43RD ANNUAL ARMAMENT SYSTEMS: GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

"Strengthening Capability through People and Technology"

APRIL 21-24, 2008

NEW ORLEANS, LA

Agenda

TUESDAY, APRIL 22, 2008

ARMAMENT DIVISION OVERVIEW

- Mr. Dave Broden, Chair, NDIA Armament Division; Bron Resource Solutions, LLc

REQUIREMENTS & TRENDS
Session Chair: Mr. Jim Ripley, U.S. Marine Corps

- 6372—Safety Qualification Process for Navy Gun and Ammuniton Systems, Ms. Eileen McConkie, Naval Surface Warfare Center, Dahlgren
- 6435—Preserving Critical Knowledge, Mr. Roy Weber, VSE Corporation
- 6526—Firing US 120MM Tank Ammunition in the Leopard 2 Main Battle Tank, Mr. Harlan Huls, ATK Advanced Weapons Division

Breakout 1- Direct Fire

DIRECT FIRE
Session Chair: Mr. Don Guziewicz, U. S. Army ARDEC

- 6491—Development of Light-weight 25MM (LW25) Family of Ammunition, Mr. Lee Olson, ATK Medium Caliber Systems
- S40MM X 180MM Common Case Design Progess, Mr. Zachary Kemp, General Dynamics-OTS
- 6351—Performance Assessment of the M1028, 120MM APERS Tank Round, Mr. Brian Levine, U.S. Army Armament Research
- 6338—Ammunition for the MBT's Changing Role on the Modern Battlefield, Mr. Jacob Moav, Israel Military Industries
- 6337—30MM PGU-13 HEI Cartridge Improvements, Mr. Kirk Gimmy, General Dynamics-OTS
- 6360—30MM Air Bursting Munitions for the MK44 Cannon, Mr. Erik Elmer, ATK
- 6392—GD-OTS 20MM X 102MM Mechanically Fuzed Projectile Program, Mr. Zachary Kemp, General Dynamics-OTS
- 6489—LW30 (30 X 113) Spotter Prototype Modeling and Simulation, Mr. Jim Roth, ATK Medium Caliber Systems

Energetics

- 6533—Accelerated Burning of Gun Propellants by Effect of Gasdynamic Oscillations within the Perforations of Propellant Grains, Mr. Gert Pauly, WTD 91, Germany
- Common Low-cost Insensitive Munitions Explosive Program to Replace TNT and Comp B, Mr. Anthony Di Stasio, U.S. Army ARDEC
- 341—Insensitive Munitions: A review of the State of the Art, Mr. Bernie Halls, MSIAC, NATO HQ, Belgium

Breakout 2

Effectiveness, Modeling, and Simulation
Session Chair:
Mr. Jeff Siewert, Arrow Tech Associates, Inc

- 6425—System Modeling for Projectile Design and Optimization, Mr. Philip Brislin, U.S. Army ARDEC
- 6519—Development and Fielding of Excalibur Warhead, Mr. Tim Sellers, General Dynamics-OTS
- Evaluation of Fragmentingm Warheads, Mr. Jason Angel, U.S. Army Research Laboratory, WMRD
- 6517—Development of the NLOS-LS PAM Warhead, Mr. David Hunter, General Dynamics- OTS
- 6440—Lean System Simulation of Guided Projectiles in the Early Development Stage, Mr. Mark Steinhoff, Arrow Tech Associates, Inc.
- Benefits of Steeper Angle of Fall for Precision Projectiles, Mr. Jim Rodrigue, Raytheon Missile Systems

WEDNESDAY, APRIL 23, 2008

U.S. NAVY KEYNOTE

- CAPT Joseph McGettigan, Commander, Naval Surface Warfare Center, Dalgren

INDUSTRY KEYNOTE

- MG Julian Burns, USA (Ret), Vice President, Business Development, BAE Systems

PANEL DISCUSSION: UNMANNED AND AUTONOMOUS SYSTEMS WEAPONS INTEGRATION
Moderator: Mr. Dave Broden, Chair, NDIA Armament Division; Broden Resource Solutions, LLC

- Mr. Ed Hackett, iRobot/EH Group, Inc.
- Mr. Ricky Houghton, IBIS TEK
- Mr. Adrian Erkenbrack, Foster Miller/Defense Technology Solutions, LLC
- Mr. Charlie McCullough, BAE Systems

Breakout 1- Armament Subsystems

- 6484—Guide MLRS Electronic Safety & Arming Devices, and Electronic Safety & Arming Fuze Mr. William Kurtz, KDI Precision Products
- 6364—Transmission of Data Message through Contact Type Fuse Setter, Mr. Ki-Up Cha, Agency for Defense Development, South Korea
- 6460—120MM Advanced Case Systems, Mr. Antonio Spinella, U.S. Army ARDEC
- 6483—Common Safety & Arming For the ERGM and Excalibur Precision Guided Munition Systems, Mr. William Kurtz, KDI Precision Products
- Barrel Vibration for Rapid-Fire Guns, Dr. Thomas Dawson, U.S. Naval Academy
- 6415—The Deployment Dynamics: Analysis of the 81MM Illumination Mortar Cartridge, Mr. Seungeuk Han, U.S. Army RDECOM-ARDEC
- MK44 IPT Update, Maj John Medeiros, Jr., USMC, DRPM, Advanced Amphibious Assault

Precision Weapons

- 6355—Precision Strike to Enable the Battle Continuity in Space and Time, Mr. Motti Eis, Israel Aerospace Industries
- 6530—Impact of Precision Mortar Fires for the IBCT, Mr. Rollie Dohrn, ATK
- 6524—PGK and the Impact of Affordable Precision on the Fires Mission, Mr. Douglas Storsved, ATK
- 6390—Quo Vadis After DPICM, Mr. Harald Wich, Diehl BGT Defence
- 6522—MRM Dual Mode Seeker Gun Firing Test Results, Mr. Rick Williams, Raytheon Company

Breakout 2 - Platforms and Weapon System Integration

- 6358—120MM XM360 Gun Technology Base Transition into (FCS) System Design & Development Program, Mr. David Smith, U.S. Army ARDEC
- 6317—Capability Advancements in Gun Systems for Remote Weapon Systems, Mr. James Lamb, ATK
- 6342—F-35 Lightning II STOVL/CV Gun System Update, Mr. Douglas Parker, General Dynamics-ATP
- 6359—F-35 Lightning II CTOL Gun System Update, Mr. David Maher, General Dynamics-ATP
- Electronic Test Fuze, Mr. Wayne Worrell, Naval Surface Warfare Center, Dahlgren

Energetics

- 6344—Insensitive Gun Propellants with Low Temperature Coefficient Based on DNDA, Dr. Dietmar Mueller, Fraunhofer Institute Chemische Technologie
- 6371—Enhanced Ammunition Performance with ECL Technology, Mrs. Kelly Moran, ATK AES
- 6527—Reduced Vulnerability and Enhanced Lethality of Direct Fire Large Caliber HE Ammunition for Mobile Gun Systems, Mr. Roger Gelinas, General Dynamics-OTS/Canada
- 6510—Accelerated Aging of the M864 Baseburner Assembly, Dr. Eric Bixon, U.S. Army RDECOM ARDEC
- Sub-caliber Rocket Training Systems, Mr. Kevin Thomas, Nammo Talley Defense Systems
- 6339—Improved Lethality Test Capabilities of the Arnold Engineeing Development Center, Mr. Brian Roebuck, Aerospace Testing Alliance

THURSDAY, APRIL 24, 2008

MISSILE AND ROCKETS KEYNOTE

- COL Dave Rice, USA, Project Manager, Precision Fires Rocket & Missile Systems

TACTICAL ROCKET AND MISSILES
Session Chair: Mr. Ed DePasqual, Nammo Talley Defense Systems

- AARGM: Strengthening DEAD Capability in the Fleet, Mr. Austin Miller, ATK
- 6363—Water Piercing Missile Launcher, Mr. John Busic, Naval

NAVAL PLATFORMS
Session Chair: Mr. Mike Till, U.S. Navy

- Advanced Gun System-DDG 1000, Mr. Joseph McPherson, NAVSEA (PEO-IWS3C)
- Long Range Land Attack Projectile, Mr. John Rinko, Naval Surface Warfare Center, Dahlgren
- Advanced Gun Systems: Gun and Magazine, Mr. James Kidwell, Naval Surface Warfare Center, Louisville Det

EMERGING TECHNOLOGIES

Session Chair: Mr. Steve French, BAE Systems

- 6373—Non-Destructive Internal Temperature Erosion and Heat Flux Measurements for Large Caliber Guns, Mr. Mark Mutton, Industrial Measurements Systems, Inc.
- 6349—The Combustion Light Gas Gun: A novel yet proven high velocity technology, Mr. David Kruczynski, UTRON, Inc.
- 6332—Plasma-Enchanced Magnetron Technology for Durable Pollution-Free Coatings, Dr. Sabrina Lee, U.S. Army ARDEC, Benet Labs
- 6314—Alternatives for Architecturing Low Cost Guide Projectiles, Mr. Chris Geswender, Raytheon Company
- TBD, Mr. Bryan Freeman, Naval Surface Warfare Center, Dalgren

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43RD ANNUAL ARMAMENT SYSTEMS:

GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

Strengthening Capability through People and Technology

CONFERENCE HIGHLIGHTS:

- Panel session discussing UAV Weapon System Integration
- Discussion of gun and missile system requirements and trends
- Don't miss the Acquisition Training Seminar on Monday afternoon from 2-4pm. This session will provide program managers, scientists, and engineers with essential information to understand and operate effectively within the DoD acquisition system.
- The full scope of gun and missile tactical weaponry and related components will be discussed.

APRIL 21-24, 2008

WWW.NDIA.ORG/MEETINGS/8590

SHERATON NEW ORLEANS ▸ NEW ORLEANS, LOUISIANA

EVENT #8590

43RD ANNUAL ARMAMENT SYSTEMS: GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

APRIL 21-24, 2008 ▸ NEW ORLEANS, LOUISIANA

This conference will address the theme, "Strengthening Capability through the Development of People and Technology". The conference will provide a forum for discussing methods to enhance defense-related capabilities - not only through available technology, but also through development of personnel. A broad range of topics related to design and development of technology and training and development of people in the gun and missile system industry will be presented.

The full scope of gun and missile tactical weaponry and related components will be discussed including: direct/indirect/precision fire systems, tactical rockets and missiles, energetics, effectiveness, modeling and simulation, platform integration and emerging technologies.

GENERAL CONFERENCE INFORMATION

During conference registration and check in, each participant was issued an identification badge. Badges must be worn at all conference functions.

Proceedings will be available on the web one to two weeks after the conference through the Defense Technical Information Center (DTIC). You will receive notification via email that proceedings are posted and available.

Appropriate dress for this conference is business casual for civilians and Class B uniform or uniform of the day for military.

Advertise in National Defense magazine and increase your company's exposure at this conference. National Defense magazine will be distributed to attendees at this conference and all other NDIA conferences. For more information, contact Dino Pignotti at 703-247-2541 or dpignotti@ndia.org.

MONDAY, APRIL 21

NEW IN 2008

MONDAY AGENDA

10:00 am - 4:00 pm
Exhibit Registration & Set-up

10:00 am - 6:00 pm
Registration Open

2:00 pm - 4:00 pm

ACQUISITION TRAINING SEMINAR
Mr. Jim Ripley, *PM Fire Support Systems, U.S. Marine Corps*

Overview: *This session will provide program managers, scientists, and engineers with essential information to understand and operate effectively within the DoD acquisition system.*

5:00 pm - 6:00 pm RECEPTION
Located in the Exhibit Hall

TUESDAY, APRIL 22

7:00 am - 8:00 am Registration & Continental Breakfast
Located in the Napoleon Foyer

8:00 am **OPENING COMMENTS**
- Mr. Sam Campagna, *Director, Operations, NDIA*

8:05 am **CONFERENCE OVERVIEW**
- Mr. Matthew Solverson, *NDIA Conference Chair; General Dynamics-OTS*
- Mr. Michael Till, *Chair, NDIA Gun & Missile Committee; Naval Surface Warfare Center Dalgren*

8:25 am **USMC ARTILLERY**
- COL Scott Campbell, USMC, *Commanding Officer, Marine Detachment, Ft. Sill*

8:55 am **TBD**

9:25 am **ARMAMENT DIVISION OVERVIEW**
- Mr. Dave Broden, *Chair, NDIA Armament Division; Broden Resource Solutions, LLC*

9:35 am **EXHIBIT HALL OPENS AND BREAK IN EXHIBIT HALL**

10:15 am - 11:15 am **REQUIREMENTS & TRENDS**
Session Chair: Mr. Jim Ripley, *U.S. Marine Corps*

10:15 am **6372—Safety Qualification Process for Navy Gun and Ammuniton Systems**
- Ms. Eileen McConkie, *Naval Surface Warfare Center, Dahlgren*

10:35 am **6435—Preserving Critical Knowledge**
- Mr. Roy Weber, *VSE Corporation*

10:55 am **6526—Firing US 120MM Tank Ammunition in the Leopard 2 Main Battle Tank**
- Mr. Harlan Huls, *ATK Advanced Weapons Division*

11:15 am - 11:55 am **DIRECT FIRE**
Session Chair: Mr. Don Guziewicz, *U. S. Army ARDEC*

11:15 am **6491—Development of Light-weight 25MM (LW25) Family of Ammunition**
- Mr. Lee Olson, *ATK Medium Caliber Systems*

11:35 am **S40MM X 180MM Common Case Design Progess**
- Mr. Zachary Kemp, *General Dynamics-OTS*

11:55 am - 1:15 pm Luncheon
Located in Rhythms Ballroom, 2nd floor

KEYNOTE BIOGRAPHIES

COL SCOTT CAMPBELL, USMC

Commanding Officer, Marine Detachment, Ft. Sill

Colonel Scott T. Campbell is from Canton, Ohio. He received his Bachelor of Science degree in Physical Education from Norwich University and was commissioned a Second Lieutenant in May 1980.

He completed the Field Artillery Officer Advanced Course at Fort Sill, Oklahoma along with the Marine Corps Command and Staff College in Quantico, Virginia. He was selected for follow on assignment to the Naval War College in Newport, Rhode Island and received his Masters Degree in National Security and Strategic Studies.

He served as the S-3A where he participated in Operation Desert Shield and Desert Storm as part of the 5th Marine Expeditionary Brigade.

He was assigned to Headquarters, U.S. Marine Corps in Washington, DC where he served as Commanding Officer, Headquarters and Service Company, Headquarters Battalion; the Battalion S-3 Officer; and the Administrative Officer for Manpower Management Department, Navy Annex.

Colonel Campbell has served in several commanding positions to include command of the 12th Marine Regiment during July 2003 and was the Commanding Officer until July 2005. Following his command assignment, he served as the Chief of Staff, 3d Marine Division until June 2006.

Colonel Campbell assumed his current duties as the Commanding Officer, Marine Artillery Detachment, U.S. Army Field Artillery School, Fort Sill, Oklahoma, on 27 July 2006.

His personal decorations include the Legion of Merit, Bronze Star, Meritorious Service Medal with two gold stars, Navy Commendation Medal with two gold stars, Navy Achievement Medal, and the Combat action Ribbon.

KEYNOTE BIOGRAPHIES

CAPT JOSEPH MCGETTIGAN, USN

Commander, Naval Surface Warfare Center, Dalgren

Captain Joseph L. McGettigan became the Commander of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) on April 23, 2004, after serving as the Aircraft Carrier and Large Deck Combat System Project Manager in the Program Executive Office for Integrated Warfare Systems. He is a native of Pennsauken New Jersey and is a 1980 graduate of the U.S. Naval Academy.

His first assignment following graduation was onboard the USS MILLER (FF 1091) where he served as both the Anti-submarine Warfare Officer and the Auxiliaries and Electrical Officer. His subsequent sea tour was onboard the USS BELLEAU WOOD (LHA 3) as the Combat Systems Officer.

Shore assignments include the Naval Postgraduate School where he graduated with distinction; Puget Sound Naval Shipyard where he served as the assistant Ship Superintendent for the USS WHALE (SSN 638) and as the Senior Ship Superintendent for the USS TAUTOG (SSN 639); Mobile Technical Unit Fifteen in Seattle WA where he was designated as the first Officer in Charge; the Naval War College; Naval Undersea Warfare Center in Newport RI where he performed duties as the Test and Evaluation Officer for the AN/BSY 2 Submarine Combat System and the AN/BQG 5 Wide Aperture Array Sonar; Cooperative Engagement Capability Program Office (PMS 465) where he served as the ACDS Block 1 Integration Manager and also as Deputy Program Manager; and the Director for International and FMS Programs within PEO IWS.

From January of 1999 until October of 2001 he was in Command of the Surface Combat Systems Center, Wallops Island, Virginia.

His academic degrees include a Bachelor of Science Degree in Naval Architecture, a Master of Science Degree in Undersea Warfare Technology and a Master of Arts Degree in National Security and Strategic Studies. His personal awards include the Legion of Merit, the Meritorious Service Medal, the Navy Commendation Medal, and the Armed Forces Expeditionary Medal. He is also the recipient of the Arleigh Burke Leadership Award presented by Surface Warfare Officer's School Command and the 2005 Nathaniel Stinson Equal Employment Opportunity Leadership Award presented by the Chief of Naval Operations and the Assistant Secretary of the Navy (Manpower and Reserve Affairs).

TUESDAY, CONTINUED

	Breakout 1	Breakout 2
	Direct Fire Session Chair: Mr. Don Guziewicz, U.S. Army ARDEC	*Effectiveness, Modeling, and Simulation* Session Chair: Mr. Jeff Siewert, Arrow Tech Associates, Inc.
1:15 pm	**6351—Performance Assessment of the M1028, 120MM APERS Tank Round** **Mr. Brian Levine, U.S. Army Armament Research**	**6378—Alternative Lethality Mechanism** **Mr. Michael Lewis, Lockheed Martin Corporation**
1:35 pm	**6338—Ammunition for the MBT's Changing Role on the Modern Battlefield** **Mr. Jacob Moav, Israel Military Industries**	**6425—System Modeling for Projectile Design and Optimization** **Mr. Philip Brislin, U.S. Army ARDEC**
1:55 pm	**6337—30MM PGU-13 HEI Cartridge Improvements** **Mr. Kirk Gimmy, General Dynamics-OTS**	
2:15 pm	**6360—30MM Air Bursting Munitions for the MK44 Cannon** **Mr. Erik Elmer, ATK**	**6519—Development and Fielding of Excalibur Warhead** **Mr. Tim Sellers, General Dynamics-OTS**
2:35 pm	**6362—40MM Cased Telescope Technology Coming of Age: How France and the UK are working to bring the technology into the hands of the user** **Mr. Charles Hookey, BAE Systems, Land Systems**	**Evaluation of Fragmenting Warheads** **Mr. Jason Angel, U.S. Army Research Laboratory, WMRD**

2:55 pm **BREAK IN EXHIBIT HALL**

	Breakout 1	Breakout 2
	Direct Fire Session Chair: Mr. Don Guziewicz, U.S. Army ARDEC	*Effectiveness, Modeling, and Simulation* Session Chair: Mr. Jeff Siewert, Arrow Tech Associates, Inc.
3:20 pm	**6392—GD-OTS 20MM X 102MM Mechanically Fuzed Projectile Program** **Mr. Zachary Kemp, General Dynamics-OTS**	
3:40 pm	**6489—LW30 (30 X 113) Spotter Prototype Modeling and Simulation** **Mr. Jim Roth, ATK Medium Caliber Systems**	**6517—Development of the NLOS-LS PAM Warhead** **Mr. David Hunter, General Dynamics-OTS**

	Breakout 1	Breakout 2
	Energetics Session Chair: Mr. Brian Tasson, ATK	*Effectiveness, Modeling, and Simulation* Session Chair: Mr. Jeff Siewert, Arrow Tech Associates, Inc.
4:00 pm	**6533—Accelerated Burning of Gun Propellants by Effect of Gasdynamic Oscillations within the Perforations of Propellant Grains** **Mr. Gert Pauly, WTD 91, Germany**	**Extended Area Protection and Survivability ATO Status** **Mr. Arthur Aeberli, U.S. Army ARDEC**
4:20 pm	**Common Low-cost Insensitive Munitions Explosive Program to Replace TNT and Comp B** **Mr. Anthony Di Stasio, U.S. Army ARDEC**	**6440—Lean System Simulation of Guided Projectiles in the Early Development Stage** **Mr. Mark Steinhoff, Arrow Tech Associates, Inc.**
4:40 pm	**6341—Insensitive Munitions: A review of the State of the Art** **Mr. Bernie Halls, MSIAC, NATO HQ, Belgium**	**Benefits of Steeper Angle of Fall for Precision Projectiles** **Mr. Jim Rodrigue, Raytheon Missile Systems**

5:00 pm - 6:30 pm Reception
Located in the Exhibit Hall

6:30 pm **EXHIBIT HALL CLOSES**

6:30 pm **ADJOURN FOR THE DAY**

WEDNESDAY, APRIL 23

7:00 am - 8:00 am Registration & Continental Breakfast
Located in the Napoleon Foyer

8:05 am **U.S. NAVY KEYNOTE**
- CAPT Joseph McGettigan, *Commander, Naval Surface Warfare Center, Dalgren*

8:35 am **INDUSTRY KEYNOTE**
- MG Julian Burns, USA (Ret), *Vice President, Business Development, BAE Systems*

9:05 am **PANEL DISCUSSION: UNMANNED AND AUTONOMOUS SYSTEMS WEAPONS INTEGRATION**
Moderator: Mr. Dave Broden, *Chair, NDIA Armament Division; Broden Resource Solutions, LLC*
- Mr. Robert Fondren, *Naval Surface Warfare Center, Dalgren*
- Ms. Kim Jones, *U.S. Army ARDEC*
- Mr. Ed Hackett, *iRobot/EH Group, Inc.*
- Mr. Ricky Houghton, *IBIS TEK*
- Mr. Adrian Erkenbrack, *Foster Miller/Defense Technology Solutions, LLC*
- Mr. Charlie McCullough, *BAE Systems*

KEYNOTE BIOGRAPHIES

MG JULIAN BURNS, USA (RET)

Vice President, Business Development, BAE Systems

Julian (JB) H. Burns, Jr., is Vice President for Business Development, Land & Armaments, BAE Systems, the producer of most combat and artillery systems for the US Army and Marine Corps, all the guns for the Navy, and for most of the Defense Industry in the UK and Sweden. He joined BAE in January 05 after some 3 decades of Army Service with worldwide experience in operations, force management and modernization in the Army and Joint arenas.

He has led the Company in unprecedented growth in a Global Armaments business in combat systems production and modernization, in FCS development (to include new solutions in robotics, survivability and lethality), in BRAC deliberations, in the Reset of returning forces from Southwest Asia to include the First Cavalry, the 3 ACR, and 3rd and 4th Infantry, and game-changing ventures in new business such as the Wheeled Market. He serves on the DOD Task Force for Business Transformation, in which capacity he works to re-industrialize Iraqi State-owned Industries, and has made several trips to the Theater.

General Burns holds a Bachelor of Science degree from West Point and was commissioned a Cavalry Officer, with Airborne and Ranger qualifications, in 1970. He holds a Master's Degree in ORSA/Systems Management from the University of Southern California; and is a graduate of Executive Programs with Indiana University for Philanthropic Studies, the Center for Creative Leadership, Harvard Business School, Darden Business School at UVA, and Chicago School of Business.

General Burns is an active athlete and sportsman. His wife, Ruth Ann (a native of El Paso), is the first female graduate of Texas A&M and a former Army Captain. They have three daughters: Joan, 1LT Julia Burns, 82nd ABN, USA, and Jacqueline, a Junior in Mid Eastern studies at Washington and Lee.

AWARD RECIPIENT

MR. LEO D'ULISSE

Posthumously

After graduating from the New Jersey Institute of Technology with an Engineering degree, Leo started his career at Picatinny Arsenal in the Spring of 1989 as a ARCED Quality Assurance Engineer in the Tank Ammunition Branch. While in this group, Leo worked primarily on the 120mm M829A1 Kinetic Energy Tactical Cartridges. Some of his many accomplishments included coordination of the Production Qualification Testing and spearheading the Materiel Release Action for the M829A2, key involvement in resolution of early production issues involving the new M829A2 composite sabot and performing an environmental assessment of Tank Ammo.

In 1997 he was matrixed to then PM-TMAS' Quality Assurance Group where he supported the offices tank ammunition programs and became involved with Medium Cannon Caliber when that mission moved into TMAS.

Leo left the Government for Lucent Technologies in August of 2000 where he worked on 3rd Generation Wireless Technology initiative specifically in assuring Lucents' Base Station technology interfaced with the various cellular telephone manufacturers' technology.

Leo returned to Picatinny Arsenal ARDEC in June 2002 where he was hired as a Quality Engineering group leader for 40mm Grenades. Leo led a 3D Technical Data Package Update/ Re-write in support of the 40mm Systems Contract RFP.

He then returned to PM-MAS in 2005 to manage the M789 Light Weight 30mm HEDP Cartridge In-Bore Detonation Investigation effort for PM-MCC. Leo lead a formal cross-organizational investigational team to determine the root causes and necessary corrective actions to eliminate historical problems with in-bore detonations in the 30mm M789 used with the Apache Helicopter. As a result of his leadership skills, issues which haunted the ammunition for decades are better understood and multiple production process improvements were implemented in the ammunition production facility which will minimize the opportunity for the occurrence of an in-bore detonation.

WEDNESDAY, CONTINUED

9:30 am **EXHIBIT HALL OPENS**

10:15 am **BREAK IN EXHIBIT HALL**

	Breakout 1	Breakout 2
	Armament Subsystems Session Chair: Mr. Greg Hill, Meggitt Defense Systems	*Platforms and Weapon System Integration* Session Chairs: Mr. Bob Glantz, ATK Gun Systems Mr. Scott Martin, Raytheon Company
10:50 am	**AGS Rifling Twist Trade Study and Analysis** **Mr. Eric Laxton, Naval Surface Warfare Center, Dahlgren**	**6358—120MM XM360 Gun Technology Base Transition into (FCS) System Design & Development Program** **Mr. David Smith, U.S. Army ARDEC**
11:05 am	**6484—Guide MLRS Electronic Safety & Arming Devices, and Electronic Safety & Arming Fuze** **Mr. William Kurtz, KDI Precision Products**	**6404—V-22 Defensive Weapon Systems** **Mr. William McCartney, NAVAIR**
11:25 am	**6364—Transmission of Data Message through Contact Type Fuse Setter** **Mr. Ki-Up Cha, Agency for Defense Development, South Korea**	**6317—Capability Advancements in Gun Systems for Remote Weapon Systems** **Mr. James Lamb, ATK**
11:45 am	**6460—120MM Advanced Case Systems** **Mr. Antonio Spinella, U.S. Army ARDEC**	**6342—F-35 Lightning II STOVL/CV Gun System Update** **Mr. Douglas Parker, General Dynamics-ATP**

12:05 am - 1:35 pm Luncheon & Awards
Located in the Rhythms Ballroom, 2nd floor

Trifiletti Award Recipient
- Mr. Leo D'Ulisse *(Posthumously)*

Military Operations Award Recipient
- COL Michael Smith, *Director, Armaments Engineering and Technology Center, U.S. Army ARDEC, Picatinny Arsenal, NJ*

	Breakout 1	Breakout 2
	Armament Subsystems Session Chair: Mr. Greg Hill, Meggitt Defense Systems	*Platform and Weapon System Intgegration* Session Chairs: Mr. Bob Glantz, ATK Gun Systems Mr. Scott Martin, Raytheon Compnay
1:35 pm	**6483—Common Safety & Arming For the ERGM and Excalibur Precision Guided Munition Systems** **Mr. William Kurtz, KDI Precision Products**	**6359—F-35 Lightning II CTOL Gun System Update** **Mr. David Maher, General Dynamics-ATP**
1:55 pm	**Barrel Vibration for Rapid-Fire Guns** **Dr. Thomas Dawson, U.S. Naval Academy**	**Electronic Test Fuze** **Mr. Wayne Worrell, Naval Surface Warfare Center, Dahlgren**

	Breakout 1	Breakout 2
	Armament Subsystems Session Chair: Mr. Greg Hill, Meggitt Defense Systems	*Energetics* Session Chairs: Mr. Mike Thornton, NSWC Indian Head Mr. Brian Tasson, ATK
2:15 pm	**6415—The Deployment Dynamics: Analysis of the 81MM Illumination Mortar Cartridge** **Mr. Seungeuk Han, U.S. Army RDECOM-ARDEC**	**6344—Insensitive Gun Propellants with Low Temperature Coefficient Based on DNDA** **Dr. Dietmar Mueller, Fraunhofer Institute Chemische Technologie**
2:35 pm	**MK44 IPT Update** **Maj John Medeiros, Jr., USMC, DRPM, Advanced Amphibious Assault**	**6371—Enhanced Ammunition Performance with ECL Technology** **Mrs. Kelly Moran, ATK AES**

	Breakout 1	Breakout 2
	Precision Weapons Session Chair: Mr. Joe Buzzett, General Dynamics-OTS	*Energetics* Session Chairs: Mr. Mike Thornton, NSWC Indian Head Mr. Brian Tasson, ATK
2:55 pm	**6355—Precision Strike to Enable the Battle Continuity in Space and Time** **Mr. Motti Eis, Israel Aerospace Industries**	

3:15 pm **BREAK IN EXHIBIT HALL**

AWARD RECIPIENT

COL MICHAEL SMITH, USA

Director, Armaments Engineering and Technology Center, U.S. Army ARDEC, Picatinny Arsenal, NJ

Colonel Michael J. Smith was born in Washington, D.C. and grew up in Booneville, Mississippi. He received a Regular Army commission in the Ordnance Corps at Mississippi State University in 1980 where he earned a Bachelor of Science in Nuclear Engineering. He also holds a Master of Science in Engineering Science from the Naval Postgraduate School and a Masters in Strategic Studies from the Army War College.

His military education includes the Basic and Advanced Ordnance Officer Courses, Command and General Staff College, the Advanced Program Management Course, and the Army War College.

His awards and decorations include the Legion of Merit (with Oak Leaf Cluster), the Defense Meritorious Service Medal (with two Oak Leaf Clusters), the Meritorious Service Medal (with two Oak Leaf Clusters), the Army Commendation Medal, the Army Achievement Medal, the National Defense Service Medal (with Oak Leaf Cluster), the Iraq Campaign Medal, the Global War on Terrorism – Service Medal, the Army Service Ribbon, the Army Overseas Ribbon, the Air Force Space Master Badge, the Office of the Secretary of Defense Staff Badge, and the Army Staff Badge.

He is married to the former Rita (Reets) Goddard of Booneville, Mississippi and has two Jack Russell Terriers - Sadie and Shyla.

GUN AND MISSILE SYSTEMS COMMITTEE MISSION

The Gun and Missile Systems Committee promotes the exchange of program plans, system descriptions, and technical approaches for present and future gun systems greater than Cal 0.50. The term "Gun System" includes guns, feed systems, ammunition and associated fuzing, fire control, and platform integration. The Committee strives to provide the forum for users, program managers, developers, and producers throughout the U.S. and international industrial and government communities. We emphasize the need to improve the mission and cost effectiveness of gun systems through the use of innovative techniques in the areas of unique materials and processes, novel warhead designs, guided projectiles, and advanced propulsion systems.

WEDNESDAY, CONTINUED

	Breakout 1	Breakout 2
	Precision Weapons Session Chair: Mr. Joe Buzzett, General Dynamics-OTS	*Energetics* Session Chairs: Mr. Mike Thornton, NSWC Indian Head Mr. Brian Tasson, ATK
3:45 pm	**6530—Impact of Precision Mortar Fires for the IBCT** **Mr. Rollie Dohrn, ATK**	**6527—Reduced Vulnerability and Enhanced Lethality of Direct Fire Large Caliber HE Ammunition for Mobile Gun Systems** **Mr. Roger Gelinas, General Dynamics-OTS/Canada**
4:05 pm	**6524—PGK and the Impact of Affordable Precision on the Fires Mission** **Mr. Douglas Storsved, ATK**	**6510—Accelerated Aging of the M864 Baseburner Assembly** **Dr. Eric Bixon, U.S. Army RDECOM ARDEC**

4:00 pm **EXHIBIT HALL CLOSES**

	Breakout 1	Breakout 2
	Precision Weapons Session Chair: Mr. Joe Buzzett, General Dynamics-OTS	*Tactical Rockets/Missiles* Session Chair: Mr. Ed DePasqual, Nammo Talley Defense Systems
4:25 pm	**6390—Quo Vadis After DPICM** **Mr. Harald Wich, Diehl BGT Defence**	**Sub-caliber Rocket Training Systems** **Mr. Kevin Thomas, Nammo Talley Defense Systems**
4:45 pm	**6522—MRM Dual Mode Seeker Gun Firing Test Results** **Mr. Rick Williams, Raytheon Company**	**6339—Improved Lethality Test Capabilities of the Arnold Engineeing Development Center** **Mr. Brian Roebuck, Aerospace Testing Alliance**

5:05 pm **ADJOURN FOR THE DAY**

THURSDAY, APRIL 24

7:00 am - 8:00 am Continental Breakfast
Located in the Napoleon Foyer

8:05 am **MISSILE AND ROCKETS KEYNOTE**
- COL Dave Rice, USA, *Project Manager, Precision Fires Rocket & Missile Systems*

8:35 am - 9:35 am **TACTICAL ROCKET AND MISSILES**
Session Chair: Mr. Ed DePasqual, *Nammo Talley Defense Systems*

8:35 am **AARGM: Strengthening DEAD Capability in the Fleet**
- Mr. Austin Miller, *ATK*

THURSDAY, CONTINUED

8:55 am **6363—Water Piercing Missile Launcher**
- Mr. John Busic, *Naval Surface Warfare Center, Dahlgren*

9:15 am - 10:25 pm **NAVAL PLATFORMS**
Session Chair: Mr. Mike Till, *U.S. Navy*

9:15 am **Advanced Gun System-DDG 1000**
- Mr. Joseph McPherson, *NAVSEA (PEO-IWS3C)*

9:35 am **BREAK IN NAPOELON FOYER**

10:05 am **Long Range Land Attack Projectile**
- Mr. John Rinko, *Naval Surface Warfare Center, Dahlgren*

10:25 am **Advanced Gun Systems: Gun and Magazine**
- Mr. James Kidwell, *Naval Surface Warfare Center, Louisville Det.*

10:45 am - 12:05 pm **EMERGING TECHNOLOGIES**
Session Chair: Mr. Steve French, *BAE Systems*

10:45 am **6373—Non-Destructive Internal Temperature Erosion and Heat Flux Measurements for Large Caliber Guns**
- Mr. Mark Mutton, *Industrial Measurements Systems, Inc.*

11:05 am **6349—The Combustion Light Gas Gun: A novel yet proven high velocity technology**
- Mr. David Kruczynski, *UTRON, Inc.*

11:25 pm **Fuel Cells for Munitions**
- Mr. Edgar Seydel, *The Ashlawn Group*

11:45 pm **6332—Plasma-Enchanced Magnetron Technology for Durable Pollution-Free Coatings**
- Dr. Sabrina Lee, *U.S. Army ARDEC, Benet Labs*

12:05 pm - 1:15 pm Luncheon
Located in Napoleon CD123

1:15 pm - 2:15 pm **EMERGING TECHNOLOGIES**
Session Chair: Mr. Steve French, *BAE Systems*

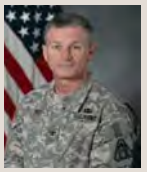
1:15 pm **6314—Alternatives for Architecturing Low Cost Guide Projectiles**
- Mr. Chris Geswender, *Raytheon Company*

1:35 pm

1:55 pm **TBD**
- Mr. Bryan Freeman, *Naval Surface Warfare Center, Dalgren*

2:15 pm **CONFERENCE ADJOURNS**

KEYNOTE BIOGRAPHIES



COL DAVE RICE, USA

Project Manager, Precision Fires Rocket & Missile Systems

Colonel Dave Rice earned his commission through Officer Candidate School. Prior to accession in the Acquisition Corps, he held a variety of command and staff positions in Tactical Field Artillery units. As an Acquisition officer, he has been assigned to the MLRS Project Office, various positions on the Army and OSD Staffs in the Pentagon, and as Product Manager, Large Caliber Ammunition, Picatinny Arsenal, NJ. He is currently serving as Project Manager, Precision Fires Rocket and Missile Systems, Redstone Arsenal, AL.

SAVE THE DATE:

44th Annual Armament Systems: Gun & Missile Systems Conference & Exhibition

Event # 9590

April 6-9, 2009

Hyatt Regency Crown Center

Kansas City, Missouri

PROMOTIONAL PARTNER

Promotional Partner

ATK is a leading provider of advanced weapon and space systems with $4.1 billion in annual sales, approximately 17,000 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 U.S. Marine Corps' new Expeditionary Fighting Vehicle and the 30mm M230 cannon for the AH-64 Apache and AH-64D Apache Longbow helicopters.

Building on the capabilities of our core ammunition and rocket motor businesses, ATK is developing several breakthrough advanced weapon systems, such as the U.S. Navy's Advanced Anti-Radiation Guided Missile (AARGM) and the U.S. Army's Precision Guidance Kit (PGK), Spider Man-in-the-Loop Anti-Personnel Munition and Individual Airburst Weapon System (IAWS). 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 at affordable procurement costs.

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.

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

ADDITIONAL AUTHORS

6314—Stephen Bennett

6317—Mark Coppens

6317—Roger O'Dell

6332—Rong Wei

6339—Richard Rushing

6349—Dennis Massey

6351—James Woodhouse

6358—Anthony Cannone

6360—Mark Tomes

6362—Trevor Sheehan

6362—Mike Duckworth

6363—Samuel Koski

6363—Jon Yagla

6364—Gun-Ha Lee

6364—Hong-Cheol Kim

6364—Chang-Ki Cho

6371—Beat Vogelsanger

6371—Steven Ritchie

6372—Dennis Bushor

6372—John Filo

6372—Dwight Roberson

6373—Donald Yuhas

6373—Greg Walker

6373—Peter Schmidt

6374—Elias Jelis

6377—Tung Chan

6404—William Cosgrove

6404—Dave Weinstein

6415—Raymond Trohanowsky

6415—Andrew Maulbeck

6460—Enrico Mutascio

6515—Dan Boeka

6515—Dave Saito

6515—Art Daniels

—Christopher English

6517—David Hunter

6517—Jim Strom

6517—William Zarr

6518—Rick Tuznik

6518—Tracey Westmoreland

6519—Terry Young

THANK YOU FOR COMING!

Notes

Raytheon

Customer Success Is Our Mission

Presentation to 43nd Annual Gun & Missiles Conference

Alternatives for Architecturing Low Cost Guided Projectiles

Chris E Geswender
cegeswender@raytheon.com
Stephen Bennett
Stephen_E_Bennett@raytheon.com

April 23, 2008

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

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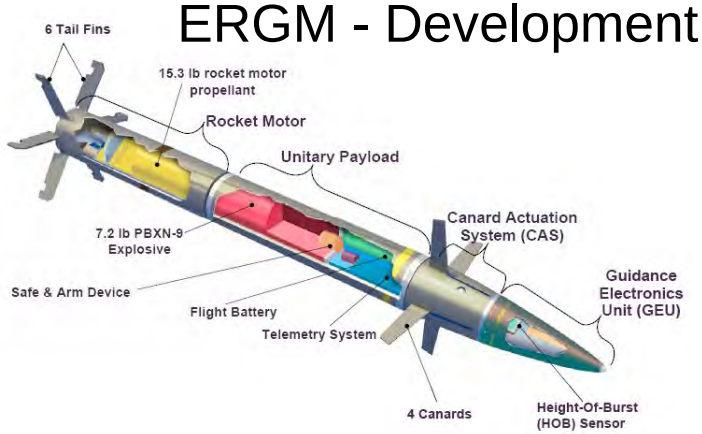
Existing Projectile Guidance Activities

Raytheon Missile Systems

EXCALIBUR - Production

ERGM - Development



LRLAP - Development

Krasnopol - Production

PGK - Development

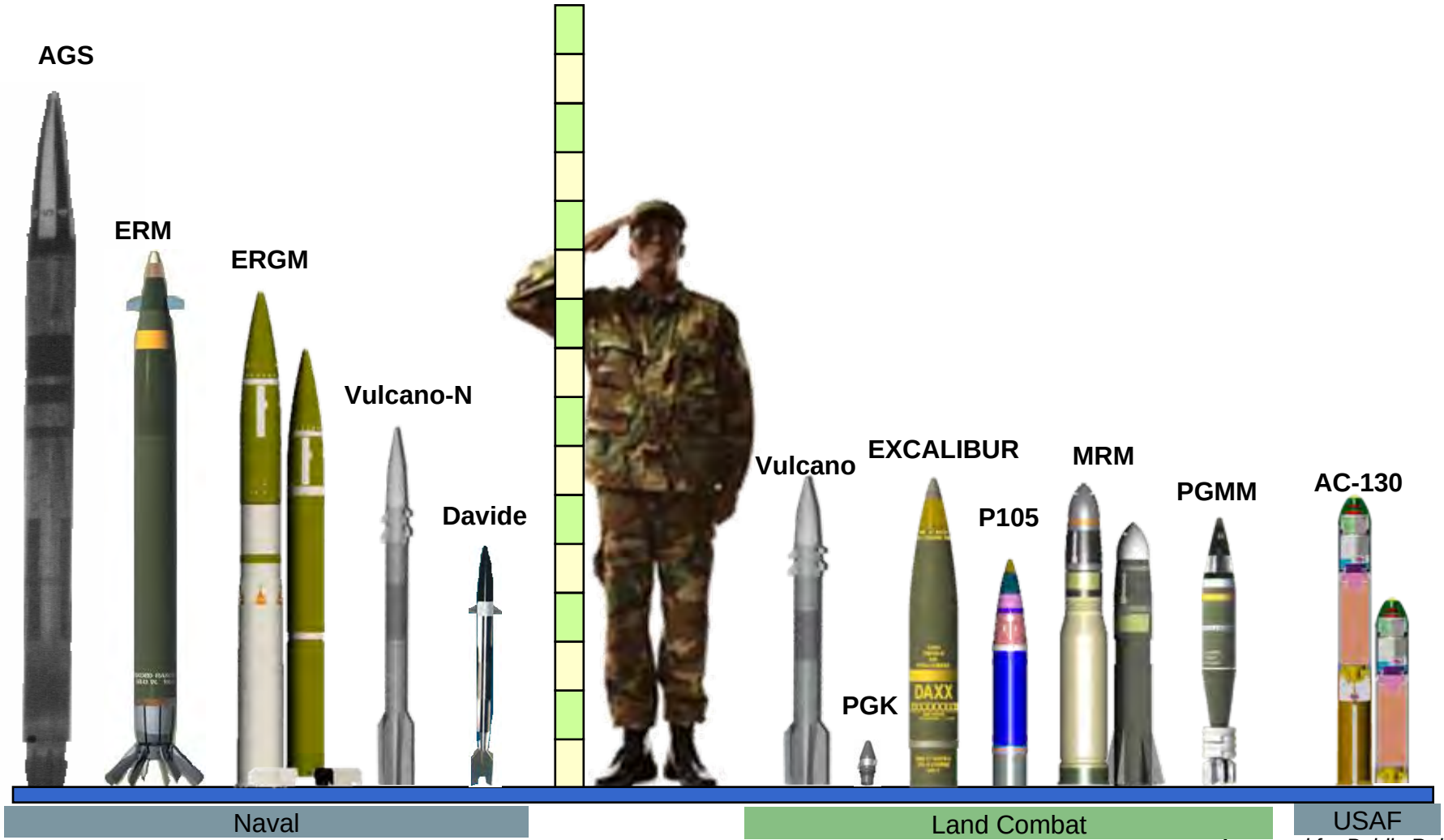
Copperhead (OOP) – In Service

Vulcano - Development

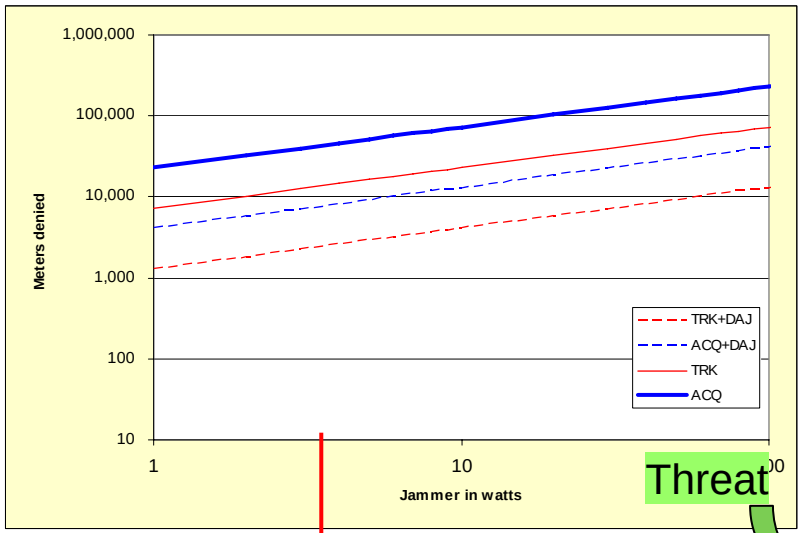
Present generation build with missile-like Specifications

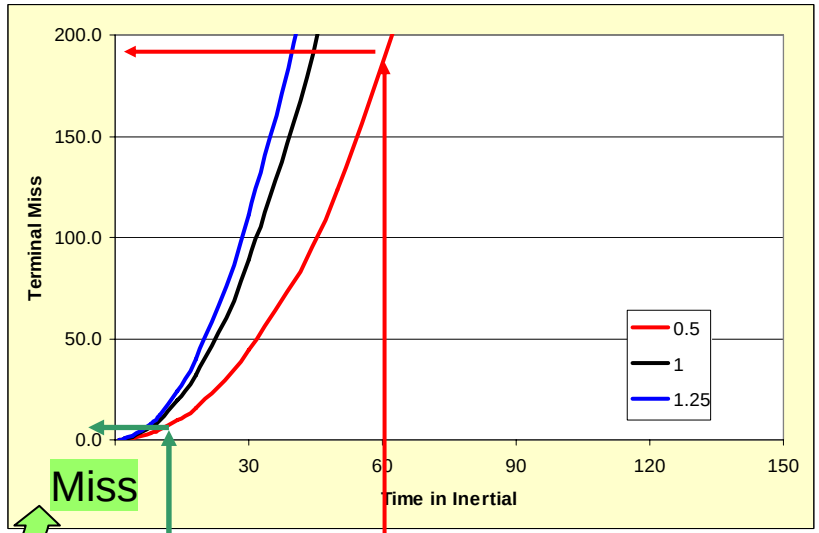
Wide Variety of Concepts and Programs

Raytheon
Missile Systems



How we tradeoff GPS AJ and CEP performance (gliding weapons w IMU)



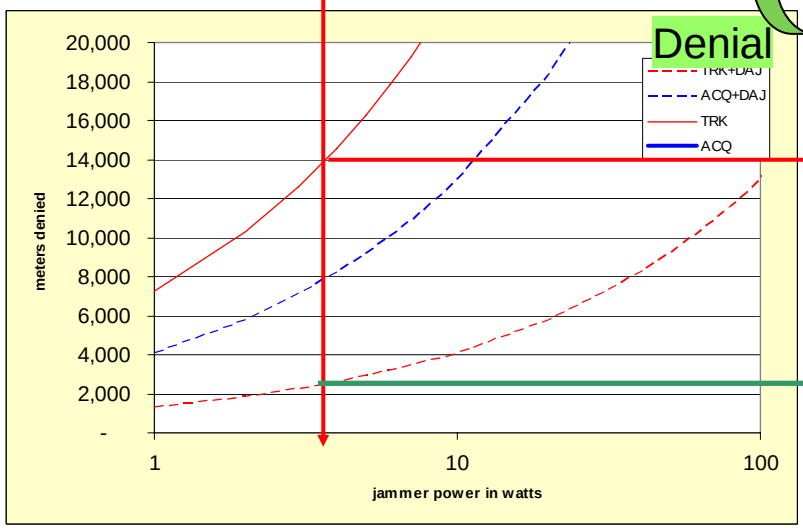


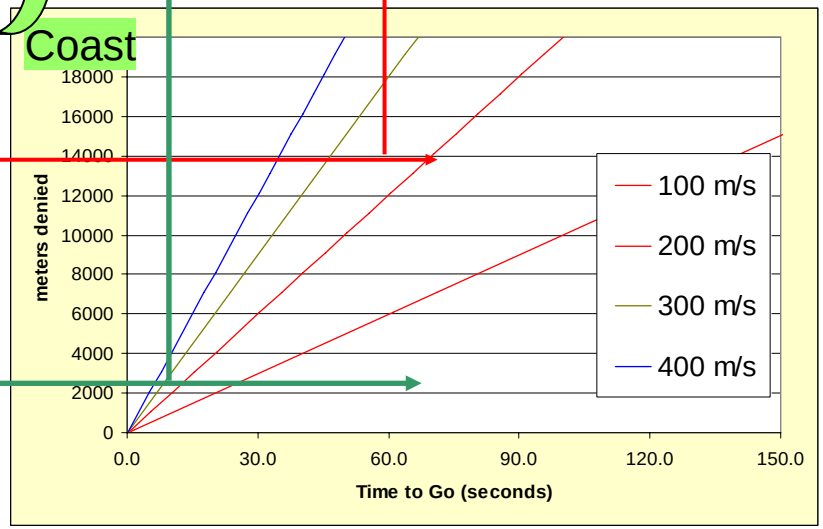
Threat

Miss

Denial

Coast

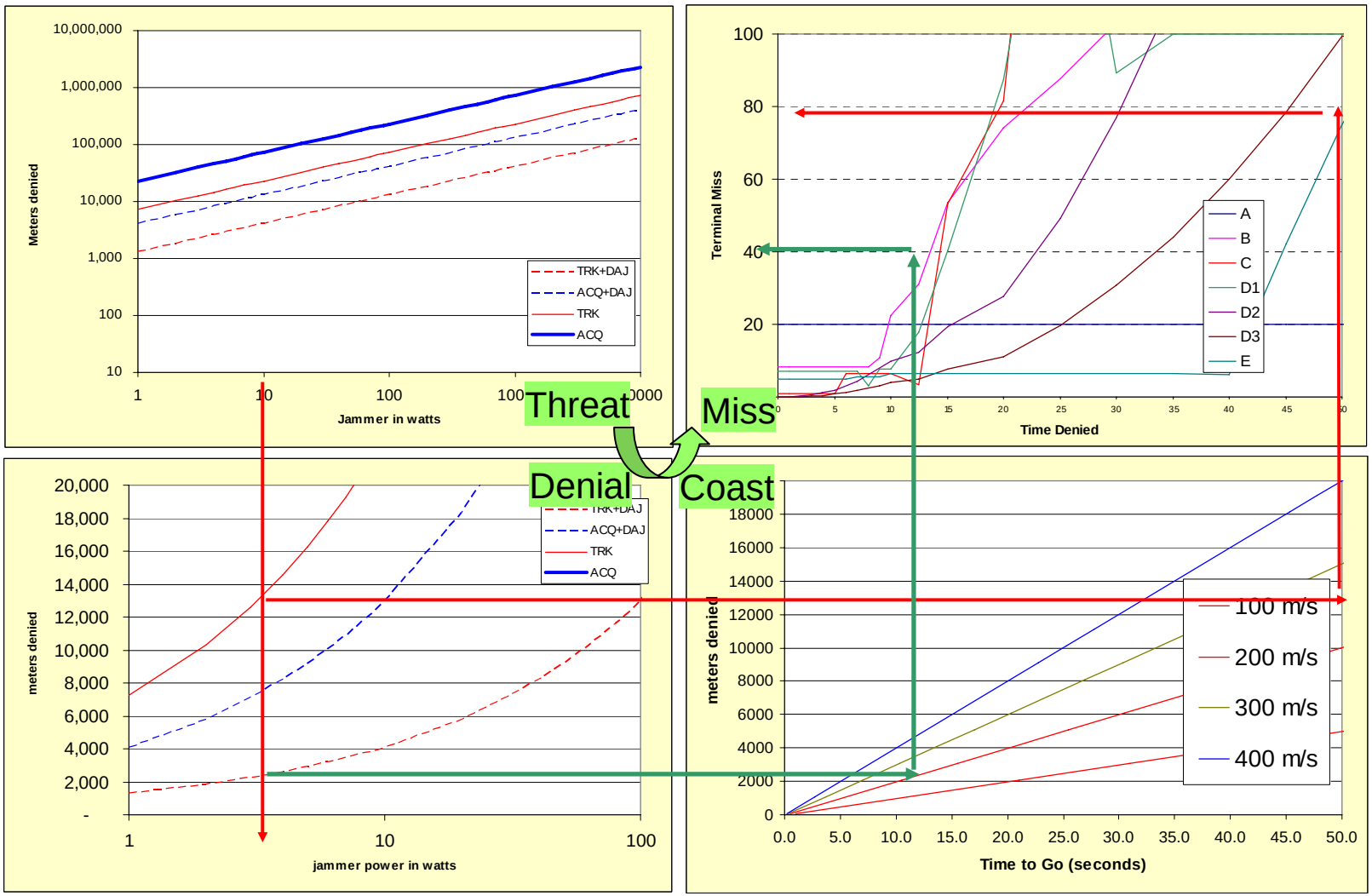




Traditional Trade Off between GPS and IMU Specifications

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

How we tradeoff GPS AJ and CEP performance (trajectory correcting weapons)



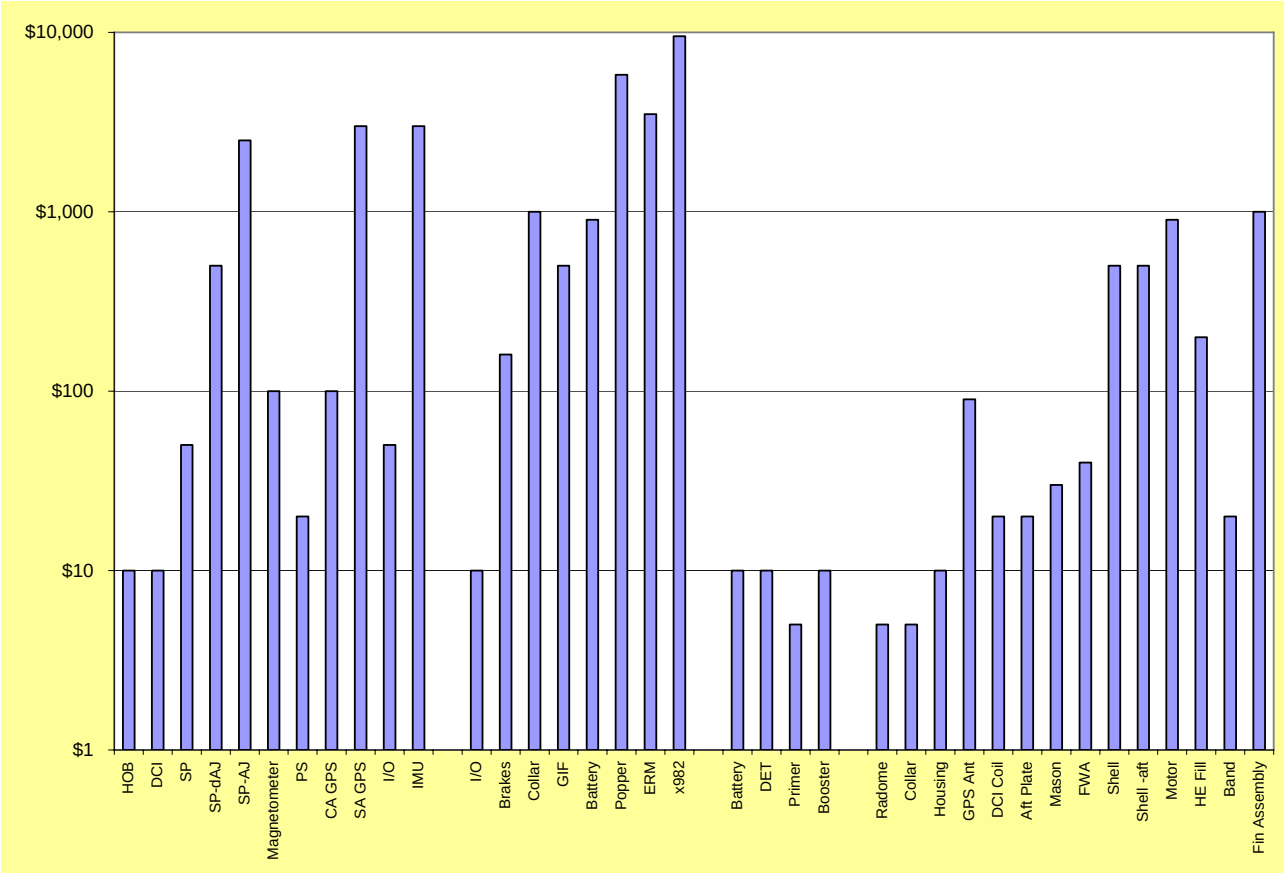
Trade Off between GPS and Trajectory Correction

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

Raytheon
Missile Systems

Study used "Functionality Based Costs"

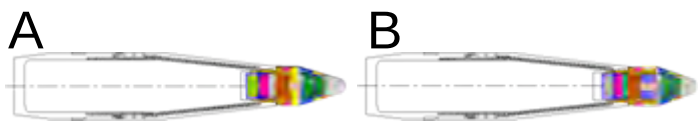
Technique in NATO Study Groups to Compare Concepts



Technology / Cost – Best Architecture Evolves
(use for relative – not absolute costs analysis)

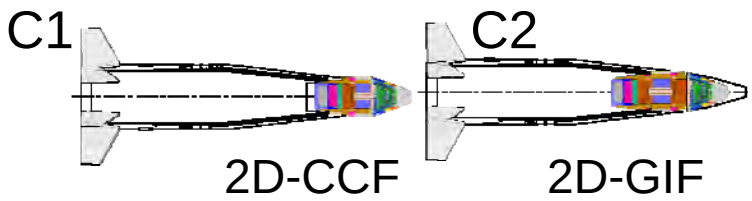
Relative Concept Architectures and Functionality Derived Costs

PGK (<50 m CEP)



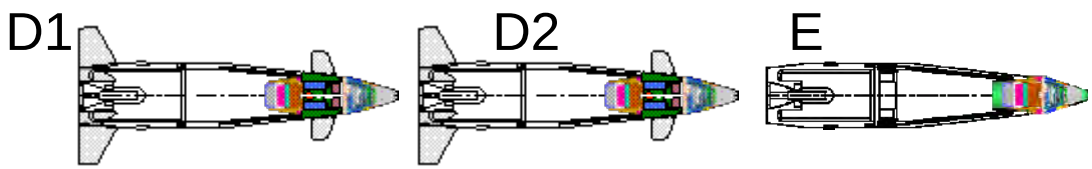
	1D-PGK	2D-PGK
AUPC ($K)	2.2	3.4

Hybrid (<20 m CEP)



	2D-CCF	2D-GIF
AUPC ($K)	4.6	10.3

Precision (<10 m CEP)



	3D-"ERM"	6D-"Excal"	2D- "HAMR"
AUPC ($K)	14.5	31.0	17.3

HW Functional Differences

Raytheon Missile Systems

Concept A 1D PGK	Concept B 2D PGK	Concept C1 2D "PGK"	Concept C2 2D "GIF"	Concept D1 2D "ERM"	Concept D2 6D "Excal"	Concept E 2D HAMR
DCI HOB CA GPS Power Design MOFA Flight Computer I/O to 1D	Magnetometer I/O CCA to 2D		I/O to Act Collar Assembly Extra battery	I/O to Act ERM CAS Extra Battery	I/O to Act I/O to IMU CAS IMU Extra Battery	(I/O to TC) TC Assembly Extra Battery
Brake Assembly	2D CAS					
		Finned base	Finned base	Finned base	Finned base	
PGK-like Weapon Architecture		**Hybrid Weapon Architecture**			**Precision Weapon Architecture**	

SW Functionality is Remarkably Consistent

Raytheon Missile Systems

Concept	FUNCTION	Aimpoint estimation	Arming function - Brake	Arming function - FS&A	Ballistic aiding of GPS	BIT	DCI	Fail Safe	Fuzing	GPS HOT START	GPS Processing Interface	Jamming Detection	Latitude / Altitude compensation	Launch detection	Mini- TM/HOB interchange	Operating system	Optimum braking timing	Power up processing	Precession Drag count	Provisions - Unique projectile characteristics	Reprogramability	Telemetry Output Subsystem	WGS-84 Earth Model Transformations	Winds Aloft compensation	Factory / Manufacturing / Test Functions	PIL/HIL data entry test ports	Special factory tests	Telemetry	New 2D KIT FUNCTIONS	Collar braking command	Control "UP"	DOD WMM 2005 Integration	Magnetometer "UP"	Magnetometer calibration function	New Projectile variants FUNCTIONS	CAS commands	Control section BIT	GPS- AJ / or Coast Logic	Trajectory shaping	Autopilot	IMU	Popper firing logic
	today	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
PGK																																									
A		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x															
B		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x								
Hybrid																																									
C1		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x								
C2		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x						
D1		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x				
D2		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	
E		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x			x	x				x
Precision																																									

Insertion Of new function into SW

Software Infrastructure Needs Support Many Solutions

Raytheon Missile Systems

Concepts vs. Precision 105 Requirements (of 8-2007)

Attribute	B PGK	C1 PGK	C2 GIF	D1 ERM	D2 982 jr	E HAMR	Comments
Precision							HAMR depends on achievable popper impulse
Reliability							.90
Net Ready							All support NET
Lethality							New Pre-formed fragment warhead
Range							Min 5km, Max 20 km
Compatibility							All EPIAFS compatible
Initialization							All Support requirements
Fuze Function							All Use MOFA fuze well
SAL Compatible							All would require different packaging to support
Angle of Fall							70 degree angle achievable at 2/3 range (spec)
Projectile Weight							<54 lbs
Projectile Length							<40 inches
Render Safe							Unused Poppers may still initiate
Reset							
Reset after Ram							
Extraction							
Query							Power up charges caps and fuze can answer queries
20 year Shelf							IMU 20 yr uncertain
IM Compliant							Poppers on surface and are “projectiles”
Risk of meeting KPPs							Combined assessment of simultaneously meeting CEP / impact angle / packaging / concept risk

Candidate Space Offers Multiple Potential Solutions

Concept Trade Space
AJ performance vs System Architecture

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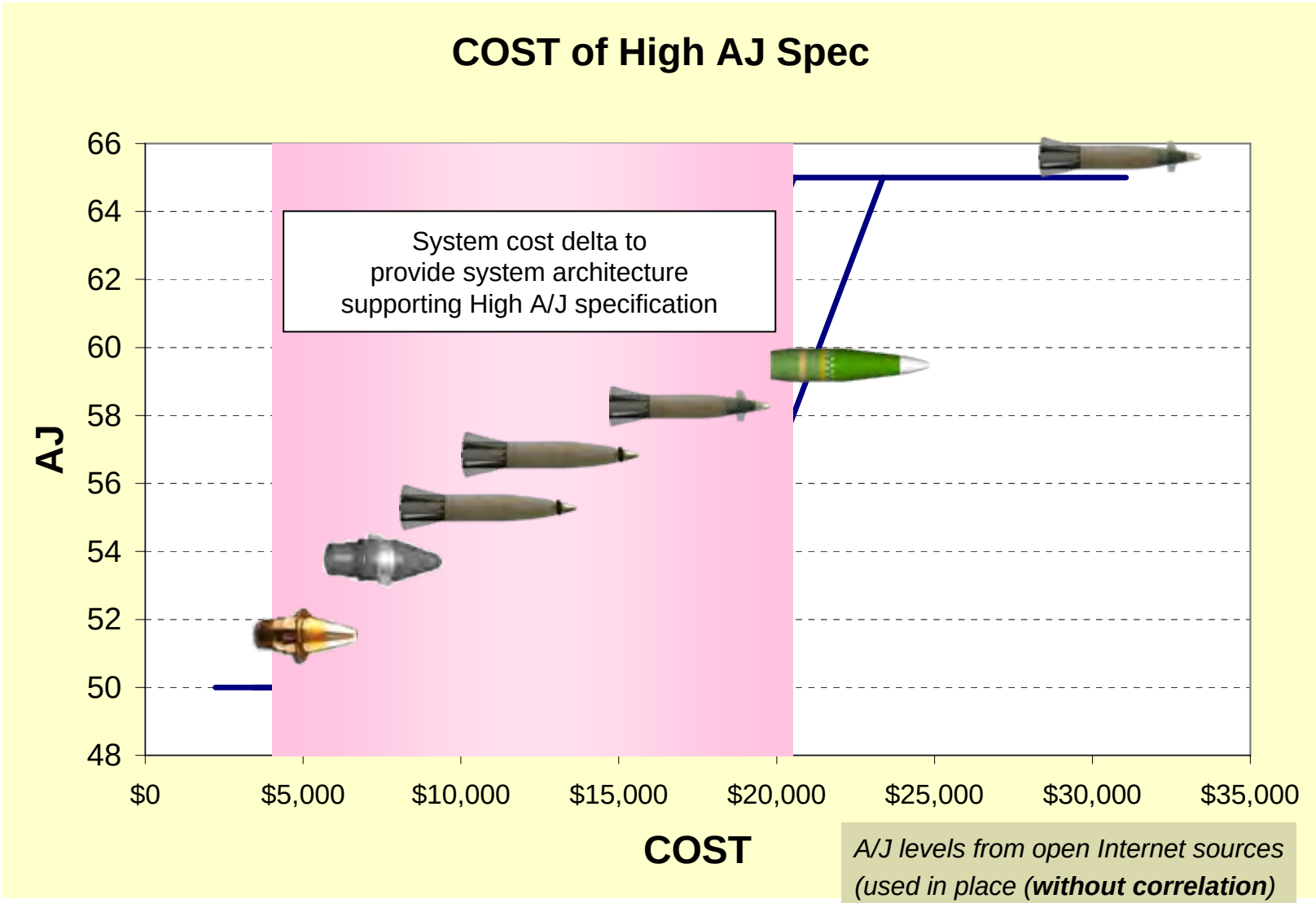
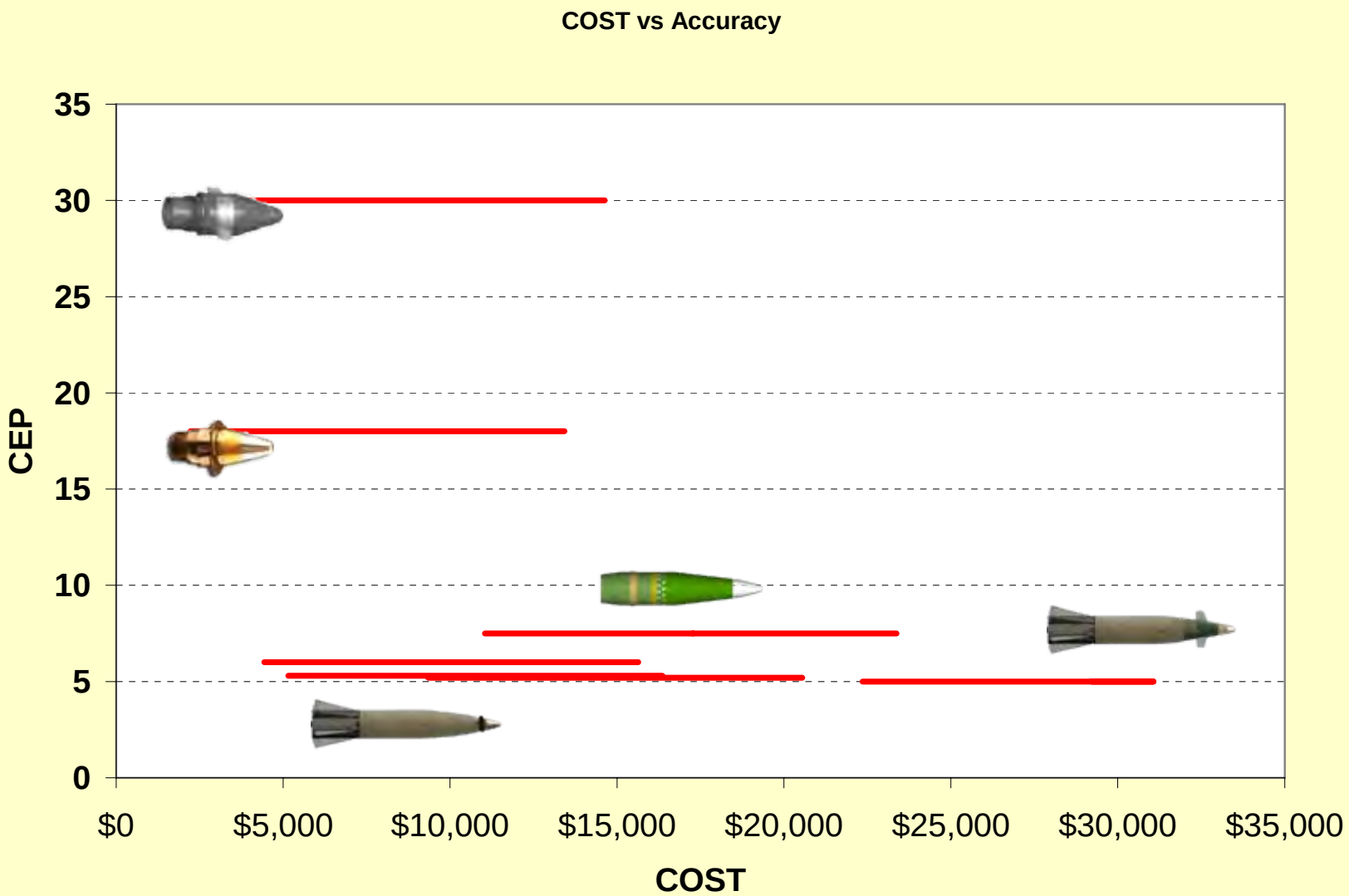
Missile Systems



Concept Trade Space
CEP performance vs System Architecture

Raytheon
Missile Systems



Potential Cost of Specification Compliance

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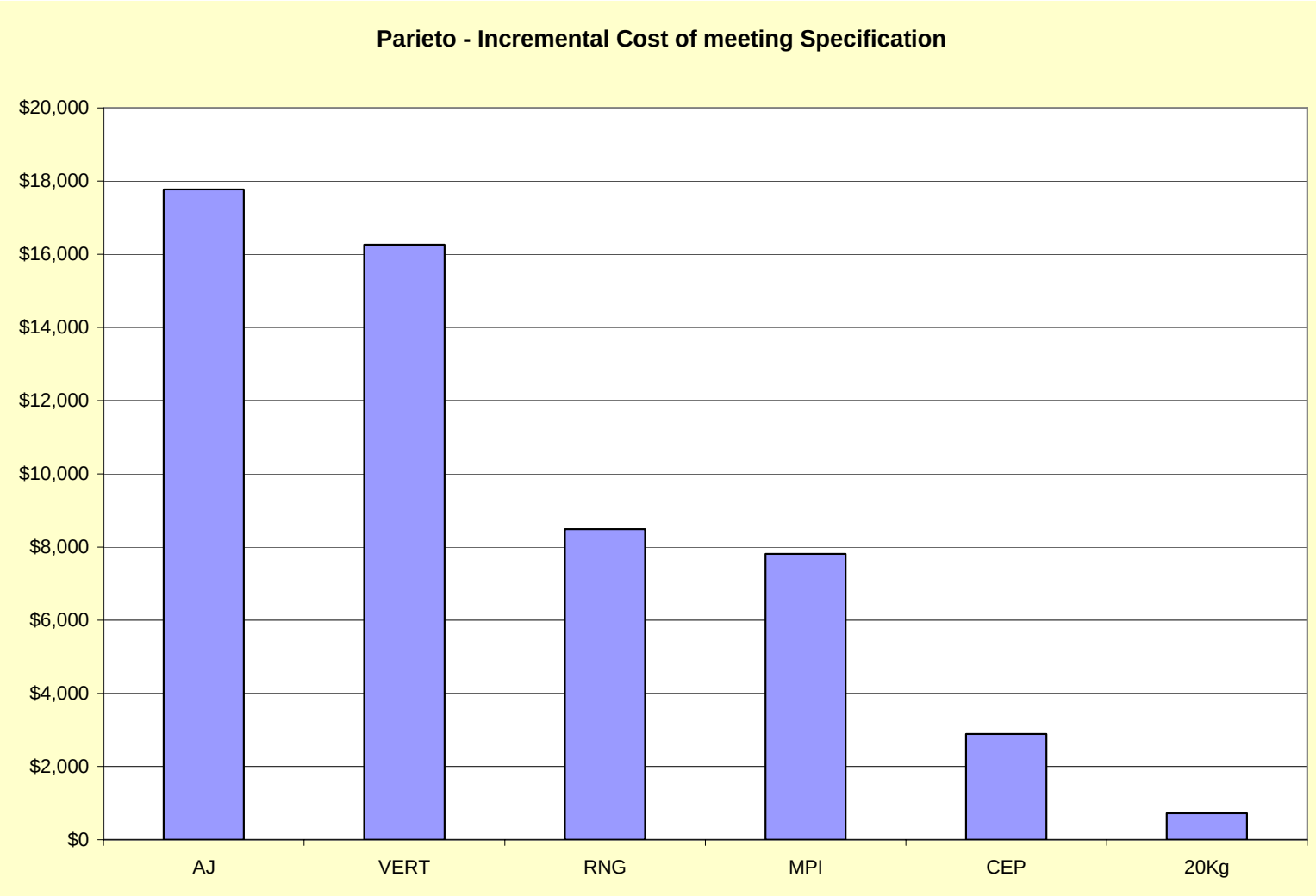
Missile Systems



Some Requirements Drive Majority of Architecture Costs

Summary

Raytheon
Missile Systems

- There are a number of viable guided projectile concepts that can meet both 20km and 10 meters CEP
  - PGK like
  - Other trajectory correcting concepts
  - Gliding / guiding concepts
- Specifications will drive viable concept architecture
  - GPS A/J performance
  - Verticality
  - Maximum Range
  - Robustness to MET / MPI variations
- Concept architecture will drive cost
- A/J level specified is largest potential cost driver
  - High A/J eliminates most projectile concept architectures
  - Remaining concepts are EXCALIBUR like in components required
- Interpretation of Vertical requirement next largest cost driver

Customer is in control of the specification and therefore
The customer is in control of the potential system AUPC

ATK Medium Caliber Systems

Lightweight 25 mm / .50 Caliber Bushmaster Cannon

NDIA Gun and Missile Systems Conference

April 21-24, 2008

New Orleans, LA

Jim Lamb

OSR No. 07-S-1411

Bradley with M242, 25mm

LW25mm Bushmaster

Medium Caliber Ammunition

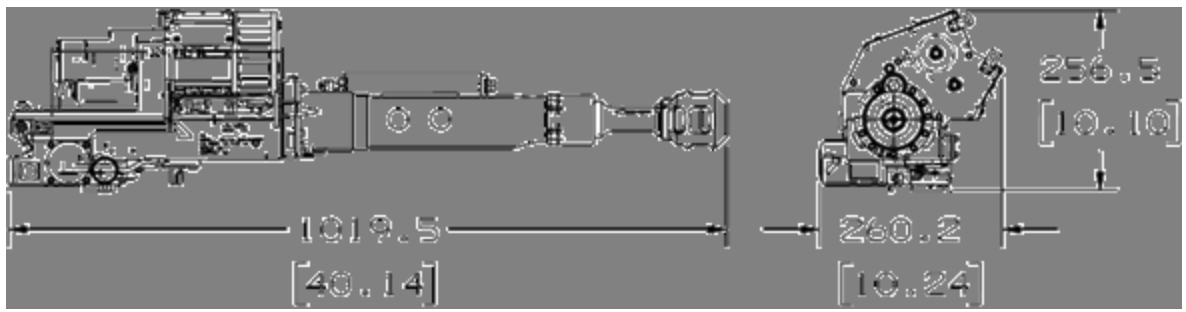
M230 Chain Gun

Welcome

- **Introduction**
- **.50 caliber Progress to Date**
- **Similarity Between .50 cal and LW25 Ammunition**
- **Design Goals**
- **Commonality of Parts**
- **LW25 Specifications**
- **Size Comparison**
- **Potential Applications**
- **Current Status**

Introduction

The .50 caliber/LW25mm Bushmaster Chain Gun is a derivative of the combat proven M242 25mm Bushmaster Automatic Cannon. It incorporates all of the battle proven features of the Bushmaster series of cannons, with significant system commonality for low-risk, proven performance.

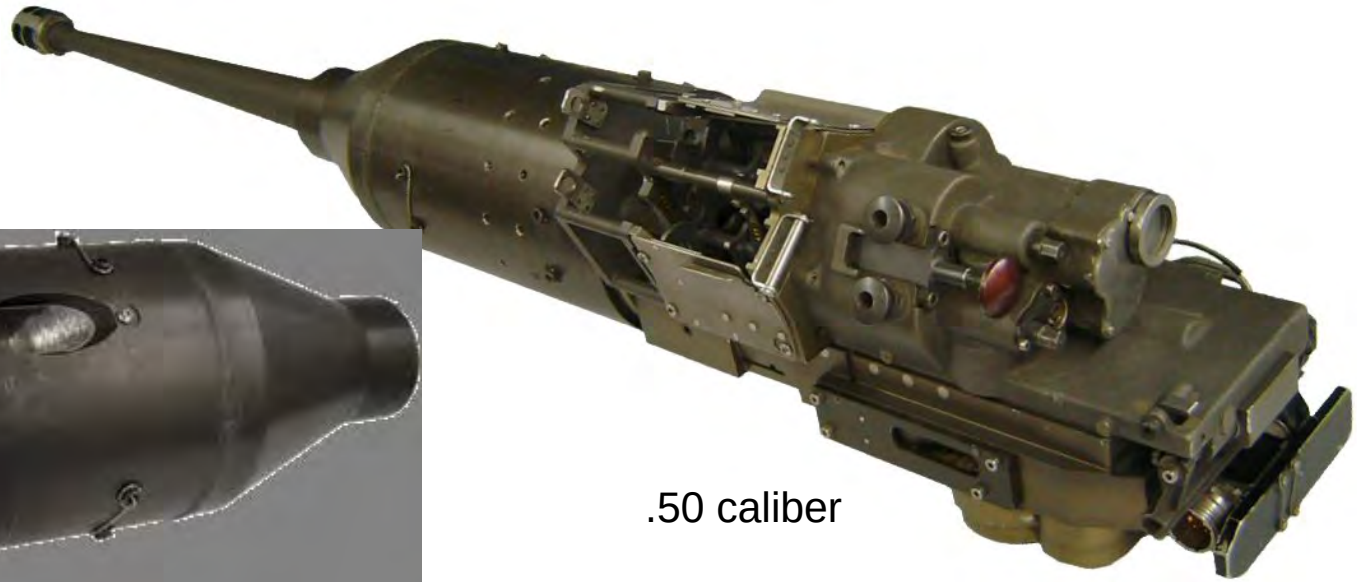


.50 Cal Progress To Date

- **Characteristics**
  - Weight:
    - Receiver 35 lbs
    - Feeder 14 lbs
    - Barrel 27 lbs
    - Total 75 lbs
  - Rate of Fire: 400-500 spm.
  - Anti-hangfire safety
  - Dual feed with forward or side eject
  - 28 VDC system
  - Hard Mount Recoil = 1500 lbs; ATK Developed Soft Mount Recoil < 600 lbs
- **30,000+ rounds fired**

.50 Cal Progress To Date

- **Hardware Development**
  - ATK Soft Mount developed and tested; recoil reduced to <600 lbs.



.50 caliber

ATK Soft Mount

2-sided muzzle brake developed and tested for aircraft applications.

.50 Cal Progress To Date

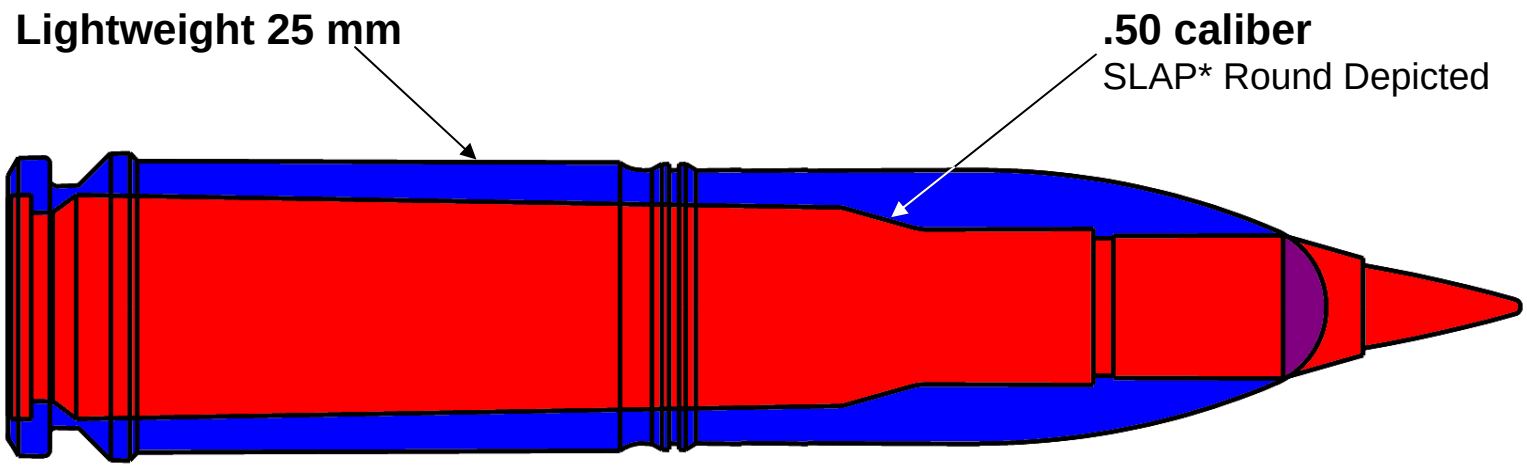
- **Air Platform Integration and Testing**
  - Successfully fired from Boeing Unmanned Light Attack Recon. Testbed (ULART): August 2006 Yuma Proving Grounds, AZ

.50 Cal Progress To Date

- **Land Platform Integration and Testing**
  - Successfully fired from Boeing Agile Multi-Role Weapon System (AMWS): September 2006 ATK Range Mesa, AZ

Similarity Between .50 cal and LW25 mm Ammunition

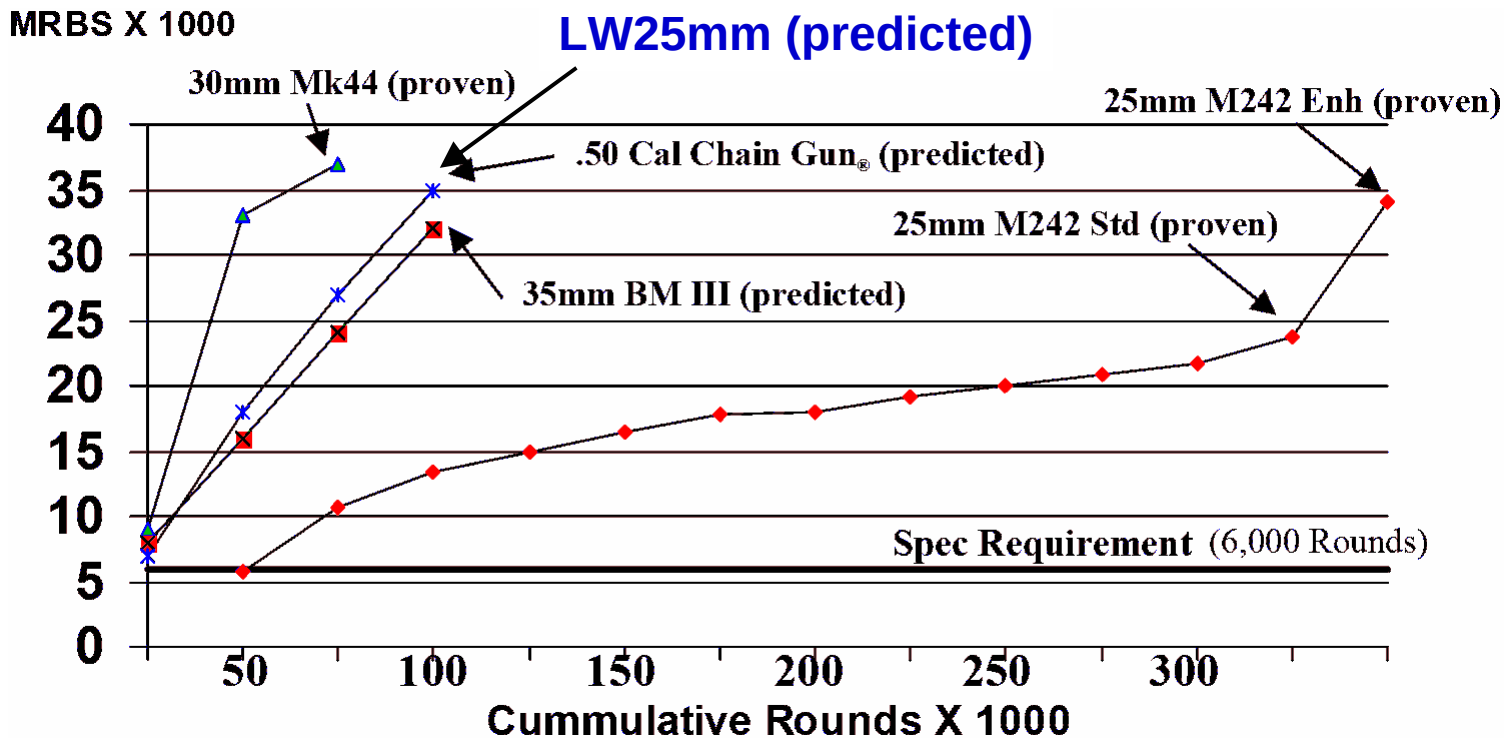
- **The size of the .50 caliber receiver and chain was well-matched for the conversion to LW25 mm.**



*SLAP = Saboted Light Armor Penetrator

Lightweight 25mm Design Goals

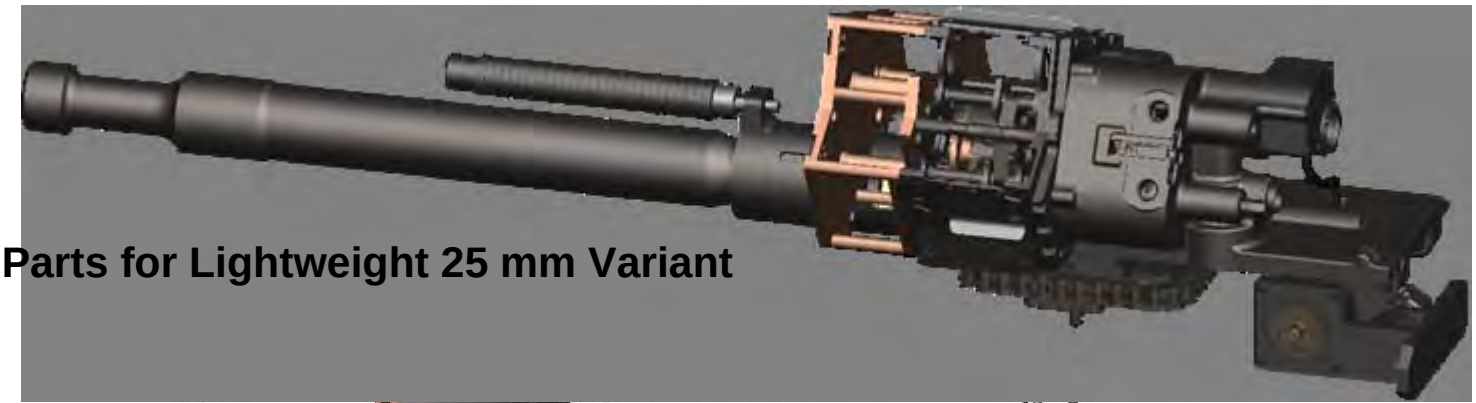
- **Build on the similarity between .50 caliber and lightweight 25 mm ammunition.**
- **Reduce errors by utilizing as many common parts and designs from the current Bushmaster family of cannons as possible.**
- **Maintain the reliability characteristic of the Bushmaster line of cannons.**



Commonality of Parts

LW25 mm Unique	38.0%
.50 cal Common	55.4%
Other BM Series	6.6%

Standard 25 mm M242 Muzzle Break



New Parts for Lightweight 25 mm Variant

Common Parts to the Current .50 caliber

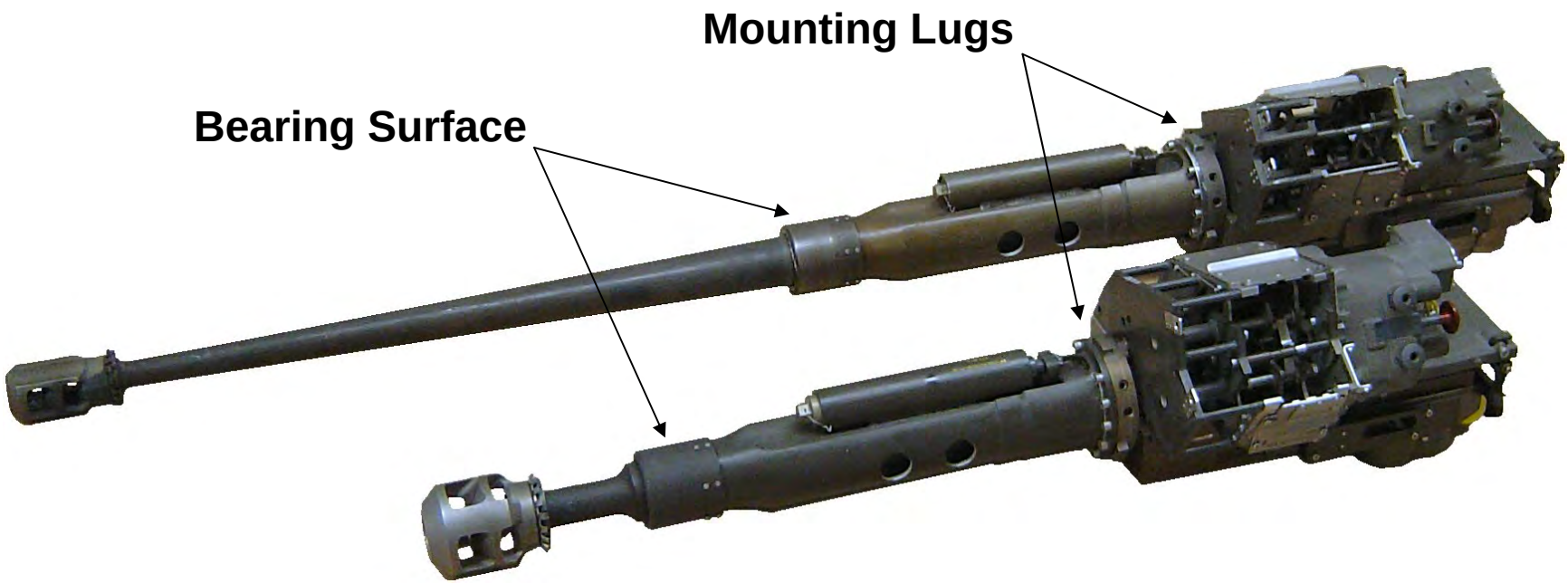
All of the LW25 mm and .50 Caliber Components Are of Equivalent Design, Fabrication and Function as Other Currently Fielded Bushmaster Guns

Lightweight 25 mm Bushmaster Specifications

- **Characteristics**
  - **Weight:** **Receiver 34.9 lbs**
    Feeder 19.0 lbs
    Barrel 13.6 lbs
    Total 67.5 lbs
  - **Rate of Fire: 230-260 spm.**
  - **Anti-hangfire safety**
  - **Dual feed with side eject**
  - **First Round Selectable**
  - **28 VDC system**
  - **Capable for Firing Both ATK and General Dynamics (GD-OTS) Ammunition, Including Air Bursting Munitions.**

Relative Size of Each Variant

Common Mounting Lugs and Features

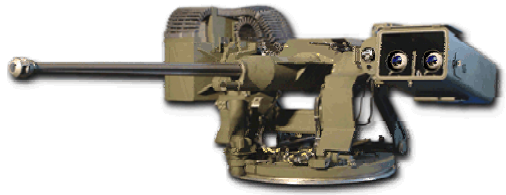


Potential Applications

- **Close in Support for Manned Vehicles:**
  - **FCS**
  - **NLOS Vehicles**
  - **Troop Transports**
  - **Mounted Combat Systems (MCS)**
  - **Stryker**
  - **Kiowa Warrior**
  - **Avenger**
  - **SOCOM Aviation**

Potential Applications

- **Main Protection for Remote Vehicles**
  - **Remote Weapon Station Integration**
  - **ARH**
  - **FCS Mule**
  - **ARV RSTA**
  - **Base Security**



- **Any Application Currently Mounting .50 cal**

Current Program Status and Future Plans

- In Testing

(Video of gun firing)

- **<u>Future Plans</u>**
  - Develop Remote Feed Select Operation
  - Develop Dual Purpose (LW25/.50 cal) Common Feed Chutes and Magazines
  - Develop .50 caliber “Quick Change” Hardware

Contact Information

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OSR No. 07-S-1411

Weapon Systems & Technology Directorate
US ARMY ARDEC- BENÉT LABS

TITLE: PLASMA ENHANCED MAGNETRON TECHNOLOGY FOR DURABLE POLLUTION-FREE COATINGS

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Sabrina Lee and Dr. Rong Wei

NDIA Gun and Missile Conference, New Orleans, LA
April 21-24, 2008

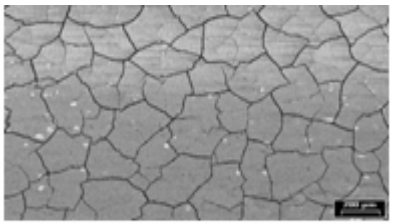
Outline

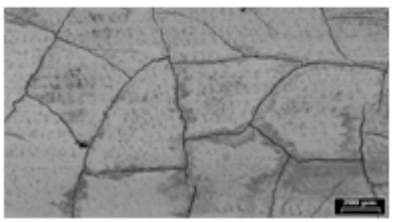
- Problems with HC Cr electroplating process.
- Alternative pollution-free coatings against high temperature wear and erosion.
- Plasma enhanced magnetron surface cleaning.
- Plasma enhanced magnetron deposition.
- Analytic characterization and adhesion testing.
- Conclusion

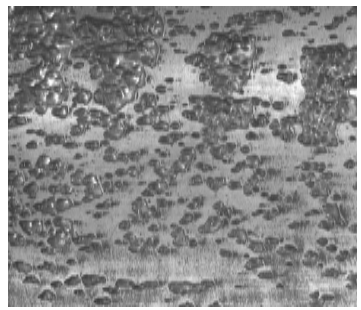
Problems with Electroplated Cr

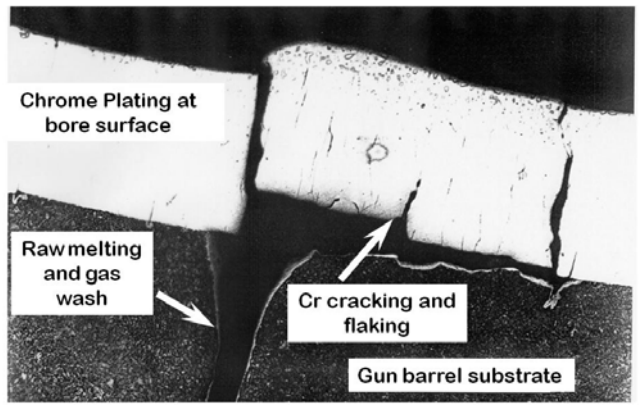
Environment Problem: Aqueous toxic Cr VI from Cr Electroplating Process

Performance Problem: Inadequate substrate protection, reduced service life for high temp wear & erosion applications



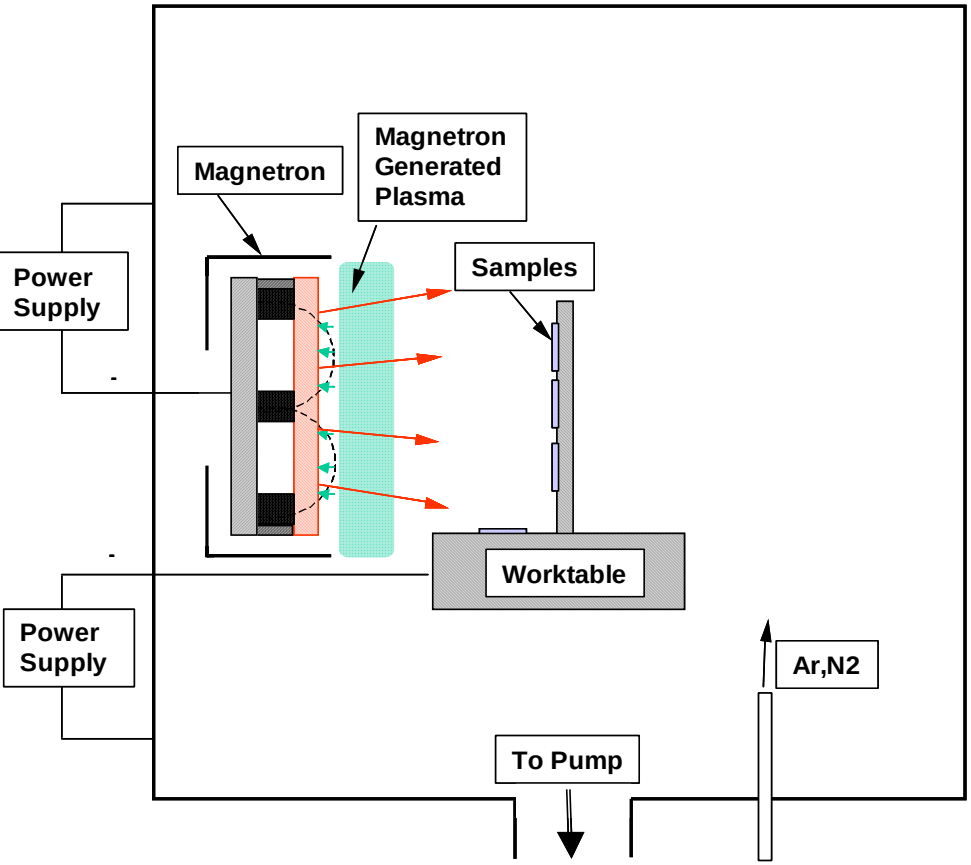




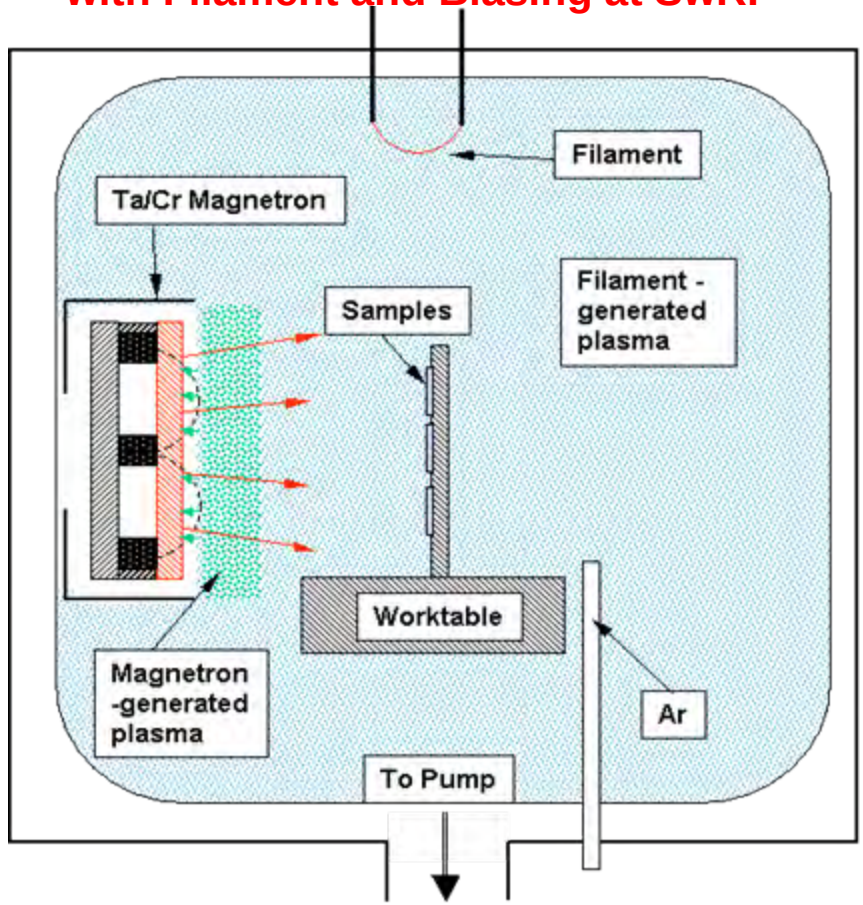


Plasma Enhanced Magnetron Sputtering

Conventional Physical Vapor Deposition via DC Magnetron Sputtering



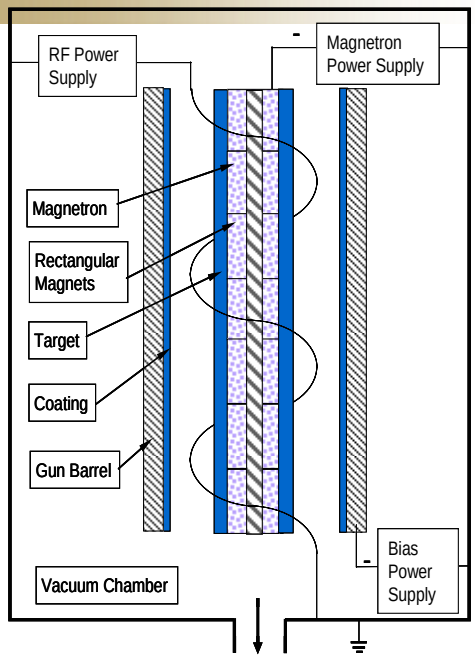
Plasma Enhanced Magnetron Sputtering with Filament and Biasing at SwRI

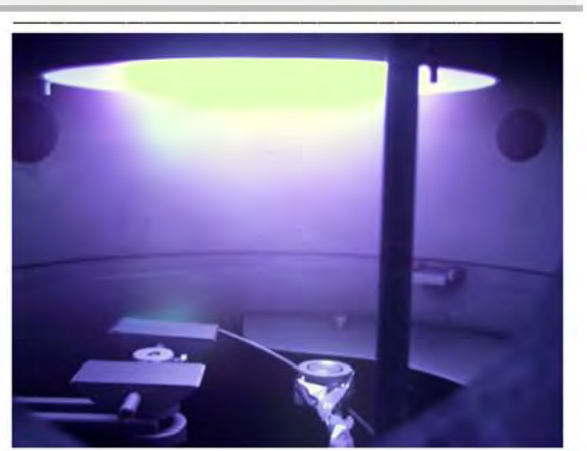


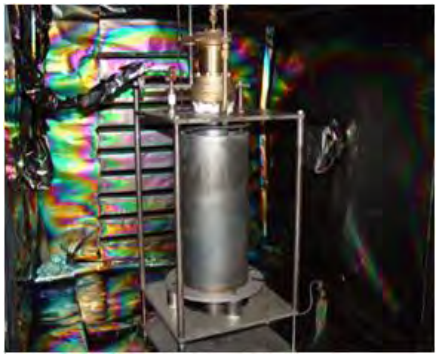
Filament Plasma + Magnetron Plasma ➡ Current Density ~ 4.9 mA/cm^2

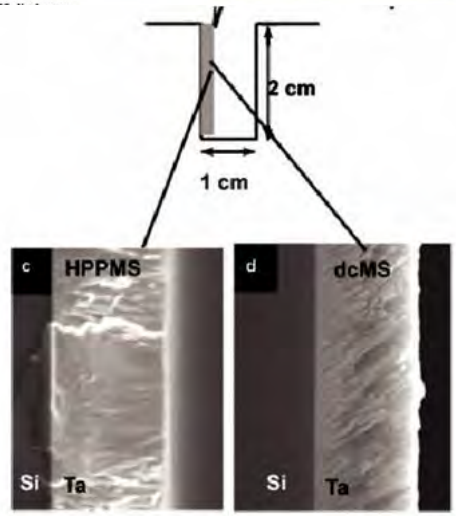
Magnetron Plasma without Filament Plasma ➡ Current Density ~ 0.2 mA/cm^2

Planned Plasma Enhanced Cylindrical Magnetron Deposition









LEFT- RF-plasma enhanced cylindrical magnetron sputtering experiments at SWRI.
MIDDLE- HIPIMS (high power impulse magnetron sputtering) from- Dr. J. Bohlmark, Dr. J. Alami.
RIGHT- ARDEC-Benet Labs CMS platforms for coating full-length 120mm large cal bore.

Potential Applications of Technology

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Properties of Ta, Cr, A723 Gun Steel

Properties	Steel	Cr	α-Ta
Melting Point Temperature [°C]	1535	1857	2996
Lattice Parameter [Angstroms]*	2.8665	2.8847	3.298
Lattice Mismatch with alpha Fe		-0.6%	-15.1%
Lattice Mismatch with alpha Ta	13.1%	12.5%	
*Thermal expansion at RT (K-1)***	1.35E-05	6.50E-06	6.50E-06
Difference in thermal expansion with Fe		51.9%	51.9%
*thermal conductivity, k [W/mK]****	45.1	98.5	57.7
*Young's Modulus, E (GPa)*****	207	248	173

*Cullity

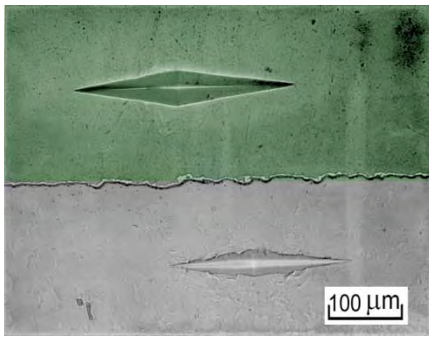
**Smithell's 6th Ed.

***Underwood; Incorpera & DeWitt, Introduction to Heat Transfer

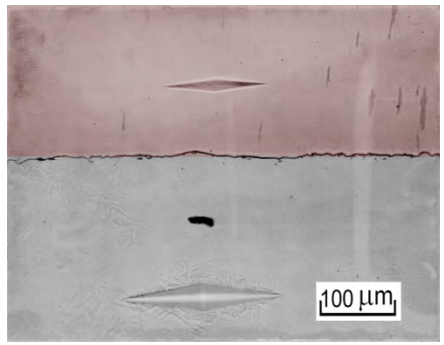
****Thornton & Colangelo, Fundamentals of Engineering Materials

Properties of bcc and tetragonal Ta

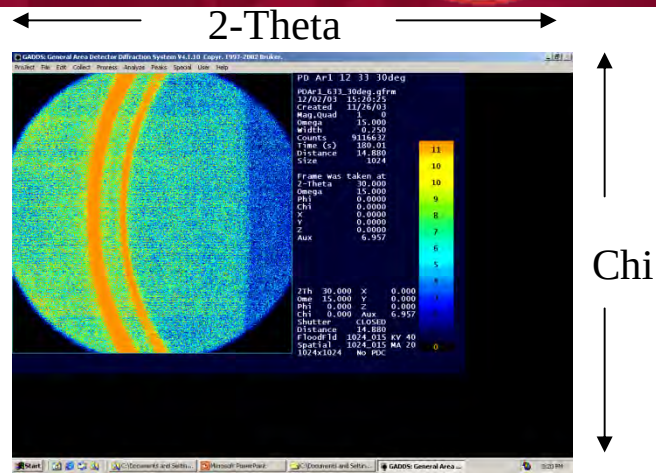
	α-Ta	β-Ta
Structure	BCC	Tetragonal
Lattice Parameters	$a=b=c=$ 0.33058 nm	$a=b$=1.0194 nm c=0.5313 nm
Hardness	100-200 KHN	1000-1200 KHN
Resistivity	15-60 μΩ-cm	200 μΩ-cm
Thermal Stability	T_m = 2996°C	$T_{\beta\Rightarrow\alpha}$ ~ 750°C
Ductility	Ductile	Brittle



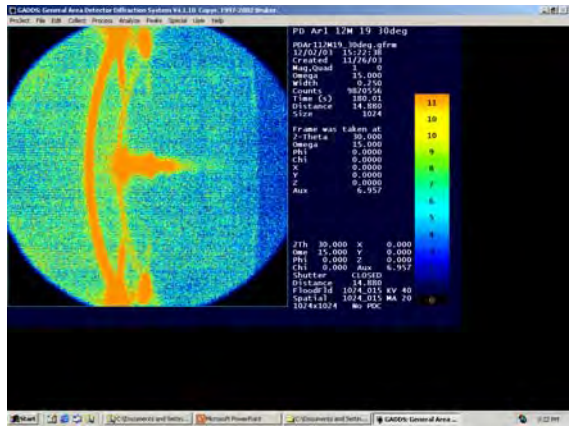
"softer" bcc Ta on Steel



"harder" tetragonal Ta on steel



Random α Ta (110) (left ring)
Random β Ta (002) (right ring)

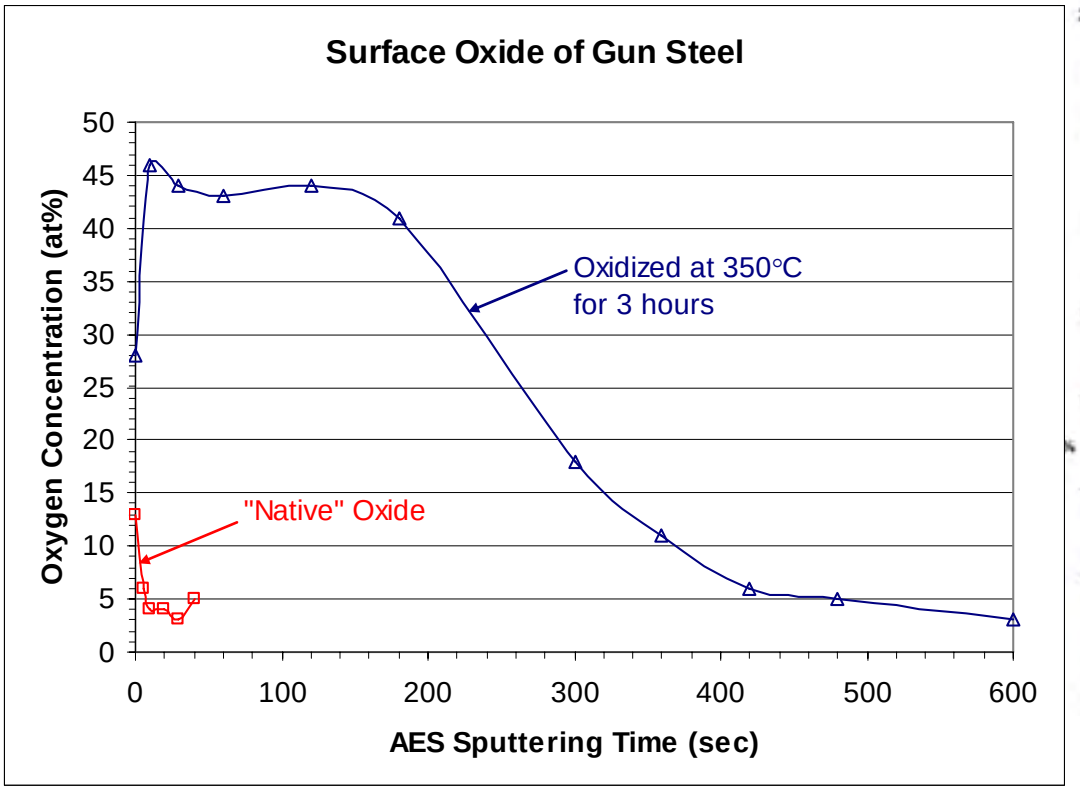


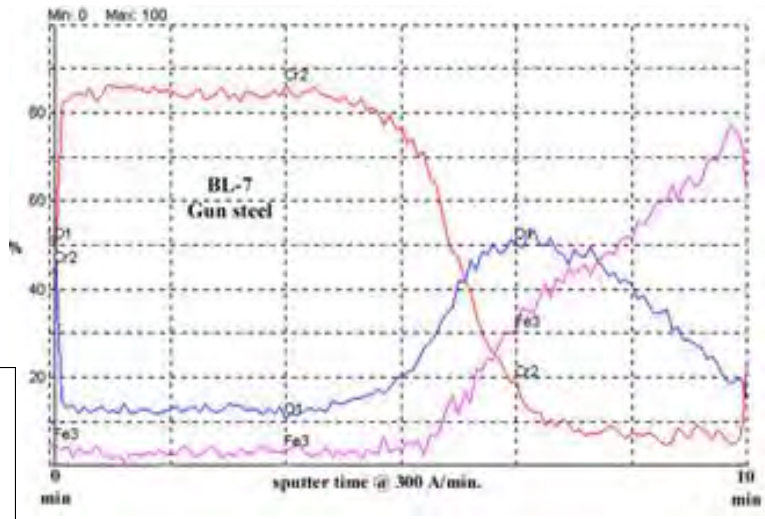
Random α Ta (110) (left ring)

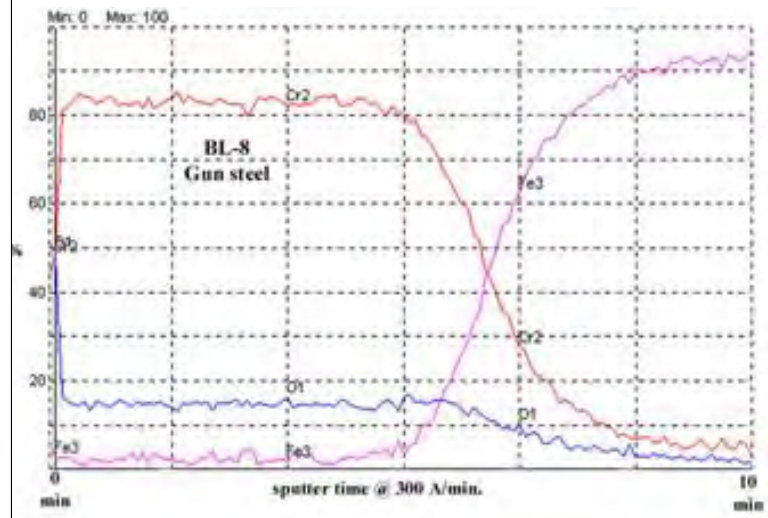
Textured β Ta (002) (right ring)

Sputter Cleaning of Gun Steel

- Native oxide on gun steel surface is ~10-20 nm
- Heat-Generated (350ºC for 3 hrs in air) oxide is ~300-350 nm.
- AES showed ion sputter cleaning for 60 min removed all native and heat-induced oxides.

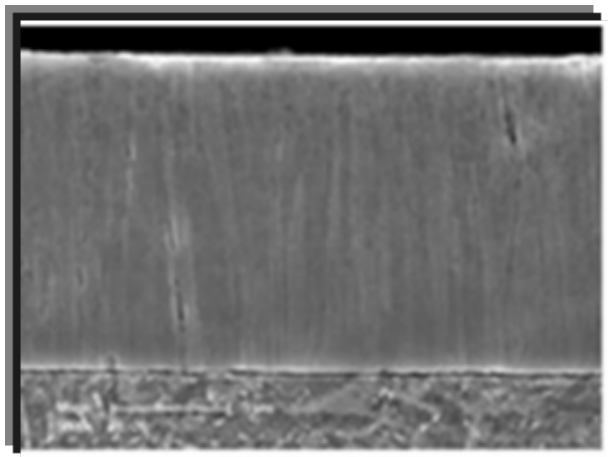


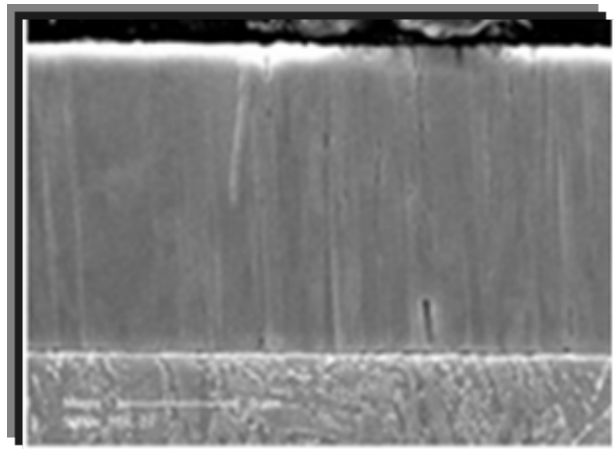


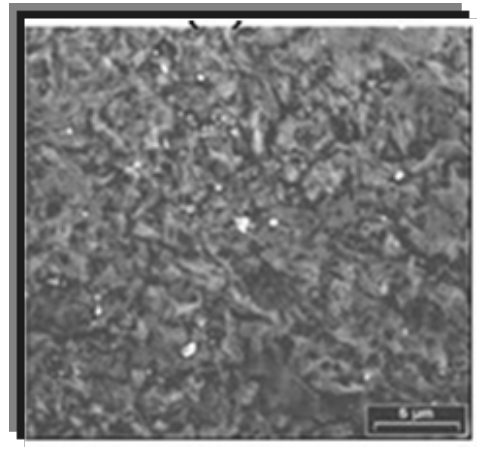


Sputtered Cr on A723 Gun Steel

Higher discharge current increases hardness, density, improves microstructure

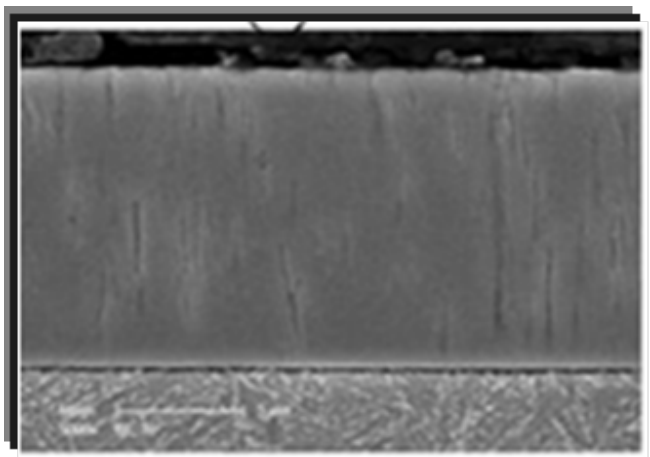


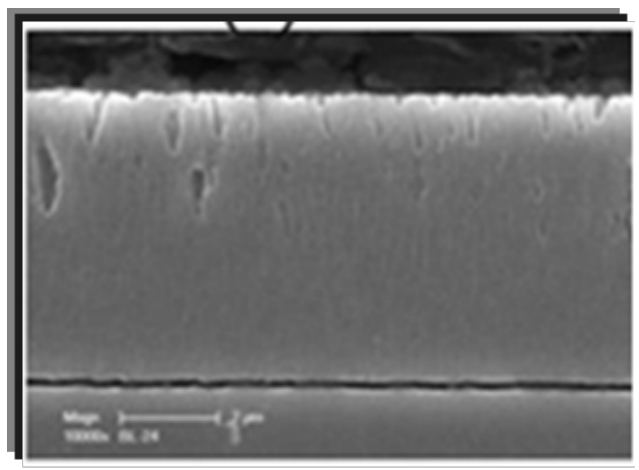


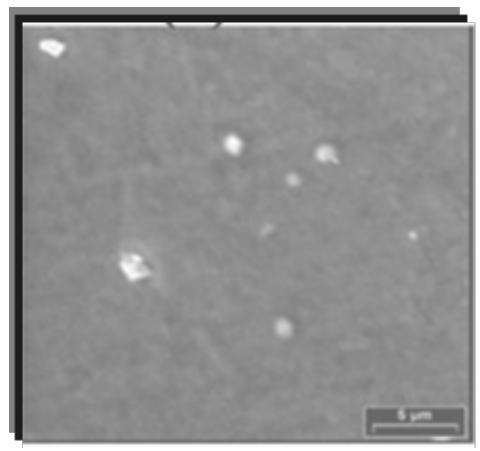


0A, 14 µm, 85 min, HK_{10} 399

5A, 13 µm, 85 min, HK_{10}633





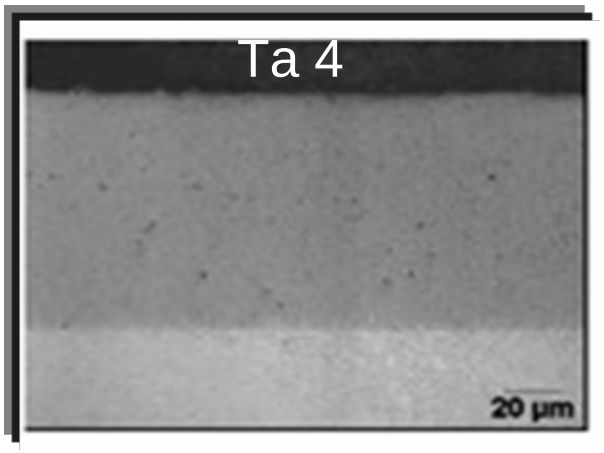


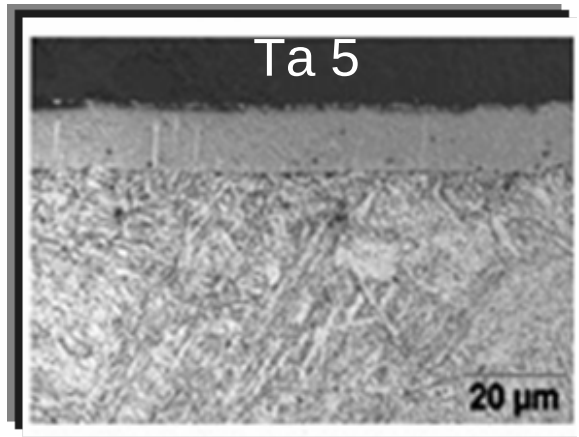
10A, 13 µm, 85 min HK_{10}1226

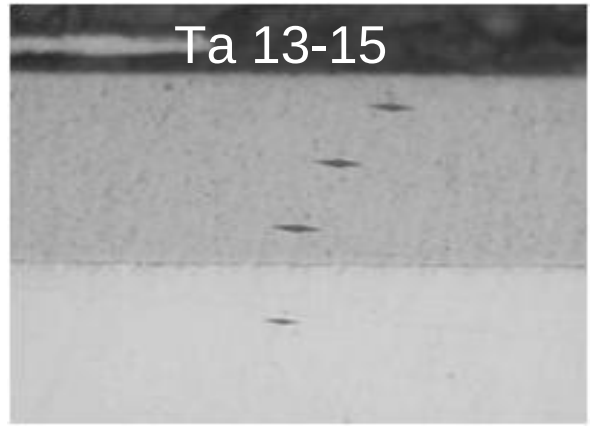
20A, 6 µm, 90 min, HK_{10}2144

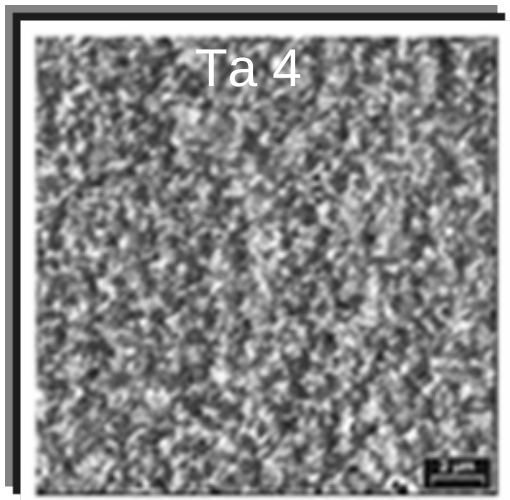
Sputtered Ta on A723 Gun Steel

Higher discharge current increases hardness, density, residual stresses, α-Ta formation

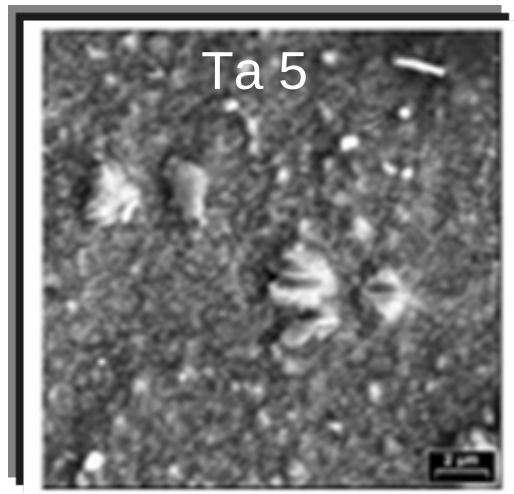




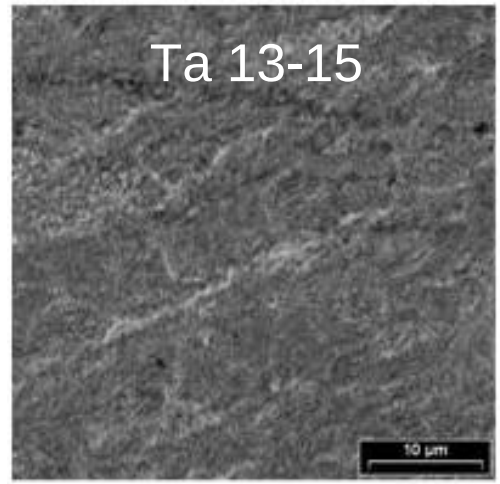




10A, 90µm, 600 min HK_{10}602, α-Ta



0A, 10µm, 60 min HK_{10} 552, (α+β)-Ta

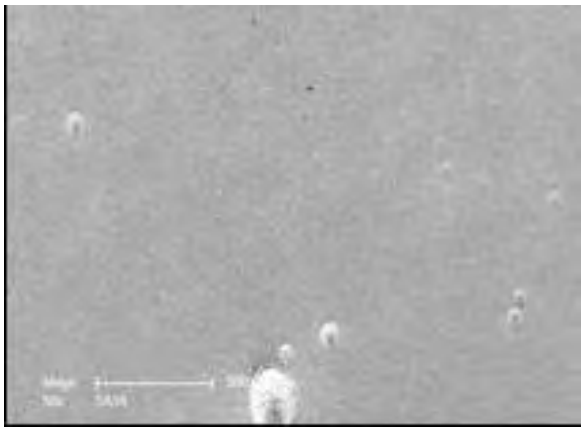


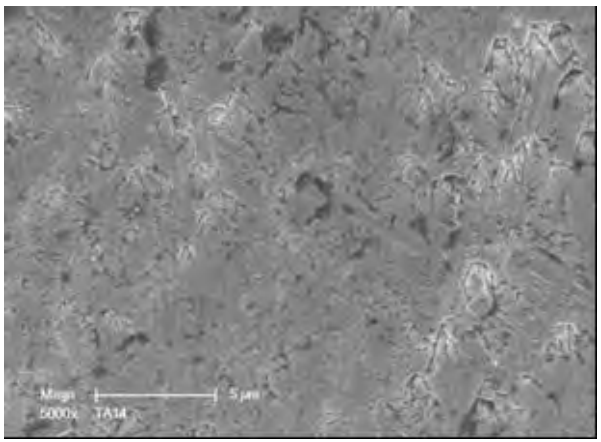
10A, 148µm, 900 min, HK_{10} 337, α-Ta

Sputtered Ta on Rifled 155mm

Plasma Enhanced DC Magnetron Coating Topography

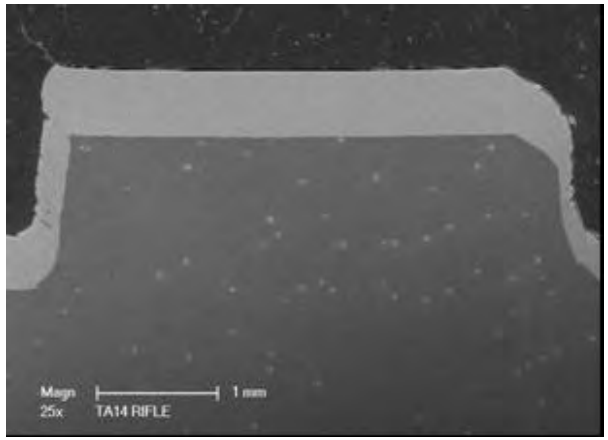
Land-Groove, 450 micron Ta Walls- 250 micron Ta

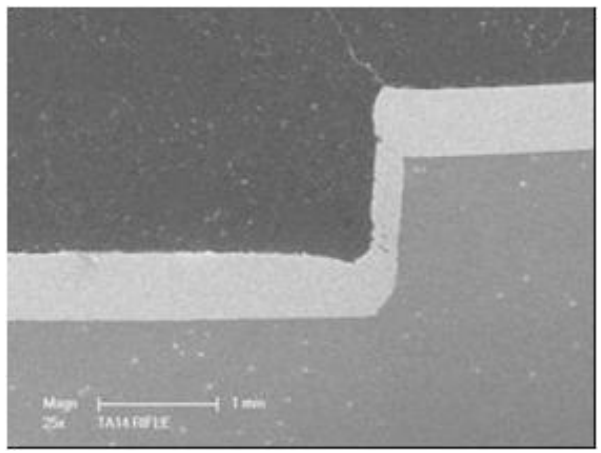




Plasma Enhanced DC Magnetron Coating Microstructure

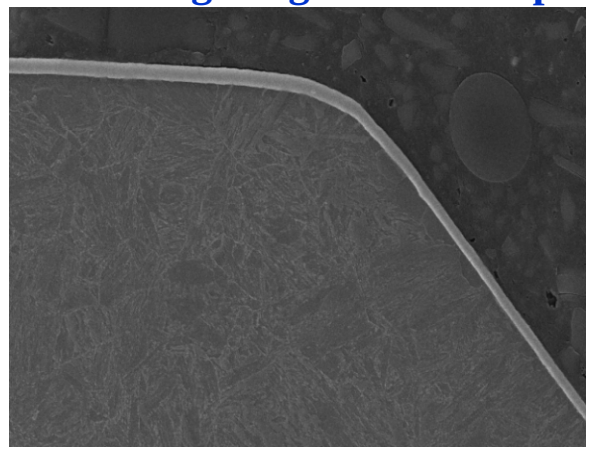
Land-Groove, 450 micron Ta Walls- 250 micron Ta

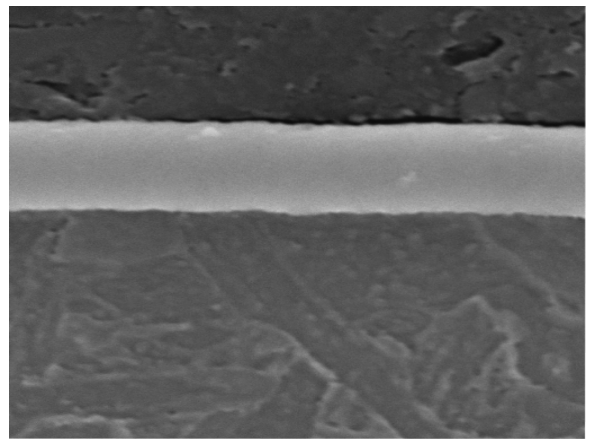




HIPIMS (High Intensity Impulse Magnetron Sputtering) (Helmersson/Rhode/Lee)

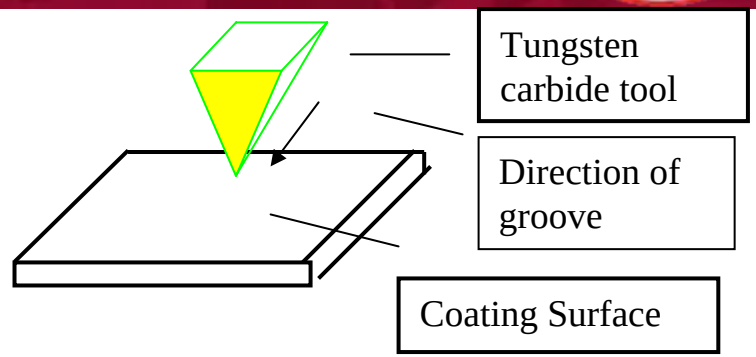
Uniform 2 micron bcc Ta on slanted edge of gun steel sample



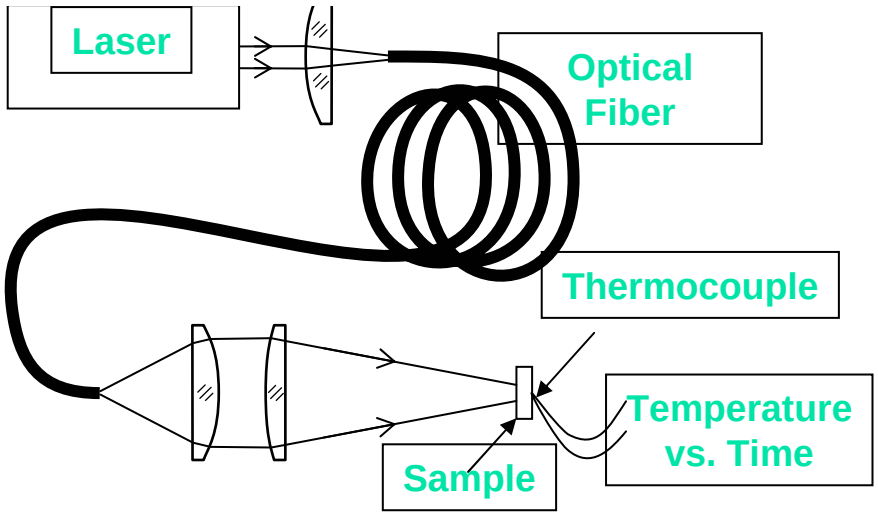


Coatings Adhesion Testing

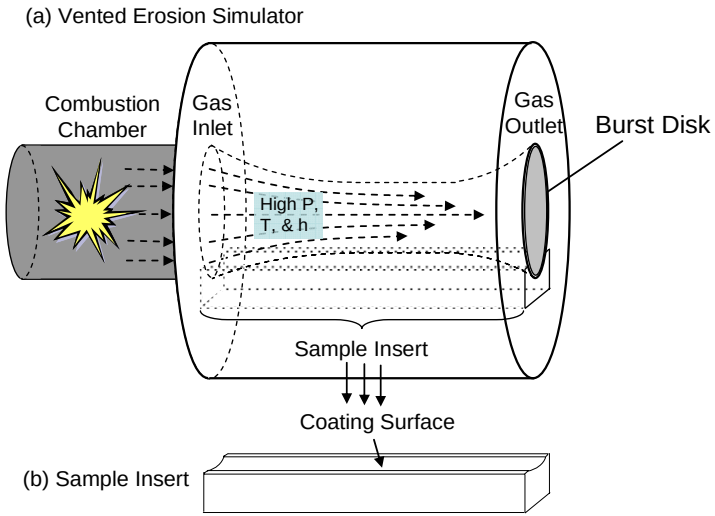
- Microscratch Test of Thin Coatings
- Groove Test (ASTM B571-91)
- Pulsed Laser Heat Test
- Vented Erosion Simulator Test (In-Door Firing Range)



Groove Test for Coatings Adhesion Strength



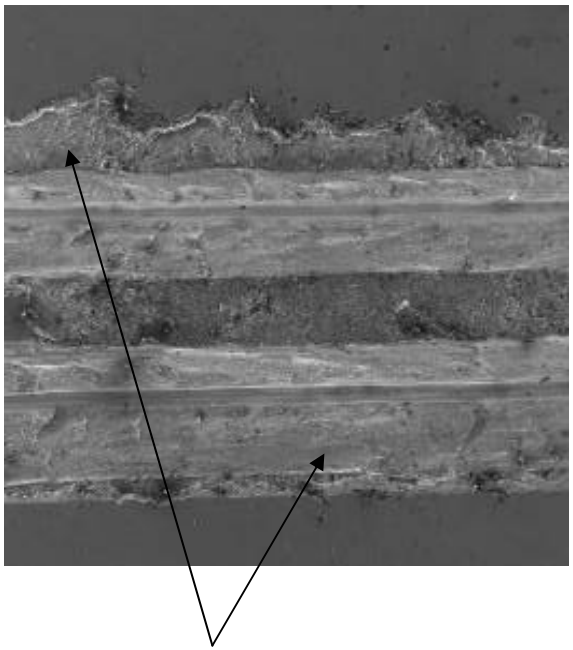
PLH (Pulsed Laser Heating) Test of Thermal Properties of Coatings



VES (Vented Erosion Simulator) Test of Thermal-Mechanical-Chemical Properties of Coatings

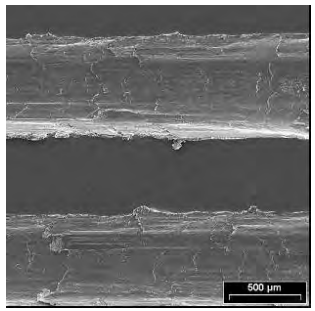
Groove Adhesion Testing
(ASTM B571-91)

Electroplated Cr

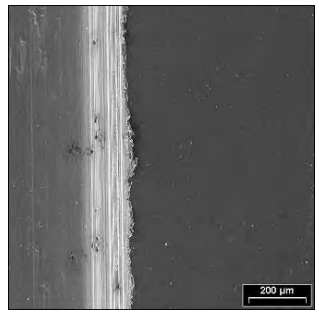


Cohesive failures

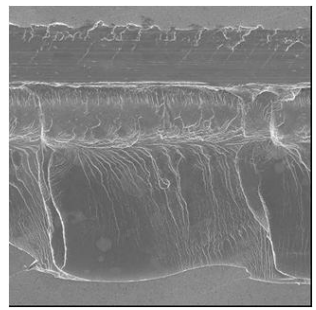
Cr16



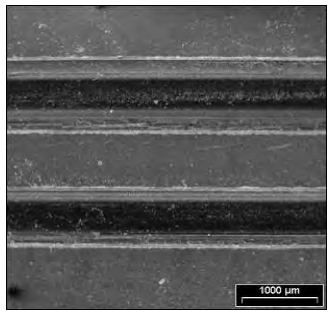
Cr24



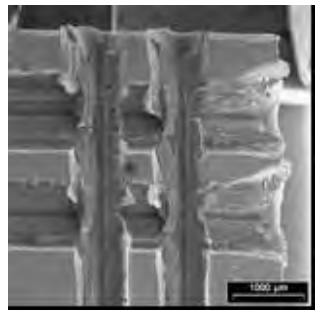
Cr 15



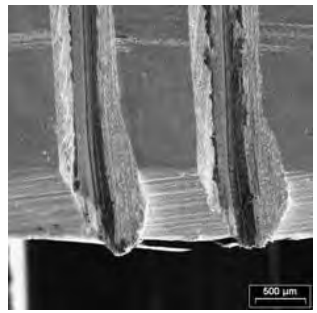
Ta3



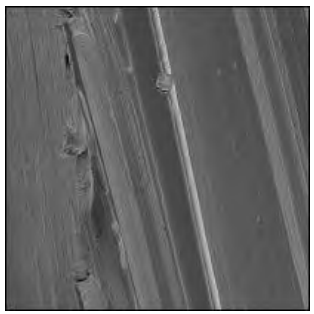
Ta12-2

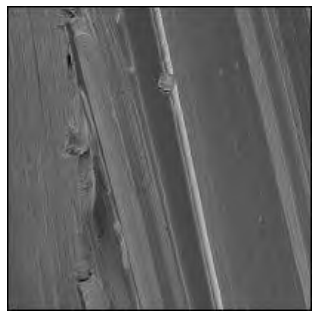


Ta13-15

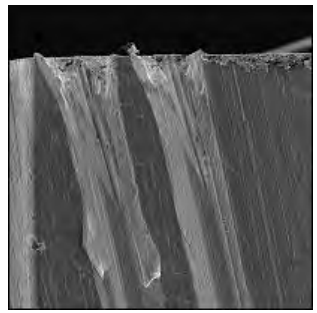


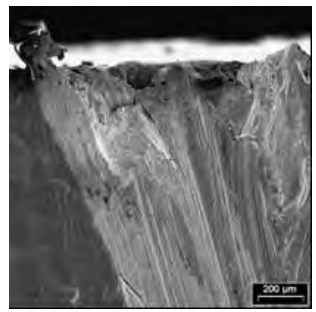
155mm Land



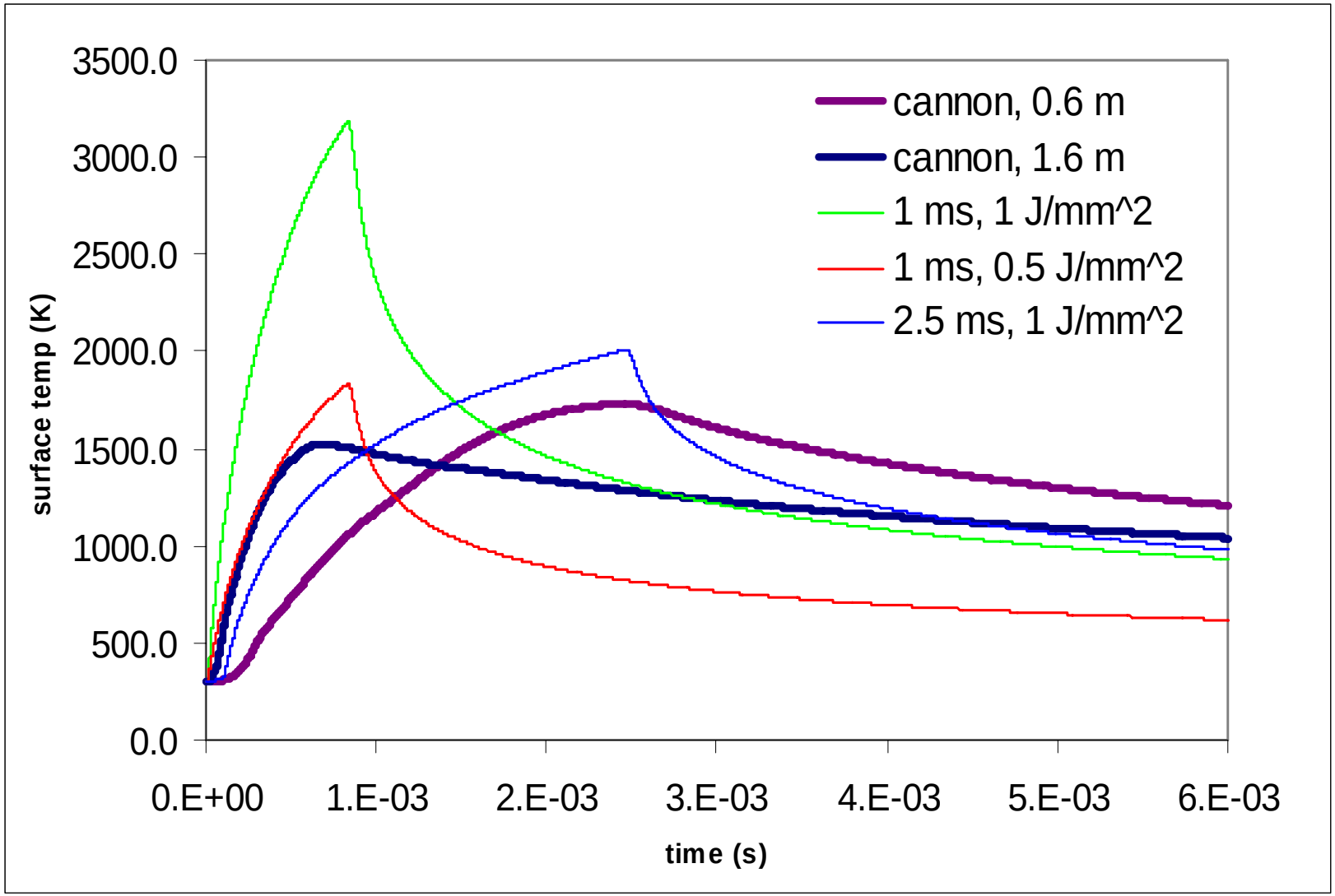


155mm Groove



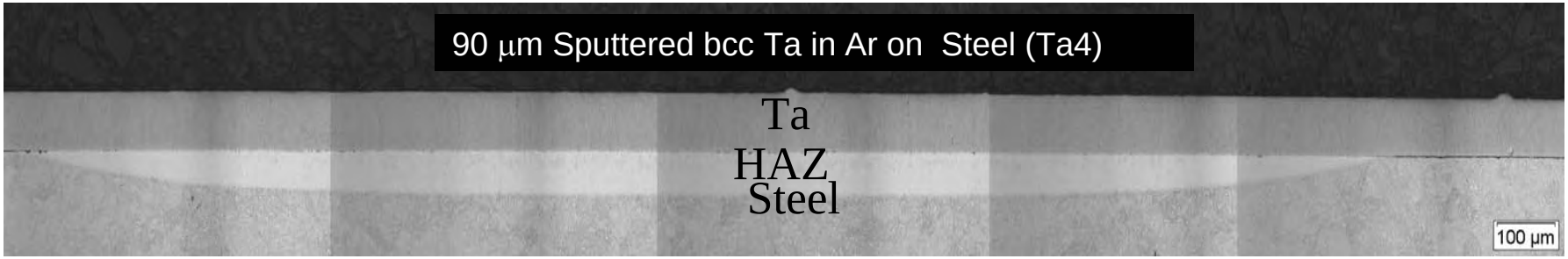


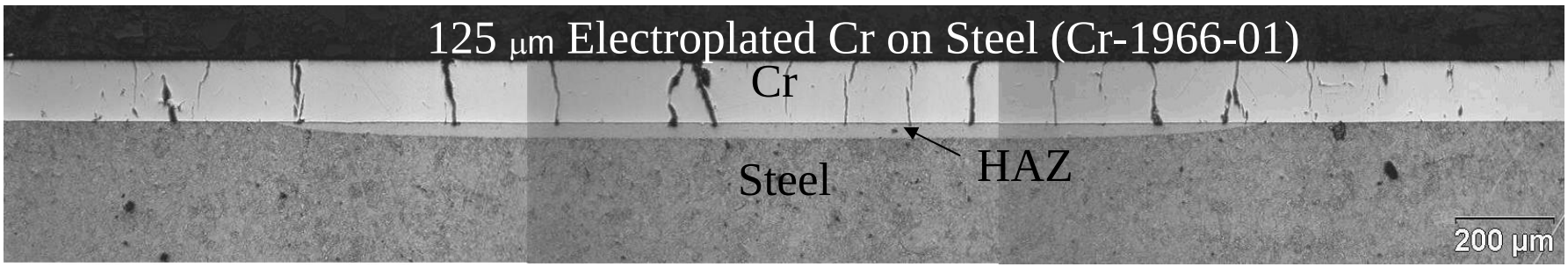
Internal Ballistic and Transient Thermal Simulation
120mm Cannon Firing and Pulsed Laser Heating



Comparative Pulsed Laser Heating Tests

PLH parameters (2.5 msec, 1.0 J/mm2, 20 cycles, simulating ~1480°C temperature)

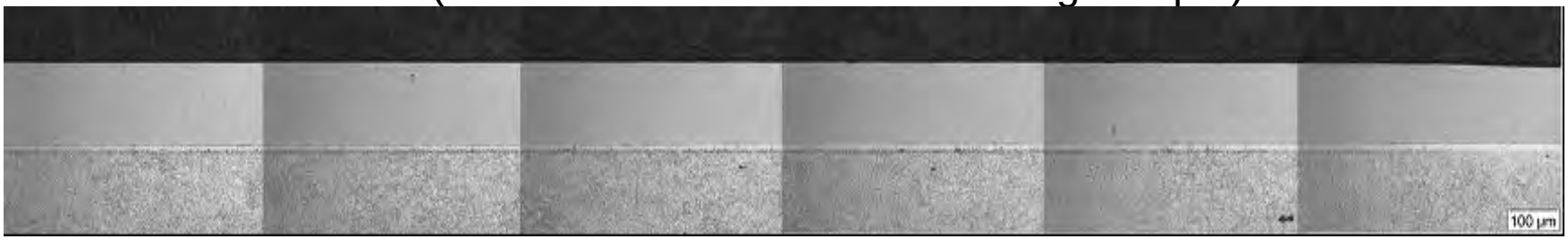




- **HAZ (Heat affected zone) in steel is due to tempered to untempered martensite transformation.**
- **During heating-cooling cycle, martensite transforms to austenite, then back to martensite**

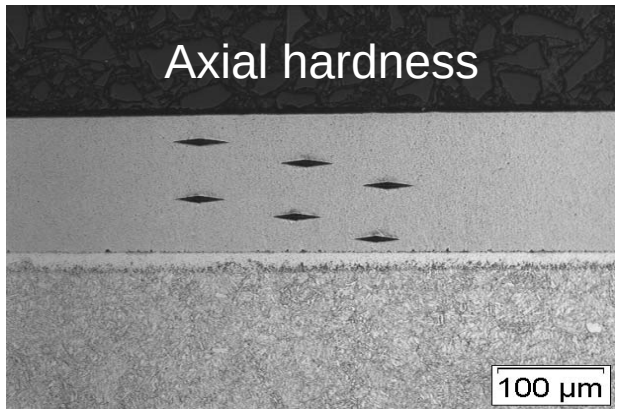
148μm Ta on Gun Steel after 25 VES Firing High Erosive RDS

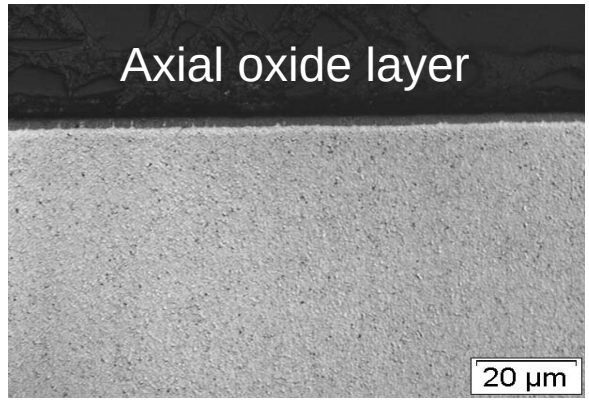
Axial (1.0 inch from end of 1.6 inch long sample)



After 25 rounds

DACP-Ta-15hr	
Indents (Top Down)	
Knoop (Hk50)	Depth of Diamond (μ)
216	28.87
254	52.99
267	77.02
278	91.91
298	110.90
322	135.60
422	steel



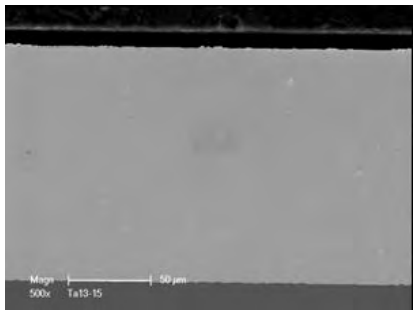


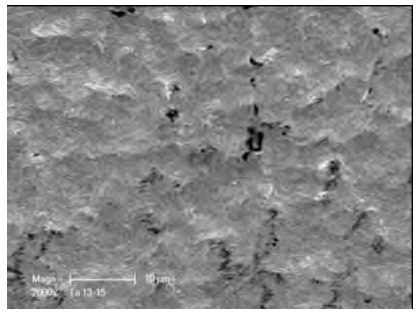
As-deposited topography - microstructure

After fired surface

As deposited

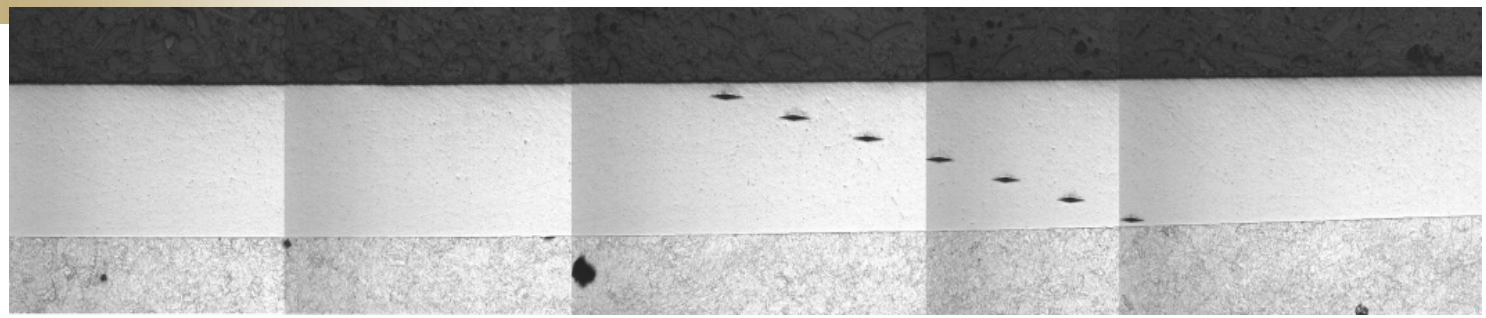
Ta-13_15	
Indents (Top Down)	
Knoop (Hk50)	Depth of Diamond (μ)
323	24.62
340	73.14
349	128.90
523	208.90





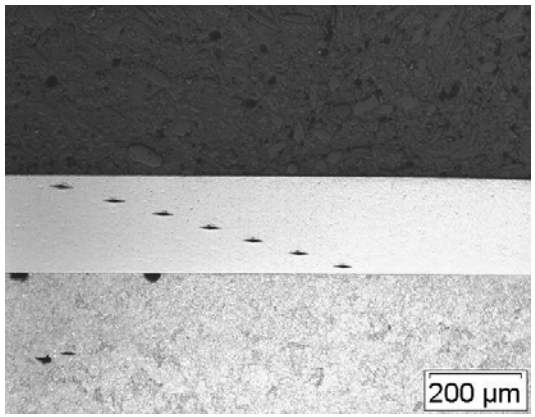
Minimal softening, good adhesion, no cracking after 25 VES rds!

286μm Ta on Steel After 129 VES Firing High Erosive RDS



DACP-Ta-13-20hr
Indents (Top Down)

noop (Hk50)	Depth of Diamond (μ)
216	19.32
247	49.35
249	80.25
273	108.00
303	137.00
325	165.70
420	195.30

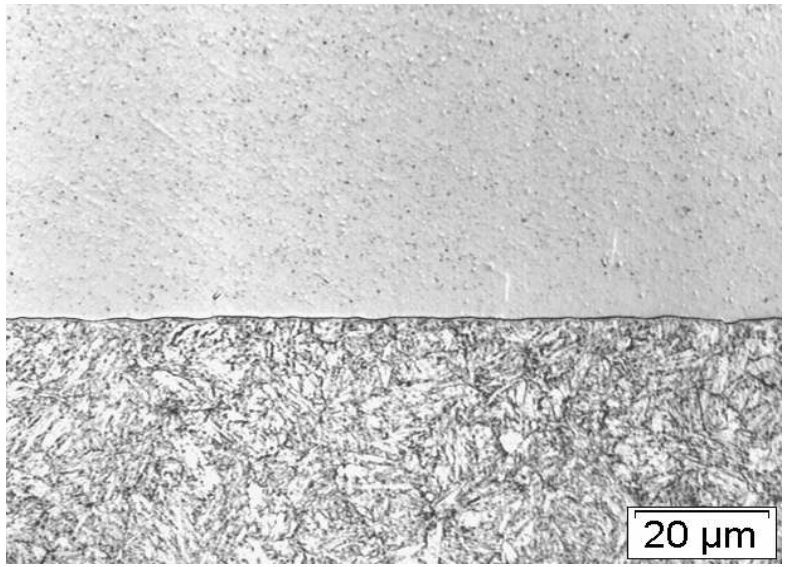


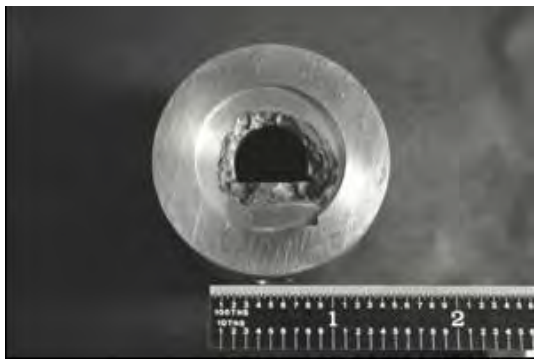
DACP-Ta-13-20hr
Indents (Top Down)

Knoop (Hk50)	Depth of Diamond (μ)
240	21.64
267	50.84
289	78.45
299	108.30
328	135.60
344	162.30
371	190.10

Longitudinal Ta Thickness = 204 μm

Transverse Ta Thickness = 203 μms

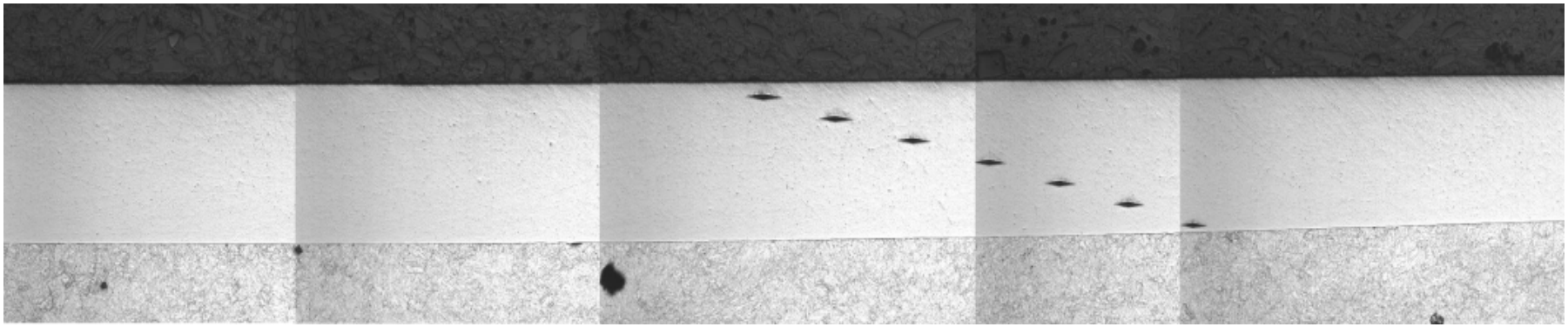




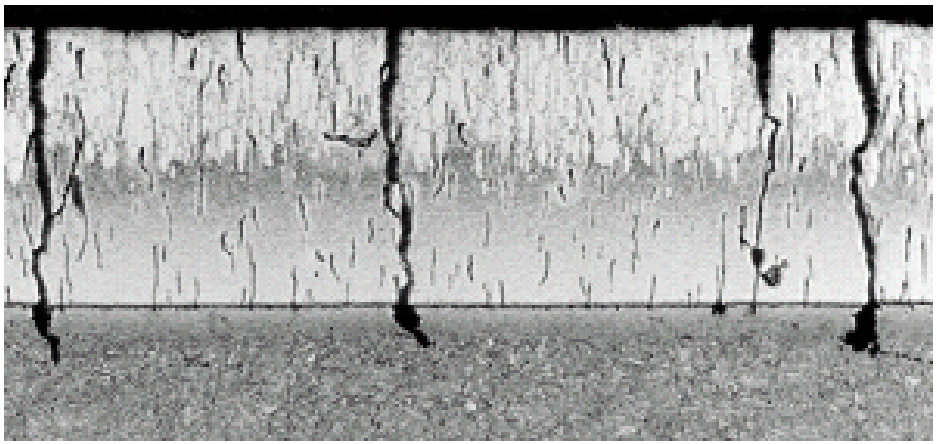
Minimal softening, good adhesion, no cracking after 129 VES rds!

VES Firing Comparison: Electroplated Cr vs. Plasma Enhanced Sputtered Ta

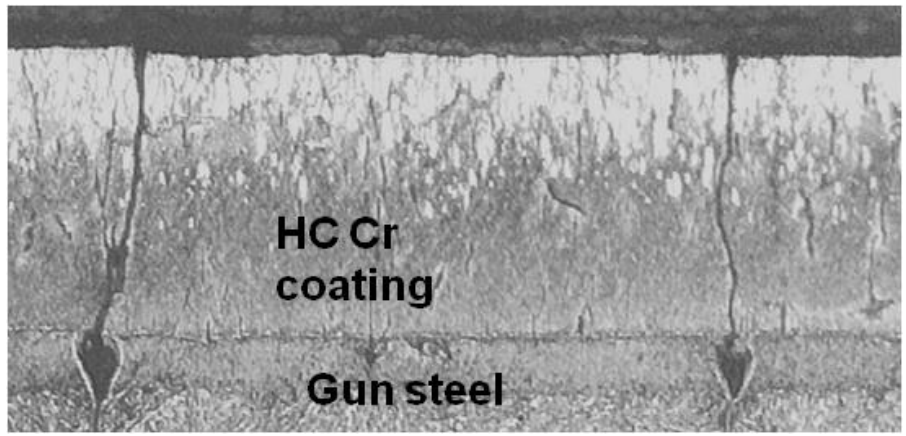
Plasma Enhanced bcc Ta (286µm) on steel after 129 cycles VES high erosive rds
Showing excellent structure, adhesion, and crack-resistance properties



Electroplated HC Cr (120µm) on Steel
~ 100 cycles of VES under same conditions



Electroplated HC Cr (120µm) on Steel
~100 cycles of actual firing of high erosive rds



Conclusions

1) Plasma enhanced magnetron technology using higher ion bombardment can deposit hard, dense, adhesive, pollution-free coatings on steel with improved microstructure.

2) Plasma enhanced sputtered Ta on 120mm and 155mm test samples demonstrated excellent structure, ductility, adhesion, and resistance against thermal shock cracking and high temperature erosion.

3) Plasma enhanced sputtered Ta has potential to coat 120mm and 155mm barrels and other armament components, with expected improved cycle life due to the high melting point temperature and absence of cracks.

GENERAL DYNAMICS
Ordnance and Tactical Systems

NDIA 43rd Annual Armament Systems: Gun and Missile Systems
Conference & Exhibition Event #8590
April 21-24, 2008
New Orleans, Louisiana

30x173mm High Explosive Incendiary Product Improvement

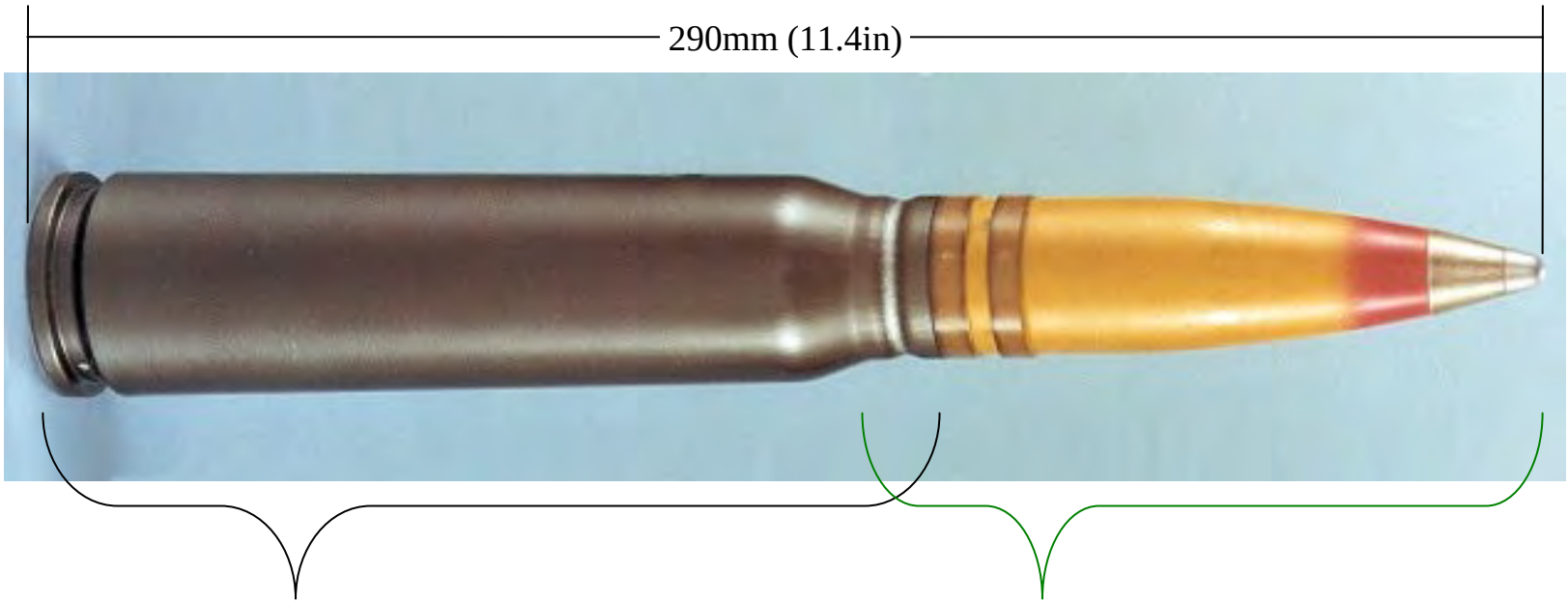
Approved For Public Release

30x173mm PGU-13/B HEI Improvement

GAU-8 Avenger
- **7 Barrel Rotary Cannon**
- **30x173mm ammunition mix**
- **PGU-14/B Armor Piercing Incendiary (API)**
- **PGU-13/B High Explosive Incendiary (HEI)**
- **Light and Heavy Armored Ground Targets**

USAF A-10 THUNDERBOLT II

PGU-13/B High Explosive Incendiary (HEI) Cartridge

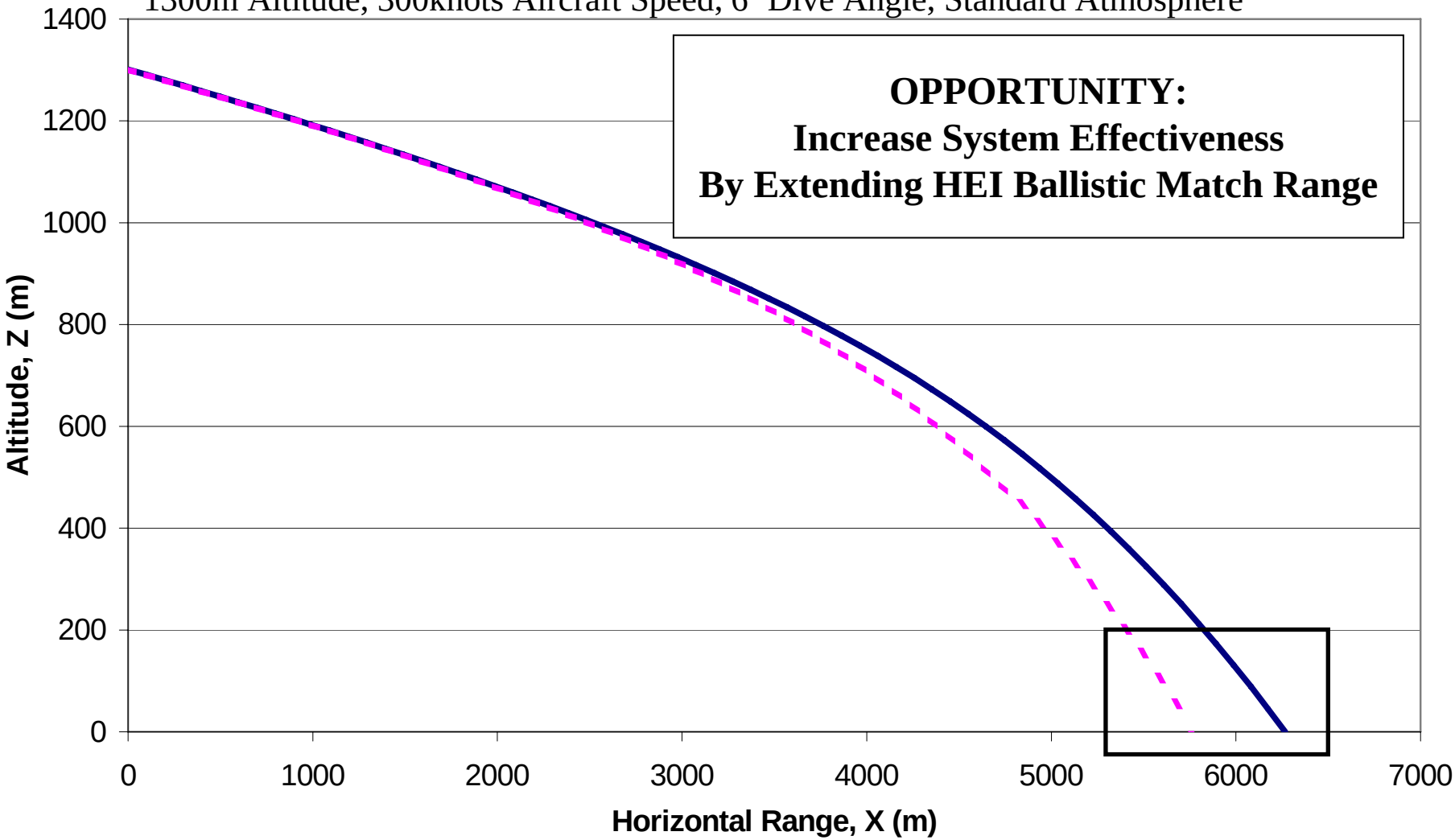


Propulsion System
- **Aluminum Cartridge Case**
- **Percussion Primer**
- **Flashtube**
- **Extruded Propellant**

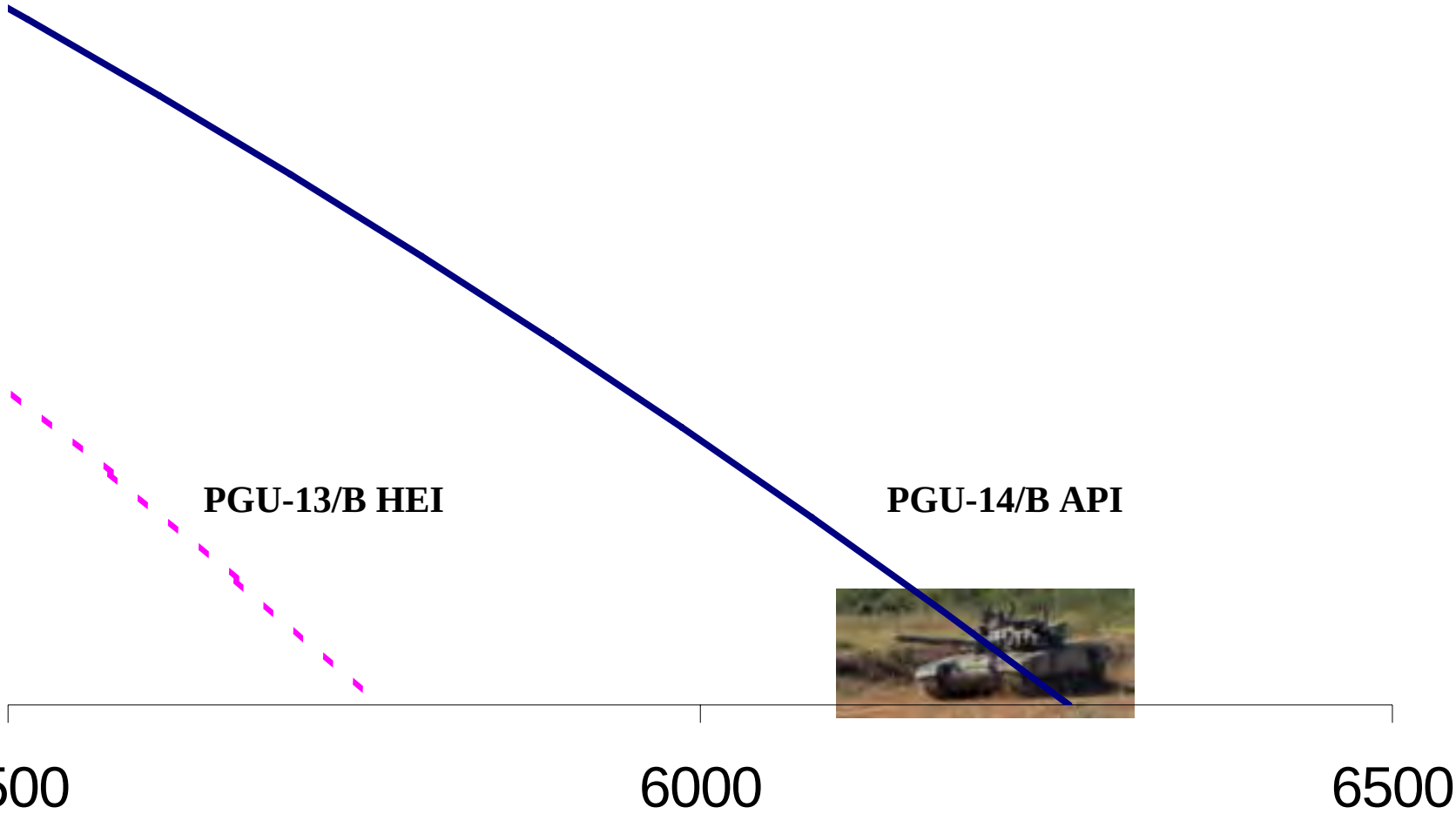
Projectile
- **Steel Body**
- **Dual Plastic Driving Bands**
- **High Explosive Fill**
- **M505 Point Detonating Fuze**

30x173mm PGU-13/B HEI Improvement

1300m Altitude, 300knots Aircraft Speed, 6º Dive Angle, Standard Atmosphere



30x173mm PGU-13/B HEI Improvement

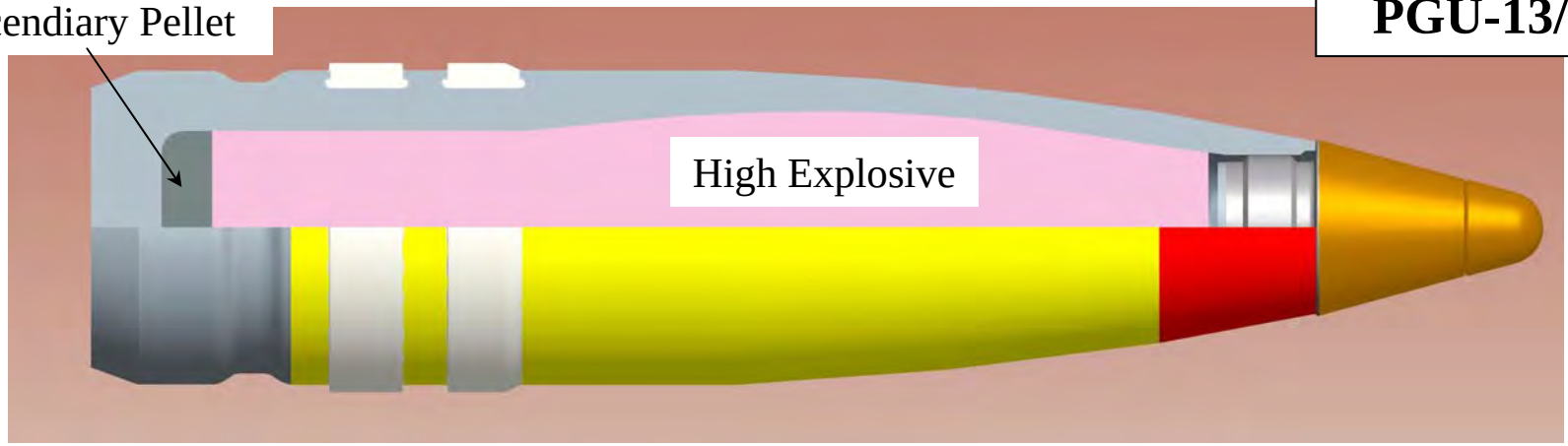


Fire Control Solution Puts PGU-14/B On Target, PGU-13/B Falls Short

30x173mm PGU-13/B HEI Improvement

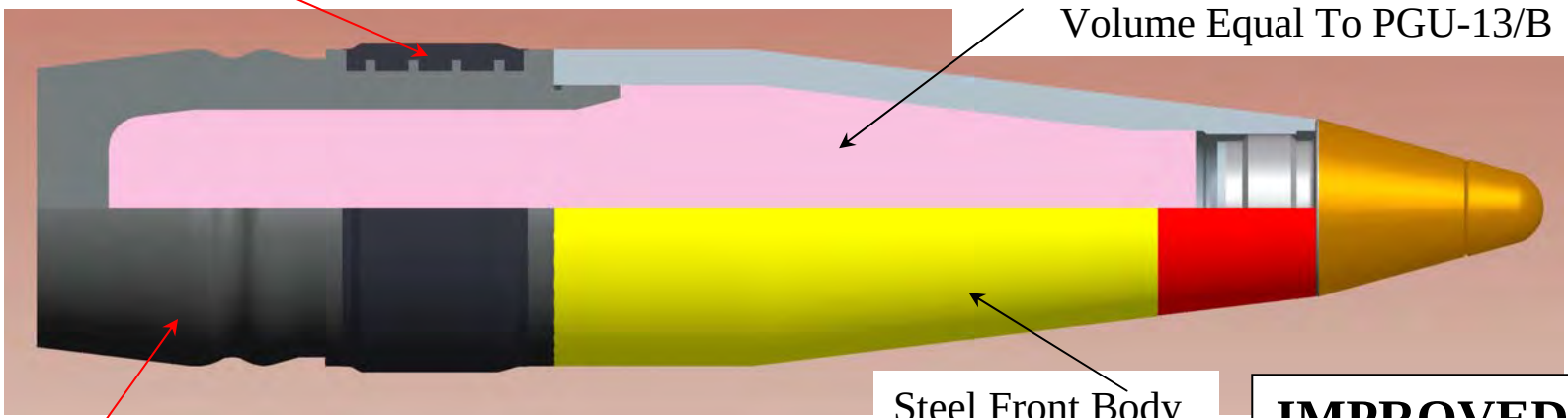
PGU-13/B

Incendiary Pellet



One-Piece Plastic Driving
Common Within Ammunition Family

Alternate Explosive Fill
Incorporates Incendiary Function
Volume Equal To PGU-13/B



IMPROVED HEI

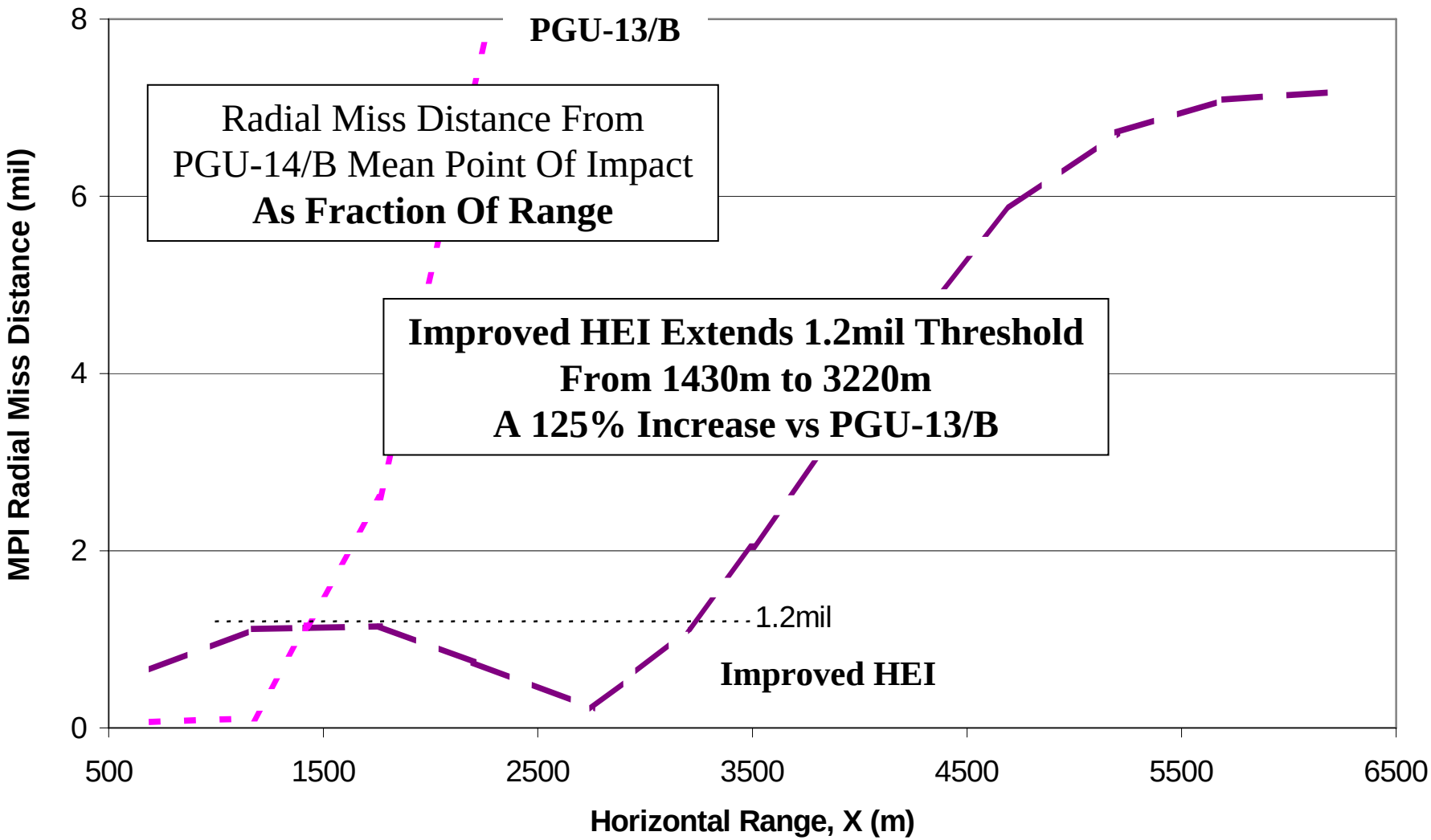
Aft Body Is Cobalt Free Tungsten Alloy With High Iron Concentration
Boattail Added For Reduced Drag, Same As PGU-14/B API

30x173mm PGU-13/B HEI Improvement

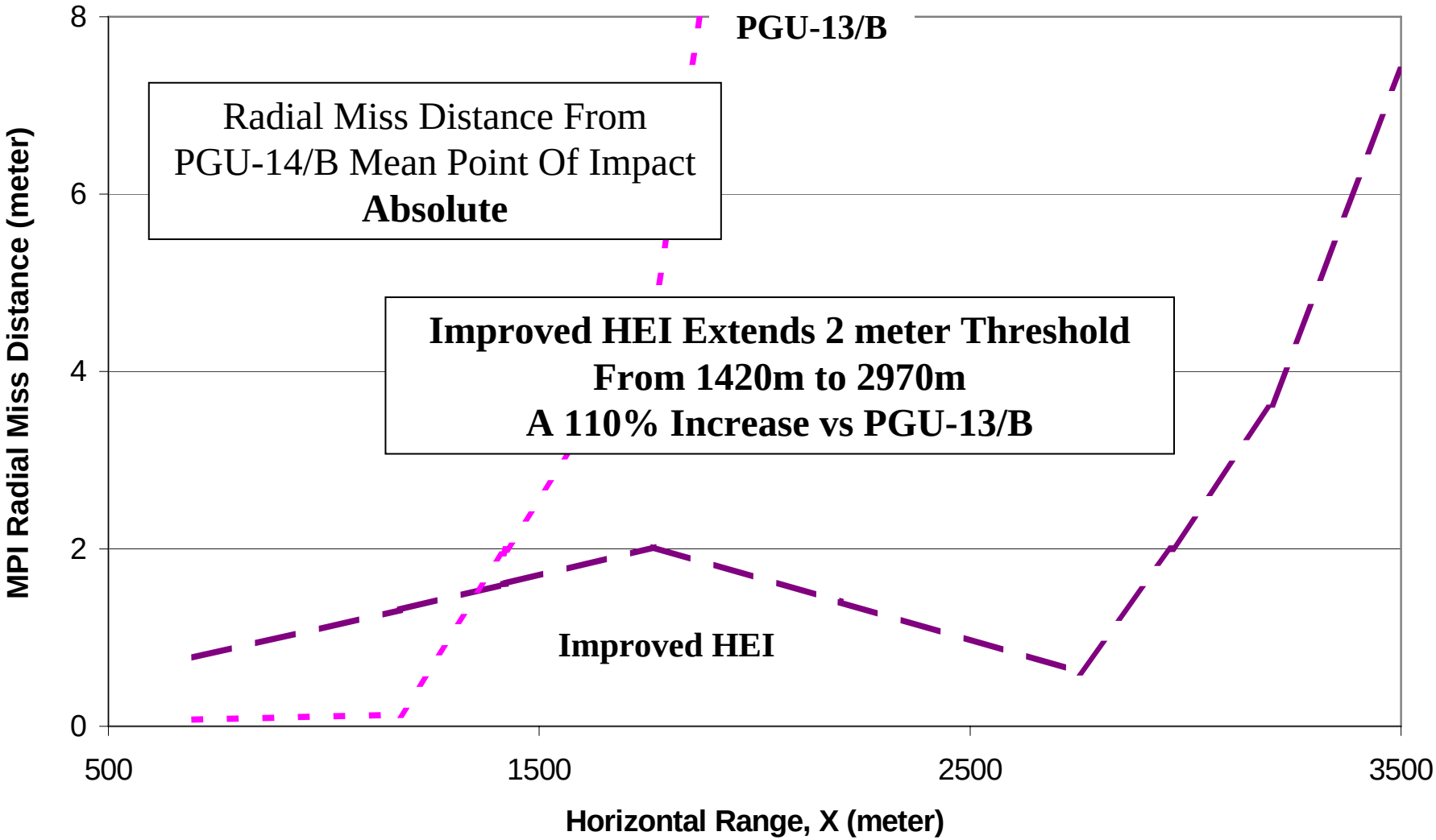
Projectile	Mass	Muzzle Velocity
PGU-14/B API	426 g	990 m/s
Improved HEI	419 g	1013 m/s
PGU-13/B HEI	367 g	1021 m/s

Improved HEI Is Predicted To Meet Pressure And Action Time Requirements Using The Same Propulsion System As PGU-14/B

30x173mm PGU-13/B HEI Improvement



30x173mm PGU-13/B HEI Improvement



IMPROVED HEI STATUS:

- **Key innovation is the use of non-standard tungsten alloy aft body material** that adds a degree-of-freedom for projectile design. This eliminates sleeved designs that are susceptible to setback induced motion with associated potential for in-bore detonation.
- **Ammunition ICD requirements are met** and the ammunition family **common propulsion system can be utilized**.
- Bourrelet length is reduced 6% versus PGU-13/B (tends to increase dispersion) but aerodynamic jump factor is also reduced 19% (tends to decrease dispersion). Net effect is predicted 14% reduction in dispersion due to balloting. **No net increase in dispersion versus PGU-13/B is expected.**
- **The projectile is gyroscopically and dynamically stable**, predicted maximum yaw limit cycle is 1 degree.
- **Ballistic match is greatly improved (smaller miss distance)** past 1400m with only a small penalty below 1400m. Bi-conic ogive is believed to provide lower drag than modeled in this example. Margin could be used to reduce pressure (through reduced muzzle velocity) or to further extend ballistic match range.

IMPROVED HEI STATUS:

- **Concept shown preserves blast and fire start lethality while eliminating separate incendiary pellet**.

POTENTIAL CONCERNS:

- Predicted aft body stresses are higher than the expected strength of the cobalt free tungsten alloys being considered. Future optimization studies will likely reduce explosive volume to allow sidewall thickness increase for reduced stress. Ballistic match will be preserved.
- Net effect on lethality for reduced explosive payload will need to be evaluated; increased density of the aft body fragments should improve penetration.
- Direct contact of tungsten alloy with the bore is not now done for any product known to GD-OTS. Potential for increased barrel wear exists. The high iron concentration of the aft body should mitigate this risk and coatings are available to further reduce it.

NEXT STEPS:

- Verify capability to fabricate aft bodies over the potential range of densities.
- Characterize aft body material strength and finalize sidewall thickness.
- Evaluate methods for joining aft and front bodies.
- Evaluate metal parts security and total drag by ballistic test.

General Dynamics 30x173mm Improved HEI Provides A High Degree Of Compliance With Technical Requirements And Is Ready For Prototyping

Israel Military Industries Ltd. (IMI)

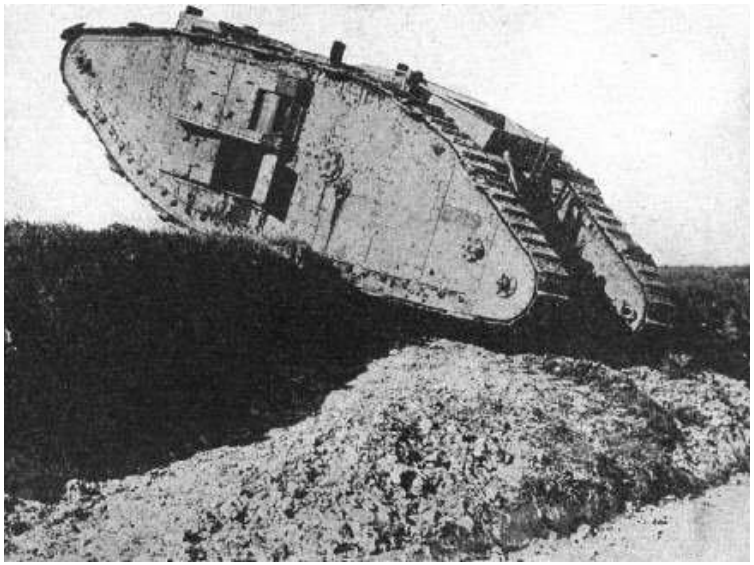
Munition Systems Division

Ammunition for the changing role of the tanks in modern battlefield

JACOB MOAV

April 2008

World War 1 – Infantry Support



World War 2 – Combined Arms Team

Cold War – The Ultimate A.T. Weapon

Cold War – The Ultimate A.T. Weapon

HEAT-MP-T

APFSDS-T

Main Role of the Tank: Direct Fire Support

21st Century – Asymmetric warfare

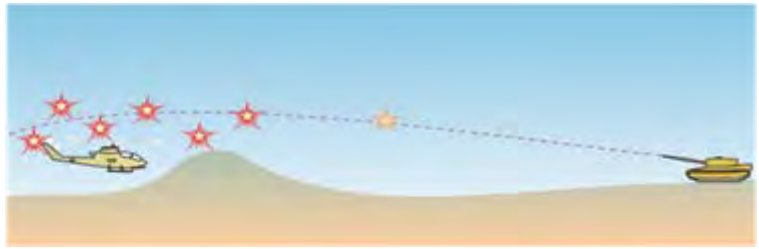
APAM

Anti-Personnel/Anti-Materiel Multi-Purpose Tank Round

THE AMMUNITION OF TOMORROW
TODAY FROM IMI

APAM - A True Multi-Purpose Round

Infantry & AT Squads



Hovering Helicopters

Light Armour

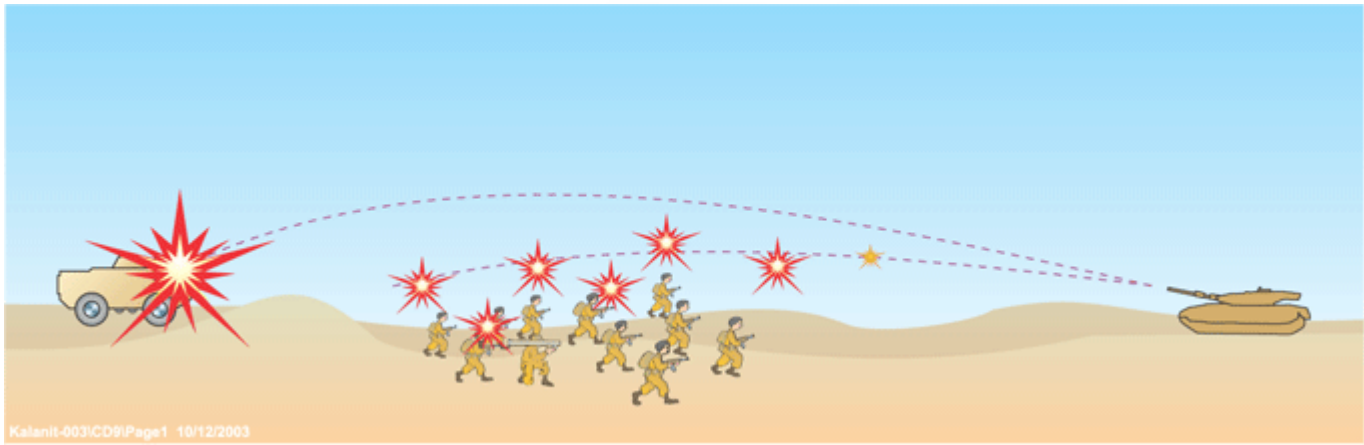
MOUT

Wall Breaching

Concrete Wall

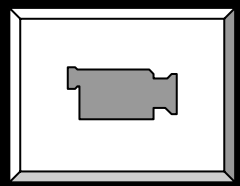
Earth & Timber Bunkers

APAM – Basic Modes of Operation

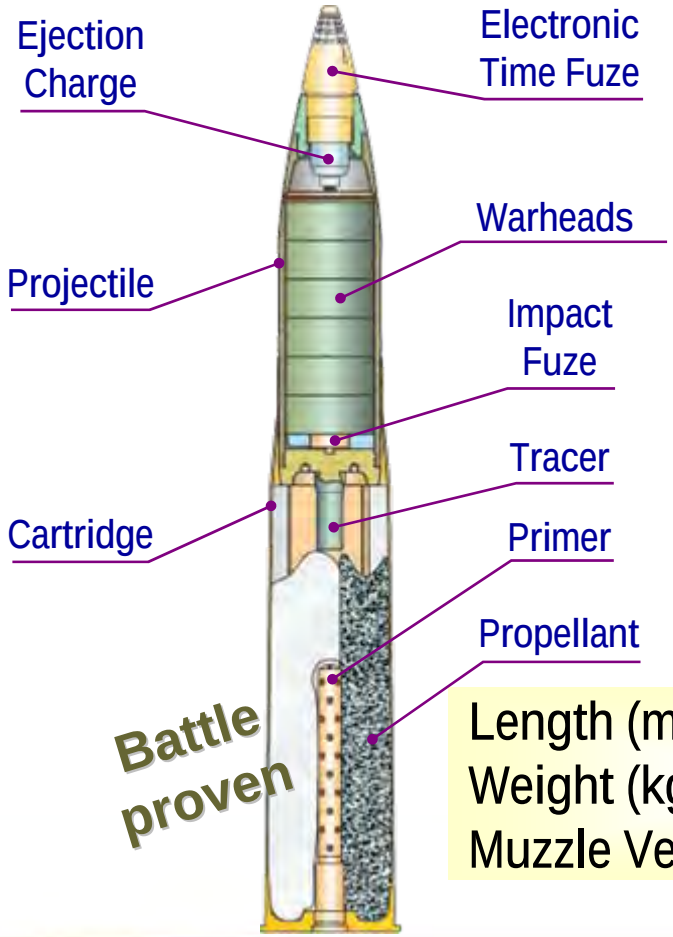


- **Ejection Mode –** Ejected Warheads explode sequentially in the air after separation.
  - ✓ Anti-Personnel
  - ✓ Anti-Helicopter
- **Impact Mode** – Entire projectile explodes as a unitary warhead upon impact.
  - ✓ LAV's
  - ✓ Bunkers & Buildings

APAM Video Clip



APAM Anti-Personnel/Anti-Materiel ROUND



120 mm

Length (mm)	984
Weight (kg)	26
Muzzle Vel. (m/s)	930

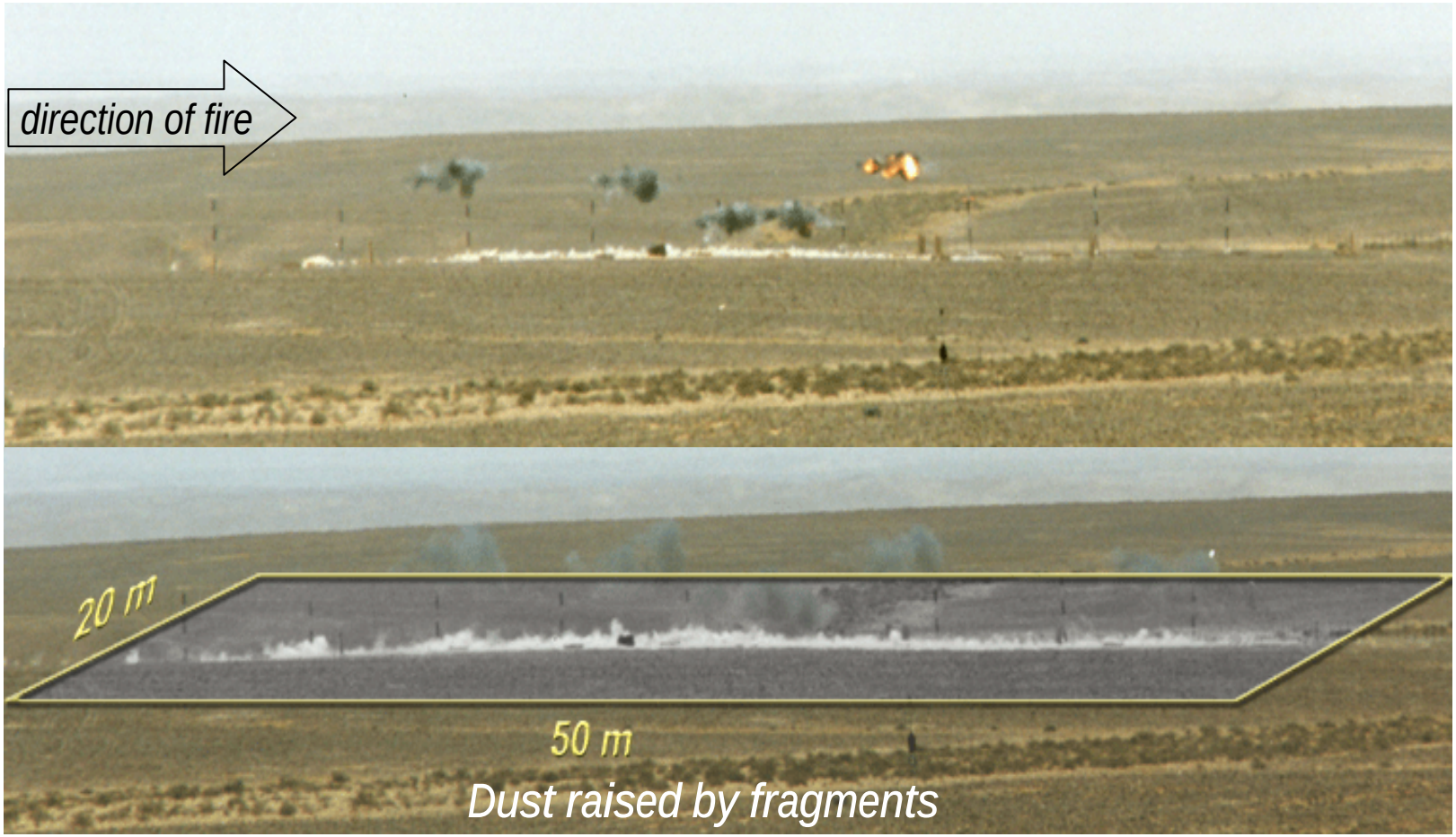
Status

- 105 mm in operational use.
- 120 mm in FSD.

105 mm

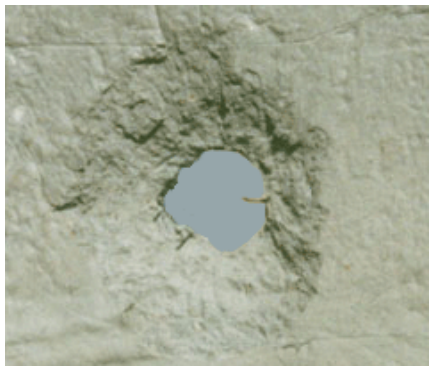
Length (mm)	998
Weight (kg)	24.7
Muzzle Vel. (m/s)	800

APAM 105 - DYNAMIC ARENA TEST

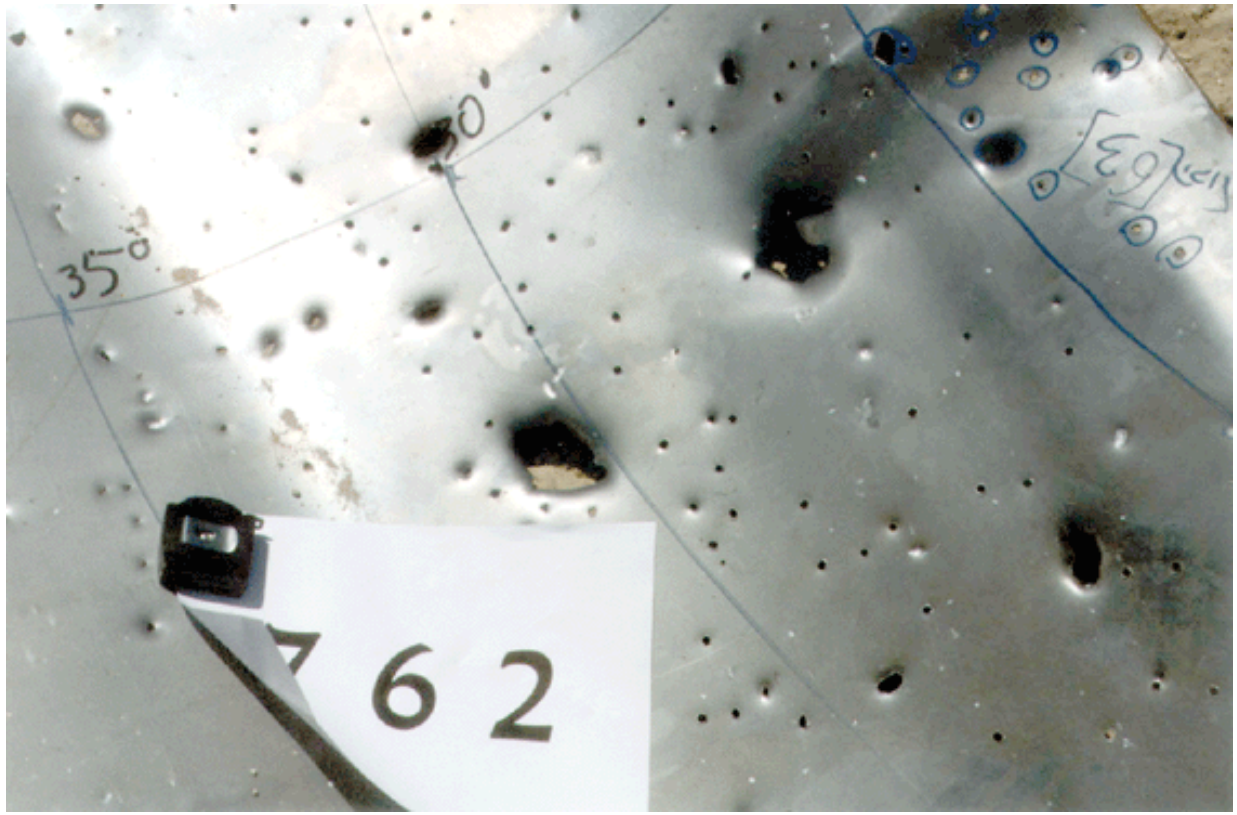


APAM 105 – Anti-Materiel Mode

light armour



double reinforced concrete wall

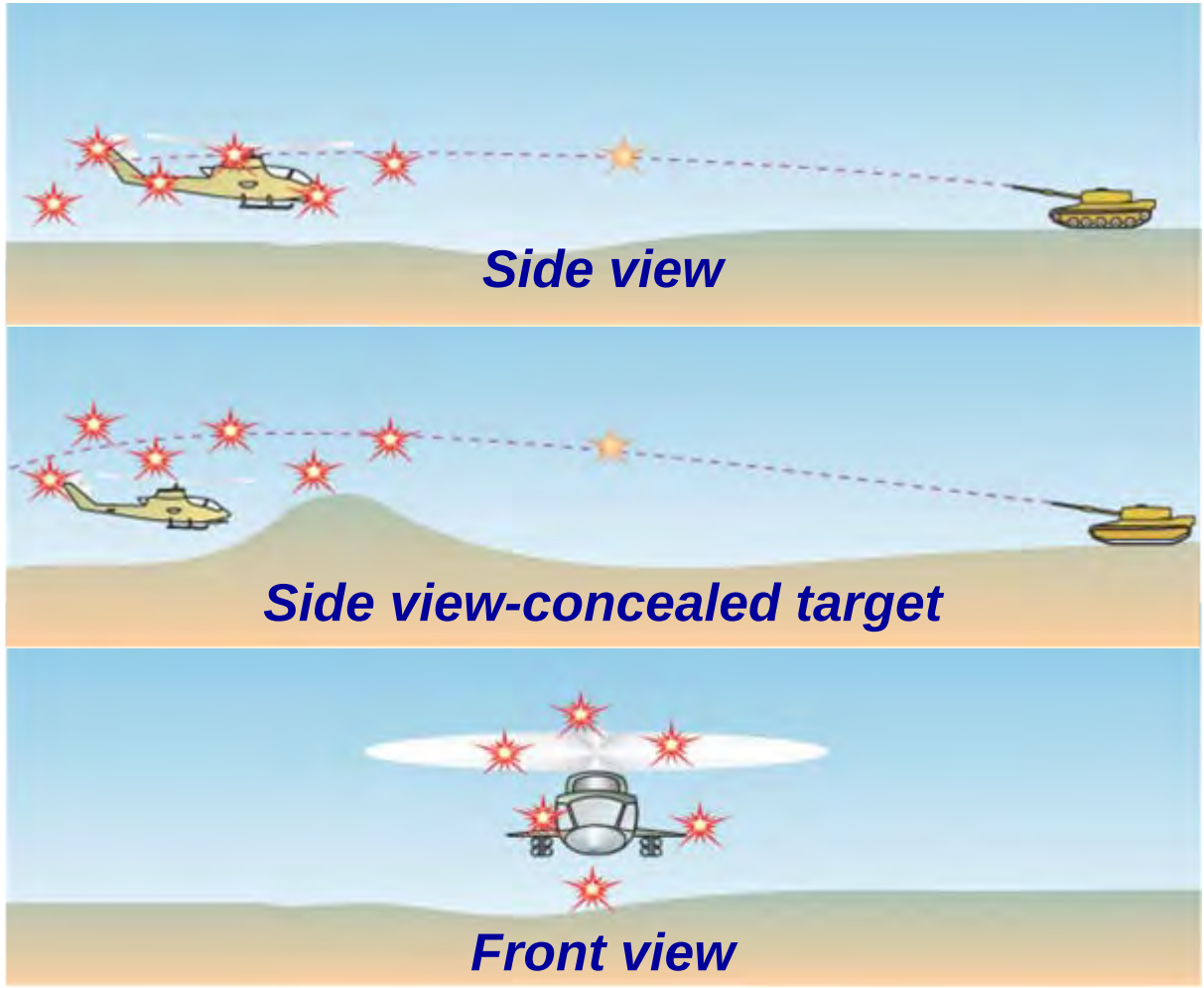


hits on witness plate

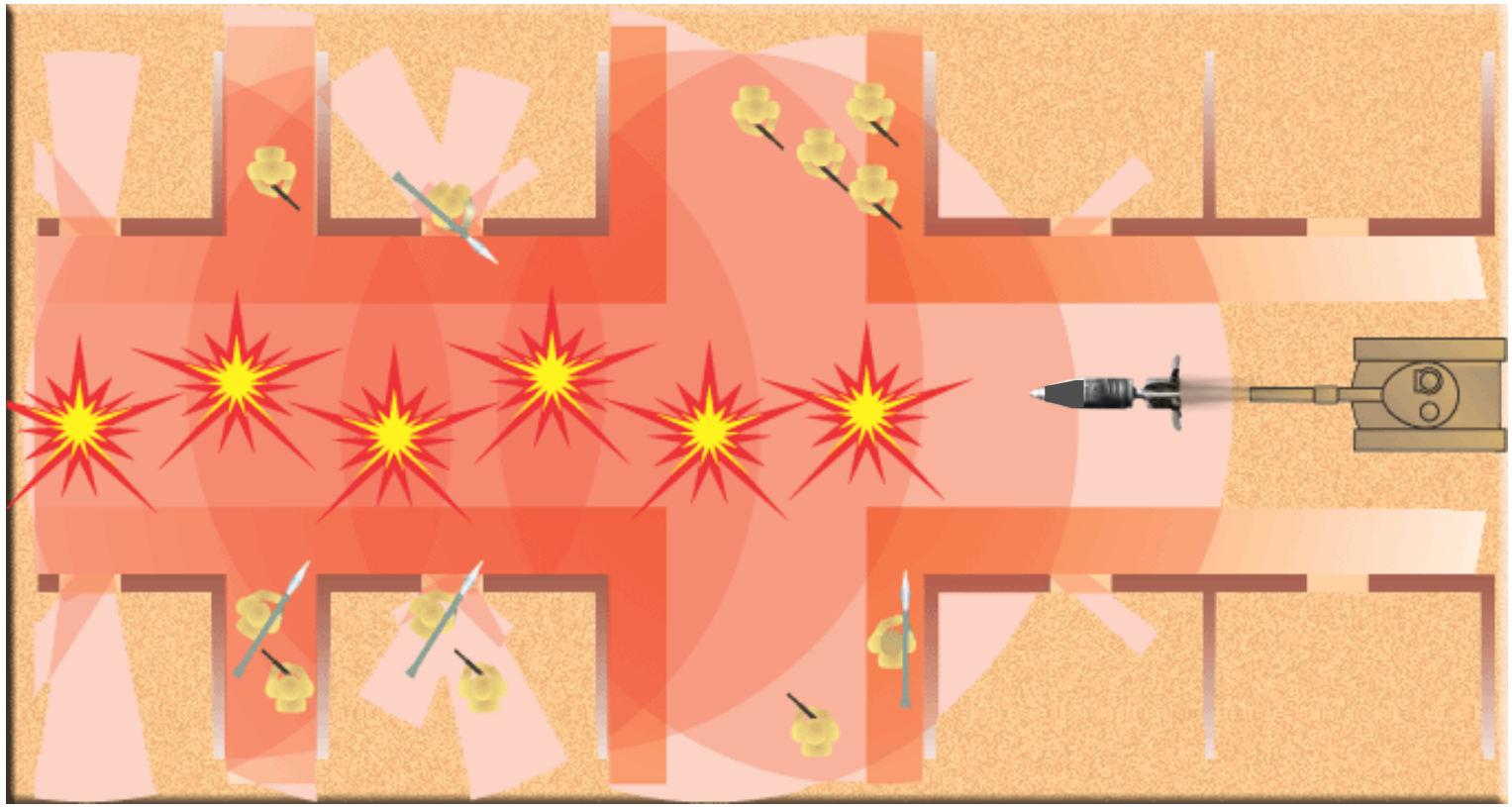
APAM 105 - Damage to Sand & Timber Bunker

APAM 105 - Wall Breaching Capability
(with optional SQ fuze)

ANTI HELICOPTER CAPABILITY



MILITARY OPERATIONS IN URBAN TERRAIN



HE-MP-T 120mm, M339

(High Explosive – Multi Purpose - Tracer Tank Round)

» Projectile

» Propelling System

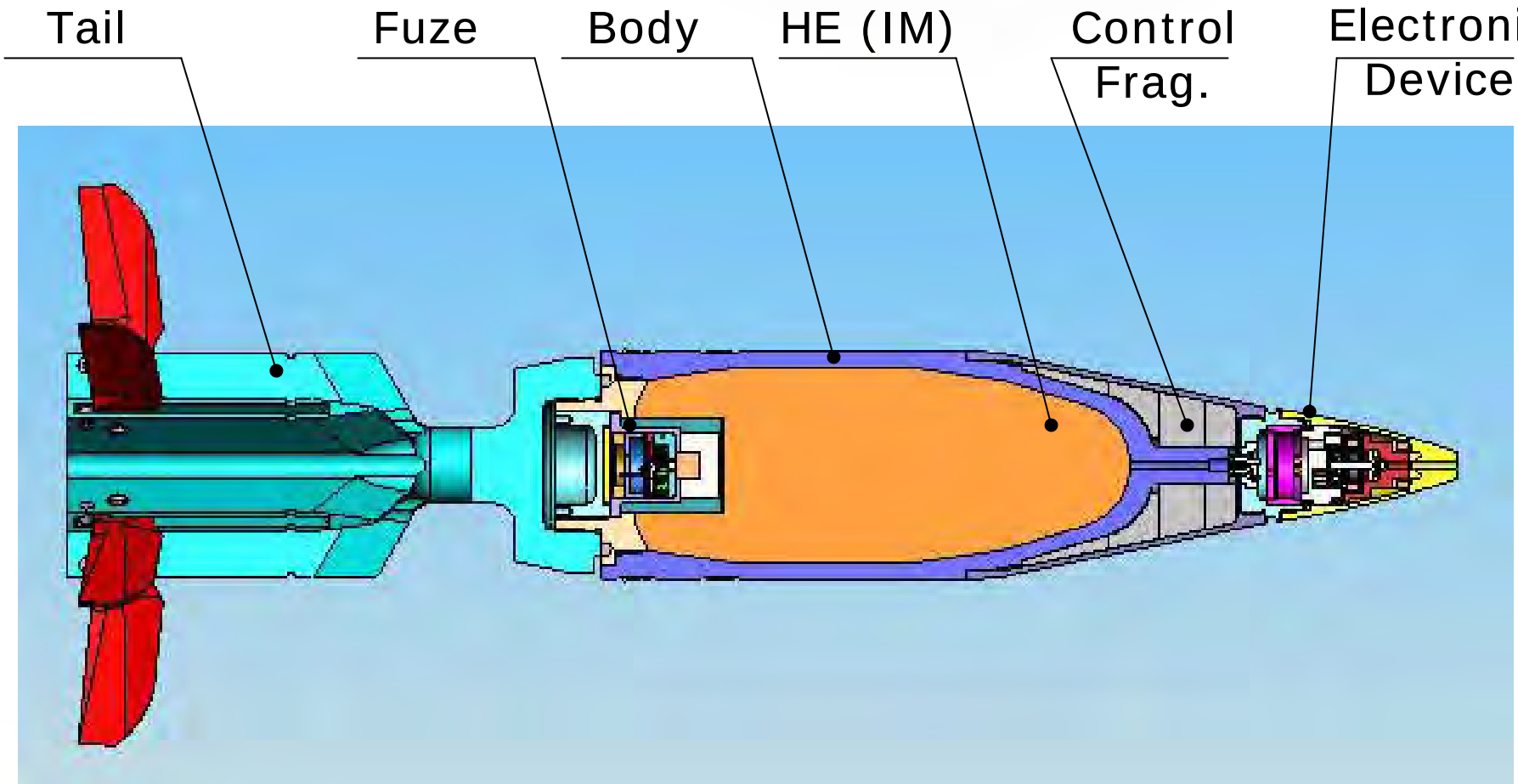
Projectile in flight

HE-MP-T 120
MISSION STATEMENT

To provide multi-purpose round for Main Battle Tanks (MBTs) against targets other than tanks:

- 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 incapacitate infantry, especially AT squads (Ambush)

HE-MP-T 120 Projectile



HE-MP-T 120
Modes of Operation

- Air-burst (AB)
- Impact W/Delay [Delay = f (range)]
- Impact - Super Quick [S.Q.]

- "Extra" features –
  - Grazing functioning
  - Impact W/Delay as default set

105 / 120 mm STUN CARTRIDGE

(Less-Than-Lethal tank round)

105 mm

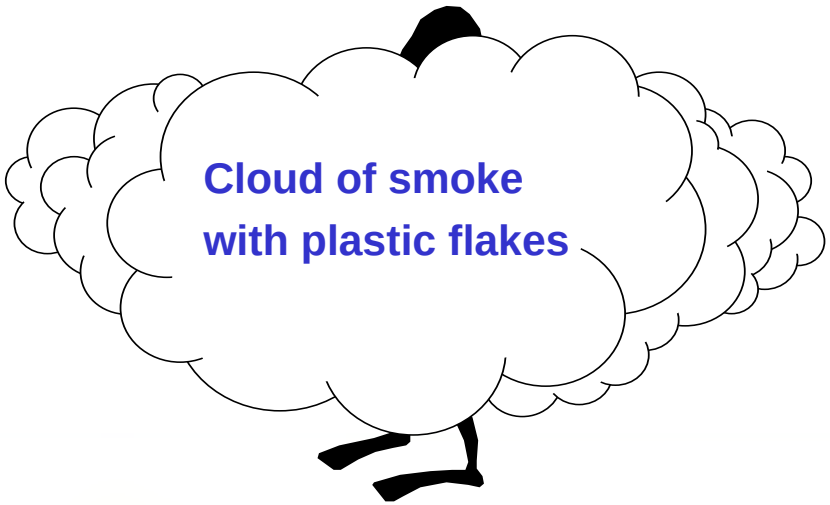
120 mm

Video film of the firing test

The Stun Cartridge creates:

Noise

Pressure (Blast)



- The cartridge can be used with all standard 105/120 mm Western tank guns.
- The stun cartridge can be loaded, unloaded, stowed and stored like any other tank round.
- This cartridge is indispensable for every armor force when action in urban and other populated terrains.

Improved Lethality Test Capabilities of the Arnold Engineering Development Center

Brian Roebuck

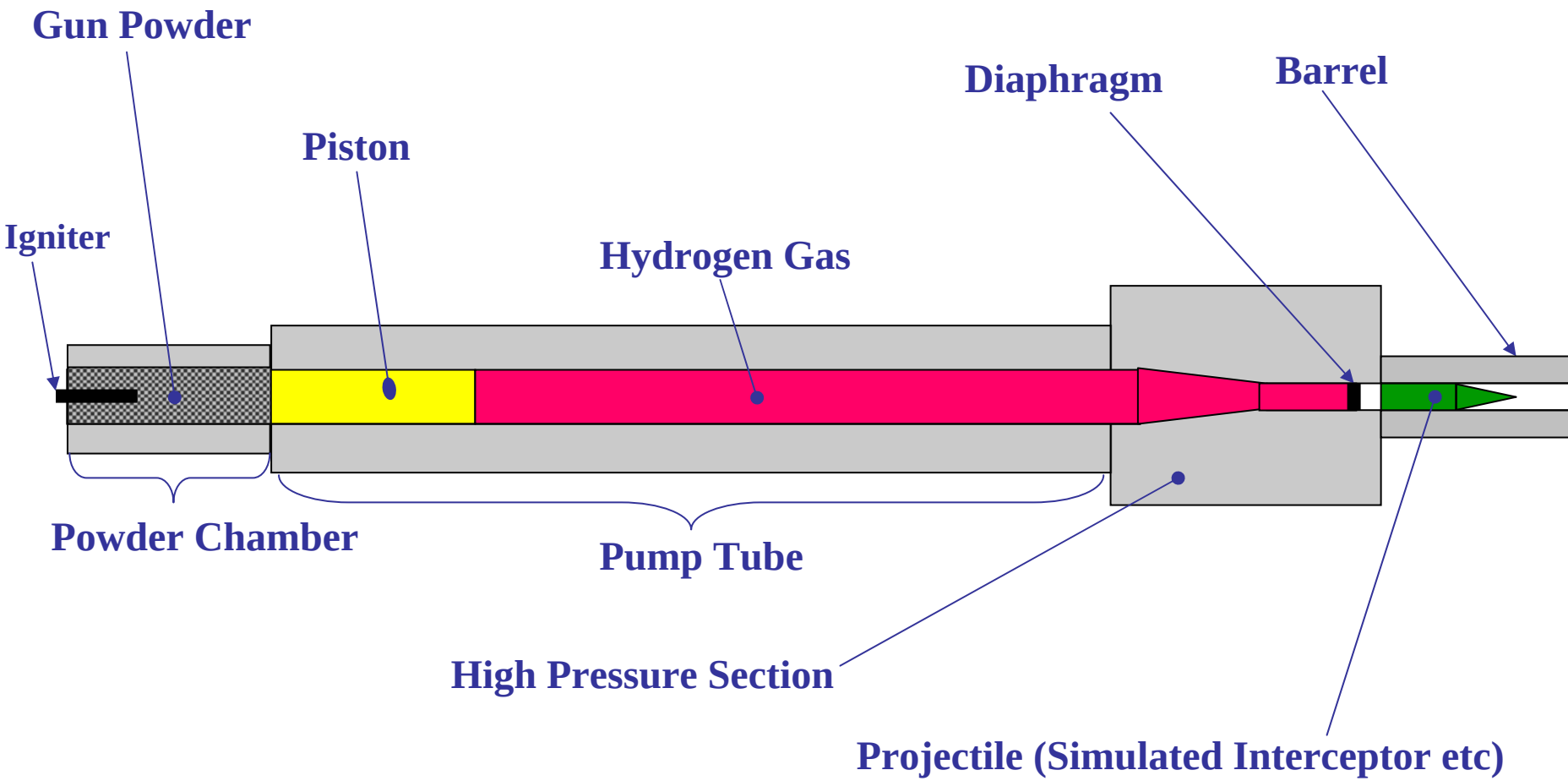
Aerospace Testing Alliance

Arnold Air Force Base, Tennessee

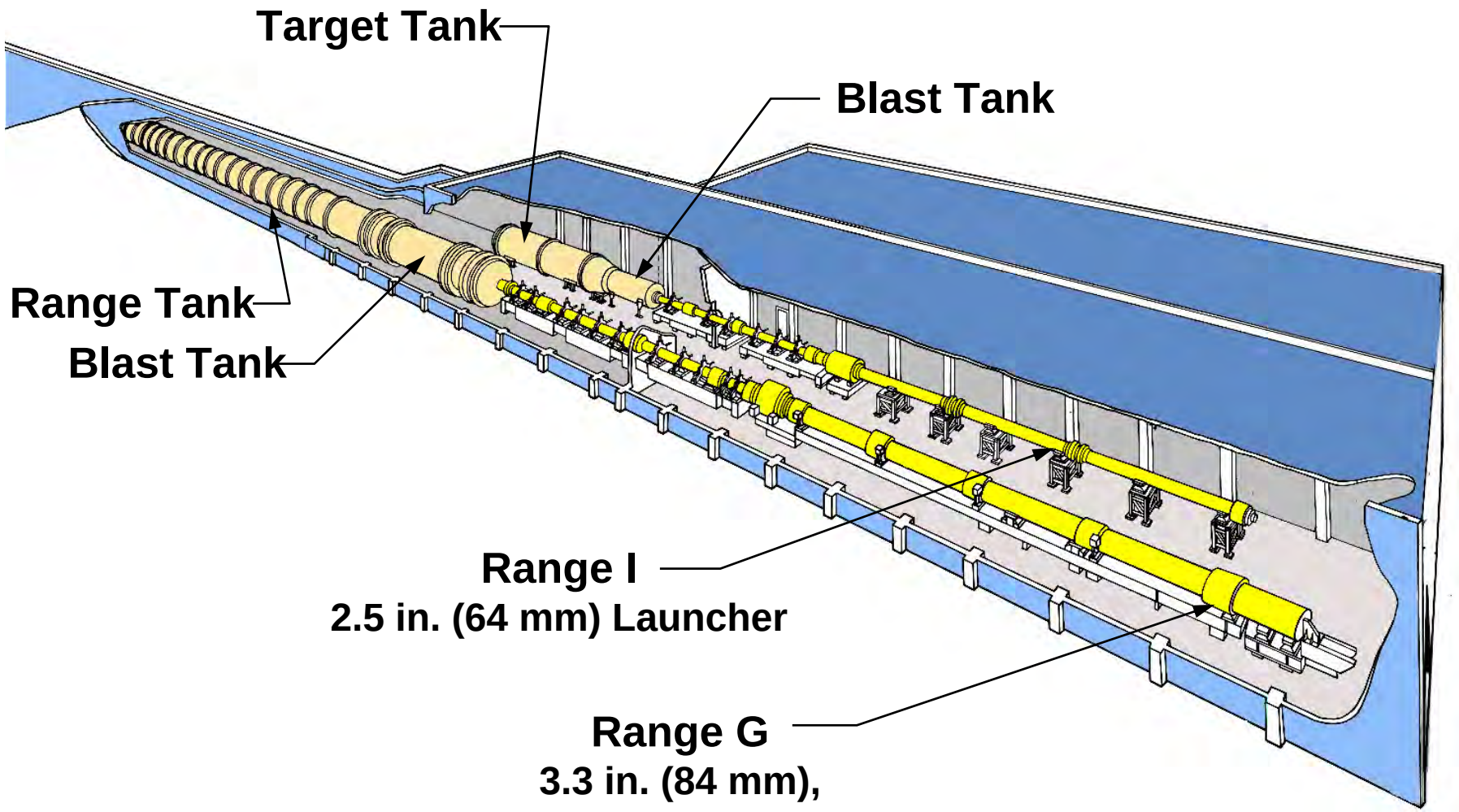
ARNOLD ENGINEERING DEVELOPMENT CENTER

This presentation is an overview of continuously improving impact lethality ground testing methods using the Range G two stage light gas gun facility and it's evolution into one of the premier ground test facilities for the Missile Defense Agency **(MDA)**

TYPICAL TWO STAGE LIGHT GAS GUN OPERATION

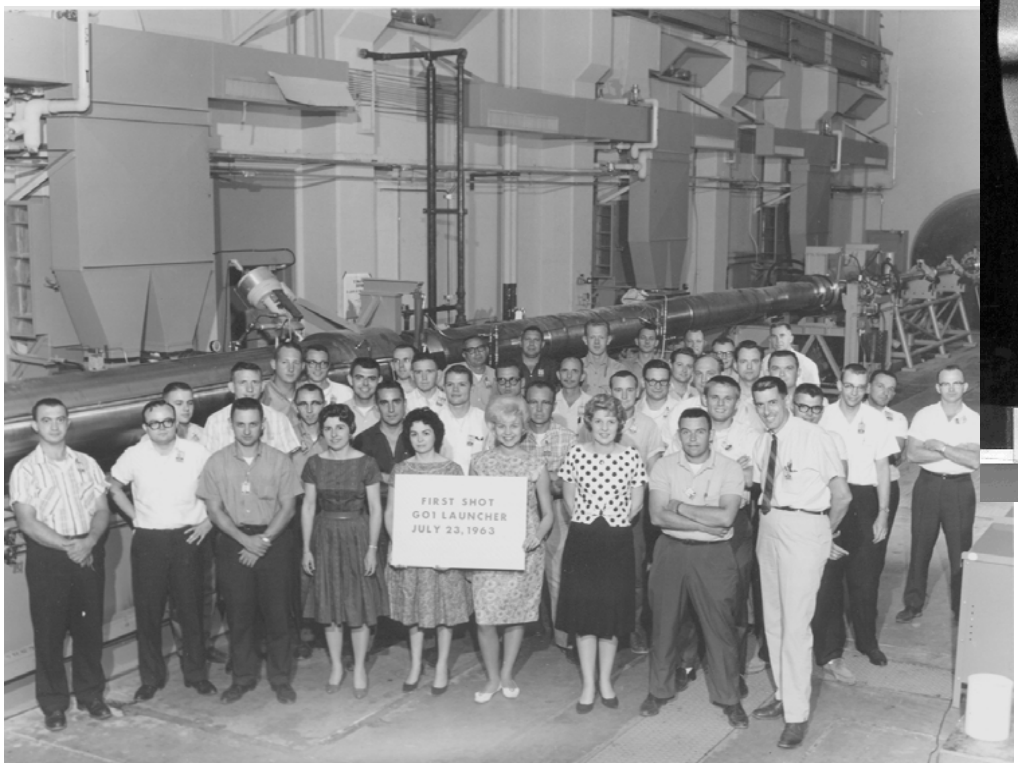


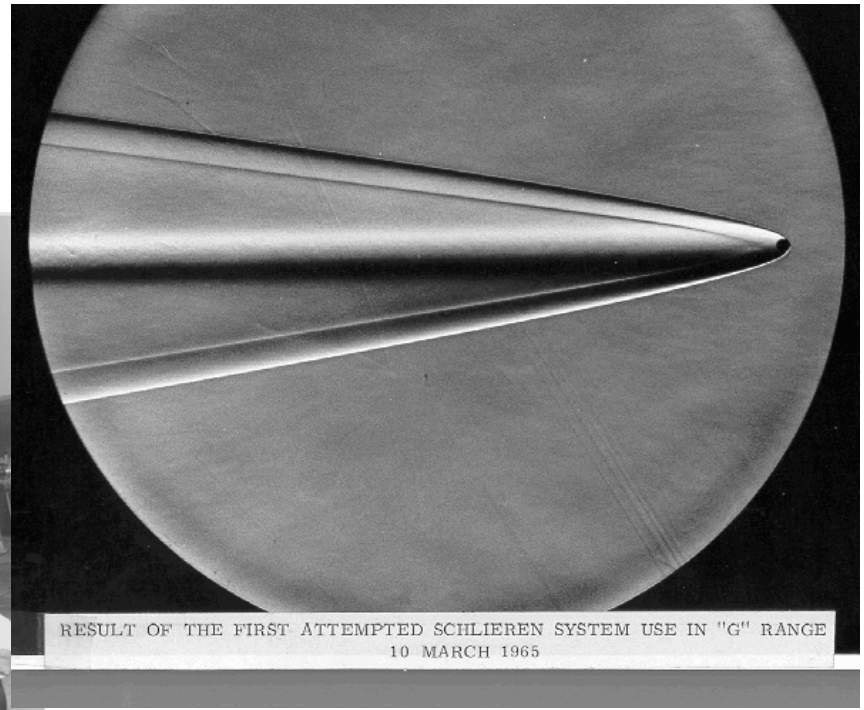
RANGE COMPLEX INCLUDING RANGE G AND RANGE I



A BRIEF HISTORY OF AEDC RANGE TEST TECHNIQUES – “The 60’s”

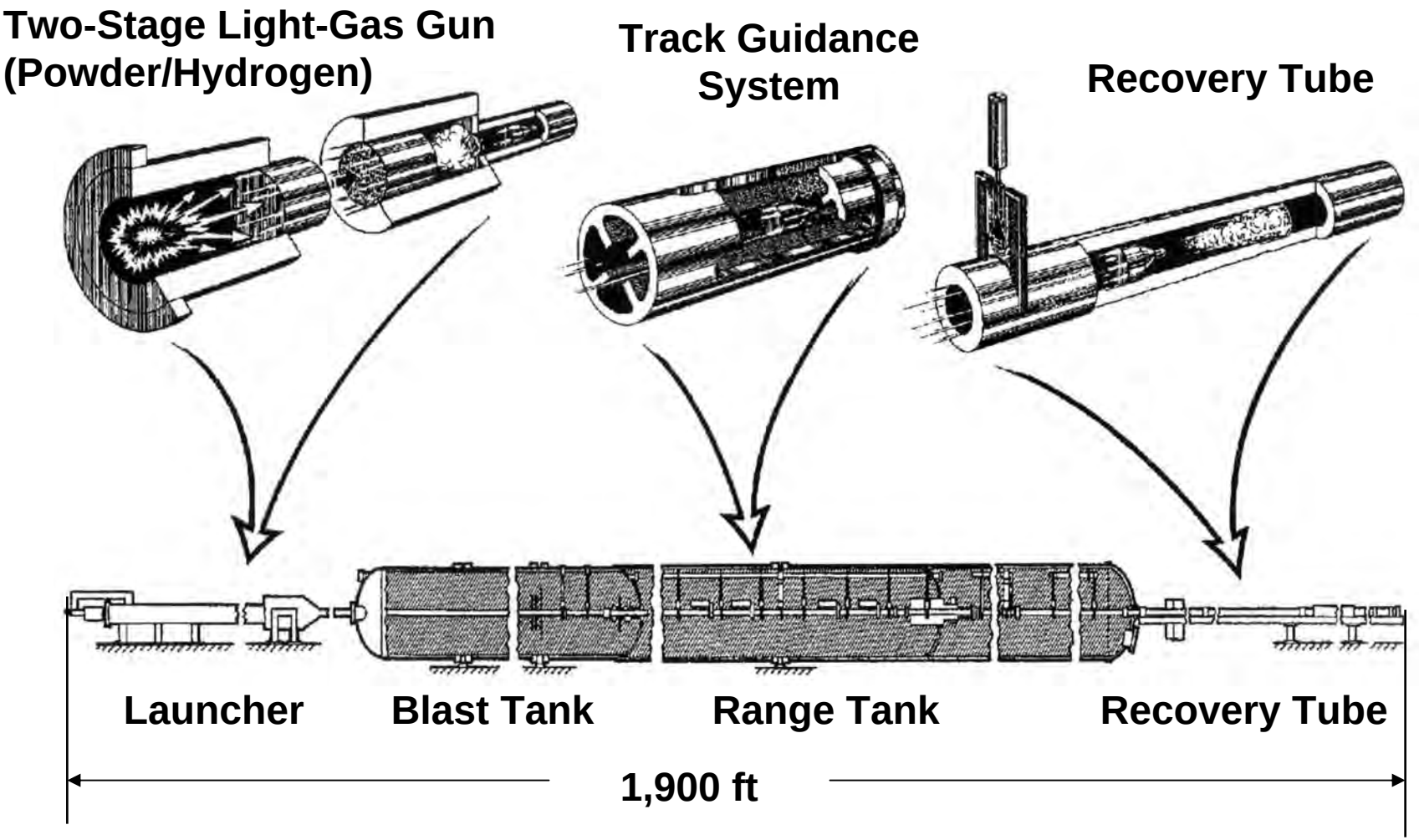
The original Range G 2.5 inch launcher and tank system was developed for high velocity Aeroballistic testing in the 1960s.



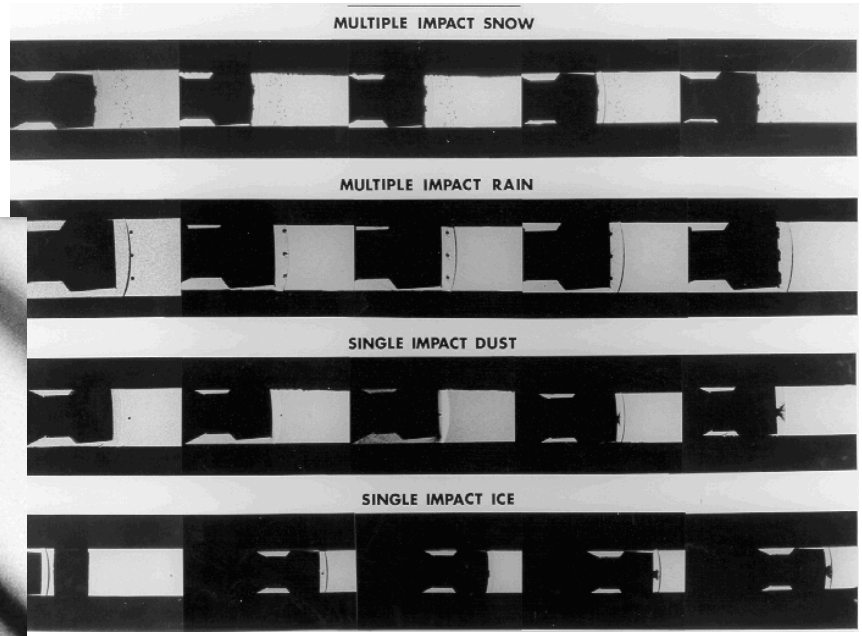


Free Flight Projectile Schlieren Image

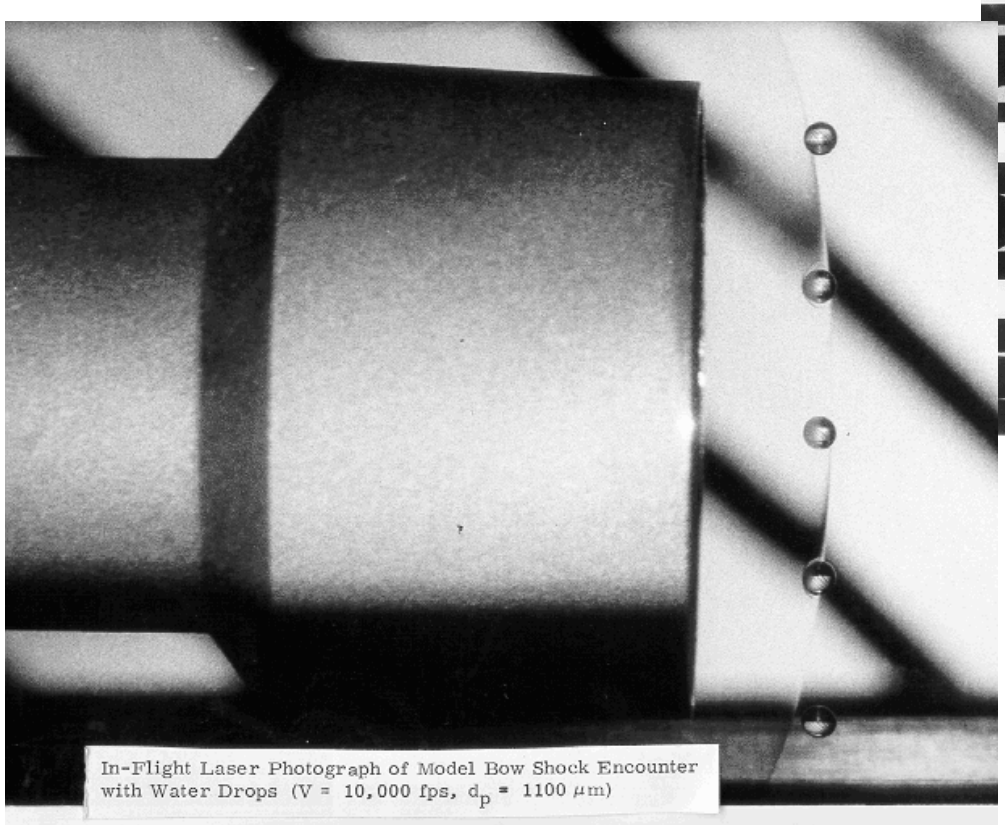
UPGRADE RANGE G TRACK AND RECOVERY TUBE SYSTEM – "The 70's"



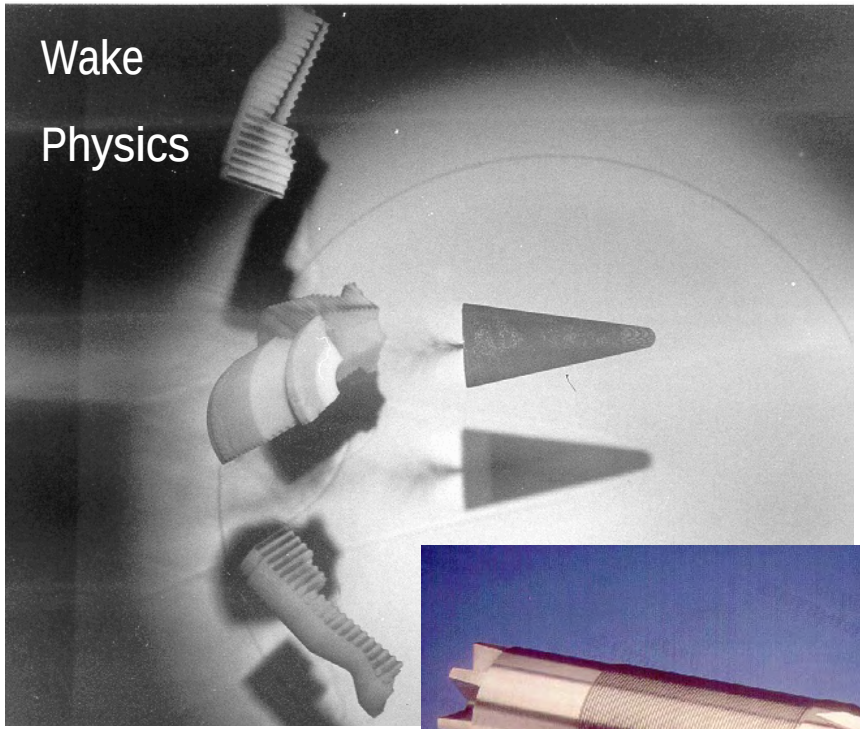
EROSIVE FIELD TRACK GUIDED RANGE TEST TECHNIQUE – “The 80’s”

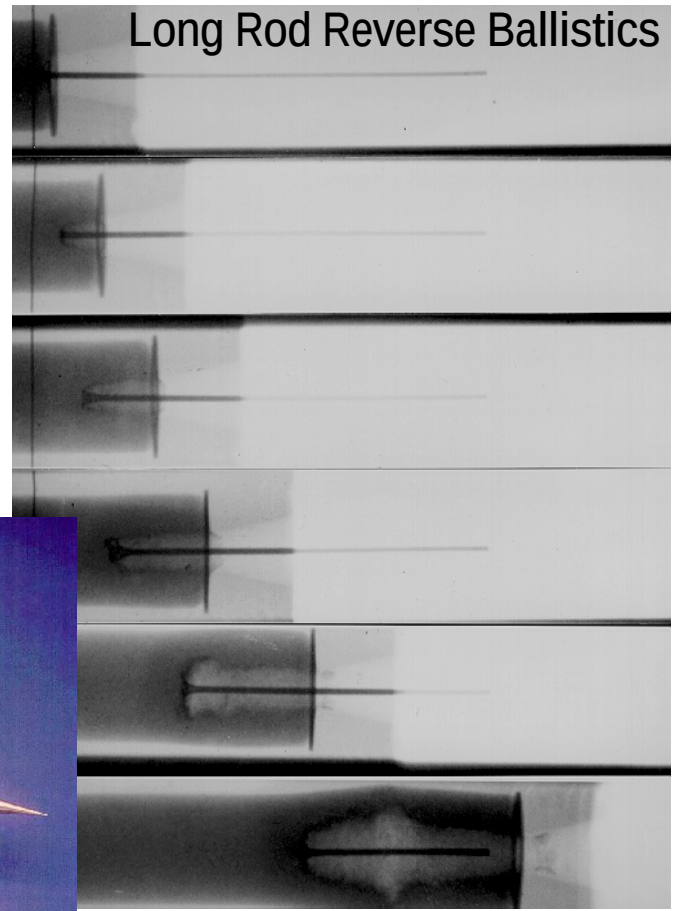


Erosive Fields
(snow, rain, dust, and ice)
testing via track


In-Flight Laser Photograph of Model Bow Shock Encounter with Water Drops (V = 10,000 fps, d_p = 1100 μm)

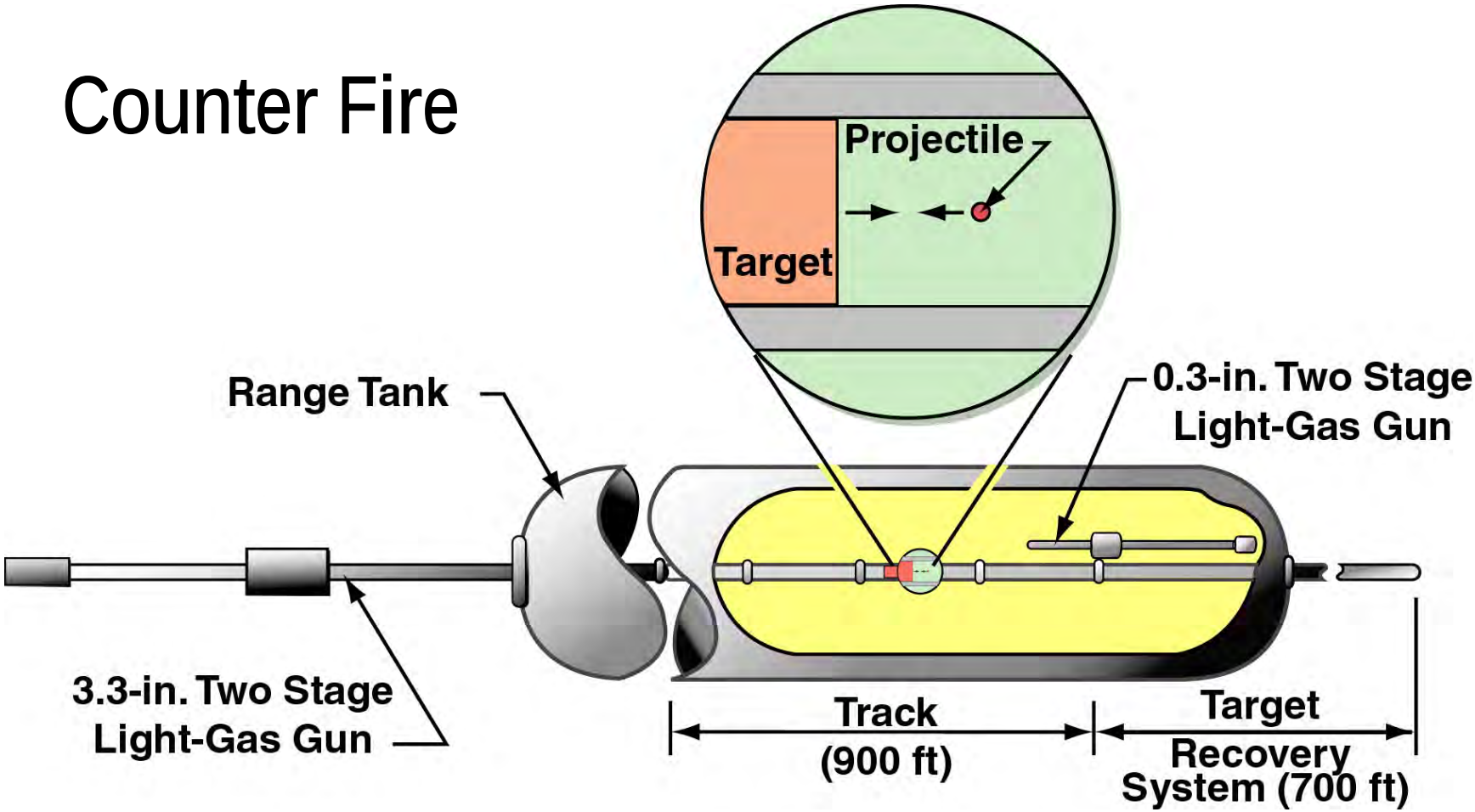
TRANSITIONAL AEDC RANGE TEST TECHNIQUES – “The 90’s”



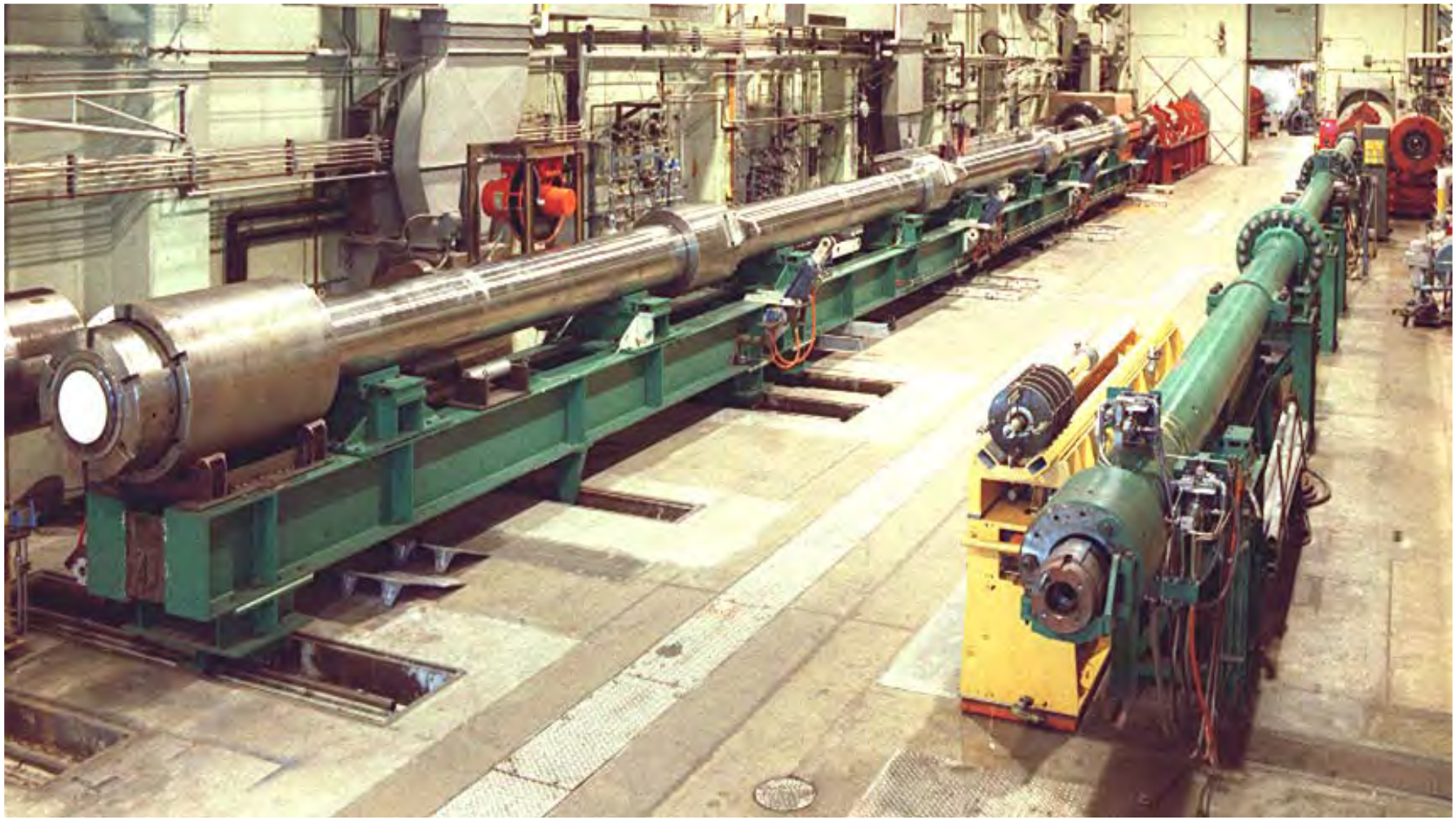


NEW RANGE TEST TECHNIQUES POSSIBLE WITH 3.3 INCH LAUNCHER

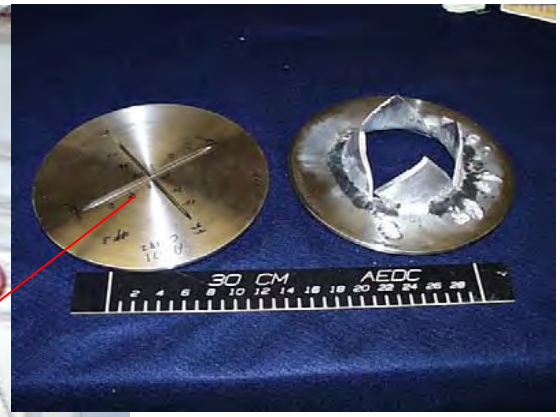
Counter Fire



RANGE G HYPERVELOCITY 3.3 INCH LAUNCHER UPGRADE



3.3 INCH LAUNCHER COMPONENTS: 60 TON HIGH PRESSURE SECTION



3.3 INCH LAUNCHER COMPONENTS: LAUNCH TUBE (3.3, 4.0, and 8.0-IN)

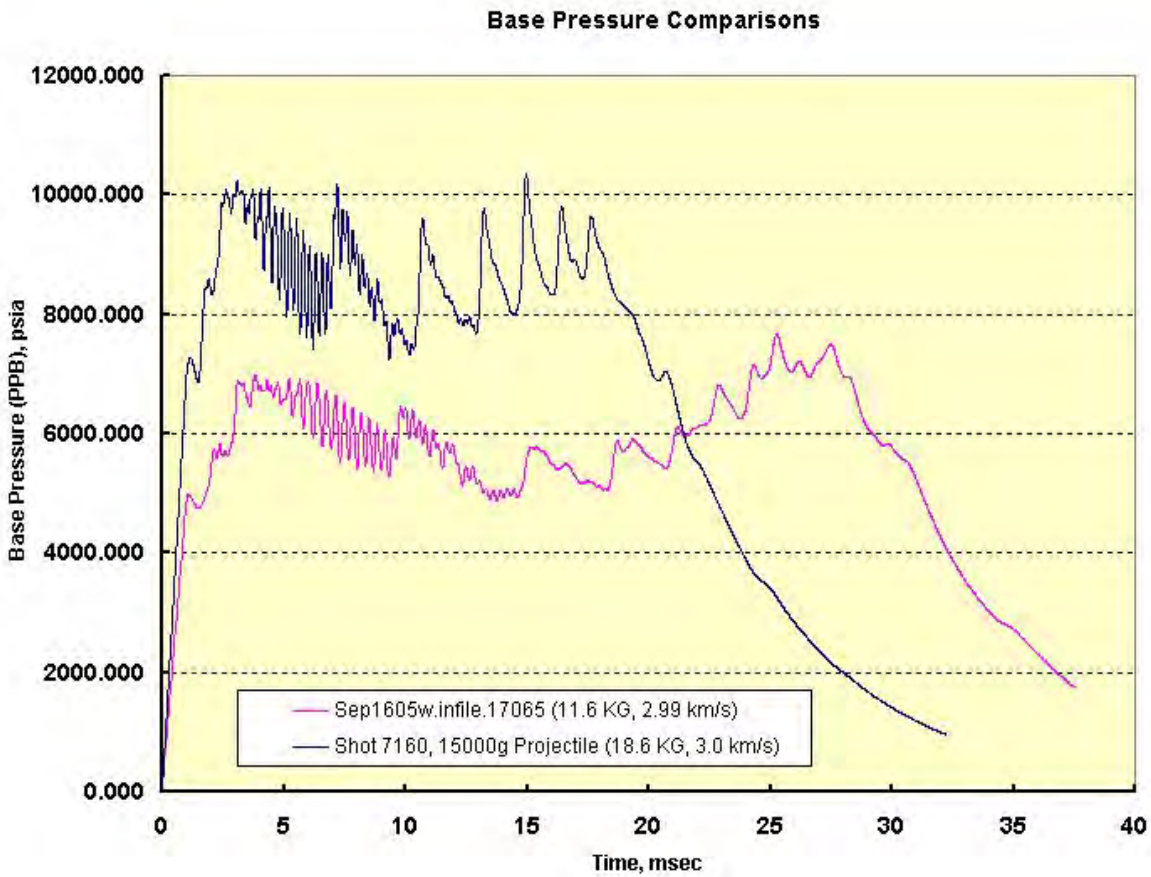
IMPROVED LETHALITY TEST CAPABILITY REQUIREMENTS

MDA funded an extended High Fidelity Development Program to enhance Range G testing capabilities for future test program support.

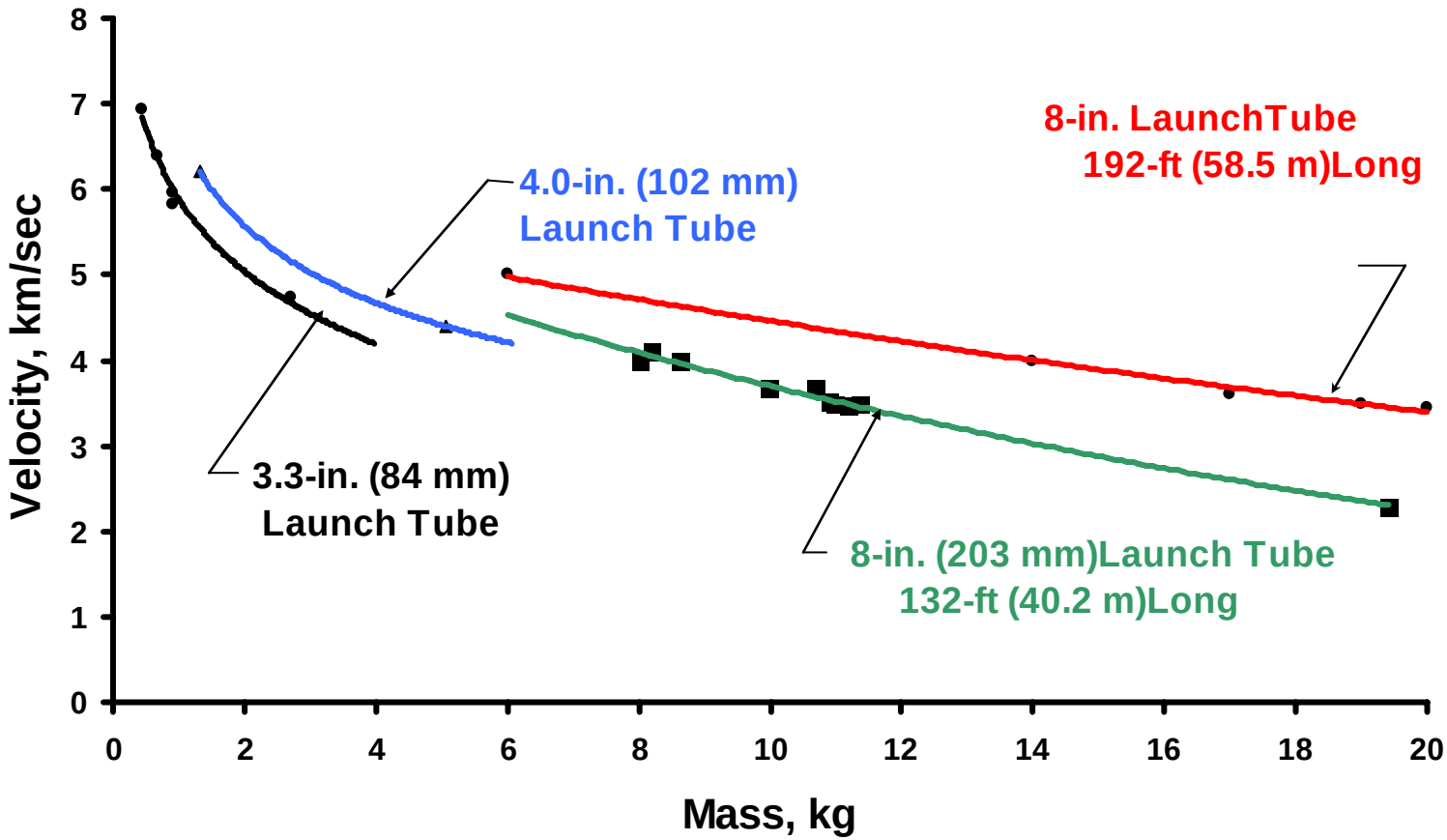
- Large Scale Hi Fidelity Projectile
- Velocities up to 5 Km/sec with 8” bore launch tube
- Improved gun cycle with lower launch accelerations
- Projectile Pitch capability
- Soft Catch of Target Debris Field
- Updated and Improved Instrumentation
- Improved Optical and X-ray recording equipment

PARAMETRIC STUDY YIELDS IMPROVEMENTS TO GUN CYCLE

- An improved gun cycle was developed based on testing requirements
- Use of a heavier piston theoretically results in a 38% reduction in peak g-loading when combined with additional hydrogen mass
- Peak acceleration and base pressure occur much further into the cycle
- Longer barrel further softens launch loads



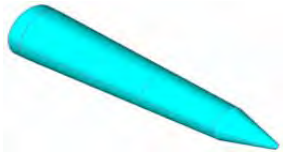
MAXIMUM VELOCITY VS PROJECTILE MASS FOR RANGE G CONFIGURATIONS



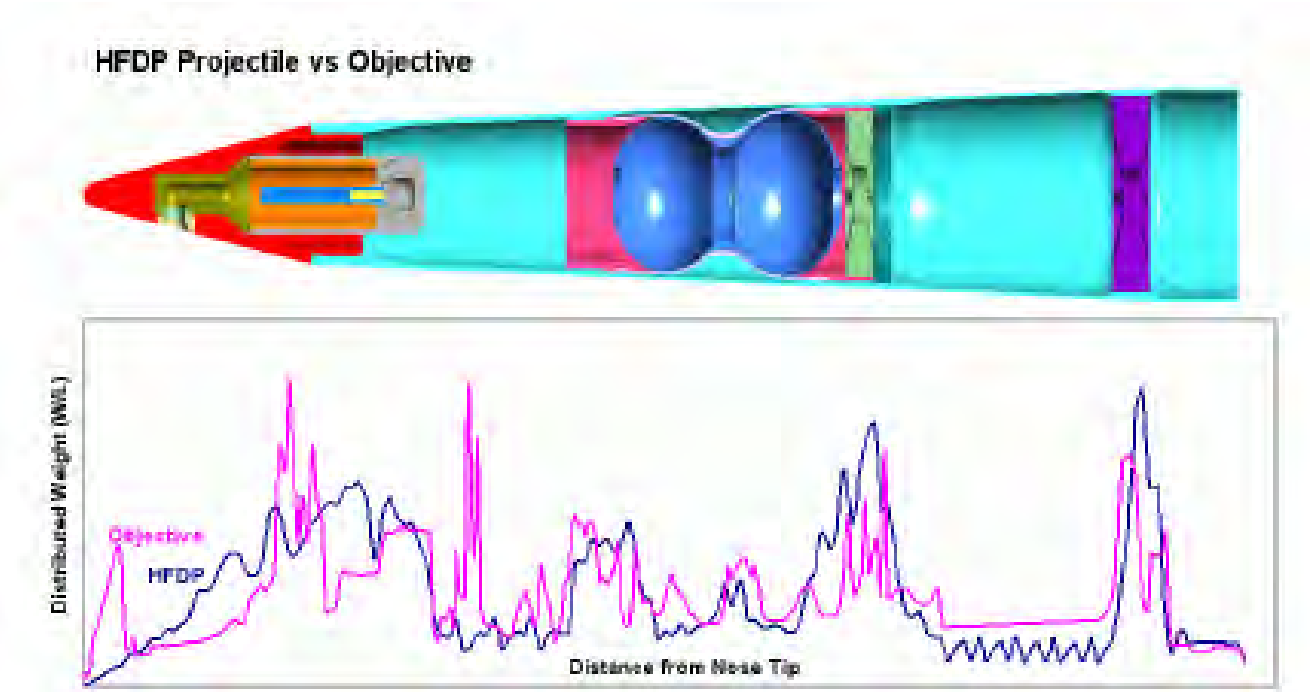
OUR GOAL: A 40%-SCALE INTERCEPTOR HIGH FIDELITY PROJECTILE

Launch Package

Sabot Separation

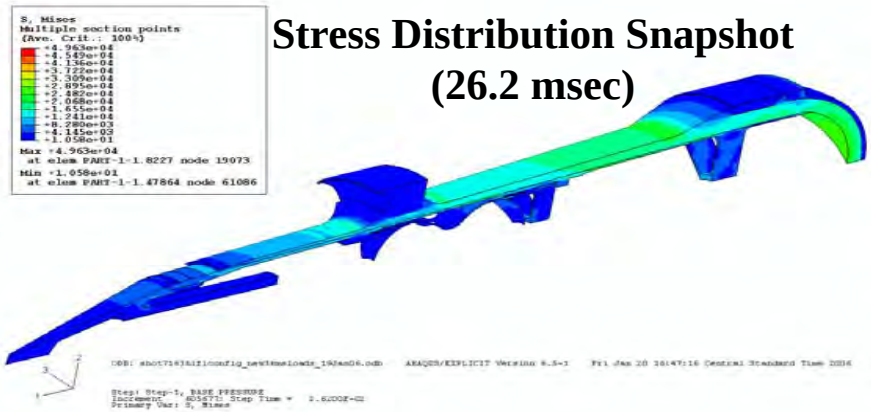


Impact Projectile

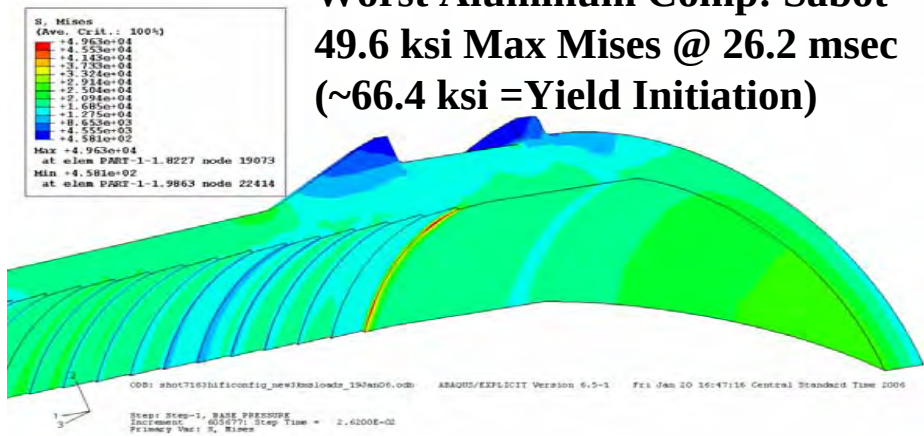


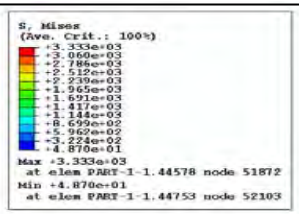
Abaqus Explicit ™ STRESS ANALYSIS FOR CANDIDATE PROJECTILE DESIGNS

Full Model
Stress Distribution Snapshot
(26.2 msec)

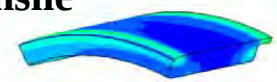


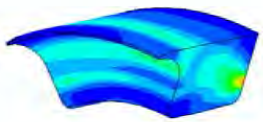
Worst Aluminum Comp: Sabot
49.6 ksi Max Mises @ 26.2 msec
(~66.4 ksi =Yield Initiation)

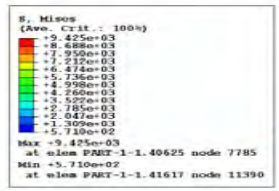




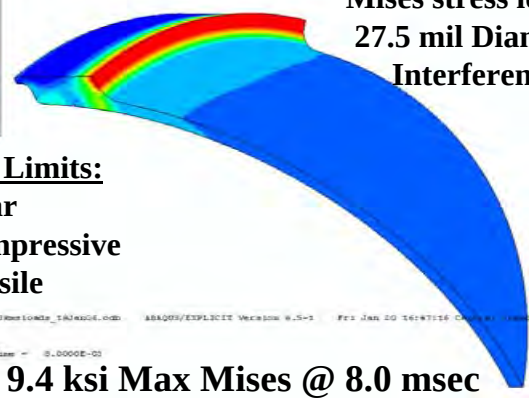
3.3 ksi Max Mises @ 8.1 msec
(~7 ksi Nylon Tensile Strength, Yield)







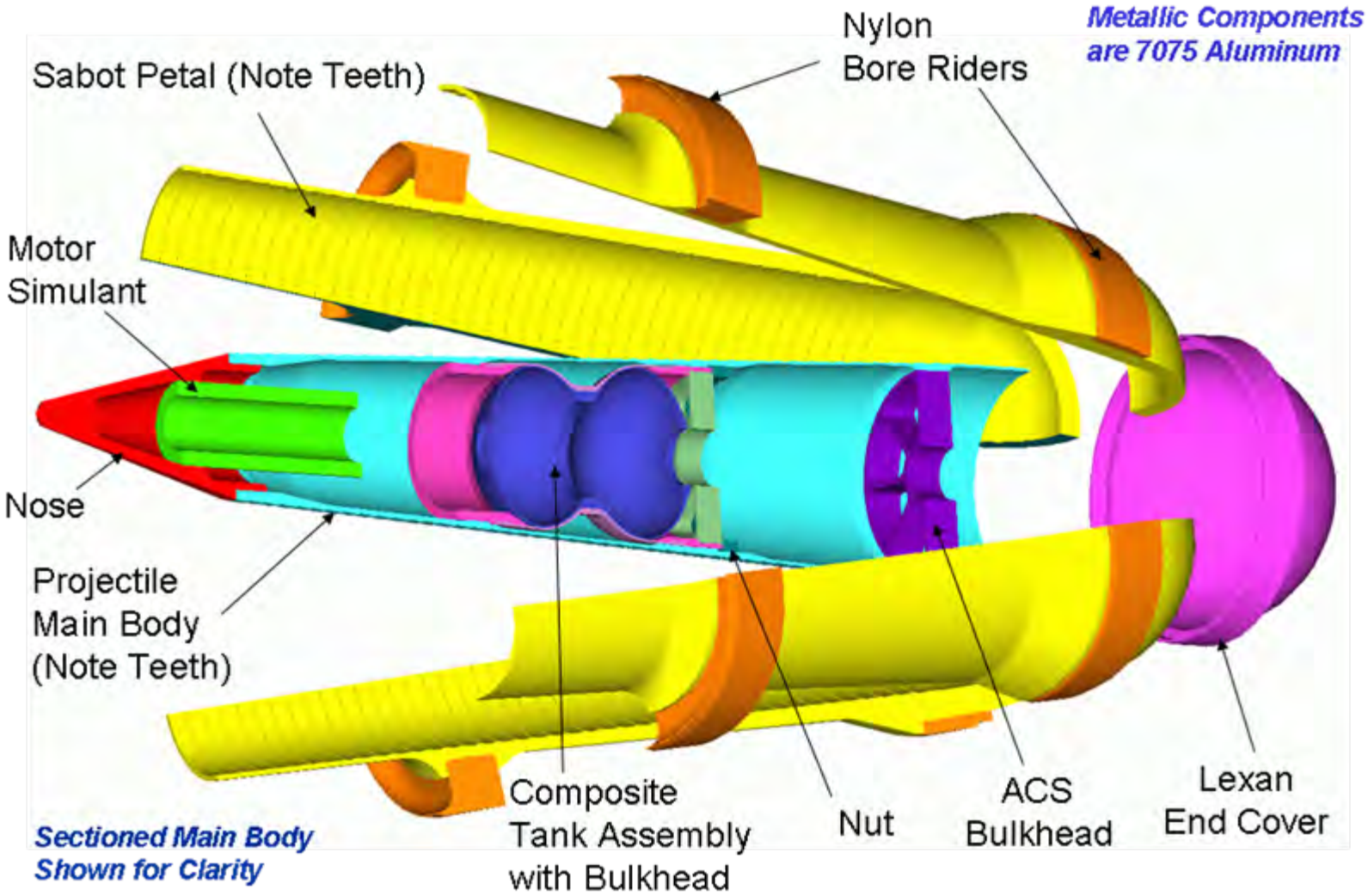
Key contributor to peak Mises stress level is 27.5 mil Diametric Interference Fit



Lexan Strength Limits:
~10 ksi Ult Shear
~12 ksi Ult. Compressive
~14 ksi Ult. Tensile

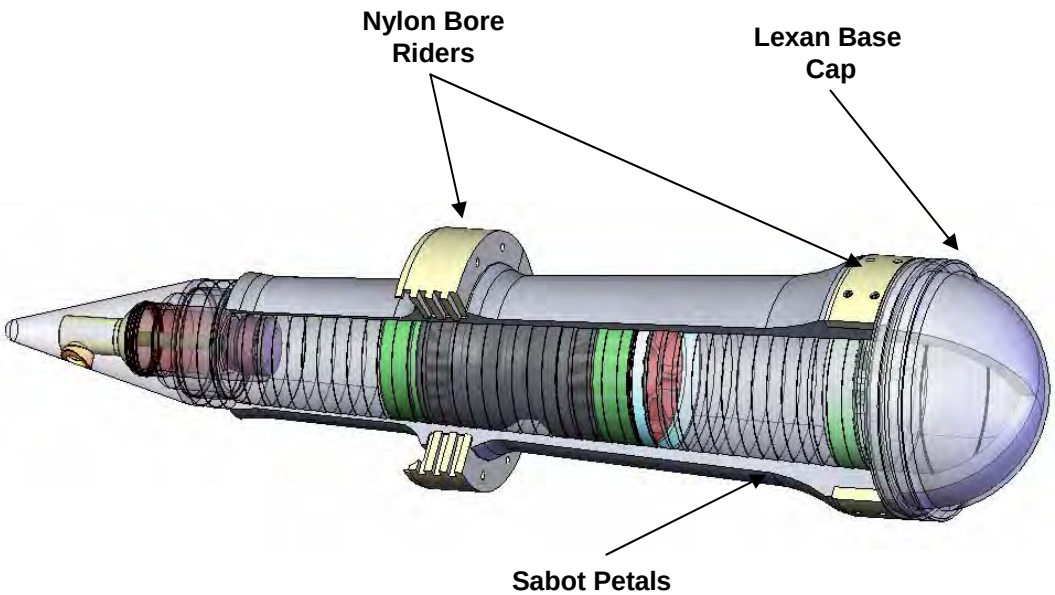
9.4 ksi Max Mises @ 8.0 msec

HIGH FIDELITY PROJECTILE FINAL DESIGN



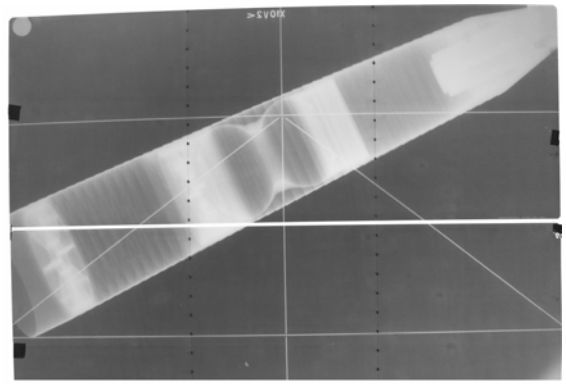
BASIC PROJECTILE DETAILS

- **Launch package is 4-petal sabot design**
- **Lexan base cap**
- **Separation event achieved in 75’ of flight in blast tank**



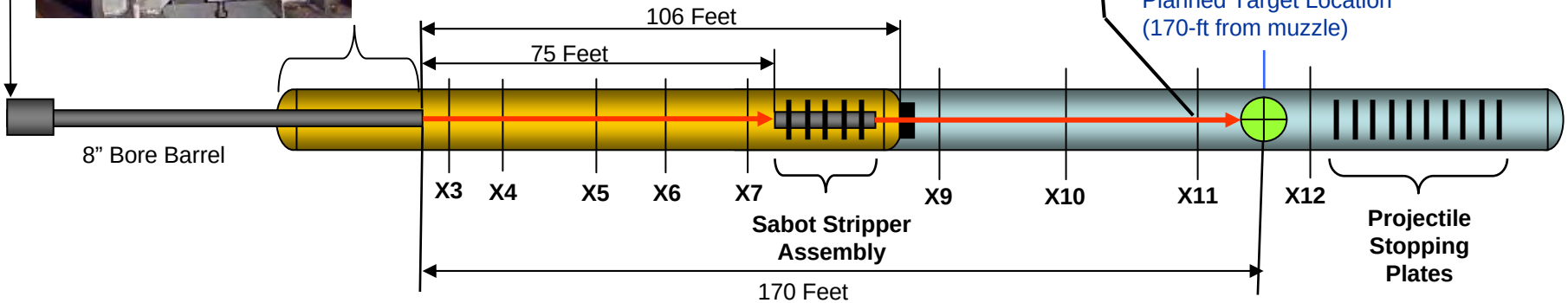
AMRDEC DESIGNED PITCH MOTOR ASSEMBLY

PITCHING PROJECTILE TEST TECHNIQUE



X-ray of projectile prior to impact

X-ray of sabot separation

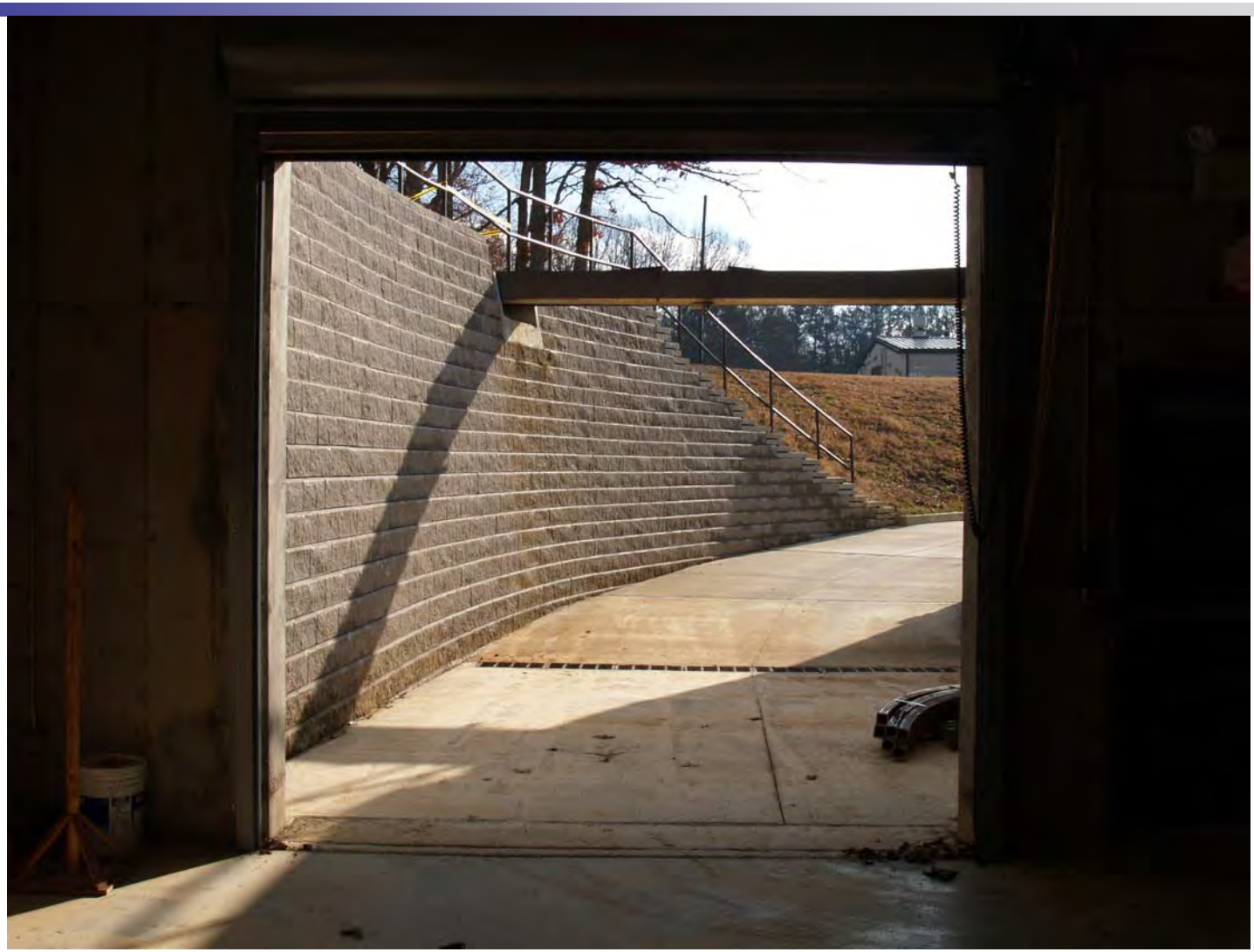


ROOM FOR TARGET AREA ACCESS – SERVICE TUNNEL ADDITION

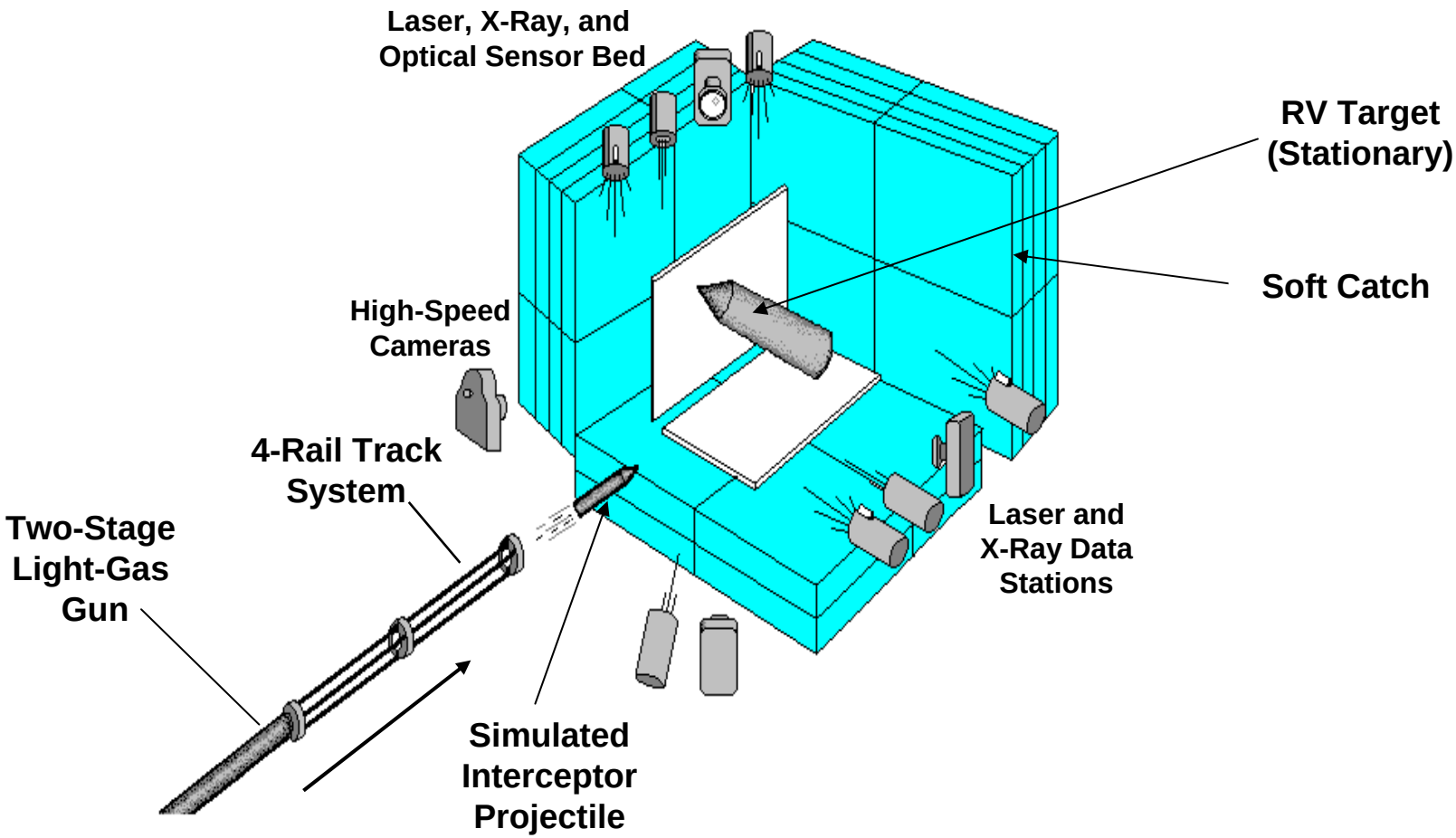
TARGET AREA ACCESS DOOR INSTALLATION

COMPLETED SERVICE TUNNEL UPGRADE

SERVICE TUNNEL UPGRADE
RAMP ADDITION

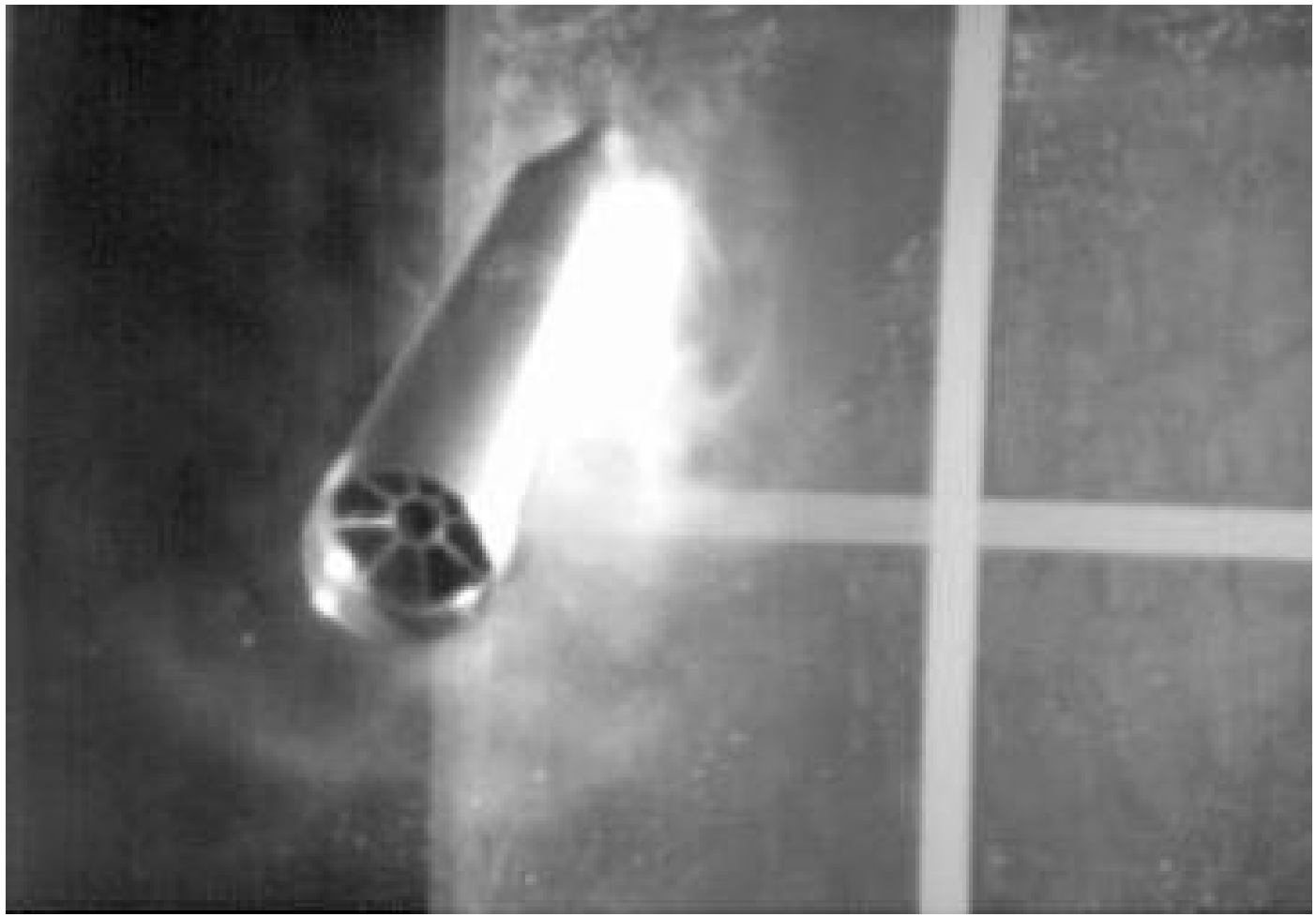


TYPICAL LETHALITY TARGET ARENA



TARGET IMPACT ARENA

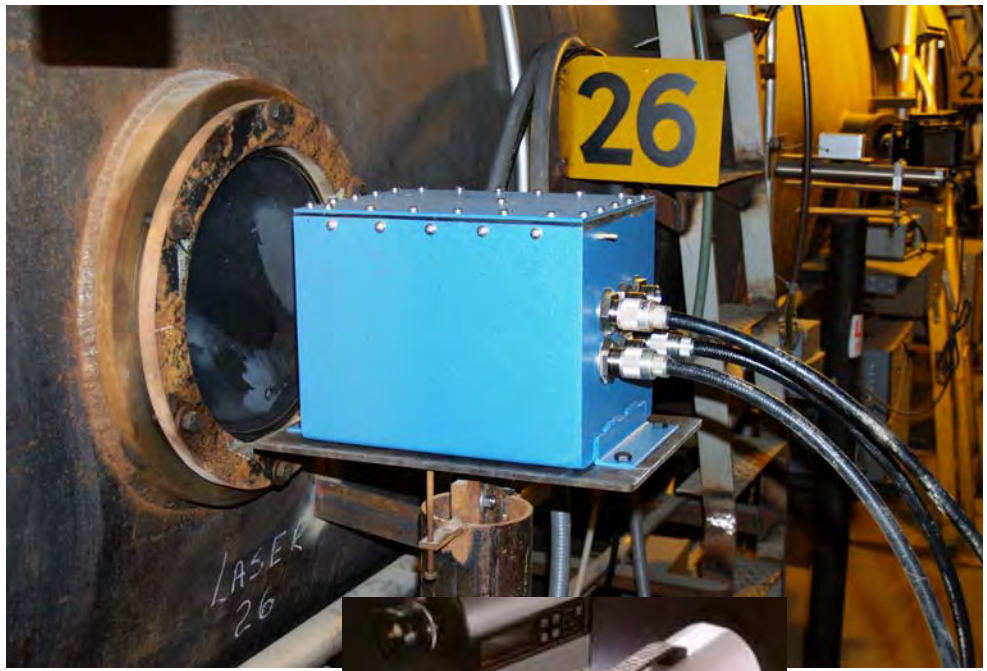
FREE FLIGHT PROJECTILE WITH PITCH MOTOR PRIOR TO IMPACT



IMPROVEMENTS TO RANGE INSTRUMENTATION

- Replacement of film cameras with high speed digital cameras such as Quik-E® single frame and Phantom 7® and Phantom 9® video cameras.
- Replacement of old PDP based computers with modern PC's used to control timing, sequencing, and firing the launcher.
- Obtained commercial VIES systems with three 10 channel pulse generators and 20 four channel delay generators.
- Replacement of old laser detectors along the range with modern systems.
- Inclusion of new X-Ray cinematography system.

X-RAY CINEMATOGRAPHY SYSTEM



SUMMARY

- AEDC has leveraged 44 years of hypervelocity range testing experience and continuous upgrades to build unprecedented capability for evolving test requirements.
- Improvements to range facilities, instrumentation, and operational parameters contributed greatly to enhance the overall testing capabilities.
- In house projectile design and systems operation expertise while partnering with other DOD contractors has achieved the required improvements in lethality testing capabilities for MDA.

CONTACT INFORMATION

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MUNITIONS SAFETY INFORMATION ANALYSIS CENTER

Insensitive Munitions State of the Art

Bernie Halls TSO
April 2008

MSIAC Unclassified

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What the Customer Wants

Department of Defense

DIRECTIVE

NUMBER 5000.01
May 12, 2003
Certified Current as of November 20, 2007

USD(AT&L)

SUBJECT: The Defense Acquisition System

E1.1.23. Safety. Safety shall be addressed throughout the acquisition process. Safety considerations include human (includes human/system interfaces), toxic/hazardous materials and substances, production/manufacturing, testing, facilities, logistical support, weapons, and munitions/explosives. All systems containing energetics shall comply with insensitive munitions criteria.

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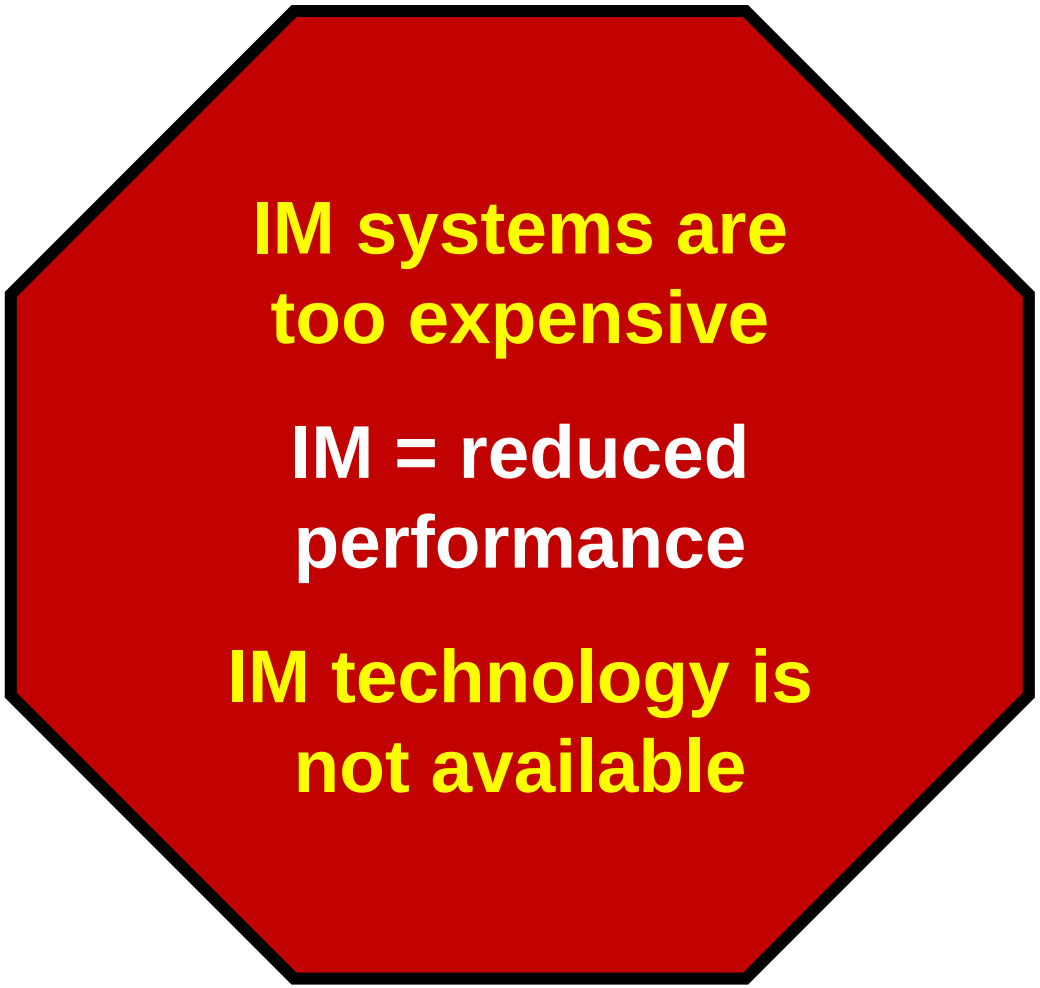
Common misconceptions



MSIAC is attempting to change these perceptions!

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Implementation – A Systems Approach

- Aspects to be considered:
  - Energetics (first point of call)
  - Design & Construction
  - Packaging
  - Stacking
  - Platform integration (ship magazines)
  - Other measures, barriers etc

- Not ‘safe’, just less violent
- Testing in accordance with Stanag 4439 gives us a signature with which we can judge progress.

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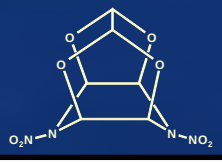
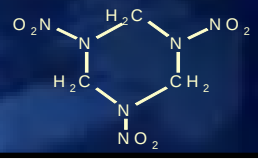
TEX v RDX





Data	TEX	RDX
Sensitivity		
– Autoignition:	282 °C	205 °C
– Friction:	>353 N	120 N
– Impact:	23 -25 Nm	7.5 Nm
– ESD:	6 – 8 J	????
– Critical Diameter@ density	21 mm	2 mm
Detonation Performance calculated with Cheetah 1.36		
– Detonation velocity	8160 m s^{-1}@1.99g cm-3	8750 m s^{-1} @1.76 g cm-3
– Detonation pressure	31.4 GPa	35.2 GPa
– Gurney Energy	2510 ms^{-1}	2830 ms^{-1}
Price Index	10 **(will decrease significantly when produced on larger scale)**1	

- ATK, EXPLOSIA, RAFAEL
- The patents mostly belong to ATK and Rafael.

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Insensitive Munitions (who started it?)

- Birth of the Insensitive Munition Program
- Nobel
  - Dynamite
- USS Forrestal, (134 Killed, 161 Injured)
- USS Oriskany (44 Killed, 156 Injured)
- More recently Camp Dohar, 3 killed in the clean up, 49 injured 102 vehicles damaged or dstroyed

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Legend

Colour coding for FCO, SCO, BI and FI results			
Colour code	Response Type	Response	Result
	V or NR	Burning or no response	Pass
	IV	Deflagration	Fail
	III	Explosion	Fail
	I or II	Detonation or Partial detonation	Fail

Colour coding for Sympathetic Reaction (SR)			
Colour code	Response Type	Response	Result
	III, IV, V, or NR	Burning to no response	Pass
	I or II	Detonation or Partial detonation	Fail

Colour coding for Shaped Charge Jet (SCJ)				
Colour code	Response Type	Response	V^2D ($mm^3/\mu s^2$)	Result
	III, IV, V or NR	Explosion, Deflagration, Burning or no response	Above 200	Pass
	III, IV, V or NR	Explosion, Deflagration, Burning or no response	Below 200	Pass
	I or II	Detonation or Partial detonation		Fail

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30 mm (NAMMO Raufoss, Mauser, ATK, Alliant, Primex)

Performance Comparisons

- **No reduction in performance**
- **Armour Piercing**: MK 258 MOD 0 and MK 268 MOD 0 (APFSDS-T) & NM30 (MPDS)
- **High Explosive Incendiary**: MK 238 MOD 0 (HEI-T w/M758 Fuze), MK 266 MOD 0 (HEI-T w/FMU-151/B Fuze),
- **Multi-Purpose**: MK 267 MOD 0 (MPLD) and MK 264 MOD 0 (MPLD-T)

Programme Phase

•IM Improvement plan

IM Technology

•MPLD-T: PBXN-5
•HEI-T: PBXN-5
•M592 Ammo container vent

IM Benefits (cost analysis)

•No cost benefit information available although greater survivability and reduced loss of stockpile inevitable.

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
APFSDS-T	III	III	III	III	>III	
MPLD-T	III	III	III	III	>III	
HEI-T	III	III	III	I	>III	

APFSDS - Armour piercing, fin stabilised, discarding sabot
MPLD - Multi purpose, low drag, HEI – High explosive, Incendiary

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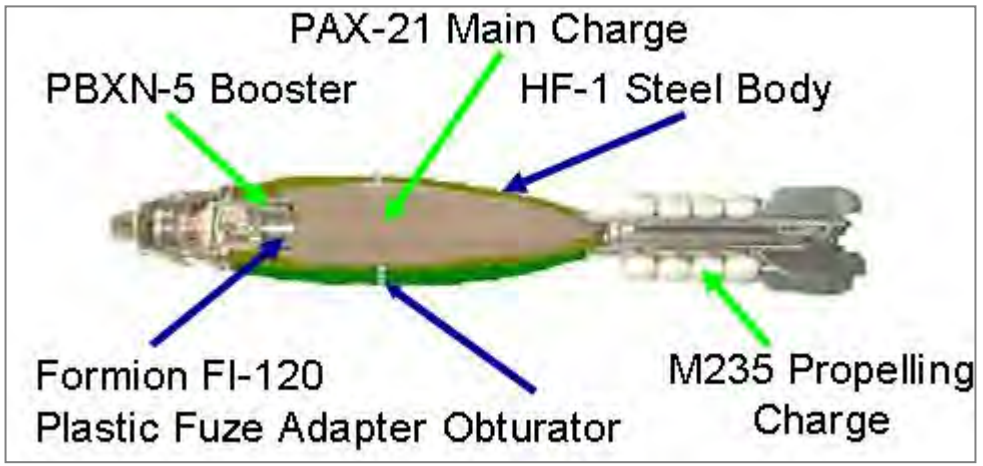
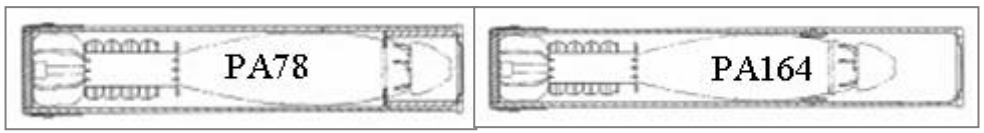
60-mm M720E1 HE Mortar Cartridge

Performance Comparisons

- 25% average increase in lethality above current configuration (1340 steel against HF-1 steel) despite 5% loss in Performance Dent Depth between PAX-21 and Comp B





Customers

- US Army

IM Technology

- IM High Explosive - PAX-21 (melt-cast)
- IM Fuze Booster - PBXN-5
- Gun propellant - no IM modifications
- Venting – Plastic Fuze adapter, obturator
- Logistic Packaging design (PA164 &PA124)
  - Round orientation: Fuze up
  - No fire A18NV Intumescent coating
  - Longer fibre tube

IM Benefits (cost analysis)

- Comp B – 6-8 USD/lb, PAX-21 – 10-12 USD/lb
- Mitigation cost 18-20 USD/round

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Comp B	I/II	III	I	I	II	I
PAX-21	V	IV	V*	III	III	III

* PA124 Ammunition (Metal) Container,
Wire bound box (16 live rounds=2 X PA124)

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105-mm DPICM (M915)

Performance Comparisons

- Ageing – no degradation in performance

Customers

- US Army (high rate production - 30,000 parts per 10-hour shift)

IM Technology

- High Explosive – PAX-2A with 0.5% flow additive (756 g for 42 grenades)

IM Benefits (cost analysis)

- Manufacturing process compatible with Comp-A5 equipment
- Cost of Comp-A5 is 30% of PAX-2A (USD$30/lbs for HSAAP)
- Extra-cost for system should be < 2%

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Comp A5		I	I		I	
PAX-2A		III*	V*		IV*	

* With inert fuze and propellant in PA117 shipping containers

Note: previous version of 105 DPICM was involved in Camp Doha accident in 1991.

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Reactive Tile Armour for Armoured Fighting Vehicle (AFV)

Performance Comparisons

- LBR6 when compared to C4 as the energetic in Explosive Reactive Armor trial produced a similar reduction in penetration result.

Customers

- US Army for Bradley, Abrams and Stryker

IM Technology

- Explosive : Low Burning Rate 6 (LBR6)
- NATO 1.2.3 (US DoD Classification) therefore has passed FCO, SCO, BI and SR.
- Must react to SCJ to be effective
- Rafael product
- Contains RDX with an inert fire retardant and an inert binder

IM Benefits (cost analysis)

- US DoD classified NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Tile Armor	*	*	*		*	

* Assumed results because of 1.2.3 assessment

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Excalibur 155mm guided projectile (XM982)

Performance Comparisons

- Precision munition, high angle of attack (near vertical)
- Packaged HE Projectile: HD 1.3 compliant during storage and transportation
- First operational firing May 2007

Radial vent holes

Customers

- US Army (725 Rounds in 2007)

IM Technology

- High Explosive : PBXN-9
- Pressed Booster:
- Flexible shell liner HDPE
- Modified packaging
- A number of vent plugs, located around the warhead body, which are also designed to melt at a lower temperature than the temperature at which the round reacts.

IM Benefits (cost analysis)

- Initial costs ~ $100K USD, reducing to ~ $30K USD in full production

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
XM-982	V	V	V	V		

* In packaging

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120-mm APFSDS (M829A3)

Performance Comparisons

- New higher energy propellant (multiplex stick charge – RPD-380)
- DU penetrator

Customers

- Currently undergoing type classification (expected to be assigned NATO 1.2.3)
- US Army

IM Technology

- New container: PA-171
- 2 single Pane Windows
- Fiberglass reinforced PE ionomer
- 90 degrees offset and 79 in^2 Vent Area

IM Benefits (cost analysis)

- Container cost increase is marginal

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
PA – 116[1]	III	III	III	II	II	II
PA – 171[2]	V	V	V	IV	III	III

1. M829A2
2. M829A3

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155/52 Artillery shell: 155 LU 211-IM

Performance Comparisons

	Comp B	XF-13333
Formulation	RDX/TNT (60/40)	NTO/TNT/Al/Wax
Density	1.67	1.75
VoD	7860	7150

Customers

- French Army – 5,000 rounds in 2004 plus 20,000 in 2006

IM Technology

- IM High Explosive: XF-13333
- NTO 48%,TNT 31%, Al 14%, Wax 7%
- Embedded booster (V-350)
- Storage pallet 20-round configuration (95% of life cycle)

Not fuzed –Plugged

IM Benefits (cost analysis)

- Hexal / XF-13333 (NTO cost sensitive)
- Increased Unit Cost shell: ~ 6 %

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Hexal	I	I	I	I	I	I
LU211-M	IV	V	V	IV *	IV	III
LU211-IM	V	V	NR	NR	IV	NR

*Heavy Fragment Impact 250 g – 2000m/s: type III MURAT ** (Latest results suggest ***)

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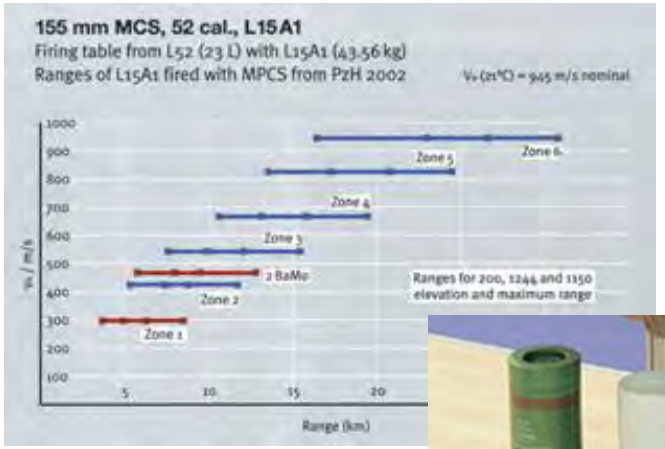
Modulares Treibladungssystem (DM72/92)

Performance Comparisons

- Full agreement with specification for muzzle velocity, maximum pressure, temperature coefficient and pressure waves for zone 6



Customers

- 5 NATO countries (>1.5M units shipped)

IM Technology

- R5730/R5733 solvent less triple base propellant with RDX
- Packaging container with vents

IM Benefits (cost analysis)

- Five modules cost no more than a US M203 unitary (NATO Zone 8) charge and are cheaper to buy than the equivalent L10 charge

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
M203A1	IV/V				≥III	
DM72/92*	V	V	V		NR	IV

* In logistics container

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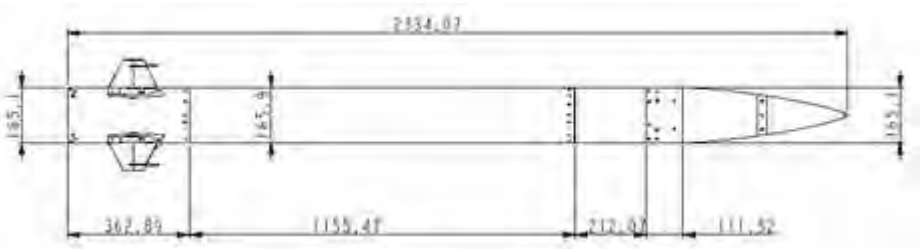
Air Defence Missile (VT1 01)

Performance Comparisons

- Maximum effective range: 11 km
- Altitude: 6 km
- Lethal blast radius : 8 m



Customers

- France, Greece, Finland, Oman

IM Technology

- Warhead: HBU88A
- Slapper initiation
- Rocket Motor: TPH-8313
- Graphite epoxy case with Carbon Fibre Reinforced Plastics

IM Benefits (cost analysis)

- No information

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Warhead		V	V			
RM			IV			
VT1	IV	IV	III*		III	

* Assessment – MURAT 1*

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Anti-Personnel Obstacle Breaching System (APOBS)

Performance Comparisons

- Improvement in deployment characteristics
- and packaging (130-pound two-man portable) over the intensive manpower M1A2 Bangalore Torpedo demolition kit
- 1 APOBS = 3 Bangalore
- Capabilities (45 m - 98% effectiveness) similar to the much larger M58 Mine Clearing Linear Charge
- Reduction in system weight

Customers

- US Army, US Marine Corps (Production)

IM Technology

- 108 grenades with PBXN-10 main charge and booster explosive
- PBXN-8 detonating cord
- Packaging design

IM Benefits (cost analysis)

- Cost of PBXN-10 is 1/3 that of PBXN-9
- Palletized load weight has been reduced

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
PBXN-9	V	V	I/III	I/III	I	
PBXN-10	V	V	V	V	>I	

In shipping package configuration

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Demolition Block No.4 Mk1

Performance Comparisons

- Penetrates 1” steel (Armor) plates
- Operating Temperatures: -54C to +71C
- TNT equivalent: 1.6
- Service life over 20 years

Customers

- Germany, Norway, Switzerland, Malaysia, Italy

IM Technology

- PX-139 RDX/HTPB (87/13)

IM Benefits (cost analysis)

- No information

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
C4			III			
PX-139	V	V	NR	NR*	V**	

* Rafael test – EFP - Cu 16.2 g, 1500 m/s
** Minimum 60mm air gap

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SPIDER (XM7) (Formerly XM155)

Performance Comparisons

- RDX/DNAN based melt cast
- Comp B replacement

Customers

- US Army

IM Technology

- Energetics PAX 41 main charge
- Low Energy Exploding Foil Initiator
- RSI 007 (CL20 based) initiation
- Venting of plastic material around GIM
- Packaging design – venting of box seal
- Use of polythene foam for shock attenuation

IM Benefits (cost analysis)

- Cost of PAX 41 is low
- Grenade initiation Module (GIM) has twice the output at ½ the cost of traditional Fuze and booster

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
C4			III			
PAX 41	*	*	*	*	*	*

* Reported as a pass/fail however response not specified

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Evolved Sea Sparrow Missile (ESSM)

Performance Comparisons

- **Rocket Motor**: As well as superior IM performance, the HTPE propellants offer comparable energy density and equivalent/superior physical properties.
- Warhead: KS-33 (90% HMX) –VoD 8480 ms^{-1}
- PBXN-4 (94%DATB) – VoD 7200 ms^{-1}
- PBXN-3 (86% HMX)

Customers

- US Navy, Norway, Germany, Australia, Netherlands, Denmark, Canada, Spain, Italy, Turkey, Greece, Belgium and Portugal

IM Technology

- IM High Explosive (15kg) – KS-33
- Dual HTPE propellant grain (119 kg)
- Laser Arm and Fire Device as Ignition System for the rocket
- Composite Case being considered for the next generation (PI)
- Al/polystyrene foam sandwich casing for the container

IM Benefits (cost analysis)

- KS-33 is cast-cured whilst PBXN 3 & 4 are pressed HE. Cost difference by HMX

IM Signature

	FCO	SCO	BI	FI	SR
KS-33 warhead	V	V	V*	V	>II
Rocket motor[1]	III	III	V*	IV	

*In launch canister. [1] Baseline motor, steel case

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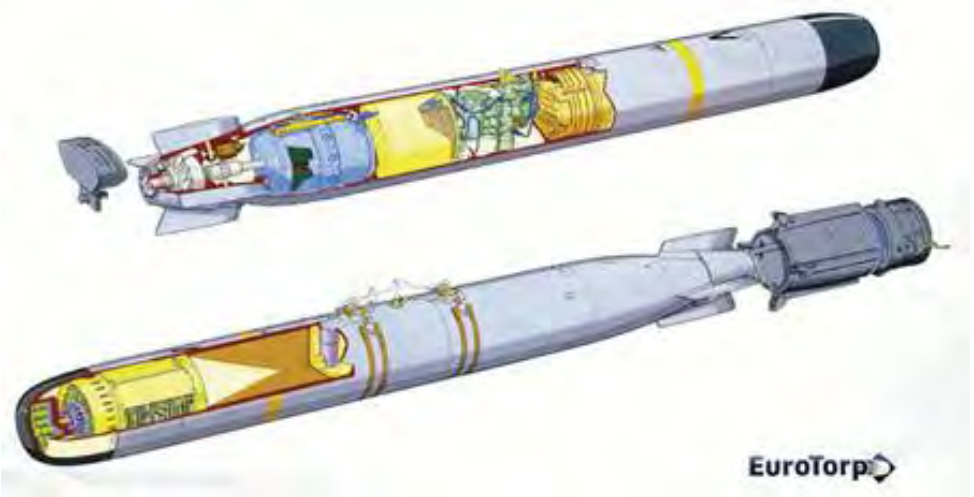
Lightweight Torpedo (MU90)

Performance Comparisons

- Tip velocity 8925 ms^{-1}



Customers

- Denmark, France, Germany, Italy, Poland, Australia, New Zealand

IM Technology

- IM High Explosive: V-350 (Isostatic pressed)
- Booster V-350
- Logistic container with a sandwich barrier

IM Benefits (cost analysis)

- MU 90 Cost: TATB-Minimal effect on unit cost

IM Signature

	FCO	SCO	BI	HFI	SR
Octol (HMX/TNT)					
MU-90	V	V	V	IV	NR*

* In logistics container

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Naval Strike Missile (NSM)

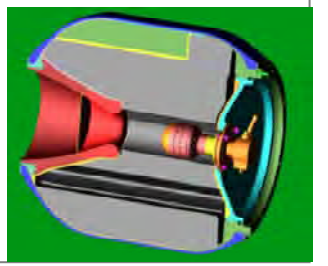
Performance Comparisons

•Hard target penetrator
•Fuze Counts voids/ (hard) layers w/ back-up timer.
Weight: approx. 400 kg. Range: in excess of 150 km. Designed for littoral waters as well as open sea scenarios. (The advanced design allows the missile to fly around and over landmasses.)

Warhead: Navel strike missile (NSM)

IM Technology

- IM High Explosive: KS22a
  (67 % RDX)(15 % Plastic Binder)(18% Al)
- Boost Motor Carbon fiber reinforced plastic casing
- Turbofan sustainer



IM Benefits (cost analysis)

- Cost difference of IM over non IM would be insignificant

Customers

- Norwegian Navy
- Platforms: Ships
- Also planned for Patrol Boats, trucks, armoured vehicles, and airborne weapon carriers.

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Warhead	IV	IV	V	V	IV	
Boost Motor	V	III	V	IV	IV	

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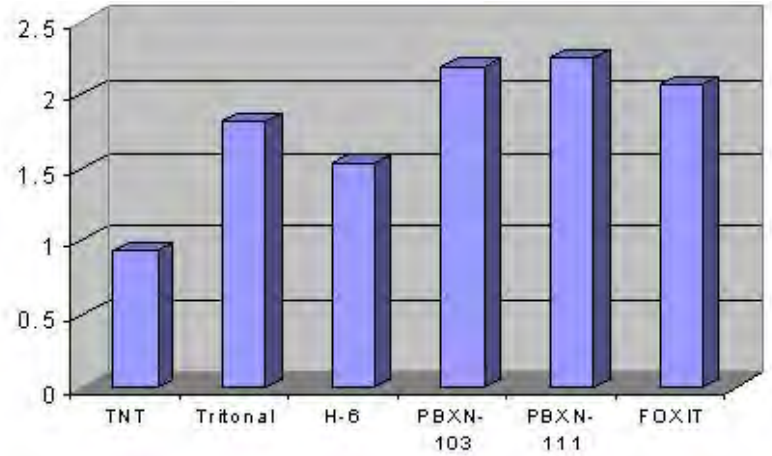
Sea Mine 2000

Performance Comparisons

- Relative bubble energy



Customers

- Finland

IM Technology

- EIDS High Explosive FOXIT (AP/Al/RS-RDX/HTPB: (38/28/20/14))
- IRDX – different crystallisation to normal RDX
- Case: Special composite material

IM Benefits (cost analysis)

- Ingredient cost (RDX cost-driven factor) FOXIT < H6
- Process cost : Cast-cured > melt-cast

IM Signature

	FCO	SCO	BI	FI	SR
Torpex					>III
FOXIT	V		V		III*

* Air gap > 50 cm

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AGM-158: JASSM

Performance Comparisons

- Requirements:
  - Blast and fragmentation similar to Mk-82 and Mk-83 (AFX-757 e.g. 2.54 kJ/cm3)
  - Hard-target case (hard steel alloy > 2 cm)

Customers

- US Air Force
- Australia

IM Technology

•EIDS High Explosive (AFX-757)
•Venting fuze booster (PBXN-9)
•Aft closure, thermally reactive retaining ring
•Logistic container

IM Benefits (cost analysis)

•240 lbs HE in the warhead (~ BLU-110)
•JASSM Unit Cost ~ USD $0.7 M
•US DoD Classified as NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR
Mk-83 (H6 fill)	I	I	I	I	I
BLU-110	IV/V	IV/V	V	V	I
JASSM	V	V	V	V	III*

*Only in the logistics container

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STORM SHADOW / SCALP EG

Performance Comparisons

- All western countries precision-guided cruise missiles are IM to a certain extent and used similar HE formulations (PBXN-109 type)

Customers

- France
- Greece
- Italy
- UK

IM Technology

- High Explosives:
  - PBXN-110 (Precursor Charge)
  - PBXN-109 (Follow-Through Bomb)
- Booster Explosive: Rowanex 3601
- Logistic Container

IM Benefits (cost analysis)

- Not Relevant as this family of large penetrator missiles is IM only
- UK MoD classified as NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR
Mk-83	I	I	I	I	I
BLU-110	IV/V	IV/V	V	V	I
Storm Shadow	V	V	V	V*	IV**

* By analysis, ** In logistics container

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IRIS-T (SHORT RANGE AIR to AIR)

Performance Comparisons

- Improved rocket motor
- 50g turns reported

IM Technology

- Warhead
  - Energetics and construction classified
- Motor
  - Thermal Initiated Venting System (trialed)
  - HTPB/AP/AL composite
  - Reduced smoke

IM Benefits (cost analysis)

- IRIS-T unit cost approx $270,000

Customers

- Germany
- Greece
- Italy
- Norway
- Spain
- Sweden

IM Signature

	FCO	SCO	BI	FI	SR
AIM-9M	V	III	IV		III
Warhead	V	V	V		
Motor Unit	V	IV	IV	III	III

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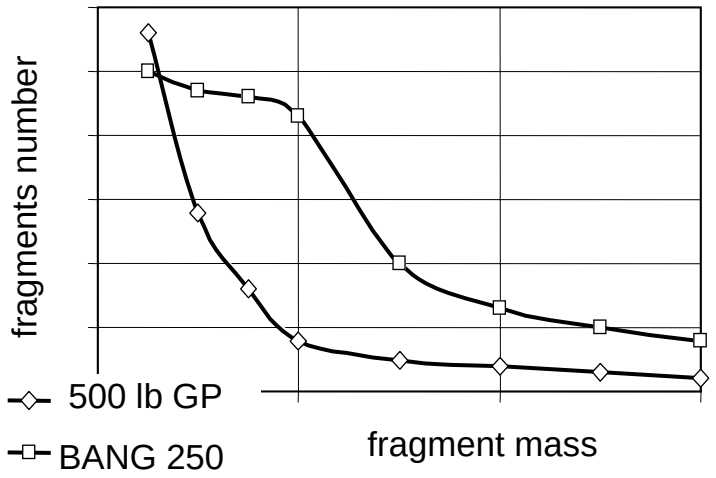
CBEMS/BANG 125 kg

Performance Comparisons

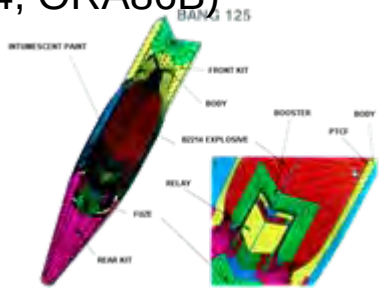


Customers

- French Naval Air Force (production)

IM Technology

- IM High explosives (B2214, ORA86B)
- Discharge of combustion gas by the liner towards the end
- Intumescent paint
- Logistic pallet geometry
- Venting devices in rear frame



IM Benefits (cost analysis)

- For the all up round (including Paveway II guidance kit), ratio between IM version and non-IM version is 1.13

IM Signature

	FCO	SCO	BI	FI	SR
Mk82 mod 2 TP	I	I	I	I	I
CBEMS/BANG	V	V	V	V	III

4 palletized bombs without the fuze MURAT **

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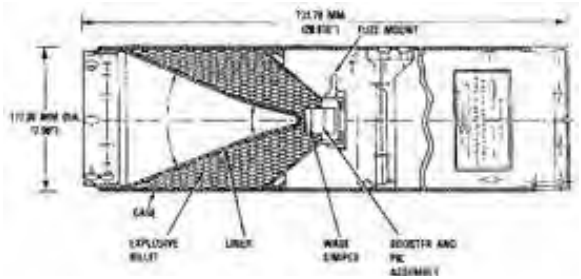
HELLFIRE II WARHEAD (AGM-114K)

Performance Comparisons

- Design adaptation studies:
  - explosive pressing, weight reduction, and liner adaptation
- At 7 CD stand-off same performance
- Over 70 tests



Customers

- US Army
- US Marines
- UK Army (Apache, Cobra Helicopters)
- France

IM Technology

- K variant incorporates an IM High explosive (PBXN-9) to improve Helicopter survivability
- IM booster
- 2" thick buffer aluminum

IM Benefits (cost analysis)

- Explosive weight reduced (<14 pounds)
- No hardware modification
- Similar loading and assembling method
- No more wave shaper

IM Signature

	FCO	SCO	BI	FI	SR*
LX14	V	V	I/III	I/III	I/III
PBXN-9	V	V	V	I/III	III

*All missiles in shipping containers

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SMALL DIAMETER BOMB (SDB) (GBU-39B)

Performance Comparisons

- Nominal range ~100 km
- Warhead mass ~48 kg Net Explosive Weight
- Current and planned launch platforms include F-15E, B-1, B-2, F-16, F-18, F-22 and F-117.

Customers

- Production approved in April 2005
- USAF plans to purchase 24,000

IM Technology

- Boeing GBU/39B, 250lb class munition
- EIDS high explosive (AFX-757)

IM Benefits (cost analysis)

- Total program cost ~US$2.59 billion including development
- 24,000 phase 1 units and 2000 carriages
- Reported USAF target price is <US$50K/bomb
- USA DoD classified NATO 1.2.3 and UN HD1.2

IM Signature

	FCO	SCO	BI	FI	SR
GBU-39	V	V	V		III

GBU-39B SDB was only the second munition to be given SsD 1.2.3 (following JASSM) which means the above signature has been achieved. SR is Type III or better.

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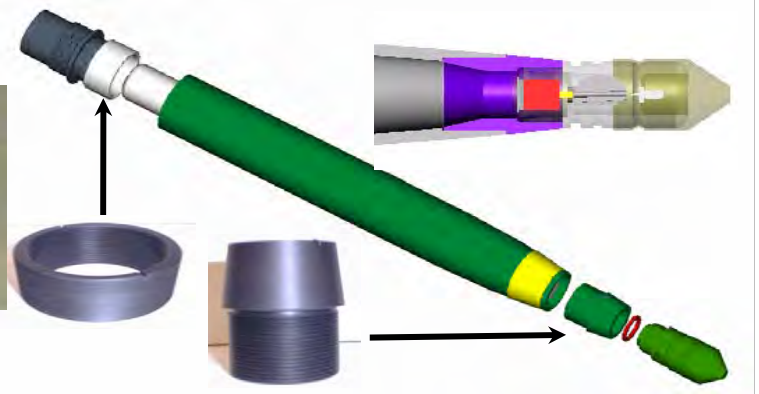
2.75” ROCKET SYSTEM

Performance Comparisons

- Mk-146 Mod 0: larger lethal area and greater fractional casualties/damage than the M229 (Mk-151) Warhead, at all ranges and all targets:
  - Standing and Prone Personnel: ~20%
  - Light Trucks: ~9%
  - Straight Flush Radar:~5%



Customers

- Mk-146: Scheduled to be introduced to production in FY04

IM Technology

- Insensitive explosives in Mk-146 Mod 0 Warhead (PBXN-110) and fuze (Lead-in charge: PBXN-5 and booster charge: PBXN-7)
- Venting on both warhead ends to improve Cook-off reaction (Polymer adapter)
- Nitinol (shape memory) ring , vented motor tube and ejectable warhead adapter for motor section

IM Benefits (cost analysis)

- None available

IM Signature

	FCO	SCO	BI	FI	SR
Mk-151 CompB	II	I	IV	I	I
Mk-146 Mod 0	V *	V *	V	I	I
RM Mk-66 Mod 5	IV/V*				

*In LAU-6CA launcher or Mk-706 mod 0 container

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US IM Strategic Plan

- Complete munitions portfolio for the Program Executive Office (legacy, developmental, production, awaiting production, Advanced Technology Demonstration, Foreign Comparative Testing, inventory)
  - For each munition:
    - Research Development Test, Evaluation and procurement profiles
    - Baseline and predicted IM performance
    - Ongoing and planned technology integration efforts with identified funding
- IM investment priorities and prioritization criteria
- Standardized detailed IM Plan of Action and Milestones for each priority program
- Service-specific and Joint IM investments
- Unfunded IM requirements
- Technology shortfalls

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Albania 15th March 2008 - The End

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GENERAL DYNAMICS
Armament and Technical Products

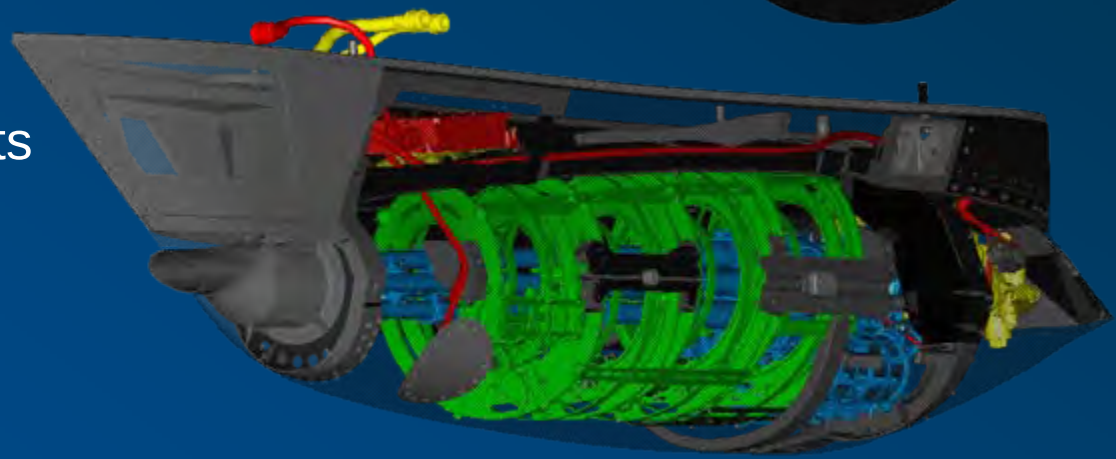
F-35 Lightning II STOVL/CV Gun System Update

Presented by:

Douglas Parker
Lead Mechanical Engineer – Joint Strike Fighter Gun System
General Dynamics Armament & Technical Products
Burlington, Vermont USA

Presentation Outline

- System Description
- Achievements since March 2007
- Engineering Test Results
  - Power
  - Dispersion & MPI
  - Interface loads
  - Gun motion
  - Design improvements
- Pod Fatigue Test Status
- Path Forward



Lockheed Martin F-35 Variants

CTOL

Span (ft)	35
Length (ft)	50.5
Wing Area (ft^2)	460

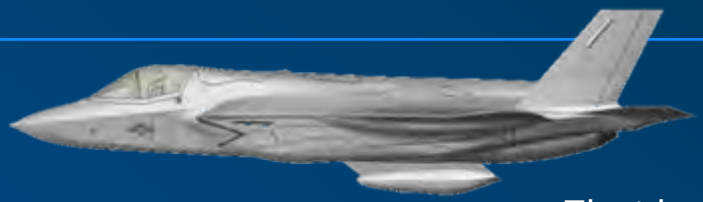
STOVL

Span (ft)	35
Length (ft)	50.5
Wing Area (ft^2)	460

CV

Span (ft)	43
Length (ft)	50.8
Wing Area (ft^2)	620

STOVL/CV Gun System



GSCU & electrical

PT & hydraulics

Gun & transfer unit

Helical feed system

Engine Nacelle vent inlet

Electrical & hydraulic connections

Bulb seal

Aft bulkhead captive fasteners & pin

Purge inlet

Fwd bulkhead captive fasteners & pin

Transparent:

Inner tube, LH side skin & access doors

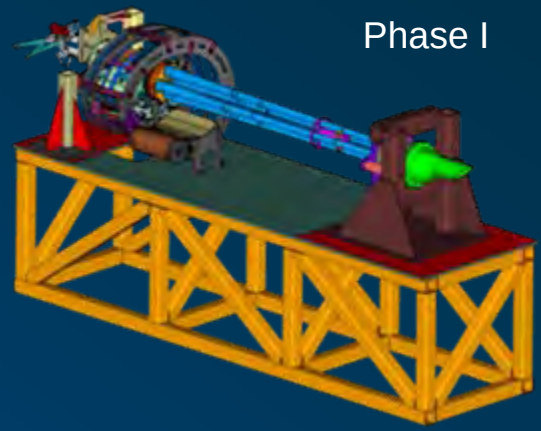
Weapon Bay Door stops

Purge exhaust

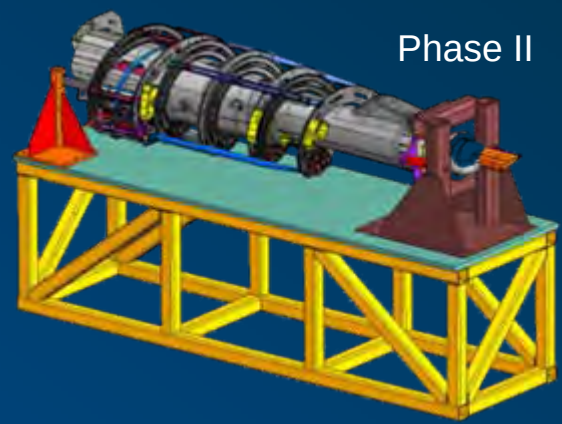
Achievements since March, 2007

- Successfully completed Phase I engineering fire testing
  - Handoffs optimized
  - Initial evaluation of helix functionality, dispersion, and power
  - Interface loads and gun motion measured
  - Recoil track design improvement implemented
- Began Phase II engineering fire testing
  - GSCU operation verified, including reverse clearing
  - Dispersion and power measured
  - Design improvements implemented for carrier durability and safing/firing cam operation,
- Fired 5,000+ and cycled 1,300+ rounds to date

Phase I



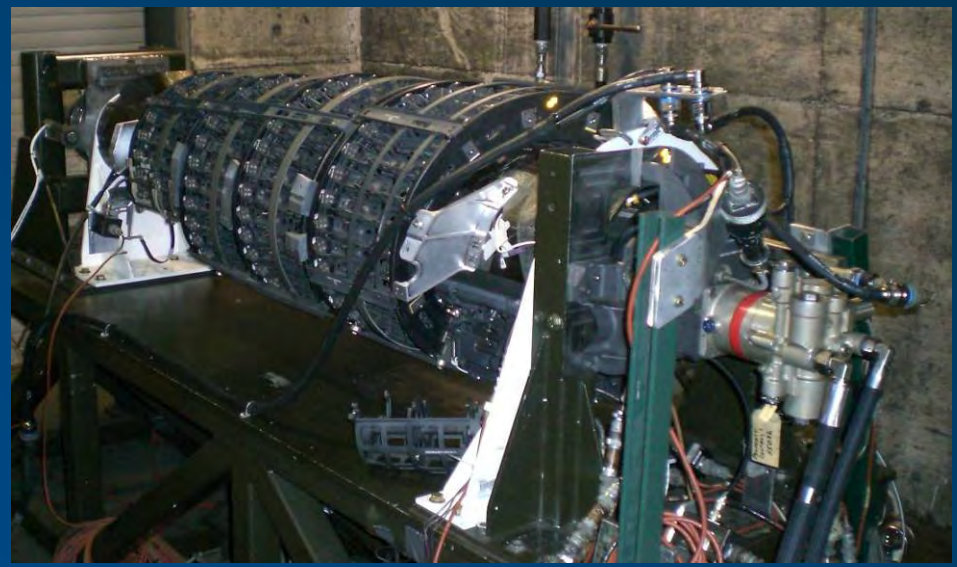
Phase II



Test - Phase II Focus

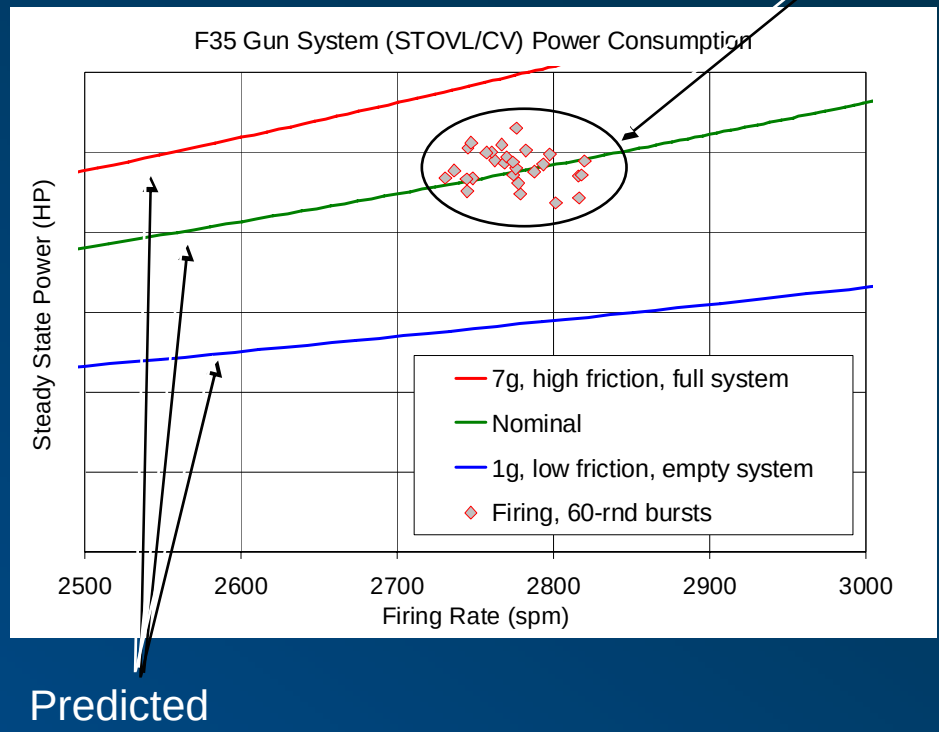
- Overall gun system functionality
  - Integration of GSCU, software, full feed system
- Validate design changes
  - Carrier durability
  - Safing/firing cam
  - Recoil track durability
- Dispersion
- Power

Firing video



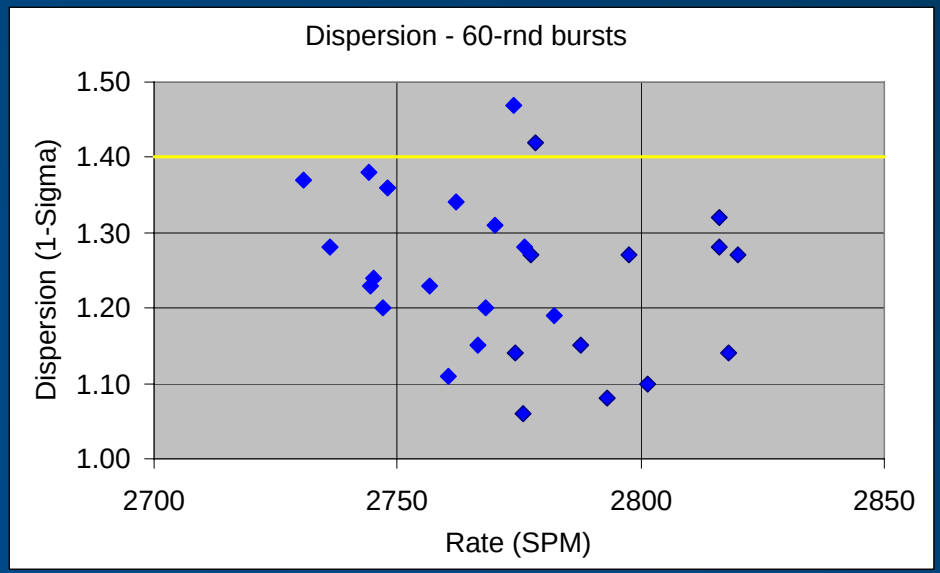
Test - Power

- System power is within expected range
- Hydraulic drive motors achieved acceleration and rate requirements



Test - Dispersion

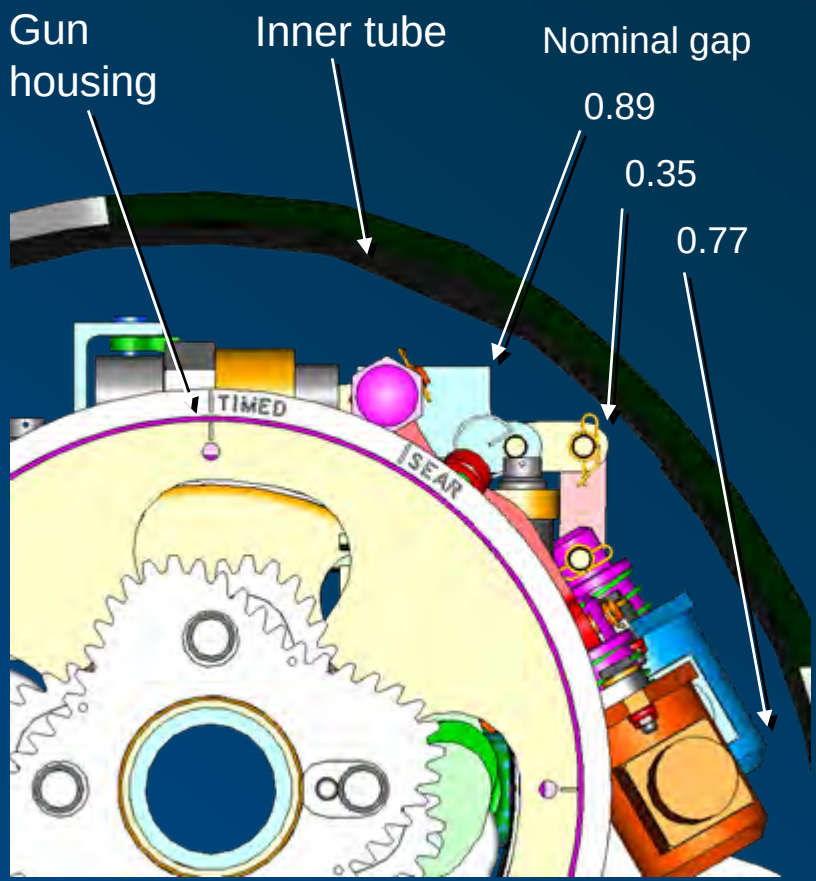
- Requirement
  - Dispersion - 1.40 milliradians one-sigma (minimum 54 rnds)
- Firing conducted with 60-rnd bursts



- Testing planned to evaluate impact from firing rate, start-up characteristics, burst length, and usage

Test – Gun Motion

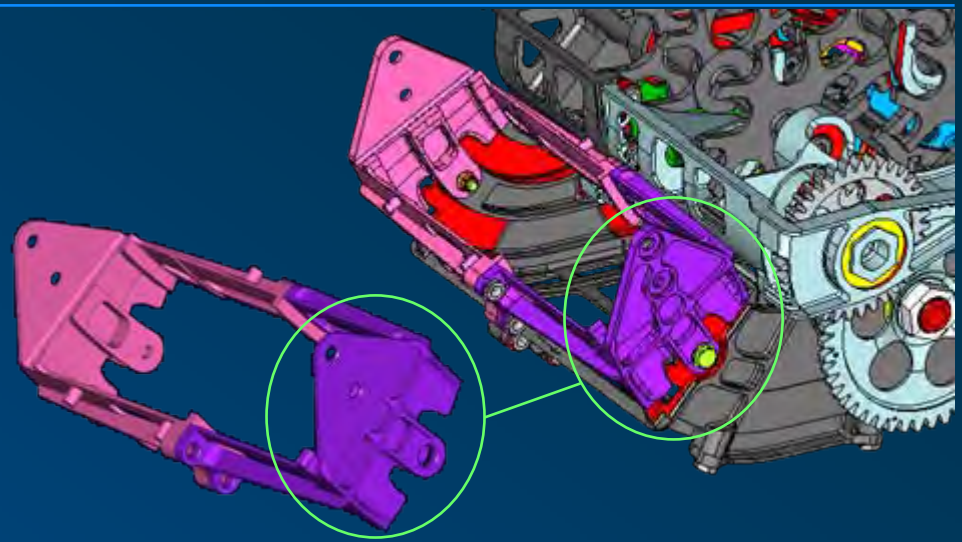
- Monitored gun motion –
  - Aft cover (vertical & lateral)
  - Forward vertical (via turnaround housing)
  - Forward lateral (opposite firing/safing cam)
- Worst case measured motion in area of greatest concern (safing/firing cam) is ~0.25”
- Slot will be incorporated on deliverable tube to accommodate gun motion/function

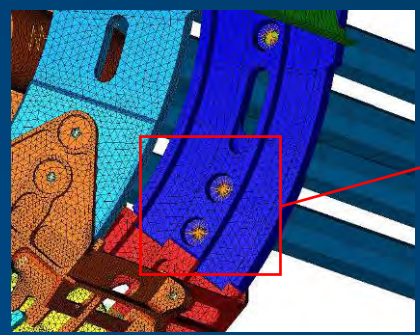


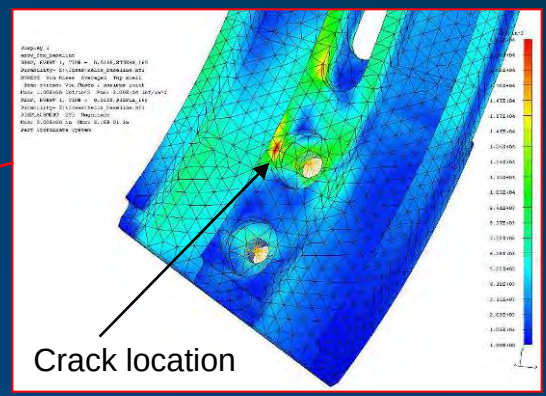
VIEW – Aft looking forward

Design Improvements – Recoil Track

- Forward recoil track crack observed at 668 rnds
- Static and dynamic analysis conducted to optimize redesign
  - Track adapter softened & track locally beefed up
- Results
  - Static 0.625” displacement testing showed a stress reduction of 30%
  - Dynamic analysis indicates >25% reduction in the stress
  - Crack has not reappeared since softened track adapter and new track installed
  - Monitoring will continue

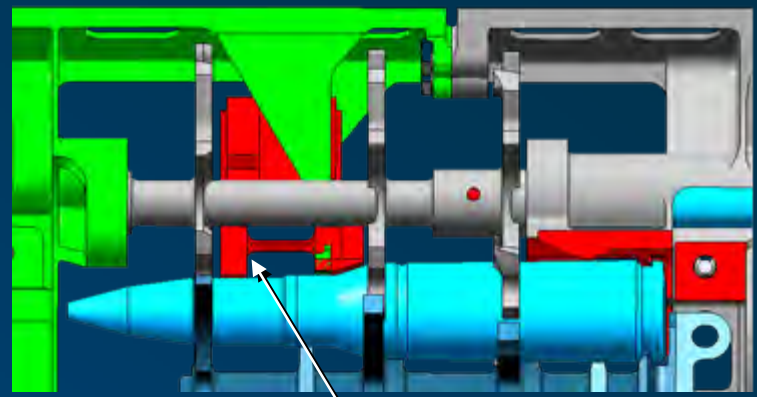


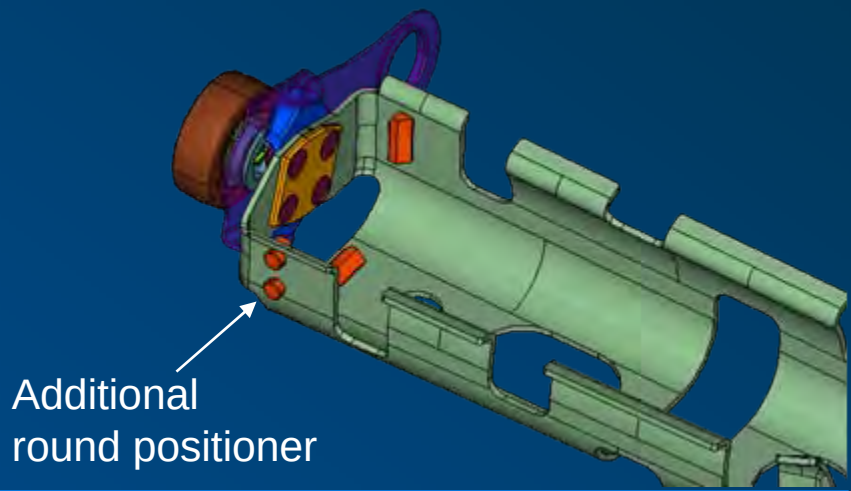




Design Improvements - Handoffs

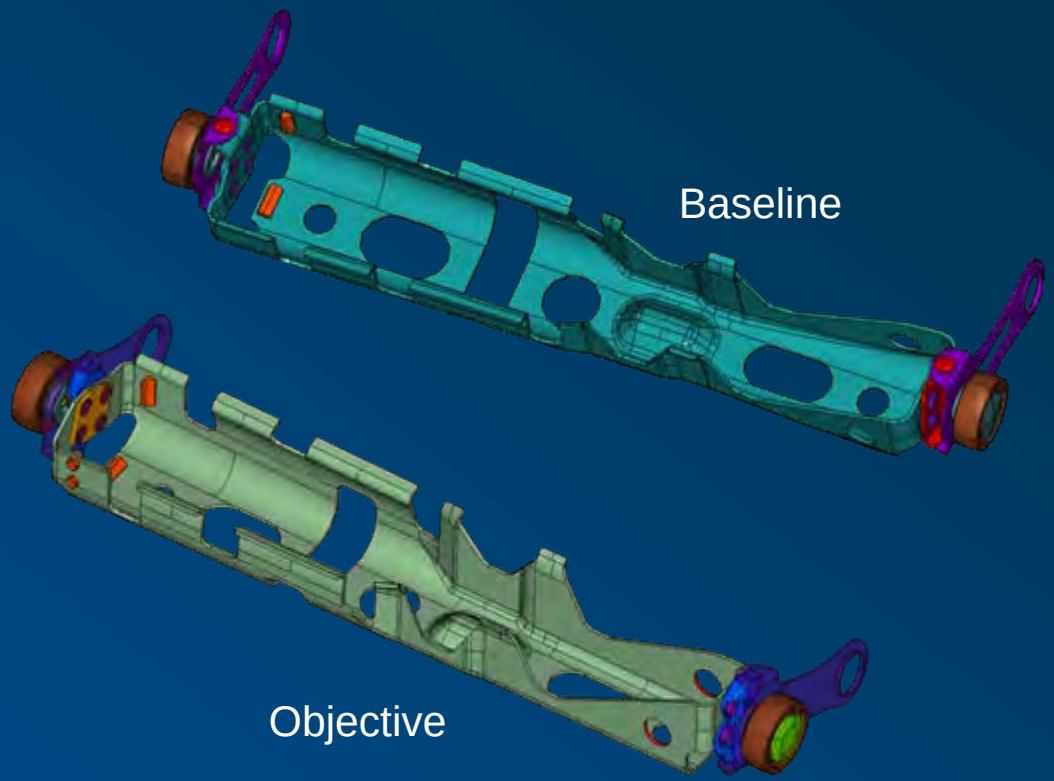
- Handoffs from the carrier to gun (and visa versa) required very little adjustment
  - Slight transfer unit sprocket tip massaging required
  - Projectile guide added to improve robustness of handoff from carrier to turnaround
  - Additional round positioner added to carrier to ensure axial control of round during turnaround unit approach





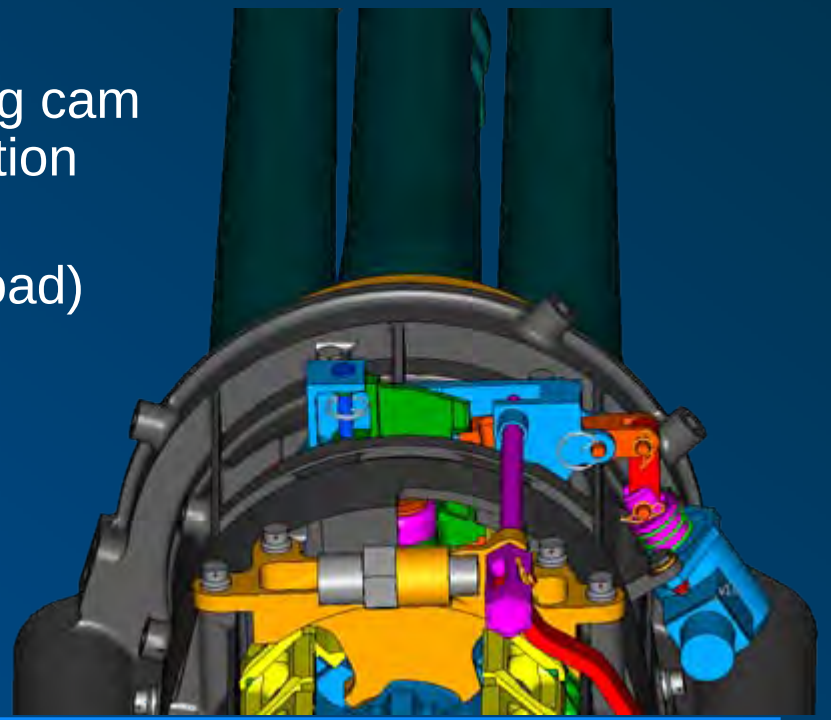
Design Improvements - Carrier

- Dynamic loads measured during test are ~4X greater than the design to loads due to gaps and dynamic response of carrier, requiring significant redesign of the carrier assembly
  - More robust roller retainer
  - Machined blocks replace sheet metal tabs
  - Simplified & stiffened carrier body
  - Directly supported link & link pin
  - Improved link material & geometry
  - Extended rim retainer in turnaround unit is under investigation



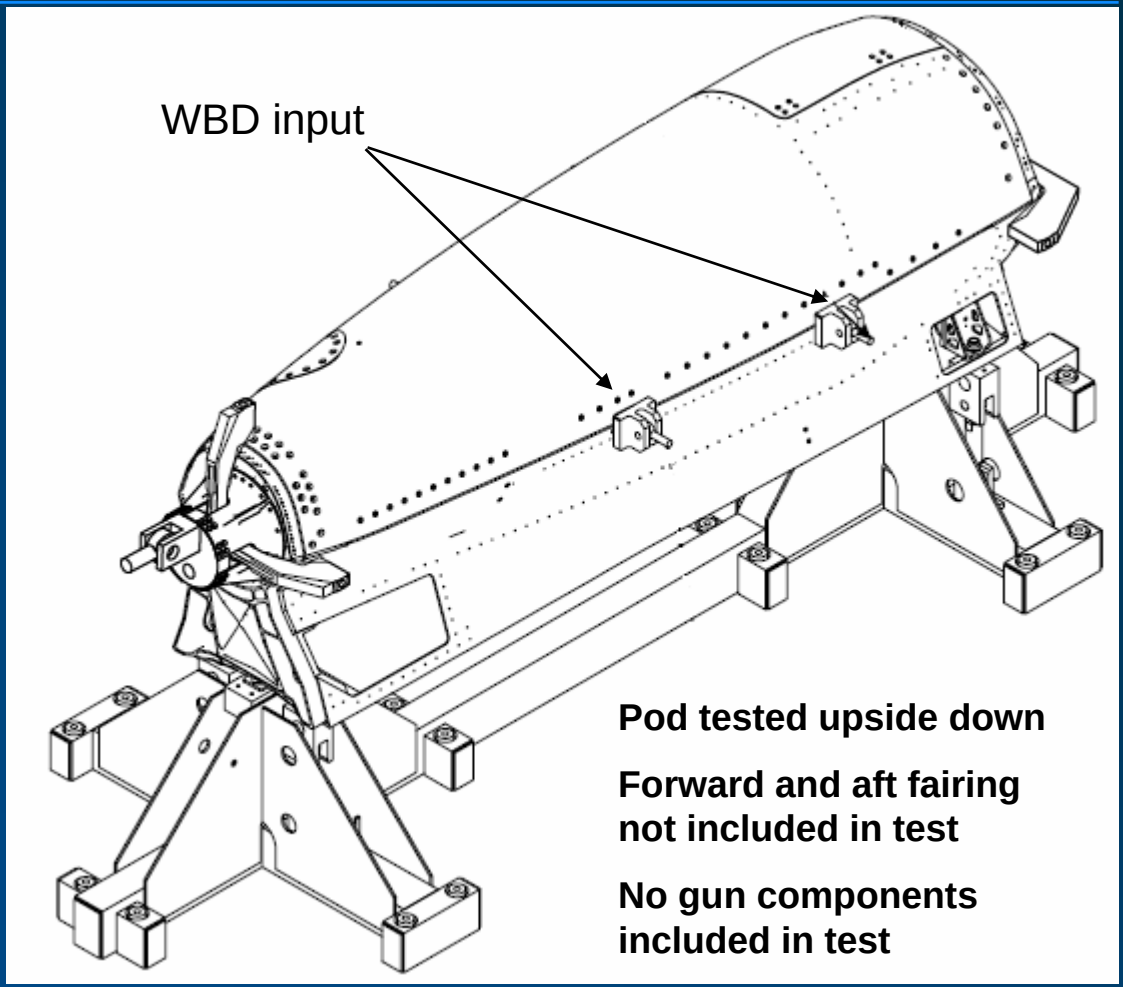
Design Improvements – Firing/Safing Cam

- Significant bouncing of firing lever observed
- Gun could fire without firing solenoid engaged if safing pin was damaged/removed
- Range evaluation . . .
  - Reducing clearance between firing cam and gun housing improved condition
  - Clearance reduction coupled with increased link length (higher preload) eliminated phenomena
- Actions
  - Use firing data to optimize firing/safing cam interface
  - Update hardware and verify fix



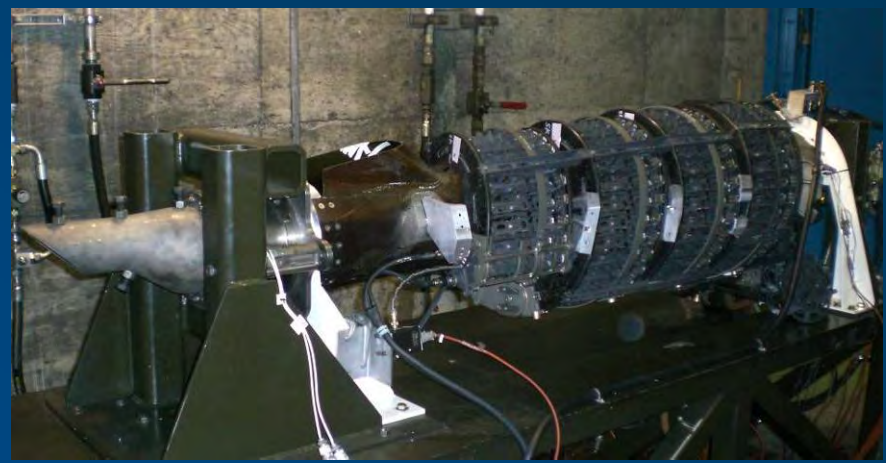
Pod ETU Testing

- Conducted on Pod engineering test unit (ETU)
- Test scheduled for 2nd quarter 2008
- Vibe - gun recoil load fatigue test, equivalent to 36,000 rounds
- Limit load – Gunfire and Weapon Bay Door (WBD) loads



Path Forward

- Complete Engineering Test
  - ~9,000 rounds remaining
  - Verify system durability and functionality
  - Verify carrier life
  - Integrate Pod
- Complete Pod ETU testing
- STOVL/CV 36,000 Round Qualification Test



GENERAL DYNAMICS

INSENSITIVE GUN PROPELLANTS WITH LOW TEMPERATURE COEFFICIENT BASED ON DNDA

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43rd GUN & MISSILE SYSTEMS CONFERENCE

April 21-24, 2008

New Orleans, LA, U.S.A.

Fraunhofer Institut Chemische Technologie

Content

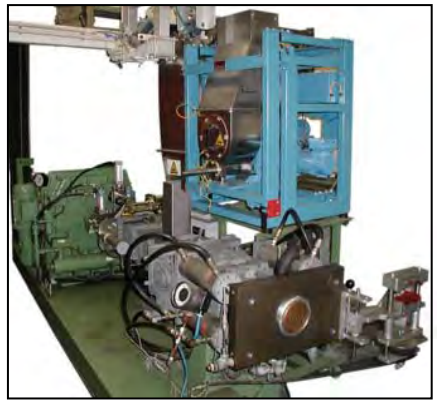
- Processing Technology
- Low Temperature Coefficient (LTC) Propellants
  - Temperature Behaviour
  - Characteristics of the Propellant Components
  - Performance, Safety & Sensitivity Datas
  - Shaped Charge Tests
  - Closed Bomb Tests
  - Gun Firing
  - Erosivity
- Results & Conclusion

INSENSITIVE GUN PROPELLANTS

Processing Technology for Insensitive Gun Propellants based on DNDA

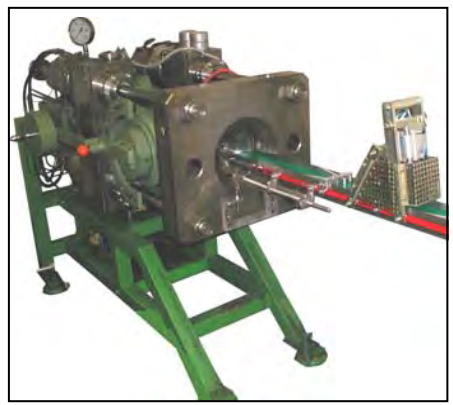
Continuous Process

- Shear Roll Mill
- Twin Screw Extruder (TSE) ZSK 58 E



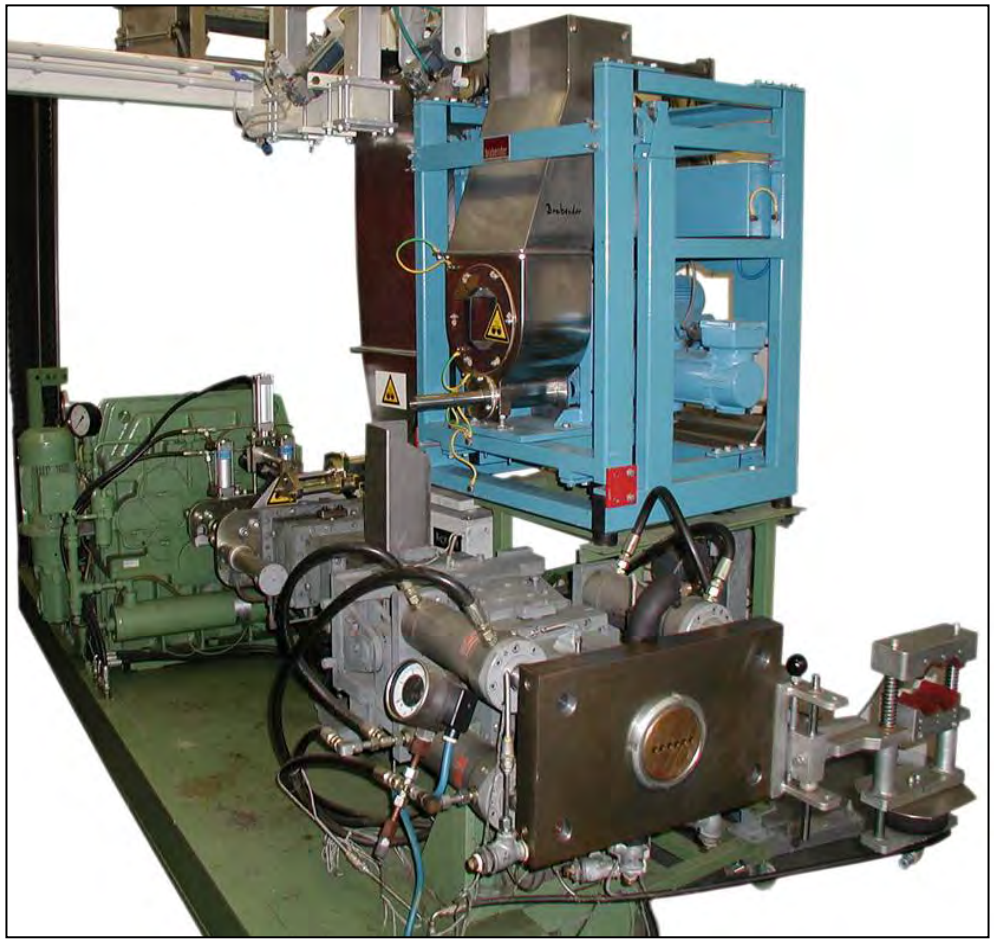
Batch Process

- Kneader / Mixer
- Rampress

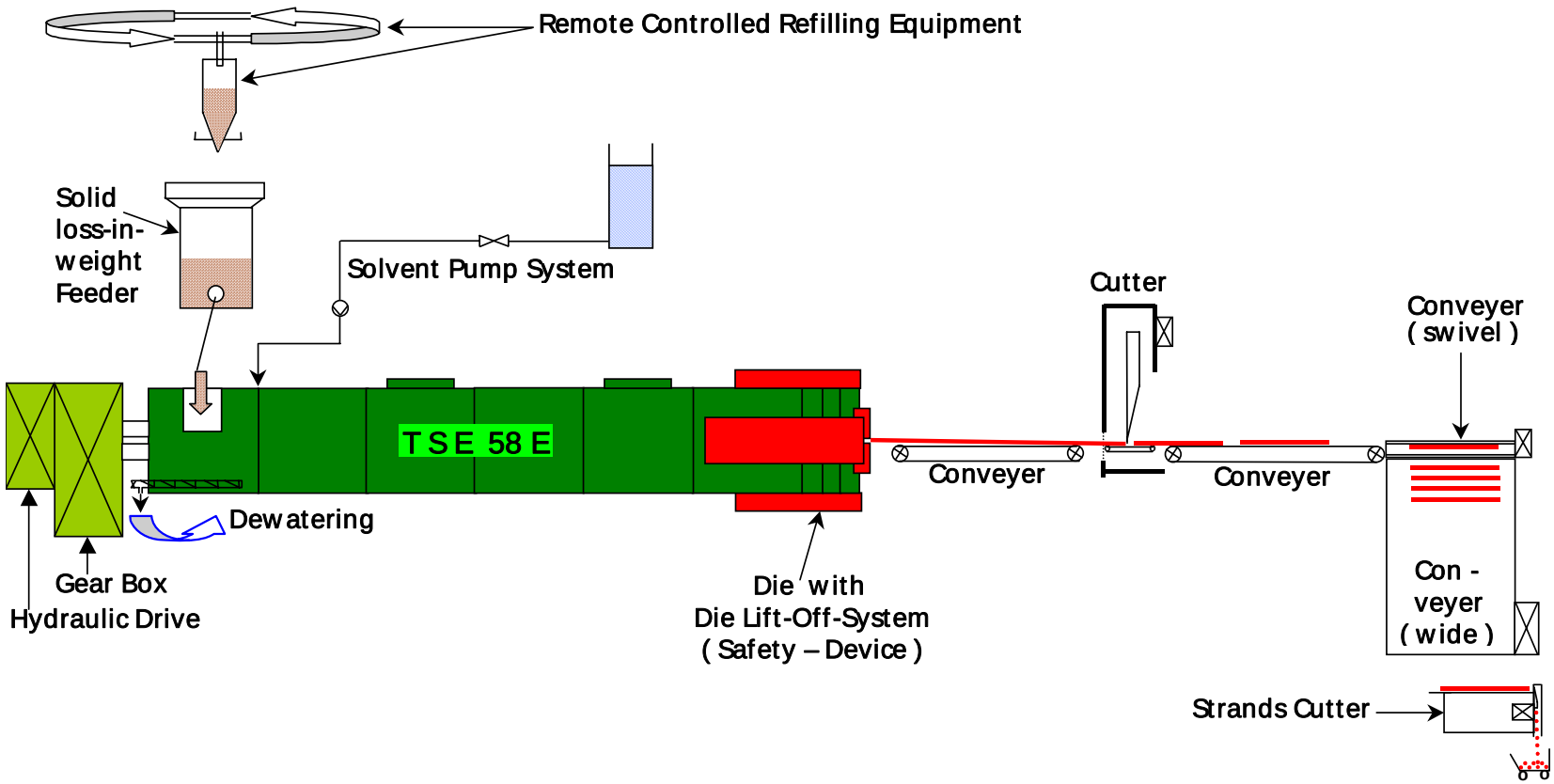


Shear Roll Mill (Continuous Process)

Corotating intermeshing Twin - Screw Extruder ZSK 58 E

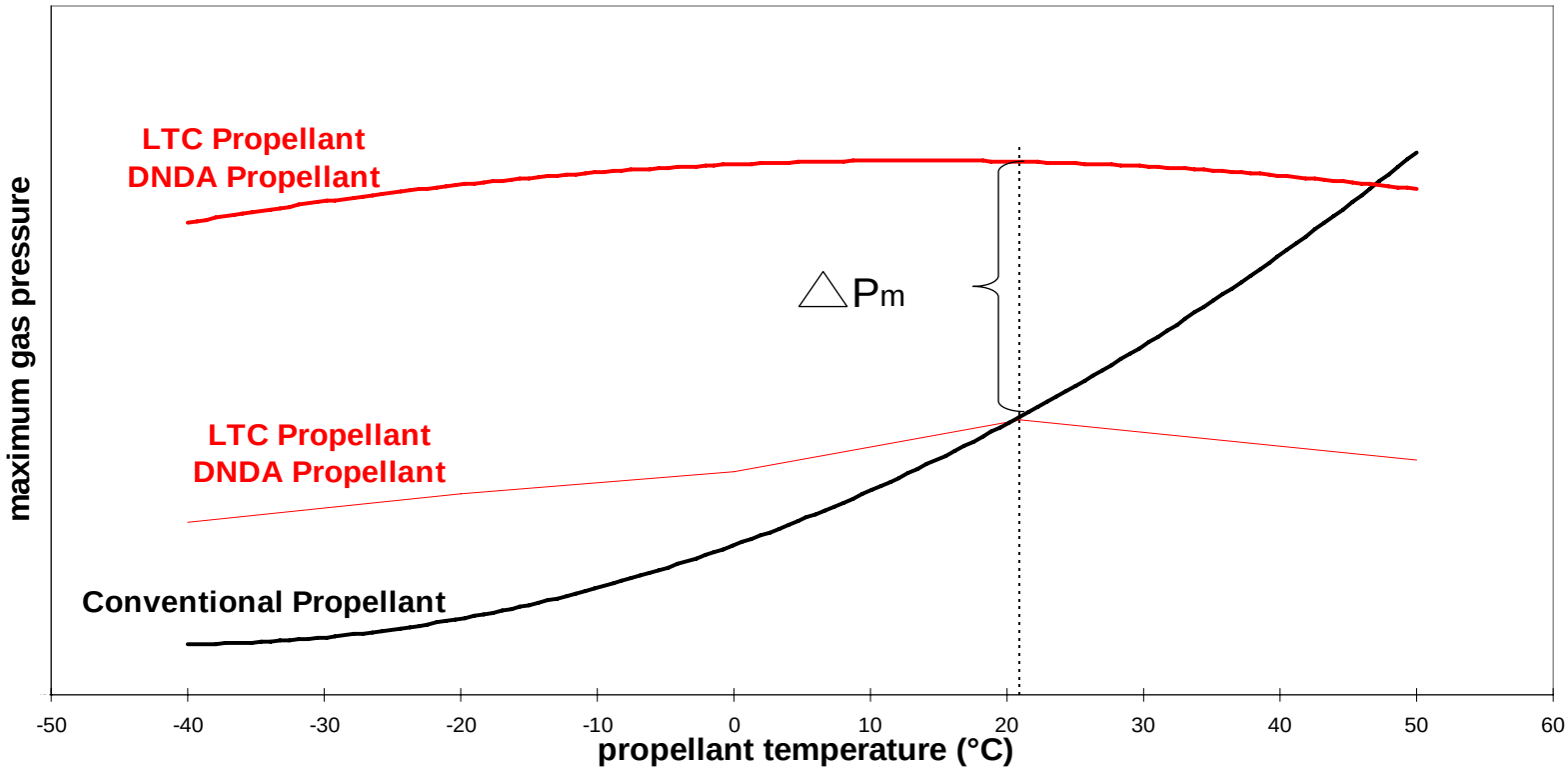


Twin - Screw Extruder Process

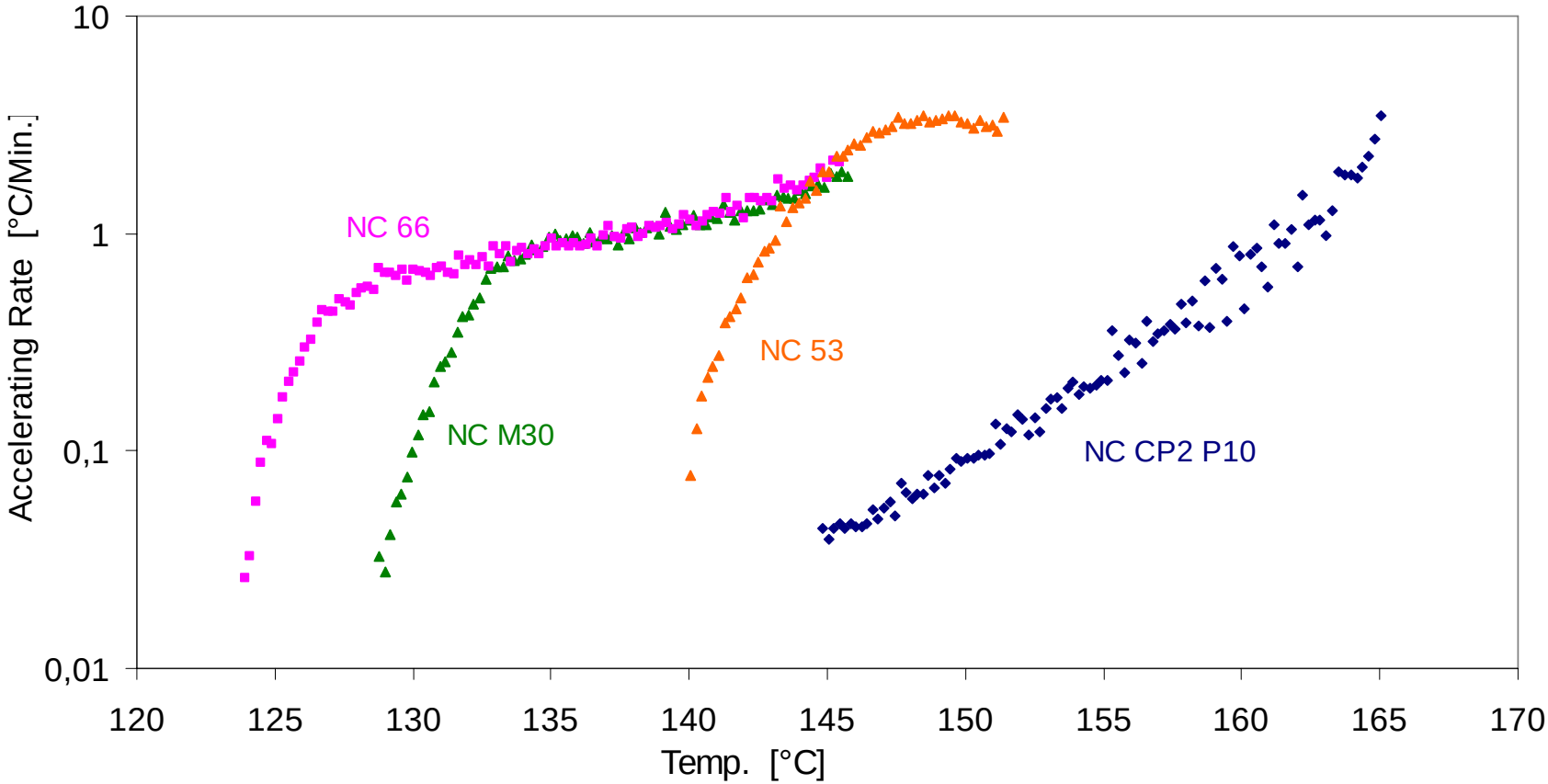


Temperature behaviour of gun propellants

Max. gas pressure vs propellant temperature



ARC measurement of several Nitrocellulose (NC) types



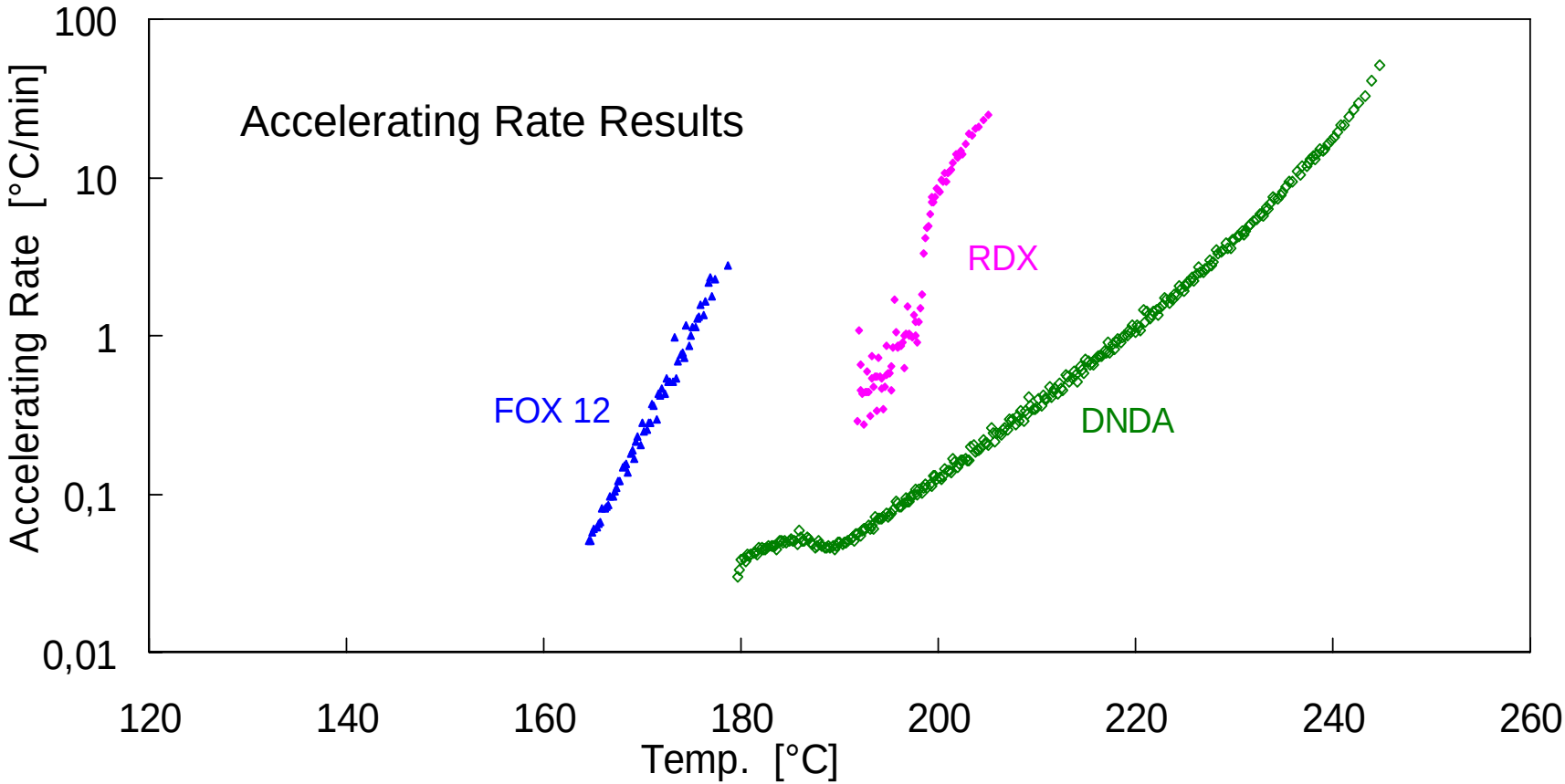
Lightmicroscope pictures of different NC types

NC M30

NC CP2

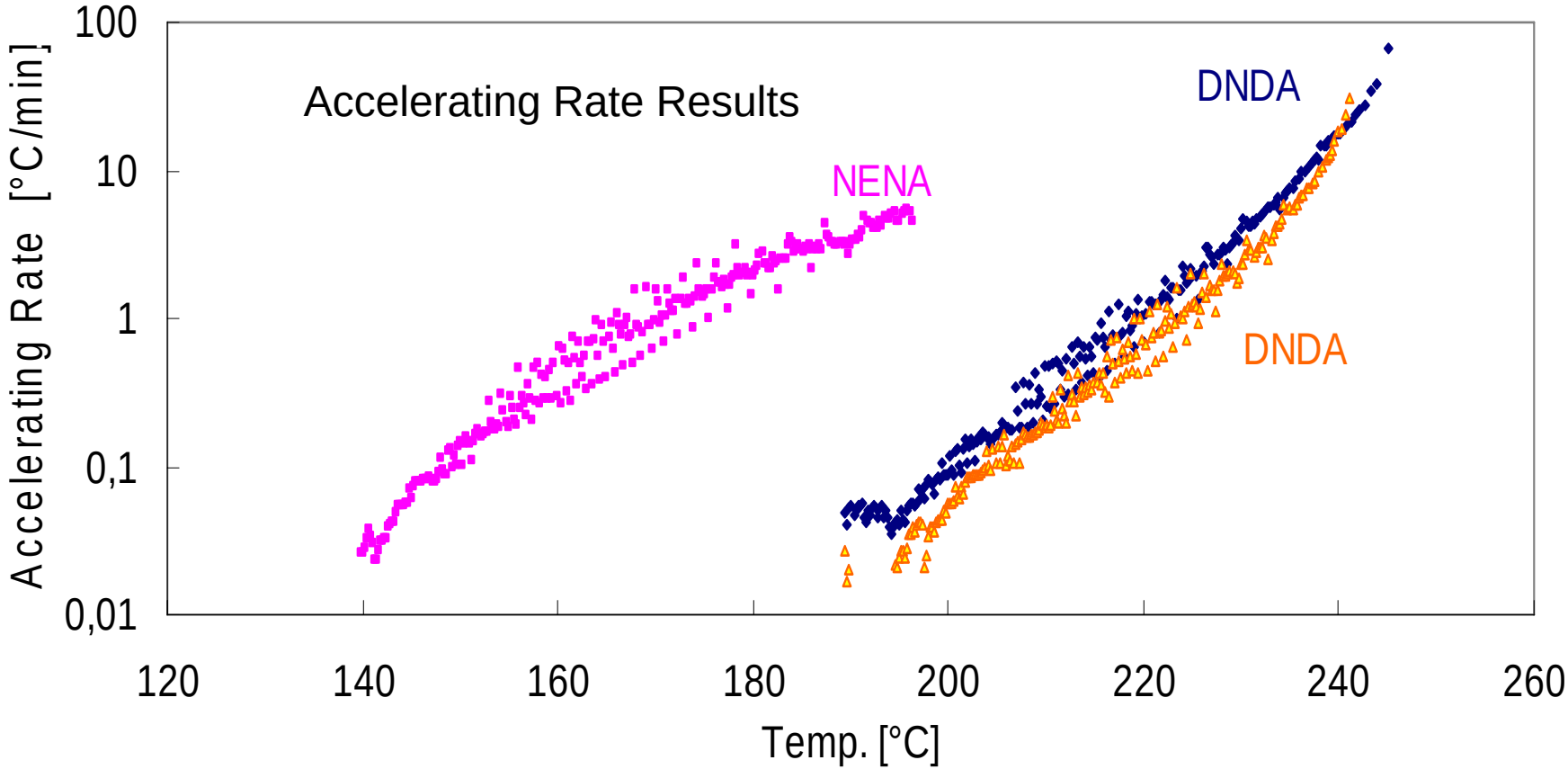
NC 53

ARC measurement of RDX, FOX-12 and DNDA

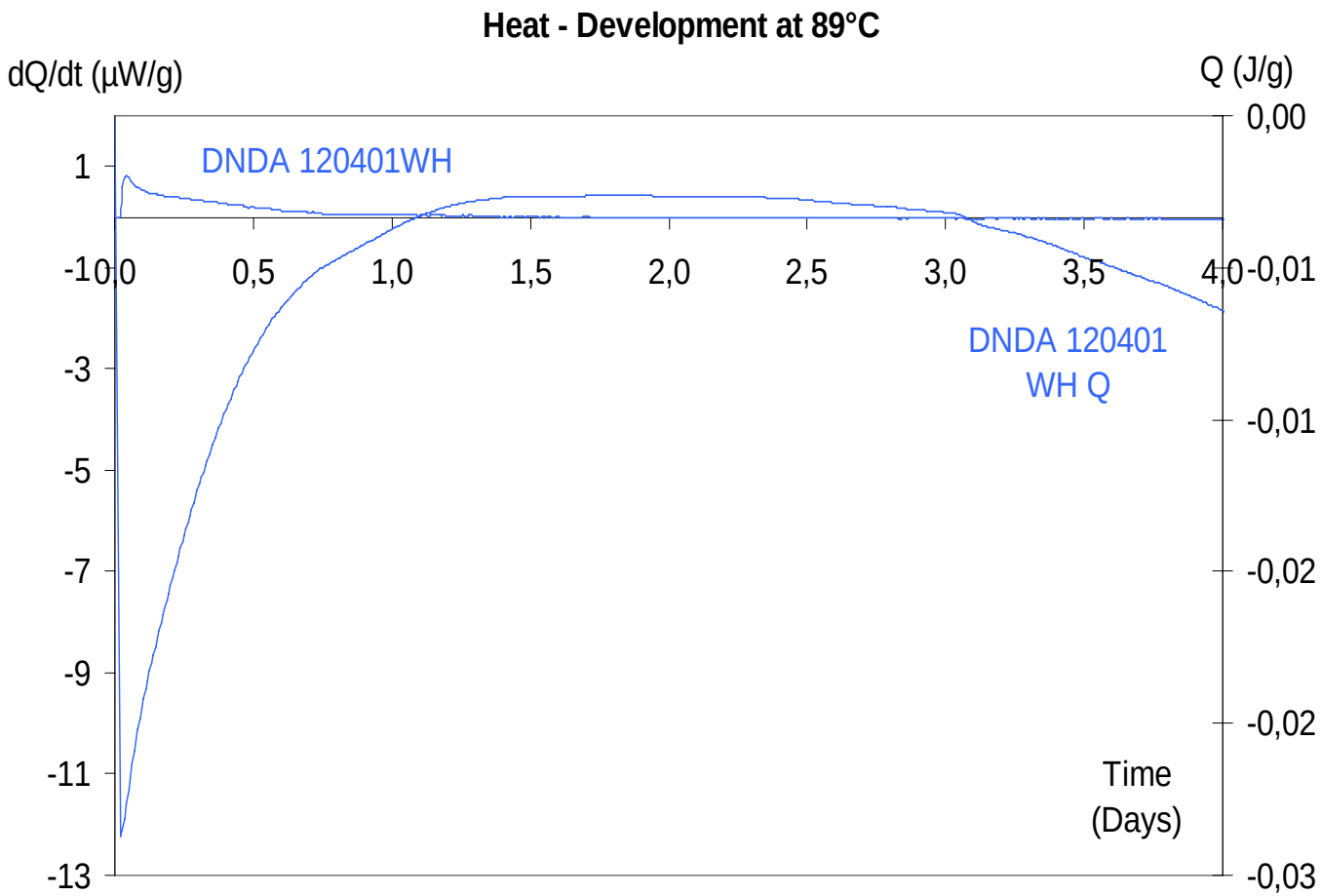


ARC

DNDA-5,7 compared with NENA



Microcalorimeter Result of DNDA-5,7
Endothermic Behaviour



Mue

Performance Data of LTC Propellants

RDX / FOX-12	x	x	x	x	x	x	x
	till max. 59 Wt. - %						
NC	x	x	x	x	x	x	x
DNDA-5,7	x	x	x	x	x	x	x
Stab., Additives	x	x	x	x	x	x	x
T [K]	2540	2913	3118	3160	3264	3335	3390
Force [J/g]	1080	1182	1212	1229	1250	1263	1300
Q_{ex} [J/g]	4000	4204	4347	4411	4519	4594	4730
Mw [g/mole] Reaction gas	19,4	20,8	21,4	21,4	21,7	21,9	22,1

Safety Data of selected LTC Propellants

Mass - Loss weight after 18 days, 90 °C	0.50 till 0.70 %
Mass - Loss weight after 30 days (no autocatalytic effects)	1.10 till 1.40 %
Ignition temperature	> 215 °C
Cook - off temperature approx.	> 210 °C

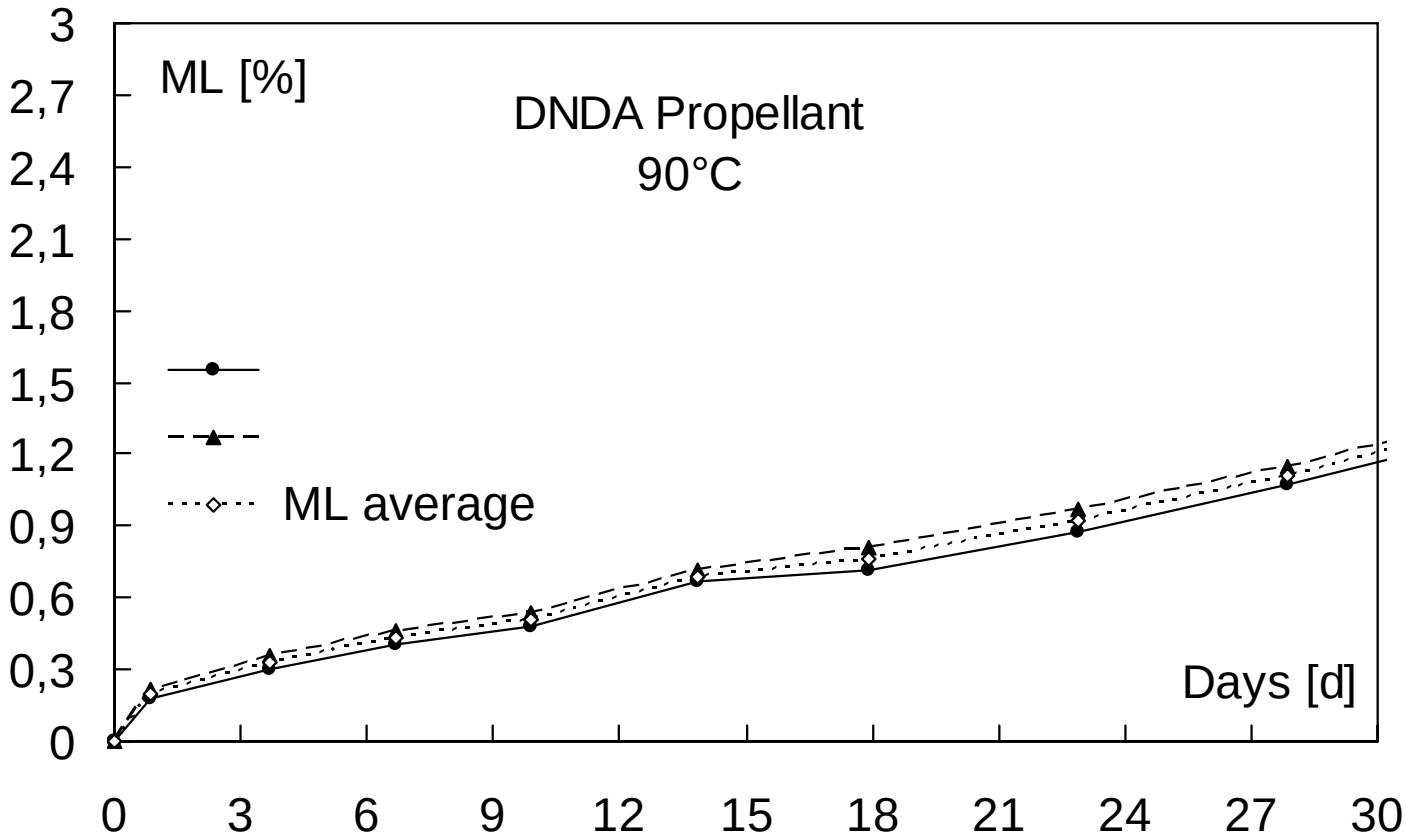
Sensitivity Data of different DNDA - Propellants

	FOX - Prop. ICT 8	FOX - Prop. ICT 7	RDX - Prop. ICT 1	i -RDX - Prop. ICT 2	RDX - Prop. mod. DNDA ICT 3
Reaktion Class Shaped Charge Test cal. 35 mm	O no Reaction	A	A	A	B
Friction Sensitivity [N]	240	252	288	240	240
Impact Sensitivity [Nm]	6,0	7,5	6,0	6,0	5,0
Ignition Temperature [°C]	~ 200	~ 200	~ 220	~ 216	~ 219
1“ Detonationtube	no Detonation				
MG cal.50 /12.7 mm	IM Reaktiontype 5 (MIL – STD 2105B)				

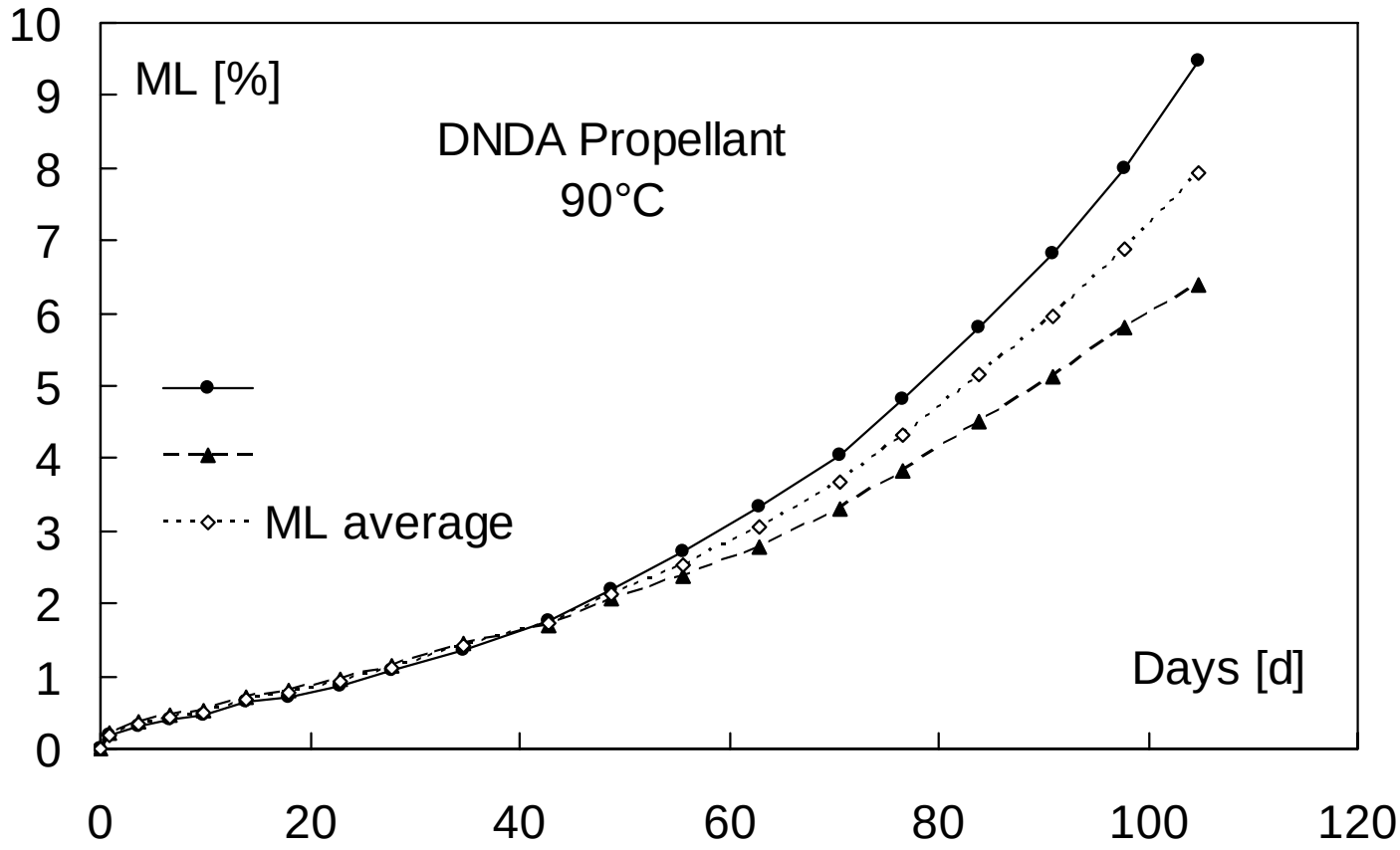
WIWEB Results

Shaped Charge Tests, FOX Propellant ICT 8 and RDX Propellant ICT 1

Longtherm - Storage Stability at 90 °C
Mass - Loss over Time

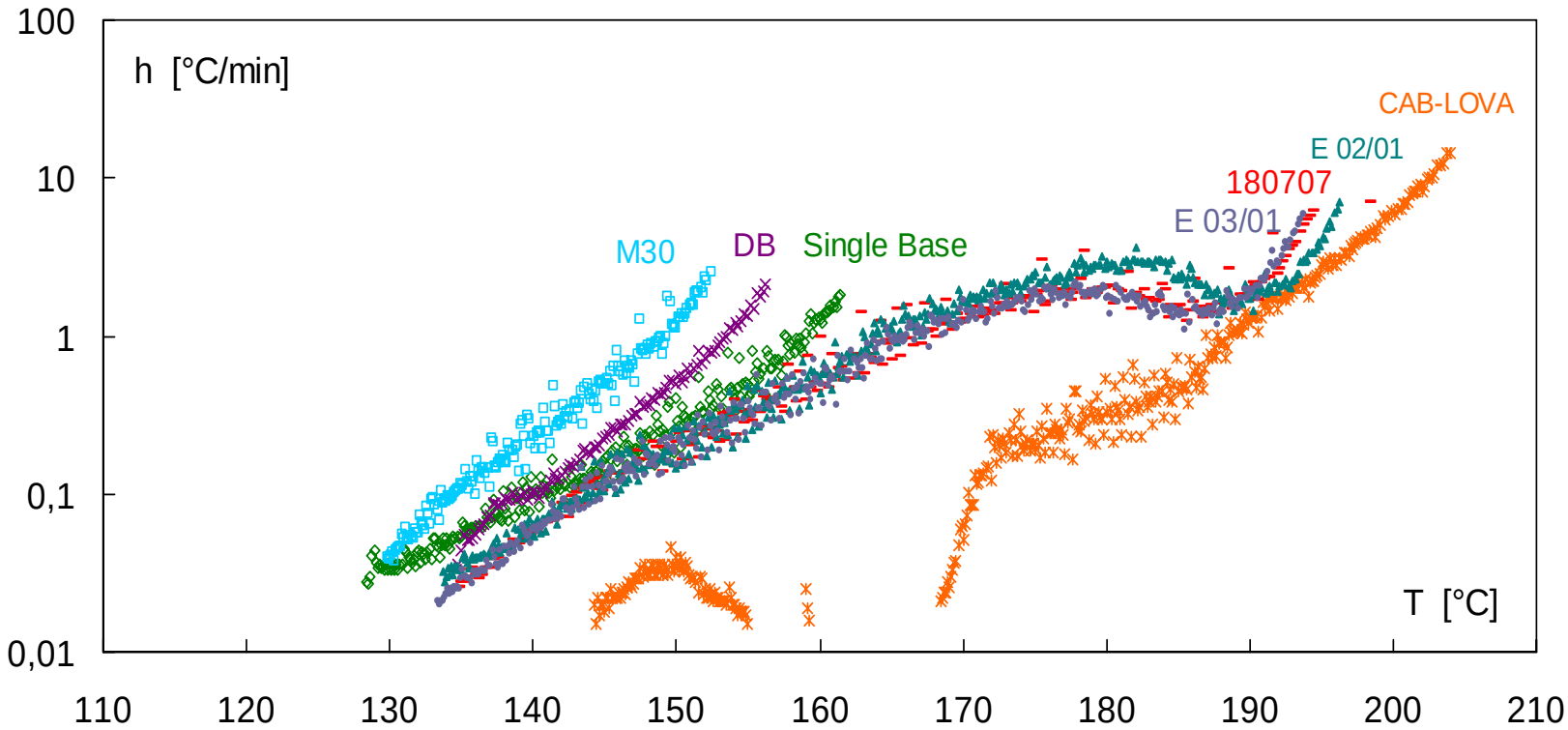


Longtherm - Storage Stability at 90 °C
Mass - Loss over Time



ARC

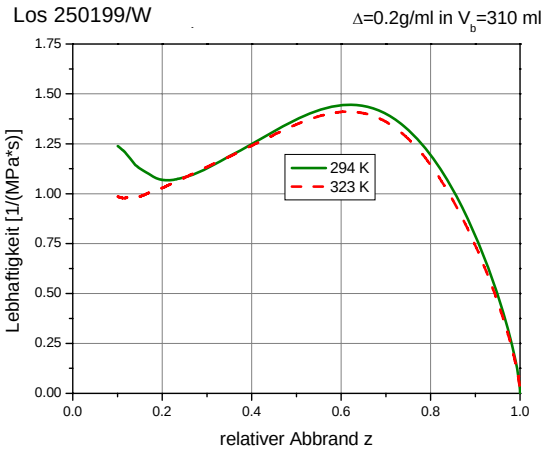
Accelerating Rate Investigations of DNDA - Propellants compared with CAB-Lova, M30, Single Base and Double Base

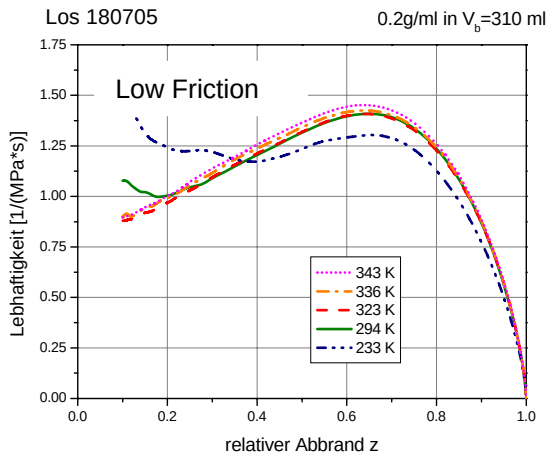


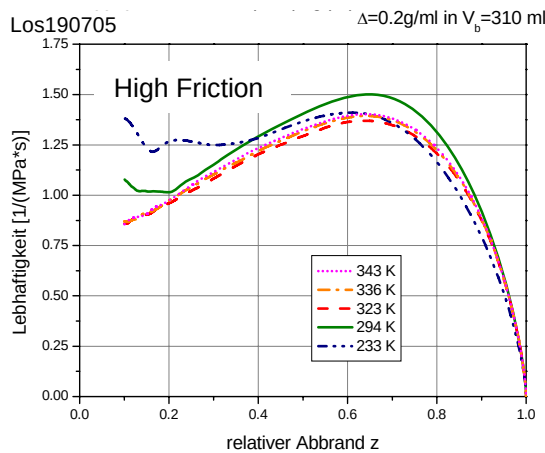
INSENSITIVE GUN PROPELLANTS

Batch Process Mixer compared with Shear Roll Mill

vivacity of the propellants







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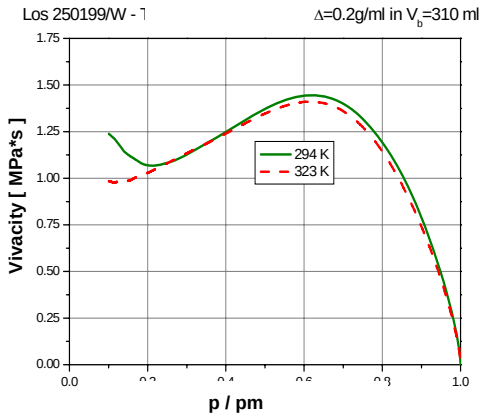
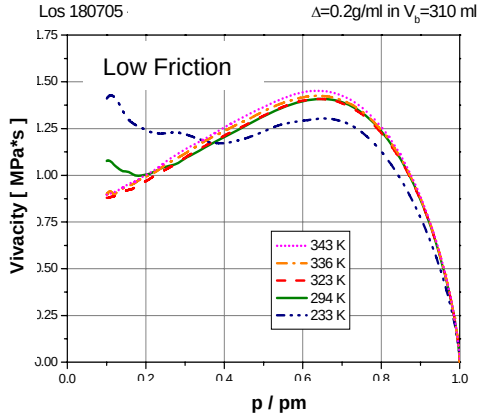
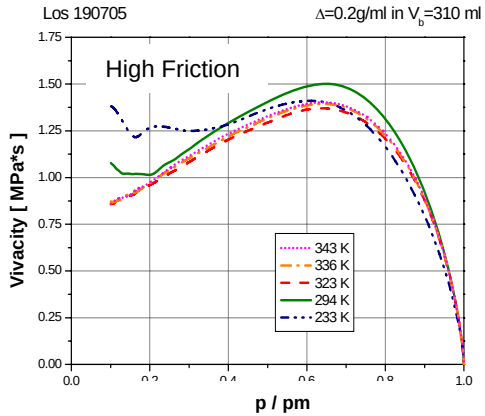
Batch Process Mixer compared with Shear Roll Mill Process

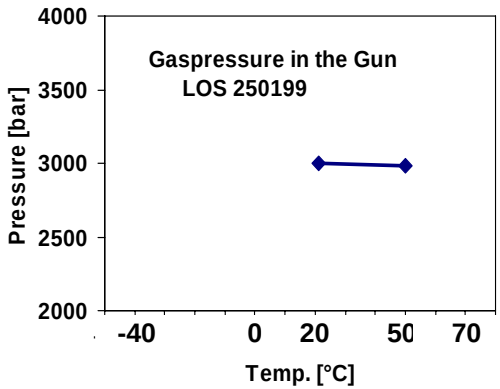
vivacity of the propellants

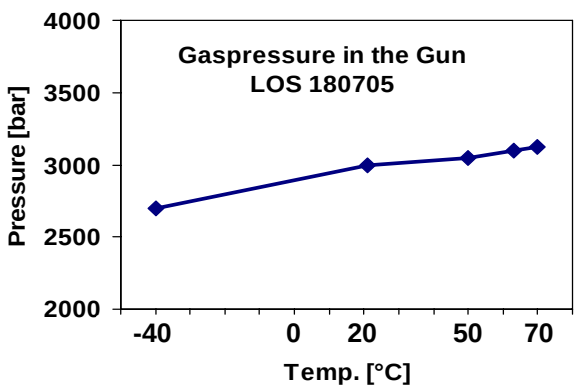


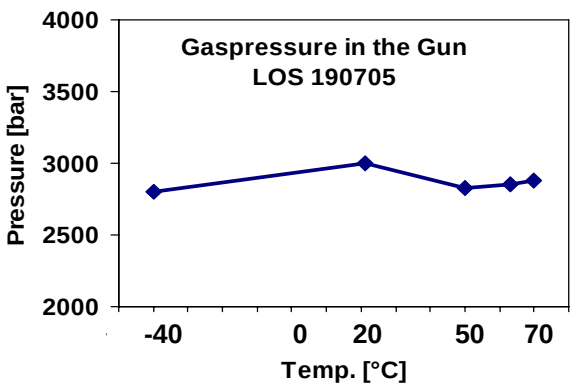




gas pressure of the propellants

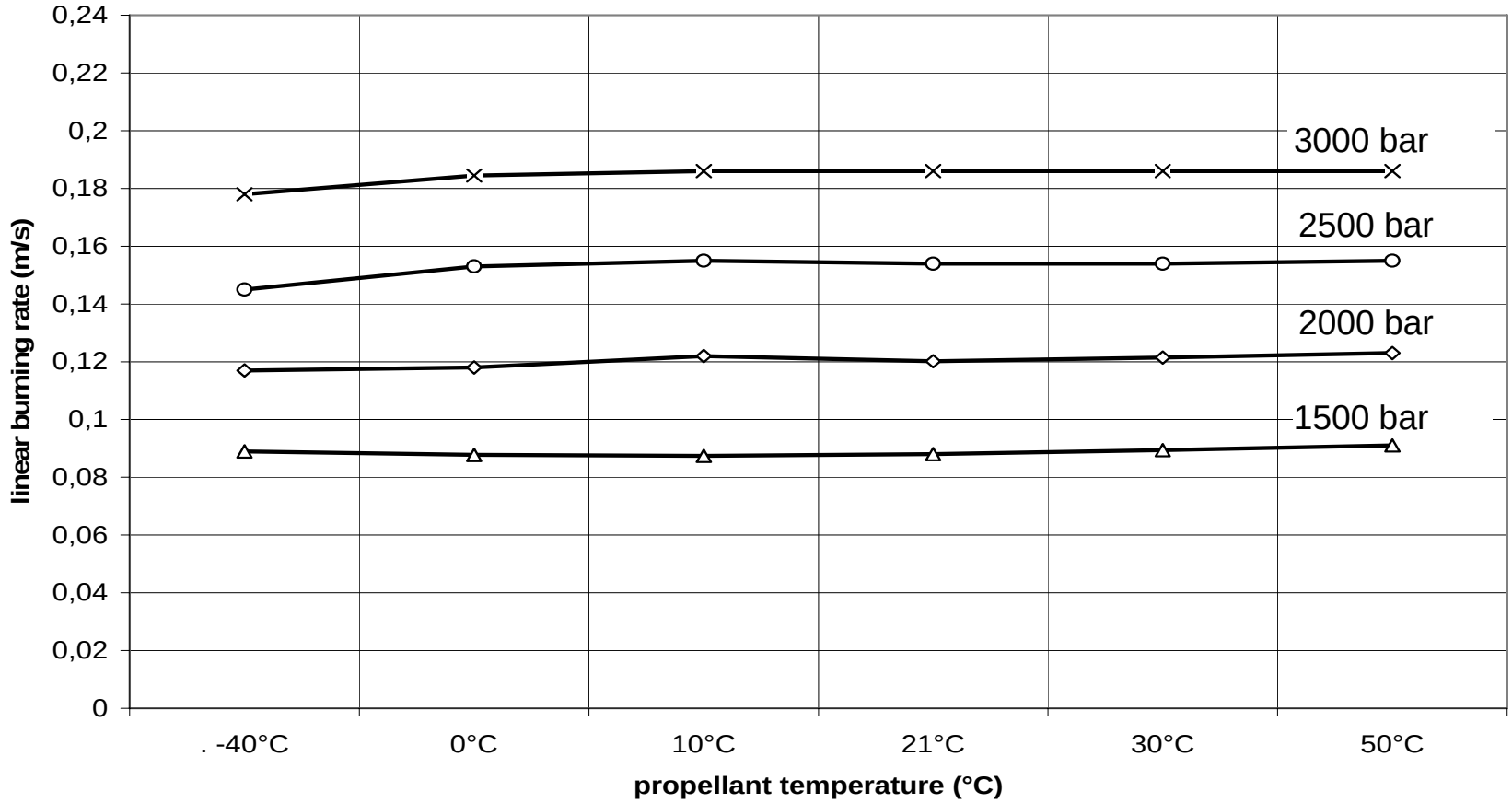




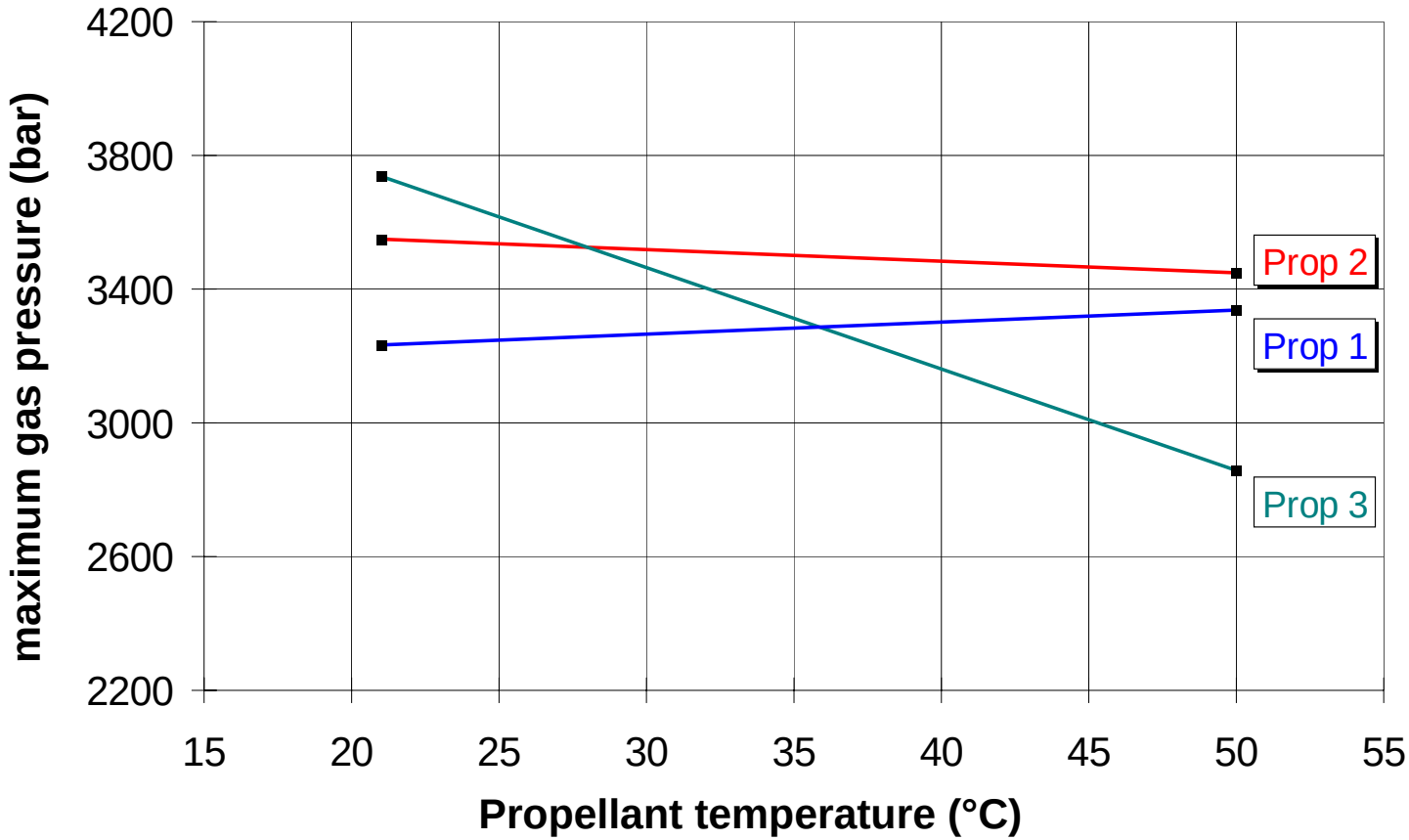


Mue

Linear burning rate of LTC Propellants at different pressures



40 mm Gun Firing Tests of 3 LTC Propellants based on DNDA, NC, RDX



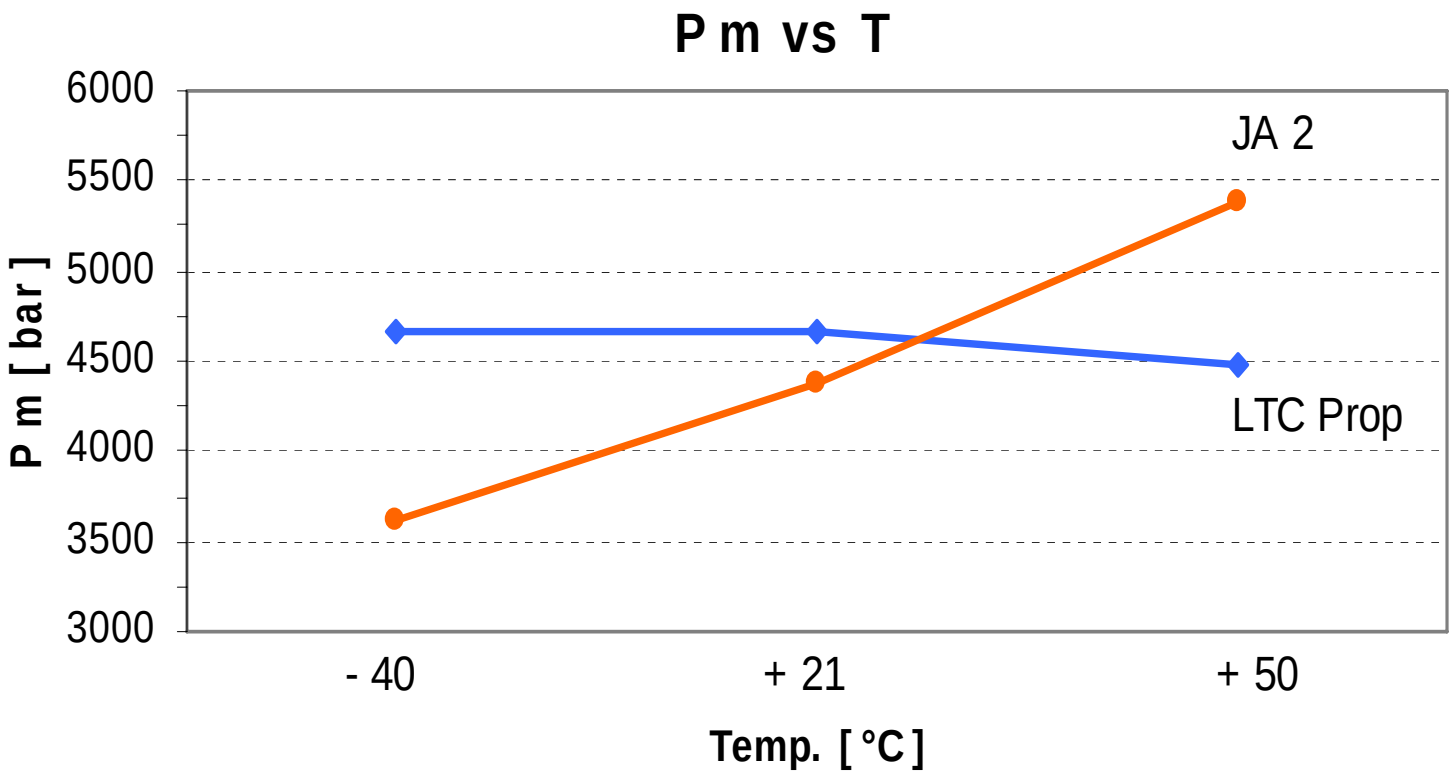
75 mm Scale model gun derived from cal. 120 mm tank gun (Diehl BGT)

- based on interior ballistic similary laws
- less cost (combustible paper case, less propellant mass)

Test Firing in 75 mm cal. Model Gun (Diehl BGT)

Optimized propellant for firing at 21°C

Gas pressure vs temp.



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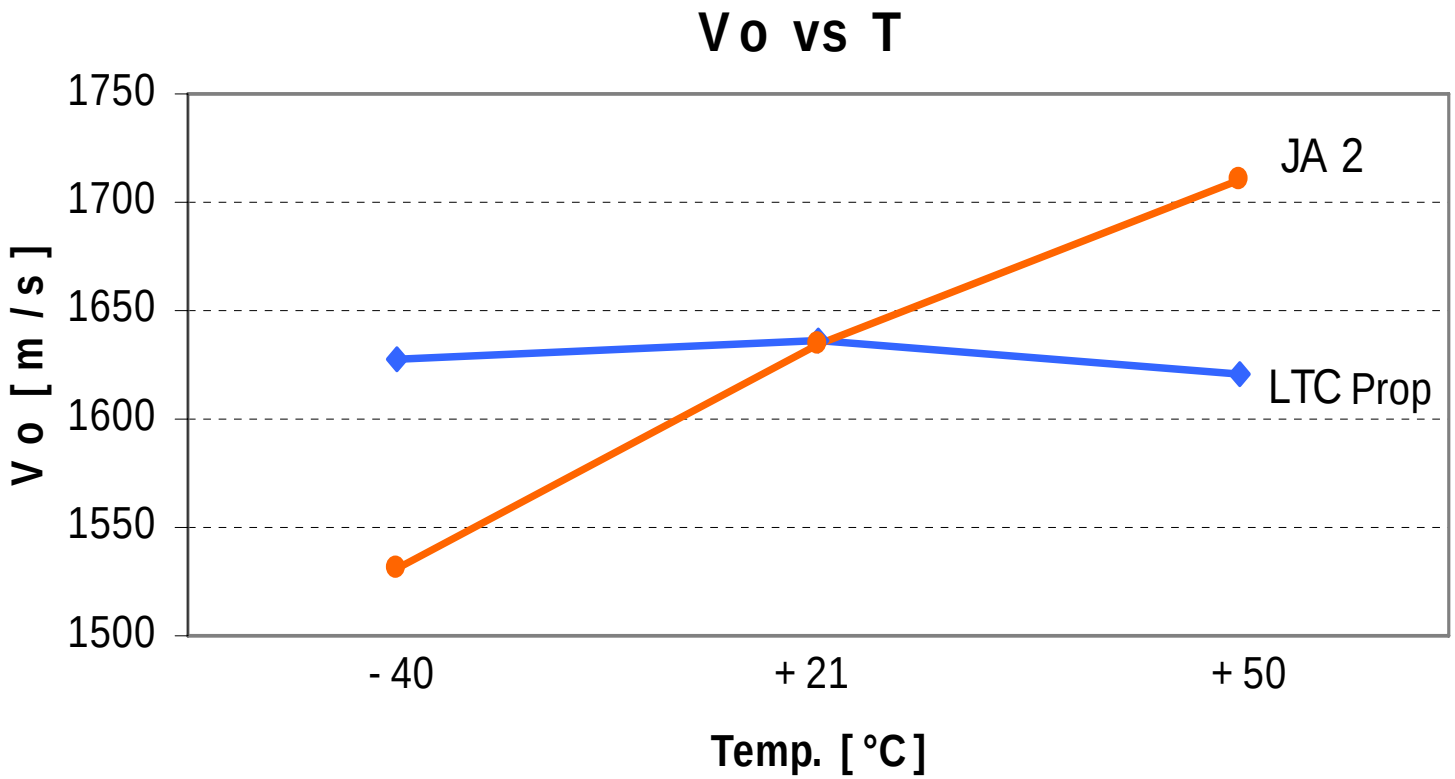
DIEHL BGT Defence

Test Firing in 75 mm cal. Model Gun (Diehl BGT)

Optimized propellant for firing at 21°C

Muzzle velocity vs temp.

Muzzle velocity of LTC propellant same at 21°C like JA 2



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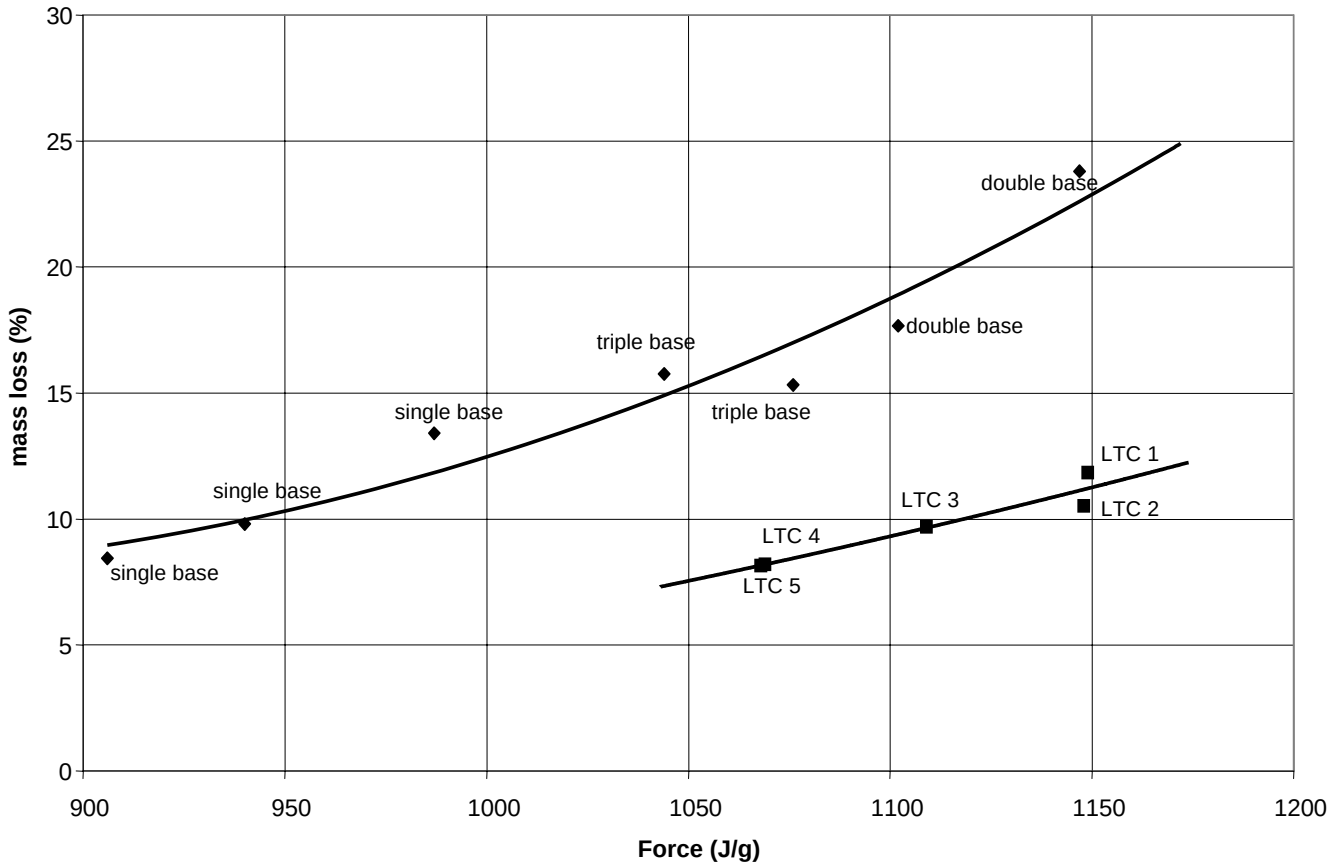
DIEHL BGT Defence

Erosivity of LTC - Propellants and Conventional Propellants
Results from Diehl BGT



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DIEHL BGT Defence

Results & Conclusion

- LTC Propellants based on DNDA 5,7 for a wide Caliber - Range
- Excellent Shaped Charge Testresults (Reaktion Class 0 or A)
- High Ignition Temperature > 215 °C
- Insensitive, Reactiontype 5 (MIL - STD 2105 B)
  Shaped Charge Test
  MG cal. 12.7 mm firing on Steeltube with propellant
- Excellent Longtherm Stability
- Low Combustion Temperature at High Force
- Low Gun Tube Erosion
- Pilot Lot for Eurofighter - Gun, Mauser cal. 27 mm

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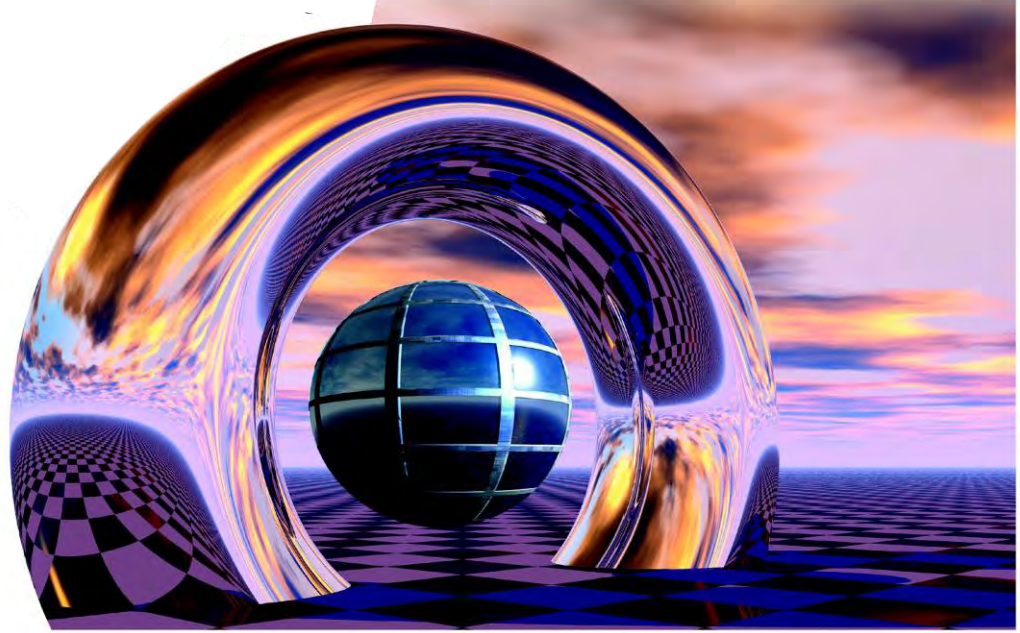
Combustion Light Gas Gun

CLGG



UTRON

DEPARTMENT OF THE NAVY
USN ONR Science & Technology

Not Your Father's Light Gas Gun

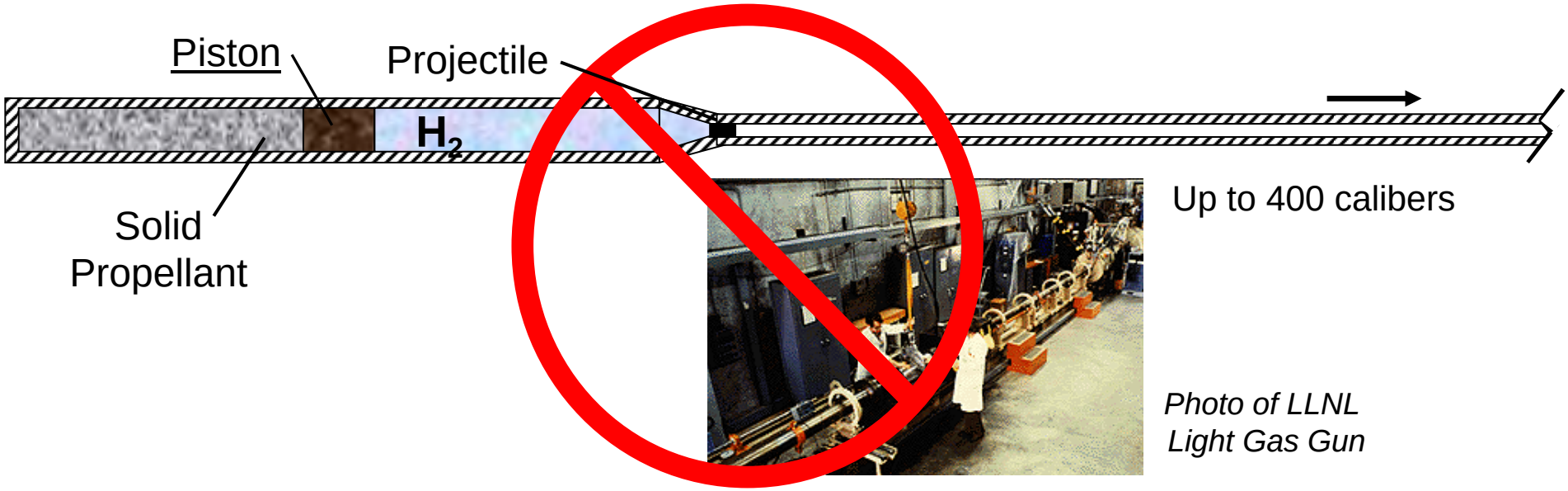
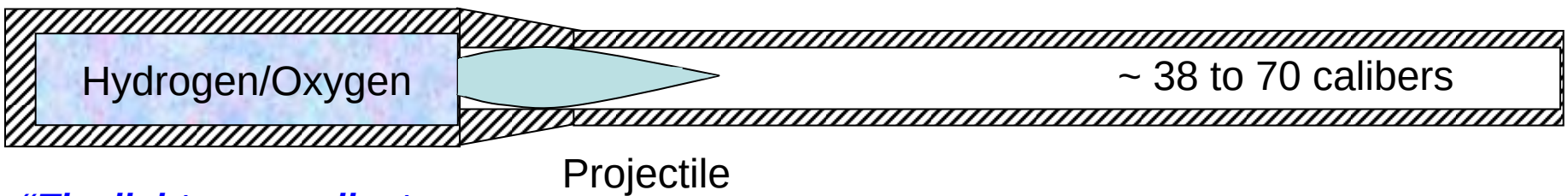


Photo of LLNL Light Gas Gun

Combustion Light Gas Gun

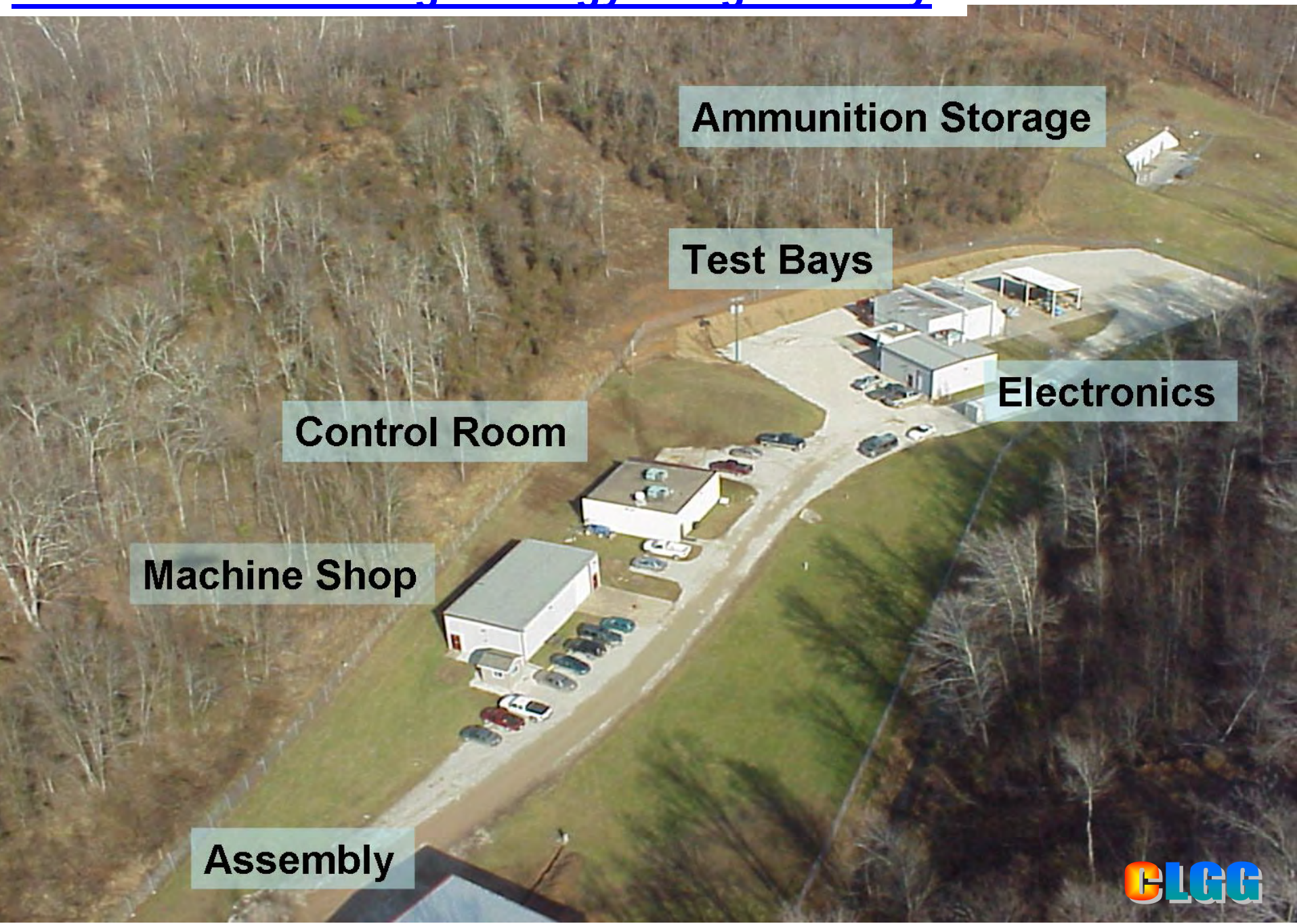


"The lighter propellant gases chase the projectile down-bore more efficiently!"

CLGG Benefits

- High velocity even with moderate tube lengths
- Infinite zoning
- Relatively low flame temperatures (long tube life)
- Lower operating pressures (lighter tubes)
- Lower acceleration on projectile
- Ability to produce propellant onsite
- Commonality of propellant across platforms

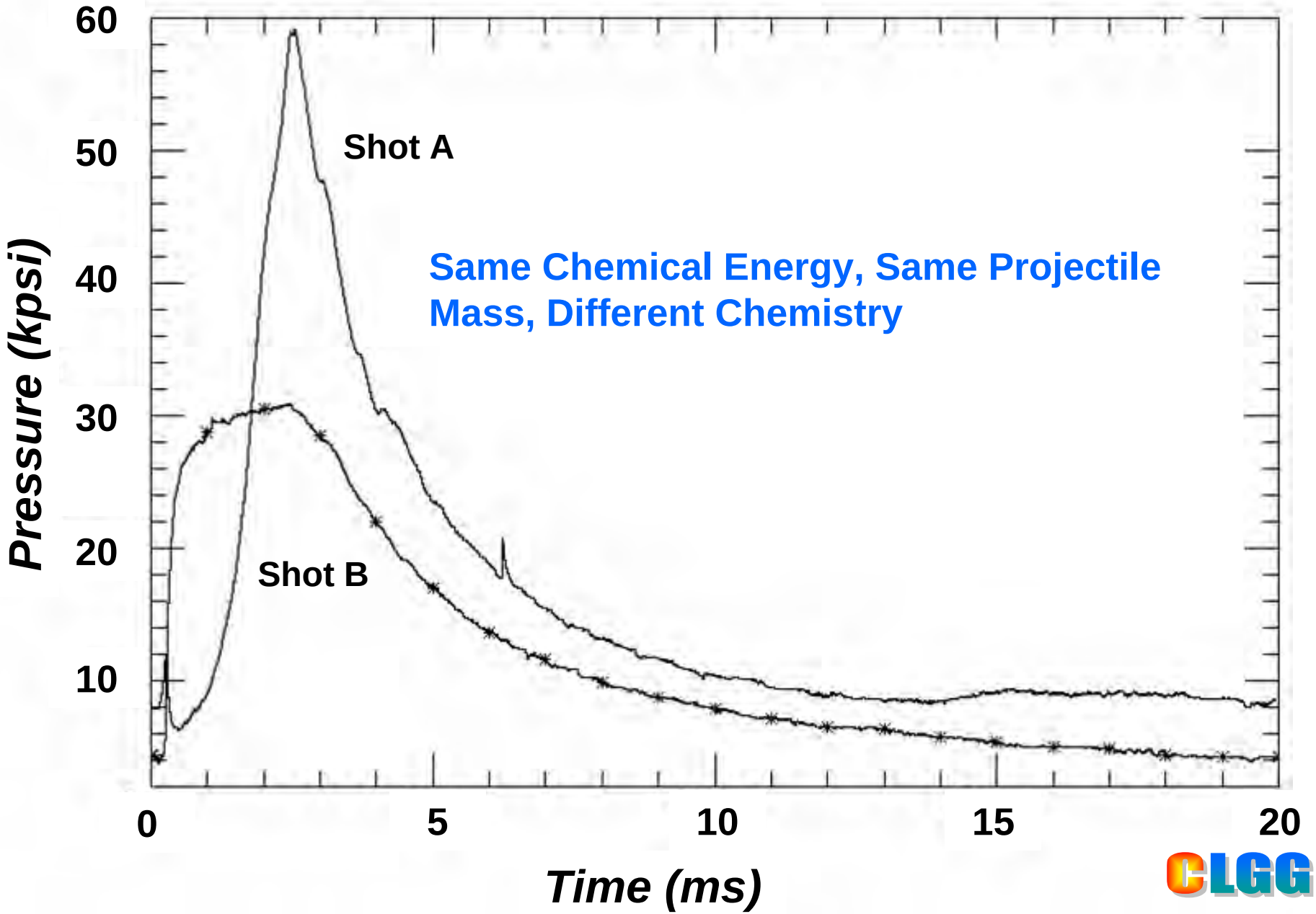
UTRON 300 Acre High Energy Range Facility



CLGG Development

- CLGG technology has been under development for 15 years.
- This 45mm has been operational for 8 years
- Autoloader added to 45mm recently

Combustion Control – Pressure Shape



45mm Performance

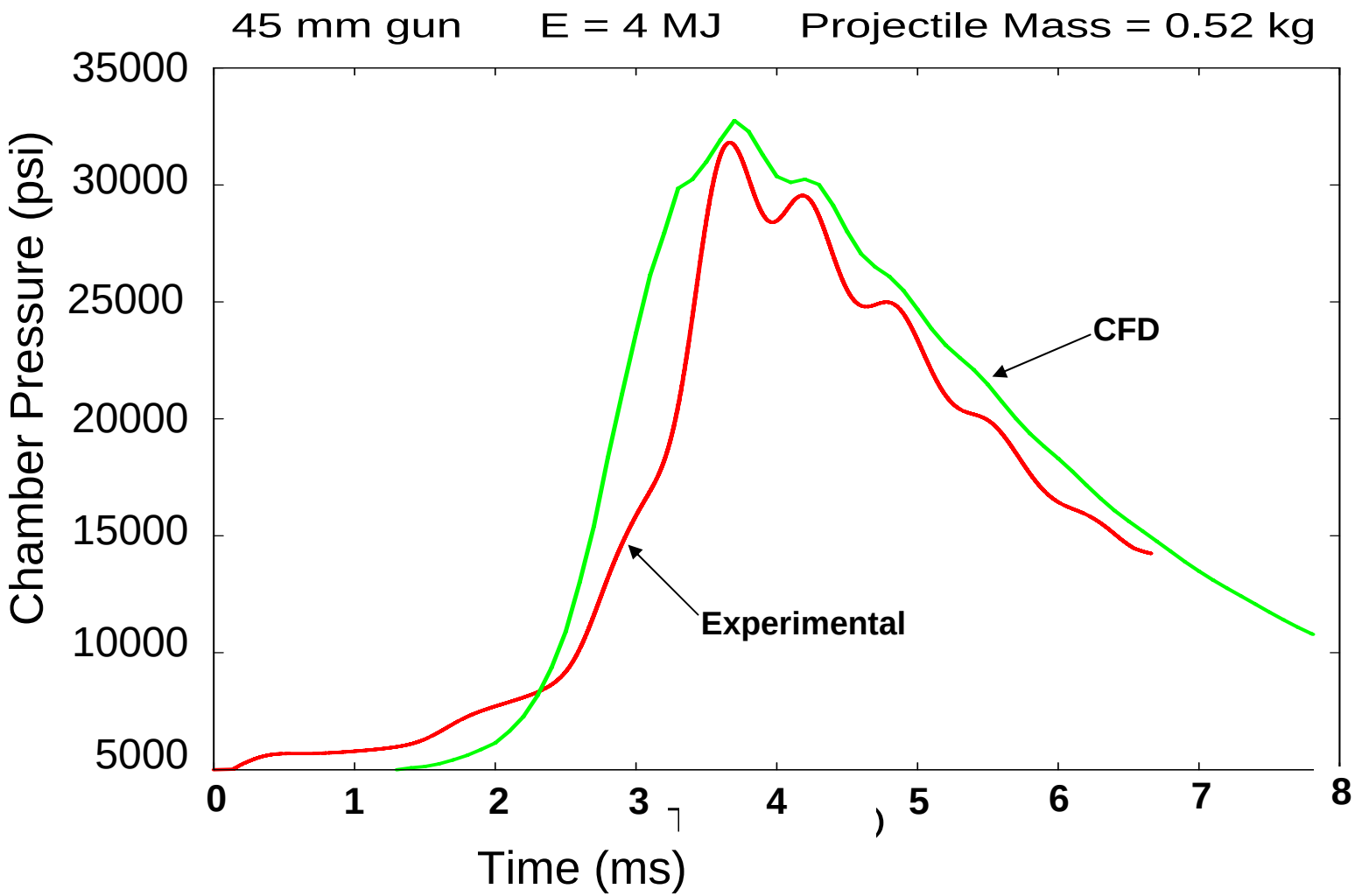
45-mm Experiments	
Mass kg	Velocity m/s
0.200	2810
0.544	2100
1.100	1700
3.365	878

Demonstrated performance gains for a broad range of projectile masses

155 mm CLGG

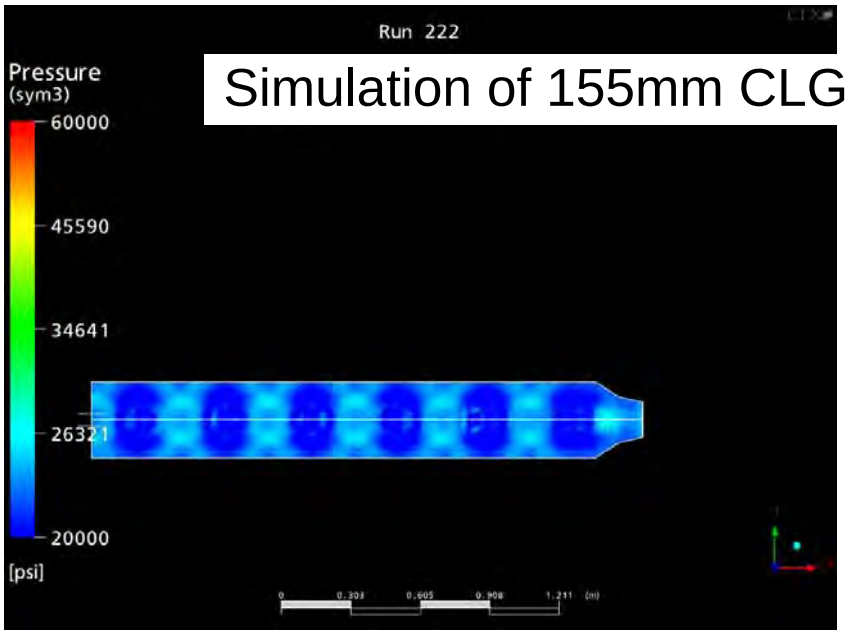
5 shots with up to 17 MJ muzzle energy to date,
A fraction of its capability, tests are ongoing

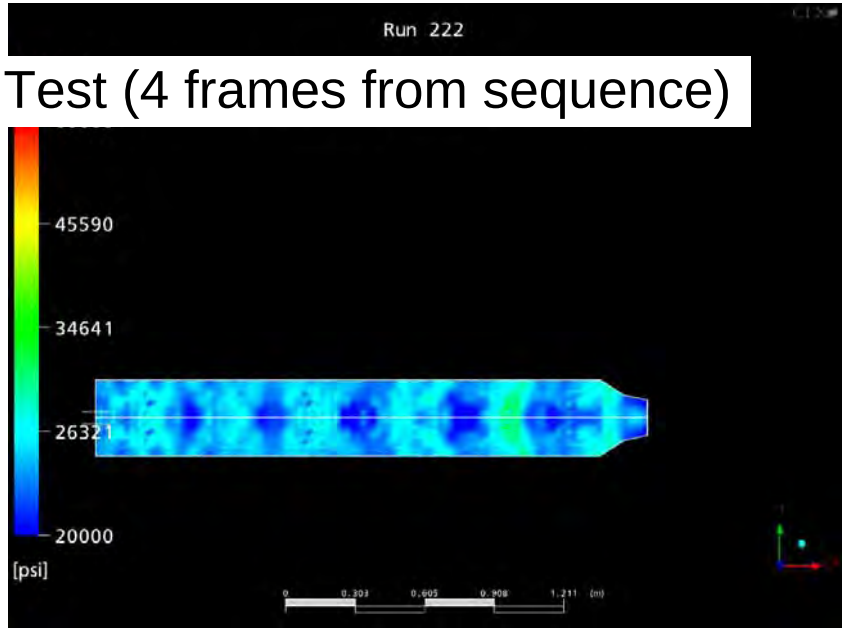
Computational Fluid Dynamics (CFD) Benchmarking

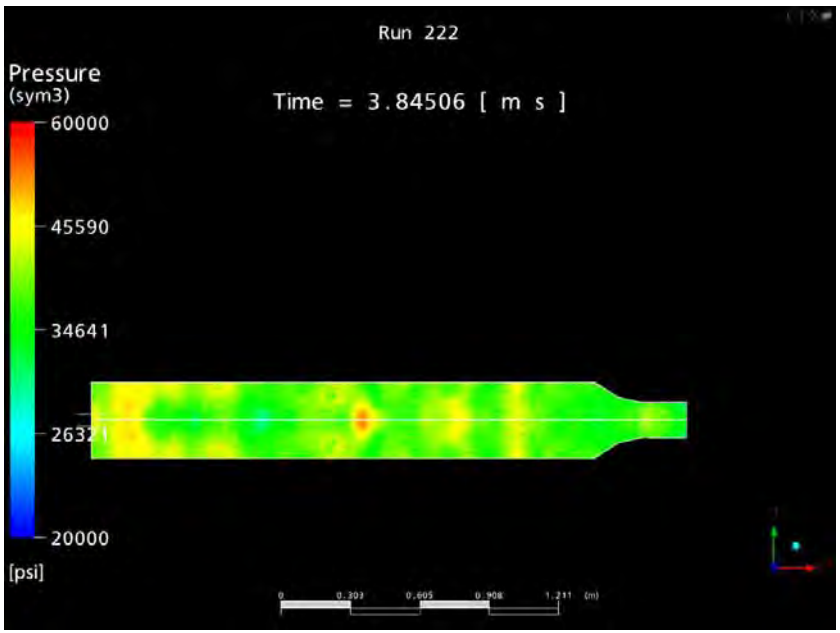


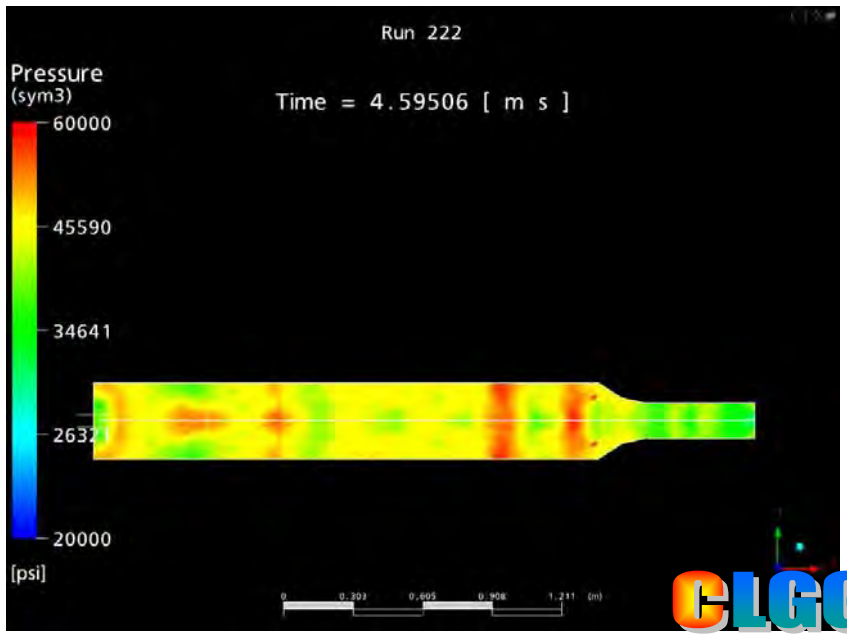
Computational Fluid Dynamics

Simulation of 155mm CLGG Test (4 frames from sequence)

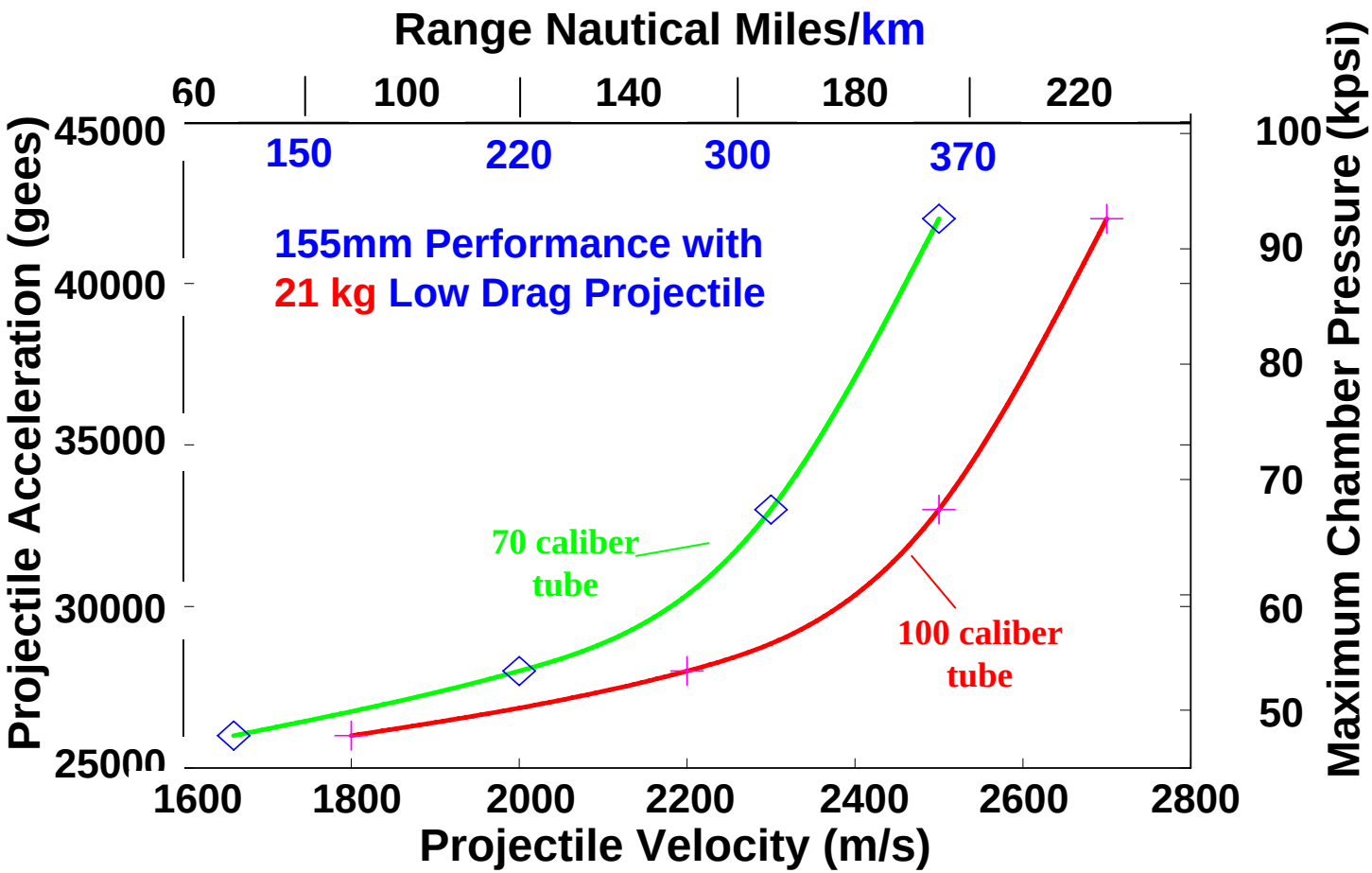






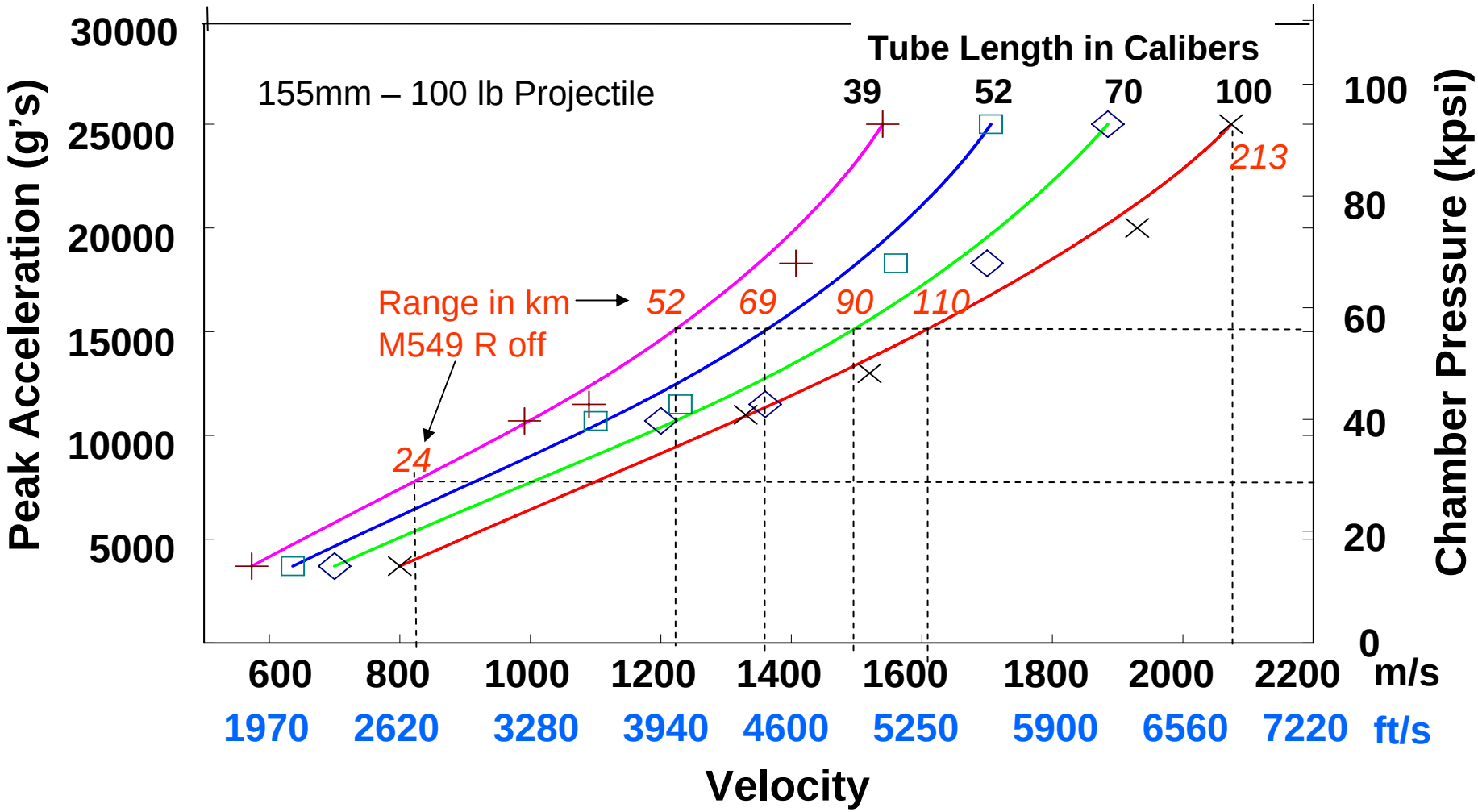


Long Range Shore Support Predictions



Notional Long Range Projectile – Navy Barrage Round

Extreme Range Artillery Predictions with 45 kg Projectile



Performance Example

- CLGG Range 200 + km
- Conventional Gun Range 30 km

Large Circle – Footprint of Single CLGG Gun

Small Circle - Footprint of Conventional Solid Propellant

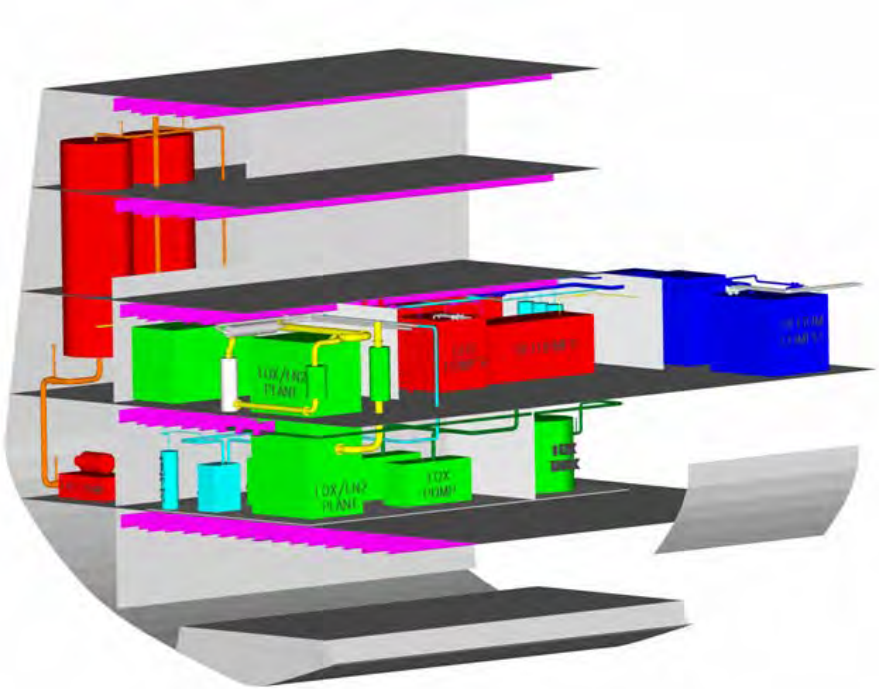
It would take ~ 50 conventional guns to cover the area of one CLGG

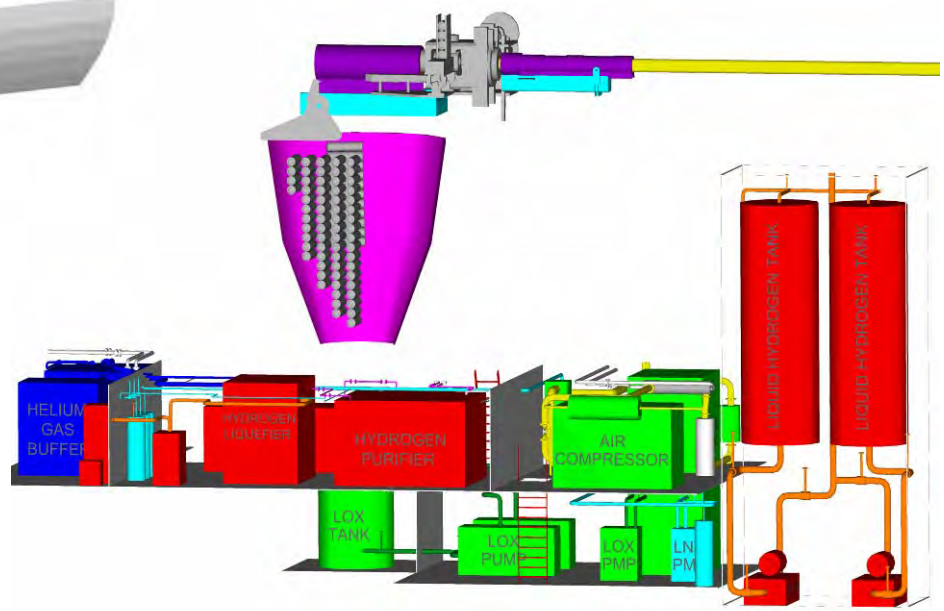
Propellant Production

CLGG technology offers the potential for propellant production as needed to meet mission requirements, on board ship or in the battle space.

- Hydrogen can be reformed from many feed stocks
  - Diesel Reforming (e.g. Navy Fuel Cell Program)
  - Natural gas
  - Electrolysis
- Oxygen can be manufactured in a number of ways.
  - By product from hydrogen production
  - Cryogenic liquefaction
  - Air membrane reactor
- Storage
  - Gas
  - Cryogenics

Notional Ship with CLGG Gun and Propellant Production Equipment Installed





Machinery is commercially available

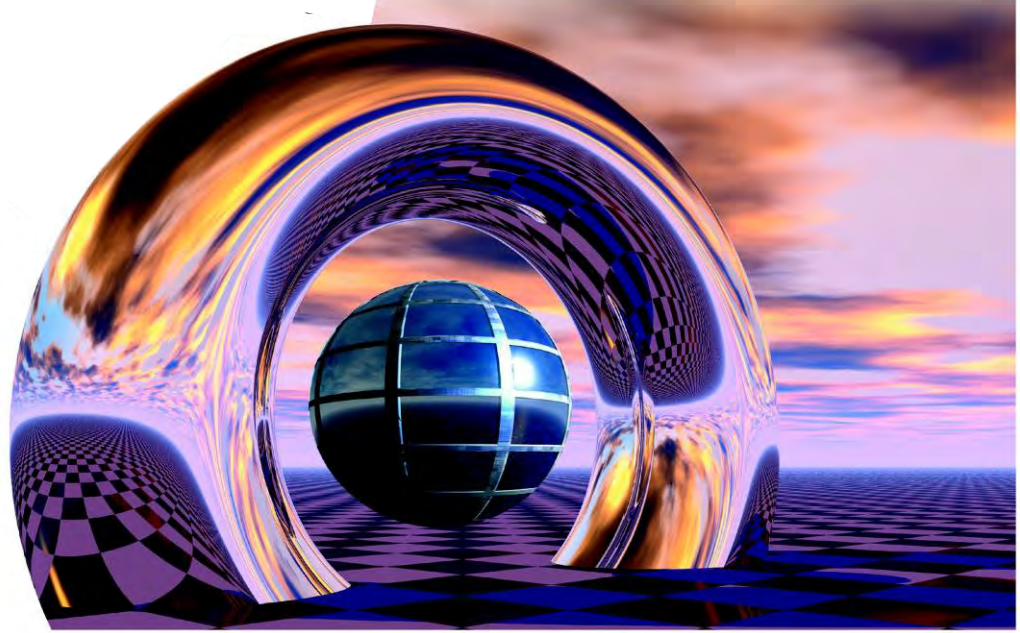
CLGG

CLGG Applications

- ***Long to Extreme Range Artillery (Navy & Army)***
- ***Light Weight Direct Fire***
- ***Ship and Land Based Missile Defense***
- ***Other***

Combustion Light Gas Gun

CLGG



UTRON

DEPARTMENT OF THE NAVY
USN ONR Science & Technology

Performance Assessment of the M1028, 120MM APERS Tank Round

Presented by:

Brian A. Levine

AMSRD-AAR-MEM-A

973-724-6719

brian.a.levine@us.army.mil

April 22, 2008

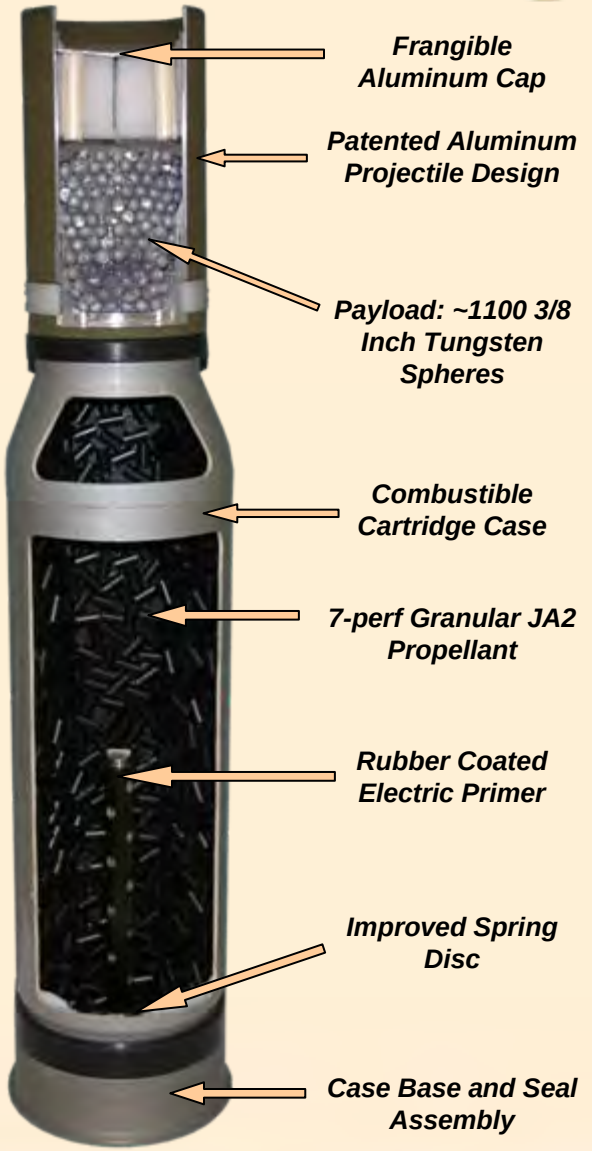
M1028 Evaluation Improvements

- M1028 Overview
- Requirements
- Lethality Evaluation
- 400 Meter Target
- 55 Meter Target
- Statistical Approach
- Conclusions

M1028 Overview

- **Provides revolutionary anti-personnel capability to the Abrams Main Battle Tank.**
- **Also provides the Abrams with a secondary capability against a variety of urban targets.**
- **Named one of the U.S. Army's Greatest Inventions of 2003**

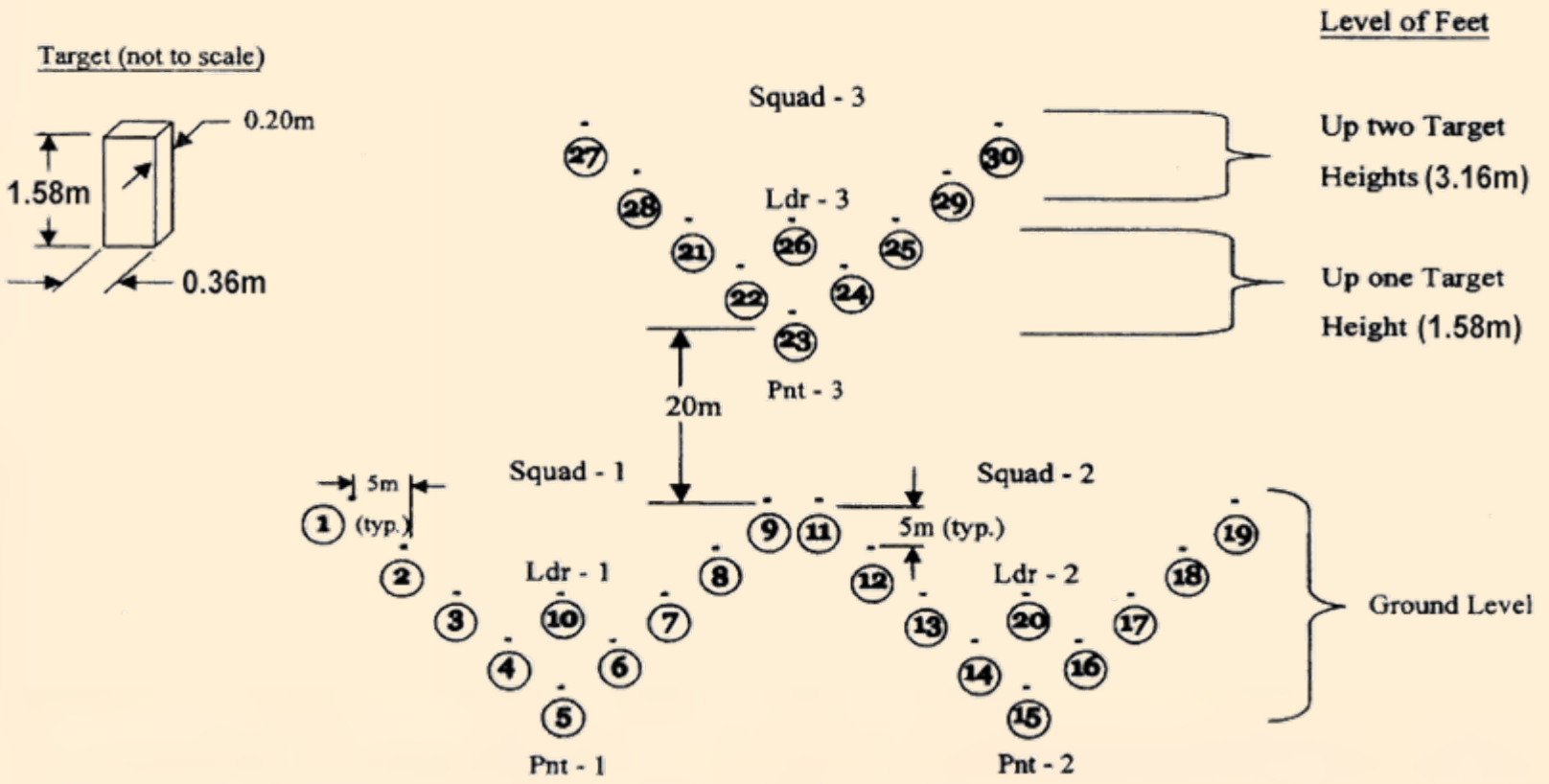
M1028 Canister Characteristics	
Muzzle Velocity (@21°C)	1410 ± 10 m/s
Chamber Pressure (@21°C)	5750 bars
Cartridge Weight	22.9 kg
Cartridge Length	780 mm



Basic Troop Array

Troop Array, Squad in Wedge

2 Up - 1 Back (Top View)



Requirements

- **Operational Requirements Documents (ORD):**
  - **Defeat 50% or more of an advancing squad with one shot.**
  - **Defeat 50% or more of an advancing platoon with two shots.**
  - **Objective: 100 – 700 meters**
  - **Threshold: 200 – 500 meters**

Lethality Evaluation

- **ComputerMan program is used to determine the level of incapacitation given a single hit.**
  - **The ComputerMan lethality model is a U.S. ARMY approved method for determining the incapacitation of a human subjected to various fragment impacts.**
- **Required data to calculate total level of incapacitation:**
  - **Downrange velocity**
  - **ComputerMan single hit incapacitation**
  - **Payload hit locations**

400 Meter Target

Shoot 5 rounds per target → Hand score each target → Excel and TableCurve calculate standard deviation of hits → MathCad calculates Estimated Incapacitation

includes ComputerMan data

Acceptance based on Estimated Incapacitation of each target

400 Meter Target - Process

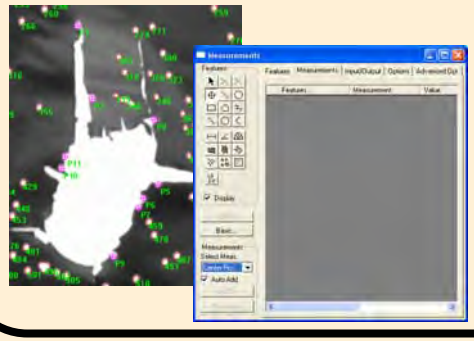
- **Benefits**
  - **Incapacitation data directly reflects the ORD.**
  - **There is a bank of historical data with which to compare.**
- **Potential Improvements**
  - **Reduce the time it takes to hang the target.**
  - **Simplify the scoring method.**
  - **Collect data on individual rounds.**

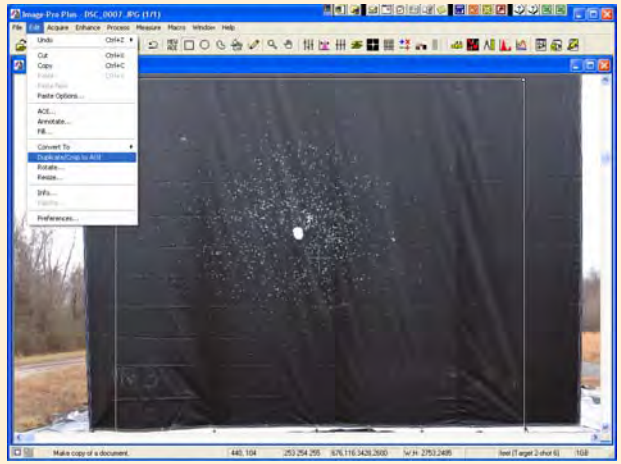
55 Meter Target - Correlation

- 25 rounds were fired through targets set at 55 and 400 meters downrange.
  - Each 55 meter target consisted of a single shot.
  - Each 400 meter target consisted of 5 shots.
- The standard deviations of dispersion on all 25 of the 55 meter targets were averaged together.
- The standard deviations of dispersion on all 5 of the 400 meter targets were averaged together.
- A linear correlation was established between 55 and 400 meters.

55 Meter Target - Digital Scoring

Image-Pro PLUS





Sort Program

Microsoft Excel - M1028 Auto Target Program

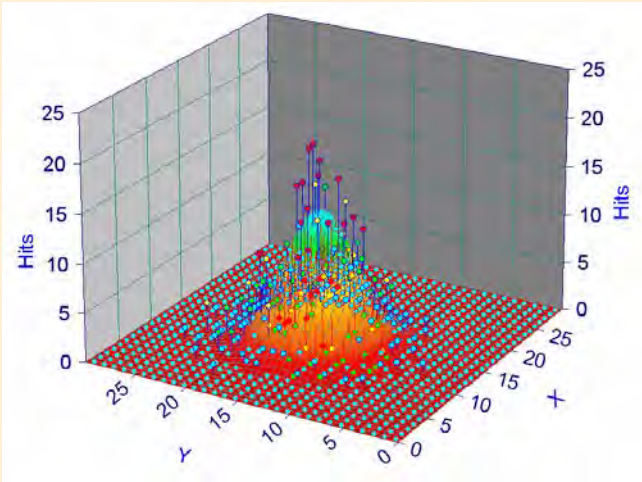
File Edit View Insert Format Tools Data Window Help

Draw AutoShapes

S48

	A	B	C	D	E	F	G
1	#Total Count:	936			BIN #	Count	
2					0.5	0	
3	Obj#				1.5	0	
4					2.5	0	
5	1	16.34545	-24.1887		3.5	0	
6	2	14.03869	-21.7623		4.5	0	
7	3	15.87378	-21.2643		5.5	0	
8	4	16.73216	-21.2504		6.5	0	
9	5	11.84659	-21.1973		7.5	0	
10	6	14.34553	-21.11		8.5	0	
11	7	15.08253	-21.0708		9.5	0	
12	8	9.643307	-20.8751		10.5	0	

TableCurve 3D



55 Meter Target - Digital Scoring

- A completely automated system introduced > 5% error.
- Revised system was set up which significantly decreased error.
  - Same sorting program as the automated system
  - Manual correction for tears and marks (~ 2 additional minutes)
- Revised automated system shows < 2% error.
- Revised automated system errs on the side of caution.
- Use non-automated digital system for any failing targets.

55 Meter Target

Shoot 1 round per target → Digitally score each target using Image-Pro Plus Software → Correlation fit converts 55 meter data to 400 meters → Excel and TableCurve 3D calculate standard deviation of hits → MathCad calculates Estimated Incapacitation

includes ComputerMan data

Acceptance based on Estimated Incapacitation of average of all targets

55 Meter Target - Process

- **Benefits**
  - Incapacitation data reflects the ORD.
  - Data is collected for each individual round.
  - Reduced time to hang and score targets.
  - There is a bank of historical data (at 400 meters) with which to compare (using the 55m – 400m correlation).
- **Potential Improvements**
  - Incorporate production variation into testing requirements.
  - Reduce data reduction.
  - Give proving ground the capability to perform analysis.

Statistical Dispersion - Concept

- Considering all production rounds in PY1 to be acceptable, if a round behaves similarly it should be considered acceptable.
- Compile 55 meter target data from all available tests.
- Find the average and standard deviation of those targets and create limits based on those values.

Statistical Dispersion - Process

	Statistical Dispersion Limits
Max Limit	Avg + 3 StdDev
Min Limit	Avg – 3 StdDev

PY1 FAAT, PY1 Lots 1-3, PY1 Lot 3 CV:

- **60 Ambient Rounds**
- **55 Hot Rounds**
- **50 Cold Rounds**

Acceptance based on statistical information from historical data

Statistical Dispersion - Process

- **Conclusion**
  - **Reduced time to hang and score targets.**
  - **Accounts for round-to-round variations due to natural randomness and production.**
  - **No additional calculations are needed.**
  - **Data is collected for each individual round.**
  - **Proving ground performs all analysis.**

PRECISION STRIKE TO ENABLE BATTLE CONTINUITY IN SPACE AND TIME

Presented by
LTC. (Ret.) Motti Eis
Precision Strike Business Development
MLM Division
Israel Aerospace Industries

At the
NDIA
Gun & Missile Systems Conference
April 23, 2008 - New Orleans

Topics

- Battles of the last two decades
- The operational need for accurate fire
- The Precision Strike Systems (PSS)
- The GPS/INS guidance
  - Breaking the accuracy linkages
  - Shaping the munition trajectory
  - High velocity flight
- The PSS Family of IAI

Battles of the Last Decades

- No more tremendous collisions of divisions
- Asymmetric warfare
- No actual front-line
- Ambushing
- Indirect fire
- The enemy avoids direct contact
- Intensity is varied unexpectedly
- Time Critical Targets (TCT)

The battlefield is only “dotted" by hostile forces

The Operational Need for Accurate Fire

- Multi Targets missions
- Urban terrain
- Effective, accurate, even surgical
- Area coverage achieved by range not maneuvers
- Unanticipated intensity $\Rightarrow$ The need to operate anywhere and anytime

The battlefield is only “dotted" by hostile forces

The Operational Characterization

The Requirements

- Continuity in time
- Continuity in battlespace
- Short response time
- Decreased engagement time
- Avoid collateral damage

The Answers

- 24 / 7
- All weather
- No visibility limit
- No link to range
- No restrictions on trajectory

GPS / INS

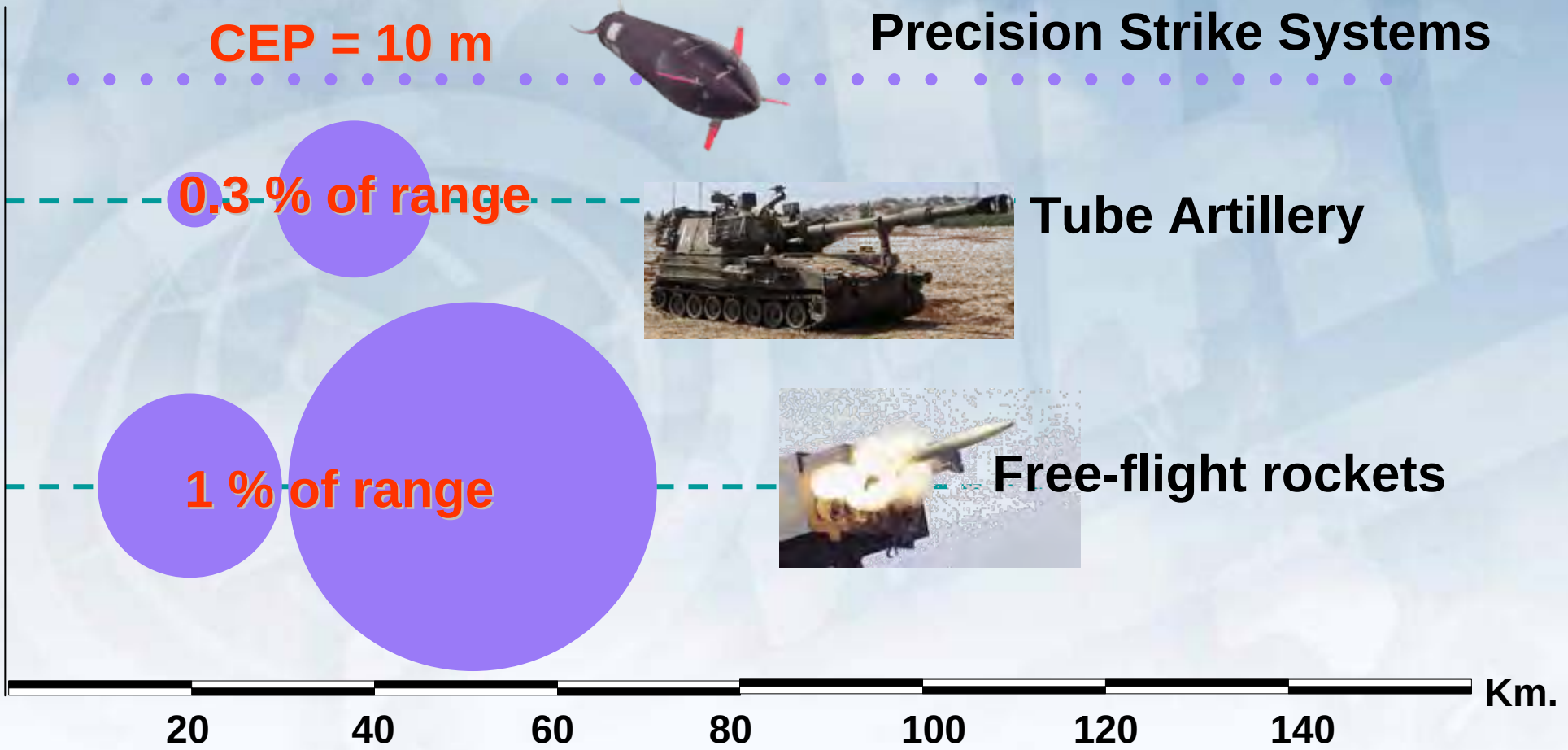
Is The Solution

Fire Control Unit

Target Locating Systems

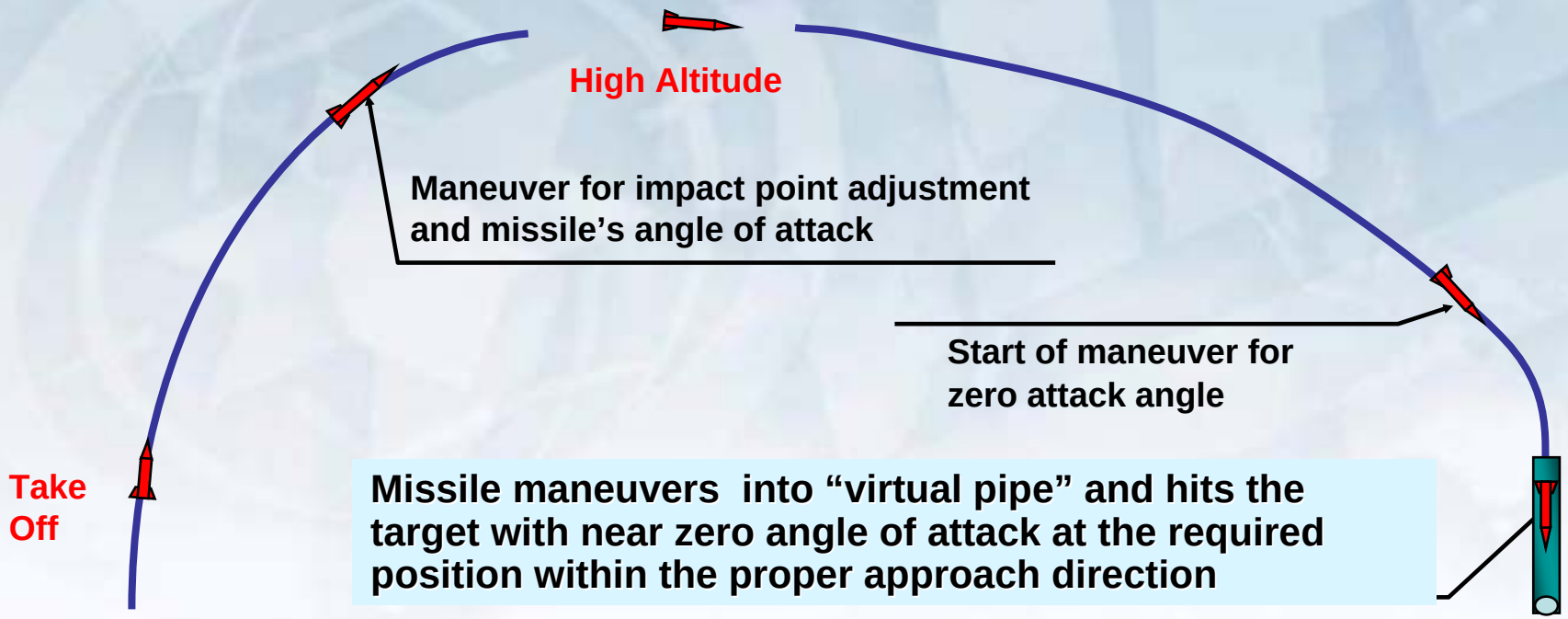
Breaking the Range - Accuracy Linkage

The Dispersion Magnitude – in terms of CEP

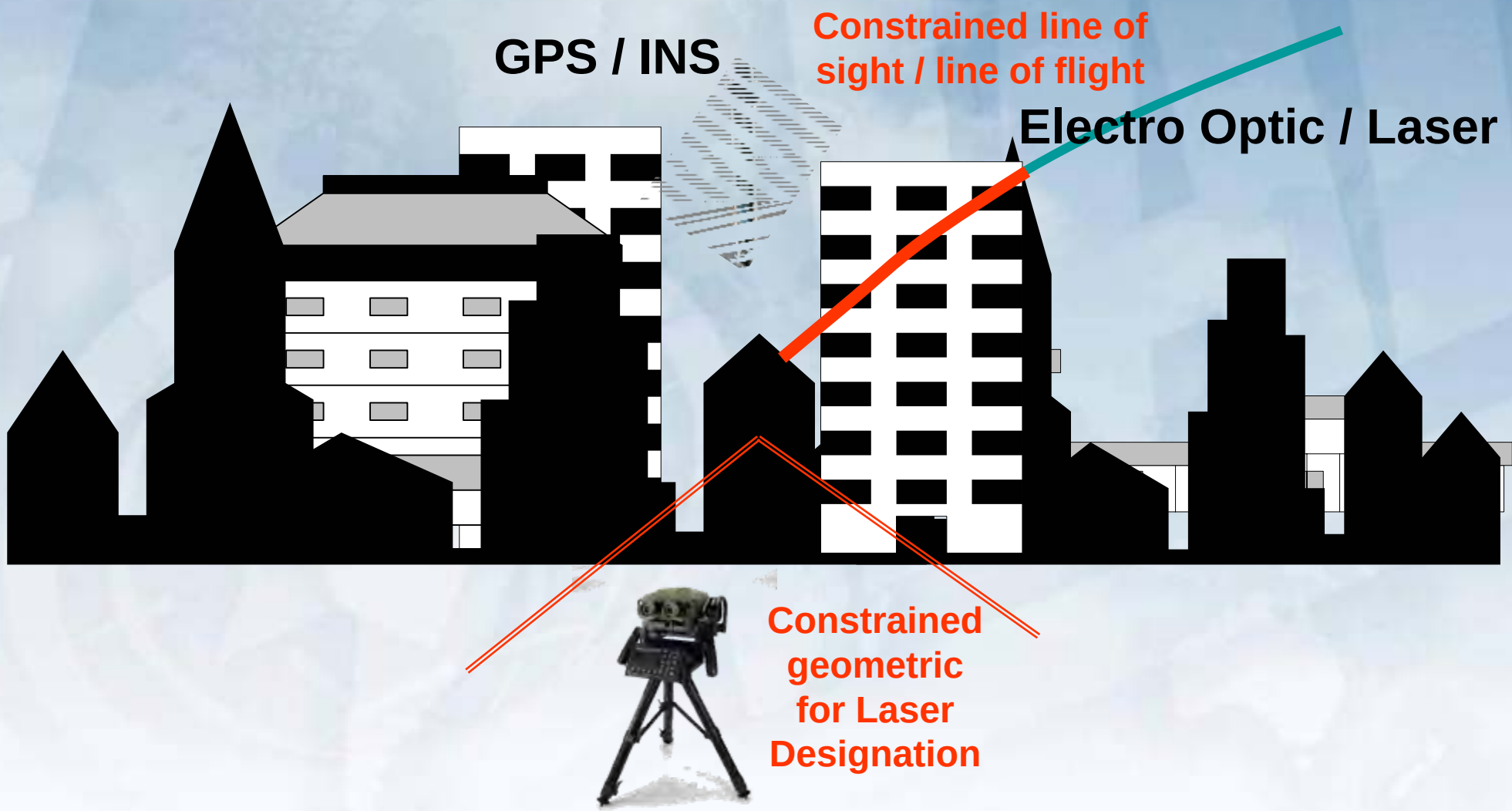


Shaping the Munition Trajectory

- Vertical angle and high velocity – at impact – are key factors for penetration
- Impact angle can be pre-determined
- Will shorten range of engagement



Breaking the Azimuth Linkage



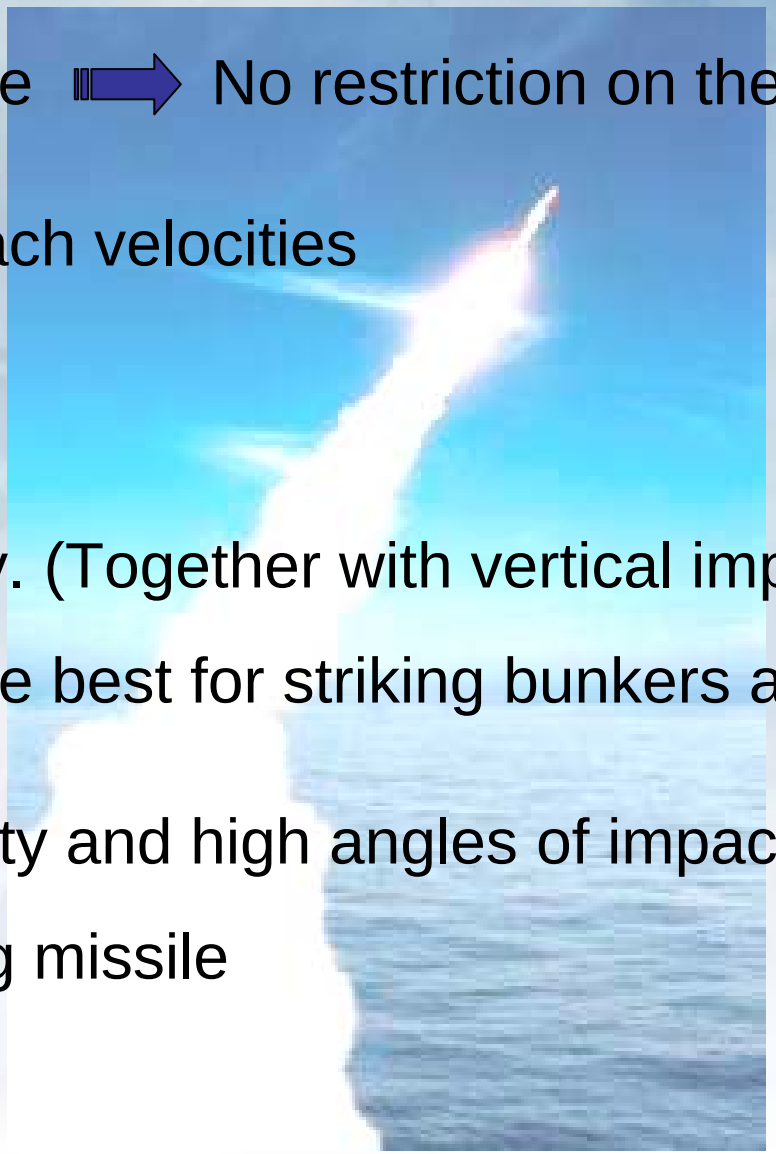
Breaking the Weather and Visibility Linkage

GPS/INS = Seekerless

Not sensitive to bad weather,

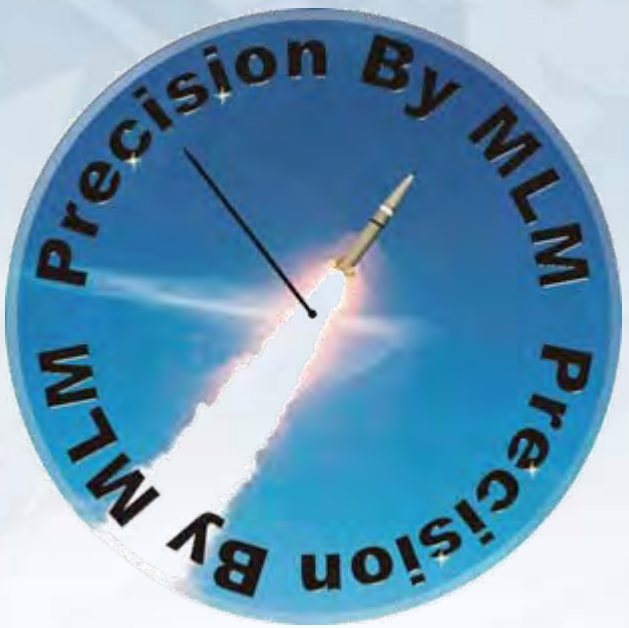
camouflage, smoke, chaff etc.

GPS / INS – High Velocity Flight



- Seekerless guidance ➡ No restriction on the flight velocity
- Supersonic high-mach velocities
- Short time of flight
- High impact velocity. (Together with vertical impact – the GPS/INS guided munitions are best for striking bunkers and fortified assets)
- High terminal velocity and high angles of impact ➡ Difficult to intercept the coming missile

IAI is Developing Seekerless Ammunition based on GPS/INS



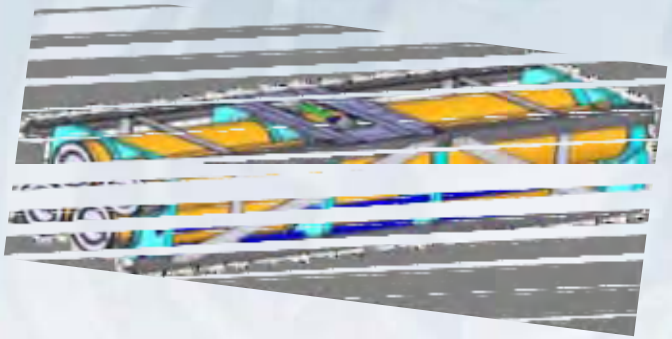
EXTRA – EXTended Range Artillery

Warhead	Max.Range	TOF
120Kg	150Km	5-6min

Rocket

- Length: 4000mm
- Diameter: 300mm
- Weight: 400Kg
- CEP: Better than 10m

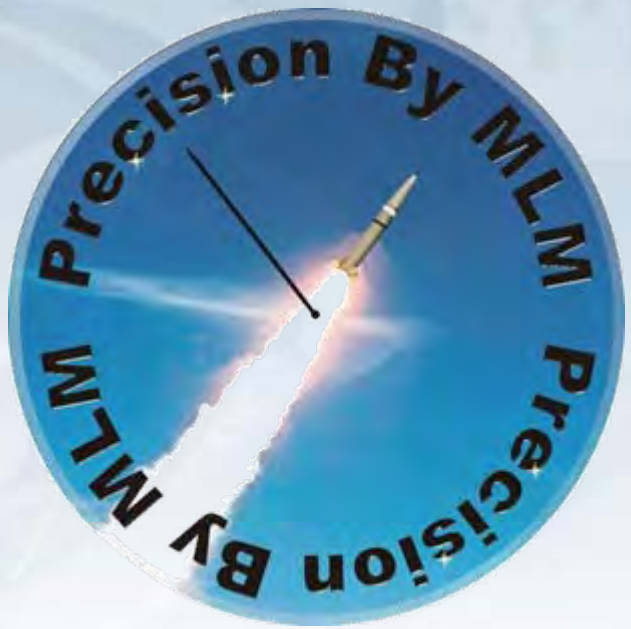
EXTRA – EXTended Range Artillery



Launcher

- Any regular launcher
- Pod with 4 missiles

Questions ?



120 MM XM360 Gun Technology Base Transition into Future Combat System (FCS) System Design & Development (SDD) Program

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

BRIEFING TO THE GUNS & MISSILES SYMPOSIUM
23 APRIL 2008

US Army ARDEC Weapon Systems & Technology Directorate
BENÉT LABORATORIES

ANTHONY J. CANNONE
DAVID C. SMITH, P.E.

INTRODUCTION & BACKGROUND

- BACKGROUND – AS EARLY AS 1999, THE US ARMY PM MANEAUVER AMMUNITION SYSTEMS, PM LETHALITY, PM FUTURE COMBAT SYSTEM RECOGNIZED A NEED FOR A HIGHLY LETHAL GUN SYSTEM TO PROVIDE COMBAT FIREPOWER FOR THE MOUNTED COMBAT SYSTEM.
- COMBINING FORCES WITH GENERAL DYNAMICS LAND SYSTEMS, ARDEC WS&T BENET LABORATORIES DEVELOPED A LIGHTWEIGHT 120 MM GUN ASSEMBLY THAT UTILIZED THE PROVEN 120 mm FAMILY OF AMMUNITION, AND COULD BE INSERTED INTO A LIGHTWEIGHT ARMOURED VEHICLE.
- BENET LABORATORIES DEMONSTRATED THIS SYSTEM IN 2004
- BENET UNDERTOOK AN INDEPENDANT TECHNOLOGY BASE PROGRAM TO MATURE THIS SYSTEM TO TRL 6 AND DESIGNATED IT THE XM360 120 MM GUN ASSEMBLY
- IN 2004 – GDLS RECOGNIZED THE CLEAR ADVANTAGE OF THIS SYSTEM AND SELECTED IT FOR USE ON THE MOUNTED COMBAT SYSTEM – IN OCTOBER 2005 – GDLS & BENET LABORATORIES SIGNED A CRADA FOR BENET TO DESIGN DEVELOP AND DELIVER THIS GUN IN A SYSTEMS DESIGN & DEVELOPMENT PROGRAM
- FROM 2005-2007 BENET INDEPENDANTLY PURSUED ADDITIONAL LARGE CALIBER ENHANCEMENTS FOR ALL FCS PROGRAMS AND TRANSITIONED THEM INTO THE XM360 AND THE XM324 PROGRAMS

XM360 LAEP
SCHEDULE & APPROACH

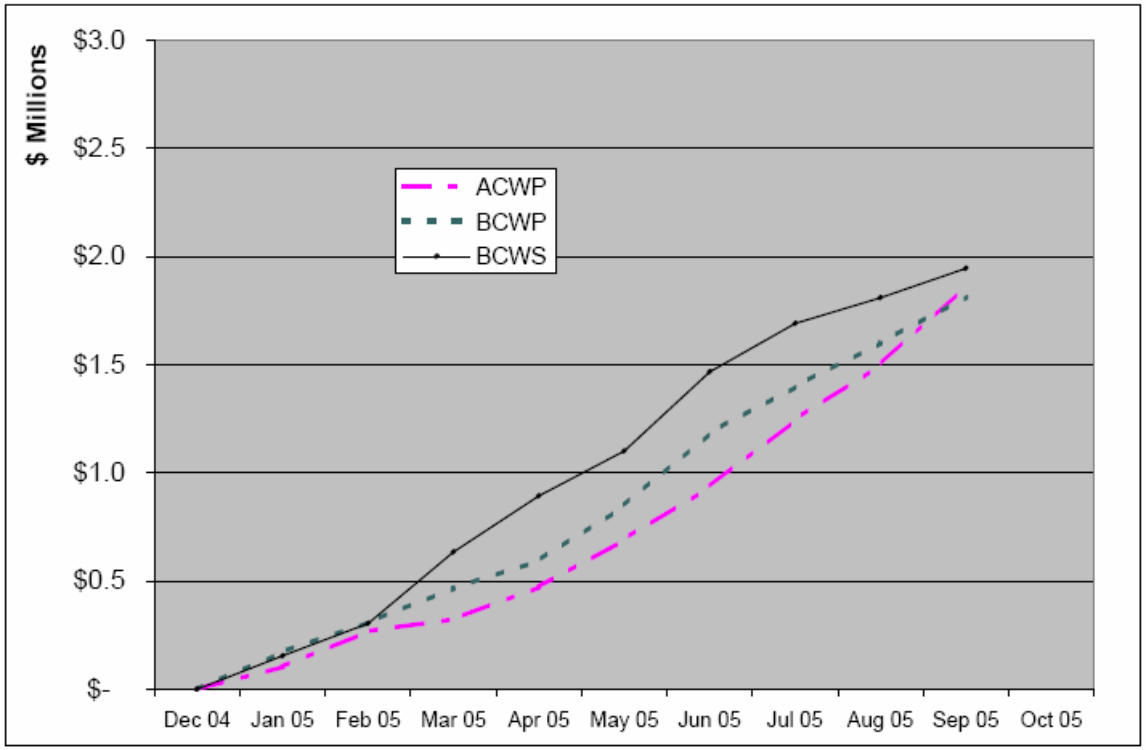
MILESTONE	FY03	FY 04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
VDRD DEMONSTRATOR									
TECH BASE - ATD									
LAEP 120-7 TEST									
LAEP 120-8 TEST									
XM360 MCS EVENTS				△ SFR		△ PDR	△CDR		
XM360 GUNS					△	FF△ FTR		MCS VEHICLES	
TESTS						FF	FTR	IQT	
IPF									IPF
FUNDING									
TECH BASE	X	X	X	X					
PM UA			X	X					
GDLS CRADA	X			X	X	X	X	X	X

- **APPROACH - STRATEGY:**
  - CREATE THE ANALYTICAL TOOLS REDUCE TESTING COSTS
  - PARTNER WITH INDUSTRY, WATERVLIET ARSENAL, ROCK ISLAND ARSENAL, ARMY RESEARCH LAB, MANUFACTURING TECHNOLOGY PROGRAMS TO ENSURE IDEAS WORKED TOGETHER
  - DEMONSTRATE NOT JUST THE TECHNOLOGY BUT THE MANUFACTURING PROCESSES AS WELL
  - WORK WITH INDUSTRY PARTNERS TO TRANSITION THIS TECHNOLOGY INTO THEIR PRODUCTS

XM360 LAEP Milestones

• LAEP Program Start	20 Jan 05
• ATD Test Phase 2/3 Complete at ATC	08 Aug 05 (Revised)
• LW 120-6/7 Preliminary Design Review	12 Dec 05
• ATD Test 4A HW Delivered to ATC	10 Aug 06 (Revised)
• ATD Test 4A Complete	31 Aug 06 (Revised)
• ATD Tube 5 Fabrication Start	01 Jun 05
• Critical Design Review – LW 120-6/7	31 Apr 06 (Revised)
• ATD Tube 5 HW Delivered to ATC	07 Feb 06
• ATD Tube 5 Test Complete	14 Jun 06
• UHSS Steel Forgings Delivered	23 Jan 06
• LW120-6/7 Fabrication Start	24 Jan 06 (Revised)
• LW120-6/7 Hardware Delivered to ATC	28 Mar 07
• LW120-6/7 Test Complete	15 May 07

EARNED VALUE MANAGEMENT WORKSHEET - LIGHTWEIGHT ARMAMENT ENHANCEMENT PROGRAM	PERIOD ENDING	30 Sep 05	10/10



CUMULATIVE PERFORMANCE		
WBS	CPI	SPI
1	0.734	0.879
2.1		
2.1.1	0.862	0.950
2.1.2, 3.8	0.939	0.975
2.1.3, 3.9, 4.1.2	0.903	0.831
2.1.4, 3.11	1.790	1.336
2.1.5,3.10,3.26,4.1.9	0.840	0.493
2.1.6	1.454	1.000
2.1.10	0.000	1.000
2.2, 4.2	1.049	0.917
2.3, 4.3	1.110	1.035
3.4		
3.27	0.451	0.500
4.4.7, 4.4.8	0.910	1.000
4.4.8		
3.1	1.581	0.908
3.23, 3.24		
3.2	0.000	0.436
4.4.1	0.456	1.000
4.4.2		
3.25		
3.3		
OVERALL	0.973	0.939

ESTIMATE AT COMPLETION (FY05)	$	1,973,583	
BCWS	$	1,931,174	(what progress we should have made)
ACWP	$	1,864,424	(what we spent)
BCWP	$	1,813,379	(what progress we have made)

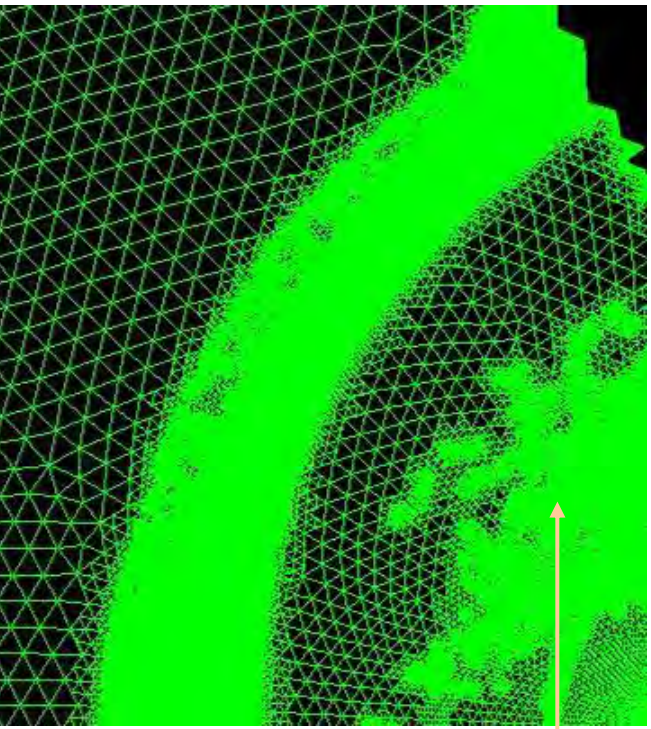
ACTUAL SURPLUS		$ 103,429

COMMENTS: Final Report
Some Unliquidated funds left
FY06 EVMS will include other measures earlier in year to identify problem areas

- **Project is complete**
  - Completed Final Report for the Sympathetic Detonation Barrier (SDB) effort.
  - 2 Major Patents Resulted
    - Multiple Autofrettage
    - Blast Wave Identification Protocol (BWIP)
  - Major Design Software Tool validated (BWIP)
    - Potential Commercial Software Licensing (BWIP)
    - Other CRADA work has been generated
- **Partnership of Tech Base programs with customer funded efforts was helpful**
- **Continuing gun/cannon Tech Base work is critical to maintaining CRADA funded programs and future business**

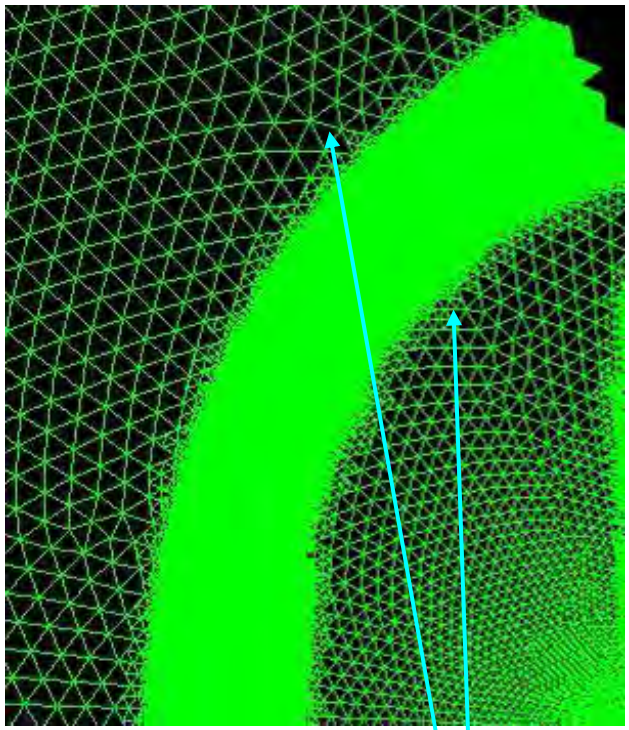
FLUENT SOFTWARE MESH ADAPTION COMPARISON

Original Technique



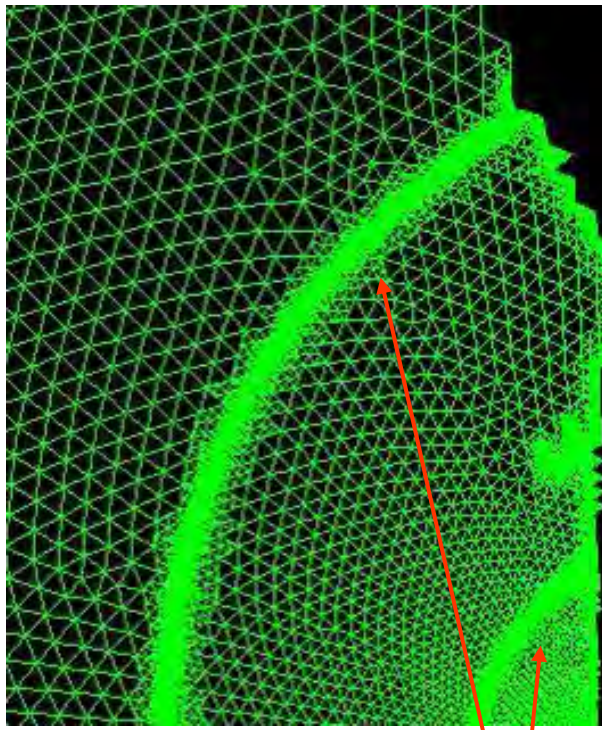
Unnecessary Adaption Behind Blast Wave

Modified Technique



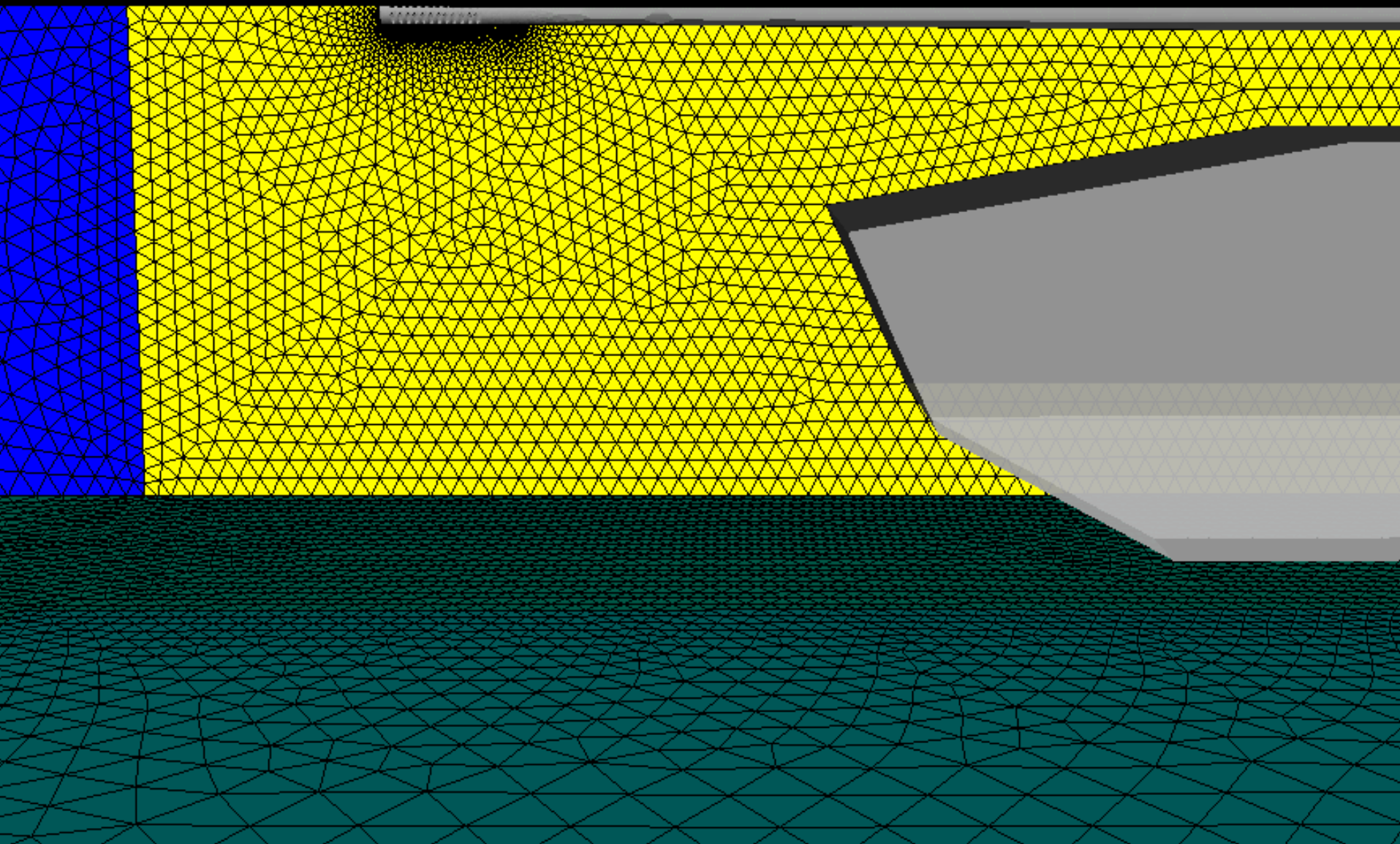
Better Identification Equals Adaption at Blast Wave Only

New Technique



Filtering better identifies shock wave boundary (s)

WS&T/BENET LABORATORIES
LEVEL 3 REVIEW
LIGHTWEIGHT ARMAMENT ENHANCEMENT PROGRAM
(LAEP)



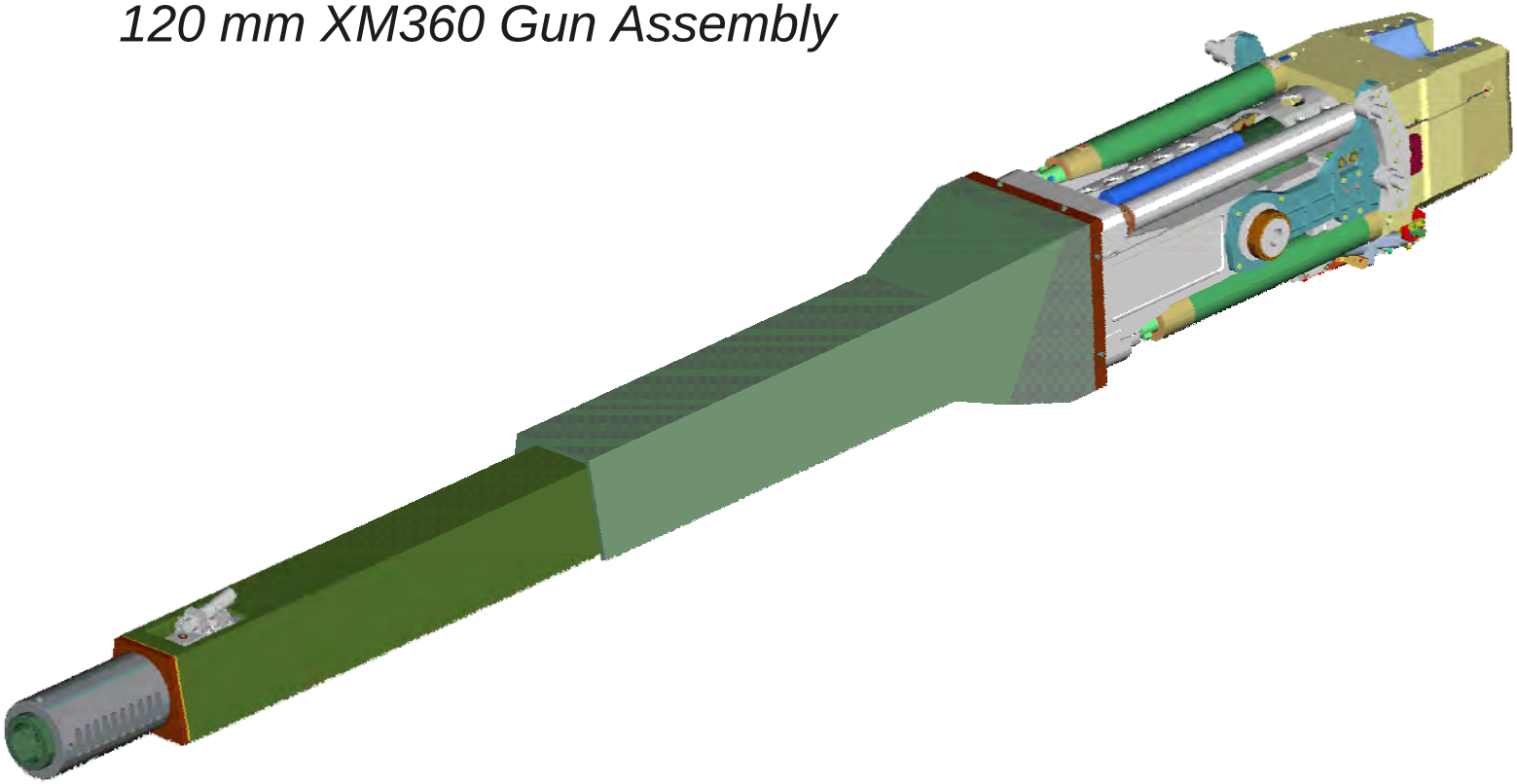
FY05-06
LAEP & MTO PROGRAMS
120mm XM360 TEST RESULTS/STATUS TO DATE

MTO GUN 5
April – June 06
120mm XM360

Round Type	VDRD	ATD 1	ATD 2	ATD 3	ATD 5	ATD 4	LAEP 6	Totals
Proof	0	0	0	0	0	0	0	0
M829A3	38	37	22	83	197	110	8	495
M829A2	0	13	12	5	11	0	16	57
M829A1	13	0	0	1	0	0	0	14
M829	0	1	0	0	0	0	0	1
M865	18	14	14	8	5	3	3	65
M831A1	42	25	10	0	37	0	0	114
MRM-CE (slug)	3	3	0	0	0	0	0	6
MRM-KE (slug)	3	3	0	0	0	0	0	6
MRM-KE Fin (slug)	0	1	0	0	0	0	0	1
MRM-CE Fin (slug)	1	0	0	0	0	0	0	1
XM1069					0	2	0	
	118	97	58	97	250	115	27	760

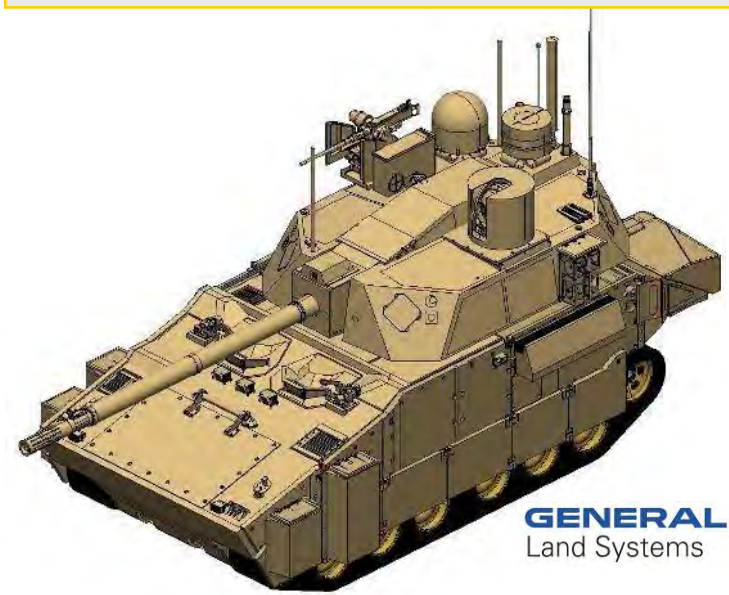
300+ LBS WEIGHT REMOVED FROM XM360 GUN SYSTEM WHILE MAINTAINING SAME IMPULSE LEVEL, INCREASING ITS ACCURACY, AND REDUCING BLAST OVER PRESSURE

Lightweight Armament Enhancement Program
120 mm XM360 Gun Assembly



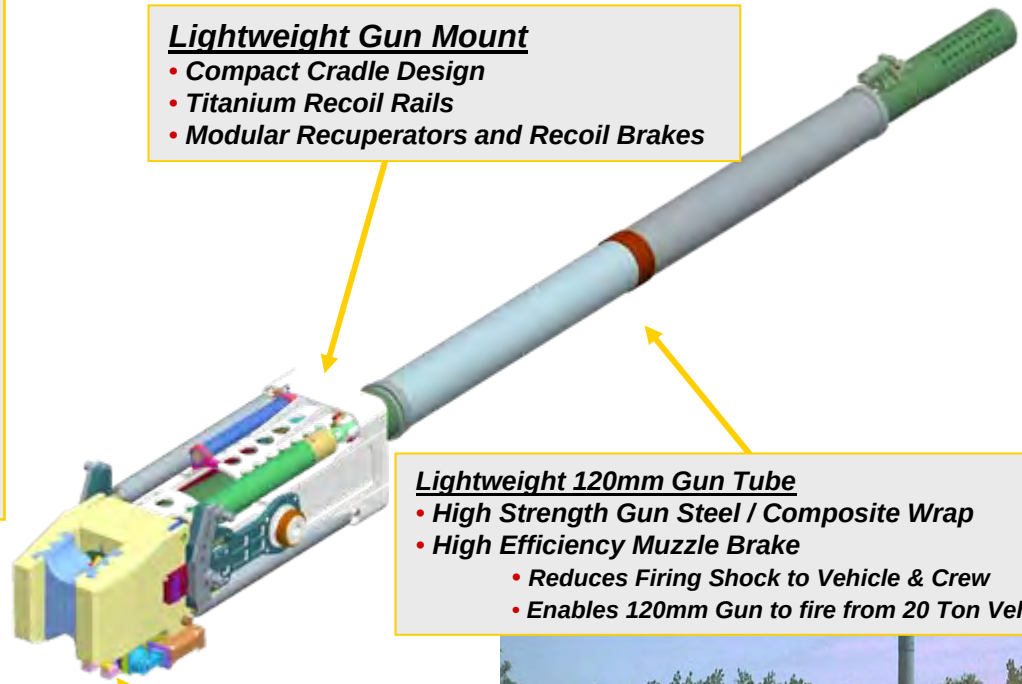
Primary Weapon for Mounted Combat System

- Provides direct fire in support of forces in the Unit of Action (UA).
- Beyond Line-of-Sight (BLOS) capability to 12 km with Medium Range Munitions (MRM).
- All the Performance of Current 120mm Cannon in a Light Weight, Compact Design
- Over 2,000 lbs lighter than 120mm Gun used on Abrams Tank
- Muzzle Brake & Recoil System Design Enables a 120mm Gun to fire from a 20 Ton Vehicle.



GENERAL DYNAMICS
Land Systems

Lightweight Gun Mount
- Compact Cradle Design
- Titanium Recoil Rails
- Modular Recuperators and Recoil Brakes



Lightweight 120mm Gun Tube
- High Strength Gun Steel / Composite Wrap
- High Efficiency Muzzle Brake
  - Reduces Firing Shock to Vehicle & Crew
  - Enables 120mm Gun to fire from 20 Ton Vehicle

Multi-Lug Breech Mechanism
- Long Life, Compact, Light Weight
- 600VDC Electrically Actuated
- Ammo Data-Link Enables Communication to Smart Rounds

•Gun Technology Demonstrated on Over 866 Rounds of Live Fire Testing

Mission

The XM360 is a 120mm high performance gun assembly being developed as the Primary Weapon Assembly for the Mounted Combat System of the Future Combat System. The mission of the XM360 is to provide lethality to defeat targets in the Line-of Sight (LOS) and Beyond Line of Sight (BLOS) areas. In simple terms the XM360 is being designed to provide the firepower of the M256 cannon assembly in the current M1A2 tank in a package over a ton lighter in weight. It also adds BLOS capability that the current system does not offer. The 360 will be able to fire all current US fielded 120mm ammunition plus all of the new 120mm rounds currently under development. This includes the new Mid Range Munition (MRM).

Features

The XM360 gun assembly features a modular recoil system with embedded instrumentation to monitor gun performance in the unmanned turret of the MCS. It is designed to provide all necessary interfaces to the turret to facilitate the gun elevation and pointing electric drives. The 360 utilizes 600 VDC electric breech operation, and utilizes muzzle brake to reduce impulse to the MCS vehicle platform. The gun also includes a new ammunition data link. This feature allows communication of the fire control system with a bullet that is loaded in the gun. This allows passage of target location information to that bullet just before actual firing. Safety certification of the XM360 gun assembly has been initiated and will continue over the next few years.

Background

The XM360 Primary Weapon Assembly (PWA) is being developed under a Cooperative Research & Development Agreement (CRADA) between General Dynamics Land Systems and ARDEC. After an extensive world wide search of available gun technology the XM360 PWA design and ARDEC were selected as being the most mature and capable gun design for the main armament of the Mounted Combat System of FCS .

Milestones – XM360 Primary Weapon Assembly

- Started formal SDD for MCS PWA (Primary Weapon Assembly) — Oct 05
- Delivery of PWA Emulator to GDLS SIL — Sep 07
- Delivery of 1st PWA for turret integration and hardstand testing — Oct 07
- PWA successfully passed proof firing and baseline accuracy firing — Nov 07
- Blast overpressure and thermal bending test also conducted — Nov 07
- GDLS & subs mate the gun, autoloader, fire control – Firing Fixture — Feb 08
- Planned Testing at TACOM Motion Base Simulator — Jun 08
- GDLS Firing Fixture goes to APG for firing tests — late 08
- Testing of PWA 2 to be used to test for ISFL — Mar 08
- Testing of PWA 3 to be used to test for ISFL — Jun 08
- XM360 PWA Interim Safety Release — Mar 09
- Delivery of 4 PWA for Final Safety Release — Nov 08 - Feb 09
- Delivery of 6 PWA's for Vehicle Integration — Aug 09 - Feb 10

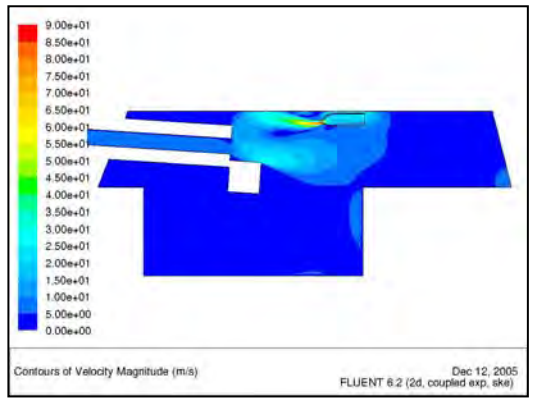
- Total Delivery: 15 PWA, 4 additional cannon, 2 spare tubes

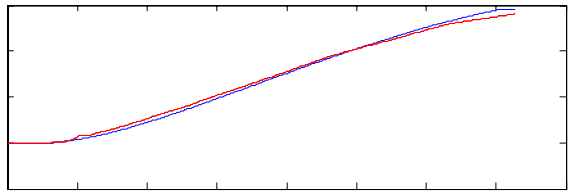
XM360 PWA SDD
General Characteristics

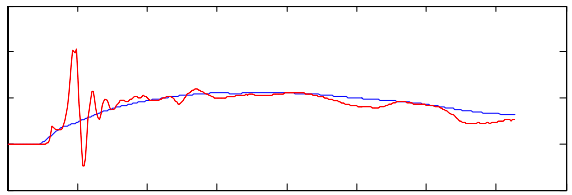
- Developer: US Army ARDEC - Benét Laboratories
- CRADA to: General Dynamics Land Systems
- Caliber/Type: 44 Caliber plus muzzle brake / High Pressure direct fire cannon
- Length: 5930 mm
- Range: 0 to 12 KM with Mid Range Munition
- Weight: 1865 kg
- Electric ignition/ breech operation
- Ammunition: All current 120mm US inventory & developmental

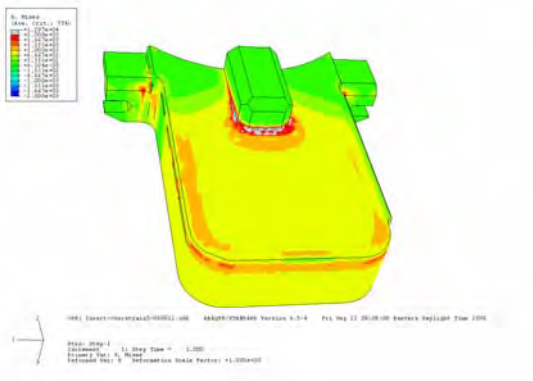
Examples of M&S To Reduce Development Time

- **Computational Fluid Dynamics-**
  - Muzzle Break
  - Bore Purge
- **Finite Element Analysis-**
  - All major and critical components
- **MatLab-**
  - Breech Controls
- **Virtual Lab-**
  - Breech Mechanism



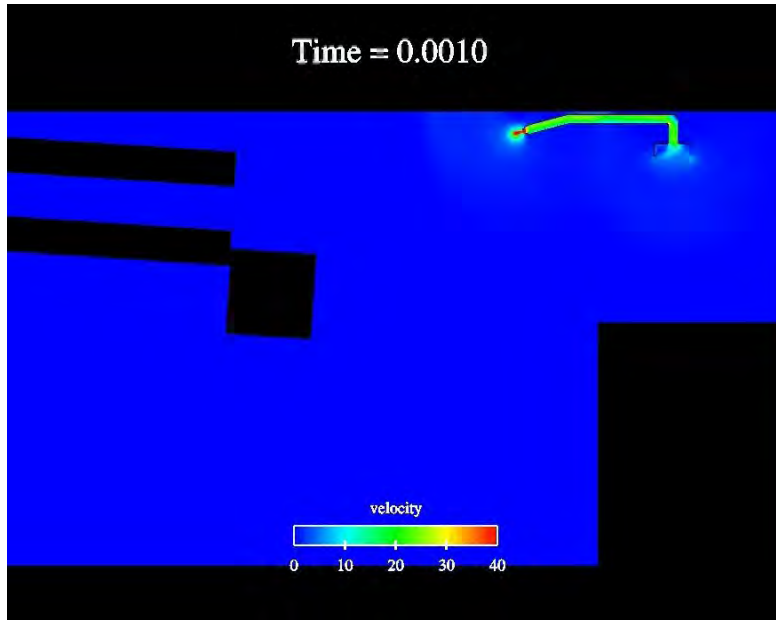


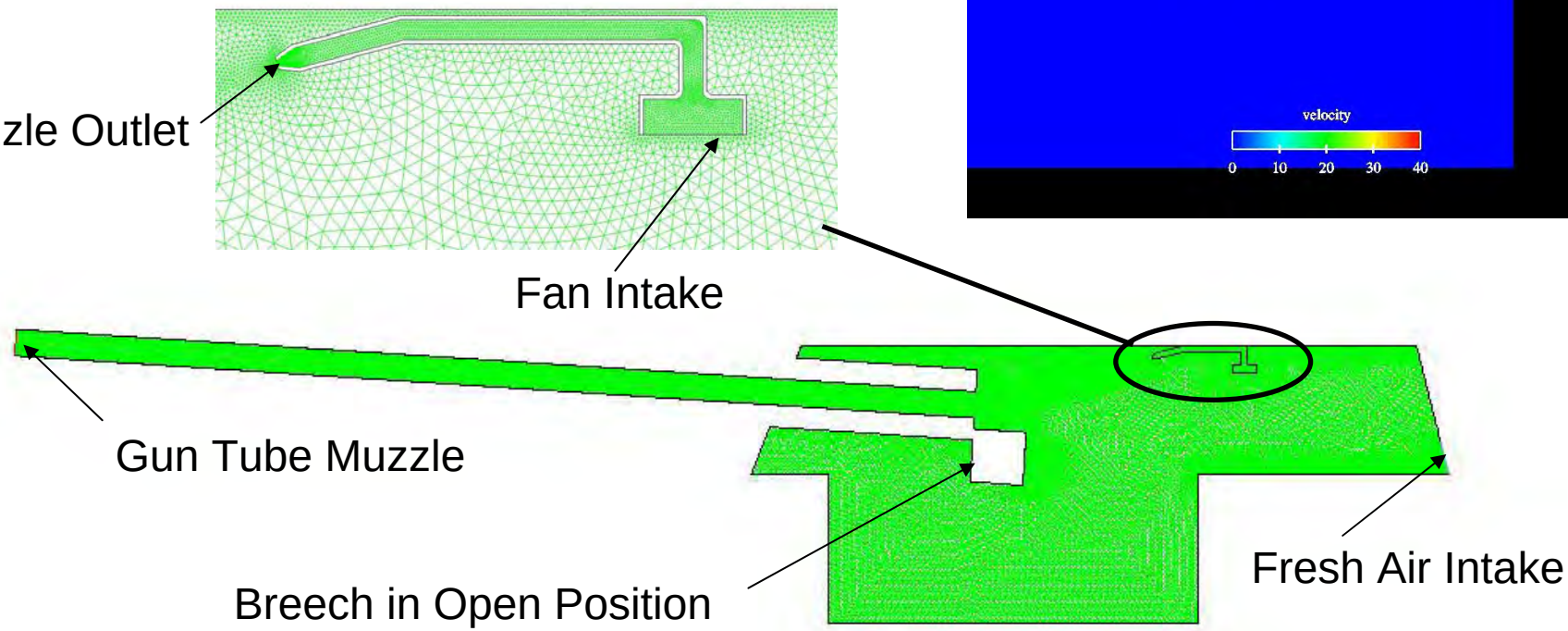


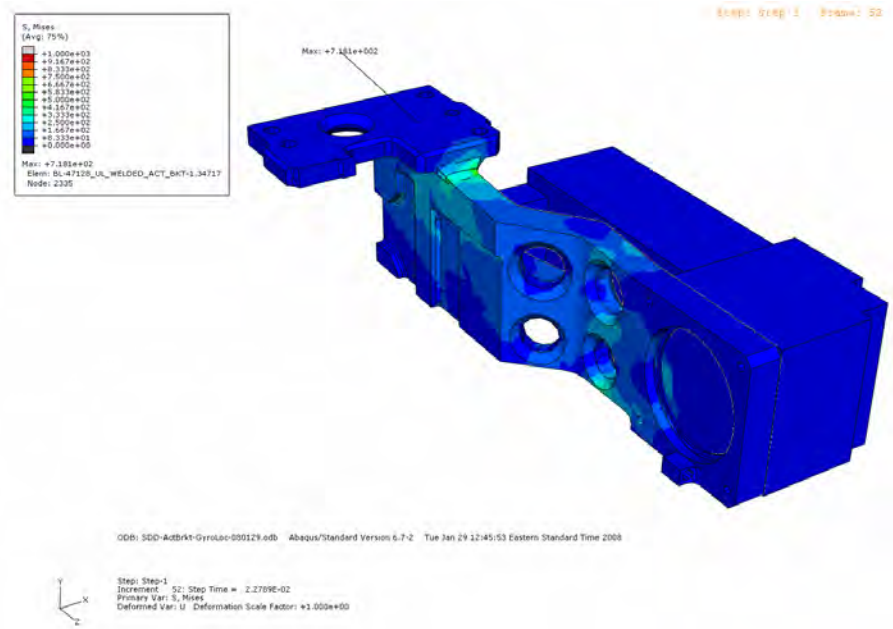


Computational Fluid Dynamics

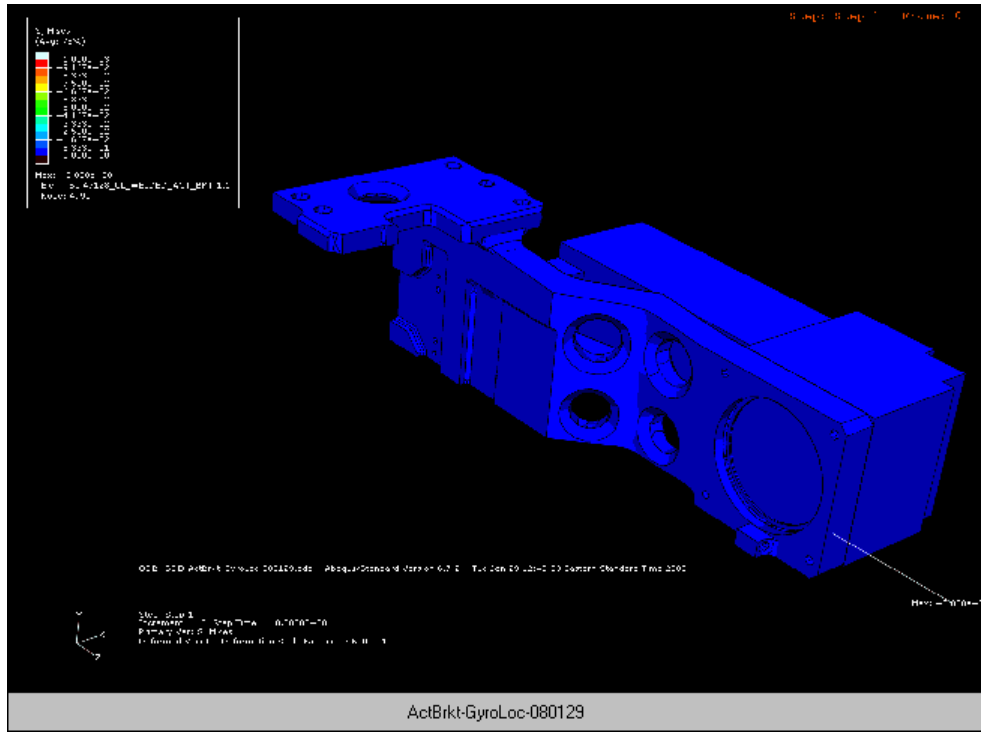
- **Fluent® 2-D CFD model of turret, basket, breech, barrel, nozzle, piping, fan system and fresh air intake.**
- **Steady-state, coupled-explicit, ideal gas model with k-epsilon turbulence model.**
- **Dynamic model without turbulence.**

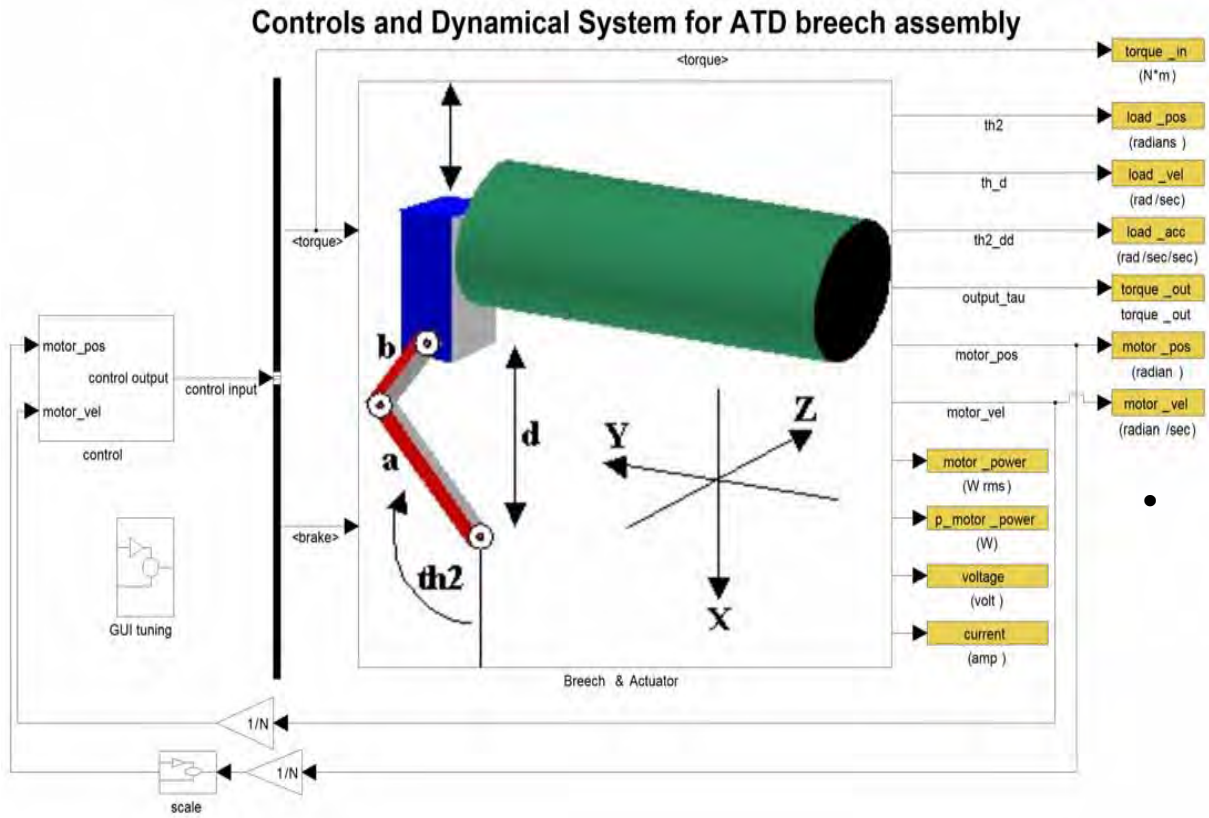




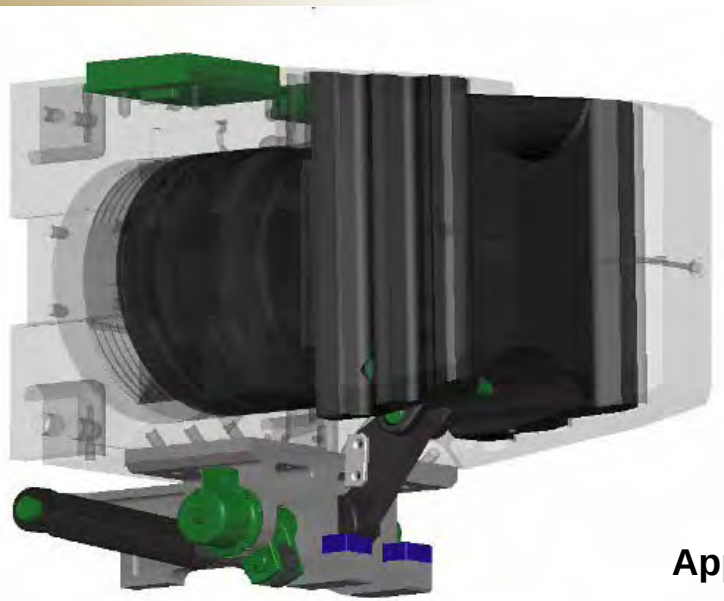


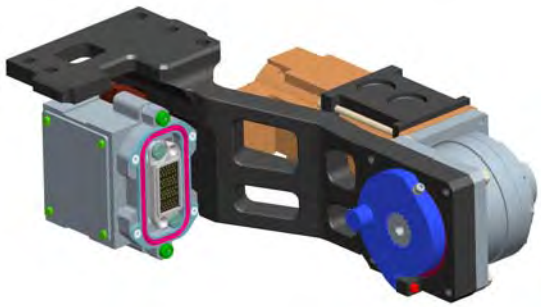
Breech Actuator FEA using accelerometer data taken during Baseline firing test of SDD01 Gun at APG.





- **Control design began in Matlab® using a hand coded dynamics model for an Advanced Technology Demonstrator (ATD) system.**
- **This allowed better prediction regarding changes in the actuation system.**





LMS Virtual.Lab®

- Simulate realistic motion and loads of multi-body mechanical systems.
- Virtual.Lab® Standard Motion
  - Rigid body analysis
- Mechanical elements include spring, friction, contact forces, and an extensive list of joint and constraint features
- Dassault Systems: CATIA®, ABAQUS®

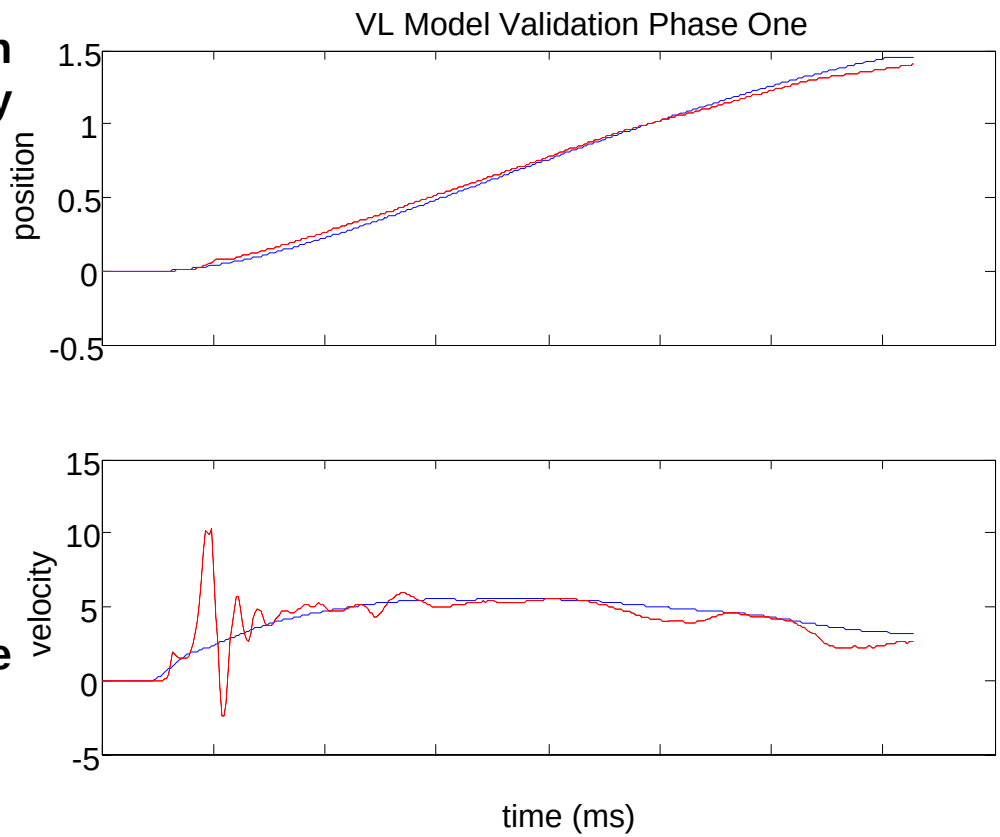
Application Process

- **Import Pro-E® part/assembly files**
- **Identify and apply joints at all interfaces**
- **Apply material densities for dynamic loading**
- **Apply external forces (i.e. gas spring preload and gravity)**
- **Apply constraints**
- **Apply motion parameters**
  - Coefficient of friction (steel on steel stiction and dynamic)
  - Crank travel angle for opening and closing
  - Time of 0.4s to complete half a cycle (open or close)
  - Gas Spring data from dynamic test on an MTS machine.

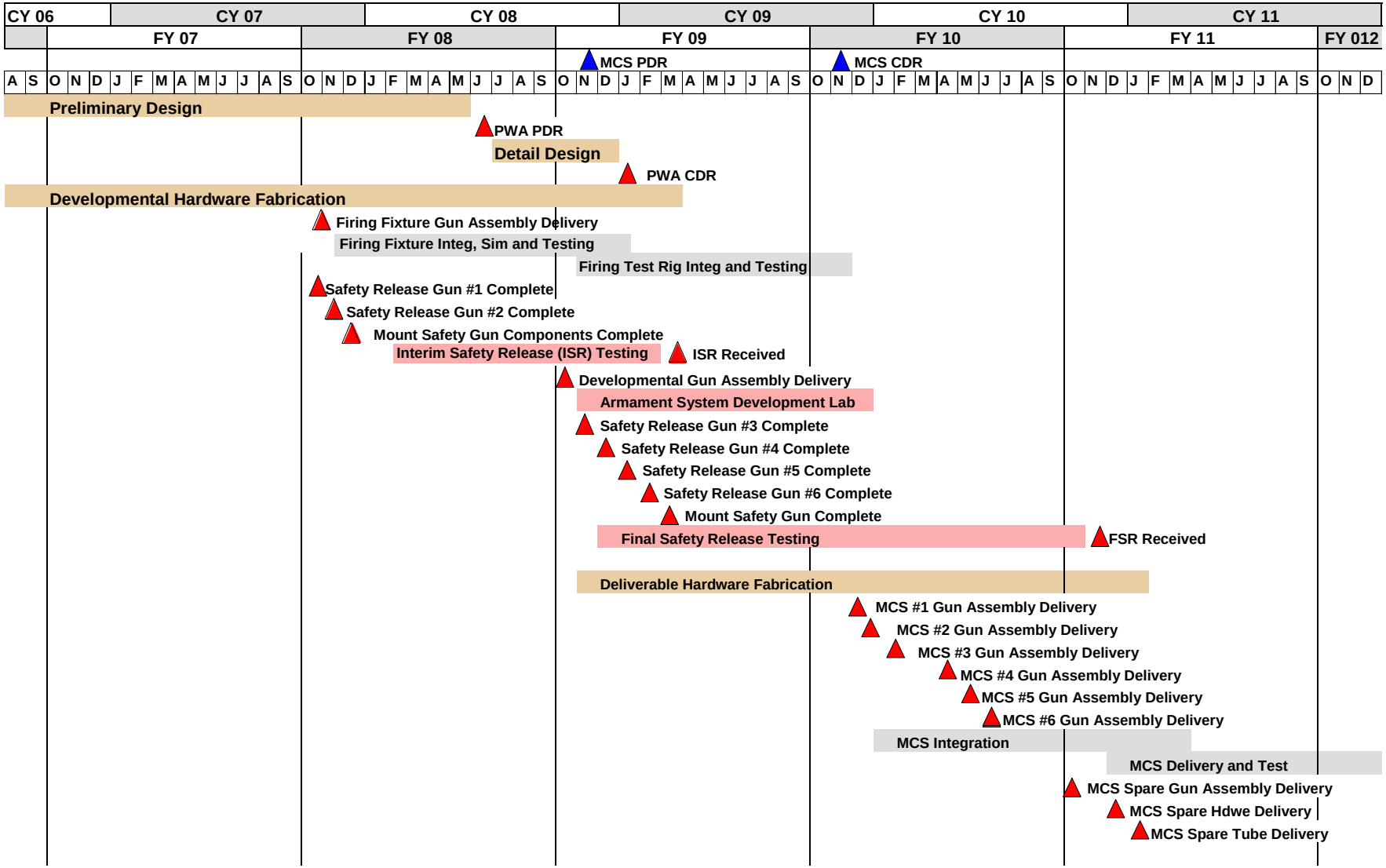
- **Virtual prototyping of the ATD breech mechanism that later transformed into the XM360 breech mechanism allowed design changes to be considered in a way not otherwise possible.**

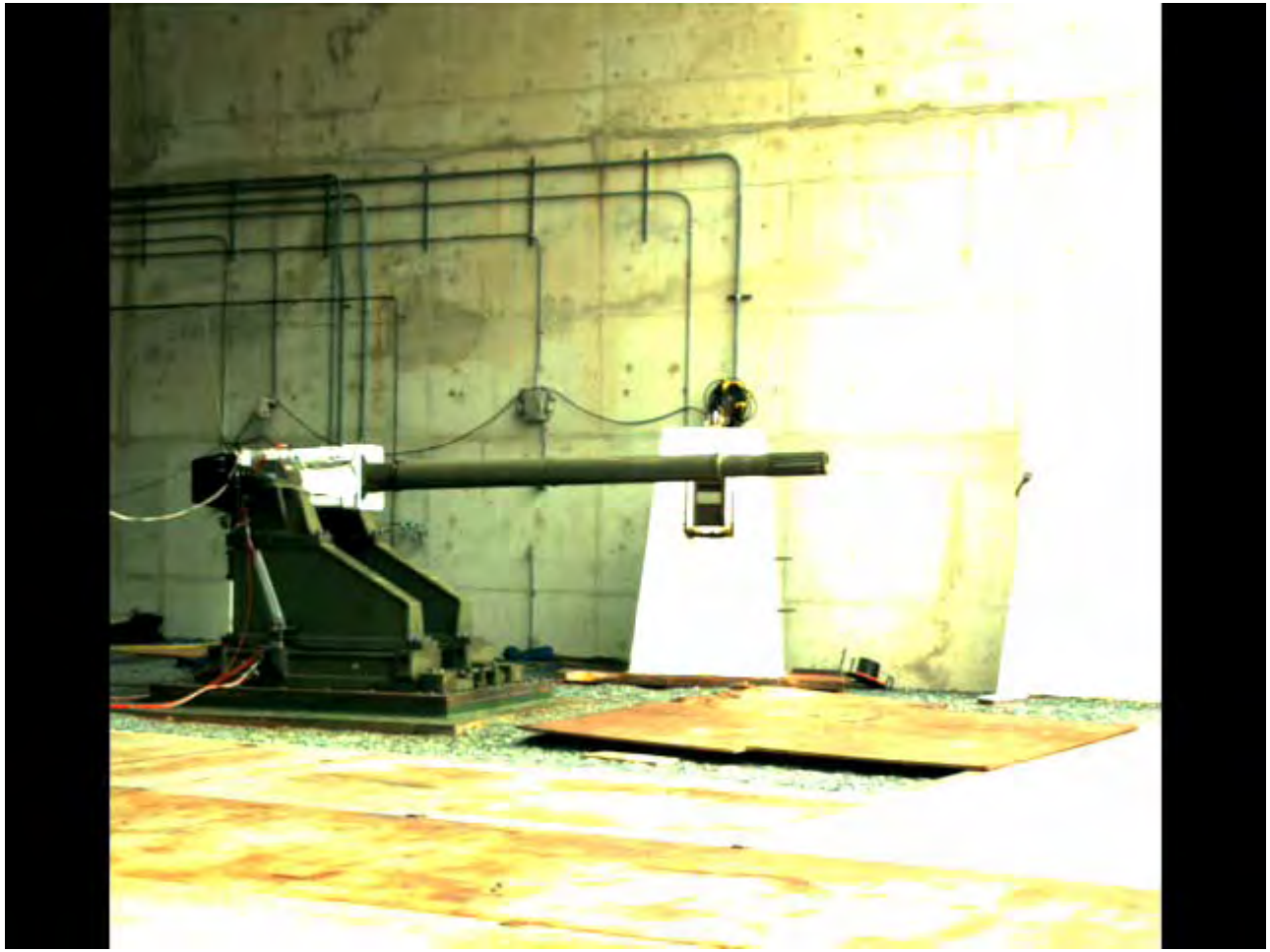
- **The validation process of virtual prototypes was and is indispensable, allowing accurate modeling using validation for the most uncertain design aspects.**

- **Across the design a more concurrent design was made more accurate, requiring fewer design iterations to meet system requirements.**



PWA Overall Schedule





GENERAL DYNAMICS
Armament and Technical Products

F-35 Lightning II CTOL Gun System Update

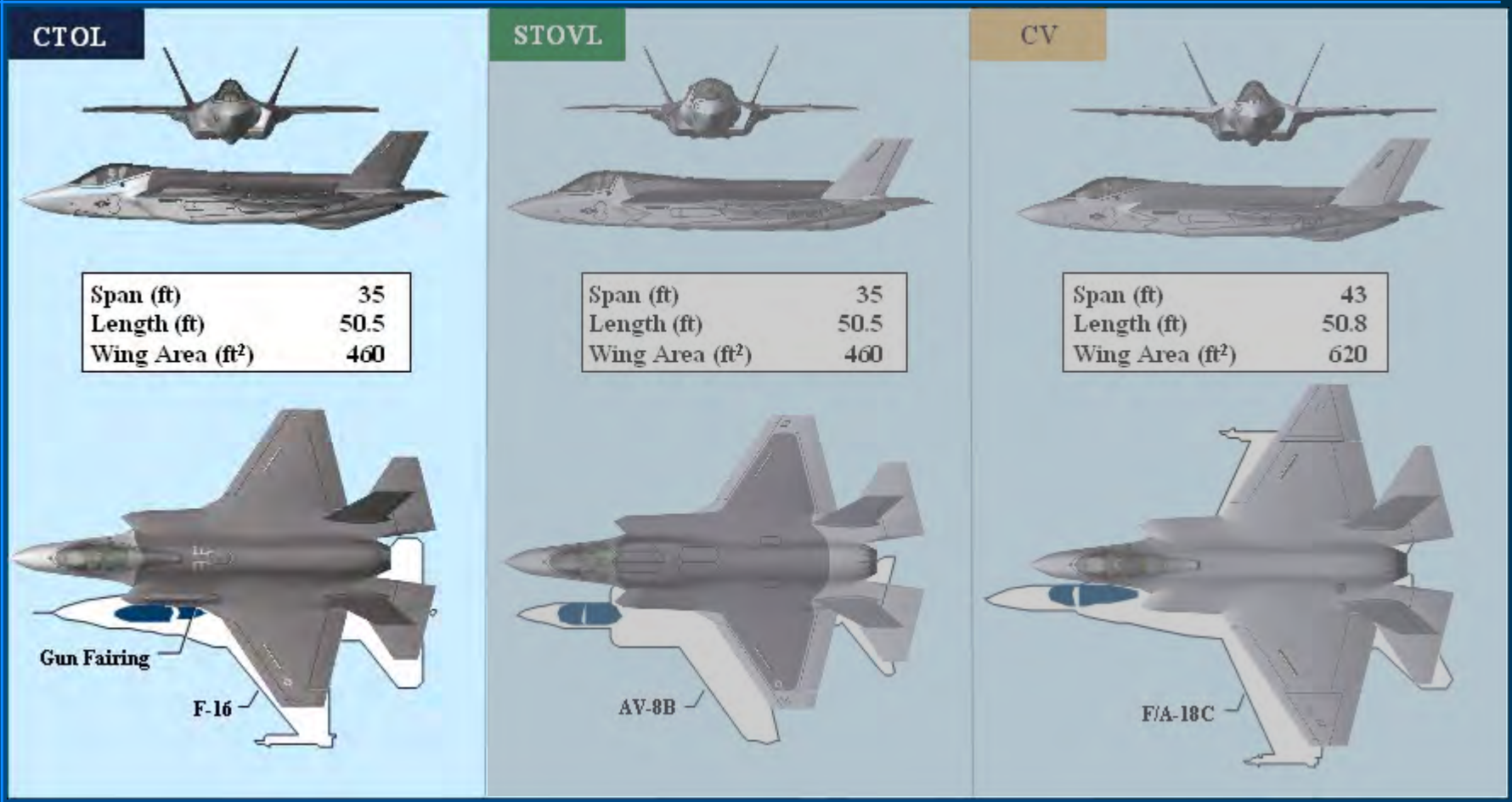
Presented by:

Dave Maher
Project Engineer – Joint Strike Fighter Gun System
General Dynamics Armament & Technical Products
Burlington, Vermont USA
802-657-7113 dmaher@gdatp.com

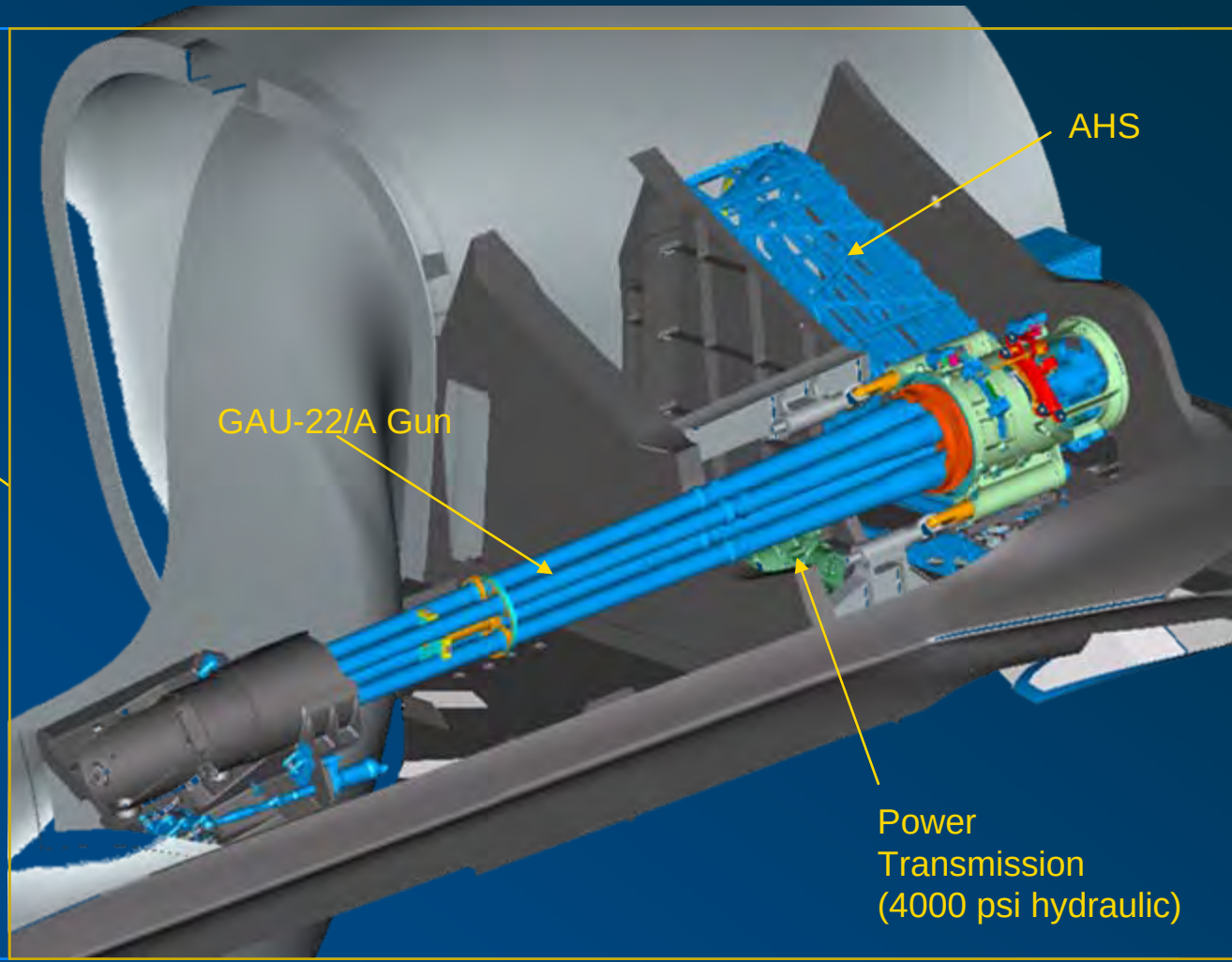
Presentation Outline

- Technical Overview
- Achievements Since April 2007
- Design Improvements
- Path Forward

Lockheed Martin F-35 Variants



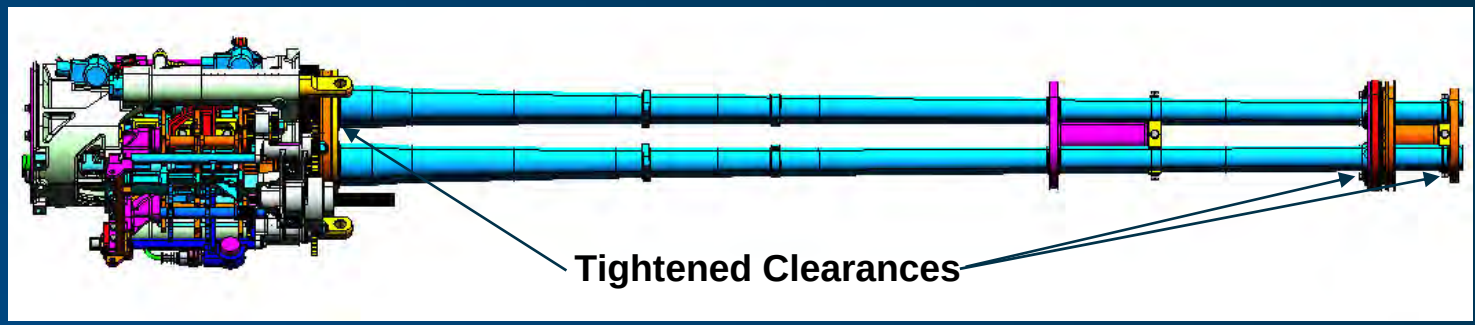
CTOL Gun System



Achievements since April, 2007

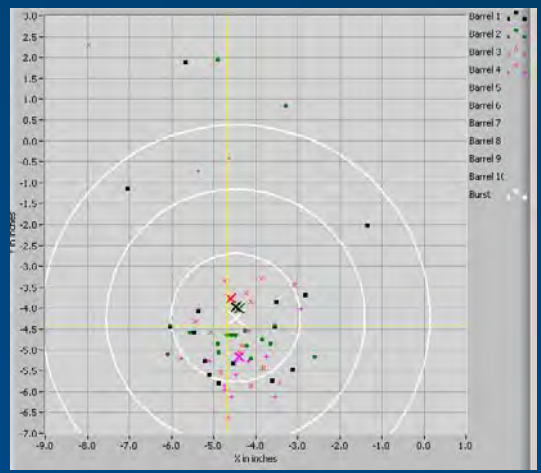
- Dispersion Improved
  - Tightened clearances between barrels and clamps
- Completed 28,000 rounds out of a planned 36,000 Round Durability Qualification Test
  - No stoppages to date in either Engineering or Qualification testing
  - Dispersion requirement (1.4 mr one sigma) met for all standard complements
  - System power has remained within acceptable limits
  - One lifetime (18,000 rounds) demonstrated (no parts replacement)
  - Several design improvements incorporated based on test results
  - Issues with hydraulic drives delayed completion of test
- Completed 90% of Planned Vibration Qualification Test
  - Load Access failure
  - Mounting Bracket wear

Dispersion Solution



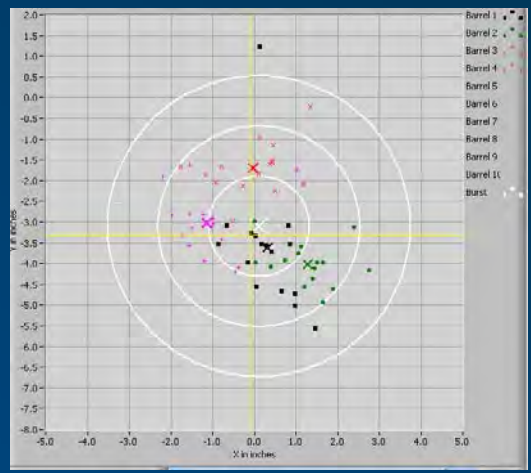
By tightening key barrel clearances, a significant improvement in dispersion was obtained

Before



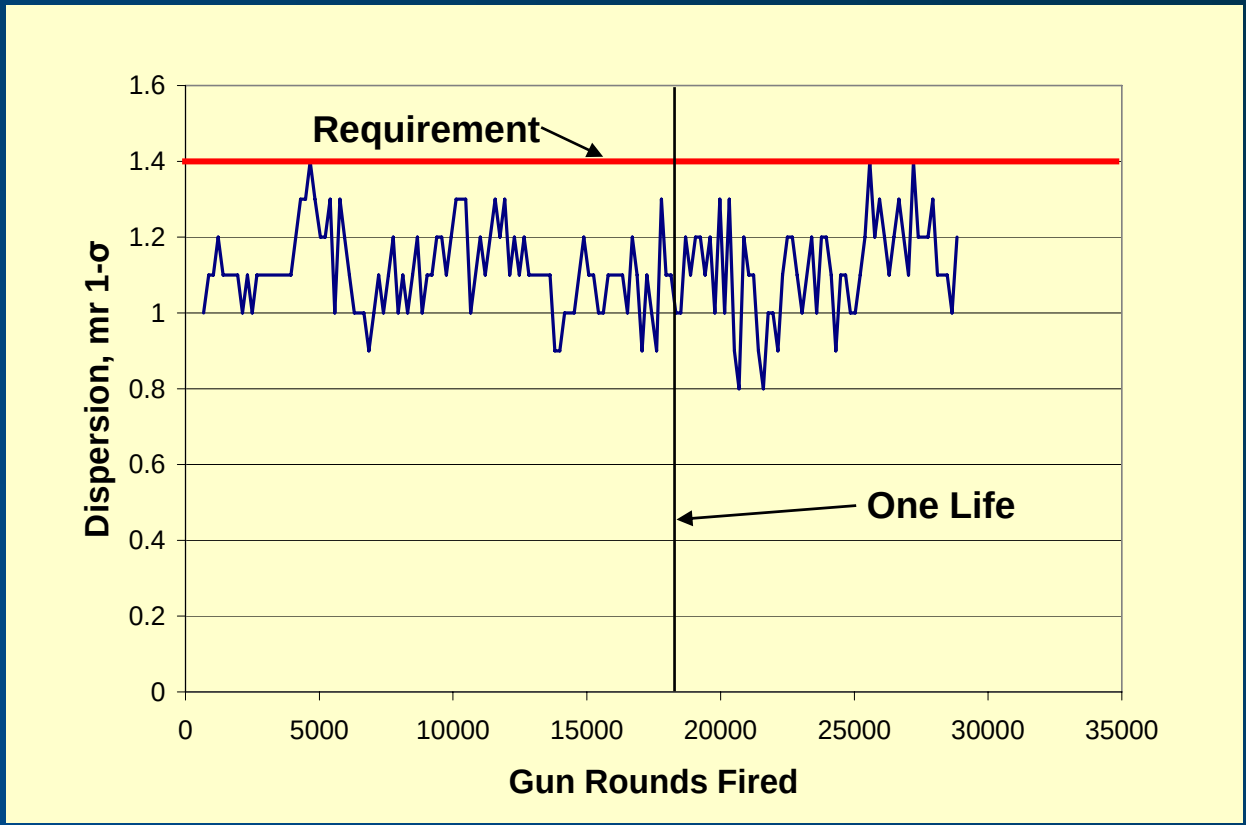
B146 1.54 mr

After



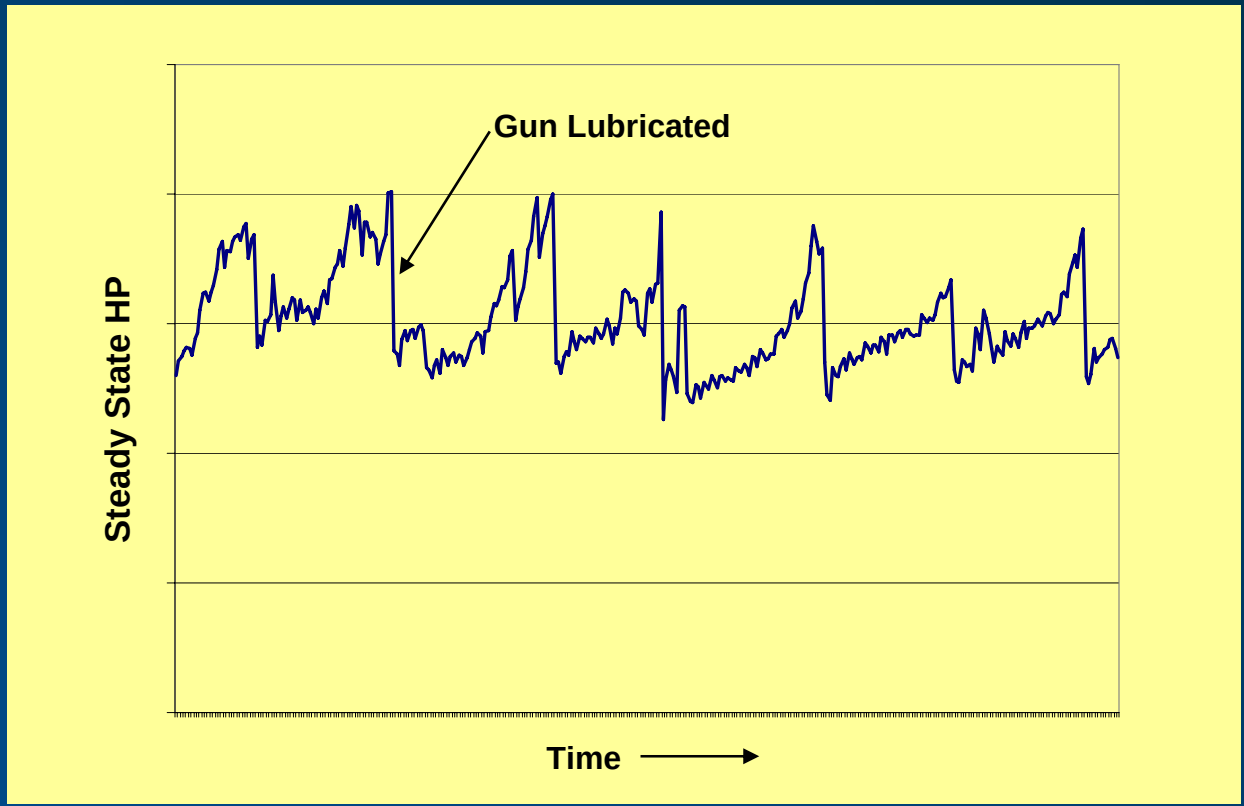
C140B1 1.21 mr

Dispersion History



Dispersion Has Remained on Track for Well Over one Gun System Lifetime

System Power History



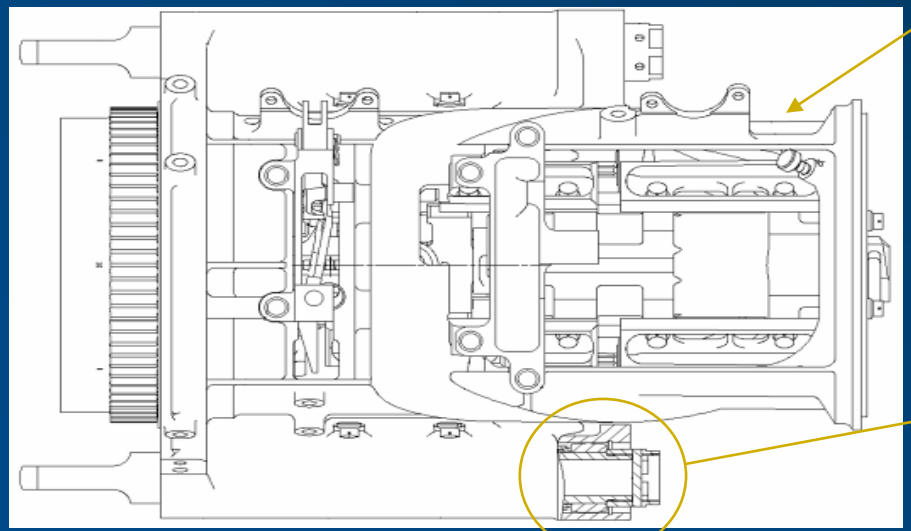
System Power Did not Increase Over the Life of the Gun System

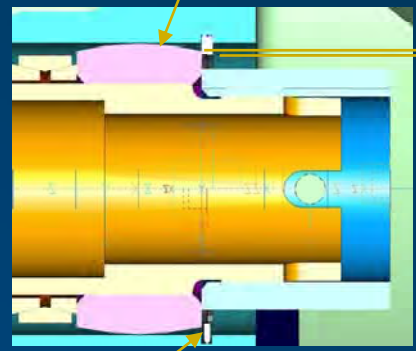
Design Improvements Resulting from Qualification Testing

- Increased engagement of Recoil Spindle Bushing with retaining ring
- Increased software time-out thresholds for safing and clearing
- Modified software clearing routine to prevent long clears
- Increased Stiffness of Load Access Door Latch Spring
- Modified AHS Lower Mounting Bracket to reduce wear

Recoil Spindle Bushing Improvement

- The Recoil Spindle Retaining Ring worked its way out of the groove during the first few complements of qualification testing.
- The bushing was re-designed to improve engagement.





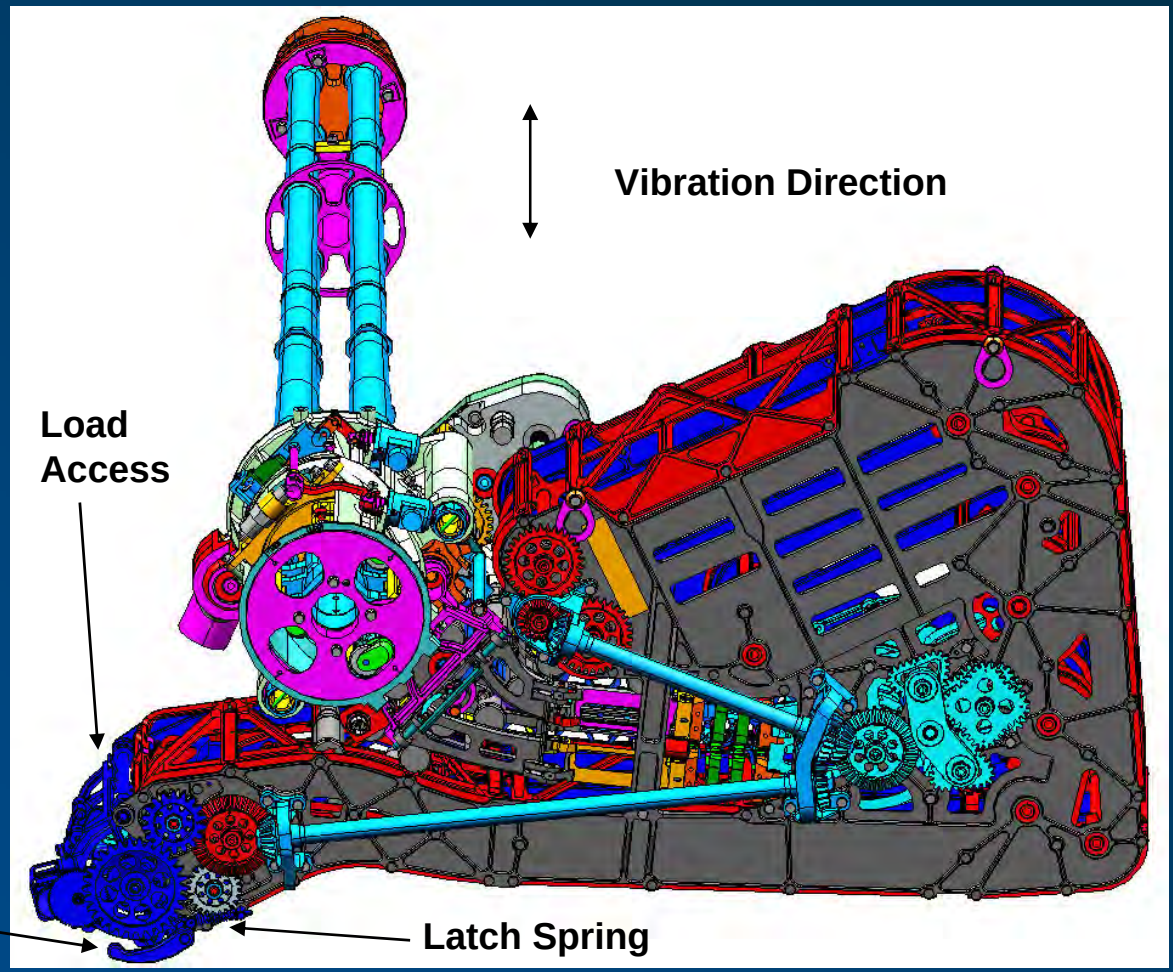
This Problem Has not Recurred in 28,000 Rounds of Qualification Testing.

Software Improvements

- During Low Temperature (-70F) testing, some functions occurred more slowly than anticipated by software
  - The Safing Pin took up to 0.169 ms to engage vs a SW timeout threshold of 0.130 ms
  - Threshold increased to 300 ms
  - Reverse Clearing took slightly longer than the 1.1 second SW timeout threshold. Threshold increased to 2.0 seconds.
- A timing scenario occurred that resulted in inaccurate rounds count during clearing, resulting in a long clear.
  - Clearing algorithm improved to eliminate this

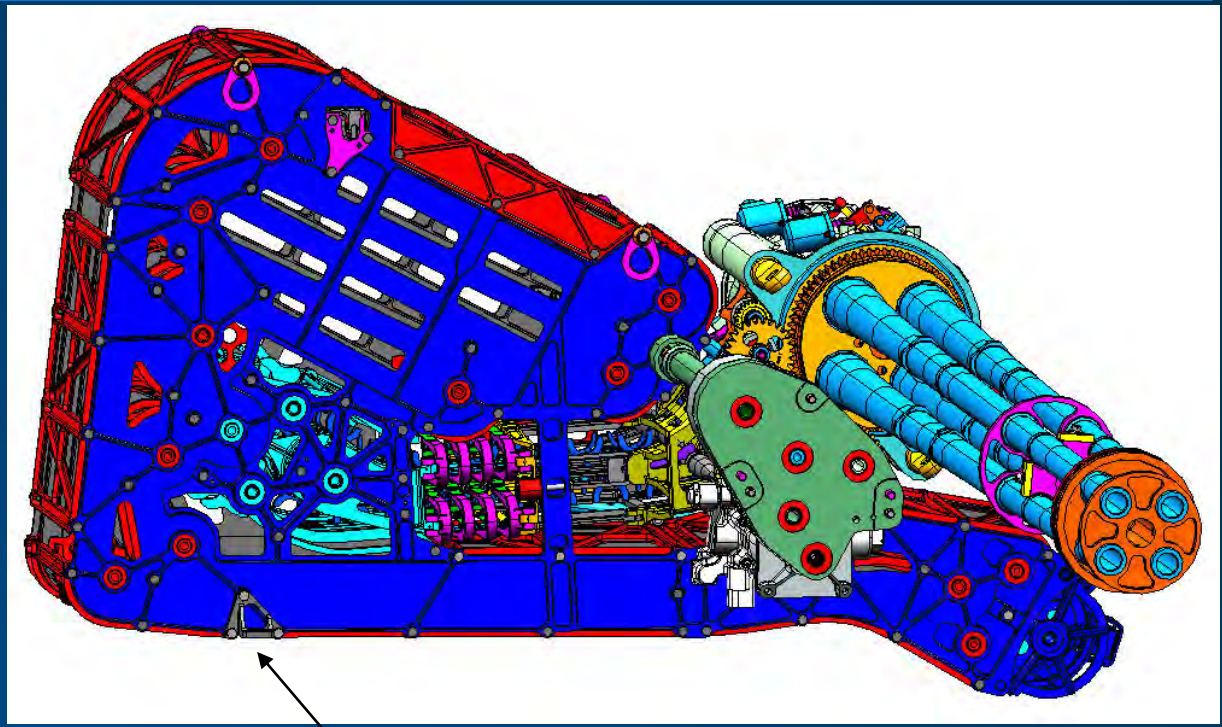
Load Access Door Latch Spring

- During vibration testing, the Load Access Release Lever vibrated to the open position.
- The load access opened up and dummy ammunition was ejected.
- This was corrected by increasing the stiffness of the Latch Spring
- Design change verified in re-test.



AHS Lower Mounting Bracket

- During the vibration test, wear was observed on the interface between the aircraft mounting pin and the lower mounting bracket.
- The bracket was redesigned to increase contact area and use a harder material.



Lower Mounting Bracket

Hydraulic Drive Motor Issues

- Excessive Flow
  - Problem: Several readings exceeded the 18.5 GPM max allowable
  - Status: Issue traced to errors in flow measurement
- Uncommanded Motion
  - Problem: Uncommanded motion occurred twice with newly installed drive, apparently due to air entrapped when drive was installed.
  - Status: Options for corrective action are being investigated
- Shaft Seal Leakage
  - Problem: Unexplained, recurring leakage from shaft seal
  - Status: Under investigation

Path Forward

- Complete 36,000 Round Qualification Test
- Complete CTOL Vibration Test
- Deliver SDD Systems 3 and 4
- Begin LRIP

GENERAL DYNAMICS

2008 NDIA
Gun and Missile Systems Conference & Exposition
21 – 24 April 2008

30mm Air Bursting Munitions for the MK44 Cannon

Erik Elmer
ABM Technical Lead
ATK Armament Systems

Approved for Public Release 07-S-2716 dated 17 September 2007

Contents

- **Gun System Overview**
- **MK44 ABM System Overview**
- **30mm ABM Ammunition Overview**
- **System Performance**
- **Contacts**

ATK ABM Overview

30mm Air Burst Munition

SELECTED FOR QUALIFICATION BY U.S. NAVY / U.S. MARINE CORPS

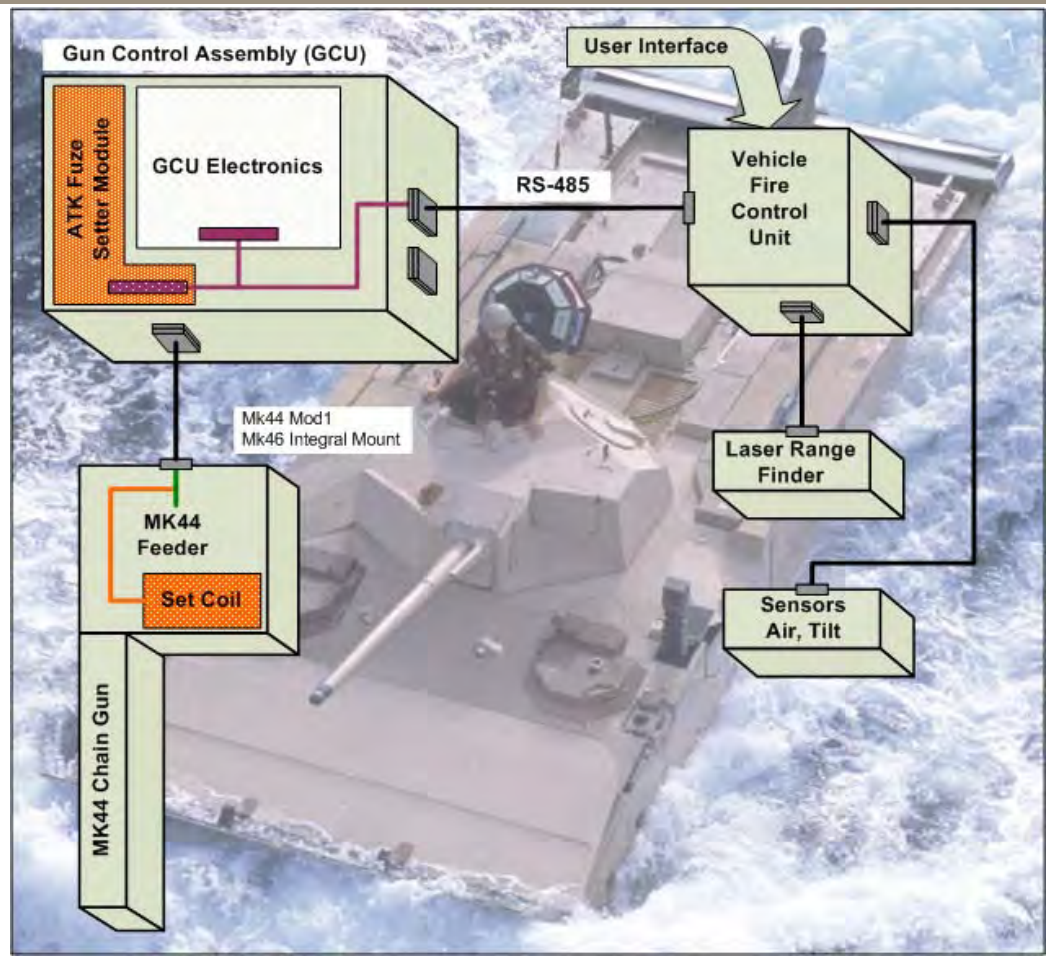
- ATK command arm fuze with turns-count technology
- Setting system integrated into Mk44 cannon
- Effective against personnel and materiel targets

EFV ABM System Requirements (ABM Baseline)

Approved for Public Release 07-S-2716 dated 17 September 2007

The following components comprise the 30mm ABM MK44 Gun System for the Marines EFV:

- MK44 with modified timing
- ABM Capable Gun Control Unit (GCU)
- Setter drive coil assembly, located within the gun assembly
- ABM Ballistic Algorithm incorporated in Fire Control software
- RS-485 Communication between FC and GCU
- Laser rangefinder
- Sensors for air temperature and pressure
- Tilt sensor on gun barrel (pitch, roll)
- Gunner display to assist and confirm target aiming

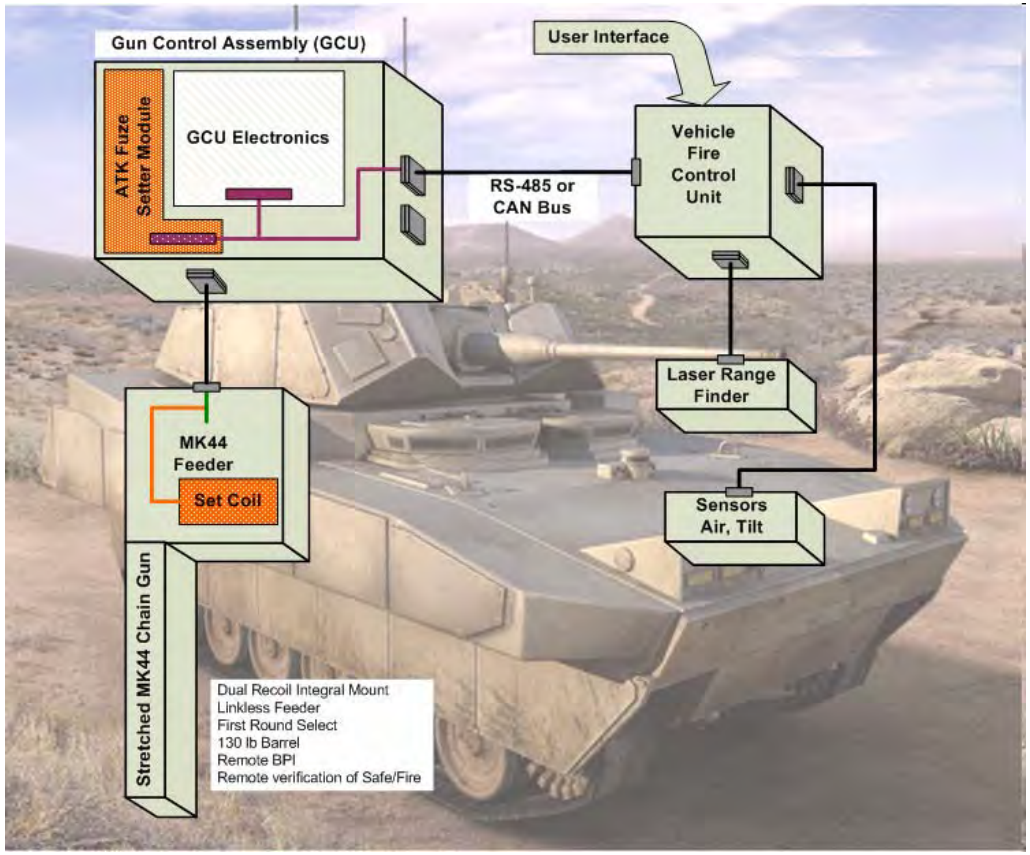


FCS ICV ABM System Requirements (ABM Baseline)

Approved for Public Release 07-S-2716 dated 17 September 2007

The following components comprise the 30mm ABM MK44 Gun System for the FCS ICV

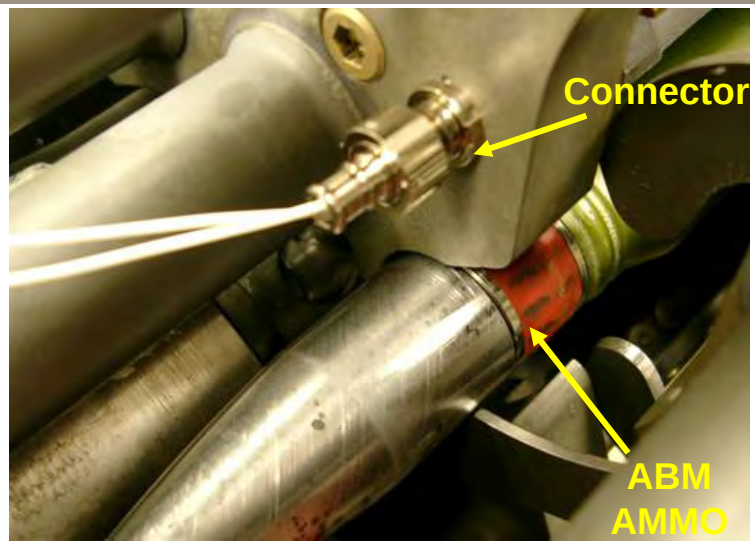
- Stretched MK44 with modified timing
- ABM Capable Gun Control Unit (GCU)
- Setter drive coil assembly, located within the gun assembly
- ABM Ballistic Algorithm incorporated in Fire Control software
- Fire Control / GCU Communication:
  - Option of RS-485 or CAN Bus
- Laser rangefinder
- Sensors for air temperature and pressure
- Tilt sensor on gun barrel (pitch, roll)
- Gunner display to assist and confirm target aiming

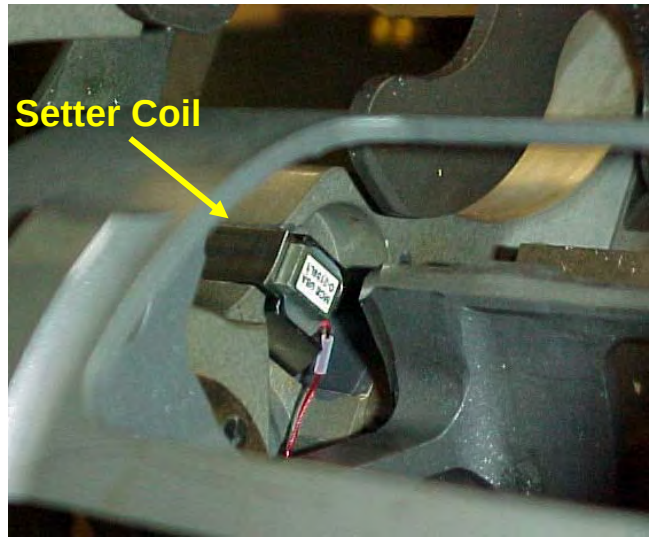


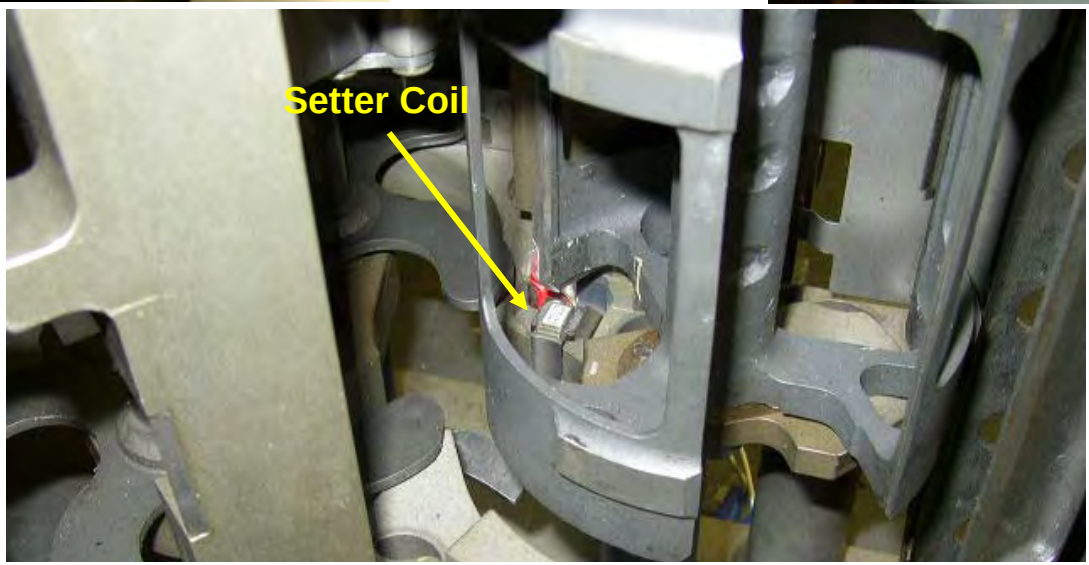
FUTURE COMBAT SYSTEMS
FCS
One Team-The Army/Defense/Industry

Integrated Fuze Setter Coil with MK44 Feeder

Approved for Public Release 07-S-2716 dated 17 September 2007







Simple Integration of Inductive Setter Coil into MK44 feeder

Mk44 ABM Integration

Approved for Public Release 07-S-2716 dated 17 September 2007

- **USN selected ATK inductive set ABM for Qualification Program**
  - ATK will incorporate ABM kits into EFV weapons in support of Qualification Program

Expeditionary Fighting Vehicle (EFV)

- **ATK on contract for ABM guns for Elbit**
  - Utilizes ATK inductive setter
  - Includes modified gun cycle timing with First Round Select

Elbit Turret

Air Burst Fuze

Fuze Location

Power Source

S&A

Fuze Electronics

Features:

- **Base fuze for improved forward fragmentation in air burst mode and superior penetration capability in PD and PD-delay modes**
- **SAPHEI-T warhead for high performance penetration**
- **Unique, cost effective Setback Generator (SBG) design**
- **Command Arm Safe and Arm (S&A) design – cost effective and flexible**

ABM Modes

Approved for Public Release 07-S-2716 dated 17 September 2007

Normal Modes

Modes of Operation	Primary Target	Comments
Air Burst Mode	Troops in Squad, ATGM, over walls	Will PD if projectile encounters a hard target prior to set air burst range
Point Detonate	LFIE, Water Craft, Lightly Armored Vehicles, etc…	Fuze functions in this mode if no inductive communication received
Point Detonate with Delay		Short Delay

Military Operations in Urban Terrain (MOUT)

Modes of Operation	Primary Target	Comments
Air Burst Mode Quick Arm	Confined Areas, Urban Targets	Will PD if projectile encounters a hard target prior to set air burst range
Point Detonate Quick Arm		
Point Detonate with Delay Quick Arm		Short Delay

ATK Air Burst Ammo Target Set

Approved for Public Release 07-S-2716 dated 17 September 2007

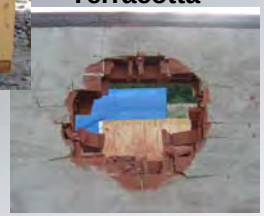
An advanced weapon and space systems company

Urban, Wall, and Bunker Targets

8” Double Reinforced Concrete

Lightly Fortified Infantry Emplacement (LFIE)

Terracotta



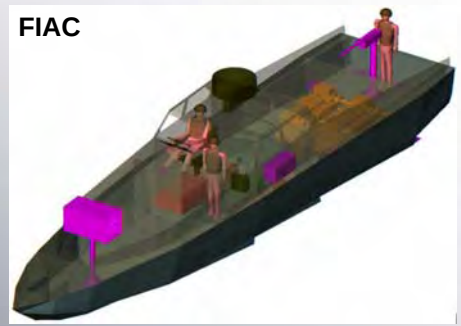
Personnel Targets

ATGM Crew

Troops in squad

Naval Targets

FIAC



Personal Watercraft

RHIB

Armored Vehicles & Automobiles

Auto

BTR

ATK

CONTACTS

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Erik Elmer	**ABM Technical Lead**	**Erik.Elmer@ATK.com**	**(480)324-8663**

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- WPML Background / Overview
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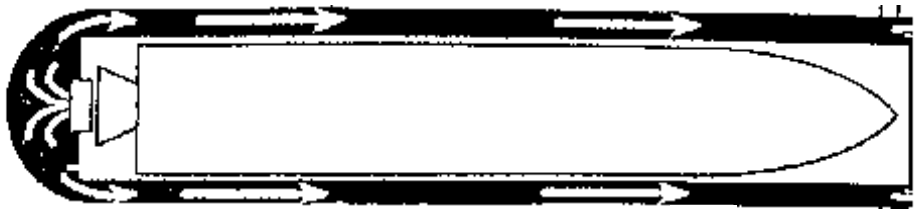
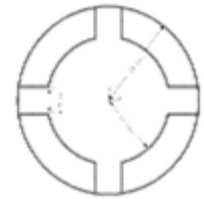
Concentric Canister Launcher (CCL)

Self-Contained Gas Management





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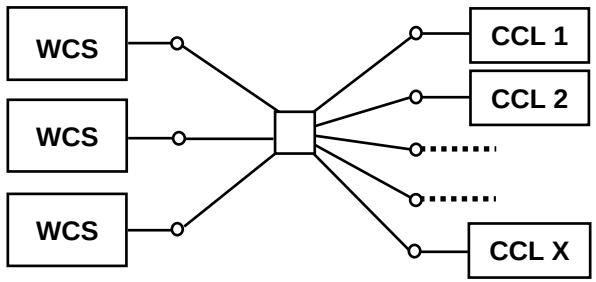
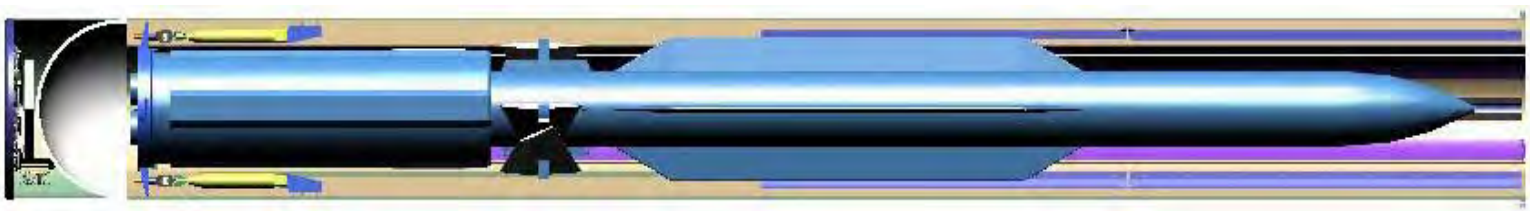
Distributed Electronic Architecture

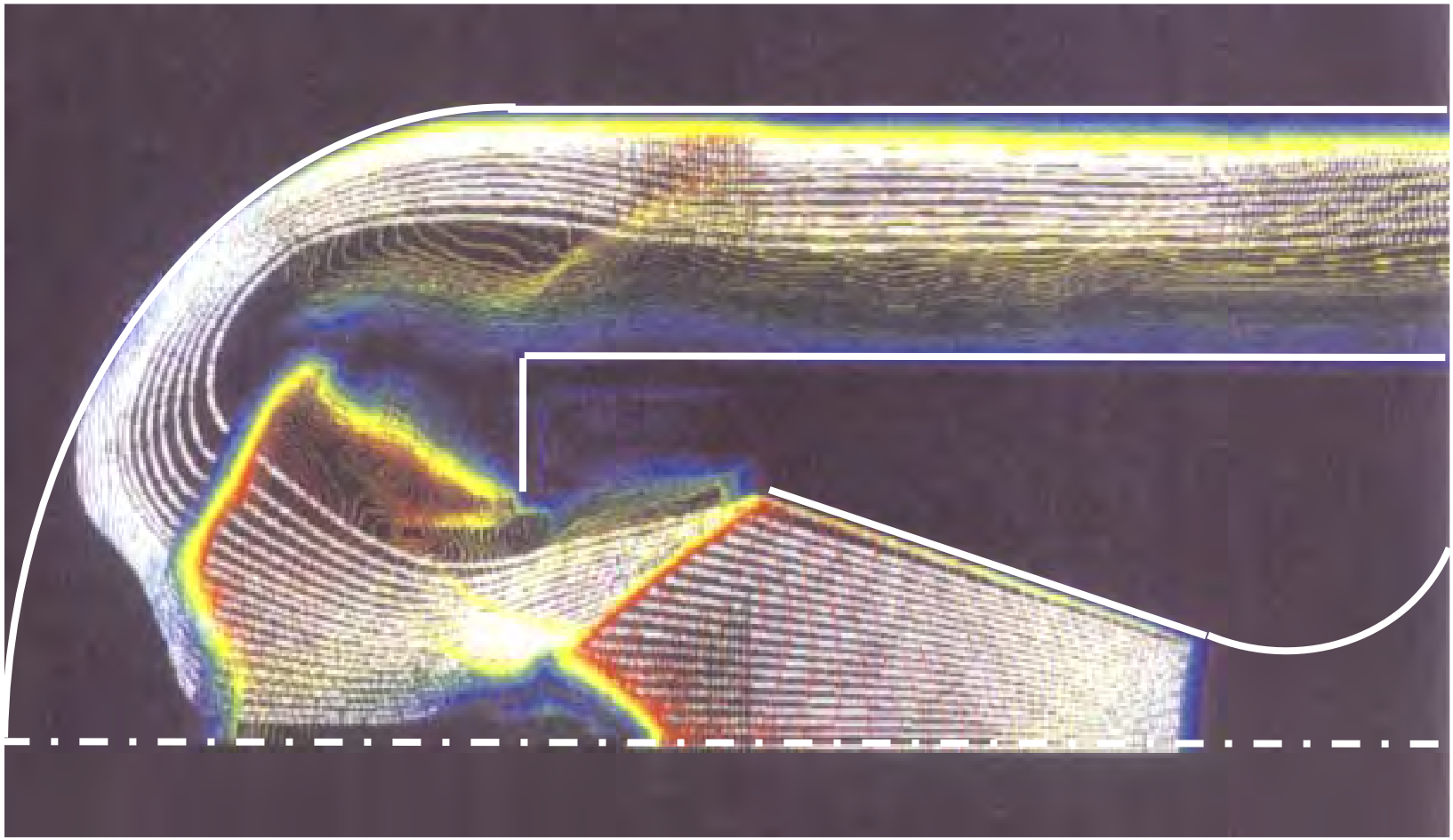


Canister is an All-Up Launcher



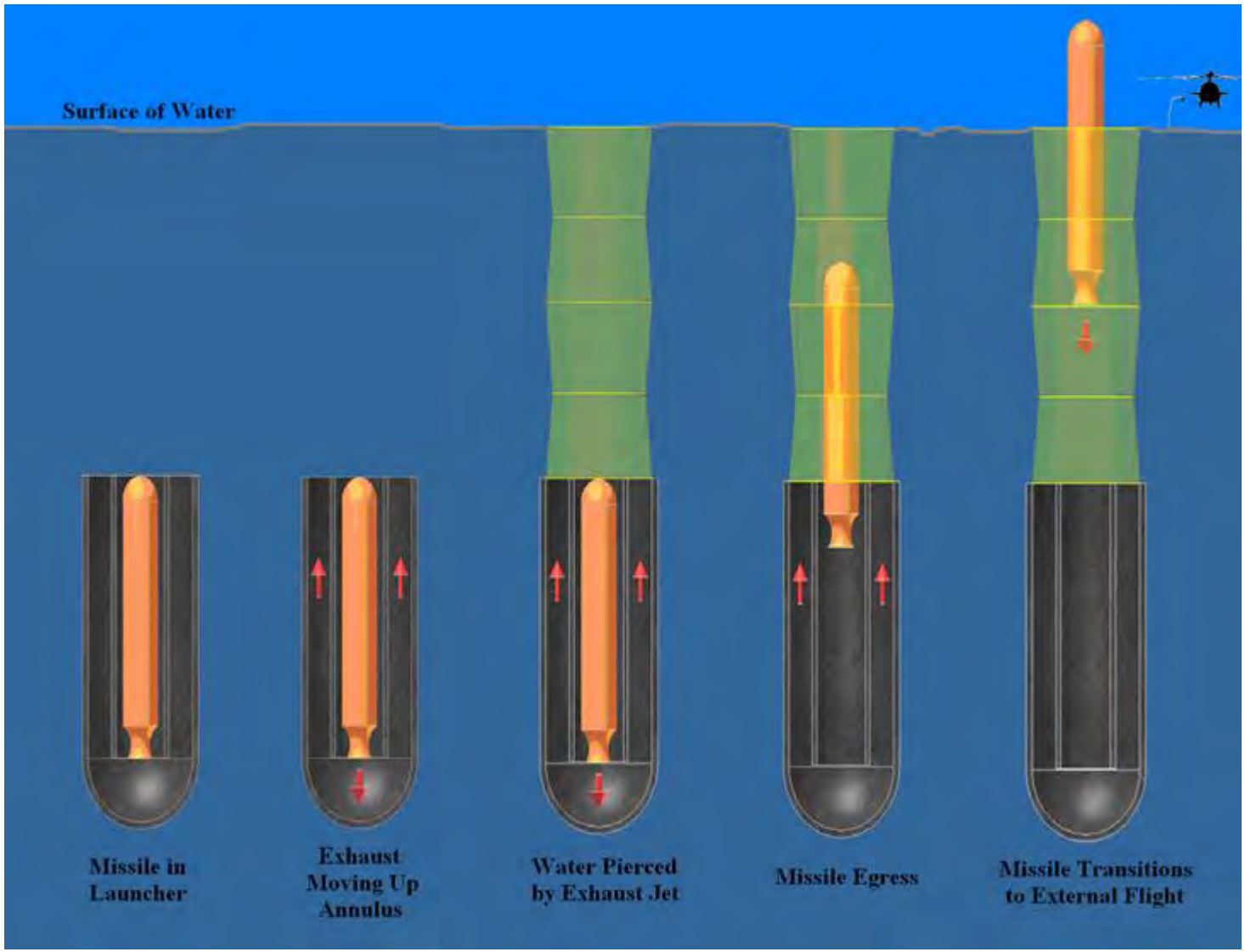
CCL is a "Plug-n-Play" Launch System, Electronically & Mechanically

CFD Computer Result for Flow of Rocket Exhaust through a CCL



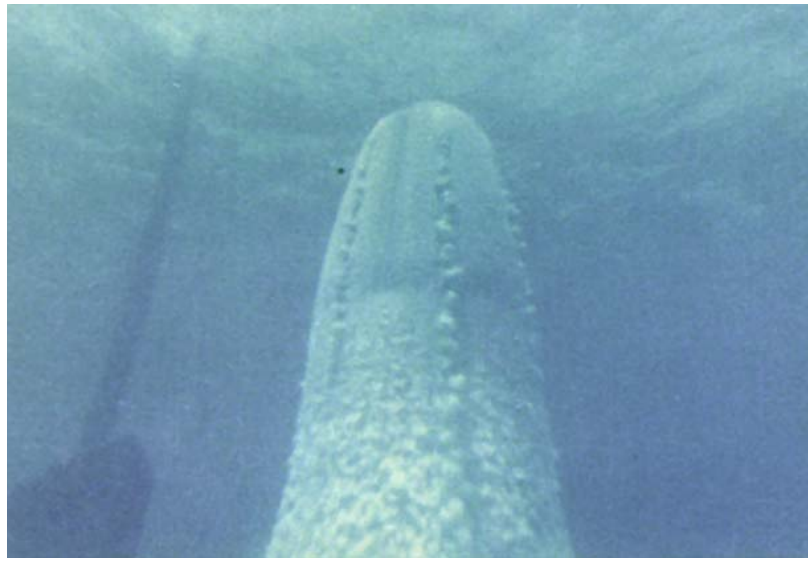
CCL Surface Launch

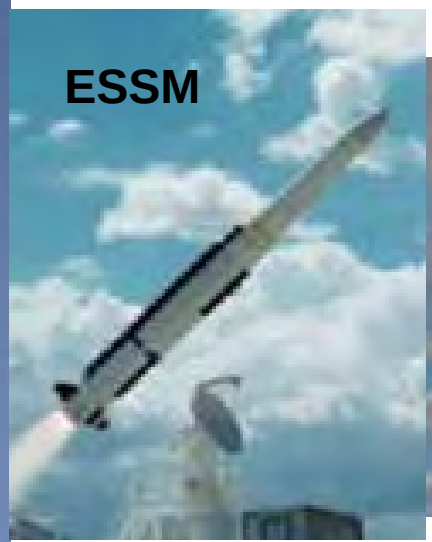
Water Piercing Missile Launcher Concept

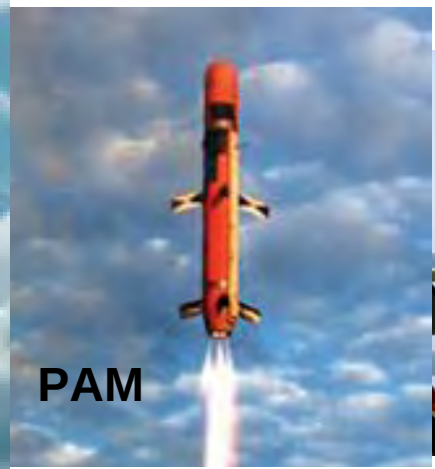


Benefits of WPML Concept

- **Precludes need to pressurize missile for underwater launch**
- **Any existing service missile can be used without modification**







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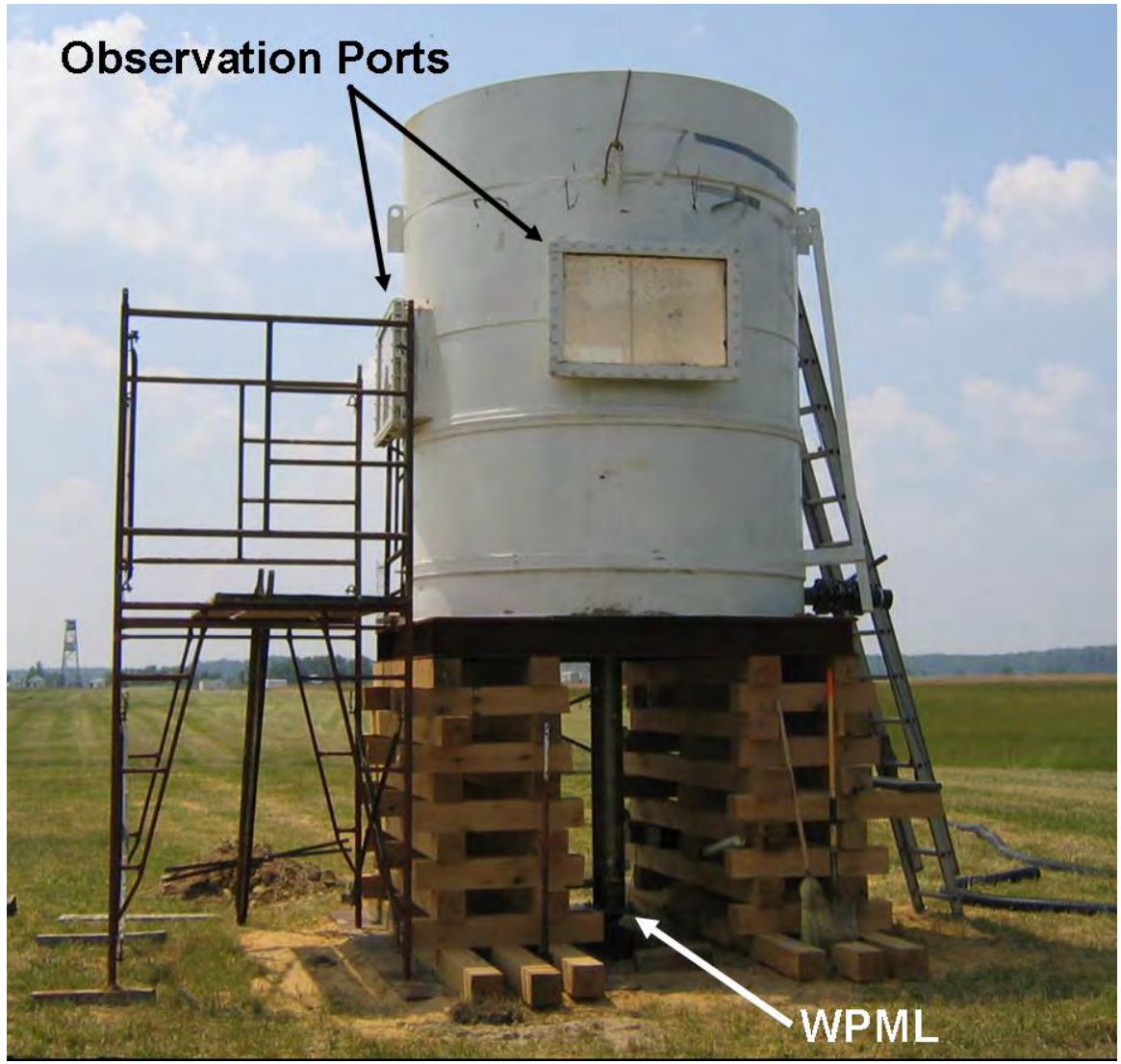
2.75-inch Rocket Motor Tests

- CCLs with 7, 8, and 9” outer diameter
- MK66 (2.75”) rocket motor as the gas source



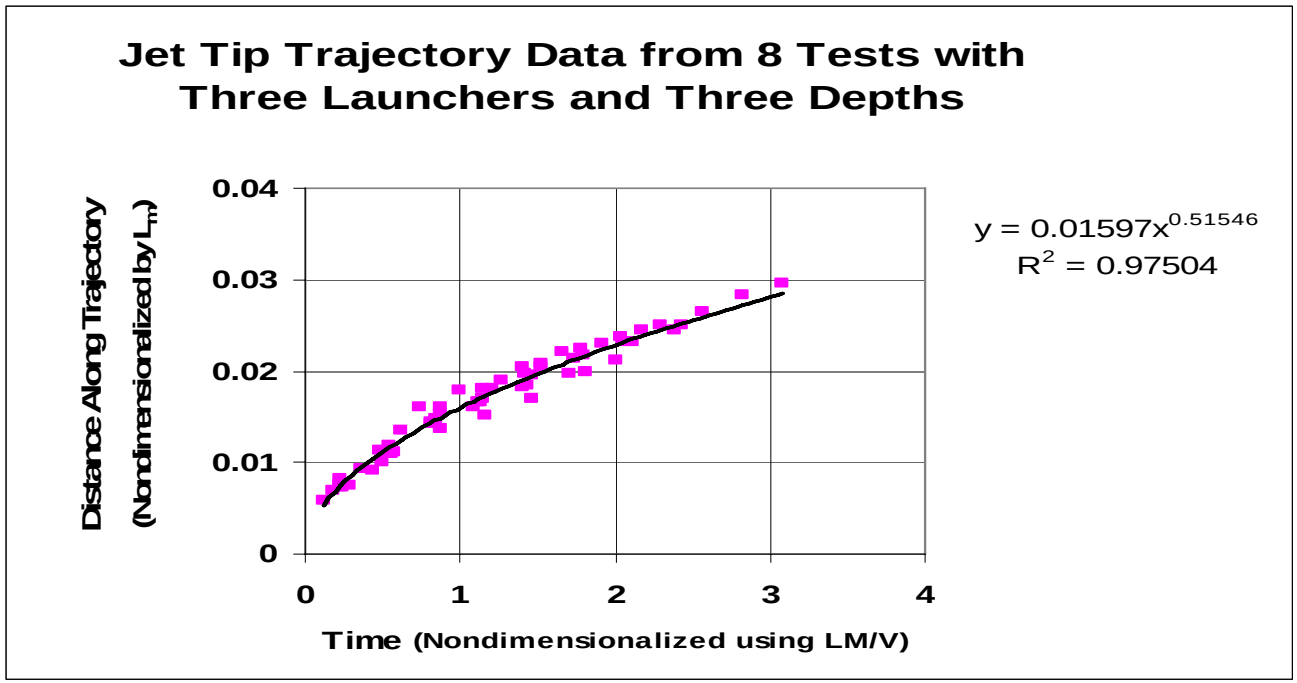
2.75-inch Restrained Rocket Motor Test

2.75-inch Fly-out Experiment

- Modified 5” Navy Hi-Frag Projectile
- Mk66 Provides Thrust

2.75-inch Rocket Motor Flyout Test

Empirical Model for Predicting Jet Tip Trajectory



Formula for trajectory from graph: $y = 0.01597x^{0.5146}$

Let Z be a coordinate along the axis of the launcher starting at the exit plane and ending at the surface of the water,

y (on the graphs above) = Z /Lm

Let t be the time in seconds

x (on the graphs above) = t/(Lm/V)

Substitute this into the equation for the trajectory on the graphs:

$Z/L_m = 0.01597x^{0.5146} = 0.01597(tV/Lm)^{.5146}$

Solve for Z:

$Z=.01597L_m(tV/Lm)^{.5146}$

Final Formula for a Jet Tip Trajectory

$$Z = 0.01597 L_m \left(\frac{tV}{L_m} \right)^{.5146}$$

Z = Jet tip height above the CCL exit

L_m = (Specific momentum flux)$^{3/4}$ / (Specific buoyancy flux)$^{1/2}$, where

Specific momentum flux = Exhaust Area of CCL x Velocity^2 , and

Specific buoyancy flux = g (Volume Flux) (Density of Water-Density of Exhaust)/ (Density of Water), and

Volume Flux = Velocity x Exhaust Area

t = Time in Seconds

V = Exit Velocity

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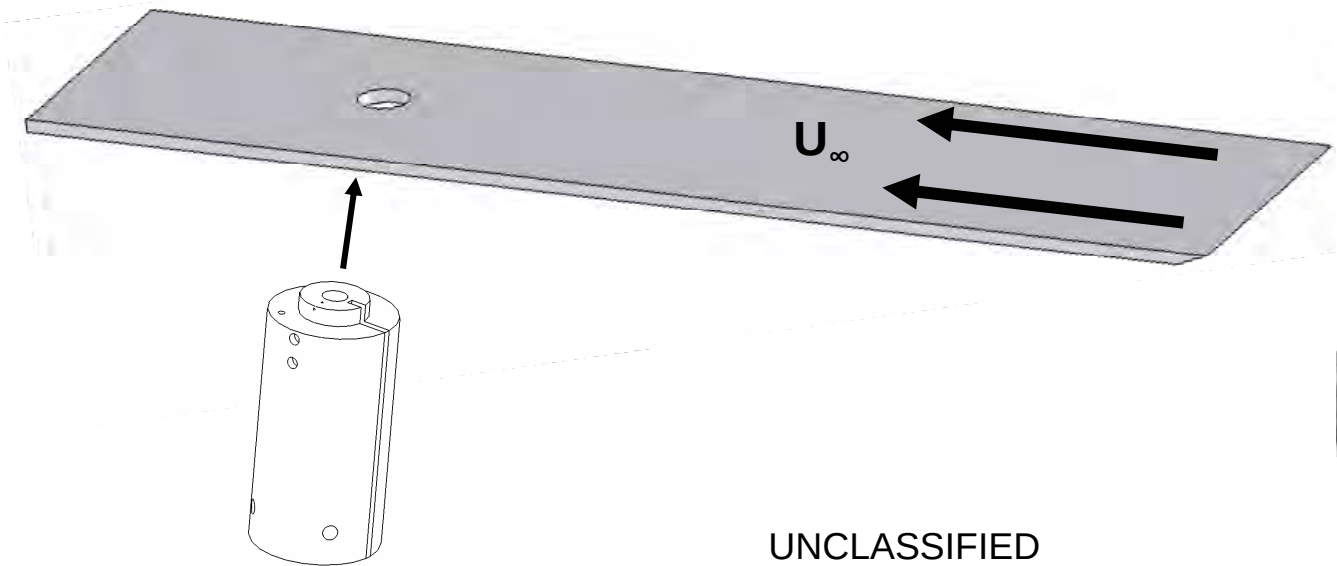
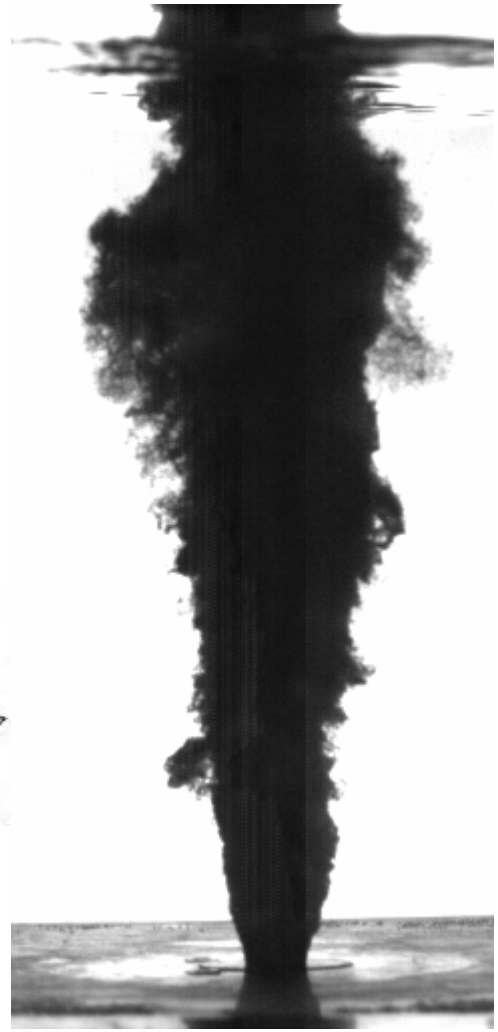
Va Tech Water Tunnel Cross Flow Setup

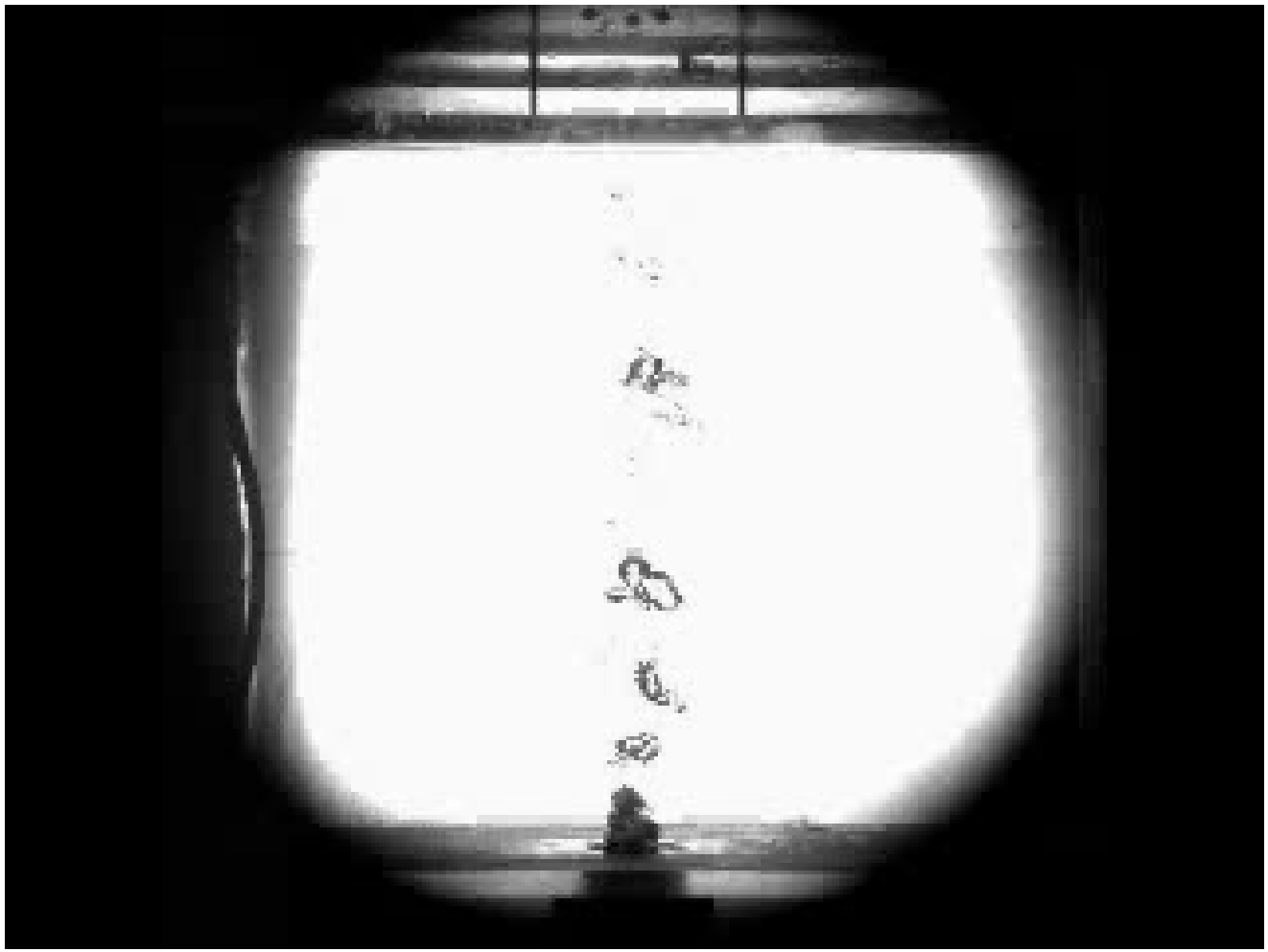
- WPML is flush mounted onto flat plate
- Control of key variables
  - Launcher exit velocity
  - Launch depth
  - Cross flow speed
- Shadowgraph images to record interface position





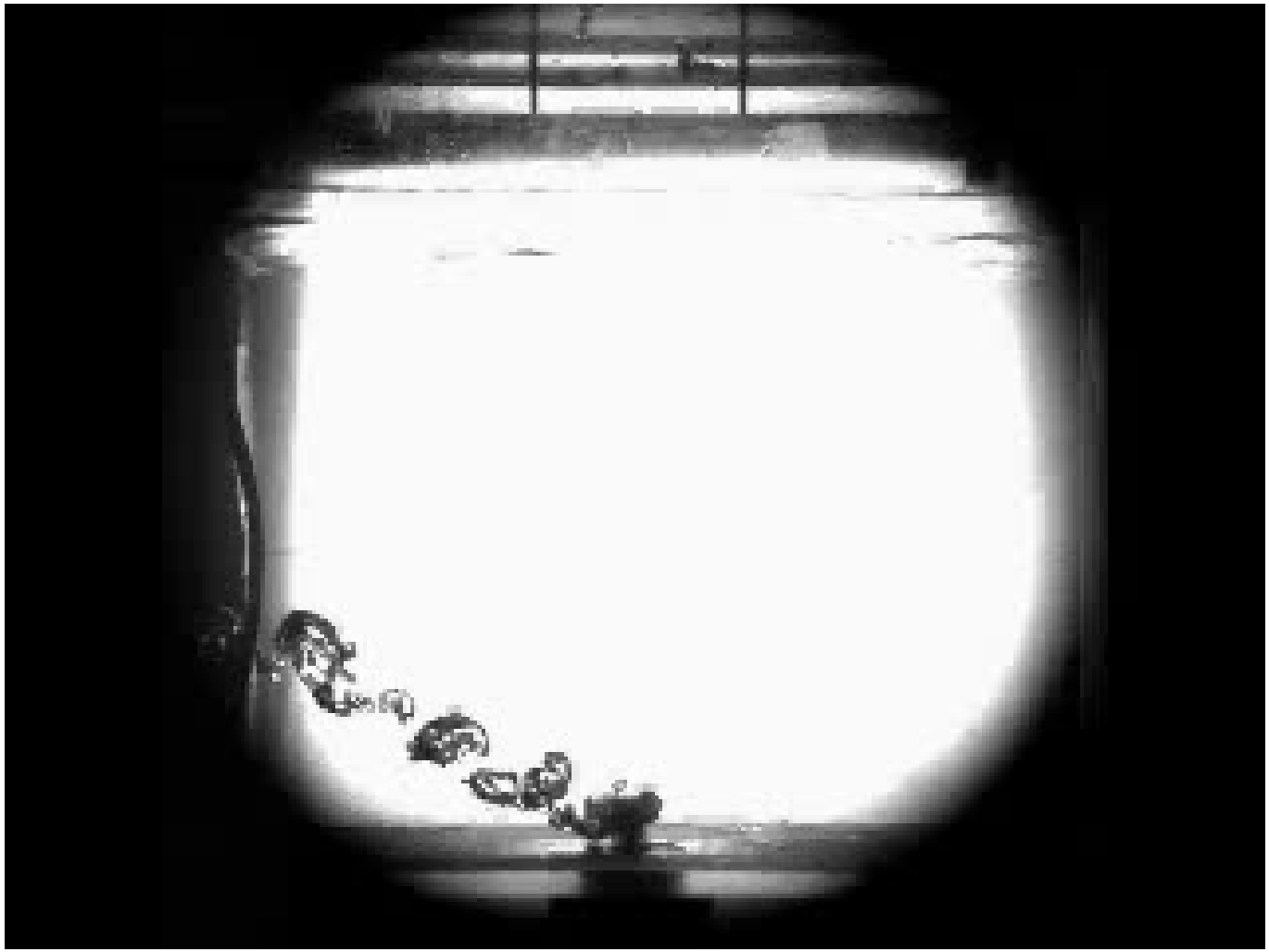
Va Tech Water Tunnel Tests

- Mach # - 2.0
- Cross Flow - 0 knots
- Time to Pierce - 43ms
- Average Jet Velocity – 31 fps



Va Tech Water Tunnel Tests

- Mach # - 2.0
- Cross Flow - 1.36 knots
- Time to Pierce - 48ms
- Average Jet Velocity – 28 fps



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Restrained Rocket Motor Test Series Objective

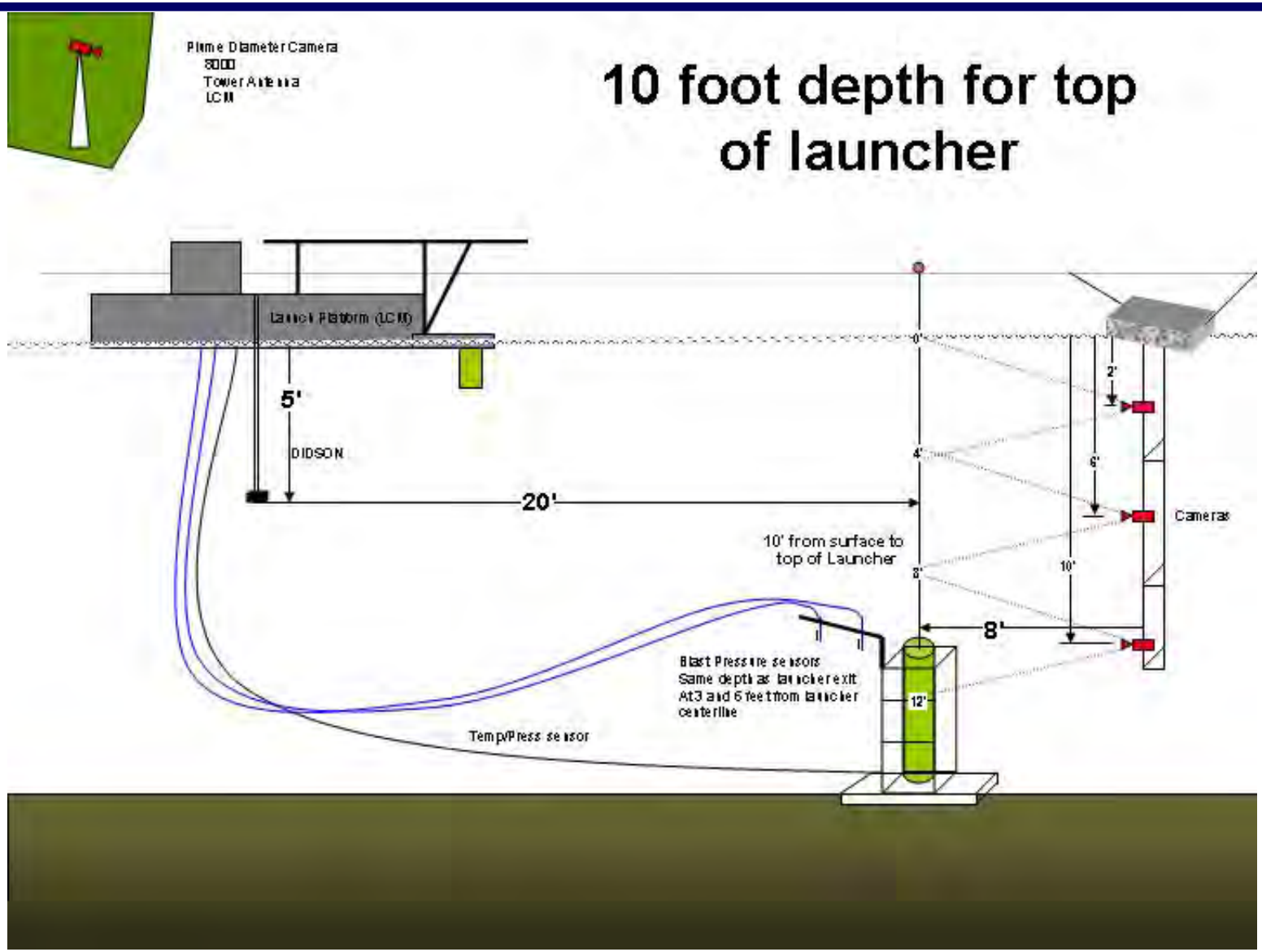
Objective: Determine the water piercing capability of two different 5-inch diameter rocket motors through restrained firing tests at depths from 10-40 feet

Results will be used to update CFD models and scaling laws

5-Inch Rocket Motors

Rocket Motor	Average Thrust (lbf)	Average Pressure (psi)	Burn Time (Seconds)	Nozzle Throat Area (square in)	Avg. Mass Flow Rate (lbm/s)
JATO	2595	1634	1.35	1.09	12.65
ZUNI	5659	1430	1.53	2.92	24.95

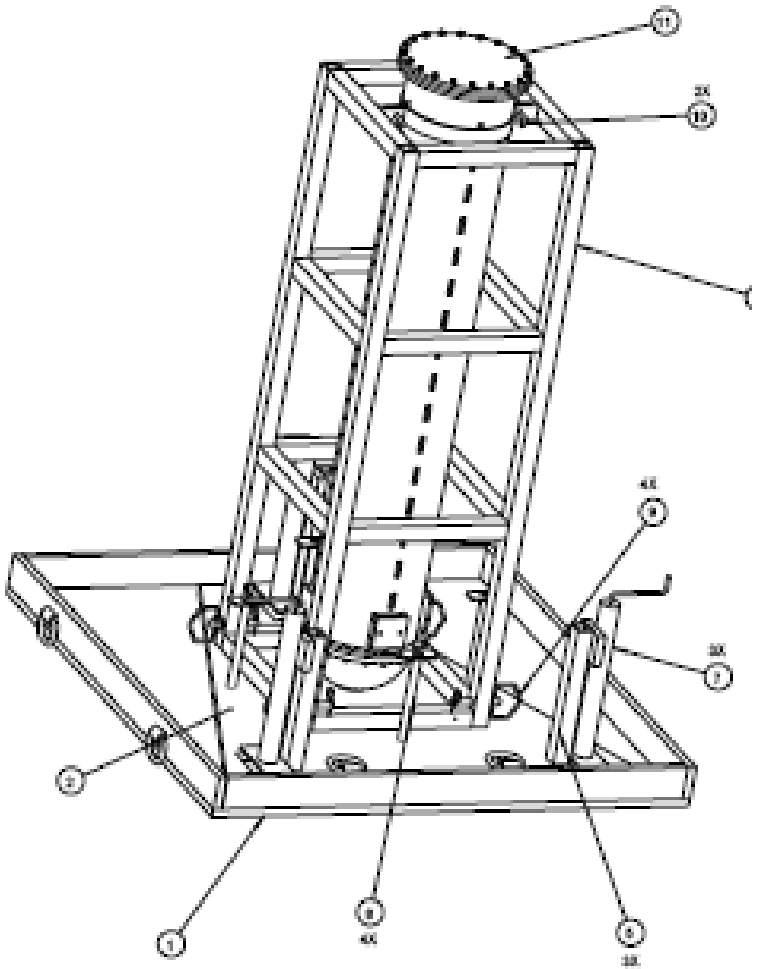
Typical Test Setup

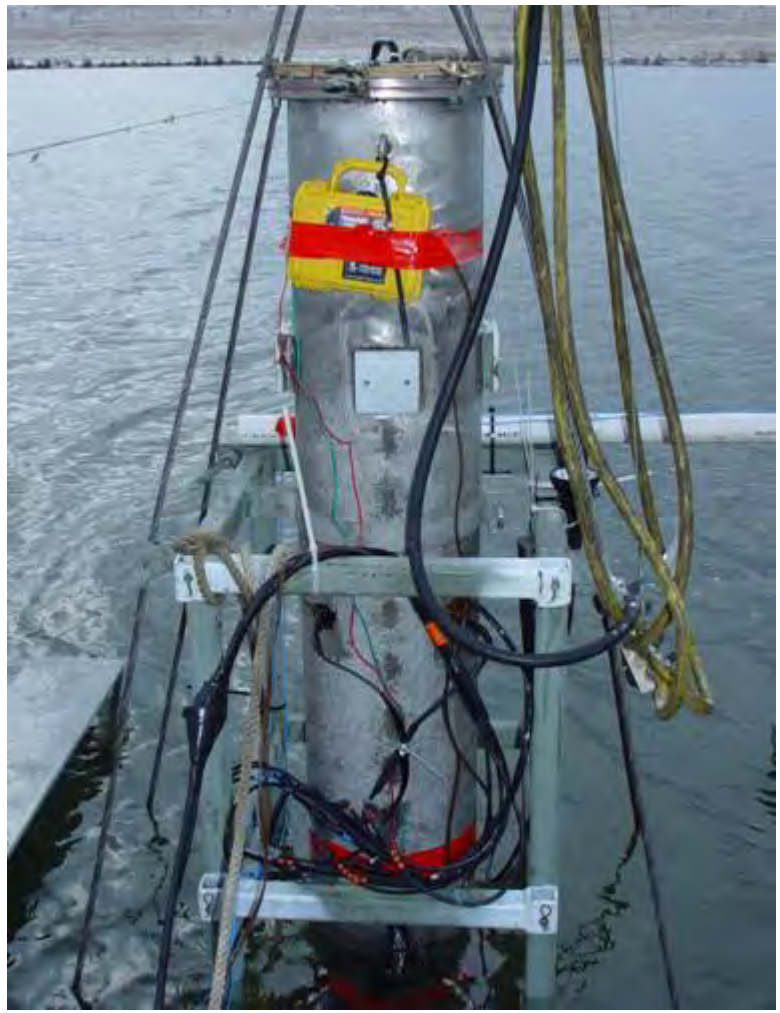


5-Inch Rocket Motor Launchers

Test Hardware Readiness Supporting Test Fixtures

Launcher Cage Platform



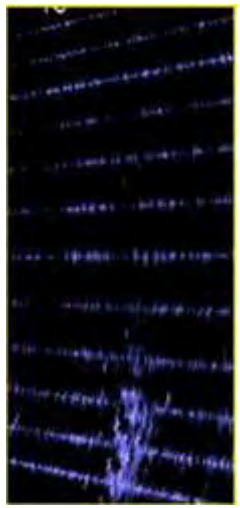


5-inch Rocket Tests Conducted

Test #	Rocket Motor	Depth (ft)	Pierce? (Y/N)
1	JATO	10	Y
2	JATO	20	Y
3	Zuni	20	Y
4	JATO	27	Y
5	Zuni	32	Y
6	JATO	42	N
7	Zuni	40	Y?
8	JATO w/ Plug Nozzle	40	N
9	Zuni	40	Y
10	Zuni w/ Plug Nozzle	40	Y

Test Results – Zuni at 32 feet Above Water Camera – High Speed

Test Results – Zuni at 32 feet DIDSON Acoustic Camera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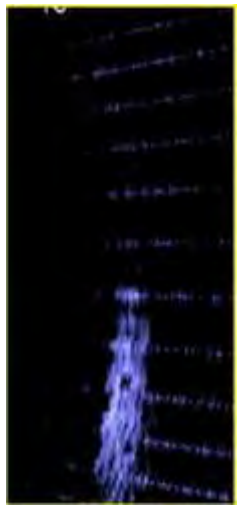
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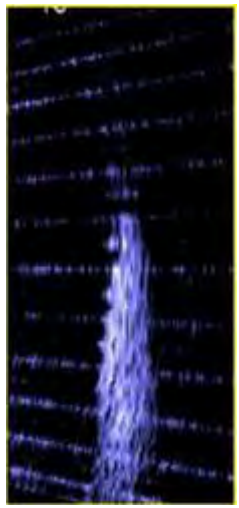
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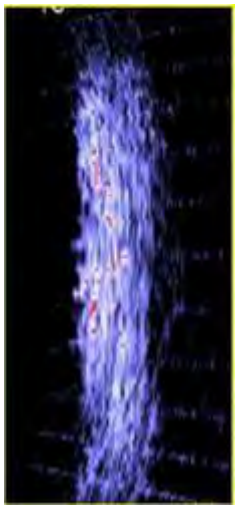
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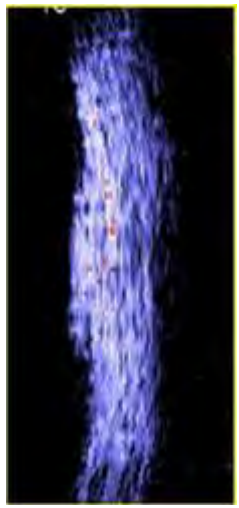
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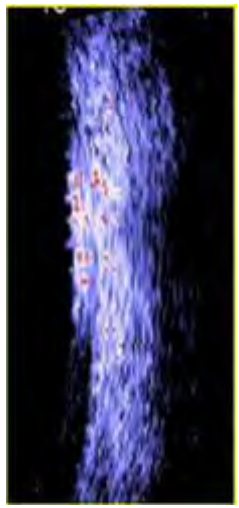
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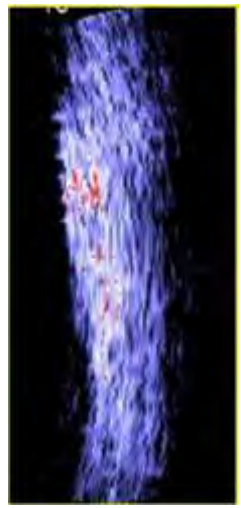
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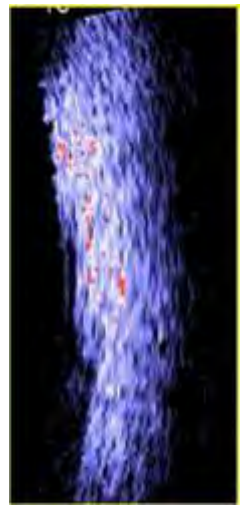
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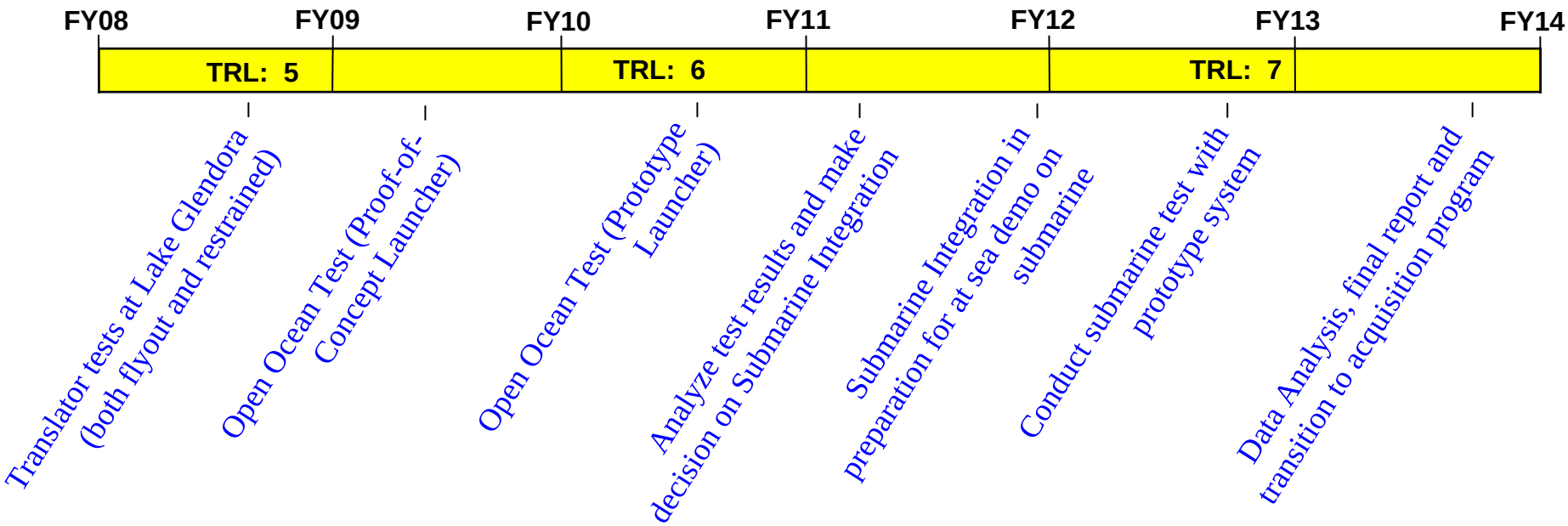
Test Results – JATO at 42 feet Above Water Camera – High Speed

Static Flyout Test – 9/25/07
20 foot depth – JATO Motor

Static Flyout Test – 9/25/07
20 foot depth – JATO Motor

Future Program Plan

- FY08 Translator Tests at NSWC Crane
- FY09, FY10 Open Ocean Fly Out Tests w/Target
- FY11 Data Analysis, Decision on Submarine Integration
- FY12,13 Submarine Test with Prototype System
- FY14 Data Analysis, Transition to Acquisition Program



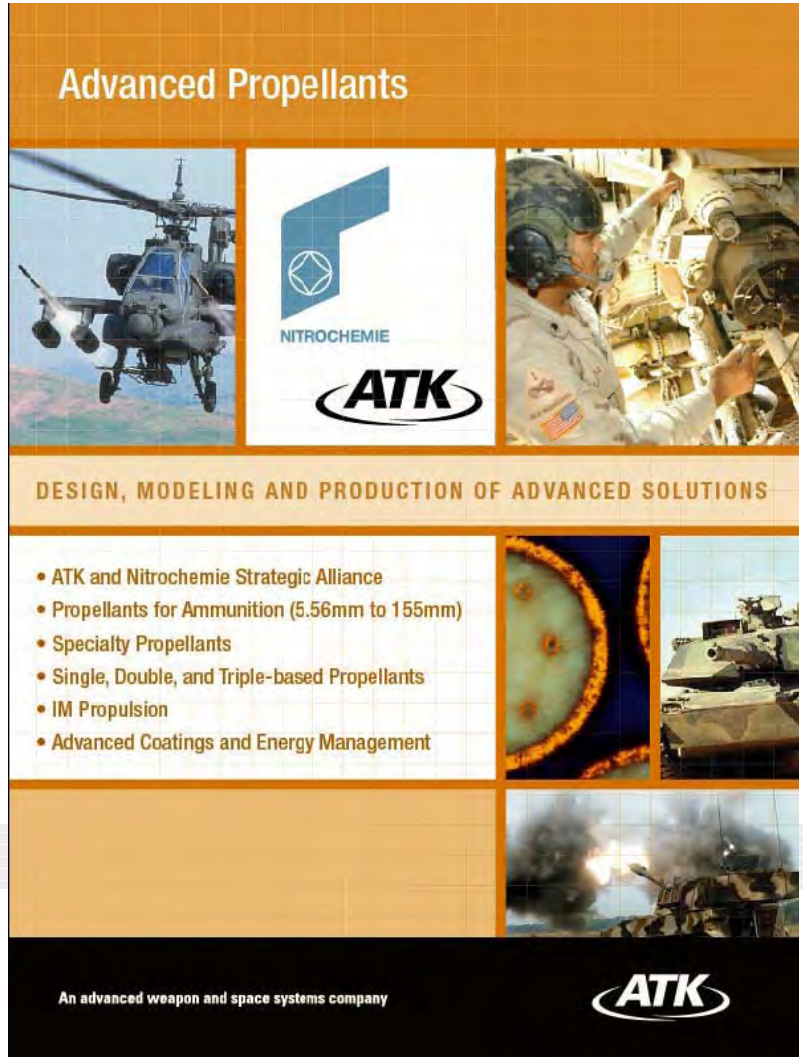
Summary

- Tests and analysis have shown that the WPML concept is valid

- Continuing to Execute Program Plan
  - FY08 Translator Tests at Lake Glendora
  - FY10 Relevant Environment Test (Underwater Rail at San Clemente Island)

Questions?

Enhanced Ammunition Performance with ECL® Technology



NDIA Conference
Gun and Missile Systems
April 21 - 24, 2008

Authored by:
Bishara Elmasri, ARDEC
Howard Shimm, ARDEC
Kelly Moran, ATK
Beat Vogelsanger, Nitrochemie

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Contents

- Introduction – Why Choose ECL Propellant?
- Results
  - 30 mm APFSDS-T Mk258
  - LW 30 mm M788 TP
- Conclusions

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Evolution of Small / Medium Caliber and Mortar Propellants

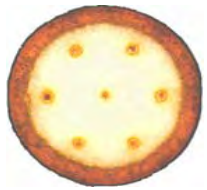
Single Base
Since 1885
Force: 950 J/g
T_{ex}: 2'500 K

- Limited performance potential; still suitable for:
  - Many small caliber applications (7.62mm, 12.7mm)
  - conventional medium calibre applications

Common Technology

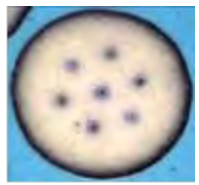
Nitrochemie Technology

EI® Extruded-Impregnated
Since 1990
Force: 1020 J/g
T_{ex}: 3'000 K



- Significantly improved performance !
  - High performance small caliber (5.56mm)
  - Medium caliber with KE projectiles
  - Mortar charges (solves migration problem, better precision)

ECL®
Since 2006
Force: 1050 J/g
T_{ex}: 2'850 K



- Further improved performance !
- Nitroglycerine-free
  - Highest performance medium caliber applications (e.g. KE and airburst projectiles)
  - Special mortar applications

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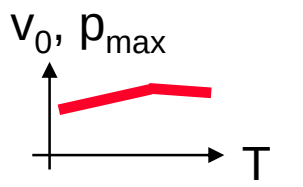
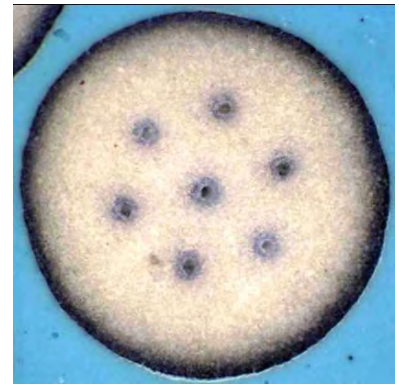
What are the Advantages of ECL® ?

Advantages of ECL® propellants, in comparison to nitroglycerine-containing propellants, are:

- **Equal or higher ballistic performance due to:**
  - **very high thermal efficiency (up to 10% higher)**
  - **very flat, tunable temperature characteristics**
  - **reduced and uniform ignition delay**
- **Lower erosivity due to lower flame temperature**
- **IM-improved; increased cook-off resistance**
- **NG-free / non-toxic "green" formulation**
- **No problems with nitroglycerine migration**
- **At least 3 times longer service life in A1 climatic zones due to:**
  - **much better chemical stability**
  - **much better ballistic stability**
  - **much better compatibility**





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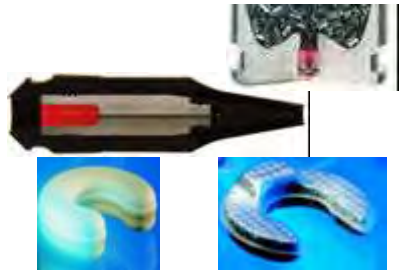
Shelf life of ECL® is increased by at least factor 3 compared to nitroglycerine-containing propellants !



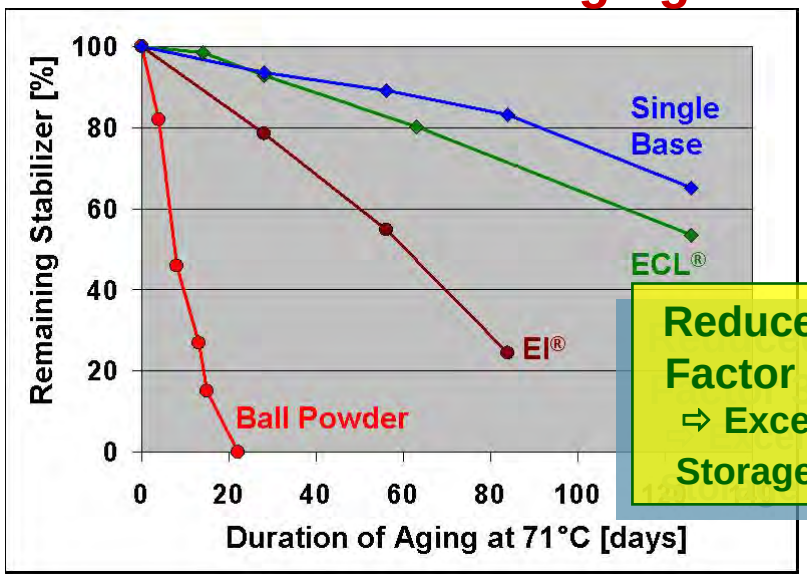
Chemical Incompatibility

Reduced by Factor 10
⇨ No Incompatibility Problems

Migration of NG / plasticizers

Reduced by Factor > 10
⇨ No Problems with Mobile Plasticizers

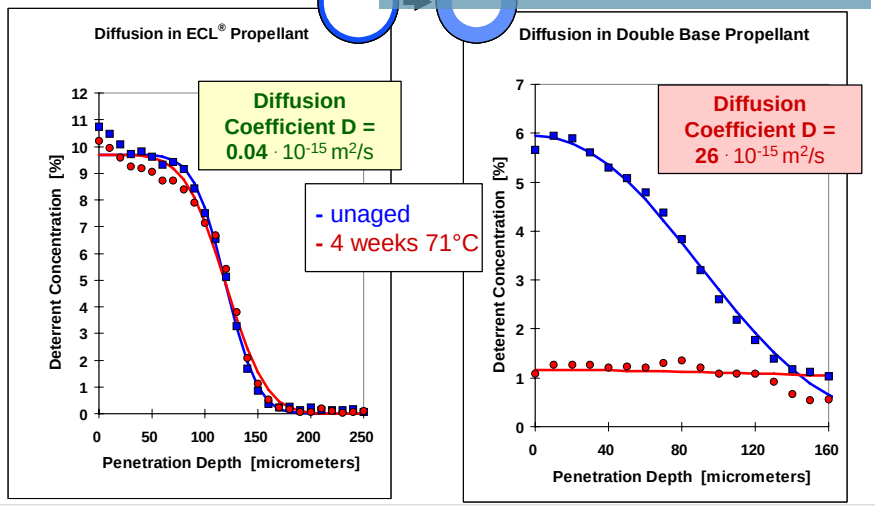
Chemical Aging



Reduced by Factor 3 – 4
⇨ Excellent Storage Life

Diffusion of Deterrents

Reduced by Factor 10 to 100
⇨ Excellent Ballistic Life



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Current US Medium Caliber Applications Investigating Use of ECL® Technology

- 30 mm APFSDS-T Mk 258

- 20mm ELC Phalanx

- 30mm ABM

- 30mm Ballistic Match (PGU 13/14)

- 50mm EAPS

- M789 LW 30mm HEDP

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US DoD Non-NG Propellant Contract

30 mm APFSDS-T Mk 258

30 mm Medium Cal Program

System:

30 mm APFSDS-T Mk 258

Contract:

DAAB07-03-D-B011 (from 2006)

Goals of Feasibility Study:

- ⇨ NG-free Propellant ☑ **(ECL is NG-free)**
- ⇨ Performance Enhancement ☑ **(+20 m/s; better penetration)**
- ⇨ IM Improvement ☑ **(slightly milder reaction; much longer time to cook-off)**

The ECL® propellant has been demonstrated for use in the Mk258 with good results but has NOT been qualified by the Army or DoD for use in the Mk258

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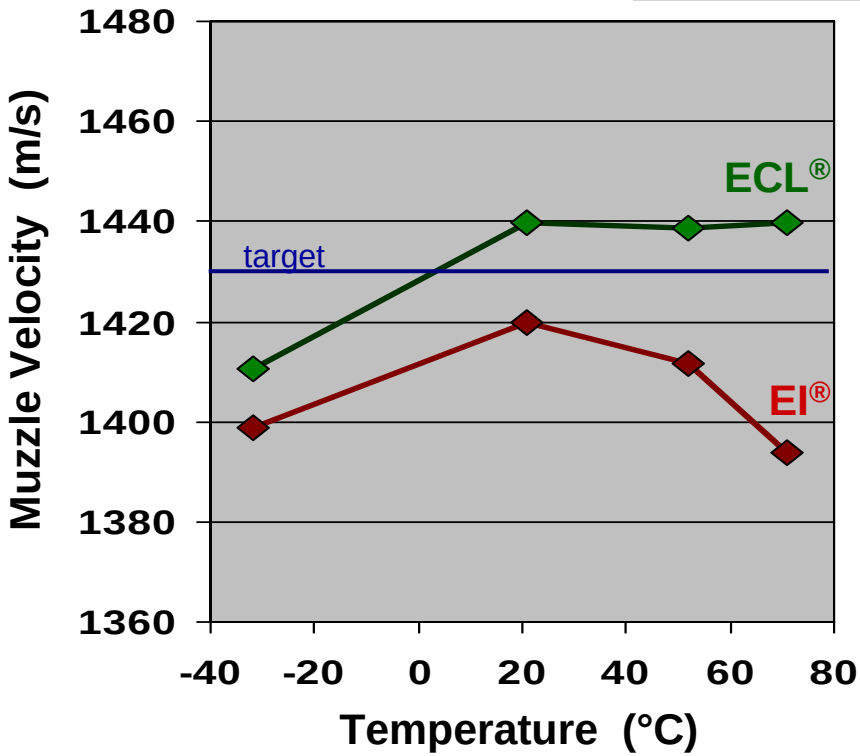
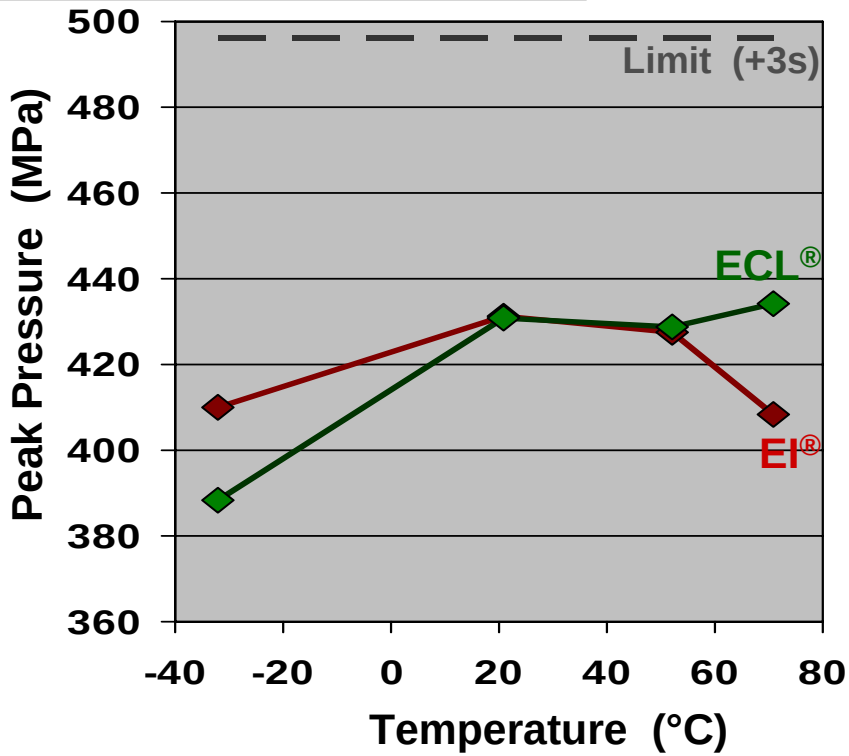
US DoD Non-NG Propellant Contract

30 mm APFSDS-T Mk 258 – Ballistic Performance

Tests performed by: Nammo NORDIC AMMUNITION COMPANY

30 mm APFSDS-T, m_p = 231g; Bushmaster II Gun





- ECL® achieves 20 m/s higher muzzle velocity than EI® at same pressure level
- Flat temperature coefficient, especially at warm / all requirements are fulfilled

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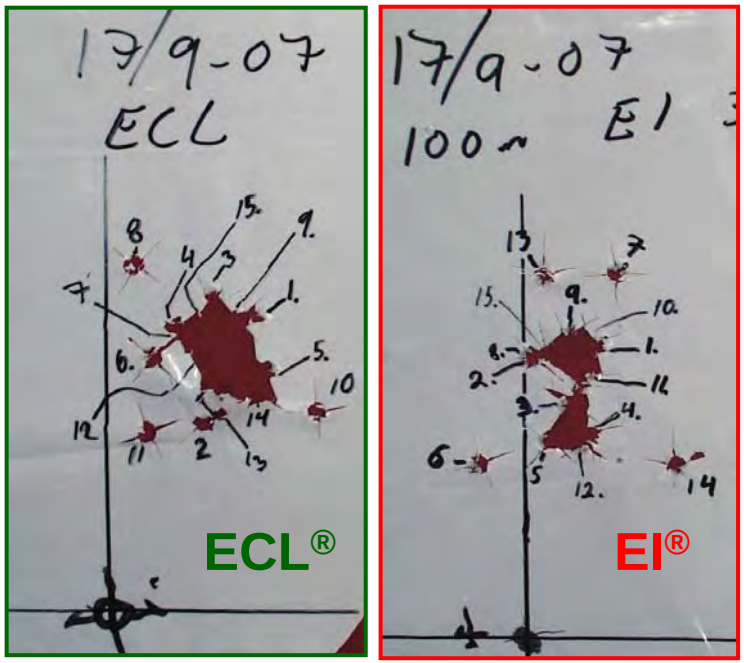
US DoD Non-NG Propellant Contract

30 mm APFSDS-T Mk 258 – Dispersion and Penetration



Tests performed by:
Nammo
NORDIC AMMUNITION COMPANY

US Spec. IAW WS 33595

⇨ Dispersion of ECL® and baseline EI® propellants are comparable and well within limits

⇨ Baseline EI® propellant: Projectile penetrates target at 100% and 120%, but not at 140% of specification

⇨ ECL®: Projectile penetrates target at 100%, 120%, and 140% of specification → 20% more distance !

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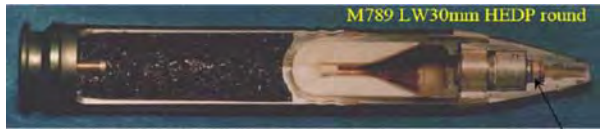
Medium Caliber Propellants for US Programs / Ammunitions

Improved LW30 Propulsion System



- **Actual M789 LW30mm HEDP (Light Weight / High Explosive Dual Purpose) cartridges for APACHE helicopter have caused serious problems:** (Source: J. Hirlinger; ARDEC; 42nd Armament Conference; Charlotte, NC; 2007)
  - **Hangfire:** Interior ballistics delayed; weapon systems destroyed
  - **Inbore detonation:** Premature initiation in the barrel; barrel destroyed

- **Hangfire signature duplicated with WC855 Ball® Powder that had been subjected to 71°C for 33 days**
  - **WC855 Ball® Powder exhibits chemical and ballistic degradation after hot temperature storage – Pressures in excess of 480 MPa when shot at ambient.**
  - **Propellant gases vented from the chamber area can damage the operating system and receiver.**
  - **Damage created in testing similar to that seen in HE-Inbore events, except no barrel bulge and generally no Blast Suppressor damage.**

ECL® propellant is excellently suited to solve these problems. ECL ® propellant combines high interior ballistic performance with excellent chemical and ballistic stability

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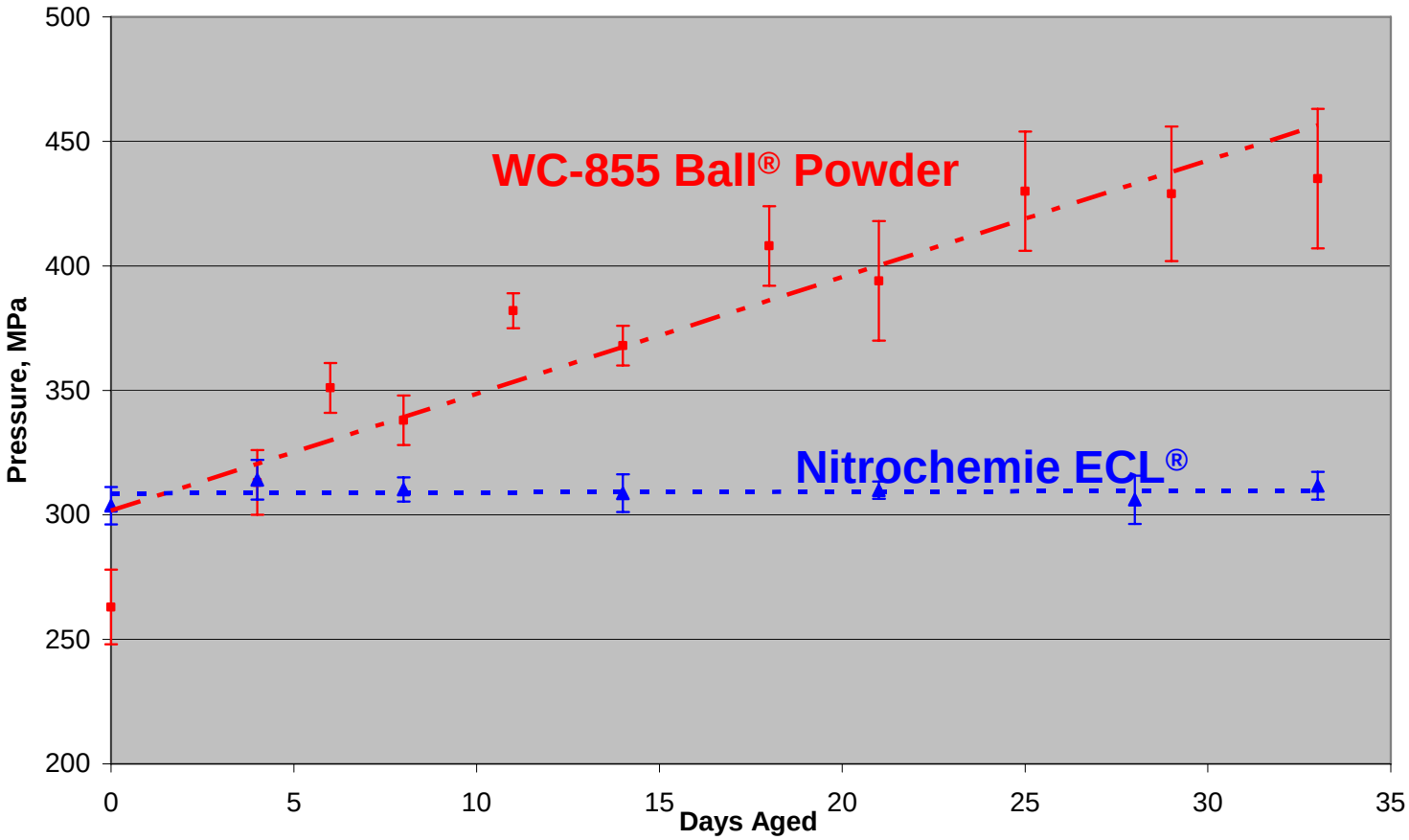
ECL® for LW30mm – Consistent Ballistics After Hot Storage

M788 Ball Powder and Nitrochemie ECL Propellant Aged at 71°C for 33 Days
Test Vehicle LW30 M788



⇨ **Increase of peak pressure by 50% (or 150 MPa) with WC855 Ball® Powder**

⇨ **No change of peak pressure with ECL® propellant after 33 days at 71°C**

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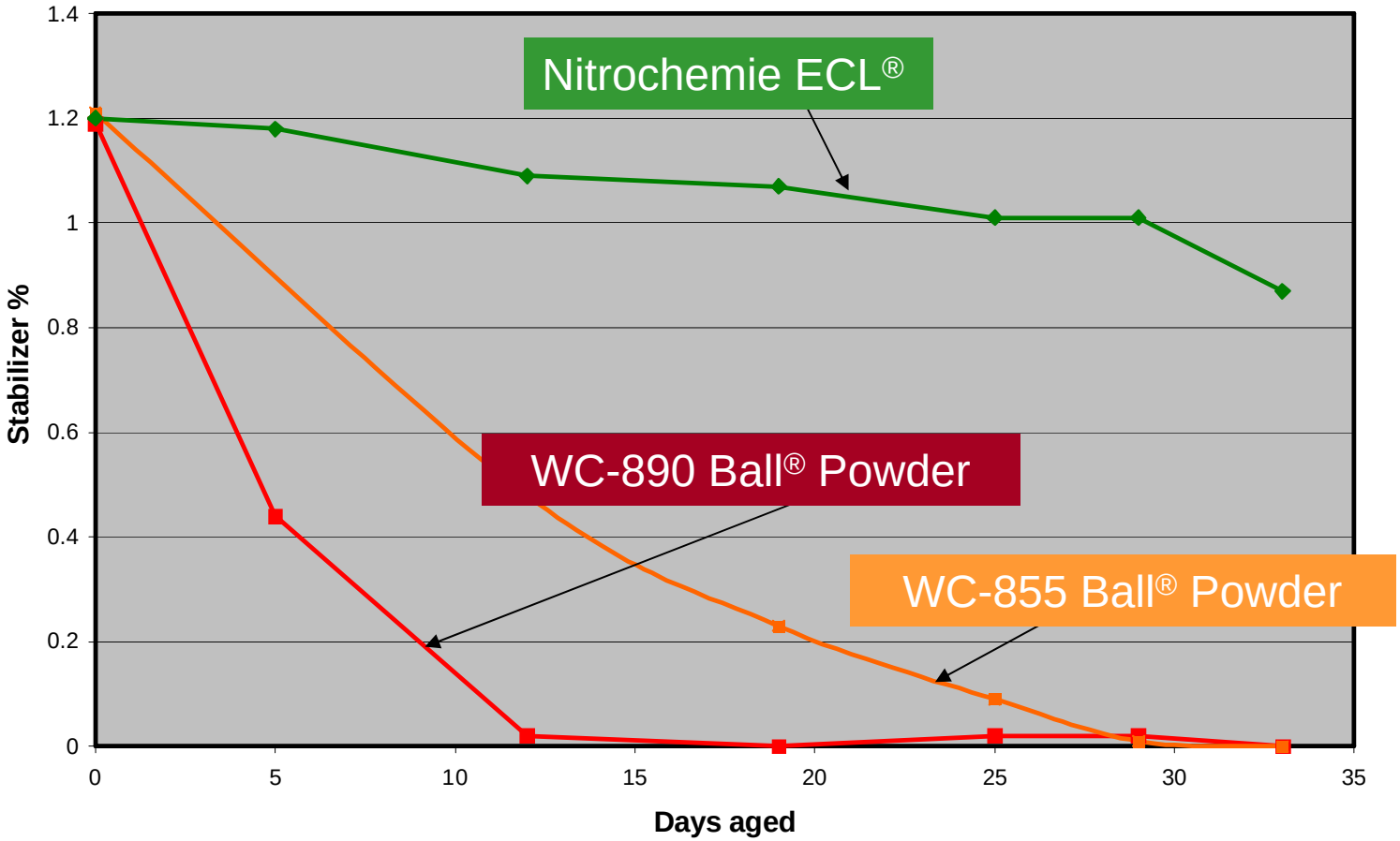
ECL® for LW30mm – Exhibits Superior Chemical Stability

Stabilizer Depletion Vs. Time After Aging at 71°C



⇨ 100% of primary stabilizer, DPA, depleted in Ball® samples after 33 days at 71°C

⇨ ECL® shows only 25% depletion of Akardite-2 after 33 days at 71°C

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Summary and Conclusions

ECL® propellant are state-of-the-art formulations with superior performance characteristics:

- **Improved ballistic performance – high thermal efficiency**
- **Flat, tunable temperature characteristics**
- **No carcinogenic ingredients**
- **Improved IM properties**

ECL® propellants demonstrate superior chemical and ballistic stability when compared to single base, double base and EI propellant formulations.

SERVICE LIFE OF AMMO EXTENDED BY FACTOR OF 3

IMPROVED SAFETY FOR THE WARFIGHTER

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Acknowledgements

- **Co-workers at ARDEC, Picatinny Arsenal**
  - **Bishara Elmasri, Howard Shimm and John Hirlinger**
- **Co-workers at Nitrochemie Wimmis AG**
  - **Ulrich Schädeli, Dominik Antenen, Kurt Ryf and Heinz Jaskolka**
- **Co-workers at ATK Radford Plant**
  - **Steve Ritchie, Jim Wedwick, Randy O'Brien and Amy Morris**
- **Audience: For your Attention**

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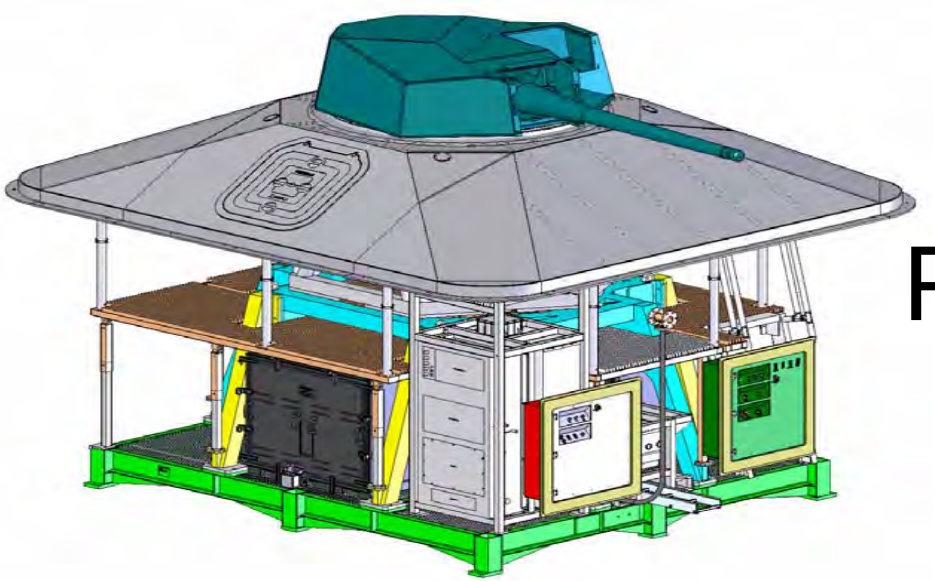

Safety Process For Navy Gun and Ammunition Systems

- Eileen McConkie
  eileen.mcconkie@navy.mil
  - **Naval Surface Warfare Center Dahlgren Division**
- **Dennis Bushor**
  - **Naval Surface Warfare Center Dahlgren Division**
- **John Filo**
  - **Naval Surface Warfare Center Dahlgren Division**

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Agenda

- Purpose
- Policies
- Define Safety
- Gun System Safety Process
  - Hardware
  - Software
- Ammunition Safety
- Hazards
  - Identification
  - Mitigation
  - Risk Acceptance
- Independent Review
- Summary

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Purpose

- Identify safety processes involved in the qualification of all gun systems and their associated ammunition for U.S. Navy
  - Gun System
    - Gun Mount (GM)
    - Fire Control System (FCS)
    - Associated Systems
  - Ammunition Safety
    - Fuze
    - Energetic
    - Transportation and Storage

System Safety Program Plan Developed for all Gun and Ammunition Systems

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Safety Process

- All Gun Systems and Ammunition Need to go Through a Rigorous Safety Process Before Deployment
  - Gun Systems for Navy Platforms
    - New Development
    - Previously Developed Systems
  - New Ammunition for New or Existing Gun Systems
  - Updates/Upgrades to Deployed Systems
  - Deployment of Existing Gun Systems on New Platforms

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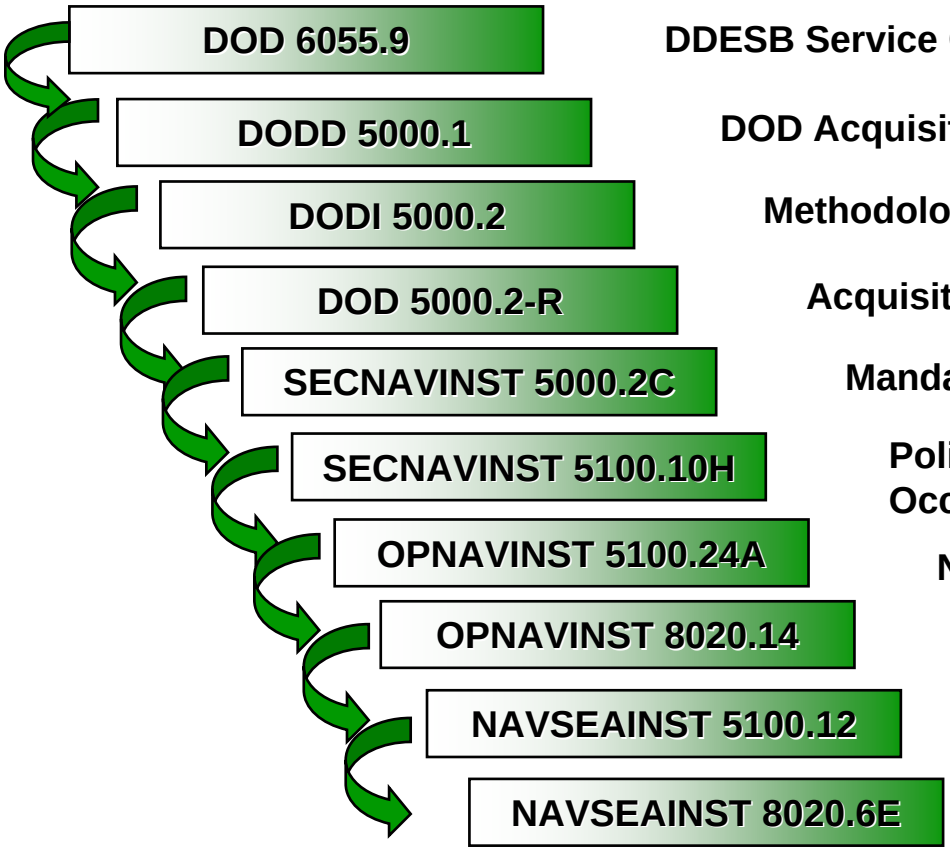
Government and Navy Safety Policy



DDESB Service Component Explosives Safety Oversight

DOD Acquisition Process

Methodology for Implementing 5000.1

Acquisition Procedures Guidebook

Mandatory Procedures for Implementation

Policy for Safety, Mishap Prevention, Occupational Health, and Fire Prevention

Navy System Safety Program

Explosives Safety Policy

Requirements for System Safety Program

Department of the Navy Weapon Systems Explosives Safety Review Board

Implementation of Government Safety Policies Ensures Safety of System Onboard Ship

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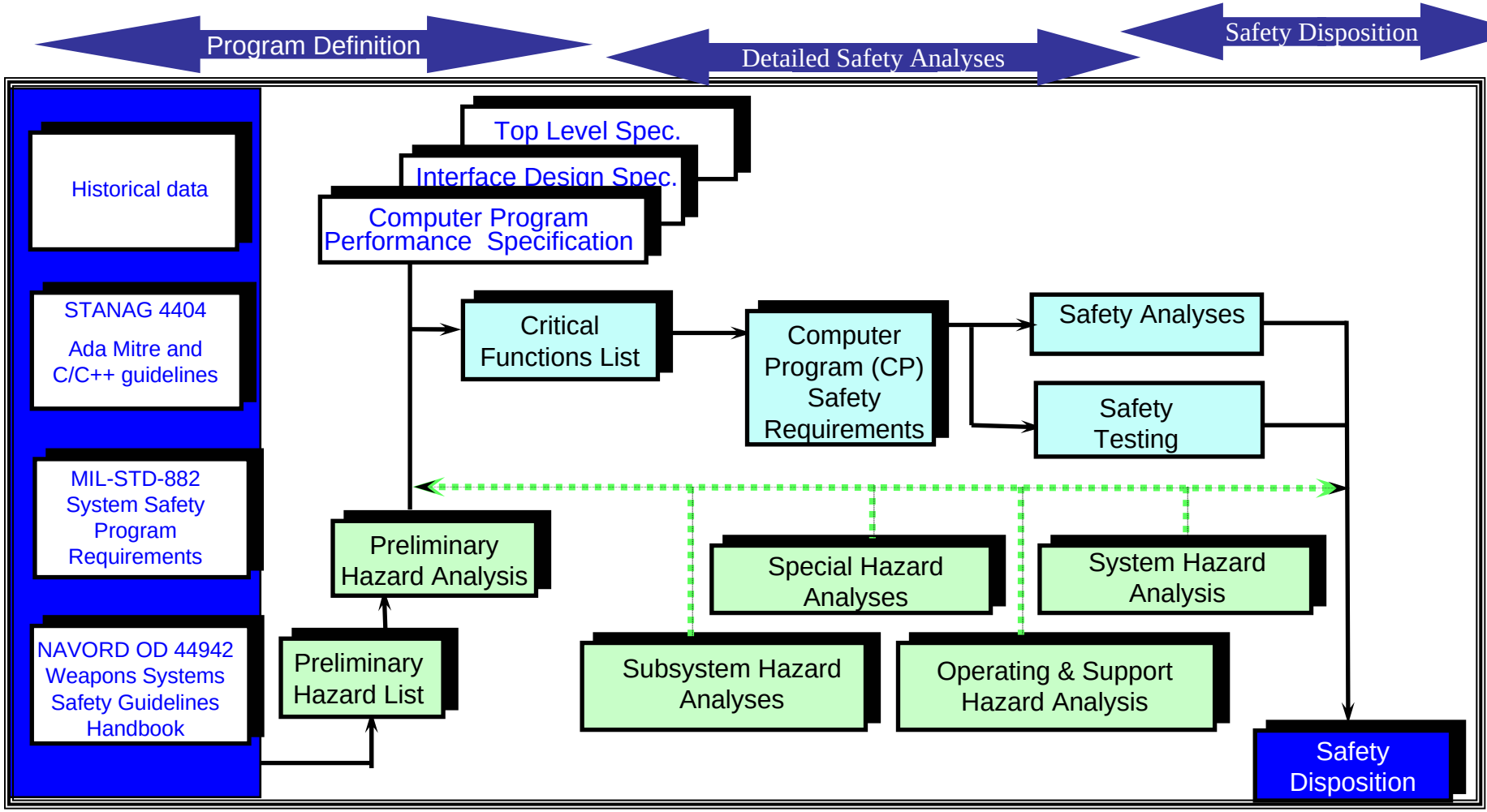
System Safety Defined

- What exactly IS a System Safety Issue?
  - –A situation in which own-platform, own-platform personnel, or friendly assets are at risk from onboard equipment / systems.
    - Personnel
    - Own-Ship Damage
    - Friendly Asset
    - Environment
- What exactly IS NOT a System Safety Issue?
  - –Operational Effectiveness and Survivability Issues
    - Operational Effectiveness
    - Survivability

Gun System Safety Analysis Process



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Gun System Hardware Safety

- Apply General Guidelines for Electronic Equipment *(MIL-HDBK-454)*.
- Inspect hardware for validation of hardware safety requirements (regardless of design phase).
- Analyze equipment motion
- Identify sources of radiated energy

System Control Software Safety

Main emphasis of gun system safety.

- Analyze Software IAW NATO Standardization Agreement (STANAG) 4404.
- Apply lessons learned from previous like systems.
- Adhere to C++ safety coding guidelines
- Address Safety Concerns with
  - Java
  - Operating System
  - Middleware
  - Firmware
  - Development tools
- Analyze test environment
- Determine the Level of Rigor of Software testing

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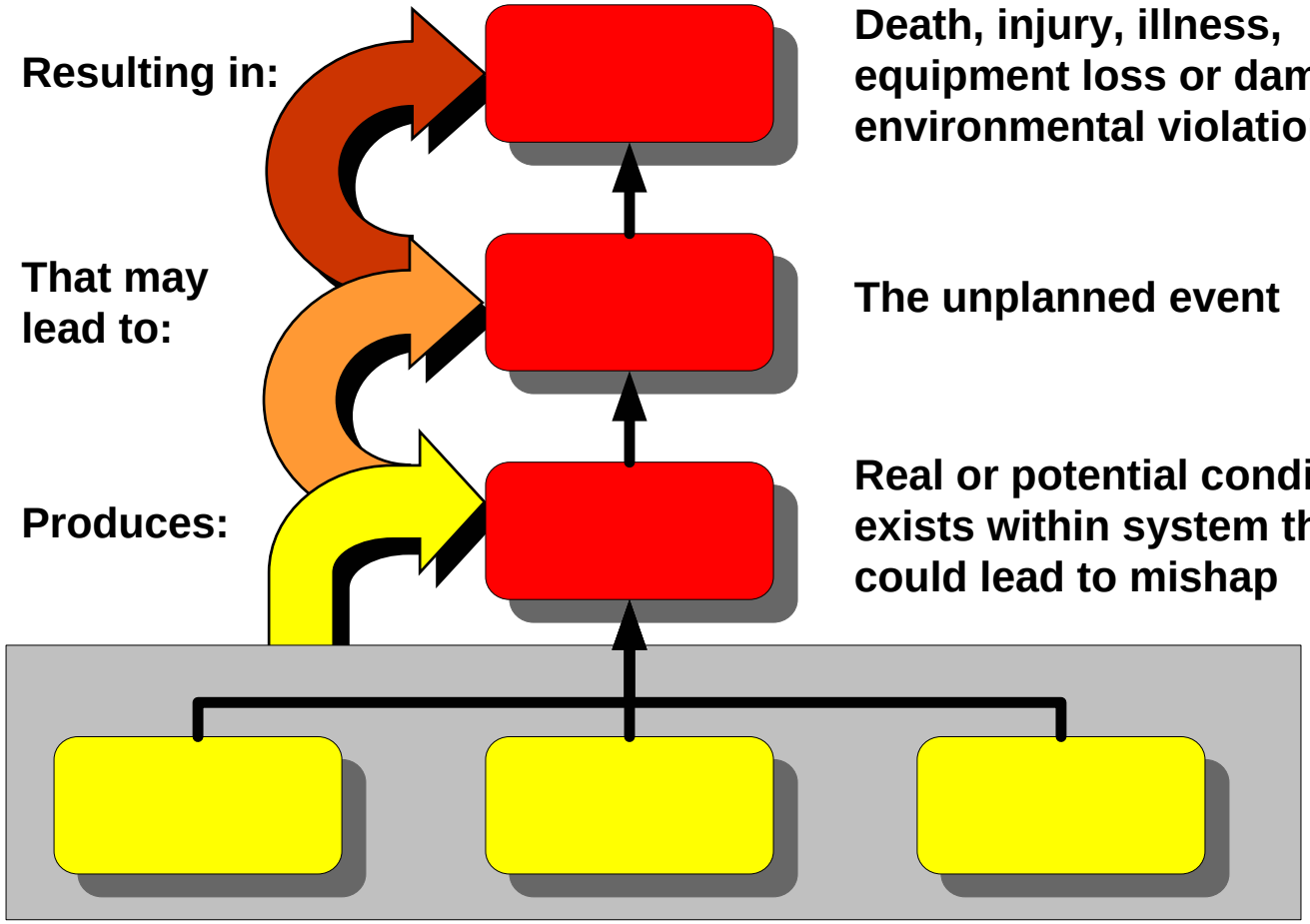
Ammunition Safety

- Design to Proven Standards
  - Fuze design *MIL-STD-1316*
  - Electronic Safe & Arm Device (ESAD) *WSESRB TM*
  - Ignition Design *MIL-STD-1901*
  - Initiator *MIL-DTL-23659*
- Ensure that the Energetic Compounds are Stable
  - *NAVSEAINST 8020.5* and *STANAG 4170*
- Analyze Design to Mitigate Hazards
  - Eliminate Single Point Failures
  - MIL-STD-882D Safety Analyses
  - Special Safety Analyses
  - Structural Analyses

Ammunition Tests

- Analyze for a variety of environments
  - Transportation (Land, Sea, Air)
  - Storage
  - Handling by service personnel
  - Drop
  - Combat or Terrorist Threats
  - Fire
  - Shock and Vibration
  - Radiation
- Test
  - ESD / HERO: *MIL-STD-464*
  - Insensitive Munitions: *MIL-STD-2105*
    - *Associated STANAG*
  - Shipboard Shock: *MIL-S-901*
  - Fuze: MIL-STD-331C
  - Hot Gun Cook-off: *NAVSEA SW300-BC-SAF-010*

Identify and Categorize Mishaps and Causal Factors



CAUSAL FACTORS
Elements within the system design, implementation, or operation that lead to, or contain, a hazard.

Hazard Mitigation

- Mitigation Methods (In order of precedence)
  - Design out hazard
  - Incorporate safety devices
  - Provide warning devices
  - Develop procedures and training

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Mishap Risk Acceptance Matrix

FREQUENCY OF OCCURRENCE	MISHAP SEVERITY CATEGORIES			
	1 CATASTROPHIC	2 CRITICAL	3 MARGINAL	4 NEGLIGIBLE
A – FREQUENT	1	3	7	13
B – PROBABLE	2	5	9	16
C – OCCASIONAL	4	6	11	18
D – REMOTE	8	10	14	19
E – IMPROBABLE	12	15	17	20

Cells:	Risk Level & Acceptance Authority:
1-5:	HIGH (UNACCEPTABLE) – Acceptance of risk by Component Acquisition Executive.
6-9:	SERIOUS (UNDESIREABLE) – Acceptance of risk by the Program Executive Officer.
10-17:	MEDIUM (Acceptable with review) – Acceptance of risk by the Program Manager.
18-20:	LOW (Acceptable with review) – Acceptance of risk by the Program Manager.

Navy Safety Review Boards

- **Weapon System Explosives Safety Review Board (WSESRB)**
  - **SECNAVINST 5000.2C**
    - Establishes the WSESRB as the Navy's independent agent for reviewing weapon system safety programs
  - **OPNAVINST8020.14/MCO P8020.11**
    - Specifies requirements for WSESRB review
  - **NAVSEAINST 8020.6E**
    - Establishes WSESRB policies and procedures
  - **Software System Safety Technical Review Panel (SSSTRP)**
    - Established by WSESRB to review software safety
    - More thorough review by technical experts
  - **Fuze & Initiation Safety Technical Review Panel (FISTRP)**
    - Established by WSESRB to review fuze/initiation systems safety
    - More thorough review by technical experts
  - **Lithium Battery Review Board**
- **Insensitive Munition Review Board (IMRB)**
- **Ordnance Hazard Evaluation Board (OHEB)**
- **Bureau of Medicine (BUMED)**
  - Laser Safety Review Board (LSRB)

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Safety Process Summary

- **Apply Mandated Policies**
- **Follow System Safety Program Plan**
- **Identify, Mitigate and Accept risk**
- **Present Safety Process to Safety Review Board**
- **Present Analysis to Safety Review Board**

All Gun Systems and Ammunition Need to go Through a Rigorous Safety Process Before Deployment.

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BACK UP

Web Site for Further Interest

- Digital Engineering Institute
  - www.klabs.org/DEI/References/Military_Specifications.htm
- System Safety Handbook
  - www.asy.faa.gov/risk/SSHandbook/Contents.htm
- Joint Weapon Safety Review Process for USSOCOM Program
  - www.acq.osd.mil/atptf

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Ammunition Qualification Tests

PVAT
Sequential Environment
- 28-Day Temperature and Humidity (T&H)
- Transportation Vibration
- Shipboard Vibration
- 4-Day T&H

Fast Cook-Off
Slow Cook-Off
Bullet Impact
Fragment Impact
Sympathetic Detonation
Shaped Charge Jet Impact
Salt Fog
Sand and Dust
Arena
5-Foot Drop
40-Foot Drop
Shipboard Shock
Waterproof
Energetics Qualification
Function and Casualty
Fuze Function
Fuze Arming Distance
Jumble
Jolt
Missing Interrupter
Thermal Shock
Detonator Safety
Lead Azide
HERO
ESD
EMV
Lightning
Progressive Arming
Primary Explosive Component Safety Test
Bonfire Test
Stack Test
POP
Unit Load

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Joint Systems

- ***JOINT WEAPON SYSTEMS HAVE JOINT REVIEWS***
- **Office of the Secretary of Defense (OSD)**
  - **Joint Weapon, Munitions, and Laser SOCOM Weapon Safety Review Process**
    - **USD AT&L Memo implementing the Joint USSOCOM Process, 9 November 07**
    - **MEMORANDUM OF AGREEMENT AMONG United States Special Operations, Command (USSOCOM), OSD AT&L, OSD Environmental Readiness and Safety, Department of the Army, Department of the Navy, Department of the Air Force**
    - **In support of USSOCOM Acquisitions**
      - **Collaborative process supported by each Service's CAE and Safety review authorities**
      - **Convenes as necessary to review Joint USSOCOM Weapon Programs**
    - **Incorporates the Joint Laser Safety Review Board (JLSRB)**
- ***Participants***
  - ***Navy WSESRB***
  - ***USAF NON-NUCLEAR MUNITIONS SAFETY BOARD (NNMSB)***
  - ***US ARMY FUZE SAFETY REVIEW BOARD (AFSRB)***
    - MEMBERS OF EACH BOARD HAVE PARTICIPATED IN MEETINGS OF THE OTHER BOARD

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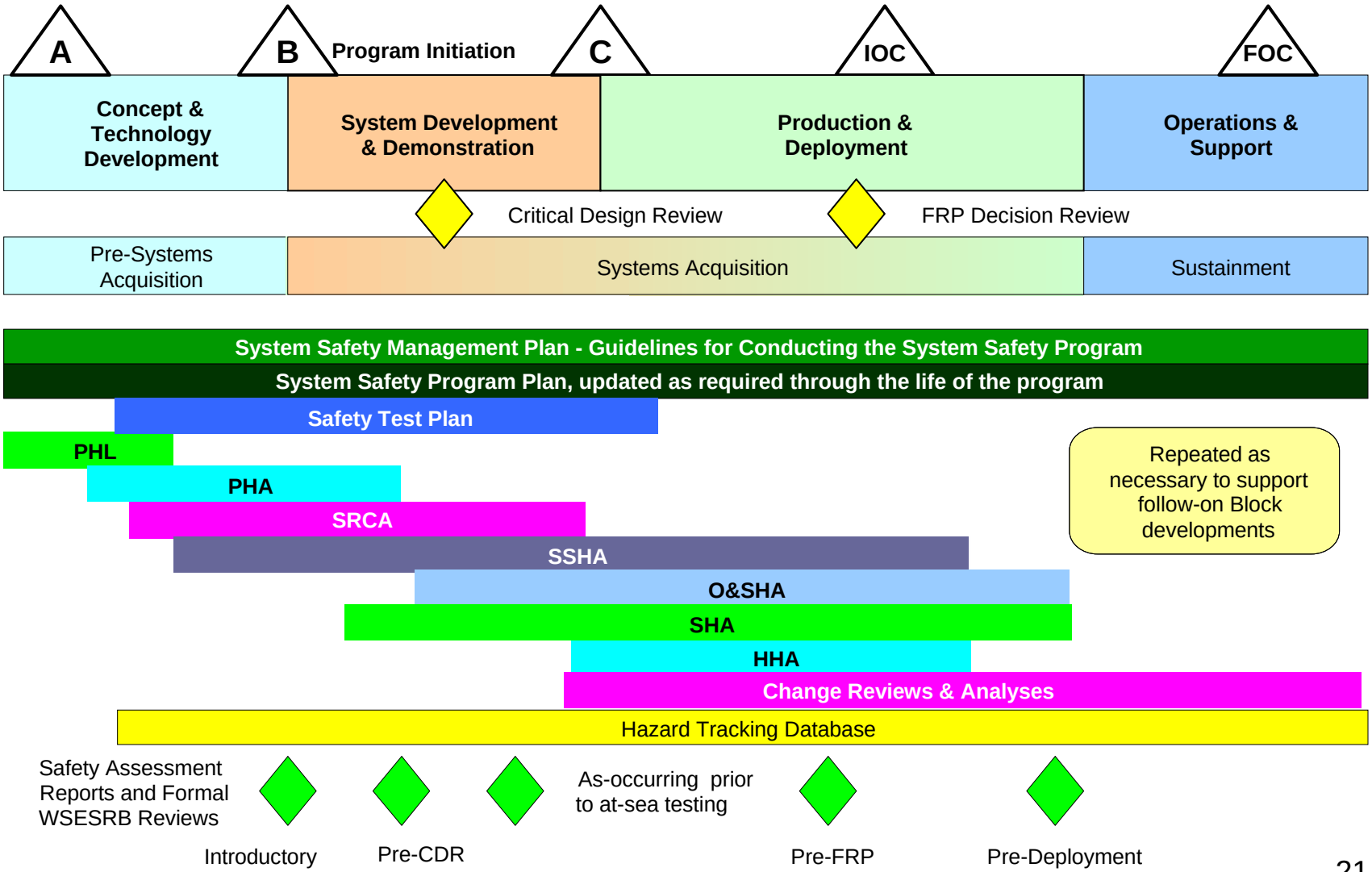
System Acquisition & System Safety



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MIL-HDBK-454

- Electromagnetic environment effects
- Shipboard bonding and grounding
- Laser safety requirements
- Human engineering
- Hazardous Materials
- Radiation protections and signs
- Radio frequency protections and signs
- Safety colors
- Other safety signs, labels, and barriers
- Safety tags

ULTRASONIC TEMPERAUTRE AND HEAT FLUX TECHNOLOGY

Industrial Measurement Systems, Inc.
2760 Beverly Drive
Aurora, IL 60502

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Website: http://www.imsysinc.com

Co-Authors:
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D. Greg Walker PhD
Peter L. Schmidt PhD
Dan Rabin DSWCDD

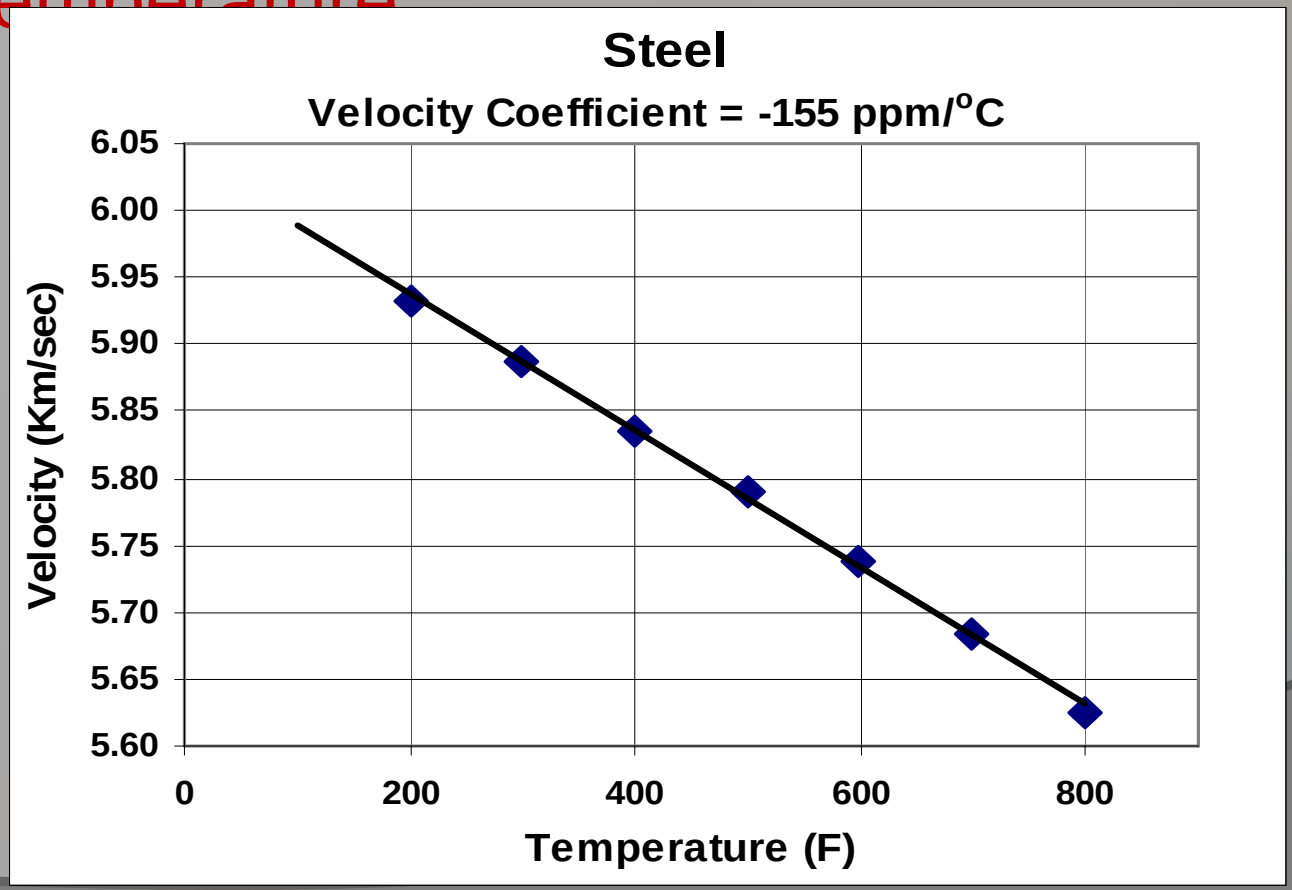
PROBLEM STATEMENT

Improved Gun Safety

- 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

FUNDAMENTALS

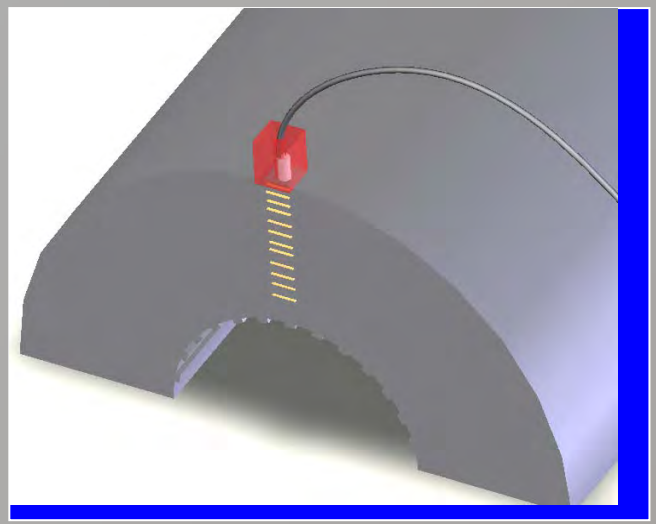
- Velocity of Sound is a Function of Temperature

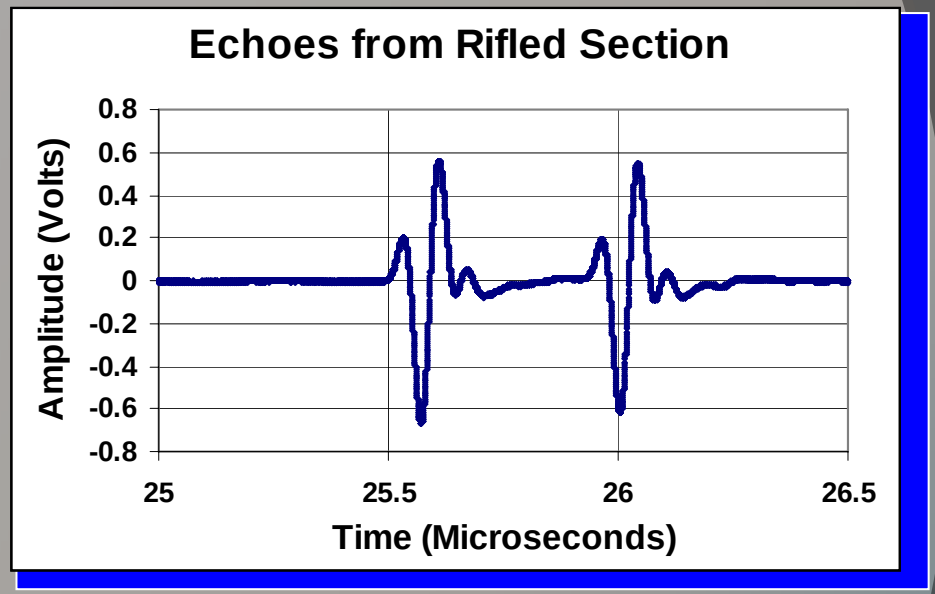


MEASUREMENT CONCEPT

Temperature Localization

- Precise Timing Measurements to Measure Temperature & Erosion





Determining Inner Chamber Surface Temperature

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

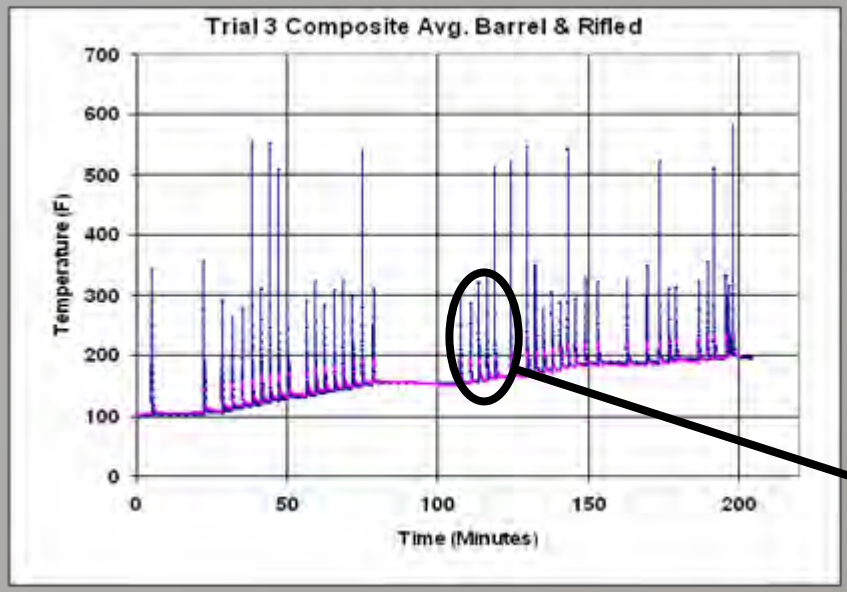
CONCEPT TO PRACTICE

Multiple Successful Live Fire Trials

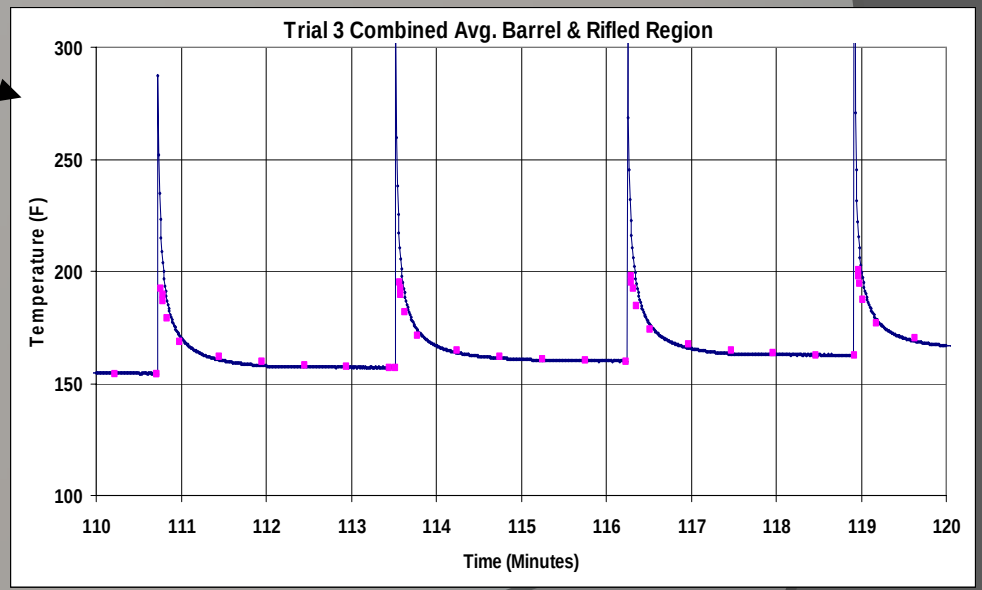
NETS (Non-Intrusive Erosion and Temperature Sensor) prototype installed on the MK45 MOD 4 Gun at NSWCDD and NLOS-C at Yuma, Az. For live fire experiments in 2005-2007

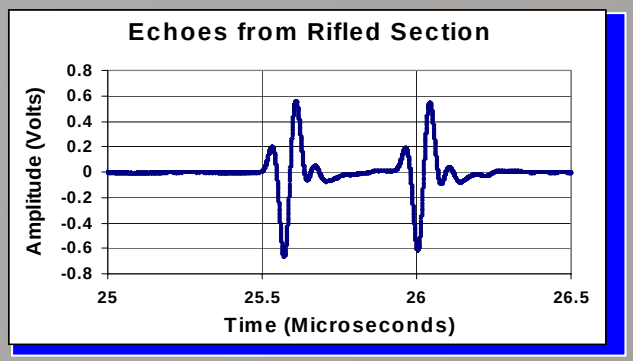
- Accurate Internal Temperature Measurement
- Transient Temperature Measurement
- Off-line Heat Flux Calculations

MULTIPLE FIRING EVENTS



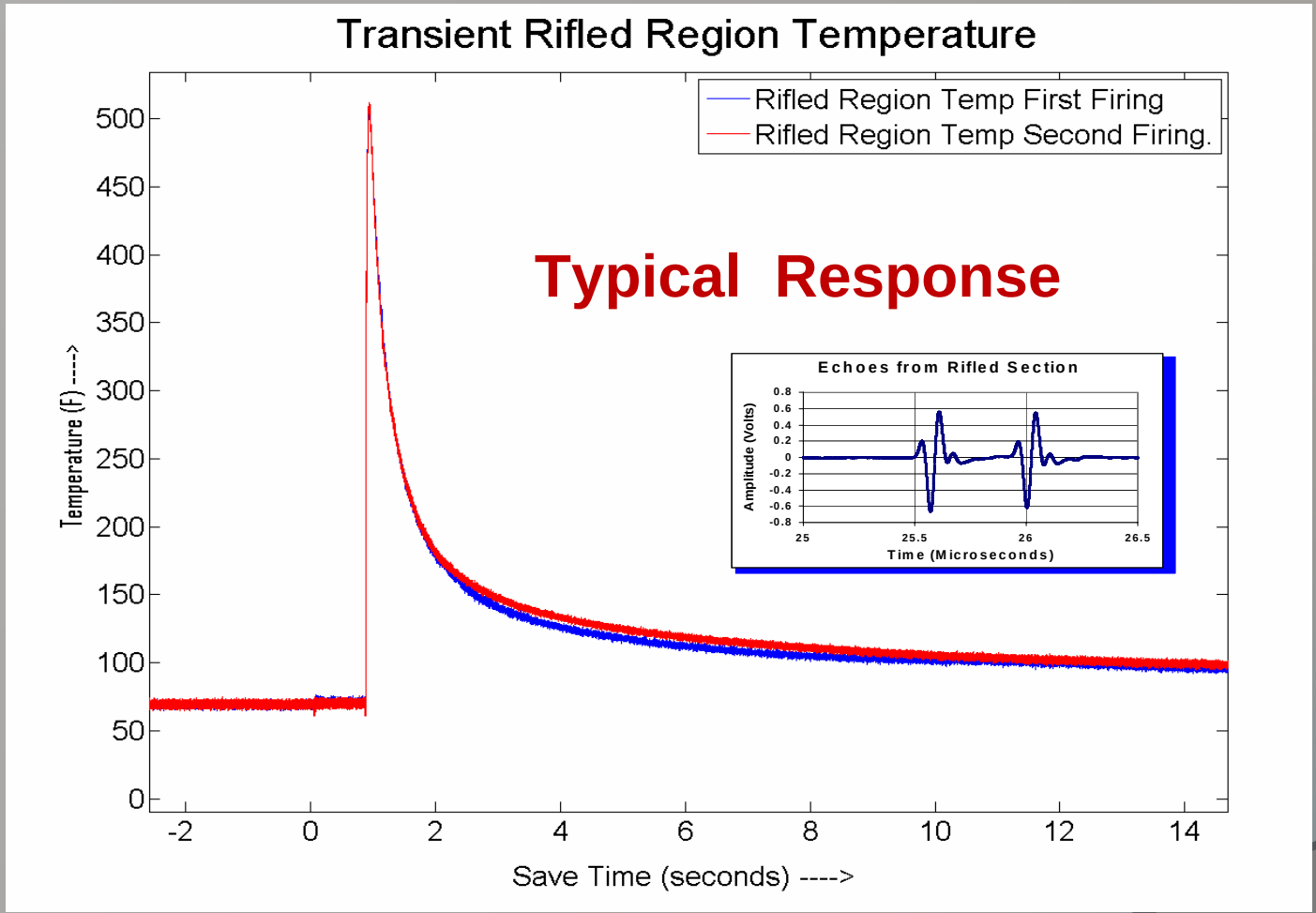
Long Term Stability





Local & Average barrel Temperature for 40 Firings of Mark 45 Mod 4 Gun

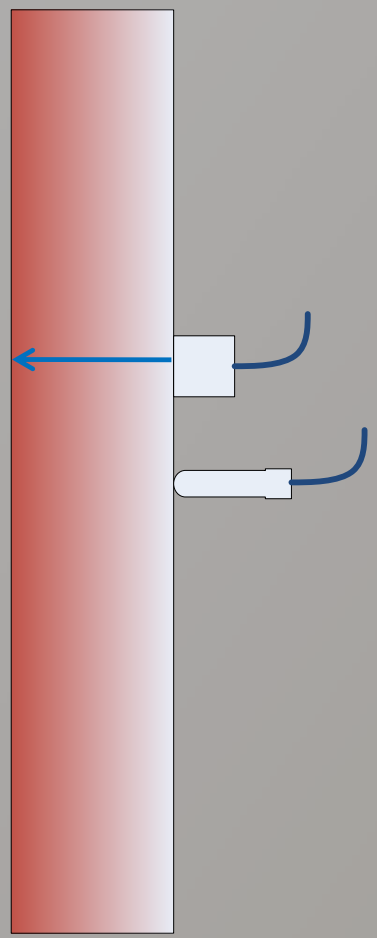
SINGLE FIRING EVENT



Ultrasonic Temperature for Two Firings of Mark 45 Mod 4 Gun Normalized to 70 degrees Fahrenheit.

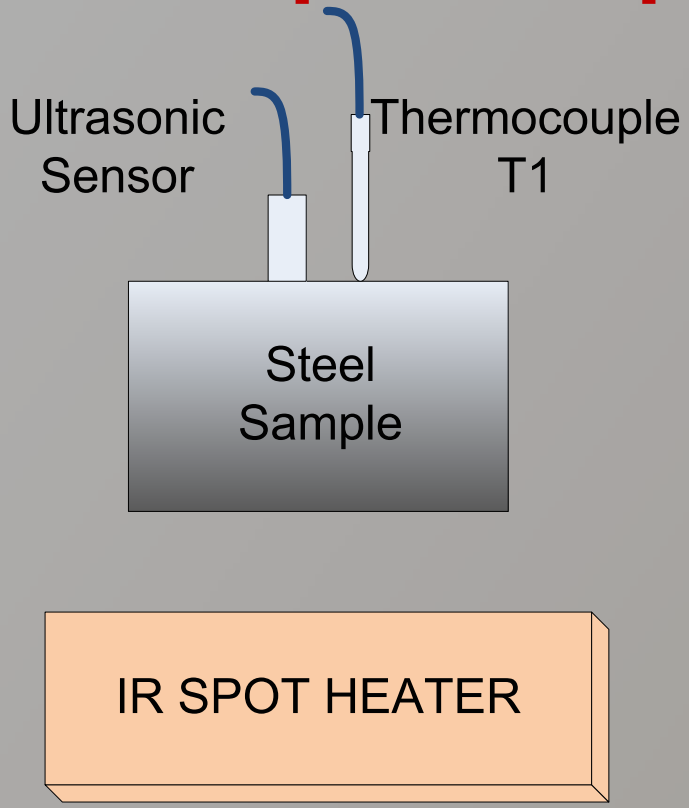
ELEMENTS OF THE TECHNOLOGY

Essential Components



- Ultrasonic Sensors
- High Speed Data Acquisition
- High Bandwidth Ultrasonic Instrumentation
- High Speed Data transfer/Storage
- Independent Temperature Sensor /Normalization
- Cooperative/Characterized Materials

Rapid Response (no lag/lead)



Technology offers the potential for temperature measurement on a microsecond timeframe.

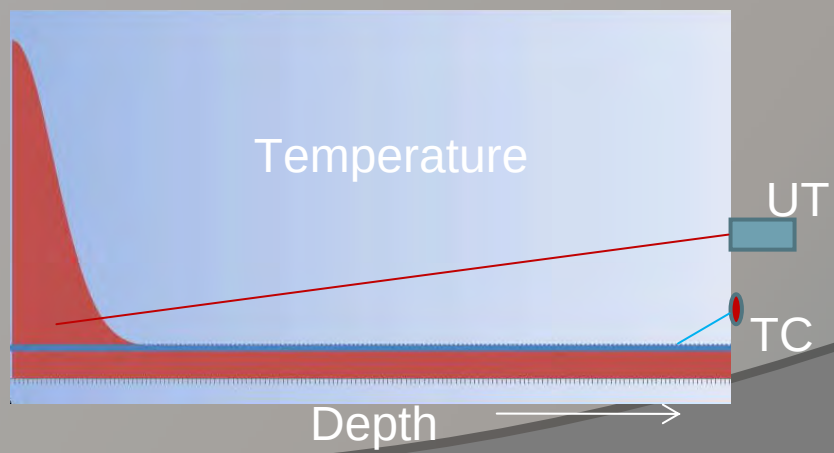
(Graphic depicts Ultrasonic Temperature data collected every 200 usec.)

SINGLE INTERFACE

Surface Temperature & Heat Flux

The Integral relation between ultrasonic time-of-flight and temperature is advantageous for inversion methods)

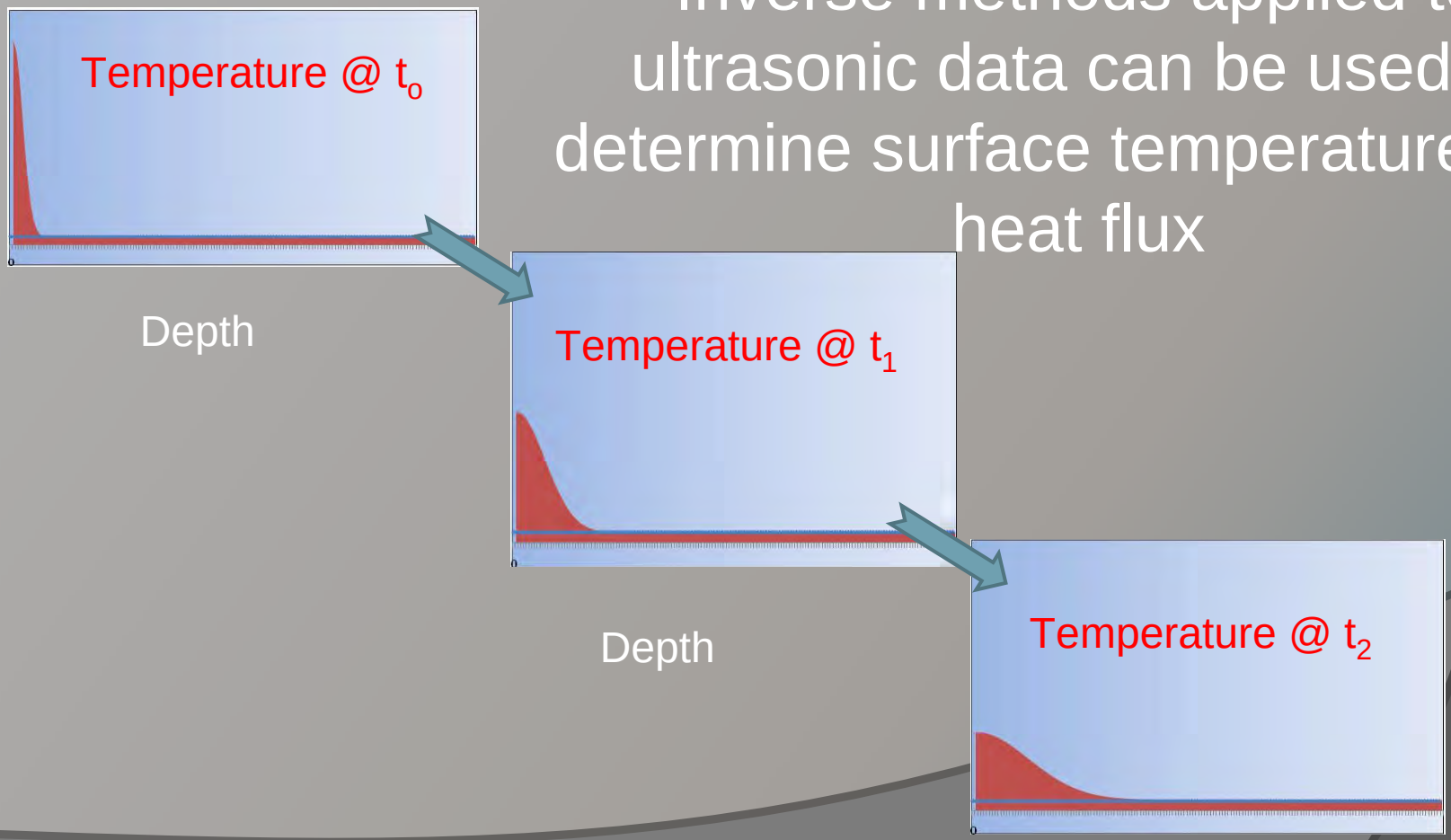
$$G(x) = 2\int_0^x \frac{1+\alpha(\xi)\delta\theta(\xi)}{c(\xi,\theta(\xi))}d\xi$$



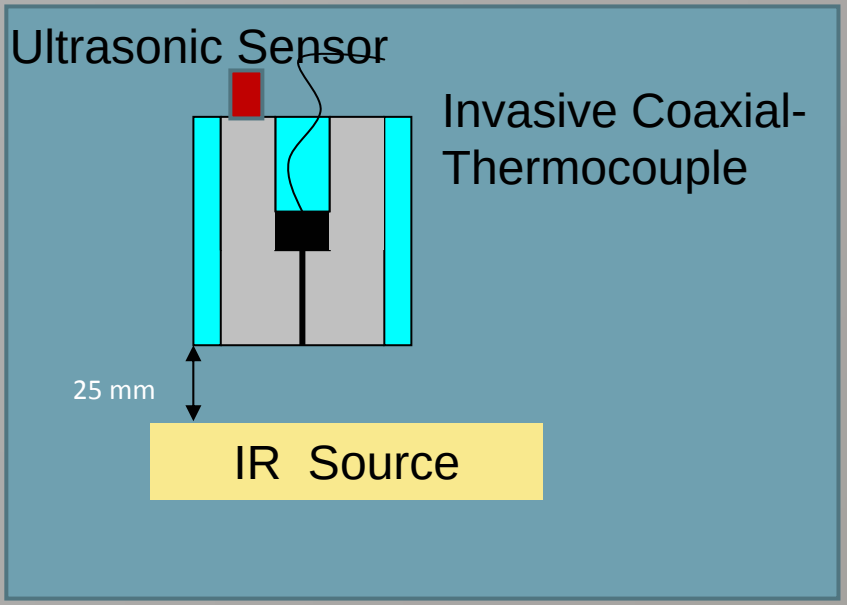
SINGLE INTERFACE

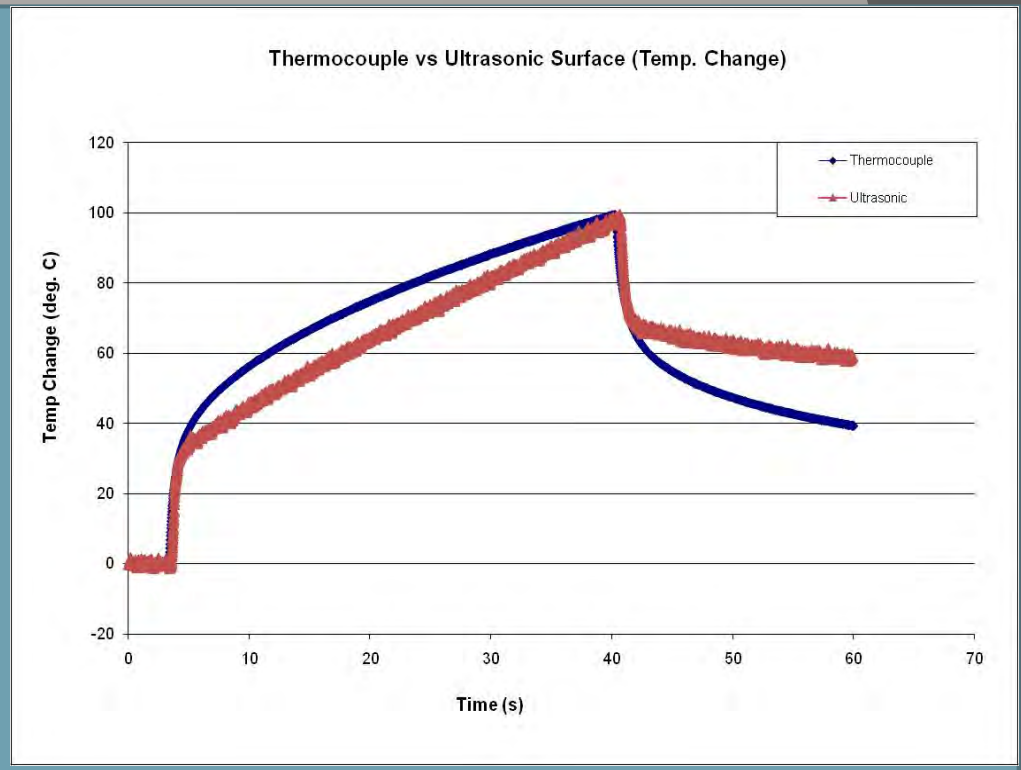
Surface Temperature & Heat Flux

Inverse methods applied to ultrasonic data can be used to determine surface temperature and heat flux

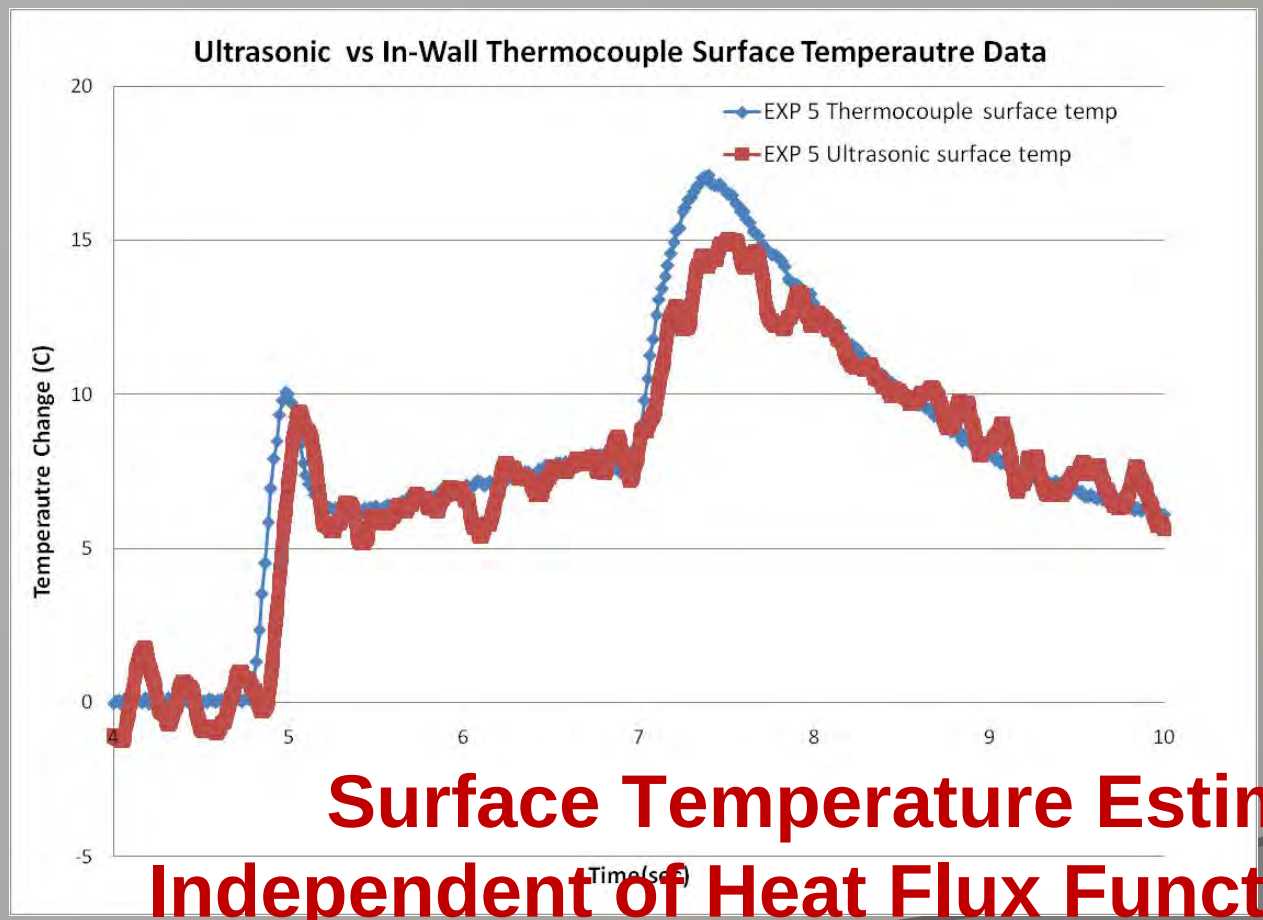


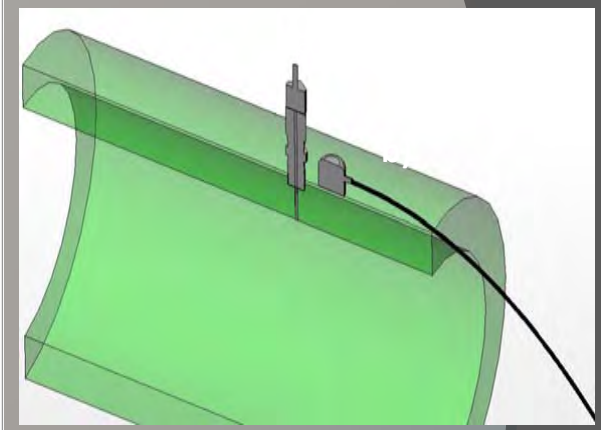
Comparison of Remote Ultrasonic and Intrusive Thermocouple Data





Comparison of Remote Ultrasonic and Intrusive Thermocouple Data



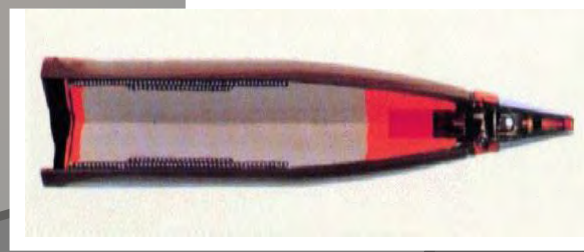


Surface Temperature Estimates Independent of Heat Flux Functional Form

OPPORTUNITIES

Ultrasonic Temperature and Heat Flux Sensor

- Gun Safety and Research
- Casting / molding Heat Transfer Studies
- Combustion Chamber Instabilities
- Jet Engines
- Hypersonic Aeroshells



MEASUREMENT POSSIBILITIES

Attributes

Features, Advantages, and Benefit of the Ultrasonic Technology

Features	Advantages	Benefits
Temperature	Non-Intrusive Direct Measurment	Remote sensing in harsh environments
Erosion	At Sea Measurement Continuously Monitor	Long term integrity reliability
Transient Temperature	Non-Intrusive High Speed Measurements	Very Rapid Remote measurements to aid in R/D
Heat Flux	Non-Intrusive High Speed Response	Instantaneous Response to Flow

STATE OF DEVELOPMENT

Ultrasonic Temperature and Heat Flux Sensor

Summary:

- **Local temperature measurements in live fire experiments on MK 45 Mod 4 and NLOS C Platforms**
- **Rapid response (no lag)**
- **Single reflector Inversions for surface temperature and heat flux estimates.**

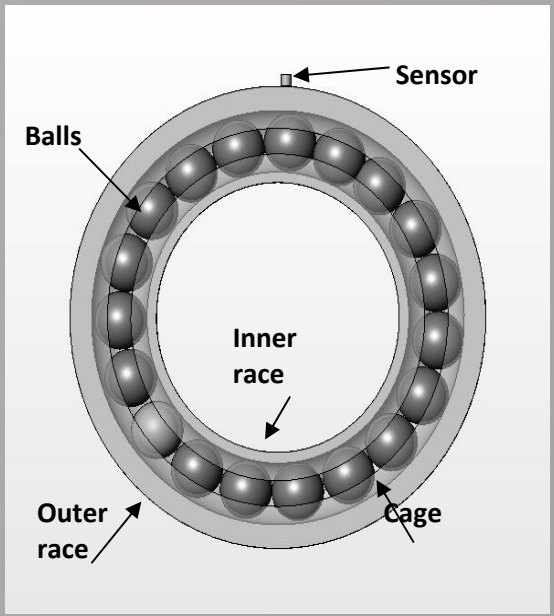
NEXT STEP:

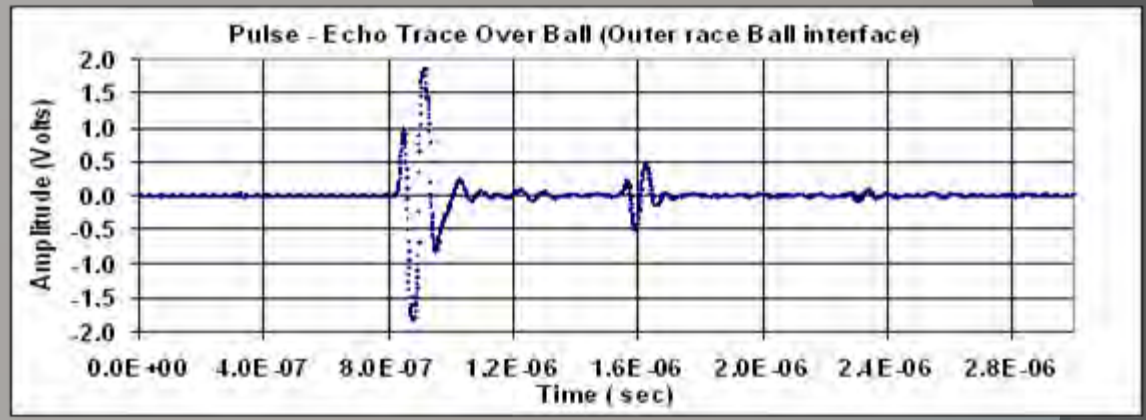
- **Improve Inversion Methods**
- **Alternate Structures**
- **Alternate Materials**
- **Incorporate Direct-Deposited Sensors**
- **More Extensive Field Testing**

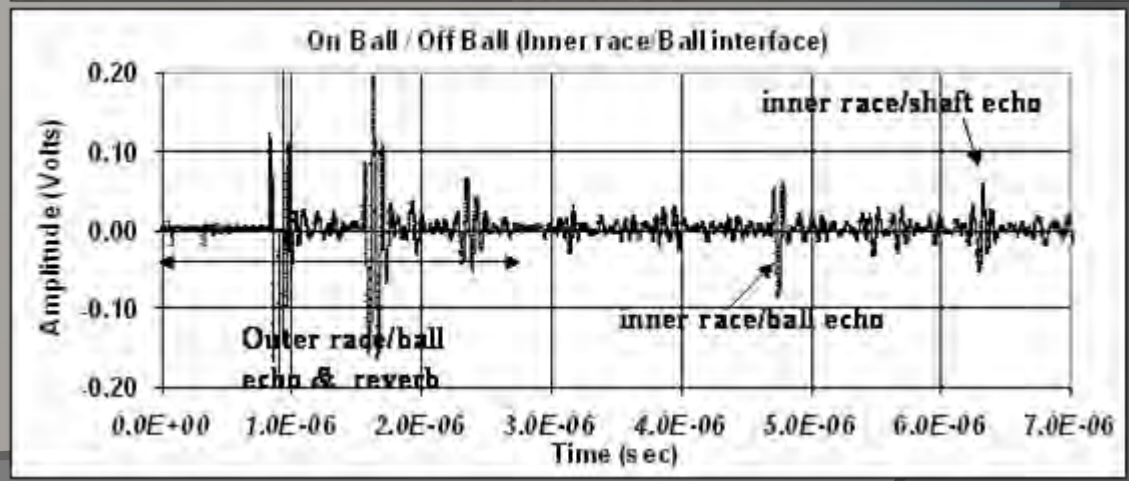
INTERESTING POSSIBILITY

Temperature Measurements in Inaccessible Places

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

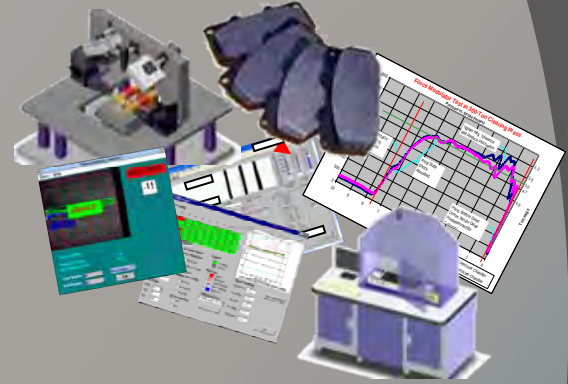






Ultrasonic Temperature and Heat Flux Sensor Technology

Thanks For Listening!



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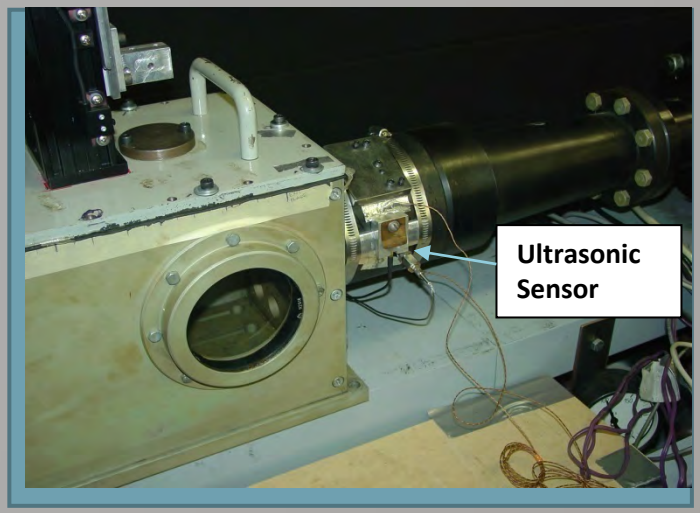
MMutton@imsysinc.com

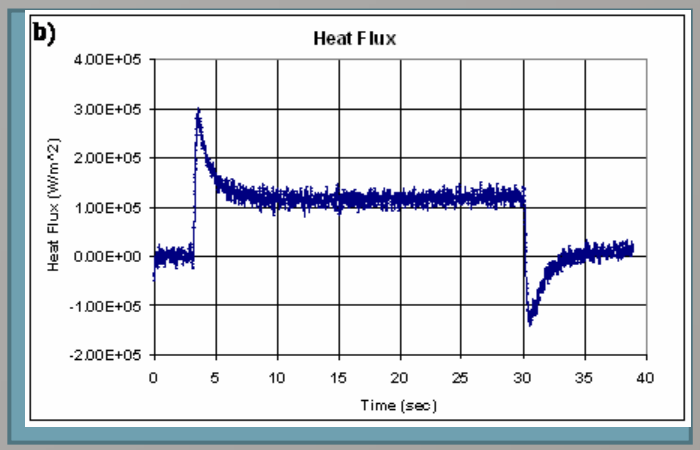
Industrial Measurement Systems, Inc.
2760 Beverly Dr.
Aurora, IL 60504

BACKUP SLIDES

HEAT FLUX RANGE

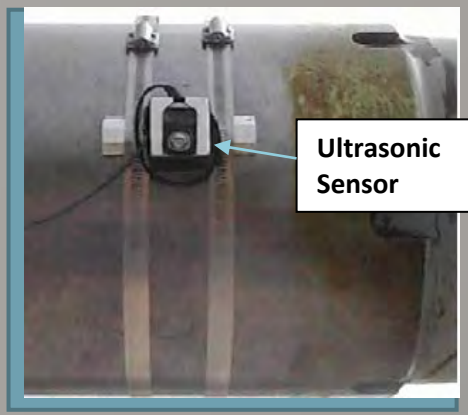
Mach 6 Wind Tunnel

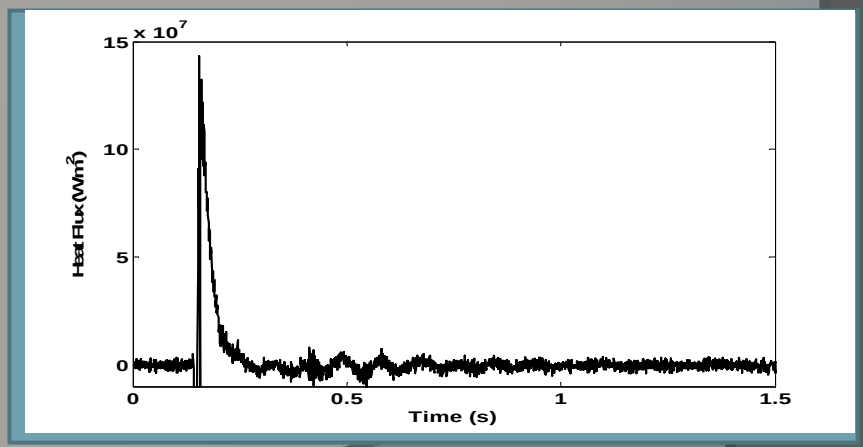




100KW/m^2

Mark 45 Mod 5

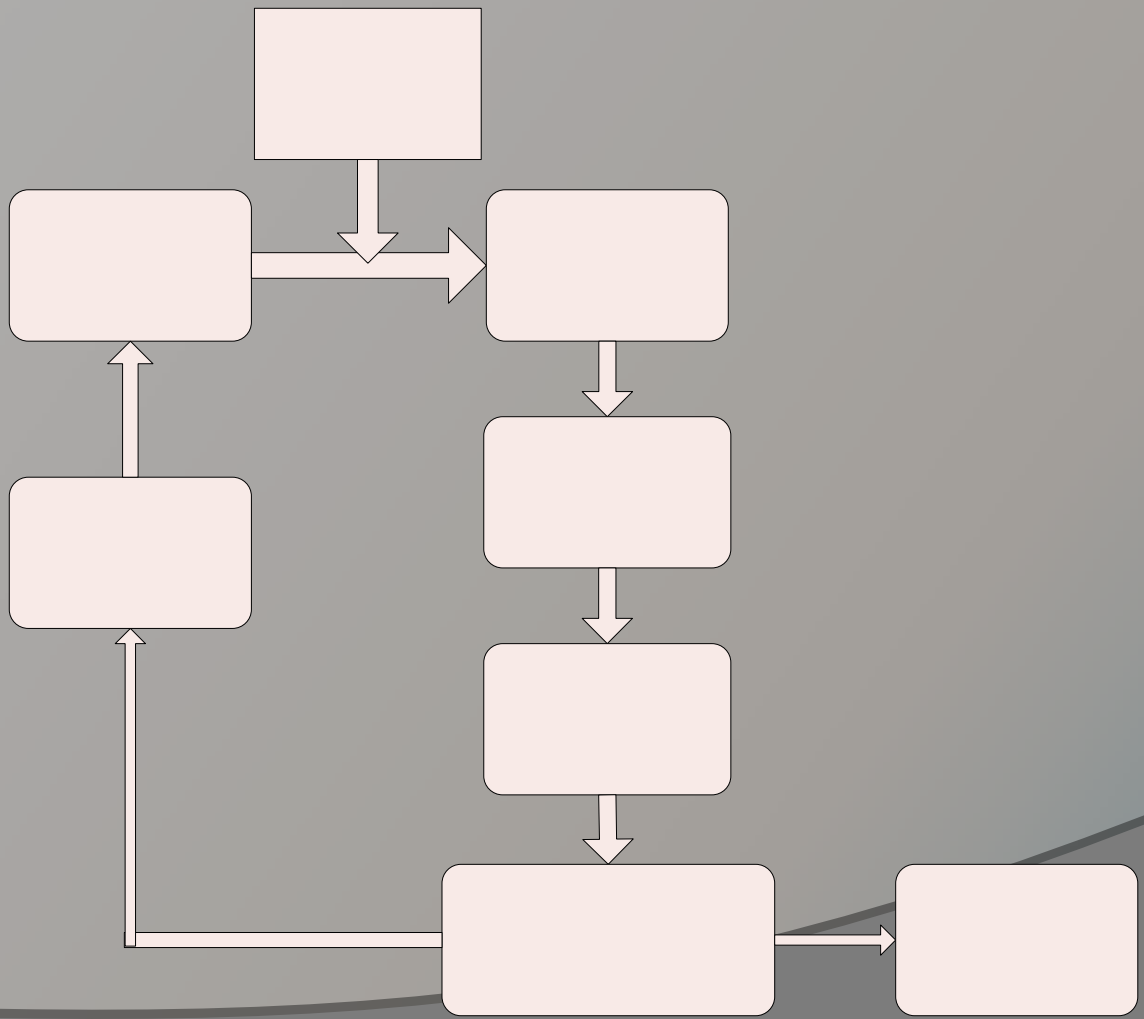




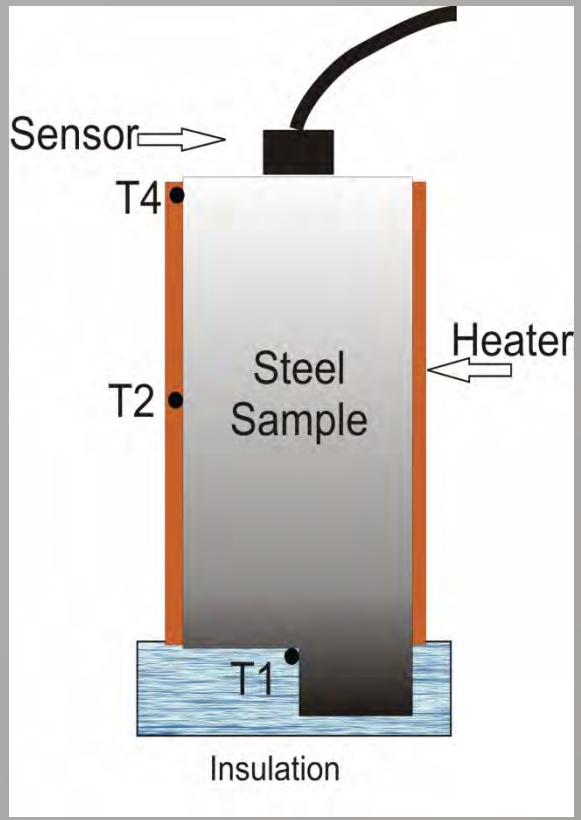
140MW/m^2

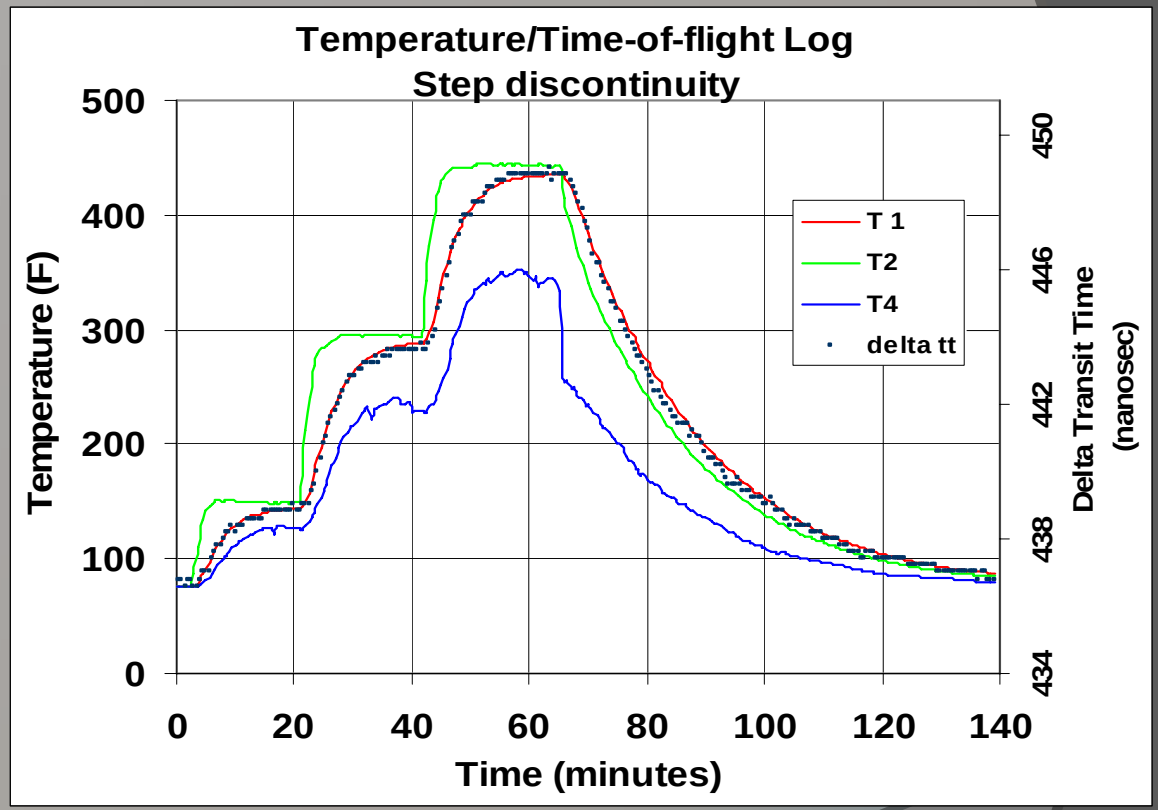
HEAT FLUX CONVERSION OVERVIEW

Inverse Solution



LAB VALIDATION EXPERIMENT

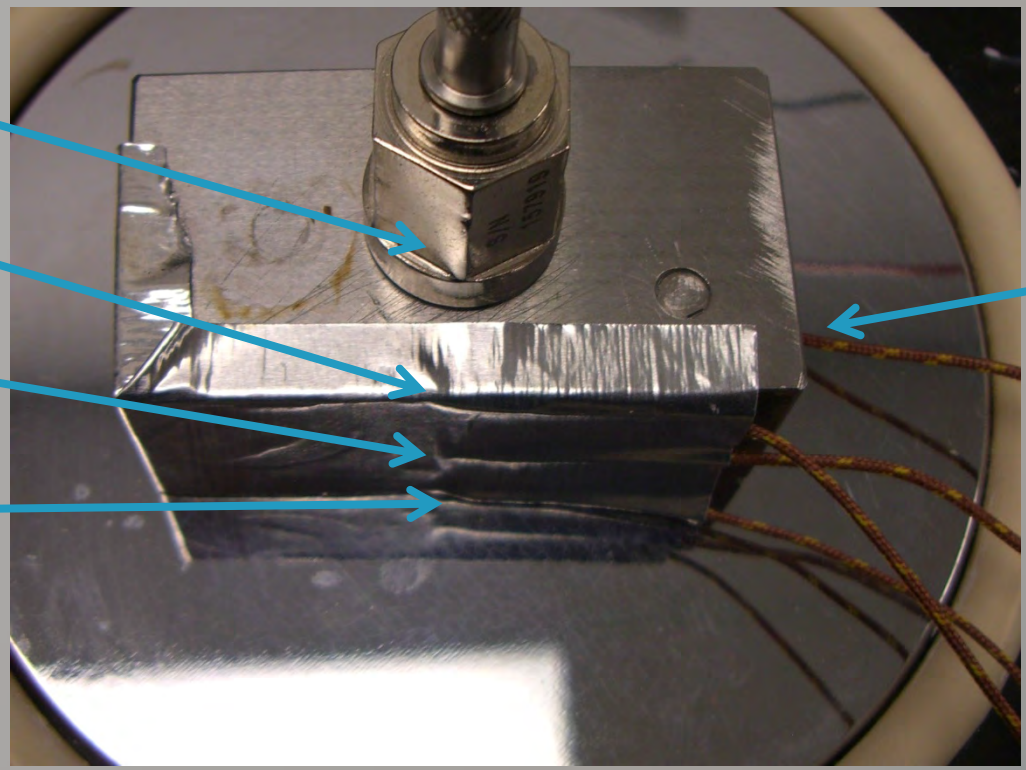




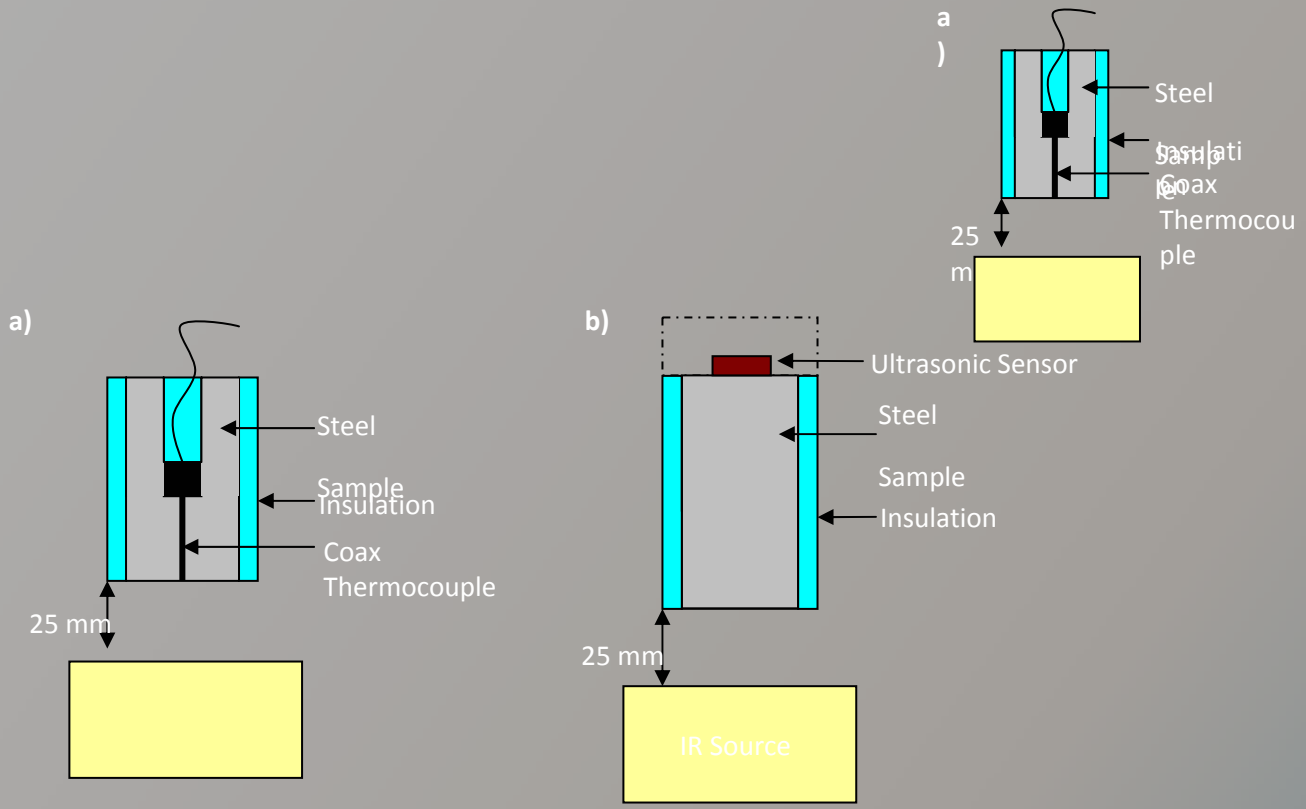
- Three Thermocouples Vs Time of flight of ultrasonic pulse

PROBLEM STATEMENT

In-Wall RTD 0.05” from Heated Surface



PROBLEM STATEMENT



PROBLEM STATEMENT

PROBLEM STATEMENT

PROBLEM STATEMENT

Quo Vadis after Cluster Munitions

GMLRS SMArt

Harald Wich
Diehl BGT Defence
Head of Indirect Fire Systems
Harald.Wich@diehl-bgt-defence.de

Content

- DPICM Background
- Requirements for Replacement
- Increasing Target Protection
- GMLRS-SMArt
- Effectiveness

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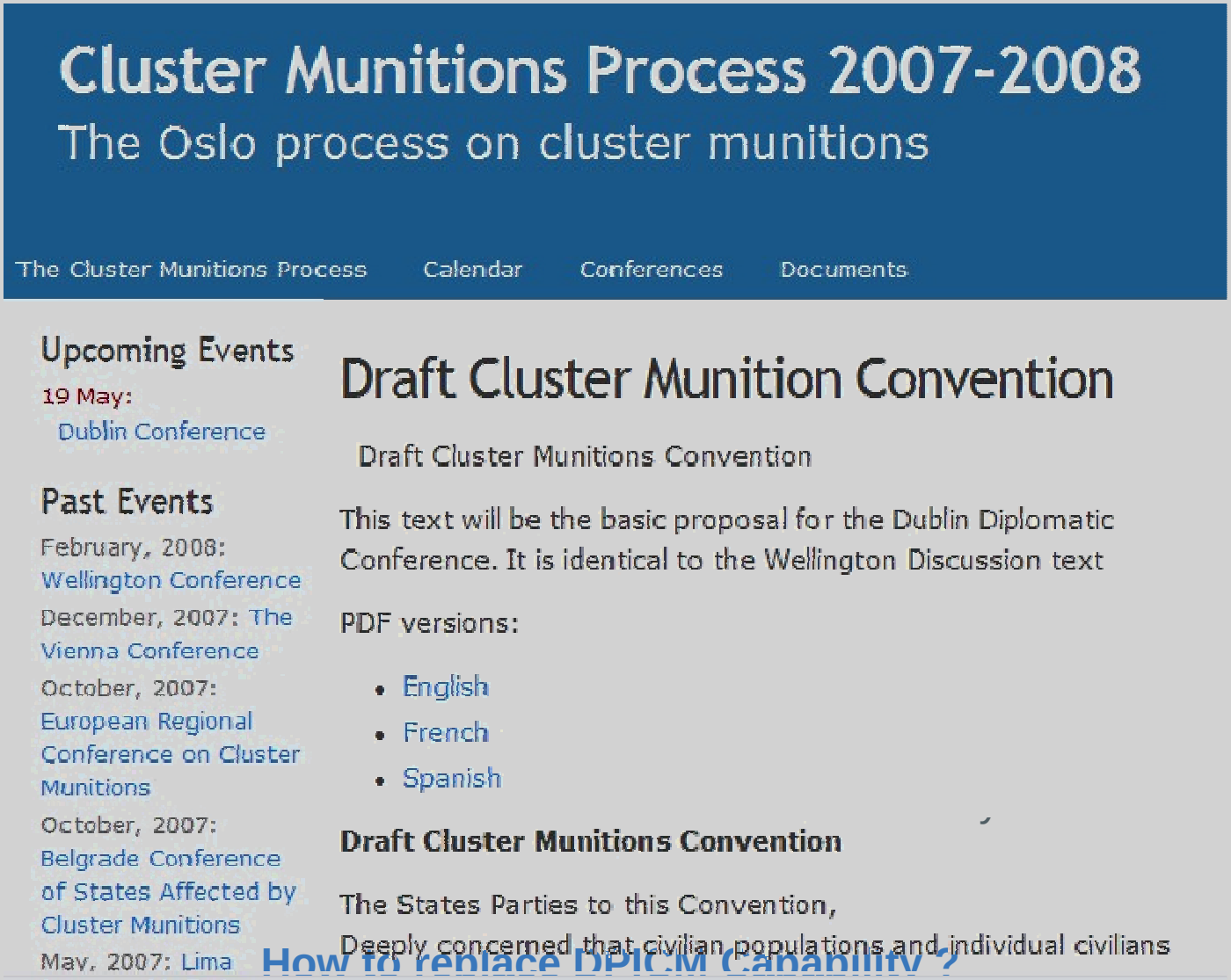
Background

DIEHL
BGT Defence



How to replace DPICM Capability ?

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Target Scenarios

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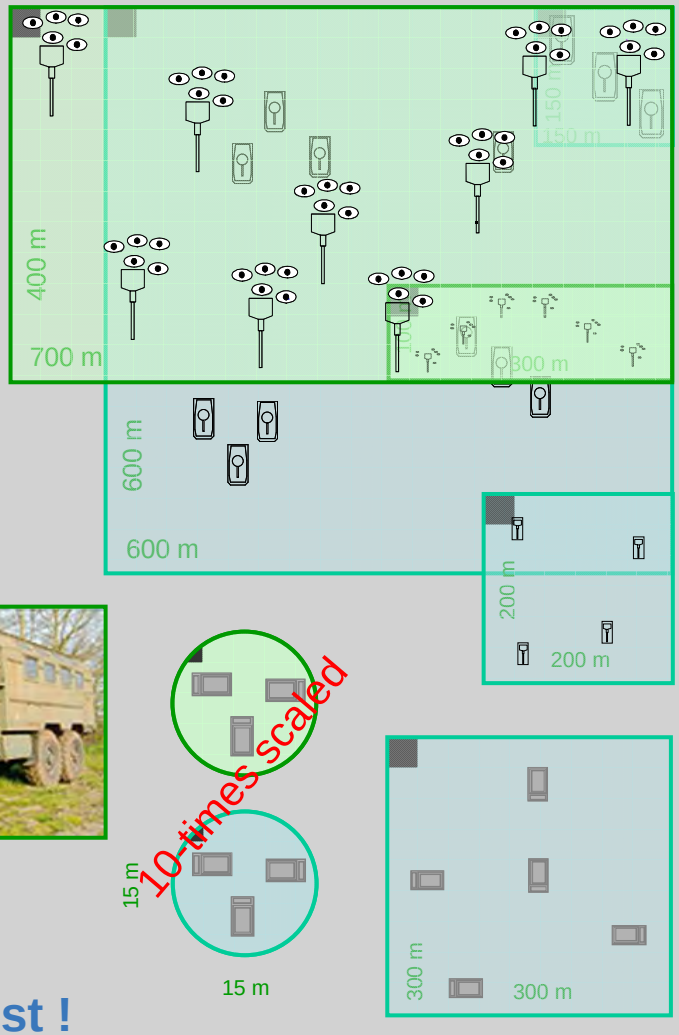
- No longer
  - huge Dimensions (“Grids”) and
  - literally countless Target Elements of “Cold War”
- But
  - small Area
  - few Target Elements
  - individual Target Coordinates not to be known
  - Target Elements are
    - unprotected
    - protected
    - lightly armoured
    - armoured



Area Targets still do exist !

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Area Coverage of Munitions

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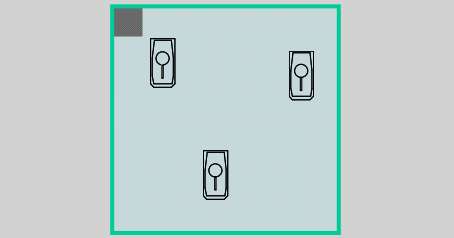
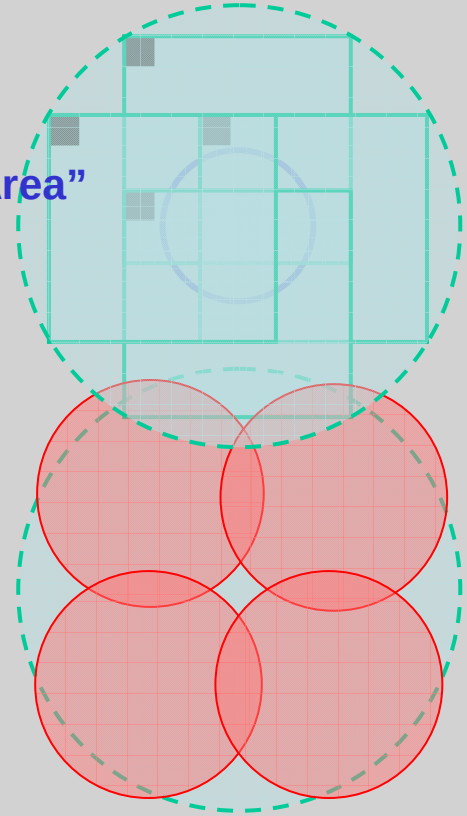
BGT Defence



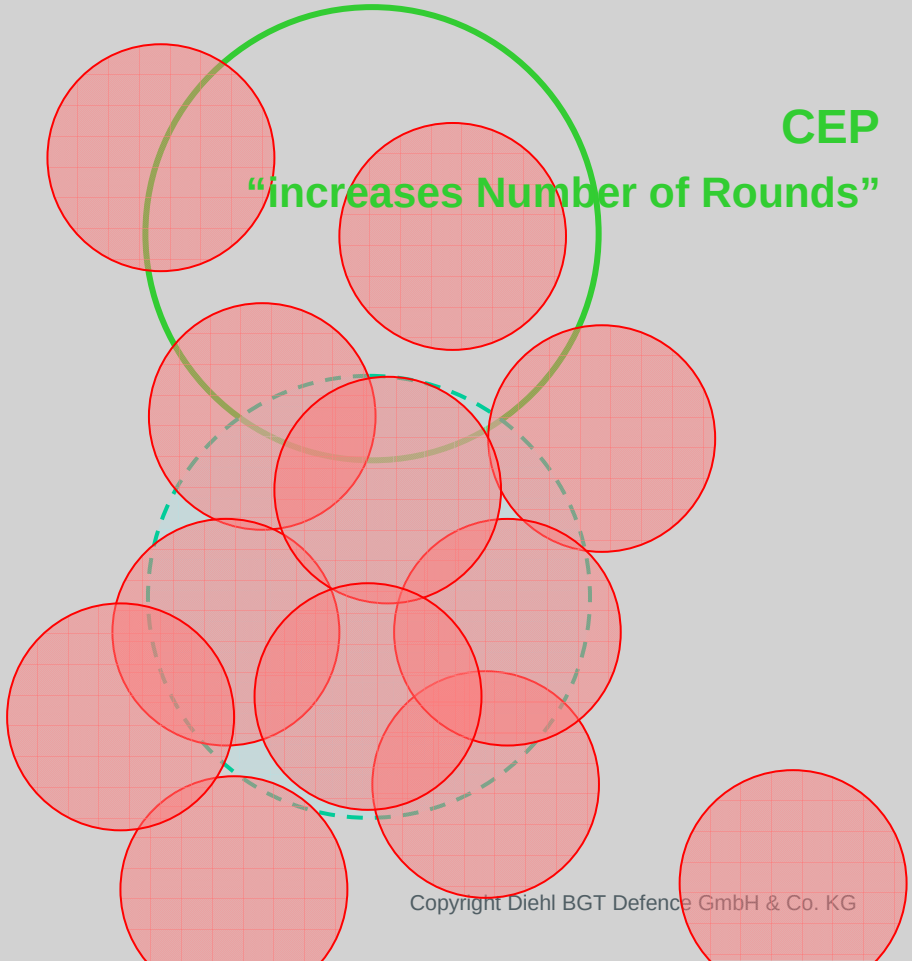
TLE

“increases Target Area”

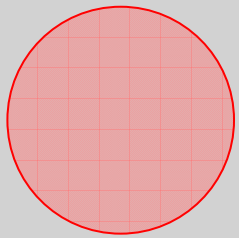


CEP

“increases Number of Rounds”



WH lethal Area



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Area Coverage of Munitions

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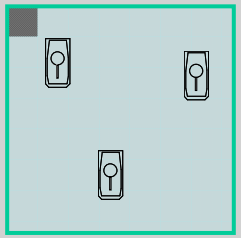

TLE

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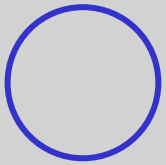
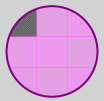
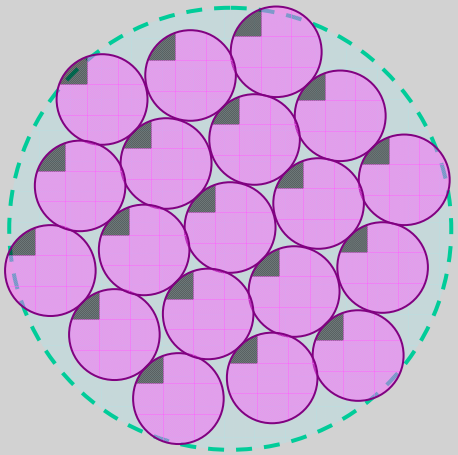


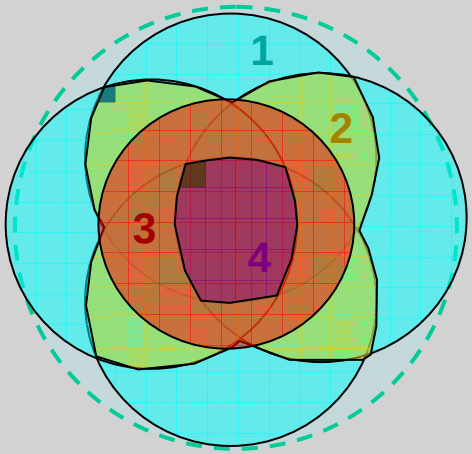
CEP

“increases Number of Rounds”

WH lethal Area







Area Effects required ! Precision is not a Replacement for Target Acquisition

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A Trend towards more Target Protection

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- Increased Protection for all Classes of Target Elements
- STANAG 4569 defines Requirements
- Some very recent Examples

Table 1 – STANAG 4569 Protection Levels

Threat Level	Ammunition	Velocity (m/s)	Threat Type
5	25 mm x 137 APDS-T, PMB 073	1258	Automatic Cannon, APDS Ammunition
4	14.5 mm x 114 API/B32	911	Heavy Machine Gun, AP Ammunition
3	7.62 mm x 51 AP (WC core)	930	Assault and Sniper Rifle, AP WC Core
3	7.62 mm x 54R B32 API	854	Assault and Sniper Rifle, AP WC Core
2	7.62 mm x 39 API BZ	695	Assault Rifles/ AP Steel Core
1	7.62 mm x 51 NATO ball	833	Assault Rifles/ Ball Round
1	5.56 mm x 45 NATO ball	900	Assault Rifles/ Ball Round
1	5.56 mm x 45 M193	937	Assault Rifles/ Ball Round

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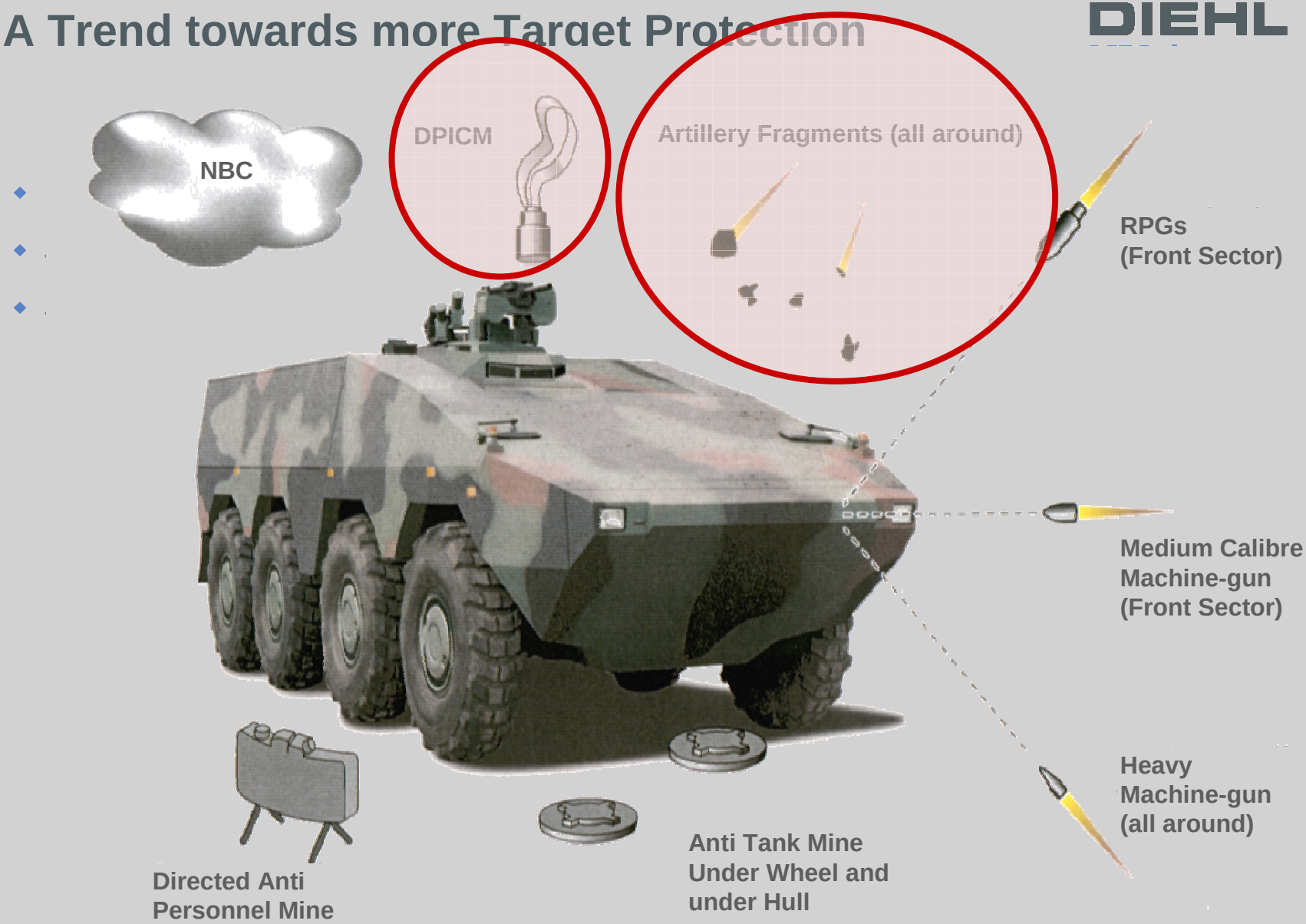
A Trend towards more Target Protection



More “Punch” needed to counter improved Protection !

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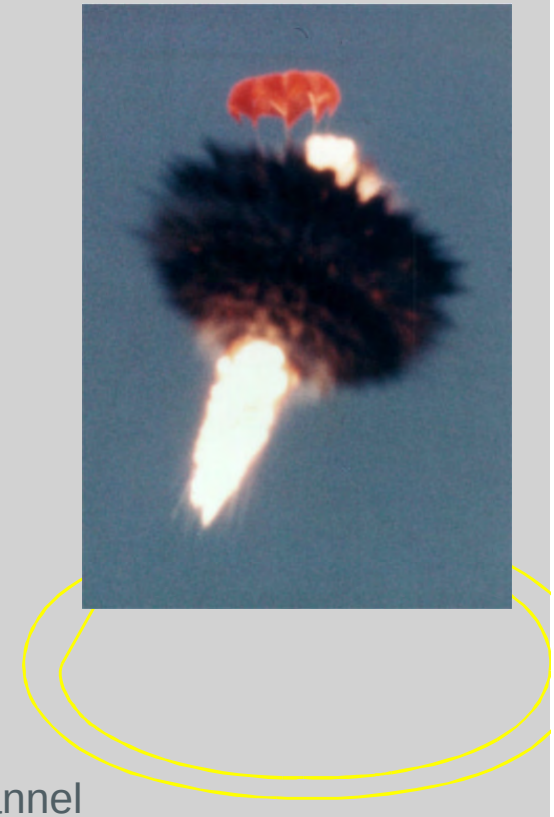
SMArt® 155 DM 702/A1

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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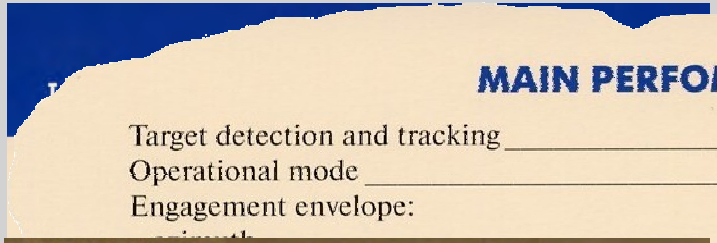
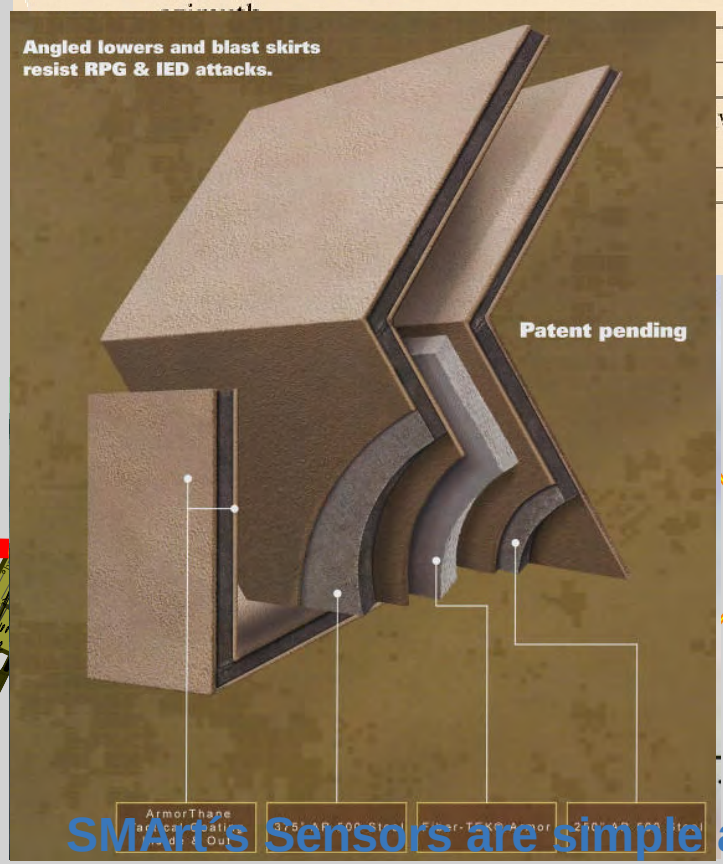
SMArt Principle of Function

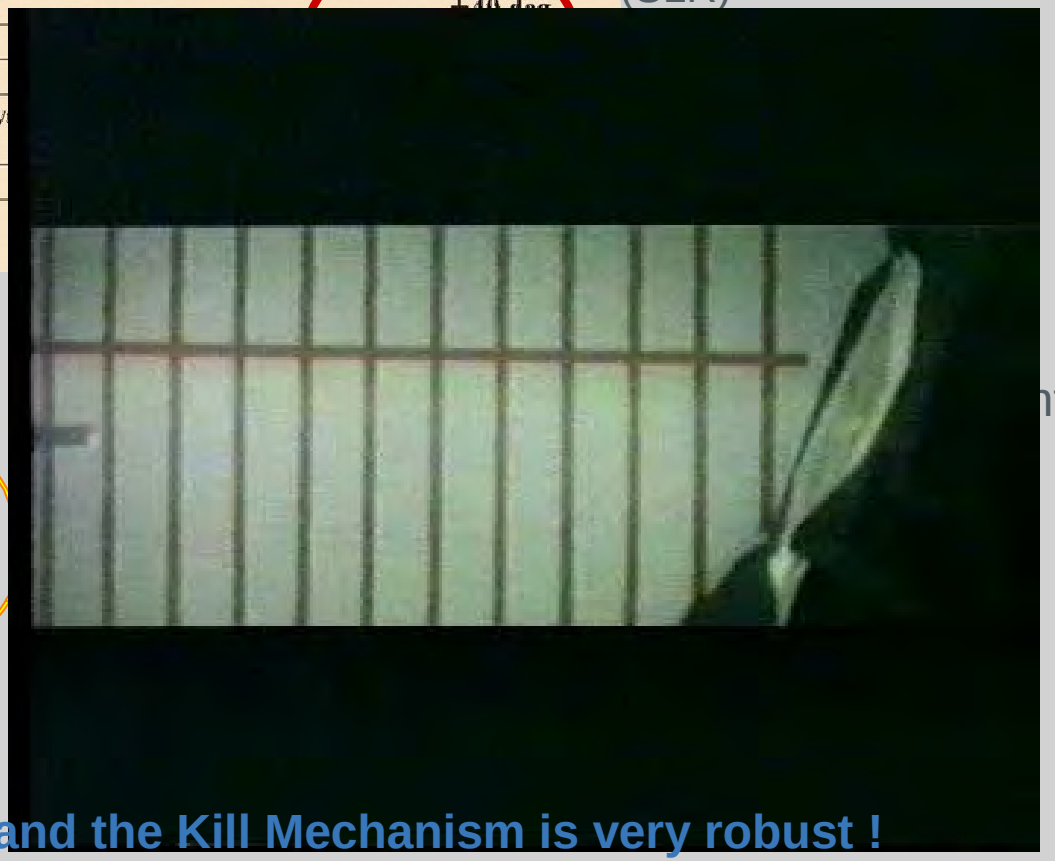
DIEHL
BGT Defence



Descent

(SLR)





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SMArt's Sensors are simple and the Kill Mechanism is very robust !

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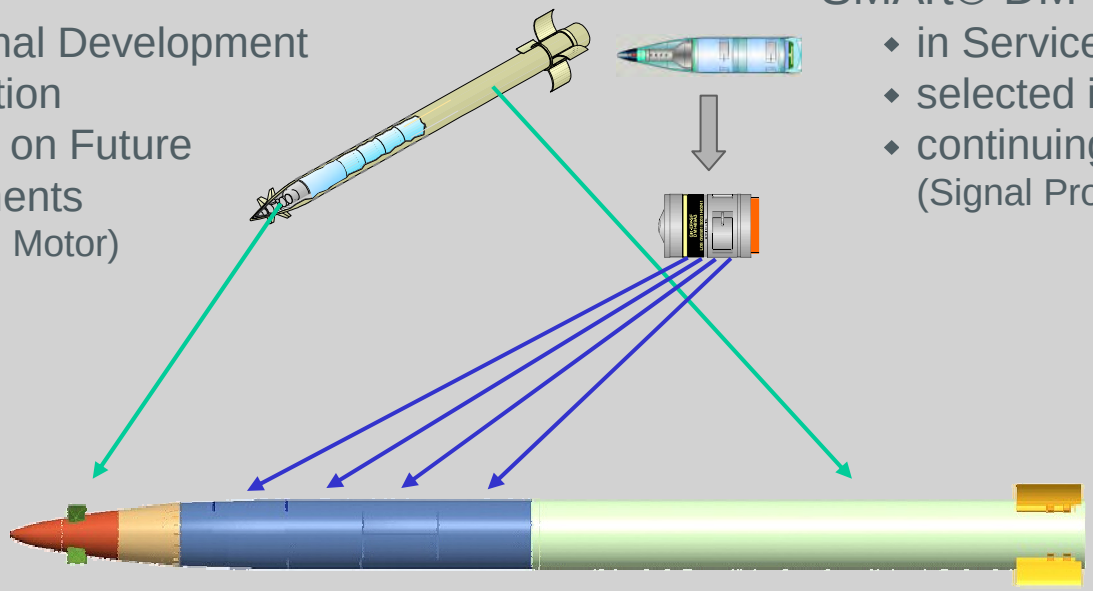
Sensor Fuzed GMLRS-SMArt

DIEHL
BGT Defence

GMLRS M30
- international Development
- in Production
- leverages on Future Improvements
  (Nav, GPS, Motor)



SMArt® DM 702
- in Service in DE, CH, GR
- selected in UK, AU
- continuing Improvements
  (Signal Processing, insensitive, …)

GMLRS M32 (GMLRS-SMArt)
- all GMLRS-Performance will be met or exceeded
- all SMArt®-Performance will be met or exceeded
- Sub Munition Pattern programmable
- Software-/Algorithms can be loaded (e.g. in Depot or on Launcher)
- can be fired by all future GMLRS Users

GMLRS is the perfect Carrier for the Sensor Fuzed Sub-Munition !

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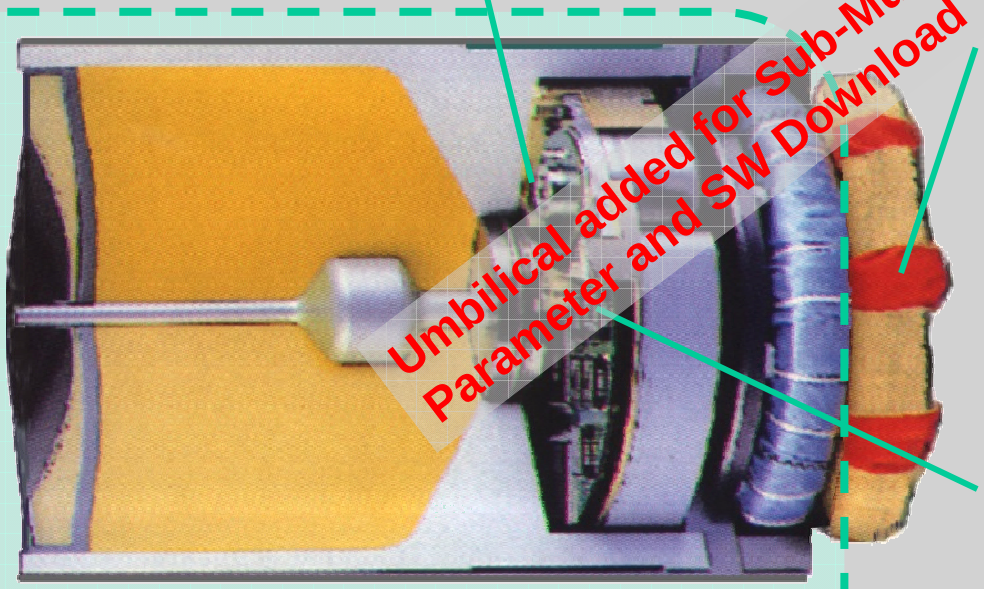
SMArt Adaptation to GMLRS

DIEHL
BGT Defence

Battery Activation under Rocket Control



Ballute changed to
High Speed Drag Chute

S&A Acceleration
Environment changed
to Rocket ESAD Control

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

Minor Modifications only to SMArt Sub-Munition !

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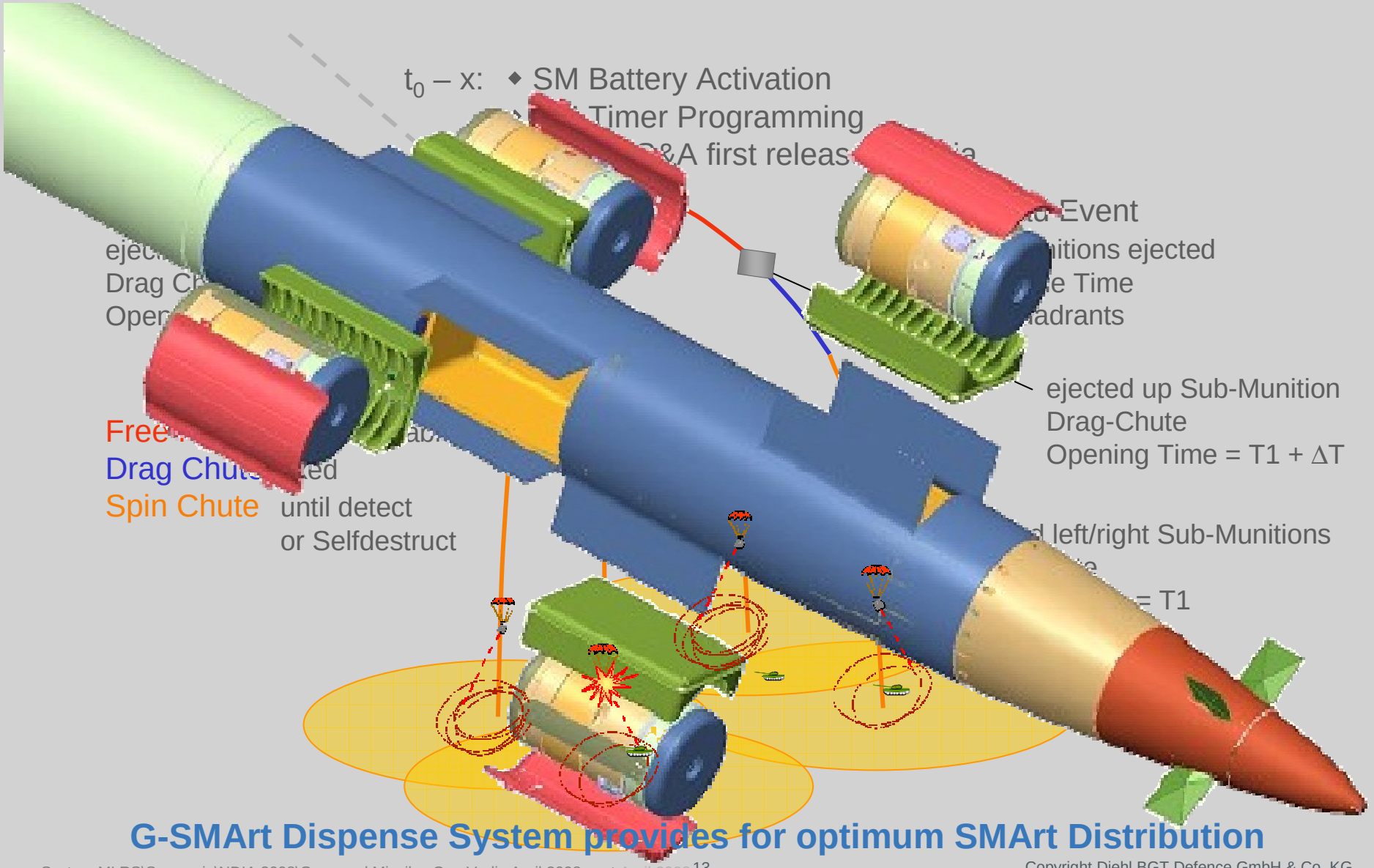
G-SMArt Sub-Munition Dispense

DIEHL
BGT Defence



G-SMArt Dispense System provides for optimum SMArt Distribution

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G-SMArt Firings on M26

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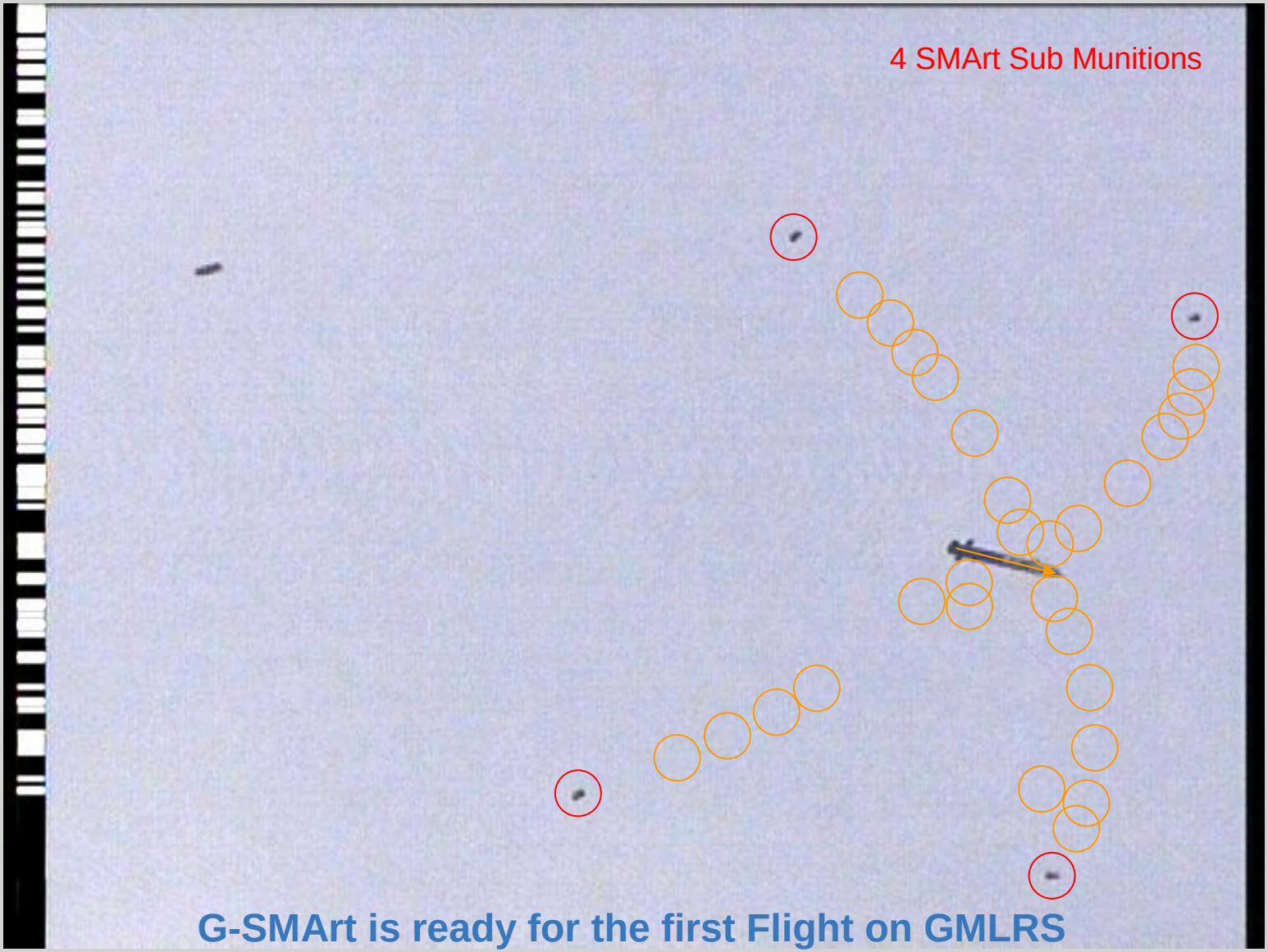
BGT Defence



G-SMArt is ready for the first Flight on GMLRS

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The “protected and lightly armoured” Targets

DIEHL
BGT Defence

- That´s what you know about SMArt

Big Holes in thick Armour!
combined with dramatic behind Armour Effect

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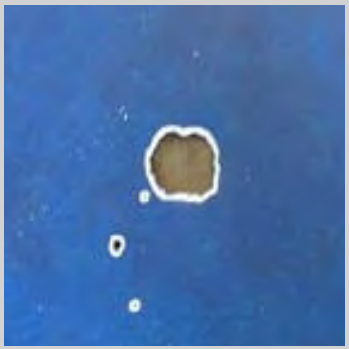
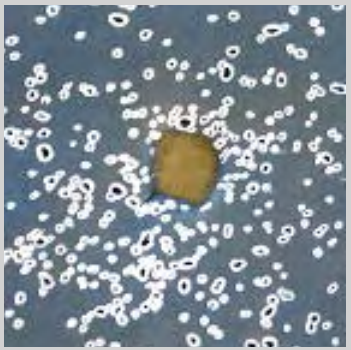
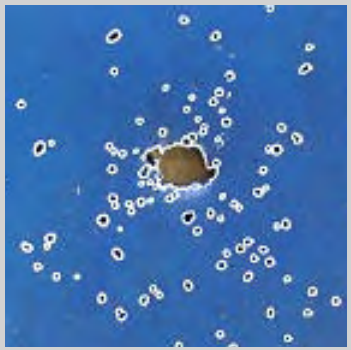
The “protected and lightly armoured” Targets

DIEHL
BGT Defence

- That´s what you know about SMArt Overwhelming Armour Penetration
- This is new: we have to learn about SMArt´s light Armour Penetration

10 mm RHA

1.5 mm St 37

SMArt´s Penetrator provides for significant Effect in light Armour !

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SMArt´s full Spectrum Capability

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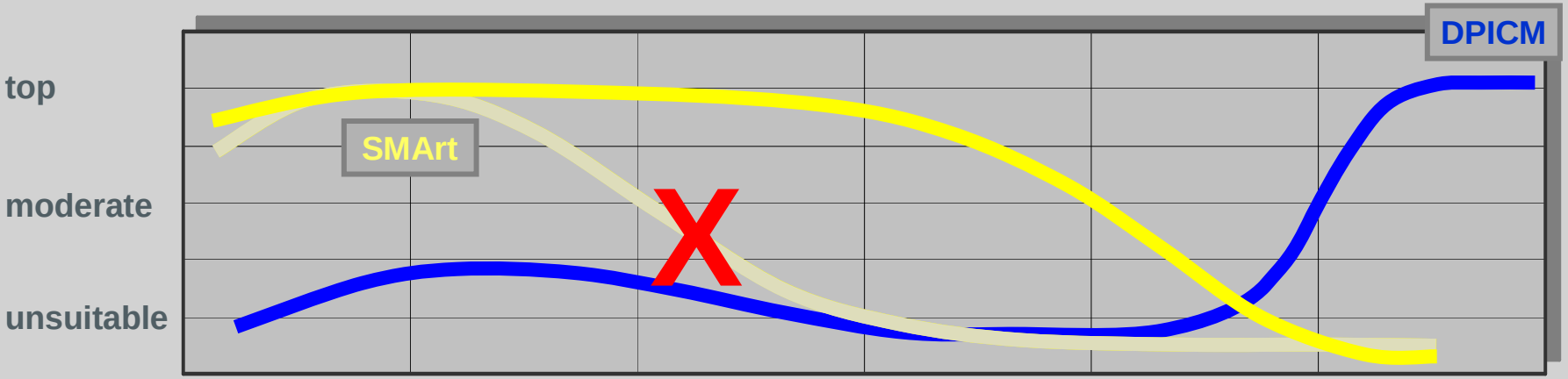

RHA (200+ mm) ← Increasing Thickness/Hardness → Soft Steel/Aluminum (0 mm)

Target Elements

SMArt engages a large Target Set for DPICM Replacement !

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DPICM Replacement Effectiveness

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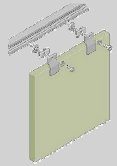
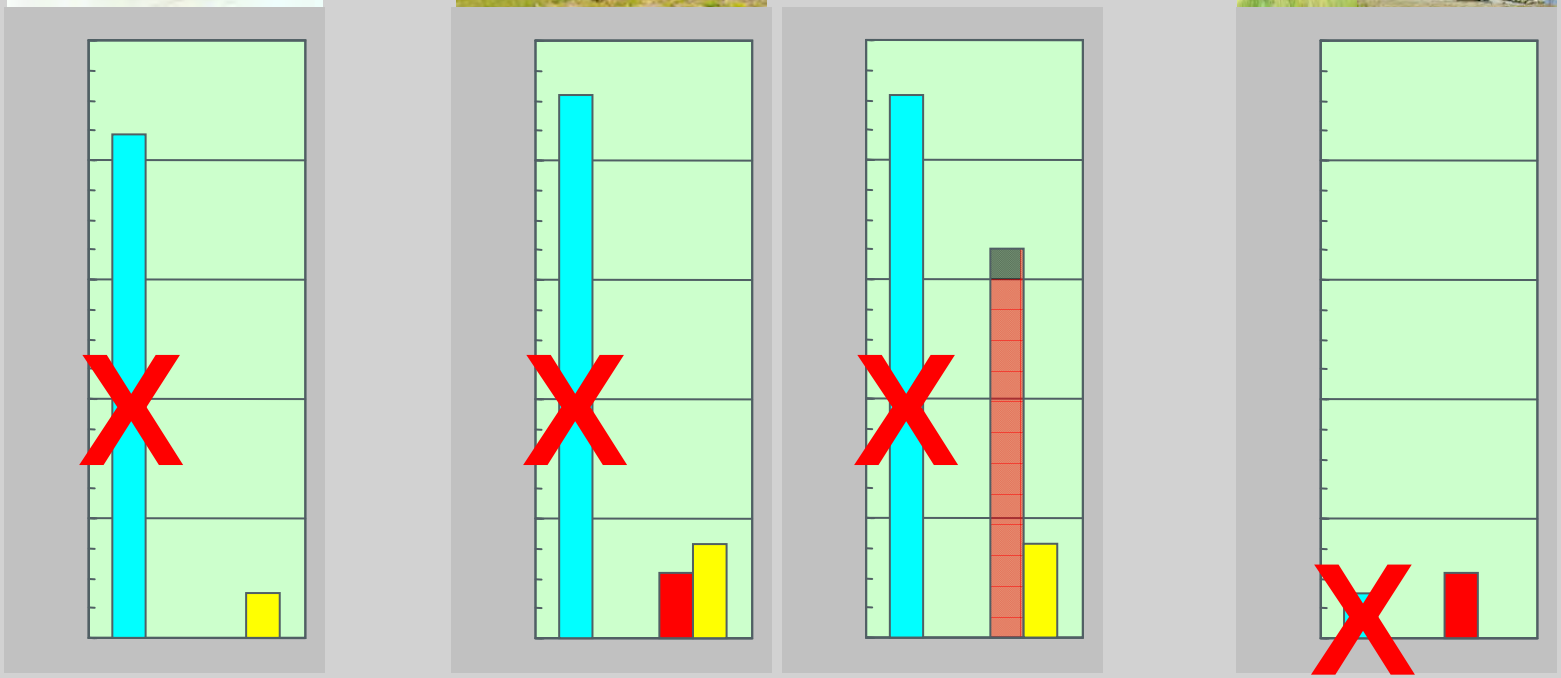
Mech Infantry

Command Post



Artillery



DPICMs can be effectively replaced by SMArt together with KE-Rod !

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G-SMArt Summary

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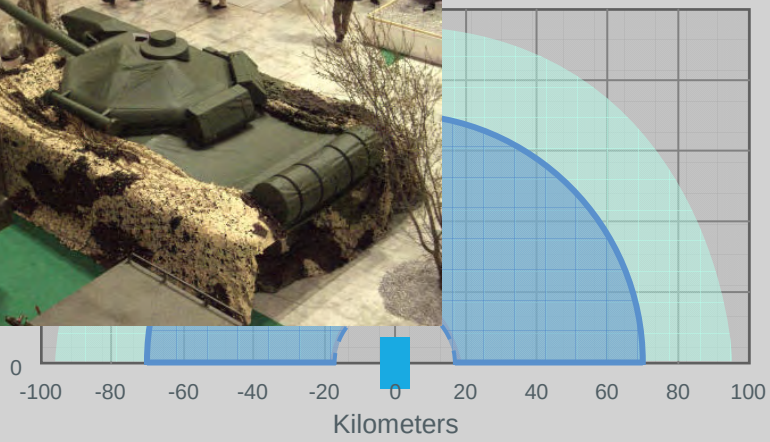
- Quick Solution based on “In Production” SMArt® and GMLRS
  - low Cost
  - low Risk
- Effective against **protected, semi-hard and hard** Targets
  - robust against passive Protection and reactive Armour
  - robust against DAS Countermeasures
  - robust against Decoys
- Wide Attack Footprint
- Minimized Collateral Damage
- Clean battlefield operation due

„Remarkably realistic Decoys“



G-SMArt will take care of all Future Needs attacking protected Targets !

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GENERAL DYNAMICS

Ordnance and Tactical Systems

43rd Annual Armament Systems: Gun and Missile Systems Conference & Exhibition
Event #8590
April 21 - 24, 2008
New Orleans, Louisiana

"Strengthening Capability through People and Technology"

GD-OTS 20mmx102mm Mechanically Fuzed Projectile Program

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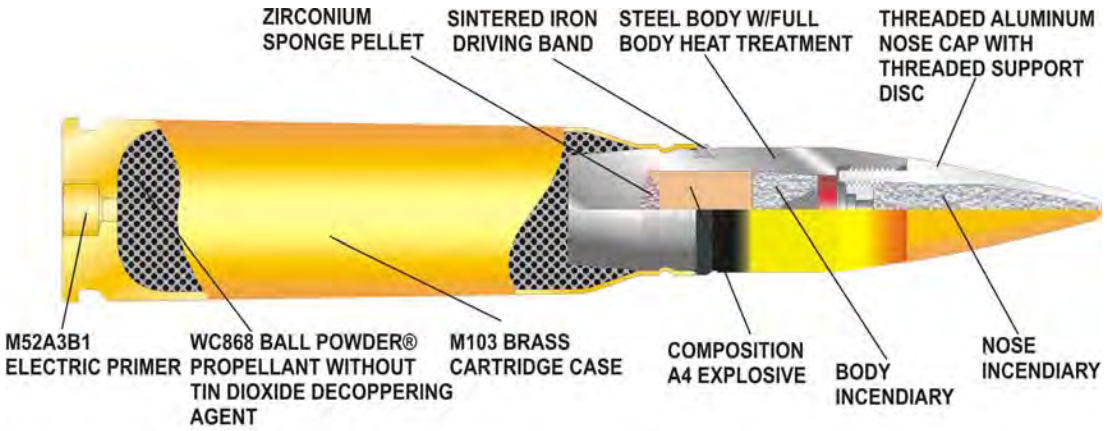
Introduction:
GD-OTS 20mm Fuzed Cartridge Alternative

- 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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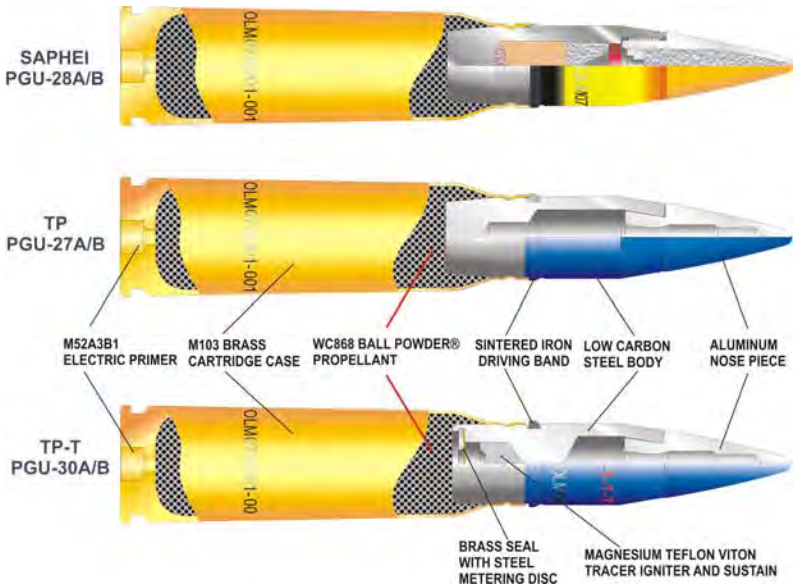
Cartridge Safety and Performance Requirements

- **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
  - Delayed function 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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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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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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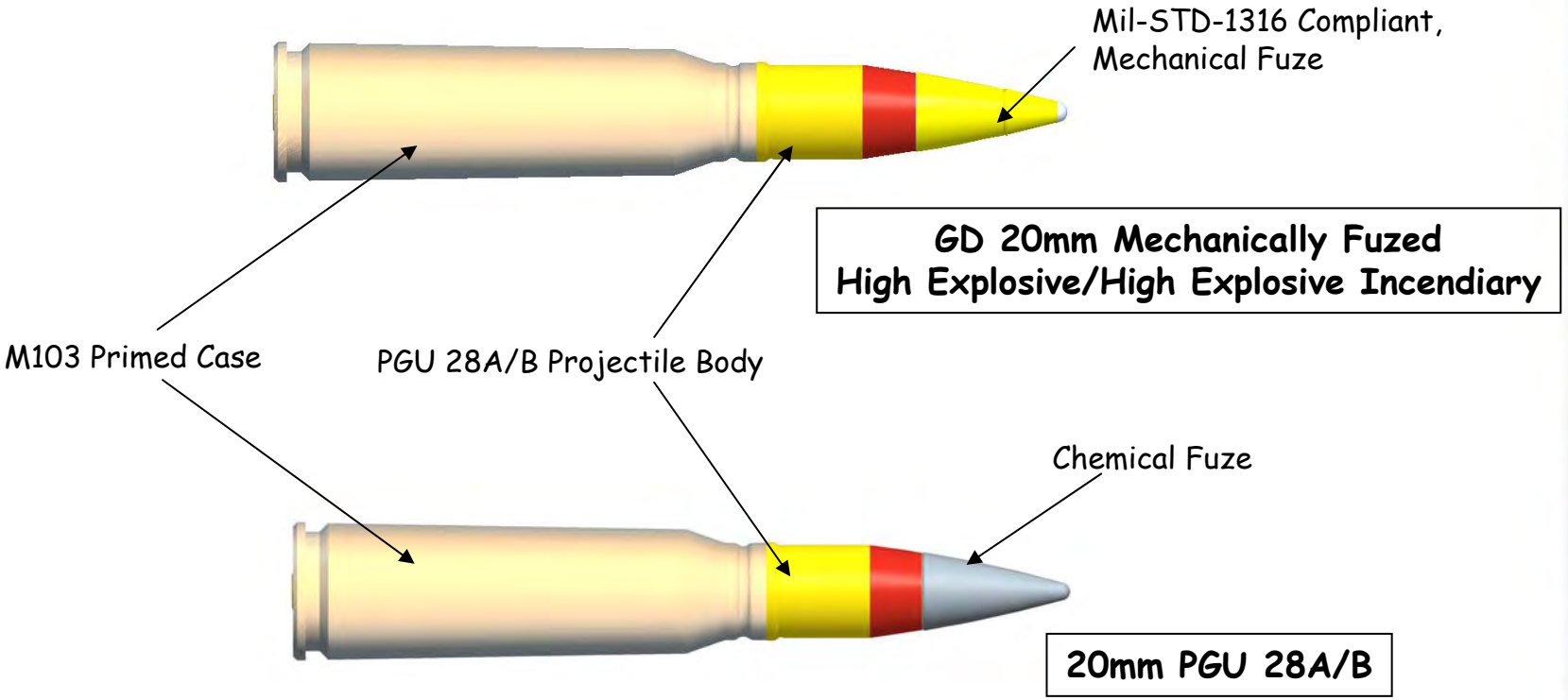
Cartridge Description



-Cartridges utilize same propellant and LAP facility.

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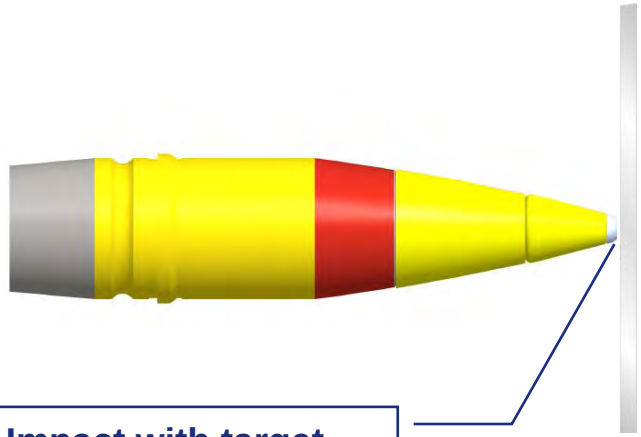
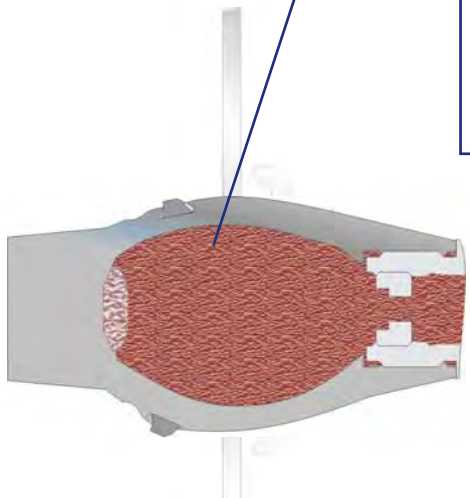
GD-OTS 20mm Fuzed Cartridge Alternative



Impact with target initiates firing train



- In PD configuration, body detonates immediately following impact with target.
- Delay mode mimics performance of current PGU-28A/B.

Fuze design can be be tailored to meet customer requirements.

Evidence of PD function, 3xcaliber holes left on 4'x4'x.080" Aluminum trigger plate

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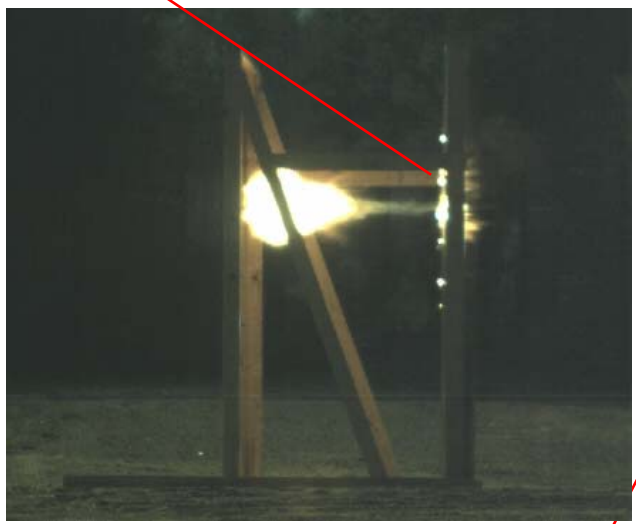
GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Fragmentation from detonating projectile body



Witness Panels

Aluminum Trigger Plate

Witness Panels

Impact with .080” and .063” Aluminum at 200 yards. Detonation occurs thousandths of a second after impact, producing lethal fragments with a flash bang effect.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Graze Sensitivity test set-up. .080" Aluminum Trigger Plate set @ 75 degrees NATO

Witness Panel 6' Behind Trigger Plate

Capable of defeating both air-to-air and air-to-ground graze targets.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Perforations of 3/8 Inch RHA. Meets penetration requirement per PGU-28A/B specification.

Penetration capabilities make the GD round highly effective against light armored targets.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Steel Construction

A vehicle, similar to enemy infantry carriers, was fired upon to test effectiveness against not only the vehicle but personnel. Mannequins were placed in the cab and bed of vehicle.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

When fired against cab of truck, mannequins suffered fatal injuries including separation of three limbs from driver's body.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Projectile achieved mobility kill after first shot fired against the engine.

After 1st shot

After 5th shot

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

Projectile inflicted severe damage on each of the four mannequins when fired at truck bed.

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GD 20mm Testing: GD-OTS 20mm Fuzed Cartridge Alternative

VIDEO

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Test Summary: GD-OTS 20mm Fuzed Cartridge Alternative

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 at Temperatures	N/A
Armor Penetration	Met Requirement	Expected to meet requirement per PGU-28A/B specification
Projectile Sensitivity	Demonstrated	Demonstrated at Temperatures
Long Range Sensitivity (600m)	Test Not Performed	Demonstrated
Point Detonating Function	N/A	Demonstrated at Temperatures
Fragmentation	Demonstrated	Demonstrated
Graze Sensitivity (75 Degrees)	Demonstrated	Demonstrated at Temperatures
Function and Casualty	Demonstrated	Demonstrated
Safety Tests	Passed Mil-Std-331 D1 Out-of-Line Safety Test @ Ambient and Cold Test at Hot to be conducted	Passed Mil-Std-331 D1 Out-of-Line Safety Test @ Ambient and Cold Test at Hot to be conducted
No-Arm (3 meters against .040" Al)	Passed	Passed

Testing against all key baseline performance requirements demonstrates enhanced lethality, safety and graze sensitivity.

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GD Mechanical Fuze Growth in other Calibers

- Integrated mechanical fuze into the 30mm x 173 HEI projectile.
- Design is a ballistic match to PGU-14 API round.
- Mechanical fuze increases capabilities from the baseline design, which utilizes the M505 fuze.
  - Increased Graze Sensitivity
  - Improved Safety
- Ballistic match comparison test fired at Yuma. Results verified ballistic match.
- Function test successful at Marion Test Facility.

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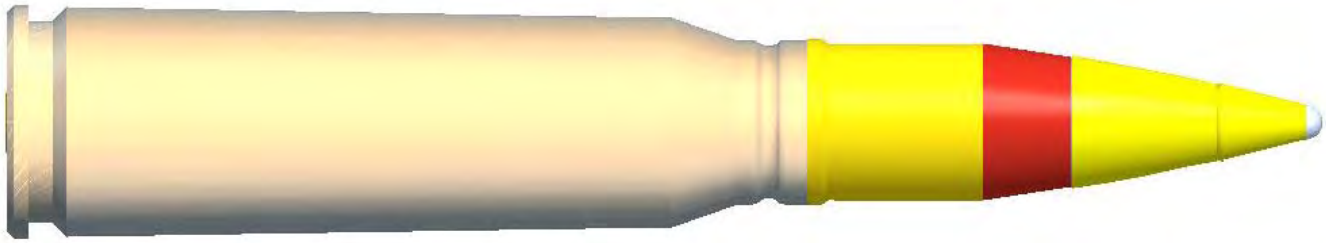
Summary: GD-OTS 20mm Fuzed Cartridge Alternative



- Meets weight and envelope requirements for 20mm PGU ammunition while using many common components
- Fuze design compliant with Mil-Std-1316
- Point detonate configuration demonstrated
- Delay function, meeting 20mm PGU-28A/B specification, demonstrated
- Ballistic match to PGU-28A/B
- Meets performance requirements established at program start
- Fuze design can be integrated into all applications ranging from 20mm to 30mm.

Ready for combat today!

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Questions?

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RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

The Deployment Dynamics: Analysis of the 81MM Illumination Mortar Cartridges

Seungeuk Han & Raymond Trohanowsky

AMSRD-AAR-MEM-A

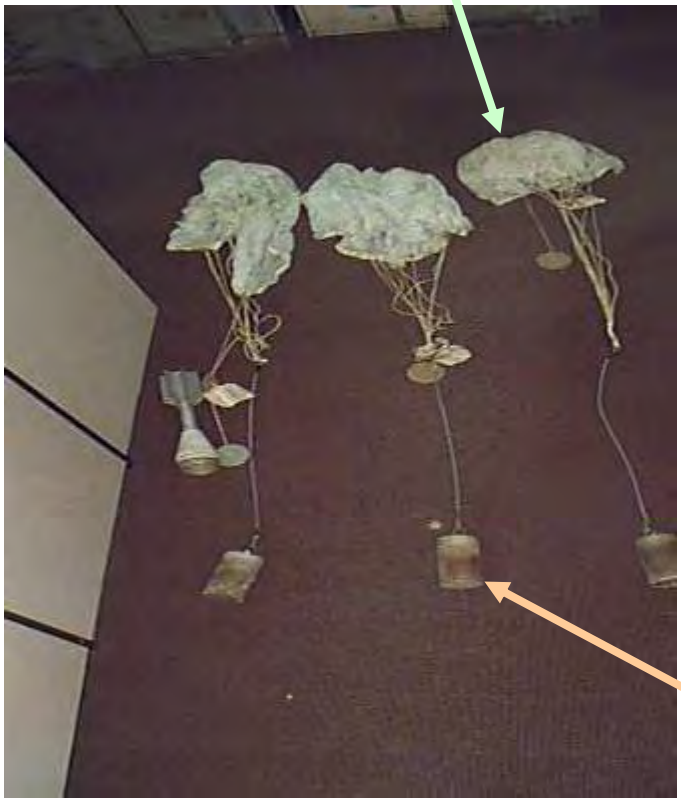
Aeroballistics Division

Munitions Systems & Technology Directorate

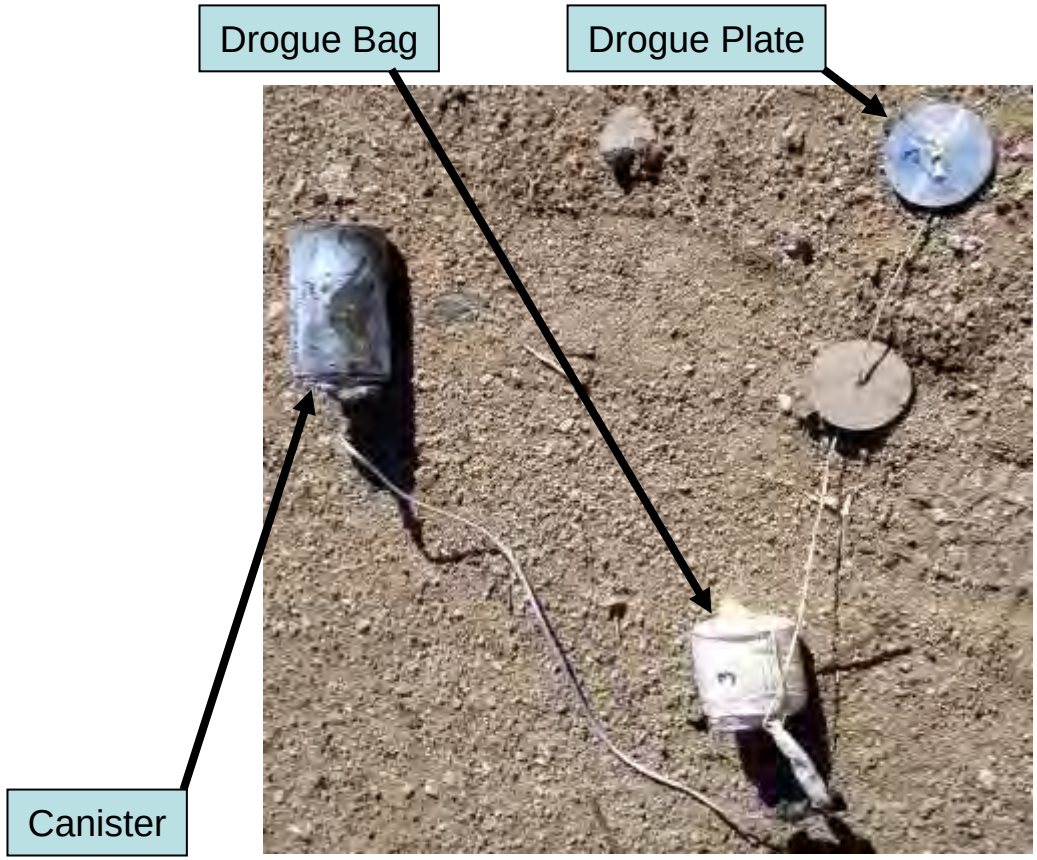
BACKGROUND

- The M853A1, 81mm Illuminating, Mortar Cartridges experienced 11 streamers during the ballistic LAT at Yuma Proving Ground on July 25, 2006.
- Nine(9) of eleven(11) streamers were reported as the non-deployment (the canopy and suspension lines still inside the bag).
- FMEA narrowed to three possible causes: frozen bag, insufficient drogue plate, or jammed main canopy.
- Pull tests and wind tunnel test had been conducted to verify the root cause.

SYSTEM DESCRIPTION

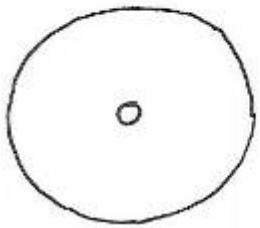


Deployed Canopy



Non-Deployed (Streamer)

Drogue Plate

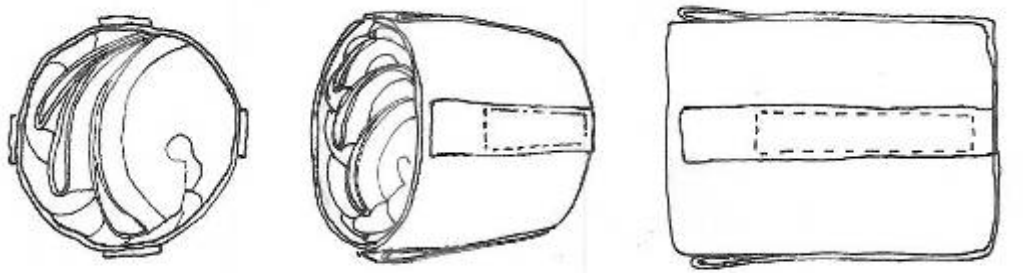


FRONT VIEW

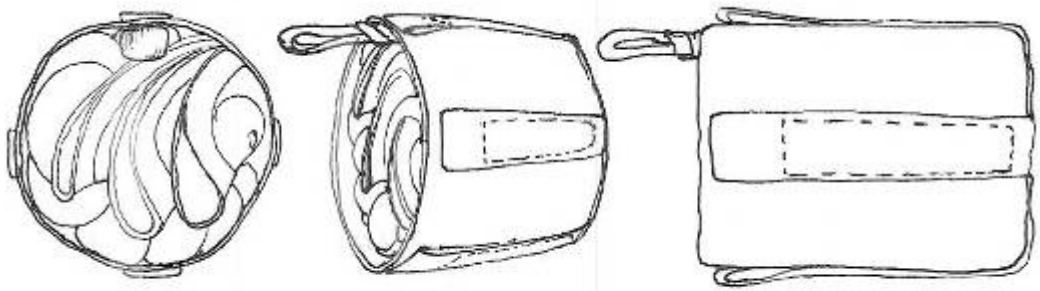
45 deg ANGLE VIEW

90 deg SIDE VIEW

Intact Drogue Bag with/without Riser

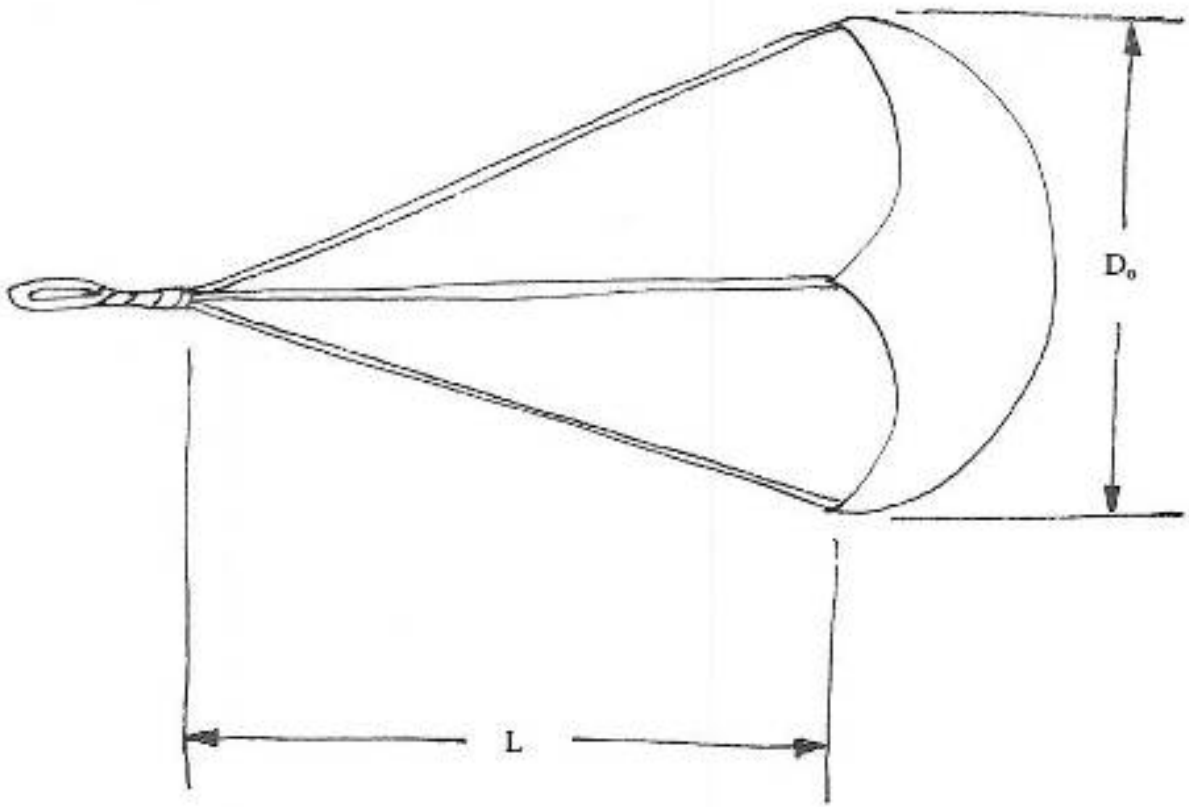


FRONT VIEW 45 deg ANGLE VIEW 90 deg SIDE VIEW



FRONT VIEW 45 deg ANGLE VIEW 90 deg SIDE VIEW

The deployed 9 inch Drogue Chute



$D_o = 0.7 * D_c$, which is inflated canopy diameter
$D_c = 9$ inches, which is constructed canopy diameter

SPECULATIONS

- Frozen Bag: A bag exposed to high humidity then frozen may require more force to deploy the main canopy than the bag stored at ambient condition.

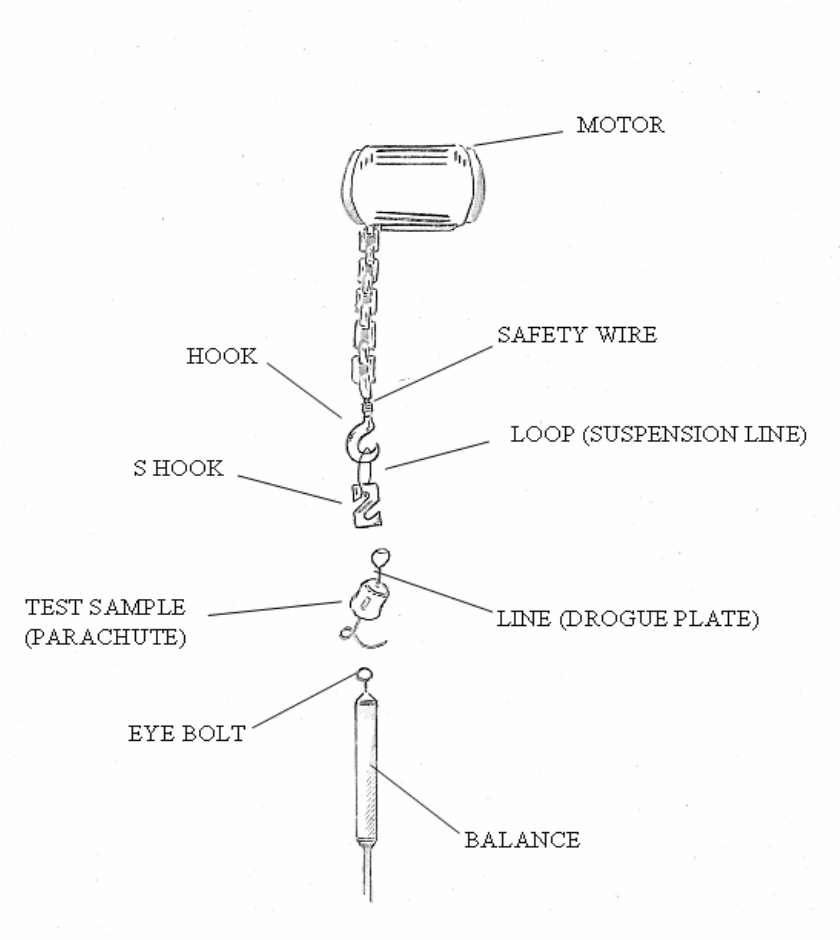
- Insufficient Drogue Plate: Drogue plate may not generate adequate drag force to deploy the main canopy.

- Jammed Main Canopy: Canopy may be jammed inside the drogue bag due to one of these phenomenon:
  - Chinese Finger-cuff Effect: due to the fiber orientation of the bag, the bag may constrict as it is pulled.
  - Piston (Vacuum) Effect: due to the vacuum inside the bag, the canopy may be difficult to deploy from the bag.

PROCEDURES

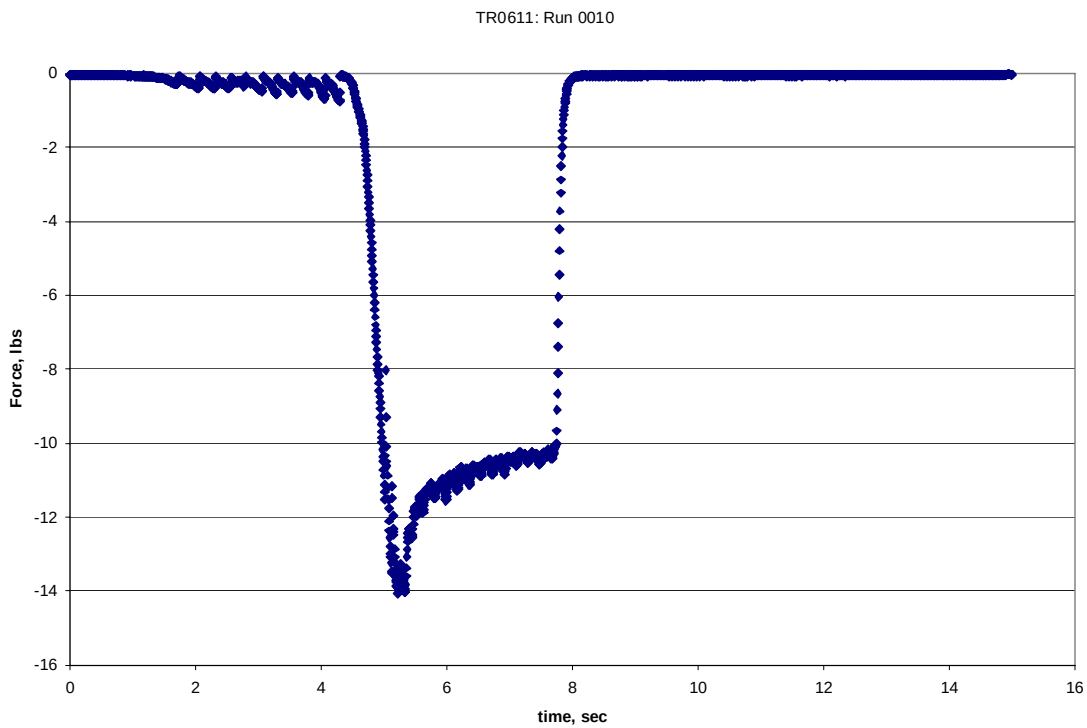
- Laboratory Tests were completed to validate FMEA alternatives
  - Pull Tests
    1. Steady Pull Test
    2. Dynamic Pull Test
  - Wind Tunnel Tests
    3. Aerodynamic Characterization Test
    4. Drag Force Comparison Test
- This test data was evaluated to determine FMEA and propose design alternatives

STEADY PULL TEST APPARATUS

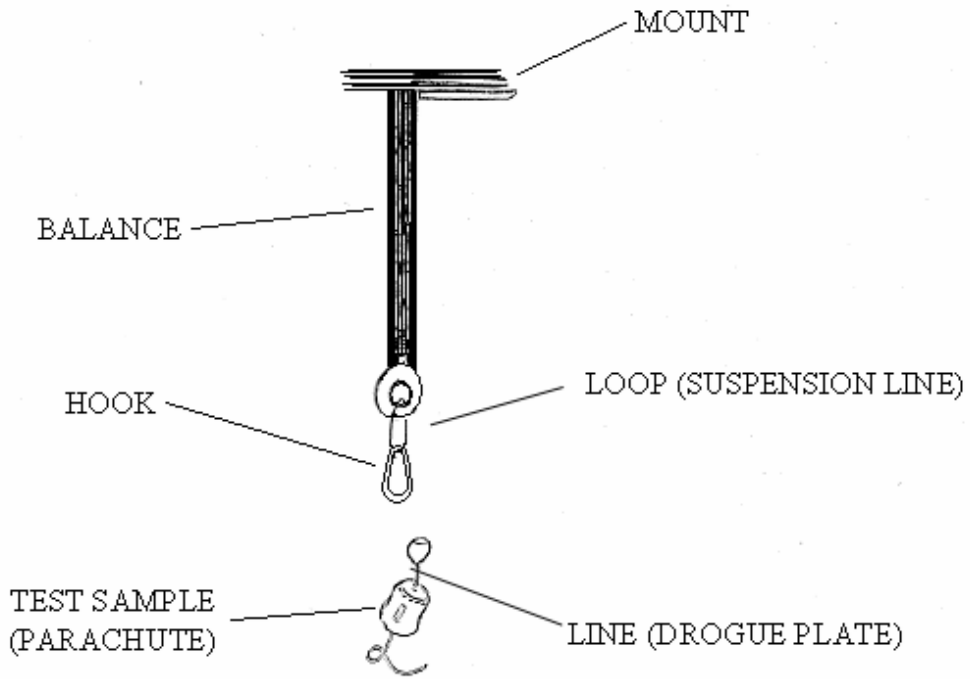


STEADY PULL TEST

- Alternative configurations were tested.
- Ten baseline configurations were temperature conditioned at –30°F for a minimum of 5 hours, then tested.
- The drogue plate suspension line was tied to an eye bolt connected to the 1.23” balance.
- The test samples were pulled at a constant rate of 1.6”/sec until the main chute is fully deployed from the drogue bag. The data acquisition system tracks the force history.

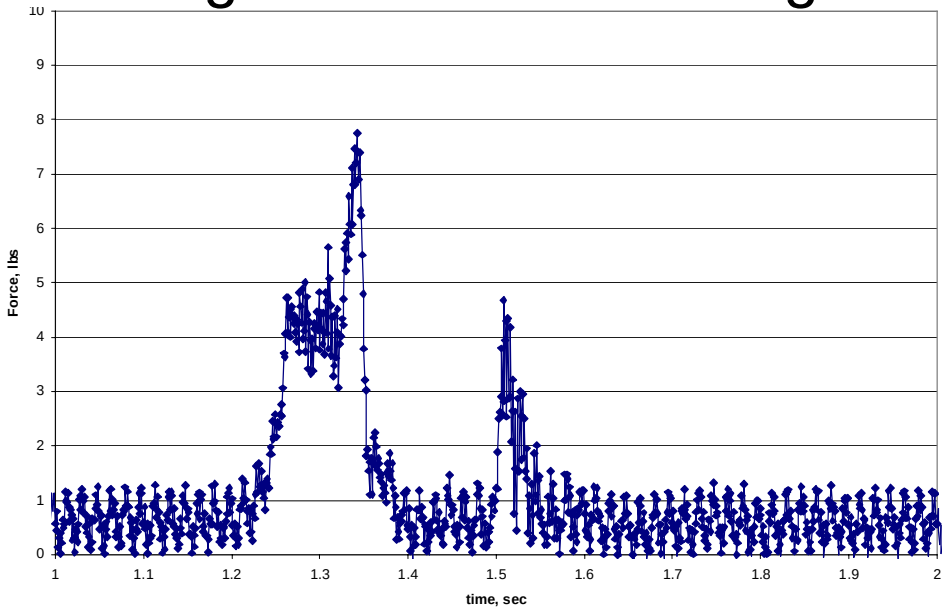


DYNAMIC PULL TEST APPARATUS



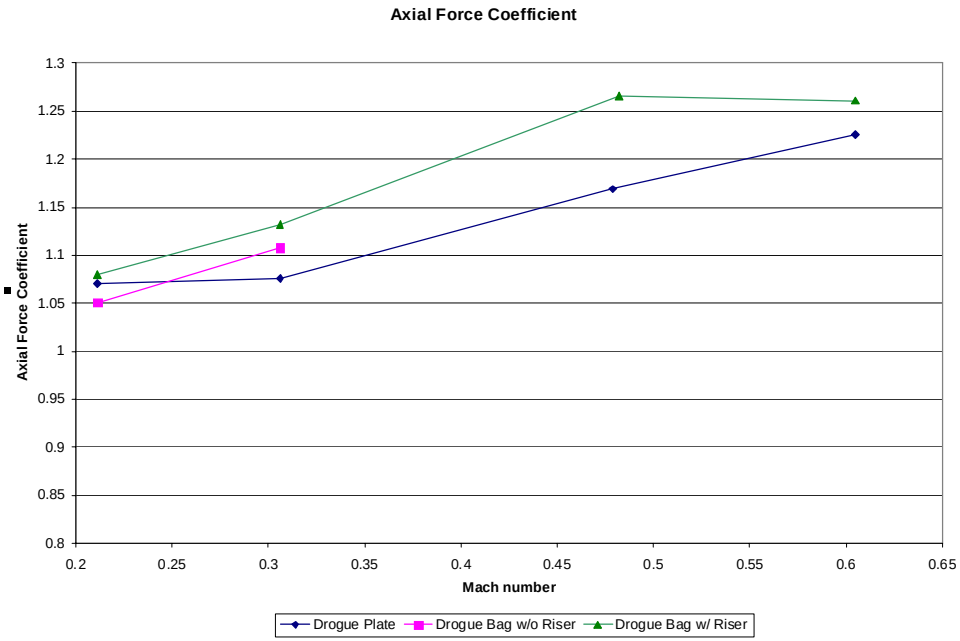
DYNAMIC PULL TEST

- A balance was mounted to an A-frame in a high bay area.
- The safety to protect the balance was 80 lbs.
- A ballast of 4 lbs was dropped at two predetermined heights (29 inches and 78 inches from the ground).
- The data acquisition system tracks the force history transmitted through the balance during the entire testing.



DRAG FORCE COMPARISON TEST

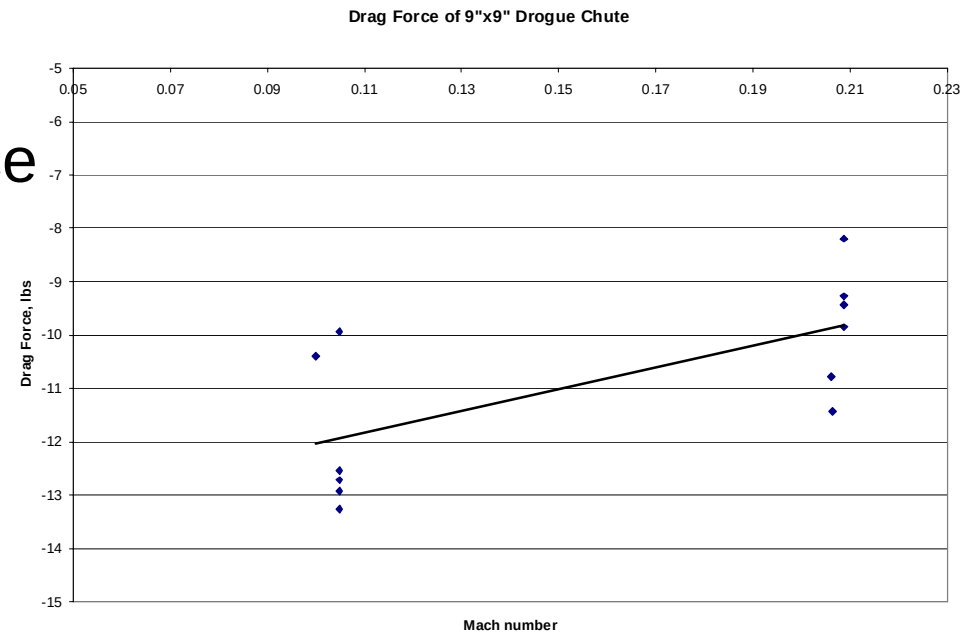
- Three configurations were tested: drogue bag without the riser, the drogue bag with riser, and the drogue plate.
- The 0.88B strain gage balance was used.
- Mach numbers tested include 0.21, 0.30, 0.50, and 0.61 with the angles-of-attack of -4 to +15 degrees.
- The aerodynamic test conditions, axial force, pitching moment, and normal force were recorded.



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

AERODYNAMIC CHARACTERIZATION TEST

- The drogue chutes were attached to an eyebolt, which was attached to the 0.88B strain gage balance inside the bomb strut assembly located upstream of the test section.
- Mach numbers tested include 0.21, 0.30, 0.50, and 0.61 at zero angle-of-attack.
- The aerodynamic test conditions, and axial force were recorded.



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RESULTS

- Steady Pull Tests:
  - Required pull force (2 -4 lbs) agreed with historical data, without any abnormality.

- Dynamic Pull Tests:
  - The required pull force increases as the snatching force increases.
  - The required pull force is not linear over snatching velocity.

AERODYNAMIC CHARACTERIZATION

- No significant differences in drag among the three configurations (the intact bag with/without riser, the drogue plate).
- Due to similar drag and weight between the drogue plate and drogue bag, there is no momentum difference between the two.
- Inversely, this finding raises a question about the successful deployments.

DROGUE CHUTE DEPLOYMENT TESTS

- The 9 inch drogue chute performance is insensitive to the tested suspension line lengths.
- The drag of the 9 inch drogue chute exhibited around 30 lbs (about 8 - 9 times of the drogue plate) at Mach 0.2.

CONCLUSIONS

- The results of the pull test came out as expected and agreed with the previously reported data (no new findings).
- The dynamic pull test showed an increase in the mean pull force but inconclusive due to a trend of nonlinearity.
- The wind tunnel test showed no drag difference between the drogue bag and the drogue plate.
- The successful deployment in the past might be done mechanically and accidentally (by swing motion of the aluminum drogue plate) rather than aerodynamically.
- In order to make the function aerodynamically, the 9” square drogue chute is highly recommended.

RECOMMENDATIONS

- Conduct a horizontal ballistic test to characterize the ADS of the 81mm, M853A1.
- A lab test to simulate and understand the steel cable bending phenomenon.

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EAPS

EXTENDED AREA PROTECTION & SURVIVABILITY

System Modeling for Projectile Design and Optimization

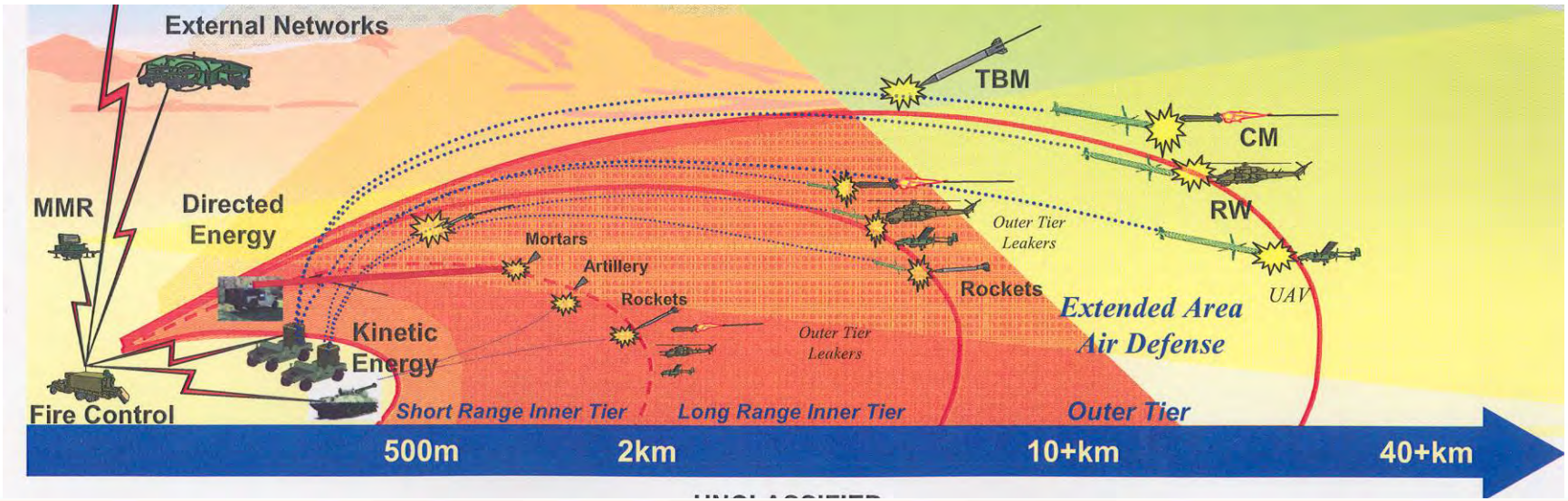
Presented By : Phil Brislin

AGENDA

- What is EAPS?
- Development of a projectile design model.
- Algorithm description.
- Benefit to the EAPS program.

Extended Area Protection & Survivability (EAPS)

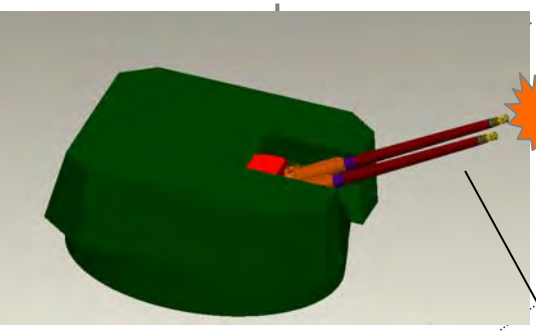
- Aerial defense system against Rockets, Artillery, and Mortars (RAM) threats.
- Two year ARDEC Advanced Technology Objective (ATO) ending in a demonstration of critical technologies including: course correction, lethality, and command warhead detonation.
- Provide future defeat capability for the Extended Area Air Defense System (EAADS) comprised of 360 degree mobile RAM defense.



EAPS Baseline System Concept

50mm Bushmaster Cannon

RF Data Link



Radar Track

Forward Fragmentation Warhead Detonation

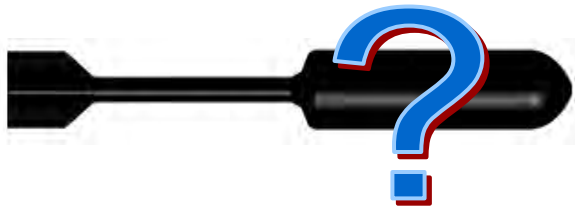
Mid-Flight Course Correction

10 Round Burst

50mm Course Corrected Projectile

Design Challenges and Goals

- The EAPs bullet has a number of difficult performance objectives that often have conflicting subsystem goals and limited available space.
- The system trade study provided a list of projectile requirements.
- What are the best projectile subsystem design compromises that will give maximum overall system performance?



- Develop one comprehensive model to evaluate projectile performance and find the best design space to begin detailed design.

Merging Requirements and Design Constraints

System Performance Requirements Flow Down

Examples

- 1000m Range
- Lethal Fragments
- Pattern Density
- Strike Velocity
- Thruster

50mm Trade Study Results

Matlab Configuration Study

Optimized Projectile Framework to Begin Detailed Design

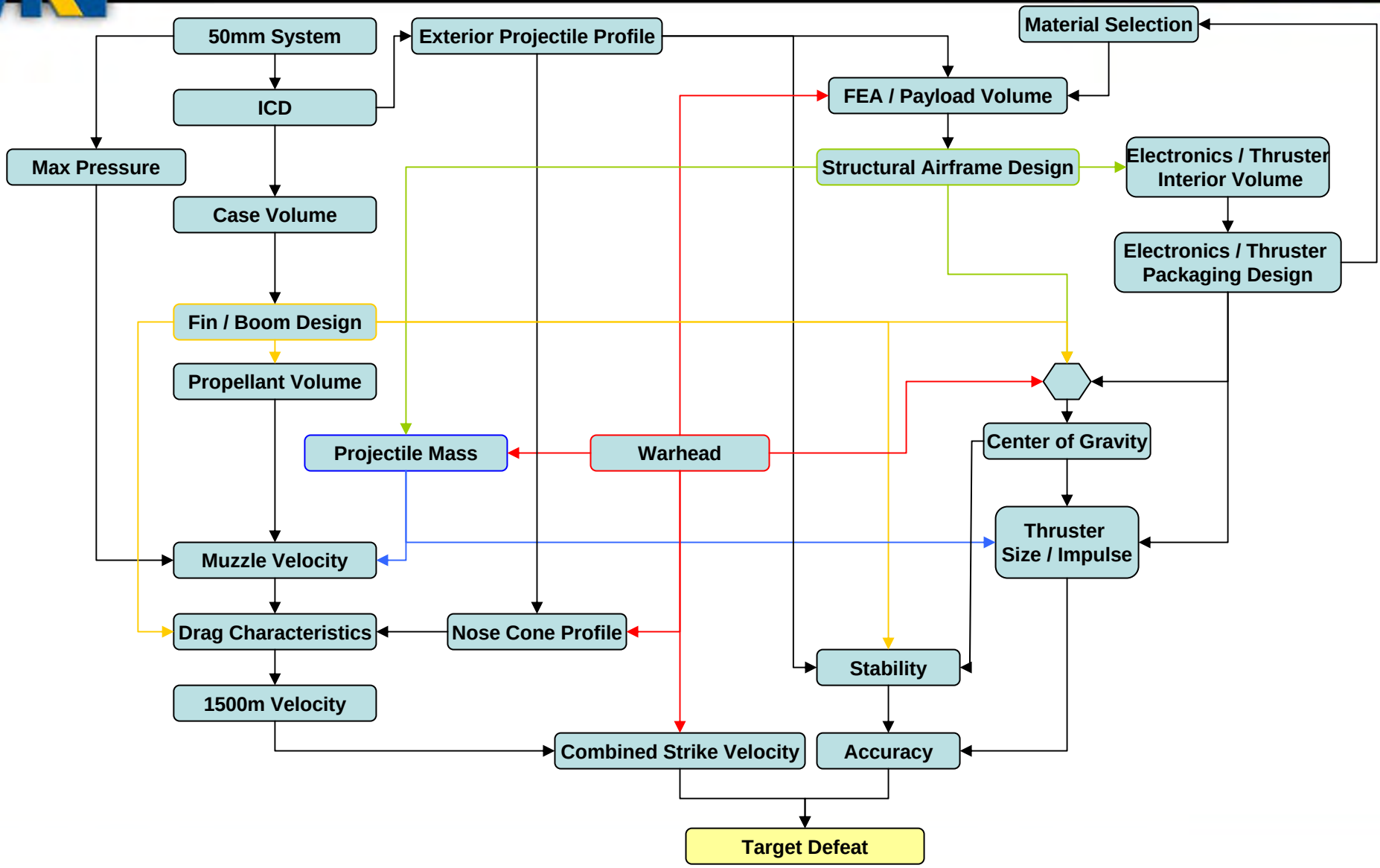
Design Constraints

Examples

- Aerodynamics
- Mass Properties / CG
- Survivability (Stress)
- Material Properties
- Propulsion Data
- Warhead Formation

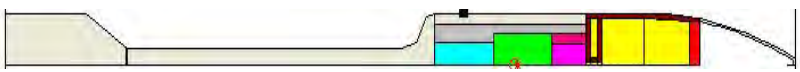
Collect Inputs from Design Groups

Understand the EAPS System

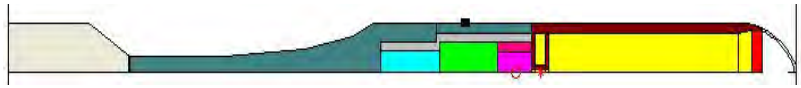


Implement a Solver Method

- Design Space Challenges
  - Numerous invalid variations exist causing convergence issues.
  - Analytic solution methods difficult to implement and adapt.



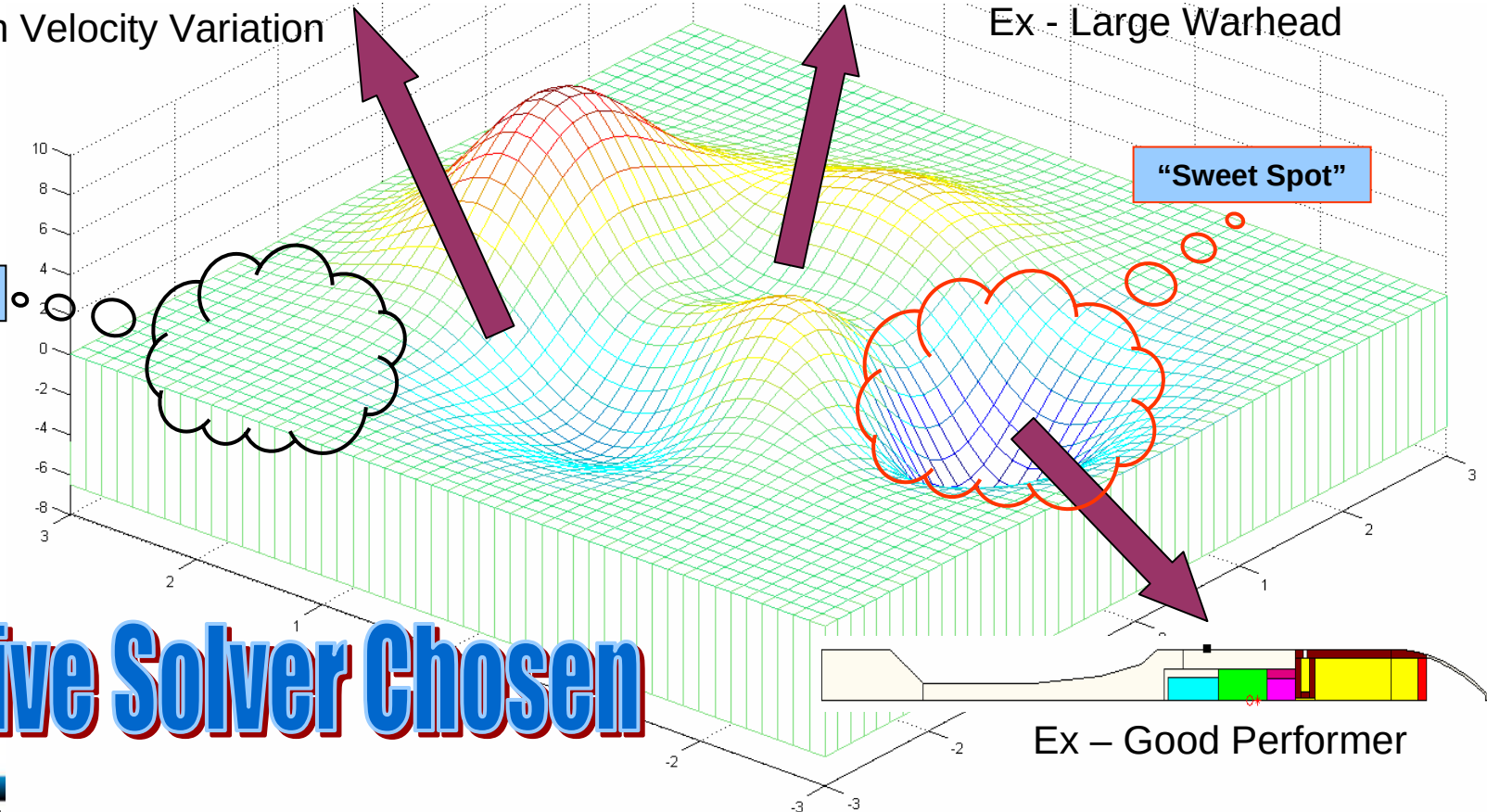
Ex - High Velocity Variation



Ex - Large Warhead

Invalid Solutions

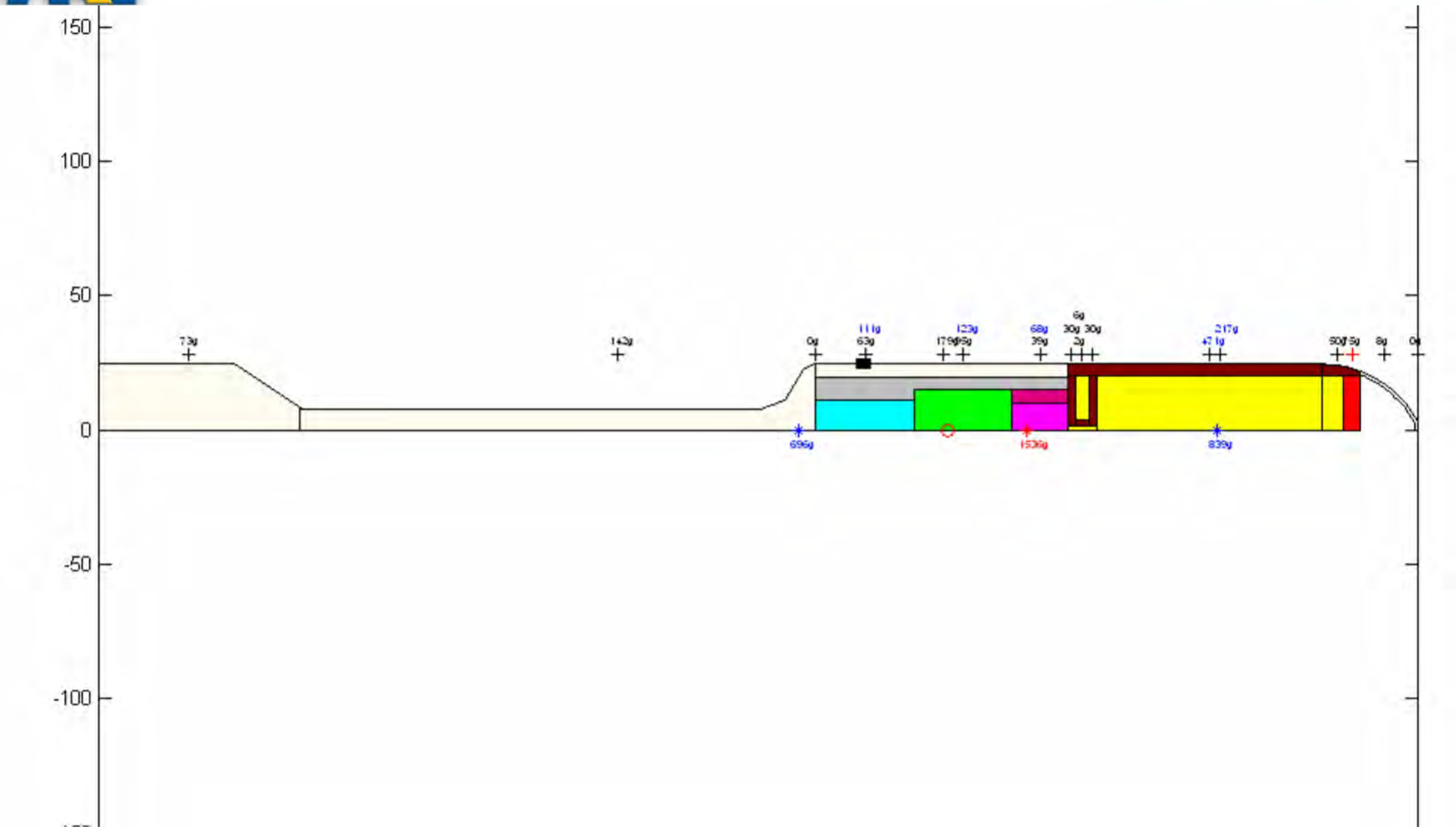
“Sweet Spot”



Iterative Solver Chosen

Ex – Good Performer

Matlab Configuration Study Video

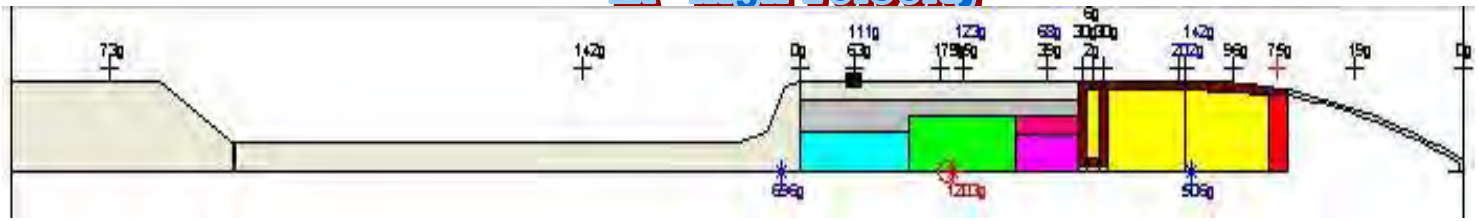


Algorithm Description

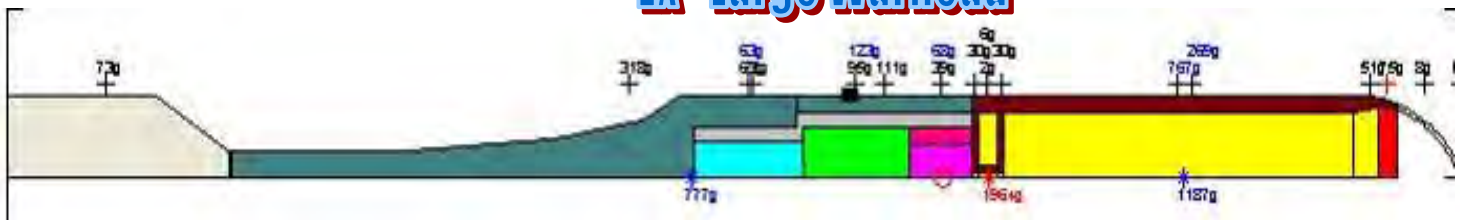
Requirements & Variable Inputs → Interior Ballistics & Survivability → Exterior Ballistics & Lethality → Requirements Check, Ranking & Summary

- Requirements - Strike velocity, center of gravity, max weight, etc.
- Generates geometry & assembles components
  - Calculates or integrates mass properties (Pro E verified).

Ex - High Velocity



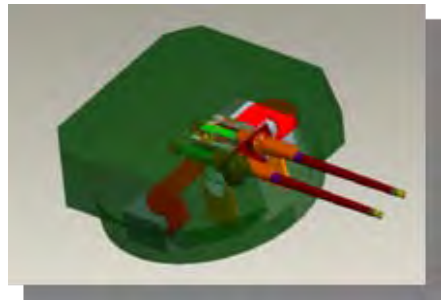
Ex - Large Warhead

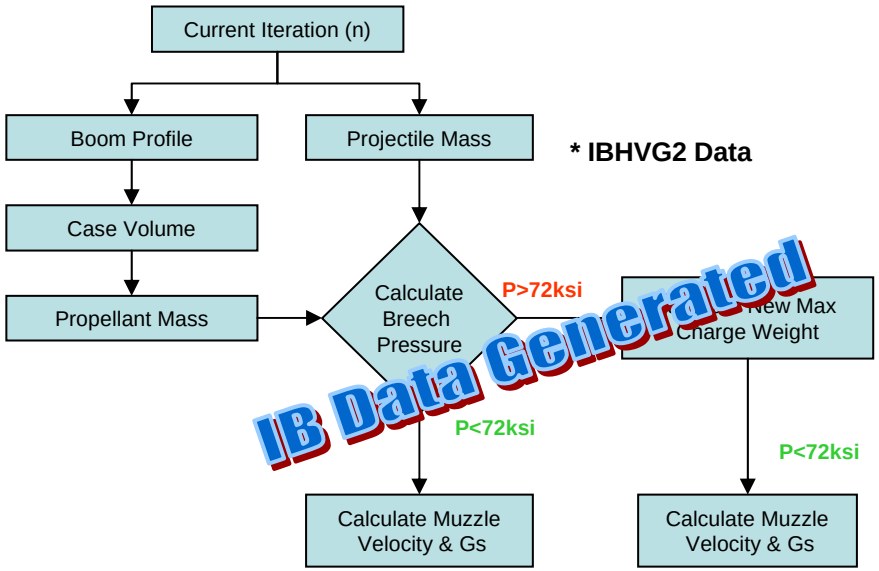


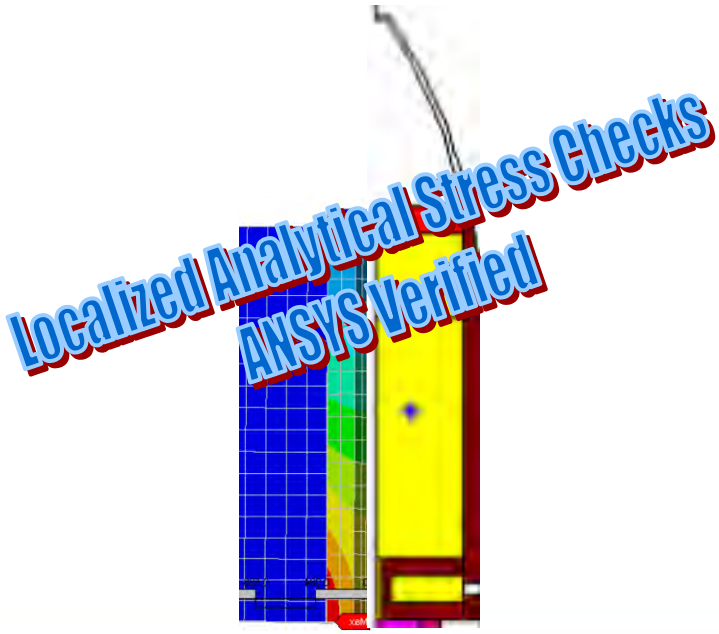
Algorithm Description

Requirements & Variable Inputs → Interior Ballistics & Survivability → Exterior Ballistics & Lethality → Requirements Check, Ranking & Summary

- Interior Ballistics and Survivability
  - Load max charge allowable
  - IBHVG2 data for max pressure and velocity
  - Stress checks throughout the projectile



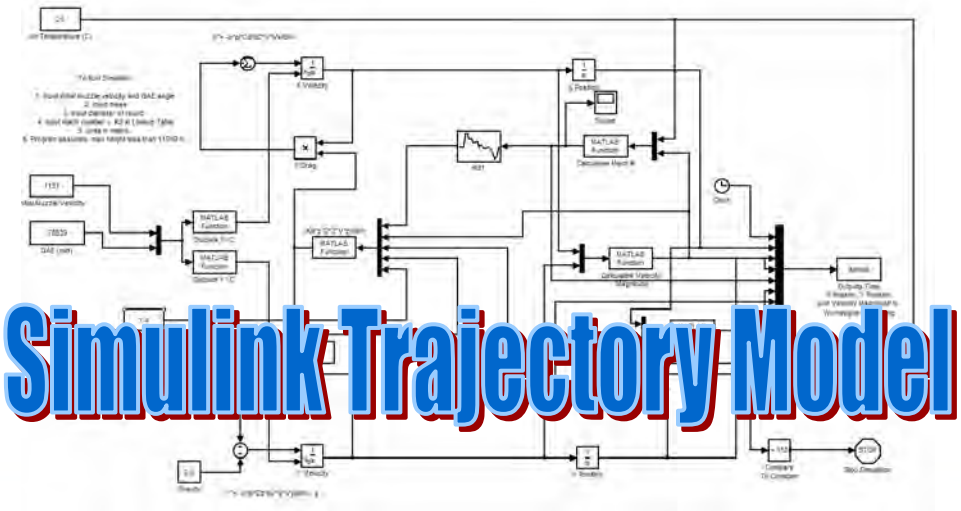




Algorithm Description

Requirements & Variable Inputs → Interior Ballistics & Survivability → Exterior Ballistics & Lethality → Requirements Check, Ranking & Summary

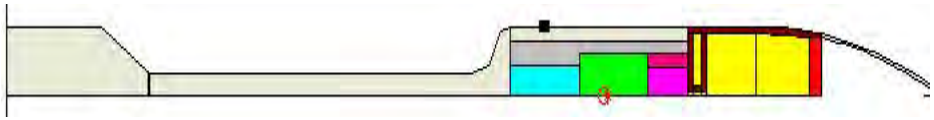
- Flight Dynamics
  - Determines velocity falloff for every unique configuration.
- Lethality
  - Determines warhead velocity (based on Dyna and CTH runs).
  - Calculates maximum effective range for target defeat.



Algorithm Description

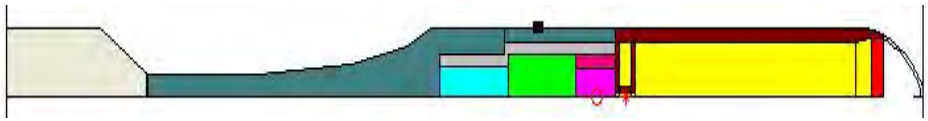
Requirements & Variable Inputs → Interior Ballistics & Survivability → Exterior Ballistics & Lethality → Requirements Check, Ranking & Summary

Ex - High Velocity



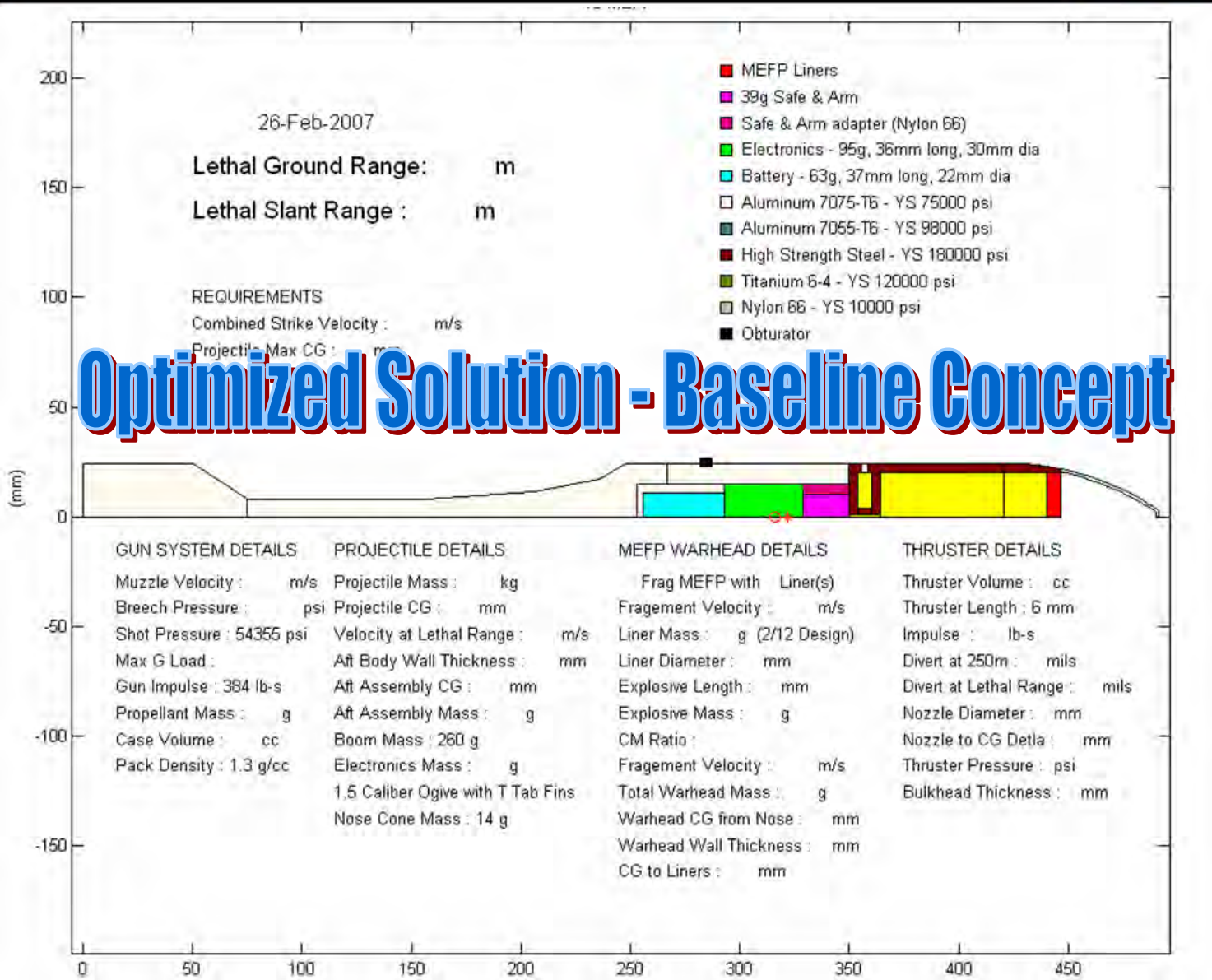
- High muzzle velocity
- Failed stress check
- Exceeds electronics G limit
- Warhead velocity insufficient
- Poor thruster location

Ex - Large Warhead

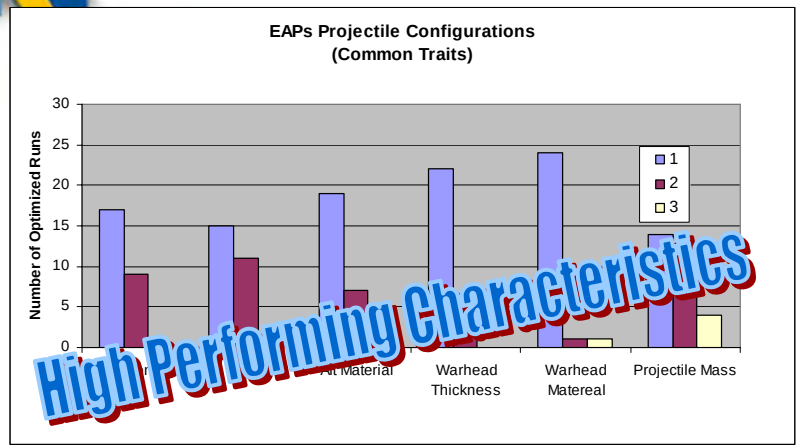


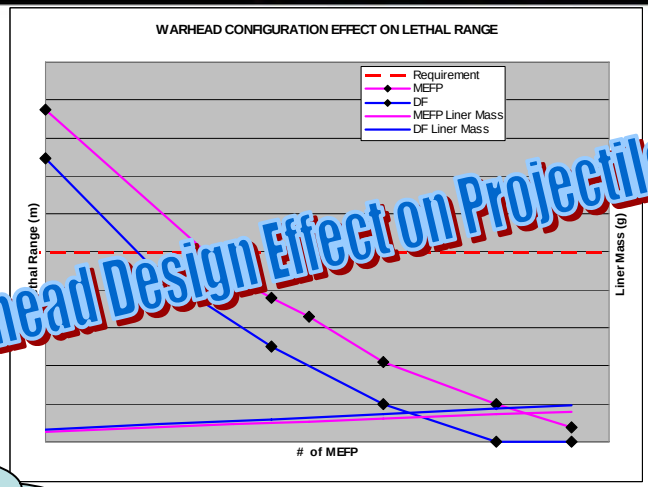
- Very low muzzle velocity
- Exceeds max weight
- High warhead velocity

Study Output Summary

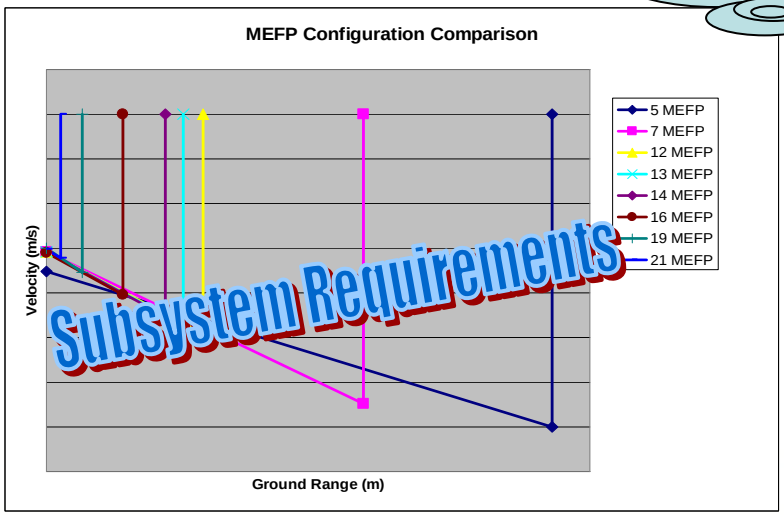


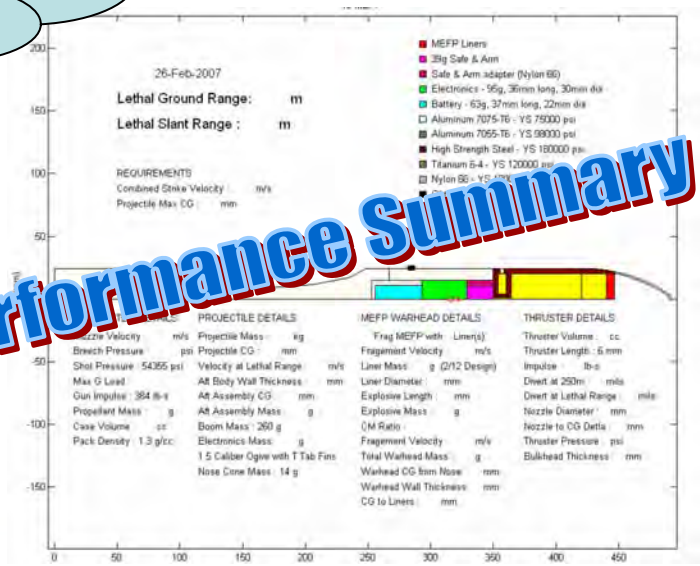
Additional Examples of Results





Solid System Understanding





Summary

- Level of fidelity and resolution of system modeling is time dependent.
- EAPS study provided an excellent first cut design for a 4 month time frame.
- EAPS subsystem design requirements established with modeling.
- Avoiding the sequential design method saved at least 4 months and ~$200k.

QUESTIONS ?

Knowledge Management and Retention

A looming crisis for the unprepared

Presented by

VSE Corporation

ENTERPRISE EXCELLENCE

Knowledge Management and Retention

Historical Attrition

- Competition
- Retirement
- Career Change
- Catastrophic Accident

Knowledge Management and Retention

Issues of the 21st Century

- Advanced Technology
- Specialized Knowledge
- Baby Boomer Generation
- Uneven Hiring Practices

Expectation: 30% to 50% Attrition within 5 Years

Knowledge Management and Retention

Knowledge at Risk:

- Historical Products Still Supported
- Networks and Contacts for Problem-Solving
- Complex Systems Corrective Actions
- Unique Diagnostic Capabilities

Usually Not Adequately Documented

Knowledge Management and Retention

Why Is It Allowed to be Lost?

- Critical Knowledge (CK) not Documented
- CK not Shared
- CK not Recognized as Critical or Unique
- Time Required to Document or Share
- The Most Critical is Usually the Most Complex

Not a Matter of Risk – A Certainty

Solving the Problem

Step 1: Identify the CK in the Workforce

Leading Questions:

- What are our core competencies?
- Why have we been able to succeed?
- What sets us apart from the competition?
- What do we do better than anyone else?

Solving the Problem

Step 2: ID Present Method of Storing CK

- May Be Adequate
- Improvement may suffice
- Major Action May Be Needed

Solving the Problem

Step 3: Identify Who Has the CK

- Who Do Managers Rely on Most?
- Can Alternates Perform the Function As Well?
- Peer Reviews
- Who Do Employees Seek Out?

Solving the Problem

Step 4: Develop a CK Storage System

- Many Options Available
- Must Be Tailored to Organization's Culture
- Must Be Efficient
- Critical Balance

Solving the Problem

Step 5: Gather & Store CK

Difficulty Dependant On:

- Organizational Culture
- Amount of Segmentation
- Time Available
- Resources Allocated
- Number of Individuals with CK
- Amount of CK

Expected Roadblocks

The Knowledge Miser

- Status Achieved Through CK
- May Be Reluctant to Relinquish Status

Knowledge Miser Solution

KM's Interests Addressed Through:

- Org. Ability to Maintain Long-Term Benefits
- Potential Near-Term Layoffs
- Status Through Knowledge Sharing

Expected Roadblocks

The Distrustful:

- Feels ill-treated by Organization
- Resentful
- No desire to help organization

Expected Roadblocks

The Distrustful Solutions:

- Identify Source of Resentment
- Re-Establish Positive Relationship
- Assign to Project Teams

Expected Roadblocks

The Contractor

- CK Increases in Value Near Retirement
- CK Considered a Commodity
- Give Away Now or Sell Later
- Only Delays the Problem

Expected Roadblocks

Contractor Solutions:

- Exchange CK Prior to Return as Contractor
- Initial Assignment: Clarify process & Methodologies

Knowledge Management and Retention

Knowledge Management Systems

- Training
  - Structured process
  - Results measured & evaluated
  - Significant resource requirements
- Storytelling
  - Informal, casual
  - Social activity

Knowledge Management and Retention

Knowledge Management Systems

- Coaching
  - Provided as needed
  - Growth process
- Exit Interview
  - Most commonly used
  - Least effective

Knowledge Management and Retention

Knowledge Management Systems

- Critical Incident Report
  - Easy implementation
  - Limited application
- Network of Specialists
  - Serious cross-training
  - Mutual support

Knowledge Management and Retention

Knowledge Management Systems

- Exit Interview
  - Most commonly used
  - Least effective
- Mentoring
  - More structured than coaching
  - Dependent on favorable relationships
  - Most effective, most challenging

CK Management & Retention Summary

- Match Culture, System, and Resources
- System Must Be User Friendly
- Resource Requirements Increase with Time
- Management Choice:
  - Develop a System that Captures and Retains CK
  - Re-create CK at a later date
  - Lose the capability

Contact Information

For additional information:

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Lean (and Agile) System Simulation of Guided Projectiles in the Early Development Stage

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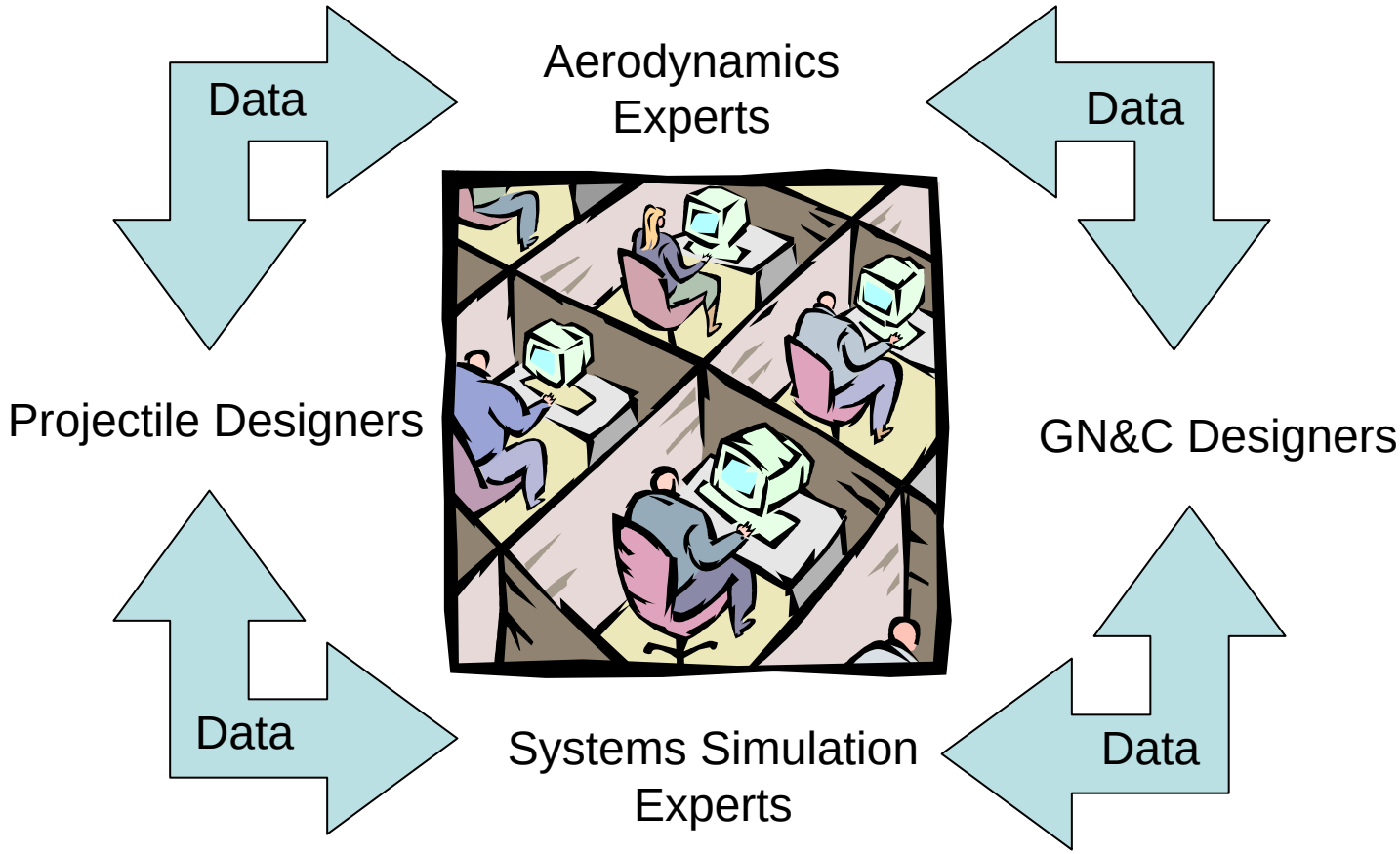
ARROW TECH
If you Can't Get a Bigger Target...

Typical Guided Projectile Development Team



Lean (and Agile) Concept

- Standardize on a validated toolset
- Eliminate waste and add value
- Streamline the process

Characteristics of the Toolset

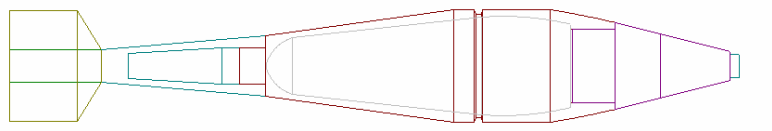
- Easy to use with common interface
- Seamless data flow between applications
- Industry standard algorithms to provide confidence in the results
- Easy to extract results for proposal support

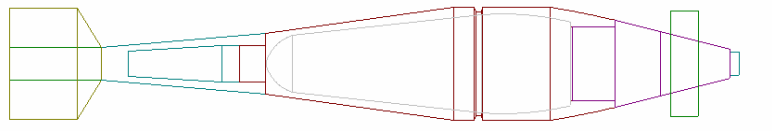
Example Walk Through

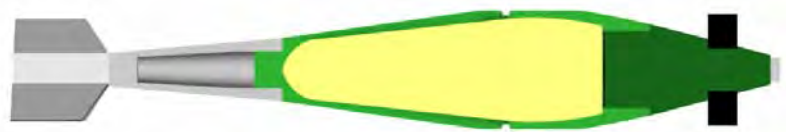
- Design a retrofit fuze to guide 81mm Mortar
  - Trade off control mechanisms
  - Trade off sensor options
- Evaluation
  - Range extension
  - CEP

Build the Model

- Multiple options
  - Build from scratch (1hr)
  - Modify existing (5 min)
  - Projectile Tracing Tool (15 min)
  - Import via DXF or IGES (30 min)

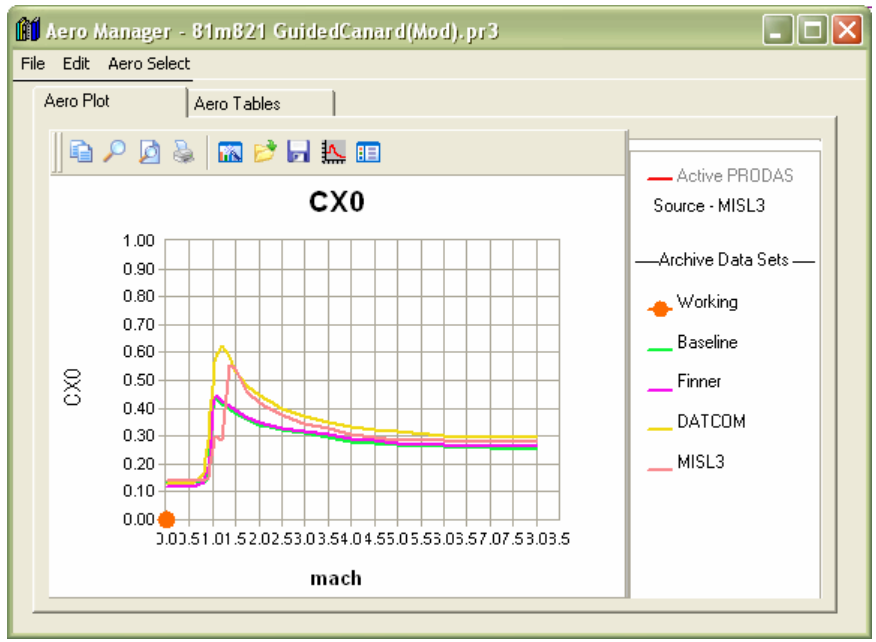






Estimate Aerodynamics

- Multiple Estimators
  - Spinner by Arrow Tech
  - Finner based on DeJonge
  - Missile DATCOM
  - MISL3 by Near
  - AP98 by NSWC

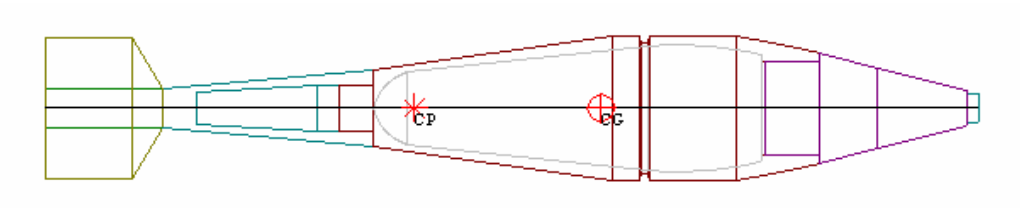


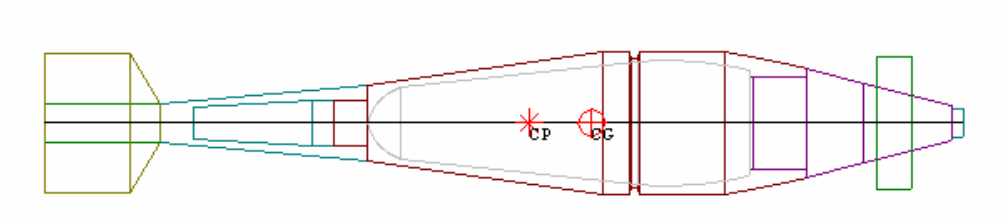
ARROW TECH

If you Can't Get a Bigger Target...

Evaluate Aero Stability

- Stability Evaluation
  - Baseline Static Margin 1.3 calibers
  - With canards 0.45 calibers



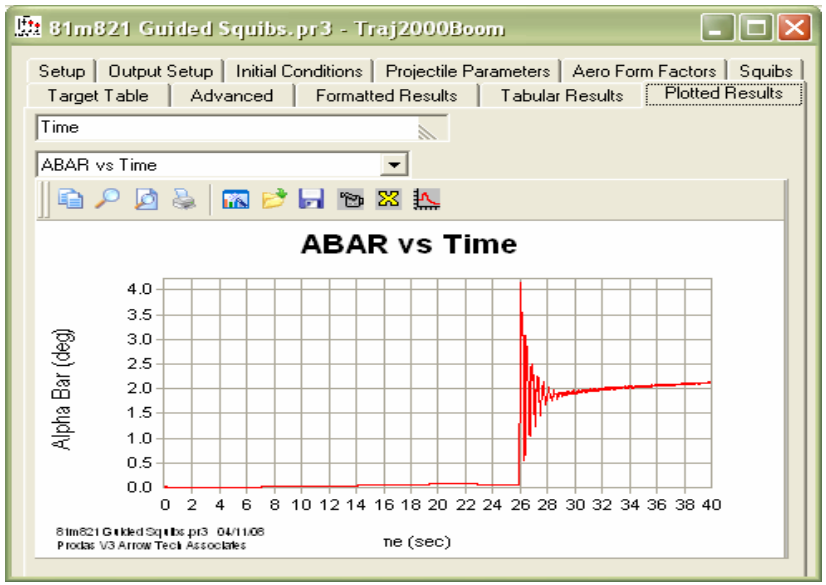


ARROW TECH

If you Can't Get a Bigger Target...

Evaluate Control Authority

- Use CONTRAJ Module (Controlled Trajectory)
- Trade off Squibs versus Canards

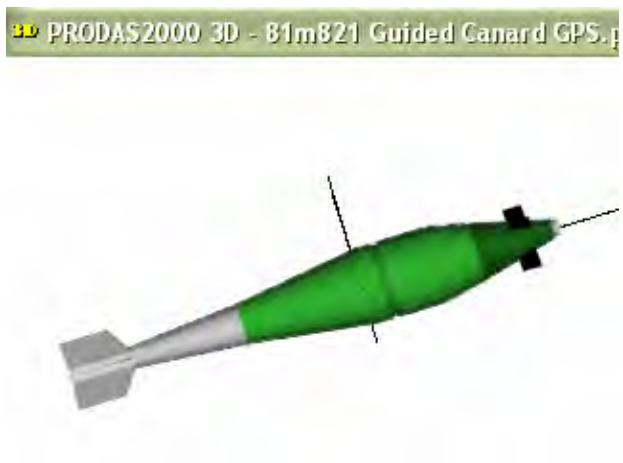


ARROW TECH

If you Can't Get a Bigger Target...

Control Authority Results for this Example

- Squibs at this location
  - Lots of Motion
  - Small lateral movement
- Canards
  - 50% more range
  - Tremendous control authority



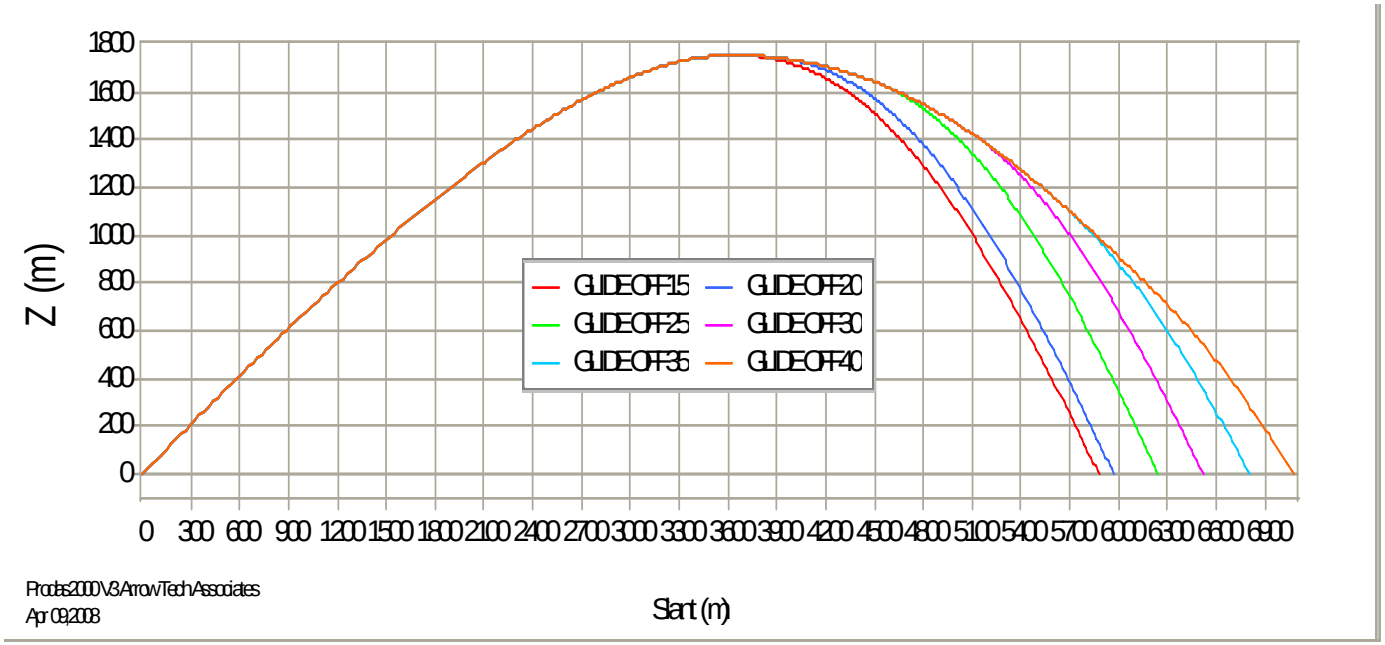
Recap

- Made two models based on an existing model
- Predicted the aerodynamics with three prediction codes
- Assessed aero stability of the modified shapes
- Evaluated control authority of squibs and canards
- Down selected the canard design

Total time invested up to this point ~ 2 hours

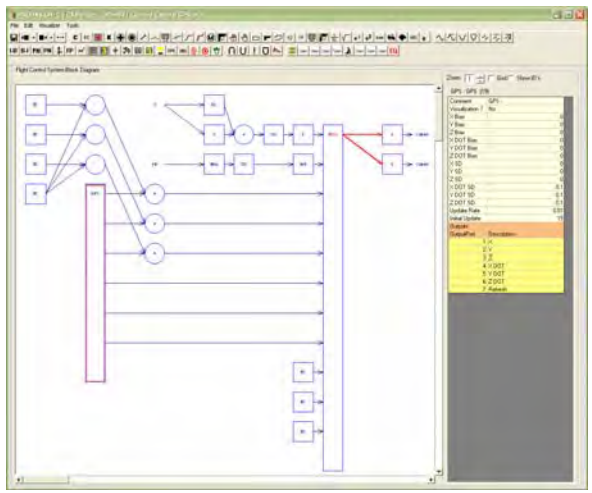
Next Step - Simulation

- Trajectory Codes
- System Effectiveness Simulation



The GN&C Prototype Module

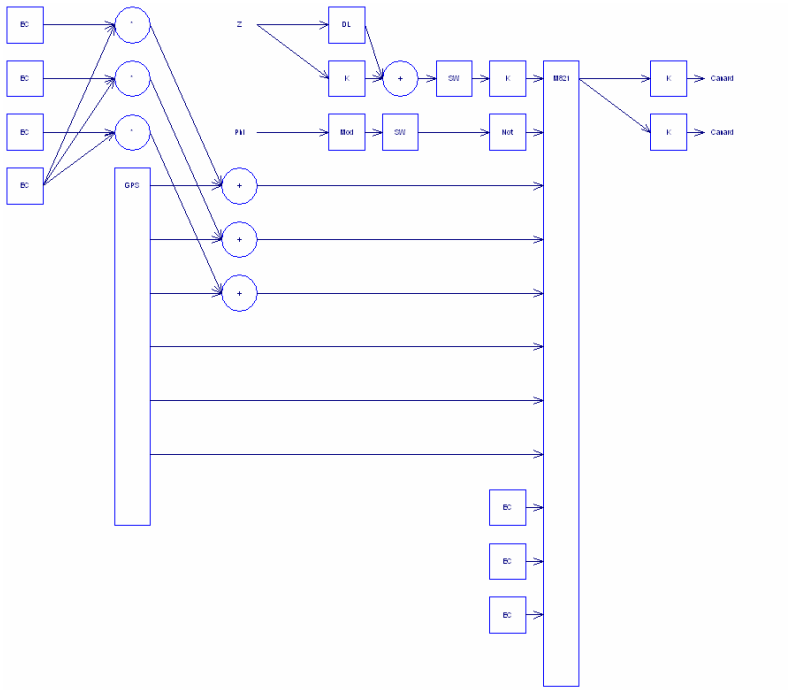
- Fully integrated 6DOF/GN&C Simulation
- Control with canards, squibs or generic forces
- Short learning curve w/ drag/drop FCS editor
- Control system can be coded in C or FORTRAN and linked at run time



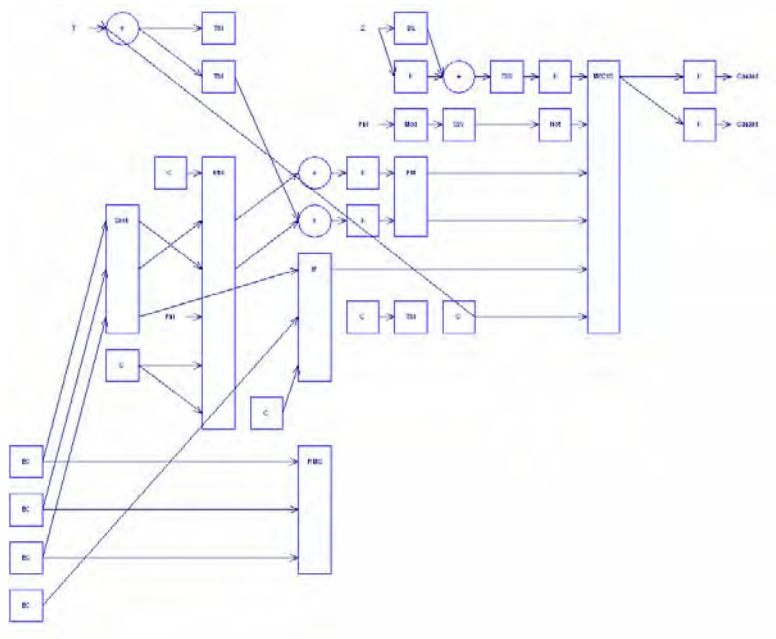
Why use the GN&C Prototype Tool

- Validated 6DOF that runs in real time or faster
- Intimately linked to the other tools
- Pre-built library of common projectile sensors and control surfaces
- Visualization modules can quickly produce reasonable marketing or training visuals

Example Systems

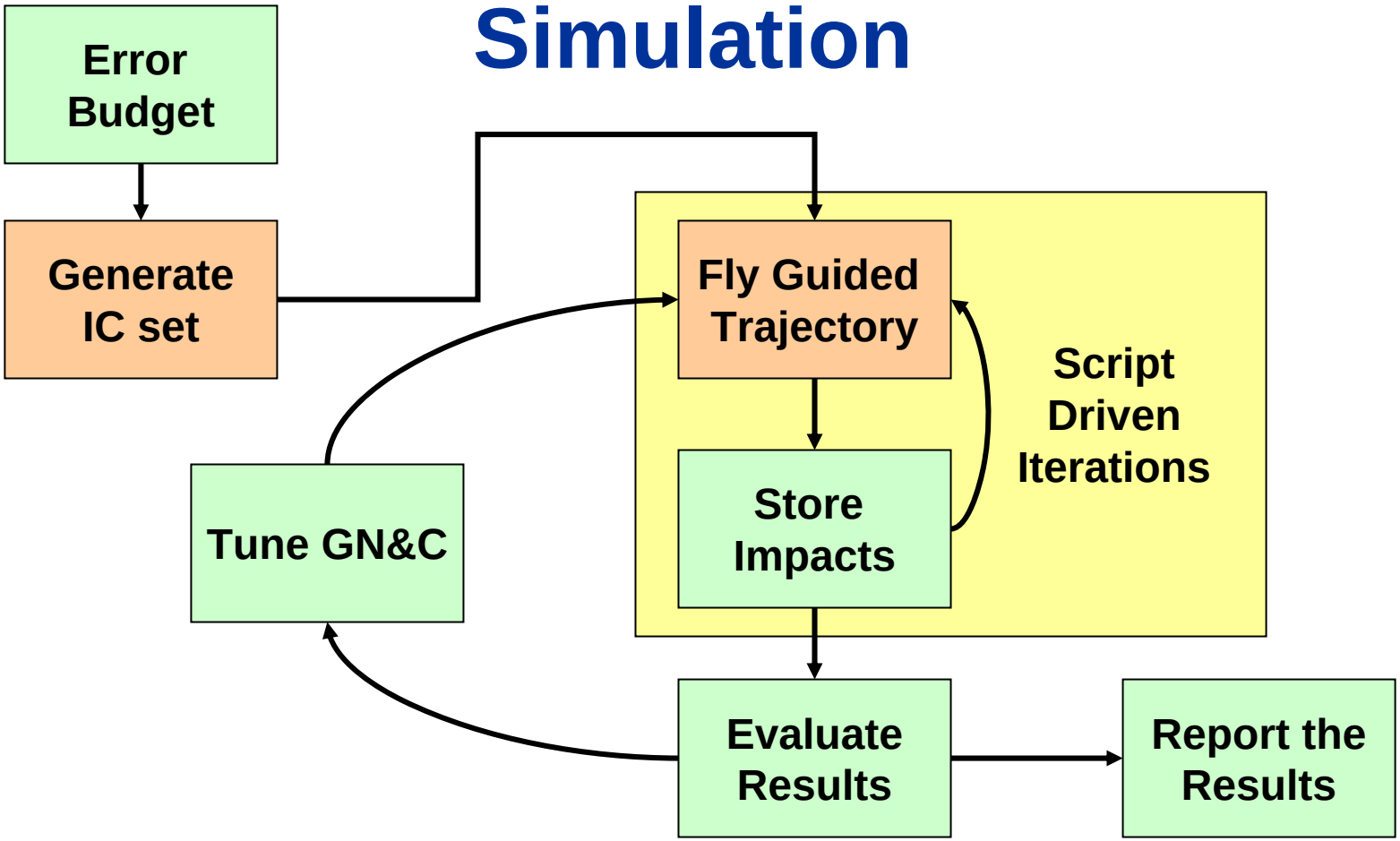


GPS guided



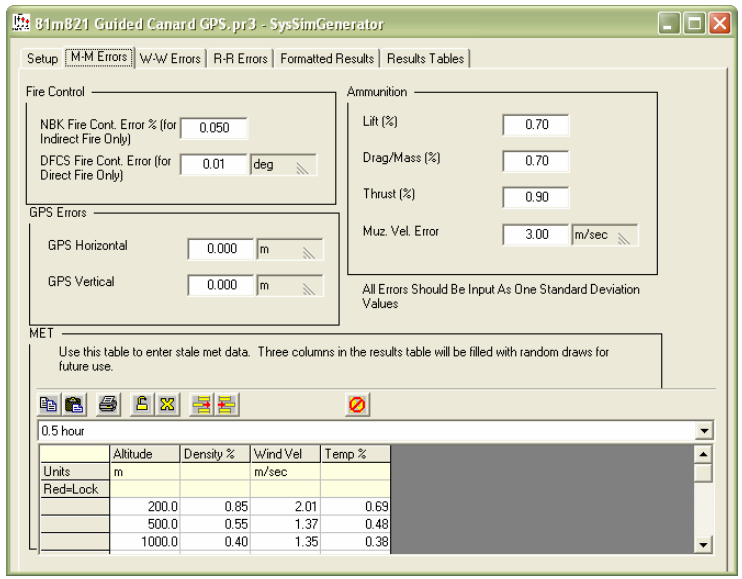
Seeker guided

Guided System Effectiveness Simulation



Initial Conditions Generator Module

- Generate error deltas from the error budget
- Delta plus nominal provide IC's for all of the subsequent runs
- Reality checked with ballistic projectile



Build an Automation Script

- Macro script language
  - Based on Visual Basic (EXCEL)
  - Projectile extensions added
- Build Options
  - Hand Code
  - Use Analysis Bot module
- Output text results file or cross plots

Recap

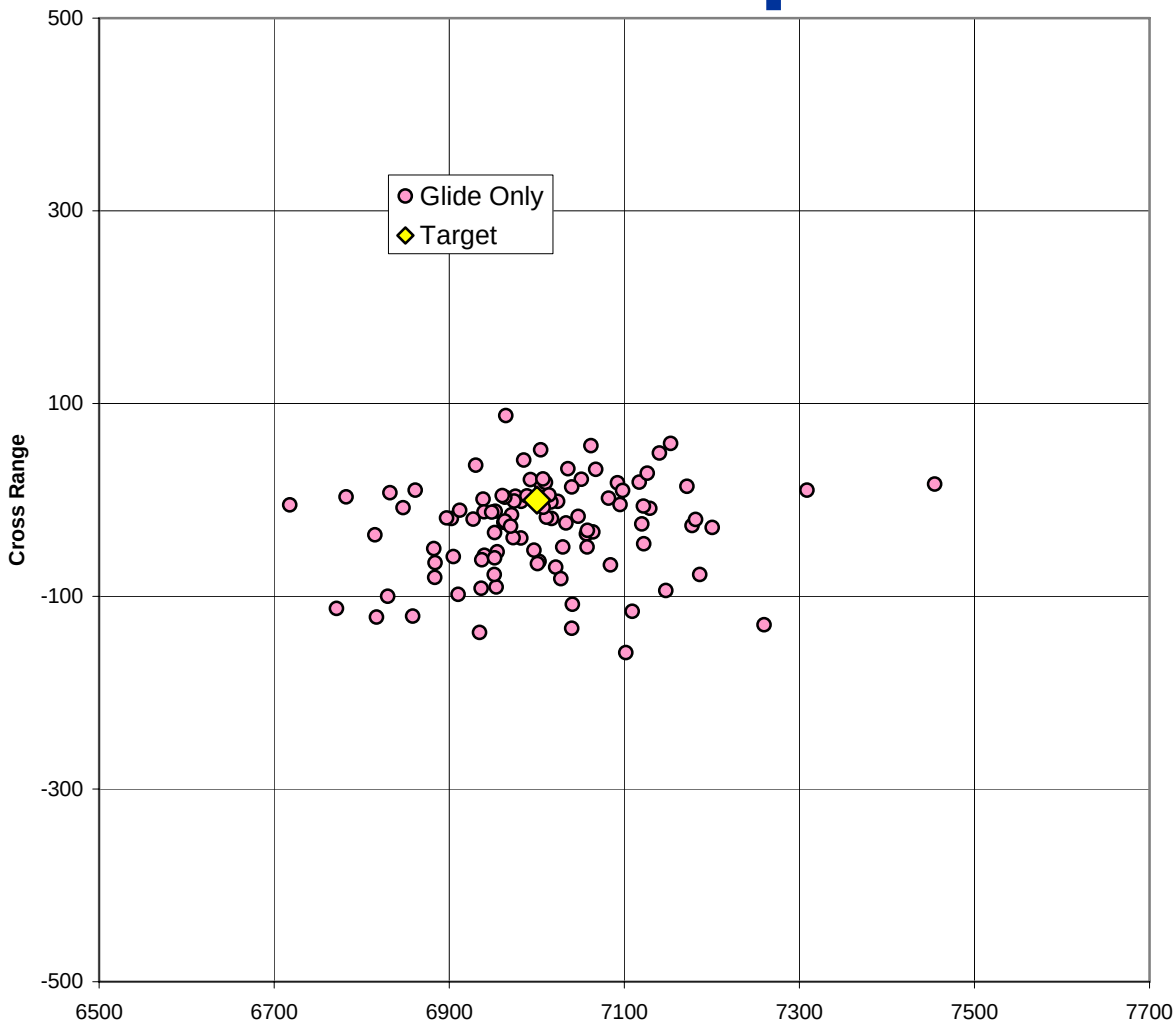
- Built Models & Estimated Aeros 2 hours
- Designed GN&C
  - GPS (modified existing) 2 hours
  - Seeker (new) 8 hours
- Developed Error budget and IC set 2 hours
- Modified existing scripts 1 hour
- Ran Systems simulations 1 hour

Total time invested up to this point ~ 16 hours

Conclusions

- It is possible to streamline the early stage development of a guided projectile
- Tools need to be integrated and inclusive
- System effectiveness comparisons of configuration changes as well as guided projectile performance can be evaluated in a timely manner, using readily available tools.
- Design the projectiles – NOT THE TOOLS

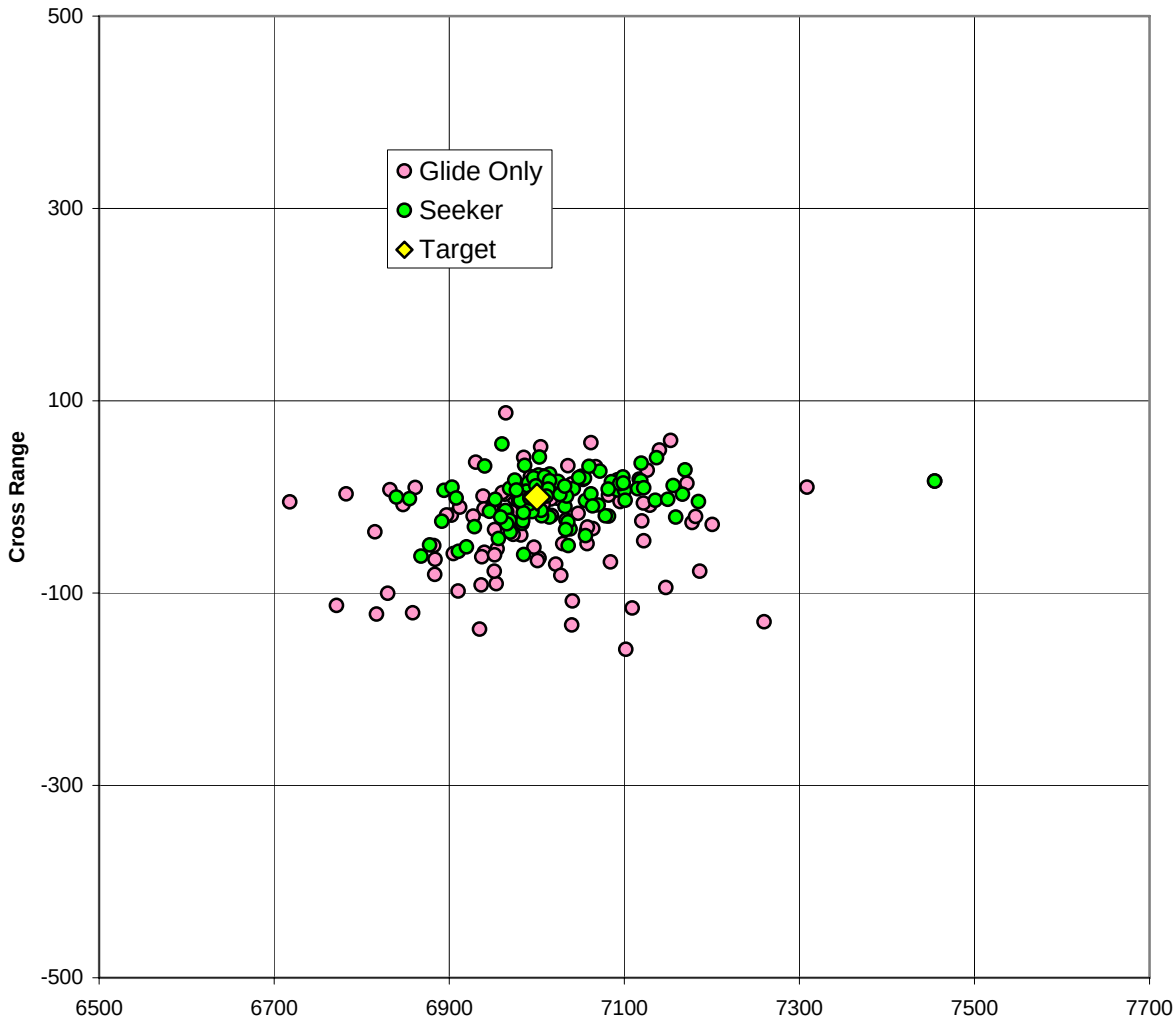
Ballistic Impacts



ARROW TECH

If you Can't Get a Bigger Target...

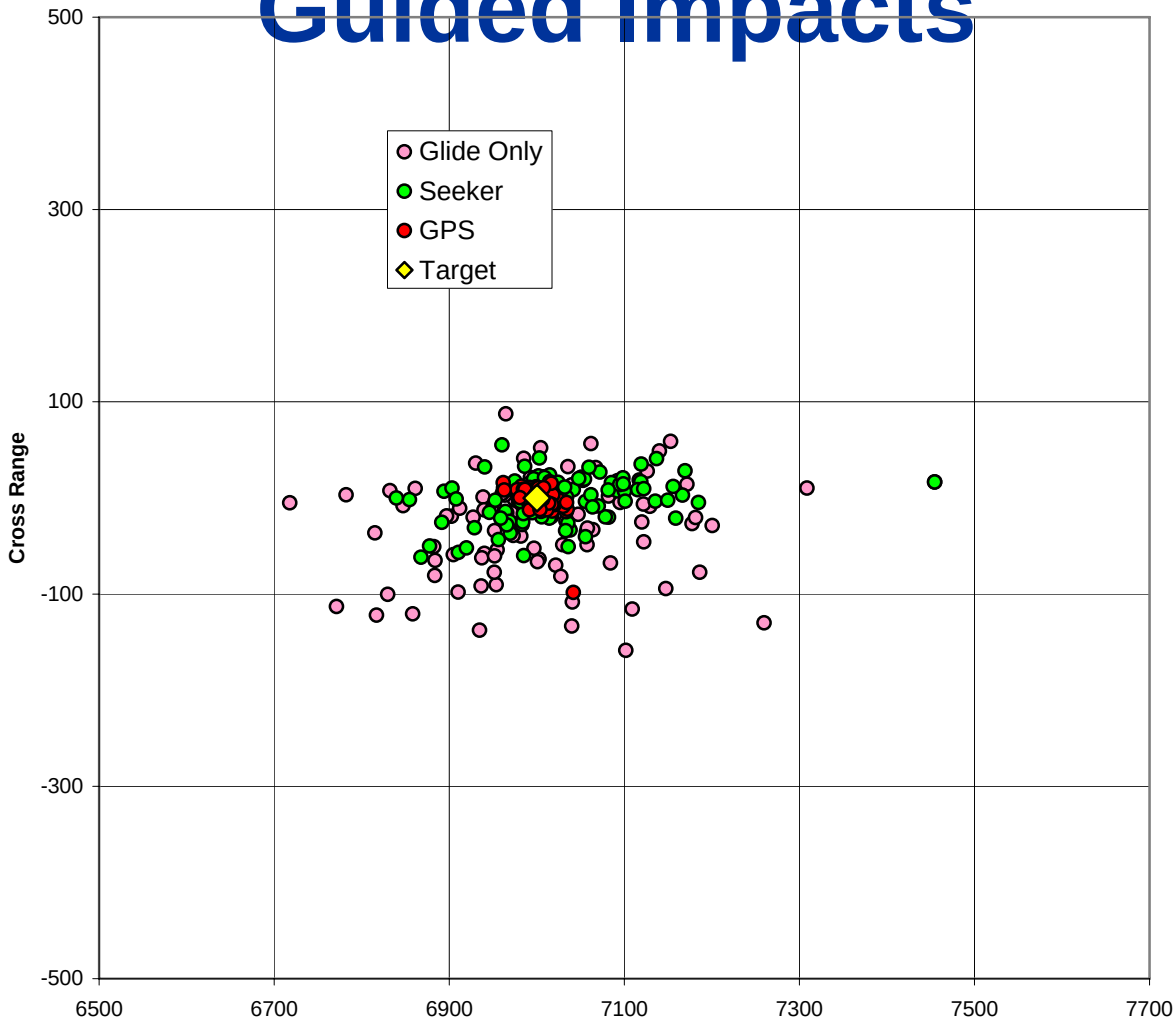
Ballistic and Seeker Guided Impacts



ARROW TECH

If you Can't Get a Bigger Target...

Ballistic, Seeker and GPS Guided Impacts



ARROW TECH

If you Can't Get a Bigger Target...

Results from our Example

	Range km	CEP m
Ballistic	5.1	96
Ballistic with Glide	7	106
Seeker Guided	7	68
GPS Guided	7	16

ARROW TECH

If you Can't Get a Bigger Target...

Questions ?

43rd Gun & Missile Conference

Raytheon

EXCALIBUR

M982

Naval Sea Systems Command
Dahlgren Division

ARMS
ARTILLERY MUNITIONS SYSTEMS

Presented by:
Mr. Perry Salyers

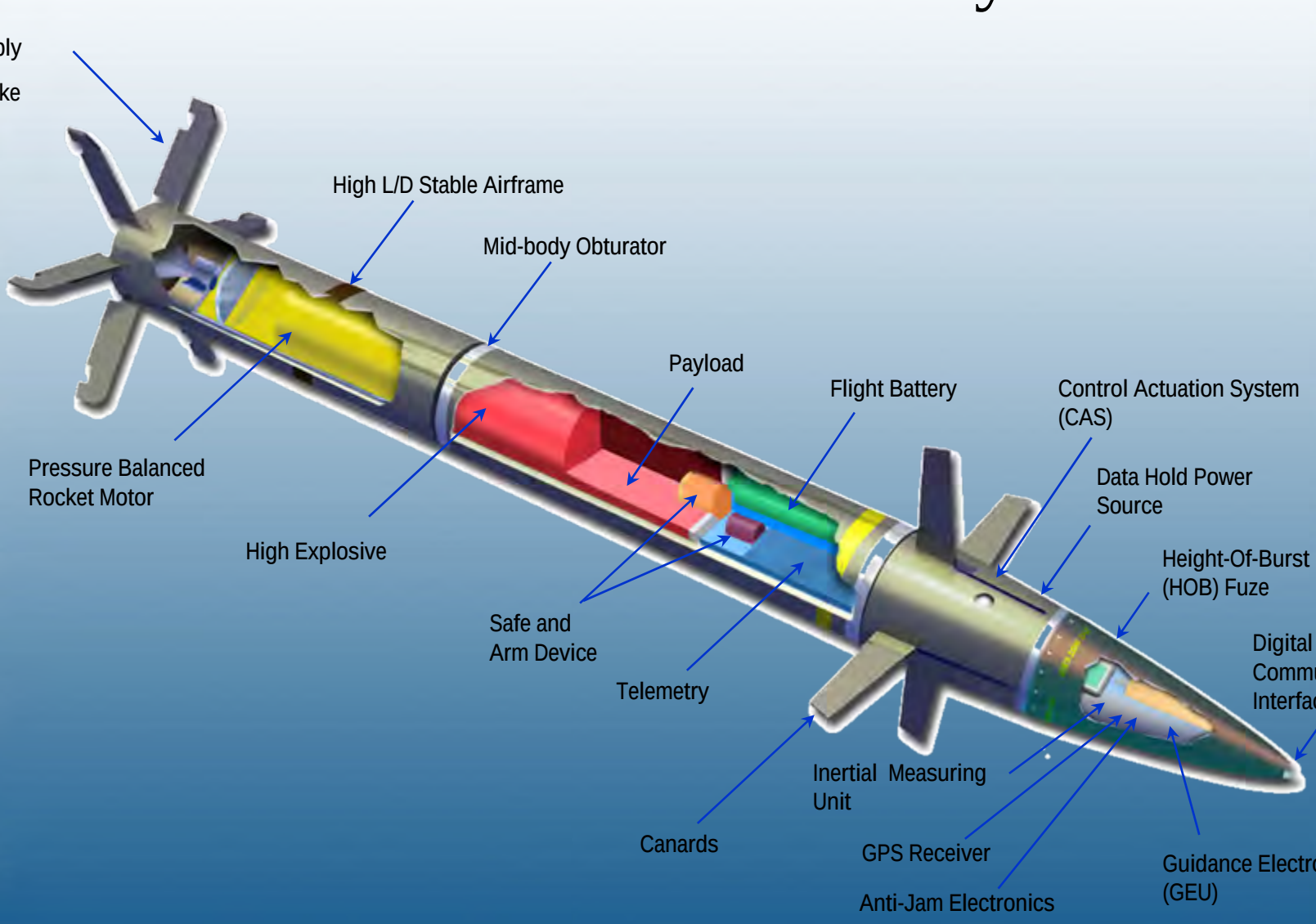
April 21 – 24, 2008

L3 communications
KDI Precision Products, Inc.

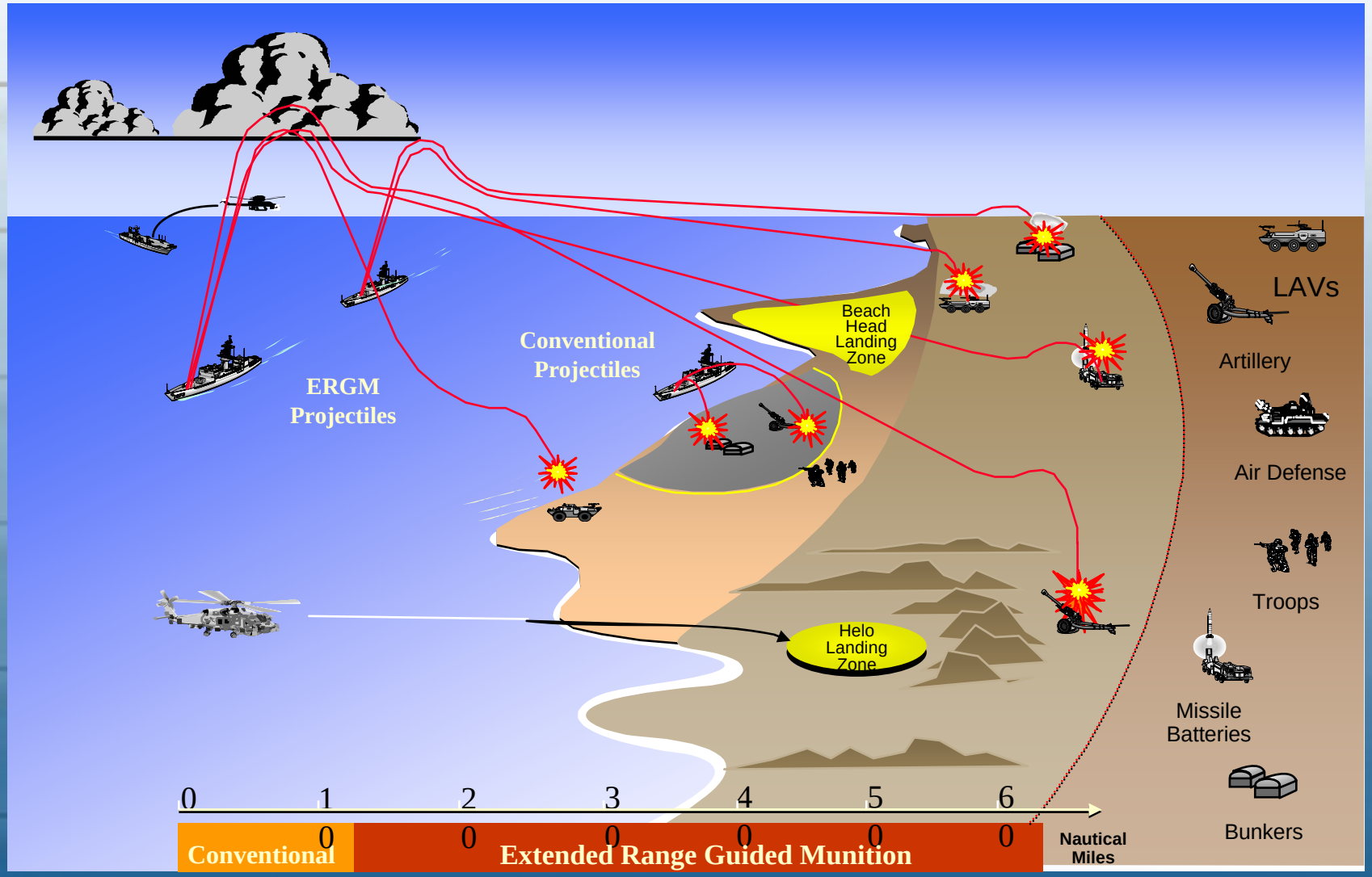
OUTLINE

- ERGM System Overview
- ERGM System Operation
- M982 System Overview
- M982 System Operation
- System Target & Excalibur Characteristics
- M982 Fuzing System
- S&A Technical Requirements
- MIL-STD-1316D Compliance
  - Excalibur FSA Time Line
  - Excalibur FSA Logic Design
- Fuze Safe & Arm Description
- S&A Mechanical Design
- S&A Electrical Design
- Electrical Module
- S&A Integration
- S&A Explosive Outputs
- HOB Sensor Description
- FS&A Description
- Program Test Results / Milestones
- ESAD Development Status

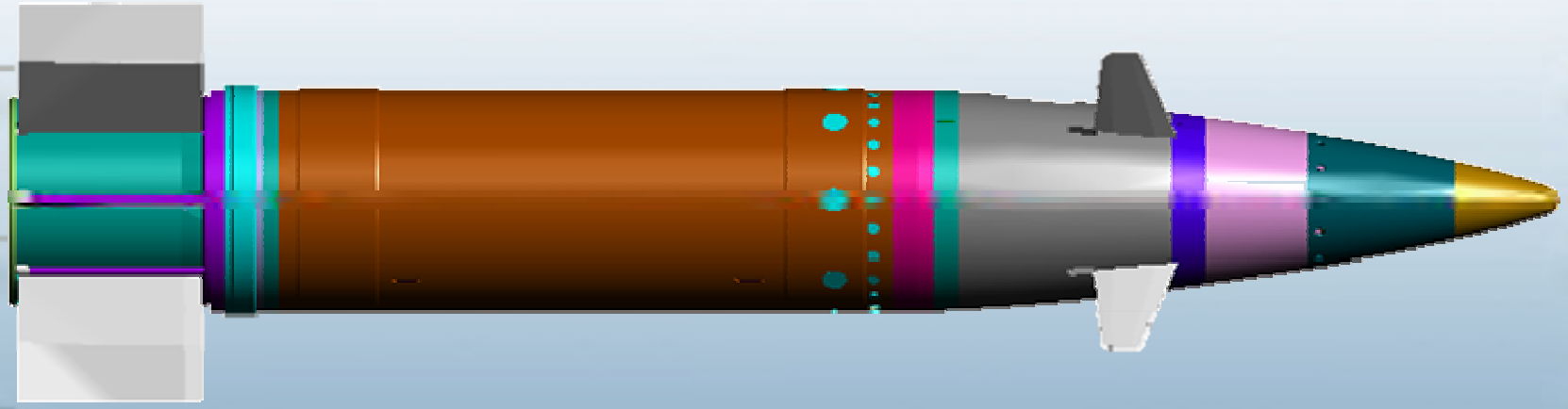
EX171 ERGM Tactical System



EX171 ERGM OPERATIONAL CONCEPT



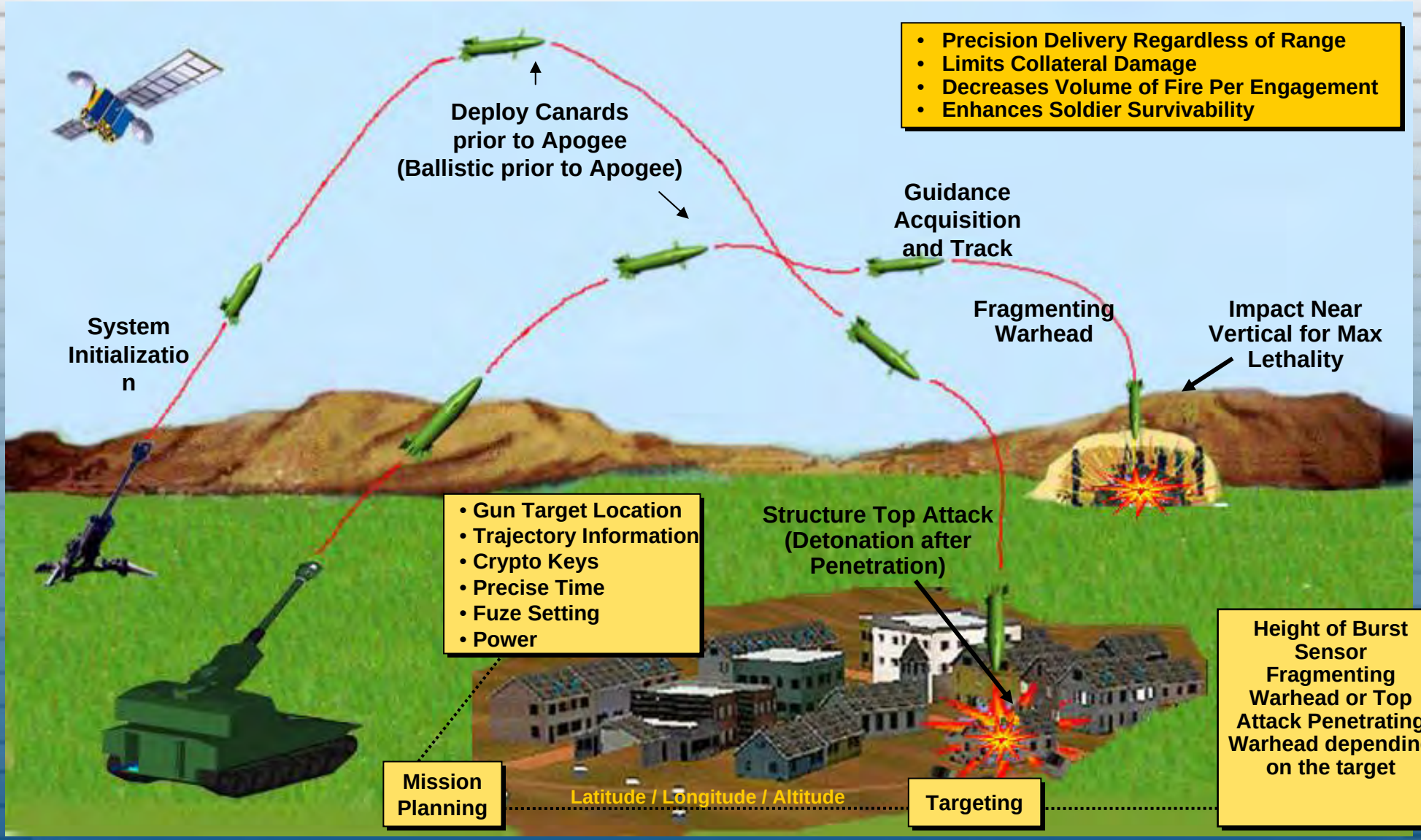
Excalibur (M982) System Overview



Characteristics/Description:

- 155MM Extended Range guided projectile
- Fin Stabilized Glide Air Frame
- Inductive Set with Enhanced Setter
- Inertial Navigation System (INS) Guidance
  - All Weather, Day and Night
  - Compatible with JLW155 & FCS Digitized
- 155mm Platforms
  - One Meter Length / 106 lb
- Warhead: Unitary
- Accuracy: 10m CEP objective
- Range: 40Km objective
- Targets : Personnel, light materiel, structures
- Fuze modes: PD, PD delay, Prox
- Environments:
  - 15.5 KG set back
    - Early fielding ~12KG
  - 50+ KG penetration

Excalibur Unitary Concept of Operations



Excalibur Characteristics Unitary Targets

Infantry Platoon

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

- ~10m CEP
- Same lethality as an 155 mm HE

System used in a complex target environment!

Command Post

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

Radar

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

Excalibur at any range

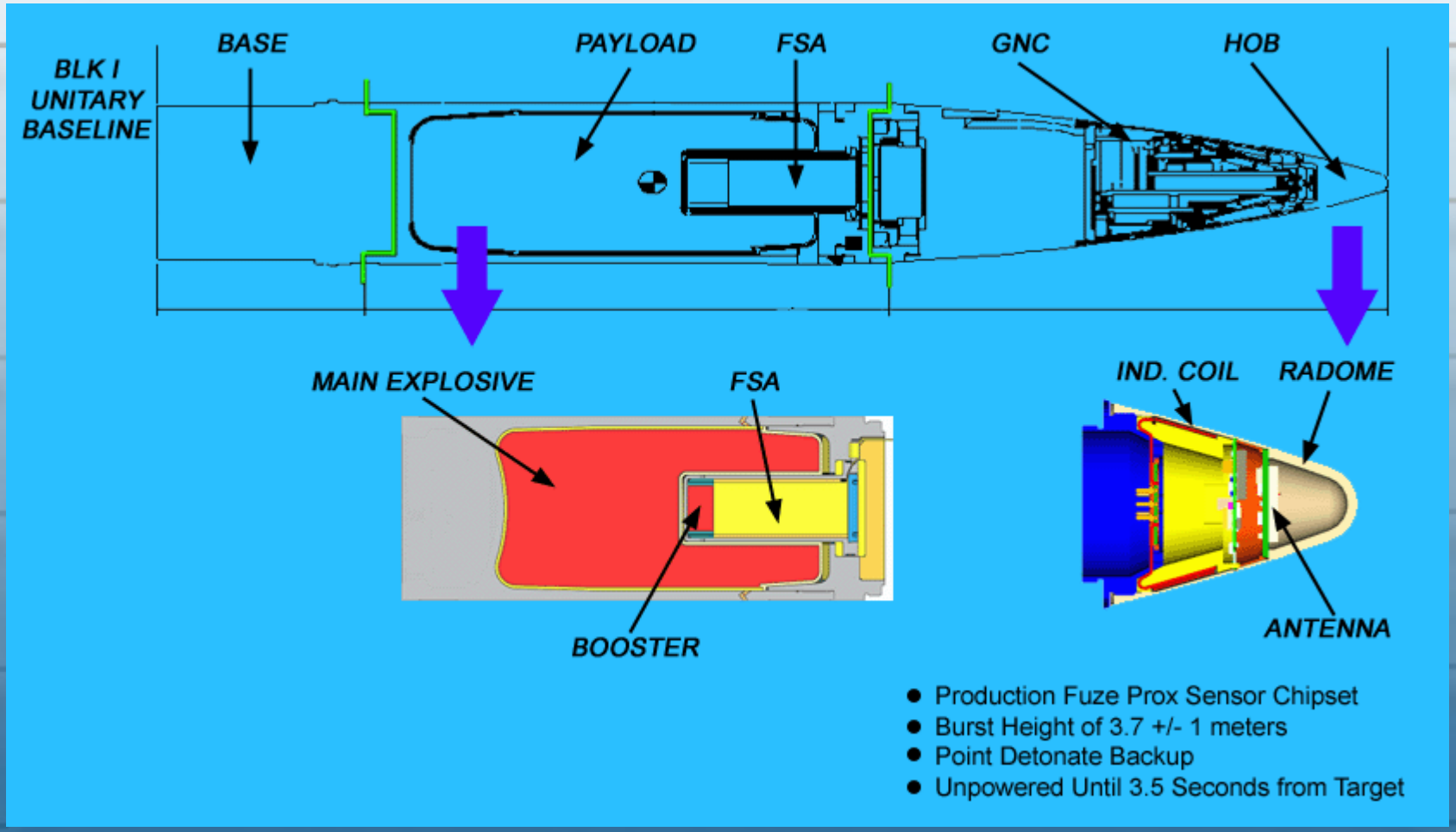
M549 at 20Km

M107 at 15Km

Structures

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

Excalibur Fuzing System (FS&A w/HOB)



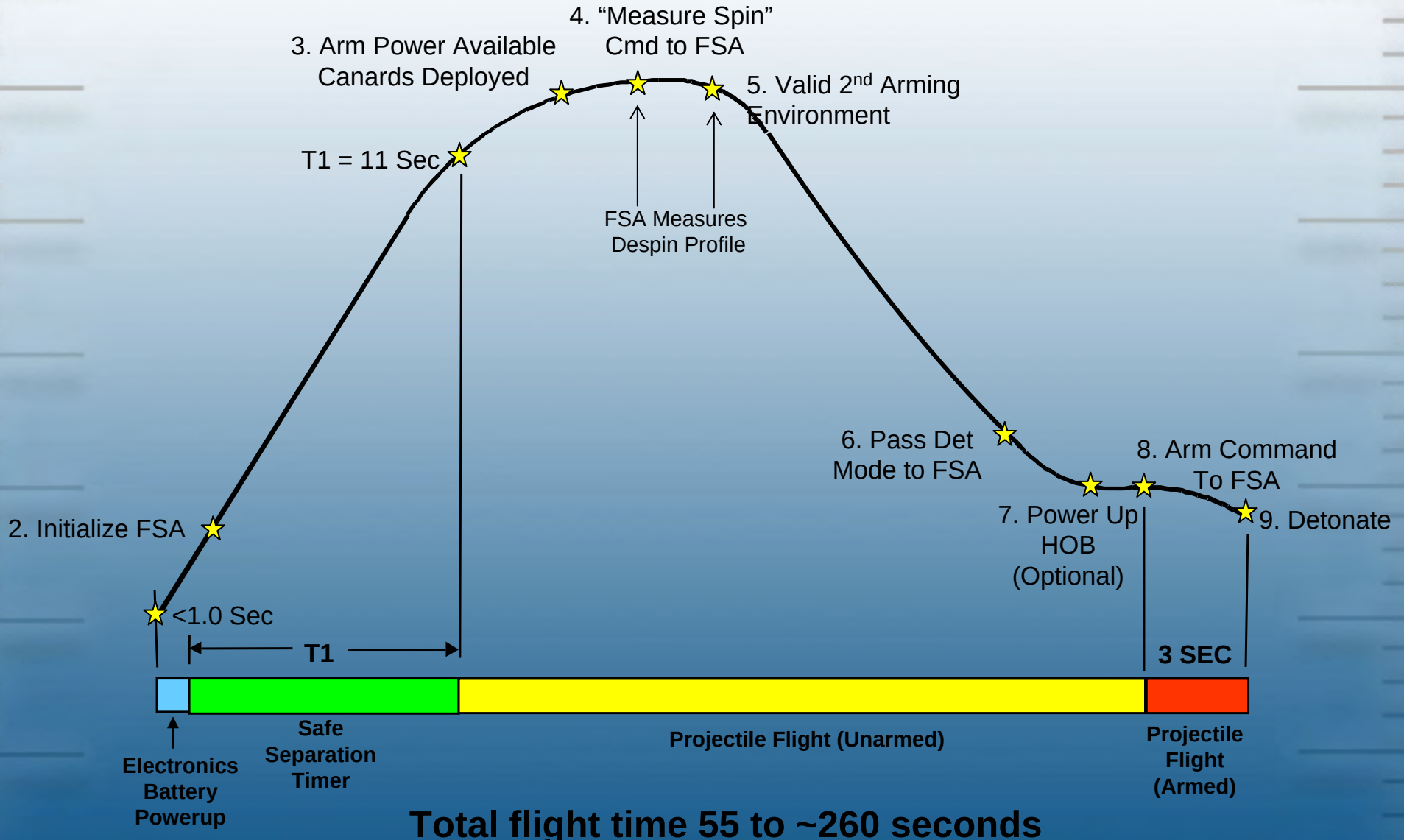
- Production Fuze Prox Sensor Chipset
- Burst Height of 3.7 +/- 1 meters
- Point Detonate Backup
- Unpowered Until 3.5 Seconds from Target

FS&A REQUIREMENTS

- Projectile Application
  - All Arm - 1,700 G's
  - No Arm - 300 G's
- Spin
- Interface With GN&C
- MIL-STD-1316D Compliant

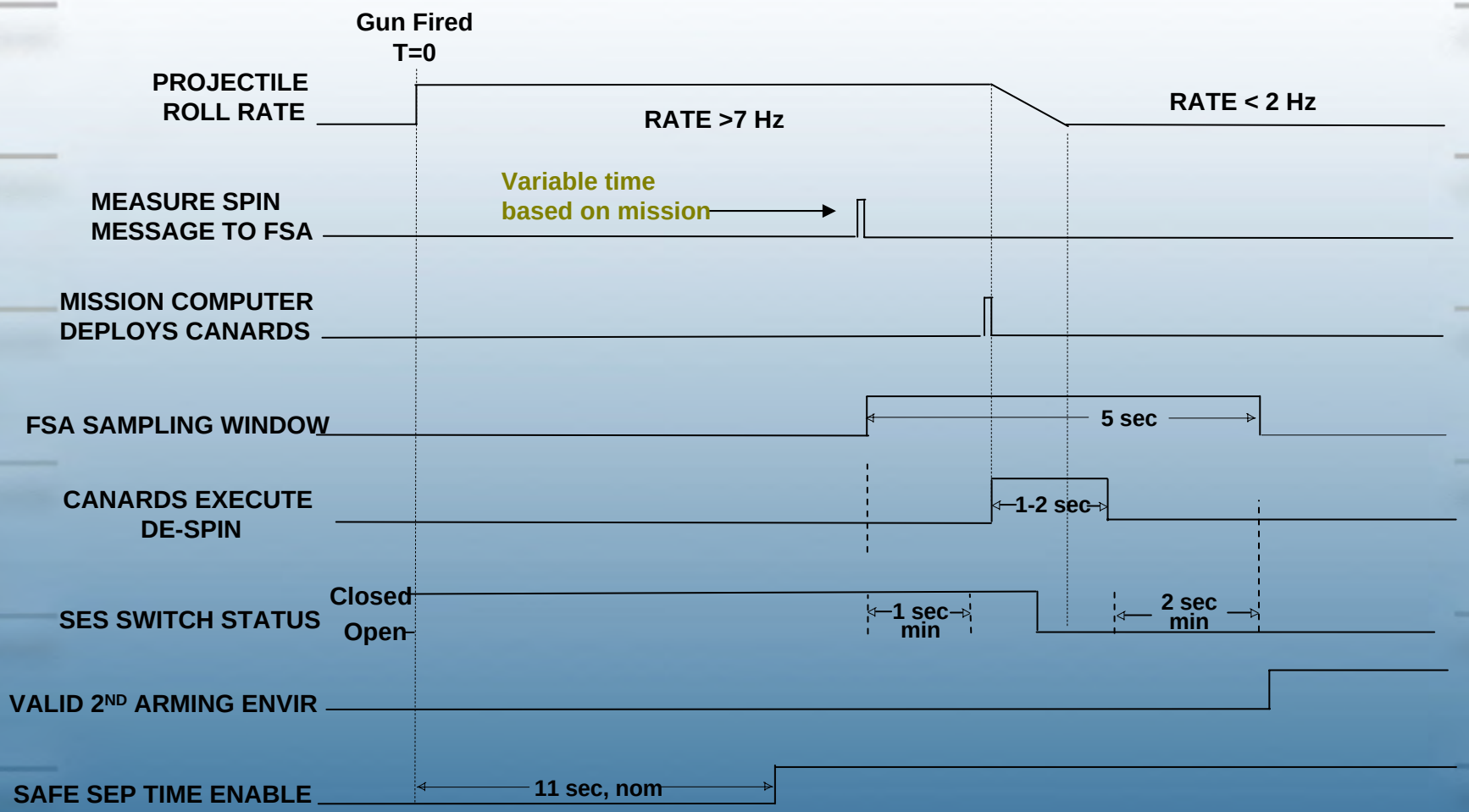
ERGM and Excalibur Mechanical S&A

Excalibur FSA /Flight Timeline



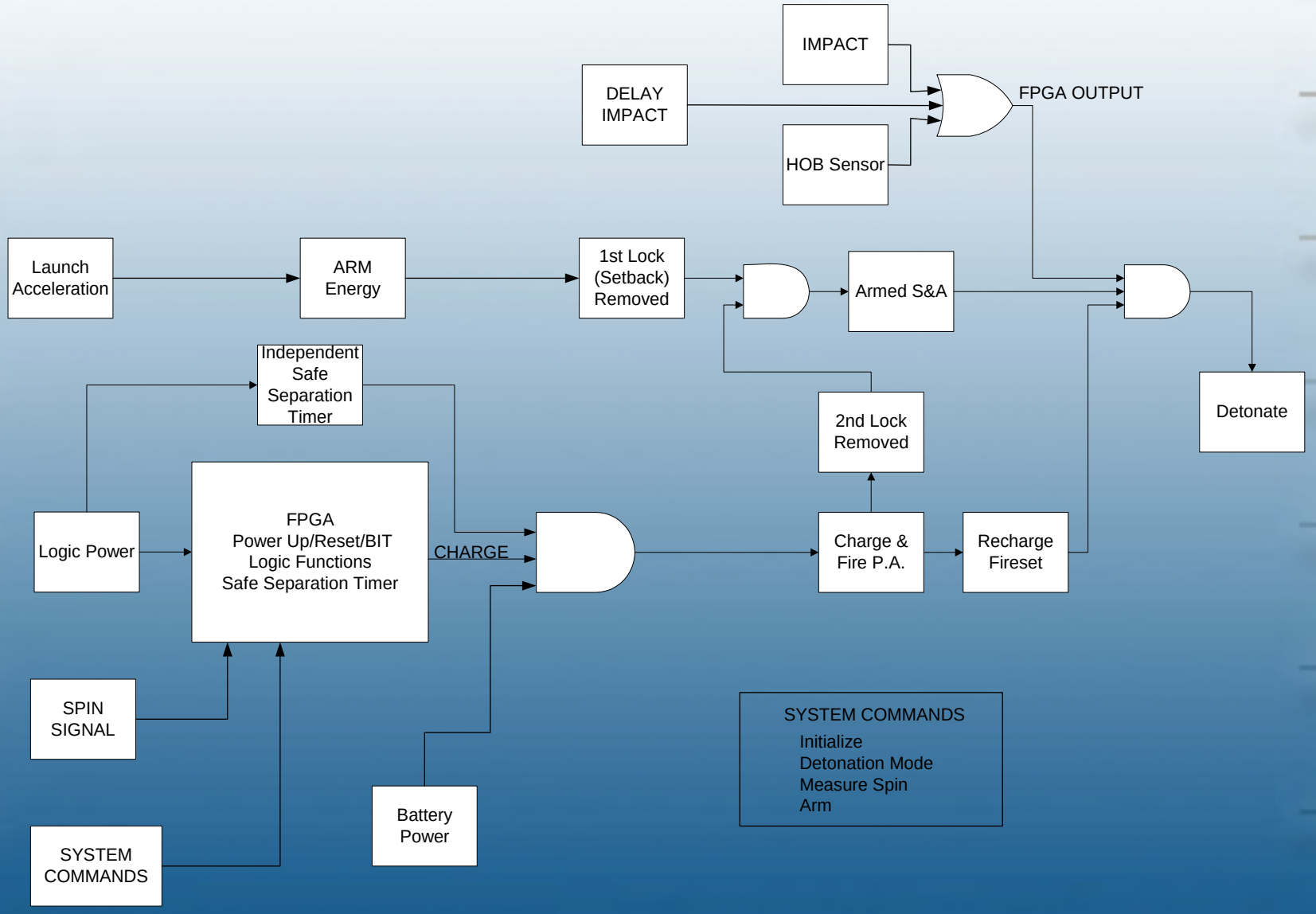
Total flight time 55 to ~260 seconds

2ND Arming Environment Timeline



- Unique Excalibur spin profile
- Spin switch closed initially (spin rate >7hz)
- Spin switch opens after canard deployment (spin rate <2hz)
- Delta spin detected within 5 second window where canard deployment occurs
- Allow 2 seconds after canard deployment event for dampening of mechanism

Excalibur FSA Logic Diagram

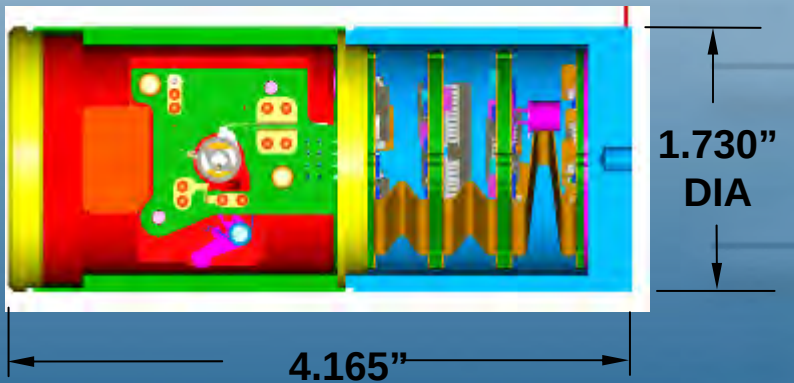


Excalibur Fuze Safe & Arm (FSA) Description

Key Features

- FSA consists of electronics module and mechanical module
- First Arming Environment is setback acceleration implemented mechanically
- Second Arming Environment is detection of de-spin event using a “g” switch
- Safe separation via independent timers
- Point Detonate fuze is implemented by a g-switch opening at impact.
- Delay after Point Detonate implemented by electronic timer
- HOB function implemented by RF proximity sensor using production fuze components

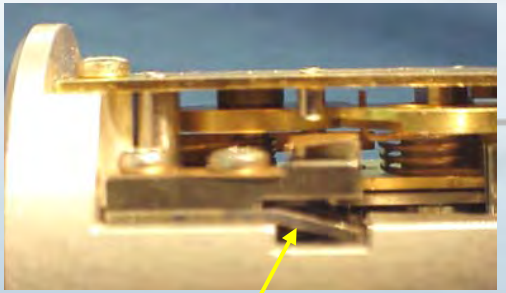
Mechanical Section	Electronics Section
Out of Line Mech Setback G-switch Rotor Control Detonator Shorting Detonator Output Lead	FPGA Power Up Logic Power Separation Timing Circuits Spin Sensing Arming Control Firing Control



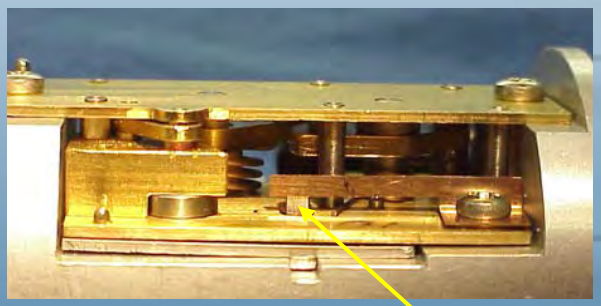
FSA Design Approach Concurred by Army & FMV Fuze Boards

S&A MECHANICAL DESIGN APPROACH

- Mechanical S&A Design Approach
  - Modified MK18 S&A
    - Higher G Loads
    - AFT Detonation Output
    - Switches Indicate Rotor Position
    - Integrated Electronics Control
  - Three (3) Leaf Set Back Mechanism



Second Rotor Lock (Safe)

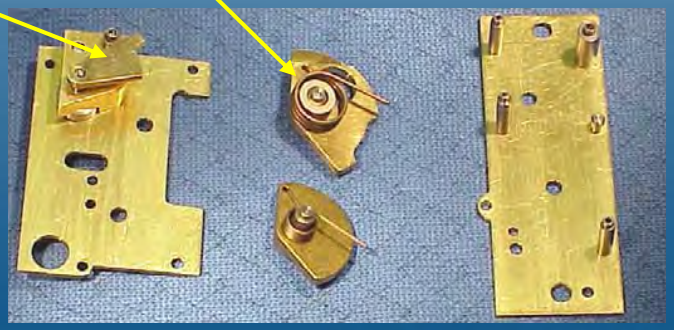


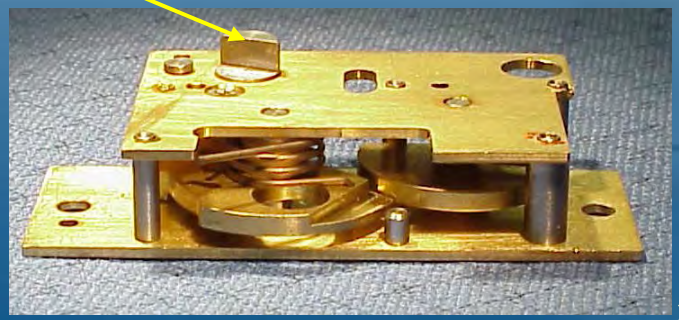
Rotor Lock (Arm)

Leaf Lock

Rotor Drive Spring

First Rotor Lock (Safe)

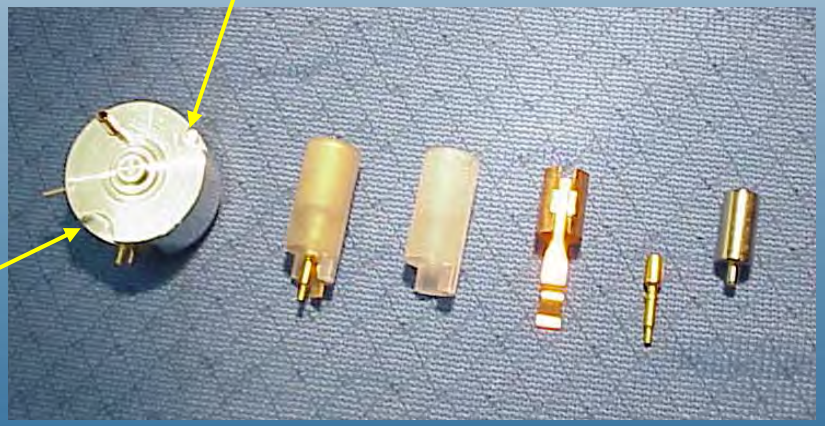




S&A ELECTRICAL DESIGN APPROACH

- S&A Electronics
  - RS232 Serial Communication Link
  - Codeword Controls Function

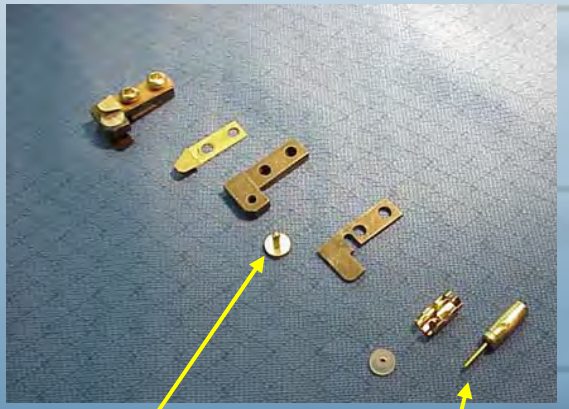
Second Safety & Arm Lock



Set Back Lock

Rotor W/Switches & M84 Detonator

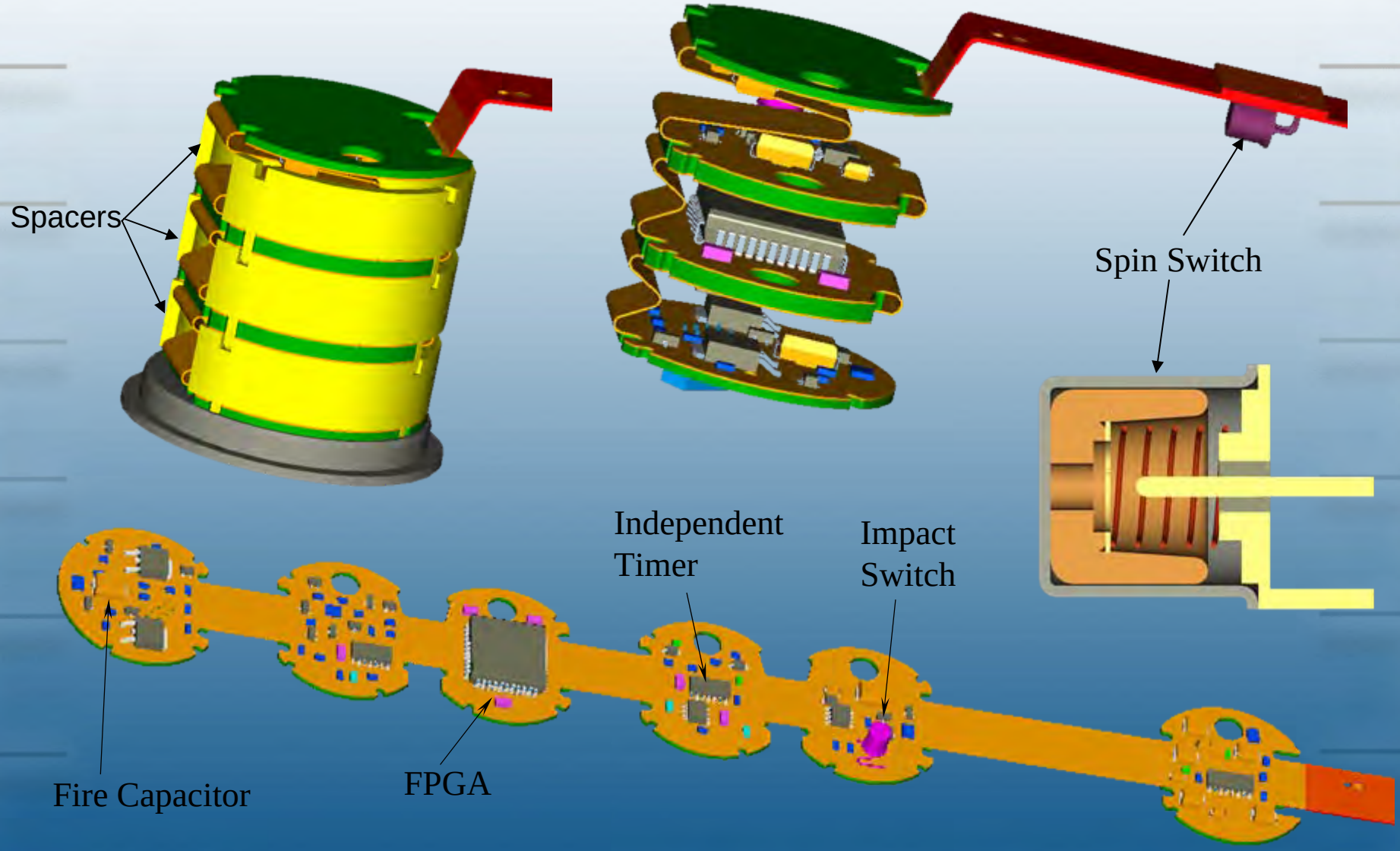
GN&C
Second Rotor Lock W/PA



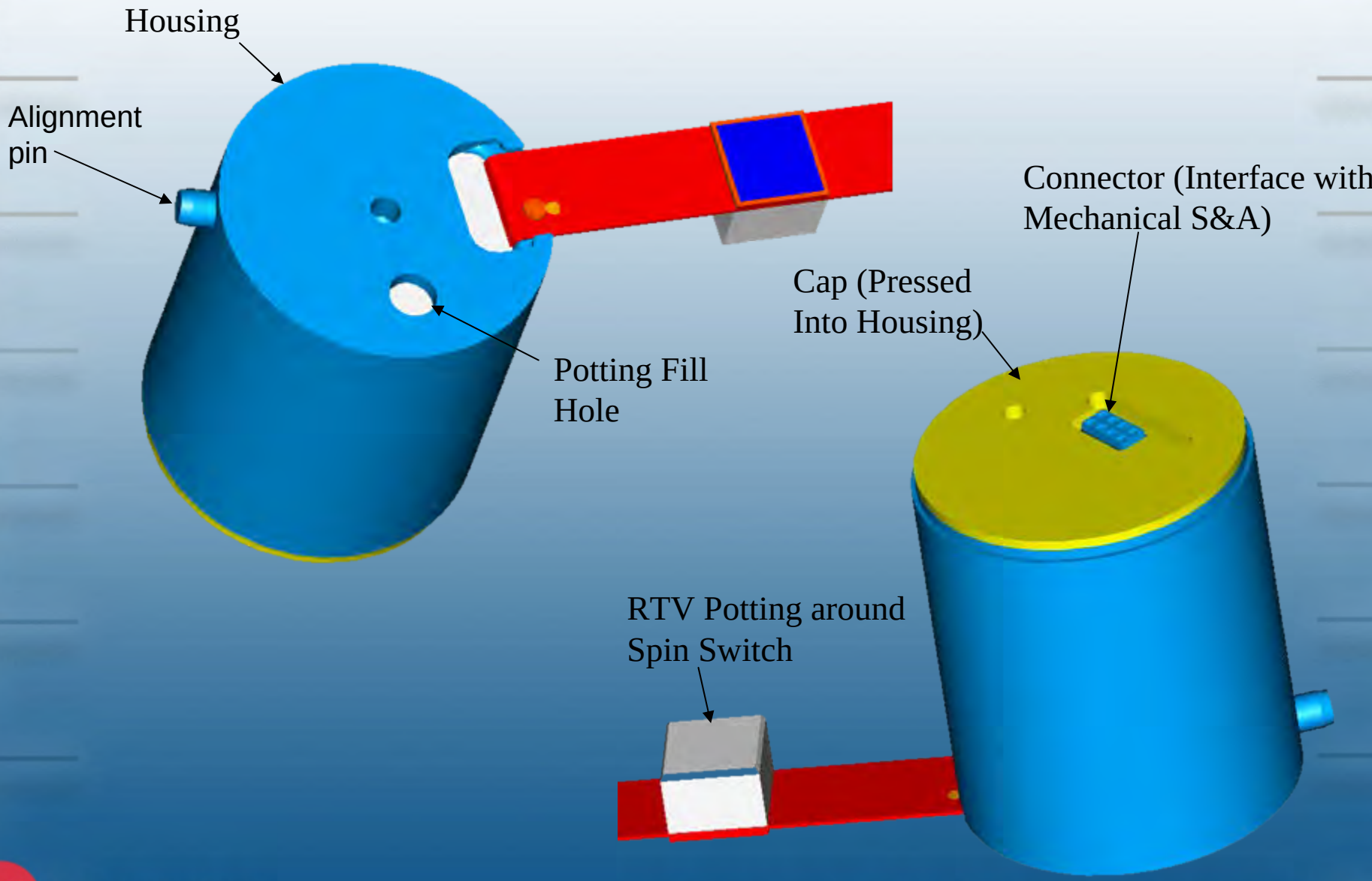
Safety Button

Piston Actuator

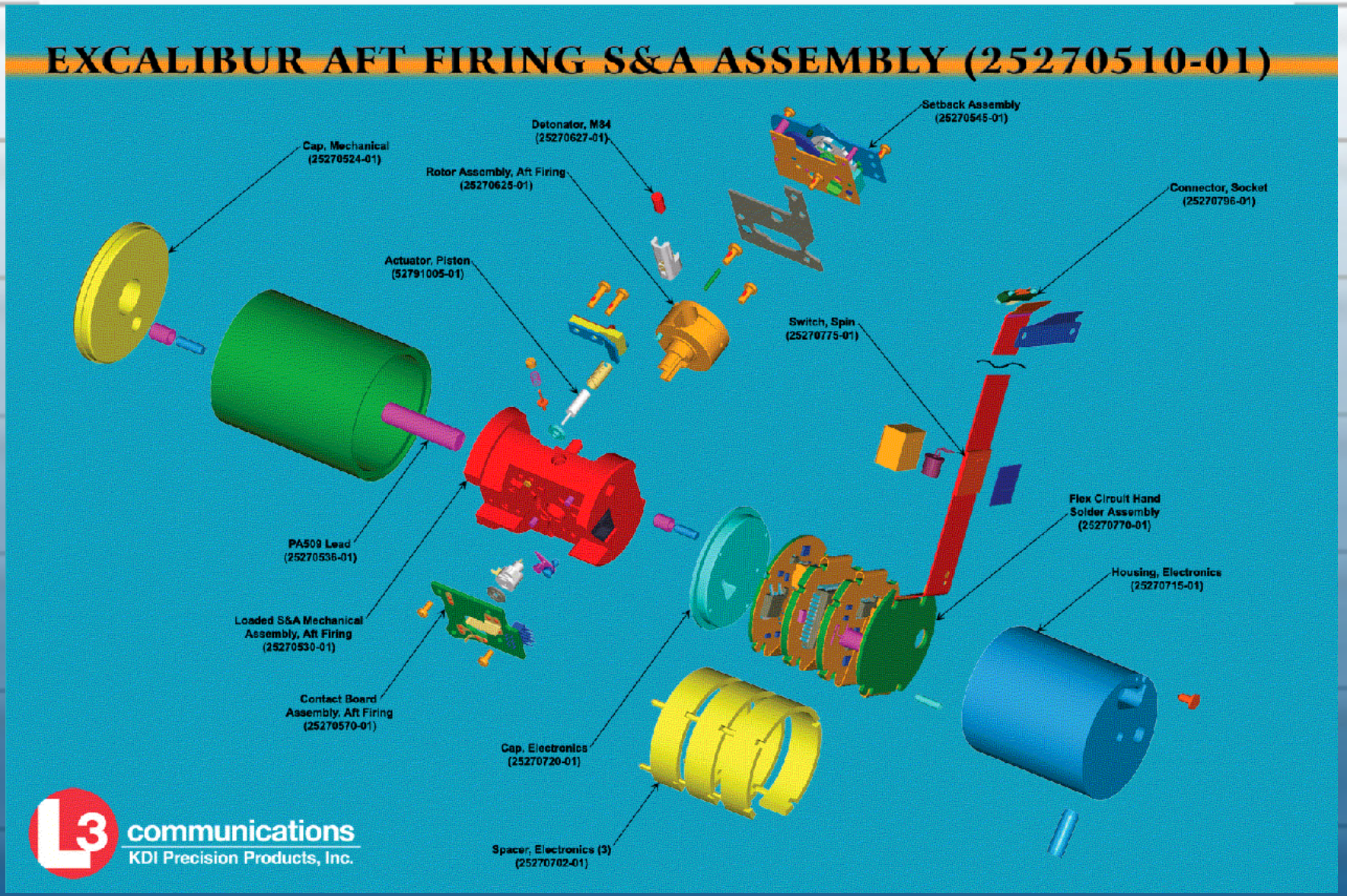
Excalibur Electronic Flex Assembly Module



Excalibur FSA Electronic Sub-Assembly

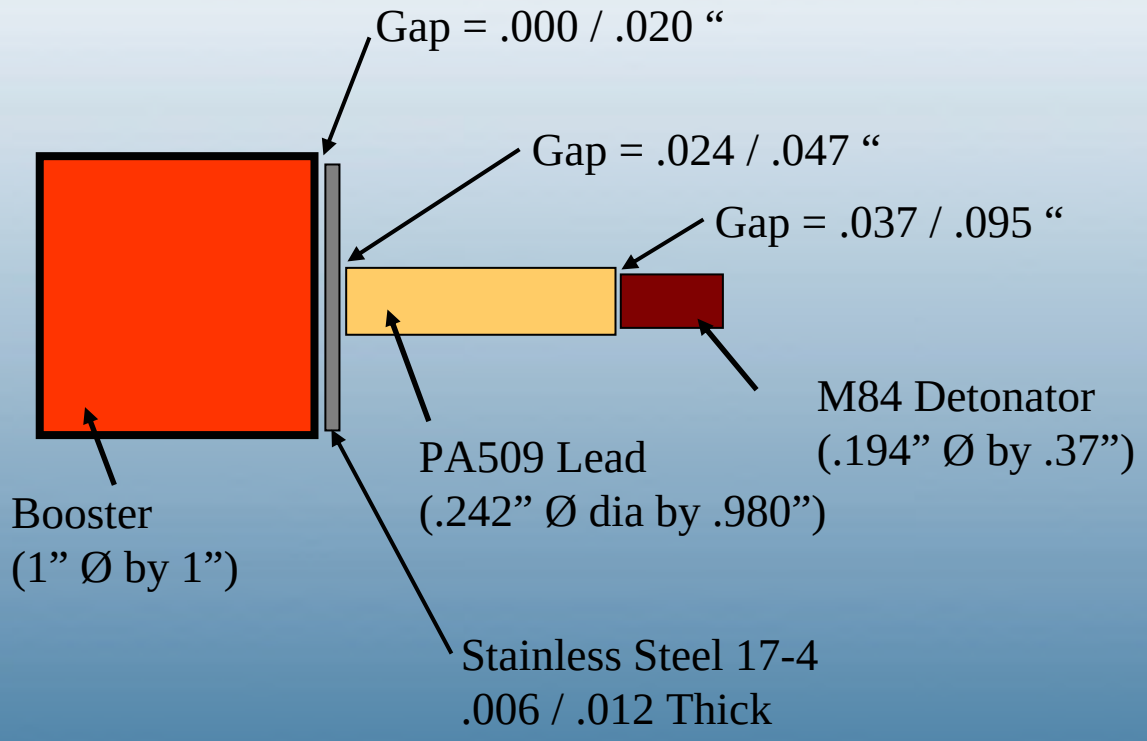


EXCALIBUR AFT FIRING S&A ASSEMBLY (25270510-01)

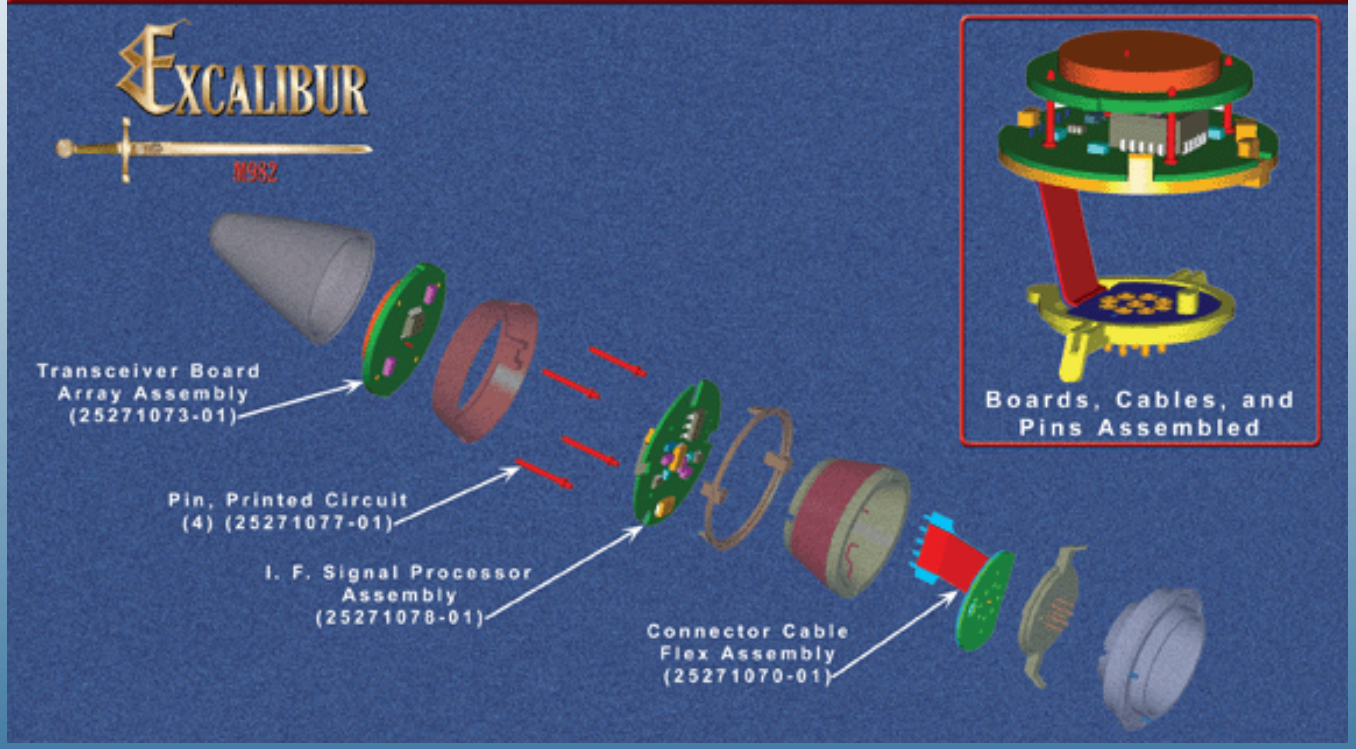


Excalibur FSA

Explosive Train



Excalibur
Height of Burst (HOB) Sensor
Module (25271000-01) Phase 2 – Qualification Configuration



- Production Fuze Prox Sensor Chipset
- Burst Height of 3.7 +/- 1 meters
- Point Detonate Backup
- Unpowered Until 3.5 Seconds from Target

FSA Design Summary

- Resulting Capabilities
  - Meets MIL-STD-1316D
  - Interactive W/ GN&C
  - Maximized Overhead Safety
    - Independent Timer
    - Arm Command issued Just Prior to Endgame
  - Excalibur was Fielded in May 2007 for Operation Use

ERGM

M982

S&A Program Milestones

- M982 (Excalibur) S&A
  - Completed Design Analysis, Design Verification Testing, Qualification, and AFSRB Certified
  - The Excalibur System was Fielded in May 2007 and is Currently in Operational Use
  - KDI is Under Contract to Develop a Low Cost ESAD Alternative S&A Design
- ERGM EX87 S&A
  - Finished DVT
  - ERGM has been terminated. The requirement for a guided extended range munition is still valid. NAVSEA is currently restructuring the program.

Excalibur ESAD Development

- Development team consisted of members from KDI, ARDEC fuze group at Picatinny and Adelphi
- Development program objectives accomplished
  - Drop-in replacement with existing S&A
  - Lower Unit Production Cost
  - Increased reliability
  - Hardware tests used to mitigate initial high risk areas
  - 1st Environment sensor designed, developed and tested
  - AFSRB informal and formal review completed
  - Preliminary Design Review completed
- Electrical and mechanical design completed
  - Functional hardware fabricated and tested
    - Explosive function test success
    - ARDEC airgun and railgun mechanical shock tests successfully completed (gun launch simulated)
    - EGLIN AFB howitzer hard target penetration tests successfully completed

43rd Gun & Missile Conference

Guided MLRS Electronic Safety & Arming Devices (ESAD) & Electronic Safety & Arming Fuze (ESAF)

communications

KDI Precision Products, Inc.
3975 McMann Road
Cincinnati, Ohio 45245

Presented by: Mr Perry Salyers

April 2008

Agenda

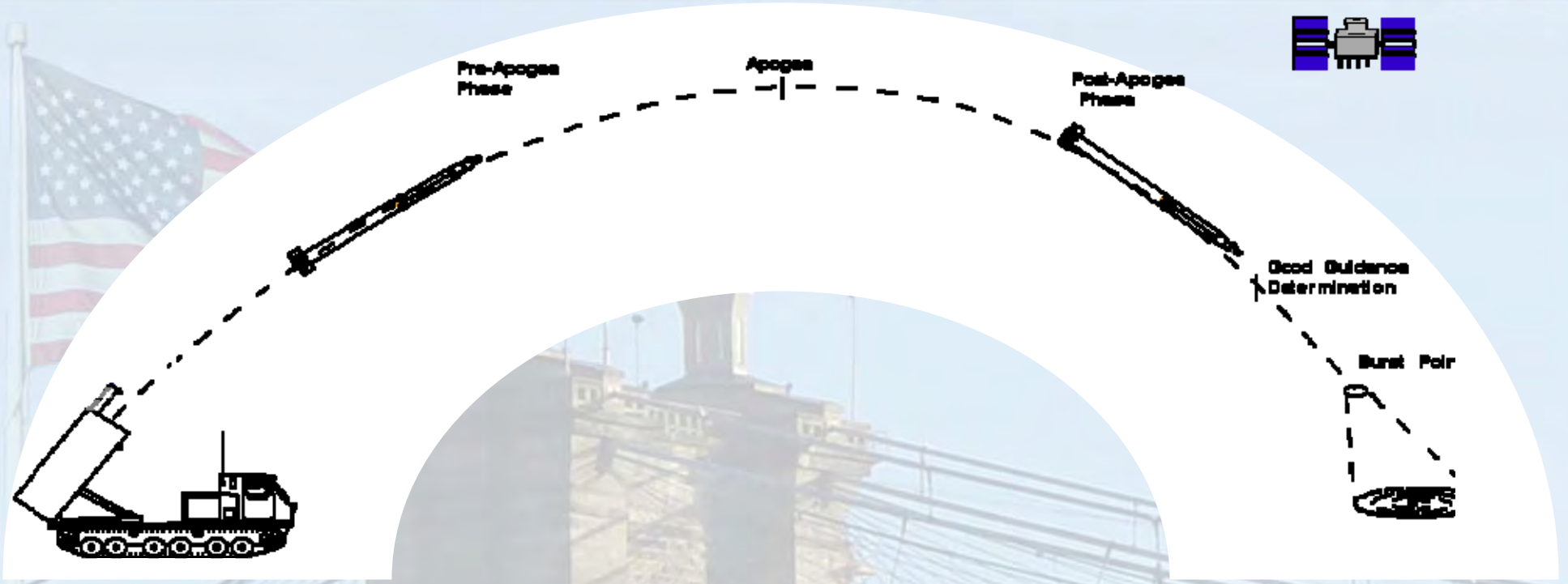
- Introduction
- MLRS Overview
- M30 Guided MLRS DPICM
- Guided MLRS Unitary (6” ESAF)
- M31 Guided MLRS Unitary (3” ESAF)
- Conclusion

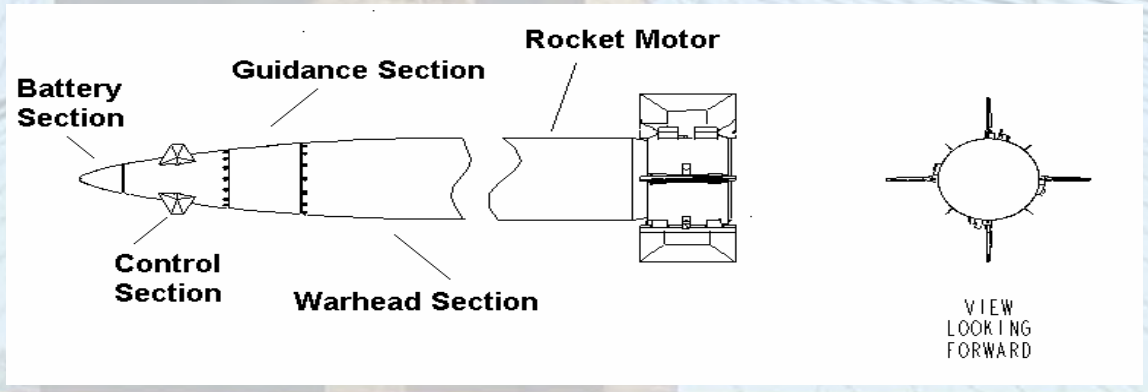
Guided MLRS USA And Foreign Partners

MLRS Background

- MLRS family of munitions includes three rockets and four missiles with others in development
- 13 feet long and 9 inches in diameter
- Tube-launched, spin-stabilized, free-flight projectile
- Range is a function of launcher elevation
- Latest designs utilize canards to correct the trajectory during the flight and rolling fins to provide stability
- Assembled, checked, and packaged in a dual-purpose launch-storage tube at the factory

GMLRS Operation



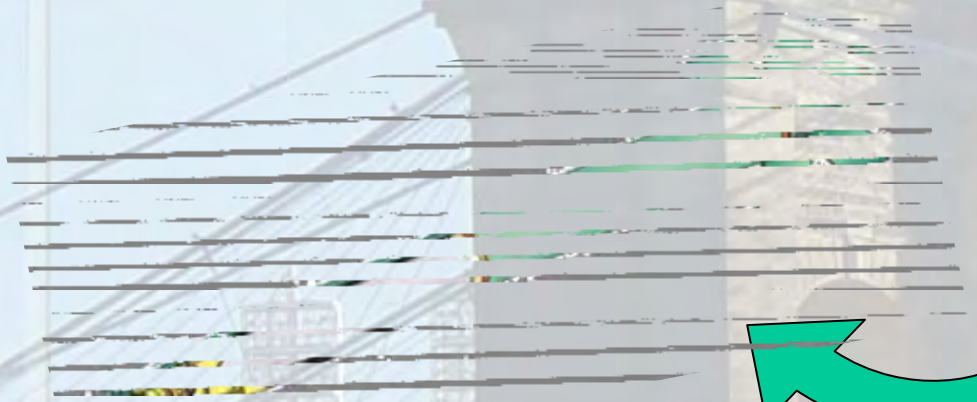


Evolutions in MLRS Rockets

1979
M26 MLRS

1992
M26A1 ER-MLRS

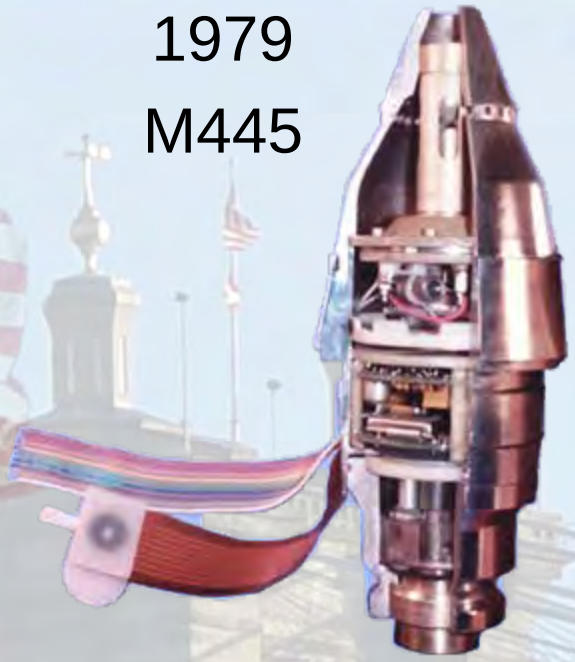
2001
M30 GMLRS DPICM



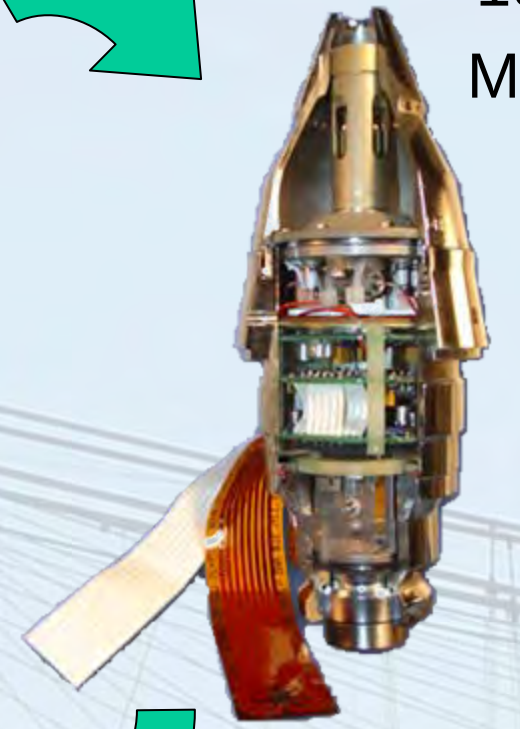
2004
XM31 GMLRS Unitary

Evolutions in MLRS Fuzing

1979
M445



1992
M451



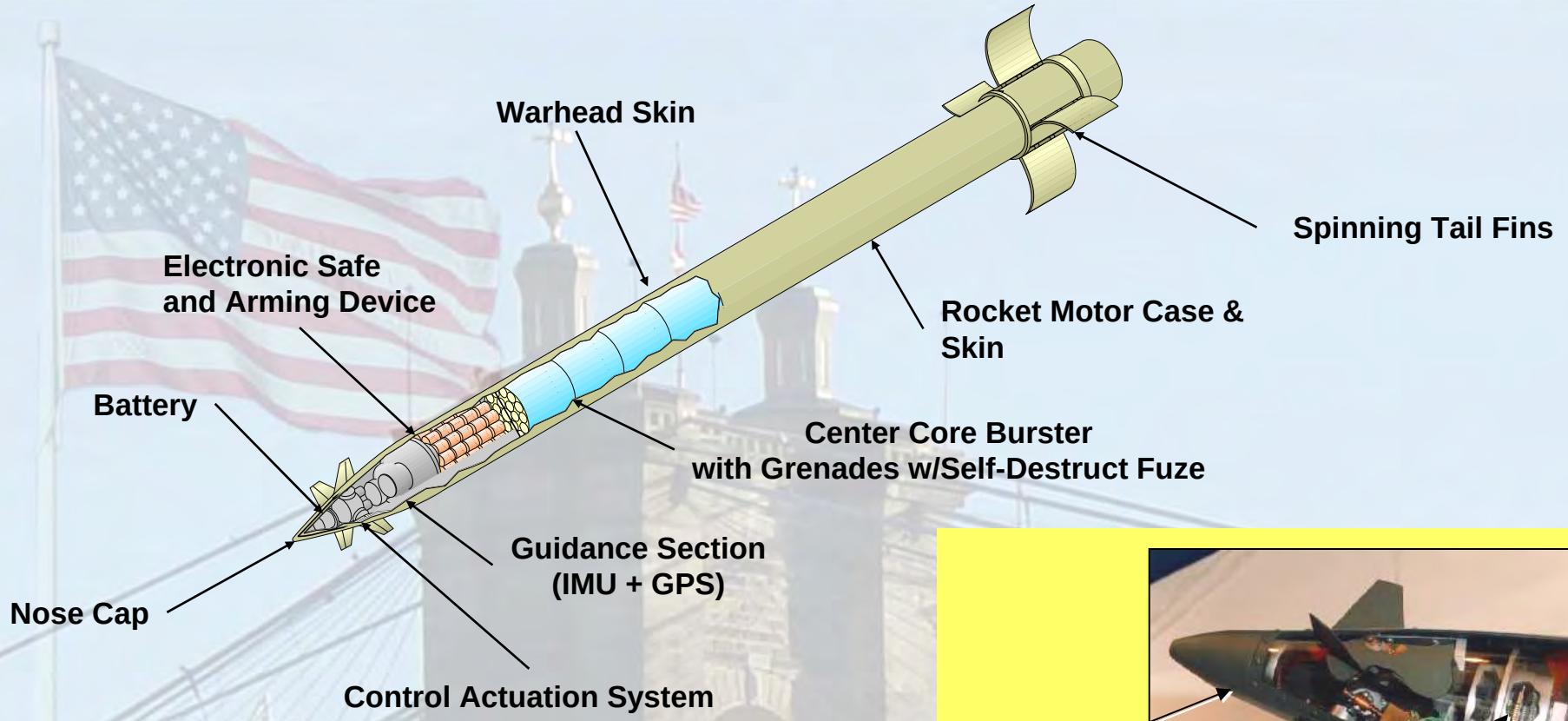
2004
GMLRS Unitary ESAF

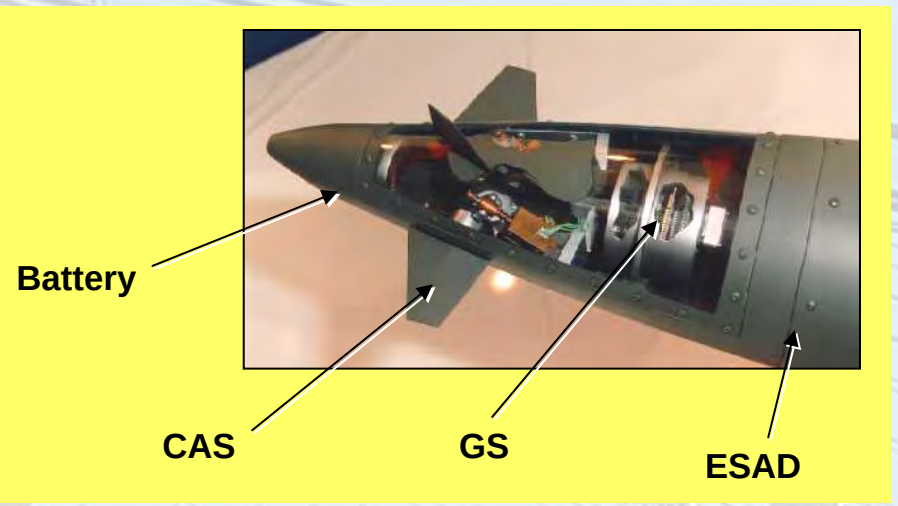
2001
GMLRS DPICM ESAD

M30 Guided MLRS (DPICM)

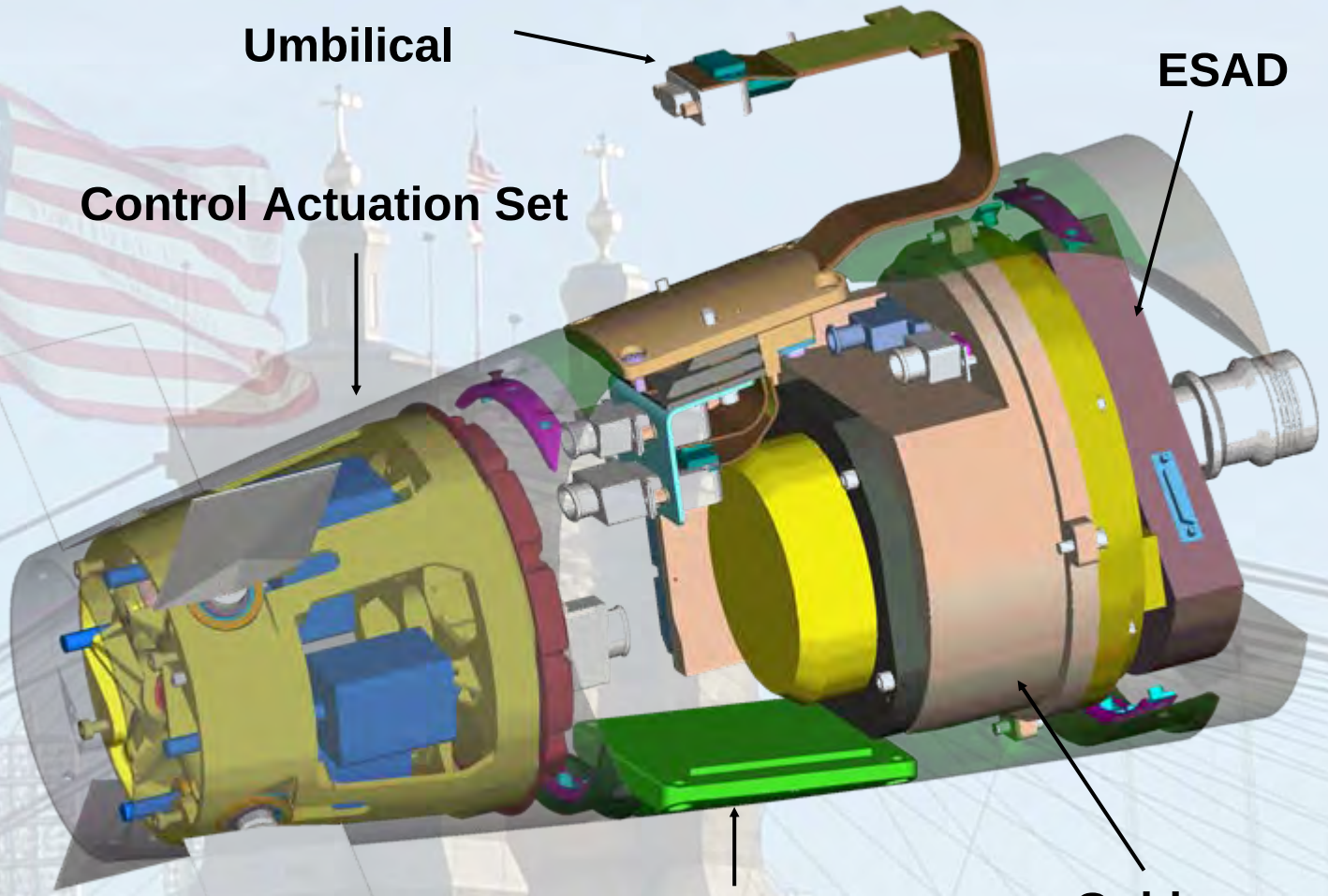
- Began EMD in 1999
- Grew from need for increased range and accuracy
  - GPS aided inertial guidance package
  - Control actuation system
  - Spinning tail fins
  - Canards provide basic maneuverability
- Maximum range 60+ km
- Accuracy measured in meters
- Enhanced anti-jam capabilities
- Dispenses 404 M101 DPICM Submunitions
- Decreases number of rockets to defeat targets by as much as 80%
- New Fuze – GMLRS ESAD

The Guided MLRS DPICM Rocket Design



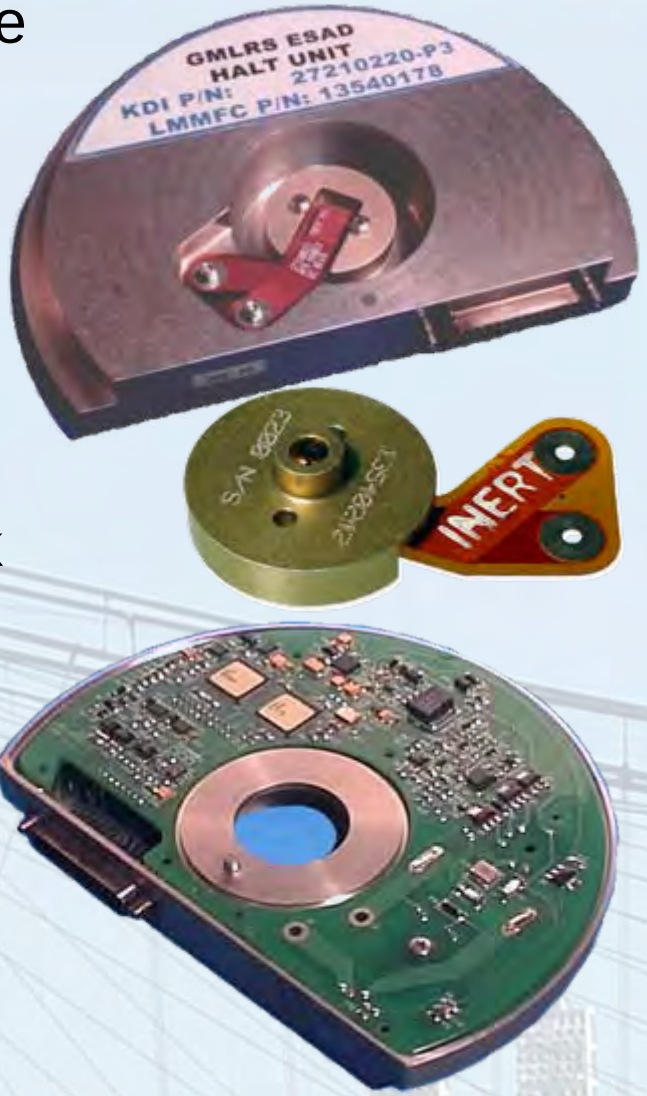


DPICM Round: Guidance and Control Section



Guided MLRS (DPICM) ESAD

- Replaced electro-mechanical fuze with In-Line Electronic Safe and Arm Device (ESAD)
- Design meets MIL-STD-1316D and STANAG 4187
- High voltage generation needed due to removal of mechanical interrupters
- Uses solid state high voltage switch (NMCT)
- Safety environments – changed from setback and ram air to umbilical disconnect and acceleration
- Utilizes MEMS accelerometer
- First motion and safe separation verification
- Sequencing and acceleration for time



Guided MLRS (DPICM) ESAD

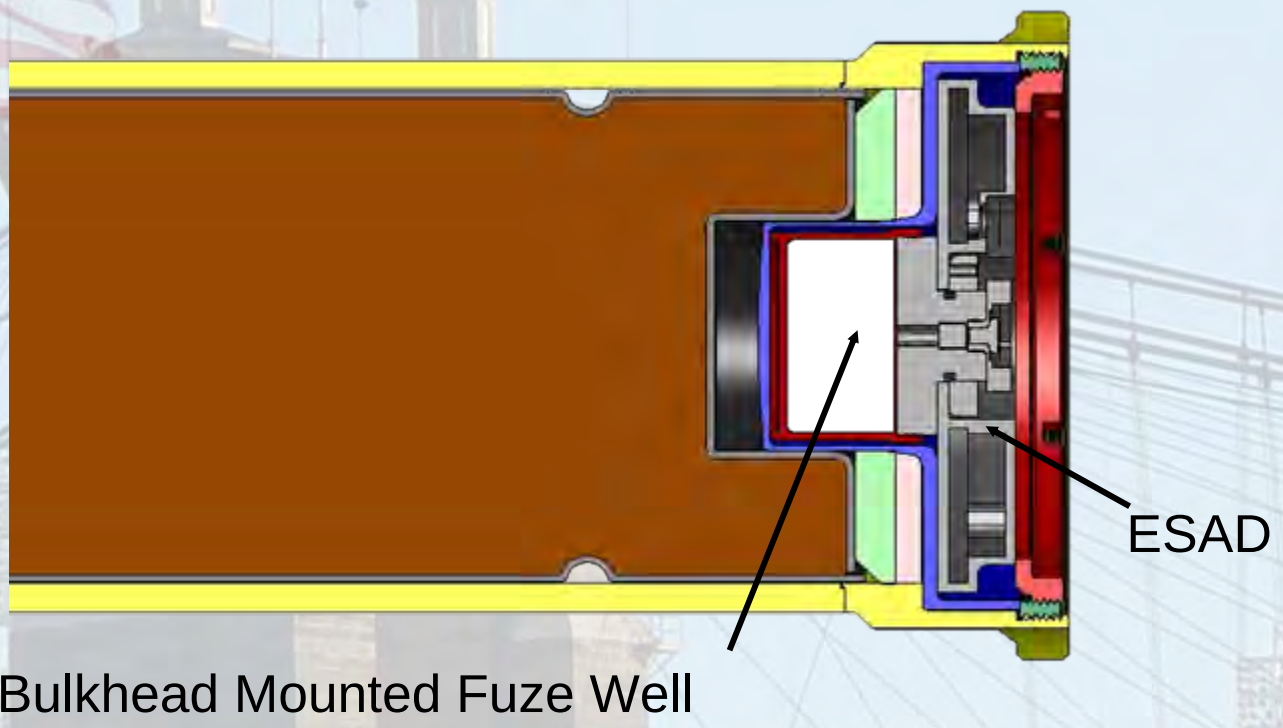
- External Low Energy EFI (LEEFI) used
  - Designed in Unison by China Lake, Reynolds Systems and Silicon Designs
  - The LEEFI Has Been Qualified by China Lake IAW MIL-DTL-23659
  - Specific Tests Designed to Demonstrate the Initiator Meets a Reliability of 0.99 at a 95% Confidence Level Were Performed
- Serial interface
  - Overhead safety timer can be programmed in launcher
  - Provides real time status of events

Guided MLRS (DPICM) ESAD

- Arm/fire command issued prior to desired detonation point
- Fuzing Modes: Arm/Fire
- Increased shelf life & reliability over mechanical system
  - No mechanical parts
  - Hermetically sealed housing
- Increased testability
  - Can be fully tested on bench to verify proper operation
- Qualified in 2002
- > 2300 Delivered to date

6 Inch Unitary ESAF Warhead Design

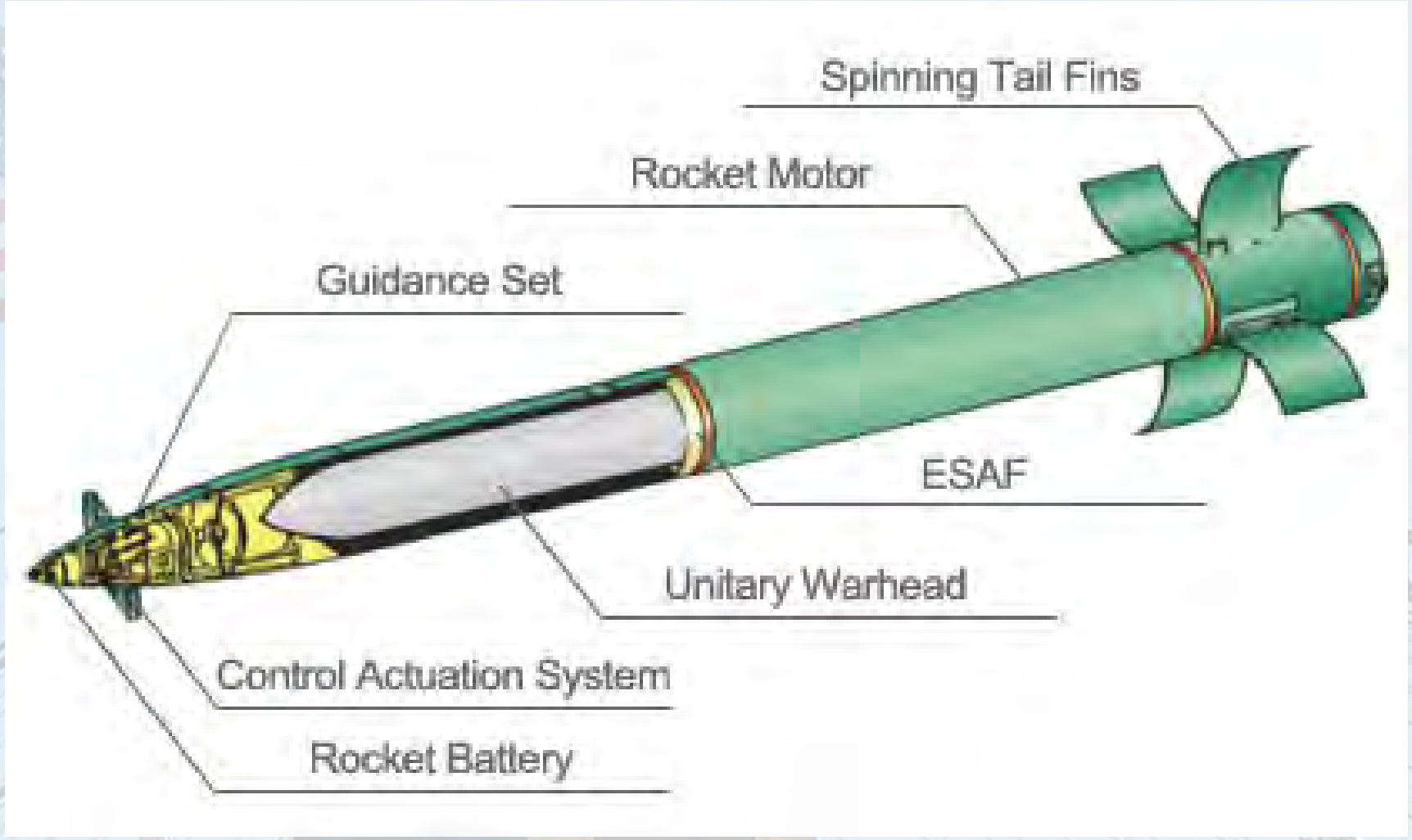
- KDI developed and qualified a variant of the DPICM Round ESAD for use on the Unitary Warhead
- Unit was developed and fielded in < 1 year



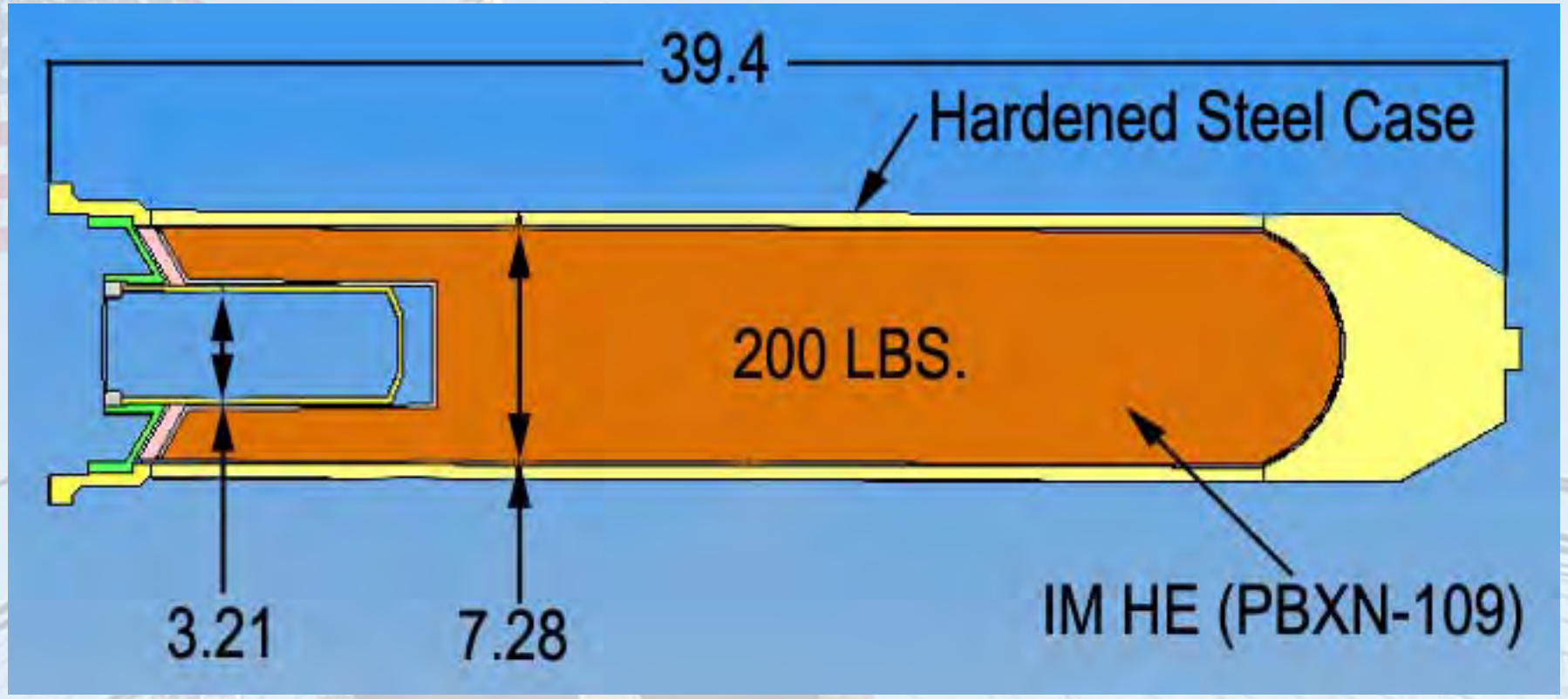
M31 Guided MLRS Unitary

- October 2003 - Lockheed Martin awarded an SDD contract for 86 unitary variant rockets; incorporates new 3” ESAF
- May 2005 - First units delivered - accelerated following a US Army Urgent Need statement
- Aug 2005 - Unitary variant began field testing in Iraq
- Sep 2005 - First GMLRS unitary rockets fired in combat operations by 3rd Battalion, 13th Field Artillery (3-13 FA), 214th Field Artillery Brigade
- > 2100 Produced to date
- Today, GMLRS unitary is the Army’s only surface-fired, precision, longer range indirect fire munition available to troops in contact in an urban environment
- Affectionately referred to as the “70km sniper round”

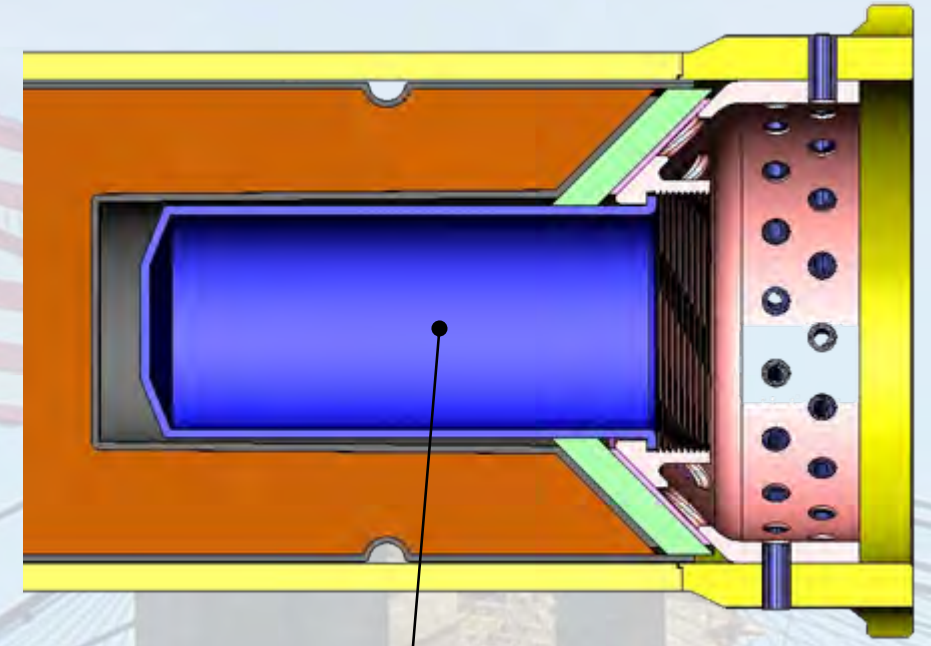
M31 Guided MLRS Unitary



Unitary Warhead Design



3” Fuzewell ESAF Warhead Design



3 Inch Fuzewell

Fuzing Modes

- PD
- Delay
- Proximity

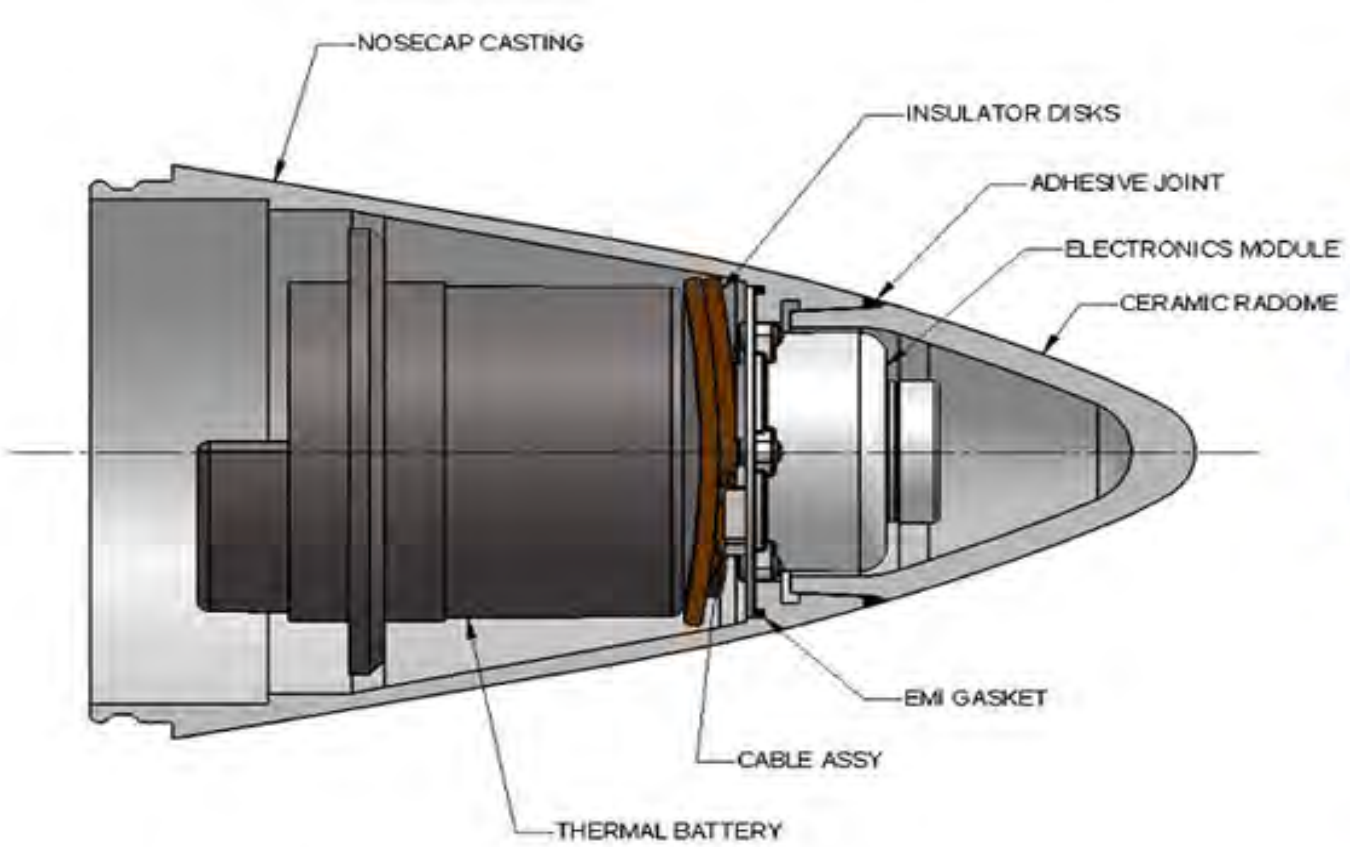
GMLRS Unitary ESAF

- Tri mode fuze functionality – proximity, impact, and impact with delay
- Design compatibility with MIL-STD-1316E and STANAG 4187
- GMLRS (DPICM) ESAD was baseline design
- Added internal impact switches
- Added external impact switch fire input
- Added proximity sensor interface
- Impact survivability
  - Survives high g longitudinal loads
  - Settable detonation delay time
- Safety Environments – Umbilical disconnect and acceleration

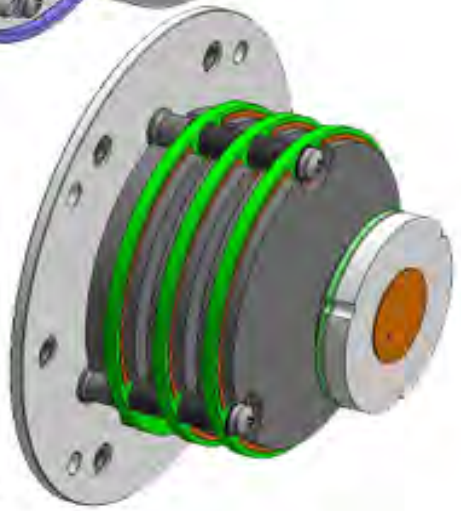
GMLRS Unitary ESAF

- Serial Communications to set overhead safety time, detonation delay time, function mode, receive arm command and provide status during test and flight
- Proximity sensor interface
  - Selectable HOB
  - High approach velocities
- Fits 3” fuze well
- Designed to be insensitive munitions (IM) compliant
- Qualified 2006

GMLRS Proximity Sensor Location

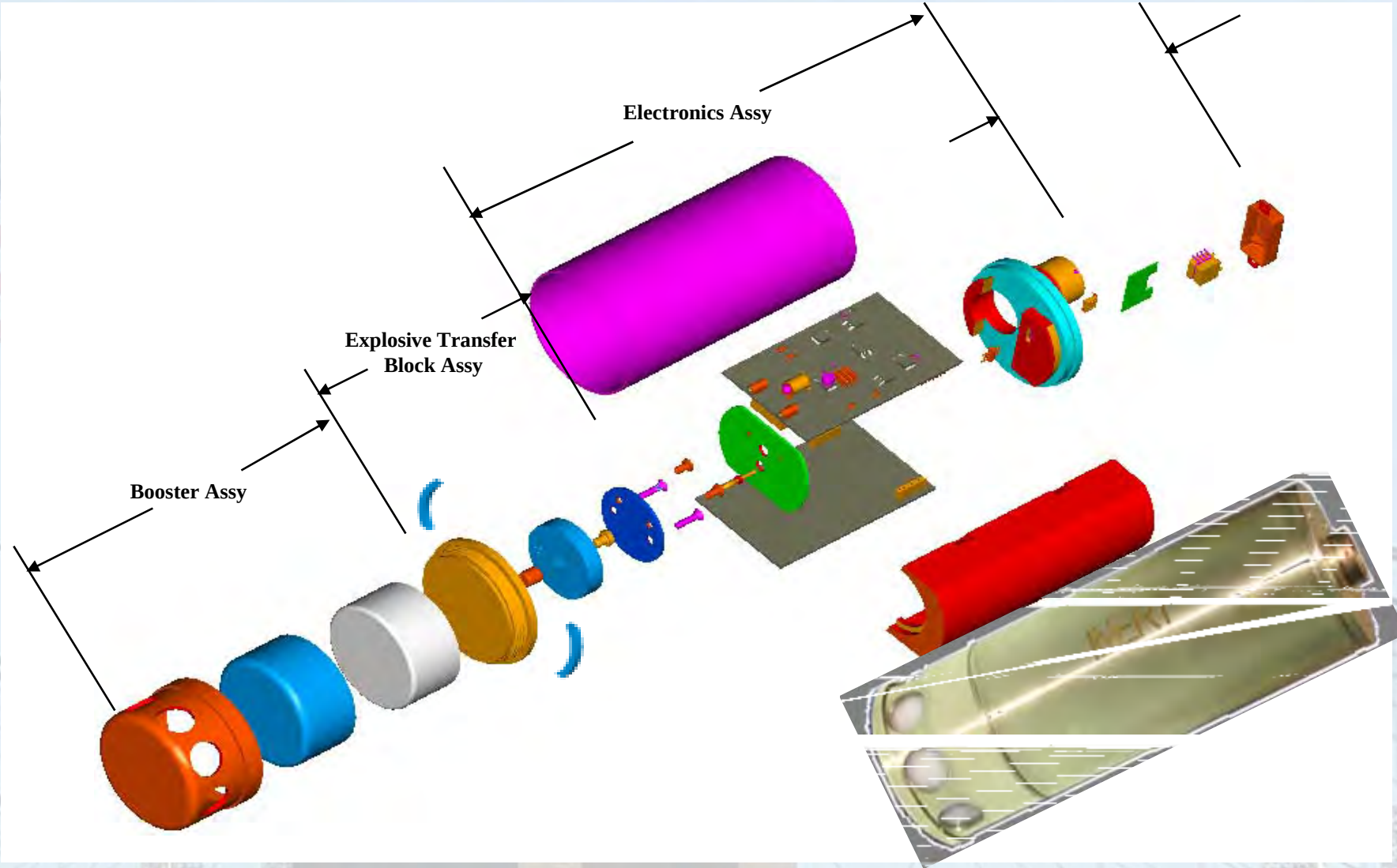


Proximity Sensor



Electronics Boards

3” Fuze Exploded View



Conclusion

- MLRS program has evolved over the last 30 years
  - MLRS improvements have focused on upgrading launcher responsiveness and enhancing the range and precision of its munitions over the last 10+ years
  - Increased range – from 30km to 70km+
  - Improved lethality and reduced collateral damage by changing submunitions / warhead – DPICM, Unitary
  - Systems have adapted to evolving technology – GPS/INS, control systems, Fire Control, Fuzing improvements
- Program team always focused on delivering weapon to meet war fighters needs - “one round, one kill capability”

2008 NDIA
42nd Annual Armament Systems:
Gun & Missile Systems Conference & Exhibition
21 – 24 April 2008
New Orleans, LA

LW30mm (30 x 113mm) Spotter Charge Prototype

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LW30mm Spotter Charge - Outline

- **Background and Need**
- **Technical Approach**
- **ATK Testing**
- **Testing at Ft. Rucker**
- **Acknowledgements/Contacts**
- **Questions & Answers**

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LW30 Ammunition – 30mm X 113mm

M789 HEDP

– High Explosive Dual Purpose

Length (max):	**113 mm**
Weight:	**343 g**
Projectile Mass:	**234 g**
Muzzle Velocity:	**805 m/s**
Max Range:	**~ 3000 m**
Dispersion:	**1.35 mils**

M788 TP

– Training Projectile matched to M789

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M230 Weapon System

- **30mm M230 Chain Gun Automatic Cannon**
- **Caliber:** 30mm X 113mm - LW30 Linkless
- **Max Range:** ~ 4000 meters
- **Rate of Fire:** 625 ± 25 Shots per Minute
- **Platforms:**
  - AH-64 / AH64A Apache Attack Helicopters
  - MH-60 Variants - SOAR
- **Targets:**
  - Light Armored Vehicles
  - Deployed Infantry

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LW30mm Spotter Need and Requirements

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Market Survey / Sources Sought Solicitation – April '07

Solicitation Number W15QPN-07-X-0665, Issued 4/13/07

ATK Resp

Descripti

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1. **Visib**
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DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY AVIATION WARFIGHTING CENTER AND FORT RUCKER
453 NOVOSEL STREET
FORT RUCKER ALABAMA 36362-5105

Memorandum May '07 states additional desired capabilities definition

- *Visibility requirements:*
  - *" …Visible 0 to 3000m*
  - *Day - Unaided eye, FLIR, DT*
  - *Night - Unaided eye, FLIR, NV goggles*
- *Target media*
  - *"…packed soil, cement, 3/4 plywood, hard metal targets,….."*
- *Ammunition should be non-dud producing*
- *Expected to be a NDI (Non-Developmental Item) solution*
- *Demonstration testing to be conducted at Ft. Rucker late '07 timeframe*

Customer includes:

- Ft. Rucker – Army Aviation Training Center/ Training and Doctrine Command (TRADOC) TCM (Tradoc Capability Manager)
- US Army Office of the Project Manager Maneuver Ammunition Systems (OPM-MAS)
- Armament Research, Development and Engineering Center (ARDEC)

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LW30mm Spotter Charge IRD – Schedule Challenge

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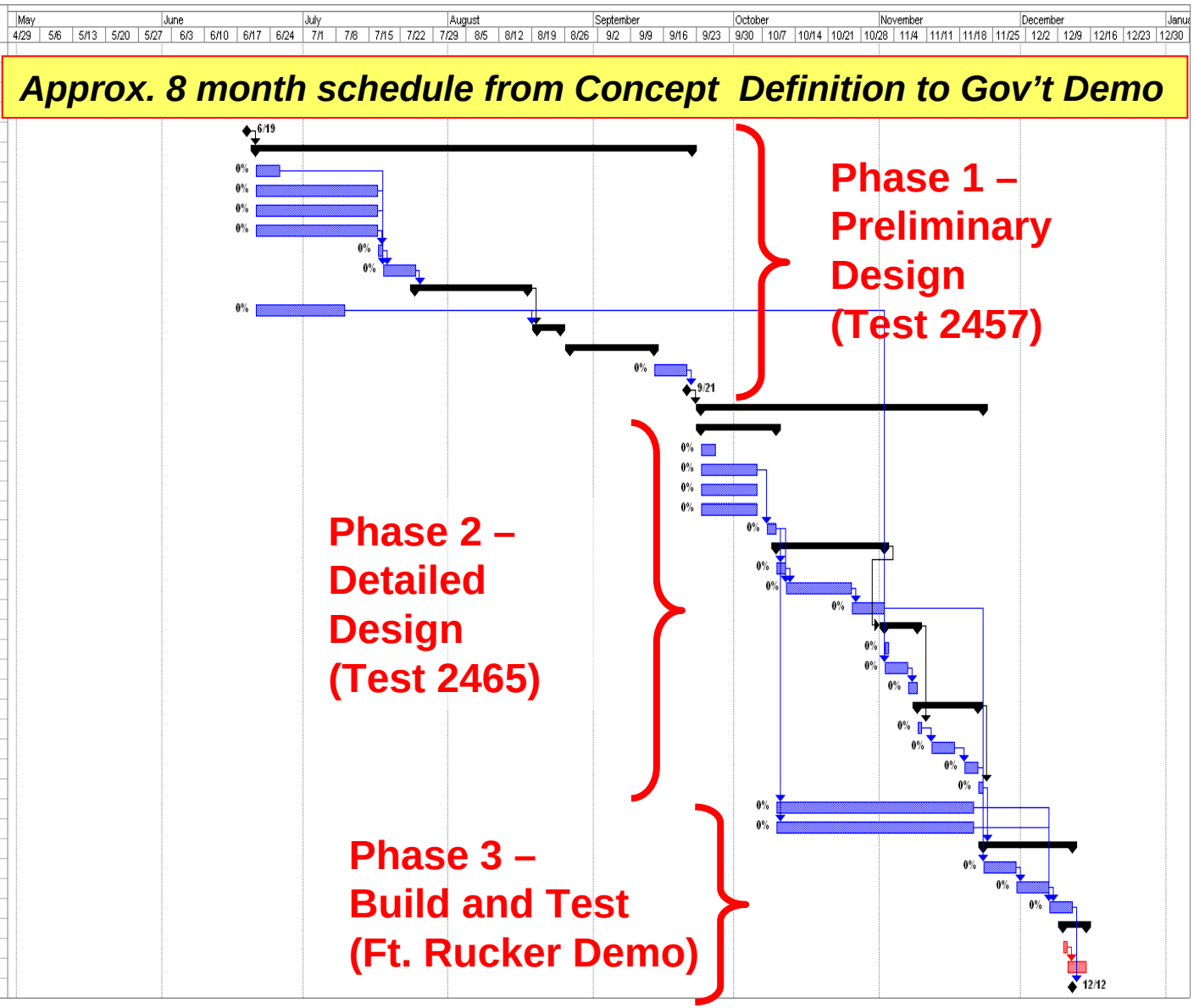
ID	Task Name
1	Concept Development Project/Pursuit Authorization (TRL 1-5)
2	Planning and Budgeting
3	Startup Review
4	**System Requirements Development & Management**
9	Peer Inspection & Management Review
10	**System Design and Analysis - Preliminary Design (5.2)**
11	Design FMEA
12	PRO-E Modeling of M789 Body with RM; maintain mass properties
13	PRODAS
14	ANSYS Stress Analysis & Thermal Analysis
15	Interim Design Review (IDR)
16	Prelim Drawings
17	**Hardware Fabrication for Preliminary Design (Build Cat 2)**
20	Ship RM Materials from Thiokol to ATPG
21	**Load & Assembly**
25	**Test**
31	Document Results
32	Preliminary Design Review (PDR) - Baseline Desgin
33	**System Design and Analysis - Detailed Design (5.3) - Phase 2**
34	**Define, Develop and Anlayze Detailed Baseline Design**
35	Update Design FMEA
36	PRO-E Modeling of M789 Body with RM; maintain mass properties
37	PRODAS
38	ANSYS Stress Analysis
39	Detailed Drawings
40	**Hardware Fabrication for Detailed Design (Build Cat 3) & Demo**
41	Place Purchase Orders
42	Fabricate / Alter / Inspect Projectile Metal Parts for Phase 2
43	Fabricate / Alter / Inspect Projectile Metal Parts for Phase 3
44	**Load & Assembly**
45	Build Readiness Review (BRR)
46	Mix and Load Projectiles at ATPG with Thiokol Reps on site
47	LAP Cartridges at ATPG
48	**Test**
49	Test Readiness Review (TRR)
50	Test at ATPG (Day and Night) up to 2km
51	Document Results
52	Critical Design Review (PDR) - Baseline Desgin
53	Hazard Classification for Projectile
54	Hazard Classification for Cartridge
55	**Build of Cartridge delivery for government demonstration - Phase 3**
56	Projectile loading
57	Cartridge LAP
58	Ship to Ft. Rucker
59	**Government Testing at Ft. Rucker**
60	Test Setup
61	Test Firing
62	Concept Development Program Closeout



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LW30 Spotter Charge – ATK Team

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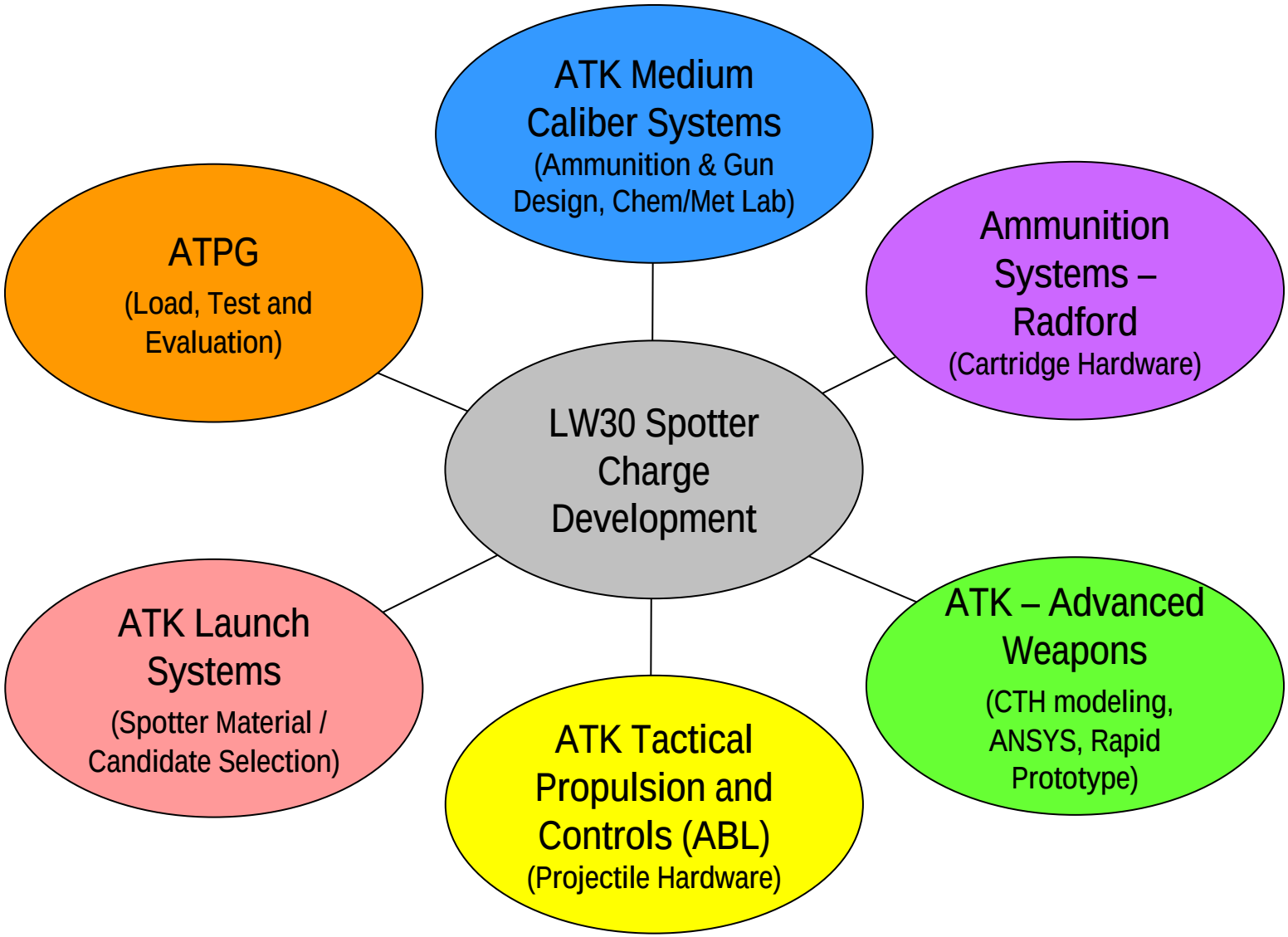

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Spotter Charge – Design Challenges

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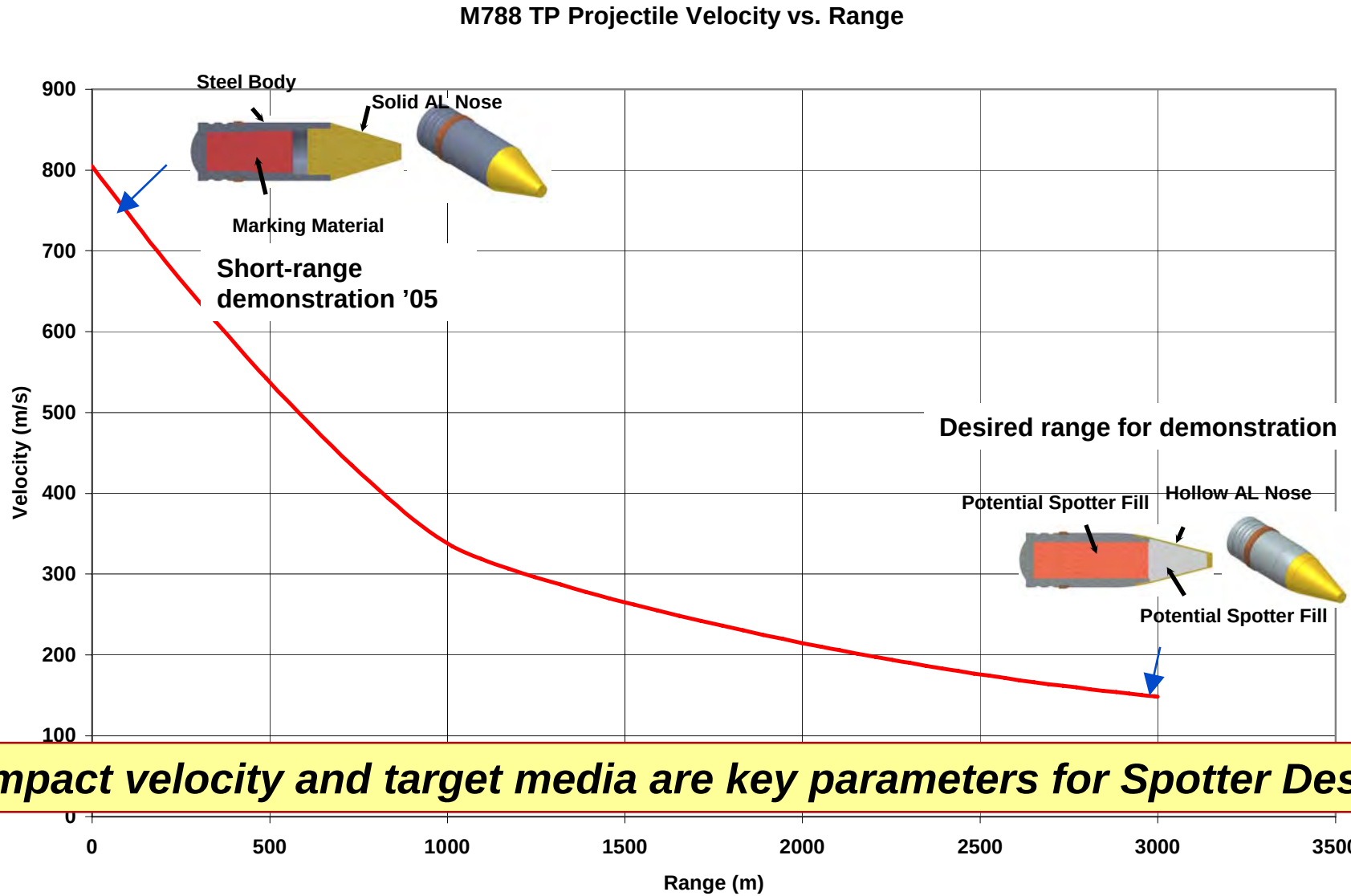

Impact velocity and target media are key parameters for Spotter Design

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Material Selection – Approach

- **Technical:**
  - Approach driven by the desired capability requirements
  - Key challenges: Spotter material sensitivity against soft ground target and reaction against plywood
- **Schedule**
  - “Off the shelf” material currently in use at ATK-LS
  - Castable material due to time constraints of load tooling and integration with projectile geometry changes
- **Selection**
  - Identified 3 initial material candidates to be evaluated in ballistic capability testing
  - Down selected to most viable materials for highest probability of success on target media

ID	Description
X-9	• Magnesium powder • Strontium Nitrate (Red marker) • ATK-LS proprietary binder
X-5	• ATK-LS proprietary Flare formulation • Potassium perchlorate
X-8	• Magnesium powder • Sodium Nitrate (White marker) • ATK-LS proprietary binder

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Spotter Charge Projectile Assy Configurations –Phase 1

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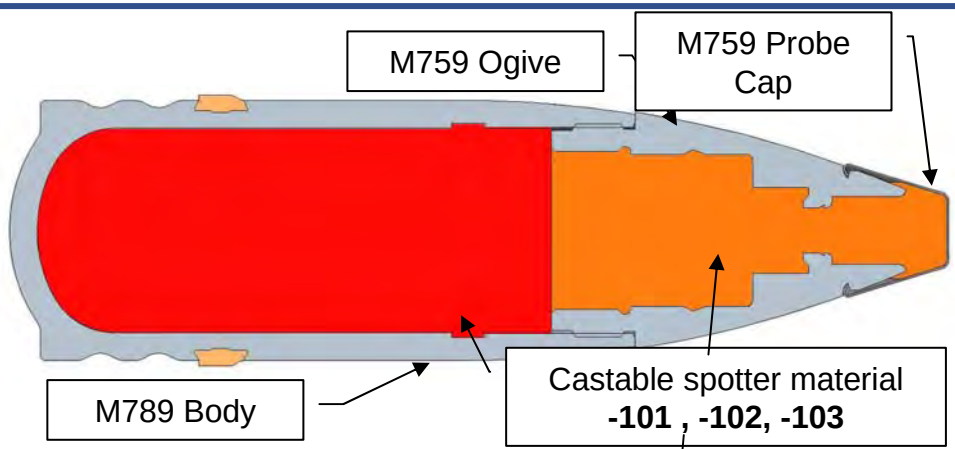
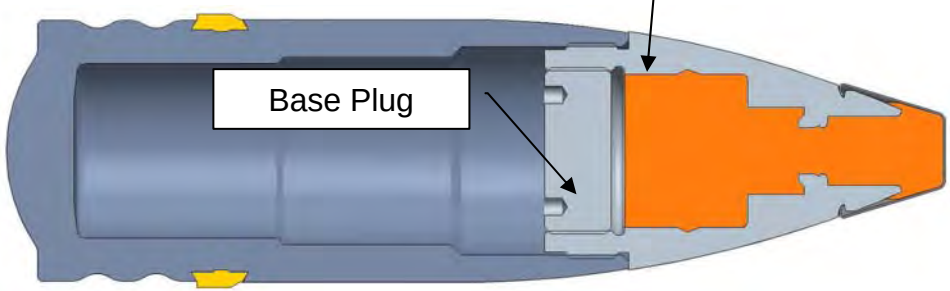


To address the aggressive schedule for demonstration, existing M788 or M789 projectile hardware will be used or altered to accommodate spotter material cast loading.

Spotter Material in Projectile Body & Nose Assembly



Spotter Material in & Nose only

As-mixed

Dispensing gun into Projectiles

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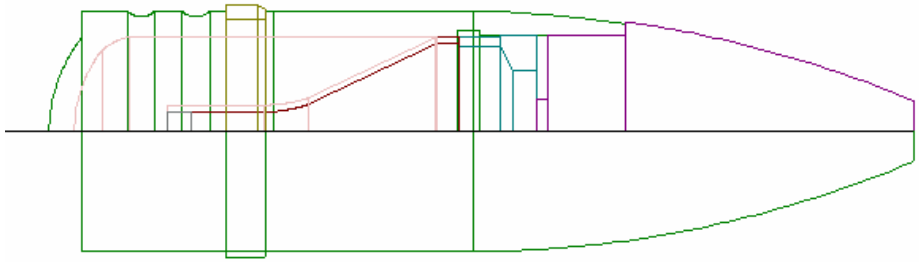
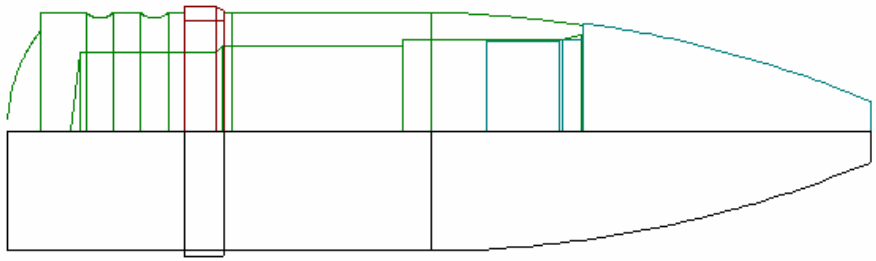
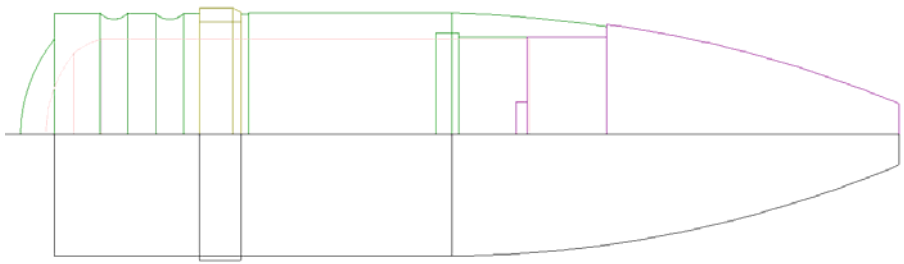
PRODAS Modeling for Ballistic Match to M788/M789



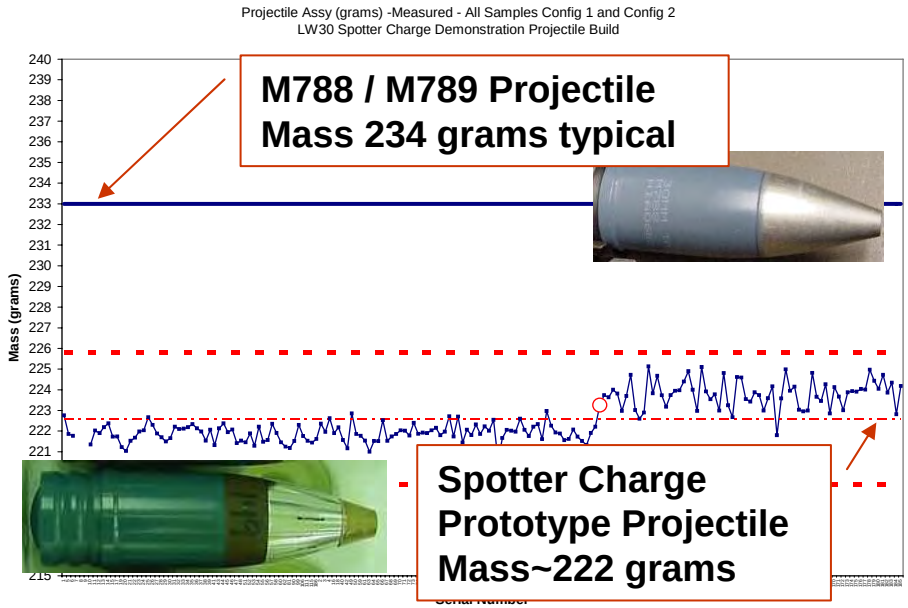
Baseline M789 Model in PRODAS Library

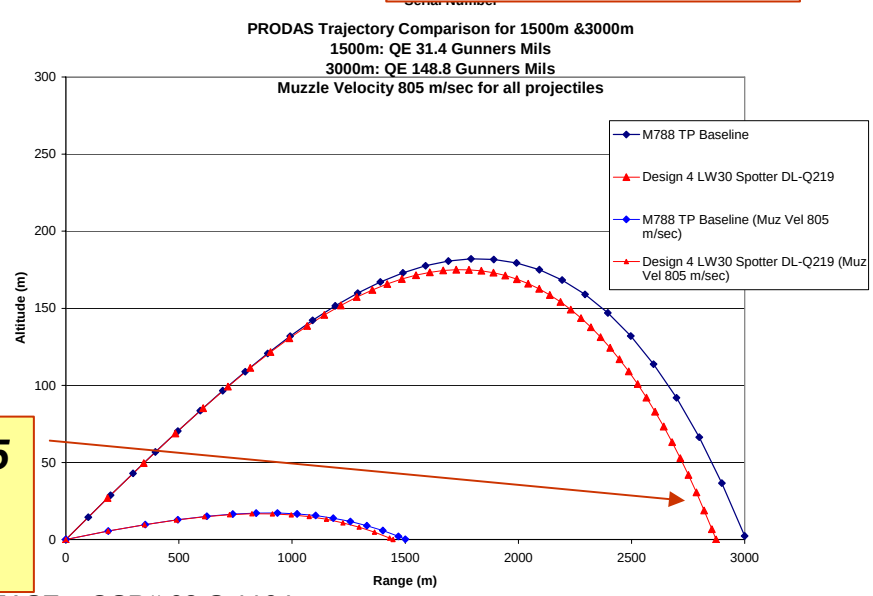


Baseline M788 Model in PRODAS Library



Initial LW30 Spotter Charge Model





Trajectory at 3000m short for same QE and 805 m/s muzzle velocity; increase MV to attain match for spotter to 3000m

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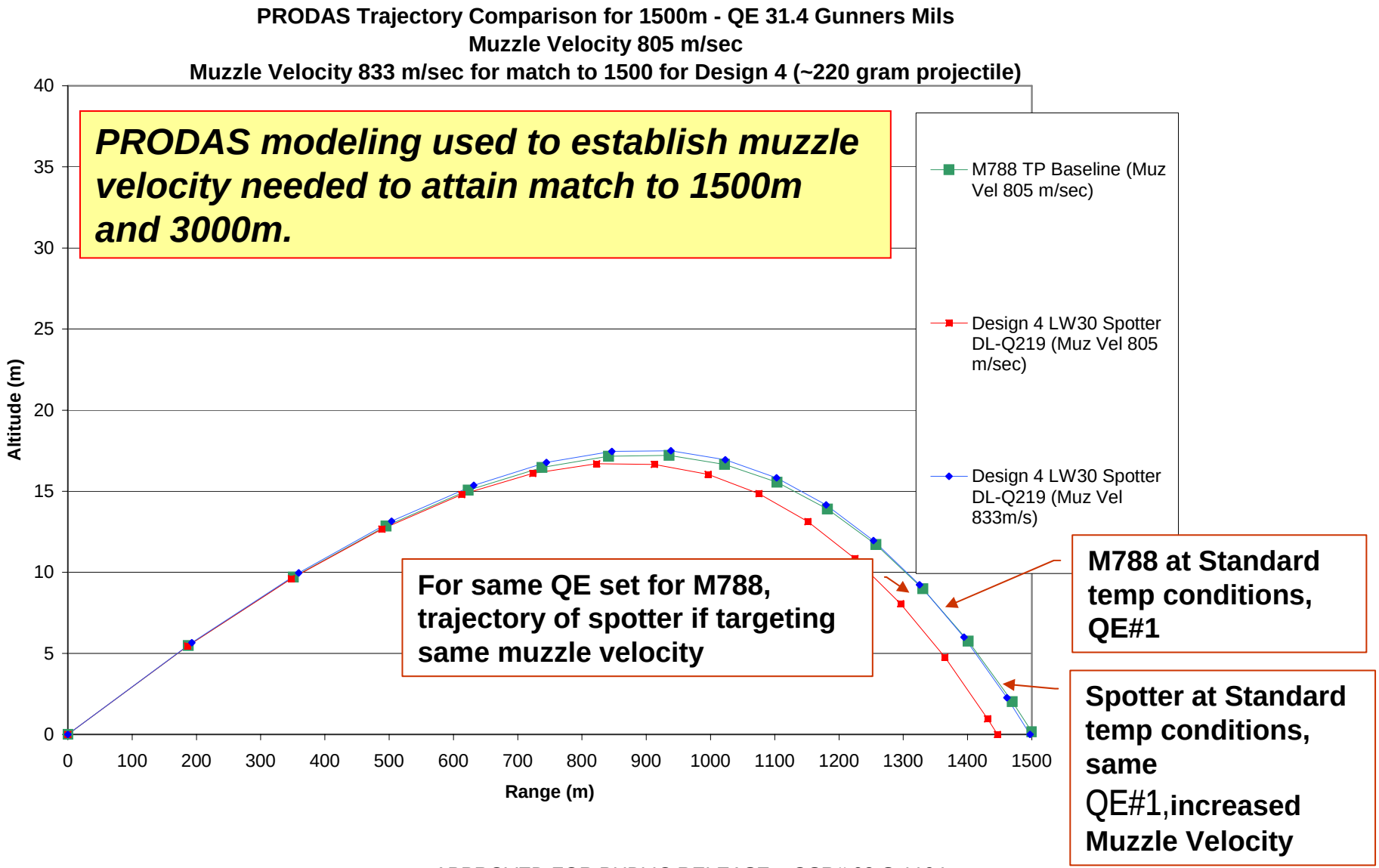
Ballistic Match – PRODAS Trajectory Plots for 1500m



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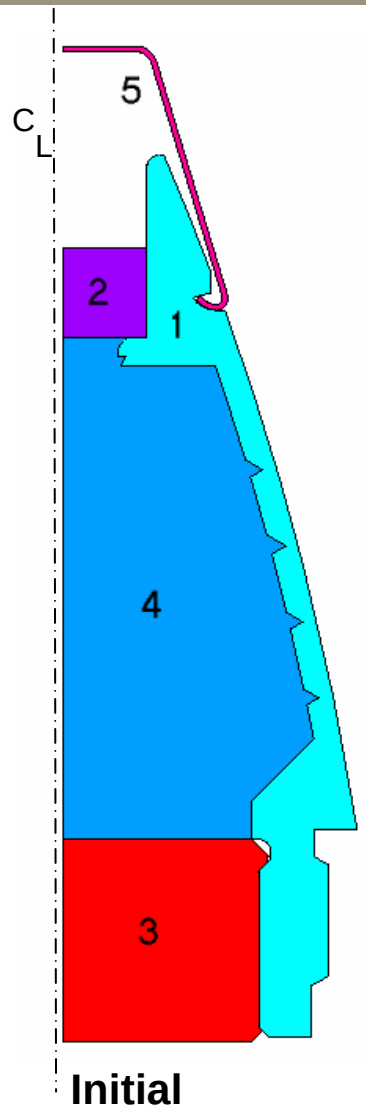
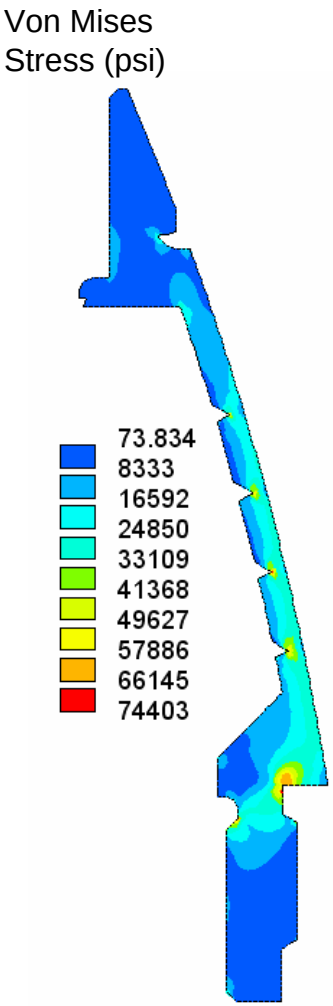
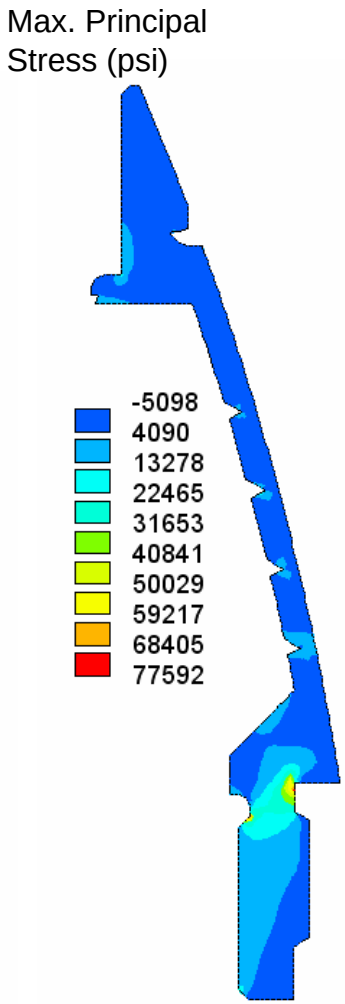
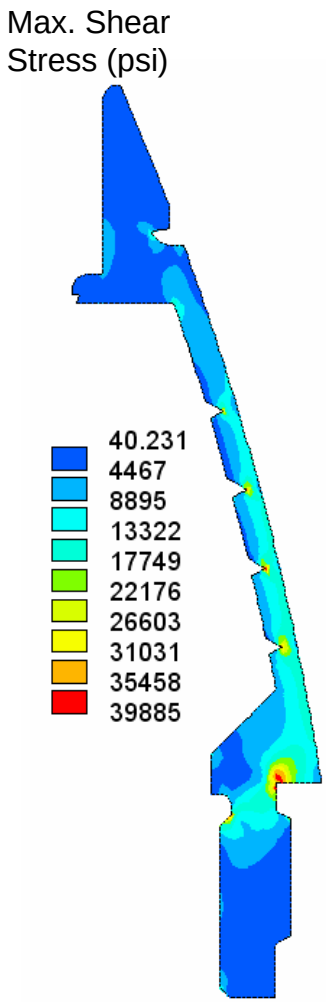
ANSYS Stress Analysis for Ogive

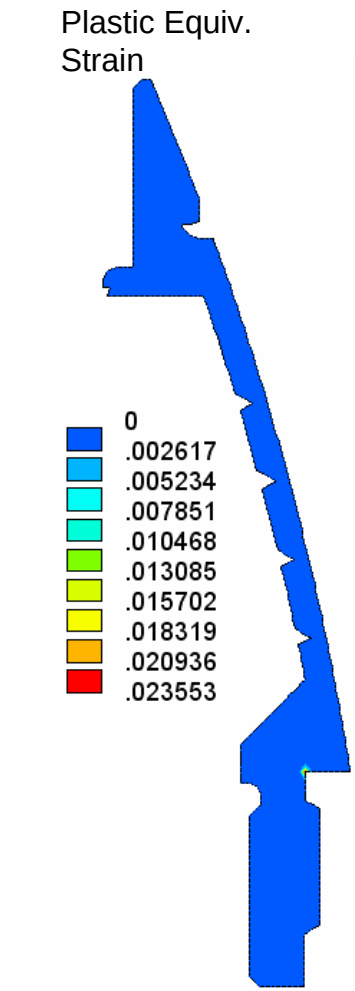


Initial Geometry









Ogive wall thickness will survive gun launch loads

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Ground Impact – Trajectory Plots
1500m / 2000m / 3000m – Gun at 0 vs. Altitude

ATK

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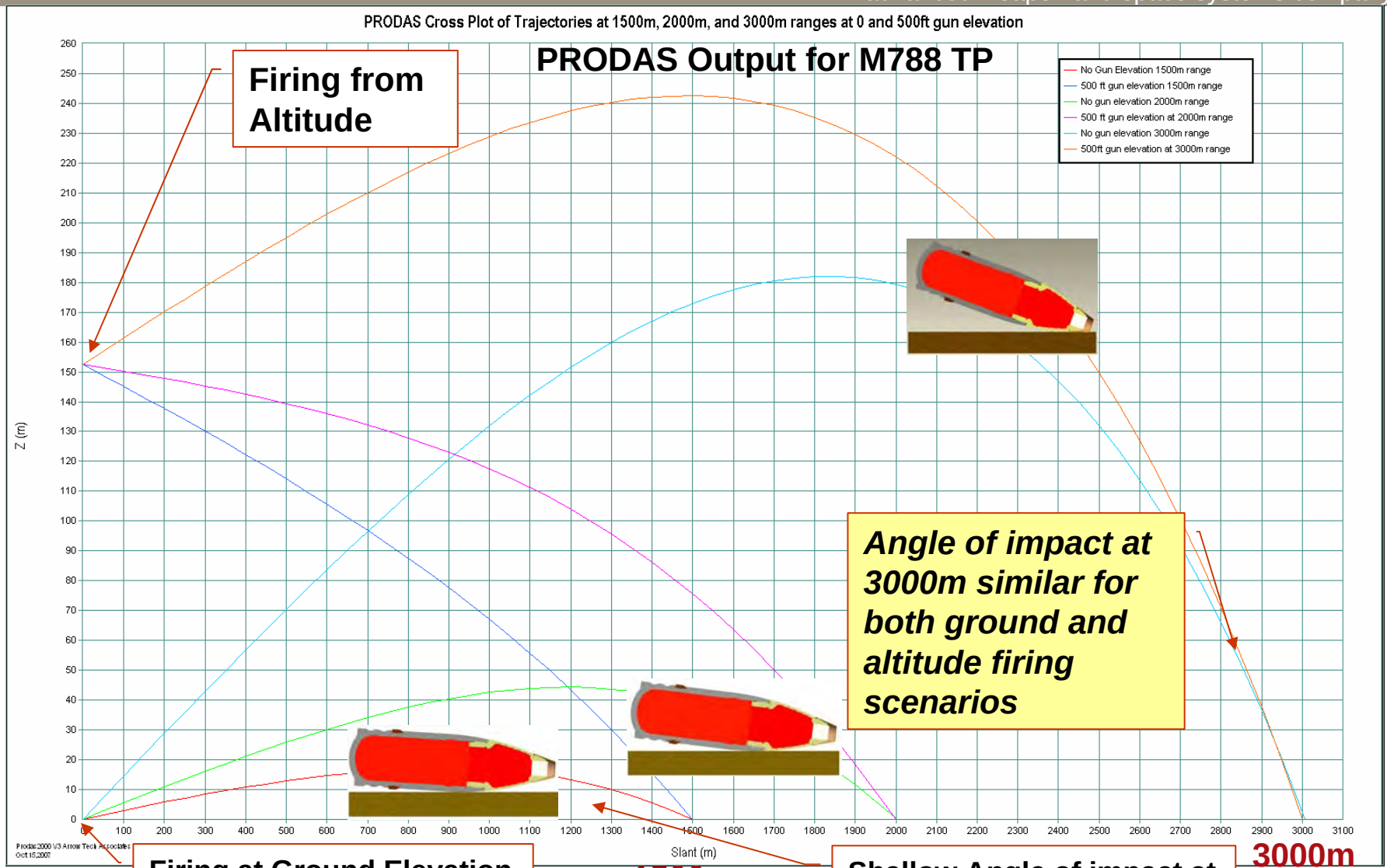

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CTH Modeling of Ground Impact – 1500m

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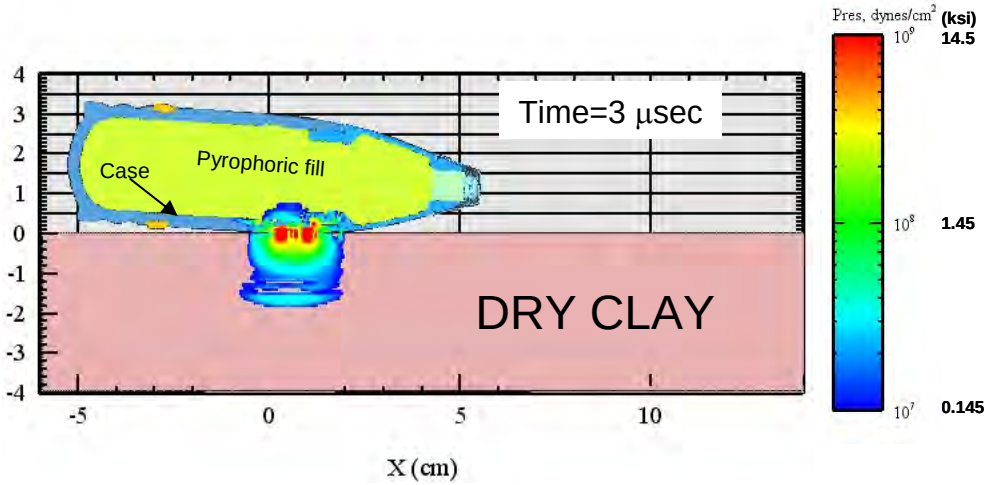

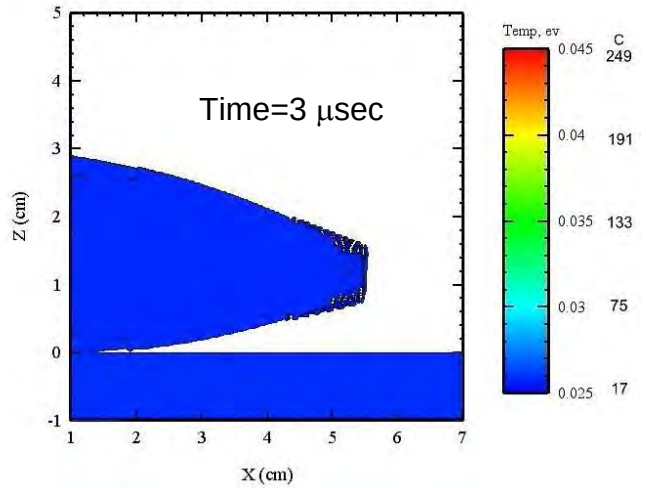

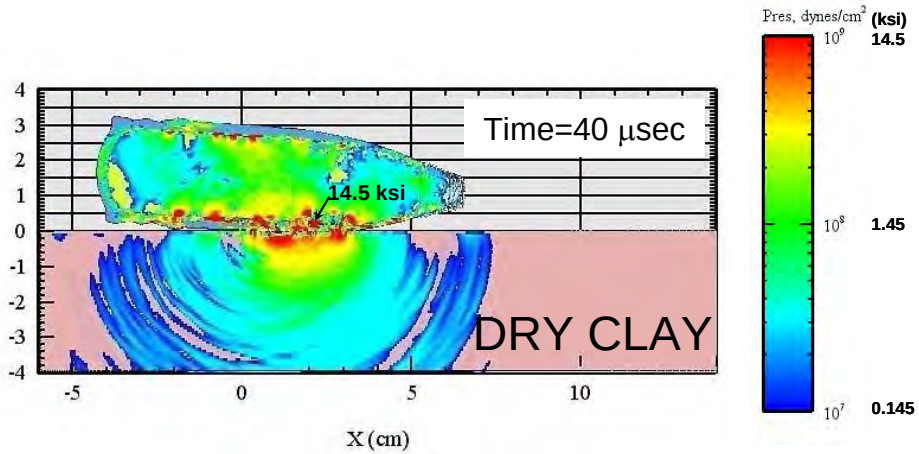

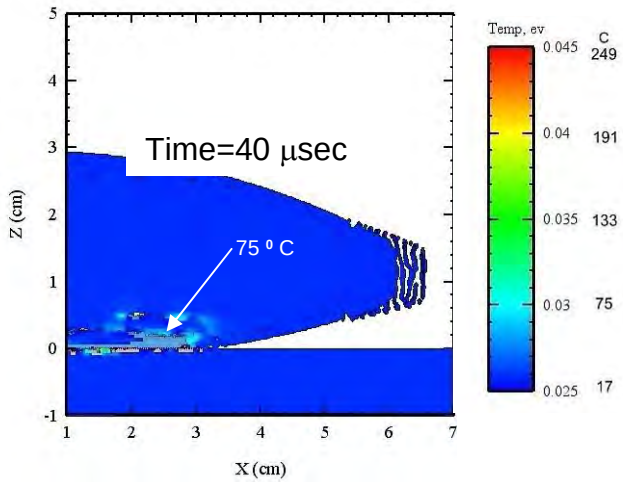

1500m test at Ft. Rucker fired from ground-mount will produce shallow angle of impact that will make it difficult to initiate spotter fill.

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CTH Modeling of Ground Impact – 3000m

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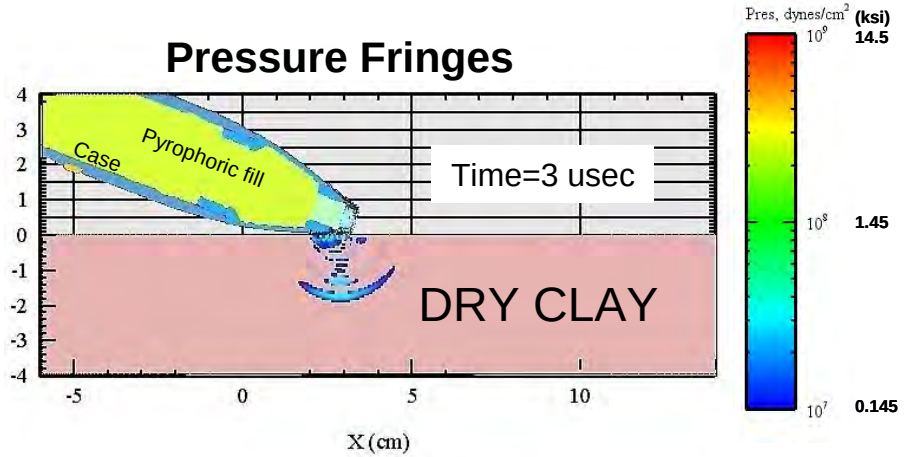
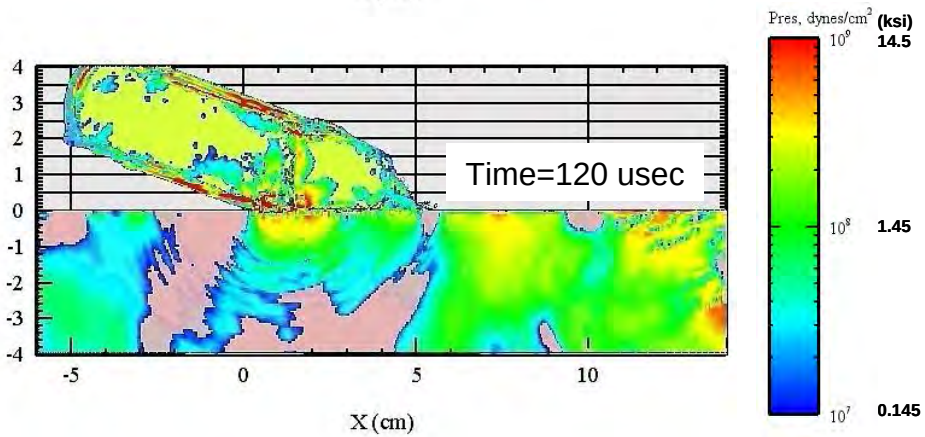
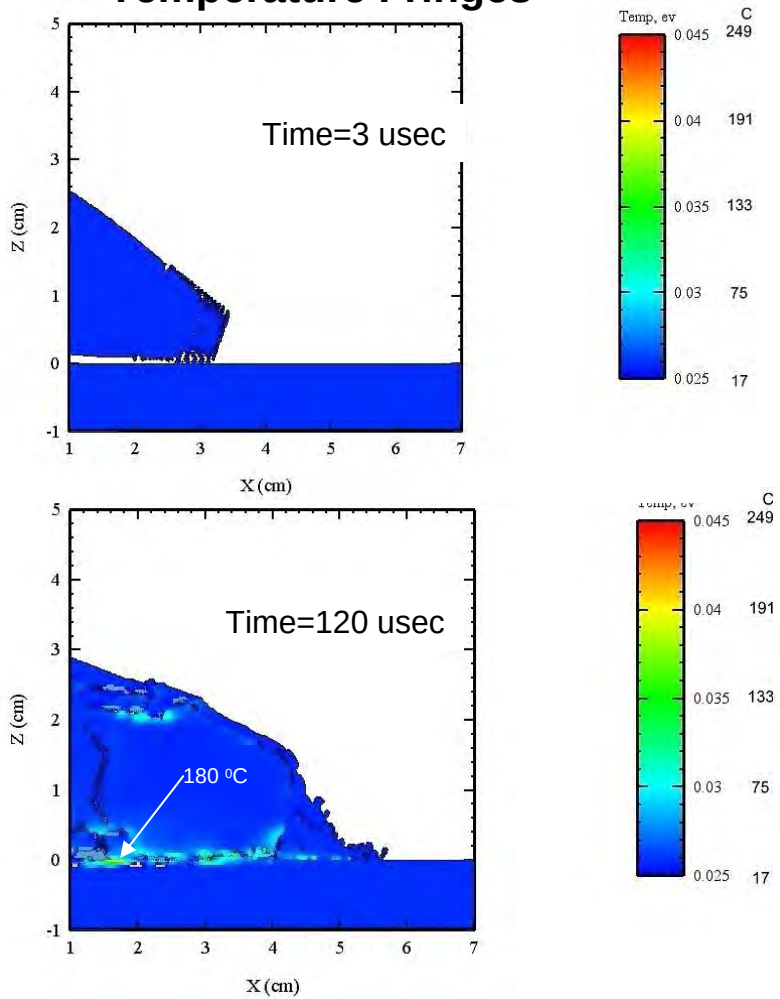
Pressure Fringes





Temperature Fringes



Increased angle of impact at 3000m may provide increased shear or thermal stress upon impact; however the impact velocity is reduced

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2000m Test Range at ATPG

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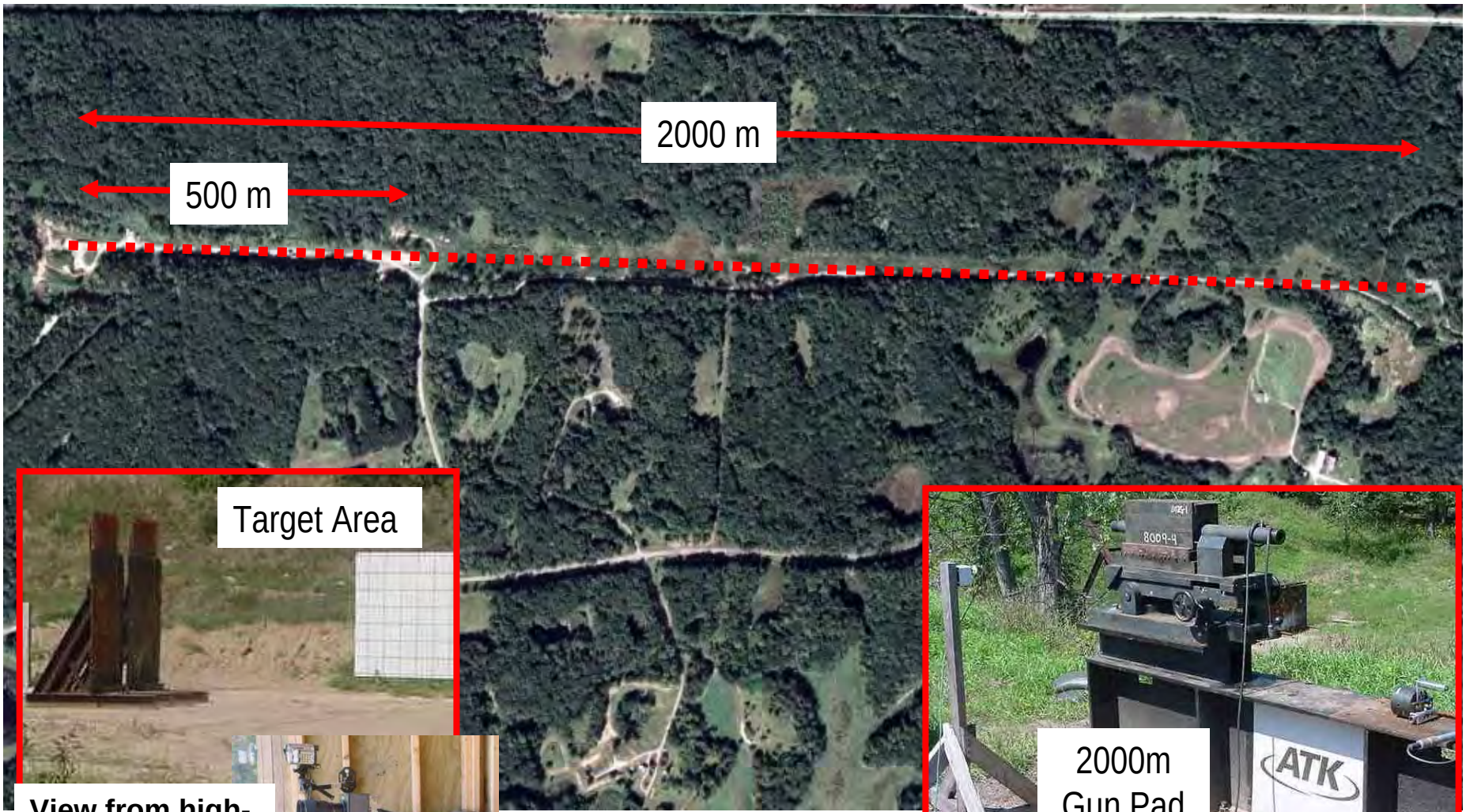

View from high-speed camera to target

Aerial View
Source: Google Earth

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ATPG Test Setup Photos – Gun to Target

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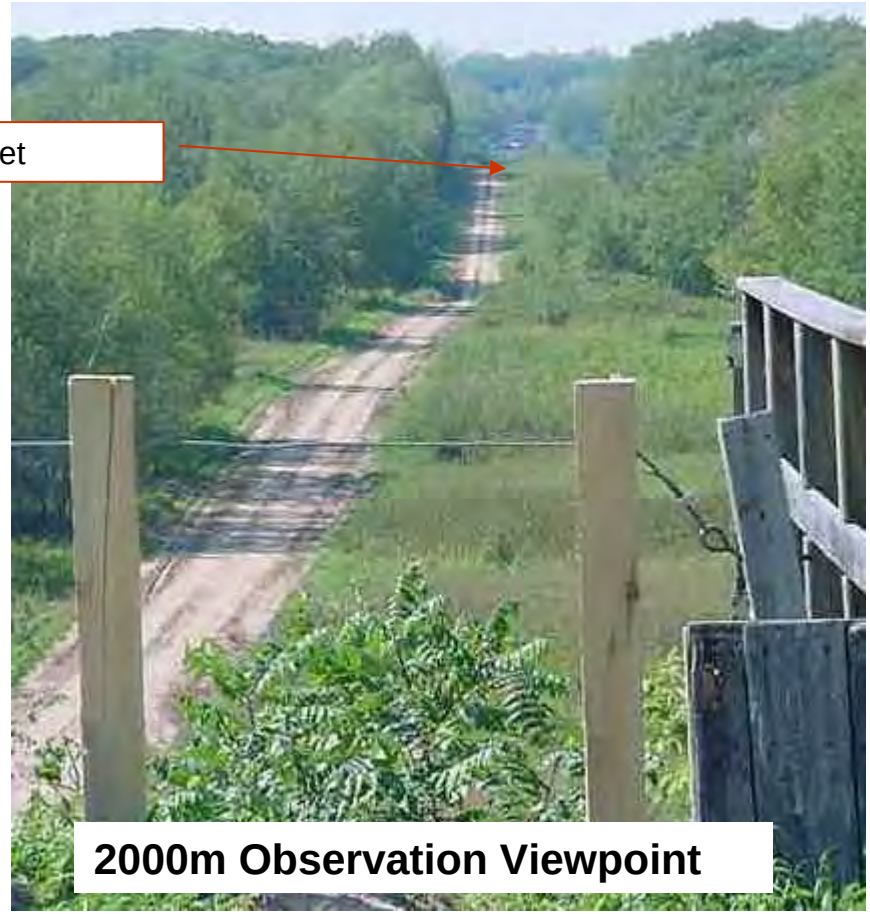
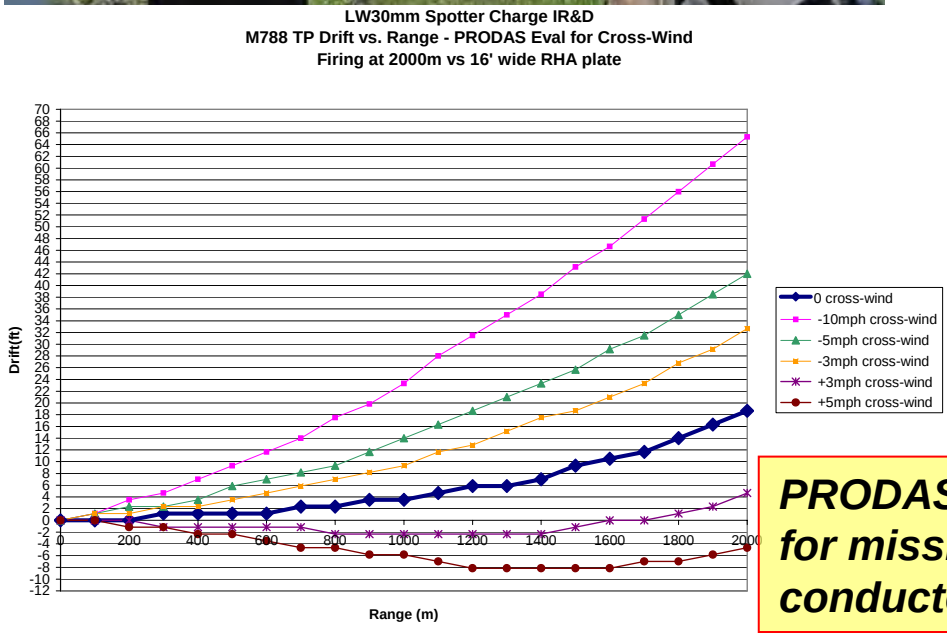
500m Gun Firing Position Viewpoint

Target



2000m Observation Viewpoint



PRODAS Modeling for cross-winds showed risk for missing test target at 2000m; therefore conducted initial capability testing at 500m

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ATPG High Speed Video – 500m testing against steel target

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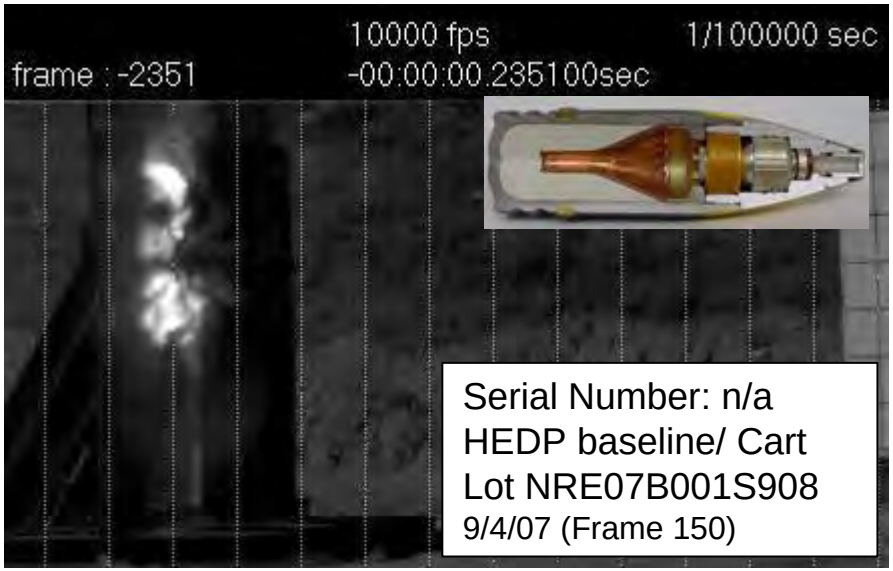

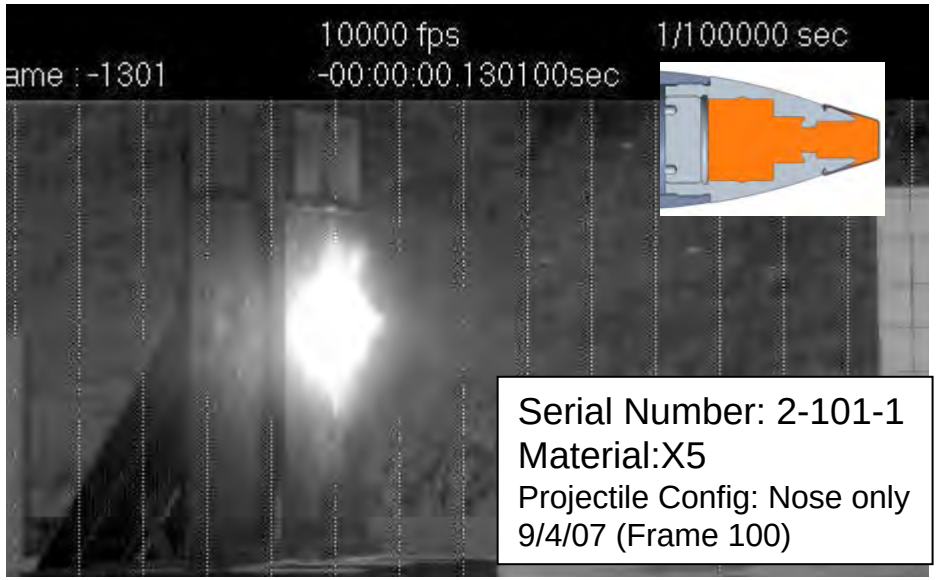

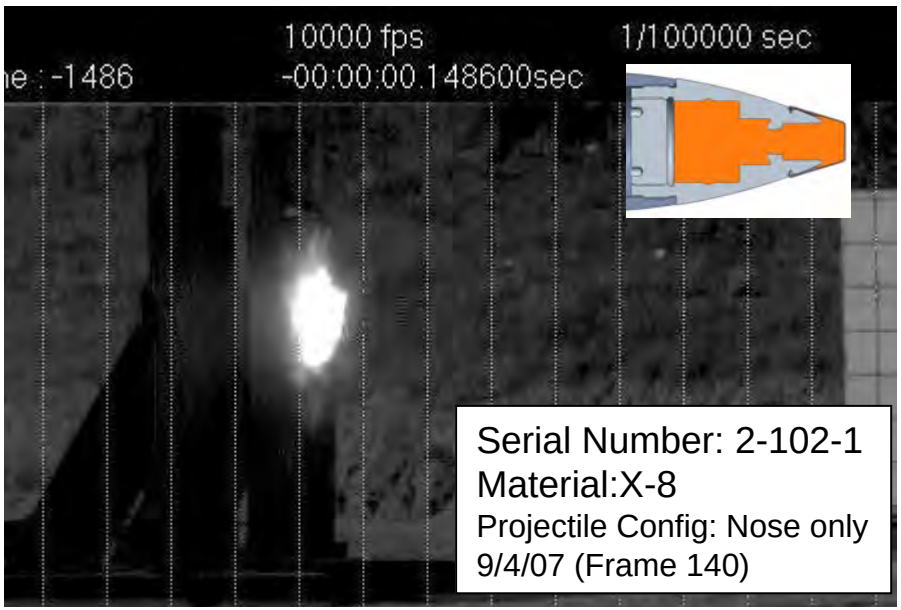

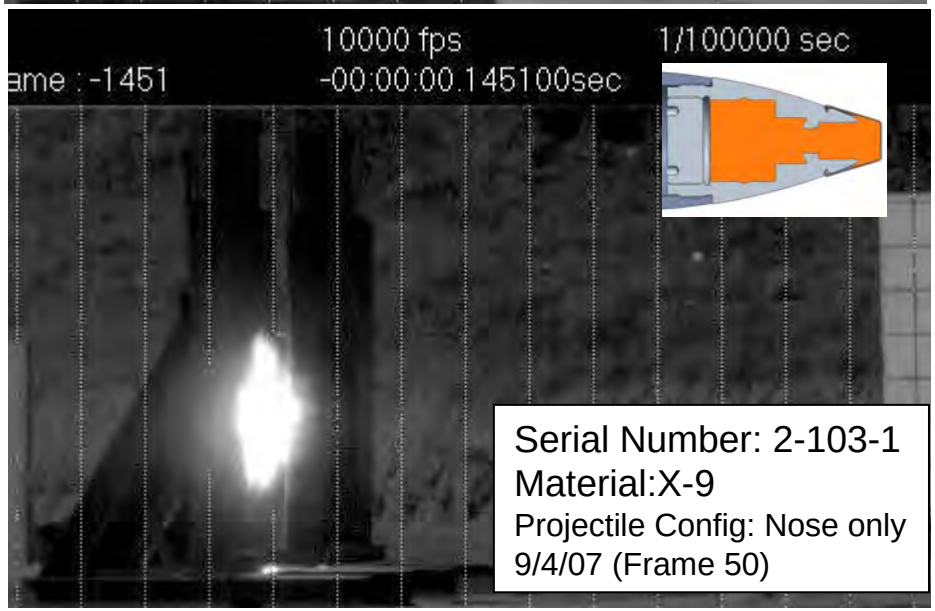

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ATPG High Speed Video - 500m testing against steel target

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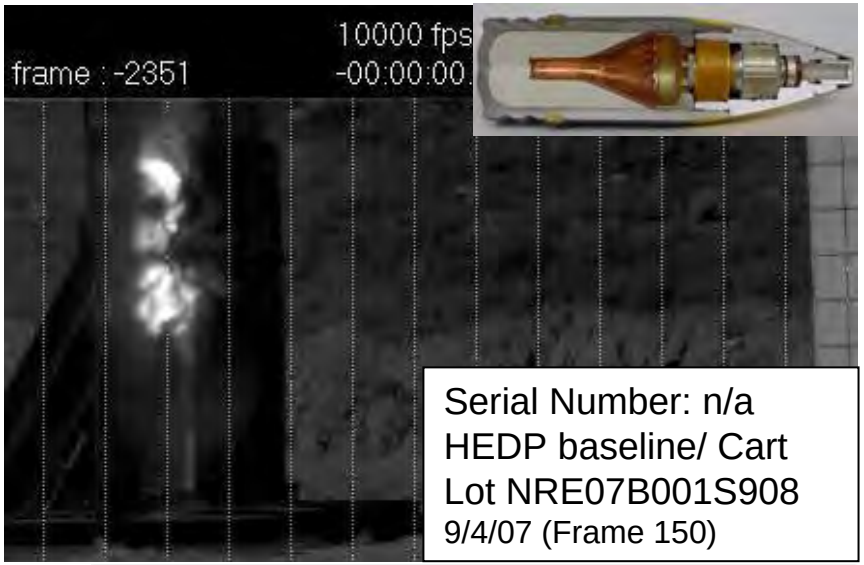
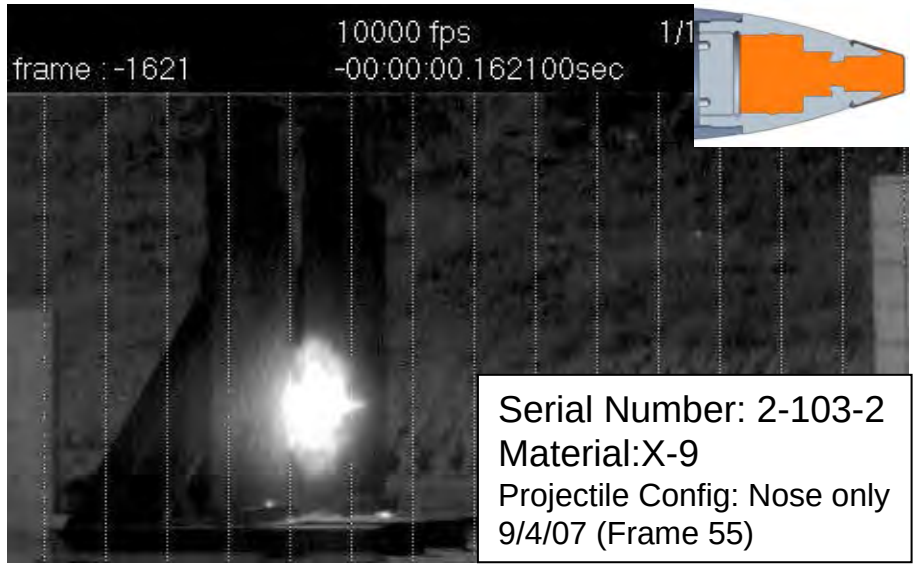
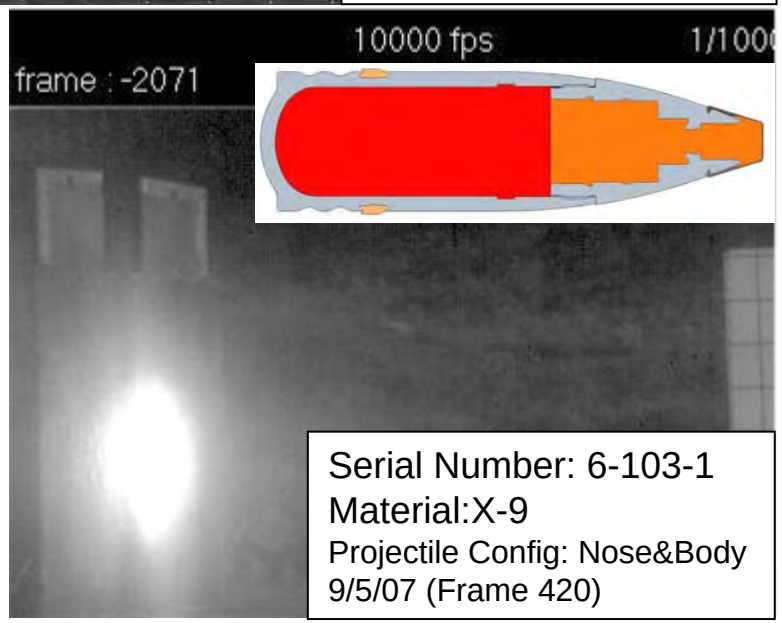


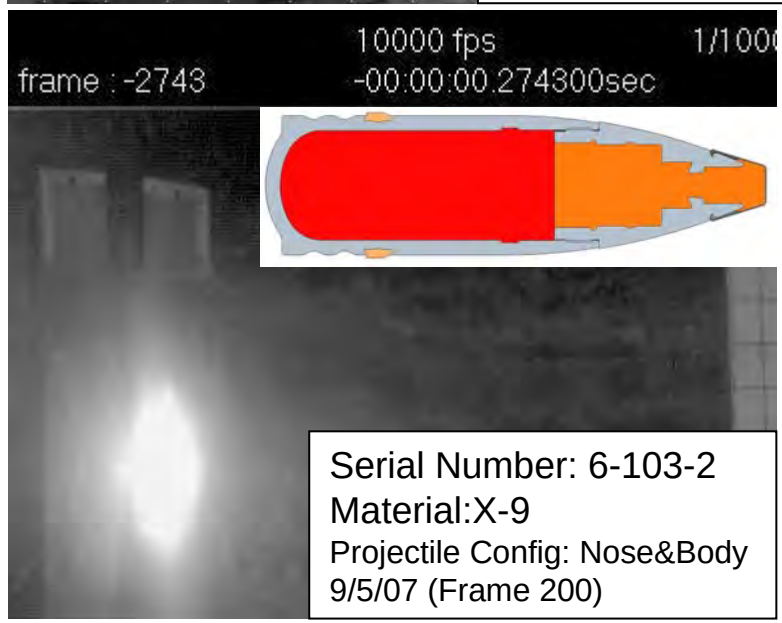
Serial Number: n/a
HEDP baseline/ Cart
Lot NRE07B001S908
9/4/07 (Frame 150)



Serial Number: 2-103-2
Material:X-9
Projectile Config: Nose only
9/4/07 (Frame 55)



Serial Number: 6-103-1
Material:X-9
Projectile Config: Nose&Body
9/5/07 (Frame 420)



Serial Number: 6-103-2
Material:X-9
Projectile Config: Nose&Body
9/5/07 (Frame 200)

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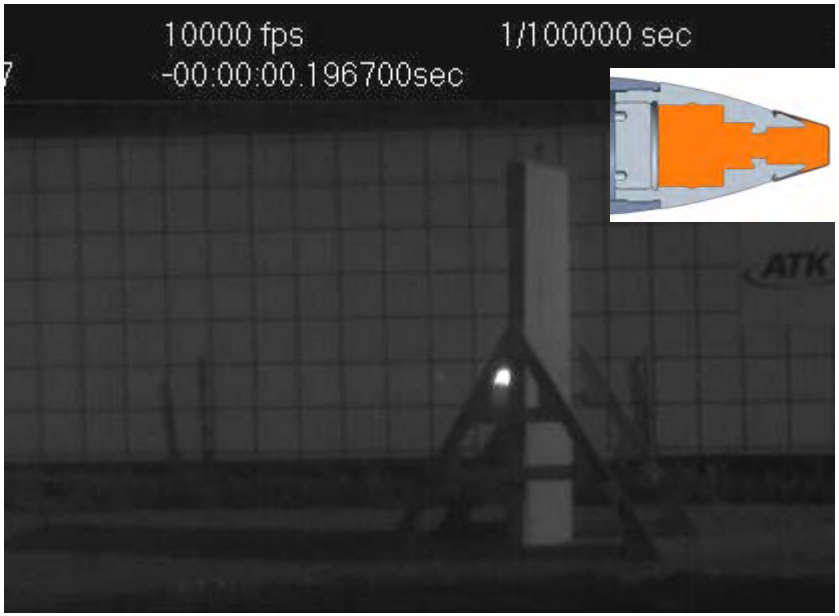
ATPG High Speed Video - 500m testing vs. plywood target



- These 2 tests were conducted at 500m with full propellant load and show reaction on plywood in high-speed video, but not visible to unaided eye at gun (500m).

- When fired at 500m with 40% propellant load (simulating 1500m impact) there was no reaction seen on high speed video.

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Demonstration Test Plan – Example of 27-Round test block

ATK

An advanced weapon and space systems company

Total of 170 cartridges shipped for Demo

	Day or Night	Firing Distance	Viewing Distance	Apache Gunner View	Apache Pilot View	Target	ATK Projectile Config: Config 1	ATK Projectile Config: Config 2
Day 1	Day	1500m	1500m	Unaided	Unaided	Steel	X	
Day 1	Day	1500m	1500m	Unai		Steel	X	
Day 1	Day	1500m	1500m	Unai		Steel	X	
Day 1	Day	1500m	1500m	Day		Steel	X	
Day 1	Day	1500m	1500m	Day		Steel	X	
Day 1	Day	1500m	1500m	Day TV	PNVS FLIR	Steel	X	
Day 1			500m	TADS FLIR	Unaided	Steel	X	
Day 1			500m	TADS FLIR	Unaided	Steel	X	
Day 1			500m	TADS FLIR	Unaided	Steel	X	
Day 1			500m	Unaided	Unaided	Plywood		X
Day 1	Day	1500m	1500m	Unaided	Unaided	Plywood		X
Day 1	Day	1500m	1500m	Unaided	Unaided	Plywood		X
Day 1	Day	1500m	1500m			Plywood		X
Day 1	Day	1500m	1500m			Plywood		X
Day 1	Day	1500m	1500m			Plywood		X
Day 1			1500m			Plywood		X
Day 1			1500m	TADS FLIR	Unaided	Plywood		X
Day 1			1500m	TADS FLIR	Unaided	Plywood		X
Day 1			1500m	Unaided	Unaided	Earth	X	
Day 1	Day	1500m	1500m	Unaided	Unaided	Earth	X	
Day 1	Day	1500m	1500m	Unaided	Unaided	Earth	X	
Day 1	Day	1500		Day TV	PNVS FLIR	Earth	X	
Day 1	Day	150		ay TV	PNVS FLIR	Earth	X	
Day 1	Day	150		ay TV	PNVS FLIR	Earth	X	
Day 1	Day	150		S FLIR	Unaided	Earth	X	
Day 1	Day	150		S FLIR	Unaided	Earth	X	
Day 1	Day	150		S FLIR	Unaided	Earth	X	

3 Target Types

3 viewing scenarios

1500 & 3000m firing range

1500 & 3000m viewing range

Day & Night firing

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LW30 Spotter Charge - Ft. Rucker Demonstration Test Setup

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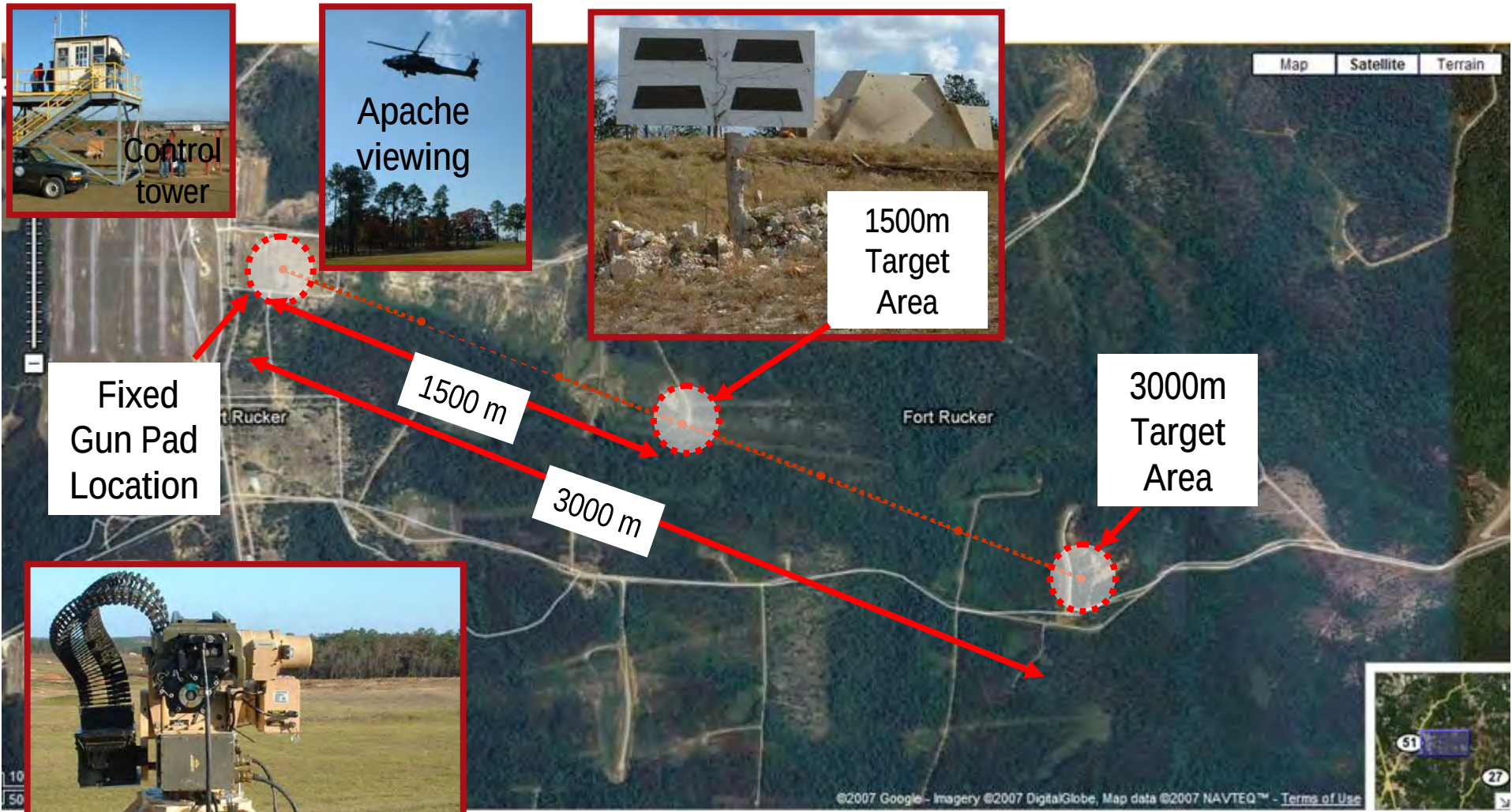

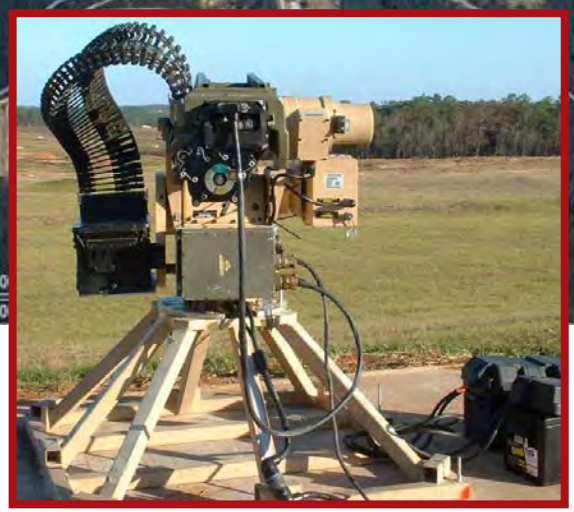

Source: Google Earth

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ATK M230 LF Gun / ROI Raven system used at Ft. Rucker

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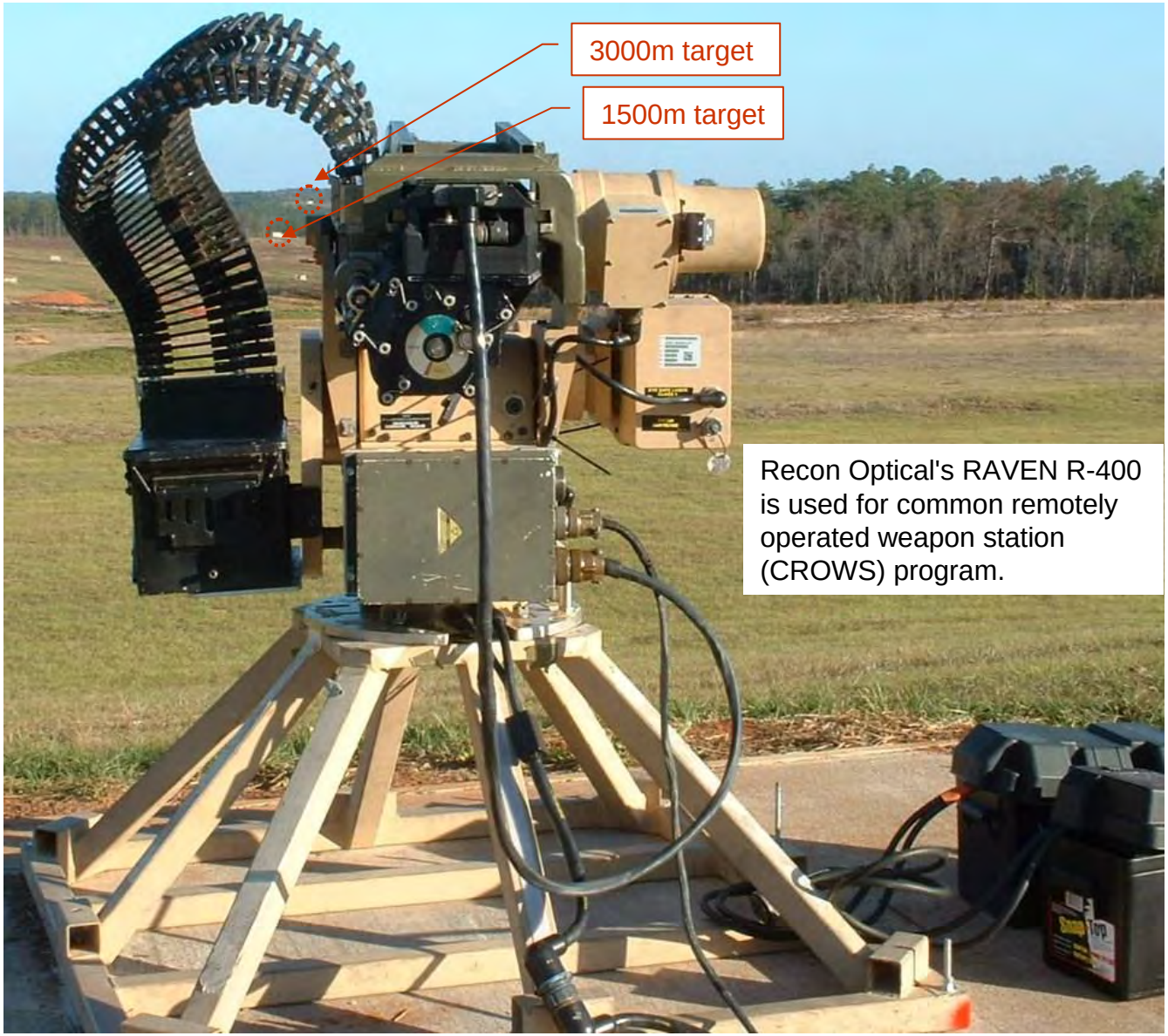

Recon Optical's RAVEN R-400 is used for common remotely operated weapon station (CROWS) program.

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Example of Steel Impact – Day and Night Testing

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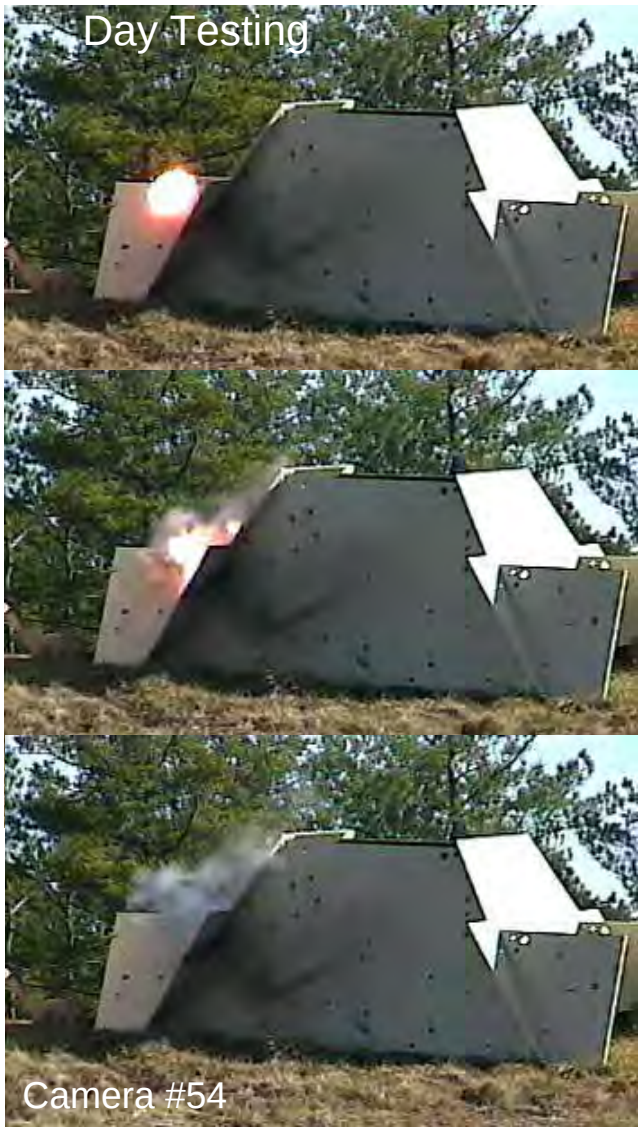

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Summary

A prototype spotter charge for the 30x113mm LW30mm Ammunition family was evaluated against multiple target media and ranges of trajectory

Modeling tools were used for analysis of mass properties, aeroballistic performance, stress analysis and impact thermal stress.

- PRODAS modeling provided ballistic match that was verified with radar tracking in ATK test.
- CTH hydrocode modeling indicated that predicted reaction of spotter material on ground impact would be marginal depending on impact angle and velocity.
- ANSYS stress analysis modeling provided design safety that was verified in structural integrity ballistic tests.

Demonstration testing conducted at Ft. Rucker tracked with the results from ATK testing:

- Reliable visible reaction when impacting Steel target, day and night at 1500m, and night at 3000m. Day impact at 3000 not available.
- Impact on Plywood target showed delay reaction behind target; at times was evident and scored by pilot as sufficiently visible allowing for adjustment. More evident at night.
- Limited frequency / Marginal short duration visible day / night when impacting ground at 1500m.
- 3000m testing did not reliably impact visible target area due to drift from cross winds (PRODAS)

Further development efforts on hold pending government evaluation of the demonstration testing and updated User need assessment.

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Acknowledgements

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ATK –LS
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ATK – ABL
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ATK –ATPG Test
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Ellis Clark
Matt Berg

ATK – AW
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Wayne Hierlmaier
Mark Krueger
Dave Fehr

ATK – AW
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Dave Darden

Recon Optical
Doug Hagie

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2008 NDIA
43rd Annual Armament Systems:
Gun and Missile Systems Symposium
21 – 24 April 2008

Development of LW25 Family of Ammunition

Lee Olson
Design Engineer
ATK Medium Caliber Systems

OSR Public Release Approval Ref 08-S-1203

Bradley with M242, 25mm

LW25mm Bushmaster

Medium Caliber Ammunition

M230 Chain Gun

Outline

- Why LW25
- Gun Characteristics Overview
- Cartridge Family
  - Cartridge Design Characteristics
  - Common Cartridge Components
  - Common Projectile Components
  - Cartridge Performance Summary
- Conclusion
- Acknowledgements & Contacts
- Questions & Answers

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Why LW25

System size and weight comparable to M2 and Mk19

Increased Lethality

- 70 to 85% of M789 and M792
- Programmable AirBurst Munition (PABM) capable

Remote or Manual Operation

Application-Nearly anywhere a M2, Mk19 or M240 is used

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LW25 Gun Characteristics

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Caliber	**25mm X 59mm**
Rate of Fire	**230-260 shots/minute**
Power Source	**External (electric) chain driven action**
Power Requirement	**0.4Hp @ 28V DC**
Predicted Reliability	**Mean Rounds Between Stoppages, 35K**
Feed System	**Dual Feed, First Round Select**

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LW25 Gun Characteristics

Size (w/o feed chutes):

Length- Less than 1,194 mm (47”)

Width- Less than 280 mm (11”)

Height- Less than 270 mm (10.625”)

Weight:

Receiver	**15.8 kg (34.9 lb)**
Feeder	**8.6 kg (19 lb)**
Barrel	**6.2 kg (13.6 lb)**
Total	**30.6 kg (67.5 lb)**

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LW25 Cartridge Family

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LW25 Ammunition

TP

DUMMY

AIRBURST

HEI

HEDP

OSR Public Release Approval Ref 08-S1203

LW25 Ammunition Family (Future Development)

Shot shell

Non-lethal

TP Marking

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Cartridge Design Characteristics

Length (max):	**138.5 mm**
Weight :	**174 g**
Projectile Mass:	**141 g**
Muzzle Velocity:	**400 m/s**
Dispersion:	**0.5 mils**

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Common Components (reduces development time)

- Primer (common with .50 Caliber)
- Cartridge Case
- Propellant

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Use of Common Components minimizes Development time

- Rotating Band for HEI, HEDP and TP common with M792, M793, PGU-23, PGU-25 etc.
- Modified M759 Fuze used on both HEI and HEDP, over 90% common with M759 Fuze used on M789 Cartridge
- Banded Projectile Body common to HEI and HEDP
- Airburst Projectile over 90% common with XM25

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HEI and HEDP Projectile

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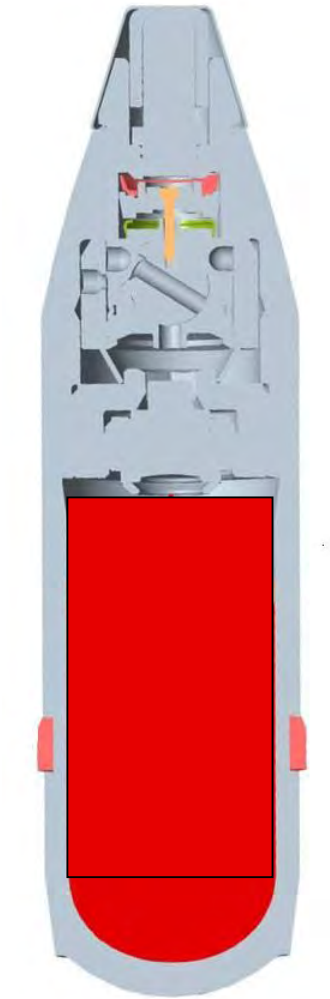
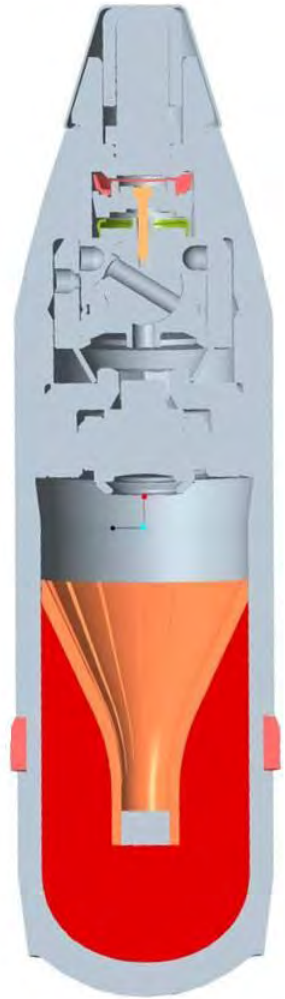
HEI



HEDP



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Cartridge Performance Summary

Velocity more than 400 m/s

Case Mouth Pressure less than 275 MPa

Dispersion less than 0.5 mil X 0.5 mil

Predicted HEDP Penetration more than 1.4”

Blast and Incendiary effects 85% of M792

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LW25 Ammunition and Gun offer:

- Low weight, low recoil, high lethality
- Combined Antipersonnel and Light Armor Penetration
- Dual Feed, First Round Select
- Lethality for Troops in defilade
- High reliability of gun and ammunition

LW25 is a Unique tactical solution.

OSR Public Release Approval Ref 08-S1203

Acknowledgements & Contacts

Acknowledgements

Mr. Larry Douma, ATK Medium Caliber Systems

Ms. Linda Heuer, ATK Medium Caliber Systems

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OSR Public Release Approval Ref 08-S1203

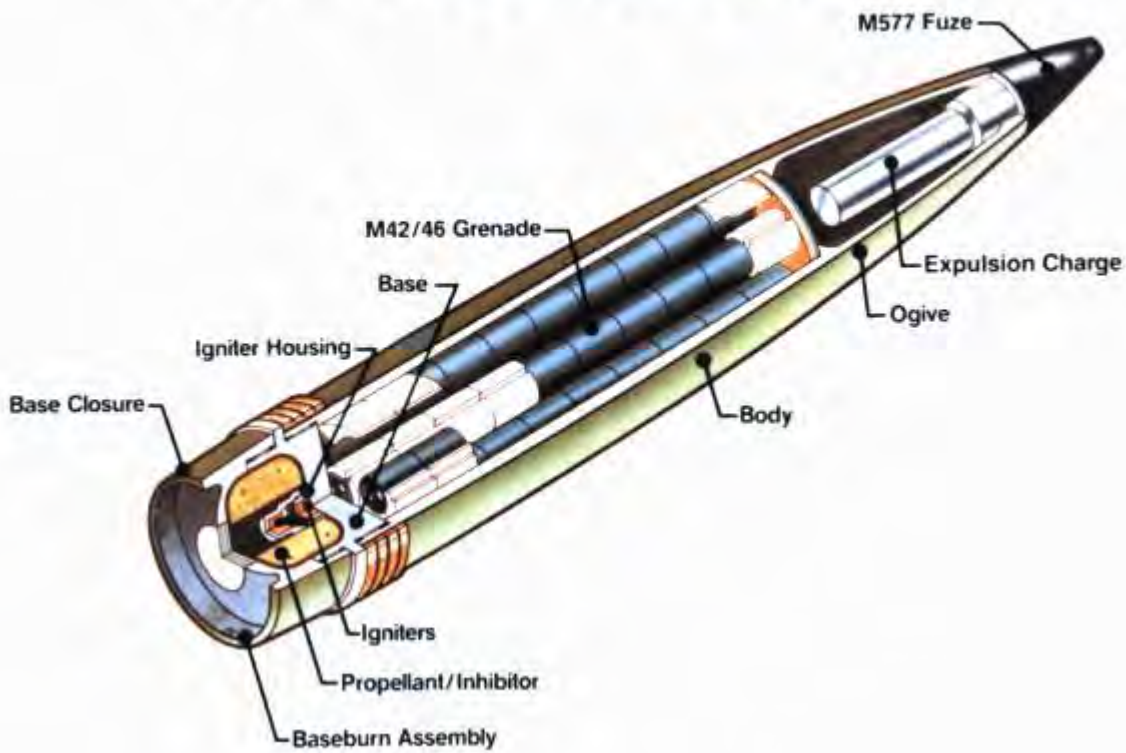
Accelerated Aging of the M864 Baseburner Assembly

Dr. Eric R. Bixon
Dr. Frank Gagliardi
US Army RDECOM-ARDEC
Picatinny Arsenal

ABSTRACT

- ***An accelerated aging program and a surveillance program were conducted to evaluate the lifetimes of the baseburner assembly for the M864.***

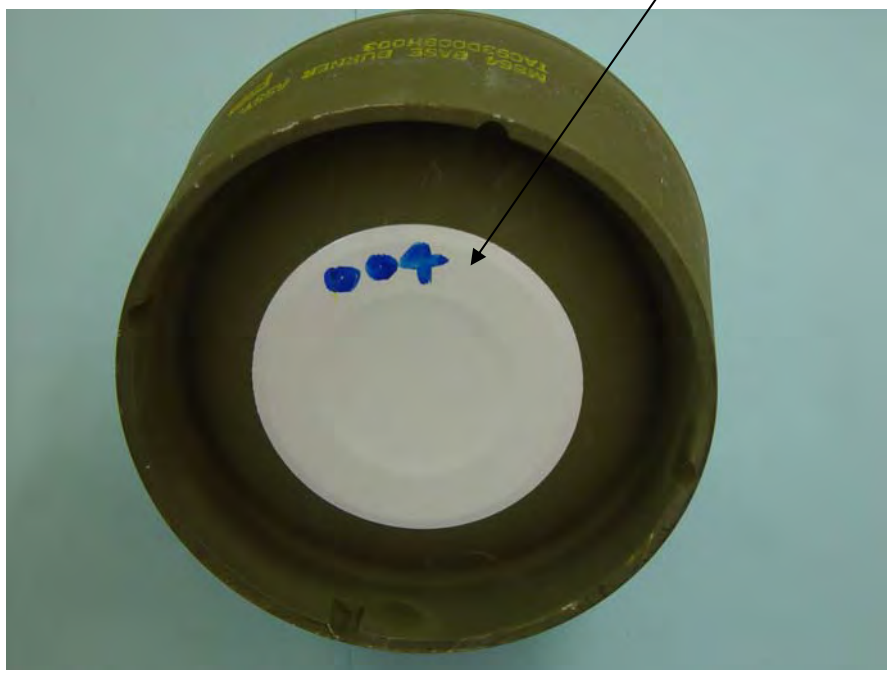
155mm M864 MAJOR COMPONENTS



Baseburner Assembly with weatherseal

EXCELLENT ADHESION UNLESS REMOVED INTENTIONALLY

Weatherseal



Mathematical Models

Theoretical Development

$C_A = C_{A0} - k*t$ — Zero Order

$C_A = C_{A0} * e^{(-k*t)}$ — First Order

$k = \{k_0 * e^{(-Ea/RxT)}\}$ — Arrhenius

$k = \{k_0 * e^{(-Ea/RT)}\} \times \{e^{(B * \%RH)}\}$ — Eyring

$F(t,V) = 1 - R(t,V)$ — Cumulative Damage Model

$\Delta C_A = C_{Af} - C_{A0}$ — Change in Property based on Surveillance Data

Nomenclature Used in Reaction Kinetic Modeling of variables data

- **C_{A0} = Initial value of property**
- **T = absolute temp**
- **t = time**
- **C_A = Property value as a function of time**
- **k = rate constant**
- **V = Stress level**

Accelerated Aging Conditions for Baseburner Assembly

Temperature (°F)	Humidity (% RH)	Weatherseal Present
225 °F	0 % RH	Yes
200 °F	90 % RH	Yes
200 °F	90 % RH	No
200 °F	55 % RH	No
175 °F	90 % RH	No

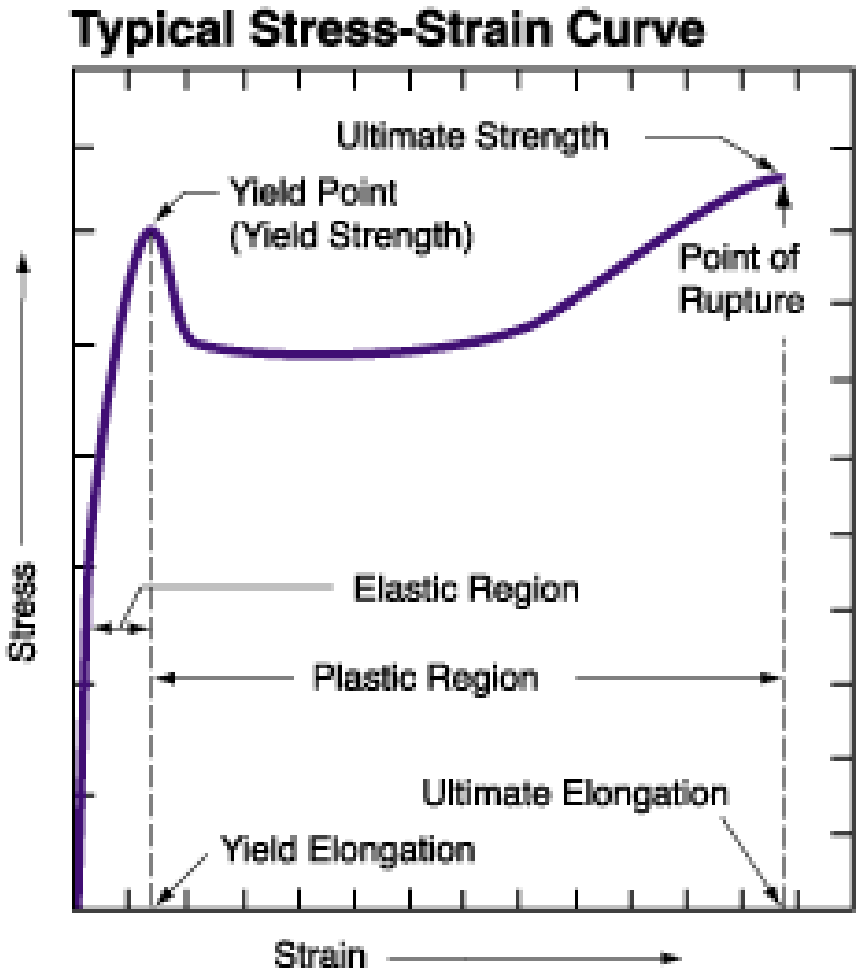
5 baseburner assemblies in chamber prior to conditioning

Samples were periodically withdrawn from the conditioning chamber

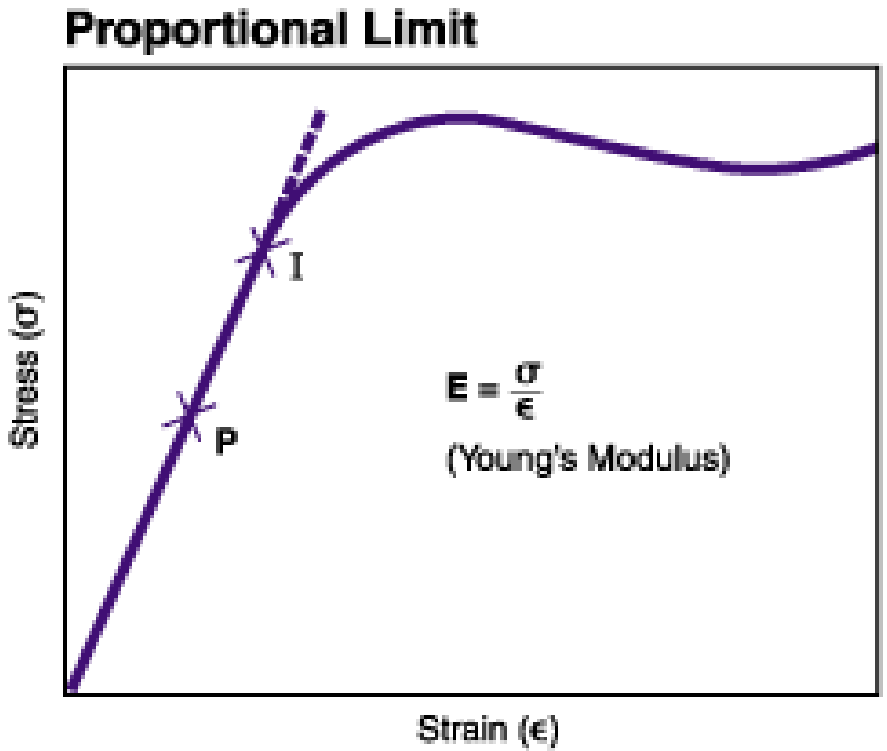
Hot and Humid Cycle Used for Uncontrolled Storage Simulations

Local Time	T in °C	%RH	Local Time	T in ° C	%RH
0100	35.00	67.00	1300	66.00	16.00
0200	34.00	72.00	1400	69.00	15.00
0300	34.00	75.00	1500	71.00	14.00
0400	34.00	77.00	1600	69.00	16.00
0500	33.00	79.00	1700	66.00	18.00
0600	33.00	80.00	1800	63.00	21.00
0700	36.00	70.00	1900	58.00	29.00
0800	40.00	54.00	2000	50.00	41.00
0900	44.00	42.00	2100	41.00	53.00
1000	51.00	31.00	2200	39.00	58.00
1100	57.00	24.00	2300	37.00	62.00
1200	62.00	17.00	2400	35.00	63.00

Mechanical Property Definitions



Young's Modulus or Modulus of Elasticity



Testing Procedure

- “dogbones” were fabricated from the baseburner assembly propellant grains
- Properties were measured prior to conditioning
- Samples were periodically withdrawn from the conditioning chamber
- Properties were measured on the samples

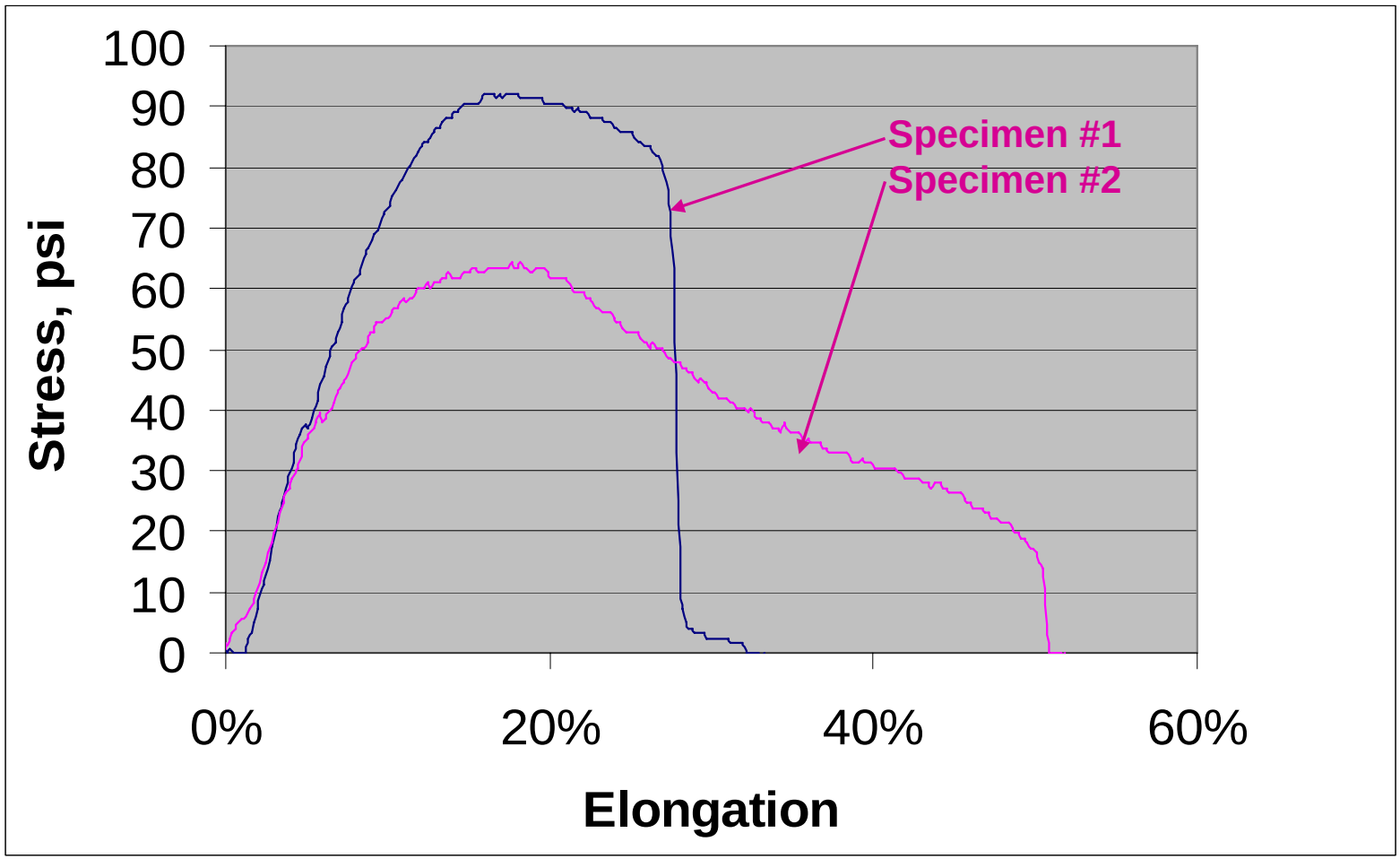
Mechanical Property Test Method for propellant grain

- Conformed to the JANNAF “CLASS B” uniaxial Tensile Specimens
- Dogbones fashioned from propellant grain and tested on an Instron tensile testing machine

Dogbones were cut from the propellant grains

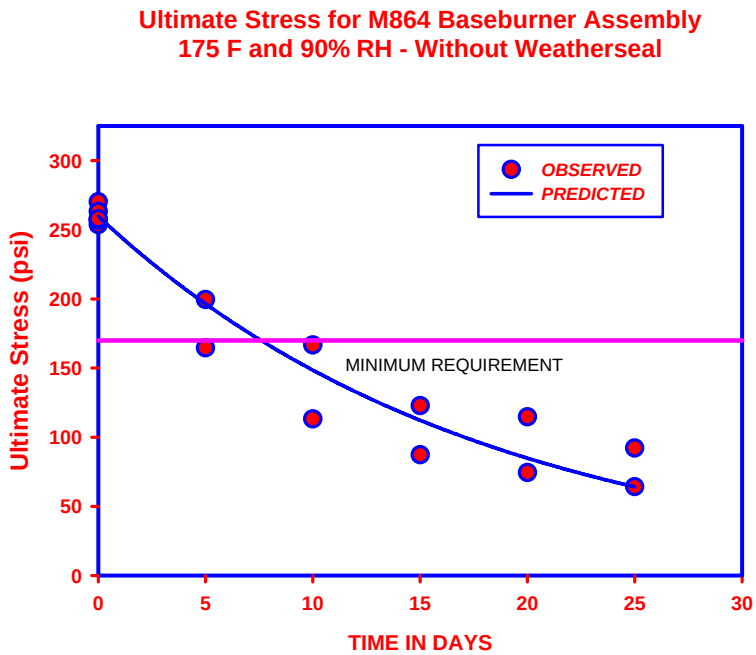
Mechanical properties of the dogbones were tested using an Instron tensile testing machine.

STRESS / STRAIN PLOT
Sample AGE-028 (25 Days @ 175F & 90% R.H.)



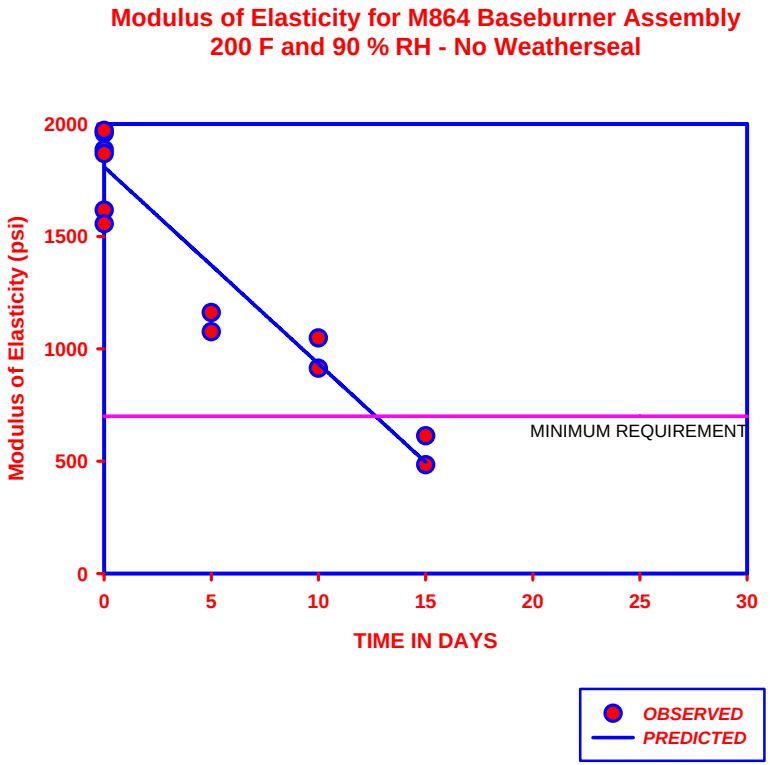
Specimen #2, taken from propellant closest to exposed surface.

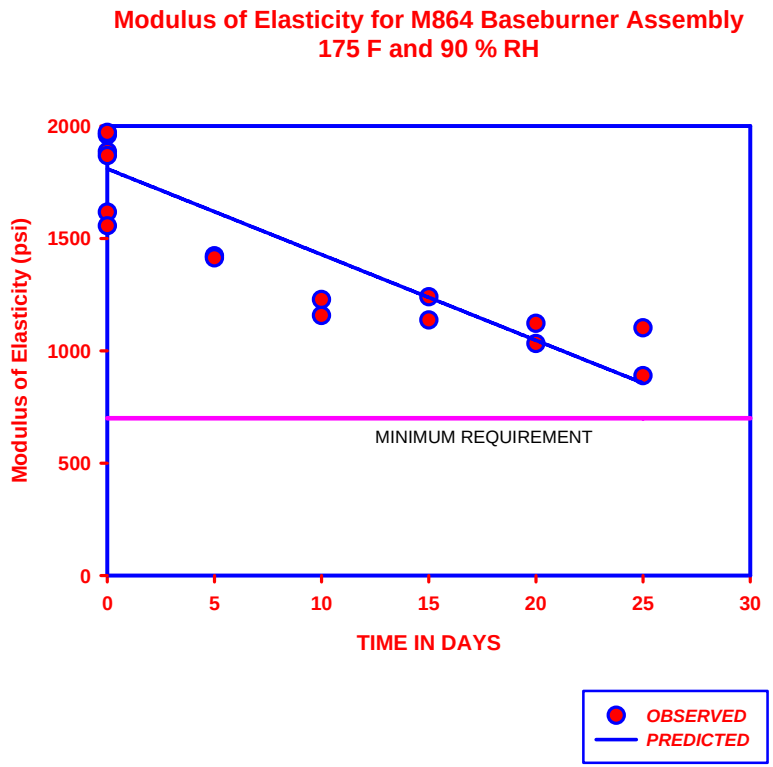
Ultimate Stress as a function of time at 175 F and 90 % RH



Data Fitted with First Order Kinetic Model

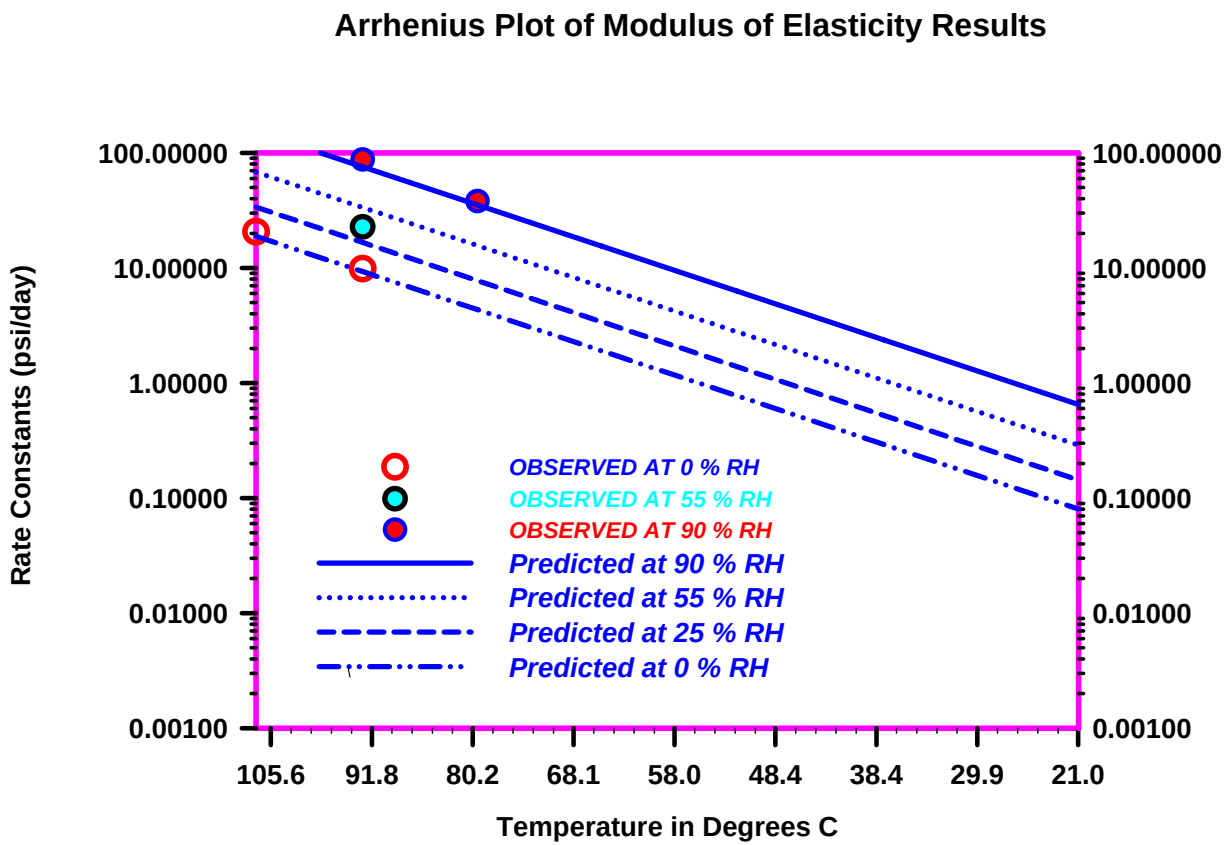
Modulus of Elasticity as a function of time at 200 F and 90 % RH





Zero Order Kinetic Model

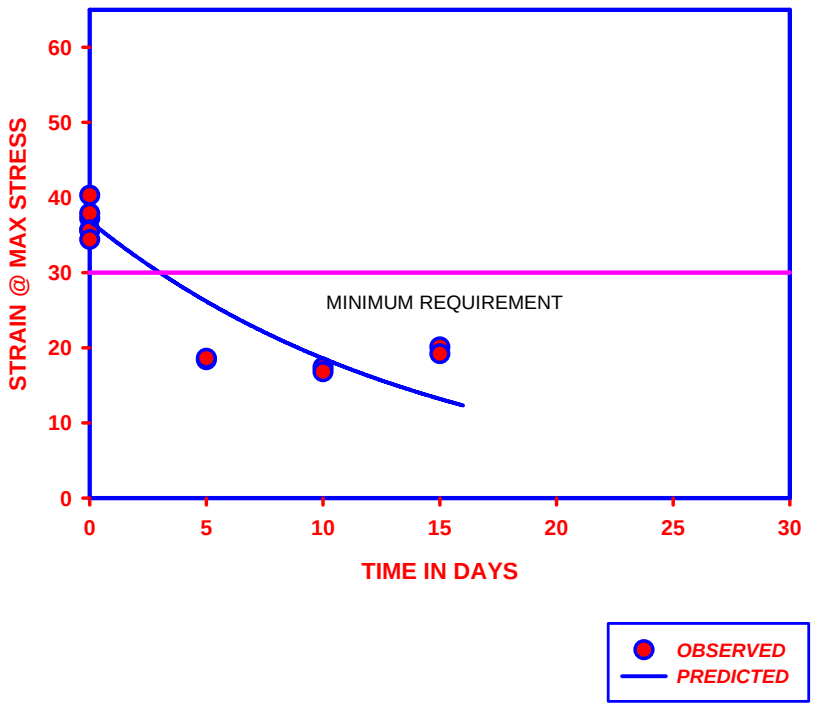
Modulus of Elasticity
Rate Constants - Correlated Using Eyring Equation – All Samples used for this correlation

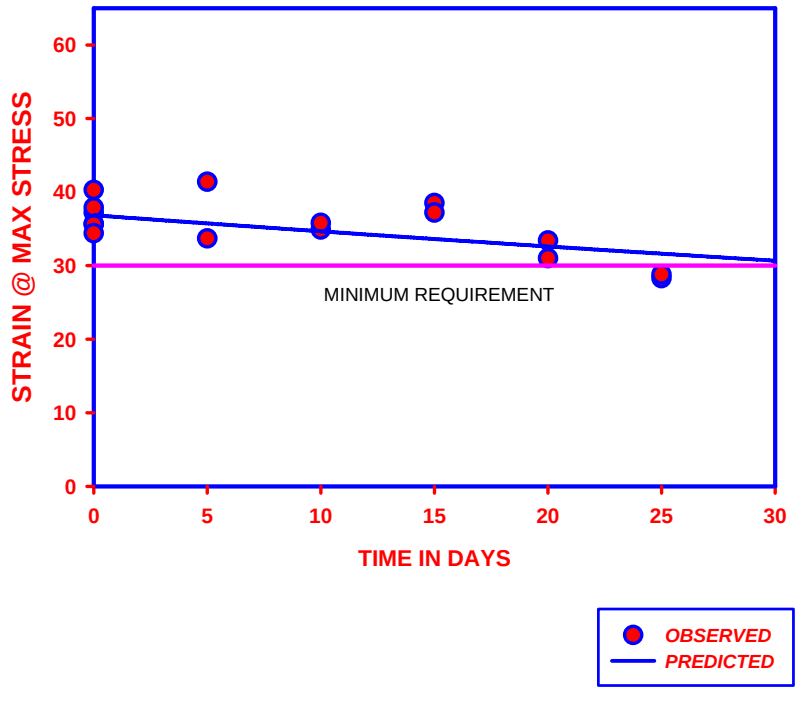


Life Predictions based on Modulus of Elasticity

RELATIVE HUMIDITY LEVEL (%)	Controlled Storage (years)	Uncontrolled Storage (years)
90	4.67	.414
55	10.55	.936
25	21.22	1.883
0	38.0	3.37

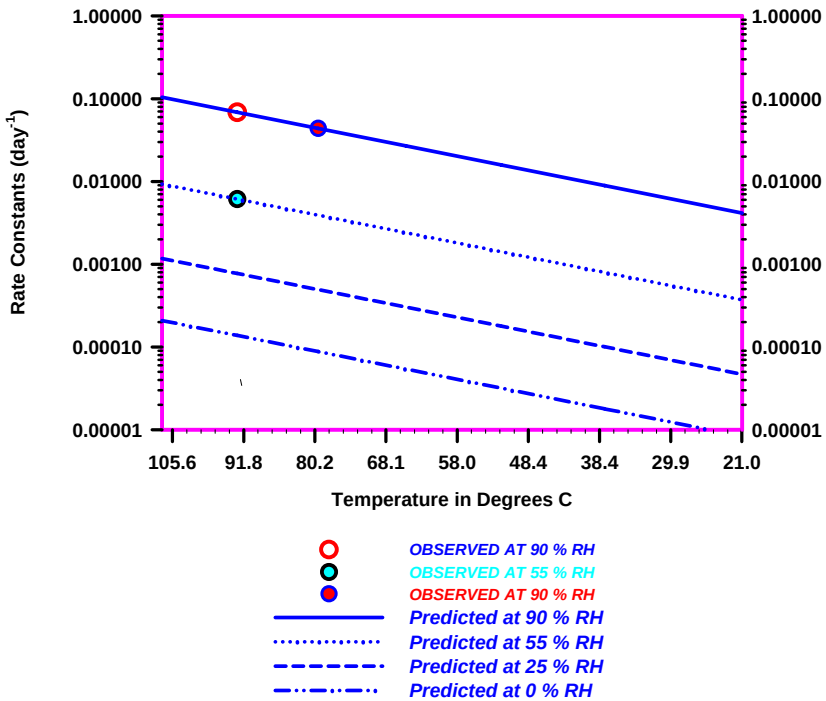
Degradation of the Mechanical Property “Strain at Maximum Stress”





First Order Degradation Rates of the Strain at Maximum Stress

Correlated Using the Eyring Equation



Lifetimes in Years of the Propellant Grain based on the Strain at Maximum Stress

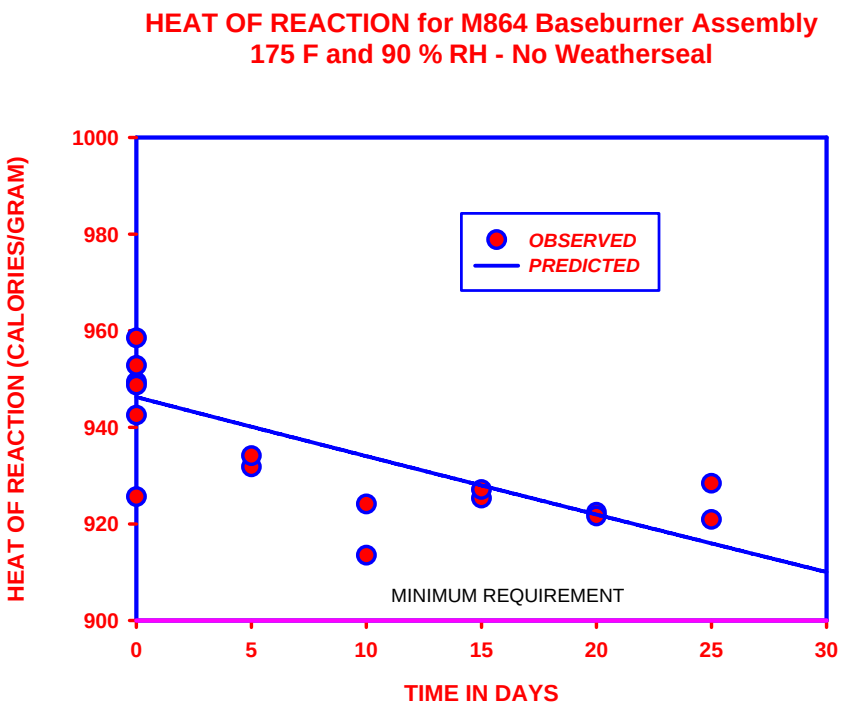
First Order Kinetic Model

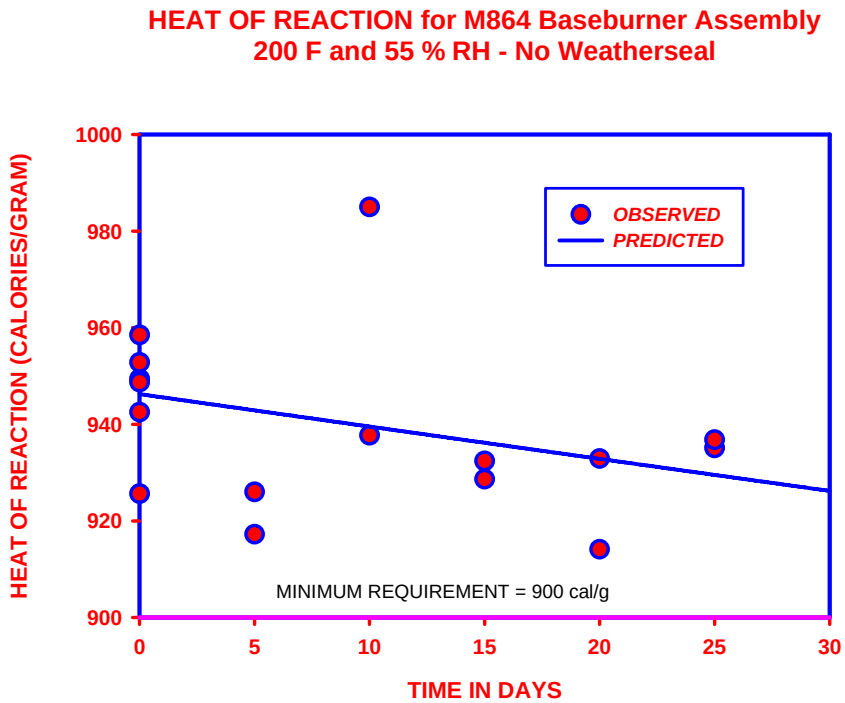
% RH	Controlled Storage	Uncontrolled Storage
0	67.6	17.9
25	12	3.19
55	1.52	.402
90	.136	.0358

Thermal Properties

Heat of Reaction

- *Minimum Value of 900 cal/gram*
- *Degraded in both stockpile and accelerated aging study*

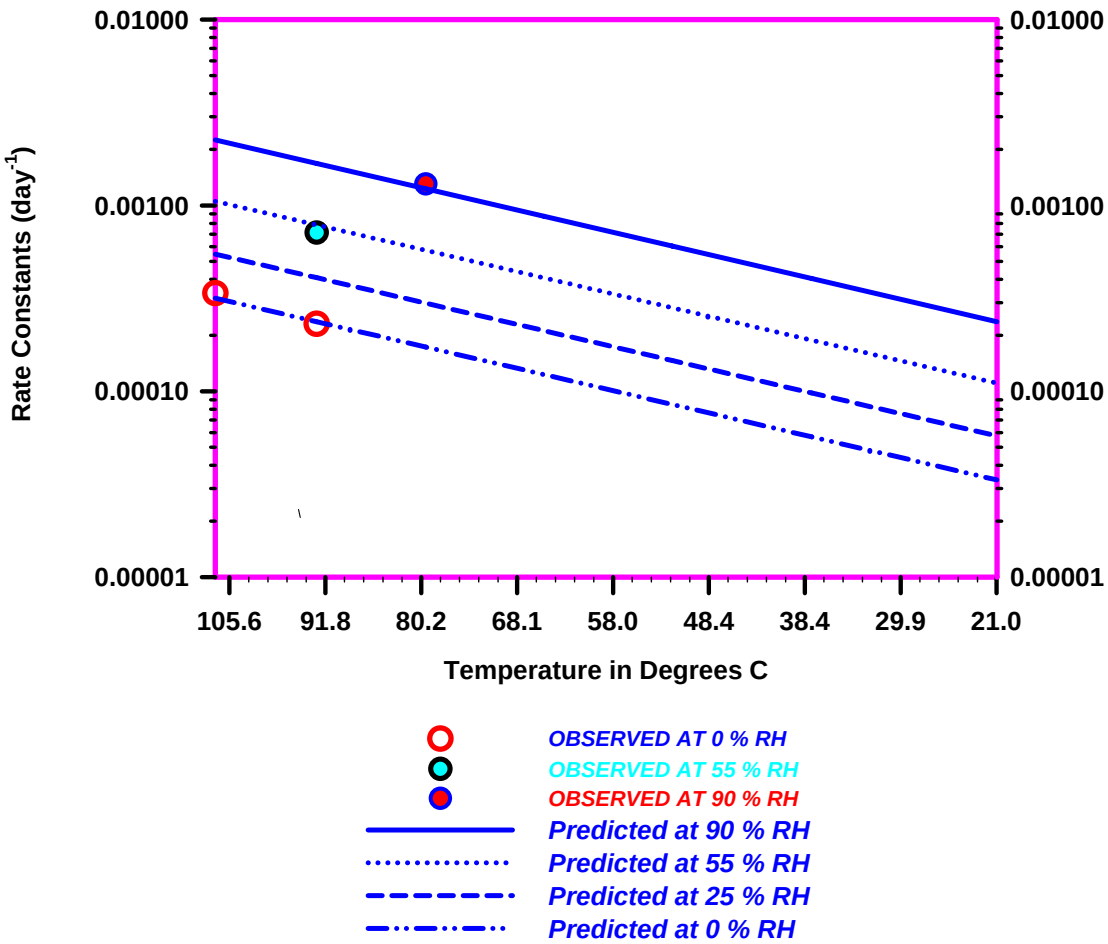




Life Predictions based on Heat of Reaction from the Accelerated Aging Experiments

Kinetic Model	ZERO ORDER		FIRST ORDER	
RELATIVE HUMIDITY LEVEL (%)	Controlled Storage (years)	Uncontrolled Storage (years)	Controlled Storage (years)	Uncontrolled Storage (years)
0	4.07	1.65	4.13	1.68
25	2.37	.961	2.39	.975
55	1.24	.501	1.24	.507
90	.578	.234	.580	.236
Eyring Equation Parameters	ZERO ORDER		FIRST ORDER	
k_0	683 cal/g-day		.697 day^{-1}	
E_A	5846 cal/mol		5817 cal/mol	
B	.0217 ($\%RH^{-1}$)		.0218 ($\%RH^{-1}$)	

Heat of Reaction rates correlated using Eyring Equation

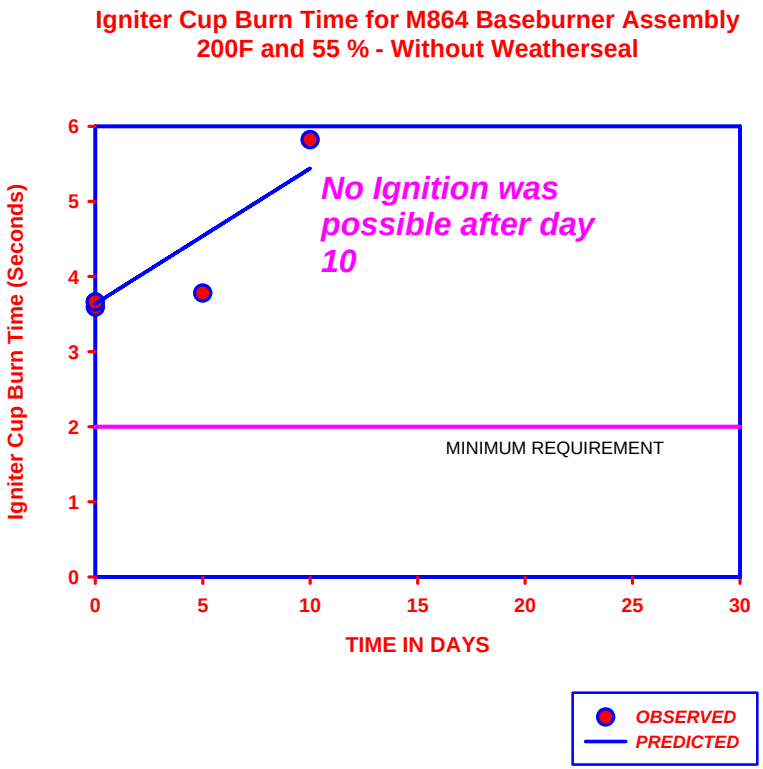


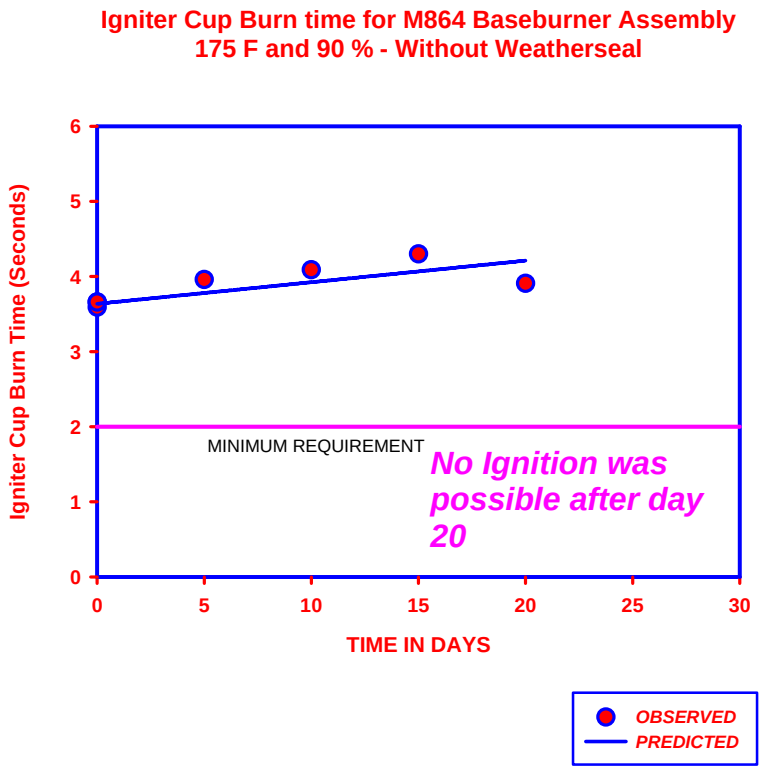
Igniter Failure Modes

- ***Igniter tended to fail due to the effect of moisture. It would not light.***

- ***Very long life predictions for this failure mode were calculated from the data***

Igniter Cup Burn Times – No Weatherseal





Summary

- ***Variables and attribute data used to estimate controlled and uncontrolled storage lifetimes for baseburner assembly of the M864***
- ***Accelerated Aging and Real Time Aging data both used to provide estimates***

Summary

- Weatherseals were removed to accelerate degradation of baseburner
- Heats of reaction showed degradation both in accelerated testing and real time aging
- Accelerated aging lifetime estimates were generally shorter than real time aging lifetime estimates – Models used for Accelerated Aging are conservative – They provide a margin of safety.

Lifetime Predictions

- ***Controlled and uncontrolled storage.***
- ***For each property measured in the study***
- ***For accelerated aging data as well as depot storage (surveillance) data.***

Lifetime Predictions by Property

DATA TYPE	Stress Required	Property	Uncontrolled Storage	Controlled Storage
Stockpile –	Depot Storage	Ultimate Stress	----------	40.8
Accelerated Aging	55 % RH	Ultimate Stress	.877	10.8
Accelerated Aging	Depot Storage	Modulus of Elasticity		Unlimited Lifetime – No Degradation
Accelerated Aging	55 % RH	Modulus of Elasticity	.936	10.6
Accelerated Aging	25 % RH	Modulus of Elasticity	1.883	21.22

Lifetime Predictions by Property

DATA TYPE	Stress Required	Property	Uncontrolled Storage	Controlled Storage
Stockpile –	Depot Storage	Heat of Reaction	----------	9.76
Accelerated Aging	55 % RH	Heat of Reaction	.507	1.24
Accelerated Aging	25 % RH	Heat of Reaction	.975	2.39
Stockpile –	Depot Storage	Strain at Maximum Stress	----------	2.10
Accelerated Aging	55 % RH	Strain at Maximum Stress	.402	1.52
Accelerated Aging	25 % RH	Strain at Maximum Stress	3.19	12
Accelerated Aging	0% RH	Strain at Maximum Stress	17.9	67.6
Accelerated Aging	75 % RH	Igniter Cup Reliability*	3.10 years	12000 years

CONCLUSIONS

- *The weatherseal integrity is fundamental to survivability of base burner assembly*
- *Heat of reaction, mechanical properties and igniter cup reliability all adversely affected by moisture*
- ***Although some of the properties have degraded slightly, there has been no effect on ballistic performance or reliability***

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER
PICATINNY, NJ

Development of the NLOS-LS PAM Warhead

43rd Annual Armament Systems: Guns & Missile Systems Conference & Exhibition

April 21 – 24, 2008
New Orleans, LA

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NLOS-PAM Team

- Prime Contractor: NetFires LLC
  - ↗ Raytheon Missile Systems
  - ↗ Lockheed Martin Missiles & Fire Control

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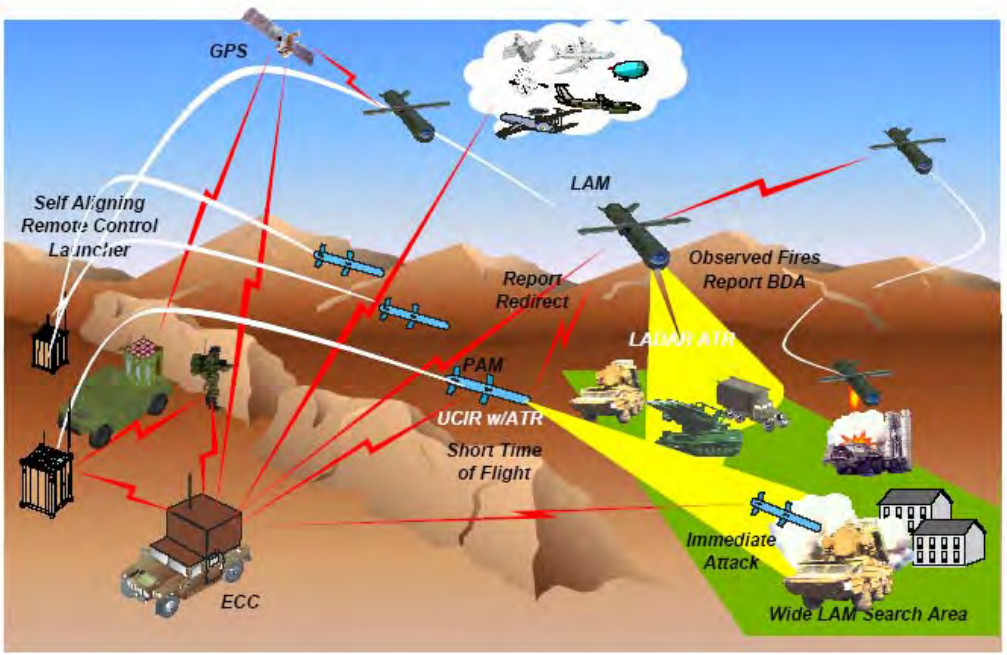
NLOS-PAM Overview

- Low cost, direct attack missile
- Provides precision fire support for the Brigade Combat Team and for USN Littoral Combat Ship



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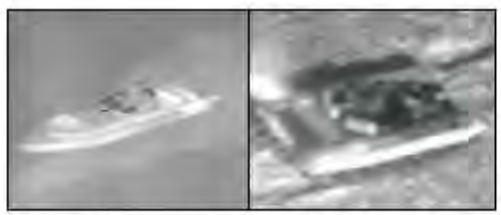
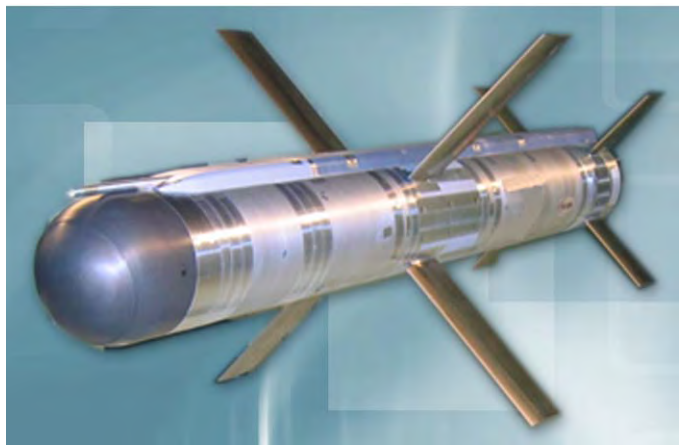
PAM System Description

- Large multi-mode warhead
- 7-inch diameter 120 lb class
- Range 0-40 kilometers
- Effective against moving and stationary targets
- In-flight updates, retargeting and image capabilities
- Target sets
  - Light armor
  - Heavy armor
  - Bunkers
  - Fortifications

PAM Warhead Effectiveness



PAM Seeker Image of Land and Sea Targets



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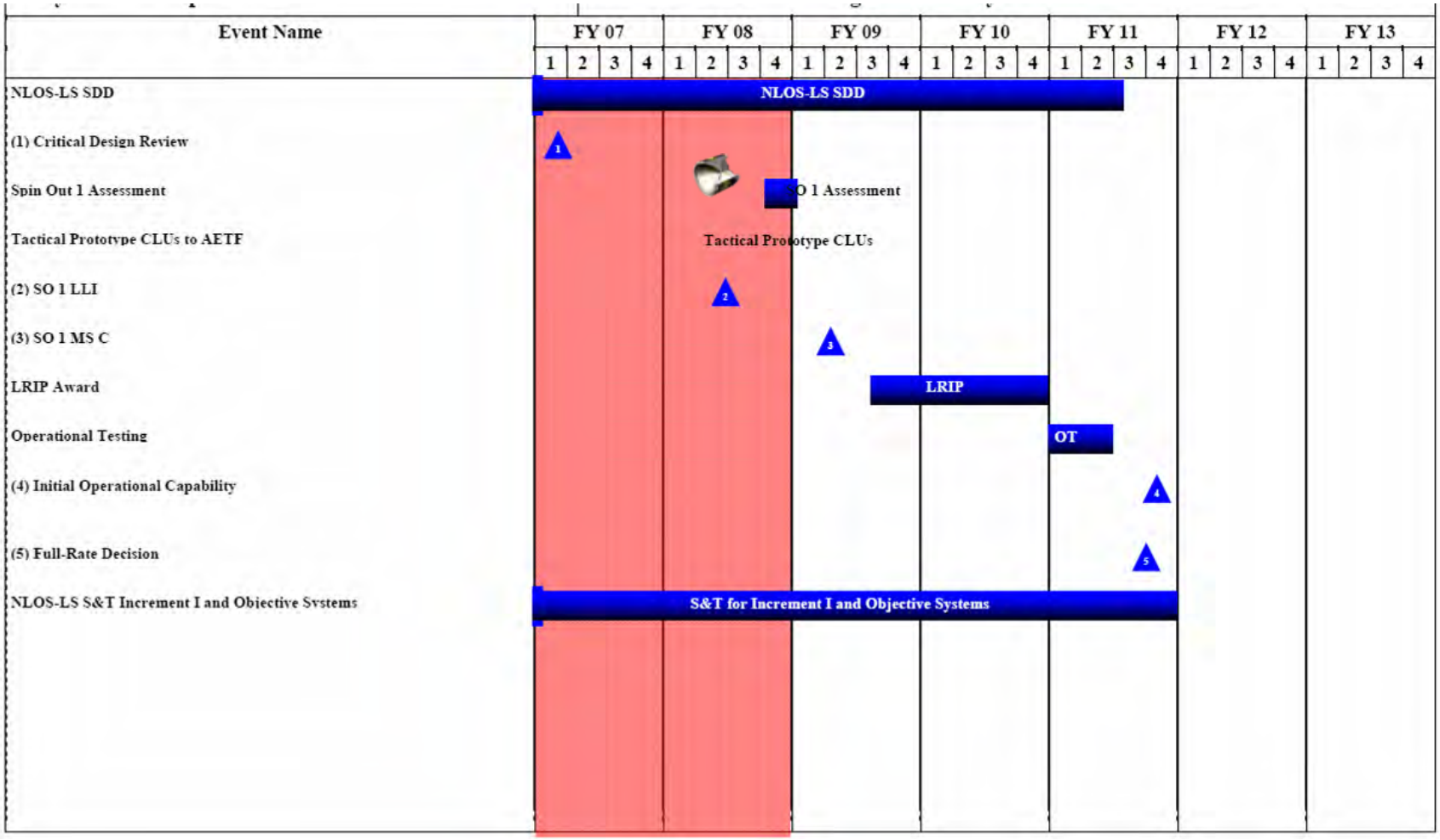
Program Schedule



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Multimode Warhead Challenges

- Short Stand-Off
- High Penetration Performance
- Strict IM requirements
- Cost as a Key Performance Characteristic
- Small Envelope
- Evolving Requirements

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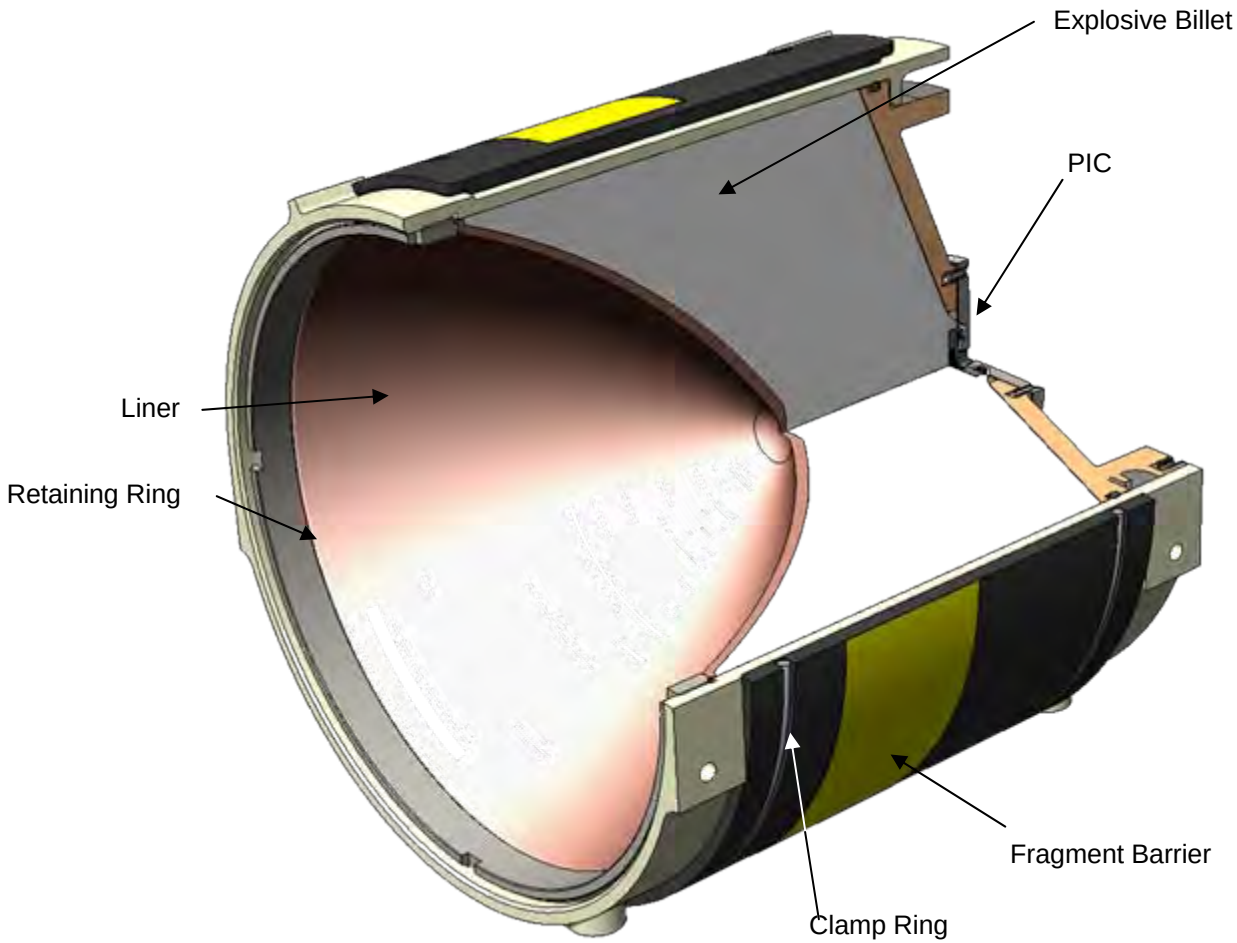
Warhead Overview



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Warhead Development

- Competitive Risk Reduction Effort
  - ↗ Trade Studies
    - Explosive Material (Penetration Performance vs. IM Performance)
    - Casing Design (Materials to reduce sensitivity to Fragment Impact)
    - Liner Material Study (Penetration Performance vs. Cost)
  - ↗ Analysis
    - Penetration Performance (Hydrocode)
    - Seeker Keep Out Zone
  - ↗ Testing
    - Jet Characterization
    - RHA and Armor Targets (Penetration Performance)
    - Soft Targets (Arena and Bunker Testing)
    - Insensitive Munitions Testing (Slow Cook-Off and Fragment Impact)
- Followed by the Detail Design Phase

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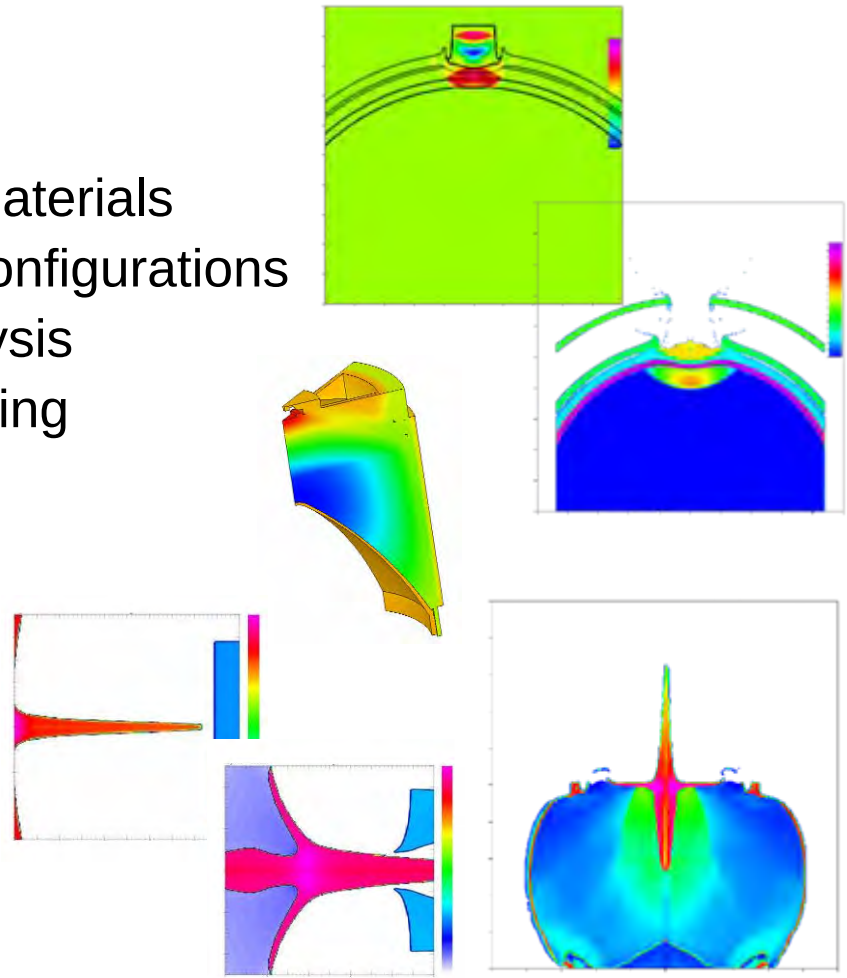
Modeling & Simulation

- Fragment Barrier Analysis
  - Understanding the Physics
  - Study the effects of different Materials
  - Study the effects of different configurations
- Slow Cook-Off Performance Analysis
  - Design Features to Allow Venting
  - Thermal Analysis
- Penetration Performance
  - 2D Hydrocode
  - Optimize Design
- Jet Characteristics
  - 3D Hydrocode
  - Ensure Straightness of Jet



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PAM Warhead Performance

Key Characteristic	Performance
Range target penetration depth	
Range target penetration diameter	
RHA penetration	
Mass	
Design to cost	

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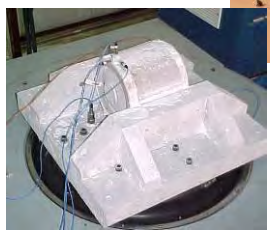
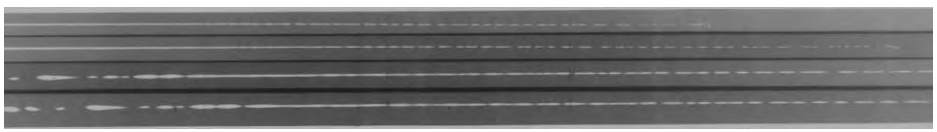
Performance Testing

- Tested 5 Different Design Variations
- Conducted over 100 Explosive Tests
  - Arena Testing
  - Jet Characterization
  - RHA Penetration
  - ERA Target Penetration
  - Environmental Testing
  - Behind Armor Debris Testing
  - Reliability (Vari-Comp)





IM Testing

Threat	Test Results
Fast Cook-off	Type V
Slow Cook-off	Type V
Bullet Impact	Type V
Fragment Impact	Type V
Sympathetic Detonation	Type V*
Shaped Charge Jet	Type I*

*=Expected

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Production Readiness

- Lean Design Effort
  - Use Low Cost Materials
  - Reduction of the number of Parts
  - Incorporation of Molded Components
  - Detail tolerance stack up analysis to optimize tolerances
  - Work with each component Vendors on reducing Cost Drivers
  - Streamline Assembly Process
- Early Development of Acceptance Testing
  - Perform Lot Acceptance Tests (LAT) to Characterize Variation
- Control of Critical Characteristics
  - Characteristics that mostly control performance variation
- Pilot Production Line incorporated on Qualification Build

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Design Challenges

- Striking a Balance between Low Cost and High Performance
- Integrating Production Processes early on
- Mitigating Fragment Impact and Slow Cook-Off Hazards
- Maintain Performance with Environmental Factors
- Incorporating Environmentally Compliant Processes and Products

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Acknowledgements

- Raytheon Missile Systems
  - ↗ Bill Zarr

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Development and Fielding of the Excalibur XM982 Warhead

43rd Annual Armament Systems: Guns & Missile Systems Conference & Exhibition

April 21 – 24, 2008
New Orleans, LA

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Excalibur Team

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

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XM982 Excalibur

GPS-Guided, Precision Long-Range Artillery Projectile

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

M109A6 Paladin
- US Army

M777A2 LW155
- US Army
- USMC

Archer

Excalibur is Transforming Cannon Artillery on the Battlefield Today

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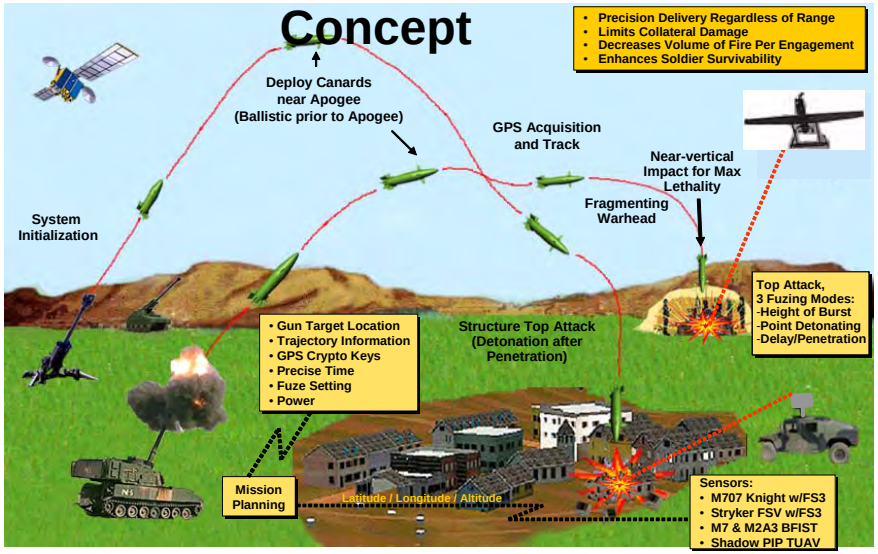
Precision Cannon Munition Capability

EXCALIBUR XM982

Concept



System Description

- Precision guided, extended range 155mm High Explosive cannon ammunition
- All weather, day/night, fire & forget capability, optimized for urban/complex terrain
- GPS-Inertial Navigation System guidance w/anti-jam technology
- <10 meter CEP Accuracy at all Ranges
- Lethality comparable to M107 HE

Value to Warfighter

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

	Block Ia-1: Early Fielding		ORD Requirements	
	User's Minimum Capability	Expected Performance	Block Ia2 *Threshold*	Block Ia2 *Objective*
*Accuracy (CEP)	=20 Meter	=6 Meter	=20 Meter	=10 Meter
*Effectiveness	=M107 HE	=M107 HE	=M107 HE	=M107 HE
*Reliability	=60%	=74%	=85%	= 96%
*Interoperability	All critical top level IERs	All critical top level IERs	All critical top level IERs	All top-level IERs
Range	=24 km	=24 km	=30 km	=40 km
Concrete Penetration	4”	=4”	4”	8”
** Anti-Jam	No	Yes	=30 Meter	=20 Meter

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

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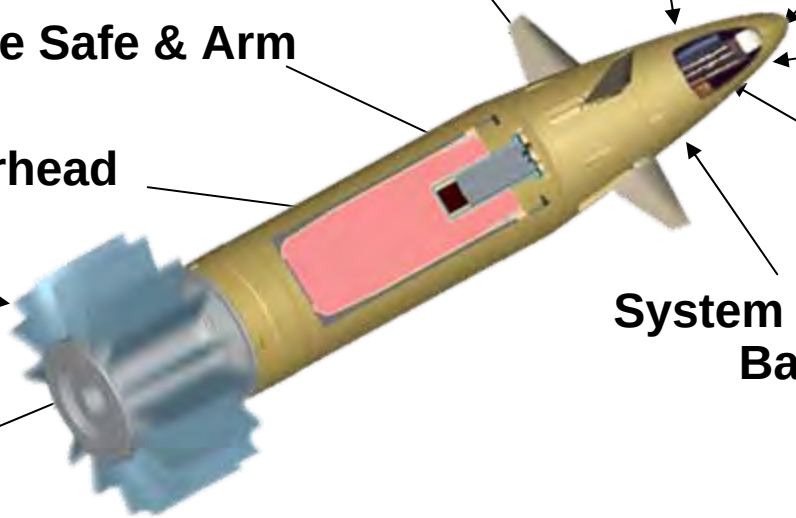
Major Components & Functions



GPS Receiver
Inertial Measurement Unit – IMU

Height of Burst, Point Detonating & Delay Sensors

Canard Actuation System - CAS

Internal Fuze Safe & Arm

GPS SAASM (Selective Availability-Anti Spoofing Module)

Unitary Warhead

GPS Antennas

Spinning Base

System & Data Hold Batteries

Base Bleed

EPIAFS - Enhanced Portable Inductive Artillery Fuze Setter

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Effectiveness Against Unitary Targets

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

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

Effects Comparison:

M107 at 15Km

M549 at 20Km

Excalibur at any range

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

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

Excalibur is used in a complex target environment!

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Gun Compatibility and Range with Base Bleed

Current US 39-caliber systems (M777, M109A6, M198)	**40km**	**MACS-5**
NLOS-C US Army	**>36km**	**MACS-4**
FH77BD* Swedish Army	**50km**	**Swedish *Uni-Flex* Charge**

*** 52 Caliber Howitzers Will Achieve the 50km Range**

M777 Joint Light Weight Howitzer (LW155)

M109A6 Paladin Howitzer and M992A2 FAASV

FH77BD "Archer"

M198 Towed Howitzer

Non-Line-of-Sight Cannon (NLOS-C)

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Design Challenges

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

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Warhead Development

- SDD Program
  - Trade Studies
    - Explosive Material (Gun Safety, Reliability, IM, and Lethality)
    - Protection of Fuze (Gun Launch and Penetration)
    - IM Liner and Vent Material Study
  - Analysis
    - Finite Element Analysis
    - Hydrocode (Concrete Penetration, BI, FI, and SD)
    - Weapon Effectiveness
  - Testing
    - Insensitive Munitions
    - JMEM Arena Testing
    - Concrete Penetration Testing
    - Proof Load Gun Testing
    - Environmental Testing
- Early Fielding to Fulfill Need for Precision Fire Support (Approx. 800 Warheads Delivered)

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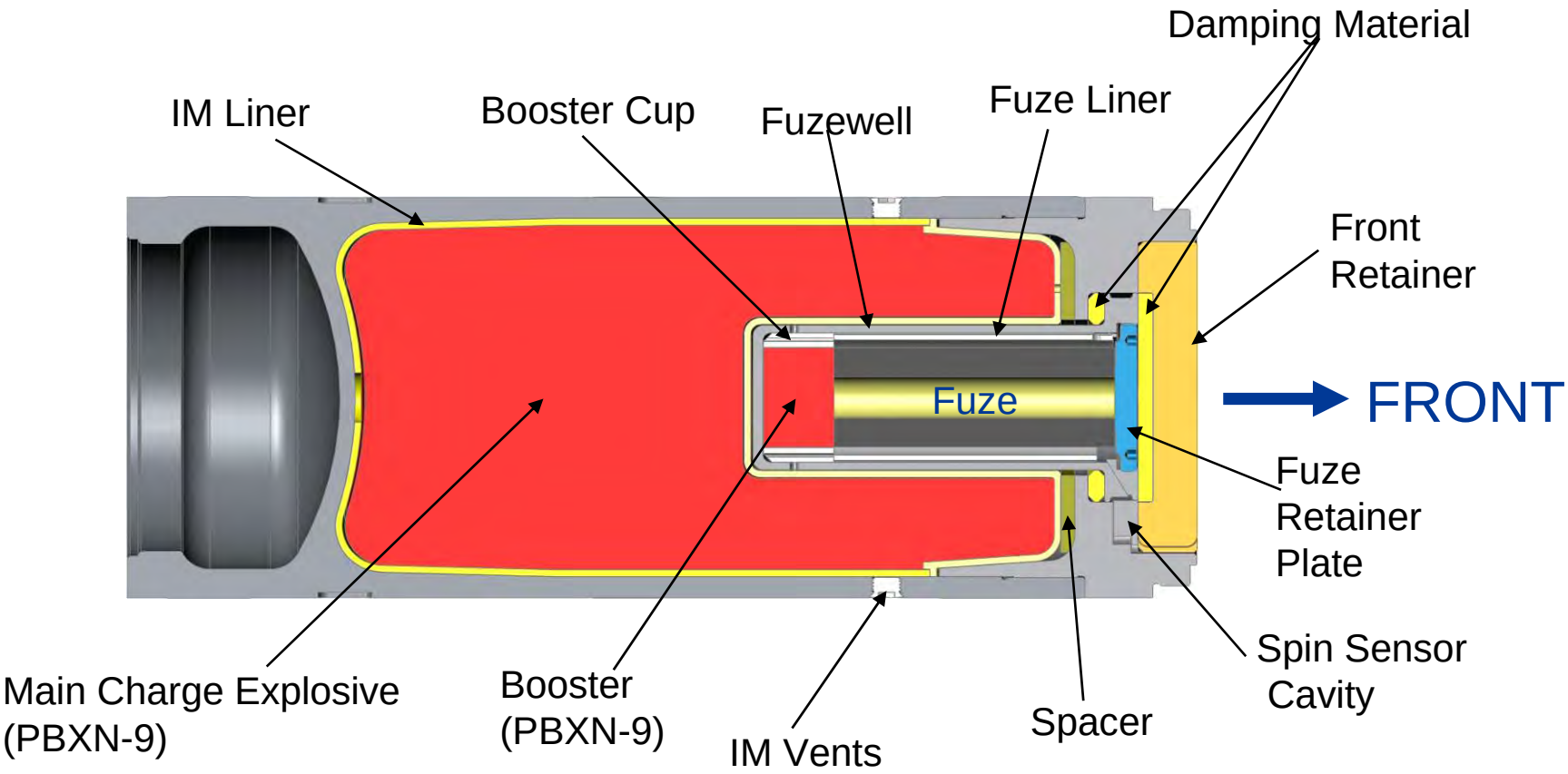
Warhead Overview



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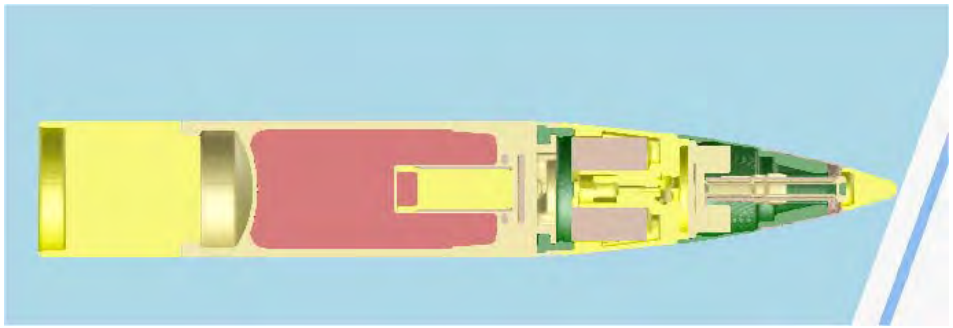
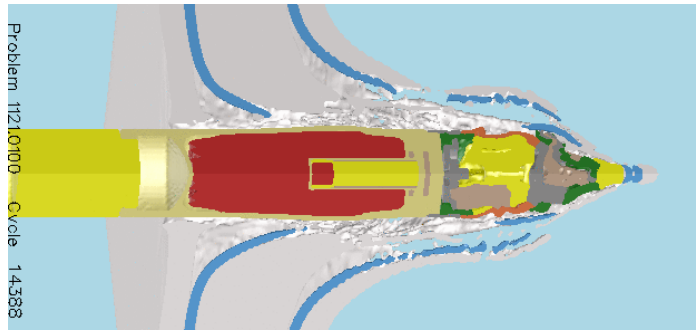
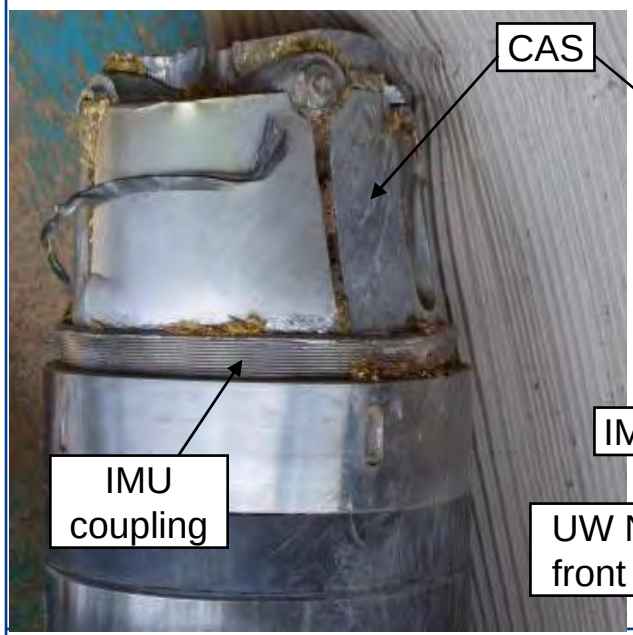
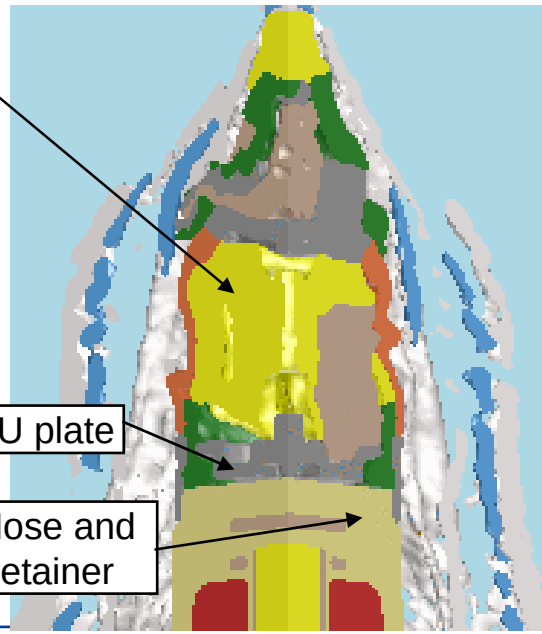
Modeling & Simulation
Target Penetration

EXCALIBUR XM982

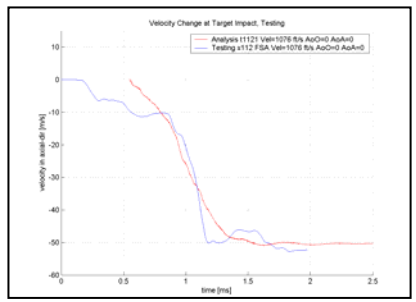








Correlation of Modeling & Test Results
Impact velocity = 328 m/s (1,076 ft/s)
Angle of obliquity = 0 deg
Angle of attack = 0 deg
Concrete Comp. strength = 4,200 psi
Exit Velocity (Simulation) = 278 m/s
Exit Velocity (Test) = 276 m/s



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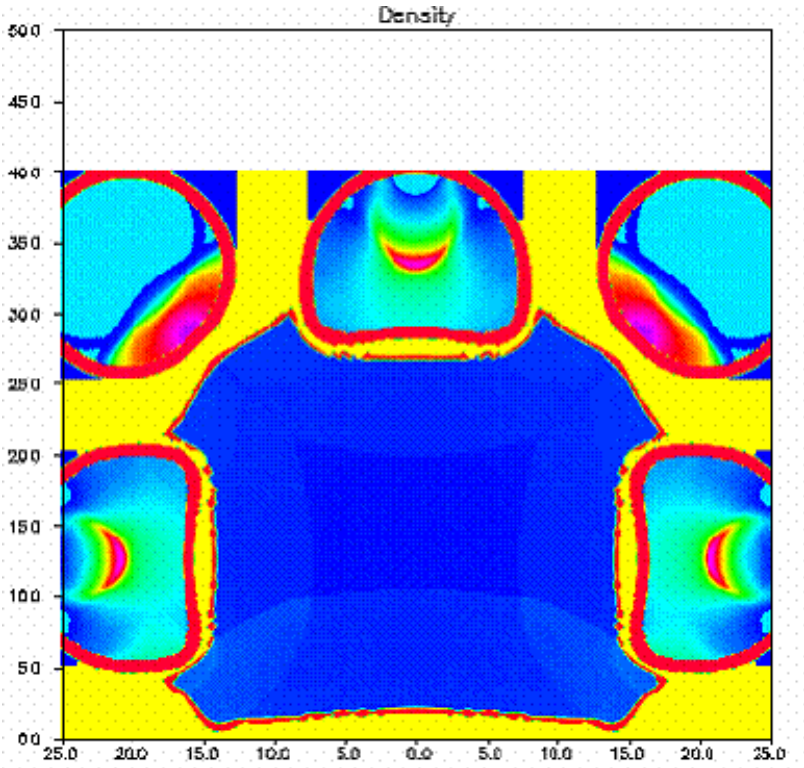
Modeling & Simulation
Sympathetic Detonation



Sympathetic Detonation Test

Prediction: No Detonation of Acceptors

Test Results: Type III (Explosion)

OTI*HULL Hydrocode Results

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XM982 Warhead Performance

Performance Measure	Requirement	Result
Environmental: Gun Launch	PMP + 5%	Meets Requirements
Environmental: Hot Gun	Functional After Exposure	Meets Requirements
Environmental: Life Cycle	20 years	Meets Requirements
IM: Bullet Impact	≤ Type V	Type V
IM: Fast Cook-Off	≤ Type V	Type V
IM: Fragment Impact	≤ Type V	Type V
IM: Slow Cook-Off	≤ Type V (Objective) ≤ Type II (Threshold)	Type III
IM: Sympathetic Detonation	≤ Type II	Type III
Performance: Lethality	Personnel, Command Post, Air Defense Radar	Meets Requirements
Performance: Penetration	8" Reinforced Concrete	Exceeds Requirements
Reliability: Initial	≥ 0.9991	0.9998
Reliability: Long Term	≥ 0.9990	0.9993

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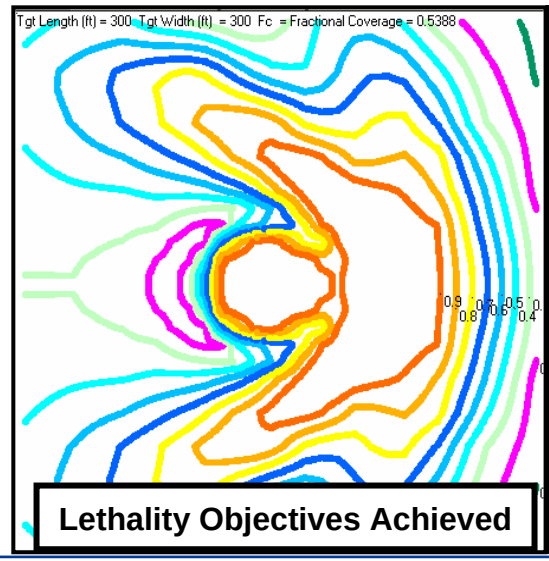
Performance Test Results

EXCALIBUR XM982

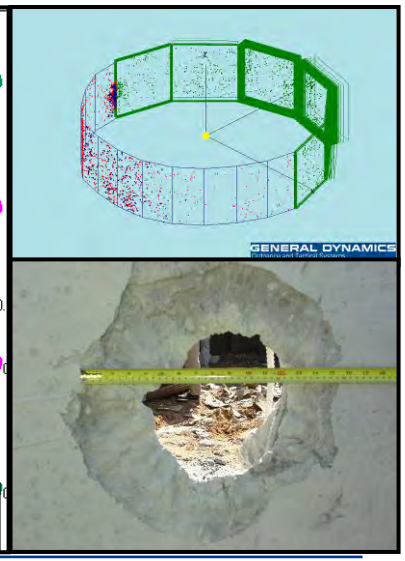
Static JMEM Arena Test

Full Scale Penetration Test (Target Exit)

Live Fire Test



Lethality Objectives Achieved



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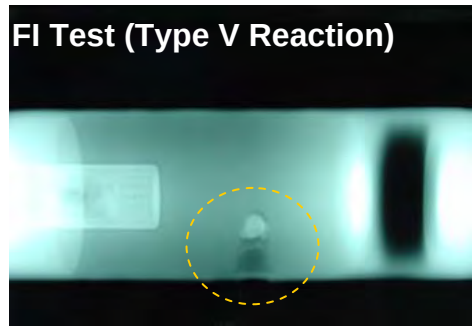
Insensitive Munitions Testing

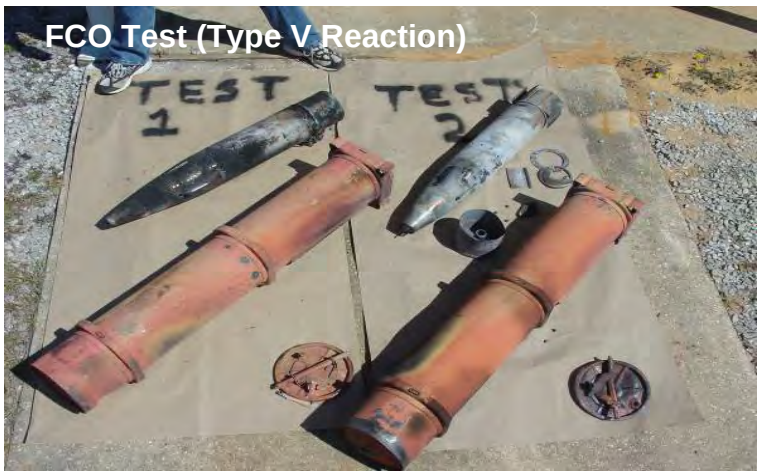
EXCALIBUR XM982

Fast Cook-Off Test

SCO Test (Type III)

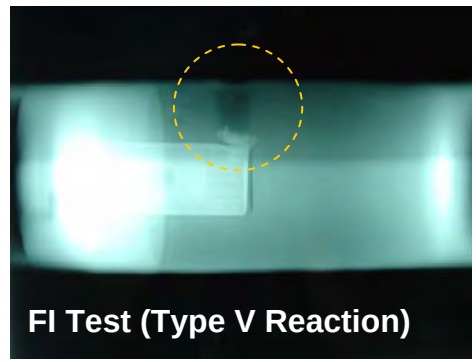
Bullet Impact Test (Type V Reaction)


FI Test (Type V Reaction)



FCO Test (Type V Reaction)

SD Test (Type III)


FI Test (Type V Reaction)

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Acknowledgements

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

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Mid Range Munition Science & Technology Demonstration

23 April 2008

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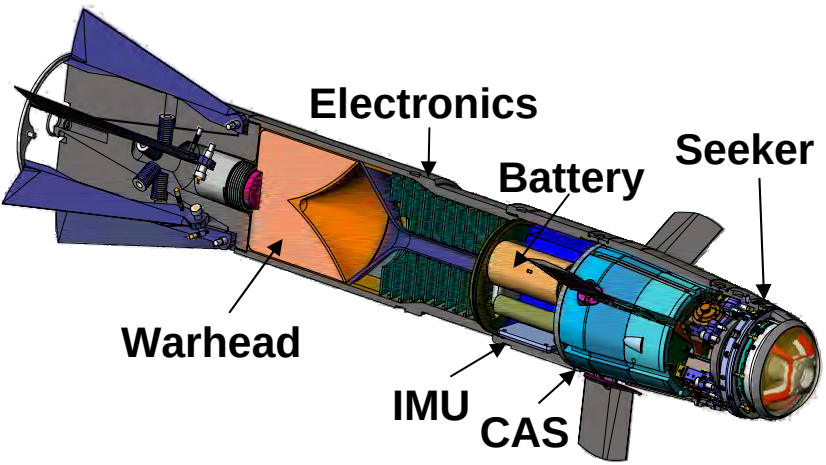
S&T Overview

Gun Fired SAL & Dual Mode MRM against a Moving & Fixed T-72 Tank

- IR Autonomous / digital Semi Active Laser
- Adaptation of Proven Javelin Tracker/ Warhead
- Successful dSAL™ & Dual Mode Gun Firings



MRM DMS Program Summary

- Projectile fully integrated into Production Capable Cartridge
- Dec 05, Successfully completed SAL Seeker Tower test at Picatinny
- 15 Aug 06, DSAL 202 Firing – **Direct Hit on Moving T-72 @ 8.7km!!!**
- 28/30 Nov 06, Fully Integrated Dual Mode Seeker CFT at Yuma
- 1 Mar 07, Dual Mode (DMS 301) Gun Firing – **Direct Hit T-72 @ 5.2 km!!!**

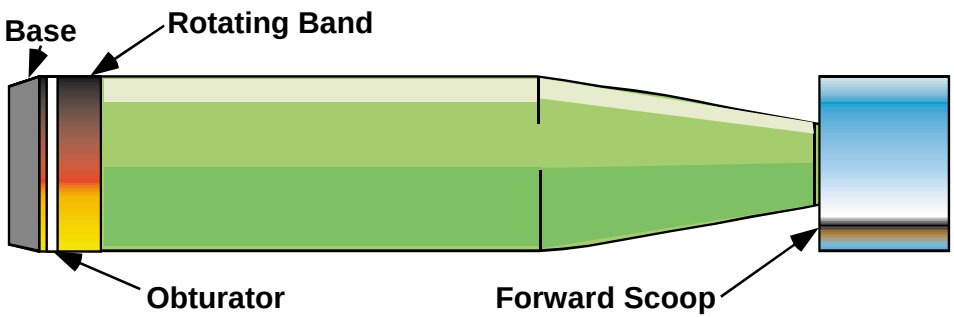
MRM DMS Contract Requirements completed within Budget and Schedule

Million Baby Steps – Design & Test

System Engineering Approach

- Design Trades
- Requirements and their Flow Down to Sub-Systems/Assemblies
- Initial Design and Engineering Reviews
- Prototyping Sub-Assemblies
- Gun Hardening Testing
- Initial Integration and Interface Check-out
- Final Design
- Fabricate all Sub-Assemblies
- Testing of Sub-Assemblies (IFS,SWES,SKR,PIL,HIL,CFT,PM)
- Integration of Sub-Assemblies
  - Cartridge-Propulsion-Airframe-Tails-CAS-Electronics-Seeker Guidance
- Final Gun Test of complete cartridge

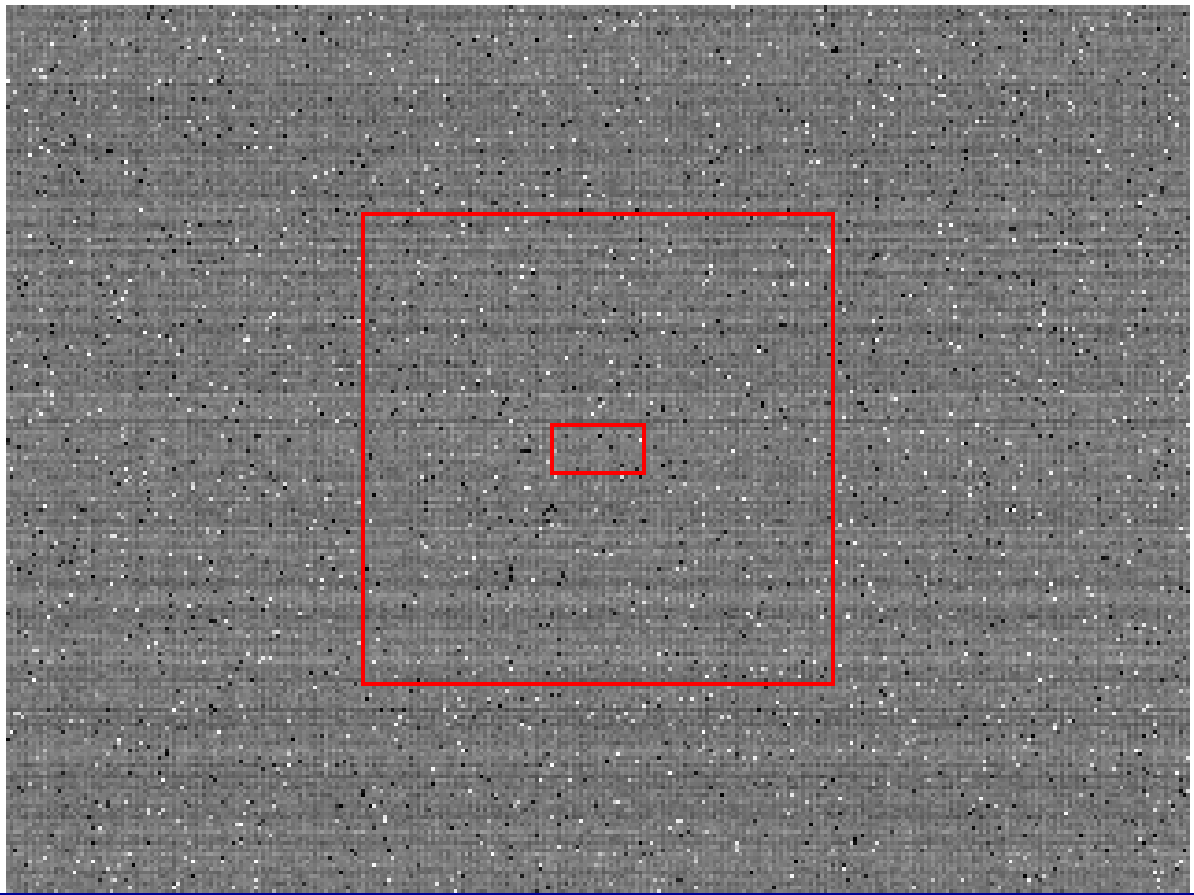
Rail Gun Testing



155mm M483 Cargo Projectile (modified)

After Analysis Prototypes are Gun Tested

Integrated Flight Simulation & Real Time Processor In Loop Capability



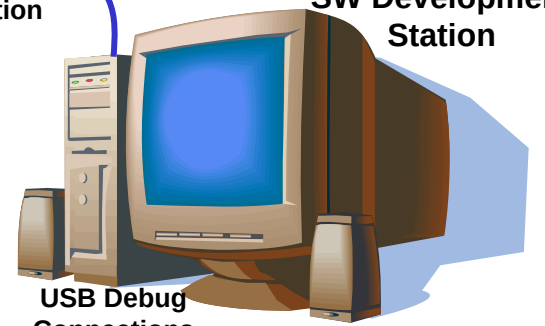
Computer Generated Scene Integrated with Flight Software Pre-Shroud Deploy Through Impact

Software Evaluation Station

CPU CCA
(MAPS Development board)

Ethernet Debug Connection

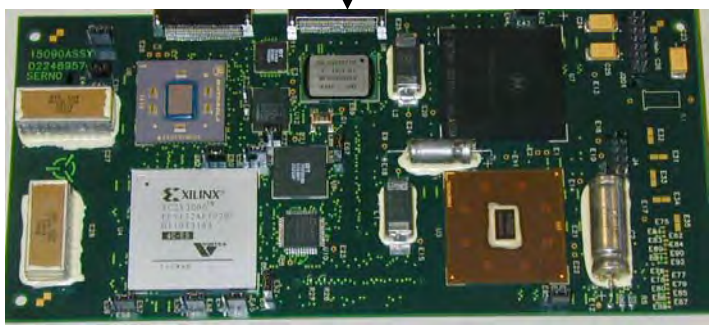
SW Development Station



USB Debug Connections

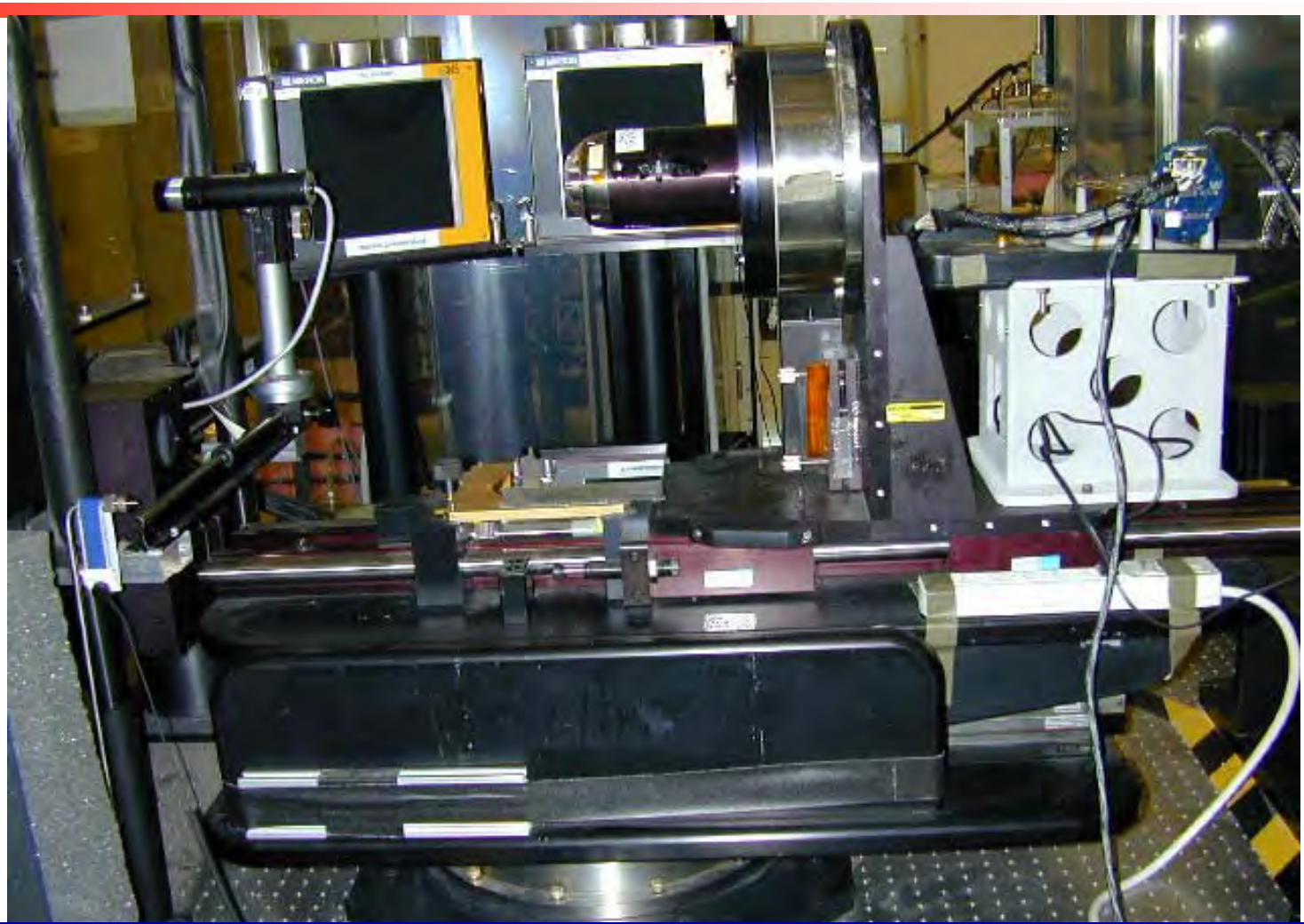
PCI Express Connection

Video/IO CCA
(MAPS FPGA Development board)



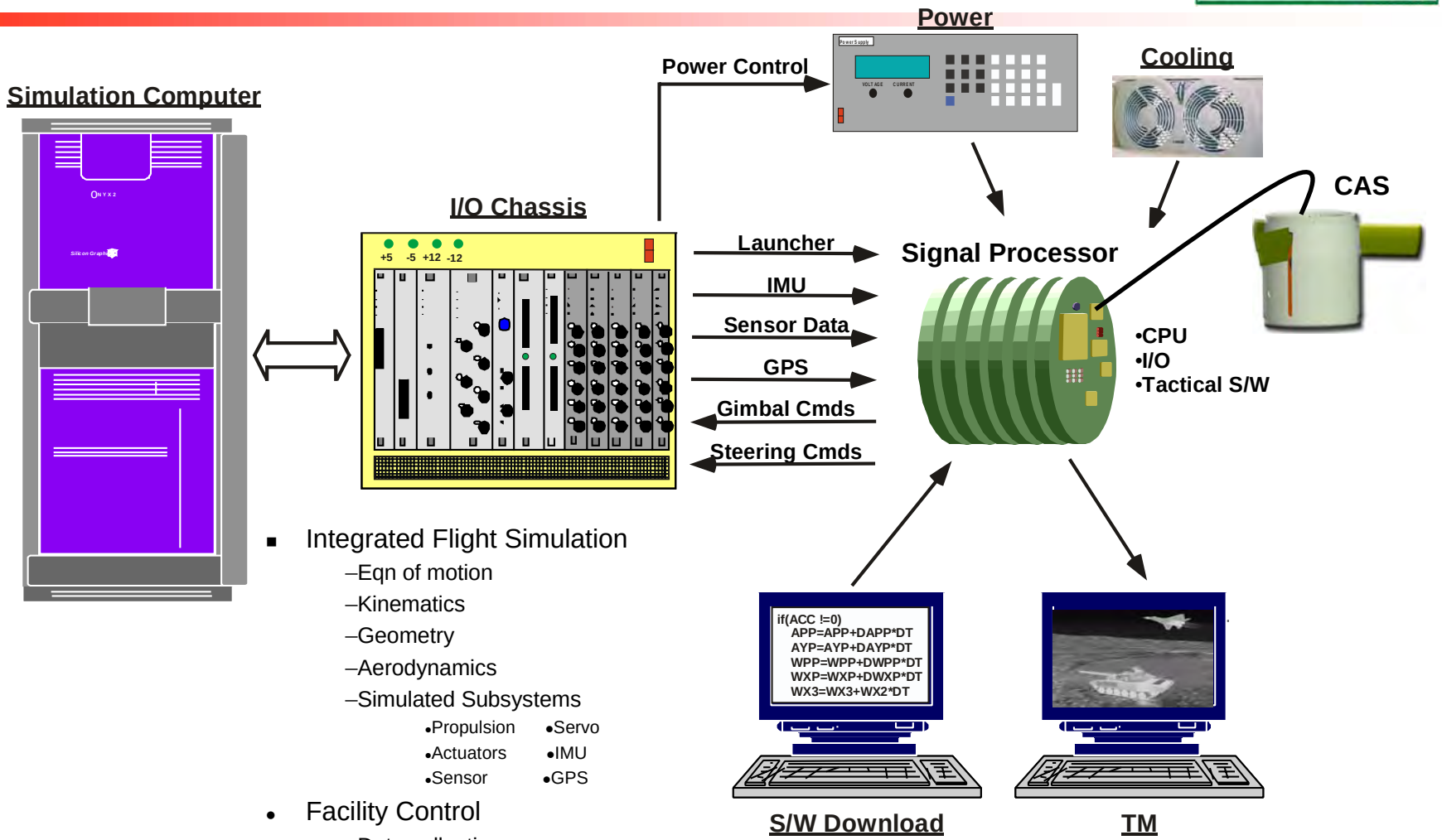
Functioning check-out of the HW interfaces with real CAS, Seeker, IMU, Control and Data Collection test equipment. Check processor throughput and execution timing

Seeker Test Station



Seeker Test Station runs precision IR and SAL performance tests.

PIL Architecture

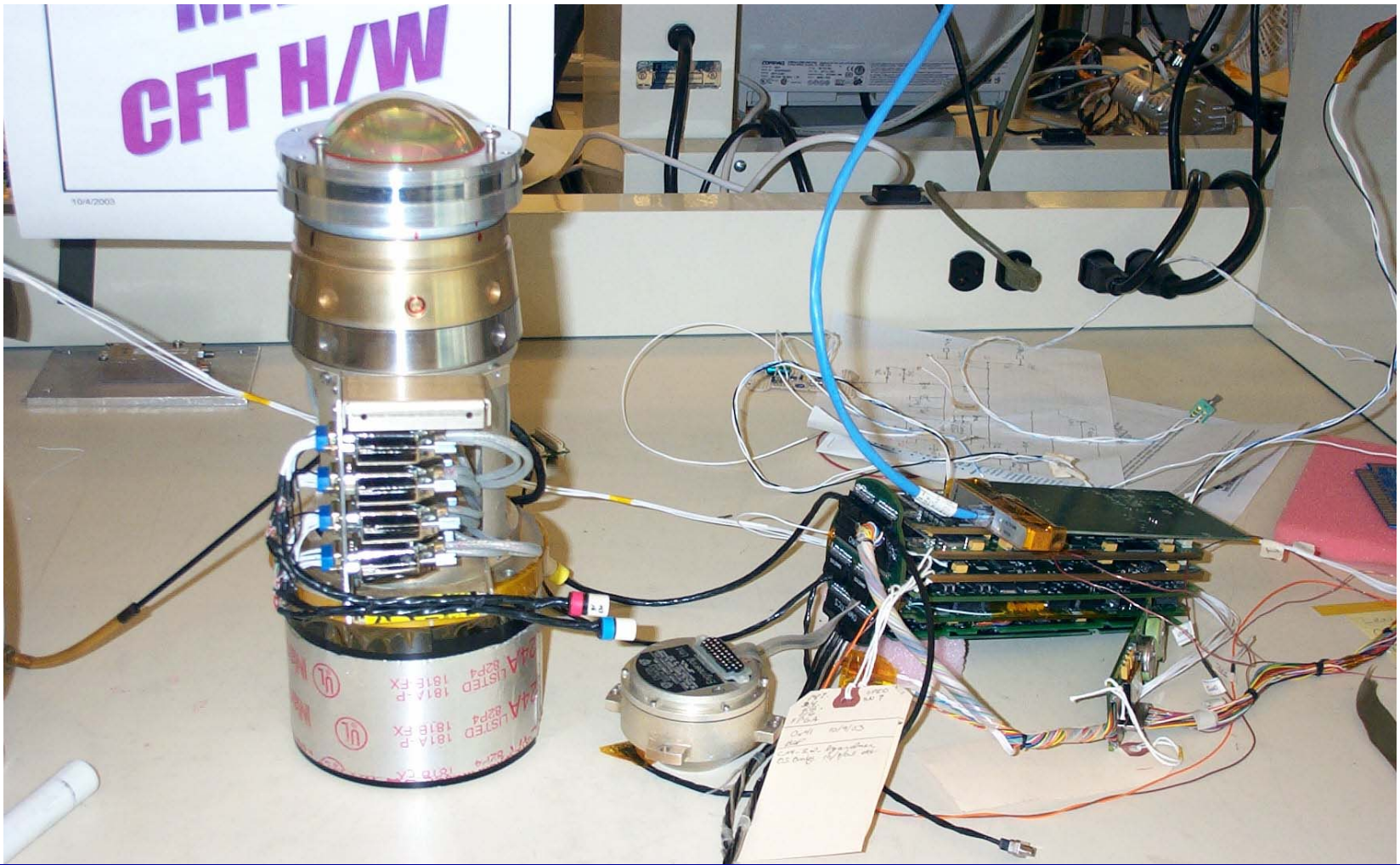


- Integrated Flight Simulation
  - –Eqn of motion
  - –Kinematics
  - –Geometry
  - –Aerodynamics
  - –Simulated Subsystems
    - •Propulsion •Servo
    - •Actuators •IMU
    - •Sensor •GPS
- Facility Control
  - –Data collection
  - –Target generation
  - –Processor I/O

Processor In the Loop Testing

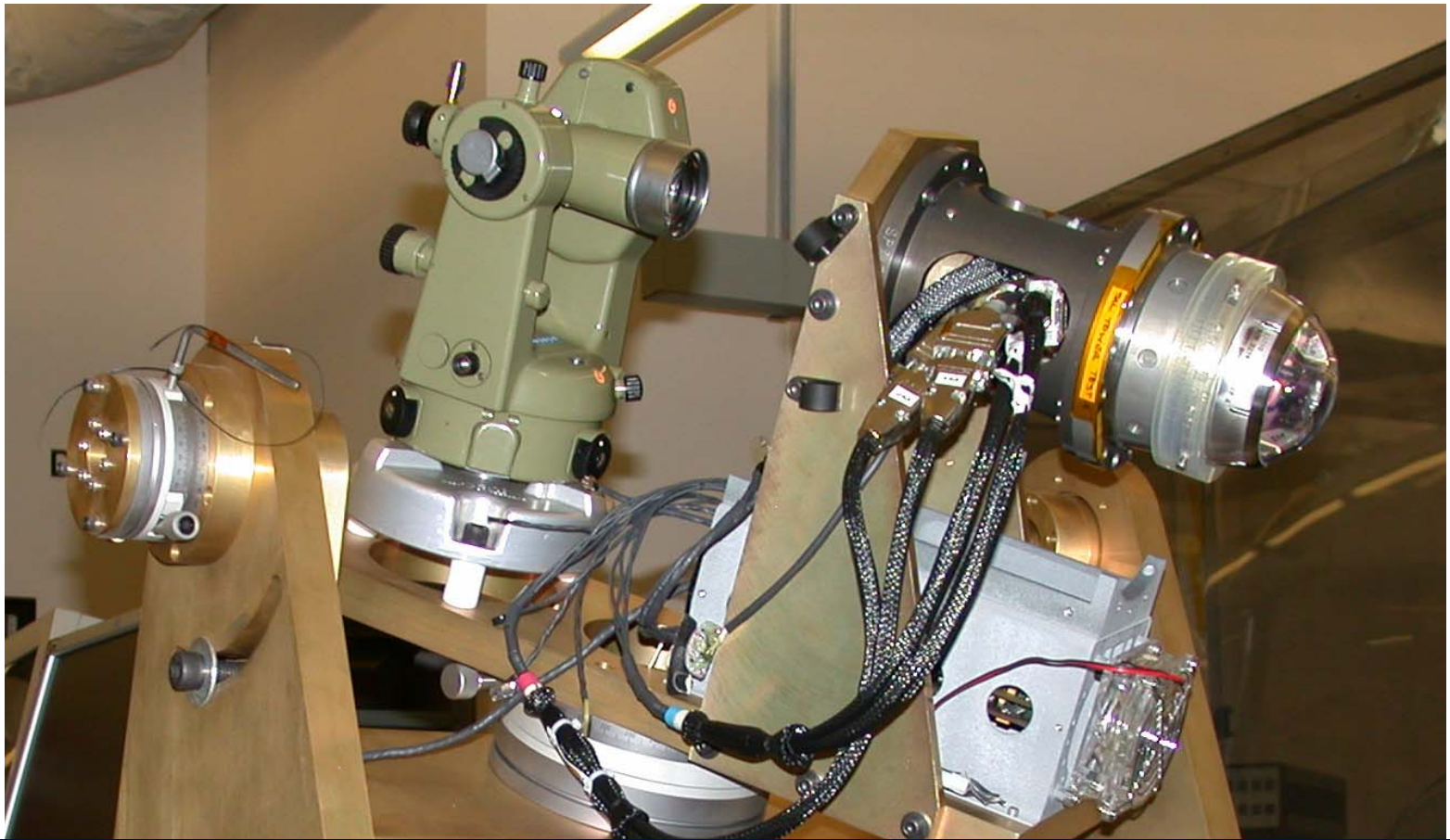
Common Computer Scene Generation, UUT Control and Data Acquisition Systems support multiple test efforts.
Closes the Autopilot control loop around the IMU, CAS and Electronics

Bench Testing



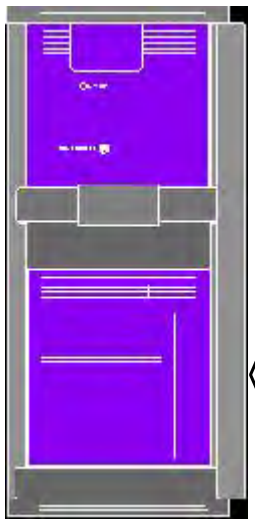
Simple Prototype Integration required Limited Test equipment & Software

DSAL Tower Test System



07 December 2005 – Successfully completed SAL tower testing at the Picatinny Tower during winter conditions. The dSAL™ seeker correctly acquired and tracked the laser source at min/max ranges.

HWIL Architecture



Simulation Computer

Target Scene data

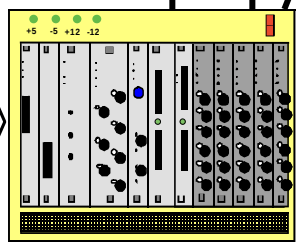
Power

Cooling

Power Control

Target Motion

I/O Chassis



Launcher

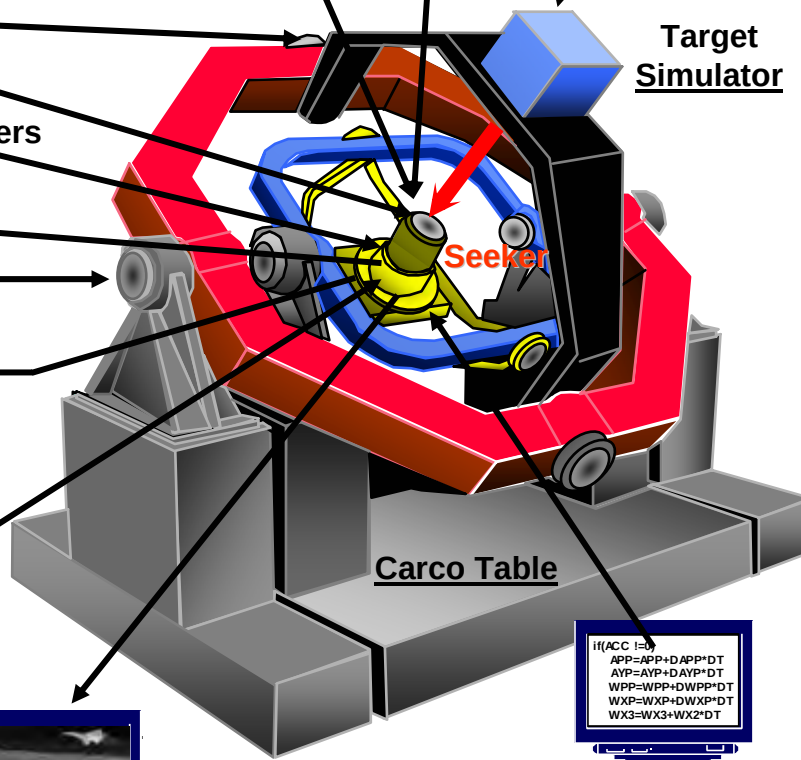
IMU ΔV, ΔΘ, Accelerometers

Steering Cmds

Carco Table Control

Target LOS Rate

Target Simulator



Target Position,Velocity, Accel, Time

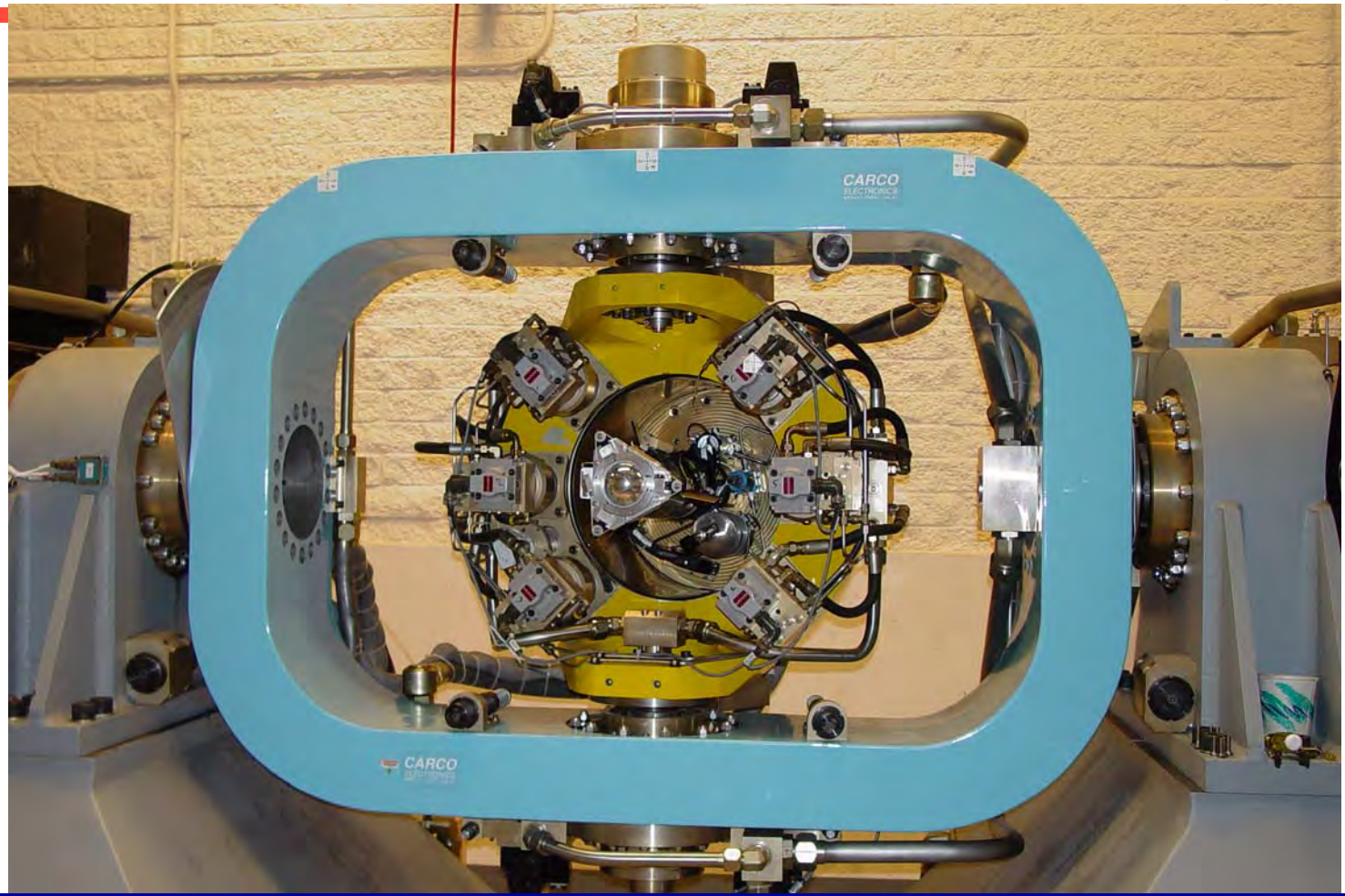
Carco Table

S/W Download

- Integrated Flight Simulation
  - –Eqn of motion
  - –Kinematics
  - –Geometry
  - –Aerodynamics
  - –Simulated Subsystems
    - •Actuators
    - •Sensor
    - •IMU
- Facility Control
  - –Data collection and I/O
  - –Target Generation
  - –Motion Platform

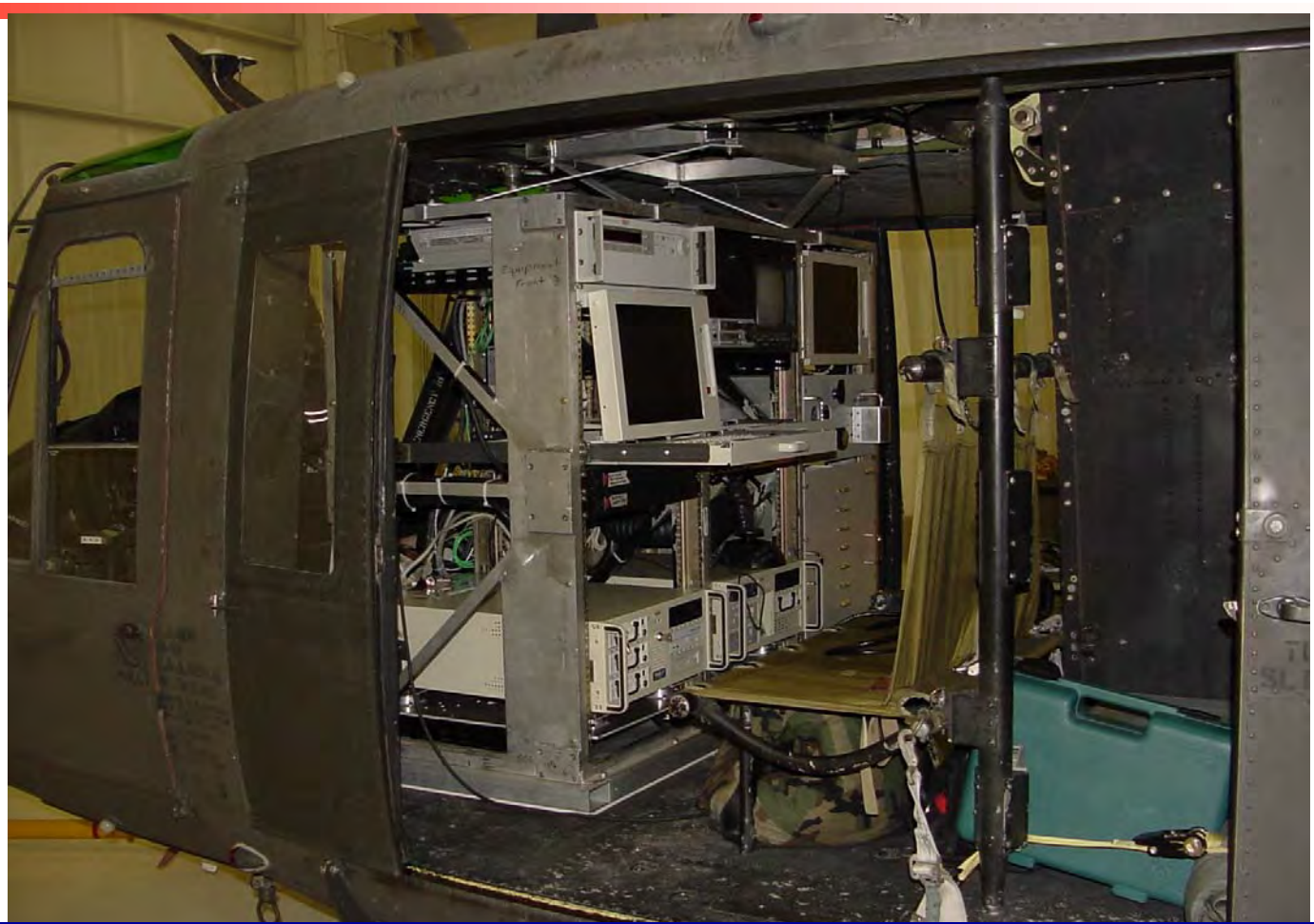
TM

Hardware In the Loop Testing



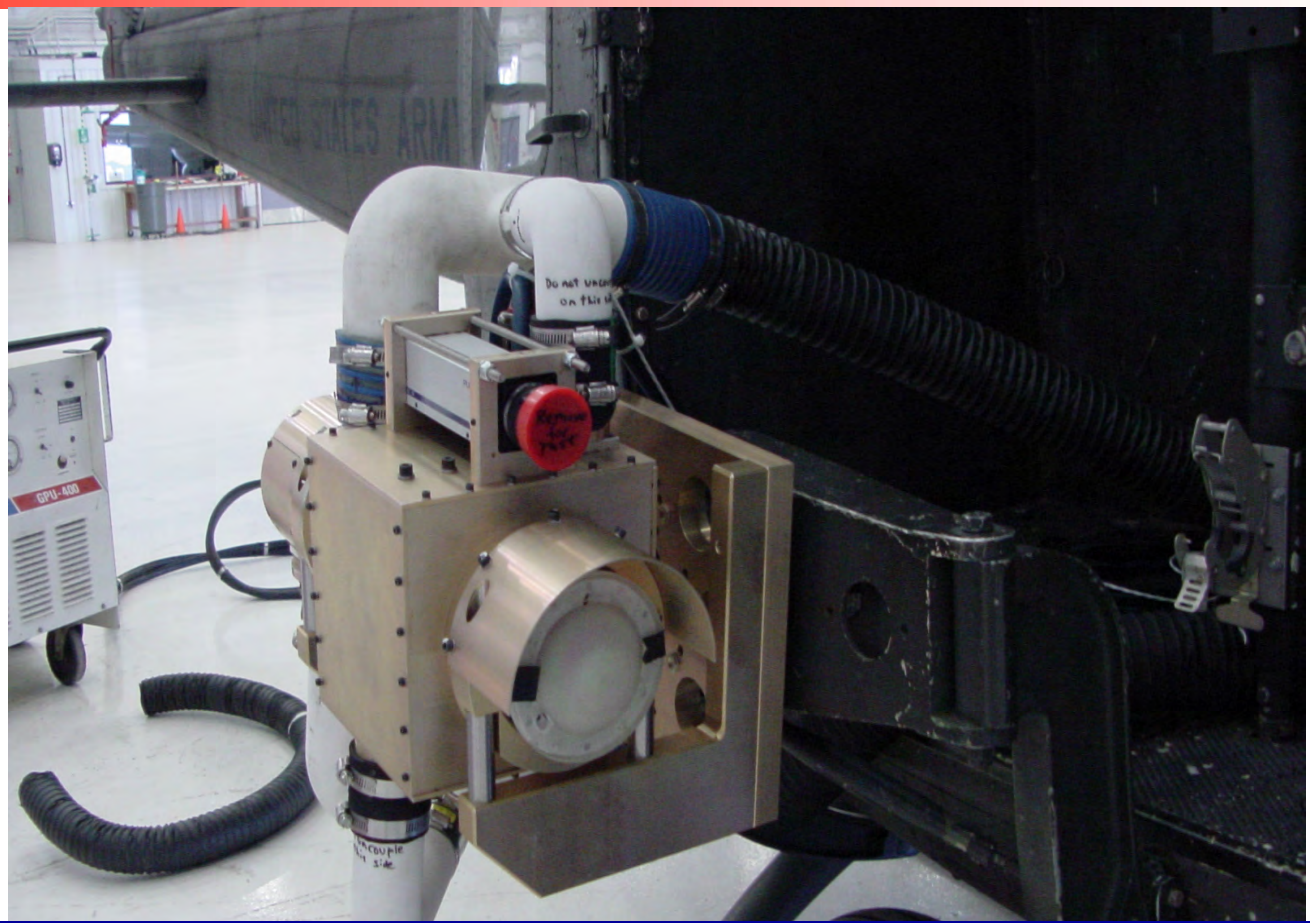
HIL verifies all guidance control loops operate correctly during a real time flight simulation

Captive Flight Test



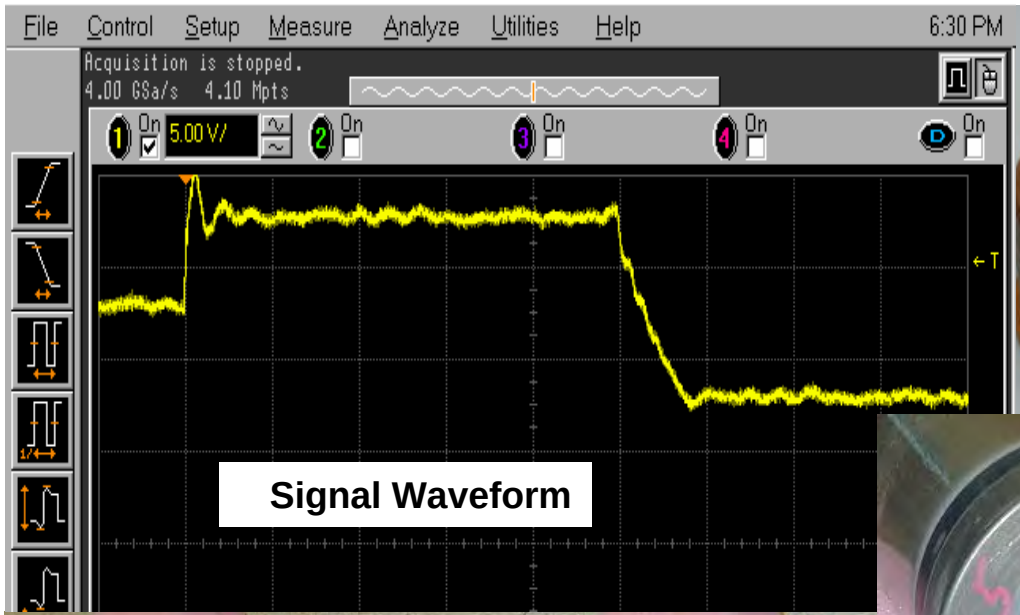
Data Acquisition and control computers used in the PIL and HIL are also used during Captive Flight Test (CFT)

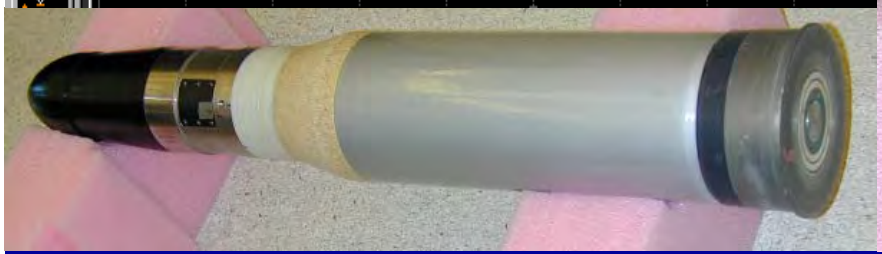
MRM CFT Assembly Mounted on Helicopter Front View



Captive Flight Testing provides end to end testing of target acquisition, tracking and guidance commands as the helicopter closes with the tank target. CFT was critical to the flight software development and debugging efforts.

Cartridge Ammo Data Link Demo





Ammo Data Link has been developed, integrated and tested

Successfully tested in M1A2 SEP using a emulator

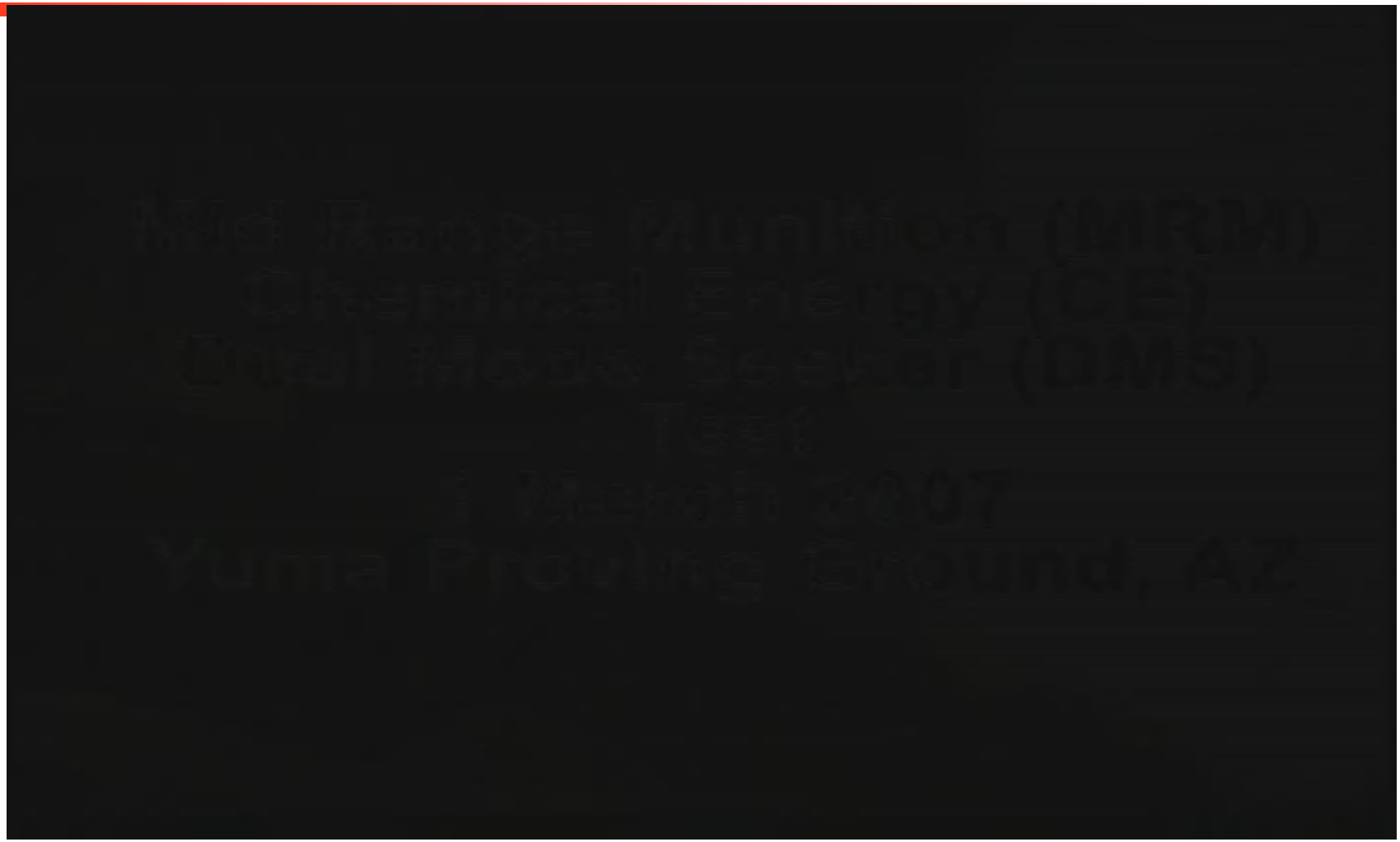
Battery Init / Shroud Video

Initial Shroud Deployment

Battery Init / Shroud Video

Shroud Deploy – Both Halves

Final Gun Tests



Direct Hits with Both dSAL™ and Dual Mode I2R/dSAL™ !!!

Summary

- System Engineering approach allowed Fast Pace
- Aggressively Pushed Detailed Testing
- Combined Test Objectives For Highest Efficiency
- Rapidly review Failure Analysis
- We always learn more after a failure than success
- Lessons Learned
  - ✓Run Detailed Post Analysis After All Tests – Even Successes !!!
  - ✓Do Not Ship Test Articles Until You Have Tested Outside Of The Expected Test Conditions. Test It until It Fails – Then Fix It. Always Understand The Failure Even If It Can Not Be Fixed !!!

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43rd Annual Guns & Missiles Symposium

21-24 April 2008

PGK and the Impact of Affordable Precision on the Fires Mission

Doug Storsved

Chief Systems Engineer
ATK Advanced Weapons

Approved for Public Release, POA 299-08, 22 CFR 125.4(b)(13) applicable

“Affordable Precision” Possible Today

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Discussion Topics:

- PGK Program and Status
- Impact on Conducting Fire Missions with PGK
- Ideas on Modern Battlefield Roles of Conventional and Precision Munitions

Technology

People

Strengthened Capability for the Warfighter

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155mm Artillery Effectiveness Gap Defined

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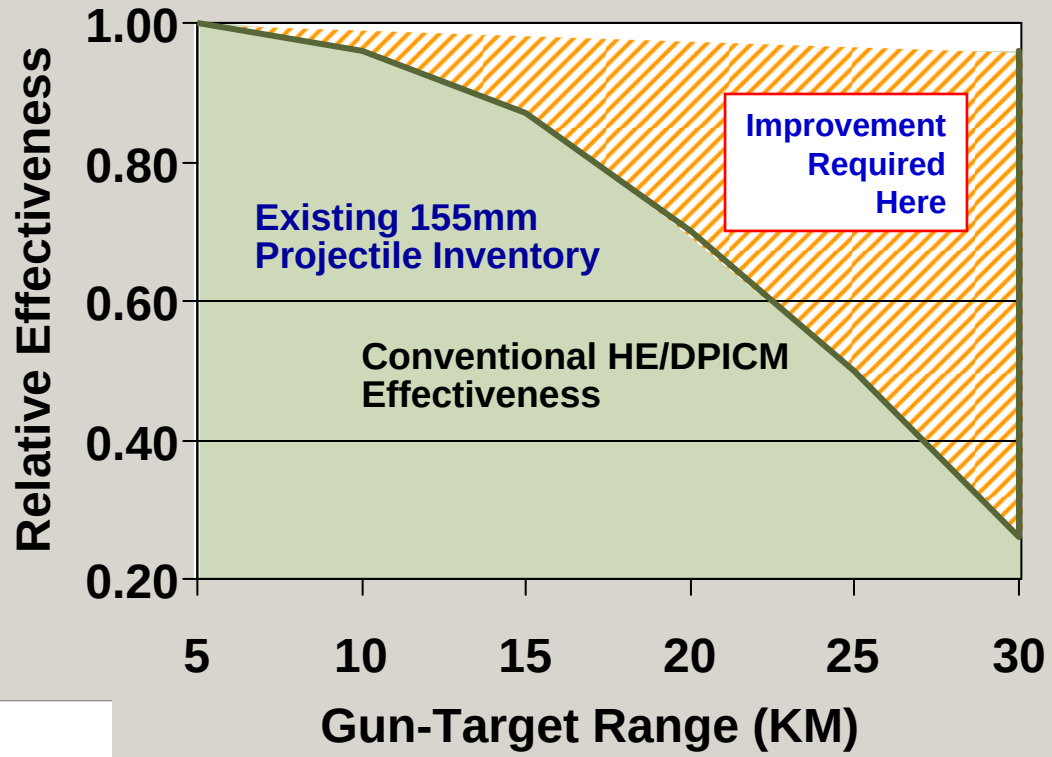
2000

Why LCCM (Low Cost Competent Munition)?

Conventional Munitions are Less Effective at Longer Ranges



TACOM

LCCM: More than Competent

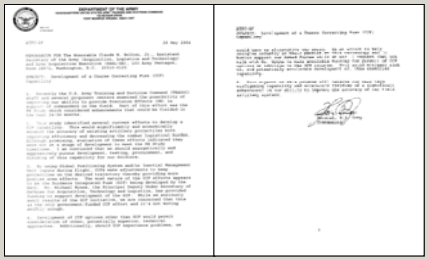
Presented at:
6th International Cannon Artillery Firepower Symposium
21 June 2000

Stephen Pearcy
Ch, PMMD, FSAC

Stephen Pearcy (Ch, PMMD, FSAC), **LCCM: More than Competent**
6th International Cannon Artillery Firepower Symposium, 21 June 2000

2004

Why CCF (Course Correcting Fuze)?



"CCF capability…would significantly and economically enhance the accuracy of existing artillery projectiles both improving efficiency and decreasing the combat logistical burden."

"…we should energetically and aggressively pursue development, testing, procurement, and fielding of this capability for our Soldiers."

General Byrnes
Commanding General
of US Army Future Force

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Types of Precision Munitions

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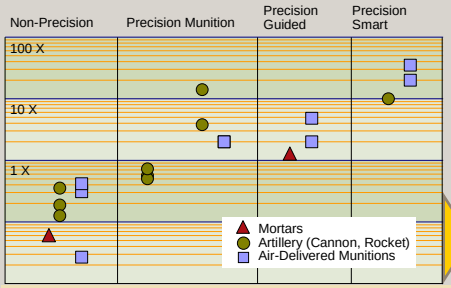


Non-Precision (Area) Munition	Precision Munition	Precision Guided Munition	Precision Smart Munition
Munition/submunitions subject to all ballistic conditions on the way to the AIMPOINT.	Munition corrects for ballistic conditions using guidance and control up to the AIMPOINT or submunitions dispense with terminal accuracy less than the lethal radius of effects. Submunitions are subject to ballistic conditions to the AIMPOINT.	Munition senses coded energy reflected from a target and uses guidance and control to the TARGET. A laser designator in the loop is required for target designation.	Munition/submunitions autonomously searches, detects, classifies, selects, and engages TARGET(s). Has a limited target discrimination capability.
1 X	10 X	10 X	100 X

120mm Mortar Ammunition

M934

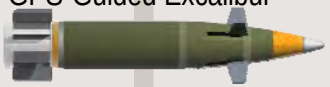
XM395 PGMM

155mm Cannon-Fired Artillery Ammunition

Unguided 155mm

GPS-Guided PGK

GPS-Guided Excalibur



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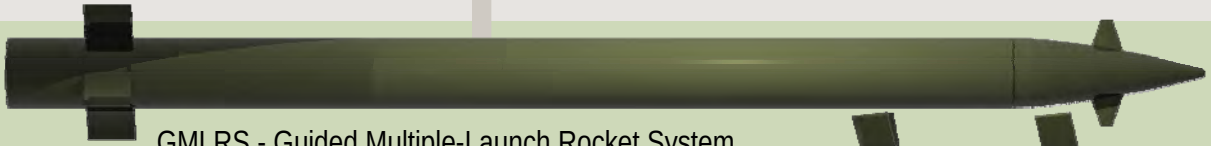
221mm Rocket-Launch Artillery Ammunition

178mm Rocket-Launch Artillery Ammunition



GMLRS - Guided Multiple-Launch Rocket System

PAM - Precision Attack Munition

Affordable Precision Concept Studies

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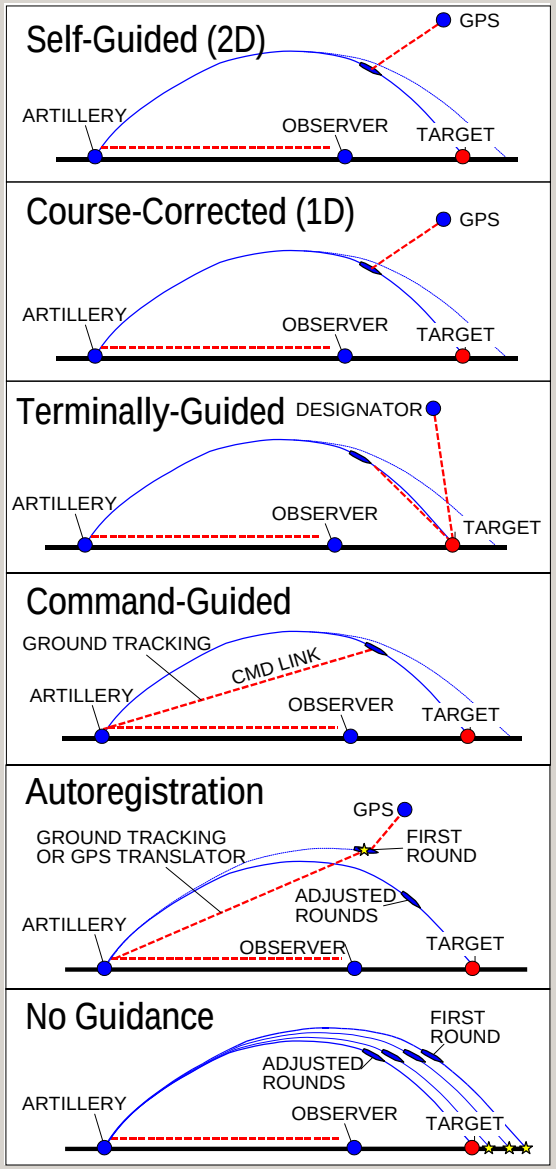

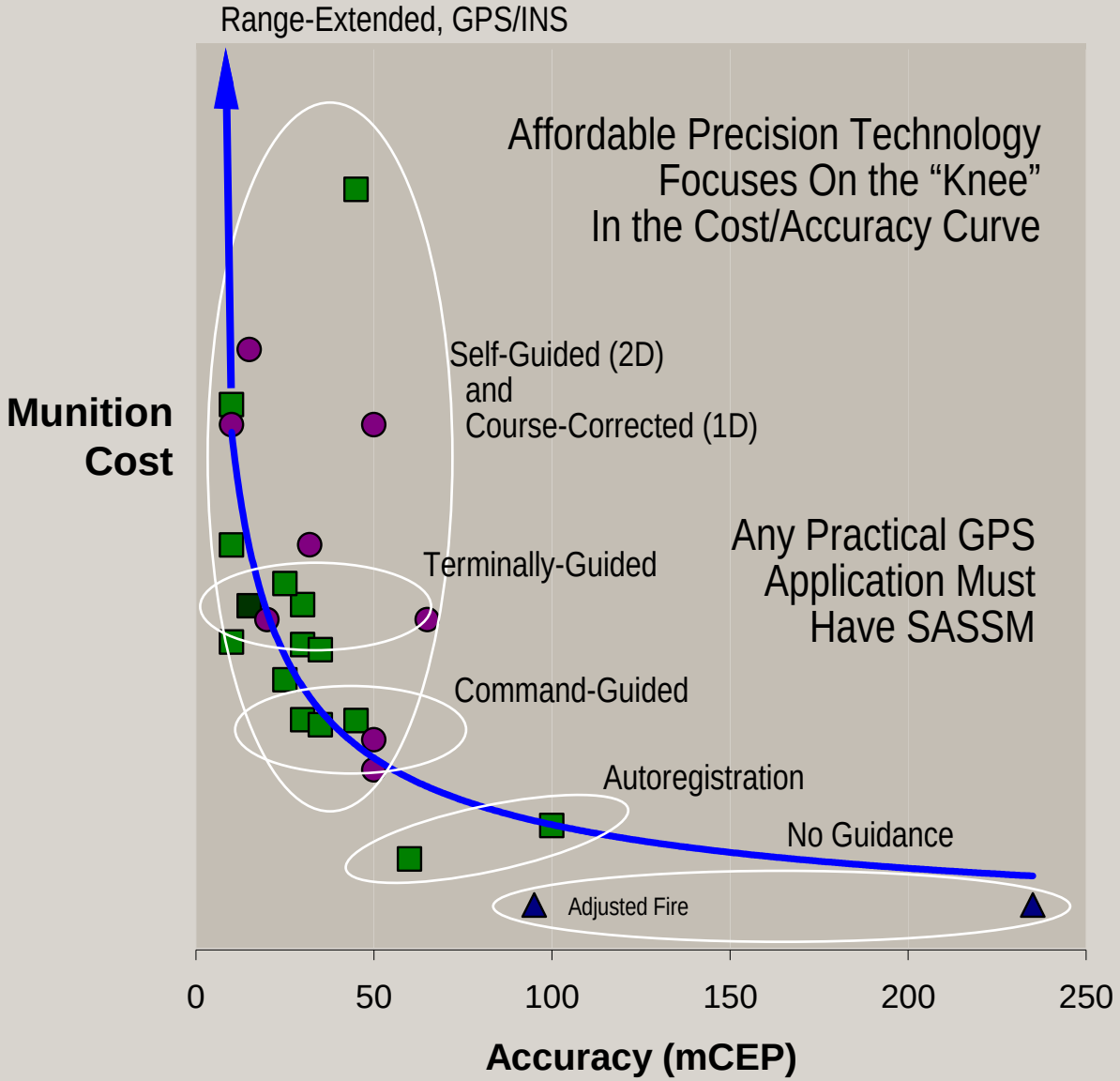

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Years of Technology Development Led to PGK

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CY93	CY94	CY95	CY96	CY97	CY98	CY99	CY00	CY01	CY02	CY03	CY04	CY05	CY06	CY07	CY08	CY09	CY10	CY11
1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4

LCCM: More Than Competent, Pearcy, 6th International Cannon Artillery Firepower Symposium, June 2000

Development of a Course Correcting Fuze (CCF) Capability, US Army Memorandum, May 2004

PGK Down-Select, May 2007

PGK Production Decision, April 2009

1-D Course Corrector Concepts

Miniaturized GPS Receivers

UK Technology Demos — Demo At YPG

Course Correcting Fuze

1-D

ARL (Hollis)

UK Team STAR

1-D+

BAE Systems CCF

2-D Course Corrector Concepts

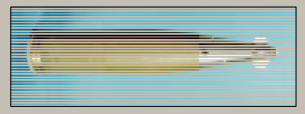
ONR Sponsored Demonstration

CM-ATD — Demo At YPG

Draper 2-D

ACT II DAAE30-95-C-005

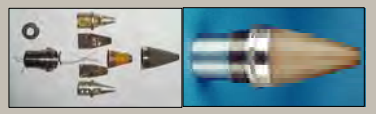
Canard Controlled 155mm — Demo At YPG



2-D

MEMS Inertial Sensors

1-D+



LCCM Contracts

Autoregistration Fuze

ATK IR&D

1D CCF

NSWC-DD

2-D ANSR

Draper ATK

ATK IR&D

2D CCF

2-D

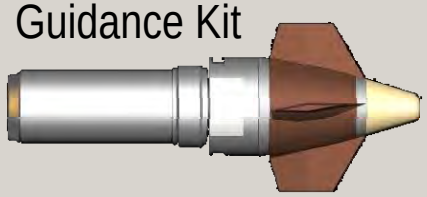
NSWC-DD

GIF

2-D

Hybrid Course Corrector Concepts

Precision Guidance Kit



A — B — MILESTONE — C

TECH DEMO — SDD-Inc1 — SDD-Inc2 — Q — P1 — SPIRAL 2

Fly-Off at YPG

US Patent

LRIP–P1 — FRP-P2 — P3

Production Ready

TD 10 months

SDD 22 months

One Decade of R&D

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Precision Guidance Kit (PGK)

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Operational Benefits

- Transforms existing artillery inventory into affordable precision weapons
- Improves combat effectiveness
- Reduces collateral damage
- Reduces logistics footprint

What is PGK?

- GPS Guidance Kit with Fuzing Functions
- Replaces the standard 155mm artillery projectile fuze
- PGK GPS guidance greatly improves the accuracy of conventional artillery in the inventory

  50m CEP vs. 175m CEP
- Maintains >90% of range capability of conventional projectile
- Requires no battery
- Has no “one-shots” or canard deployments
- Reliable - one moving “part”
- Uses COTS inertial sensors
- Full 2D Guidance to Impact

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PGK Precision Guidance Kit for 155mm Ammunition

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PGK Field Testing

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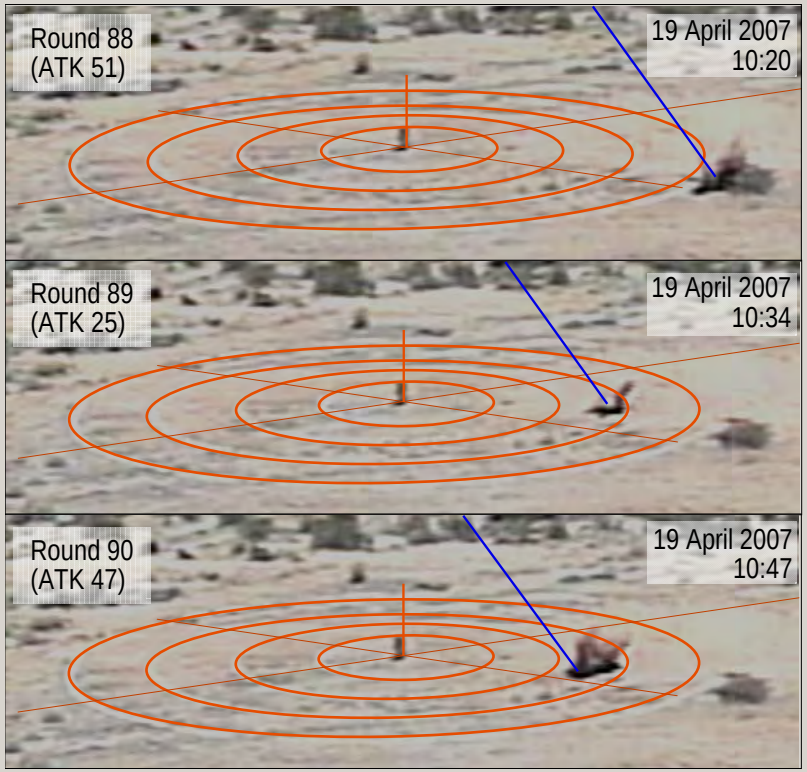
Technical Demonstration Program

Competitive Fly-Off
18 M549A1 Rounds @ 20.5 km
Demonstrated < 50m CEP
83% Reliability

2D Guidance Has Potential
To Be Very Precise (Repeatable)



Early SDD Field Test Objectives:

- Expand Aerodynamic and Guidance Characterization of PGK across family of 155mm Projectiles
- Validate Consolidation and Packaging to SDD-1 Electronics Form Factor
- Confirm System Performance of Second Source GPS Supplier

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What Level of Precision is Needed?

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Logistics Cost is Driven by Tonnage/Volume

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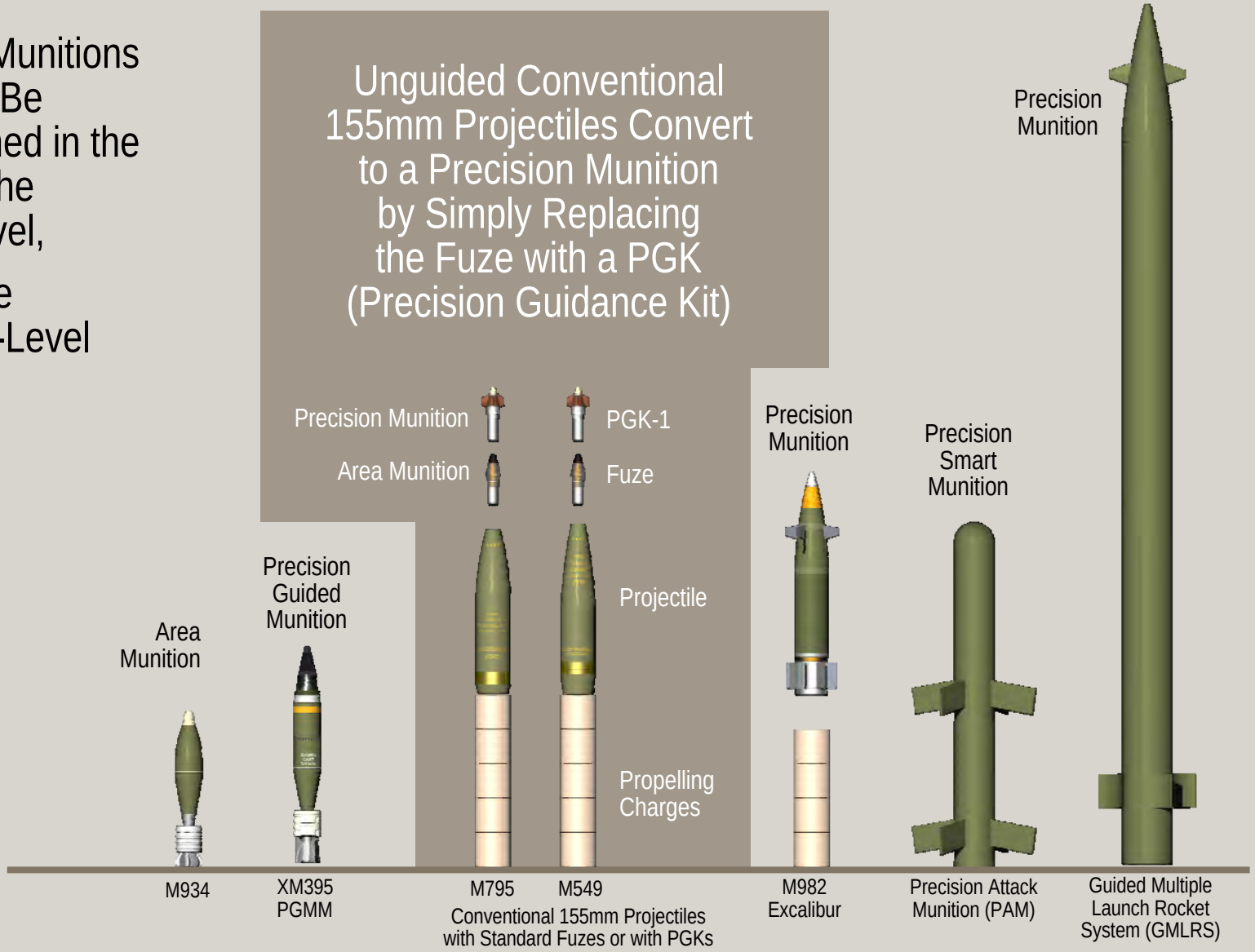
155mm Munitions Mix Can Be Established in the Field at the Fuze-Level,

Not at the Munition-Level

Unguided Conventional 155mm Projectiles Convert to a Precision Munition by Simply Replacing the Fuze with a PGK (Precision Guidance Kit)



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Non-Precision Conventional Mission

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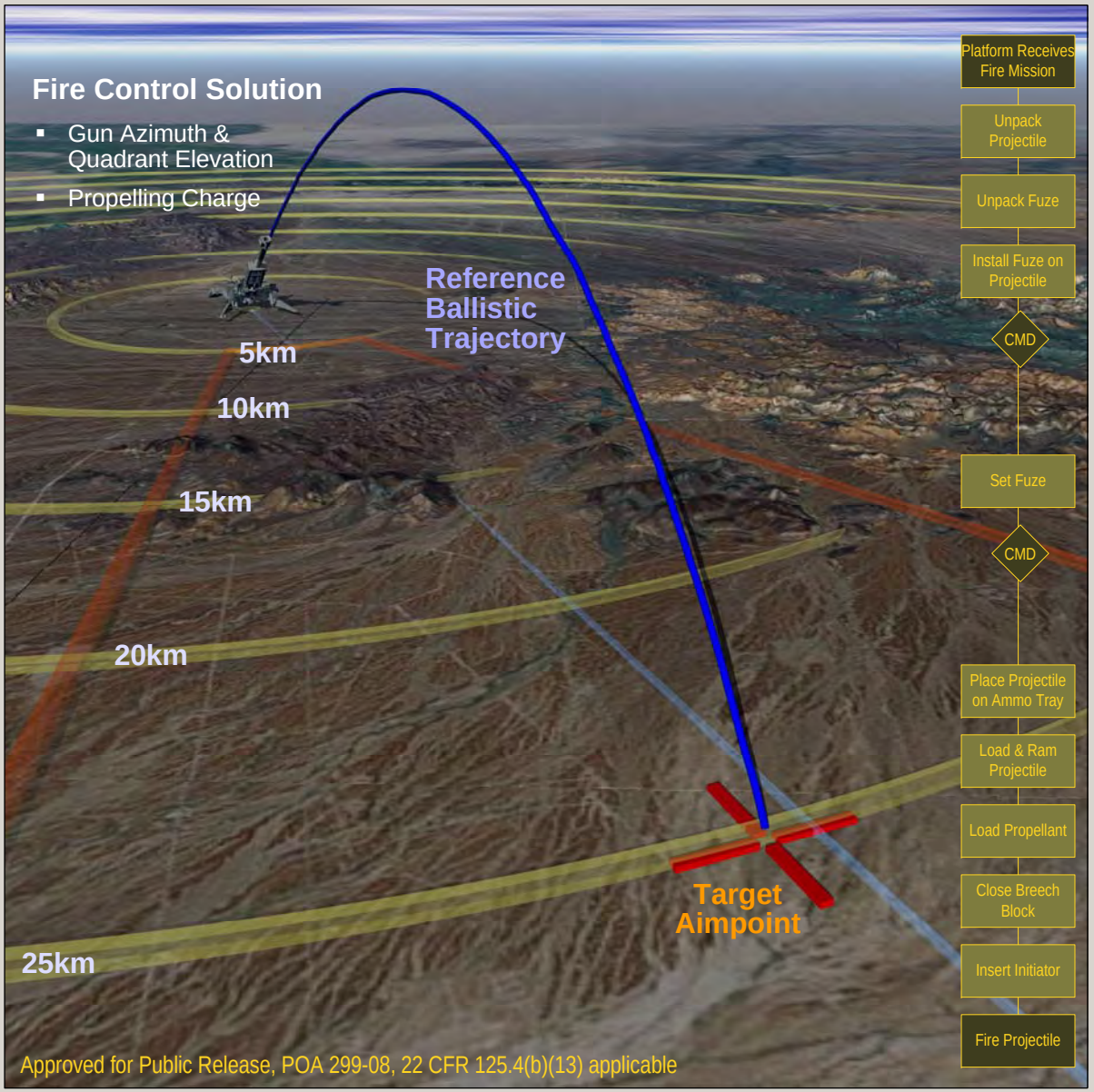

Non-Precision Conventional Mission

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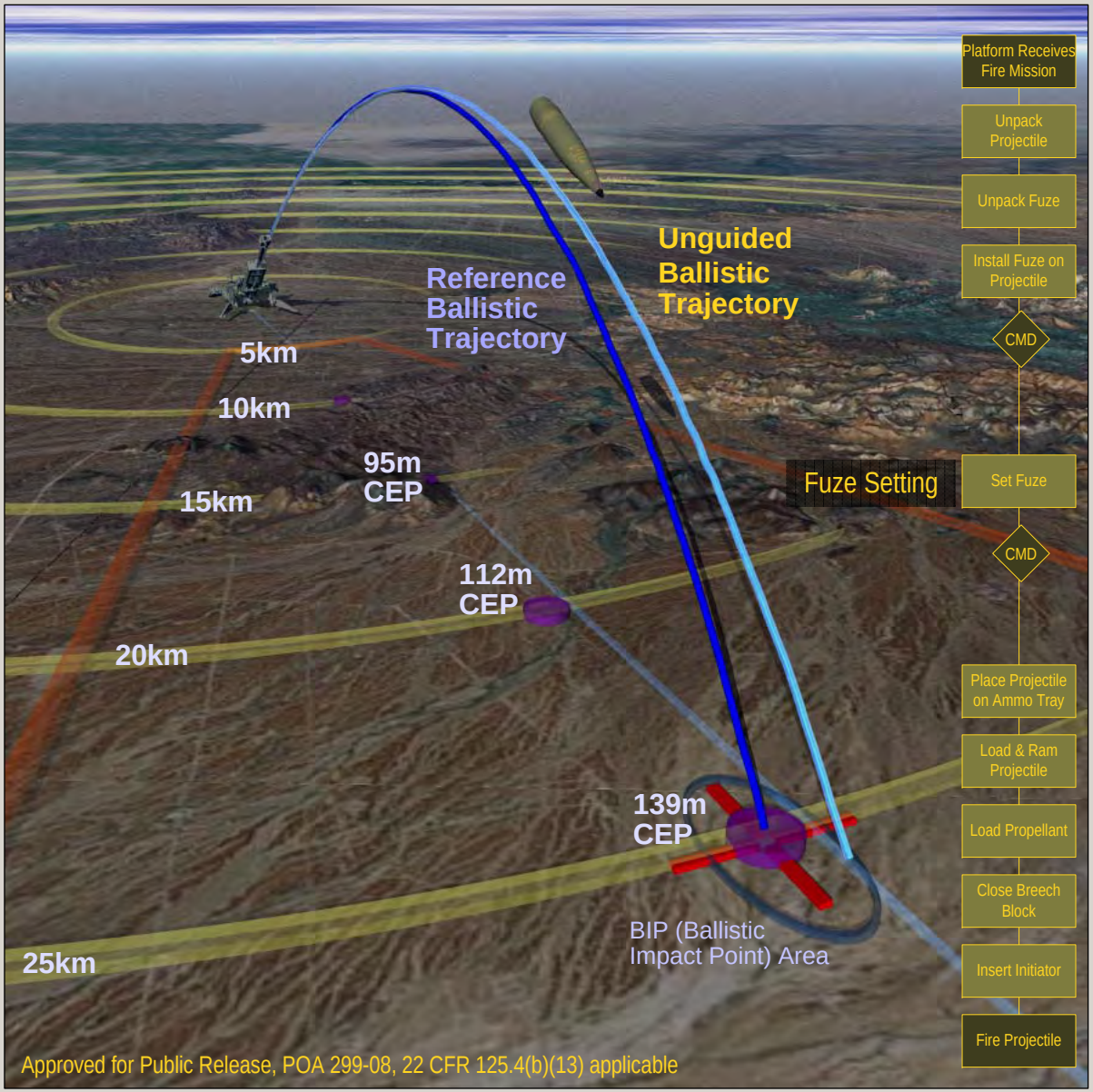

Precision PGK Mission

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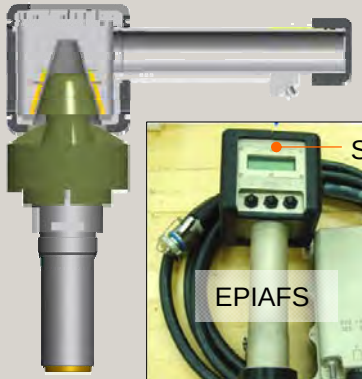
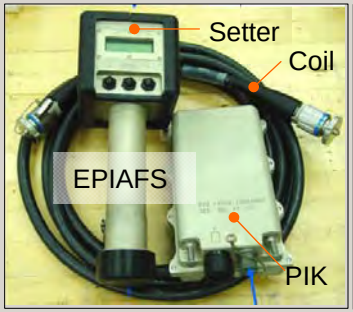
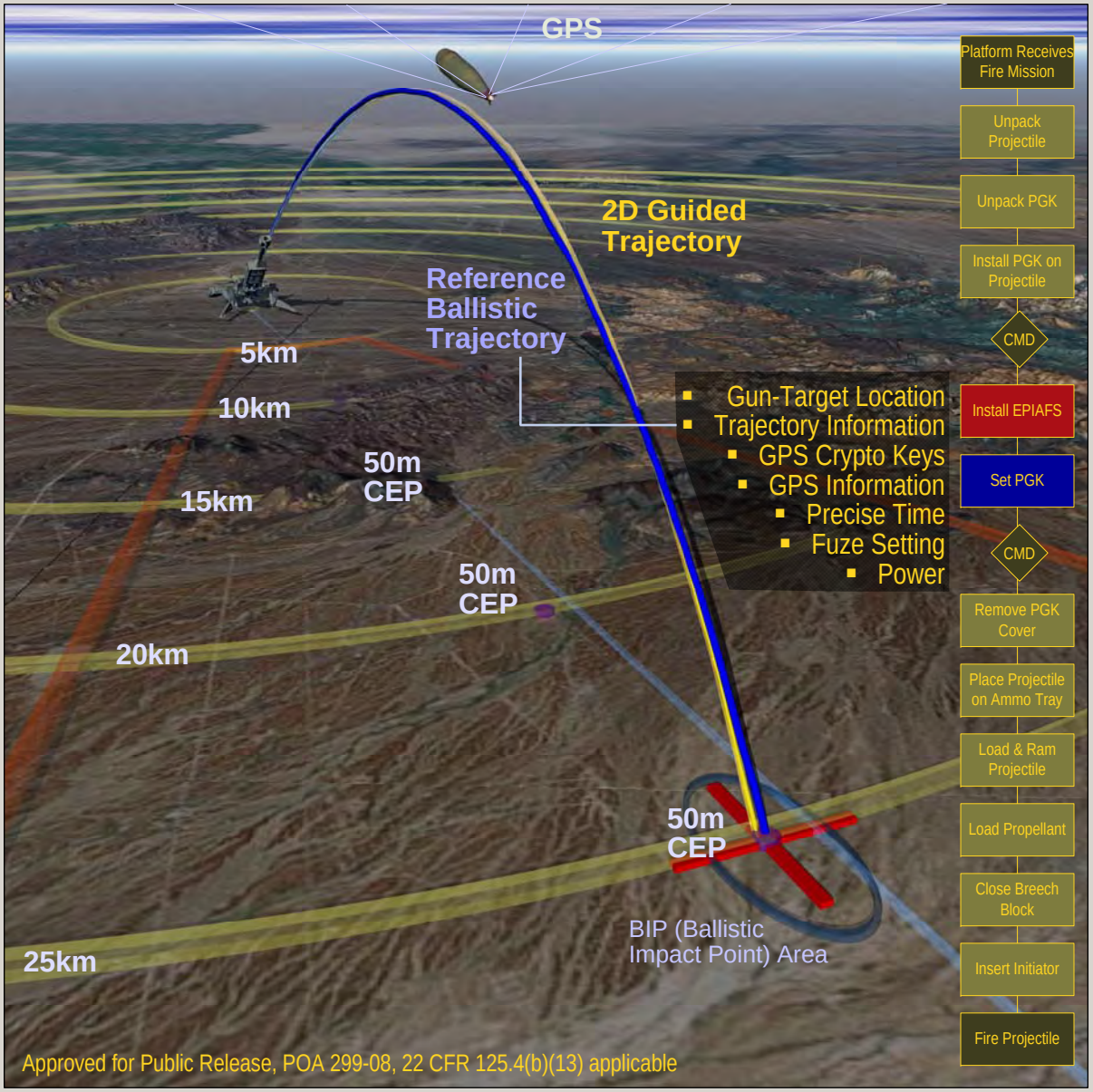
Planning the PGK Mission







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Comparative 155mm Projectile Accuracies

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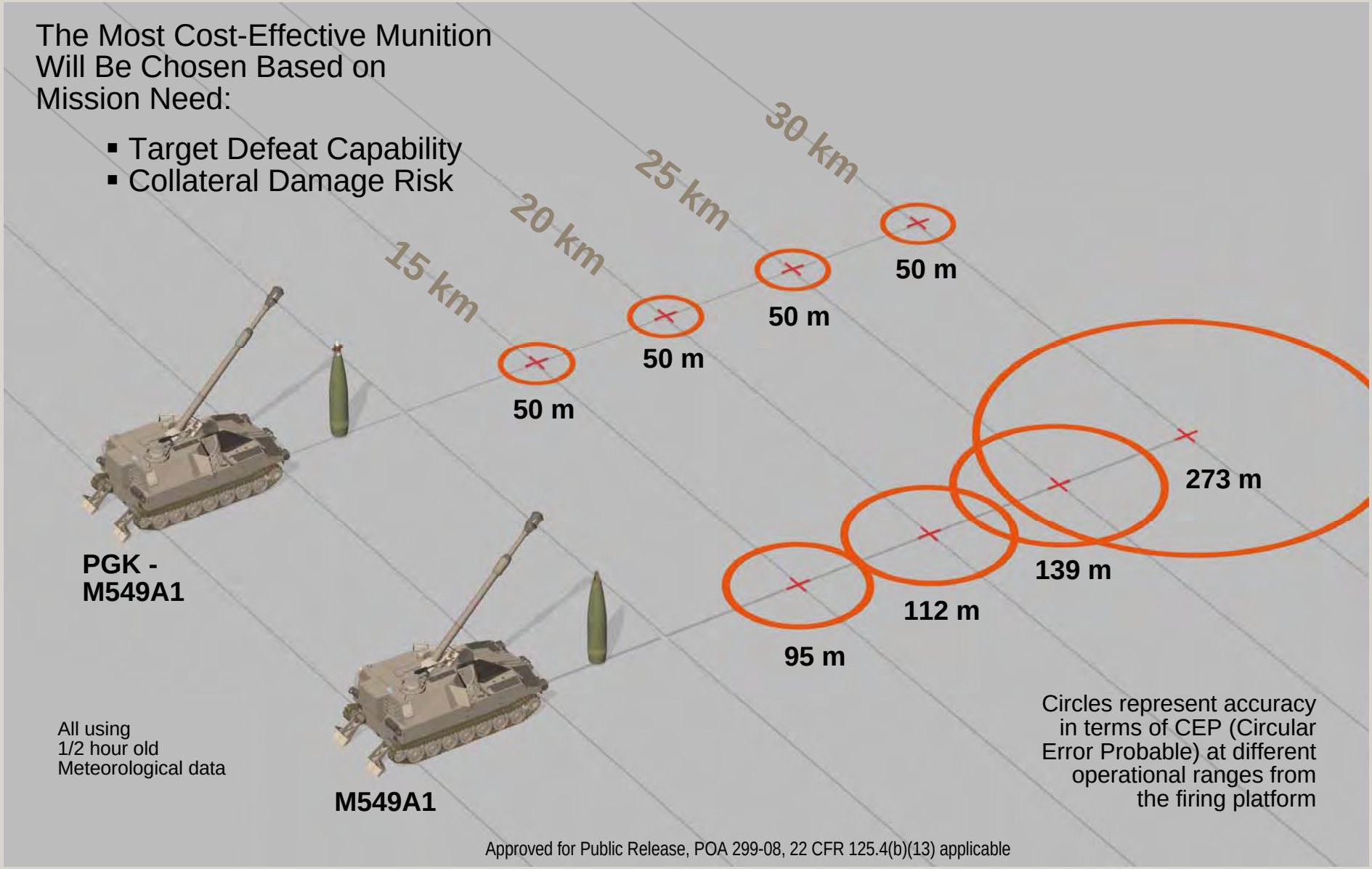
The Most Cost-Effective Munition Will Be Chosen Based on Mission Need:

- Target Defeat Capability
- Collateral Damage Risk



All using 1/2 hour old Meteorological data

Circles represent accuracy in terms of CEP (Circular Error Probable) at different operational ranges from the firing platform

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Operational Benefit

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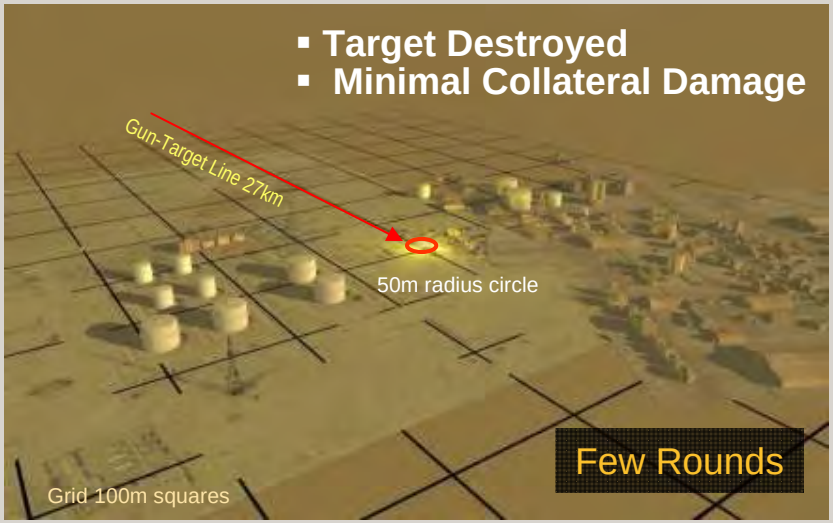
Today's Capability: 183m CEP*

PGK: ≤ 50m CEP



* M109A6 (Paladin) at 27km: 155mm (HE) M549A1

- Improves Munition Accuracy
- Greatly Reduces Possibility of Collateral Damage
- Increases Number of Kills per Basic Load of Ammunition

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PGK Missions

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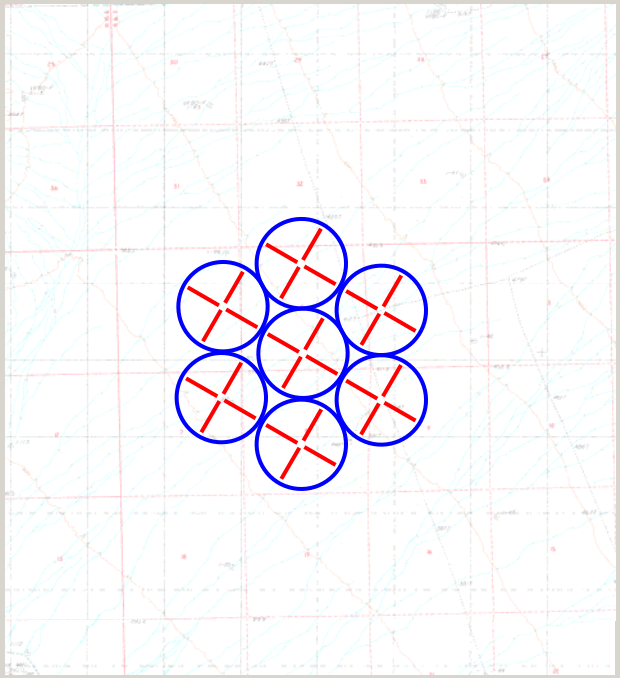

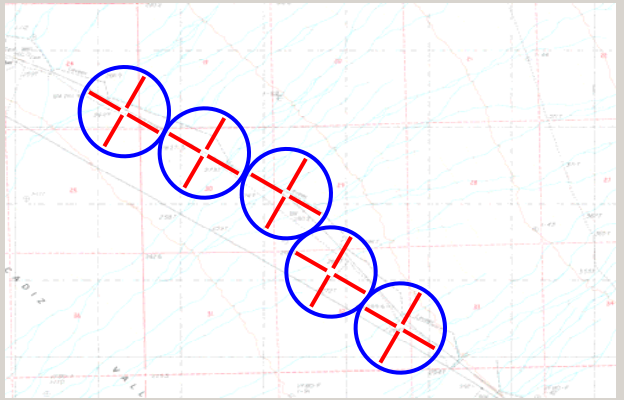

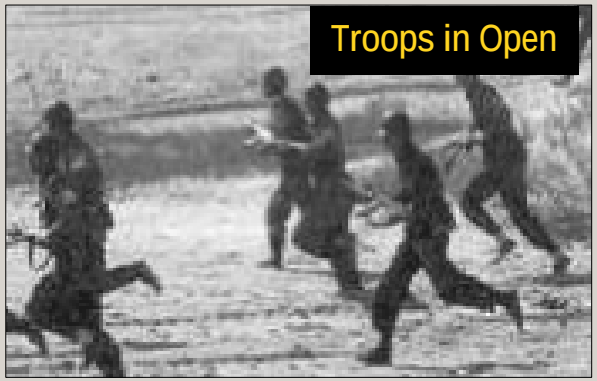

PGK performs the same missions as conventional 155mm HE munitions, but with better effectiveness consistent with a 50m CEP accuracy.

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Precision Munition Analysis

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NewVectors LLC
An Altarum Subsidiary

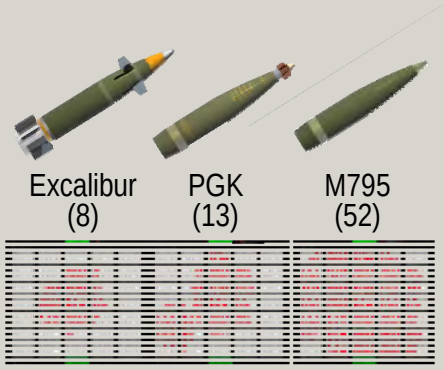
2006 Precision Munition Analysis Issues:

For the modular Brigade Combat Team:

- What are the cost and logistics impacts of using precision?
- How do these munitions affect force effectiveness?
- What is the relative collateral damage from these munitions vice "dumb" munitions?

Precision munitions: PGK, Excalibur, PGMM

Open desert scenario example



Collateral Damage example

Case 1: Conventional Munitions:

- Conventional 155mm and 105mm artillery munitions
- Conventional 120mm mortar munitions

Case 2: Precision Munitions:

- 155mm Excalibur
- 155mm PGK Munition (30m CEP capable)
- 105mm PGK Munition (30m CEP capable)
- 120mm PGMM and conventional mortar munitions

Factor	Impact to HBCT
Operational Effectiveness	▪ Increased war-fighting capability by 48% ▪ Reduced US losses by 36%
Cost Effectiveness	Increased overall cost of munitions expended by 7-18%, but this will be significantly reduced due to 2nd and 3rd order effects (logistics)
Logistics Effectiveness	▪ Reduced number of munitions by 38% ▪ Reduced tonnage of Army munitions expended by 19%

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PGK Fills the Effectiveness Gap

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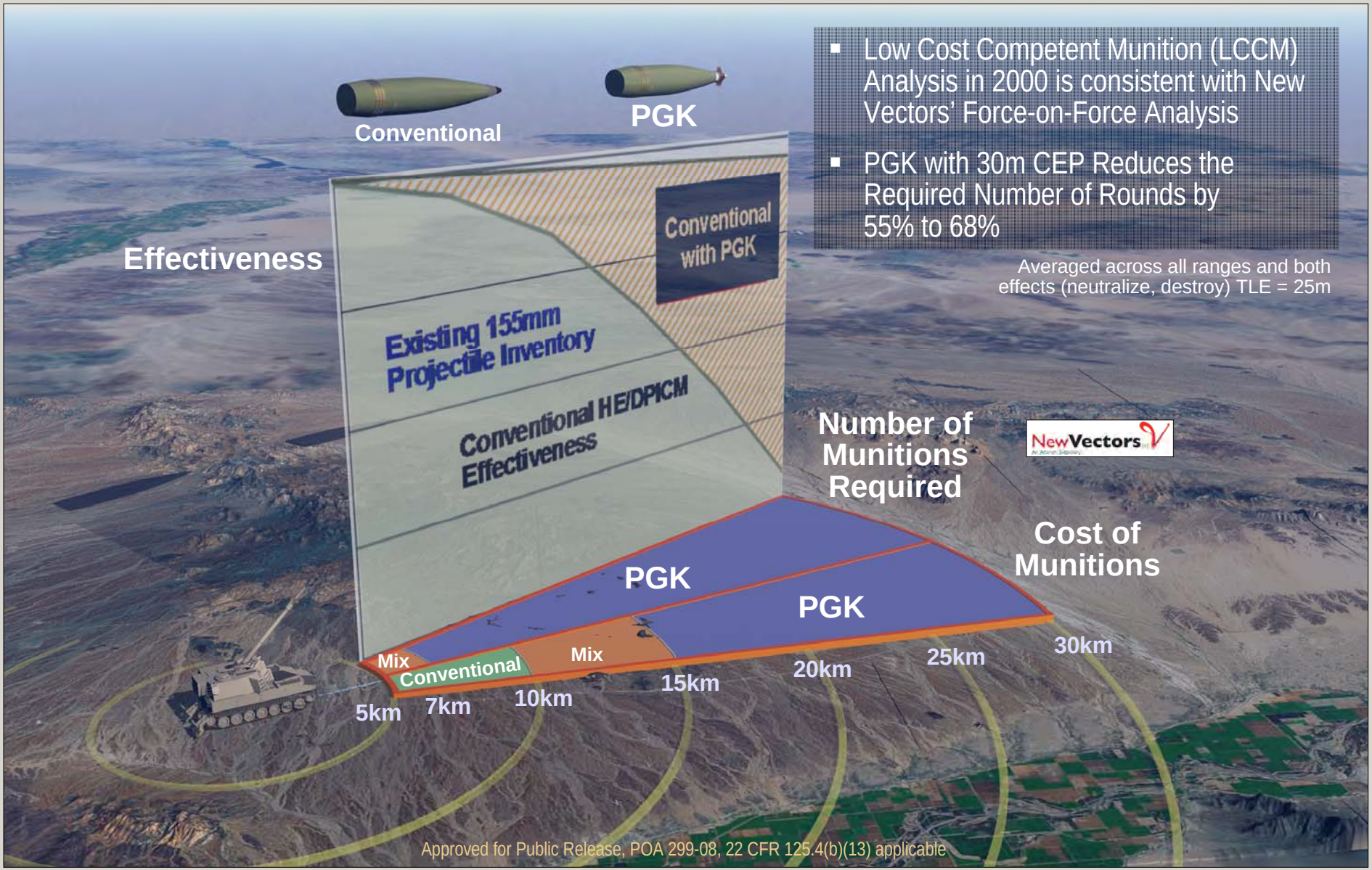

- Low Cost Competent Munition (LCCM) Analysis in 2000 is consistent with New Vectors' Force-on-Force Analysis
- PGK with 30m CEP Reduces the Required Number of Rounds by 55% to 68%

Averaged across all ranges and both effects (neutralize, destroy) TLE = 25m

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Precision Reduces the Number of Rounds

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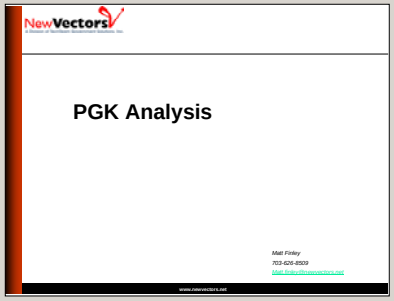
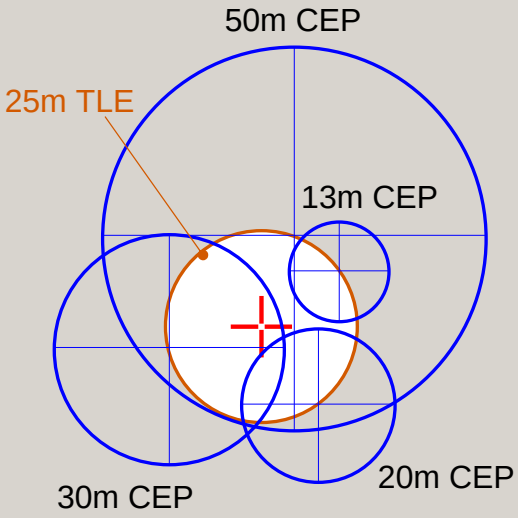
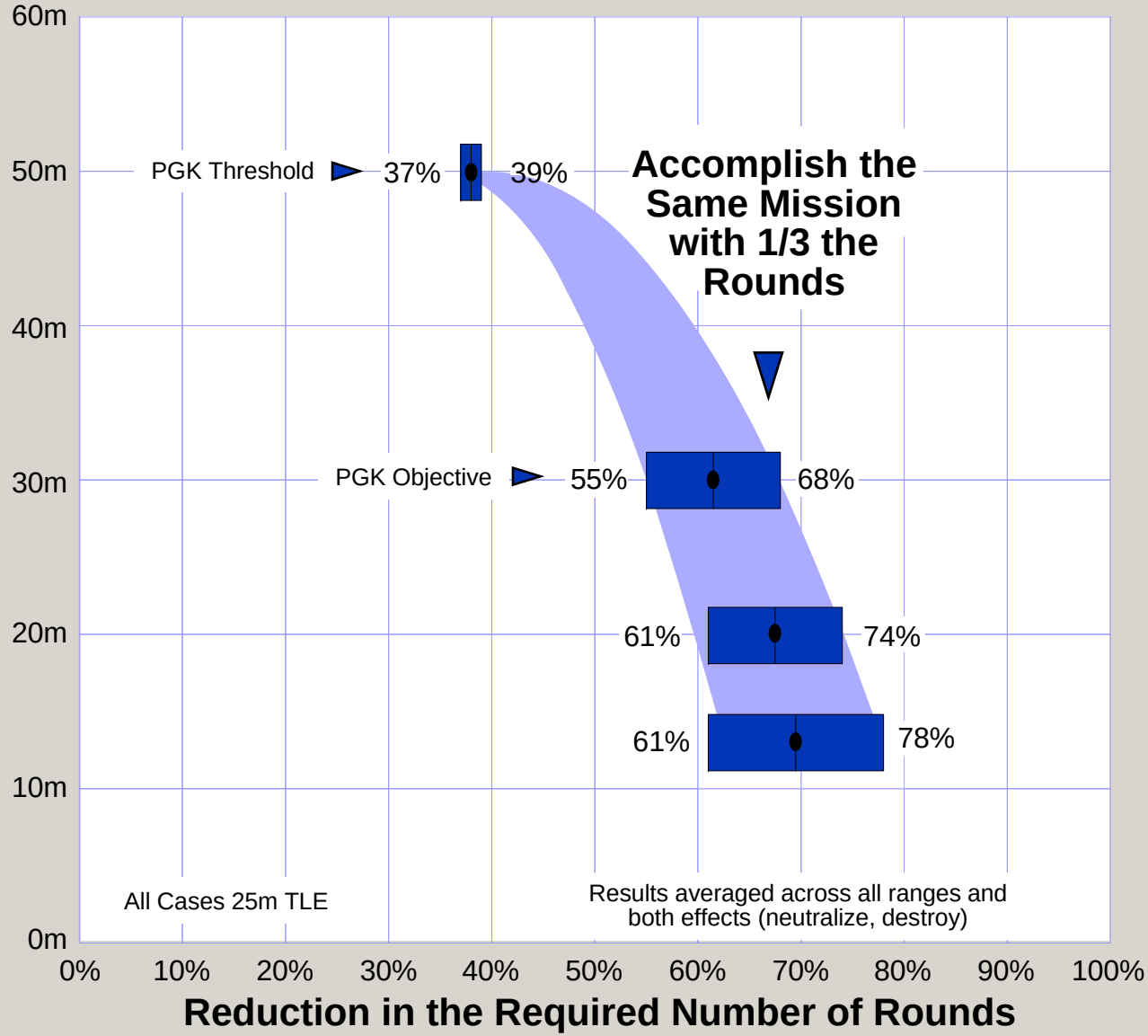


Accuracy of PGK Round (CEP)





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What Does This Mean to the Mission Cost?

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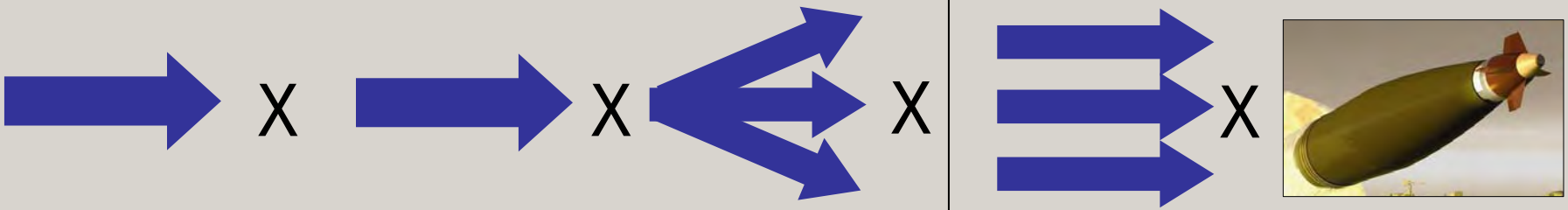
- Round Cost is Only a Small Percentage of Mission Cost
- Reduced Round Savings Has Multiplying Effect on Mission Savings

New Vectors' Study Only Considered The Round Cost



- Transit Cost
- Loiter Cost
- Supply Chain

In Theatre Depot Costs

- Sortie Costs
- Re-Supply

- Fire Mission

- Munition/Round

When the system and logistics costs are added to the cost of the rounds fired, a reduction of 55% to 68% in rounds fired makes an all-precision stockpile a realizable goal.

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Affordable PGK Fills an Effectiveness Gap

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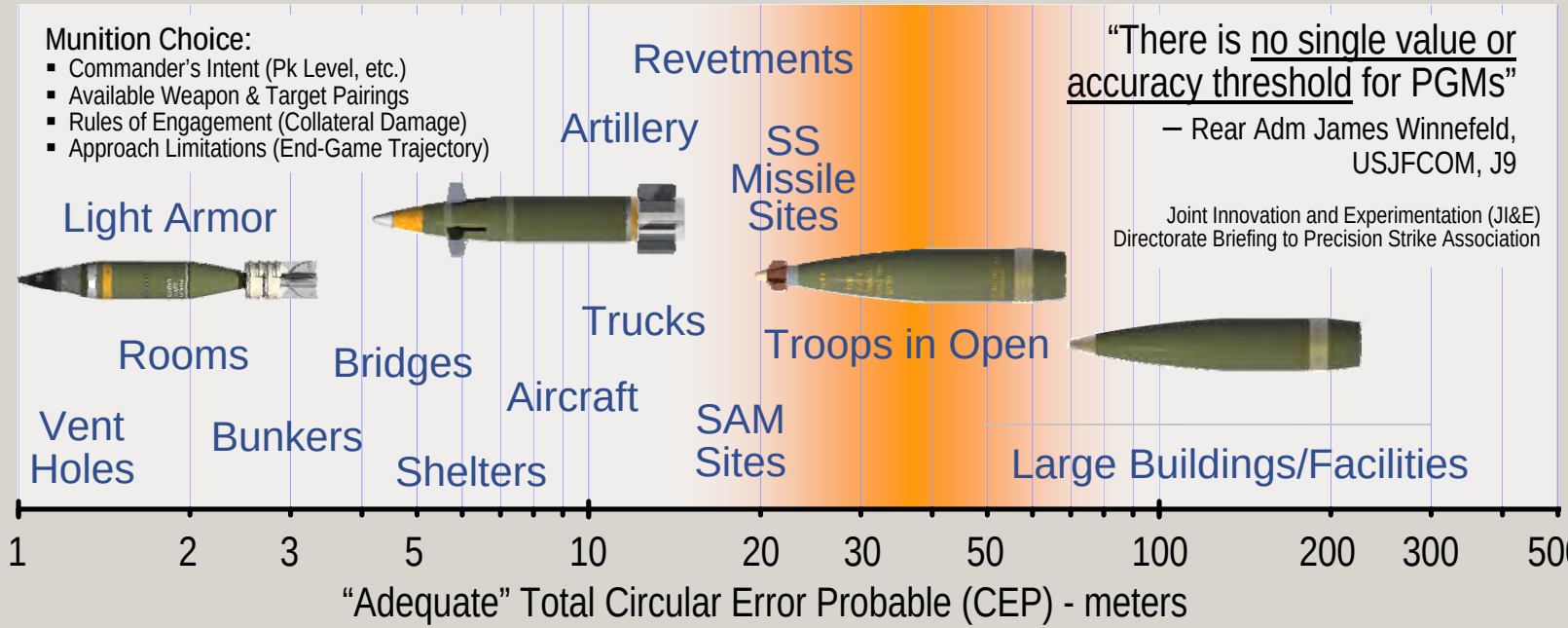

Affordable Precision Solutions Will Change the Fires Paradigm from an Inventory of

"Conventional and Precision Munitions"

to

"Precision and Very High Precision Munitions"

	Number of Missions
Precision	Conventional with Precision Guidance Kit
Very High Precision	▪ GMLRS ▪ NLOS-PAM ▪ Excalibur ▪ PGMM

Mission Munition Mix Is Integral to FCS (Future Combat System) Vision

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Precision Munition Analysis – Study Findings

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PGMM (1km – 7km)

- PGMM is the most cost and logistically effective munition
- Provides the least collateral damage

Conventional Projectiles (2km – 30 km)

- Cost effective at shorter ranges where delivery accuracy is good and collateral damage is not a concern

PGK (8km – 27 km)

- Is generally the most cost effective munition beyond 10km
- Requires only 12-51% of the number of conventional rounds
- At most ranges is cost effective and reduces logistical burden

Excalibur (8km – 40km)

- Is only tube-launched capability beyond 30km
- Is the only artillery round accurate enough to reduce collateral effects
- Is most logistically effective over 155mm operational range with a significant improvement in effectiveness

Personnel protected by point target structures

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“Affordable Precision” Possible Today

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Technology

People

U.S. Army photo

Soldier of the 2-4 Infantry, 4th Brigade Combat Team, 10th Infantry Division operates AFATDS

US Army Photo
by Spc. Katherine M. Roth

An artilleryman plans to launch a 155mm round from a howitzer of the 1st Armored Division’s 4th Battalion, 27th Field Artillery Regiment.

Strengthened Capability for the Warfighter

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Firing US 120mm Tank Ammunition in the Leopard 2 Main Battle Tank

NDIA Guns and Missiles Conference
Harlan Huls
22 April 2008

Agenda

1. Overview of tanks and ammunition
   - Interoperability of the weapon and ammunition
2. Objectives of the test conducted in Denmark
3. Results of the firings in Leopard 2 with L44 and L55 weapon system
4. Conclusions

Description of US Tank Ammunition

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US 120mm Tank Ammunition Types

M1028	KEWA2™	M829A3	M830A1	M1002	M831A1	M830	M908	M865
Canister	**APFSDS-T**	**APFSDS-T**	**HEAT-MP-T**	**TPMP-T**	**TP-T**	**HEAT-MP-T**	**HE-OR-T**	**TPCSDS-T**

Several US ammunition types with interoperability maintained through International JCB by controlling interface features (ICD)

Abrams and Leopard 2 MBT With 120mm Smoothbore Cannon

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Abrams Tanks

M1A1 Abrams

(M256 ~ L44 Weapon)

M1A2 Abrams

(M256 ~ L44 Weapon)

Leopard 2 Tanks

Leo2A6

L55 Weapon

(Dutch)

Leo2A5

L44 Weapon

(Danish)

Leo2A4

L44 Weapon

Several MBT configurations with 120mm weapon. Interoperability is maintained through international JCB by controlling interface features (ICD)

120mm Smoothbore Compatible Platforms

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Platform Picture	Type and Country	Caliber	Basic Load	Tactical Rounds	Training Rounds	Comments
	M1A1 Abrams USA, Australia, Kuwait, Egypt **M1A2 Abrams** USA, Saudi Arabia	44	40 rounds	M829A3 M829A2 M829A1 M830 M830A1 M1028 KEW, KEWA1, KEWA2	M865 M831A1 M1002	Training and Tactical designed for 120mm Compatible Weapon systems
	Leopard 2 A4 or A5 Germany, Austria, Chile, Denmark, Norway, Finland, Switzerland, Sweden, Greece	44	42 rounds	DM33 DM53 DM63 DM12A1 DM11 DM31	DM48 DM18	Training and Tactical designed for 120mm Compatible Weapon systems
	Leopard 2 A6 Germany, Canada, Netherlands, Spain, Greece	55	42 rounds	DM33 DM53 DM63 DM12A2	DM38/A1-5 DM48 DM18 M865 M865C1	Training and Tactical designed for 120mm Compatible Weapon systems

Interoperability

1. Ammunition meets the requirements of NATO STANAG 4385
   - Designed, tested and manufactured to this standard from beginning.
   - Interoperability is maintained by the Interface Control Document (ICD)
   - ICD is maintained by International Joint Configuration Board

2. Ammunition interoperability is demonstrated when fired from the compatible platform.

Where US Tank Ammunition has been fired

	L44 (M256)	L55	Countries that have fired the ammunition
M830 HEAT-MP-T	✓		USA, Egypt, Kuwait, Saudi Arabia
M830A1 HEAT-MP-T	✓	✓	USA, Australia, Denmark, The Netherlands
M831A1 TP-T	✓		USA, Australia, Austria, Denmark, Egypt, Finland, Kuwait, Saudi Arabia
M865 TPCSDS-T	✓	✓	USA, Australia, Austria, Denmark, Egypt, Finland, Kuwait, Norway, The Netherlands, Saudi Arabia
M908 HE-OR-T	✓		USA
M1002 TPMP-T	✓	✓	USA, Denmark, The Netherlands
M1028 Canister	✓	✓	USA, Australia, Denmark, The Netherlands
KEWA1 APFSDS-T	✓		USA, Egypt, Kuwait, Saudi Arabia
KEWA2 APFSDS-T	✓	✓	USA, Australia, Egypt, Kuwait, Denmark, The Netherlands

Purpose for Test Firing US Ammunition in Leopard 2 Tanks

Purpose of test firing

1. Support NATO Allies for deployment in Afghanistan
2. Demonstrate the interoperability of US ammunition in the Leopard 2 tank with L44 and L55 weapon system
   - M865 and M831A1 training ammunition is already used by countries with Leopard 2 tanks
3. Check ammunition performance across temperature and distance using the existing Leopard 2 firing control
4. Demonstrate functional performance against targets when fired from the L44 and L55 weapon system

Demonstrate the interoperability in the Leopard 2 Tanks

How We Arranged the Demonstration Test

- The Danish Army hosted the event in Oksboel Training Center
  - Provided the test range, targets, Leopard 2/A5 MBT, test crew and instrumentation, facilities and transportation on site, and focal point for logistics.
- The Dutch Army provided the Leopard 2/A6 MBT, test crew and instrumentation, and assisted in coordination and logistics
- The ammunition producers, ATK and GD-OTS, provided the ammunition and assisted in logistics and support.
- US Army provided on site support at the test

The Demonstration Test took several months of planning. As cooperation and enthusiasm grew we decided to invite other 120 user nations to witness the test.
12 Countries were able to attend the test.

Demonstration Test Firing in Oksboel, Denmark

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Test fired 4 types of US ammunition across temperatures in the
- Danish Leopard 2/A5 with L44 weapon system
- Dutch Leopard 2/A6 with L55 weapon system (longer gun)

M1002 TPMP-T

KEWA2™ APFSDS-T

M830A1 HEAT-MP-T

M1028 Canister

M1002 MPTP-T Training Round NSN 1315-01-509-3555

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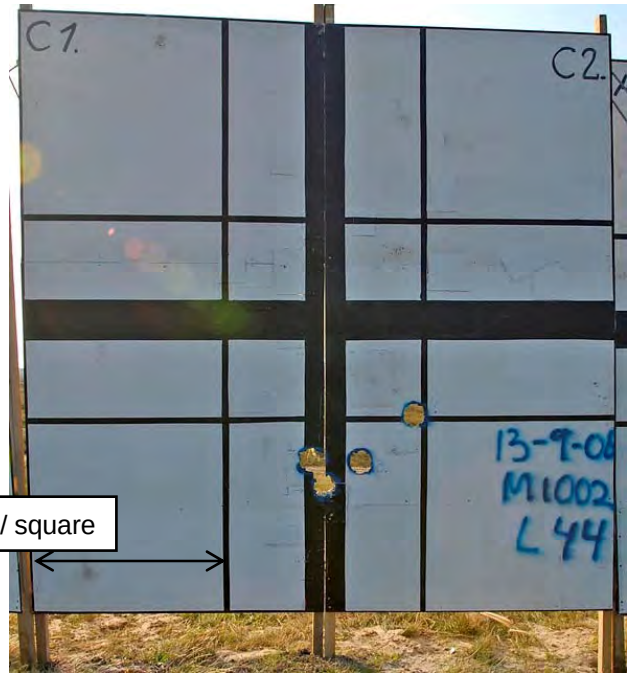
Test Fired 20 rounds to verify fire control across temperatures:

- **6 from each tank at temperature -32C, +21C, +50C tracking projectile to tank fire control**
- **4 from each tank using the existing Leopard 2 tank Ballistic setting, A2 of fire control system, at +21C for zeroing on a target at 1,000m measured for precision**
- **Results (H X V mils) L44 = 0.14 X 0.22 , L55 = 0.20 x 0.03**

Results showed ammunition works well in Leopard 2 Tank System



L44 Gun

L55 Gun

2 rounds went through the same hole

GENERAL DYNAMICS
Ordnance and Tactical Systems

M1002 Training Round Velocity Data

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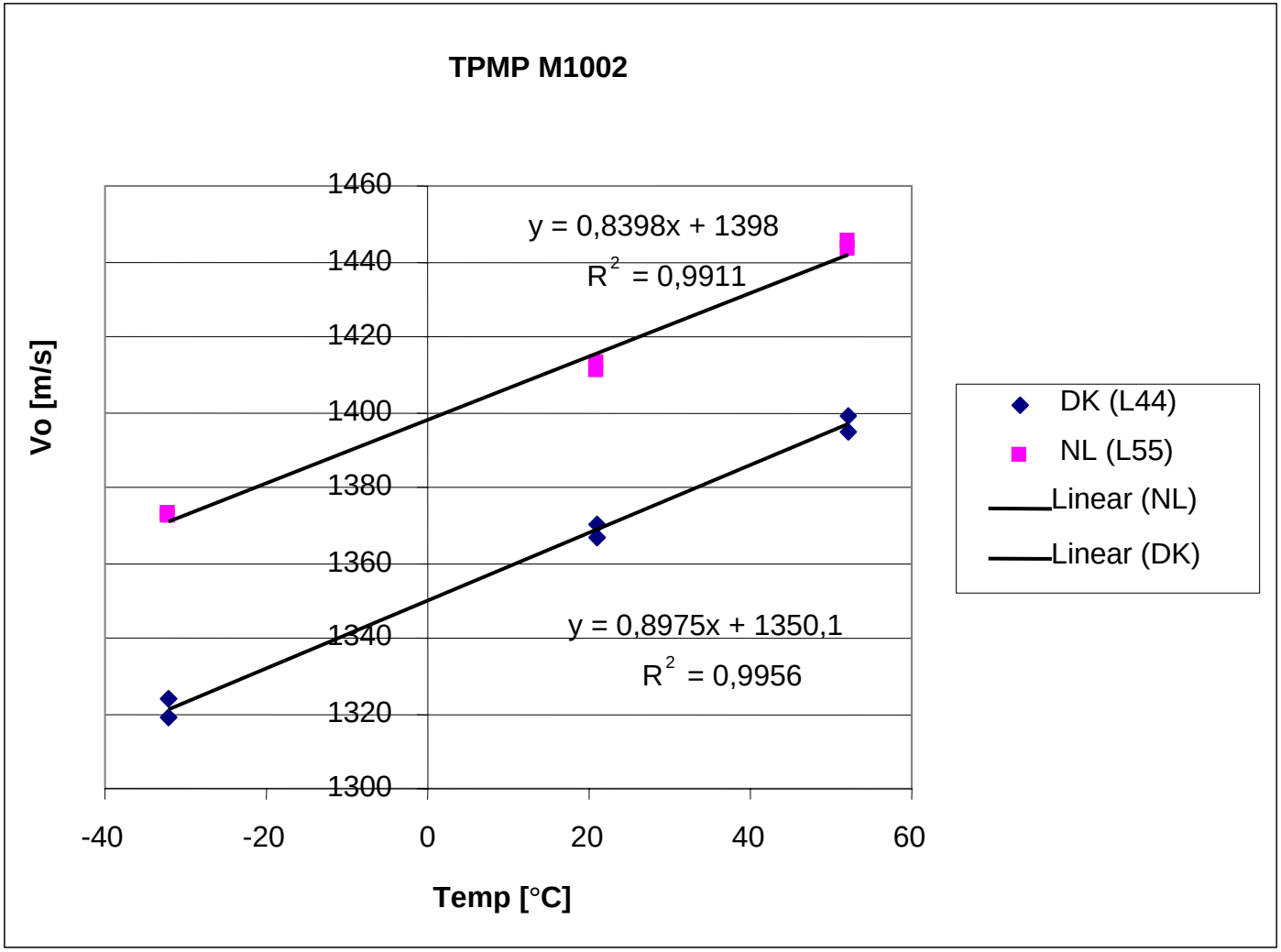
Velocity versus temperature in L44 and L55 Weapon.



KEWA2™ APFSDS-T NSN 1395-01-524-9642

ATK

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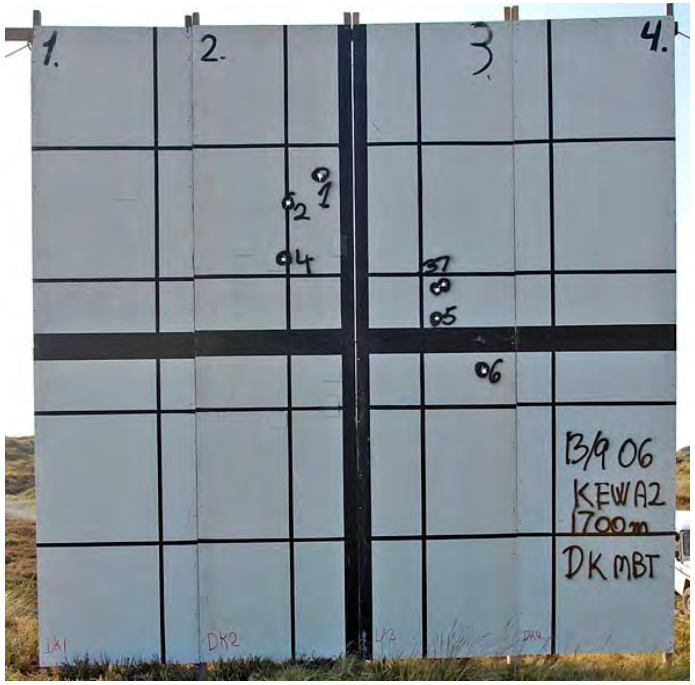
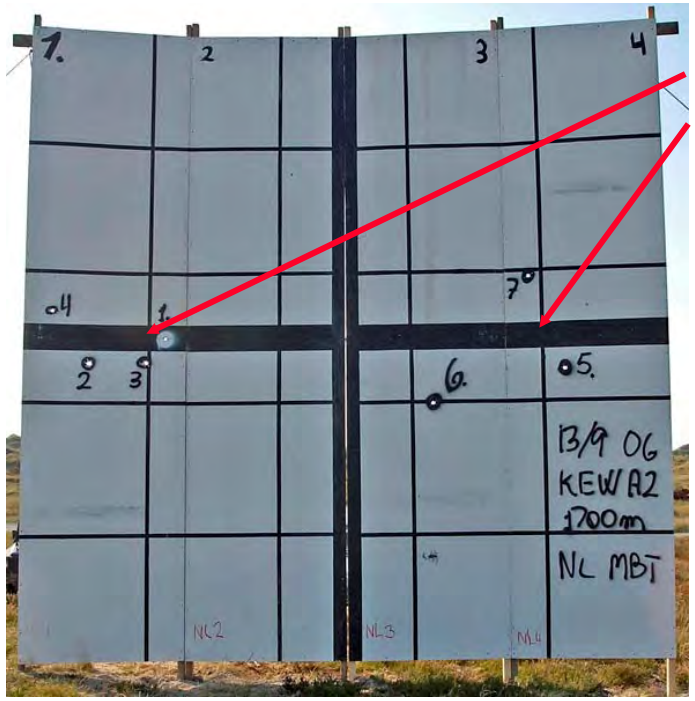
- **14 rounds fired across temperatures**
- **7 rounds in each tank across temperatures at 1700 meters**
  - 2 at -32C, 3 at +21C, 2 at +50C



L44 Gun



L55 Gun

Changed aim point after round #4

Used existing Leopard 2 tank Ballistic setting A2 of fire control system

KEWA2™ Velocity Data

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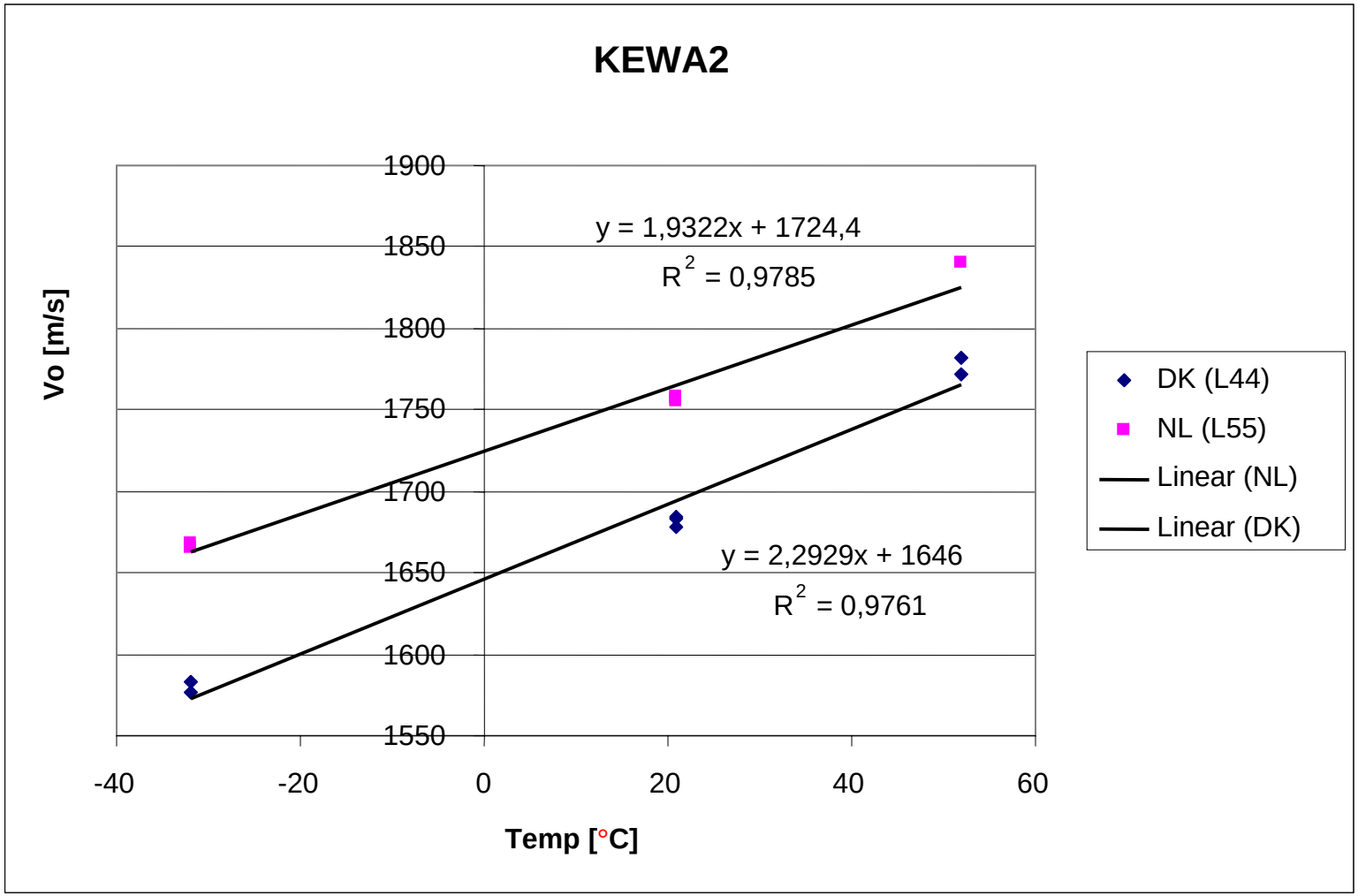
Velocity versus temperature in L44 and L55 Weapon.



KEWA2™ Fire for Effect on Target

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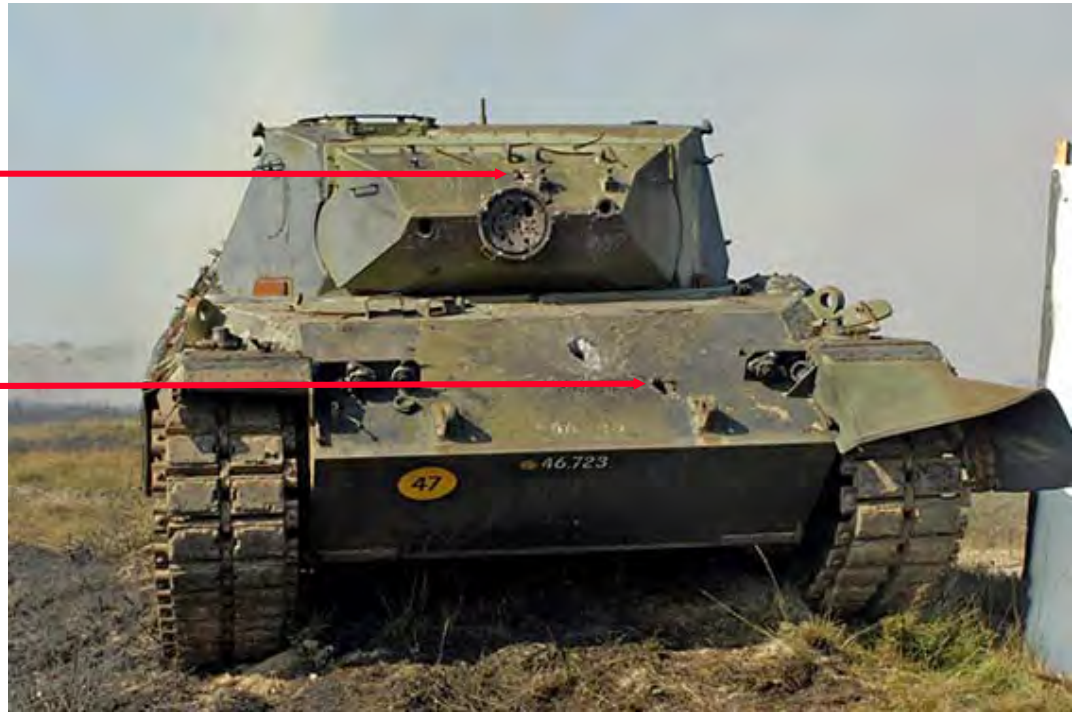
- 2 rounds fired from Danish Leopard 2/A5 Tank at +21C for effect on target
- Target is Leopard 1A5 Main Battle Tank at ~1,000 meters

Accurate and effective

1st shot through turret

2nd shot through front armor



KEWA2™ Effect on Target

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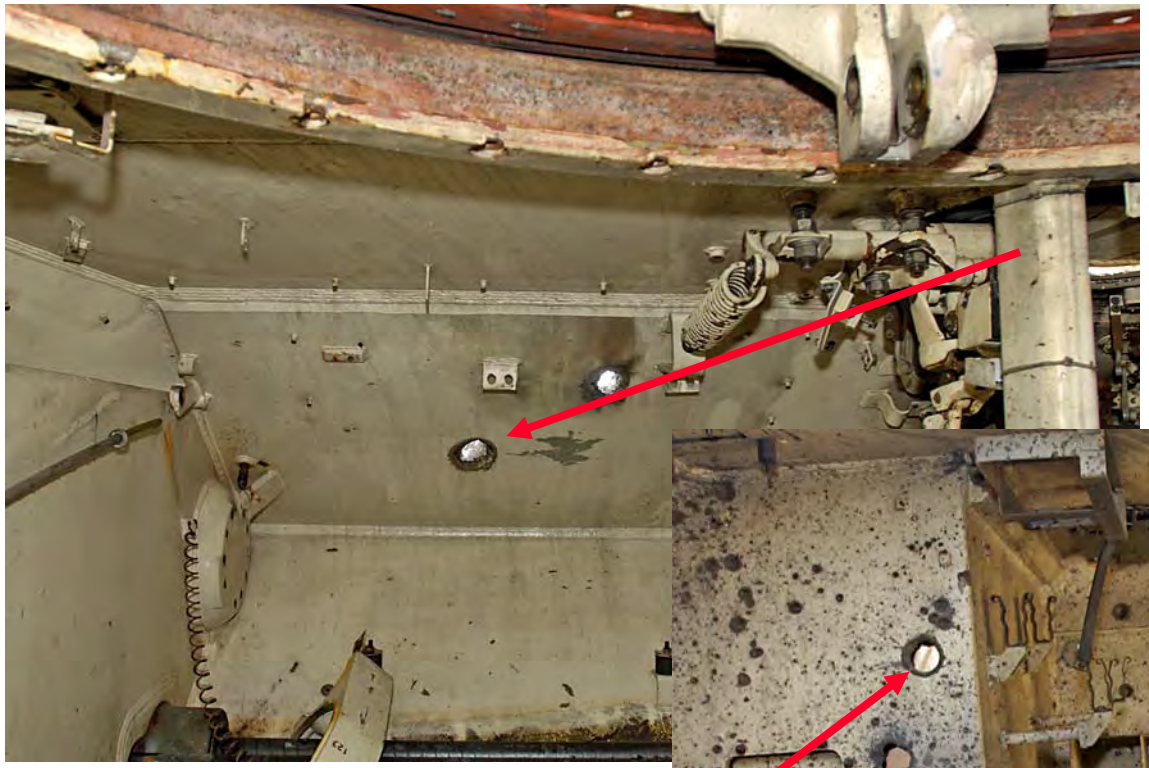

Front of vehicle
Entrance holes

Rear of vehicle
Exit holes

GENERAL DYNAMICS
Ordnance and Tactical Systems

KEWA2™ Firing on Tank Target, Gunner Sight

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M830A1 HEAT-MP-T NSN 1315-01-333-0534

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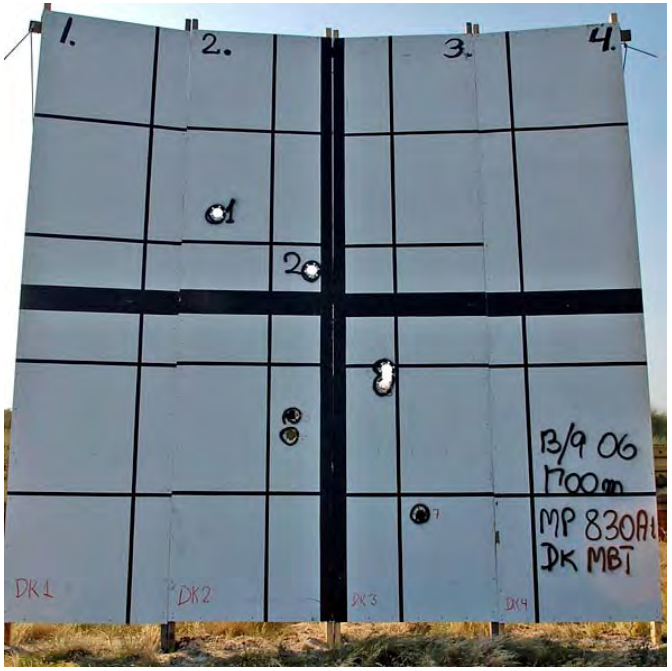
- Fired to verify fire solution across temperatures
- 7 rounds from each tank across temperatures at 1700 meters
  - 2 at -32C, 3 at +21C, 2 at +50C



L44 Gun

L55 Gun

M830A1 MPAT

Use existing Leopard 2 tank Ballistic setting A2 of fire control system

M830A1 Velocity Data

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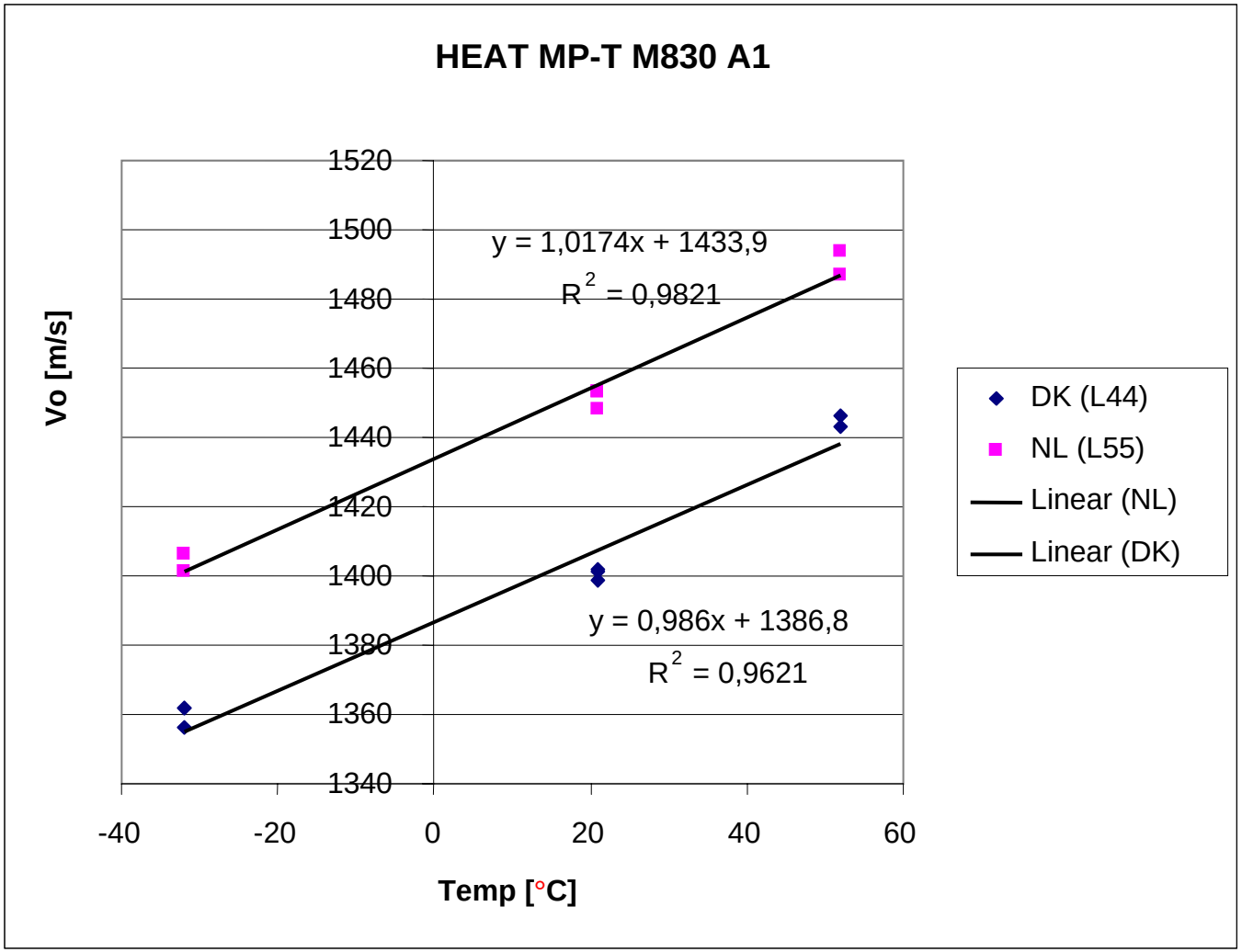
Velocity versus temperature in L44 and L55 Weapon.



M830A1 Multi-Purpose High Explosive Air Burst

ATK

An advanced weapon and space systems company

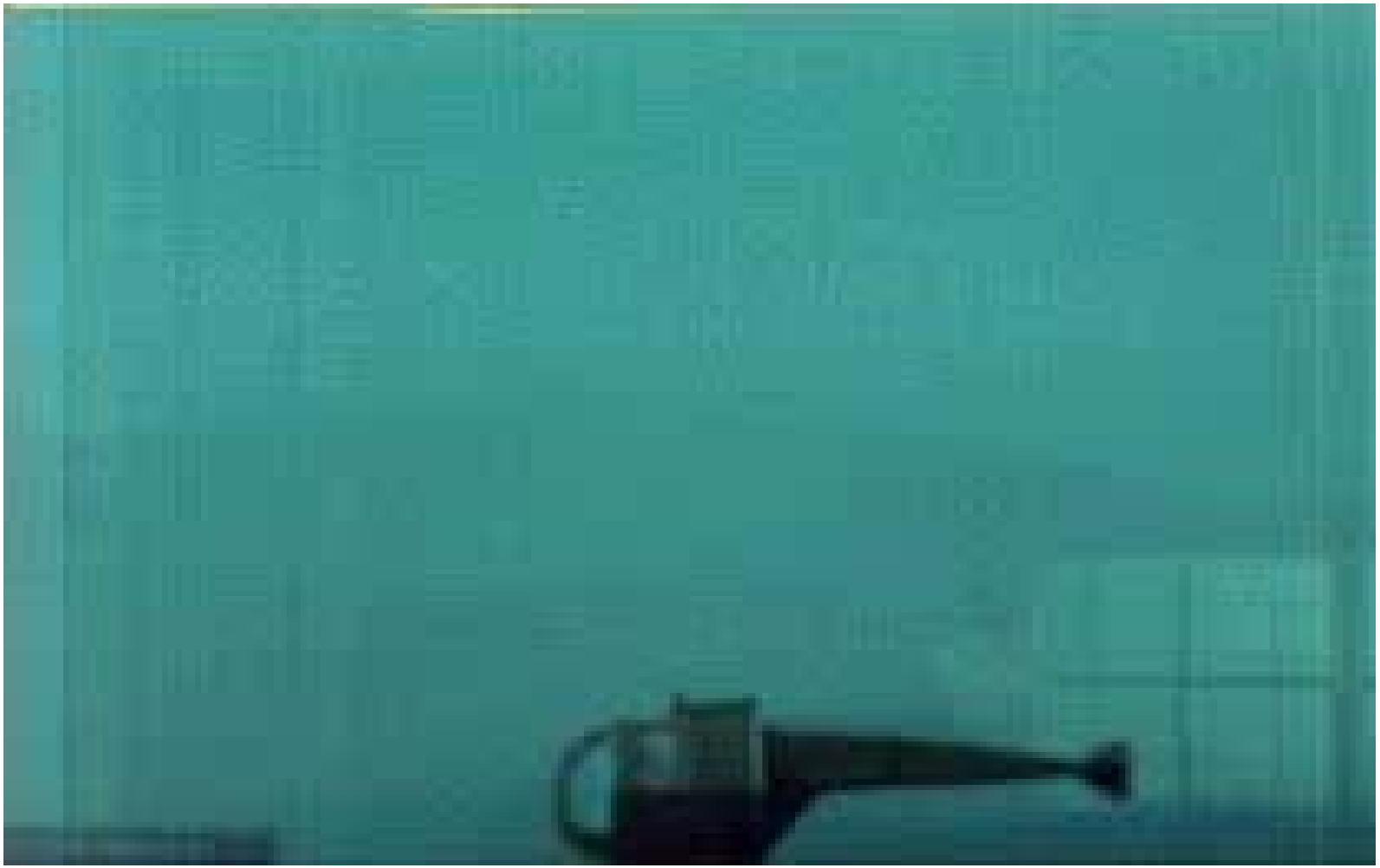
- Fired for airburst effect on target
  - Target is Simulated Helicopter at ~1,000 meters

Before

After

GENERAL DYNAMICS
Ordnance and Tactical Systems

M830A1 Fired on Simulated Air Target



M830A1 Multi-Purpose Ground Mode

- Fired for effect on ground target
  - Target is Main Battle Tank at ~1,000 meters

Impact point on tank

M1028 Canister NSN 1315-01-516-5248

ATK

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- Test Fired to establish aim point and check firing across temperatures
- 3 from Danish Leopard 2/A5 Tank
- 1 from Dutch Leopard 2/A6 Tank

Combined fire for effect and analysis on targets

- 1st Target is razor wire entanglement
- 2nd Target is wood plates to demonstrate dispersion of tungsten balls
- 3rd Target is a civilian vehicle at ~100 meters

M1028 Canister Dispersion of Balls on Plywood

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Direction of fire

M1028 Canister Fired on Vehicle

M1028 Canister on Simulated Suicide Vehicle

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Results Conclusions

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- **Ammunition is interoperable and safe to fire in Leopard 2 Tanks (L44 / L55)**
- **Demonstration showed interoperable use of these products.**
- **Demonstration in cooperation and partnering to meet common objectives**

Final Comments

- Thanks to Danish, Dutch, and US Army for supporting this Test
- Members from 12 countries attended
- Demonstration in cooperation and partnering to meet common objectives

ALWAYS ON target

105 mm HEP-IM

Reduced Vulnerability / Enhanced Lethality Direct Fire Large Caliber HE Ammunition for MGS

Presented by Roger Gelinas

23 April 2008

GENERAL DYNAMICS
Ordnance and Tactical Systems–Canada

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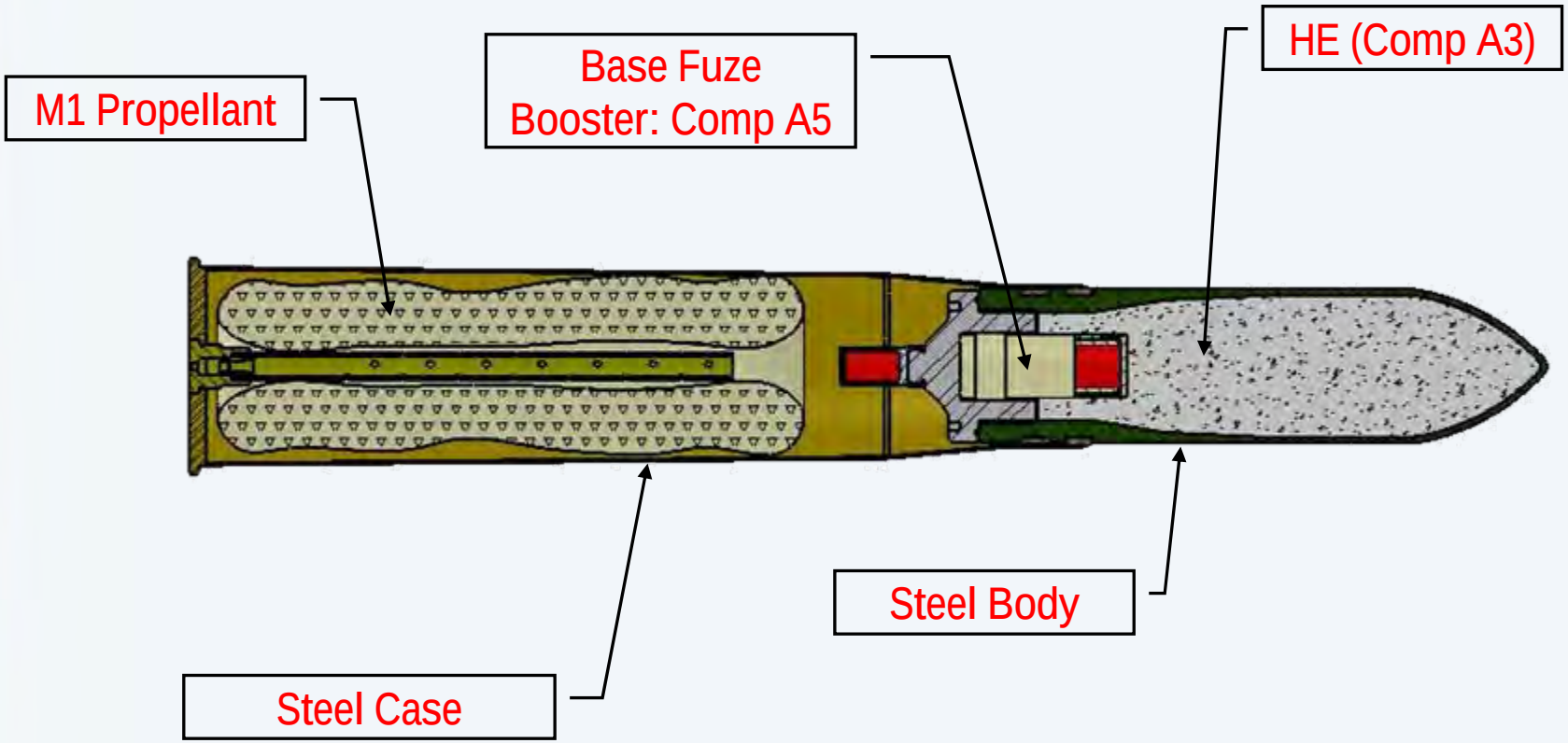
105 mm HEP-IM Cartridge

- Vulnerability of the 105 mm HEP cartridge to external threats compromises the MGS crew survivability
- GD-OTS Canada developed a low vulnerability version of the 105 mm HEP cartridge compatible with the MGS platform to meet these needs

Standard 105 mm HEP M393



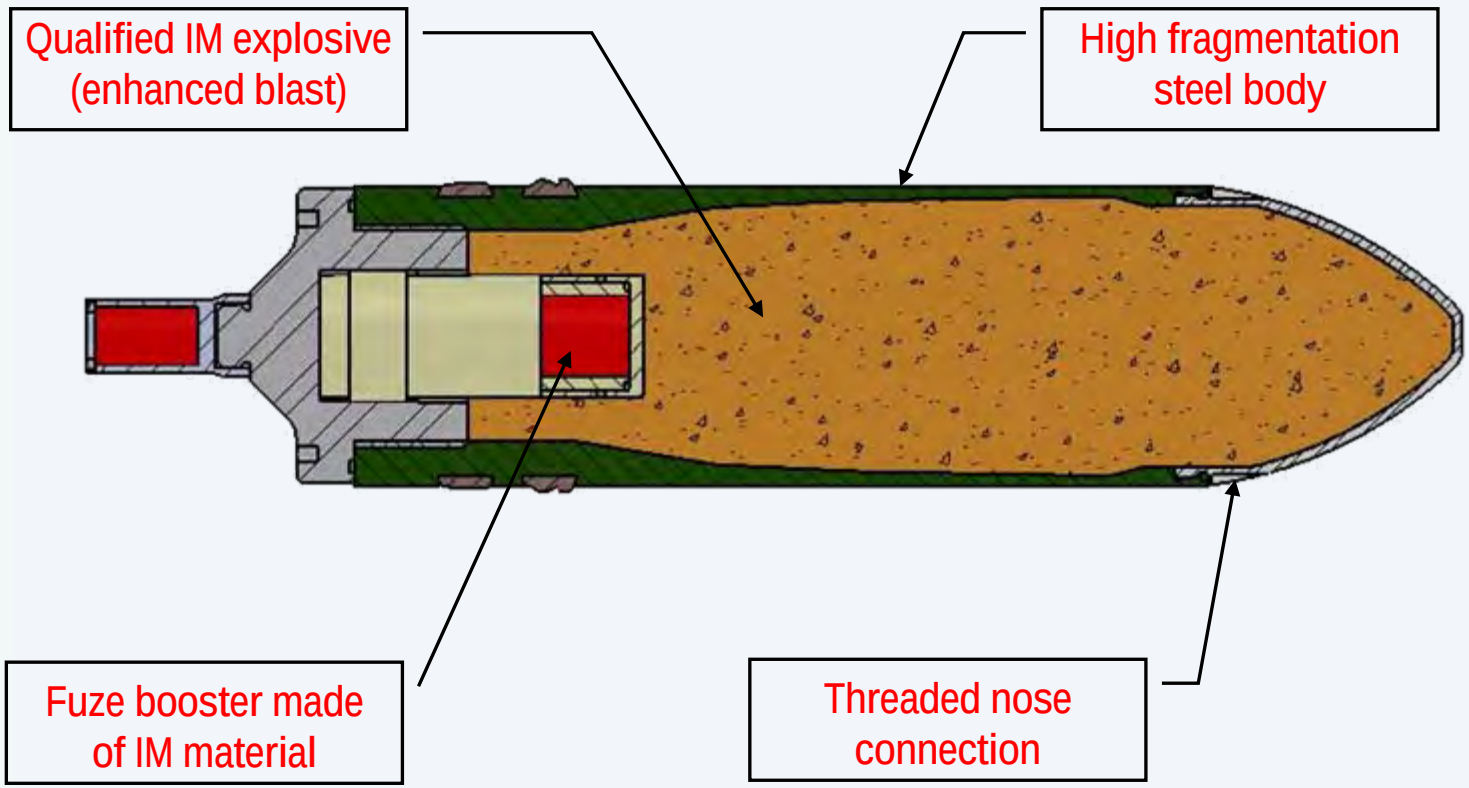
Design Constraints

- Maintain performance level with current HEP ammunition
- Maintain ballistic compatibility
- Development should not require full qualification of the cartridge
- Production cost competitive with current HEP ammunition

Technical Roadmap

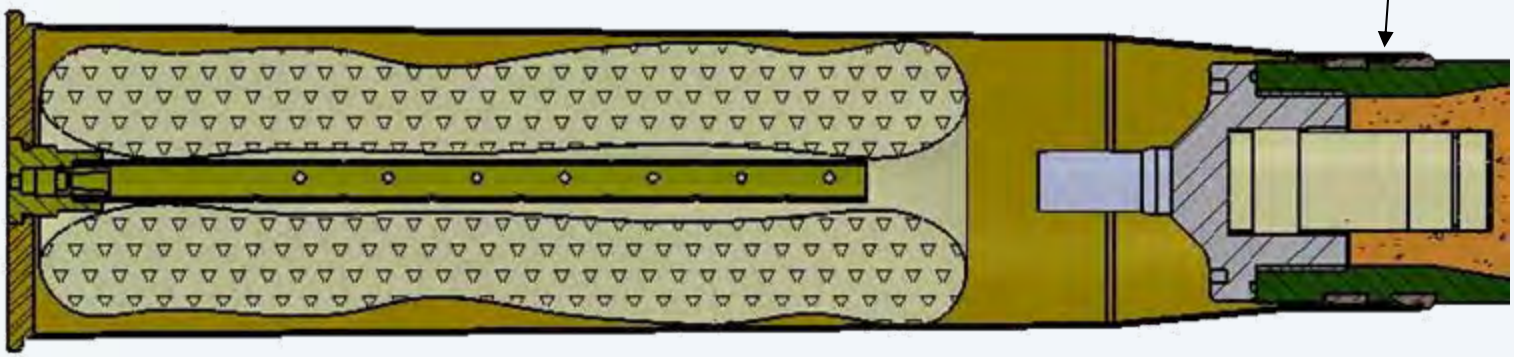
Approach	Rationale
Focus on HE projectile	Projectile is the main contributor to the reaction violence to stimuli
No change to the propelling charge system	Lower reaction than projectile Avoid extensive qualification

Changes to Projectile



Changes to Cartridge Case

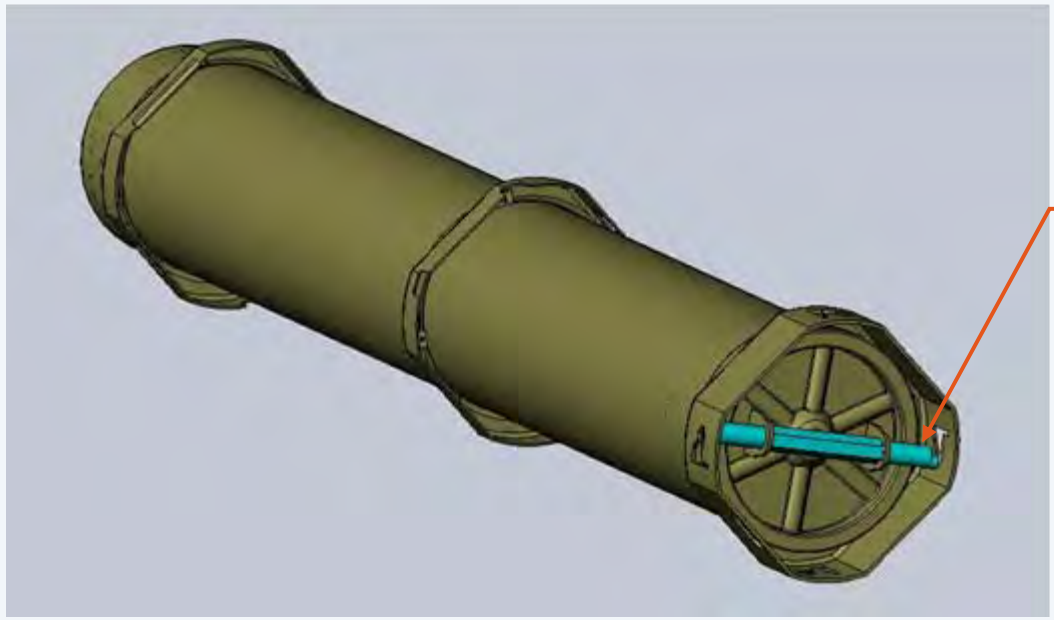
- **Replace steel with brass cartridge case**
  - Crimp force reduced by 50%



- **Reduces confinement of propellant for lower reaction to FCO**
- **Successful testing in MGS autoloader**

Changes to Packaging (PA 117 cont'd)

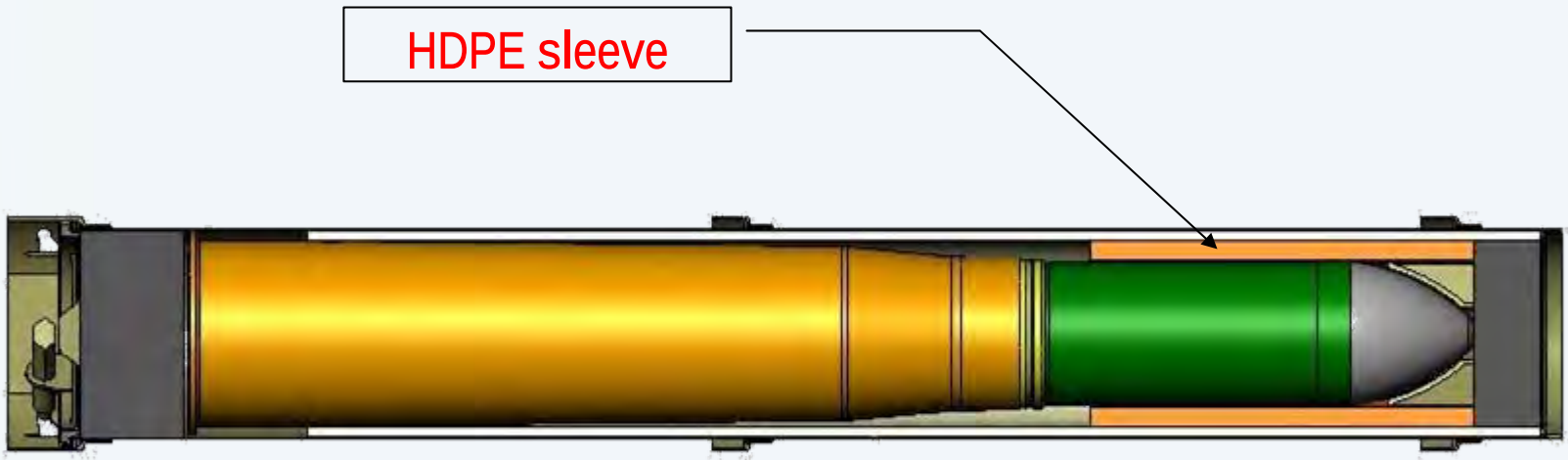
- **Reduce strength of cover locking pin**
  - Allows separation of case to projectile during Cook-Off (reduces propellant confinement)



- **Withstands 2.1m drop test**

Changes to Packaging (PA 117 cont'd)

- Use HDPE sleeve around warhead to avoid sympathetic detonation



Bullet Impact on HEP-IM Projectile Test Results

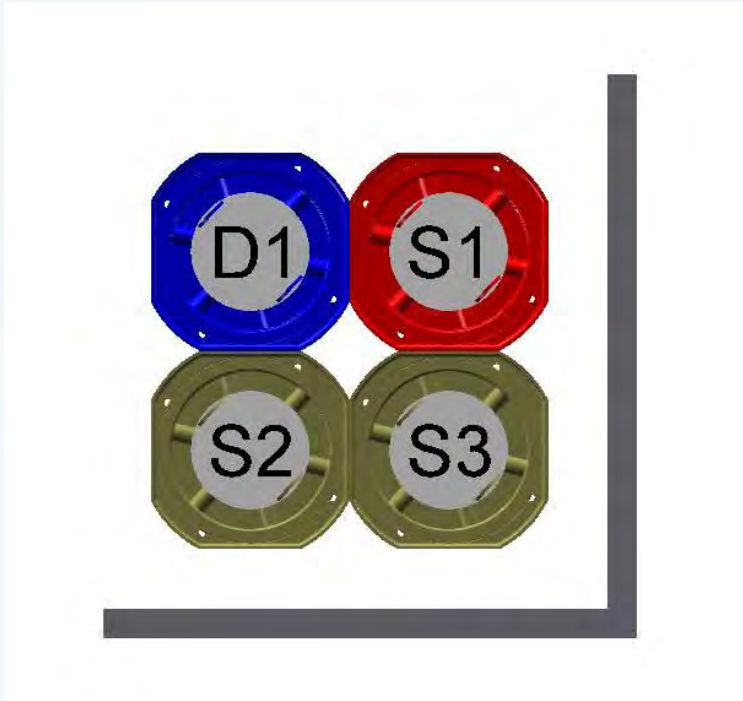
Type IV Reaction

Fast Cook-Off on HEP-IM Cartridge Test Results

Type IV Reaction

Sympathetic Detonation on HEP-IM Cartridge – Test Set-up

- Red detonates (donor)
- Green are receivers
- Blue is a dummy



Sympathetic Detonation on HEP-IM Cartridge – Test Results

Type III Reaction

- No indentation into witness plate
- IM explosive dispersed around test site
- Projectile metal parts broken in pieces without evidence of fragmentation

Warhead Terminal Effects

- Demonstrated capability to breach the 8- inch thick DRCW target

		Size of opening	# of rounds
Requirements	Minimum	24'' x 48''	5 rounds
	Objective	30'' x 50''	3 rounds
Results of gun firings		**32'' x 72''**	**3 rounds**

Warhead Terminal Effects

2 shots

27'' x 55'' Opening

3 shots

32'' x 72'' Opening

Warhead Terminal Effects (Lethality)

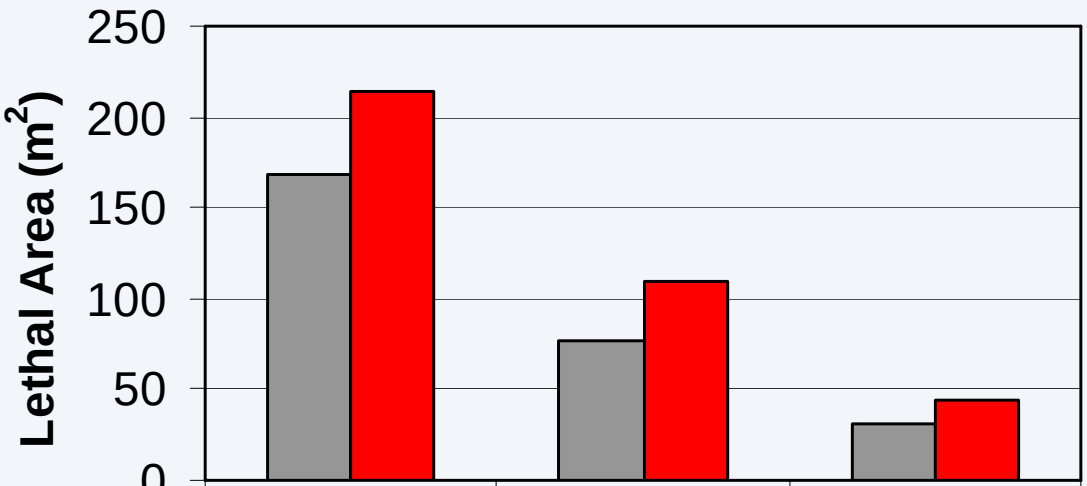
- **40% increased lethal area against personnel in the open vs current HEP**

- **Contributors**
  - High-frag steel
  - Enhanced blast explosive

Warhead Terminal Effects (Lethality)

Comparative simulation based on:

- 50% probability of kill
- Protected personnel
  (Helmet and US winter clothing)
- Standing personnel
- Ground impact



	Pk ≥ 10%	Pk ≥ 50%	Pk ≥ 90%
105mm HEP	169	76	32
105mm HEP-IM	214	109	43

105 mm HEP-IM Cartridge

	REACTION TYPES	
	HEP-IM (actual testing)	MIL-STD-2105 C
BULLET IMPACT (0.50 AP) ON PROJECTILE	IV	V
FAST COOK-OFF	IV	V
SYMPATHETIC DETONATION	III	III

105 mm HEP-IM (Conclusions)

- **Improved MGS crew survivability**
  - HE-IM explosive
- **Increased terminal effect**
  - Breaching 8'' DRCW (exceeds requirements)
  - Anti-personnel increased by 40%
- **Low risk development program approach**
  - Modification of existing cartridge
- **Propelling system does not need to be re-qualified**

Questions

43rd Annual Guns & Missiles Symposium
21-24 April 2008

Analysis of Precision Mortar fires for the IBCT

Rollie Dohrn
Technical Director, PGMM, ATK

Approved for Public Release, POA 305-08, 22 CFR 125.4(b)(13) applicable

Outline

- PGMM Operational Analysis
- PGMM Description
  - PGMM Capability
  - PGMM How it Works
    - Operational Concept
    - Projectile Overview
- PGMM Program Plan
  - Program Status – PGMM in Shut Down
  - Program Schedule (GTH Tests, Subsystem Testing, Major Program Milestones)
- Test Program Results
  - PGMM Test Program
    - Lesson Learned – Aero Prediction, Thruster Jet Interaction
    - Results of GTH Tests
- Summary

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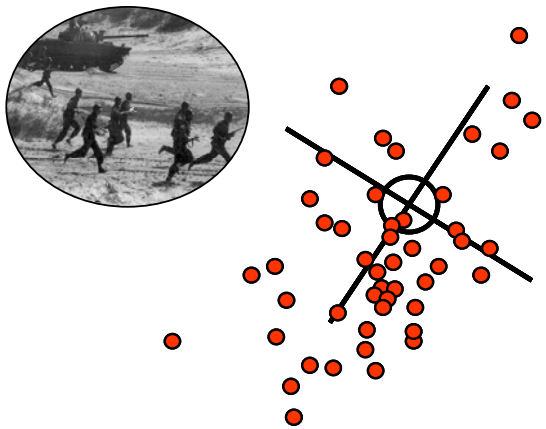
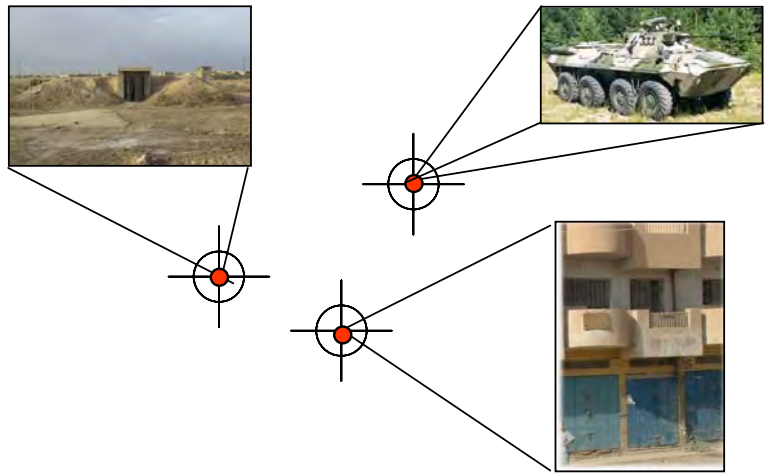
Precision Guided Mortar

Suppression → Destruction





High Explosive

- Area Effects
- High Volume Fire
- Defeat Targets in the Open
- Suppress Personnel Under Cover

Precision Guided

- Precision Effects
- 1-2 Rounds to Effect Target
- Incapacitate Personnel Under Cover
- Low Collateral Damage
- Reduced Logistics Footprint

PGMM gives Battalion Commanders Organic Precision Strike, Destructive Capability

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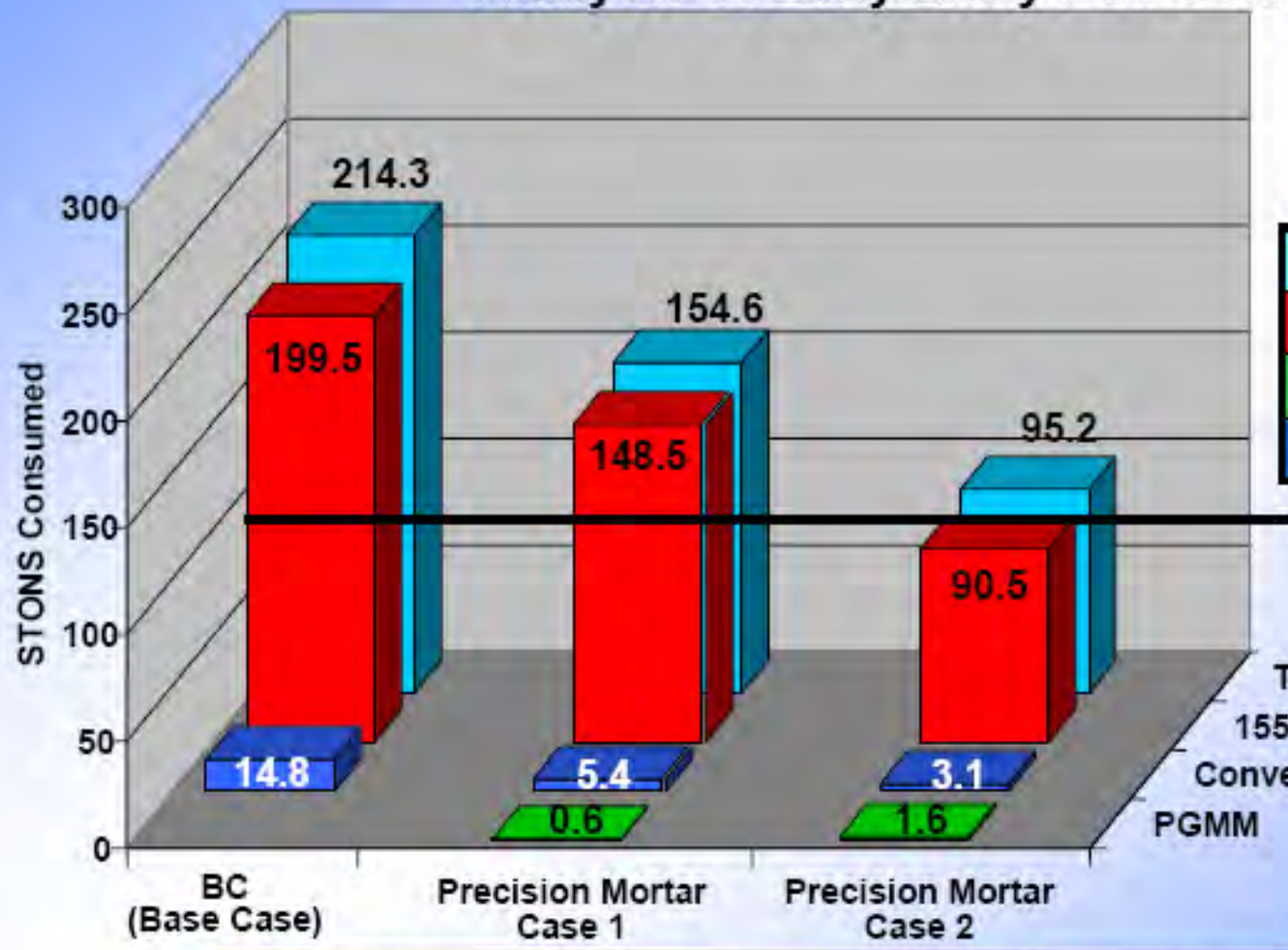
Precision Guided Mortar - Logistics

ATK

An advanced weapon and space systems company

Analysis of Early Entry Force Scenario



	Base Case (STONS)	Precision Mortar Case 2 (STONS)
TOTAL	214.3	95.2
155mm	199.5	90.5
PGMM	0	1.6
120mm	14.8	3.1

3 Days of Supply

83 PGMMs reduced logistics burden of Indirect Fire Ammunition by 122 STONS (110.7 Metric Tons)!

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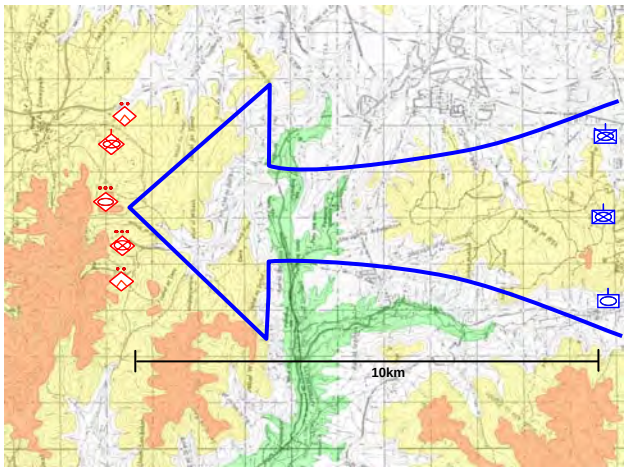
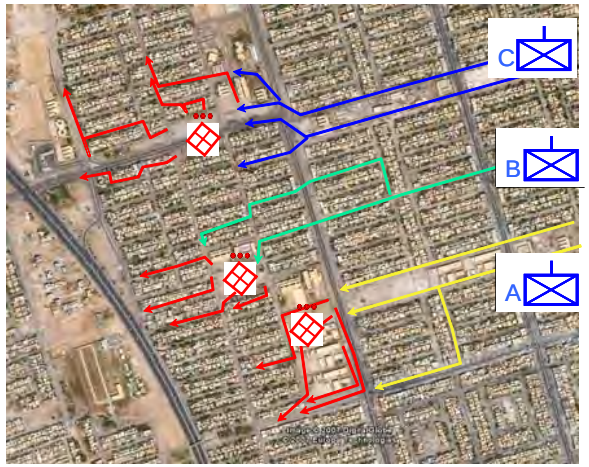
Precision Guided Mortar – Operational Scenarios

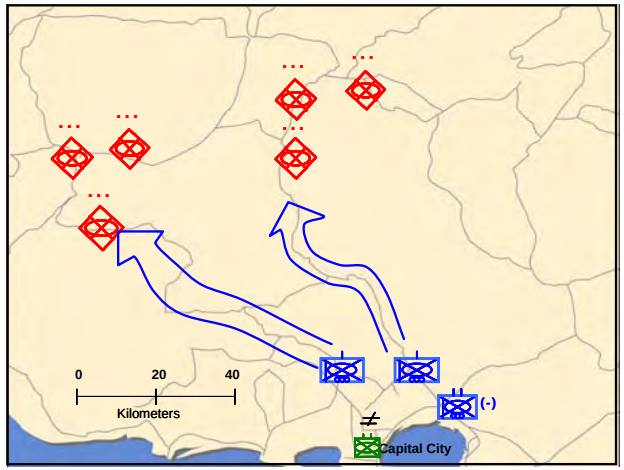
Nonlinear, Noncontiguous



Urban



Desert



- Precision Guided Mortar included in Force on Force Models to Show Impact on Force Effectiveness
  - Nonlinear, Noncontiguous:
    - US Heavy Brigade Combat Team in the Attack
    - Threat Defenders with heavy systems (tanks, mortars, artillery)
  - Urban:
    - US (3 Infantry Companies) in the Defense
    - Threat Attack with crew served weapons (hit and run)
  - Desert:
    - US Stryker Brigade Combat Team in the Attack
    - Threat Defenders with heavy weapons (Infantry Fighting Vehicles, RPGs, mortars)

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Precision Guided Mortar – Force Capability

ATK

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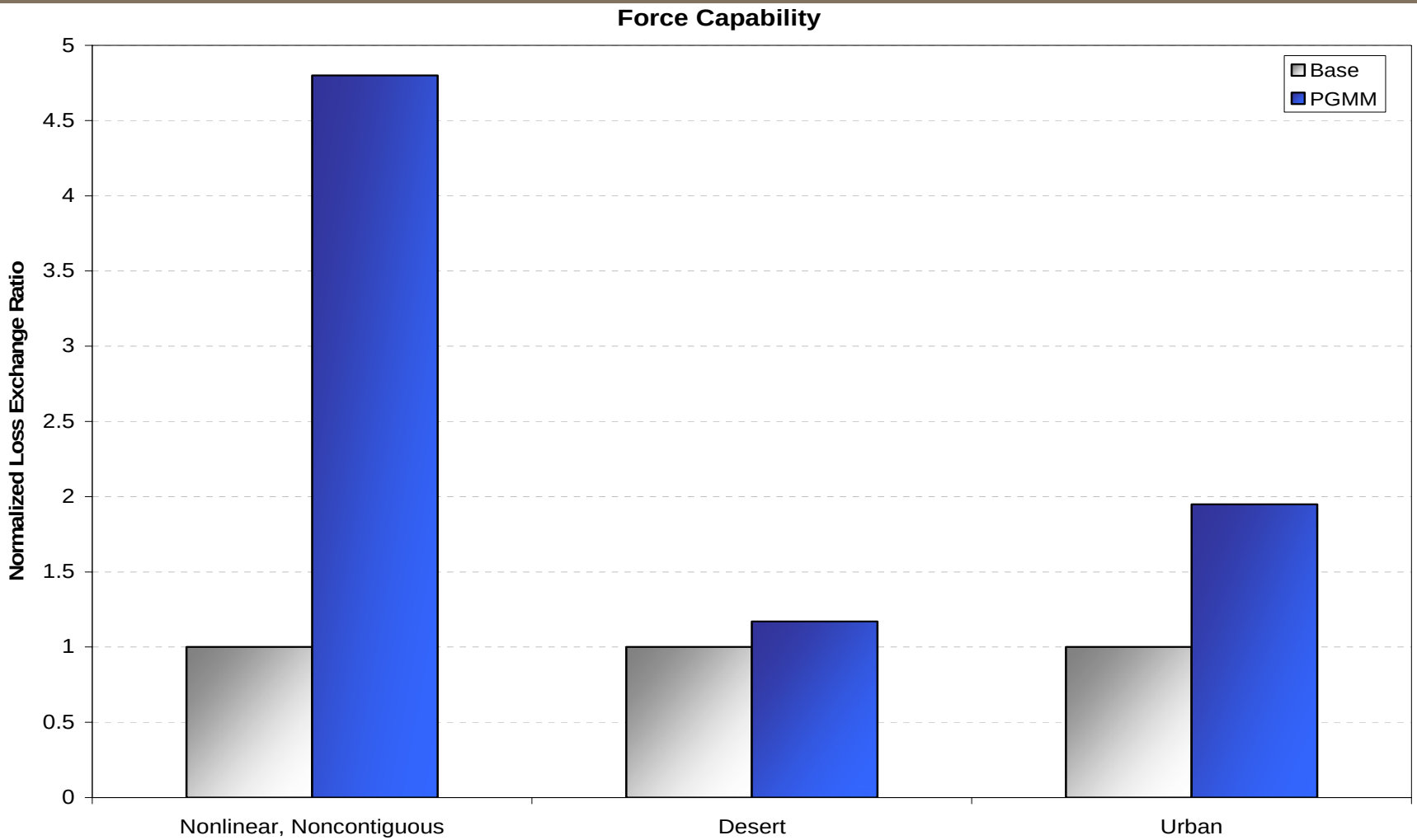

PGMM Provides Increased Force Capability In All Scenarios

Analysis Conducted By:

NewVectors
A Division of TechTeam Government Solutions, Inc.

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PGMM Operational Concept

An advanced weapon and space systems company

Ballistic Flight to Target Acquisition

Guided Flight to Hit Designated Target

SAL Enabled
SAL Calibration Complete
CTM Enabled
Target Acquired
Guidance Starts
Warhead Armed
Target Destroyed
Forward Observer Paints Target (Laser On)
Forward Observer
Fire Support Element (FSE)
Time Transfer Complete
BIT Complete
Down-Finding & Sensor Calibration Started
Fire Direction Center (FDC)
Safe Separation & Power Up
Fins Deployed
Mortar Squad
Fire PGMM
Mission Setting

Conventional Mortar Setting, Loading, Firing, and Ballistic Flight Minimize Logistics Burden

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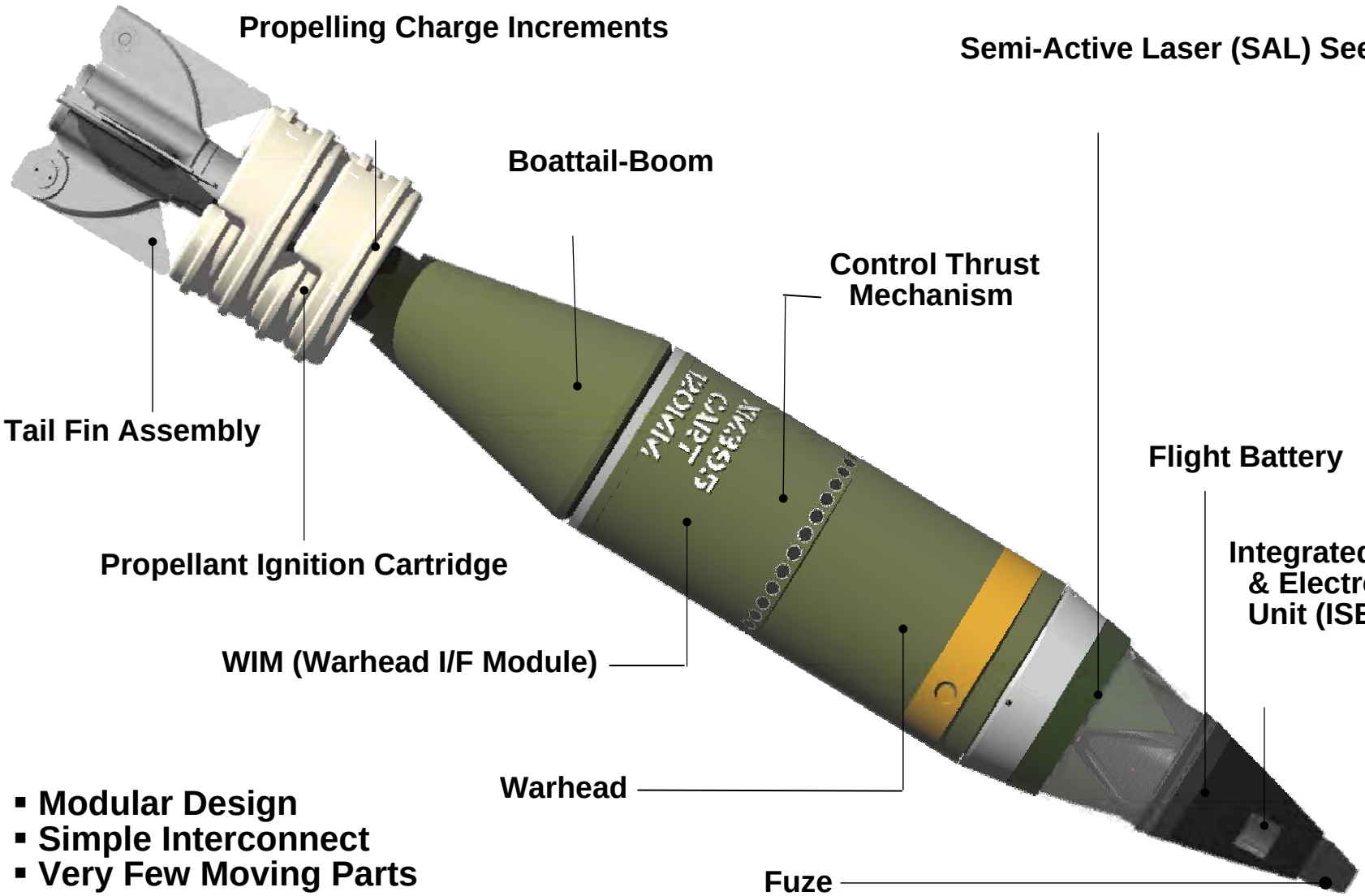
PGMM Projectile



- Modular Design
- Simple Interconnect
- Very Few Moving Parts
- Low Cost
- Mature Subsystems

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PGMM Program Status

- Army Headquarters Directed PM Mortars to End PGMM Development
  - Terminated due to Funding Constraints in Future Budget
  - PGMM's requirement is still Valid, but Unfunded

- PM Mortars & ATK are Executing an Orderly Shutdown of the program
  - Less costly and time consuming approach than outright Termination for Convenience
  - Have completed System CDR and Demonstrated Performance in Guide To Hit (GTH) series
    - Telemetry in place of Warhead to gather in flight information
    - Hit 12 of 16 targets

- Current Status:
  - Conducting GPS Integration Study
  - Two Operational Need Statements (ONS) Received from Theatre
  - PGMM being strongly considered as a solution in TRADOC's Precision Effects Studies

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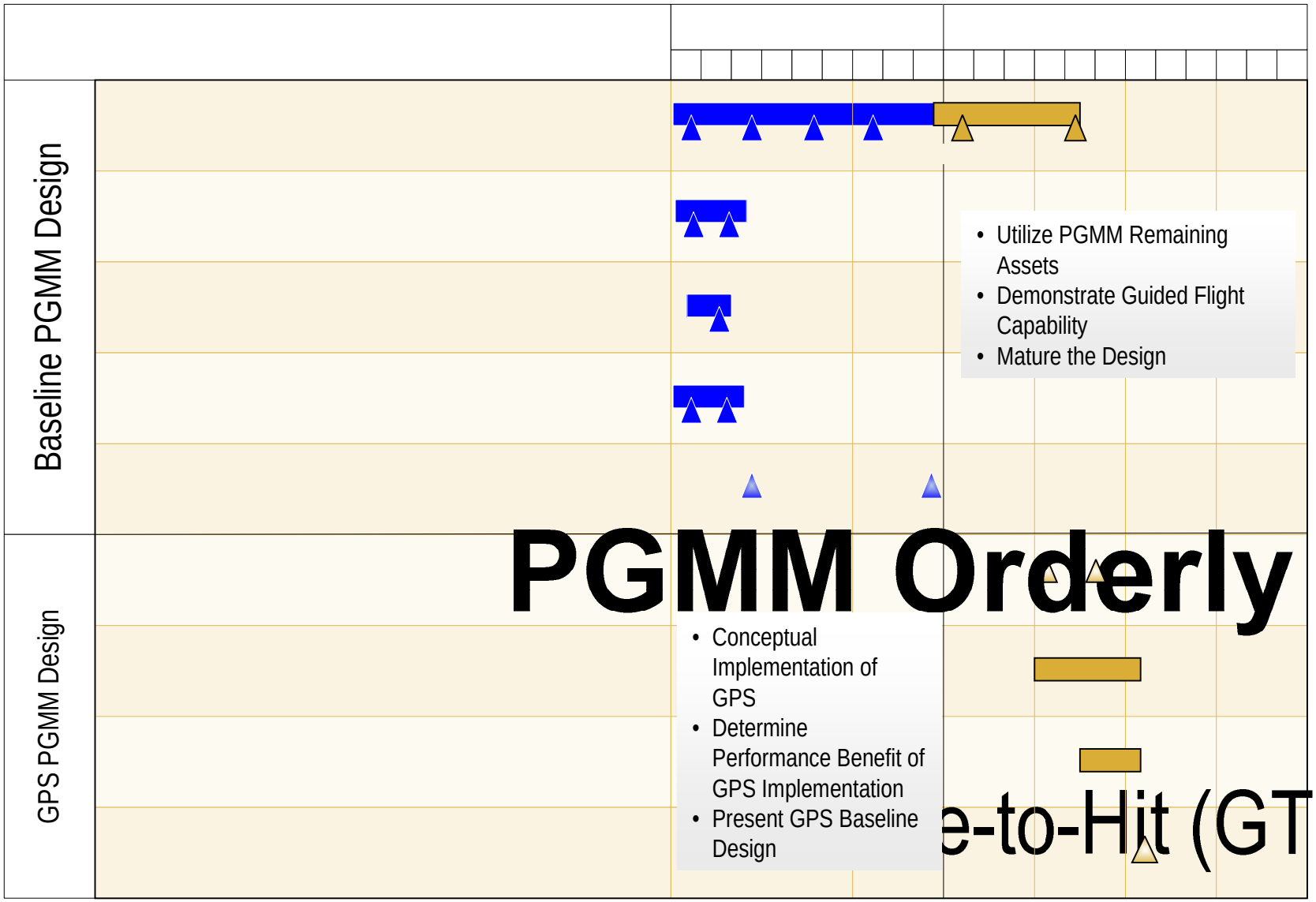
PGMM Program Plan – Orderly Shutdown



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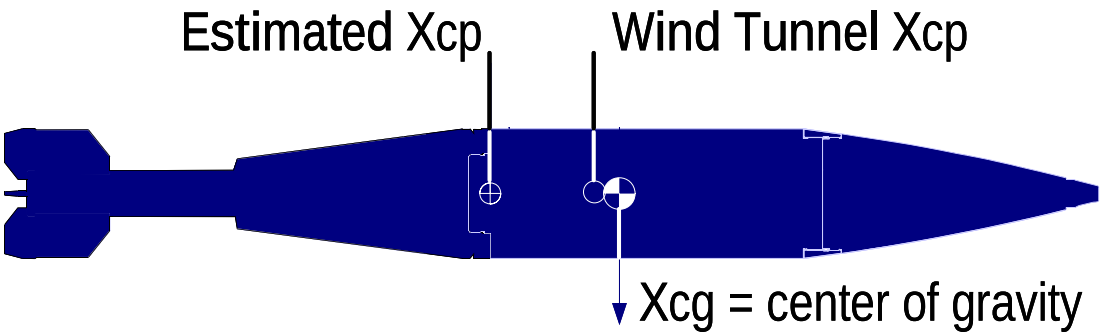
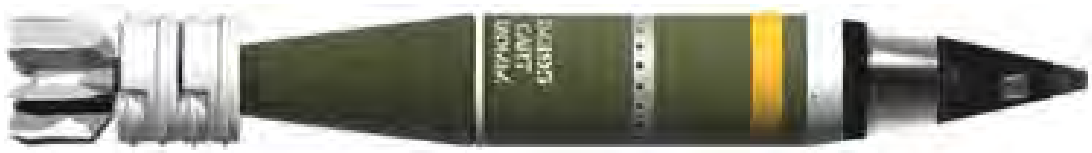
PGMM Lesson Learned – Aero Prediction



Traditional Methods were used for PGMM Aeroprediction and included:

- Empirical Aero Prediction Codes
- Review of similar shapes
- CFD



PGMM Caliber Fin Design

All methods over predicted static margin

PGMM Super-Caliber Fin Design

Early wind tunnel testing identified issue and allowed rapid development of super-caliber fin solution

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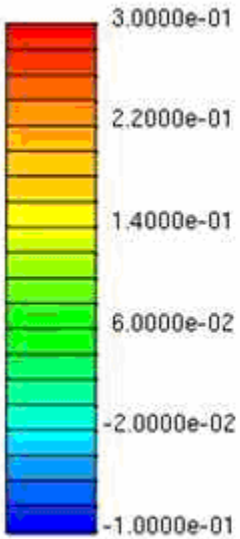
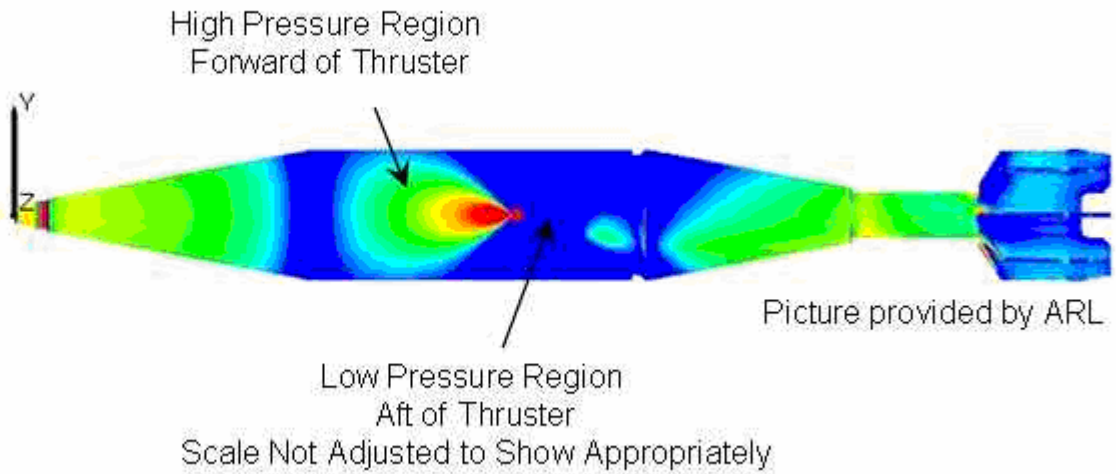
PGMM Lesson Learned – Jet Interaction

Jet Interaction is modeled as a force location offset of the thrusters causing a moment impulse at the same time as the thrust impulse.

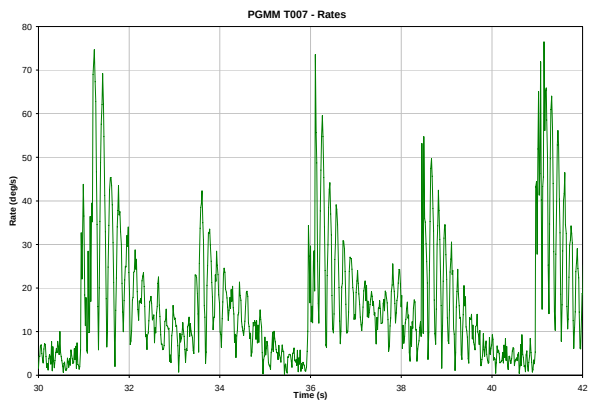




$$\Delta H = I_{trans} \cdot \omega = \int (T \cdot d)dt = I_{thrust} \cdot d$$

I_{trans} = Transverse Moment of Inertia, ω = angular velocity
T = Thrust, d = thrust distance from Xcg, I_{thrust} = Total Impulse from Thrust Event

Conservation of Momentum



RSS of Rates - ITM

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Location: Ft. Benning, GA

Scenarios / Participants

- Bunker, Sniper, Vehicle Targets
- Gun re-positioning during mission
- FO re-positioning (incoming enemy fire)
- Effects Day vs. Night

- BLUE Force: 22 Soldiers (mostly veterans OIF OEF)
  - FO Team w. Forward Observer System (FOS)
  - Infantry Mortar Section (w. MFCS modified for PGMM)
  - Rifle Squad attacking building shown

- RED Force: 6 defenders

USAIC Objectives:

- What impact did PGMM have on this urban fight?
- How difficult is it for the FO, FDC & Gun to work together with this new munition & mission?
- How will MFCS assist in re-positioning Guns or FOs to keep within Angle T ?
- What are the difficulties with “lase target” message / timing and how should we train these skills?

Results:

- Positive Impact. Troops were able to quickly take objectives with increased confidence
  - 47 Hits w. 1st round of 56 missions (balance hit w. 2nd rd
- Not a problem. All missions were done digitally and FO/FDC quickly became proficient working together
- MFCS at Mortar FDC had situational awareness of FO/Guns, were able to quickly re-position guns
- Identified time lags when sending digital messages (Designate) that needs additional work, work-around may be to send “Designate” by voice

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Soldier Comments from TTP Demo

- A precision round will give them more confidence to operate in MOUT.
  - 120mm HE “scares them to death”, don’t want to be anywhere near the impact area
  - Knowing that PGMM can quickly destroy targets of opportunity that “pop up” increases their survivability and confidence
  - The TTP maneuver squad felt that having the PGMM would make them at least 50% more survivable.
- FO will be more survivable. He can defeat a target in a few number of rounds versus firing many adjustments
- Learning how to use the round was easy, it is not very different than current procedures
- They couldn’t shoot HE in Iraq because of ROE. When an enemy was identified, they had to send a recon team which took about 30 minutes to organize and get to the target. By that time the enemy was gone. PGMM would give them the ability to quickly strike back.
- From time a target was identified to the time of PGMM impact was only about 2 minutes. A maneuver element would wait that long when a sniper was identified; PGMM would defeat it, then they continued moving into their objective area.
- Infantry goal in marksmanship (make the first round count) should be the same for its biggest weapon (120mm Mortar).

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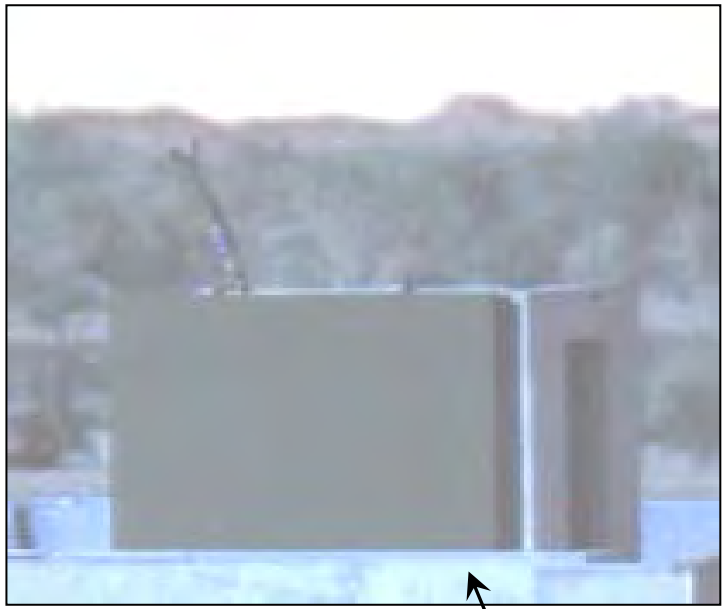
PGMM GTH Testing – Test 410B3



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Summary/Conclusion

Precision Guided Mortars (PGMM) can provide a force multiplier to the IBCT

- PGMM gives battalion commanders organic precision strike, destructive capability
- PGMM reduces the logistical burden providing a precision capability with no change to current tactics & procedures

PM-Mortars & ATK Team Addressed Several Technical Challenges Including

- Aero Prediction for novel airframes – Identified in Test and addressed with super-caliber fin design
- Thruster Jet Interaction – Characterized through test and analysis

PGMM has demonstrated performance

- TTP Demo showed tactical capability with soldiers
- 12 of 16 shots hit target in 1 year of testing
  - 6 Tests, 3 Zones, 2 Temperatures

PGMM – Lowest risk and quickest path to field precision indirect capability to the IBCT

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Accelerated Burning of Gun Propellants Caused by Pressure Oscillations Within the Perforations of Propellant Grains

Gert Pauly – Rudolf Scheibel
Wehrtechnische Dienststelle für Waffen und Munition (WTD 91)
D-49716 Meppen, Germany email: gertpauly@bwb.org

43rd Annual Armament Systems:
Gun & Missile Systems Conference & Exhibition
April 21 – 24, 2008, Sheraton New Orleans Hotel
New Orleans, LA, U.S.A.

Contents

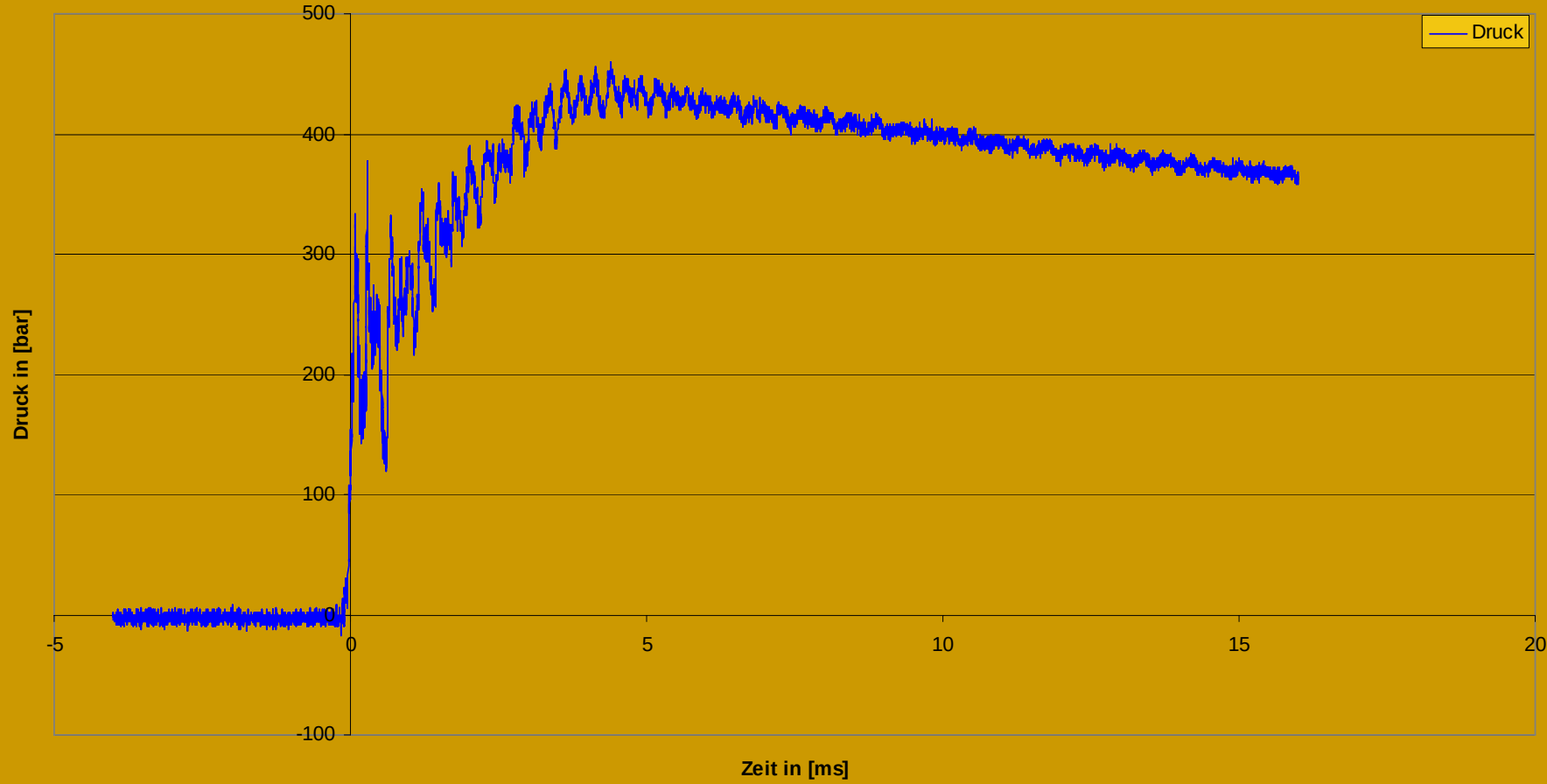
1. **Pressure oscillations in holes of propellant grains**

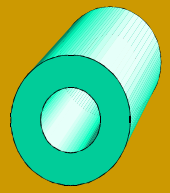
2. **Connections between pressure oscillations, accelerated burning and temperature behaviour**

3. **Working hypothesis explaining the effect of accelerated burning caused by pressure ocillations**

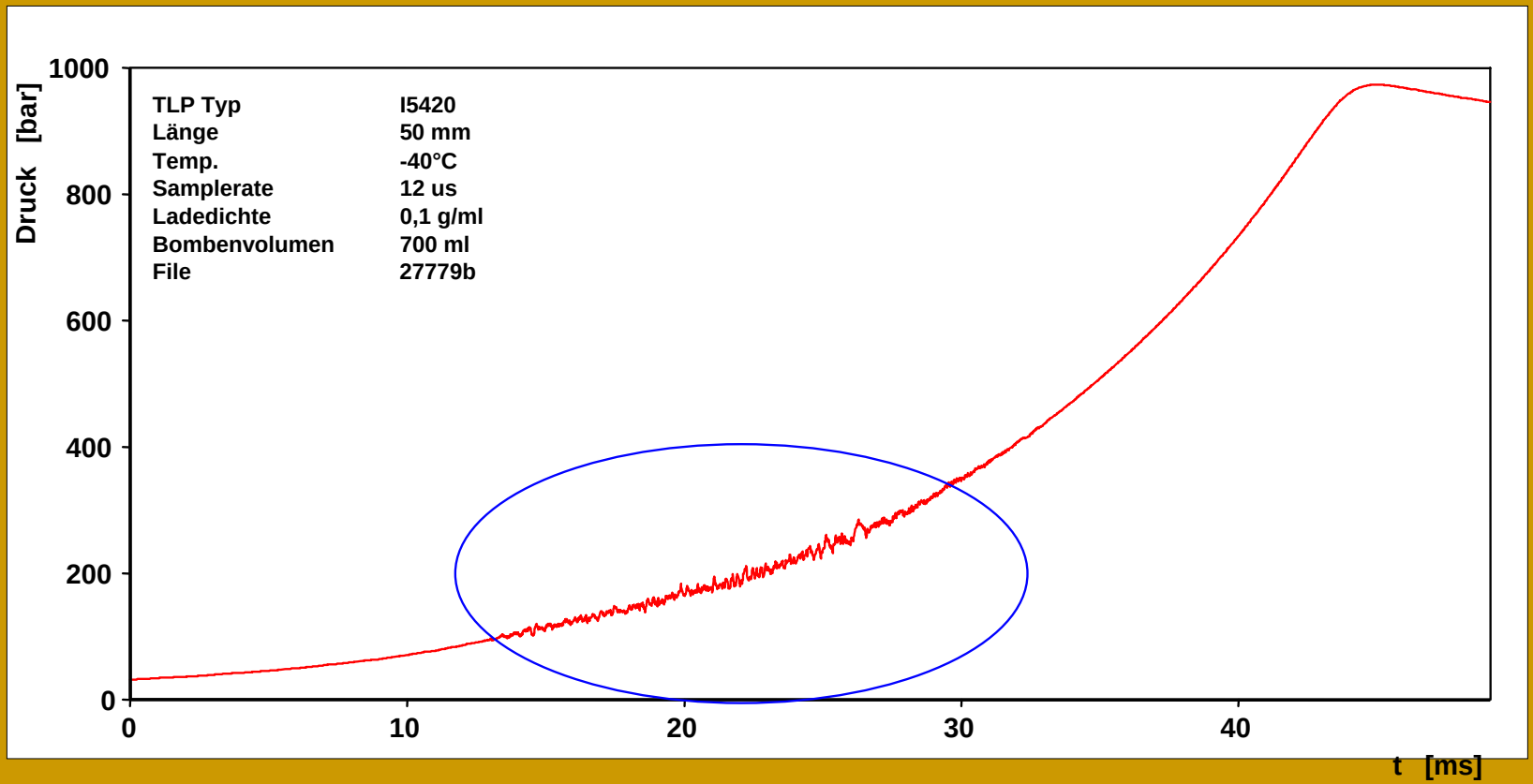
4. **Conclusions**

Example for Vieille-oscillations in a closed vessel
WTD 91 January 2007



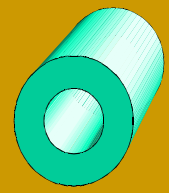


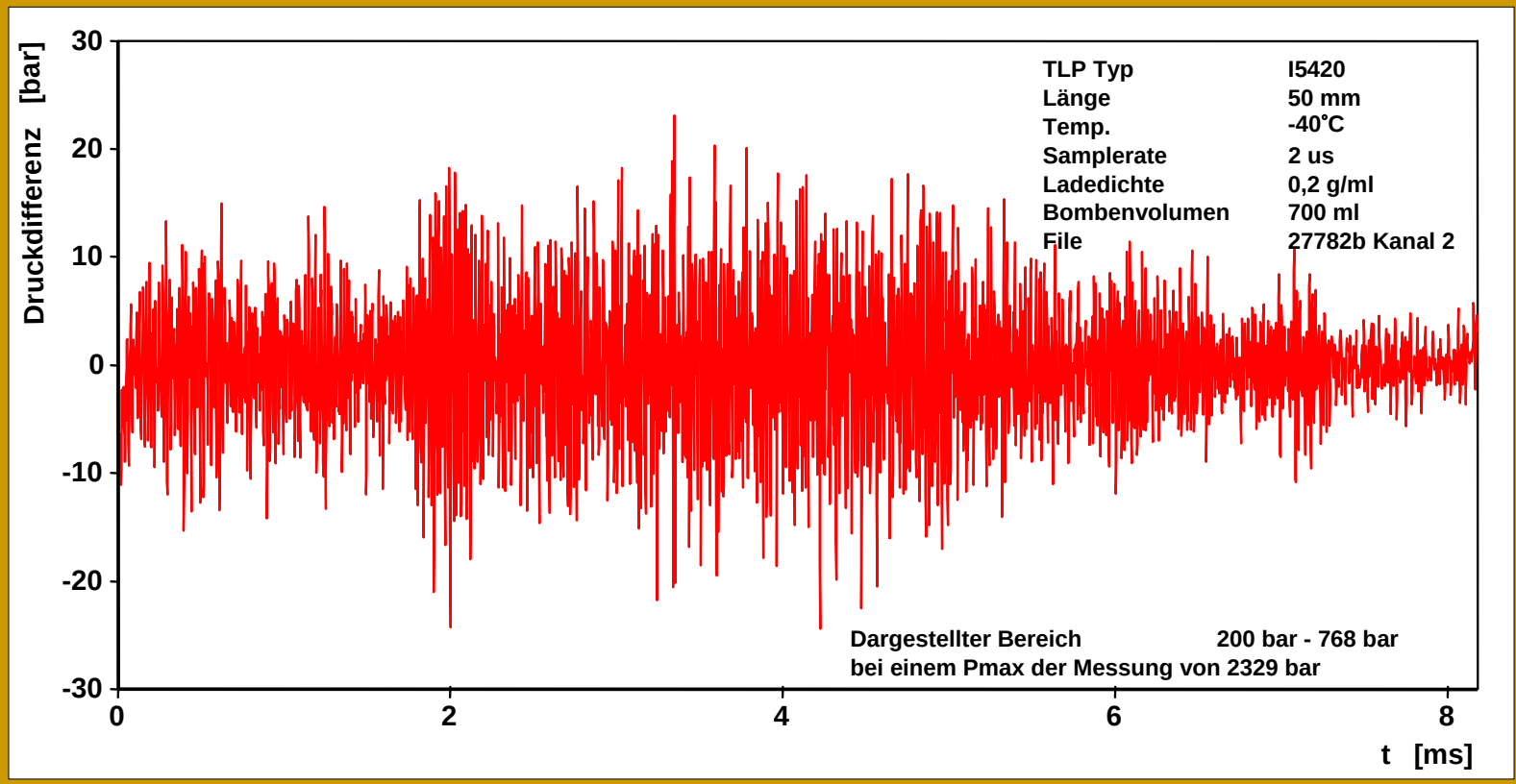
Oscillations superimposing the rise of pressure



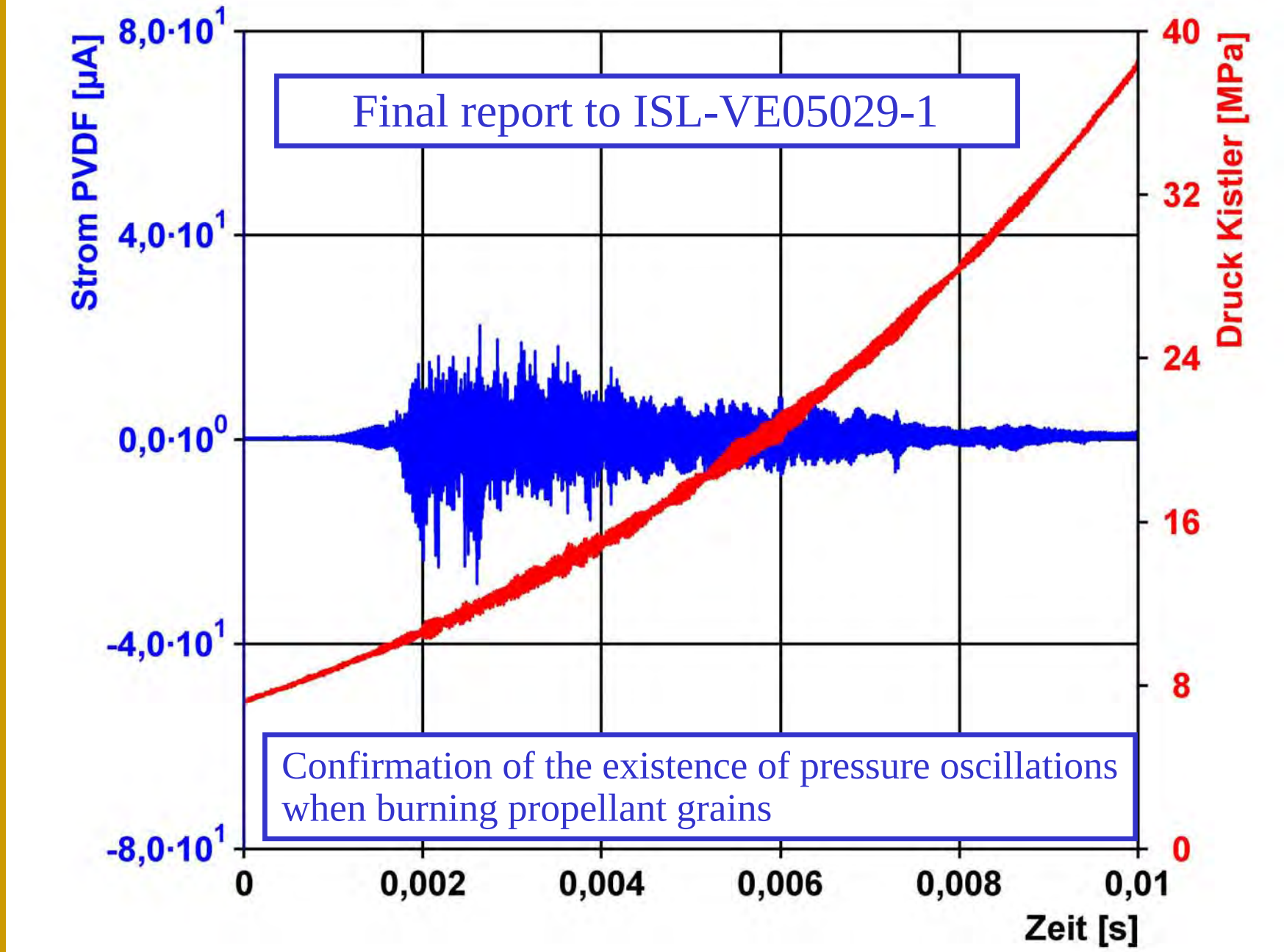
Pressure / time curve resulting from burning a tube propellant in a closed vessel. The oscillations are found in the encircled range.

Pressure oscillations when burning a tubular propellant



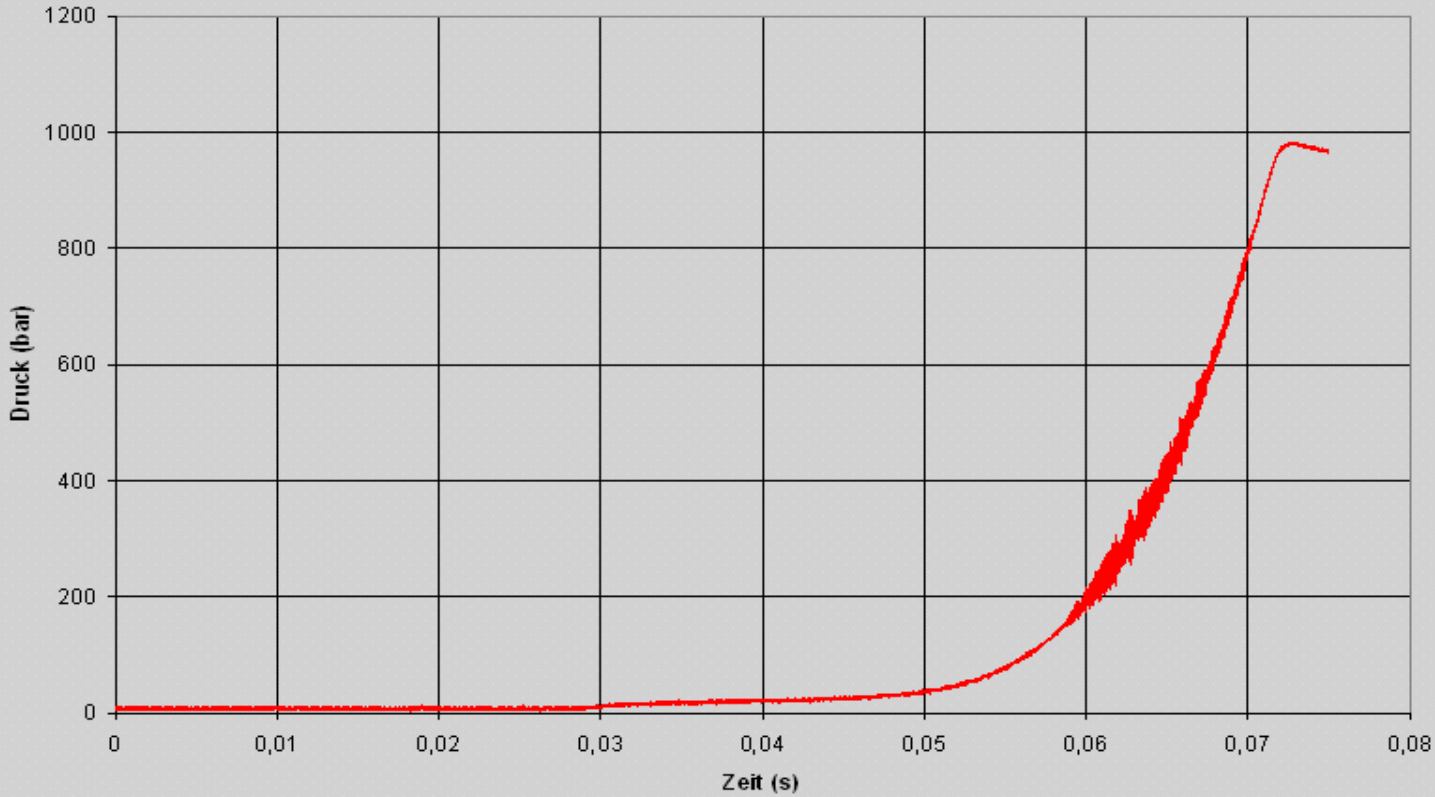


The picture was achieved by subtracting the original p / t - curve from the smoothed p / t - curve.


Final report to ISL-VE05029-1
Confirmation of the existence of pressure oscillations when burning propellant grains
Strom PVDF [µA]
8,0·10^1
4,0·10^1
0,0·10^0
-4,0·10^1
-8,0·10^1
Druck Kistler [MPa]
40
32
24
16
8
0
0
0,002
0,004
0,006
0,008
0,01
Zeit [s]

Prüfpulver C/S 2100/1; 0.1 g/cm^3; -40°C

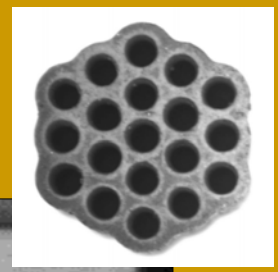
DIEHL
BGT Defence



Confirmation of the existence of pressure oscillations when burning propellant grains

Copyright

Abnormal (wavelike) erosions in the holes



The picture shows a sectional view of a triple-base 19-hole-propellant grain after interrupted burning at - 46°C (- 51°F). The wavelike erosions indicate the occurrence of standing waves in the holes.

Accelerated Burning of Gun Propellants Caused by Pressure Oscillations Within the Perforations of Propellant Grains

Gert Pauly – Rudolf Scheibel
Wehrtechnische Dienststelle für Waffen und Munition (WTD 91)
D-49716 Meppen, Germany email: gertpauly@bwb.org

43rd Annual Armament Systems:
Gun & Missile Systems Conference & Exhibition
April 21 – 24, 2008, Sheraton New Orleans Hotel
New Orleans, LA, U.S.A.

Contents

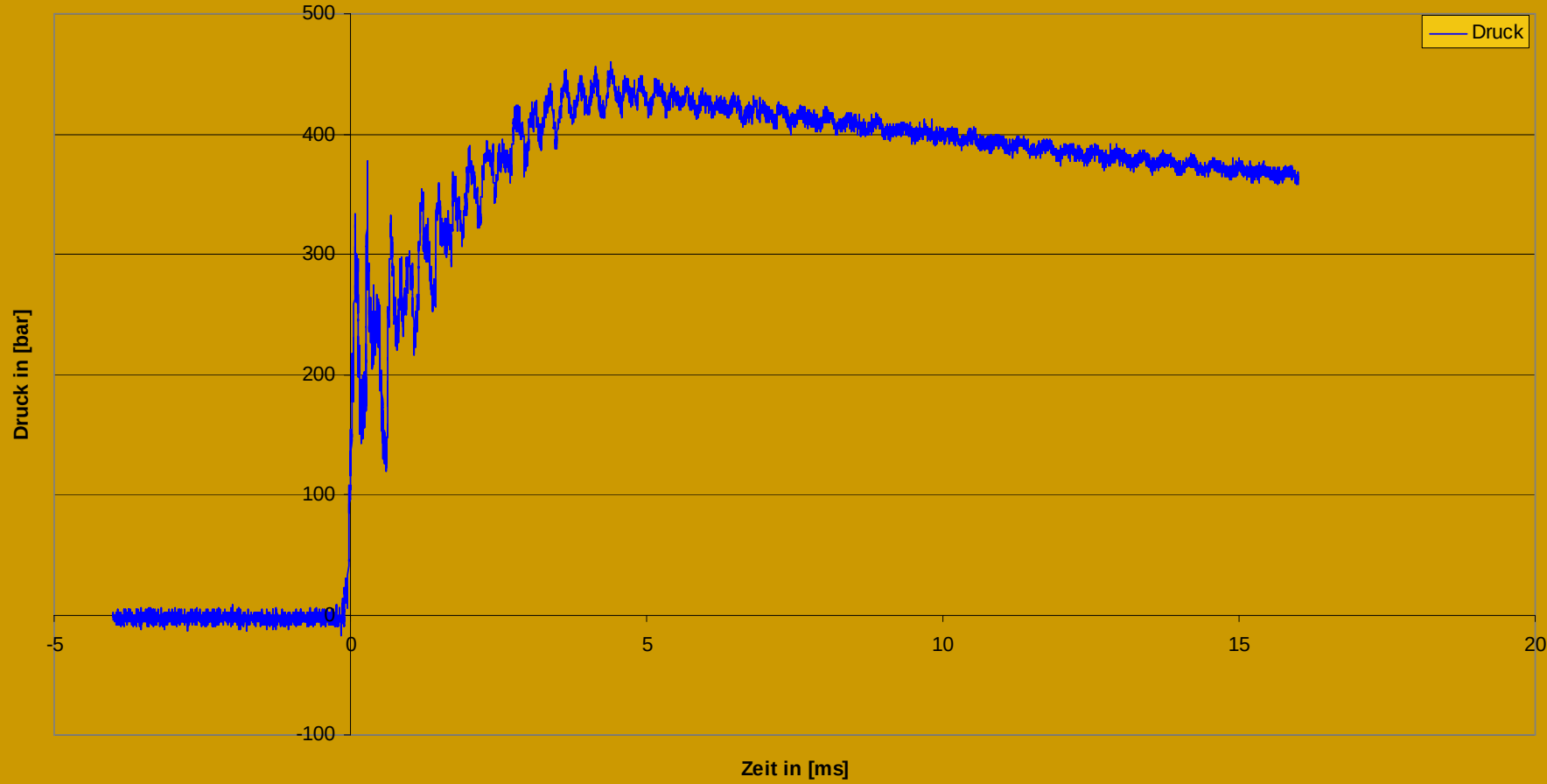
1. **Pressure oscillations in holes of propellant grains**

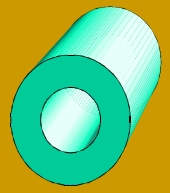
2. **Connections between pressure oscillations, accelerated burning and temperature behaviour**

3. **Working hypothesis explaining the effect of accelerated burning caused by pressure ocillations**

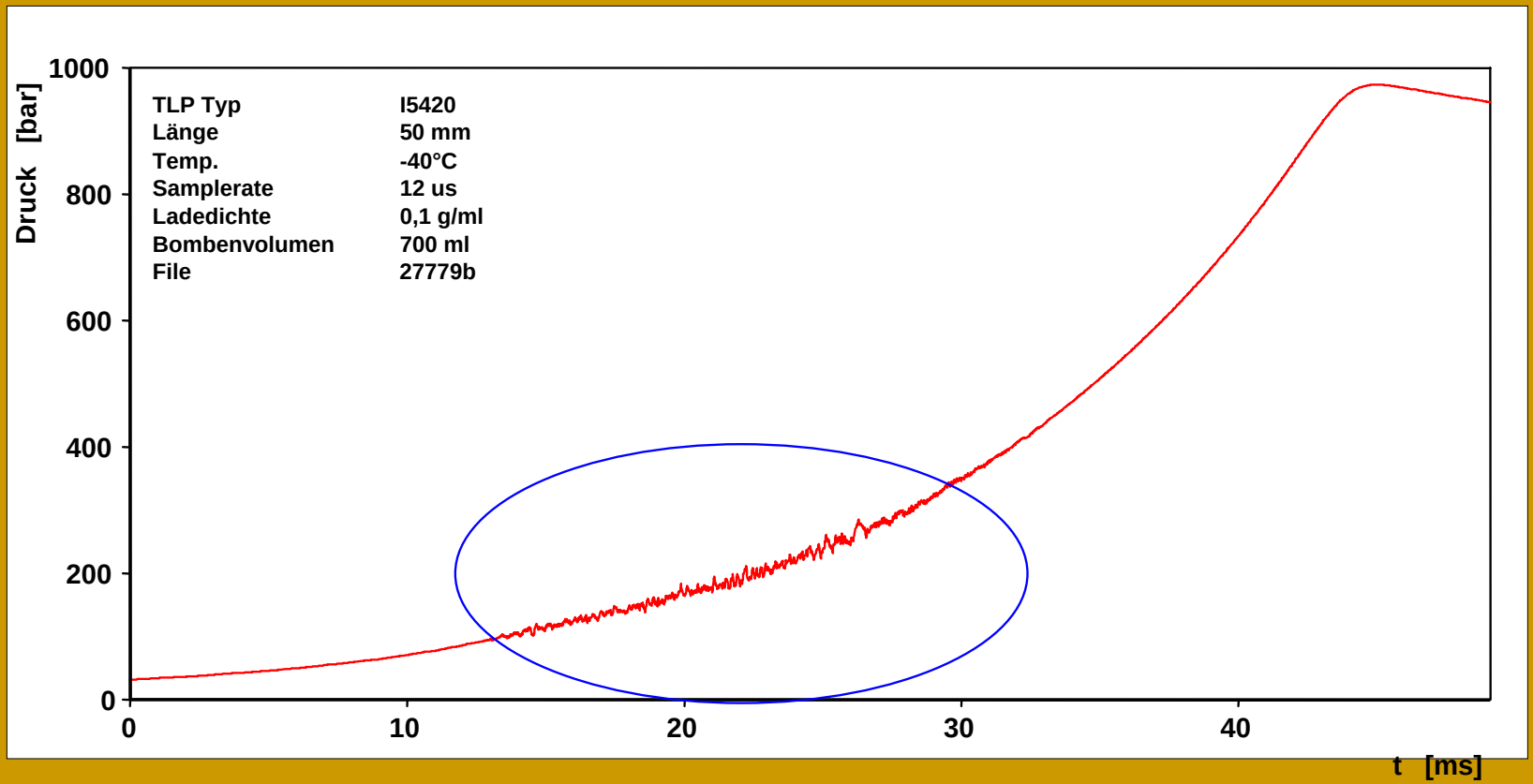
4. **Conclusions**

Example for Vieille-oscillations in a closed vessel
WTD 91 January 2007



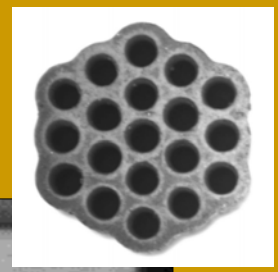


Oscillations superimposing the rise of pressure



Pressure / time curve resulting from burning a tube propellant in a closed vessel. The oscillations are found in the encircled range.

Abnormal (wavelike) erosions in the holes



The picture shows a sectional view of a triple-base 19-hole-propellant grain after interrupted burning at - 46°C (- 51°F). The wavelike erosions indicate the occurrence of standing waves in the holes.

Methodology for Dynamic Characterization of Fragmenting Warheads

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Jason Angel - U.S. Army Research Laboratory

April 22, 2008
Guns & Missiles symposium
New Orleans, LA

OUTLINE

Joint Live Fire
Ground Systems

- BOTTOM LINE UP FRONT

1 - PROPOSED METHOD TO ASSESS FRAGMENTATION FOR DYNAMIC EVENT

2 – QUESTIONING EXISTING METHODOLOGY FOR FRAGMENTATION LETHALITY

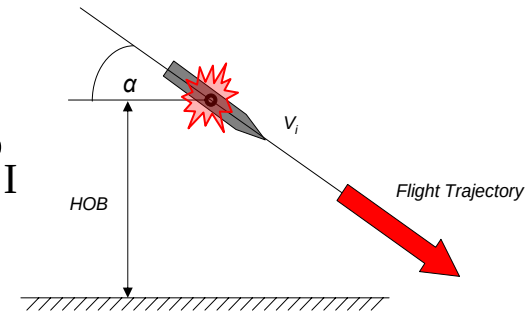
- Background/Issues
- Approach
- Test Set-up
- Results/discussion
- Conclusions

BACKGROUND/ISSUES

CURRENT METHOD TO ASSESS FRAGMENTATION

- Static ARENA test
  - Statistical representation of the fragmentation
  - Fragmentation File (Z-data file)

- Lethality models use Z-data and dynamic impact conditions
  - Impact velocity, orientation, etc
  - Predict number of impacts on personnel
  - Determine probability of incapacitation, P_I



- Currently no method to correlate to “Dynamic” testing
  - just a probability of achieving a level of Incapacitation

GMLRS as an EXAMPLE

Joint Live Fire
Ground Systems

Z-data file established

P_I for impact condition computed

Performed dynamic event

- mannequins assessed for lethality
- all personnel fell within bands (P_I +/-)

ISSUE - no statistical correlation to fragment spray

APPROACH

- Goal:
  - Demonstrate method to collect fragmentation data in a dynamic event to produce higher statistical confidence in results

- Evaluation Concept:
  - Use warhead with well established Z-data file
  - Collect fragment spray via metallic witness panels located in an arena arrangement
  - Compare perforations in the panels from the detonated warheads to those predicted using the static arena file
    - Static event – no projectile velocity, *serves as a baseline*
    - Dynamic event - incoming velocity will be applied

TEST ARTICLES

- 105mm HEP round
  - inventory since 1970s
  - new Z-data file recently produced
- Metallic Witness panels

Joint Live Fire
Ground Systems

Statically detonated from Platform

One side of Panel Arrangement

TEST OVERVIEW

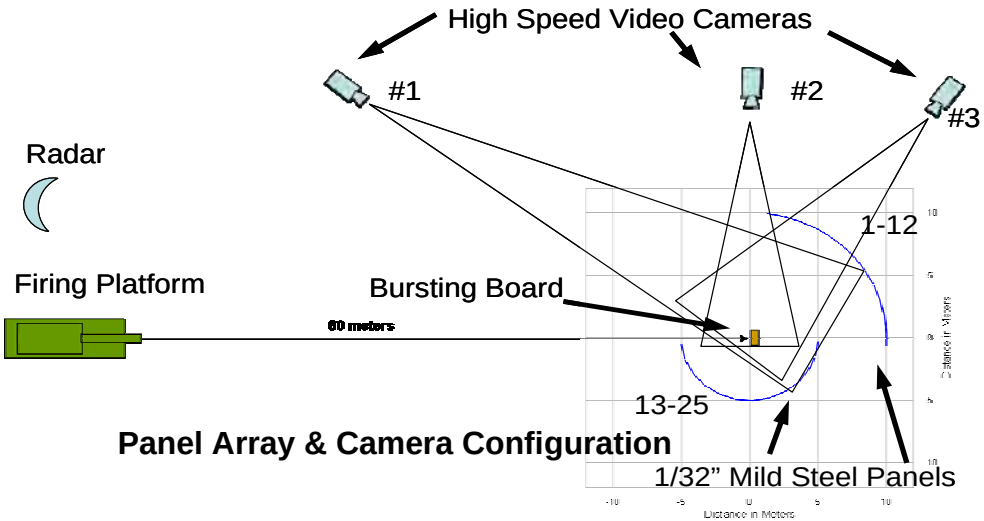
Joint Live Fire
Ground Systems

Test Setup:

- Collect fragmentation with metallic panel array in “arena”
- Dynamic – fire 105mm HEP projectile through wood to detonate
- Static – statically detonate HEP projectile

Measurements:

- Panel array surveyed prior to test
- Photograph panels, use image software to record position of impacts
- Dynamic – use radar and video to determine impact velocity and location of warhead when it burst



Panel Array & Camera Configuration

TEST RESULTS - STATIC

Joint Live Fire
Ground Systems

TEST RESULTS - DYNAMIC

Joint Live Fire
Ground Systems

R FOCUSED.

TEST RESULTS

Joint Live Fire
Ground Systems

Test Number	Detonation Condition	Velocity Muzzle/Striking (m/s)	Test Objective	Result
1	Dynamic	LOST	Verify fuze function on the selected target material.	Proper fuze function
2	Dynamic	759 / 746	Verify fuze function on the selected target material	Proper fuze function
3	Dynamic	763 / 751	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
4	Dynamic	758 / 744	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
5	Dynamic	758 / 747	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
7	Dynamic	754 / 744	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
8	Dynamic	762 / 749	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
9	Static	N/A	Collect static distribution of fragments from the witness panels	Distribution Collected
11	Static	N/A	Collect static distribution of fragments from the witness panels	Distribution Collected

All Evaluated a 90º Attack Angle and 0º Azimuth

TEST RESULTS

Joint Live Fire
Ground Systems

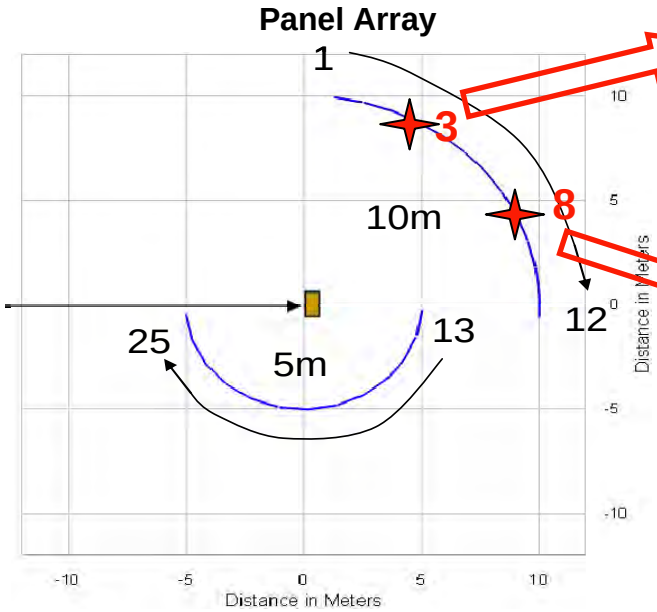
Test Number	Detonation Condition	Velocity Muzzle/Striking (m/s)	Test Objective	Result
2	Dynamic	774 / 761	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
3	Dynamic	761 / 749	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
4	Dynamic	759 / 746	Collect dynamic distribution of fragments from the witness panels	Distribution Collected
5	Static	N/A	Collect static distribution of fragments from the witness panels	Distribution Collected
6	Static	N/A	Collect static distribution of fragments from the witness panels	Distribution Collected

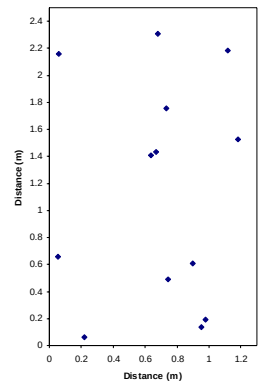
All Evaluated a 90^{o} Attack Angle and 0^{o} Azimuth

DATA REDUCTION

Joint Live Fire
Ground Systems

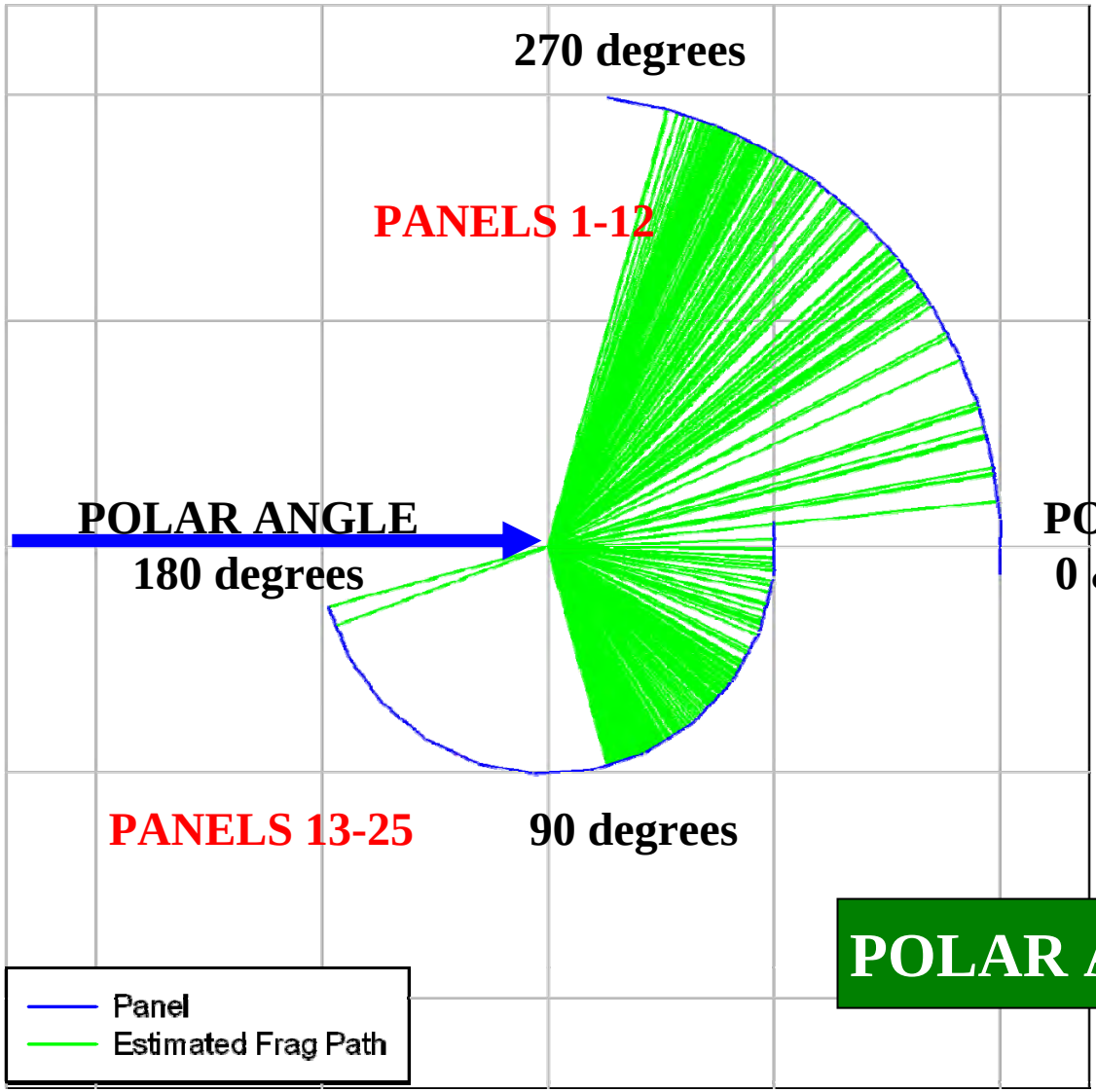
Dynamic shot





PREDICTED FRAGMENTATION

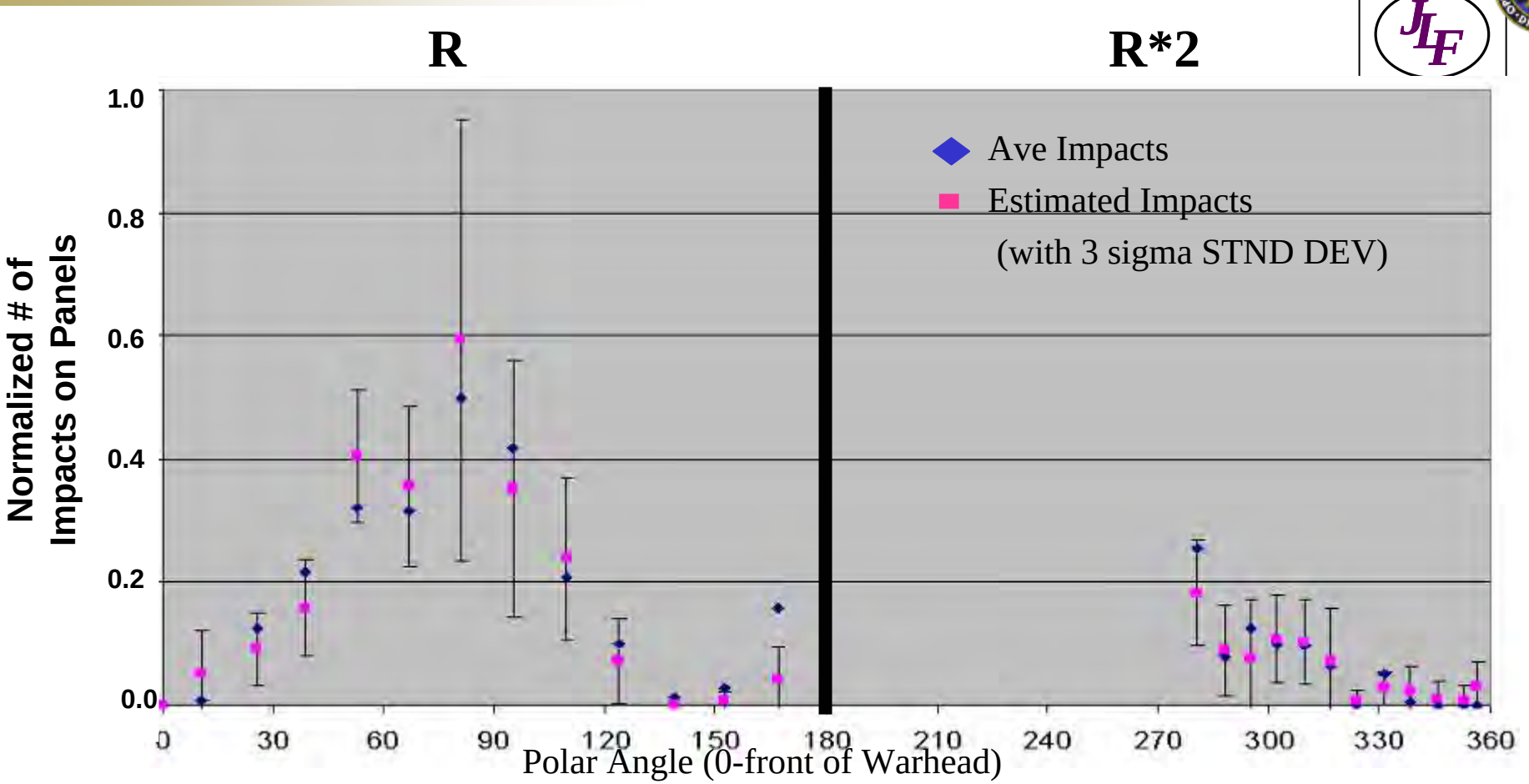
Joint Live Fire Ground Systems



ACTUAL PANEL

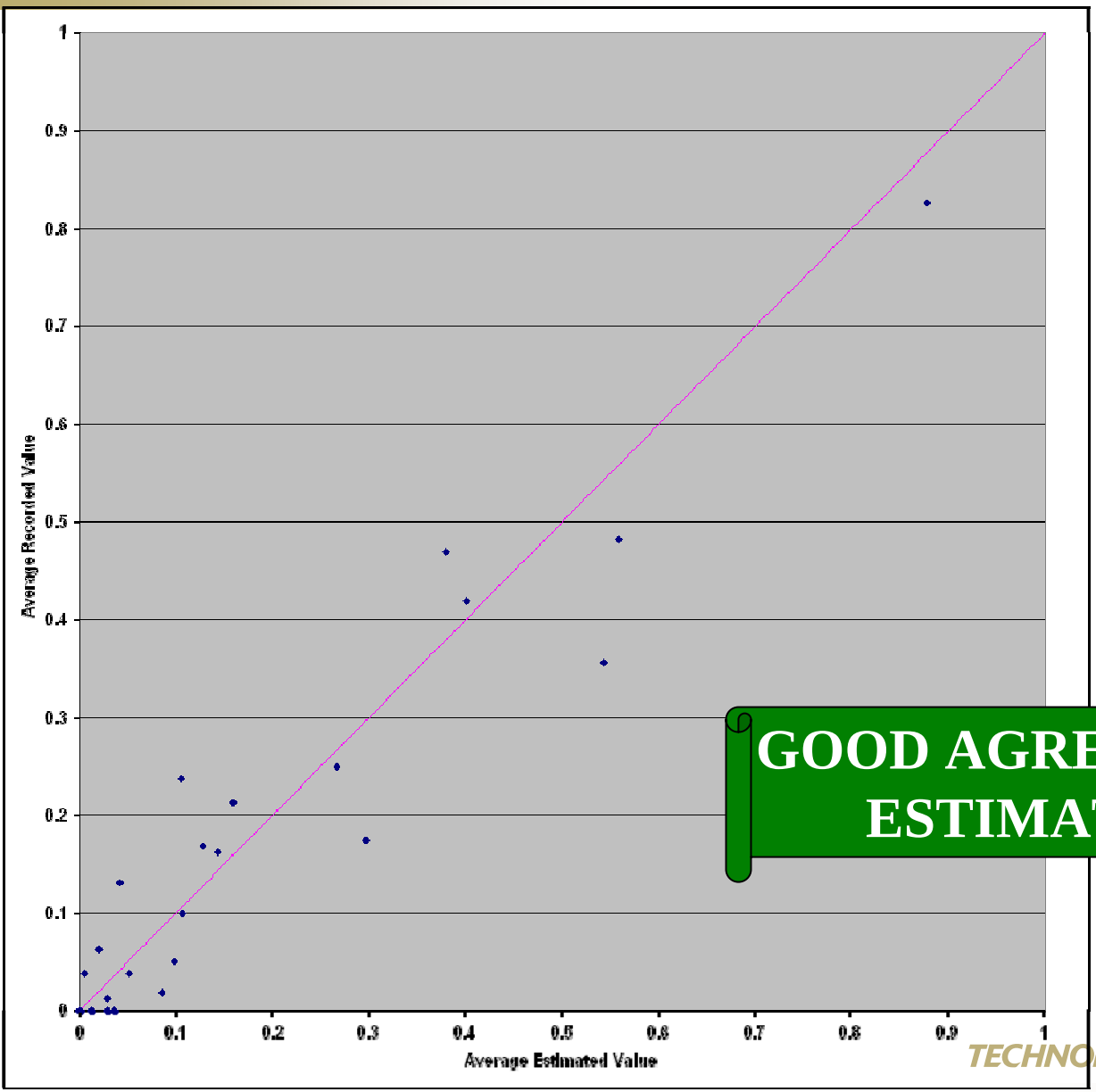
POLAR ANGLES DEFINED

STATISTICAL ANALYSIS (STATIC)



STATISTICAL ANALYSIS (STATIC)

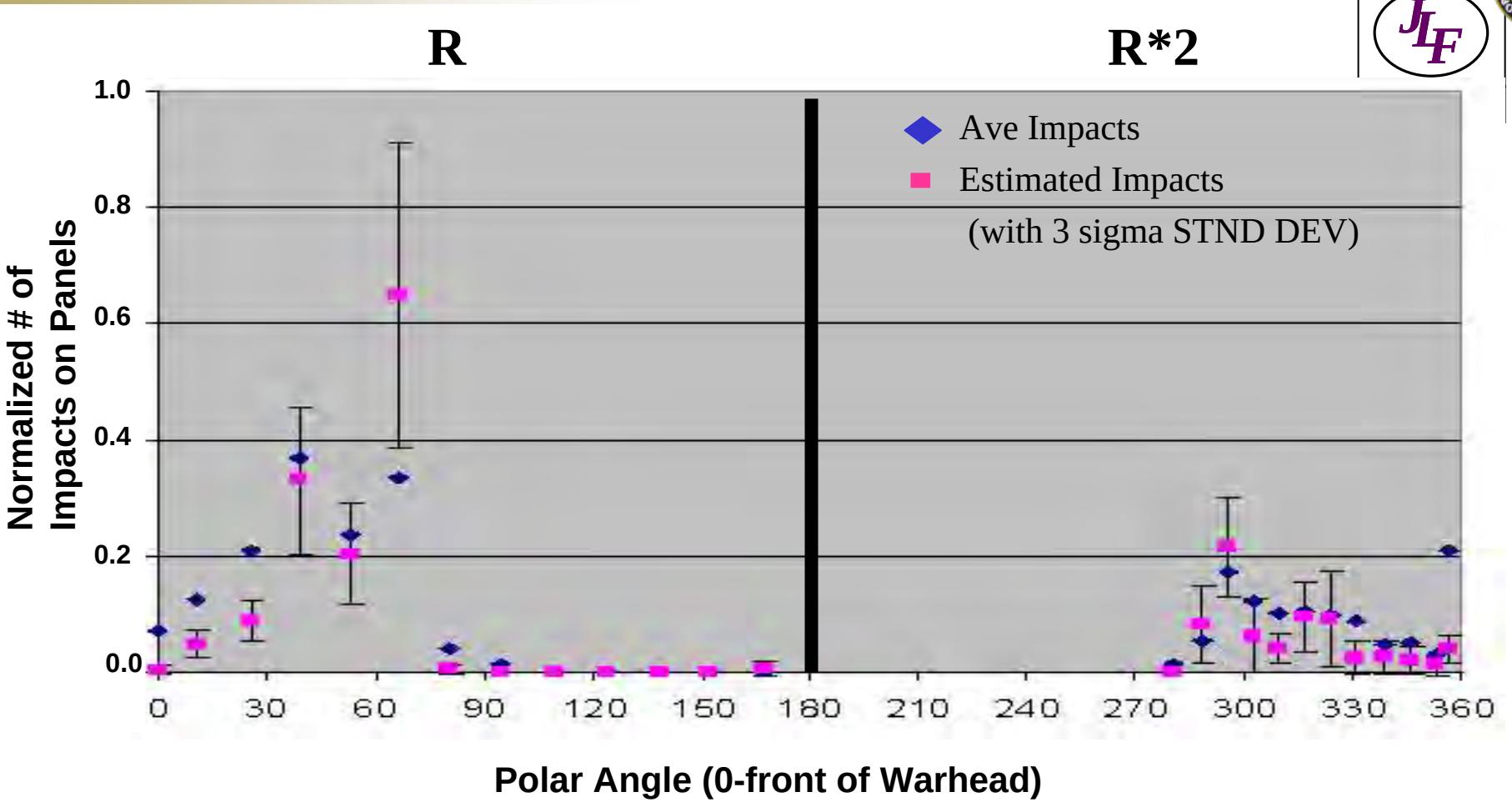
Joint Live Fire Ground Systems



Good Correlation Between the Mean Static Estimate and The Mean Recorded Value.

GOOD AGREEMENT BETWEEN ESTIMATED & ACTUAL

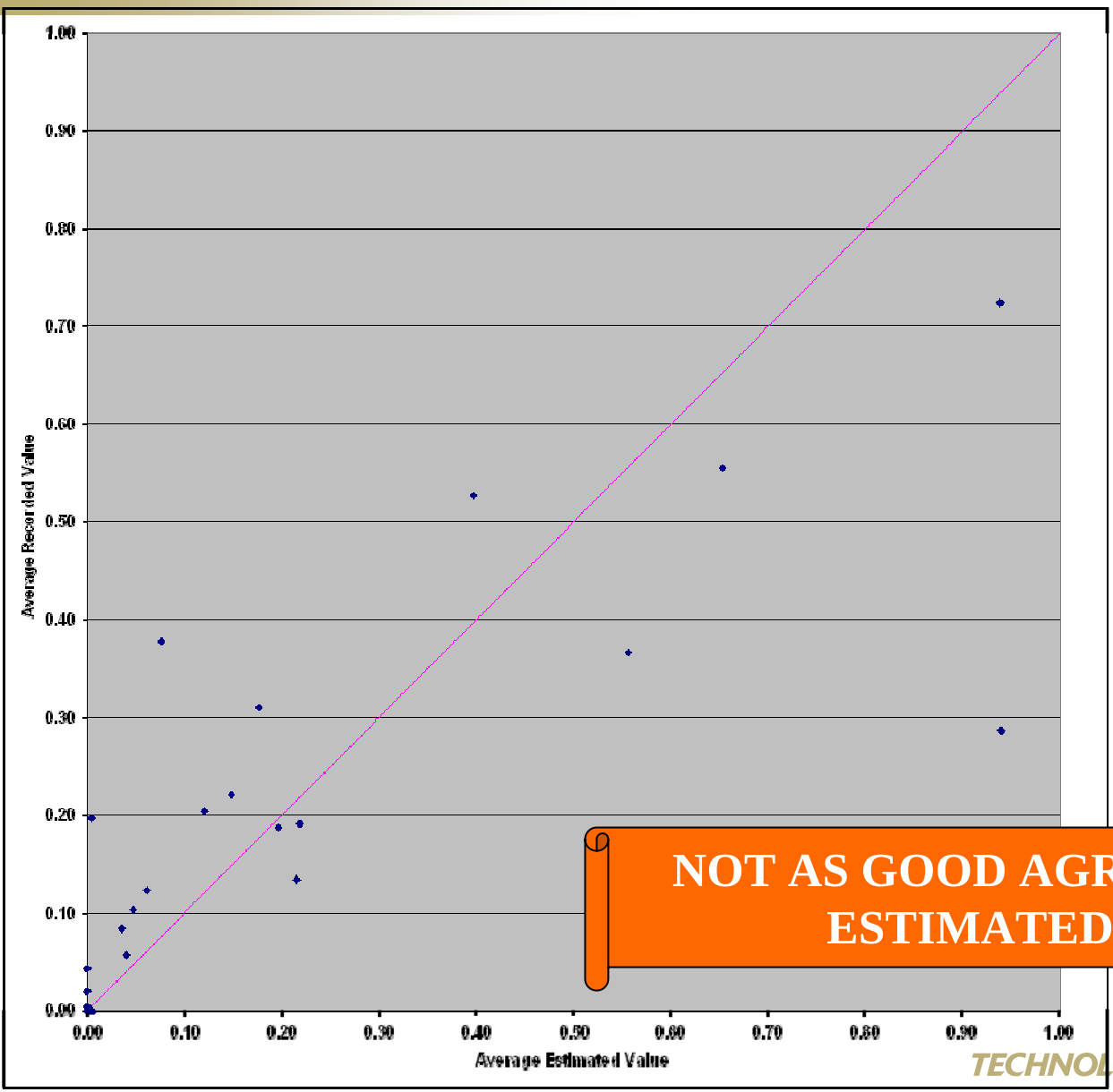
STATISTICAL ANALYSIS (DYNAMIC)



STATISTICAL ANALYSIS (DYNAMIC)

RDECOM

Joint Live Fire Ground Systems



Overestimate of fragments in the beam spray.

Underestimate of fragments in the nose and tail regions.

NOT AS GOOD AGREEMENT BETWEEN ESTIMATED AND ACTUAL

SUMMARY

Static evaluation - good agreement

Dynamic estimates show less fragments in the front

Implications of differences in results

- Interaction of warhead expansion with wood during the dynamic detonation
- Parasitic debris from warhead is hitting panels in front for dynamic event
- Accuracy of fragment velocities of Z-data file more of an effect on dynamic event
  - *May need a new format for Z-data (3-dimensional)*
- Need to evaluate other warheads under same controlled conditions to prove theory

CONCLUSIONS

Joint Live Fire
Ground Systems

Method collects data over a much larger range than previously gathered for dynamic events

This wider area results in a much greater confidence in verifying performance of fragmenting warhead

Review Current Z-data (arena) methodology

SUGGESTIONS:

1) Add metallic witness panels on “Live-Fire” evaluations
2) Include an intermediate evaluation with metallic witness panels prior to “Live-Fire” evaluations
3) Review fragmentation Evaluation methodolgy

BOTTOMLINE

DEMONSTRATED SIMPLE METHOD THAT VERIFIES THE OVERALL SPREAD OF FRAGMENTS IN DYNAMIC EVENT

OBSERVED ISSUES WITH CURRENT Z-DATA FILE METHODLOGY

QUESTIONS ????

Gun and Missile System 2008 Symposium

Unmanned and Autonomous Systems Weapon System Integration

Ground and Air System Platforms

Panel Discussion

23 April 2008

Panel Topic Theme

• **Enabling—System Integration, Operational Readiness, and Warfighter Application of:**

• **Unmanned and Autonomous Systems**
Weapon System Integration

•**Ground and Air Platforms**
Ground Robotic Systems (GRS)
Land and Sea
Unmanned Aircraft Systems (UAS)

• ***Challenges, Needs, Solutions, Opportunities***
Ensuring Integrated Systems
And
Realizing Operational Capability

Panel Objectives

- **Identify and Examine DOD and Industry Requirements, Needs, and Challenges to Enable Weaponized GRS and UAS Systems**
  - **Legal and Related Considerations**
  - **Requirements**
  - **Technologies**
  - **System Integration**
  - **Safety**
  - **Concept of Operations (CONOPS)**
  - **Risks**

- **Assess Status of System Development/Deployment Readiness**
  - **Success Demonstrated/Applied—Barriers Identified**

- **Identify Path Forward —Challenges-Technologies--Integration**
  - **DOD**
  - **Industry**

Panel Format and Process

- **Panel Opening Comments/Format Description** — **Moderator**
- **Panel Member Remarks** — **Each Member**
- **Panel Dialogue—Lead by Moderator** — **All**
- **Questions from Attendees** — **Panel Members**
  - **Written Questions**
  - **Open Format Questions (As Time Permits)**
- **Concluding Summary Comments** — **Panel Members**
- **Wrap-Up Summary** — **Moderator**

Panel Members

• Dave Broden	Moderator	Broden Resource Solutions LLC
• Robert Fondren		NSWC-Dahlgren
• Kim Jones		US Army--Picatinny-ARDEC
• Ed Hackett		iRobot EH Group

Panel Members

• Ricky Houghton	Ibis Tek
• Adrian Erkenbrack	Foster Miller Defense Technology Solutions
• Charlie McCullough	BAE Systems
• Jim Krafcik	USAF Eglin AFB

Topic Categories

- ***Integration Challenges—***
  - **The Evolving Requirements**
  - **Establishing Programs and Priorities**
  - **Funding**
  - **Matching Platforms and Technology for Capability**
  - **Linking the Technology and Resources---*Collaboration***
    - **Platforms**
    - **Integration Resources/Capability**
    - **Manufacturing**
    - **Technology**
  - **Realizing the Needed Innovation and New Technology etc.**
  - **Evolving Operational Critieria --CONOPS**
  - **How Can Resources be Captured/Shared/Applied to Meet DOD Needs and Industry Business Objectives**

    - Data Rights Considertions

Robotics Companies Establishing National Ground Robotic Consortium

Topic Categories

- **System Integration Approach and Criteria**
  - **What are the Drivers for System Design/Performance?**
    - ***Requirements Driven Pull***
    - ***Vs.***
    - ***Technology Push***

- **Role of Industry and Government In Defining/Selecting:**
  - **Requirements Pull vs. Technology Push**
    - **Innovation— "Making it Happen"**
    - **System Design**
    - **Technology**
    - **System Integration**

Topic Categories

- **DOD Requirement Evolution and Status:**
  - **Status of Requirements:**
    - **Ground Robot Vehicle Systems (Ground and Sea)**
      - **Weaponized Systems (Armed)**
    - **Unmanned Aircraft Systems**
      - **Weaponized Systems (Armed)**
  - **DOD Priorities for GRV's and UAS's**
    - **Defined or Evolving?**
  - **Program Focus**
    - **FCS**
    - **Service Mission Specific**
    - **Joint vs. Specific Service etc.?**
    - **Other**

Topic Categories

- **Unmanned And Autonomous Weaponized Platform Status**
  - **Ground Robotic Systems (GRS)**
  - **Unmmanned Aircraft Systems (UAS)**
- **Requirements and Initiatives—Opportunities**
- **Legal and Related Considerations**
- **Weaponized Platform Characteristics —Size—Weight etc.**
- **Weapon Capabilities and Characteristics**
  - **Missiles**
  - **Cannons**
  - **Other**
  - **Munitions Required**
  - **Lethal vs. Non-Lethal**

Topic Categories

- Weapons Available for Integration vs. Unique "New" Weapons?

- System Integration Considerations
  - Technologies
  - Barriers
  - Risks

- Command and Control Links
  - Sensors—Sensor Resolution—Capture Details
    Video, IR, Fusion etc.
  - Communication
  - Data Links—Content—Transfer Needs/File Size/Data Rate
  - Man in Loop Control

- System Integration Status

Topic Categories

- **Safety Assessment Factors—**
  - **Review/Approval Process**
  - **Design/Performance**
  - **Operational**
  - **Collateral Damage**

- **Situation Awareness**
  - **What is Required etc,**

- **Coordinated Missions**
  - **Apache plus UAS**
  - **Bradley plus GRS**

- **Concept of Operations (CONOPS)**
  - **Mission Flexibility**
  - **Surveillance and/or Lethal**
  - **Recon**
  - **Other**

Topic Categories

- **Barriers**
  - **Technology**
  - **To Development**
  - **To Application**

- **Opportunities**
  - **Technology**
  - **System Integration**
  - **Production**

- **Role of Industry To Enable GRV and UAS Weaponization?**

- **Path Forward—Vision Ahead**

Panel Topics and Questions

- 1. What are DOD and Service Needs and Requirements for:
  - Armed Unmanned Platforms
    - Ground Robotic Vehicles (GRV)
    - Unmanned Aircraft Systems (UAS)
- 2. Definition and Consideration of Unmanned vs. Autonomous
- 3. Military Application of Armed/Weaponized Systems--- Legal Implications
- 4. What Initiatives are In Process for: GRV? UAS?
- 5. Comments Regarding Warfighter Use of Armed Unmanned Platforms
  - "Lessons Learned"—Proven Systems—Results—Needs
  - Who Controls the Armed Platforms—Decision Maker?

Panel Topics and Questions

- **6. What are Priority Mission Objectives—Establishing Required Weapon Capability and Type?**
  - **Weapon Types Required? Lethal vs. Non-Lethal?**

- **7. What are Weapon System Integration Challenges and Barriers?**

- **8. What Technologies Drive and Enable Engagement/Defeat Objectives?**
  - **Precision Capability**
  - **Ability to Reach Into Threat Areas**

- **9. Coordinated Capability of Manned System and Unmanned System**
  - **Apache linked to UAS**
  - **Bradley linked to GRS**

Panel Topics and Questions

- 10. What New Weapon Characteristics and Capabilities are Required?
  - Mechanisms—Type—Weight--Power
  - Lethality
- 11. What System Integration Technologies Are Required?
- 12. Unmanned Platform Command and Control Links:
  - Status
  - Barriers
  - Decision Maker—Who—Where—Links etc.
  - Needs
  - Issues
- 13. Type and Size of Unmanned Platforms for Weaponization?
  - GRS
  - UAS
  - Small vs. Larger or Mix?

Panel Topics and Questions

- **14. Operational Benefits of Armed/Weaponized Unmanned Platforms**

- **15. Is Low Collateral Damage Realized?**

- **16. Safety Assessment Related to Unmanned System Integration and Operational Application**

- **17. Address Multi-Mission Capability and Flexibility:**
  - **“Surveillance Balanced with Quick and Precision Strike”**
  - **“Find, Fix, Finish” –Operational Implications and Benefits**

- **18. Operational Training**

Panel Topics and Questions

- 19. Weapon Lethality Capability—Type
  - Lethal vs. Non-Lethal

- 20. System Integration Considerations
  - Requirements Pull
  - Vs.
  - Technology Push

- 21. Weapon Integration, Capability, and Sensor Range Relative to Operational Criteria and Rule of Engagement (Legal etc.)

- 22. How does Situation Awareness Capability Drive Weaponized GRV and UAS System Integration and Application?

Panel Topics and Questions

- **23. Requirement and Challenges for Unmanned Water Craft**

- **24. Weaponization Considerations**
  - **Integration of Existing Weapon Systems vs. Development of New/Unique for Unmanned Systems**
    - **Technical Factors**
    - **Logisitics and Supportability**
    - **Schedule**
    - **Cost**
    - **Benefits**

Symposium Attendee Questions

- **Written Questions Prepared During Panel Member Remarks**
  - **Moderator will Select and Ask Questions**

- **Open Format Questions From Attendees**
  - **Following Written Questions**

Wrap-Up Comments

- **Panel Members Present Wrap-Up Remarks**
  - ***Identify Top 2-3 Focus Priorities***

- **Focus on Key Topics**
  - **Benefits of Weaponized Unmanned Platforms**
  - **Challenges**
  - **Barriers**
  - **Opportunities**
  - **Key Programs**

- **DOD and Service Objectives, Focus, and *Plans—Challenge and Opportunity for Industry***

- ***Industry Focus Thrusts to Enable Weaponized Unmanned Capability Objectives***

Closing Remarks---Technology/Integration/Application

- **Moderator Summary Comments**
- **Thank Panel Members for Participation and Candid Comments**
- **Panel Members will be Available for Discussion**
- **Panel Has Effectively Described Status of Unmanned Weaponized Systems—Indentified the Needs—Challenges and Opportunities**
- **Partnership of DOD and Industry is Key to Evolving the Capability**
- **NDIA Offers a Forum for Exchange of Information and Networking to Enable Technology and System Integration Ensuring Superior Capability and Readiness.**

Closing Remarks---Looking Ahead

- **Opportunities for Gun and Missile Community**
  - **Ground Robotic Vehicles**
  - **Unmanned Air Systems**

- **Focus on Innovation and Systems Integration**

- **Ground Robot Consortium is Being Formed**
  - **Linking the Robotic Community**
    - **Gun and Missile Community will be Complementary**

- **Collaboration of Gun and Missile Committee/Armament Division and Robotics Division –**
    - **Demonstrates Effective Leverage of Related Division Benefiting Membership/Attendees**
    - **Future Symposia will Expand Collaboration**

BAE SYSTEMS

Effectiveness of Technology for the Warfighter

A Global Approach

JB Burns, VP BAE 23 April

BAE SYSTEMS

THE GOOD, THE BAD AND THE UGLY

Warfighter's Issues Dealing with Technologies

- **Time to Fielding**
- **Usability**
- **Training**
- **Robustness**
- **Cost**
- **Modeling and Simulation**
- **Requirements and "Creep"**

1. TECHNOLOGICAL ADVANTAGE IS OUR STRENGTH, BUT TRANSITORY…

2. ASSYMETRIES – ROCK PAPER SCISSORS

BAE SYSTEMS

CUSTOMERS COUNT…LISTEN

- **Systems seldom work the way they were intended**
- **Warfighters change their minds….discover problems / improvements / new employments**
- **Technologist and warfighters talk different languages**
- **Classified data stands in the way of agility…protect the data or protect the war fighter?**
- **A relook of Depots and Arsenals and Govt R&D will probably render the same outcome**

WE ARE WHERE WE ARE……

BAE SYSTEMS

WHEN IT WORKS RIGHT

MRAP

Mine Roller

Excalibur

Naval Guns

AGS, Mk 57, Mk 38

BAE SYSTEMS

Protecting Those Who Serve: U.S. Army RG31in Iraq

“About two weeks ago I was riding in the front passenger seat of the RG-31 when an I.E.D. went off right underneath my seat, it was anywhere between 2 - 4 Anti tank mines, the blast took out the whole road, and messed up the RG pretty good. When I came to, I grabbed all my vital parts. Once I knew I was intact I yelled out “This Fu@#%! Sh*# Worked." I was so happy to be alive, surely it would be a different story if I was in a hummve”*

Corporal Benjamin (Ben) Wasson
Crewmember

BAE SYSTEMS

Protecting Those Who Serve: Canadian RG31 in Afghanistan

Crew survived with minor injuries

BAE SYSTEMS

Protecting Those Who Serve: Afghanistan 27 September 2006

Canadian RG31 Mk5 APC attacked by a suicide bomber in a pick-up

Scoreboard

RG31: 1 Bomber: 0

BAE SYSTEMS

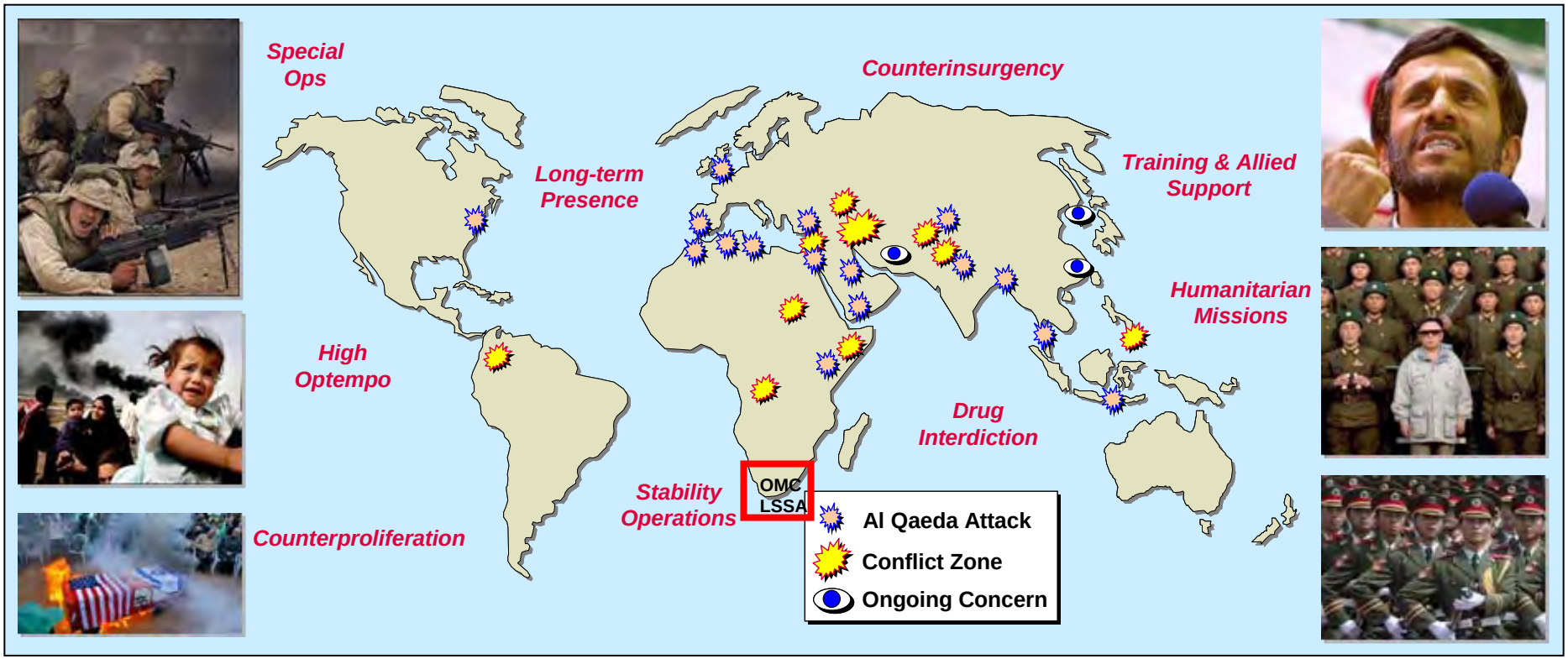
What's Next?

- **The Future of Guns and Missile Technology in the Hands of the Warfighter**
- **Defense Industrial Base…WHAT DID WE LEARN FROM A WAR TIME SURGE**
- **A Global Economy, with Dependencies on Foreign suppliers and the like**
- **Off the Shelf….Transferrence of Risk to the Provider**

AND THE IMMUTABLES…….

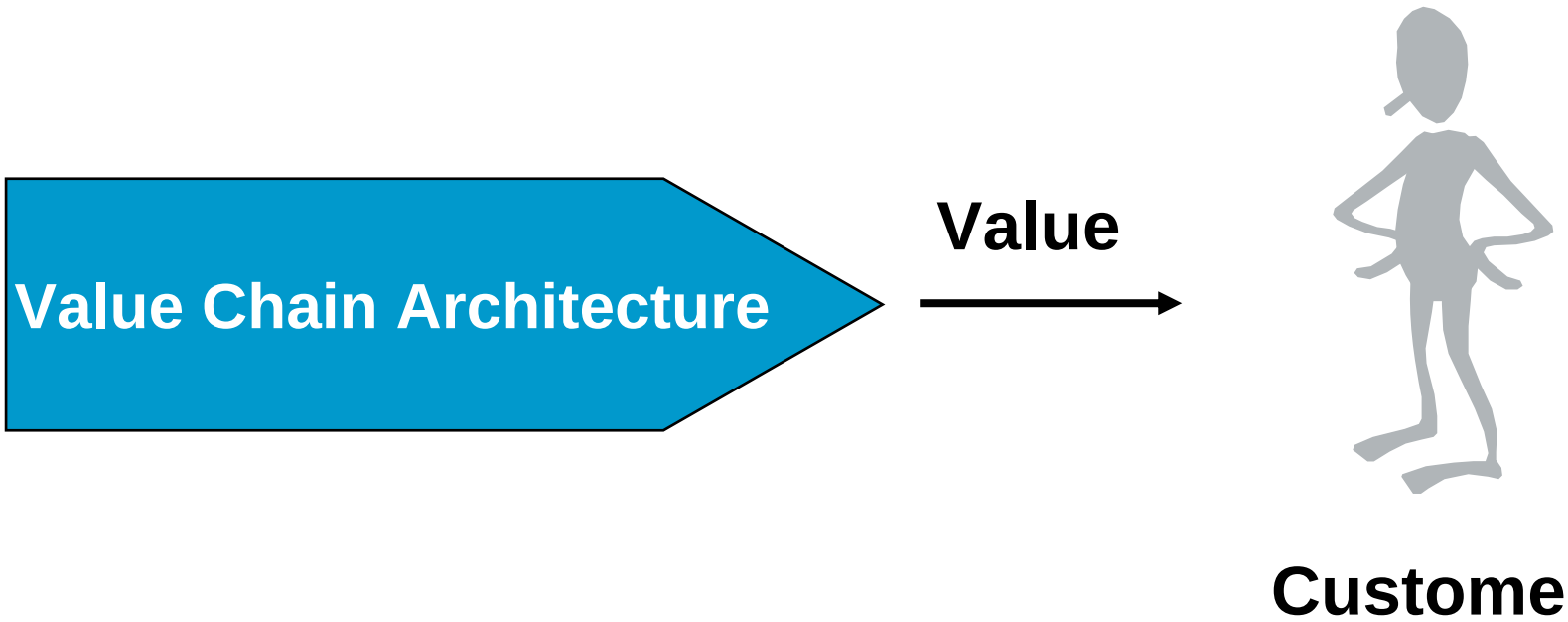
BAE SYSTEMS

THE WORLD IS A DANGEROUS PLACE



BAE SYSTEMS

FOCUS ON THE CUSTOMER



DEFENSE ACQUISITION IS GONNA CHANGE ……(AGAIN)

BAE SYSTEMS

Rapid Acquisition

Off the shelf/short development

Quick response

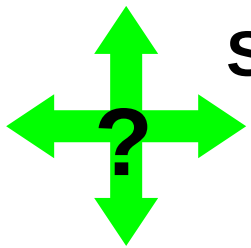
COCOM centric

Long cycle acquisition

Tech development

Platform oriented, limited production

Service centric



Install “black boxes” in existing equipment to improve and plug into network

Large, horizontal networks

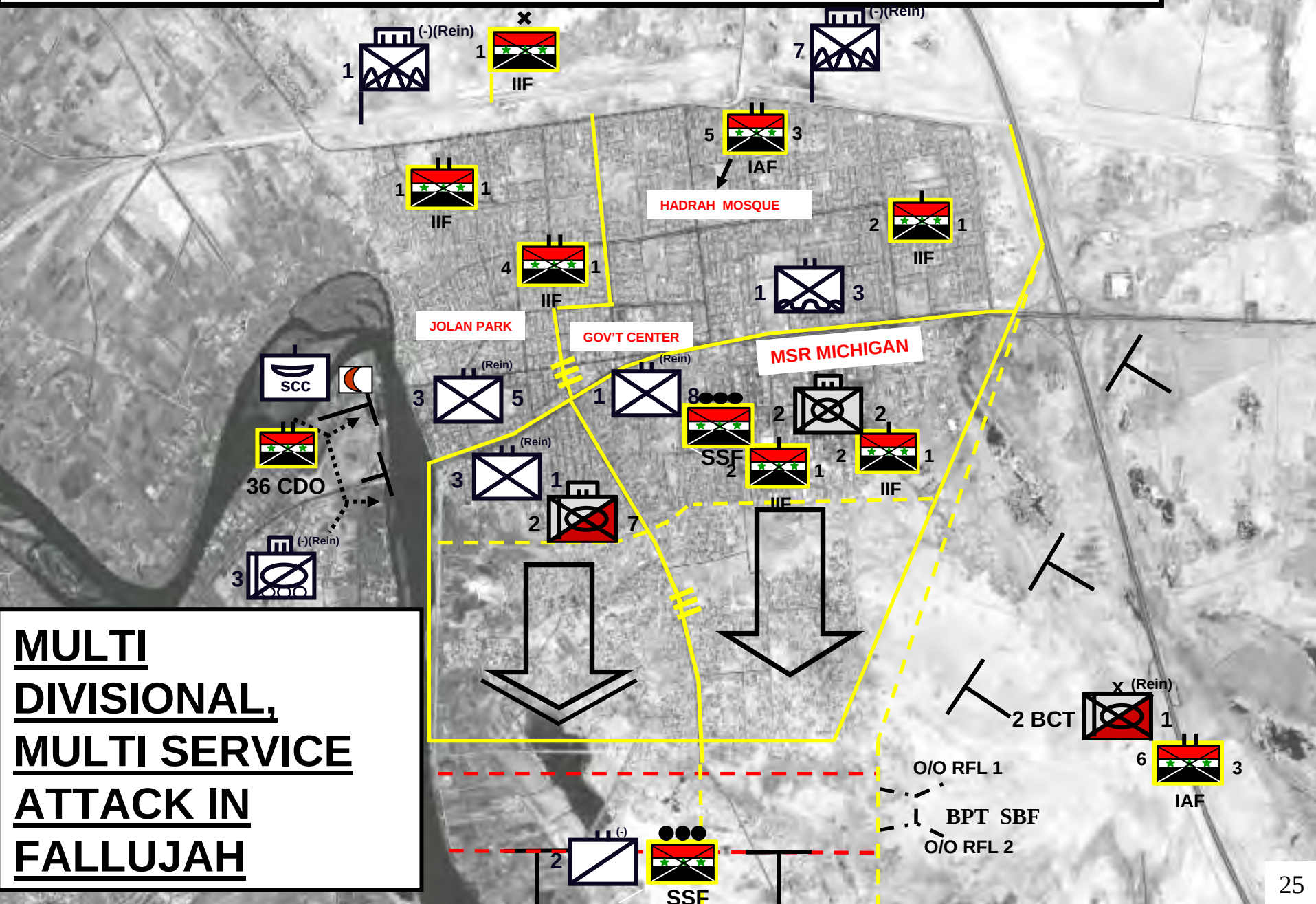
Leveraging of IT revolution

Jointness

END TO END? PRECISION?

Source: CSIS

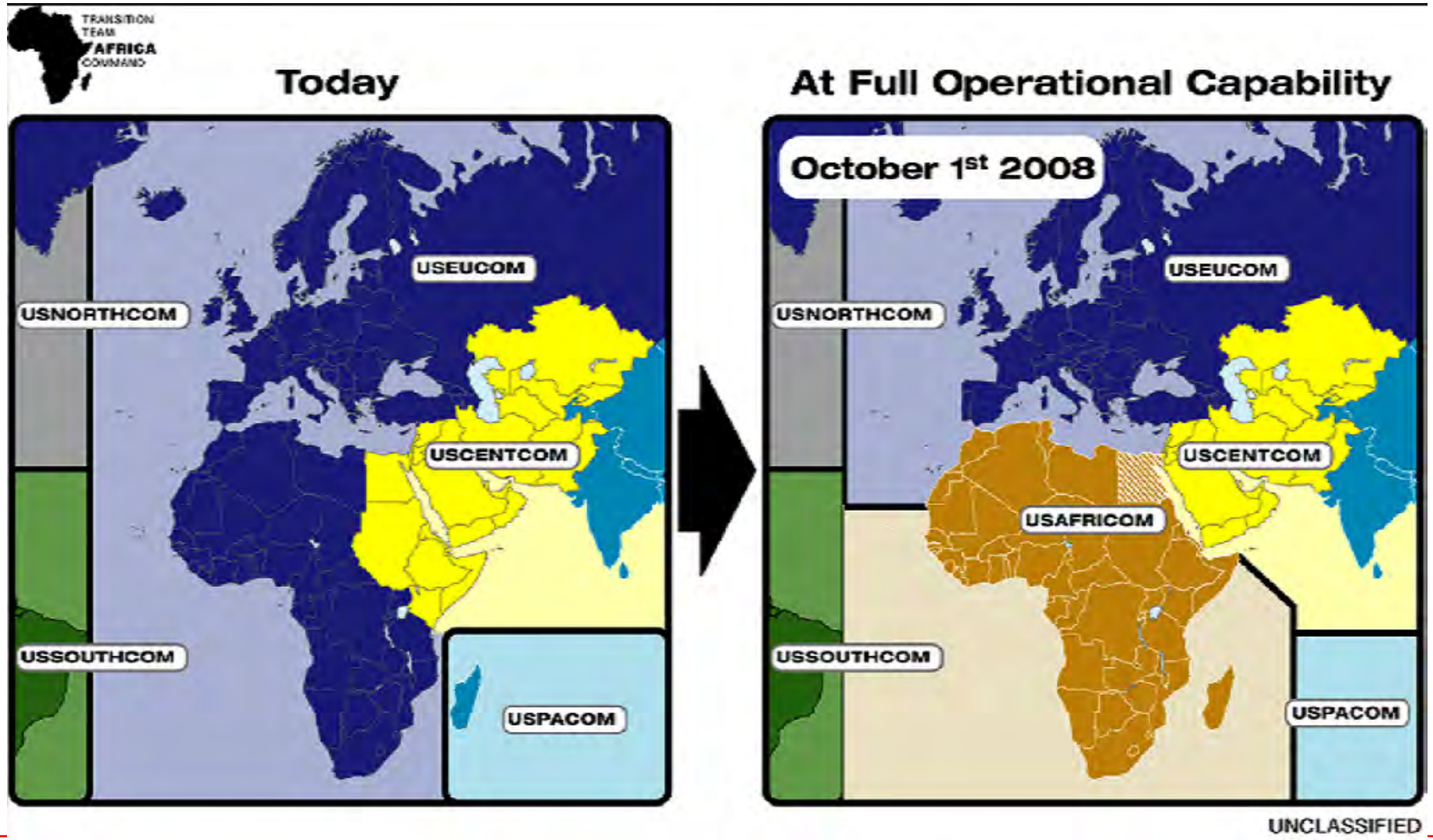
WAR FARE & THE FOE ARE CHANGING



MULTI DIVISIONAL, MULTI SERVICE ATTACK IN FALLUJAH

THE WAR FIGHTING CUSTOMER IS CHANGING

BAE SYSTEMS



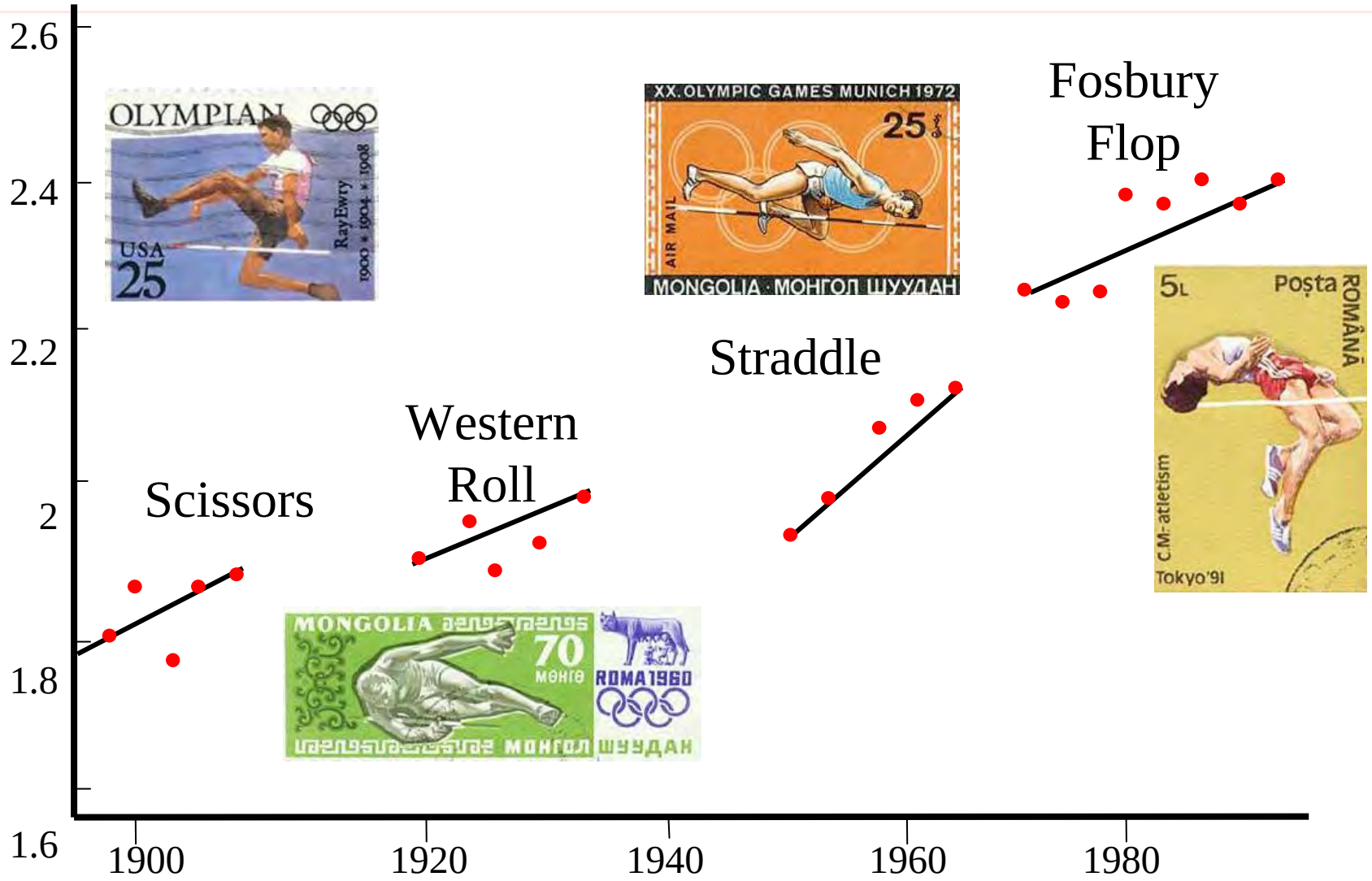
A Thought For Today

BAE SYSTEMS

The definition of insanity is doing the same thing over and over and expecting different results.

- *Benjamin Franklin*

INNOVATION IS KEY



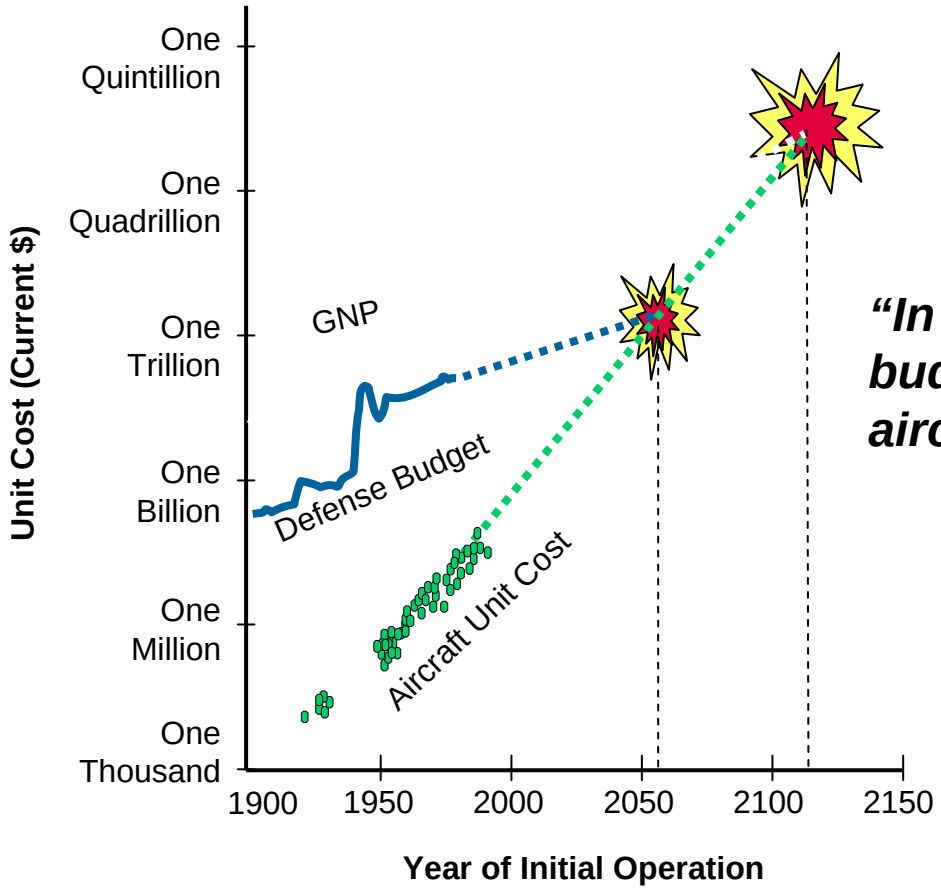
Source: Pascale

Fall 06/BAE Systems, Inc./Unclassified

BAE SYSTEMS

ADAPT TO PRESSURE ON COSTS

2



"In the year 2054, the entire defense budget will purchase just one aircraft"

Source: Norm Augustine

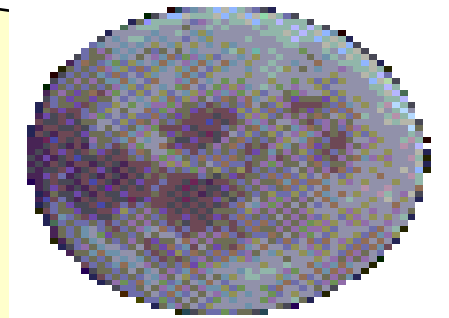
BAE SYSTEMS

BE ALERT to Innovation AND Cost Savings

BAE SYSTEMS

A CLEAR VISION IS HARD TO COME BY

"We will put a man on the moon and bring him back before the end of this decade."

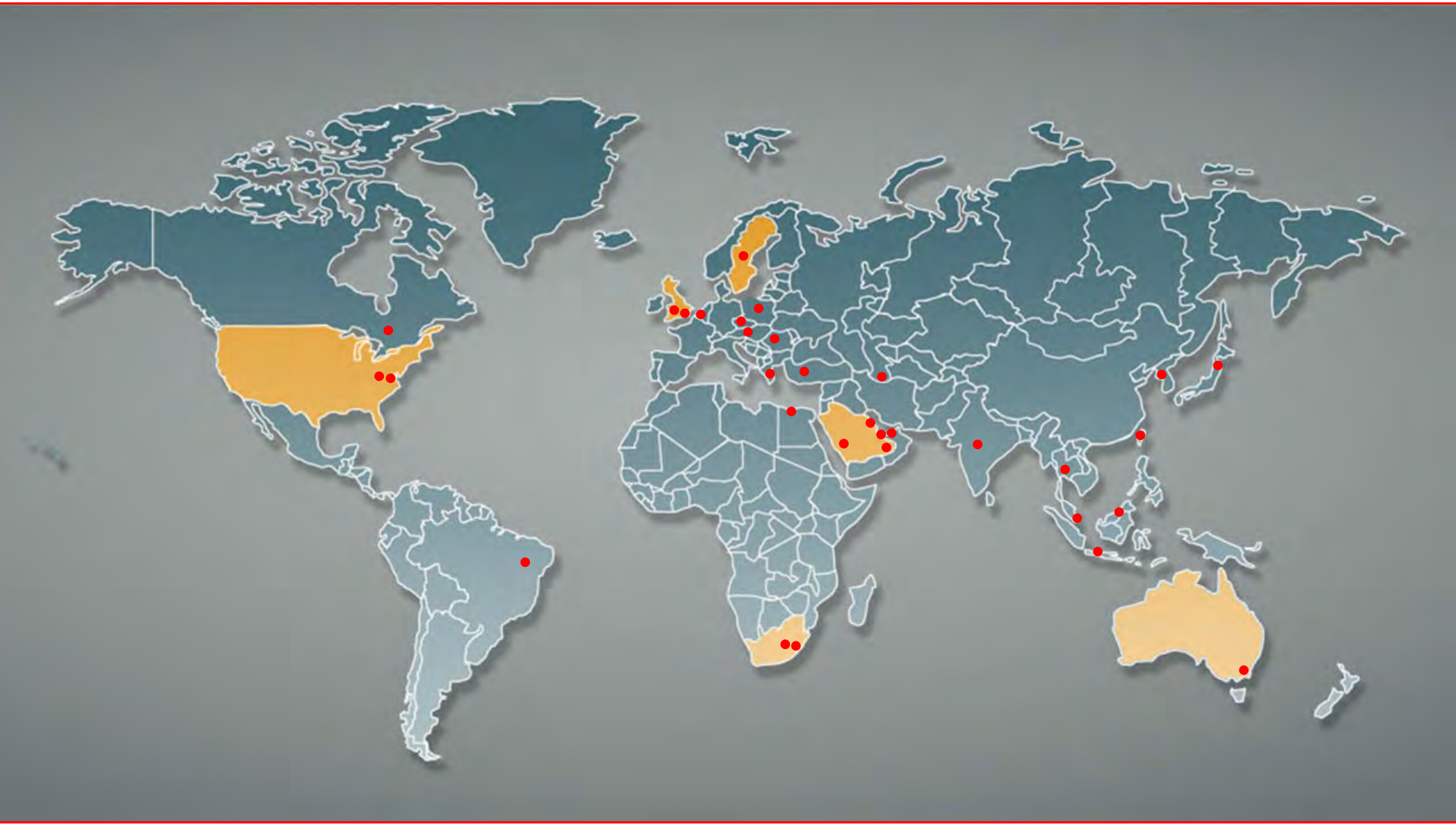


John F. Kennedy

Fall 2008/BAE Systems, Inc./Unclassified

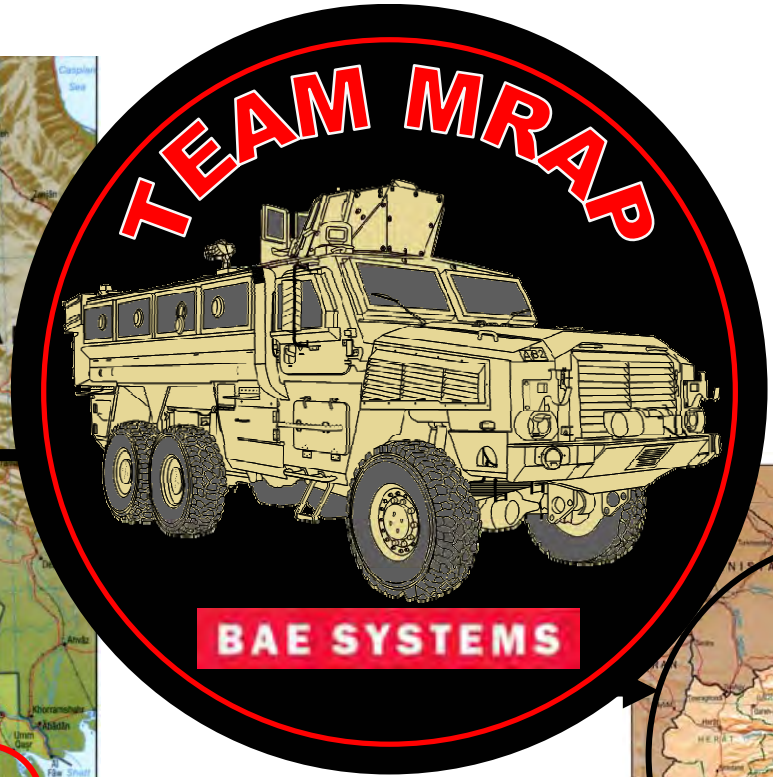
BAE SYSTEMS

THINK AND ACT AND BE GLOBAL



BAE SYSTEMS

GO WHERE THE CUSTOMER GOES

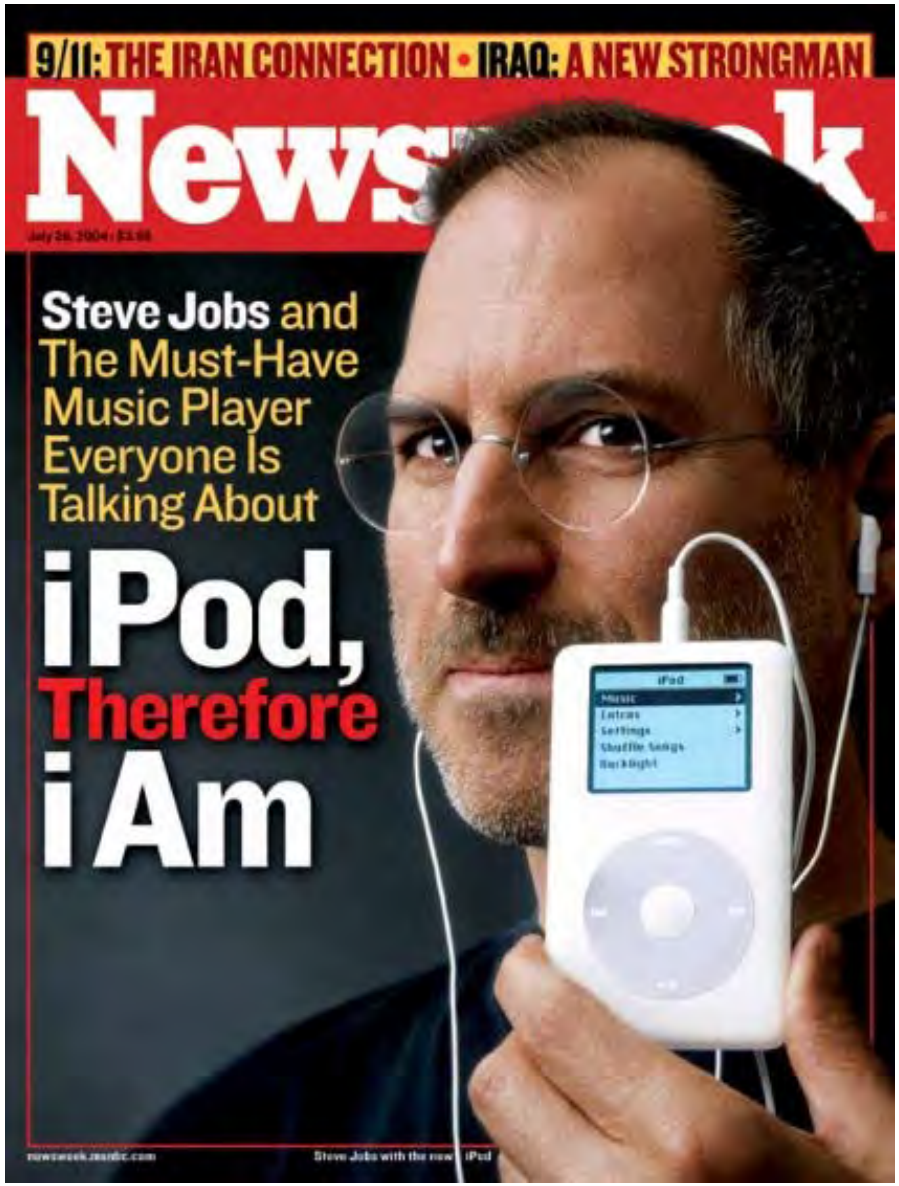


Fall 06/BAE Systems, Inc./Unclassified

BAE SYSTEMS

Leadership Challenges

- Too much focus on short-term performance
- Strong silo mentality
- Lack of a climate for risk taking
- Not embedding innovation as an organizational capability
- Lack of a global mindset


9/11: THE IRAN CONNECTION • IRAQ: A NEW STRONGMAN
Newsweek
Steve Jobs and The Must-Have Music Player Everyone Is Talking About
iPod, Therefore i Am
iPod
Music
Extras
Settings
Shuffle Songs
Backlight

BAE SYSTEMS

BACK UPS

BAE SYSTEMS

BAE Systems – A leading defense company with a commanding breadth of capabilities

Army and Marine Corps are receiving greater attention than other services due to dominant warfighting roles in Iraq and Afghanistan

- **Army**
  - THE GLOBAL WAR ON TERROR
  - AND MODERNIZATION WITH BIG TICKET ITEMS
    - FCS
    - HBCT
    - STRYKER
    - TRUCKS
    - RESET
    - BRAC
- **Marine Corps**
  - THE GLOBAL WAR ON TERROR
  - AND MODERNIZATION WITH BIG TICKET ITEMS
    - EFV
    - OSPREY
    - TRUCKS
    - RESET

BAE SYSTEMS

BAE Systems, Inc. – our global presence

BAE SYSTEMS

Global War and Business Models

The Top 10 Things You Can Do With a Dead Horse

10. Whip the horse a little harder.

9. Change the rider.

8. Harness several dead horses together for increased speed.

7. Emulate the best practices of companies riding dead horses.

6. Proclaim that it's cheaper to feed a dead horse.

SOURCE: *Net Ready*, Hartman & Sifonis with Kador

5. Affirm that “This is the way we have always ridden this horse.”

4. Declare that “This horse is not dead.”

3. Have the lawyers bring suit against the horse manufacturer.

2. Engage a consultant to study the dead horse.

1. Promote the dead horse to a senior management position.

SOURCE: *Net Ready*, Hartman & Sifonis with Kador

BAE SYSTEMS

Where I'm Coming From

- **Pertinent USA Career**
  - **34 years in Joint and Army commands**
  - **JTF commands in two fights**
- **Position / Responsibilities @ BAE**
  - **4 years with ARMY NAVY and MARINE Programs**
  - **Global company**

  ….with insights in supporting a Nation,

  and an Industry at war
- **Recent Interchange with Warfighter**
  - **Two Trips to IRAQ and KUWAIT and JORDAN**
  - **Frequent interface with MODs in four countries**

Transmission of Data Message through Contact Type Fuze Setter

NDIA 43rd Annual Armament Systems:
Gun and Missile Systems Conference & Exhibition

April 21-24, 2008

Ki-Up CHA

5th R&D Center, Agency for Defense Development, Korea

Phone : (82)42-821-3141
E-mail : undersea@add.re.kr

Jong-Do KIM

R&D Center, S&T Dynamics, Korea

Phone : (82)55-280-5521
E-mail : kimjd@hisntd.com

Agency for Defense Development

S&T Dynamics

Introduction

□ K21 development program

✓ from armored personnel carrier to infantry fighting vehicle

K21[*1)]

K200

***1) K21 : Korean Infantry Fighting Vehicle**

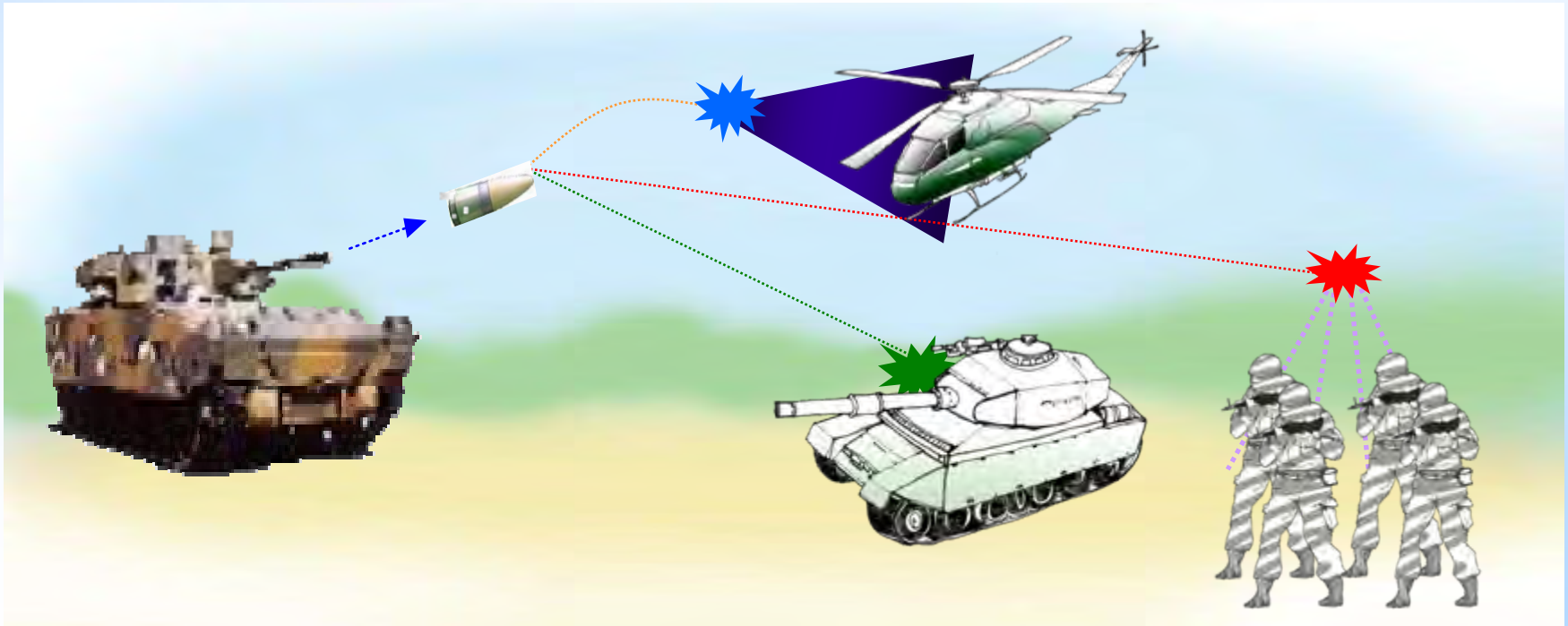
***2) MMFA : Multi-Mode Fused Ammunition**

✓ Specifications

Model		K21	K200
Armament	main	40mm	12.7mm
	secondary	7.62mm	7.62mm
Crew		3+9	3+9
Ammunition types		APFSDS, MMFA[*2)], HEI	-

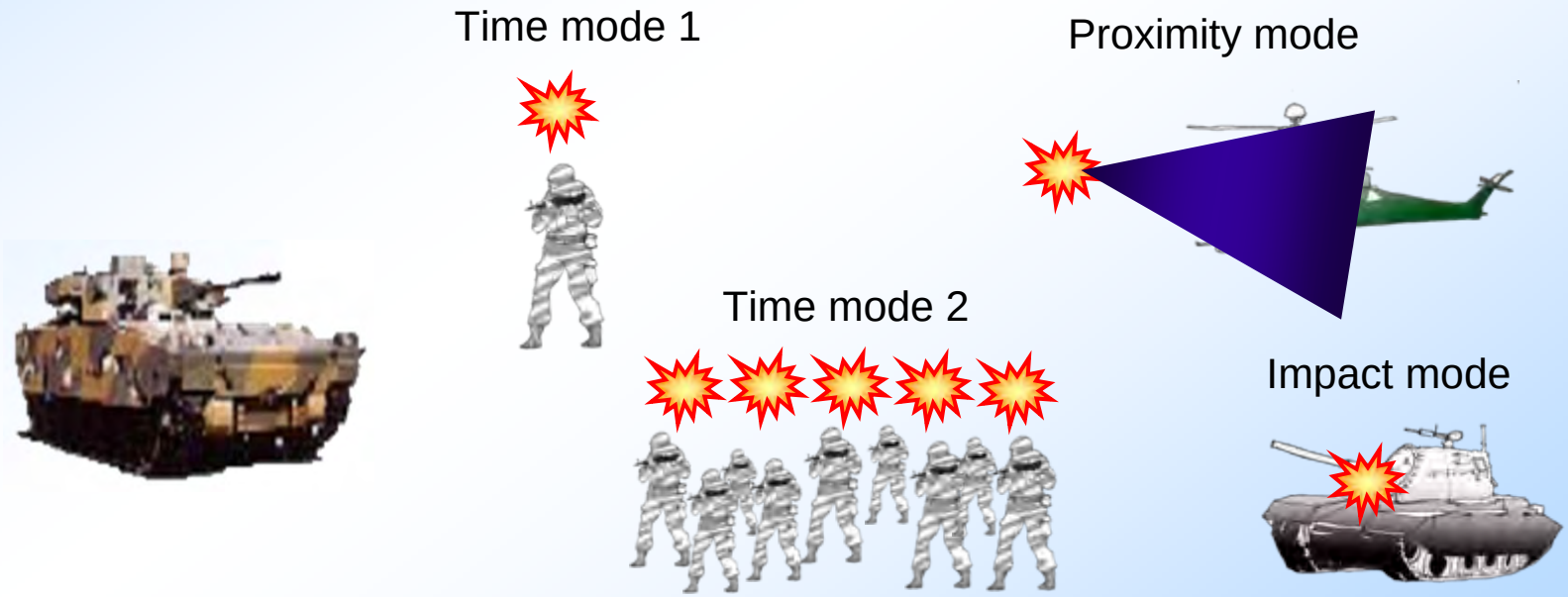
Introduction

- Necessity of MMFA
  - ✓ Threats : soldiers, light armoured vehicles, helicopters & bunkers
  - ✓ Function Modes : time mode, proximity mode & impact mode



Brief for Fuze Programming System

- Function modes of MMFA
  - ✓ Time mode 1 : accurate time function
  - ✓ Time mode 2 : increased time function
  - ✓ Proximity mode : proximity function
  - ✓ Impact mode : impact function, as default



Brief for Fuze Programming System

□ Fuze programming method

Country	Ammunition	Fuze set method	Remark
Sweden	40mm 3P*1)	Contact + HF	Contact : power
Swiss	35mm AHEAD*2)	Electro-induction	Device on the muzzle
Germany	30mm ABM*3)	Electro-induction	Device on the muzzle
U.S.A.	25mm HEAB*4)	Contact	-
	30mm HEAB	Contact	-
Korea	**40mm MMFA**	**Contact**	

•1) 3P : Prefragmented Programmable Proximity fuzed (BAE Systems-Bofors Defence)

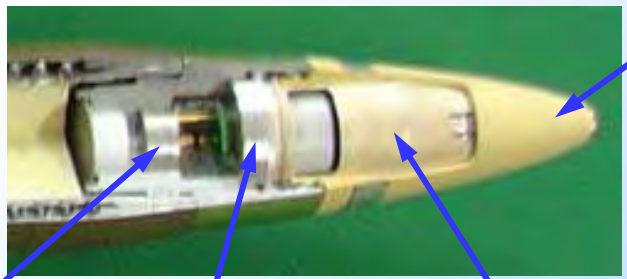
•2) AHEAD : Advanced Hit Efficiency And Destruction (Rheinmetall Detec-Oerlikon Contraves)

•3) ABM : Air Bursting Muniton (Rheinmetall DeTec -Mauser-Werke Oberndorf Waffensysteme GmbH)

•4) HEAB : High Explosive Air Bursting (GD-OTS)

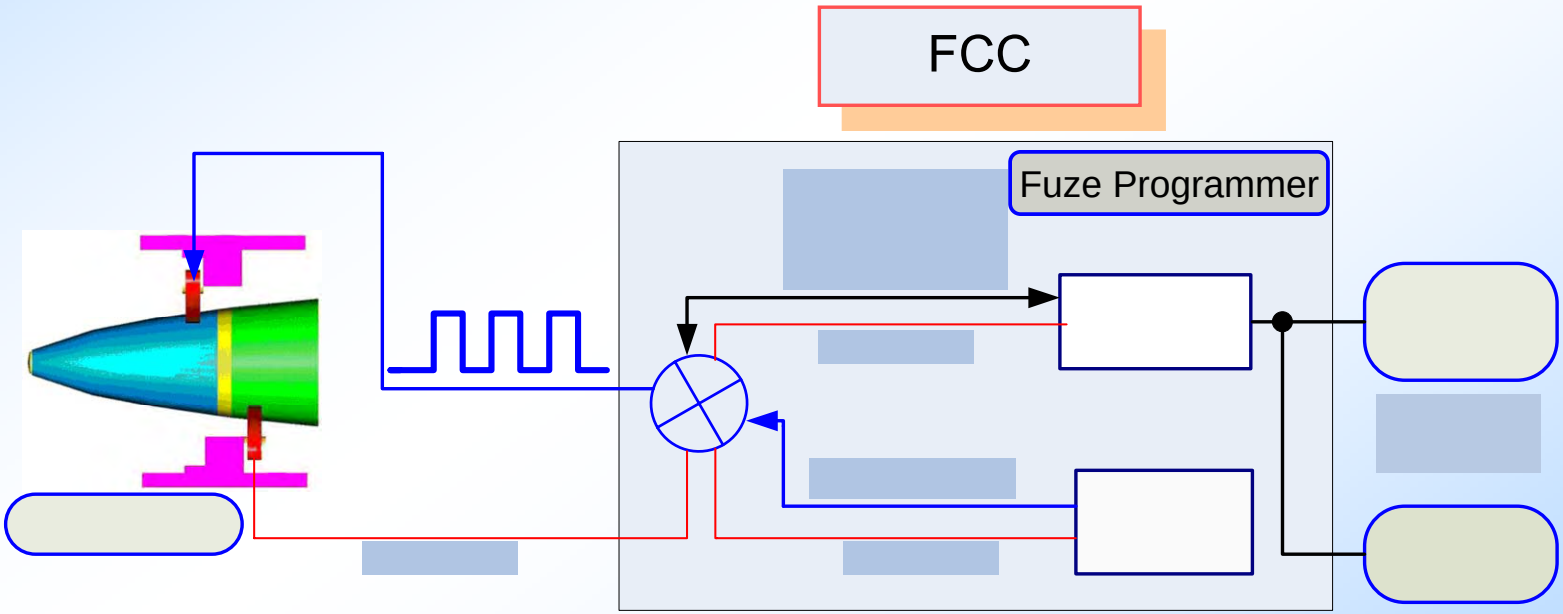
Brief for Fuze Programming System

□ MMFA Configuration



Brief for Fuze Programming System

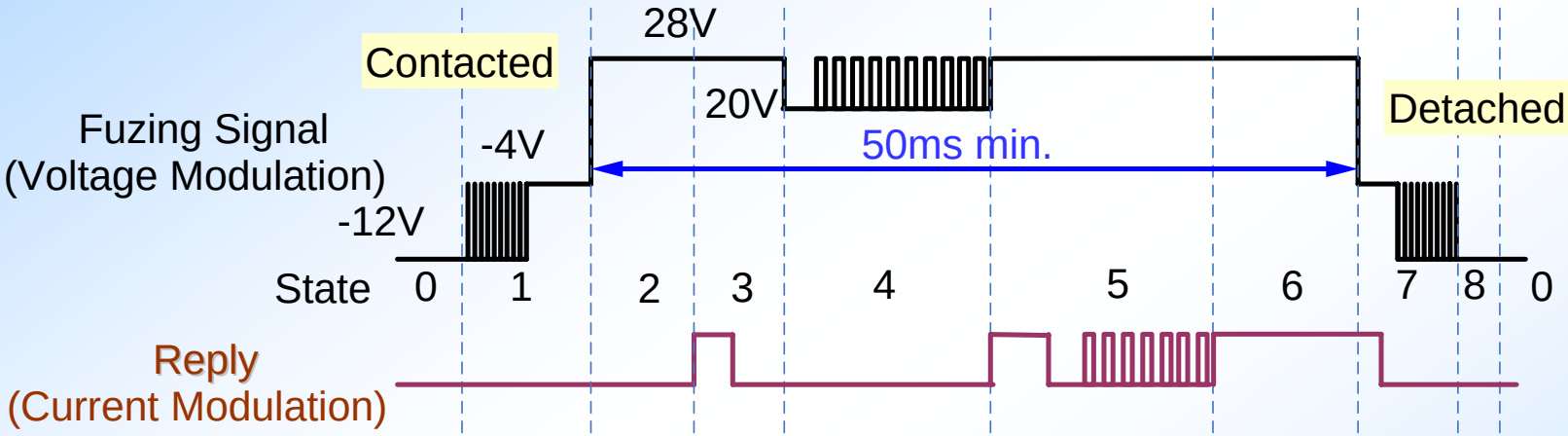
- Data Flow
  - ✓Able to check on contact state between fuze & fuze setter
  - ✓Able to keep up stable contact during transmitting data set
  - ✓Able to sense the detachment of ammunition from fuze setter



Fuze Programming System Configuration

Brief for Fuze Programming System

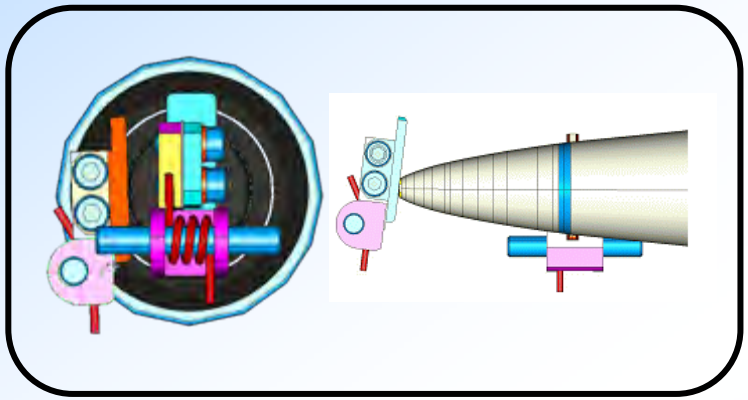
□ Fuzing Signal Arrangement



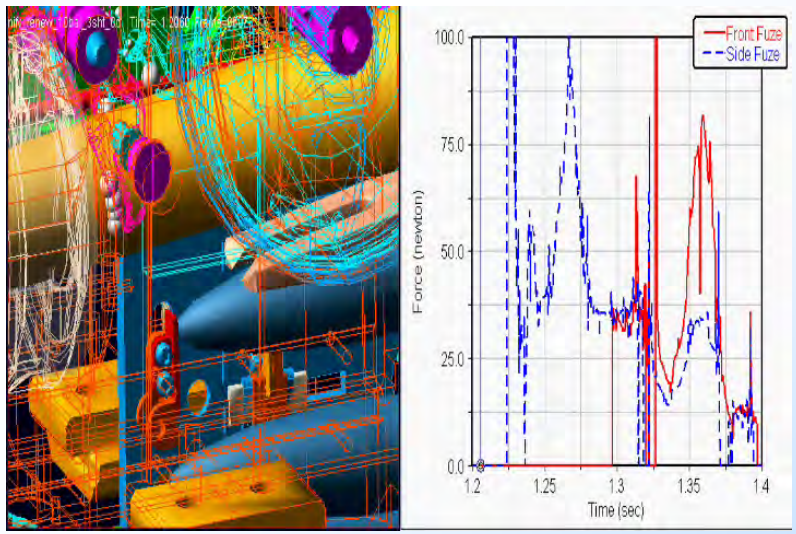
Step	State
0	Non contact state
1	Stabilized contact state between fuze & fuze setter
2	Powering up fuze
3	Activating the circuit &reply ready signal
4	Transmitting the data message to fuze
5,6	Storing the data to EEPROM & reply verified signal
7	Detaching of ammunition from fuze setter
8	Non contact state

Design of Fuze Setter

- Case 1 : Plate & Torsion Spring Type



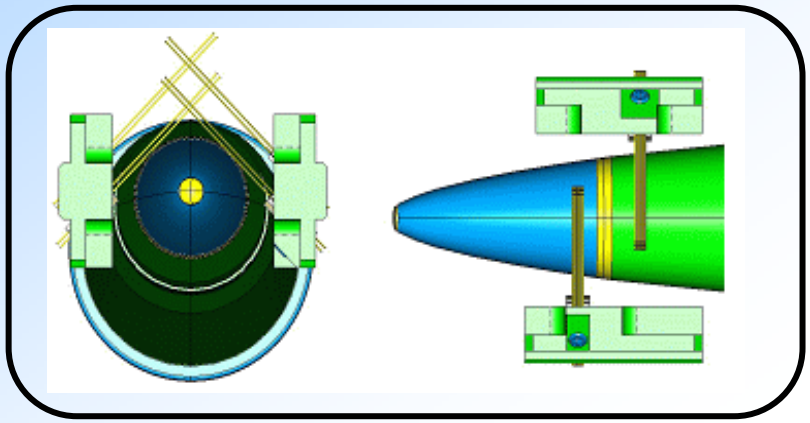
Configuration



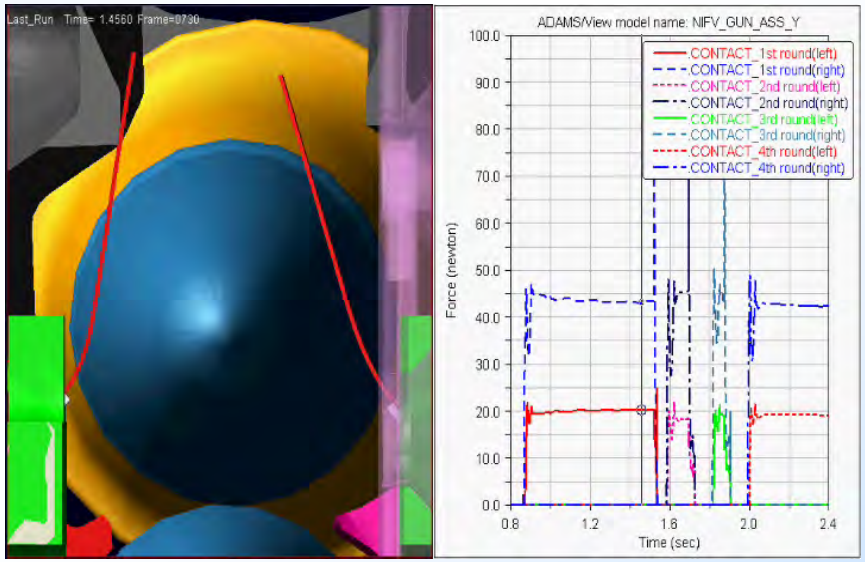
Virtual Simulation

Design of Fuze Setter

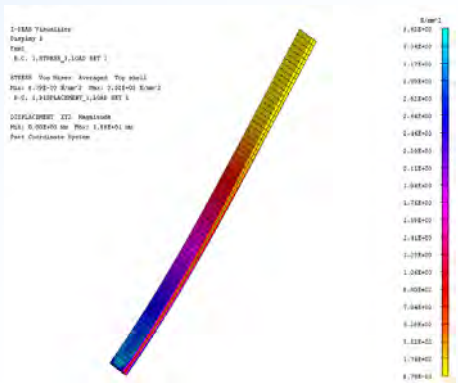
□ Case 2 : Multi-wired Brush Type



Configuration



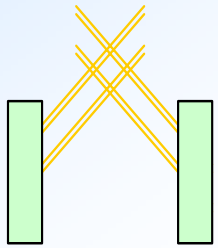
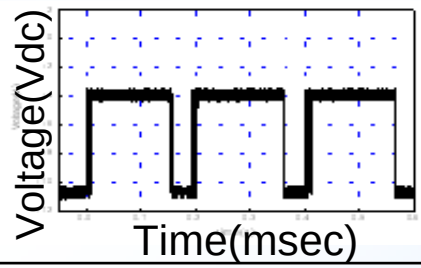
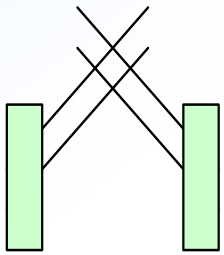
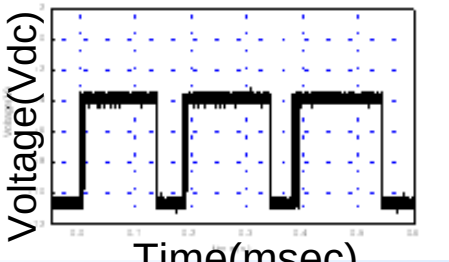
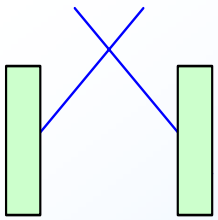
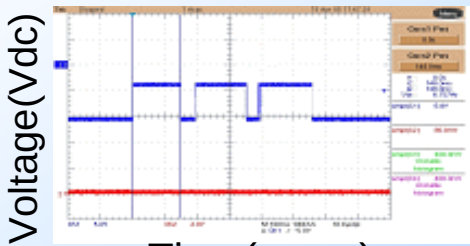
Virtual Simulation



Stress Analysis

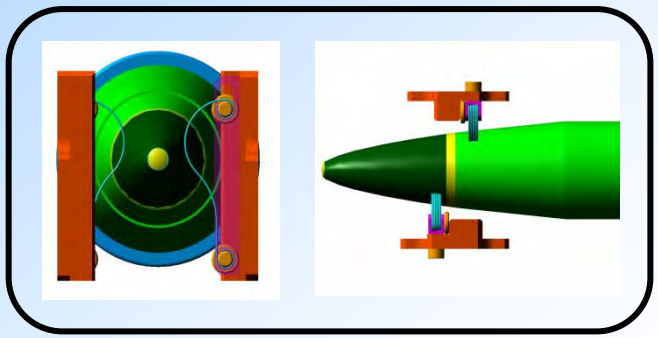
Design of Fuze Setter

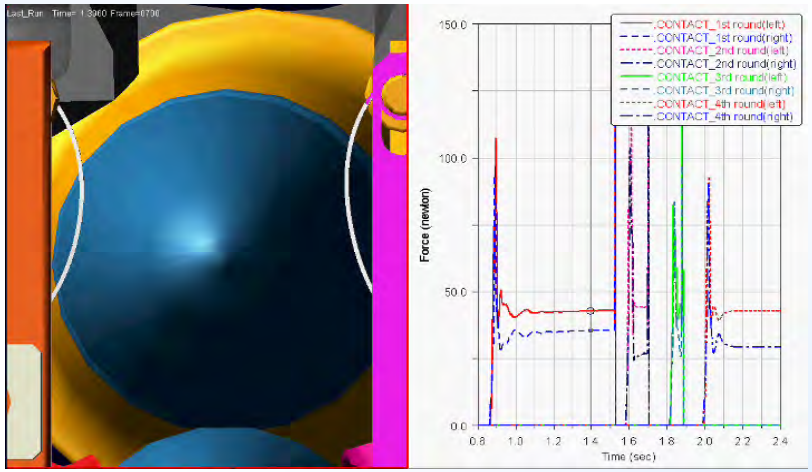
□ Design Parameters Study on Case 2

	Material	Configuration		Test Results
1	Alloy Steel with Gold		Φ0.5 * 6 pieces * 4 layer	
2	Stainless Steel		Φ0.5 * 6 pieces * 2 layer	
3	Stainless Steel		t0.5 * w4.0	

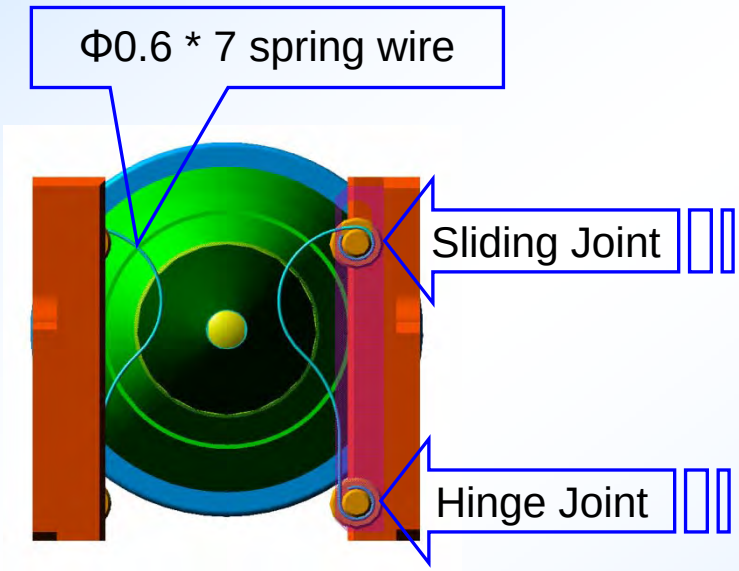
Design of Fuze Setter

□ Case 3 : Hinge & Sliding Joint Type with Multi-wired Spring

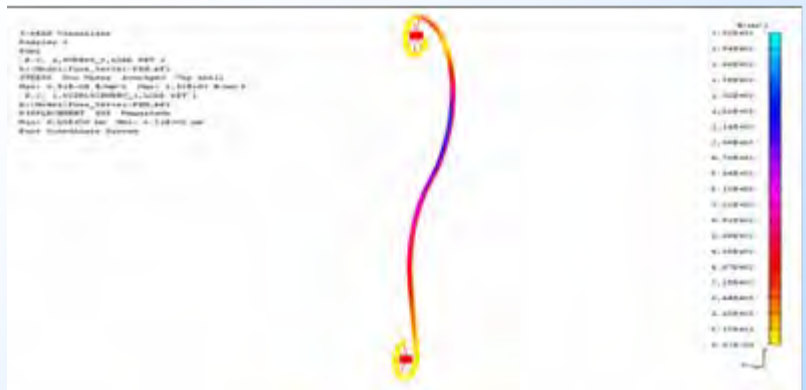




Virtual Simulation



Configuration

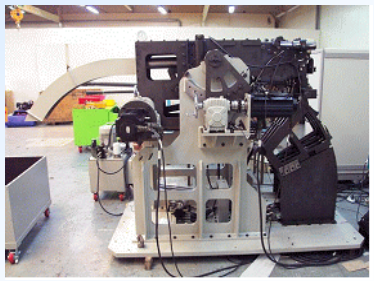


Stress Analysis

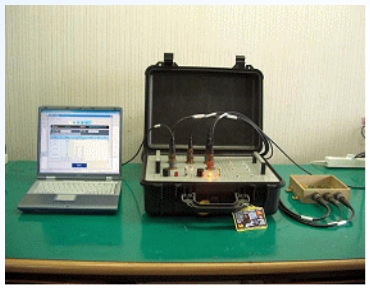
Test Results

- Simulation with No-Fire

Fuze setter

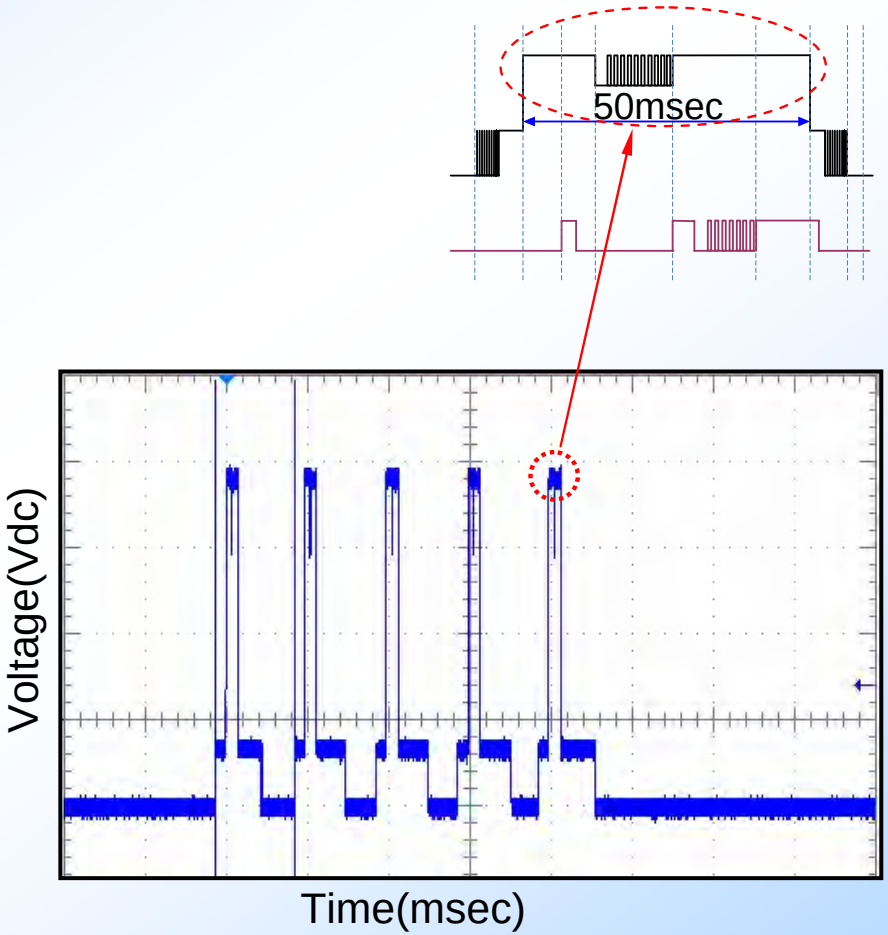


Test Simulator



Tester

Dummy MMFAs



Test result (5 burst rounds)

Test Results

- Live Firing Test

Time mode 1 Time mode 2

Test Results

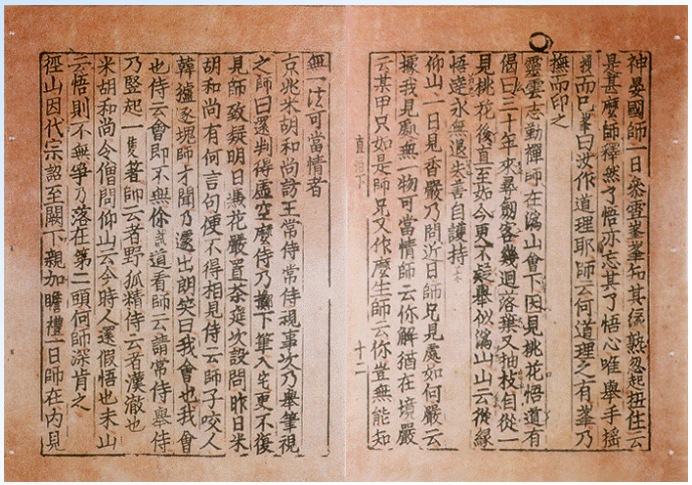
- Demonstration

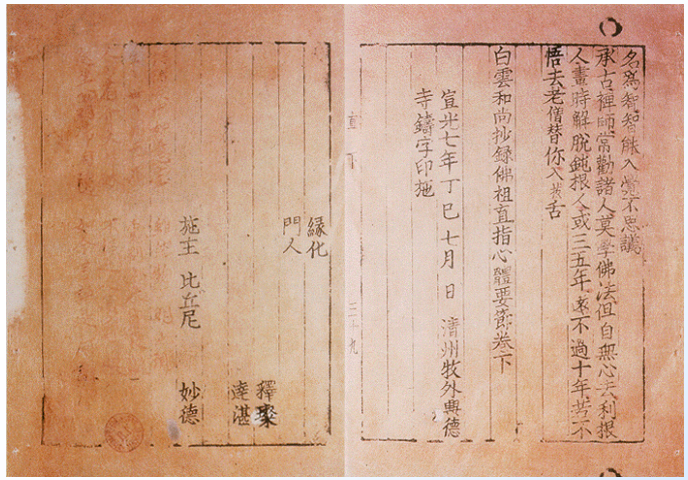
Summary

- Fuze programming system with contact type fuze setter has been successfully developed for K21's MMFA.
  - ✓ The method of transmitting power and data message through voltage modulation have been developed. Also the verified signal through current modulation has been developed.
  - ✓ Contact type fuze setter proves its stability of contact state against burst firing mode through multi-wired spring combination.
  - ✓ Fuze programming system has been verified by firing test.

Korean cultural legacy

“Jikjii”, the oldest book printed by metalloid type





It had been made in 1377, which was 78 years earlier than “the Bible in 48 lines” made by Gutenberg.

End of Presentation

THANK YOU

43RD ANNUAL ARMAMENT SYSTEMS:
GUN & MISSILE SYSTEMS CONFERENCE

Gun-Barrel Vibrations of Rapid-Fire Medium Caliber Guns

Prof Tom Dawson
U. S. Naval Academy

April 23, 2008

with support from
NAVSEA Naval Gunnery Project Office
and
Naval Surface Warfare Center Dahlgren

I. Background

Barrel Vibrations

- Barrel vibrations can affect accuracy of both slow firing and rapid firing guns by causing positive or negative “muzzle jump”during projectile launch.
- Vibrations can arise from gravity-caused barrel droop or barrel curvature from manufacturing… or both.
- Possible enhanced effect with rapid-fire guns where vibrations from one round continue to exist and can be reinforced by subsequent rounds.

Present Interest

… in rapid-fire *medium-caliber* gun mounts and the effects of barrel vibrations on their accuracy.

Motivation

…generated by evaluation and selection of gun mounts for the new Littoral Combat Ships and for other similar Navy needs

Early Navy Work

Near-muzzle barrel vibrations of 3-in/70 Gun Mount during travel of projectile through the barrel

-Single Firings

Dahlgren Report of 1951

NPG REPORT NO. 804

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

First Partial Report

on

Foundational Scientific Investigations

First Partial Report

on

Vibrations of Gun Barrels

B. M. Gurley

B. M. GURLEY
Physicist, Interior
Ballistics Branch

S. E. Hedden

S. E. HEDDEN
Head, Interior
Ballistics Branch

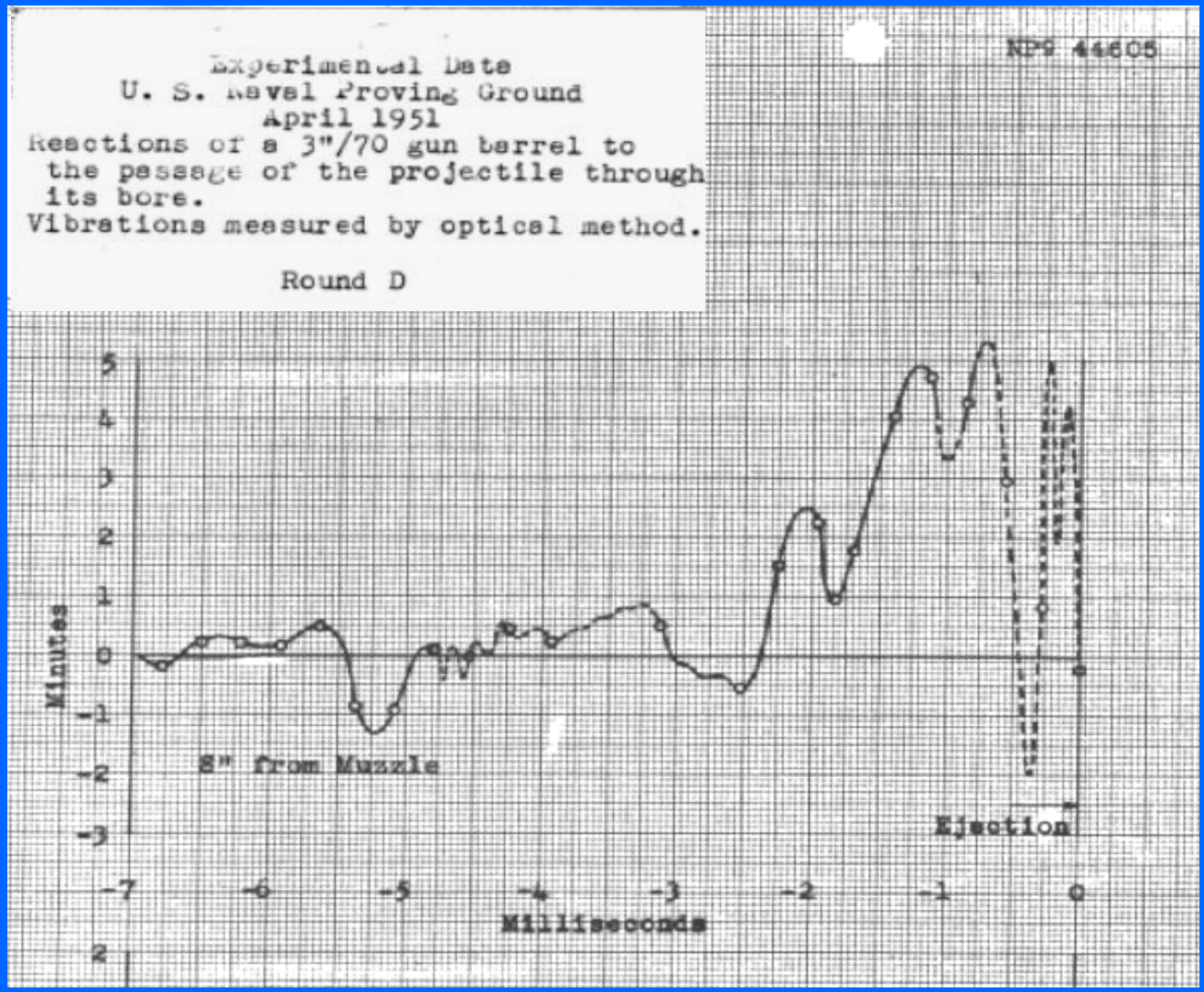
Copy No.: 22
No. of Pages: 10

Date: JUN 22 1951

B. M. Gurley
&
S.E. Hedden

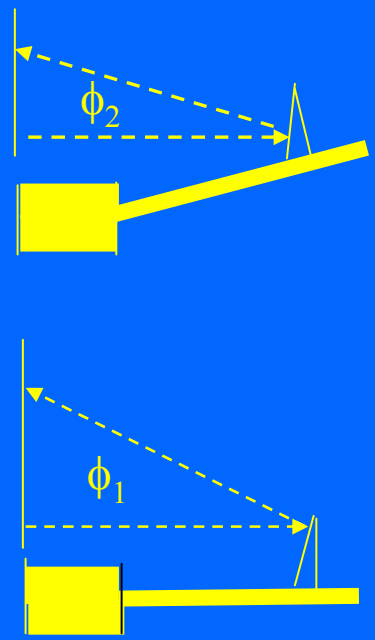
Novel use of optical reflections and “Fastax” camera to measure rotations (slopes) of barrel section near muzzle during projectile launch

…and Early Record of Barrel Vibrations



Section Rotation

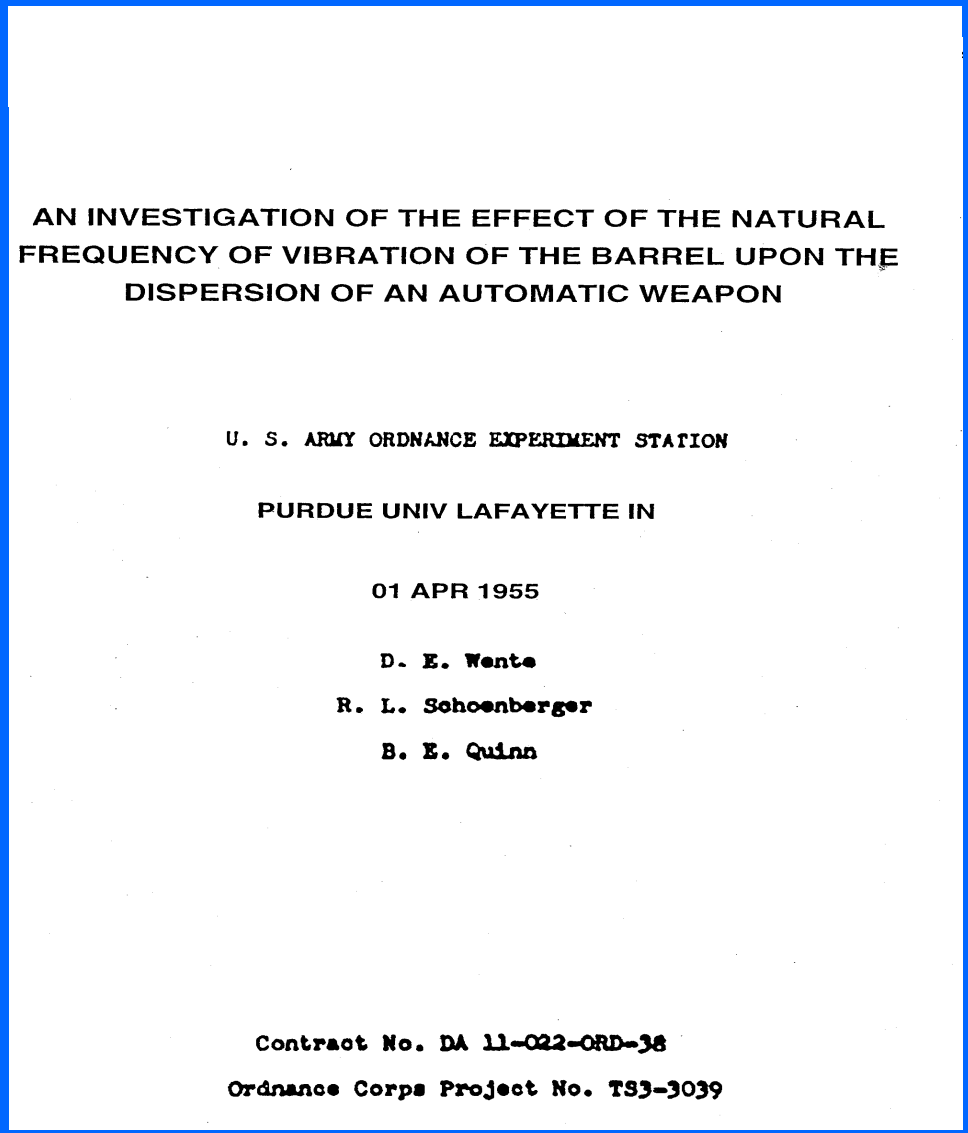
$\Delta\phi = \phi_1 - \phi_2$



Early Army Work

- Dispersion of machine-gun fire as influenced by firing rate.
- Increased dispersion measured when firing rate near fundamental barrel vibration frequency - or twice that frequency.
- Basis for design criterion that: *barrel frequency in cycles/sec should generally be 4 (or more) times the firing rate in rounds/sec.*

1955 Report on Barrel Vibrations



AN INVESTIGATION OF THE EFFECT OF THE NATURAL FREQUENCY OF VIBRATION OF THE BARREL UPON THE DISPERSION OF AN AUTOMATIC WEAPON

U. S. ARMY ORDNANCE EXPERIMENT STATION

PURDUE UNIV LAFAYETTE IN

01 APR 1955

D. E. Wente

R. L. Schoenberger

B. E. Quinn

Contract No. DA 11-022-ORD-38

Ordnance Corps Project No. TS3-3039

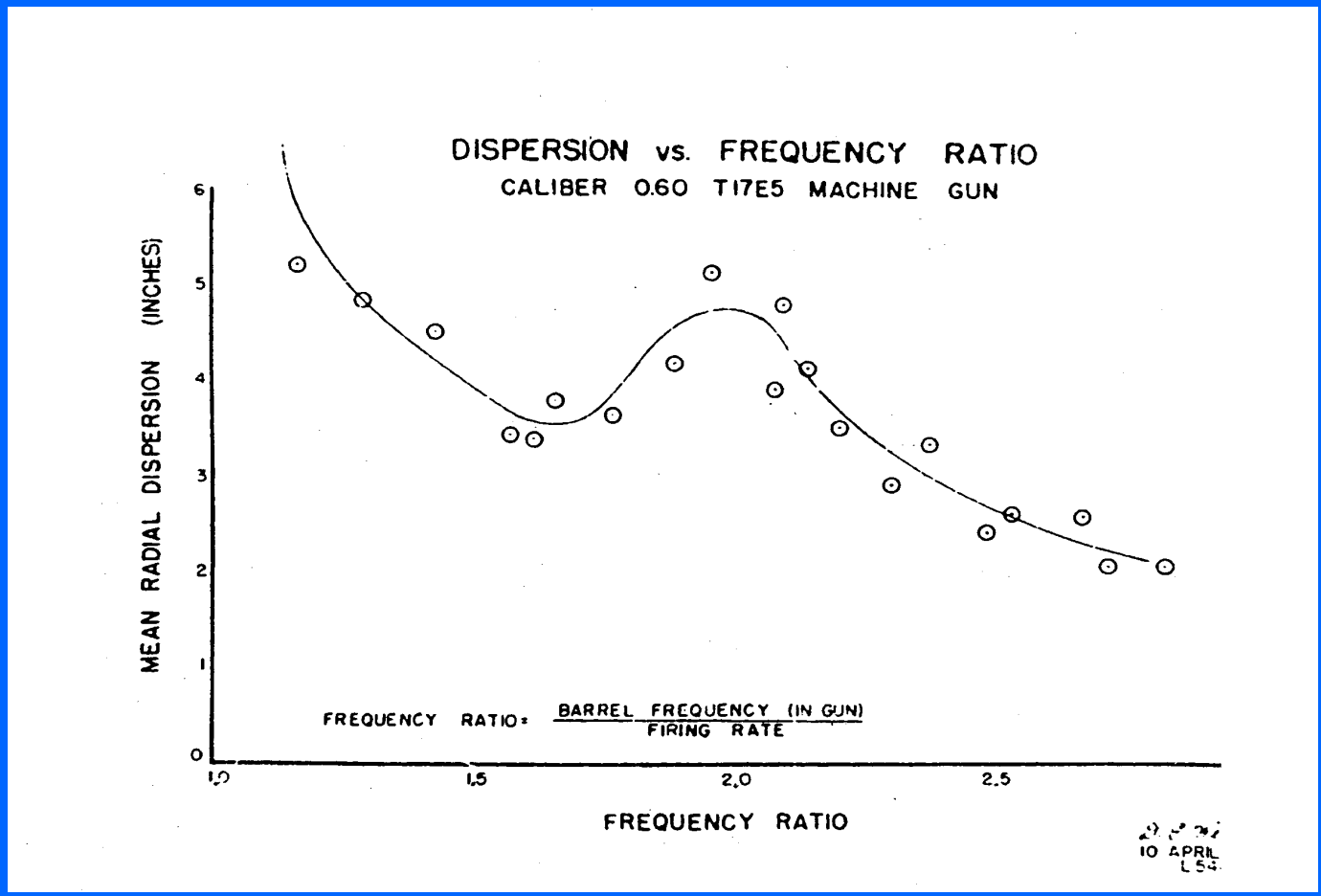
D. E. Wente

R. L. Schoenberger

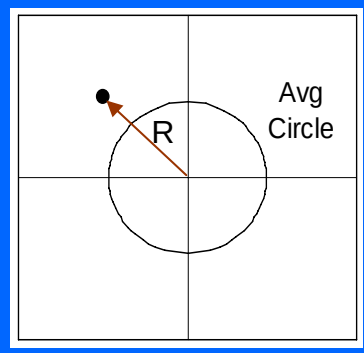
B. E. Quinn

First study of dynamic amplification of barrel vibrations from “tuned” firing rates

Dynamic Amplification of Barrel (from 1955 Army Report)



Dispersion



Barrel curvature from manufacture

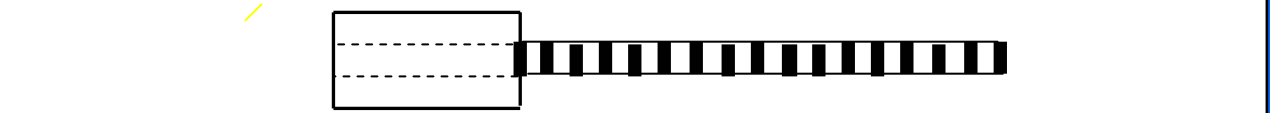
Previous Numerical Work on Barrel Vibrations

Numerical studies were carried out at the Army's Watervliet Arsenal during 1970's (and onward) *with attention restricted to barrel vibrations before projectile exit: No multiple firings.*

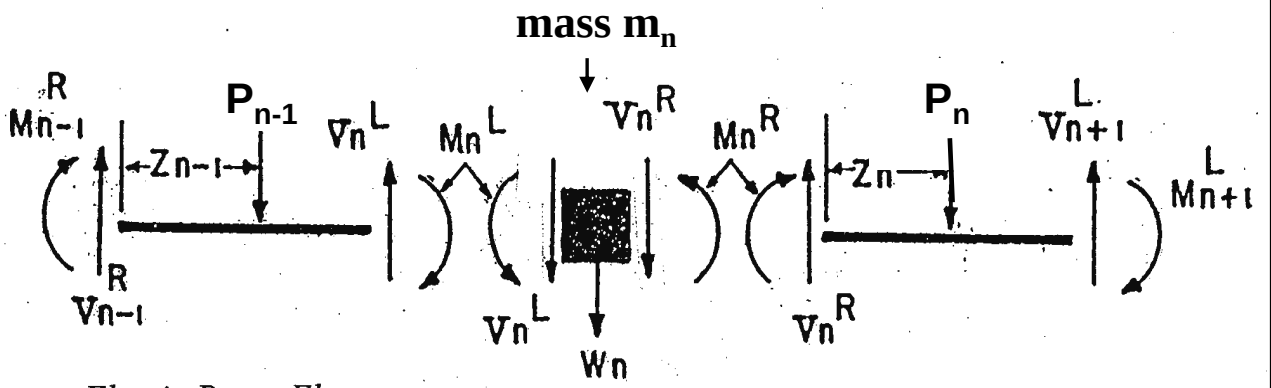
II. Computer Model

Lumped-Mass Model & Mechanic

V's & M's depend on *v*'s at n-1, n, n+1 & projectile load P (if between n-1 and n+1)



16 mass model



Governing Equations for Deflection v_n of Mass m_n

If P between n-1 and n
P_{n-1} = F
Otherwise 0

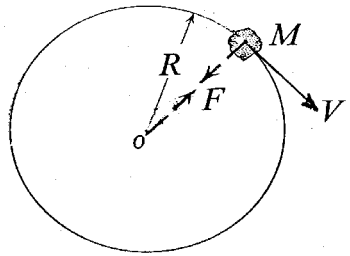
$$m_n \frac{d^2 v_n}{dt^2} = -(V_n^L + V_n^R) - w_n$$

$$M_n^L + M_n^R = 0$$

If P between n and n+1
P_n = F
Otherwise 0

Projectile Forces on Barrel

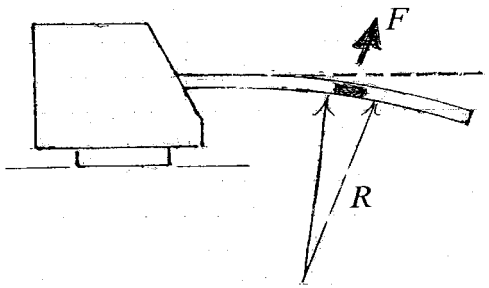
Centrifugal Forces



Constant radius

$$F = \frac{MV^2}{R}$$

Simple Example

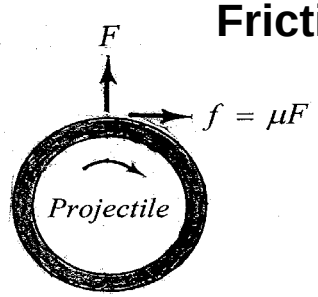


Instantaneous radius of curvature

$$F = MV^2 \frac{\partial^2 y}{\partial x^2}$$

Actual Case

Friction Forces



Vertical Centrifugal Force

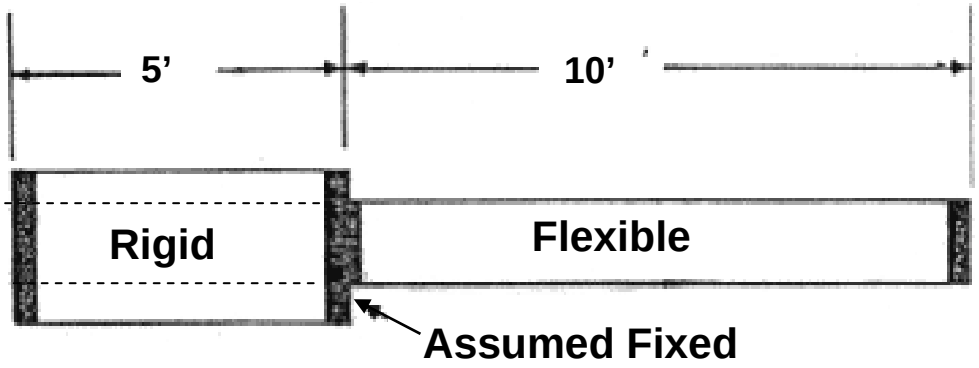
Horizontal Centrifugal Force

Typical
Coeff of Friction
$\mu \approx$ 0.20 to 0.30

III. “Generic” 3in /60 Gun Mount (Firing 14 lb Projectiles)

Generic Barrel

Barrel (No attachments)



Flexible Length
Inside Dia = 3 in
Outside Dia = 4 in

vibration frequencies

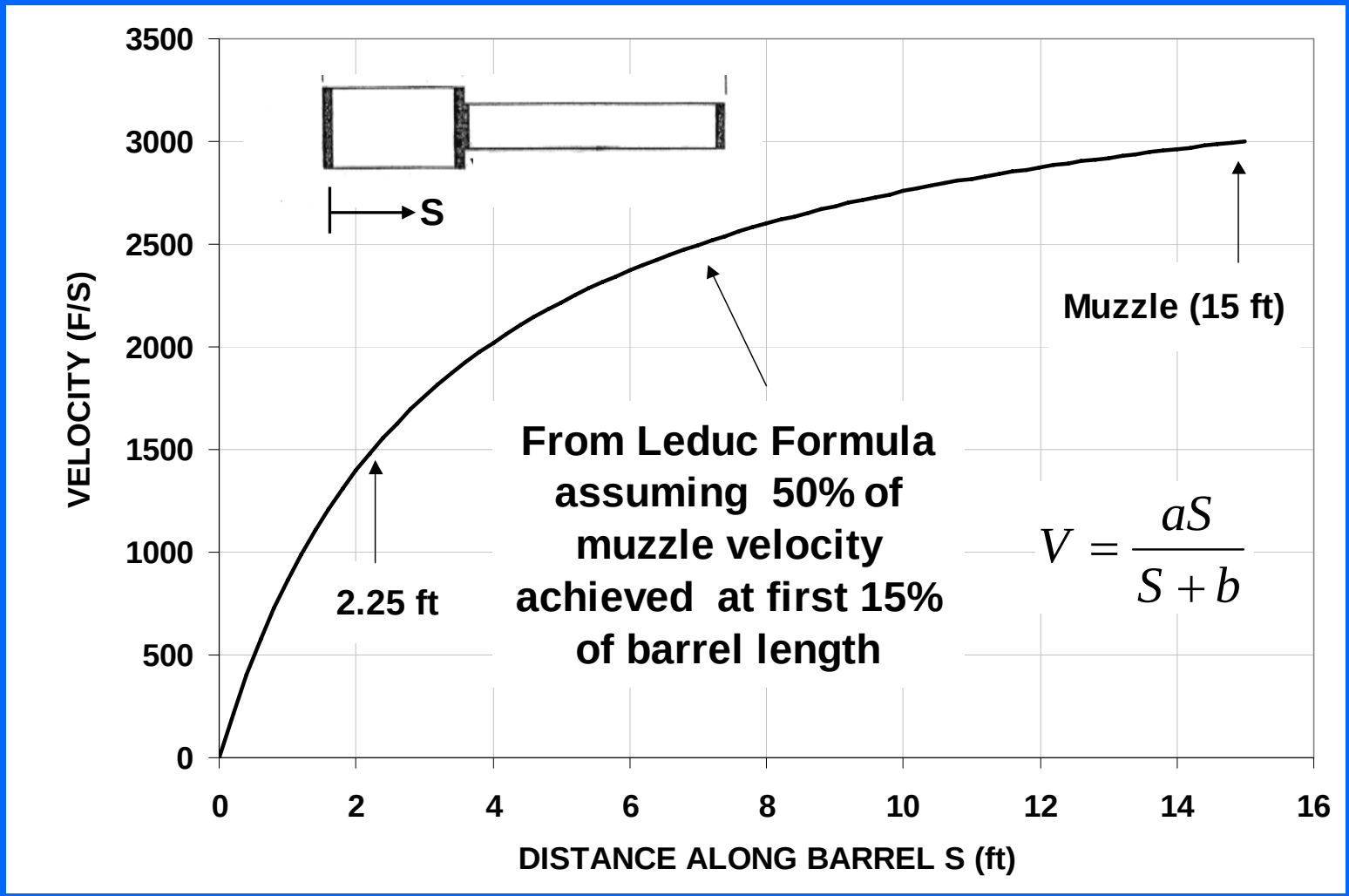
$\omega_1 = 62.0$ rad/sec = 9.87 cycles/sec

$\omega_2 = 387$ rad/sec = 61.6 cycles/sec

etc

Flexible section divided into 16 lumped masses. Accuracy checked by increasing number to 32 and then to 48 … as shown in the following

Assumed Projectile Velocity in Barrel

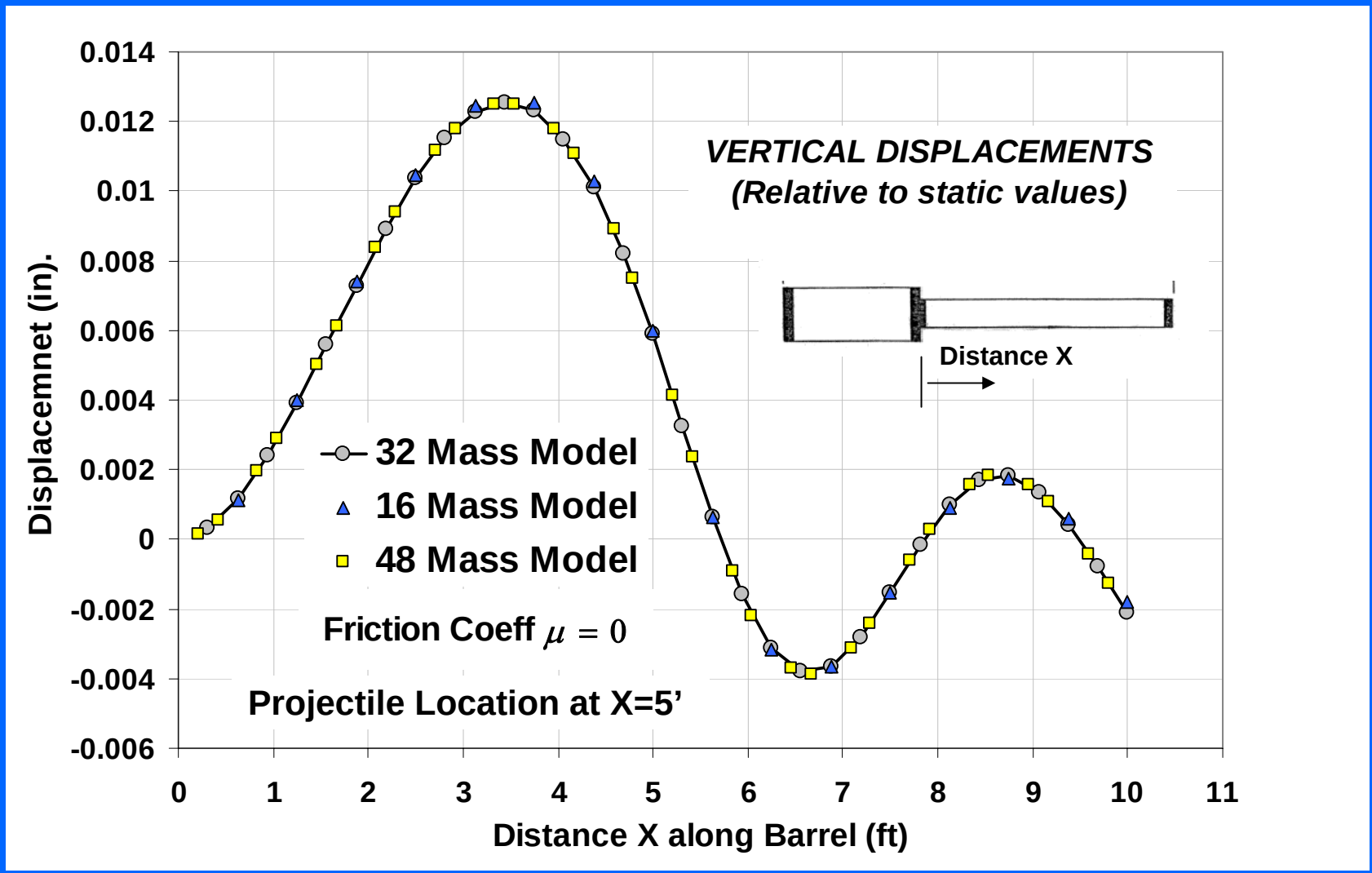


Demonstration of Adequacy of Lumped-Mass Model

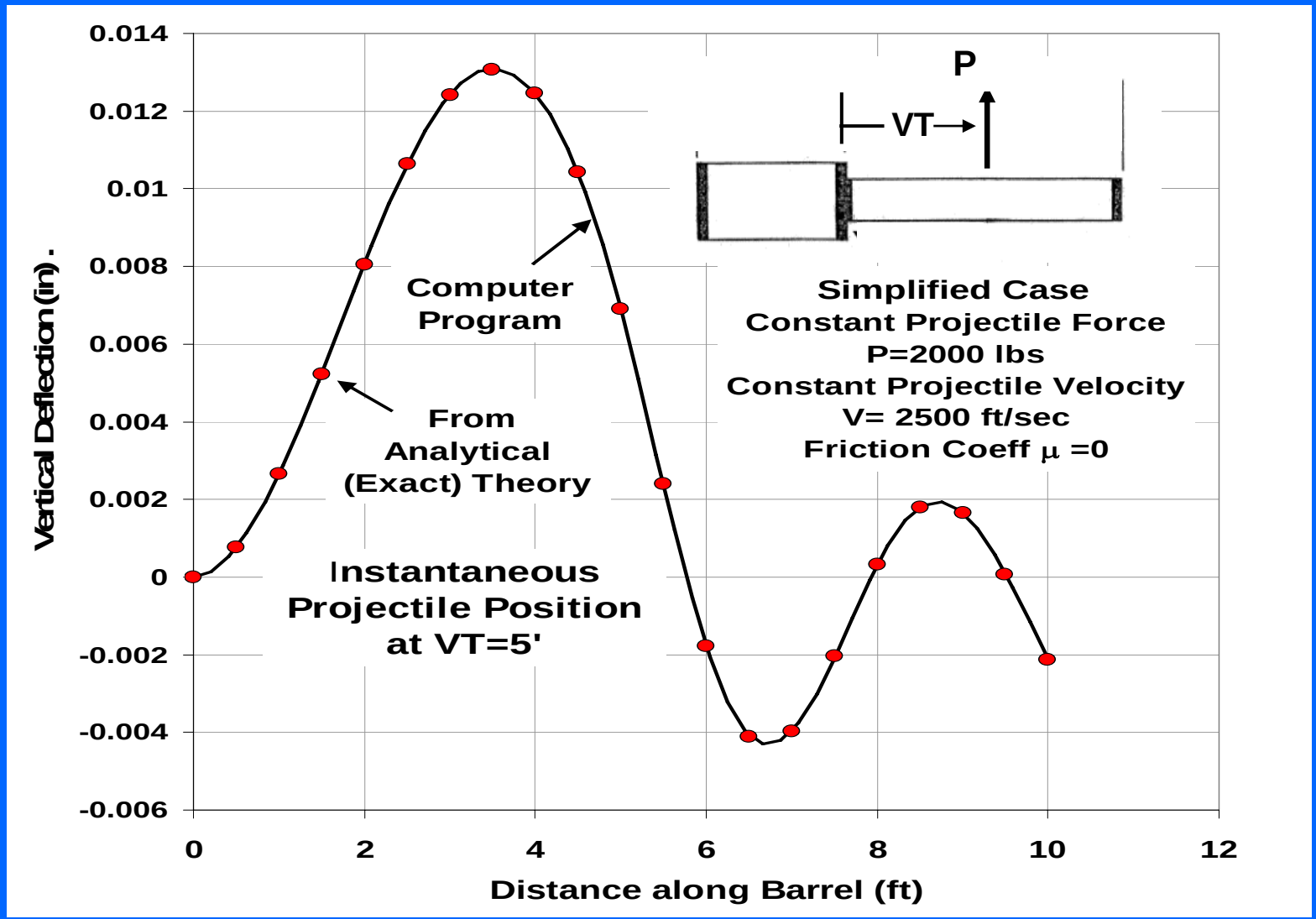
- Idealized Case-

Negligible Friction between Spinning Projectile and Barrel

Convergence with number of mass elements



Adequacy of Computer Solution



Detailed Results
-Actual Case-

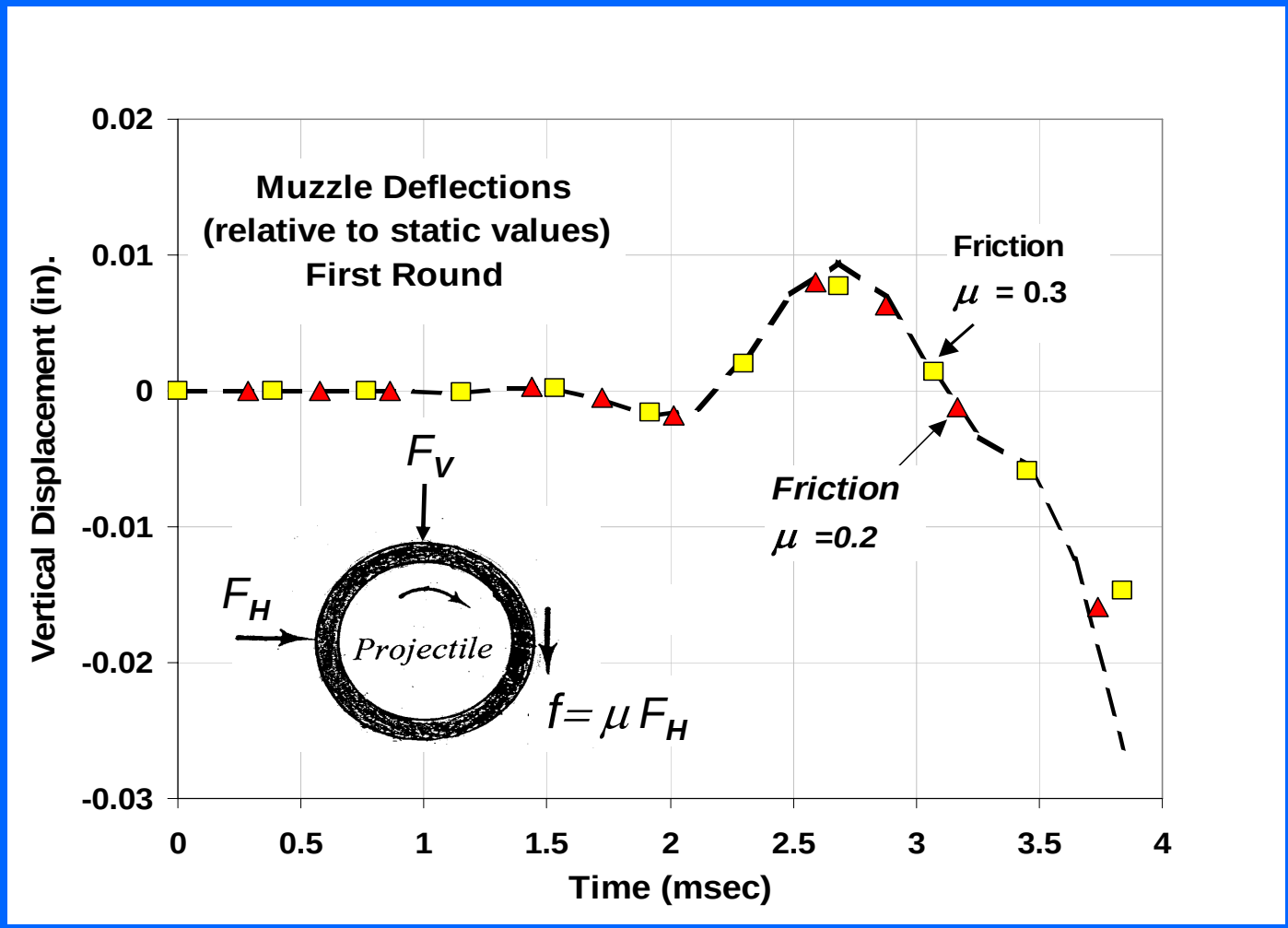
First-Round Barrel Response

Free Vibrations following First Round

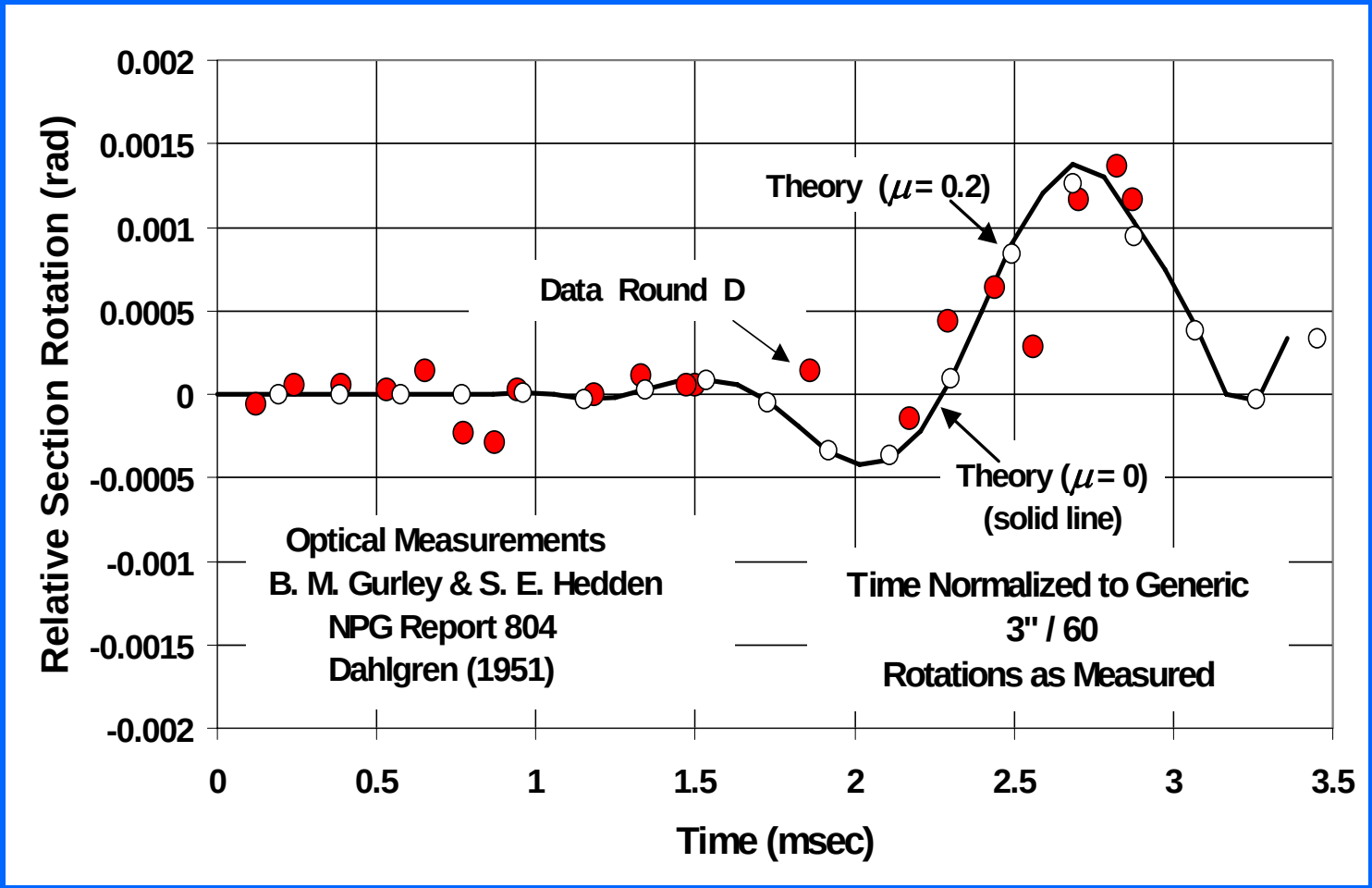
Response Characteristics after Multiple Rounds

First-Round Barrel Response

Muzzle Deflections vs. Time

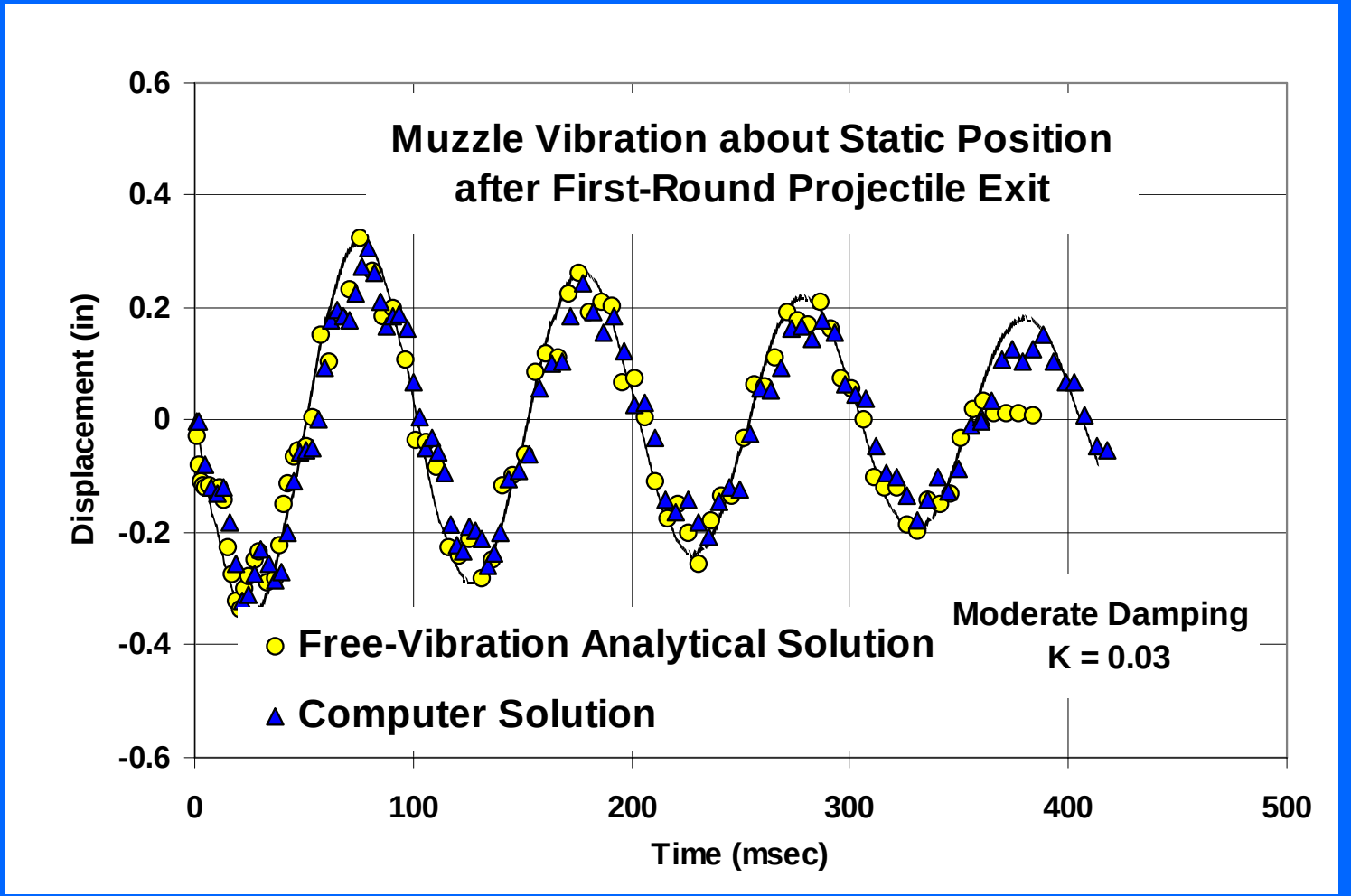


Dynamic Section Rotation Comparison with 1951 Dahlgren Data



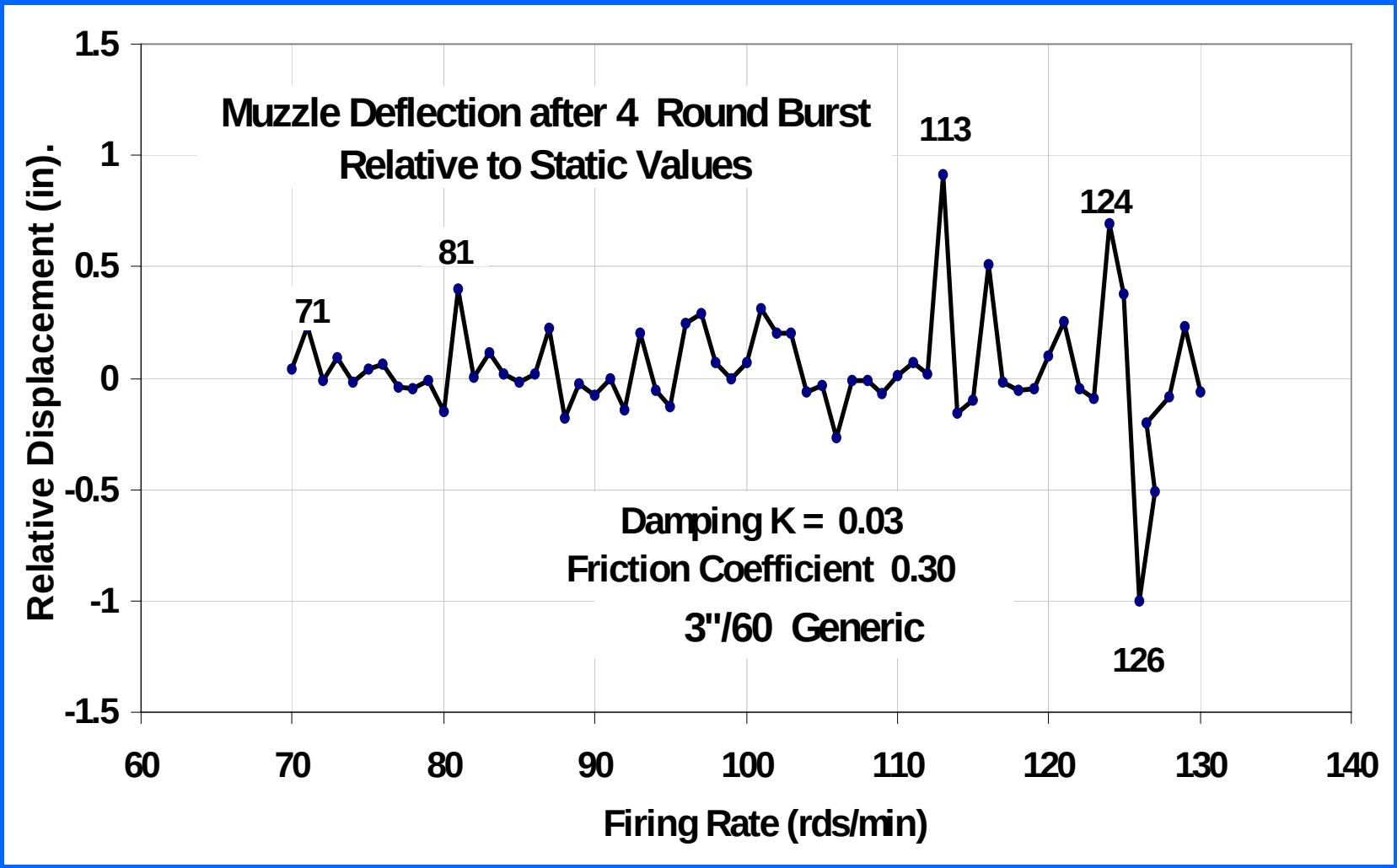
Free Vibrations following First Round

Free Vibration of Muzzle (note check of analytical solution & damping value)

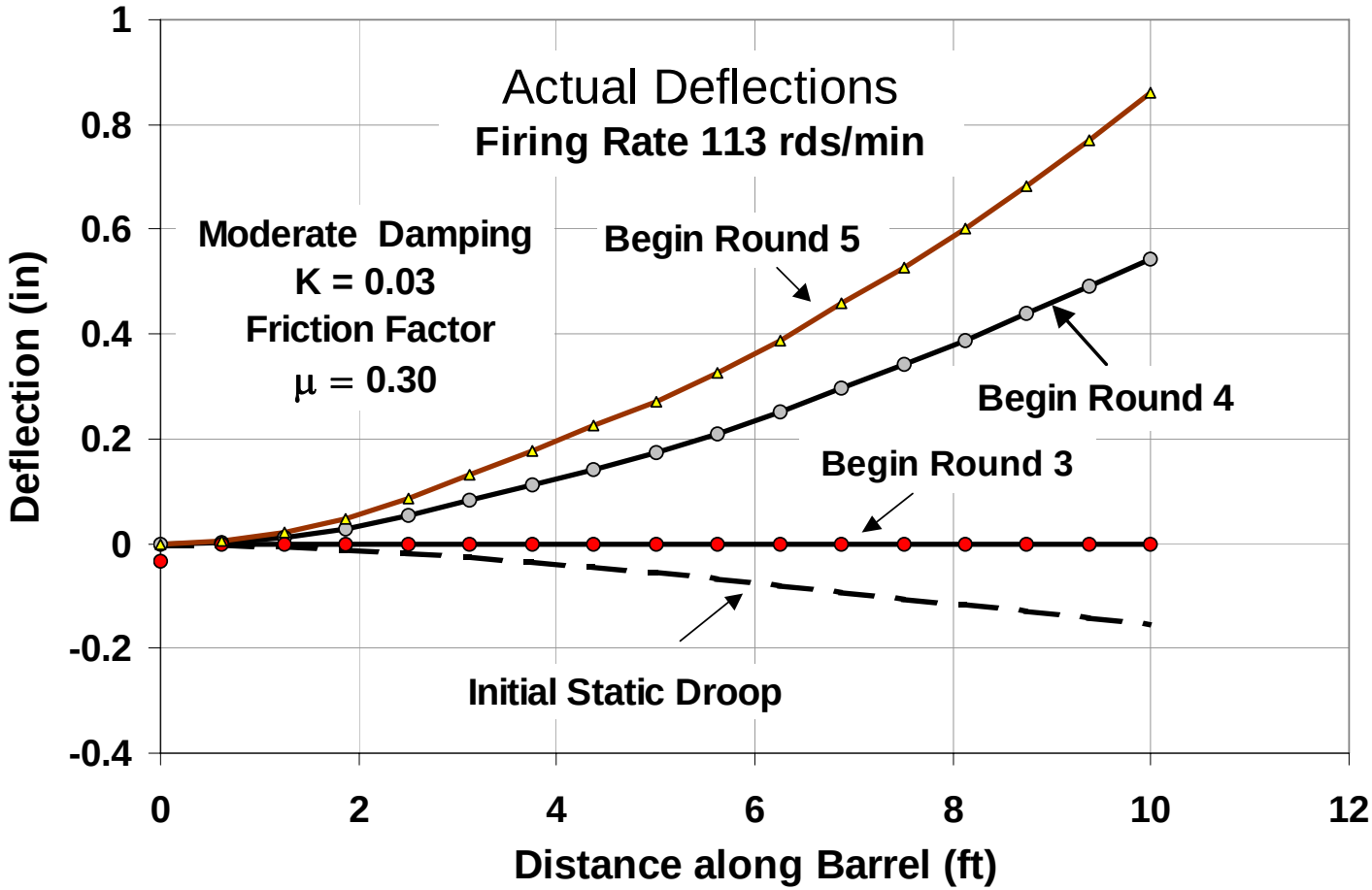


Response Characteristics after Multiple Rounds

Dynamic Amplification



Barrel Deflections
(note continuing input of energy

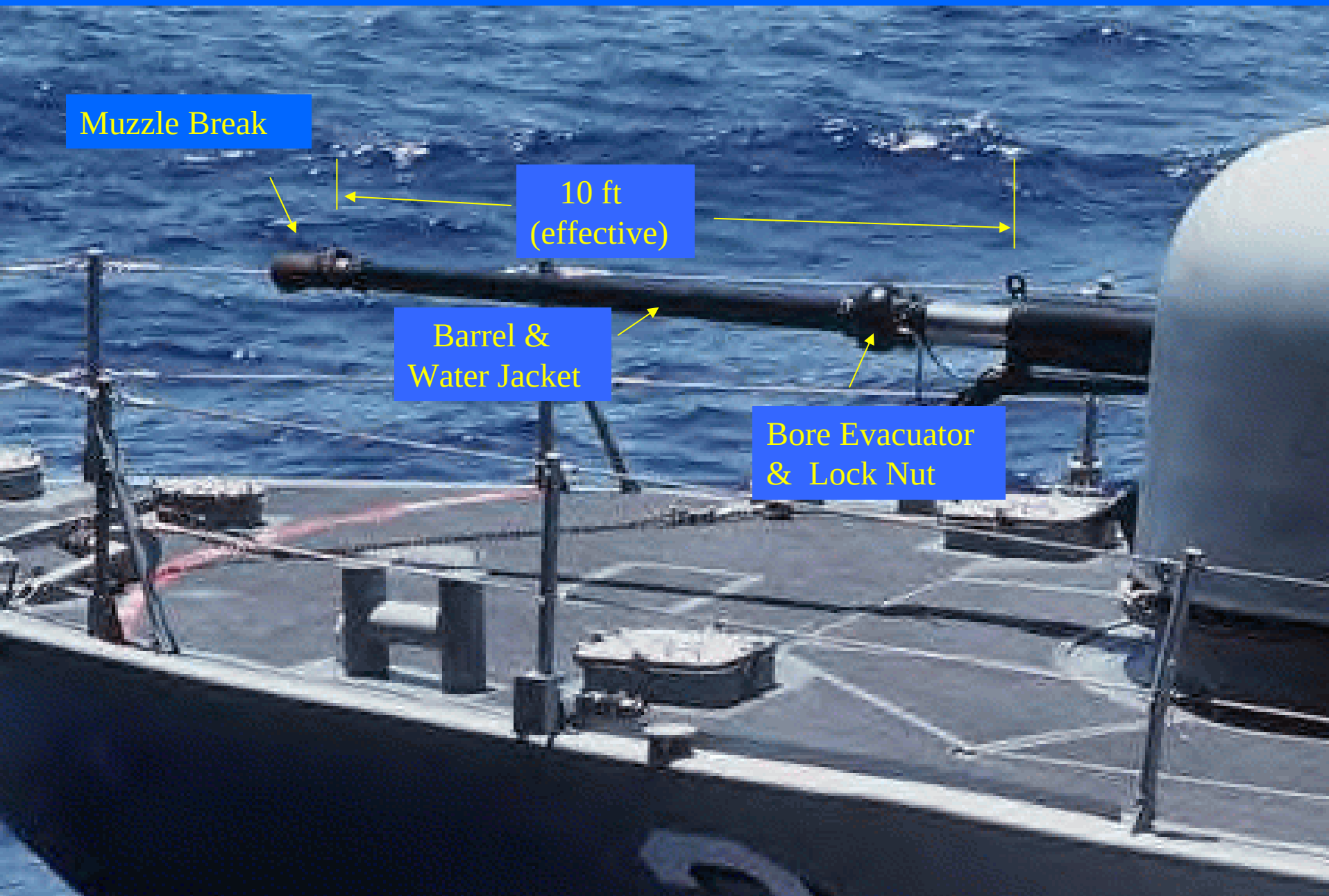


IV. Application to USN Mark 75 (80 rds/min)

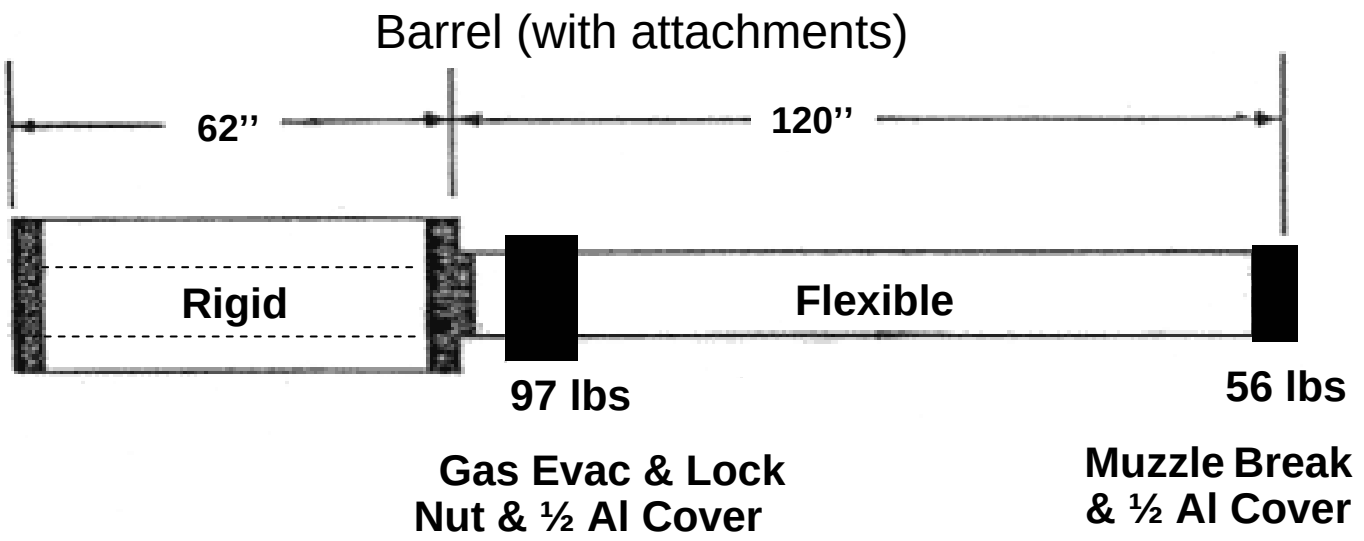
Mark 75 3"/62 (80 rds/ min)

USS Curts FFG 38

Barrel Details –Mark 75 (3in/62) Gun Mount



Mark 75 - Idealized Barrel Description



Modal Frequencies

ω_1 = 41 rad/sec (6.5 cycles/sec)

ω_2 = 276 rad/sec (44 cycles/sec)

etc

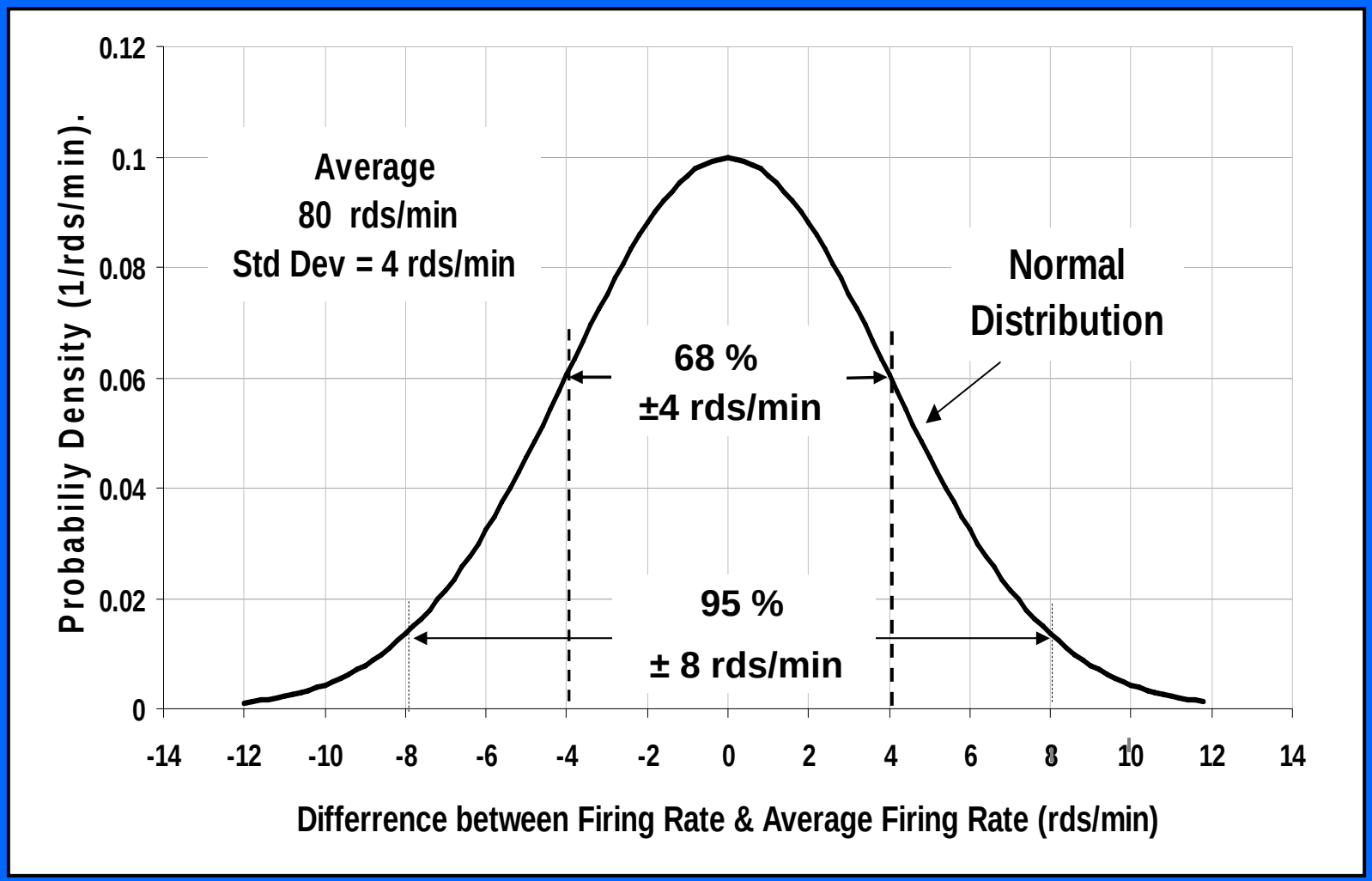
Flexible Length

Inside Dia = 3 in

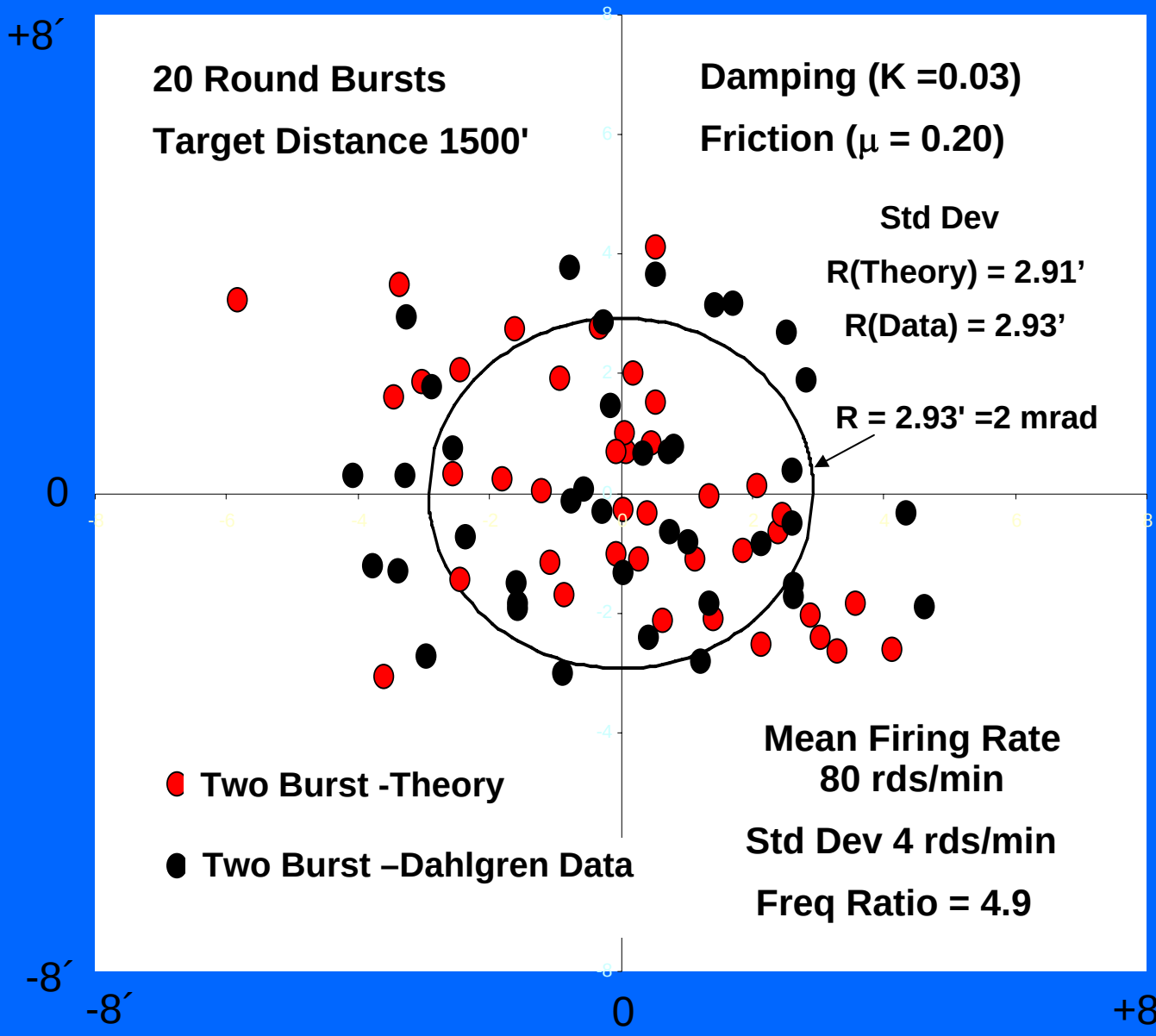
Outside Dia = 4 in

Leduc formula for projectile velocity

Variable Firing Rates
Normal (Bell-Shaped) Distribution



Dispersion: Theory *vs.* Measurement



USN
Mark 75
3"/ 62
Gun Mount
firing
14 lb
Projectiles

V. Application to Study of Oto Melara 76 mm/62 SR (120 rds/min)

Oto Melara 76mm/62 SR (Super Rapid Gun Mount

Mark 75 *vs* 76mm SR

Mark 75

76mm SR with standard shield

Mark 75 (~1970)	***SR(~2000)***
Firing	
Out of Battery	In Battery
Avg Firing rate	
80 rds/min	120 rds/min
Accuracy (10-rd burst)	
~1.9 *m*rad	0.30 *m*rad*

*Reported on web page

Extracted From Web Page: *Italian 76mm/62 (3″)…*

The SR is an improved faster-firing version of the Mark 75…. Accuracy improved partly by reducing the weights of the moving parts. Claims are that these changes have reduced the radial-error standard deviation values to less than 0.3 *m*rad for 10-round burst

Examination with Theory

What if firing rate of Mark 75 is increased 50% to 120 rds/min?

See table. Dispersion increased from about 1.9 mrad at 80 rds/sec to about 6.5 mrad at 120 rd/min (for 10-Rd Bursts)

Mark 75 (modified)

Firing Rate (rds/min)	Radial Dispersion* (Std Dev in mrad)
80	1.9 mrad
120	6.5 mrad

* 10 Rd Bursts (avg of 4)

What if weights of gas evacuator & muzzle break are then reduced by 50%?

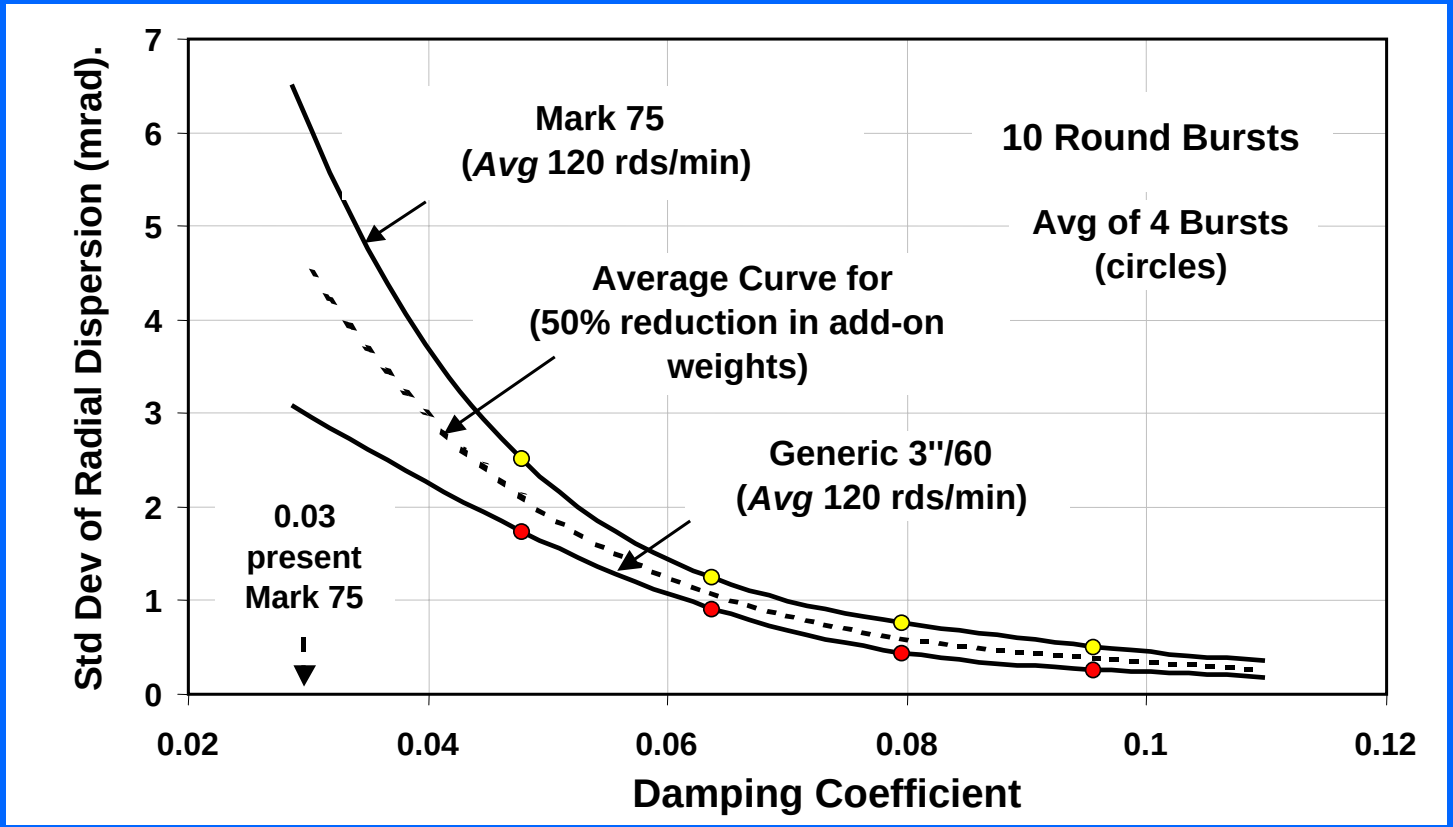
(Avg of data from generic and Mark 75)

Dispersion reduced from about 6.5 mrad to about 4.5 mrad (for 10-rd bursts)

Conclusion: Cannot achieve reported accuracy for 120 mm SR with only a reduction of add-on weights of Mark 75 when modified for 120 rds/min

What if increased damping of barrel vibrations?

See graph below. Dispersion (dashed line) reduced from about 4.5 mrad to about 0.5 mrad for 200% increase in damping.



VI. Concluding Remarks

Barrel Vibrations Work

*A*nalysis can explore performance aspects of rapid fire guns not possible with limited testing. Can be of value in assessing factors for Navy needs when considering cost, accuracy, sensitivity to firing rate, inherent damping of vibrations, age effects, etc.

*B*arrel vibrations can affect gun effectiveness and barrel wear. Longer term implications of work are improved fire control & accuracy and improved maintainability regarding barrel wear…

Common Low-cost IM Explosive Program

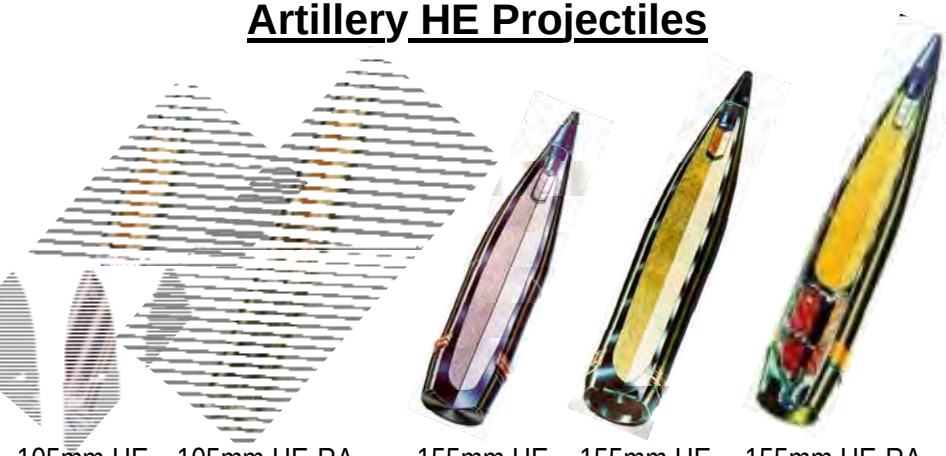
Joint U S Army & U S Marine Corps

NDIA-2008

Department of the Army
Army Research Development and Engineering Center
Attn: Mr. Anthony Di Stasio
Tel 973-724-4547 Fax 973-724-4308
anthony.r.distasio@us.army.mil
Picatinny Arsenal, New Jersey 07806-5000

Common Low-cost IM Explosives

Artillery HE Projectiles

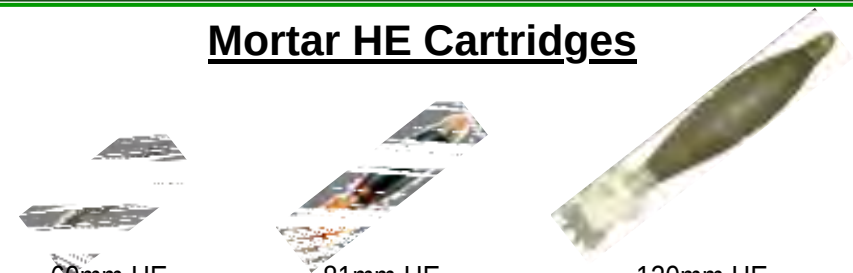


105mm HE (M1, M760) | 105mm HE-RA (M927, M913) | 155mm HE (M107) | 155mm HE (M795) | 155mm HE-RA (M549A1)

Baseline Explosive = TNT

TNT filled Projectiles FAIL all IM Tests

Mortar HE Cartridges



60mm HE (M720, M768, M888) | 81mm HE (M821, M889) | 120mm HE (M933, M934)

Baseline Explosive = Comp-B

Comp-B filled Cartridges FAIL IM Tests

- **ISSUE:**
  - ✓ TNT & Comp-B explosives have poor IM results
  - ✓ HE items require IM Waiver
    - IM explosives identified under prior efforts
      - Specific to individual program requirements
      - Lacked commonality
      - Some IM improvements – still need waiver
      - NTIB Cost Impacts

- **CORRECTIVE ACTION:**
  - ✓ Investigate new IM Explosives with intention to insert into production in near-term

Background

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

Primary Objective is to provide a Common IM Fill
-- or --
one common TNT replacement (Artillery)...
...and one common Comp-B replacement (Mortars)

Background: IM Test Results
155mm Artillery Baseline

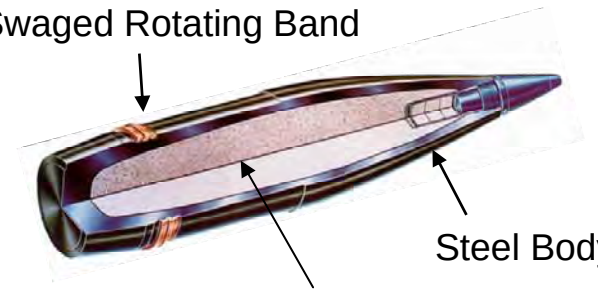
Reactions:						
	VI No Sustained Reaction	V Burn	IV Deflagration	III Explosion	II Partial Detonation	I Detonation

IM Test:	FCO	SCO	BI	FI	SD	SCJI
Passing Criteria	V	V	V	V	III	III
155mm M107 (TNT)	III	III	III	III	(I)*	(I)*
155mm M107 (Comp-B)	III	III	III	I	(I)*	(I)*
155mm M795 (TNT)	III	III	IV	IV	(I)*	(I)*

* Assessment (not tested)

M107

Swaged Rotating Band

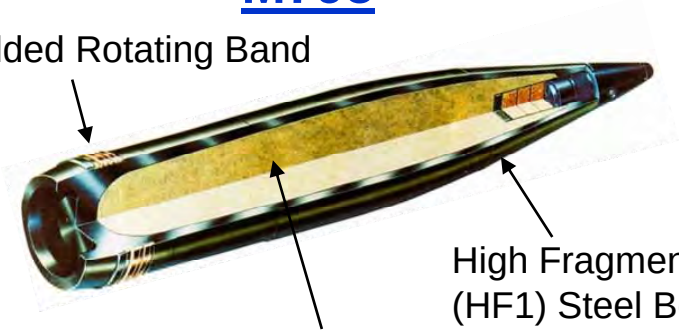


Steel Body

15.4 lb Explosive Fill [Comp-B]

M795

Welded Rotating Band



High Fragmenting (HF1) Steel Body

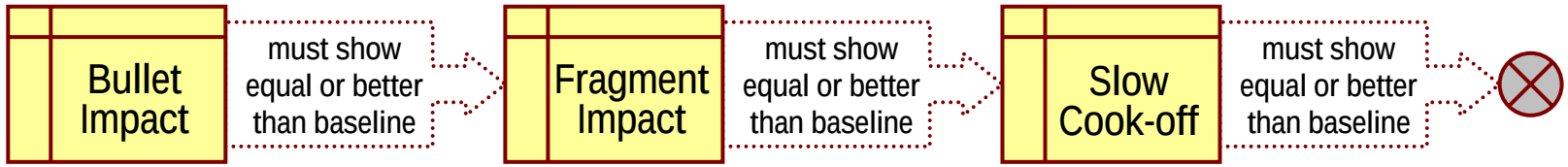
23.8 lb Explosive Fill [TNT]

Background
Test Configuration

- ✓ **Established IM Test Configuration for TNT-Replacement**
  - ✓ **155mm established as test vehicle**
    - M795 Projectile with HF1 Steel
    - Vented Nose Plug
    - Supplementary Charge of Pressed-TNT (or other standard explosive)
  - ✓ **Palletization**
    - 8 Projectiles per Pallet, Wood (2 x 4)
    - No S.D. Barriers

Background
Test Protocol

- ✓ **Established IM Test Protocol for Artillery (155mm M795)**
  - ✓ **Tier 1 Tests**

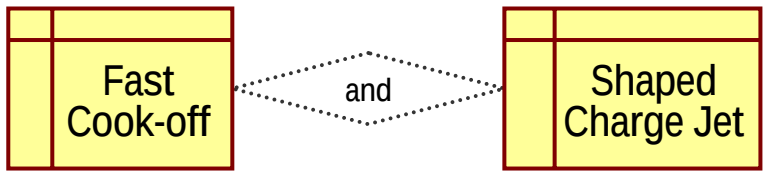


(.50 cal AP) (6,000 ft/s) (+145°F condition) (50°F/hr rate)

  - ✓ **Tier 2 Tests -- must show improvement in at least 1 of Tier 1 Tests**

(single-rd detonation)
(2x2 diagonal acceptor/donor)

  - ✓ **Tier 3 Tests – Candidates based on Tier 1 & 2 Test Results**



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

Tier 1 & 2 Summary

- ✓ **Performed IM Tests**
  - 23 Explosive candidates considered
  - 9 candidates tested (melt-pour, cast-cure, pressed)
  - Top 3 Candidates
    - **All three are Melt-pour and each passed SD test without Barriers**
      - » Insufficient difference to select the go forward candidate
    - **Perform Tier 3 prior to entering Qualification Testing and address**
      1) Producibility
      2) High Risk Areas
      3) Lethality Assessment

BAE SYSTEMS

Booz | Allen | Hamilton

Bullet Impact

MIL-STD-2105C / .50 Caliber AP Bullet / Witness Plate & Pressure Gage

IMX -101	Pass
IMX -102	Pass
IMX -103	Fail - Equivalent to TNT (Type IV)

Fragment Impact

MIL-STD-2105C / 6000 fps Army Fragment / Witness Plate & Pressure Gage

IMX -101
IMX -102
IMX -103

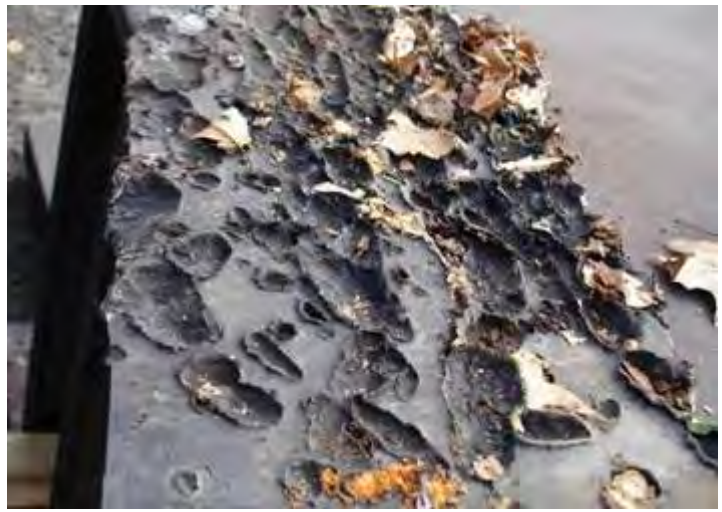
Pass

Sympathetic Detonation

Sympathetic Detonation never passed before without Barriers

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

SD Test Setup


Donor Side Witness Plate

Acceptor Bottom Witness Plate

IMX -101
IMX -102
IMX -103
} Pass

Donor Bottom Witness Plate - Dented

Common Low-cost IM Explosives
TNT Replacement Program
50mm Shaped Charge Jet Impact (SCJI)

May 4th, 2007
(Picatinny Arsenal)

Test Set-up with 50mm SCJ

IMX-101

3 “Large” Pieces
NO Detonation
PASS

IV

IMX-102

4 “Large” Pieces
NO Detonation
PASS

IV

Common Low-cost IM Explosives
TNT Replacement Program
81mm Shaped Charge Jet Impact (SCJI)

May 17th, 2007
(Picatinny Arsenal)

Test Set-up with 81mm SCJ

IMX-101

NO Detonation
PASS

III

IMX-102

NO Detonation
PASS

III

Common Low-cost IM Explosives
TNT Replacement Program
FCO Results

Without adequate venting

Pass

With adequate venting

Common Low-cost IM Explosives
TNT Replacement Program
IMX-101 Slow Cook-Off

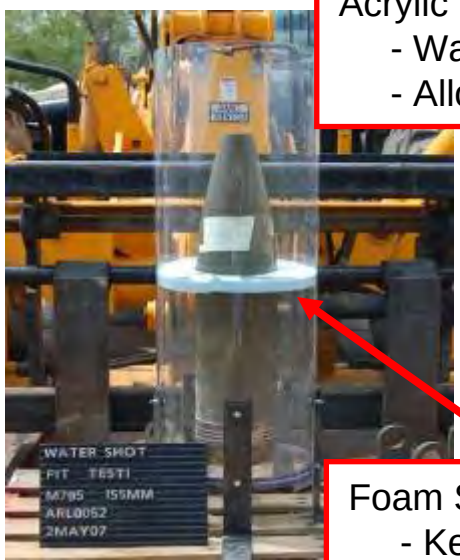
Type IV – Fail

Without adequate venting

Pass

Common Low-cost IM Explosives
TNT Replacement Program
Lethality Assessment

- ✓ **Comparison to TNT**
  - ✓ **Water Pit Tests**
    - M795 projectiles loaded with IM formulations
  - ✓ **Cylinder Expansion Tests**
    - 4” copper cylinders due to large critical diameters



Acrylic Tube
- Watertight seals
- Allows expansion to 2x CD

Foam Spacer
- Keeps projectile upright
- Centering device

All 3 formulations have fragmentation and Gurney Energy equivalent or better than TNT

Summary

- ✓ **Phase 1 identified 3 formulations that exceeded expectations**
  - ✓ **Passed SD in standard pallet**
- ✓ **Phase 2 attained what many considered unattainable**
  - ✓ **<u>Demonstrated IM Compliance</u>**
  - ✓ **Lethality comparable to TNT**

IMX-101 & IMX-102 Formulations made on Production equipment with Production ingredients

IM Test:	FCO	SCO	BI	FI	SD	SCJI	
Passing Criteria	V	V	V	V	III	III	
M795 Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	
						50mm	81mm
IMX - 101	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IMX - 102	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IMX - 103	PASS	PASS	FAIL	PASS	PASS	PASS	FAIL

Qualification Program Schedule for TNT-Replacement

- ✓ **Phase 1 – Screening / Downselect**
- ✓ **Phase 2 – Selection / Qualification**
- ✓ **Phase 3 – Transition / Qualification**
  - ✓ **EMQB Certification and Gun Qualification of top candidate**

Phase 3 STATUS:

•Several production batches of IMX-101 have been produced

•LAP of projectiles has commenced

•Energetic qualification testing of IMX-101 has begun

TNT-Replacement (IMX-101)

Phase 1 "Screening"

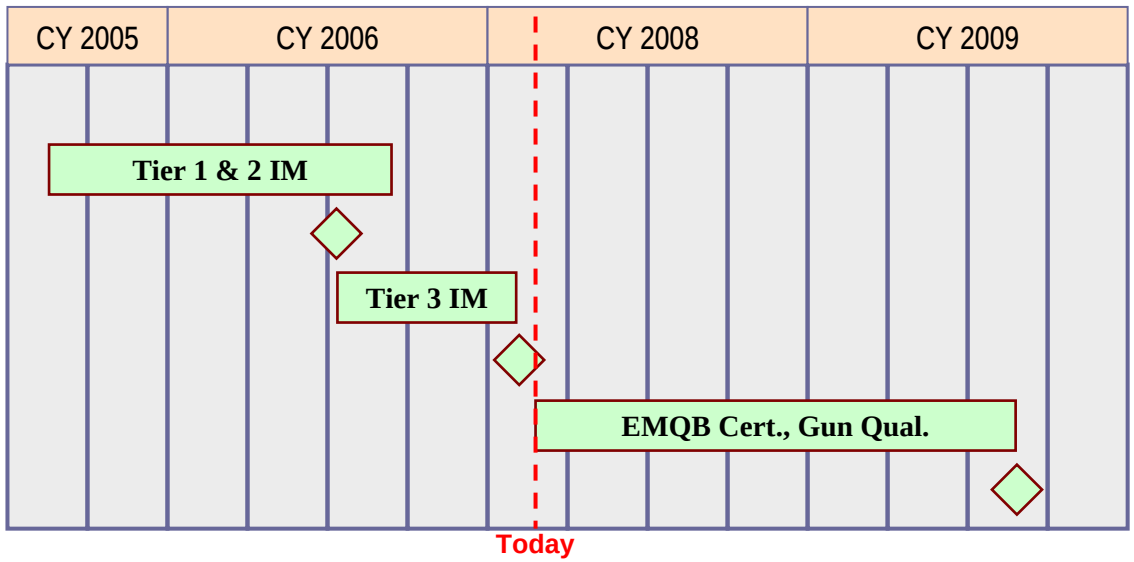
- **Identify & Test Candidates**
- **Downselection**

Qualification Phase 2

- **Selection (**IMX-101**)**

Qualification Phase 3

- **ECP into TDP**



Realizing an Armed Unmanned Ground System DoD Capability

DoD Need – There is no recognized DoD requirement other than FCS (Very large)
Challenge – Fielding a "natural extension of the soldier/marines reach on the battlefield"
Opportunity – Change the nature of combat by providing US forces an overmatch capability

Status of Armed Unmanned Armed Ground System Development

The good news for every soldier and marine in combat today!

Concept of Operations (CONOPS)

Lethality

Serves as a natural extension of the soldier/marine in battle

- Remotely over watch suspected ambush/IED locations > day/night and all weather with no mission degradation due to mental fatigue or weather
- "Point man" during squad recon/movement to contact
- "First in" to buildings or doors suspected on being booby trapped/IED/direct fire
- "Escalation'" capable – Non-lethal, Less than lethal, lethal all on one platform

Concept of Operations (CONOPS)
Force Protection

Preserving the force and other high value assets to fight another day

- Serves as the "unblinking eye", day and night to guard Forward Operating Bases (FOB), Fire bases, expeditionary airfields, and logistics supply points or ammunition dumps remotely – paired with other unattended ground sensors
- Serves as an over watch element or "first station" in a personnel or vehicle check point to provide stand off against suicide bombers
- Force multiplier – by "adding" technical capability to stand guard you significantly decrease human requirement – allow soldiers/marines to rest or prepare for next mission instead of guard duty

Concept of Operations (CONOPS)

Situational Awareness

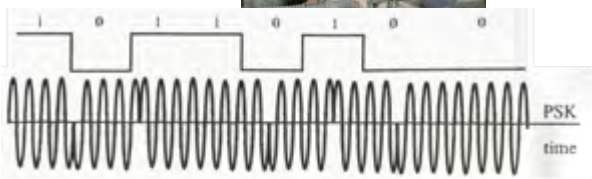
Projecting sensors to significantly increase combat effectiveness

- Provides sensor "stand-off" for the operator creating "tactical patience" that allows more deliberate fire/no-fire decisions
- Using on-board laser range finder, platform allows you to accurately target combatants with both direct and indirect means
- Eyes, ears and mouth - Utilizing the five on-board camera systems, and loudhailer the platform acts as another remote sensor on the battlefield

The Future is Bright and….. Full of Challenges

- Rules of Engagement (ROE)
- Requirements
- System Integration
  - Existing manned and unmanned systems
  - Common Operational systems
  - C3I systems
- Concept of Operations and Tactics, techniques and procedures (TTP) development

NDIA Gun & Missile Systems Conference



Micro Pulse Laser Designation (MPLD) System

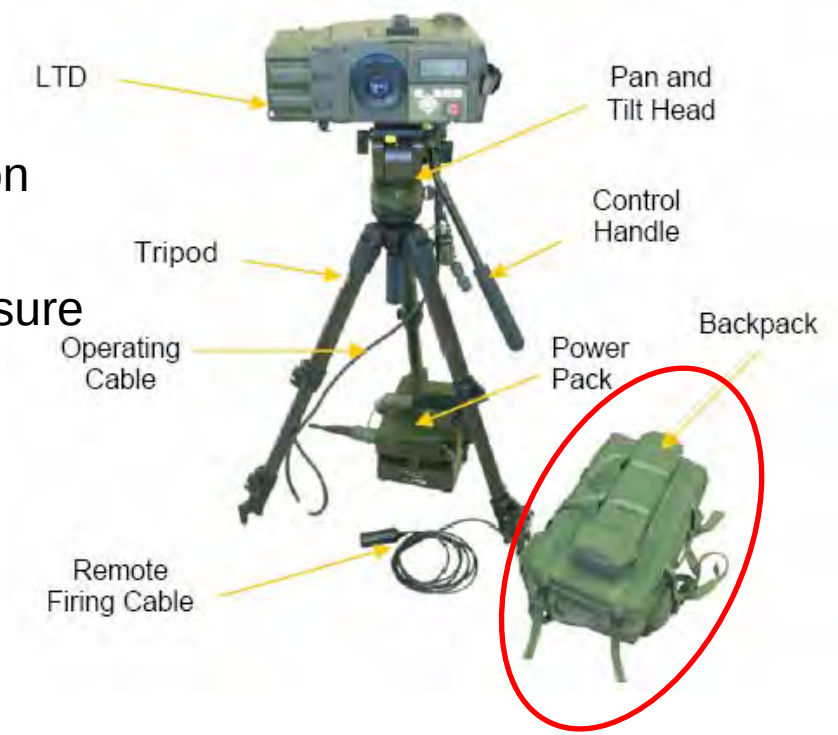
Current State of Ground Designators

- Designator Use:
  - Mark targets for engagement by laser guided weapons
  - Mark targets for identification by pilots and ground forces equipped with laser spot imaging equipment
- USMC Designator: Portable Lightweight Designator Rangefinder (PLDR)
  - Procurement in FY07
  - Fielding in FY08

USMC Portable Lightweight Designator Rangefinder

Ground Designator Shortcomings

- Ground Designators are:
  - ***Too Damn Heavy!*** PLDR system weighs 28 lbs
  - ***Expensive!***
    - Costs are typically $60-80K
    - Battery refresh is also a consideration
  - ***Dangerous!***
    - Eyesafe range is 20+km direct exposure
    - Reflections are an issue
    - Difficult to train due to safety issues
  - ***One Race Ponies!***
    - Designators do little else other than mark targets and measure range (limited use due to eye hazard)



USMC Portable Lightweight Designator Rangefinder

Get Rid of Designators?

Option: Get rid of designators, who needs them when we have GPS guided weapons?

- GPS weapons require accurate targeting
  - Vector 21B + DAGR provides target location, but has there problems:
    - Azimuth
    - Azimuth
    - Azimuth
  - PSS-SOF can provide very accurate targeting but:
    - Need computer
    - Need accurate up to date maps
    - Need features to pick out in images
- What about…Jammers, Urban Canyons, Inside Buildings?

Vector 21B “CLRF” Rangefinder

Get Rid of Designators?

Option: Most aircraft have designation capability – why not just use aircraft?

- You still need to get the pilot's eyes on the target
- Most laser guided weapons are air delivered, but this is due (in part) to the limitations of the ground designator
- If there was a covert, eye safe, lightweight laser designator, wouldn't we develop laser guided artillery and mortar rounds?

Delivery of Paveway-III

“New” Designator?

- Vector 21B
  - Eyesafe 1540nm 10km laser rangefinder
  - Excellent Optics
  - Integrated Digital Magnetic Compass and Vertical Angle sensor
  - Interfaces with DAGR
  - <$20K
  - <8 lbs (including tripod)
- Is it possible to use this as a ‘Designator’?

Quick PLDR and Vector 21B Comparison

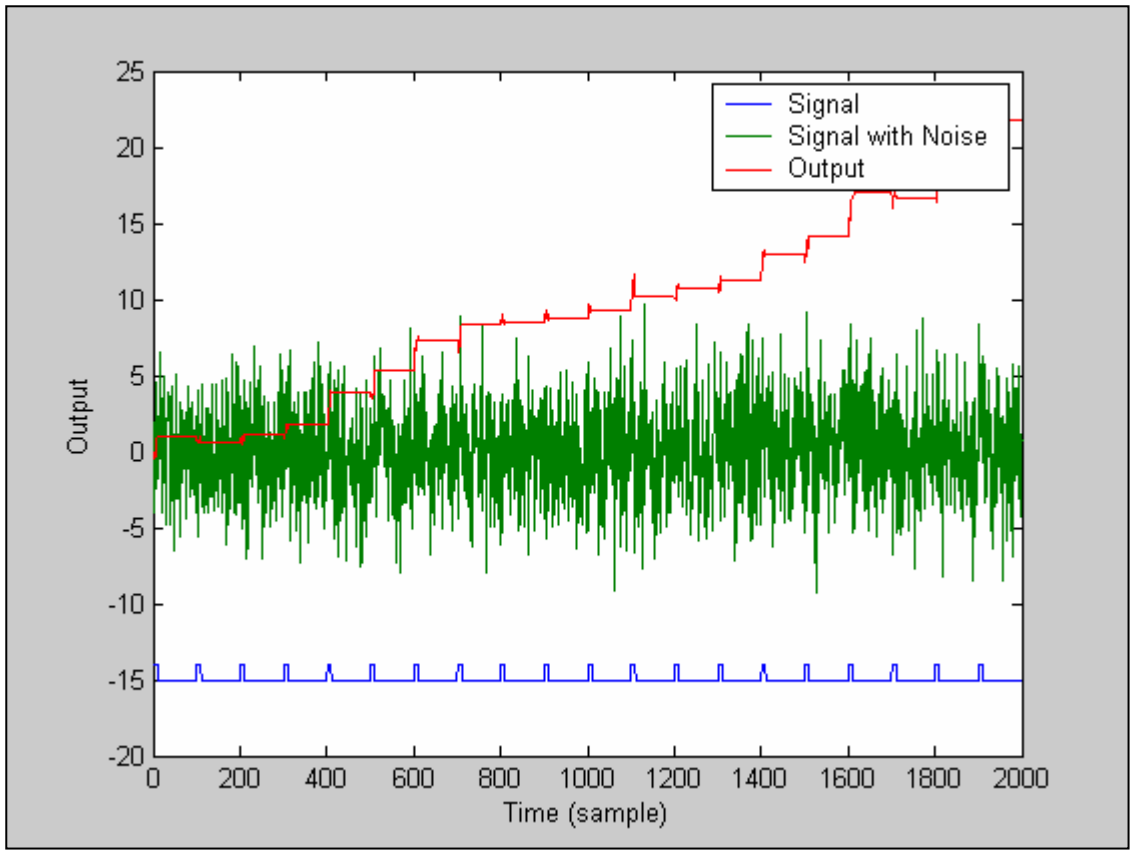
Laser Energy	50-100 mJ	1.2µJ
Laser Wavelength	1064nm	1540nm
Laser Output Rate	10-20 Hz	10 kHz
Covert?	No	Yes
Eyesafe?	No	Yes
Weight	28 lbs	<8 lbs

Project Technical Description

- Objective: To design a laser seeker that uses high-rate low amplitude pulses for guidance and determine what weapon systems can utilize the technology
  - –Current laser codes: 20Hz , 50-100mJ pulses
  - –Common Laser Range Finder (CLRF): 10Khz, 1.2µJ pulses
- Advantages:
  - Gives designation capability to all current rangefinder users
  - Switch to 1.54µm wavelength
    - Less atmospheric attenuation
    - Detector sensitivity 2X
    - Eye safe
  - Higher pulse rate
    - Pulses lower energy - more covert (like GPS)
    - Data rate increases when closing on the target

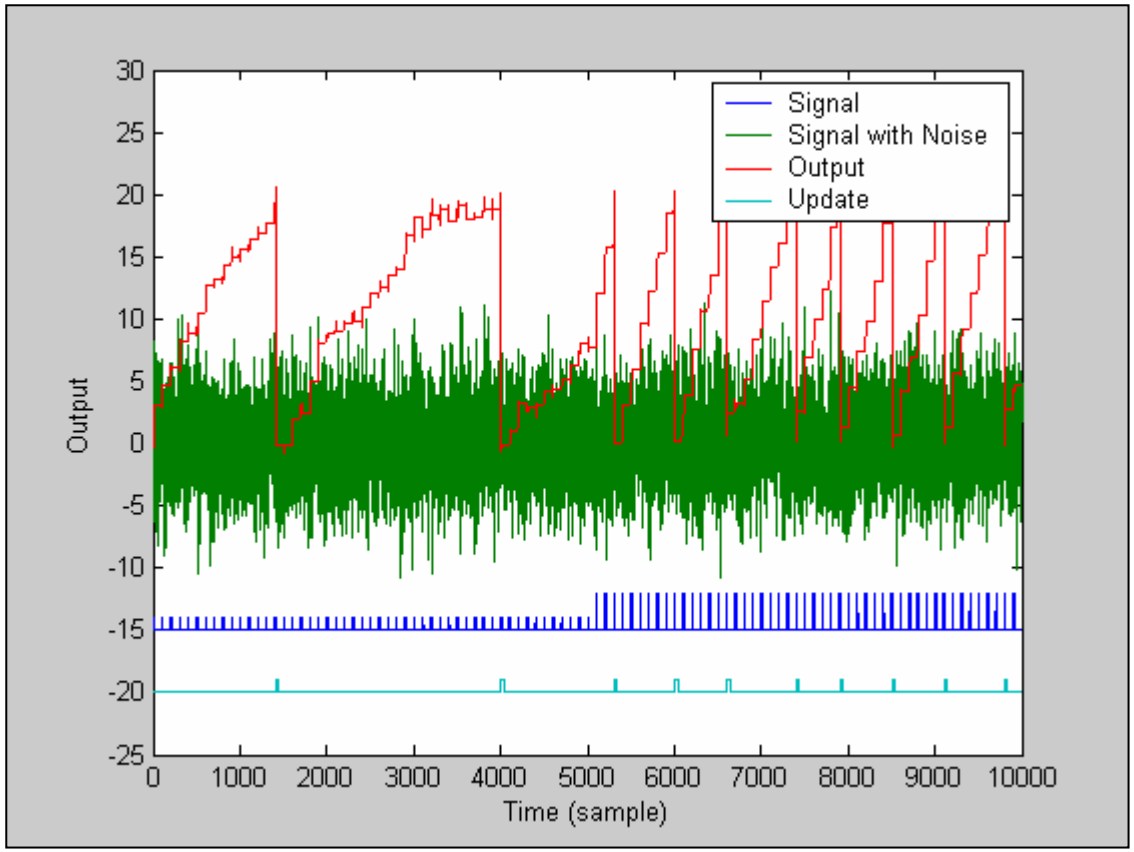
Micro Pulse Laser Designation (MPLD) System

Integrating Micropulses



Like GPS, integration of the signal+noise using the proper code (PRF) allows us to pull the signal out of the noise.

Integrating Micropulses



With a constant signal to noise, the data rate will increase as we close on the target. This is needed to reduce miss distance and occurs naturally!

FY08 Plans/Progress

- Analyzed shortcomings of existing laser designation systems
- Selected existing USMC laser range finder (CLRF) as the candidate designator
  - <4 lbs. vs. 28 lbs. for USMC PLDR (new acquisition FY07)
- Bench technology development and demonstration (ongoing)
  - Laser ‘lock’ range
  - Mortar guidance strategy
- Conduct Modeling and Simulation (ongoing)
  - 81mm Aerodynamic Analysis
  - Lens ray tracing
  - Matlab micropulse S/N analysis
- Conducted Trade Analysis on entire laser designation system
  - Developed new detector scheme which utilizes COTS developed for the telecommunications industry
  - Superior to existing quad-detector technology which is only used for military applications
  - Much lower cost and available immediately

Technical Approach

- FY09 Plans
  - Develop and test breadboard and analyze range performance
  - Begin development of mortar guidance section based on FY08 Aero Analysis
  - Test different seeker field of views, aperture size, and other system parameters
  - Work with selected vendor on ‘productionizing’ design
  - Seeker exits FY09 at TRL3, guidance section exits FY09 at TRL2

Q&A

Questions?

Panel Discussion:

Unmanned and Autonomous Systems

Weapons Integration

Ed Hackett
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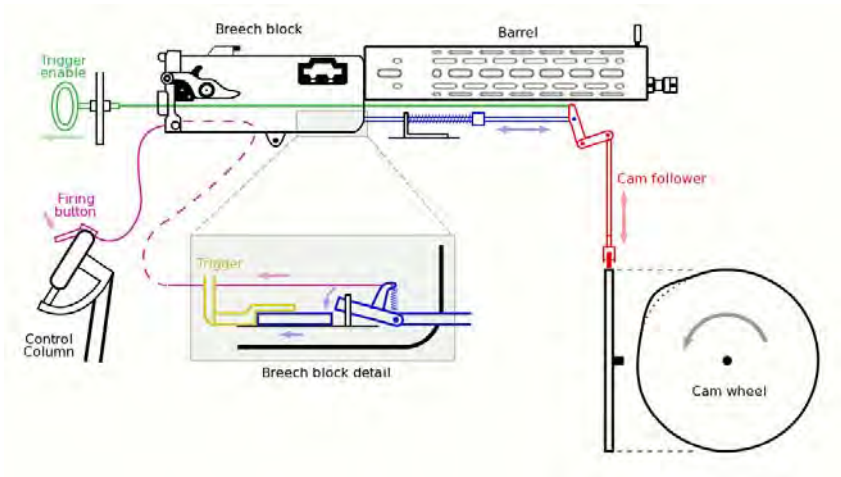
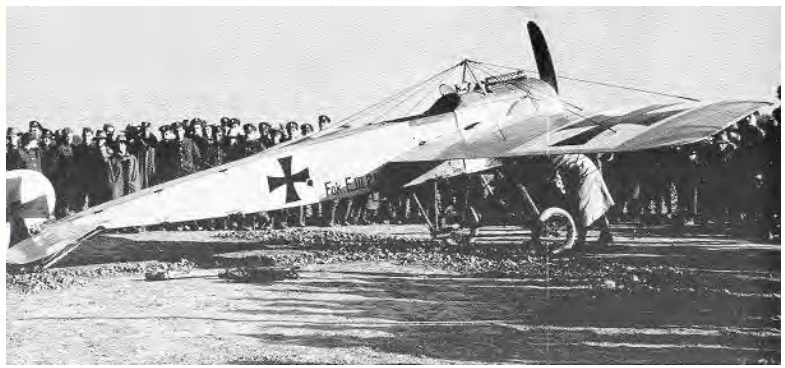
Lessons From History: The Aircraft Analogy





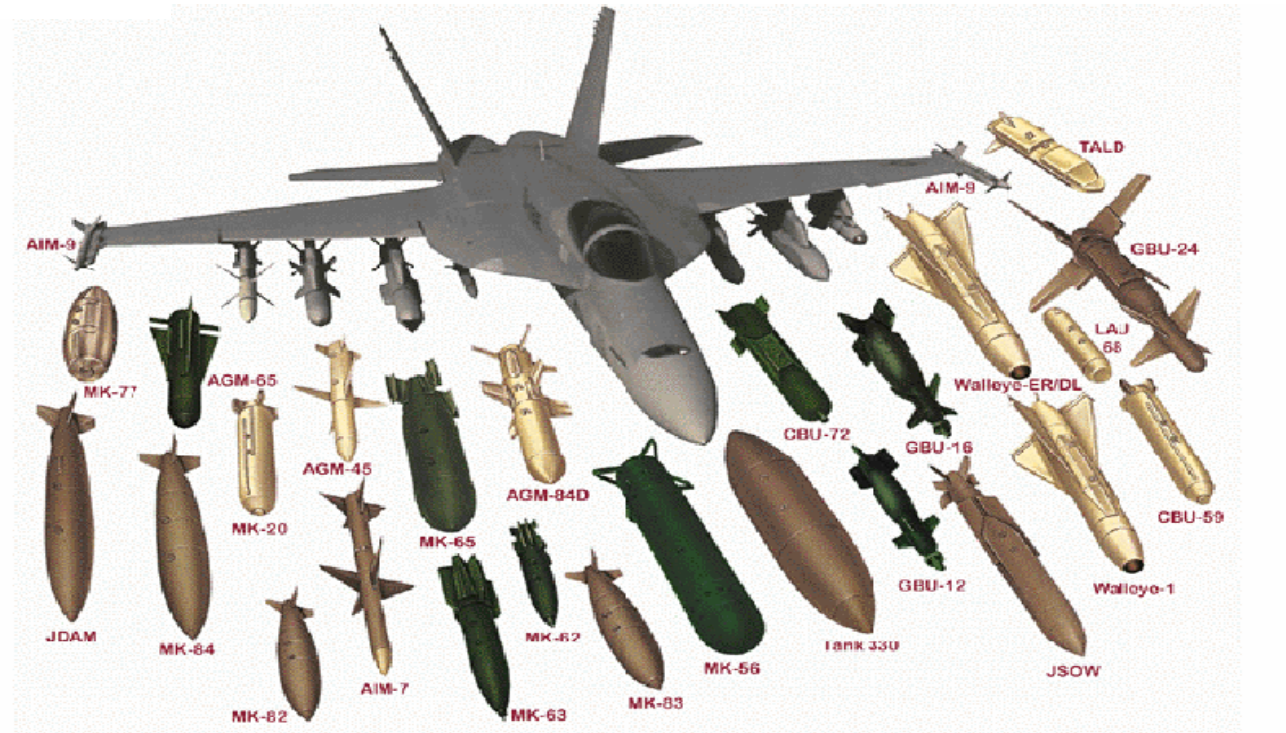
Ferdinand Foch, allied commander in chief in 1918, reputedly stated in March 1913
”Aviation is fine as sport.
I even wish officers would practice the sport, as it accustoms them to risk.
But, as an instrument of war, it is worthless (c'est zero).”

Lessons From History: The Aircraft Analogy

1940: North American Aviation contracted to develop the P-51 Mustang. The original NA-73X had (2) chin mounted 50 cal guns.

Within a few short years the P-51 had all wing mounted guns and began carrying rockets mounted to external wing stations.

Lessons From History: The Aircraft Analogy



60 years later, the FA-18 exemplifies a mission and systems integration focus:

The entire platform design enhances capabilities and effects for the tactical mission

Lessons From History: The Aircraft Analogy

The UAV community has turned the corner and adopted the concept of matching armed capabilities to mission requirements

Turning the Corner For UGVs

Where, when and how does the UGV community make this transition up the evolutionary ladder?

Desired Endstate

- ***Effectiveness/Combat Effectiveness***
  - Efficient, reliable, and accurate

- ***Scalability***
  - Responsive via lethal and non-lethal applications
  - Meets multiple battlespace requirements ranging from effective passive deterrence to combat force multiplication

- ***Multiplicity***
  - Multiple platforms deployable on a single mission set

- ***Safety***
  - Unquestionable and trusted ally

Future Capabilities

Ricky Houghton

Ibis Tek

Hand Controller

- Why does the industry still deploy toy controllers?
- Mil-Spec versions exist
  - Deadman switches
  - Estop
  - Trigger Guards

IbisTek

UGV needs are different from UAV

- Video quality is critical
  - MPEG solutions are good for UAV, bad for UGV
  - Can’t realistically target/shoot with 640x480 MPEG
  - Need infrastructure to support higher resolution
- Low latency is critical
  - Can’t realistically shot a moving object with 250+ ms latency
  - Some currently deployed solutions are inadequate
  - MPEG memory require grow exponentially

Safety at the core

- It all starts with the education
  - Safety is not part of traditional software engineering training
  - Not sure it is part of electrical either
  - We need to fix this
- There are a lot of very bright people in robotics
  - Electrical, mechanical, software engineers
  - They want to solve interesting problems
    - Usually not safety
- Aerospace engineers and transportation engineers know safety, it is a culture thing

IbisTek

GENERAL DYNAMICS
Ordnance and Tactical Systems

43rd Annual Gun & Missile System Conference

Presentation by: Donald E. Dillard, P.E.

Title: S40mm x 180mm Common Case Design Progress

Time & Date: 1135 – 1155 Tuesday April 22, 2008

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30/40mm Comparison
ALACV Super 40mm

Cartridge OAL = 289.97mm

PGU 13

ALACV Design

W/2 Case Lengths

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S40mm ALACV with Steel Cases

KE with 218mm OAL Case

TP-T & AB with 165 OAL Case

- The Selected Case Lengths Provide Optimum Performance For Each Round
- Case Taper is only .009 in/in – Extraction issue?

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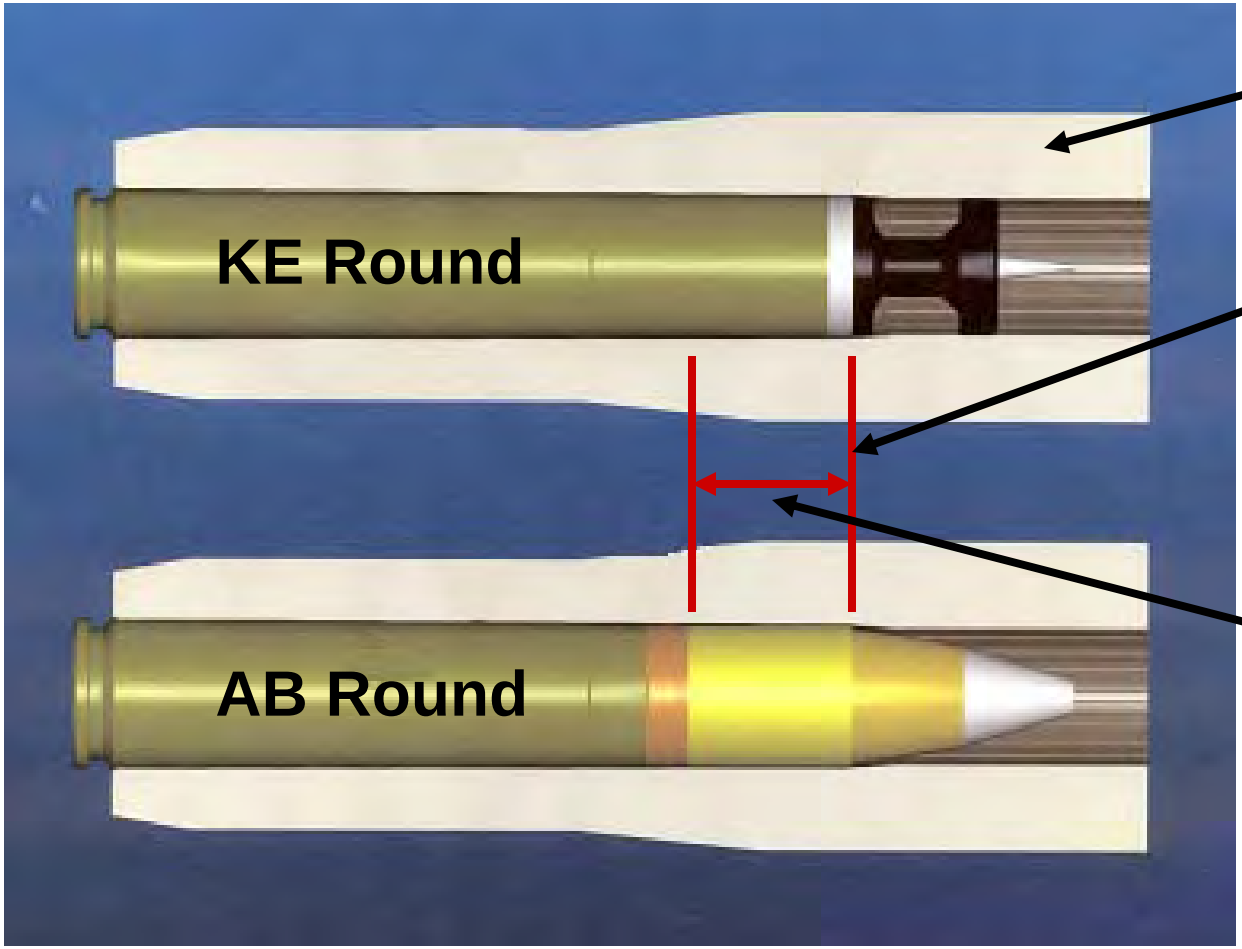
S40mm ALACV Demonstration Rounds



Barrel

Start of Forcing Cone

2” Free Travel
2 ¼” to start of Rifling

Free Travel Results in Excess Barrel Wear

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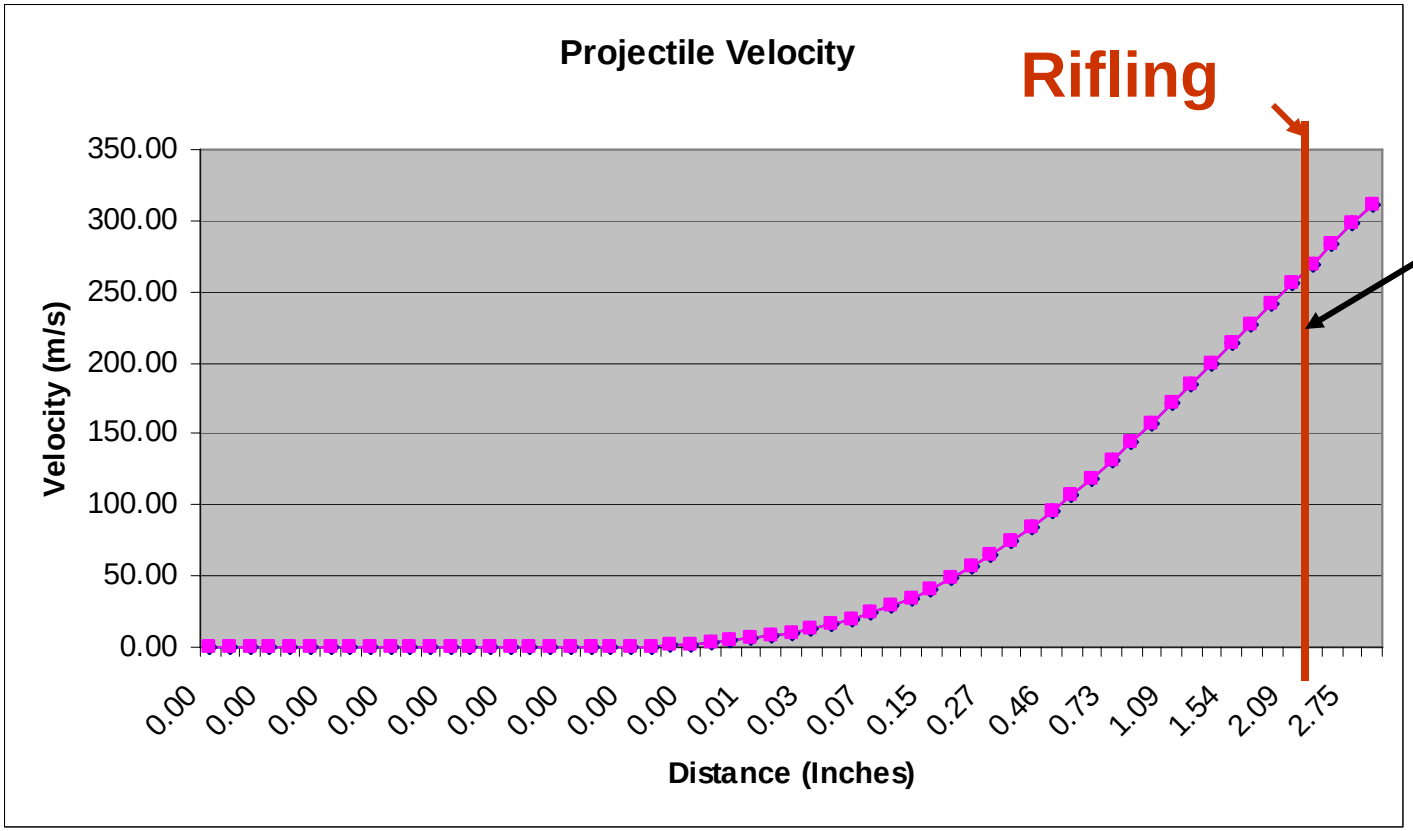
S40mm ALACV – Velocity vs. Travel



Velocity at beginning of Rifling is >260 m/s

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S40mm Design Improvement

- **Common Case Length is a Necessity to Provide Long Barrel Life**
- **Increased Case Taper is Desirable**
- **Parametric Study Undertaken to Establish Optimum Length**
- **Case Lengths Evaluated from 165mm to 215mm**
- **180mm Selected – Provides Acceptable Taper and Area for AB Fuze Communication**

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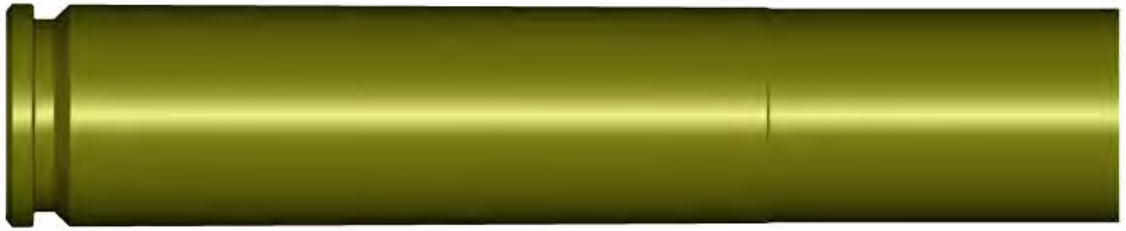
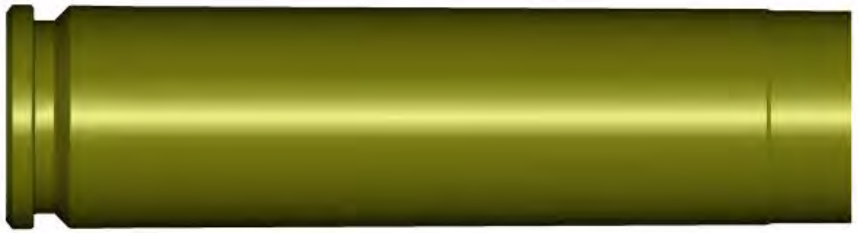
S40mm Case Comparisons



ALACV Cases – 165mm & 218mm

40mm



39mm for Add'l Case Taper

GD-OTS S40mm x 180mm

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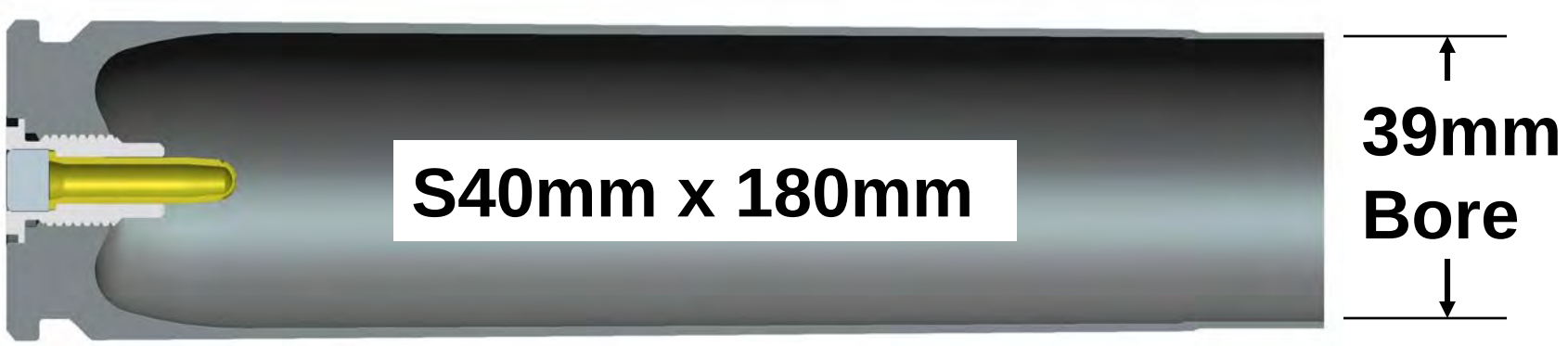
S40mm Common Case



1. **Steel Case for Robustness**
2. **Threaded Primer Insert Allows Propellant Fill from Rear If Necessary**
3. **Uses Standard M36 30mm Primer and Flashtube**
4. **Taper Increased From .009 to .0166 in/in**

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S40mm With Common Case

1. **Forward Edge of Driving Bands Are At Forcing Cone**
2. **AB Has Adequate Area for Communication & Bearing Surface**
3. **Both Rounds use St. Marks Powder Hybrid Propellant – High Performance & Low Barrel Erosion**

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Why S40mm?

30mm x 173 Shown Superimposed over S40mm

1. **Compatible With Highly Reliable ATK MK44 30/S40mm Chain Gun**
2. **Same Link and Stowage Space as 30mm**
3. **Increased Payload & Lethality**
4. **Modest Cost Increase Over Tactical 30mm Rounds**
5. **S40mm ALACV Demonstrated @ High Rate Burst in the MK44 Weapon**

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Why S40mm APFSDS-T?

Penetrator Comparisons

25mm M919

30mm

S40mm

1. Muzzle Velocity Approx. Same as 25/30mm
2. S40mm Provides ~ 20% to 25% Penetration Increase over 30mm

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Why S40mm HEAB-T?

1. **Muzzle Velocity Equal or Greater Than 30mm With Pressures Near 400 MPa**
2. **Approx. 60% More Payload Delivered to Target**

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S40mm Summary

- S40mm Lethality is Greater Than 30mm
- High Vehicle Stowed Load Capacity
- Modest Cost Increase Over 30mm
- MK44 30/S40mm Chain Gun Uses a Highly Reliable and Proven Design
- S40mm Common Cases Available in July 08

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S40mm Common Case Design Progress

Questions

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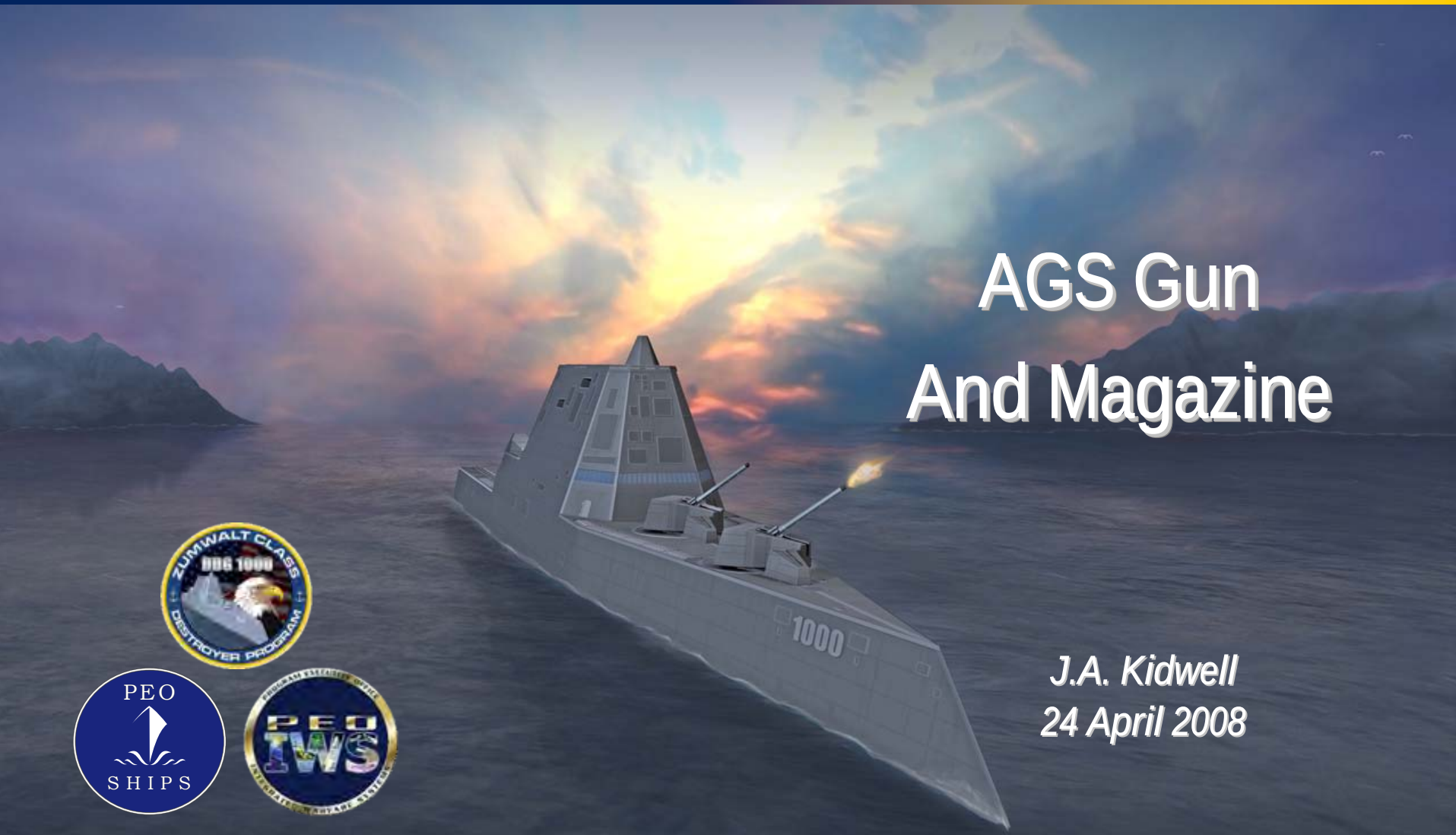
Advanced Gun System (AGS)



AGS Gun And Magazine

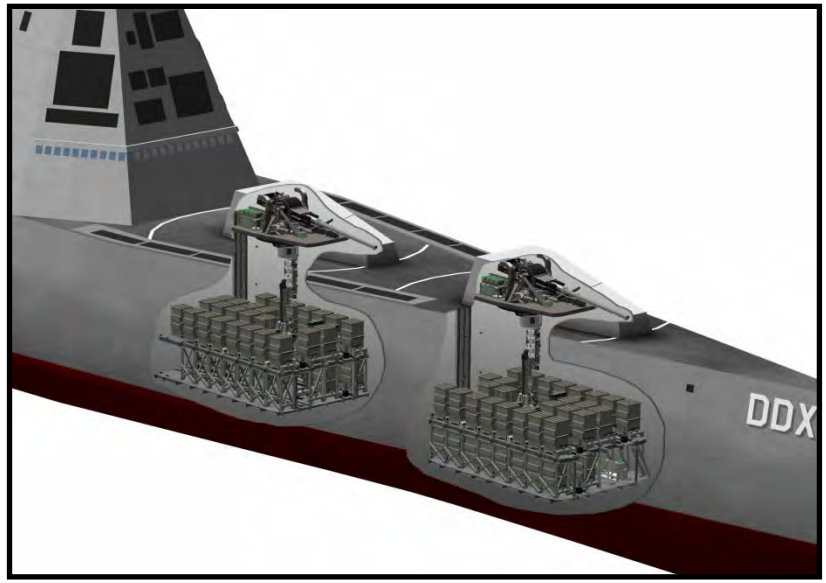
J.A. Kidwell

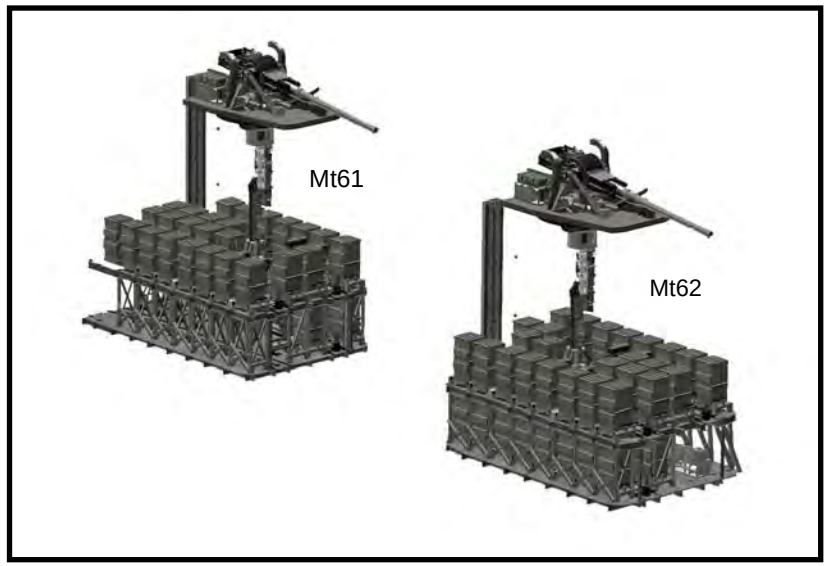
24 April 2008

Distribution Statement A: Approved for Public Release; Distribution Unlimited. (4/29/2008).
This Brief is provided for Information Only and does not constitute a commitment on behalf of the U.S. government to provide additional information and / or sale of the system

AGS Background

- Mission:
  - Destruction, interdiction, suppression and other fire support missions to support ground and expeditionary forces
- Platform:
  - DDG1000
- Employment:
  - Engage enemy land targets at long range with precise, high volume fire support
- Description:
  - 155mm automated gun system which includes:
    - ★ Fully Automated magazine
    - ★ Unmanned gun mount
    - ★ GPS guided projectile
    - ★ Pallet (transport & storage)
- Contractors: BAE Systems, GDATP, LMCO

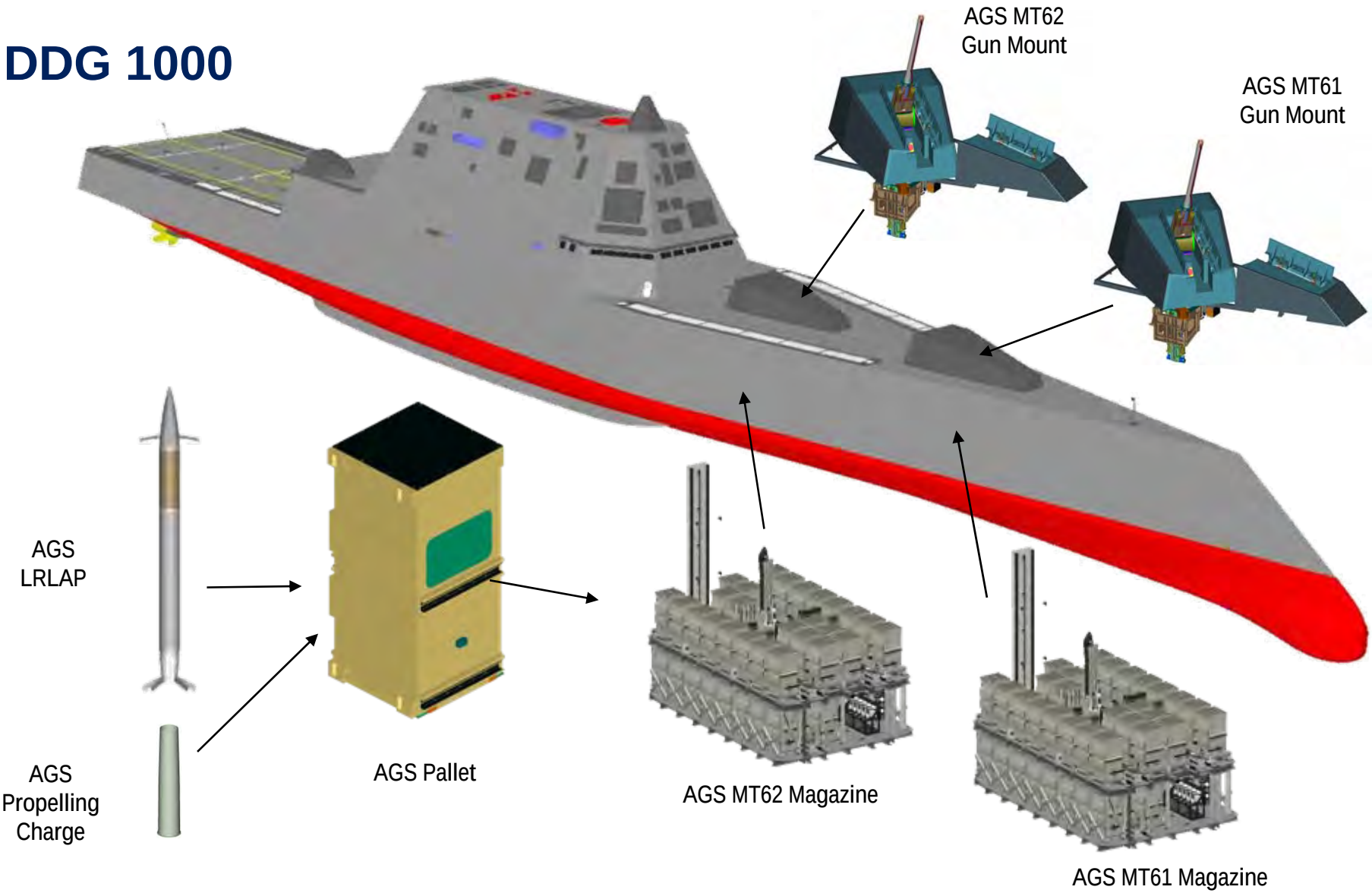




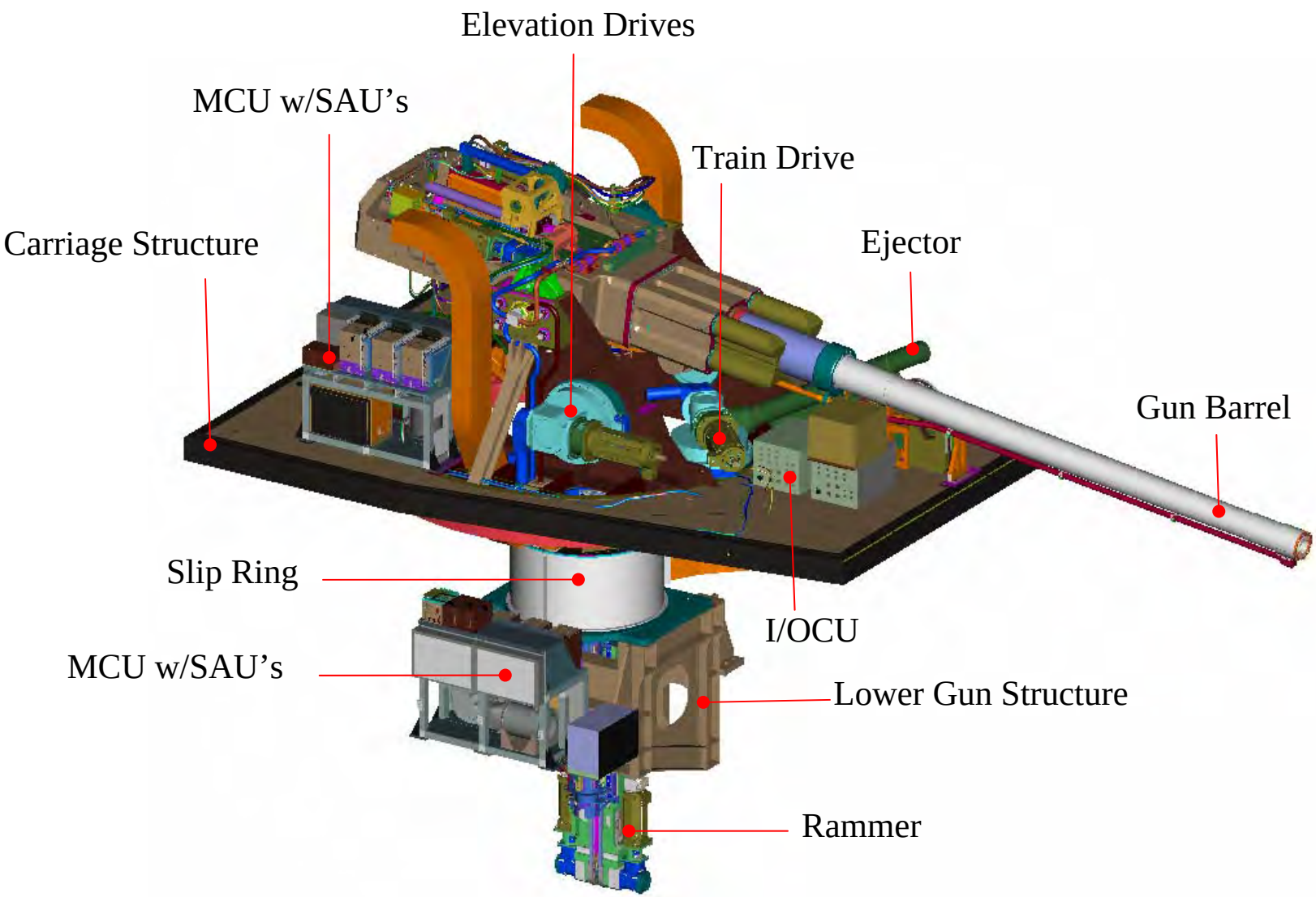
AGS Key Requirements

(U) Key AGS Element Performance and Operational Requirements		
Parameter	**Performance Requirement**	**AGS Design Features**
Magazine Capacity	600 LRLAP rounds per ship (minimum).	8-Round Pallets and Capacity for 75 Pallets (minimum).
Signatures (RCS and Infrared [IR])	Use design practices that minimize ship signatures.	Low signature shield design for gun mount – hides the barrel eliminating the major RCS signature source for AGS. AGS baseline incorporates ship-level design guidance concerning signature reduction.
Maximum Land Attack Range	> 63 nautical miles (nm).	155 mm, 62 Caliber Gun and Rocket Assisted, Guided, Projectiles
Max. Rate-of-Fire/Sustained Rate-of-Fire	10 rounds/minute	Fully Automated Magazine and Liquid Cooled Barrel
Accuracy (Land Attack)	Classified.	LRLAP has precise targeting by using a Global Positioning System (GPS) guidance system with a backup Inertial Navigation System (INS) guidance system.
Lethality	Provide equivalent lethality to that of current 155 mm gun M795 ordnance.	Arena tests conducted confirm performance.
Multiple Rounds Simultaneous Impact	Provide MRSI capability of 6 LRLAP rounds within 1 sec. from 36 nm to 67 nm.	AGS will be capable of achieving the specified MRSI effect with its LRLAP guided projectile.
Replenishment Modes	At-sea or in port.	Design enables at-sea and in port replenishment of AGS pallets

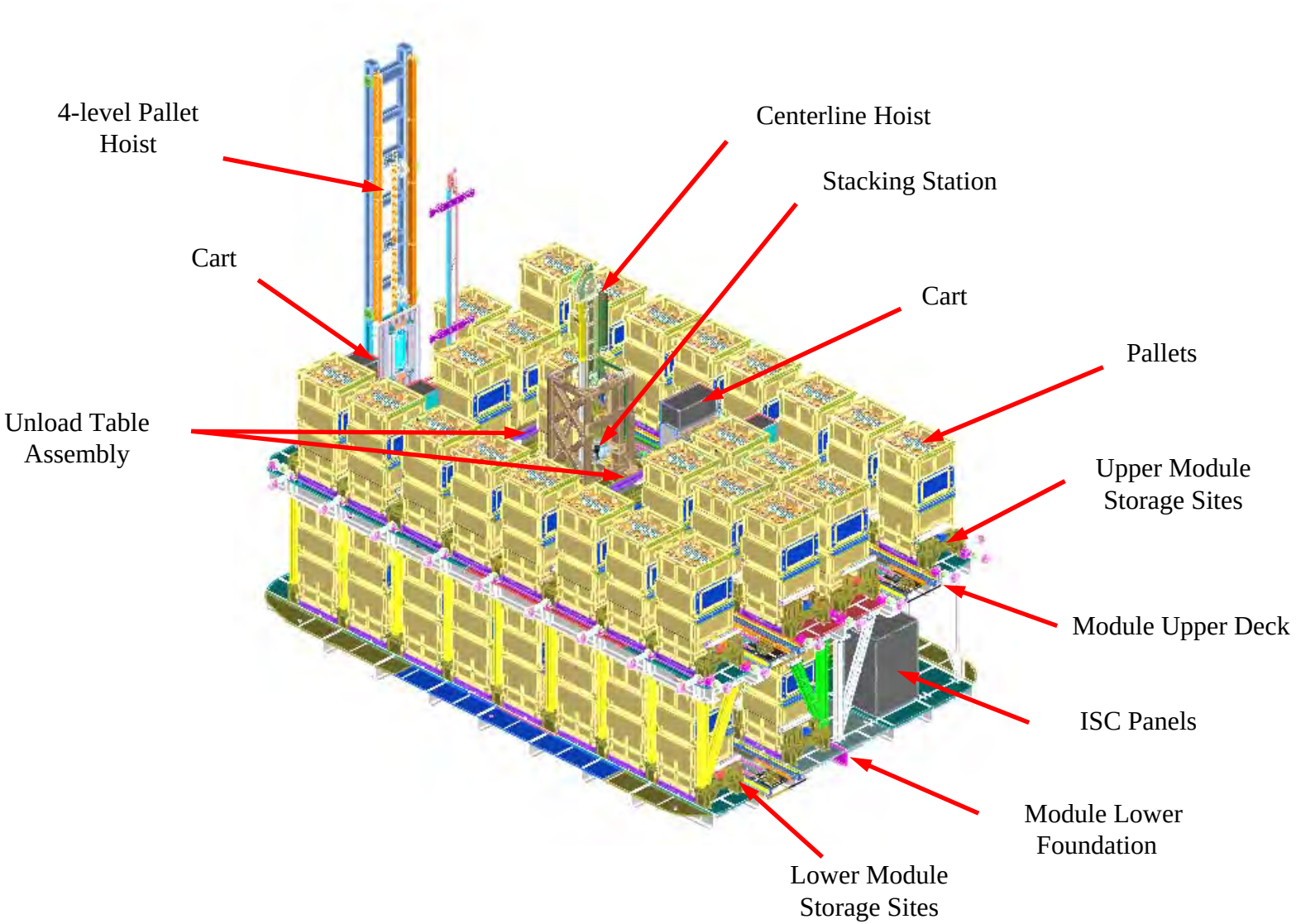
ADVANCED GUN SYSTEM MAJOR COMPONENTS



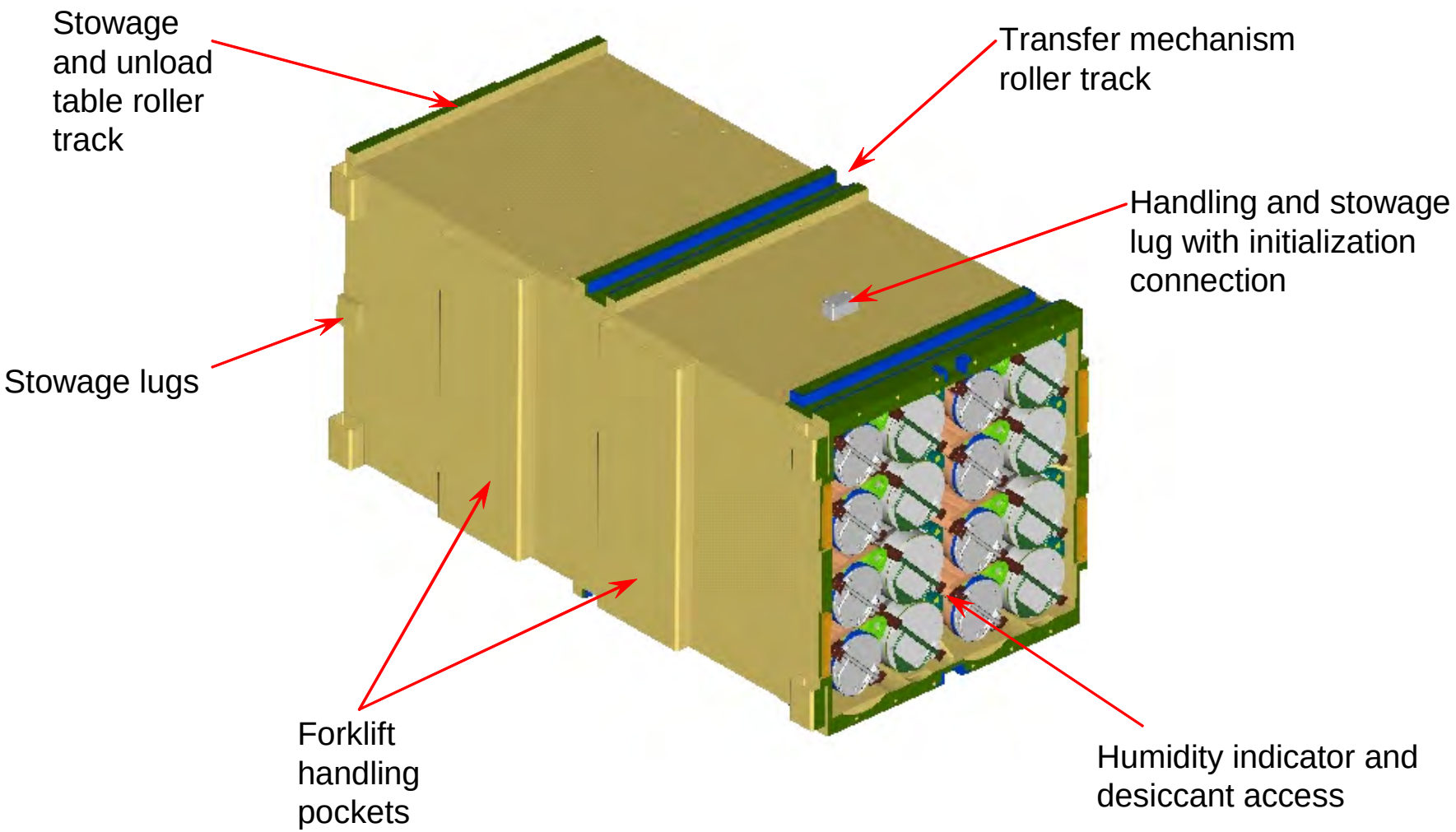
AGS Gun Mt Overview



AGS Magazine Overview



AGS Pallet Overview



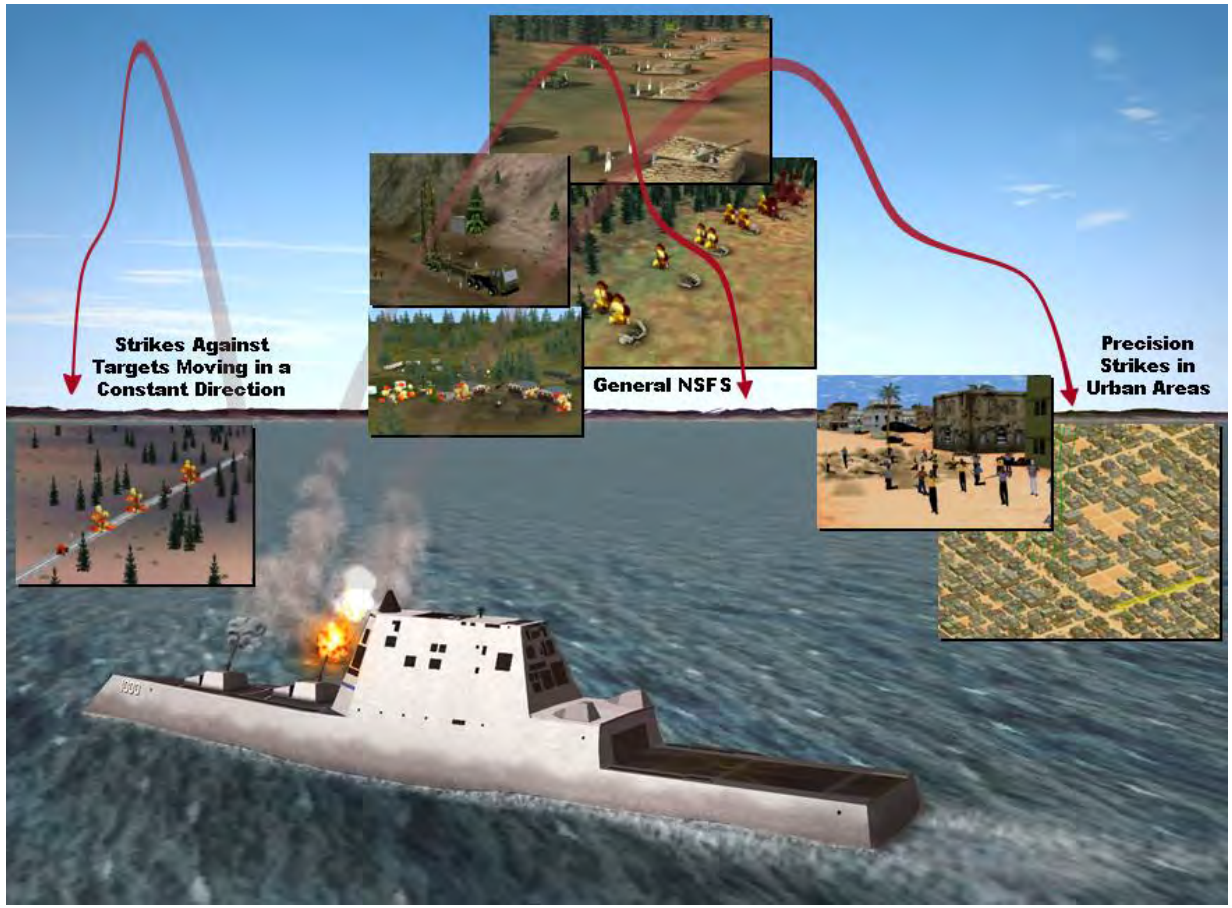
Advanced Gun System (AGS) & Magazine

Accomplishments

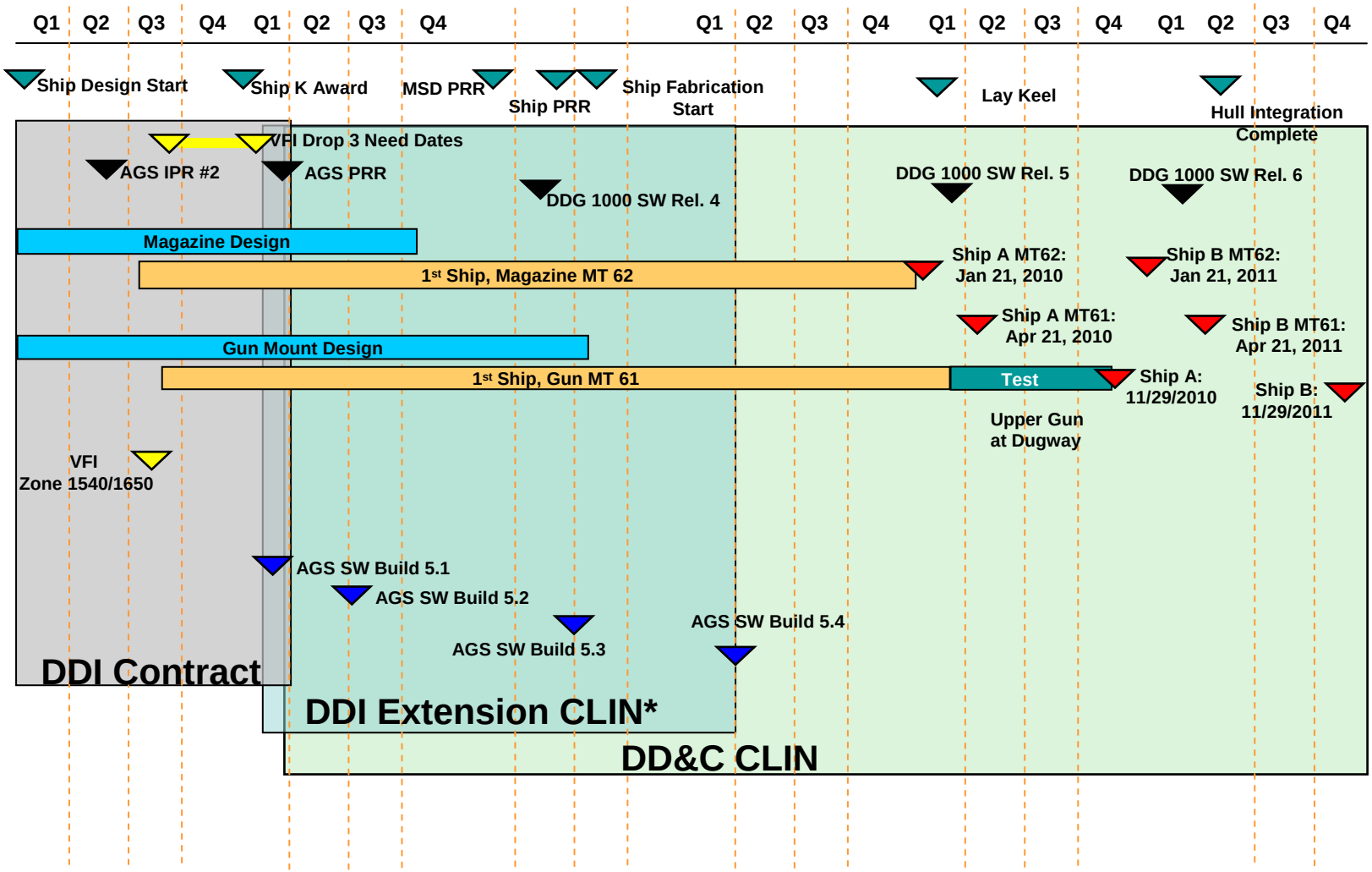
- Component testing to validate design
  - Gun and Magazine single axis testing (SAT), multi-axis testing (MAT), and factory acceptance testing (FAT) complete
- Gun mount and magazine integrated testing at Dugway, UT Land-Based Test Site
  - Verified maximum rate of fire of 10 rounds per minute
  - Verified maximum rate of fire in 8-round bursts
  - Verified magazine capable of unloading all 8 complete rounds from pallet in 45 seconds or less

AGS Fire Control

- Provides a set of services to support the planning and execution of EAGS engagements
  - Estimation of number of rounds and estimated effectiveness
  - Determination of target aim points and fuzing
  - Calculation of firing solutions
    - ★ Guided and unguided projectile trajectories
    - ★ Gun pointing angles
    - ★ Time of flight
    - ★ Terminal conditions
- Supports up to 6 round AGS Multiple Round Simultaneous Impact (MRSI) engagement execution



AGS Program Schedule



* Minimal effort extends through Sept 2013

AGS Summary

- Rapid Response
- Will Deliver Precision, High Volume Fire In Support Of The Warfighter
- High Reliability
- Major Technologies Demonstrated Through EDM

Contact Information

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  - Naval Surface Warfare Center, Port Hueneme Division, Louisville
  - (502)364-5047
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    NSWC PHD Det Louisville

    ATTN: James A. Kidwell, G61

    160 Rochester Drive

    Louisville, KY 40214

Guns and Missiles Systems Conference
23 April 2008

Unmanned Surface Combat System

Environment

Emergence of Asymmetric/Unconventional Threats Requires Different Capabilities to Counter/Thwart

High Value Asset Threat

Homeland Threat

Suicide Bomber/Israeli Navy

Small Attack Boat Threat

USS COLE Bombing

Clear Operational Need

Asymmetric/Unconventional Threats Drive Need for:

- **Fixed/Mobile High Value Asset Security**
- **Harbor and Port Security**
- **Maritime Intercept Operations**
- **Surveillance and Reconnaissance**
- **Riverine Operations**

What's Needed?

Capability to Detect and Respond Rapidly to Potential and Emergent Threats in Military and Public Environments

- Protect Waterways and Oceans
- Persistently Survey Wide Maritime Areas
- Remove or Distance Humans from Hazards
- Detect Hostile Intent via Remote or Automated Means
- Operate Continuously: 24/7, All Weather
- Remain Affordable

Why An Unmanned Surface Vehicle?

- Dramatically Reduces Risk To Personnel And High Value Assets
- Optimally Performs The Hazardous Missions – Day And Night
- Provides Mission Flexibility With Reconfigurable Mission Modules
- Can Provide Real-time Input To Wider Tactical Picture
- Proportionate And Scalable Response

Why PROTECTOR?

Proven in real world operations

PROTECTOR is an unmanned, integrated Combat System for Force Protection / Anti Terror Missions

Ready for Deployment Now

Protector Is:

Control
- Sea or Shore-based Control Unit with ability to hand-off unit control

Platform
- Length: 9-11 m.
- Propulsion: Water Jet
- Engine: Diesel
- Payload: 1000 Kg.

Security Payload
- Spotlight
- Public Address

Communication
- Data Link
- Video Link
- Audio Link

Mission Modules
- Anti-Terror/Force Protection
- Modular Design supports other missions
  - SOF
  - Anti-Surface Warfare
  - Electronic Warfare

Navigation
- Radar
- GPS
- Nav. Lights
- Nav. Camera

Advanced Electro-Optical System - Toplite

Multi-Sensor Electro-Optical payload

CAPABILITY

- Day & Night Surveillance
- Highly stabilized mount
- Automated Target Tracking

SENSORS

- FLIR
- Low Light TV
- Laser Range Finder

In U.S. Inventory

Naval Stabilized Gun - Mini Typhoon MK49 MOD0

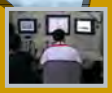
In U.S. Inventory

Lightweight, Remote Controlled,

Stabilized Machine Gun System

Robust, Proven NLOS Communications Link

Control Station



20KM

Shore

Sea

400-2000M

Controlled from Sea or Shore with ‘hand off’ capability

"During its time in theatre, Resolution was tasked with assisting the protection of the Al-Basrah Oil Terminal from terrorist attacks, according to MINDEF"

"Singapore...acknowledged ...purchase of ...Protector to support maritime security and interdiction operations ... in the northern Arabian Gulf"

"Protector had 'proven to be highly effective' ... vessels challenged by the USV had turned away immediately"

"Manning constraints and the desire to reduce the vulnerability of its personnel have seen the RSN emerge as a keen advocate for the potential offered by unmanned vehicles"

Singa...

BY RICHARD S...

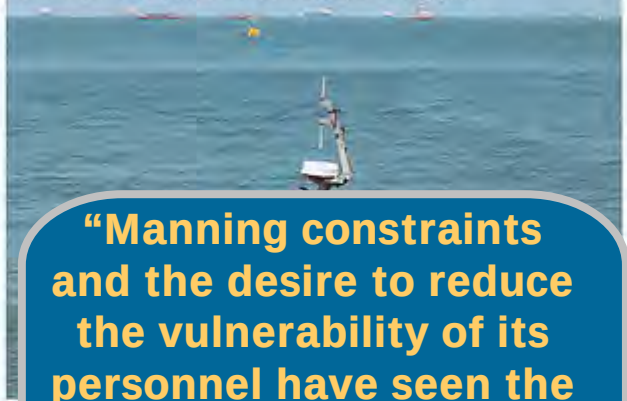
Singapore's Ministry of Defence (MINDEF) has acknowledged the hitherto undisclosed purchase of Rafael Protector unmanned surface vehicles (USVs) to support maritime security and interdiction operations recently undertaken by the Republic of Singapore Navy (RSN) in the northern Arabian Gulf.

The Singapore Armed Forces' house journal *Pioneer* acknowledged that a small number of Predator USVs were acquired from Rafael, Israel's Armament Development Authority, last year to operate ... the landing ship RSS *Resolution* during its three-month deployment to the gulf, which was completed in March 2005. During its time in theatre, *Resolution* was tasked with assisting the protection of the Al-Basrah Oil Terminal from terrorist attacks, according to MINDEF.

Pioneer noted that Protector had "proven to be highly effective", adding: "In the northern Arabian Gulf, the [USV] was deployed for more than eight hours at a go." Line-of-...ht communications and control ... exercised from aboard *Reso...n*, with operators reporting that ...els challenged by the USV had ...ed away immediately. It is und...ood that the line-of-sight cond...s enabled the ship to maintain ...rol of the Protector vehicle at ...es of up to 18 n miles.

...otector is based on a 9 m rigid-... inflatable boat adapted for ...ote operator control. The mission ...oad comprises a Toplite elec-...

One of the RSN's Rafael-supplied Protector unmanned surface vehicles seen during demonstrations at the recent IMDEX Asia 2005 event in Singapore.



...cap... more ... developed a ...ed a non-line-of-s... ...nications mode for th... ... augment the standard lin... ...ght link.

Manning constraints and the desire to reduce the vulnerability of its personnel have seen the RSN emerge as a keen advocate for the potential offered by unmanned vehicles. "Unmanned systems are an area which the RSN is exploiting as we continue our transformation," ... the Protector USV 'off the shelf', the RSN is also a participant in the US Navy's Spartan Scout USV advanced concept technology demonstration programme, which is exploring the concept of a USV that is able to flex between roles using interchangeable mission modules. A developmental Spartan vehicle was recently taken to Singapore for trials and demonstration purposes.

RAFAEL
ARMAMENT DEVELOPMENT AUTHORITY

BAE SYSTEMS

Current Status

- Protector Actively Being Used with Weapon for High Value Asset Protection and Area Surveillance
- Protector Bought by 3 Navies and counting
- Product Improved with 360 Viewer
- Protector Asset is Available for User Operational Evaluation Now

PROTECTOR USV
Rafael • BAE Systems

NDIA Guns and Missiles Conference

21-24 April 2008

CAPT Joseph L. McGettigan
Engineering and Weapons Division
US Naval Academy

My Goal For This Brief Is To Give You A High Level Exposure To:

- Surface Navy's role in the Maritime Strategy
- Shipbuilding and Modernization
- New Surface Ship Technologies

Surface Navy: Ready and Relevant

Maritime Strategy

"Our challenge is to apply seapower in a manner that protects U.S. vital interests even as it promotes greater collective security, stability and trust."

- ADM Gary Roughead, CNO

- **Forward-deployed** forces will provide regionally concentrated, credible **combat power** to limit regional conflict, **deter** major power war, and should deterrence fail, win our Nation's wars as part of a **joint or combined campaign**.
- **Persistent**, **mission-tailored** maritime forces will be **globally distributed** to contribute to **homeland defense-in-depth**, foster and sustain **cooperative relationships** and prevent or mitigate local disruptions and crises.

Preventing Wars is as Important as Winning Wars

Surface Forces Today

Surface Forces Provide Persistent, Visible Presence Around the Globe

Shipbuilding

Forward Presence

Deterrence

Sea Control

Power Projection

Maritime Security

Humanitarian Assistance Disaster Response

- DDG 51
- LCS
- DDG 1000
- LCC(R)
- CG(X)

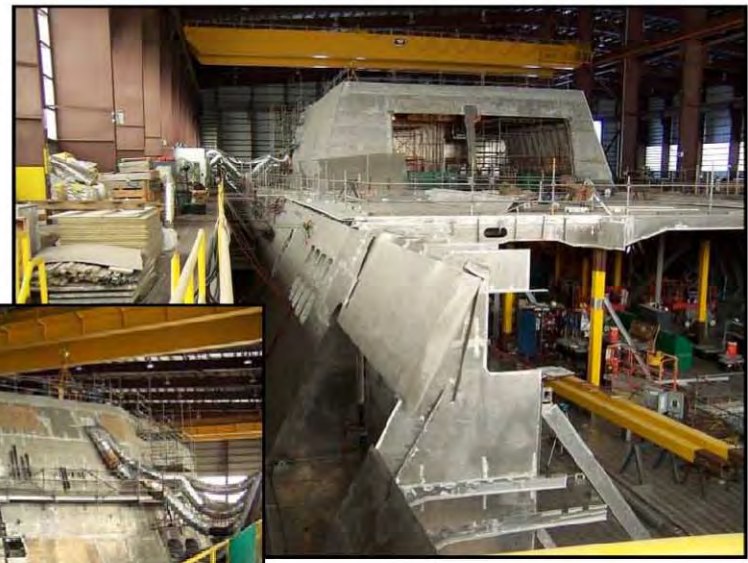
DDG 51 Class

- Last ships in Class under construction
- USS STERETT (DDG 104) will be commissioned Aug 2008
- USS Dewey (DDG 105) will launch 26 Jan 2008
- Arleigh Burke Class ends with DDG 112 (FY 2011)

10 Hulls Remaining

LCS

- MCM Mission Package delivered Aug 2007
- LCS 1 Delivery Aug 2008
- LCS 2 Delivery Oct 2008



DDG 1000

- Multi-mission surface combatant built for full spectrum of littoral dominance
- Brings unique new capabilities to the fleet
- Program Status
  - Lead ship construction contract awarded Jan 2008
  - Build profile remains 7 ships
  - Dual Band Radar (DBR) testing continues with outstanding results

CG(X)

- Will deliver and expand upon six core capabilities of Maritime Strategy
  - 21st Century AAW and Ballistic missile threats
  - Sea Base Defense
  - ESG and CSG support
  - APOD and SPOD defense
- Program status
  - Analysis Ongoing for Radar/Hull/Power Concepts

Multi-Mission Ship to Fill 21st Century Capability Gaps

Modernization

- Forward Presence
- Deterrence
- Sea Control
- Power Projection
- Maritime Security
- Humanitarian Assistance Disaster Response

CG Modernization

DDG Modernization

Amphib Modernization

FFG Modernization

Life-cycle cost saving upgrades are a must!

- Required for 313 floor
- Build on innovative successes
  - New weapons systems
  - Upgraded weapons systems
  - HM&E upgrades

AEGIS Modernization is the Clearest Way to the 313 Ship Floor

Making 313 Ships a Reality

The calculus is simple. If you have 280 ships, and you need 313, you have to build more, maintain those that are already in-service, and modernize the ones that are in-service.

VADM Paul Sullivan

11 April 2008

- VADM Sullivan

CG Modernization

Navy Precision Fires:
5" / 62 Gun/MK 160 GCS

Force Protection:
SPQ-9B
CIWS 1B

ASW:
SQQ 89A V(15)
Multi-Function Towed Array (MFTA)

SM-6

Improved Air and Missile Defense:
Aegis Advanced Capability Build (ACB)
Cooperative Engagement Capability (CEC)
Evolved Sea Sparrow Missile (ESSM)
Naval Integrated Fire Control – Counter Air (NIFC-CA)
Surface Electronic Warfare Improvement Program (SEWIP)
SM-6

All Electric

SMART SHIP

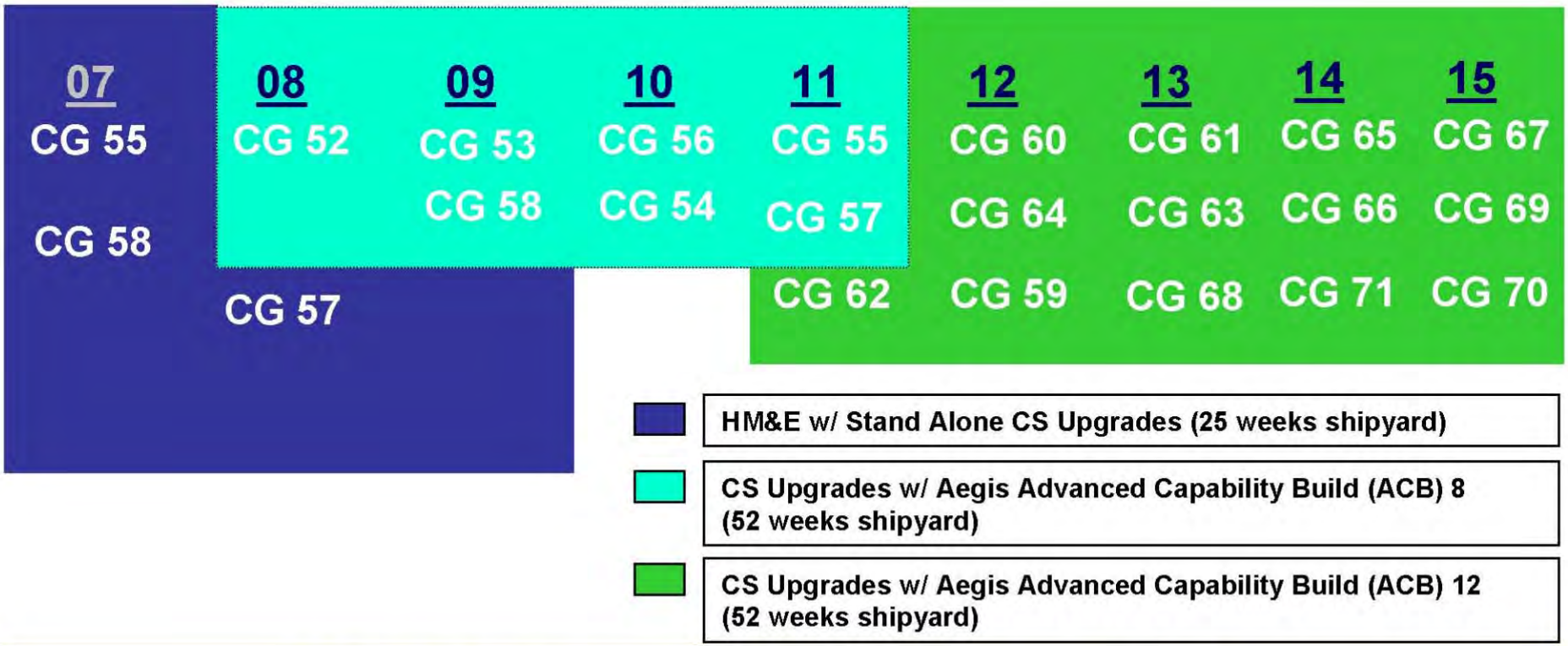
MH-60R

Hull, Mechanical & Electrical (HM&E) upgrades

Significant AAW Upgrades

CG Modernization Availabilities

- Homeport Shipyards
- Fleet priority HM&E alts such as All Electric accelerated as much as possible
- Cruiser Modernization Program completes FY17



CG Modernization is on track

DDG Modernization

Force Protection:
CIWS BLK1B

Navy Precision Fires:
MK 160 GCS

ASW:
SQQ 89A V(15)
Multi-Function
Towed Array

Improved Air and Missile Defense:
Ballistic Missile Defense
Aegis ACB
CEC
ESSM
Multi-Mission SIGPRO
SEWIP
SM-6
NIFC-CA

Reduced Life-Cycle Costs

Hull, Mechanical & Electrical (HM&E) upgrades

True Multi-Mission IAMD Capability

DDG Modernization Availabilities

- Homeport MSMO Shipyards
- Split into two avails, HM&E followed 2 years later by Combat Systems
- Flight I and II DDG's complete in FY 21

10	11	12	13	14	15
DDG 51	DDG 52	DDG 51	DDG 52	DDG 61	DDG 57
DDG 53	DDG 55	DDG 53	DDG 55	DDG 64	DDG 58
	DDG 65		DDG 65	DDG 69	DDG 54
		DDG 61	DDG 57	DDG 59	DDG 72
		DDG 64	DDG 58	DDG 56	DDG 77
		DDG 69	DDG 54	DDG 68	DDG 78

HM&E Availability (20 weeks shipyard + 4 weeks testing)

C/S Availability w/ Aegis Advanced Capability Build (ACB) 12 (20 weeks shipyard + 20 weeks testing)

DDG Modernization is on track

IAMD Capability

- Netted and Distributed Force
- Paces the threat
- Employed through an Open Combat System

Navy BMD Systems

Aegis BMD Baselines

- **BMD 3.0E – Fielded Today - SENSOR**
  - Long Range Surveillance and Track (LRS&T)
- **BMD 3.6 – Fielded Today - SENSOR/SHOOTER**
  - LRS&T and Engage
  - SRBM and MRBM Defense
  - Some AAW capability
- **BMD 4.0.x – Future - SENSOR/SHOOTER**
  - LRS&T and Engage
  - SRBM, MRBM and limited IRBM Defense
  - 2010- 2012 timeframe
- **BMD TBD – Future - SENSOR/SHOOTER**
  - LRS&T and Engage
  - SRBM, MRBM, IRBM, and limited ICBM Defense
  - 2012 – 2014 timeframe

SPY-1

- Legacy Aegis radar
- BMD Capable after MDA-funded Signal Processor (SIGPRO) mods
- Increased Capability with FY10 addition of BMD SIGPRO – Allows Better Target Discrimination

SM-3 Block I/IA/IB

Theater BMD

MDA Funded
- IOC: Blk IA FY06
- Kinetic Kill Vehicle for exoatmospheric hit-to-kill

SM-2 BLK IV

Gap-Filler Sea-Based Terminal (SBT)

- Available upon fuze conversion (100)
- Currently three CGs with emergency Linebacker software load
- Provides limited SRBM Terminal Defense (APOD/SPOD defense only)

SM-3 Block II/IIA

Regional/Homeland BMD

MDA/Japan Co-development (50/50 – MOU signed)
- IOC: Blk II FY 11
- Full 21" propulsion stack; increases ship station flexibility

Sea-Based Terminal Interceptor

Robust Sea-Based Terminal (SBT)

APOD/SPOD & Joint Sea Base Defense
- Missile TBD
- IOC: FY15
- MDA planning in progress

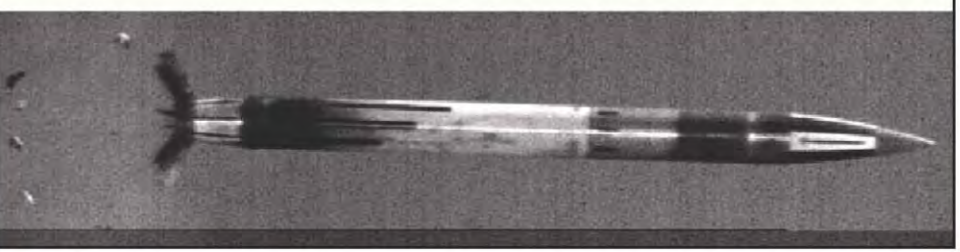
9 for 11 in SM-3 Midcourse Intercepts
1 for 1 in SM-2 Block IV Terminal Intercepts

Recent / Future Testing

- **FTM-13 (10/07): Engage Two Near Simultaneous SRBMs**
- **FTM-14 (6/08): Engage IRBM Threat (Launch on TADIL)**

Strike / SuW Capability

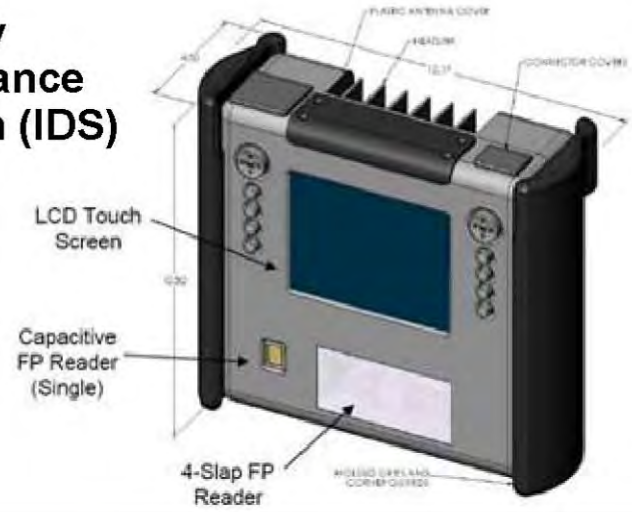
- Long Range Precision Strike
- Support to the Joint Expeditionary Warfighter
- Address Modernization



Anti-Terrorism/Force Protection
Extended Maritime Interdiction Operations

- Use of biometrics to identify terrorists at sea
- Expanding WMD detection capabilities
- Improving ATFP/VBSS equipment and systems

Identity Dominance System (IDS)

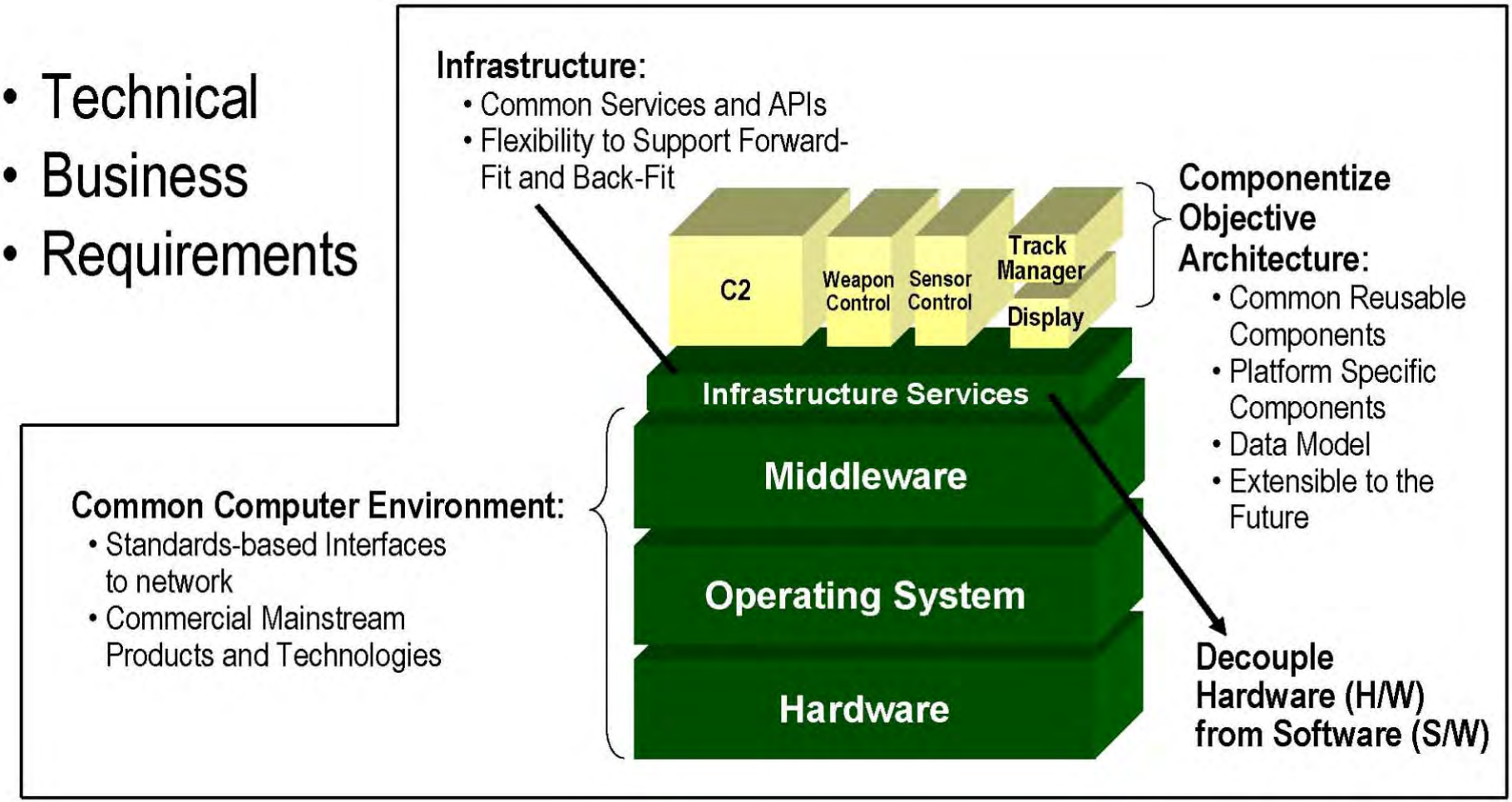


25mm Chain Gun

VBSS Tactical Gear

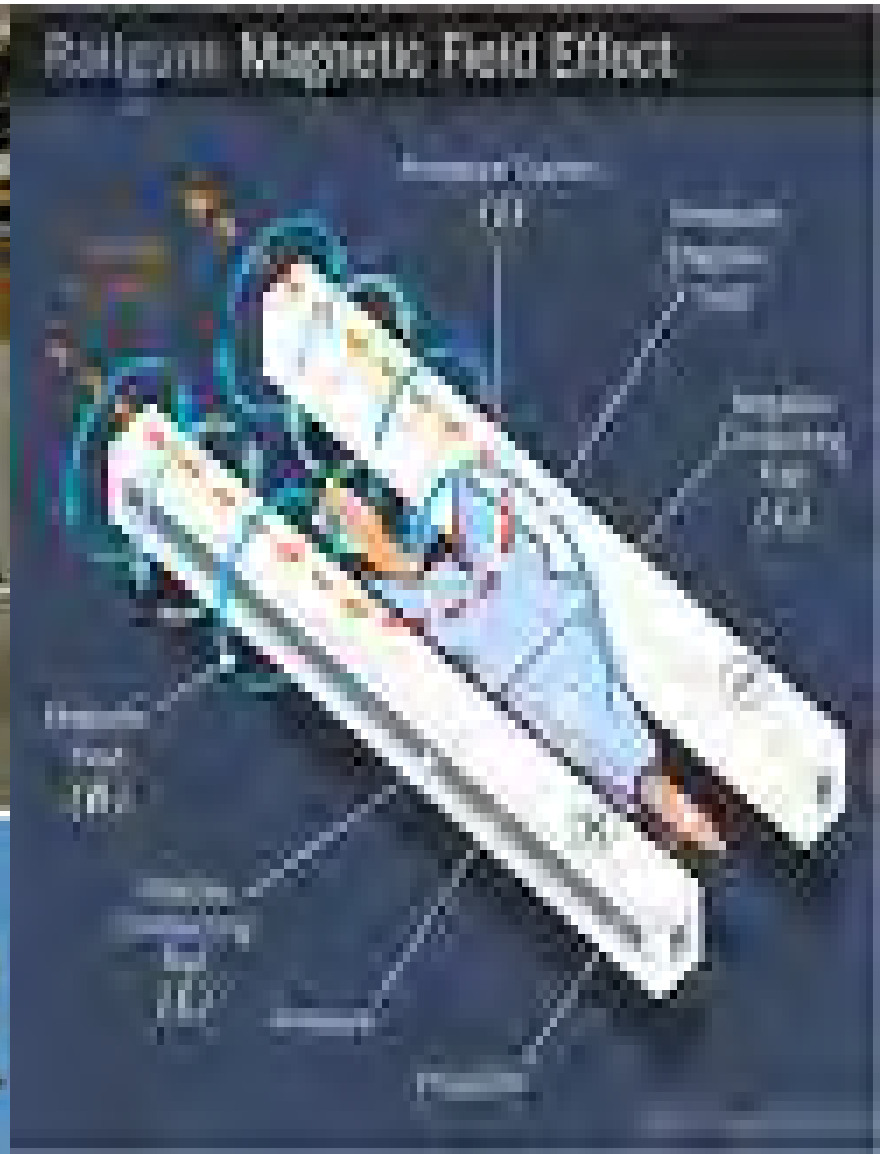
Implementing Open Architecture: Surface Navy OA Technical Model

- Technical
- Business
- Requirements



OA creates a business and technical environment that encourages collaborative competition by 3rd party developers

Electromagnetic railgun



Takeaways

- Surface Navy has a compelling and enduring role in the Maritime Strategy
- Shipbuilding and modernization programs are critical to maintaining that role
- The framework for warfighting modernization is open architecture

Questions?

DDG 1000 Zumwalt Class

Joe McPherson

Advanced Gun System
Program Manager

PEO (IWS)

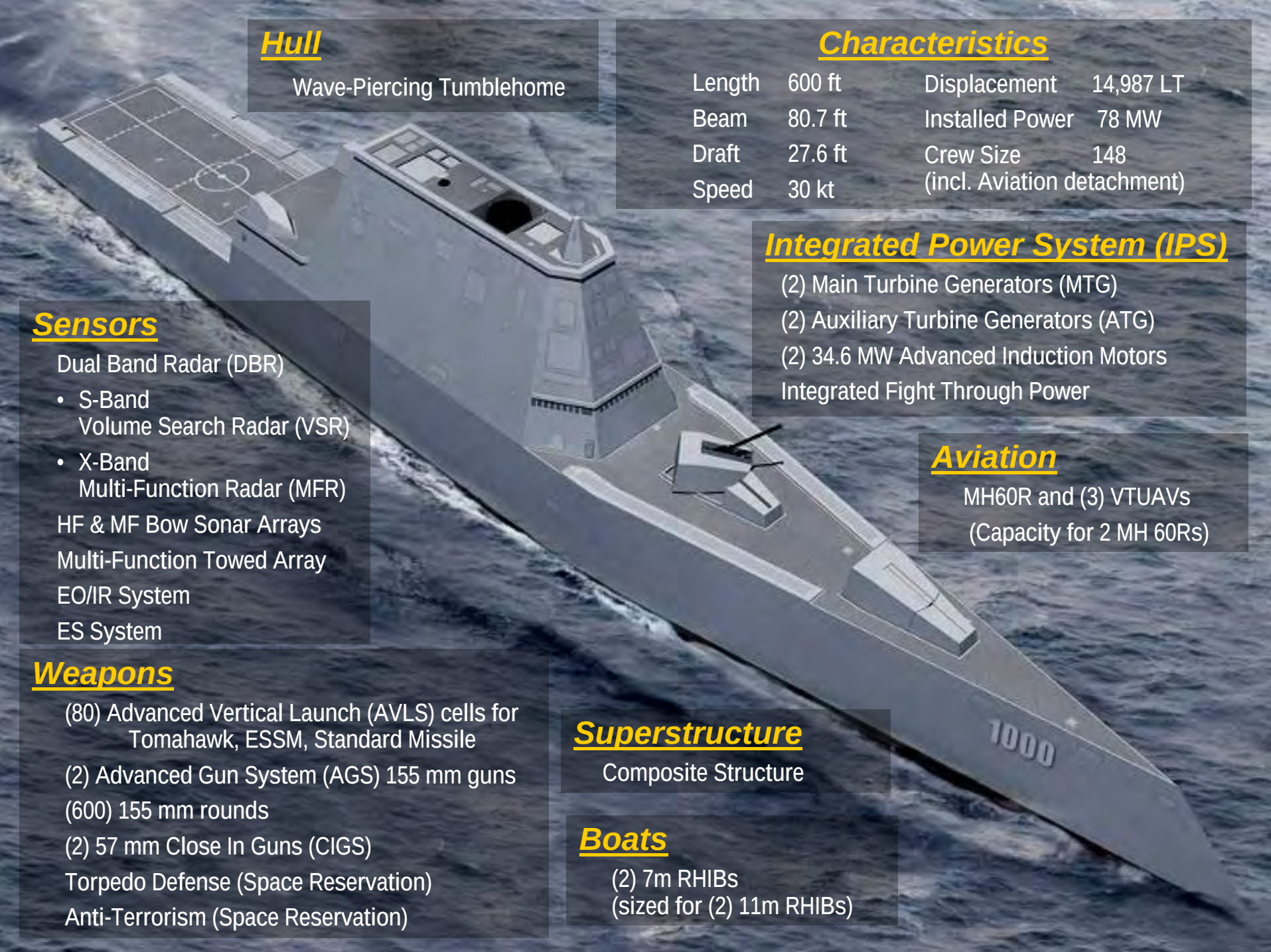
Distribution Statement A: Approved for Public Release; Distribution Unlimited. (4/29/2008).
This Brief is provided for Information Only and does not constitute a commitment on behalf of the U.S. government to provide additional information and / or sale of the system

Zumwalt Description

- Mission
  - Littoral Battlespace Dominance
  - Multi-mission capable
  - Network-centric operations
- Description
  - Precision strike
  - Naval surface fire support
  - In-stride mine avoidance
  - Optimized crewing
  - Life cycle affordability
  - Robust survivability
- Employment
  - Provide forward presence and power projection, independently, and in connection with Joint Forces

Key Performance Parameters

Interoperability
Number of Guns
Gun Magazine Capacity
Vertical Launch Cells
Radar Cross Section
Manning
Force Protection
Survivability



Hull

Wave-Piercing Tumblehome

Characteristics

Length	600 ft	Displacement	14,987 LT
Beam	80.7 ft	Installed Power	78 MW
Draft	27.6 ft	Crew Size	148 (incl. Aviation detachment)
Speed	30 kt		

Integrated Power System (IPS)

(2) Main Turbine Generators (MTG)

(2) Auxiliary Turbine Generators (ATG)

(2) 34.6 MW Advanced Induction Motors

Integrated Fight Through Power

Sensors

Dual Band Radar (DBR)

- S-Band Volume Search Radar (VSR)
- X-Band Multi-Function Radar (MFR)

HF & MF Bow Sonar Arrays

Multi-Function Towed Array

EO/IR System

ES System

Aviation

MH60R and (3) VTUAVs

(Capacity for 2 MH 60Rs)

Weapons

(80) Advanced Vertical Launch (AVLS) cells for Tomahawk, ESSM, Standard Missile

(2) Advanced Gun System (AGS) 155 mm guns

(600) 155 mm rounds

(2) 57 mm Close In Guns (CIGS)

Torpedo Defense (Space Reservation)

Anti-Terrorism (Space Reservation)

Superstructure

Composite Structure

Boats

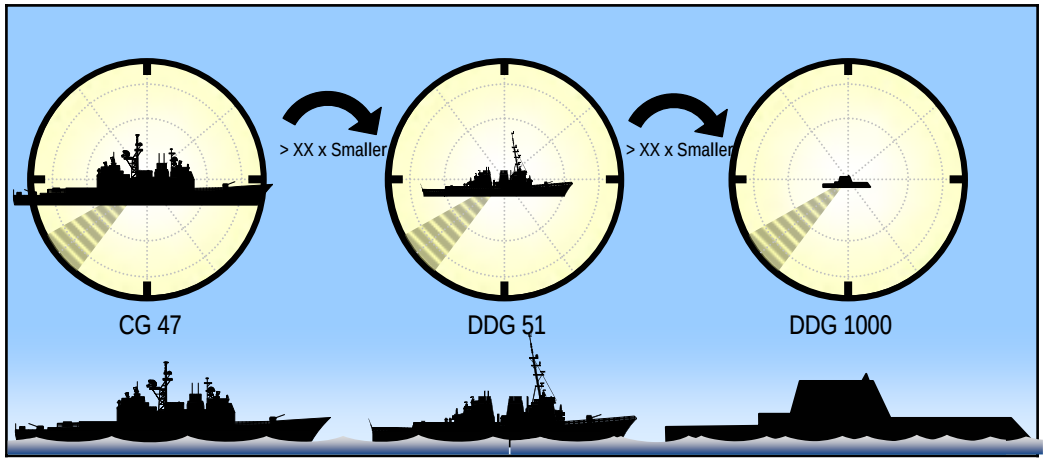
(2) 7m RHIBs
(sized for (2) 11m RHIBs)

Zumwalt / DDG 51 Flight IIA Comparison

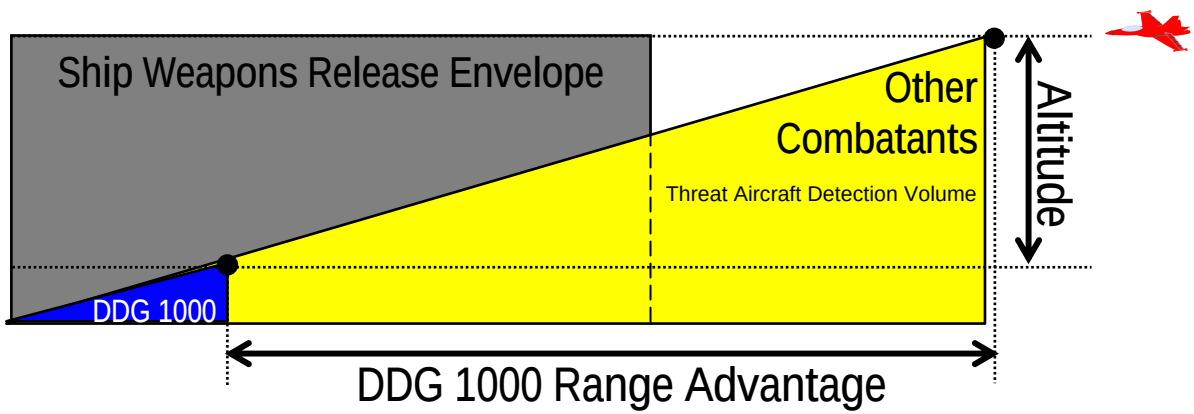
Zumwalt	
Displacement	14,987 LT
Length / Beam	600 ft / 80.7 ft
Draft	28 ft
Crew Size	148
Flight Deck	150 ft x 51 ft
Freeboard	22 ft
Electric Power Available	78 MW
Connectivity	Net-Ready / Unmanned Radio Room

DDG 79	
Displacement	9,217 LT
Length / Beam	509 ft / 67 ft
Draft	31 ft
Crew Size	314
Flight Deck	71 ft x 57 ft (fwd) 44 ft (aft)
Freeboard at hangar at transom	 13 ft 16 ft
Ship's Service Power	7.5 MW
Connectivity	14 Radio Personnel

Zumwalt Advantage
Anti Air Warfare -- Aircraft and ASCMs in Littoral

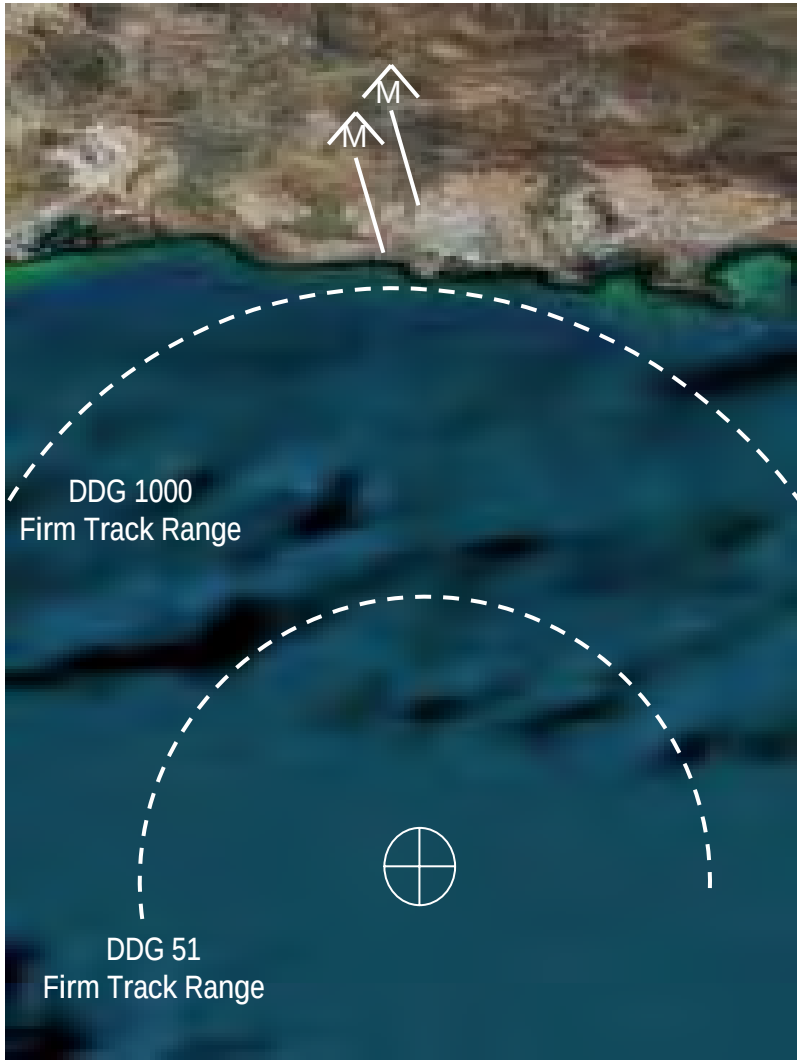


Radar Cross Section of a Fishing Boat



Harder to Detect, Localize, Classify, and Target; Improved Detection and Engagement Ranges of Threats

Zumwalt Advantage
DBR vs SPY-1D in Clutter



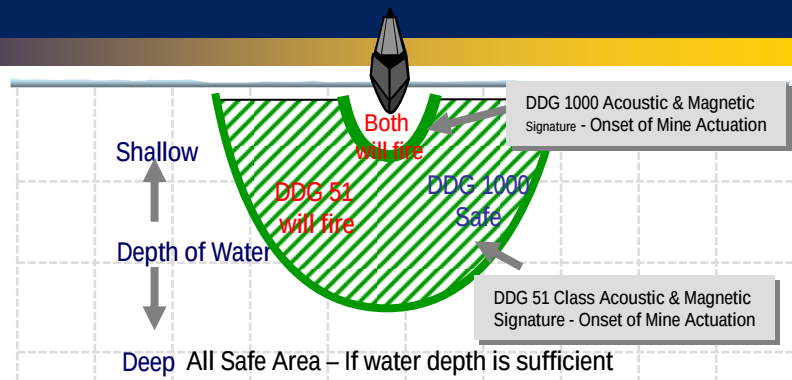
DBR (SPY-3)

SPY-1D(V)

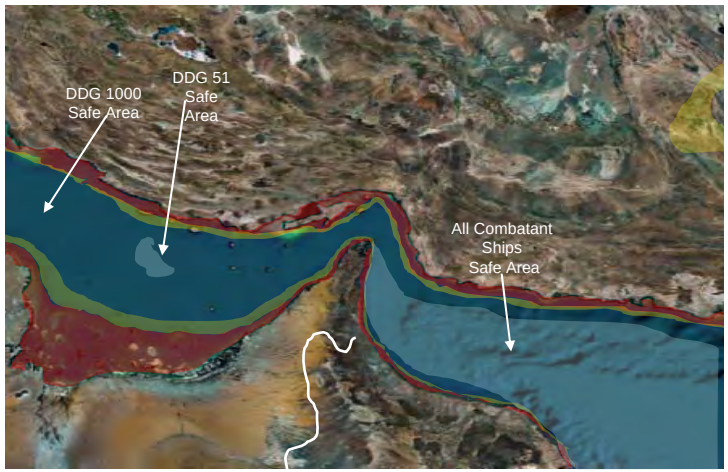
Enhanced Performance Against Advanced Threats and Targets in Clutter

Zumwalt Advantage
Integrated Undersea Warfare

- **Quieter Acoustic and reduced Magnetic Signature**

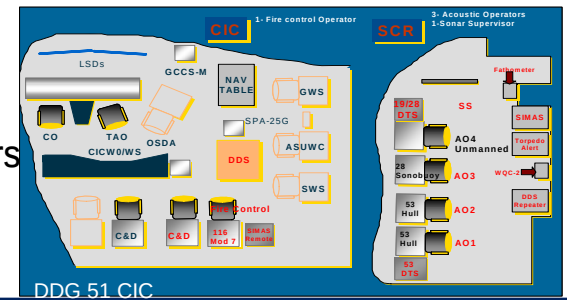


- **Enables significant increase in safe operating Area against mine threats**



- **With 50% decrease in manning for In Stride Mine Avoidance plus ASW**

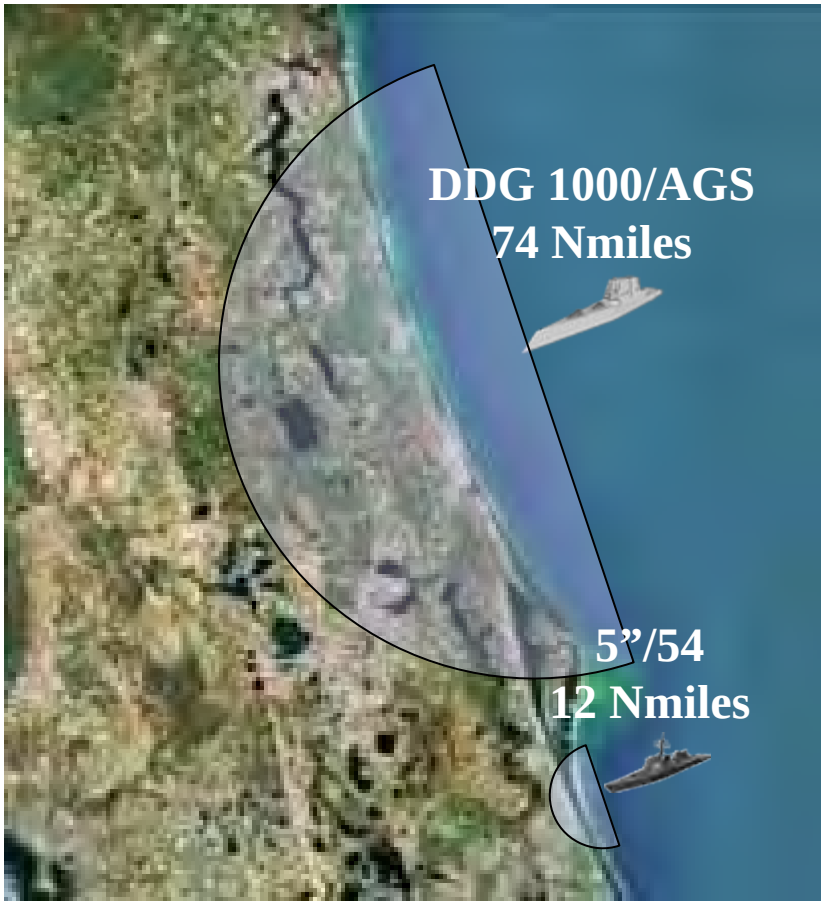
DDG 51 = 10 watchstanders



DDG 51 CIC

DDG 1000 = 5 watchstanders

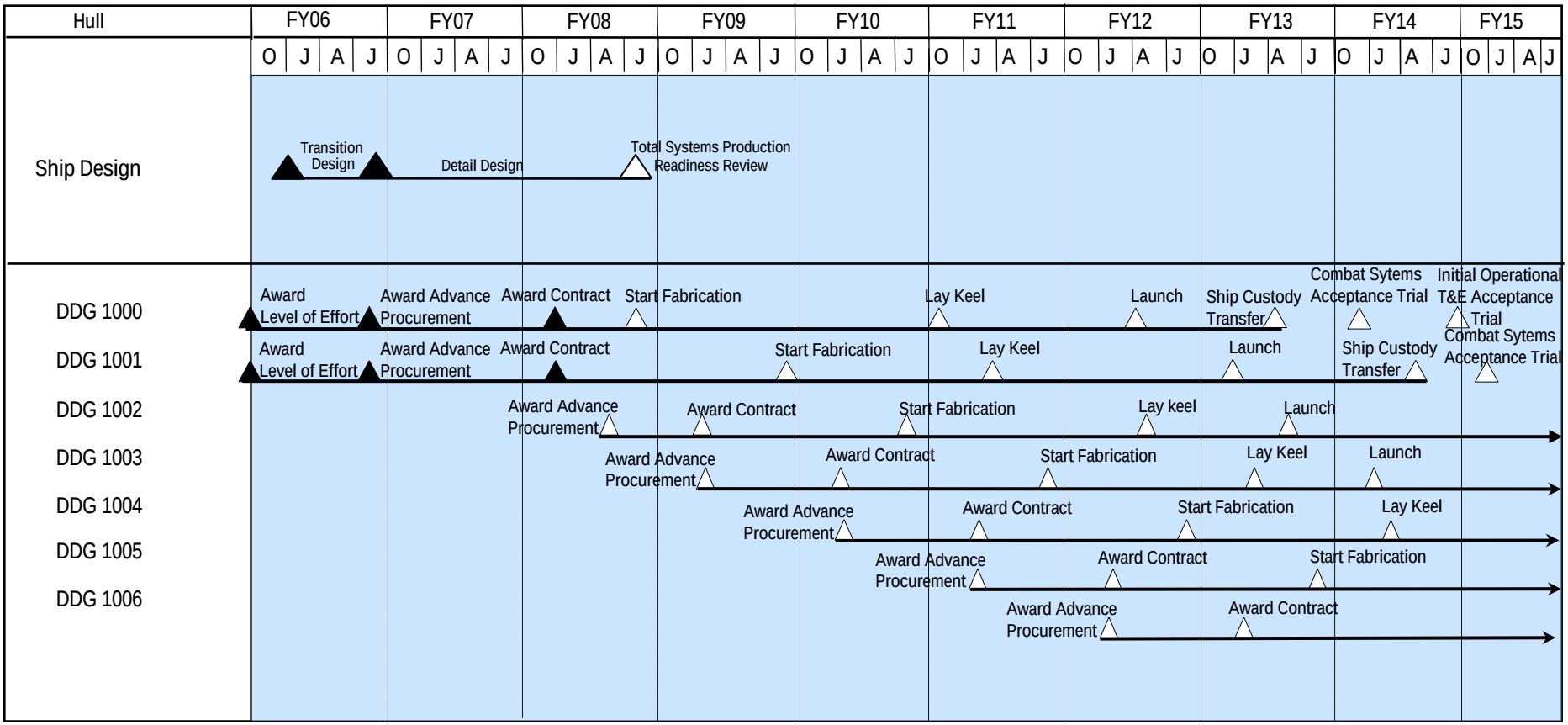
Zumwalt Advantage
Land Attack



AGS / LRLAP

	DDG 1000*
Munition Weight (AUR)	320 lbs
Magazine Capacity	600 LRLAP
Ordnance Stored	192,000 lbs
Manning (excl Fire Control)	Unmanned
Warhead Weight	60 lbs
Sustained ROF	20 rpm
Volume of Fire (W/H*ROF)	1200 lbs/minute
Range (spec)	74 nmiles
Ashore Coverage @ 25 nmile standoff	5,000 nmiles^2

DDG 1000 Program Schedule



BAE Systems Mission System Equipment

Cordova, AL

AGS Components

First Production Barrel
on Hollow Spindle Lathe

Carriage Weld Sub Assembly

United States Marine Corps
PM-AAA
Expeditionary Fighting Vehicle

43rd NDIA-Guns & Missile Systems

Major John L. Medeiros

Product Group Turret Systems, Guns/Ammo

Topics

- Program Update
- MK44, 30x173mm Guns/Ammo IPT
- Current PG-TS efforts

"Revolutionizing Expeditionary Maneuver Warfare"

Present: AAV

- **WWII Doctrine**
- **No Standoff Distance for ATF**
- **Slow Speed Amphibious Assault**
- **1960's Technology**
- **Limited Survivability**

Future: EFV

- **EFV directly supports the Marine Corps' Capstone Concept: Expeditionary Maneuver Warfare**
- **The EFV will provide the tactical mobility asset required to spearhead the EMW concept and permit the Marine Corps to fully exploit littoral areas as maneuver space**
- **The EFV will allow immediate, high speed maneuver of Marine infantry units as they emerge from ships located beyond the horizon (25 nm and beyond)**
- **The EFV's unique combination of offensive firepower, armor, NBC protection, and high speed mobility on land and sea represent major breakthroughs in the ability of Naval and Marine expeditionary forces to avoid the enemy's strength and exploit its weakness**

Leap Ahead to 21st Century Technology

Program Status

- **Where we are**: Certified Program, June 07
- **Essentially- latter phases of SDD-1 (reliability focused)**
- **Vehicle meets KPP's, but not reliability-wise**
  - **Nunn-McCurdy**
  - Stems from Operational Assessment, reliability not as expected
  - Blue Ribbon Panel review (Dec 06)
  - Bottom-Up requirements review by MCCDC (Jan 07)
  - Congressional Inquiry (May 07)
- **ASN to Final approved contract award for SDD-2 vehicles**.
  - SDD-2 Contract Award to build 7 new EFV's
    - 5 P7s, 2 C7s
    - Mileage/hours on current models exhausted
  - Extending LRIP to 2012 (likely)
- **SecDef/SecNav- USMC will field this vehicle**

EFV PROGRAM HIGHLIGHTS BY ACQUISITION PHASE

FY88 - FY95	FY95 - FY01	FY01 – FY12	FY12 – FY15	FY15 – FY25
Concept Exploration	Program Development & Risk Reduction (PDRR)	System Development & Demonstration (SDD)	Low Rate Initial Production (LRIP)	Full Rate Production (FRP)
Component Technology Demonstrators	***1st Generation Prototypes***	***Prototypes 2nd Generation – 10 3rd Generation - 7***	***LRIP Vehicles***	***FRP Vehicle***
Hydrodynamic & Automotive Test Rigs	Integrated Functionality, Full Up System	Mature the Design, Prepare for Production	Production, IOT&E, and Live Fire Testing	Fielding the "EFV"
Design Cycles →				

Product Group Breakdown

ASN

PEO Land Systems
Colonel Taylor

Program Manager
Colonel Bryant

Deputy PM
Mr. Joe Teets

PM AAA Staff functions:
- T & E
- Comptroller
- Operations
- Systems Engineer
- Budgets

PG
Distributed
Mechanical System

PG
Powertrain

PG
Turret Systems

PG
Structure/Armor &
Attachment

PG
Vetronics, C4I,
Electronics

Systems Engineer
Chris Melkonian

Fire Controls
Will Sedmak

Lasers/VTC
Mike Kreiner

MK44
Shawn Haag

Ammo/Logistic
Lou Hearrell

Business Manager
Skip Benyo

Publication
John Wright

Operational
MSgt Baker

Turret Structure
Jeff Snyder

Guns/Ammo
Major Medeiros

MK44 30x173mm
Guns and Ammo IPT

Mission Statement:

The MK44 Guns/Ammo IPT exist to bring together all Military/Government and Industrial users of the the MK44 Gun and 30mmx173 Ammunition in order to increase the information flow within the MK44 and 30mmx173 guns/ammo community.

- Meets Semi-Annually Chaired by the US Marine Corps, PM Advance Amphibious Assault (EFV)
- User needs and Industrial solutions.
- IPT- Integrated Product Team- “Team”

ENDSTATE: Increased information flow!

MK44 30x173mm
Guns and Ammo IPT

Previous IPT notes:

- IPT overview
- US Forces/Foreign Military updates
- Industrial updates
- NATO update
- Vendor/industry briefs
- USMC/USA/USN Joint spec. briefs
- Other vendor briefs
- Test results
- Specification discussions

30mm Guns and Ammo IPT Meetings

- *Jan 1998 – DRPM-AAA Barrel Symposium (MAJ Richter hosts) Forerunner of IPT.*
- *Aug 1998 - NSWC Crane and Camp Atterburry. First IPT meeting.*
- *Oct 1998 - DRPM-AAAV Woodbridge.*
- *Jan 1999 - DRPM-AAAV Woodbridge. Ammo producers welcomed*
- *Oct 1999 - DRPM-AAAV Woodbridge. (Govt and Boeing)*
- *Mar 2000- IPT receives DoD Top Acquisition David Packard Award*
- *May 2000 - DRPM-AAAV Woodbridge*
- *Sep 2000 - Quantico (MAJ Cushing hosts)*
- *Oct 2001 - DRPM-AAAV Woodbridge*
- *Mar 2002 – DRPM-AAAV Woodbridge*
- *Aug 2002 – DRPM-AAAV Woodbridge*
- *Dec 2002 – DRPM-AAAV Woodbridge*
- *Feb 2004 – DRPM-AAAV Woodbridge (MAJ Mullins hosts)*
- *Jul 2004 – Mesa, AR. ABM Program Re-established. Plan for FCT*
- *Mar 2005 – DRPM-AAAV Woodbridge. UK MOD welcomed*
- *Aug 2005 - Mesa, AR. Norwegian AMC welcomed*
- *Feb 2006 – Hawthorne, NV. Pre-ABM Lethality Evaluation.*
- *Aug 2006 – Mesa, NV. (MAJ Medeiros hosts). Austria and Switzerland welcomed.*
- *Oct 2006 – Crane, IN. WIPTs established.*
- Mar 2007 – Carlsbad, CA.
- Oct 2007 – Fredericksburg, VA.
- April 2008 - Tampa, FL.

30mm Air Burst Munition Down Select

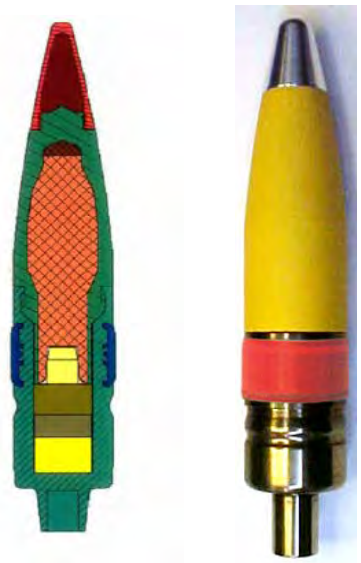
- ATK/Diehl cartridge recommended by SSP for down select and qualification.

– General Information

– Warhead
  - High Explosive Air Burst with Base Mounted Fuze
  - SAPHE Performance Against Materiel Targets (MK240 Hardened Nose Design from Diehl)
  - Explosive: PBXN-5
  - Incendiary: Zirconium
  - Inductive Fuze Setting in Gun Feed

– Cartridge
  - Aluminum Case
  - Propellant: Single Base
  - Primer: M36A2 Percussion

– Fuze: Operates with or without the Inductive Fuze Setter
  - Point Detonate Mode
    – Default Fuze Configuration
    – Fuze Detonates Upon Target Impact
  - Point Detonate Delay Mode
    – Fuze Detects Impact with Target and Delays up to 1 ms before Detonating
    – Several Fixed Delays are Offered
  - Air Burst Mode
    – Fuze Detonates at User Programmed Distance
    – Fuze has Point Detonate Capability if impact with Target Occurs before Set Point
  - Self-Destruct: Detonates at Maximum Mission Time



30-mm Ammunition Qualification Tests

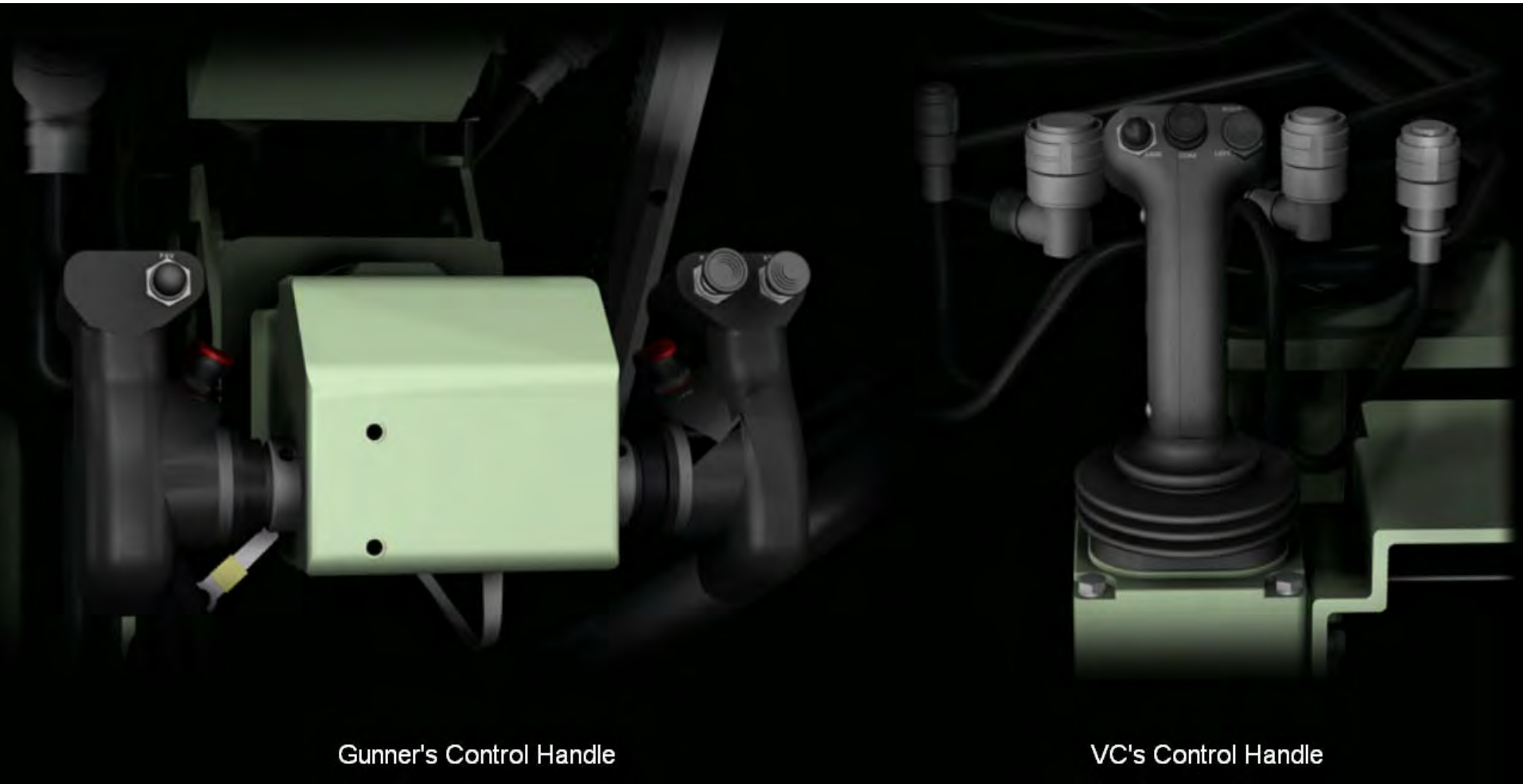
AT-1	Interior, Exterior, and Terminal Ballistics: Baseline
AT-1B	Interior, Exterior, and Terminal Ballistics: Post Environment Tests
AT-2	Sequential Environment - 28 Day Temperature and Humidity - Transportation Vibration - Shipboard Vibration - 4 Day T&H
AT-3	Fast Cook-Off
AT-4	Slow Cook-Off
AT-5	Bullet Impact
AT-6	Fragment Impact
AT-7	Sympathetic Detonation
AT-8	Shaped Charge Impact
AT-9	Salt Fog
AT-10	Sand and Dust
AT-11	Arena
AT-12	Seq. Rough Handling
AT-13	5-Foot Drop
AT-14	40-Foot Drop
AT-15	Shipboard Shock
AT-16	Waterproof
AT-17	Energetic Qualification
AT-18	Function and Casualty
AT-19	Fuze Function
AT-20	Fuze Arming Distance
AT-21	Primary Expl. Safety
AT-22	Numerical Effectiveness
AT-23	Jolt
AT-24	Jumble
AT-25	Extreme Temperature
AT-26	Thermal Shock
AT 27	Lead Azide
AT-28	HERO
AT-28	HERO
AT-29	ESD
AT-30	EMV
AT-31	ESD
AT-32	Brush Impact No Fire

Recent & Upcoming Test Events

- Dynamic Arena Testing: Nov 07 and Feb 08
  - Data reduction on-going
- Lightning & ESD Testing: 26-29 Nov 07
  - Sending test articles to ATK for inspection Apr 08
- 28 Day T&H Testing: Begins 11 Apr 08
  - Begins Environmental Sequence to include: Vibration, Sequential Rough Handling, 4 Day T&H, Extreme Temperature, 40ft Drop, Thermal Shock
- Fast Cook-off Testing: Rescheduled to 24 Apr after weather prevented testing 8 Apr
- Numerical Effectiveness of Interrupter Testing
  - Late May-Early June
- Primary Explosive Safety Testing
  - Early July
- Jolt and Jumble Testing
  - Mid May
- Bullet and Fragment Impact Testing
  - May/June
- Salt Fog Testing
  - May/June

Systems Integration / User Jury

- User preference and functional integration on-going.



PG-TS Timeline

PABM Rd Qualification effort

Sept 07 — Dec 08

- NSWCDD - Dahlgren
- US Army to conduct parallel effort

GD Integration Program Plan Systems Integration

Sept 07 — Sept 09

- Demonstrate on SDD 1 turret

PM AAA PABM Verification

Sept 09 — Sept 12

- SDD II
- Fire controls
- User functions
- TTP's

- PM AAA (PG-TS) intends to have PABM fully integrated for LRIP Lot 1

Other Ammo Efforts

- Armor Piercing Training Round Need
  - RFI on the street
  - Price/cost
  - Training value
- 30x173mm Surface Danger Zone Testing
  - ATC
  - Validate SDZ for ammo inventory
- PABM Trainer?
  - How to train with PABM
  - Training/spotting round, turret Simulators?

SURFACE DANGER ZONES

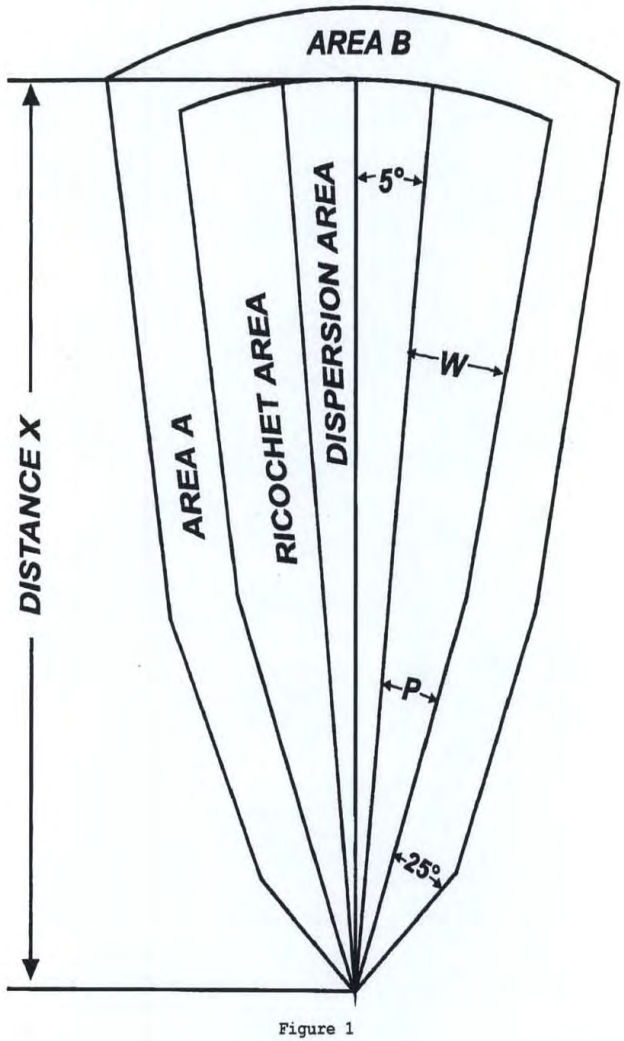


Figure 1

Background:

• 2004- Data review, MCPD/USMC Safety/ARDEC Safety
insufficient data statistically

• 2005-06- USMC continued utilizing waivers

UPDATE:

- John Riley- Test Director Ammo Systems Division
- April 08- rounds down range Aberdeen (New Bombing Field)
    - • MK239, MK258, MK268, AP trainers…
    - •planned 7-8 week test

MK44 incident

- Date – 27 February 2008
- Location – Marine Corps Base, Camp Pendleton, Ca.
- Activity – Gunnery Skills Training
- Failure – Barrel Separation
- Injuries – Minor
- Damage to MK44 - Major

Feeder

Feeder & Receiver Assembly

How/prevention

- There are three plausible causes as to how the barrel came to be unlocked
  1. Hardware - The barrel came unlocked on its own
  2. Procedure & Training - The barrel was inadvertently unlocked while performing maintenance on the coax mg the previous day
  3. Procedure & Training - The barrel was not properly installed
- Because none of the three possible causes can be disproven beyond question, the EFV program has decided to address them all

Hardware/Training

- ECP being processed by ATK that will:
  - Increase spring tension in the barrel release pin
  - Provide visual indication within the turret to ensure the barrel release pin is fully seated

- PM AAA and GDAMS is revising EFV gunnery skills training program
- Gunnery Skills Test (GST) will be administered to all test personnel expected to operate the MK46 Weapon System
- Only certified personnel will be allowed to operate as gunner or vehicle commander

Procedure

- Ensure established operational checks are completed daily while on a live fire range
- Greater detail provided on how to inspect barrel status
- Increase the frequency of barrel status inspection

Questions

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NAVAIR

Advanced Anti-Radiation Guided Missile: Strengthening DEAD Capability in the Fleet

43rd Annual Armament Systems: Gun and Missile Systems Conference and Exhibition
April 21-24, 2008
Austin Miller

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The Capability to Destroy Enemy Air Defenses (DEAD)

AARGM Can…

- **Defeat Integrated Air Defenses,**

By employing…

- **Emitter Geo-location**
- **Active Terminal Guidance**
- **Network Integrated Communications,**

As proven in…

- **Numerous Development Tests.**

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Outline

- **Capabilities**
  - Counter Shutdown
  - High Speed Standoff Strike Weapon
  - Expanded Threat Coverage
  - Geo- Specificity - Reduced Fratricide & Collateral Damage
  - Net Ready Communications
- **Subsystems**
  - Anti-Radiation Homing
  - Millimeter Wave
  - Guidance, Navigation & Controls
  - Network Connectivity
- **Concept of Operations**
  - Target of Opportunity
  - Pre-Briefed Target
  - Point to Point Target
- **Testing**

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AARGM Defeats Integrated Air Defense Systems

- **New for AGM-88E**
  - **Counter Shutdown**
    - From SEAD to DEAD
  - **High Speed Standoff Strike Weapon**
    - GPS guided point-to-point mode
  - **Expanded Threat Coverage:**
    - Modern Air Defense Threats
    - Expanded Frequency Coverage
    - Non-Emitting Mobile Targets
  - **Geo- Specificity - Reduced Fratricide & Collateral Damage**
    - GPS Defined Missile Impact and Exclusion zones
  - **Net Ready Communications**
    - Off-board correlation via Integrated Broadcast Service receiver (IBS-R)
    - Weapon impact assessment via WIA Transmitter

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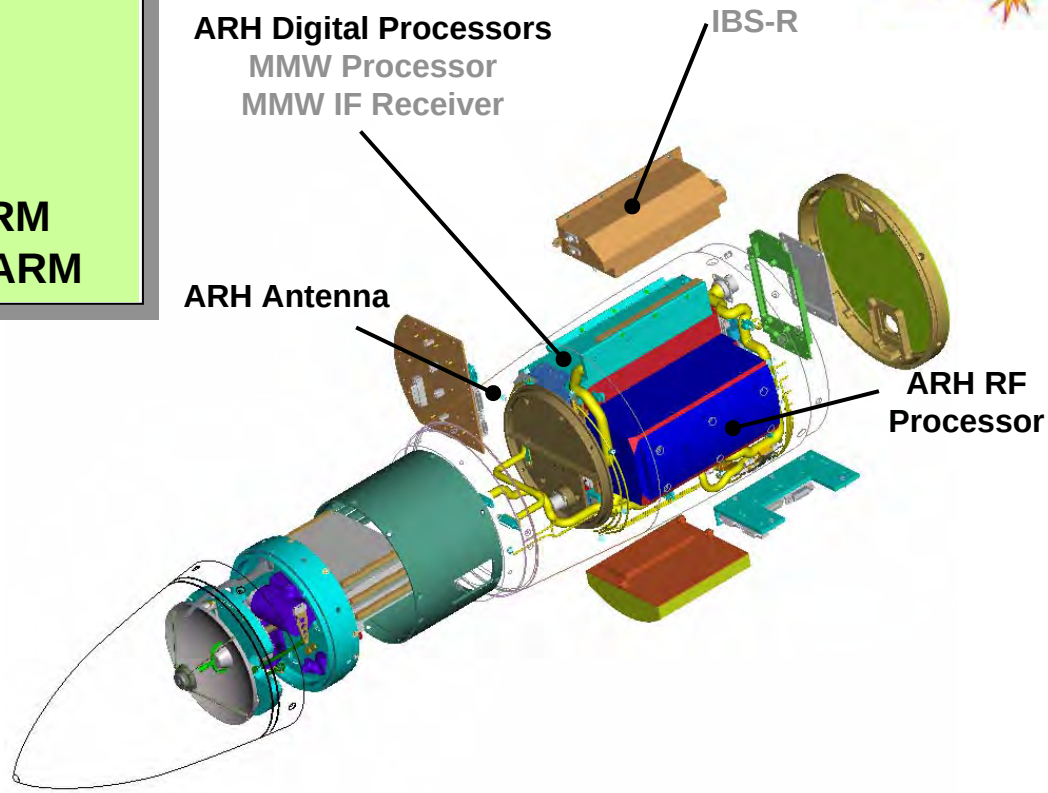
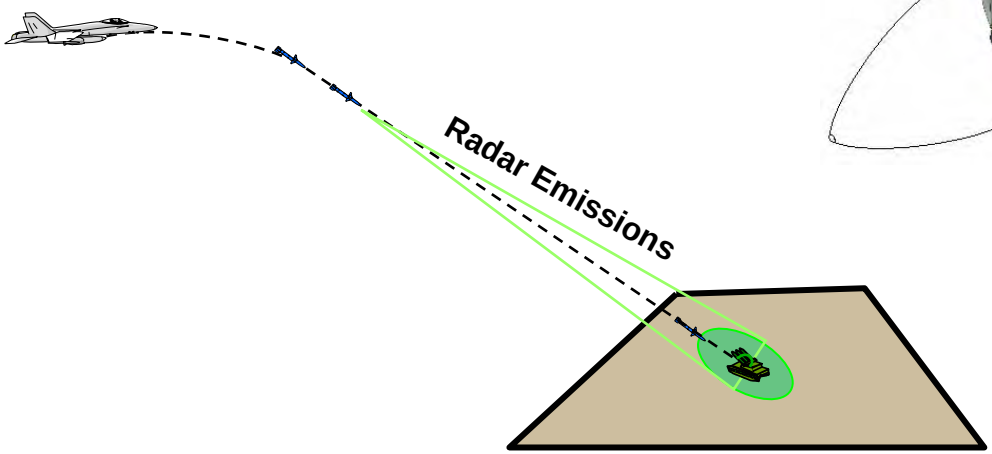
Anti-Radiation Homing Subsystem

Key Features

- ARH Seeker
  - Digital Receiver
  - Autonomous Detection and ID
  - Increased Field-of-View from HARM
  - Increased AOA Accuracy from HARM





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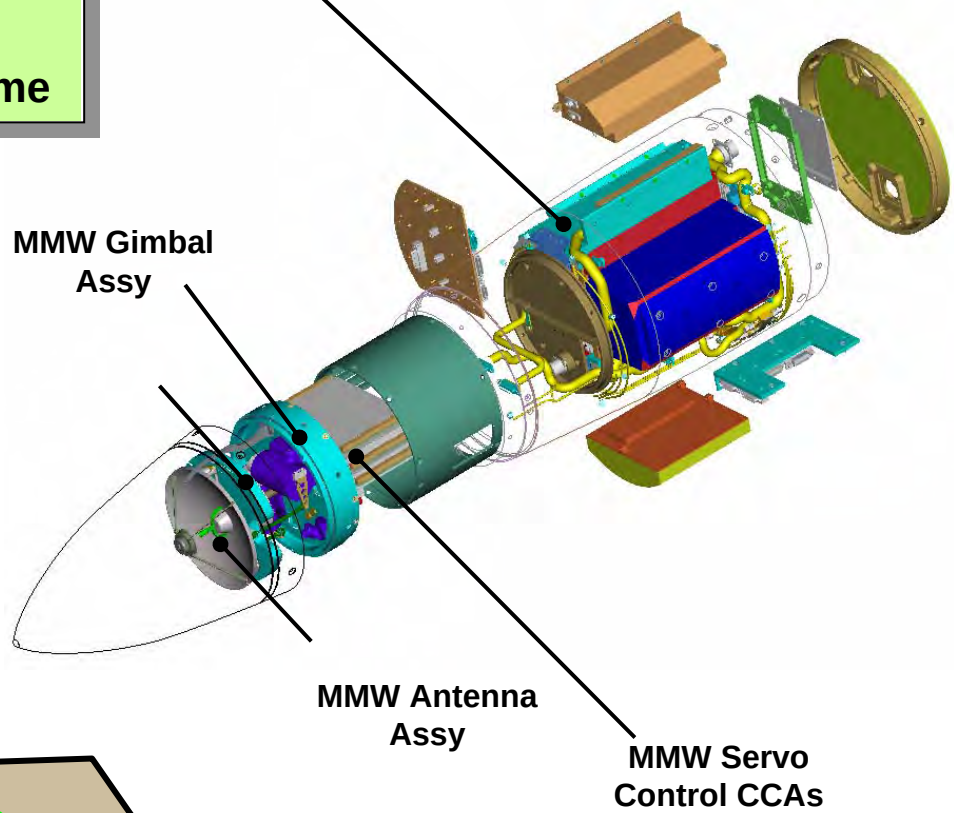
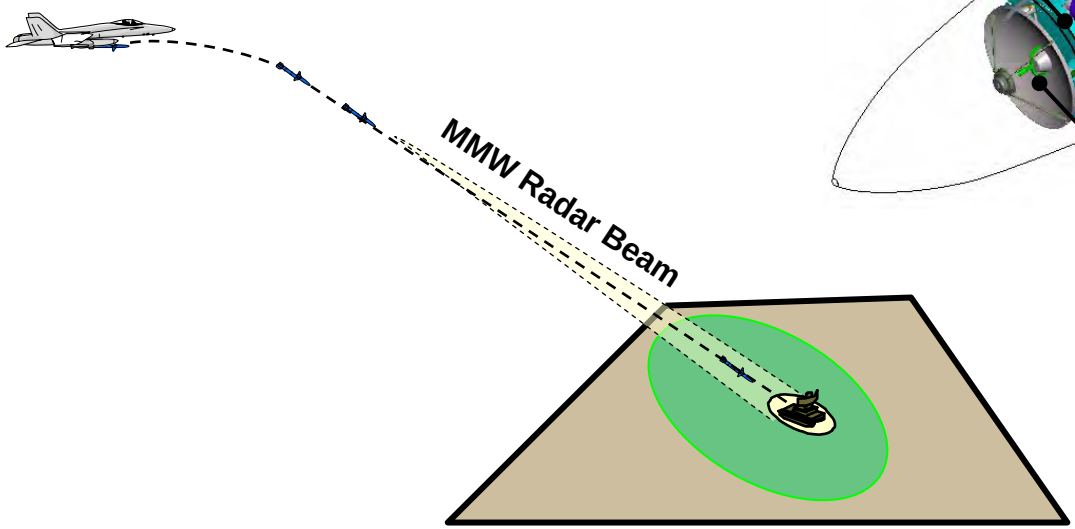
Millimeter Wave Subsystem

- **Key Features**
- **MMW Seeker**
  - **Ball Joint Gimbal**
  - **High Power Solid State Xmtr**
  - **Rugged, High Temperature Radome**





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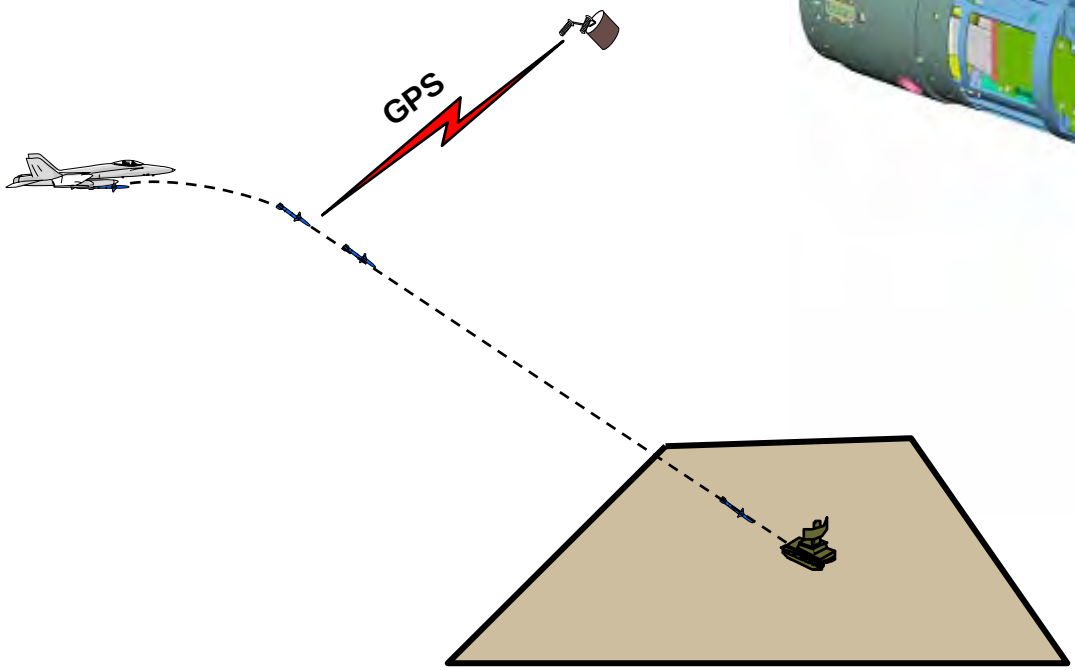
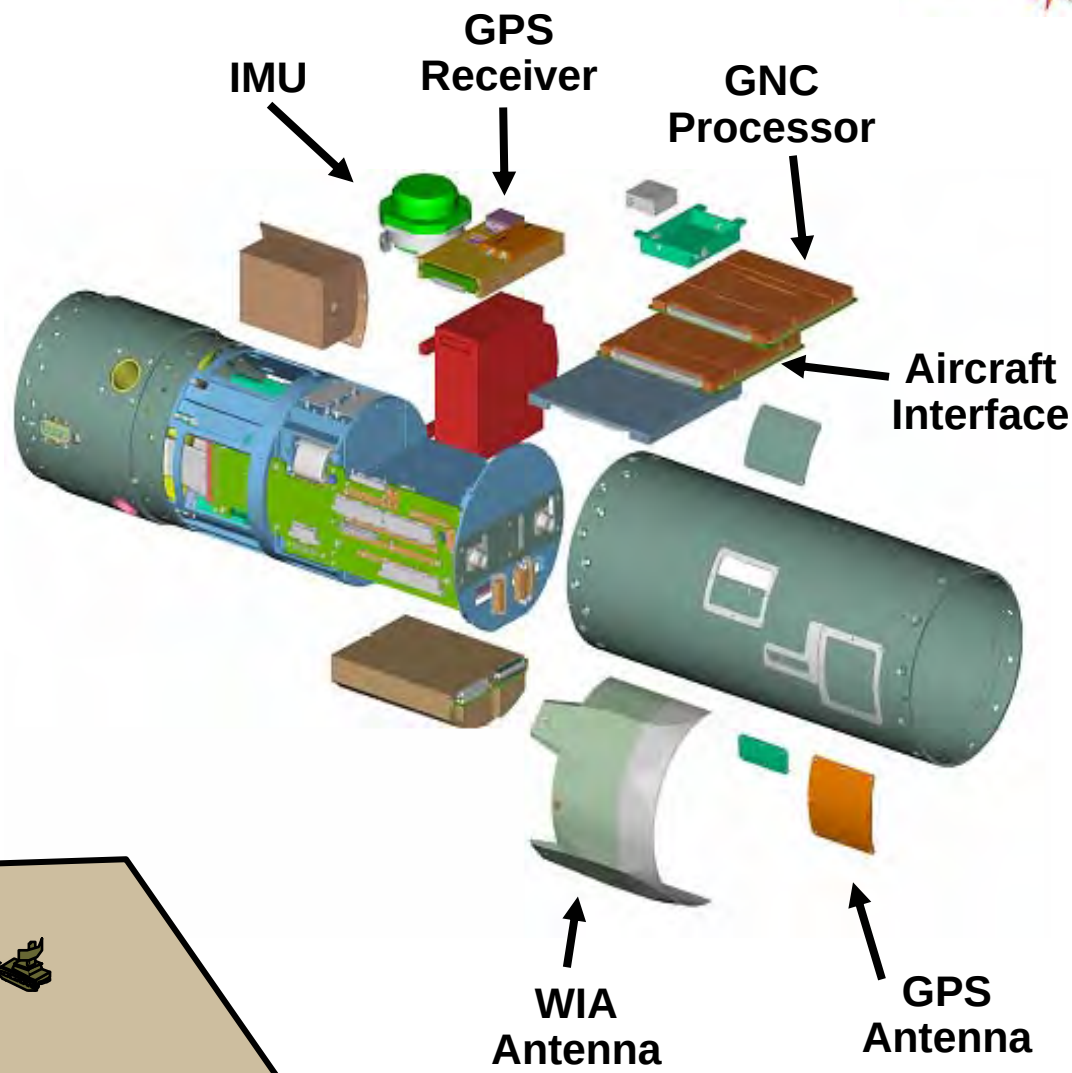
Control Section and GNC Subsystems

- **Key Features**
- GNC Subsystem
  - Tightly Coupled INS
  - A/C Transfer Alignment
  - Target Geo-location (DTED)
  - Geospecificity (IAZ,MIZ,AOR)
  - 1553 Interface Compatible
  - HARM Seeker Compatible





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Netcentric Capabilities

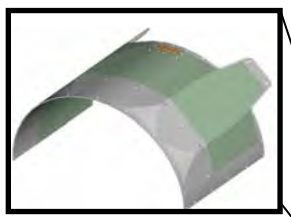
- **IBS provides real-time target cue**
- **WIA provides real-time battle damage assessment**

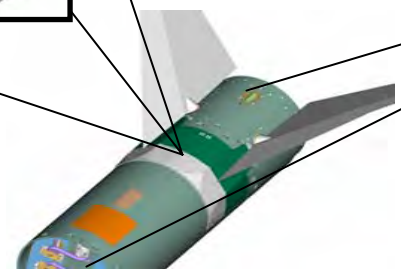
Integrated Broadcast Service Satellite Network

IBS Target Report

Weapon Impact Assessment
Message includes impact data to determine lethality

WIA Antenna





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Expanded Capability with Data Link Enabled AARGM

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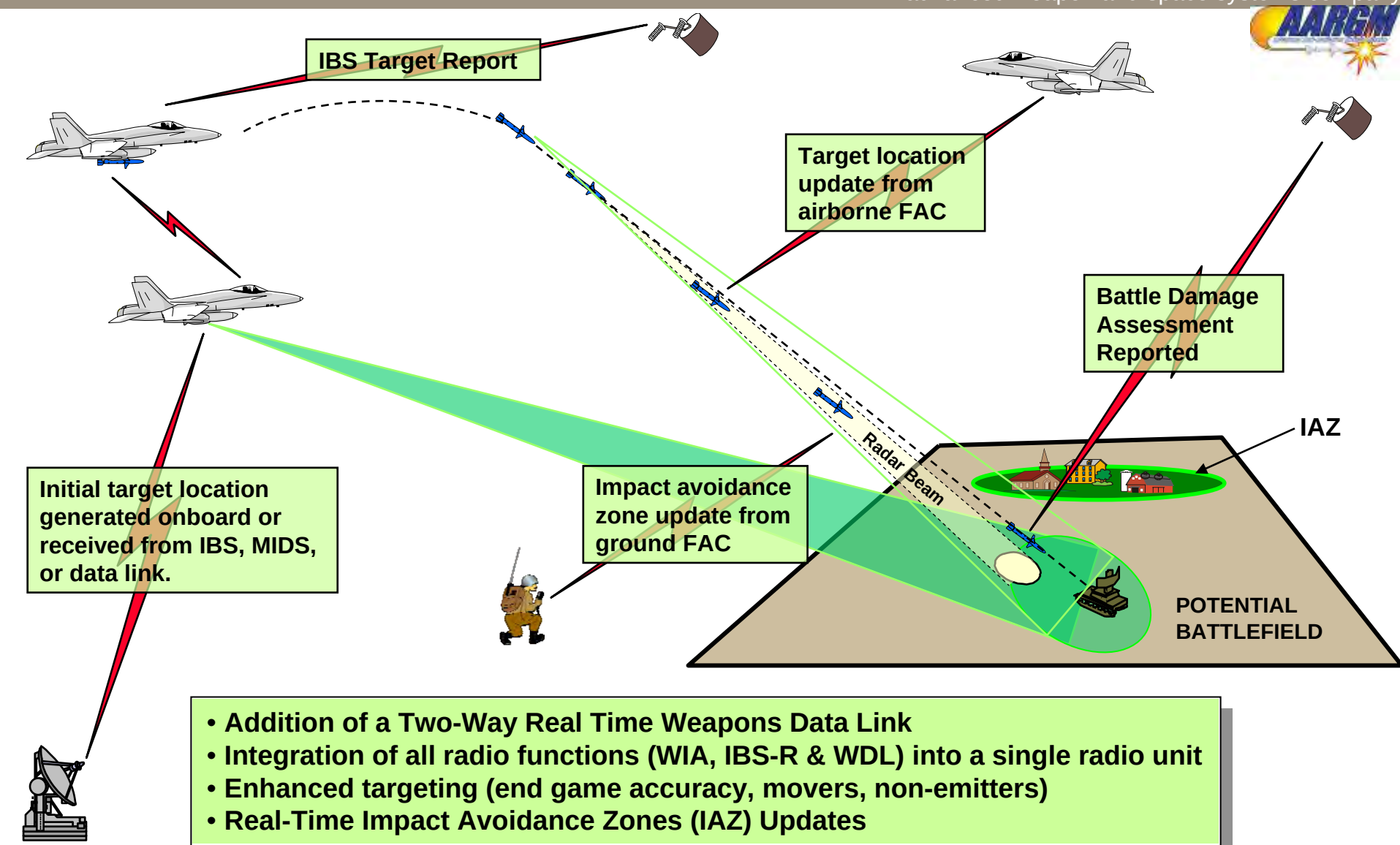

- Addition of a Two-Way Real Time Weapons Data Link
- Integration of all radio functions (WIA, IBS-R & WDL) into a single radio unit
- Enhanced targeting (end game accuracy, movers, non-emitters)
- Real-Time Impact Avoidance Zones (IAZ) Updates

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AARGM Engages a Target of Opportunity

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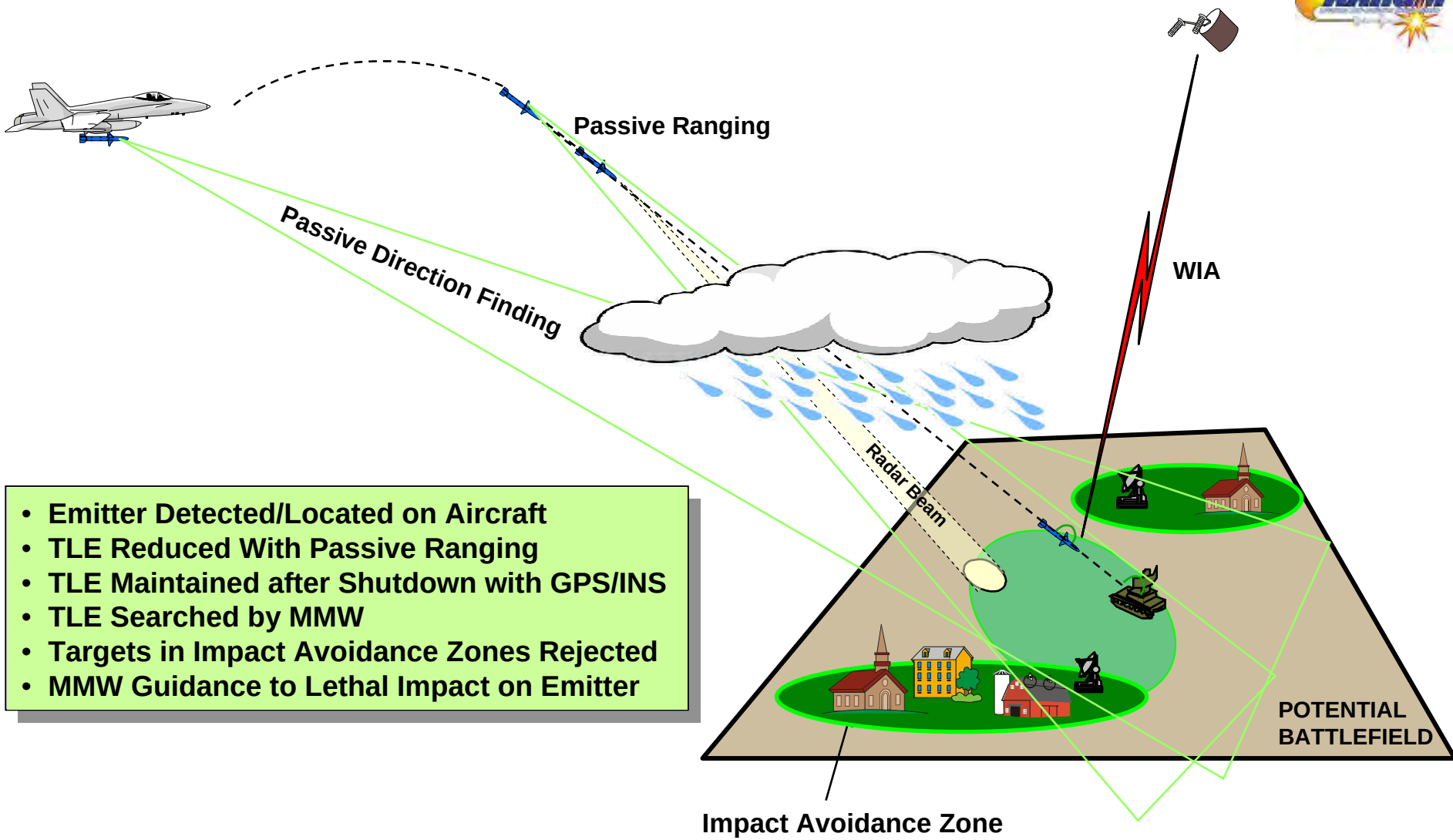
AARGM



- Emitter Detected/Located on Aircraft
- TLE Reduced With Passive Ranging
- TLE Maintained after Shutdown with GPS/INS
- TLE Searched by MMW
- Targets in Impact Avoidance Zones Rejected
- MMW Guidance to Lethal Impact on Emitter

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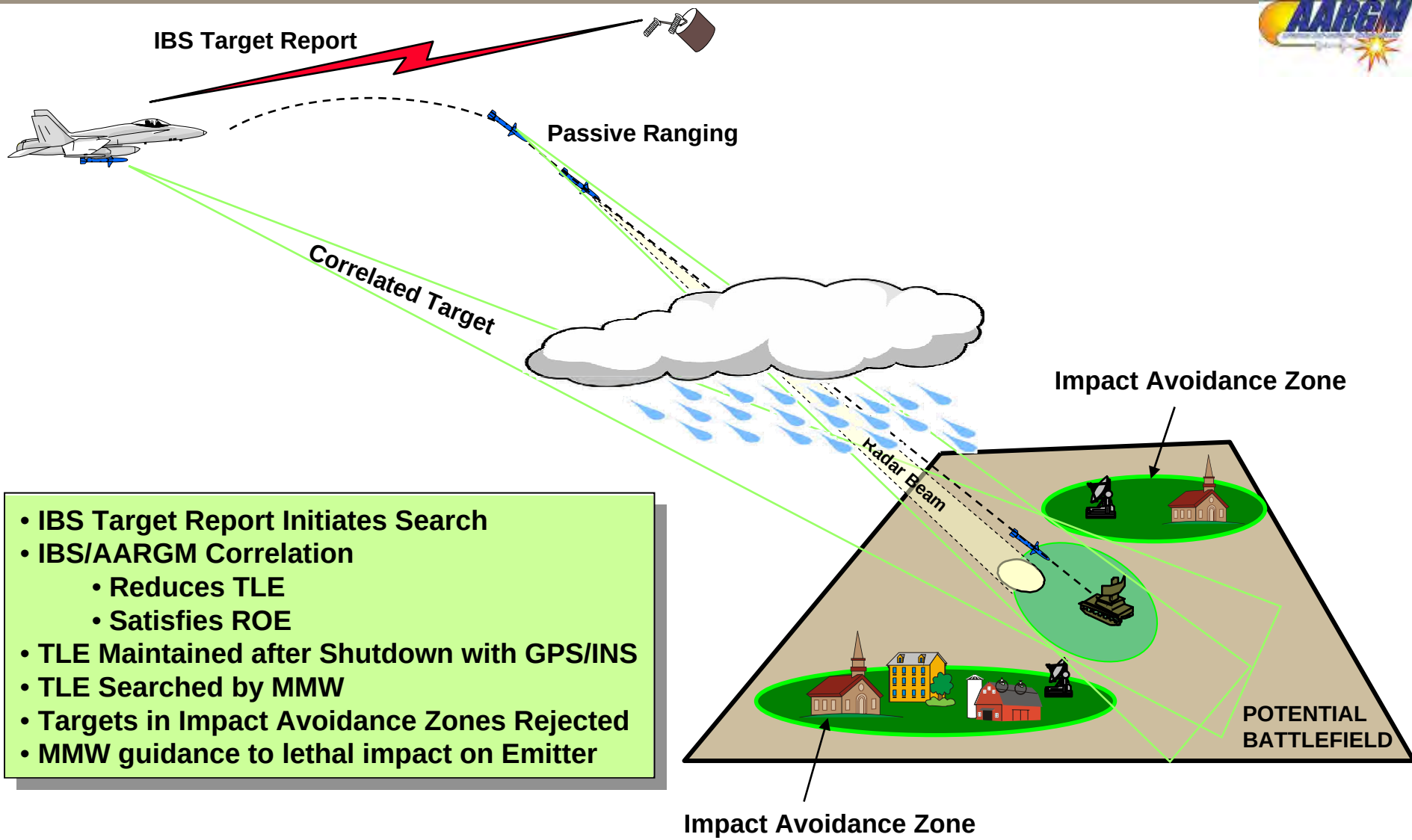
AARGM Engages an Off-board Emitter Cue



- IBS Target Report Initiates Search
- IBS/AARGM Correlation
  - Reduces TLE
  - Satisfies ROE
- TLE Maintained after Shutdown with GPS/INS
- TLE Searched by MMW
- Targets in Impact Avoidance Zones Rejected
- MMW guidance to lethal impact on Emitter

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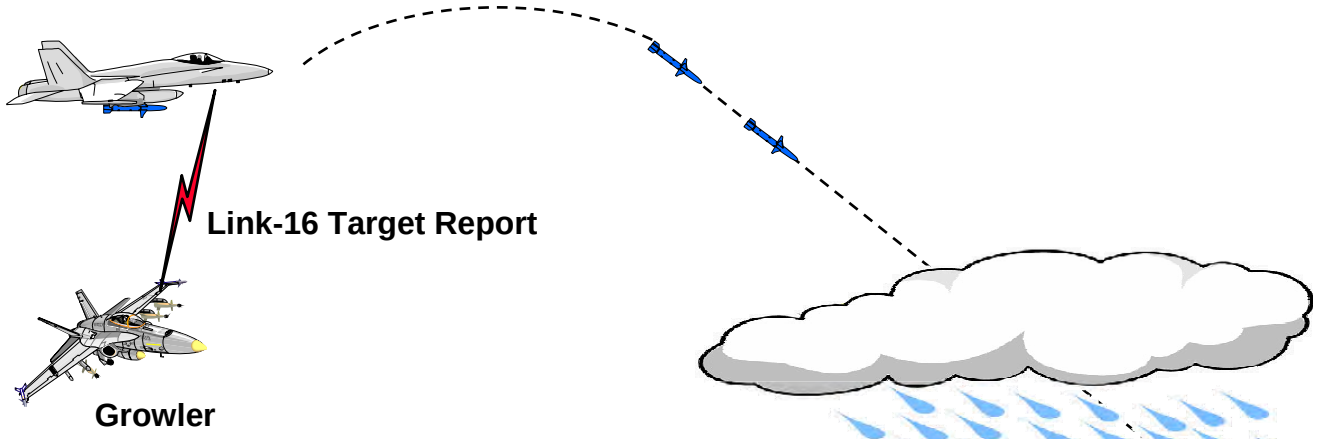
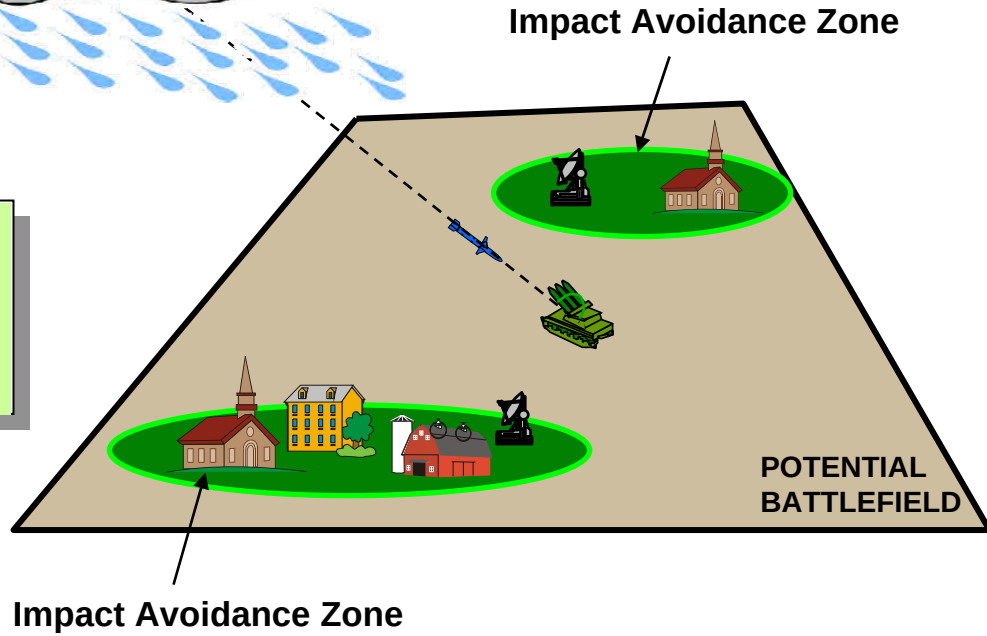
AARGM Engages a Time-Critical GPS Target





- Target coordinates received from aircraft
- AARGM launched to minimize time-to-target
- Geospec boundaries will be maintained
- Precise GPS guidance to lethal impact

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AARGM Completes 8 Successful Launches

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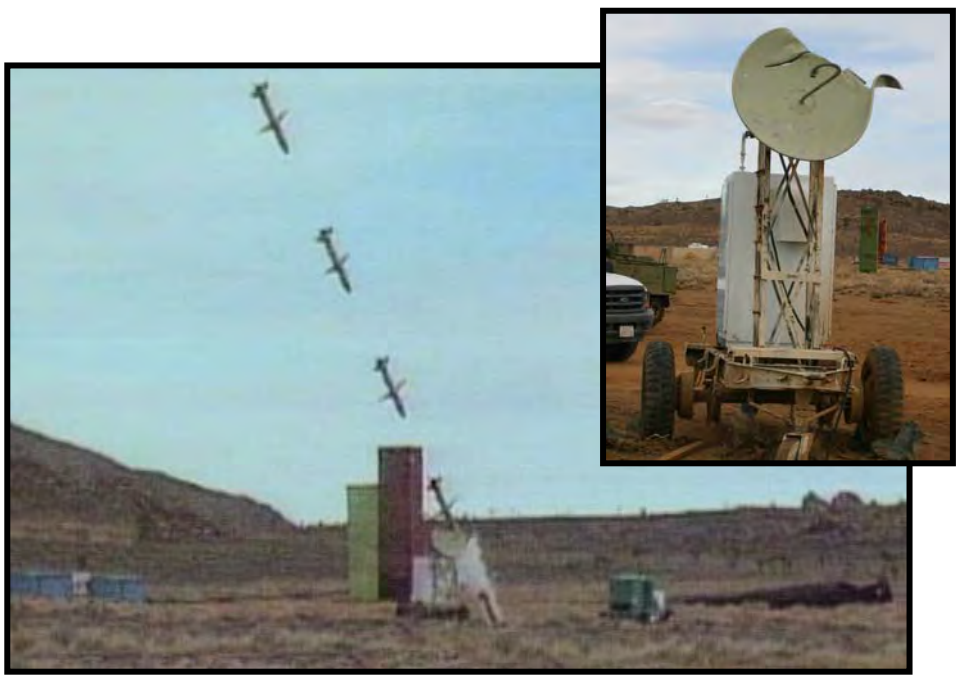
AARGM

- CTV-1: Point to Point GPS Guidance
- CTV-2: Point to Point GPS Guidance
- GTV-1: ARH Acquisition Before Launch
- GTV-2: ARH & MMW Terminal Guidance
- QB-1: ARH, MMW, WIA, IBS
- QB-2: ARH, MMW, WIA, IBS, Geospecificity, Emitter Shutdown
- DT-1: Point to Point Tightly Coupled GPS/INS Guidance
- DT-2: Pre-Briefed Cue, ARH Acquisition after launch, Geospecificity



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SD&D Development Test 1: May 25, 2007

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Questions

?

Missiles and Rockets Overview

NDIA Gun & Missile Systems Conference
New Orleans, LA

24 April 2008

COL Dave Rice
Project Manager
Precision Fires Rocket and Missile Systems
Phone (256) 876-1195 (DSN 746)
Email: david.rice@msl.army.mil

Recipients of the 2008
William J. Perry Award

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Topics

- Precision Fires products and performance
- Rocket and missile industrial base
- Contemplated capabilities
- Suggestions

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PFRMS Systems at War

- All systems are supporting the Global War on Terrorism
- Currently supporting Operation Iraqi Freedom and Operation Enduring Freedom
- Performance is above Army Standards
- Launchers returning in excellent condition requiring only routine & minimal maintenance

M270A1
98% Readiness Rate

HIMARS
99% Readiness Rate

GMLRS Unitary
676 Rockets Fired
98% Reliability

ATACMS
537 Missiles Fired
98% Reliability

Play Video

Any Warfighter - Anywhere - All The Time

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Any Warfighter
Any Where
All The Time

MLRS Worldwide

MOU Partners

- United States
- United Kingdom
- France
- Germany
- Italy

Any Warfighter - Anywhere - All The Time

* Potential Customer

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MLRS Worldwide

MOU Partners

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Any Warfighter - Anywhere - All The Time

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Terminated Army Missile Programs

AD
- ~~STINGER~~

AV MANEUVER
- ~~JAVELIN P3I~~
- ~~LOSAT~~
- ~~CKEM~~
- ~~Common Missile~~
- JAGM
- ~~APKWS~~

FIRE SUPPORT
- GMLRS
- ~~ATACMS Unitary/ Penetrator~~
- ~~BAT P3I~~
- NLOS-LS

6 Km
4 Km
4 Km +
5 Km
12-16 Km
7.2 Km
60 Km
270 Km
180 Km
~~LAM~~ 145 Km
100 Km + Loiter
PAM 45Km

FLOT

Patriot and SLAMRAAM missiles also part of Army Missile Enterprise

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THE SPECTRUM OF THREATS REQUIRES A MIX OF MISSILE SYSTEM CAPABILITIES

Contemplated Capabilities

- Precision, precision, precision
- Elimination of UXOs
- Selectable warheads
- In-flight redirect
- Programmable trajectory
- Reduced signature
- Demil

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Suggestions

- PM / TCM relationship and requirements
- Get plugged into G-3 Ammo
- ASA(ALT)
- OSD
- Media – tell your story

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...we never forget our real customer....

Any Warfighter - Anywhere - All The Time

2008 NDIA Guns & Missiles Brief

Long Range Land Attack Projectile

(LRLAP)

John Rinko

24 April 2008

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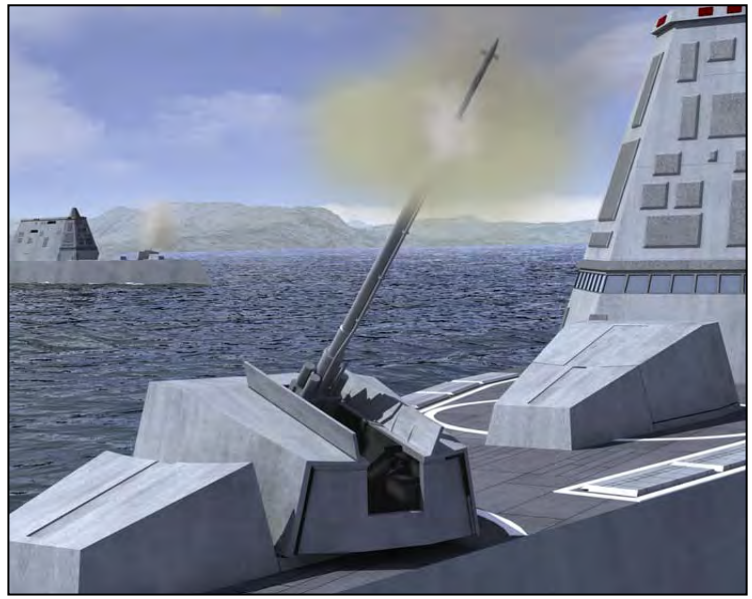
This Brief is provided for Information Only and does not constitute a commitment on behalf of the U.S. government to provide additional information and / or sale of the system

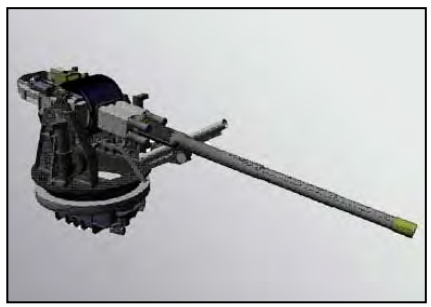
DDG 1000 AGS & LRLAP Introduction

155-mm Advanced Gun System

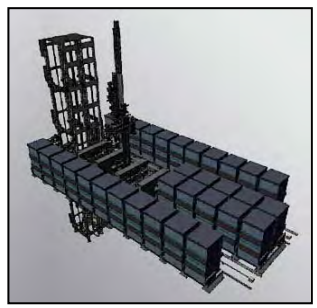
- Primary land attack armament for DDG1000
- Fully automated high volume magazine
- All weather, accurate, multi-mission support
- 10 rounds per minute rate of fire
- Sustainable fires 24 / 7
- Multiple round simultaneous impact



LRLAP

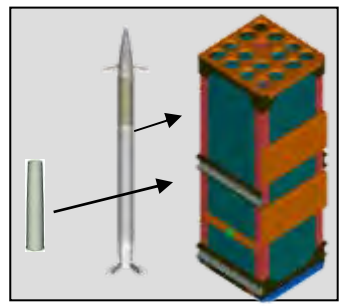


Fully Automated 155-mm Vertical Load Gun



Fully Automated High-Volume Magazine

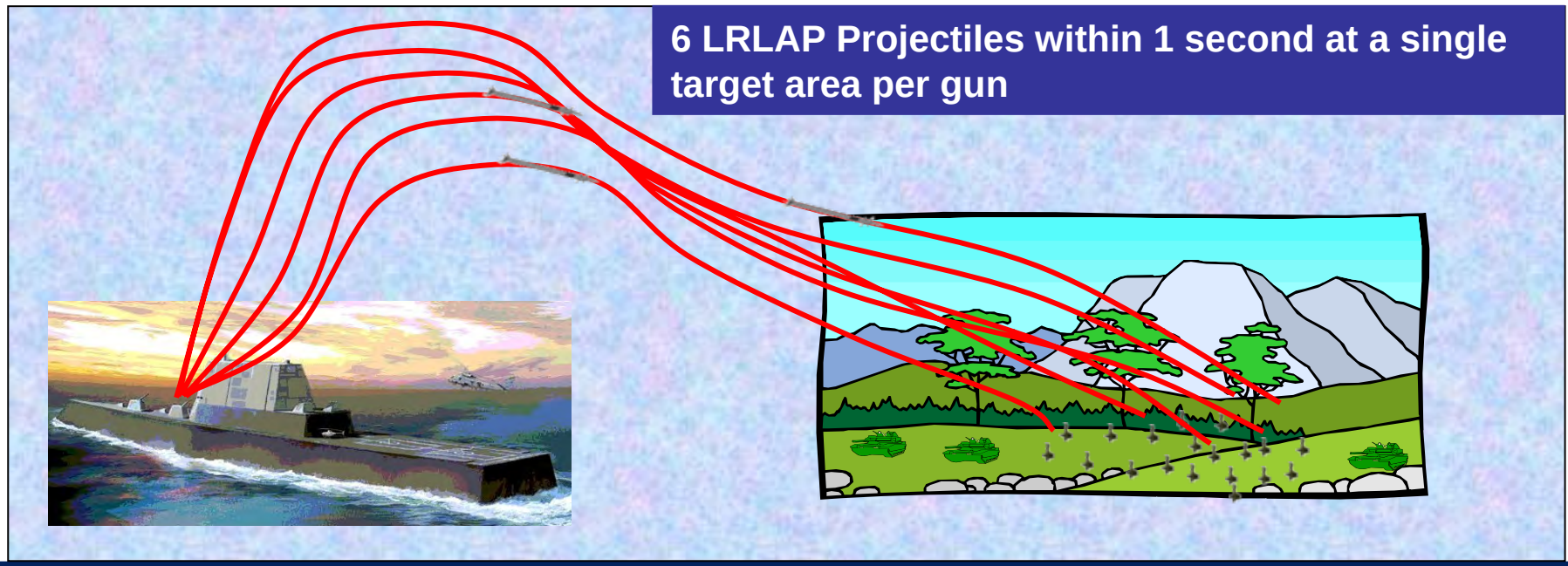
Reduced RCS/IR Signatures



Munitions Integrated into AGS Pallet

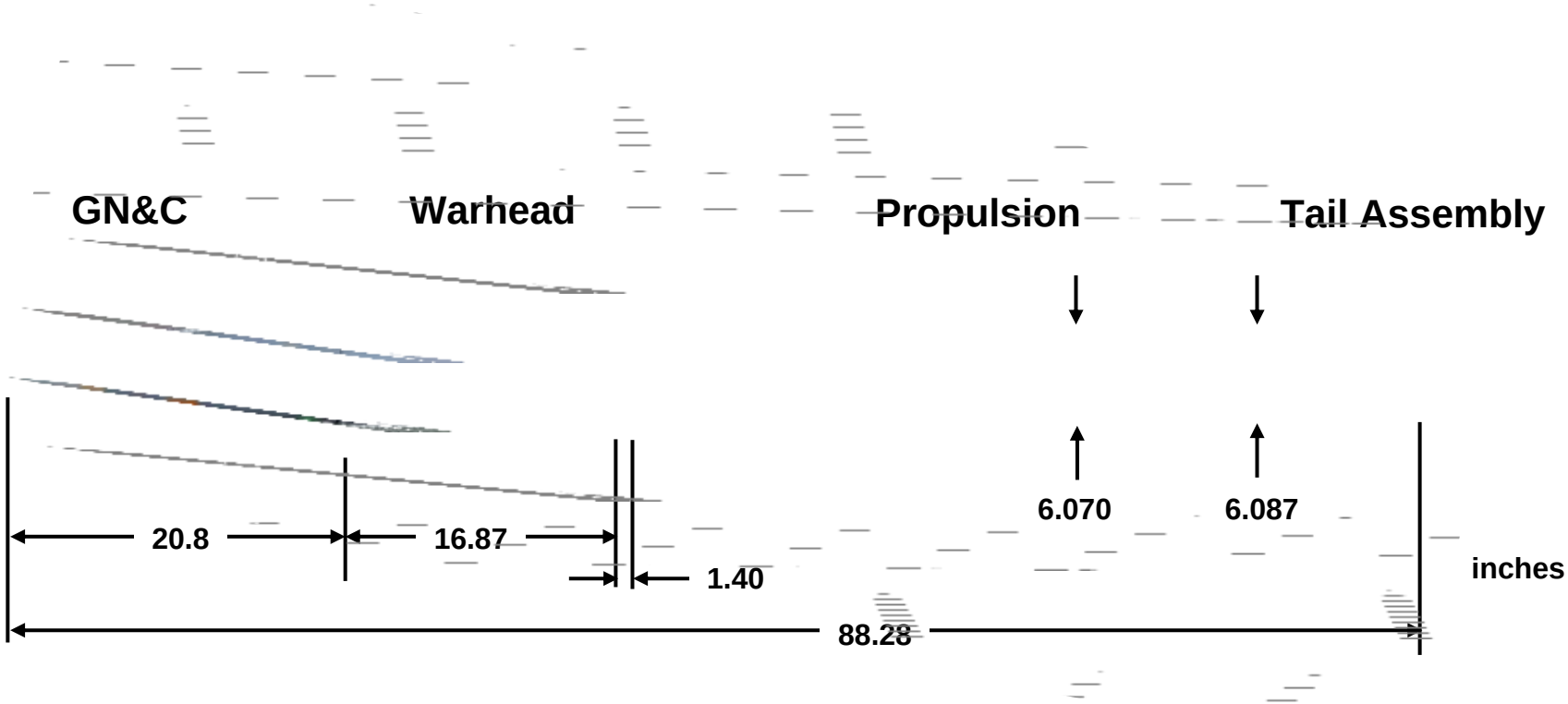
LRLAP Capabilities

- Multiple Round Simultaneous Impact (MRSI)
- Greater than 63 nautical mile range
- Unitary high-explosive warhead
- Effective for wide range of targets
  - Operational in close proximity with friendly forces and in urban terrain
  - Effective against reverse slope targets

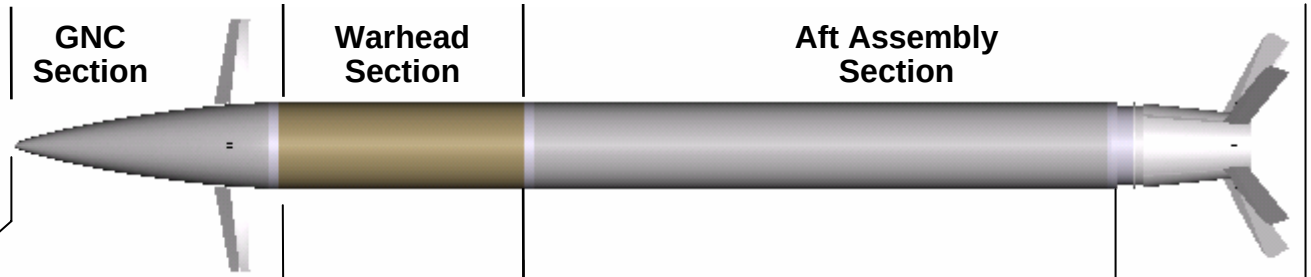


LRLAP Contractor Team

LRLAP Tactical Baseline Description



LRLAP System Overview



GN&C

- DII
- Radome
- Thermal Battery
- DIGNU2
- CCU
- GPS Antennas
- Canard covers
- SES (2)
- HOB Sensor
- DII
- GNC Networks

Payload

- ESAD with PD sensor
- HE Warhead
- Warhead ESAD-ISD Interconnect

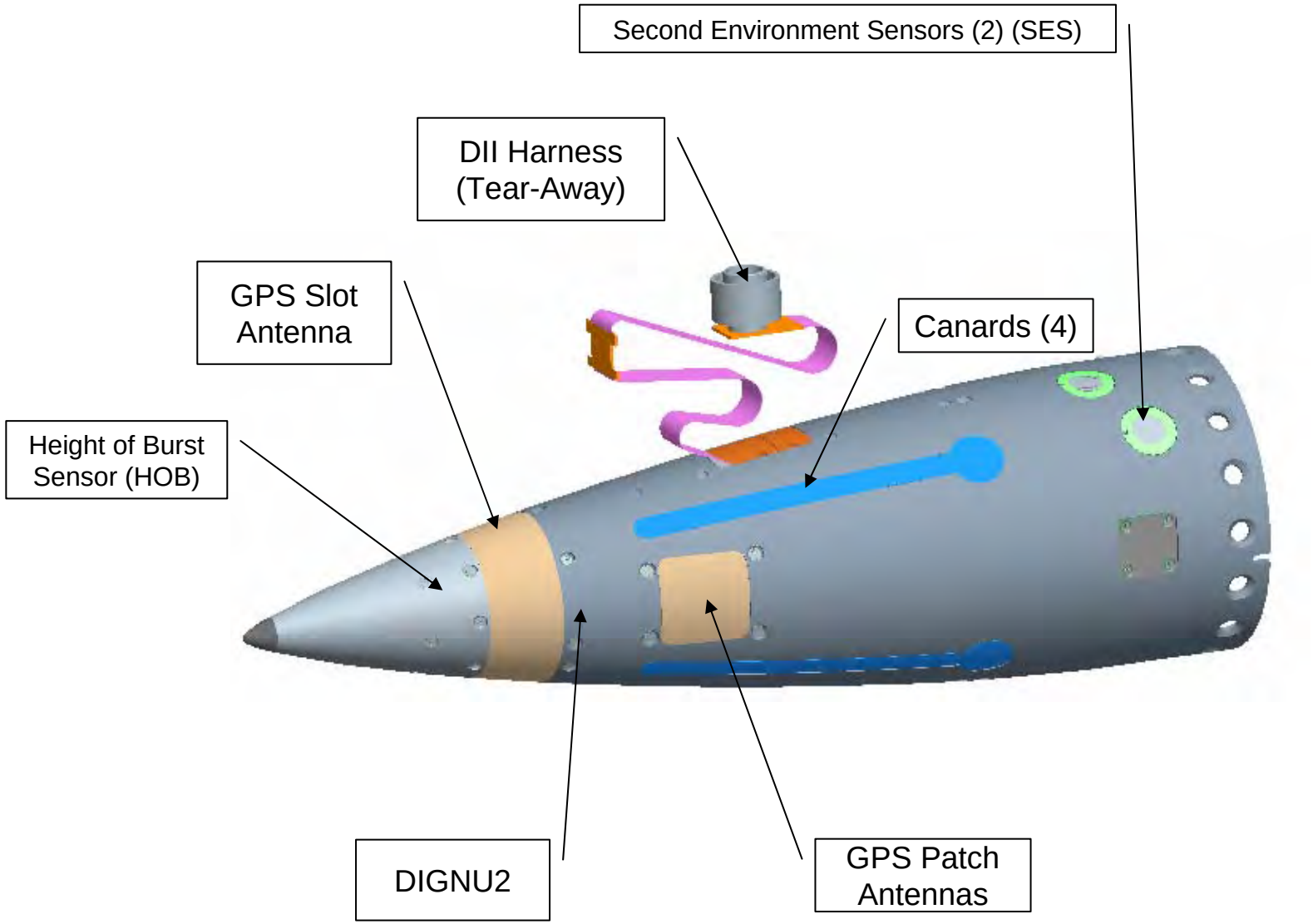
Propulsion

- Case and bulkhead(s)
- Insulation
- Motor ESAD-ISD Interconnect

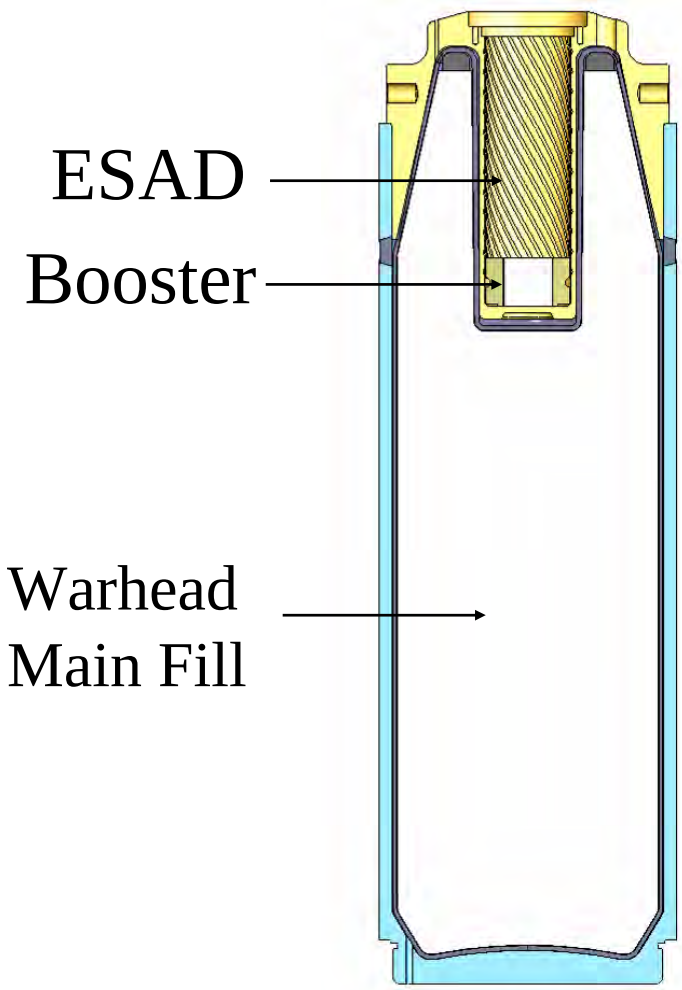
Tail

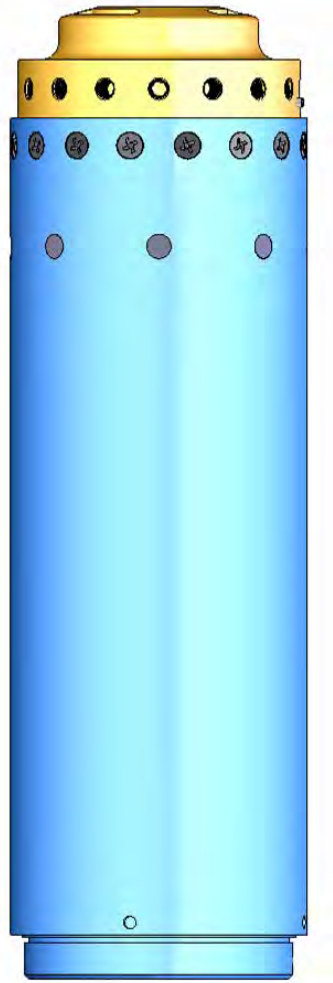
- Housing
- Hinge plate
- Fin locks
- Fin cap
- Obturator
- Blast tube/nozzle
- Initiation train
- ISD
- Tail Fins

GN&C Section

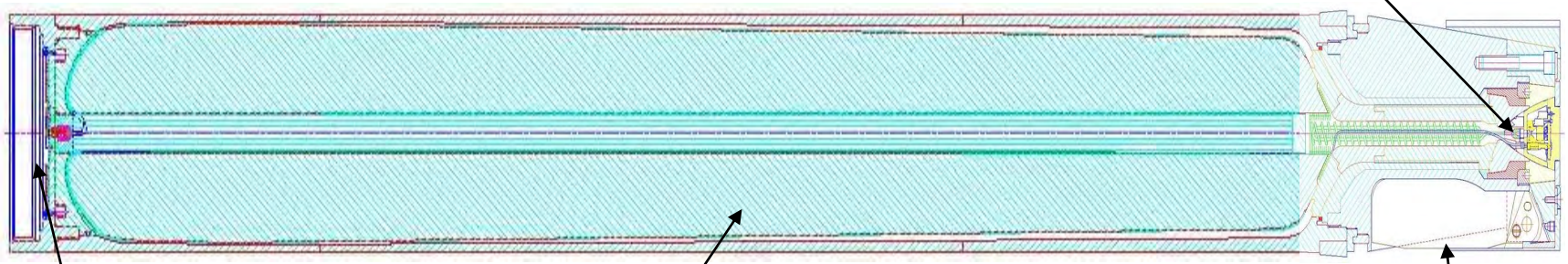

Second Environment Sensors (2) (SES)
DII Harness (Tear-Away)
GPS Slot Antenna
Canards (4)
Height of Burst Sensor (HOB)
DIGNU2
GPS Patch Antennas

Warhead Section



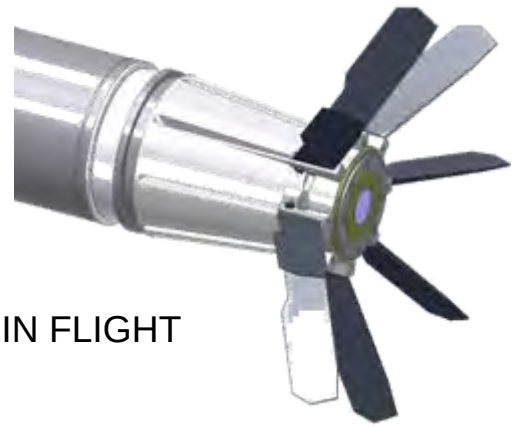


Aft Assembly Section



Tail Assembly sub- Section

IN BORE

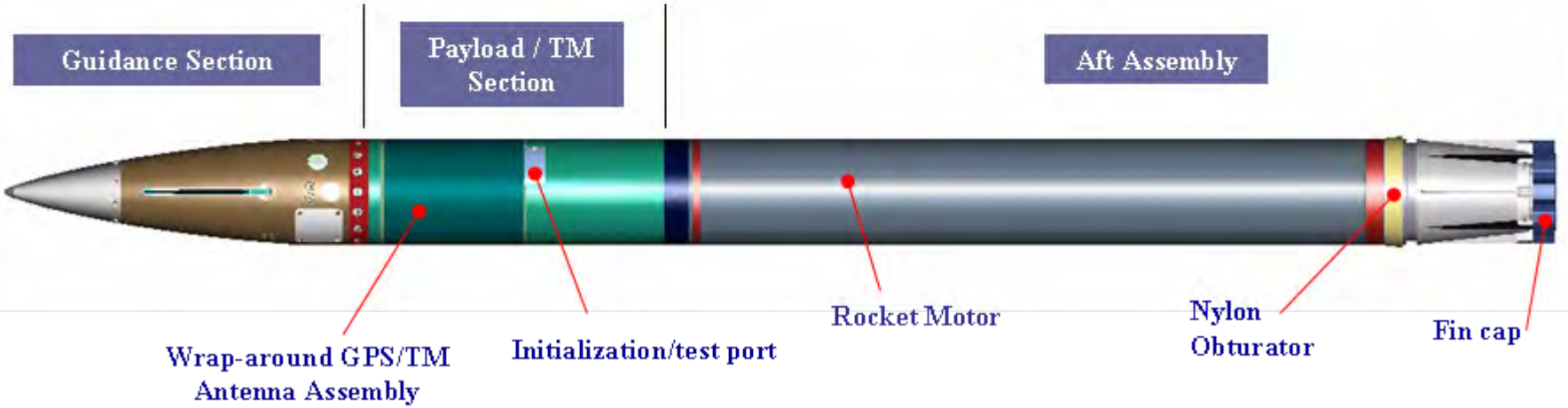


IN FLIGHT

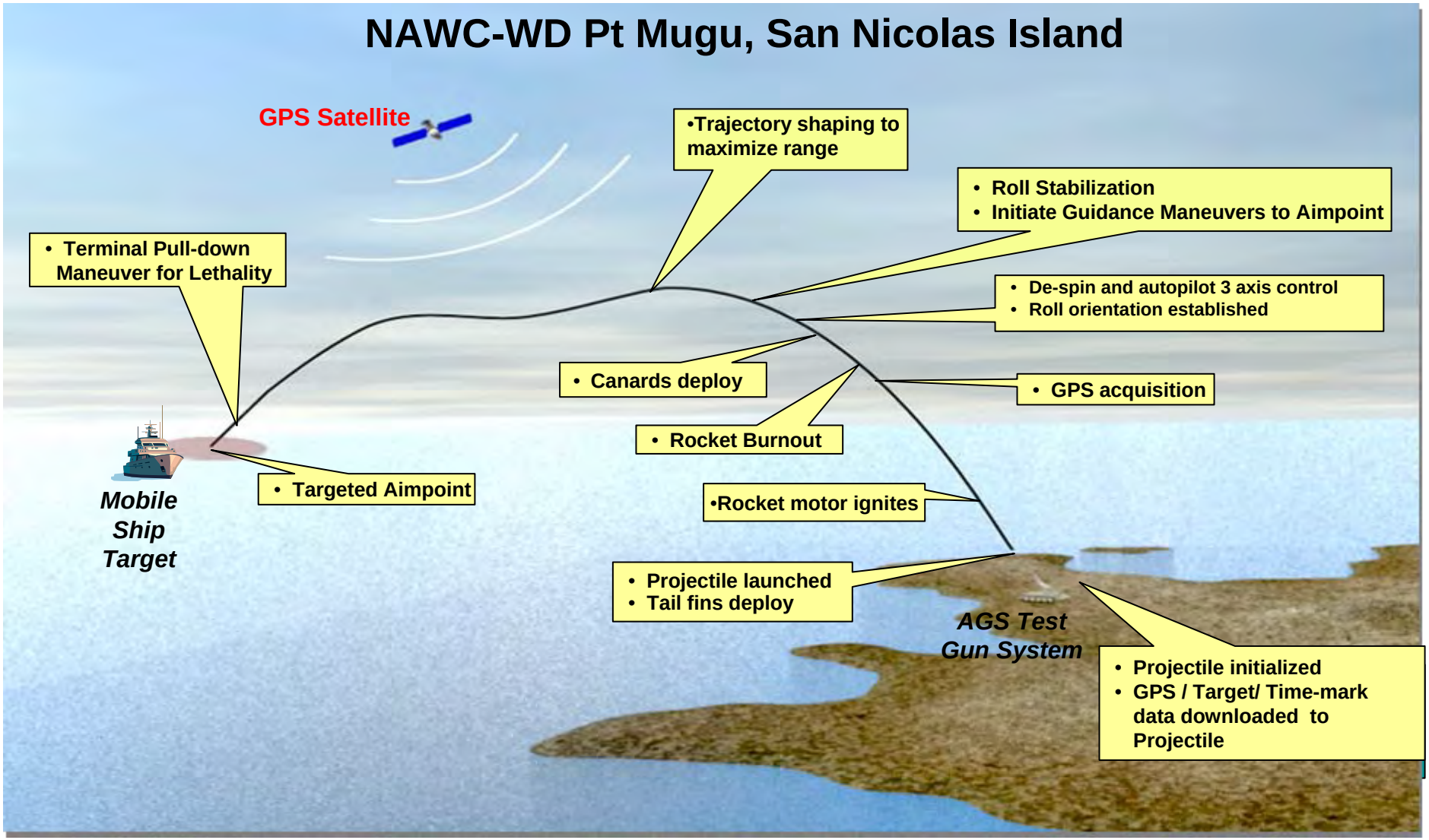
LRLAP Test Results - EDM Flight Tests

- Numerous Recoverable Gun Tests
  - Common Guidance Program
  - LRLAP Program
- 1 Electronics Ballistic Flight Test
  - EG-1: Ballistic Flight Test of GN&C Electronics
- 9 Guided Flight Tests
  - GF-1: Engineering Integration Test
  - GF-2&3: DD(X) Milestone B Tests
  - GF-4: Engineering Flight Maneuver Test
  - GF-5 through 9: Extended Range Flight Tests

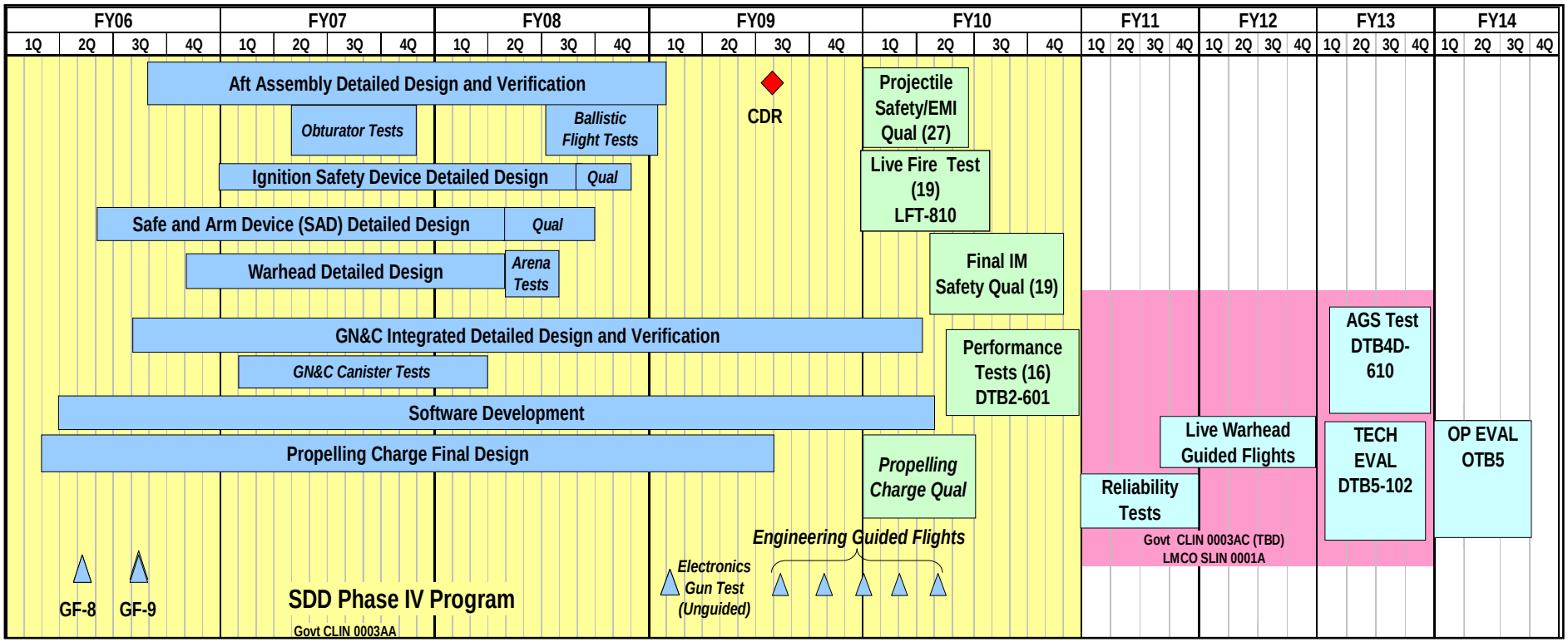
LRLAP Test Results - EDM Projectile Configuration



LRLAP Test Results - EDM Guided Flight Description

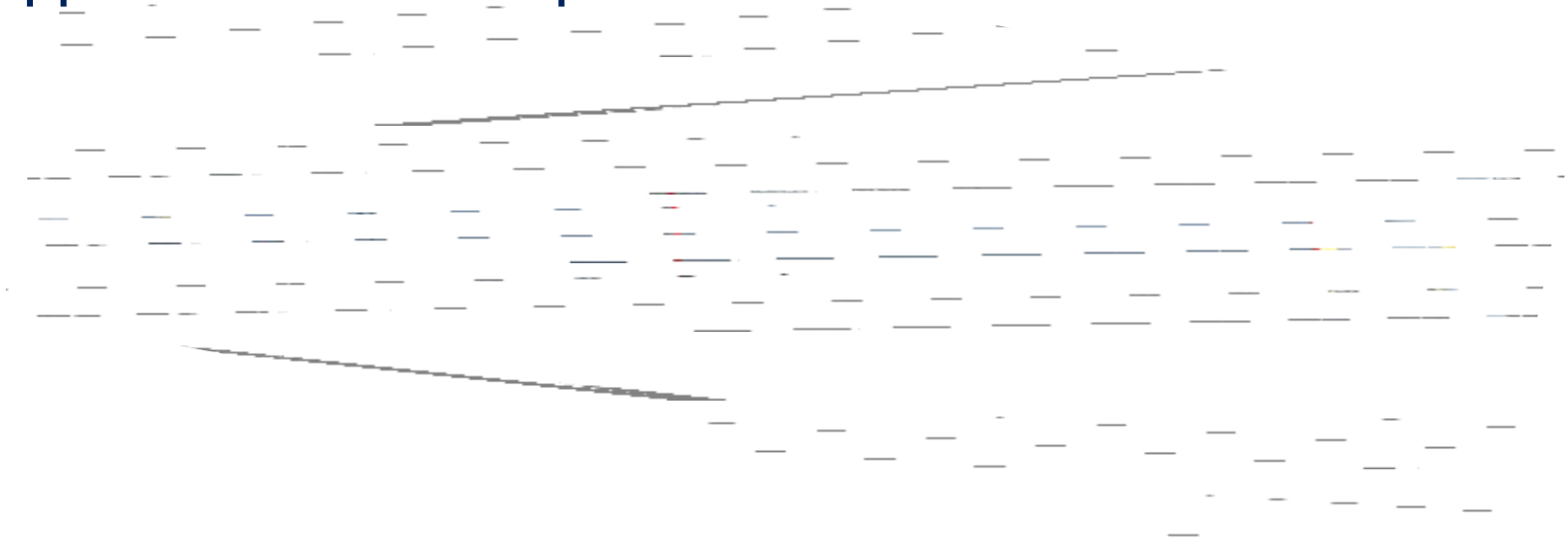


LRLAP Path Forward



Conclusion

- Proven Guidance Capability
- Threshold Range Requirement Met
- Qualification Testing In FY10
- IOC in FY14
- Funded Program of Record
- Supports DDG1000 Ship Schedule



Contact Information

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  - (540)653-3195
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    6096 Tisdale Road, Suite 303

    DAHLGREN VA 22448-5114

Introduction to Systems Acquisition

Jim Ripley

Marine Corps Systems Command

Mission of the Acquisition System

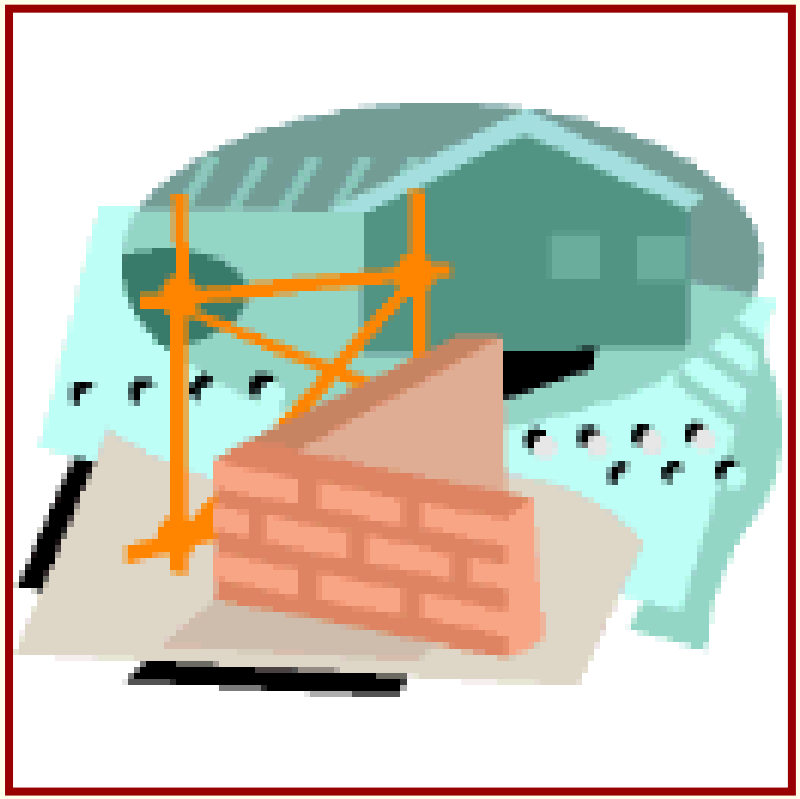
The mission of the acquisition system is to develop, acquire, modernize and maintain the most advanced combatant capabilities and associated systems, ensuring continuous, cost-effective innovation that advances warfighting capability.

Outline

1. Acquisition Fundamentals
2. The Defense Acquisition System
3. Acquisition Planning
4. Financial Management
5. Contract Management
6. System Engineering
7. Acquisition Logistics
8. Production, Quality and Manufacturing Management

Module One

Acquisition Fundamentals



Key Terms

Authorities

Critical Concepts

Decision Support Systems

Authorities: Statutory Direction

- Acquisition Laws
  - Armed Services Procurement Act (1947) as amended
  - Small Business Act (1963)
  - Office of Federal Procurement Policy Act (1983)
  - Competition in Contracting Act (1984)
  - DOD Procurement Reform Act (1985)
  - DOD Reorganization Act (1986) (Goldwater-Nichols)
  - Federal Acquisition Streamlining Act (FASA (1994)
  - Clinger-Cohen Act (1996)
- Fiduciary Laws
  - Budgeting and Accounting Procedures Act
  - Federal Managers Financial Integrity act
  - Anti Deficiency Act
  - Chief Financial Officer Act of 1990
  - Government Performance and Results Act
  - Government Management Reform Act

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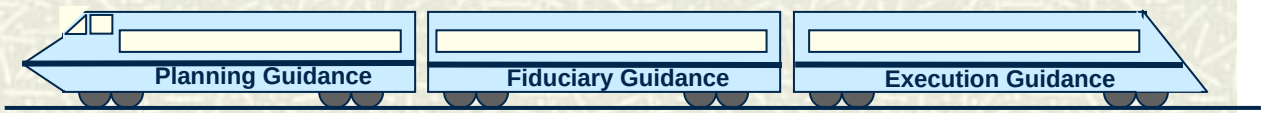
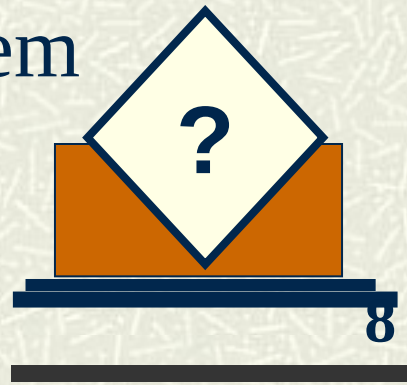
Authorities: Policy Guidance

- Acquisition Policy
  - DODD 5000.1, The Defense Acquisition System
  - DODI 5000.2, Operation of the Defense Acquisition System
- Financial Management Policy
  - DOD 7000.14-R, Financial Management Regulation
  - DODD 7045.14, The Planning, Programming, and Budgeting System
  - DODI 7045.7, Implementation of the Planning, Programming, and Budgeting System
- Federal Acquisition Regulation (FAR)



Decision Support Systems

- Joint Capabilities and Integration Development System (JCIDS)
- Acquisition Management System
- Planning, Programming, Budgeting and Executing System
- Financial Systems



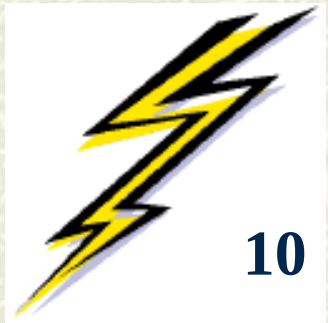
Critical Concepts

- Up Front and Early
- Risk
- Requirements
- Funding Planning
- Acquisition Strategy
- Teamwork
- Communications

Critical Concept: Program Manager's Mantra

Critical Concept: Risk and Risk Factors

- Risk – the measure of the potential inability to achieve objectives
  - (1) the ***probability/likelihood*** of failure
  - (2) the ***consequence/impact*** of the failure
- Risk Factors
  - Technical performance
  - Cost
  - Schedule
- Risk Assessment



Critical Concept: Risk Handling

- Four techniques for handling risk:
  - Control – reducing the probability of occurrence
  - Avoid – changing the source of the potential risk
  - Assume – planning for the potential consequences
  - Transfer – making someone else accountable

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Critical Concept: Requirements

- What capability is needed?
- When is the capability needed?
- Can we afford the new capability?
- Does the need flow from Combat Command, Coalition, and Service operational concepts and architectures?

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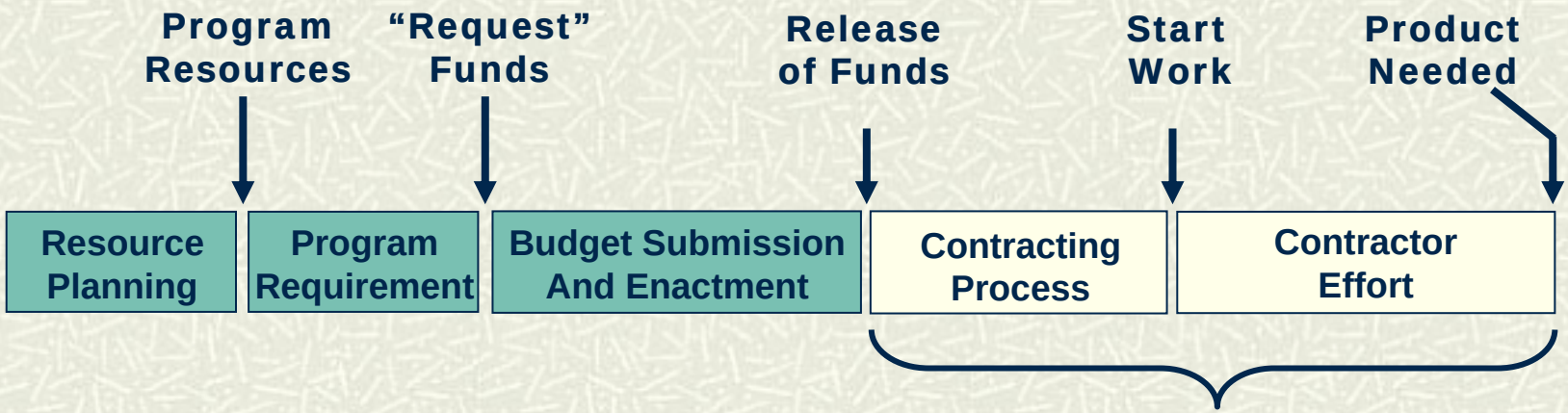
Critical Concept: Funding Planning

- **Rule #1**: Establish funding requirements at least nine years prior to the need.
- **Rule #1a**: Consider process schedules in defining when funding will be needed.
- **Rule #2**: Do not reduce front-end funding to save money. It does not work!
- **Rule #3**: Delays during the program – schedule slips – increase total ownership costs.

Critical Concept: Funding Planning

Funding: Start early and know the Rules.



	Example	
IOC	IOC FY 0	FY 06
Production Period		1 yr
Contract Start	FY -1	FY 05
Contracting	FY -2	FY 04
Budgeting	FY -3	FY 02-03 (Budget FY04)
Programming	FY -7	FY 98-01 (POM 04)
Planning	FY -9-10	FY 95-97

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Critical Concept: Acquisition Strategy

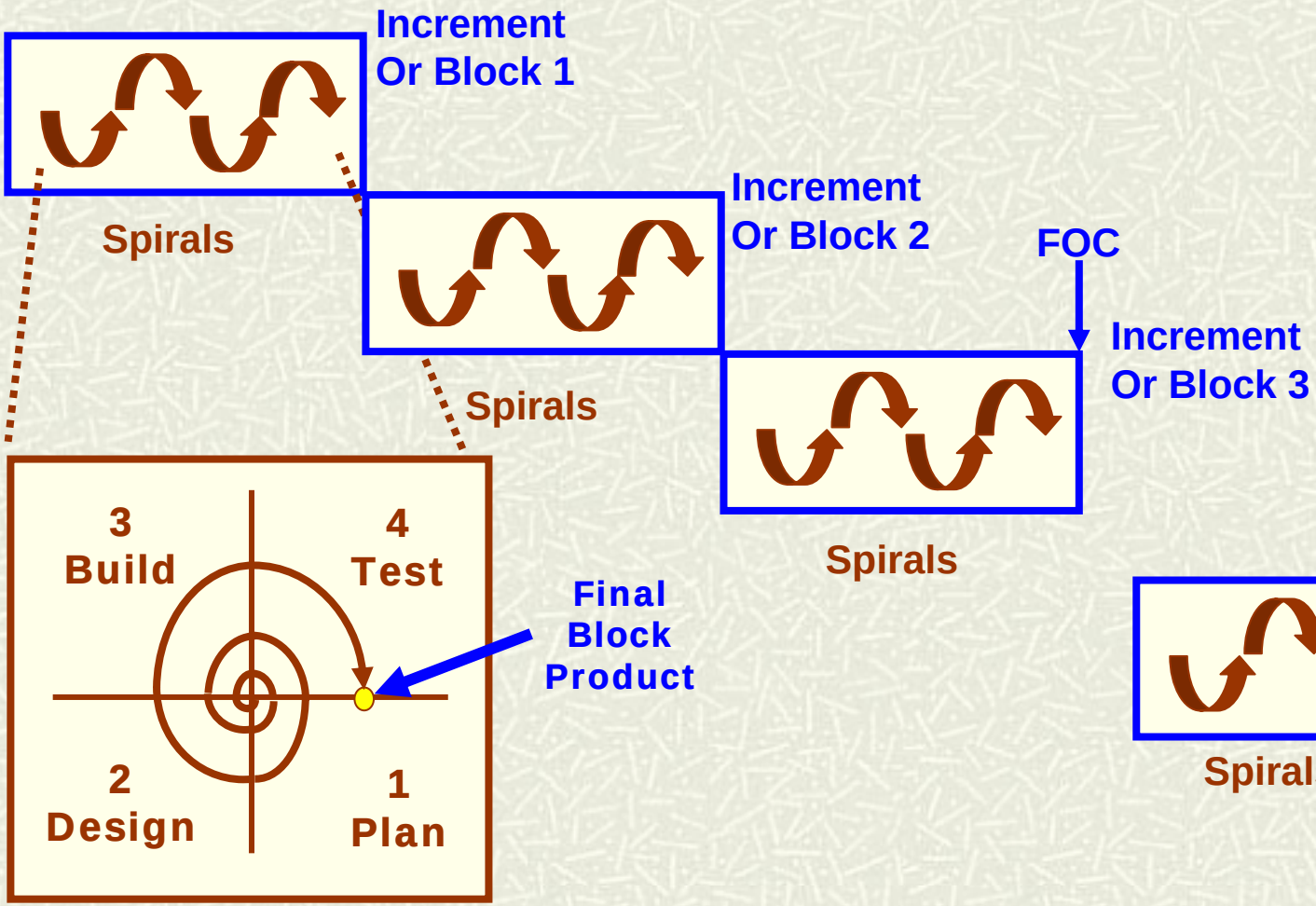
- **Concurrency**: Parallel planning and development from concept through disposal
  - System development
  - Test and Evaluation
  - Acquisition Logistics
  - Production

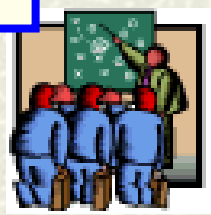
- **Evolutionary Acquisition** – the ultimate capability is delivered to the user in two or more blocks with increasing increments of capability

- **Spiral Development –** continuously expanding versions based on learning from earlier prototypes or development.

- **Pre-Planned Product Improvement (P^3I) –** process for adding improved capabilities to a mature system.

Evolutionary Acquisition, Spiral Development, and Pre-Planned Product Improvement (P^3I)





Critical Concept: Teamwork

- **Teamwork –** the involvement of all stakeholders throughout the entire acquisition process

Stakeholders:

- Science and Technology
- Engineering
- Acquisition Logistics
- Production
- Operations
- T&E/OPTEVFOR
- Program Management

Teamwork: A Cooperative Effort

Critical Concept: Communications

Program Office

Communications: A Daily Routine

- **Requirements Officer**
- **Resource Sponsor**
- **Comptroller**
- **Contracting Officer**
- **Design Agent**
- **In-Service Agent**
- **Fleet**

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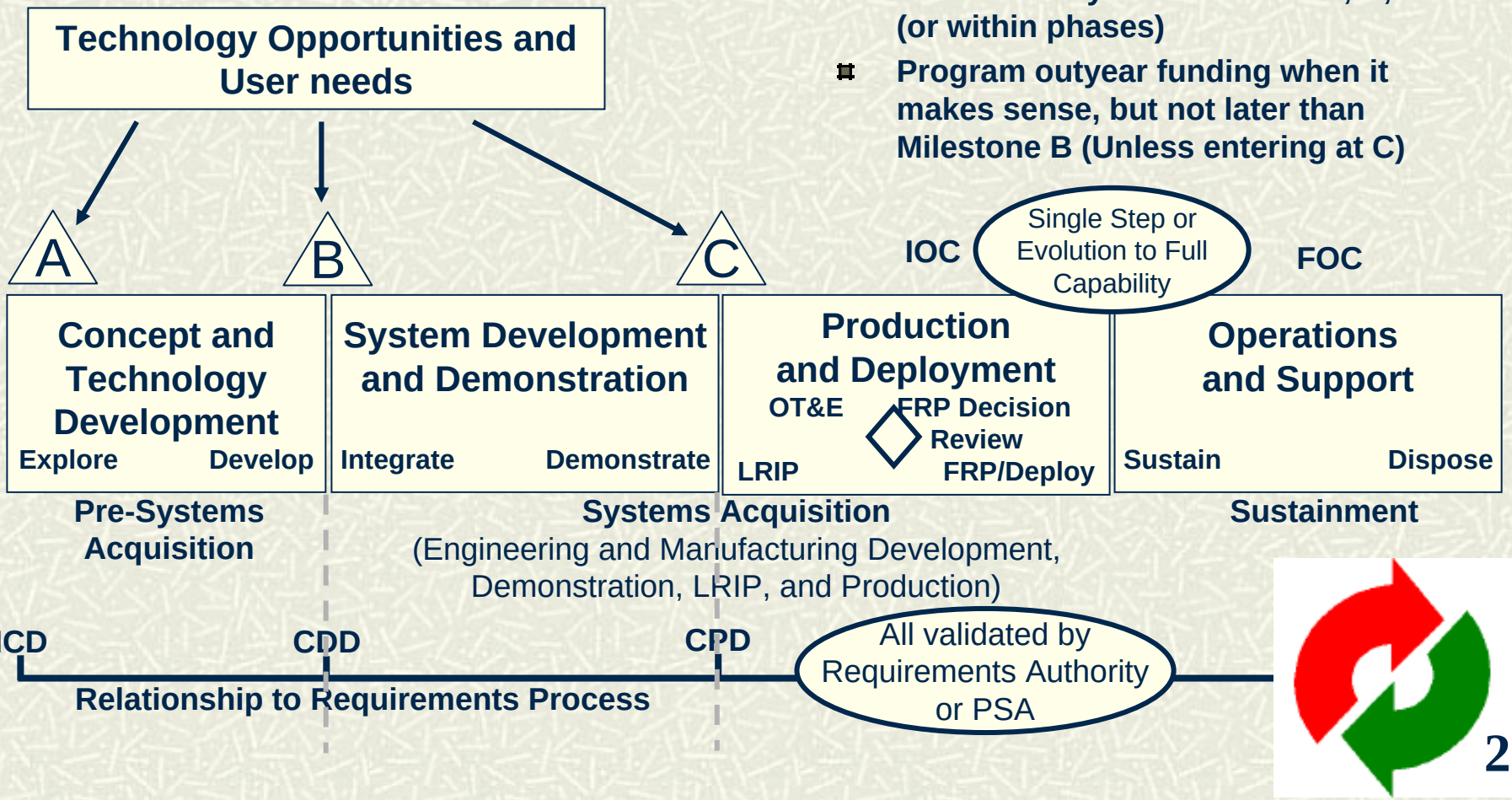
Module Two

Defense Acquisition System

- Framework
- Needs
- Milestones
- Phases
- Work Efforts
- Entrance Criteria
- Exit Criteria

The Acquisition Life Cycle

- Process entry at Milestones A, B, or C (or within phases)
- Program outyear funding when it makes sense, but not later than Milestone B (Unless entering at C)



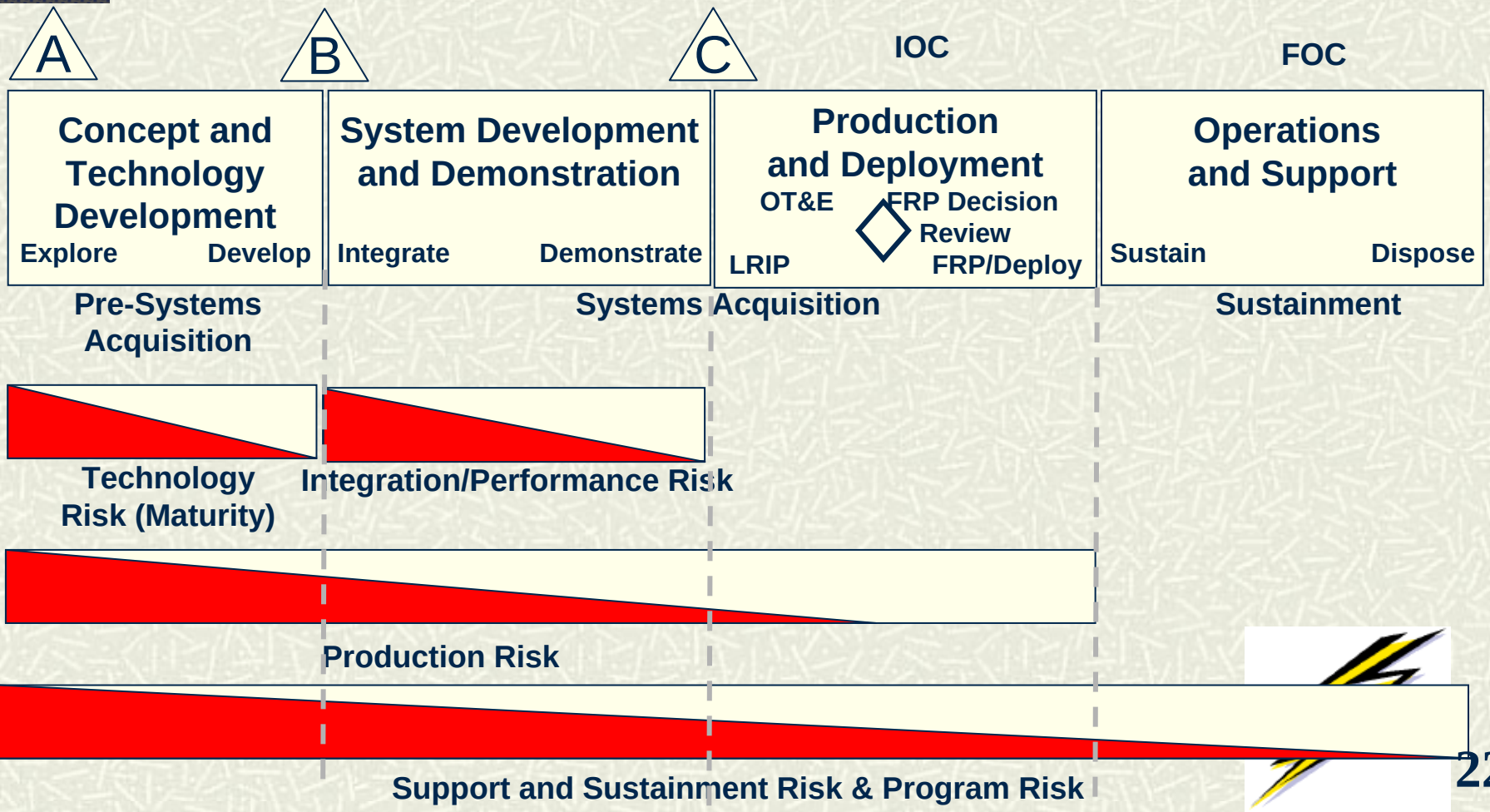
Transitioning through the Acquisition Process

If technical maturity is:	then enter at
Unproven	Milestone A or between A and B
Proven	Milestone B or between B and C
Ready or nearly ready for deployment (commercially available)	Milestone C

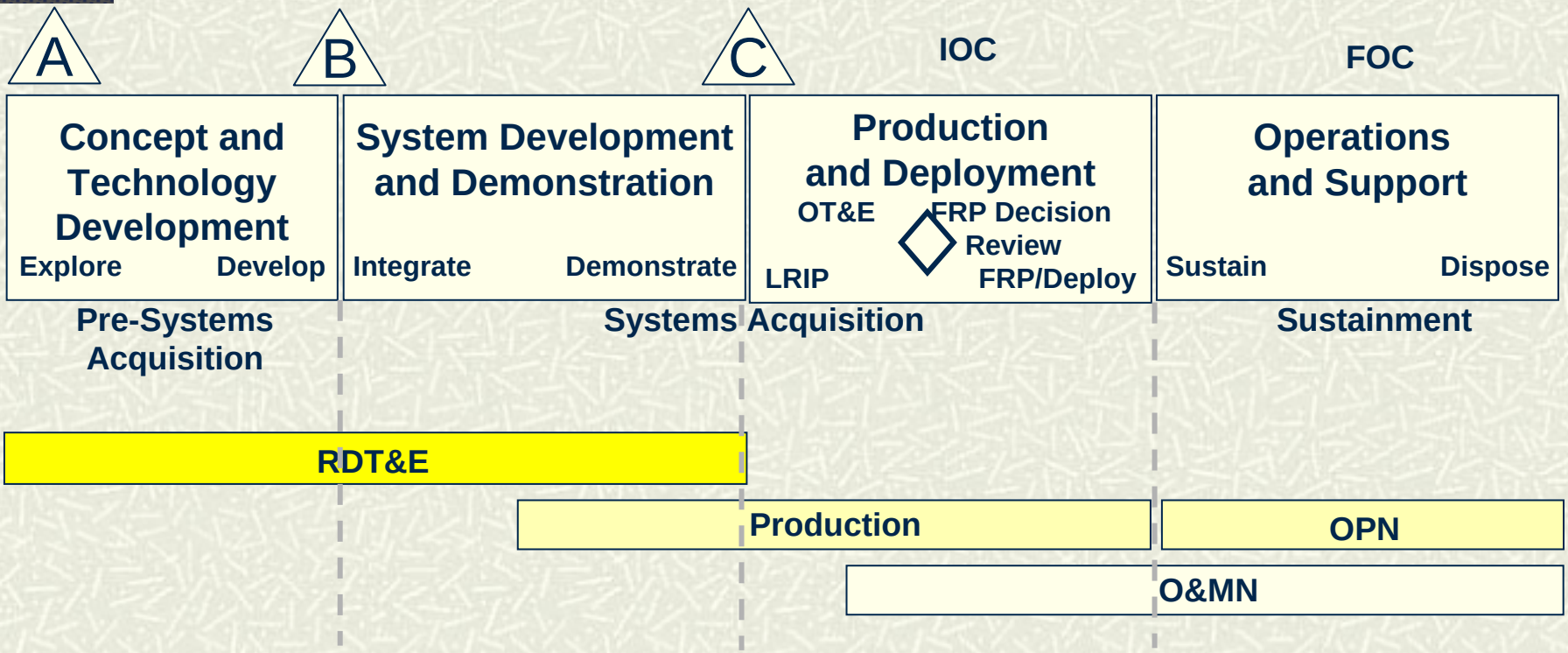
- Phase **Entrance** Criteria
  - *Phase*-specific
    - Documentation
    - Technology maturity
    - Technology risk
    - Technology maturation and demonstration needs

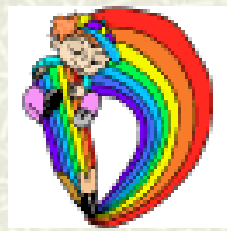
- Phase **Exit** Criteria
  - *Program*-specific
    - Measurable or observable performance conditions
    - Defined in the Acquisition Decision Memorandum

The Acquisition Life Cycle and Risk



The Acquisition Life Cycle and the Color of Money





Module Three

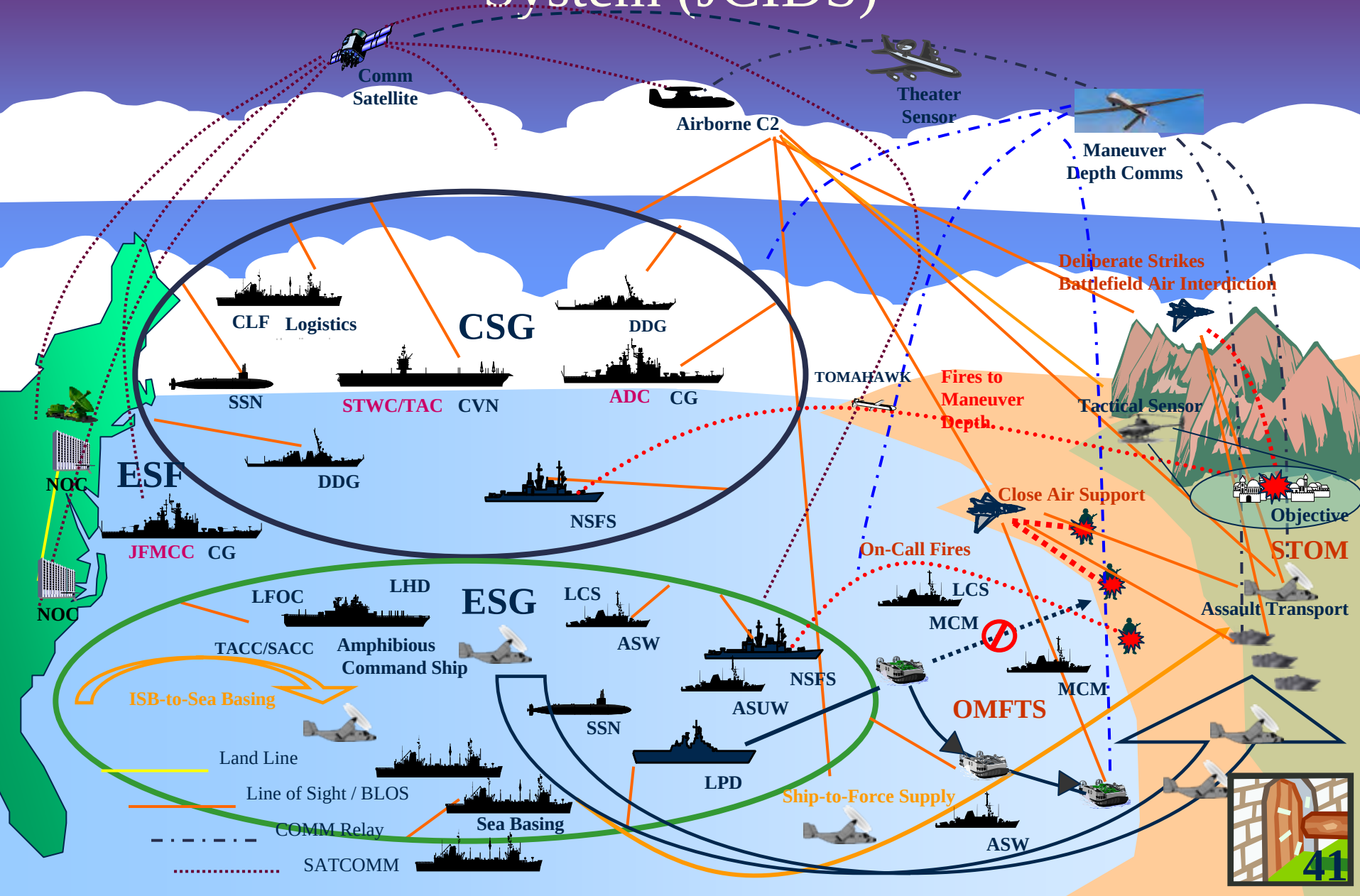
Acquisition Planning

- Requirements
- Acquisition Organizations
- Acquisition Categories
- Acquisition Team
- Work Breakdown Structure
- Acquisition Initiatives
- Acquisition Program Baseline
- Acquisition Strategy

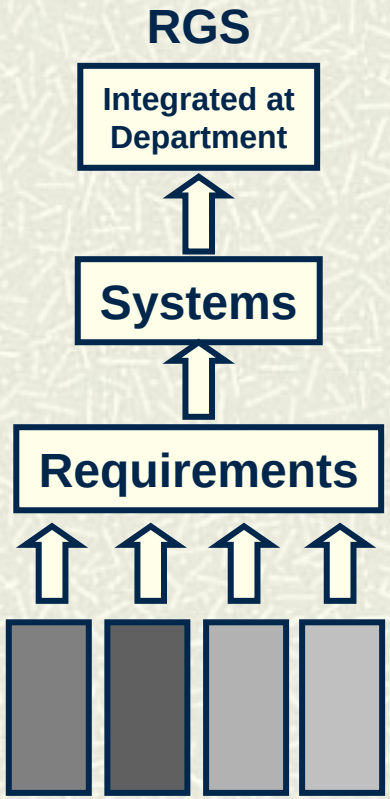
Requirements

- The JCIDS Process
- A Top-Down Process
- Functional Analysis
- An Integrate Proceess
- A Collaborative Effort
- The DoN Requirements Process
- OPNAV Requirements and Programs (N7)
- Influencing Pressures

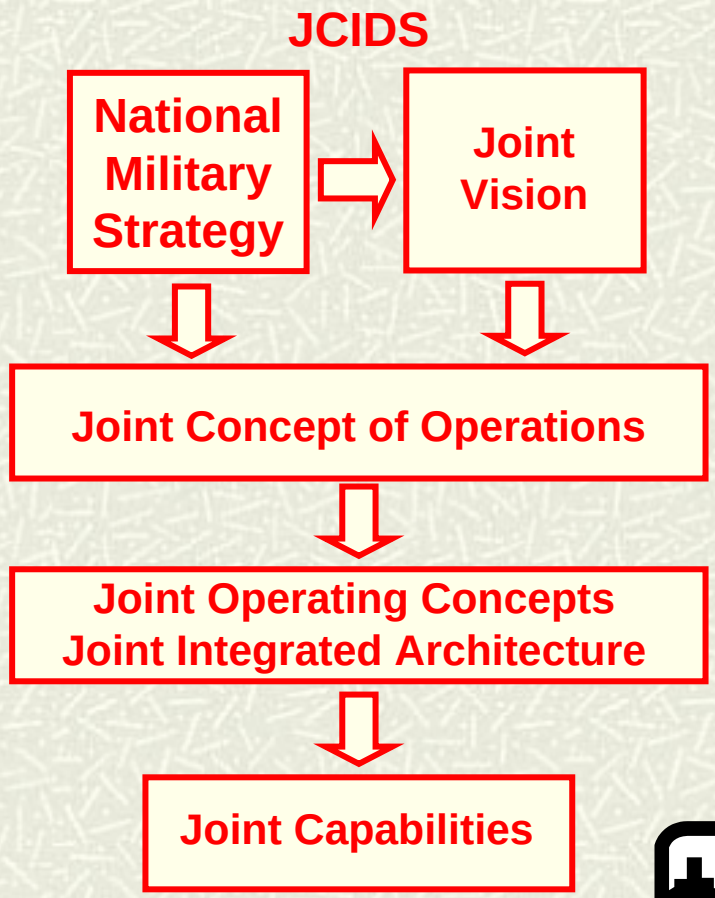
Joint Capabilities and Integration Development System (JCIDS)



A Top-Down Process



Bottom Up, Often Stovepiped



Top Down, Born Joint

Functional Analysis

- **Functional Area Analysis (FAA)**
  - Threat versus Capability
  - Future Threats
  - Current and Projected Capabilities
  - Opportunities for Change
  - Advances in Technology
  - Impact of Policy Changes
  - Cost Reduction
- **Functional Needs Analysis**
  - Shortfalls and Duplications
  - Opportunities
  - Reliability and Maintainability
- **Functional Solution Analysis (DOTMLPF)**
  - Non-materiel (DOTLPF)
  - Materiel (M)

An Integrated Process

The Requirements/Acquisition Handshake

Functional Solution Analysis

- Capability Gap
- Range of Military Operations
- Joint Concepts and Integrated Architectures
- Threat/Operational Environment
- DOTMLPF Analysis
- Capability Sets
- Analysis of Materiel Approaches
- Recommended Alternative

ICD

A — Concept and Technology Development

- Key Performance Parameters (KPPs)
- Performance Thresholds
- Performance Objectives
- CAIV
- Interoperability
- Information Exchange
- Information Assurance
- Program Strategy (for achieving full capability)

CDD

B — System Development and Demonstration

- Measures of Effectiveness
- Refined KPPs
- Threat Summary
- Program Summary
- Shortcomings of systems in place
- C4ISR architectures
- Program Support
- Joint DOTLPF Impact
- Logistics and Facilities Consideration
- Interoperability Certification
- Program Schedule
- Program Affordability

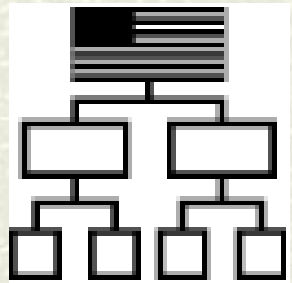
CPD

C — Production And Deployment

- LRIP
- OT&E
- FRP
- Log Support
- Deployment

Key Acquisition Organizations

- DoD Acquisition Organizations
- OSD Acquisition Functions
- DoN Acquisition Organizations
- Program Executive Offices
- System Commands
- Program Offices



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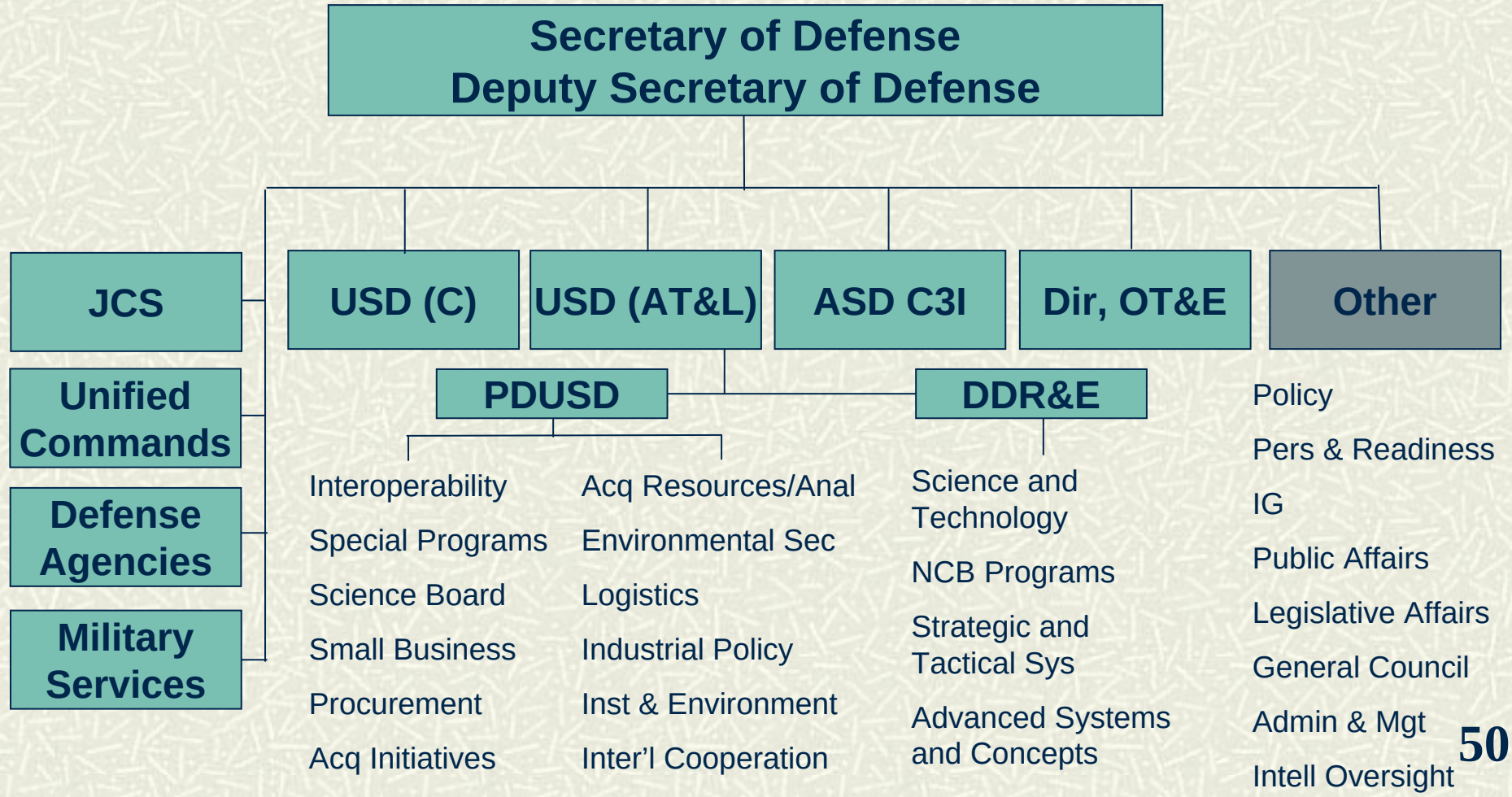
The DOD Acquisition Organization



Acquisition Categories

ACAT	Parameters	MDA
ACAT I	>$365M RDT&E/$2.19B Proc or special interest to USD(AT&L)	
ACAT ID		USD(AT&L with DAB advice
ACAT IC		Delegated to component head
ACAT IA	MAIS >$32M in a single year or total cost >$126M	ASD(C^3I)
ACAT II	>$140 RDT&E/$660M Proc	Component head
ACAT III	Below ACAT I and II	Component acquisition Executive (ASN(RDA)
ACAT IV	Do not affect mil characteristics of ships or aircraft Do not involve combat capability	Designated by component head
ACAT IVT	Requires OT&E	
ACAT IVM	Does not require OT&E	

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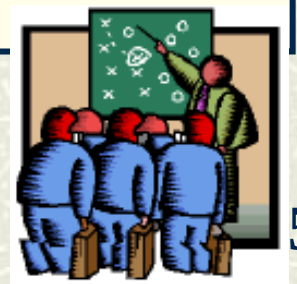
Acquisition Strategy

- Comprehensive guidelines for program execution throughout the system's life cycle
- Event driven linking decisions to demonstrated accomplishments
- Developed using an iterative process
- Documents the major issues in program execution
- Developed prior to program initiation and updated prior to each milestone decision point

The Acquisition Strategy Guidelines:

- Requirements
- Program Structure
- Acquisition Approach
- Risk
- Program Management
- Design Considerations Affecting the Acquisition Strategy
- Support Strategy
- Business Strategy



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Acquisition Strategy: Some Examples

- Development Strategies
  - Evolutionary Acquisition
  - Concurrent Development
  - Spiral Development
- Business and Contracting Strategies
  - Full and Open Competition
  - Sole Source
  - Firm-Fixed Price
  - Indefinite Delivery Indefinite Quantity
  - Cost Plus Fixed Fee
- Support Strategies
  - Organic
  - Contract
    - Contractor Logistic Support
    - Virtual Prime Vendor
    - Contractor Support and Sustainment

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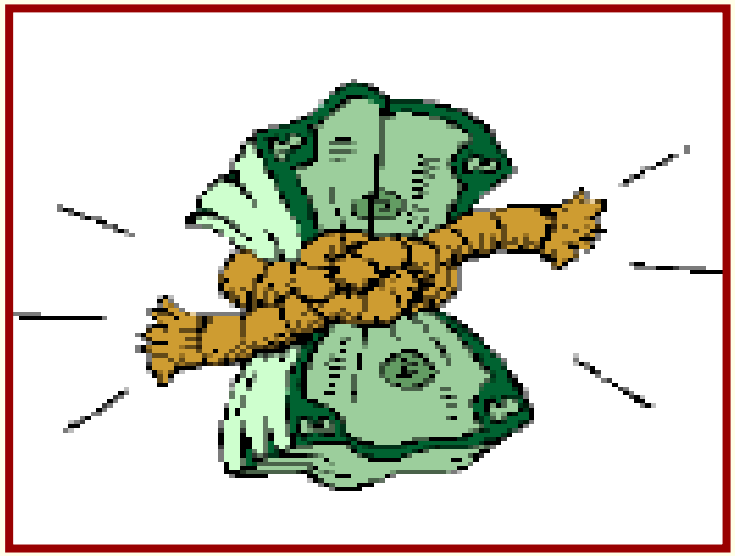
Module Four

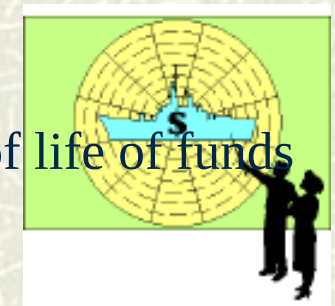
Financial Management



Cost Estimation → Resource Allocation → Budget Enactment → Budget Execution

Purpose and Definitions

- Purpose
  - To aid executives in planning and controlling their organizational operations
    - Ensure that obligations and costs are within the law
    - Funds, property, and other assets are safe-guarded against waste, loss, unauthorized use or misappropriation
- Definitions
  - Budget Authority – legal authorization
  - Commitment – administrative reservation of funds
  - Obligation – legal reservation of funds
  - Expenditure – actual payment of funds
  - Outlay – disbursement to suppliers from concept to end of life of funds



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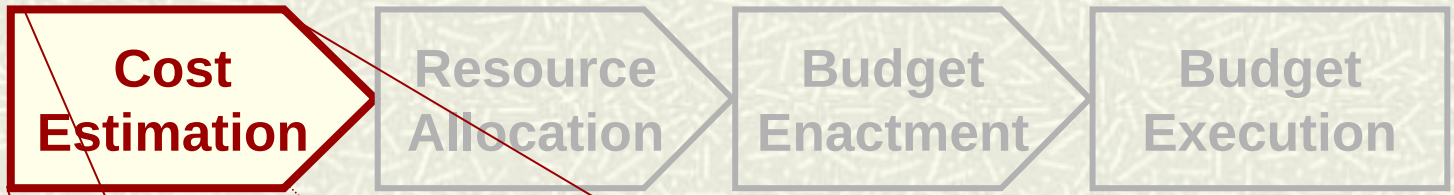
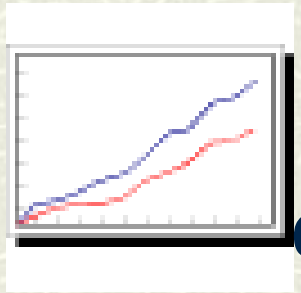
Cost Estimation



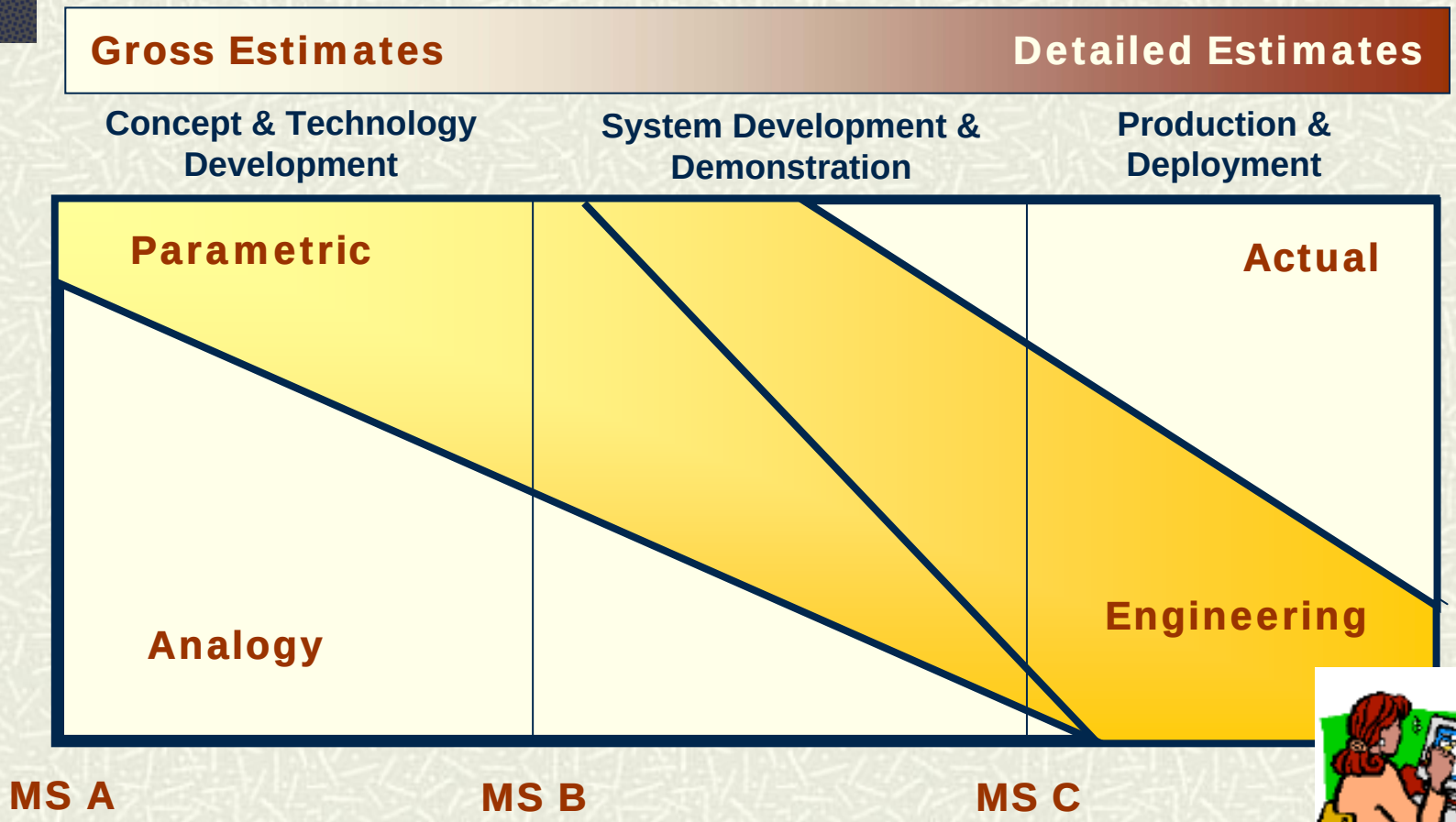
- Life-Cycle Cost Estimates
- Cost Estimation Techniques
- Cost Estimation Types
- Cost Estimate Review

Life-Cycle Cost Estimates

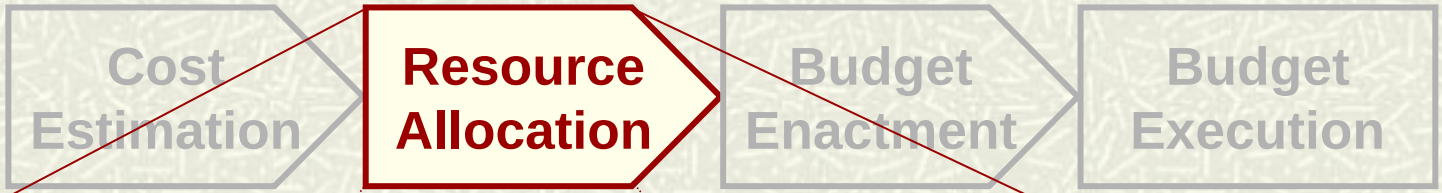
- Life-Cycle Costs (LCC)
- Life-Cycle Cost Estimates (LCCEs)
- Life-Cycle Cost Breakdown
  - Appropriations
  - WBS
  - Cost Categories



Estimation Techniques and the Acquisition Life Cycle



Resource Allocation

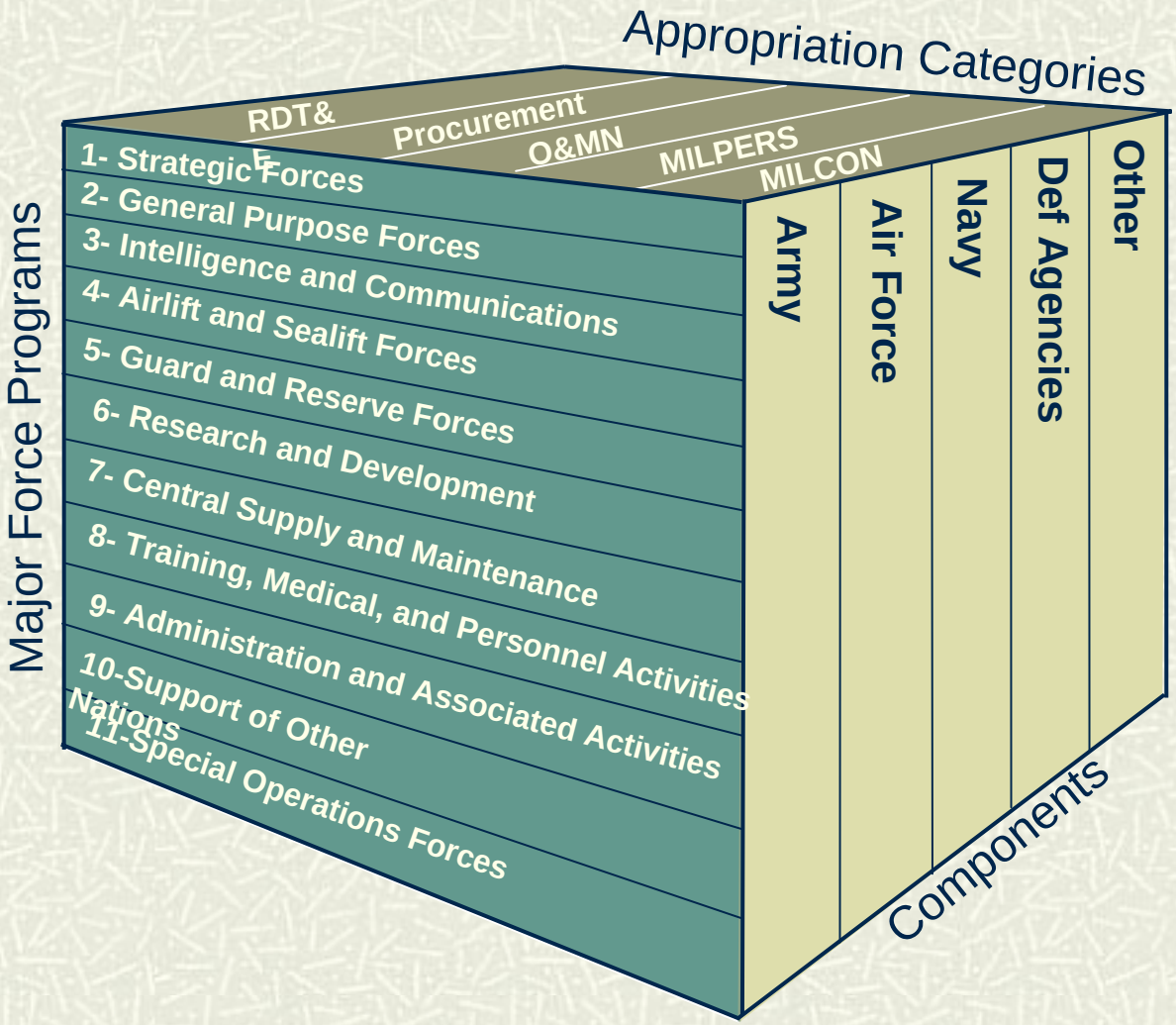


- **Defense Appropriations, Obligation, and Funding Policies**
- **Planning, Programming, and Budgeting System (PPBS) and the Future Year Defense Program (FYDP)**
- **PPBS Phases**
- **Congressional Action**
- **Budget Reviews and Annual Budget Overlap**
- **OPNAV Resources, Requirements and Assessments (N8)**

Defense Appropriation Categories, Obligations and Funding Authority

Appropriation Categories		Type	Obligation Period	Funding Authority
RDT&E		Expense & Investment	2 year	Incremental
Procurement	APN OPN WPN PANMC PMC SCN	Investment	3 year 5 year	Full
O&M	O&MN FHN&MC (Ops) O&MMC RPN O&MNR RPMC O&MMCR	Expense	1 year	Annual
MILPERS (O&M)	MPN MPMC			
MILCON (Proc)	MCON MCONR FHN&MC	Investment		Full

The Planning, Programming and Budget System (PPBS) and the Future Years Defense Program (FYDP)



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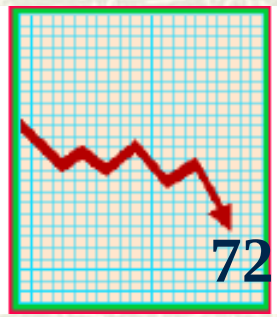
PPBS Phases

- Planning Phase (How much defense is enough?)
  - Defense Planning Guidance (DPG), SECDEF guidance for POM development
  - Service Planning Guidance
- Programming Phase (How much defense can we afford?)
  - Program Objectives Memorandum (POM) or (PR) and Program Decision Memorandum (PDM), OSD decisions concerning Service programs
- Budgeting Phase (Are we executing efficiently?)
  - OSD/OMB Budget submission
    - Budget Estimate Submission (BES)
    - Budgetary implementation of PDM
    - Program Budget Decisions (PBD)
  - President's Budget (PB) Submission



Navy PPBS Overview

PPBS Flow

FY/FY/FY/FY/FY/FY
FY (FY)

PLANNING

- STRATEGIC VISION
- NAT'L POLICY
- NSPG / LRPO
- COMBAT COMMANDS, AGENCIES, SERVICES
- JSR/JPD
- MCP/FNC
- NMSD
- WORLD SITUATION
- CPAM ISSUES
- OSD PLANNING
- CPAM ANALYSIS
- SUMMARY CPAM
- DPG/FG

PROGRAMMING

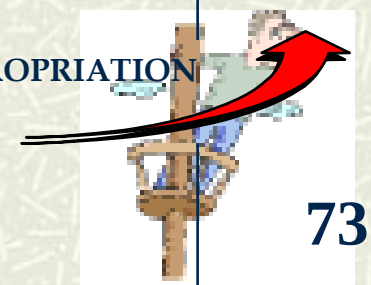
- NAVY ISSUES
- PROGRAMMING GUIDANCE
- SPP
- T-POM
- POM
- OSD REVIEW
- DECISION (PDM)

BUDGETING

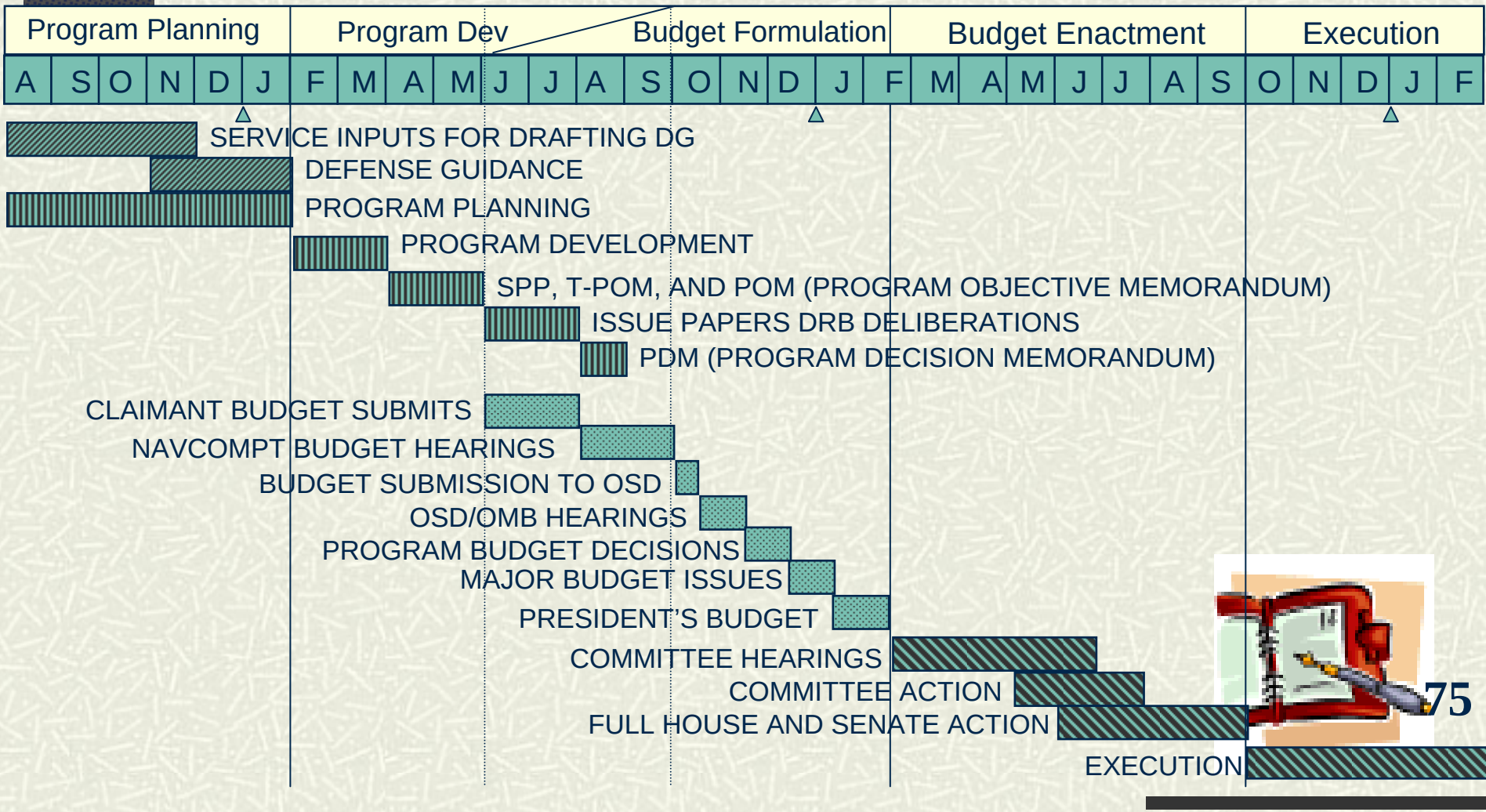
- NAVY BUDGET PREPARATION & REVIEW
- OSD/OMB BUDGET SUBMIT
- OSD/OMB REVIEW
- DECISION (PBD)

EXECUTE

- PRES. BUDGET
- CONGRESS
- APPROPRIATION



PPBS Timeline

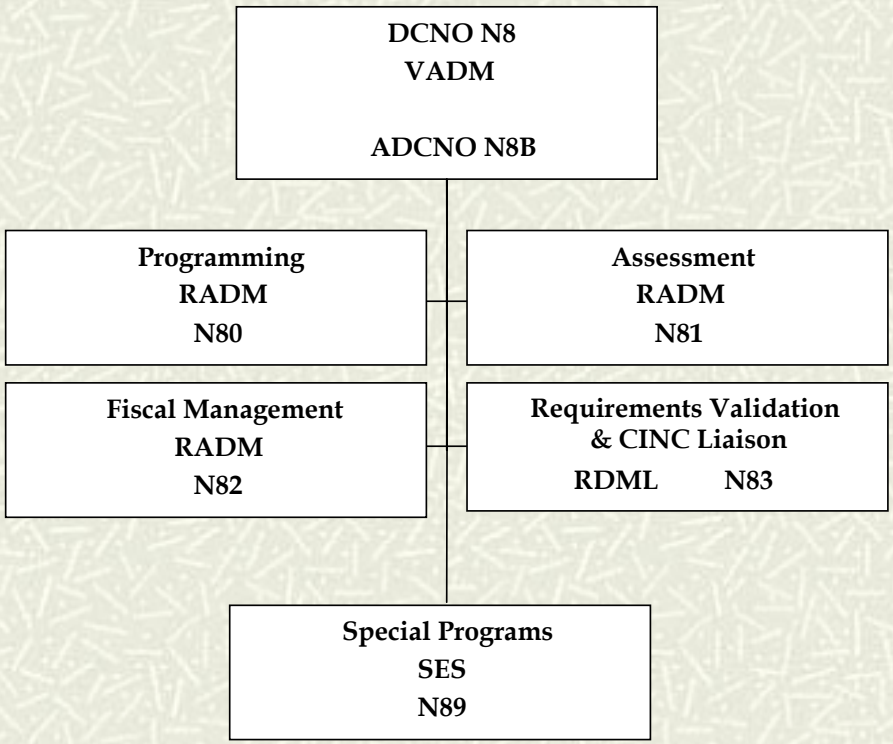


Annual Budget Overlap

	CY 02	CY 03	CY 04
FY 02	Execution	Yr 2	Yr 3
FY 03	Enactment	Execution Yr 1	Yr 2 / Yr 3
POM 04	Budgeting	Enactment	Execution Yr 1 / Yr 2
PR 05	Programming	Budgeting	Enactment / Execution Yr 1
POM 06	Planning	Programming	Budgeting / Enactment
PR 07		Planning	Programming / Budgeting

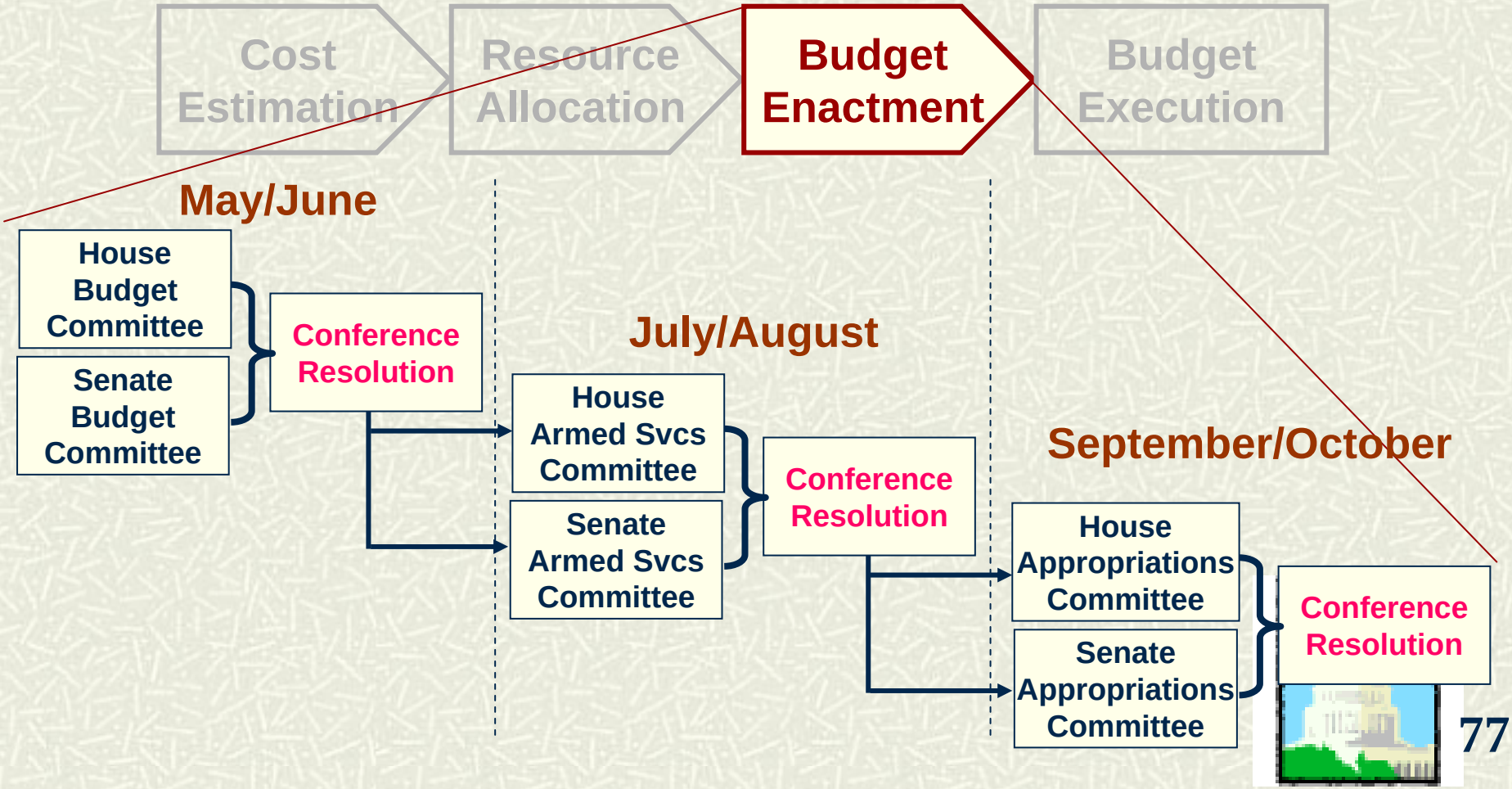
OPNAV Resources, Requirements and Assessments (N8)

Resources, Requirements & Assessments (N8)



- **Acts as CNO's principal advisor for the allocation of resources**
- **Assesses strategy, requirements, and resources to achieve military capabilities through the IWAR and CPAM process**
- **Directs the development of the Navy POM**
- **Supports the CNO/Secretary in the budget process**
- **Oversees the CEB and NROC**
- **Directs the CNO studies program and the Quadrennial Defense Review**
- **Provides the Fleet CINCs, unified CINCs, and Navy Component Commanders representation on the OPNAV staff**

Budget Enactment (Congressional Action)



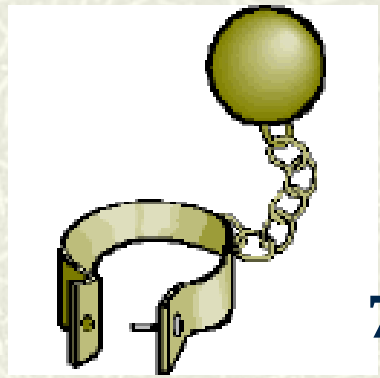
Budget Execution

Cost Estimation → Resource Allocation → Budget Enactment → **Budget Execution**

- **Statutory Requirements**
- **Congressional Prior Approval Reprogramming**
- **Internal Reprogramming**
- **Below Threshold Reprogramming**

Budget Execution: Statutory Requirements

- Expiration of Funds
- Cancellation of Funds
- Misappropriation of Funds
  - (Title 31, U.S. Code, Section 1301)
- Anti-Deficiency Act
  - (Title 31, U.S. Code, Section 1517)



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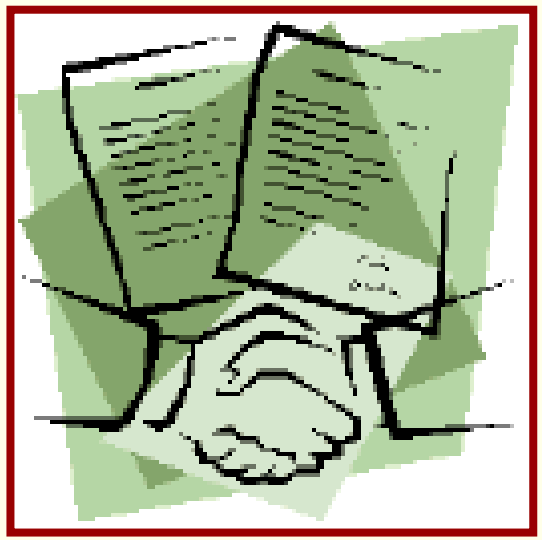
Module Five

Contract Management



Solicitation Planning → **Solicitation Evaluation & Contract Award** → **Post Award & Contract Mgt / Earned Value Mgt**

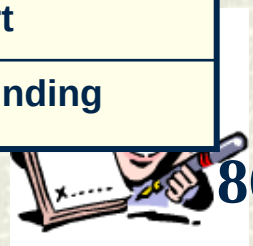
Solicitation Planning

Solicitation Planning → Solicitation Evaluation and Contract Award → Post Award and Contract Management / Earned Value Management

- Definition and Elements of a Contract
- The FAR and the Contracting Officer
- Requirements for Competition
- Determination of Requirements
- Contracting Methods
- Contract Types

Definition and Elements of a Contract

Essential Elements	Features
Offer	**Must:** 1. Express Intent 2. Be communicated 3. Have completer terms 4. Be clear and unambiguous
Acceptance	**Must be:** 1. Timely 2. Clear and unequivocal 3. A mirror image of the offer
Consideration	**Types include:** 1. Promise to perform 2. Promise in return for performance 3. Sufficiency and adequacy of consideration
Legal and Binding	**Objective or purpose needs to be legal to be enforced in court**
Competent Parties	**Both parties must be legally competent for a contract to be binding**



The FAR and the Contracting Officer

- The Federal Acquisition Regulation (FAR)
- Types of Contracting Officer
  - Procuring Contracting Officer (PCO)
  - Administrative Contracting Officer (ACO)
  - Termination Contracting Officer (TCO)

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The Program Manager and the Contracting Officer

	Program Manager	Contracting Officer
Authority	Charter	Warrant
Responsibility	Entire Program	Contract
Background/Training	Technical/Programatic	Business
Guiding Directives	DoD 5000 Series Regs	FAR
Organization	IPT	IPT

The only person who can discuss a contract in detail with a contractor is the contracting officer.

Requirements for Competition

Competition Requirements	Description
Requirement for full and open competition	All responsible sources are permitted to compete for the effort. The CO decides how full and open competition will be achieved.
Allowance for full and open competition after exclusion of sources	Excluding sources may be done to facilitate: 1. Establishing or maintaining alternate sources. 2. Setting aside work for small business concerns. 3. Fulfilling Small Business Administration's objectives for Section 8(a)
Allowance for exceptions to full and open competition (Sole Source)	Seven exceptions to full and open competition include: 1. Only one source will satisfy requirements 2. Unusual and compelling urgency 3. Industrial mobilization 4. International agreement 5. Authorized or required by statute 6. National security 7. Public interest
Requirement of approval of other than full and open competition	Requested by Justification and Approval (J&A) or a Determination and Finding (D&F)

Contracting Methods

Sealed Bidding	Negotiated
Well-defined requirements	Less well-defined requirements
Adequate competition required	Competitive or sole source (can be a defined requirement)
Uses an Invitation for Bid (IFB) solicitation	Uses a Request for Proposal (RFP) solicitation
Award based on price and price related factors	Award based on evaluation criteria
No discussions allowed	Discussions/negotiations expected
Usually Firm-Fixed Price (FFP)	Usually Cost Plus Fixed Fee (CPFF)

Contract Types

Fixed-price

- Low risk to Government
- Moderate risk to contractor
- Well-defined requirements, higher degree of certainty
- Guaranteed delivery by contractor
- Payment after delivery/performance
- Profit based on efficient performance and cost control
- Use of either IFB or RFP

Cost-reimbursed

- Higher risk to Government
- Reduces risk to contractor
- Less well-defined requirements, higher degree of uncertainty
- Contractors best efforts
- Payment as cost are incurred
- Fee or formula to compensate the contractor beyond cost
- Use of an RFP

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Comparison of Contract Types

	Fixed-Price	Cost-Reimbursement
What is promised	Acceptable goods and services	Best efforts
When is payment	After delivery (progress payment possible)	As costs are incurred
Cost risk to Contractor	High	Low
Cost risk to Government	Low	High

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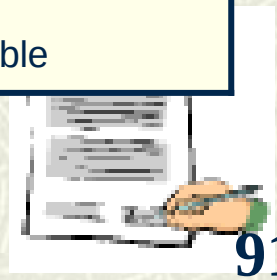
Other Contract Types

This type of contract…	Provides for …	And may be used when…
Indefinite Delivery: Definite Quantity	Delivery of a definite quantity for a fixed period	1. Definite quantity of supplies or services will be required 2. The supplies or services are regularly available
Indefinite Delivery: Indefinite Quantity	Indefinite quantity within stated limits during a fixed period with performance to be specified in delivery orders	Exact quantity of supplies or services is unknown
Indefinite Delivery: Requirements	Filling all actual purchase requirements of a designated activity during a specified period with deliveries or performance to be specified in delivery orders	Acquiring any supplies or services on a recurring basis when specific quantities are not known at the outset

Other Contract Types (Continued)

This type of contract…	Provides for …	And may be used when…
Time and Materials	Acquisition of supplies and services on the basis direct labor and material costs	It is not possible to estimate extent and duration of work or costs with confidence
Letter	Preliminary contractual instrument containing a price ceiling permitting contractor to begin providing services or supplies	1. Government's best interest for contractor to begin immediately 2. Time does not permit negotiating a definitive contract
Multiyear	Purchase of supplies or services for more than one, but not more than five, program years	1. There will be substantial savings of total anticipated cost 2. Quantity or rate is expected to remain unchanged 3. Funding is expected to be stable



Solicitation Evaluation and Award

Solicitation Planning

Solicitation Evaluation and Contract Award

Post Award and Contract Management

Earned Value Management

- **Proposal Evaluation and Source Selection**
- **Fair and Reasonable Price Determination**
- **Contract Award**

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Evaluation and Source Selection

Key Player	Responsibilities
Contracting Officer (CO)	Process compliance with law/regulation Proposal compliance with solicitation Establishing competitive range for discussions
Source Selection Evaluation Board (SSEB)	Evaluating proposals for weaknesses and deficiencies
⌗ Technical Evaluation Panel (TRP)	Evaluating the technical proposal against evaluation factors Supporting the CO in discussions and negotiations
⌗ Cost Review Panel (CRP)	Conducting price and/or cost analysis of offeror's proposals Supporting the CO in discussions and negotiations
Source Selection Advisory Council (SSAC)	On request, perform comparative analysis of SSEB evaluations of each proposal Forward recommendations to SSA
Source Selection Authority (SSA)	Appoint qualified personnel to the SSEB and SSAC Oversee process, ensure integrity Select best value source
Contracting Officer (CO)	Communicate with offerors

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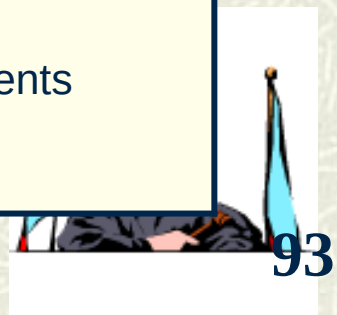
Fair and Reasonable Price Determination

Analysis	Definition	Techniques include:

Price Analysis	the process of examining and evaluating a proposed price without evaluating its separate cost elements and proposed profit.	▪ Comparing offerors' proposed prices
		  ▪ *(#hours x hourly rate + material)*
		▪ Applying rough yardsticks
		▪ Comparing with:
		  ▪ Competitive price lists
		  ▪ Government cost estimates
		  ▪ Market prices

Cost Analysis	the process of reviewing and evaluating the separate elements and proposed profit in the contractors cost proposal.	▪ Applying judgmental factors to proposed costs ▪ Examining all cost elements



Contract Award

SSA

- Decides which offer(s) to accept for contract award
- Briefs a higher authority before the selection is approved, if necessary

CO

- Signs and distributes the contract
- Notifies unsuccessful offerors of the final decision.
- If requested, debriefs unsuccessful offerors,

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Post Award and Contract Administration

Solicitation Planning → Solicitation Evaluation and Contract Award → **Post Award and Contract Management** → Earned Value Management

- **Post Award Roles and Responsibilities**
  - **Agencies**
  - **Key Personnel**
- **Contract Administration**
- **Delivery and Contract Closeout**
  - **Contract Modification**
  - **Contract Closeout**

Post-Award Roles and Responsibilities

- Agencies
  - Defense Contract Audit Agency (DCAA) – *accounting and financial advisory services*
  - Defense Finance and Accounting Service (DFAS) – *timely payment to the contractor*
  - Defense Contract Management Agency (DCMA) – *contract administrative services*
- Key Personnel
  - Program Integrator (PI) – *contract management office's POC for a specific program*
  - Administrative Contracting Officer (ACO) – *performs administrative functions for the contract*
  - Termination Contracting Officer (TCO) – *negotiates equitable settlement with the contractor*
  - Contracting Officer Representative (COR) – *designated qualified person authorized to assist in contract administration*
  - Procuring Contracting Officer (PCO) – *handles procurement from pre-solicitation through award*
  - Technical Point of Contract (TPOC) – *provides technical oversight for a contract or contract task orders*

Contract Administration

- Purpose
- Role
- Functions
- Contract Management Office Functions
  - Informal Performance Assessment Reporting System (IPARS)
  - Contractor Performance Assessment Reporting System (CPARS)

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Delivery, Modification and Closeout

- Delivery – time and place, quantity, method, and person authorized to receive
- Contract Modification
  - Bilateral – adjustment to contract price due to change order; definitize letter contracts; and incorporate other agreements
  - Unilateral – administrative changes; issue a change order; make authorized changes; and issue a termination notice
  - Change order – directs contractor to make a change prior to agreement on terms and conditions
  - Constructive Change – an unauthorized change requiring the contractor to perform beyond contract requirements
- Contract Closeout – when all deliveries and services have been completed and accepted

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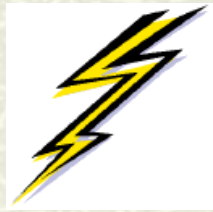
Risk In Contracting

- To the Government
- To the Contractor



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Earned Value Management (EVM)

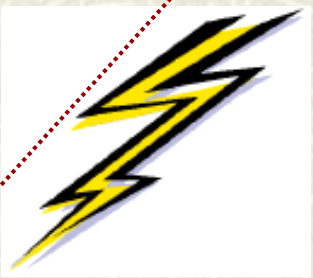
Solicitation Planning

Solicitation Evaluation and Contract Award

Post Award and Contract Management

Earned Value Management

- **Definition**
- **Objectives Measures**
- **EVM Systems**
- **EVM Surveillance and Review**



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EVM: Definition

- EVM is a series of processes that relate scope of the work with schedule and budgets.

	Scope	Schedule	Budget
Work Planned	What work is scheduled?	When is it scheduled?	How much is budgeted?
Work Completed	What work was done?	When was it done?	How much was budgeted for it?
Cost of Work	How much was actually spent?		

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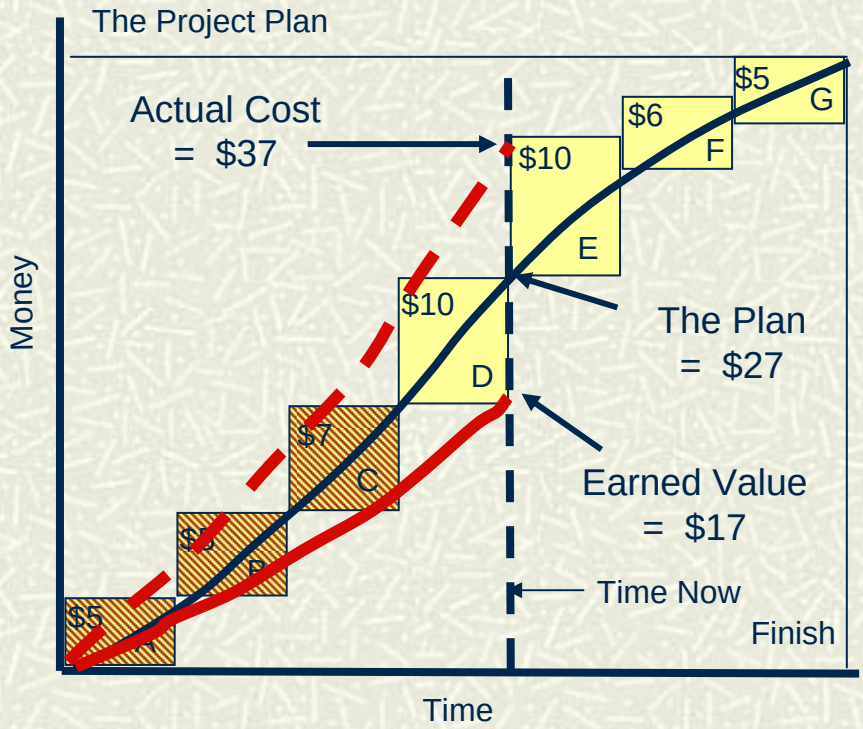
EVM: Example



Case Two

- Schedule Status = $10 behind schedule
- Cost Status = $37, the planned value plus the value of the task to completed

Module Six

System Engineering

Test and Evaluation

Software Acquisition

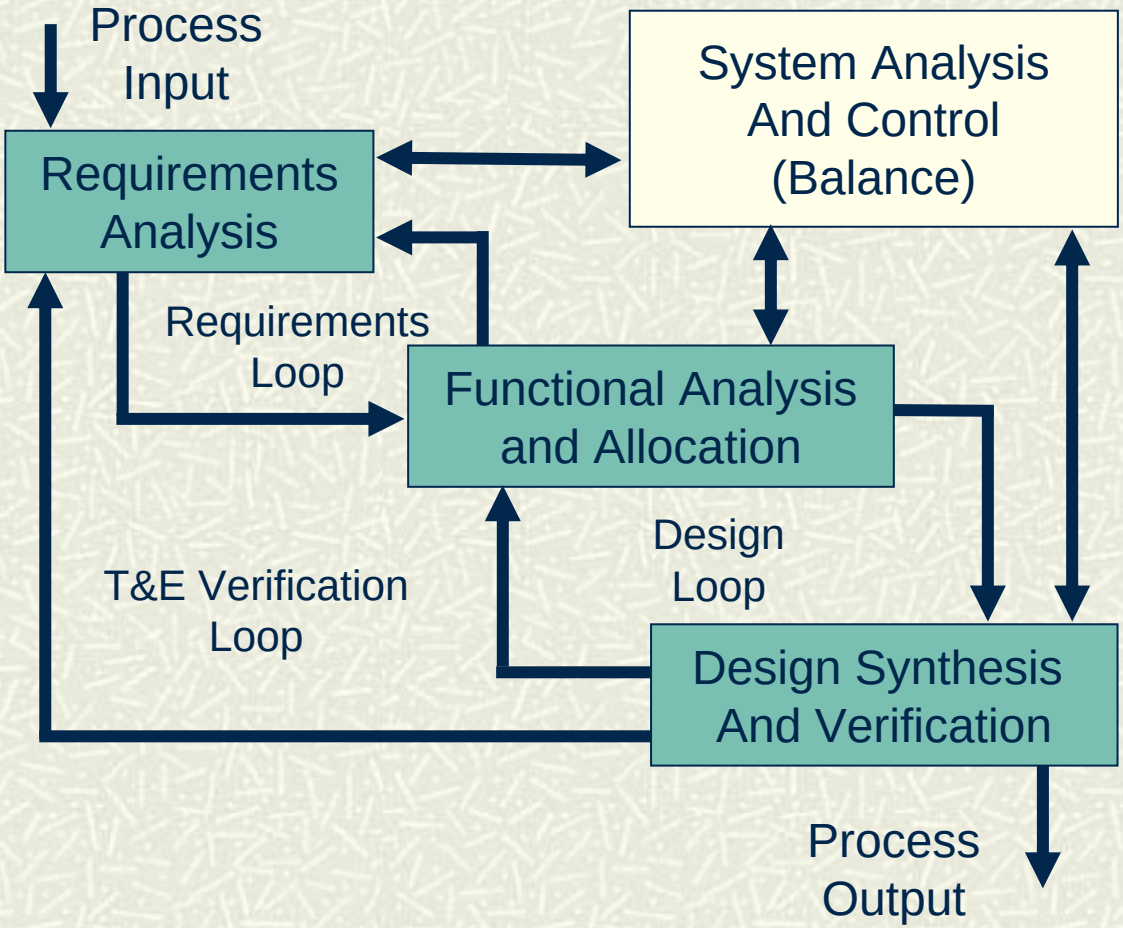
Science and Technology

Software Acquisition

The Systems Engineering Process

- The Feedback Process
- Systems Engineering Disciplines
- Involvement in the Life Cycle
- Influence on the Life Cycle

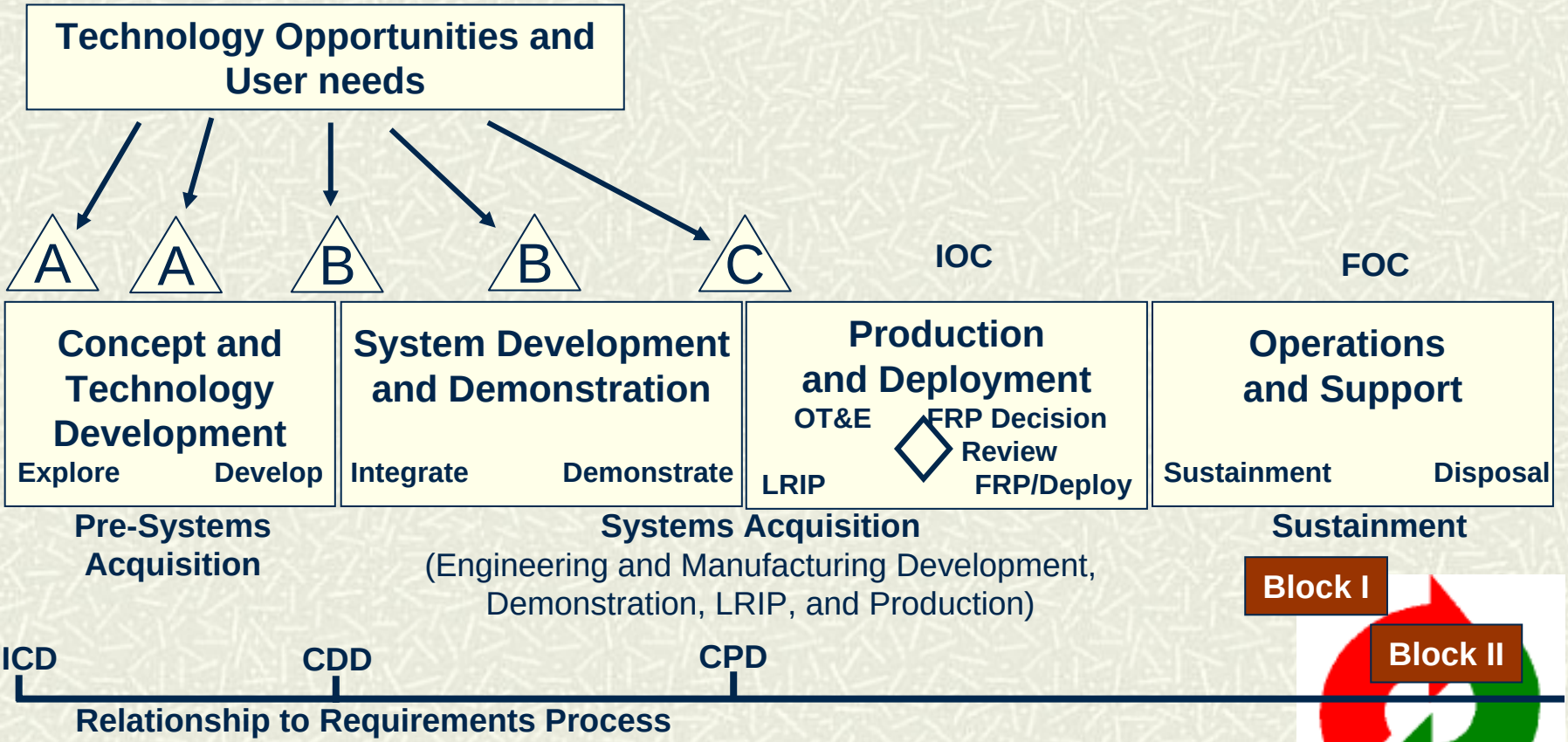
The System Engineering Process



Process Outputs

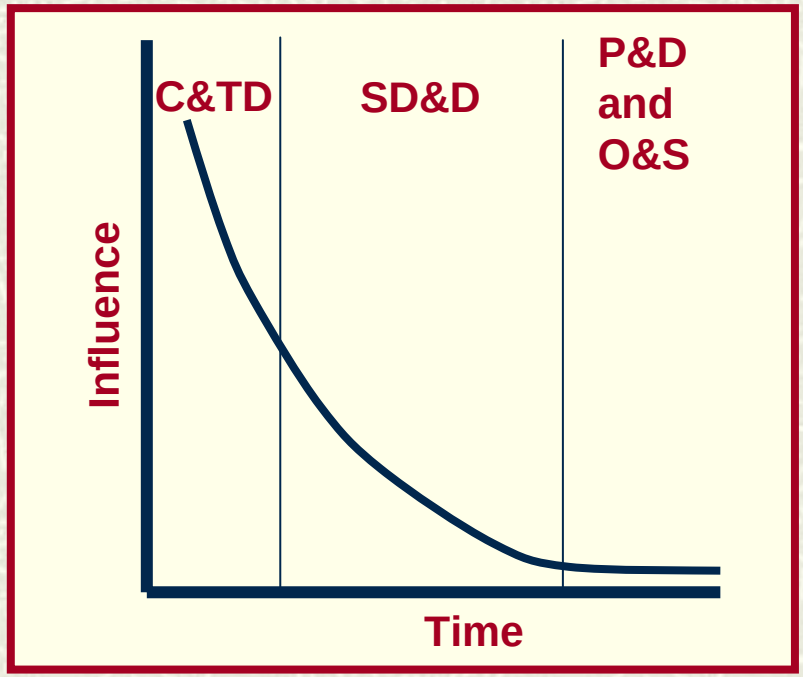
- Specification functions
- Performance-based Specs and Standards
- Program-unique Specifications
- Specification development
- System specifications
- Item specifications
- Process and material specifications
- Specification flowdown

Involvement in the Life Cycle



Influence on the Life-Cycle

- System concept
- Preliminary design
- Detailed design
- Fabrication, test, and integration
- Life-cycle costs
  - Concept and Technology Development
  - System Development and Demonstration
  - Production and Deployment
  - Operations and Support



Potential influence on LCC by acquisition phase

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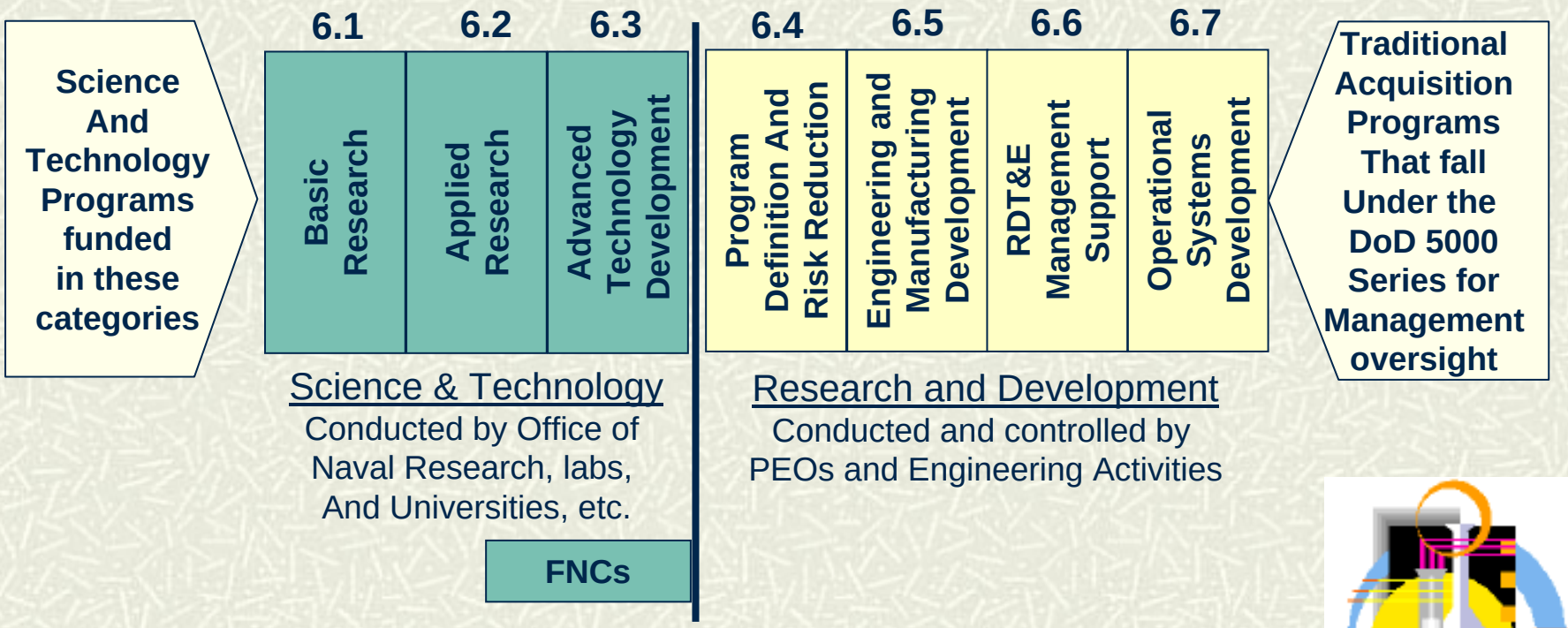
RDT&E Budget Categories

Major Force Program 6 Breakdown



Introducing New Technology Into the System

Assess pay-off, risks, benefits

Assess impact on, baseline.

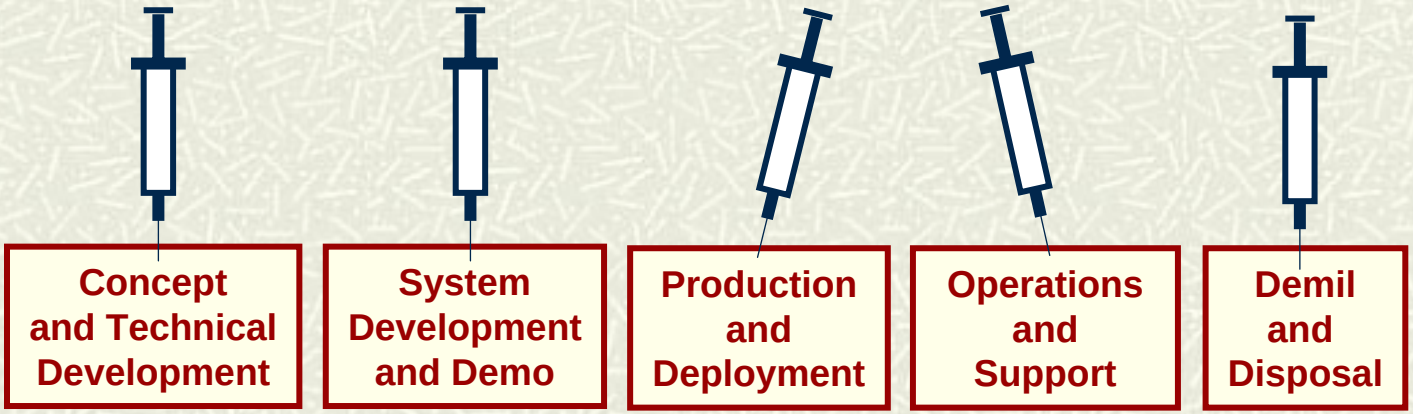
Pre-planned Product Improvement (P^3I)

P3I, new manufacturing techniques

Block Upgrades

Compliance

Improved Techniques



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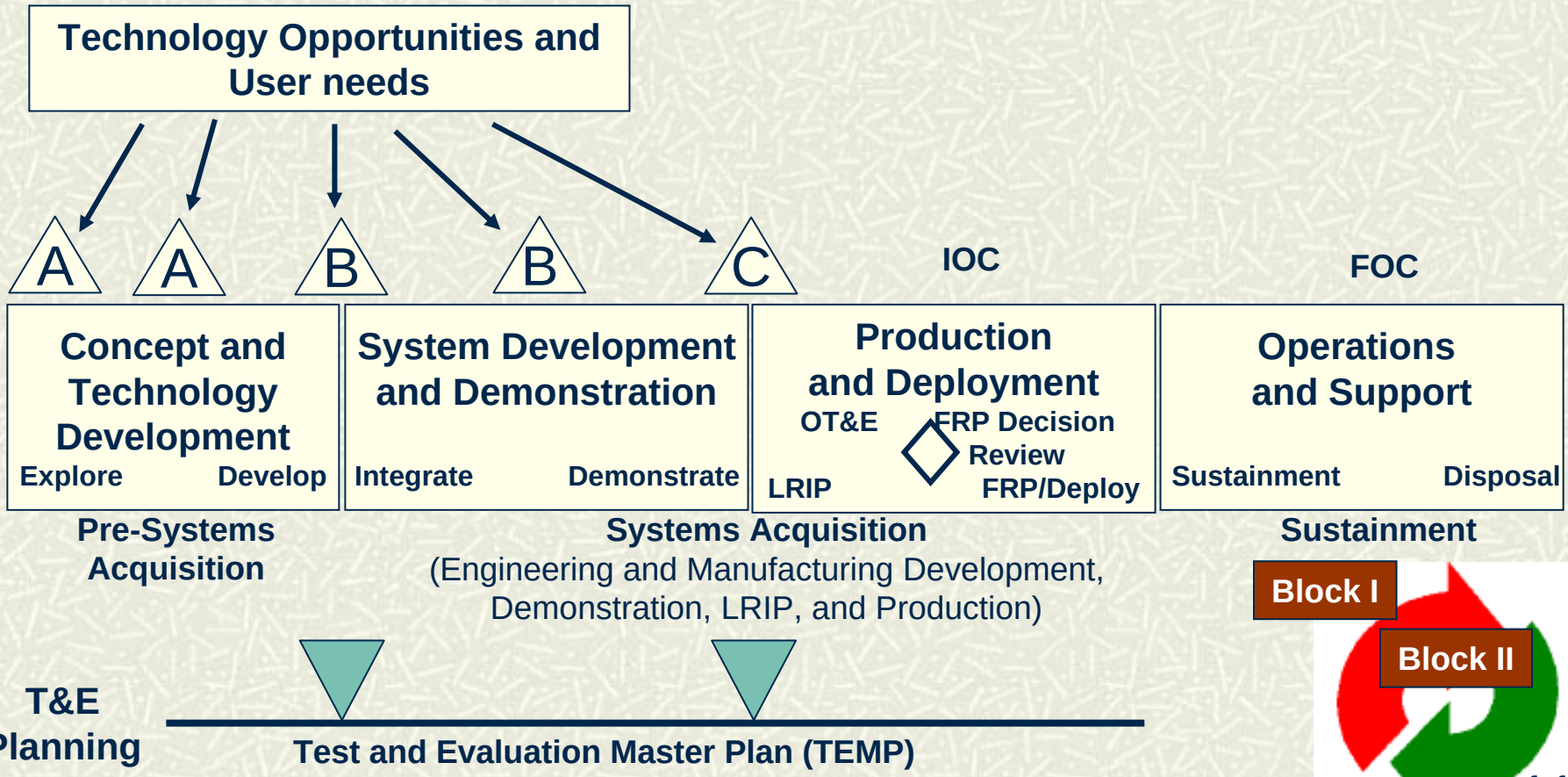
T&E and the Acquisition Life Cycle



Developmental and Operational T&E

	DT&E	OT&E
What is tested	Measures technical performance against the design specifications in a controlled environment	Determines operational effectiveness and suitability as defined in the Operational Requirements Document (ORD)
Who conducts tests	Government and Contractor	Government
Who is responsible	Program manager	OPTEVFOR

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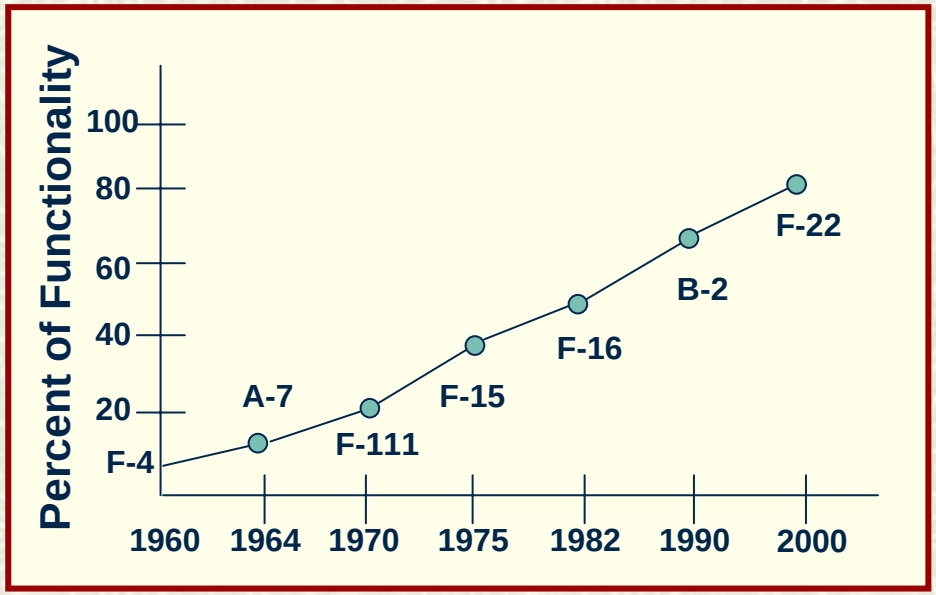
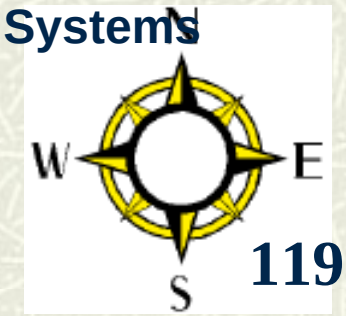
Software Acquisition Fundamentals

- Architecture, Open Systems, and Interoperability
- DoD Software Acquisition Guidelines
- System Engineering and Software Development
- Final Thoughts on Software Development



The Growth of Software Dependencies in DoD Systems



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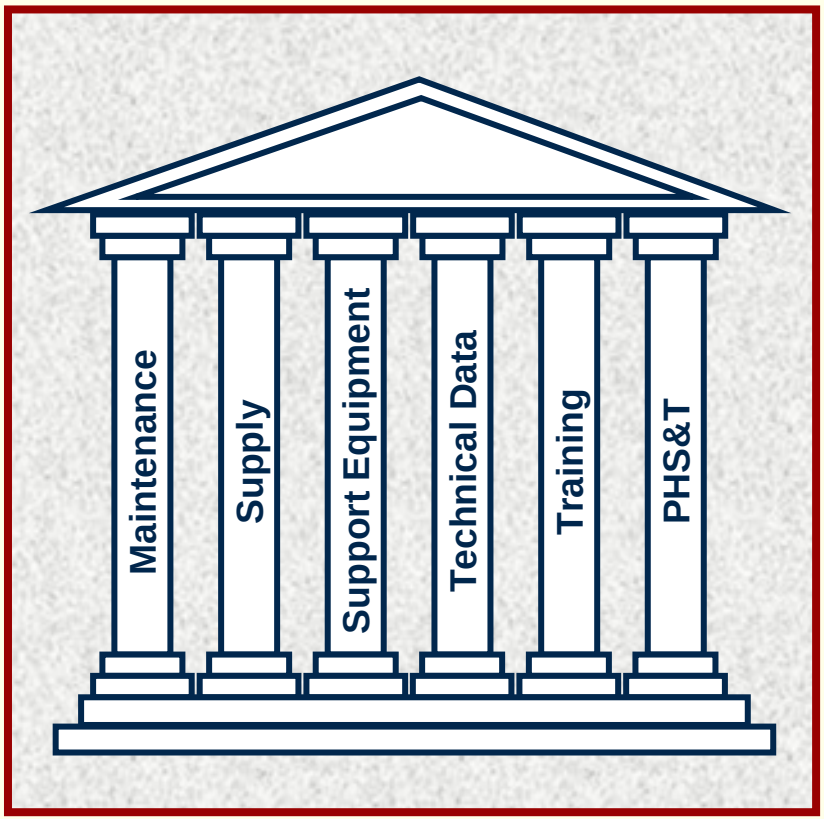
Module Seven

Acquisition Logistics



Logistic Elements

Reliability, Availability and Maintainability

Supportability and System Costs

Support Considerations and Analysis

"I don't know what the hell this 'Logistics' is that Marshall is always talking about, but I want some of it."
Fleet Admiral E. J. King, 1942

Supportability Planning

- Support Elements
  - Maintenance Planning
  - Manpower and Personnel
  - Supply Support
  - Support Equipment
  - Technical Data and the Technical Data Package
  - Training and Training Devices
  - Computer Resources Support
  - Facilities
  - Packaging, Handling, Storage, and Transportation
  - Design Interface

Fundamental Concepts

- Acquisition Logistics is
  - A multifunction discipline
  - Integral to design and development
  - Concerned with peacetime and wartime sustainment

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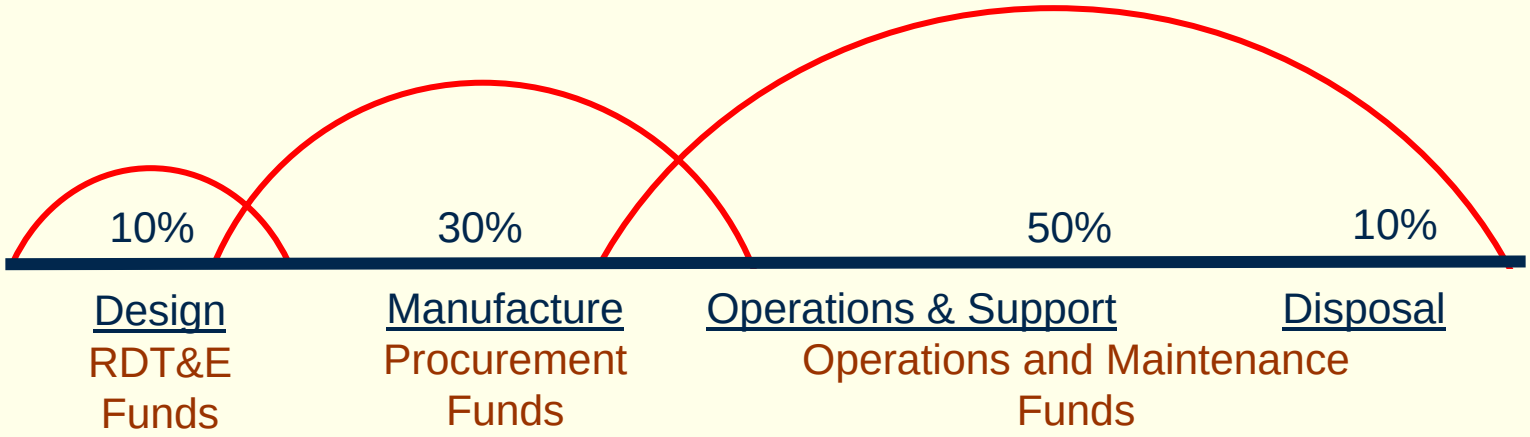
Commercial-Off-the-Shelf Items (COTS)

- COTS/Non-developmental items are more affordable
- COTS/Non-developmental items become obsolete quickly
- COTS Support Planning
  - Life-time buy of parts
  - Design for replacement of obsolete parts
  - Buy parts for support until planned upgrade is in place

Supportability and System Cost Over Time



- Reduce supportability costs by:
  - Considering supportability during design phase
  - Apply system engineering practices to improve reliability, availability and maintainability
  - Use Integrated Product and Process Development (IPPD)

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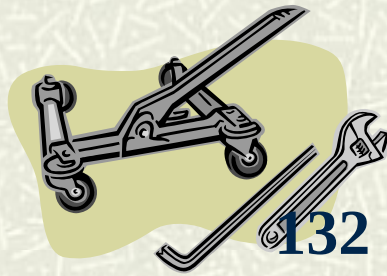
Reliability, Availability, and Maintainability

- Reliability: MTBF = $\dfrac{\text{Total \# of unit operating hours}}{\text{\# of failures}}$

- Maintainability: MTTR = $\dfrac{\text{Total Time for Corrective Actions}}{\text{Total \# of Corrective Actions In a Given Time Period}}$

- Availability: $A_O = \dfrac{\text{Up Time}}{\text{Up Time + Down Time}}$

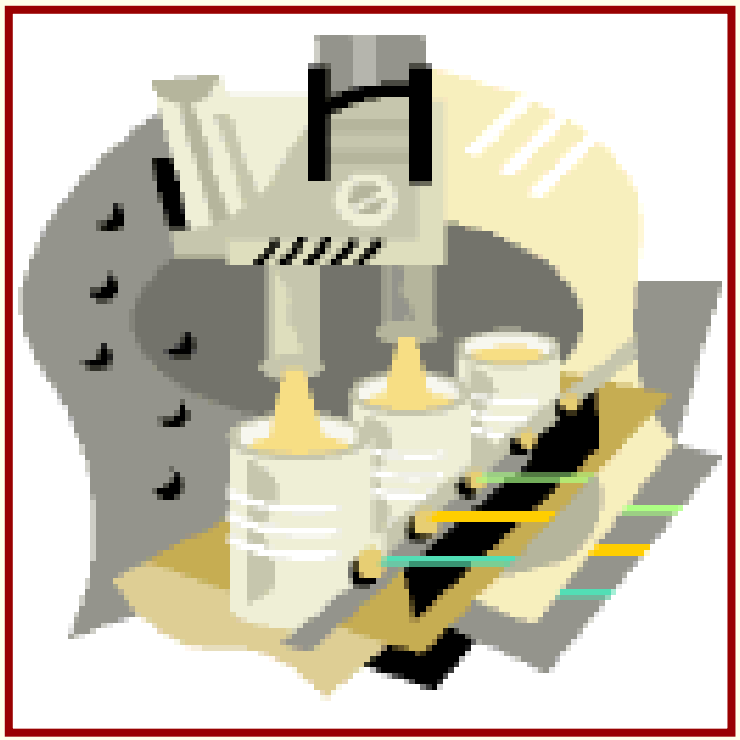


Support Considerations

- Developing support concepts
- Providing support data
- Acquiring support resources
- Conducting supportability analyses as a part of the systems engineering process

Module Eight

Production, Quality, and Manufacturing Management



Manufacturing Processes

Design Goals

Quality Standards

Production Problems

Design Engineering and Production

- Three Step Process
  - Influence the design process
  - Prepare for production
  - Execute the manufacturing plan
- Manufacturing Process
  - Manpower
  - Measurement
  - Method
  - Machinery
  - Material
- Design Goals
  - Ease of fabrication
  - Ease of assembly
  - Multiuse
  - Minimize the number of parts
  - Maximize the number of common parts
  - Maximize the use of COTS Parts

Quality

- Key Quality Activities
  - Establish Capable Processes
  - Monitor and Control Critical Product and Process Variations
  - Establish mechanism for feedback of field product performance
  - Implement an effective root-cause analysis and corrective action system
  - Continuous process improvement
- Quality Standards and Systems
  - ISO 9000
  - DI 9000 (Boeing)
  - Six Sigma (Motorola)
  - AS 9000 (Aerospace Industry)
  - QS 9000 (Automotive Industry)
  - Quality Function Deployment (QFD)
- Statistical Process Control (SPC)

Quality is fitness for use

Production Problems

- Unstable Rates and Quantities
- Design Instability
- Undue Emphasis on Schedule
- Inadequate Configuration Management System
- Inattention to Environmental Impact

Raytheon

Customer Success Is Our Mission

Benefits of Steeper Angle of Fall for Precision Projectiles

Jim M Rodrigue

April, 2008

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Background and Study Objective

Raytheon Missile Systems

Background

- Battlefield has changed since initial requirements for precision projectiles were developed:
  - Counterinsurgency vs. Mobile Armored Warfare
  - Combat among the population vs. on unoccupied terrain
  - Collateral Damage relationship to strategic outcome
- FA is again relevant: cannon-delivered precision fires have been achieved, demonstrated in combat, and early expectations surpassed
- Requirements have not yet reflected technology capability for AOF.

Study Objective

- Quantify benefits of having steeper Angle of Fall (AOF) for precision projectiles within urban terrain
- Measure of Merits include Engageable Area, Lethality, Operational Effectiveness, and Cost

Effects of Angle of Fall on Engageability of Different Urban Terrains

Methodology: Measuring Effects of Angle of Fall

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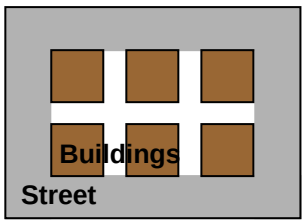
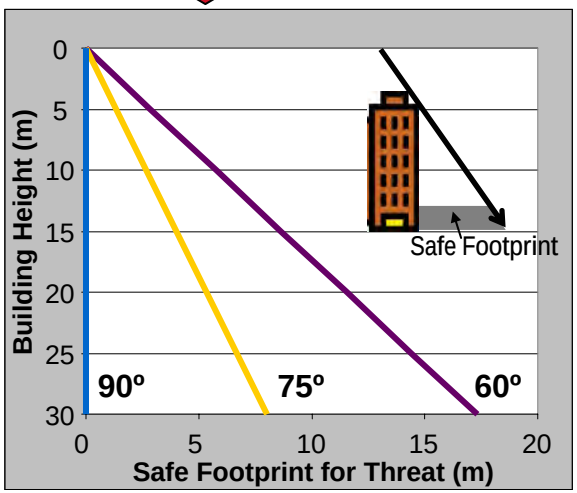
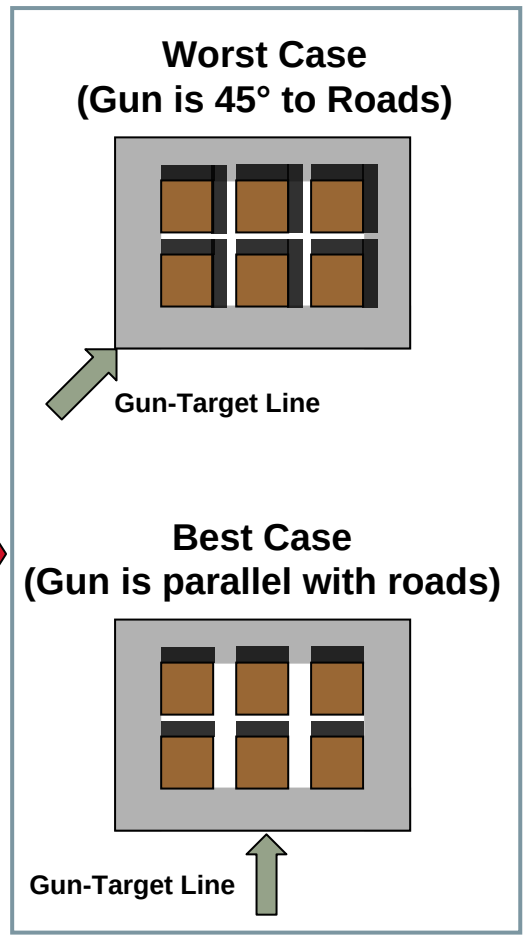
1. Build urban terrain based on real-world measurements of street width, building height, and block sizes



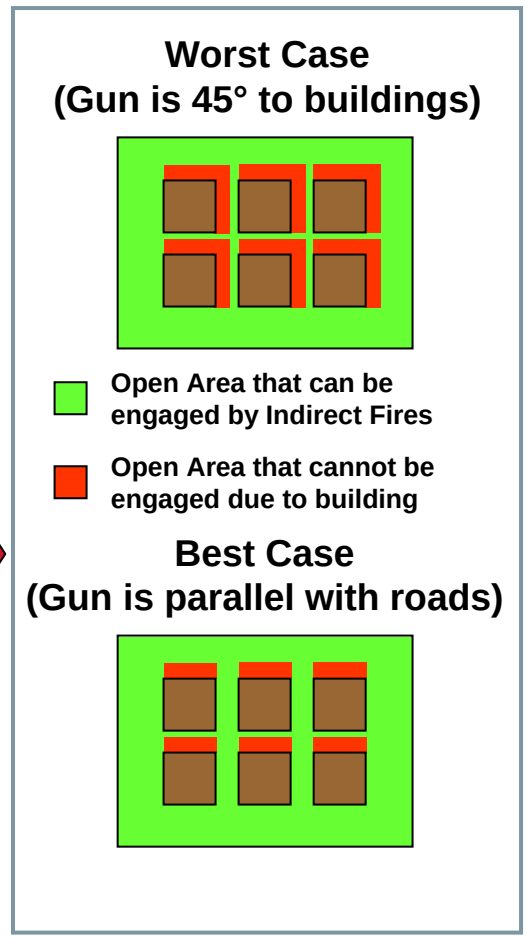


2. Calculate Safe Footprint shadow created by each building for AoF

3. Apply Safe Footprints Shadows to urban terrain for two gun-target lines



4. Measure how much of open terrain is still engageable



Urban Terrain Types

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City Core

- **Block Size:** 340 x 430 meters
- **# Roads:** 2 (vert.) 3 (horiz)
- **Avg. Road Size:** 18.5 meters
- **Avg. Building Size:** 20 x 20 meters
- **Avg. Building Height:** 12.2 meters
- **Height Std Dev:** 6.1 meters
- **Avg. Distance Between Buildings** 8 meters

Commercial

- **Block Size:** 80 x 330 meters
- **# Roads:** 2 (vert.) 4 (horiz)
- **Avg. Road Size:** 18.5 meters
- **Avg. Building Size:** 15 x 15 meters
- **Avg. Building Height:** 6.1 meters
- **Height Std Dev:** 3.05 meters
- **Avg. Distance Between Buildings** 7 meters

Core Periphery

- **Block Size:** 320 x 260 meters
- **# Roads:** 3 (vert.) 4 (horiz)
- **Avg. Road Size:** 16 meters
- **Avg. Building Size:** 18 x 18 meters
- **Avg. Building Height:** 7.6 meters
- **Height Std Dev:** 1.525 meters
- **Avg. Distance Between Buildings** 7 meters

Residential

- **Block Size:** 270 x 330 meters
- **# Roads:** 3 (vert.) 7 (horiz)
- **Avg. Road Size:** 10 meters
- **Avg. Building Size:** 10 x 10 meters
- **Avg. Building Height:** 4.5 meters
- **Height Std Dev:** 1.525 meters
- **Avg. Distance Between Buildings** 5 meters

Industrial

- **Block Size:** 610 x 610 meters
- **# Roads:** 3 (vert.) 3 (horiz)
- **Avg. Road Size:** 18.5 meters
- **Avg. Building Size:** 25 x 25 meters
- **Avg. Building Height:** 9.2 meters
- **Height Std Dev:** 6.1 meters
- **Avg. Distance Between Buildings** 10 meters

1. Building size/height, road size, and distance between buildings from Marine Corps Warfighting Pub (MCWP) 3-35.3 – Military Operations in Urban Terrain

2. Block size and number of roads obtained from observations of Baghdad terrain using Google Earth.

Analysis:
Effects of Angle of Fall on Engageability

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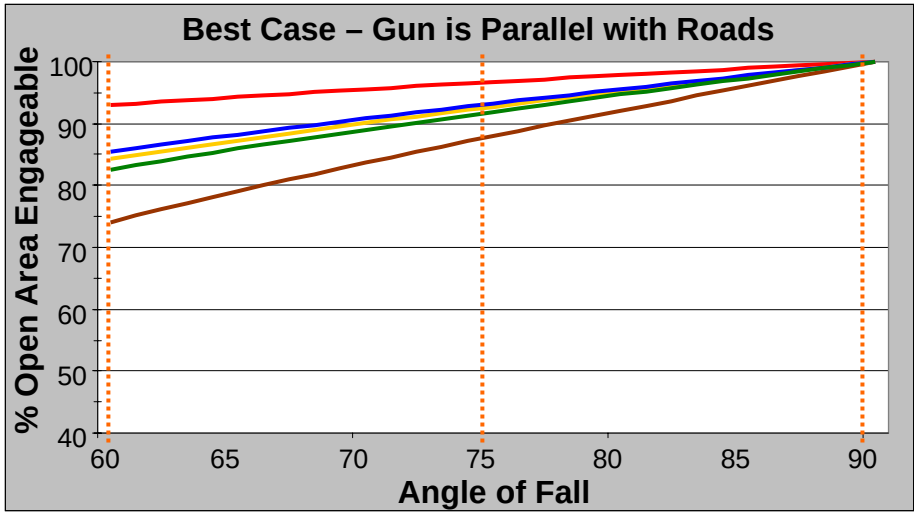

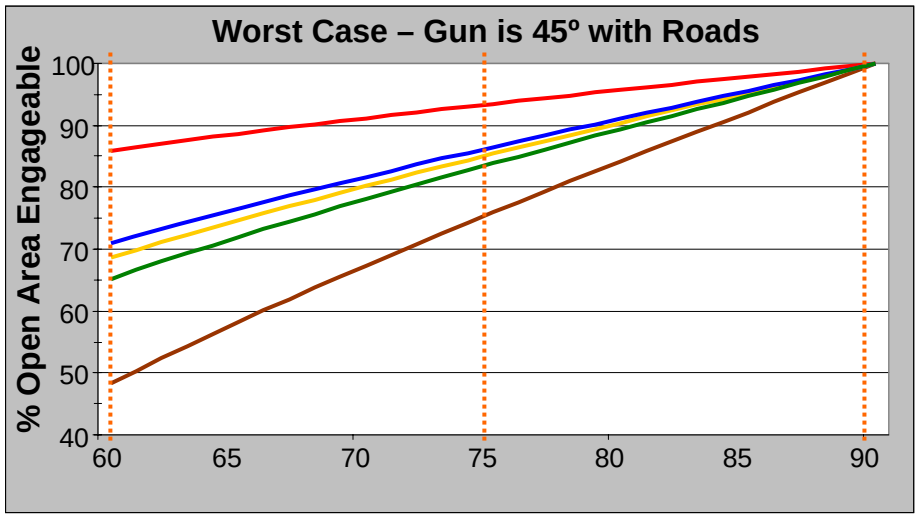

Urban Terrain Type

- City Core
- Commercial Ribbon
- Core Periphery
- Residential Sprawl
- Outlying Industrial Areas

- **MoE:** Measure what percentage of the open area is engageable by indirect fire
  - Open Area is any area not occupied by a building
  - Indirect Fire cannot engage open area if round's angle of fall would clip the nearby building
- **Results:**
  - Steeper AoF can engage more open area in all urban terrain types:
  - % more open area engageable in worst case vs. 60º
    - City Core: **75º:** +57.5% **90º:** +107.3%
    - Commercial: **75º:** +8.8% **90º:** +16.3%
    - Core Periph: **75º:** +24.5% **90º:** +45.8%
    - Residential: **75º:** +21.9% **90º:** +40.9%
    - Industrial: **75º:** +28.5% **90º:** +53.2%

Steeper Angle of Fall enables Indirect Fire to engage significantly more Urban Terrain, especially if ideal Gun Placement is not possible

Methodology:
Measuring Effects of Angle of Fall in a Real City

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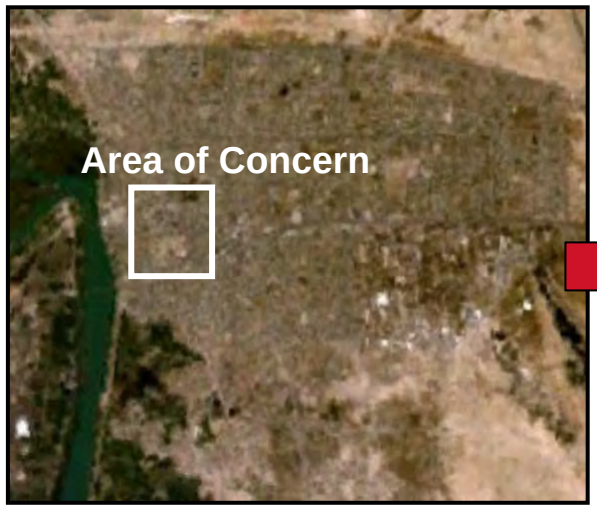
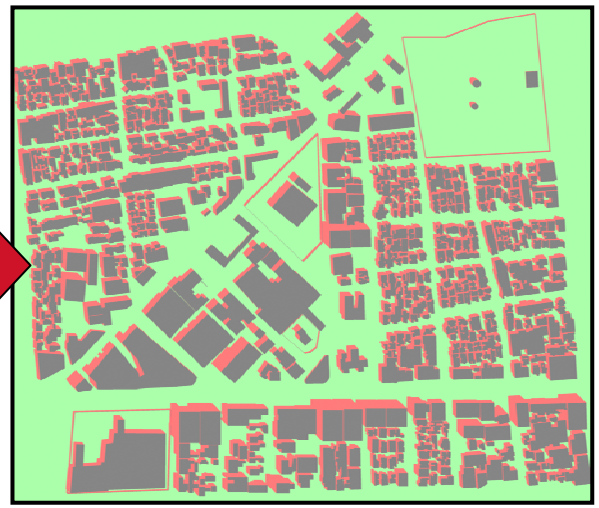
Analysis Questions: Does a steeper Angle of Fall (AoF) provide a tactical advantage in an urban area? How much area is "hidden" by buildings?





1. **Use a real-life example of terrain with varying urban areas (Al Fallujah):**
   - **Residential Sprawl**
     Many small buildings, close together
   - **City Core (downtown)**
     Large / tall buildings
   - **Commercial District**
     Large buildings / warehouses

   See middle picture for examples

2. **Convert terrain into a 3d model.**
   - Building size based on satellite images
   - Building height based on shadow analysis of satellite images and from aggregate data collected from various urban areas

3. **Use sophisticated graphics programs to cast light down on model at desired AoF.**
4. **Measure the amount of area still engageable**
   - Non-Engageable "Safe Footprint" Shadows in red
   - Engageable area in green

Analysis:
Effects of Angle of Fall on Engageability

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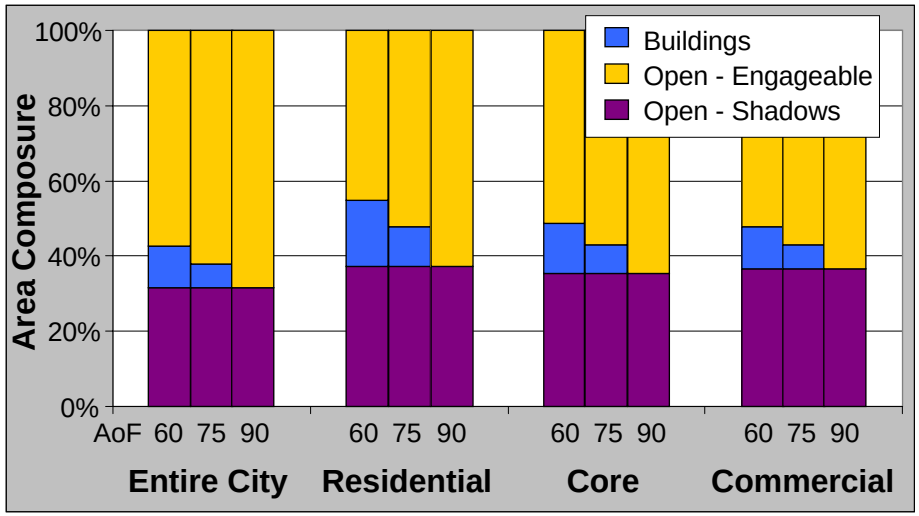

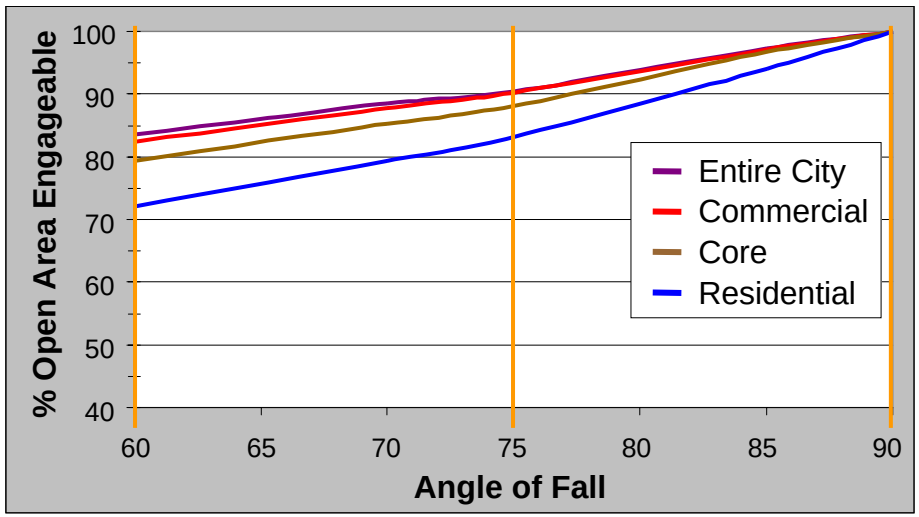

- **MoE:** Measure what percentage of the open area is engageable by indirect fire
  - Open Area is any area not occupied by a building
  - Indirect Fire cannot engage the open area if the round's angle of fall would clip the nearby building
  - Area Composure:
    - ***Residential:*** *37% Buildings* *63% Open*
    - ***City Core:*** *35% Buildings* *65% Open*
    - ***Commercial:*** *37% Buildings* *63% Open*
    - ***Entire City:*** *31% Buildings* *69% Open*
- **Results:**
  - Steeper angles of fall can consistently engage more open area in all Al Fallujah terrain types
  - % more open area engageable vs. 60º
    - Residential: **75º:** +15.2% **90º:** +38.6%
    - City Core: **75º:** +10.9% **90º:** +25.9%
    - Commercial: **75º:** +9.4% **90º:** +21.3%
    - Entire City: **75º:** +8.4% **90º:** +19.7%

In central Al Fallujah, a round with a steep Angle of Fall enables Indirect Fire to engage significantly more of the city's open area

Effects of Angle of Fall on Lethality, Operational Effectiveness, and Cost

Analysis:
Effects of Angle of Fall on Lethality

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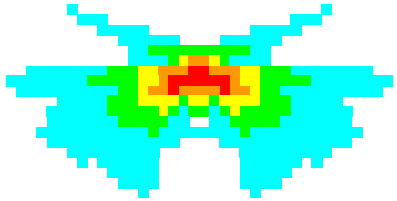
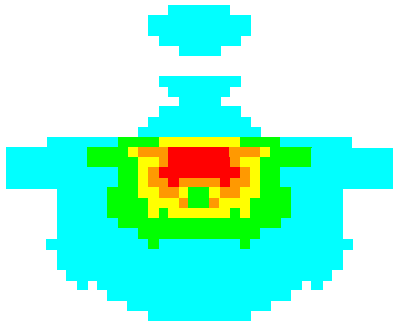
Example
Pk Map



AOF = 60º

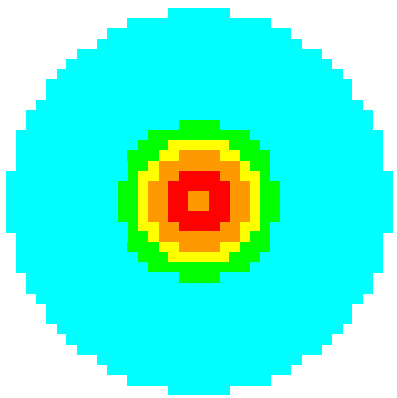
P_K

1.0-0.8
0.8-0.6
0.6-0.4
0.4-0.2
0.2-0.05



AOF = 75º

Gun-Target
Line



AOF = 90º

Comparison of Lethality vs. 60º AoF

AoF	75º	90º
Total Area	+61%	+206%
Lethal Area	+62%	+141%
Pk > .8	+120%	+180%
.8 > Pk > .6	+33%	+189%
.6 > Pk > .4	+58%	+67%
.4 > Pk > .2	+39%	+21%
.2 > Pk > .05	+67%	+272%

Total Area = Area affected by munition

Lethal Area = Measure of effectiveness for particular target/weapon pairing. Computed as the sum of (Pk*Area) across all individual cells in the PkMap.

Increased Angle of Fall results in significantly Increased Lethality

Methodology:
Measuring effects of AoF on Operational Effectiveness

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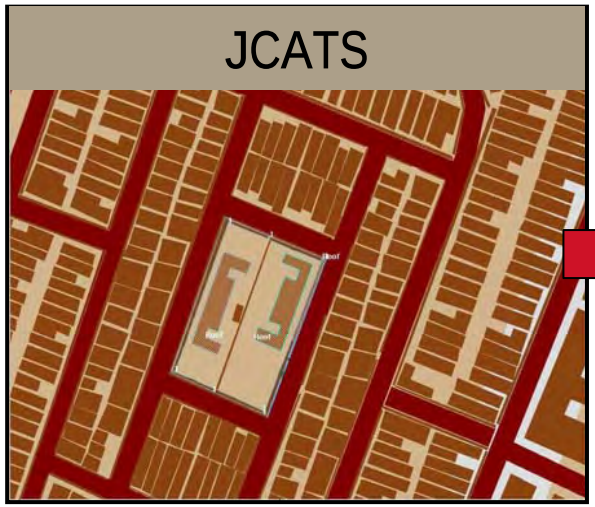
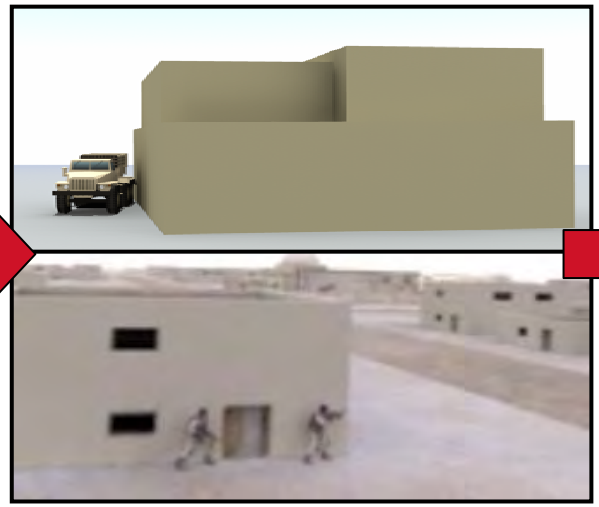
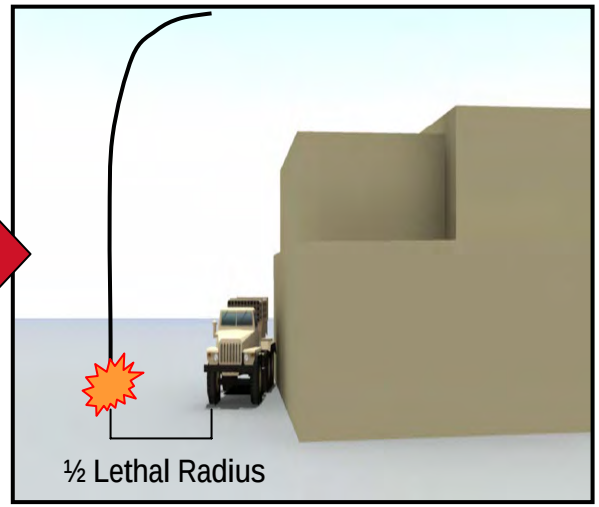
Analysis Questions: In urban terrain, what Angle of Fall (AoF) is necessary to put effects on target and to minimize structural collateral damage?







1. **Build the 5 urban terrain templates into JCATS :**
   - City Core (downtown)
   - Commercial District
   - Core Periphery
   - Residential Area
   - Industrial Area
- **Results based on average across all terrains**

2. **Place primary targets behind buildings in the different terrains.**
   - Targets placed in alleys 0.5 – 1.5m away from building
   - Represents truck "parked" next to building and infantry hugging building wall
   - Assume reporting TLE is 10m

3. **Launch rounds at the targets with varying CEP and AoF. Measure rounds to reach 30% EFD and measure collateral damage.**
   - Aimpoints offset from target = ½ lethal radius (or middle of Alley if lethal radius too large)
   - Lessens chance of impacting nearby buildings
   - Clipping buildings played

Analysis:
Effects of Angle of Fall on Operational Effectiveness

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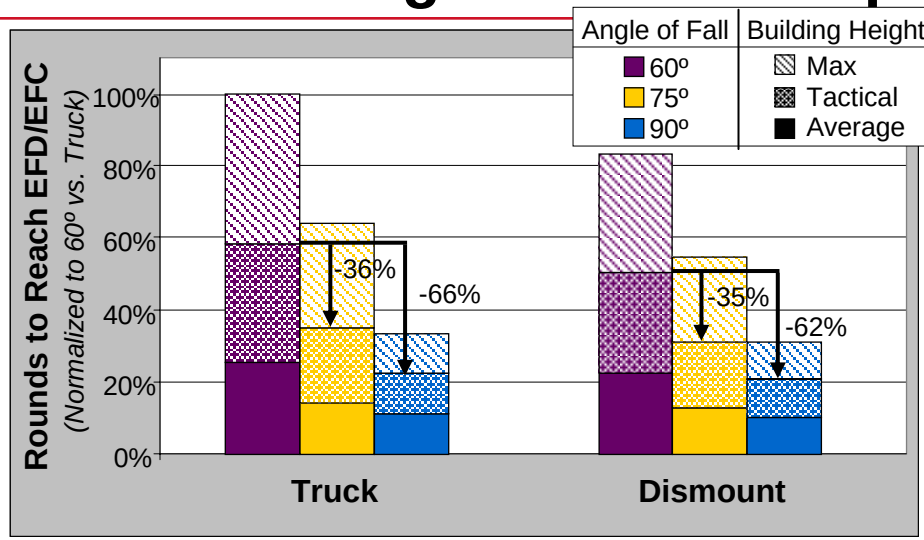

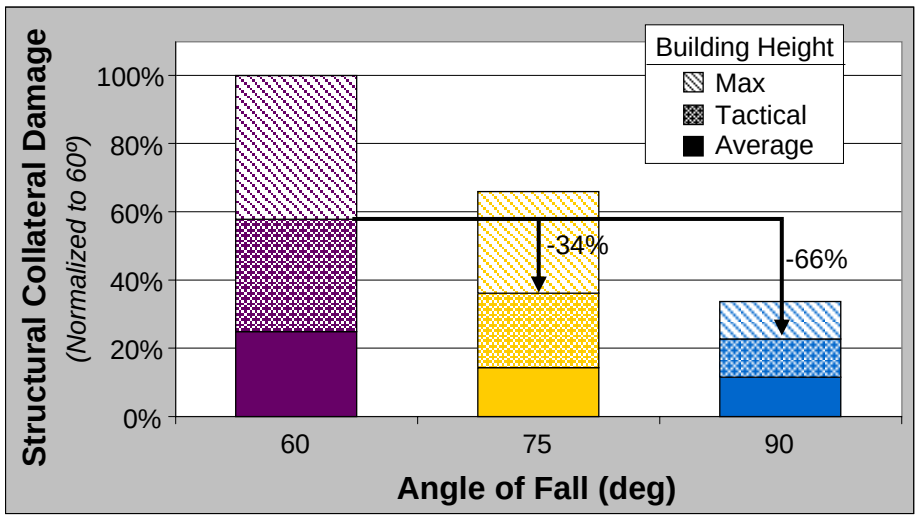

- **Building Heights:**
  - **Average building height** comes from the 5 Urban Terrain Templates
  - **Max building height** is average + 3-sigma variance
    - *Sigma values provided in the Urban Terrain templates*
  - **Tactical building height** is between average and max
    - *Threat would realize capability of projectiles to come over buildings*
    - *Threat would tactically choose a taller than average building to mitigate this advantage*
- **MoE:** Rounds needed to reach EFD of 30%; Collateral Damage produced from rounds impacting on/near buildings
  - Assumes 10m TLE
  - Rounds will clip building if AoF is too shallow
- **Results for the Tactical Case:**
  - Comparison to 60º Angle of Fall
    - % fewer rounds vs. Truck: **75º:** -36% **90º:** -66%
    - % fewer rounds vs. Dismnt: **75º:** -35% **90º:** -62%
    - % Less Structural Damage: **75º:** -34% **90º:** -66%

Steeper Angle of Fall provides significant Operational benefits against targets in Urban Terrain; Targets are eliminated with fewer rounds and less Structural Damage is created

Analysis:
Effects of Angle of Fall on Cost

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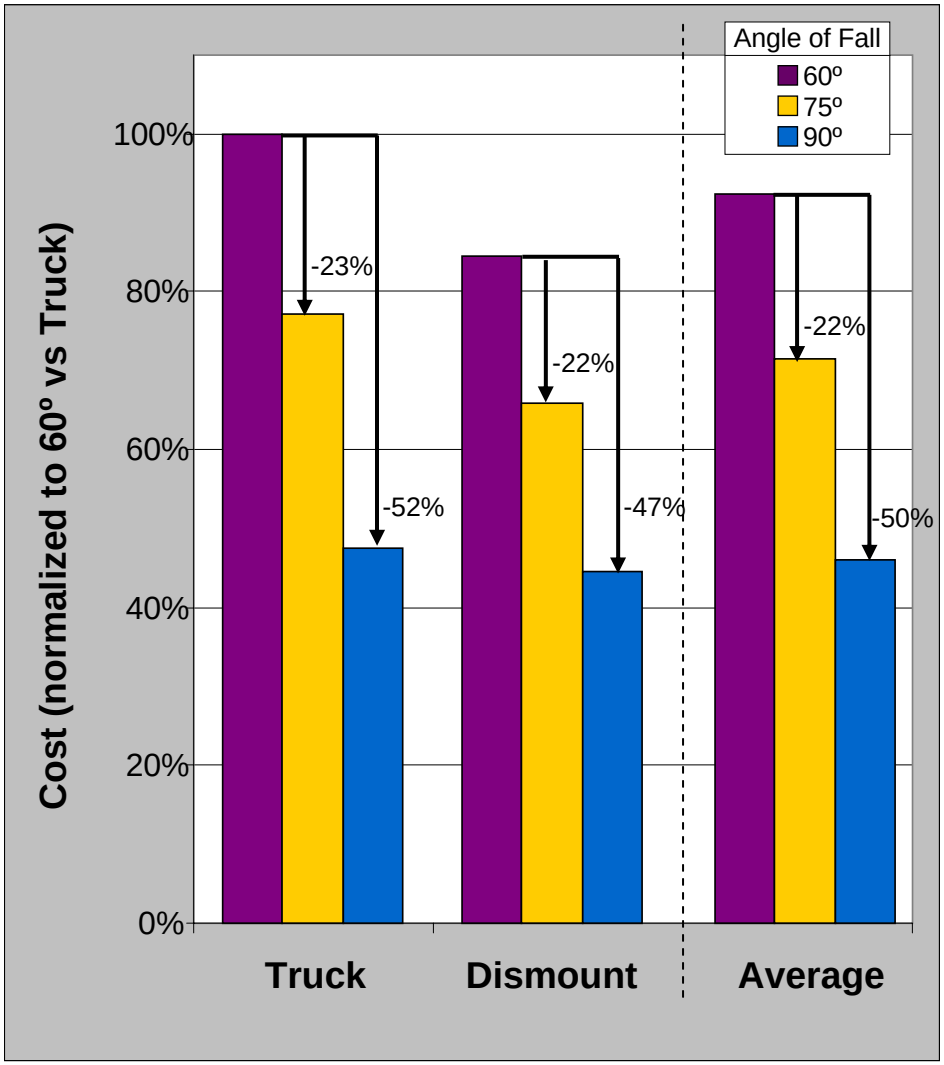

- **Methodology:** Apply costs to the number of rounds required to reach EFD computed by JCATS
- **Assumptions:**
  - Tactical building height results used
  - 75º round costs 20% more than 60º round
  - 90º round costs 40% more than 60º round
- **Results:**
  - Steeper angle of fall results in significantly less cost
    - *Steep angle of fall maximizes lethality*
    - *Steep angle of fall avoids clipping of buildings*
  - If 10 missions are fired on each target daily:
    - *75º will save $363.8k per day*
    - *90º will save $812.7k per day*
  - To be as cost effective as a round with 90º:
    - *A round with 60º would need a unit cost 64% less than the 90º round*
    - *A round with 75º would need a unit cost 45% less than the 90º round*

Steeper Angle of Fall achieves effects for less cost; Cost per Kill much more affordable

Nammo Talley

Enhancing War Fighter Shoulder Fired Weapon Training

NDIA Gun & Missile Systems Conference April 21-24 2008 New Orleans, LA

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  - Lethal Shoulder-Launched Munitions
  - Gas Generators, Actuators, Dispersion Systems, Rocket Motors
- Nammo Talley
  - Only US producer of Shoulder-Launched Munitions

Introduction - Subcaliber Training

- Subcaliber Rocket
  - Close replication of tactical round firing
    - Blast overpressure
    - Back blast
    - Recoil
- Why Train with Subcaliber Munitions ?
  - Provides for more realistic training
  - Improved gunner target hit percentage with tactical weapon
  - Lower cost than tactical
  - Environmentally friendlier to training bases/installations

Shoulder Launched Munition Training

M72 LAW

Shoulder Launched Munition Training

M141 Bunker Defeat Munition (BDM)

M72 LAW - Weapon Characteristics

Caliber	66 mm
Carry Length	30.5 in.
Firing Length	38.6 in.
Weight	7.9 lbs
Range	10 to 500 m
Max Effective	350 m

M72 LAW History

M72 LAW has been used in every United States conflict since Vietnam

USArmy TC Basic LAW

1962

1991

1972

1993

USArmy TC M72A4-A5-A6

USMC Fields M72A7 OEF OIF

2004

2006

USSOCOM & UK Field M72A9 ASM

2008

Advanced M72E8 & 10 Qualification

M72 LAW - Subcaliber Rocket Trainer

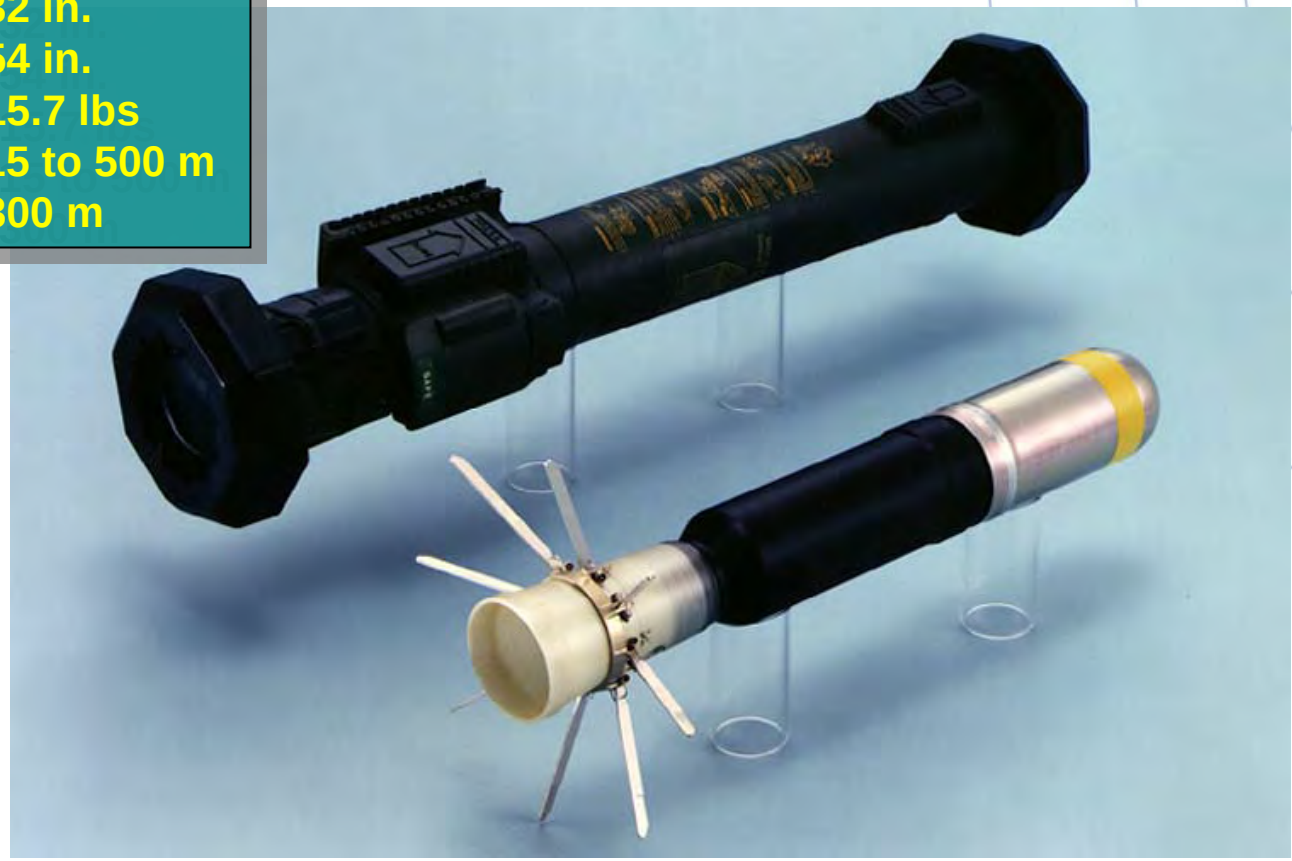
Caliber . . . . . 21 mm
Carry Length . . . . 30.5 in.
Firing Length . . . . 38.6 in.
Weight . . . . . 7.9 lbs
Range . . . . . 15 to 250 m

M72 Trainer Weapon Overview

- Duplicates Tactical Weapon Features in Reusable Form:
  - Compact and lightweight (constructed from used tactical launcher)
  - Fires both right or left handed without modification
  - Identical gunner interfaces, weight and center of gravity
- Replicates Tactical Weapon Performance:
  - All propulsion occurs within the launcher tube
  - Trainer round ballistically matched with tactical rounds
- Training System Type Classified by US Army and Navy

M141 BDM - Weapon Characteristics

Caliber . . . . . 83 mm
Carry Length . . . . 32 in.
Firing Length . . . . 54 in.
Weight . . . . . 15.7 lbs
Range . . . . . 15 to 500 m
Max Effective . . . . 300 m



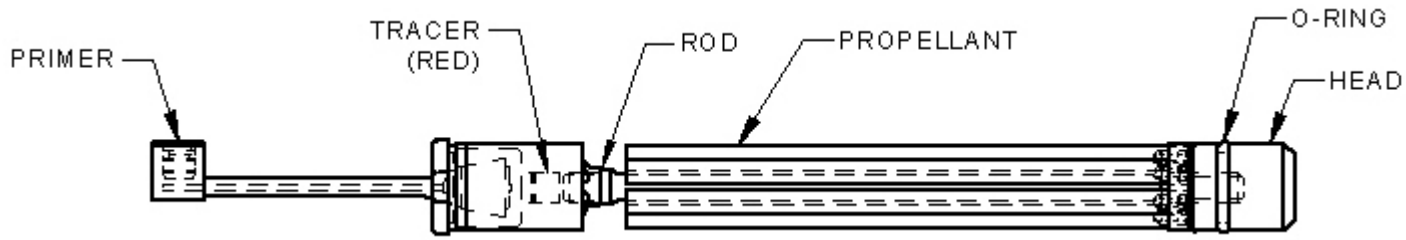
M141 BDM - Subcaliber Rocket Trainer

Caliber . . . . . 21 mm
Carry Length . . . . 32 in.
Firing Length . . . . 54 in.
Weight . . . . . 15.7 lbs
Range . . . . . 15 to 250 m

A Common 21 mm Trainer Rocket

21mm Training Rocket Overview

- Trainer Rocket



Issued as round of ammunition, requires no maintenance or tools

Prepackaged at the factory in protective, throw-away aluminum tube

Transport by rail, air, sea, road - tactical tracked or wheeled vehicles

Certified for air delivery - individual parachutist or air-dropped pallet

Same round used for M72, BDM, and USMC SMAW

M72 Training Overview

- Replicates tactical acoustic signature without full energy content
- Permits more than 100 shots/day with single hearing protection
- Replicates back blast field, but safer for training environment

Training with Subcaliber System

- Classroom and Field Learning Objectives:
  - Familiarization with training weapon and ammunition
  - Perform pre-fire serviceability inspection
  - Prepare weapon for firing
  - Firing positions and correct sight picture
  - Engaging stationary and moving targets
  - Misfire procedures
  - Reloading and unloading of trainer weapon
  - Returning weapon to carry configuration

Training Program Summary

- Nammo Talley has developed a pair of 21-mm sub-caliber training systems that approximate the 66-mm M72 LAW and 83-mm M141 BDM (SMAW-D) and USMC SMAW tactical round firing effects for gunner training purposes.
- These training systems complement classroom instruction with field handling trainers and allow for a cost-effective alternative to training with the tactical round with inert warheads.
- Nammo Talley offers a comprehensive training curriculum designed to enhance the benefits of training under the military's currently established doctrine, tactics, and techniques.

Subcaliber Rocket Training Contacts

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Electronic Test Fuze

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Hamish Malin
NSWCDD G33
Precision and Advanced
Systems Branch

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ELECTRONIC TEST FUZE - ETF

- What is ETF?
  - Designed to support realistic gun-shock testing of myriad subsystems
  - Digital processor can command and control subsystems under test in flight.
  - ETF is a diagnostic suite of sensors including 3 axis magnetometer and single axis accelerometer
  - ETF is an analog and digital signal multiplexer that encodes data into a single stream used to modulate an RF transmitter
  - ETF is a gun hardened system with self contained power modules

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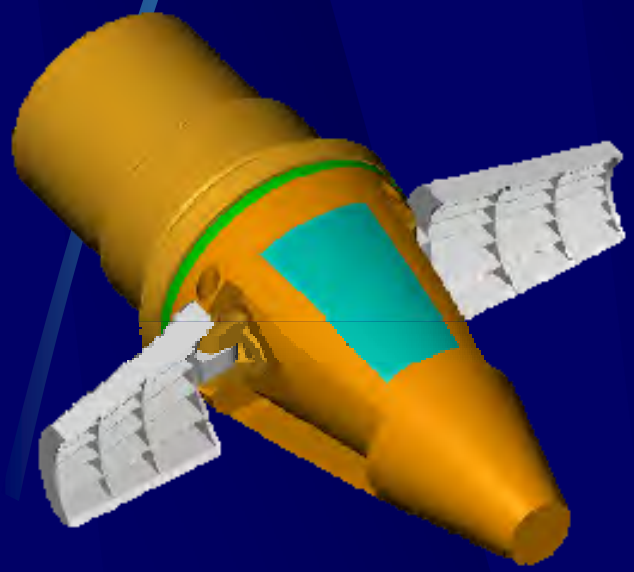
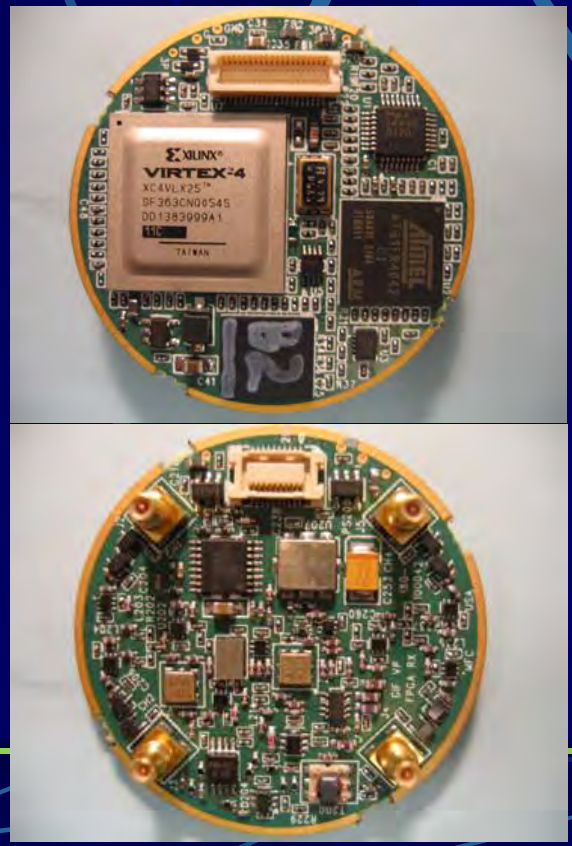
Program Overview

- Electronic Test Fuze (ETF) designed to support Guidance Integrated Fuze (GIF) program





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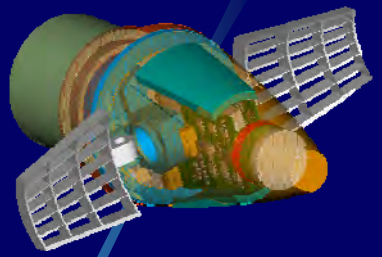
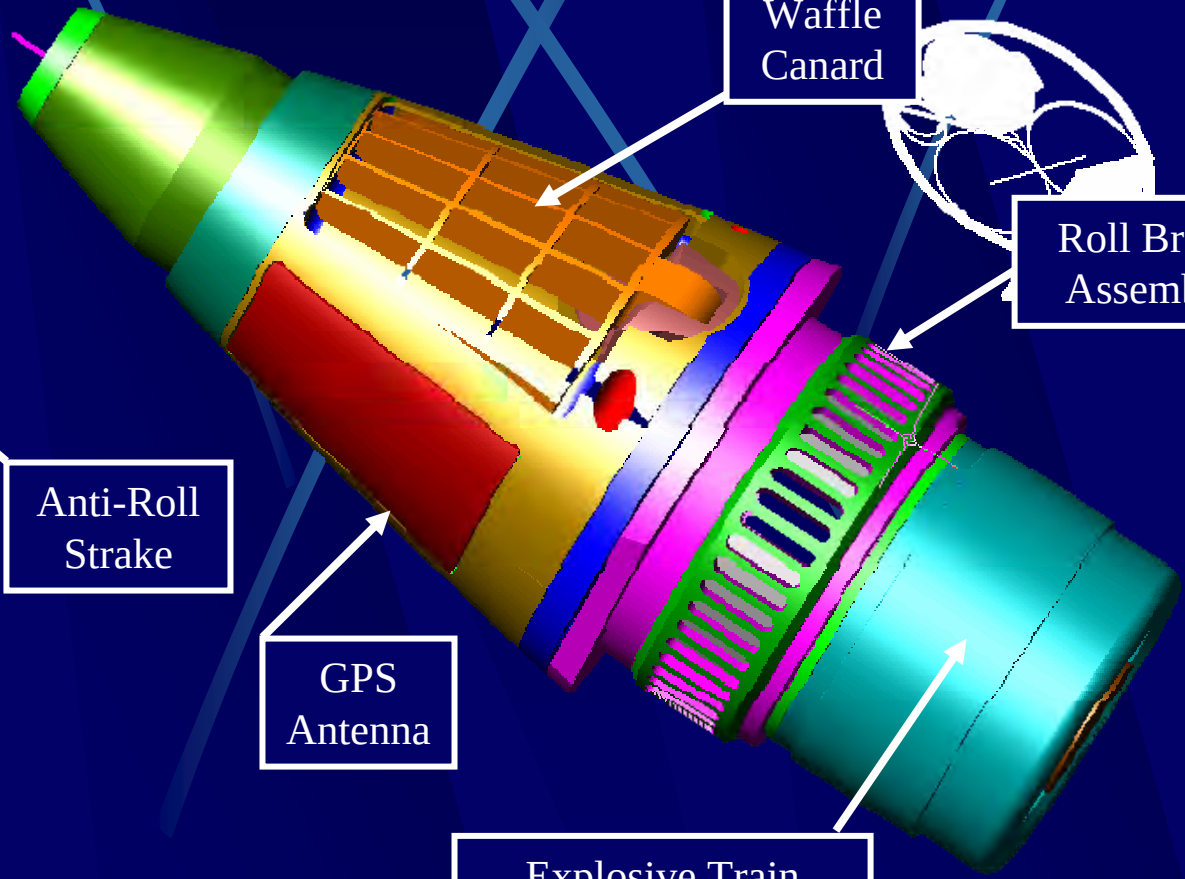
Lift-GIF





Waffle Canard

Roll Brake Assembly

Anti-Roll Strake

GPS Antenna

Explosive Train
OR
TM Support Housing

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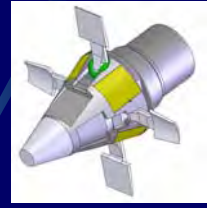
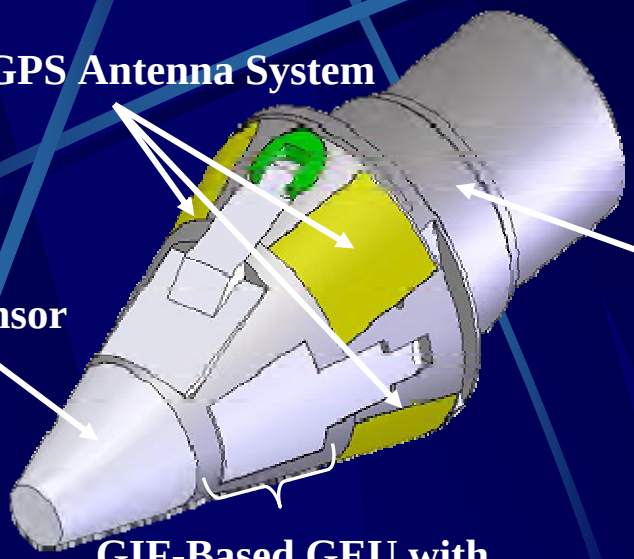
VariPitch



4-Patch GPS Antenna System

HOB Sensor

COTS Battery Module

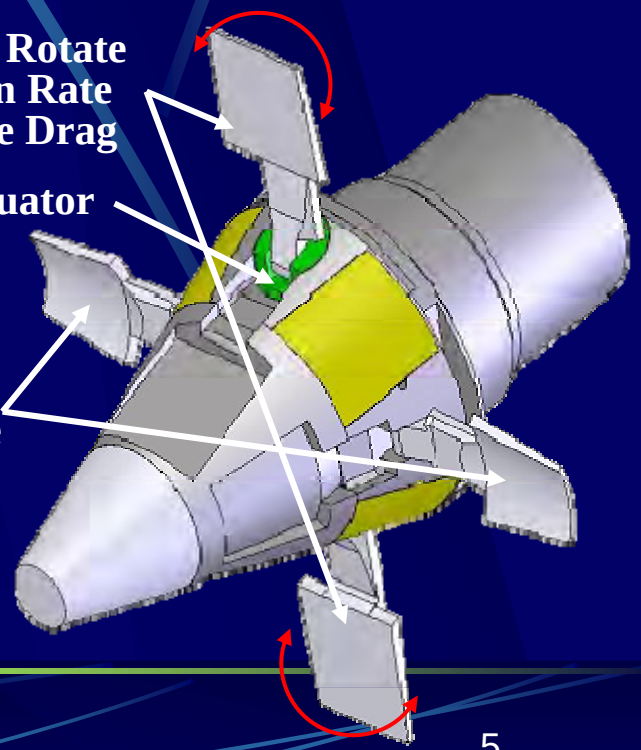


GIF-Based GEU with Advanced Anti-Jam and Backup "Command Mode" using PTS if GPS is Denied

Control Panels that Rotate Controlling the Spin Rate and "throttling" the Drag

GIF COTS Actuator

Drag Panels Don't Rotate



GIF/VP Advantages:

- Simpler than Navy "Lift-GIF" yet more robust in terms of Jamming and Reliability.
- ~$1K Less Expensive in Production
- Capable of a 15m to 20m CEP.
- Applicable to All Ammo Types.
- Meets or Exceeds PGK Inc 1/2/3 Requirements.
- Leverages All Previous Navy-GIF Developments except the Roll Brake and Bearing Assemblies.

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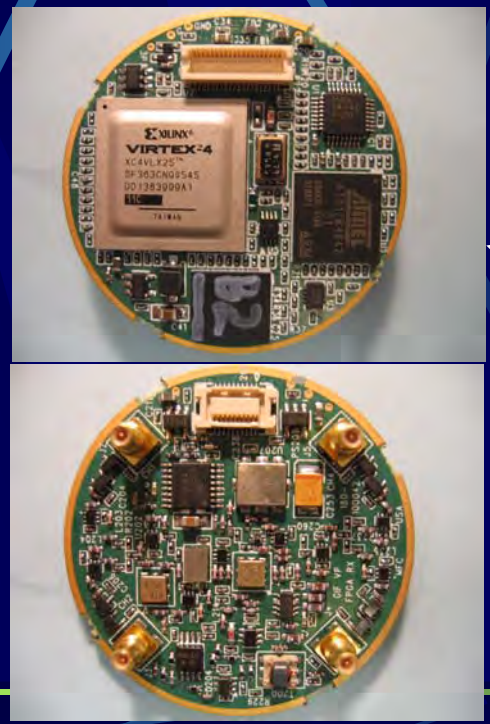
Miniaturized GPS SAASM Receiver Technology

- No Existing Product Could Meet GIF Requirements
- Awarded Contract to Mayflower Communications for Development of GPS Receiver
  - Low Cost (< $500)
  - Low Power (< 1W)
  - Small Size (< 2 in^2)
- Phased approach:
  - C/A Version w/ FPGA Available Now!!
  - P(Y) SAASM Receiver (TRL 6) Available Fall 2008
- Not GIF-Centric
  - One Product, Many Applications



40mm diameter
(VP Form Factor)

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Overview - ETF

- Fully designed in-house at NSWCDD
- Initially designed to support in-flight testing of ElectRelease™ for Lift-GIF
- Designed to support realistic gun-shock testing of myriad subsystems
- Six successful flight tests to date

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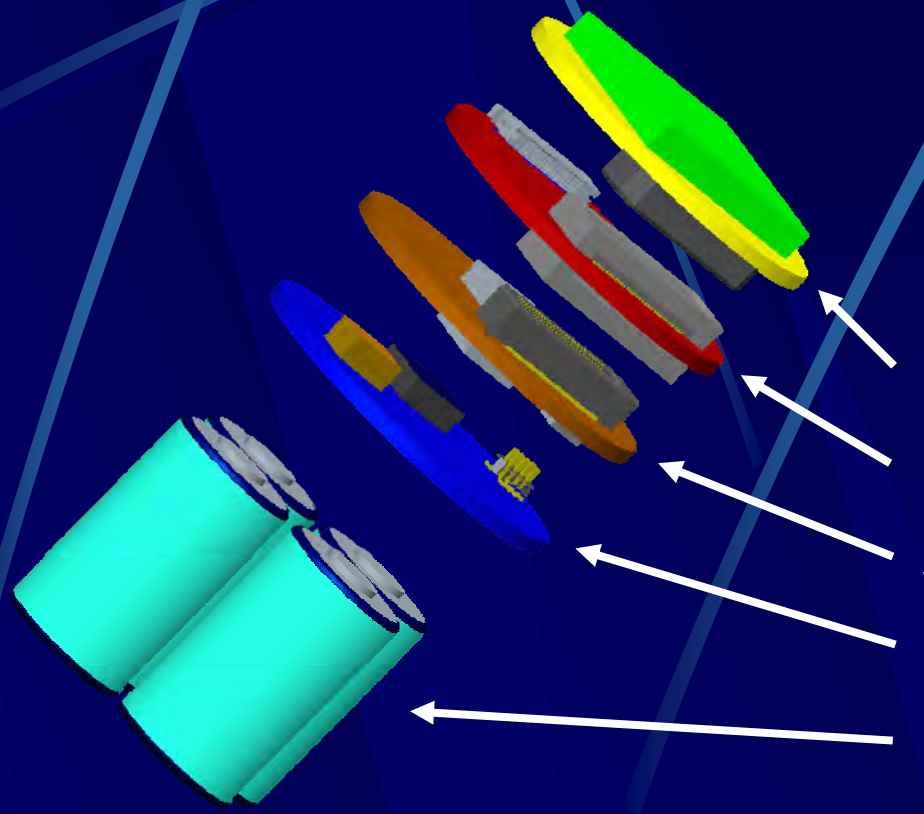
Board Stack - General



FPGA Board

FPGA I/O Support Board

Sensor Board

Power Board

Batteries

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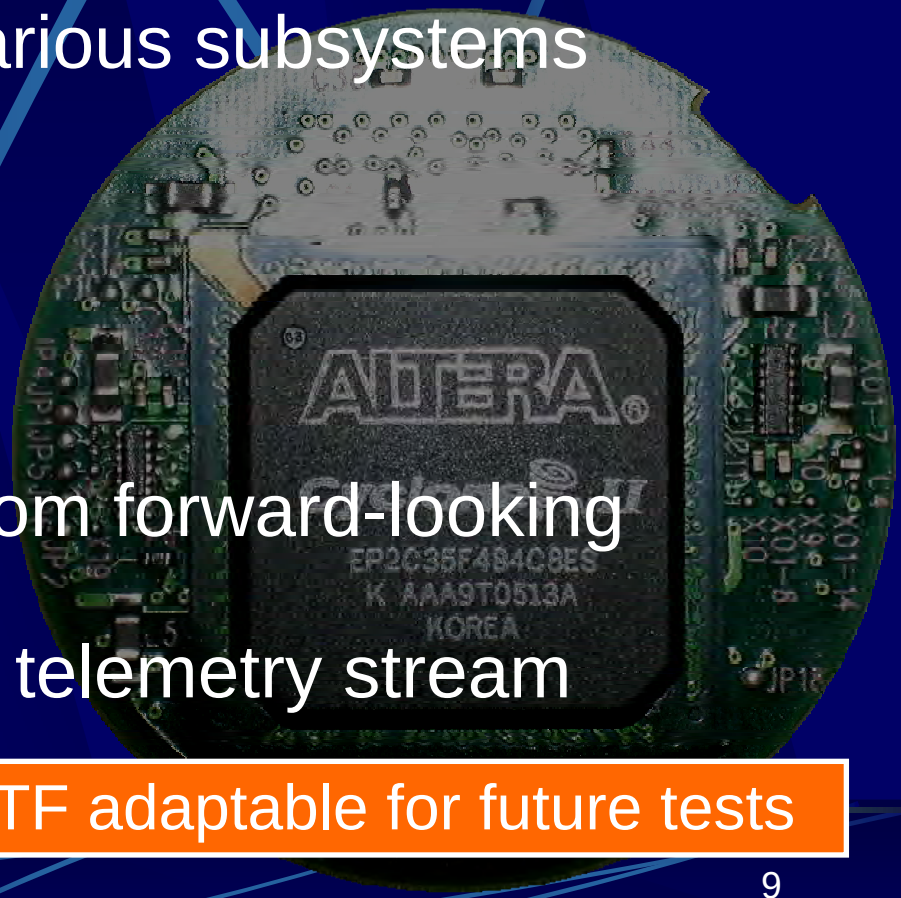
FPGA Board

- Interfaces with ADCs and sensors
- Controls & monitors various subsystems under test
  - HOB sensor,
  - ElectRelease actuator,
  - IR transceivers,
  - GPS Rx
- Measures (time = 0) from forward-looking accelerometer
- Encodes test data into telemetry stream



FPGA architecture makes ETF adaptable for future tests

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Sensor Board

- Silicon Designs 20k-g 1-axis accelerometer
- Honeywell HMC 1053 3-axis magnetometer
- 2 Maxim MAX274 8th-Order Active Filters provide 2nd-Order Chebyshev LPF for each channel
- 2 12-bit, 8-channel TI ADS7852 ADCs sample at up to 32 ksps

Vias available for additional external sensors

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Battery Puck & Power Board

- Current configuration utilizes 4 CR2s
- Puck is designed to be removable such that fresh batteries can be used for flight
- Supplies 5V, 2A; 4V, 500mA
- Other voltages possible
- Current puck can power full ETF stack for > 2hrs

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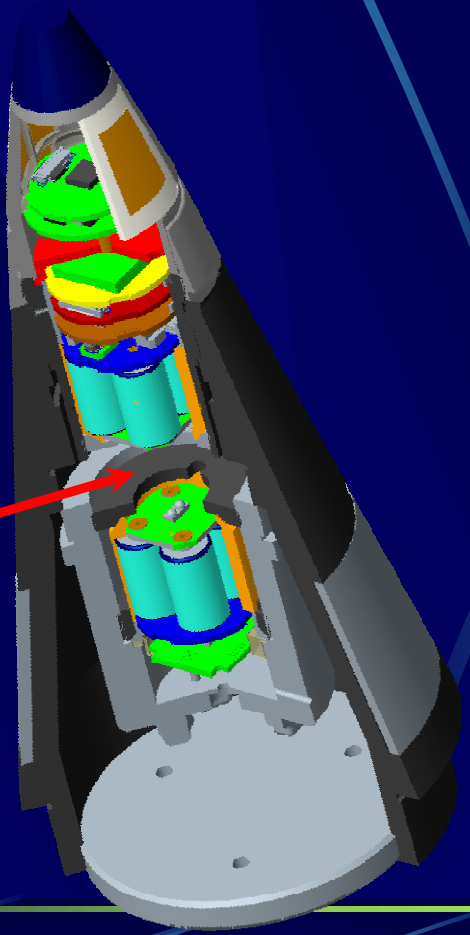
Projectile-Embedded Telemetry



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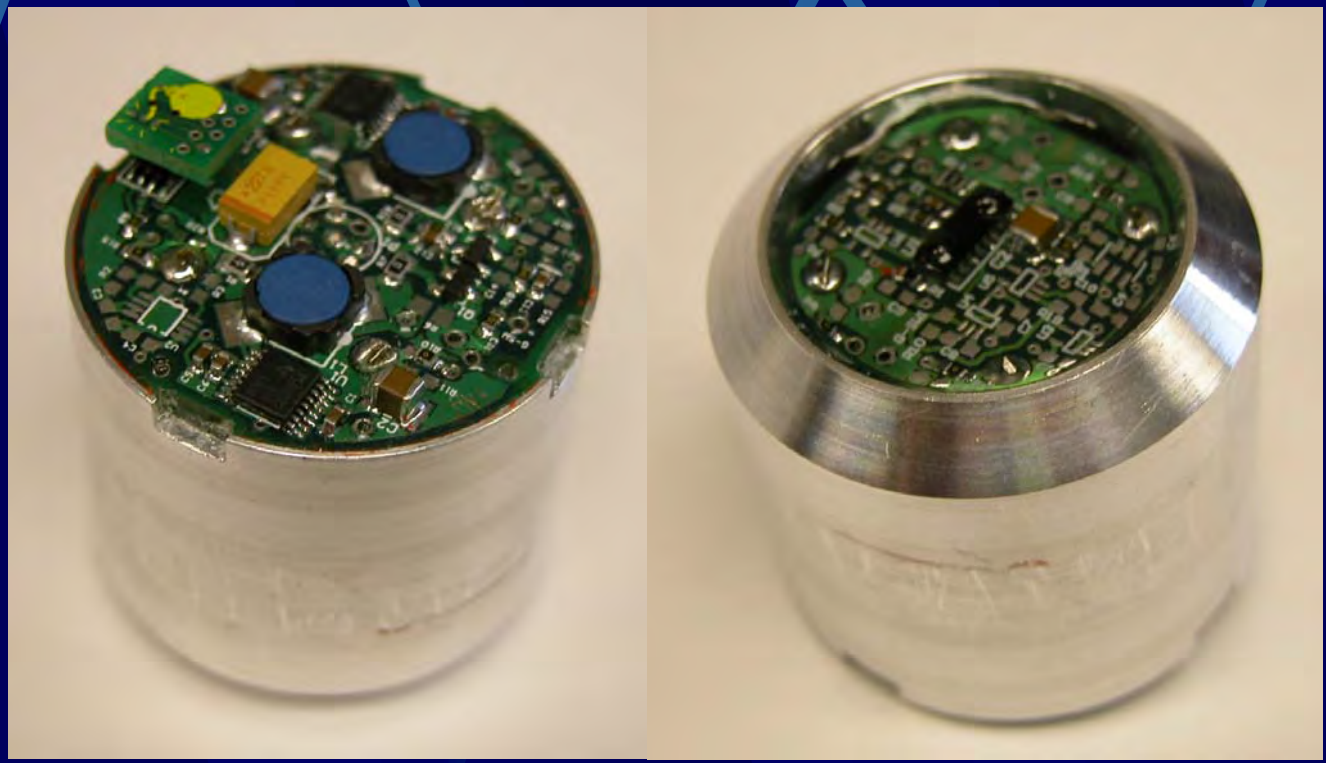
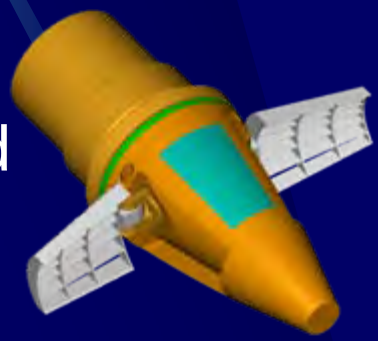
IR Battery Puck



TM Transmitter & Antenna

- M/A-COM MA06836 ½-Watt S-Band HSTSS Telemetry Transmitter
- Three Antenna Versions
  - Round D-Fuze TM Antenna for ‘simple’ ETF
  - IR link integrated between the fuze & the projectile to expand fuze test volume
  - GIF GPS Antennas also re-tuned to S-Band for future test applications



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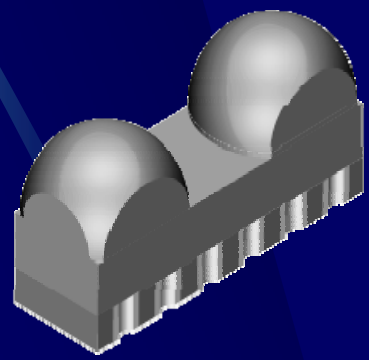
IR Transceivers

- Vishay TFBS6614 IrDA used for IR Battery Puck for TM link
- Vishay TFBS4711 IrDA to be used for cover release verification
  - Determine if canard covers have been successfully deployed
  - 2 transceivers/cover



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TM Data format

- Manchester encoded
- 1 Mbps data rate
- 1024 bits/frame (1.024 ms frame), including:
  - 32 bit frame sync
  - 24 bit frame counter
  - 32 bit checksum

ETF Telemetry Frame - 18 April 2007 Test Shot

updated on 16 April 2007

Byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
16-bit word	0		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
32-bit word	0				1				2				3				4				5				6				7			
Data	Frame Sync (0xFAF32019)					A	F	Power	GPS				GPS					Frame Counter				A			M1(i)		M1(j)		M1(k)			

Byte	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
16-bit word	16		17		18		19		20		21		22		23		24		25		26		27		28		29		30		31	
32-bit word	8				9				10				11				12				13				14				15			
Data			GPS			A		GPS			GPS				GPS				GPS			A										

Byte	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
16-bit word	32		33		34		35		36		37		38		39		40		41		42		43		44		45		46		47	
32-bit word	16				17				18				19				20				21				22				23			
Data						A																A			M1(i)		M1(j)		M1(k)			

Byte	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
16-bit word	48		49		50		51		52		53		54		55		56		57		58		59		60		61		62		63	
32-bit word	24				25				26				27				28				29				30				31			
Data						A																A			TOF				CRC Checksum			

	Label	Signal	Resolution (bits)	# of Channels	Samples / Frame	Sample Rate (kHz)	Bandwidth (kHz)
	A	High-G Accelerometer	12	1	8	7.81	93.75
*	M(i) M(j) M(k)	3-axis Mags (1 = South, 2 = North)	12	3	2	1.95	70.31
	TOF	Time of Flight (ms)	20	1	1	0.98	19.53
*	F	Flags: In flight; Actuator Power; HOB Power; HOB CO	1	1	1	0.98	0.98
	GPS	GPS Data, see additional sheet for more info	168	1	1	0.98	164.06
	Frame Sync	Frame Sync (0xFAF32019)	32	1	1	0.98	31.25
	Frame Counter	24-bit counter (~4.8 hours of unique numbers)	24	1	1	0.98	23.44
	CRC Checksum	32-bit Cyclic Redundancy Check	32	1	1	0.98	31.25
						Total:	**43.46%**

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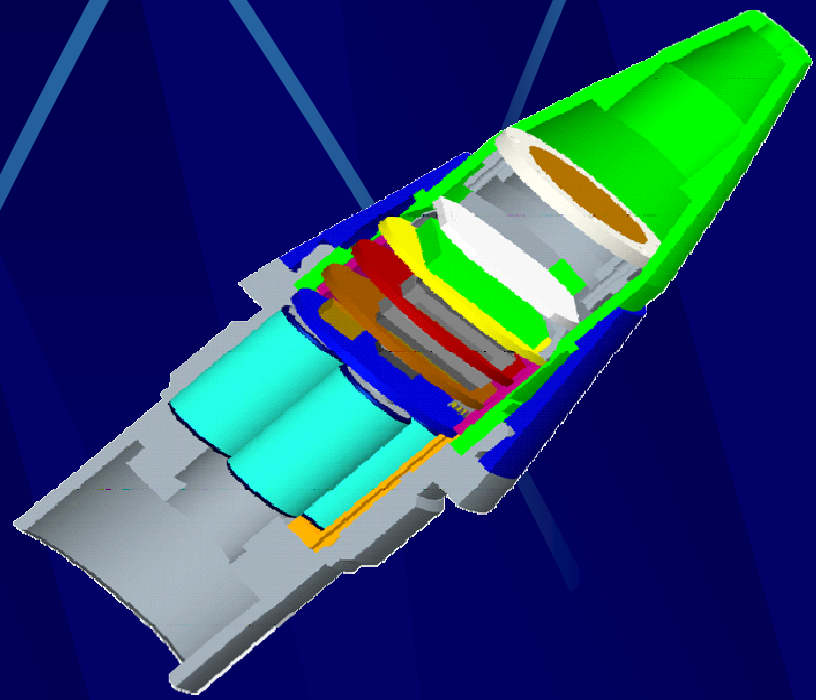
Flight Test 1 August 2006

- Core ETF stack shot at 7R out of 155mm Howitzer on Dahlgren AA Fuze Range
- Primary objective of survival met
- 99.96% of telemetry data recovered with receivers stationed at fuze range
- Primary sensors survived and functioned



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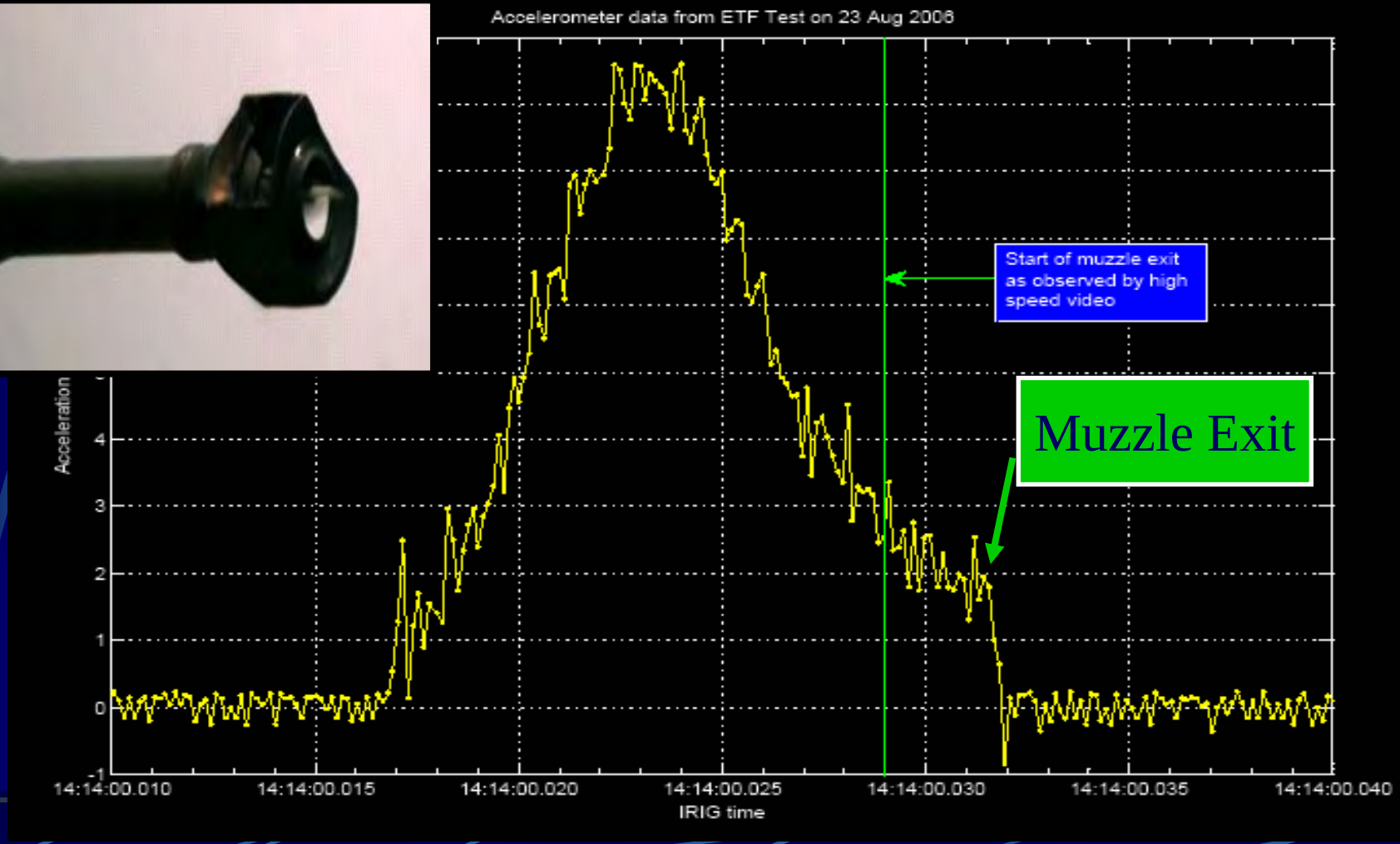
Flight Accel. Data



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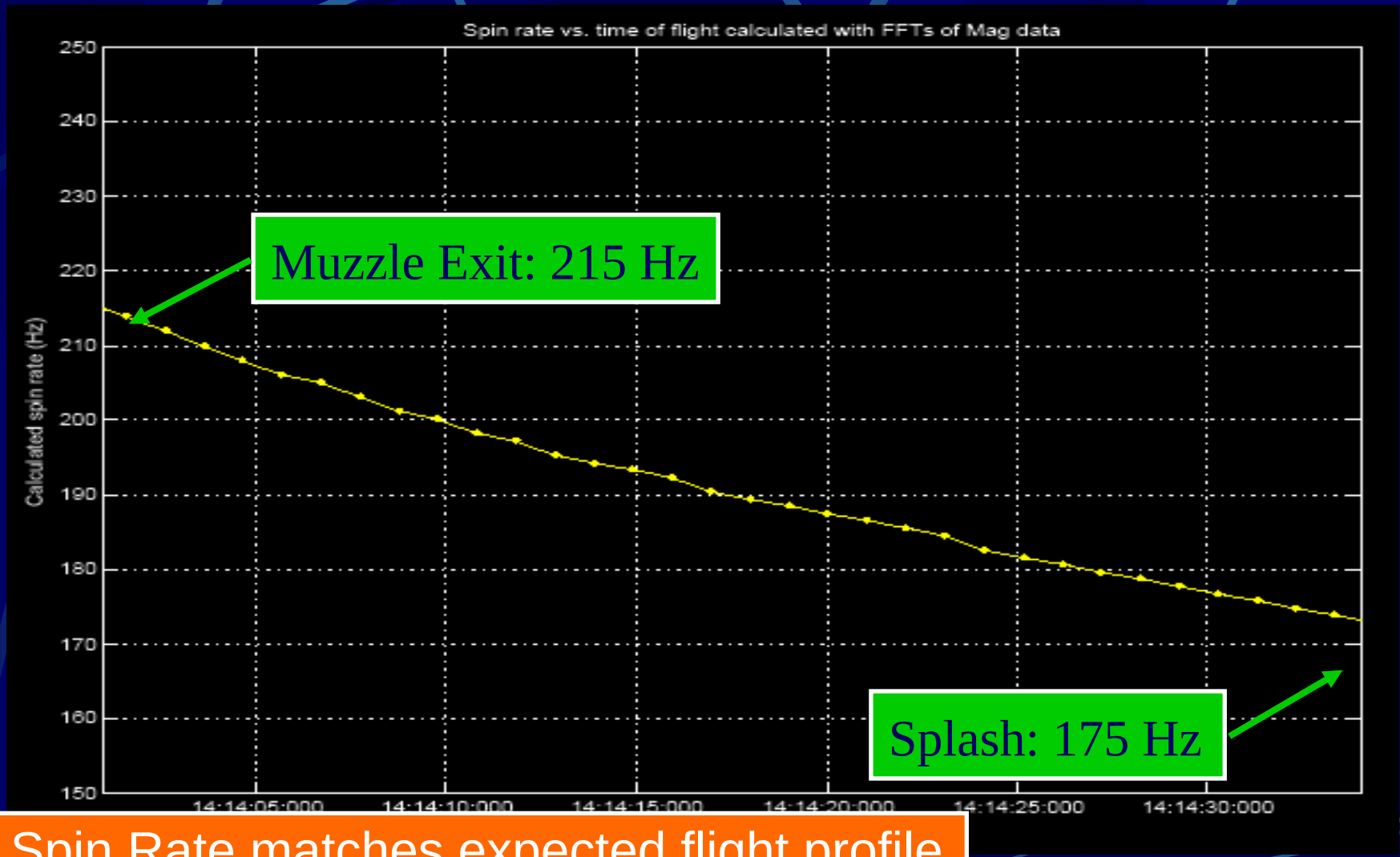
Flight Mag. Data



Spin Rate matches expected flight profile

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Flight Test 2 November 2006

- ETF with IR Link shot at 7R out of 155mm Howitzer on Dahlgren AA Fuze Range
- Primary objective of survival met, both for fuze and aft TM section
- Primary sensors survived and functioned

Flight Test 3
April 2007

- ETF with Mayflower GPS receiver shot at 7W out of 155mm Howitzer on Dahlgren AA Fuze Range
- Primary objective of receiver survival met

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Flight Test 4 August 2007

- ETF with Mayflower GPS receiver shot at 7W on Dahlgren AA Fuze Range
- 99% of telemetry data recovered with receivers stationed at fuze range
- Primary sensors survived and functioned
- Valid GPS Receiver data collected the duration of the flight

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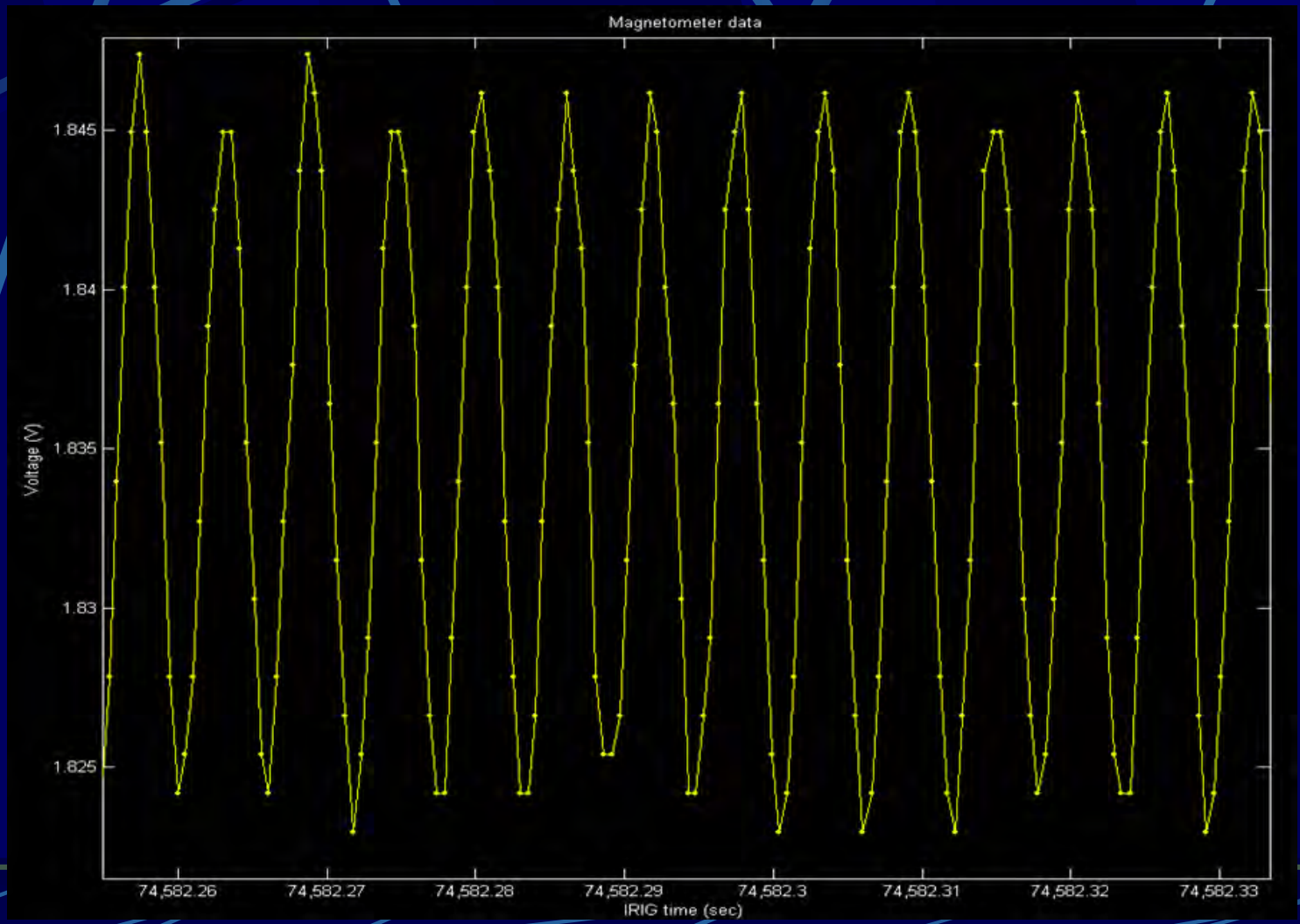
Mag. Data



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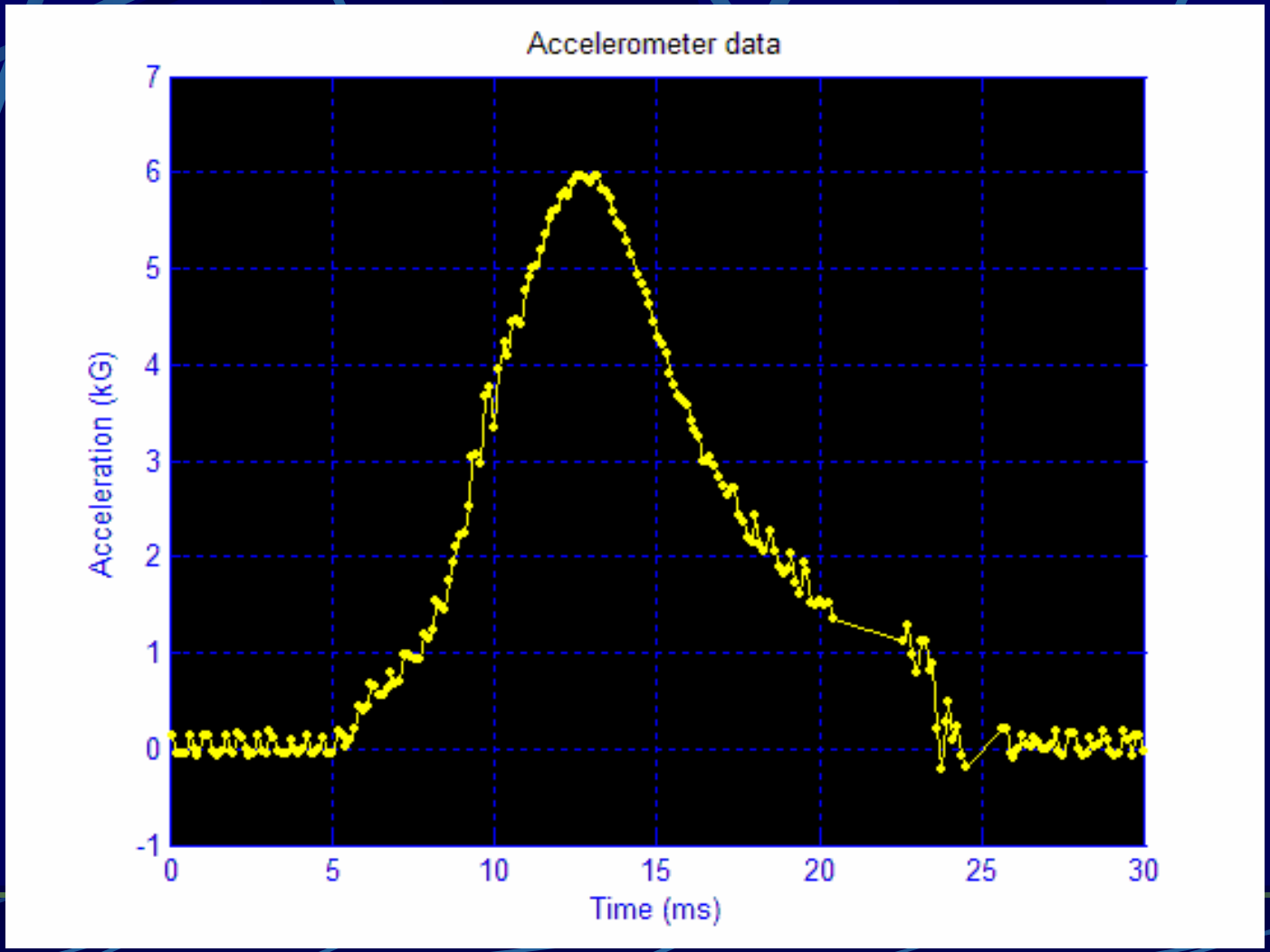
In-Bore Accel. Data



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Future ETF Uses

- May 2008 – Follow-up C/A GPS Receiver Test Shot
- Used on other gun programs to record gun fire dynamics - Ongoing
- December 2008 – Mayflower P(Y) GPS Receiver Test Shot
- This bullet reserved for YOUR subsystem!

2+ cubic inches available to test other subsystems

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Basic Cost

- Core Electronics: $3500
- Mechanical Hardware: $3000
- EE Hardware Test: $2000
- Mechanical Assembly: $1500

Total: $10K / unit

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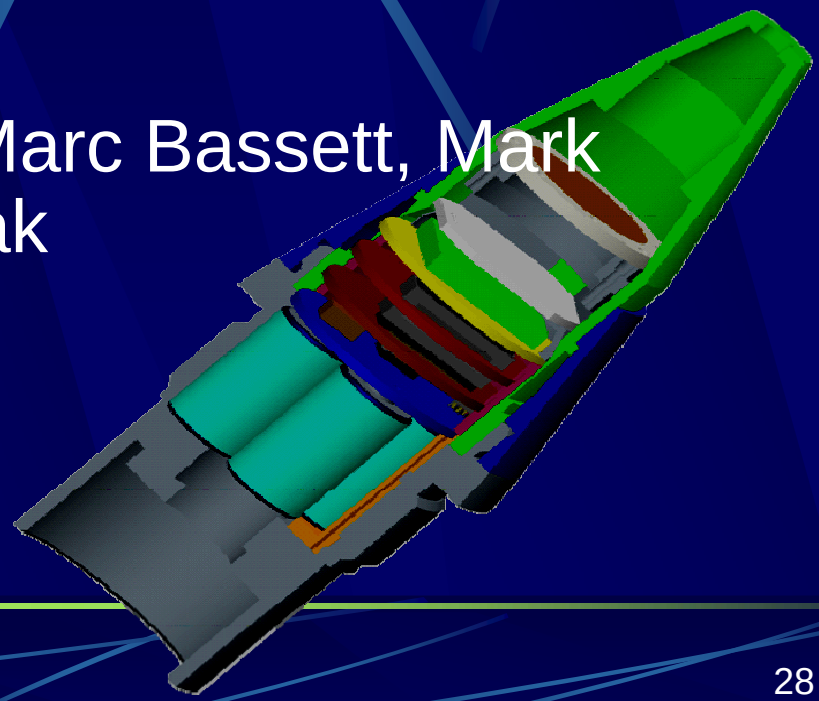
Acknowledgements

- Electrical Team – Mike Irwin, Travis James, Hamish Malin, Wayne Worrell
- Mechanical Team – Marc Bassett, Mark Engel, Nathan Joswiak



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QUESTIONS ?

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Backup Slides