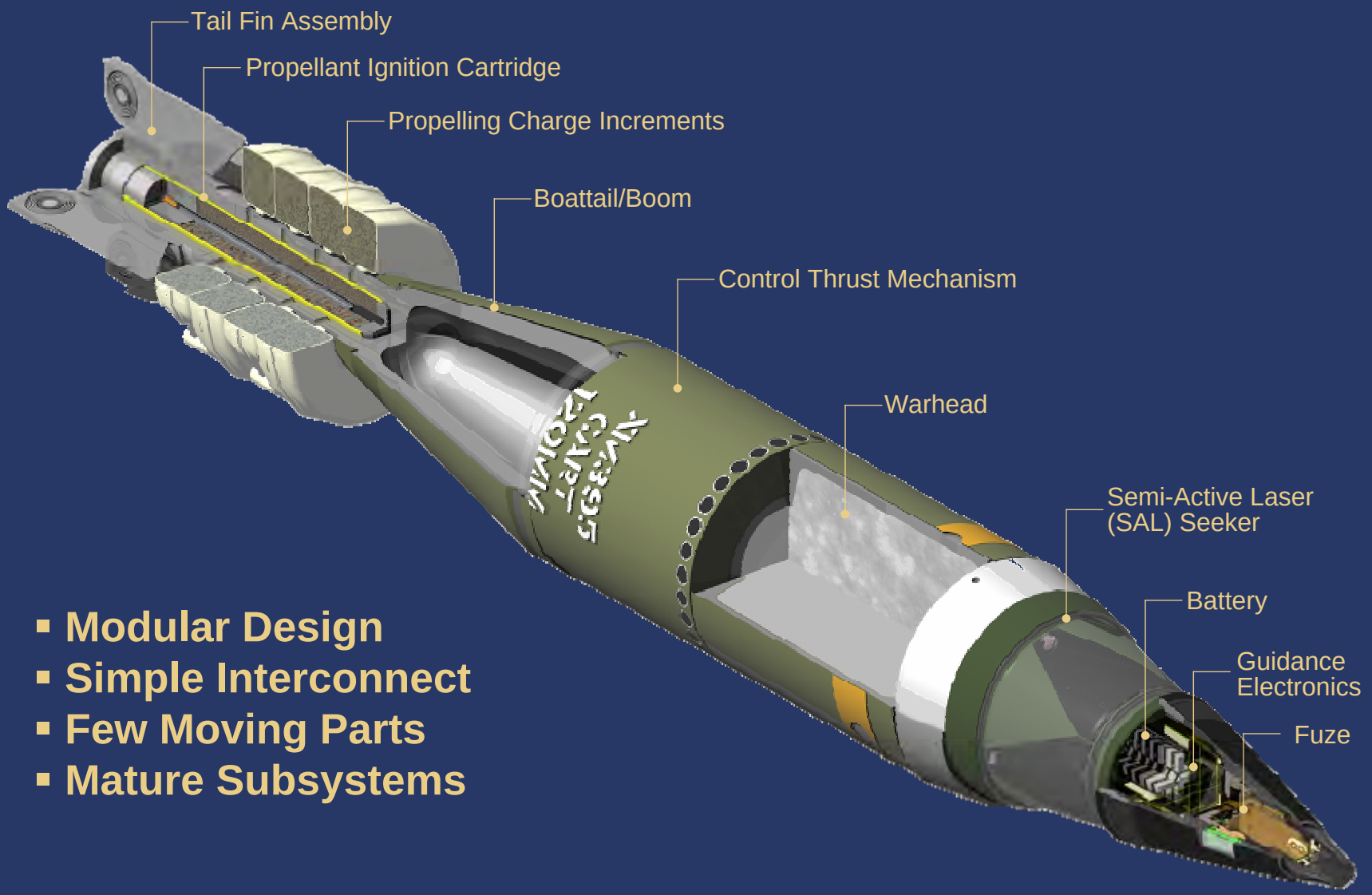
PGMM Operational Elements



PGMM Incapacitates Personnel Protected by:

Masonry Structures, Earth/Timber Bunkers, or Light Armor Vehicles

PGMM Cartridge – Simple, Rugged, and Precise

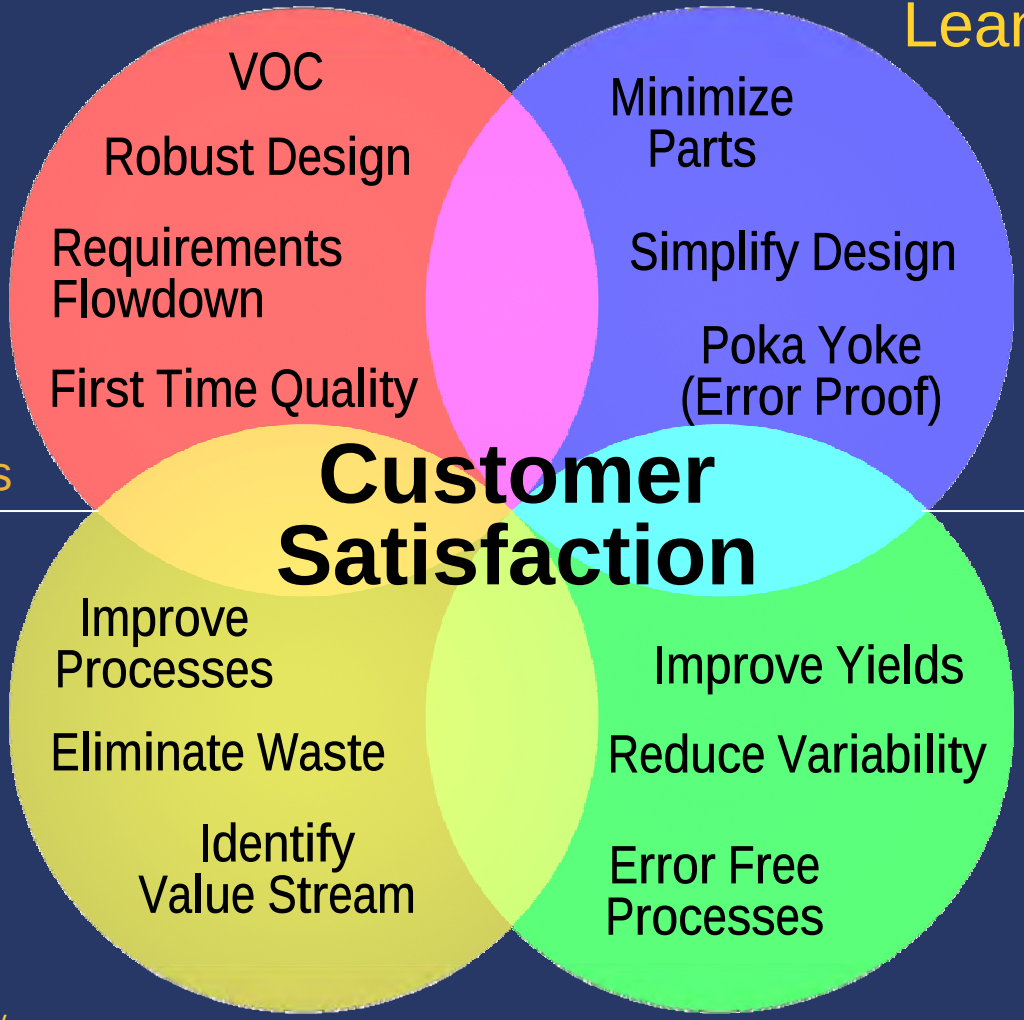


- **Modular Design**
- **Simple Interconnect**
- **Few Moving Parts**
- **Mature Subsystems**

Six Sigma & Lean Enterprise Model for PGMM

DFSS, CDOV

Lean Design,™ DFA



Improve Effectiveness

Avoid Problems

Customer Satisfaction

Improve Efficiency

Fix Problems

Lean Manufacture

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

Project Objectives

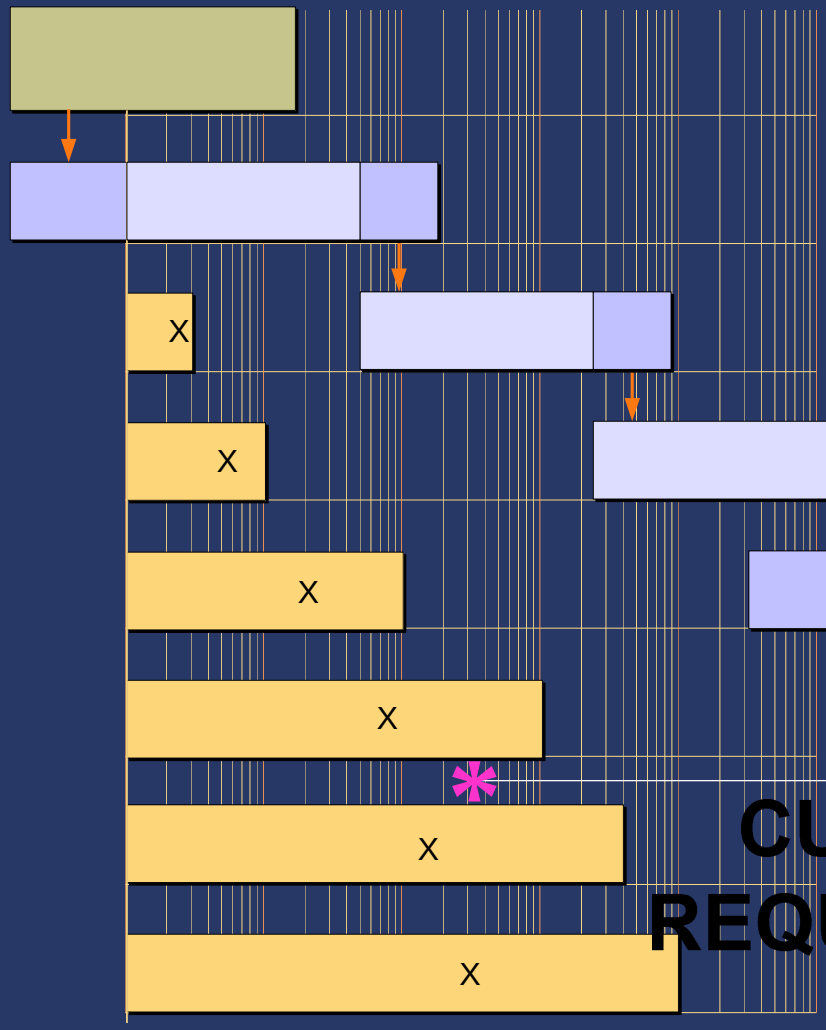


Objectives

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)

DFSS Tool	Status	ATK Technical Excellence Standard
Stakeholder Analysis	Complete	2. Data Based Decision Making
Operational Crosswalk	Complete	3. Consideration of System-Level Issues and Interactions
Requirements Development and Mgmt	Complete	1. Requirements Defined and Tracked
QFD (Quality Functional Deployment)	Complete	3. Consideration of System-Level Issues and Interactions
FMEA (Failure Modes Effects Analysis)	Complete	3. Consideration of System-Level Issues and Interactions
System-Wide Defects Tracking	Complete	2. Data Based Decision Making
Producibility Scorecard	Complete	7. World Class Process Control at ATK and our Suppliers

Traditional Approach to Product Development



- 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

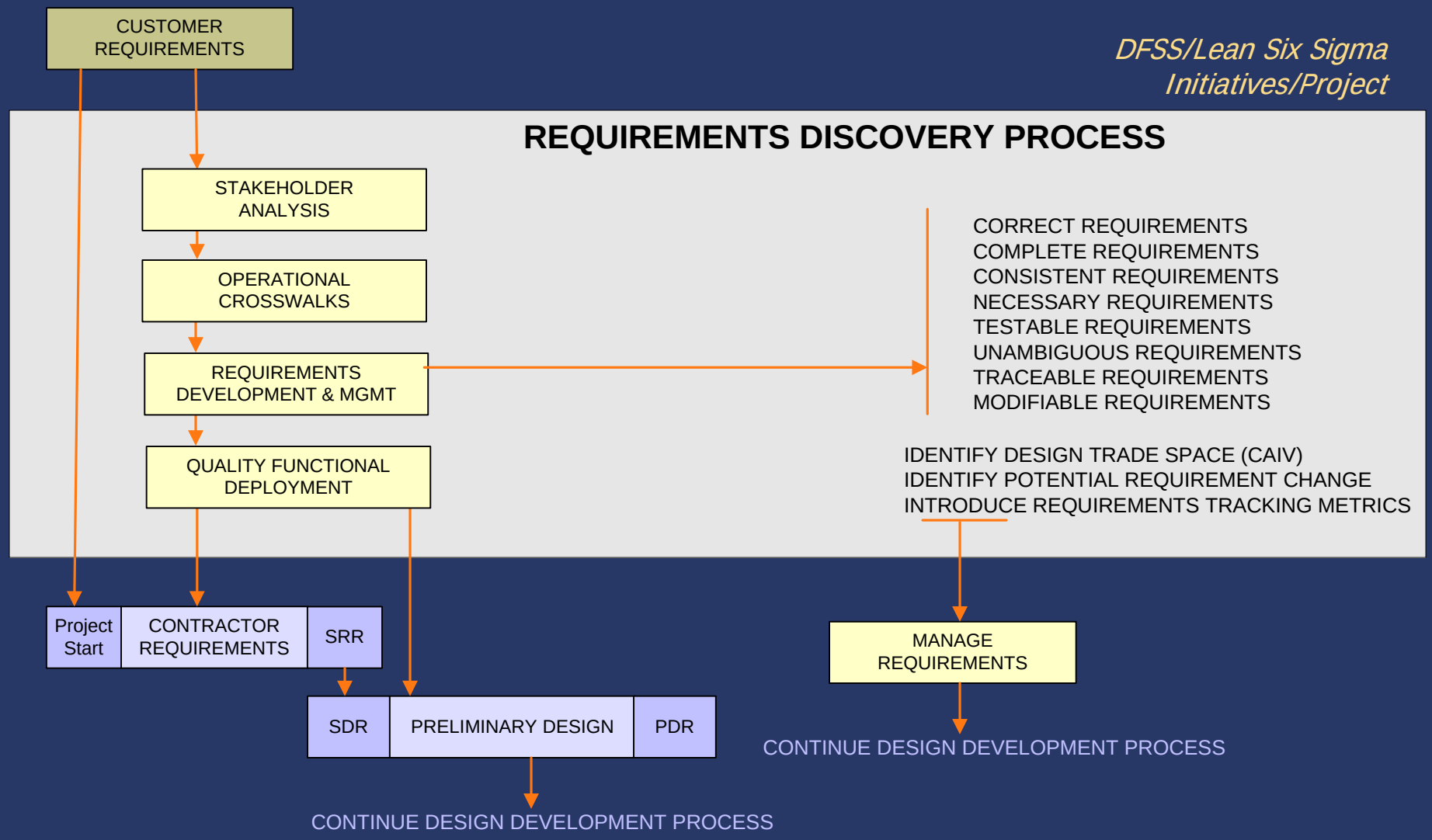
Design for Competitiveness, Advance copy by Bart Huthwaite

1

Project

CONTRACTOR

New Approach to Product Development



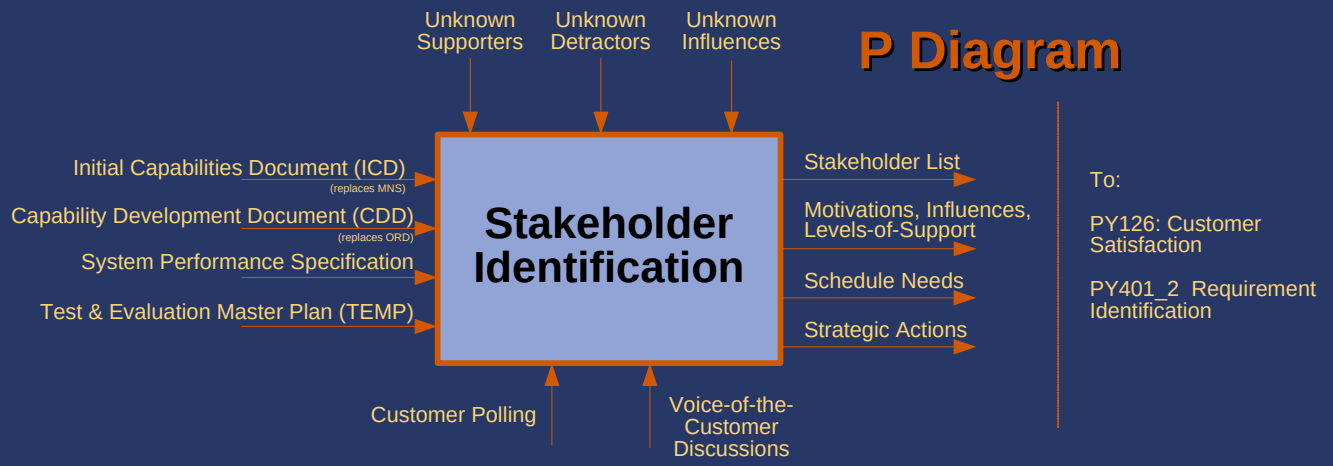
ATK Technical Standard

Requirements Defined and Tracked

Stakeholder Analysis



P Diagram



Database Information	Database Example
Interest Category	Seeker Subsystem
Organization	US Industry
Stakeholder	BAE Systems
Location	Nashua, NH
Role	SAL Seeker Supplier
Motivation	Expand SAL Seeker Product Base
Level of Support [+3 For, -3 Against]	3
Level of Influence [+5 High, +1 Low]	2
Stakeholder Effect	6
Strategic Action	- -

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



Requirements Development and Management

CUSTOMER REQUIREMENTS

DFSS/Lean Six Sigma Initiatives/Project

REQUIREMENTS DISCOVERY PROCESS

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

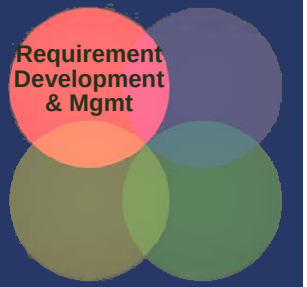
Project Start | CONTRACTOR REQUIREMENTS | SRR

SDR | PRELIMINARY DESIGN | PDR

CONTINUE DESIGN DEVELOPMENT PROCESS

MANAGE REQUIREMENTS

CONTINUE DESIGN DEVELOPMENT PROCESS



ATK Technical Standard

Requirements Defined and Tracked

Performance Requirements Walkthrough

Requirements Walkthough

Consolidated Walkthrough Review

3.3.5.2 KPP 2 - Lethality

Verbatim from Customer Performance Specification

REFERENCE: System Performance Specification Draft 31-Jan-03

OWNER: USAIC

DESCRIPTION:

3.3.5.2 KPP 2 – Lethality. The XM395 cartridge SHALL have the ability to incapacitate or fractionally casualtize personnel protected within and by point…

EVALUATION:

X	INCOMPLETE		INFEASIBLE		UNTESTABLE
	INCONSISTENT		UNMODIFIABLE		UNTRACEABLE
	INCORRECT		UNNECESSARY		AMBIGUOUS

CROSS-REFERENCE: CTP 9. Draft ORD Para. 4.1.1.1.1, 4.1.1.1.2

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?

PRIORITY:

9	MISSION/SAFETY CRITICAL	X	NON-NEGOTIABLE	X	UNLIKELY TO CHANGE
	USEFUL		NEGOTIABLE (CAIV)		MAY CHANGE
	DESIRABLE		FLEXIBLE		MOST LIKELY TO CHANGE

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)?

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…

Verbatim from Customer Performance Specification

SUPPORTING ANALYSIS:

Note: Since we are verifying performance through modeling, we are most interested in validating our models. Further discussion needed.

Performance Requirements Walkthrough

Requirements Walkthough

Consolidated Walkthrough Review

3.3.5.2 KPP 2 - Lethality

Information Capture Directly from Customer

Information Capture Directly from Customer

REFERENCE: System Performance Specification Draft 31-Jan-03	OWNER: USAIC
DESCRIPTION: 3.3.5.2 KPP 2 – Lethality. The XM395 cartridge SHALL have the ability to incapacitate or fractionally casualtize personnel protected within and by point…	EVALUATION: [X] INCOMPLETE [ ] INFEASIBLE [ ] UNTESTABLE [ ] INCONSISTENT [ ] UNMODIFIABLE [ ] UNTRACEABLE [ ] INCORRECT [ ] UNNECESSARY [ ] AMBIGUOUS
CROSS-REFERENCE: CTP 9. Draft ORD Para. 4.1.1.1.1, 4.1.1.1.2	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?
[9] MISSION/SAFETY CRITICAL [X] NON-NEGOTIABLE [X] UNLIKELY TO CHANGE [ ] USEFUL [ ] NEGOTIABLE (CAIV) [ ] MAY CHANGE [ ] DESIRABLE [ ] FLEXIBLE [ ] MOST LIKELY TO CHANGE	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)?
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…
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Performance Requirements Walkthrough

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	INCORRECT		UNNECESSARY		AMBIGUOUS

Feedback To Customer From Contractor

CROSS-REFERENCE: CTP 9. Draft ORD Para. 4.1.1.1.1, 4.1.1.1.2

PRIORITY:

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Notes to Formulate Action Plan

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:

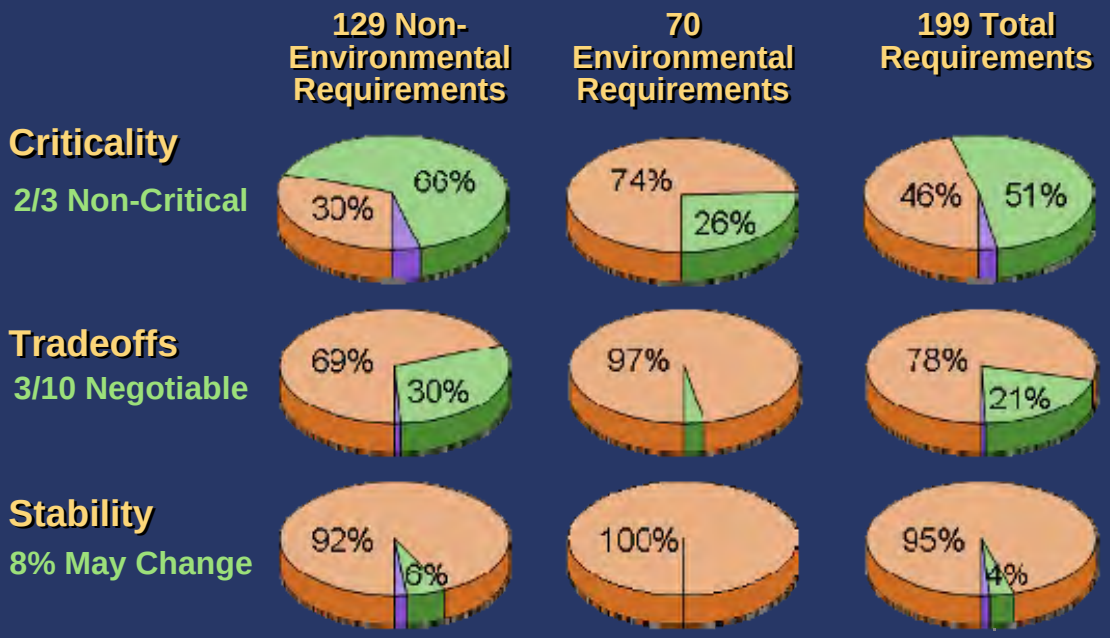
4.3.5.2 Lethality. To be verified via analysis and test of XM395 subsystem and system flight hardware against all targets specified in section…

SUPPORTING ANALYSIS:

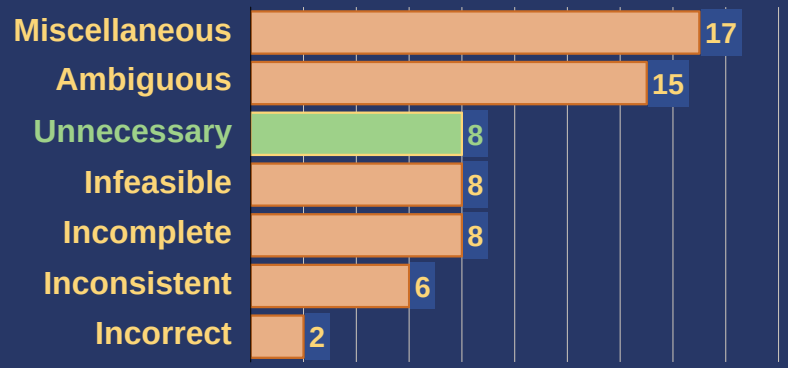
Note: Since we are verifying performance through modeling, we are most interested in validating our models. Further discussion needed.

Requirements Walkthrough Statistics

Customer Priorities	129 Non-ENV REQ	70 ENV REQ	199 Total REQ
Mission/Safety Critical	39	52	91
Useful	85	18	103
Desireable	5	0	5
Non-Negotiable	89	68	157
Negotiable	39	2	41
Flexible	1	0	1
Unlikely to Change	118	72	190
May Change	7	0	7
Most Likely to Change	2	0	2



Contractor Feedback (64 Issues)



- 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).

Accomplishment - Requirement Reduction



Reduced Customer Requirements

- 199 "SHALL" requirements in US Army SPS (System Performance Specification)
- Deleted 17 requirements (8.5%)
- Relaxed another 5 requirements (2.5%)

} 11%

Significance

Eliminated requirement to meet safety and reliability performance for one environmental requirement (unnecessary)

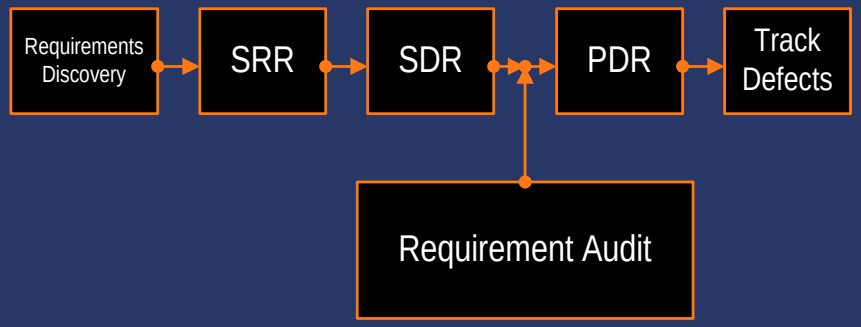
- Avoided fuze redesign cost of ~$300K to safely reset after exposure to the second environment

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

Process



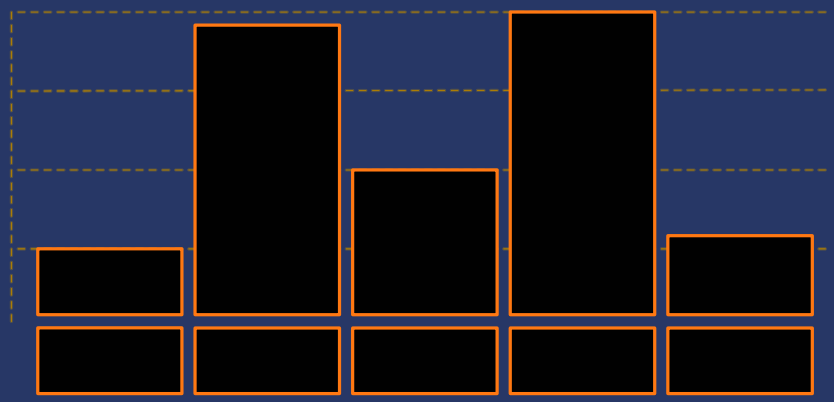
Requirement Defects	Examples
Incorrect Information	Incorrect Test Standard Incorrect Paragraph Reference Incorrect Environmental Levels
Omissions	Missing Test Standard Missing Requirement Missing Verification
Ambiguities	More Than One Interpretation
Poorly Written	Multiple “Shalls” In One Requirement Spelling and Grammar Requirement Not Clear
Misplaced	Requirement in Wrong Section Requirement Applied to Wrong Subsystem

ATK Technical Standard

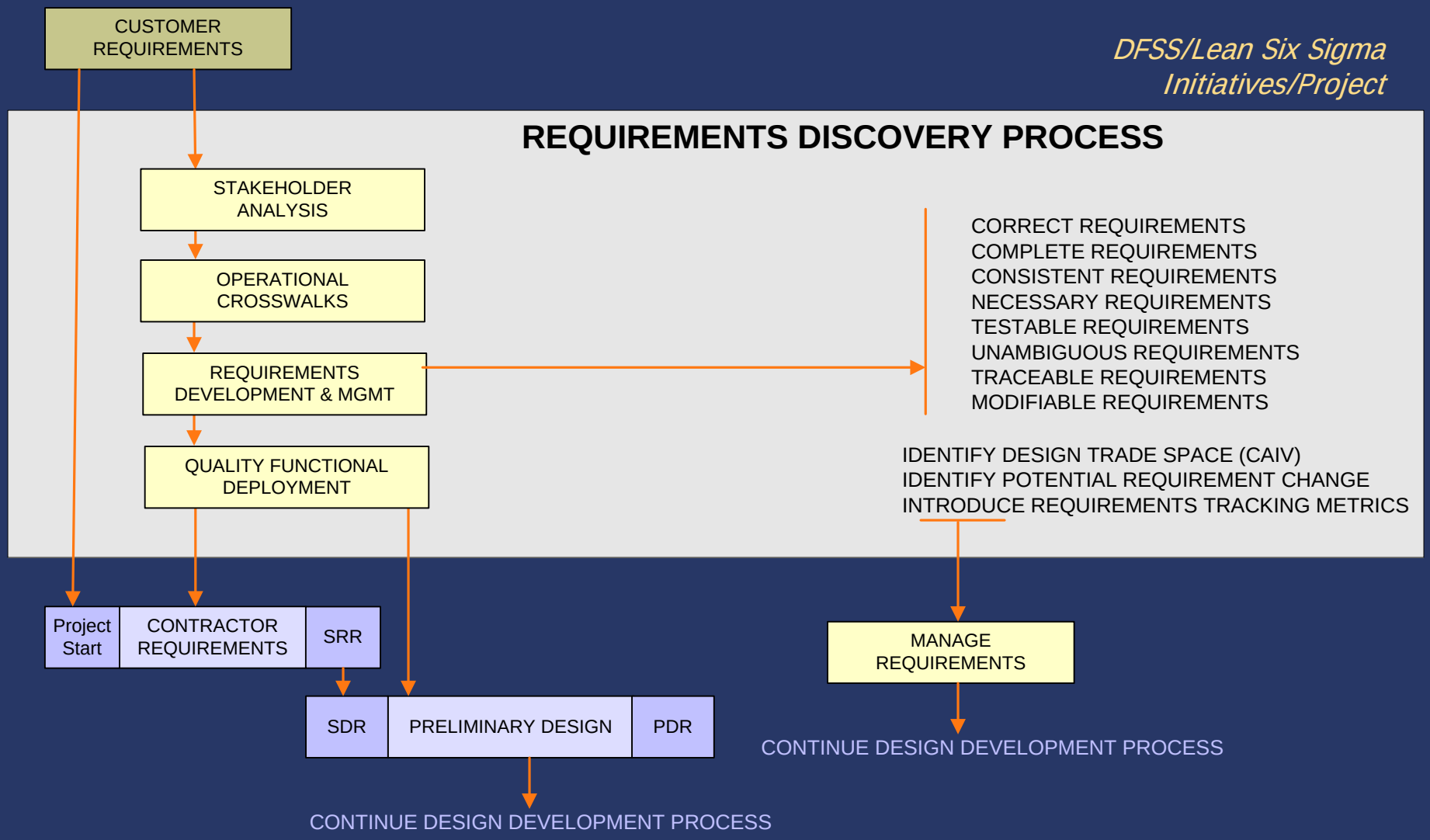
Early elimination of deficiencies

Results

- 946 System and subsystem requirements audited
- 46% had at least 1 potential defect
- 87% of potential defects realized a change to the requirement



Quality Functional Deployment



ATK Technical Standard

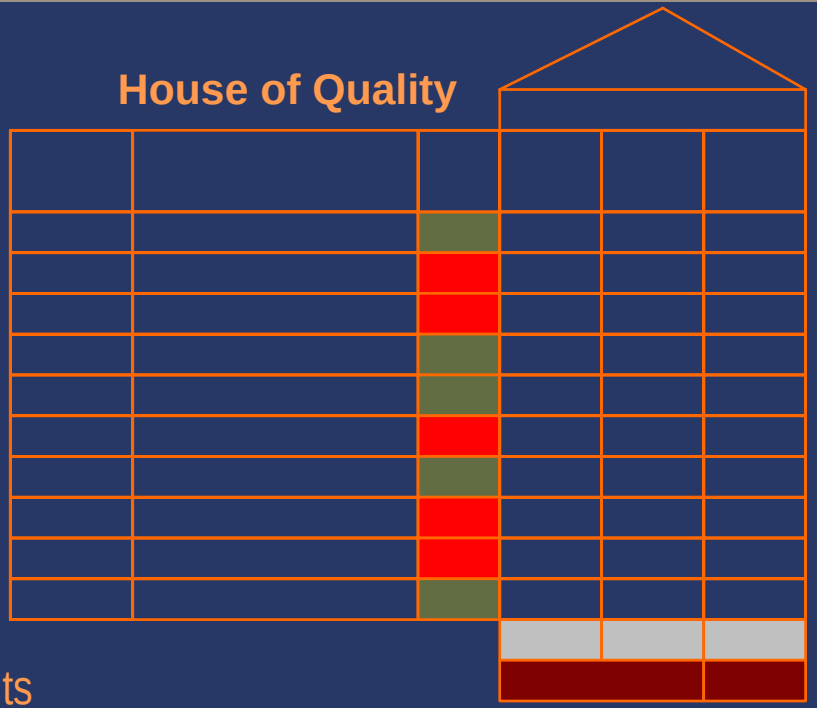
Requirements Defined and Tracked

Quality Functional Deployment (QFD)



Requirement Priority X Correlation

9	Mission/Safety Critical	±9	Critical
3	Useful	±3	Necessary
1	Desirable or Deleted	±1	Helps Satisfy

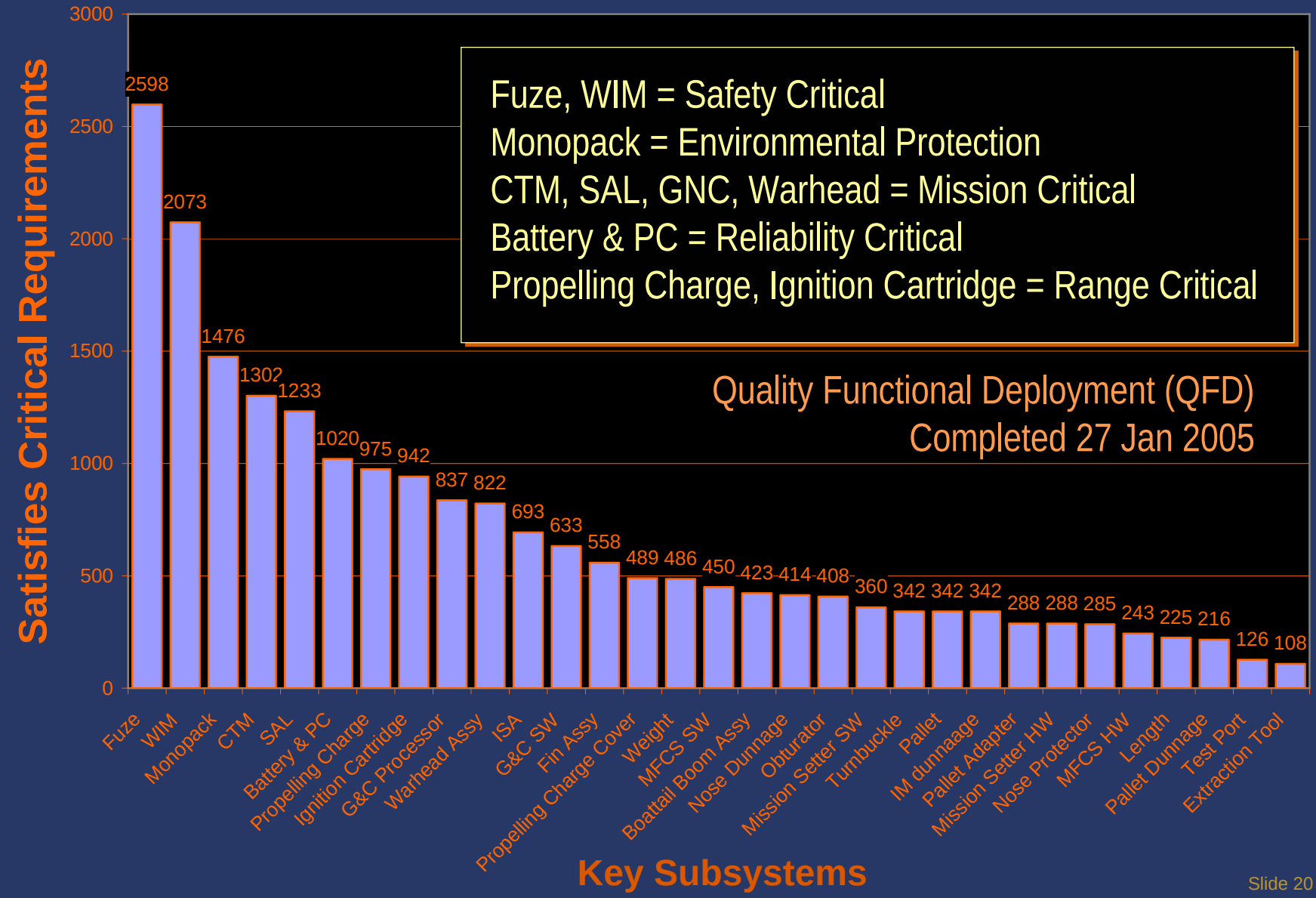




Results

- 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

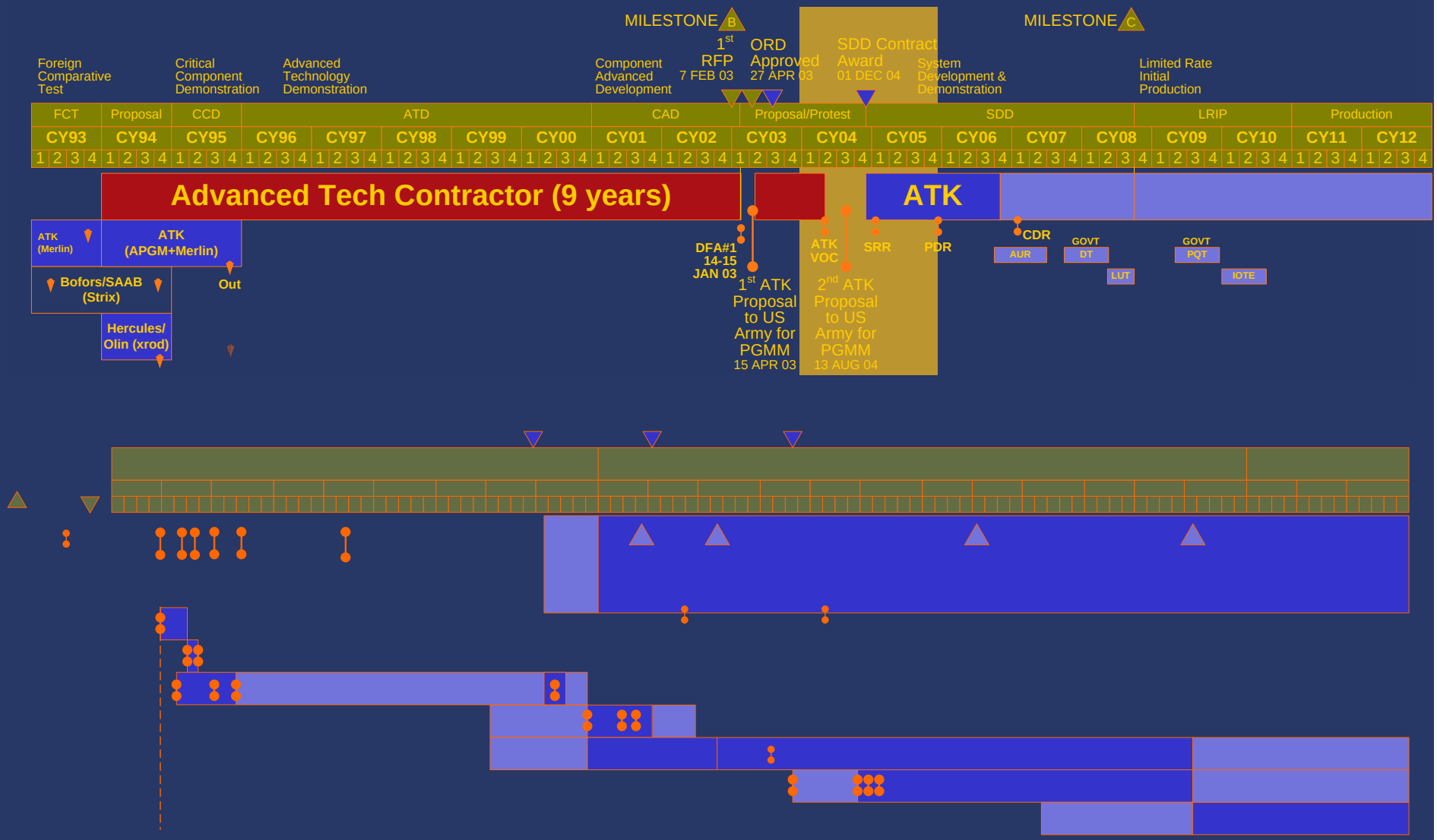
Quality Functional Deployment (QFD) - Results



Design for Six Sigma Tool Implementation

Project Summary

An advanced weapon and space systems company



Quest for Practical DFSS Tools Summary

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
- ☑ **Forged Strong Customer Relationship:** DFSS Tool application facilitated communication across the design team



Developed Product = User Need



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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

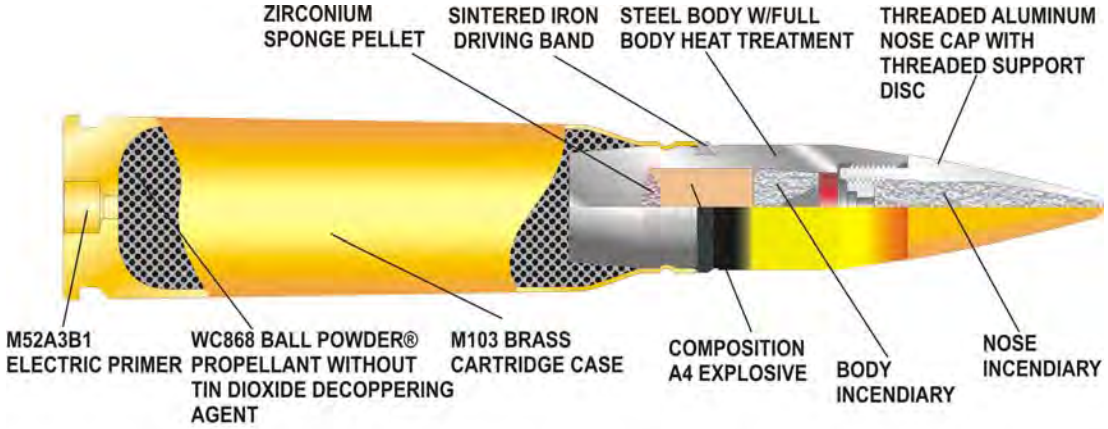
"Meeting Warfighter Needs for the Asymmetric Threat"

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.



PGU-28A/B Cartridge

- 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.

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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.



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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

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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

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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**

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Cartridge Description

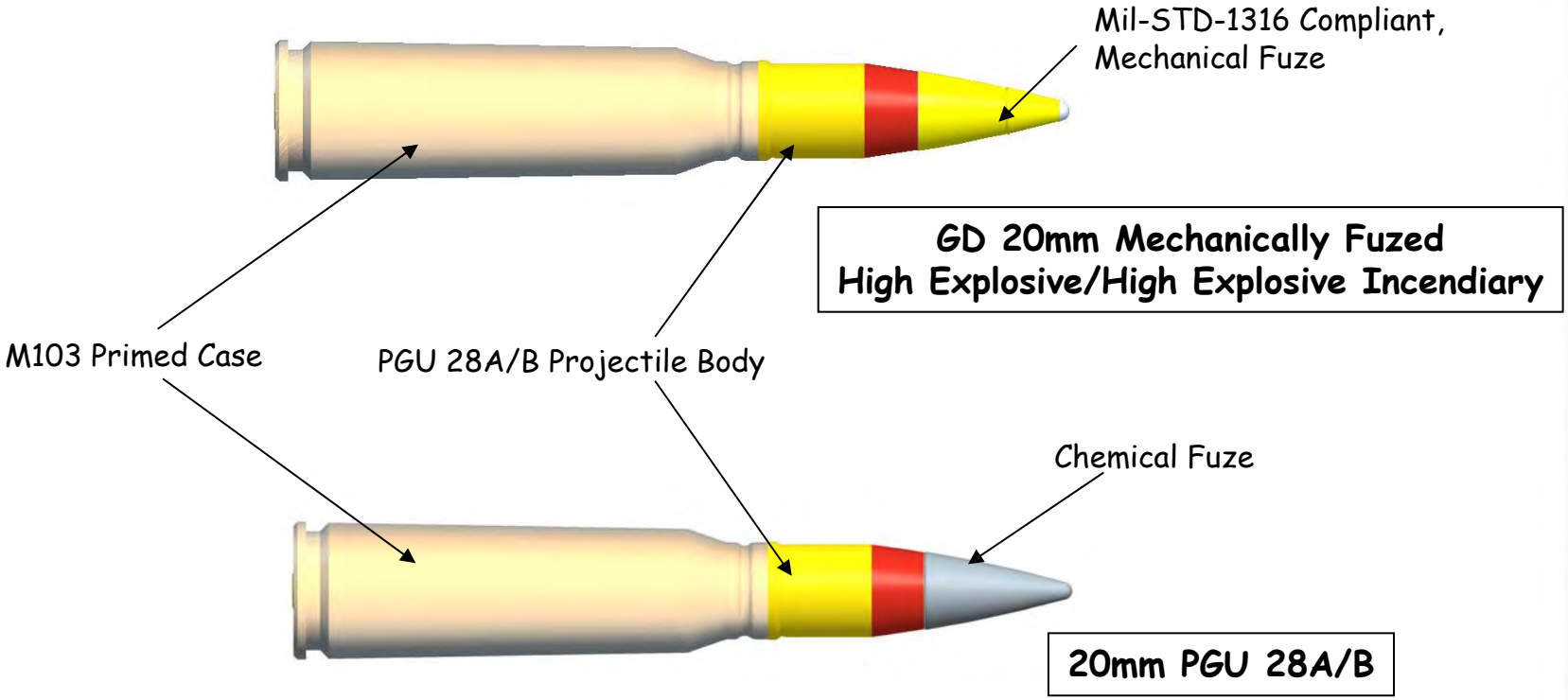
- **The General Dynamics-OTS solution utilizes the following:**
  - A ball rotor approach fuze similar to the M505 that employs dual independent safeties and can function in either the delay or point-detonating mode.
  - Ballistic match to the 20mm PGU family of ammunition.
  - Meets the 20mmx102mm Cartridge 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.

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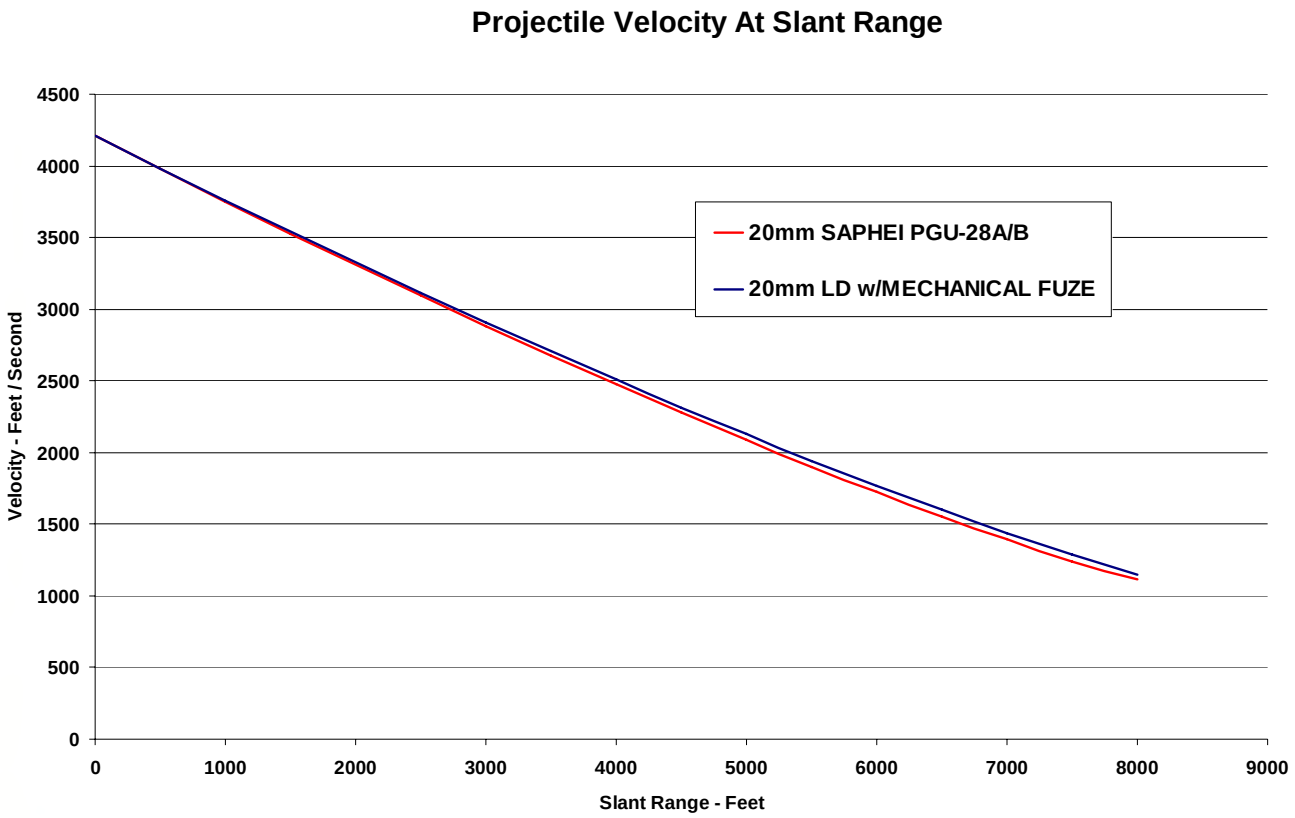
Cartridge Description



-Cartridges utilize same propellant and LAP facility.

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PGU-28A/B, 20mm Mechanically Fuzed Variant Trajectory Comparisons



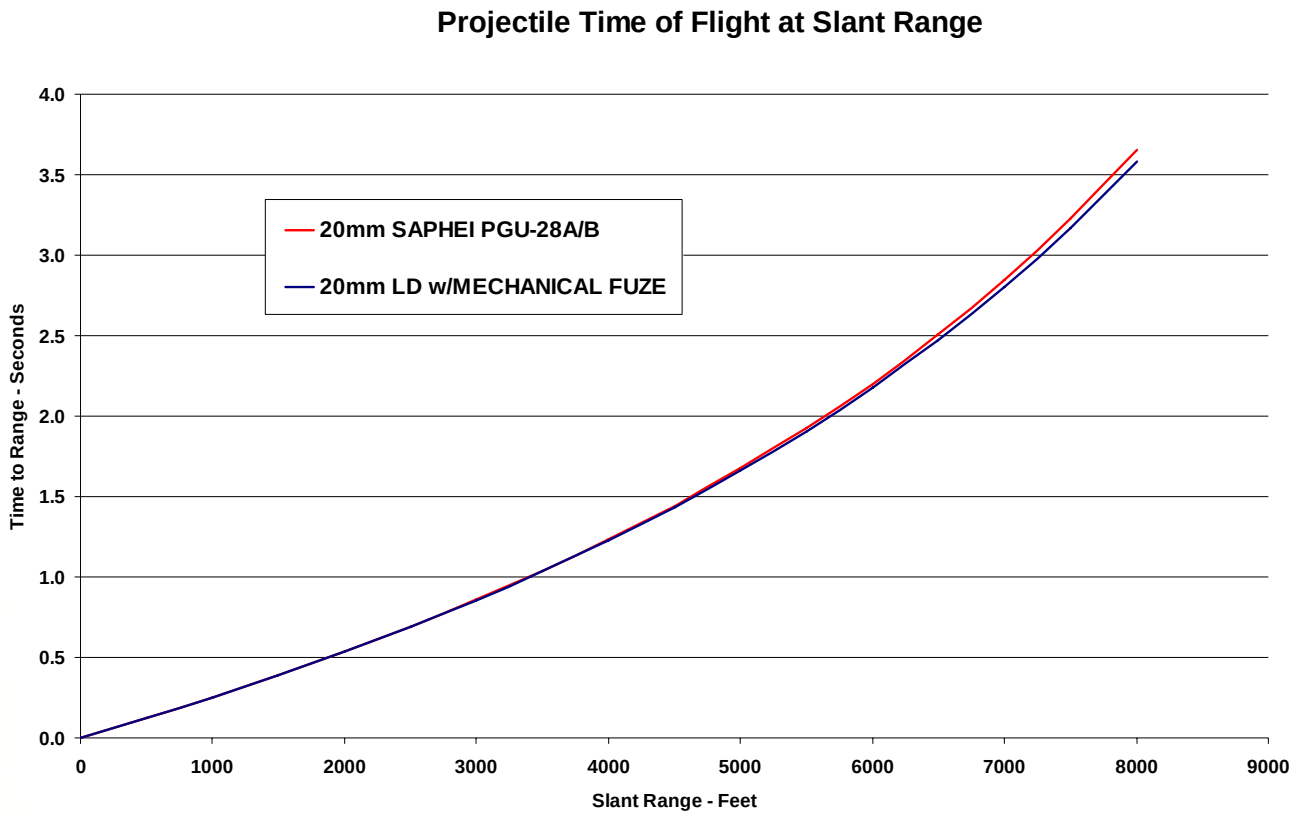
Trajectory Conditions:

- **Aircraft Altitude: 6,000 ft ASL**
- **Aircraft Airspeed: 450 knots**
- **Muzzle Velocity: 3440 ft/sec**
- **Standard Atmospheric Conditions**

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PGU-28A/B, 20mm Mechanically Fuzed Variant Trajectory Comparisons



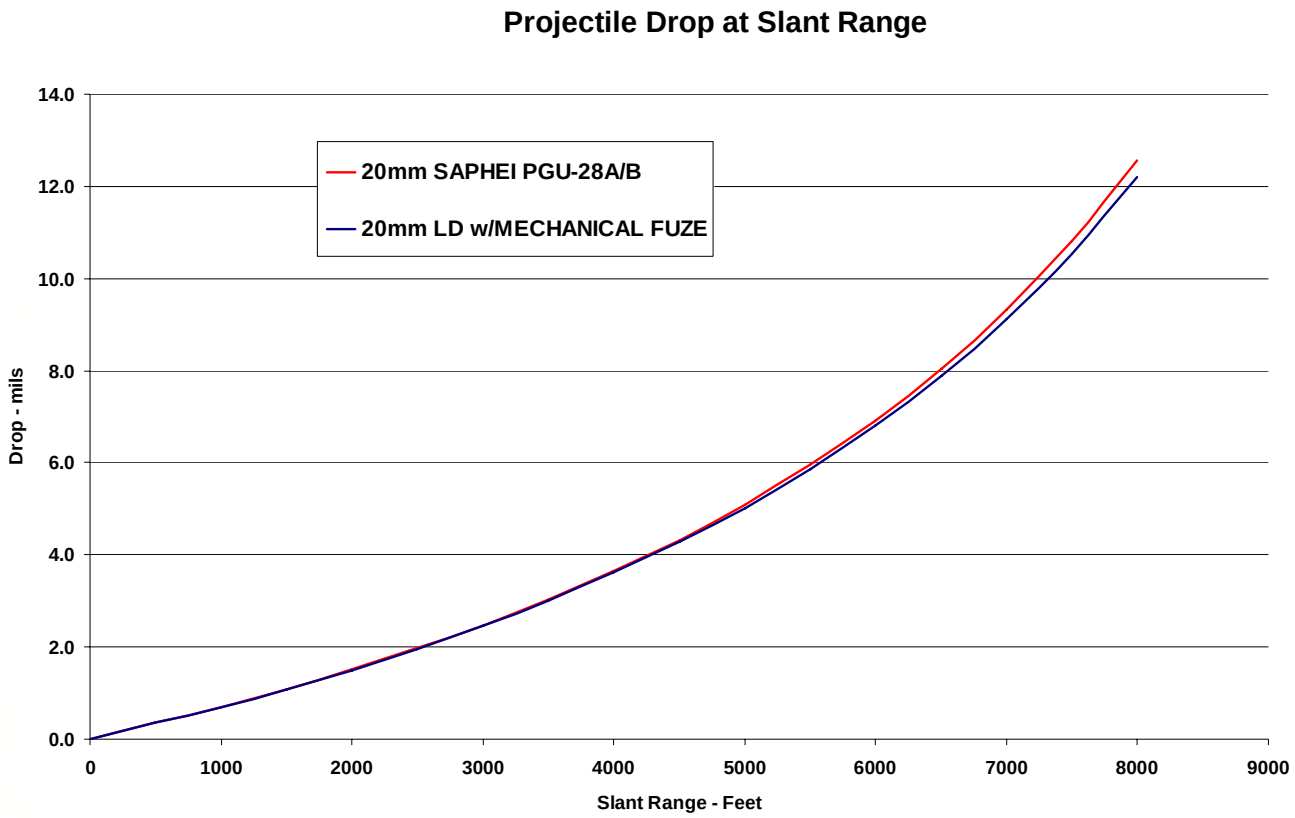
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PGU-28A/B, 20mm Mechanically Fuzed Variant Trajectory Comparisons



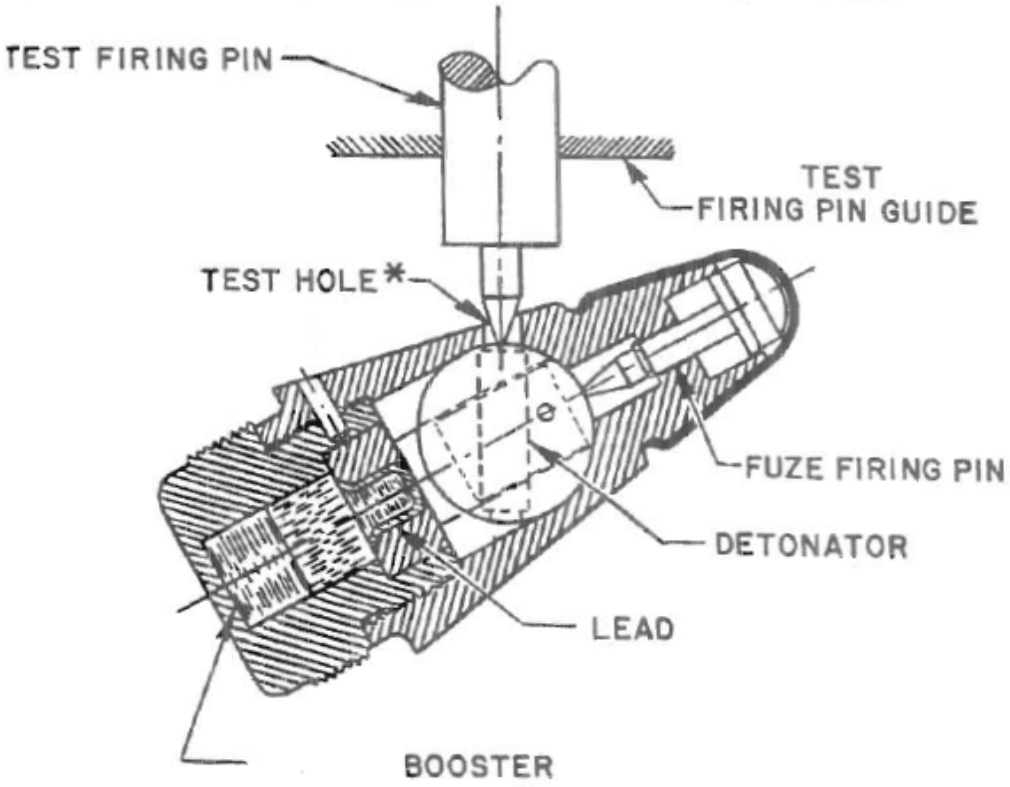
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Hand Safety Testing



Primary Component
Safety Test Set Up from
Mil-Std-331

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Hand Safety Testing

Final Configuration

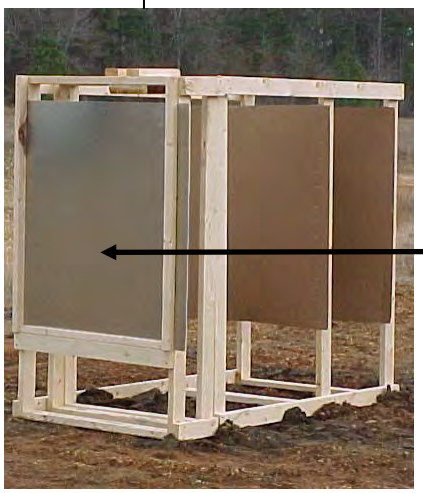


Design passes the D1 "Out of Line" safety test per Mil-STD-331

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Detonation Delay/Point Detonating Test Set-Up Description

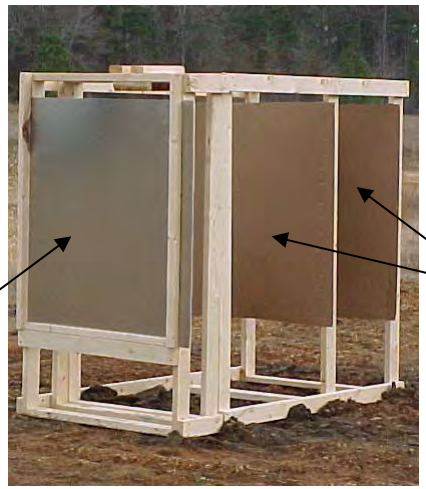
630 ft



Target Array



Gun and Mount

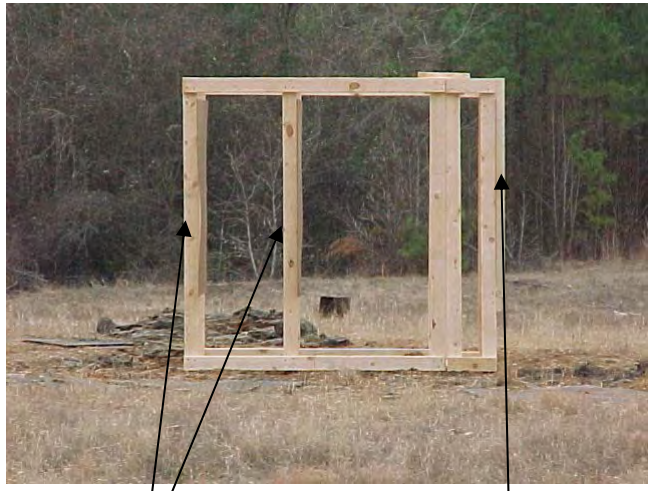


Aluminum Trigger Plate

Witness Panels 4' and 6' Behind Trigger Plate

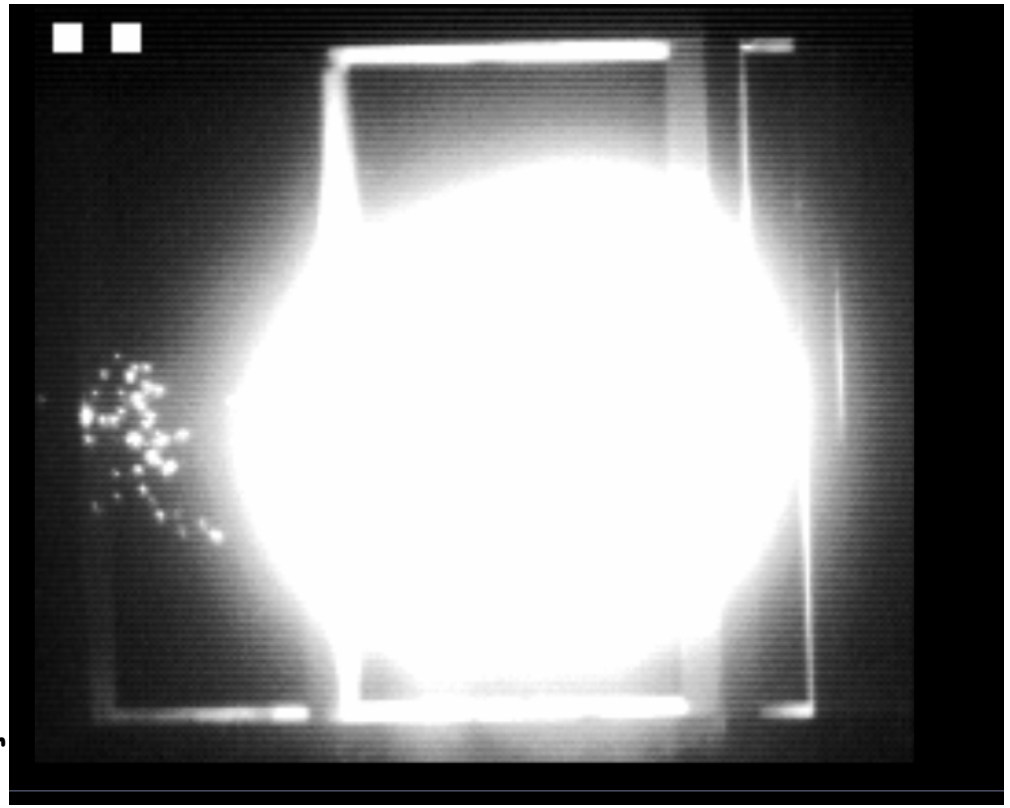
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Pictures from Demonstration Testing



Witness Panels

Aluminum Trigger Plate

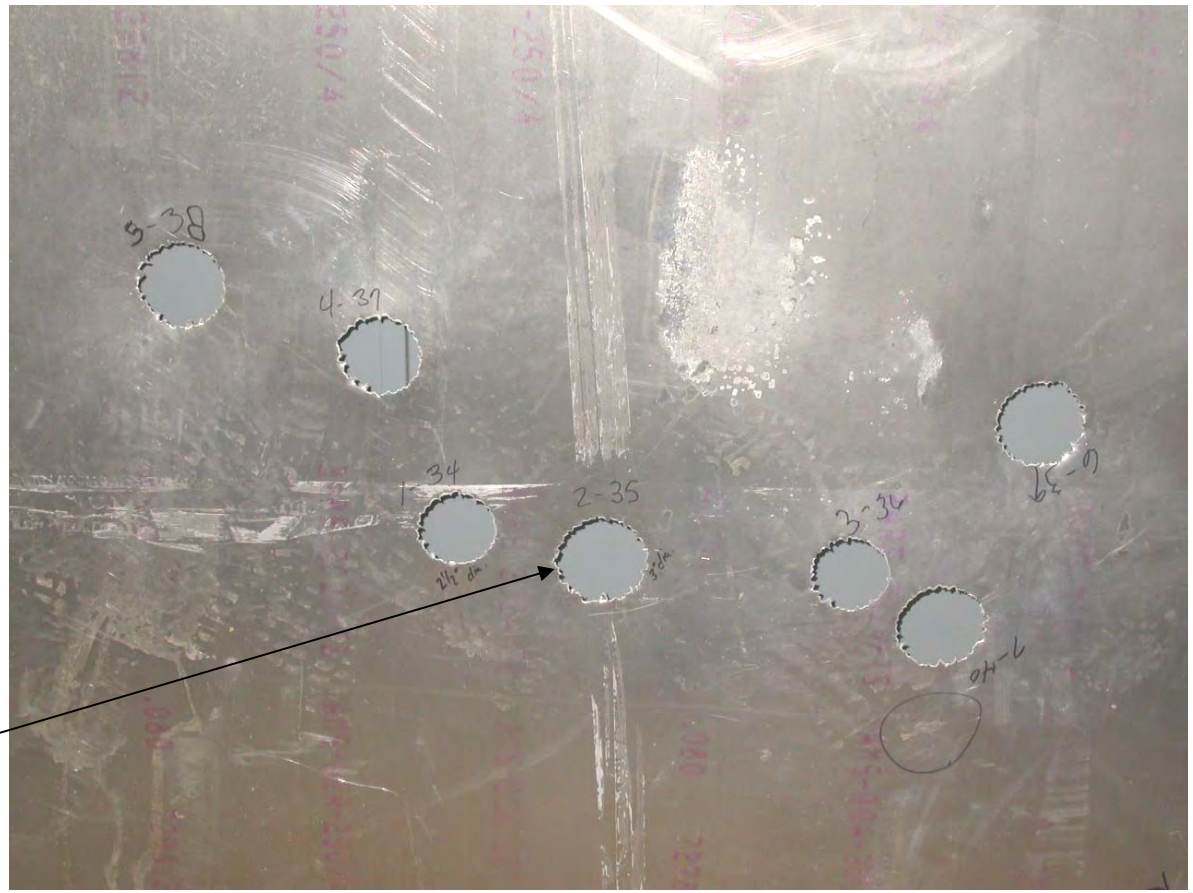


Impact with .080"
Aluminum at 200 yards

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Pictures from Demonstration Testing

Ø of hole is approximately 60mm



.080" Aluminum trigger plate
for point detonating test

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Pictures from Demonstration Testing



.080" Aluminum Trigger plate (75 degrees)
for Graze Sensitivity Test, 100% Function

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Pictures from Demonstration Testing



Witness Panel 4' behind trigger plate for Graze Sensitivity Test

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Summary of Results

Verification Tests	Delay Function	Point Detonating Function
Static Booster Testing	Complete	Complete
Booster Material Ballistic Evaluation	Complete	Complete
Low Drag Shape Concept	Complete	Complete
Explosive Train Development	Complete	Complete
Explosive Train Down Select	Complete	Complete
Detonation Delay	Demonstrated	N/A
Armor Penetration	Met Requirement	Expected to meet requirement per AS6120
Projectile Sensitivity	Demonstrated	Demonstrated
Point Detonating Function	N/A	Demonstrated
Fragmentation	Test Not Performed, witness panel comparison to PGU 28-A/B yields better fragmentation	Test Not Performed
Graze Sensitivity (75 Degrees)	Demonstrated	Demonstrated
Function and Casualty	Test Not Performed	Test Not Performed
Safety Tests	Passed Mil-Std-331 D1 Out-of-Line Safety Test @ Ambient, Tests at Hot Yet to be Conducted	Passed Mil-Std-331 D1 Out-of-Line Safety Test @ Ambient, Tests at Hot Yet to be Conducted
No-Arm (3 meters against .040" Al)	Passed	Passed

GD-OTS has performed testing against all of the key baseline performance requirements to ensure future success

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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.

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Questions?

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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 ACA^{2}P 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



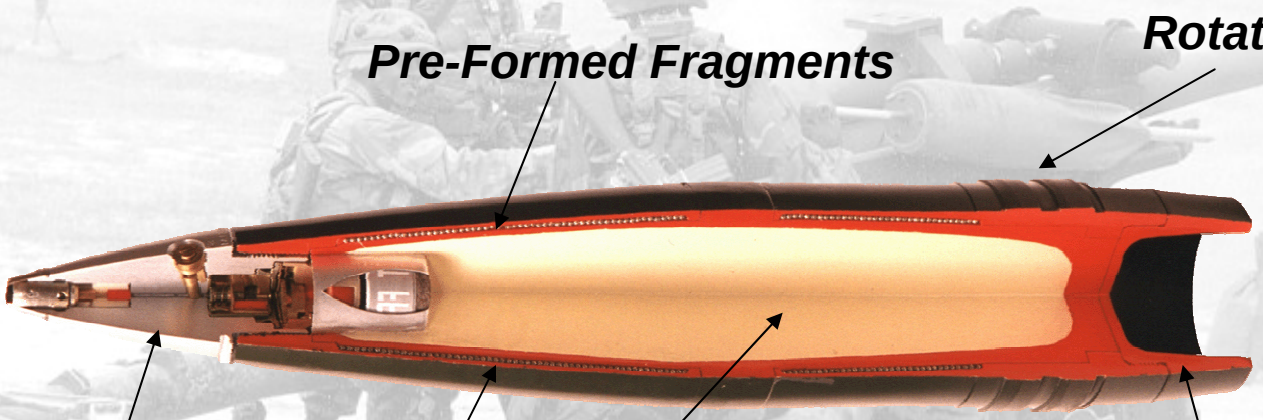
- Visible Illumination
- IR Illumination
- Bi-spectral screening smoke
- RP Incendiary
- HE Practice
- VLAP - Velocity Enhanced Long-Range Artillery Projectile

105mm PFF Background

- In 2002, the Advanced Cannon Artillery Ammunition Program (ACA^{2}P) 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

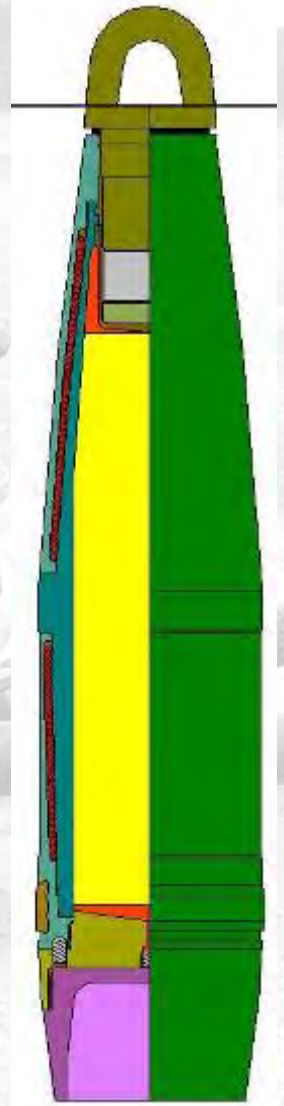


System Description
XM1131 105mm IM HE PFF



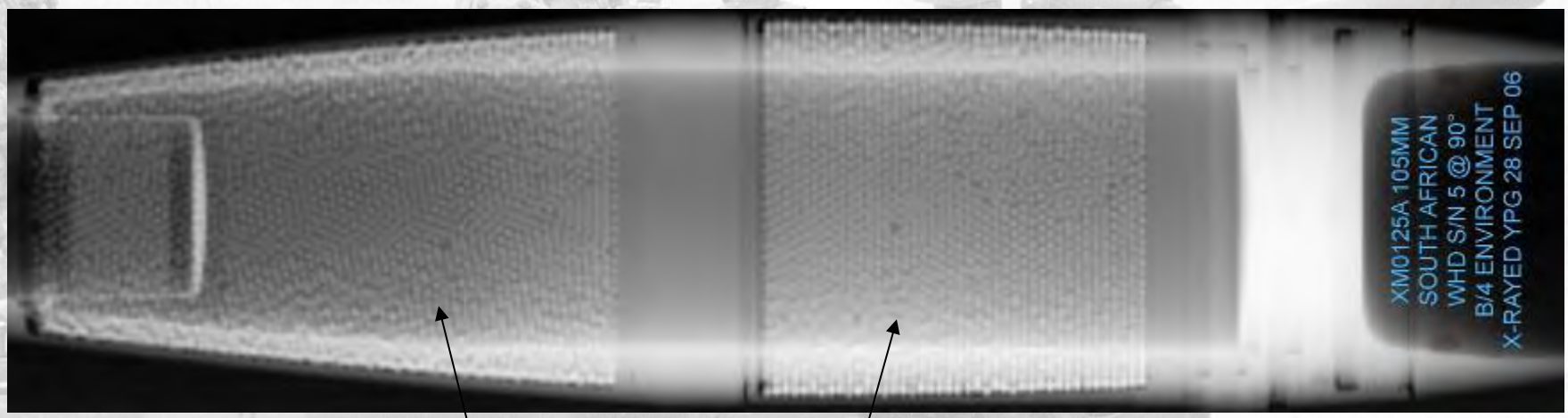
*Assumptions based on artillery usage: Basebleed could provide better stand-off, accuracy, and tracer capability, if desired.

System Characteristics
XM1131 105mm IM HE PFF



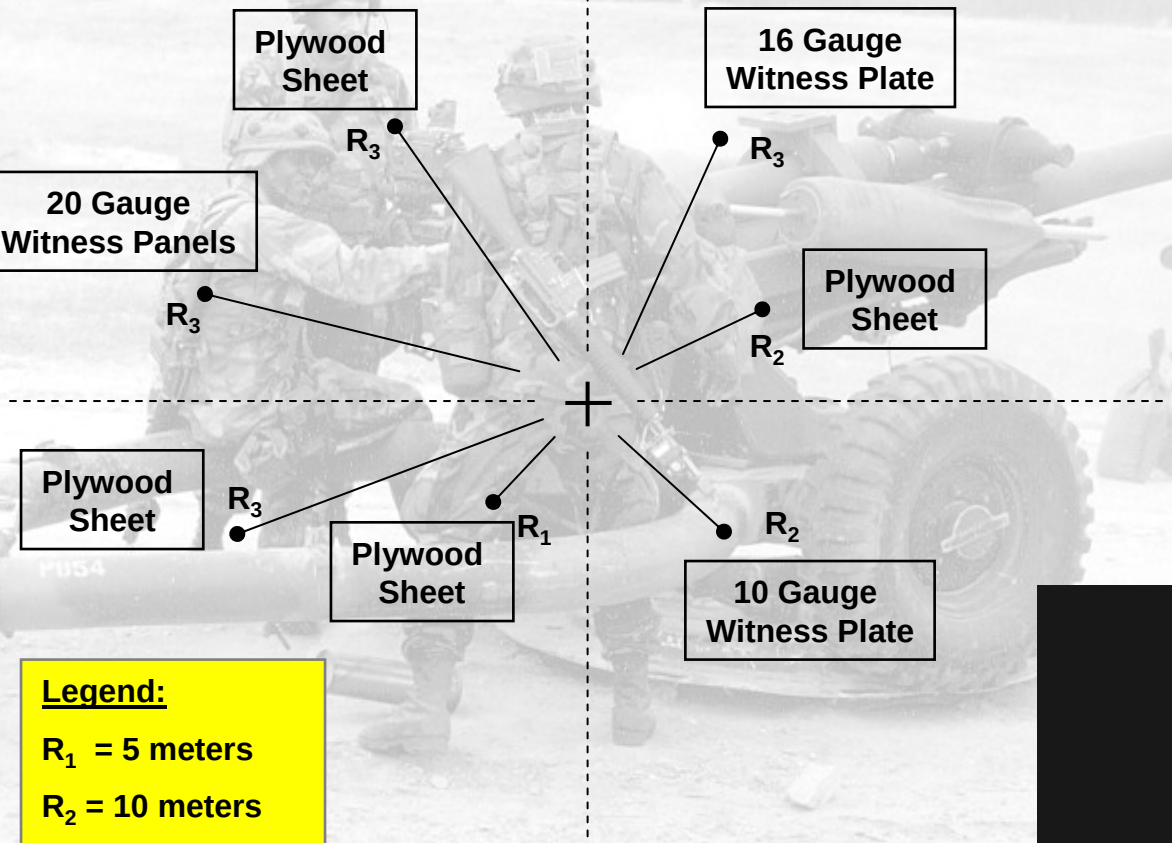
- Type – HE w/ Pre-Formed fragments
- Weight – 34.8lbs (16kg)
- Length – 21.6in (551mm) (fuzed)
- Projectile Body – High fragmentation steel with inner lining of > 9,000 ~3mm tungsten balls
- IM Explosive Fill – 4.1lbs (1.8 kg) of PBX blend (80% RDX)
- Max. Ranges – M119A2 105mm howitzer
  M67 11.5km 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:

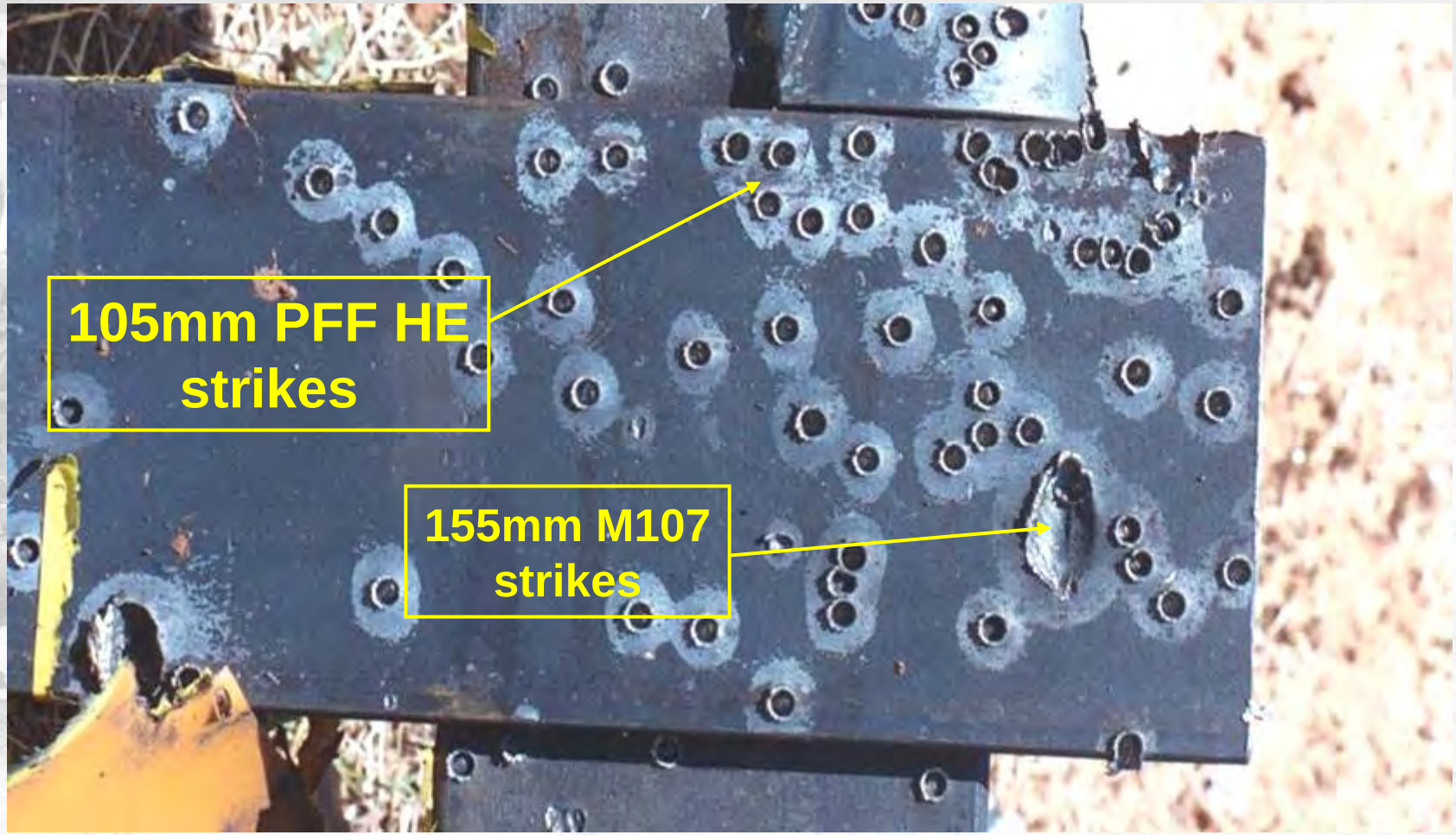
R_1 = 5 meters

R_2 = 10 meters

R_3 = 15 meters

[redacted]

Greater Lethality versus Personnel and Soft Skinned Targets

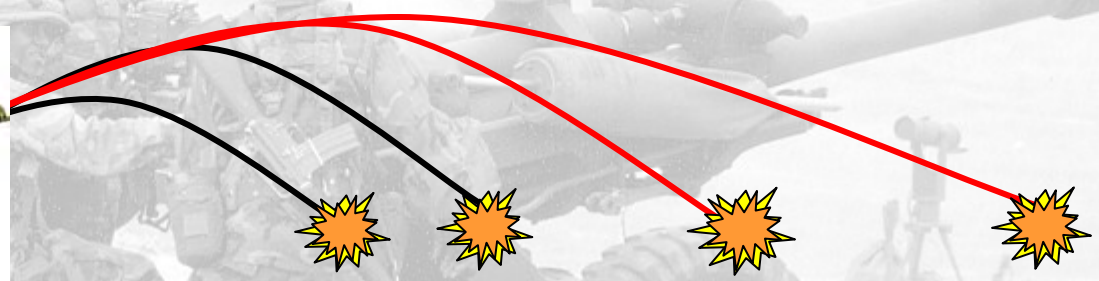


Increased Ground Operational Reach

105mm Range Comparison



M119A2



Current Operational Limits

ACA²P Extended Operational Reach

105mm Lethality Comparison

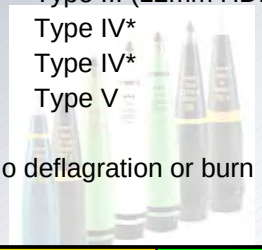
- PFF has 2 - 4X improvement in lethality compared to current M1(HF) against select targets
- Improved first shot P_{kill}
- Reduction in collateral damage
- Growth to precision accuracy

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



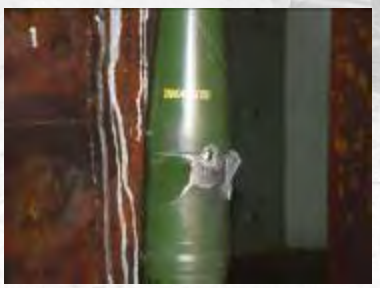
Type I Detonation	Type II Partial Detonation	Type III Explosion	Type IV Deflagration	Type V Burn

GENERAL DYNAMICS Ordnance and Tactical Systems

ACAP Leadership Review 6-2006

DENEL LAND SYSTEMS

22



- U.S. Army moving ahead with pressed warhead
- Passed all but one IM test



IM Compliance





Bullet Impact



Fragment Impact





Sympathetic Detonation



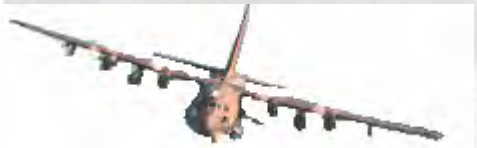
Fast Cook-off

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

105mm HE PFF

M1(HF)

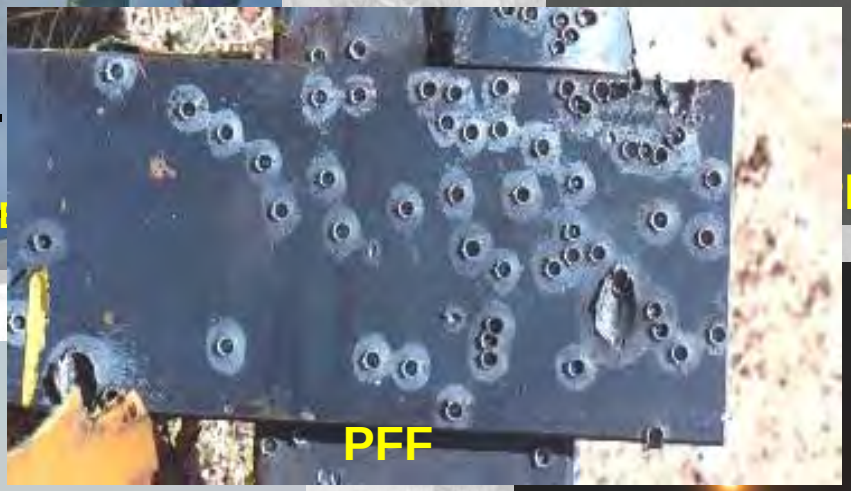


ACA²P Technologies Demonstrated





hosphorus



PFF



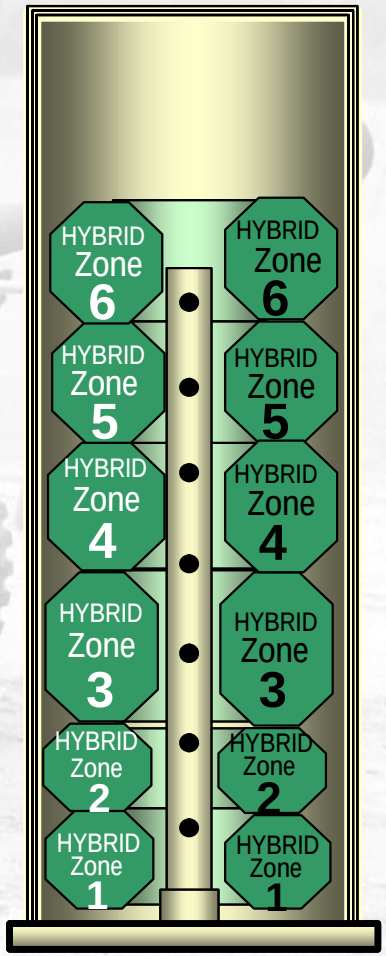
Bi-spectral smoke



IR illumination

Propelling Charge Path

- 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**

ATK-ES IM Energetic Replacement Strategy

• **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

An advanced weapon and space systems company

- **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**



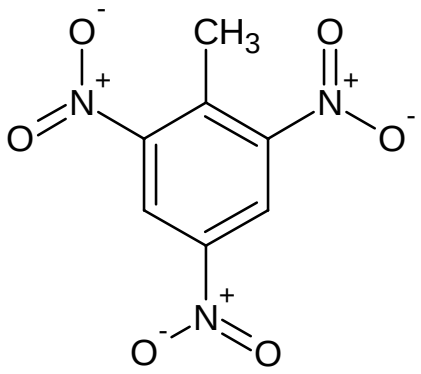


PAX-44

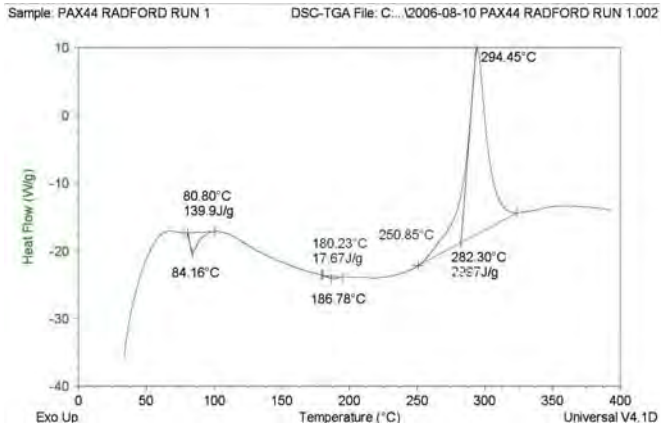
- **TNT Based IM energetic**

- **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**

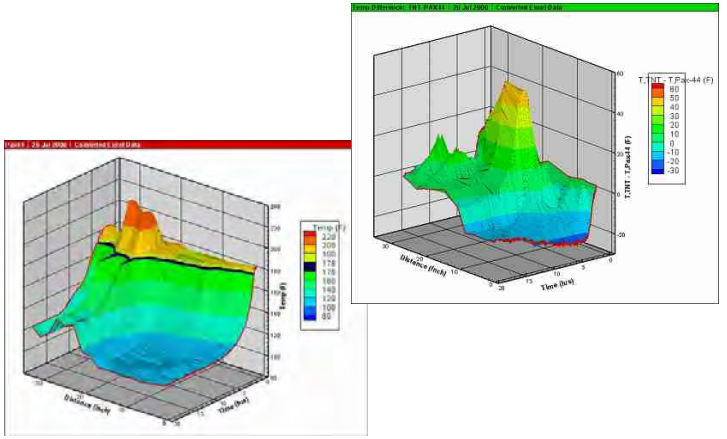
LAP Study

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- **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

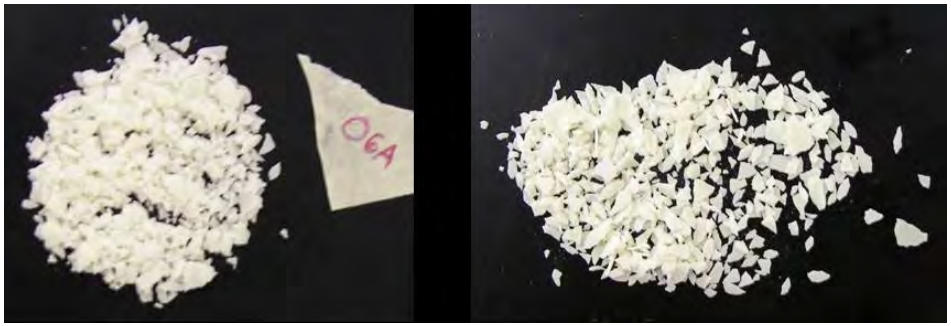
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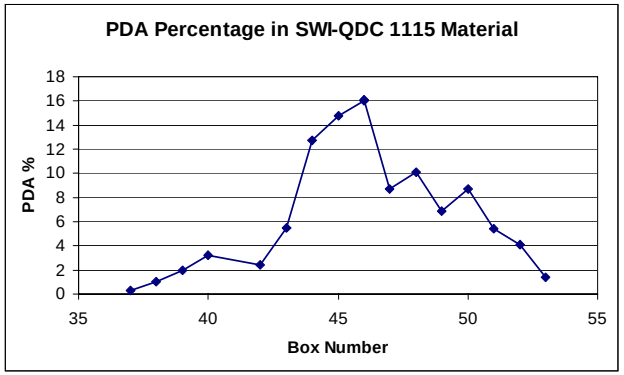
Finishing Study

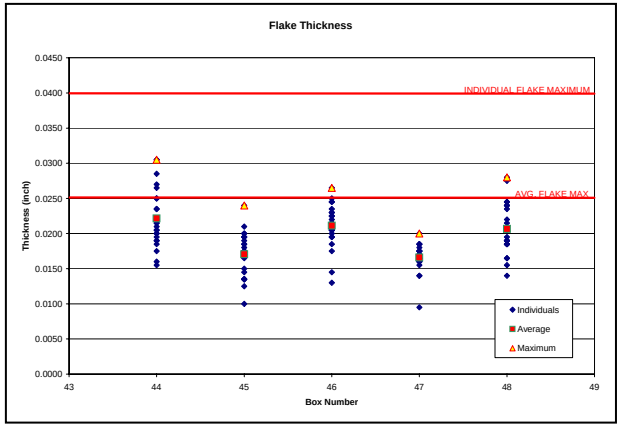
An advanced weapon and space systems company

- **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



NTIB TNT – Jan 2006 PAX-44 SWI-QDC 1115





IM Study

- **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

An advanced weapon and space systems company

- **Efforts to improve casting quality (Feathering, Process Additives, MBC Cooling)**
- **Consistent Improvement of Bullet Impact Response over range of cast-qualities**



Type III

Type IV





Type V

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

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- **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

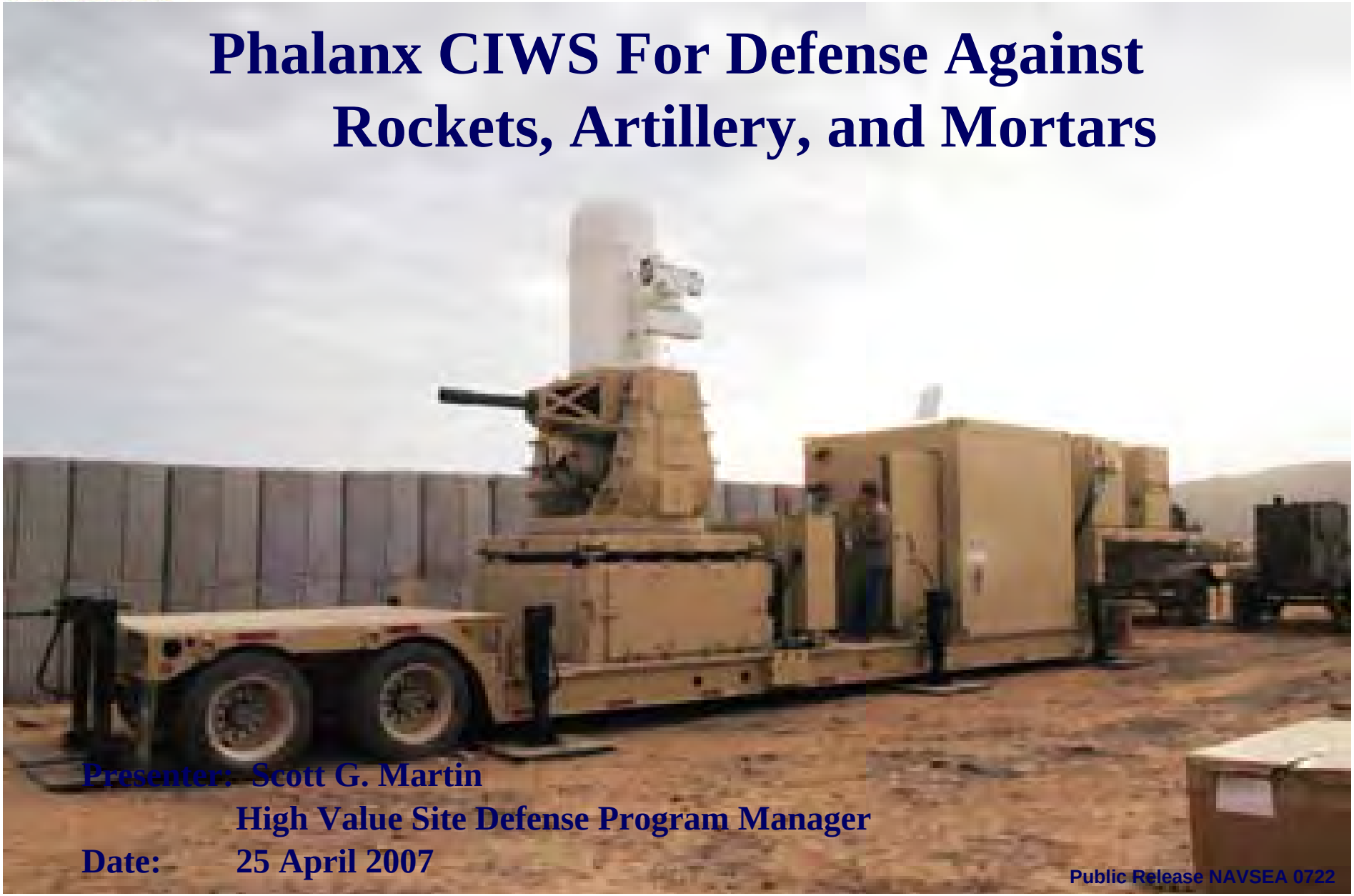
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Raytheon

Phalanx CIWS For Defense Against Rockets, Artillery, and Mortars



Presenter: Scott G. Martin
High Value Site Defense Program Manager

Date: 25 April 2007

Public Release NAVSEA 0722

The Current Tactical Situation…

Raytheon

Requires The Capability To Defeat …

- **Cruise Missiles**
- **Various Military Aircraft**
- **UAVs**
- **Slow Civilian Aircraft**
- **Helicopters**
- **Lightly Armored Vehicles**
- **Small Boats With Weapons**



<u>AND</u> 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

Raytheon

- 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

Phalanx Block 1B Overview

Raytheon

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**

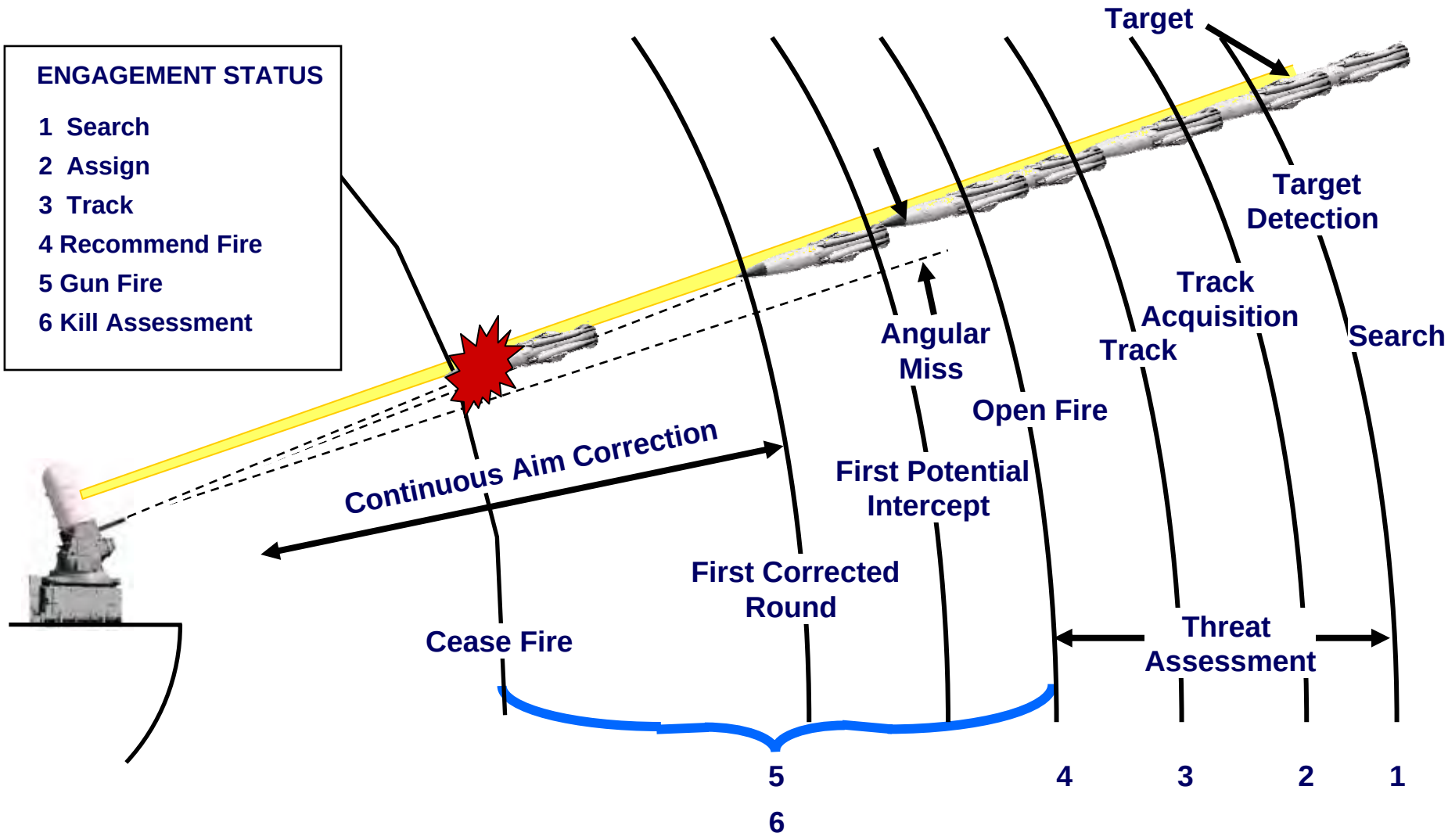
Benefits:

- **Supports Multiple Roles In Ships Self Defense**
- **Man-in-the-Loop, Autonomous or Integrated Operation**
- **Fast Reaction**



Phalanx CIWS AAW Operational Sequence

Raytheon



Proven Against Threats in Both Anti-Air and Surface Mode

Raytheon

SeaSkimming ASM



Diving ASM







UAV

155mm

- 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



Cobra Helo w/Flares



A4 Jet Aircraft



Small Boat Engagement



Rigid Inflatable Boat



Boghammar

Track Only Op

Today's HVSD Solution: Land-Based Phalanx Weapon System (LPWS)

Raytheon

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

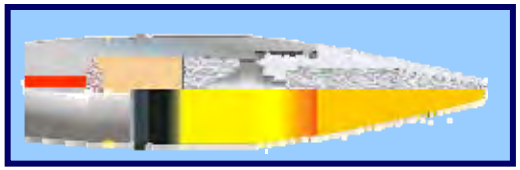
- Accurate Point of Impact Prediction

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





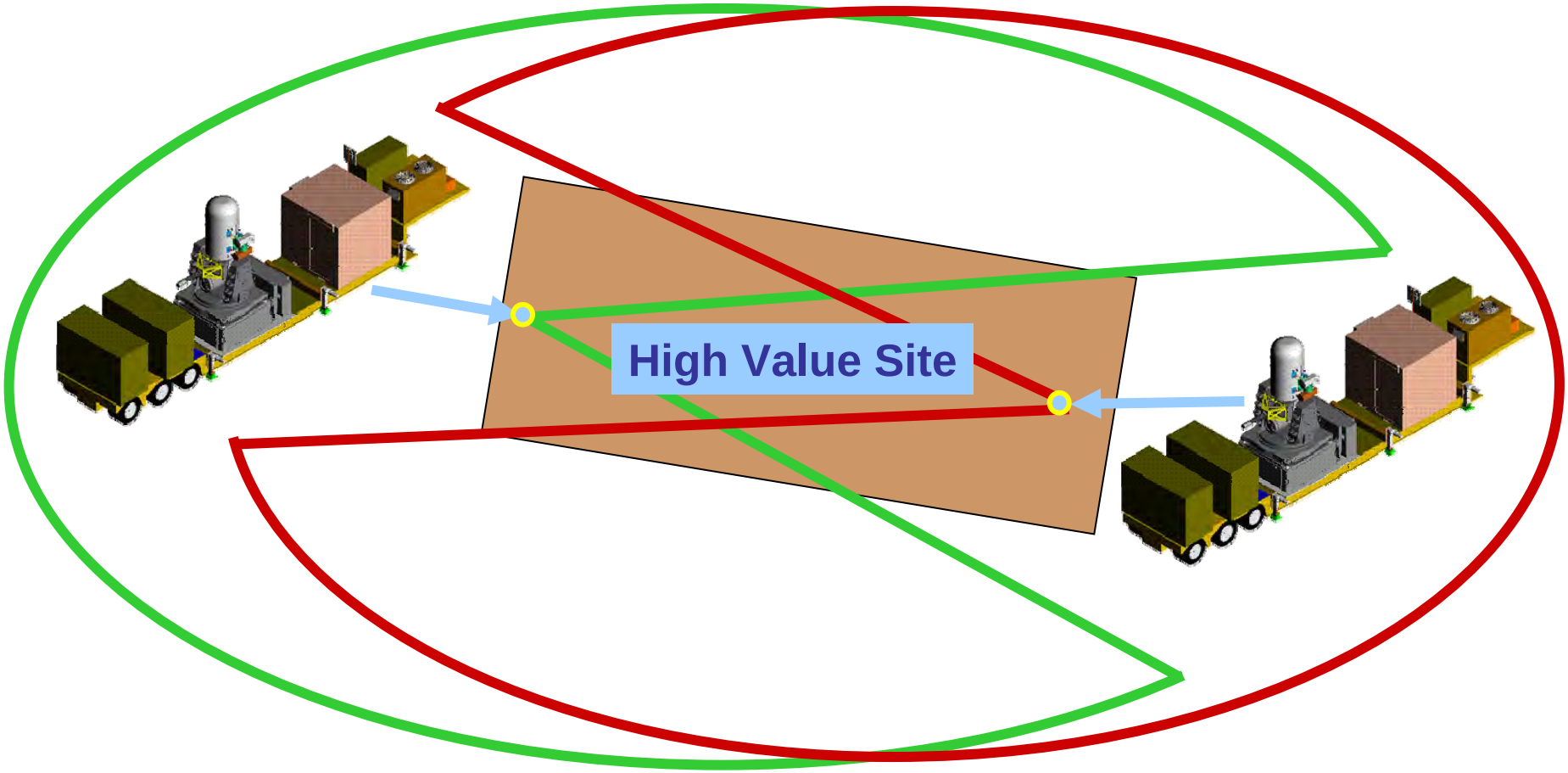
Standard Mk-149 (Penetrator) Ammunition Could Be Lethal

M-940 Ammunition Eliminates Collateral Damage

Strategic Placement Provides for Overlapping Protection

Raytheon

- 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





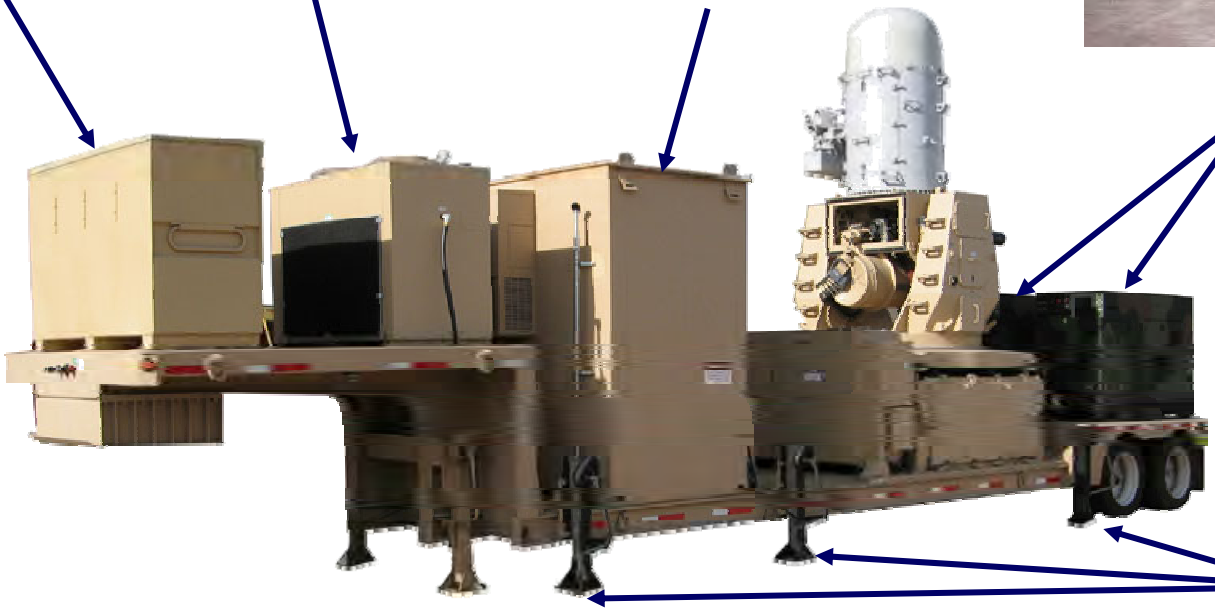


Tool Box

Chiller

COTS Portable Structure

Generators



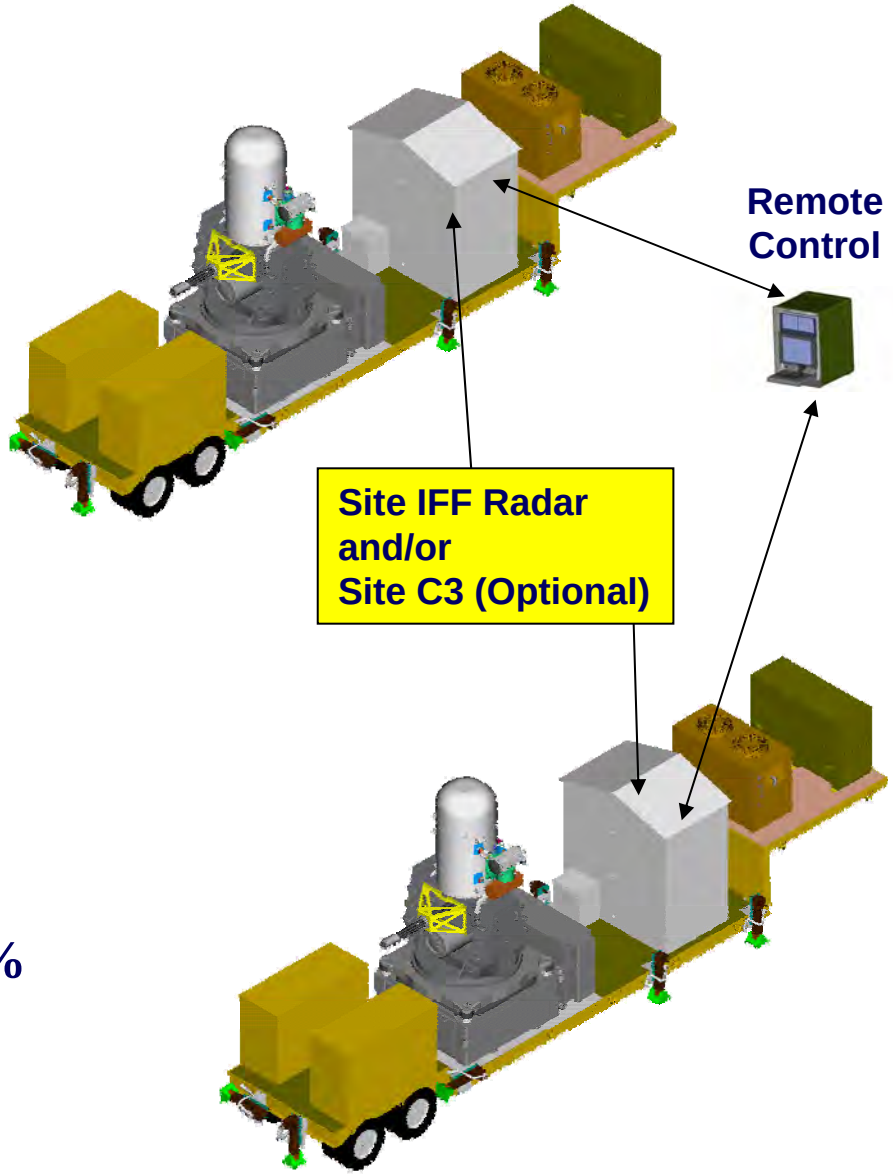


Manual Jacks

LPWS
Site Hardware Arrangement

Raytheon

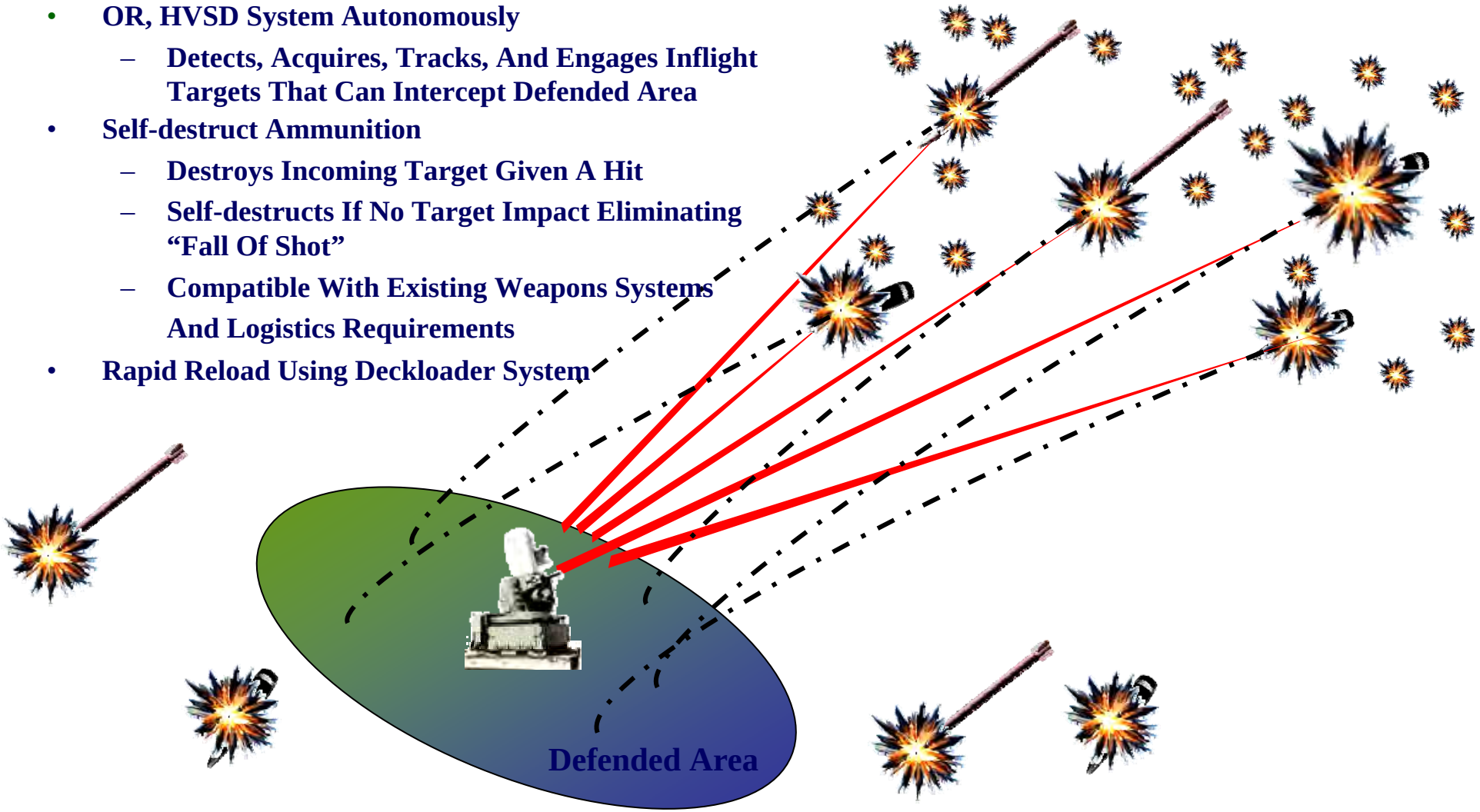
- "Movable" Installation
  - Self Contained
    - Power
    - Cooling
    - Operator Station
  - Trailer Mounted
    - Commercial Chiller
    - Jacks Provide Stability
- Ethernet Fiber-optic Based Interfaces
  - Allow Several Km Distances Between Protected Areas And Site Control
  - Portable Remote Control 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

Raytheon

- 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

Raytheon

- **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!

An advanced weapon and space systems company

30mm x 173mm Air Burst Munition

Applications for Ground and Sea Platforms



NDIA

24 April 2007

Approved for Public Release 06-S-1905 dated July 10, 2006



Presentation Outline

This briefing will discuss:

- ATK Air Burst Munitions Evolution
- System Overview
- Air Burst Munition Test Shots and Video

Approved for Public Release 06-S-1905 dated July 10, 2006

Air Burst Ammo Target Set

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Urban & Wall



Lightly Fortified Infantry Emplacement (LFIE)



ATGM Crew



Troops in squad







Watercraft







BTR
Lightly Armored Vehicles

Approved for Public Release 06-S-1905 dated July 10, 2006

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

Approved for Public Release 06-S-1905 dated July 10, 2006

ATK Air Bursting Munitions Evolution

An advanced weapon and space systems company

1999 2001 2002 2003 2004 2005 2006

Shoulder Fire



OICW
20mm Ammo





MEMS



20mm Firing



25mm
Non-Lethal





XM25 25mm
MEMS 25mm

Common
Air Burst
Fuze



Cannon Caliber



30mm ABM
Nose Fuze



30mm Firing
Demonstrations
Dec 2001
May 2002
Nov 2002



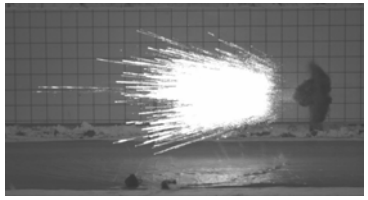
Super 40mm
Development
ALACV



30mm ABM
Base Fuze

MK44 30/40mm Cannon





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
  - Setter
  - Gun
  - Fire control interface
  - Human interface

Approved for Public Release 06-S-1905 dated July 10, 2006

ATK Air Burst System Overview

An advanced weapon and space systems company

Key Components

MK44 Chain Gun





Gun Control Unit (GCU)
with Inductive Fuze Setter



Fire Control
System

ATK ABM Projectile





Expeditionary Fighting Vehicle (EFV)
Other MK44 platforms include:
LPD-17, Bradley Fighting Vehicle & FCS

Target Set



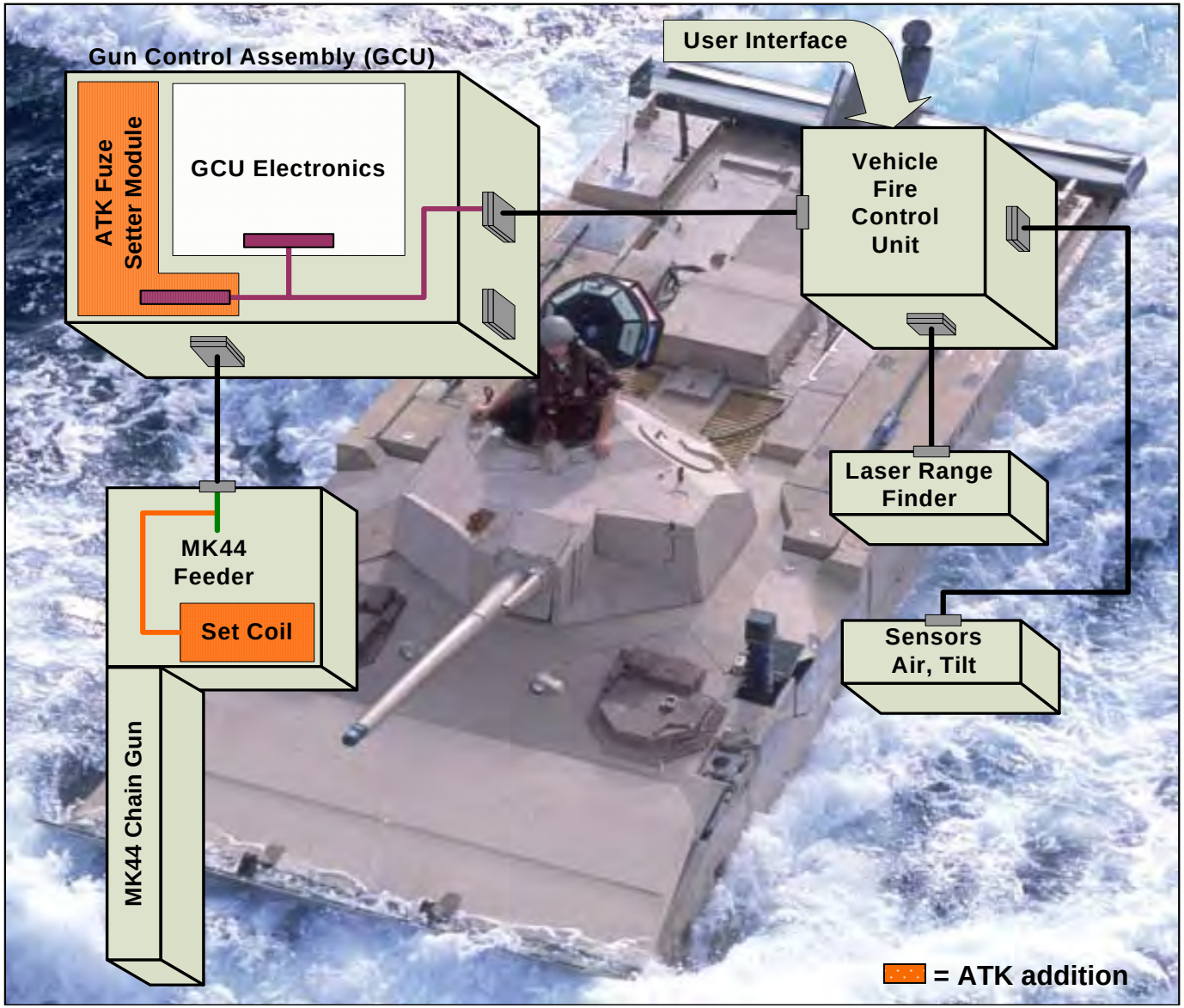




02_T107624.ppt

MK44 Inductive Setting: System Configuration

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30mm ABM Data

An advanced weapon and space systems company

Physical Data

Cartridge Length:	290mm
Cartridge Weight:	728g
Projectile Weight:	423g
Propellant Type:	Single Base
Cartridge Case Length:	173mm
Cartridge Case Material:	Aluminum
Primer:	M36A2 Percussion
Fuze:	ATK Turns/Time

Performance Data

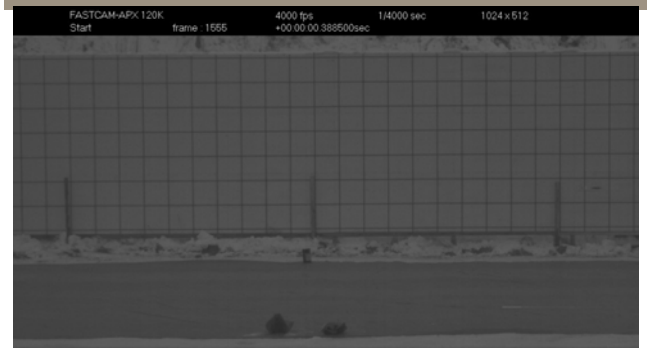
Muzzle Velocity:	980m/s
Chamber Pressure (ambient):	360MPa
Dispersion:	0.5mr
Penetration:	TBD
Trace Time:	2 sec min, 5-6 sec typical



Approved for Public Release 06-S-1905 dated July 10, 2006

Shot 2 – 500m Air Burst Sequence Highspeed

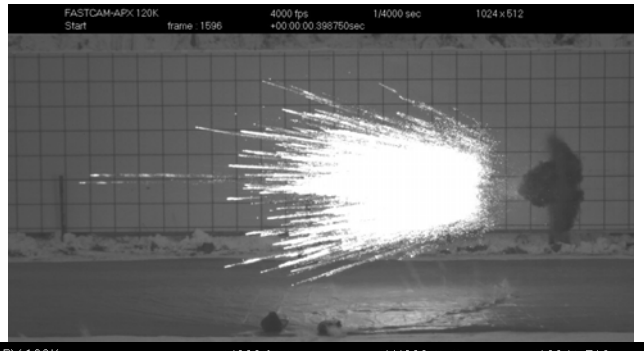
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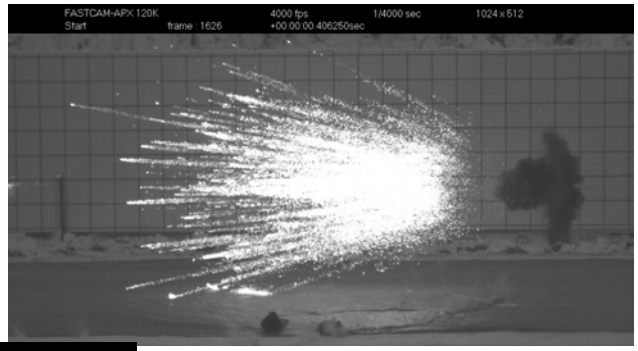


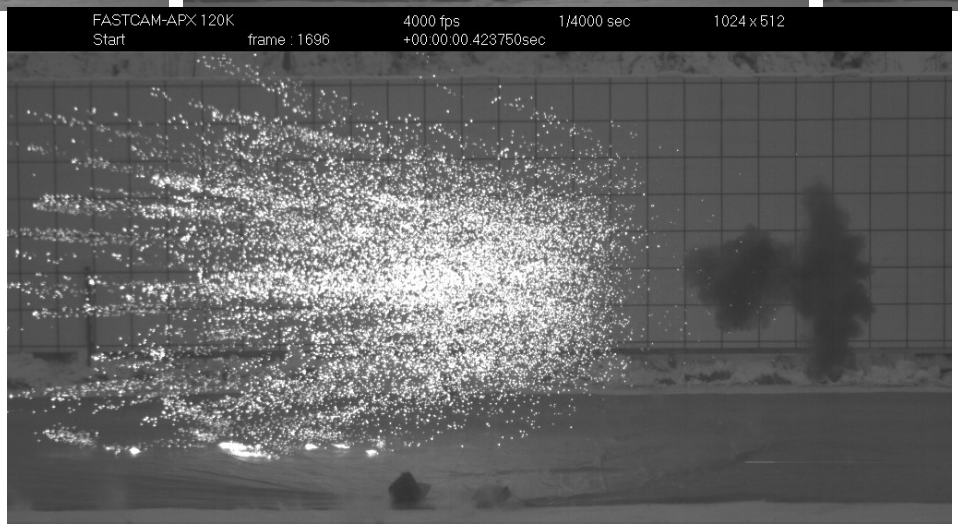












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Shot 3 – 500m Air Burst

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Down Range Views

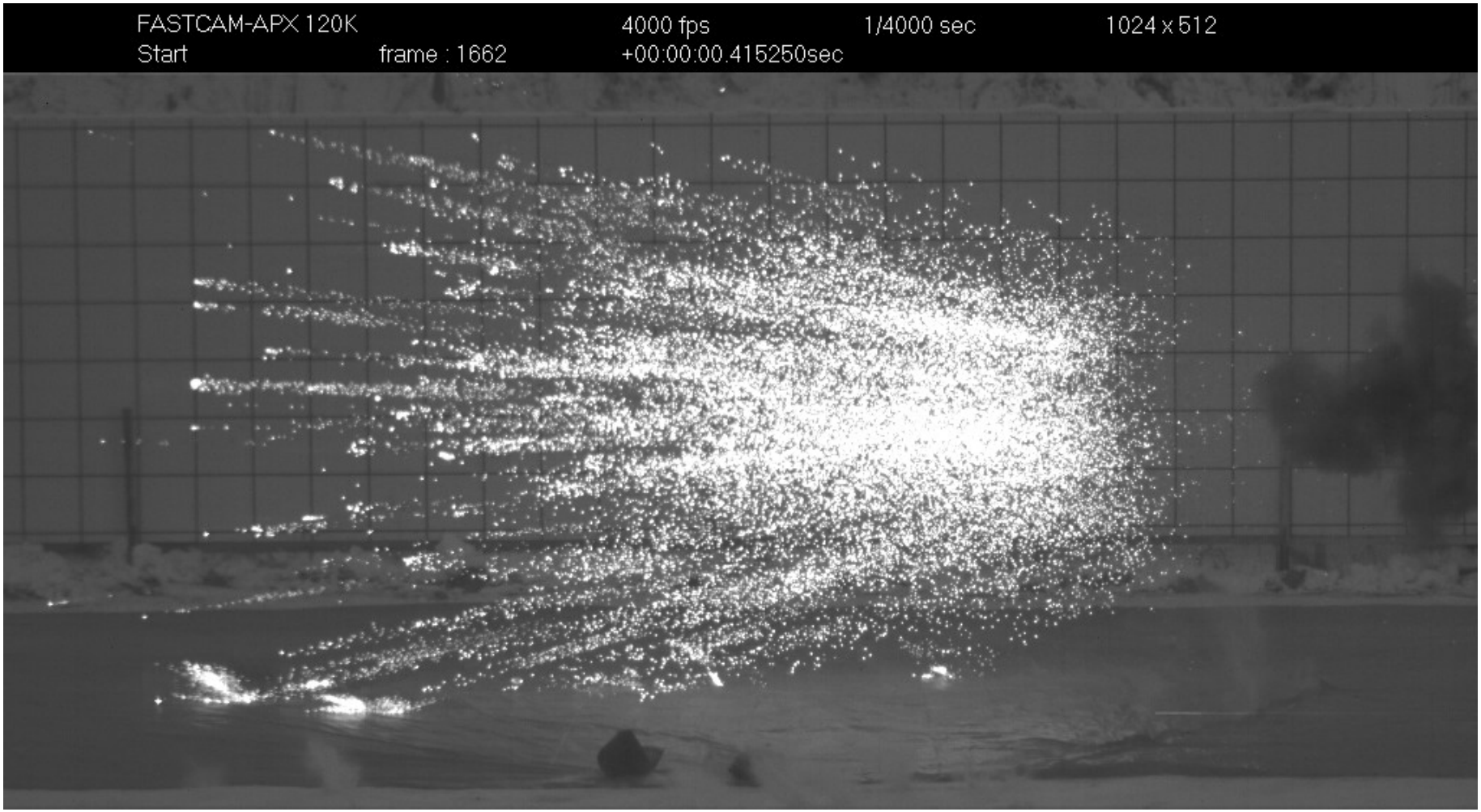


Side View

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Shot 3 – 500m Air Burst Highspeed

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Summary

ABM Test Video

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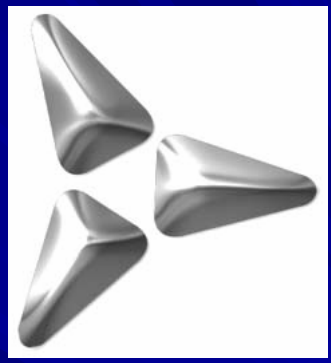
Telepresent Rapid Aiming Platform (TRAP)



Spiral Development of a Lightweight Remote Weapon System and Integration Into a Mobile Sensor-Shooter Network

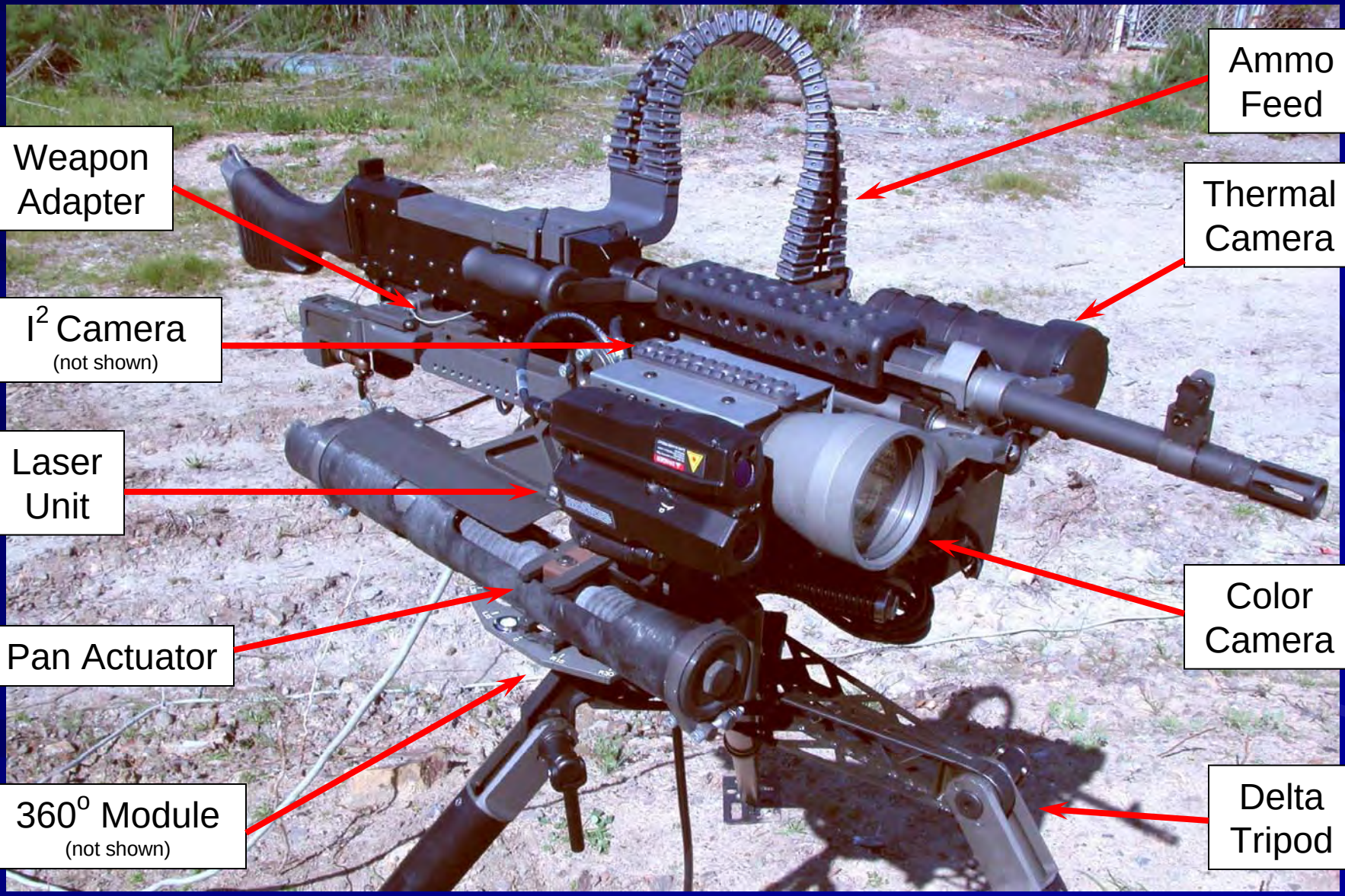
Outline

- 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?



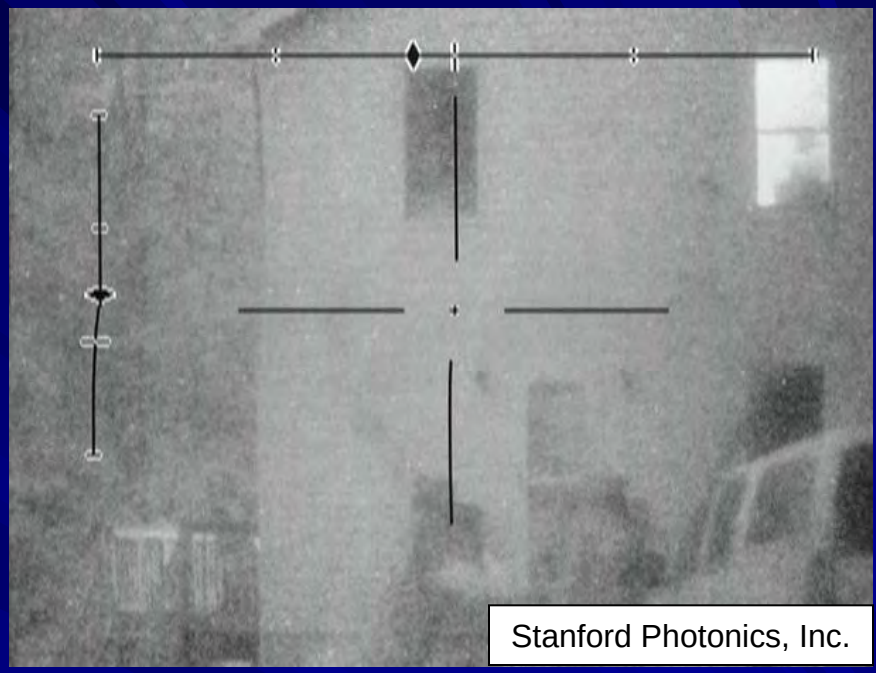
NAVSEA
WARFARE CENTERS
DAHLGREN

TRAP T-250D MK IV



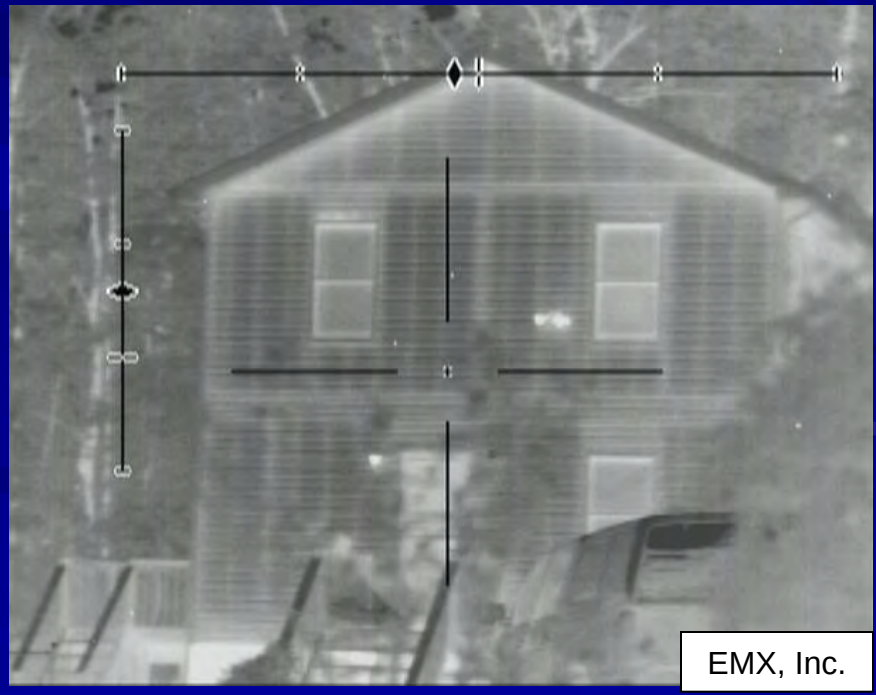
Cameras

- Color - Sony FCB-980S camera + US Optics booster lens; 19^{o} – 1.2^{o} HFOV; 3.75 lbs
- I^{2} - XR/MEGA-10LC tube, Sony XX285 CCD, CAT lens; 12^{o}, 6^{o}, 3^{o} HFOV (digital zoom); 2.7 lbs
- Thermal – L3 320 x 240 core; 12^{o}, 6^{o} HFOV (digital zoom); 1.7 lbs

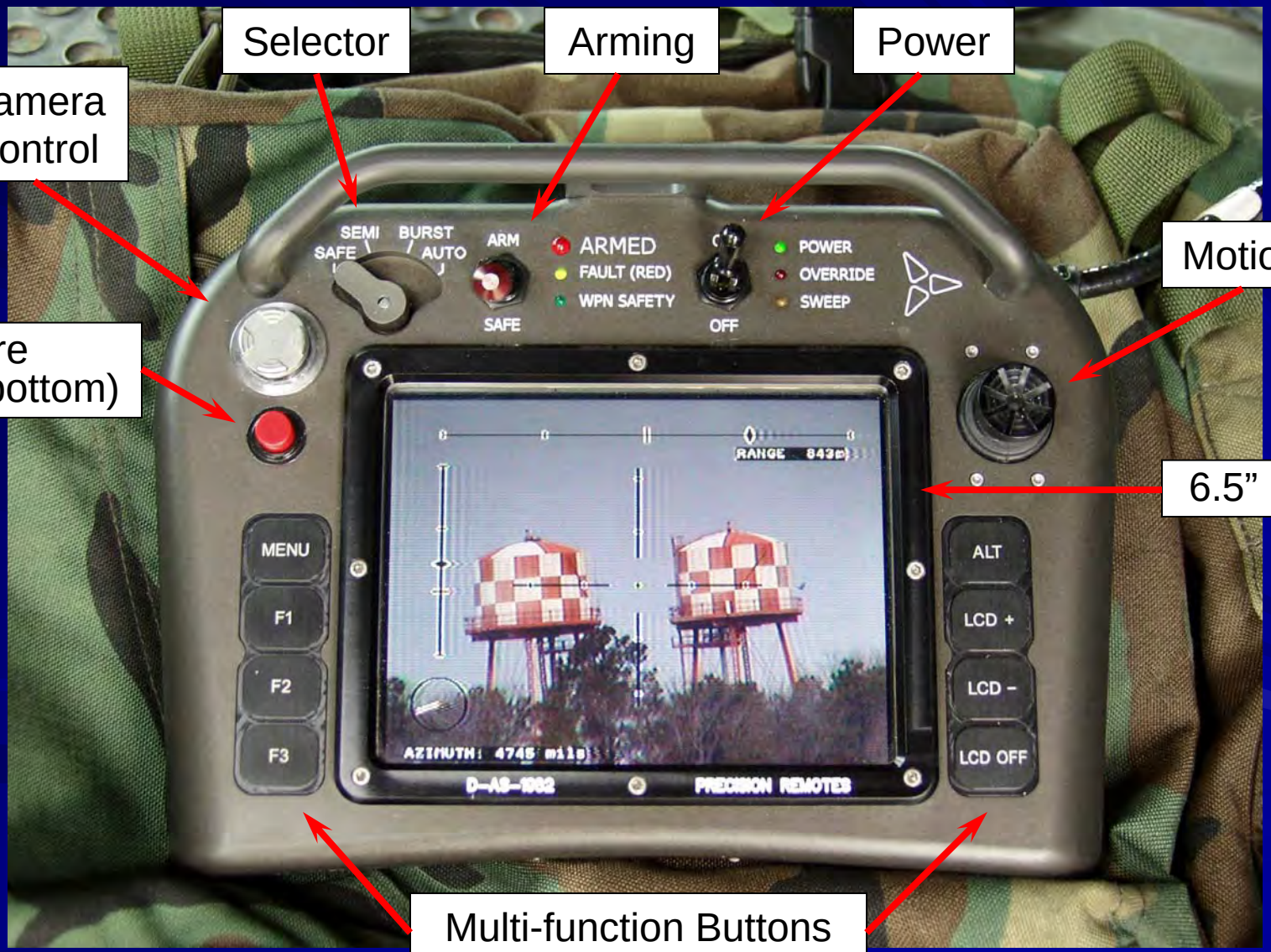

Stanford Photonics, Inc.



Precision Remotes, Inc.


EMX, Inc.

User Interface



Tactical Display



Position

Range

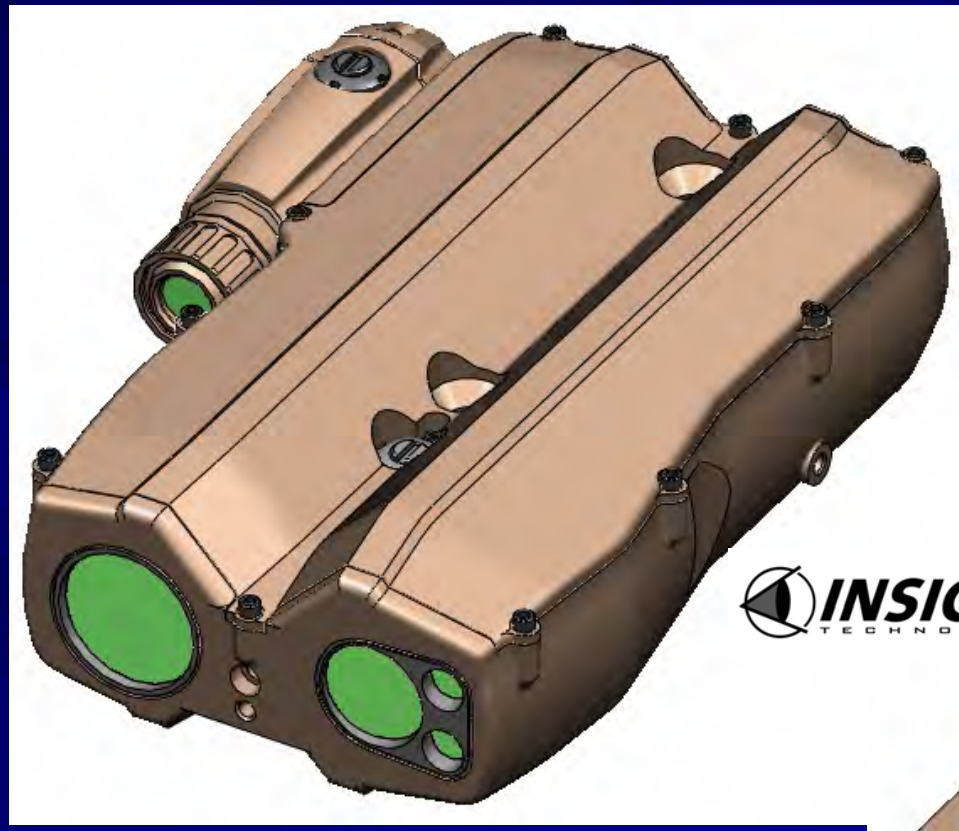
Laser Aim

360 Position

Weapon Aim

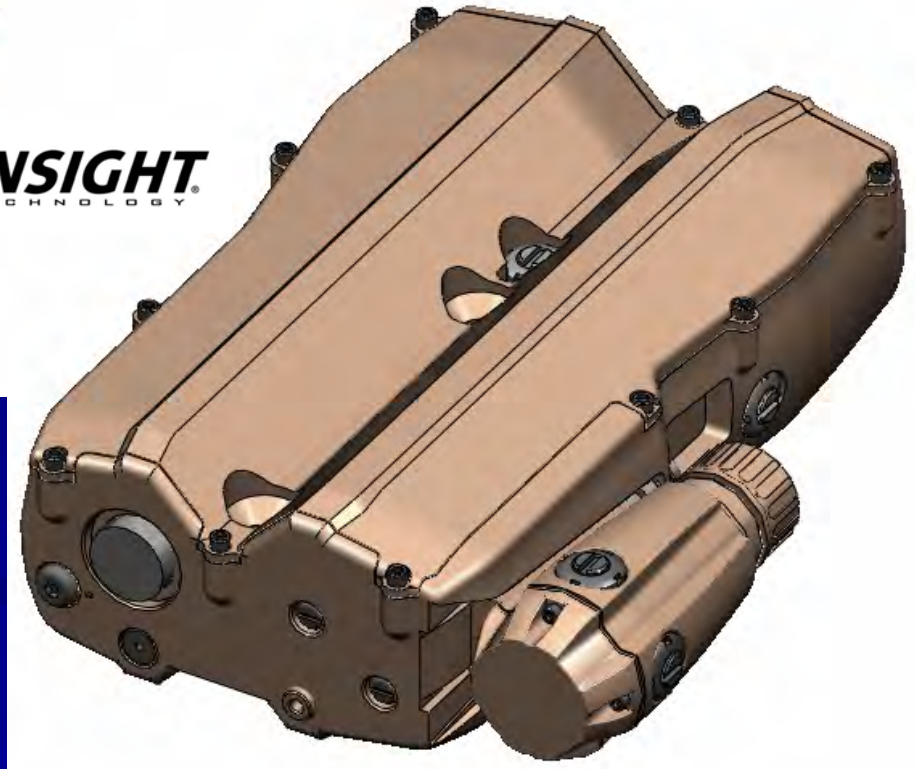
Heading

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)

INSIGHT TECHNOLOGY



- 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

Counter Sniper Vehicle



Sensor: Boomerang



Platform: HMMWV, etc.



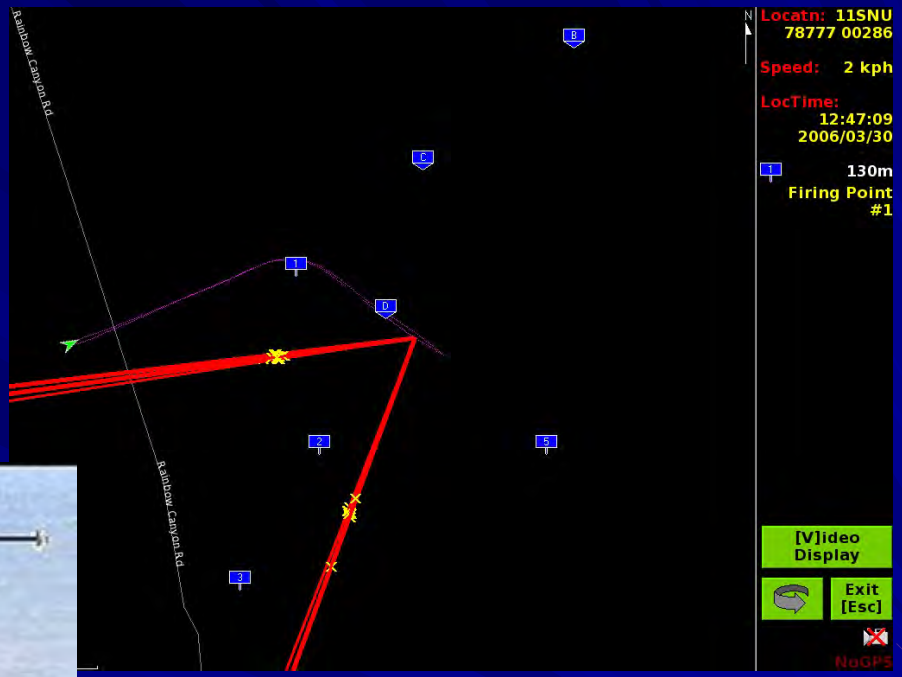
Shooter: TRAP T250

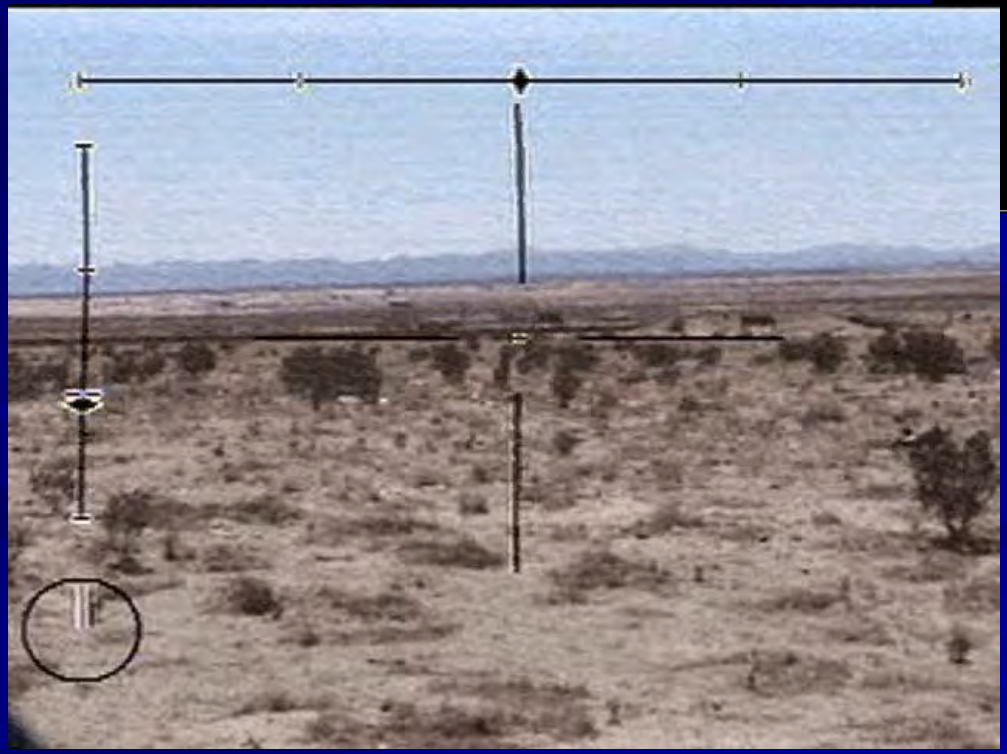
CSV concept to combine emerging / COTS technologies in a light weight, low-cost package to counter the ongoing sniper threat in Iraq and Afghanistan

- 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

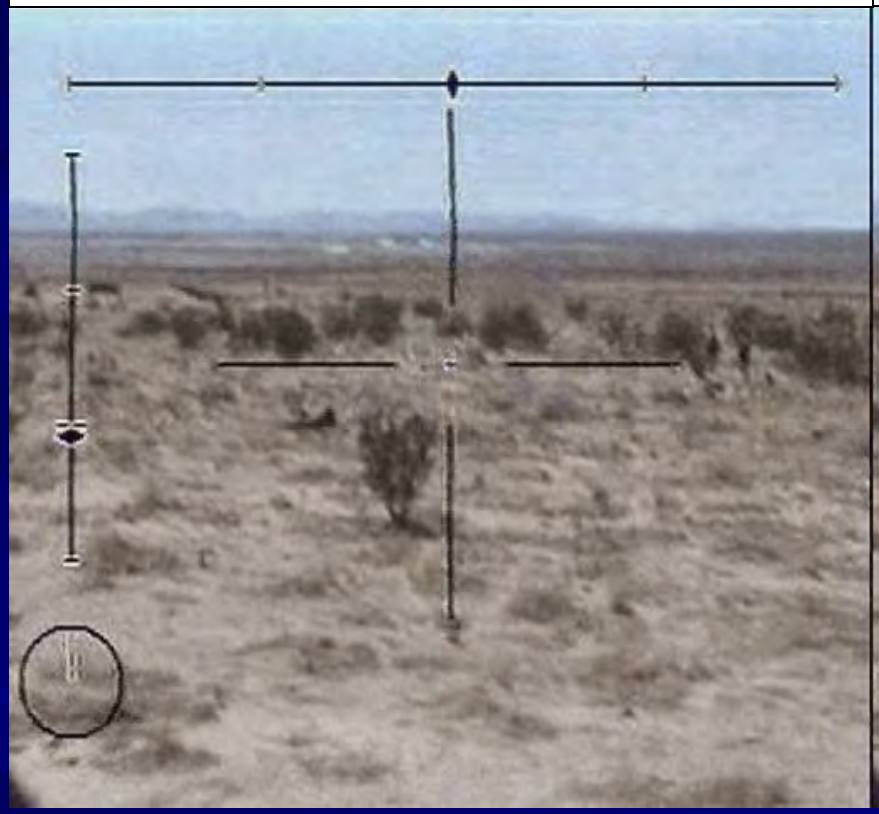
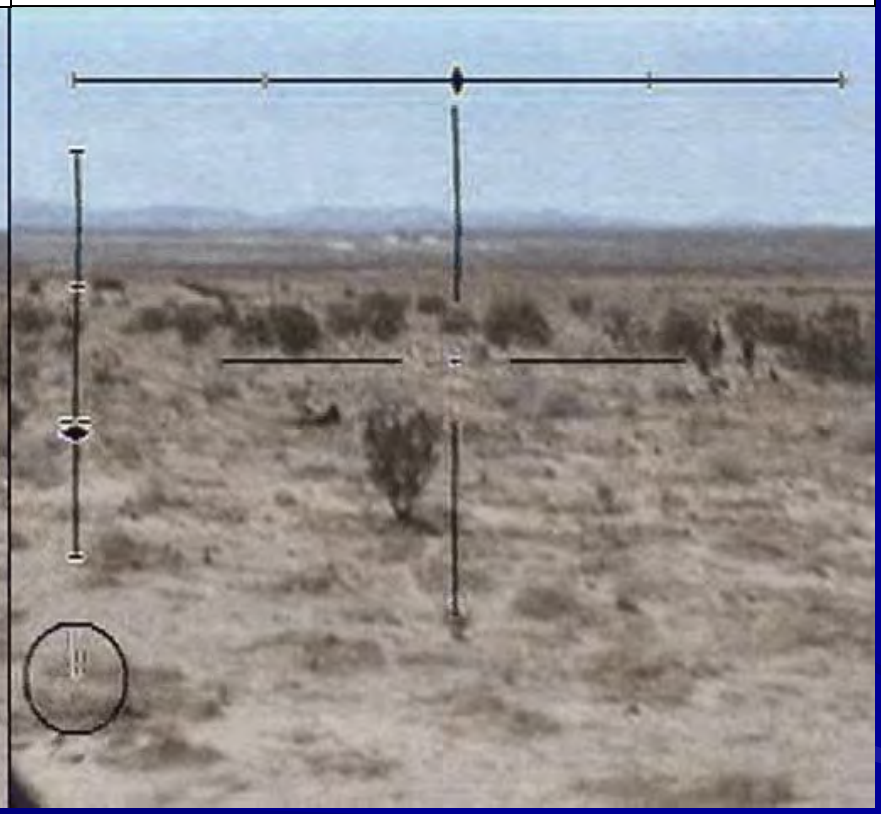




- System can store video/stills for analysis
- Current controller may be replaced with the system in use on Gunslinger and the Full Spectrum Effects Platform (FSEP)
- In-theater testing Summer ‘07

Image Stabilization

Uses Ovation Systems “Stable Eyes” module by QinetiQ Technology

Stabilized	Un-Stabilized
	

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^{o} depression, 190^{o} 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 + I^2), 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

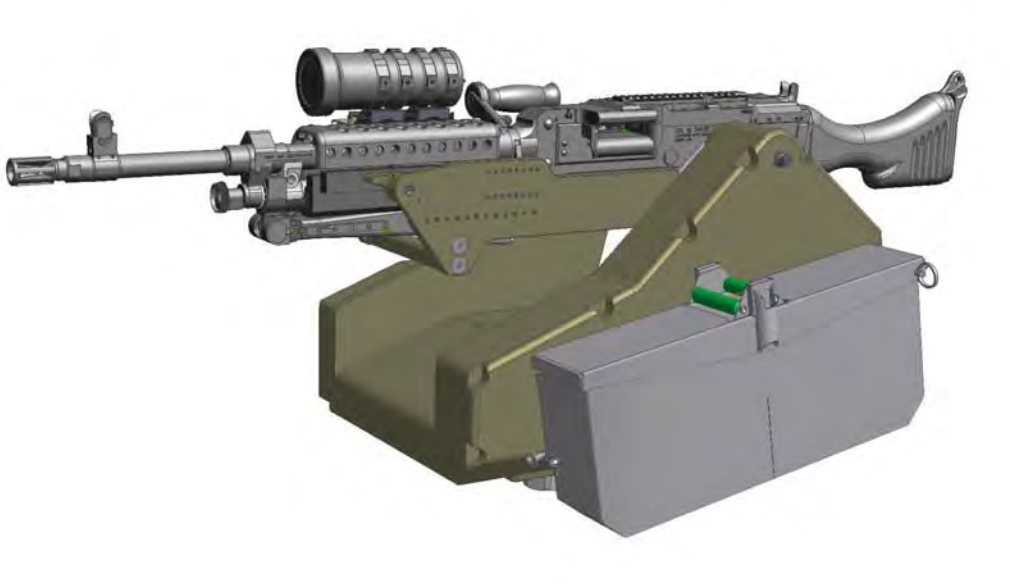
- M42 at 50 m
- 130mm rounds at 500 m
- MK82 bomb at 1,000 m

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) 744-6858 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
- I^2 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



GENERAL DYNAMICS
Ordnance and Tactical Systems

155mm XM1063 Non-Lethal Personnel Suppression Projectile

April 23-26, 2007
Charlotte Convention Center – Charlotte, North Carolina

Public Release Authorization PAO# 194-07

GENERAL DYNAMICS
Ordnance and Tactical Systems

XM1063 - Outline

- Introduction
- Why Non-Line of Sight Non-Lethal?
- XM1063 Design
- Program Timeline
- Program Successes
- Upcoming Program Events
- Summary/Conclusions
- Acknowledgments

Public Release Authorization PAO# 194-07

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

Public Release Authorization PAO# 194-07

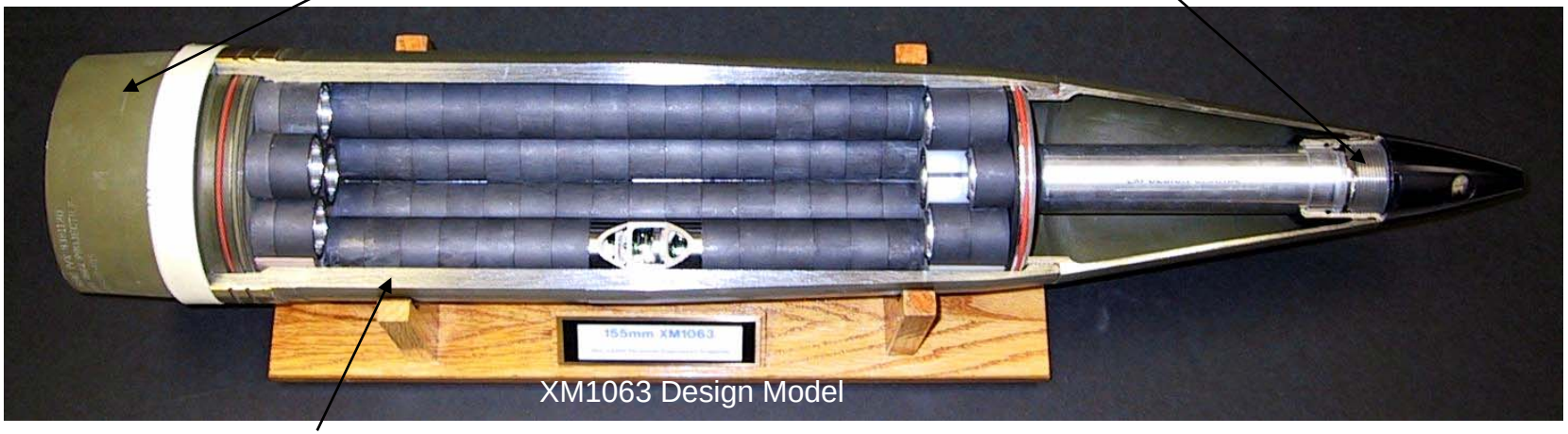
XM1063 – Why Non Line of Sight Non-Lethal?

- 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

Public Release Authorization PAO# 194-07

XM1063 Design

Utilizes Type Classified M864 DPICM Projectile Body, Base Burner, Fuze, Expulsion Charge



XM1063 Design Model

Non-Lethal Submunitions Replace DPICM Payload

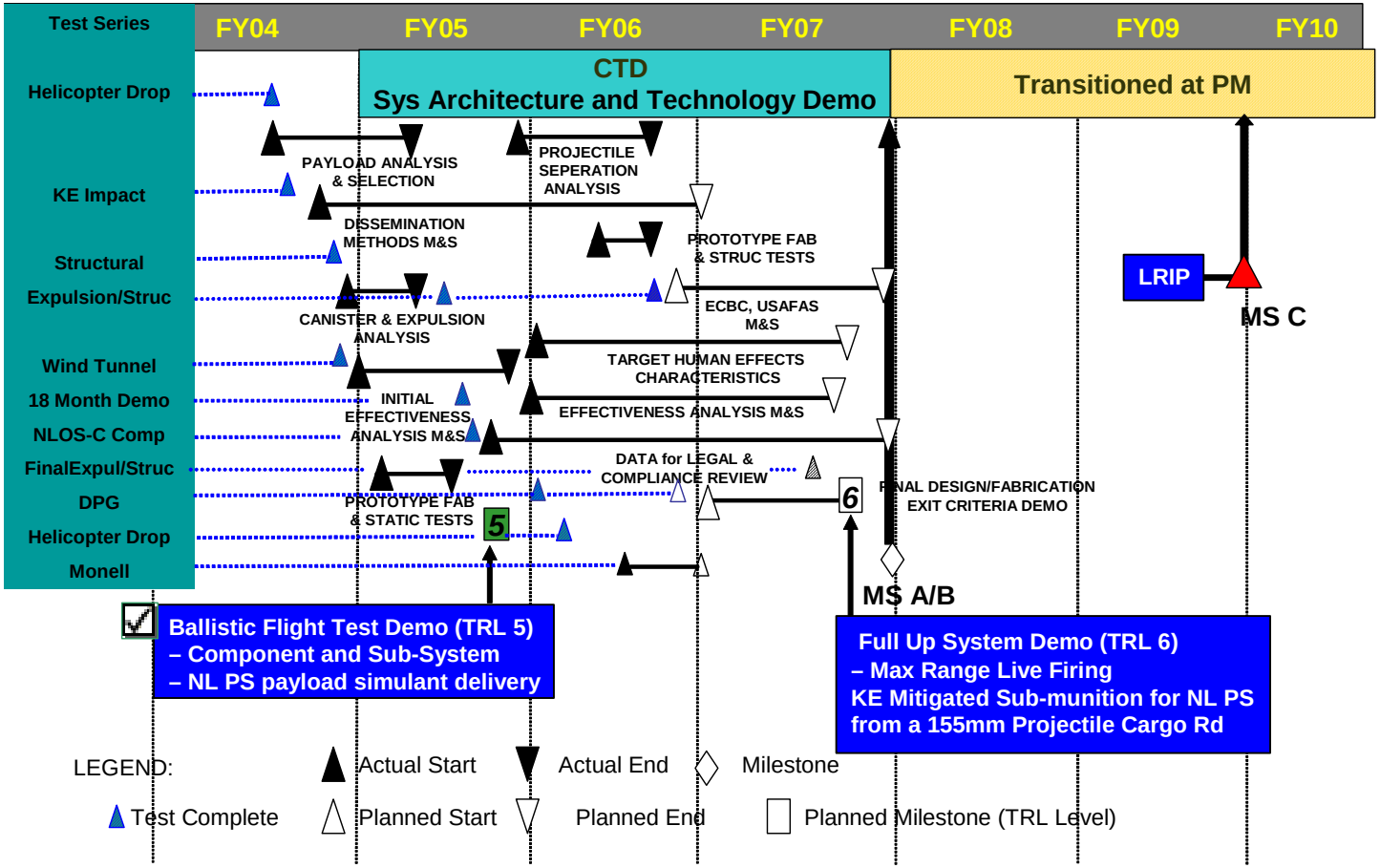

XM1063 Non-Lethal Submunition – Post Dispense

Submunitions Dispense Non-Lethal Personnel Suppression Agent Without Detonators or Explosives

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GENERAL DYNAMICS
Ordnance and Tactical Systems

XM1063 – Program Timeline



Public Release Authorization PAO# 194-07

GENERAL DYNAMICS
Ordnance and Tactical Systems

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)

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GENERAL DYNAMICS
Ordnance and Tactical Systems

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

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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

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GENERAL DYNAMICS
Ordnance and Tactical Systems

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

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GENERAL DYNAMICS
Ordnance and Tactical Systems

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.

Public Release Authorization PAO# 194-07

GENERAL DYNAMICS
Ordnance and Tactical Systems

XM1063 POC Information

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  - General Dynamics OTS
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  - jennifer.mccormick@red.gd-ots.com
- Co-author:
  - Robert Lee
  - US Army ARDEC
  - (973) 724-4134
  - robert.lee10@us.army.mil

Public Release Authorization PAO# 194-07

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

KEVIN MINER

WEAPON SYSTEMS & TECHNOLOGY DIRECTORATE

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**
  - **PERFORANCE TESTING**
- **TRANSITION**
- **SUMMARY**

LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT

- 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

RAVEN was Invented at Benet Laboratories, US Army, Oct 2002 by Dr. Eric Kathe (Patent: 6,460,446)

While Maintaining the Efficiency & High Projectile Velocity of Conventional Guns (No Loss in Projectile Velocity)



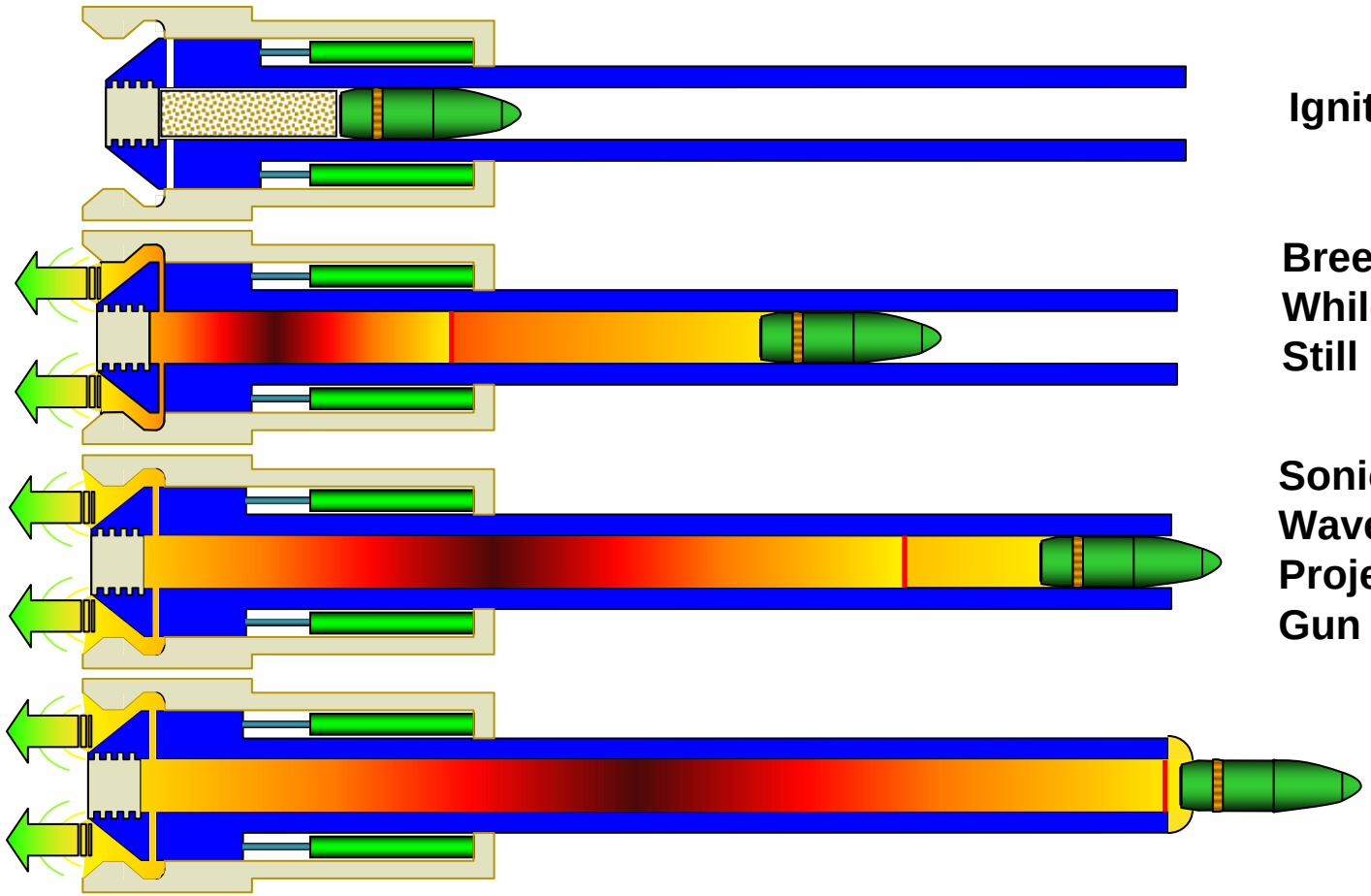




Lightweight Systems



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

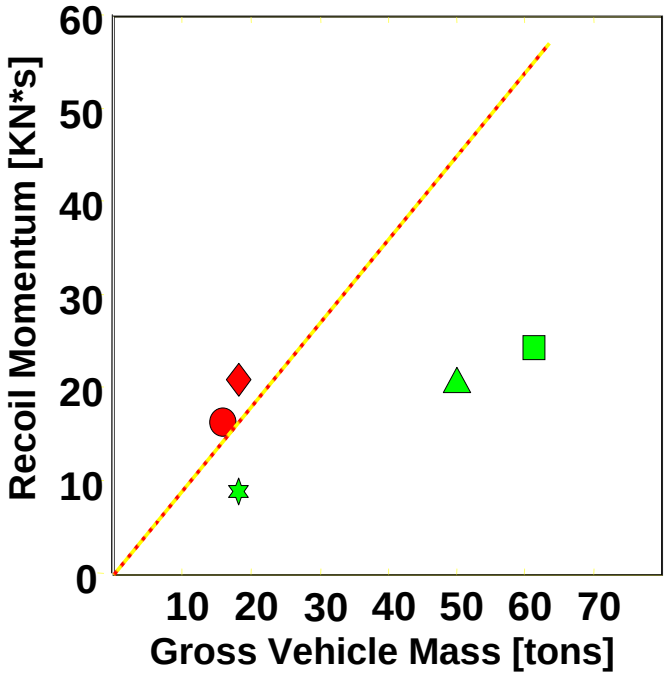
Sonic Rarefaction Wave Catches Projectile At the Gun Muzzle

No Velocity Loss

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**





M551	116%	OSL
M1A1	49%	OSL
M8 AGS	128%	OSL
M60A1	43%	OSL
105mm RAVEN	54%	OSL

Ogorkiewicz Stability Limit (OSL)



LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT



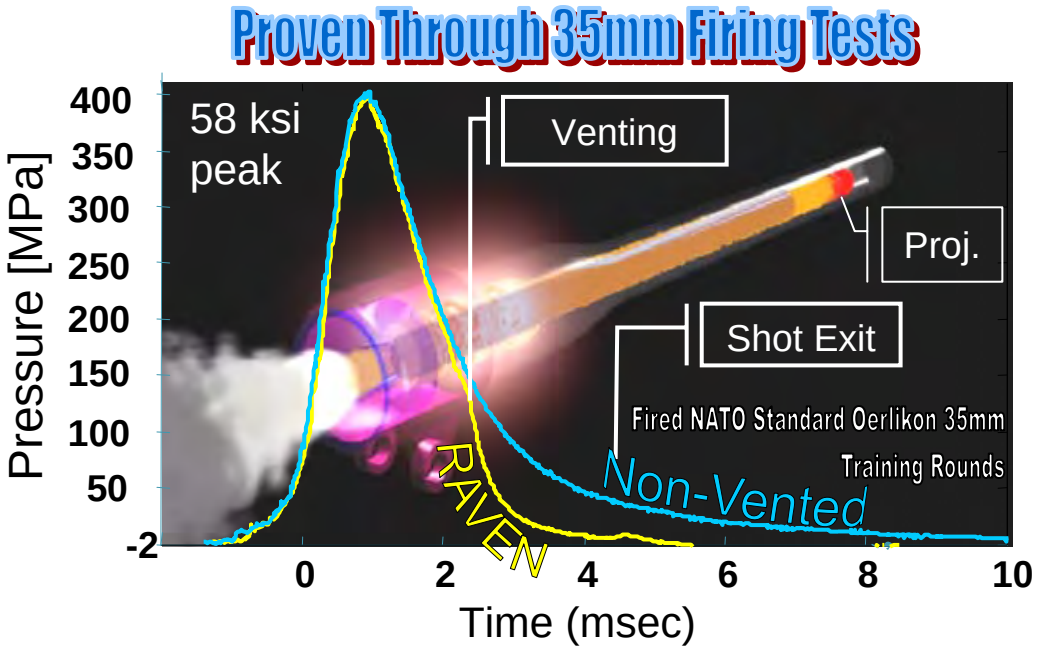
- **Approximately 50% Reduction in Barrel Heating**
  - **Enables Lightweight Gun Barrel Technology**
  - **Allows Increased Firing Rate**
  - **Mitigates Need for Erosion Protective Coatings**
  - **May Use More Energetic Propellants**
- **Approximately 2/3 Reduction in Muzzle Blast**
  - **Lower Vision 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**



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**

Advanced Interior Ballistics Models

Design & Testing, Fabrication

Gun & Ammo Design, Systems Engineering

MENTIS SCIENCES, INC.
150 Dow Street, Tower Two • Manchester, NH 03101
603.624.9197 • Fax 603.624.9254

Advanced Materials Development & Application



LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT



- **<u>Direct Fire RAVEN Demonstrator</u> (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)**
- **<u>Next Generation RAVEN Demonstrator</u> (FY07 Design, FY08 Build & Test)**
  - **Design for Minimum Weight – Advanced Materials**
  - **Alternative & More Efficient Vent Methods**

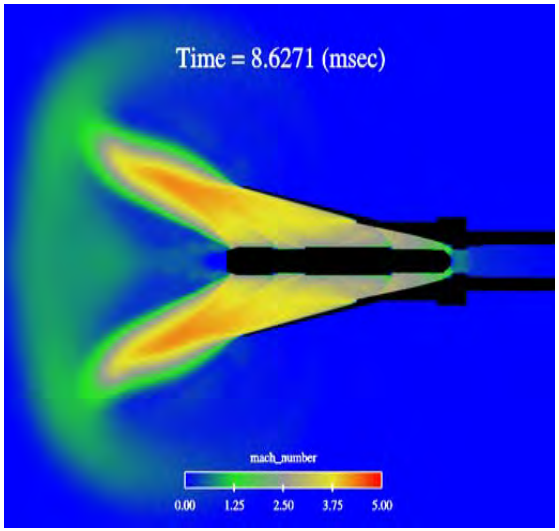
- **Modeling & Simulation**

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**

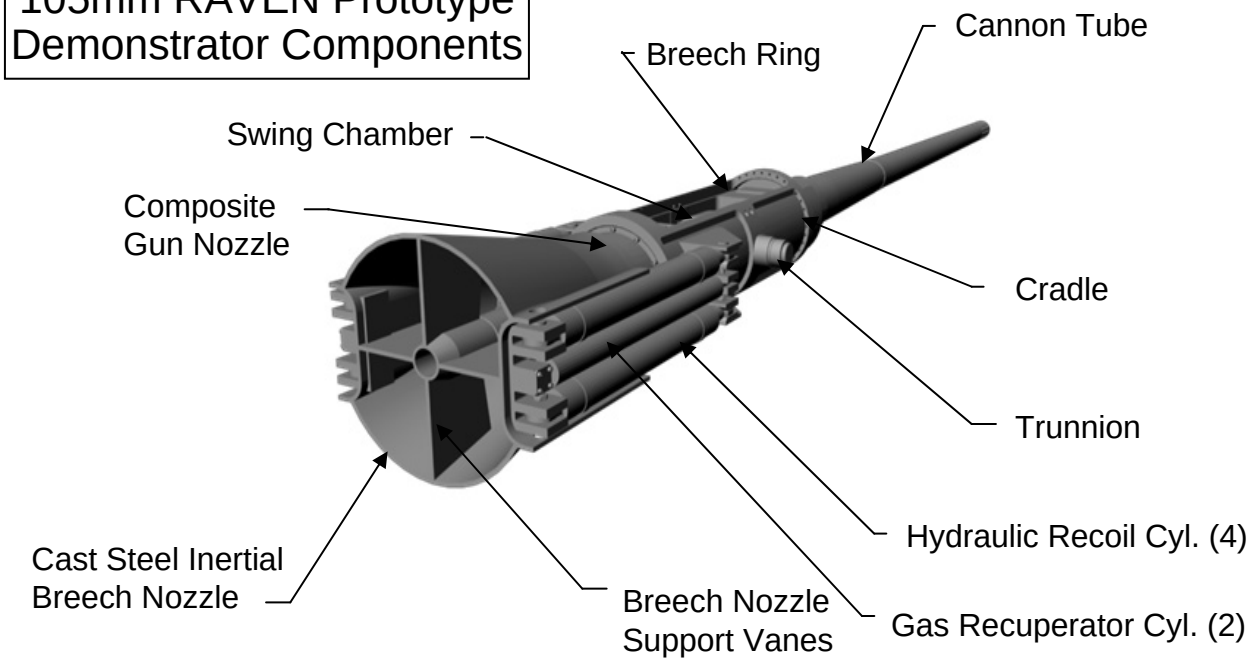
Computational Fluid Dynamics_Fluent, GTBL, NGEN

- **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 Demonstrator Components







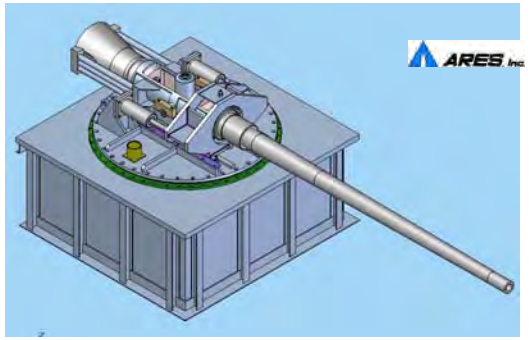
System	Trunnion Impulse	Muzzle Energy*	Energy/Impulse
105mm M68/M900	19,100 NS	7.86 MJ	412
105mm MRAAS/Slug	23,580 NS	8.97 MJ	380
120mm M256/M829A3	29,400 NS	11.7 MJ	398
105mm RAVEN	9,852 NS	8.76 MJ	889

* Ambient

58% Recoil Reduction
Over RAVEN Closed Breech
& FCS MRAAS Baseline

- **Performance Testing**

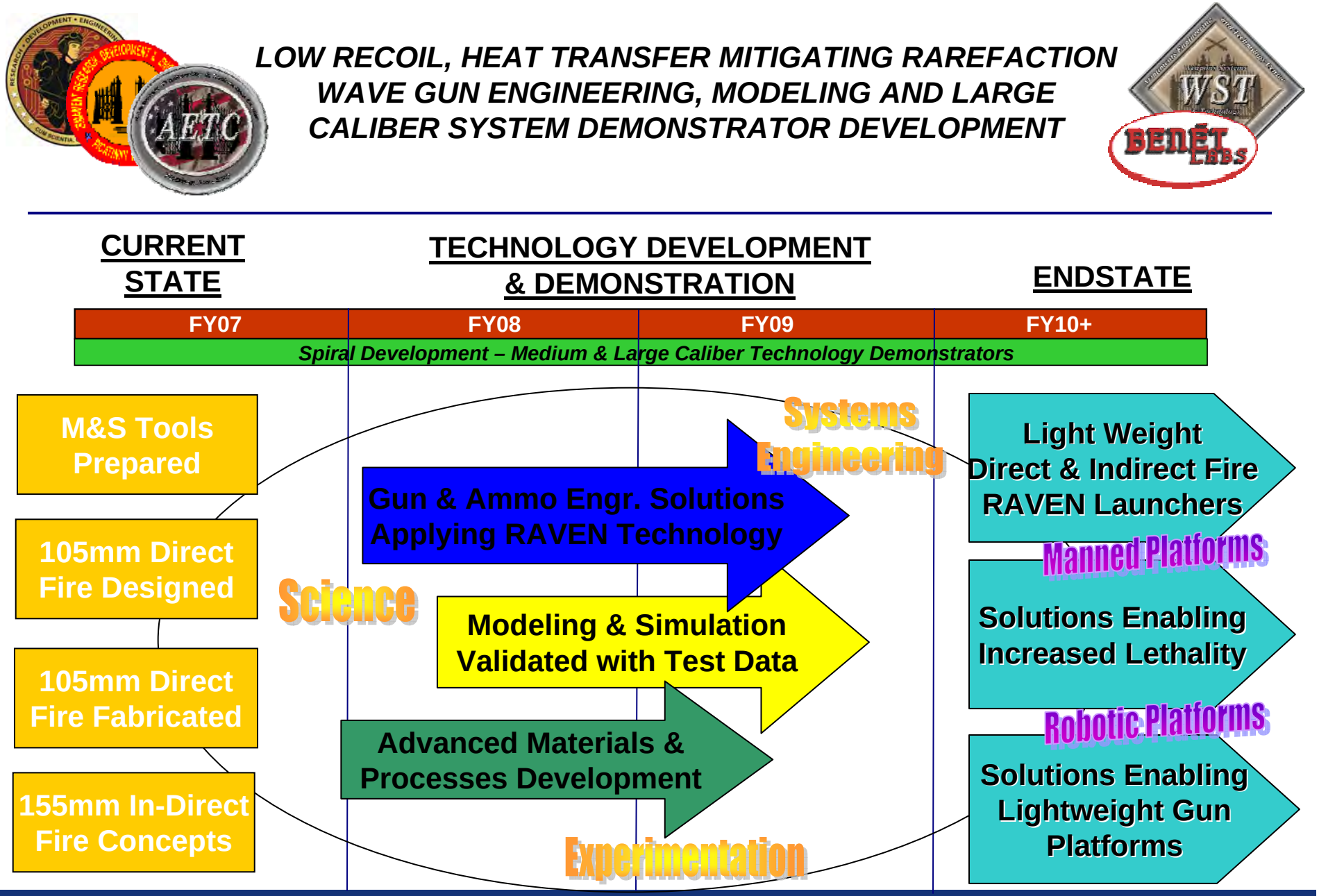
  - **Hardstand Testing _ M&S Validation**
    - **Interior Ballistics Engineering Data**
    - **Recoil Dynamics Engineering Data**
    - **Thermal Measurements**
    - **Blast Field Characterization**



  - **Light Weight Vehicle Platform Testing**
    - **Stability Analysis**
    - **Blast Field Characterization**



LOW RECOIL, HEAT TRANSFER MITIGATING RAREFACTION WAVE GUN ENGINEERING, MODELING AND LARGE CALIBER SYSTEM DEMONSTRATOR DEVELOPMENT





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

Ultrasonic Temperature and Heat Flux Sensor Technology



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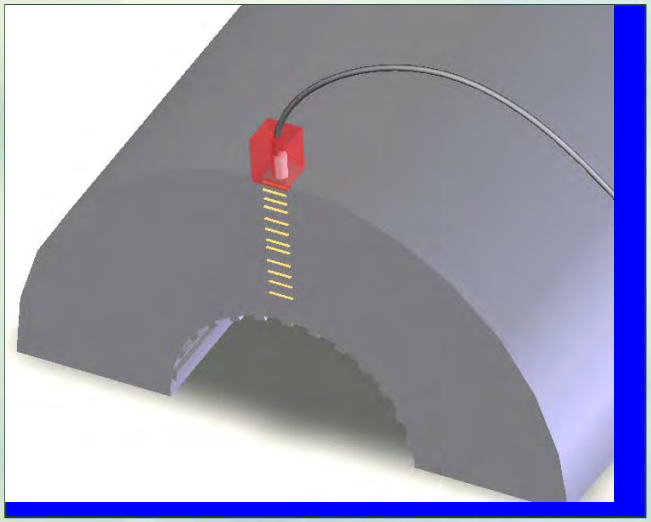
Problem Statement

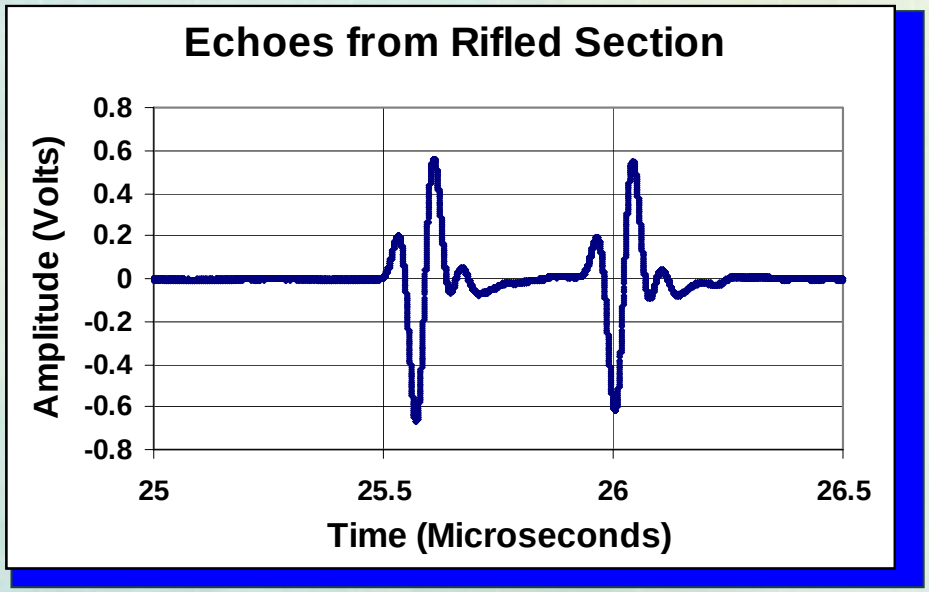
- Auto ignition or “cook-off” is one of the most serious safety concerns when firing large caliber guns.
- Researchers inability to perform measurements at locations where they are needed



Measurement Concept Temperature

- Precise Timing Measurements to Measure Temperature & Erosion





Determining Inner Chamber Surface Temperature

$$\frac{\text{Change of Echo Separation}}{(\text{Velocity Temperature Coefficient}) \times (\text{Echo Separation})}$$

Mark 45 MOD 4 Live Fire Trials

Multiple Successful Live Fire Trials

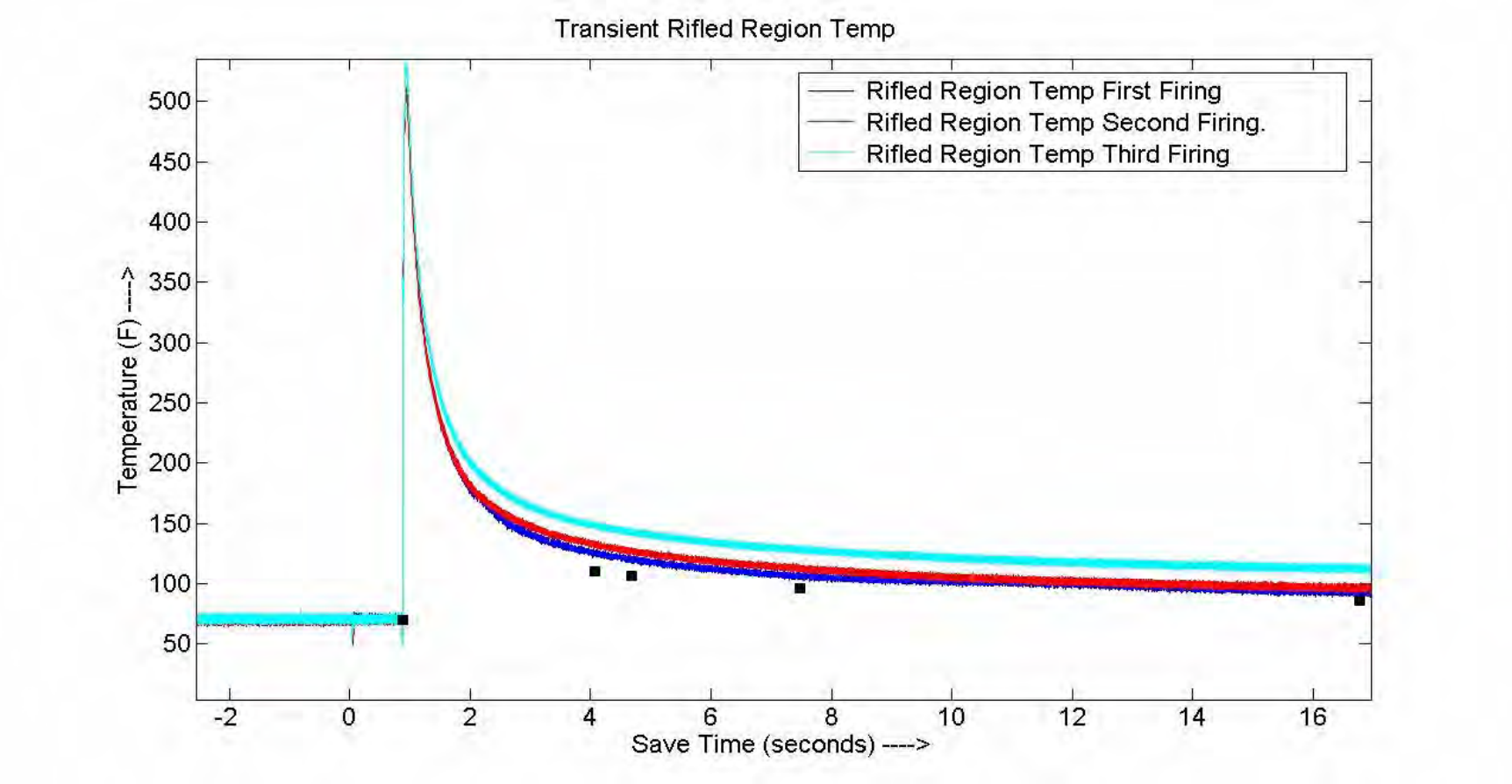


NETS (NON-Intrusive Erosion and Temperature Sensor) prototype installed on the MK45 MOD 4 Gun at NSWCDD for several live fire experiments in 2005-2006

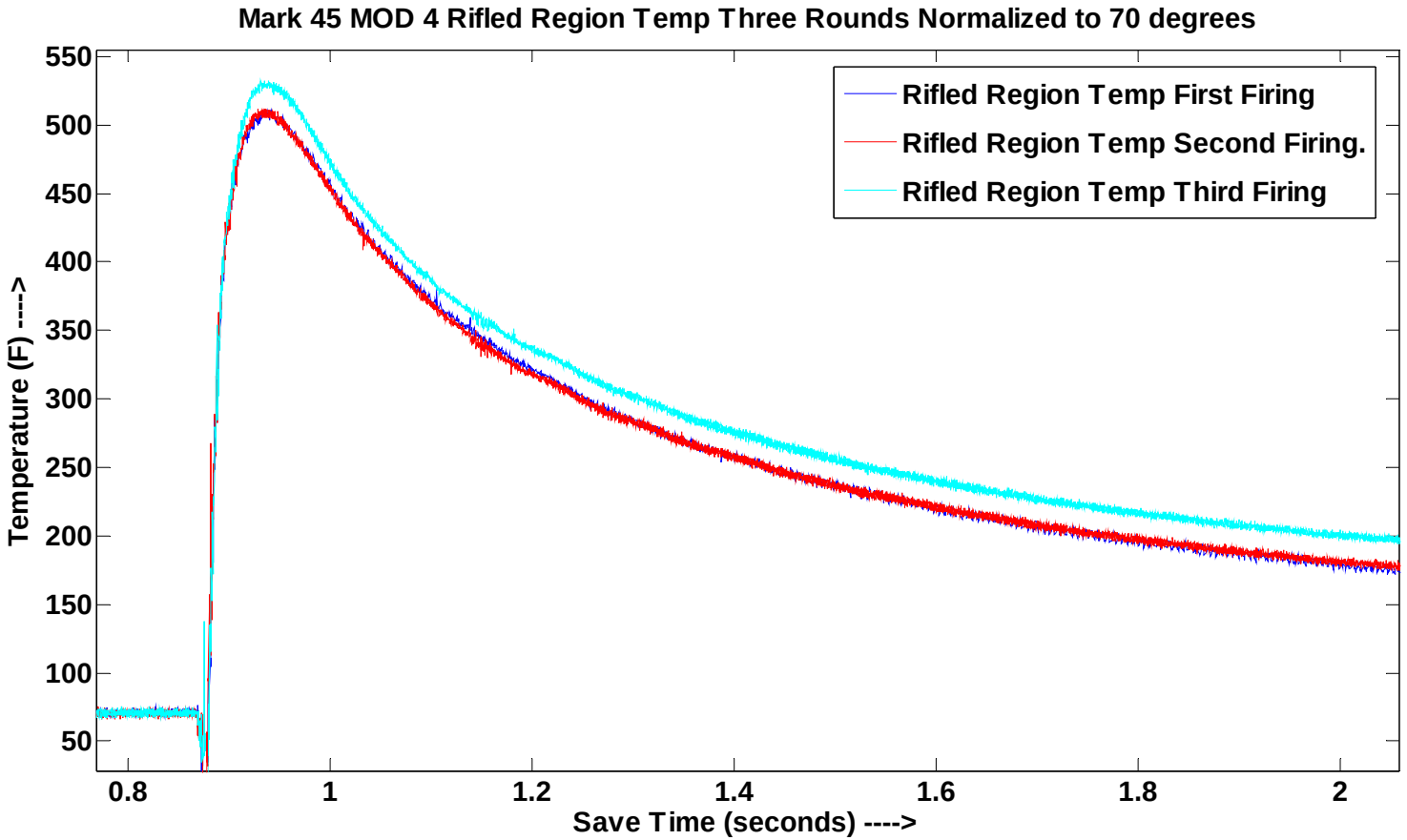


- **Accurate Internal Temperature Measurement**
- **Transient Temperature Measurement**
- **Off-line Heat Flux Calculations**

Precise Internal Temperature Measurement

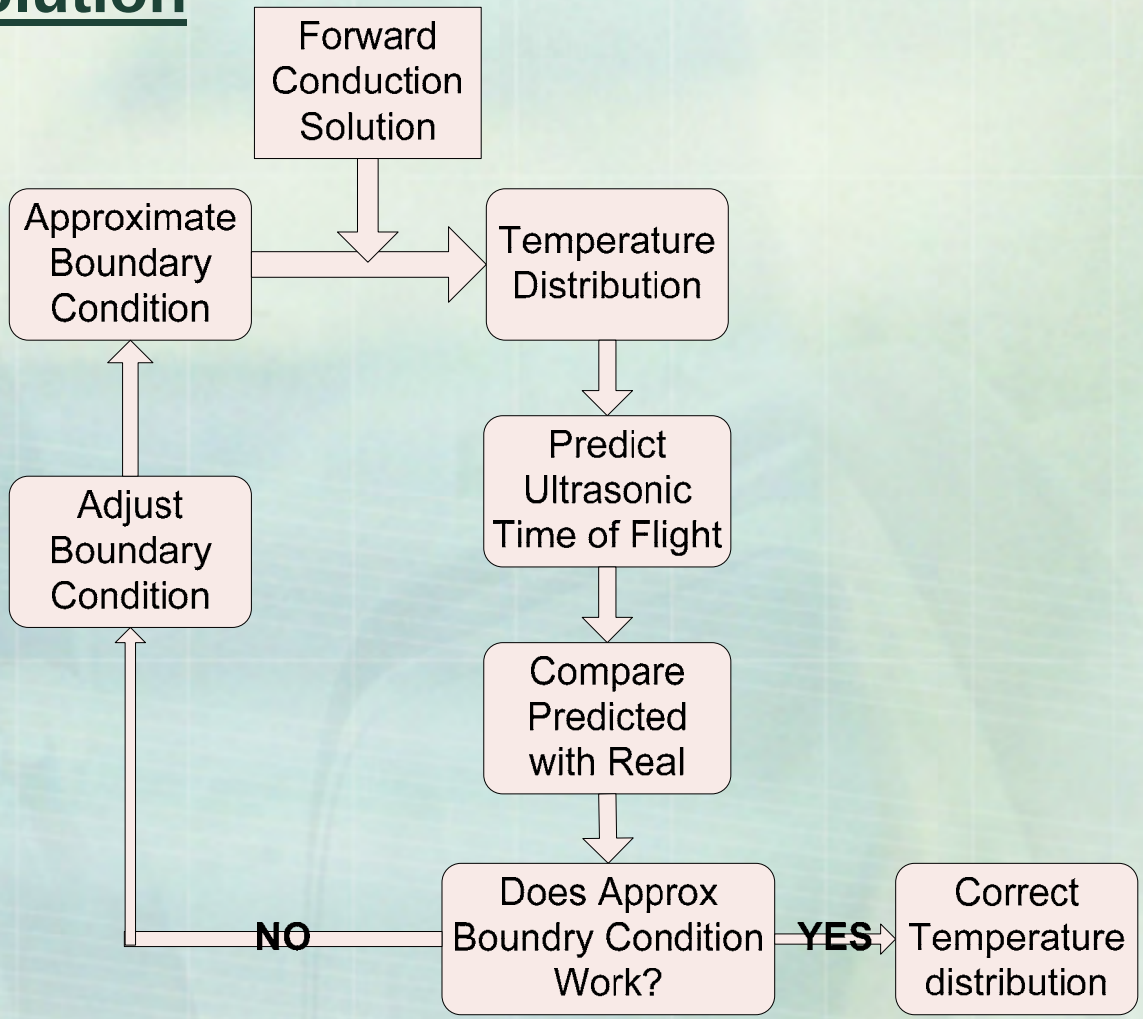


Transient Temperature Measurement

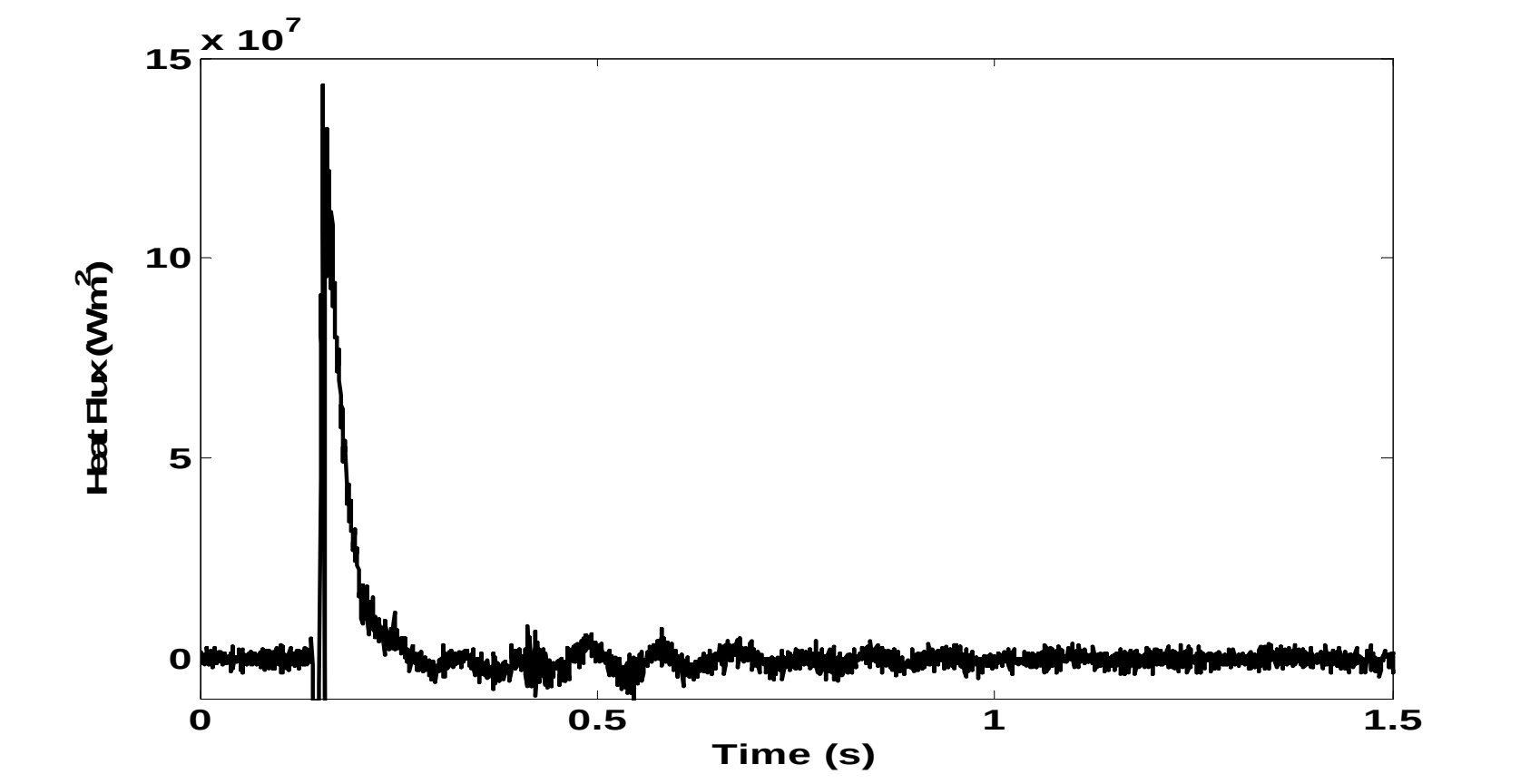


Measurement Concept for Heat Flux:

Inverse Solution



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

Features	Advantages	Benefits
Gun Temperature	Non-Intrusive Direct Measurment	Increased Gun Safety
Gun Erosion	At Sea Measurement Continuously Monitor	Tactical and Safety
Transient Temperature	Non-Intrusive High Speed Measurements	Barrel Coatings/ Propellants Combustion Instability
Heat Flux	Non-Intrusive High Speed Response	Barrel Coatings/ Propellants Gun Research

Opportunities for the *Ultrasonic Temperature and Heat Flux Sensor*



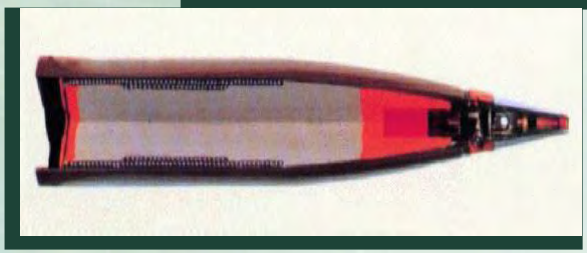
Gun Safety

- 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.

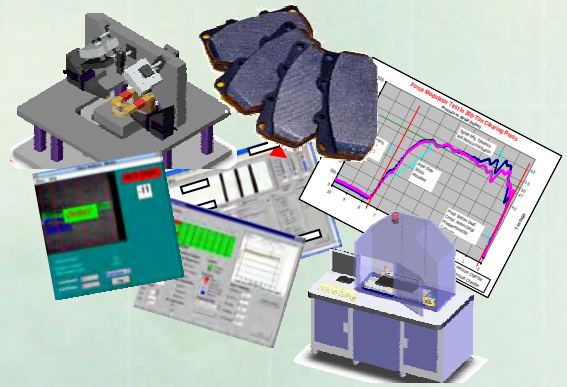
Non-destructive nature of the measurements allows for easy implementation without disruption to ongoing tests.



Ultrasonic Temperature and Heat Flux Sensor Technology

Thanks For Listening!





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US ARMY ARMAMENTS RESEARCH, ENGINEERING AND DEVELOPMENT CENTER

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

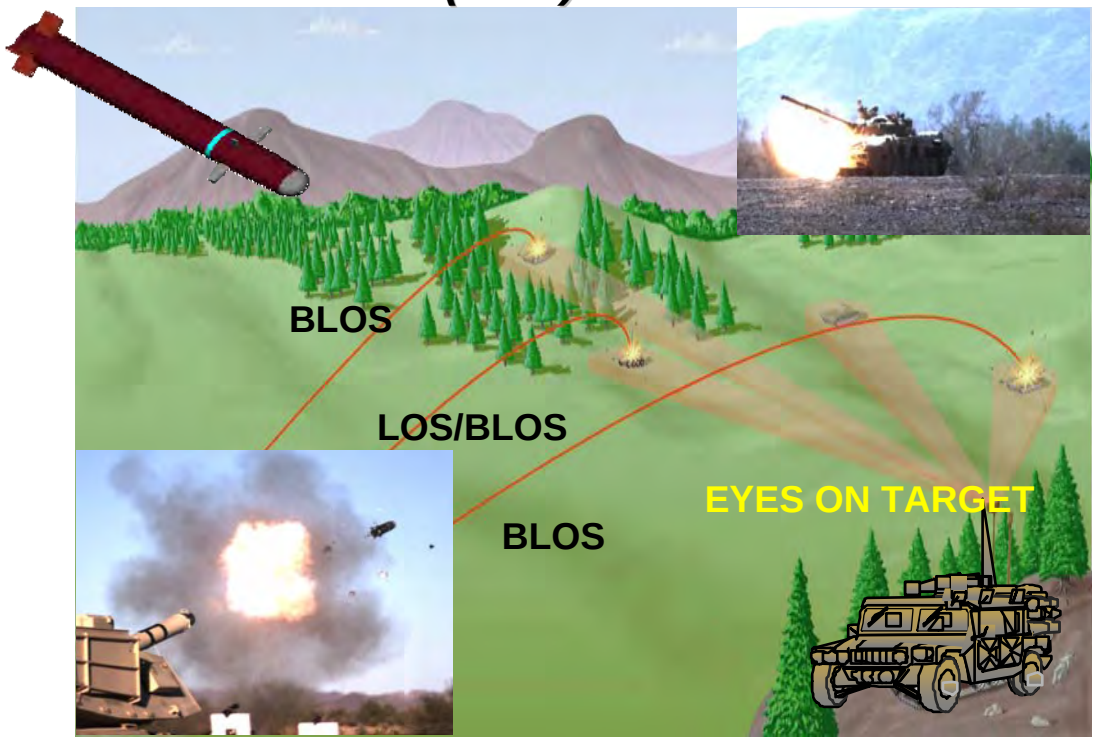
Outline

- **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

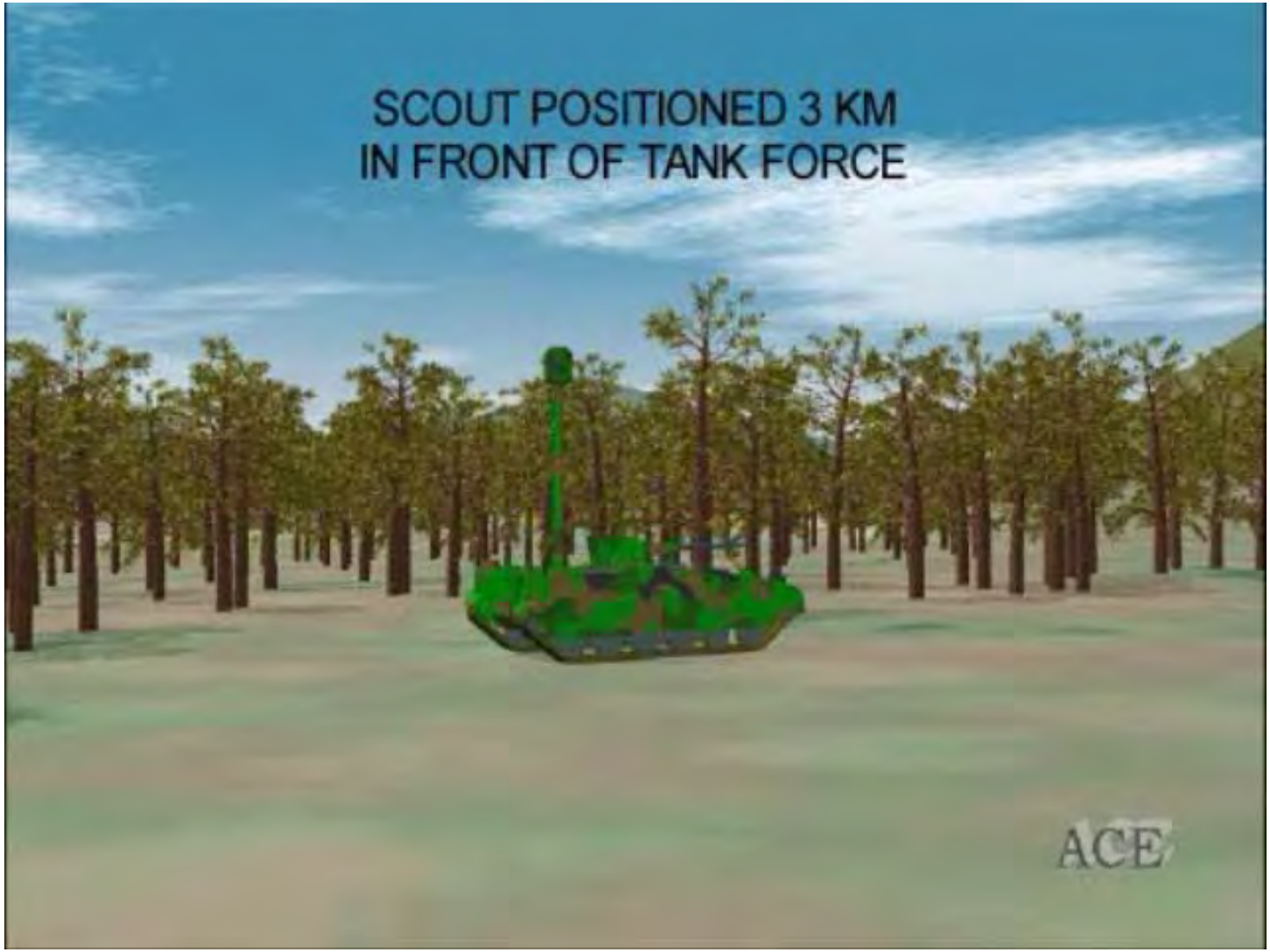
BLOS Operational Modes

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



Mid-Range Munition Concepts

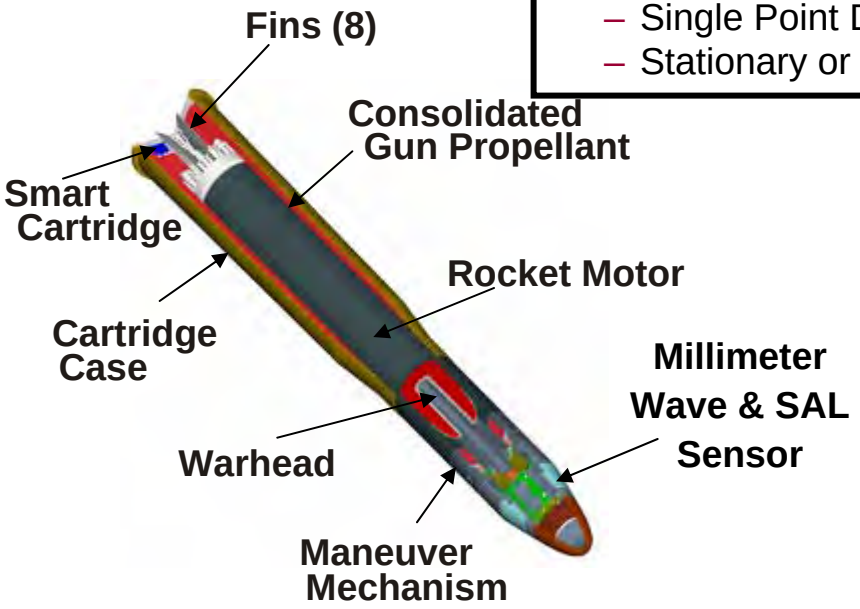
MRM-KE

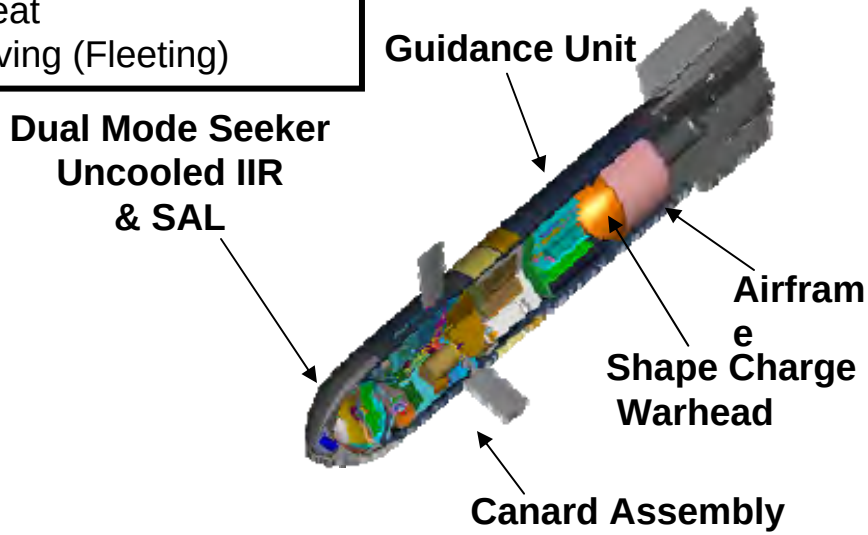


- **Target Types**
  - Main Battle Tanks (MBT) w/ ERA
  - Light Armor (BMP)
  - Self Propelled Artillery (SPH)/(MRL)
  - Air Defense Artillery (ZSU)
  - Bunkers (Earth & Timber)
- **Attributes**
  - Fleeting High Payoff Targets
  - Single Point Defeat
  - Stationary or Moving (Fleeting)

MRM-CE

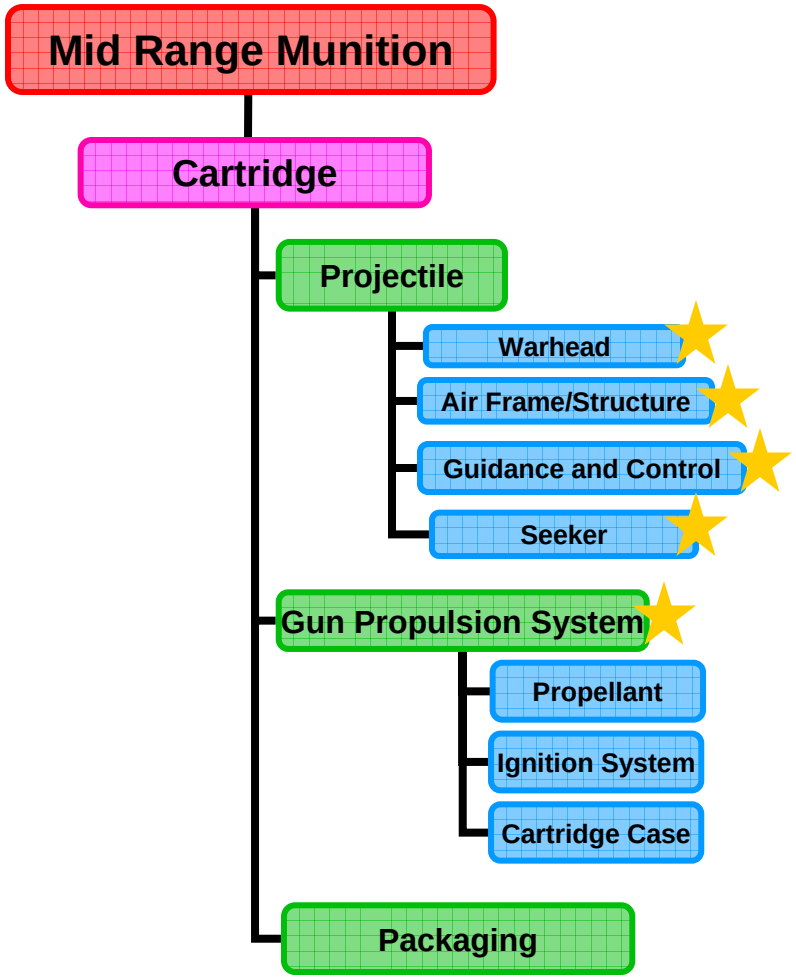






Program has Achieved Autonomous, SAL, and Dual Mode TRL 6!

MRM Program Approach



★ Recommended Critical Technologies

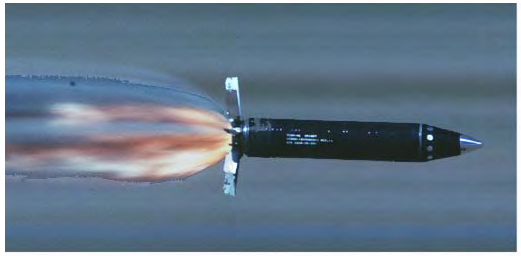
- Bring all Critical Technologies to TRL 6
- Develop two concepts in parallel to reduce program risk
- Team with PEO-AMMO (PM-MAS) to facilitate/accelerate transition to SDD

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**



Kinetic Energy warhead



Smear from Round #109



Shaped Charge Warhead



Air Frame Subsystem

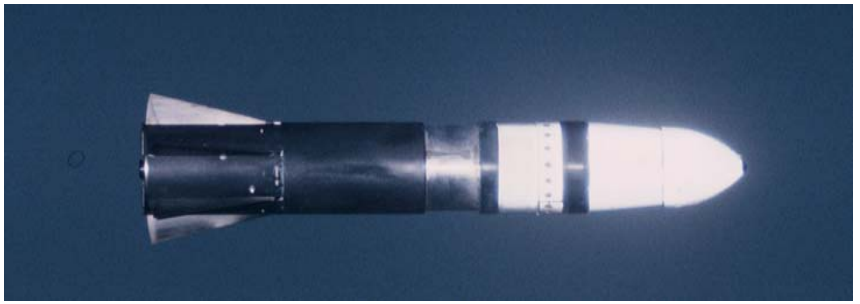
- **Technology:**
  - **Robust and maneuverable airframe for BLOS rang**
  - **Deployable Fins**
- **Achieved: TRL 6**
- **Basis for Assessment:**
  - **Conducted Wind tunnel testing and 6-DOF Aero. Model**
  - **Demonstrated Airframe structure integrity and BLOS flight at tactical velocities**
  - **Verified max. range capability**
  - **Demonstrated rocket motor boost to kill velocity**
  - **Demonstrated performance across temp. range**
  - **Validated in GTH testing**







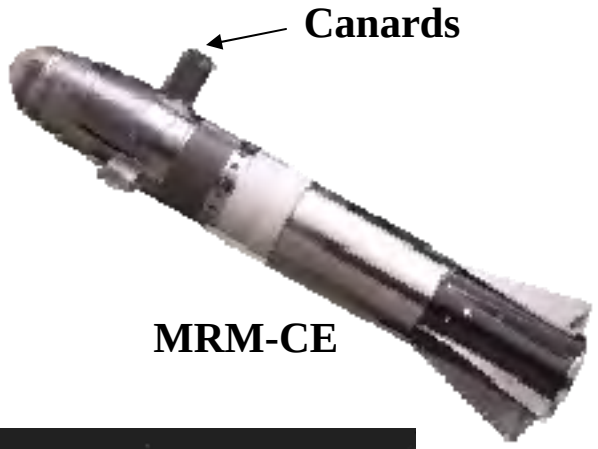
MRM-KE



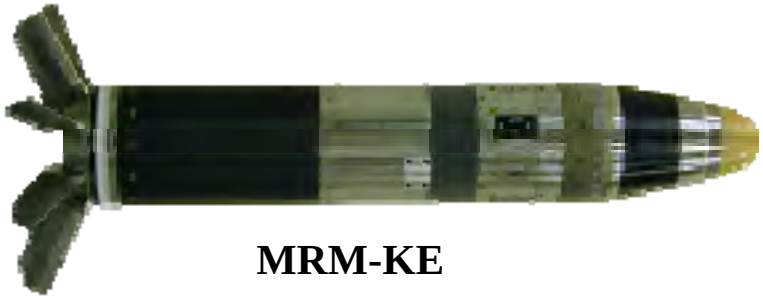
MRM-CE

MRM
Guidance and Control

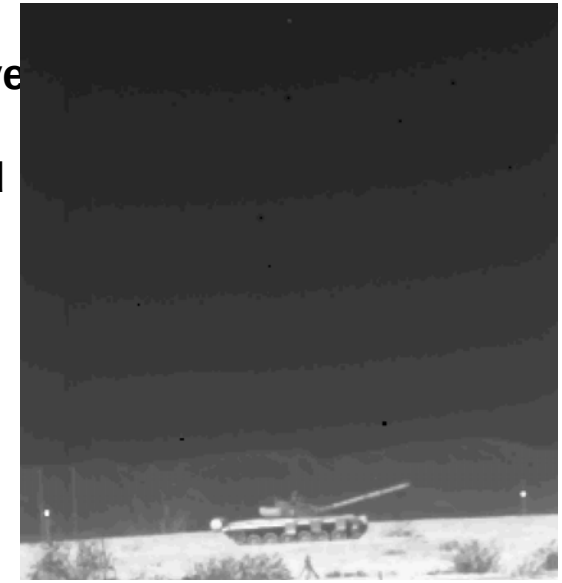
- **Technology:**
  - **Thrusters, Canards, IMU**
- **Achieved: TRL 6**
- **Basis for Assessment:**
  - **Verification of designs was completed through Finite element modeling, rail gun testing, bench testing and ballistic testing.**
  - **Demonstrated pre programmed maneuver projectiles fired from 120mm gun – all survived setback**
    - **All projectiles performed requisite maneuve commands**
  - **Tactical maneuver authority was demonstrated**
  - **Software verified through IFS, PIL and HIL**
  - **Validated in GTH testing**



MRM-CE



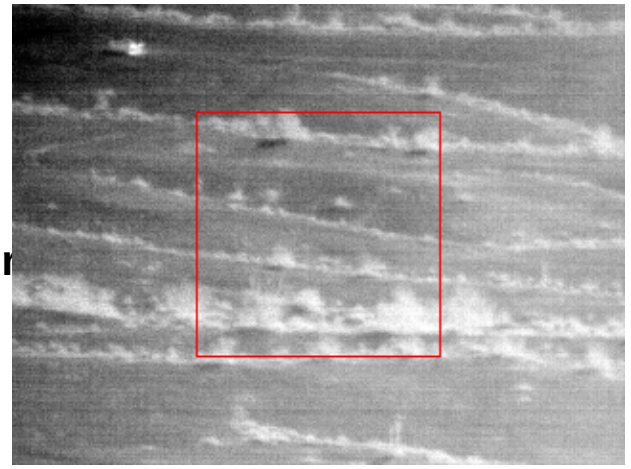
MRM-KE



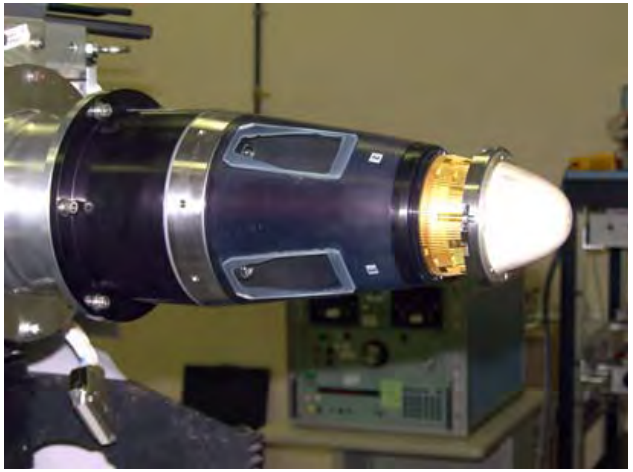
MRM-KE

MRM
Seeker Subsystem

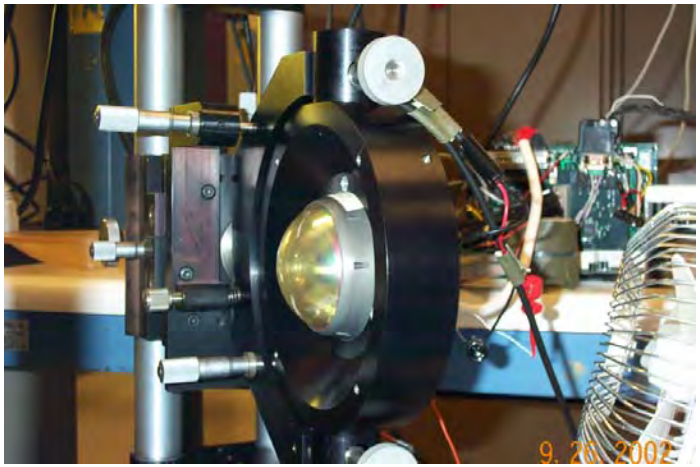
- **Technology:**
  - **Un-cooled IIR and SAL sensor**
  - **MMW and SAL sensor**
- **Achieved: TRL 6**
- **Basis for Assessment:**
  - **Performed extensive rail and gun testing of the Seeker Assembly to ensure Hi G survivability.**
  - **Extensive CFT testing/demonstrated Pacq and tracking capability**
  - **Software verified through IFS, PIL and HIL**
  - **GTH demo's validated integrated system**



MRM CFT



MMW & SAL



IIR & SAL

MRM Accomplishments

- ☑ **Autonomous GTH Demo - 2004**
  - **Stationary target at 5.2 Km**



- ☑ **SAL GTH Demo - 2006**
  - **Moving target at 8.7 Km**

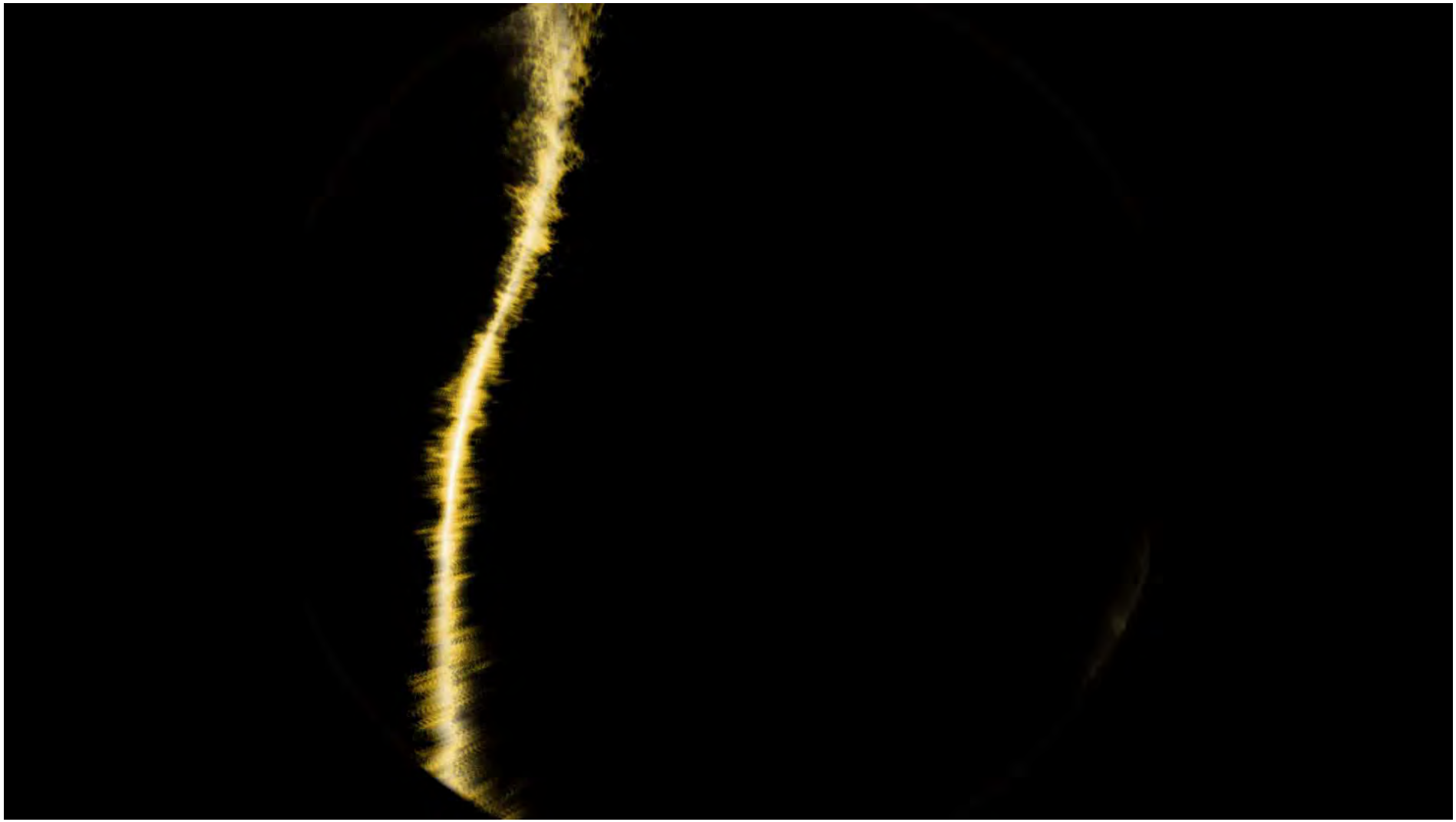


- ☑ **DMS GTH Demo - 2007**
  - **Stationary target at 5.2 Km**
  - **Off set designation**



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
  - ☑ Integrated Dual Mode Seeker (Autonomous & SAL) Only Guide to Hit - 2007



ABRAHAM to C-RAM

Börje Nyquist
Director
BAE Systems Bofors AB

Our Vision

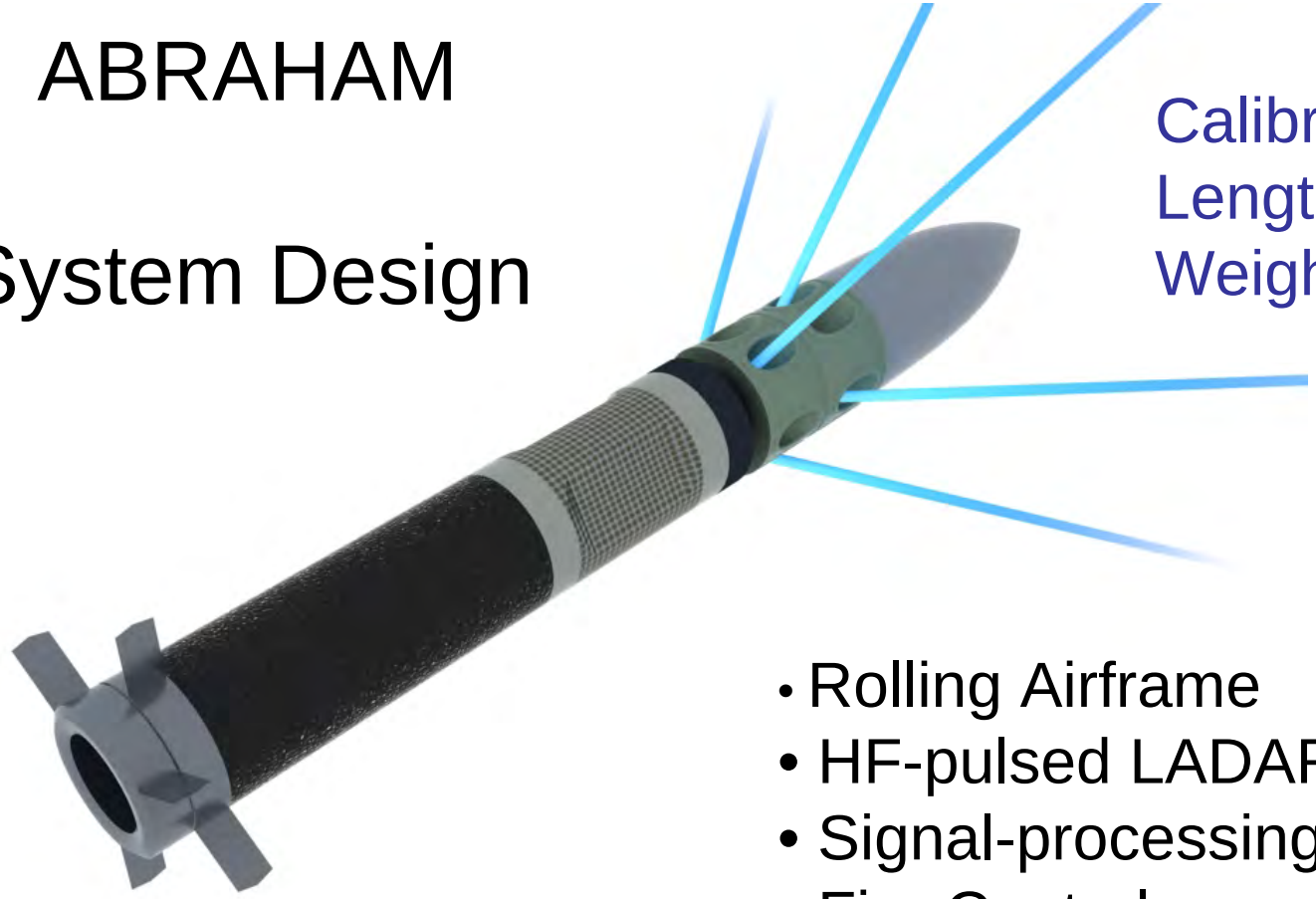


ABRAHAM

BAE SYSTEMS

ABRAHAM

System Design



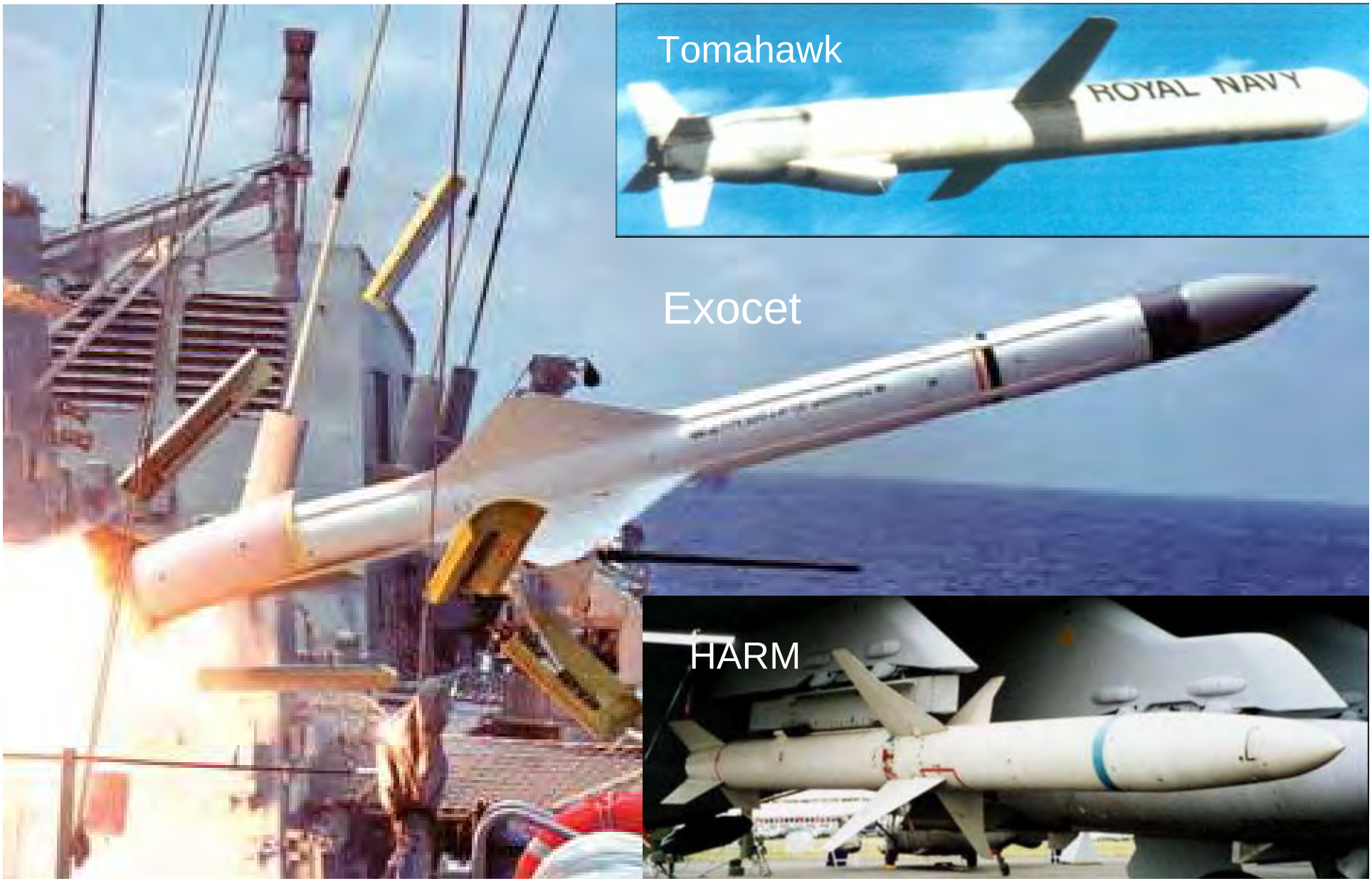
Calibre: 120 mm
Length: 1600 mm
Weight: < 25 kg

- Rolling Airframe
- HF-pulsed LADAR
- Signal-processing
- Fire Control
- Advanced Warhead

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Primary Targets

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Additional Targets

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Secondary Targets

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Other targets

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System Components

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- Surveillance RADAR
- C^2
- Fire Control
- Firing Units





ABRAHAM System

BAE SYSTEMS

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

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ABRAHAM - Sensor

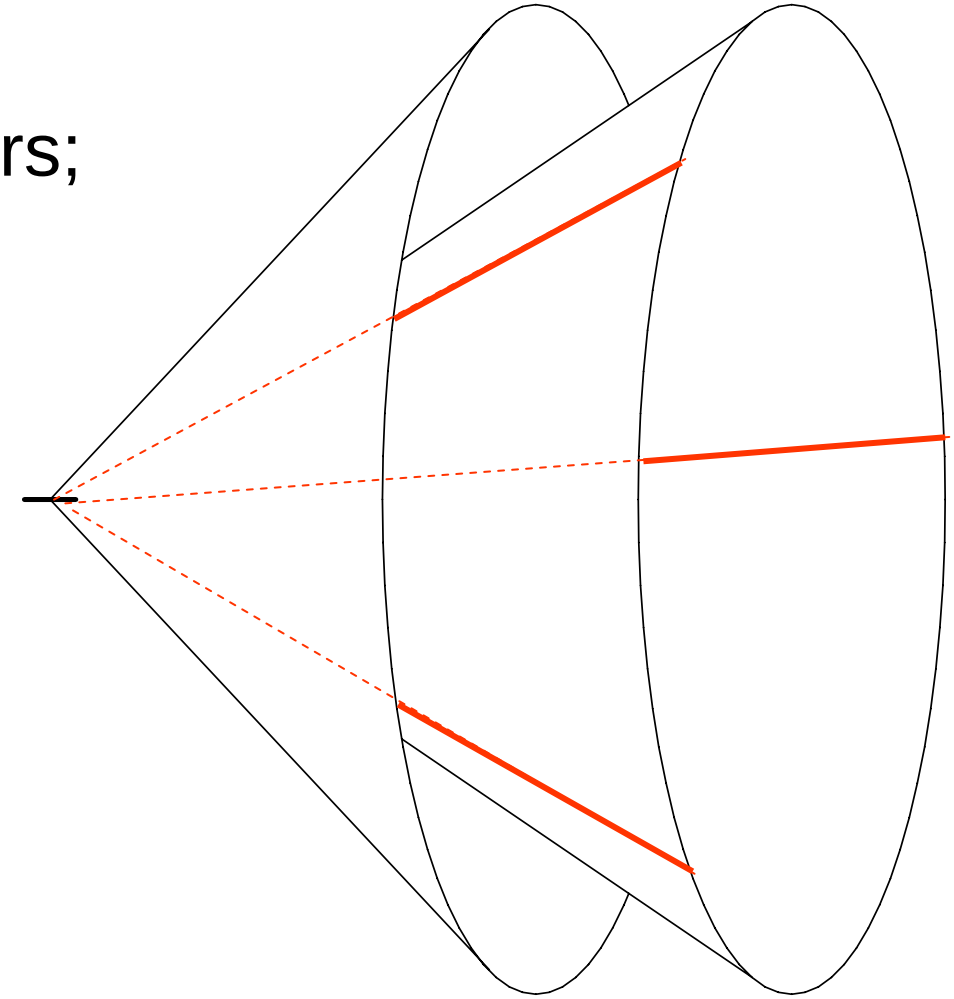


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Sensor -- Principal

BAE SYSTEMS

– Six laser range-finders; three per helix
  - Laser transmitter
  - Laser receiver
  - Software
– Target Detection Software

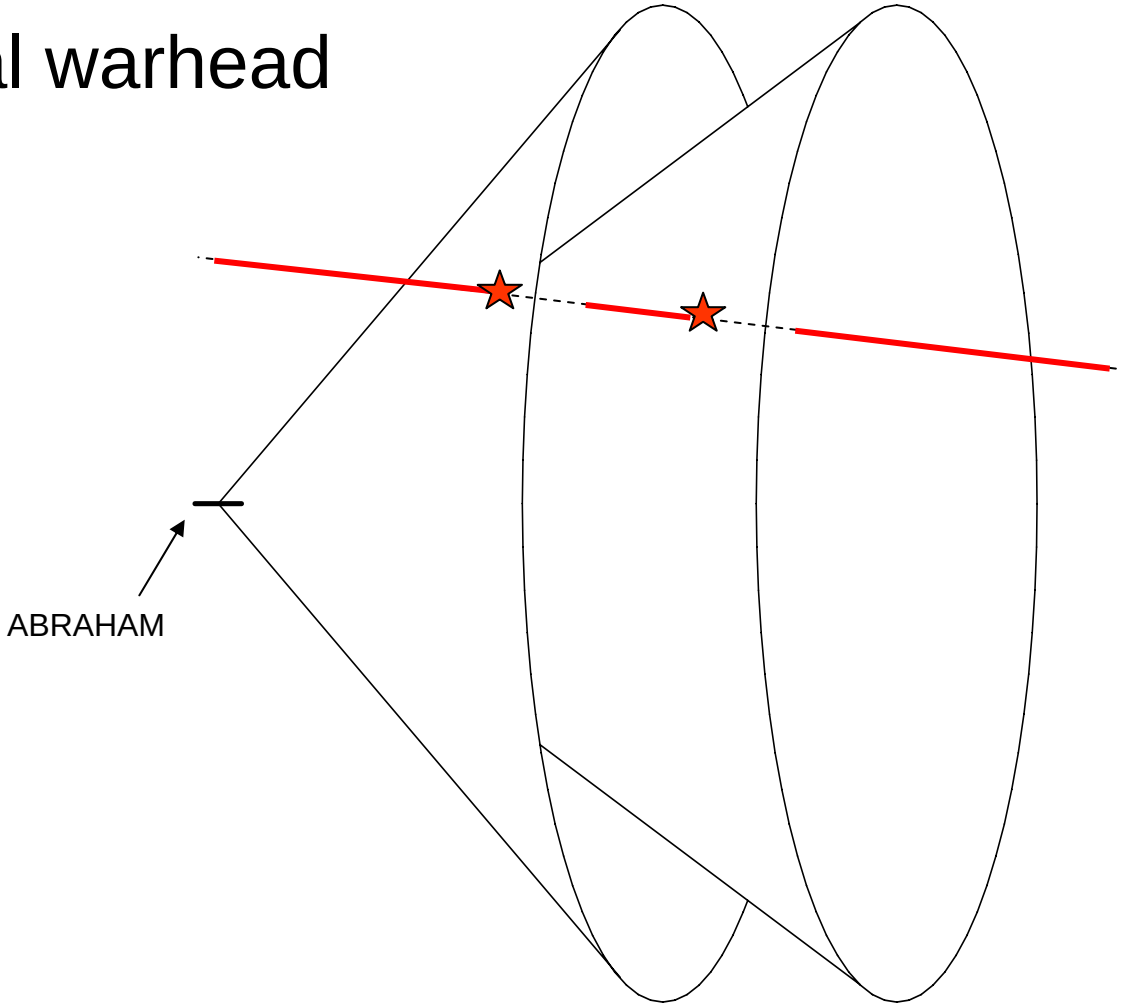


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Sensor -- Principal

BAE SYSTEMS

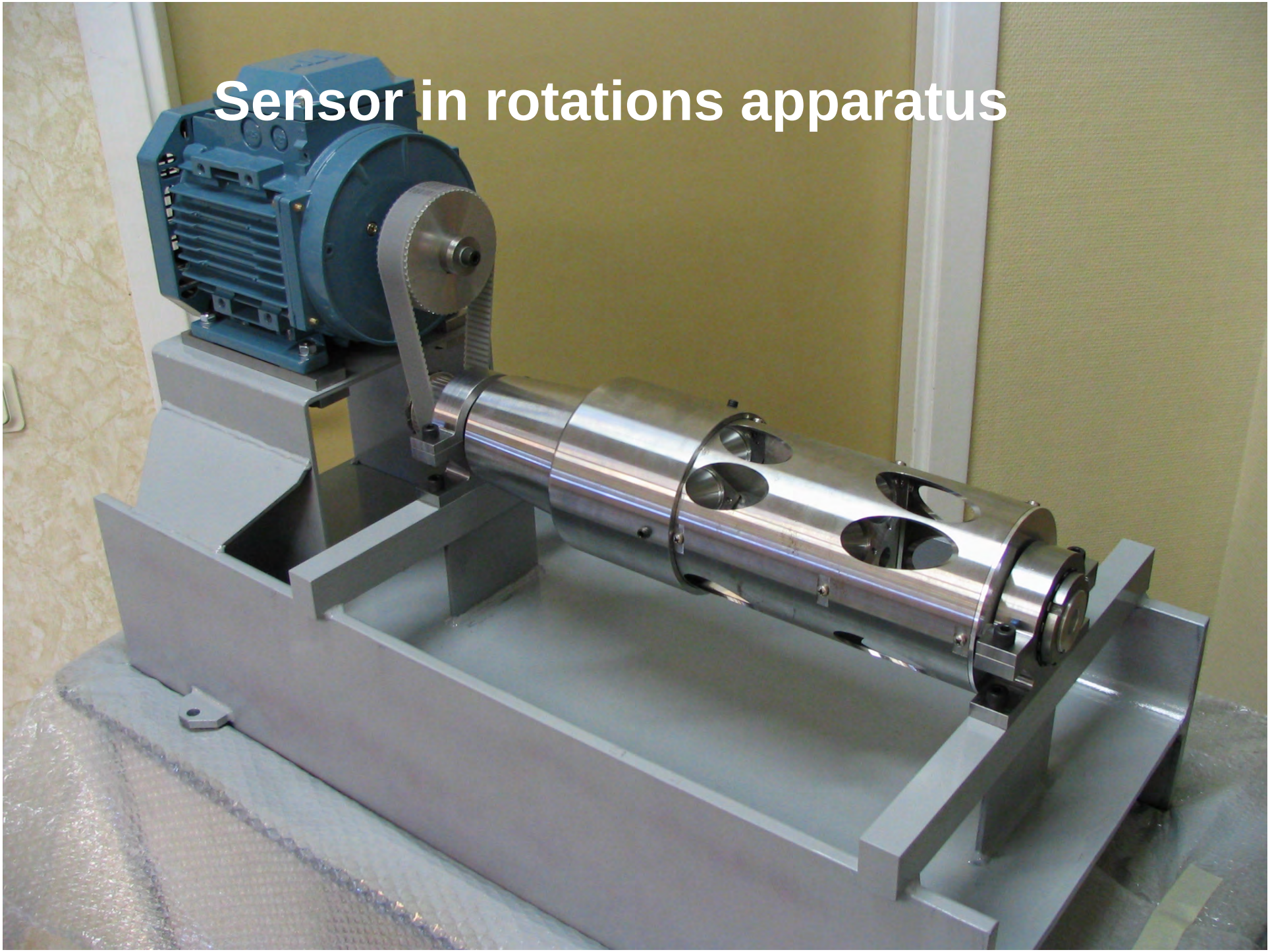
- Rotating directional warhead
- Rotating sensor
- Two helixes
  - Distance
  - Angle



Laser range-finder

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Sensor in rotations apparatus



Sensor trial – Shot no.1



ABRAHAM - Warhead



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Warhead Design

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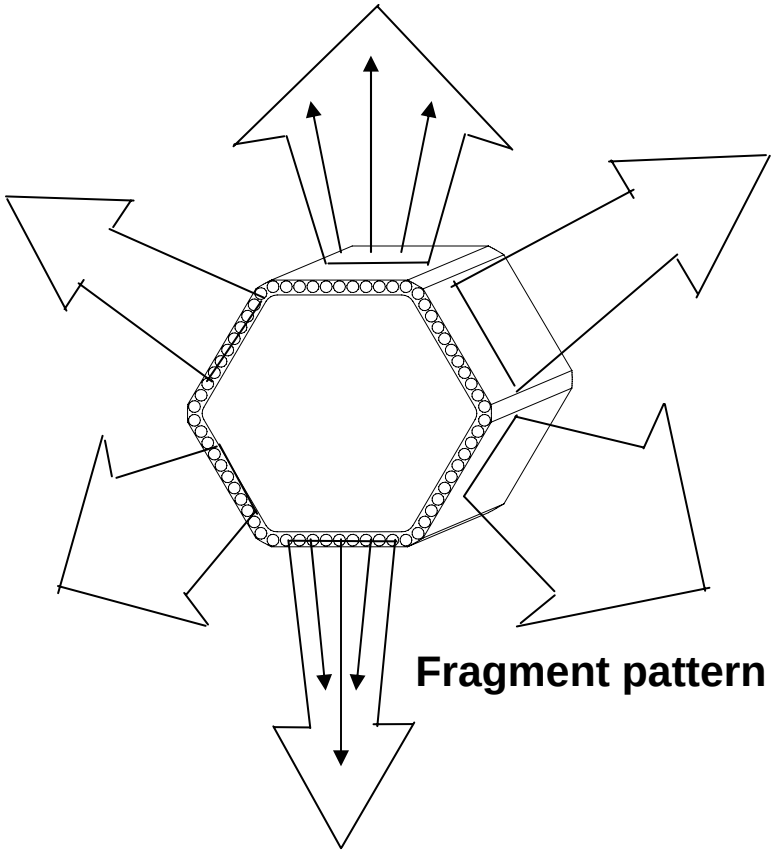


METAL MATRIX
AIRFRAME BODY
- Tungsten Pre-Formed Fragments

ADVANCED SHAPE
Simultaneously
- Long Range
- Short Range



Rolling Airframe



Foot-print of 1m² @ 50m

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Warhead Rotation Trial

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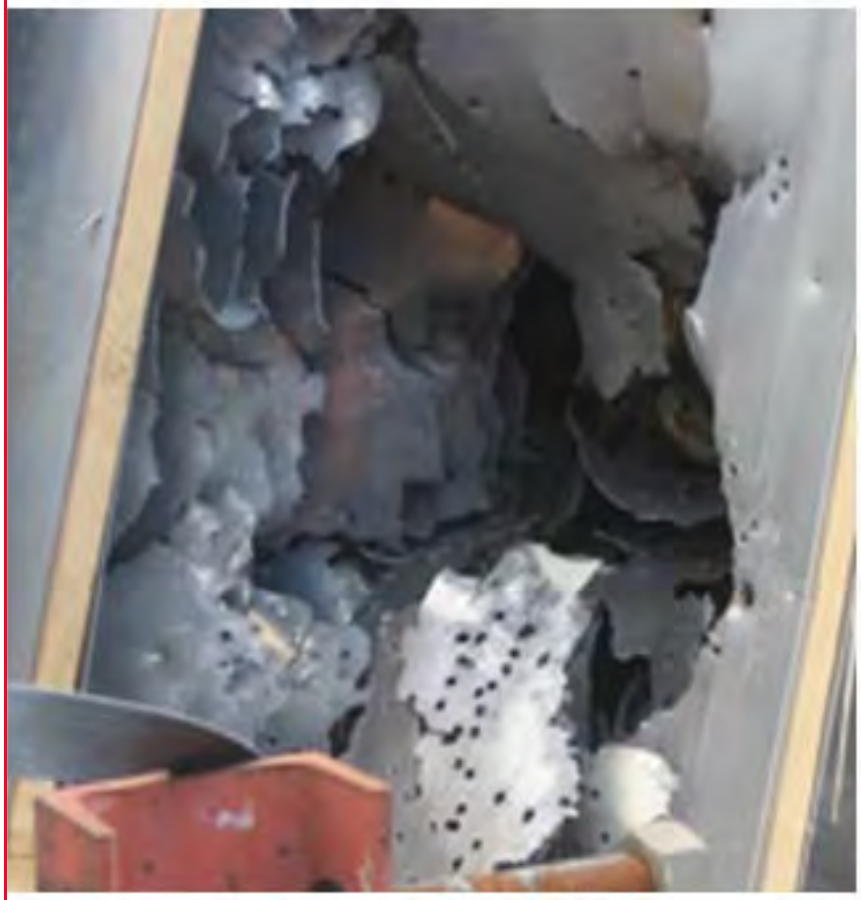


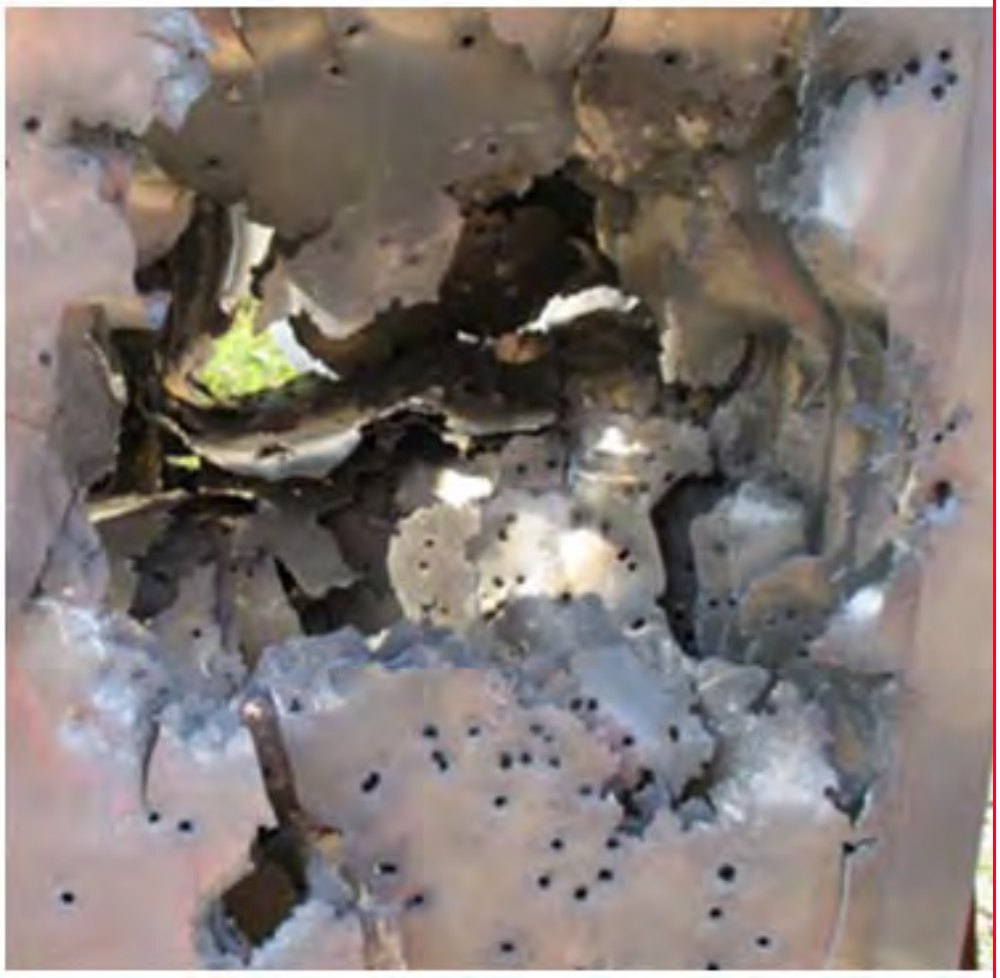
A: Warhead with rotation device.
B: Target setup with dural aluminum sheets (20 with 2,5 cm spacing)
C: High speed video.
D: Camera for surveillance of safety- and arming functions.

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Warhead Impact with rotation

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Penetration Capability

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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.

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ABRAHAM
Launch and Propulsion

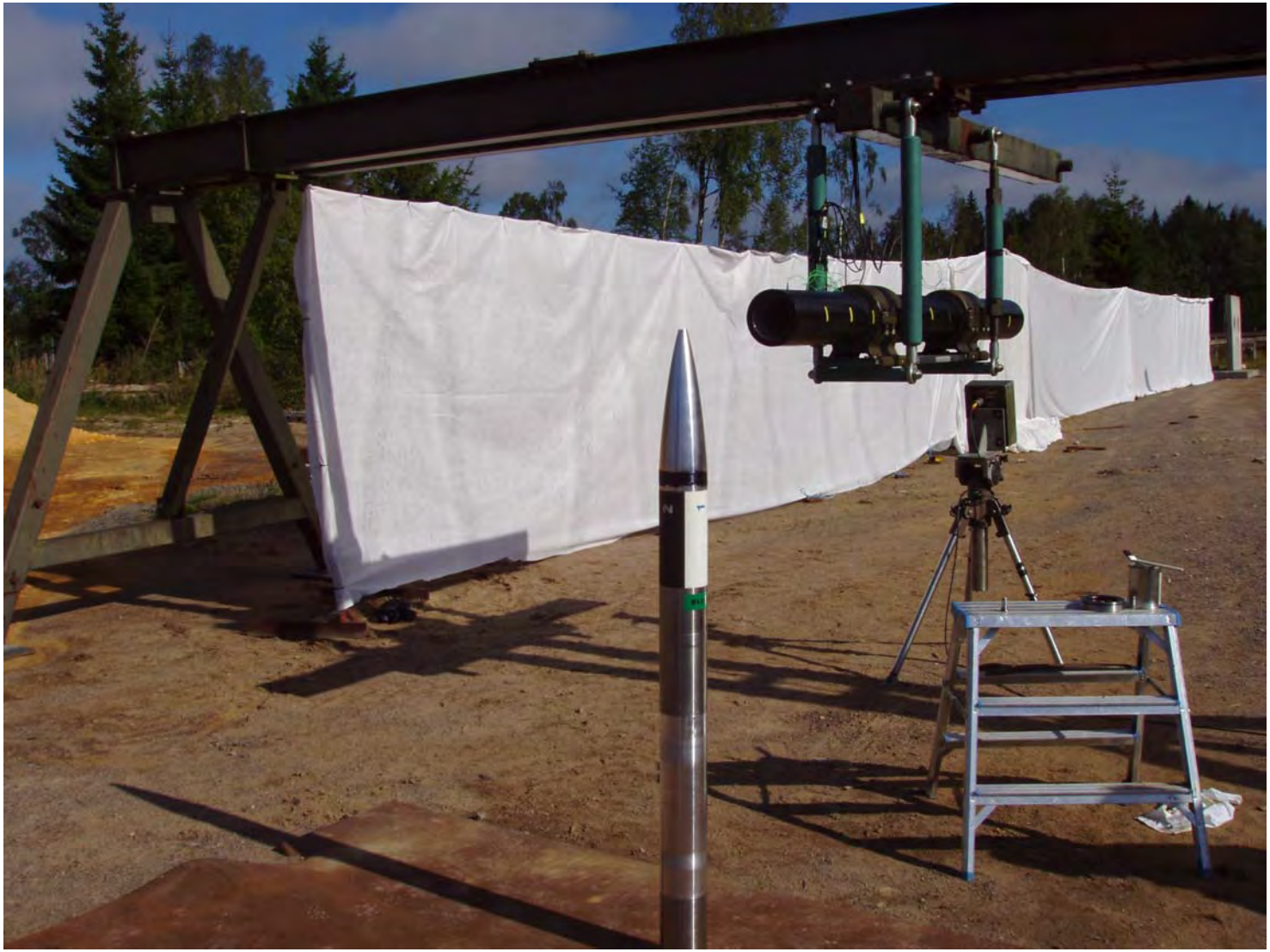
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Launch Trial

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Fin Deployment Test

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- 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

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ABRAHAM

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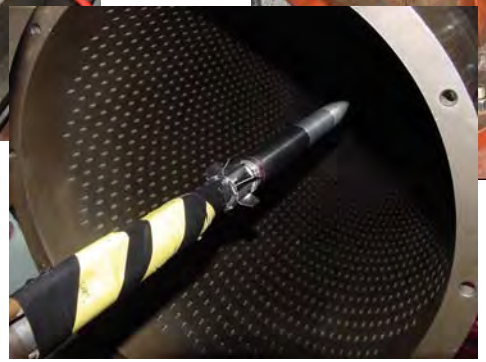
ABRAHAM from a Launch and Propulsion perspective:

- A “recoilless” launch gives the rocket ~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





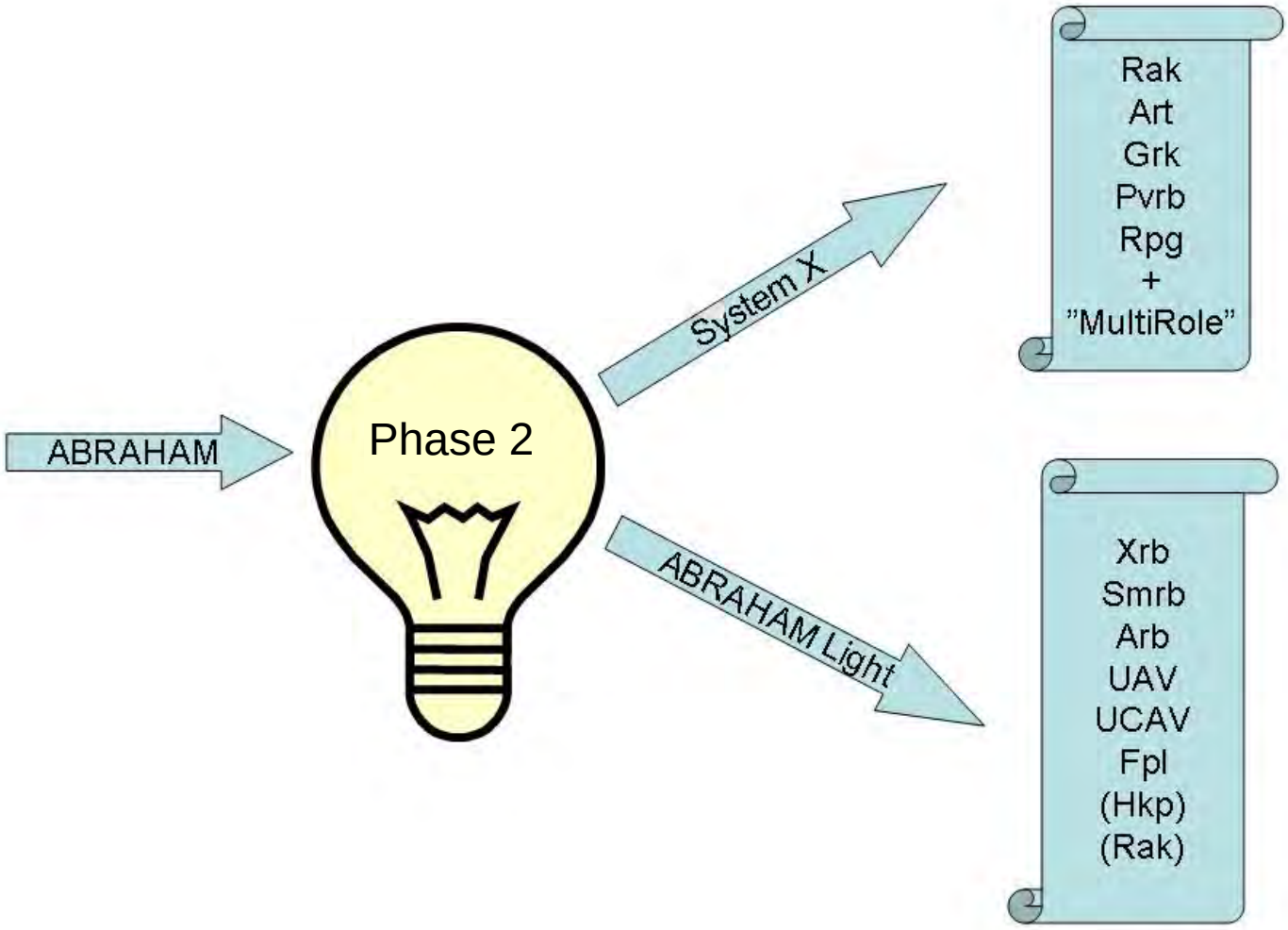




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TWO WAYS TO GO

BAE SYSTEMS



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System Development Philosophy

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Sub-systems

Philosophy

Systems

Low risk
Low cost
Modular approach

Warhead
Fuze
SAU
Propulsion
Guidance and Control
Power
Airframe
Aerodynamics
Launcher/Mount
Launch Tubes(s)
Fire Control
Eject Motor
Interface
IFF
Safety
Sub-Systems

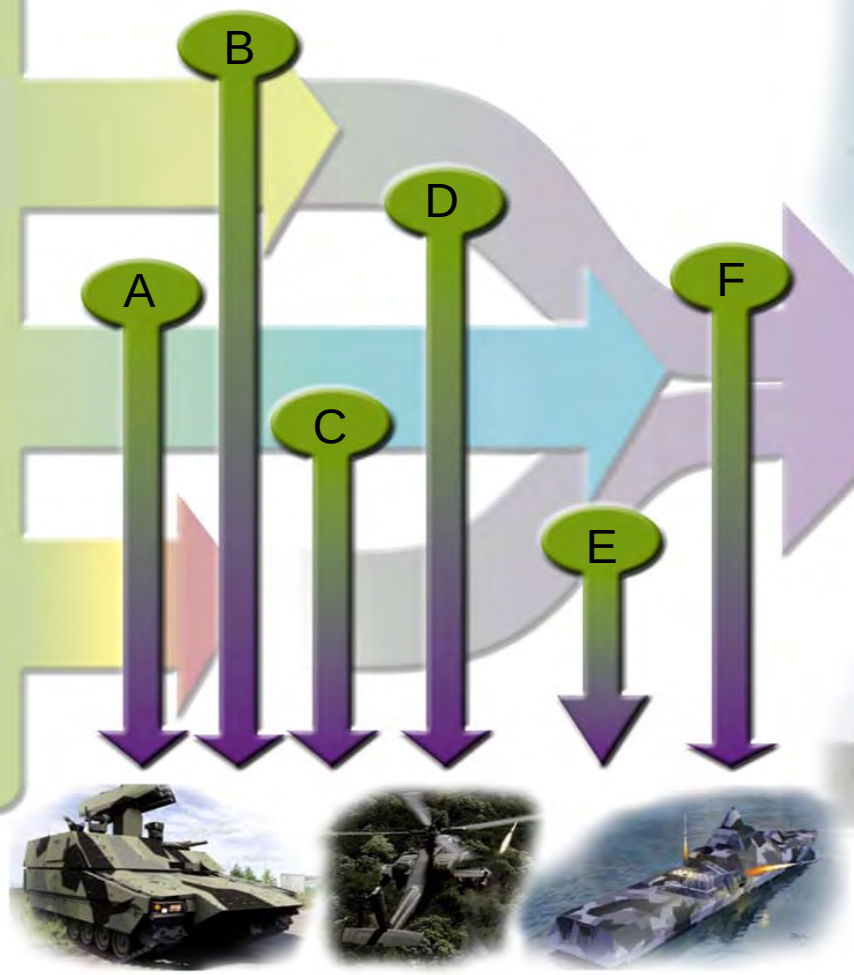


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System Development Philosophy

BAE SYSTEMS

Warhead
Fuse
SAU
Propulsion
Guidance and Control
Power
Airframe
Aerodynamics
Launcher/Mount
Launch Tubes
Fire Control
Eject Motor
Interface
IFF
Safety
Sub-Systems



- **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**

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Objects that needs Protection



Camp Victoria in Kosovo







Escort under preparations, munitions handling and evacuation.







Recon party driving on road and off road. Destroyed vehicle.



East gate at Camp Fylke in Arbuzove

The object various in:

- size
- mobility
- passive protection levels

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Terrorist Threat

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Iraq rebel with American 60 mm mortar.





QUASSAM 2, improvised rocket.



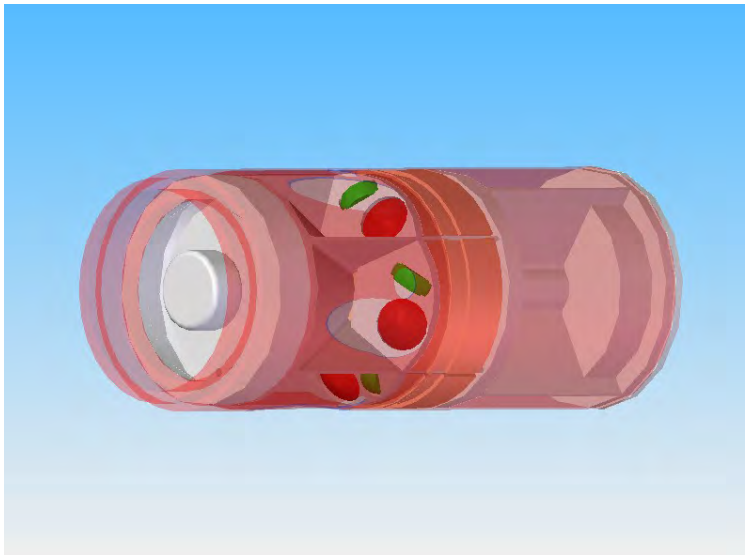
RPG can be used for indirect fires. The grenades AD-function after approx. 900 m of fight has been used to obtain airburst.

The most common targets are small and many are hard.

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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.

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ABRAHAM

BAE SYSTEMS

Potential Applications of ABRAHAM Technology

- **Future Ground Based Air Defence Adjunct**
- **Low Cost Naval Point Defence**
- **Naval Anti-Surface - Counter Attack Craft**

Original Concepts

- **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**

Evolving Concepts

- **Replacement of current payloads**

Payload Concepts

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Our Vision









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**

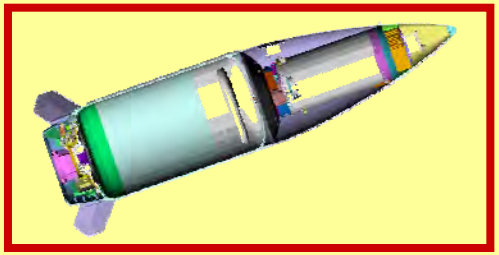
For the first time, the ground commander now has dedicated precision munitions that he can employ quickly and efficiently.

Precision Munitions

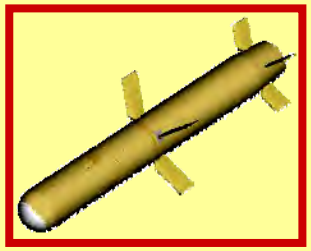
- **Rockets & Missiles**



Guided MLRS - Unitary



ATACMS Unitary



Precision Attack Munition

- **155 mm**



Excalibur



Precision Guidance Kit

- **Future Possibility - Precision 105mm**

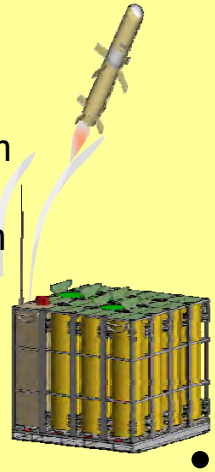
Rockets and Missiles

Guided MLRS Unitary



Combat Proven!

- **Range: 15-70+ Km**
- **Multi-Mode Fuze (PD,Delay,Proximity)**



Precision Attack Munition (PAM)

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

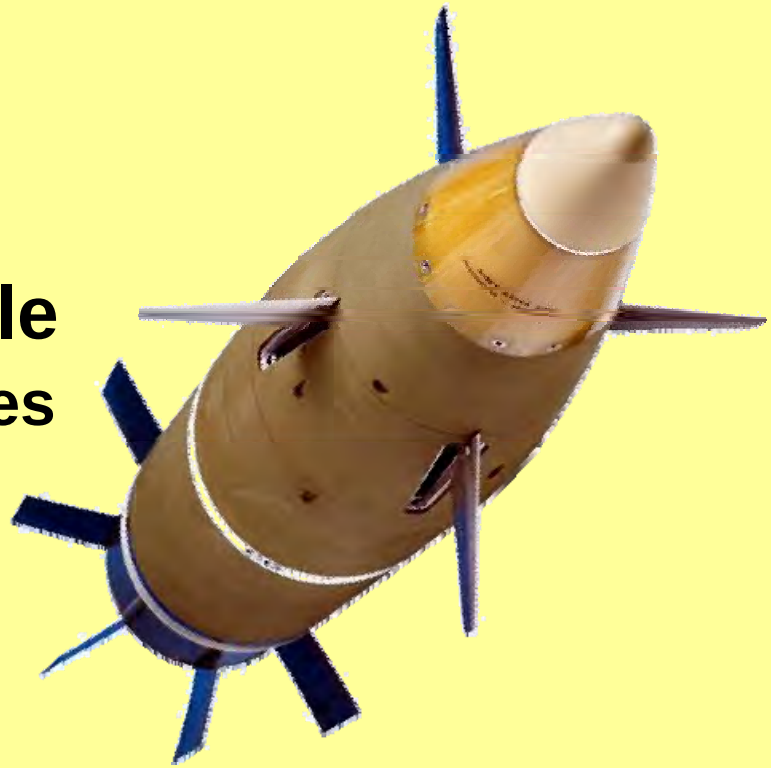
NLOS-LS (PAM)



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**



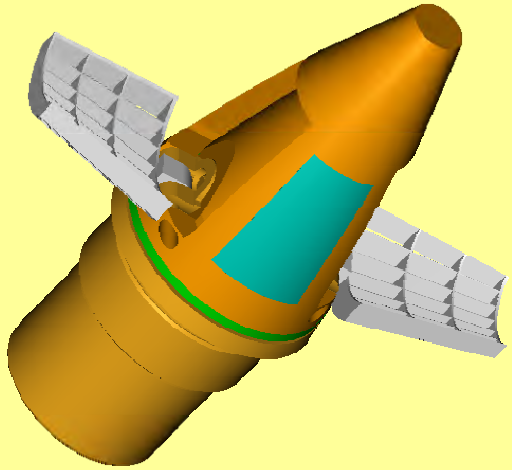
Precision Munitions

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

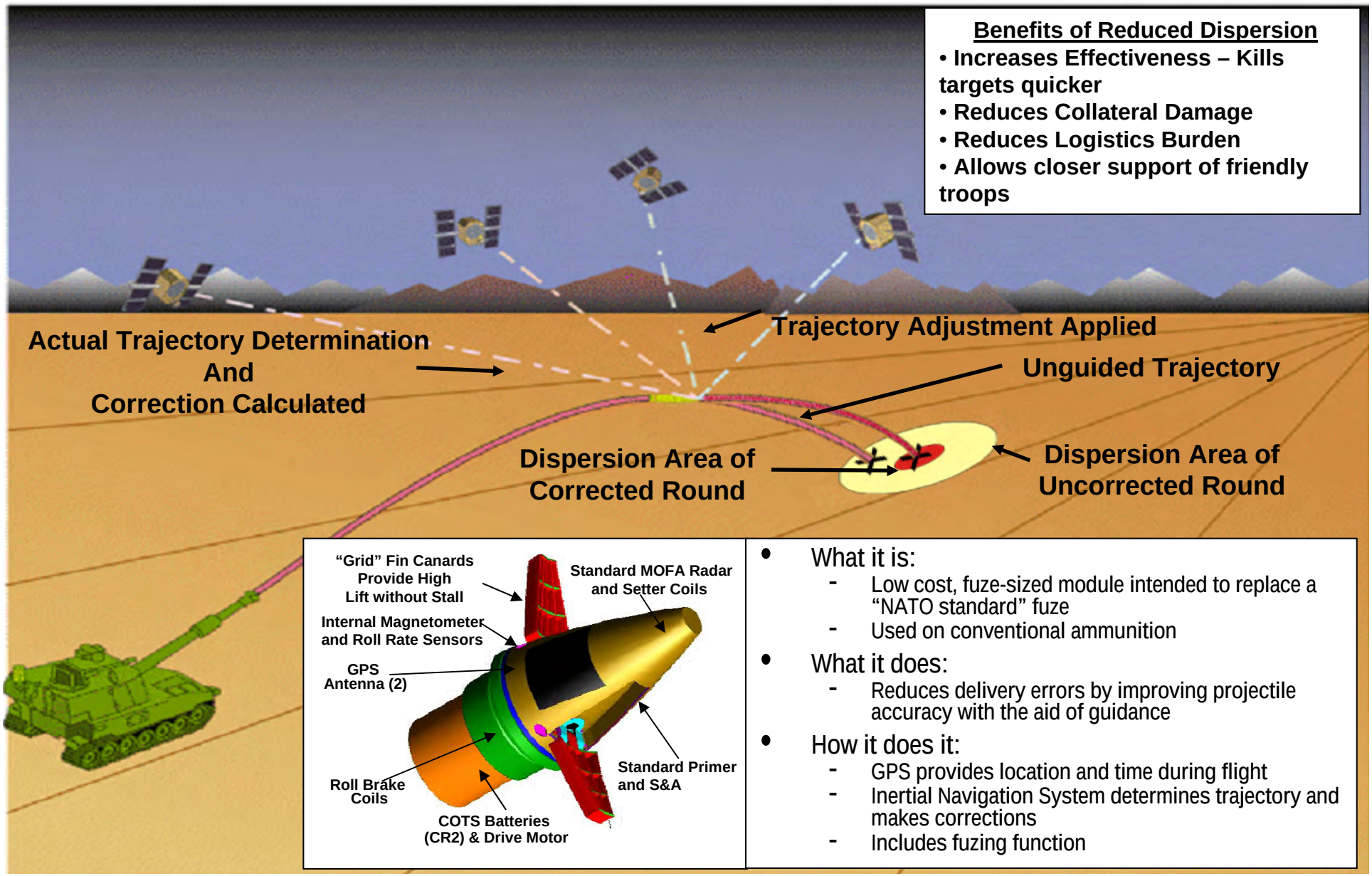
- **CEP of less than 50m (T) and 10m (O).**
- **Four operational modes: super quick, delay, proximity, and electronic time**
- **Apr 06 – PM award Technology Development contracts**
- **27 Mar- 6 Apr 07 – Shoot off and Contract Award**

Precision Munitions

PGK Operational Concept

Benefits of Reduced Dispersion

- **Increases Effectiveness – Kills targets quicker**
- **Reduces Collateral Damage**
- **Reduces Logistics Burden**
- **Allows closer support of friendly troops**



- 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

Accurate Targeting



Joint Effects Targeting System

- "Born Joint" requirement
- Requirement of 10M TLE at 10KM
- Modular components

- *Common mounted*
- *Common dismounted*
- *< 25M TLE*
- *< 5M with PSS-SOF*



Light Weight Locator Designator Rangefinder

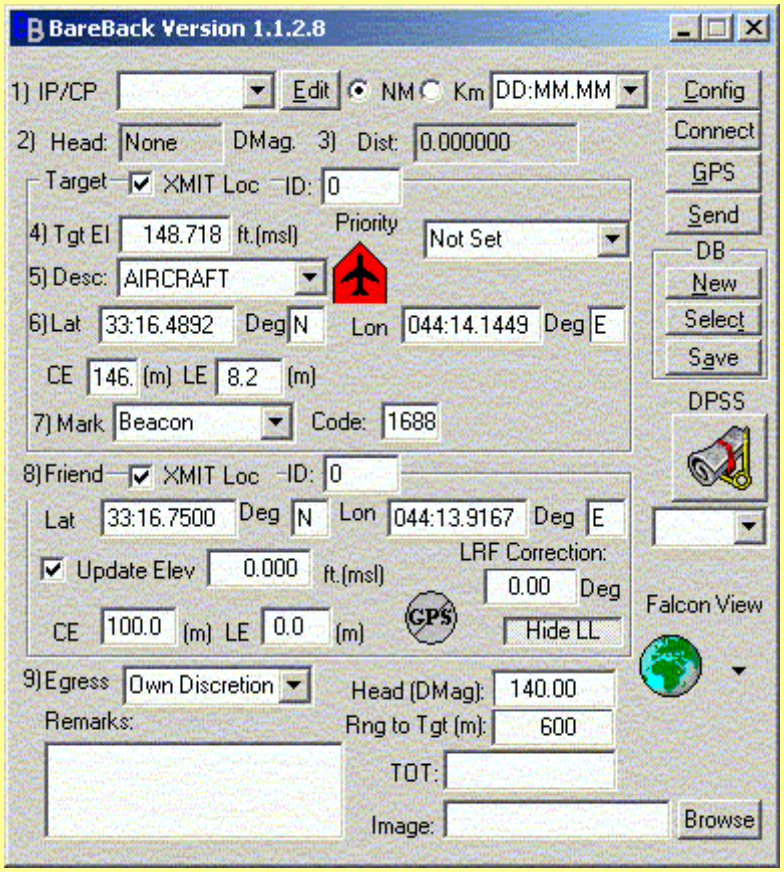
- Very large modular force requirement
- 40M TLE at 10KM
- Weight – 35 lbs



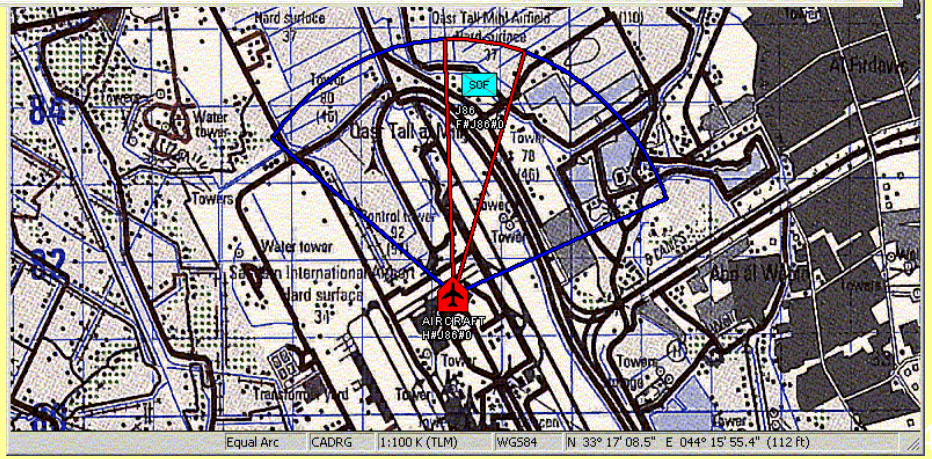
Fire Support Sensor System

- 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**



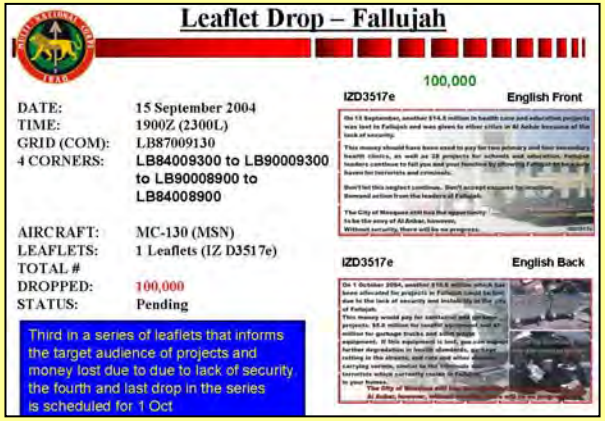




Non-lethal

- **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)



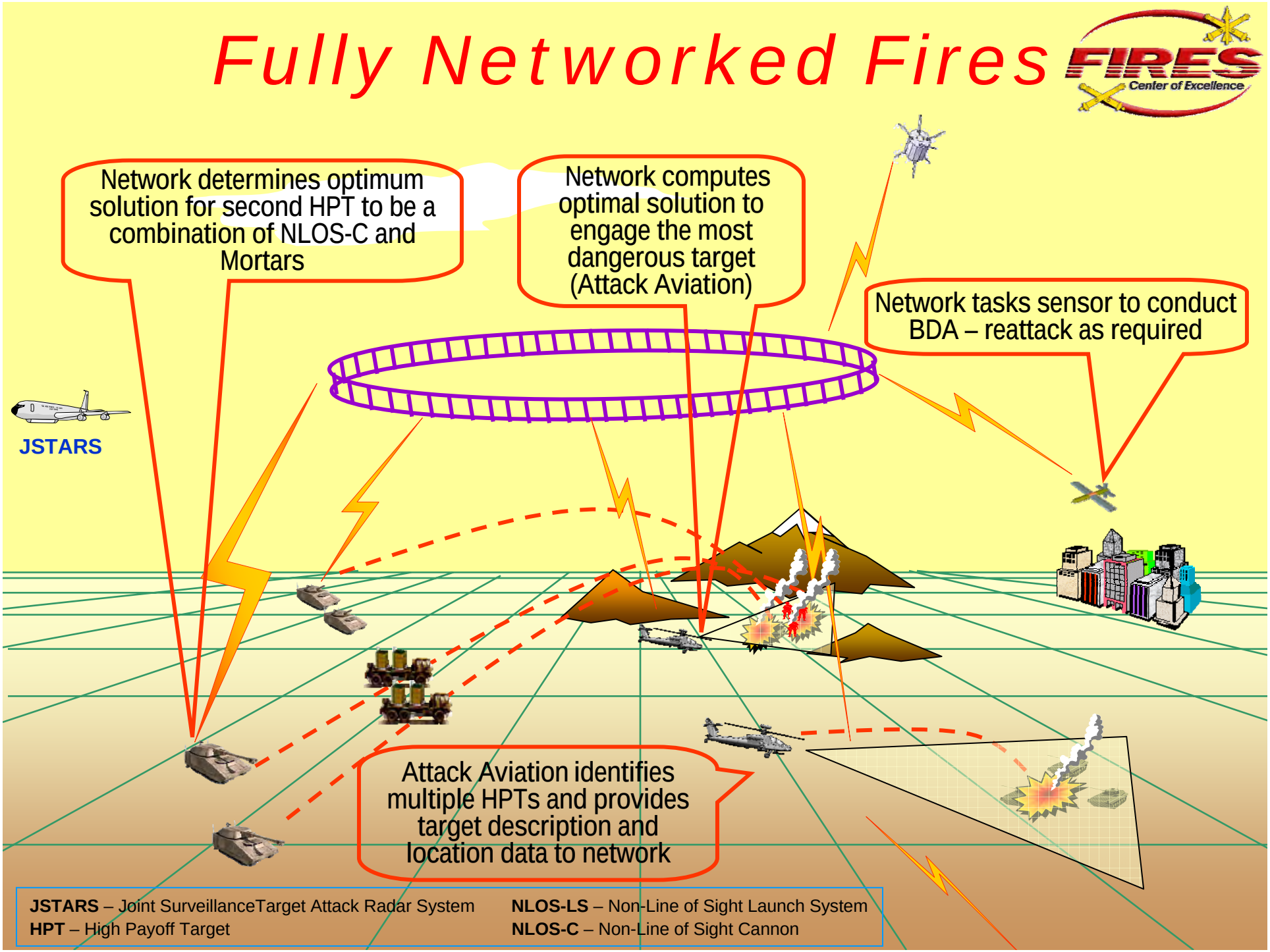
NLOS-Cannon



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

Fully Networked Fires



JSTARS – Joint SurveillanceTarget Attack Radar System
HPT – High Payoff Target
NLOS-LS – Non-Line of Sight Launch System
NLOS-C – Non-Line of Sight Cannon

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***

Project Manager Maneuver Ammunition Systems

Direct Fire Ammunition:
"Meeting Warfighter Needs for the Asymmetric Threat"

DISTRIBUTION STATEMENT A.
Approved for Public Release; distribution is unlimited.
Other requests shall be referred to the:
Office of the Project Manager for Maneuver Ammunition Systems
ATTN: SFAE-AMO-MAS, Picatinny, NJ 07806-5000



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

Project Manager
Maneuver Ammunition Systems (MAS)-Direct Fire



PM MAS

PM
Small & Medium
Caliber

PM
Large Caliber

PM
Medium Cannon
Caliber





MISSION: PM MAS Provides Direct Fire Combat And Training Ammunition Capabilities To All Warfighters (Army, Navy, Air Force, Marines)

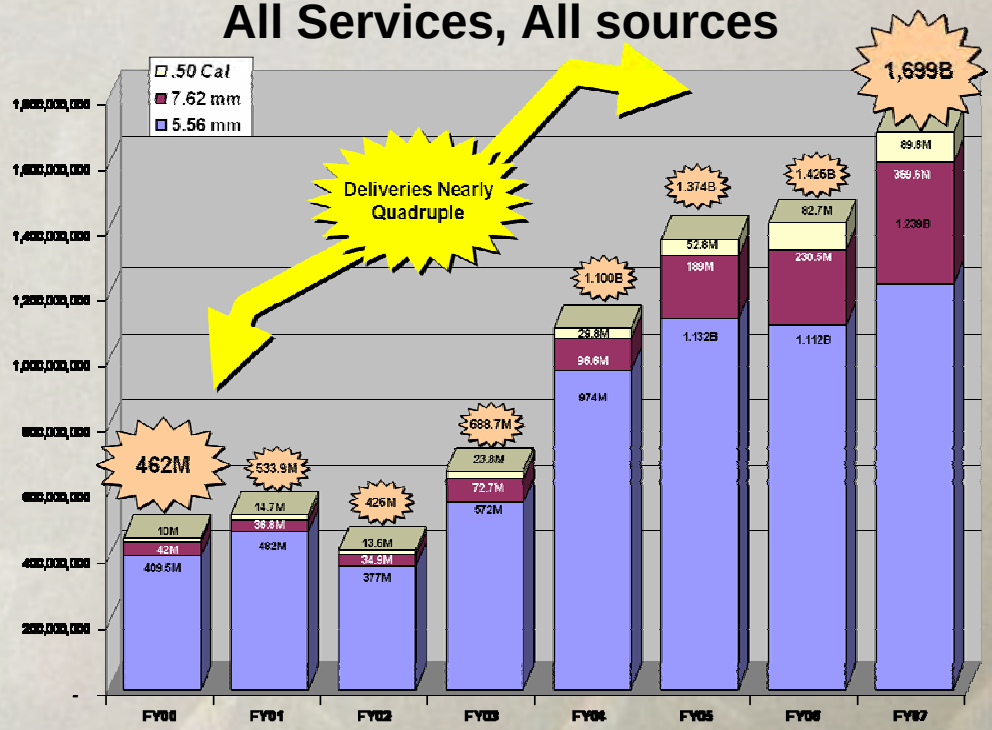
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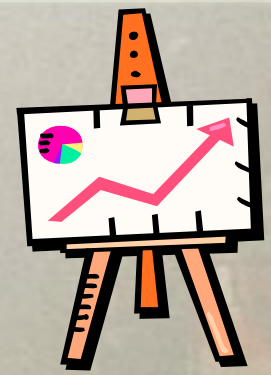
Use or Disclosure of Data Contained on the Page is Subject to Restrictions on Title Page

Significant Direct Fire Production Ramp Up

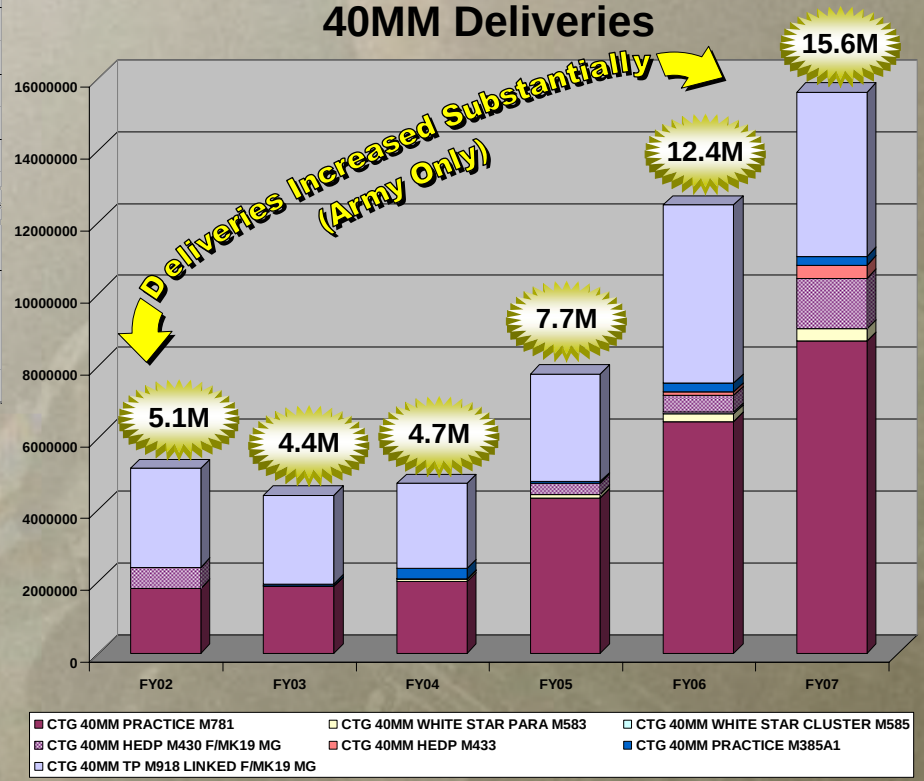
Small Caliber Deliveries

All Services, All sources





40MM Deliveries

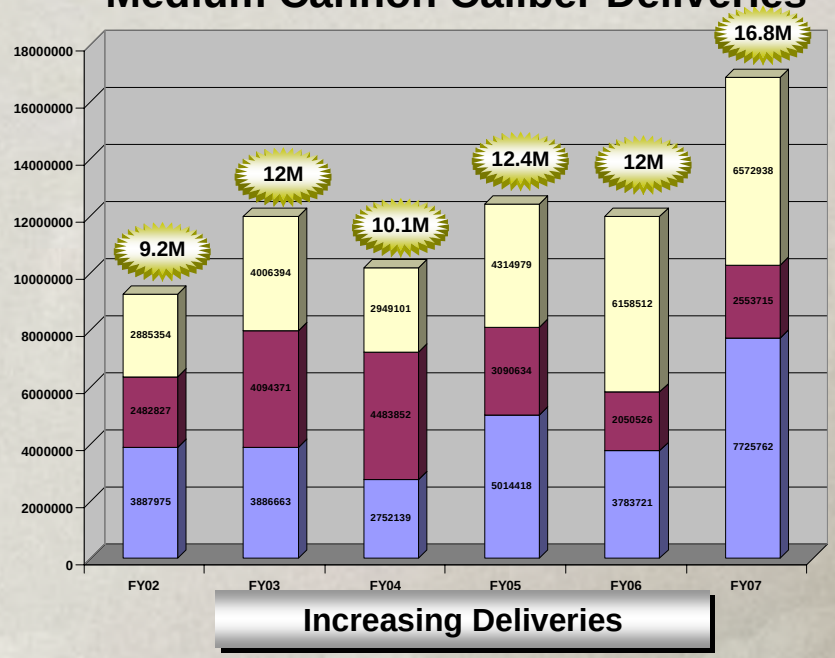


DISTRIBUTION STATEMENT A:

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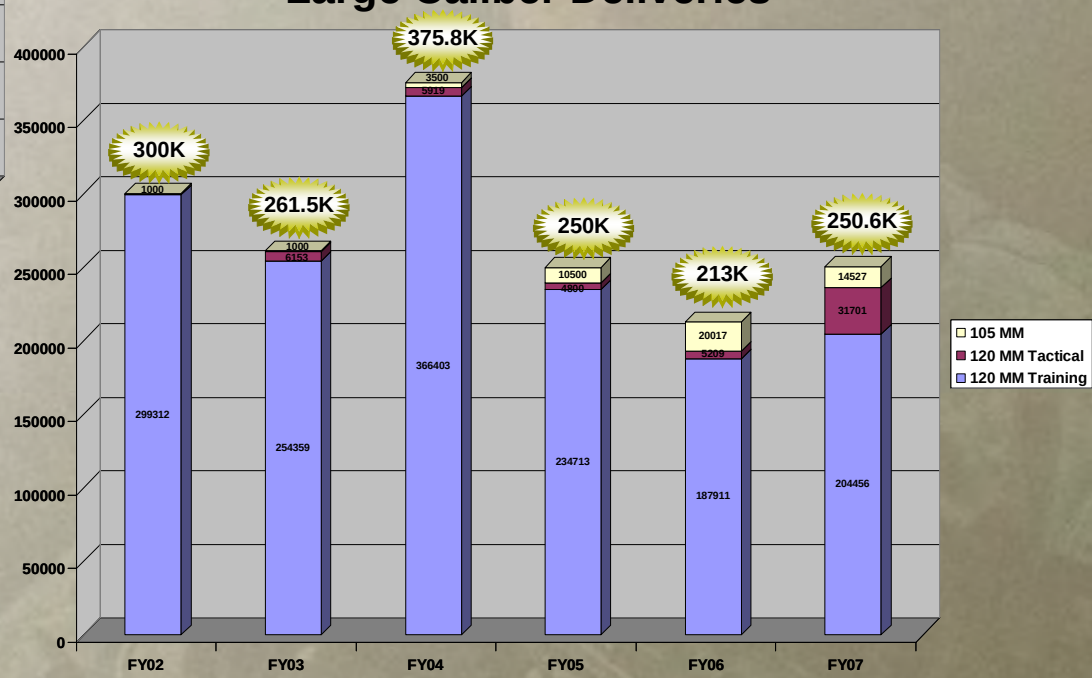
Significant Direct Fire Production Ramp Up

Medium Cannon Caliber Deliveries



Increasing Deliveries

Large Caliber Deliveries



Consistent, Significant Deliveries

New Capabilities in Theater
MGS and 105mm Ammunition

M393A3 HEP



- 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

M1040 APERS

- 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

M393A3 HEP

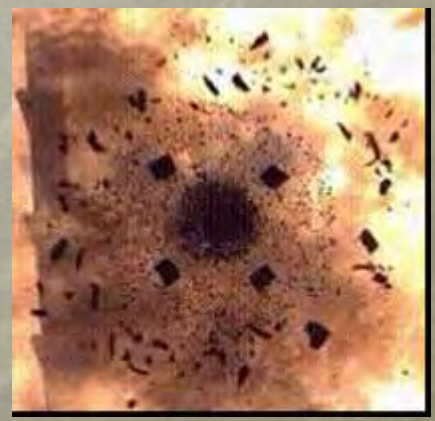






M1040 APERS







Capabilities for the Warfighter in the Asymmetrical Fight

New Capabilities in Theater 120mm Ammunition

M1028 Anti-Personnel Cartridge



- 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

BEFORE





AFTER

BEFORE





AFTER

BEFORE





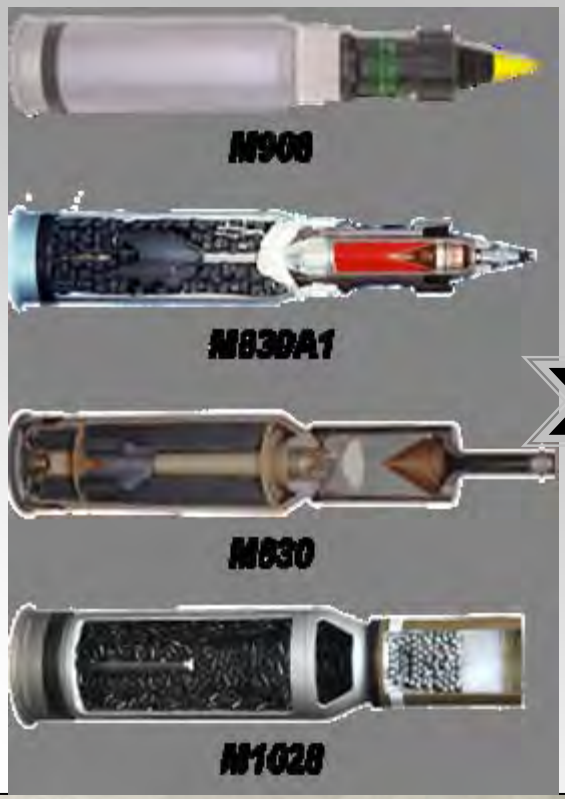
AFTER

Capabilities for the Warfighter in the Asymmetrical Fight

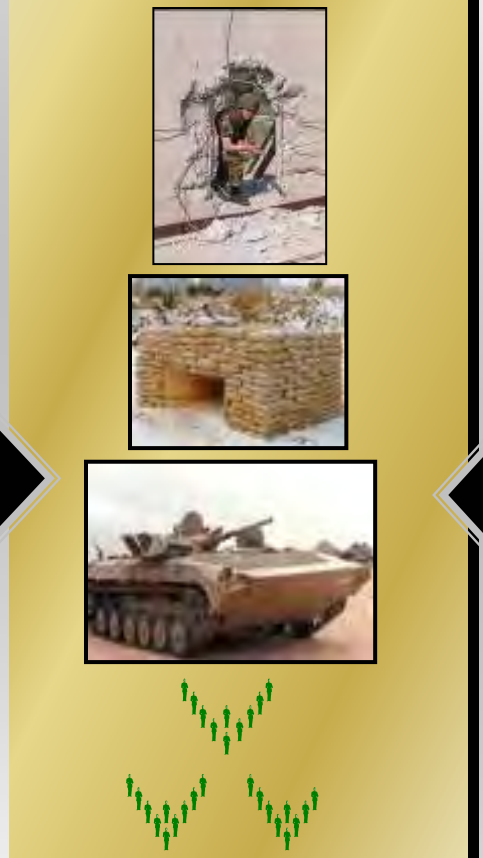
Future Capabilities
120MM Ammunition

Advanced Multi-Purpose

PRESENT: 4 ROUNDS



TARGET SET



FUTURE: 1 ROUND

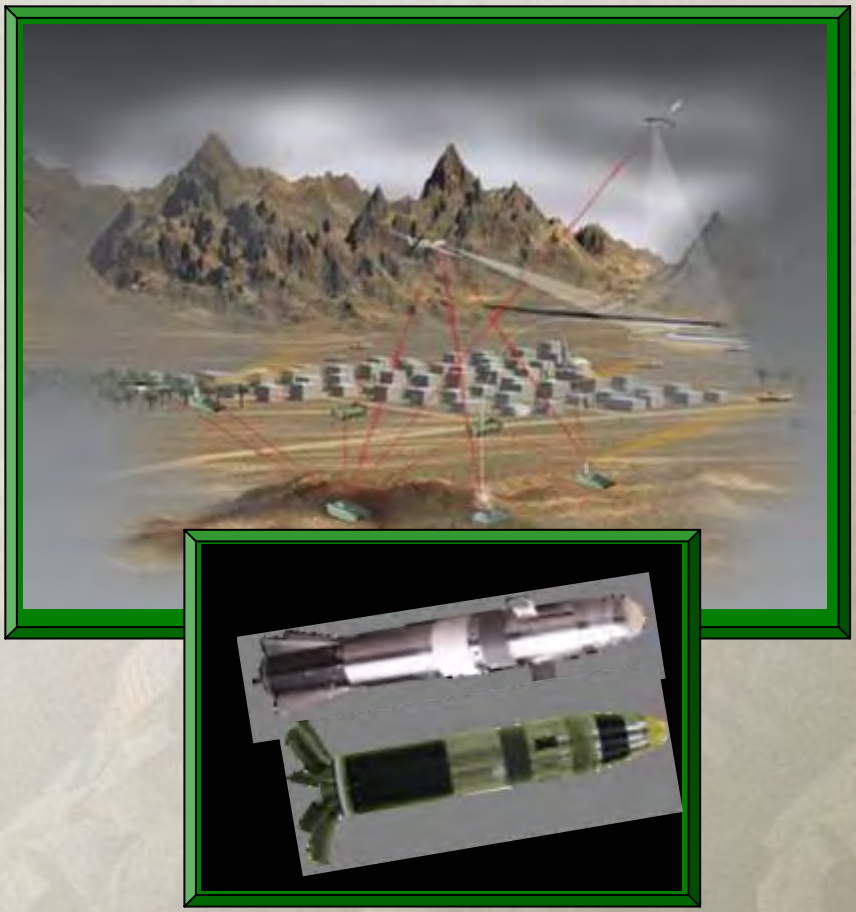


Combines capabilities of M1028, M830A1, M908 and M830 into ONE Round

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

Israel Military Industries Ltd. (IMI)

Heavy Ammunition Division



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

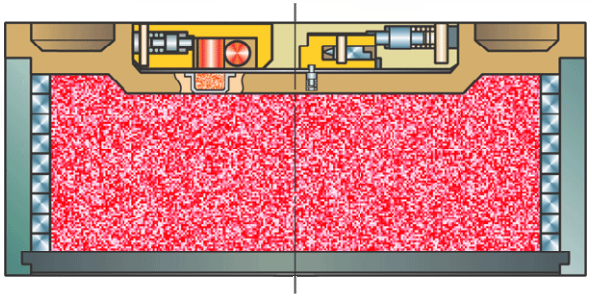


Cartridge length	984 mm
Cartridge weight	27 Kg
Projectile weight	17 Kg
Projectile Length	750 mm
Muzzle velocity	900 m/sec
Chamber pressure	3,400 bar
Accuracy (SD)	0.3 mil
Temperature limit - Storage	- 40 ÷ 63 °c
Temperature limit - Firing	- 40 ÷ 52 °c

(*) – 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

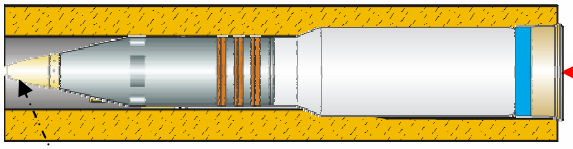
1) Ejection of 6 warheads at the set range -
   - Anti - Personnel [AP]
   - Anti Helicopter [AH]
2) Impact W/Delay [Delay = f (range)]
3) Impact - Super Quick [S.Q.]
4) Air-burst at the set range [unitary warhead]

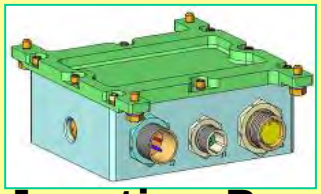
- "Extra" features –
  - Air-Burst functioning as Back-up to Ejection Mode
  - Grazing functioning
  - Impact as default set



APAM 120
Ammunition Data Link/Fuze Setting
Round in Gun

120mm smoothbore NATO gun



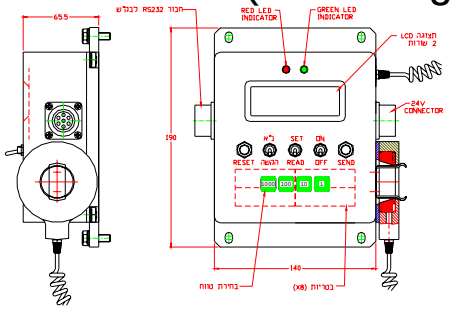


Junction Box

Trigger

Inductive Setting -

Fuze Setter (in emergency)



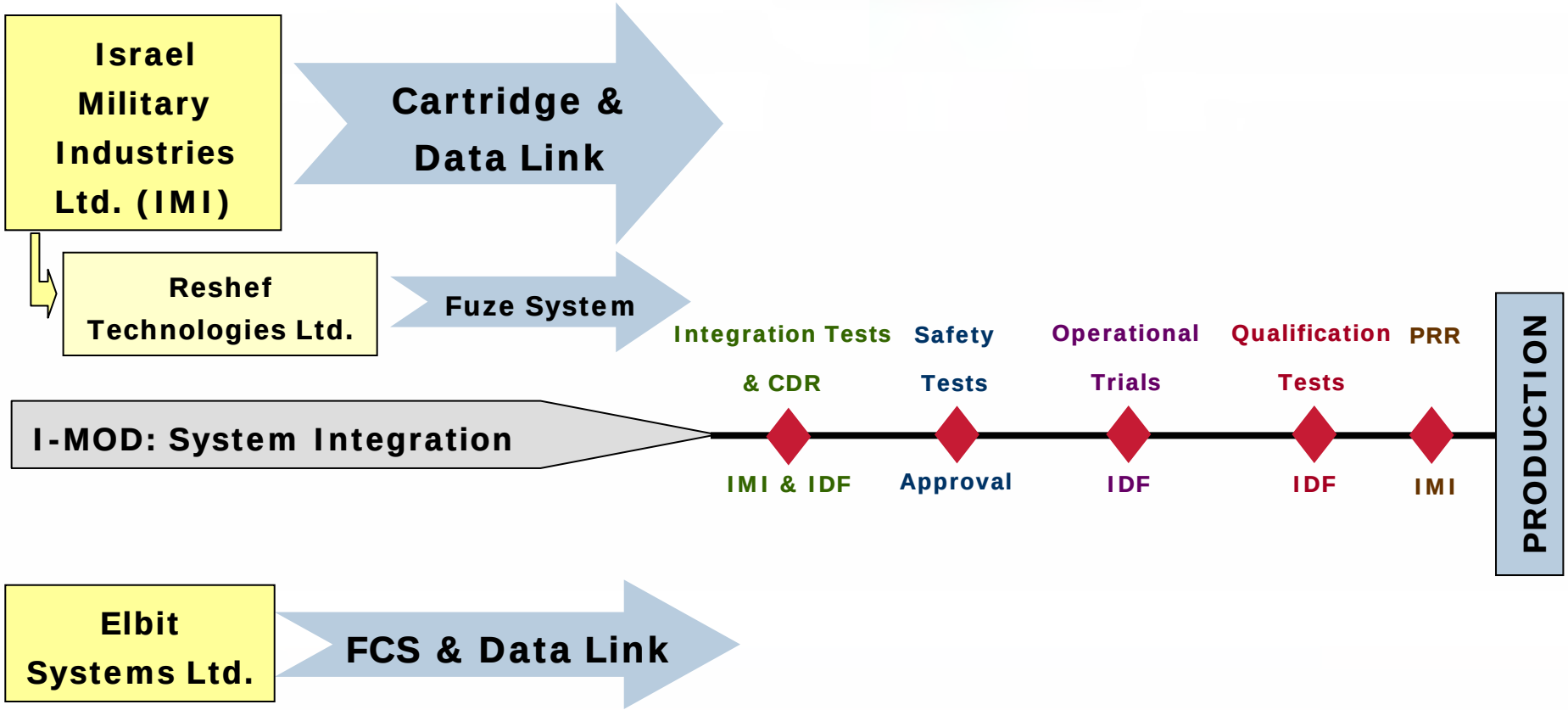
- **FCS (Bi-Directional Date Link)**
  - Round ID –

    Type, Muzzle Velocity, Temp.
  - Talk forward (Data Link to Round in Gun) –

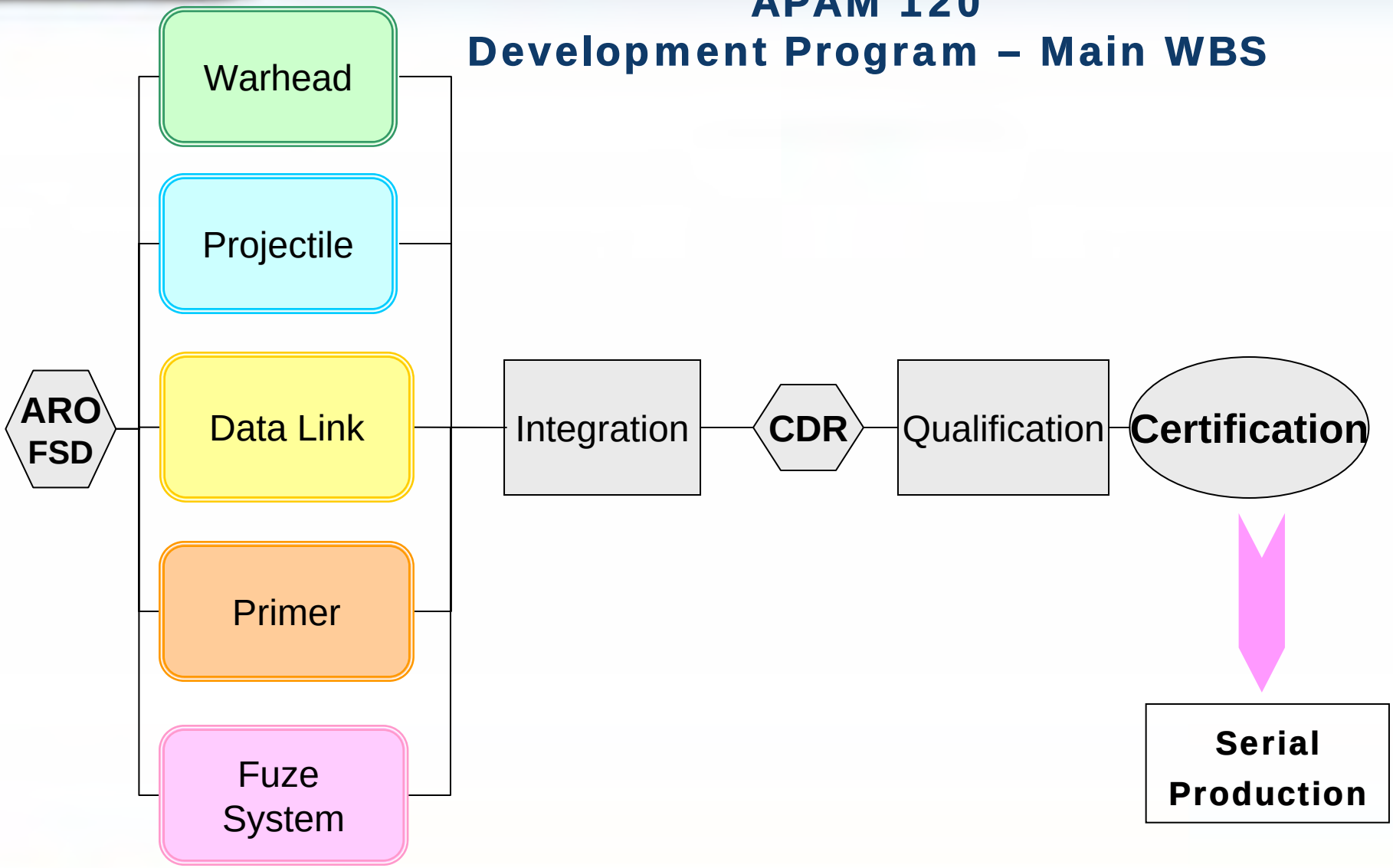
    Mode of operation, Range, Power, Continuous Programming up date
  - Talk-back message (from the Round) -

    Data Linked, Errors.

Program Integration Management Chart & Main Milestones



APAM 120
Development Program – Main WBS



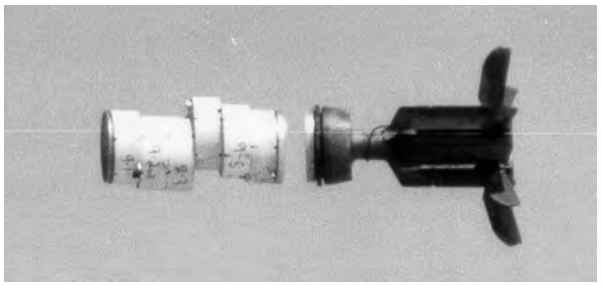
APAM – AP mode on the Battlefield



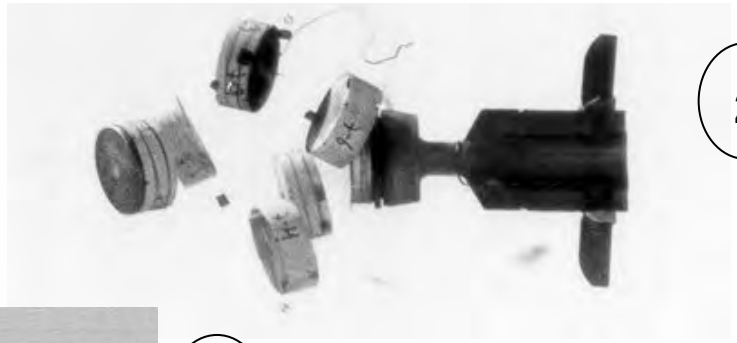
APAM 120
High Stability at Long Ranges – Excellent Accuracy



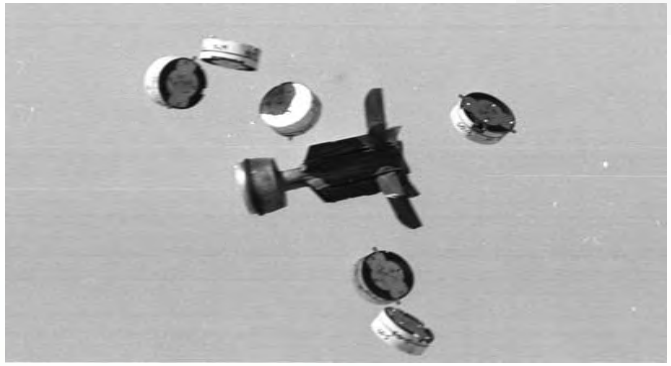
APAM 120
Warhead Separation and radial dispersion



1

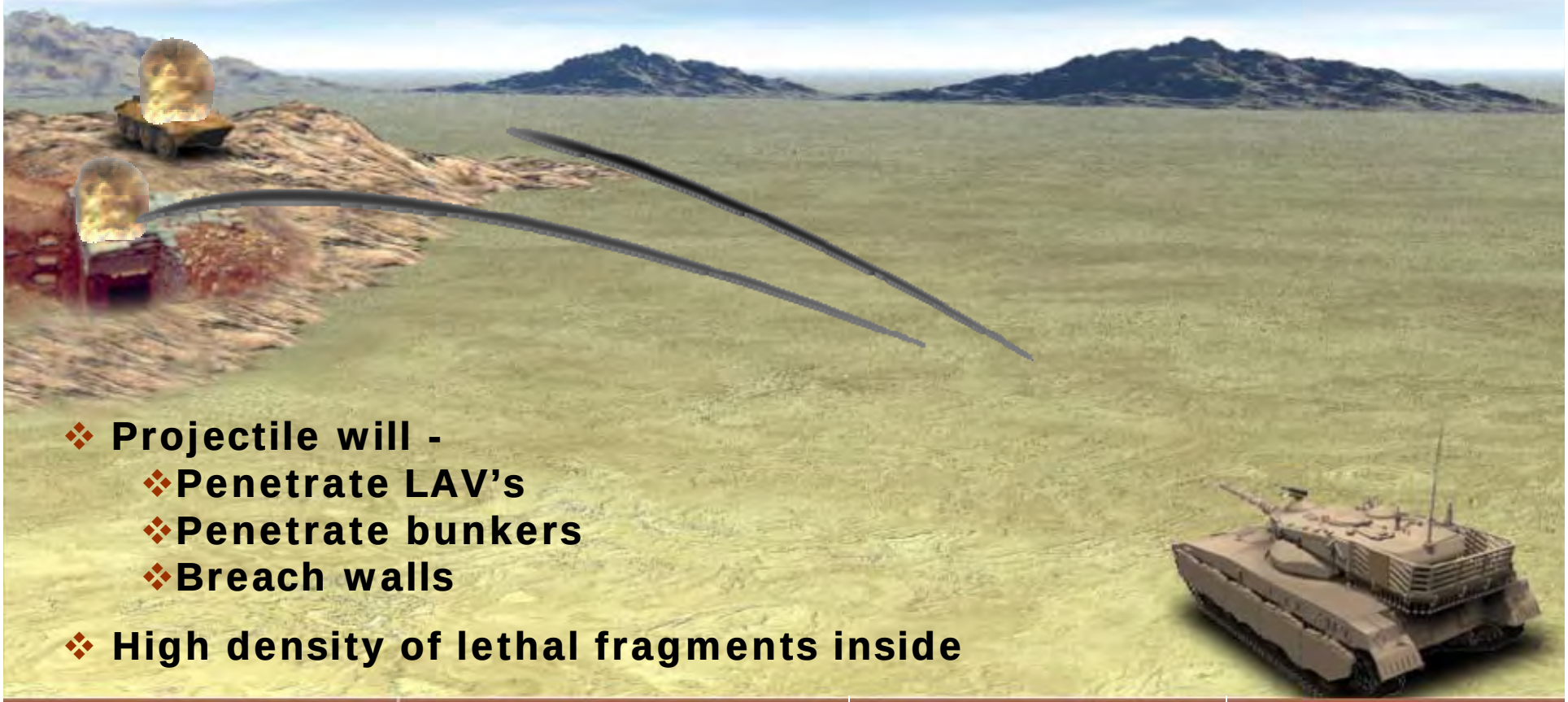


2



3

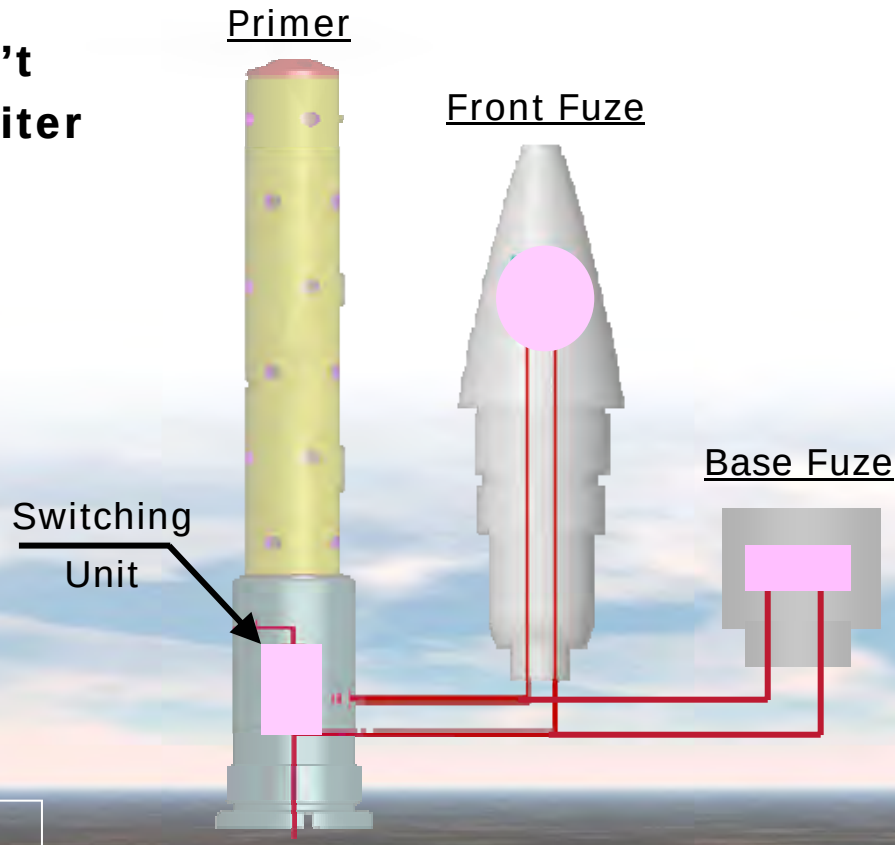
AM MODE (IMPACT)



- Projectile will -
  - Penetrate LAV's
  - Penetrate bunkers
  - Breach walls
- High density of lethal fragments inside

APAM 120
Primer and Ammunition Data Link

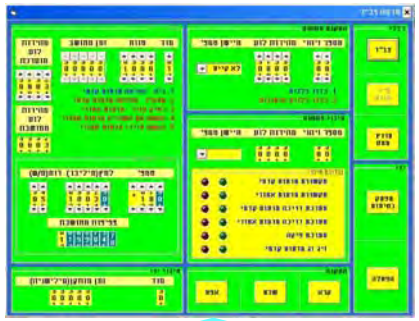
- The Data Link current doesn't pass through the primer igniter
- MIL-STD 1512
- MIL-I-23659C
- All Fire > 2.1A
- No Fire < 1.0A
- Safety: ∞ db



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

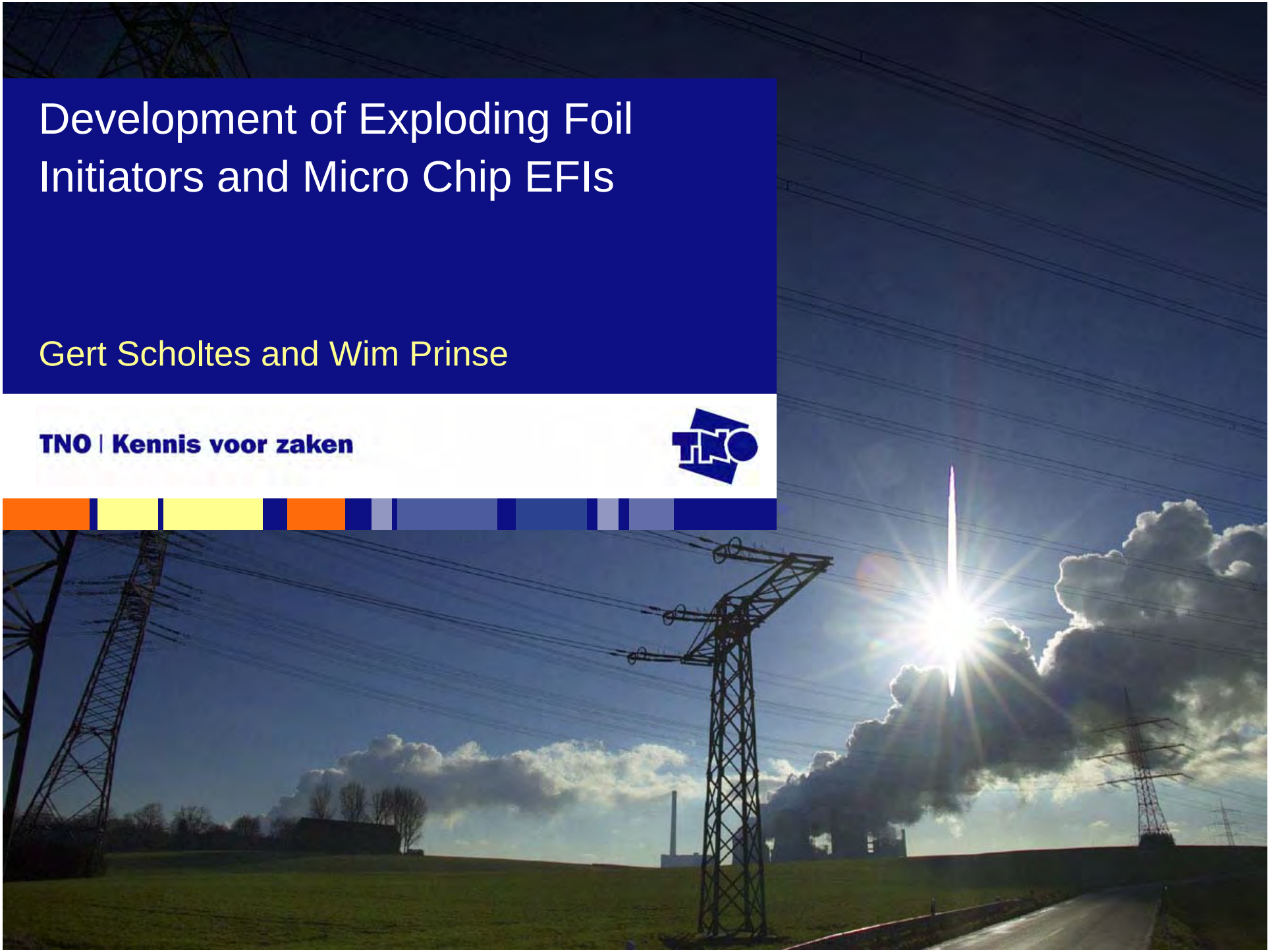


THE AMMUNITION OF TOMORROW
TODAY FROM IMI

Development of Exploding Foil Initiators and Micro Chip EFIs

Gert Scholtes and Wim Prinse

TNO | Kennis voor zaken

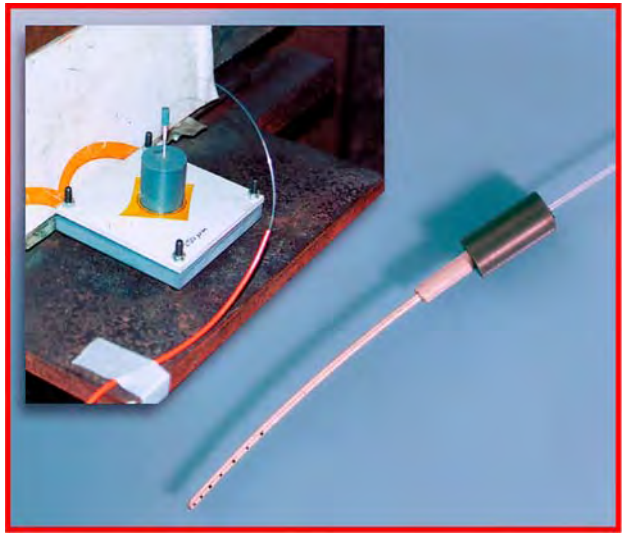


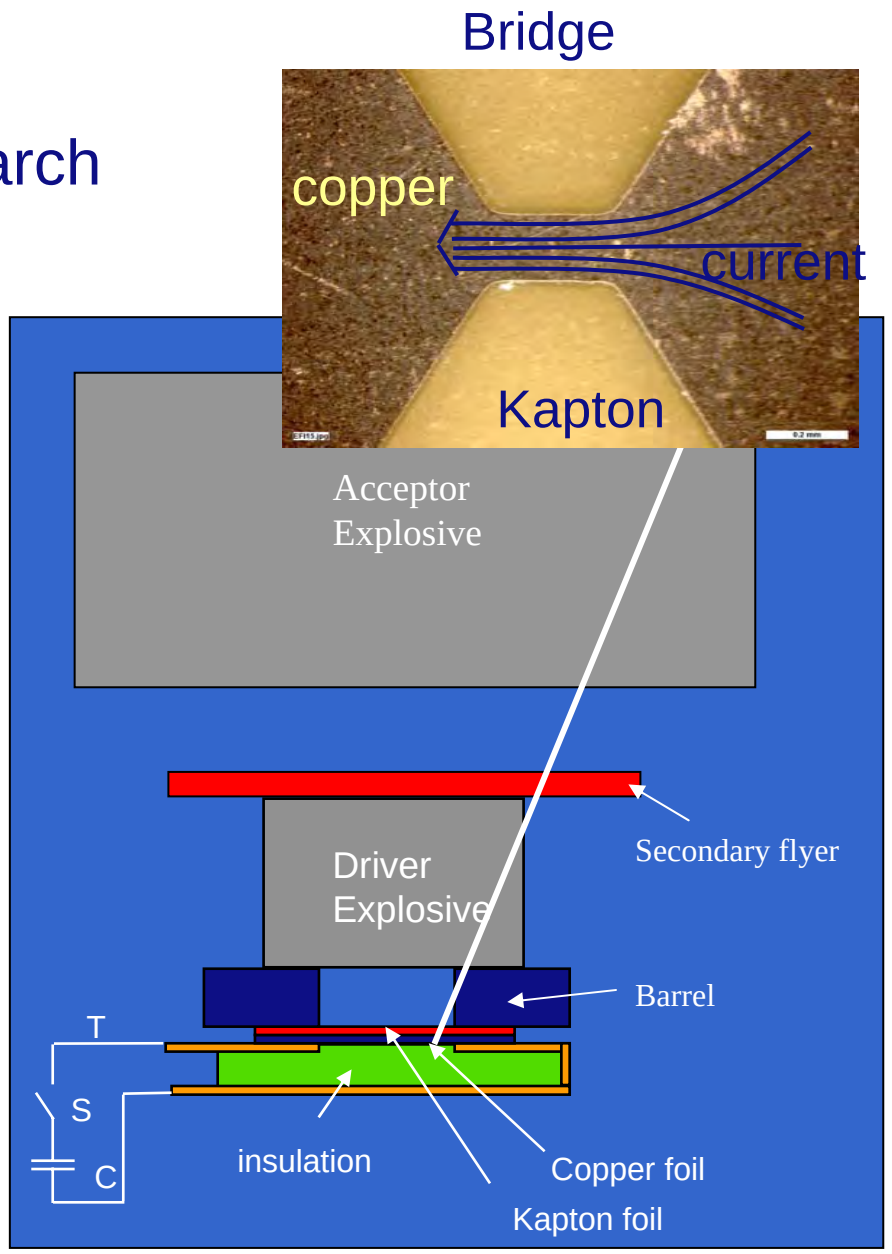
Overview

- Introduction
- Why EFI systems
- Exploding Foil Initiator Research
- Research on Explosives
- Conclusions

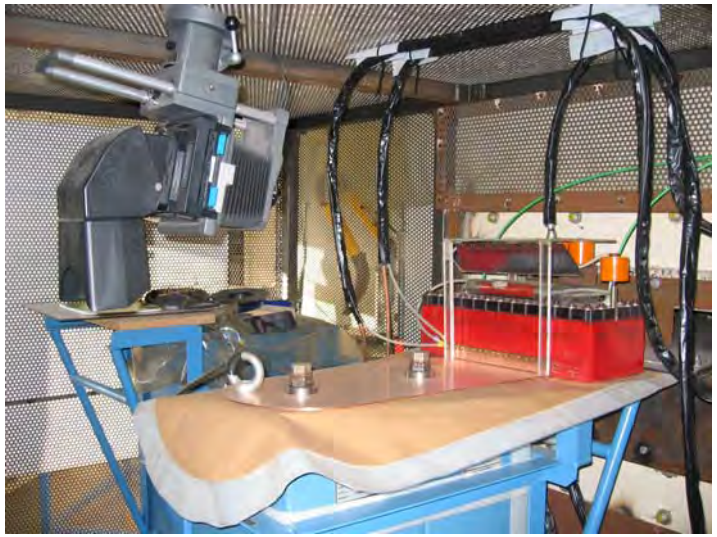
Introduction
Exploding Foil Initiator Research

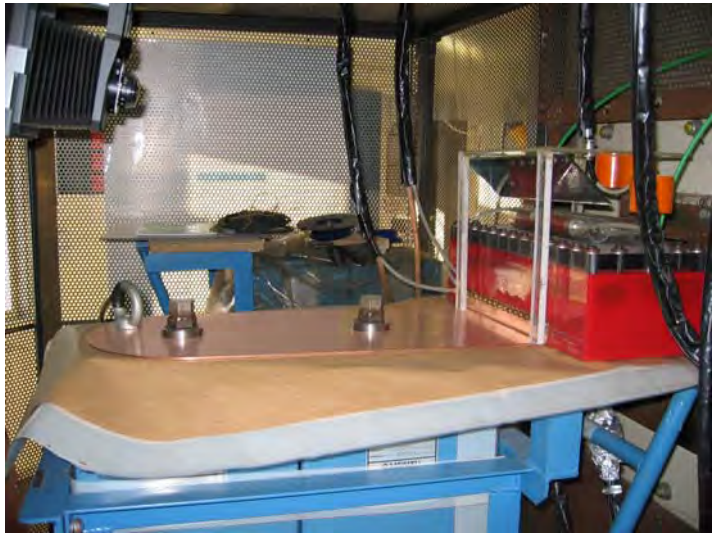
- Exploding foil
- Electrical circuit
- Velocity of the flyer
- Driver Explosive
- Secondary flyer
- Acceptor explosive





Shock initiation research at TNO: Mega Ampere Pulsar and Flyer Impact





~4 feet



Wim Prince



Why an EFI system

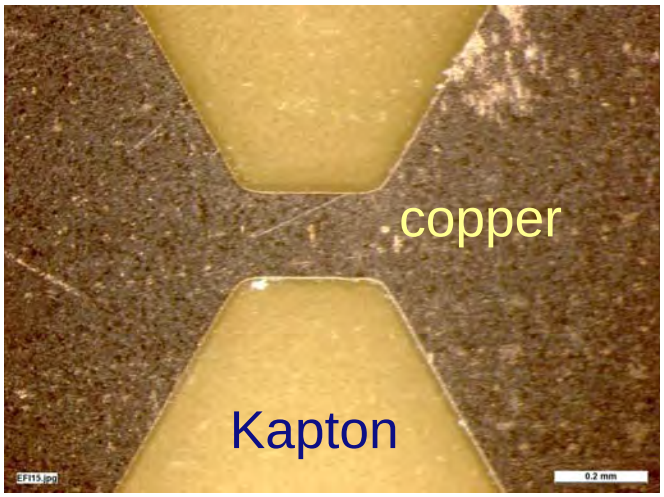
- An EFI is intrinsically safer than standard initiators (no primary explosive)
- More reliable (so hardly no UXO's)
- Works much faster < microseconds
- Can be smaller (near future)
- Is compliant with new STANAG (4560) regulations
- New opportunities (tandem charges, aim able warheads)

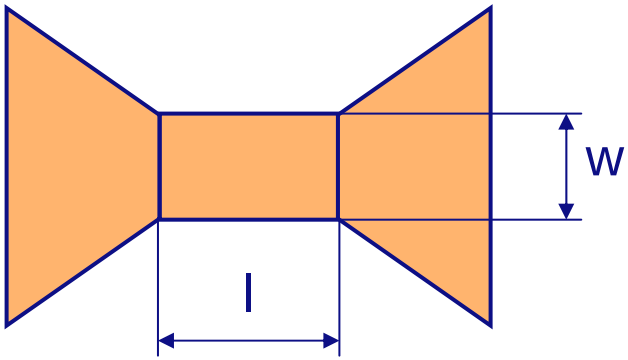
- Disadvantage : More expensive (at the moment)

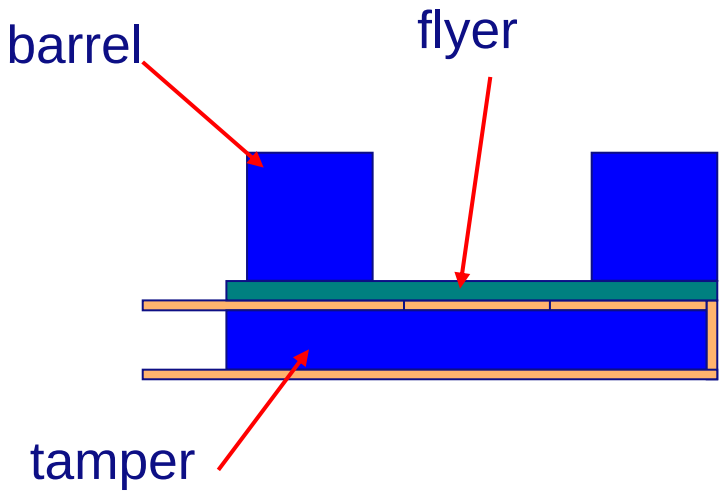
- Future: Micro Chip EFI (McEFI) → inexpensive

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

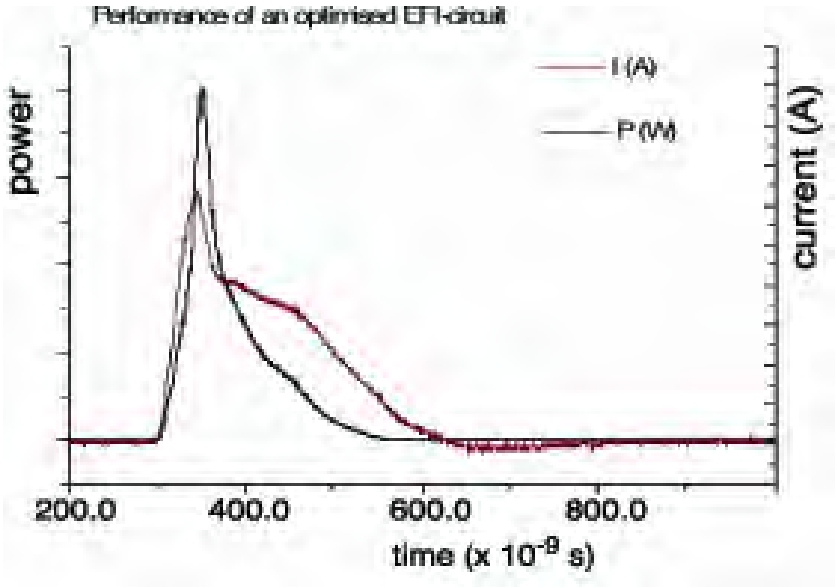




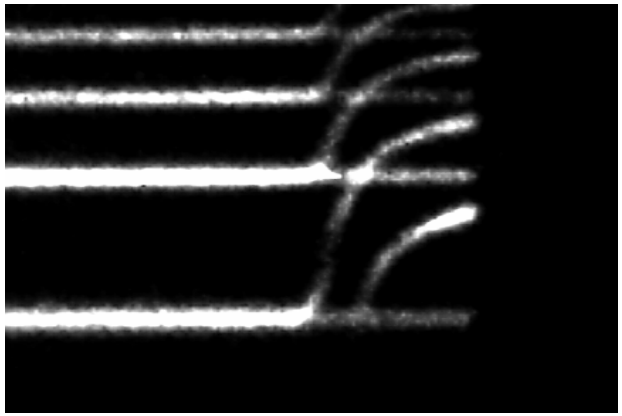


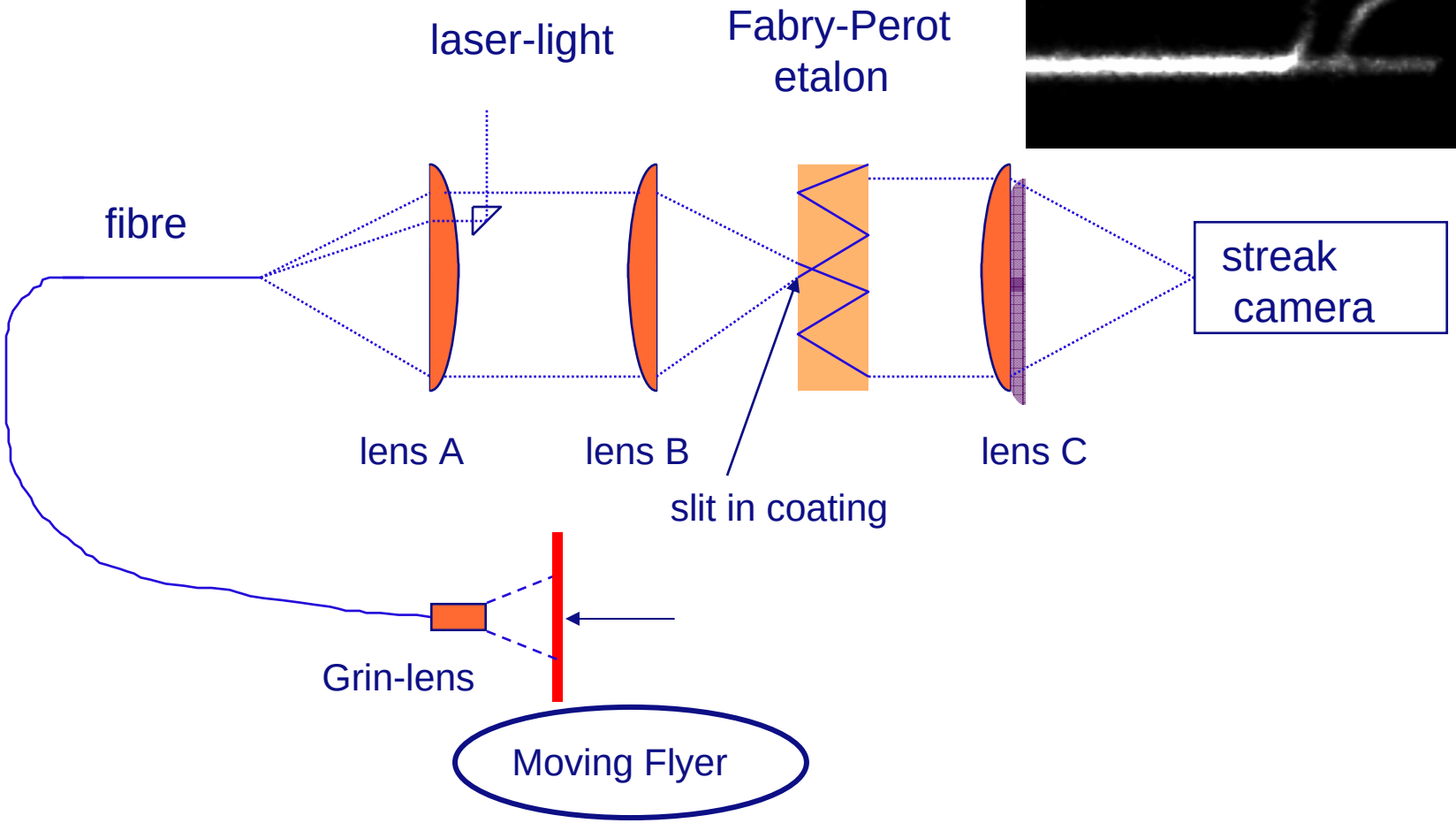
Electrical circuit

- 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)

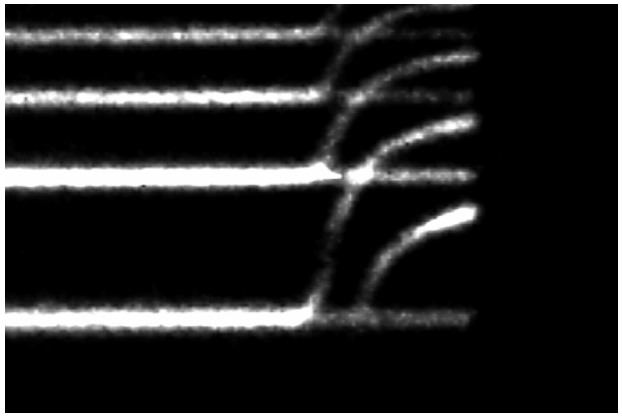


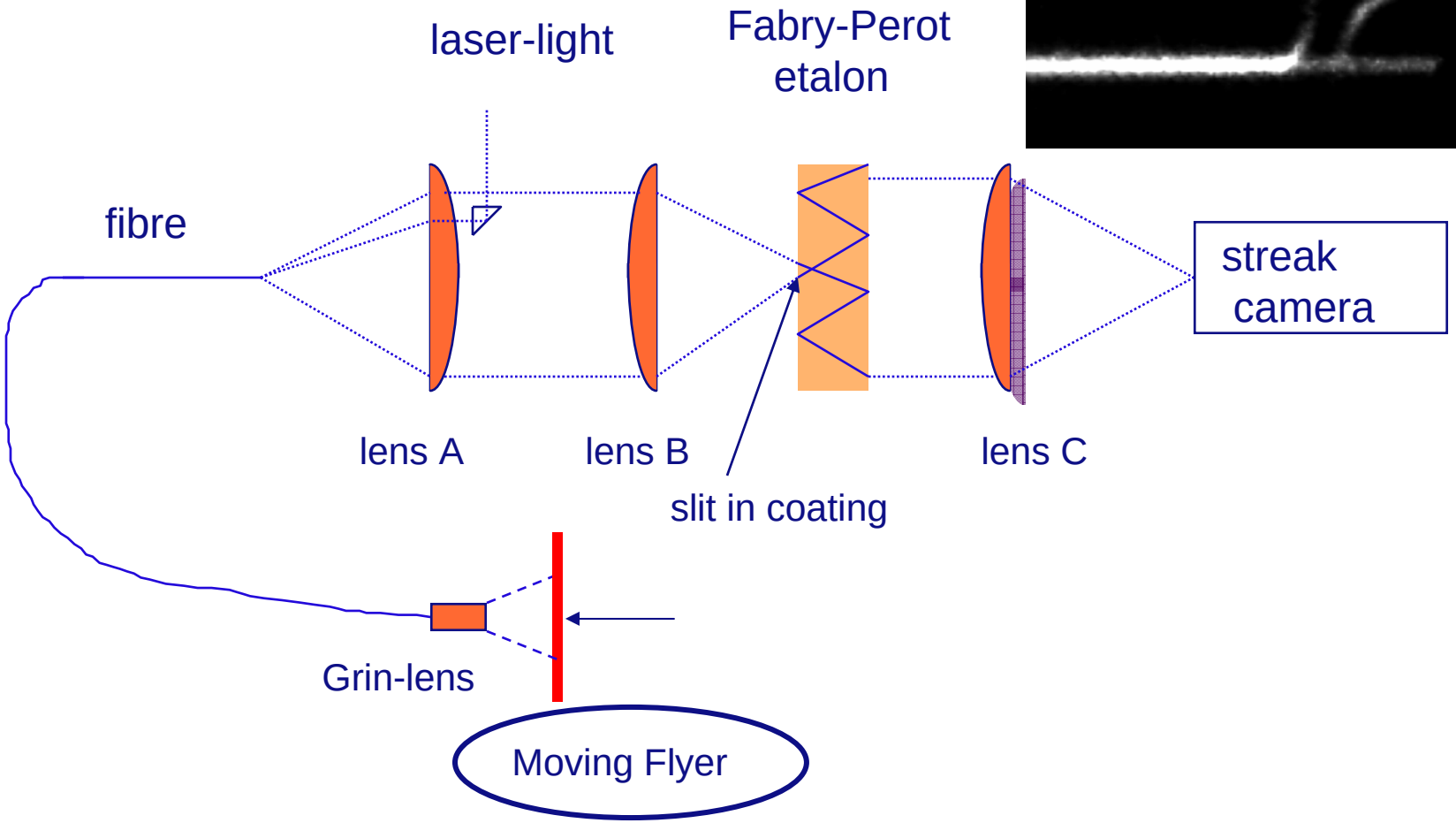
Fabry-Perot system





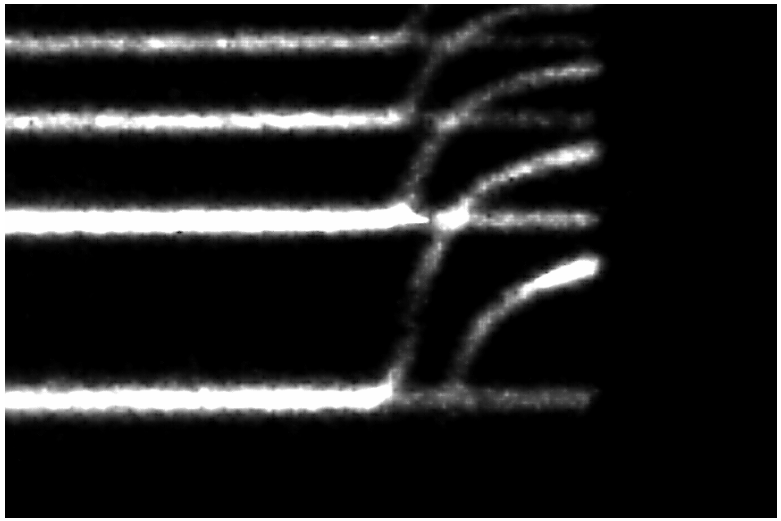
Fabry-Perot system

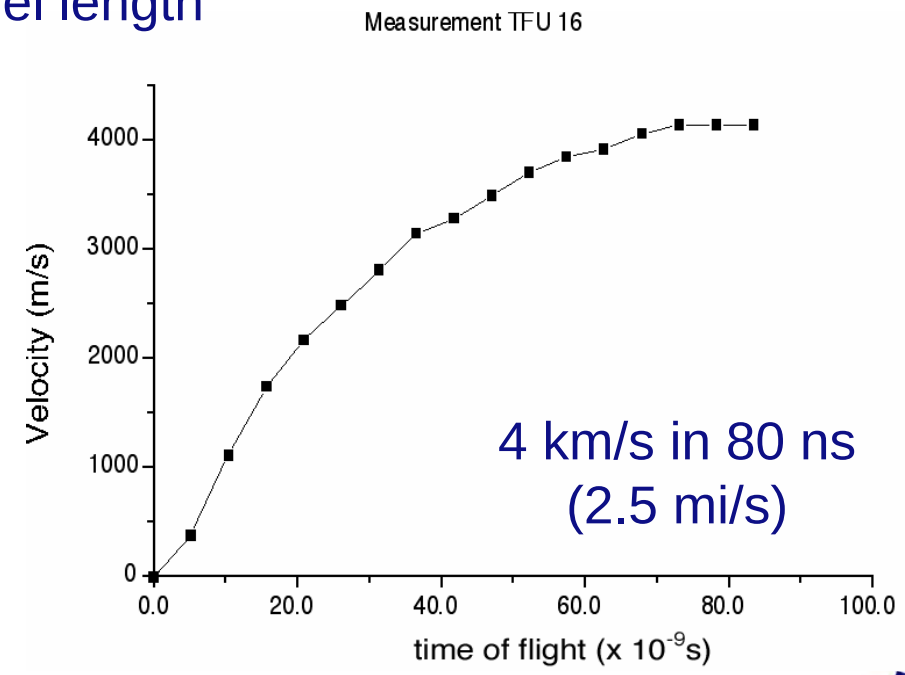




Flyer velocity measurement by F-P Interferometer

- 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

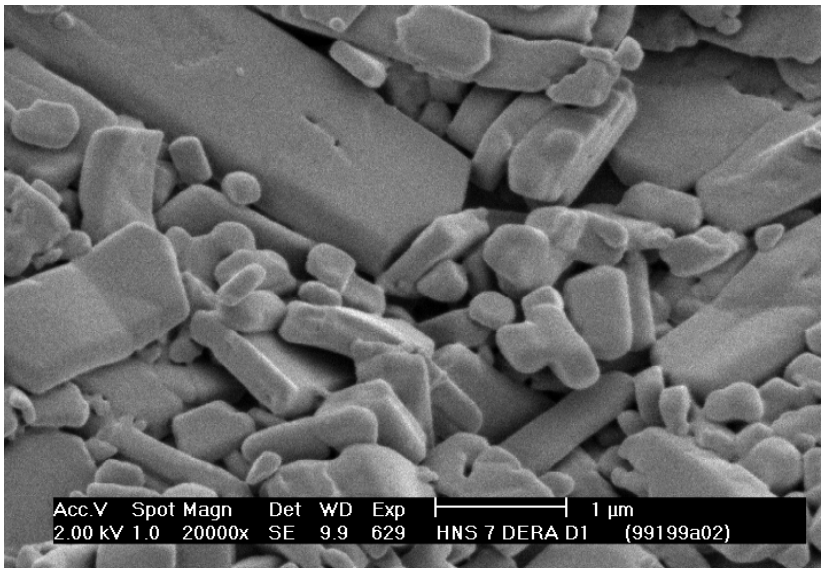




Research on Explosives I

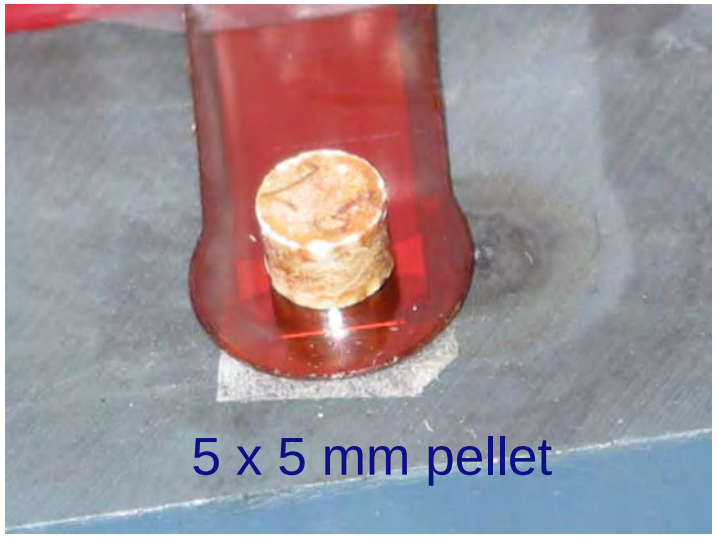
- Recrystallisation of HNS II to HNS IV
- The crystals are more uniform (smaller distribution)
- The length to width to thickness is 10:3:2
  a further increase in specific surface area is possible

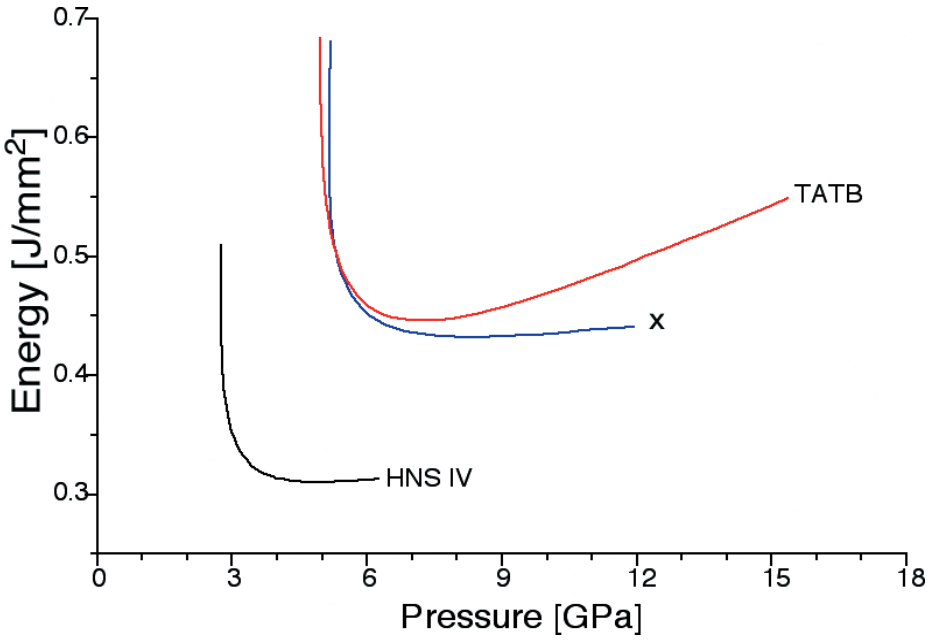




Initiation behaviour of different explosives

- Different types of explosives
  - HNS IV several brands
  - TATB several grades
  - New explosives
- Initiation energy depends on flyer thickness and velocity

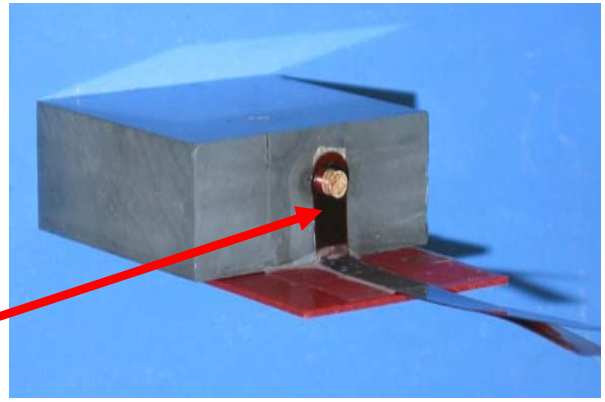


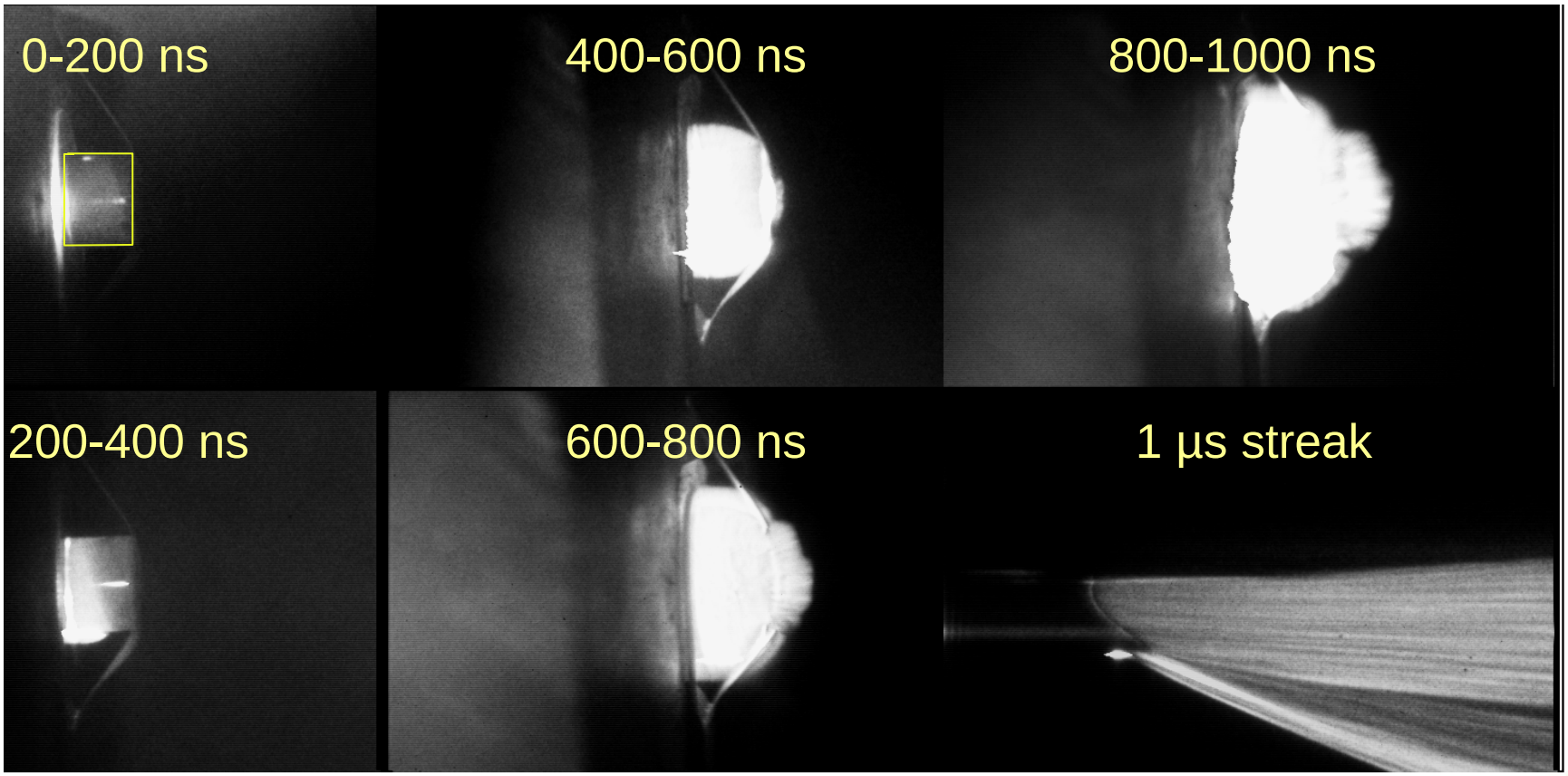


Initiation of 5 x 5 mm HNS IV pellet

Voltage < 1300Volt

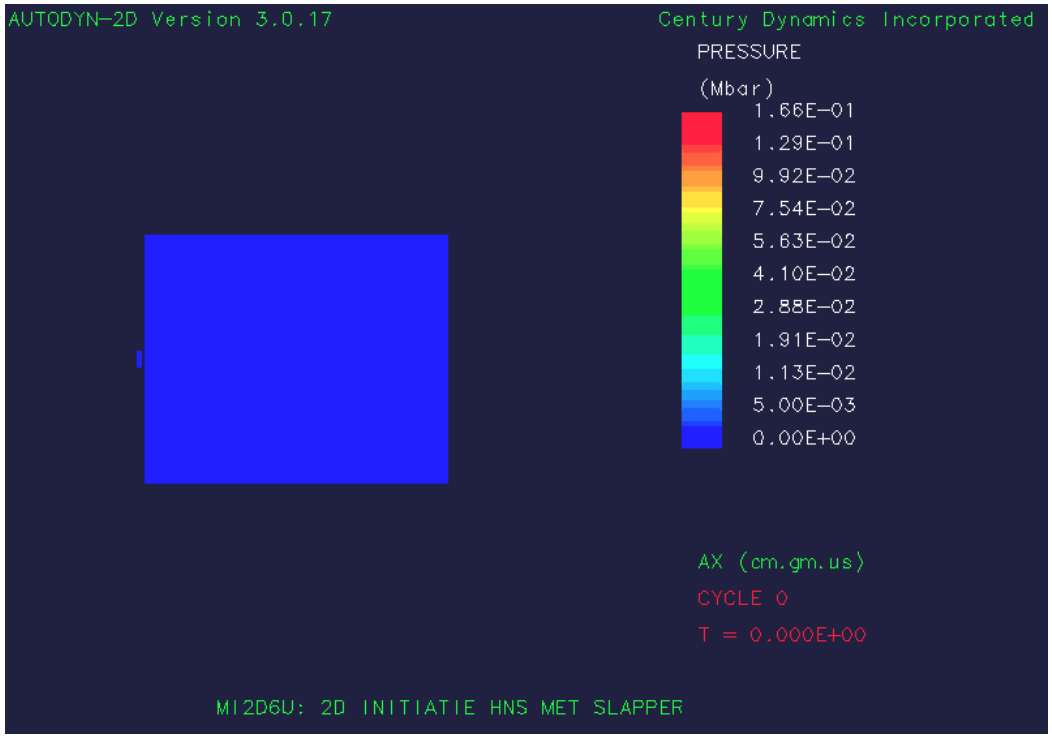
Transmission line





Numerical simulations of flyer impact

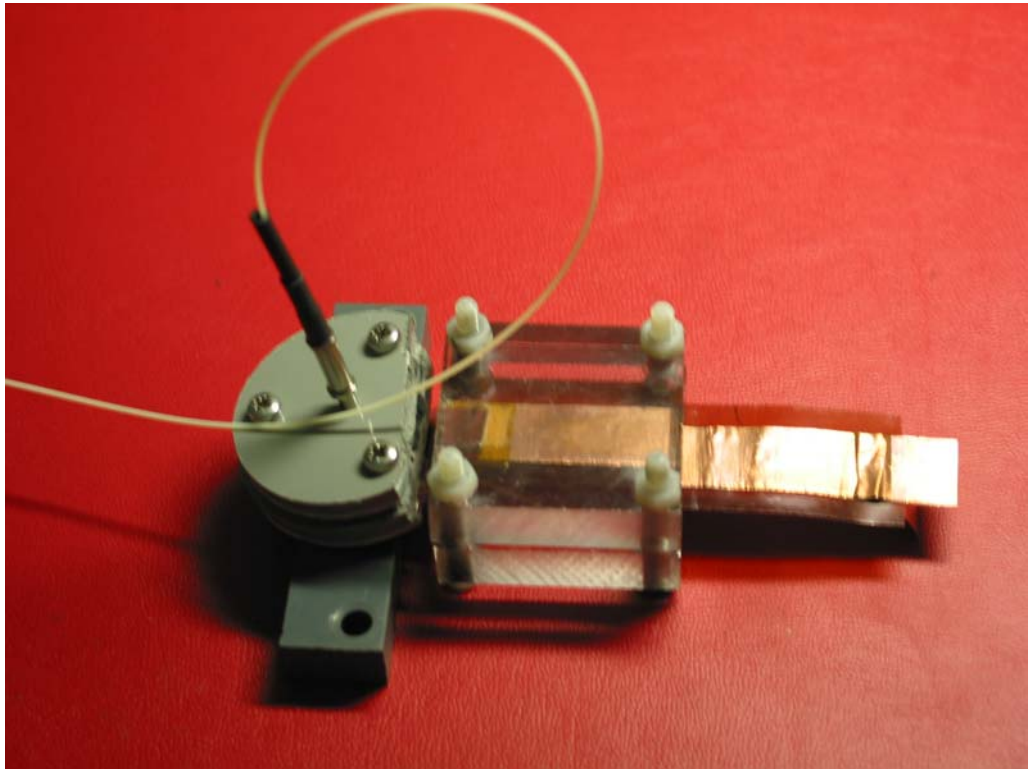
- Lee-Tarver model modified with visco-plastic pore collapse model
- Qualitatively the simulations can explain the experiments



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

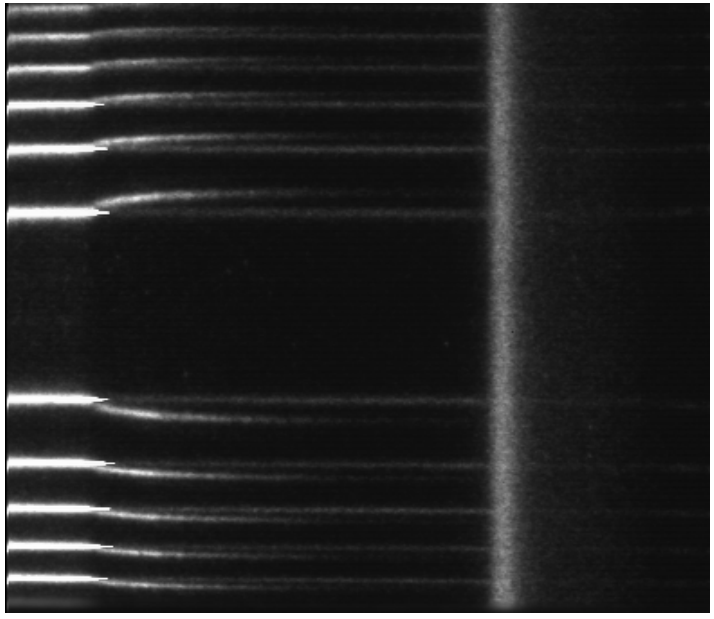


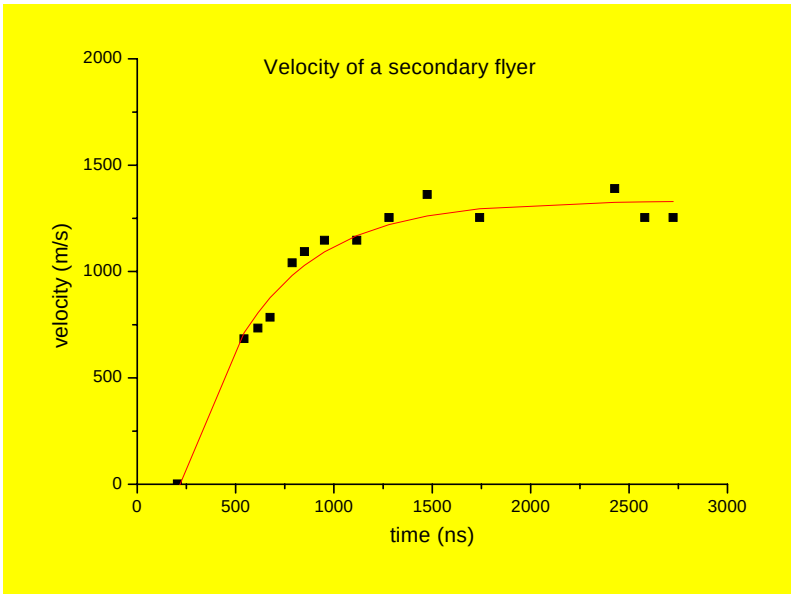
Secondary flyer impact

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

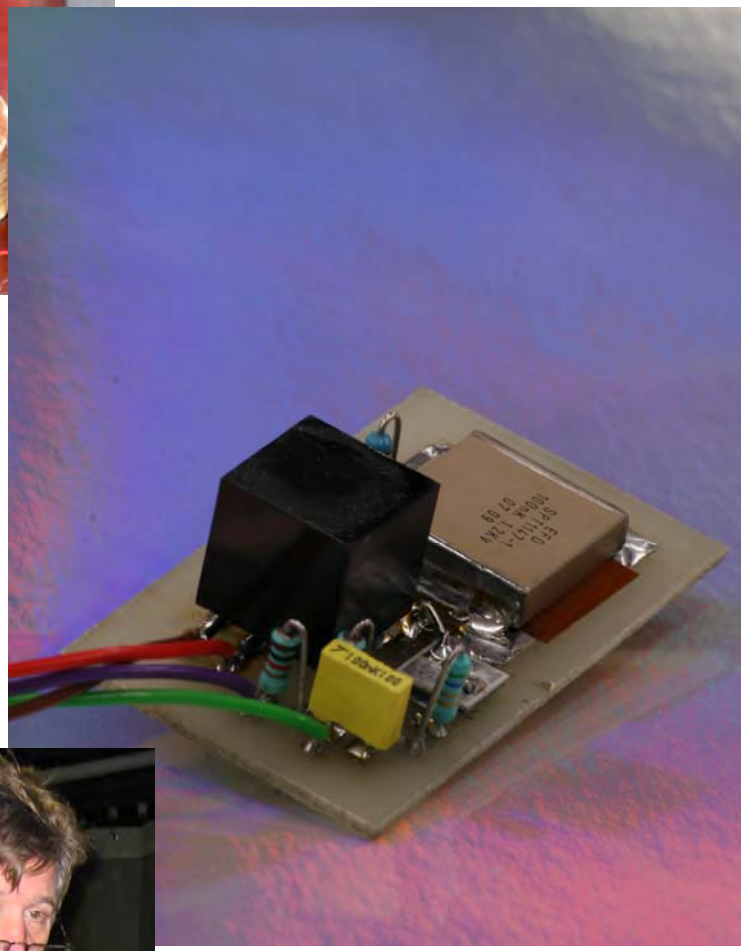


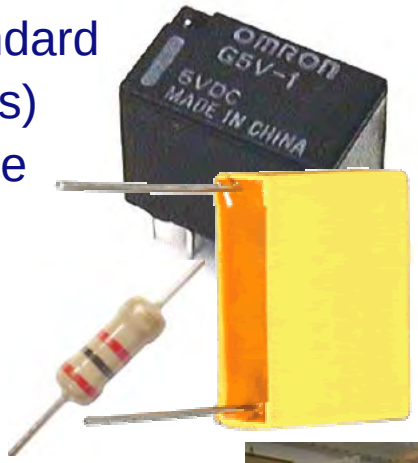


Development of mini EFI and developer platform for Micro Chip EFI (McEFI)

- 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





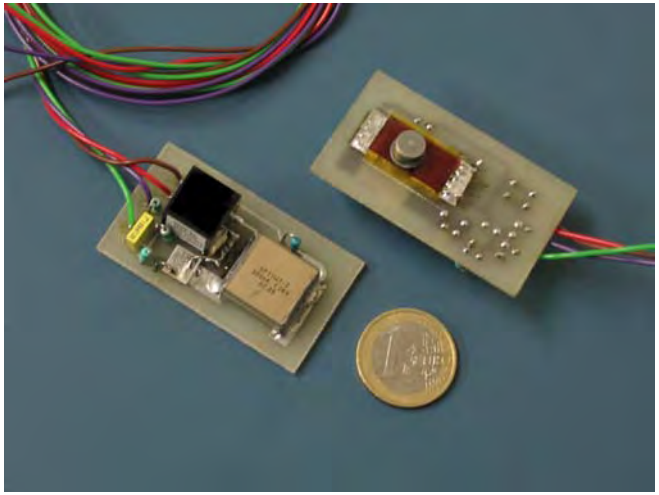


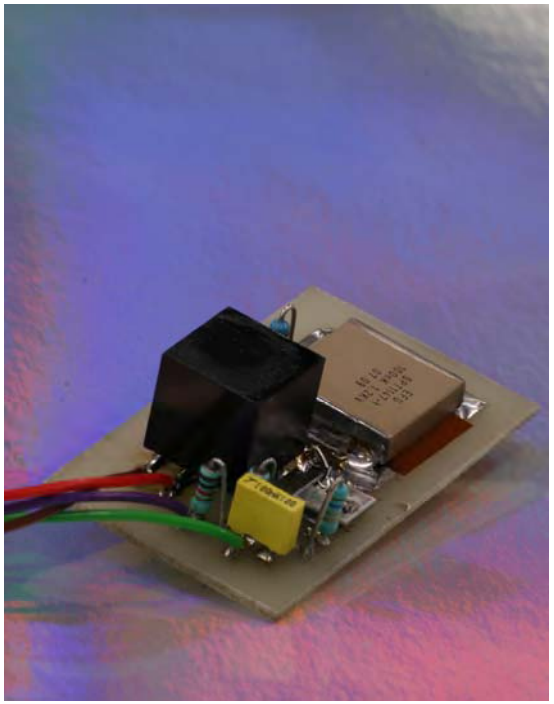


- Mini-EFI and developer platform for McEFI

Conclusions

- A very efficient electrical circuit (η = 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





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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

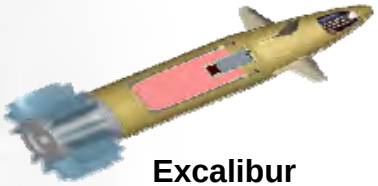
25 April 2007

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



Excalibur



Lightweight Handheld Mortar Ballistic Computer, XM32



Plasma Arc Furnace

R&D

DEMIL

SUPPORT TOTAL LIFE CYCLE

PROD

FIELD SUPPORT



Supercritical Water Oxidation



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

ARDEC at a Glance

- 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

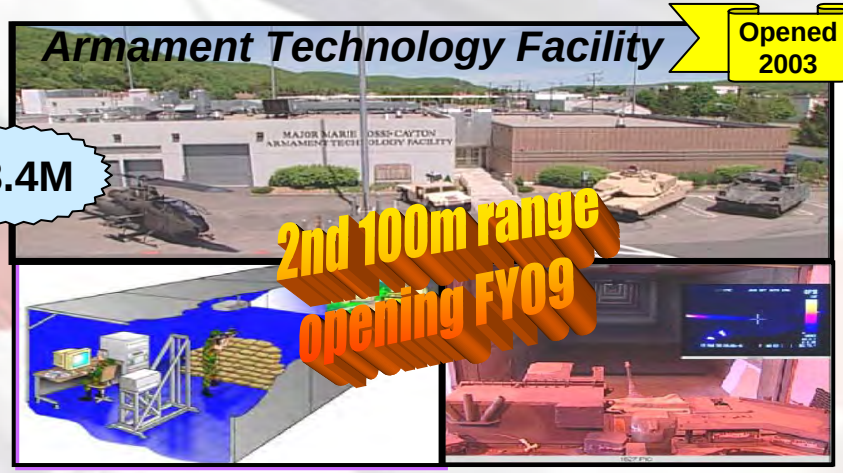


- 2 Lab grade elevators for sensor dev
- 3 Target locations; 150m, 400m, & 1500m

Armament Technology Facility

Opened 2003

$8.4M



- 100 & 300m indoor ranges
- Environmental chambers

Armament Software Engineering Cntr

Opened 2005

$15.5M



- Integrated S/W & H/W development/integration
- Multi-platform SOSI highbay capability

New Facilities Under Construction

Breaking "Old" Grounds

Soft Recovery System (SRS)

Opening May FY07

$9.0M

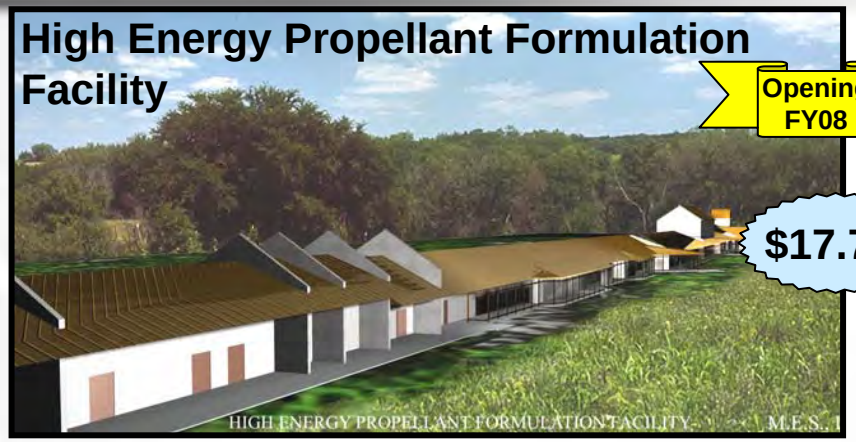


- High-g test Munition/Components to 20K g's
- 155mm capability (current); Only one in existence
- Navy 5", 120mm mortar, and EM Gun planned

High Energy Propellant Formulation Facility

Opening FY08

$17.7M

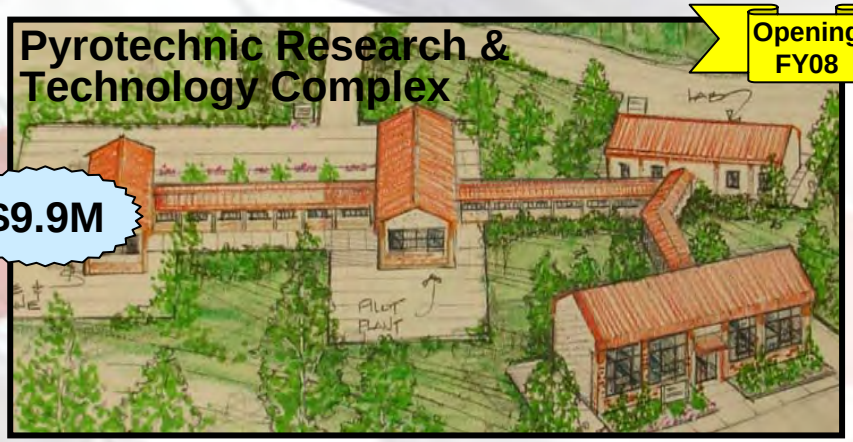


- 45,000 ft2 Propellant Pilot Plant
- Characterization Laboratories
- Magazine Storage / Offices

Pyrotechnic Research & Technology Complex

Opening FY08

$9.9M



- 33,000 ft2 Engineering Offices & Laboratories
- Pilot manufacturing facility
- Energetic stowage

Explosives R&D Loading Facility

Opening FY09

$8.0M



- 28,000 ft2 Melt Pour Operations & Engineering
- Climate Controlling Machining
- Explosive Pressing, Cast Cure, & X-Ray

Material Releases (MR) & Urgent MRs

FY05 to Present

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

Material Releases (MR) & Urgent MRs
FY05 to Present

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)
- Software Version 7.P for the M109A6 Paladin Digital Fire Control System (PDFCS)
- 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.

M113A2 Rapid Entry Vehicle (REV)

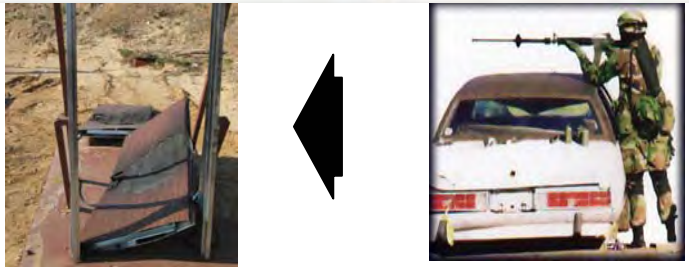




- Non-lethal response under armor with
  - 4 modified M870 shotguns
  - 6 Modular Crowd Control Munitions
- 4 vehicles fielded

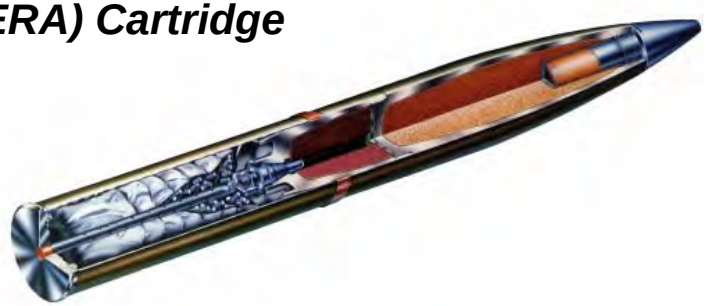
M100 Rifle Launched Grenade Munition





- Door Breaching Munition fired from M16A2 and M4 with standard 5.56mm M855 rounds.
- 300 tactical/1250 training rounds fielded

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

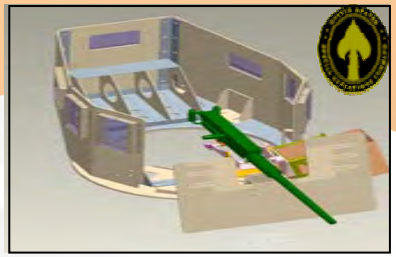
Gunner's Protection Kits (GPKs)



M1114 Objective GPK (O-GPK)
- **Concept Demo in 6 Months**
- **ARDEC Level III TDP**
- **Depot Production for >15K GPKs**



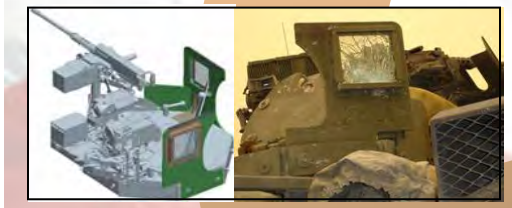
RG31 GPK
- **Modified O-GPK**
- **ARDEC LRIP underway**



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**



Engineering Boat (MK1) Survivability Enhancements
- **Baseline Design Complete**
- **Prototype Demo Planned May 07**
- **LRIP Quantity Planned 3rdQ FY07**

Concept Design

Initial Production Prove-Out and Fielding Support

Close Coordination with Customers Key to an Integrated Solution for Survivability, Lethality, and Situational Awareness

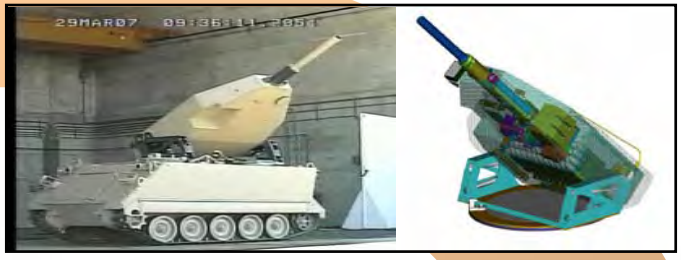
Rapid Prototyping Initiatives

Examples of "Tech Push" for Early User Demo's AND
Support to Production/Fielding Requirements

Remote Armaments for Unmanned Platforms



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



"I'm ready to deploy with this unit and SWORDS"

- SGT, 1-3 Cavalry, 3BDE/3ID

Special Weapon Observation-Reconnaissance Direct Action System (SWORDS)
- Safety Confirmation Jun 06
- 3 Deployed to 3rd ID for Training
- Urgent Material Release expected

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

Initial Production Prove-Out and Fielding Support

Valuable Lessons Learned on Design and Safety Considerations to Apply to Remote Armament Programs

Concept Design

Engineering Analysis/Evaluation

Example of evaluation of system technology performance

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**





SYSTEMS	MANUFACTURER
PD-Cue® 4 Corner	AAI
PD-Cue® Tetrahedral	AAI
Ferret	MacDonald Detwiller & Associates
VM-GDS	01dB, Metravib
Boomerang v2.5	BBN Technologies
SNIPOS	Axcess Technologies
VAAPS/LWAS	Land Warrior Acoustic Systems
Red Owl	iRobot

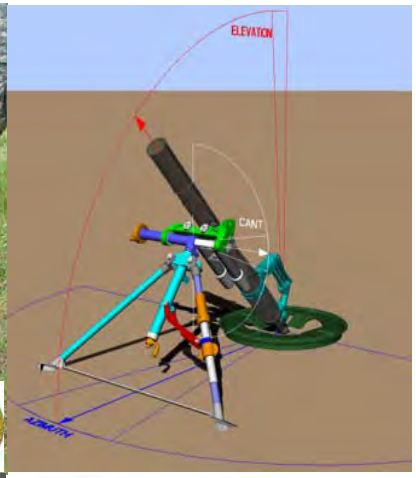
Testing Critical for Requirements Generation and Establishing TTPs

Recent Tech Base Transitions

Major Examples-Weapons

LtWt 81mm Dismounted Mortar





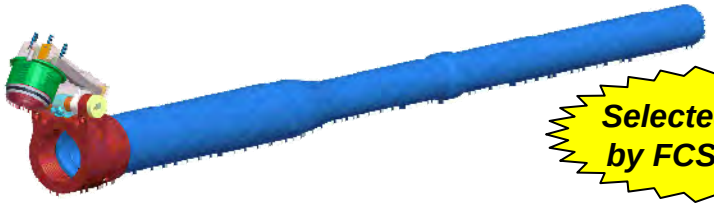




- Joint Army/Navy Funded
- ~30% weight reduction (to <70lbs)
- New Inconnel Tube Mat'l & Process
- Simpler, More Ergonomic Bi-Pod
- ~50% UPC reduction
- Transitioning to Prod ECP FY07

XM325 120mm Mortar Cannon





Selected Cannon by FCS Program

- 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)

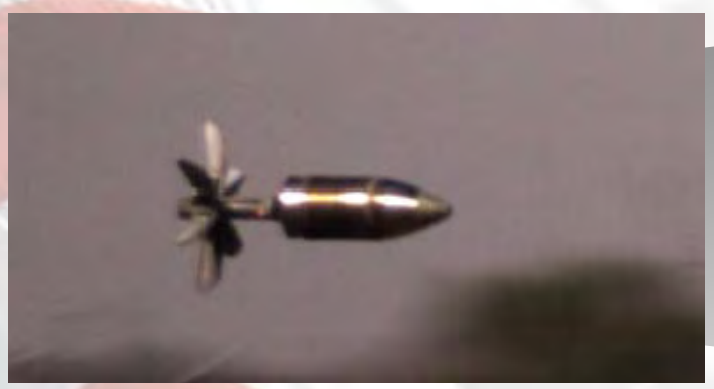
Current



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

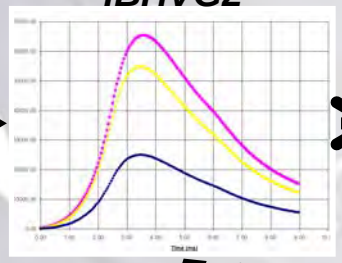
Enabled TRL 6 Demo in 2 Years

- Initial conceptualization to meet requirements
- Definition of high risk process and long lead items
- Define shortfalls of M&S: Fill gaps with test, experience

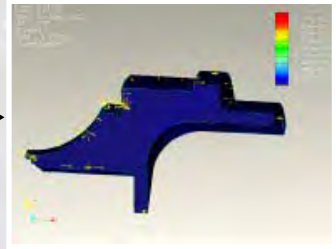
Modeling/ Configuration Pro Engineer/ Intralink



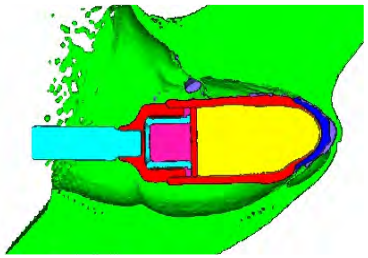
IB Simulation IBHVG2



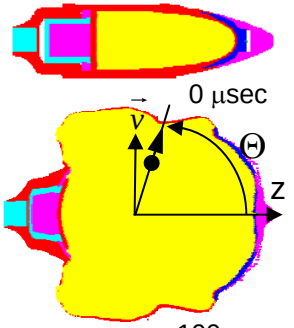
Structural analysis FBD/ ANSYS



Target penetration CTH

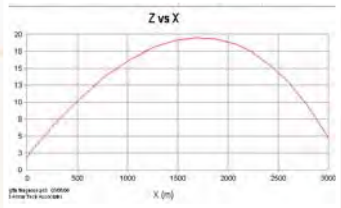


Fragmentation CALE/PAFRAG

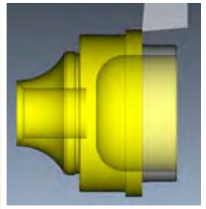


Failure in any model reiterates design process

Flight performance PRODAS



3D numerical control Pro Manufacture



Verify Models

Fragmentation



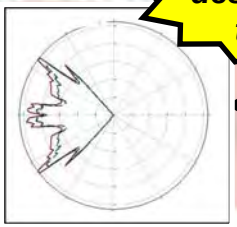
Flight Performance



DR concrete wall



Lethality Models CASRED/MPR3D/ AJEM/MUVES



No iteration of design during testing !

Modeling and Simulation Saved $6.8M and 27 Months

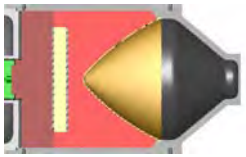
LOS-MP Video



ARDEC Tech Base Investments

Some Examples w/ Joint Service Applications

Hardened Combined Effects Penetrator Warheads (FY04-08)





- Single warhead to defeats armor, bunkers, personnel, UAVs with capability to bash-through and detonate within urban structures and clear re-bar.
- Broad applications across guns and missiles

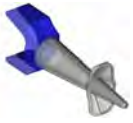
~$38M

Electromagnetic Gun (FY04-08+)

$85M+









- 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

USMC Interest expressed

LtWt Small Arms Technologies (FY05-08)



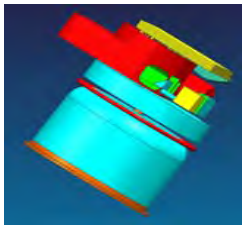


- Technologies to reduce weight, increase reliability, and decrease training burden
- Plastic cased and caseless ammo under evaluation
- 35-45% total weapon/ammo weight reduction in 5.56mm achievable (Baseline: M249)

~$35M

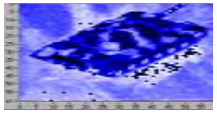
Common Smart Submunition (FY04-09)

$60M





Combined Effects Explosively Formed Penetrator (EFP)



LADAR



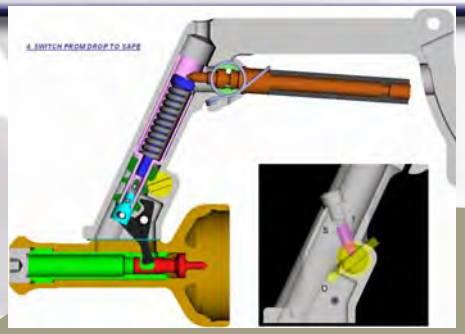
- Next generation smart submunition
- High kill probability against threat spectrum incl APS
- Application across munitions/missiles(≥120mm) & UAVs
- Supports Air Force “Area Dominance” via MOA

Navy Interest expressed

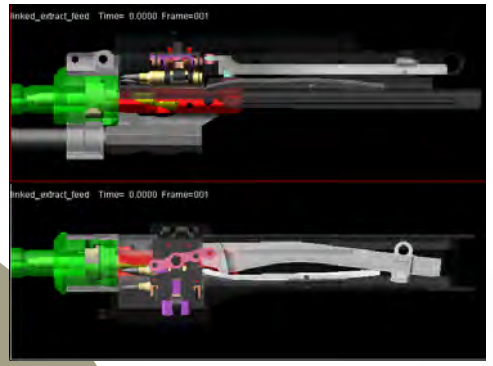
$xM = Army Funding

Engineering Design and Analysis









PRO-E

GLO/CALE

ABAQUS

ANSYS

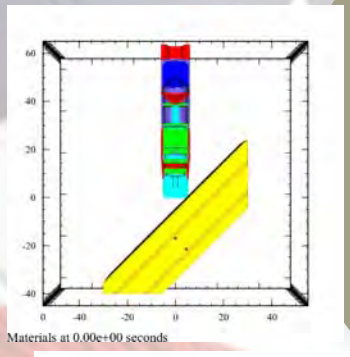
ALE3D

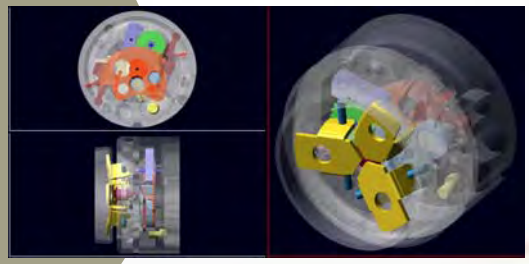
LS-DYNA

LSTC
Livermore Software Technology Corp.

Weapons Dynamics

MSC.ADAMS





Exterior/Terminal Ballistics

Component Design

FLUENT

FLOWTRAN

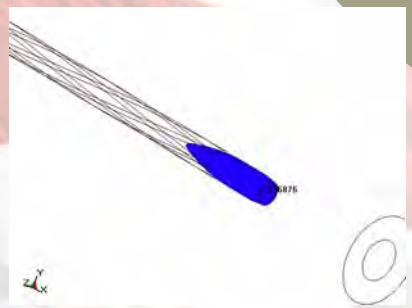
PRODAS

CTH

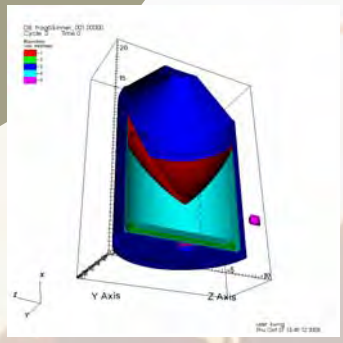
Interior Ballistics

PAFRAG

Cheetah







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

ISO 9001 Certified
FS15149

- 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

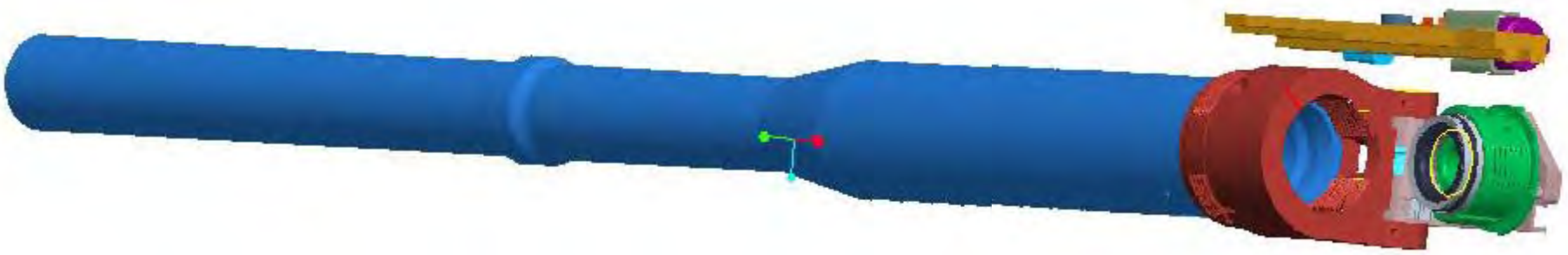
ISO 9001 Certified
FS15149

- 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

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CAM PLATE &
ELECTRIC ACTUATOR

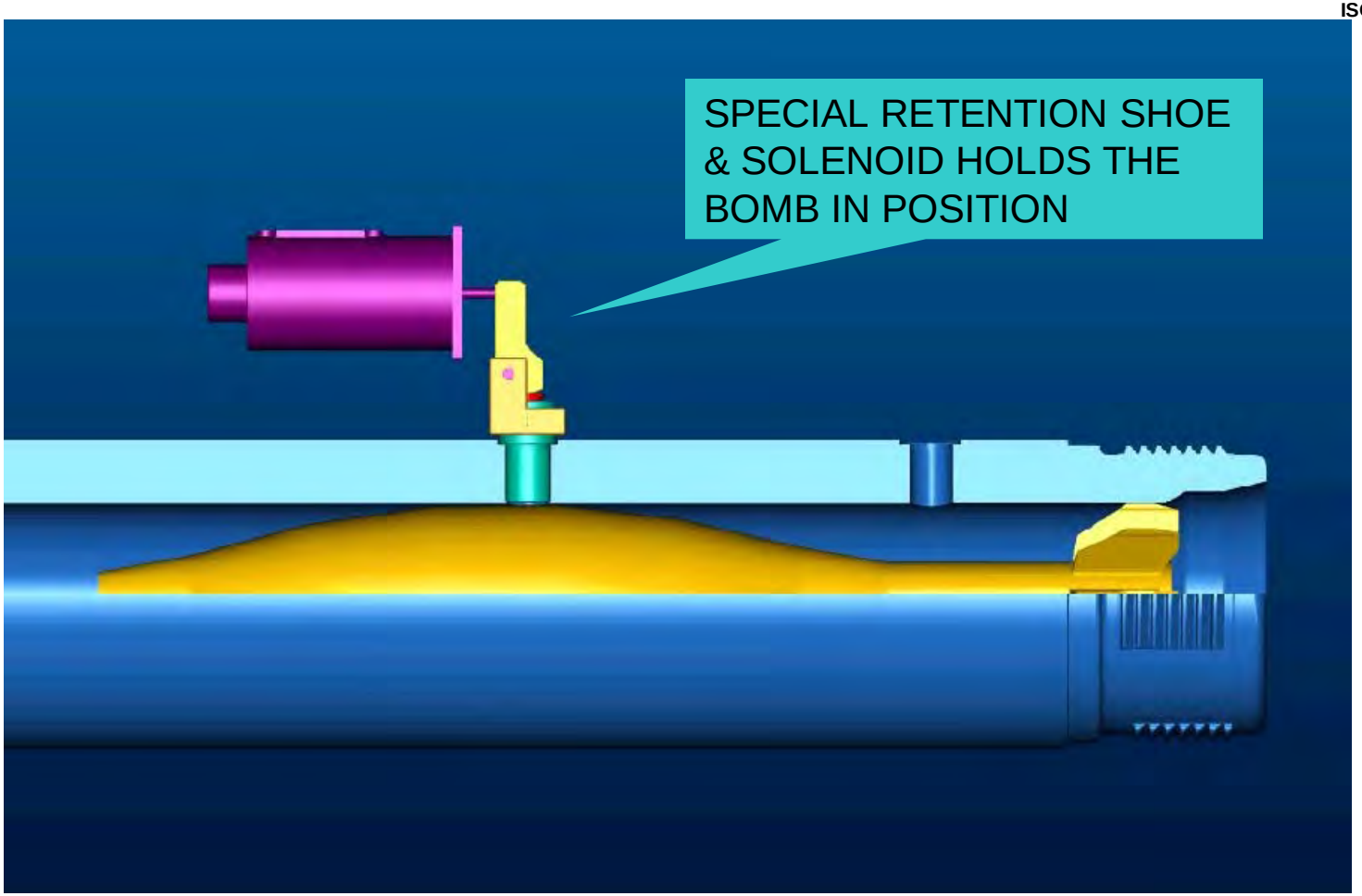


SCREW BLOCK
BREECH

DEBANGE OBTURATOR
(SPINDLE NOT SHOWN)

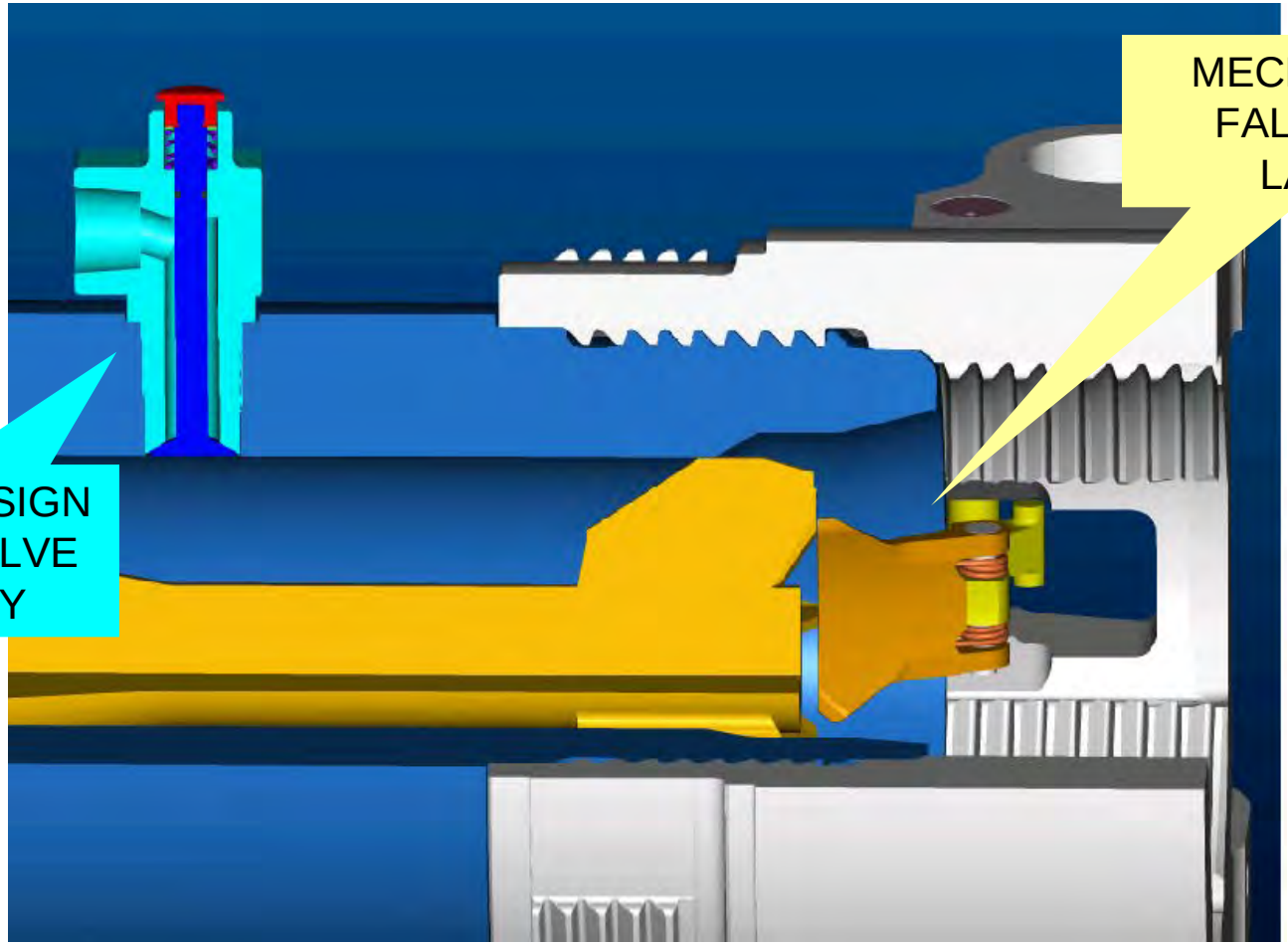
ON-MT MORTAR CANNON
MORTAR BOMB RETENTION SHOE

ISO 9001 Certified
FS15149



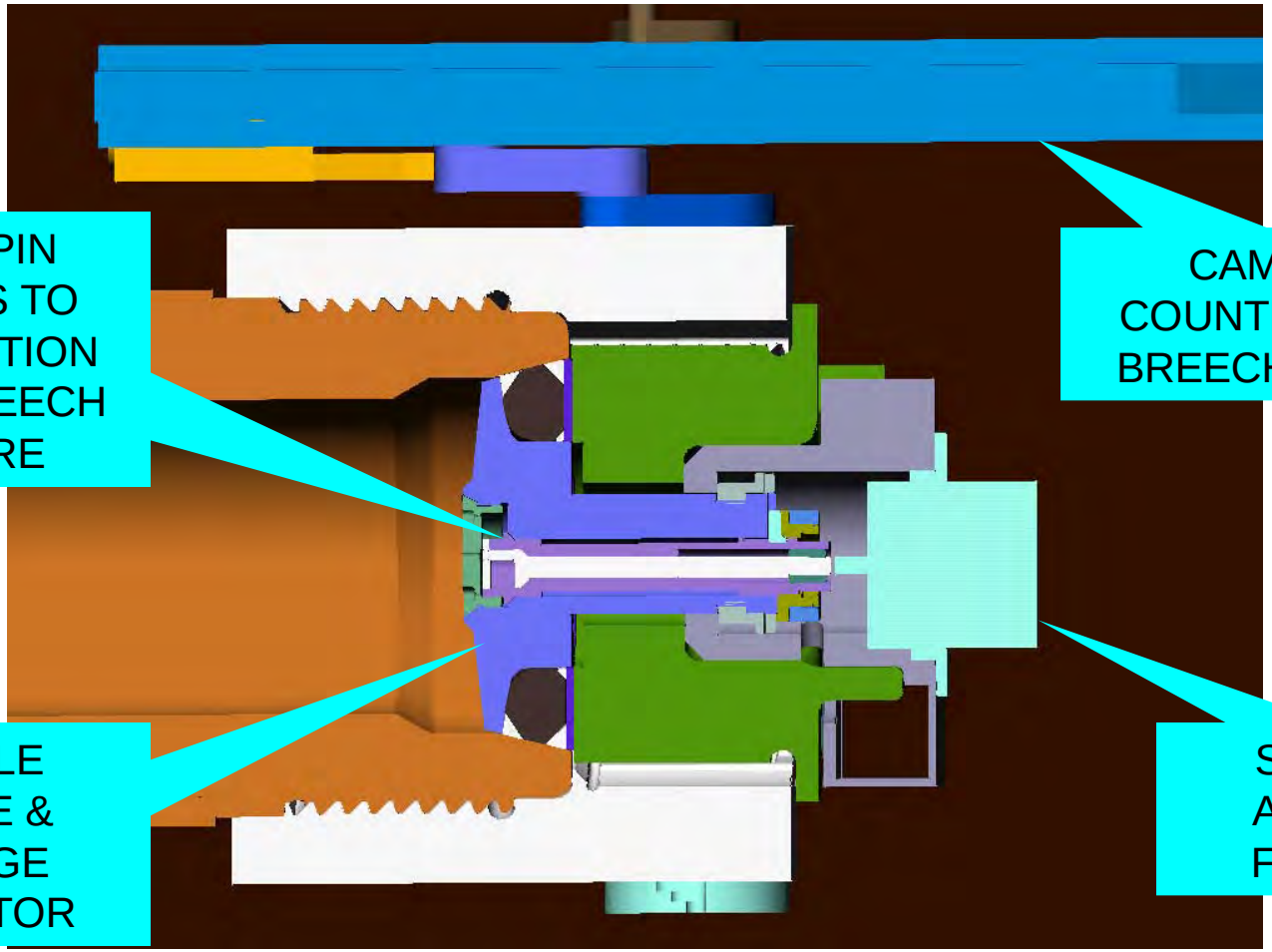
ON-MT MORTAR CANNON
VACUUM - BOMB POSITIONING DEVICES

ISO 9001 Certified
FS15149



ON-MT MORTAR CANNON IGNITION SYSTEM

ISO 9001 Certified
FS15149



FIRING PIN ROTATES TO FIRE POSITION AFTER BREECH CLOSURE

CAM PLATE COUNTER RECOIL BREECH OPENING

RELIABLE SPINDLE & DEGANGE OBTURATOR

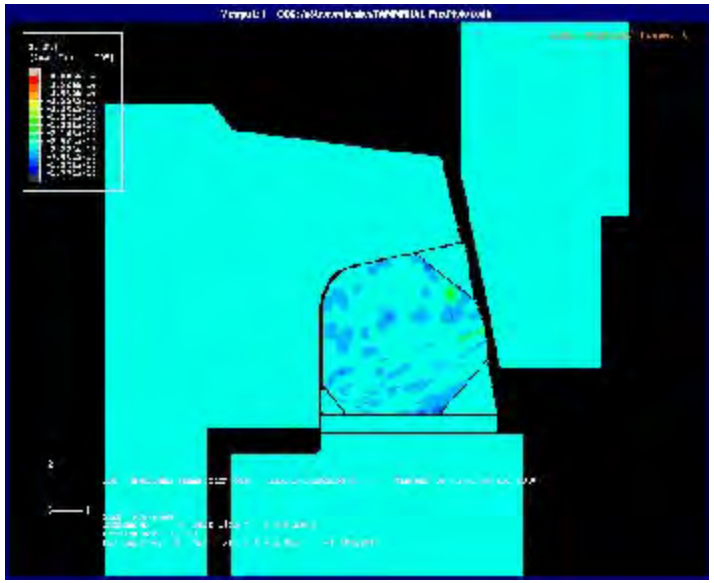
SOLENOID ACTUATES FIRING PIN

ON-MT MORTAR CANNON COMPONENT ANALYSIS - SEAL

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FS15149

FINITE ELEMENT ANALYSIS OF DEBANGE SEAL CONDUCTED TO ASSESS:

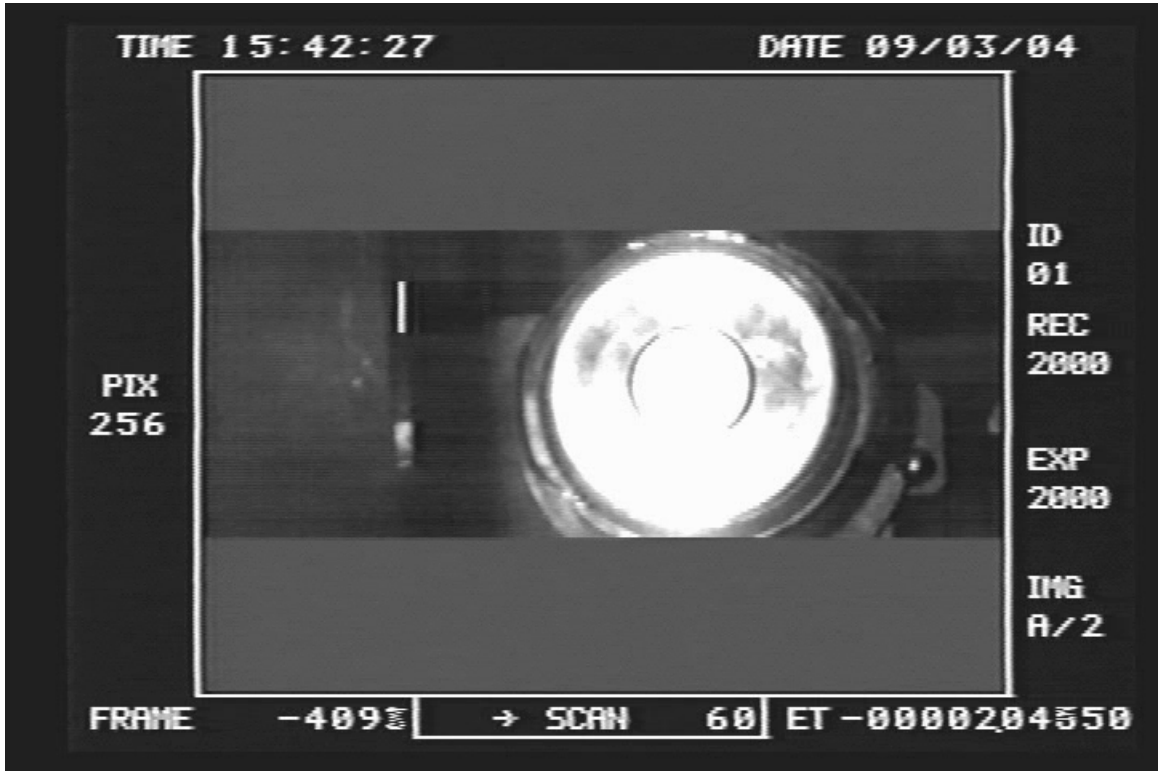
- ROBUST OPERATION WITH CLOSURE PRE-LOAD
- MIN & MAX MATERIAL CONDITIONS
- EFFECTS OF THERMAL EXPANSION (RATE-OF-FIRE)
- ADEQUATE SEAL ACROSS ALL ZONES



ON-MT MORTAR CANNON
COMPONENT ANALYSIS - MECHANISM

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- 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

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FS15149

- 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

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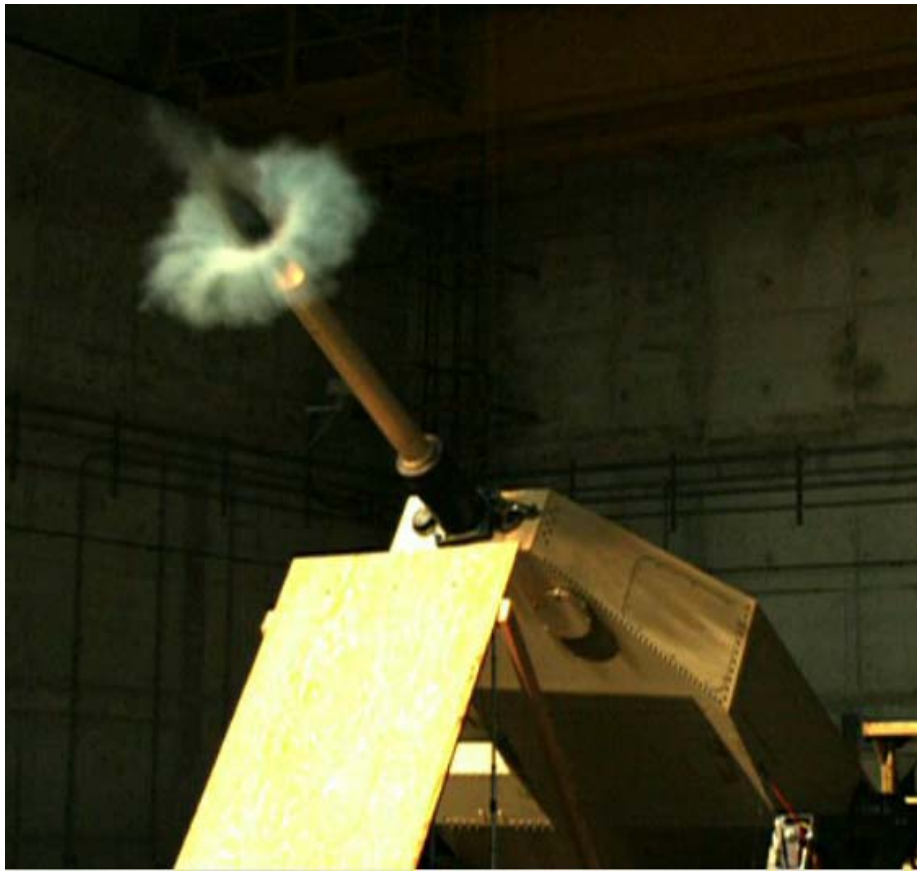
ON-MT MORTAR CANNON DEVELOPMENT SCHEDULE (cont'd)

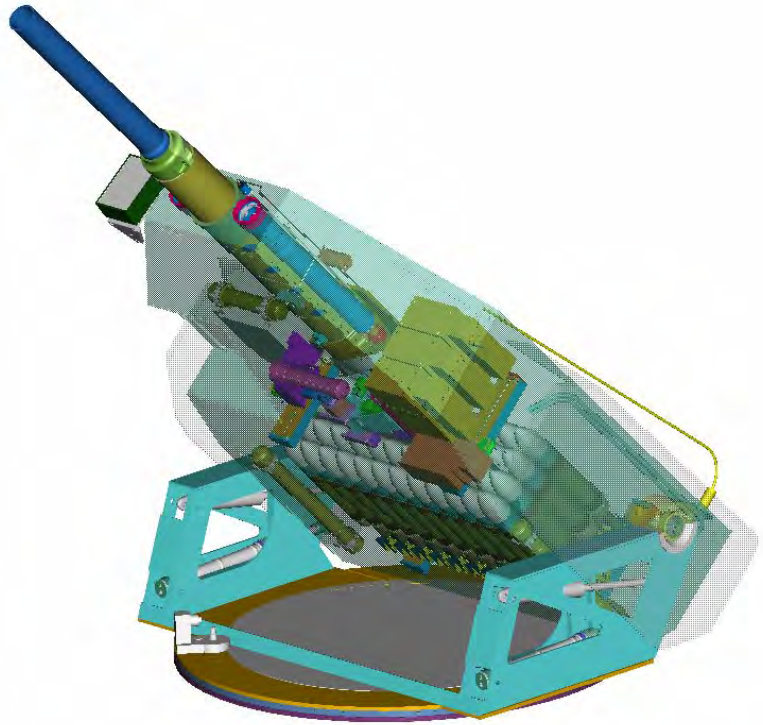
ISO 9001 Certified
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- Systems Integration & Autoloader Tests (Picatinny Arsenal Firing Range)
  - Cannon shipped 02 March 05
  - Integration Complete 15 May 05
  - Firing Test 16 May – 14 June 2005
  - Total Shots Fired: 15 (including Proof Rounds)
- 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

ISO 9001 Certified
FS15149





SEPARATE BRIEFING COVERING THE OTHER SUBSYSTEMS AND SYSTEM INTEGRATION – SYSTEM INTEGRATION SESSION

ON-MT MORTAR CANNON SUMMARY

ISO 9001 Certified
FS15149

- XM325 CANNON:
  - ALLOWS LOADING OF ALL CURRENT 120 MM MORTAR AMMO WITHOUT MODIFICATION
  - PROVIDES ROUND POSITIONING AND FALLBACK 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!!

U.S. Army
Armament Research, Development & Engineering Center
Picatinny, NJ

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

  } *Modeling & Simulation*
- ***XM1069 Testing***
  - Warhead
  - Structural
  - Concrete Wall
  - Anti-Personnel

  } *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

120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

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



The LOS-MP combines capabilities of M1028, M830A1, M908 and M830 into ONE Round

Improved Lethality with Reduced Logistic Burden

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

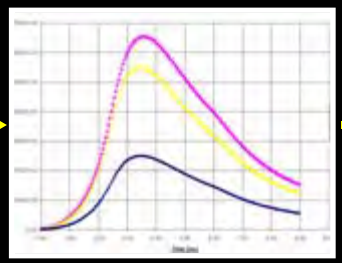
Decrease design time and tests

M&S Savings: $6.8 mil/27 months

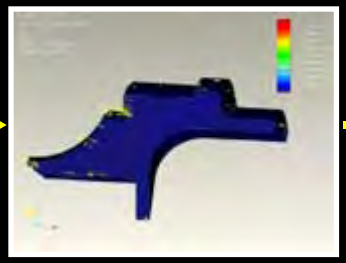
Modeling/ Configuration
Pro Engineer/ Intralink



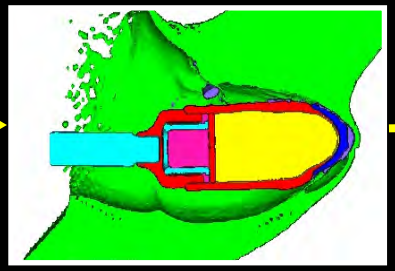
IB Simulation
IBHVG2



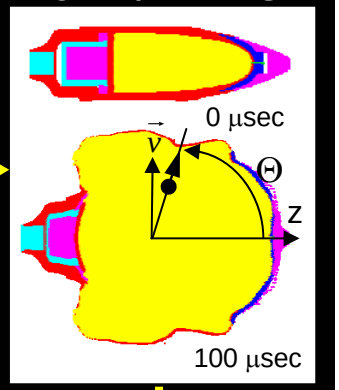
Structural analysis
FBD/ ANSYS



Target penetration
CTH



Fragmentation
CALE/PAFRAG

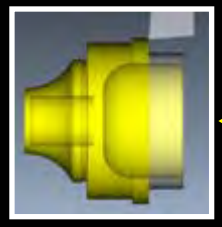


Failure in any model reiterates design process

Flight performance
PRODAS



3D numerical control
Pro Manufacture



Verify models

Flight Performance



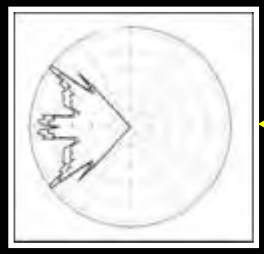
Fragmentation



DR concrete wall



Lethality Models
CASRED/MPR3D/
AJEM/MUVES



No iteration of design during testing !

120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

XM1069 CARTRIDGE



Practical Application of New Technology

120MM LOS-MP

LINE OF SIGHT MULTI-PURPOSE

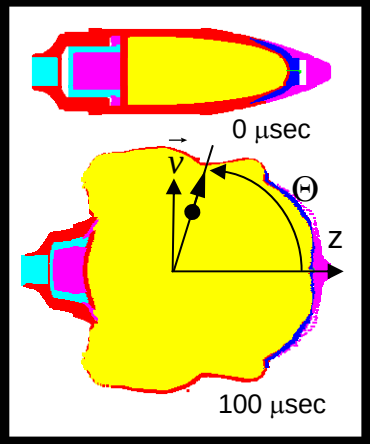
XM1069 Warhead Design

- ***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**

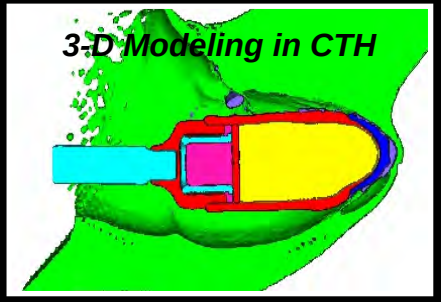
  Fragmentation:
    - **~24000 fragments**

Four ARDEC Patents Pending



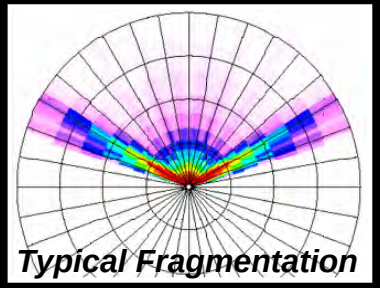


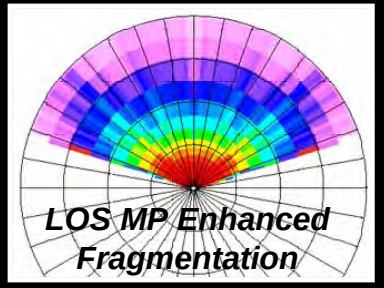
CALE/ PAFRAG predictions







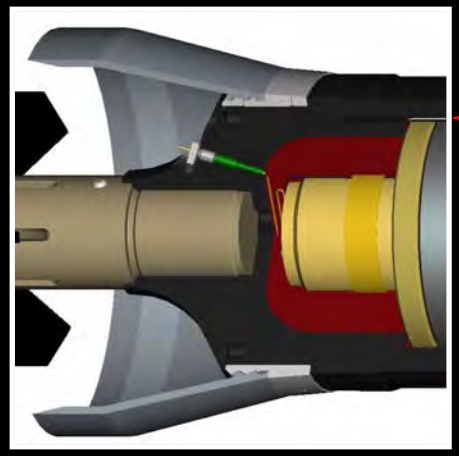




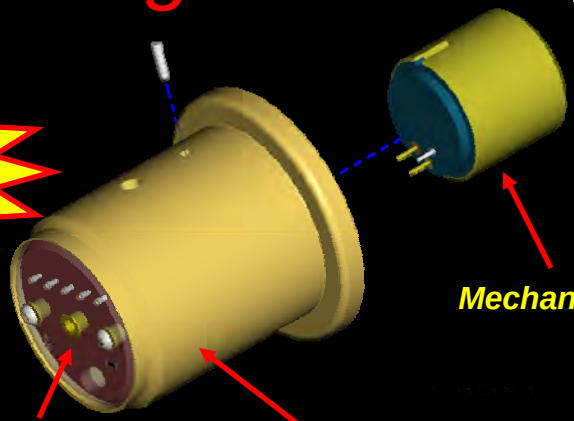
Survivable & Lethal

120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

XM1069 Fuze Design



ARDEC Patent Pending

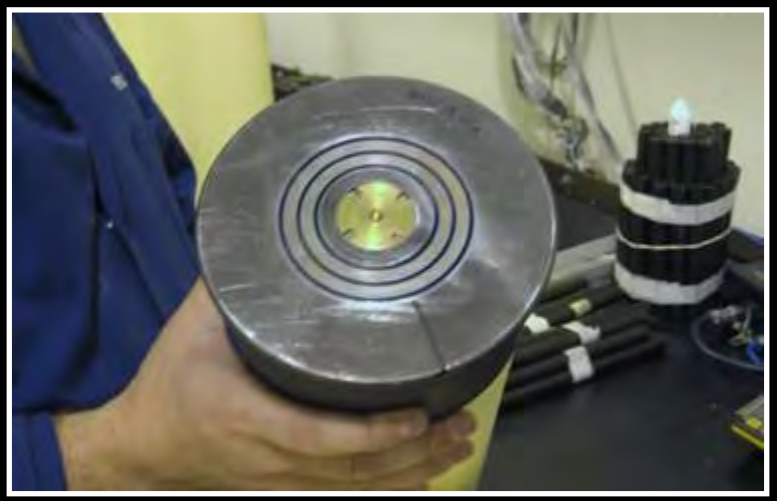


- *Multimode Programmable Base Detonating (XM1157)*
  - **5 modes: 4-Point Detonate, Timed airburst**
  - **Dual safe: Setback, commit to launch**
    - 3 leaf mechanism
    - Electronically controlled piston actuator
  - **Power, function mode and time sent via data link**
  - **S&A**
    - **No rotating contacts**
    - **90 degree rotor**
  - **Electronics**
    - **Dual Micro-controller**
    - **Enhanced Capabilities**

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

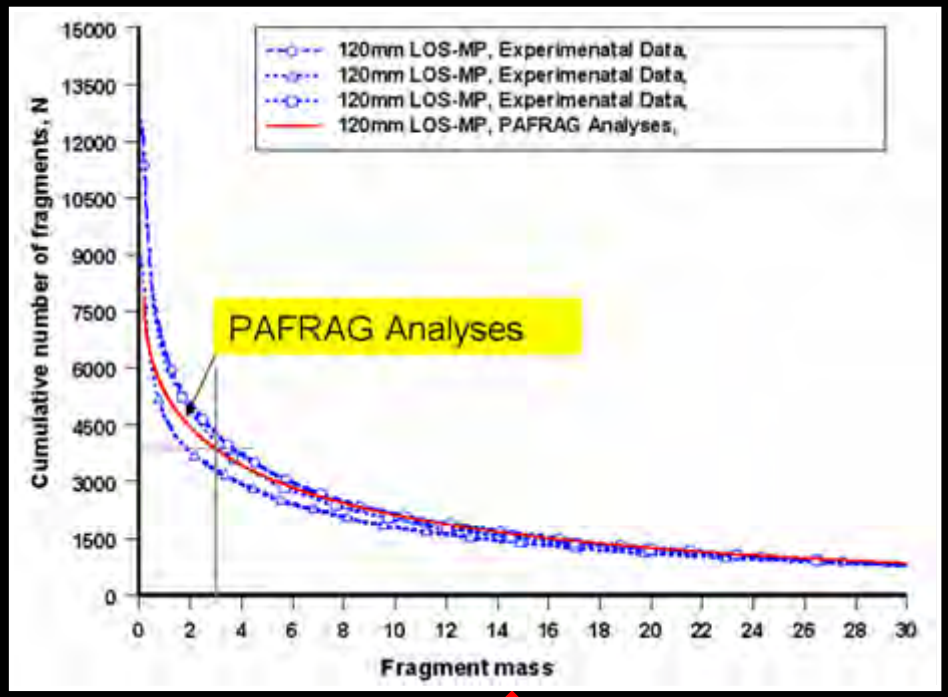


93% fragment mass recovery was achieved

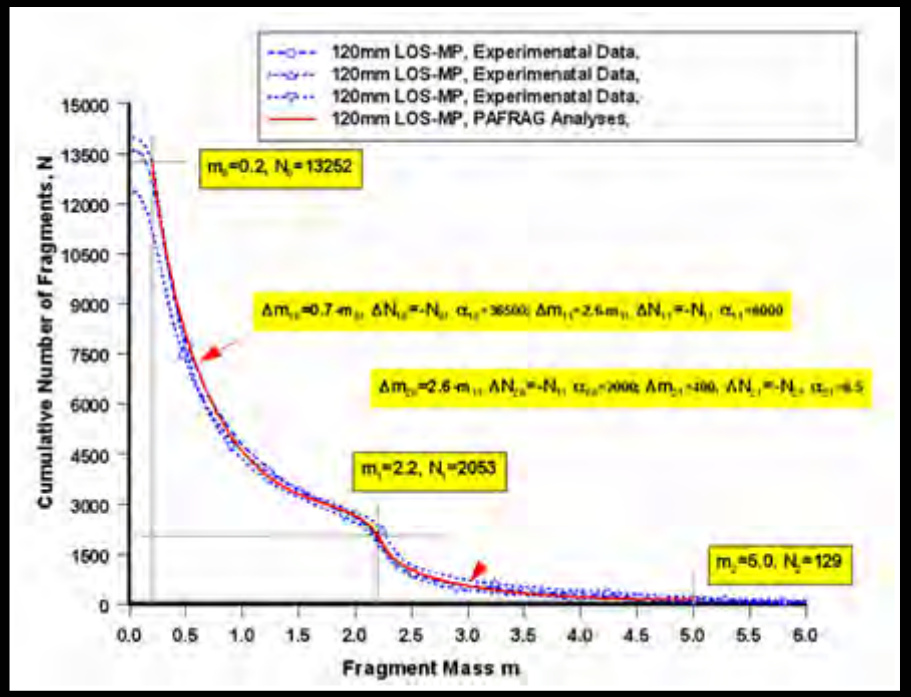
Fragment Recovery Data

Experimental vs CALE/ PAFRAG Analysis

Body Fragment # vs Mass



Nose Fragment # vs Mass

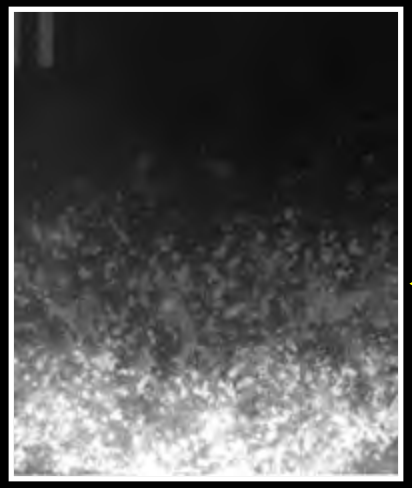


Simulation predicted experimentation

120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

Warhead Testing: Frag Velocity

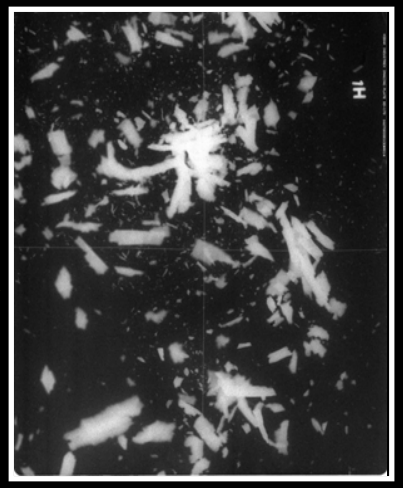
- ***Fragment Velocity***
  - Determines static detonation fragment velocity
  - Fragmentation velocity results validate and refine PAFRAG/CALE modeling data



Nose Fragment Velocity
Test: 0.740 mm/µs
Predicted: 0.750 mm/µs



Fragment Velocity Test Setup



Body Fragment Velocity
Test: 1.360 mm/µs
Predicted: 1.200 mm/µs

Projectile Structural Testing

- ***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

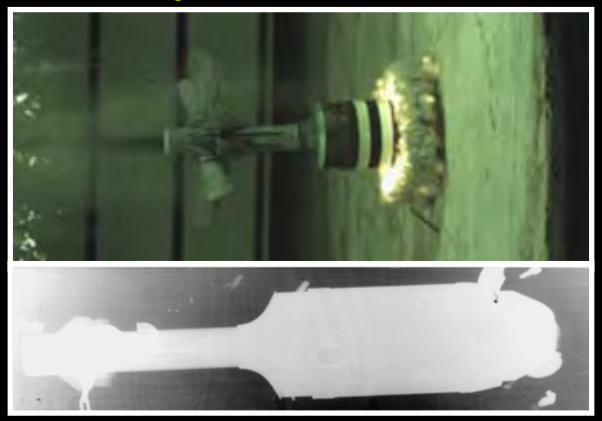


Muzzle Exit Integrity

DR Concrete Wall

Energy Decrease: 32KJ

Velocity Decrease: 60 m/s



E&T Bunker

Energy Decrease: 210KJ

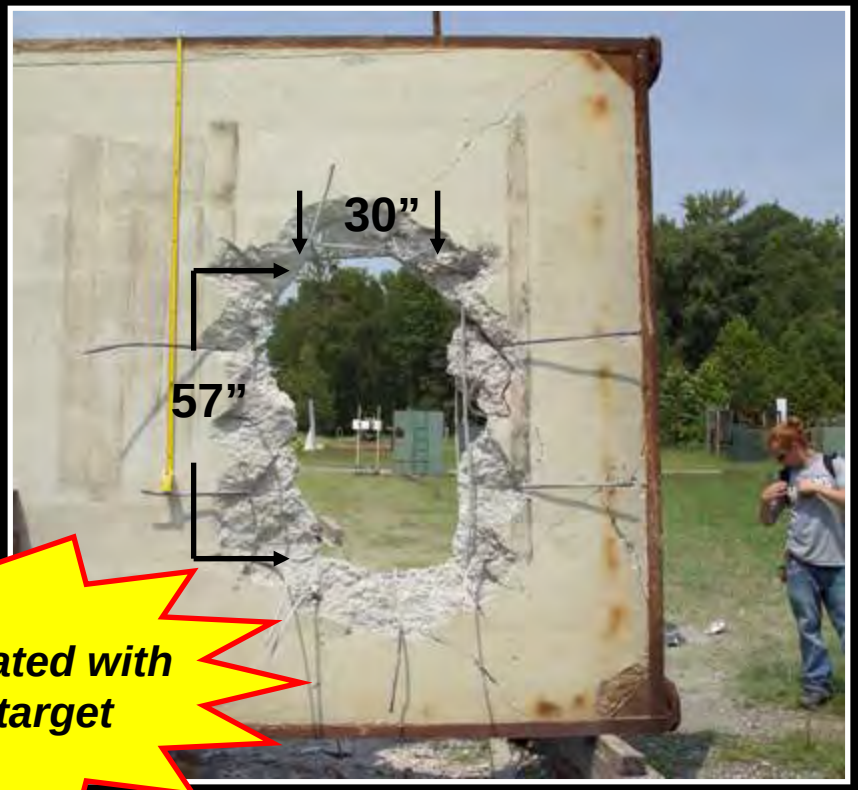
Velocity Decrease: 162 m/s



TRL6: Concrete Wall Test

- ***Demonstrated XM1069 integrated with XM1157 fuze & data link***
- ***Defeated target in 2 shots***





Warhead integrated with fuze defeats target

MOUT standard 8” double reinforced wall

120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

TRL6: Anti-Personnel Test

- ***Demonstrated airburst performance between threshold and objective ranges***

Demonstrated performance at 1000 meters



29 - 40' by 40' tarps to capture fragment spread





Sample silhouette from test:

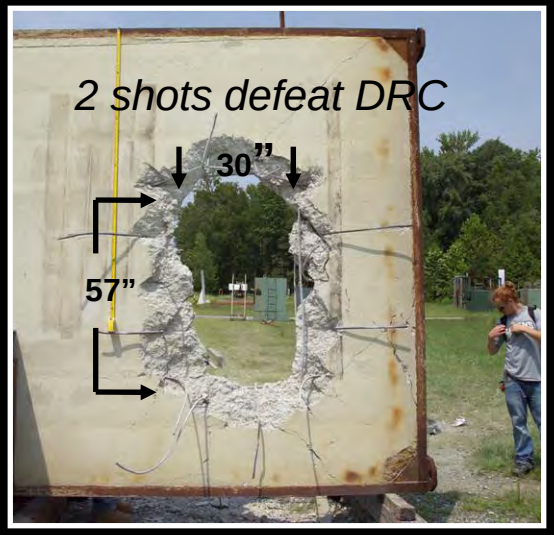
- ***Large Dots: Body frag hits***
- ***Small Dots: Nose frag hits***

Fired from Abrams SEP Tank with Data link

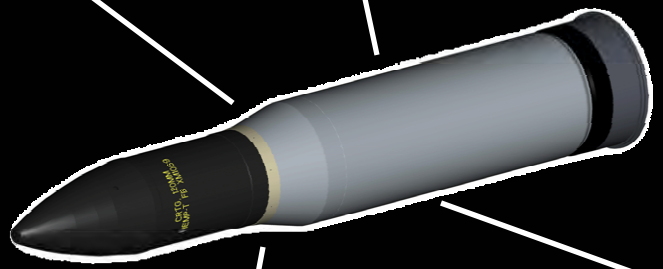
120MM LOS-MP
LINE OF SIGHT MULTI-PURPOSE

XM1069 Test Successes

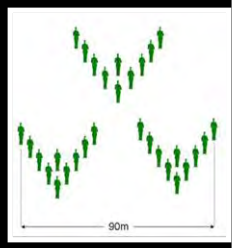

Bunker defeat 1 shot



Light Armor
(Classified)




T-55 defeat 1 shot





30 man platoon defeated
past 1000m


Simulated ATGM defeat 1000m



120mm LOS-MP
LINE OF SIGHT MULTI-PURPOSE

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

42nd Annual Armament Systems: Gun and Missile Systems Conference

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

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steven.nicolich@us.army.mil

Presented by:

Dr. Rao Surapaneni

US ARMY RDECOM-ARDEC

Picatinny Arsenal, NJ

Outline

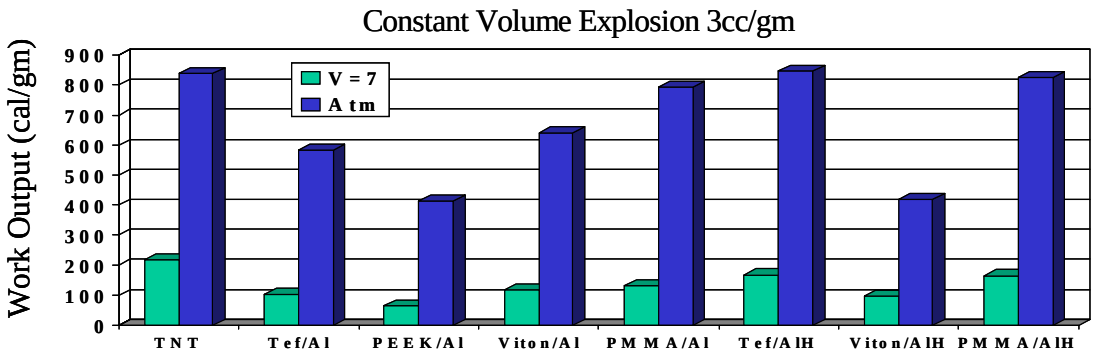
Selected US Army RDECOM-ARDEC Energetic Materials Programs

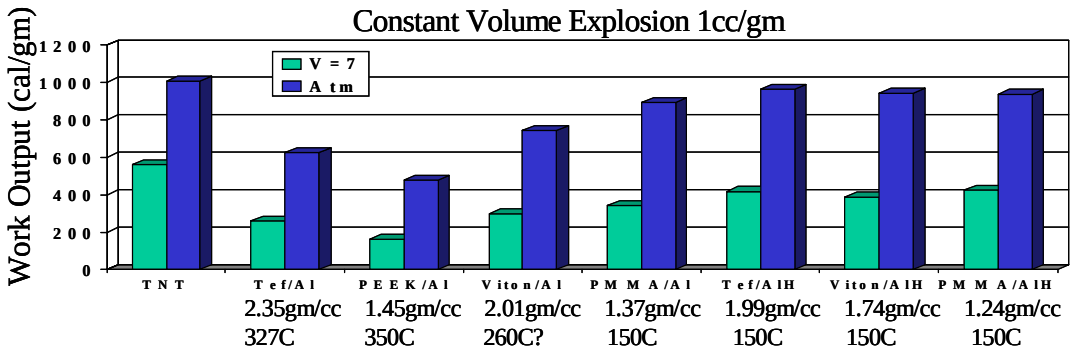
- Reactive Materials
- Insensitive Munitions Technology
- High Energy/High Blast Explosives
- Nanocrystalline Energetics & Nano Composites
- Summary

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

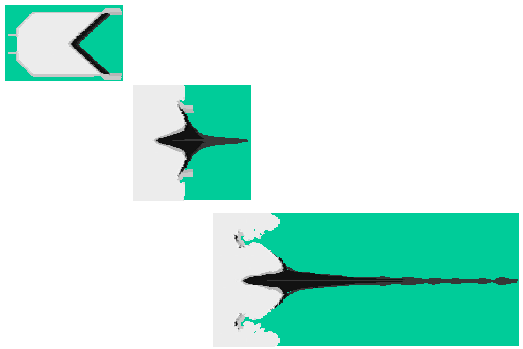




Unitary Demolition Reactive Material Warhead

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!*





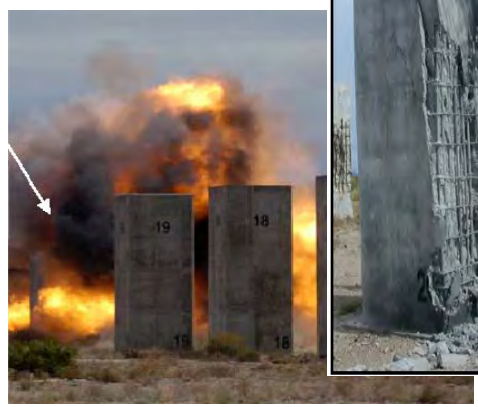
Scaled up "*Bam-Bam*" Warhead



Roadway Cratering Test



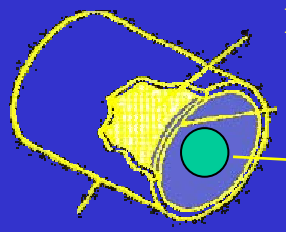
PAM Bridge Pier Target Testing

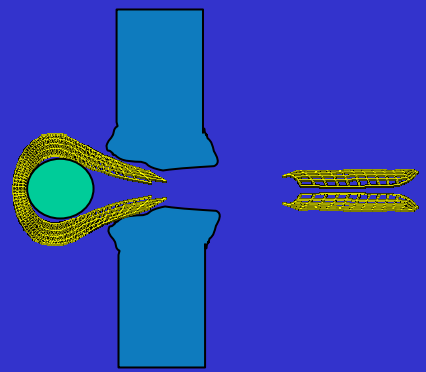


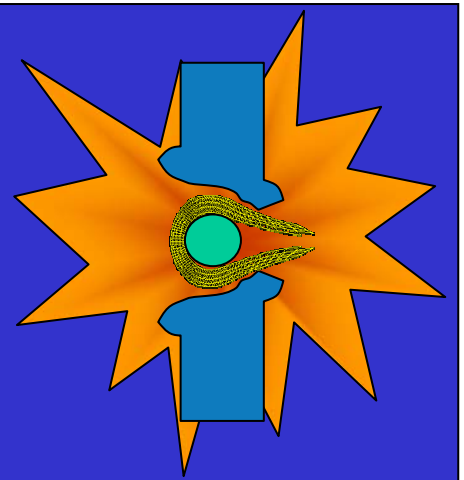


REACTIVE MATERIAL ENHANCED LETHALITY EFP

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)

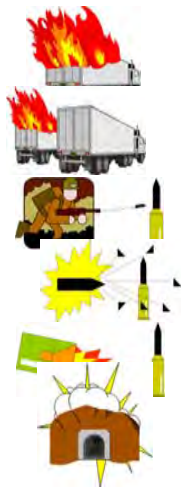


S1 @ 100 μs S2 @ 300 μs S3 @ 500 μs S4 @ 700 μs S5 @ 1170 μs

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

Six Threats



Fast cook -off (FCO)

Slow cook -off (SCO)

Bullet impact (BI)

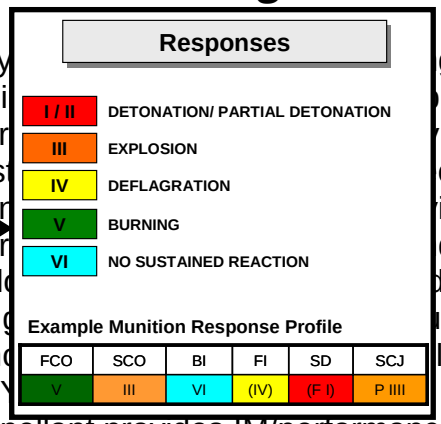
Fragment impact (FI)

Sympathetic detonation (SD)

Shaped Charge Jet Impact (SCJ)

IV WF 2005.03 IM Technologies for Guns, Miss





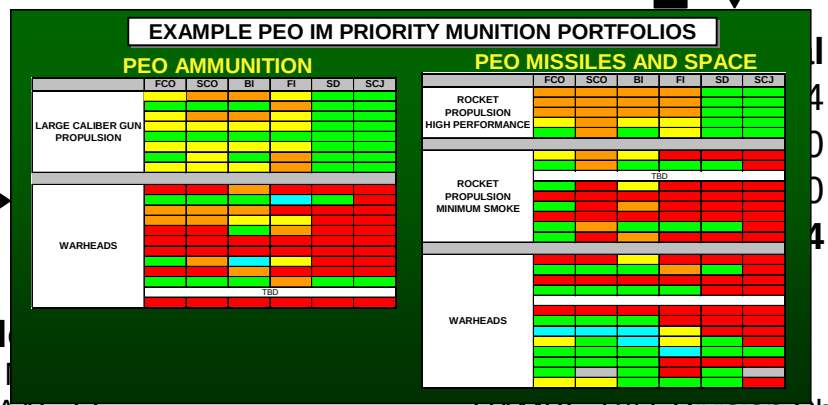


ce survivability g ability, while prov for Army
ormance requi ined with lightening nsitivity
arfighter. Curr does not enable I
frames consist chnologies, both e itigation, will
designing munition aging weight,
logistics benefits d improved safety. getics efforts
technology develo dressed. FY05. De ation the
threshold for a late benchmark ex dictive
4). FY06. Apply/demo lity to laboratory ha ential of a
rmulation (TRL 4). FY addition of barriers STD-2105C
compliance, (b) a new high-energy propellant provides IM/performance potential equivale propellant, (c)
near tactical design of warhead venting (TRL 5) FY08.Apply venting design to full-scale ctive 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 e munition (TRL 5). SUPPORTS: PEO
Missiles and Space, UAMBL, M, NLOS-LS, PGMM,
PAC-3 MSE, GMLRS.

IM ATO PROVIDES TECHNOLOGY TO THE ARMY'S MUNITION PORTFOLIO



FY05
1,100
750
4,450



AT
Dr.
ARL-WMRD

Technol
Ms. Mary
HQDA, SAAL-TT

UAMBL, S&T Division Chief

IM ATO provides technology for reducing the vulnerability and hazard of the Army's future munition portfolio

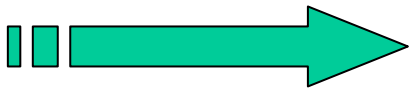
IM Warhead Venting for Cook-off Response Mitigation (Tech Base/PEO Ammunition Leveraging)

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





Venting Thrust

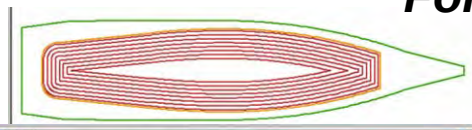


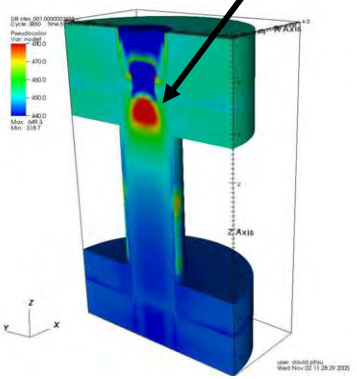
Techbase transfer For PEO Demo

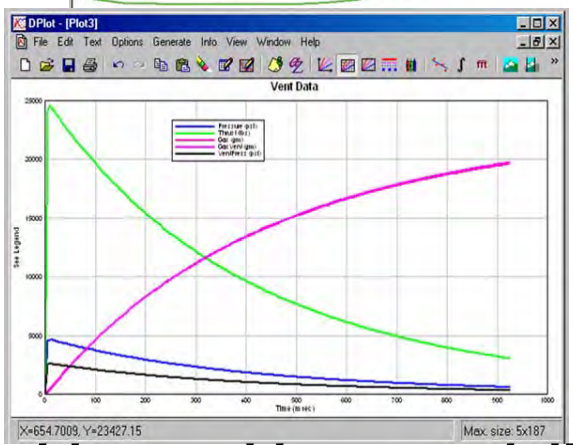
PEO IM Venting Large-scale 3" test

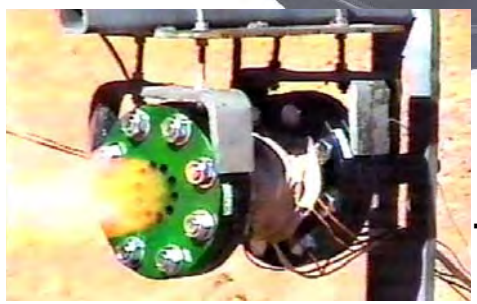


Ignition









Pressure Transducer Port

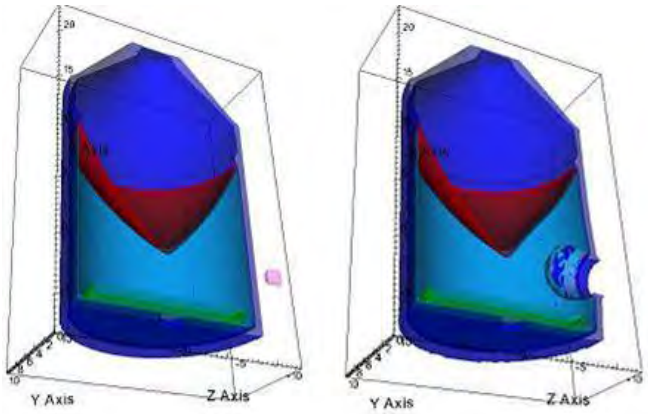
Tech base ignition and burn modeling:

Predict and design ignition and required venting calibrated using small scale tests

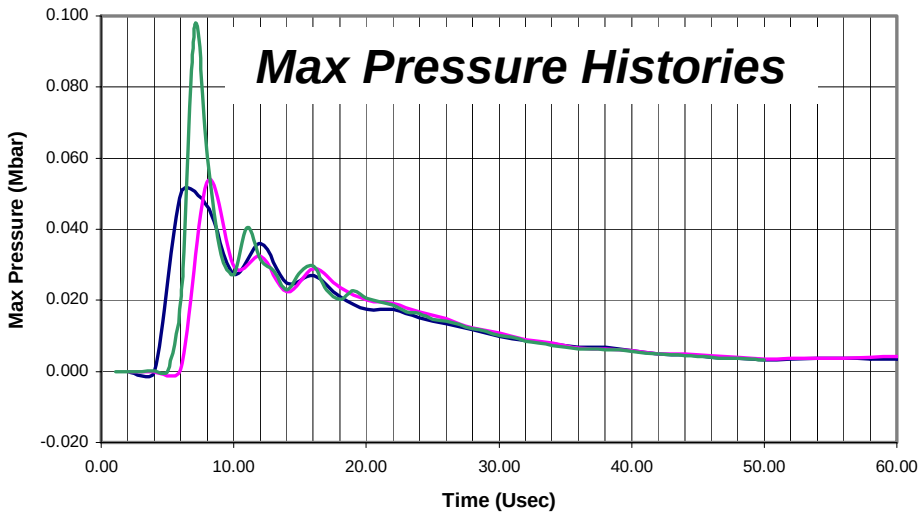
GENERAL DYNAMICS
Strength on Your Side™

Predictive Technology Description
FI/BI/SD IM Warhead Development

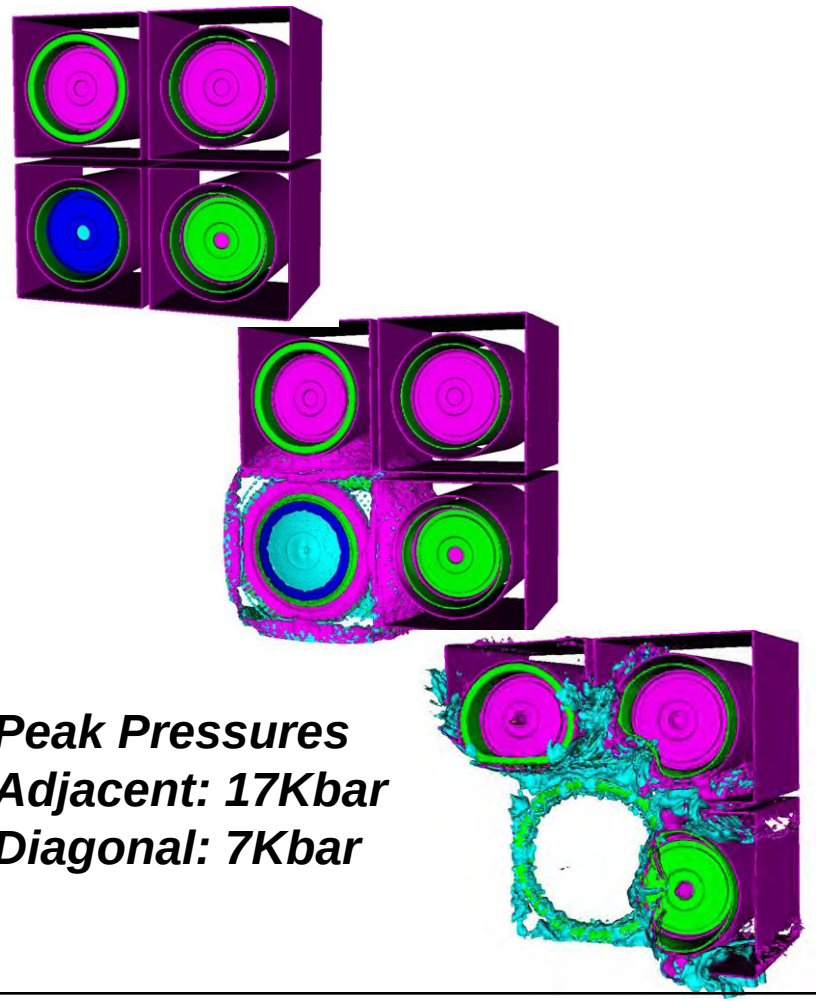
NLOS-LS & MRM Impact Modeling



ALE3D



NLOS-LS & MRM SD Modeling

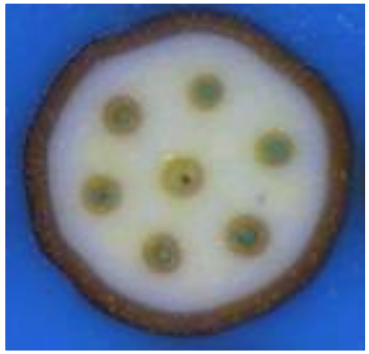


Peak Pressures
Adjacent: 17Kbar
Diagonal: 7Kbar

- ***BI/FI/SD Modeling Results Provide Design Capabilities to Mitigate Responses***
- ***MRM & NLOS-LS: Being Designed to Pass IM Tests!***

PEO AMMO IM Propellant Thrust Evaluation of Non-Nitroglycerin Propellants

NG Free Propellant





Description

- **Propellant formulations with NG sensitive to ignition from outside stimuli (Poor IM characteristics)**
- **Potential of a basic non-NG propellant formulation that can be tailored through changes to grain geometry to work with a wide range of munitions**
- **Feasibility study to test and evaluate non-NG extruded propellants for use in DOD munitions items (medium cal and mortar)**

Approach

- **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**

Warfighter Payoff

•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

155 mm M795	FCO	SCO	BI	FI	SD	SCJ
A	TBD	IV	V	V	III	TBD
B	TBD	V	V	V	III	TBD
C	TBD	V	IV	V	III	TBD
TNT	III	III	III	III	I	TBD

I / II	III	IV	V	VI
Detonation / Partial Detonation	Explosion	Deflagration	Burn	No Sustained Reaction (Unofficial)

Bullet Impact



Fragment Impact

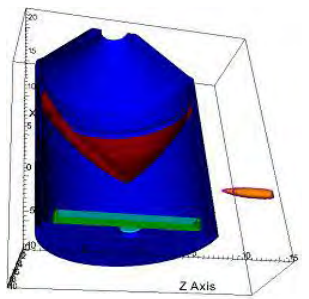


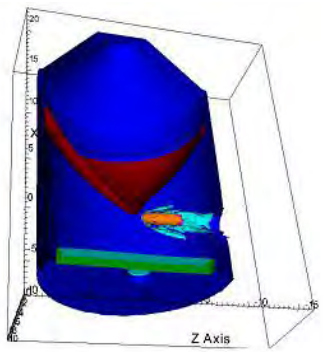
SD



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

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

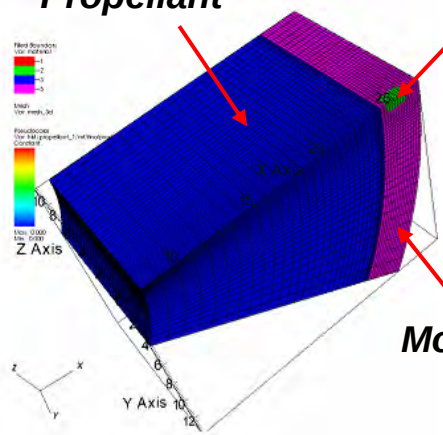




BI on Warheads

Fragment

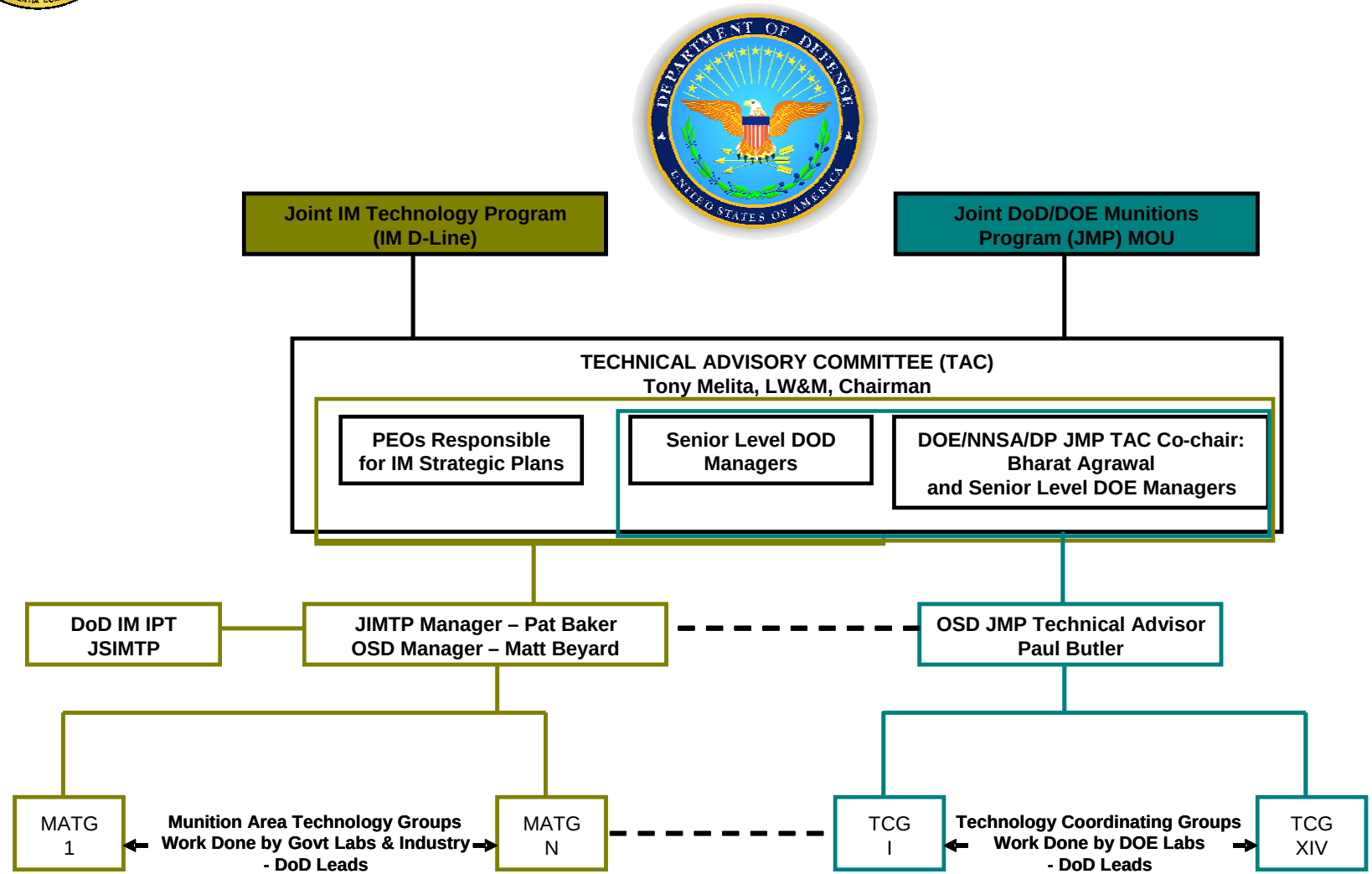
Propellant



Motor case

FI on Rocket Motors

JIMTP Structure



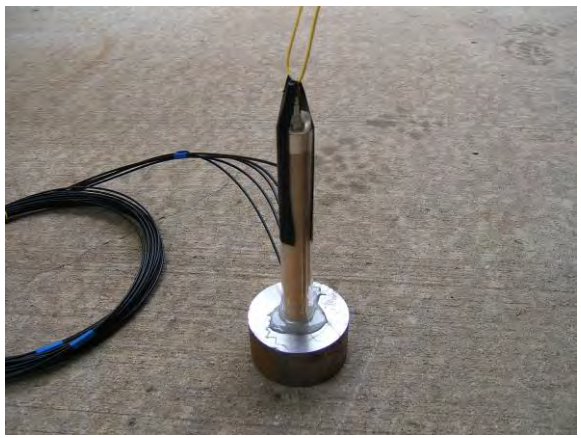
OSD D-Line IM Program
A Joint Service Collaboration & Partnership

IM Melt-Cast Explosives

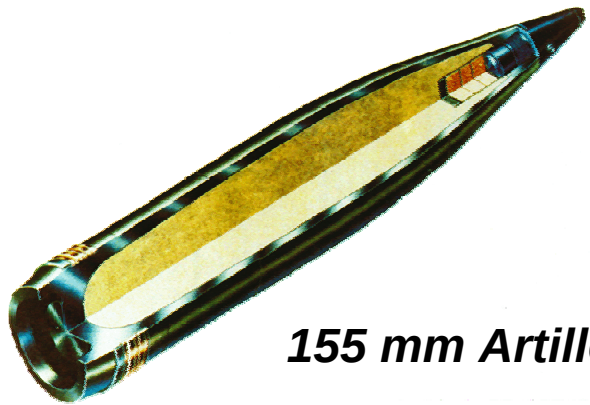
- ***New IM Melt-Cast explosive compounds***
- ***Synthesize compounds of interest and evaluate safety, toxicity, compatibility & performance at small scale***



Mortar



Measurement of Detonation Velocity



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

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

2000 — PAX-24, TNT Replacement

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)

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)

1987 — PAX-2, 80% HMX IM (25mm)

PAX 3 Tested in LOS-MP and BDM

- Warhead design and process
  - PAX 3 has excellent loading and machining characteristics
- Integrated PAX3 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



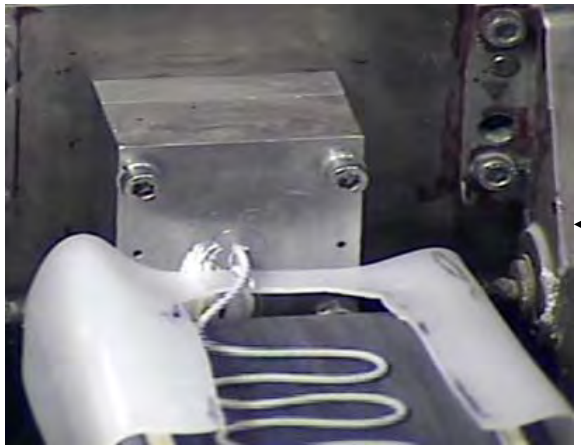








Twin Screw Extrusion of PAX-3



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

Percent Change in Performance Compared to LX-14			
HE	**Cost of Explosive Fill ($)/lb.**	**Metal Pushing/Unit Volume (Experimental)**	**Blast (Calculated)**
LX-14 (HMX)	18	0 (Baseline)	0 (Baseline)
PAX-29c (CL-20)	600	17 %	43 %
PAX-29n (CL-20)	600	17 %	38 %
PAX-3 (HMX)	18	-28 %	32 %
PAX-30 (HMX)	18	6 %	30 %
PAX-42 (RDX)	7	3 %	24 %

- 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



JAVELIN



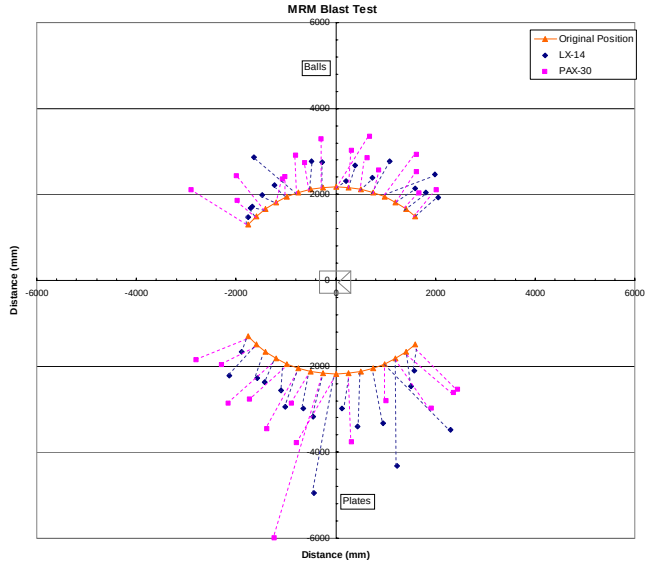
PAX-30 penetration ~10% better than current production with LX-14 in Javelin

'Stonehenge' Impulse Test Setup



PAX-30 vs. LX-14 Blast Output

MRM



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

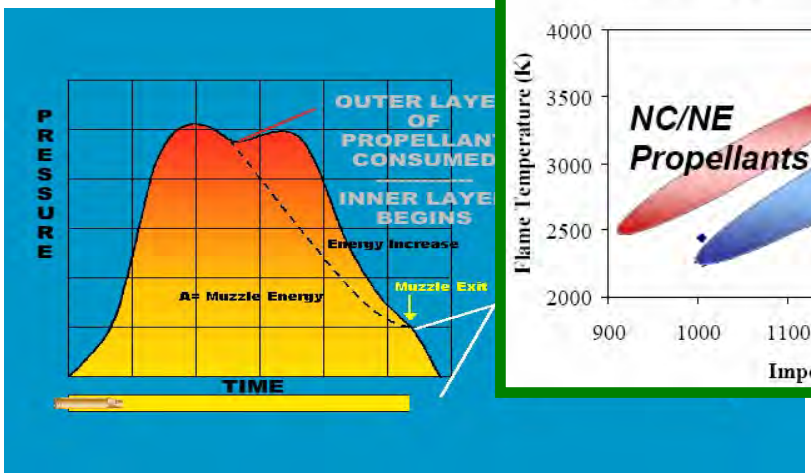


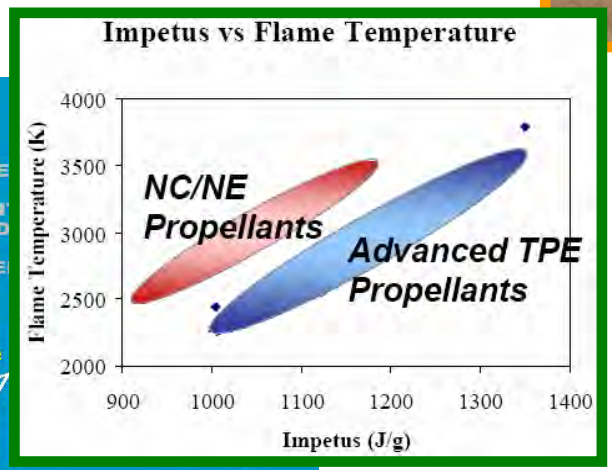
Novel Energetic Materials ATO – Advanced Gun Propellants

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***

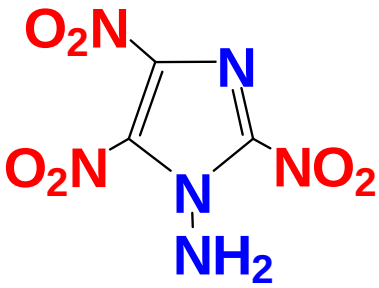
Reduced barrel erosivity

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

Reduced sensitivity/vulnerability

Synthesis Program Target Compounds

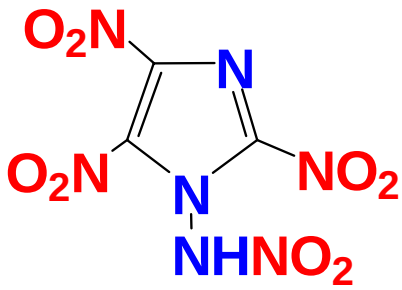
High Density High Energy Compounds



ATNI - Amino Trinitroimidazole

Cal. Density 1.92 g/cc

Performance 10 % better than HMX and Insensitive due to hydrogen bonding

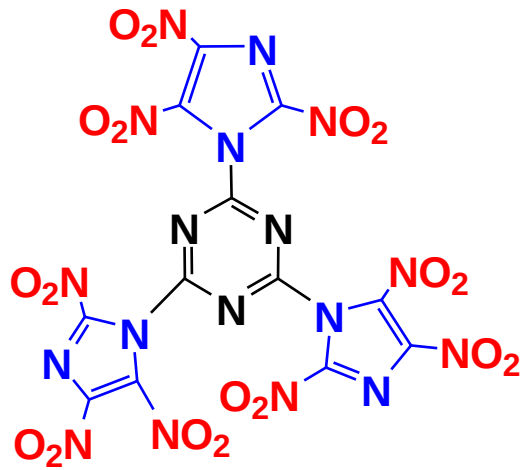


NATN – Nitramino Trinitroimidazole

Cal. Density 1.96 g/cc

Insensitive due to hydrogen bonding

High Energy High Nitrogen Compounds

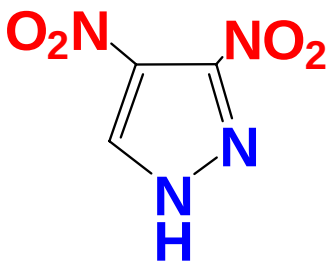


TTIT - Tris(Trinitroimidazole) Triazine

Cal. Density 2.06 g/cc

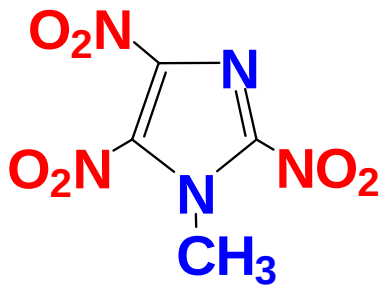
Performance 20% better than HMX

Insensitive Melt-Cast Materials



DNP - Dinitropyrazole

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

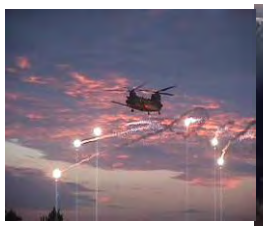


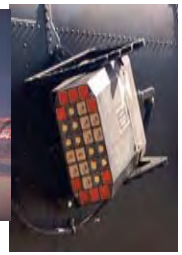
MTNI - MethylTrinitroimidazole

Density, 1.79

Detonation velocity better than Comp. B, Melt cast and Insensitive

Nano-materials / Nano-energetics





Counter Measures



Igniters



Green LEI Primers

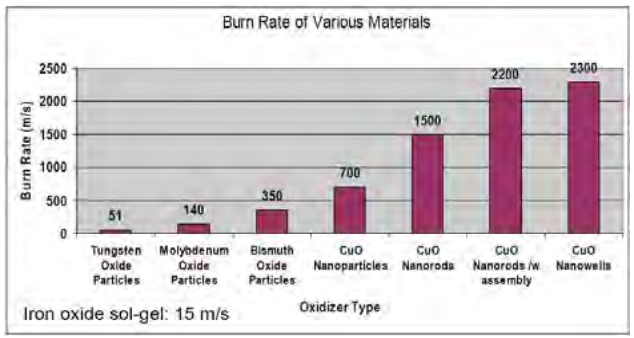


Illum Candles

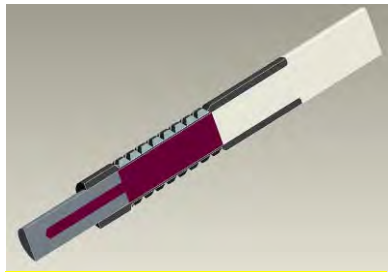


Primers

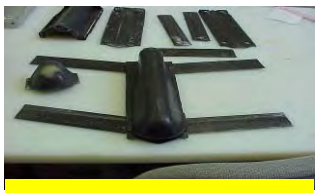
On-going Efforts



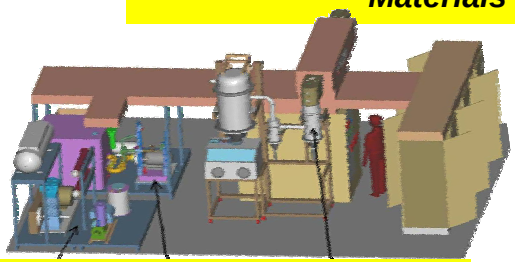
Formulation of New Reactive Materials



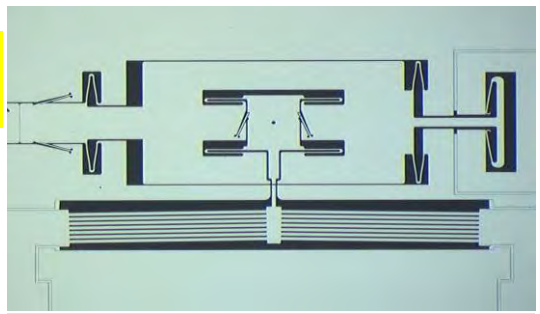
Reactive Tungsten Penetrator



Dual Use Composites



Material Fab & Characterization

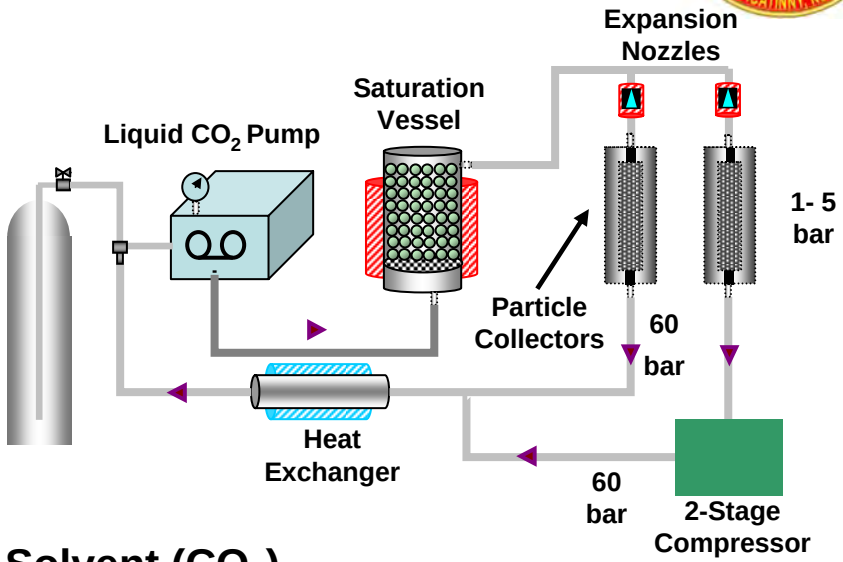


MEMs S&A Designs

Production of Nano RDX by RESS

RESS Set-up

- Solvent: Carbon Dioxide
- Saturation P\T: 350 bar\85 ^{o}C
- Expansion Pressure: 1 – 60 bar



Current Process Capabilities

- Precise Particle Size Control:100–500nm
- Production Capacity: 10-12 g/hour
- Continuous Operation: > 10 hours
- Contained Operation with Full Recycle of Solvent (CO_2)

Sensitivity Testing

Impact Test

150 nm RDX Pellet: H_{50} – 41 cm

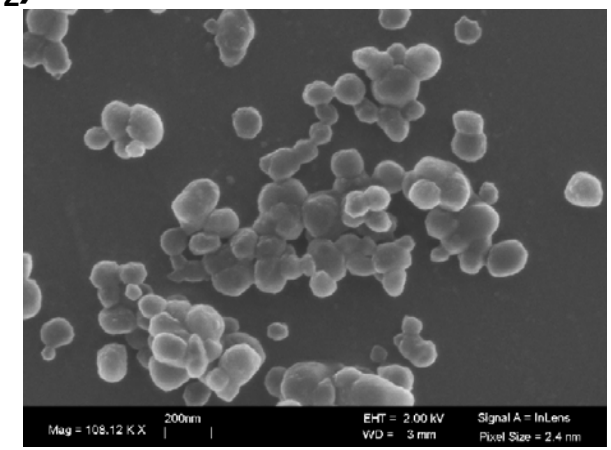
150 nm RDX Powder: H_{50} - >100 cm

Holston C-5 RDX Powder: H_{50} – 23 cm

Small Scale Gap Test

500 nm RDX in 88/12 wax formulation: Gap_{50}- 32 kbar

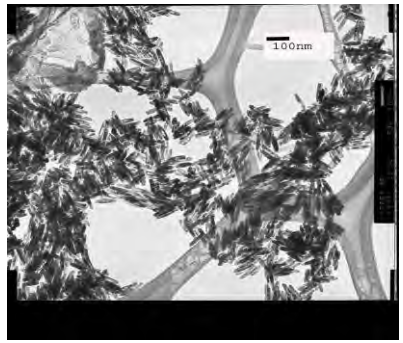
4.8 micron RDX in 88/12 wax formulation: Gap_{50}- 21 kbar



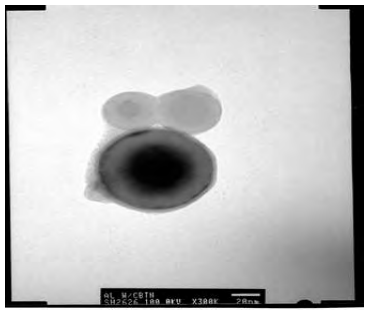
SEM Image of Nano RDX

Nanocomposite Synthesis and Production

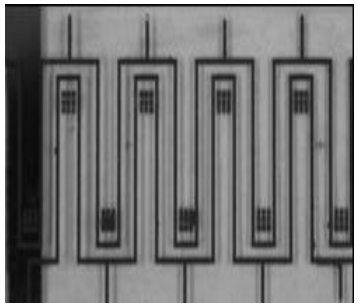
- *Tunable super-thermites*
- *Multiple uses, safe to handle*

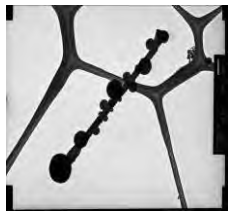


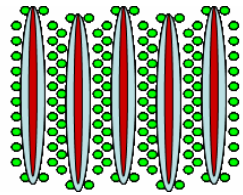
Coated Nanoparticles



Patterned Energetics



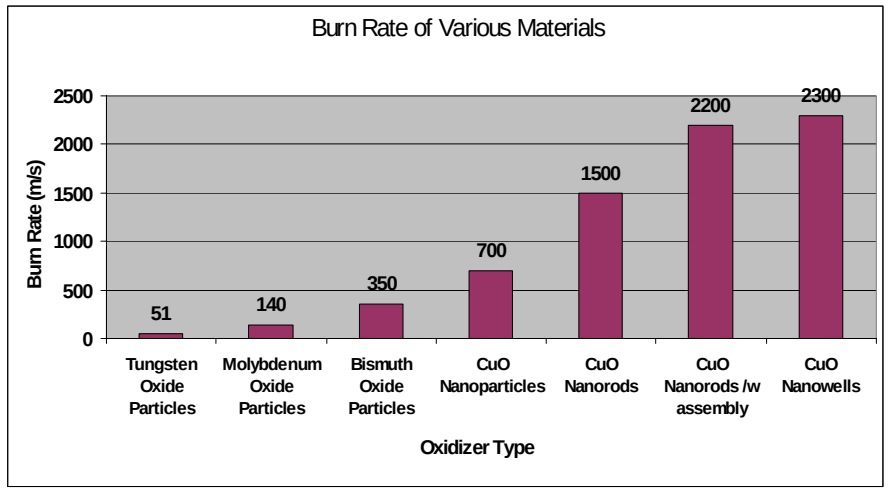




Ordered Energetic Composites



Microencapsulation



Summary

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

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

AGBT Program Background

Future Naval Capabilities Program

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

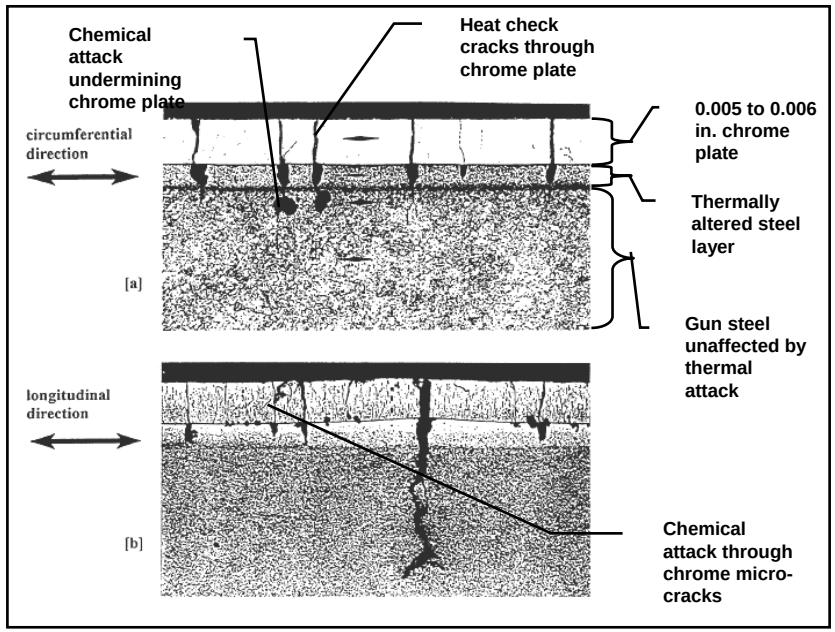
Transition

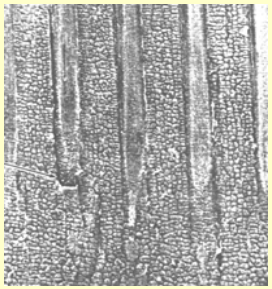
- Develop/Demonstrate Improved Barrel Life and Ballistic performance over AGS Baseline for Transition into Future DD(X) Flights

AGBT Program Background

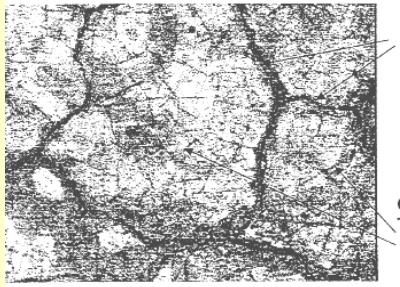
Root Problem: Chrome Plated Barrel Wear and Erosion

- 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

Technical Approach

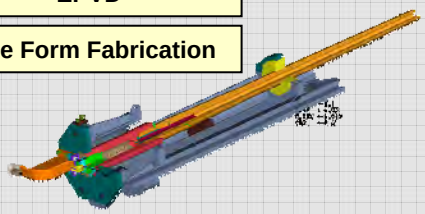
Advanced Gun Barrel Technology Detailed Approach

- Application to small sample
- Low cost gun firing test
- Proof of concept demo

Technology Assessment

- Electroless Nickel-Boron
- Sputtering
- Explosive Cladding
- CED
- EPVD
- Free Form Fabrication

45mm Screening Evaluations



45mm Laboratory Gun Fixture

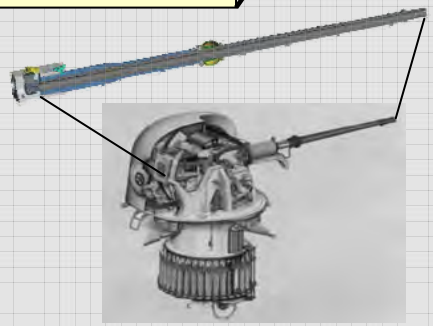
- Six technologies evaluated
- Hand loaded lab fixture
- Single shot testing

- Application to large sample
- Complex geometry
- Integrate with production
- High rate of fire gun test
- Proof of technology demo

Subscale Competition/Demo

- Explosive Cladding
- EPVD Coating
- Chrome Plating

76mm Gun Tests



MK75 76mm Naval Gun

- Two technologies evaluated
- Fielded gun mount
- Chrome baseline comparison

- Application in full scale
- Most difficult application
- Most expensive testing platform
- Production quality process
- Transition requirements demo



- One technology transitioned

FY03	FY04	FY05	FY06	FY07	FY08

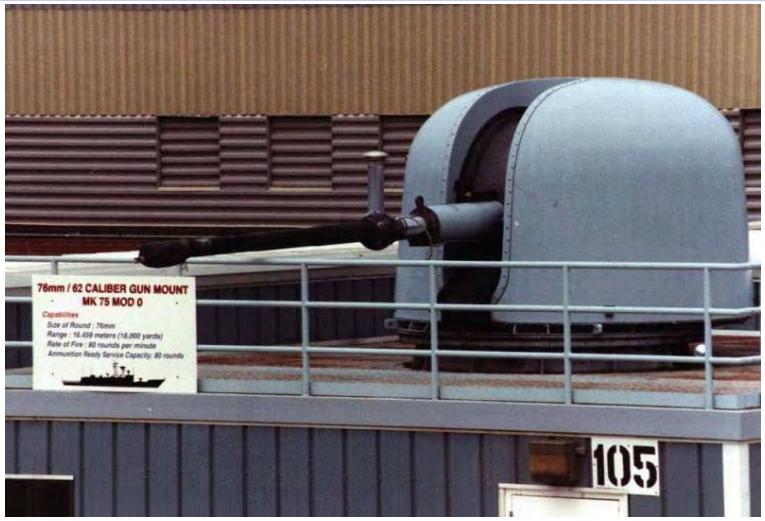
76mm Test Planning

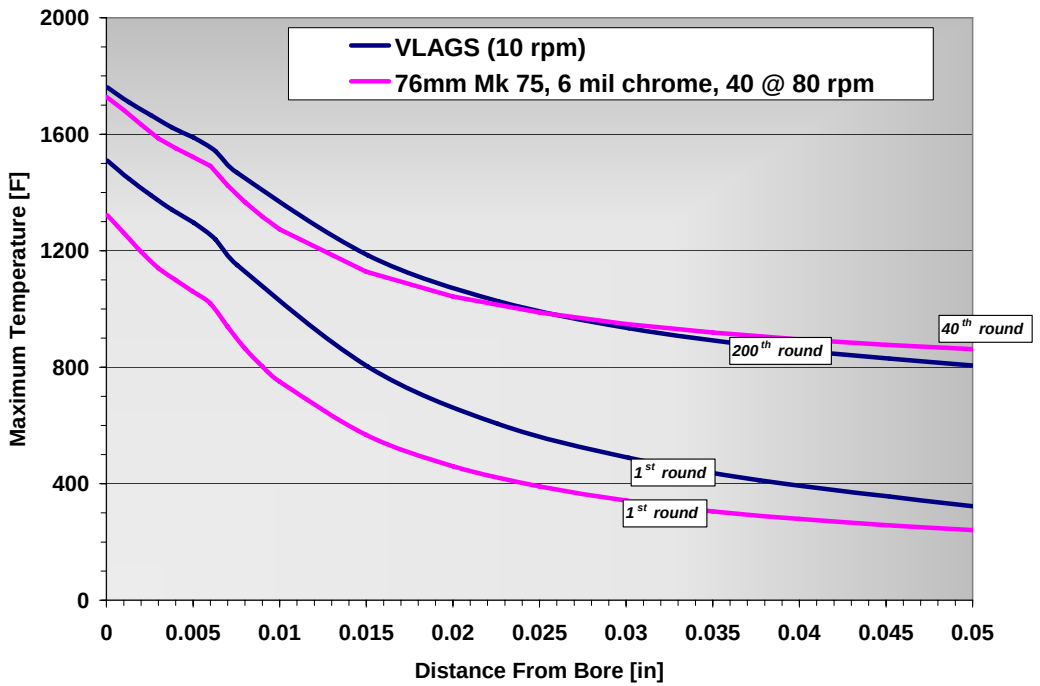
Test Approach:

- 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

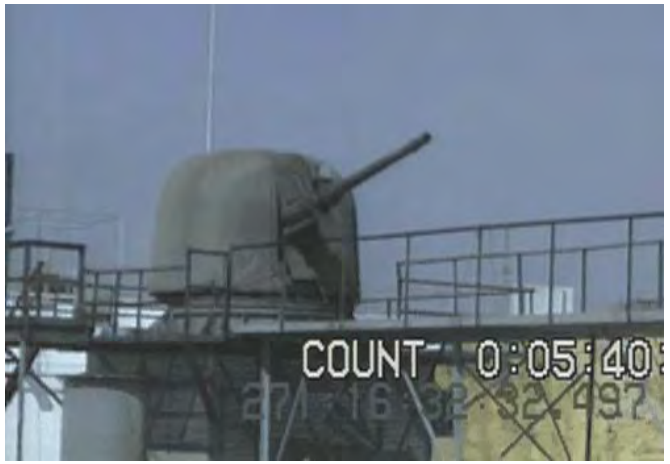
- 76mm platform selected for close match to the AGS environment
- Advanced technology prototype gun barrel assemblies will be fired at high rates to determine robustness of bore surface
- Historical 76mm service records indicated that measurable wear and erosion would occur within 400 rounds fired.
- 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.



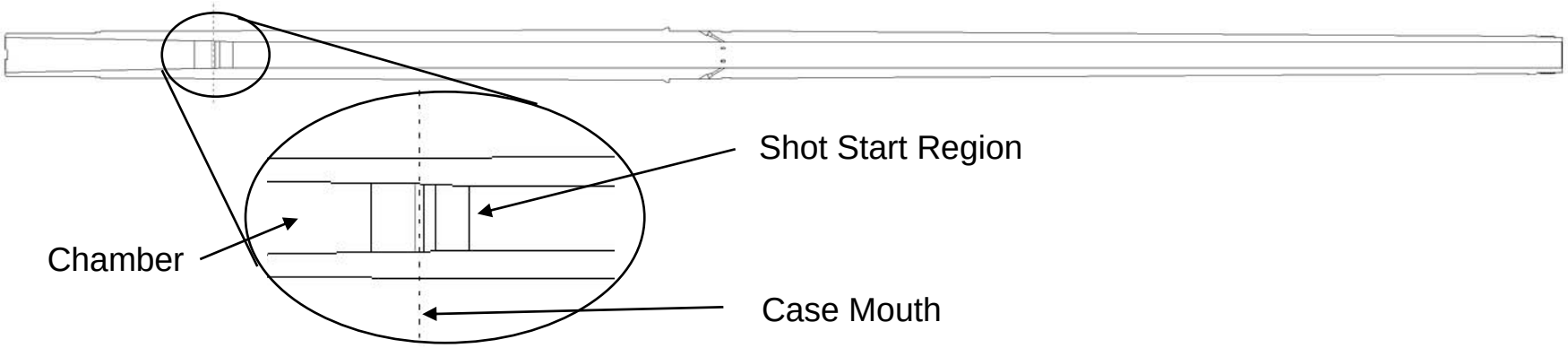


76mm Rapid Fire Test Results

- Rapid fire testing of competing technologies will be complete this summer
- The following results will examine the performance of the Chrome Baseline liner only.

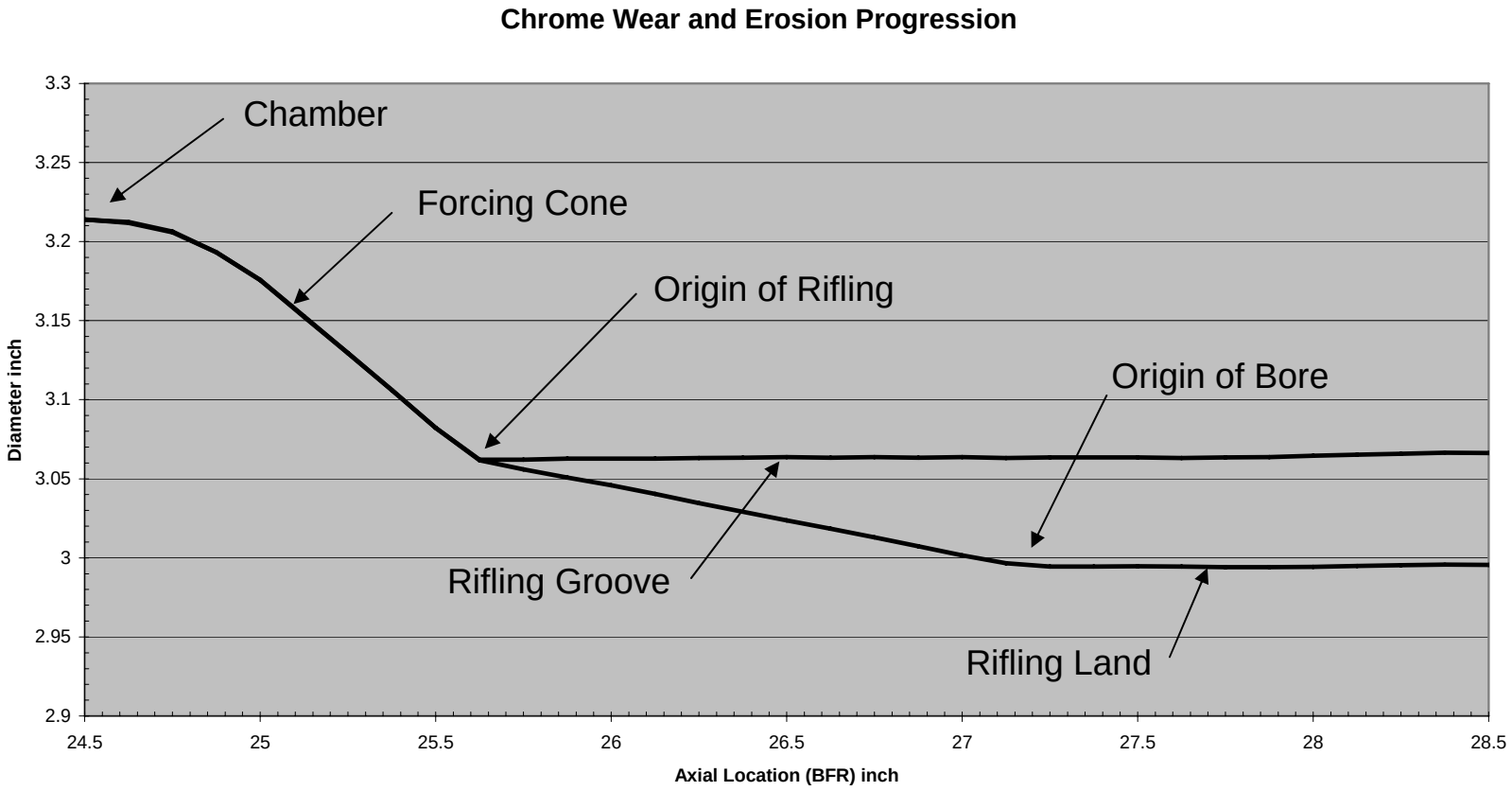
76mm Rapid Fire Test Results

- 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.



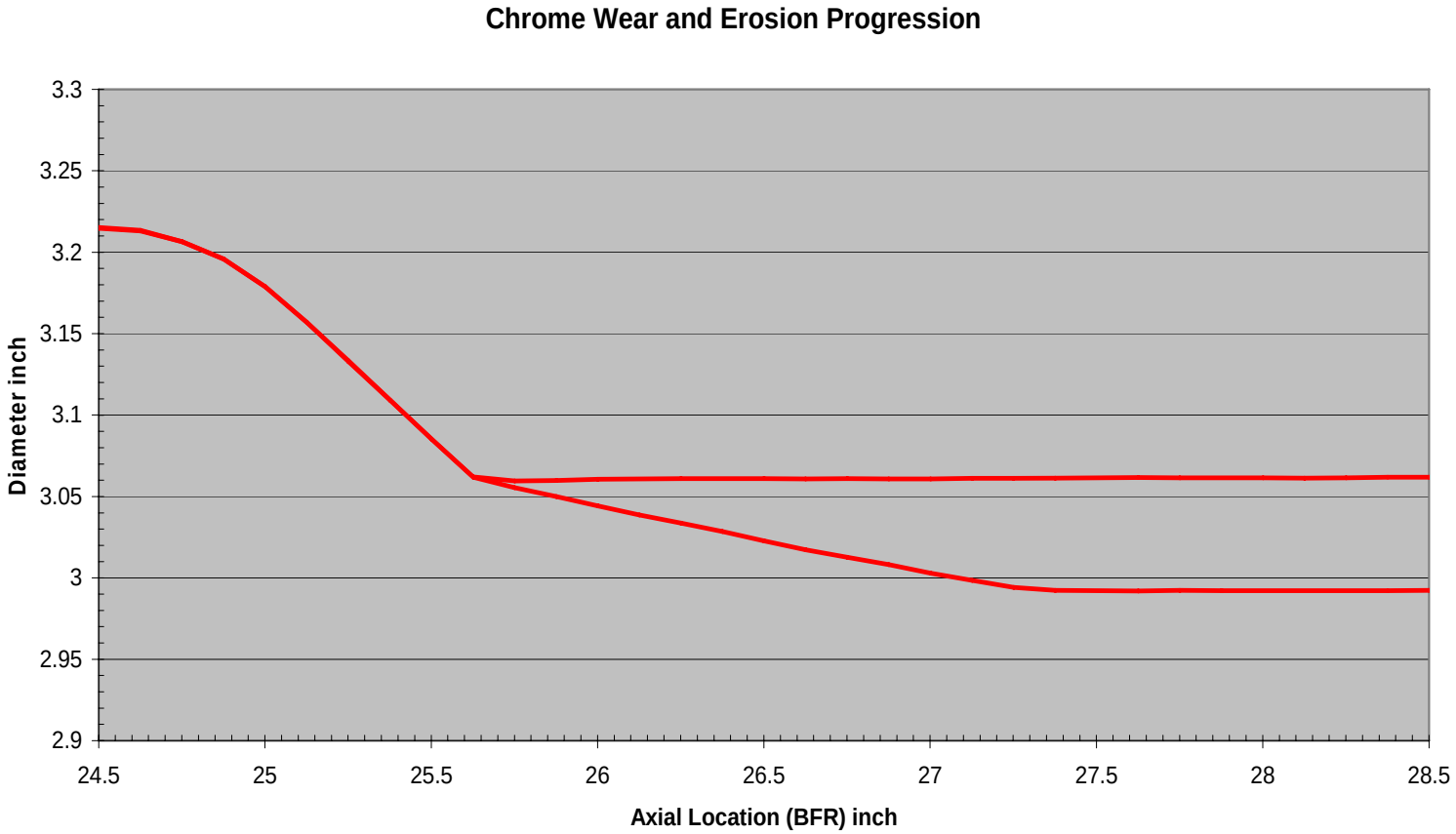
76mm Rapid Fire Test Results

- Chrome liner, Proof shots only



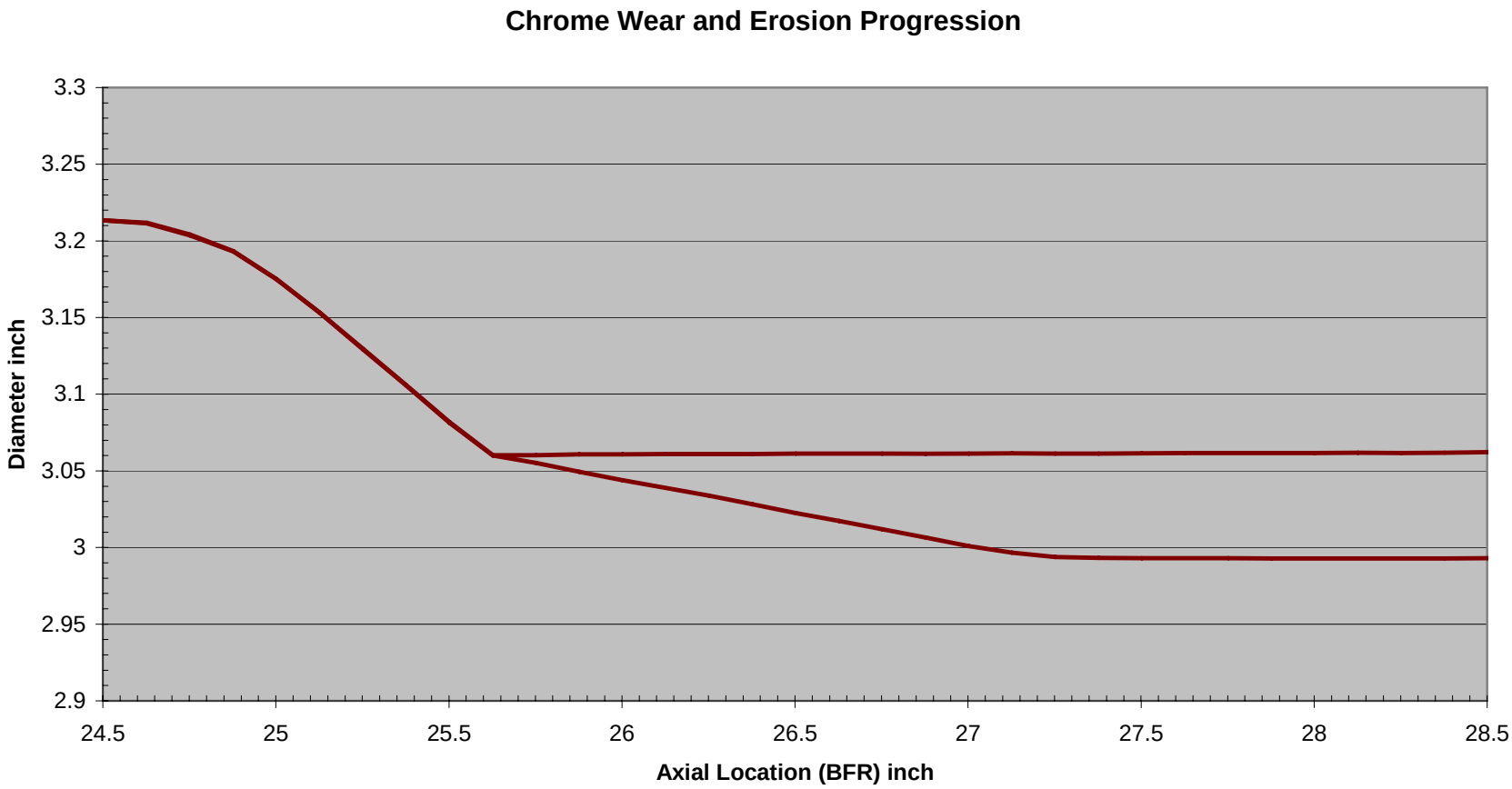
76mm Rapid Fire Test Results

- Chrome liner, after 80 shots



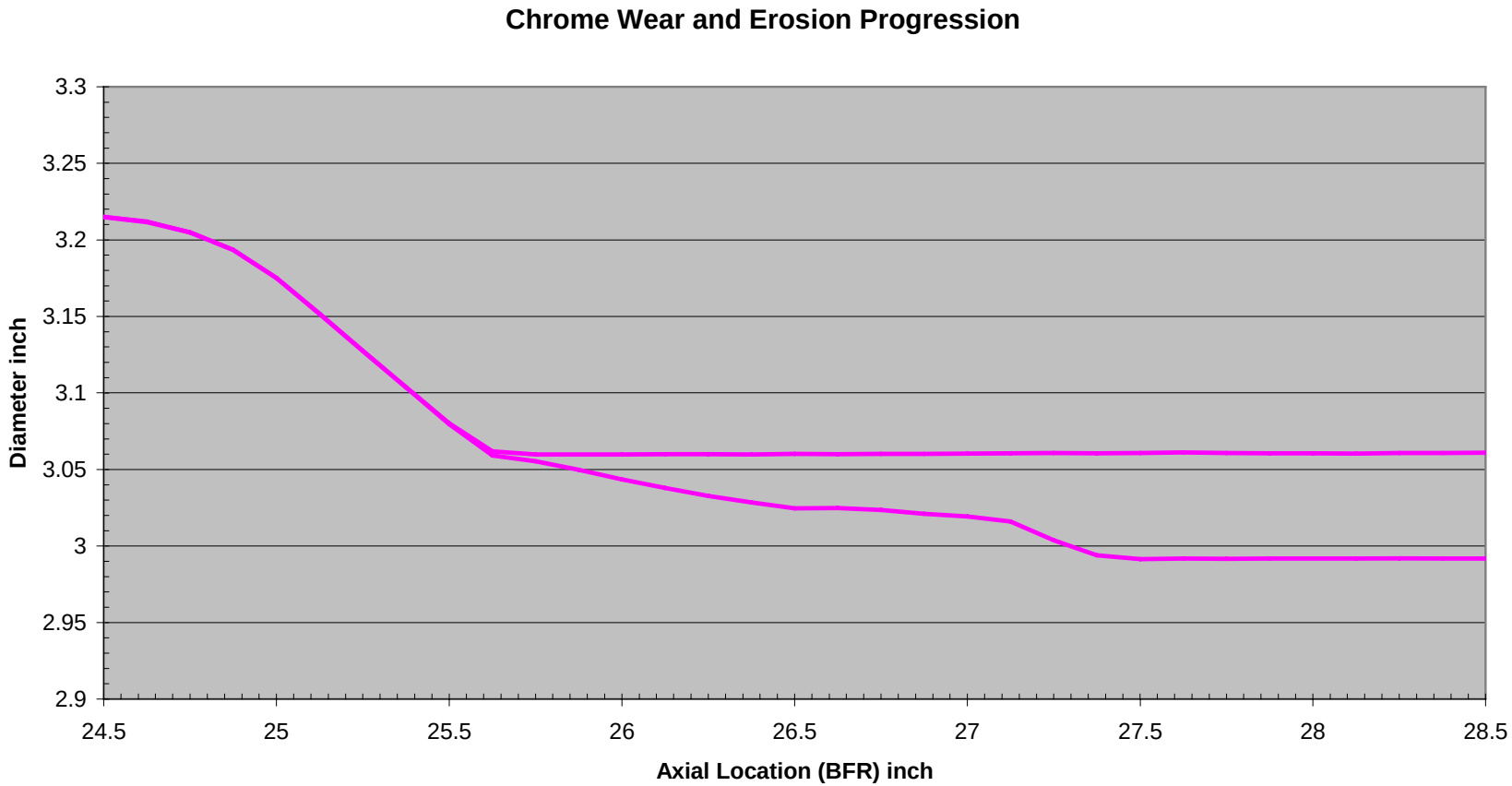
76mm Rapid Fire Test Results

- Chrome liner, after 160 shots



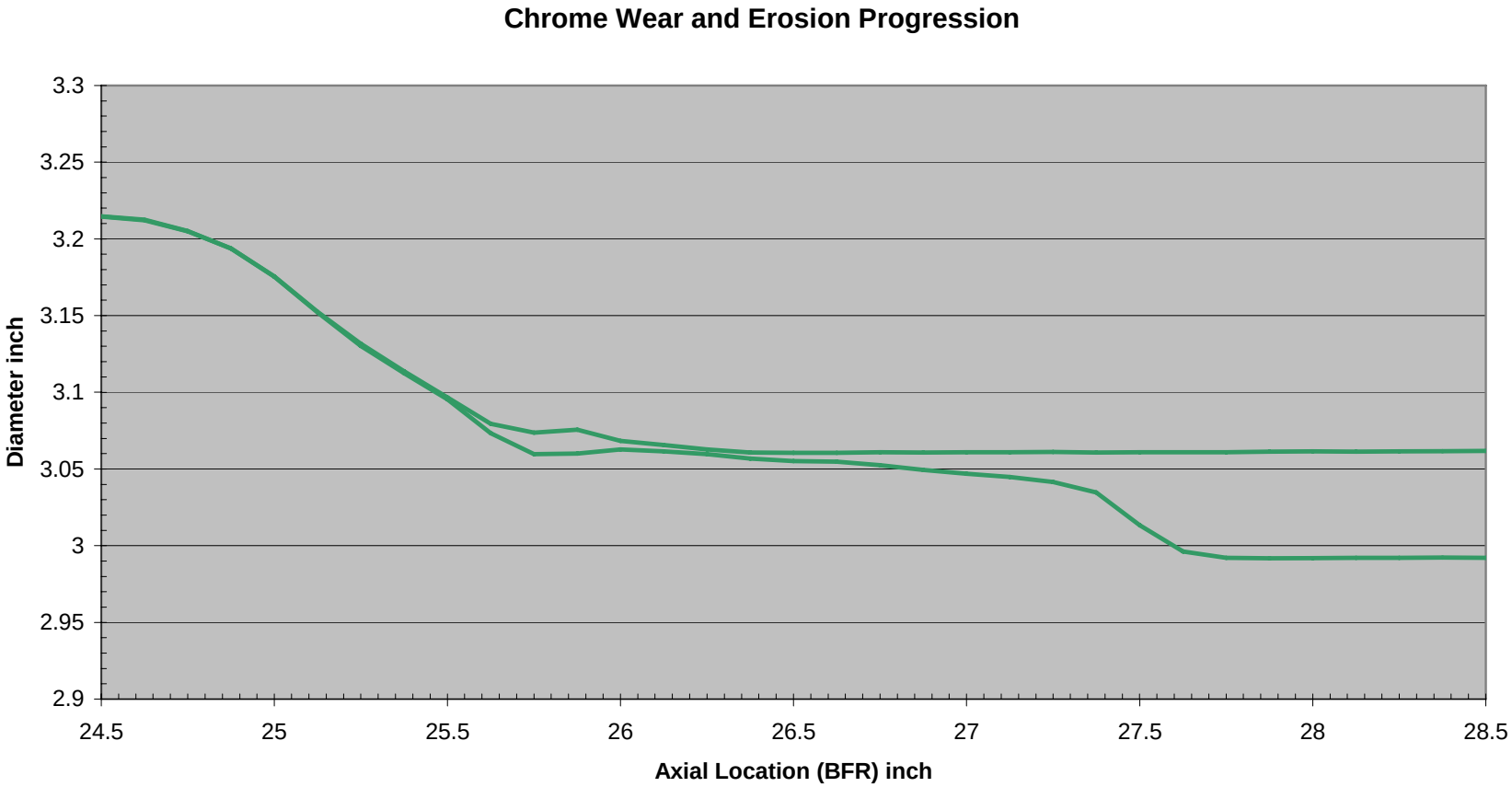
76mm Rapid Fire Test Results

- Chrome liner, after 240 shots



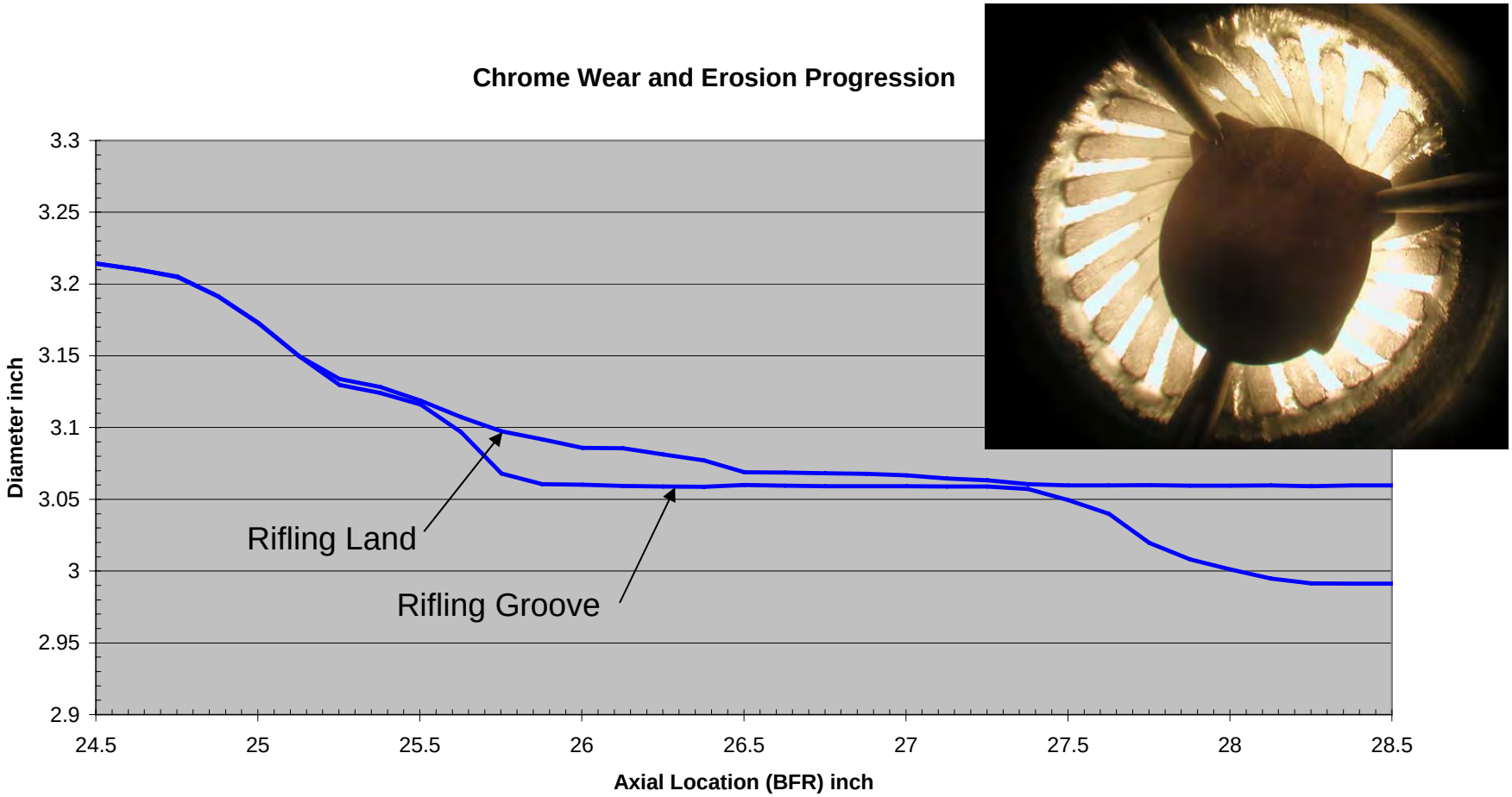
76mm Rapid Fire Test Results

- Chrome liner, after 320 shots



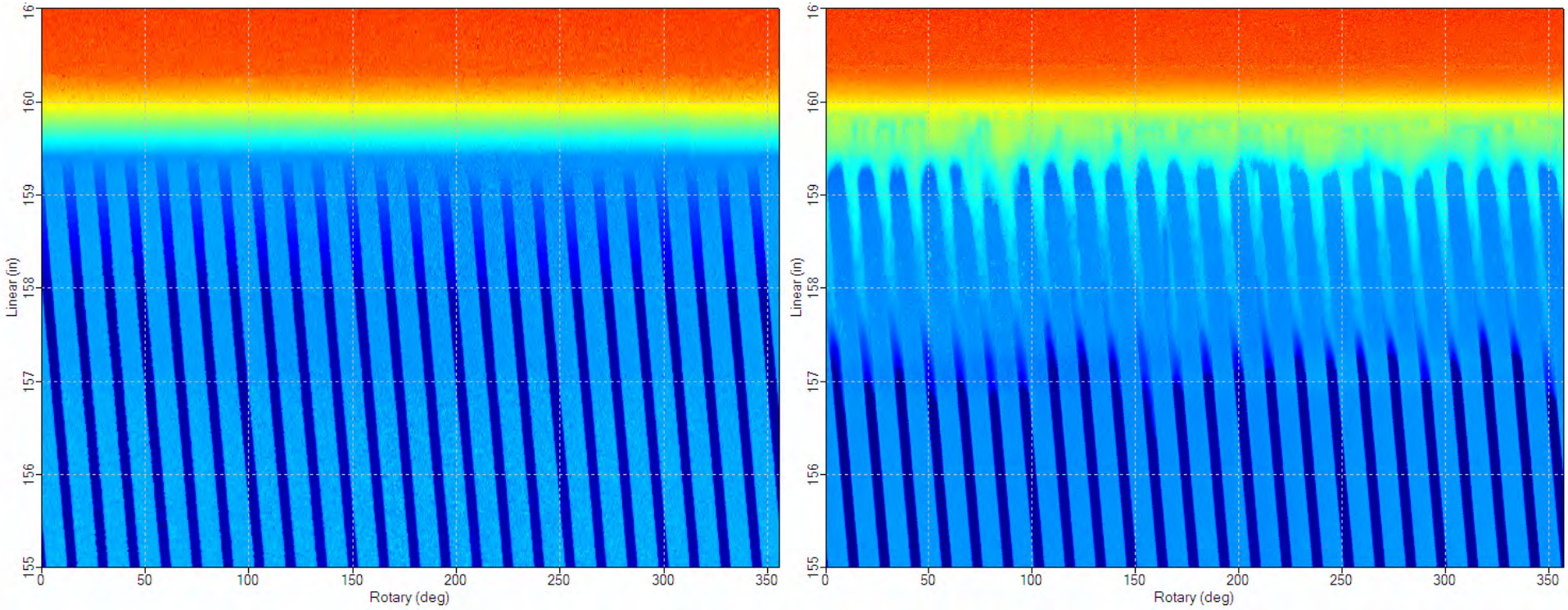
76mm Rapid Fire Test Results

- Chrome liner, after 400 shots



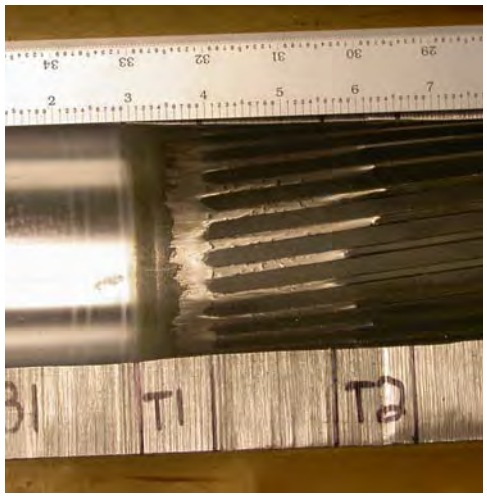
76mm Rapid Fire Test Results

- Laser Bore Mapping images of Chrome liner new, and after 400 rounds.
  - Note, depth of lands has progressed deeper than grooves.

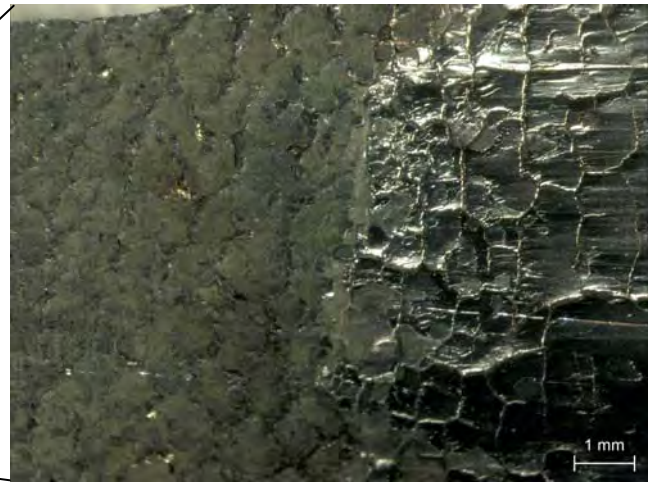


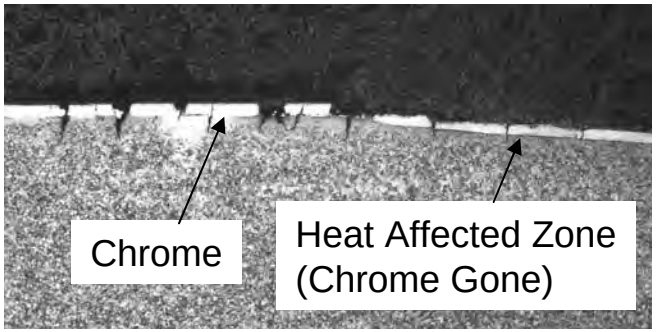
76mm Rapid Fire Test Results

- Micrographic analysis.
  - Surface and axial section view of chrome loss transition area in forcing cone region.



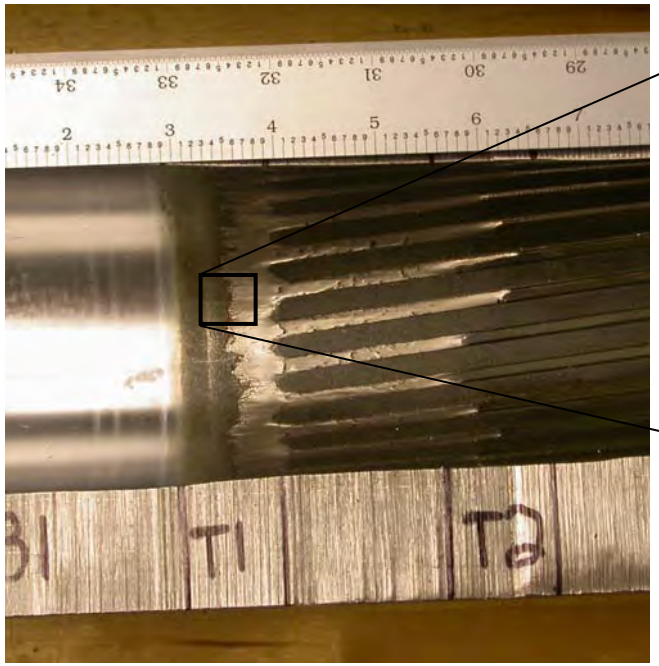






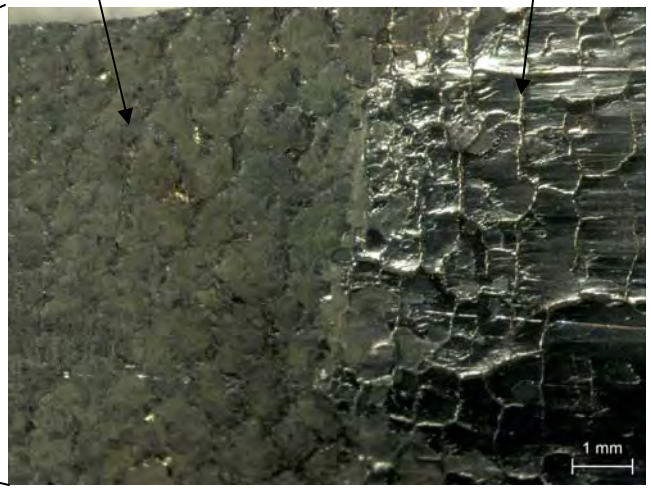
76mm Rapid Fire Test Results

- Noteworthy observation
  - Effect of projectile induced mechanical loads



Typical Chrome
Heat Check Cracks

Exposed Gun
Steel (gas washed)



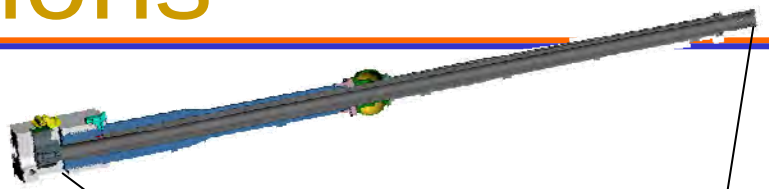
Similar thermal and chemical environment between these two areas. But the mechanical environment is dramatically different. The area to the right was subject to the physical impact of the projectiles, as well as the additional radial strain caused by the engraving of the rotating band.

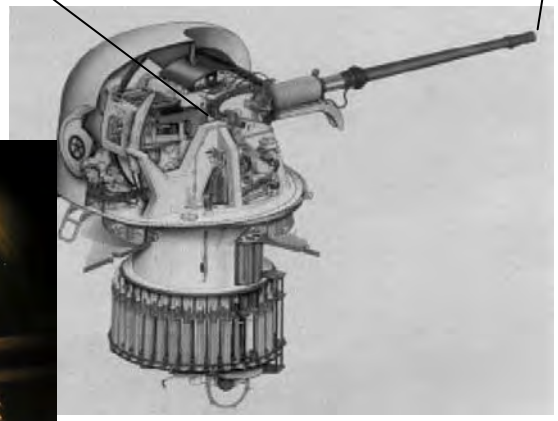
AGBT Current Status/Path Forward

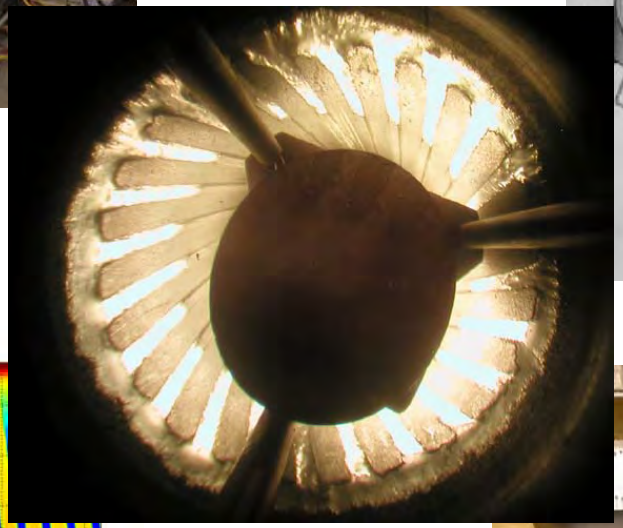
- 76mm HRF Testing of Competing Technologies will be completed summer 2007.
- Winning technology will be selected for development into 155mm AGS barrel design.
- 155mm AGS barrel will be tested to demonstrate compliance with AGS transition requirements
  - 50% improvement in life
  - Reduction in life cycle cost
- If compliant with transition criteria, the Advanced Gun Barrel Technology will transition to the acquisition program for insertion into DDG 1000

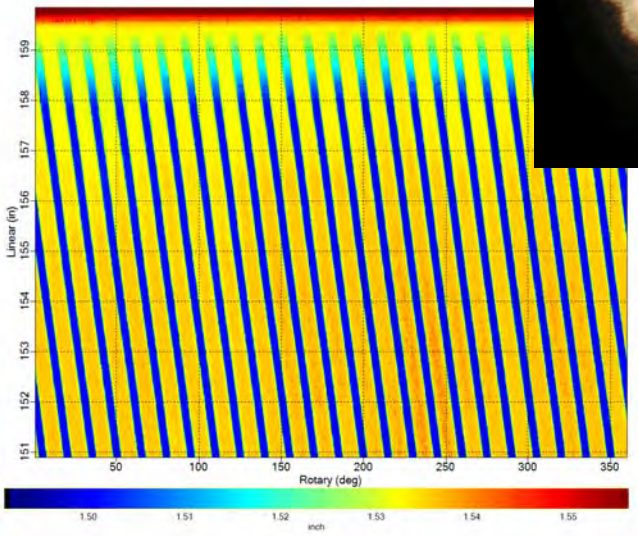
Questions

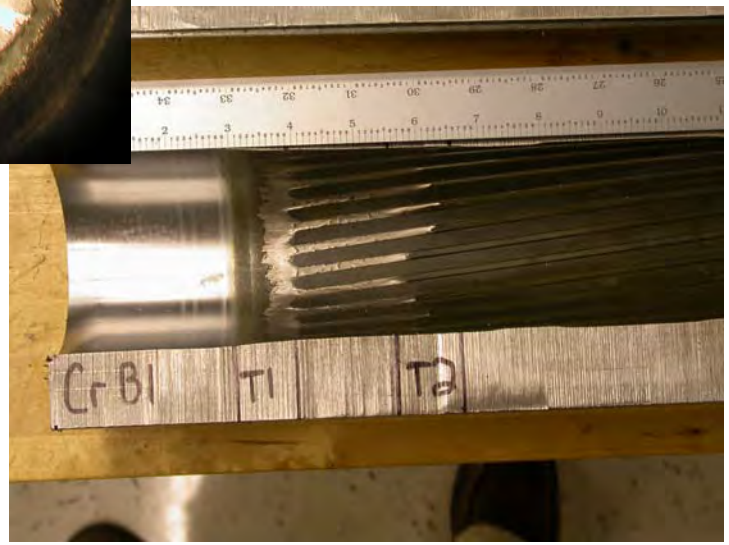

EXIT








Linear (in)
151
152
153
154
155
156
157
158
159
50
100
150
200
250
300
350
Rotary (deg)
1.50
1.51
1.52
1.53
1.54
1.55
inch


Cr B1
T1
T2

MRM-KE: A Lethal Solution

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

Charlotte, North Carolina, 23 -26 April 2007

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited (PAO # 237-07)

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….**

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited (PAO # 237-07)

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**



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Platforms and Targets

An advanced weapon and space systems company

Potential Platform



M1A2 Abrams

Planned MRM Platform



FCS Mounted Combat System Concept

Primary Target



Secondary Targets





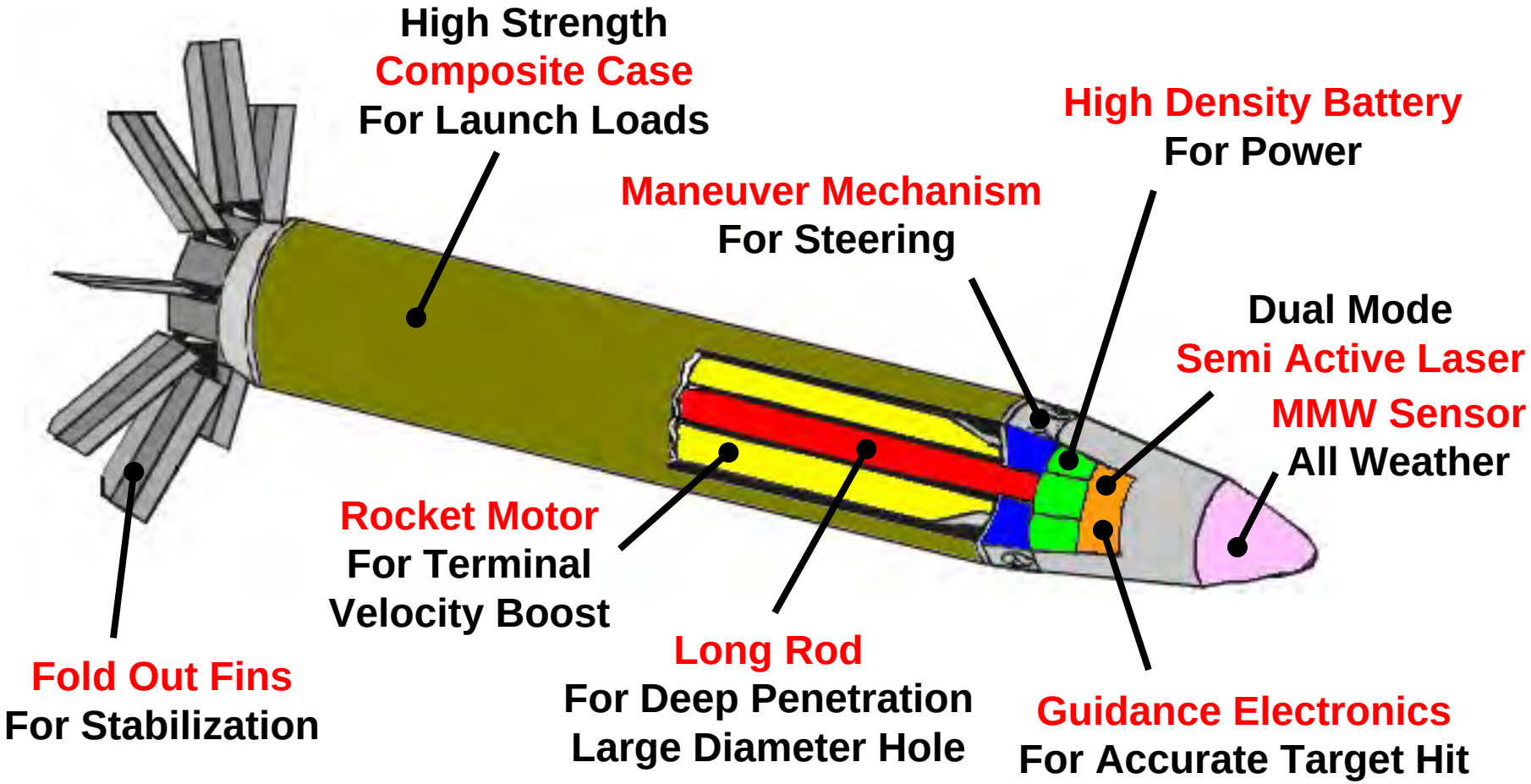




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Basic Design

- **Evolution of XM1007 Tank Extended Range Munition (TERM-KE) into MRM-KE**



Total Projectile used in Target Defeat

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How It Works

An advanced weapon and space systems company

VIDEO

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Speed Kills – MRM-KE Advantage

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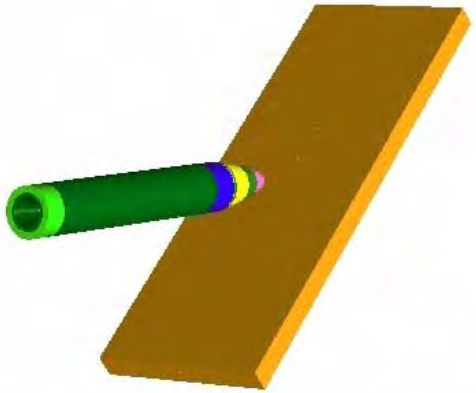
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Terminal Ballistics Modeling and Test

An advanced weapon and space systems company

- **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**

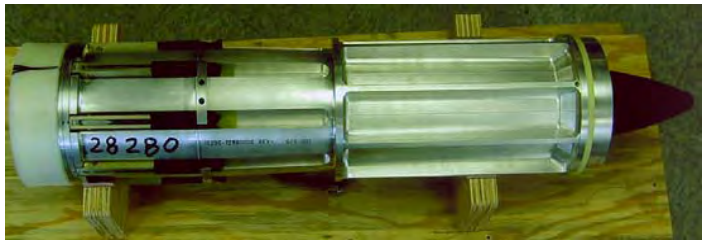
VIDEO



Simulation Example



Experimental Gun



Test Round in Sabot

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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**



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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**

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DIEHL
BGT Defence

Rocket Artillery in Future Scenarios, First Answer



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

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Outline

DIEHL
BGT Defence

- Who we Are
- The Past
- The Future
- Options
- A Solution
  - Concept
  - Benefits
  - Performance
  - Programme Timeline
- Summary/Conclusions

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Who we Are in a nutshell

DIEHL
BGT Defence

- 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











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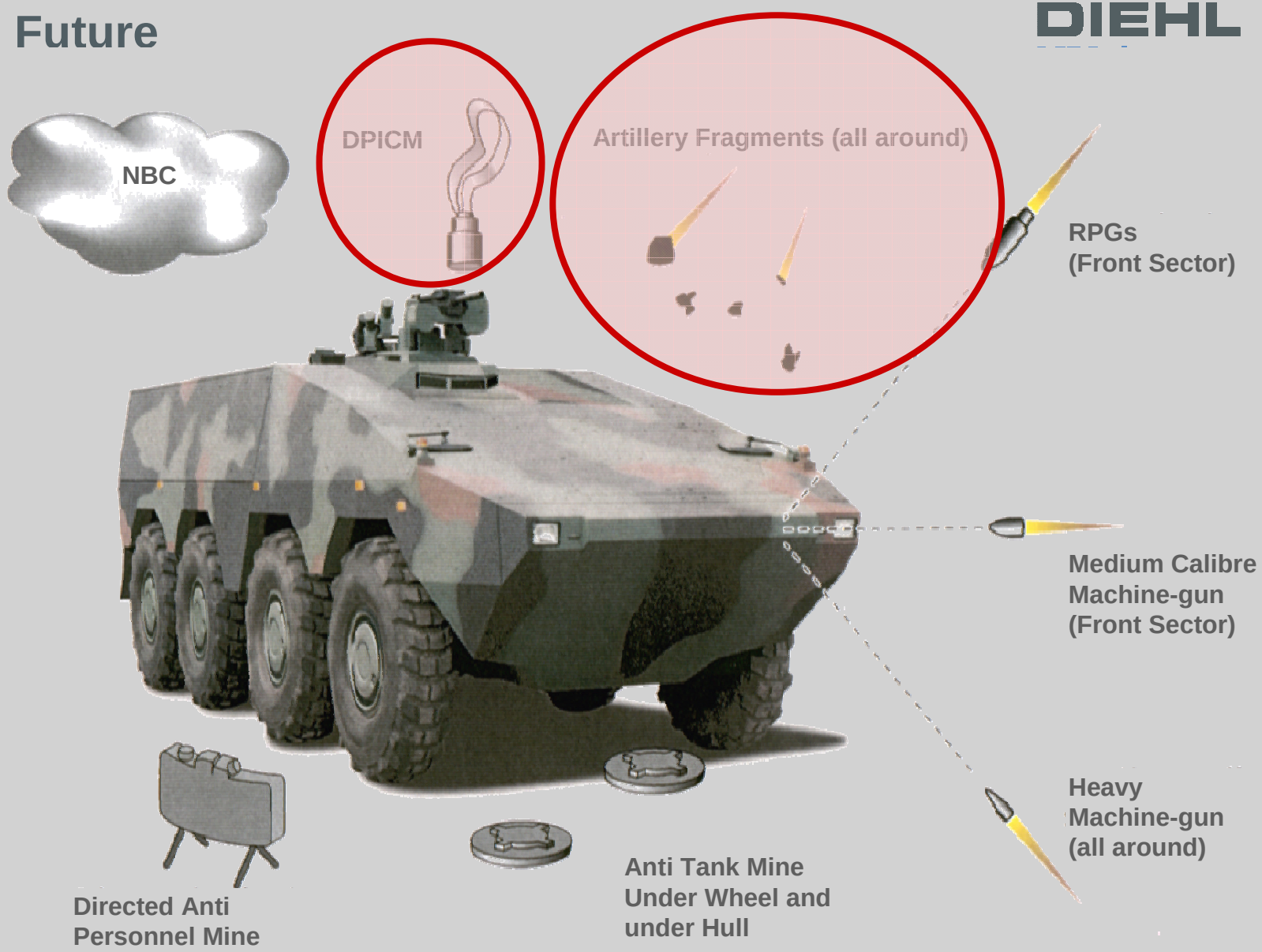
The Past

DIEHL
BGT Defence



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The Future



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Options

DIEHL
BGT Defence

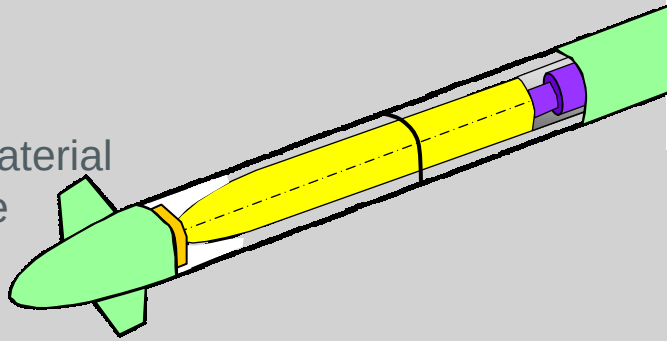
- DPICM, (**D**ual **P**urpose **I**mproved **C**onventional **M**unition)
  - small Fragments → Anti Personnel/(Material)
    shaped Charge → Anti Armor/Material

Is it still as good as we believe ?



- Unitary, (a single HE filled Effector in a Carrier)
  - Fragments → Anti Personnel/Material
    Penetrator → Anti Infrastructure

Precision is Mission critical !
Includes TLE !



- SFM, (**S**ensor **F**uzed **M**unition)
  - Designed to fight hard and semi-hard Targets



SFM´s are perfect to fight all protected Targets !

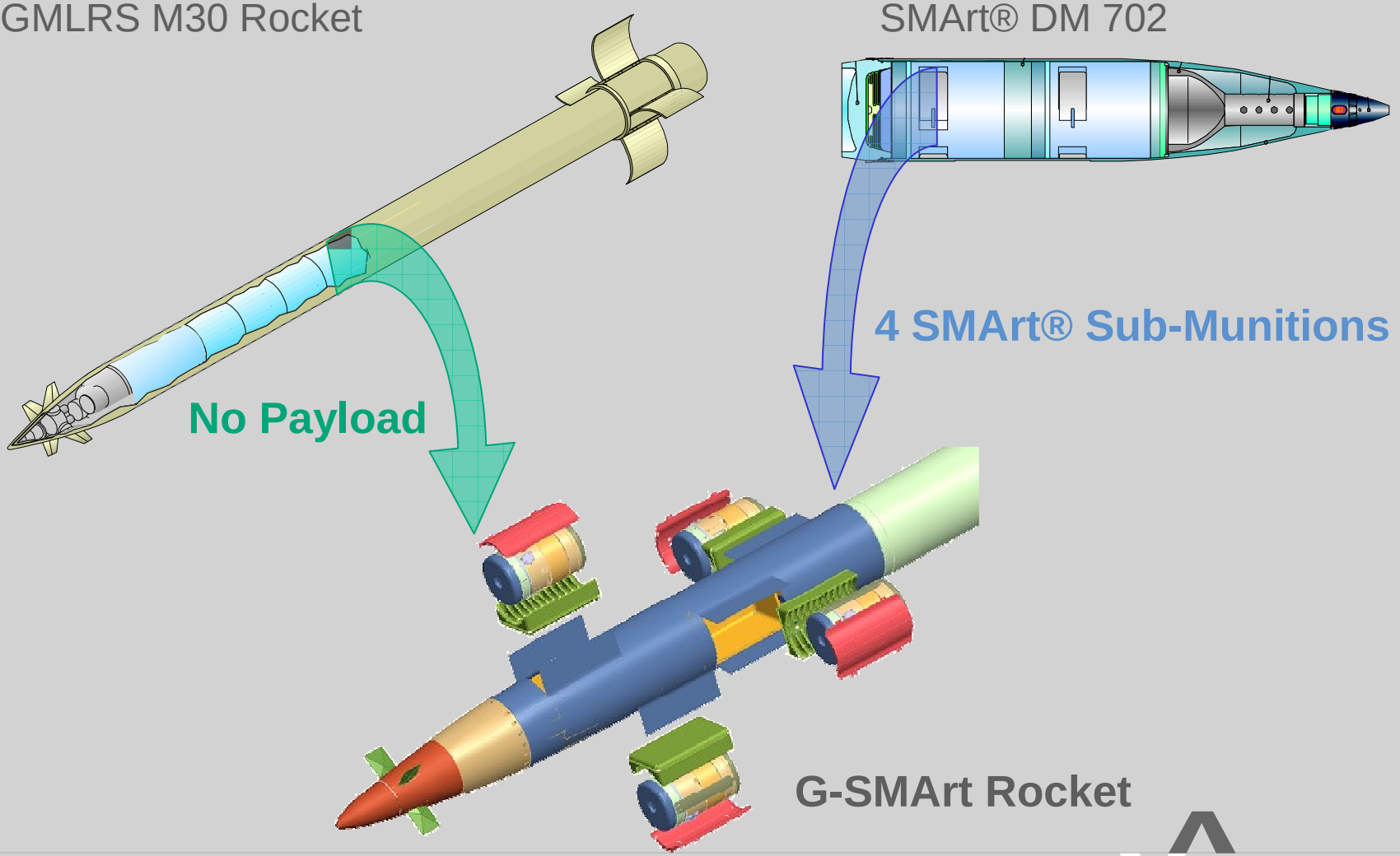
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A Solution

DIEHL
BGT Defence

GMLRS M30 Rocket

SMArt® DM 702



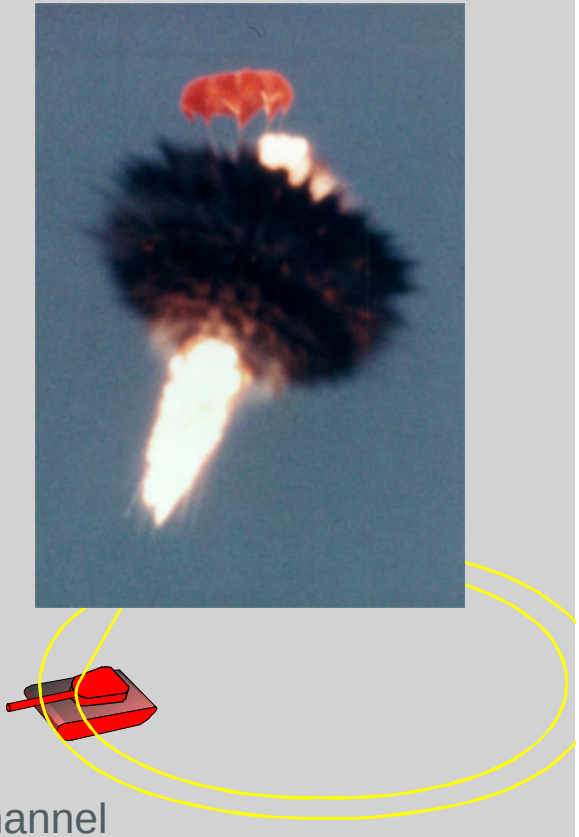
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SMArt®

DIEHL
BGT Defence

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 !

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SMArt Principle of Function

DIEHL
BGT Defence

MAIN PERFOMANCE DATA

Target detection and tracking _____ radar
Operational mode _____ automatic
Engagement envelope:

Descent

(SLR)







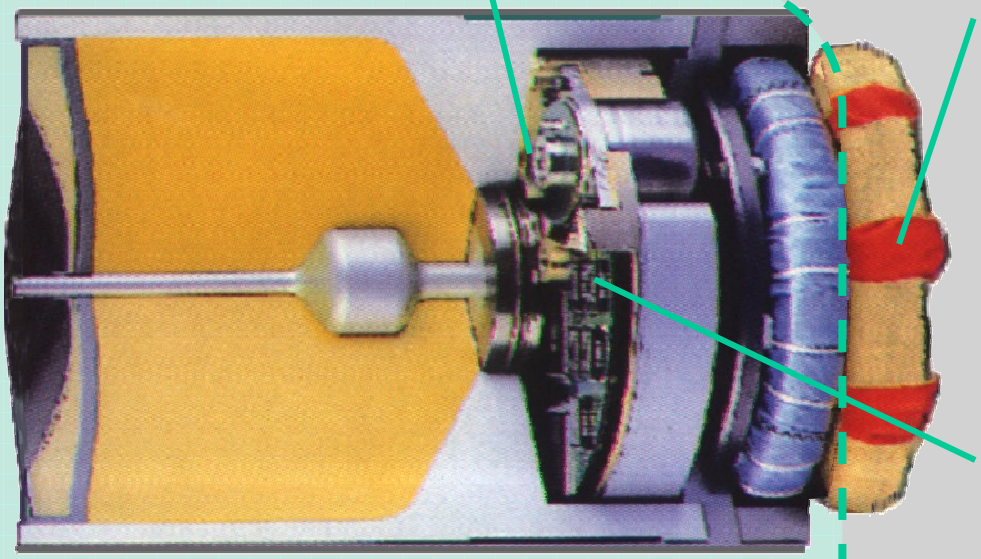
SMArt`s Sensors are simple and the kill Mechanism is very robust !

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SMArt Adaptation to GMLRS

DIEHL
BGT Defence

Change Spin released Battery
Activation to Rocket Control



Change Spin opened
Ballute to high Speed
Drag Chute

Change Acceleration
Environmental Criteria
of S&A to Rocket
ESAD Control

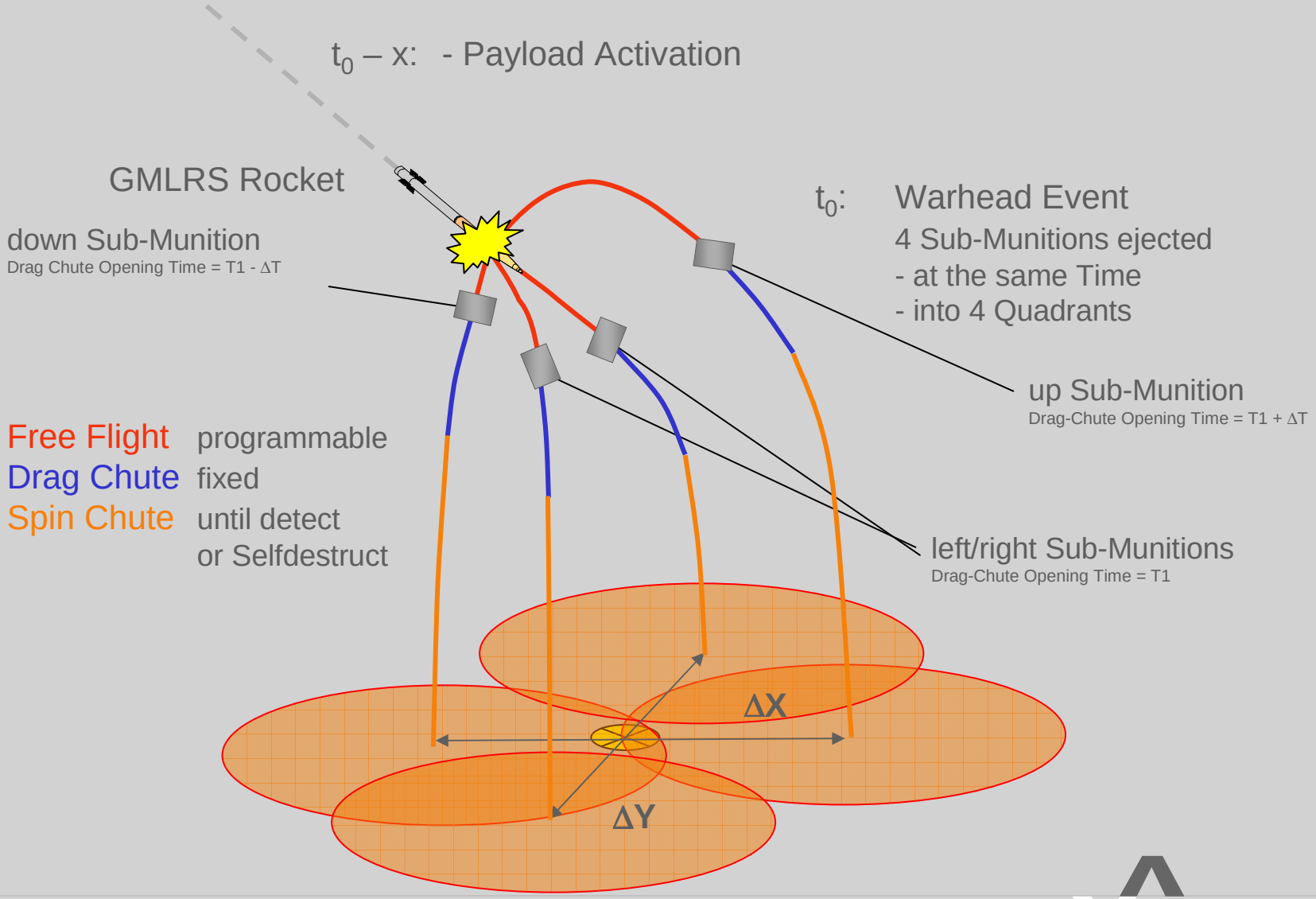
No Change on Sub-Munition Descent, Search and Detect and Self Forging Fragment Function

Minor Modifications only to SMArt Sub-Munition !

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G-SMArt Sub-Munition Dispense

DIEHL
BGT Defence



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G-SMArt Sub-Munition Function

DIEHL
BGT Defence

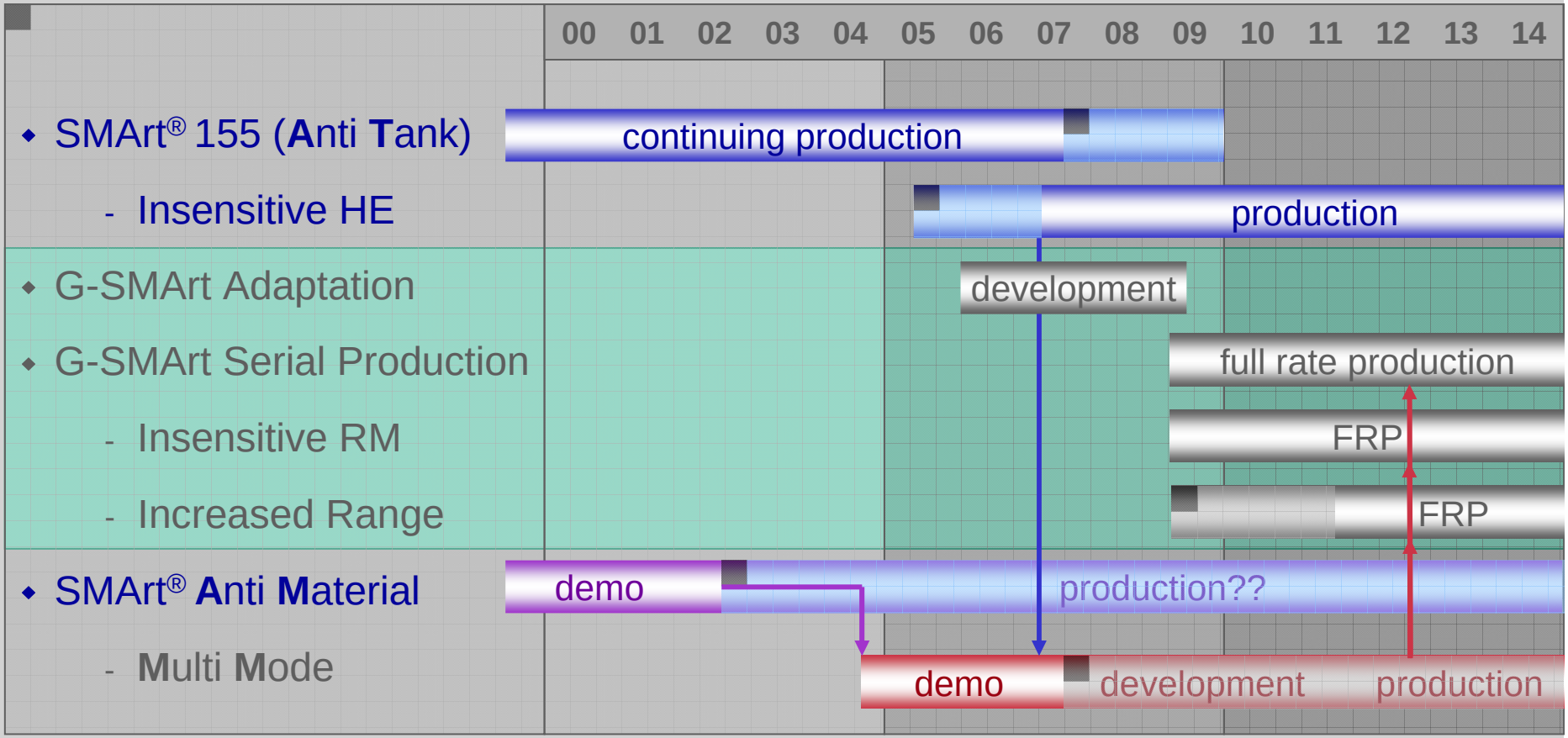
Free Flight, Drag Chute Flight and Spin Chute Flight, some Hit Examples



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Programme Timeline and Growth Potential

DIEHL
BGT Defence

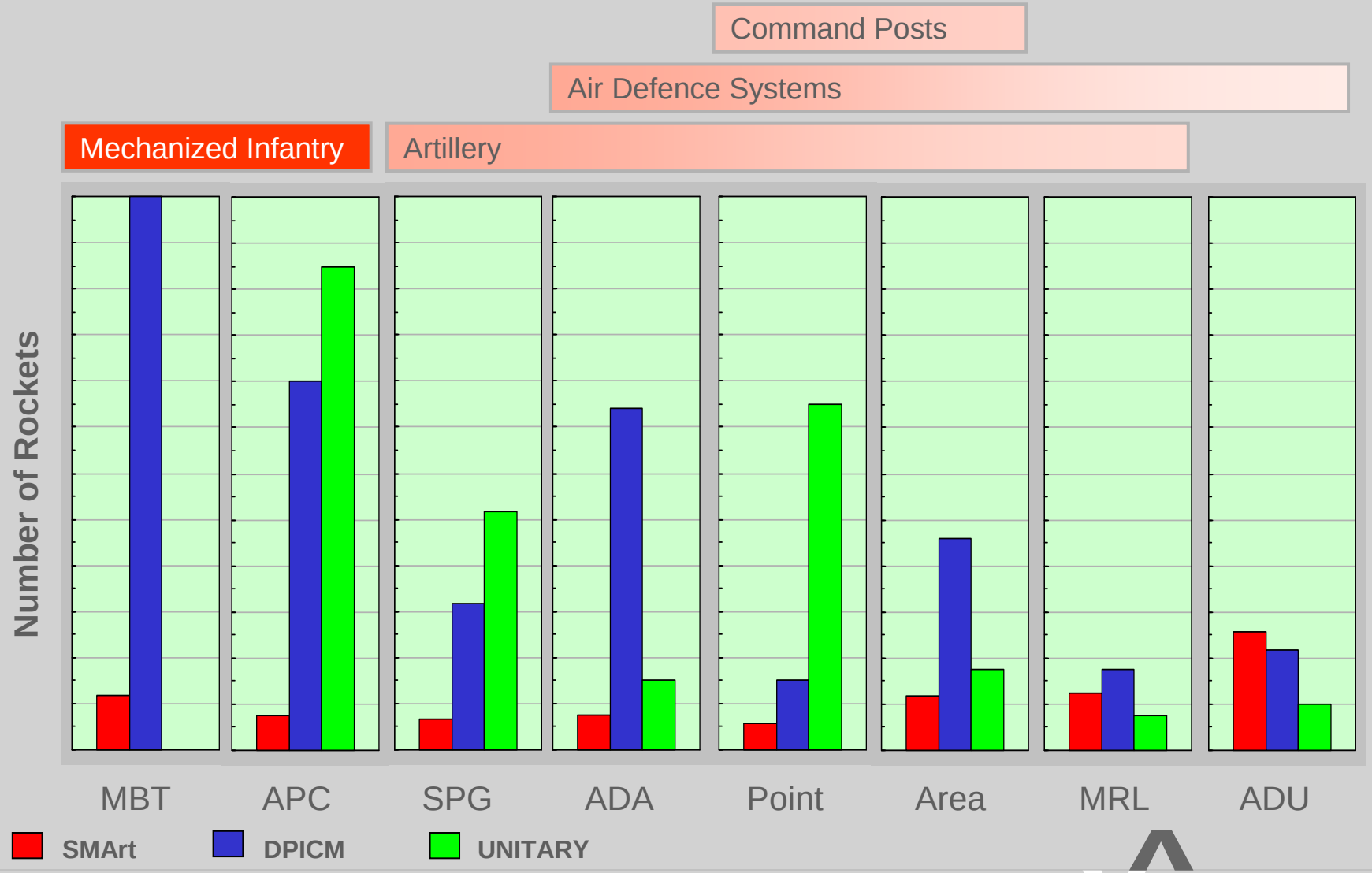


Leveraging form both GMLRS and SMArt® Improvements
G-SMArt will always be up-to-date

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Performance Prediction

DIEHL
BGT Defence

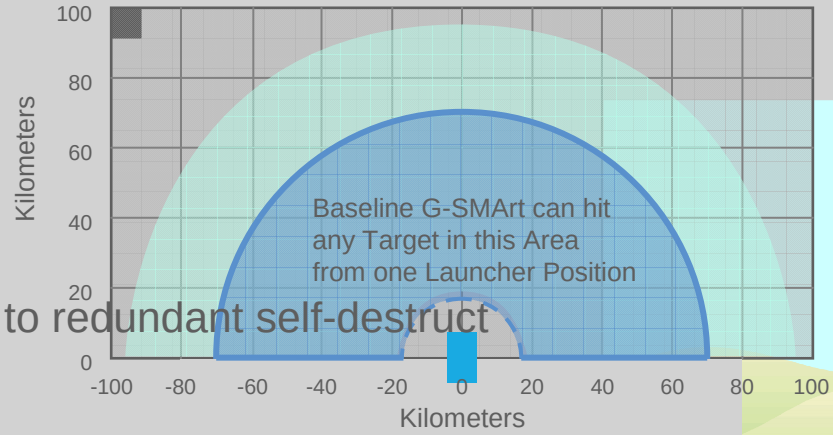


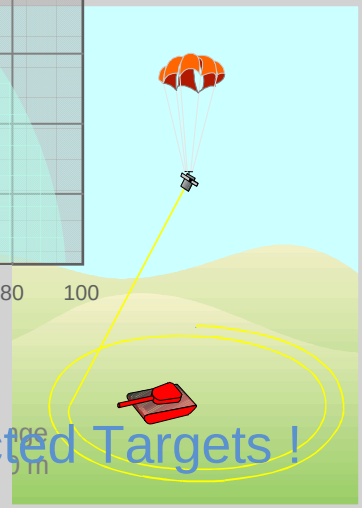
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G-SMArt Summary

DIEHL
BGT Defence

- 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 !

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Thank you for your Attention!
Lance Corporal Klöbke is currently our only operational Rocket Launcher Colonel !
Any Questions?

GENERAL DYNAMICS
Armament and Technical Products



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

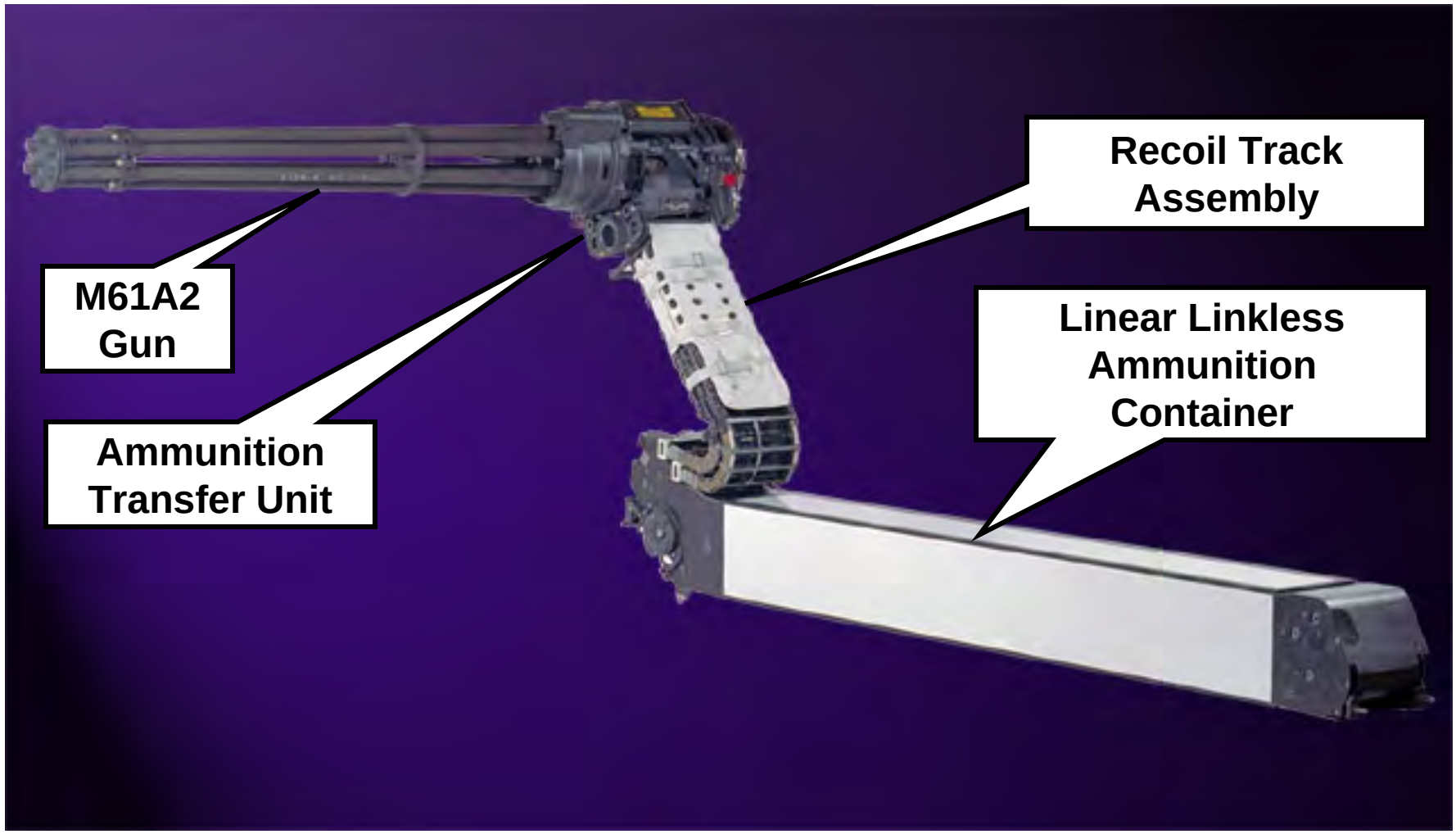
Agenda

- Overview of the F-22A Gun System
- Comparison to Legacy Gun Systems
- Application of Composite Materials
- Lightweight Composite Conveyor Element

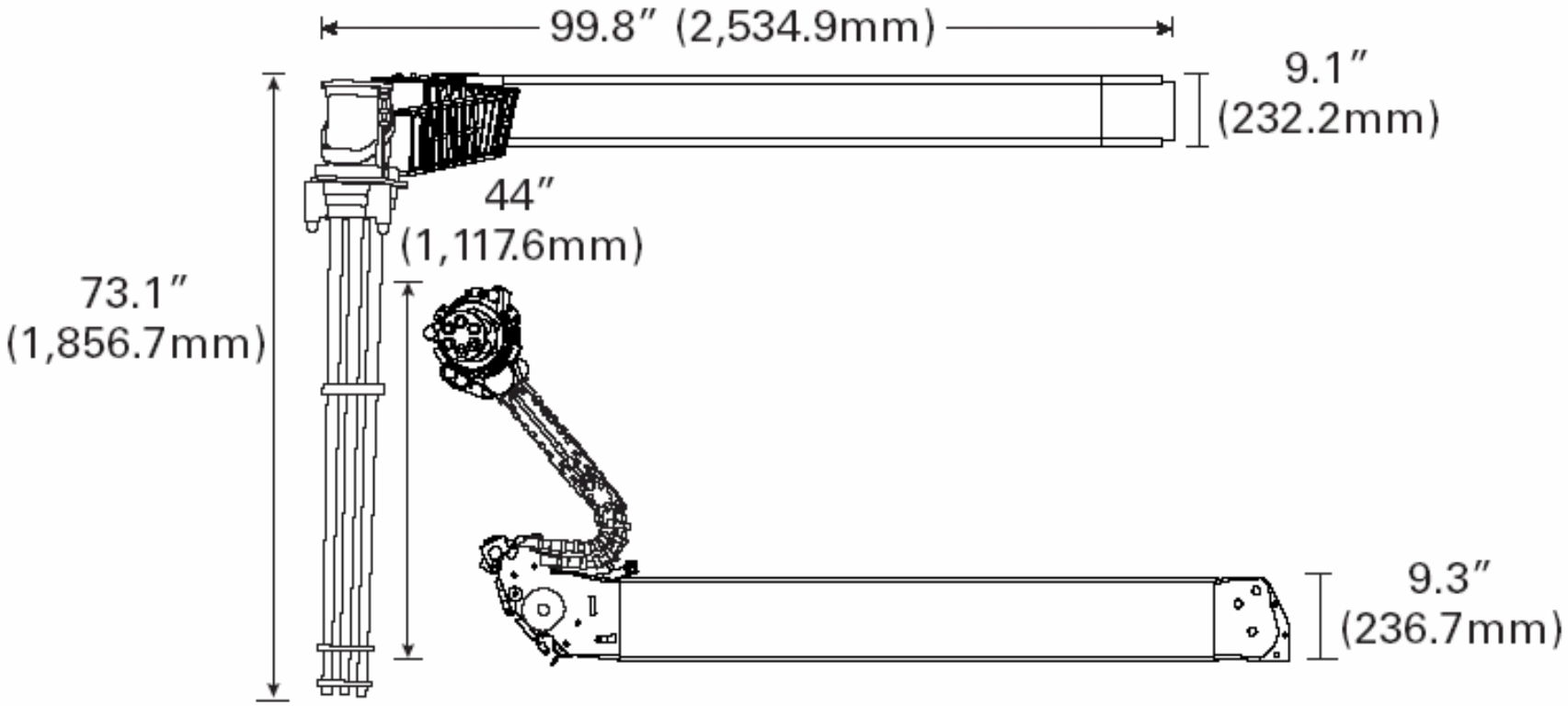
Background Information

- 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



LLAHS Overall Size



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



F-16 & F/A-18 E/F

Rotary Linkless, Closed Loop Ammunition Handling System

Mainly Metallic Construction

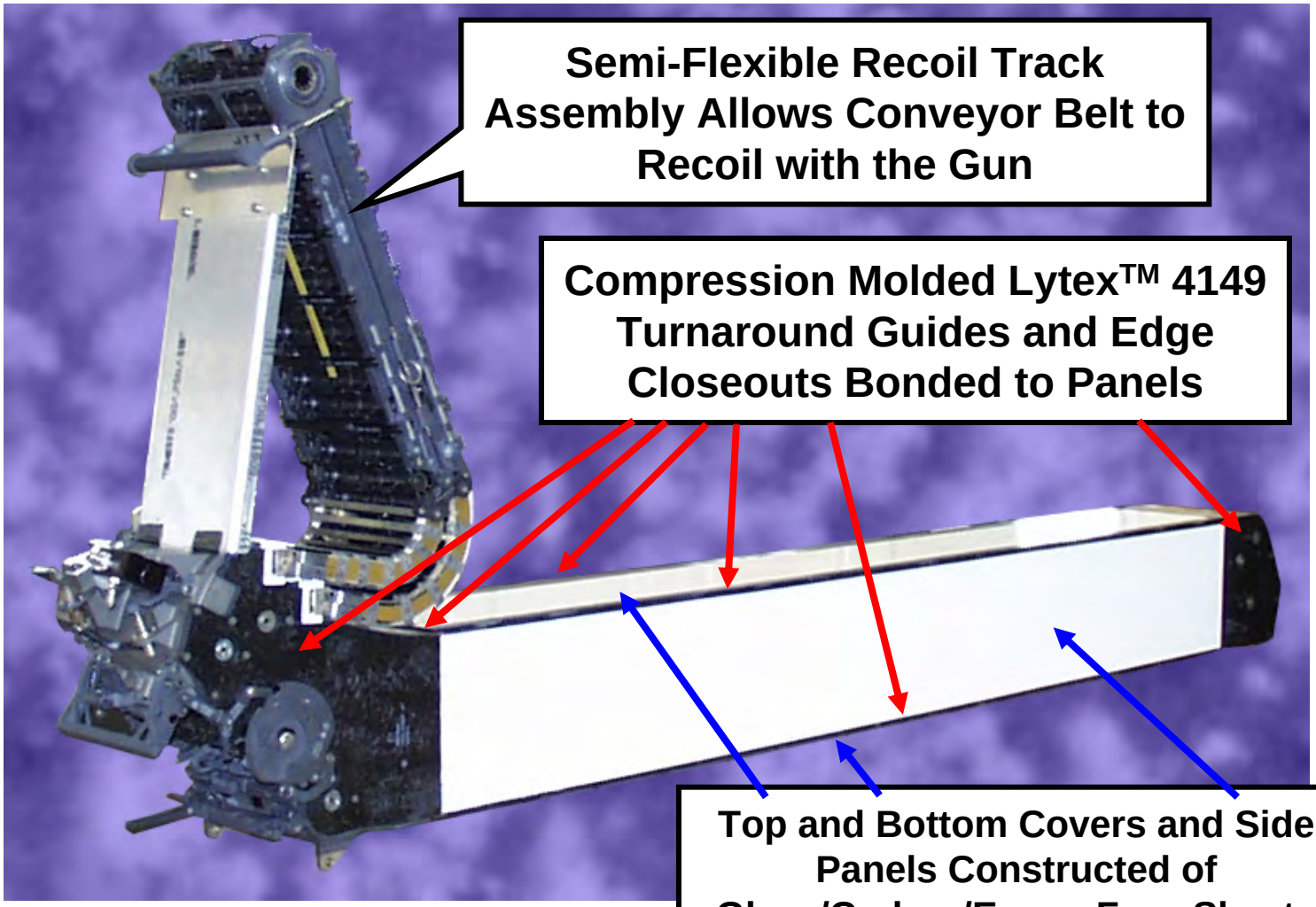
F/A-18 E/F



Specifications and Weight Comparisons of 20mm Aircraft Gun Systems

SYSTEM DESIGNATION:	***F-22A***	***F-15E***	***F-16***	***F/A-18 E/F***
Feed System Type (closed loop)	Linear Linkless	Linear Linkless	Rotary Linkless	Rotary Linkless
Ammunition Capacity	480	500	511	412
Gun Type	M61A2	M61A1	M61A1	M61A2
Firing Rate (shots/minute)	6000	4000/6000	6000	4000/6000
Empty System Weight (pounds)	378	484	506	451
Gun Weight	202	248	248	202
Feed System Weight (pounds)	176	236	258	249
Feed System Weight Delta from F-15E (pounds)	***-60***	0	+22	+13
System Specific Capacity (lbs/rd)	***0.79***	0.97	0.99	1.09

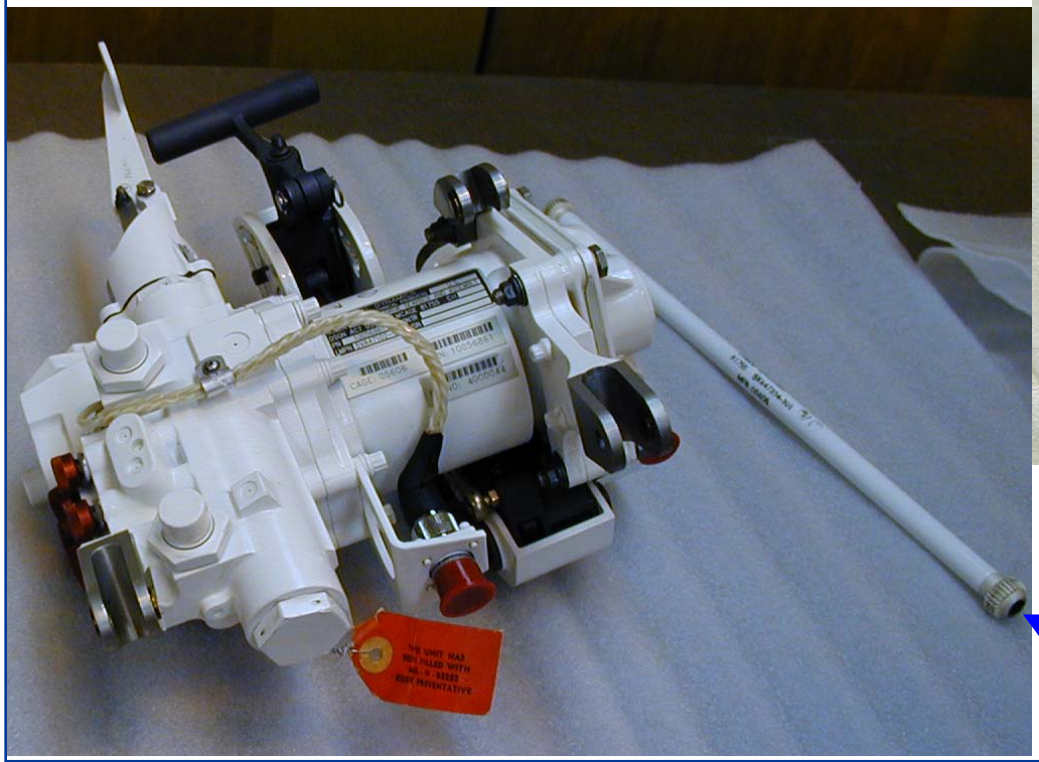
F-22A Ammunition Container Assembly Line Replaceable Unit (LRU) Makes Extensive Use of Composites



Hydraulic Drive, Container Drive Shaft, and Transfer Unit LRUs

These LRUs Use Conventional Metal Construction

Hydraulic Drive Assembly



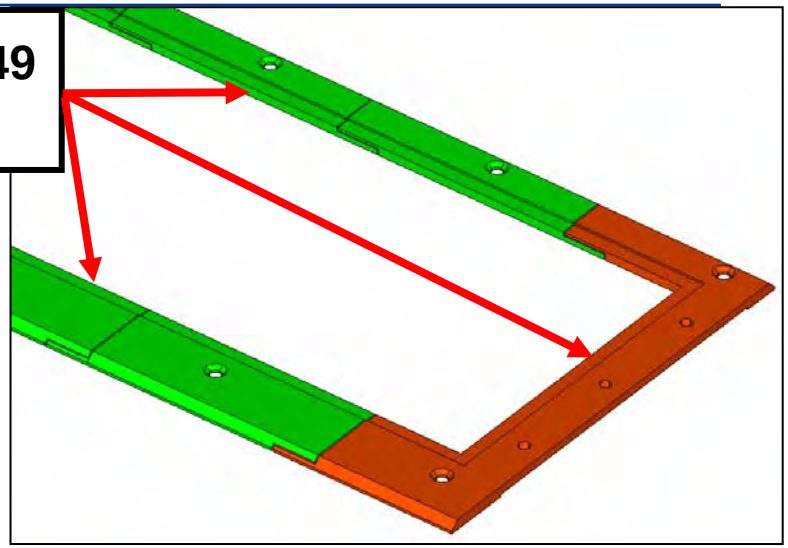


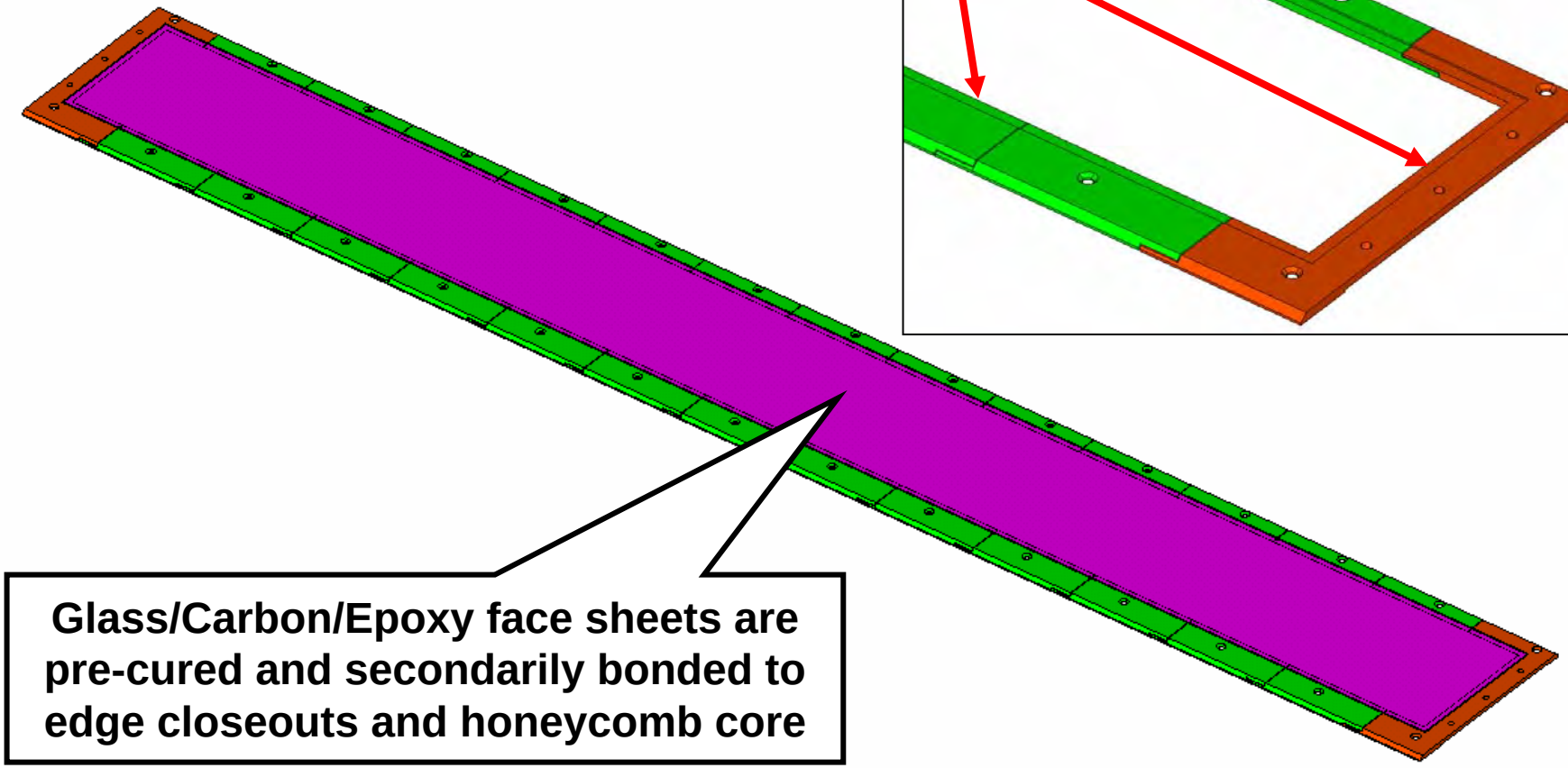
Transfer Unit Assembly

Container Drive Shaft

Compression molded Lytex™ 4149 Edge Closeouts Form Panel Perimeter

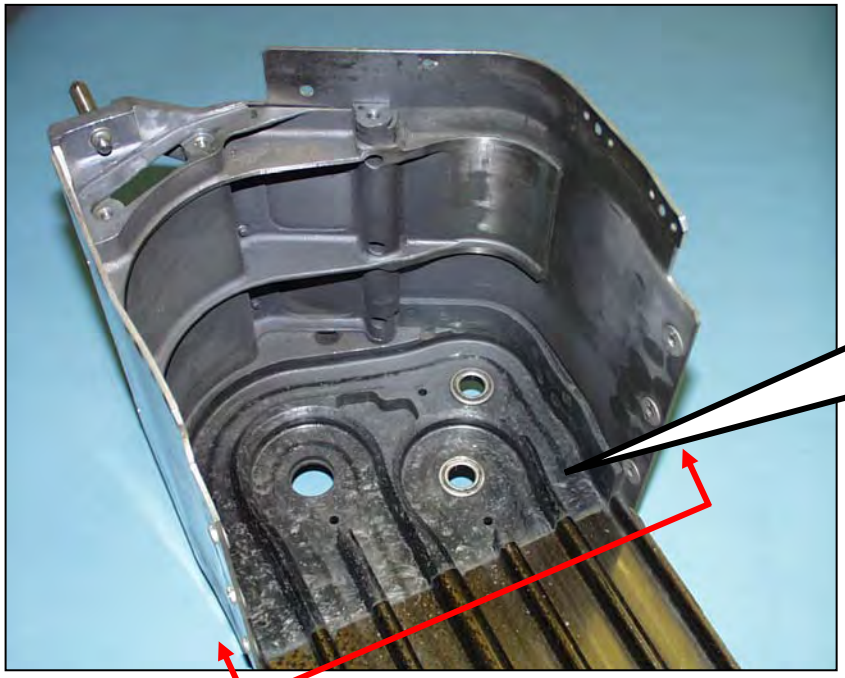
Compression Molded Lytex™ 4149 Edge Closeouts





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



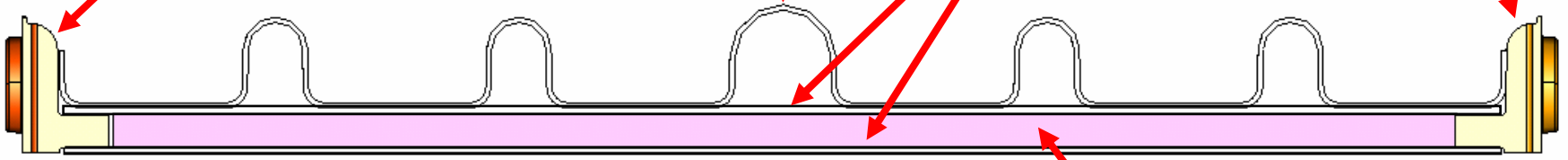
Compression Molded Lytex™ 4149 Turnaround Guide is Bonded to a Composite Track Panel

Lytex™ 4149 Edge Closeout

Glass/Graphite/ Epoxy Track Panel

Glass/Graphite/ Epoxy Face Sheets

Lytex™ 4149 Edge Closeout

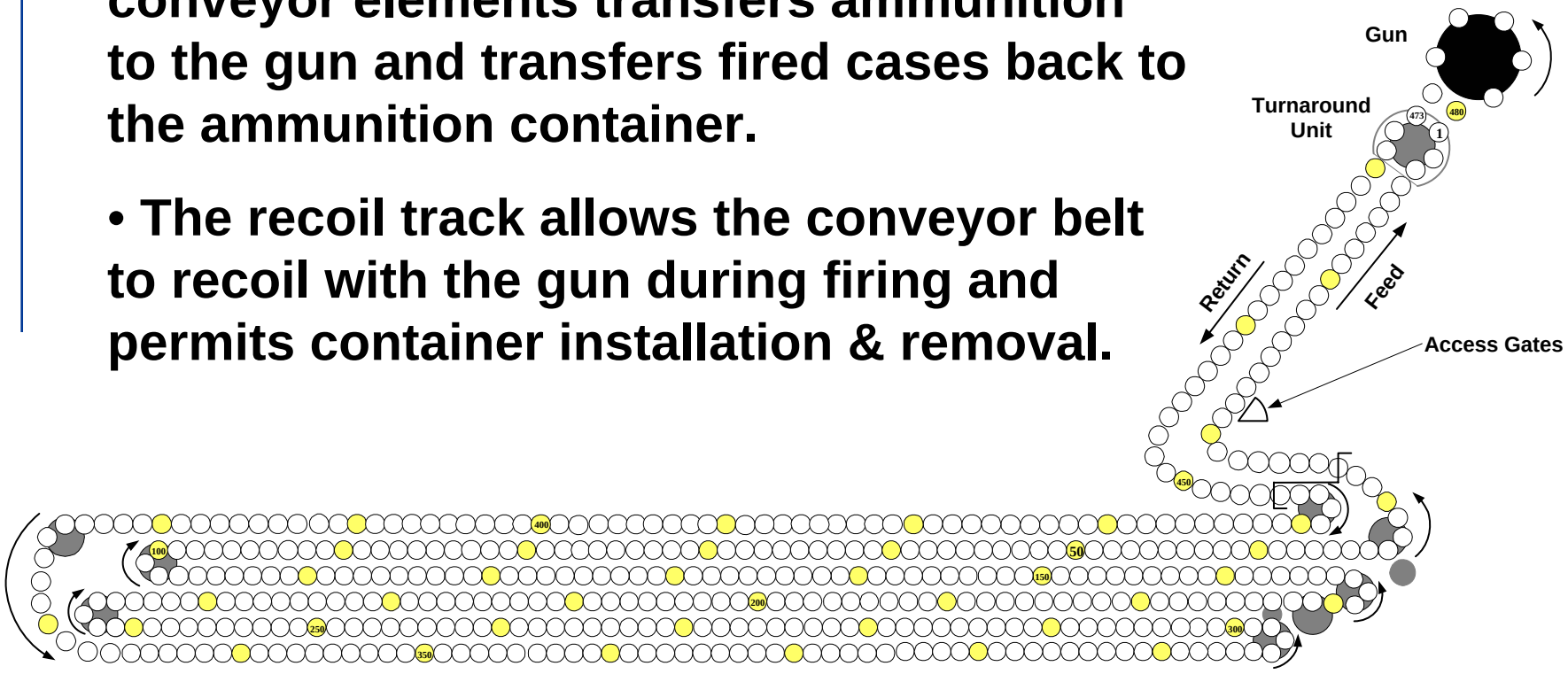


CROSS SECTION OF TRACK PANEL

Aluminum Honeycomb Core

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

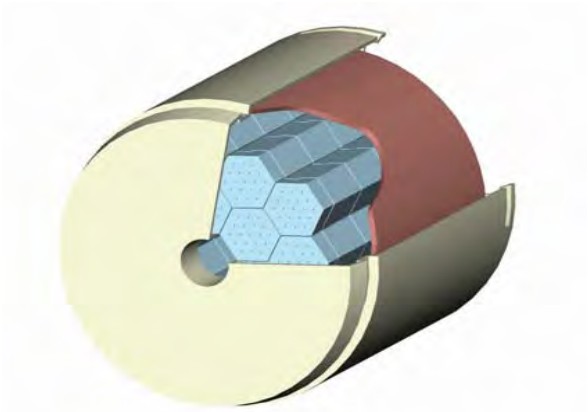


Photo from Parkway Products

- Quantum Composites – Bay City, MI
  - ➢ Supplier of Lytex™ 4149 material
- Parkway Products Inc. – Erlanger, KY
  - ➢ Lytex™ 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

GENERAL DYNAMICS

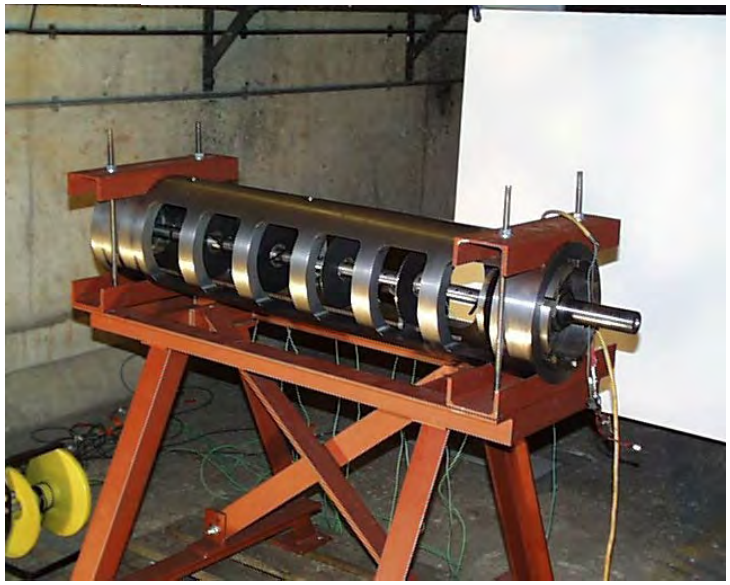




Modelling the Ignition of Modular Charges

Clive Woodley & Steve Fuller

A presentation to: 42nd Guns & Missiles Conference



April 2007

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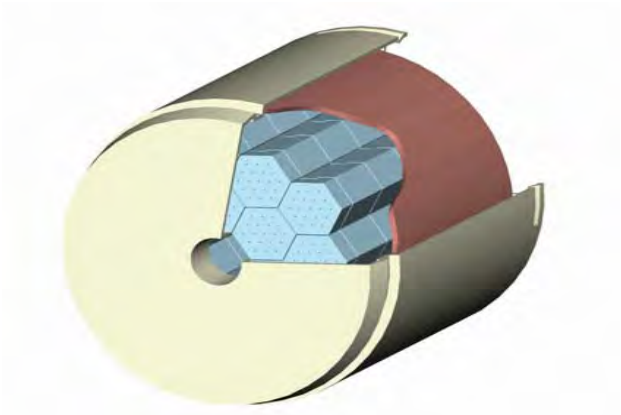
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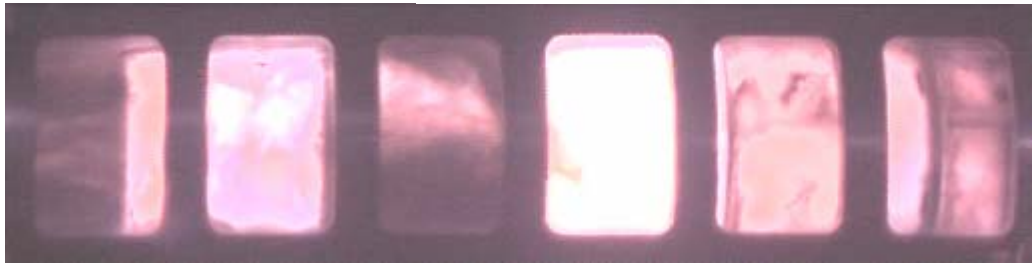
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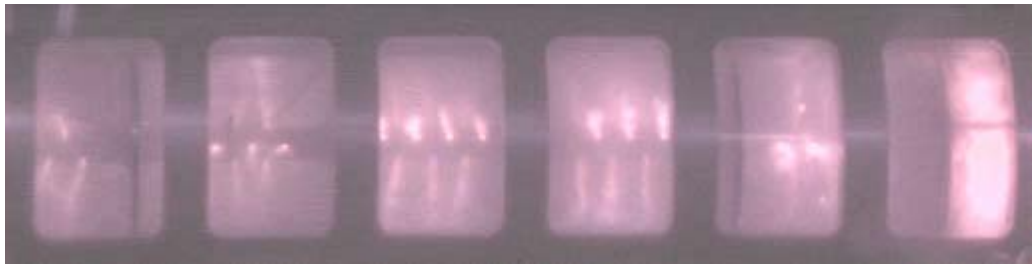
02 Validation

03 Simulations

04 Conclusions & future work

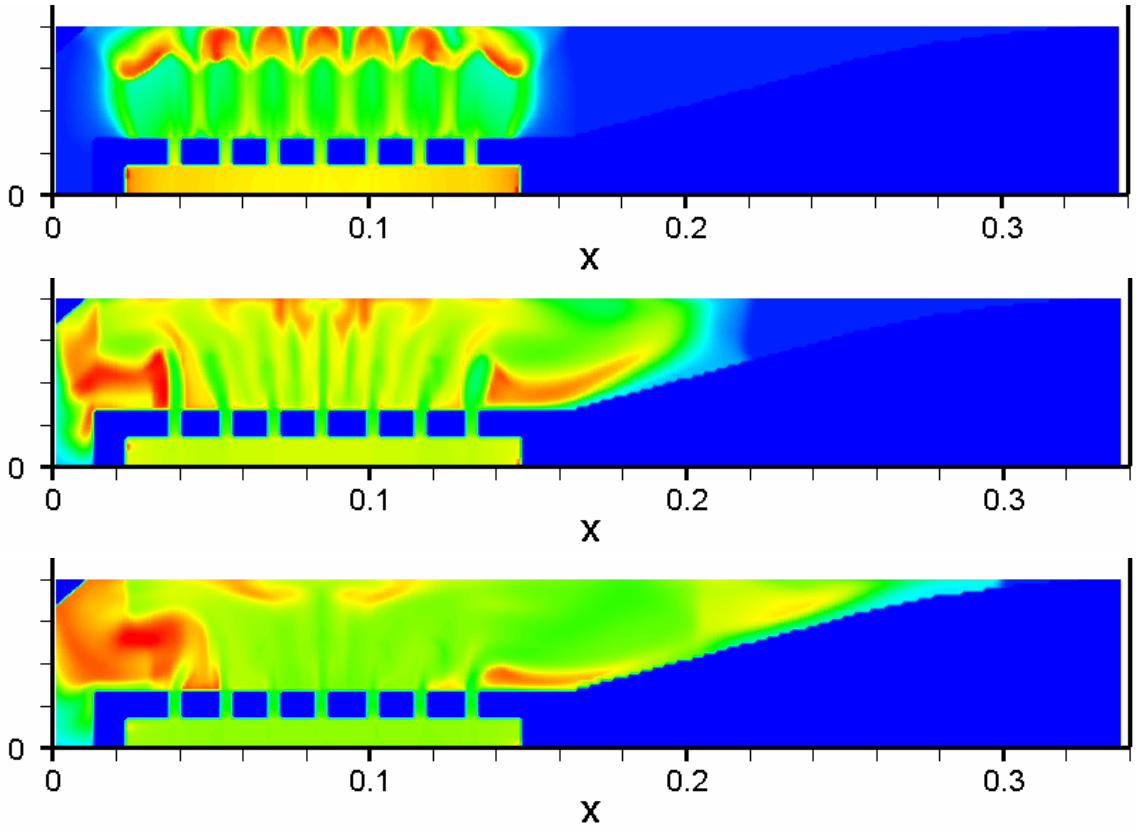






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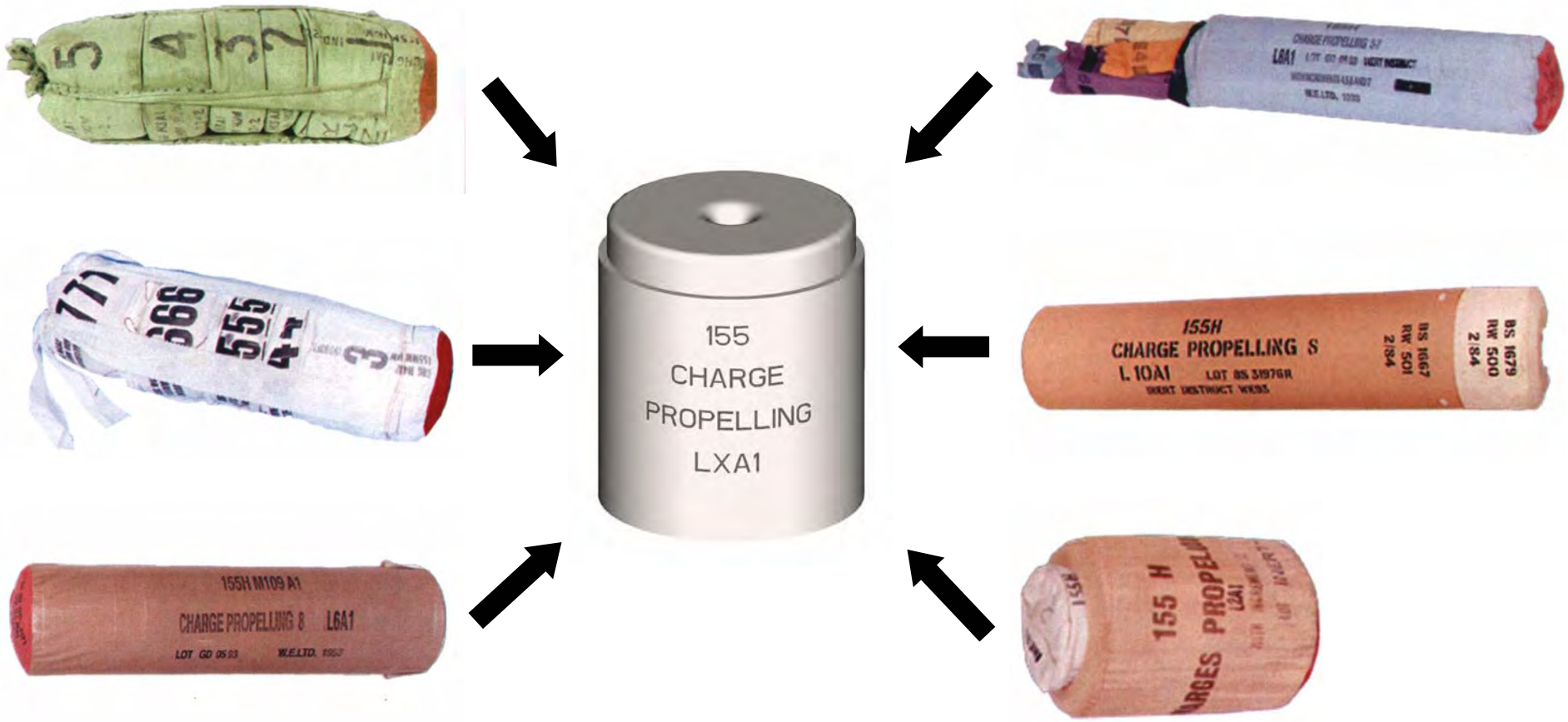
01
Background



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01 Charge design – why UPCS?

Existing inventory replaced with 1 module



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01 Charge design – advantages of UPCS

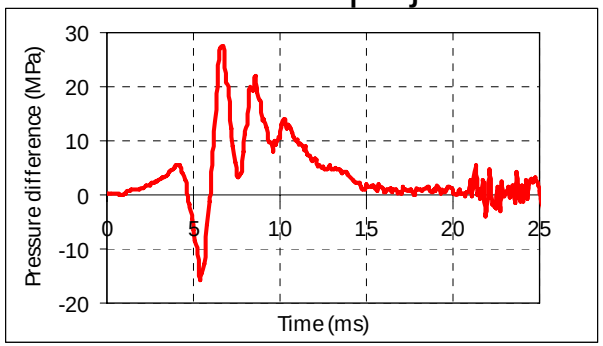
- Current charges
  - Not fully IM compliant
  - Not cleared for A1/C2 climatic conditions
  - Wasteful – decremental system
  - Costly & L10 can't routinely be used for training
  - Often remain in WMR until they 'life out'
- With UPCS
  - Same charges are used in training as are deployed for war fighting
  - Training simplified/more realistic
  - Substantial cost savings can be achieved through incremental system
  - Logistic burden reduced
  - Autoloader compatible

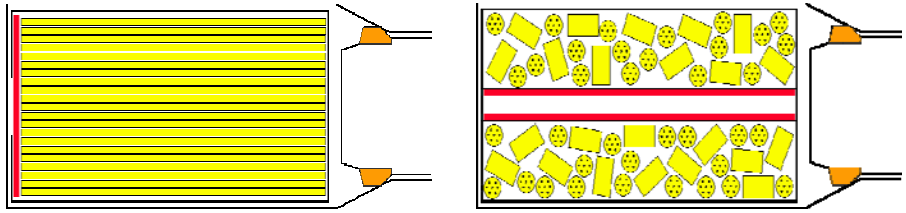
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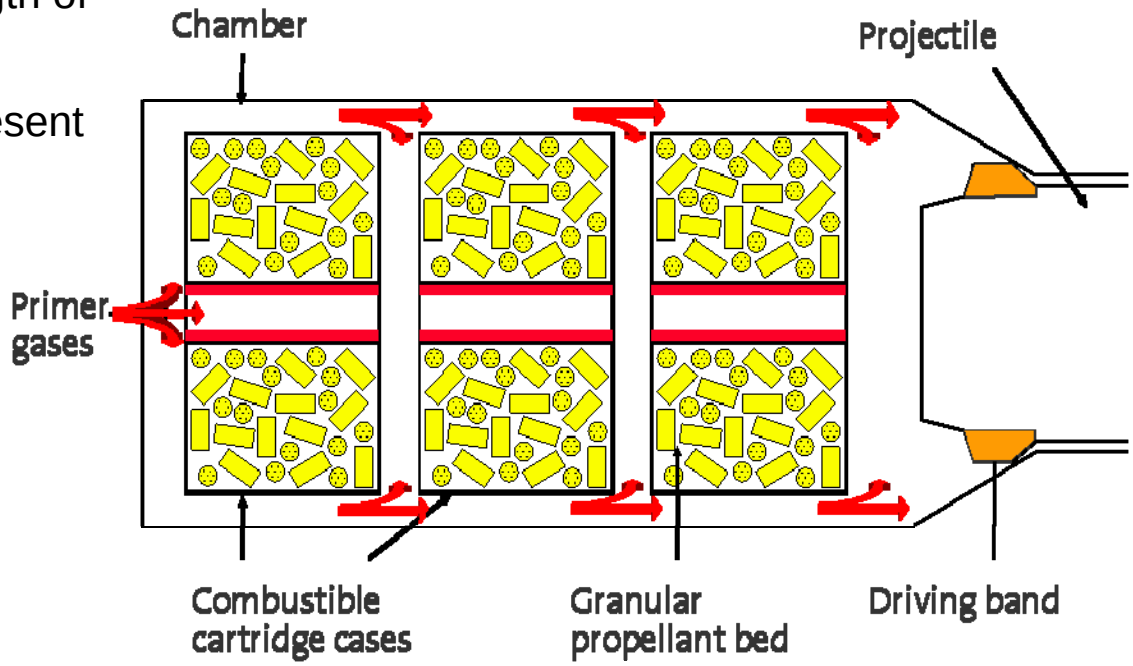
01 Modular charges – the problem being addressed

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!





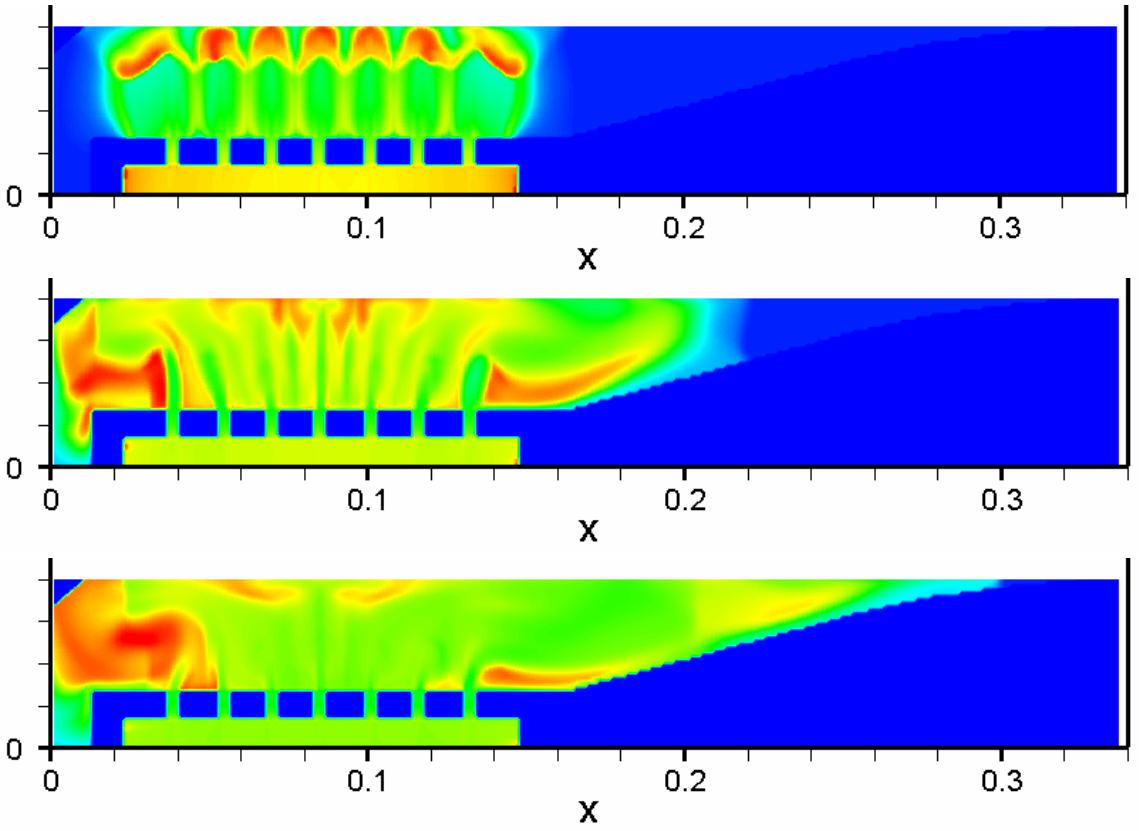


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01 Modelling approach - QIMBS

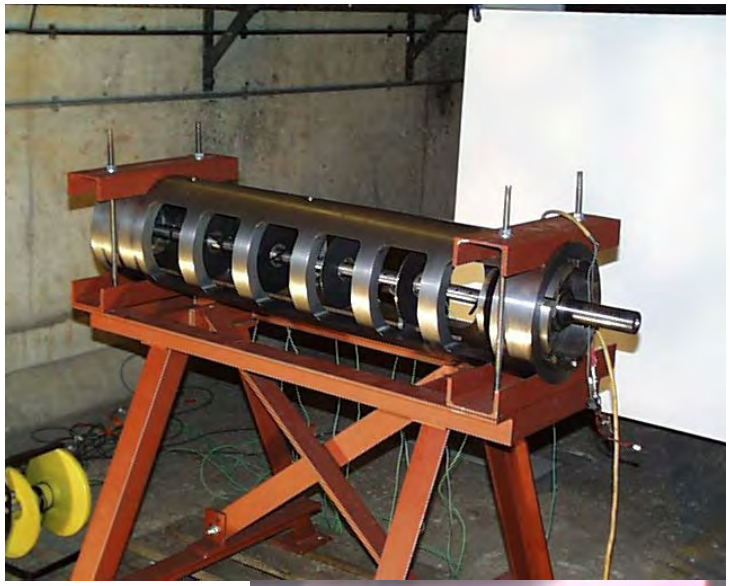
2D mortar code

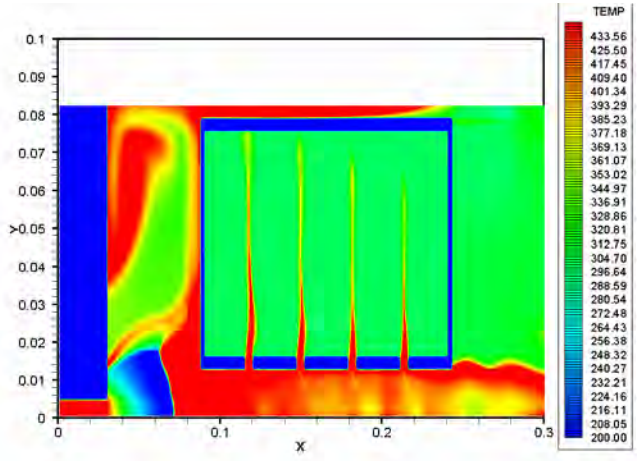
- Developed initially with MOD funding
- Developed further using QinetiQ funding
- Details presented at 22nd International Symposium on Ballistics
- Ability to represent internal solid boundaries

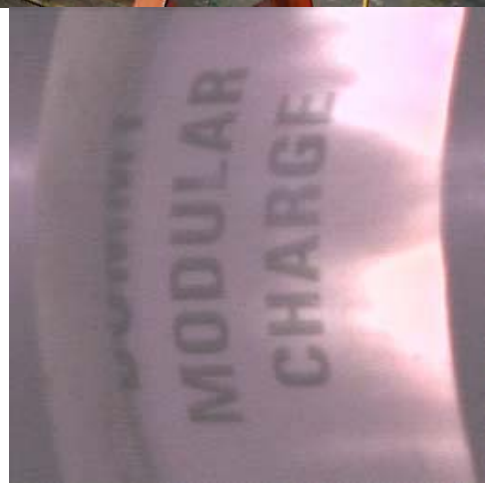


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02
Validation

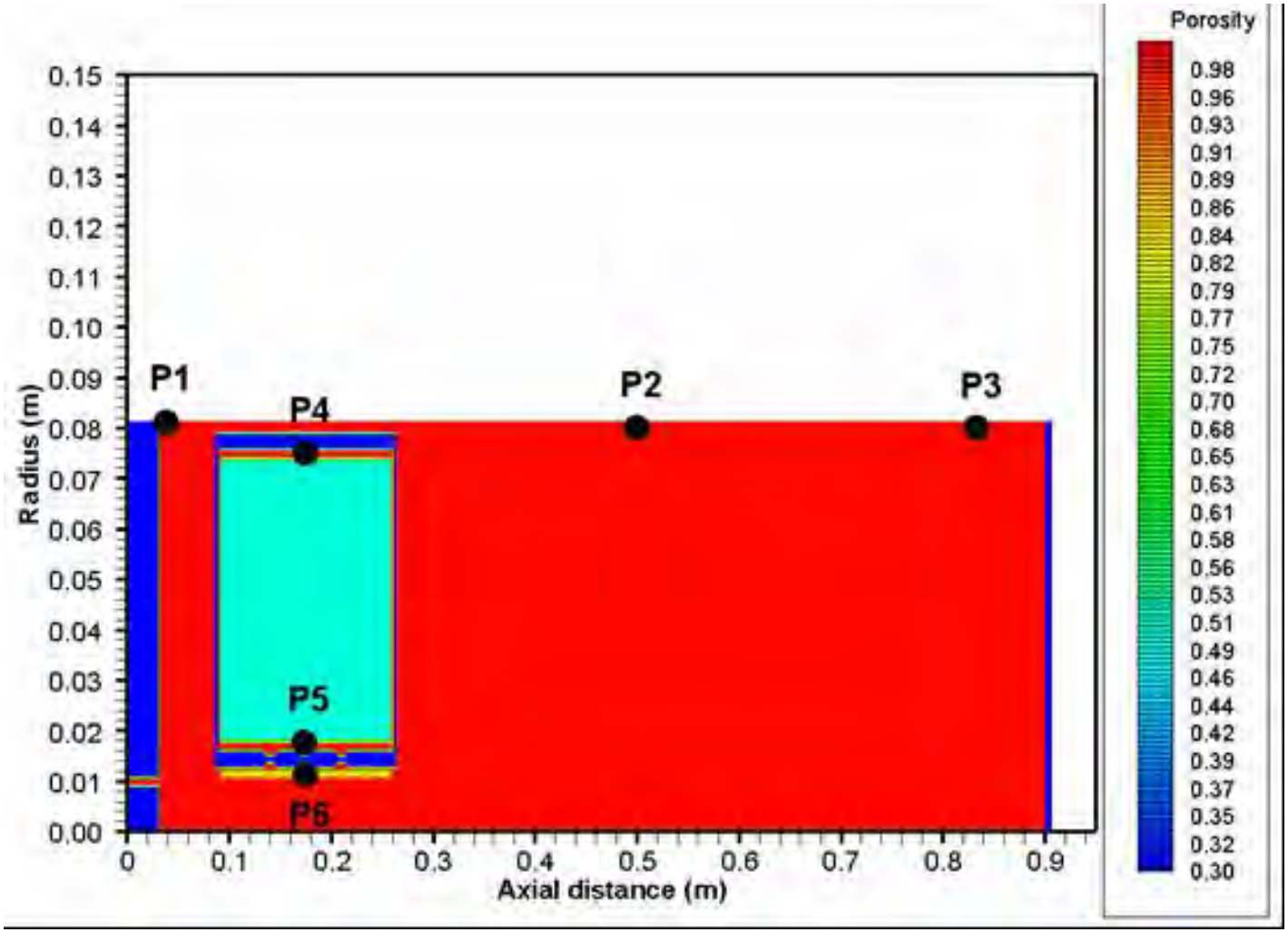






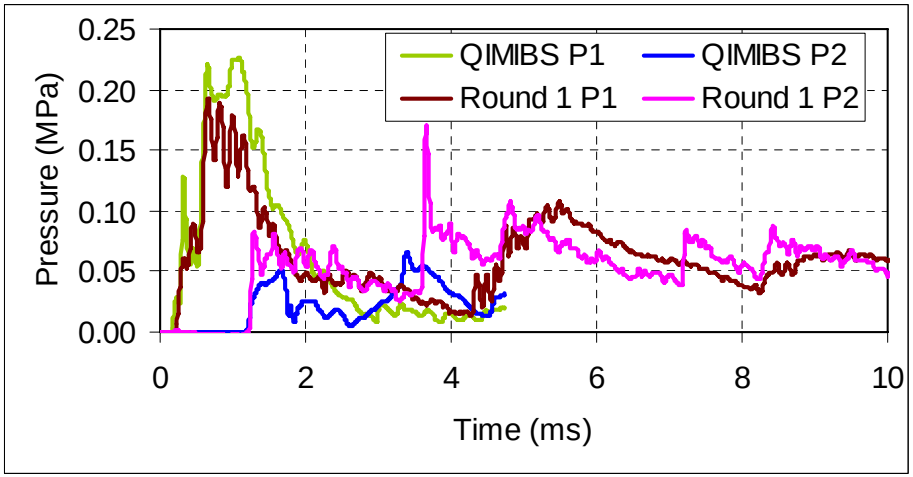
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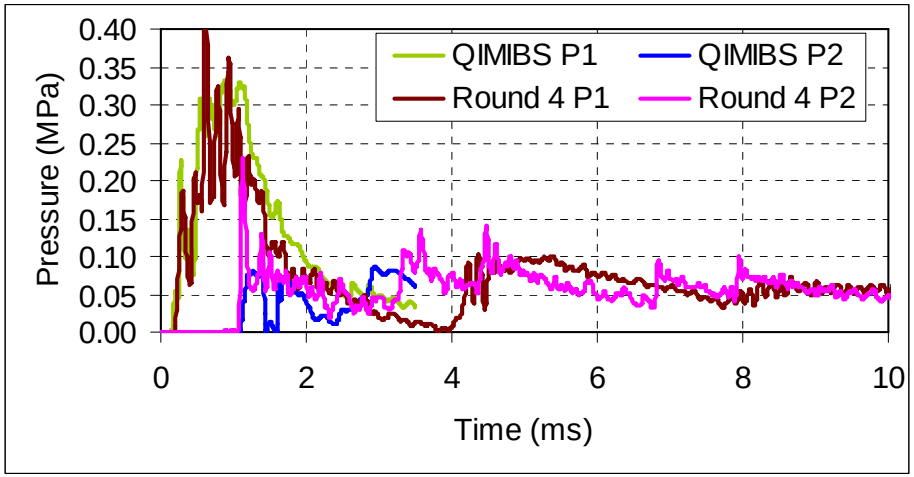
02 Primer only – single module – initial geometry



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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

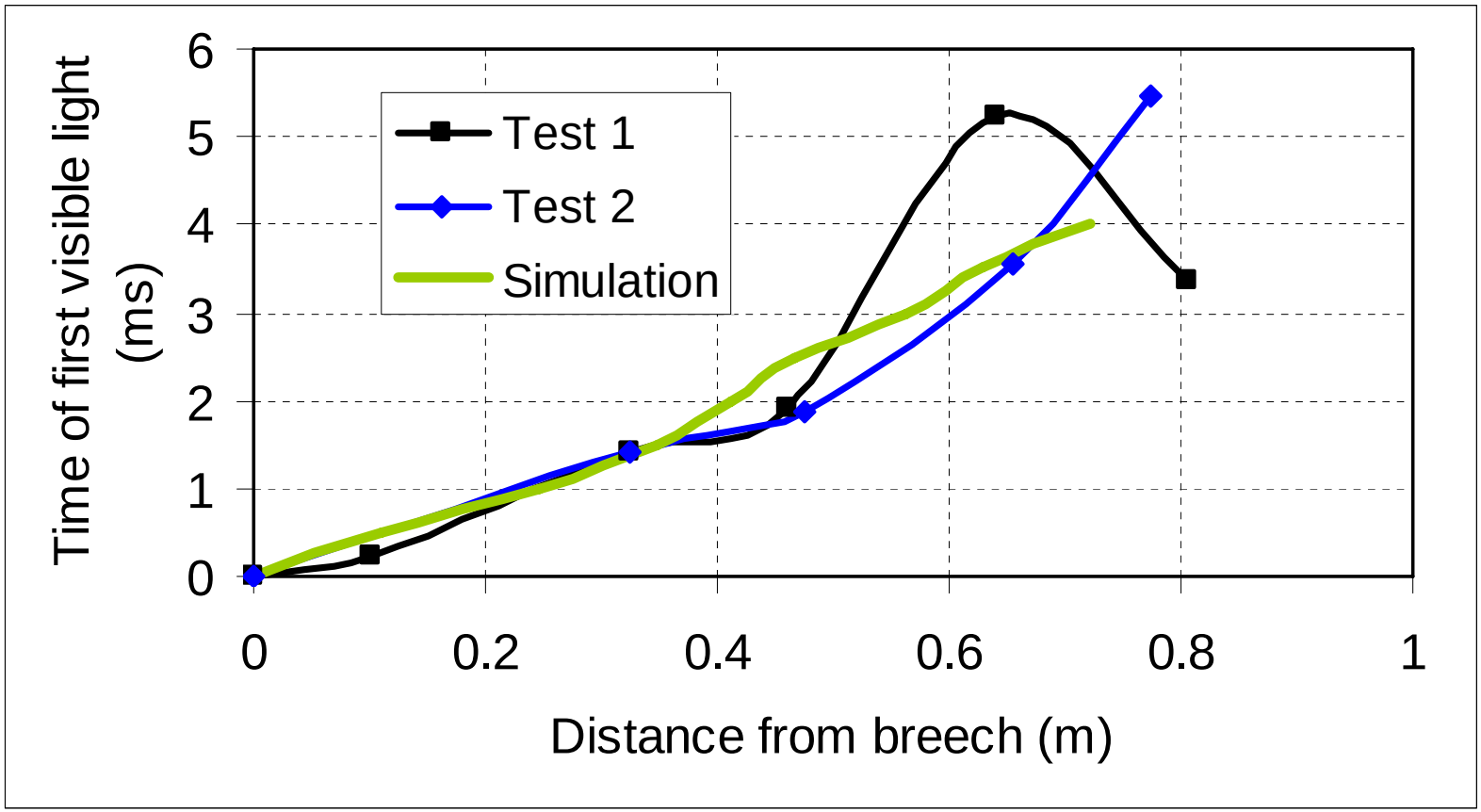
Max velocity predicted: 5.0m/s

Correct trend predicted for pressure and module velocity

Module velocities overpredicted but no account taken of sliding resistance

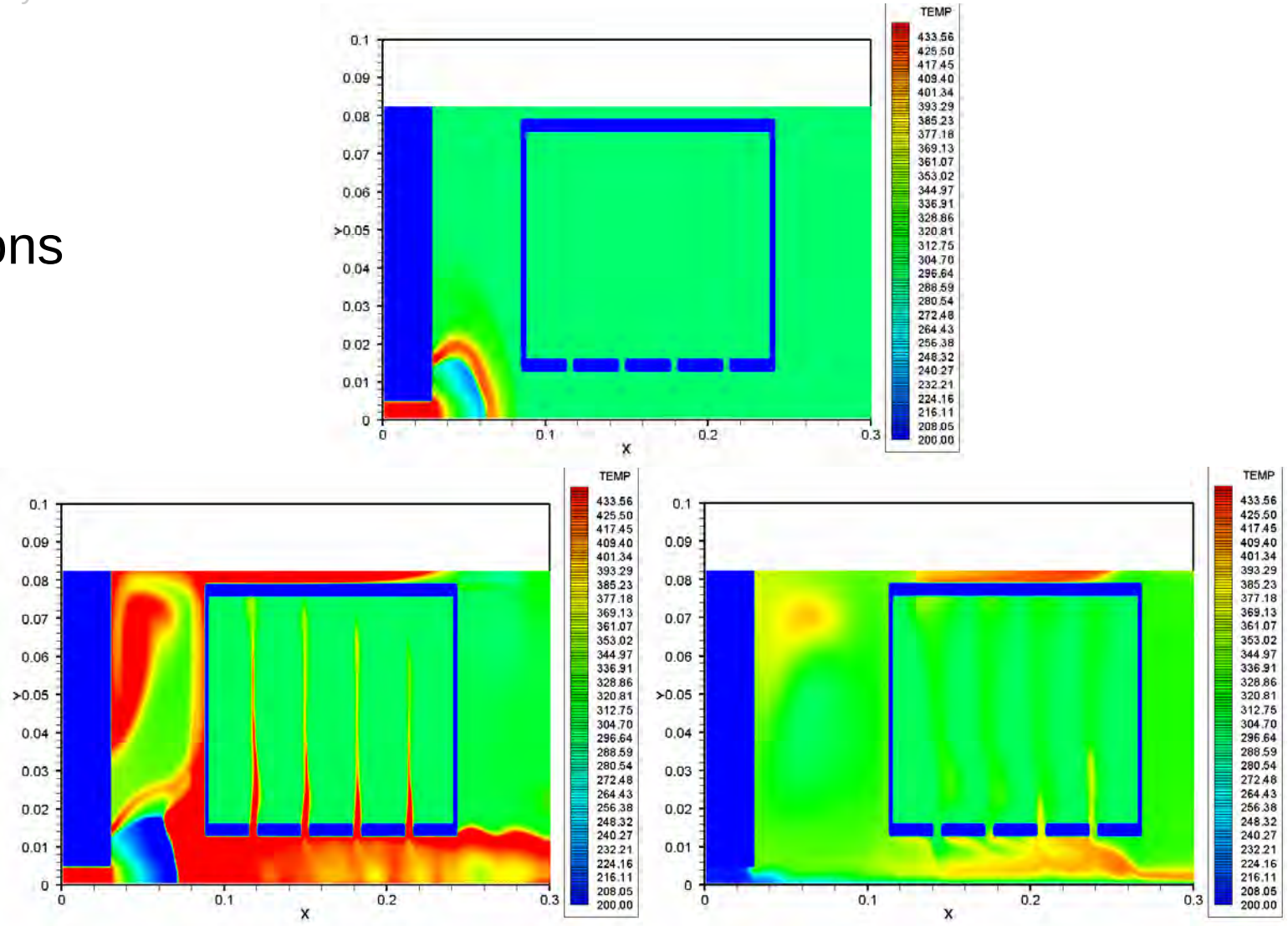
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02 5 modules - flamespread



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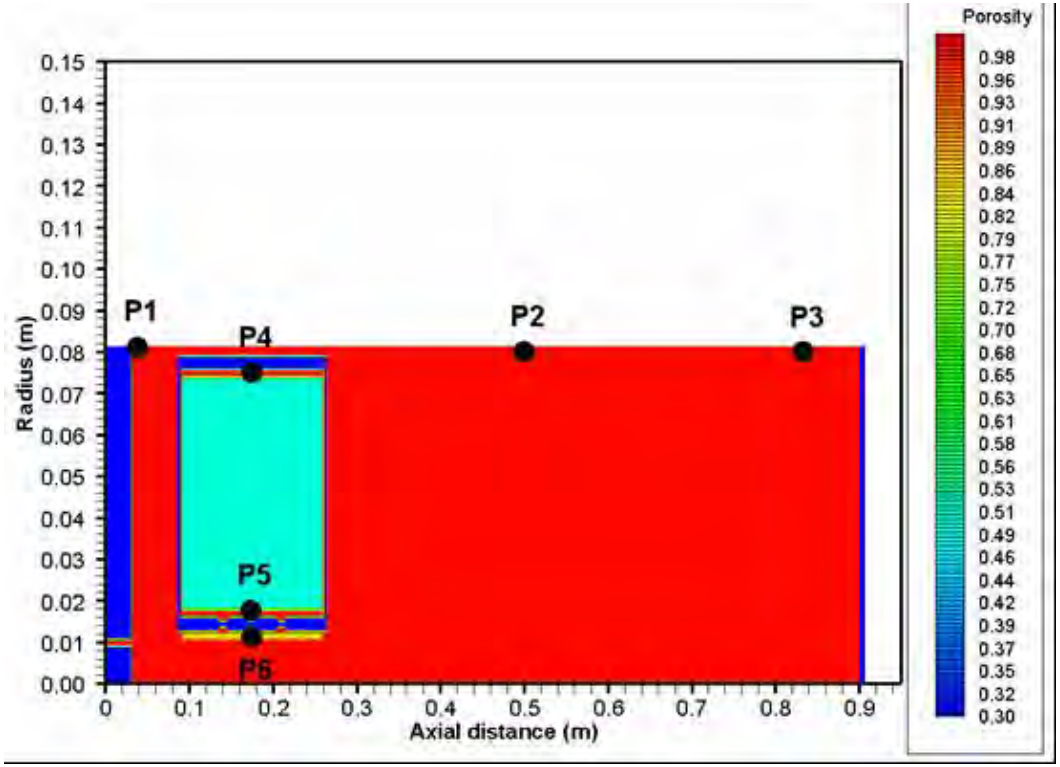
03
Simulations



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03 Simulations

- Single module
  - Igniter mass & location
  - Flash tube diameter & vent hole size

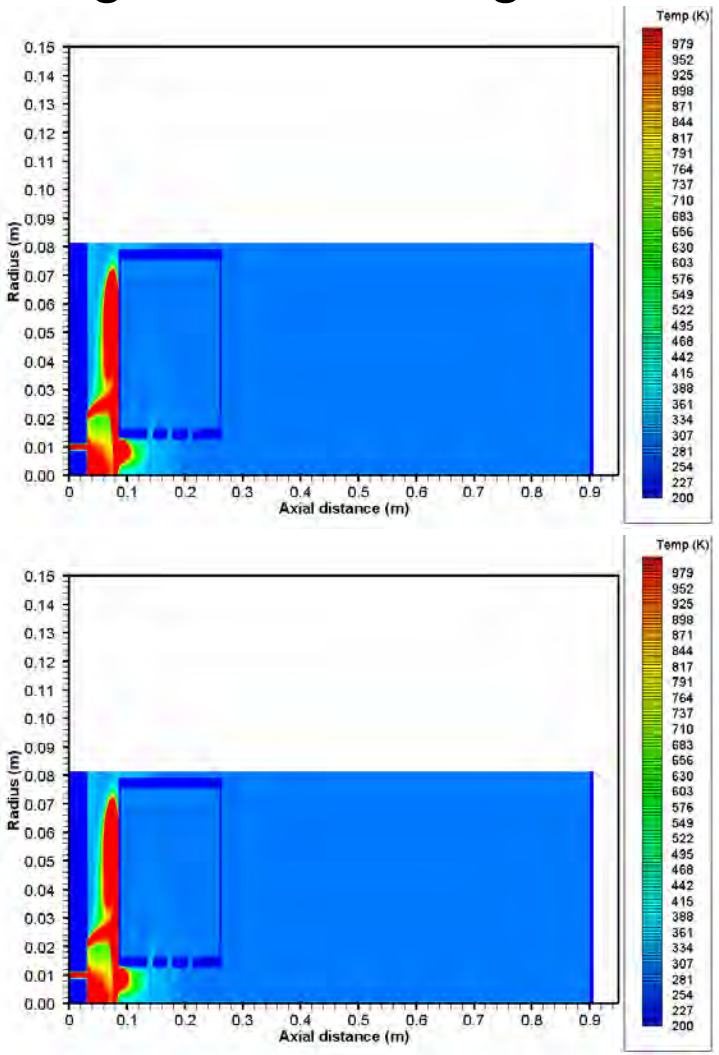


- Three modules
- Five modules

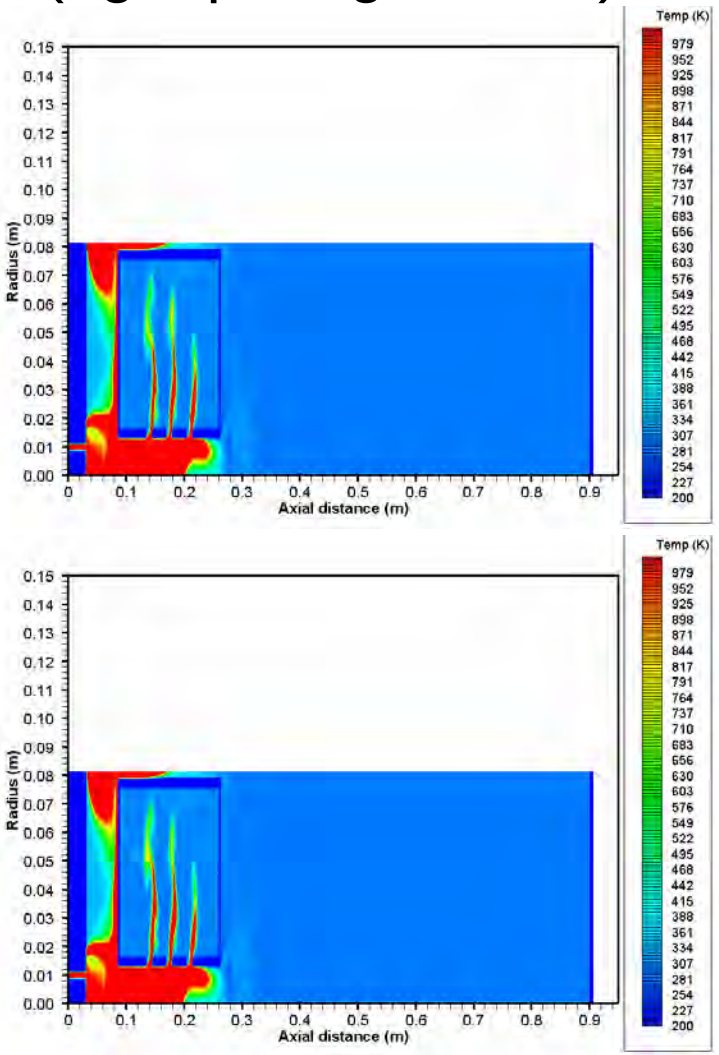
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03 Single module – igniter mass (5g top, 15g bottom)

0.5ms



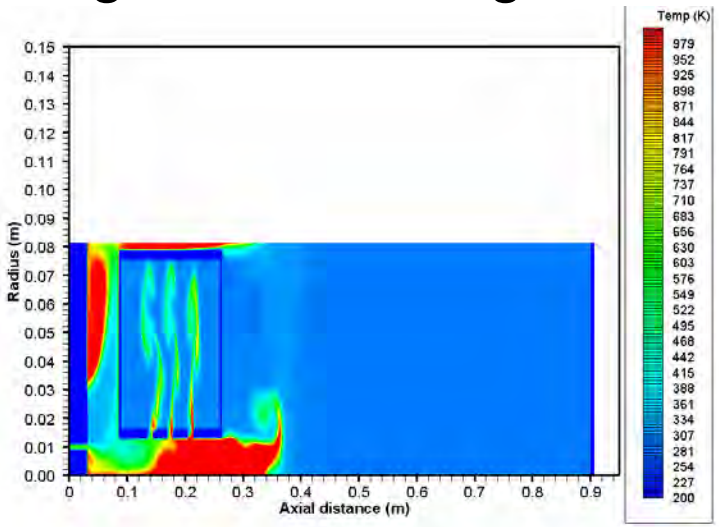
1.0ms

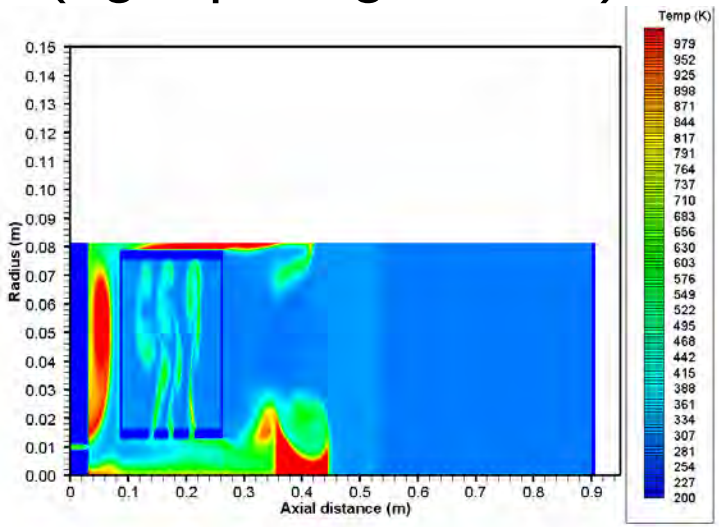


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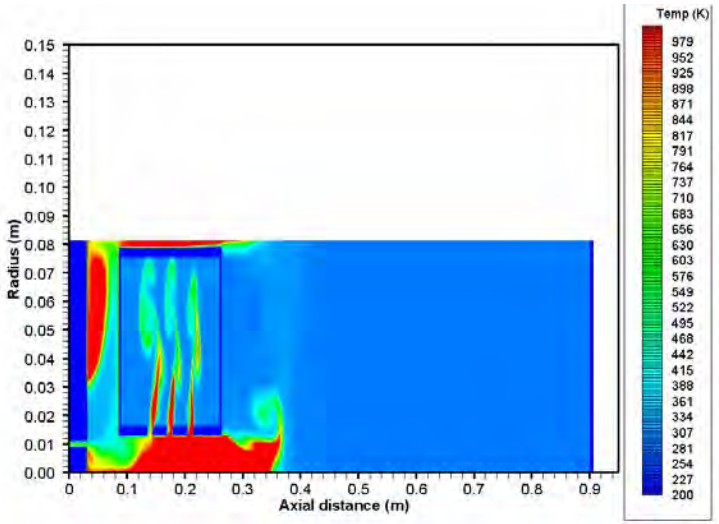
03 Single module – igniter mass (5g top, 15g bottom)

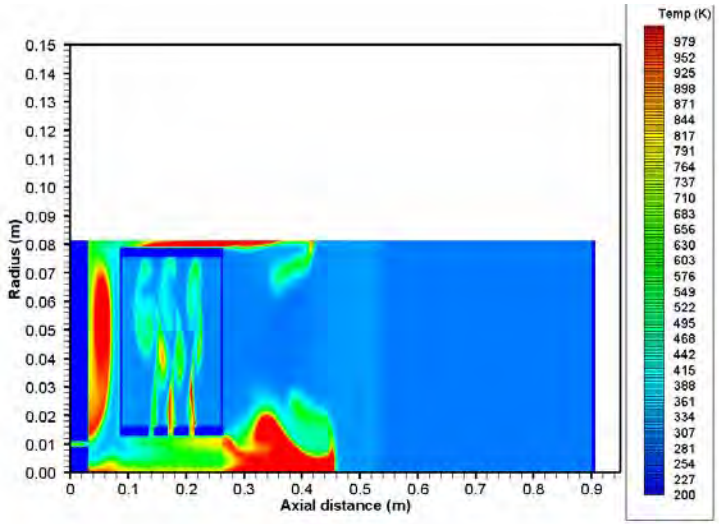
1.5ms





2.0ms

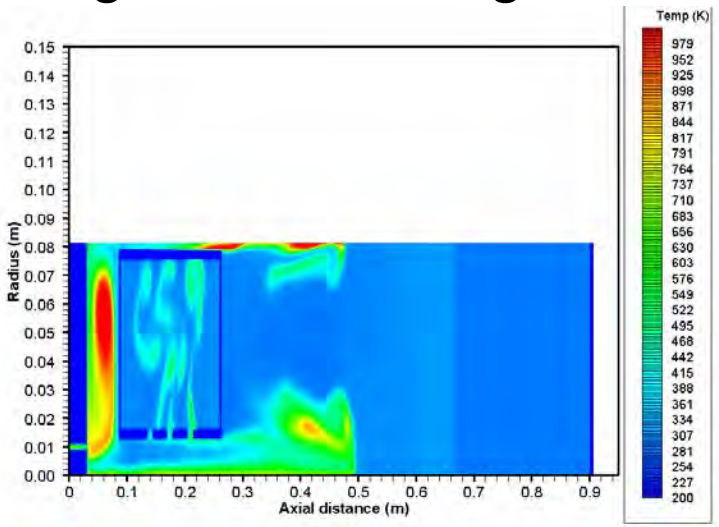


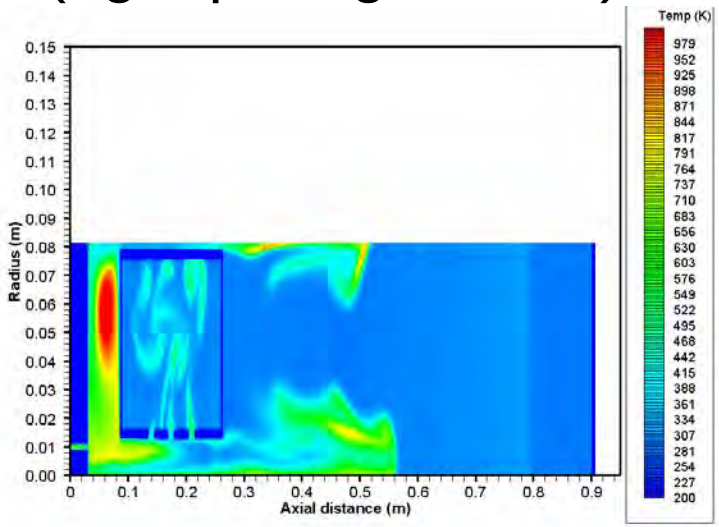


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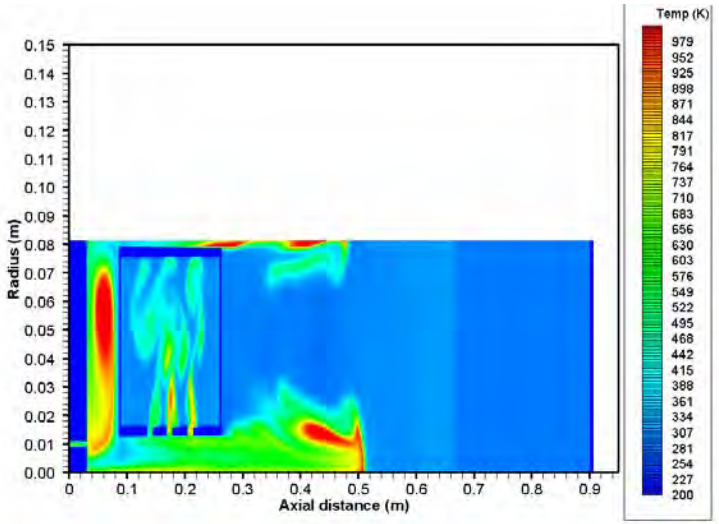
03 Single module – igniter mass (5g top, 15g bottom)

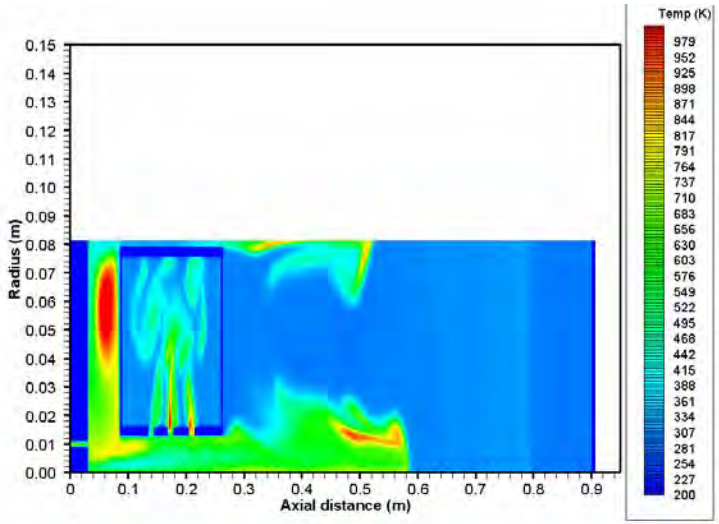
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3.0ms

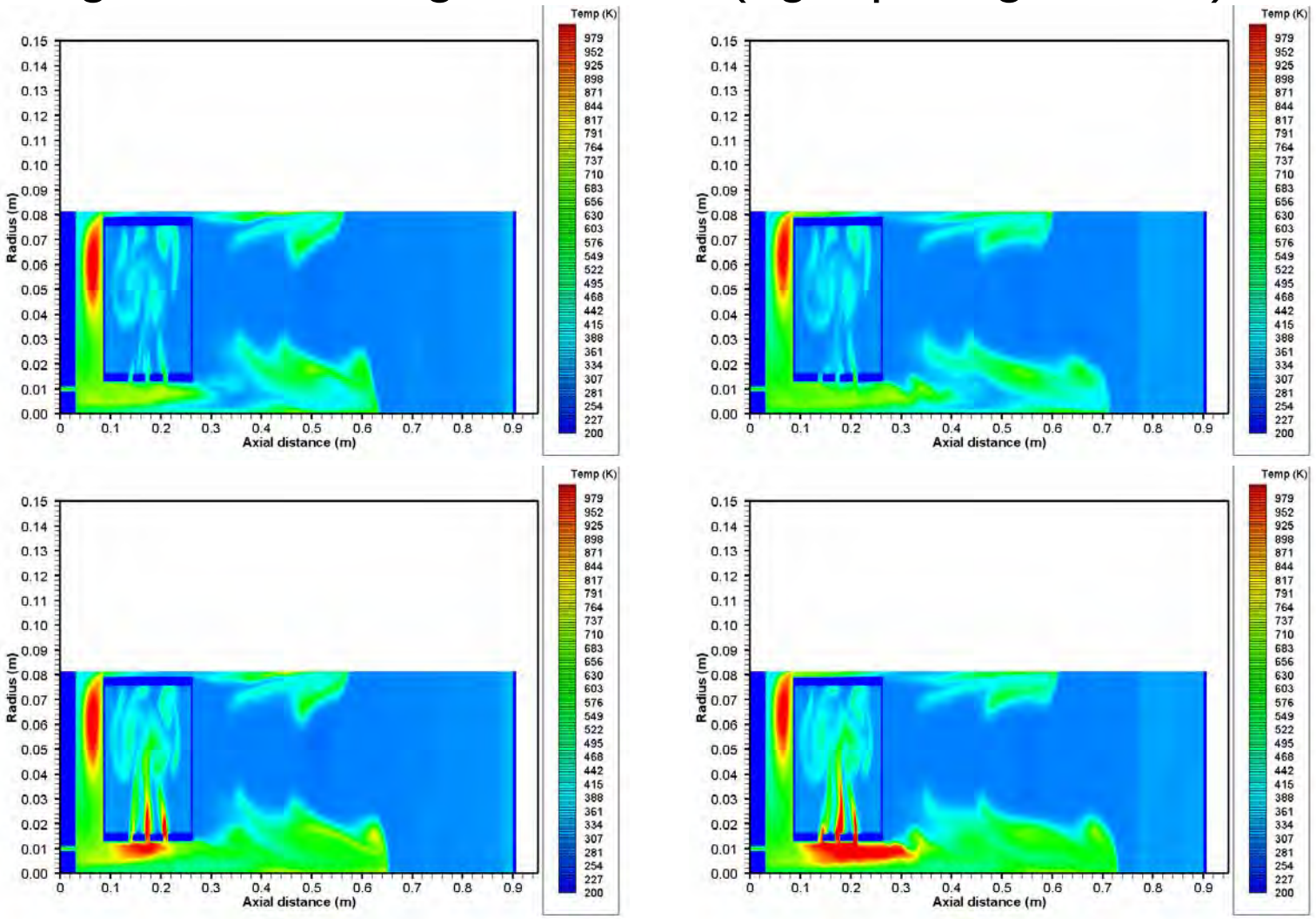




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03 Single module – igniter mass (5g top, 15g bottom)

3.5ms

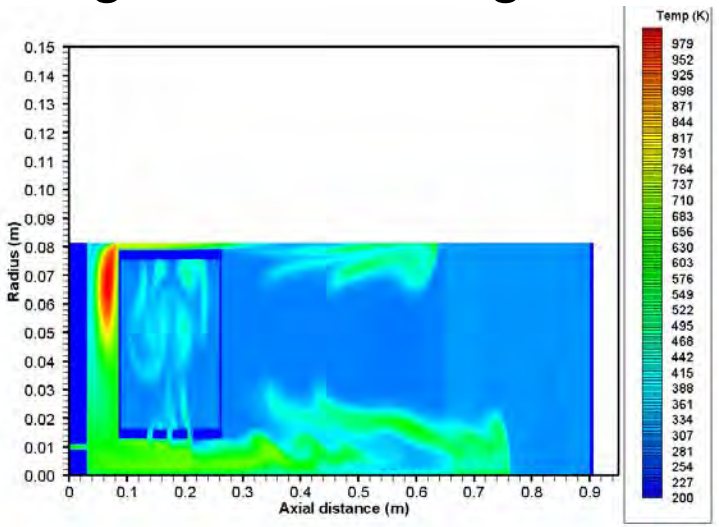


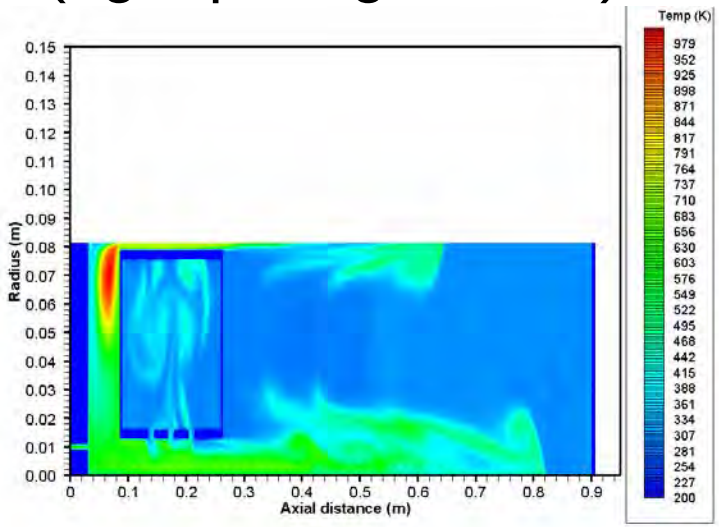
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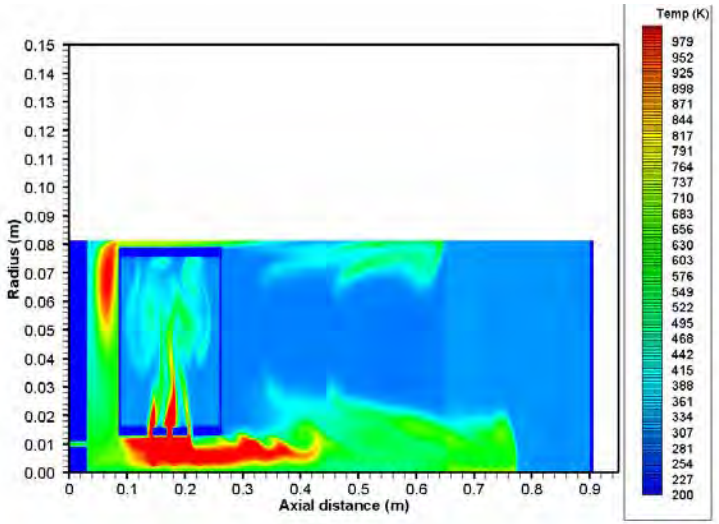
03 Single module – igniter mass (5g top, 15g bottom)

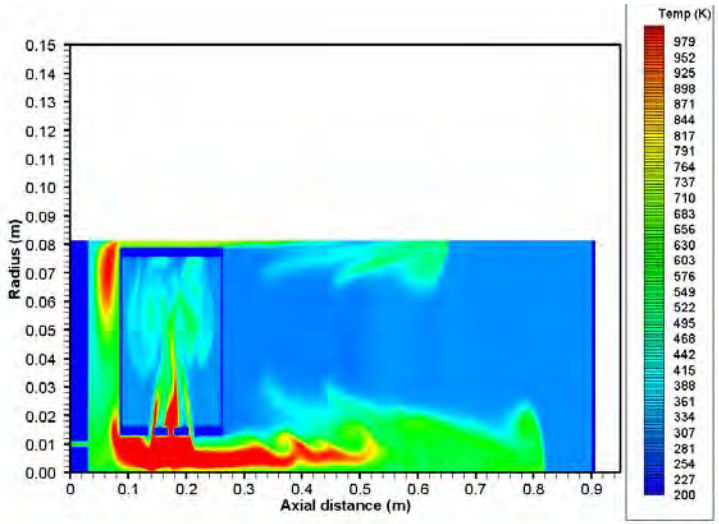
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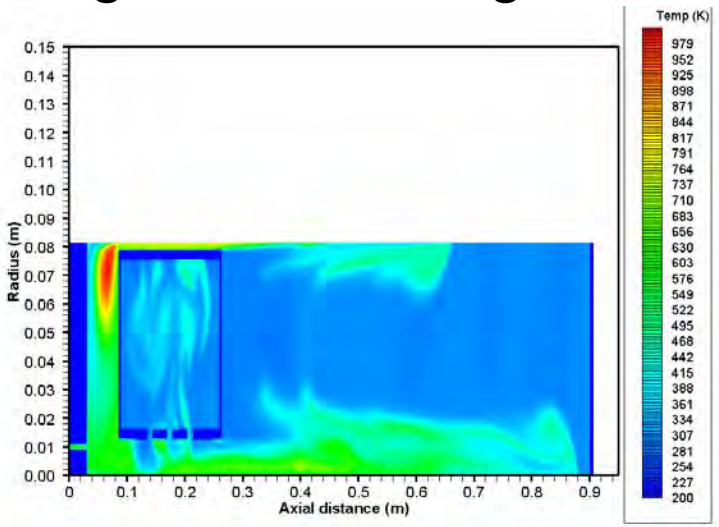


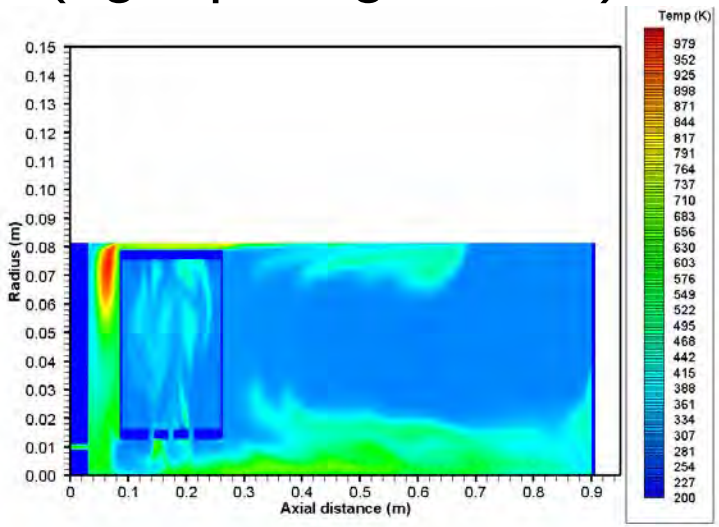


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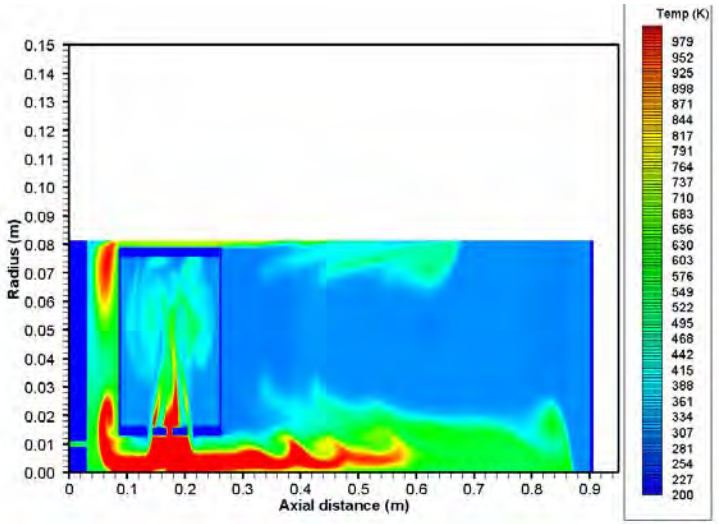
03 Single module – igniter mass (5g top, 15g bottom)

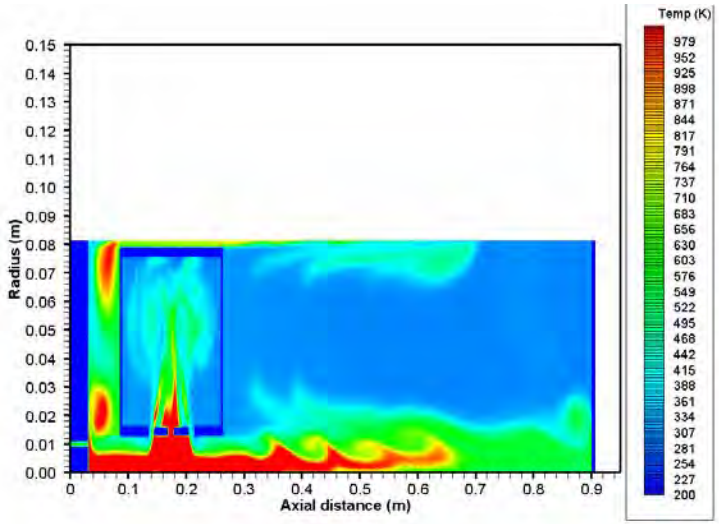
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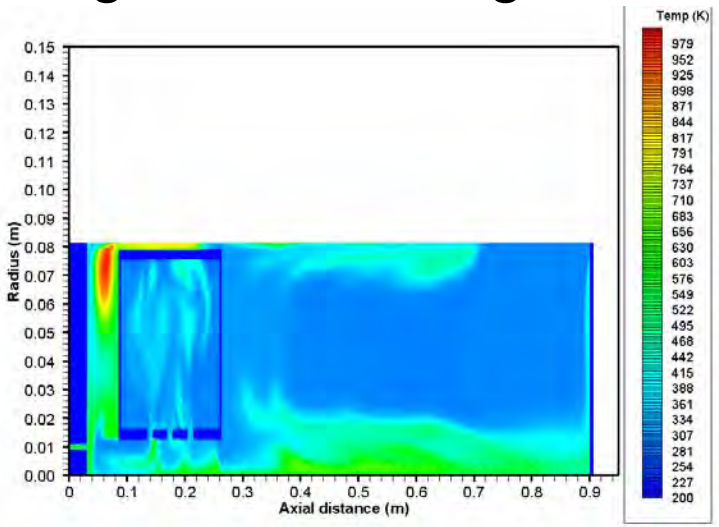


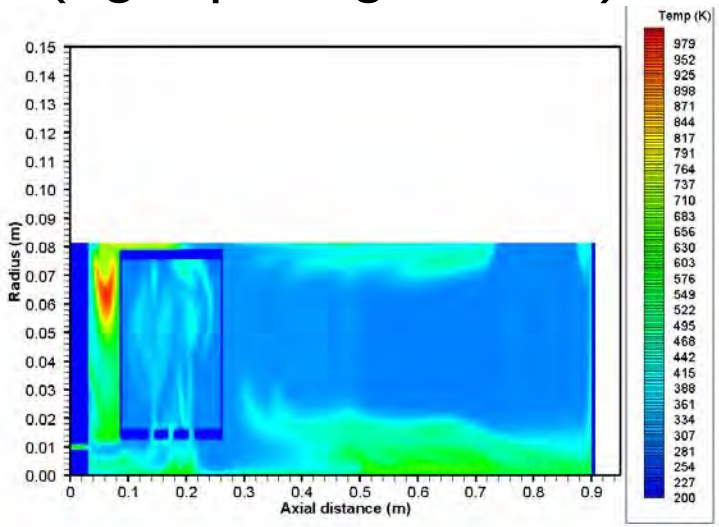


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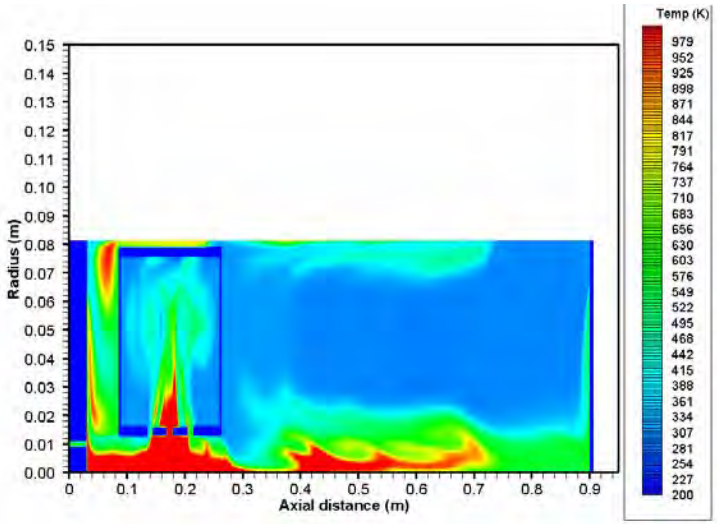
03 Single module – igniter mass (5g top, 15g bottom)

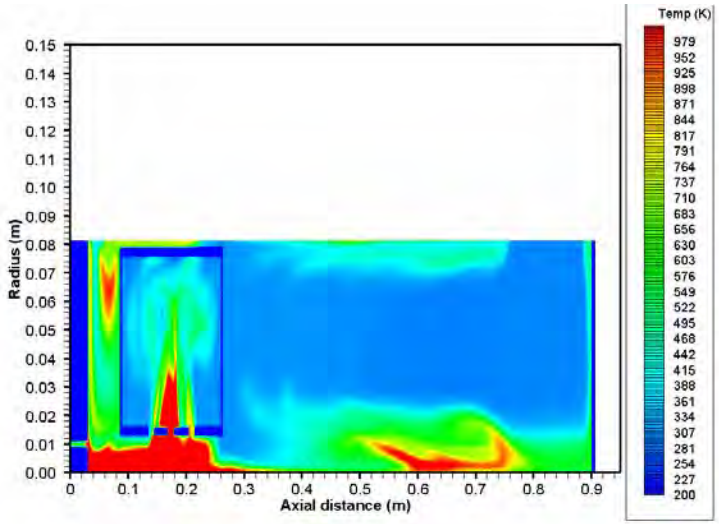
6.5ms





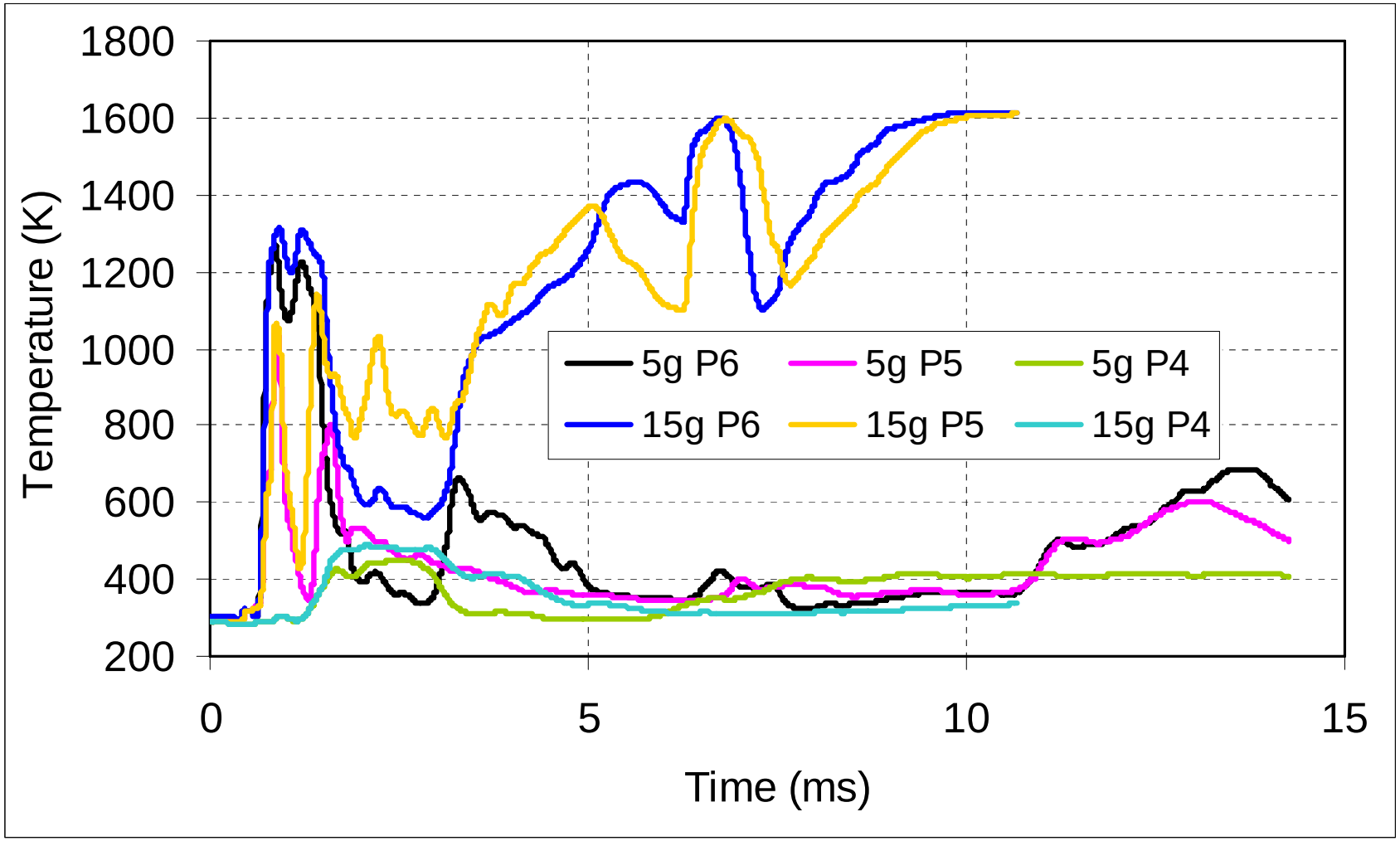
7.0ms





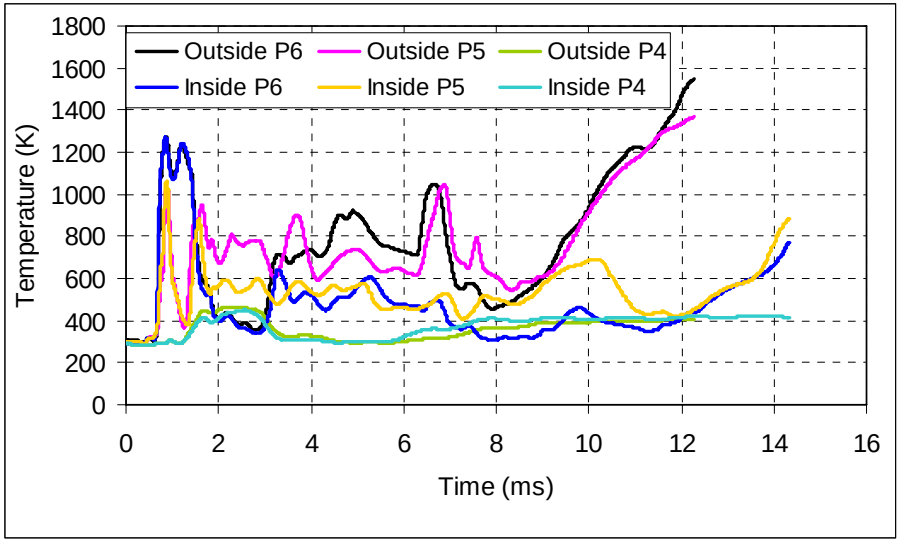
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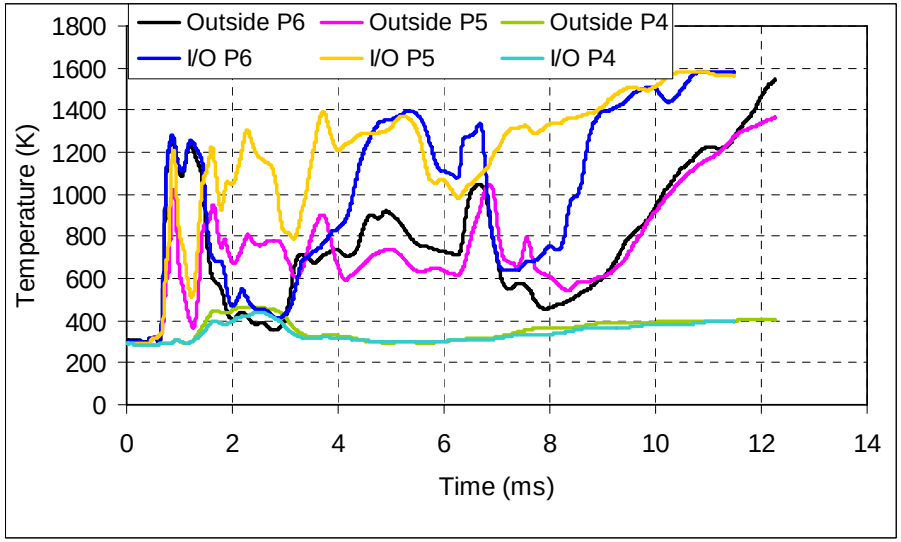
03 Single module – igniter mass



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03 Single module – effect of igniter position

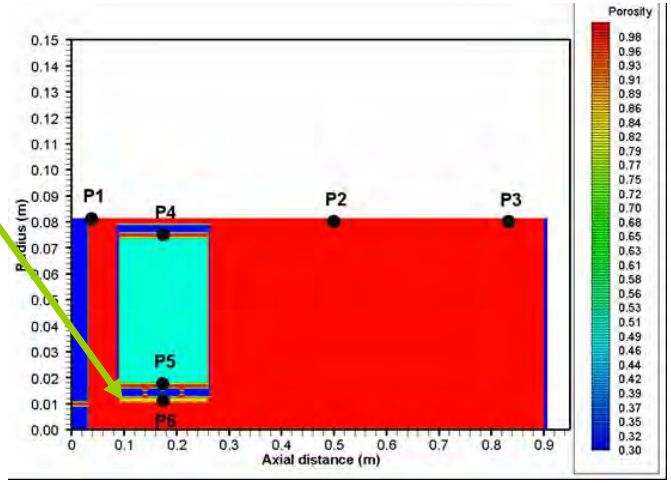




Outside = outside module but inside flash tube

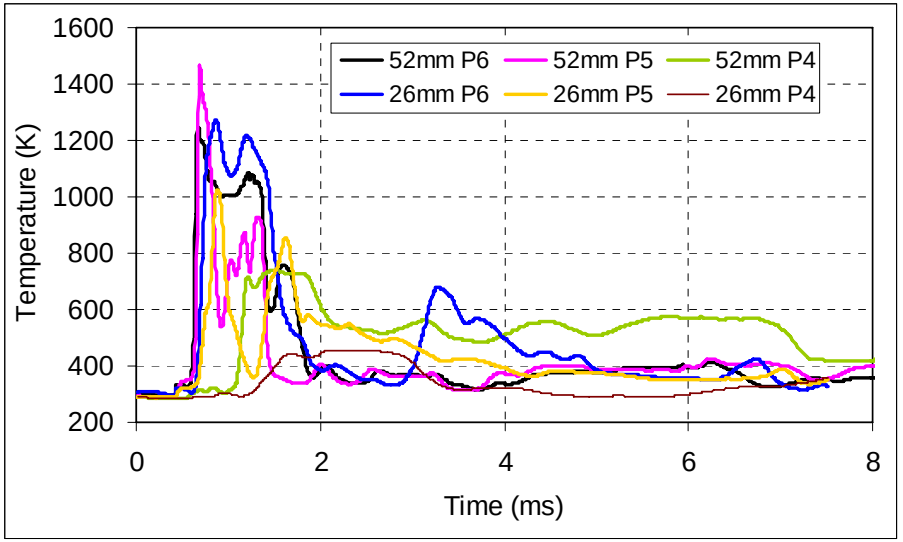
Inside = inside module but outside flash tube

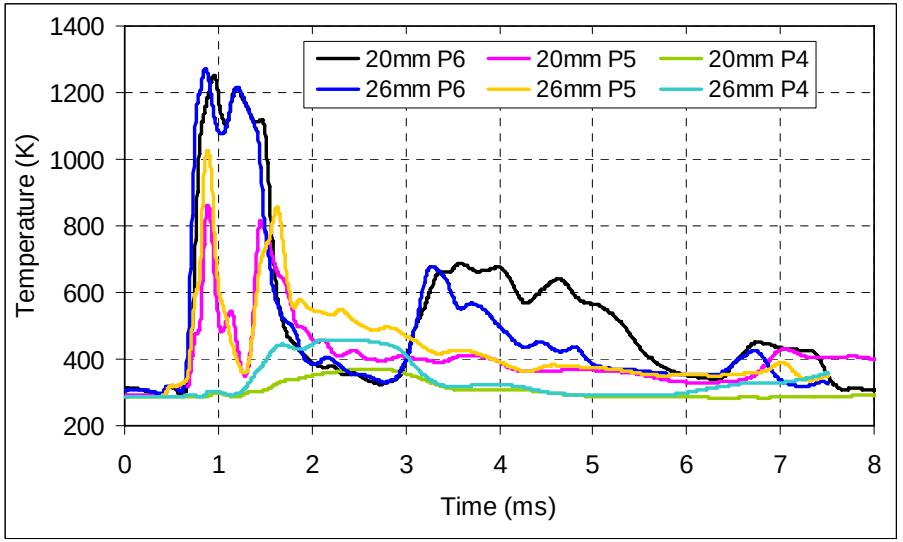
Modelling indicates better ignition if igniter material is both sides of the flash tube



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03 Single module – effect of flash tube diameter

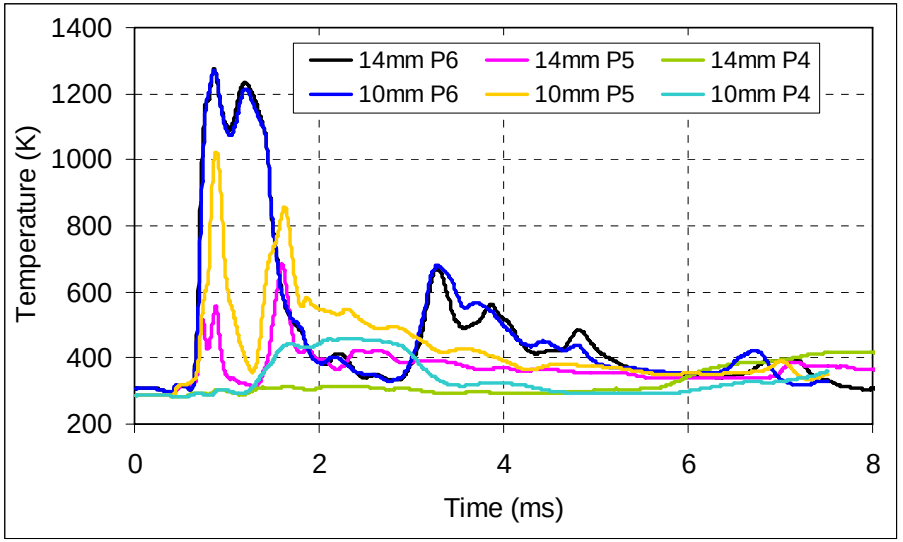


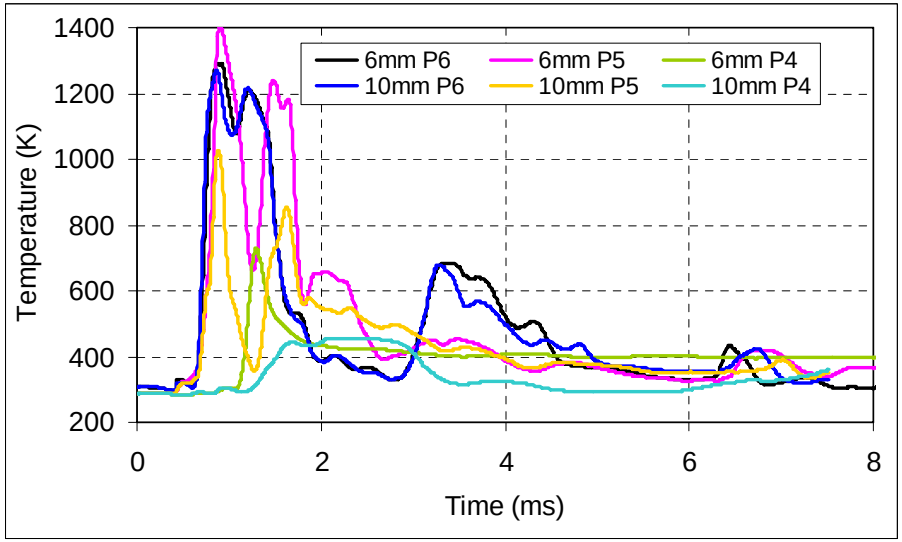


Modelling indicates better ignition for 26mm flash tube diameter

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03 Single module – effect of flash tube hole size

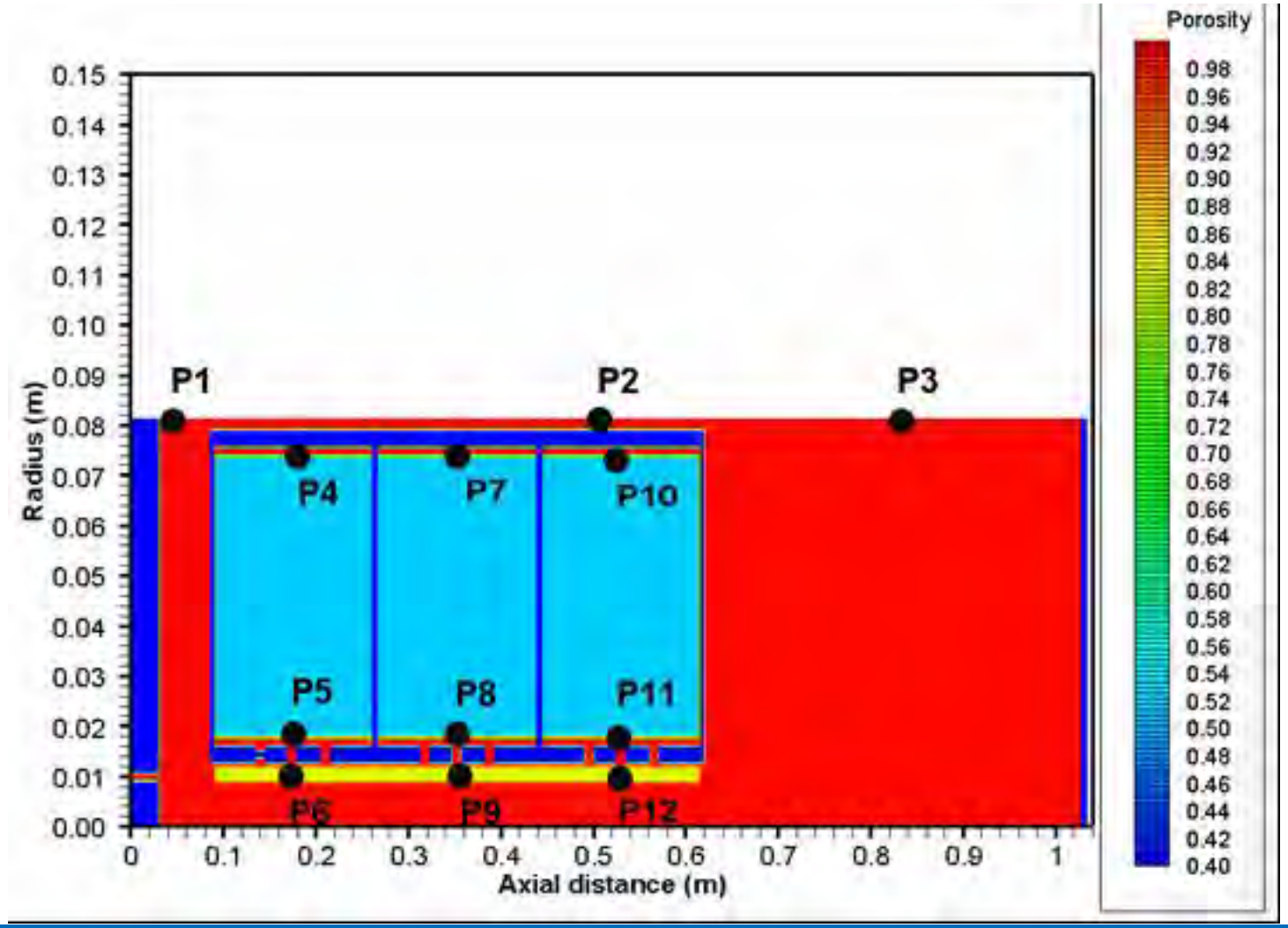




Modelling indicates better ignition for 6mm flash tube holes

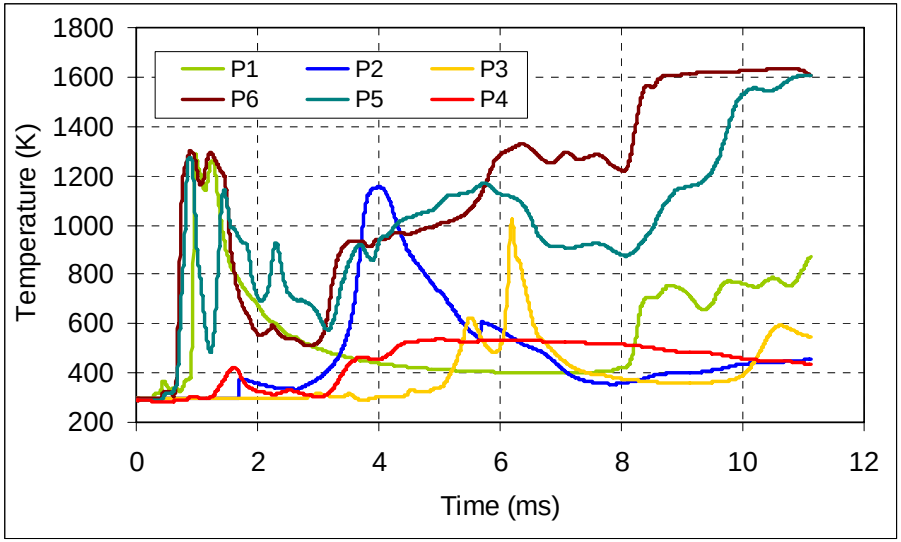
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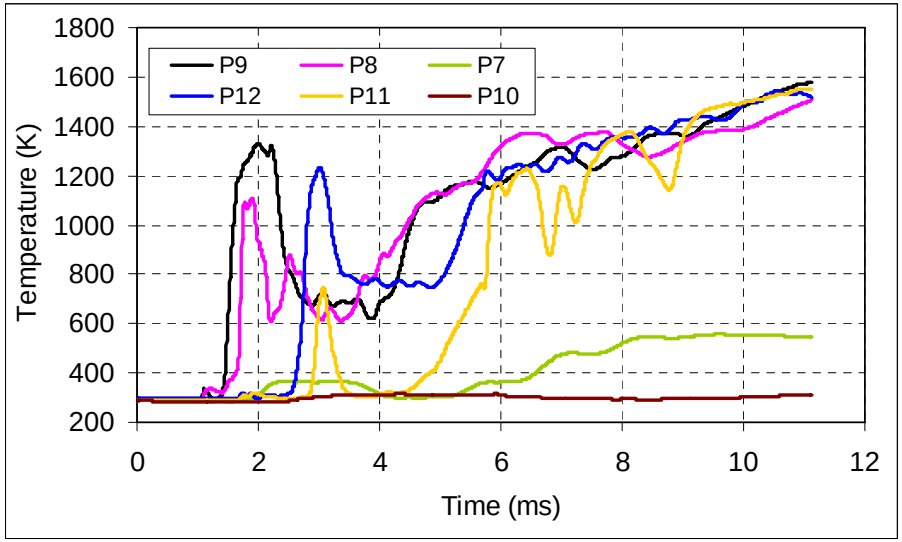
03 Three modules – initial geometry



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03 Three modules – 10g black powder per module



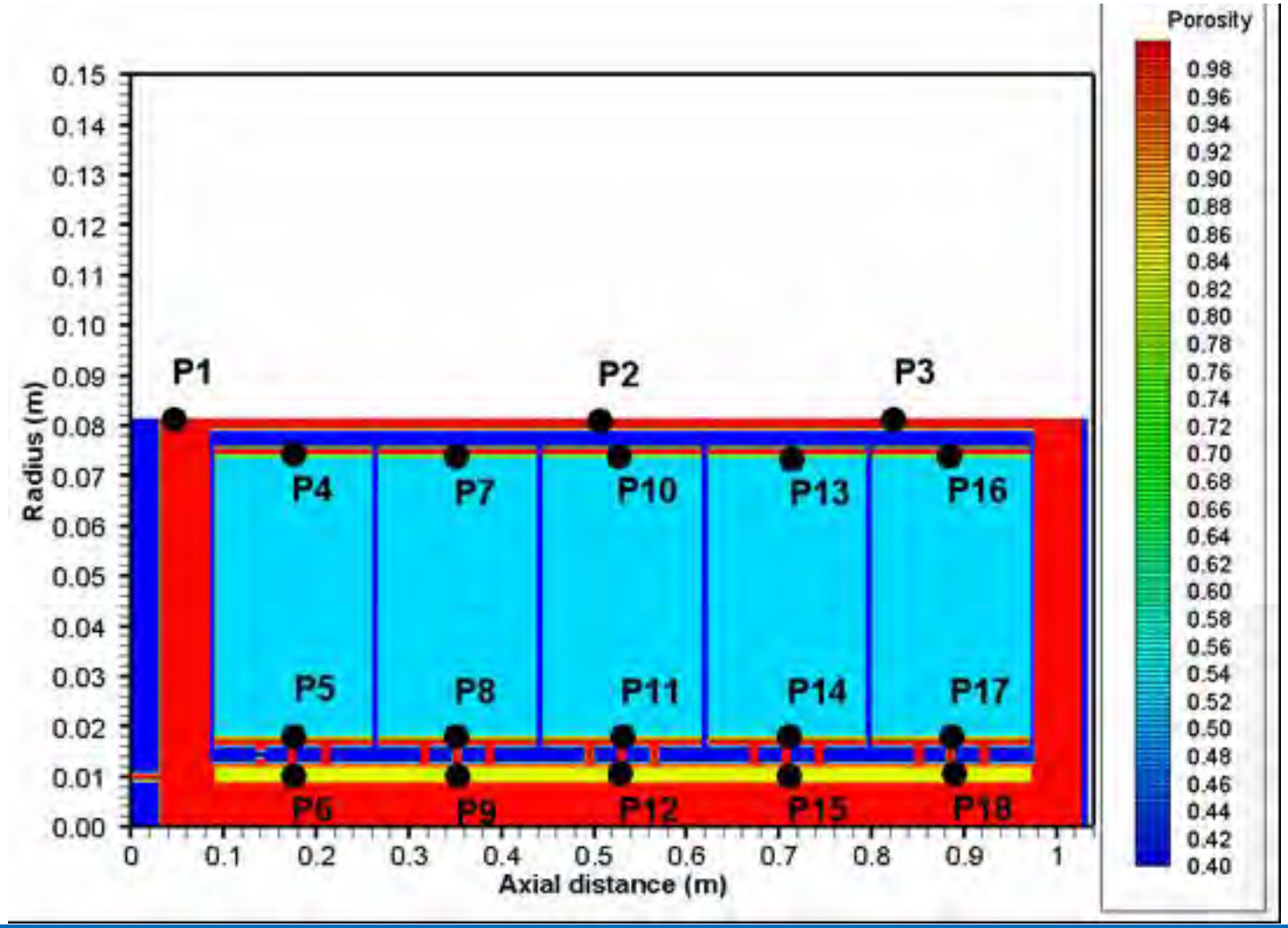


Taking 600K as the propellant ignition temperature, propellant in 2nd & 3rd modules ignited 0.8ms & 1.7ms after the 1st module

Use another internal ballistics code to predict pressure waves

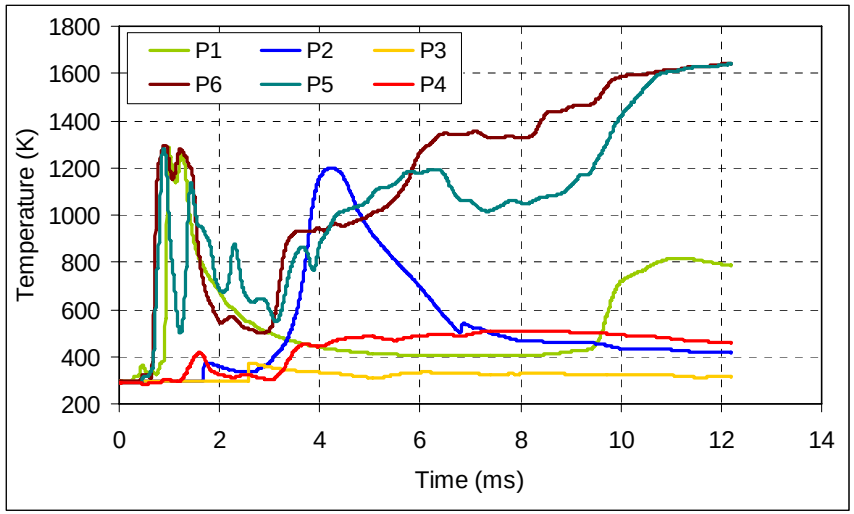
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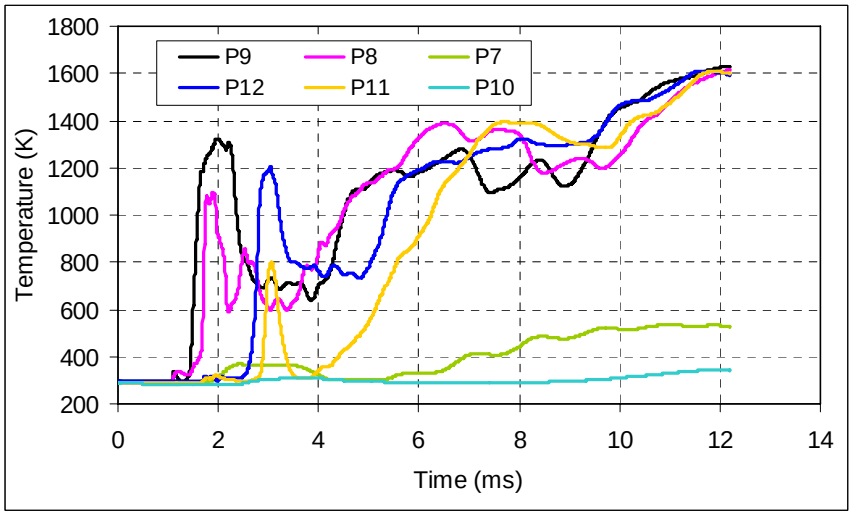
03 Five modules – initial geometry

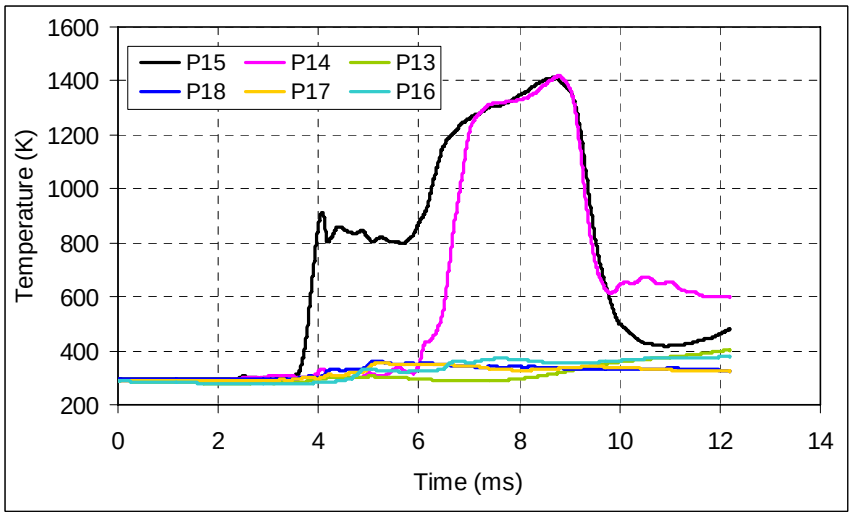


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03 Five – 10g black powder per module







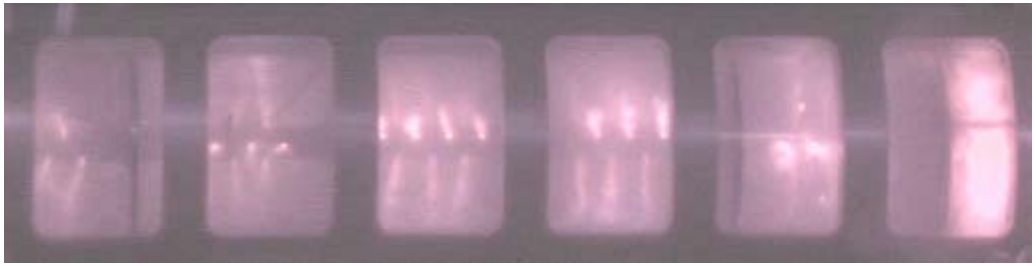
Igniter in last module not ignited

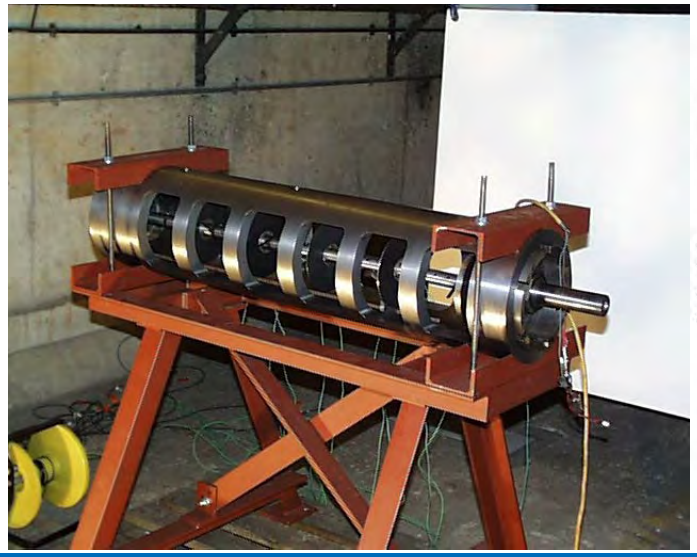
Module 2 might ignite first

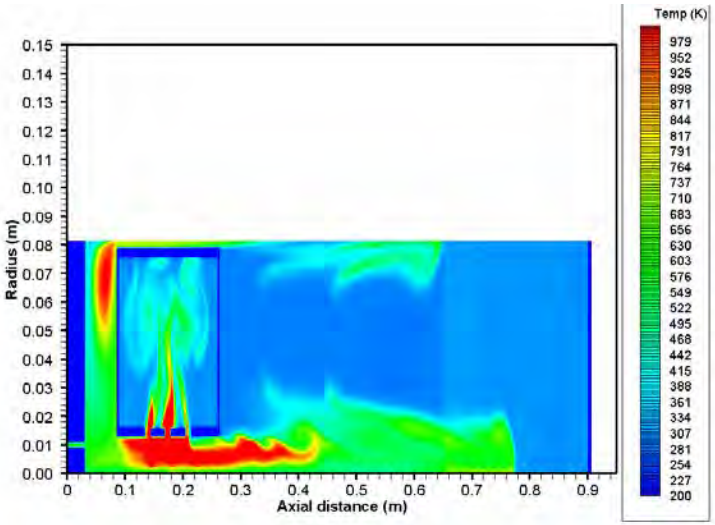
Taking 600K as the propellant ignition temperature, propellant in 2nd , 3rd & 4th modules ignited 1ms, 2ms & 5ms after the 1st module – use another internal ballistics code for ΔP

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04
Conclusions & future work







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04 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 (5^{th}) module adjacent to the projectile
  - Module 2 might ignite before module 1
  - Possibility of significant ignition delay for 4^{th} module
- 155mm gun firings planned & further modelling
- **Conclusions likely to be very dependent on primers and geometries used in this study**

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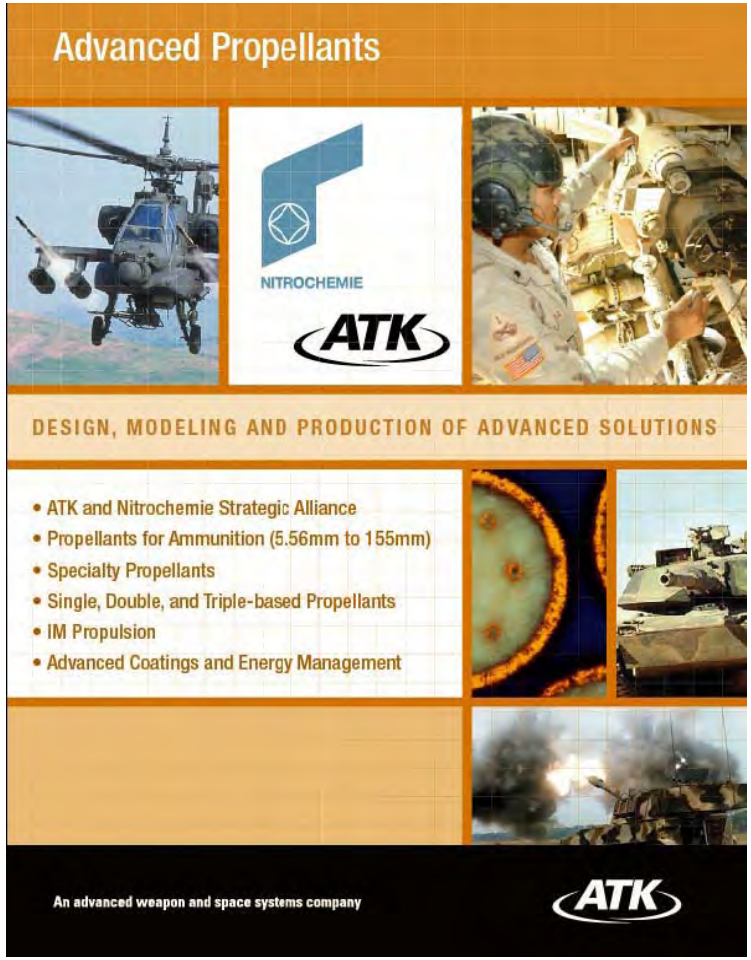
ECL® – A New Propellant Family for Small and Medium Caliber Applications

42nd Gun and Missile Conference

April 23 – 26, 2007

Charlotte, North Carolina

B. Vogelsanger, Nitrochemie
W.J. Worrell, ATK Radford
Jim Wedwick, ATK Radford



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Shock Aspects of Lightweight Artillery on Mounting Electronics

William T. Zepp

42nd Annual Armaments Systems Conference
26 April 2007

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

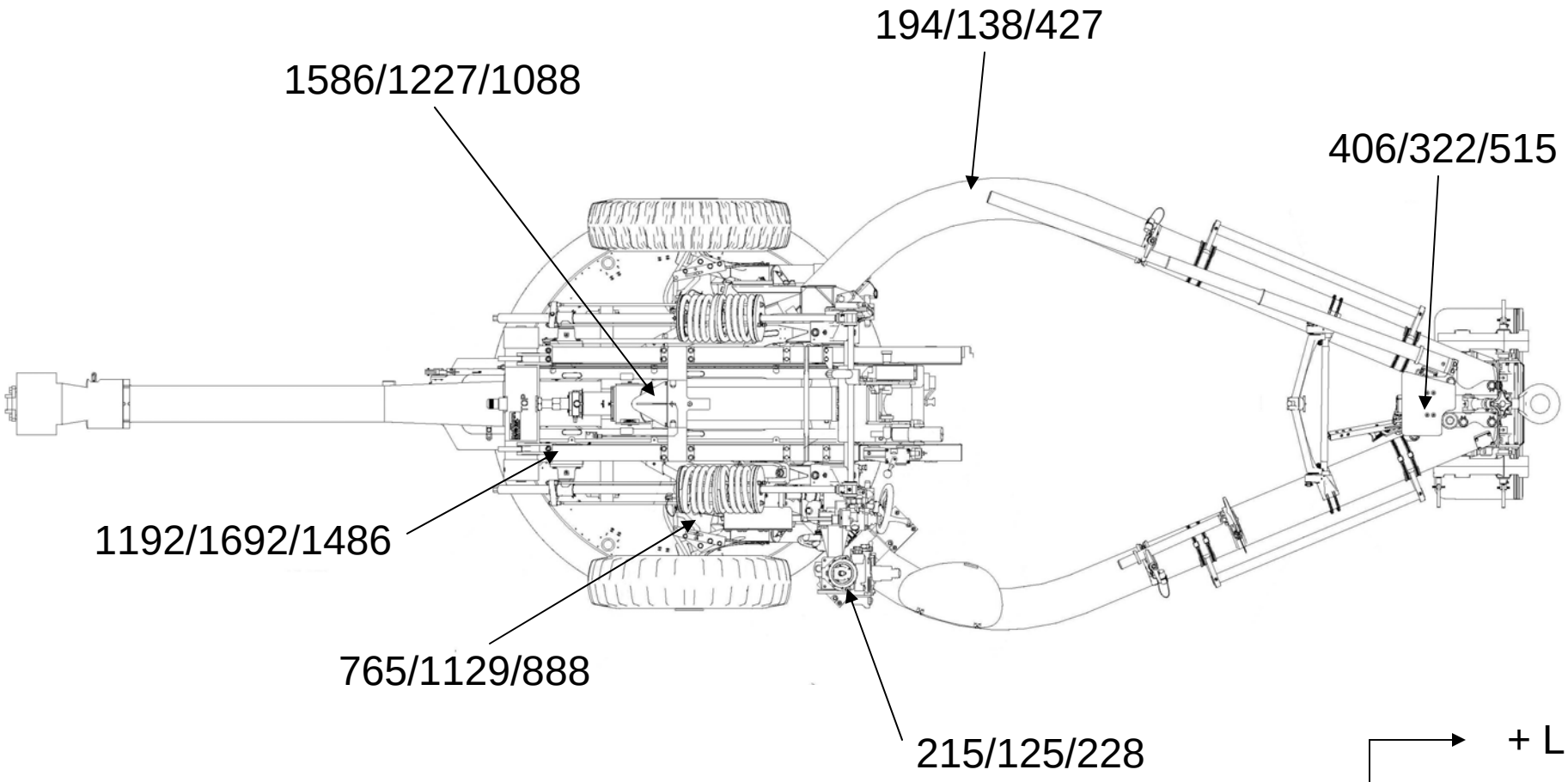


800 mils



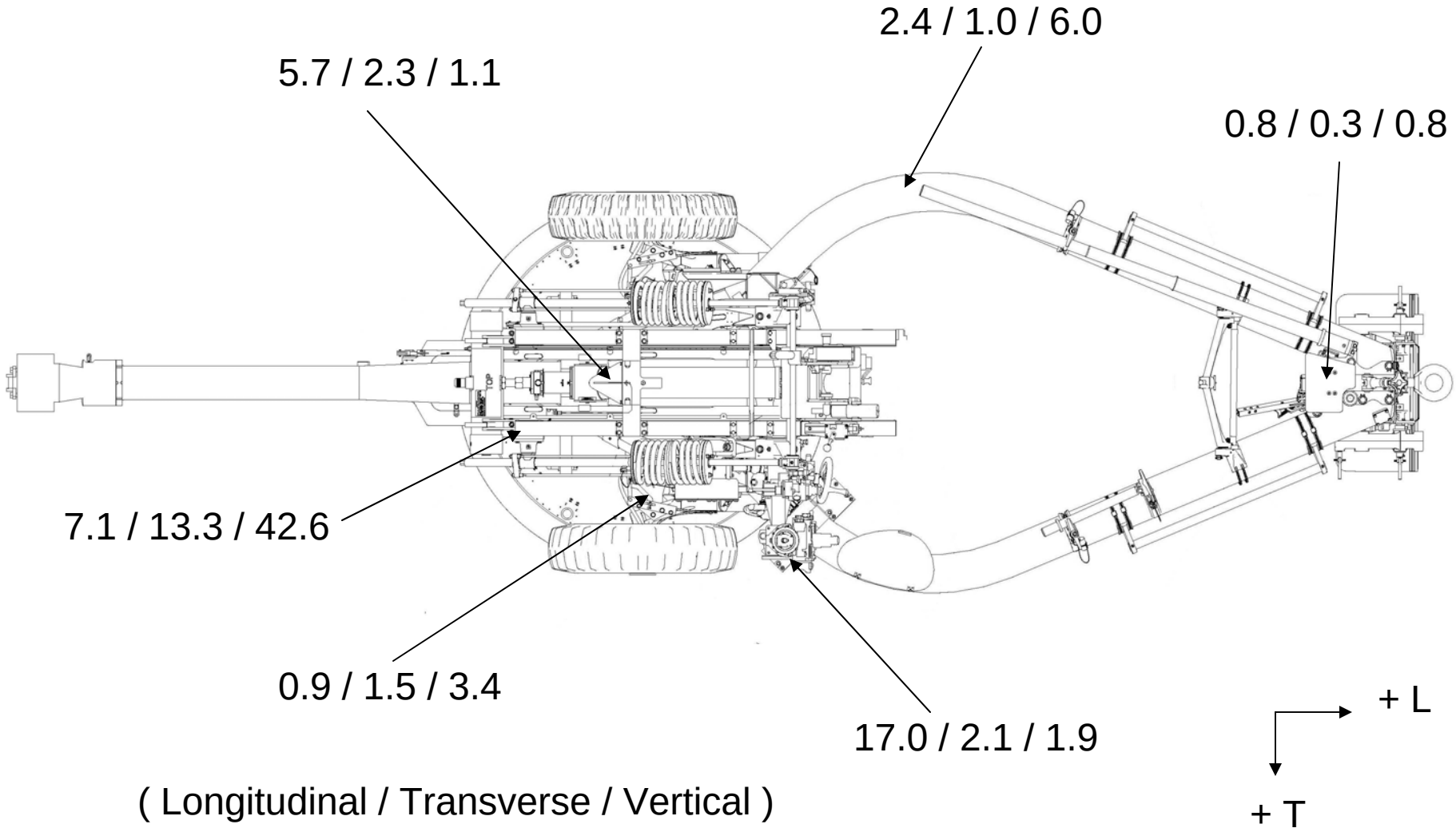
1244 mils

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

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