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46th Annual Gun & Missile Systems Conference & Exhibition

"Shaping Weapon Systems for Rapid Deployment: Development, Interoperability & Flexible Response"

Miami, FL

29 August – 1 September 2011

Agenda

Monday, August 29, 2011

TUTORIAL B

"Ready or not? Using Readiness Levels to Reduce Risk on the Path to Production", Mr. Dan Chien, Vice President, Engineering, General Dynamics Armament and Technical Products

Tuesday, August 30, 2011

DIVISION UPDATE/2012 JOINT ARMAMENTS SYMPOSIUM

Mr. Dave Broden, NDIA Armaments Division Chair; Broden Resource Solutions

KEYNOTE ADDRESS:

"Air and Missile Defense Overview", COL Cavalier, USA, Program Executive Officer, Missile and Space, U.S. Army

KEYNOTE ADDRESS:

"Close Air Support and Joint Operations", Mr. Andrew K. Balding, Associate, Booz Allen Hamilton

KEYNOTE ADDRESS:

"The Role of the Government Laboratory in Shaping Weapon Systems Development; An ARDEC Perspective", Mr. Anthony J. Sebasto, Senior Associate for Munitions, U.S. Army ARDEC

CONCURRENT SESSIONS

MONROE

– INDIRECT FIRES

- 11503 - An Analysis of the Indirect Fires Portfolio of Munitions, Mr. Jim Rodrigue, Raytheon Land Combat
- 11830 - Development of an Extended Range, Large Caliber, Modular Payload Projectile, Mr. Pierre-Antoine Rainville, GD-OTS, Canada
- 11528 - XM1128 155mm Insensitive Munition (IM) High Explosive (HE) Extended Range Artillery Projectile, Mr. Ductri Nguyen, U.S. Army ARDEC
- 11511 - Technologies Utilizing the M483 Carrier, Mr. George Kurzik, GD-OTS, Red Lion

– EMERGING TECHNOLOGIES: SYSTEMS

- 11586 - Introduction of Wireless and MEMs based MDevices into Fire Control Systems, Mr. Ralph Tillinghast, U.S. Army ARDEC

- 11641 - Extended Area Protection and Survivability Program (EAPS), Mr. Manfredi Luciano, U.S. Army ARDEC
- 11720 - Development of the Interceptor System for the Extended Area Protection & Survivability (EAPS), Mr. E. Mitchell Danielson, ATK, Plymouth

– REQUIREMENTS & PROGRAM TRENDS

- 11786 - Naval Forces Capabilities Gap Against Swarm Attacks, Mr. Andrew Bradick, Rheinmetall
- 11861 - U.S. Forces Light and Medium Mortar Ammunition Insensitive Munitions Path, Mr. Nick Baldwin, U.S. Army RDECOM-ARDEC
- 11863 - IM Compliance for Mortar Illumination Cartridges, Mr. Thomas Peter, U.S. Army RDECOM-ARDEC
- 11482 - Precision Guided Indirect Munitions — Operational Evolution, Mr. Justin Skaret, Raytheon, Missile Systems
- 11792 - Enhancing Convoy Security by Means of Rapid Deployable Weapons, Mr. Gerrie Van der Merwe, BAE Land Systems, South Africa

TUTTLE

– MODELING & SIMULATION I – DESIGN

- 11791 - Gun Launch Dynamics Modeling—Benchmarking the State of the Art, Mr. Rollie Dohrn, ATK, Plymouth\
- 11774 - Gun Launch Dynamics and Aeroballistic Analysis via Onboard Laser Diode, Mr. Rollie Dohrn, ATK, Plymouth
- GD-OTS/Nammo 25 mm JSF Combat Ammunition, Mr. Zack Kemp, GD-OTS
- 11824 - Design, Analysis and Weight Optimization Techniques for Joint Strike Fighter Missionized Gun Pod Support Equipment, Mr. Gary Miller, GD-ATP

– **MODELING & SIMULATION II: TEST METHODS**

- 11838 - A Method for Assessing the Effects of Overpressure from Small/Medium Caliber Weapons Fire, Mr. Steven Backer, NSWC-Crane
- 11793 - The Challenge of Environmental Testing of the Expeditionary Fighting Vehicle Ammunition Feed System Separate from the Expeditionary Fighting Vehicle, Mr. Ron Hopkins, GDATP

– TACTICAL ROCKETS & MISSILES

- 11808 - Design Synthesis for Large Shaped Charges: From Requirements to Qualification, Mr. Jason Shire, Raytheon
- 11802 - Use of COTS O-rings as a Pyrotechnic Safety Barrier in a Rocket Motor Ignition Safety Device, Mr. Brian Erickson, ATK, Plymouth
- 11756 - Hellfire Integrated Blast Fragmentation Sleeve Multipurpose Warhead, Mr. Jonathan Thomas, GD-OTS

Wednesday, August 31, 2011

AWARDS LUNCHEON

2011 Robert Trifiletti Award Winner

- Dr. Norbert D’Souza

Combat Archer

- Capt Jesse “Magoo” Proctor

CONCURRENT SESSIONS

MONROE

– ENERGETICS I

- 11822 - Novel ARDEC Igniters **f**or Gun Systems, Dr. Eugene Rozumov, U.S. Army ARDEC
- 11787 - The Effects of Igniter Design on the Interior Ballistic Performance of Deterrent Coated Propellants, Dr. Thelma Manning, U.S. Army, RDECOM-ARDEC

– ENERGETICS II

- 11867 - IM in the Field—Experience of Reduced Sensitivity Mortar Cartridges to Actual Combat Threat Stimuli, Ms. Pamela Ferlazzo, U.S. Army RDECOM-ARDEC
- 11537 - Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications, Mr. Virgil Fung, BAE Systems Ordnance Systems Inc
- 11832 - Development and Characterization of IM Gun Propellant for the 120mm Tank System, Mr. Duncan Park, U.S. Army RDECOM-ARDEC
- 11821 - The Advance Case System (ACS) Program for 120mm Tank Training Ammo- Phase 2, Mr. Jeff Berg, ATK, Plymouth
- 11761 - High Explosives Charges for Insensitive Artillery and Mortar Ammunitions: Performances, Technology, Producibility, Affordability, Dr. Bernard Zeller, SNPE

– DIRECT FIRES I

- 11747 - Direct Fires & Precision Weapons for Rapid Deployment at the Modern Battlefield, Mr. Danny Schirding, Israel Military Industries, Ltd.
- 11725 - Medium Calibre Goes in a New Direction, Mr. David Leslie, BAE Systems Global Combat Systems
- 11572 - The Development and Testing of the Improved Kinetic Energy Electronic Time (IKE-ET) Round, Mr. Geoffrey Bland, NSWC Dahlgren
- 11809 - Composite Sabot Technology for the 105mm Rifled Tank Gun System, Mr. Velan Mudaliar, U.S. Army RDECOM-ARDEC

– PRECISION WEAPONS

- 11719 - Common GPS: Development of the Subsystem Specification and ICD for the Common GPS Subsystem for the Family of Precision Guided Projectiles, Dr. Karl Flueckiger, Draper Laboratory
- 11635 - Very Affordable Precision Projectile (VAPP) System and Flight Experiments, Mr. Christopher Stout, U.S. Army ARDEC
- 11459 - Evolution of the EXCALIBUR Guided Projectile, Mr. Chris Geswender, Raytheon Missile Systems
- 11526 - Precision Urban Mortar Attack (PUMA), Mr. Luke Steelman, NSWC Dahlgren
- 11788 - Leveraging Proven Systems to Develop a Guided Mortar for APMI, Ms. Kelly Hanink, Program Manager, Projectile Systems ATK Advanced Weapons Division, Plymouth

TUTTLE

– EMERGING TECHNOLOGIES: MATERIALS & PROCESSES

- 11583 - New PVD Processes for Durable Pollution-Free Ordnance, Dr. Sabrina Lee, U.S. Army, ARDEC
- 12179 - The “Perfect” Time for an Upgrade to US Propellant, Mr. Donald Messner, ATK, Radford

– MODELING & SIMULATION III: SYSTEMS & MANUFACTURING

- 11648 - System Analysis with Integrated Modeling and Optimization, Mr. Philip Brislin, U.S. Army ARDEC RDAR-MEM-L
- 11502 - A Virtual Learning Environment for Precision Indirect Fires, Mr. Jon Peoble, Raytheon
- 11779 - Next Generation Manufacturing & Modeling Technology, Mr. David Smith, U.S. Army Benet Laboratories

– NON-TRADITIONAL WEAPONS I

- 11840 - Development of a Large Caliber Naval EM Railgun, Mr. Roger Ellis, Office of Naval Research
- 11841 – Electromagnetic Railgun, a Multi-Mission Weapon System, Mr. Alan Kull, General Atomics
- 11828 - Scalable Gen-Set for Directed Energy Weapons: Resolving the Power Problem, Mr. Bryan Bockmon, Rocky Mountain Scientific Laboratory

– NON-TRADITIONAL WEAPONS II

- 11509 - Aggressor Suppression via the Use of Non-Lethal Projectiles and Launcher Systems, Mr. Dan Hartman, GD-OTS
- 11697 - Netted Smart Precision Engagement Autonomous Rounds (NetSpears) for Navy and Army Weapons, Mr. Allan Vanuga, Raytheon Missile Systems
- 11781 - Gun-Launched Aerial Precision Munition, Mr. Jay Canela & Mr. Lloyd Khuc, U.S. Army RDECOM-ARDEC
- 11525 - Cannon Cluster Munition Replacement for 155mm Artillery Systems, Mr. Ryan Gorman, U.S. Army ARDEC
- 11644 - Determination of the Shelf Life of MEMS Navigation- Grade Sensors through Use of Accelerated Aging Principles, Mr. James Sarruda, U.S. Army ARDEC

Thursday, September 1, 2011

CONCURRENT SESSIONS

MONROE

– EMERGING TECHNOLOGIES: AMMUNITION

- 11581 - Precision Air Dropped Guided Munition (PADGM) System, Mr. Asad Khan, U.S. Army ARDEC
- 11759 - Scalable Airburst Fuze Technology—Shaping the Future, Mr. Paul Reynolds, GD-OTS, Marion
- 11790 - LW25 Programmable Air Burst Munitions, Mr. Donavan Gloude, ATK, Plymouth
- PRODAS GNC Trajectory System Simulation, Mr. Jeff Siewert, ArrowTech

– DIRECT FIRES II

- 11611 - USMC EFV Program Cartridge Qualification and Integration Program Status, Maj Ian McDuffie, USMC, PM AAA
- 11615 - 30mm MK317 TPDS-T Cartridge Development and Qualification, Mr. James McConkie, ND5, Office of the Program Manager
- 11758 - 30mm x 173 Ammunition Suite—The Appropriate Response for Any Target, Mr. Rick Wright, GD-OTS
- 11800 - LW30 Target Practice-Traced (TP-T) Ammunition, Mr. Kyle Nerison, ATK, Plymouth
- 11819 - 30 x 173mm TPDS-T Development, Mr. Donavan Gloude, ATK, Plymouth

TUTTLE

– PLATFORM & WEAPON SYSTEM INTEGRATION

- 11681 - Next-Gen Fire Control: Free Software & Video Game Math, Mr. Marc Santoro, NSWC Dahlgren
- 11777 - Development of a Moveable Weapon Mount System for the CH47 Helicopter, Mr. Michael Colonnello, U.S. Army ARDEC
- 11584 - Rapid Integration of the M197 onto the MH-60S, Mr. Joseph Burkart, NSWC Crane
- 11660 - Gun Weapon System (GWS) MK 48 for USCG Legends Class Cutters, Ms. Kaye Aswegan, NSWC Dahlgren

– ARMAMENT SUBSYSTEMS

- 11799 - Developing Reliable Software in a Rapid Deployment Product, Mr. Steve Gunderson, ATK, Plymouth
- 11823 - M197 Weapon Command and Control System for the MH-60S, Mr. William Reed, U.S. Navy
- 11804 - Pivoting Coupling—Army’s Greatest Invention, Mr. Steve Kotefski, Savit Corporation

NDIA
National Defense Industrial Association

PROMOTING NATIONAL SECURITY SINCE 1919

46TH ANNUAL GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

"Shaping Weapon Systems for Rapid Deployment: Development, Interoperability & Flexible Response"

AUGUST 29 -
SEPTEMBER 1, 2011

HYATT REGENCY MIAMI ▸ MIAMI, FLORIDA

WWW.NDIA.ORG/MEETINGS/1590

EVENT #1590

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ANNOUNCEMENT

The 46th Annual NDIA Armament Systems: Gun and Missile Conference and Exhibition will be held August 29-September 1, 2011 in Miami, Florida. The conference will address the theme, "Shaping Weapon Systems for Rapid Deployment: Development, Interoperability & Flexible Response." 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. Representatives of the U.S. and International defense communities including both goverment and industry members are invited to participate.

SESSION CHAIRS

Indirect Fires:
- Mr. John Altrichter, *BAE Systems*; Mr. Scott Martin, *Raytheon*

Modeling & Simulation I - Design
- Mr. Jeff Siewert, *Arrow Tech*; Ms. Shellie Clift, *NSWC-Dahlgren*

Emerging Technologies - Systems:
- Mr. Mark Serben, *U.S. Army ARDEC*; Mr. Joe Buzzett, *GD-OTS*

Modeling & Simulation II - Test Methods:
- Mr. Jeff Siewert, *Arrow Tech*

Requirements and Program Trends:
- Mr. Steve French, *BAE Systems;* Mr. Jay Brannam, *ATK*

Tactical Rockets and Missiles:
- Mr. Ed DePasqual, *Nammo Talley*; Mr. John Bednarz, *Raytheon*

Energetics I:
- Mr. Matt Solverson, *GD-OTS;* Mr. Ric Mutascio, *Esterline Defense Technologies*

Emerging Technologies - Materials & Processes:
- Mr. Bob Glantz, *ATK*; Mr. Jeff Caratelli, *Alcoa*

Energetics II:
- Mr. Matt Solverson, *GD-OTS;* Mr. Ric Mutascio, *Esterline Defense Technologies*

Modeling & Simulation III - Systems & Manufacturing
- Mr. Jeff Siewert, *Arrow Tech*; Mr. Steve Piper, *Piper Pacific*

Direct Fires I:
- Mr. Tony Gabriele, *Benet Labs*; Mr. Doug Wong, *PM-MAS*

Non-Traditional I:
- Mr. Scott Martin, *Raytheon*; Mr. Dave Panhorst, *U.S. Army ARDEC*

Precision Weapons:
- Mr. Bill Beard, *LMMFC;* Mr. Rollie Dohrn, *ATK*

Non-Traditional II:
- Mr. Scott Martin, *Raytheon*; Mr. Dave Panhorst, *U.S. Army ARDEC*

Emerging Technologies - Ammunition:
- Mr. Mark Serben, *U.S. Army ARDEC*; Mr. Joe Buzzett, *GD-OTS*

Platform & Weapon System Integration:
- Mr. Rob Brewer, *NAVAIR*; Mr. Greg Hill, *Meggitt Defense Systems*

Direct Fires II:
- Mr. Tony Gabriele, *Benet*; Mr. Doug Wong, *PM-MAS*

Armament Subsystems:
- Mr. Steve Kelley, *BAE Systems*; Mr. Greg Hill, *Meggitt Defense Systems*

Poster Sessions:
- Mr. Rob Brewer, *NAVAIR*

ATTENDEE INFORMATION

REGISTRATION

CONFERENCE REGISTRATION FEES	EARLY (ON/BEFORE 2/19)	REGULAR (2/20-8/19)	LATE (AFTER 8/19)
GOVERNMENT/ ACADEMIA/ALLIED GOV.	$720	$800	$880
INDUSTRY NDIA MEMBER	$820	$900	$990
INDUSTRY NON-NDIA MEMBER	$900	$990	$1,090

Register online at the event website: www.ndia.org/meetings/1590

Mail Registration To:
NDIA - Event #1590
2111 Wilson Boulevard, Suite 400
Arlington, VA 22201

Fax Registration to: (703) 522-1885
Please do not fax or mail any registration forms after August 19, 2011

Cancellation Policy: All cancellations on or before August 19, 2011 will receive a refund minus a cancellation fee of $75. Refunds will not be given for cancellations after August 19, 2011. Please be sure you are registering with the correct credit card or form of payment, as a $25 fee will be applied to registrations switching credit cards or forms of payment. Substitutions welcome in lieu of cancellations! Please make your cancellation or substitution in writing to Allison Doherty at adoherty@ndia.org.

HOTEL INFORMATION

A block of rooms has been reserved at the Hyatt Regency Miami. In order to ensure the discounted rate, you must make your reservations early and ask for the National Defense Industrial Association (NDIA) room block. Rooms will not be held after Saturday, March 19, 2011 and may sell out before then. Rates are also subject to change after this date.

Hyatt Regency Miami
400 SE Second Avenue
Miami, Florida 33131

To make your reservation, please call the hotel directly at (305) 358-1234.

- Industry Rate - $149 (single/double)
- Government Rate* - $104 (single/double) or the prevailing government per diem

Note: The government per diem rate is available only to active duty or civilian government employees. ID will be required upon check-in.

Any active U.S. Military attendee with ID and travel order will be tax exempt (subject to state's regulation of tax exemption). Any U.S. Government employee paying with U.S. Government check or credit card will be tax exempt (with supporting documentation as required by some states). Check with the hotel for specific state and local requirements when booking hotel reservations.

ATTIRE

During conference registration and check in, each participant will be issued an identification badge. Please be prepared to present picture ID. Badges must be worn at all conference functions. Appropriate dress for this conference is business casual for civilians and Class B uniform or uniform of the day for military.

SPECIAL NEEDS

NDIA supports the Americans with Disabilities Act of 1990. Attendees with special needs should contact Ms. Allison Doherty, Meeting Planner, NDIA, at adoherty@ndia.org.

TRAVEL INFORMATION

From Miami International Airport (8 miles)
Take 836 East, go through tolls and stay to right side. Take I-95 South Exit - Downtown. Once on I-95, stay in left hand lane and take Exit 2A / Biscayne Boulevard. Stay in right hand lane at the end of the ramp, the hotel will be on your immediate right side.

Super Shuttle service from Miami International Airport: (fees apply): 24 hour service to hotel. $18.00 per person. The Super Shuttle station is located at the Van/Limo booth directly outside of the lower level baggage claim area near curbside pick-up.

Taxi from Miami International Airport: Approximately $20.00-$25.00 one-way.

PARKING

Valet parking charges: 0-2 hours $10.00, 2-3 hours $12.00, 3-4 hours $16.00, 4-5 hours $20.00, overnight $30.00. Valet parking charges include in and out privileges. No vans, trucks or large vehicles.

Self parking: $12.75 with a validation sticker provided by the front desk staff upon request for the discounted rate. Self parking is in a garage with no in/out privilege.

MONDAY, AUGUST 29, 2011

10:00 AM - 3:00 PM	**EXHIBITOR MOVE-IN — RIVERFRONT HALL**
12:00 PM - 5:00 PM	**REGISTRATION — LOWER PROMENADE**
2:00 PM - 4:00 PM	**TUTORIALS**

2:00 PM - 3:00 PM	**TUTORIAL A - TUTTLE** **"Legislative Update"** Mr. Pete Steffes, *Vice President, Government Policy, NDIA*
3:00 PM - 4:00 PM	**TUTORIAL B - TUTTLE** **"Ready or not? Using Readiness Levels to Reduce Risk on the Path to Production"** Mr. Dan Chien, *Vice President, Engineering, General Dynamics Armament and Technical Products*

5:00 PM - 6:00 PM **WELCOME RECEPTION IN EXHIBIT HALL**

TUESDAY, AUGUST 30, 2011

7:00 AM - 5:00 PM **REGISTRATION — LOWER PROMENADE**

7:00 AM - 8:00 AM **CONTINENTAL BREAKFAST — REGENCY BALLROOM PREFUNCTION**

8:00 AM - 8:15 AM **WELCOME REMARKS & CONFERENCE OVERVIEW — TUTTLE/MONROE BALLROOM**

- Mr. Sam Campagna, *Assistant Vice President, Operations, NDIA*
- Mr. Jim Talley, *NDIA Conference Chair; General Dynamics Armament and Technical Products, Inc.*
- Mr. Steve French, *NDIA Gun & Missile Committee Chair; BAE Systems*

8:15 AM - 8:30 AM **DIVISION UPDATE/2012 JOINT ARMAMENTS SYMPOSIUM**

- Mr. Dave Broden, *NDIA Armaments Division Chair; Broden Resource Solutions*

8:30 AM - 9:00 AM **KEYNOTE ADDRESS:**
"Air and Missile Defense Overview"

- BG Ole Knudson, USA, *Program Executive Officer, Missile and Space, U.S. Army*

9:00 AM - 9:30 AM **KEYNOTE ADDRESS:**
"Close Air Support and Joint Operations"

- Mr. Andrew K. Balding, *Associate, Booz Allen Hamilton*

9:30 AM - 10:00 AM **KEYNOTE ADDRESS:**
"The Role of the Government Laboratory in Shaping Weapon Systems Development; An ARDEC Perspective"

- Mr. Anthony J. Sebasto, *Senior Associate for Munitions, U.S. Army ARDEC*

10:00 AM - 6:30 PM **EXHIBIT HALL OPEN - RIVERFRONT HALL**

10:00 AM - 10:35 AM **BREAK IN EXHIBIT HALL**

10:35 AM - 12:15 PM **CONCURRENT SESSIONS**

	MONROE **INDIRECT FIRES**	**TUTTLE** **MODELING & SIMULATION I - DESIGN**
10:35 AM - 10:55 AM	11503 - **An Analysis of the Indirect Fires Portfolio of Munitions** Mr. Jim Rodrigue, *Raytheon Land Combat*	11791 - **Gun Launch Dynamics Modeling—Benchmarking the State of the Art** Mr. Rollie Dohrn, *ATK, Plymouth*
10:55 AM - 11:15 AM	11830 - **Development of an Extended Range, Large Caliber, Modular Payload Projectile** Mr. Pierre-Antoine Rainville, *GD-OTS, Canada*	**Guided Projectile Simulation** Mr. Jeff Siewert, *Arrow Tech*
11:15 AM - 11:35 AM	11528 - **XM1128 155mm Insensitive Munition (IM) High Explosive (HE) Extended Range Artillery Projectile** Mr. Ductri Nguyen, *U.S. Army ARDEC*	11774 - **Gun Launch Dynamics and Aeroballistic Analysis via Onboard Laser Diode** Mr. Rollie Dohrn, *ATK, Plymouth*
11:35 AM - 11:55 AM	11463 - **155mm HE Projectile Qualification Program** Mr. Charlie Patel, *U.S. Army ARDEC*	**GD-OTS/Nammo 25 mm JSF Combat Ammunition** Mr. Zack Kemp, *GD-OTS*
11:55 AM - 12:15 PM	11511 - **Technologies Utilizing the M483 Carrier** Mr. George Kurzik, *GD-OTS, Red Lion*	11824 - **Design, Analysis and Weight Optimization Techniques for Joint Strike Fighter Missionized Gun Pod Support Equipment** Mr. Gary Miller, *GD-ATP*

12:15 PM - 1:30 PM **LUNCHEON SPEAKER**

"Changes in the World of ITAR"

- Mr. Larry Christensen, *Miller Chevalier Chartered*

1:30 PM - 2:50 PM **CONCURRENT SESSIONS**

	MONROE **EMERGING TECHNOLOGIES: SYSTEMS**	**TUTTLE** **MODELING & SIMULATION II: TEST METHODS**
1:30 PM - 1:50 PM		11692 - **AFRL Munitions Directorate Fuze Experimentation Research Activities** Mr. Scott Turner, *AF Munitions Directorate, Eglin AFB*

1:50 PM - 2:10 PM	11586 - **Introduction of Wireless and MEMs based Devices into Fire Control Systems** Mr. Ralph Tillinghast, *U.S. Army ARDEC*	11838 - **A Method for Assessing the Effects of Overpressure from Small/Medium Caliber Weapons Fire** Mr. Steven Backer, *NSWC-Crane*
2:10 PM - 2:30 PM	11641 - **Extended Area Protection and Survivability Program (EAPS)** Mr. Manfredi Luciano, *U.S. Army ARDEC*	11793 - **The Challenge of Environmental Testing of the Expeditionary Fighting Vehicle Ammunition Feed System Separate from the Expeditionary Fighting Vehicle** Mr. Ron Hopkins, *GDATP*
2:30 PM - 2:50 PM	11720 - **Development of the Interceptor System for the Extended Area Protection & Survivability (EAPS)** Mr. E. Mitchell Danielson, *ATK, Plymouth*	11668 - **Design and Fabrication of a Novel High-g Soft Recovery System for 155mm Precision Munitions and Components** Mr. Greg Hader, *U.S. Army ARDEC*

2:50 PM - 3:30 PM **BREAK IN EXHIBIT HALL**

3:30 PM - 5:10 PM **CONCURRENT SESSIONS**

	MONROE **REQUIREMENTS & PROGRAM TRENDS**	**TUTTLE** **TACTICAL ROCKETS & MISSILES**
3:30 PM - 3:50 PM	11786 - **Naval Forces Capabilities Gap Against Swarm Attacks** Mr. Andrew Bradick, *Rheinmetall*	11808 - **Design Synthesis for Large Shaped Charges: From Requirements to Qualification** Mr. Jason Shire, *Raytheon*
3:50 PM - 4:10 PM	11861 - **U.S. Forces Light and Medium Mortar Ammunition Insensitive Munitions Path** Mr. Nick Baldwin, *U.S. Army RDECOM-ARDEC*	11842 - **Advanced Aluminum Alloys Enabling High Performance Missile Components** Mr. Travis Schmidt, *Alcoa*
4:10 PM - 4:30 PM	11863 - **IM Compliance for Mortar Illumination Cartridges** Mr. Thomas Peter, *U.S. Army RDECOM-ARDEC*	11802 - **Use of COTS O-rings as a Pyrotechnic Safety Barrier in a Rocket Motor Ignition Safety Device** Mr. Brian Erickson, *ATK, Plymouth*
4:30 PM - 4:50 PM	11482 - **Precision Guided Indirect Munitions — Operational Evolution** Mr. Justin Skaret, *Raytheon Missile Systems*	11756 - **Hellfire Integrated Blast Fragmentation Sleeve Multipurpose Warhead** Mr. Jonathan Thomas, *GD-OTS*
4:50 PM - 5:10 PM	11792 - **Enhancing Convoy Security by Means of Rapid Deployable Weapons** Mr. Gerrie Van der Merwe, *BAE Land Systems, South Africa*	

5:10 PM - 6:30 PM **RECEPTION IN EXHIBIT HALL**

WEDNESDAY, AUGUST 31, 2011

7:00 AM - 5:00 PM — **REGISTRATION**

7:00 AM - 8:10 AM — **CONTINENTAL BREAKFAST**

8:10 AM - 9:30 AM — **CONCURRENT SESSIONS**

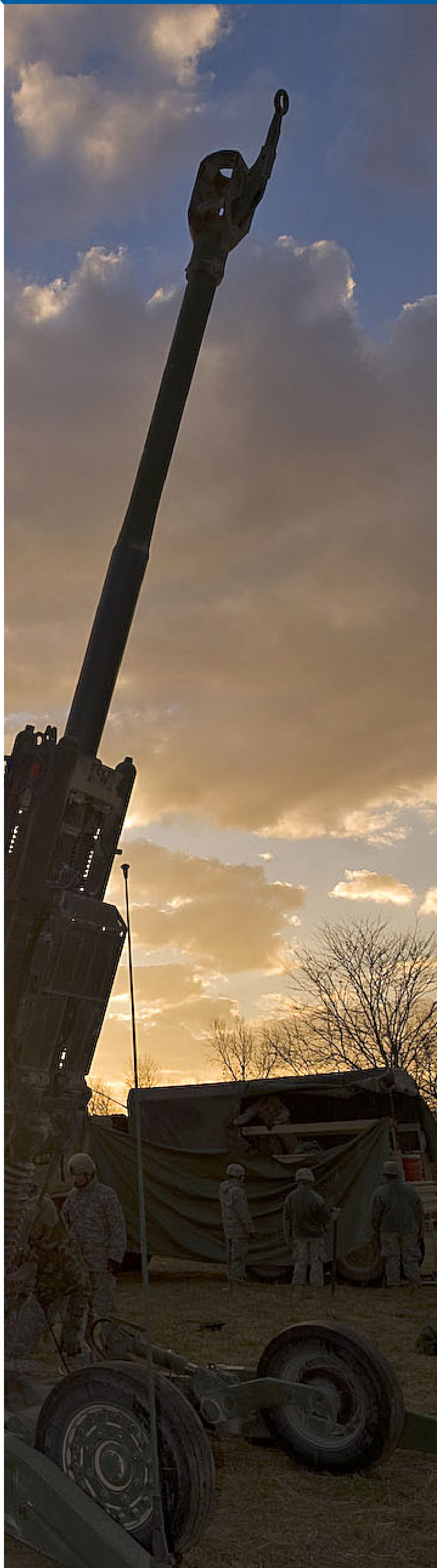
	MONROE ENERGETICS I	TUTTLE EMERGING TECHNOLOGIES: MATERIALS & PROCESSES
8:10 AM - 8:30 AM	11822 - **Novel ARDEC Igniters for Gun Systems** Dr. Eugene Rozumov, *U.S. Army ARDEC*	11813 - **Potting of Electronic Components for High-G Gun Environments** Dr. Peter Vo, *Raytheon Missile Systems*
8:30 AM - 8:50 AM	11787 - **The Effects of Igniter Design on the Interior Ballistic Performance of Deterrent Coated Propellants** Dr. Thelma Manning, *U.S. Army RDECOM-ARDEC*	11829 - **Investment Cast Titanium in Gun and Missile Systems** Mr. Chris Jensen, *Alcoa Howmet*
8:50 AM - 9:10 AM	11590 - **Foamed Celluloid Technology** Mr. Mohammed Elalem, *U.S. Army ARDEC*	11583 - **New PVD Processes for Durable Pollution-Free Ordnance** Dr. Sabrina Lee, *U.S. Army ARDEC*
9:10 AM - 9:30 AM		12179 - **The "Perfect" Time for an Upgrade to US Propellant** Ms. Kelly Moran, *ATK, Radford*

9:30 AM - 3:30 PM — **EXHIBIT HALL OPEN**

9:30 AM - 10:15 AM — **BREAK IN EXHIBIT HALL**

10:15 AM - 11:55 AM — **CONCURRENT SESSIONS**

	MONROE ENERGETICS II	TUTTLE MODELING & SIMULATION III: SYSTEMS & MANUFACTURING
10:15 AM - 10:35 AM	11867 - **IM in the Field—Experience of Reduced Sensitivity Mortar Cartridges to Actual Combat Threat Stimuli** Ms. Pamela Ferlazzo, *U.S. Army RDECOM-ARDEC*	11648 - **System Analysis with Integrated Modeling and Optimization** Mr. Philip Brislin, *U.S. Army ARDEC RDAR-MEM-L*



THE TRIFILETTI AWARD

The Trifiletti Award is presented by the NDIA Gun & Missile Executive Committee to recognize and honor an individual who has made a significant contribution benefiting the warfighter, thus strengthening national defense. This contribution can be in the areas of the advancement of technology, systems, system integration or to someone who through his/her work provided unique leadership resulting in changes and progress in the community.

The award is named in honor of Mr. Robert Trifiletti who made significant contributions to the advancement of technology, and by whose leadership many other accomplishments benefiting the warfighter came to fruition. The award is open to anyone in the gun and ammunition or rocket and missile community.

MILITARY OPERATIONS AWARD

The Military Operations Award is presented to recognize an individual, crew or unit who in the opinion of the NDIA Gun & Missile Executive Committee has made significant contributions in operational employment, tactics or combat applications of guns and ammunition and/or rockets and missiles which have impacted the readiness, capabilities or results of U.S. military activity. A significant contribution is considered to be superior performance in an operational environment, development of tactics, training or leadership.

10:35 AM - 10:55 AM	11537 - **Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications** Mr. Virgil Fung, *BAE Systems Ordanance Systems Inc.*	11502 - **A Virtual Learning Environment for Precision Indirect Fires** Mr. Jon Peoble, *Raytheon*
10:55 AM - 11:15 AM	11832 - **Development and Characterization of IM Gun Propellant for the 120mm Tank System** Mr. Duncan Park, *U.S. Army RDECOM-ARDEC*	11779 - **Next Generation Manufacturing & Modeling Technology** Mr. David Smith, *U.S. Army Benet Laboratories*
11:15 AM - 11:35 AM	11821 - **The Advance Case System (ACS) Program for 120mm Tank Training Ammo-Phase 2** Mr. Jeff Berg, *ATK, Plymouth*	
11:35 AM - 11:55 AM	11761 - **High Explosives Charges for Insensitive Artillery and Mortar Ammunitions: Performances, Technology, Producibility, Affordability** Dr. Bernard Zeller, *SNPE*	

11:55 AM - 1:15 PM **AWARDS LUNCH**

1:15 AM - 2:35 PM **CONCURRENT SESSIONS**

	MONROE DIRECT FIRES I	TUTTLE NON-TRADITIONAL WEAPONS I
1:15 PM - 1:35 PM	11747 - **Direct Fires & Precision Weapons for Rapid Deployment at the Modern Battlefield** Mr. Danny Schirding, *Israel Military Industries, Ltd.*	11840 - **Development of a Large Caliber Naval EM Railgun** Mr. Roger Ellis, *Office of Naval Research*
1:35 PM - 1:55 PM	11725 - **Medium Calibre Goes in a New Direction** Mr. David Leslie, *BAE Systems Global Combat Systems*	11841 - **Electromagnetic Railgun, a Multi-Mission Weapon System** Mr. Alan Kull, *General Atomics*
1:55 PM - 2:15 PM	11572 - **The Development and Testing of the Improved Kinetic Energy Electronic Time (IKE-ET) Round** Mr. Geoffrey Bland, *NSWC-Dahlgren*	11828 - **Scalable Gen-Set for Directed Energy Weapons: Resolving the Power Problem** Mr. Bryan Bockmon, *Rocky Mountain Scientific Laboratory*
2:15 PM - 2:35 PM	11809 - **Composite Sabot Technology for the 105mm Rifled Tank Gun System** Mr. Velan Mudaliar, *U.S. Army RDECOM-ARDEC*	

2:35 PM - 2:55 PM **BREAK IN EXHIBIT HALL**

3:00 PM - 7:00 PM **EXHIBIT HALL CLOSES & EXHIBITOR MOVE OUT**

2:55 PM - 4:55 PM **CONCURRENT SESSIONS**

	MONROE PRECISION WEAPONS	TUTTLE NON-TRADITIONAL WEAPONS II
2:55 PM - 3:15 PM	11810 - **Inherent Reliability and Affordability of Ballistic Solutions and Their Operational Benefits** Mr. Larry Linde, *ATK, Plymouth*	11805 - **Electronic Ballistics Systems: A Scalable Integrated Weapons Systems with Applications Footprint for Fixed and Mobile Platforms and Delivery of Same Caliber Lethal and Non-Lethal Munitions or Payloads** Mr. George Orrison, *Metal Storm Inc.*
3:15 PM - 3:35 PM	11719 - **Common GPS: Development of the Subsystem Specification and ICD for the Common GPS Subsystem for the Family of Precision Guided Projectiles** Dr. Karl Flueckiger, *Draper Laboratory*	11509 - **Aggressor Suppression via the Use of Non-Lethal Projectiles and Launcher Systems** Mr. Dan Hartman, *GD-OTS*
3:35 PM - 3:55 PM	11635 - **Very Affordable Precision Projectile (VAPP) System and Flight Experiments** Mr. Christopher Stout, *U.S. Army ARDEC*	11697 - **Netted Smart Precision Engagement Autonomous Rounds (NetSpears) for Navy and Army Weapons** Mr. Allan Vanuga, *Raytheon Missile Systems*
3:55 PM - 4:15 PM	11459 - **Evolution of the EXCALIBUR Guided Projectile** Mr. Chris Geswender, *Raytheon Missile Systems*	11781 - **Gun-Launched Aerial Precision Munition** Mr. Jay Canela & Mr. Lloyd Khuc, *U.S. Army RDECOM-ARDEC*
4:15 PM - 4:35 PM	11526 - **Precision Urban Mortar Attack (PUMA)** Mr. Luke Steelman, *NSWC-Dahlgren*	11525 - **Cannon Cluster Munition Replacement for 155mm Artillery Systems** Mr. Ryan Gorman, *U.S. Army ARDEC*
4:35 PM - 4:55 PM	11788 - **Leveraging Proven Systems to Develop a Guided Mortar for APMI** Mr. Nicholas Ward, *ATK, Plymouth*	11644 - **Determination of the Shelf Life of MEMS Navigation-Grade Sensors through Use of Accelerated Aging Principles** Mr. James Sarruda, *U.S. Army ARDEC*

4:55 PM **ADJOURN**

THURSDAY, SEPTEMBER 1, 2011

7:00 AM - 12:00 PM **REGISTRATION**

7:00 AM - 8:00 AM **CONTINENTAL BREAKFAST**

8:00 AM - 10:00 AM **CONCURRENT SESSIONS**

	MONROE **EMERGING TECHNOLOGIES: AMMUNITION**	**TUTTLE** **PLATFORM & WEAPON SYSTEM INTEGRATION**
8:00 AM - 8:20 AM	11581 - **Precision Air Dropped Guided Munition (PADGM) System** Mr. Asad Khan, *U.S. Army ARDEC*	11681 - **Next-Gen Fire Control: Free Software & Video Game Math** Mr. Marc Santoro, *NSWC-Dahlgren*
8:20 AM - 8:40 AM	11759 - **Scalable Airburst Fuze Technology—Shaping the Future** Mr. Paul Reynolds, *GD-OTS, Marion*	11777 - **Development of a Moveable Weapon Mount System for the CH47 Helicopter** Mr. Adam Jacob, *U.S. Army ARDEC*
8:40 AM - 9:00 AM	11790 - **LW25 Programmable Air Burst Munitions** Mr. Donavan Gloude, *ATK, Plymouth*	11584 - **Rapid Integration of the M197 onto the MH-60S** Mr. Joseph Burkart, *NSWC-Crane*
9:00 AM - 9:20 AM		11660 - **Gun Weapon System (GWS) MK 48 for USCG Legends Class Cutters** Ms. Kaye Aswegan, *NSWC-Dahlgren*
9:20 AM - 9:40 AM	11784 - **Non-Traditional Impact Detection Using Triboluminescence** Mr. William Hollerman, *University of Louisiana at Lafayette*	1869 - **Digitized M119A2 105mm Howitzer** Mr. John Allen, *U.S. Army ARDEC*

9:40 AM - 10:00 AM **BREAK**

10:00 AM - 12:20 PM **CONCURRENT SESSIONS**

	MONROE DIRECT FIRES II	TUTTLE ARMAMENT SUBSYSTEMS
10:00 AM - 10:20 AM	11611 - **USMC EFV Program Cartridge Qualification and Integration Program Status** Maj Ian McDuffie, USMC, *PM AAA*	11799 - **Developing Reliable Software in a Rapid Deployment Product** Mr. Steve Gunderson, *ATK, Plymouth*
10:20 AM - 10:40 AM		11775 - **Development of a Field Inspection Vehicle Designed to Autonomously Analyze Large-Bore Tubes for Fatigue and Wear** Mr. Cory Mettler, *American Science & Technology*
10:40 AM - 11:00 AM	11615 - **30mm MK317 TPDS-T Cartridge Development and Qualification** Mr. James McConkie, *ND5, Office of the Program Manager*	11823 - **M197 Weapon Command and Control System for the MH-60S** Mr. William Reed, *U.S. Navy*
11:00 AM - 11:20 AM	11839 - **Rheinmetall 30mm x 173 Weapon Systems: Two Guns, Two Solutions** Mr. Stephan Kerk, *Rheinmetall Waffe Munition*	11804 - **Pivoting Coupling—Army's Greatest Invention** Mr. Steve Kotefski, *Savit Corporation*
11:20 AM - 11:40 AM	11837 - **The Rheinmetall 30mm x 173 Ammunition Family: Lethality and Urban Effectiveness** Mr. Stephan Kerk, *Rheinmetall Waffe Munition*	
11:40 AM - 12:00 PM	11758 - **30mm x 173 Ammunition Suite—The Appropriate Response for Any Target** Mr. Rick Wright, *GD-OTS*	
12:00 PM - 12:20 PM	11800 - **LW30 Target Practice-Traced (TP-T) Ammunition** Mr. Kyle Nerison, *ATK, Plymouth*	

12:20 PM **CONFERENCE ADJOURNS**

PROCEEDINGS

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.

ABSTRACT ID	ABSTRACT TITLE	ADDITIONAL AUTHORS
11463	IM testing and Initiation Trials of the IMX-101 Explosive in the M795 projectile	Mr. Philip Samuels, Mr. Anthony Di Stasio, Mr. Ductri Nquyen
11482	Precision Guided Indirect Munitions – Operational Evolution	Mr. Conan Davis
11502	A Virtual Learning Environment for Precision Indirect Fires	Mr. Jim Rodrigue
11503	An Analysis of the Indirect Fires Portfolio of Munitions	Mr. Jon Peoble
11506	Advanced Cannon Bore Cleaning System	Mr. Jonghyun Shim, Mr. Seil Jeon
11509	Aggressor Suppression via the Use of Non-Lethal Projectiles and Launcher Systems	Mr. Dan Hartman, Mr. Steve Broussard
11528	XM1128 155mm Insensitive Munition (IM) High Explosive (HE) Extended Range Artillery Projectile	Mr. John Magrogan
11537	Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications	Mr. Brian Alexander, Mr. Mike Ervin, Mr. Philip Samuels, Mr. Charlie Patel
11572	The Development and Testing of the Improved Kinetic Energy Electronic Time (IKE-ET) Round	Mr. James Barnes, Mr. Todd Cloutier
11581	Precision Air Dropped Guided Munition (PADGM) System	Mr. Marc Ritt
11583	New PVD Processes for Durable Pollution-Free Ordnance Based on Ionized PVD Technology	Mr. Dan Schmitt, Mr. Fang Yee, Mr. Mick Cipollo
11586	Introduction of Wireless and MEMs Based Devices into Fire Control Systems	Mr. Michael Wright
11609	30MMX173 310 MOD 0 PABM-T Cartridge Qualification Program	Mr. Jay Fitzsimmons
11644	Determination of the Shelf Life of MEMS Navigation-Grade Sensors Through Use of Accelerated Aging Principles	Mr. Scott Gift
11657	Modeling of the Autofrettage Processes of a Gun Barrel	Mr. Sudhir Puttagunta, Mr. Chandra Penumarthy
11668	Design and Fabrication of a Novel High-g Soft Recovery System for 155mm Precision Munitions and Components	Mr. Nigel Gray, Mr. Brian DeFranco, Mr. Donald Carlucci
11670	Versatile Electromagnetic Mortar Launcher for the JLTV-B	Mr. Ronald Kaye, Mr. Steven Dron
11681	Next-Gen Fire Control: Free Software & Video Game Math	Mr. Anthony D'Alessandro
11692	AFRL Munitions Directorate Fuze Experimentation Research Activities	Mr. James Cross, Mr. Don Clabaugh
11697	Netted Smart Precision Engagement Autonomous Rounds (NetSpears) for Navy and Army Weapons	Mr. Sam Ghaleb, Mr. Mark Elkanick
11719	Common GPS: Development of the Subsystem Specification and ICD for the Common GPS Subsystem for the family of Precision Guided Projectiles	Mr. Paul Manz, Mr. Brian London Mr. Tim Easterly
11761	High Explosives Charges for Insensitive Artillery and Mortar Ammunitions: Ferformances, Technology, Producibility, Affordability	Mr. Jacques Cardin, Mr. Pierre Vignaud
11775	Development of a Field Inspection Vehicle Designed to Autonomously Analyze Large-Bore Tubes for Fatigue and Wear	Mr. John Duffy, Mr. Jesse VanOverbeke, Dr. Fereidoon Delfanian
11781	Gun-Launched Aerial Precision Munition	Mr. Daniel Vo, Mr. Hjalmar Canela, Mr. Lloyd Khuc
11784	Non-Traditional Impact Detection Using Triboluminescence	Dr. Shawn Goedeke, Mr. Ross Fontenot, Mrs. Kamala Bhat, Mr. Brady Broussard
11787	The Effects of Igniter Design on the Interior Ballistic Performance of Deterrent Coated Propellants	Dr. Eugene Rozumov, Mr. Carlton Adam, Mr. Duncan Park, Dr. Joseph Laquidara
11790	LW25 Programmable Air Burst Munitions	Mr. Erik Elmer
11791	Gun Launch Dynamics Modeling – Benchmarking the State of the Art	Dr. Donald Carlucci, Dr. James Newill
11802	Use of COTS O-rings as a Pyrotechnic Safety Barrier in a Rocket Motor Ignition Safety Device	Mr. Tom Larson

11807	Using JLOC (GPS Jammer Detection and Location System) to Improve the Effectiveness of Mission Planning for GPS Guided Weapons and to Support Flexible Response	Mr. Rick Edwards
11809	Composite Sabot Technology for the 105MM Rifled Tank Gun System	Mr. Saif Musalli, Dr. William Drysdale, Mr. Michael Minnicino
11811	Cartridge Case Venting Technologies, 25mm M910 Ctg Test Vehicle	Mr. Philip Abbate
11814	Structural Integrity Evaluation of Composite Cylinders	Mr. Ajay Srinivasa, Dr. Fereidoon Delfanian
11819	30mm Target Practice Discarding Sabot, Traced (TPDS-T) Ammunition Development	Mr. Don Gloude
11822	Novel ARDEC Igniters for Gun Systems	Dr. Thelma Manning, Dr. Joseph Laquidara, Mr. Duncan Park, Dr. Kimberly Chung
11823	M197 Weapon Command and Control System for the MH-60S	Mr. Alan Ford, Mr. John Proctor
11828	Scalable Gen-Set for Directed Energy Weapons: Resolving the Power Problem	Mr. Travis Swanson
11829	Investment Cast Titanium in Gun and Missile Systems	Mr. Eric Foos, Mr. David Lee
11832	Development and Characterization of IM Gun Propellant for the 120mm Tank System	Mr. Sam Moy, Dr. Thelma Manning Mr. Donald Chiu, Dr. Eugene Rozumov
11837	The Rheinmetall 30mm x 173 Ammunition Family: Lethality and Urban Effectiveness	Mr. Brian Sullivan
11839	Rheinmetall 30mm x 173 Weapon Systems: Two Guns, Two Solutions	Mr. Brian Sullivan
11840	Development of a Large Caliber Naval EM Railgun	Mr. Ryan Hoffman
11841	Electromagnetic Railgun, A Multi-Mission Weapon System (Non-Traditional Armaments Category)	Mr. Thomas Hurn
11842	Advanced Aluminum Alloys Enabling High Performance Missile Components	Mr. Les Yocum, Mr. Dustin Bush, Mr. Jeff Caratelli
11861	US Forces Light and Medium Mortar Ammunition Insensitive Munitions Path	Mr. Roger Wong, Mr. John Niles, Mr. William Kuhnle, Mr. Rei Martinez
11863	IM Compliance for Mortar Illumination Cartridges	Mr. Eli Martinez, Mr. John Niles, Mr. Sal Ghazi, Mr. Jeffrey Smith
11867	IM in the Field – Experience of Reduced Sensitivity Mortar Cartridges to Actual Combat Threat Stimuli	Mr. Roger Wong, Mr. John Niles, Mr. William Kuhnle, Mr. Jeffrey Smith
11869	Digitized M119A2 105mm Howitzer	Mr. Ray Espinosa, Mr. Jose Santiago, Mr. Norm Lionetti
11877	Acoustic Emissions Measured on the Outer Portion of a Composite Barrel	Ms. Rushie Ghimire

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10:00 AM – 3:00 PM (Must be set by 3:00 PM)

Show Hours:
Monday, August 29, 2011
5:00 PM - 6:00 PM (Opening Reception in Exhibit Hall)

Tuesday, August 30, 2011
10:00 AM - 5:00 PM (Breaks in Exhibit Hall)

Tuesday Night Reception
5:00 PM - 6:30 PM Reception in Exhibit Hall)

Wednesday, August 31, 2011
9:30 AM - 3:30 PM (Breaks in Exhibit Hall)

Move Out:
Wednesday, August 31, 2011
3:00 PM - 7:00 PM

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"Shaping Weapon Systems for Rapid Deployment: Development, Interoperability & Flexible Response"

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Raytheon

Customer Success Is Our Mission

Presentation for the 46th Annual Guns and Missiles Conference

Development History and Evolution of the XM982 Excalibur

Chris E. Geswender
cegeswender@raytheon.com
David Brockway
dabrockway@raytheon.com

April 13, 2011

NOTE — All equations, weapon descriptions and equipment-specific information are from open (Internet) sources without correlation to U.S. products to avoid ITAR or classification issues.

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EXCALIBUR

Contains Excalibur Technical Data Approved for Public Release. PAO Log 36-11

Raytheon
Missile Systems

Excalibur Description

- GPS-guided, extended-range 155 mm artillery projectile
- Precision and accuracy — consistently within 10 meters
  - Minimizes collateral damage and risk to civilians
  - Employment flexibility — close support missions
  - Achieves target effects with fewer rounds
- Steep terminal approach angle — optimizes unitary effects
  - Ideal for urban, complex and mountainous terrain
- Significant maneuverability — supports offset firing
- Integral multi-option fuze — point detonate, delay and HOB
- U.S. and Sweden international cooperative program
- Initial capability (XM982 Ia-1) — fielded to deployed forces in 2007
- Fully ORD-compliant — M982 Ia-2 pending full-rate production
- Low cost — M982E1 Ib in final design and qualification phase
- Exportable since 2008 — Excalibur Ia FMS cases in progress
- Current platforms
  - M777
  - M109A6
  - M198
  - FH77BW
  - AS90 (limited qual)


M109A6 Paladin — U.S. Army


M777 — U.S. Army, USMC, Canada


FH77BW Archer — Sweden


AS90 — U.K.


M198 — Australia

Responsive, accurate and lethal precision effects

EXCALIBUR

IRAQ Urban Combat Experience — Avoiding Collateral Damage

Raytheon
Missile Systems

Warfighter perspective on Excalibur

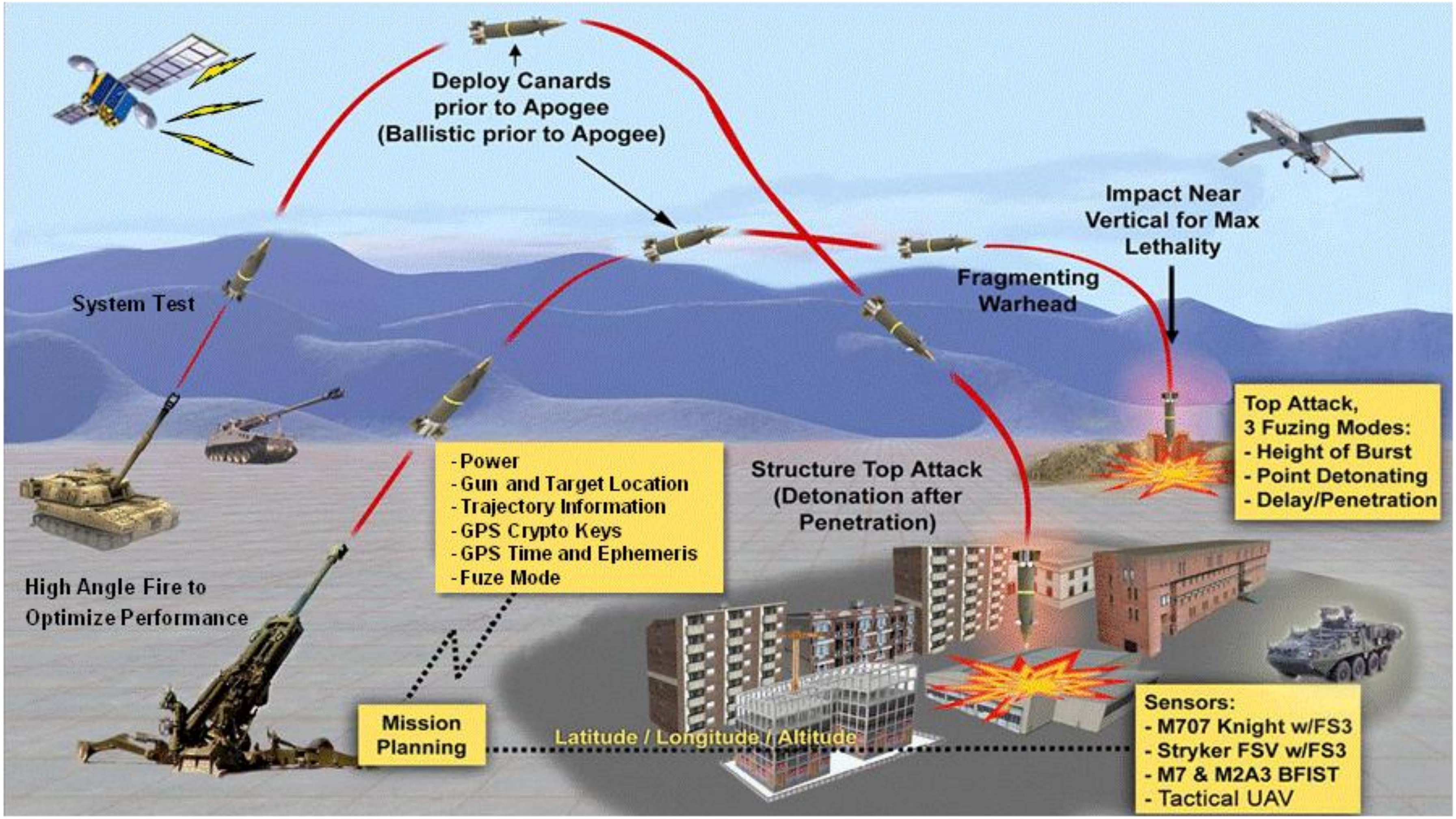
- More responsive than air-delivered assets — “Every soldier and Marine has access because the artillery directly supports every battalion and company in contact”

- “Incredibly accurate … at its minimum/maximum range, you get that same level of accuracy”
- Easy to use — “Firing Excalibur was similar, if not easier, than firing conventional artillery”

Saving lives today — “The unit was able to fire an artillery round at a target within 50 meters of infantrymen on the ground. If we did not have Excalibur, we would not have been able to engage that target."

EXCALIBUR

Operational Concept



Excalibur Warfighter Rationale

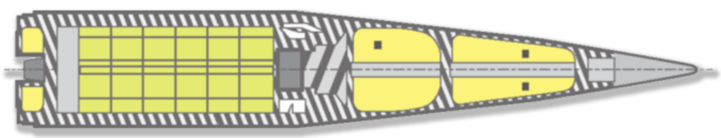
- Extended-range fire extends maneuver's tactical reach
- Range-independent ten-meter Radial Miss Distance and off-axis capability increase operational flexibility
- Close-combat capability reduces risk to friendly forces while protecting civilians and minimizing collateral damage
- Near-vertical terminal attack angle permits urban and complex terrain uses
- Concrete penetration, integrated multiple-mode fuze, scalable effects — expands cannon artillery target set
  - Point detonate, Delay, Height of burst
- Fewer rounds to achieve target effects — minimizes logistics burden
- Minimal change to unit-level training and TTP

Autonomous, all-weather, day and night — responsive, organic firing capability

Approved for Public Release. PAO Log 36-11

Original Excalibur Concept Was a Radical Departure From Initial Army Plans

Raytheon Missile Systems



- Government design (ARDEC)
- LCCM guidance
- Tractor rocket motor
- IMU — N/A
- GPS — unknown
- Warhead(s)
  - XM-80 bomblets
  - One SADARM

- Fixed tail
- CAS — two axis
- IMU — FOG
- GPS — IEC
- Payloads via Block Insertions
  - DPICM – changed to Unitary warhead in ‘01
  - Smart sub-munition – 2 SFMs (SADARM)
  - Discriminating munition
- No propulsion

www.globalsecurity.org/military/systems/munitions/images/

120.10 Non Technical Data as defined under ITAR

Designing for Operational Challenges

- Gun hardening
  - Multiple charges
    - Angular acceleration variation (also a worn gun barrel issue)
    - Muzzle exit over pressure decay profile
    - Variable spin rate at tail fin deployment
    - Effective gas flow, engraving
  - Muzzle brakes
  - Ramming/handling
- Operational
  - EPIAFS
    - Carrier frequency
    - Message protocol
  - Integration with AFATDS
  - 20-year storage life
  - Handling
  - Training

120.10 Non Technical Data as defined under ITAR

Naive Engineering Toolbox Slowed Early Progress

Raytheon
Missile Systems

- Models/analysis/understanding
  - FEA — modeling transient loads, high-pressure differentials
  - Material science — strength of materials to transients, elasticity/tear
  - Pressure management — obturation, muzzle exit
  - Base design — spin/overpressure/muzzle brake design tools
- GPS
  - Clock — loss of time reference
    - Vendors, orientation, suspension
  - Evolution — new environments
    - Hardware, software, integration
- IMU
  - FOG — did not gun harden — spool too fragile
  - MEMS #1 — did not gun harden — masses too large
  - MEMS #2 — did not gun harden — almost
- CAS
  - Two to four axis required
  - Increased span on canards
- Affordable testing
  - Early, aggressive gun engineering testing
  - Capable, affordable OBR development and use

Excalibur Evolved With the Market

- Major program restructure affects SDD (2001-December 2002) – merger with Swedish TCM; transition from DPICM to Unitary

Block I to Increment Ia

  - Structural design and testing to be done early
  - Critical components were still technologies — not products

- Early fielding (April 2004) to full compliance (October 2007)

Ia-1 to Ia-2

  - Test-structured, early program paid big benefits in execution
  - Clever algorithm design makes things possible without hardware changes

- Cost improvement; increased reliability; new, more stringent A/J requirement (September 2008 to present)

Ia-2 to Ib

  - Pay attention to **cost, cost, cost**
  - Systems expertise in many areas critical to good architecturing and execution

Demonstrated Capability Exceeded Some Requirements

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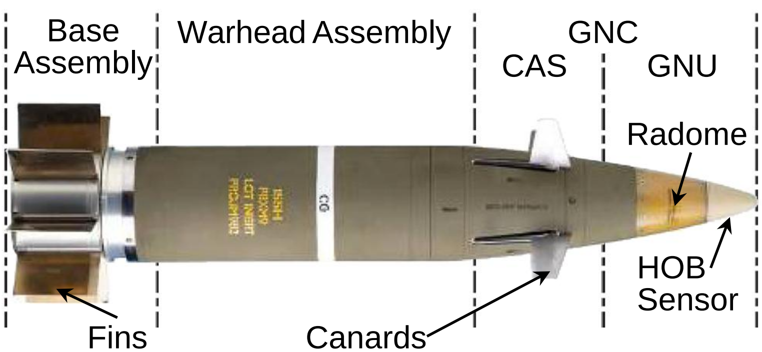
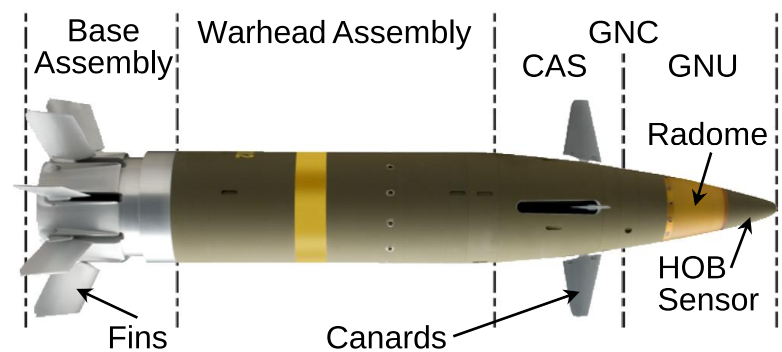
Requirements Comparison Summary

KPP	Threshold			Objective			Demonstrated		
	Ia-1	Ia-2	Ib	Ia-1	Ia-2	Ib	Ia-1	Ia-2	Ib
Precision (CEP)	20 m	20 m	10 m	—	10 m	6 m	<6m	<6m	<5 m
Maximum Range	24 km	35 km 39-Cal 50 km 52-Cal	35 km 50 km	—	40 km 60 km	40 km 60 km	>24 km	41 km 39-Cal	>32 km 39-Cal >46 km 52-Cal
Reliability	60%	85%	93%	—	96%	96%	85%	85.9%– 91.5%	93% for shoot-off
Lethality	Effectiveness ≥ M107			Effectiveness ≥ M107			Effectiveness ≥ M107		

Increment Ia

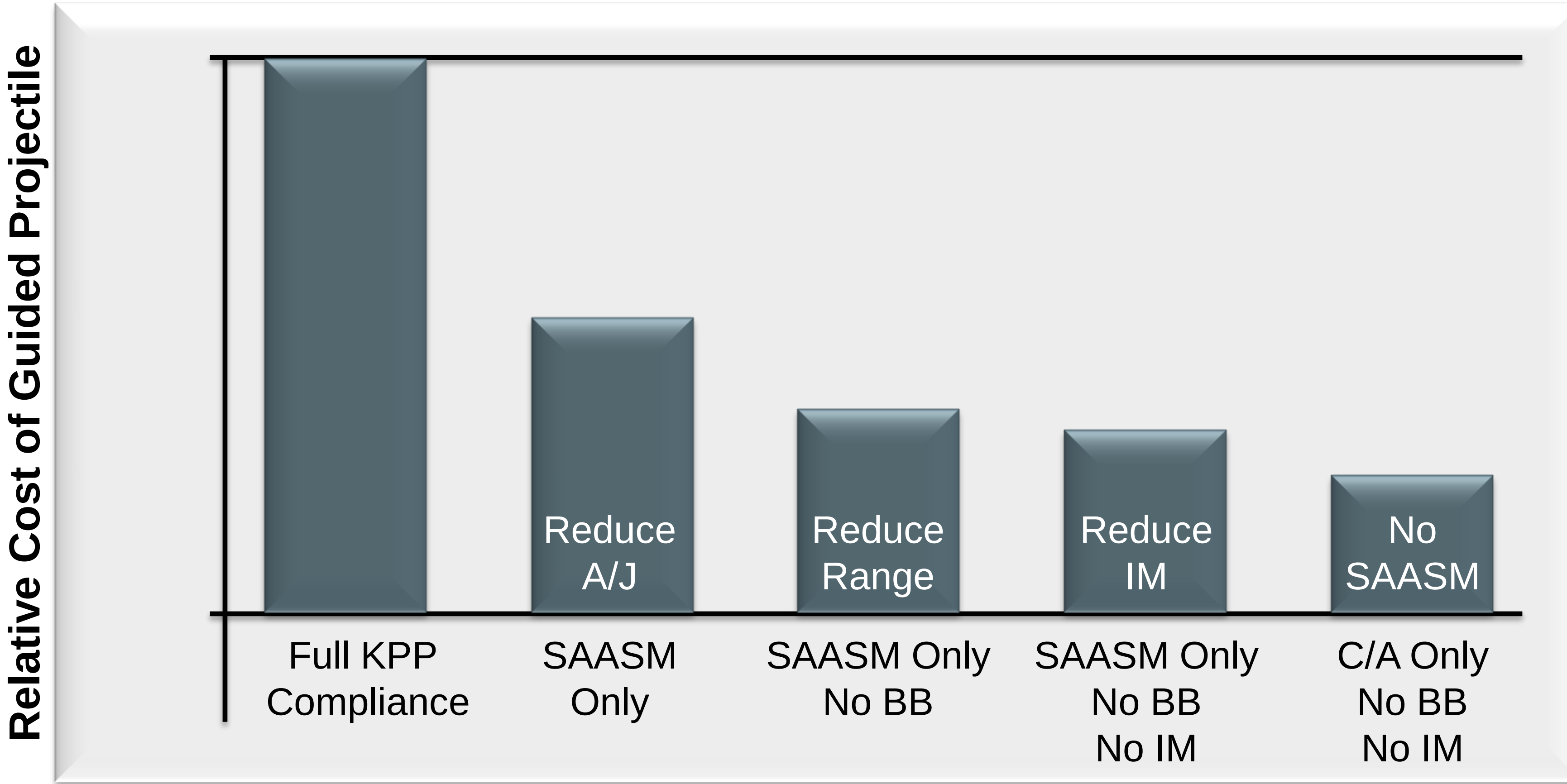


Increment Ib



Excalibur

Specifications Drive System Cost



Majority of architecture costs driven by requirements (A/J requirement sets major architecture population)

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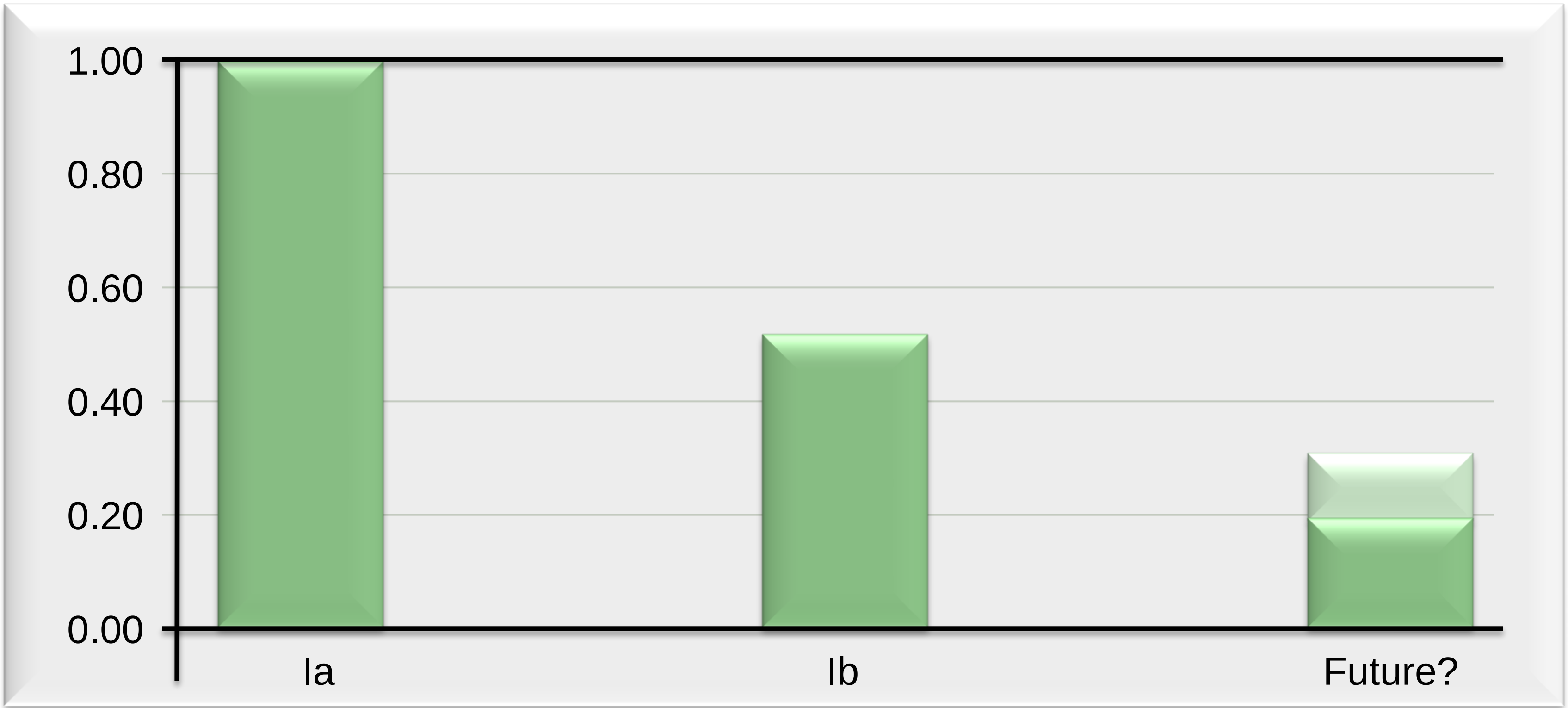
Missile Systems

What Is the Future Cost of Precision?



Requirements and technology (and production quantity) likely to continue to have a significant impact on the future

Excalibur Benefits the Warfighter

- Excalibur was the first and still the **only** fielded, autonomous, precision-guided, extended-range artillery projectile
  - GPS/IMU
  - CAS
  - Finned base
- When we started, we were unable to see the course
  - The industrial base overestimated readiness at SDD start
  - Analysis/models were naive
    - Impulsive loads — pressure variation — SOM under impulse
  - Requirements evolution increased the challenge (increased AJ, new payload, platform…)
- Increased experience denoted the turning point
  - Chasing subtle problems in IMU and GPS
  - Mechanical failures solved
  - A baseline set of tools and processes available
- More capable and able to evolve
  - Activities based on cost reduction, reliability improvement, large industry investment
  - ARDEC/RMS successfully supported warfighter

Progress flowed from solid engineering and operational lessons

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Customer Success Is Our Mission

46th Annual Gun and Missile Systems Conference

A Virtual Learning Environment for Precision Indirect Fires

Jon Peoble
Jim Rodrigue
April 13, 2011

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Agenda

- The Need for Virtual Environments
- Precision Fires Virtual Environments
  - Phase 1: Virtual Learning Environment
  - Phase 2: Virtual Training Environment
- Summary

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The Evolving Fires Kill-Chain

- Role of indirect fires is evolving to include tasks normally serviced by Joint or direct fire munitions
  - Precision strike, danger-close situations, avoidance of collateral damage
- Indirect fire munitions are becoming more precise and the kill-chain needed to employ them is becoming more complex
  - Target location requirements
    - FO must report an accurate grid
    - FDC must program TLE constraints into AFATDS
  - Employment planning
    - Off-axis planning, fail safe impact zones, collateral damage planning
  - Munition initialization
    - Munition must be properly initialized with grid coordinates and fuze settings
- As Copperhead exemplifies, when the kill-chain becomes complicated, the munition often does not get used due to lack of familiarity
  - Virtual Learning Environments can help the Warfighter better understand and properly employ the new, evolving Fires kill-chain

The precision fires kill-chain is becoming more sophisticated and virtual environments can aid in familiarization and training

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The Case for Virtual Environments

- As precision indirect fires munitions become more capable and thus more costly, traditional live fire exercises for training become less cost-effective
- Virtual exercises can provide effective training for a fraction of the cost of live fire exercises
  - Inclusion of accredited in-flight simulations (6-DOF) vital to ensuring accurate representation of munitions
  - Supplements live fire exercises for mission rehearsal
- Virtual already being employed in school-houses for other sophisticated weapon systems, supplemented with occasional live fires
  - Air-to-air missiles, ballistic missile defense, direct fire missiles
- Virtual already being used for parts of the Fires kill-chain
  - VBS2Fires for FO training (Ft. Bragg)
  - VRSG for JTAC training (AFRL-MESA)

Virtual environments can provide effective, inexpensive supplemental training to live fire exercises

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Precision Fires VLE: Phase 1

- **Overview**
  - A virtual environment that represents the entire precision fires kill chain, from Forward Observer to the Firing Unit and munitions
  - User makes decisions to progress through a tactical scenario and see the outcomes of their actions
  - Collaborative effort between RTN and Fires Center of Excellence to explore technology for virtual learning environments

- **Objective**
  - Increase the Warfighter's understanding of precision fires
  - Model the entire precision-fires kill-chain to an appropriate level of fidelity
  - Present the user with decisions that are doctrinally correct
  - Model relevant combat scenarios that illustrate when to use precision

The Virtual Learning Environment will reinforce and improve the Warfighter's understanding of precision fires

The Virtual Learning Environment

- **VLE Concept**
  - User will select a scenario and his role
  - VLE will develop the scenario by showing the user animation clips
  - At key points, the user will be asked to make a decision on how to respond to events in the scenario
  - Scenario will continue to unfold based on the user's decisions
  - User will see the outcome of their decision and will be able to go back and explore other options
- **User Roles**

Forward Observer

- Conduct a call for fire (CFF)
- Understand when precision munitions should be employed
- Request a precision munition and fuze mode and provide the necessary TLE
- Observe results and request further actions if necessary

Fire Direction Center

- Decide which area or precision munition to use
  - Examine target, collateral damage concerns, and TLE
- Process the CFF through AFATDS and generate Fire Mission

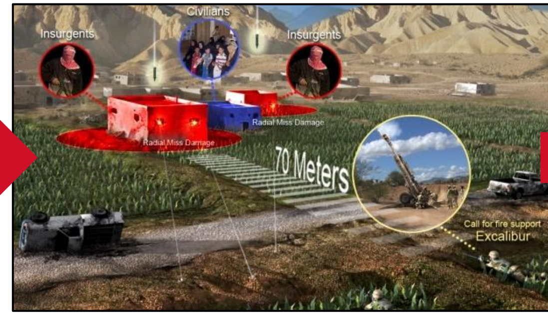
Firing Unit

- Place the guns while taking Excalibur's large maneuver footprint into consideration
- Unpack and inspect the munitions
- Set the fuze (EPIAFS) and load the munition
- Execute the Fire Mission

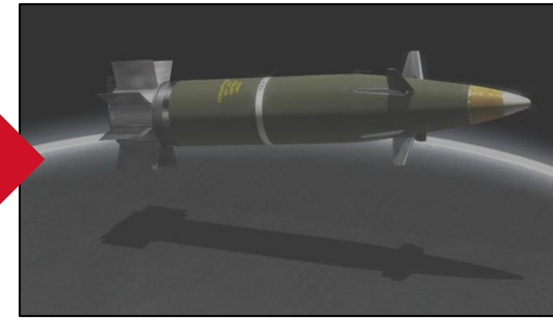
VLE will expose the user to every role, giving them a complete understanding of the precision fires kill-chain

An Example of the VLE (FO User)

Scenario is presented to FO user; *troops pinned down by ambush from nearby structure*



FO is instructed to conduct a CFF and is presented a choice of munitions and the required scenario information



FO selects a precision munition; VLE instructs him to obtain TLE < 10m for the structure target and explains need for a tight TLE

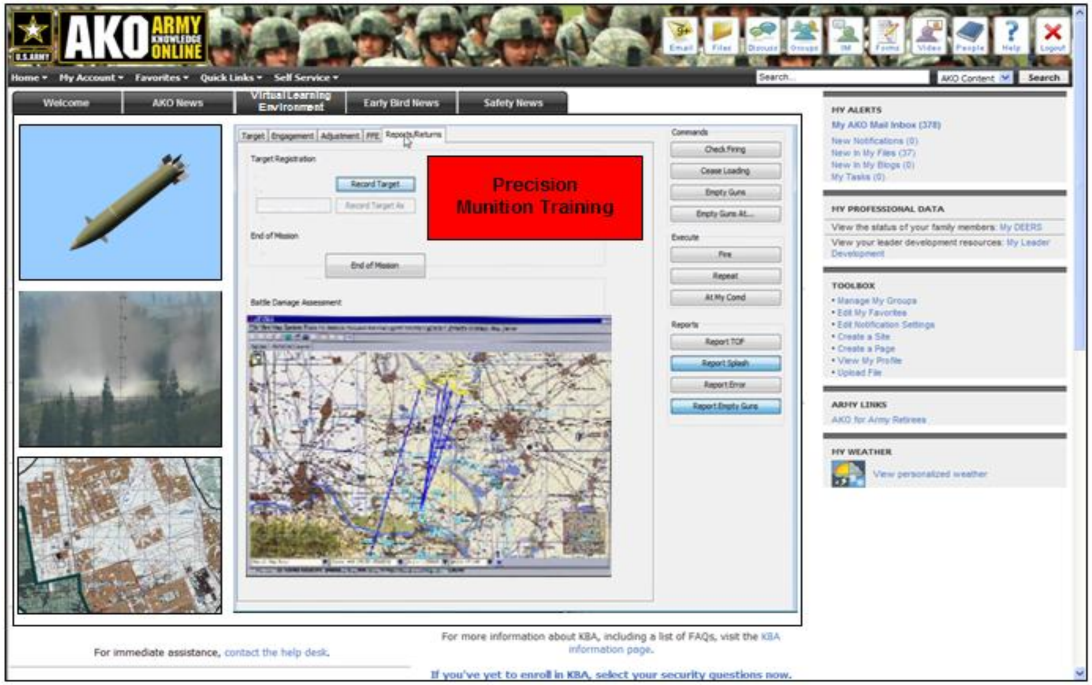
FO sends CFF by selecting appropriate commands to send to FDC, including munition selection and Fuze setting

FO observes effects of decisions and must decide if re-engagement with adjustments is necessary

Scenario presents the user with a relevant mission that enables a better understanding of precision munitions and how to employ them

Deploying the VLE

- VLE will be a light-weight, browser based application that can be deployed on multiple devices
- Possible deployment methods:
  - Web-based deployment on AKO / FKN / DKO
  - DVD deployment for personal computer use and rapid deployment
  - App deployment for use on touch-based devices



Light-weight nature of VLE allows it to be easily and rapidly deployed on multiple devices

Precision Fires VLE: Phase 2

- **Overview**
  - A full training version of the kill-chain that makes use of virtual and live devices combined with digital IFS / 6DOFs
  - Virtual FO devices created in VBS2 (LRAS3, PSS-SOF, etc)
    - Allows for individual soldier training with an accurate representation of their system
    - Could be connected to live training devices for added fidelity
  - FDC would use live AFATDS
    - Virtual FO sensors in VBS2 would send live JVMF messages to AFATDS for the FDC to process
    - Live JVMF messages would also be sent to the FU
  - Virtual representations of the guns, munitions, and EPIAFS created for FU in VBS2
  - Once the round is fired, the 6DOF would accurately fly the munition to the target grid

- **Objective**
  - Replicate the Fires kill-chain in an L-V-C environment to a level of fidelity that enables realistic and effective training

The virtual training environment will provide the Warfighter with an accurate, virtual representation of the fires kill-chain

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The Virtual Training Environment

FO Environment

- Live / Training devices view Virtual world
- Accurate representations of FO devices
  - PSS-SOF, BFIST, FS3, LLDR, etc
- VBS2 and VBS2Fires

JVMF

VBS2

FDC Environment

- Live AFATDS receiving and sending JVMF messages

FU Environment

- Virtual representations of guns and munitions
- VBS2

DIS/HLA

Munitions

- Munitions IFS / 6DOFs fly munition accurately

All participants in the kill-chain would interact with the virtual world using either live or virtual versions of their devices

Summary

- As precision indirect fires munitions become more capable and thus more costly, traditional live fire exercises for training become less cost-effective
- Virtual environments can provide effective, inexpensive supplemental training to live fire exercises
- Phase 1: The Virtual Learning Environment
  – A scenario driven, interactive tool to reinforce and improve the Warfighter's understanding of the entire precision fires kill-chain
- Phase 2: The Virtual Training Environment
  – An accurate representation of the kill-chain that makes use of virtual and live devices combined with digital IFS / 6DOFs

The precision fires virtual learning environment is being collaboratively investigated by the customer and Raytheon

Questions?

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MEDUSA 66mm Launcher System

Aggressor Suppression via the use of Non-lethal Projectiles and Launchers

GENERAL DYNAMICS
Ordnance and Tactical Systems

Presentation Overview

- **Review the warfighter's "Escalation of Force" (EoF) needs and non-lethal, EoF requirements**

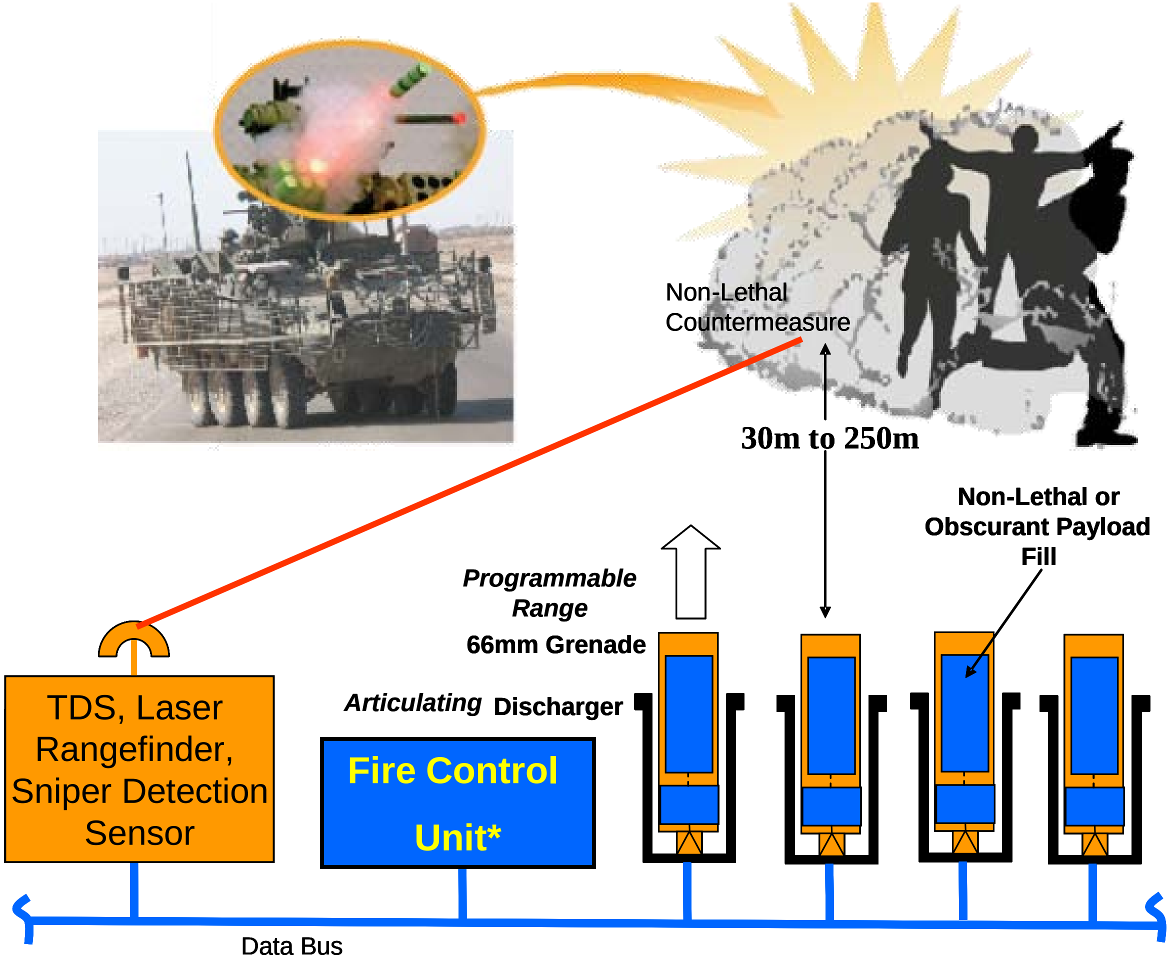
- **MEDUSA: a vehicle-mounted, digital, grenade launcher system**
  - 66mm Articulating Grenade Launchers
  - Fire Control Unit
  - Programmable, Electronically-Fuzed Grenades
  - Demonstration Videos

- **Points for Discussion**

What is a Digital Grenade Launcher System ?

OBJECTIVES:

- Multirole, networked countermeasures delivery including sensors, fire control, launchers and electronically-fuzed ammunition.
- Integrate countermeasure response delivery to platform sensors for rapid, automated or man-in-the-loop response to detected threats with precision placement of countermeasure effects.



*** Fire Control Unit function may be integrated within existing commander display computer or weapon station**

GD-OTS' MEDUSA System

- MEDUSA supports a full range of 66mm combat effects grenades including; nonlethal human temporary incapacitation, obscuration and sensor defeat, illumination, marking and combat countermeasures.

- The MEDUSA Launchers and Fire Control Unit are a next-generation spin-off of a system developed for the US Army's Escalating Response System (ERS) for the Full Spectrum Effects Platform (FSEP Stryker) fleet

- MEDUSA provides longer range, greater coverage area, extended effects duration, low risk of permanent injury, better scalability of effects, and supports the government's EoF needs.

Non-lethal Weapon System Requirements

- Capable of being easily installed on any tactical; B-kit architecture
- The non-lethal effect must be capable of suppressing the aggressors for an extended period of time without risk of significant or permanent injury
- The non-lethal effect must be capable of being delivered with precision anywhere between 30 to 250 meters
- The NLWS must have the capability to support urban patrolling, convoy operations, crowd control and area denial operations (of approx 250 m^2)


Medusa: USMC MPM-NLWS TD Phase

Program Objectives: MPM-NLWS is a new weapon system that launches non-lethal payloads to greater ranges with broader area coverage, greater duration of effects, and volume of fire.

Hardware Overview: Lightweight, dual articulating launchers, fire control and LRF integrated on MC-TAGS. Grenade ammunition incorporates thermobaric NL temporary incapacitation payload.

Results Significance:

- HECOE validation of human incapacitation effectiveness and acceptable levels of injury risk.
- Mortar grenade projectile with programmable fuzing provides extended range and effects placement accuracy.

GENERAL DYNAMICS
Ordnance and Tactical Systems

System Overview

- The MEDUSA kit has six major components:
  - Fire Control Unit
  - Laser Range Finder
  - Left & Right Dischargers
  - Thermobaric Grenades
  - Installation Kit (cables & mounting brackets)

(Note: The system is very modular and installs readily on most tactical vehicles)

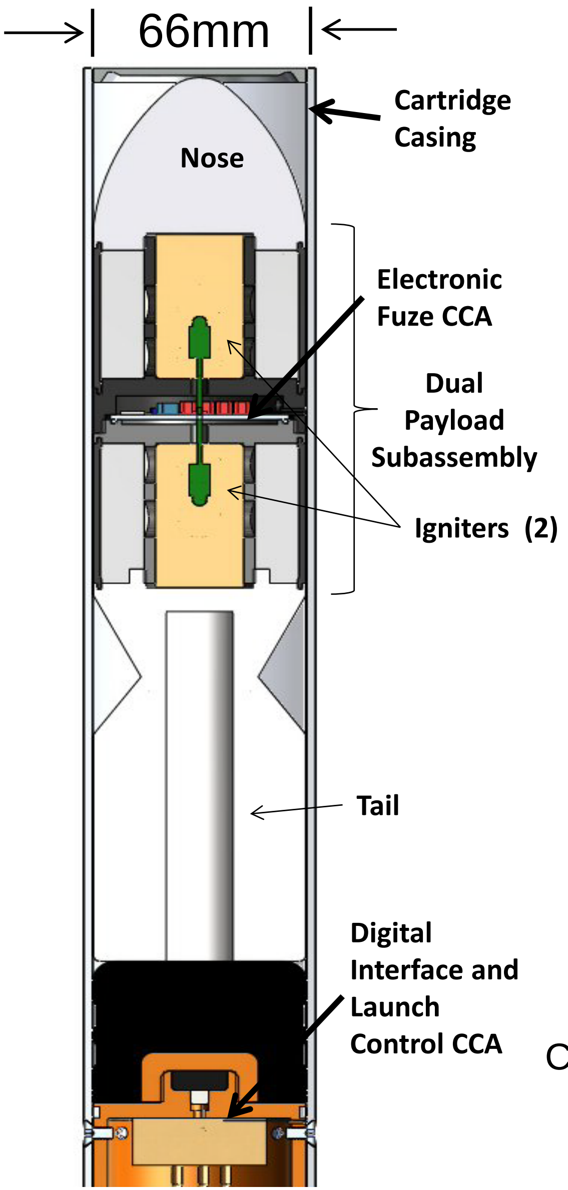
Fire Control Unit

Left & Right Launchers

66mm Thermobaric Grenade

Grenade Overview

- Large, dual payload capacity; 7.5 in^3 each, 15 in^3 (246 cm^3) total
- Independent payload initiation control; simultaneous or separate function
- "Smart" capabilities include:
  - Self type identification
  - In-tube BIT
  - Each payload individually programmable for range-time of activation
- Range accuracy – Spherical Error Probability (SEP)
  - 0.8m at 30m range
  - 2.5m at 90m range
  - 4.0m at 150m range
- Max range to 300m
- Low fragmentation hazard



Flight Configuration

Medusa Demonstration Video

How is suppression achieved?

The grenade payload temporarily incapacitates targeted personnel through the use of **intense physiological (auditory/visual) human effects:**

- **Light stimuli:** 25 k-lux/s with a fireball diameter of approx 3 meters. Intense light emitted by the grenade will temporarily blind aggressors. This light can be seen several miles away.
- **Sound stimuli:** 146 dBA measured 1 meter from the burst. Intense sound will affect hearing so that an aggressor will not be able to hear (i.e., take or give commands) for several minutes
- **Pressure stimuli:** Approx 5.2 psi measured 1 meter from the burst to disorient an aggressor when he is within several meters of the burst
- **Psychological effects**: harder to quantify, but seeing is believing.

Issues for Further Discussion

- Backward and forward compatibility with legacy and digital discharger/launcher and grenade ammunition.
- Standardization of networked fire control, launcher and ammunition interfaces.
- Single System Multirole Functionality; vehicle self-protection and sensor-defeating obscuration and decoys, NL counter-personnel and EOF, hard-kill APS, illumination, marking, lethal (?), other effects.

GENERAL DYNAMICS

Strength On Your Side™

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Abstract # 11509

RDECOM

Cluster Munitions Replacement

Gun & Missile Symposium

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Presented by:

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Current Landscape

- Cluster Munitions have come under ever increasing scrutiny for unexploded ordnance (UXO)
- US submunition payloads are classified as Cluster Munitions & required to meet a <1% UXO rate by 2018
- “Legacy” cannon fire Cluster Munitions in inventory not compliant
- Retrofit Self-Destruct Fuzing Technology has not been able to reach <1% UXO in current systems
- Monitor Domestic & Foreign Policy
- Significant opportunity to provide solutions through maturation of viable technologies




Cluster Munition's Role

- Studies performed to examine CMs role
- Conclusions:
  - "A **<u>residual capability gap remains</u>** for the attack of area targets even after programmed solutions are applied"

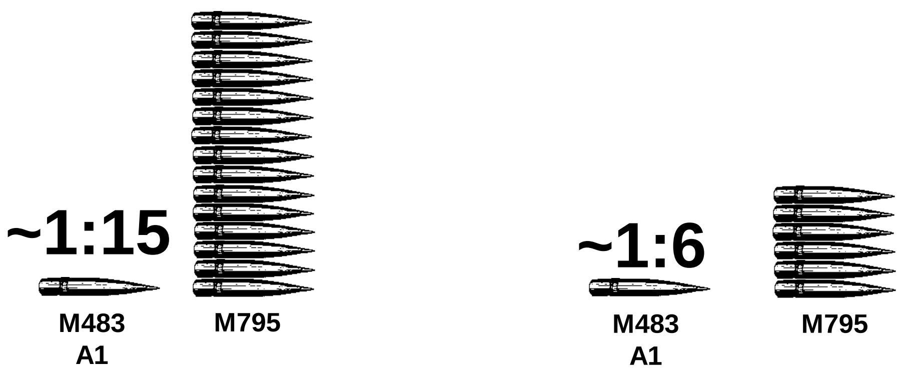
    (TRADOC Cluster Munitions Assessment)
  - "…a need for an alternative to cluster munitions (CM) in the attack of **<u>area targets</u>** and **<u>inaccurately located targets</u>**"

    (CAN 12-17 Materiel Domain Gap 1-n List)
- Recommendations:
  - TRADOC/FCoE recommends developing PRAXIS for 155mm cannon artillery
  - Presented to VCSA on 16 February 2010

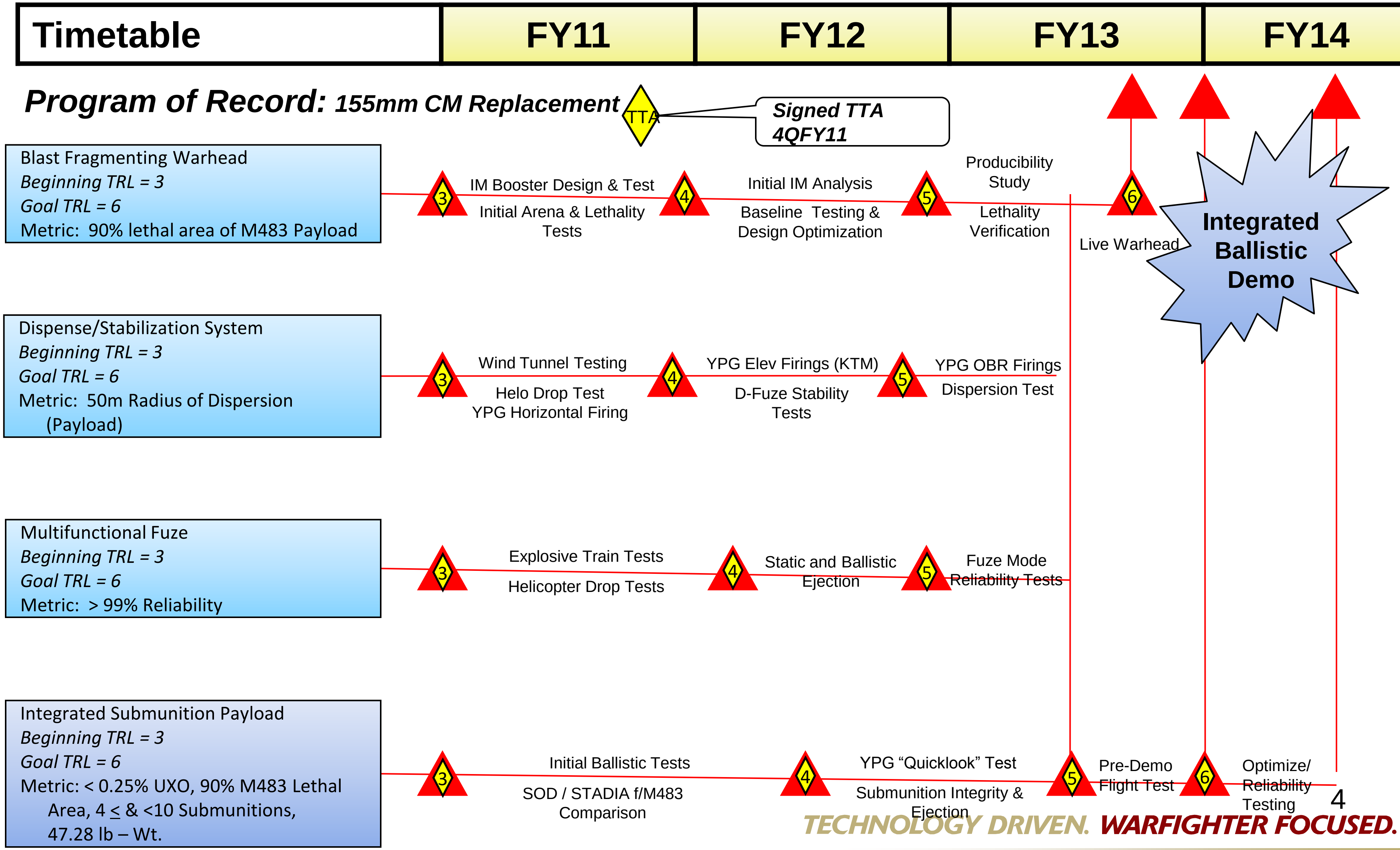
<u>Relative Rounds to Defeat:</u>

<u>CM (M483A1) vs. HE M795)</u>

<u>Hard Targets</u> **<u>Soft Targets</u>**



ARDEC Cluster Munitions Replacement Plan

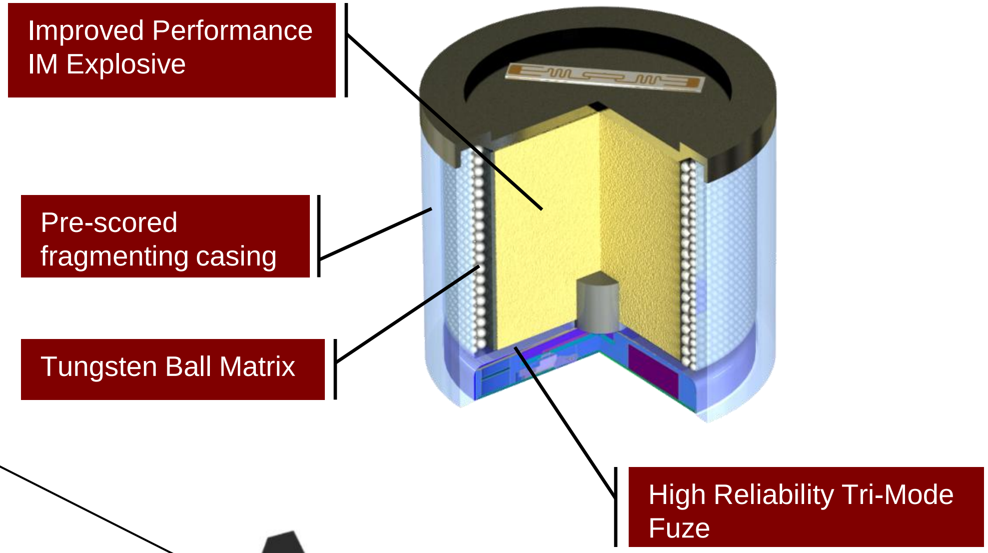


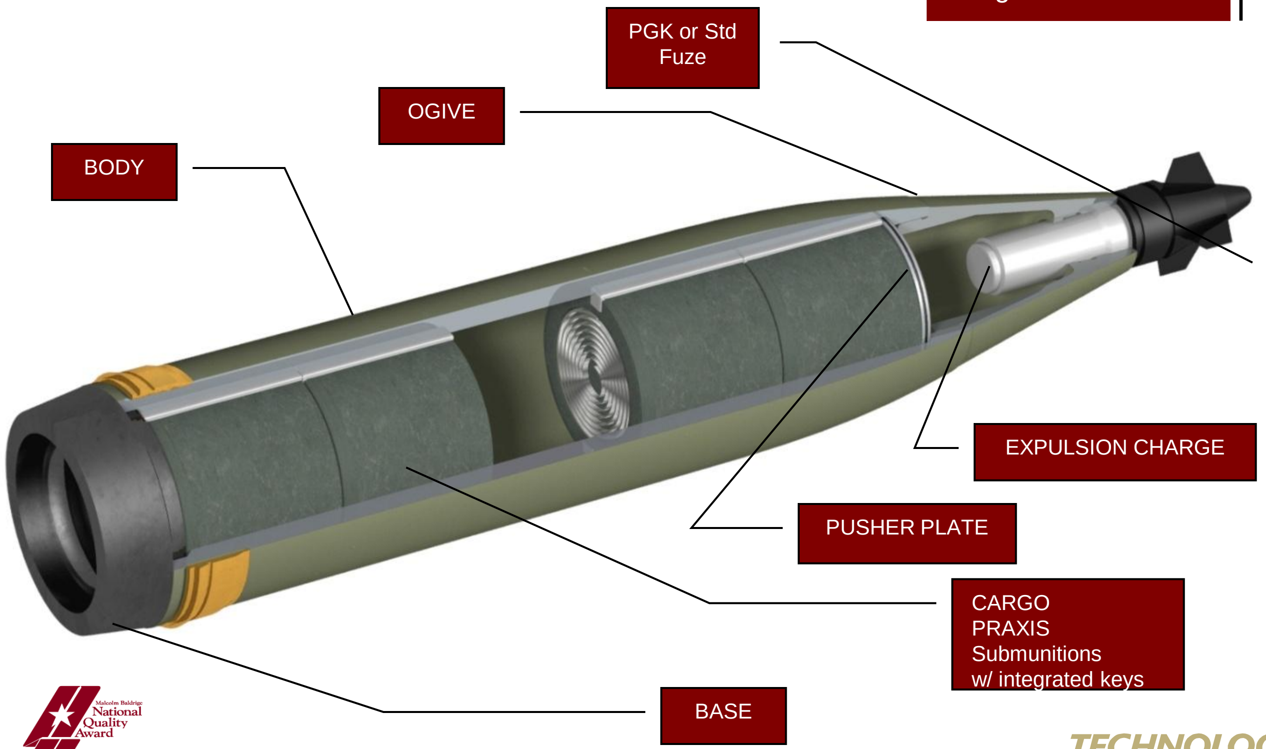
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Cluster Munition Replacement: PRAXIS

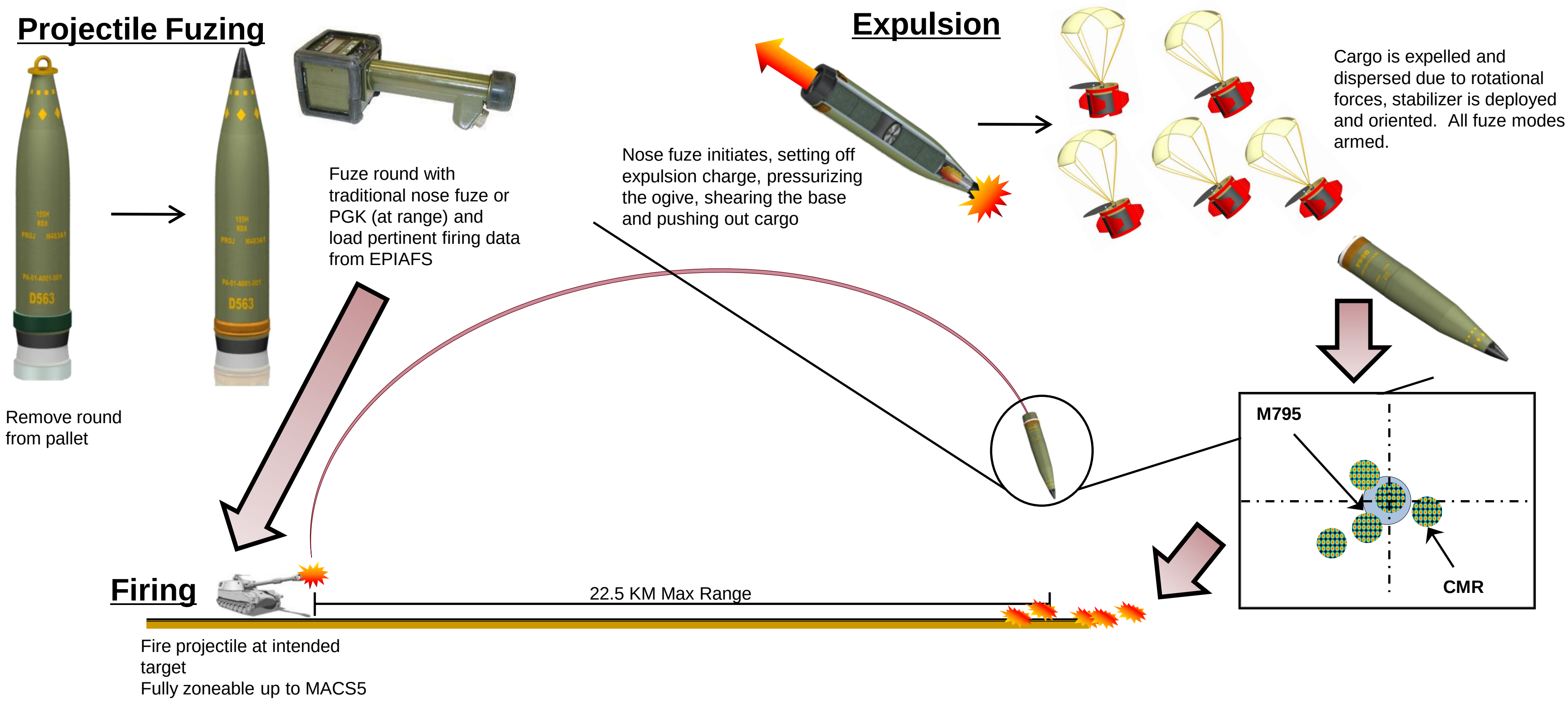
PRAXIS features

- Full bore submunition
- Extreme Reliability Tri-Mode Proximity Fuze
  - Proximity
  - Impact
  - Time
- CMR Objective- < 0.25% UXO
- Fired at MACS5
- Reuse existing M483A1 metal parts





PRAXIS Order of Operation

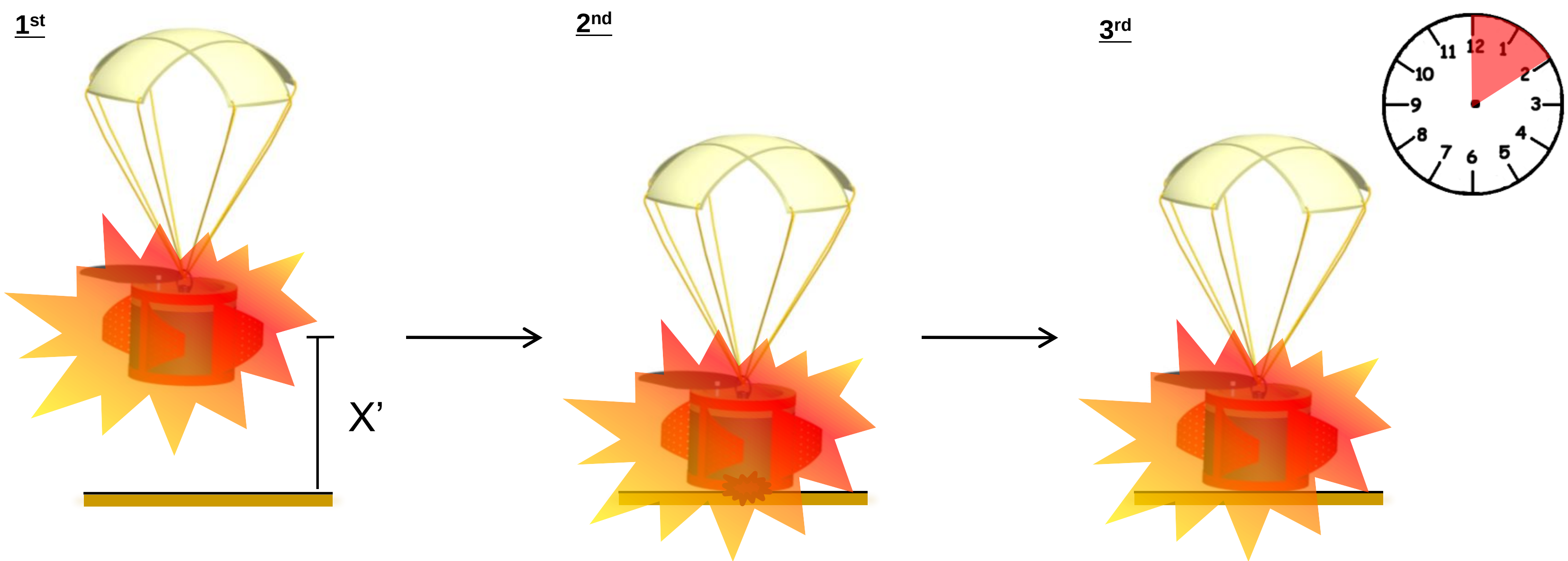


Malcolm Baldrige National Quality Award 2007 Award Recipient

PRAXIS
Order of Operation: Fuze

Fuze Functioning

All three fuze functioning modes operate in parallel, removing common point failures.



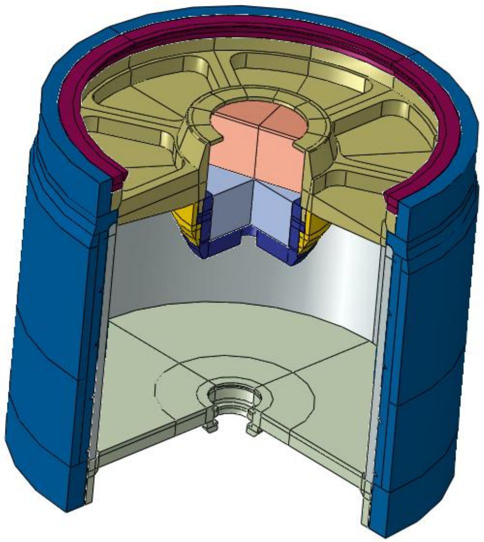
Primary mode is **proximity**, detonating PRAXIS a set distance off the ground

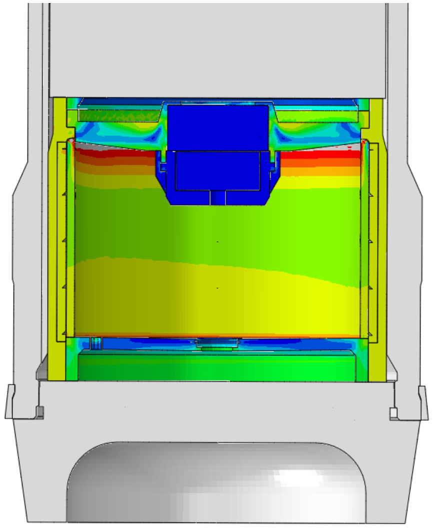
If proximity does not initiate, secondary **impact** mode will detonate PRAXIS

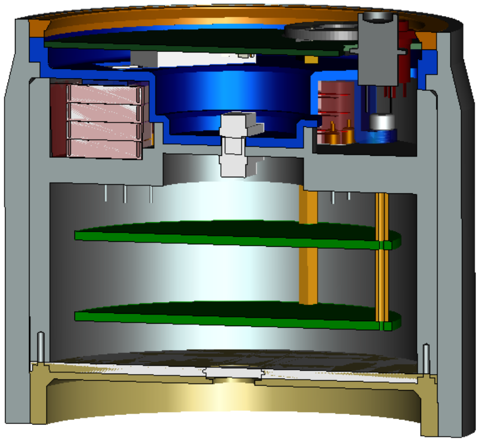
If impact does not initiate, tertiary, **time** mode will detonate PRAXIS after a set amount of time has elapsed

Electronic Development Fuze/Telemetry

- Fuze will have three modes of functioning in parallel
  - Prevents common point failure
- Will incorporate advanced technologies in new applications while leveraging existing, proven components
- Pursuing risk mitigators in parallel to ARDEC effort
  - Advanced battery work
  - Parallel fuze design

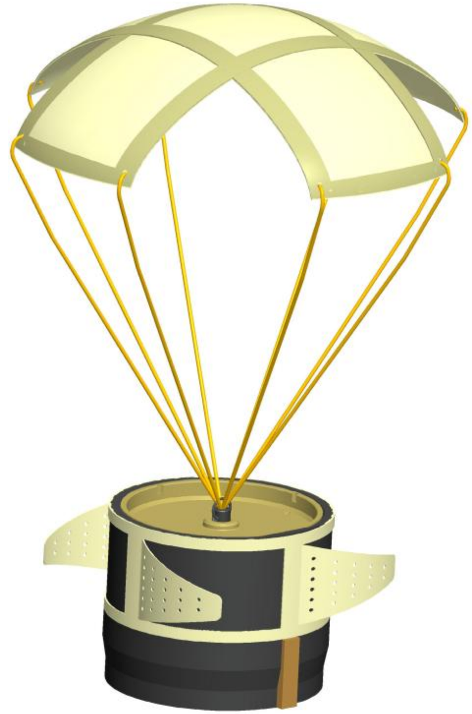


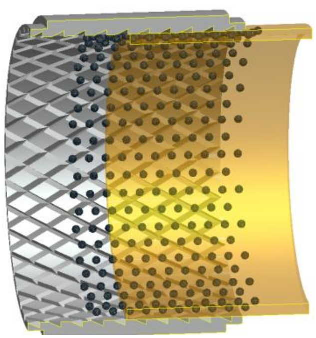


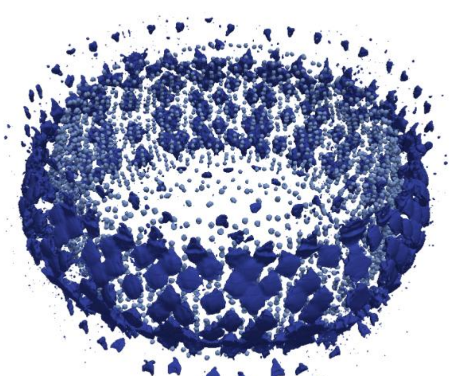


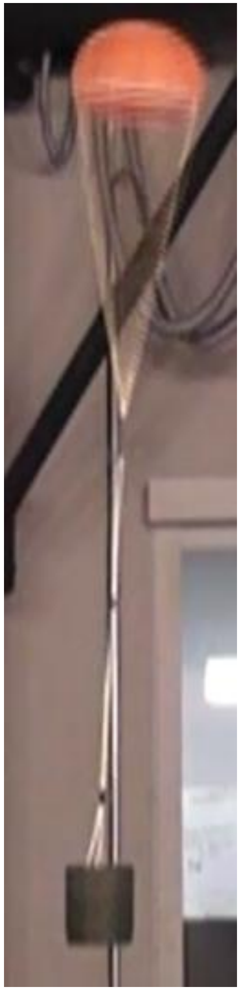
Physical Development Warhead/Stabilizer/Integration

- Aero will separate, despin and orient submunition
  - Stabilizer, expulsion concepts being refined
- Warhead will address soft to medium targets
  - IM explosives have been selected
  - Testing being conducted on performance
- Solid, structural, fragmentation and fluid dynamic models being utilized
- Solution to fit within existing M483A1 space and weight claim



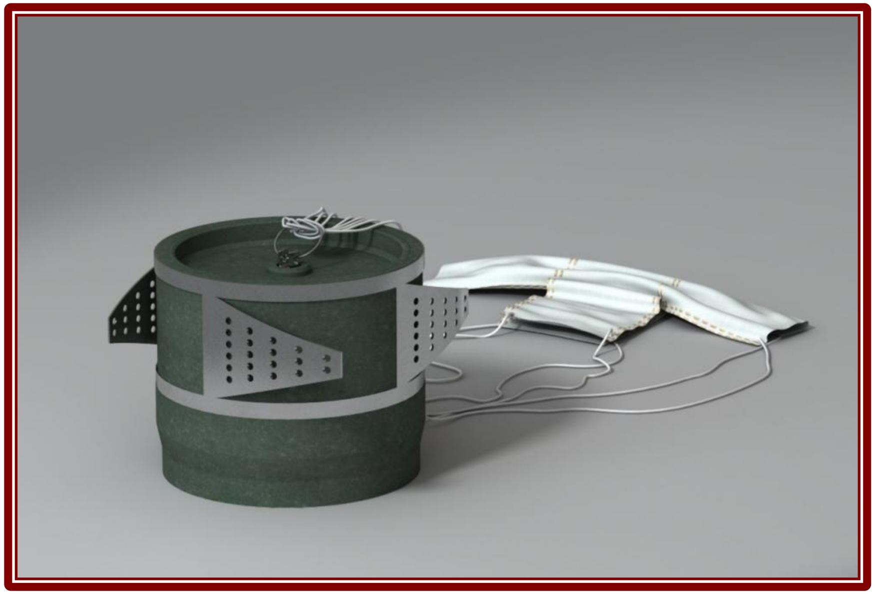




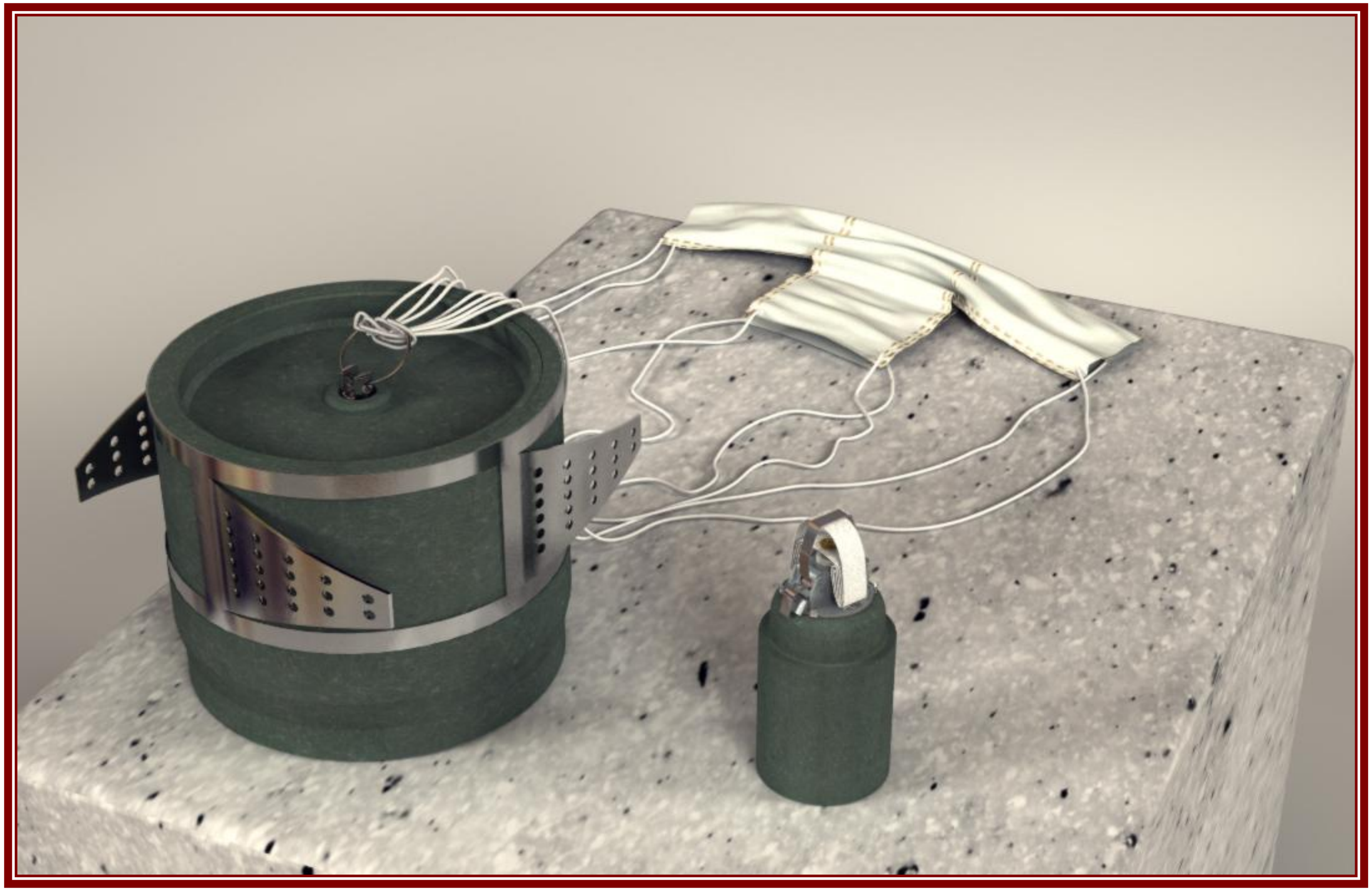


Summary

- In 2018, User will lose Cluster Munitions
- Cluster Munitions still desirable
- ARDEC currently developing a viable solution
- Mature advanced technology while leveraging existing components
- Baseline design backed by extensive M&S
- Component testing underway
- Demonstration tests planned for FY13



Questions



Precision Universal Mortar Attack (PUMA)

NDIA 46th Annual Armament Systems:

Gun & Missile Systems Conference & Exhibition

29 Aug – 1 Sep 2011

Distribution Statement A: Approved for Public Release; Distribution is Unlimited

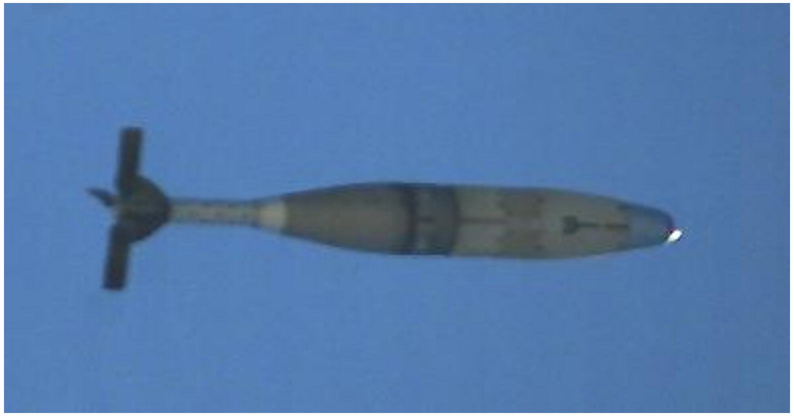
What is PUMA?

- ONR Future Naval Capabilities (FNC) Program
  - Demonstrate critical technologies to support a system capability for enhanced mortar engagements
    - Precision Guidance
    - Trajectory Shaping
    - Range Extension
  - Lighten the Load for the Warfighter
    - More Stowed Kills
    - Lighter/Smaller Support Equipment
  - Cost Effective Solution
    - Utilization of Novel technologies & COTS products
  - Joint Services, Gov't Lab Partnership Development Team

TRL 6 Demonstrations & Transition to Acquisition Program in FY14

Guided Flight Testing

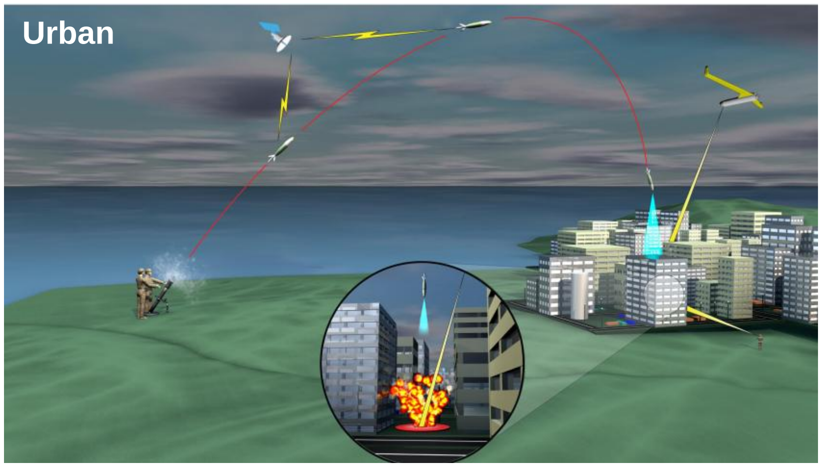
- Successful Demonstration of Guided 81mm Mortar Airframes
  - 22 Jun 2011 @ YPG, AZ
  - 6 Test Rounds: 2 Ballistic, 4 Guided
  - Pre-Programmed Maneuvers
  - Divert authority well in excess of ballistic delivery accuracy

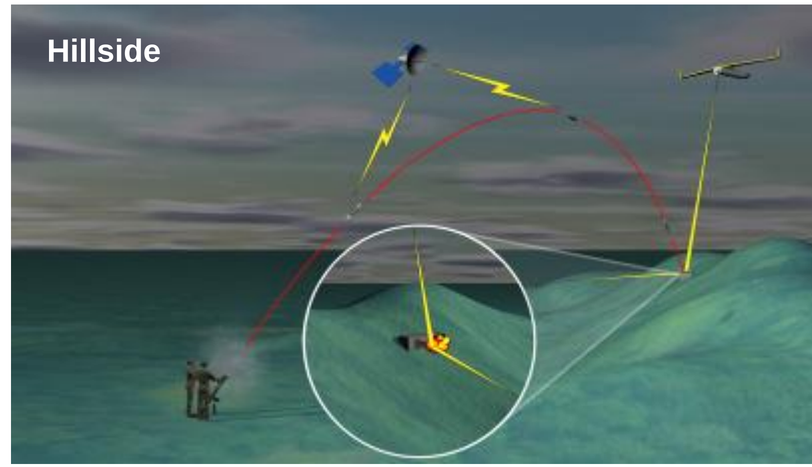


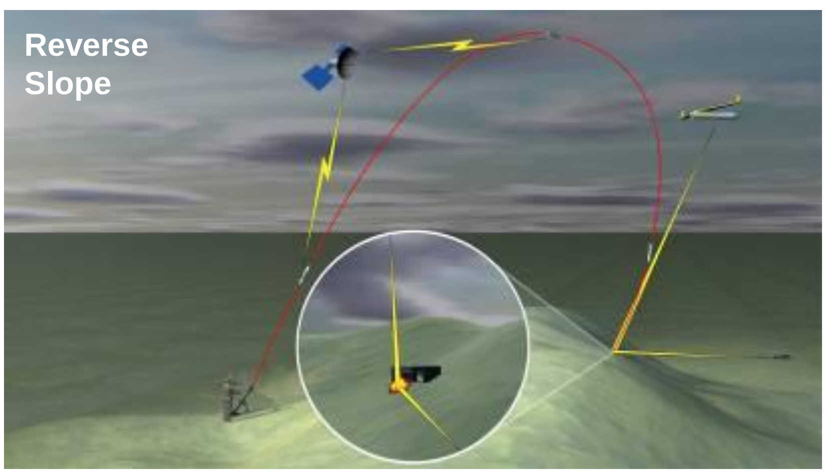
GPS Guide-to-Hit Demonstration in FY12

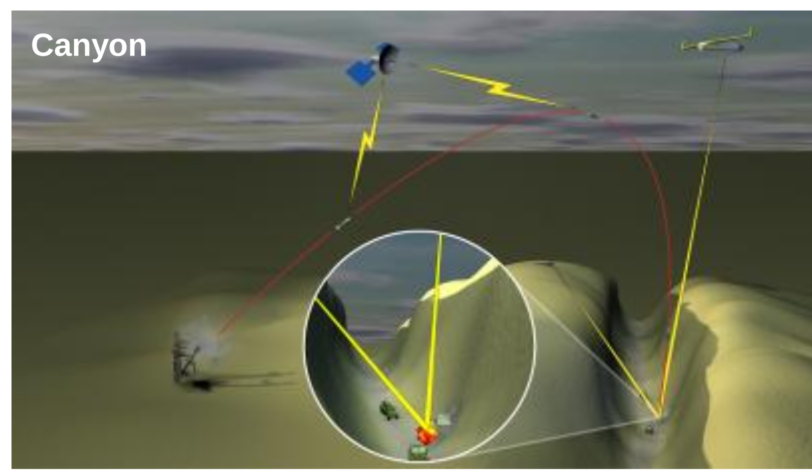
81mm Future Engagement Capability

Precision Universal Mortar Attack (PUMA) – 46th Annual NDIA Armament Systems – 29 Aug-1 Sep 2011





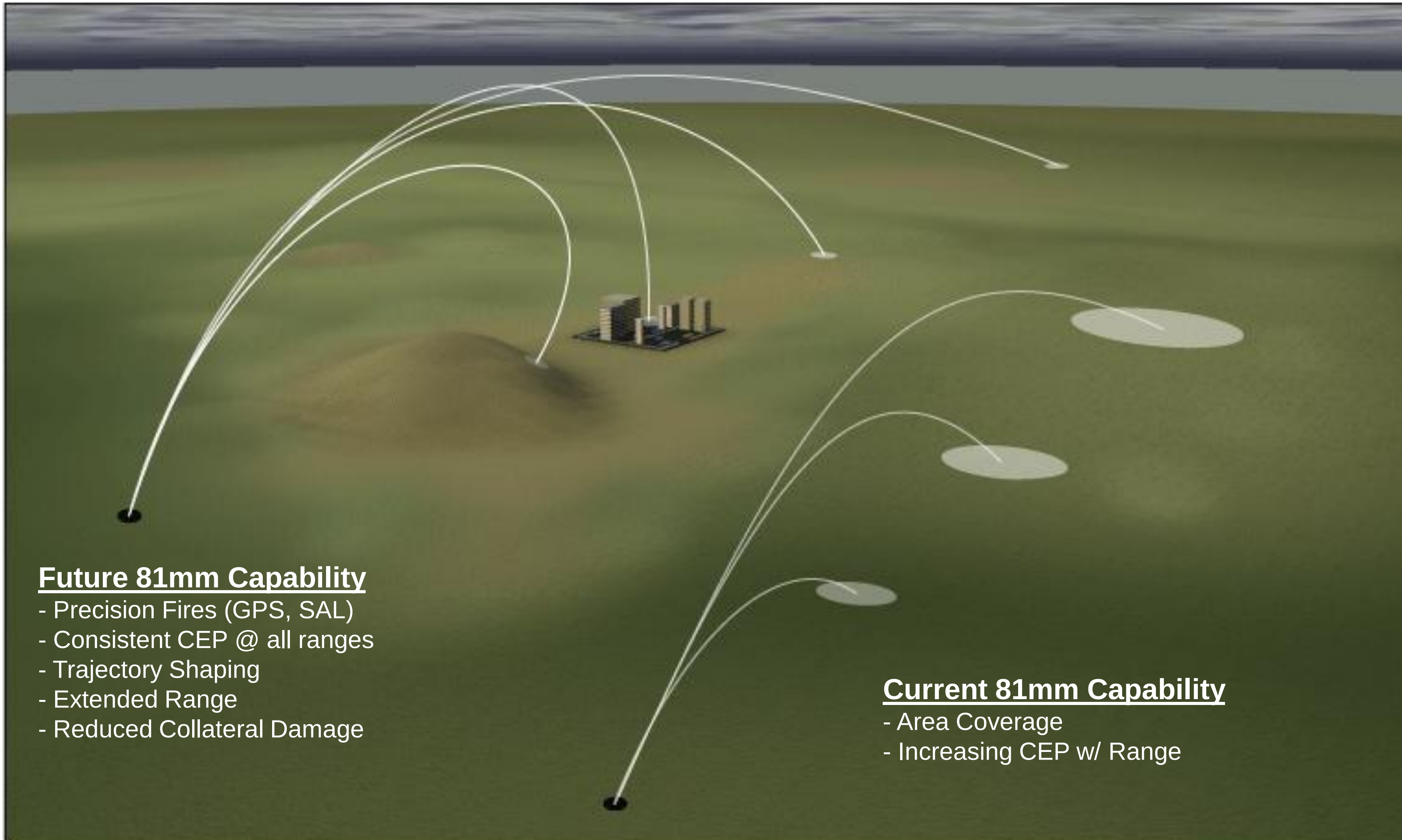




Ability to Address Targets Masked by Terrain Topology

Current vs. Future 81mm Mortar

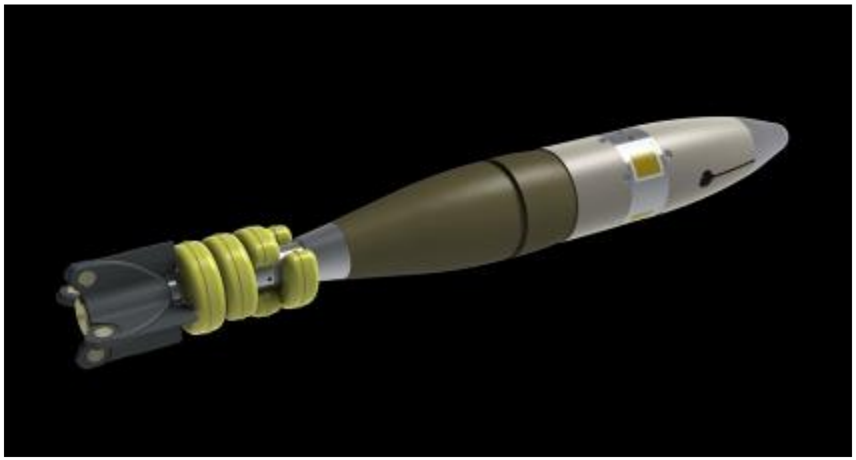
Precision Universal Mortar Attack (PUMA) – 46th Annual NDIA Armament Systems – 29 Aug-1 Sep 2011



Distribution Statement A: Approved for Public Release; Distribution is Unlimited

Enabling Products

Precision Universal Mortar Attack (PUMA) – 46th Annual NDIA Armament Systems – 29 Aug-1 Sep 2011



Flight Controlled Mortar (FCMortar) – (NSWCDD, ARL)

- Guidance Kit for Mortar Ammunition
  - Depot/Factory level conversion kit for HE projectiles
  - Reuses existing Primer/Igniter assembly
- Global Positioning System (GPS) Guidance
  - Fire & Forget Precision
- Semi-Active Laser (SAL) Guidance
  - TLE Elimination
  - GPS, Setter denied operations
- Non-ballistic flight path capable Airframe & GNC
  - Vectored approach guidance
  - Range extension
  - Proven pedigree (VAPP)
- Modular Design
  - "Plug & Play" modules allow for easy upgrade to alternate configurations
  - Sub-systems portable to other systems

Precision Compliment to Existing HE Inventory

Enabling Products

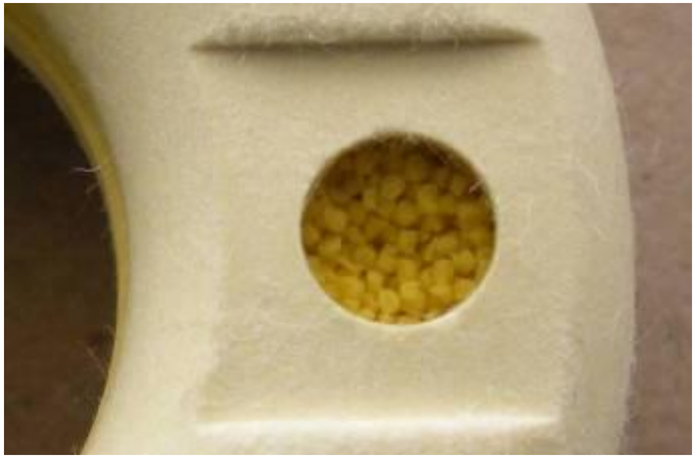
Precision Universal Mortar Attack (PUMA) – 46th Annual NDIA Armament Systems – 29 Aug-1 Sep 2011

Miniaturized SAL Seeker – (NSWCDD)

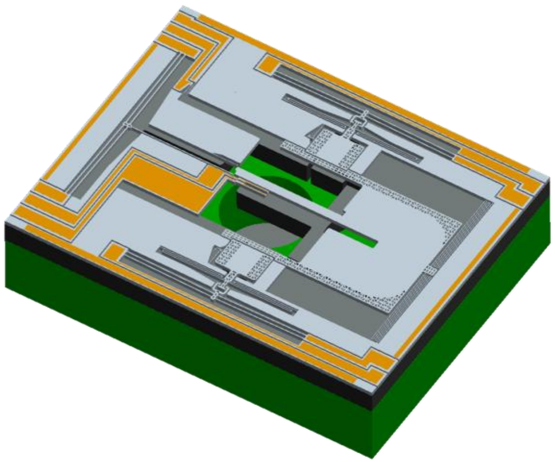
- Strap-Down, Body Fixed Architecture
  - No mirrors, gimbals, or gyros
- STANAG 3733 compliant
  - Compatible with all fielded designators
  - Works with proposed lower pulse energy (20-30 mJ) designators
- Form factor units ready for flight testing in FY 12

Extended Range Mortar Ammunition (ERMA) Propellant (NSWCIHD)

- Advanced artillery propellant adapted for mortar use
- Increased muzzle velocity
  - Extends FCMortar operational range
- Improved cook-off & IM performance
- Lower barrel erosion & fouling
- Already demonstrated on ballistic mortar ammo



Enabling Products



MEMS S&A Based Fuze (NSWCIHD)

- Reduces size of PD/PDD Fuze to that of conventional mortar Fuze S&A device
- Based on silicon MEMS chip with integrated micro-detonator
- Connector for external HOB sensor
- Successful fabrication of first S&A chips complete

Mission Setter (NSWCDD, ARDEC)

- Small Form Factor precision weapon pre-flight initialization device (hand-held)
- Provides trajectory, guidance, and fuze mode data prior to launch
- Miniaturization of EPIAFS system starting FY12
  - New Non-Inductive link to be developed
- Backwards compatible w/ current EPAIFS interface (inductive & direct connect) based systems through add-on kit

Conclusions

- Guidance Capability Demonstrated on 81mm
  - Successful controlled divert testing in July ’11
  - GPS Guide to Hit Demonstration in FY12
- Modular Guidance Kit Solution
  - Easily upgraded
  - Enabling technologies portable to other systems
- Government Lab Partnership developed/owned design
  - Maximum flexibility in meeting acquisition sponsor requirements
- TRL 6 Solution Demonstration in FY14 to support transition to USMC Acqusition POR

Development and Manufacture of an Insensitive Composition B Replacement Explosive IMX-104 for Mortar Applications

46th Annual Gun & Missile Systems Conference & Exhibition

* Virgil Fung, Mike Ervin, Brian Alexander
BAE SYSTEMS Ordnance Systems Inc.
Holston Army Ammunition Plant, TN, USA

Charlie Patel, Philip Samuels, Leila Zunino
U.S. ARMY PM-CAS
Picatinny Arsenal, NJ, USA

Briefing Outline

- Program Goals & Background
- Formulation Development
- Material Characterization
  - IM Testing (IMX-104 in 81mm and 120mm Mortar)
  - IMX-104 Qualification Status
- IMX-104 Large Scale Manufacturing
- Concluding Remarks
- Acknowledgements

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited (S2DESA2011-0051)

Program Goals & Background

- PM-Mortars funded PAX-21 Product Improvement Program (PIP) for the 60mm Mortar with the primary goals:
  - Replace AP in PAX-21 (environmental issue)
  - Achieve PAX-21 or better performance
  - Achieve PAX-21 or better IM Response
- Secondary goal - utilization of ingredients manufactured on production scale at Holston in these new formulations:-
  - RDX, HMX (conventional Holston ingredients)
  - DNAN, NTO, TATB, HBD NQ (new ingredients)
- Utilizing manufacturing technologies that were a good-fit for the U.S. Industrial base
  - Traditional Melt-pour processing
  - Large capacity equipment
    - Recrystallization
    - Incorporation, drying & flaking of product
    - Dry Fluid Energy Milling of ingredients as required (a contributing technology)

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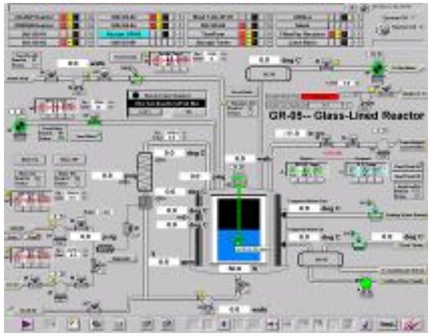
Insensitive Ingredients

- DNAN, NTO and NQ - inherently less sensitive than traditional high explosives and melt base ingredients
- Selected as materials for scale-up and production at Holston because of their perceived benefits and adequate suitability with the existing infrastructure
- Now STANDARD PRODUCTS from Holston Army Ammunition Plant
    - Manufactured in Agile Facility at Holston



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Insensitive Explosive Formulations

- Development Efforts resulted in several new formulations, the most promising of which include:
  - **IMX-101** (formerly OSX-CAN) for Artillery Ammunitions
    - Achieved the best IM results in full-scale ammunition trials:-

IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Detonation	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
M795 Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
IMX-101	PASS	PASS	PASS	PASS	PASS	Ø 81mm PASS

  - IMX-101 is QUALIFIED by the U.S. Army as a main charge explosive and TNT replacement. Type (system) qualification evaluation for Artillery Ammunition is completed
  - **IMX-104 (formerly OSX-7)** (DNAN, RDX, and NTO) for Mortars
    - Qualified by the U.S. Army as a main charge explosive and Composition B replacement
    - Type (system) qualification testing will be performed in FY 2012
  - **PAX-48 (formerly OSX-8)** (DNAN, HMX, and NTO) for Mortars and Direct-Fire Ammunition
    - Qualified by the U.S. Army as a main charge explosive for the 120mm IM HE-T Ammunition

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Formulation Development - Overview

- Two formulations of greatest interest to OSI Customers
  - IMX-104 (DNAN, NTO and RDX based)
  - PAX-48 (DNAN, NTO and HMX based)
  - Both formulations possess energetic performance similar to Composition B

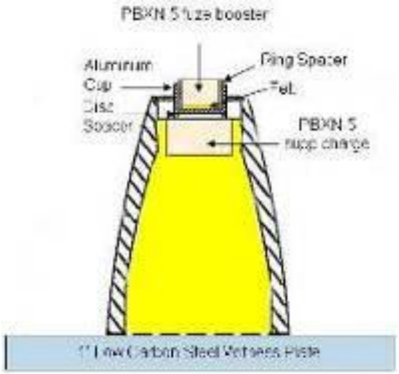
Typical Properties of IMX-104 and PAX-48 Versus Traditional Mortar Fillings

Material	TMD (g/cc)	VOD (% Comp B)	LSGT (50% Card Gap)	Reference	Scale of Manufacture	DSC MP / Exotherm Onset (C)	Efflux Viscosity (sec.) @ 96 C
TNT	1.65	84	133	MSIAC		-	-
Comp B	1.76	100	207	LLNL/NOL		80 / 215	-
PAX-21	1.72	83	161	UTEC/ARDEC	1,200 – 1,500 LB Full Production Scale	89 / 193	< 10
IMX-104	1.73	95/92 *	118	OSI/GD-OTS Canada*		89 / 213	< 10
PAX-48	1.76	93/91 *	110	OSI/GD-OTS Canada*		93 / 231	< 10

- Both are proving worthy candidates for evaluation in IM Mortar applications
  - Undergoing evaluation in USA and Europe
  - IMX-104 & PAX-48 both achieved U.S. Army Qualification status (as explosive material) in the U.S.

Formulation Development – Performance Comparison

- IMX-104 and PAX-48 designed to have performance similar to Composition B



120mm mortar ogive
(initiation test set up)

IMX-104

PAX-48

Comp B

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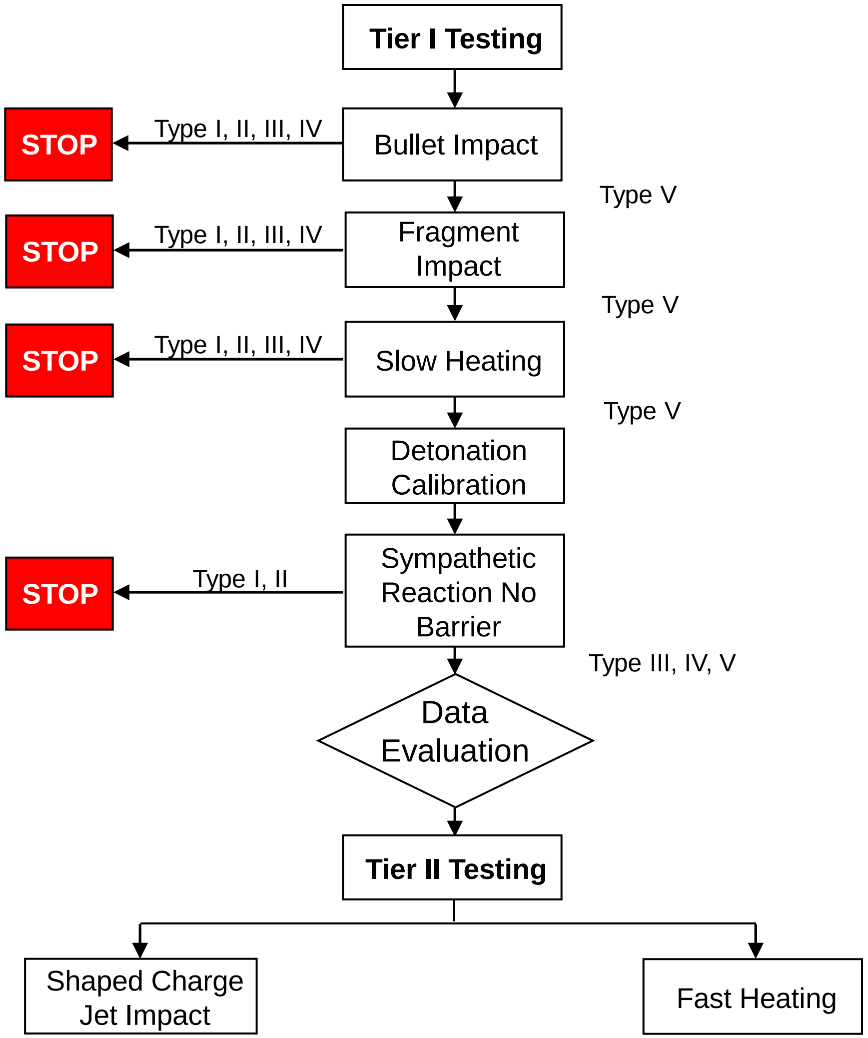
Formulation Development - Large Scale Manufacturing Process Development

- IMX-104 & PAX-48
  - Large scale manufacture in Holston production equipment (1200 lb. batch)
  - Material supplied to PM-CAS for loading into mortars for IM Testing, and to General Dynamics for the 120mm IM HE-T Program
  - Both formulations successfully scaled up with adequate processability

IM Assessment Testing in Mortar Ammunitions

- US ARMY PM-CAS Common Low-cost IM Explosive Program (CLIMEx) Phase 2
  - Evaluation of IM explosive candidates as Comp B replacement in 81/120mm Mortar
  - IMX-104 and PAX-48 selected as OSI's candidates
  - Also evaluated were candidates from other manufacturers including melt- pour, cast-cure and pressable explosives



IM Assessment Testing – Baseline Test Results

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

IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Detonation	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
60mm (Comp-B/PAX-21)	II / V**	III / II**	V	III	(I)*	(I)*
81mm (Comp-B)	(II)*	(II)*	(III)*	(III)*	(I)*	(I)*
120mm (Comp-B)	II	I	I	I	(I)*	(I)*

* Assessment -- not tested

** with PAX-21 and Intumescent Coating

60mm

0.8 lb (1.8kg) PAX-21/Comp B

81mm

2.0 lb (4.4kg) Comp B

120mm

6.6 lb (14.5kg) Comp B

Results and images courtesy of PM-CAS

IMX-104 IM Test Results (81/120 mm Mortar) – Summary

Bullet Impact 81/120mm (TYPE V – 7.62mm)

Fragment Impact 120mm (TYPE V)

Fast Heating 81mm (TYPE V)

Sympathetic Detonation 81/120mm (TYPE III)

Slow Heating 81/120mm (TYPE V)

mages courtesy of PM-CAS

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IMX-104 IM Test Results - Summary

Reactions:

VI	V	IV	III	II	I
No Sustained Reaction	Burn	Deflagration	Explosion	Partial Detonation	Detonation

IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet Impact
Passing Criteria	V	V	V	V	III	III
81mm (Comp-B) Baseline	(II)*	(II)*	(III)*	(III)*	(I)*	(I)*
81mm (IMX-104)	V	V	12.7mm: IV; 7.62mm: V	8300 ft/s: III; 6000 ft/s: IV	III	I
120mm (Comp-B) Baseline	II	I	I	I	(I)*	(I)*
120mm (IMX-104)		V	IV	V	III	

- Engineering IM Tests in the M934A1 120mm Mortar and M821A2 81mm Mortar with IMX-104 show significant improvement in IM properties over baseline Comp B
- IMX-104 selected as the prime candidate as an IM Comp. B replacement for Mortar Ammunitions for the US ARMY

* Assessment -- not tested

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IMX-104 Material Qualification Status

- IMX-104 material qualification began in late 2009
- Follow protocols as per NATO Allied Ordnance Publication AOP-7 Qualification Procedures for the United States
- All tests including accelerated aging are now completed and PASS ratings achieved across the board
- Test results presented to the US DOD Energetic Material Qualification Board (EMQB) in June 2011
  - Material qualification granted

BAE SYSTEMS

IMX-104 loaded Mortars Insertion Schedule

- IMX-104 type qualification currently in progress
  - 81mm mortars
  - Extensive evaluation testing including
    - IM System Tests
    - Environmental/Aging Tests
    - Gun Launch Survivability Tests
    - Range and Accuracy
    - Lethality / Fragmentation / Initiation

End Item	Current Main Charge Explosive	IM Main Charge Explosive	Project Start Date	ECP Date
60mm Mortar (M720A1/M768/M888)	PAX-21	IMX-104	2007	FY 2013
81mm Mortar (M821A2/M889A1/ M889A2)	Composition B	IMX-104	2007	FY 2012
120mm Mortar (M933A1/M934A1)	Composition B	IMX-104	2007	FY 2013

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IMX-104 Large Scale Manufacturing Overview

Load Ingredients (DNAN, NTO, RDX)

Melt and Mix

Molten IMX-104

Cast onto flaker belt

Molten IMX-104 in thin strip

Cool/solidify and break-up

IMX-104 flakes (Final Product)

Pack and ship

BAE SYSTEMS

IMX-104 Manufacturing Process Development

- Processing Parameters identification
  - Processing temperatures at various stages
  - Ingredient Feed Rate & Order of Addition
  - Use of dry/wet ingredients
  - Final Incorporation (mixing) Time
  - Agitator Speed
- Material Processibility indicated by Efflux Viscosity and consistent Product Homogeneity
  - Composition, sensitivity and other physical/chemical properties testing
- Close interaction with ARDEC EM and LAP Producibility Teams
- Continuous Improvement and Process Optimization

IMX-104 Manufacturing Process Summary

- Current batch size over 1300 lb (> 600 kg)
- Over 90,000 lb (> 41000 kg) of IMX-104 had been manufactured at HSAAP
  - Support US ARMY Mortar Loading Trial and Qualification
  - Round-the-clock operation
- Although process is relatively young, it can be considered as robust and repeatable
- Process optimization planned for FY 2012
  - Design of Experiment technique to evaluate various process parameters
  - Reduce process cycle time to lower overall product cost
  - Collaborate with Loading Facility in the evaluation of suitability in loading operation

Concluding Remarks

- A NEW GENERATION of IM melt-pour explosives now available
    - IMX-104 demonstrated excellent IM properties over Composition B
- Low-cost replacement for Composition B
- Reduced shock sensitivity vs. Composition B (and PAX-21)
- Ingredients readily available and manufactured at Holston
- Robust large scale manufacturing process for IMX-104
- Viable candidate for common fill across all mortar sizes
    - Insertion for 81mm by FY 2012, 60mm and 120mm mortar by FY 2013
- Achieved significant IM improvement over current munitions
- Significant National and International interest
    - Insensitive Composition B replacement in other weapon systems

Acknowledgement

- RDECOM-ARDEC
  - Mr. P. Vinh, Mr. A. Di Stasio, Ms. L. Zhao
- PM-CAS / PM Mortars / ARDEC
  - Mr. J. Rutkowski, Mr. P. Samuels, Mr. C. Patel, Mr. B. Kuhnle, Ms. W. Balas Hummers
- BAE SYSTEMS OSI
  - Mr. A. Carrillo, Mr. P. Lucas, Dr. D. Price, Mr. M. Hathaway, Mr. E. LeClaire, Ms. L. Hale, Mr. B Schreiber, Ms. D. Bowyer
  - Plant Operators in the Explosive Finishing Area
- NTS Camden
  - Mr. D. Mann, Mr. M. Brian

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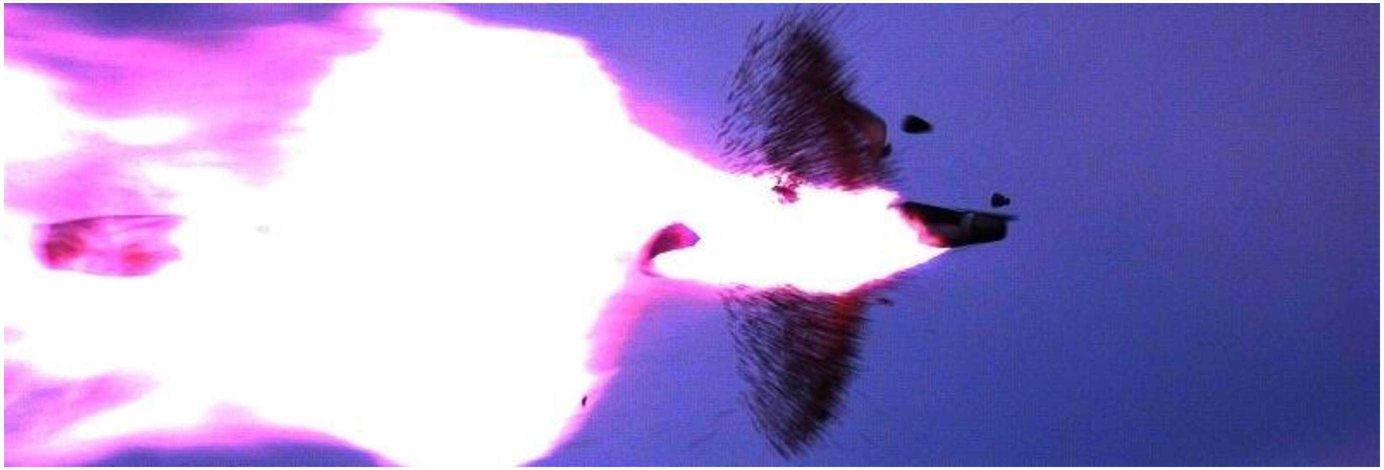
Gunfire Test of the U.S. Navy's Improved Kinetic Energy – Electronic Time Projectile

Geoffrey Bland
Naval Surface Warfare Center, Dahlgren Division, G32



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The Navy's 5" 54 and 62 Caliber Guns

Cruisers (CG's)

Destroyers (DDG's)

"History does not long entrust the care of freedom to the weak or the timid" – General Eisenhower

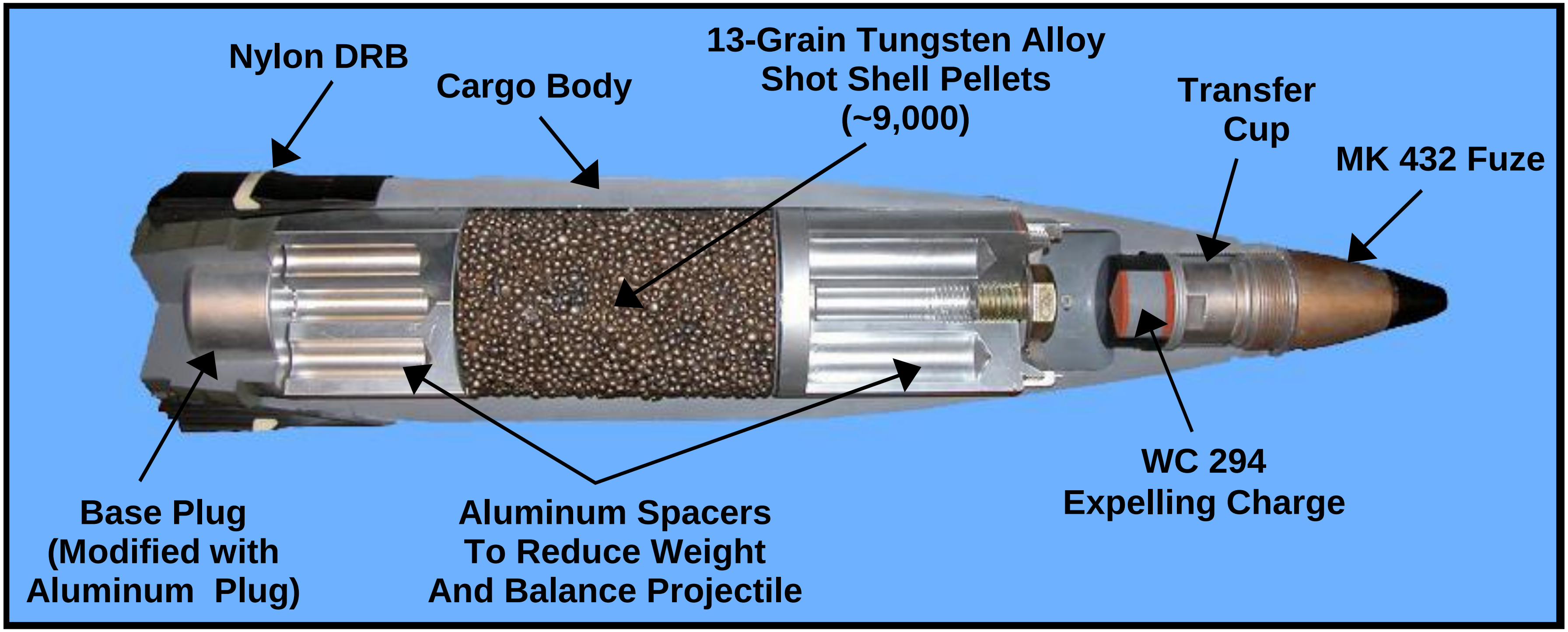
Navy's Requirement

The Navy's 5" 54/62 caliber guns have an anti-surface warfare requirement to defend against small boat threats

- **Swarming tactics**
- **Terrorists**
- **Pirates**

MK 182 KE-ET Anatomy

- The MK 182 KE-ET is currently fielded in the fleet
- KE-ET: The pellets <u>lose</u> kinetic energy by being expelled from the base
- IKE-ET: The pellets <u>gain</u> kinetic energy by being expelled from the nose



IKE-ET Anatomy

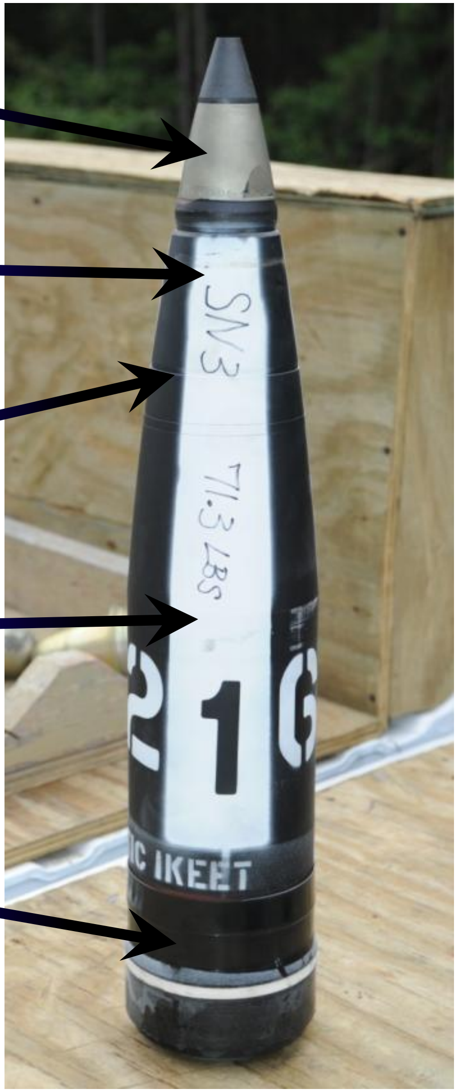
Fuze

Nose Removal Charge

Nose Joint

Tungsten Pellet Payload

Payload Expulsion Charge



NAVSEA WARFARE CENTERS DAHLGREN

IKE-ET Test September 16 2010

VERITAY TECHNOLOGY, INC.

4 BL&Ps
2 KE-ETs
3 Reduced Charge IKE-ETs (1 fuze failure)
5 Full Charge IKE-ETs

KE-ET 1 | KE-ET 2 | IKE-ET RC 1 | IKE-ET RC 2 | IKE-ET RC 3 | IKE-ET FC 1 | IKE-ET FC 2 | IKE-ET FC 3 | IKE-ET FC 4 | IKE-ET FC 5

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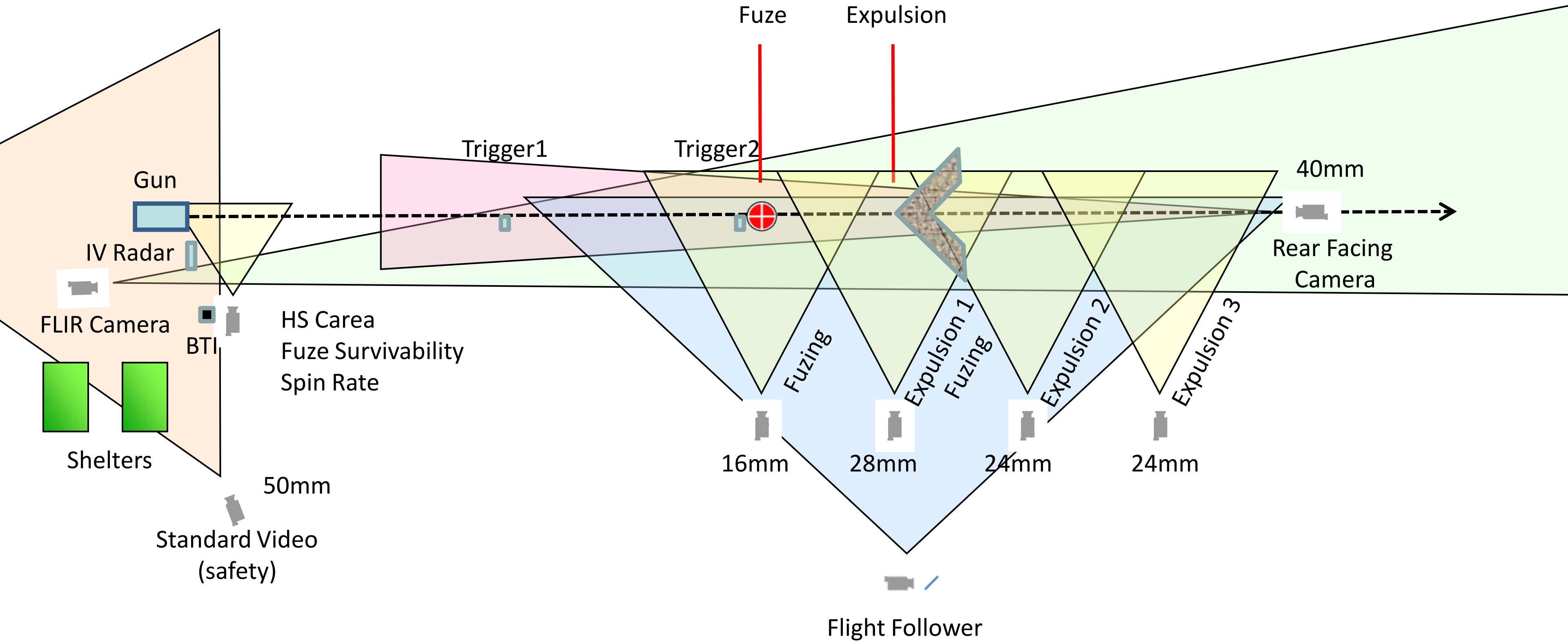
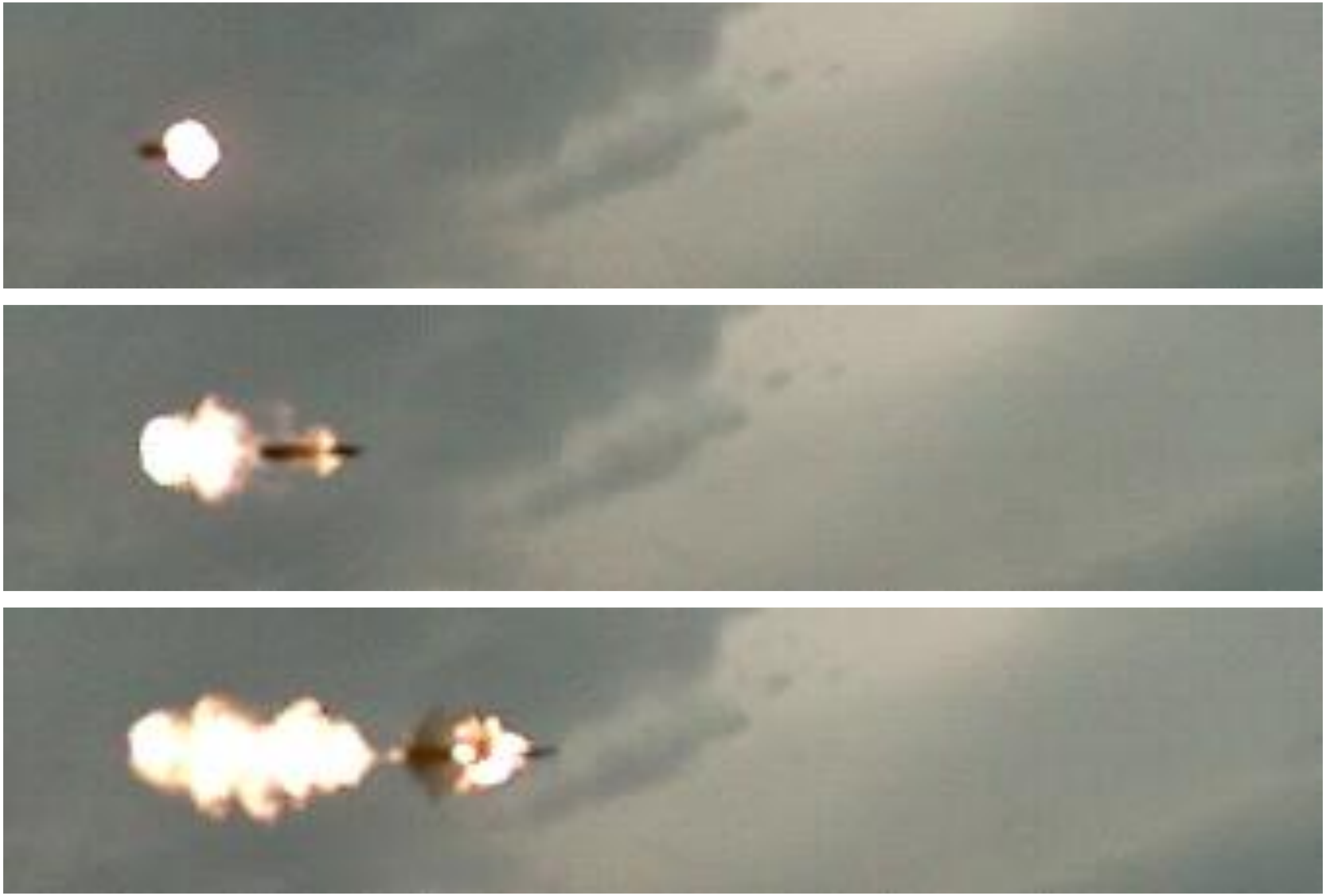
Test Instrumentation Layout



Test Photos (Nose Separation)



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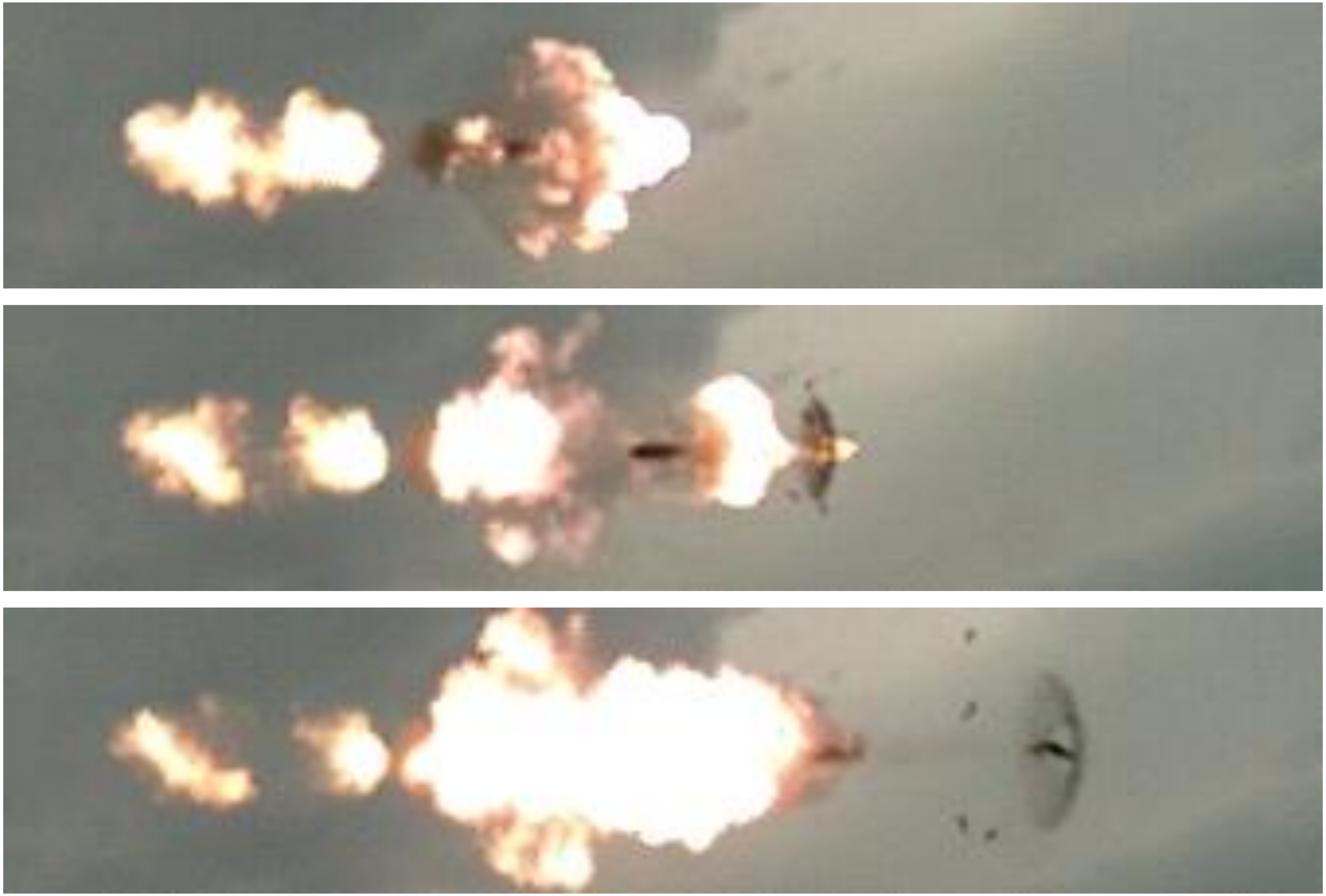
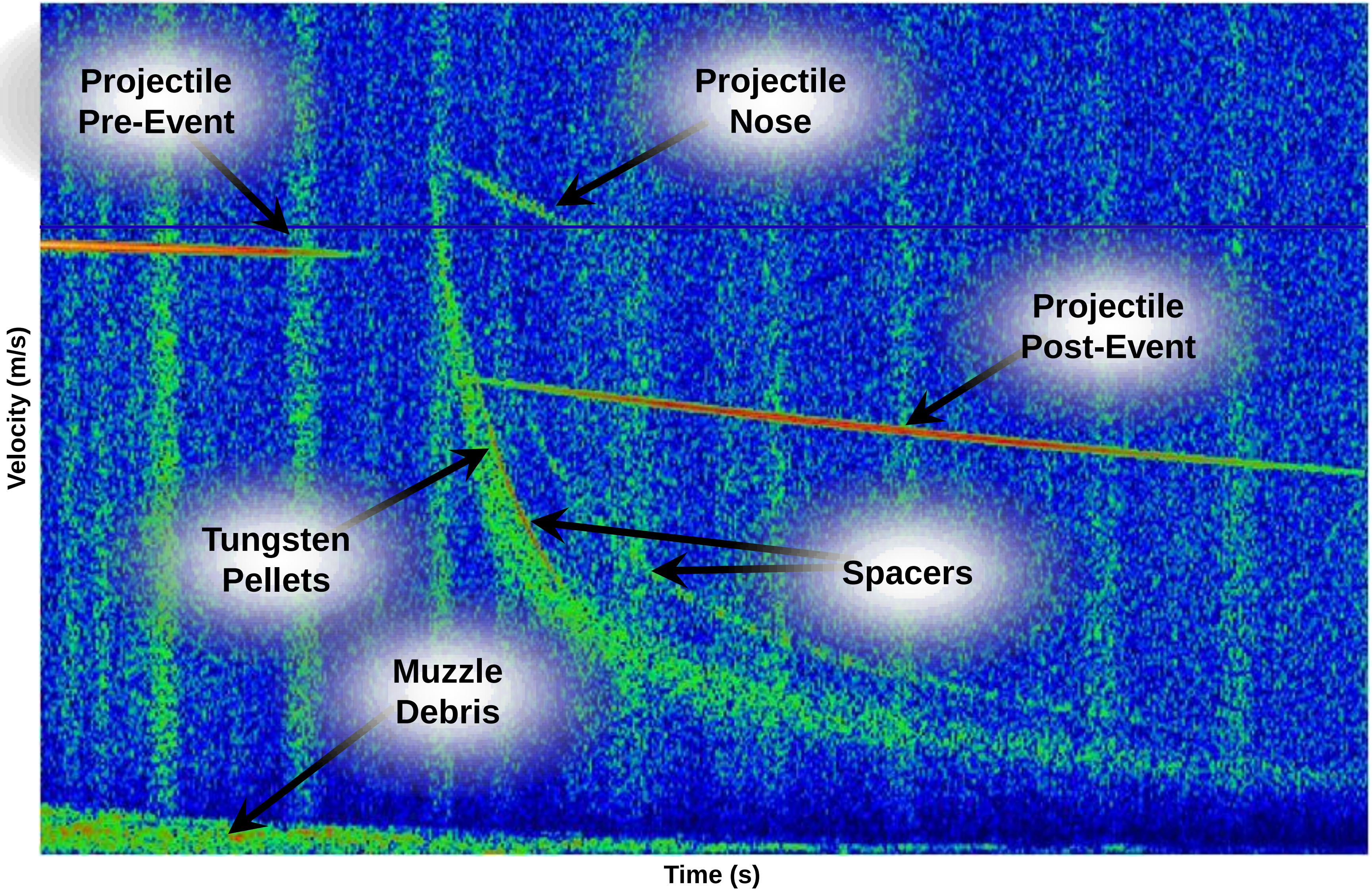
Test Photos (Payload Expulsion)



Test Photos (Flight Follower)

Sample Radar Plot



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Results Photos

Debris Impact Divots

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Results Photos

Spacer vs. Sandbag

Results Photos

IKE-ET vs. Camera Shelter

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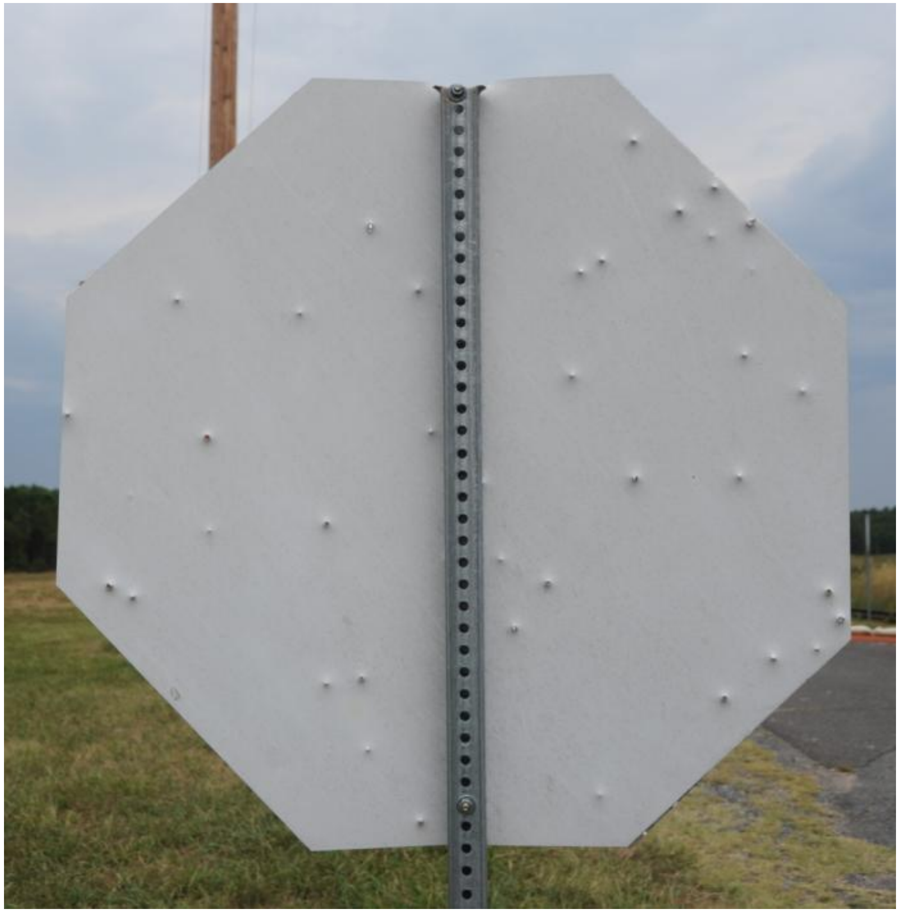
Results Photos



IKE-ET vs. Stop Sign

The Future of IKE-ET

- The IKE-ET is still in the Small Business and Innovative Research (SBIR) phase
- What's to come?
  - Currently the contractor is redesigning the projectile specifically for this application
  - After the redesign phase we will test fire the projectile again to verify survivability and functionality
  - The test will also attempt to acquire dispersion and velocity data (Z-data)
  - The Z-data will be provided to the lethality analysts to characterize IKE-ET's effectiveness vs. certain targets
  - The lethality results will support a decision whether or not to proceed with the program

NAVSEA WARFARE CENTERS DAHLGREN

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Naval Surface Warfare Center, Dahlgren Division, G32
geoffrey.bland@navy.mil

Backup Slides

5 Inch 54 Caliber Gun Mount

Shelters

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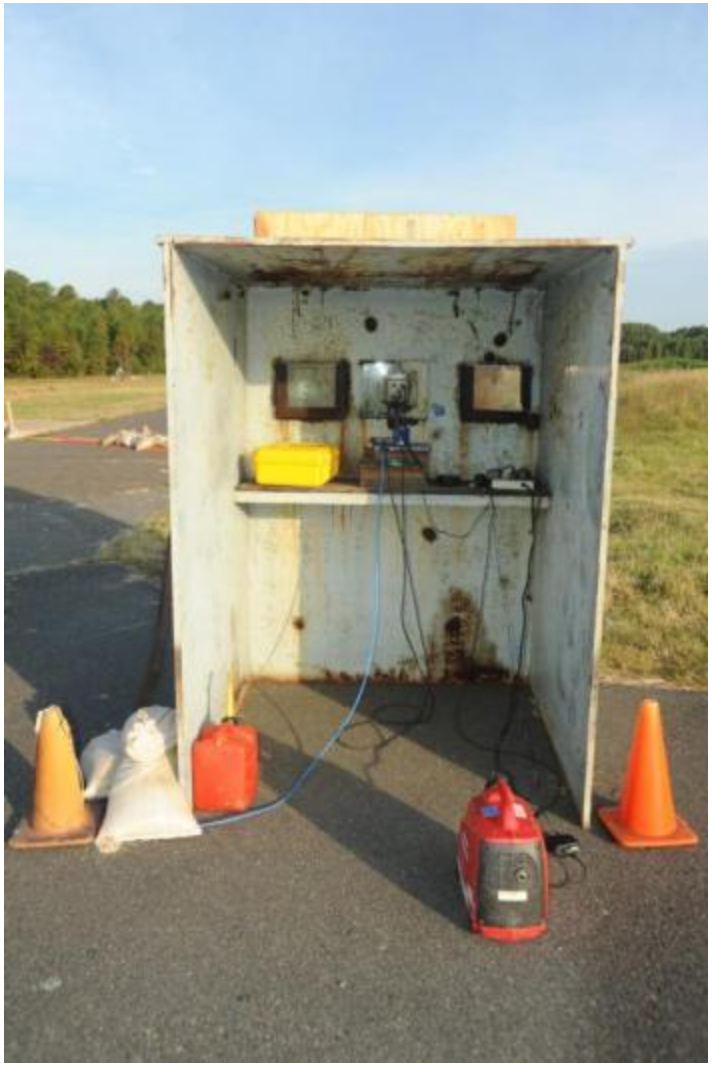
FLIR

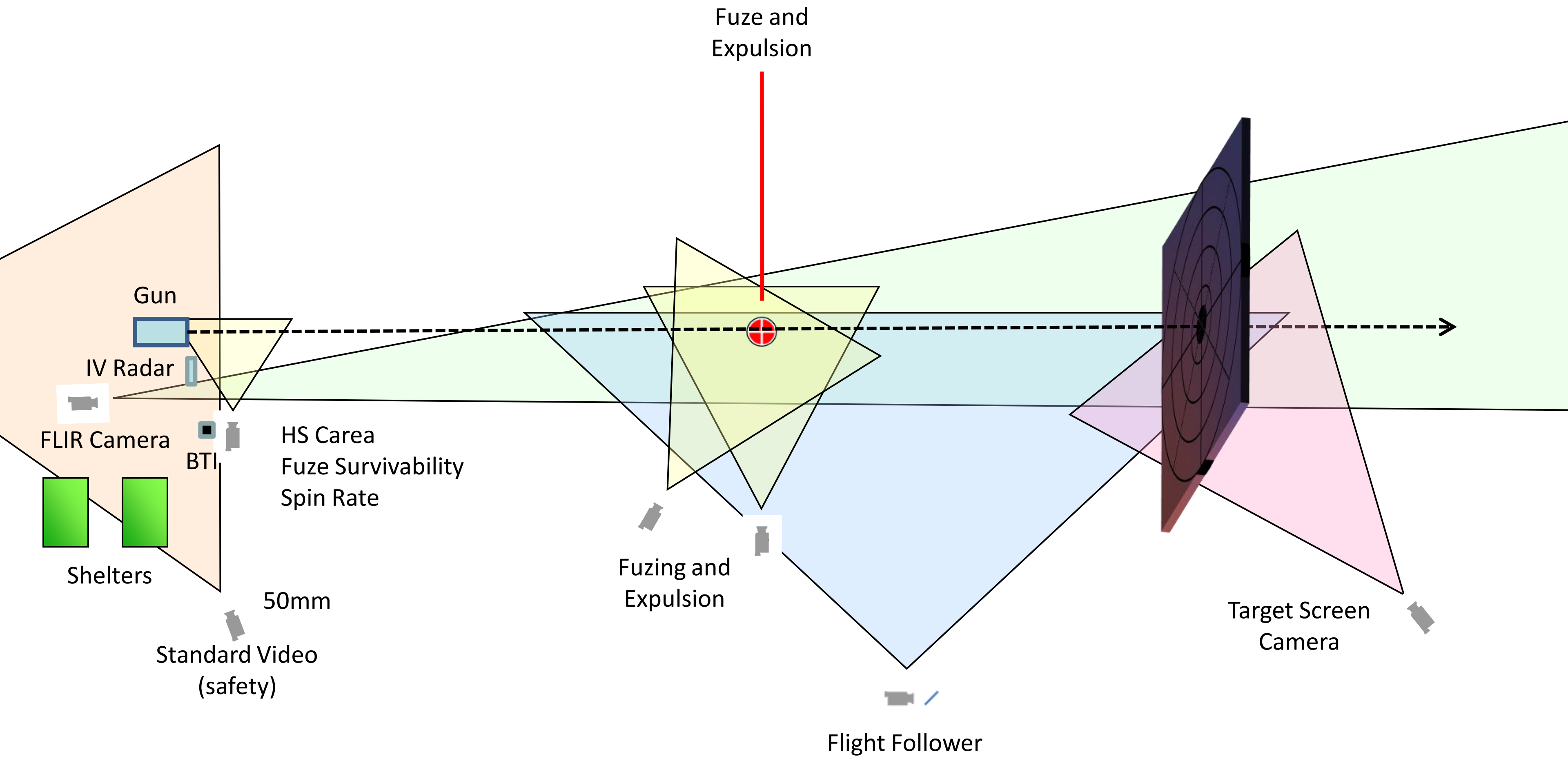
Field Cameras

Flight Follower and Triggers

Rear Facing Camera



Future Dynamic Arena Test Layout



Weapon Systems & Technology Directorate
US ARMY ARDEC and ARDEC- BENET Labs

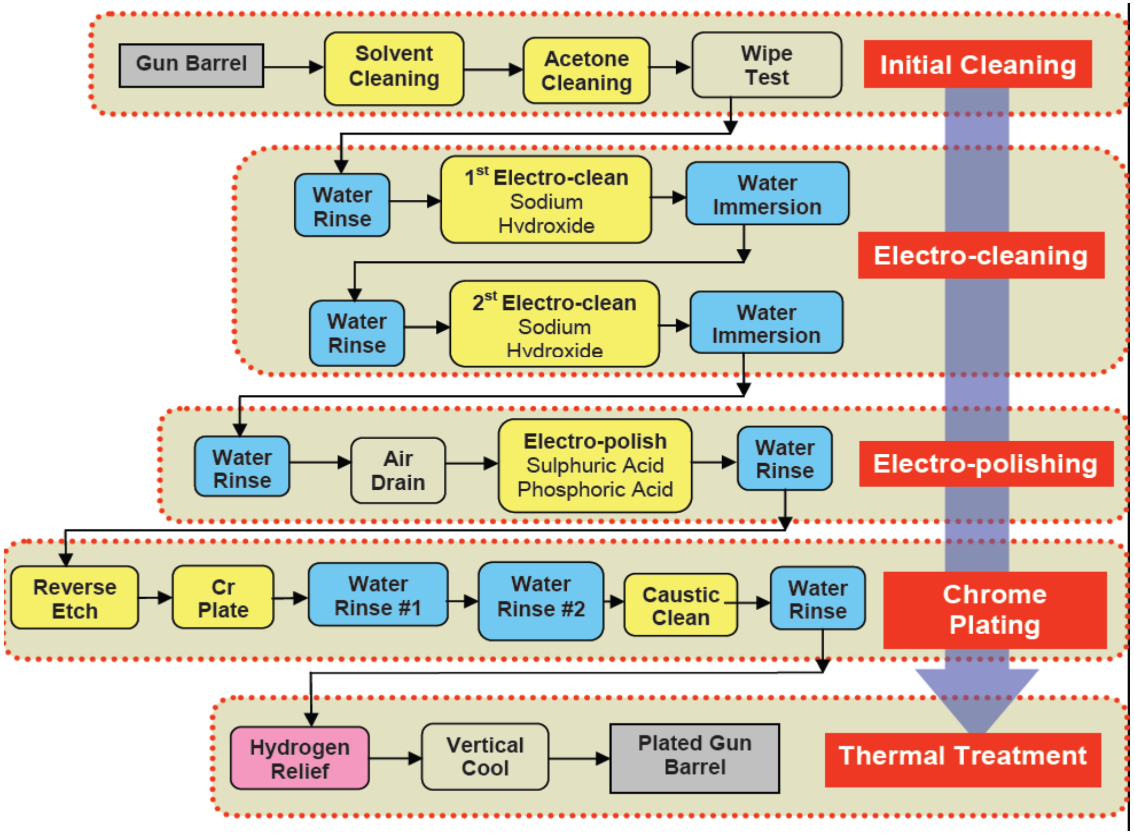
New Physical Vapor Deposition Processes for Durable Pollution-Free Ordnance

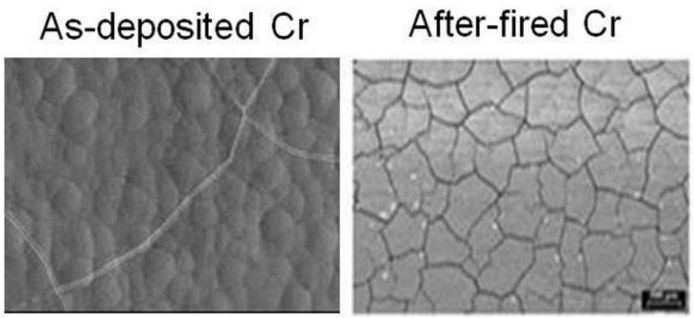
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Sabrina Lee and Daniel Schmidt

2011 NDIA Gun and Missile Conference
Miami, Florida, Aug 29- Sept 1, 2011

Production High Contraction Chrome (HC Cr) Process to Coat Ordnance





From- M. Audino. DOD Metal Plating Workshop, May 22, 2006.

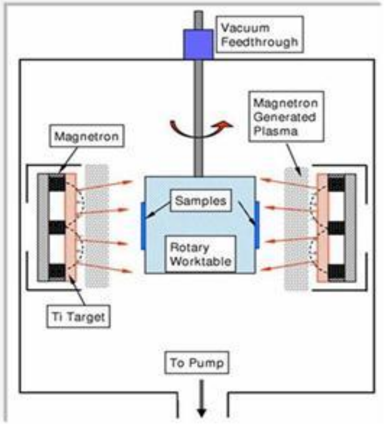
Physical Vapor Depostion Technology Alternative to HC Cr Process

- ***Arc Evaporation (filtered, steered, switched) Process.***
- ***Direct Current Magnetron Sputtering (DCMS) Process.***
- ***Plasma Enhanced Magnetron Sputtering (PEMS).***
- ***High Power Impulse Magnetron Sputtering (HIPIMS).***
- ***PEMS/HIPIMS Deposited CrN Coatings and Applications.***
- ***PEMS/HIPIMS Deposited Ta Coatings and Applications.***
- ***Conclusions.***

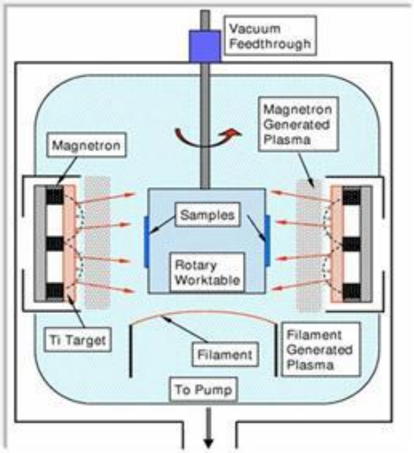
Plasma Enhanced Magnetron Sputtering (PEMS) Using Higher Plasma Intensity

Multiple Target PVD- DCMS and PEMS systems at SWRI

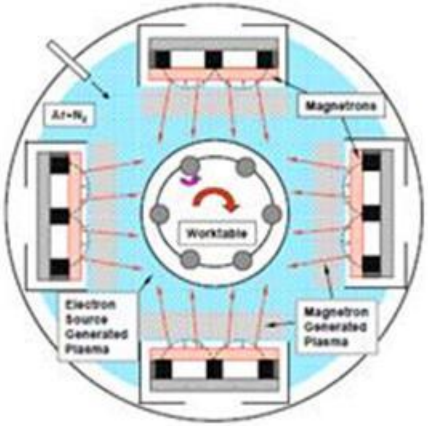
DCMS (0.2mA/cm²)



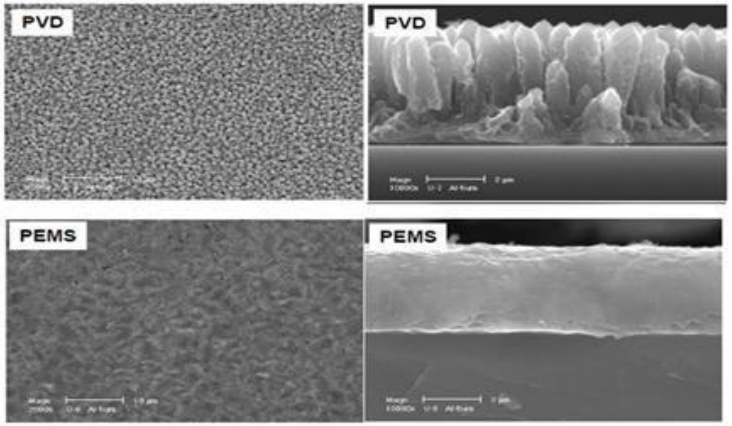
PEMS (4.9 mA/cm²)



Multiple Target System



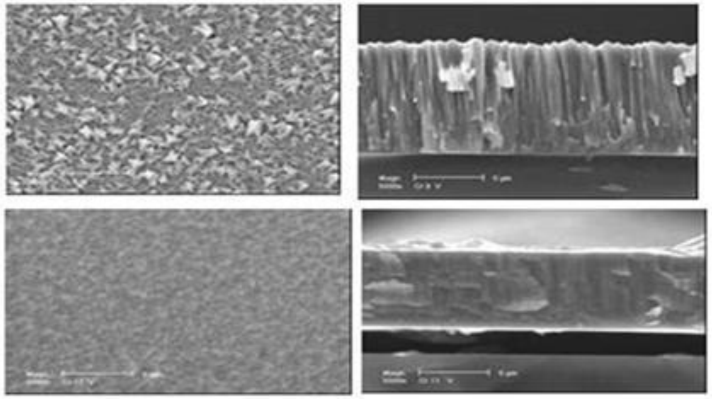
Aluminum



DCMS

PEMS

Chromium



DCMS Versus HIPIMS-HPPMS-MPP
High Power Impulse Magnetron Sputtering

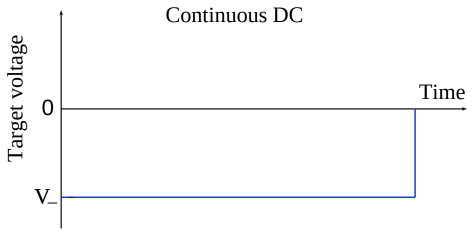
DCMS Continuous DC

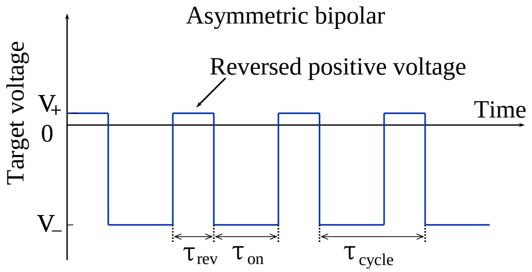
DCMS Pulsed DC

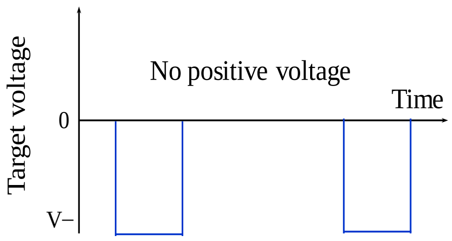
Frequency: in kHz
Duty cycle: 50~90%

HIPIMS-HPPMS-MPP*

Frequency: in Hz
Duty cycle: 1-10%





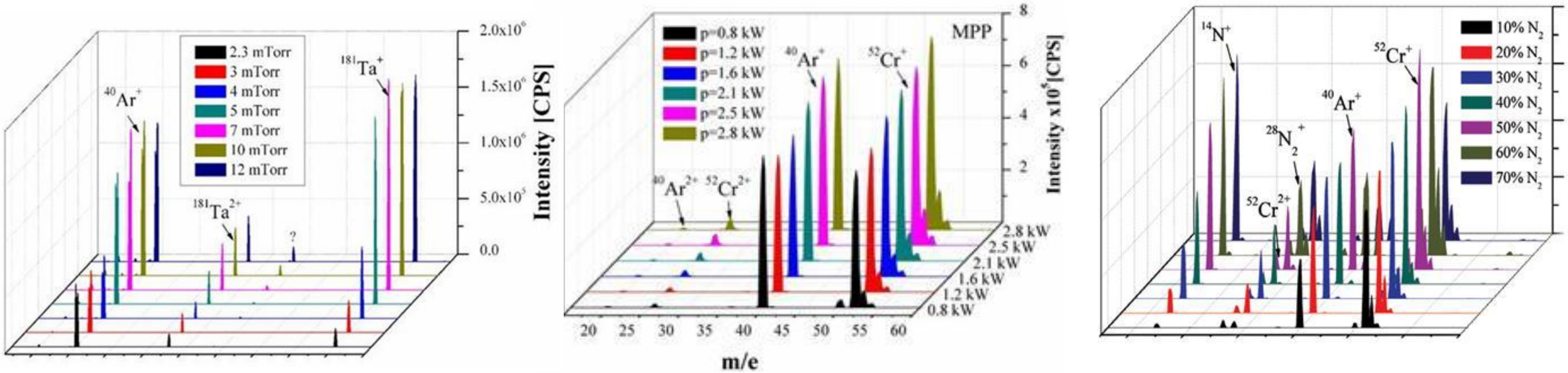


- **Introduced by Kouznetsov et al; HPPMS-MPP are slight variances of HIPIMS.*
- *Large number of target material ions and enhanced plasma density.*
- *High power pulses of short duration (100-150 μs); low duty cycle (1-10%).*
- *Peak value (1-3 kW/cm^2) typically 100 times greater than conventional DC magnetron sputtering (1-3 W/cm^2).*

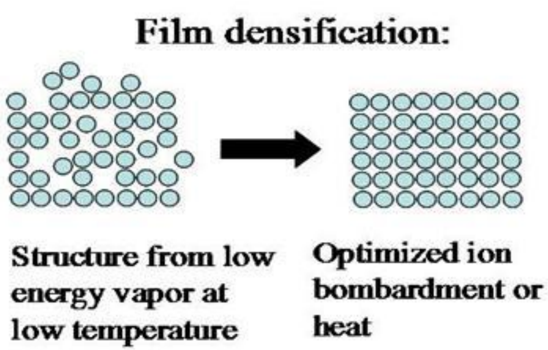
** From- V. Kouznetsov, K. Macák, J. M. Schneider, U. Helmersson, and I. Petrov, "A Novel Pulsed Magnetron Sputter Technique Utilizing Very High Target Power Densities," Surf. Coat. Technol. 122 (1999) 290.*

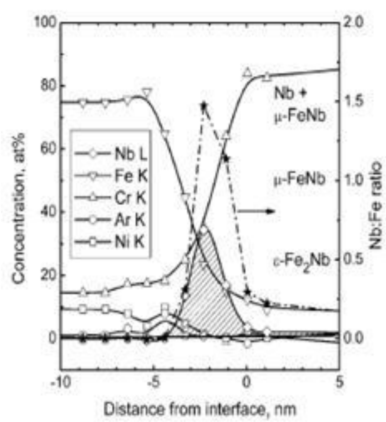
New High Power Impulse Magnetron (HIPIMS) Process Using Metal Plasma

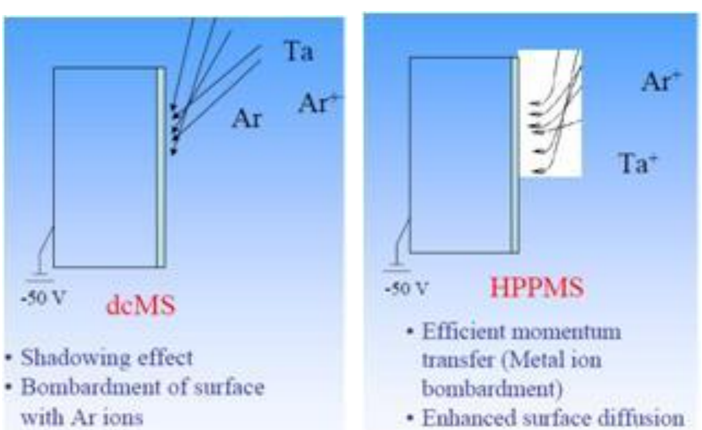
- ***High intensity target Metal Plasma Instead of Argon Plasma***
- ***Deposition of dense coatings at low temperature on complex shape.***



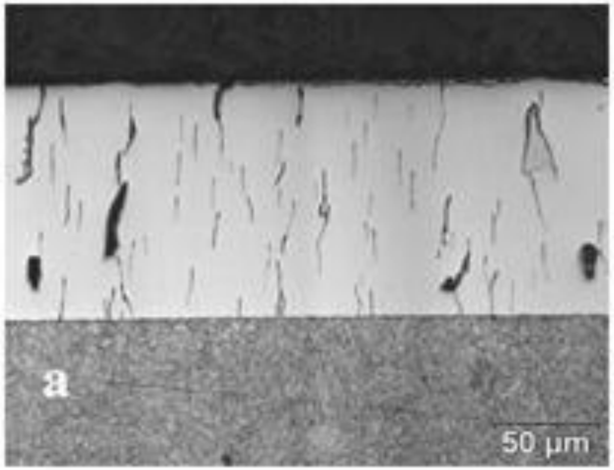
Plasma Mass-Ion Distribution using Tantalum and Chrome Targets measured using an electrostatic quadrupole plasma (EQP) mass spectrometer



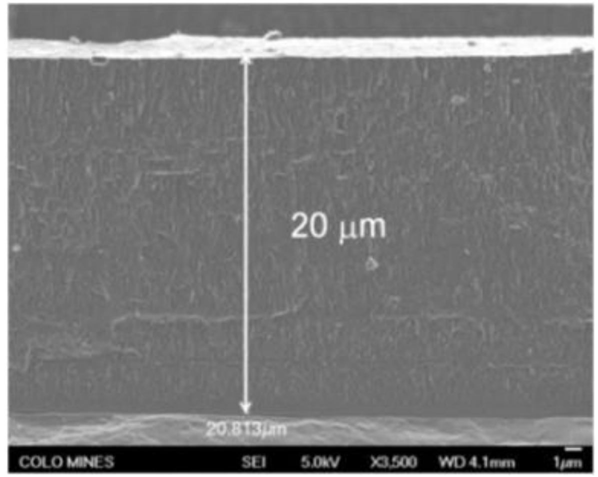


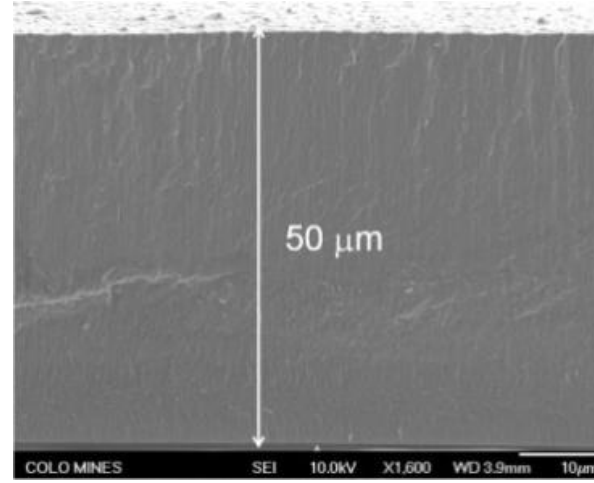


Improved Microstructure in HIPIMS-MPP Deposited Thick Ta and CrN Coatings

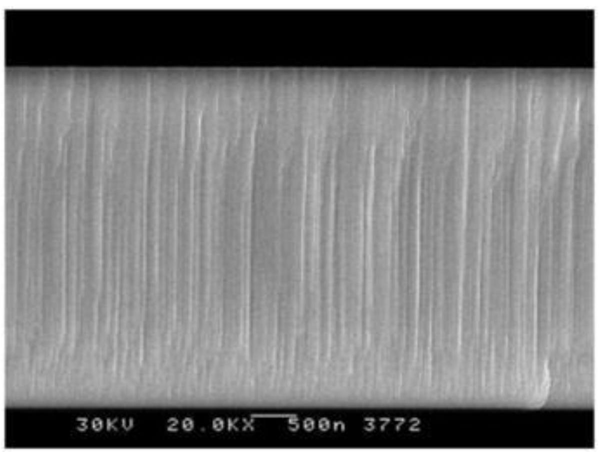


Production Electroplated Cr

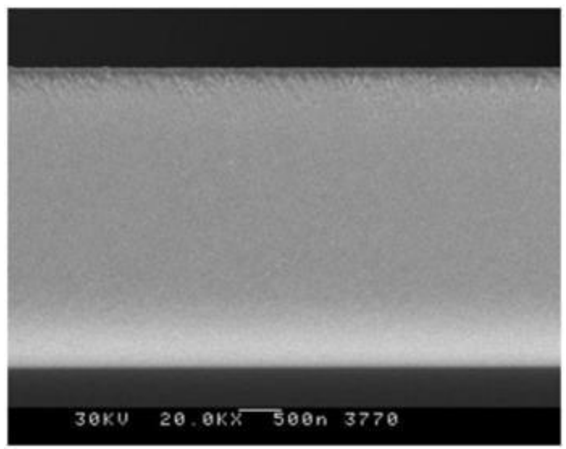




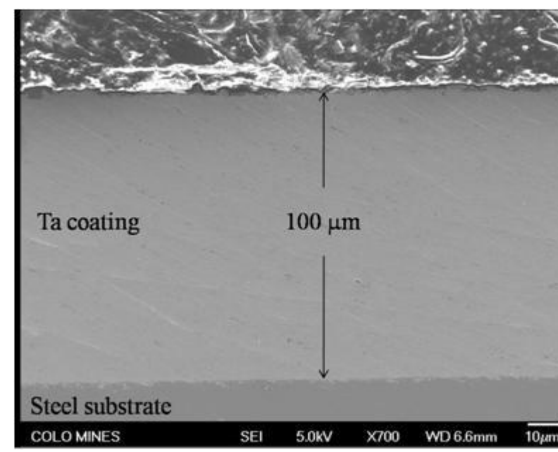
HIPIMS-MPP Deposited Thick CrN



DCMS Ta (10µm)

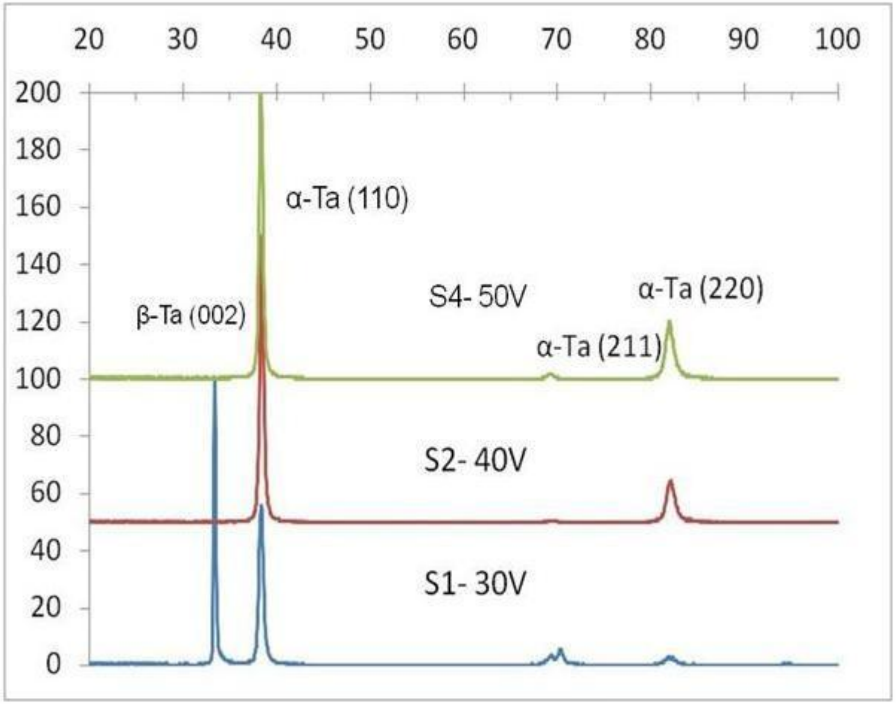


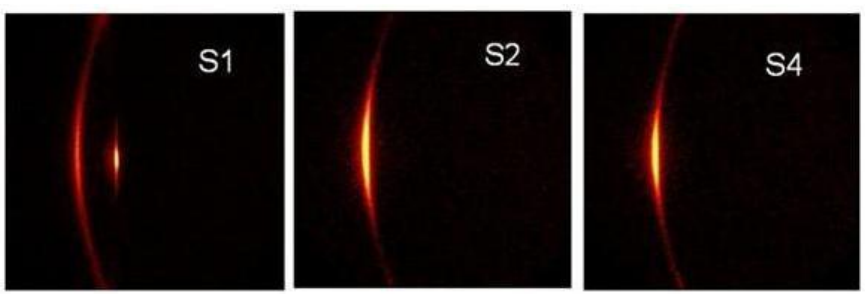
HIPIMS Ta (10µm)



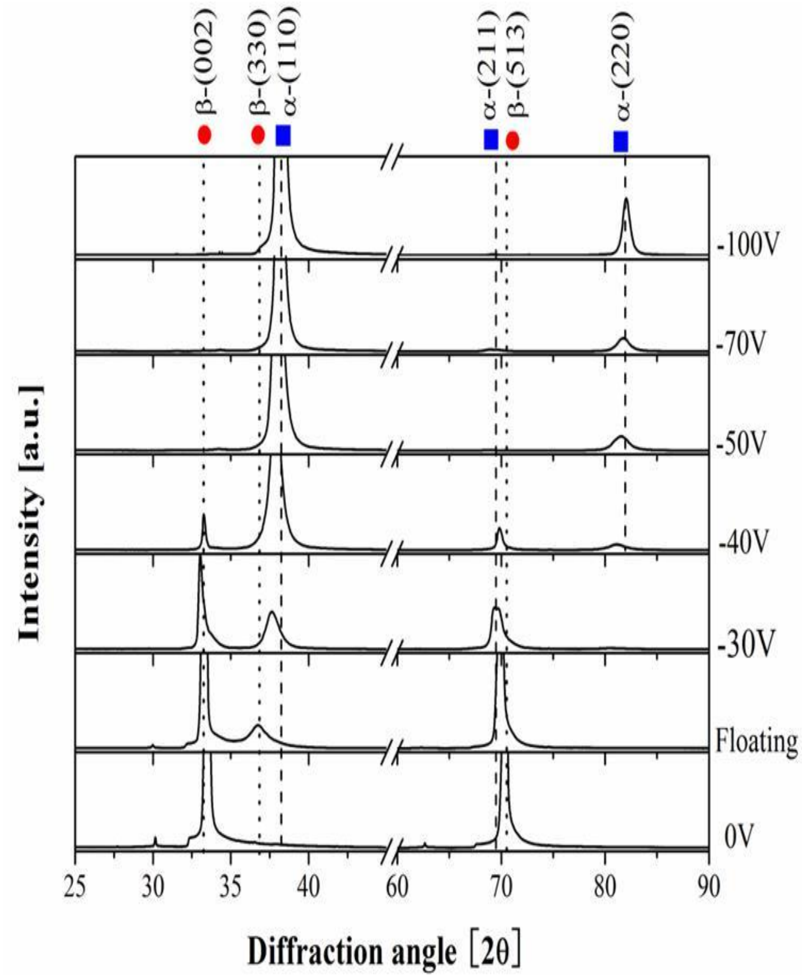
HIPIMS Ta (100µm)

HIPIMS Tantalum Phase Dependence on Deposition Parameter- Bias Voltage



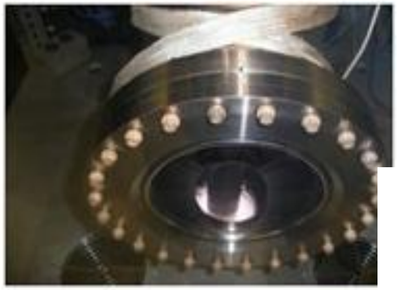


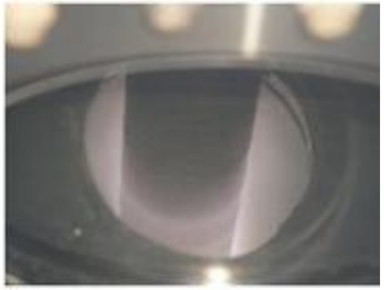
** From- S.L. Lee, M. Cipollo, F. Yee, R. Chistyakov, B. Abraham, SVC 52nd Tech Conf. Proc.,(2009) 44-49.*



* From- J. *Lin, J. Moore, W.D. Sproul, S.L. Lee, J. Wang, IEEE Transactions on Plasma Science, Vol 38, No. 11, (2010) 3071-3078.*

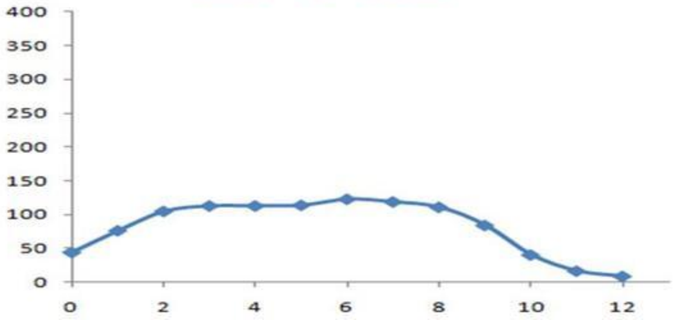
PEMS-HIPIMS-MPP Cylindrical Magnetron Systems for Ta Depositions on 120mm Bore



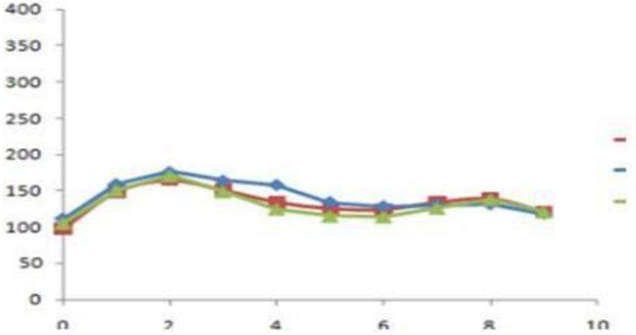


Adding biasing and HIPIMS-MPP to Benet DOE Cylindrical System

Benet DOE, HIPIMS-MPP Barrel
8 hrs,100-120µm thick
blue- 6 o'clock

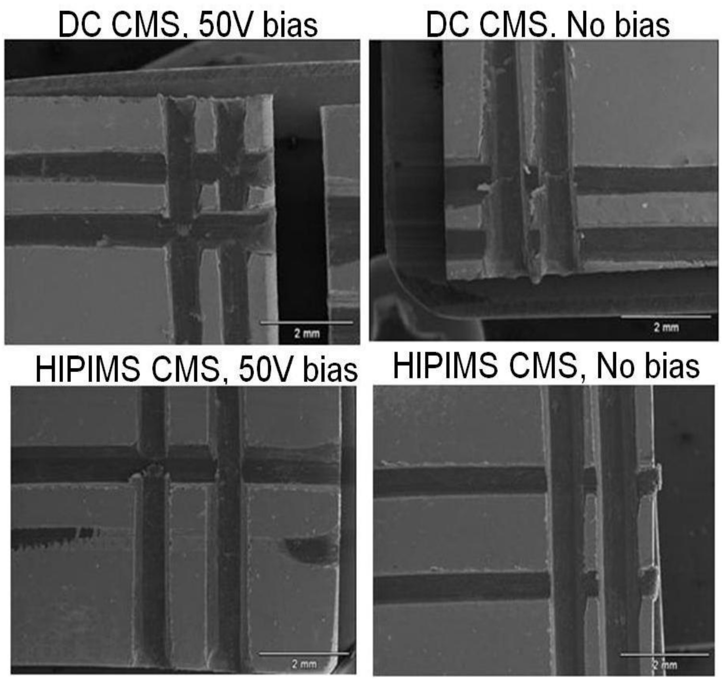


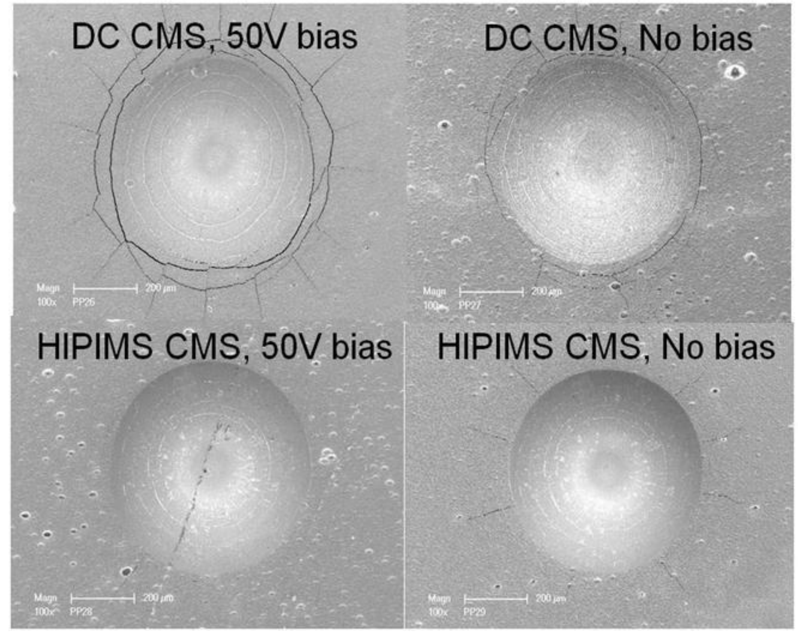
Tube PP36 on Carbon Tube; Biased DC, 15 hrs, **100-150 µm thick**; red- 6, blue- 9, green 12 o'clock



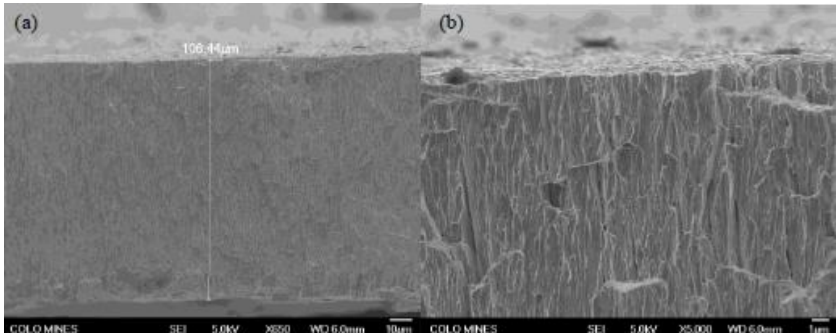
From- S.L. Lee, R. Wei, F. Yee, M. Cipollo, W. Sproul, J. Lin, presentation at ICMCTF, San Diego, CA, April 26-30, 2010.

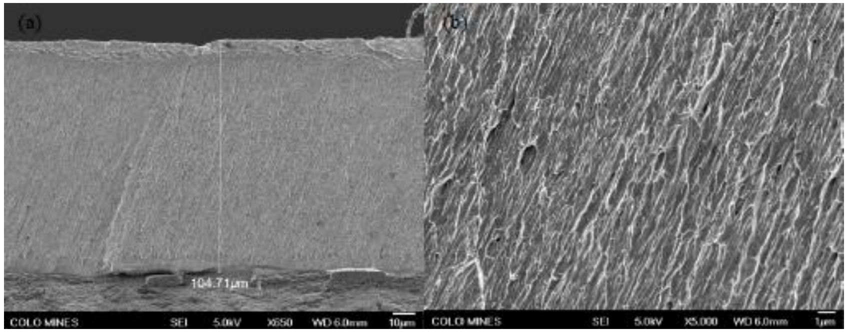
PEMS-HIPIMS Cylindrical Magnetron Deposited Ta on 120mm Steel Cylinder Bore





Fractured surface of 104-106 μm PEMS Ta on 1-ft long steel cylinder



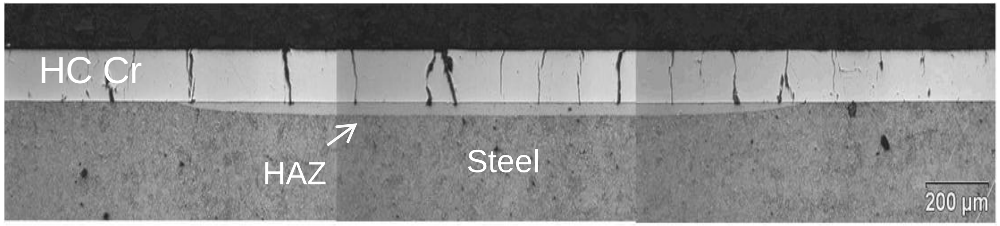


From- S.L. Lee, M. Todaro, S. Smith, R. Wei, K. Coulter, SVC 52nd Tech Conf. Proc., (2009) 558-563.

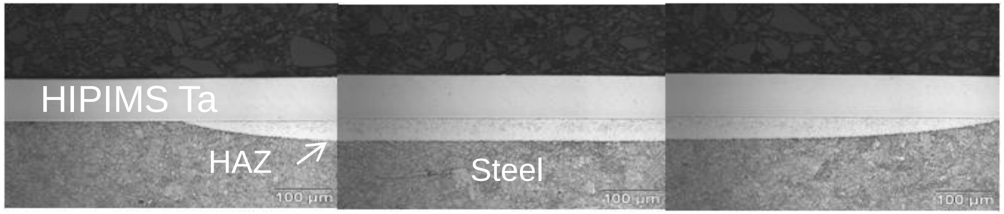
Properties of HIPIMS-MPP Deposited Thick Ta Coatings on A723 Steel

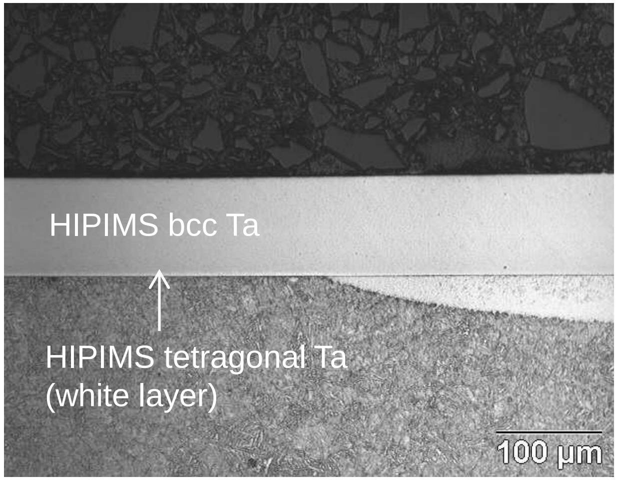
Pulse Laser Heating (2.5 msec, 1.0 J/mm2, 20 cycles, simulating ~1400°C temperature)

125 µm HC Cr on 120mm Diameter Steel Cylinder

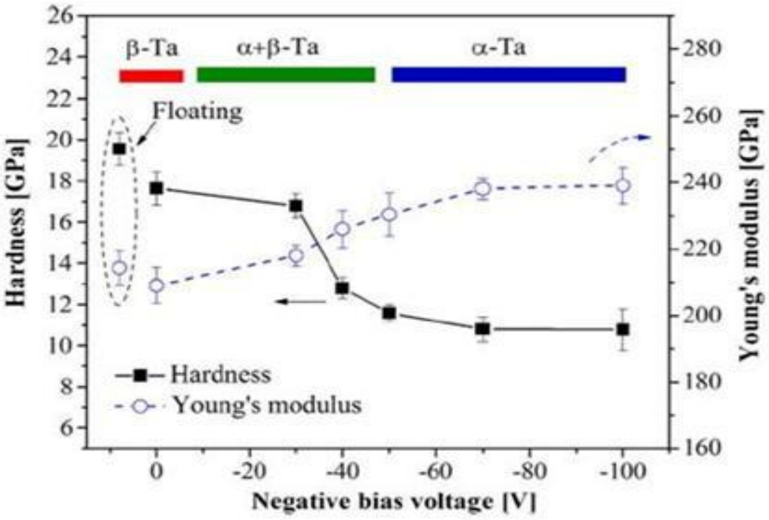


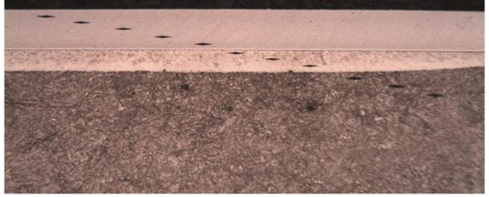
90µm HIPIMS-MPP Ta on Steel





HAZ (Heat affected zone) in steel is due to tempered to untempered martensite transformation.



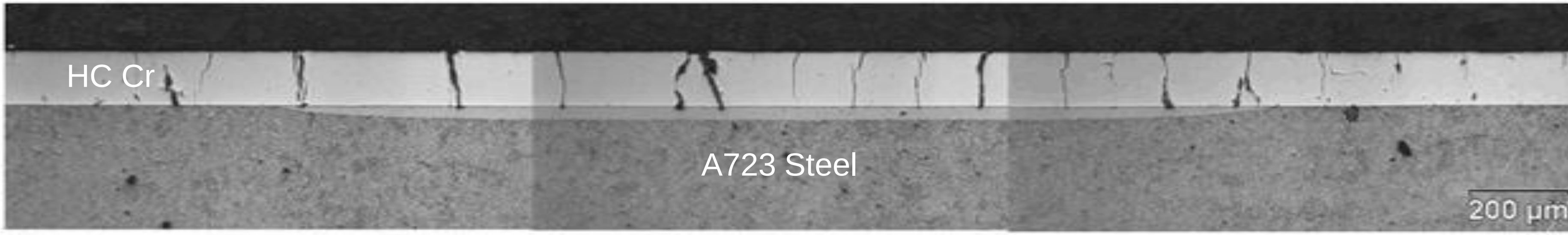


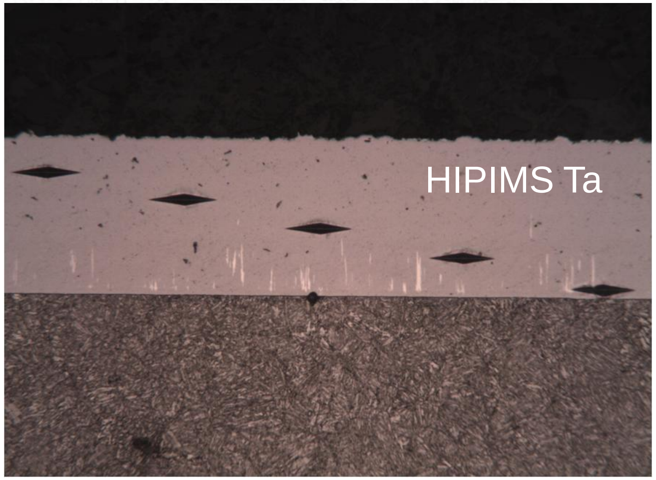
Knoop hardness depth profile of MPP deposited 90 µm Ta on A723 steel

PL-Ta Mines 2-01			
Diamond Length (µ)	Knoop (Hk_{50})	Depth of Diamond (µ)	
36.64	530	-98.35	-Steel
37.57	505	-79.34	
39.68	451	-62.38	
29.54	815	-31.43	- HAZ
30.75	752	-16.72	
29.84	823	-6.63	
35.33	569	12.15	- Ta
34.52	598	28.53	
33.10	649	46.51	
33.10	649	61.02	
33.82	623	75.43	

HIPIMS-MPP Cylindrical Magnetron Deposited Ta on 120mm Cylinder Bore

* Pulse Laser Heating (2.5 msec, 1.0 J/mm2, 20 cycles, simulating ~1400°C temperature)
* DOE-Z2-2 (MPP, substrate ground, 106 µm, no HAZ, no cracking, no delamination)

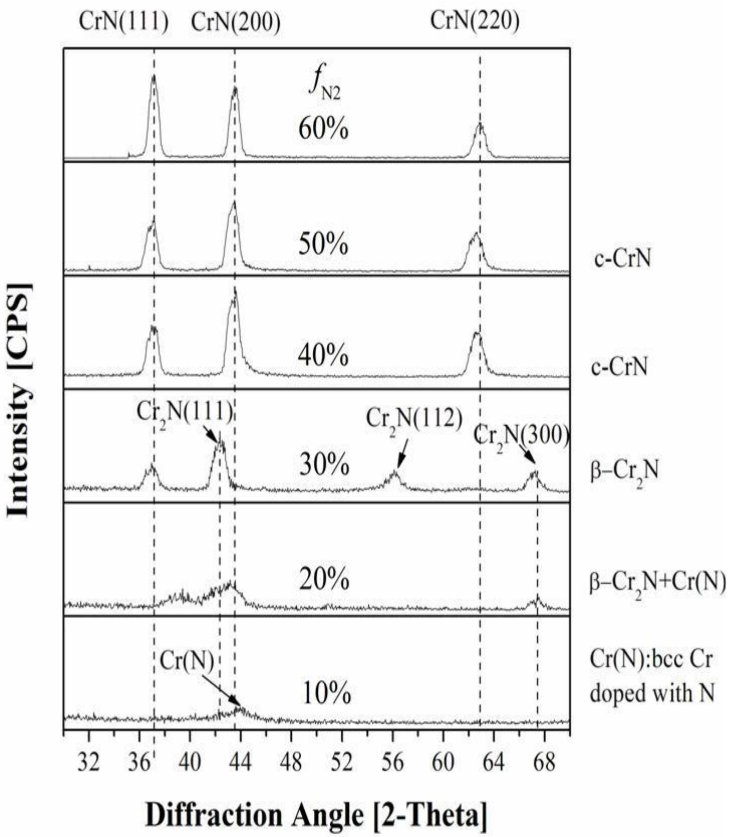




Z2-2		
Diamond Length (µ)	Knoop (Hk_{50})	Depth of Diamond (µ)
46.86	326	5.67
47.18	319	25.78
47.51	315	45.53
47.32	318	64.51
48.96	297	82.74

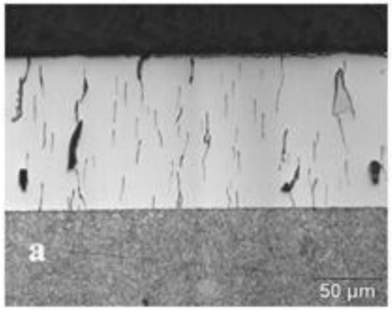
HIPIMS-MPP CrN Coatings For Weapons Coatings and Remediation

Phase formation of CrN coatings depends on the % N_2 in Ar gas.

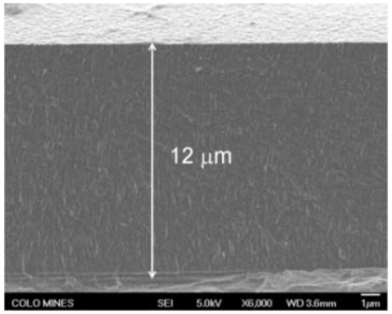


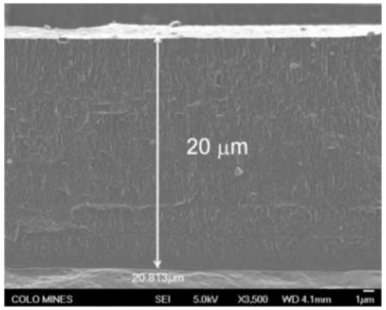
From- *Jianliang Lin, William Sproul, John Moore, Sabrina Lee, S. Myers, Surf Coat Tech 205 (2010), 3226-3234.*

HC Cr

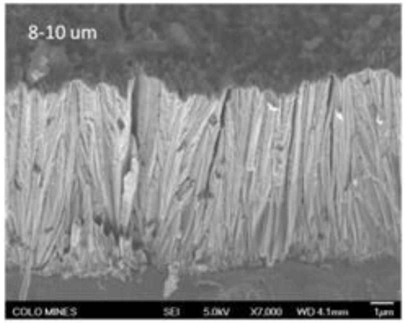


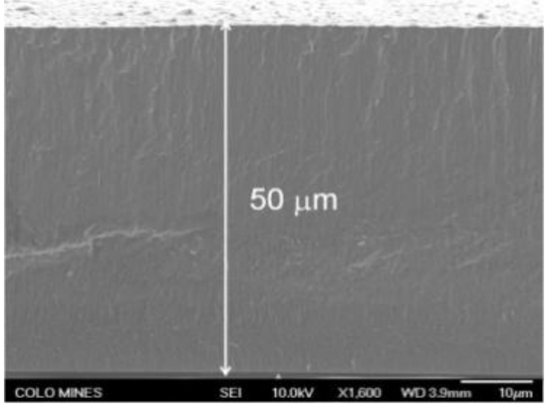
HIPIMS-MPP CrN

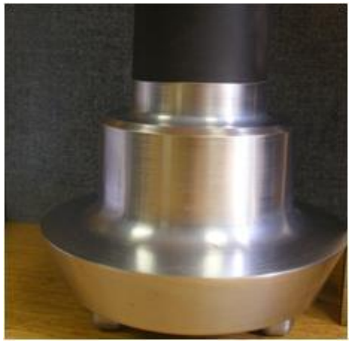




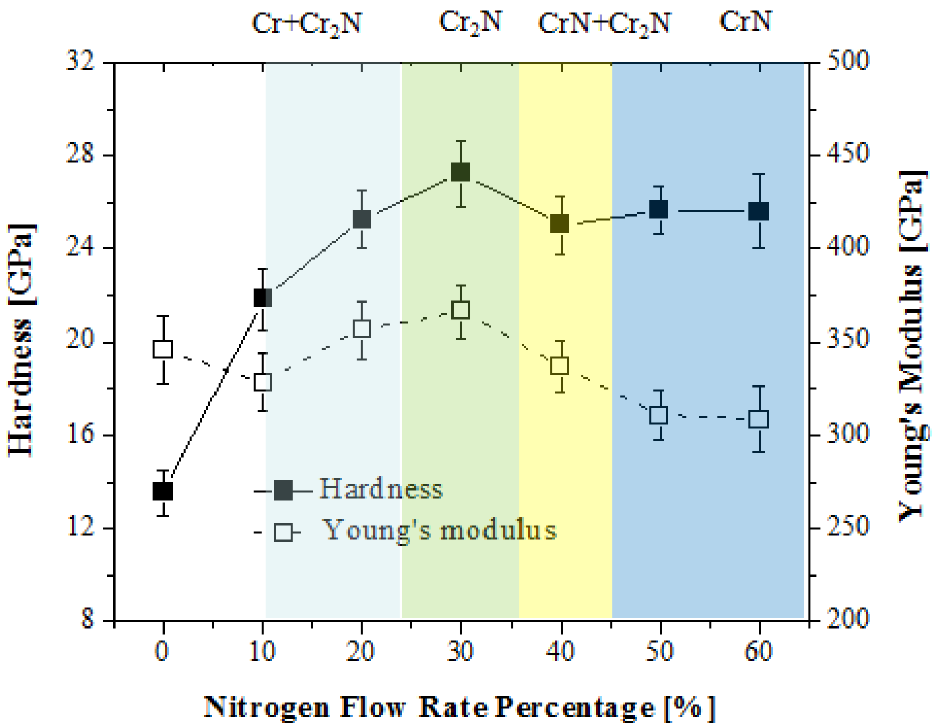
DCMS CrN



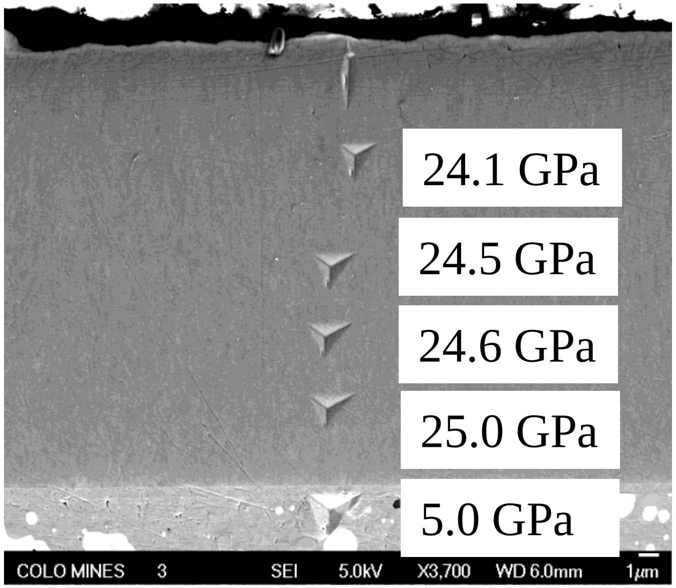




HIPIMS-MPP CrN Coatings
Hardness and Young's Modulus

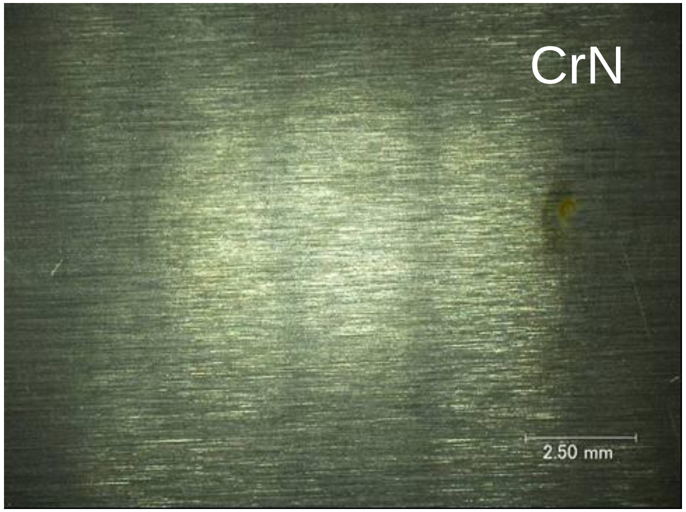


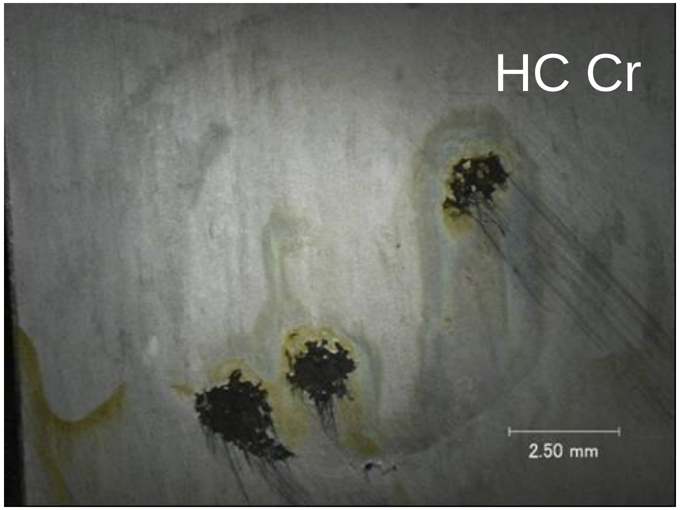
20 μm CrN coating



From- *Jianliang Lin, William Sproul, John Moore, Sabrina Lee, S. Myers, Surf Coat Tech 205 (2010), 3226-3234.*

ASTM Standard Corrosion Test Using a Potentiodynamic Tester & Sea Water

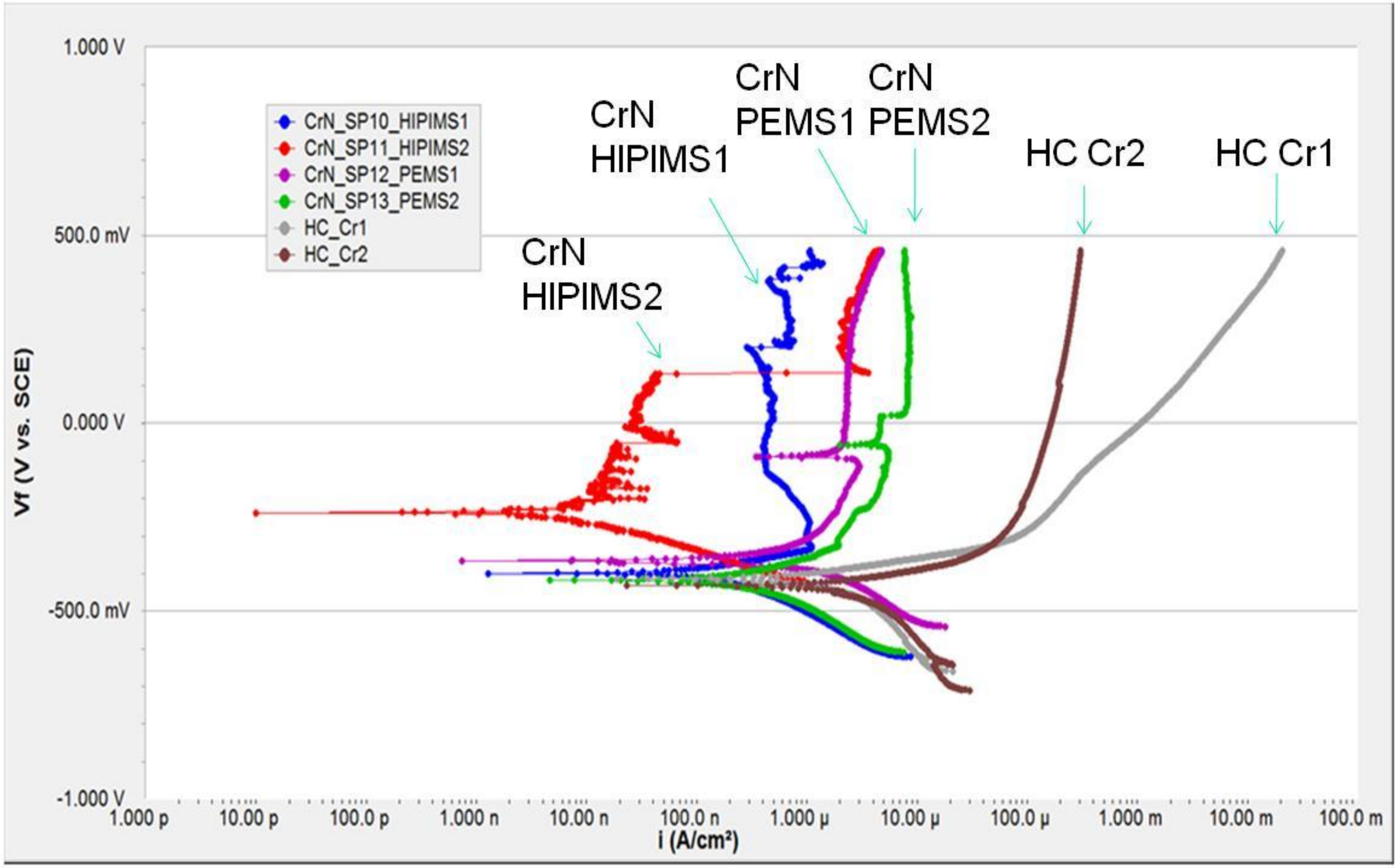




- ASTM D1141-98 "Standard Practice for the Preparation of Substitute Ocean Water"
- ASTM G3-89 "Standard Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing"
- ASTM G5-94 "Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements"

ASTM Standard Corrosion Test Potentiodynamic Polarization Test

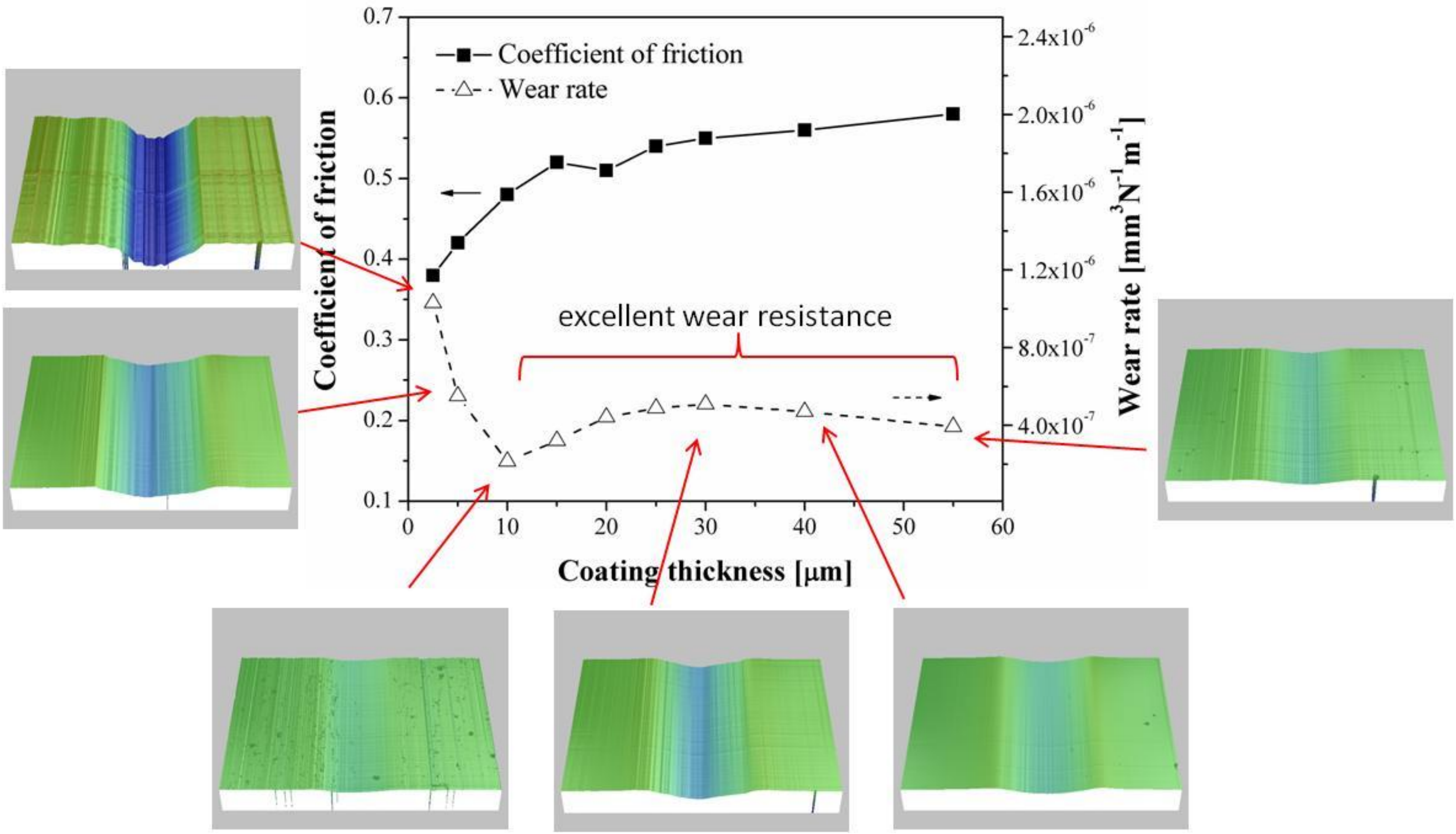
PEMS and HIPIMS CrN coatings showed 2 orders of magnitude improved corrosion resistance compared to electroplated HC Cr



Current Density in µA/cm^2, Log Scale

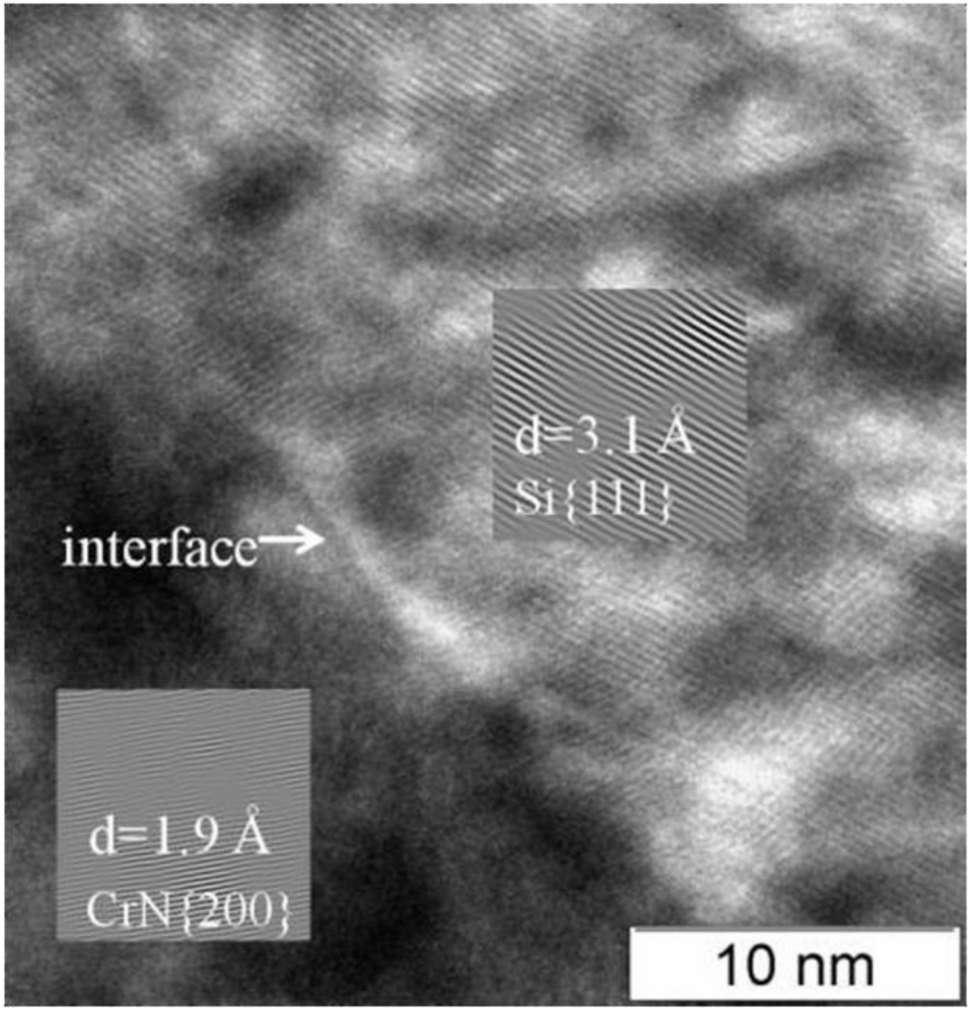
HIPIMS-MPP CrN Coatings Coefficient of Friction and Wear Rate

Test conditions: 10 N normal load, 200 rpm, 5hr, sliding against a 5 mm Al_2O_3 ball



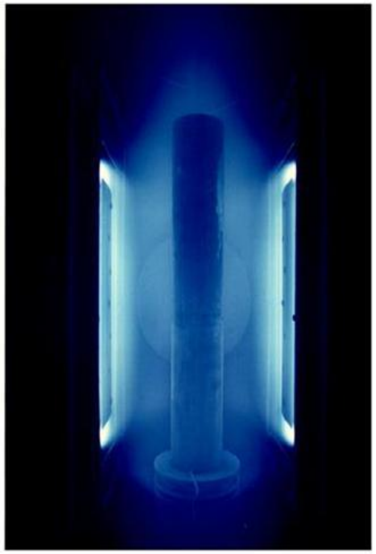
* Jianliang Lin, William Sproul, John Moore, Sabrina Lee, S. Myers, Surf Coat Tech 205 (2010), 3226-3234.

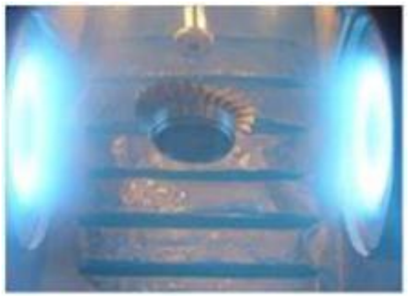
Clean and Dense Interface Microstructure of MPP CrN Film on Si

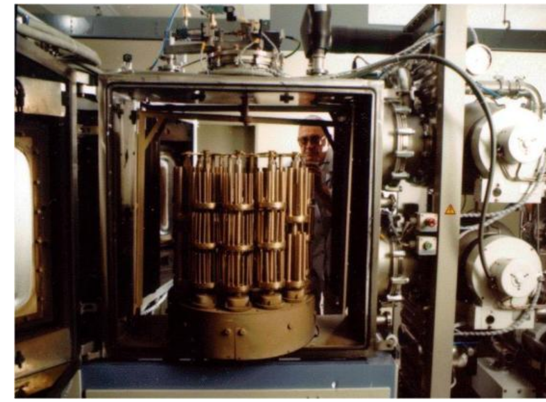


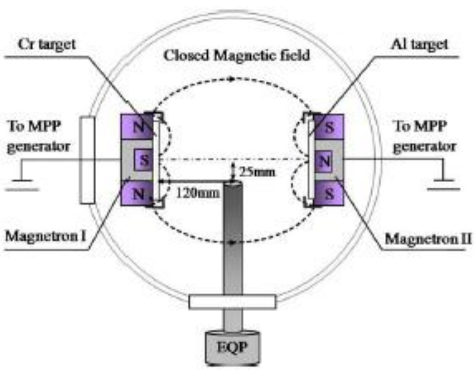
From- J. Lin, W.D. Sproul, J. Moore, S. L. Lee, R. Chistyakov, 'Recent advances in Modulated Pulsed Power Magnetron Sputtering for Surface Engineering', JOM, June (2011) 48-58.

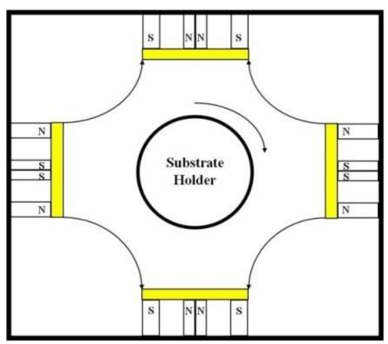
State-of-Art PVD Deposition Systems

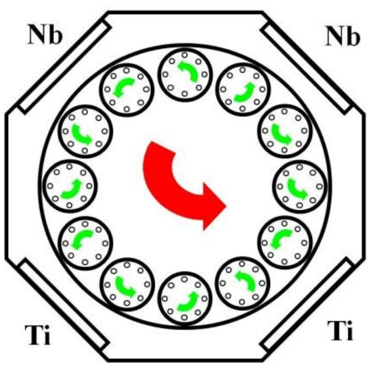


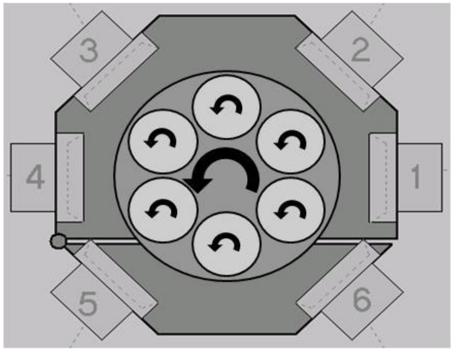












Conclusions

- *New PVD technology PEM with higher plasma density, and HIPIMS-MPP processes generating high intensity metal plasma for deposition of dense quality coatings with less columnar microstructure.*
- *New technology successfully deposited Ta 100-150 µm on 120mm diameter cylinder bore; Ta phase is sensitive to deposition parameters.*
- *New technology successfully deposited 10-55 μm fcc CrN coatings on steel; formation of CrN and Cr_2N phases depends on N_2 concentration.*
- *New thick PVD Ta demonstrated dense bcc Ta coatings with excellent ductility, microstructure, and high temperature properties.*
- *New thick PVD CrN demonstrated dense coatings, good microstructure, high hardness, good modulus, superior corrosion resistance, superior wear resistance properties.*
- *New technology can deposit environmental-friendly coatings, Ta & CrN, for potential replacement of production HC Cr coatings for ordnance.*

Very Affordable Precision Projectile System and Flight Experiments

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Chris Stout – Analysis & Evaluation Technology Division , FPAT ARDEC

Frank Fresconi, Gordon Brown, Ilmars Celmins, James DeSpirito, Mark Ilg, James Maley, Phil Magnotti, Adam Scanlan, Chris Stout, Ernesto Vazquez

ARDEC/ARL

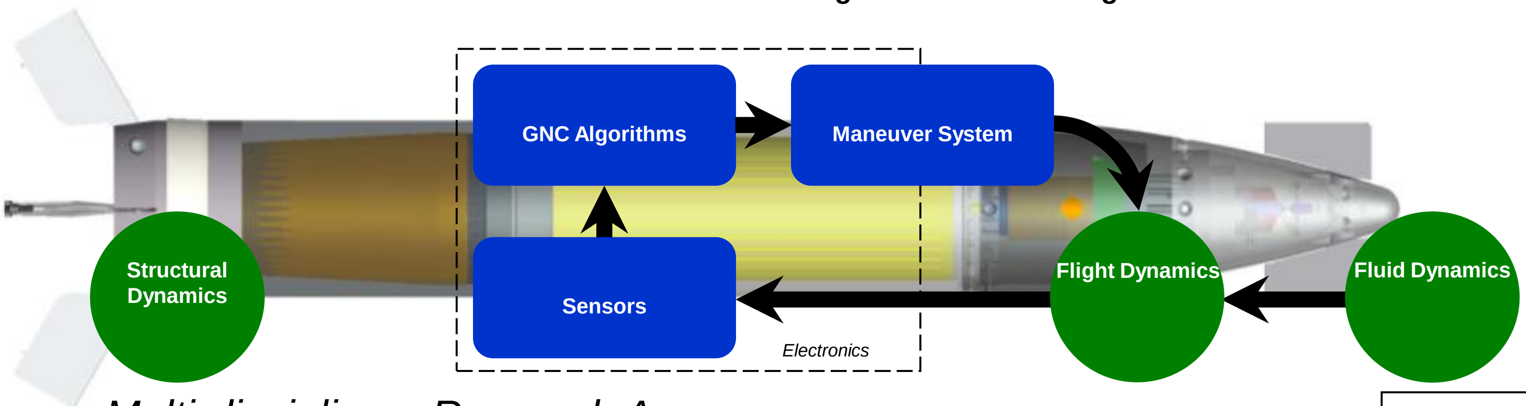
Motivation

- Provide soldier with an organic precision lethality solution for indirect fire systems
- Growing demand for precision capability across multiple caliber systems
  - First-round lethality
    - more stowed kills
    - more timely
  - Limit collateral damage
    - use in urban terrain
    - use in close proximity to friendly troops and civilians
- Deliver scalable effects warheads

Guidance, Navigation, and Control (GNC) Overview and Challenges

Three basic questions:

Where am I? **Where do I need to go?** **How do I get there?**



Multi-disciplinary Research Area

Requirements

Integrate into miniature, gun-hardened package with real-time processing

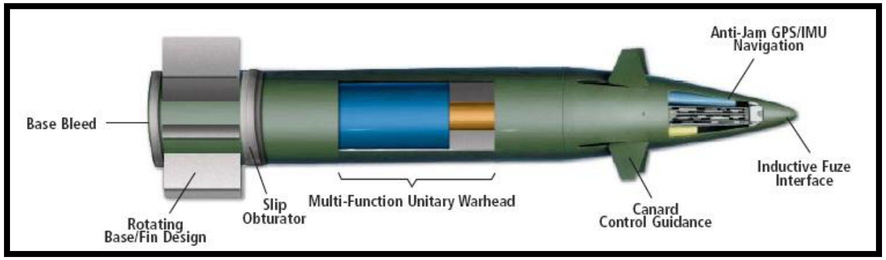
Unique Challenges for GNC in the Gun-Launched Environment:

- Rifled guns → spin-stabilized projectiles (Magnus moment, gyroscopic action, actuation freq.)
- Survivability of components at gun launch event
- Sensors in high-dynamic environment
- Physics of flight for novel concepts
- Embedded processing
- Varied applications (*1*s < *time-of-flight* < *100*s, *0*Hz < *spin rate* < *1000*Hz)
- Size, weight, and power
- Affordability ($/round, $/kill)

Technical Approaches

Current Approaches:

- Gun-hardened missile technology
  - maneuver system complexity/tolerance
  - high grade sensors
  - expensive
- Retro-fit existing stockpiles
  - narrowed design space



Alternate Approach for Affordable Precision

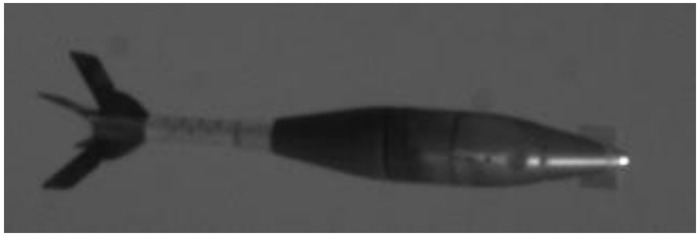
- DoD scientists and engineers develop technical underpinnings
  - Accept greater technical risk
  - Non-proprietary
  - Fund R&D once and apply to all

Fundamental understanding of science and technology enables general, caliber-independent GNC solutions

Very Affordable Precision Projectile - Overview -

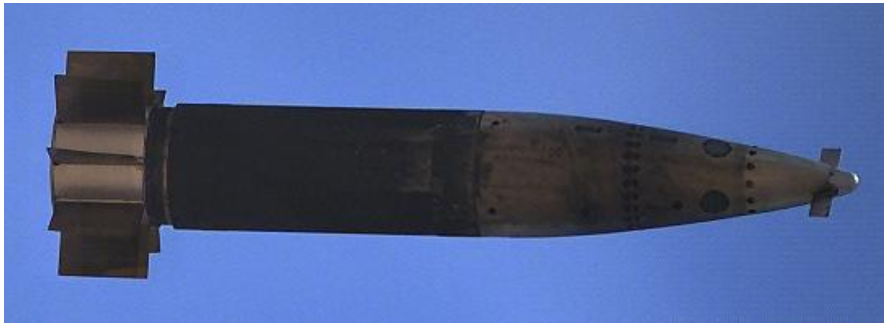
Objective

- To develop and demonstrate affordable precision technologies independent of projectile caliber applicable across all indirect fire platforms
- Requirements
  - Cost
  - Precision
  - Angle-of-Fall
  - Range



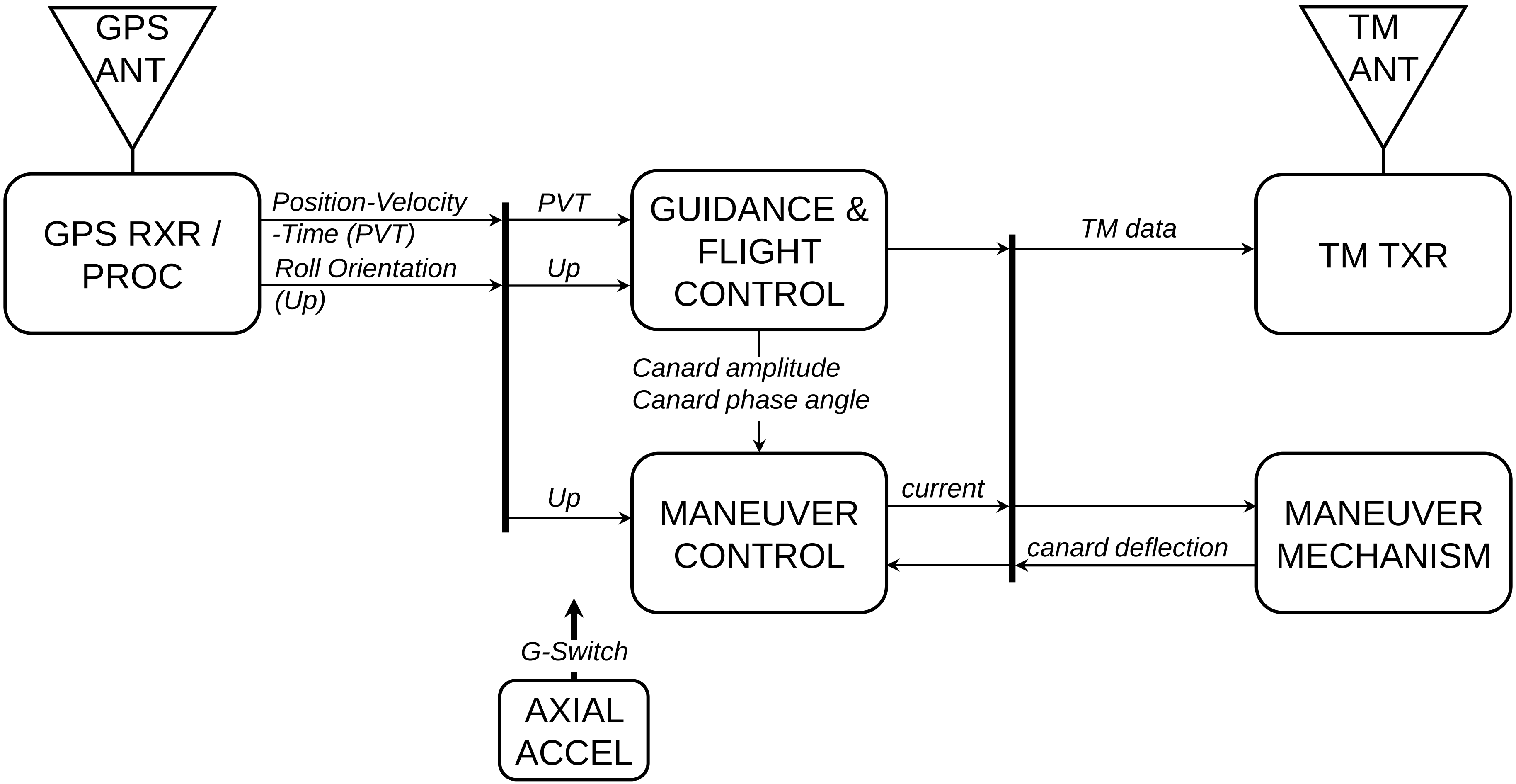
- ***Solution***: rolling airframe with single-axis maneuver mechanism, reduced sensor requirements and ballistic-based guidance algorithm

- Joint ARDEC-ARL effort with support from PM-CAS
- CRADA with industry for GPS expertise
- Fuzing, warhead, rocket, tactical battery leveraging other efforts



Demonstrated guide-to-hit capability in flight experiments on multiple calibers

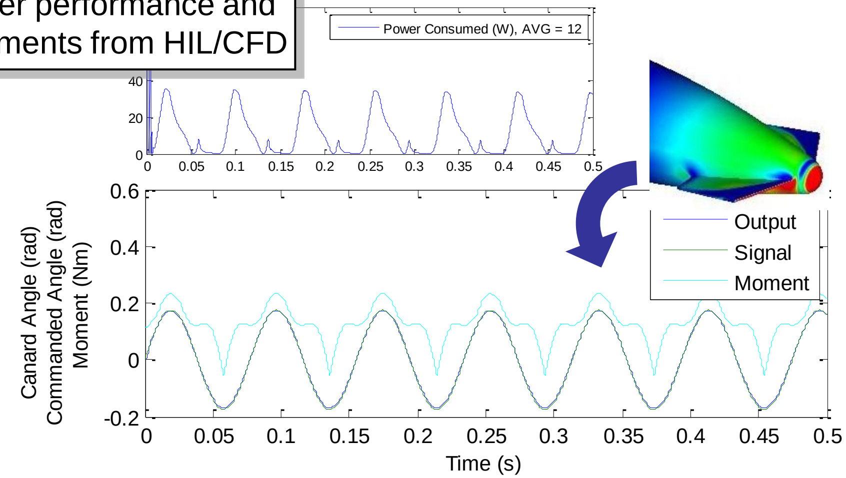
VAPP Architecture



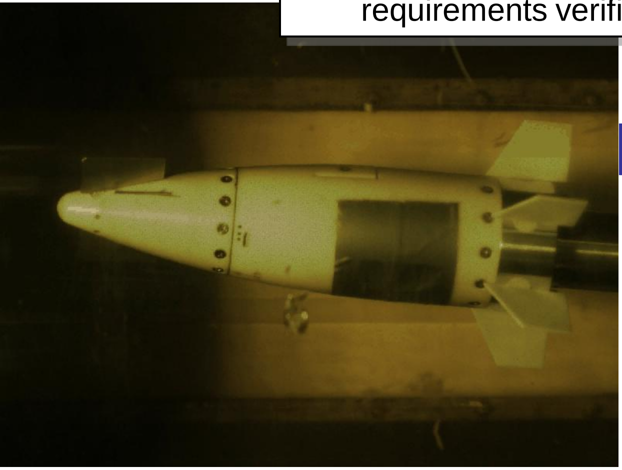
Maneuver System - Development -

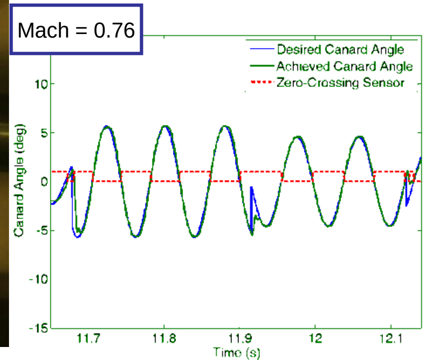
- Mechanical design
  - Linear voice coil coupled to canards with locking mechanism
- Electrical design
  - Algorithms embedded for real-time processing on DSP
  - H-bridge driven by pulse width modulated signals from DSP
  - Encoder and zero-crossing sensors provide feedback
- Controller algorithm
  - LQR controller tracks sinusoidal reference signal

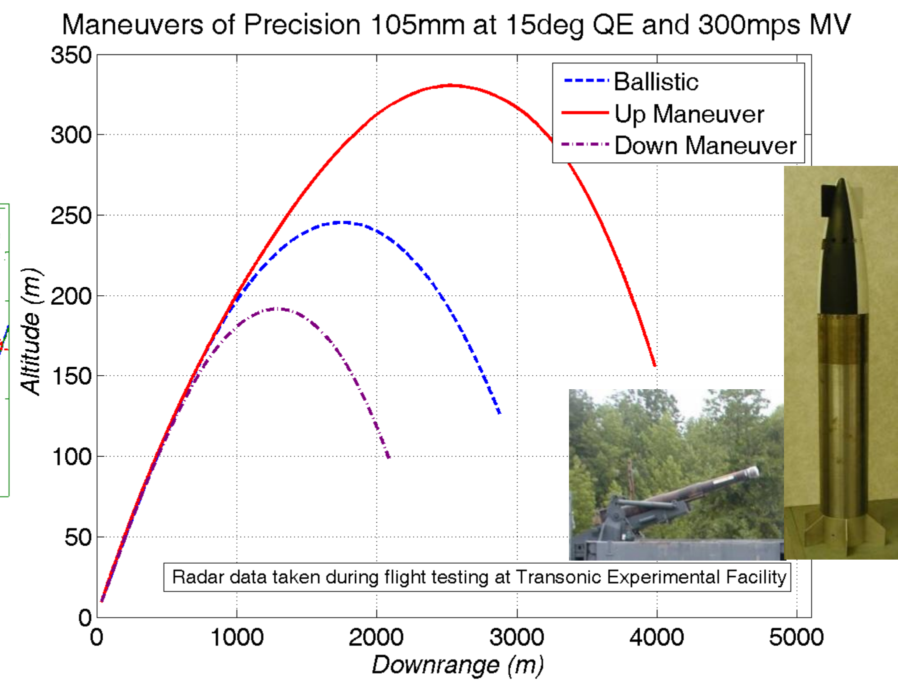
Initial controller performance and power requirements from HIL/CFD



Maneuver system performance and power requirements verified in wind tunnel







Maneuver system developed with M&S and verified in experiments

RDECOM

Guidance and Flight Control - Development -

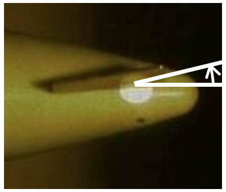
- Guidance algorithm based on flight dynamics → impact point p

$$\ddot{x} = \frac{-\pi C_{x0} d^2 \rho V_\infty}{8m}\dot{x} + \left(\cos(\phi_{CAN})\cos(\psi)\sin(\theta) + \sin(\phi_{CAN})\sin(\psi)\right)\frac{(L_{CAN} + L_B)}{m}$$

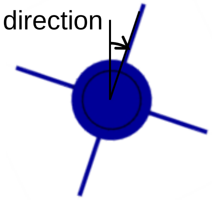
$$\ddot{y} = \frac{-\pi C_{x0} d^2 \rho V_\infty}{8m}\dot{y} + \left(\cos(\phi_{CAN})\sin(\psi)\sin(\theta) - \sin(\phi_{CAN})\cos(\psi)\right)\frac{(L_{CAN} + L_B)}{m}$$

$$\ddot{z} = \frac{-\pi C_{x0} d^2 \rho V_\infty}{8m}\dot{z} + g + \left(\cos(\phi_{CAN})\cos(\theta)\right)\frac{(L_{CAN} + L_B)}{m}$$

canard deflection



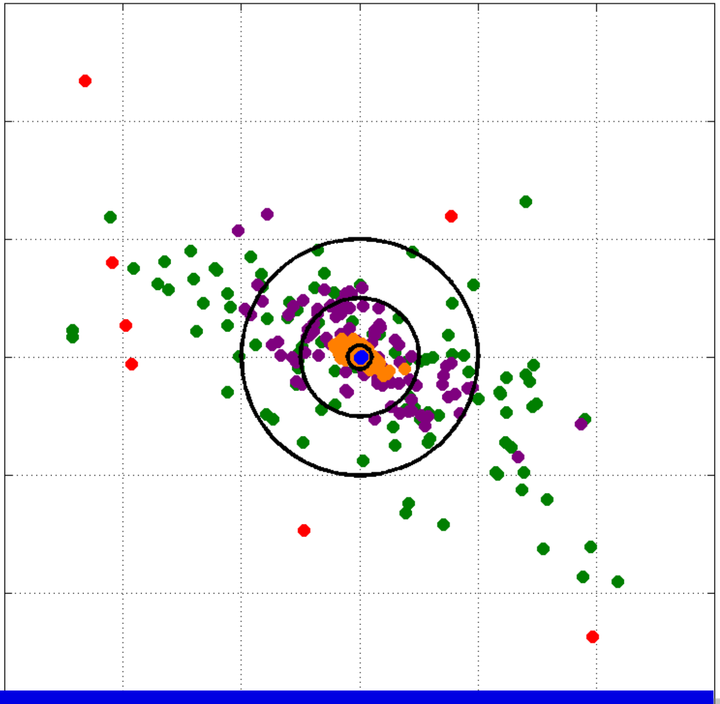
maneuver direction



- Guidance and flight control algorithms developed in 6DOF / system simulation environment with full-spectrum error sources
  - Initial conditions
    - muzzle velocity
    - roll rate at muzzle exit
    - gun pointing angles
  - Physical properties
    - mass
    - diameter/length
    - inertia tensor
  - Aerodynamics
  - Atmosphere
    - temperature
    - pressure
    - steady wind
    - turbulence
  - CAS
  - GPS

12 rigid body states

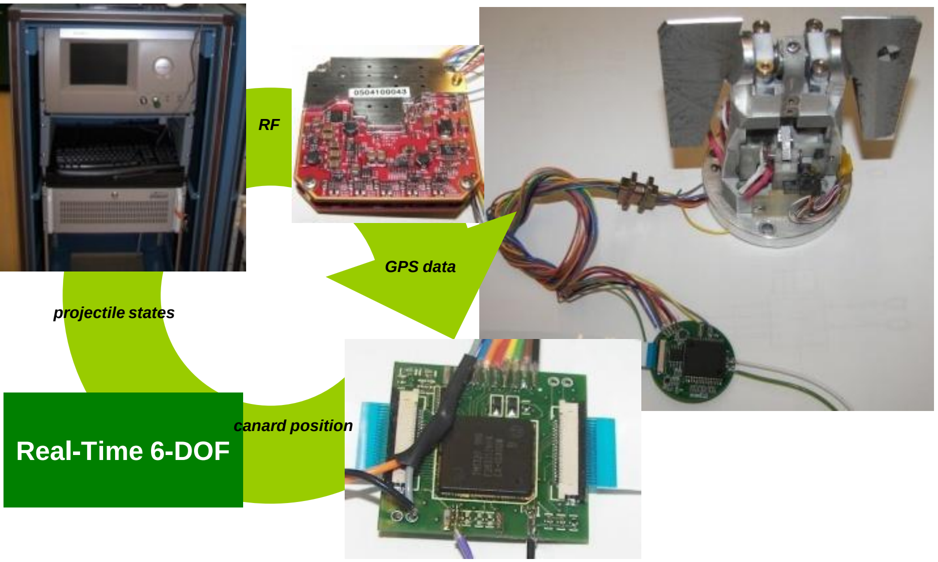
7 states for G&C

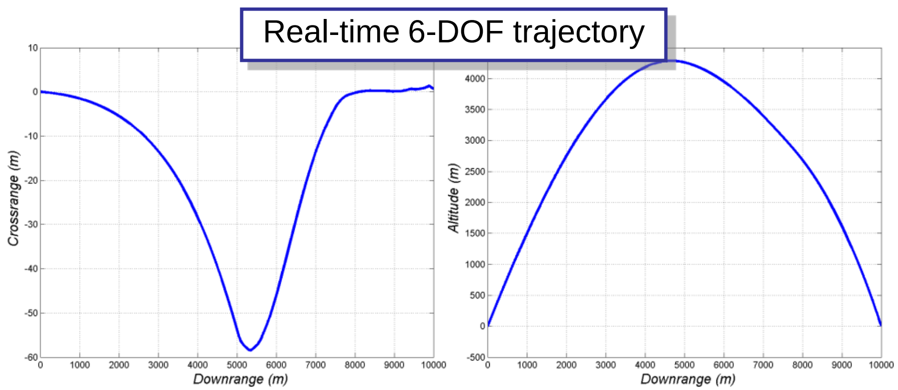


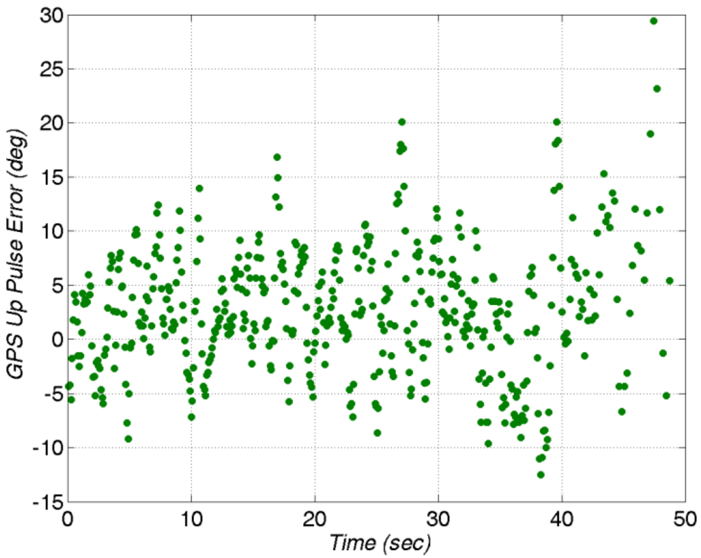
Guidance algorithm reduces sensor and actuator requirements

- Auto-code generation tools transfer algorithms to embedded proc.
- GNC implemented on DSP for flight experiments

Integration of Technologies







Extensive laboratory/field efforts reduce risk before flight experiments

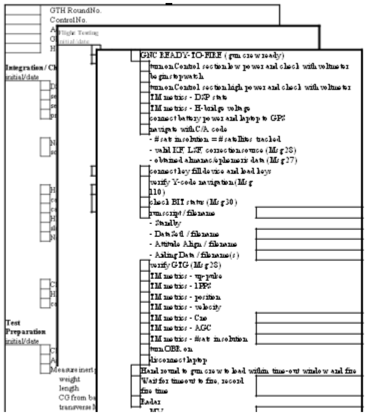
Guided Flight Experiments - Check-out / Procedure / Setup -

120mm mortar

APG

Target at 3.8 km

Detailed check-out and test procedure


GTH Round No.
Control No.
Integration / Ch
initial/date
Flight Testing
initial/date
GNC READY-TO-FIRE (gun crew ready)
turn on Control section low power and check with voltmeter
begin stopwatch
turn on Control section high power and check with voltmeter
TM metrics - DSP state
TM metrics - H-bridge voltage
connect battery power and laptop to GPS
navigate with C/A code
- # sat in solution = # satellites tracked
- valid KF, LSF, correction source (Msg 28)
- obtained almanac/ephemeris data (Msg 27)
connect key fill device and load keys
verify Y-code navigation (Msg 110)
check BIT status (Msg 30)
run script / filename
- Standby
- DataSet1 / filename
- Attitude Align / filename
- Aiding Data / filename(s)
verify GTG (Msg 28)
TM metrics - up-pulse
TM metrics - 1PPS
TM metrics - position
TM metrics - velocity
TM metrics - Cno
TM metrics - AGC
TM metrics - # sat in solution
turn OBR on
disconnect laptop
Hand round to gun crew to load within time-out window and fire
Wait for timeout to fire, record fire time
Radar
Test Preparation
initial/date
Measure inert
weight
length
CG from ba
transverse

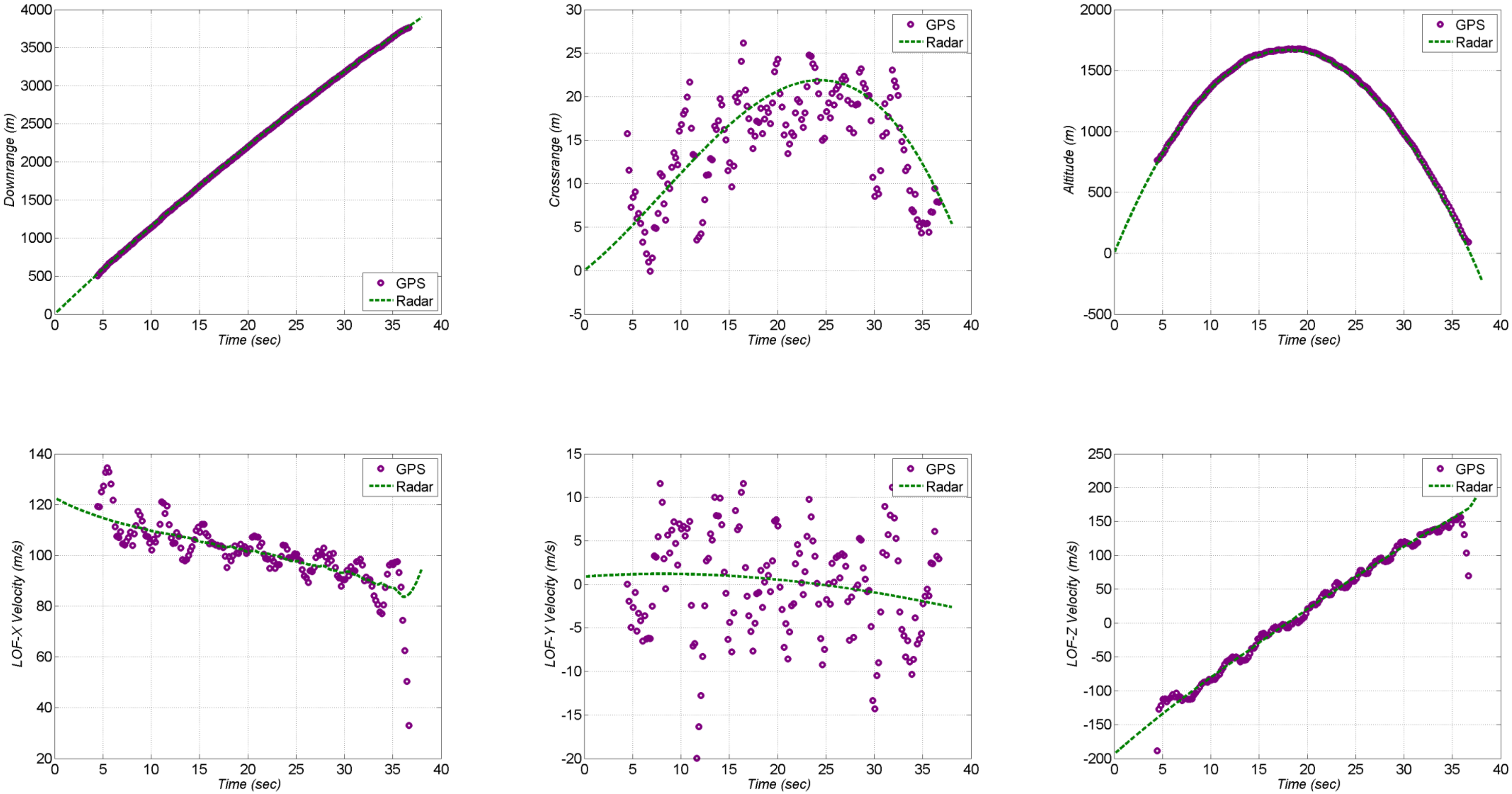
Full ballistic range support

155mm artillery

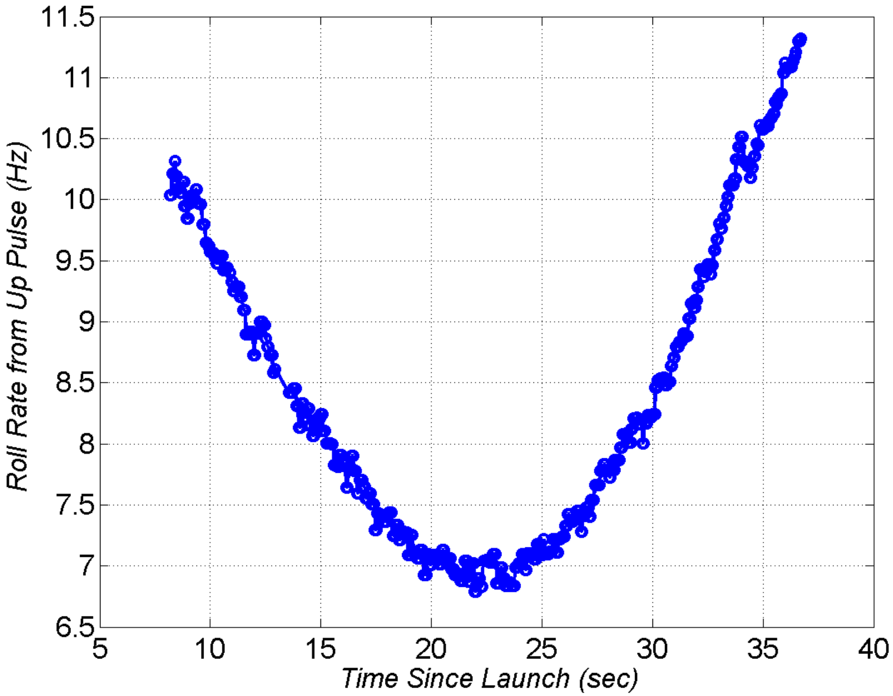
YPG

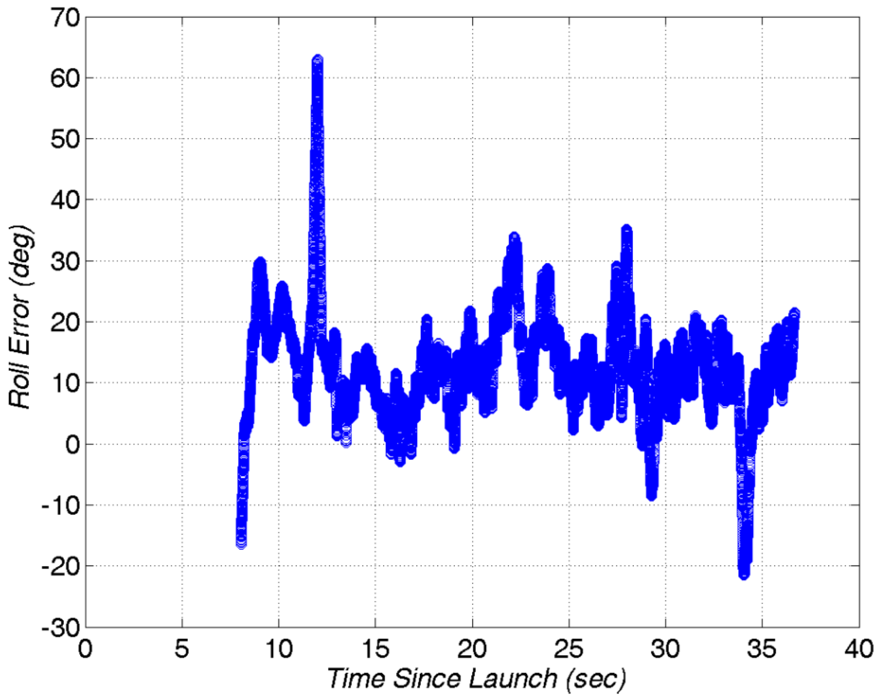
Target at 16.4 km

Flight Experiments - GPS / Radar -

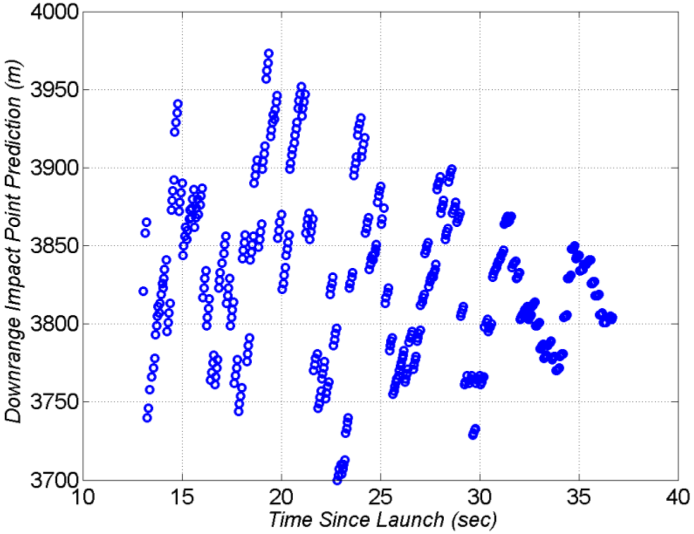


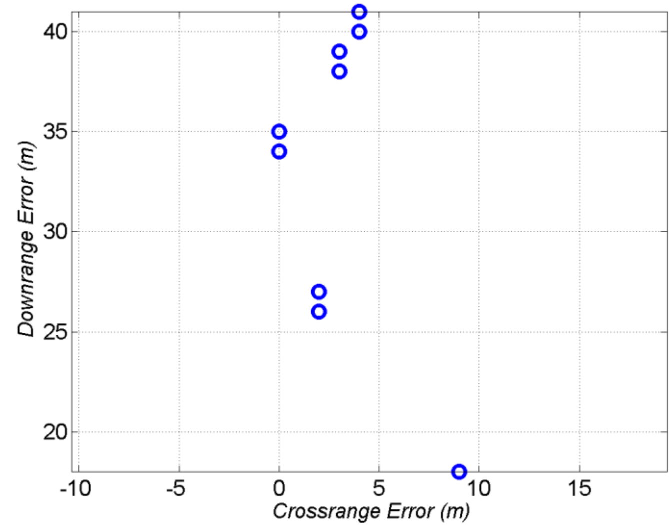
Flight Experiments - Upfinding -

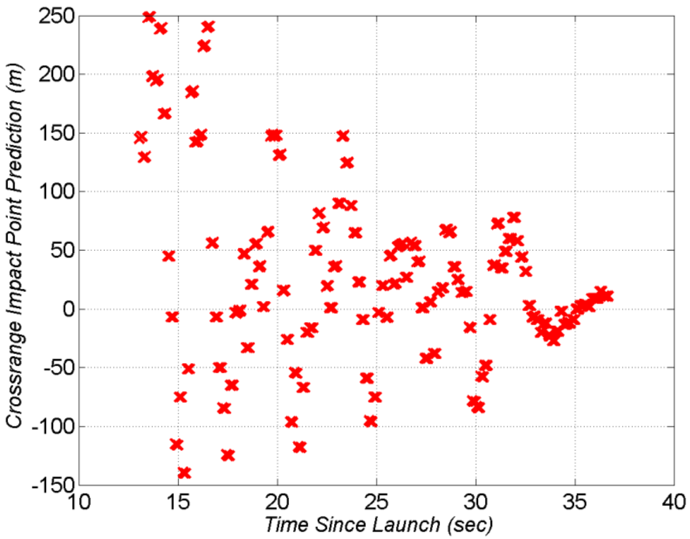




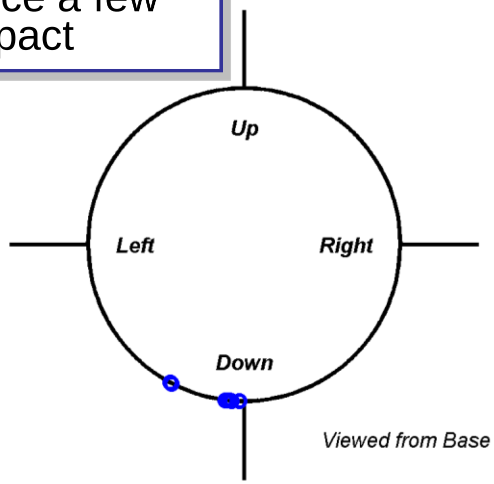
Flight Experiments
- Guidance -



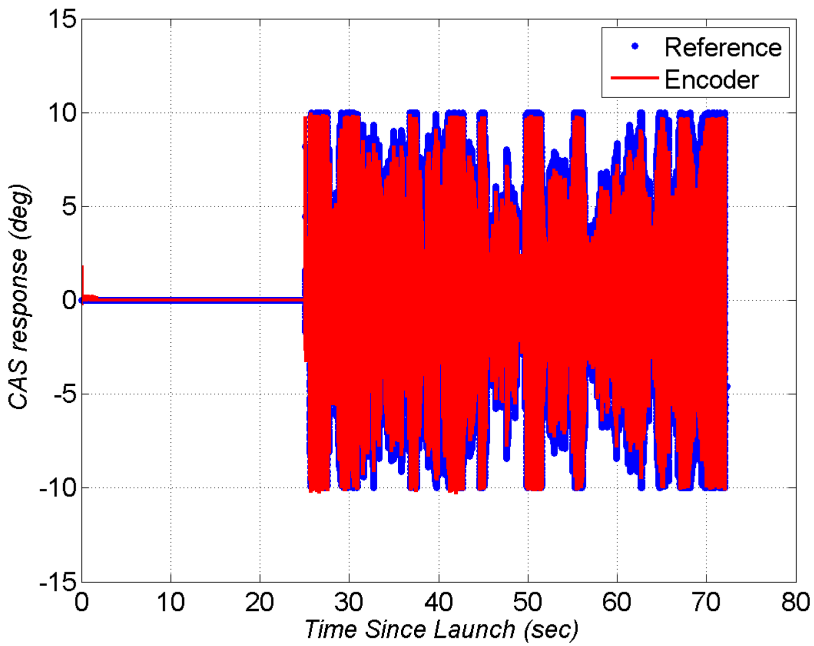


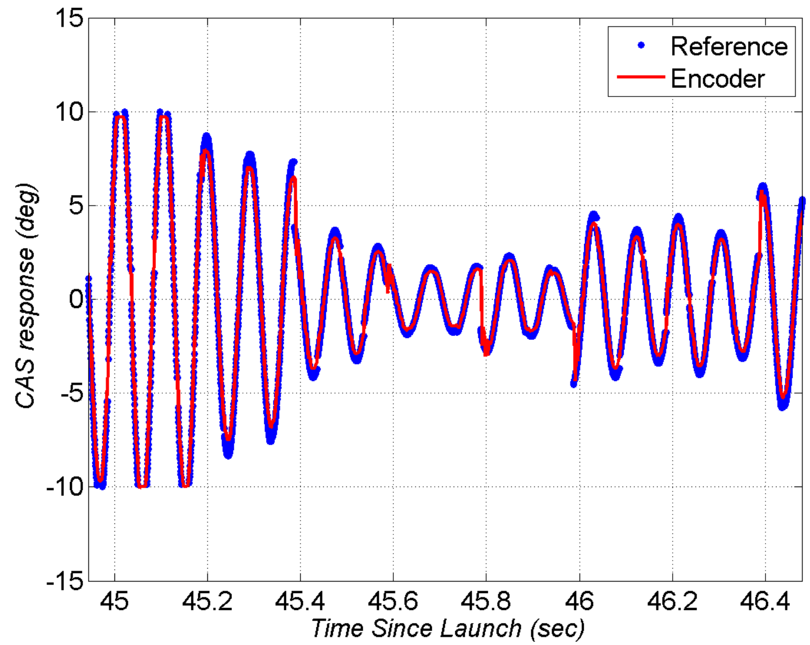


Snapshot of guidance a few seconds prior to impact

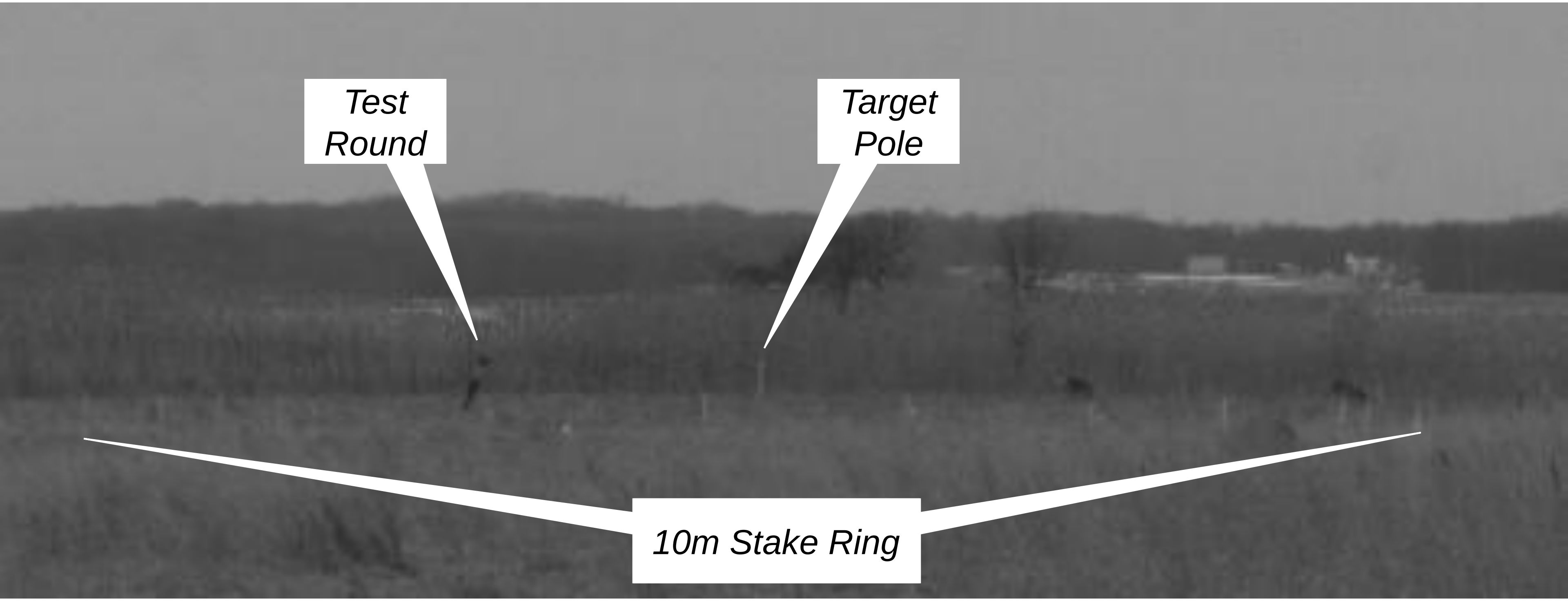


Flight Experiments
- Maneuver System -



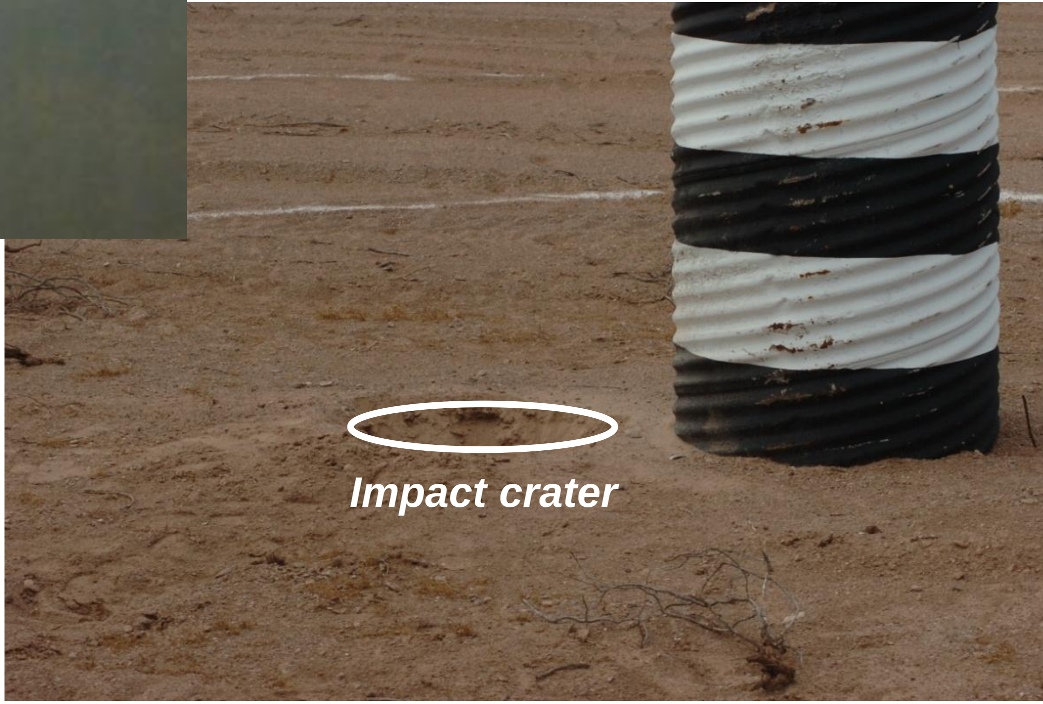


Guide-to-Hit Flight Experiments - 120mm -



Guide-to-Hit Flight Experiments - 120mm -

Guide-to-Hit Flight Experiments - 155mm -

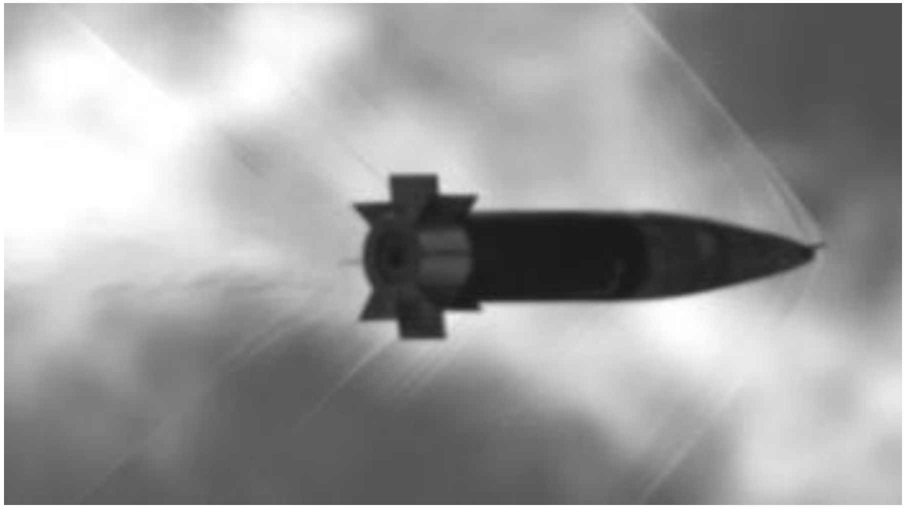


Flight Experiments – VAPP-26

Summary

- Affordable precision solutions enabled through fundamental understanding of technology by DoD scientists and engineers
  - accept higher technical risk
  - caliber-independent (fund R&D once)

- Successful guide-to-hit flights
  - validated technologies and approach
  - confirmed TRL
  - provided transition vehicle to other government labs and industry



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ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER · PICATINNY ARSENAL, NJ

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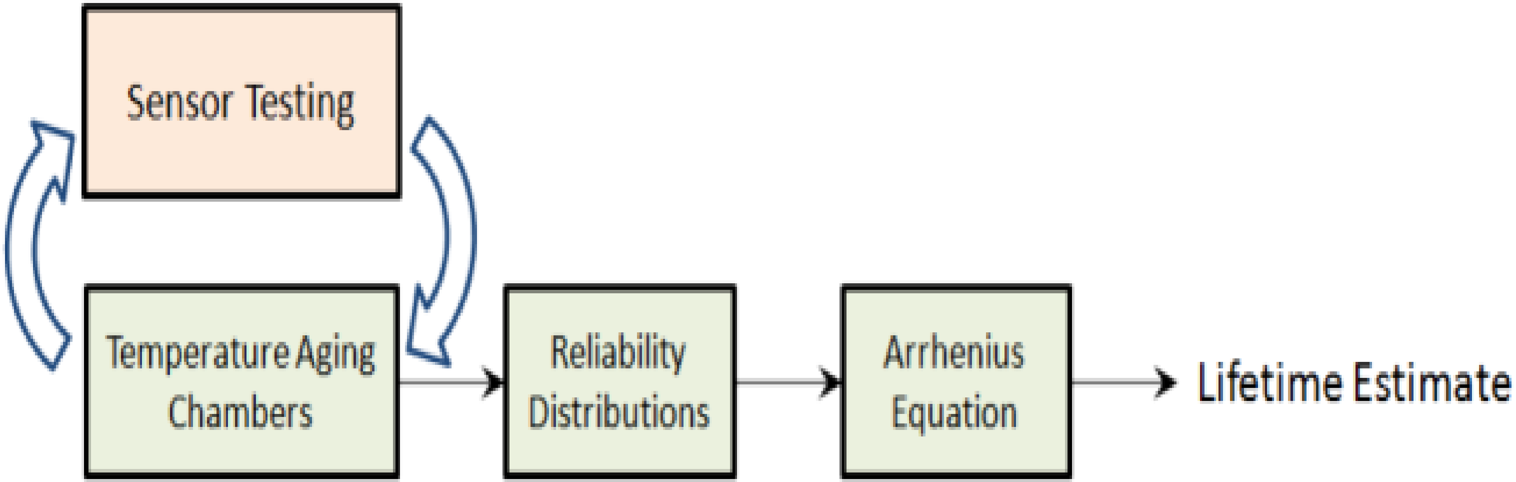
Determination of the Shelf Life of MEMS Navigation-Grade Sensors through Use of Accelerated Aging Principles

April 14, 2011

James A. Sarruda

Project GOAL

- Determine the life expectancy of a generic micro electro-mechanical systems (MEMS) inertial measurement unit (IMU) designed specifically for the use in a precision munition.

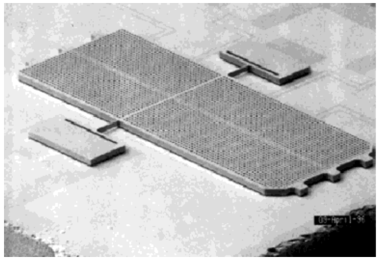


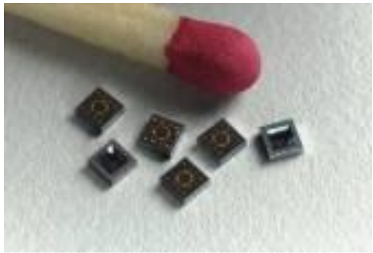
Background Information

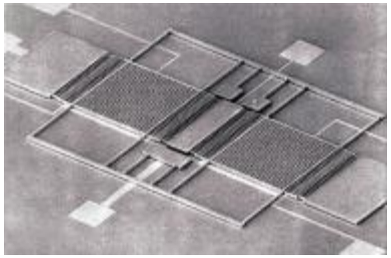
- Degradation in performance parameters of a MEMS IMU over time is not well understood.
  - Natural aging not an option
  - Developing navigation capability
- Artificial aging is a viable option to understand product reliability.
  - Precision munitions have been expensive
  - Guidance and Control is a key cost driver

Why This Matters

- Guided munition weapon systems are in need of extremely miniaturized, navigation-grade sensors in order to increase the lethality of the Army's precision guided products.
  - Complex environments pose a severe challenge to the warfighter, and therefore the advancement of key technology is necessary to meet stringent user requirements.
  - MEMS IMU provides full six-degrees-of-freedom triaxial motion measurements.
  - All indirect fire systems substantially benefit from precision capability.



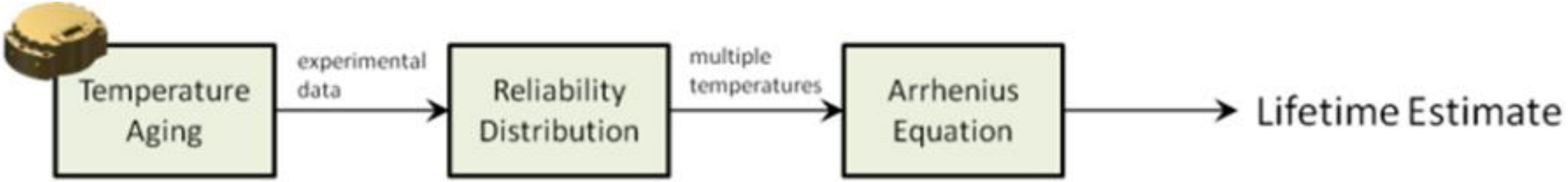




Approach and Test Limitations

- Testing is designed to obtain the life expectancy of the inertial sensors within the inertial measurement unit system, not the life expectancy of the IMU system as a whole.
  - Performance independent of sensor integration
  - Greater sample size
- Reliability Prediction
  - A "time to failure" population distribution is required to predict shelf life
  - Weibull distribution is commonly used in reliability engineering
- Success Criteria
  - Sensors must "fail" for lifetime equations to be appropriate.
  - Sensor performance outside program goals will be considered a failure.

Accelerated Aging Principles



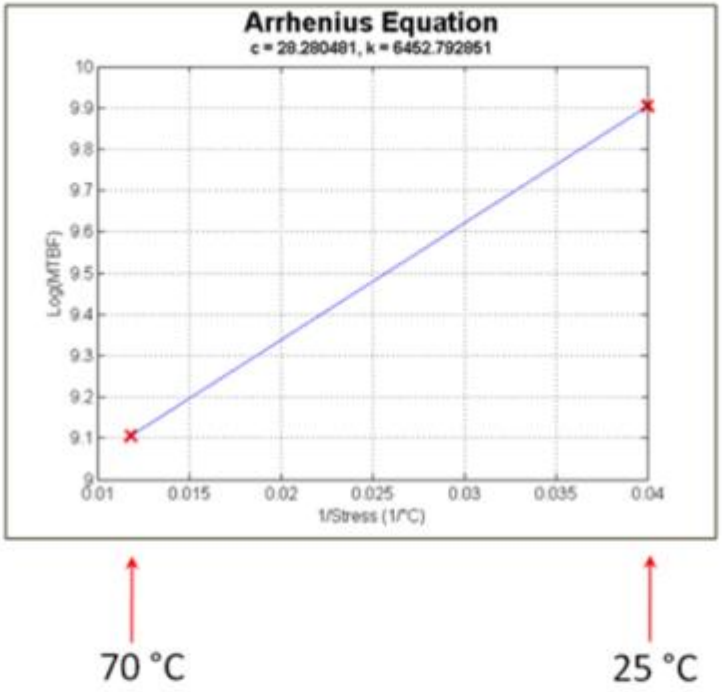
- Arrhenius equation correlates lifetime to temperature stress.

$$t = ke^{\frac{c}{S}}$$

Where

t is the time to failure for a percentage of the population
k and c are constants
S is the amount of stress

- At a minimum, two temperature age estimates are needed to estimate the equation's parameters.



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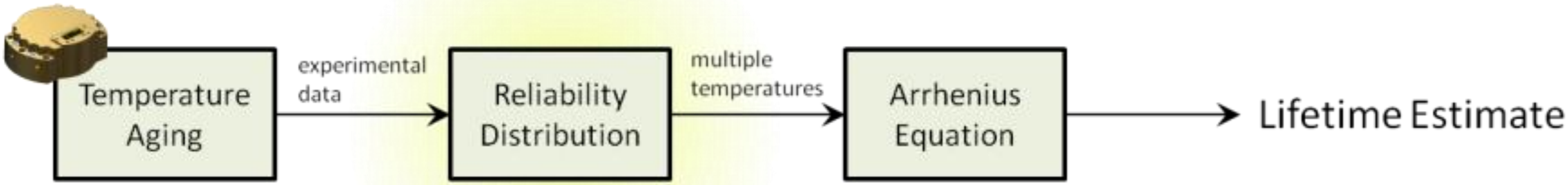
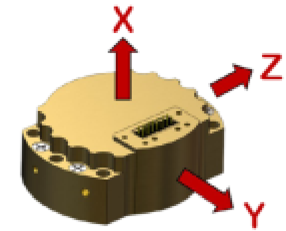
Accelerated Aging Principles



- A “time to failure” population distribution (reliability distribution) is required to use the Arrhenius equation.
- A reliability distribution is selected from a best fit to the experimental data failure times.
- The sensor parameters must fail for the reliability distribution to be determined.
- Weibull distribution will be utilized for this testing as this distribution is commonly used in reliability engineering.

IMU Performance Parameters

- Each inertial IMU contains an inertial sensor assembly (ISA) with six inertial sensors.
  - Angular rates are measured using three orthogonal MEMS gyroscopes along the x, y, and z axes.
  - Linear acceleration is measured using three orthogonal MEMS accelerometers along the x, y, and z axes.



Name	Symbol[1]	Units
Angle Random Walk (ARW)	$g_{i,ARW}$	°/√hr
Bias Error	$g_{i,Berr}$	°/hr
Bias Instability	$g_{i,Bstab}$	°/hr
Turn-on to Turn-on Bias Error Repeatability	$g_{i,Brep}$	°/hr
Self-Heating Settling Time	$g_{i,setT}$	hr
Scale Factor Error	$g_{i,SFerr}$	PPM
Scale Factor Asymmetry	$g_{i,SFsym}$	PPM
Scale Factor Nonlinearity	$g_{i,SFlin}$	PPM
In-Run Scale Factor Stability	$g_{i,SFir}$	PPM
In-Run Bias Stability	$g_{i,Bir}$	°/hr
Sensor Misalignment	$g_{\delta i}$	µrad

Name	Symbol[1]	Units
Velocity Random Walk (VRW)	$a_{i,VRW}$	m/s/√hr
Bias Error	$a_{i,Berr}$	mg
Bias Instability	$a_{i,Bstab}$	mg
Turn-on to Turn-on Bias Error Repeatability	$a_{i,Brep}$	mg
Self-Heating Settling Time	$a_{i,setT}$	hr
Scale Factor Error	$a_{i,SFerr}$	PPM
In-Run Scale Factor Stability	$a_{i,SFir}$	PPM
In-Run Bias Stability	$a_{i,Bir}$	mg
Sensor Misalignment	$a_{\delta i}$	µrad

Accelerated Aging Principles

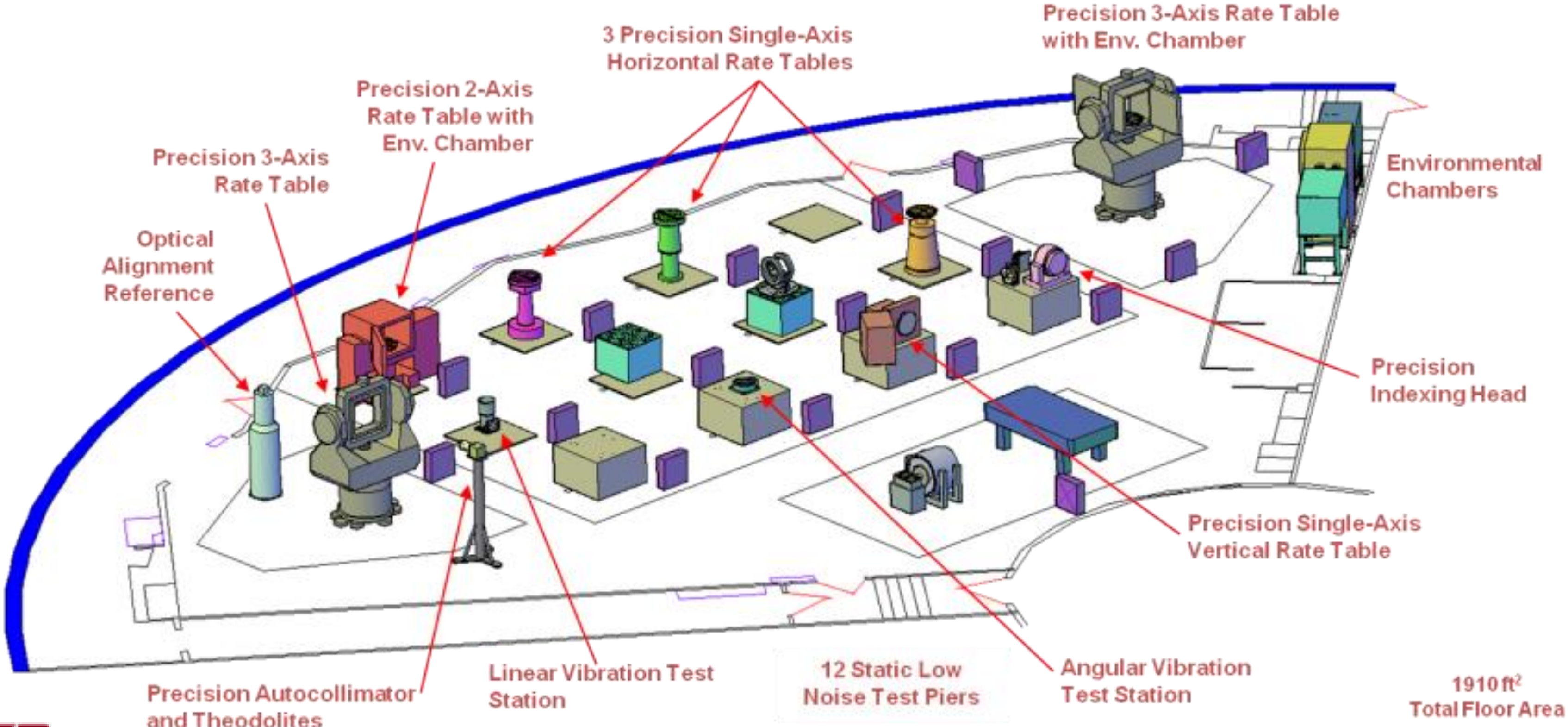
- Shape and scale parameters will be determined via linear regressions.

Gyros Parameter	Weibull Reliability Distribution Parameters	25 °C	70 °C	Arrhenius Constants
Bias Error	Shape (β)			K = , C =
	Scale (θ)			
Scale Factor Error	Shape (β)			K = , C =
	Scale (θ)			
Non-Orthogonality	Shape (β)			K = , C =
	Scale (θ)			

Accelerometer Parameter	Weibull Reliability Distribution Parameters	25 °C	70 °C	Arrhenius Constants
Bias Error	Shape (β)			K = , C =
	Scale (θ)			
Scale Factor Error	Shape (β)			K = , C =
	Scale (θ)			
Non-Orthogonality	Shape (β)			K = , C =
	Scale (θ)			

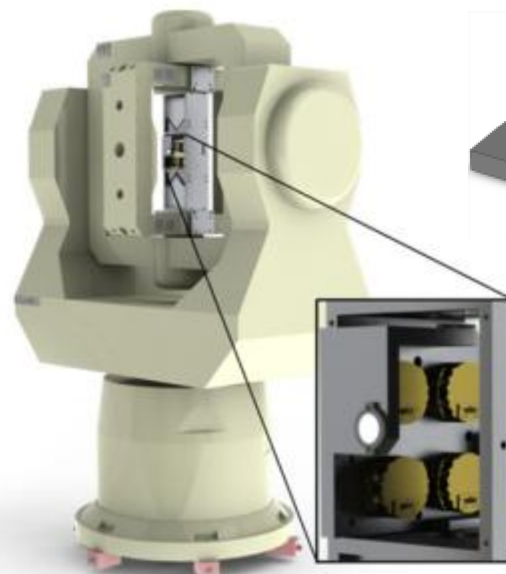
Penn State Navigation Center

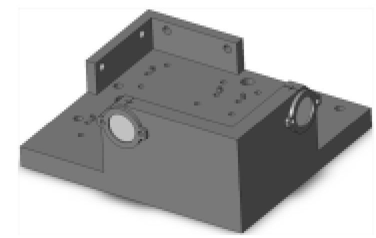
- Provides capabilities to conduct research as well as test the most precise navigation sensors and equipment
- Building design reduces noise internal to the building itself



Test Setup

- **Artificial Aging**
  - The temperature chamber provides air temperature, pressure, and humidity data.
  - Mounting fixture stabilized at target temperature during aging.
- **3-Axis Characterization**
  - Two alignment mirrors allow sensors to be precisely oriented on the fixture to the North, East, and to gravity.
  - No need to remount sensors.





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Test Procedures

- Static Test
  - Sensors are powered on and held motionless for a period of 30 minutes.
- Rate Test
  - The sensor input axis of the gyros under test is positioned along the table's axis of rotation.
  - Sensor data is collected ten times according to a rate profile.
- Tumble Test
  - The sensor input axis of the accelerometers under test were positioned along north.
  - Sensor data is collected five times according to a tumble profile.

1	Static – X axis
2	Static – Y axis
3	Static – Z axis
4	Rate – X axis
5	Rate – Y axis
6	Rate – Z axis
7	Static – X axis
8	Static – Y axis
9	Static – Z axis
10	Tumble – X axis
11	Tumble – Y axis
12	Tumble – Z axis
13	Static – X axis
14	Static – Y axis
15	Static – Z axis

Rate Profile

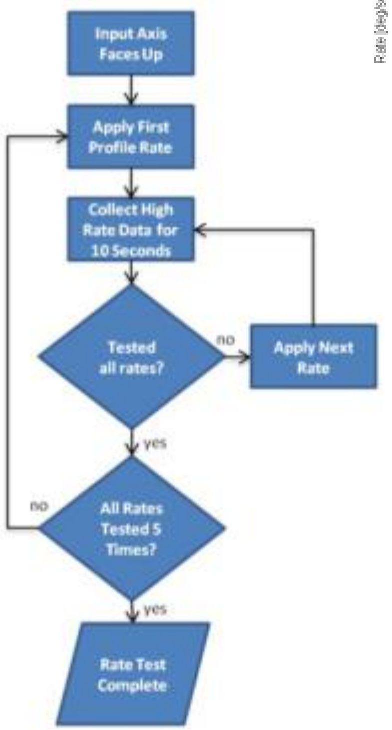
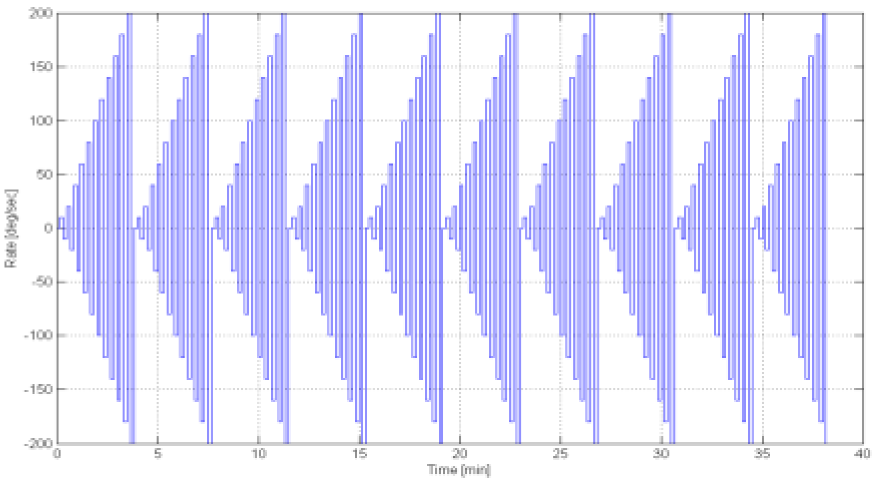


Table 16: Single Rate Profile



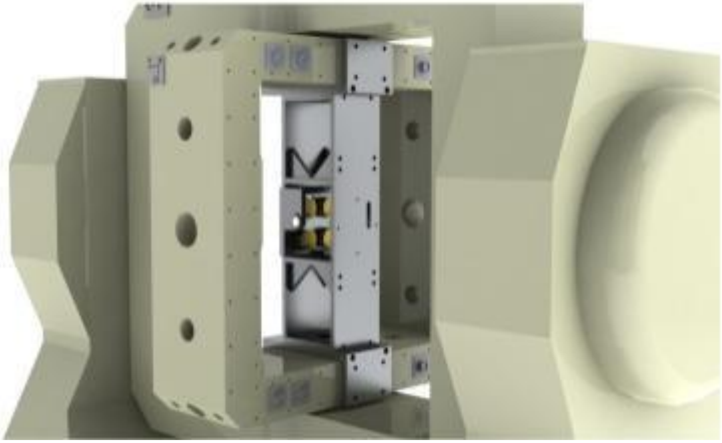
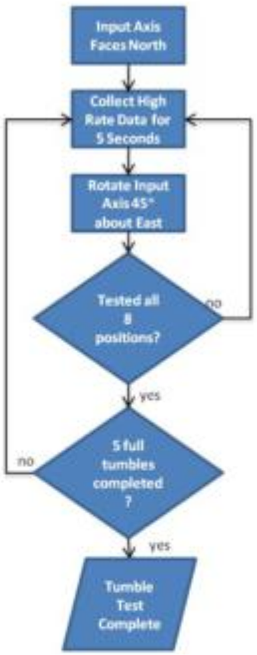
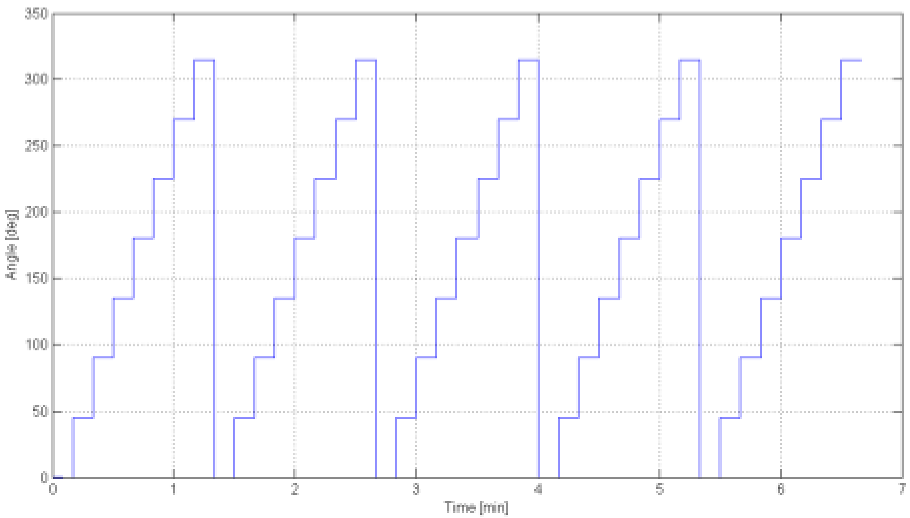


Table Rate deg/sec	Dwell Time sec
0	10
±10	10
±20	10
±40	10
±60	10
±80	10
±100	10
±120	10
±140	10
±160	10
±180	10
±200	10

Tumble Profile





	Angle deg	Input Axis Orientation
1	0º	North
2	45º	
3	90º	Up (+g)
4	135º	
5	180º	South
6	225º	
7	270º	Down (-g)
8	315º	

Test Schedule

- Initial characterization to baseline sensor performance parameters.
- Monthly characterization at the beginning of each month.
- Final characterization at the end of the 14 month period.

Year	Month	Action
2010	May	Test Setup
	June	Baseline Characterization
		Age
	July	Characterization
		Age
	August	Characterization
		Age
	September	Characterization
		Age
	October	Characterization
		Age
	November	Characterization
		Age
	December	Characterization
		Age
2011	January	Characterization
		Age
	February	Characterization
		Age
	March	Characterization
		Age
	April	Characterization
		Age
	May	Characterization
		Age
	June	Characterization
		Age
	July	Characterization
		Age
	August	Final Characterization

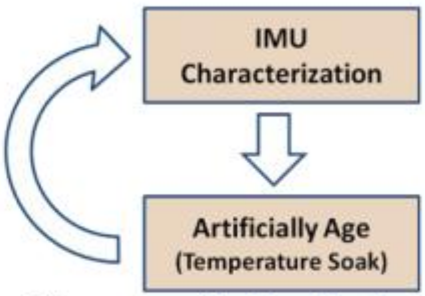


Illustration 45: Test Cycle

Path Forward

- Ongoing effort to be completed in September 2011
- Complete results are not available at this time
- Future MEMS IMU lifetime predictions can leverage off the process demonstrated in this testing program

Recommendations

- Increase the determination of reliability distributions by testing more IMUs.
  - Eight IMUs at each temperature step
- Additional temperature steps
- Further increase the aging process by increasing the aging temperature
  - More accurate lifetime prediction
- **Point of Contact**

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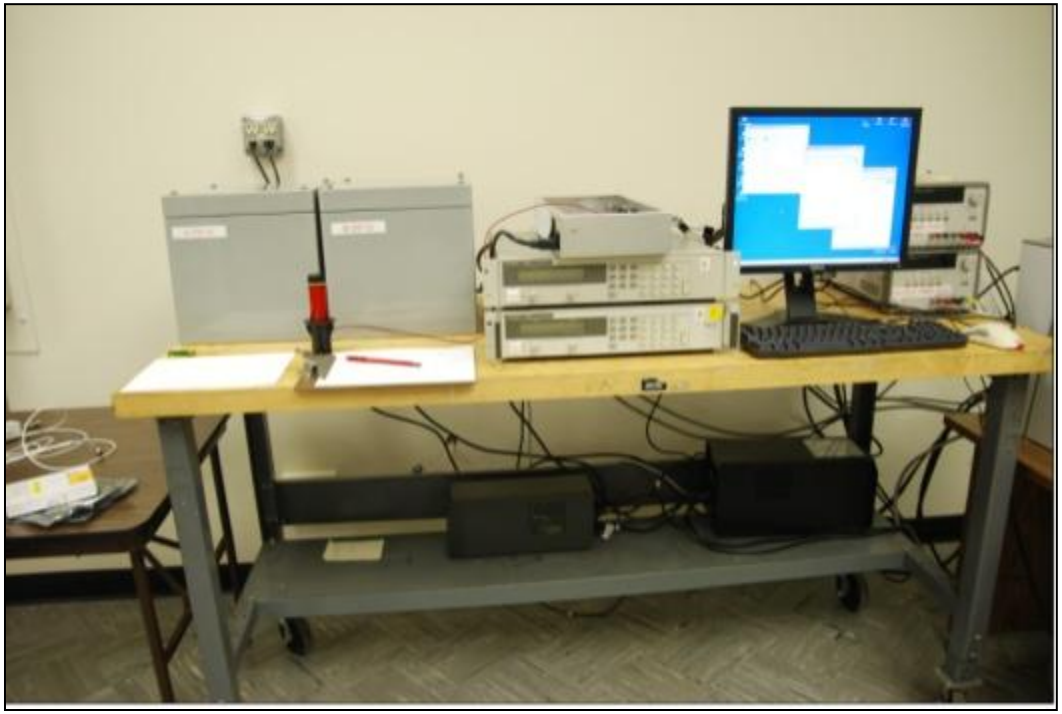
Picatinny Arsenal, NJ

Backup – Artificial Aging Setup

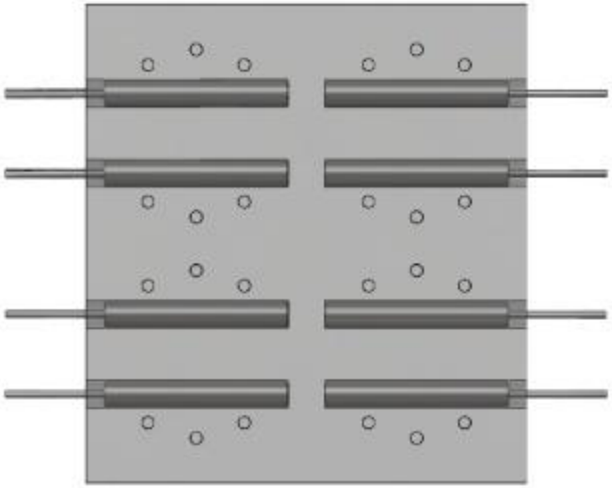
- Two thermal chambers and support electronics.
- IMUs are mounted to a custom fixture in each chamber .

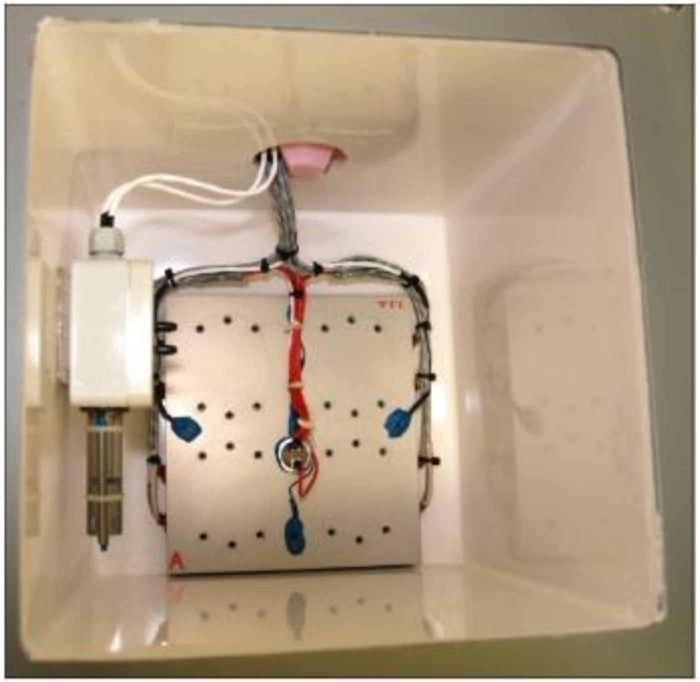


Malcolm Baldrige National Quality Award 2007 Award Recipient

Backup – Artificial Aging Setup

- The temperature chamber provides air temperature, pressure, and humidity control back to the support computer.





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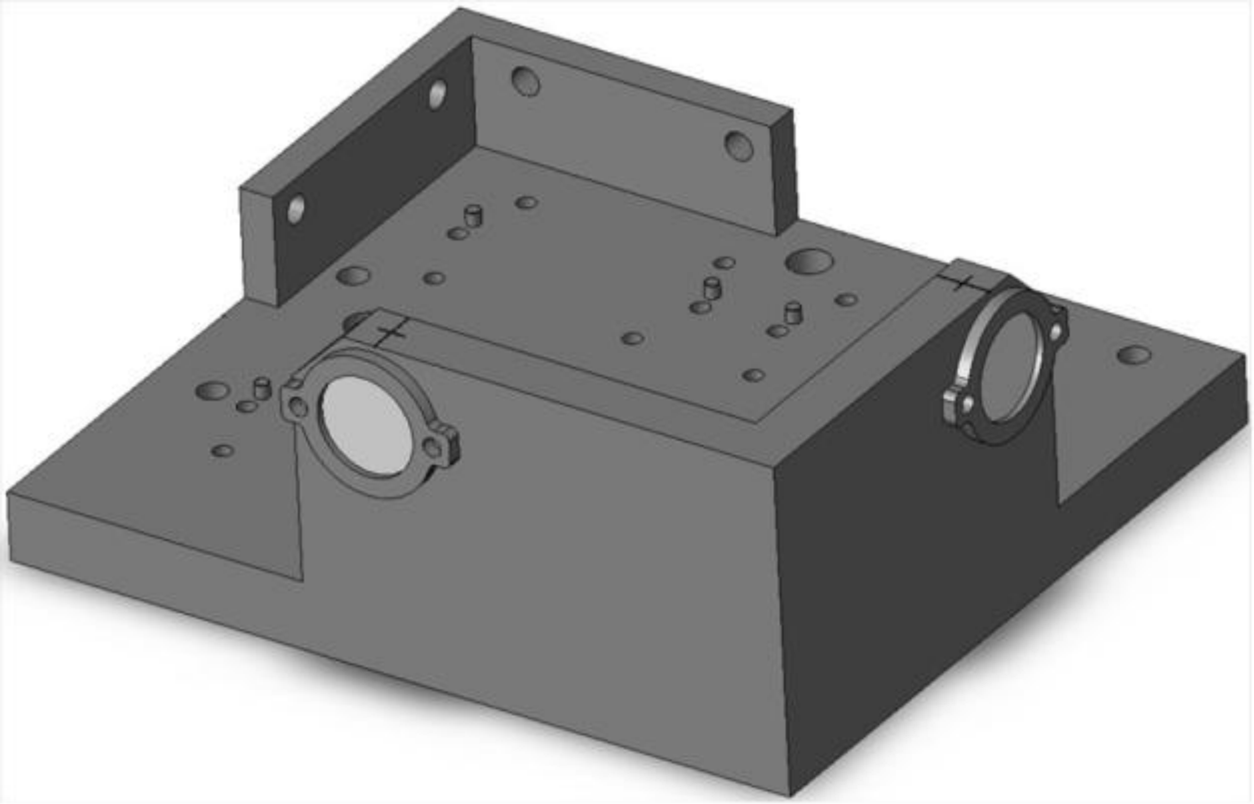
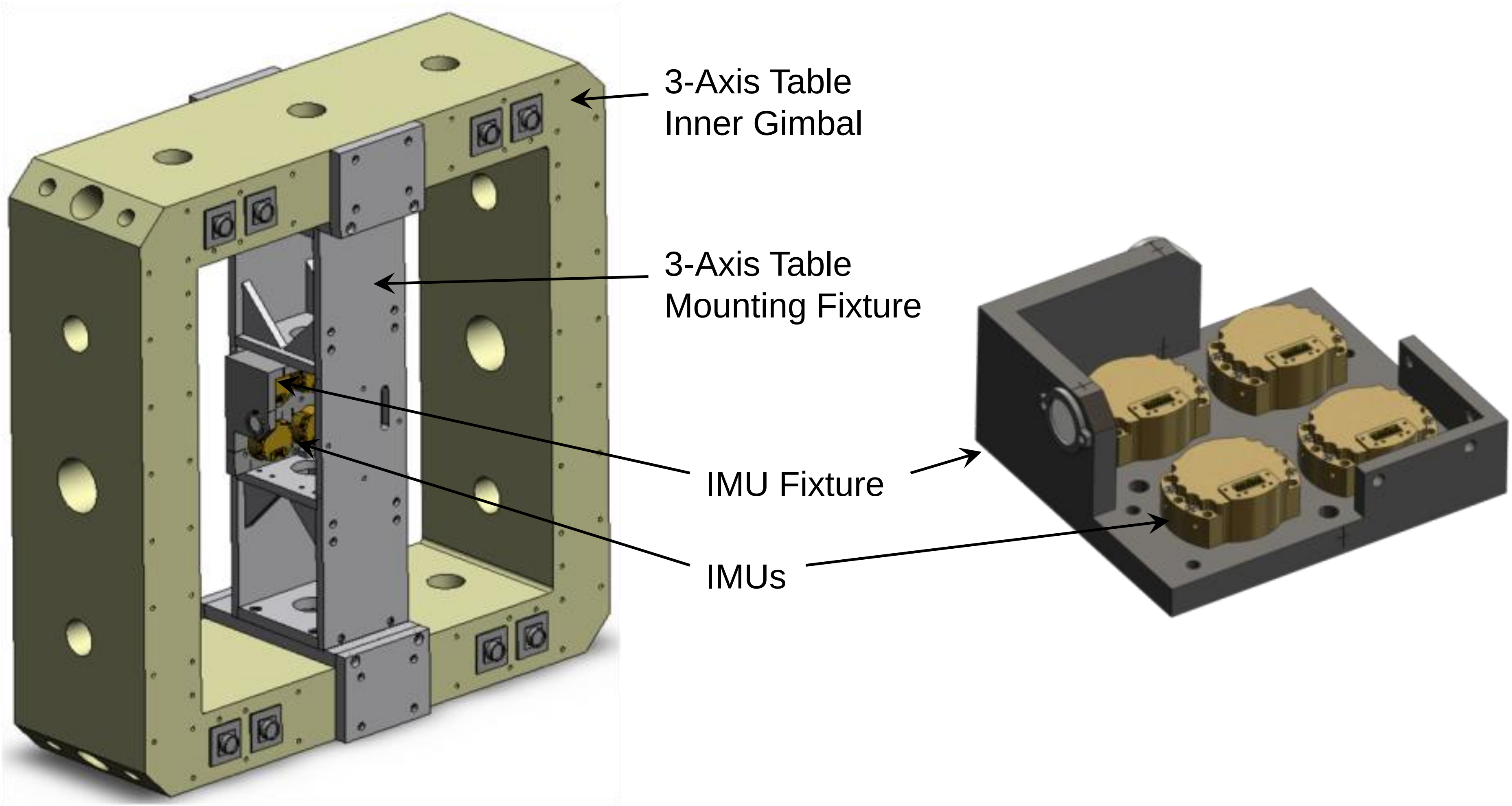
Backup – Sensor Fixture

- Two alignment mirrors allow sensors to be precisely oriented on the fixture to the North, East, and Down.



Backup – Characterization Setup



Backup - Accelerated Aging Principles

- The Arrhenius equation can be generalized to correlate any stress to a population failure.
  - At minimum, two temperature age estimates are needed to estimate the equation's parameters.

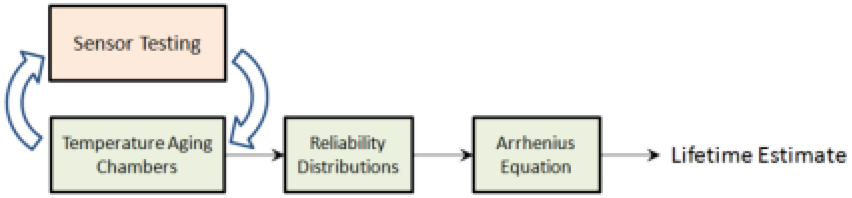
$$K = K_0 e^{-\frac{E}{BT}}$$

K_0 is the reaction rate at a known temperature

E is the activation energy of the reaction

B is Boltzmann's constant

- The devices under test do not fail simultaneously.
  - Weibull distribution used to model reliability



$$R(x) = e^{-\left(\frac{x}{\theta}\right)^{\beta}}$$

R(x) is the population reliability at time x

θ is the Scale parameter

β is the Shape parameter

Backup – Arrhenius Equation

- Direct measurements of aging degradation can take decades.
- The Arrhenius model describes the effect temperature has on chemical reactions.

$$K = K_0 e^{-\frac{E}{BT}}$$

K_0 is the reaction rate at a known temperature

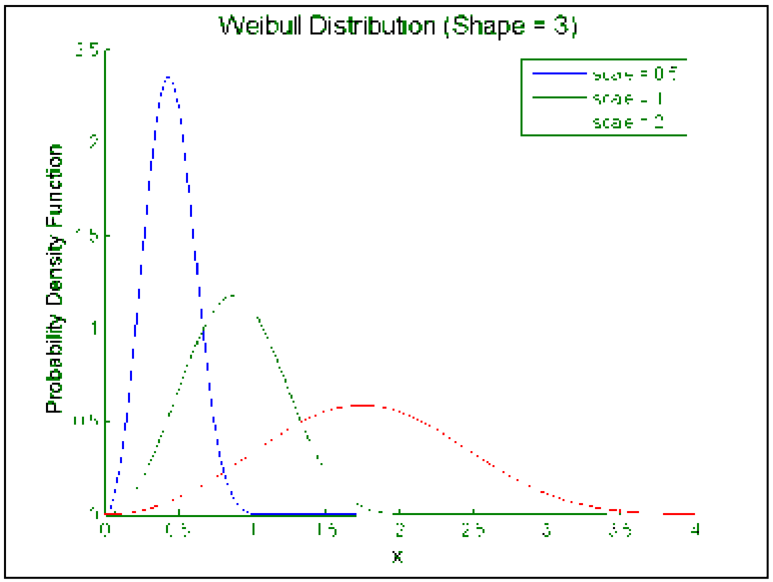
E is the activation energy of the reaction

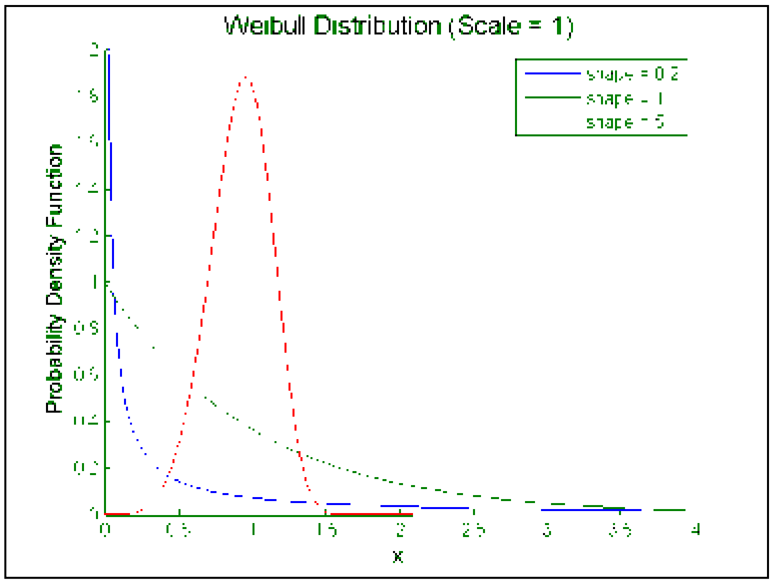
B is Boltzmann's constant

- It is possible to induce artificial aging in a material or device by applying some form of stress.
- By calculating the reliability distributions at differing stress levels, the Arrhenius model can be utilized to calculate the failure rate at intermediate stresses.

Backup – Weibull Distribution

Weibull distribution has two parameters to be calculated from the "failed" parameters data: Shape (β) and Scale (Θ)





$$f(x) = \frac{\beta}{\theta}\left(\frac{x}{\theta}\right)^{(\beta-1)} e^{-[(\frac{x}{\theta})]^{\beta}}$$

Backup – Current Results

- An appropriate out-of-spec value was chosen for each parameter
- The values are based upon the Common Guidance Common Sense (CGCS) program goals
  - Some of the sensor values were out of CGCS program thresholds at the start of the program
- Some of the gyro parameters are shown here

Gyro Parameter	Maximum Threshold
Bias Error	±100 °/hour
Scale Factor Error	±400 PPM
Non-orthogonality	±1400 µrad

Backup – Current Results

- From the extrapolated parameter failure times, the shape and scale parameter for the Weibull distributions were determined via linear regressions on the data

Gyros Parameter	Weibull Reliability Distribution Parameters	25 °C	70 °C	Arrhenius Constants
Bias Error	Shape (β)	1.04	0.97	K = 0.86, C = 70.00
	Scale (θ)	14.07	2.33	
Scale Factor Error	Shape (β)	1.18	1.34	K = 0.20, C = 94.32
	Scale (θ)	8.81	0.78	
Non-Orthogonality	Shape (β)	0.61	1.27	K = 5.28, C =1.12
	Scale (θ)	459.76	26.04	

- From the calculated Weibull distributions, the population reliability for each parameter across temperature can be computed

US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

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System Analysis with Integrated Modeling and Optimization

46th Annual NDIA Conference April 13, 2011

Presented by Phil Brislin

Munitions Engineering & Technology Center

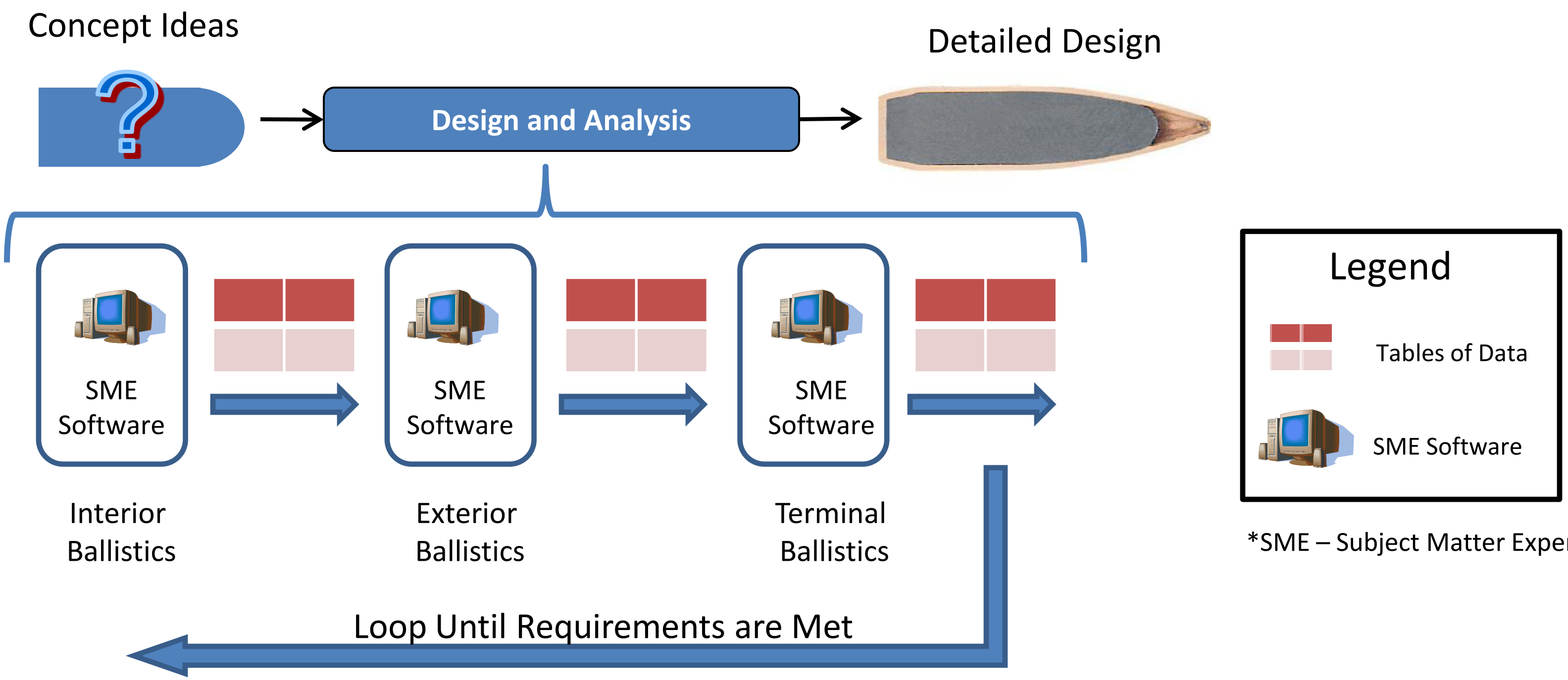
DISTRIBUTION STATEMENT A

Approved for public release; distribution is unlimited.

Agenda

- Integrated System Modeling for Munitions
- Integrated Modeling and Optimization (IMO) Software
- Extended Area Protection and Survivability Example
- Questions

Munitions Design Example



*SME – Subject Matter Expert

- Goal – Develop a design that meets or exceeds the requirements.
- Questions :
  - Is there enough time to perform sufficient design iterations?
  - Are the design dependencies well understood and quantified?
  - Is the sum of the parts the best for the system?

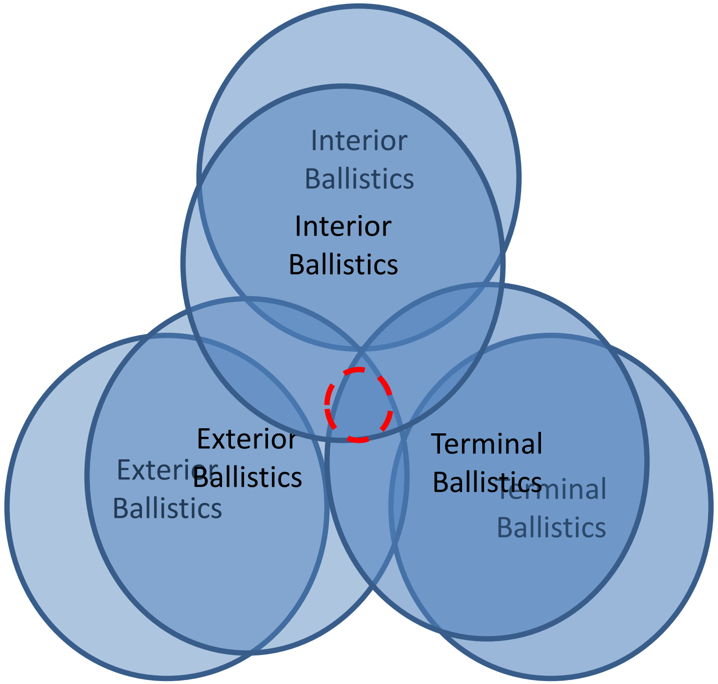
Integrated Modeling & Complex Systems

- New munitions seek more lethality in a lighter weight system
  - Multipurpose munitions.
  - Overdesigning is not an option.

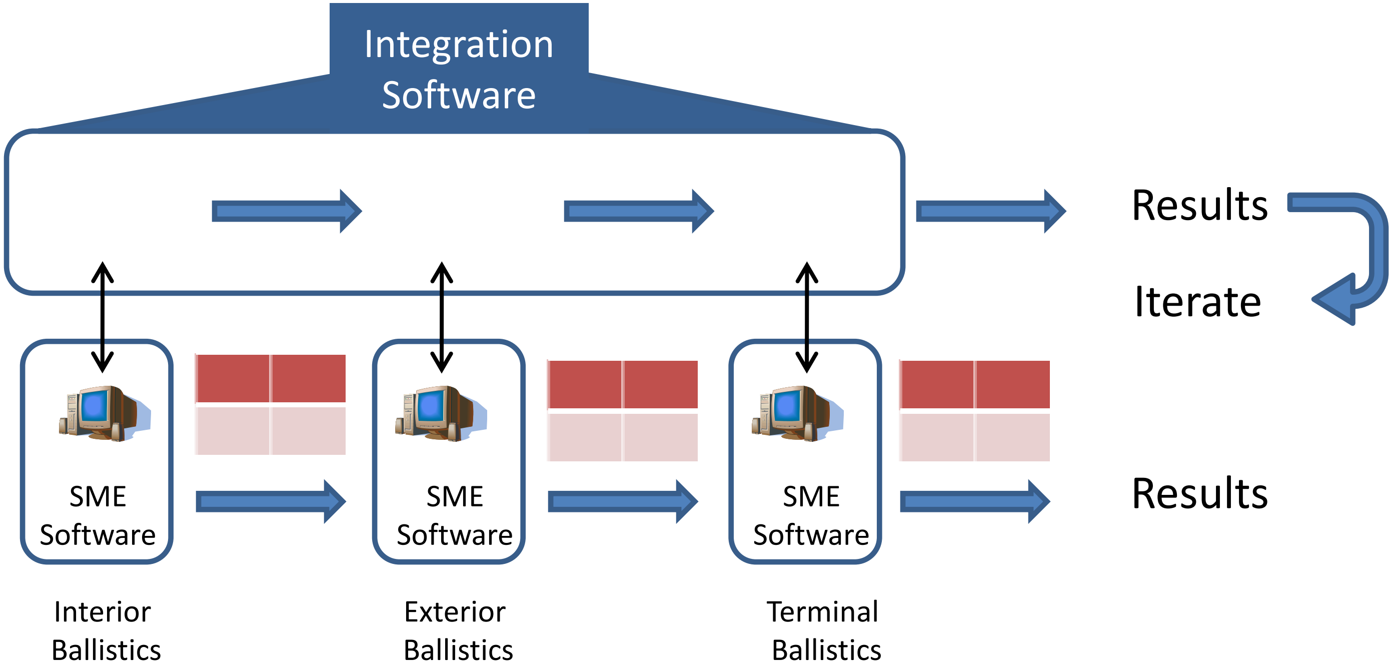
- Overall system performance dependent on compromises between subsystems.
  - Systems or integration engineer tasked with this challenge.

- Using an integrated approach helps to find more common ground.
  - Quantitative rather than qualitative data for decisions.

- Establish working baseline for more detailed analysis.
  - Start with best design possible.



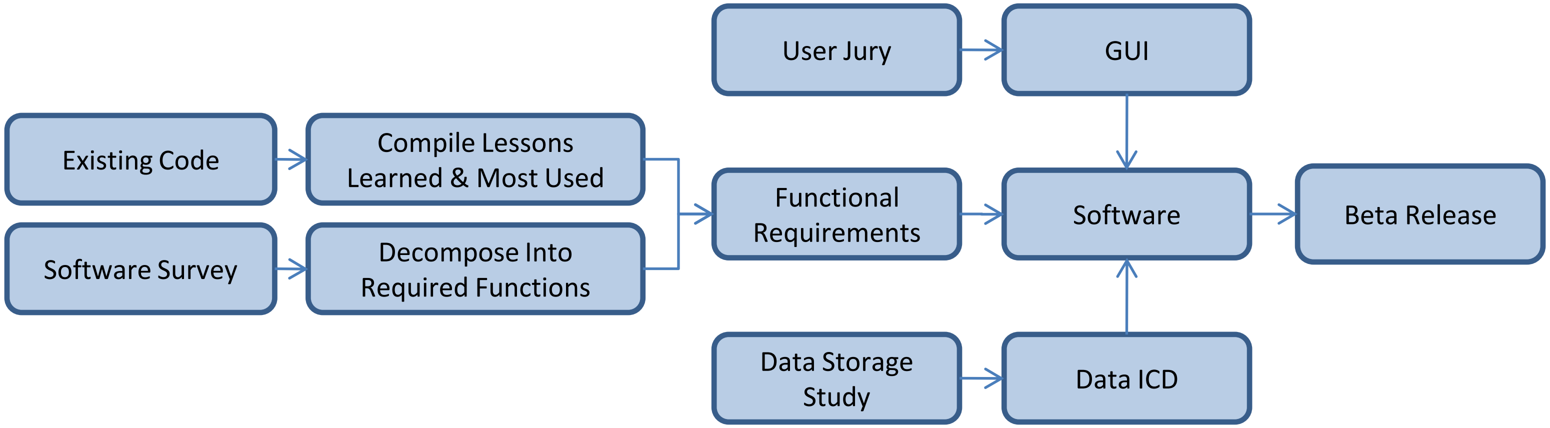
Integrated Modeling & Design



- An integrated workflow increases efficiency and permits more design evaluations than could be done before.
  - Increase the understanding of the design concepts via increased data availability.
- Well defined requirements lead to good designs.
  - Translation of performance requirements into design features with supporting qualitative data.

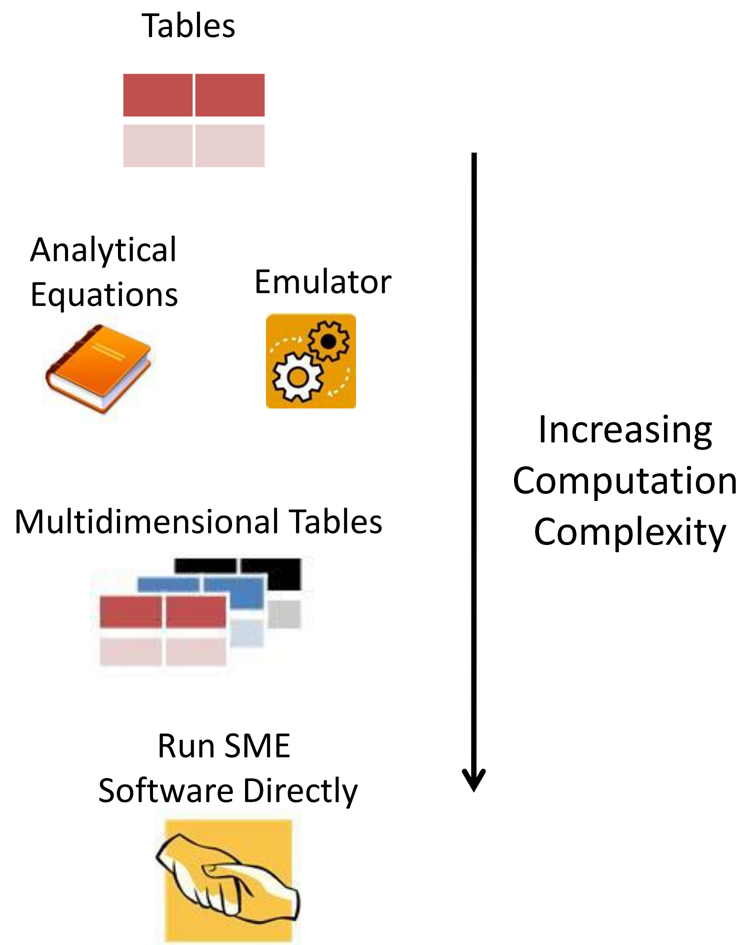
Integrated Modeling and Optimization Project Overview

- Integrated Modeling and Optimization (IMO)
  - ARDEC software development project in 2011
- Mission Statement :
  - Increase the ARDEC wide integrated modeling capability through the development of software tools and by expanding SME use of the process via ATO support.
- IMO IPT is a subset of the ARDEC competencies.
  - Performed survey to identify software codes in use and workflow examples.



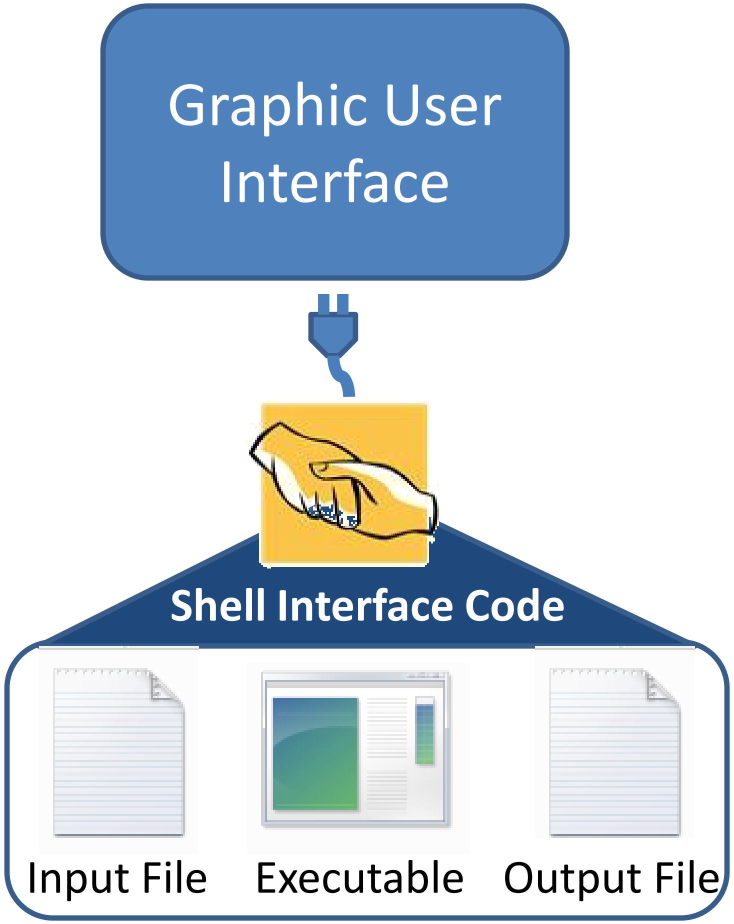
Integration Forms

- Empirical data or manually created databases
  - A few variables, medium to low fidelity, low run time.
- Analytical Equations or “Emulator”
  - Medium fidelity, medium to low run time
  - Simplified model or equations to capture physics.
- Multidimensional Tables
  - Medium fidelity with fast run time
  - Multivariable relationships
  - Potential for reduced accuracy depending on system
- Build “shell” around existing software.
  - High fidelity and potentially higher run time
  - Complex multivariable analysis
  - ProEngineer, CTH, Abacus, Excel, Custom Executables, etc.



Selection of Form Factor Based on **Scope** of Analysis and **Time**

Shell Concept



Generic Example

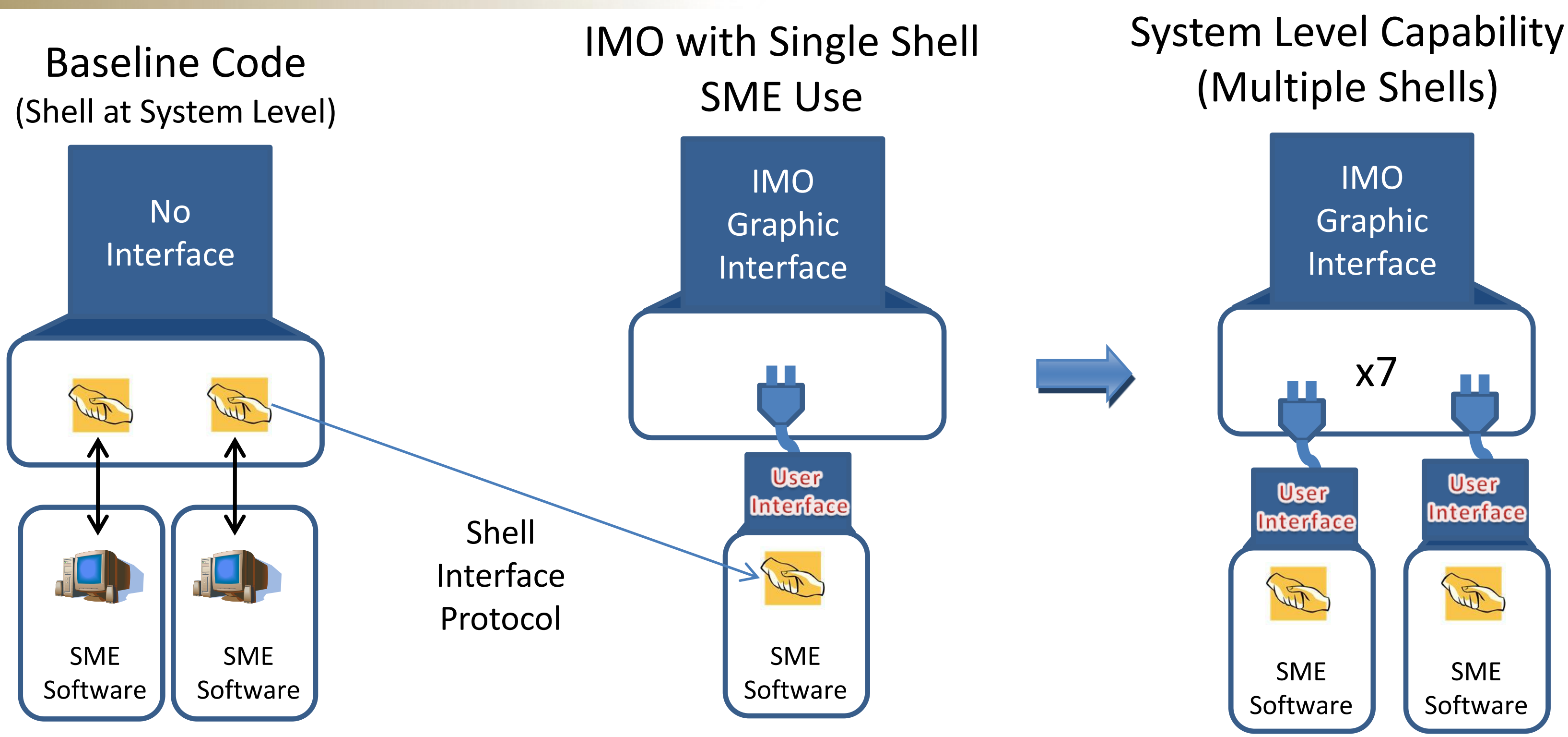
- A software “shell” is a set of execution instructions and data protocols to operate the software of interest via a third party software.

- IMO Analysis Software :
    - Run shells
    - Manage data
    - Run studies : optimization, Monte Carlo, etc.
    - Post processing

- IMO Graphic User Interface Aids SME in
    - Creating shell
    - Managing desired inputs / outputs.
    - Running single shell studies

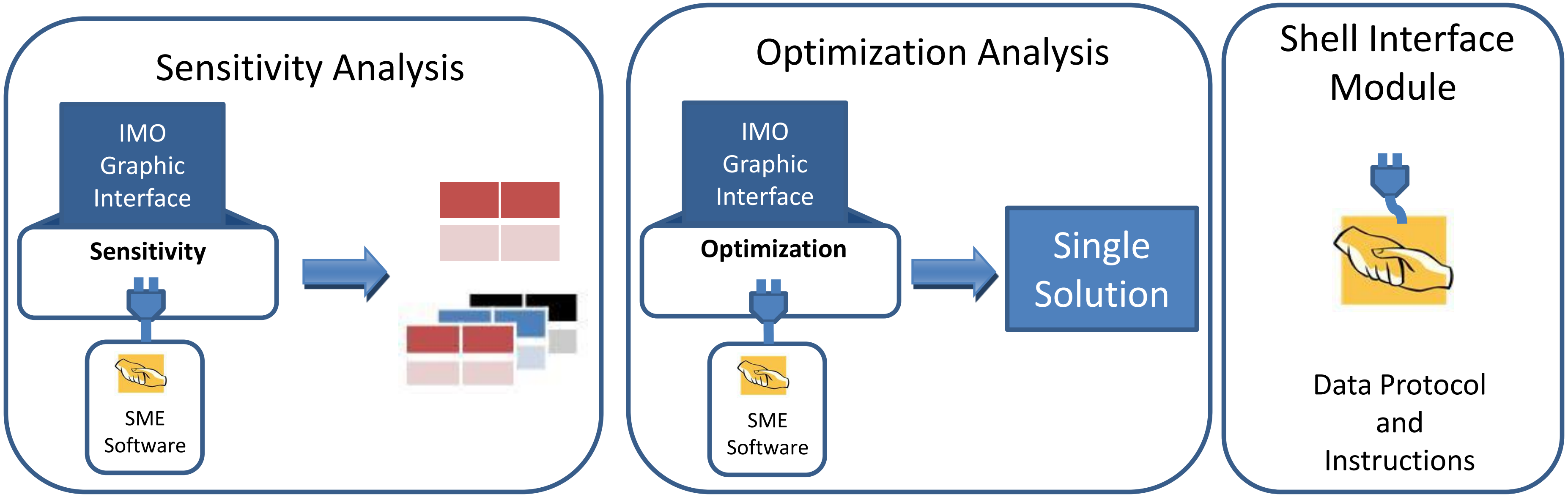
- **SME takes ownership of shell.**

Accessibility to SME User



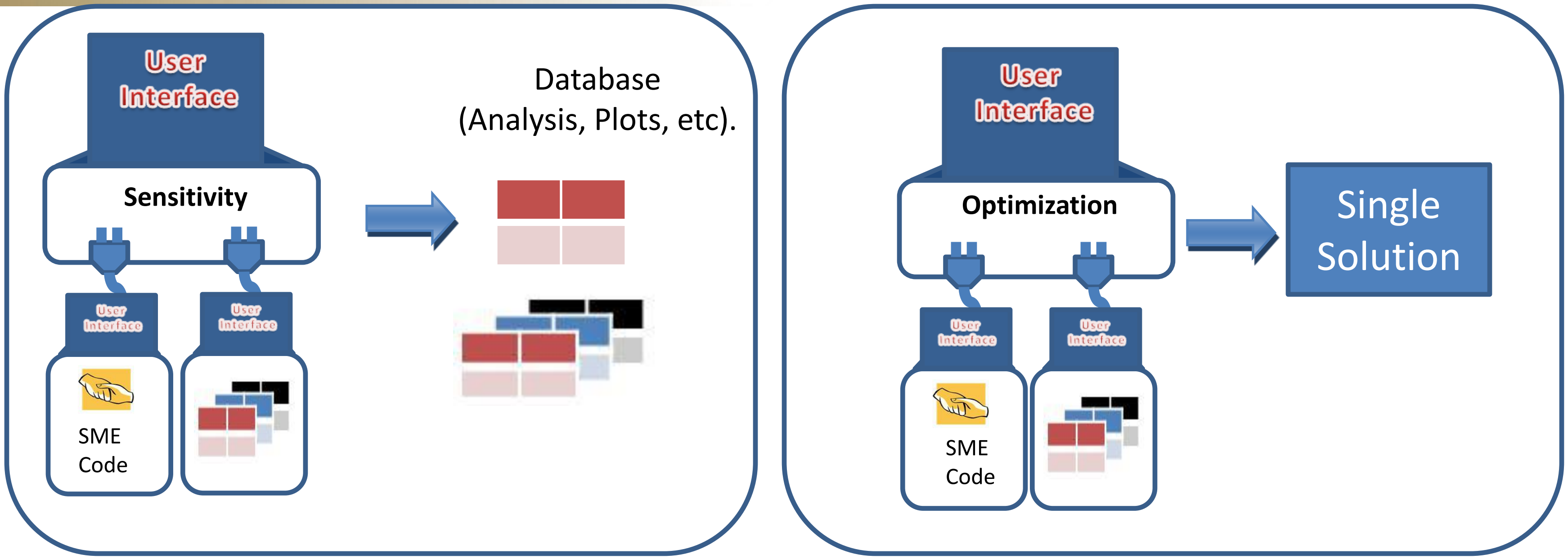
- Integration protocol transitioning from the system level to the SME level.
  - Provides the ability to "plug in" to larger system level analysis.
- Puts parametric and trade study code in the hands of modelers.
  - Allows for greater SME involvement, capability, and level of verification and validation.

SME Level Outputs



- Sensitivity
  - Generate databases, analyze, mine data, plots, etc.
- Optimization Analysis
  - Perform simple goal seek or more advance nonlinear discontinuous optimization.
- Shell Interface Module
  - Export shell for other SME users

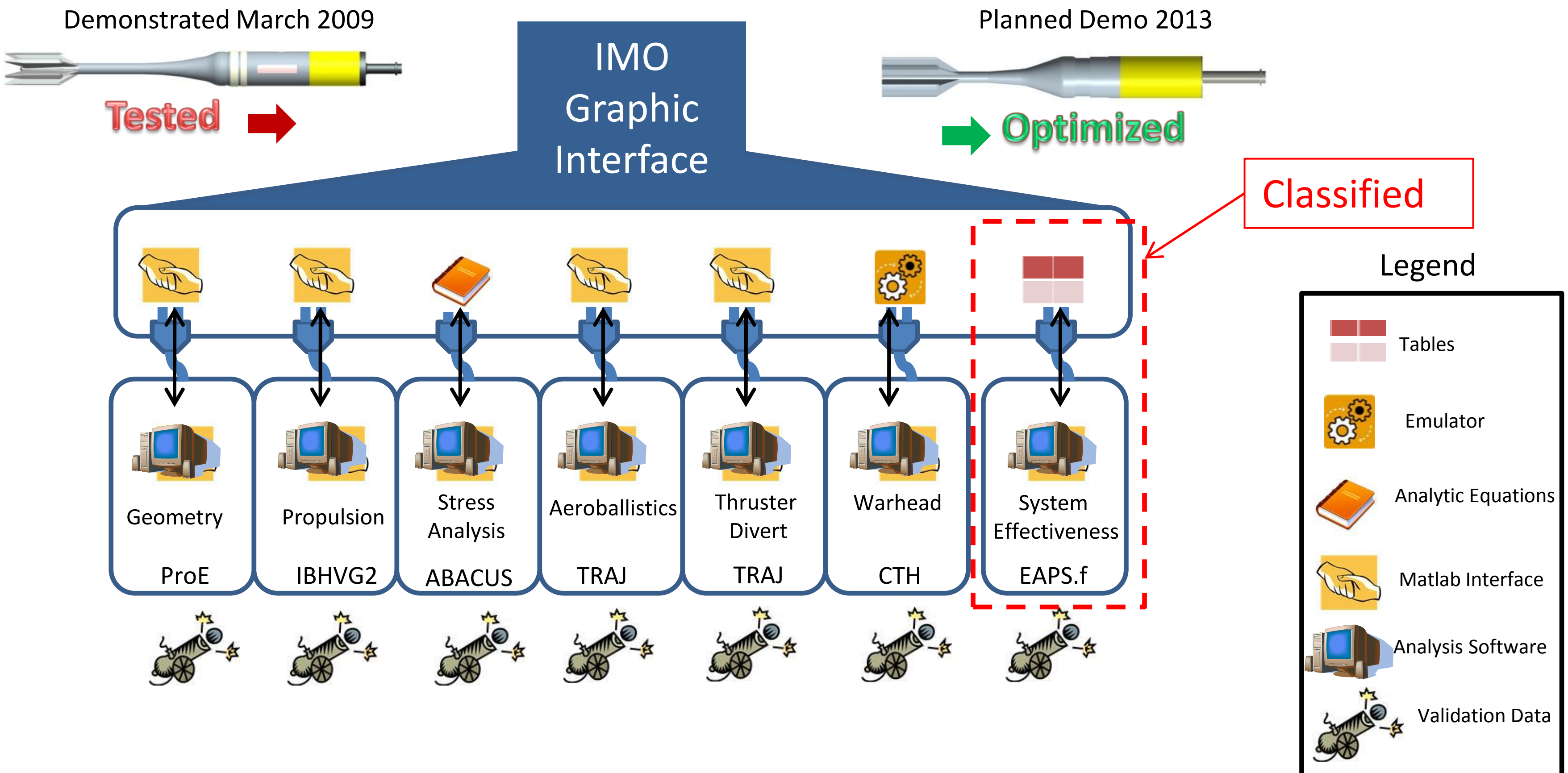
System Level Outputs



- System level users work with the same software as the SME level user.
  - Multiple shells can be fed into IMO software for system analysis.
  - Type of shell can vary from databases to "plug in" shell modules.
  - IMO shells developed by the SME engineers to ensure a verified / validated implementation.
- Sensitivity & Optimization Analysis
  - Perform the same functions available to the SME user but at a more complex level.
  - Quantity cross functional design tradeoffs.

Extended Area Protection and Survivability Workflow Example

- 50mm ground to air defense projectile in technology demonstration phase.
- IMO used extensively to perform design refinements and numerous studies since 2006.



Conclusions

- An integrated modeling approach has proved very successful from multiple programs.
  - The M1040 was type classified in 2006 and had two related patents for the design concept and software.
  - The EAPS design has been influenced by numerous studies using integrated modeling.
- System modeling and optimization is not a new concept, but it's success is heavily tied to pairing the right tools to the organizational structure.
- The IMO software under development is tailored to ARDEC's specific needs and design practices.

Questions

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NDIA 46th Annual Armament Systems:
Gun & Missile Conference & Exhibition

Netted Smart Precision Engagement Autonomous Rounds (NetSpears) for Navy and Army Weapons

Allan C. Vanuga
Engineering Fellow
Raytheon Missile Systems
13 April 2011

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- **Mark E. Elkanick, Senior Engineering Fellow Raytheon Missile Systems**

SUBJECT DATA GENERATED DURING PERFORMANCE OF NAVY CRADA (NCRADA-NAWCWDCL-04-124) BETWEEN RAYTHEON COMPANY AND NAVAL AIR WARFARE CENTER WEAPONS DIVISION.

Overview

- This smart submunition was designed to be utilized by both existing Army and Navy weapon platforms in order to deliver a lower cost and more capable munition to increase warfighter effectiveness.

- Briefing Objective:
  – Overview of the Small Boat Attack Problem
  – Describe the smart submunition, subsystem components, design trades and predicted simulation performance results
  – How the weapon system can be delivered by current Army and Navy weapon platforms and the CONOPS for its employment

The benefit to the gun and missile community is that this type of weapon enables a capability equivalent to massed fires with precision lethality against both asymmetric and conventional threats.

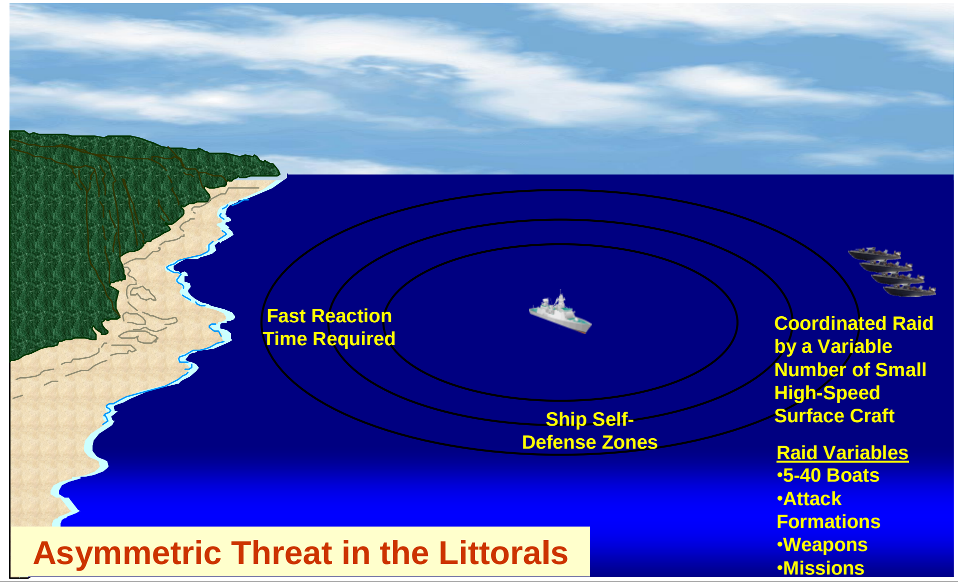
Small Boat Attack Problem

NEED: Countering the Small Boat Attack Problem is Still a Top World Problem

US APPLICATIONS:

- **ASuW Mission Module for LCS**
- **Littoral Battle Space**
  - **Air Launched: JSOW**
  - **Ship Launched Helos**

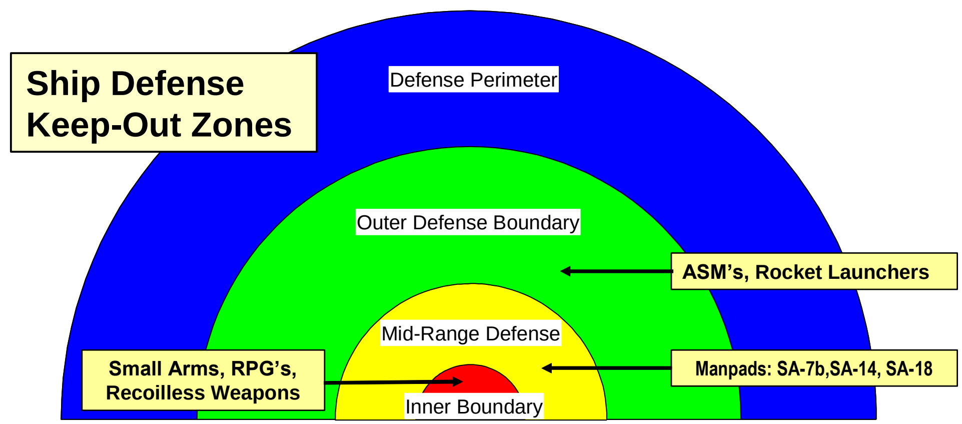
DoD Movie



Littoral ASuW Requirements

1. **A Layered Defense is Required for the "Many-on-One" Attack**
2. **Guided Weapons Are Needed to Defeat The Small High Speed Boat Threat**
3. **Weapon Load-Out is One of the Most Important Factors**
   - **The More the Better!**
4. **The Farther Out You Start to Engage Them, The Better**
   - **If You Wait Too Long, You Don't Have the Reaction/Engagement Time Available**

- **Zone Descriptions**
  - **Defense Perimeter: Lowest Risk Defense (15 nm Radius)**
  - **Outer Defense Boundary: Moderate Risk Defense (8-10 nm Radius)**
  - **Mid-Range: Threshold for Surface-to-Surface Missile Threat (5 nm Radius)**
  - **Inner Boundary : Highest Surface-to-Surface Missile Threat (2.5 nm Radius)**



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The Small Boat Threat

- **Wide Spectrum of Asymmetric Threats**
  - Detection Issues
  - Large and Small Raid Sizes
  - Multitude of Attack Scenarios
  - Numerous Weapon Keep-Out Ranges
- **Compressed Timelines**
- **Restrictive Rules of Engagement (ROE)**
- **Likelihood of Collateral Damage**

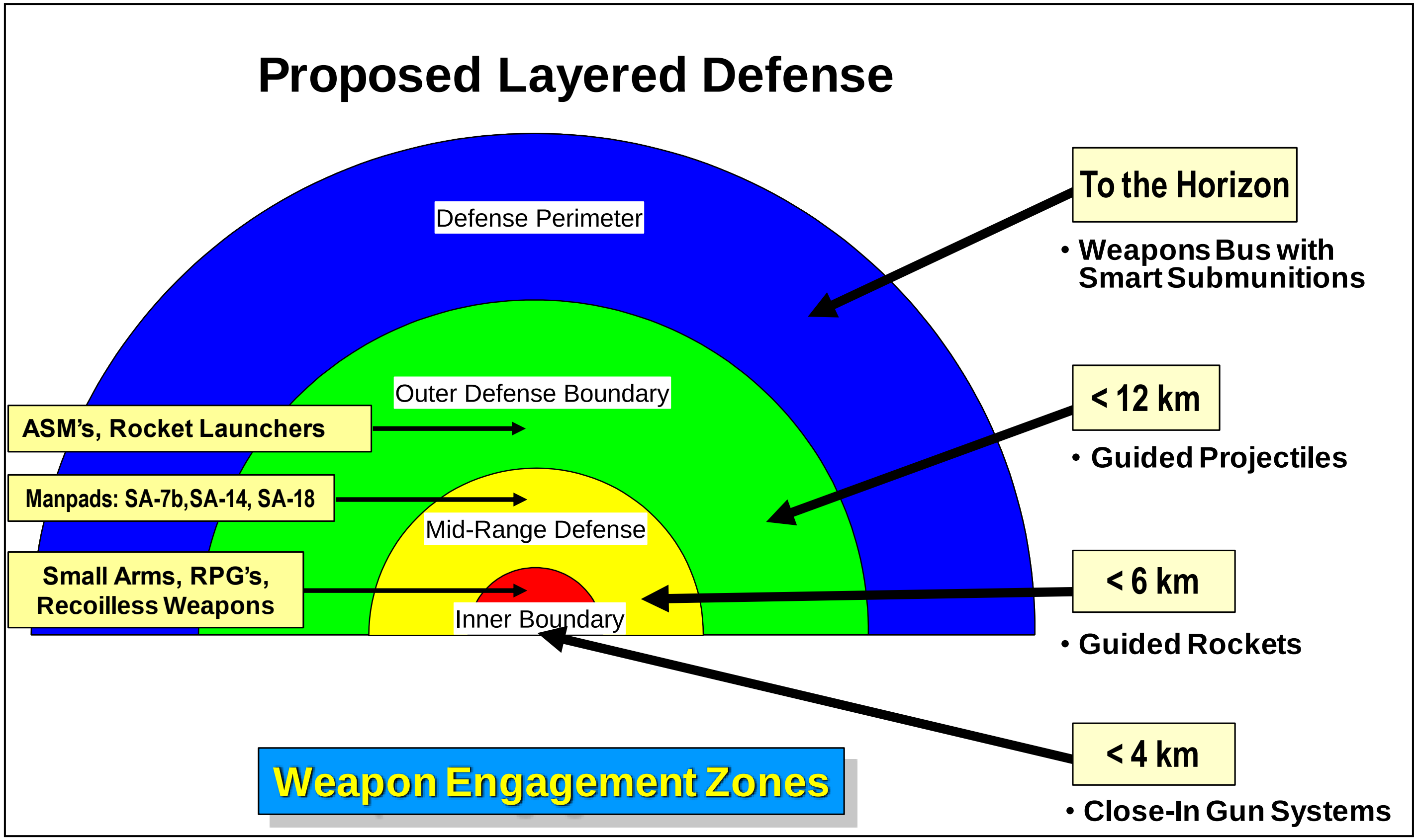
- **Small Craft Threats Range In Size, Agility And Load-Out Capacity**
  - **Craft sizes range from 20 to 70 feet**
  - **Speeds range from 25 to 70+ knots**
  - **Payloads range from 300 to 1000 pounds**
- **Craft As Launch And Attack Platforms**
- **Missile Threats Include Surface-to-Surface and Land-Combat Weapons**
- **Small Arms, RPG's, Explosives**

"A formation of warships is ill-suited to fight a swarm of small craft, because powerful missiles are wasted in overkill while the swarm sucks the large warships dry of their ordnance." *

* "Take the Small Boat Threat Seriously", Capt Wayne P. Hughes Jr., US Navy (Ret), U.S. Naval Institute Proceedings, October 2000

NetSPEARS Program Overview

- **OBJECTIVES:** Develop a Design for a Low-Cost Smart Submunition That Employs an Optimized Weapon-Target Pairing Concept to Increase Probability of Kill (P_k). Determine Optimum Delivery Bus and CONOPS
- **APPROACH:** Cooperative Effort (CRADA) with NAWCWD China Lake to Employ Their Smart Swarming Algorithms in a Future Weapon System for the Outer Defense Layers
  - Smart Submunition Design
  - Applicable Weapon Delivery Platforms & CONOPS



NetSPEARS Concept

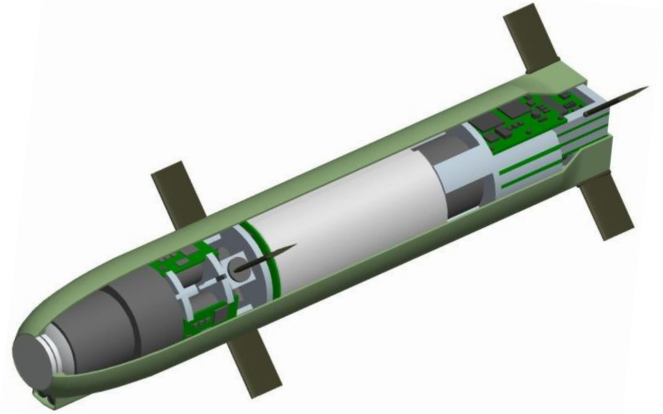
Weapon Bus Dispensing Large Number of Inaccurate Dumb Submunitions

To

Loitering Bus Dispensing a Small Number of Low-Cost Smart Submunitions

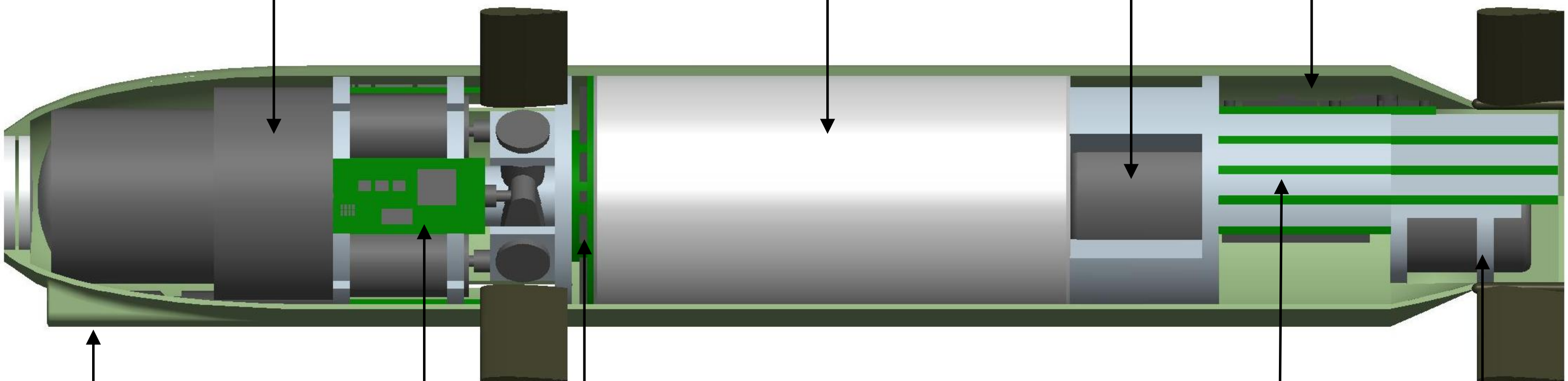
Smart Submunition Features

- A Fast Acting LAN for Communications Between Submunitions
- Optimized Weapon-Target Pairing Algorithms
- Low-Cost Electro-Optical Sensor Form Factored for the Weapon
- A Miniaturized Laser Altimeter for Submunitions
- Effective Warhead Technology
- All Other Relevant Subcomponents Such as IMU, G&C, GPS



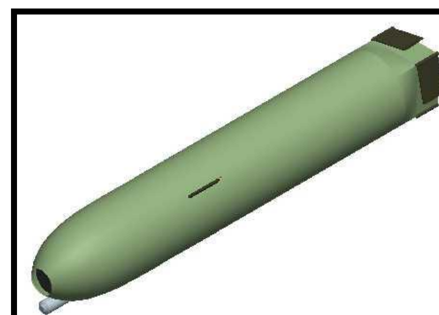
Cut-Away of the Smart Submunition

Submunition Model



Diameter: 2.75 in
Length: 17 in
Weight: ~8 lbs

- **Articulated Canards Offer Directional Control**
  - **Four Channels Provide Roll Control**
- **Fixed Pop-Out Tailfins For Longitudinal Stability**
- **Typical Deployment from 1000' AGL Horizontally at M=0.8**
- **Approximate 1.5-g Endgame Maneuverability**



Stowed Configuration

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Swarming Algorithms Overview

- **NAWCWD China Lake Has Developed and Simulated the Algorithms for a Smart Submunition Concept Which Have the Following Key Features:**

- **Submunition-to-Submunition Communication via Wireless LAN**

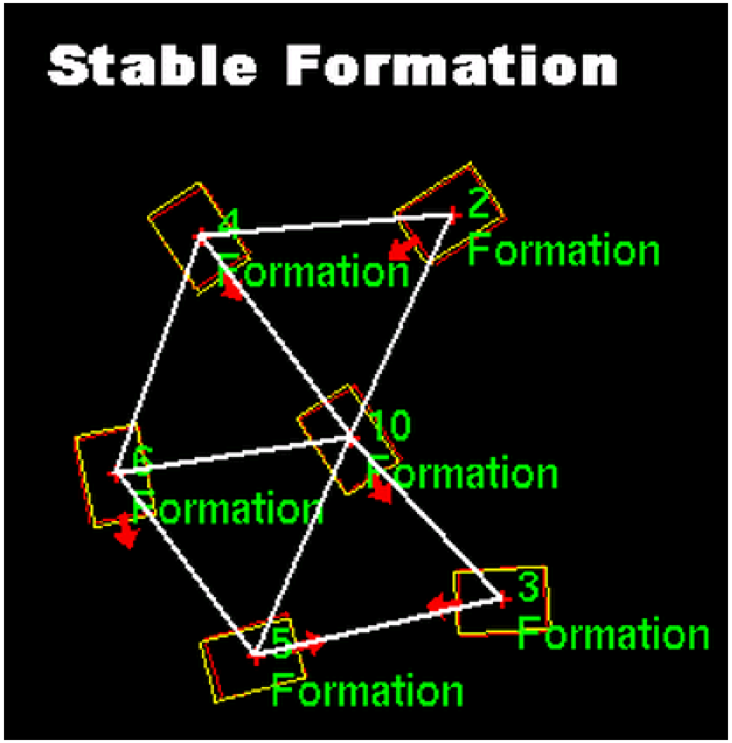
- **Forms a Stable and Cohesive Formation in Space (Virtual Coupling)**
  - Based on the idea of a virtual network of inter-connecting spring forces.

- **Robust Weapon-Target Pairing**
  - Algorithms for Optimally Assigning Submunitions to Targets with Capability to:
    - Maximize the global probability of intercepting all targets
    - Maximize the probability of intercepting a specific high-value target at the expense of missing a lower value target
    - Distribute impacts on the target to maximize the probability of a submunition entering a vulnerable volume

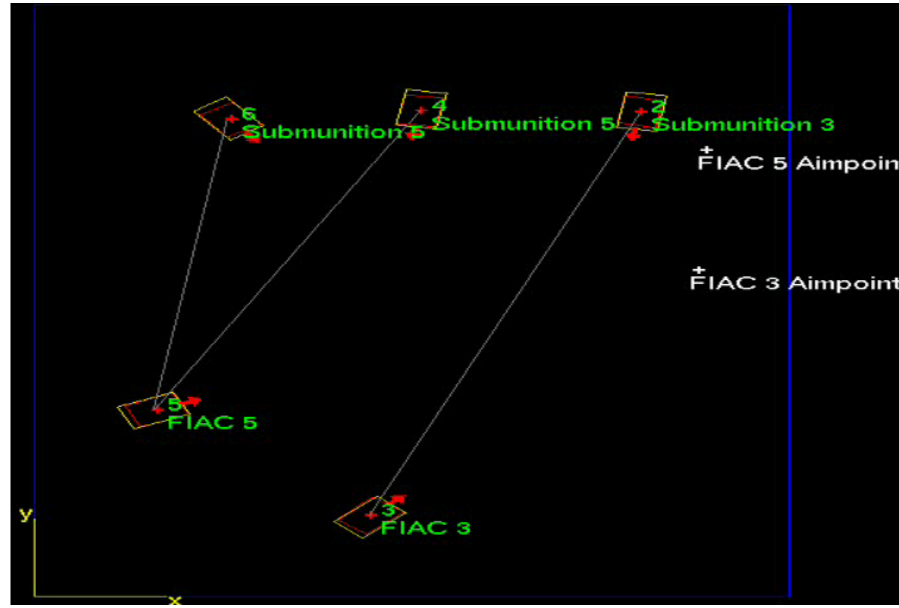
Distributed information sharing via the Wireless LAN is key to achieving cooperation and is essential for maintaining: group cohesion, avoiding submunition collisions, pursuing multiple targets and optimally assigning submunitions to engage maneuvering targets.

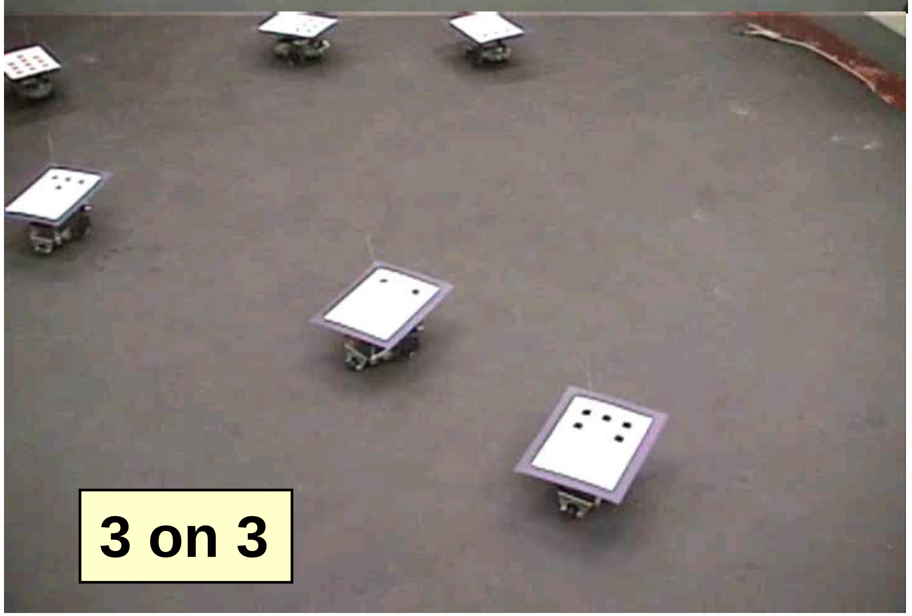
Virtual Coupling Demo

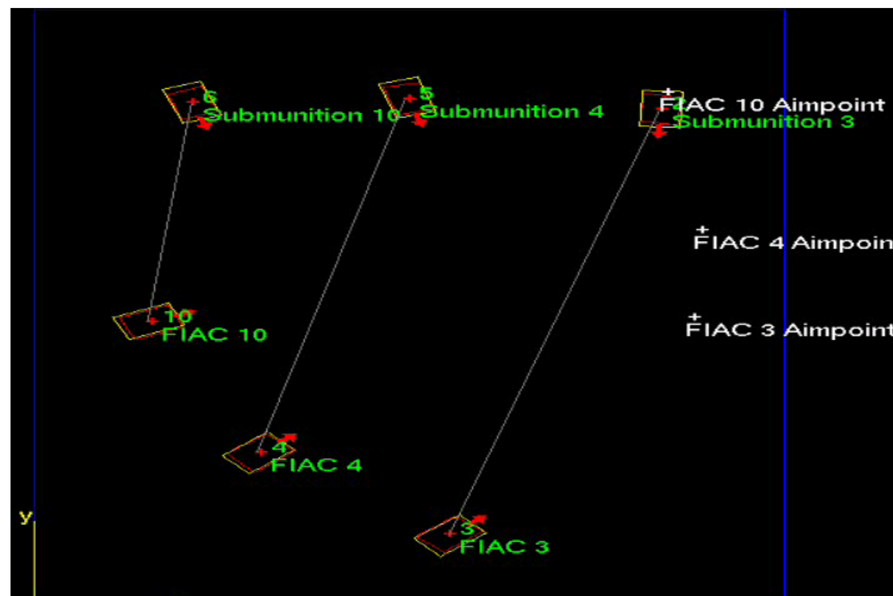
- **Convergent Network Formation Example**
  - The robots begin separated from each other and converge toward the center of the arena.
  - As the robots approach the center of the arena, they begin to enter each other's local neighborhoods and autonomously alter their respective courses.
  - An ad-hoc network forms near the center of the arena as the robots' virtual springs reach their rest distances.



Weapon-Target Pairing Examples



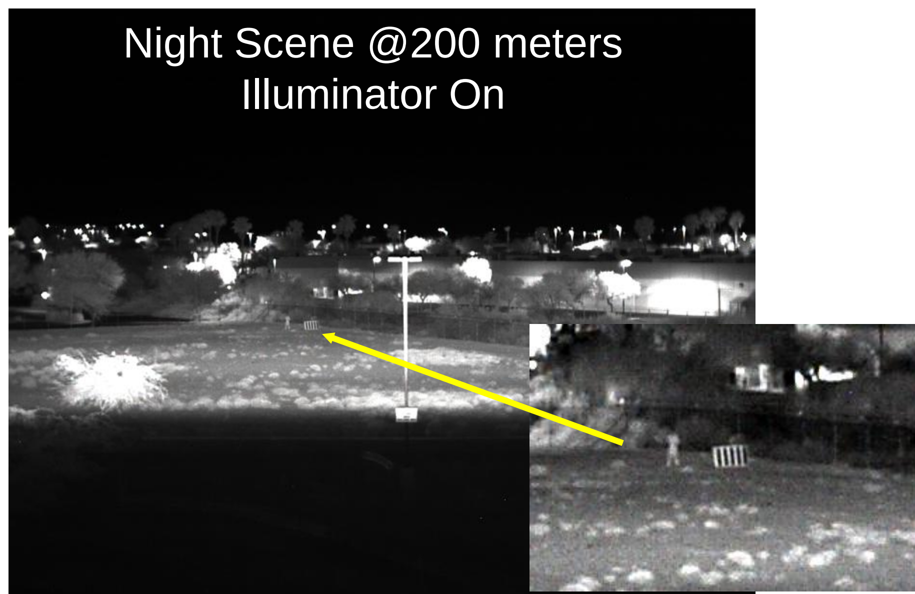




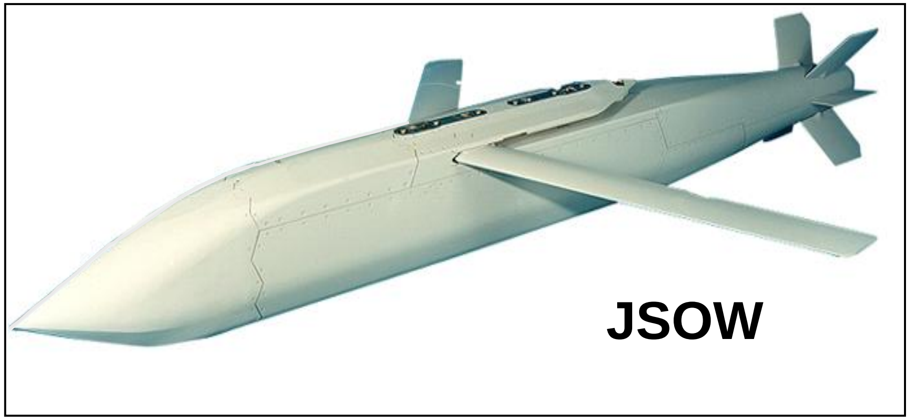
Approach to Meeting Low-Cost Goals for E-O Sensor

Raytheon Missile Systems

- **Strap-Down Illuminated CMOS Visible Sensor**
  - Provides Short Range Night Performance Using a Pulsed Laser Diode
  - Added Benefit: Provides Ranging Capability for
    - Detection & Tracking Algorithms
    - Warhead Fuzing



Candidate Delivery Platforms



Delivery Weapon Concepts

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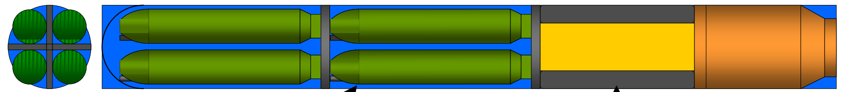
Hellfire-Like Bus Airframe for Rail Launched



7" OD by 70" Long Notional Fitment Volume

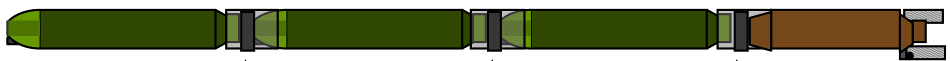
Submunitions, 2 bays of 4 each

Sustain propellant

Boost propulsion to provide design release speed for submunition

Coupled for Helo or UAV Rocket Pod Launched

Submunition | Submunition | Submunition | Propulsion



fins

Interconnect/Interface Connector Mechanisms

72"

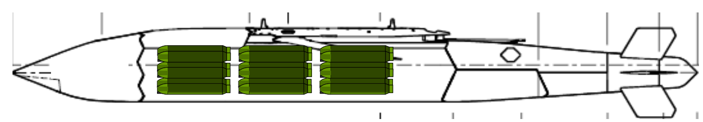
Three Coupled, 36.5 lbs.

Helo Launched:
114 with Nominal Range or
76 with Extended Range

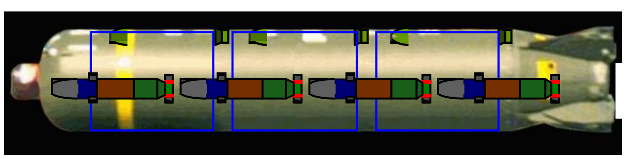
Munitions Truck & Cruise Missile Like Airframes

JSOW

36 Smart Submunitions



Dispenser Munition for Tactical Aircraft

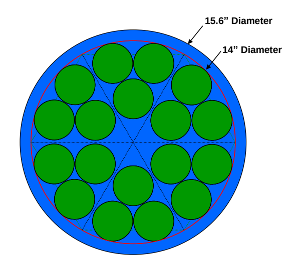


15.6" OD

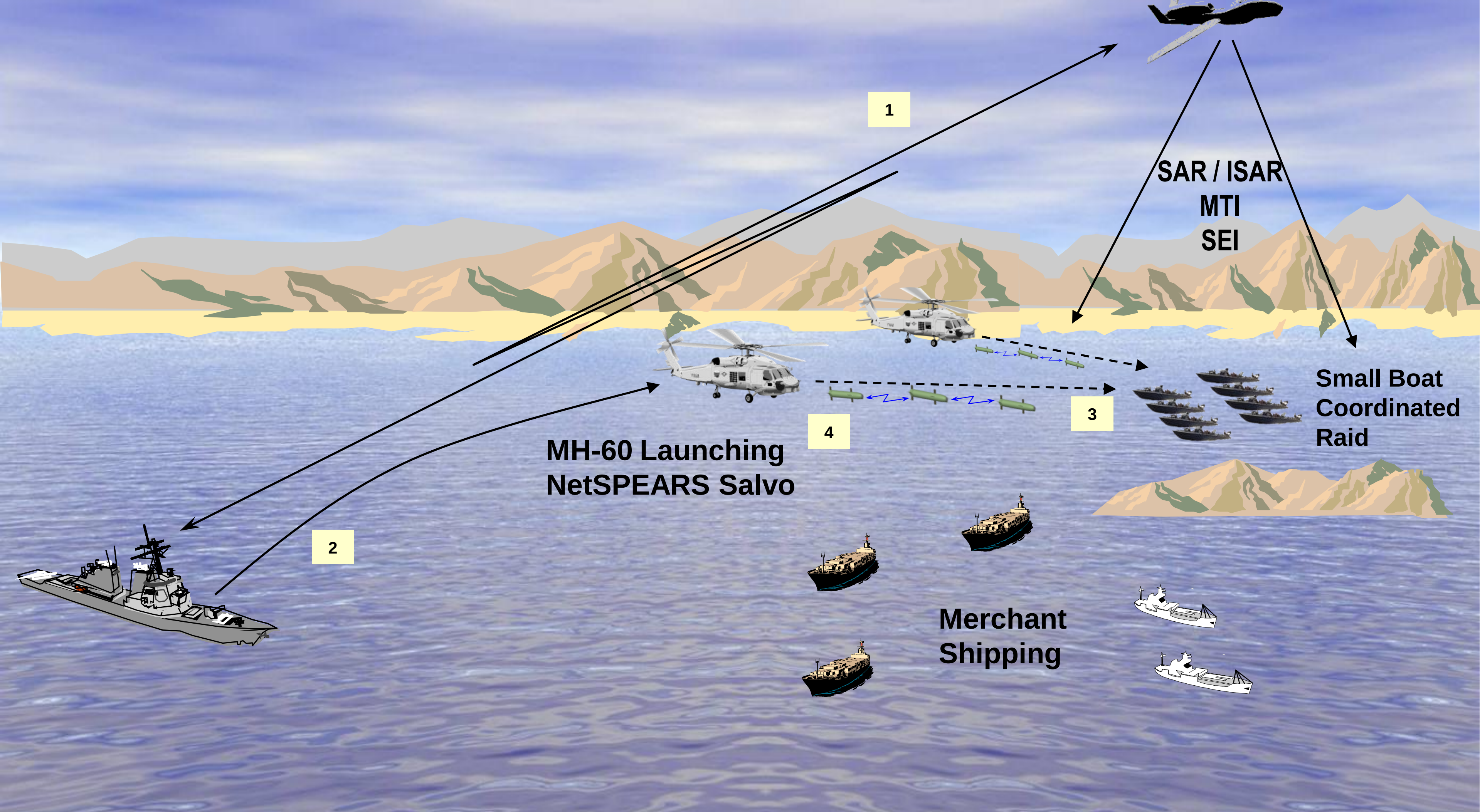
92"

72 total Submunitions in 4 bays of 18 Submunitions each

CBU-105 (CBU-97) Fitment Volume

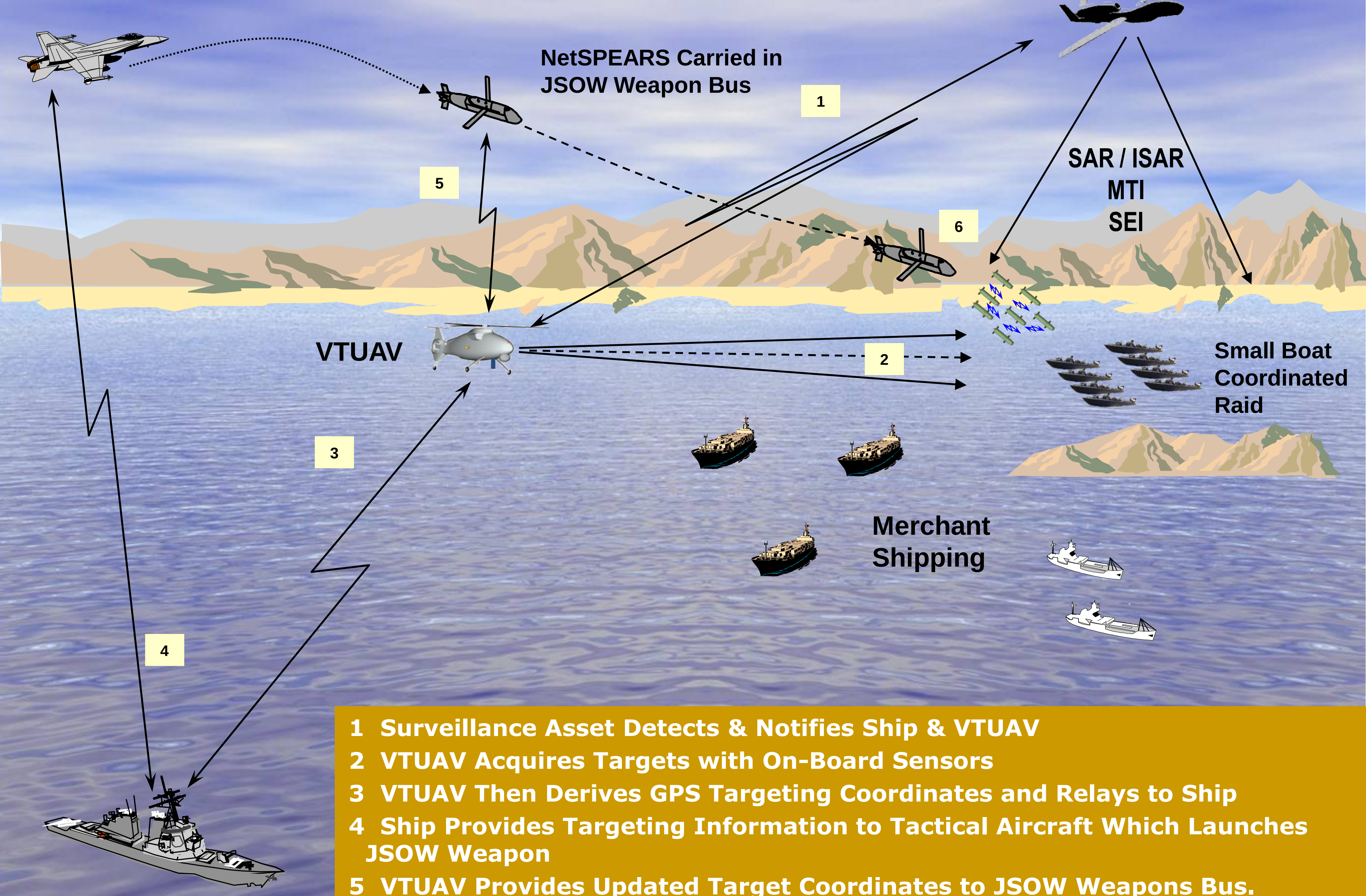


NetSPEARS OV-1



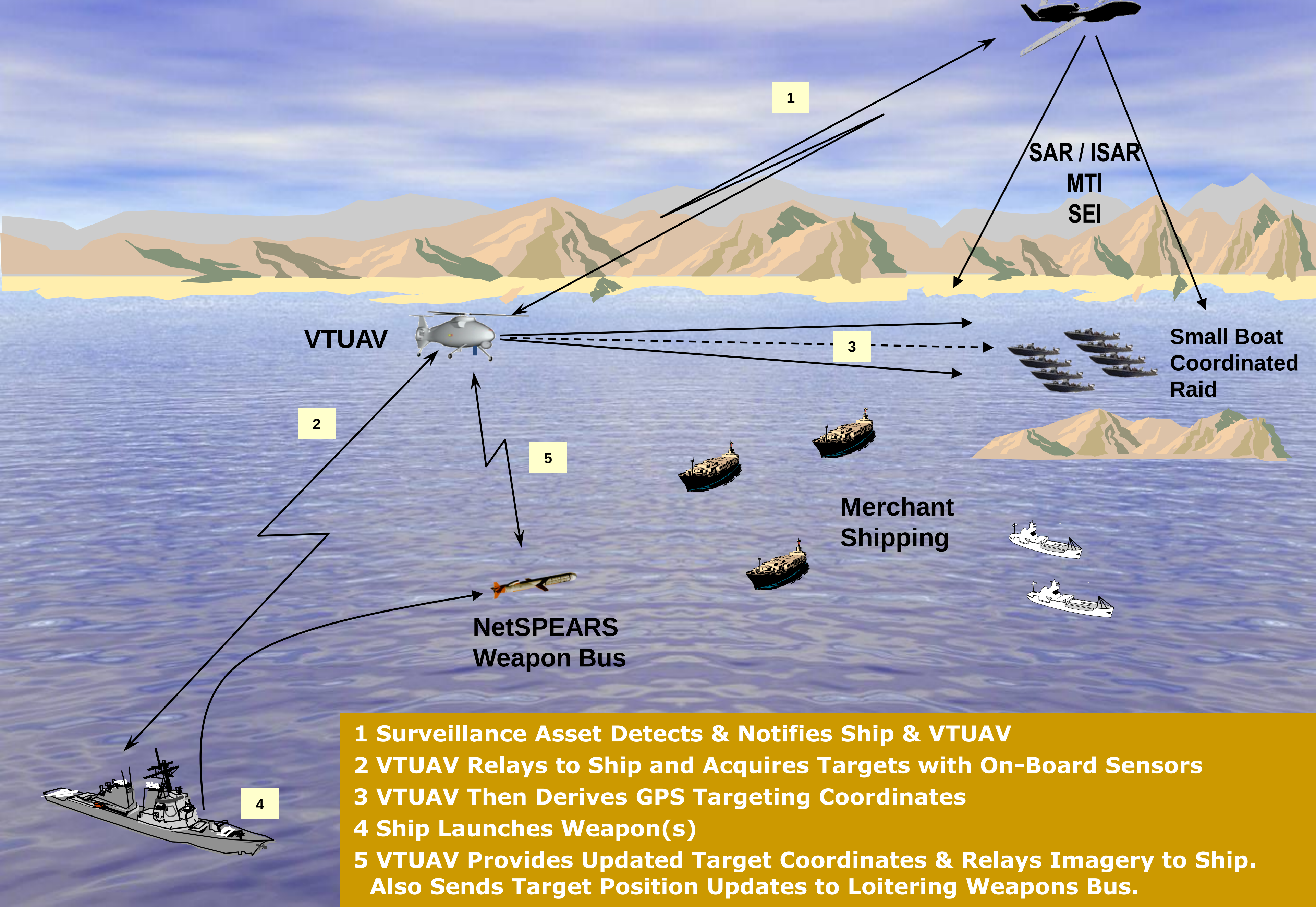
1. **Surveillance Asset Detects Threat & Notifies Ship**
2. **Ship Dispatches MH-60 Helos with NetSPEARS to Threat Area**
3. **MH-60 Acquires Targets with On-Board Sensors & Transfers Data to NetSPEARS**
4. **MH-60 Ripple Fires NetSPEARS Salvos as Required**

NetSPEARS OV-2



1 Surveillance Asset Detects & Notifies Ship & VTUAV
2 VTUAV Acquires Targets with On-Board Sensors
3 VTUAV Then Derives GPS Targeting Coordinates and Relays to Ship
4 Ship Provides Targeting Information to Tactical Aircraft Which Launches JSOW Weapon
5 VTUAV Provides Updated Target Coordinates to JSOW Weapons Bus.
6 JSOW Dispenses NetSPEARS Weapons over Target Area

NetSPEARS OV-3



1 Surveillance Asset Detects & Notifies Ship & VTUAV
2 VTUAV Relays to Ship and Acquires Targets with On-Board Sensors
3 VTUAV Then Derives GPS Targeting Coordinates
4 Ship Launches Weapon(s)
5 VTUAV Provides Updated Target Coordinates & Relays Imagery to Ship.
Also Sends Target Position Updates to Loitering Weapons Bus.

Application to Army Rocket Artillery Munitions

Photo: Lockheed Martin

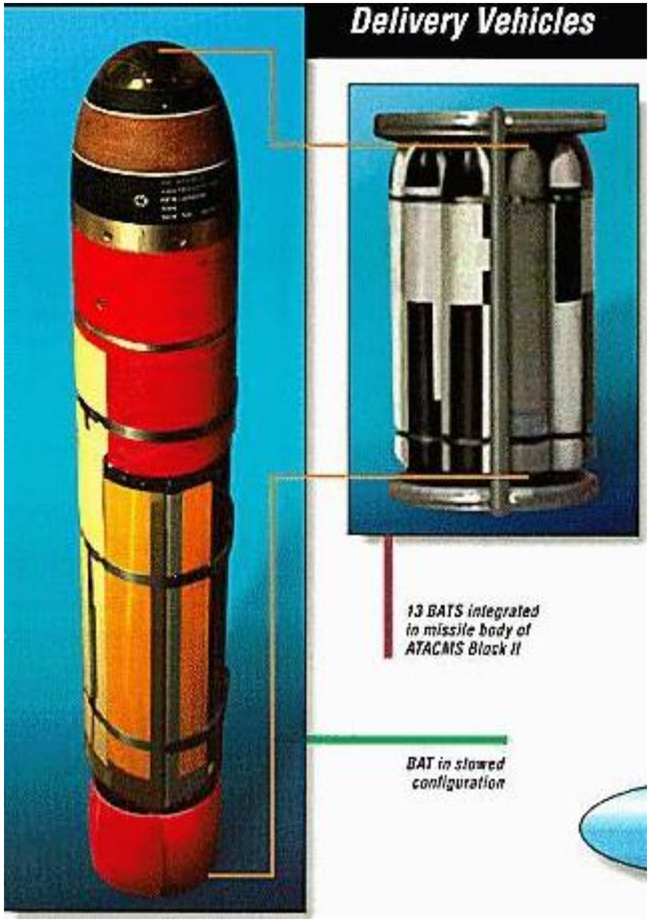
M26 *MLRS* Rocket (M270 launcher)

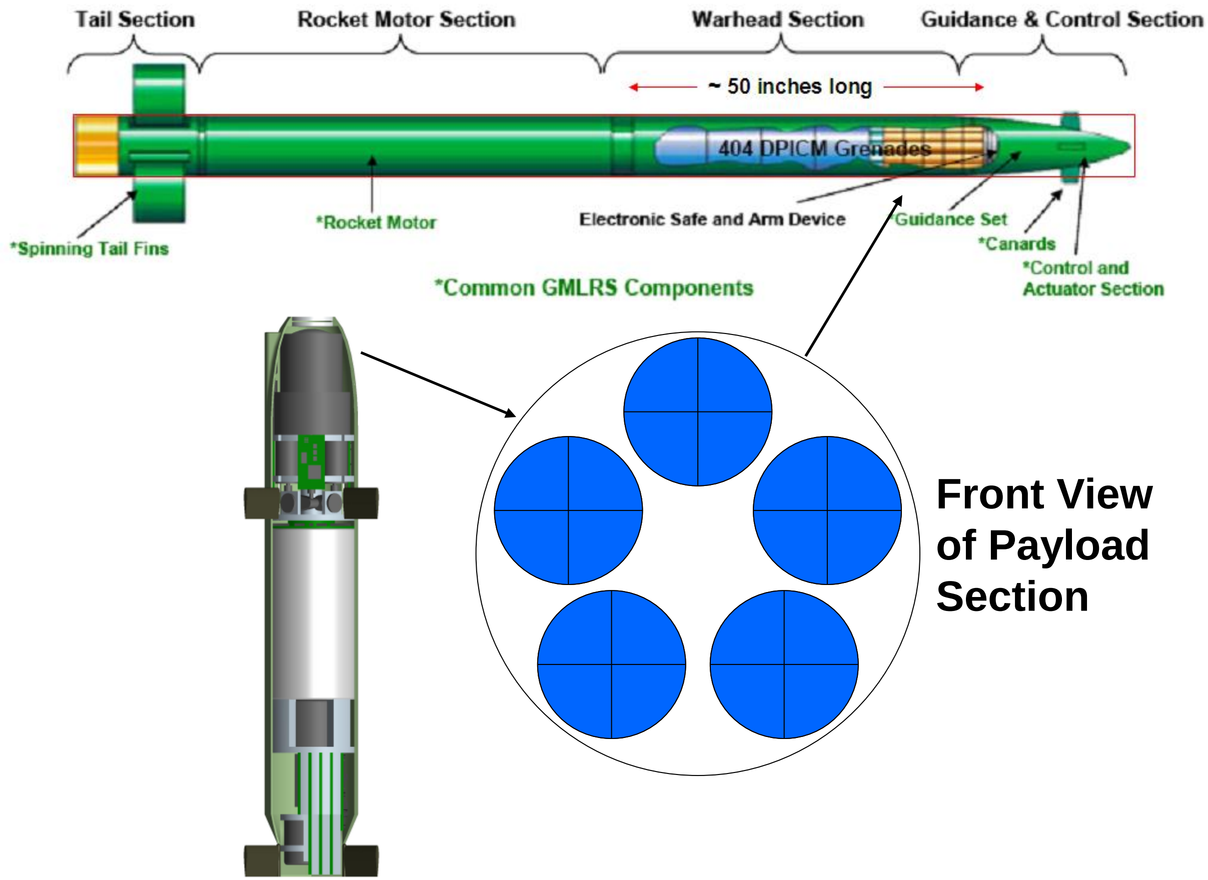
ATACMS Blk-1A

http://www.fas.org/man/dod-101/sys/land/atacms.htm

Preliminary Fitment Results for NetSPEARS Submunition in MLRS & ATACMS

NAVAIR — Raytheon Missile Systems





26 NetSPEARS in ATACMS
- Based on 13 BATS in MGM-164A (Two to a BAT Dispenser)

10-15 NetSPEARS in MLRS Based on Fitment of 2 to 3 Weapon Bays (5 each)

*http://www.fas.org/man/dod-101/sys/land/atacms-bat.htm

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NetSPEARS Technology for Army Artillery

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Trade Study Summary

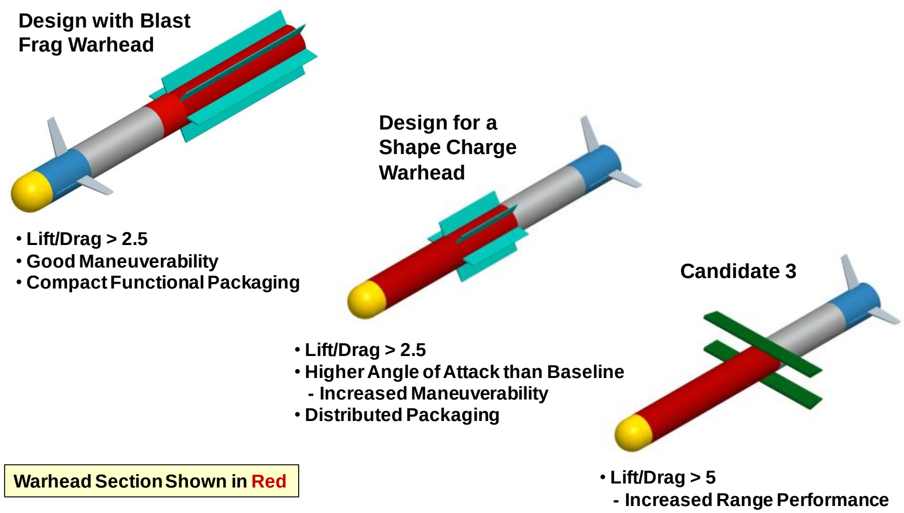
- **Based on Preliminary Fitment Analysis of a Navy NetSPEARS Submunition**
  - **Only One Would Fit in a 105mm Howitzer Shell**
  - **Only Two in a 155 mm Howitzer Shell**

- **Based on Our Analysis, the Current Design Can be Modified for Artillery Applications**

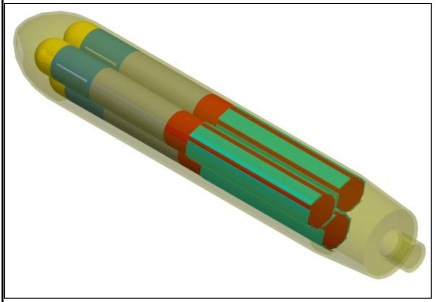
- **Specific Design Areas to Trade for Artillery Applications**
  - **Airframe Design Trades for Length/Diameter Changes (Aero Analysis)**
  - **Seeker Performance**
  - **Warhead Size & Lethality**
  - **Gun-Hardening Requirements**
  - **Packaging Ramifications**
  - **Shell Modifications (e.g. Nose Shape)**

- **Analysis of New Submunition Footprints vs Shell Dispersion and TLE**
  - **Needed to Derive the New Required Submunition Authority**

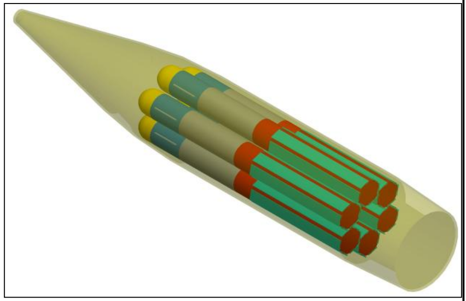
Airframe Configuration Trades



Preliminary Fitment Results for Candidate Submunition



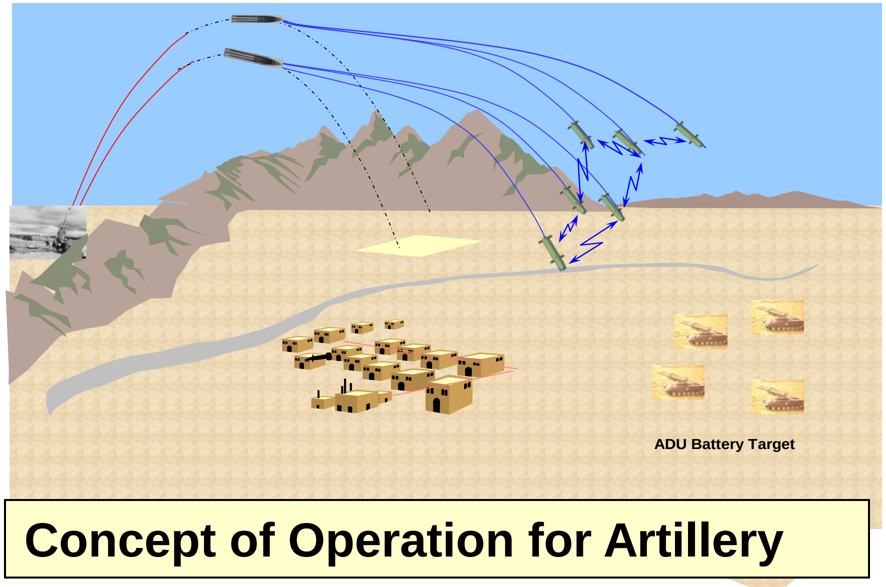
Fit 3 Submunitions Within the 105 mm



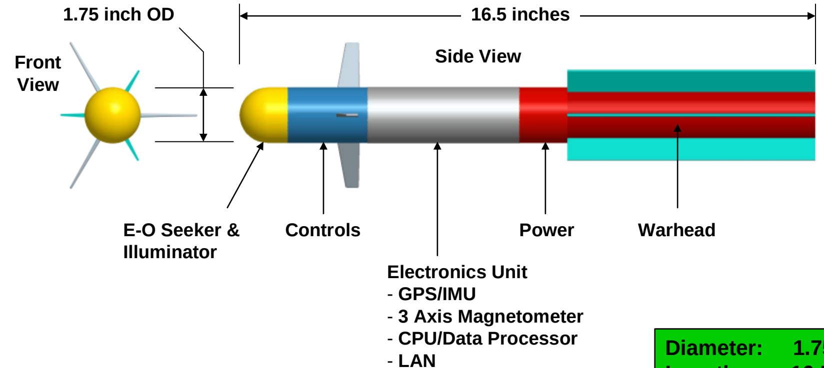
Fit 6 Submunitions Within the 155 mm

Folded Strakes and Pop-Out Canards

Army NetSPEARS for Conventional Artillery (DPICM Replacement)

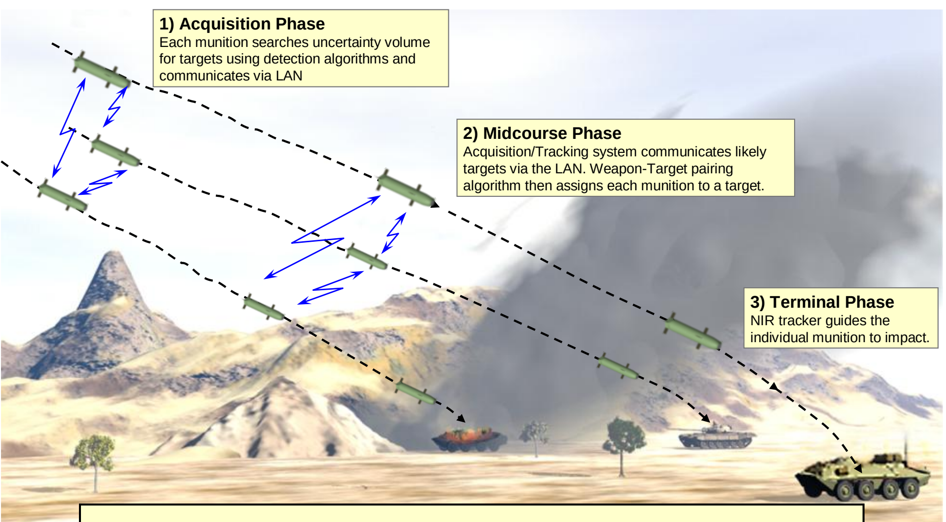


Concept of Operation for Artillery

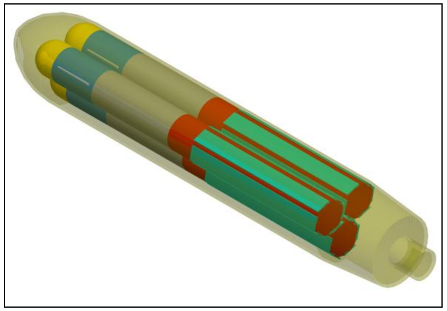


Diameter:	1.75 in
Length:	16.5 in
Unit Weight:	7.2 lbs
Warhead:	1.6 lbs

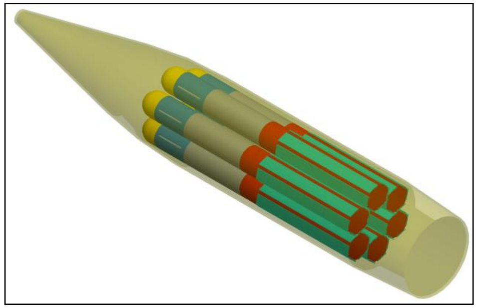
- Fixed Pop-Out Tail Stakes For Longitudinal Stability
- Canards for Directional Control
  – 3-Axis Control
- Gun-Hardened
- NAWCWD LAN Technology and Algorithms
- Dispensed Near Ballistic Apogee for Maximum Range



End-Game Functional Operation



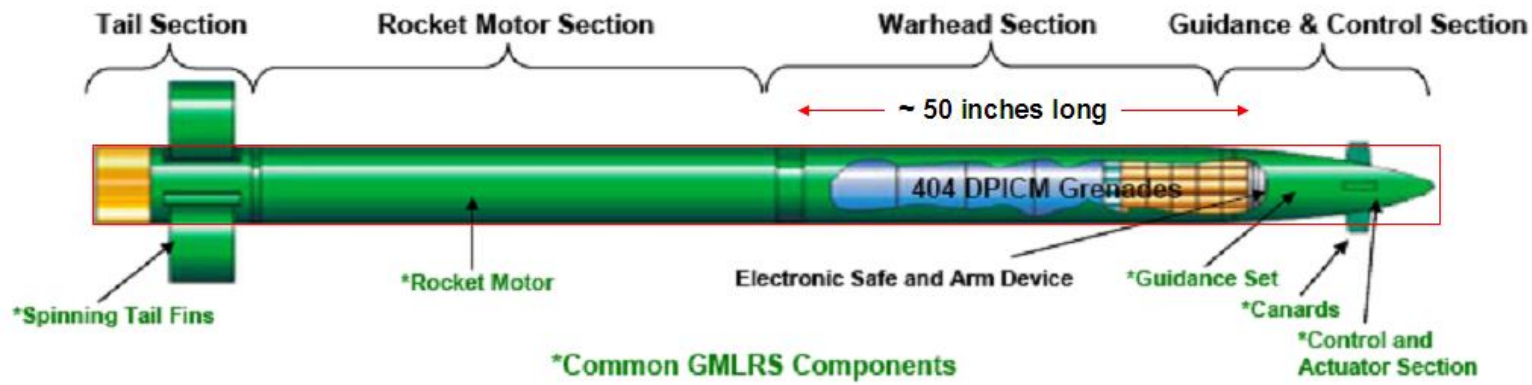
Fit 3 Submunitions Within the 105 mm



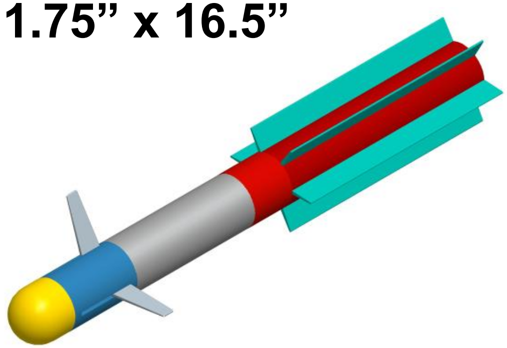
Fit 6 Submunitions Within the 155 mm

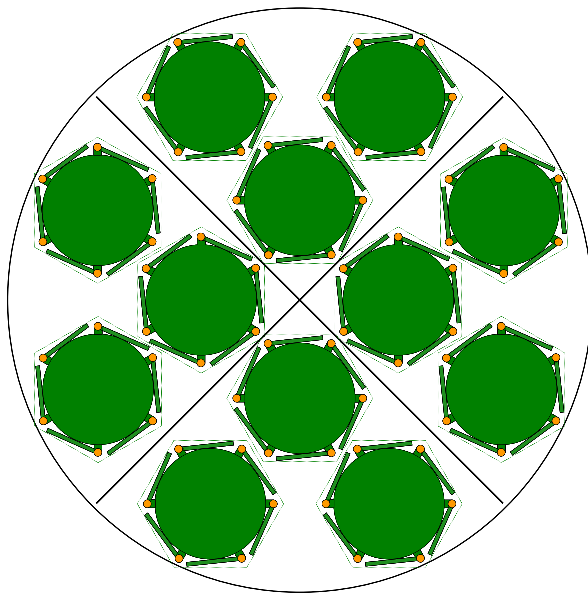
Folded Strakes and Pop-Out Canards

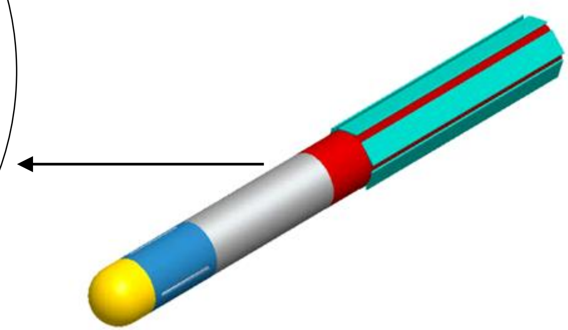
Preliminary Fitment Results for 1.75” NetSPEARS Submunition in GMLRS



1.75” x 16.5”







GMLRS Cross Sectional View of Warhead Area Showing Fitment of 1.75” Submunition with Surfaces Folded

36 Army NetSPEARS in GMLRS Based on Fitment of 3 Weapon Bays (12 each)

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NetSpears Weapon System Performance Prediction Studies

Mission Utility Study for Helo Launched NetSPEARS

- Evaluation of both helicopter-launched and truck-launched (JSOW) NetSPEARS munitions in the Small Boat Suppressor Mission Level Model scenario to provide a rough idea of the military effectiveness of the submunition
  - JSOW version deployed from F/A-18s
  - Helo-launched version carried in a 19-round rocket launcher, two or three NetSPEARS munitions per rocket tube

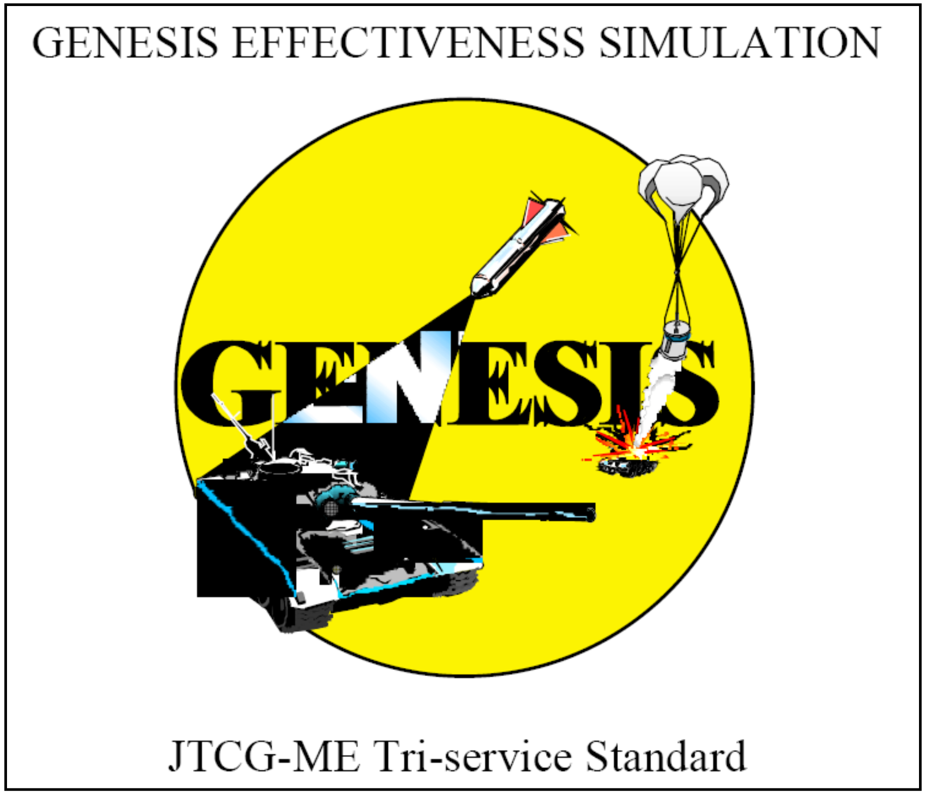
- The effort was to evaluate the lethality of the NetSPEARS submunition concept against small boat targets. This required a two-step process. The first was to generate small boat damage for single submunition encounters. Next, when these values were completed they were used as input to a SUPRESSOR many-on-many simulation.

- This study leveraged previous, similar work for an AOA study of small guided warheads. Because of this, the target models, effectiveness methodology, lethality input scripts, and parametric analysis schemes were available, in place, and tested.

- The kill criterion used: Mission Kill

Performance Model Description

- **The GENEric Smart Indirect Fire Simulation (GENESIS) is used to perform effectiveness evaluations based on user defined engineering parameters and system performance data.**
  - **Monte Carlo Based US Army/Air Force Performance Model for Dumb & Smart Submunitions**
  - **Many-on-Many**
  - **Indirect fire**
  - **End game (effects of targeting and delivery errors modeled)**
  - **Effectiveness model (1 volley of smart munitions vs. target arrays**



Scenario and Approach for Navy System Performance Evaluation Trade

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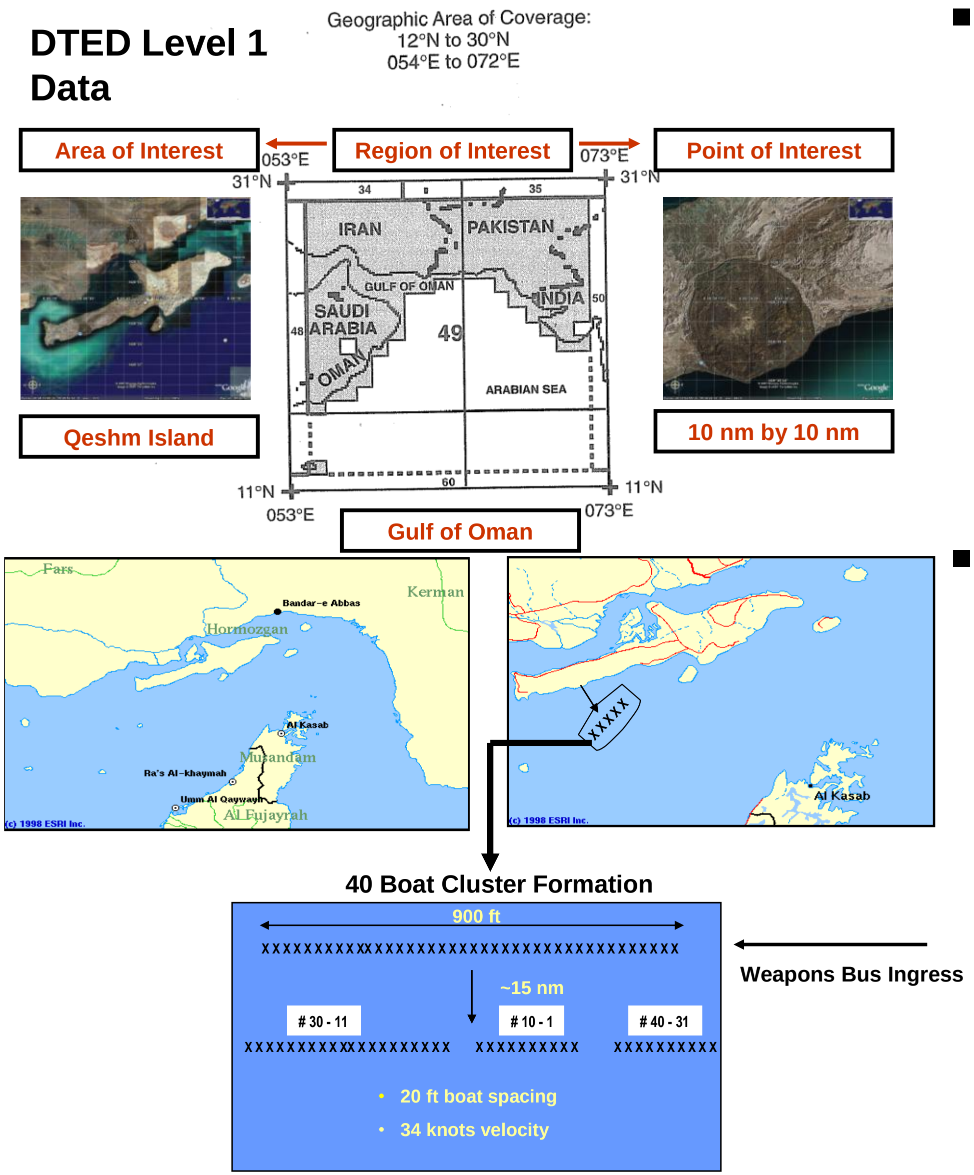
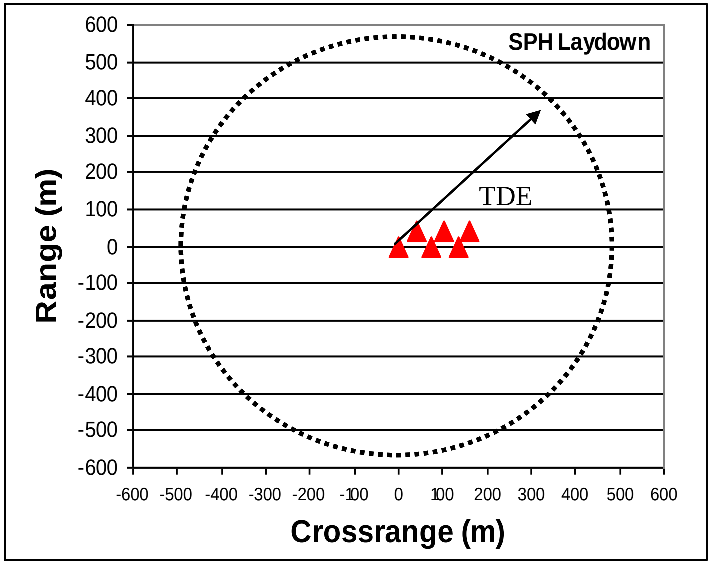


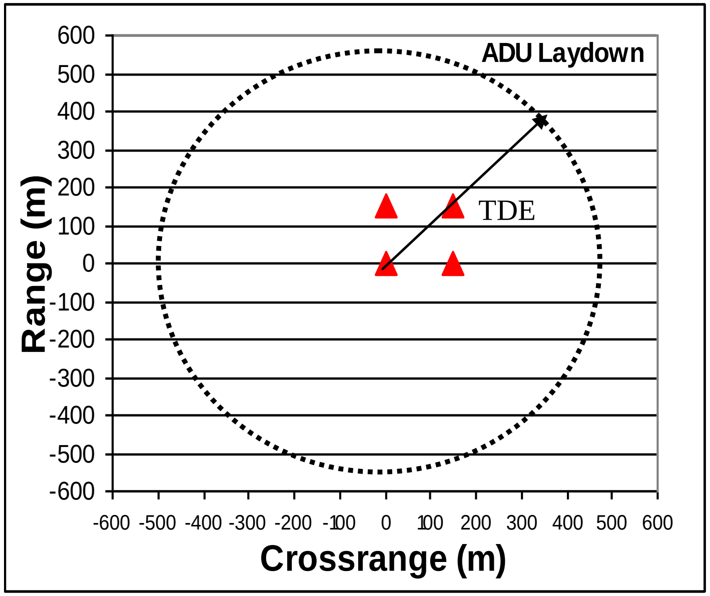
- **Dumb Submunitions Tactics, Techniques and Procedures**
  - 4 Cruise Missile Target the Cluster
  - 166 BLU-97 CEBs per Bus
  - Payload Dispenses ~ 1000 ft Altitude
  - Single Dispense Location per Weapon
  - 1 Pass Only Over Target Area
- **Smart Submunitions Tactics, Techniques and Procedures**
  - 1 Cruise Missile Targets the Cluster
  - 88 NetSPEARS Submunitions on the Bus
  - Payload Dispenses ~ 1000 ft Altitude
  - Evaluate Single & Multiple Dispenses from Weapon
  - 1 Pass Only Over Target Area

Army Systems Performance Evaluation Run Matrix

- **Targets**
  - Self-Propelled Howitzer Battery (SPH)
  - Air Defense Unit (ADU)

- **Rounds Fired**
  - Artillery w/NetSPEARS: 6, 12, 18
  - Artillery w/DPICM: 18, 36, 54
  - MLRS: 6, 12 (All Cases)
  - ATACMS: 1, 2 (All Cases)





Weapon & Payload
105mm (Unguided & Precision) a) 42 DPICM b) 3 SmartCATS (1.75”)
155mm (Unguided & Precision) a) 72 DPICM b) 6 SmartCATS (1.75”)
MLRS (Unguided) a) 404 DPICM b) 10 SmartCATS (2.75”) c)200 lb Unitary
GMLRS (Guided) a) 72 DPICM b) 10 SmartCATS (2.75”)
ATACMS Blk 1A a) 300 APAM b) 26 SmartCATS (2.75”)

NetSPEARS System Attributes

- A smart submunition containing sensors and power can be programmed to detonate under virtually all conditions thus leaving ***no UXO*** on the battlefield

- A warhead design that will assure at least a mission or functional kill and will meet IM requirements.

- Loaded with a qualified Insensitive High Explosive, the small SmartCATS warhead in its life-cycle (containerized) configuration will meet most IM requirements (FI, BI, SCO, FCO), and, with appropriate packaging, will pass SD

- Low cost by the heavy use of COTS components

Summary

- **NetSPEARS Weapon System Benefits**:
  - Submunitions will attempt to engage the entire incoming small boat raid simultaneously rather than targeting just one boat at a time.
  - The submunitions themselves are smart, meaning they have their onboard sensors to acquire and track targets and determine their own altitude and GPS coordinates. ***The delivery vehicle is free to move on after the dispense***.
  - The target-weapon pairing algorithm is optimized so that the appropriate number of submunitions can be allocated to each target of interest in order to maximize lethality

NetSPEARS Weapon System Employs a New Paradigm:

“The Submunitions Pair-Up with Targets as They Drop & Talk”

Can Provide a Low-Cost Solution for Neutralizing Large Coordinated Raids of Fast Moving Asymmetric Surface Targets

Common GPS: Development of the Subsystem Specification and ICD for the Common GPS Subsystem for the family of Precision Guided Projectiles

Paul Manz — **US Army, PEO Ammo**
Karl Flueckiger, Tim Easterly, Brian London — **Draper Laboratory**

13 April 2011

Outline

- Objectives and Rationale
  - Common GPS goals
  - Unique requirements imposed by indirect fire gun-launched PGMs
- Development Approach and Current Status
  - Participants and stakeholders
  - Relevant milestones and future activity
- Overview of Documents
  - Scope of requirements
  - What is and is not covered
- Conclusion

Objectives

- **Define req'ts for common GPS with A/J subsystem across future Joint gun-launched Precision Guided Munitions (PGMs)**
  - **Develop vendor-neutral Specification and ICD that addresses gun-launched PGM needs (applicable across 81, 105, 120, and 155 mm projectiles) without favoring any one particular solution or technical approach**
  - **Address A/J req'ts and hardware needs, including projectile spin environments up to 300 Hz**
  - **Address anti-tamper and modernization imperatives**

- **Enable GPS hardware commonality benefits**
  - **Competition in the supply chain: lower unit production cost and hardware availability**
  - **Simplified integration**

Focused on Common GPS Solution for Major Joint M-Code Market Segment

Why are Indirect Fire Gun-Launched PGMs Different?

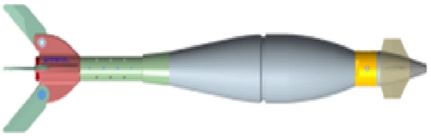
	Indirect Fire Gun-Launched PGMs
Initial Conditions	Load GPS Ephemeras data prior to launch and reacquire after muzzle exit at high velocity (up to 800 m/s)
Shock Environment	Extreme (up to 21,000 Gs)
Spin Environment	High Spin (up to 300 Hz)
Size, Weight, Power (SWP)	Desired 40mm Diameter
Set-Time Requirement	Less than 10 seconds
POR Quantities	> 100,000
Durable vs. Consumable	Consumable
Shelf Life	20 Years

Gun-Launched PGMs Represent Most Demanding Environment

Indirect Fire Gun-Launched PGMs

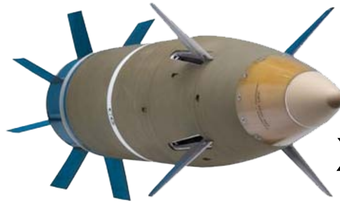
Mortars

XM395 Accelerated Precision Mortar Initiative (APMI)



- 120mm conventional High Explosive (HE) mortar cartridges equipped with GPS guidance fuse and modified stabilization fins
- Provides Battalion commander with organic precision capability ≤10m CEP
- Urgent Need Fielding: Mar 2011

Provides for complementary employment of precision capacity across the tactical battle space



Artillery

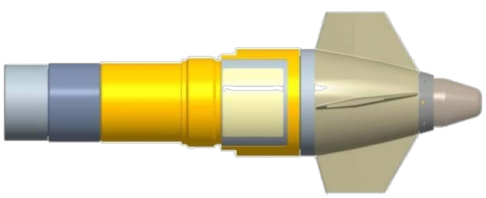
XM982 Excalibur

Autonomous fire & forget, optimized for urban/complex terrain

Increment	Range	Accuracy	Fielding Status
1a-1	8-24Km	≤ 10m*	Fielded
1a-2	8-40Km	≤ 10m*	2QFY11
1b	8-40Km	≤ 10m	3QFY14

*significantly exceeding accuracy requirements >6m

XM1156 Precision Guidance Kit (PGK)



- GPS guidance fuze for 155mm conventional High Explosive (HE) artillery projectiles
- Turns our conventional HE stockpile into near precision rounds ≤ 50m CEP (range independent)
- MS C in FY13

Requirements Development Approach

- **Team of stakeholders and experts**
  - **Government**
  - **Vendors**
  - **Integrators**
  - **Draper Laboratory**

- **Interface Control Working Group (ICWG) consensus building approach**
  - **Focus initially on areas of agreement**
  - **Iteration - Multiple review cycles**

Definition of MGUE CDD Appendix for PGMs underway

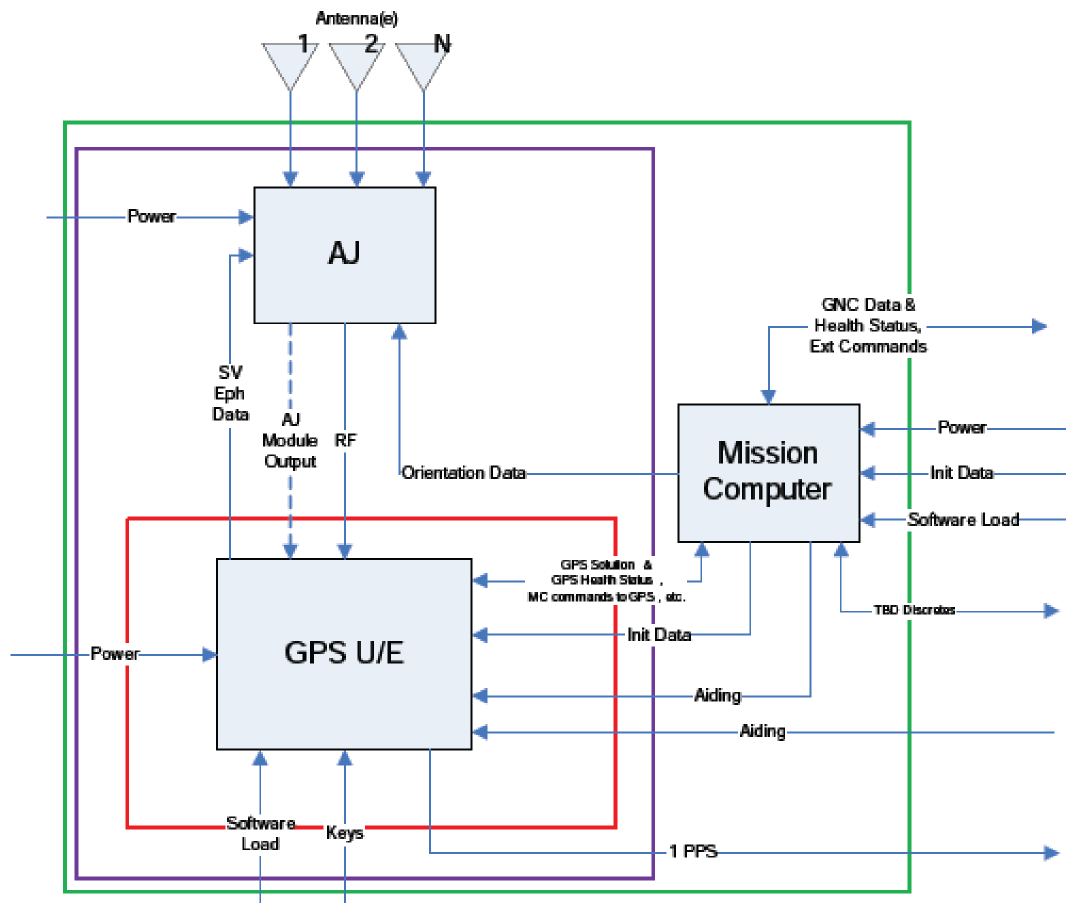
- **Milestone/Timeline**
  - **Kickoff: May 2009**
  - **ICWG Meetings #1 and #2: Nov 2009, March 2010**
  - **Finalized Initial Spec and ICD: Aug 2010**
  - **Planned near-term "one pass" revision: April/May 2011**

Approved for Public Release – Distribution Unlimited

Specification and ICD Scope

- Generic projectile guidance system architecture functional block diagram
  - GPS U/E only
  - GPS + A/J electronics
  - Guidance & Navigation System

- System boundary defines included functionality and interfaces
  - Trade study identified benefits/detriments of each approach



Common GPS Specification and ICD Scope defined by Purple Box

Enables a Common GPS Supplier Paradigm for Gun-Launched PGMs

Approved for Public Release – Distribution Unlimited

Mechanical/Form Factor Requirements

- **ICWG Team consensus not attainable today**
  - **Vendors have divergent SAASM roadmaps**
    - Circular card perpendicular to axis line-of-fire
    - Gum-Stick form factor along axis line-of-fire
  - **Integrators do not want design constraints**

- **Common GPS Program strongly influenced by Fuze Well Volumetric SWP considerations**
  - **Constraints imposed by legacy SAASM-based designs**
  - **User Equipment not based on KDP hardware enable greater design flexibility for miniaturization**

Focused on modularity imperative for Joint Service PGM applications

Specification Contents

- **External Interfaces (electrical and data exchange requirements)**
- **States and Modes**
- **Functional Requirements**
  - **Self Test**
  - **Reprogramming**
  - **Data Storage**
  - **Operating Conditions [GPS Signal]**
  - **GPS Reacquisition**
  - **Security Requirements**
- **Performance Requirements**
  - **Time-to-Usable-Navigation**
  - **Reacquisition**
  - **Position, Velocity, and Attitude accuracy**
  - **Timing**
  - **Performance in a Jamming Environment**
- **Quality and Reliability**
- **Environmental Requirements**
  - **Storage & Transportation**
  - **Operating**
- **Verification Methods**

Jamming Requirements

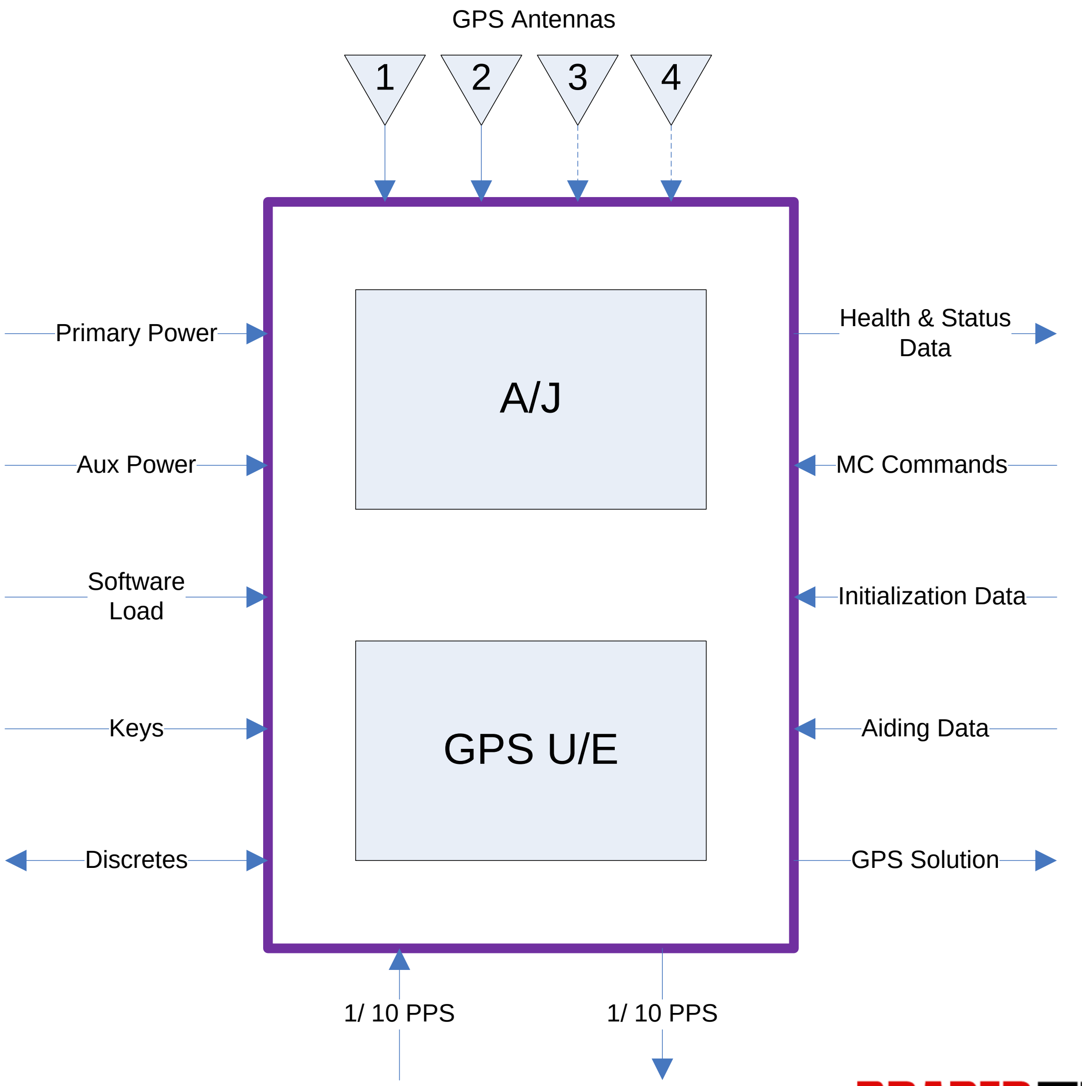
- **Developed from multiple sources:**
  - **Excalibur requirements: laydown and jammer types**
  - **Joint Navigation Warfare Center (JNWC) intelligence briefings focused on current threats**
  - **Operational considerations for mortars and cannon munitions**

- **Captured as a classified Appendix to Specification where J/S levels are defined**

- **Verifiable by reasonable methods as outlined in the Specification**
  - **Reference antenna characteristics**
  - **Analysis and test at specified points on a reference trajectory**

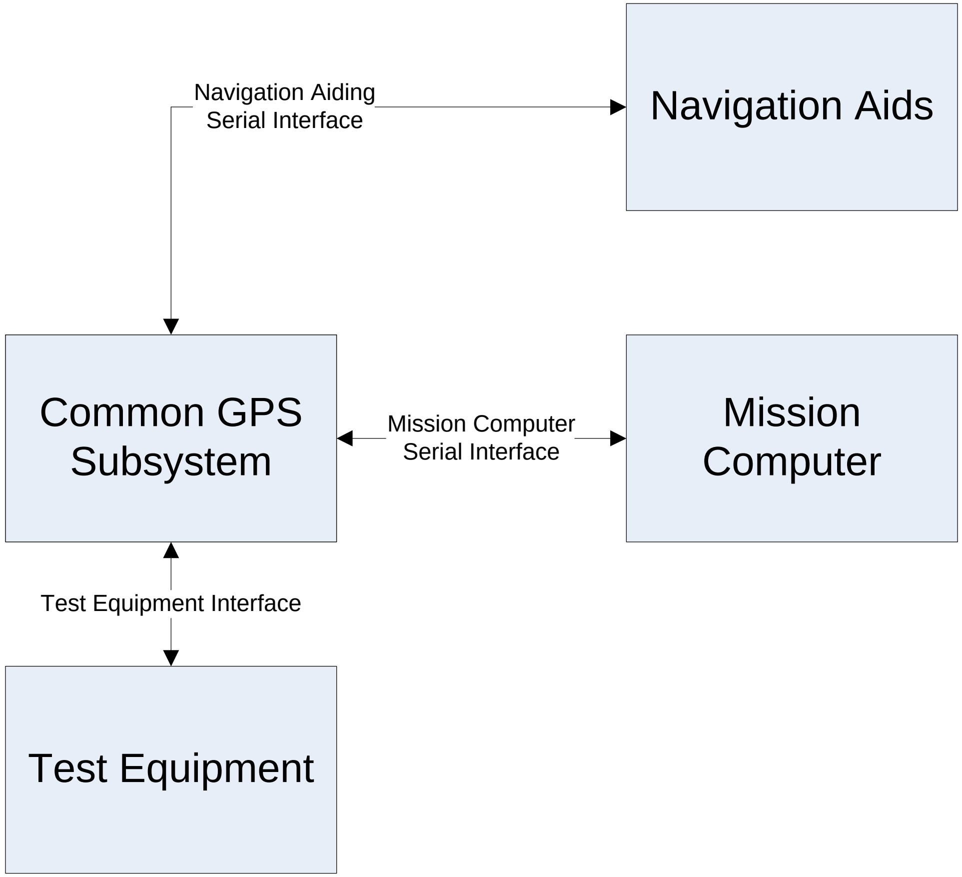
ICD Boundary

- **2 or 4 (L1-only or L1/L2) antenna input**
- **Keying through Mission Computer or dedicated interface**
- **Data messages based on existing AF GPS Directorate ICDs**
- **Mechanical interfaces not defined**
- **Electrical connectors not defined**



ICD Data Detail

- Trade study investigated using a modern data bus such as FireWire (IEEE 1994b)
  - Unanimous pushback from integrators and vendors
  - Other multi-point and point-to-point protocols considered
- MCSI (Mission Computer Serial Interface) and TEI (Test Equipment Interface) are 3.3V CMOS serial with selectable data rates
  - MCSI messages based on IS-GPS-153D
  - All TEI data messages vendor defined



Conclusion

- **Focused on a Common GPS Solution for major Joint Service M-Code Market Segment**
- **Gun-Launched PGMs Represent Most Demanding Environment**
- **Definition of MGUE CDD Appendix for PGMs underway**
- **Enables a Common GPS Supplier Paradigm for Gun-Launched PGMs**

This Common GPS Spec and ICD will continue to be refined and evolve

Guns & Missiles Symposium #11725

31st August 2011 13:35-1355

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40mm CTAS “Medium calibre goes in a new direction”

David Leslie, Chairman CTA-International

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CTA-International

- CTA International (CTAI) - private joint venture (JV) company 50/50 BAE Systems and Nexter Systems
- Dedicated Anglo-French team, focused on 40mm Cased Telescoped Armament System (CTAS)
- All UK and French staff are based in Bourges, France

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Key Points:

The 40mm Cased Telescoped Armament System:

- **Demonstrated “Game changing” benefits at a system level**
- **Mandated by the UK MoD and preferred by the French DGA**
- **Development of the system is complete**
- **Qualification and Industrialisation has started**
- **Seeking global partners**

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CT Technology background (Ammunition)

Unlike conventional rounds, the projectile is *'telescoped'* within the cartridge case and surrounded by propellant;

The cartridge case diameter is increased to provide efficient internal volume;

CT Ammunition is volumetrically 30% more efficient than conventional ammunition;

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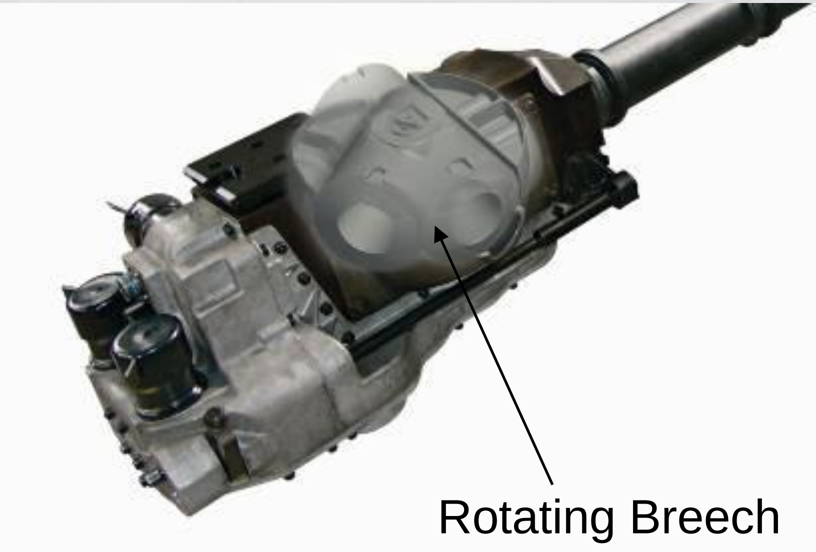
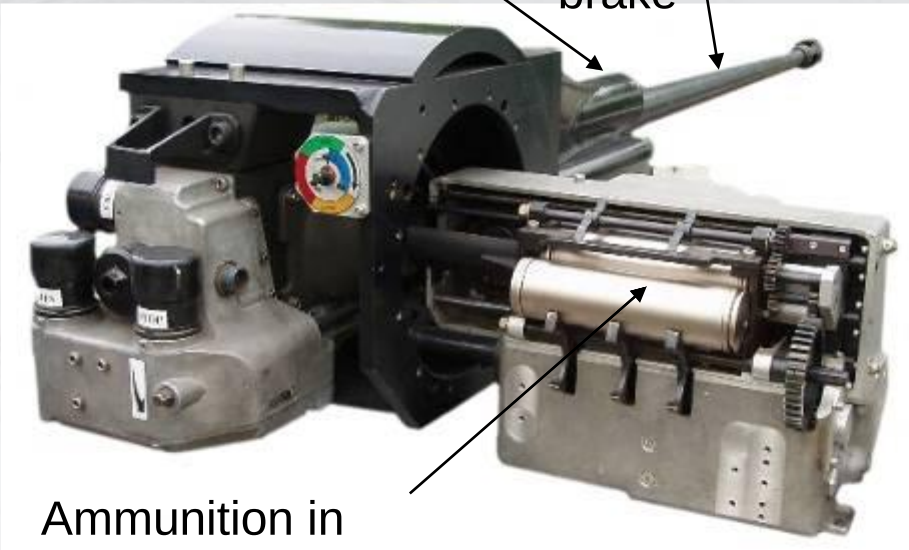
CT Technology background (Cannon)

Rounds introduced through rotating breach





- ‘Push-through’ concept
- Commercial ‘Gear box’ technology
- High reliability

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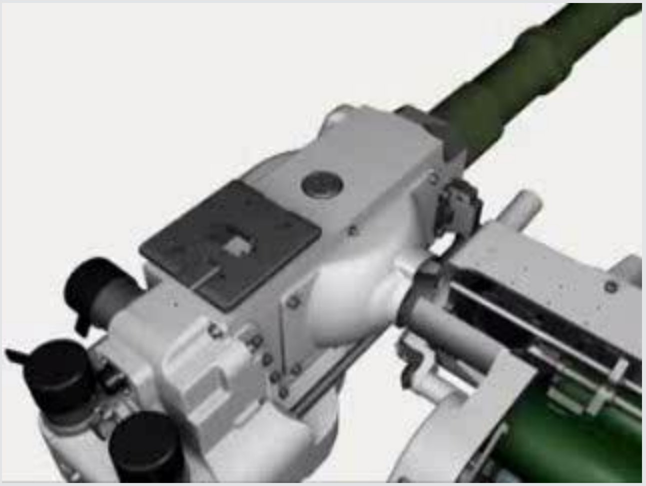
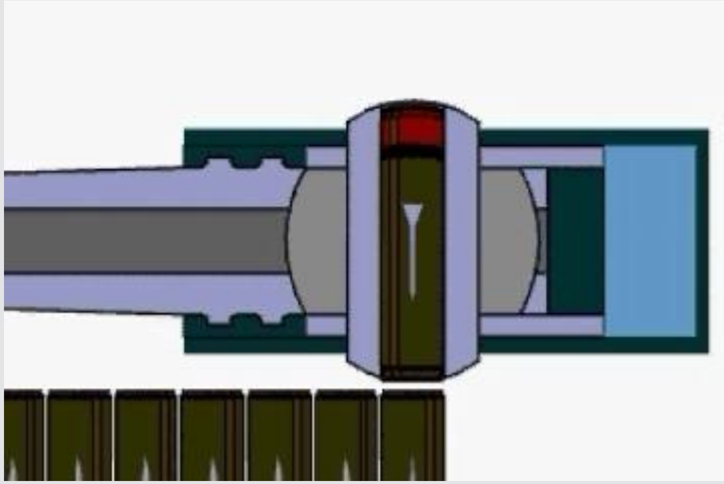
CT Technology background (System)

1. Ammunition enters the rotating breech
2. Breech revolves thru 90° to align with barrel
3. Round is fired, the breech recoils, the projectile leaves the barrel
4. breech revolves another 90°
5. Empty case is pushed out by the next round





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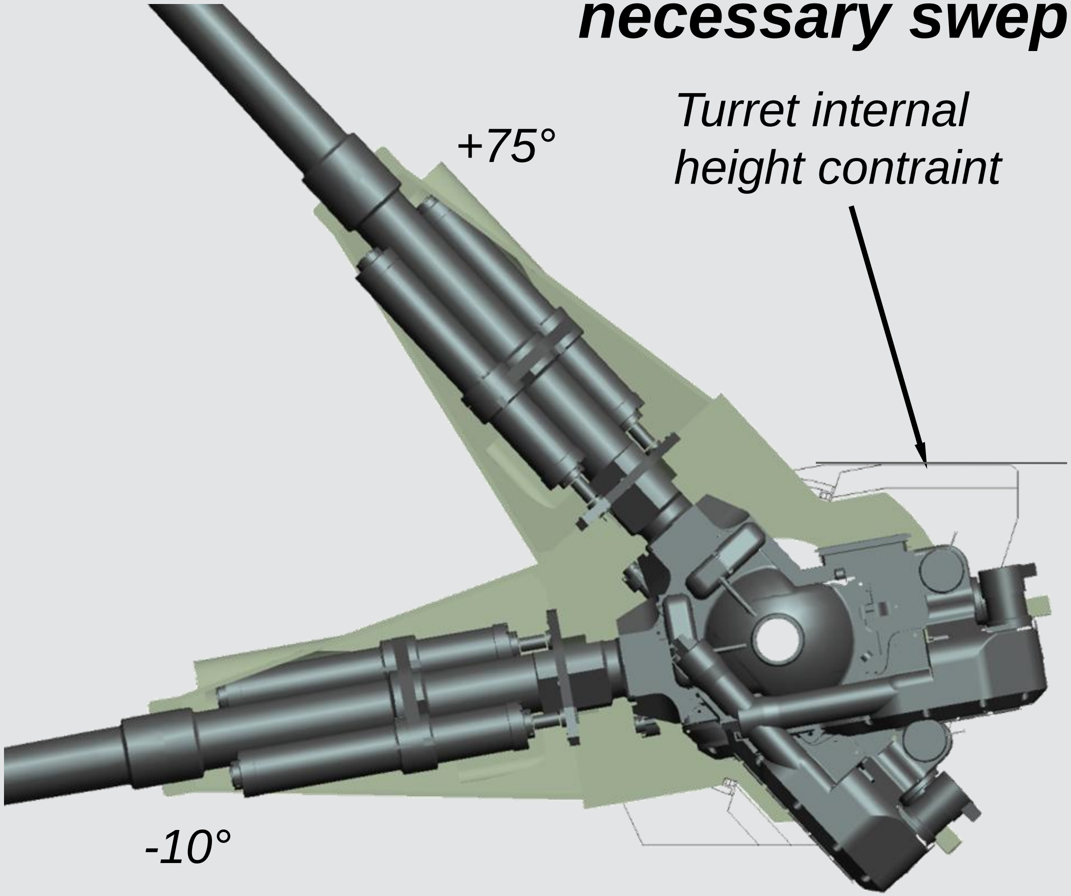
CT Technology background (System)

The ease of integration into a turret is defined by the necessary swept volume



- **Limits of elevation set by turret roof and floor plate**
- **Free space created behind breech**
- **Managed out-of-balance**
- **Fixed trunnion location**

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CT Technology background (ammunition)

UK MoD Operational Analysis of 40mm CT (Unclassified quotes)

"…clear advantage in urban Operations, increases platform survivability…"

Defeat of RHA and add-on special armours

Point Detonating defeat of structures with behind-structure effect

Airburst suppression, both 'line of sight' & 'non line of sight' land and air targets

Defeat of soft skin targets

'APFSDS' ammunition

'GPR' ammunition

i.e. Point Detonating + Air Burst fuzed HE ammunition combined in one general purpose round (GPR)

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CT Technology system level impact

Minimal intrusion to the crew compartment compared to conventional weapon systems

Source: Janes

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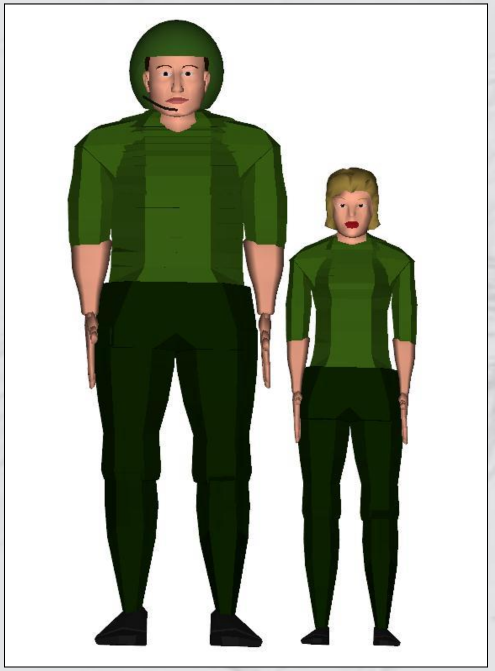
CT Technology system level impact

Future User needs:



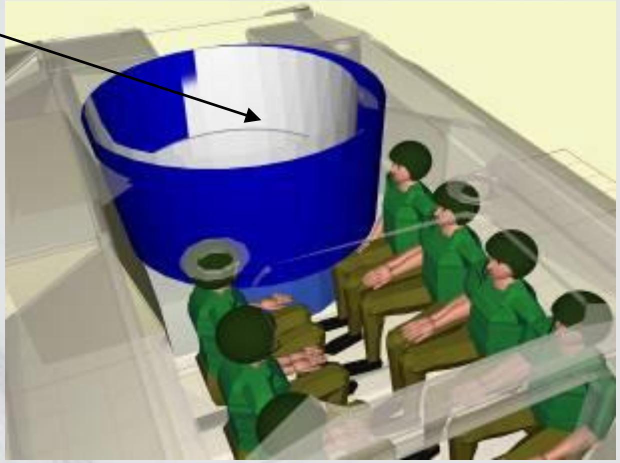
illustrative

"…higher firepower…"

…and need to maximise use of limited turret basket volume, small turret ring diameters and increases in crew carried kit…

…and need to accommodate

- ***2x 95th percentile men***
- ***or 2x 5th percentile women***
- ***in full body armour and helmet…***



"…and increase crew survivability…"

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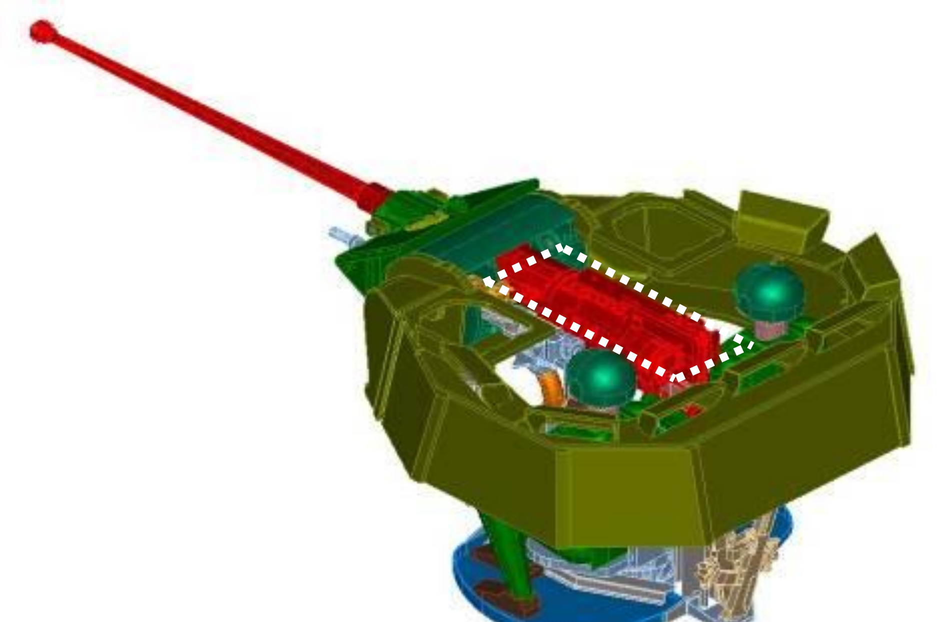
CT Technology system level impact

Conventional gun and ammunition systems:

- **over 200 litres of swept volume**
- **limited gun elevation/depression**
- **limitations on crew evacuation/survivability**
- **crew tasks compromised**



Conventional 35mm

Conventional 30mm

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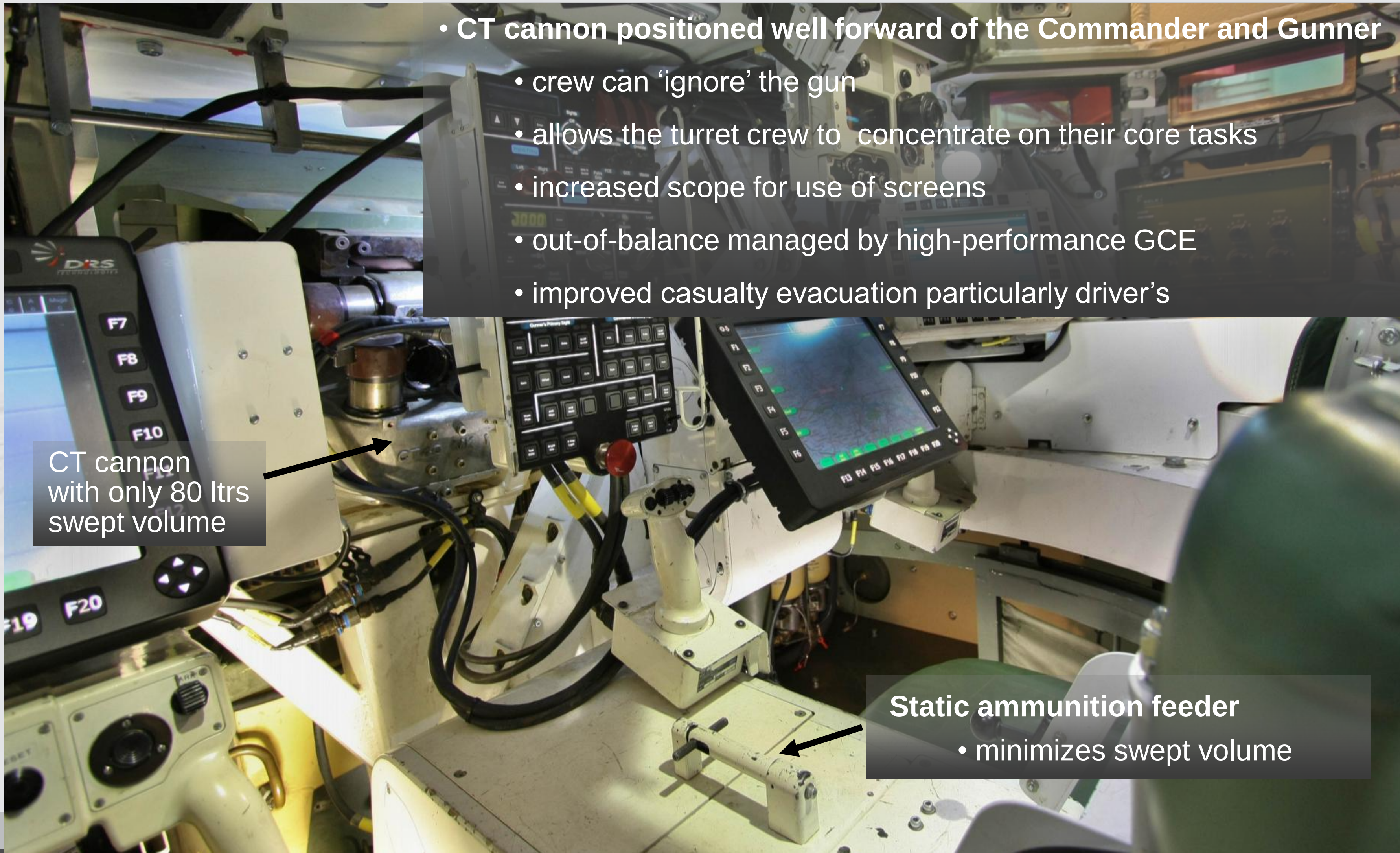
CT Technology system level impact

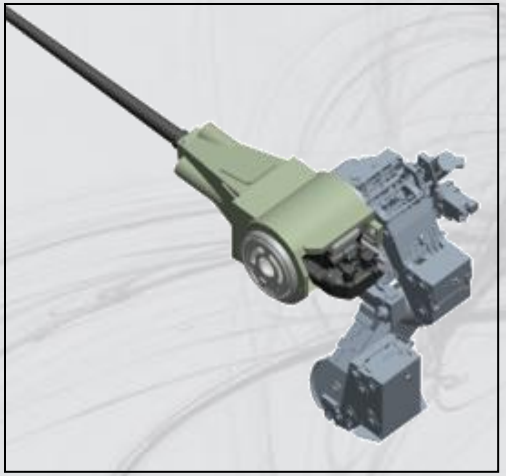
CT Technology system level impact

- **CT cannon positioned well forward of the Commander and Gunner**
  - crew can ‘ignore’ the gun
  - allows the turret crew to concentrate on their core tasks
  - increased scope for use of screens
  - out-of-balance managed by high-performance GCE
  - improved casualty evacuation particularly driver’s

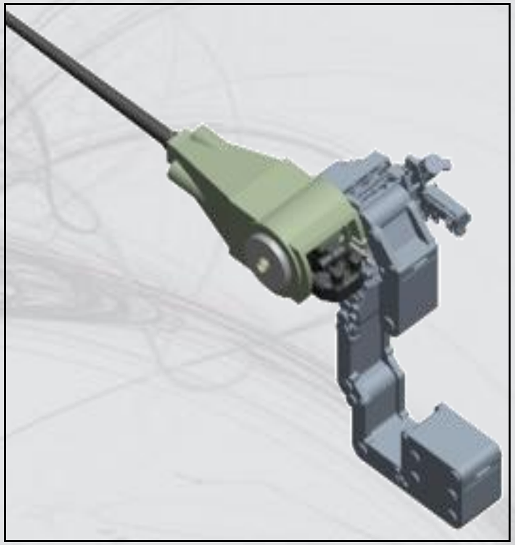


Turret Integration scope

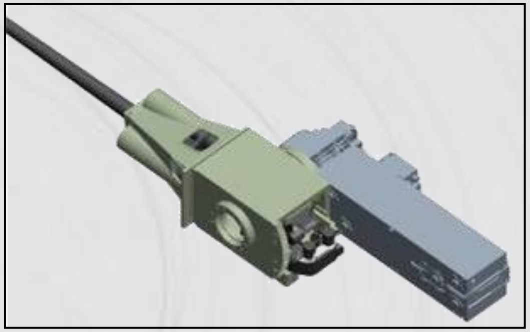
- Ammunition Handling systems adaptable to user requirements and turret design
- Sustainable reloading
- High/low turret elevations and depression angles possible



Tracked vehicle: narrow turret ring, shallow basket.



Wheeled vehicle: narrow turret ring, deep basket.



Tracked or wheeled vehicle: remotely operated turret.

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Vehicle integration examples (2001-2011)

MTIP **(CTAI)**

Bradley **(United Defence)**

MTIP2 **(BAE Systems)**

VBCI **(Nexter)**

FSCS **(Sika)**

FRES SV **(General Dynamics)**

Toutatis **(CTAI)**

FSCS **(Lancer)**

WCSP **(Lockheed Martin)**

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Demonstrated Performance

FIRING ON THE MOVE ON MOVING TARGETS

- Full stabilization
- Coincidence firing mode
- High accuracy whilst in moving/moving scenario

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UK MoD and French DGA Cooperation

"The MoD has down selected … the cannon developed by CTAi….for both Warrior and FRES Scout programmes, as it meets the lethality requirements of both systems, and a single common solution is more efficient and effective." Minister UK MoD, 2008

- **UK MoD / French DGA Joint qualification of:**
  - CT40 Weapon System (Mandated Items)
  - Armour Piercing Fin Stabilised Discarding Sabot - Tracer (APFSDS-T)
  - General Purpose Point Detonating - Tracer (GPR-PD-T)
  - Target Practice - Tracer (TP-T)
  - General Purpose Air Burst – Tracer (GPR-AB-T)

  - Over 70 trials & 100 Evaluations over 2 years (>12000 rounds of ammunition and >22000 weapon cycles)
    - Ammunition Sequential Trials Programme
    - Ammunition Non Sequential Trials
    - Cannon Trials

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Industrialisation

Use of existing Ammunition Manufacturing Facilities within the shareholder companies operating under licensed production

CTA INTERNATIONAL

BAE SYSTEMS

Bourges, France

nexter MUNITIONS

Glascoed, Wales

La Chapelle, France

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Seeking global partners

Licence available for the complete system

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Summary

- 40CT is moving from ‘development’ to ‘industrialisation’
- 40CT offers an innovative approach to high lethality and lower integration burden
- Its introduction will radically change the medium calibre choices to potential global customers
- It is a rare business opportunity for new partners

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Questions?

46th Annual Armament Systems: GUN & MISSILE SYSTEMS

Direct Fires & Precise Weapons for the modern battlefield

Danny Schirding
Program Manager & Marketing Director
Munition Systems Division, IMI
Tel: +972 3 5486122
E-mail: dschirding@imi-israel.com

2011

Israel Military Industries Ltd.
Munition Systems Division (MSD)

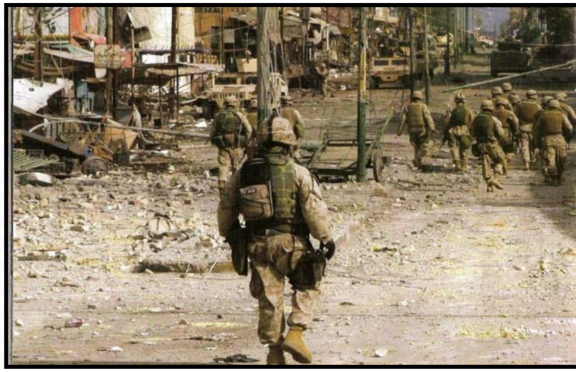
Lessons learned from the battle field

The Battlefield Scenarios

War

Non Limited Conflicts at High Friction (NLCHF) / Major Operations

Limited Conflict at Medium Friction (LCMF) / Routine security operations



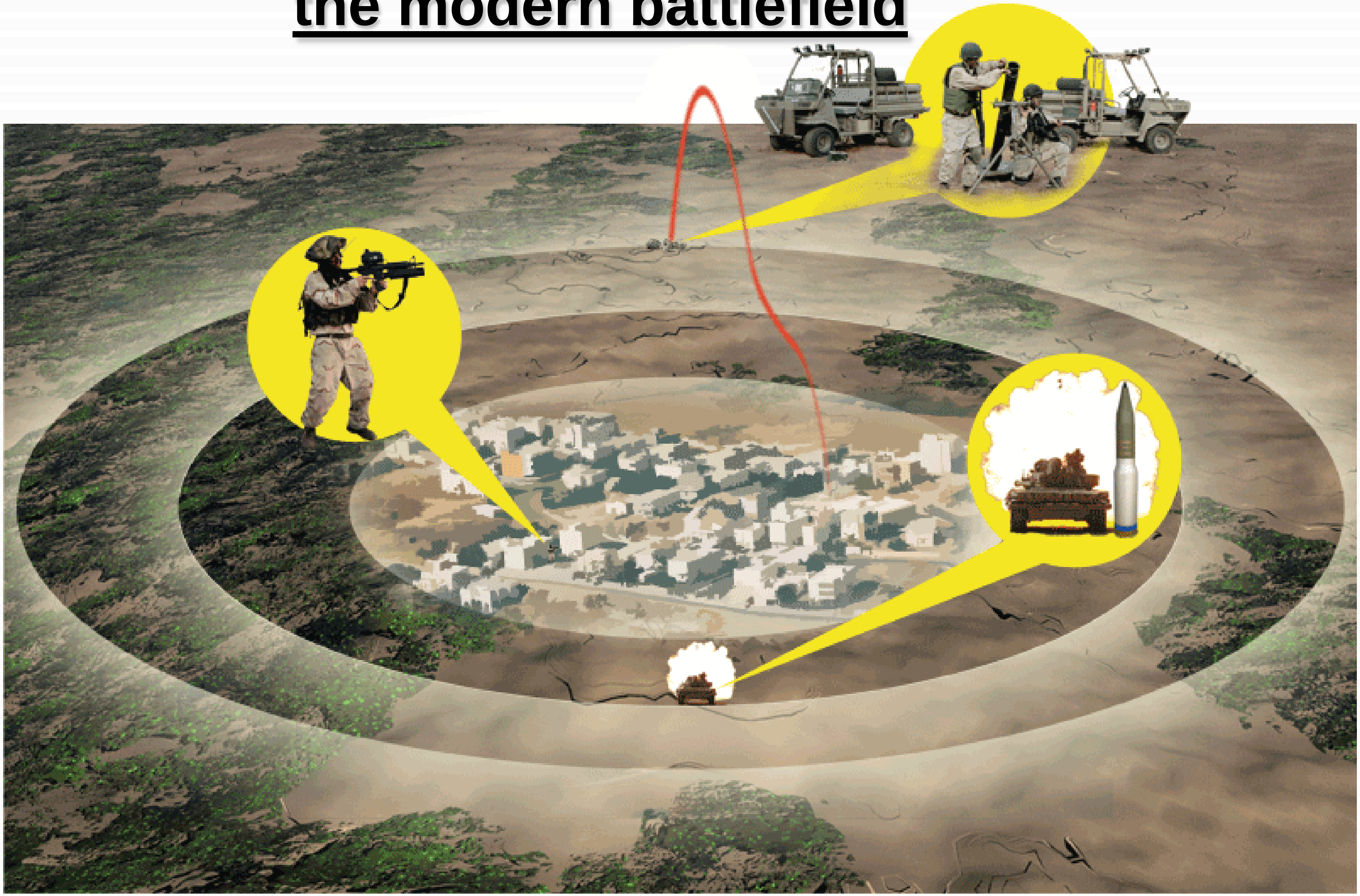
Challenges (Typical targets) Vs. scenarios

	Dismounted Infantry (Short / long range A.T Teams…)	Tanks	Assault Helicopter	IFV's	Military infra-structures (Bunkers, field fortifications …)	Mines / IED's	Buildings	Snipers	Tracks / Cars
1) WAR	+	+	+	+	+	+	+	+	+
2) NLCHF	+			+	+	+	+	+	+
3) LCMF	+					+	+	+	+

NLCHF= Major Operations including MOUT

LCMF= Routine security operations

Direct Fires & Precise Weapons for the modern battlefield



120mm Guided Mortar Munitions (GMM)

↓

Indirect Fire

Israel Military Industries Ltd.
Munition Systems Division (MSD)

2011

System Requirements

120mm mortar bomb which provides combat teams with organic, rapid response, and all weather indirect fire capability

The Requirements:

- Precision
- First round on the target
- Increased lethality
- Minimized collateral damage
- Reduced logistical support
- Leveraged joint fire networking

Performance Goals

- Ballistic Range : 7.2 Km (K6-charge 5)
- Gliding range : ≈ 10 Km (K6-charge 5)
- GPS guidance, CEP (Circular Error Probable) < 10. m
- Laser guidance, CEP (Circular Error Probable) < 1.5 m

Operational Sequence

- The bomb could be fire from existing platforms
- The bomb operation procedures are like regular bombs except loading of mission data

Israel Military Industries Ltd.
Munition Systems Division (MSD)


120 GMM
Guided Mortar Munition
Video Clip

"HORNET"
120-mm Light Mobile Mortar System

2011

Israel Military Industries Ltd.
Munition Systems Division (MSD)

IMI's Hornet System

An Organic, light, highly mobile and Helicopter carried Weapon System, that consists on off-the-shelf military components.

The solution

To generate accurate and effective fire to support the Operational forces (Activities of infantry) in an independent and fast fire networking for immediate response.

Two 4X4 All Terrain Vehicles (ATV)

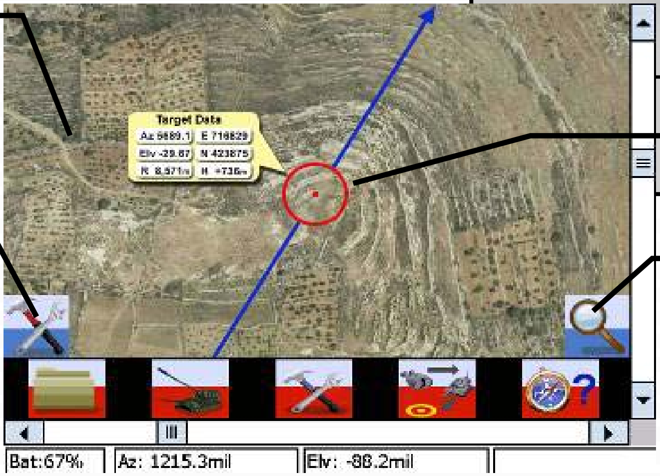
Command Control Communication & Computer (C4) Systems

Munitions

Light Mortar

Passive Target Acquisition Goniometer System

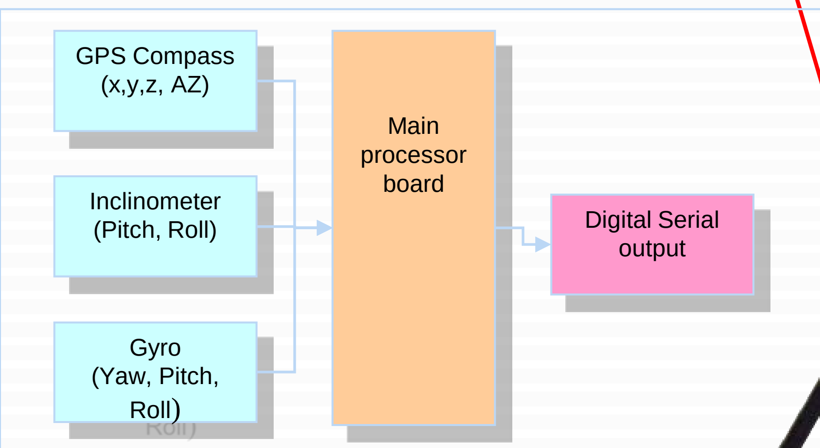
Target Screen



Israel Military Industries Ltd.
Munition Systems Division (MSD)

Light 120 mm mortar

Mortar's Positioning & Orientation Sensor Box (POSB)



Mortar

Mortar Fire Control System (MFCS)

System Advantages

Optimal and most cost-effective solution for the user's Elite Units or Special forces:

- High Mobility
- First Round on Target - capability with low collateral – damage when firing the 120mm GMM.
- Can be carried by helicopters.
- Capable of firing wide-rang of mortar ammo. (GMM, Smoke, Illumination etc.) for various operational-tasks.
- Increasing the lethality and survivability of the fighting-forces.

120 mm HE–MP–T, M339

Multi-Purpose Tank Cartridge

↓

Direct Fire

2011

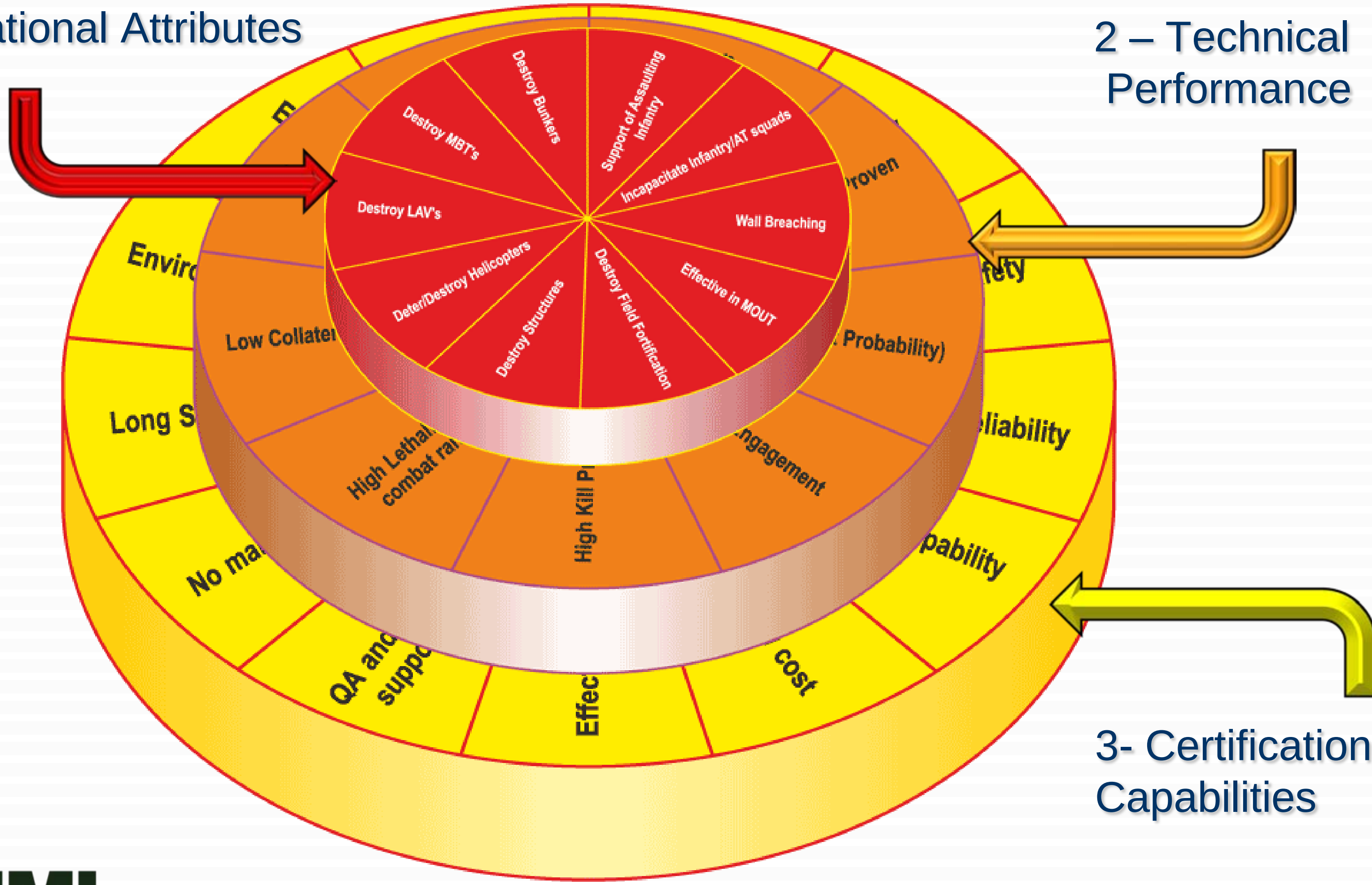
Israel Military Industries Ltd.
Munition Systems Division (MSD)

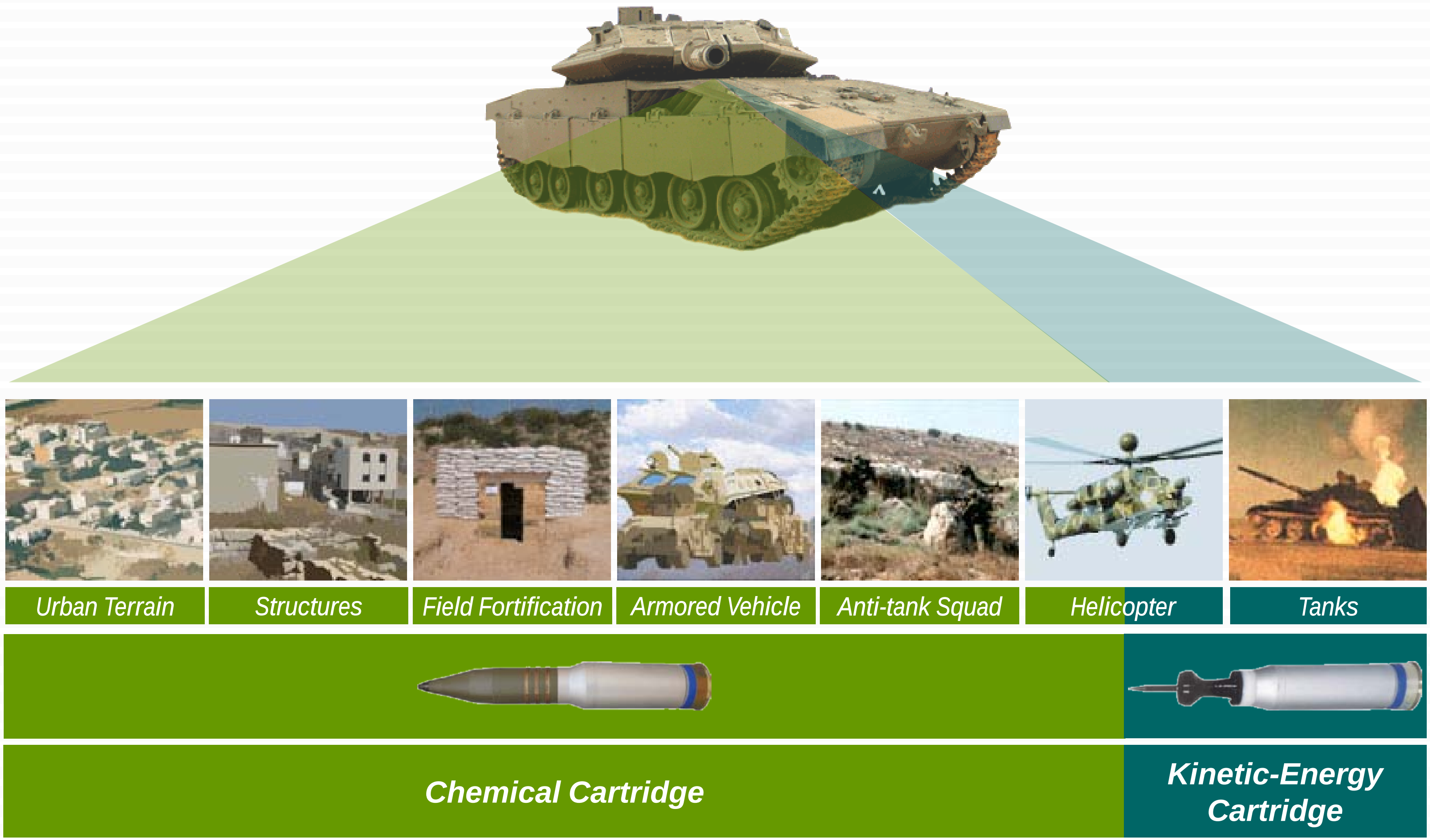
The Main Requirement of The Armor Corps - Analysis

1 – Mission Statement / Operational Attributes

2 – Technical and Performance

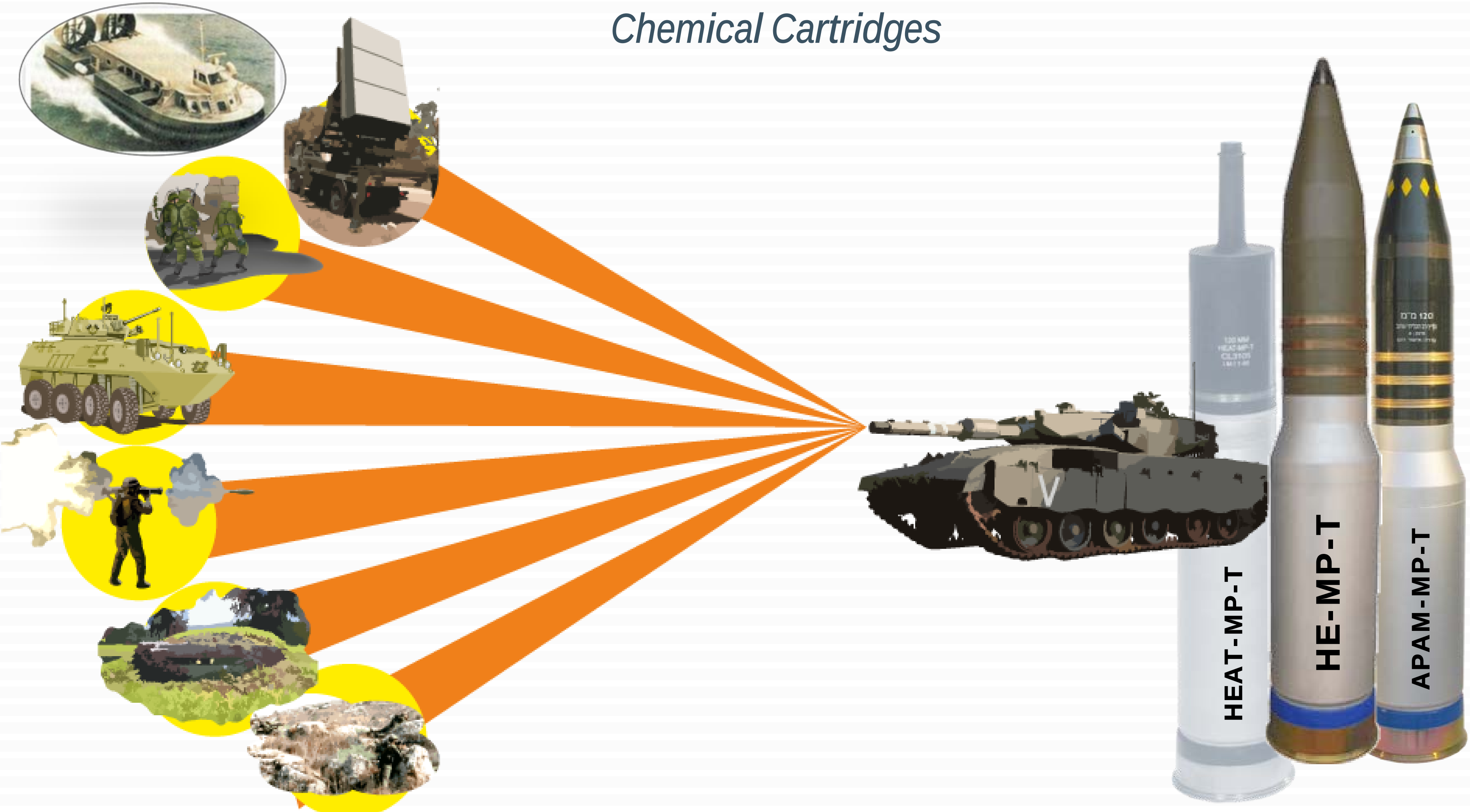
3- Certification and Capabilities




Urban Terrain
Structures
Field Fortification
Armored Vehicle
Anti-tank Squad
Helicopter
Tanks
Chemical Cartridge
Kinetic-Energy Cartridge

Destroy Multi Threats

Chemical Cartridges



HE-MP-T 120, M339 - Introduction

- **Multi-Purpose Tank Cartridge**
- **Can be fired with 120mm smooth bore guns L44/L55**
- **Developed and qualified according NATO STANAG 4385 and IDF requirements**
- **Complies with:**
  - **STANAG 4493**
  - **STANAG 4369 & AOP 22**
  - **STANAG 4157**
  - **MIL-STD-810, ITOP and others**

- **IM round includes –**
  - **HE (CLX663) – Qualified by the IDF**
  - **LOVA propellant (optionally) – Qualified by the IDF**

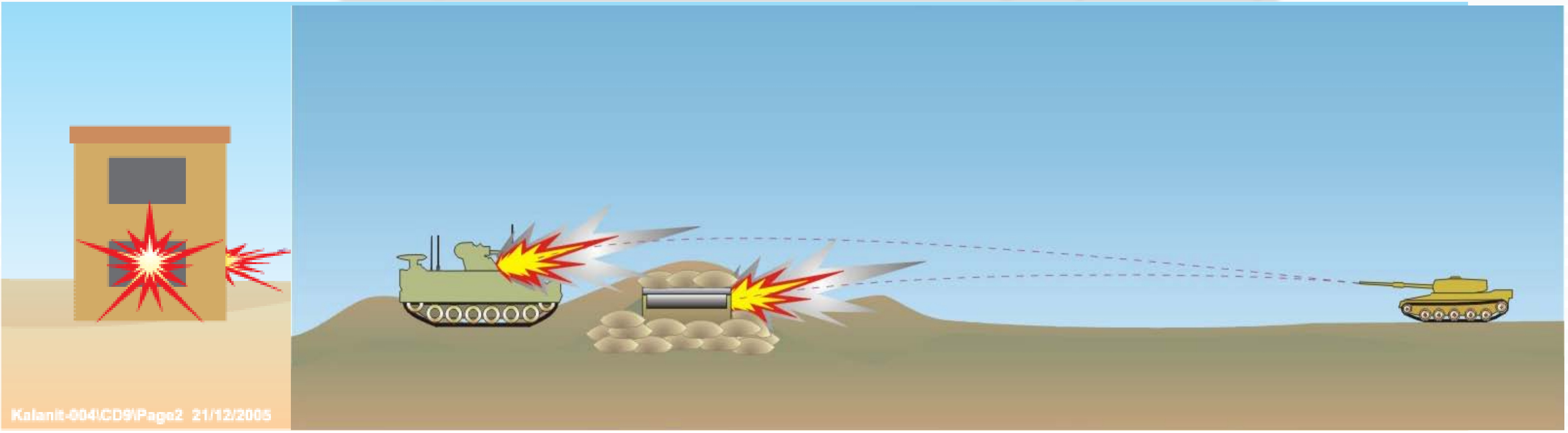
HE-MP-T 120, M339

Cartridge length	984 mm
Cartridge weight	27 Kg
Projectile weight	17 Kg
HE weight (TNT / IM-CLX663)	2.7 / 3 Kg
Muzzle velocity	900 m / sec
Chamber pressure	3,300 bar
Accuracy (SD)	0.3 mil

Data Link

(*) – Programmable Electronic Base Fuze

Impact - with Delay (PDD)



Typical penetration
(Ø 40~60 cm)

Line of site

Penetrate at least, 200mm double reinforced concrete wall

Impact - with Delay (PDD)

Before

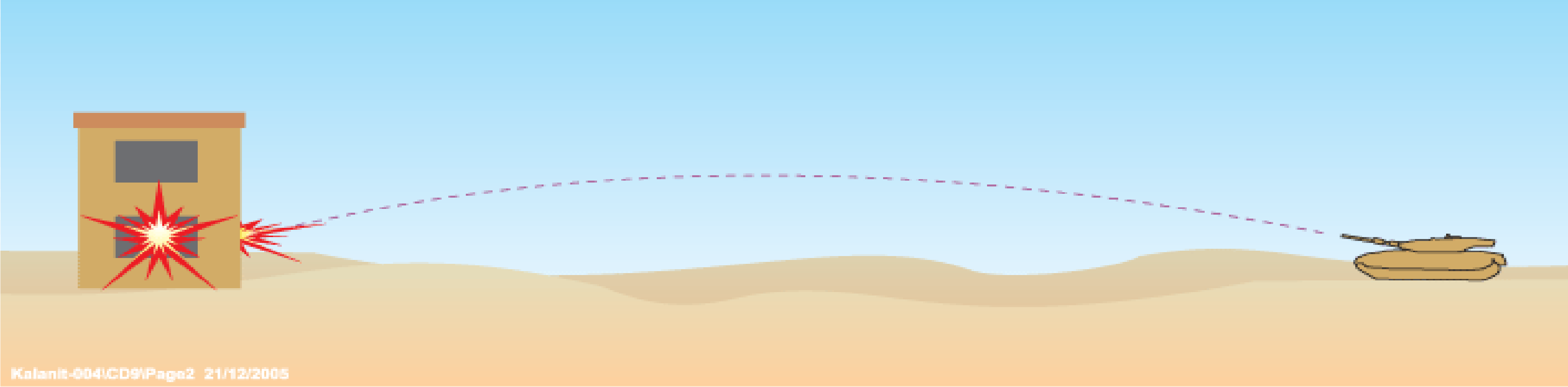
After

Impact - with Delay (PDD)

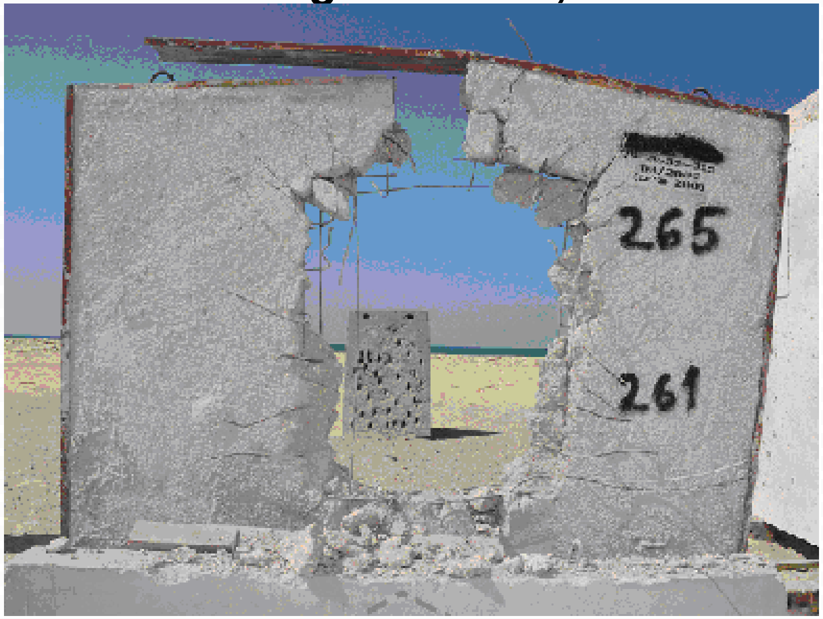
Before

After

Impact - Super Quick



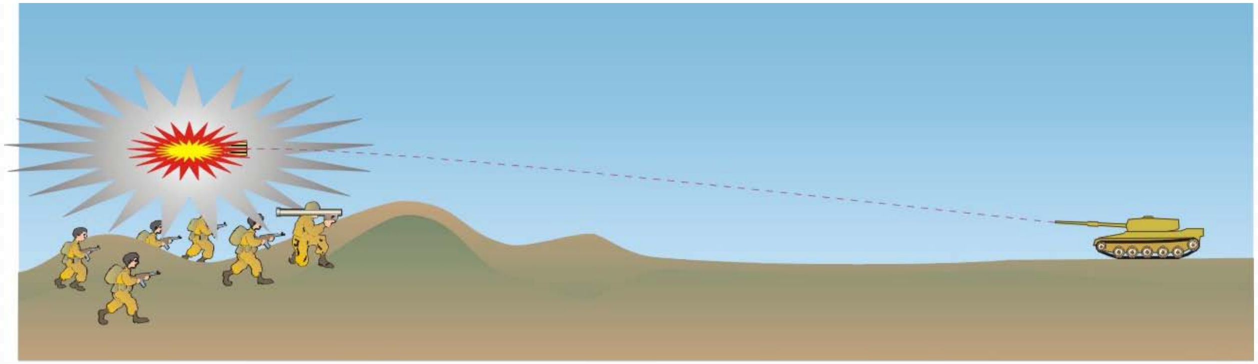
Range = 300 m, T= 200mm, 30MPa, Hole = 120x180 cm



Line of site

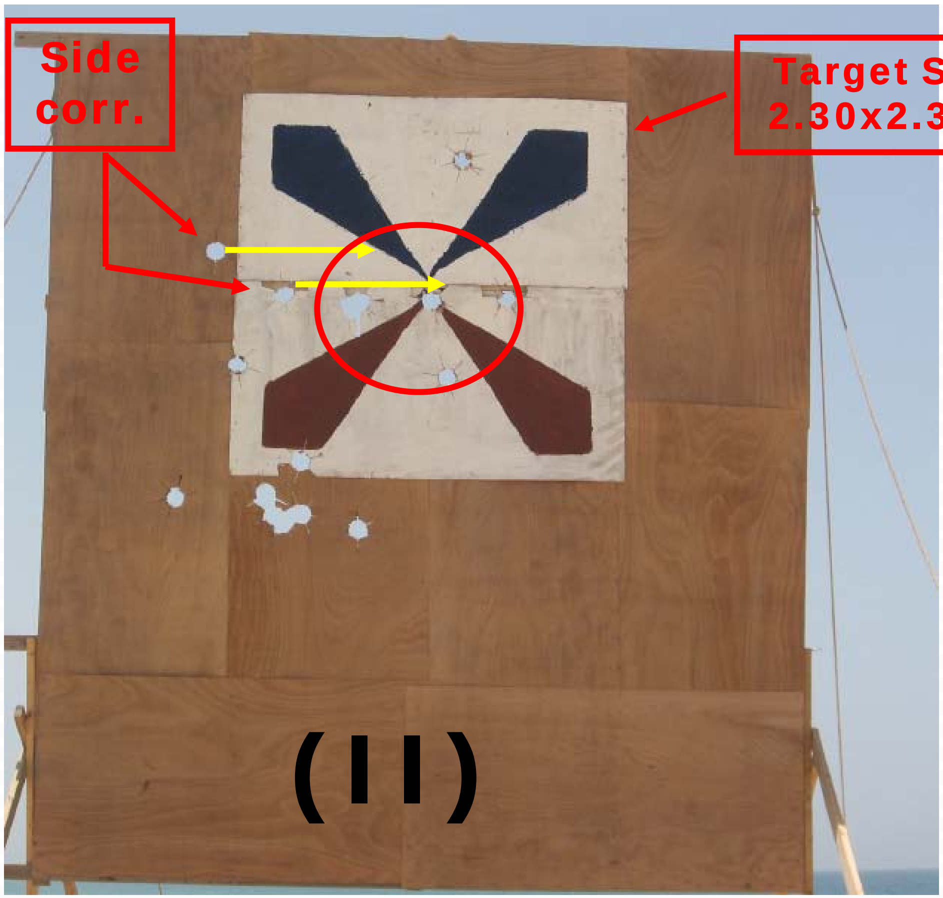
Breach wall for infantry pass by using 2 rounds

Air Burst



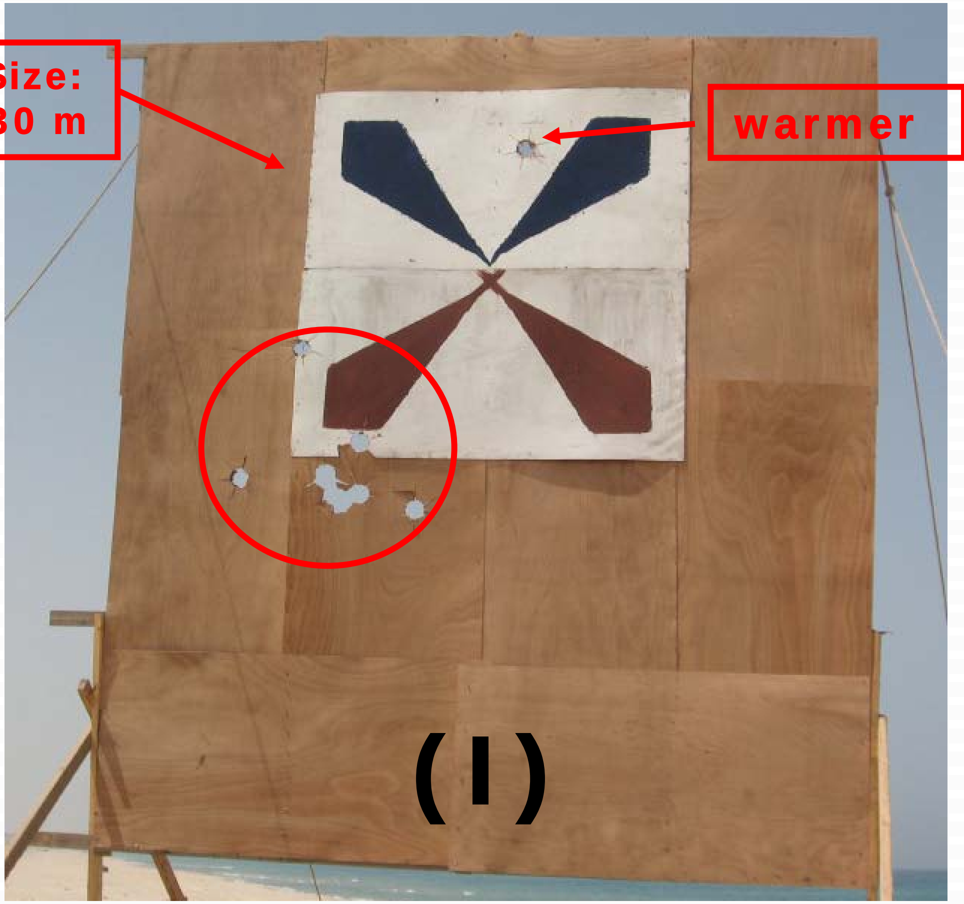
Air Burst operation – view from the tank

HE-MP-T 120 – Accuracy Test (2,000 m)



7 Rounds

0.12x0.19 mils



7 Rounds

0.18x0.19 mils

IM Reaction Levels (with CLX663)

IM Stimulus	Cond.	Reaction Level	Results
Liquid Fuel Fire (Fast Cook-Off)	N	5	
Slow Heating (Slow Cook-Off)	N	5	
Bullet Impact	N P	4 5	X3 In Fuze  X3 In Primer 
Fragment Impact	N P	5 5	In Fuze  In Primer 
Sympathetic Reaction	N	4	
Shaped Charge Jet Impact	N	1	

1 – Detonation; 2 – Partial Detonation; 3 – Explosion; 4 – Deflagration; 5 - Burning

N – Without Package; P – In Package

Video Clip – Demonstration test

Every one could sling at a hairbreadth and not miss

Judges 20/16

MPRS

More Than an Assault Rifle

↓

Direct Fire

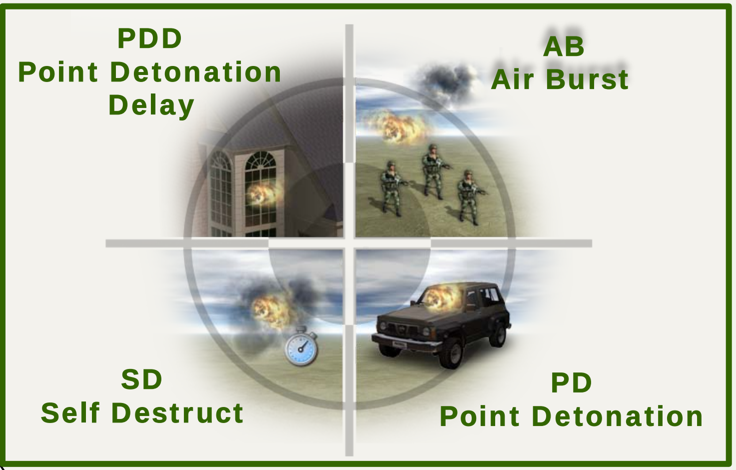
MPRS - Multi Purpose Rifle System

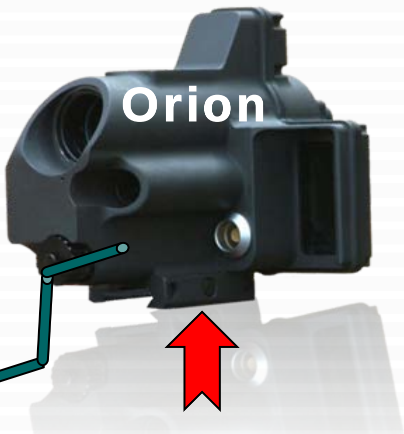
•Data I/O interface to C4I systems

•Launcher breechblock inductive coil

•Bi directional data link

•Unique multipurpose 40mm grenades





•Keypad (x2)

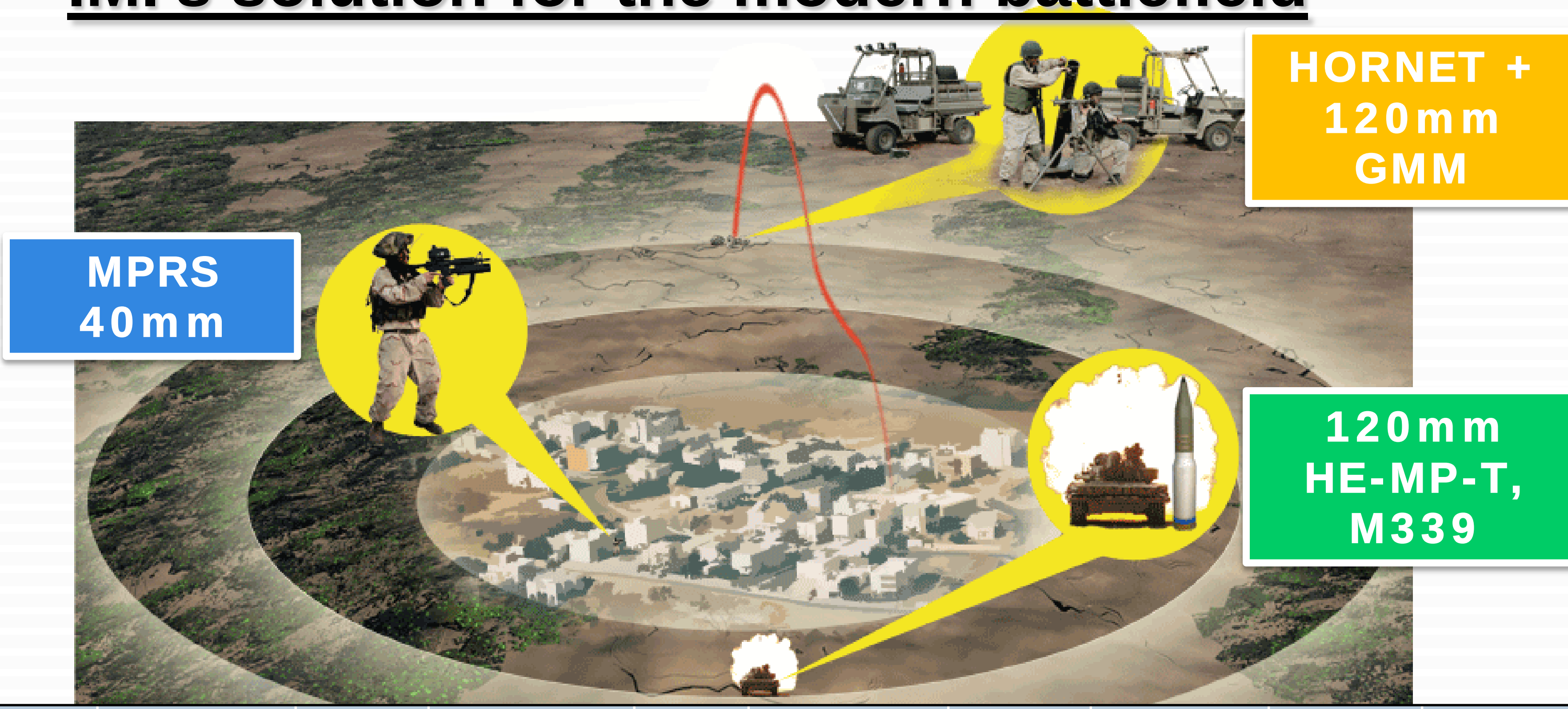
•Internal LRF , eye-safe invisible

•Ballistic computer - FCS

•Direct view optics

•Sensors (inclinometer etc.)

IMI's solution for the modern battlefield



	Dismounted Infantry (Short / long range A.T Teams…)	Tanks	Assault Helicopter	IFV's	Military infra-structures (Bunkers, field fortifications …)	Mines / IED's	Buildings	Snipers	Tracks / Cars
NLCHF	√			√	√	√	√	√	√

Thank you for your attention !

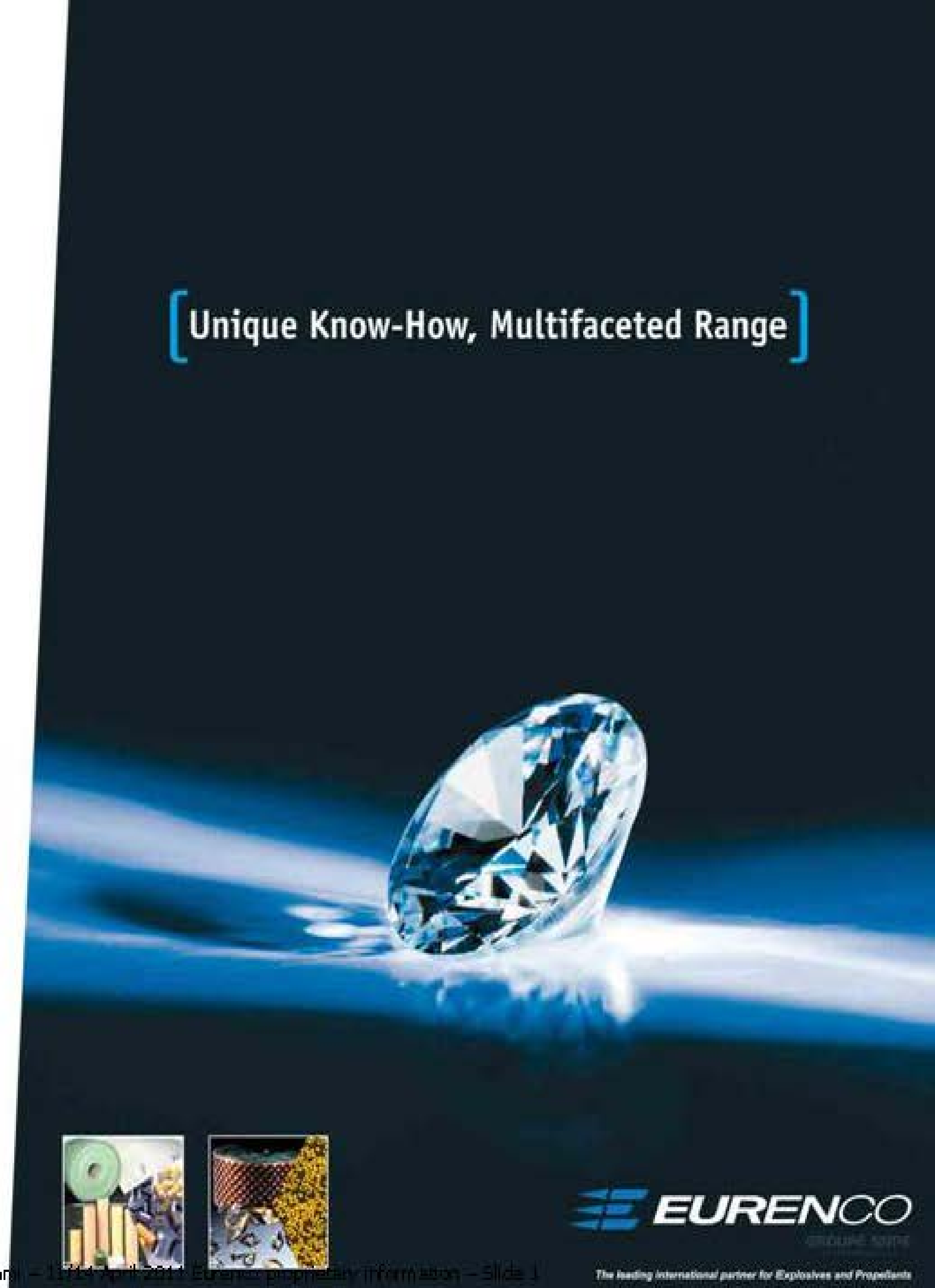
QUESTIONS ?

The Technology is Proven and In the Market

EURENCO
GROUPE SNPE

High Explosives Charges for Insensitive Artillery and Mortar Ammunitions

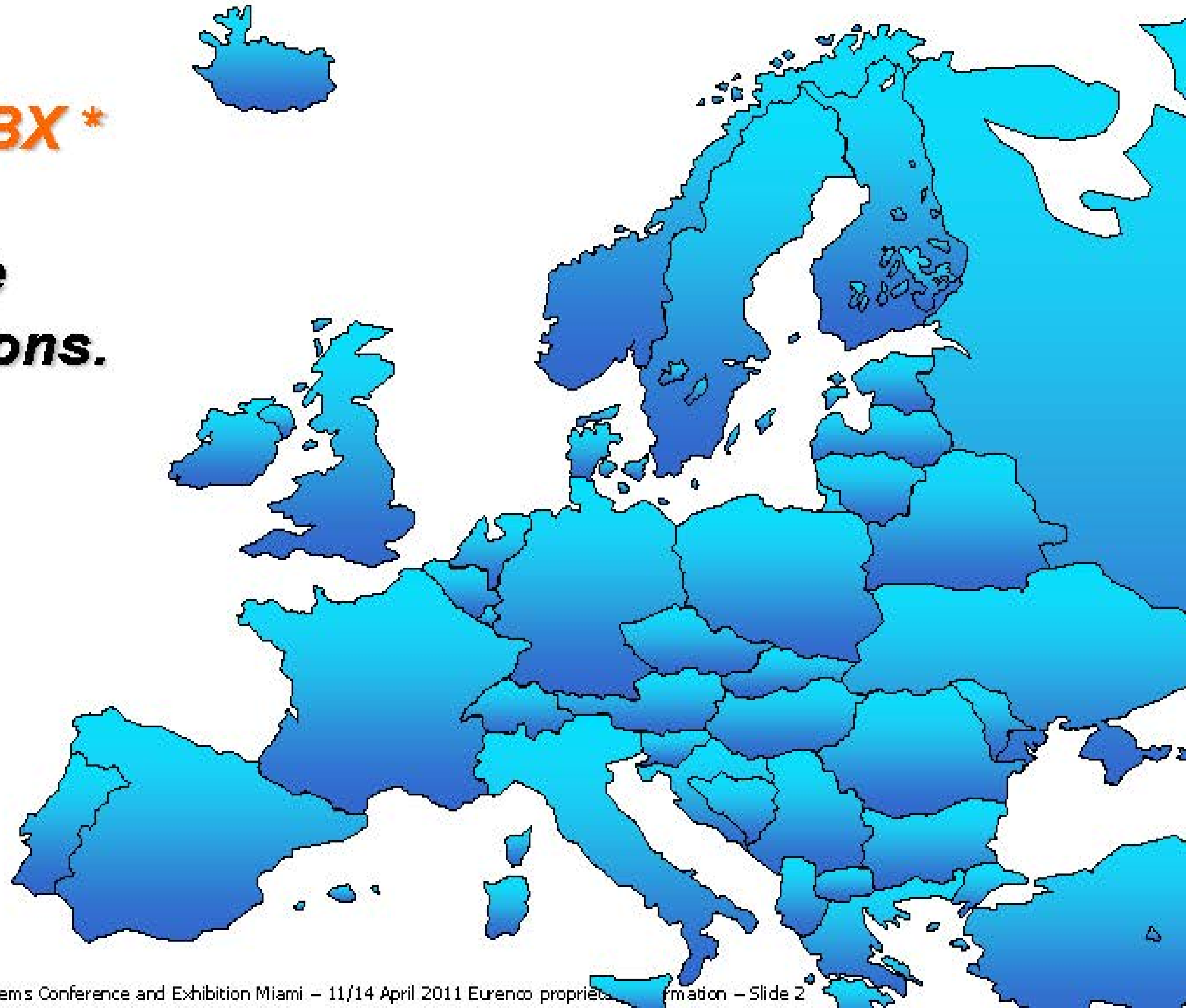
46th Annual Gun & Missile Systems Conference and Exhibition
Miami – 29 Aug / 01 Sept 2011



EURENCO
GROUPE SNPE

CAST PBX in the European Defense and Technological Base (DITB)

In Europe, Cast PBX * is the Most Used Explosive to make Insensitive Munitions.

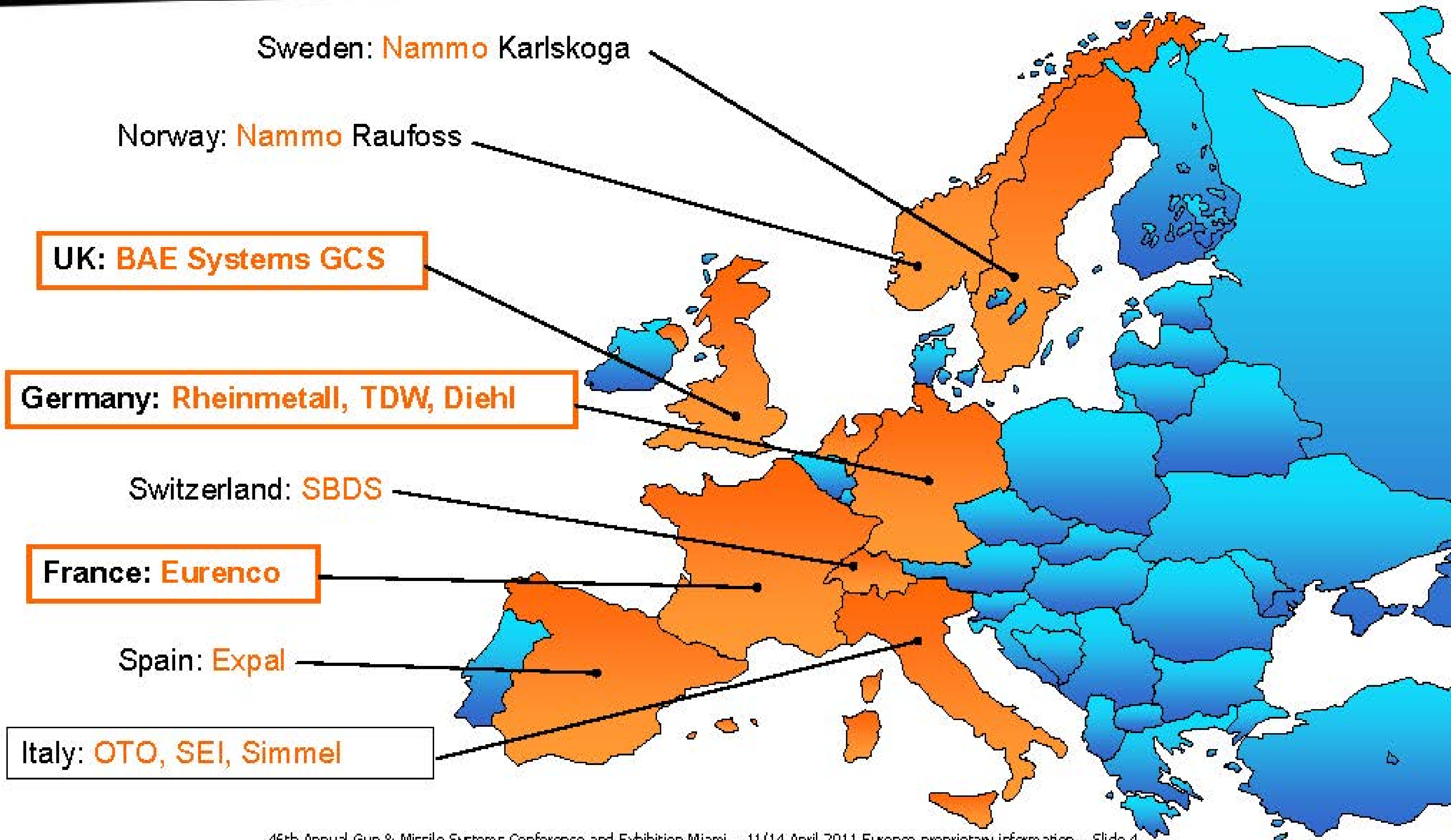


CAST PBX Material Description

* **Cast PBX: Cast Plastic Bonded eXplosive**

- *Binder = HTPB (synthetic rubber)*
- *Energetic Filler = RDX, HMX, NTO…*

CAST PBX in the European DITB



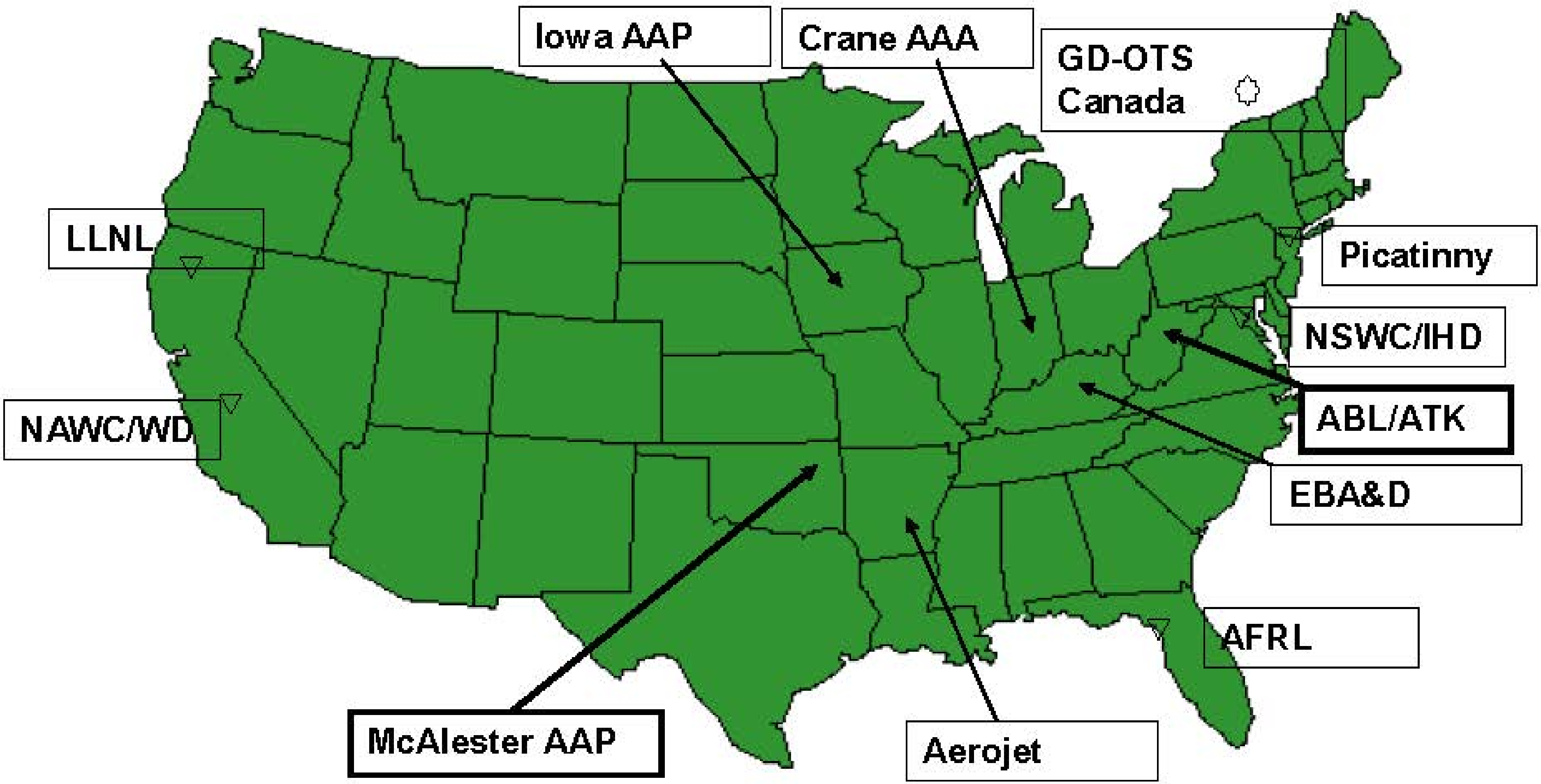
European Countries using cast PBX in Insensitive 60mm to 155mm Caliber Ammunitions

• UK	81mm, 105mm, 155mm…
• GERMANY	120mm, 155mm
• NETHERLANDS	81mm, 155mm
• FRANCE	76mm, 81mm, 120mm
• ITALY	76mm, 127mm
• SWITZERLAND	60mm, 120mm

EURENCO GROUPE SNPE

CAST PBX in the US NTIB

Cast PBX in USA: A well established Technological and Industrial Base



The Most Implemented Insensitive High Explosive

CAST PBX: The Origins

Major Disasters on High Value Combat Platforms led to find a Mature and Effective IM Solution

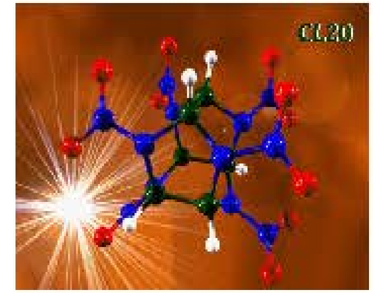
Aircraft Carriers Accidents

→

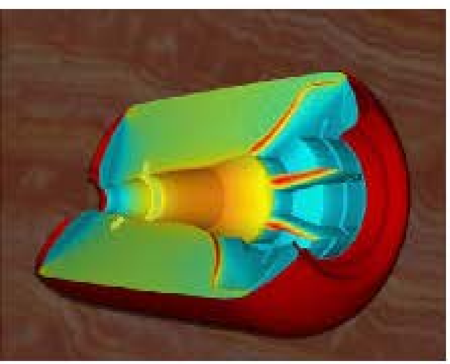
Best Insensitive Explosive for IM Bombs

CAST PBX: Background

Cast PBX technology is based on a 50 year background shared with Solid Rocket Motor technology.



- Large Catalogue of Qualified Formulations

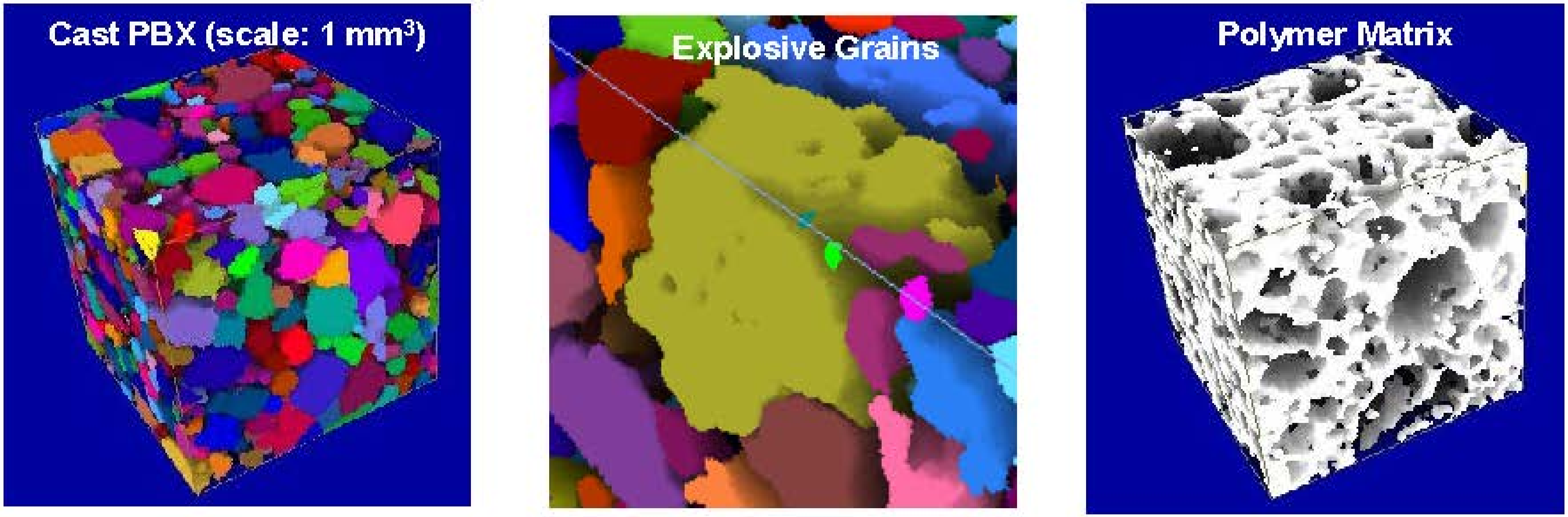


- Extensive Scientific Knowledge on these formulations (chemical, physical, mechanical properties, ageing…)

- Production Processes adapted to various types of applications

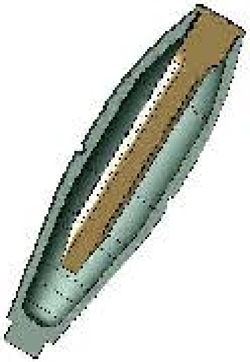
CAST PBX: Advantages for IM

A material with Excellent Intrinsic Properties

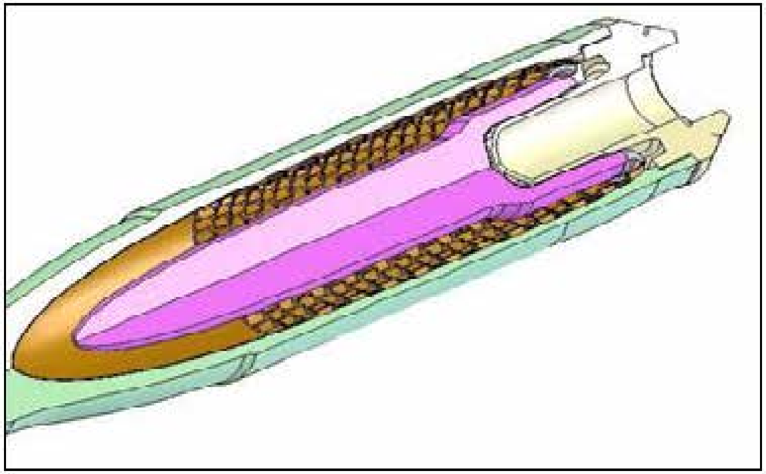


- **Structural Reliability** (no internal cracks)
- **Homogeneity** (no micro-voids)
- **Thermal Stability** (no reverse melting)

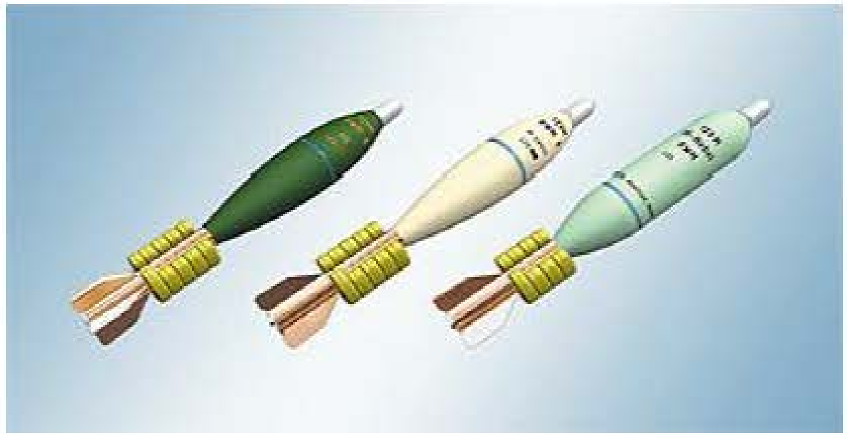
CAST PBX: Performances and Cost



- Affordable product (no high-cost ingredient needed)
- Performances comparable to non-IM explosives (Comp-B, TNT/Al…)
- Flexibility of design



How to Produce High Volumes of Cast PBX Shells?



CAST PBX: The Batch Process

Batch Process is well adapted for Production of Explosive Charges for Bombs, Missile Warheads…

- Step 1: **Mixing** (with cross linking agent)

- Step 2: **Casting** (pot life limited)

- Step 3: **Curing** (several days)

CAST PBX: Issues with Batch

Batch Process is Not Optimized for Production of Shells (60mm, 81mm, 105mm, 120mm, 155mm...)

- **Casting time is limited** (pot life constraint)
- **Curing takes days** (large oven areas)
- **Large mass** of explosive in the workshop

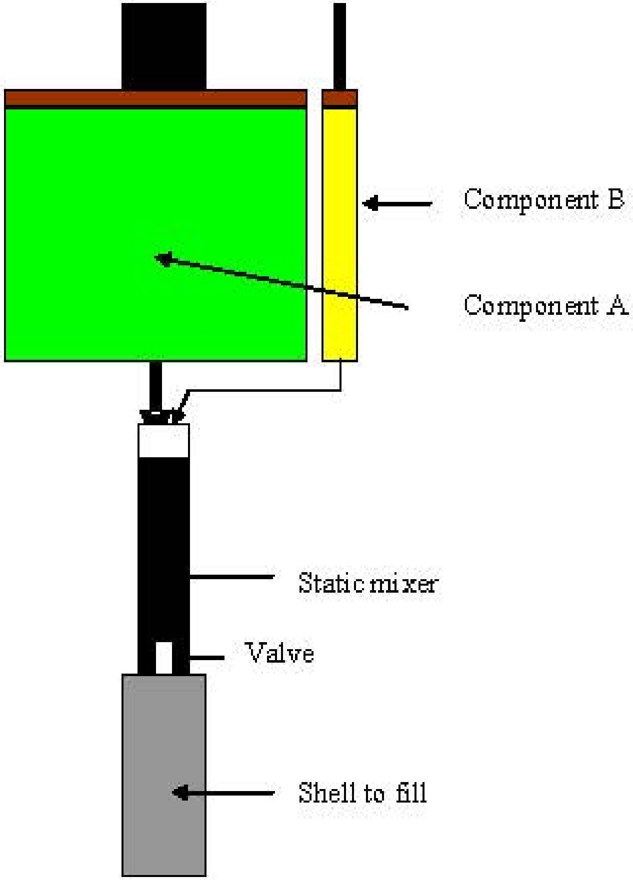
The Solution: The Bi-Component Process

- **Two components:**

  . Component A: All ingredients, **except curing agent**

  . Component B: Curing agent

- **Filling « on demand »** through a static mixer



EURENCO GROUPE SNPE

CAST PBX: The Solution for Shells

Static Mixer

Advantages of Bi-Component Process:

NO POT LIFE ISSUE

- Reduced Curing Time (< 24 h) short cycle
- Minimized Costs (production & capital investment)
- Versatile Industrial Organization…

Well Adapted to medium and large caliber shells

EURENCO
GROUPE SNPE

Bi-Component Process: EURENCO Facilities

Full scale production line commissioned in 2006

"POGS Workshop"

1.3 HD
1,200 m²

Capacity (items/year)
with one Filling Station

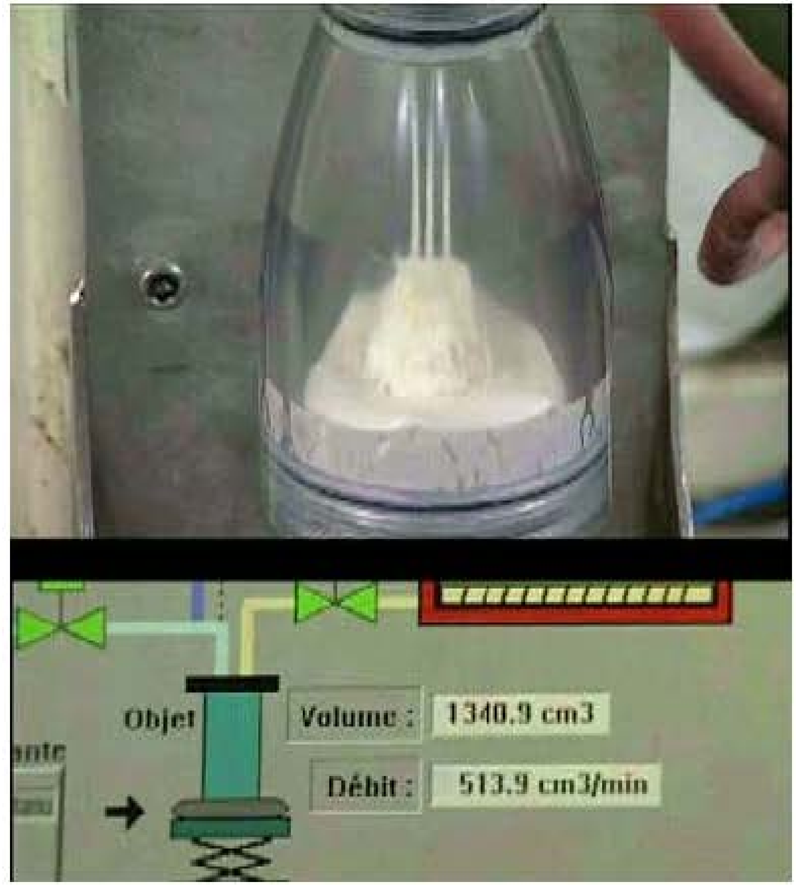
155 mm: 50,000
120 mm: 100,000

Bi-Component Process: EURENCO Facilities

"All-in-One" Workshop
(Empty Shells Get In ………….. Packed Filled Shells Go Out)

EURENCO
GROUPE SNPE

Bi-Component Process: EURENCO Facilities



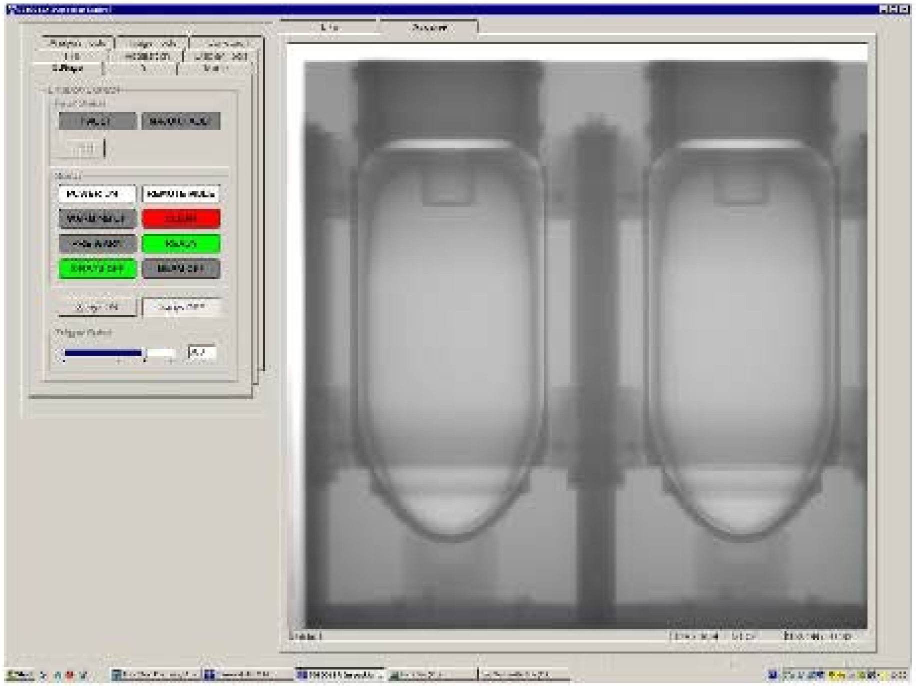
AUTOMATED HANDLING

AUTOMATED CASTING

Bi-Component Process: EURENCO Facilities

LINEAR CURING OVEN

Bi-Component Process: EURENCO Facilities



IN-LINE DIGITAL X-RAYS

Some Applications

Naval Artillery

76mm n°1	Artillery	Qualified, Production 2011
76mm n°2	Artillery	Development
127mm (5")	Artillery	Production 2011

Field Artillery

155mm n°1	Artillery	Qualified, Production 2011
155mm n°2	Artillery	Production 2006-2007 (Combat Proven)

EURENCO GROUPE SNPE

155mm Artillery (RWM RH30-40)

IM SIGNATURE						
	FCO	SCO	BI	FI	SR	SCJ
Comp-B	I	I	I	I	I	I
RH26	V	IV/V	V	-	-	-

Source : RWM and MSIAC

I = Detonation | II = Partial Detonation | III = Explosion | IV = Deflagration | V = Burn

155mm Artillery (New EURENCO Formulations B2268& B2267)

EURENCO GROUPE SNPE

	IM SIGNATURE					
	FCO	SCO	BI	FI	SR	SCJ
Comp-B	I	I	I	I	I	I
B2268 /B2267	V*	V*	V*	V*	IV/III*	V/III

* Prediction ; Source : EURENCO

Tank Ammunitions

120mm n°1	Tank HE	Production 2010/2011
120mm n°2	Tank HE	Development
105mm	Tank HE	Development

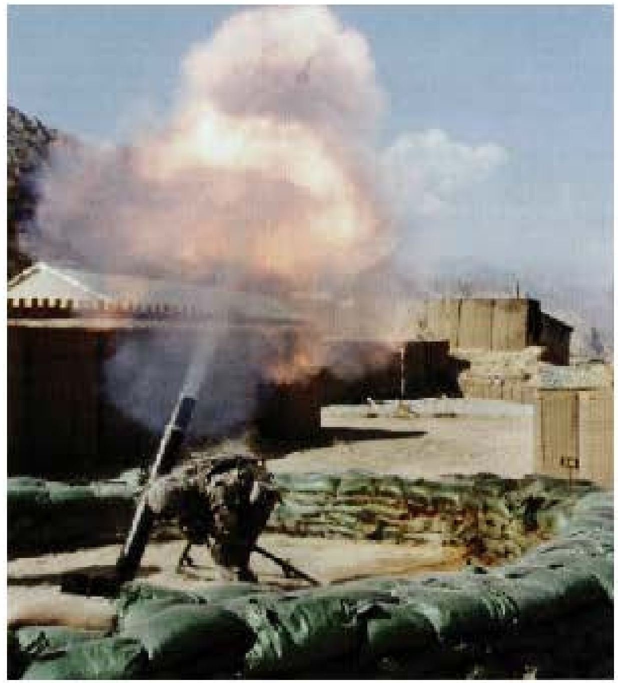
Mortar Ammunitions

120mm n°1	Mortar	Qualified
120mm n°2	Mortar	Qualified
120mm n°3	Mortar	Development
81mm n°1	Mortar	Development
81mm n°2	Mortar	Production 2009/2010

Mortars for USA

As a reminder: *120mm HE Mortar Ammunition (M934A2)*

- Prime Co. : GD-OTS CANADA
- Customer: US ARMY
- Development: 2001/05 ; TC 2006
- High Blast / Frag (ref. Comp-B)
- Meets IM Requirements
- Licenses for HBU88-B and BC Process



Mortars for USA

120mm HE Mortar Ammunition M934A2
(US ARMY Type Classified with EURENCO HBU88B)

IM SIGNATURE	FCO	SCO	BI	FI	SR	SCJ
Comp-B	II	I	I	I	I	I
HBU88B	IV*	IV*	IV*	IV*	IV-Pass	IV-Pass

* Fuze/Adapter Thrown >49 ft ; Source : US ARMY

Conclusion

- **Cast PBX** is the **most used and mature** IM explosive technology available
- **Cast PBX** is affordable and provides same performances as non-IM Explosives
- **Bi-Component** process is the **right economical / technical trade-off** for filling large caliber ammunitions with cast PBX.

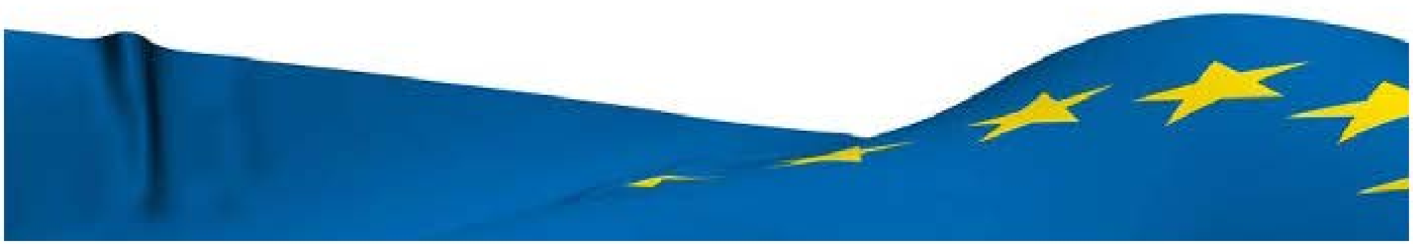
EURENCO
GROUPE SNPE

EURENCO is Member of IMEMG

The Insensitive Munitions European Manufacturers Group

IMEMG
MURAT
EUROPEAN MANUFACTURERS GROUP

GOING FROM STRENGTH TO STRENGTH



DISTRIBUTION STATEMENT A: Unlimited Distribution

Next Generation Machining & Modeling Technology

Presentation NDIA Guns & Missiles 2011

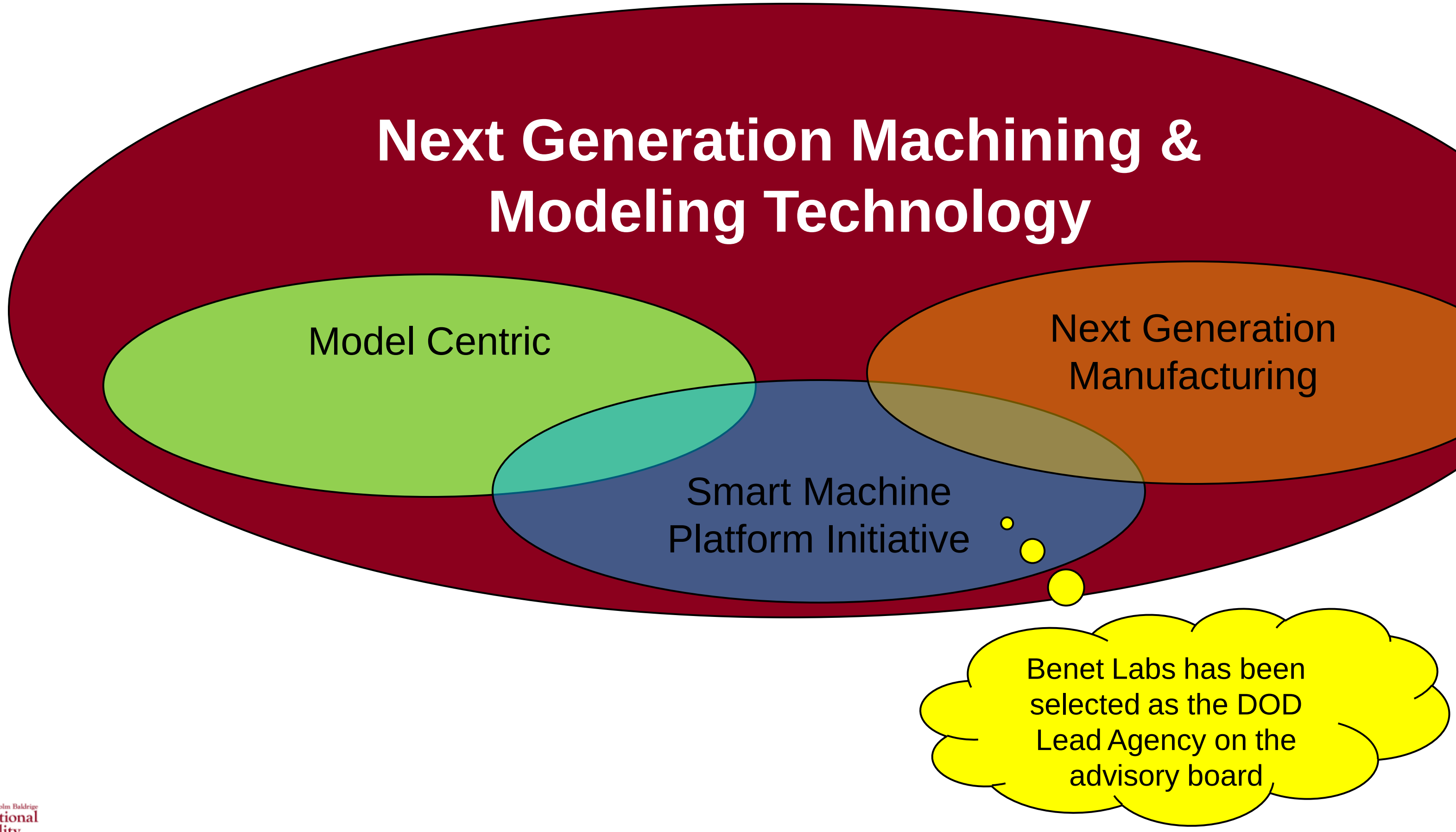
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

David C. Smith, P.E.
US Army Benét Laboratories
1 Buffington Street
Watervliet, NY 12189
518-266-4741

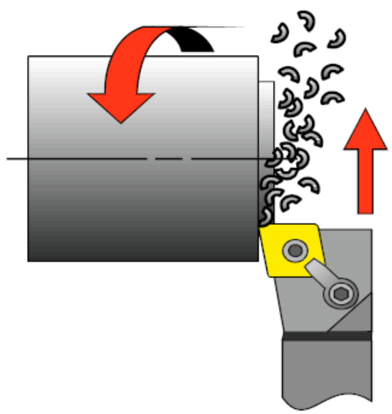
- Objective: To provide an overview of the US Army Benet Laboratories strategy to advance the state-of-the-art in defining product data, acquiring products in a timely, cost effective manner, and to update and maintain the techniques used to model products, maintain and improve the data, and to fabricate the end items. Further to serve as a model for the Department Of Defense agencies in the modernization of design, fabrication, acquisition capabilities

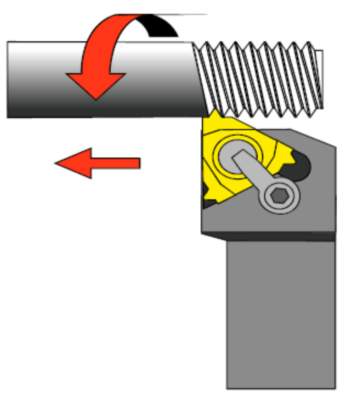
- Facts:
  - Government Technical Data Packages (TDPs) contain design information but no information about manufacturing
  - 85% of companies surveyed indicate that they use 2D drawings as their baseline, even when solid models are available. (1) The US DOD still uses 2D drawings as the legal documentation for acquisition and database
  - Studies by industry and DoD have demonstrated that the use of 3D modeling during design can reduce development cycle time by 30%+ (1).
  - Studies by industry indicate that the use of 3D modeling during design can reduce non-conformances by 35%+ (1, 2).

- Next Generation Machining and Modeling Technology is not a single element program but a strategy that looks at the:
  - Design process
  - Fabrication process
  - Management of these elements

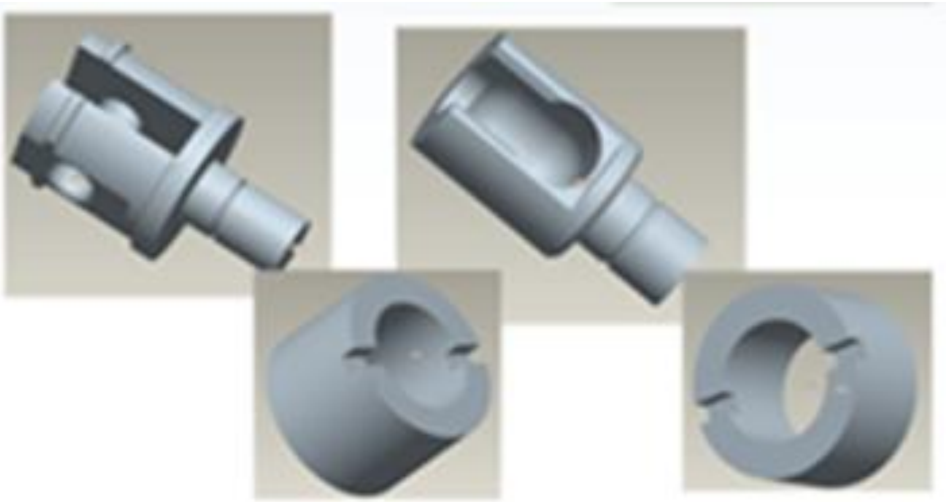

Next Generation Machining & Modeling Technology
Model Centric
Next Generation Manufacturing
Smart Machine Platform Initiative
Benet Labs has been selected as the DOD Lead Agency on the advisory board

- Model Centric Approach:
  - Actually comprised of 3 separate elements
    - Model Centric Design
    - Model Check
    - Model Based Environment
  - Not a project or a program, but a new strategy in how parts are concepted and designed
  - Not just the design information and intent, but all information necessary to support manufacturing the part to it's design intent





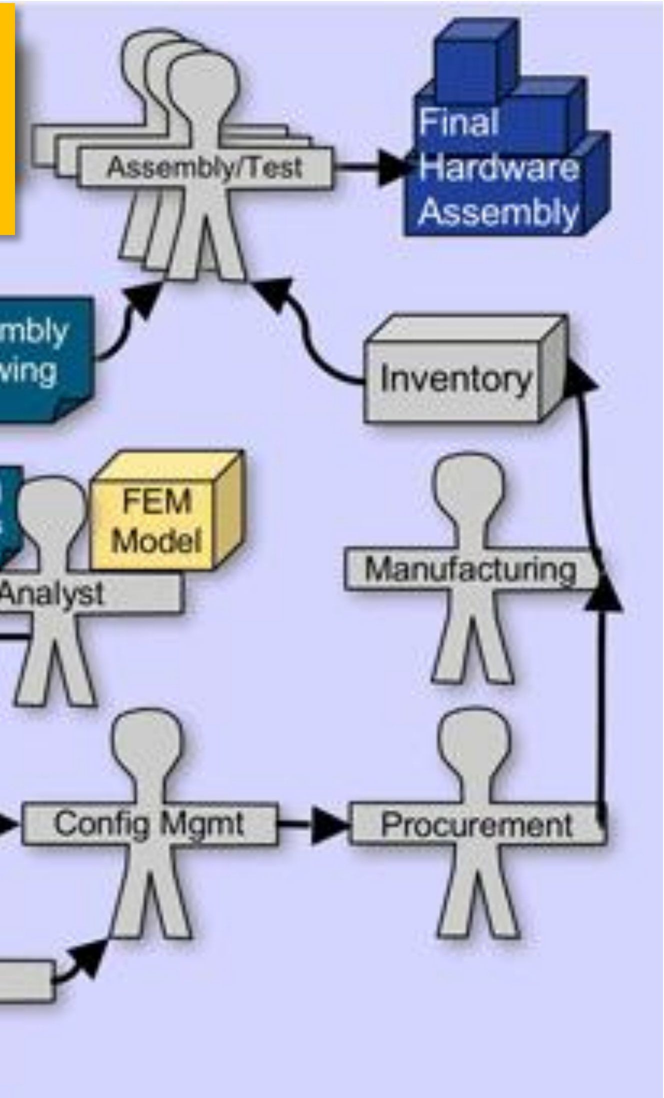
- Model Centric Design:
  - Defined as ". . a Model-based (or -centric) design is an approach that puts 3D models at the center of the design (1)."
  - The 3-Dimensional model serves as the basis of information for all design, analysis, fabrication, inspection, maintenance, repair, re-work, etc
  - Detailed data or characteristics is contained in the solid model files including
    - Physical geometry
    - Tolerances
    - Material characteristics
    - Coating/Finishing
    - Manufacturing Data *
  - Allows re-use of solid data across the enterprise
    - in other designs
    - in other software tools
    - for other purposes



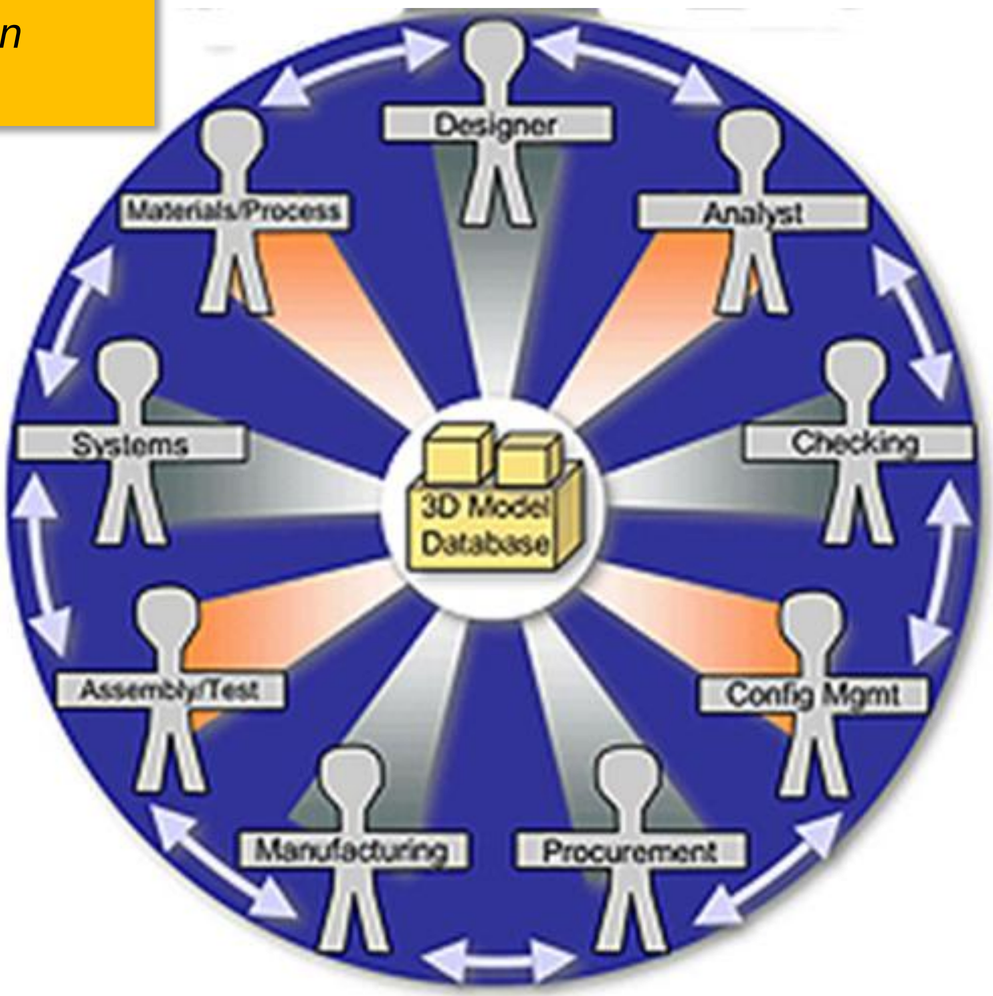
- Model Check:
  - Is a process that compares the solid geometry and tolerancing to an established set of standards to validate the *design.*
    - Can utilize a mix of automated software tools
    - Should include independent review by other individuals
  - Model Check can be tailored
    - To review only tolerancing
    - To address producibility
    - To assess model geometry for stability

- Model Based Environment:
  - A fully integrated and collaborative environment founded on 3D product definition detailed and shared across the enterprise; to enable rapid, seamless, and affordable deployment of products from concept to disposal.
  - An approach to maintain all data in a common data base to serve as the basis for all:
    - Design – Analysis
    - Interface to Enterprise Resource Planning: Raw material orders, Fabrication
    - Re-Use of data
  - May utilize native CAD formats or neutral file formats

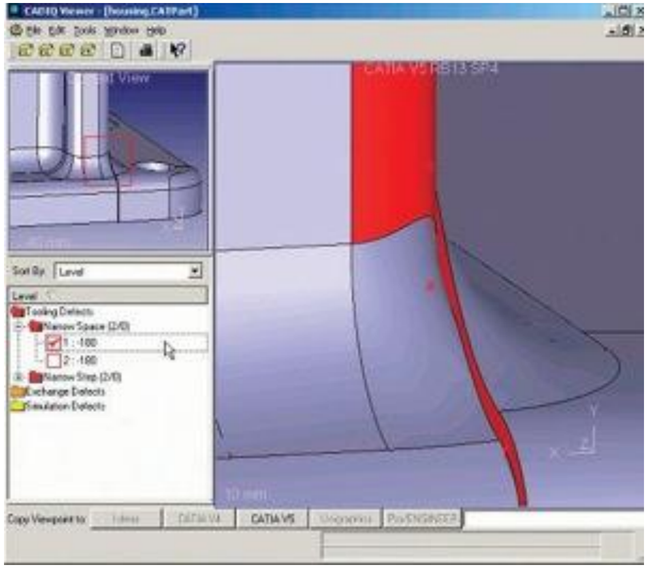
Existing Design Cycle
- *People Transfer Data*
- *2D Drawings Take over at some point in the cycle*

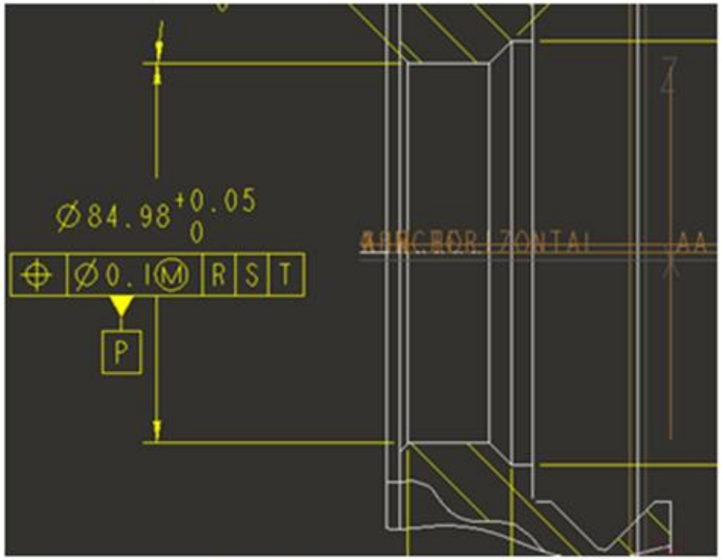


In a Model Based Environment
- People Access Data
- 3 D Models contain all design information



- Challenges to realize Model Centric within DOD (organic design & manufacturing)
  - Not all design details can be accurately modeled in CAD Packages
  - Not all CAD packages generate solid data that will:
    - Translate accurately into neutral formats
    - Translate accurately into Manufacturing Software
  - 3D models not transferable into other platforms
  - 3D file format changes can render old formats obsolete
  - Information Technology structure are at odds with government security protocols
  - Units translation needs additional user modification

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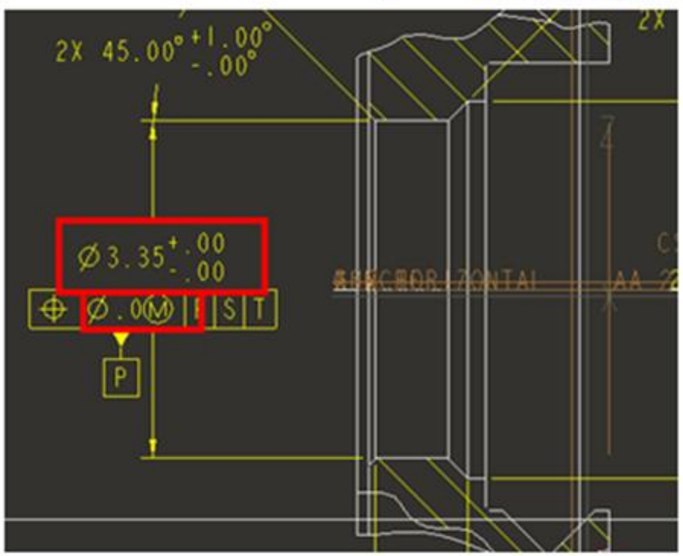
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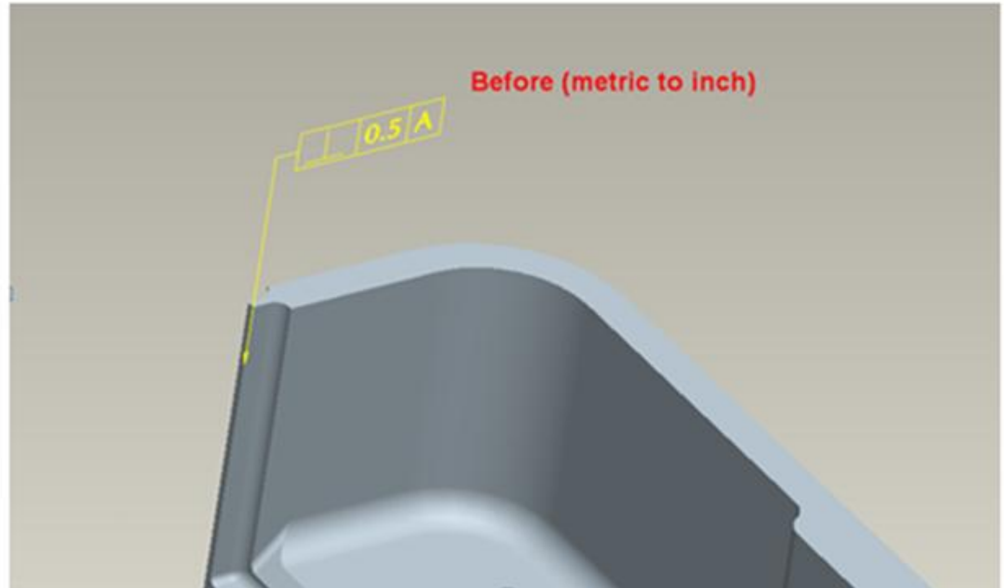
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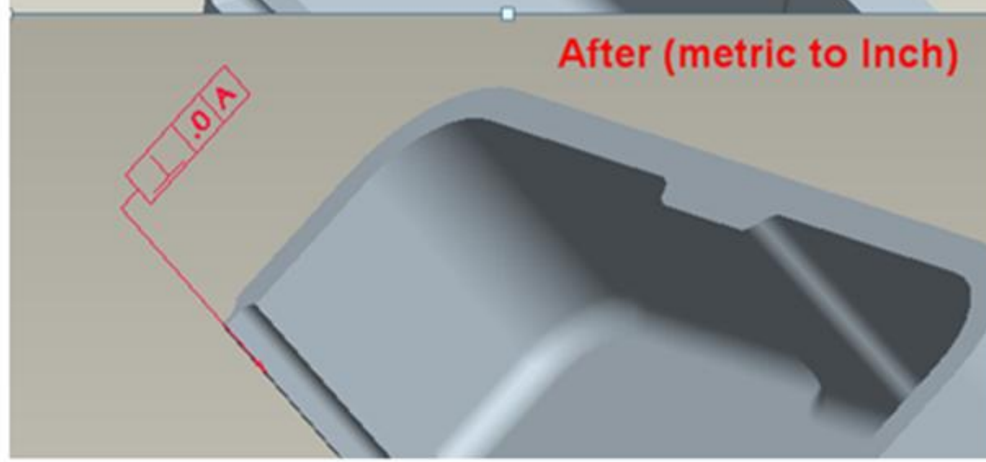
After (metric to Inch)
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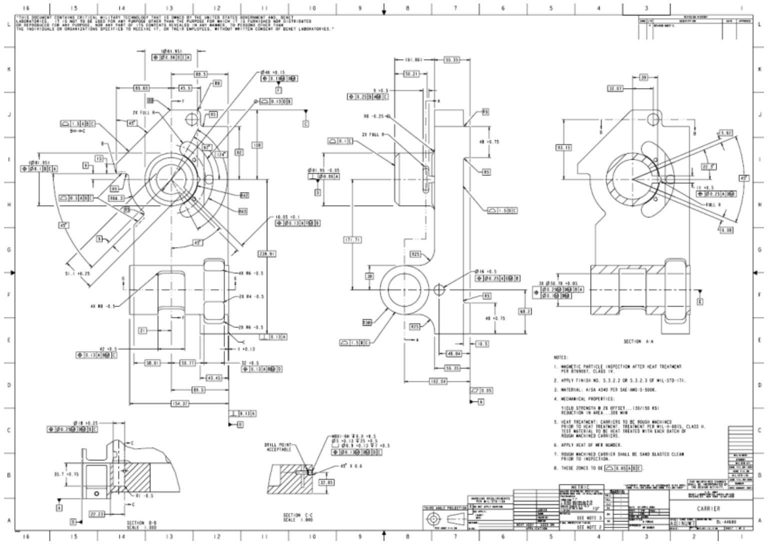
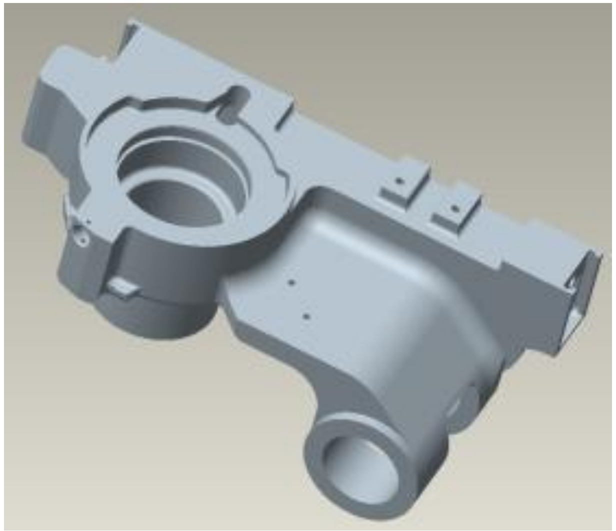
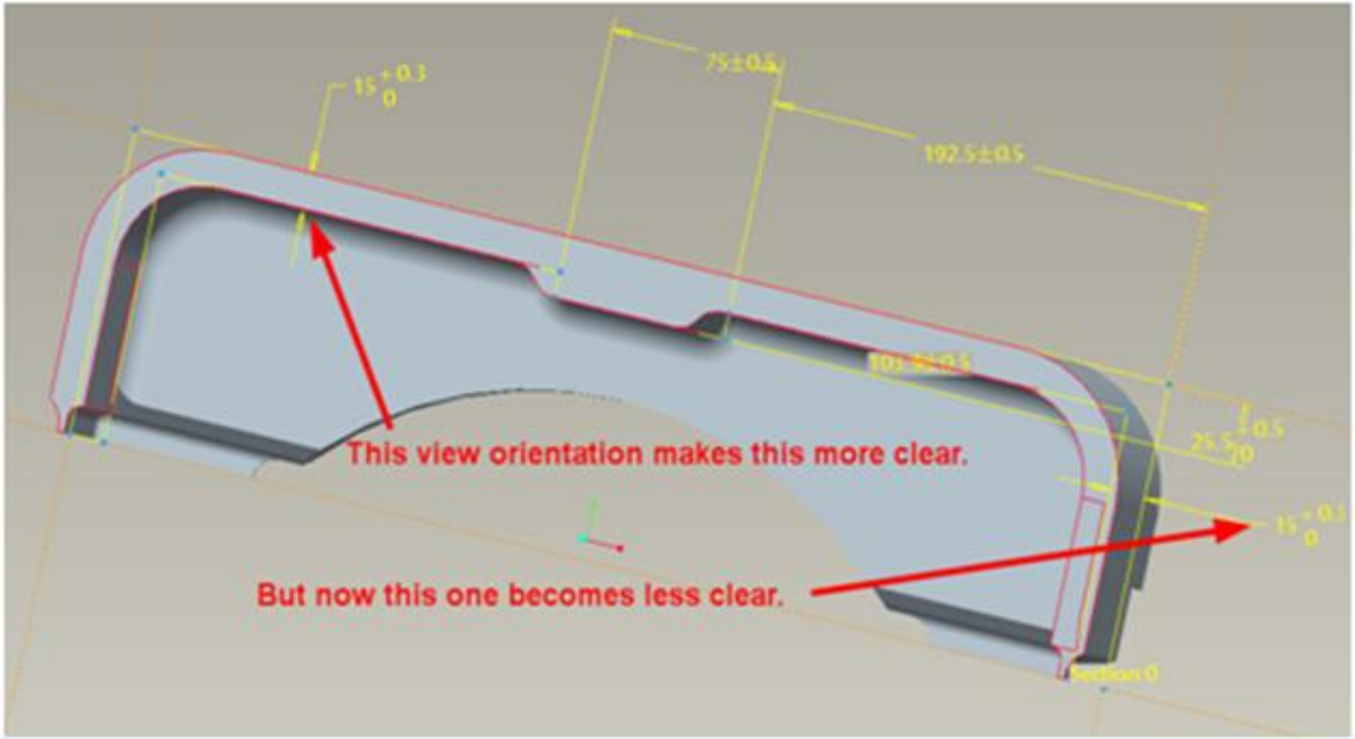
- Challenges to realize Model Centric outside DOD
  - Substantial amounts of legacy data exist in 2 D records only:
    - 2D PDF and C4: Current Army Document of Record
    - Investments in modeling these products must be driven by an economic model
  - Intellectual Property protections not well defined in 3D models
  - Optimal design for 1 vendor/process may be suboptimal for another vendor/process
  - Use of 3D data can create barriers to smaller vendors unable to make 3D capability investments





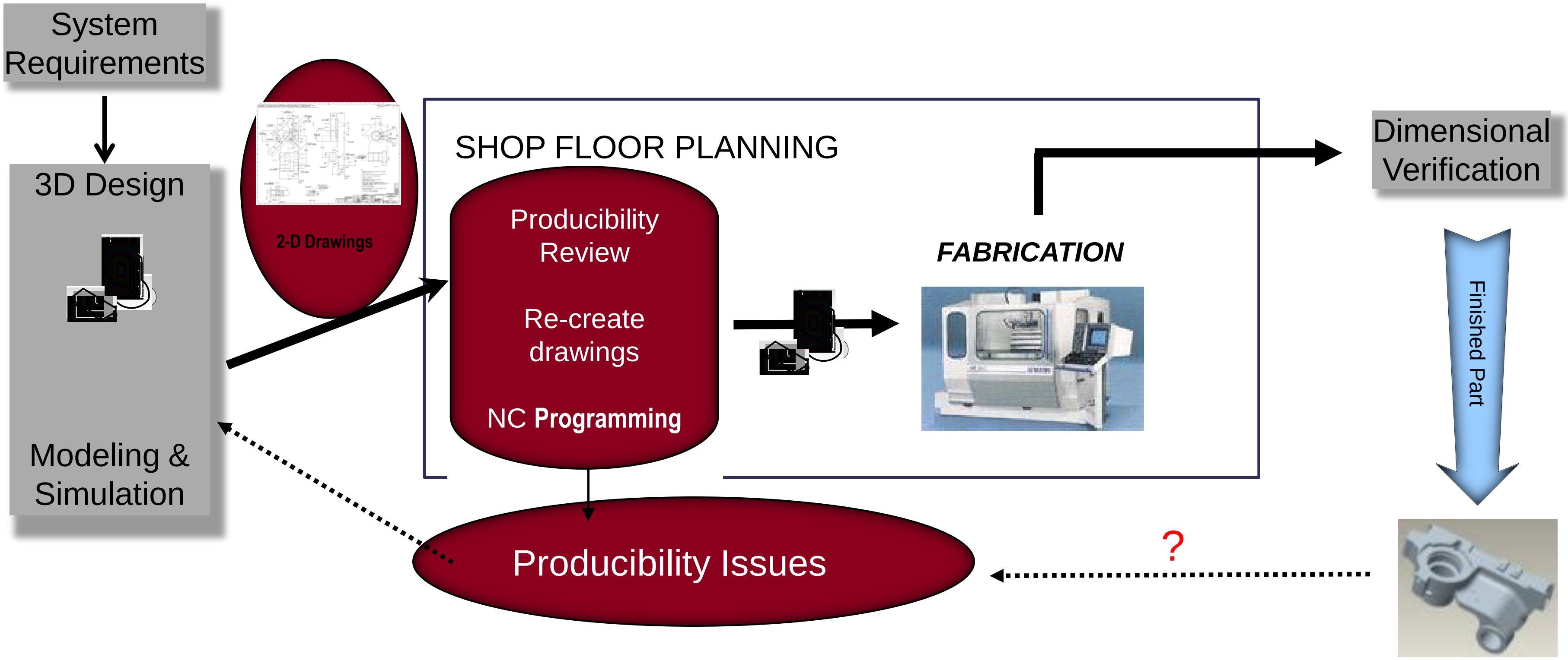
- Challenges to realize Model Centric outside DOD
  - Visualization of data



- Smart Machine Platform Initiative
  - A framework for the identification, development and transition of technologies that recognize the goal of ‘First Part Correct’ Manufacturing
  - Demonstrate technologies identified to produce the first and every subsequent part and part feature to specification without unscheduled delays or significant human intervention.
  - Transition program through organic DoD facilities and DoD contractors
  - Bottom line: Timely and cost effective acquisition of DoD components
  - Issues Addressed
    - Rapid production and cost reductions required
    - Costly tooling for low volume production
    - Producibility issues / Rework and scrap rates
    - Knowledge retention / Aging workforce
    - Diminishing supplier base

- Thrust Areas:
  - Intelligent Process Planning
    - Feature Recognition – semi automatic programming: 120 mins → 15 mins
    - High Performance Machining Optimization - saves 30% - 50% of machining time
    - Tool Data Management - Integrated with ESPRIT (CAM)
    - Virtual Machining - Reduced cutting errors
  - Machine Tool Health & Maintenance
    - Increased Tool Life & Availability
    - Reduced Turnaround time
      - Correction of minor problems, preventing catastrophic ones
      - Plan for maintainance during downtime
  - Tool Condition Monitoring
    - Reduced Costs & Scrap; Fewer Process Interruptions
    - On-Machine Vision
  - Intelligent Machining Network
    - Allows storage & organization of CNC programming
    - Communication of objective, real-time process data

- How is it done today?



Limitations:

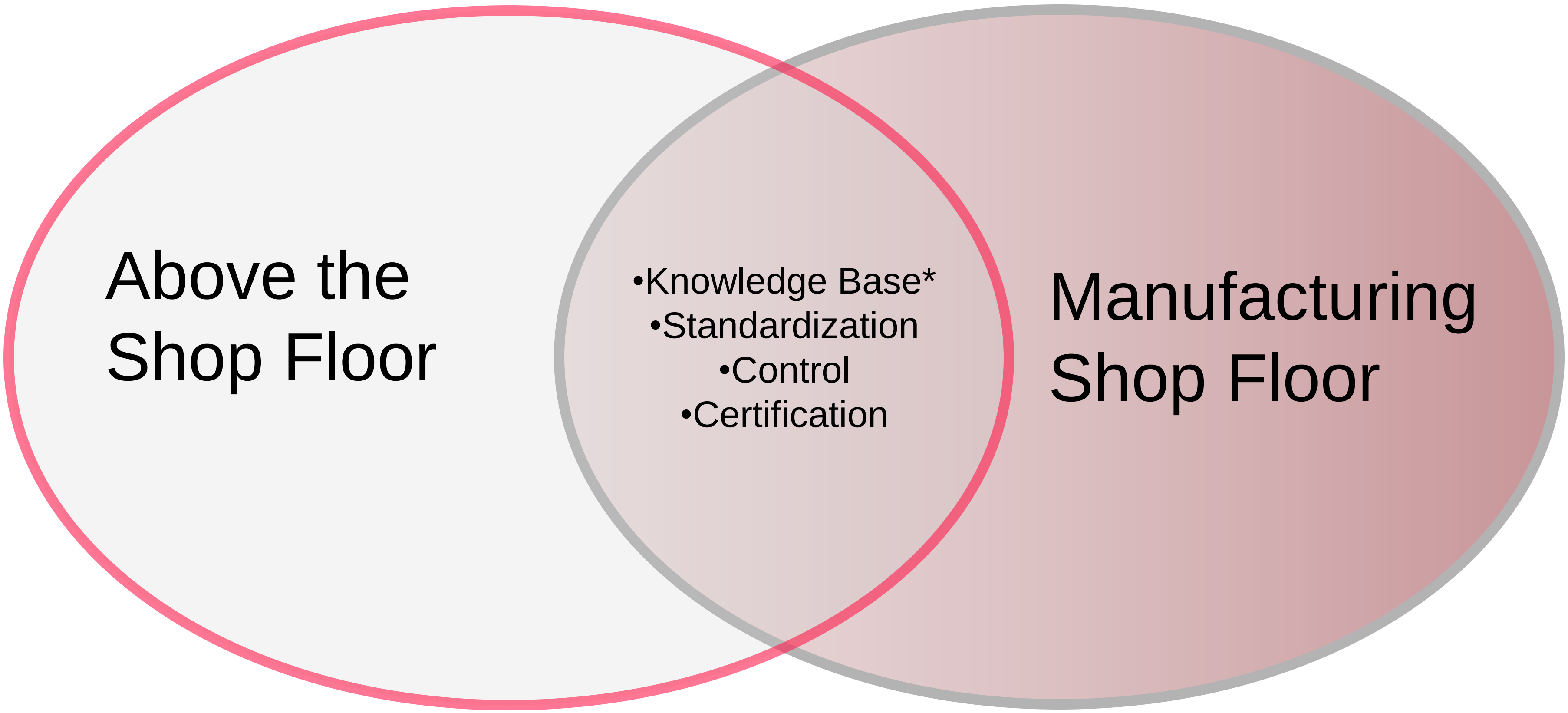
- 2-D TDP as "master" / Regeneration of 3-D Model
- Lack of lessons learned / feedback
- Limited in-process verification
- Ineffective producibilty review

- How are we approaching the Smart Machine Platform Initiative?
  - Identify / Develop, Validate and Demonstrate enabling technologies:
  - Create demonstration test beds for enabling (Smart Machine) Technologies
    - Assess the Capabilities and Limitation of the technologies
    - Assess & Validate each Technology to “First Part Correct”
      - Focus: Return on Investment
    - Determine the Inter-relationships between technologies
    - Identify Technology Gaps

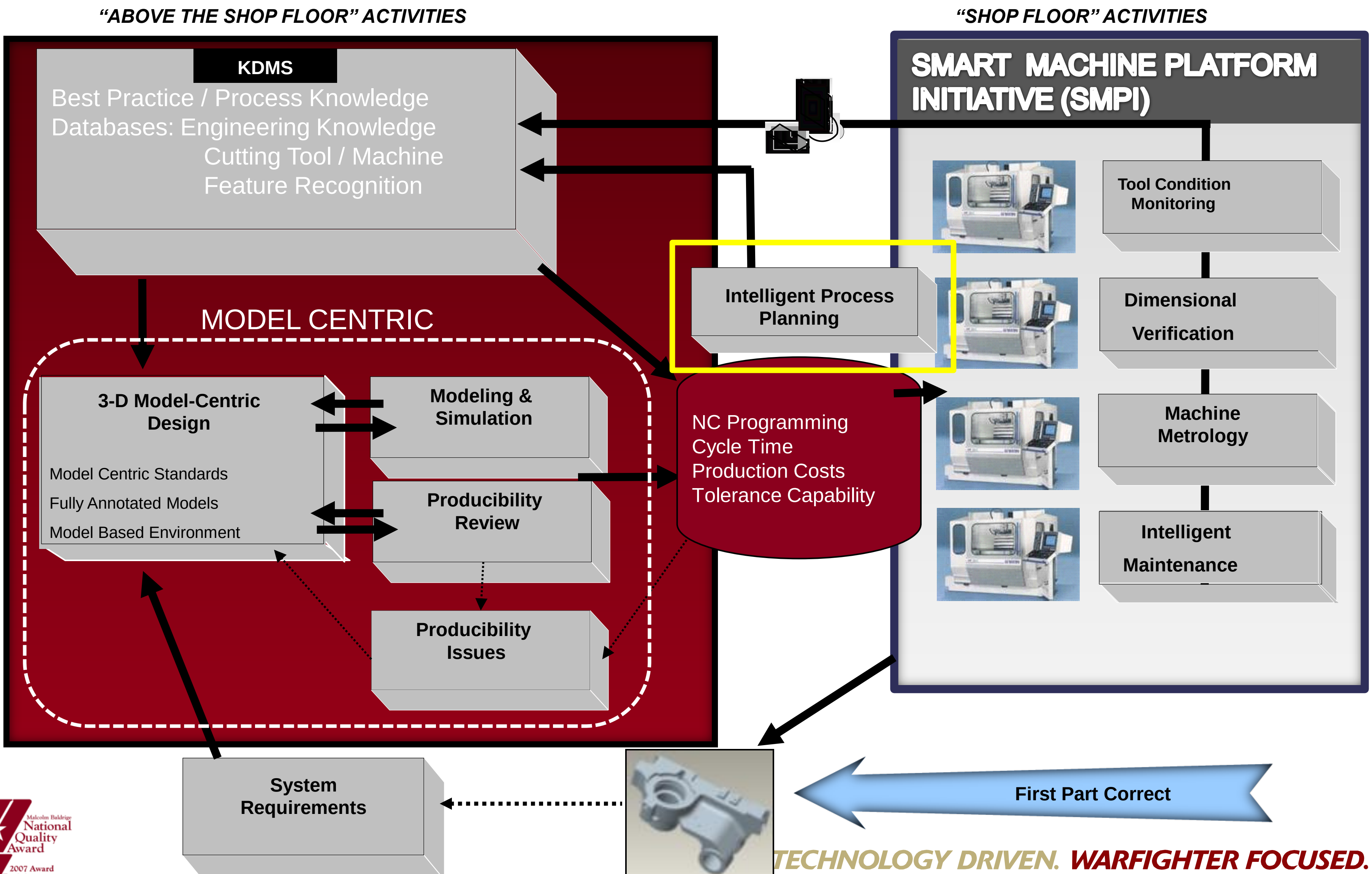
  - Provide the introduction of technology to industry & DoD
    - Demonstrate technologies in in-house (Benet) shops
    - Demonstrate/Transition technologies to organic (DOD) facilities
    - Involve private vendors through SMPI Umbrella

- Interaction with Logistics Modernization Plan

Benét Process Vision and Theme
Knowledge Driven Manufacturing



* Knowledge Base = Intellectual IP



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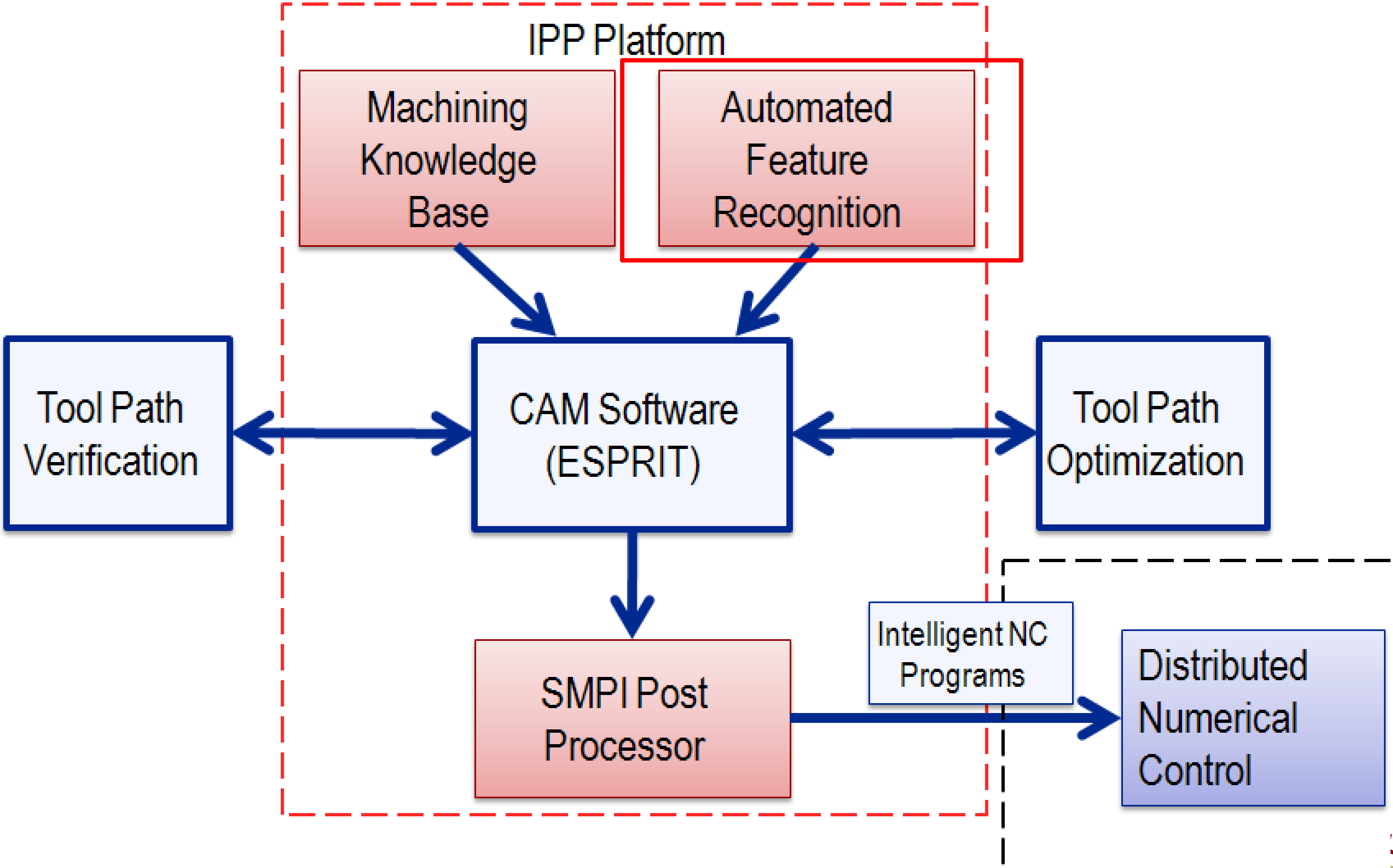
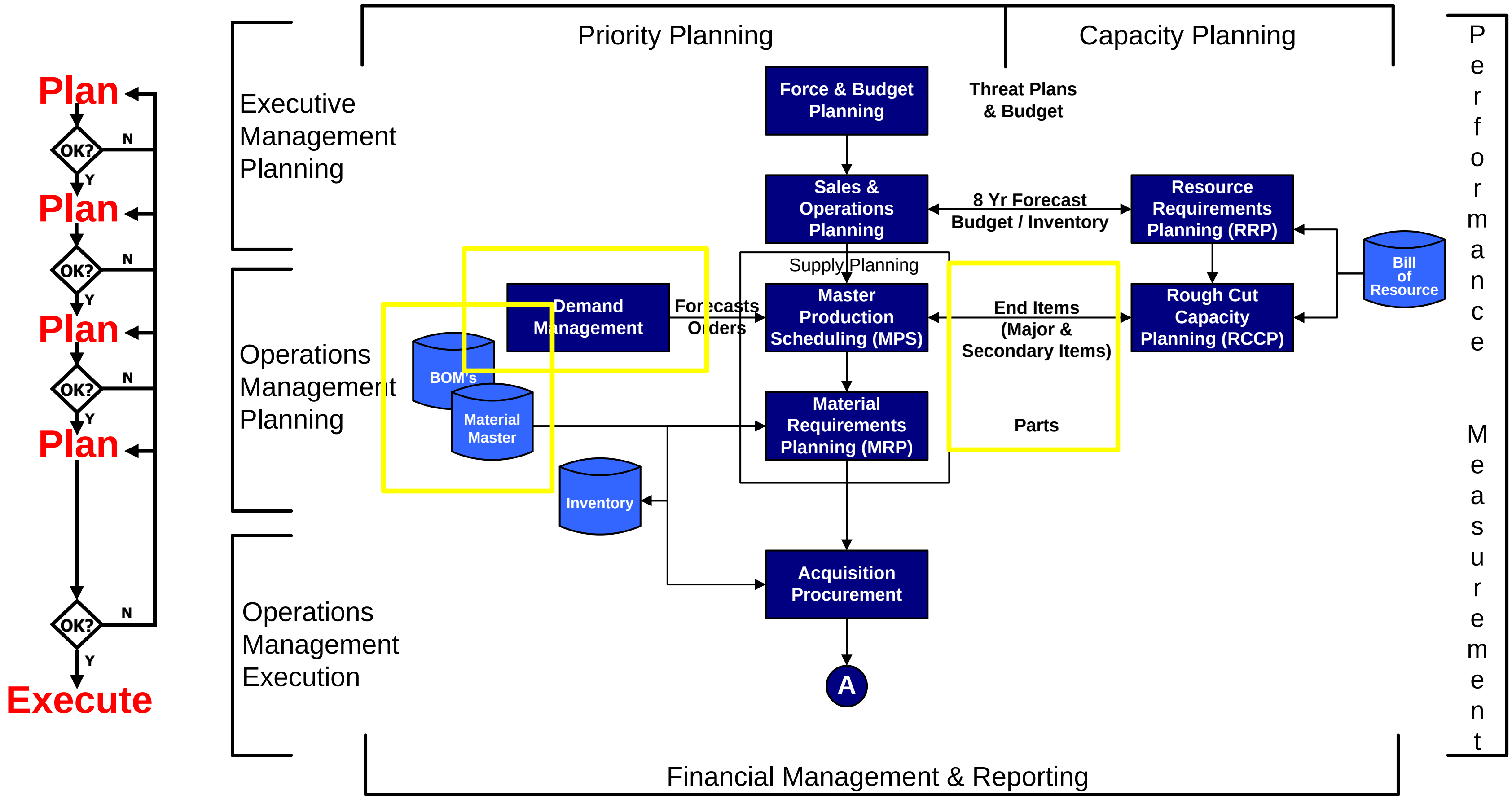
Intelligent Process Planning



- Logistics Modernization Plan
  - An Army wide Enterprise Resource Planning system being implemented now.
  - Dovetails with SMPI by:
    - providing a smart network to distribute information
    - Extending planning into materials, tooling, acquisition
    - Addressing user demand/needs
    - Creating a database for evaluation

ERP Business Process Overview

High Level ERP Closed-Loop Business Process Model - LCMC View



Customer / Partner / Supplier Integration

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Advisory Group (Est. 2006)

Smart Machine Platform Initiative (SMPI)

Future Intelligent Integrated Machining Technologies

(FITMaT)

Government Advisory Group

- U.S. Army ARDEC Benét Labs – **DoD Lead**
- U.S. Army Research Laboratory
- U.S. Air Force – ManTech
- Defense Logistics Agency
- NIST – Manufacturing Engineering Lab
- NNSA Y-12 National Nuclear Complex

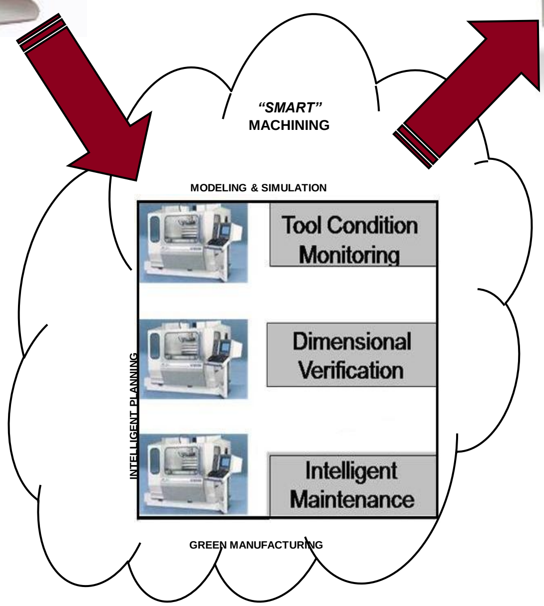
Industrial Advisory Group

- BAE Systems
- The Boeing Company
- Caterpillar, Inc.
- Cincinnati Machine
- Delphi Automotive
- Ex One
- Ford Motor Company
- GE Aviation
- GD Land Systems
- GD Ordinance & Tactical Systems
- Hurco Companies, Inc.
- Lockheed Martin
- Pratt & Whitney
- Remmele Engineering
- Rolls Royce
- Sikorsky Aircraft Corporation
- Vought Aircraft

- Challenges to implementing Smart Machine Platform Initiatives within organic manufacturing *or using other vendors*
  - Disparate file formats, databases, optimization approaches create communication barriers.
  - Low demand quantity environment makes it difficult to identify large scale cost savings to justify investment, implementation
  - Established workforce sees increasing ‘knowledge based’ tools as a threat
  - Outside the organic manufacturing base, many unique, small vendors lack the resources, communications links, skill levels to implement some of the SMPI elements

- Why does Smart Machining Platform make more sense for DOD than many other industries
  - Low demand level, wide variety of parts needed on high priority basis
    - Allows very flexible manufacturing approach
    - Allows lessons learned to be retained outside of organic (human) skill base

- Next Generation Manufacturing:
  - A series of initiatives to explore advanced manufacturing techniques to reduce costs and to bring new capabilities into DOD Products
  - Focus on “Additive Manufacturing Processes” to exploit the digital models available through the Model Centric approach and reduce waste materials
    - Laser Enhanced Net Shaping (LENS) System – an additive system approach
    - StereoLithogrAphy (SLA) generation of near net shape parts in polymers
  - Other approaches include the integration of new techniques with existing processes to focus on net-shape or near-net-shape results
    - Use of SLA with castings
    - Direct tool path generation for waterjet cutting machines
  - Utilizes features of SMPI to enhance routing, material processing
  - Provides cost effective fabrication of low production runs on unique parts
  - Provides new capabilities



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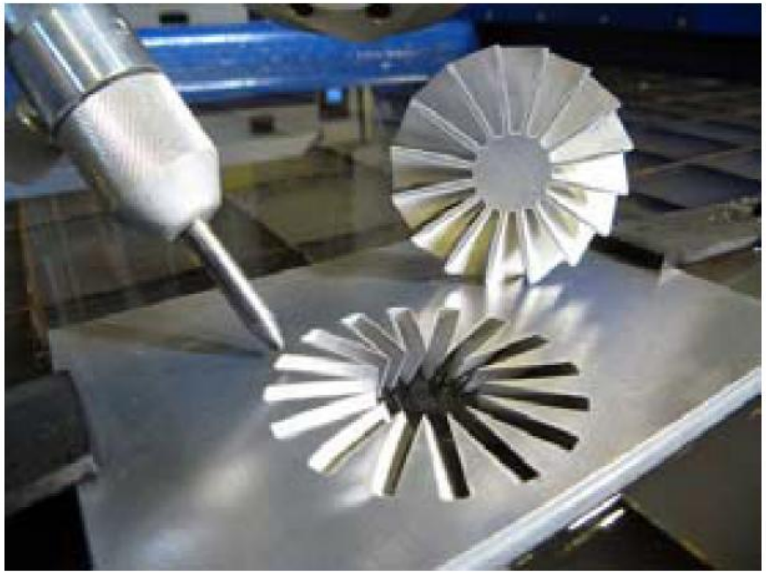
- Challenges to implementing Next Generation Manufacturing
  - Modeling of parts for new processes may require new design approaches and optimization
- <u>Why does Next Generation Manufacturing make sense</u>
  - Focus on additive manufacturing processes leads to less waste
  - Focus on additive manufacturing processes means lower investment in raw materials
  - New processes can yield new materials that increase performance of equipment



Questions?

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RDECOM

46th Annual Gun and Missiles Conference
29-31 August2011

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Gun-Launched Aerial Precision Munition (G-L APM)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

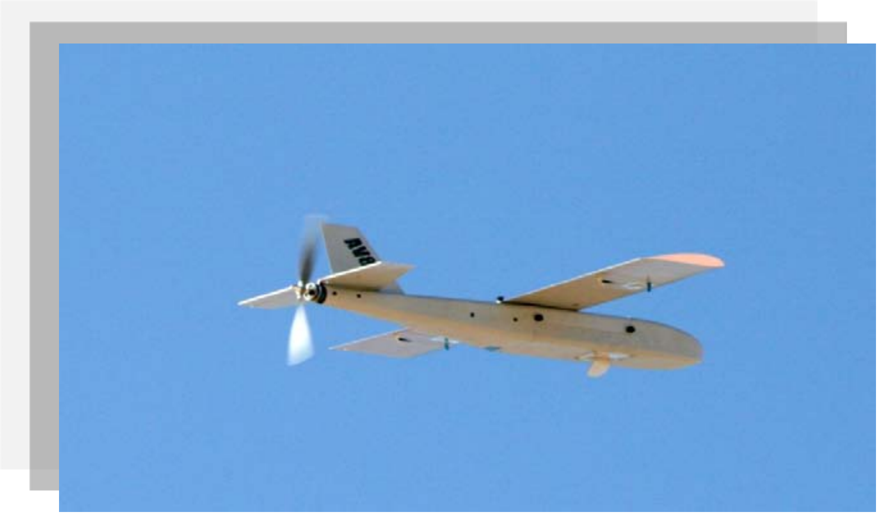
Hjalmar “Jay” Canela/ Lloyd Khuc
US ARMY
METC, ARDEC
Picatinny Arsenal, NJ

Distribution Statement A: Unlimited Distribution

Background

- Urban warfare targets can be effectively identified, targeted and neutralized by small Remote Armament System (RAS) capable of delivering warheads.

- This paper will cover the design such a system, how it is implemented in the Unmanned Aerial Vehicle (UAV) used as a prototype flight platform, and includes the results for its initial test flights.



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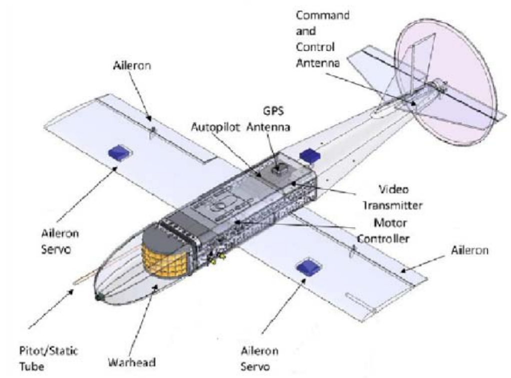
Why Gun-Launched APM?

- Added lethality component to non-tactical small RAS
- Elimination of RAS capture
- Technology protection through self-destruction
- Added lethality to projectile (increase lethal range)
- Deterrence to terrorism activities
- Force protection

Test Vehicle (surrogate) Characteristics

Unmanned Aircraft Vehicle

Length ~ 4.5’
Wingspan ~ 4.5’
Speed ~ 60-65 knots
Range ~ 12mi
System Weight ~ 10 lbs
Warhead Weight ~ 2 lbs



Launch method ~ Air Pressure Rail Launch
Power source ~ Lithium-Polymer rechargeable battery pack
Avionics ~ Piccolo lite autopilot and radio, 900 MHZ
Camera ~ Color Analog Video Transmitter, 2.4 GHZ

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Test of Warhead Effects Against Trucks

Ford

Ranger or F150

Truck A (0.5 lb C-4)	Truck B (1.0 lb C-4)	Truck C (1.0 lb Frag Whd)	Truck D (2.0 lb Frag Whd)
			

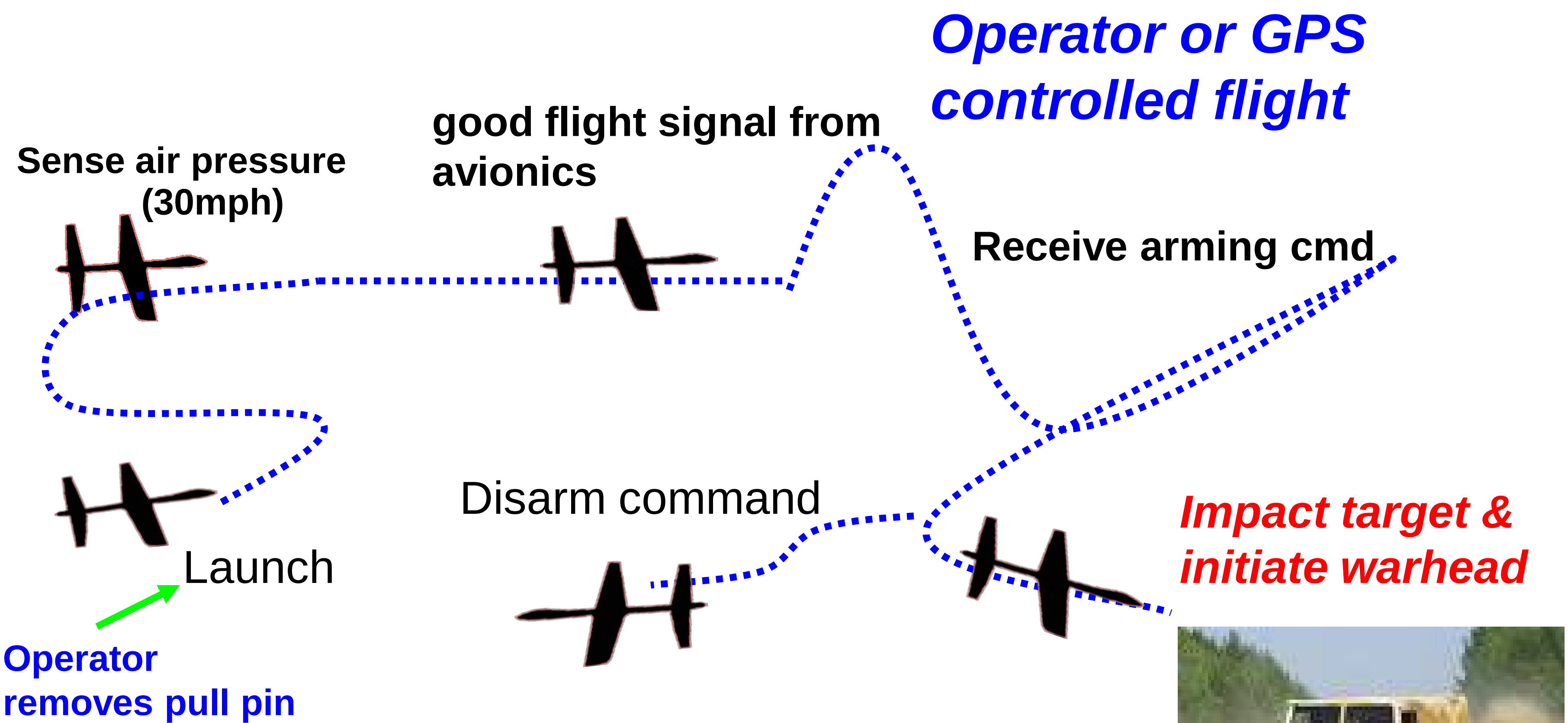
- Socorro, NM 3/26/2009

Fuze Requirements/Design Approach

- Requirements:
  - Must provide safety during handling & launch
  - Meet Mil-STD-1316/MIL- STD-1901 type safety requirements
  - Function on impact with the target
  - Receive commands from the ground station to arm, fire and disarm in flight
  - Radio Communicates fuze status back to the ground station

- Approach: An Electronic Safe and Arm (ESA) was selected
  - Reliable
  - Compatible with the system avionics functions and communications system
  - Can be readily fire and disarmed in flight
  - Impact or Remote Self-destruction mode

Fuze Flight Sequence



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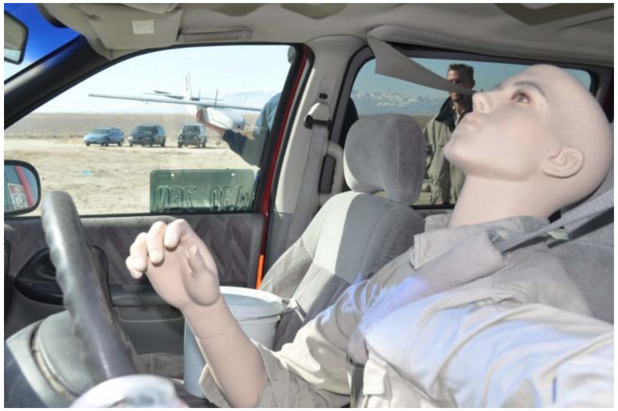
G-L APM Demo Test Set up



G-L APM Demo Test Result

- Live Fired Flight Tests were conducted on Feb-23-2010 at Dugway Proving Ground, Utah.
- Two UAV's were programmed to autonomously fly a preset pattern and home in on stationary SUV's used as demo targets with 100% success.
  - Info transmitted from UAV validated all fuze safety features worked as designed
  - Firing pulse 1,200V through LEEFI initiation warhead on target impact.
  - Both stationary SUV targets were significant damage.

- In Summary:
  - Universal fuze functioned flawlessly, technology demonstrated.
  - Multi-purpose warhead function demonstrated with low collateral damage.
  - APM Flight Platform precision demonstrated.

Movie1.wmv

launch.wmv

Test 1 impact small.wmv

Summary

- ARDEC was committed to developing Gun-Launched APM technology.
- Fuzing and Novel Warhead are key parts of ARDEC's Gun Launched APM program.
- On-going effort to reduce size of fuze to fit into small APM airframe.

=> ***Areas/technologies for collaborative effort?***

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Fuze Division

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THE EFFECTS OF IGNITER DESIGN ON THE INTERIOR BALLISTIC PERFORMANCE OF DETERRENT COATED PROPELLANTS

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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RDECOM

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Briefing Outline

- Overview
- System Description
- Performance Test
- IM Test
- Conclusions

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Purpose of the Program

- Develop an environmentally friendly propellant for medium caliber applications
  - Elimination of ether and alcohol processing solvents
  - No ingredients from the EPA watch list
  - Step improvement of IM performance

Snapshot of Program

- Solventless PAP8386 tailored for medium caliber
- M793/PGU-23 selected as test vehicle
  - Ignition system optimized for propellant
  - Ballistics demonstrated across temperatures
  - Insensitive Munitions Testing of M793 Vented Cartridge Cases and PA125 Container with Developmental PAP-8386 Propellant
- IM testing completed

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Vented Case and Container

- Despite the improved IM properties of PAP-8386 propellant a system level approach is needed for all of the IM tests
- A separate ARDEC program has developed a vented case and container
  - Designed to relieve undesired pressure
  - This case and container are expected to provide improved IM response of the loaded round to the Slow Cook-Off test in particular
- Vented cases and containers were used for the IM test

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Technical Approach

- Propellant Manufacturing at RFAAP
- Propellant Testing
  - Reproducibity (RFAAP)
    - PVAT (-46C, +21C, +63C)
    - Chemical and physical
  - Characterization
    - Insensitive Munitions Testing (Mil Std 2105C) (NTS)

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SMALL SCALE SENSITIVITY SCREENING TEST

Propellant	ERL Type 12 Impact 50% point (cm)	Electrostatic Discharge Test (ESD) NR (NO REACTION)	BAM Friction (N) N (NEWTON)
RDX Lot # 21-18	24.8± 1.2 25.1± 1.7	-	212N reacted 188N 10/10 no go
RPD380 Lot # ARV01A002001	27.1± 2.1	NR 20 trials @ 0.25 Joules	192N reacted 168N 10/10 no go
L1M Lot # NC-00J2890	27.6 ± 1.5	NR 20 trials @ 0.25 Joules	212N reacted 188N 10/10 no go
JA2 Lot # PD-065-5	32.0 ± 1.4	NR 20 trials @ 0.25 Joules	212N reacted 188N 10/10 no go
M14	48.4 ±1.3	NR 20 trials @ 0.25 Joules	252N reacted 240N 10/10 no go
PAP-8386 (RPD-469)	75.4 $\underline{+}$ 1.2	NR 20 trials @0.25 Joules	252N reacted 240N 10/10 no go

PAP-8386 is less impact sensitive than M14 and JA2 propellant

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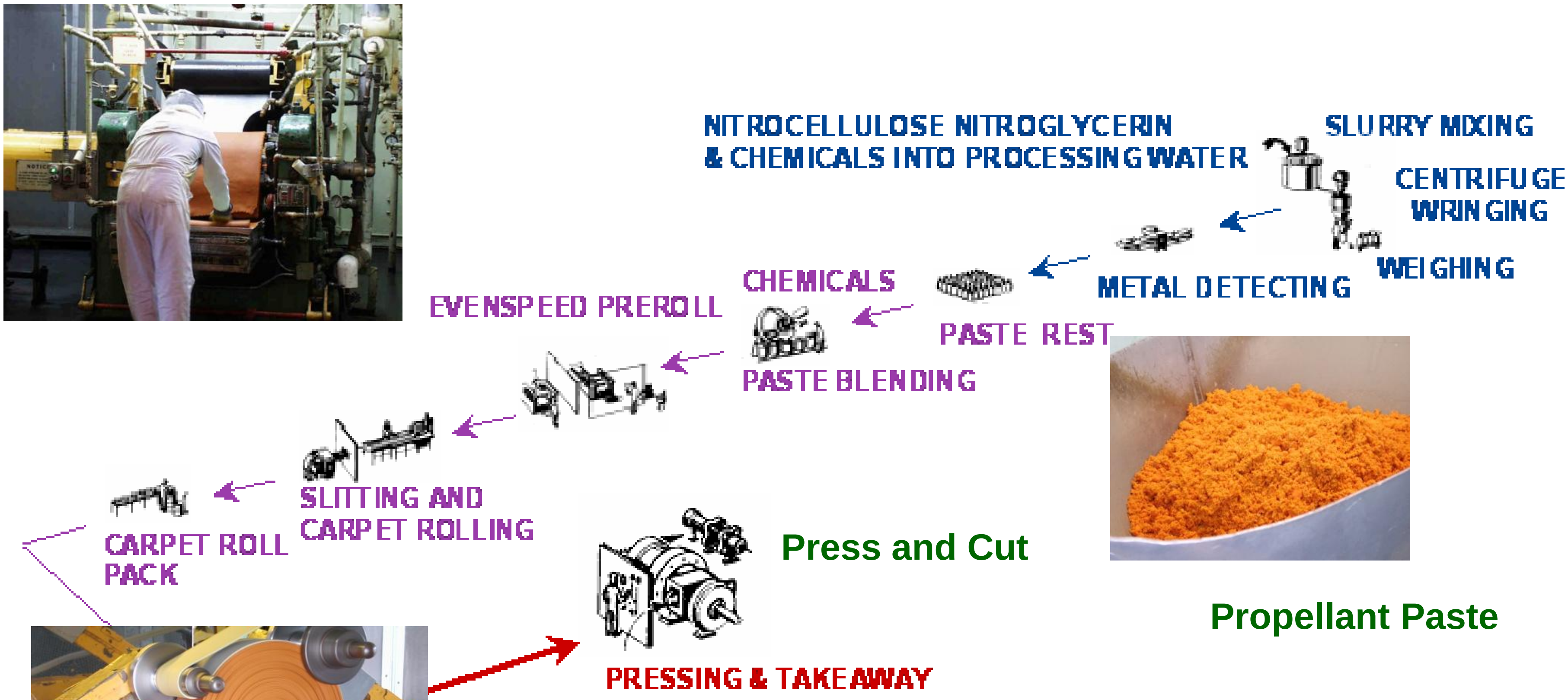
Solventless Propellant Process



Propellant Paste

Carpet Roll

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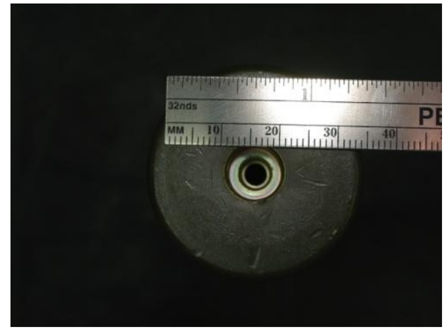
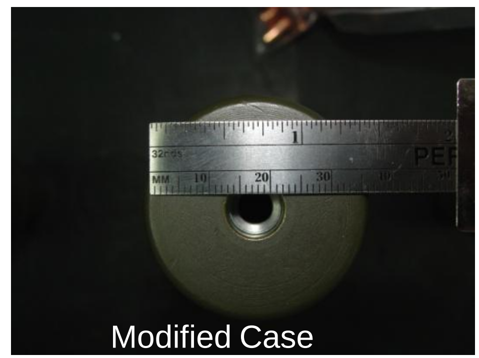
Technical Progress Ignition Study Using Flash Tube Igniter

Blend Study Results (w/Flashtube)





Loaded Round

Flash Tube

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Pressure Velocity Action Time (PVAT at +63C, +21C and -46C)

PVAT RESULTS MET THE PERFORMANCE SPECS

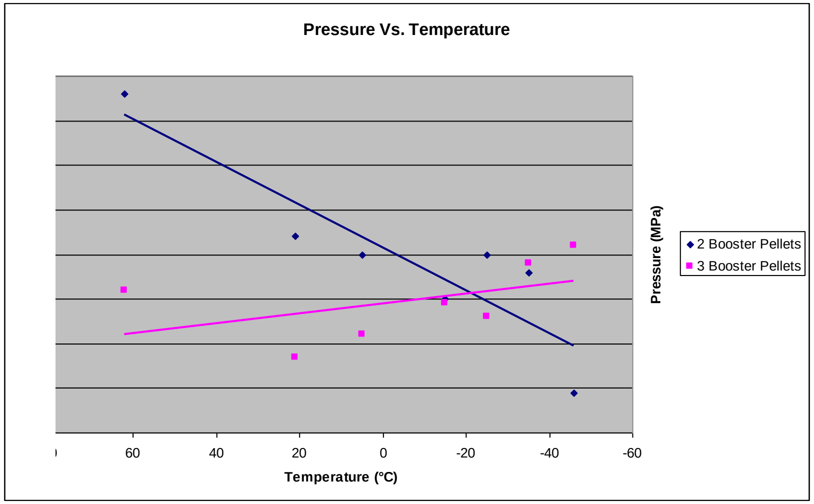

Figure 1: Pressure Vs Temperature results from cold walk-down

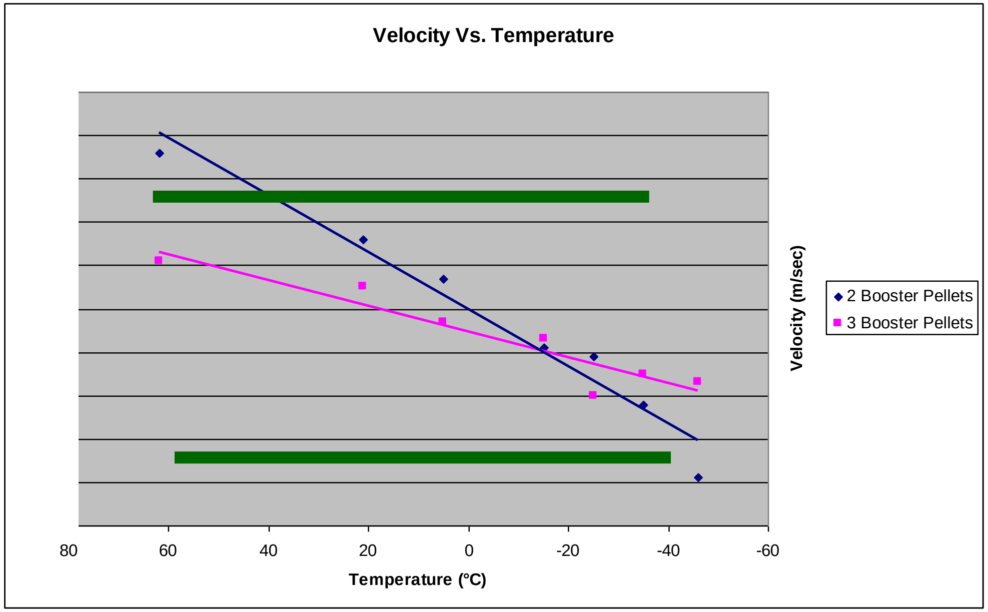

Figure 2: Velocity Vs Temperature results for cold walk-down

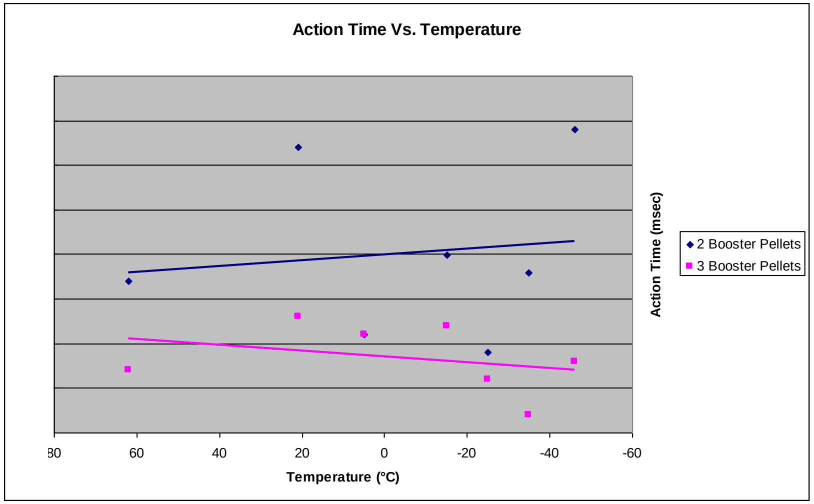

Figure 3: Action Time Vs Temperature results for cold walk-down

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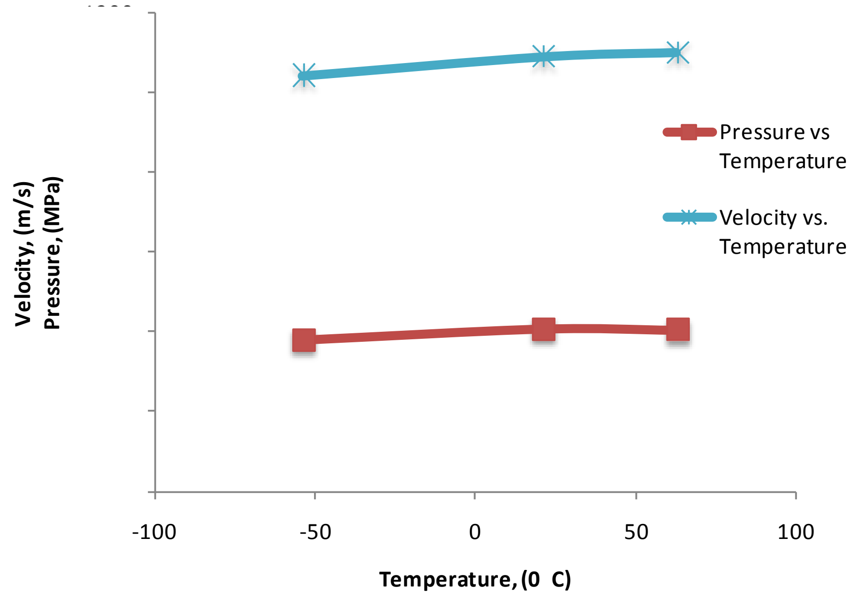
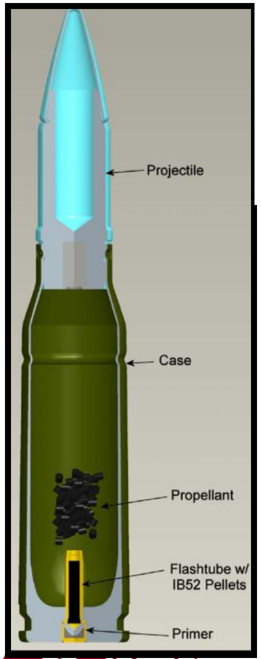
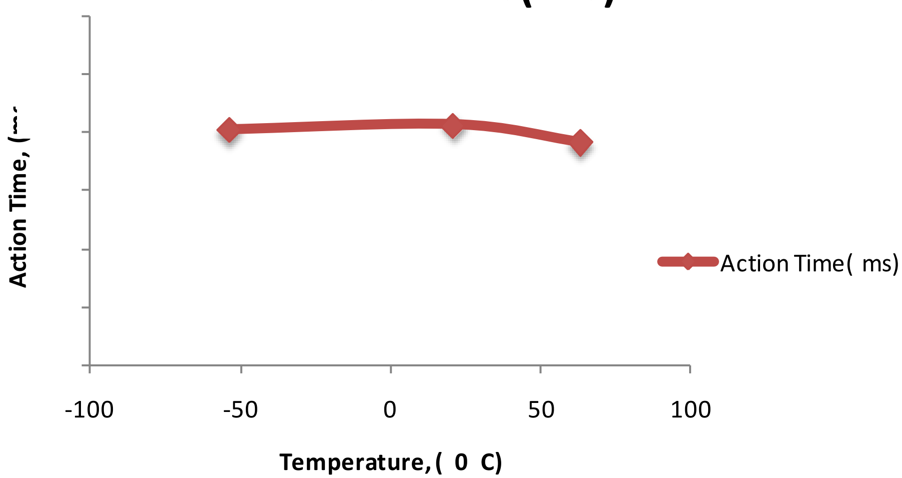
PAP-8386 Pressure Final Performance Across Temps







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Recommended Testing

IM Test	MIL-STD-2105C	Test Parameters
Fast Cook-Off (Liquid Fuel/External fire)	V	• Per STANAG 4240 (Edition 2) • Complete engulfment of the test item by the fire for a min of 20 min
Slow Cook-Off (Slow Heating)	V	• Per STANAG 4382 (Edition 2) • Test item to be pre -conditioned at +50°C for 8 hours prior to test or until it reaches equilibrium at +50°C • Oven temperature to be increased +3.3°C per hour from +50°C
Bullet Impact	V	• Per STANAG 4241 (Edition 2). • 0.50 cal Type M2 AP bullet @velocity of 2790±66 ft/sec
Fragment Impact	V	• Per STANAG 4496 (Edition 1). • 0.50 inch mild steel conical fragment@velocity of 8,300±300 ft/sec
Shaped Charge Jet Impact	III,IV,V (PASS)	• Per STANAG 4526 (Edition 1, Ratification Draft 1) • 81mm shaped charge loaded with LX-14 • Impact at the propellant location
Sympathetic Detonation	III,IV,V (PASS)	• Per STANAG 4396 (Edition 2) • Required if SCJI test is a failure • 81mm shaped charge loaded with Comp B

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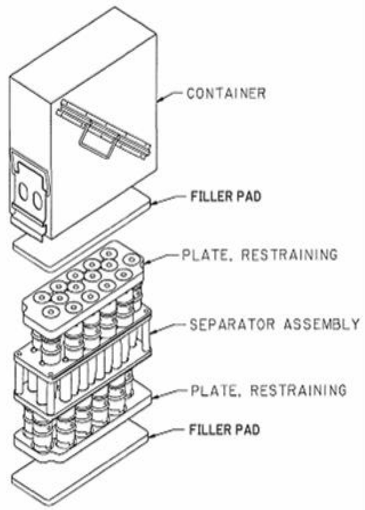
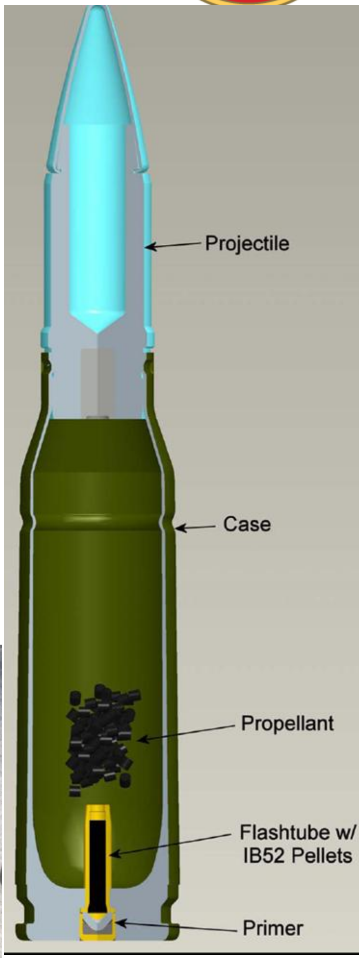
Modified Ammunition Configuration

- General Information
  - All tests to be repeated
  - 1 or 2 Cans per test
  - 2 Groups of 15 linked rounds per can
  - Rounds are modified M793 configuration
  - Energetic components
    - M115 primer
    - IB-52 pellets
    - PAP-8386 propellant
  - Projectiles are inert
    - Not traced



PA125 Ammunition Container

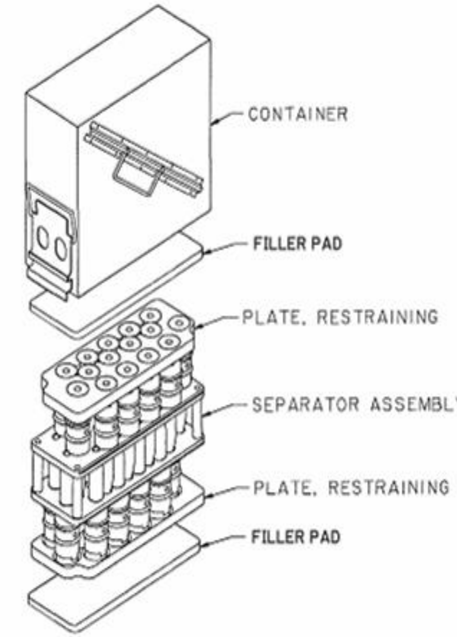


M793

Ammunition Configuration

Vented Cases

Vented PA125 Containers



PA125 Ammunition Container

Fast Cook-Off

The liquid fuel fire (FCO) tests were conducted IAW MIL-STD-2105C, 14 Jul 2003 and STANAG 4240(Edition 2), 15 Apr 2003 and the test plan to determine and evaluate the response of the test item to a rapid heating in a liquid fire, which completely engulfs the PA125 container packed with 30 rounds of M793 25-mm vented cartridge cases.

- Fuel Basin 14' W x 20'L to be filled with 1000 gallons JET A1 Fuel. From the control room, the JET A fuel was ignited underneath the test unit.
- Minimum of 30 minutes complete engulfment
- Average flame Temperature 1733-1754°F minimum
- One (1) ammunition container per test
- Container centered approximately 36 in. above fuel pan
- Four(4) thermocouples to be placed on each container
- One (1) on each side of the container
- Four (4) blast transducers positioned as shown on next page
- Two (2) video cameras positioned as shown on next page
- Temperature profile and reaction history to be recorded.
- After testing visual inspection and mapping was performed after the safety waiting time.

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Fast Cook-Off – Test Set-Up

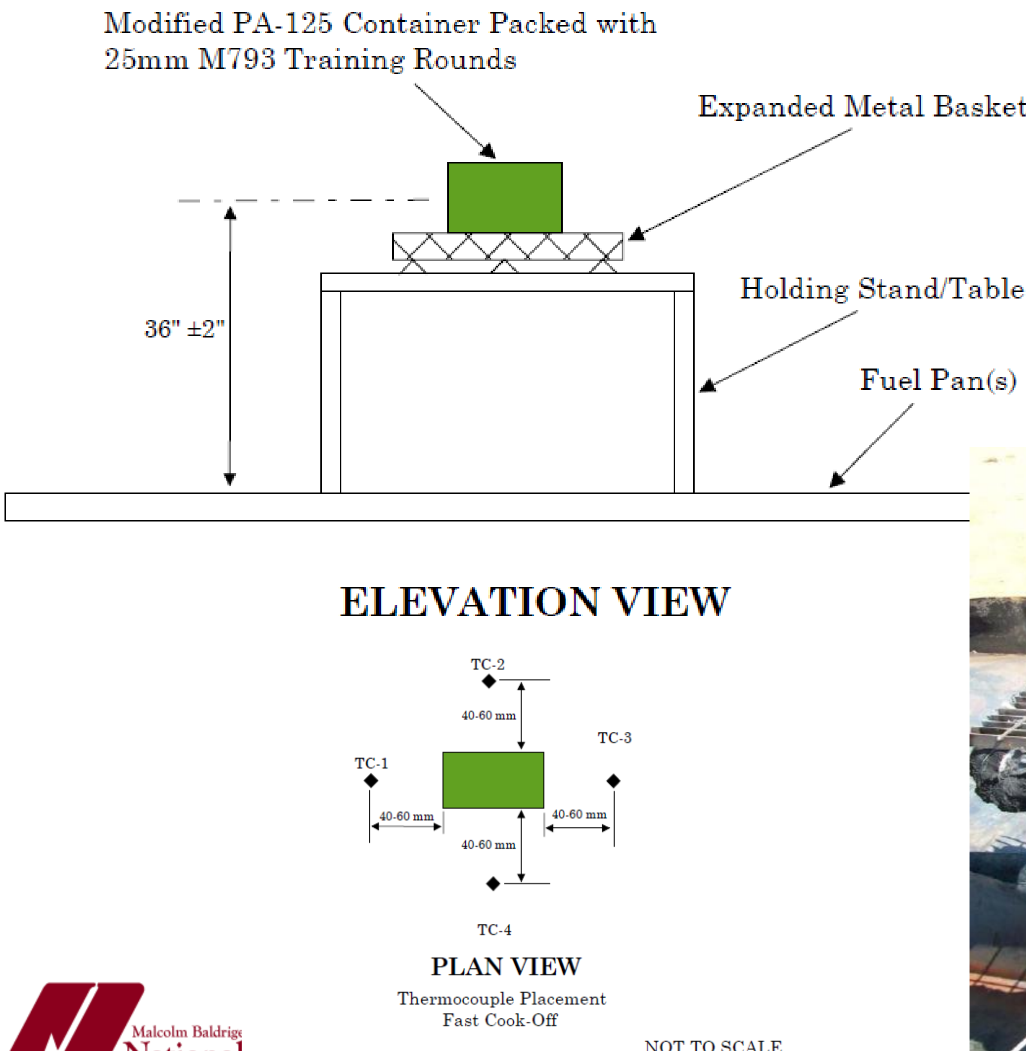

Figure 5
Fast Cook-Off Test Setup

Post Test Results
T/S 151-180 / Test 2
Fast Cook-Off Test

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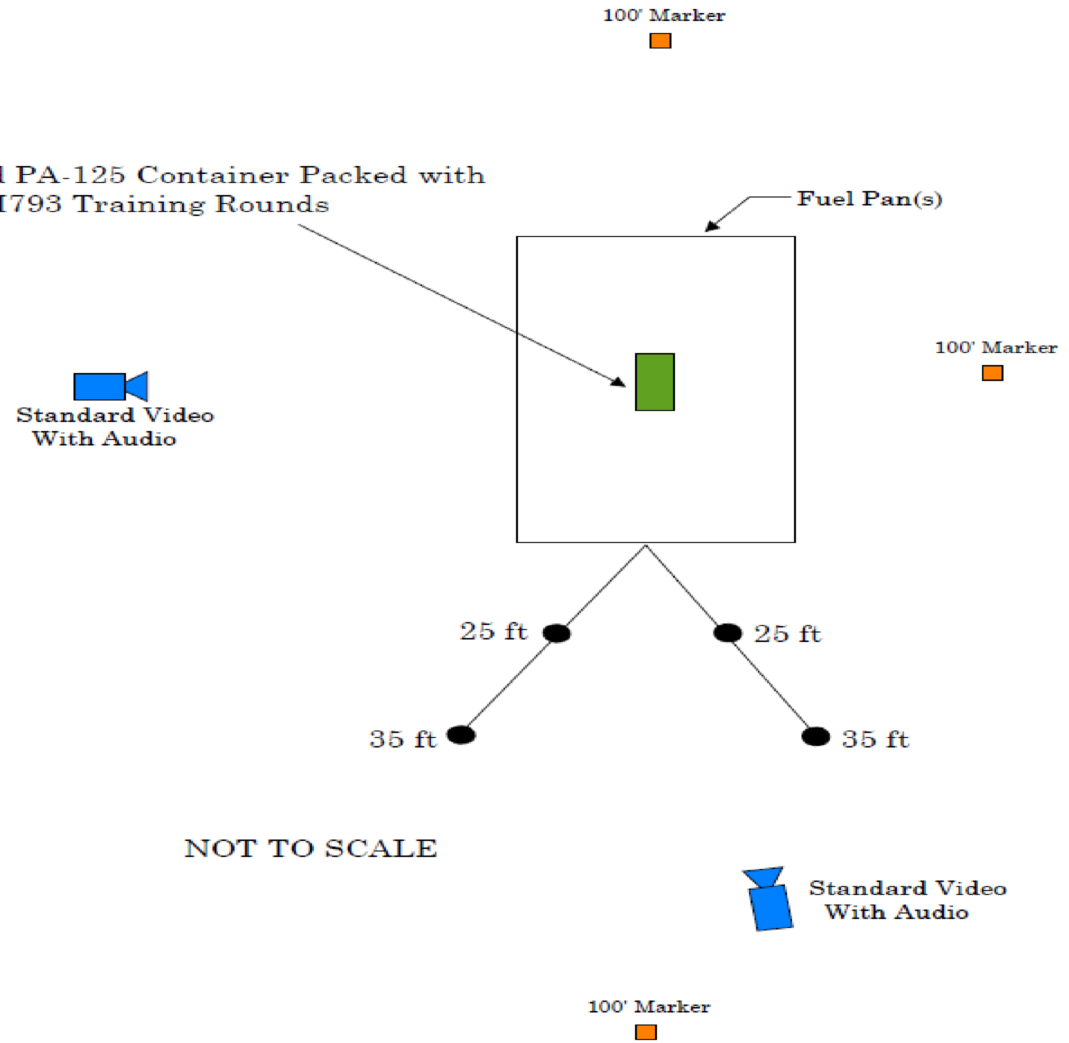
Fast Cook-Off – Test Set-Up



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Fast Cook-Off – Test Set-Up

Test Setup
T/S 121-150 / Test 1
Fast Cook-Off Test

Test Setup
T/S 121-150 / Test 1
Fast Cook-Off Test

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Fast Cook-Off – Test Result

S/N: 121-150			
Fuel Type	Jet-A	**Avg. Flame Temp**	1754°F
Fuel Quantity	1000 Gallons	**Time to reach 1022°F**	12 Seconds
Pan Dimensions	14'W x 20'L		
Reaction Type	Type IV Reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	25'	0	4	25'	0
2	35'	0	5	35'	0

Results: At 1810 on 3/18/10 the fire was ignited. The first reaction was approximately 2 minutes into the fire and continued for approximately 3 minutes. There was no debris found out past 61'. There was no recordable blast pressure. The fire burned for approximately 30 minutes. All explosives were consumed except for one Live Primer End Cap. The High Vent side of the PA 125 Container was facing 90°.

Post Test Results
T/S 121-150 / Test 1
Fast Cook-Off Test

se.

Post Test Results
T/S 121-150 / Test 1
Fast Cook-Off Test

Fast Cook-Off Test Result

S/N: 151-180

Fuel Type	Jet-A	**Avg. Flame Temp**	1733°F
Fuel Quantity	1000 Gallons	**Time to reach 1022°F**	32 Seconds
Pan Dimensions	14'W x 20'L		
Reaction Type	Type IV Reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	25'	0	4	25'	0
2	35'	0	5	35'	0

Results: At 1922 on 3/19/10 the fire was ignited. The first reaction was approximately 3 minutes into the fire and lasted approximately 1 minute. There was no debris found out past 70'. There was no recordable blast pressure. The fire burned for approximately 30 minutes. All explosives were consumed except for one Live Primer End Cap. The High Vent side was facing 270°.

Post Test Results
T/S 151-180 / Test 2
Fast Cook-Off Test

Post Test Results
T/S 151-180 / Test 2
Fast Cook-Off Test

Slow Cook-Off

The Slow Cook-Off (SCO) tests were conducted IAW MIL-STD-2105C, 14 Jul 2003 and STANAG 4240(Edition 2), 15 Apr 2003 and the test plan to determine and evaluate the response of the PA125 container packed with 30 rounds of M793 25-mm vented cartridge cases when subjected to a gradual increasing heat temperature at a rate of 50 F per hour until reaction occurs.

A 4' X 4' expanded metal grate was placed on top of concrete blocks and covered with 1" high temperature insulation.

One (1) 10" X 20" X ½" thick mild steel witness plate was placed on top of the high temperature insulation. A second witness plate 10" x 18" x ½" thick was placed on the side of the Test Unit.

A calibration Test of the blast transducers was performed by detonating a 1 pound sphere of C-4 explosives.

Test Unit was placed on top of the bottom witness plate.

The Test Unit S/N's 241-270 were instrumented with thermocouples as referenced in Table 3 and Figure 10.

Two (2) standard video cameras, one (1) internal video and four (4) blast transducers were positioned as referenced in Figure 11.

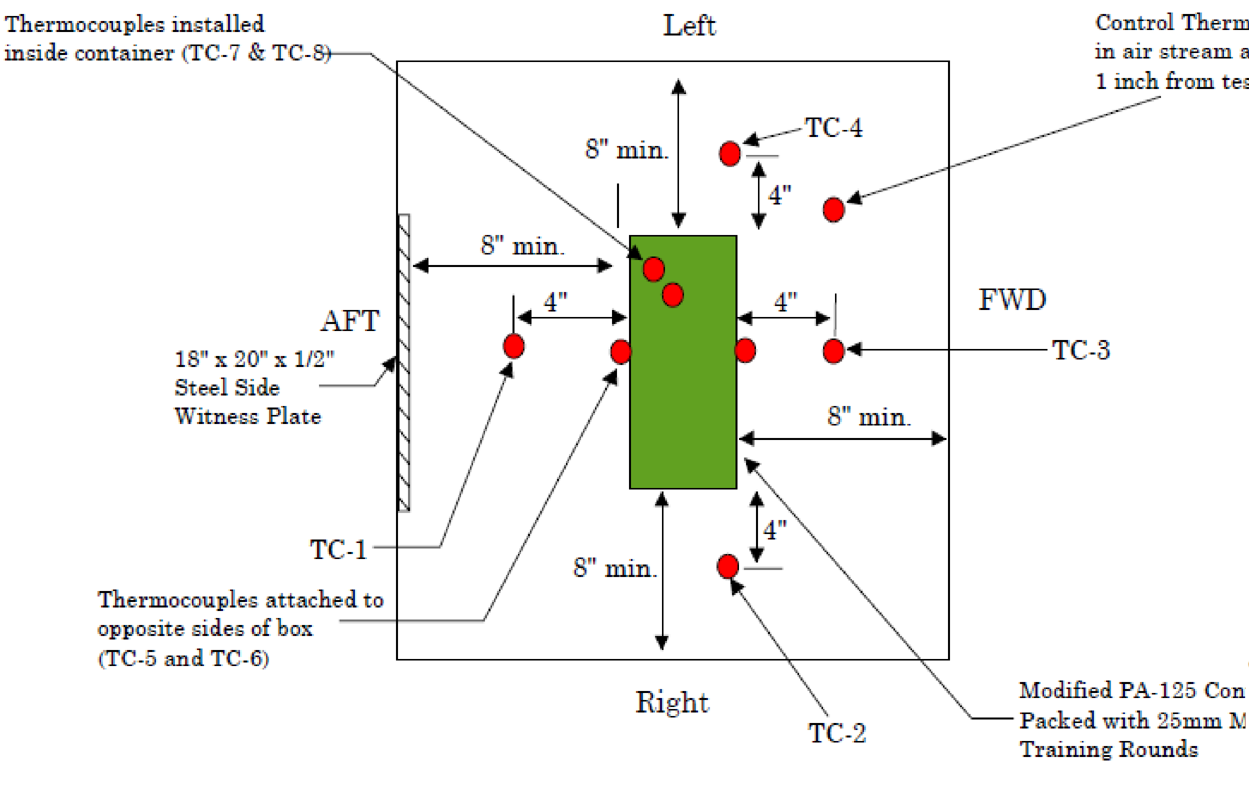
The oven (40" tall x 36" wide x 46" long) was placed over the Test Unit.

The internal temperature of the oven was ramped to +122°F over a period of one (1) hour.

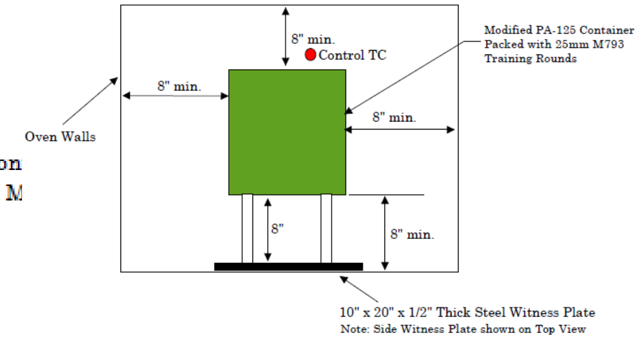
Once at a temperature of +122°F, the eight (8) hour minimum soak was performed.

Upon completion of the eight (8) hour minimum soak at +122°F, the internal temperature of the chamber was ramped at a rate of +6°F per hour until reaction occurs.

Slow Cook-Off Test Set-Up



Top View (Bottom witness plate not shown)



Elevation View (rotated 90° for clarity)

NOT TO SCALE

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Slow Cook-Off Test Result

S/N: T/S 241-270			
Bottom Witness Plate	10" x 20" x 0.5"	**Witness Plate Damage**	No Damage
Side Witness Plate	10" x 18" x 0.5"	**Witness Plate Damage**	No Damage
Oven Size:	40" Tall x 36" Wide x 46" Long		
Reaction Type	Type V reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	25'	0	3	25'	0
2	35'	0	4	35'	0

Test Results: On 3/26/10 at 0210 the first reaction occurred at approximately 276.5°F. There was a small pop and then a fire started all of the rounds went but did not breach the oven. The oven would not continue to heat so the test was ended. All pieces remained inside the oven at ground zero. There was no damage to either witness plate. All debris mapped and pictures taken. The test article was oriented with the handles pointing to 0° and 180°, and the blowout ports to 90° and 270°.

T/C	Location	Reaction Temperature (°F)
1	Air Temperature – Aft end high vent side 90°	266.0
2	Air Temperature – Right side 0°	267.3
3	Air Temperature – Forward end low vent side 270°	267.4
4	Air Temperature – Left side 90°	265.8
5	Skin Temperature – Aft end high vent side 9	[illegible]
6	Skin Temperature – Forward end low vent s	[illegible]
7	Internal Temperature – Right side 0°	[illegible]
8	Internal Temperature – Left side 180°	[illegible]

Post Test Results
T/S 241-270 / Test 1
Slow Cook-Off Test

Post Test Results
T/S 241-270 / Test 1
Slow Cook-Off Test

Post Test Results
T/S 241-270 / Test 1
Slow Cook-Off Test

Slow Cook-Off – Test Set-Up

Test Setup
T/S 271-300 / Test 2
Slow Cook-Off Test

Test Setup
T/S 271-300 / Test 2
Slow Cook-Off Test

se.

Slow Cook-Off – Test Result

S/N: T/S 271-300			
Bottom Witness Plate	10” x 20” x 0.5”	**Witness Plate Damage**	No Damage
Side Witness Plate	10” x 18” x 0.5”	**Witness Plate Damage**	No Damage
Oven Size:	40” Tall x 36” Wide x 46” Long		
Reaction Type	Type IV reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	25’	0	3	25’	0
2	35’	0	4	35’	0

Test Results: At 2305 on 3/30/10 the container was breached by a round going off. The container caught on fire and all rounds proceeded to go off but remained inside the oven. The lid was blown off of the container and a few rounds came out of the container. There was no visual damage to the witness plates. The oven was not breached and remained in tact. The temperature at time of reaction was 270.0°F. The container was oriented with the handles to 0° and 180°, and the blow out ports to 90° and 270°.

T/C	Location	Reaction Temperature (°F)
1	Air Temperature – Aft end high vent side 90°	269.1
2	Air Temperature – Right side 0°	270.4
3	Air Temperature – Forward end low vent side 270°	267.9
4	Air Temperature – Left side 90°	267.4
5	Skin Temperature – Aft end high vent side 90°	265.6
6	Skin Temperature – Forward end low vent side 90°	266.6
7	Internal Temperature – Right side 0°	270.2
8	Internal Temperature – Left side 180°	268.9

Post Test Results
T/S 271-300 / Test 2
Slow Cook-Off Test

Post Test Results
T/S 271-300 / Test 2
Slow Cook-Off Test

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Bullet Impact

The bullet impact tests were conducted IAW MIL-STD-2105C, 14 July 2003 and STANAG 4241 (Edition 2), 15 April 2003 to determine and evaluate the response of the test item to the impact of a .50 caliber Type M2 armor-piercing (AP) bullet traveling at a velocity of 2,790 ± 66 ft/s.

Projectile is .50 caliber type M2 armor-piercing (AP) bullet with a velocity of 2790±66 ft/sec.

Four (4) blast transducers were placed at a 45° angle to the rear of the Test Unit as referenced in Figure 4.

A calibration Test of the blast transducers was performed by detonating a 1 pound sphere of C-4 explosives.

The triple .50 cal guns were positioned, the test stand was constructed, and a piece of 10" x 20" x 1" thick mild steel witness plate placed on top.

Velocity screens were placed along the gun line.

A second 18" x 20" x 1" witness plate was placed on the side of the Test Unit 25" from the center.

One (1) high-speed digital camera and three (2) standard video cameras were positioned to monitor and record testing.

All instrumentation was connected and calibration shots were performed using .50 caliber Armor Piercing ammunition. All data met within the test specification.

Test Unit S/N's 301-330 were placed on top of the witness plate.

Three (3) .50 cal M2 AP rounds were fired at the Test Unit. The first and third bullets were aimed 2 ½" up from the bottom of the round and ¾" the second bullet centered between side walls as referenced in Figure 10.

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Bullet Impact –Test Set-Up

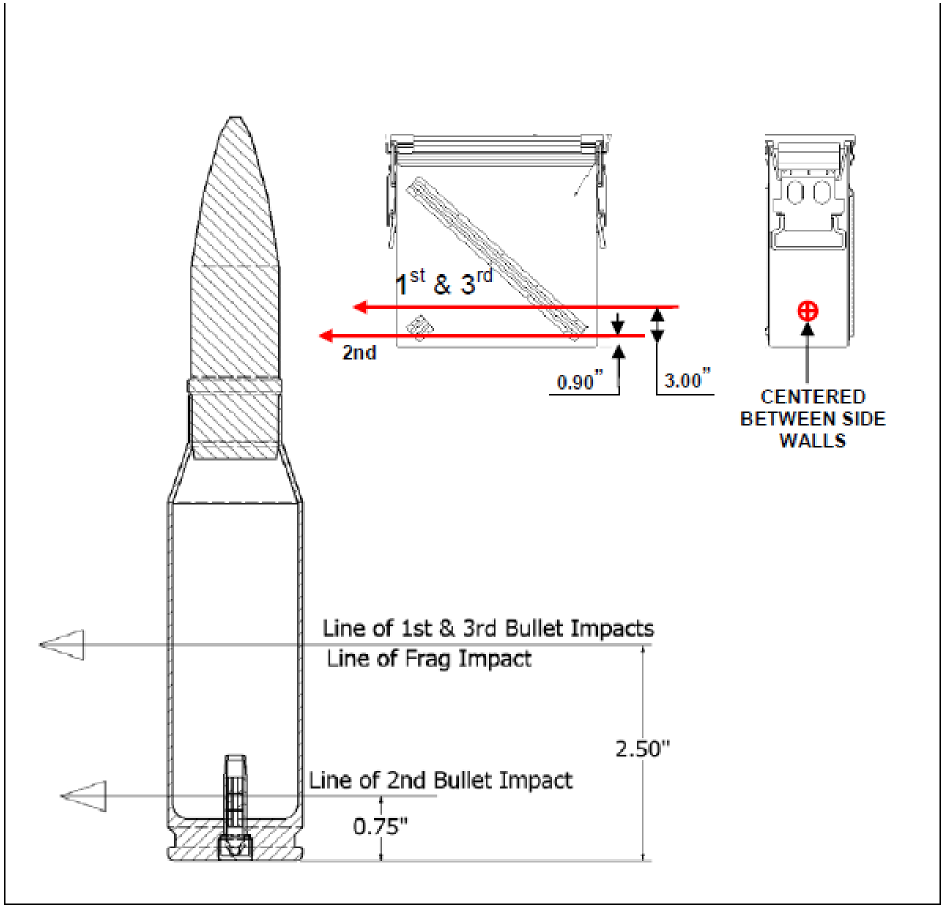

Figure 13
Aim Point and Shot Line for Bullet and Fragment Impact

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Bullet Impact – Test Set-Up

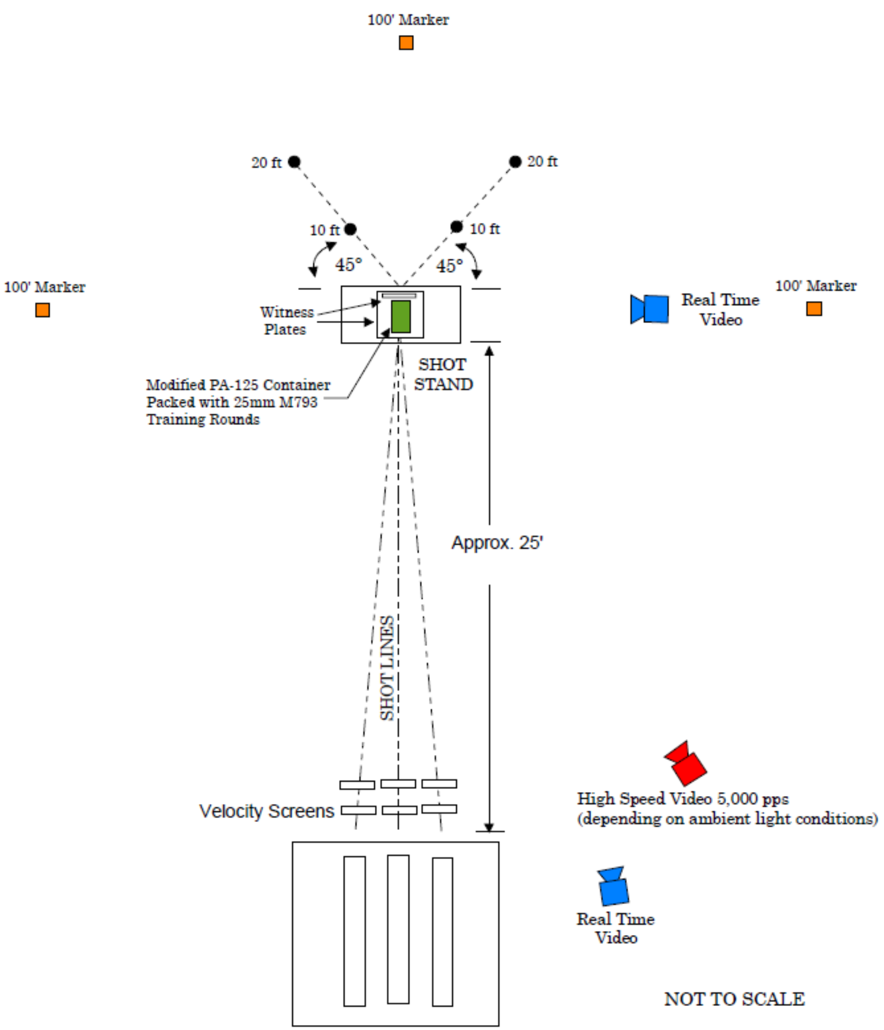
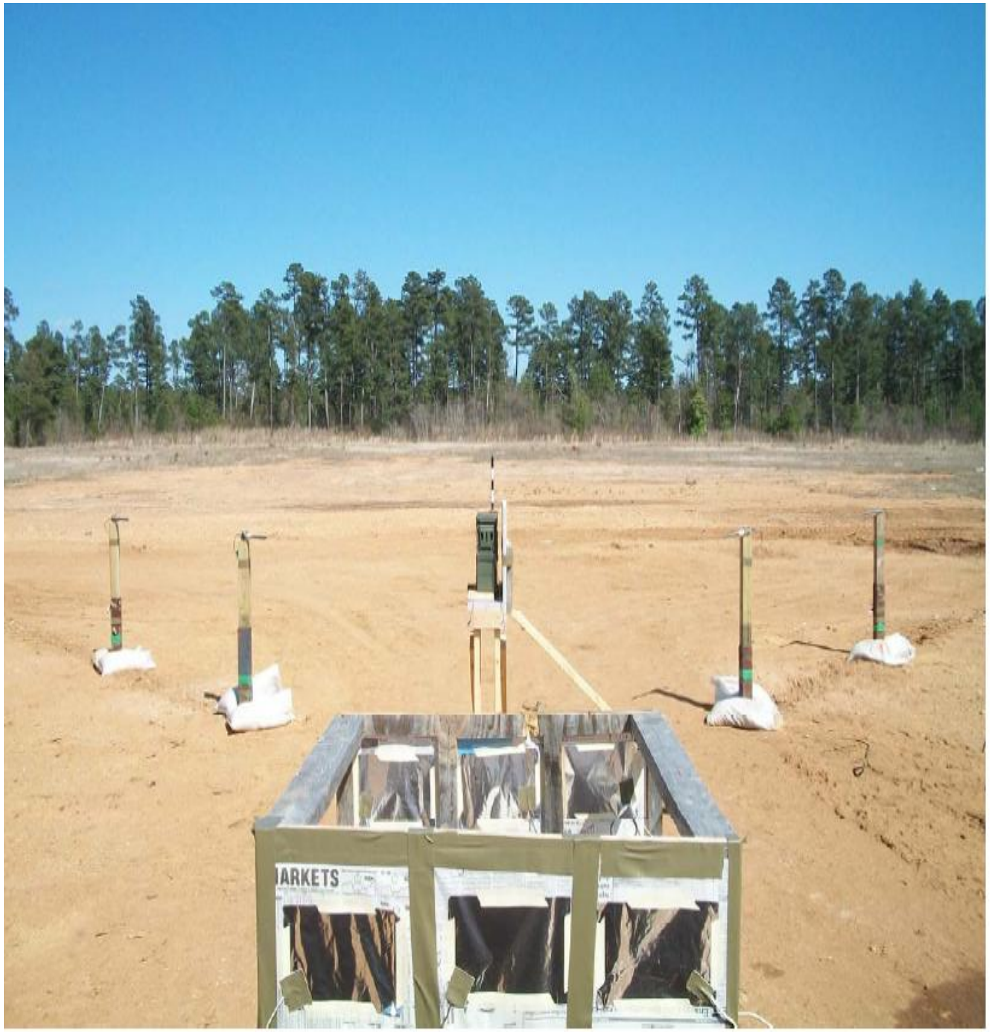


Figure 12
Bullet Impact Test Setup



Test Setup
T/S 331-360 / Test 2
Bullet Impact Test

Bullet Impact – Test Result

S/N: T/S 301-330			
Temperature	76°F	Relative Humidity	30%
Barometric Pressure	30.08 inHg	Wind Speed/Direction	2.0 mph/SW
Bottom Witness Plate	10"x20"x1" Thick Aluminum Plate	Witness Plate Damage	Burn/Gouge
Side Witness Plate	18"x20"x1" Thick Aluminum Plate	Witness Plate Damage	No Damage
Reaction Type	Type V Reaction	Bullet Type	Three (3) .50 Cal M2 AP

Bullet Velocity		Time	
Gun 1 Velocity	2840.9 Ft/Sec	Gun 1 to Gun 2	92.7 ms
Gun 2 Velocity	2854.8 Ft/Sec	Gun 2 to Gun 3	107.4 ms
Gun 3 Velocity	2835.5 Ft/Sec		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	9'9"	0	3	9'10"	0
2	19'9"	0	4	19'8"	0

Aim Point: 2.50" up from the bottom of the round and .75" for the second bullet centered between the side walls

Test Results: Unit was impacted with all three bullets. The shipping container remained on the shot stand. The units started to catch fire for a brief minute and then started to smoke for about four minutes. There was a few pieces found from 358° to 86° and out to 39' 7". The bottom witness plate had some burnt propellant on top of it and also had a gouge in it that looked like it was from a bullet. The side witness plate had no visual damage. The test article was oriented with the handles on the container to 90° and 270°.

Post Test Results
T/S 301-330 / Test 1
Bullet Impact Test

Post Test Results
T/S 301-330 / Test 1
Bullet Impact Test

Post Test Results
T/S 301-330 / Test 1
Bullet Impact Test

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Bullet Impact –Test Result

S/N: T/S 331-361			
Temperature	78°F	Relative Humidity	28%
Barometric Pressure	30.03 inHg	Wind Speed/Direction	5.0 mph/SW
Bottom Witness Plate	10"x20"x1" Thick Aluminum Plate	Witness Plate Damage	No Damage
Side Witness Plate	18"x20"x1" Thick Aluminum Plate	Witness Plate Damage	Gouge
Reaction Type	Type V Reaction	Bullet Type	Three (3) .50 Cal M2 AP

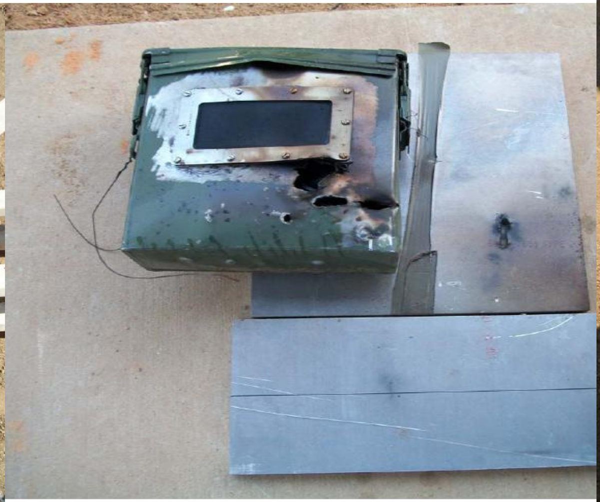
Bullet Velocity		Time	
Gun 1 Velocity	2801.1 Ft/Sec	Gun 1 to Gun 2	92.8 ms
Gun 2 Velocity	2830.2 Ft/Sec	Gun 2 to Gun 3	99.7 ms
Gun 3 Velocity	2846.3 Ft/Sec		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	10'2"	0	3	10'2"	0
2	20'2"	0	4	20'	0

Aim Point: 2.50" up from the bottom of the round and .75" for the second bullet centered between the side walls

Test Results: Unit was impacted with all three rounds. The unit and the shot stand both were knocked over from the impact of the rounds. The units started to burn and smoked for about two minuets. The bottom witness plate had no visual damage and the side witness plate had a gouge that looked to be from a bullet coming out of the container. All rounds remained in the container. The test article was oriented with the handles on the container to 90° and 270°.

Post Test Results
T/S 331-360 / Test 2
Bullet Impact Test



Post Test Results
T/S 331-360 / Test 2
Bullet Impact Test

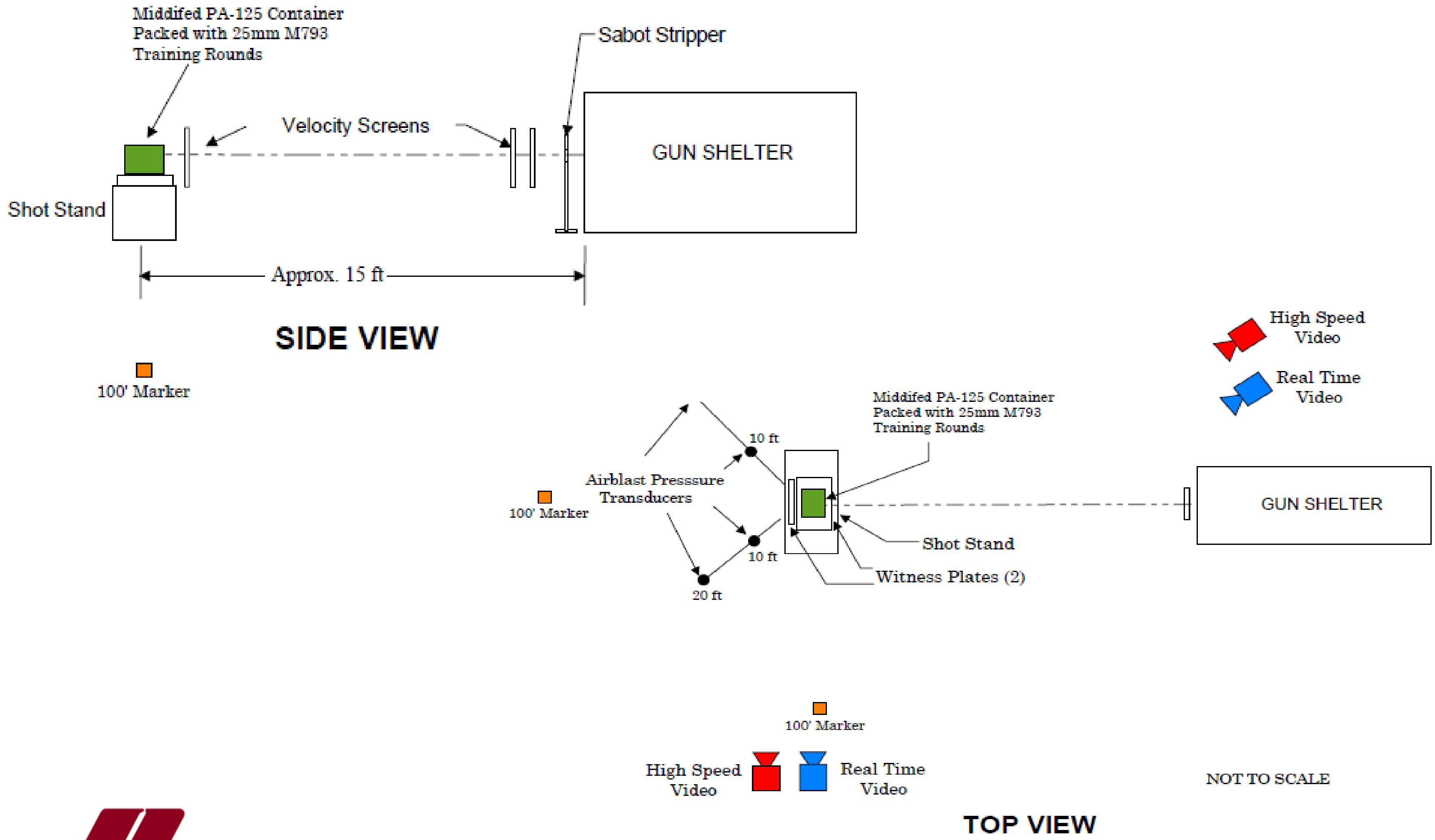
Post Test Results
T/S 331-360 / Test 2
Bullet Impact Test

Fragment Impact

The Fragment Impact (FI) tests were conducted IAW MIL-STD-2105C, 14 Jul 2003 and STANAG 4240(Edition 2), 15 Apr 2003 and the test plan to determine and evaluate the response of the PA125 container packed with 30 rounds of M793 25-mm vented cartridge cases to the impact of a 50-in mild steel conical fragment army fragment travelling at a speed of 8,300 fps.

- One (1) ammunition container per test
- Standard projectile is .50” diameter mild steel with a velocity of 8,300±300 ft/sec
- Gun To Be Located 15’ From Test Article
- Fragment gun positioned, test stand was constructed, and a 10”x20”x1” thick steel witness plate was placed on top of the shot stand
- One conical fragment was shot into the Test Unit. The aim point was handle side of the shipping container 3” from the bottom. Line of fragment impact will be the same as the bullet impact test
- Velocity screens placed along the gun line
- Four (4) blast transducers to the rear of the test units gages positioned as shown on next page
- Second aluminum witness panels located on the side of test unit.
- Two (2) video cameras and two (2) high-speed camera positioned as shown on next page

Fragment Impact Test Set-Up



Note: Cameras and airblast pressure transducers may be repositioned as needed.

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Fragment Impact Test Set-Up

Test Setup
T/S 211-240 / Test 2
Fragment Impact Test

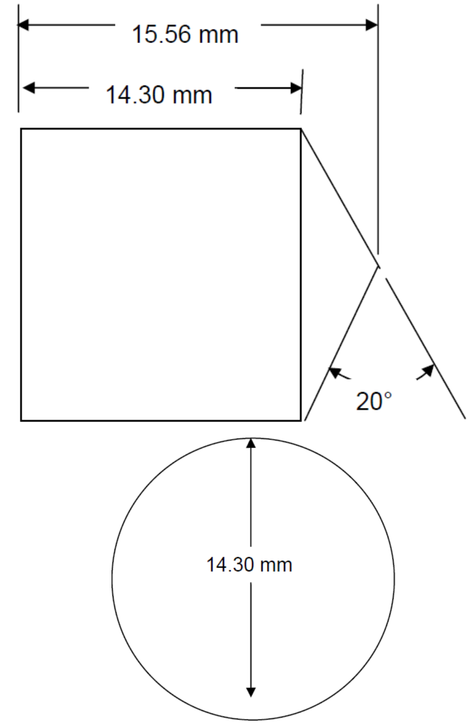


Figure 18
.50-in. mild steel conical army fragment

Fragment Impact Test 1 Result

S/N: T/S 181-210			
Temperature	52°F	**Relative Humidity**	47%
Barometric Pressure	30.09 inHg	**Wind Speed/Direction**	0 MPH
Bottom Witness Plate	10”x20”x1” Thick Mild Steel	**Witness Plate Damage**	Scarring/ Indentions
Side Witness Plate	18”x20”x1” Thick Mild Steel	**Witness Plate Damage**	Scarring/ Indentions
Reaction Type	Type IV Reaction	**Fragment Velocity**	8237.7 Ft/Sec

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	10’0”	0.96	3	10’0”	0.48
2	20’4”	0.33	4	19’11”	0.22

Aim Point:

Test Results: Test article was impacted on aim point and was knocked off of the test stand. The container split open and the rounds all came out with the packing materials. Both blow out ports were blown out of the container, with the lid staying attached. The furthest piece recovered was located at a distance of 90' 4" on the angle of 345°. There was minimal damage to the witness plates with some scarring and indentations from the test article. The test article was oriented with the handles on the container to 90° and 270°.

Post Test Results
T/S 1-30 / Test 1
Shaped Charge Jet Impact Test

Post Test Results
T/S 211-240 / Test 2
Fragment Impact Test

Fragment Impact Test 2 Result

S/N: T/S 211-240			
Temperature	81.3°F	**Relative Humidity**	27%
Barometric Pressure	30.00 inHg	**Wind Speed/Direction**	7.6mph/WSW
Bottom Witness Plate	10”x20”x1” Thick Mild Steel	**Witness Plate Damage**	Scratching
Side Witness Plate	18”x20”x1” Thick Mild Steel	**Witness Plate Damage**	Scratching
Reaction Type	Type IV Reaction	**Fragment Velocity**	8235.2 Ft/Sec

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	10’2”	2.03	3	10’3”	0.44
2	20’6”	0.4	4	19’11”	N/A

Aim Point:

Test Results: Test article was impacted on target and knocked off of the test stand. The container was split open with the rounds being strewn out of the container. The lid came off of the container and was recovered at a distance of 11' 1" on the respected degree of 90°. The blow out port frame broke off and landed at a distance of 196' 7" and at 25°. Rounds were found from 3° to 100° and out to 130' 8". The witness plates showed some slight scratching from the test article. Test article was set with the handles on the container to 90° and 270°.

Post Test Results
T/S 211-240 / Test 2
Fragment Impact Test

Post Test Results
T/S 211-240 / Test 2
Fragment Impact Test

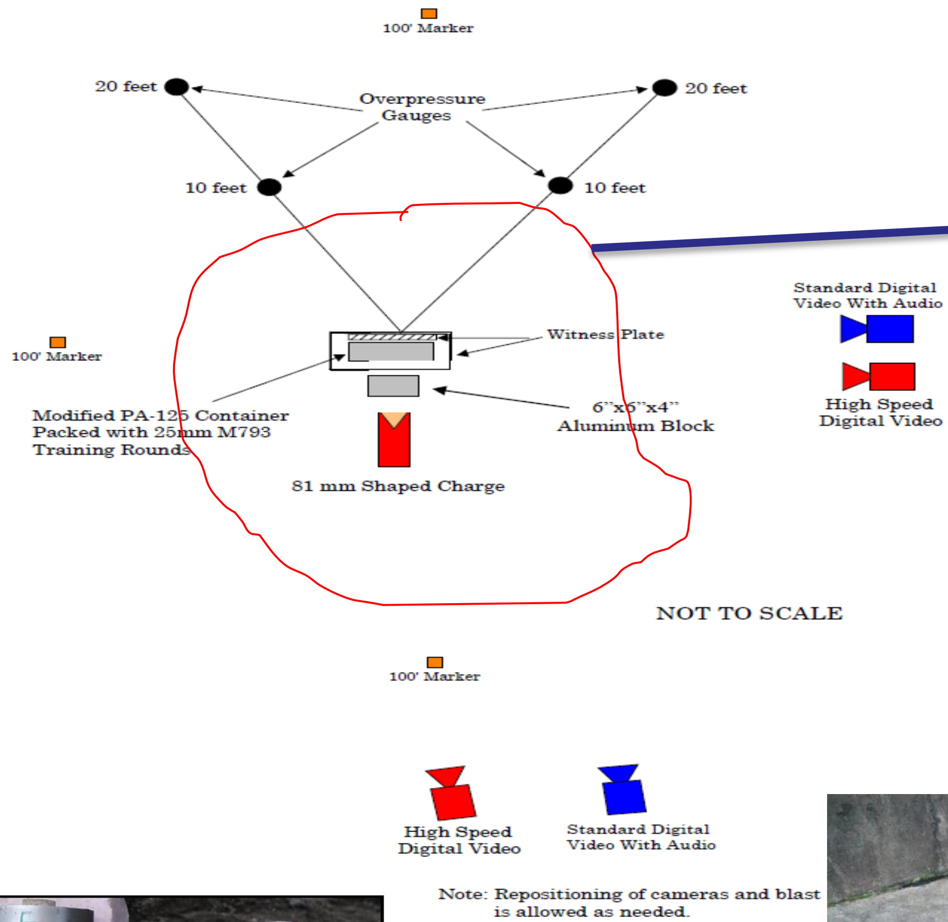
Shaped Charge Jet Impact

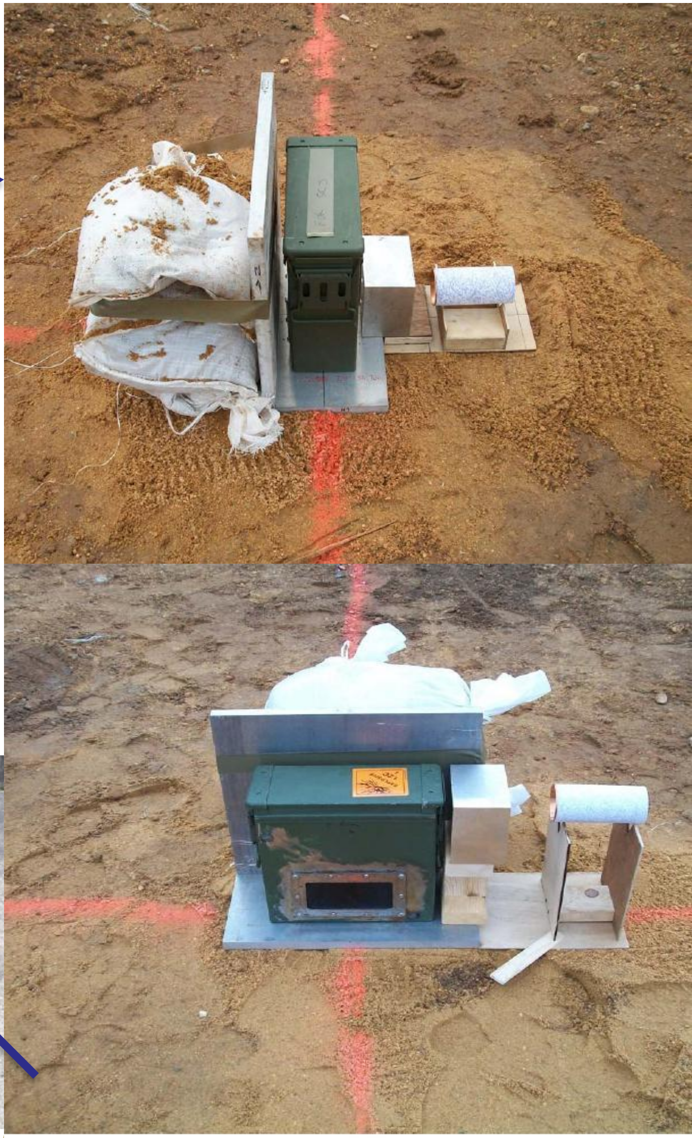
- The Shaped Charge Jet (SCJ) tests were conducted IAW MIL-STD-2105C, 14 Jul 2003 and STANAG 4240(Edition 2), 15 Apr 2003 and the test plan to determine and evaluate the response of the PA125 container packed with 30 rounds of M793 25-mm vented cartridge cases to the impact of an aluminum cased 81mm shaped charge loaded with LX-14 explosive.

- ❑ One (1) ammunition container per test
- ❑ 81mm shaped charge to be placed 243mm from the test article. Used an LX-14 explosives and a 4 inch conditioning plate between the 81mm SC and Test Article.
- ❑ Test Unit S/N's 1-30 placed on support stand with a 2" standoff. Aim point was 3"from the bottom of the shipping container and centered on the side.
- ❑ Four(4) blast transducers positioned 45^0 angle to the rear of the Test Unit as shown on the next page
- ❑ One (1)18" x 20" x 1" thick aluminum plate placed behind ammunition can
- ❑ Two (2) video cameras and two (2) high-speed camera positioned as shown on the next page
- ❑ One (1) RP detonator was secured to the firing line and placed in contact with the PIC of the 81mm SC and the RP-2 detonator held in place with a tape.

Shaped Charge Jet Impact Test Set-Up

Side View





Test Setup
T/S 31-60 / Test 2

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Shaped Charge Jet Impact Test Results

S/N: 1-30

Temperature	63.5°F	**Relative Humidity**	60%
Barometric Pressure	29.76 inHg	**Wind Speed/Direction**	2.1mph/SE
Back Witness Plate	18"x20"x1" Thick Mild Steel	**Witness Plate Damage**	Hole/Scratching/ Pitting
Bottom Witness Plate	10"x20"x1" Thick Mild Steel	**Witness Plate Damage**	Scratching/Pitting
Shaped Charge Size	81mm with copper liner and LX-14 explosive		
Reaction Type	Type IV Reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	10'0.5"	16.5	3	10'3"	15.2
2	20'3.5"	5.6	4	20'1"	5.6

Aim Point: 3" from the bottom of the can and centered on the side of the container

Test Results: Container was impacted on target with jet and separated into several pieces. The rounds were scattered from 0° to 360° with the furthest round being recovered at 347.67'. Both witness plates were located at 5' and 90° in tact but did have some scratching and pitting from debris, with the back witness plate having a hole from the jet in it. The orientation of the test was with the shape charge aimed at 90° and the blast pressure probes at 45° and 135°.

Test Setup
T/S 1-30 / Test 1
Shaped Charge Jet Impact Test

Post Test Results
T/S 1-30 / Test 1
Shaped Charge Jet Impact Test

USED.

Shaped Charge Jet Impact Test Results

S/N: 31-60

Temperature	67.8°F	**Relative Humidity**	76%
Barometric Pressure	29.73 inHg	**Wind Speed/Direction**	5.8mph/SE
Back Witness Plate	18"x20"x1" Thick Mild Steel	**Witness Plate Damage**	Scratching/Pitting
Bottom Witness Plate	10"x20"x1" Thick Mild Steel	**Witness Plate Damage**	Scratching/Pitting
Shaped Charge Size	81mm with copper liner and LX-14 explosive		
Reaction Type	Type IV Reaction		

Probe Number	**Distance**	**PSI**	**Probe Number**	**Distance**	**PSI**
1	10'1.5"	15.6	3	10'0"	14.0
2	20'4"	5.5	4	19'8"	5.9

Aim Point: 3" down from the top of the can and centered on the latch end of can

Test Results: Test article was impacted on target with the jet and separated into several pieces. The furthest piece that was recovered was found to be at 210.25' and at the angle of 15°. Rounds were scattered from 0° to 110°, and at a distance up to 127'. The witness plates were in tact and suffered minimal damage with pitting and scratching from debris. The shape charge was aimed at the end of the container 3 inches down from the top and centered. The container was oriented with the blow out ports to 0° and 180°.

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Post Test Results
T/S 31-60 / Test 2
Shaped Charge Jet Impact Test

Unconfined Sympathetic Detonation

- Test Set-Up is Identical to Shaped Charge Jet Impact Test
- Two (2) Ammunition Containers Per Test
- Four(4) blast transducers placed at 45^0 angle of the Test Unit.
- Two(2) high speed camera and two (2)std video camera. All instrumentation were connected and calibration shot performed using 1 pound C-4 explosives.
- One(1) 18”x20”x1” thick aluminum witness plate placed on level ground in the range set up as shown in the figure.
- Test Units placed next to each other
- One (1) blasting cap with a short piece of det cord was secured during firing. Blasting cap inserted into the fuze of th etest Unit and secured in place.
- From the safe area, blasting cap was detonated.

Unconfined Sympathetic Detonation Test Set-Up

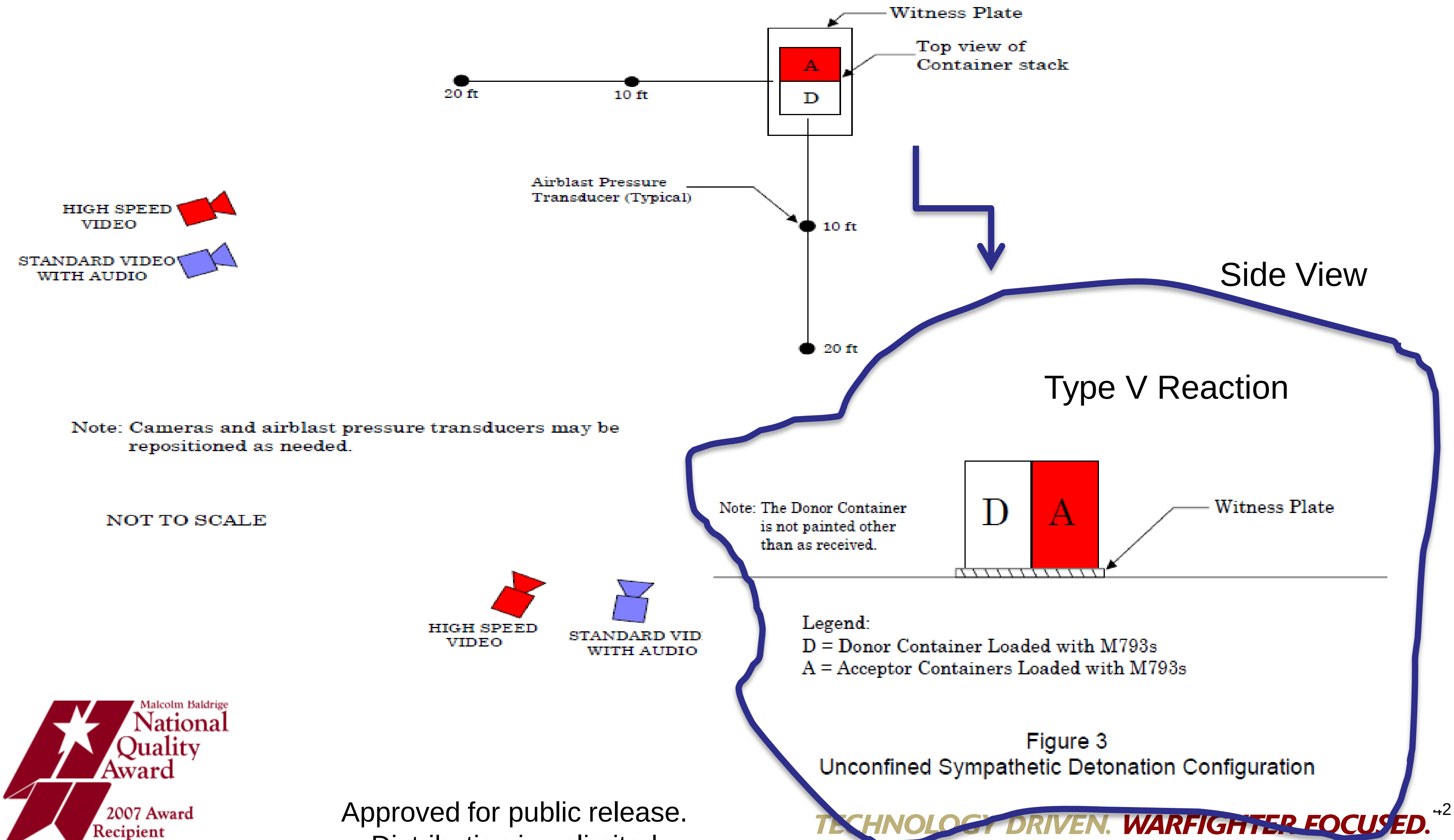

Figure 3
Unconfined Sympathetic Detonation Configuration

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Unconfined Sympathetic Detonation Test Set-Up

Test Setup
T/S 61-120
Unconfined Sympathetic Detonation Test

Unconfined Sympathetic Detonation Test Set-Up

S/N: 61-90 and 91-120			
Temperature	78.6°F	**Relative Humidity**	45%
Barometric Pressure	29.75 inHg	**Wind Speed/Direction**	0 MPH
Witness Plate	18"x20"x1"	**Witness Plate Damage**	No Damage
Reaction Type	Type V Reaction		

Probe Number	Distance	PSI	Probe Number	Distance	PSI
1	9'10.5"	1.0	3	10'1.5"	0.9
2	20'1.5"	0.4	4	19'11"	0.3

Test Results: The Donor round was detonated and caused one blowout port to blow out, and the other, that was facing the acceptor, to crack around the edge. The bottom of the donor box where round was detonated, was cracked and the primer housing was forced through the bottom of the can. The lid of the donor can remained latched, but was bulged which created a gap. All other rounds inside of the donor box remained inside of the box. The cases of the rounds surrounding the donor round were dented. Both Donor and Acceptor cans were laying on their sides after detonation. There was no damage to the acceptor cans except for small dents on the can from screws of the donor box. Units were oriented with the outer face of the Donor box at 315° and the outer face of the Acceptor box at 135°. There was no visual damage to the witness plate.

Recommended Testing

IM Test	MIL-STD-2105C	Actual IM Test Results	Test Parameters
Fast Cook-Off (Liquid Fuel/External fire)	V	IV	• Per STANAG 4240 (Edition 2) • Complete engulfment of the test item by the fire for a min of 20 min
Slow Cook-Off (Slow Heating)	V	V	• Per STANAG 4382 (Edition 2) • Test item to be pre -conditioned at +50°C for 8 hours prior to test or until it reaches equilibrium at +50°C (+122°F) • Oven temperature to be increased +6°F per hour from +50°C until reaction occurs
Bullet Impact	V	V	• Per STANAG 4241 (Edition 2). • 0.50 cal Type M2 AP bullet @velocity of 2790±66 ft/sec
Fragment Impact	V	IV	• Per STANAG 4496 (Edition 1). • 0.50 inch mild steel conical fragment@velocity of 8,300±300 ft/sec
Shaped Charge Jet Impact	II,IV,V	PASS	• Per STANAG 4526 (Edition 1, Ratification Draft 1) • 81mm shaped charge loaded with LX-14 and 4”Conditioning Plate bet ween SC and Test Article • Impact at the propellant location
Sympathetic Detonation	II,IV,V	PASS	• Per STANAG 4396 (Edition 2) • Required if SCJI test is a failure • 81mm shaped charge loaded with LX-14

CONCLUSIONS

- Ballistic Performance Test Results met the Mil Spec requirements.
- IM Test completed. Results show great IM improvement

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Leveraging Proven Systems to Develop a Guided Mortar for APMI

L109027_1

Approved for Public Release, PAO680-11, dated 26 Aug 11, 22 CFR 125.4(b)(13) applicable

Agenda

- Overview of Accelerated Precision Mortar Initiative (APMI) Program
- Mortar Guidance Kit (MGK) – ATK's Solution to APMI
- Leveraging Proven Systems – Design Methodology
- Development Timeline
- Summary of Test Results
- Current APMI Program Status

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Current Threat Requires Precision Capability

- Seeks cover in reinforced structures and vehicles
- Executes widely dispersed, often well-equipped, small unit operations
- Seeks sanctuary in urban and complex terrain
- Intentionally uses civilians as obstacles
- Exploits terrain and geography
- Capitalizes on media's response to U.S. military power.

Logistics challenges and the need to avoid collateral damage make it difficult, if not impossible, to provide indirect fire support using conventional munitions

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Accelerated Precision Mortar Initiative (APMI)

APMI responds to an Operational Need Statement (ONS) from troops deployed in Afghanistan

- Requested a responsive, all-weather precision 120mm mortar capability
- Need precision capability to
  - Minimize collateral damage
  - Respond to smaller, fleeting targets
  - Reduce risk to soldiers by providing first round effects, and
  - Reduce logistics burden

APMI is a complete precision system

- 120mm XM395 precision munition
- Fuze setter and fire control software

APMI provides affordable precision capability for the battalion commander

L109027_4

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APMI – A System of Systems

ATK

XM395, 120mm HE Cartridge

UMR Four Systems

M32 Lightweight Handheld Mortar Ballistic Computer Software v4.0

Mortar Fire Control System M150/M151 Dismounted Software v6.1

Precision Lightweight Universal Mortar Setter System (XM701 PLUMSS)

L109027_5

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XM395 Required Capabilities

- **Accuracy:** 10m Circular Error Probable (CEP) (Threshold); 5m (Objective)
- **Lethality:** Similar kinetic effects of current munitions
- **Maximum Range:** 6.2km (Threshold); 7.0km (Objective)
- **Guidance:** GPS Selective Availability Anti-Spoofing Module (SAASM)
- **Compatibility:** US 120mm Smooth Bore Mortar System

XM395 meets or exceeds all threshold requirements

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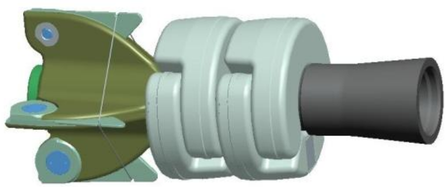
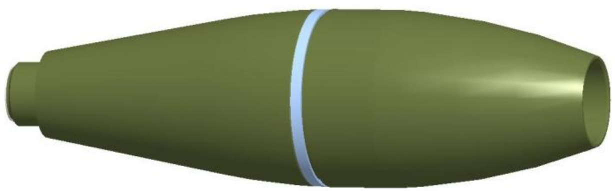
XM395 – JDAM for the Infantry Soldier

ATK

Folding Fin Tail	M934 Body	Guidance Fuze Assembly





Folding Fin Tail

- Proven folding fin design induces body spin
- Standard M1020 igniter
- Proven high-hat M47 charge increments

M934 Body

- Standard M934 body
- Obturating ring for pressure seal
- Comp B explosive fill
- Modified for deep intrusion fuze

Guidance Fuze Assembly

- PGK nose assembly with minor modifications
- Fixed canard assembly
- GPS receiver
- Safe & Arm
- PGK booster assembly
- Canard cover Enhanced Portable Inductive Artillery Fuze Setter (EPIAFS) interface

Direct application of ATK's PGK guidance fuze reduces cost, risk, and schedule

L109027_7

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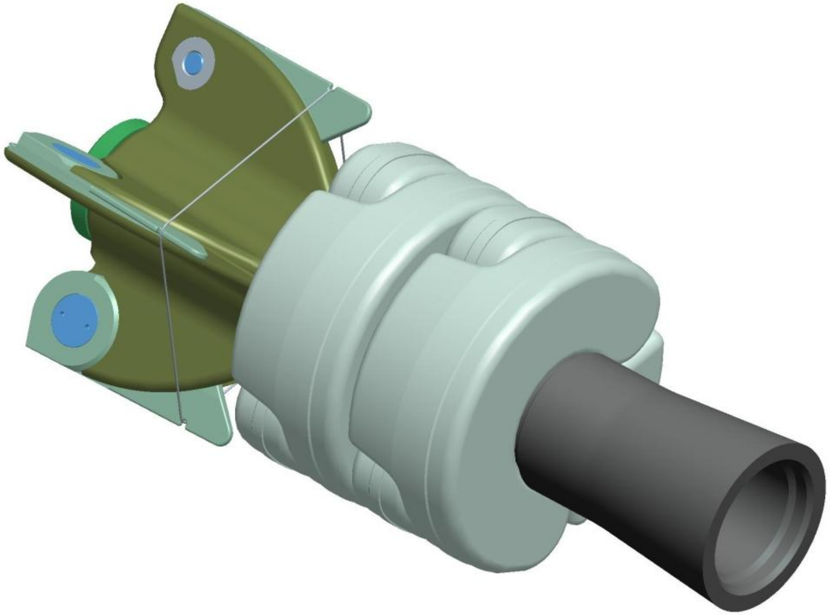
Leveraging Proven Systems – Fin Assembly

- Folding fin assembly developed under Precision Guidance Mortar Munition (PGMM) program
- Gun-hardened design proven successful in numerous PGMM shots
- Modified for MGK:
  - Shortened fin span
  - Optimized hub cant to improve spin rates



- ***Benefits of Leveraging:***
  - ***Proven design concept***
  - ***High confidence of passing qualification testing, such that separate fin/tail assembly testing wasn't necessary***

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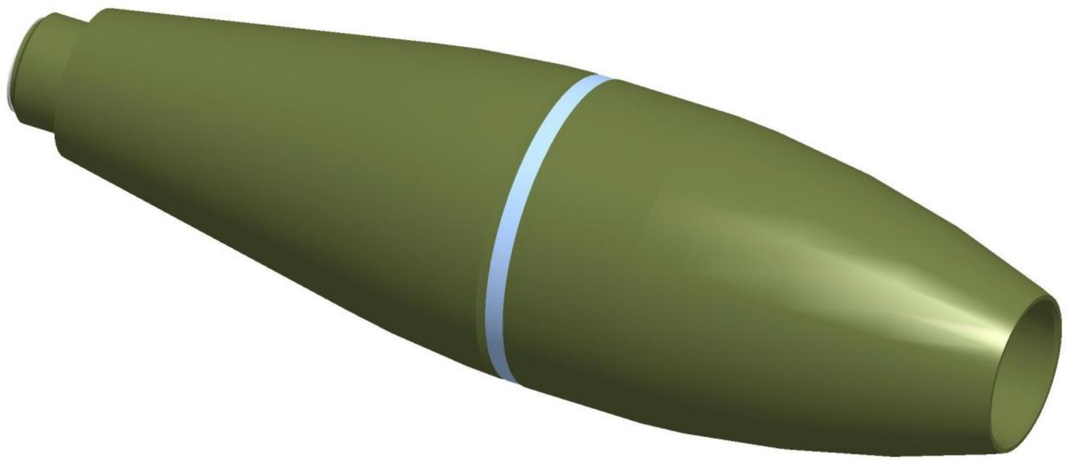
Leveraging Proven Systems – Mortar Body

ATK



- Modified for MGK – Explosive content machined away to create deep intrusion fuze well

- ***Benefits of Leveraging:***
  - ***Utilizes current M934 loaded mortar bodies***
  - ***Only requires simple modification to enable interface with MGK fuze***
  - ***Maintains lethality of existing M934 cartridge***

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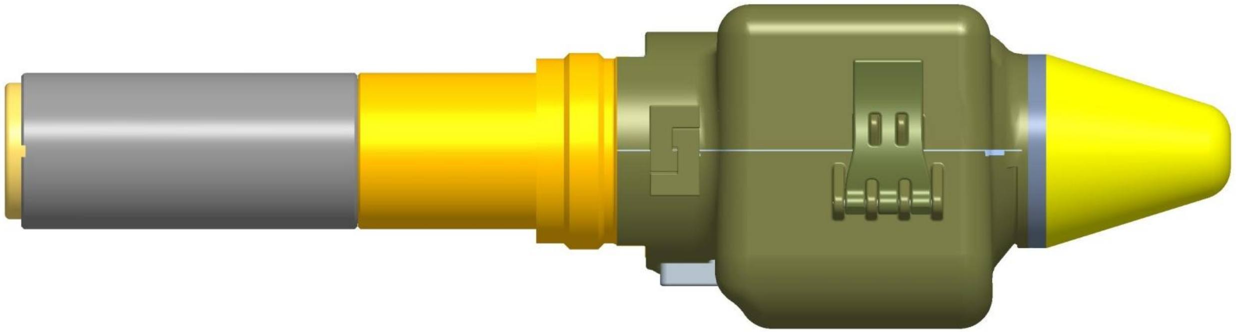
Leveraging Proven Systems – Fuze Assembly

ATK

- Fuze assembly adapted from Precision Guidance Kit (PGK), which is designed to guide a 155mm spin-stabilized projectile
- Modified for MGK:
  - Added thermal battery for power management
  - Integrated common mortar S&A to accommodate lower spin rates
  - Modified fuze thread interface
  - Optimized electronics for operating in a mortar environment

- ***Benefits of Leveraging:***
  - ***Utilize proven guidance, navigation, and control system***
  - ***System proven on PGK under more severe artillery launch environment***
  - ***Commonality of parts allows for purchasing efficiencies***



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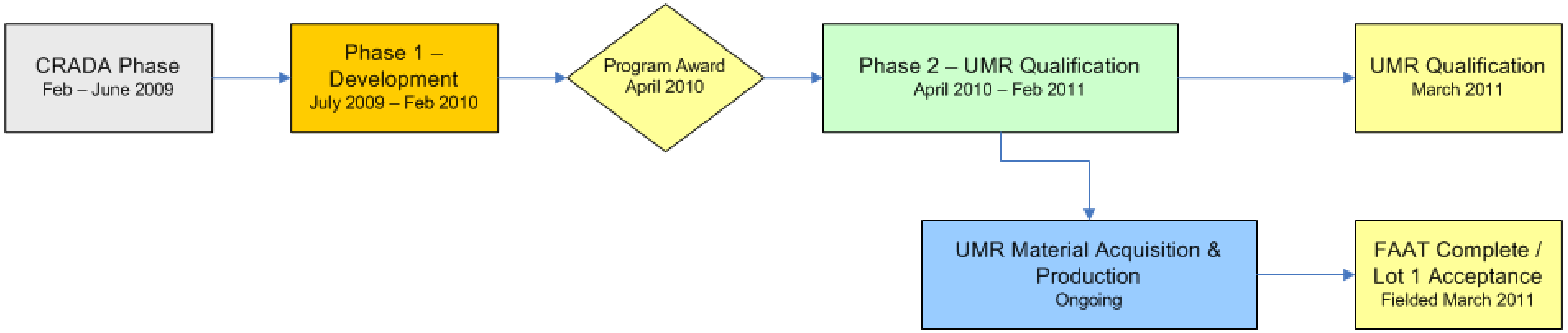
Reduced Development Timeline



- APMI is part of an Urgent Material Release (UMR) due to the critical operational need
- ATK was selected as winner of competitive demonstration in April 2010
- Completed UMR system qualification testing in February 2011
- UMR Qualification received and Lot 1 fielded to theater in March 2011
- ***Less than 1 year from Qualification Program Award to first unit fielded***

Use of existing proven systems allowed for rapid development to meet APMI urgent need request

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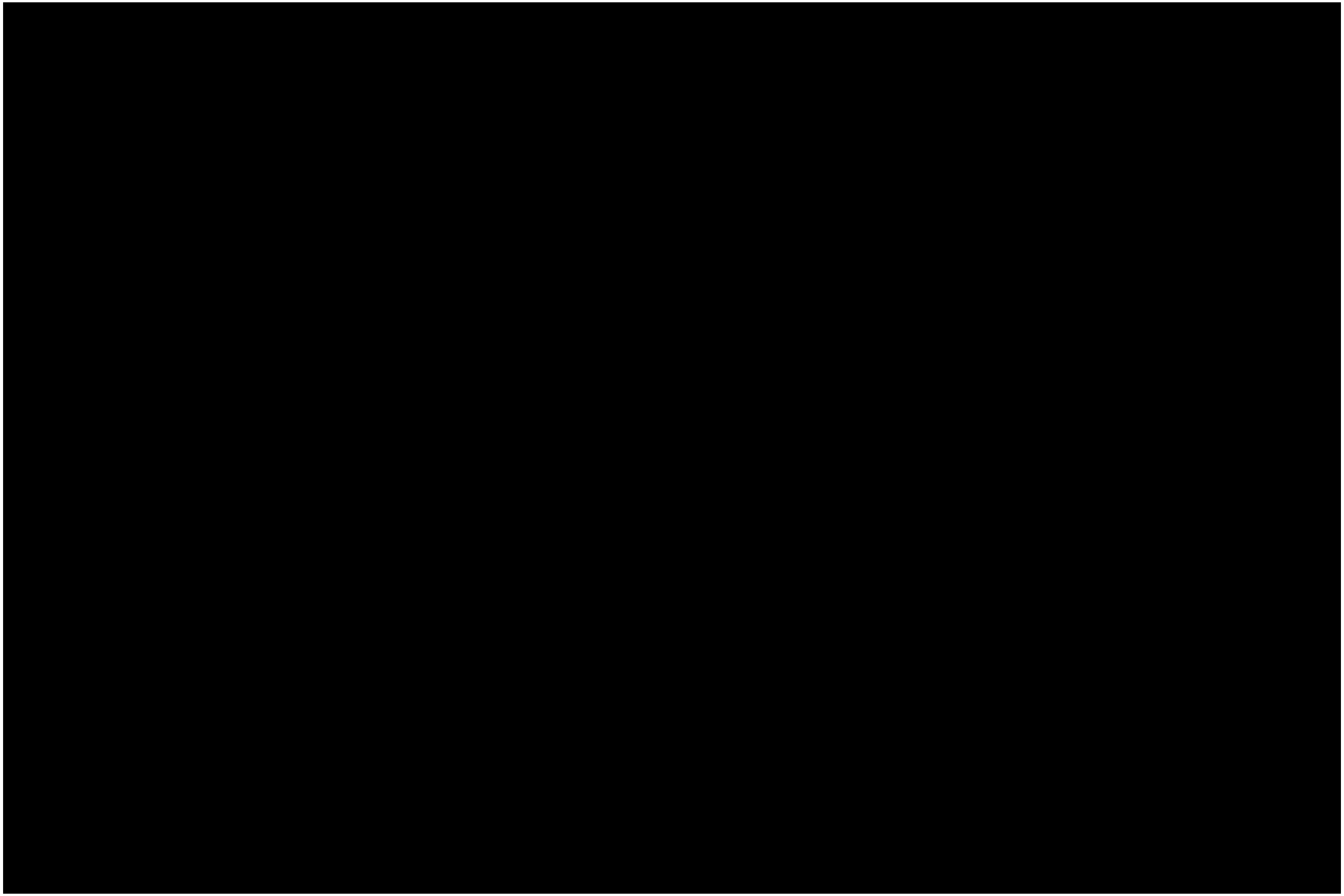
XM395 Video



L109027_12

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Qualification Testing Summary

Qualification Objectives

- **Demonstrate performance to CEP and reliability requirements** in operational environments such as temperature extremes, blowing rain, sand and dust, thermal shock, low altitude, high elevation
- **Demonstrate no safety issues** with cartridge after exposure to sequential environments representing extreme storage, transportation and handling; Electromagnetic Environmental Effects (E3) and other safety-related exposures; fuze safety – jolt, jumble, thermal shock, temperature and humidity cycling, vibration

Requirement	CEP $\leq$10 m	Reliability $\geq$90%
~60 Rounds Fired for Performance Scoring		
~150 Rounds Fired Overall in Qualification – **ALL SAFE**		

APMI meets or exceeds all threshold requirements

L109027_13

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XM395 Program Status

- ATK under contract for full UMR production quantity– February 2011
- Urgent Material Release of APMI approved – March 2011
- First lot of production hardware shipped to Afghanistan – March 2011
- Production builds continue at ATK facilities

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Summary

- APMI addresses an Urgent Material Release to provide the Army war fighter with a precision mortar capability
- ATK was able to respond rapidly to this request by integrating proven systems to shorten the lifecycle to field deployment
- Keys to Rapid Development and Deployment
  - Leveraging success of other programs by implementing proven design concepts
  - Optimizing existing systems to be more effective in a new application
- XM395 is now in production and in the field
- APMI gives the battalion commander needed precision capability
  - Effective attack of fleeting targets with limited collateral damage and first round effects
  - Fewer rounds to complete mission with significantly reduced logistics burden

APMI will change the way infantry units fight

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Contact Information

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Composite Sabot Technology For 105-mm Gun System

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

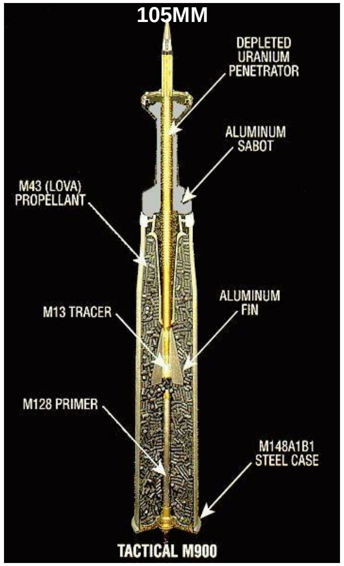
Velan Mudaliar

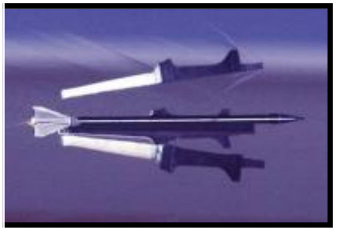
August 2011

UNCLASSIFIED

Background

- Long Rod Kinetic Energy(KE) Penetrator
  - Armor-Piercing defeat mechanism against enemy tanks.
- Sabot and Obturator Sub-Assembly
  - Provides sealing and structural support for KE Penetrator as projectile is accelerated inside gun tube upon ignition of cartridge's internal propellant bed
  - Obturator band separates and three segments of sabot are discarded upon exiting the muzzle of the gun tube
- Defeating Target
  - Long Rod KE Penetrator flies downrange towards the target and provides enough kinetic energy to pierce armor of enemy Tank.





<u>Contributors</u>

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ARL – Michael Minnicino, William Drysdale
General Dynamics Ordnance Tactical Systems (GD-OTS)
Alliant Tech Systems (ATK)

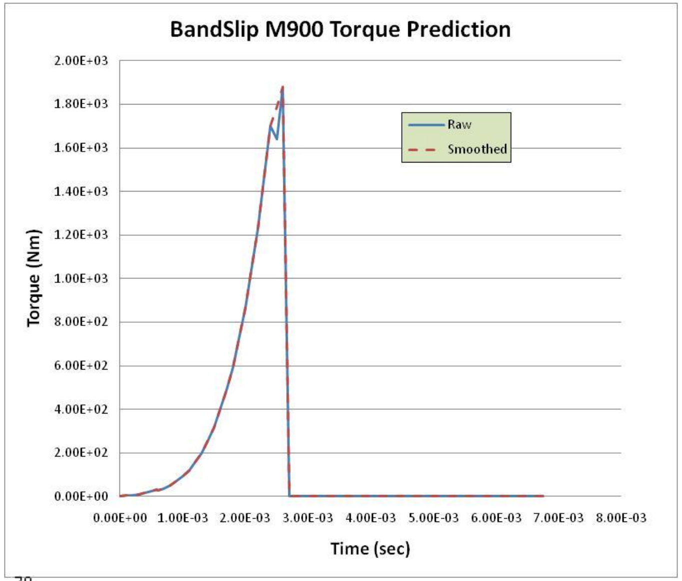
Performance Enhancement Opportunity

- Current 105-mm anti-armor ammunition uses aluminum sabot
- Lightweight composite sabot reduces the sabot mass, which increases velocity
  - Increased velocity delivers more kinetic energy to target or defeats enemy tanks at an extended range
  - Composite technology currently used in the 120MM smooth bore gun system.
- 105-mm gun system is rifled
  - The spin environment provides unique challenge to composite sabot technology
  - Survivability against spin environment favors strength enhancement in the hoop direction
  - Current manufacturing process for 120-mm composite sabot does not offer a good solution to provide strength in the hoop direction.
- ARDEC and ARL concepts should enable lightweight composite sabot structure to survive launch from 105-mm gun system
- Goal: Reduce sabot weight by at least 25%

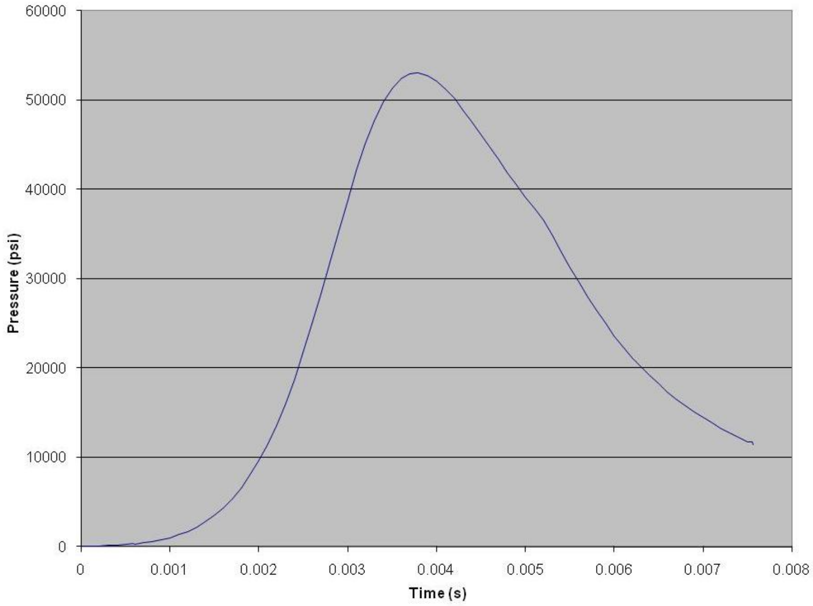
Bandslip Torque-Time History Estimation

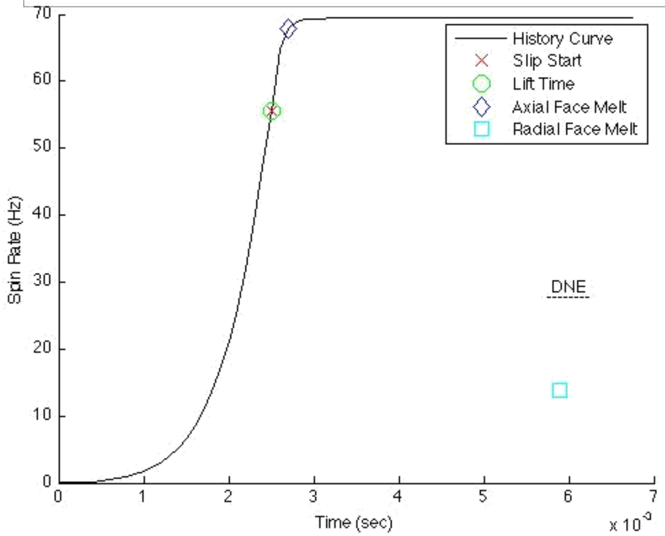
- Bandslip Input: projectile & gun geometry, projectile inertial properties, base pressure-time history
- Bandslip Output: projectile dynamic time histories

Torque-Time History



Base-Pressure-Time History

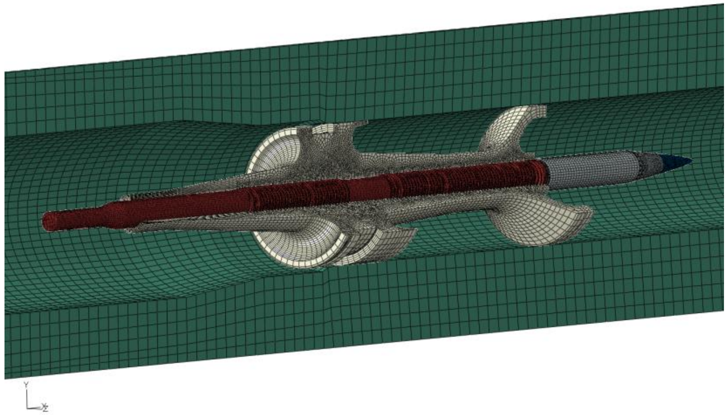


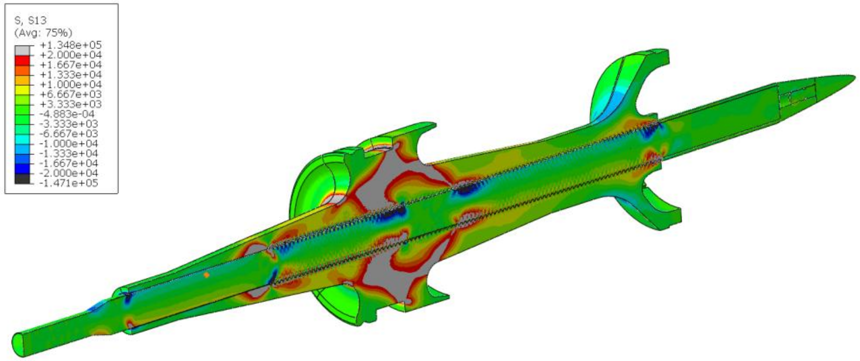


Spin Rate-Time History

Initial Modeling & Simulation

- Modeling & Simulation of spin environment in 105-mm rifled gun tube system is very complex.
  - Considers spin induction from the rifling of the gun system and the obturator with the slip band.
  - Empirical values were used for inputs
    - Initial torque when the obturator is engaged in the forcing cone of the gun tube
    - Spin data
- M&S Results:
  - Composite sabot structure lacks sufficient strength in the hoop direction to survive 105-mm gun launch.





Four Approaches Examined

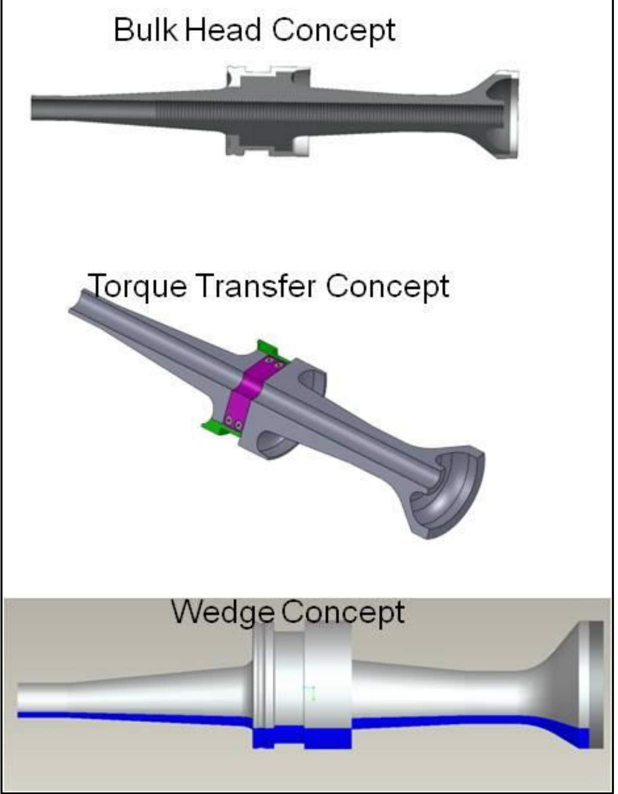
1. Reduce Torque
2. Increase Interlaminar Shear Strength
3. Rotate Architecture
4. Hybrid Concepts (Current Focus)

Hybrid Concepts

Concept description

- Bulk Head Concept
  - Provides a metallic surface for interfacing with the obturator/slip band
  - Protects composite sabot from exposure to propellant gases inside gun tube.
- Torque Transfer Concept
  - Same capabilities as Bulk Head Concept but with an additional function: transfer of torque to the penetrator.
- Wedge Concept
  - Transfers the torque along the length of the sabot.

Concept sketches



Current Status

•Contracts awarded to GD-OTS and ATK to develop full-scale prototypes of hybrid concepts discussed
•Live-fire testing of prototypes will take place at Yuma Proving Ground in October 2011
•Concepts will be refined based on test results and prototypes will be fabricated for final iteration of testing in early FY12

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M1002

120 mm Tank Ammunition Advanced Case System (ACS) Phase 2

Presented At
The National Defense Industrial Association's
46th Annual Gun and Missile Systems
Conference and Exhibition

31 August 2011

Jeff Berg
Project Engineer
120mm Training Ammunition
ATK

M865

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 383-11

Agenda

120 mm Tank Ammunition Advanced Case System (ACS)

- Background and Program Summary
- M865 Qualification
- M865 Transition to Production
- M865 Refurbishment to ACS Design
- M1002 Qualification
- Technical Challenge – M1002 case-to-obturator joint
- M1002 Recovery Plan
- M1002 Transition to Production
- Summary - Current Program Status
- Questions

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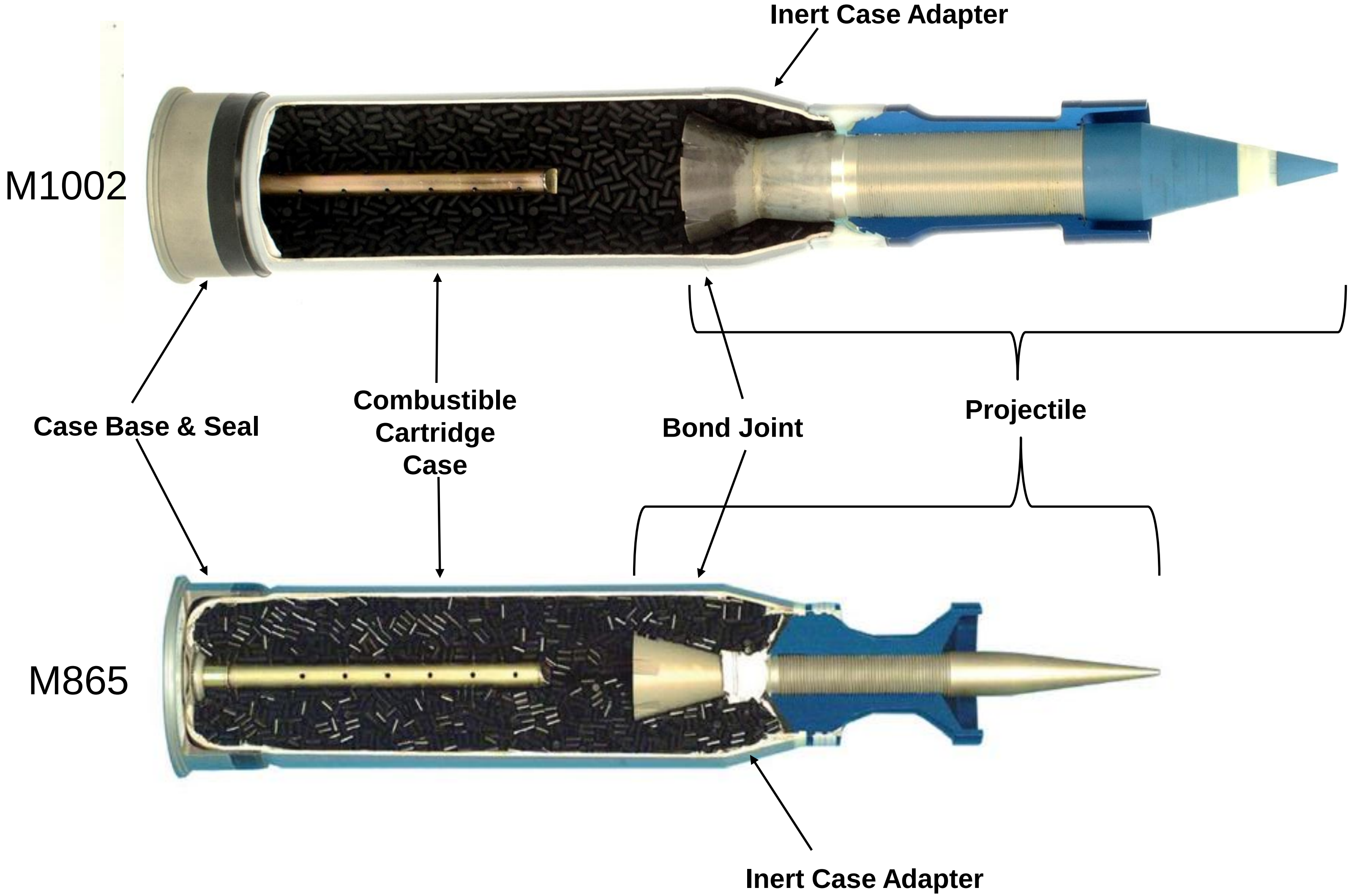
M1002/M865 Cartridge (current case design)



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Background

Advanced Case System (ACS)

- **Program**:
  - **Product Manager Large Caliber Ammunition: Program Management and Guidance**
  - **Joint Munitions Command (JMC): Executes and Manages the 120mm Multi-Year contracts**

- **Members: PM-MAS, PM-LC, JMC, ARDEC, ATK, GD-OTS, Esterline Defense Technologies (EDT), American Ordnance**

- **Objective: Redesign cartridge to eliminate a contributing cause of damaged rounds during training.**
  - **Relocate the cartridge bond joint**
  - **Qualify the modified cartridge design**
  - **Transition into production with qualified design**

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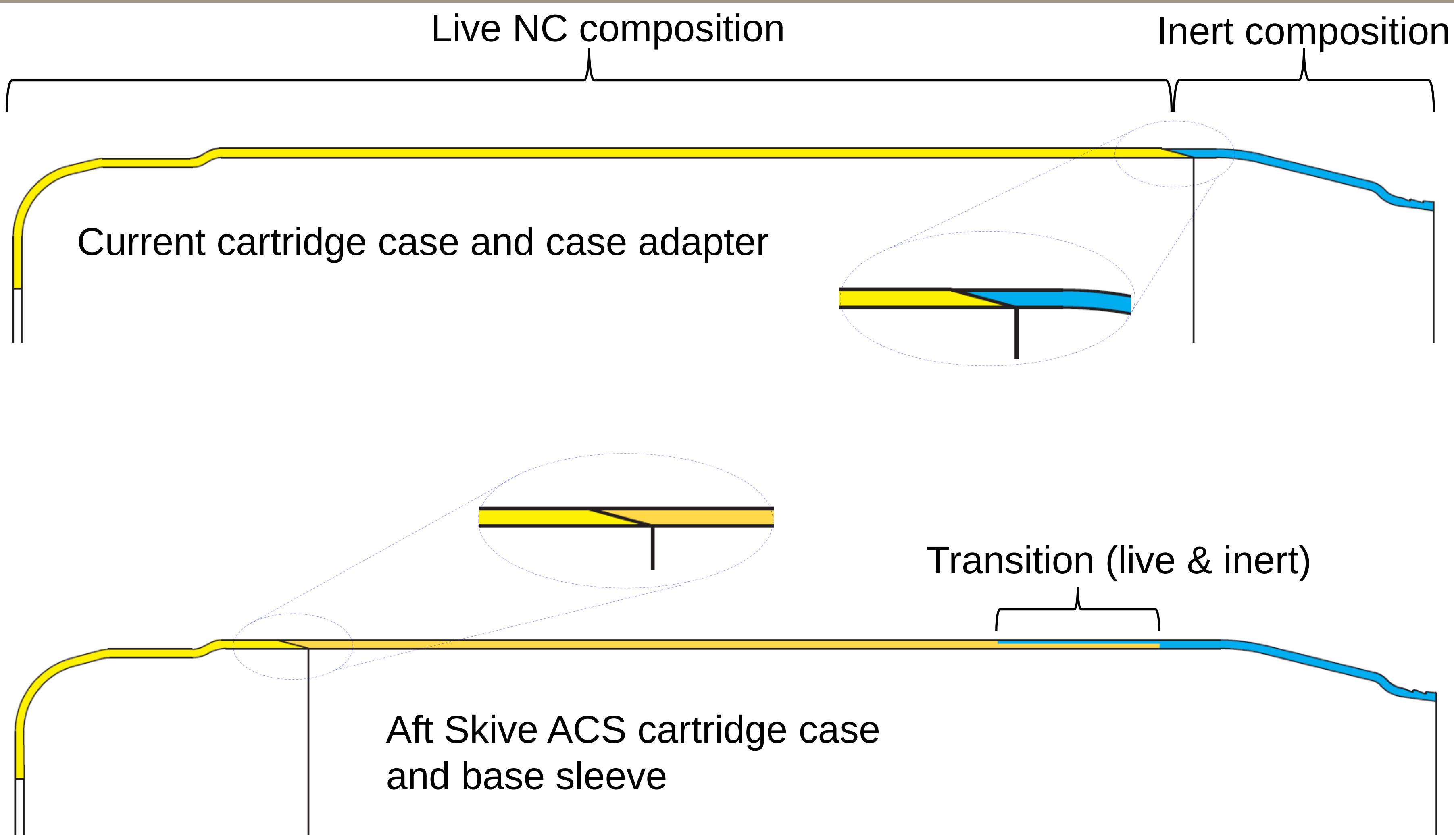
ACS Objective – Relocate Cartridge Joint



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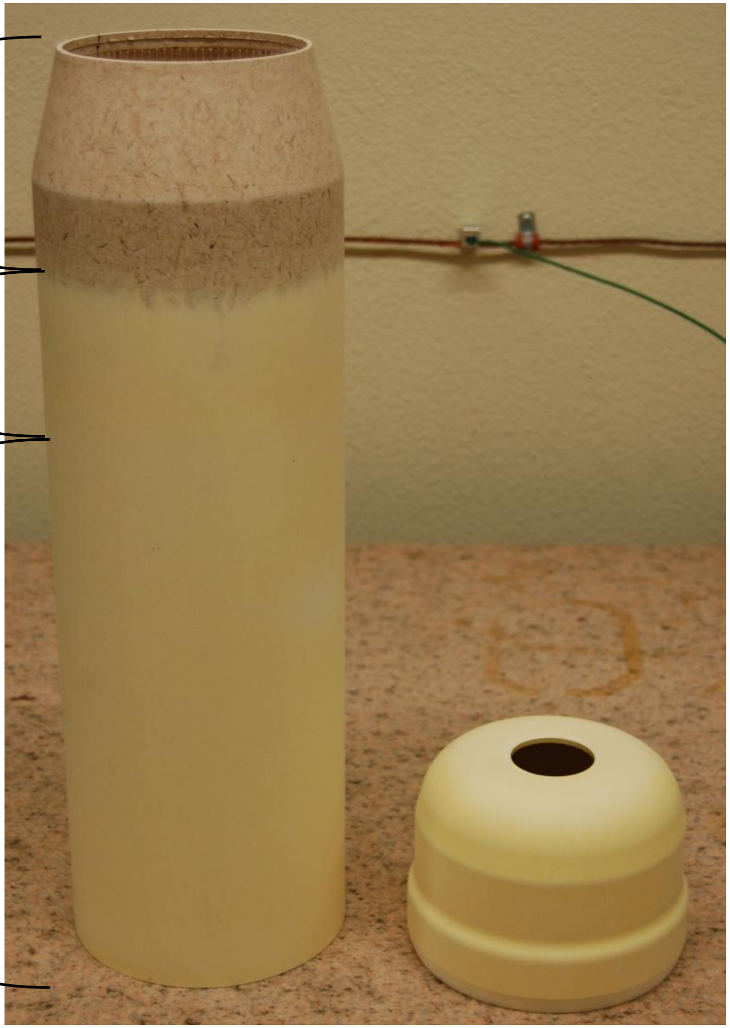
M865 ACS Case and Base Sleeve

Inert composition

Transition (live & inert)

Live NC composition



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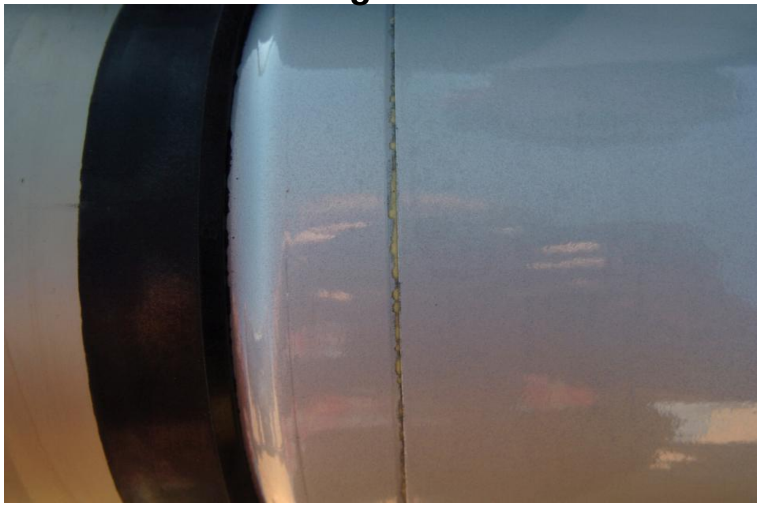
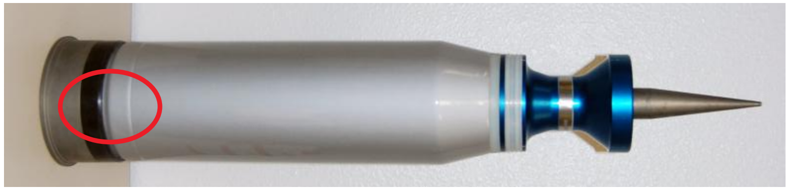
Qualification

- **M865 ACS aft skive joint has passed qualification testing.**
  - **All results were as good or better than the current design.**

Post User Handling test - Current Design

Post User Handling test - ACS Aft Skive





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M865 Transition to Production

Transition to Production

- Production of M865s for the next production year will be ACS
- Facilitization efforts are underway at both American Ordnance and Esterline Defense Technologies
  - ATK leading the AO Facilitization efforts
  - GD-OTS leading the EDT Facilitization efforts
- Tooling, gages, and facility requirements are on schedule
- Component and cartridge level First Articles are planned for summer and fall of 2011
- ACS design will replace current design in M865 production effective December, 2011
  - Production of M865 in the current configuration will end in September, 2011

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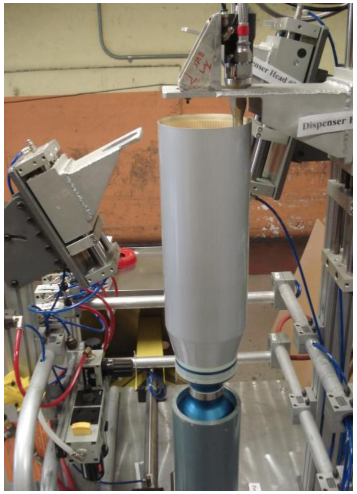
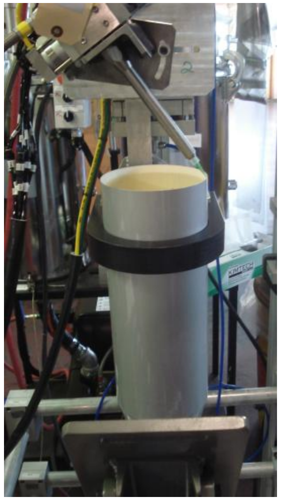
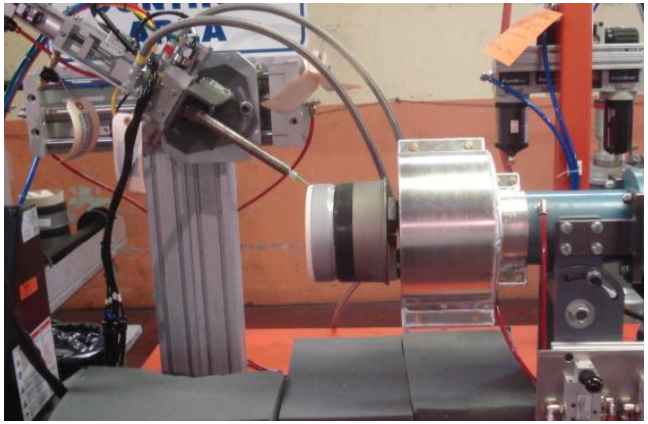
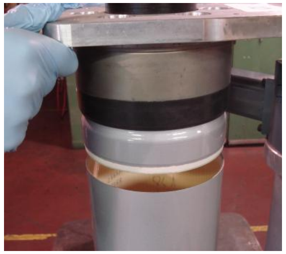
M865 AO Facilitization







Adhesive Application



Cartridge Bonding

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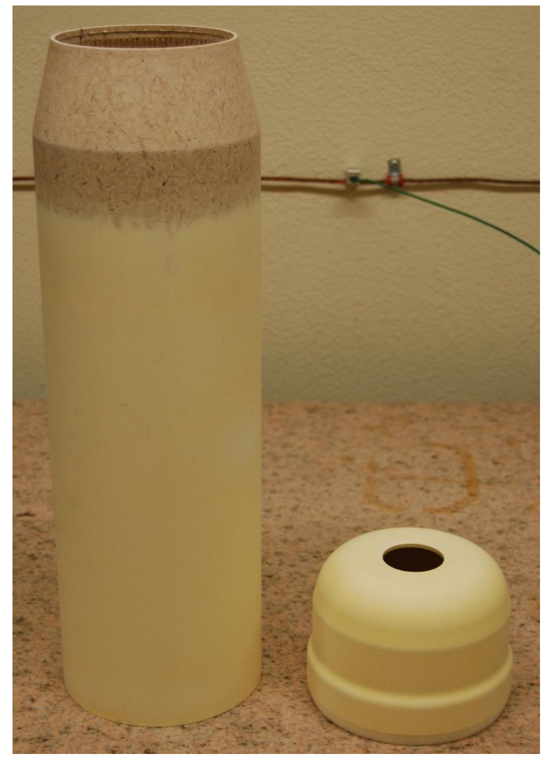
M865 EDT Facilitization

Case Trimmer



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M865 Refurbishment – Current design to ACS

M865 Refurbishment

- Significant inventory of M865s with the current design
- Design allows for removal of current case / adapter and replacing with the ACS case / base sleeve.
- Process has been developed and proven.
- Refurbished M865s have been provided for evaluation in a gunnery exercise.
- Plan is to refurbish M865 existing inventory starting in calendar year 2013.

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M1002 Qualification

Qualification

- **M1002 qualification testing has been suspended prior to completion.**
- **User handling tests resulted in failure of saw-tooth joint between ACS case and projectile obturator.**
  - **Inert material failed internally on the ACS cases.**
  - **Control M1002 cartridges (current design) had zero failures.**

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 383-11

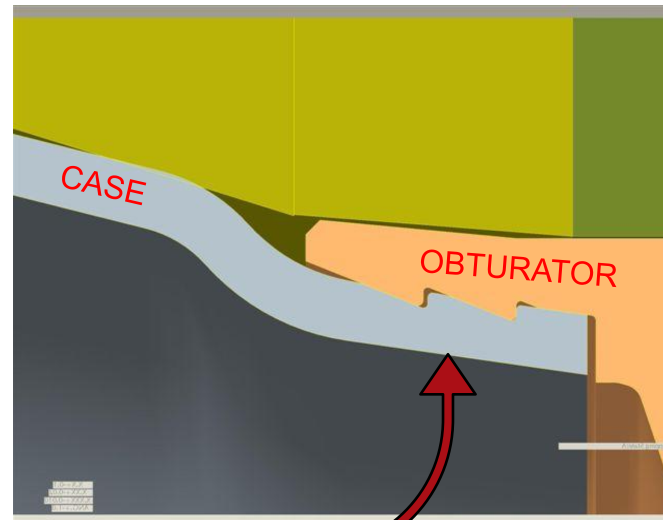
Technical Challenge – M1002 sawtooth joint

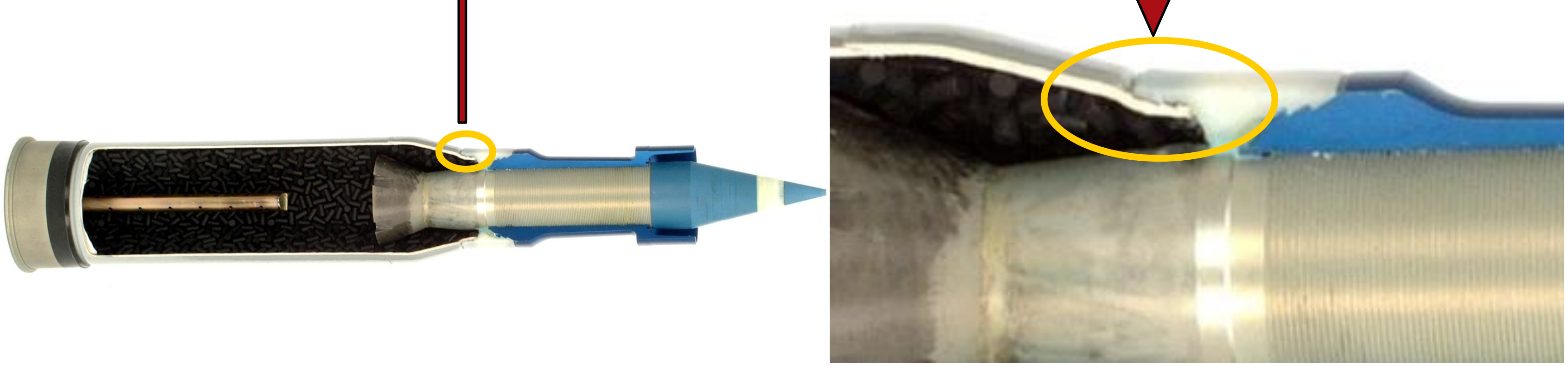
M1002 Sawtooth Joint:

- ACS Case: Inert wood pulp material.
- Obturator: Extruded Nylon

Failure Investigation:

- Focused on mechanical properties of case.
- Process adjustments and refinements.
- Increased mechanical properties in inert material.





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M1002 – Recovery plan

M1002 Recovery Plan:

- **Demonstrate improved mechanical properties based on lab testing.**
- **Build test samples to validate results.**
- **Build cartridges – full scale simulated handling and comparative testing.**
- **Build qualification cartridges**
    - **Repeat qualification tests to complete qualification**

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 383-11

M1002 Transition to Production

Transition to Production – Current Plan

- **Production of M1002 for next production year will be current design (Sep 2011 through Dec 2011)**
- **Comparable facilitization efforts required at both American Ordnance and Esterline Defense Technologies.**
  - **Anticipate ATK leading the AO Facilitization efforts.**
  - **Anticipate GD-OTS leading the EDT Facilitization efforts.**
- **Planning for component and cartridge level First Articles during spring of 2012.**
- **ACS design will replace current design in M1002 production effective in the fall 2012.**
  - **Production of M1002 in the current configuration will end in December, 2011.**

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 383-11

Summary – Current Program Status/Plans

M865 ACS:

- **ACS Qualification complete.**
- **Last M865 with the current design: Sept 2011**
- **Facilitization and First Articles are on schedule**
- **First M865 with the ACS design: Dec 2011**
- **Refurbishment of inventory to ACS planned for 2013**

M1002 ACS:

- **ACS Qualification – interrupted to resolve joint strength.**
- **Complete recovery plan / re-qualification testing: Apr 2012**
- **Last M1002 with the current design: Dec 2011**
- **First M1002 with the ACS design: Fall 2012**

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QUESTIONS???

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RDECOM

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Novel ARDEC Igniters for Gun Systems

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Eugene Rozumov, D. Park, T. Manning, C.P. Adam, J. O'Reilly, J. Laquidara, E. Caravaca

Armament Research Development Engineering Center

NDIA – 46th Annual Gun & Missile Systems Conference & Exhibition
August 2011

Distribution authorized for Public Release: March, 2011.

STAR ATO
High Performance Igniter

❖ Problems:

- Benite doesn't perform as well as $BKNO_3$ in 120MM tank rounds
- Benite gives inconsistent performance results.
- Future rounds need smaller igniter tubes.

❖ Solution:

- ARDEC has developed an igniter formulation
  - **Excellent and consistent performance**
  - **Less sensitive than Benite**
  - **Is more energetic than Benite.**
  - **Extrudable**
  - **Smaller Ignition Delays**

High Performance Igniter

- **Possible Causes:**
  - **Type IV $BKNO_3$ igniter has an oxygen balance of -35%**
    - After firing, all of the oxygen in the barrel is exhausted
    - Boron combustion requires large amounts of oxidizer
    - Opening of breach allows a rapid influx of oxygen which ignites uncombusted boron (or other fuel)

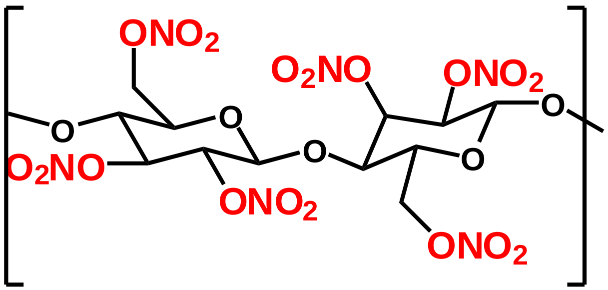
$BKNO_3$

- Made of:
  - 70% Potassium Nitrate
  - 30% Boron
- Easily ignited at low **P**.
- High Gas Content
- Burn Rate insensitive to **P**.
- Hygroscopic (less than Black Powder)
- Flare Back (Incomplete oxidation)

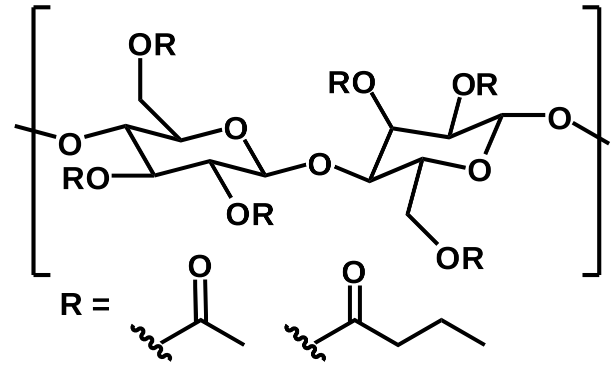
Benite

- Made of:
  - 40% Nitrocellulose
  - 6.3% Sulfur
  - 44.3% Potassium Nitrate
  - 9.3% Charcoal
  - 0.5% Ethyl Centralite
- Performance as an igniter is adequate for tank applications.

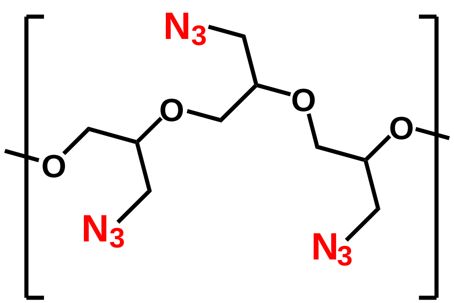
Properties of Binders Considered



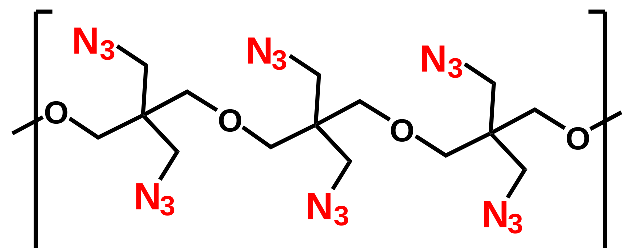
Nitrocellulose
ρ = 1.66 g/cc
ΔH_f = -690 kJ/mol
T_v = 3331 K
O.B. = -31%



Cellulose Acetate/Butyrate
ρ = 1.22 g/cc
ΔH_f = -1630 kJ/mol
T_v = 1052 K
O.B. = -160%



Glycidyl Azide Polymer (GAP)
ρ = 1.29 g/cc
ΔH_f = 176 kJ/mol
T_v = 2288 K
O.B. = -121%



poly-Bis-AzidoMethyl-Oxetane
ρ = 1.30 g/cc
ΔH_f = 373 kJ/mol
T_v = 2246 K
O.B. = -124%

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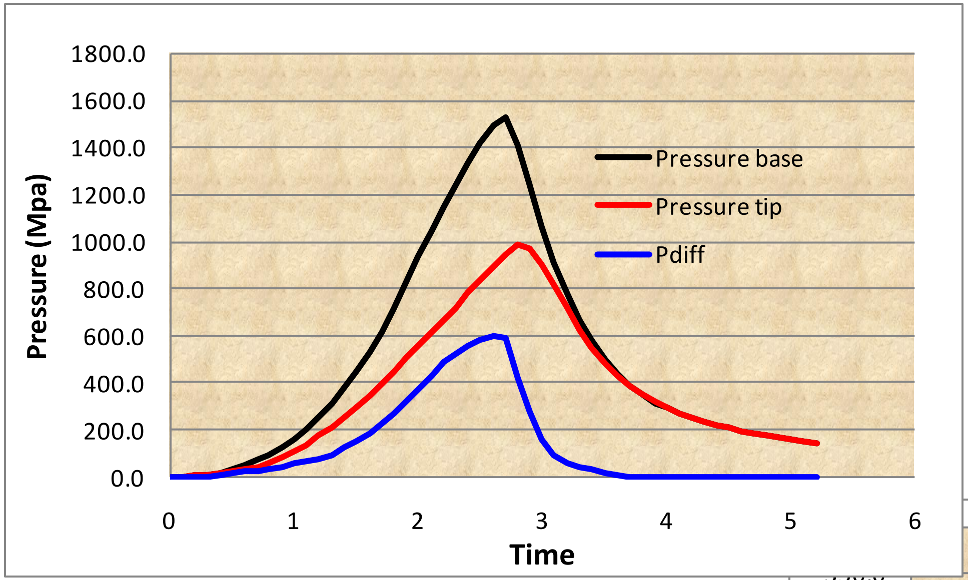
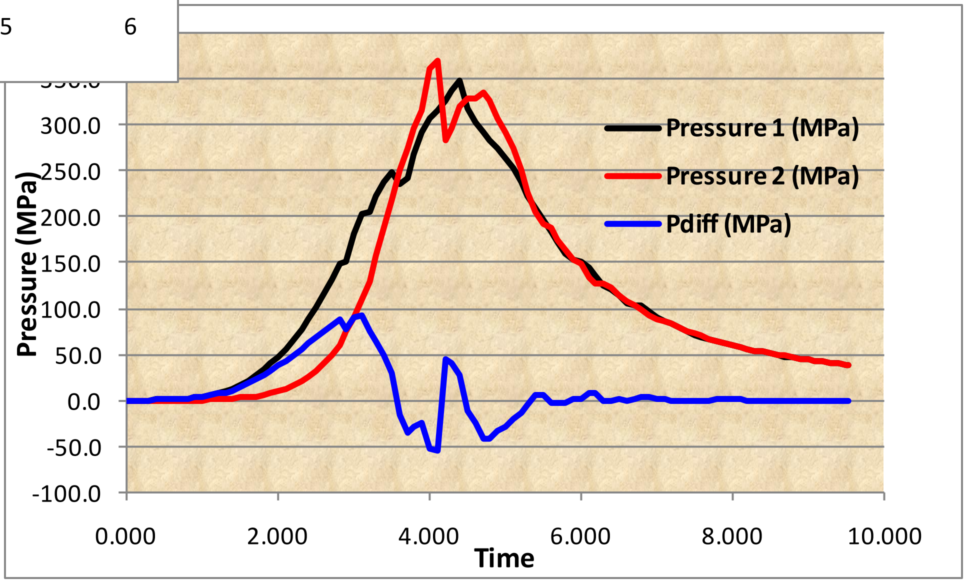
FNGUN Analysis



- Instantaneous Ignition along the igniter tube.
- No Pressure Differentials.

- Staged Ignition from the middle of the igniter tube.
- -50 MPa Pressure Differentials.



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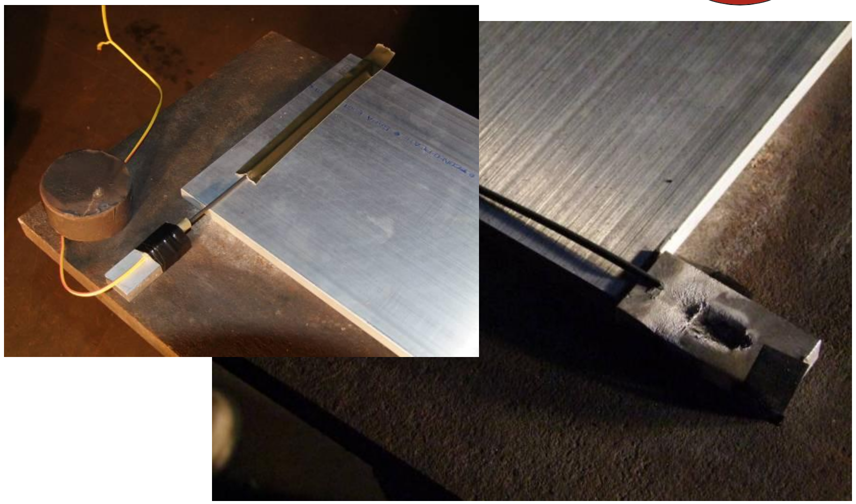
Sensitivity Analysis

Formulation	Igniter Sensitivity			
	Impact ERL (cm)	BOE	Friction (GO / No GO) (N)	ESD (J)
Benite	18.8	6 of 10	288 / 252	>0.25
BKNO3	23.2	10 of 10	> 360	>0.25
PAI-8556	22.4	7 of 10	240 / 216	>0.25
PAI-8557	24.6	5 of 10	324 / 288	>0.25
PAI-8558	>100	0 of 10	252 / 240	>0.25



Small Scale Burn

Material	Burn Time	Explosion	Detonation	Pass/ Fail
PAI-8556	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
PAI-8557	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
	Less 1 Sec.	NO	NO	Pass
PAI-8558	2.01 Sec.	NO	NO	Pass
	2.79 Sec.	NO	NO	Pass
	3.05 Sec.	NO	NO	Pass

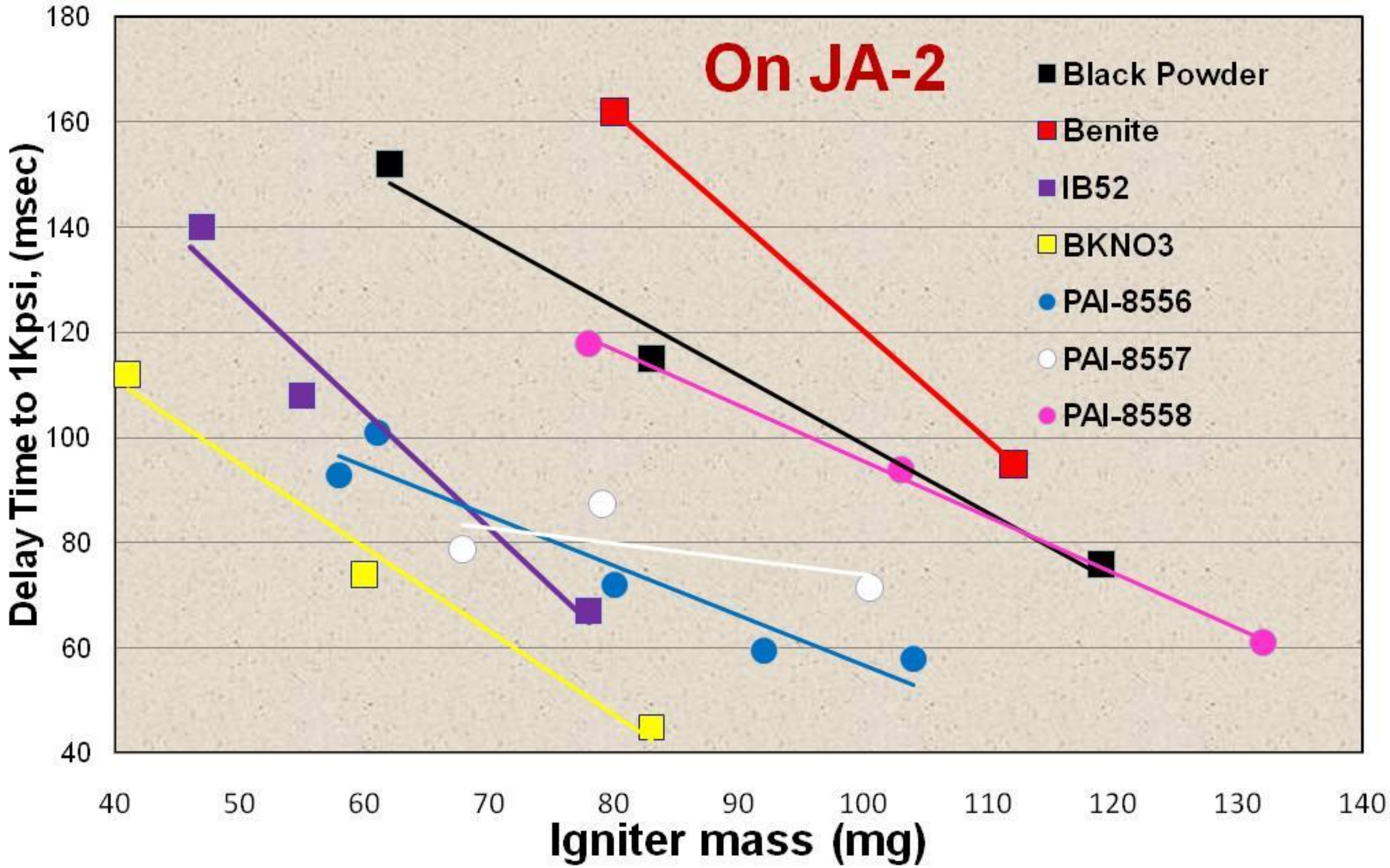
Critical Diameter

Lot #	Diameter	Result
8551	0.1345	NOGO
8551	0.1350	NOGO
8558	0.1405	NOGO
8558	0.1415	NOGO
8556	0.1420	NOGO
8556	0.1440	NOGO
8557-3	0.1400	NOGO
8557-3	0.1385	NOGO

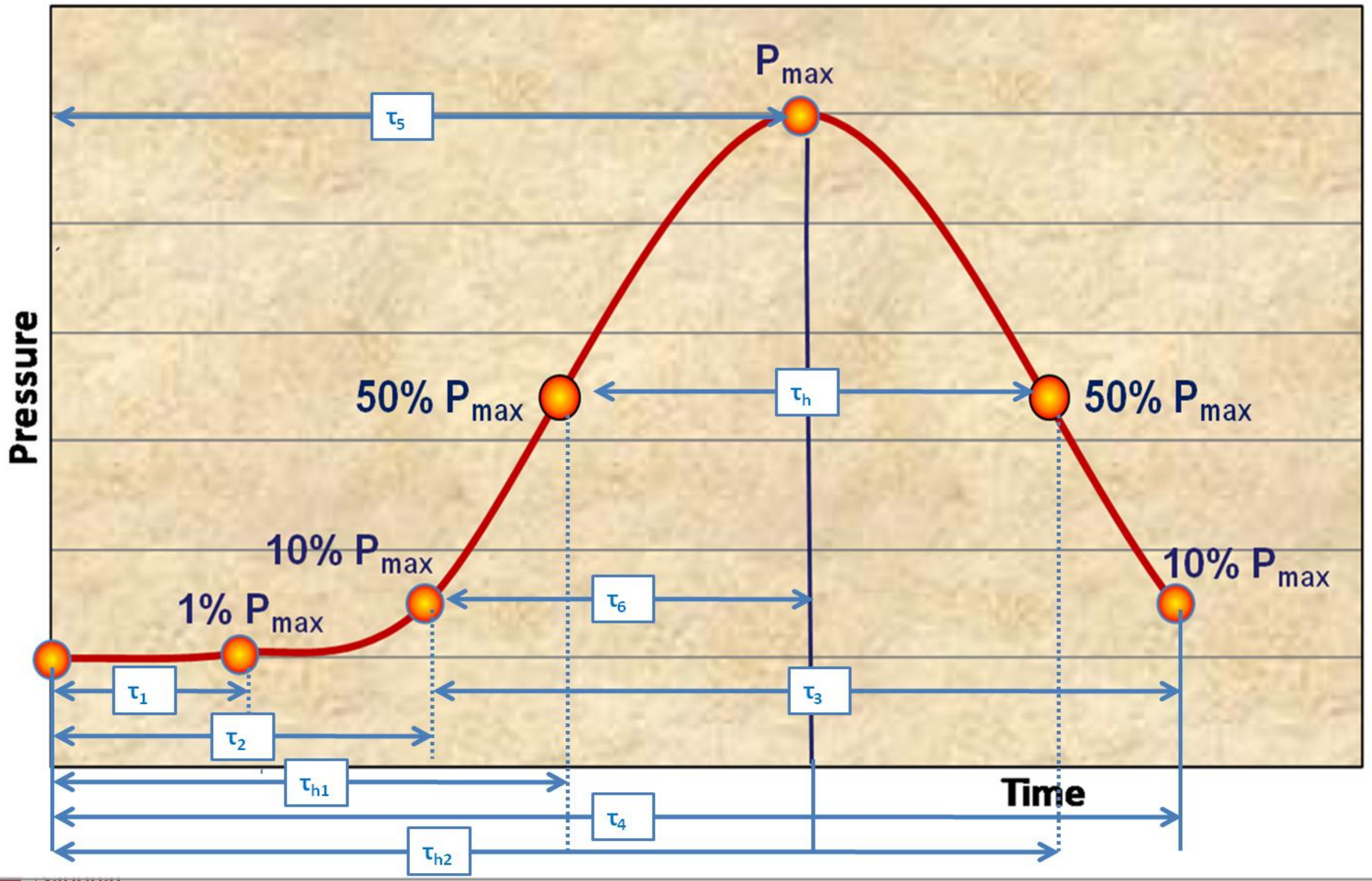
Thermal Stability

Material	Starting Weight	Total Loss	Pass - Fail
PAI 8556	50.4135gms	.1464gms	PASS
PAI 8557	50.2485gms	.2614gms	PASS
PAI 8558	50.2745gms	.1545gms	PASS

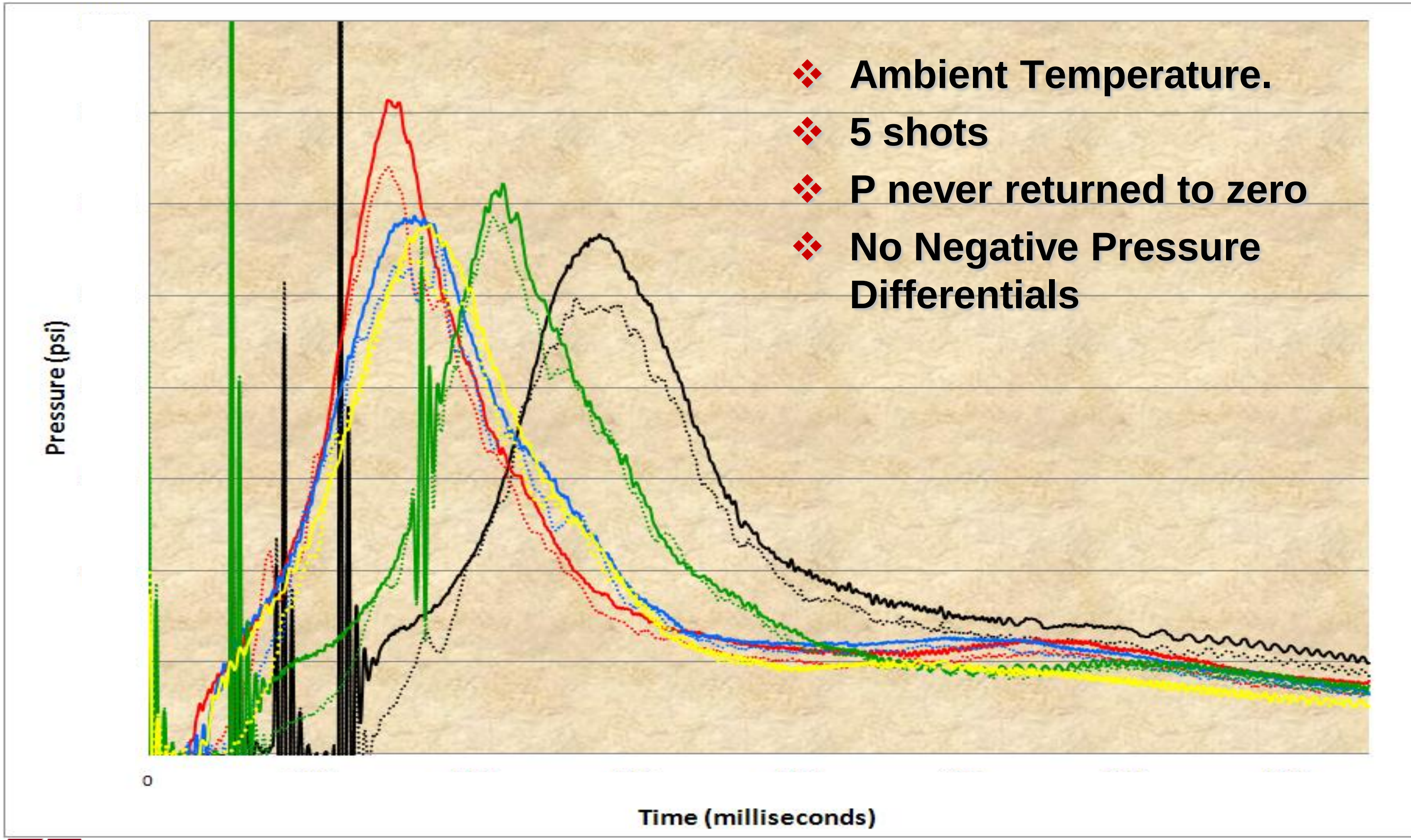
Small Scale Ignitability Study



Expected Data



Benite at Ambient Temperature



- Ambient Temperature.
- 5 shots
- P never returned to zero
- No Negative Pressure Differentials

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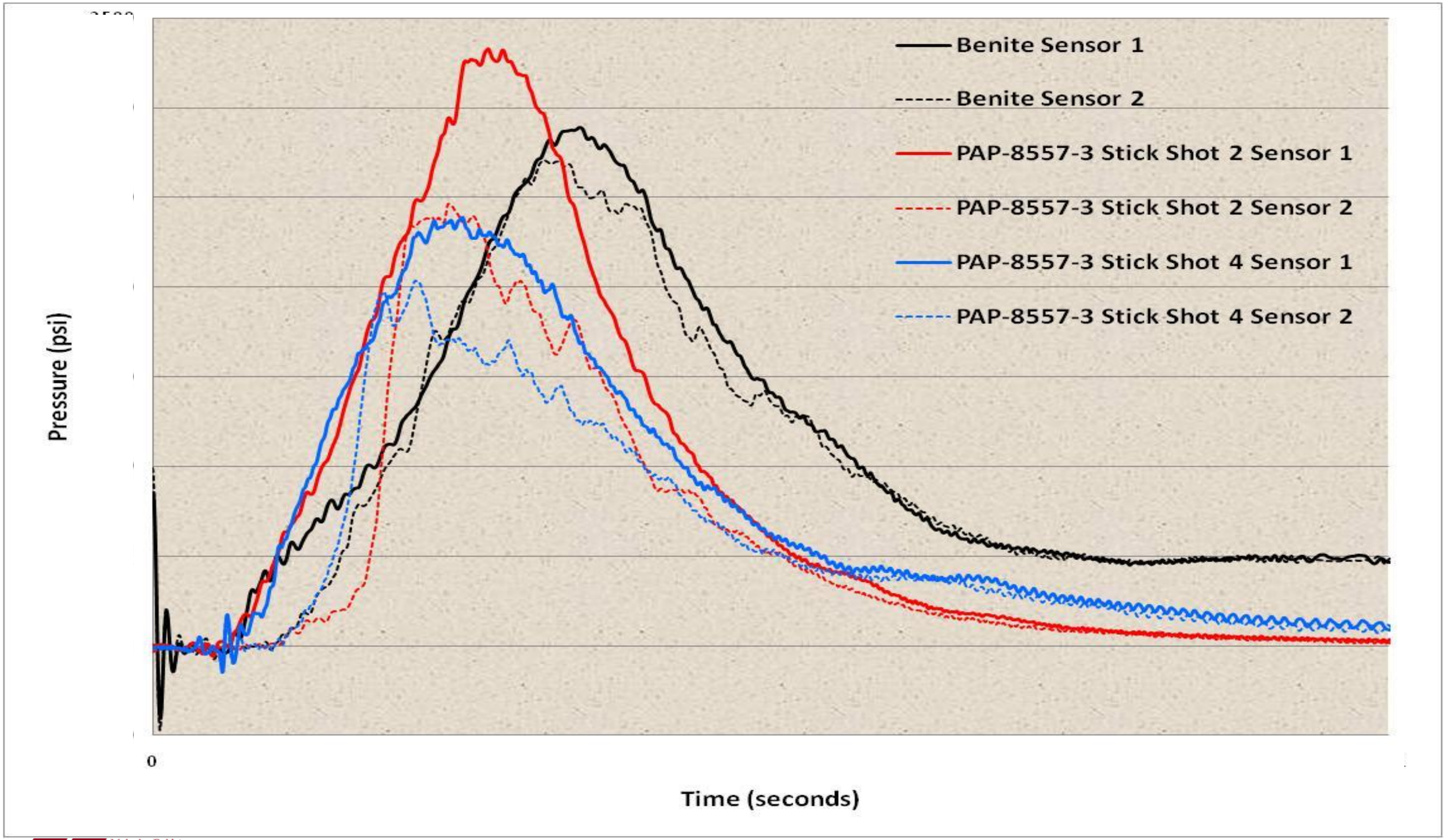
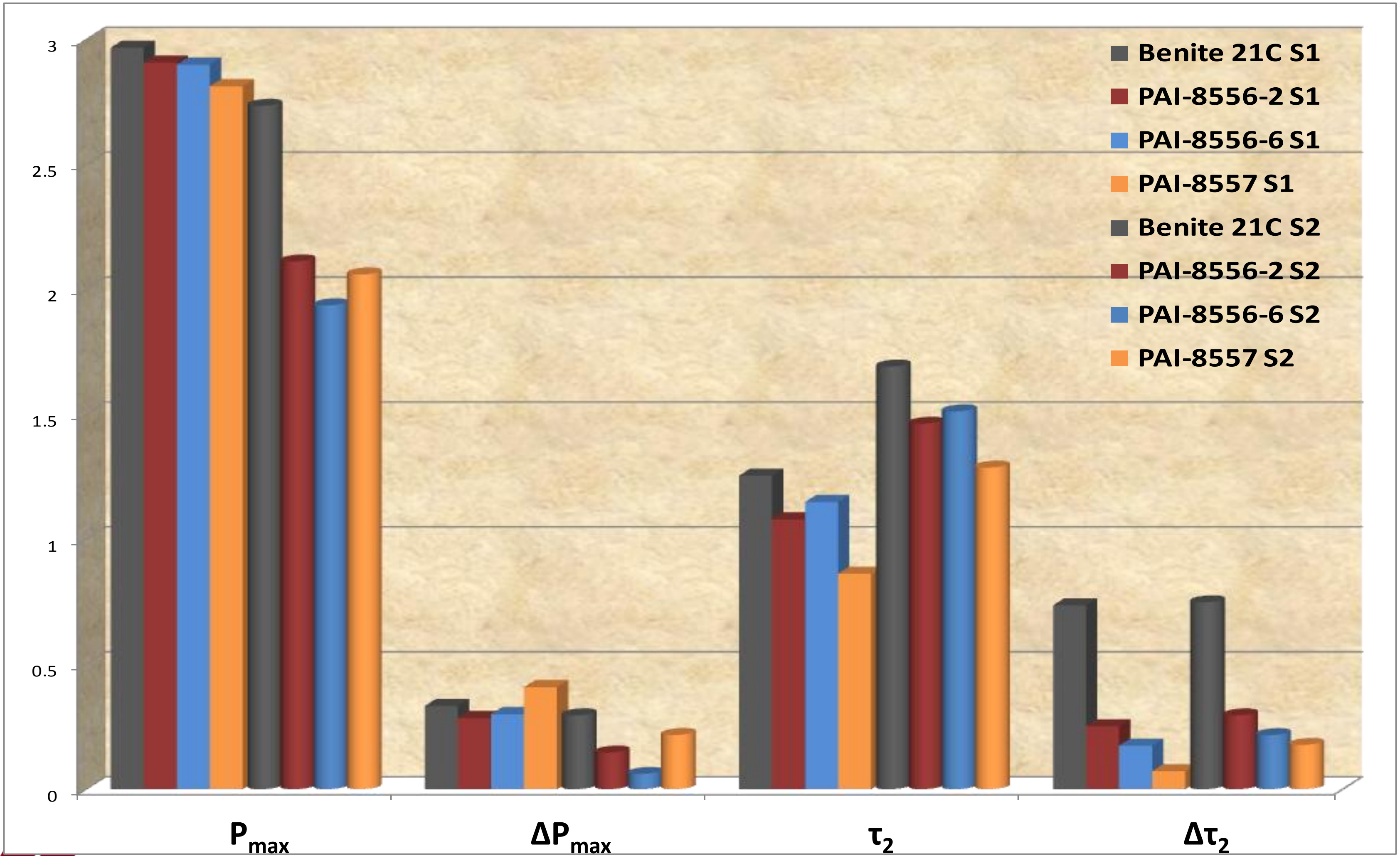
PAI-8557 Un-Ground $BKNO_3$



Analysis of P_{max} and t_2



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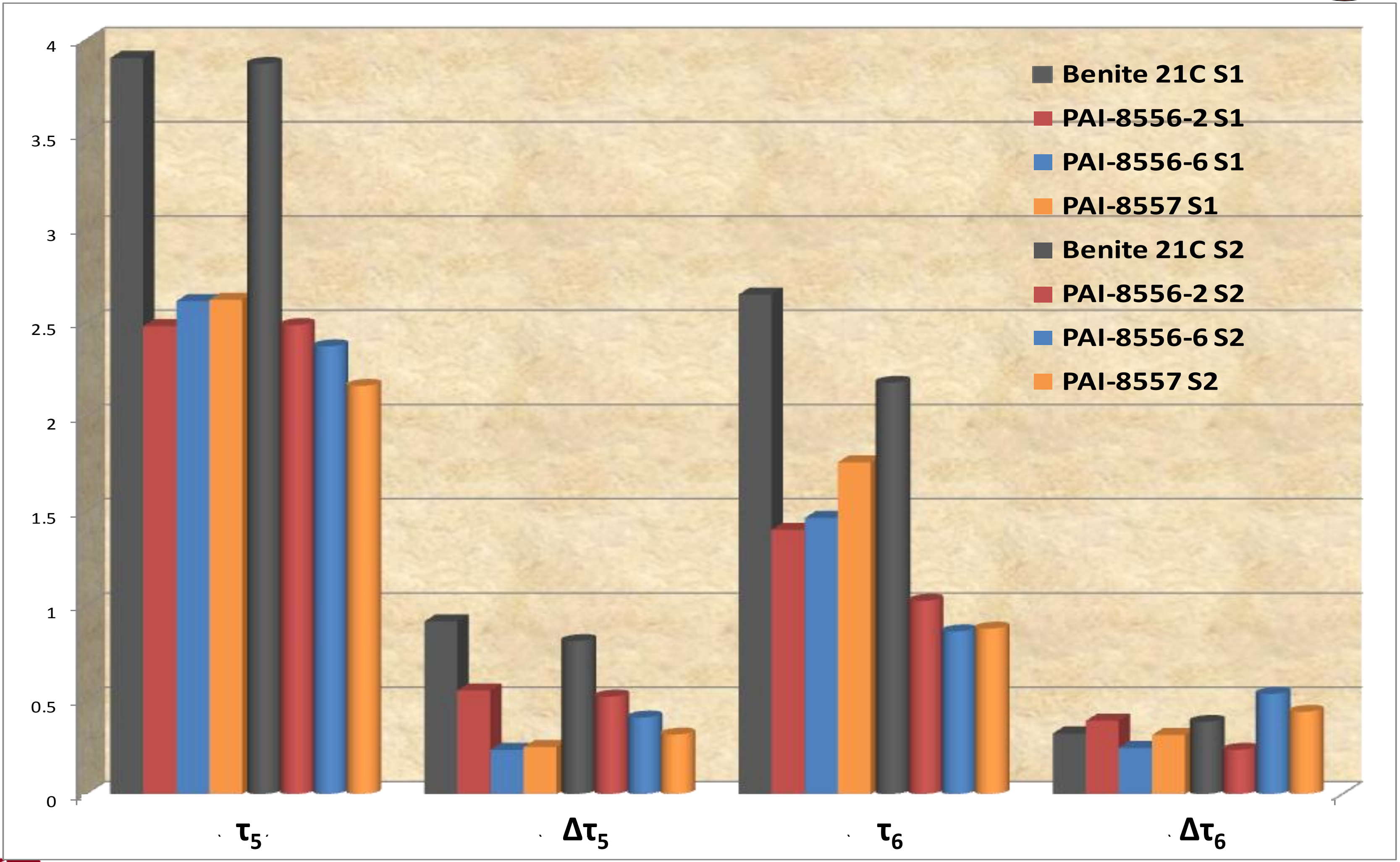
Analysis of t_5 and t_6



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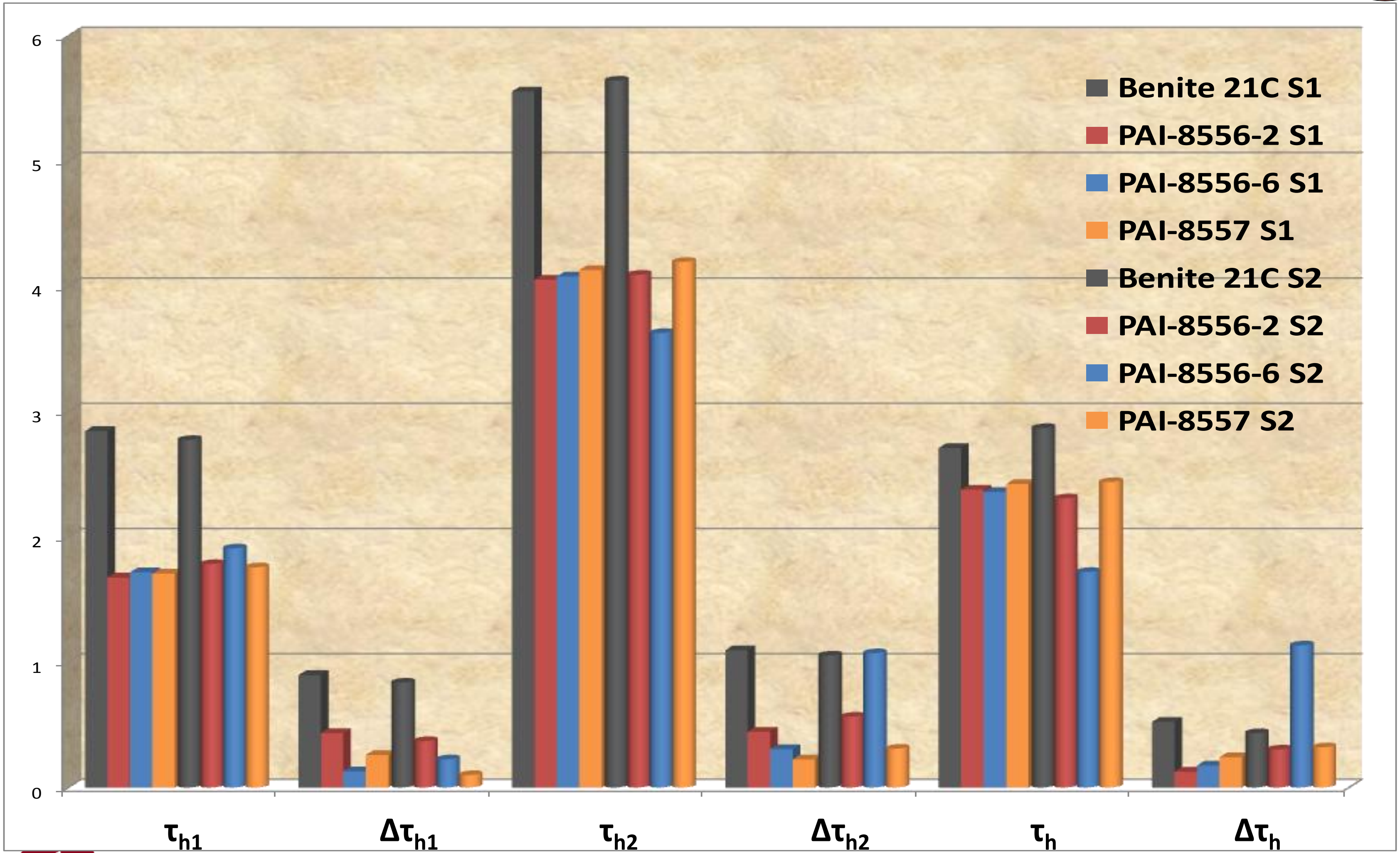
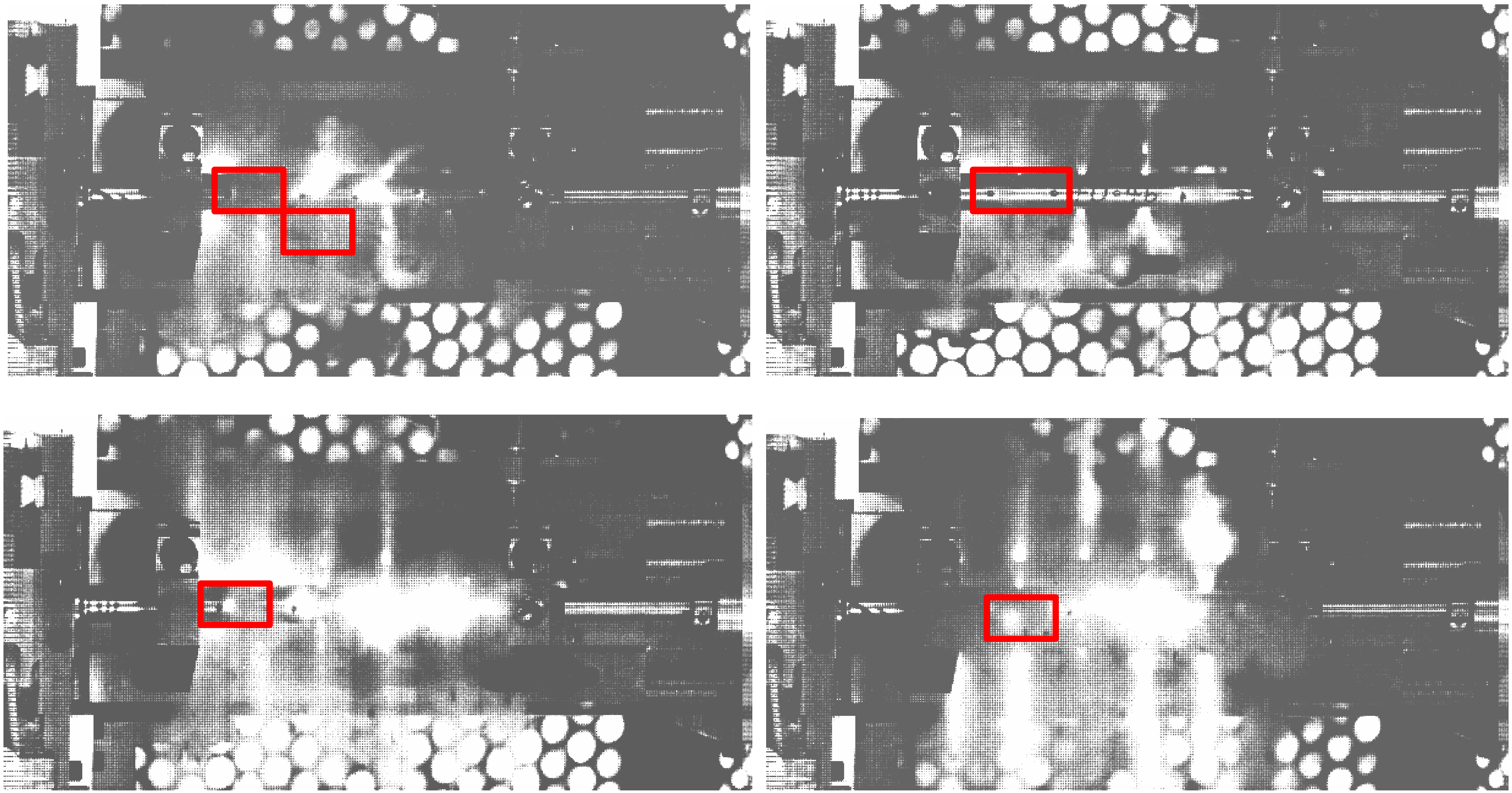
Analysis of t_{h1}, t_{h2}, and t_h



High Speed Video Stills of Benite Igniter at Ambient Temperature



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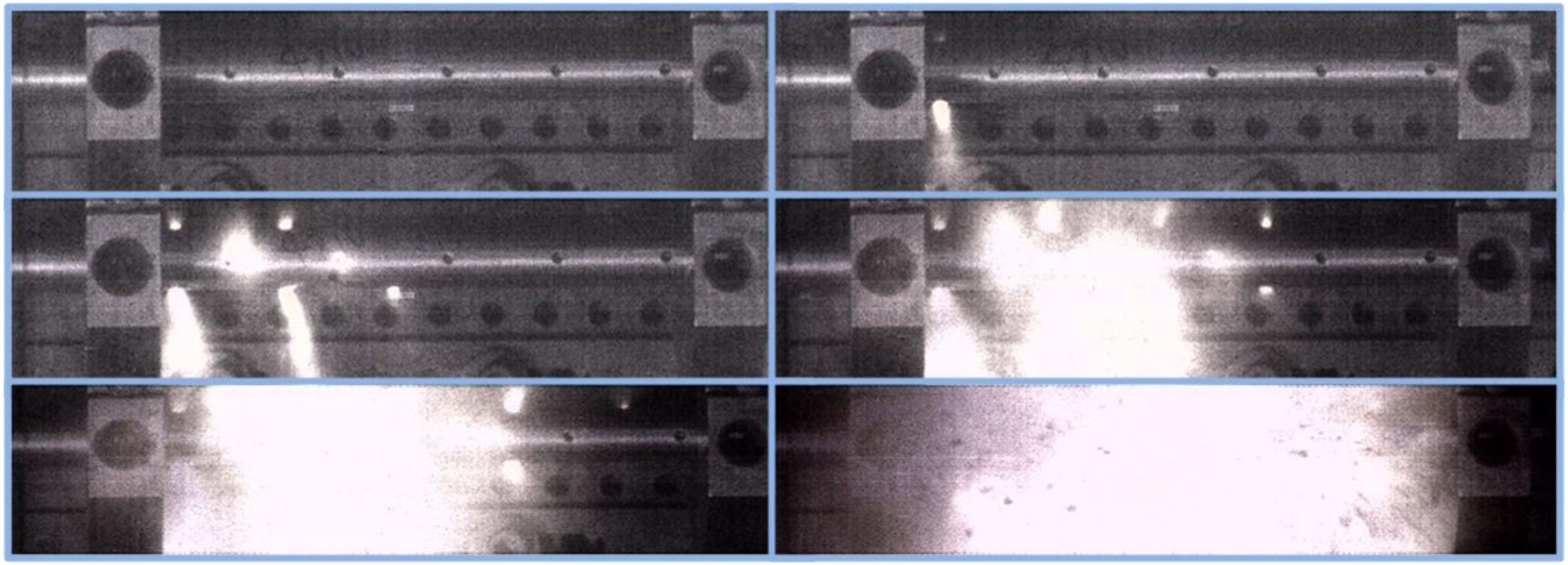
High Speed Video Stills of PAI-8556 at Ambient Temperature



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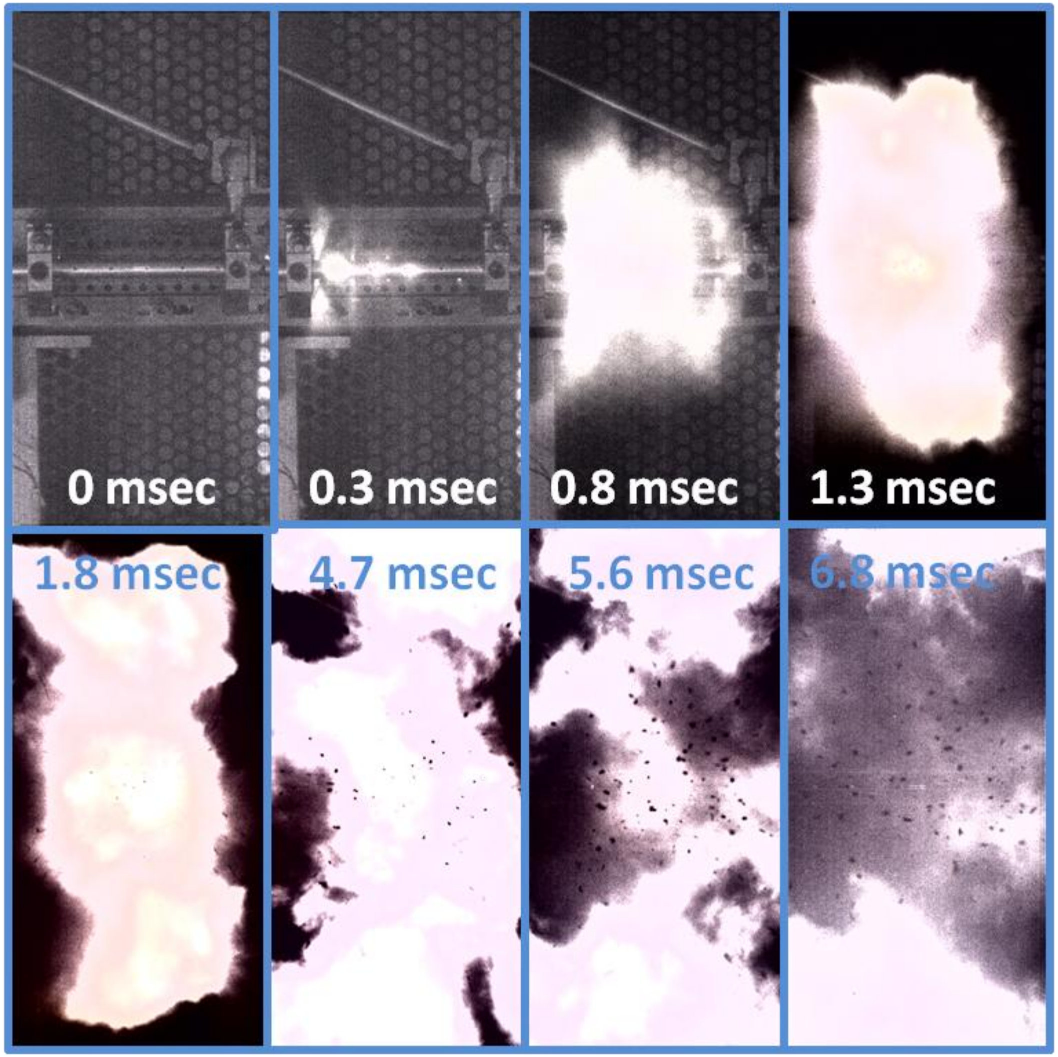
High Speed Video Stills of PAI-8556 at Ambient Temperature



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Conclusions

- **Benite was found to have significant shot to shot variability in terms of pressure and time.**
- **Extrudable $BKNO_3$ analogue igniters were able to achieve P_{max} faster than benite with less variance in ignition delays and output pressures than benite demonstrating that the analogue igniters are more consistent.**
- **High speed video of the ignition events also demonstrated more hot particle and flame generation in the $BKNO_3$ analogue igniters in comparison to benite.**

Scalable Gen-Set Concept for Directed Energy Weapons

Presented for:

The 46th Annual NDIA Armaments Systems, Gun & Missiles Conference, Abstract 11828

Aug 29 – Sept 1, 2011

Presented by:

Mr. Bryan Bockmon, President

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RMSL ROCKY MOUNTAIN SCIENTIFIC LABORATORY

RMSL Background

Energetic Materials Specialists

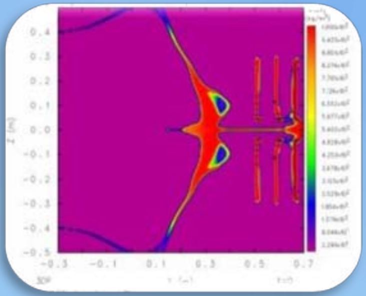
- Explosives, propellants, pyrotechnics, nano-composites, fuels, oxidizers, etc.
- Design & Synthesis
- Chemical and Material Characterization
- Performance Evaluations

Test Engineering

- Laboratory & Field Studies
- Improvised Explosive Devices
- Munitions

Modeling

- FEA, CFD, Hydrocode, Multi-Physics



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SCIENTIFIC LABORATORY

Directed Energy Overview

Pros – Tunable Energy

- Anti-Materiel
- Area Denial
- Vehicle/Vessel Disablement
- Counter-Personnel
- Crowd Dispersal
- Distract/Disorient
- Reversible Effects

Cons – Power & Weight

- Rapid Start
- High Demand
- Short Duration
- Proportional Control
- Portability

Area Denial System – 95 GHz

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Problem Definition

Develop a power supply system that offers the following:

- Near instant response
- High-demand capabilities
- Refueling/recharging/reloading convenience
- Smaller, lighter, and more scalable than other gen-sets
- Potential for man-portable DE systems

IT BECOMES A POWER TO WEIGHT RATIO PROBLEM WITH INTERESTING CONSTRAINTS!

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ROCKY MOUNTAIN SCIENTIFIC LABORATORY

Power to Weight Statistics

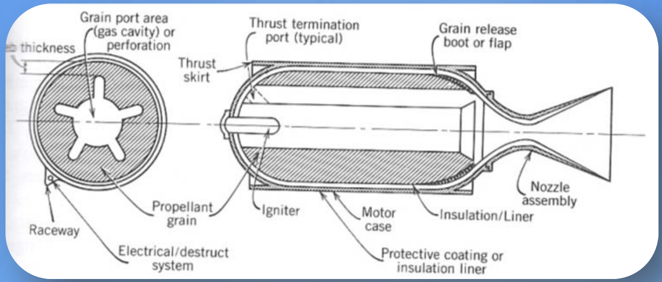
Generator	Type	Power	Weight	Power/Weight
Smart Fuel Cell Jenny 600S[7]	Fuel Cell	.0038 hp	3.8 lbs	**.001 hp/lb**
Energizer 522 Alkaline 9V[6]	Battery	.006 hp	.1 lbs	**.06 hp/lb**
GM 6.6L V8 turbo Diesel[3]	ICP	330 hp	825 lbs	**.4 hp/lb**
Mazda 13B-MSP 1.3 L Wankel[4]	ICR	247 hp	268 lbs	**.92 hp/lb**
BMW V10 3L P84/5[5]	ICP	925 hp	201 lbs	**4.6 hp/lb**
Pratt and Whitney J58[1]	Jet	160,000 hp	6000 lbs	**26.7 hp/lb**

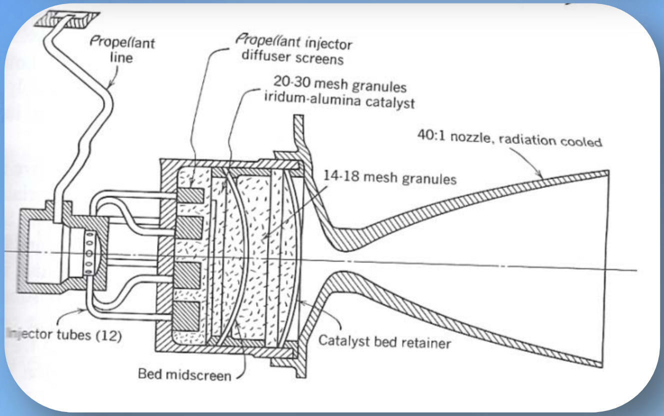
Generator	Type	Thrust	Weight	Thrust/Weight
Pratt and Whitney J58[1]	Jet	150,000 N	26,700 N	**5.62 N/N**
GE90-115B[8]	Jet	511,545 N	81,221 N	**28 N/N**
Pratt and Whitney RD-180[2]	L Rocket	4,152,000 N	53,700 N	**77.3 N/N**
Rocketdyne F-1[9]	L Rocket	7,740,500 N	82,290 N	**94.1 N/N**
Solid Rockets[10]	S Rocket	Varies	Varies	**5 to 200 N/N**

[1] http://www.marchfield.org/sr71a.htm [2] http://www.astronautix.com/engines/rd180.htm [8] http://www.geae.com/engines/commercial/ge90/ge90-115b.html
[3] http://eogld.ecomm.gm.com/images/mediumduty/techspecs/engine.pdf [4] http://www.mazda.com/mazdaspirit/rotary/about/
[5] http://www.allf1.info/engines/bmw.php [6] http://data.energizer.com/PDFs/522.pdf [7] http://www.sfc.com/en/man-portable-jenny.html
[9] http://www.rocketdynearchives.com/engines/f1.html [10] Sutton, George. Rocket Propulsion Elements (1986)

Types of Rocket Motors

- **Solid** – Propellant carries all of it's own oxygen, can be single or multi component.
- **Liquid** – Liquid propellant is injected into combustion chamber. Propellant carries all of it's own oxygen, can be single or multi-component.
- **Hybrid** – Solid fuel with injection of liquid oxidizer, allows for easy adjustment of power.





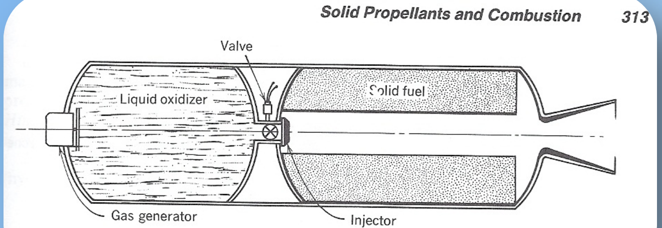
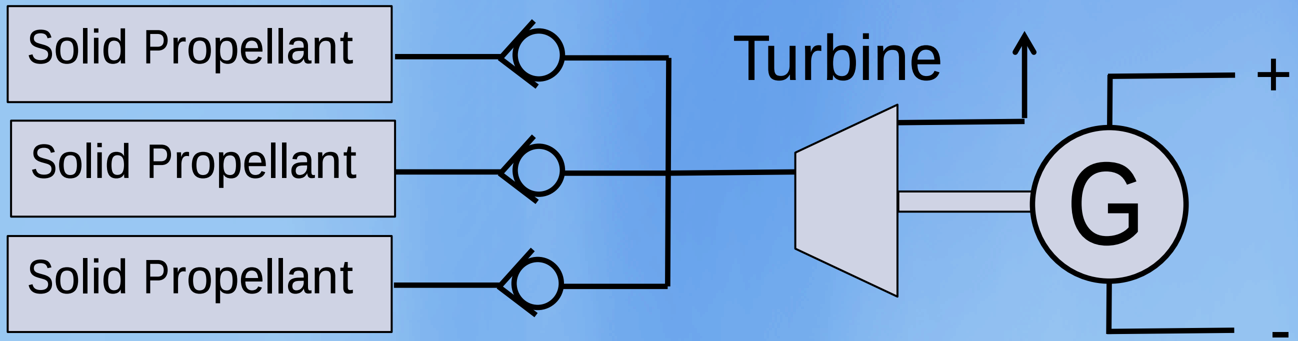


Fig. 11–7. Schematic diagram of a hybrid rocket.

All pictures from Sutton, George. Rocket Propulsion Elements (1986)

Prior-Art Analysis

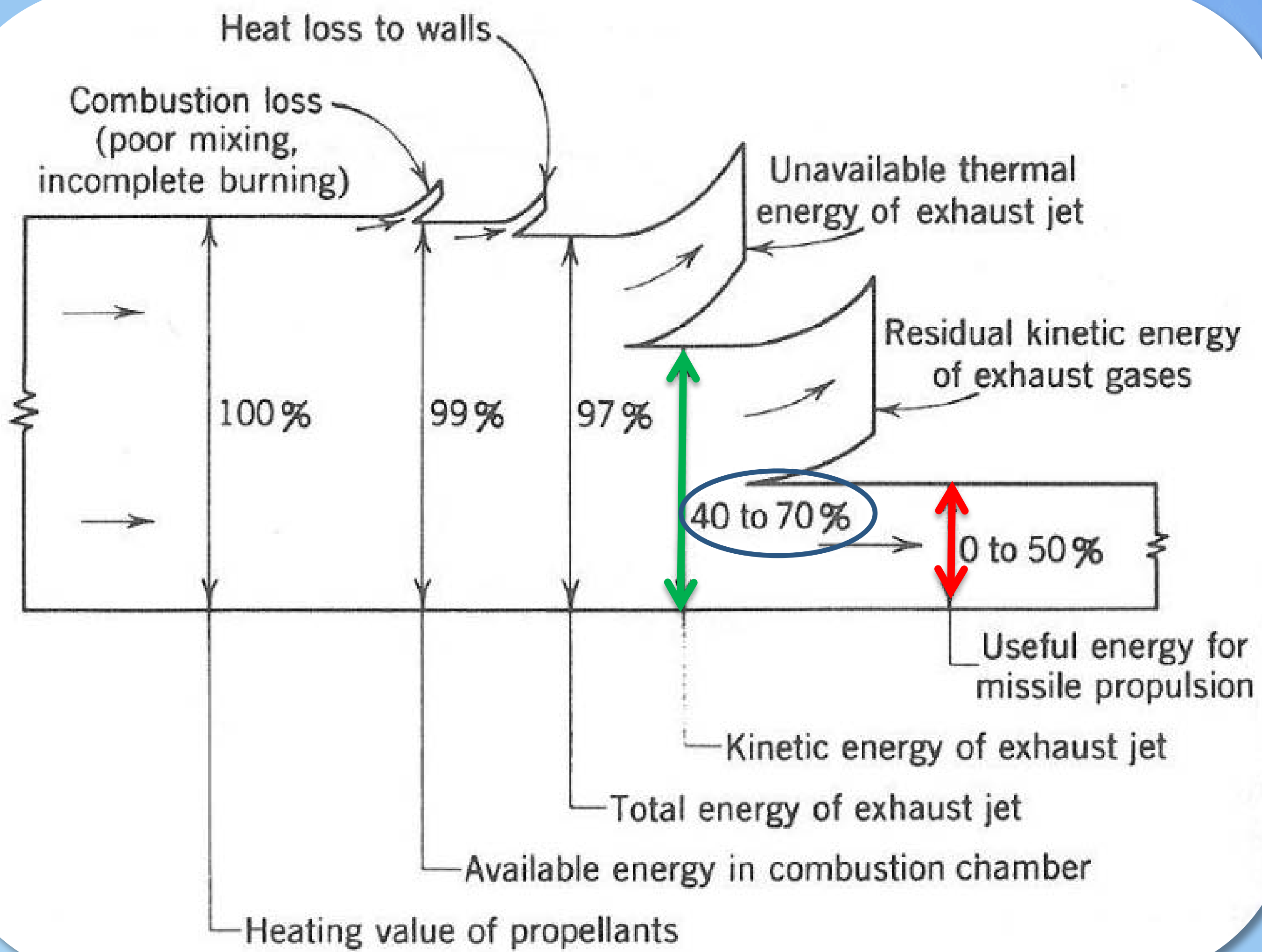


Existing Patent

- Backup electrical power for aircraft with engine failure
- One or more solid propellant motors
- Turbine power extraction
- Instant response, short duration, light weight (compared to batteries)

RMSL ROCKY MOUNTAIN SCIENTIFIC LABORATORY

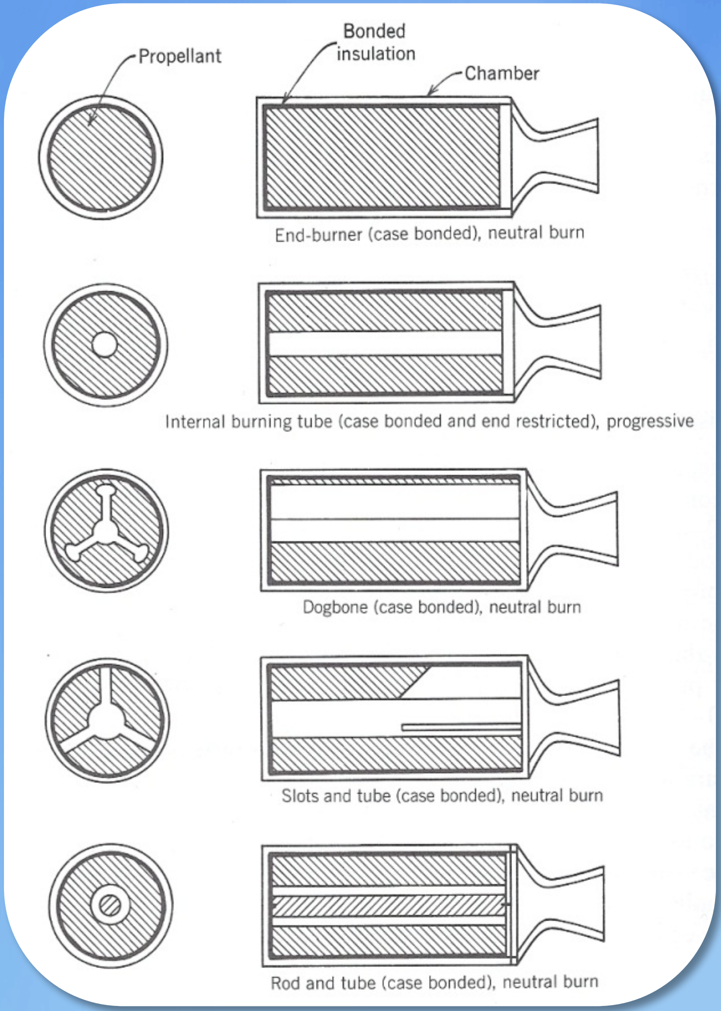
Efficiencies



All pictures from Sutton, George. Rocket Propulsion Elements (1986)

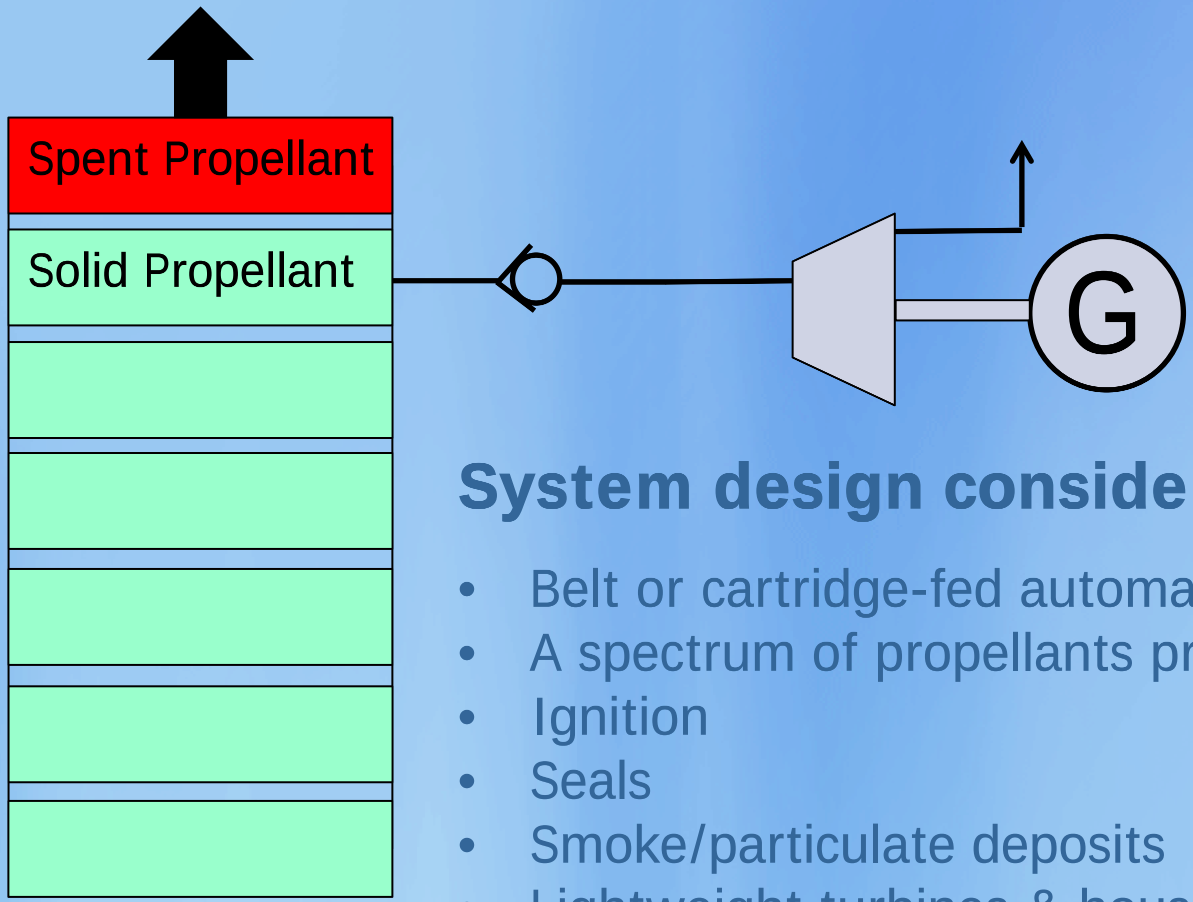
Motor Design Considerations

- Up to 98% of the mass in solid propellant motors can be energetic
- Neutral burn rates keep constant power applied to the turbine
- End-burning propellant configuration increases duration of burn
- Center-perforated motors maximize power
- Hybrid motors allow throttling



All pictures from Sutton, George. Rocket Propulsion Elements (1986)

System Integration



System design considerations

- Belt or cartridge-fed automatic loading
- A spectrum of propellants provide varying effects
- Ignition
- Seals
- Smoke/particulate deposits
- Lightweight turbines & housings
- Lightweight generators
- Capatteries (Batteries/Capacitors)

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Weekend Research Project

Version 1.0

- Hobby grade motors (Estes)
- Die grinder turbine
- 18VDC generator, 20,000 RPM
- Worked with air supply
- Worked for seconds with motors

Version 2.0

- Custom motors
- Double based propellant
- Motorcycle turbo
- Size mismatch
- Ruptured motor casings

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Desired End-State

Conclusions

- Solid propellant gen-sets show promise for DE applications
  - Extensive scalability
  - Propellant motors already in logistics chain
  - Instant response, high power, light weight, reloadable, compact,
- Quantum-leap developments are not always necessary for a significant capability increase
- Recycling/re-applying existing technologies offers a wealth of potential
- Questions?

RDECOM

Development and Characterization of IM Gun Propellant for the 120mm Tank System

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

April 13, 2011

Duncan Park, S. Moy, T. Manning, E. Rozumov, D. Chiu, and A. Eng
U.S. Army RDECOM-ARDEC, Picatinny, NJ
duncan.park@us.army.mil; 973-724-4398

Distribution A: Unlimited Distribution. Approved for public release.

OUTLINE

- Objectives
- Approach
- Results
- Summary and Conclusions
- Acknowledgments

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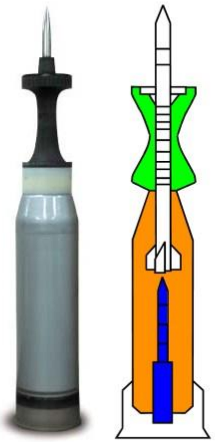
OBJECTIVES

- Goal

Develop high energy and less sensitive propellants to minimize soldier and weapon platform vulnerability from unplanned stimuli

- Technical Objectives:
  - Maintain High Performance:
    - Performance Baseline → JA2 propellant in M829A2
  - Lower the sensitivity of propellants against:
    - Shape charge jet (SCJ):
    - Spall:
  - No anomalies in gun environment:
    - Test fire in a sub-scaled gun → 30 mm gun firing



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APPROACH

- Formulation
  - Use less sensitive ingredients
  - Use less of energetic solid fills
- Conduct various characterization tests
  - To observe any trends
  - To discriminate and downselect formulations
  - Tests/Calculations conducted:
    - Closed bomb
    - Interior ballistic (IB) calculation
    - Erosivity Calculation
    - Critical diameter
    - Shock initiation sensitivity→ predictor against shock stimulus
    - Uniaxial Compression (Mechanical Properties)
    - Hot fragment conductive ignition → predictor against spall threat
    - Small scale (1.77 lbs) and 5 lb SCJ ballistic pendulum → predictor against SCJ threat
    - 30mm gun firing (to be completed)

Most of the work was performed during 2005-2008

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RESULTS: Muzzle Velocity and Erosion

Theoretical Muzzle Velocity and Erosion Prediction

Formulation	Solid Load (wt%)	Relative Muzzle Velocity (%JA2)	Tflame (K)	Relative Erosivity (%JA2)
JA2	**0**	**100**	**3450**	**100**
A	40	**103**	3454	72
C	50	**103**	3558	92
D	30	**102**	3348	57
E	40	**102**	3486	80
F	40	**102**	3432	70
G	40	**102**	3362	58
H	25	**101**	3299	52
I	25	**101**	3290	51
J	0	**99**	3043	32
K	20	**100**	3246	46
L	10	**99**	3138	38
M	0	**98**	3149	41
B	40	**102**	3454	72

Relative Muzzle Velocity Range: 98-103%

Relative Erosivity Range: 32-92%

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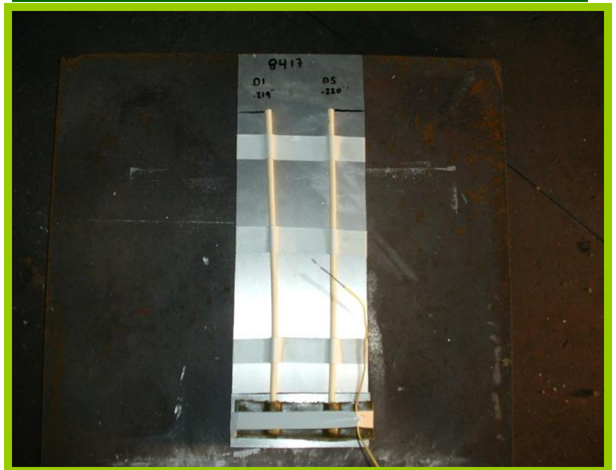
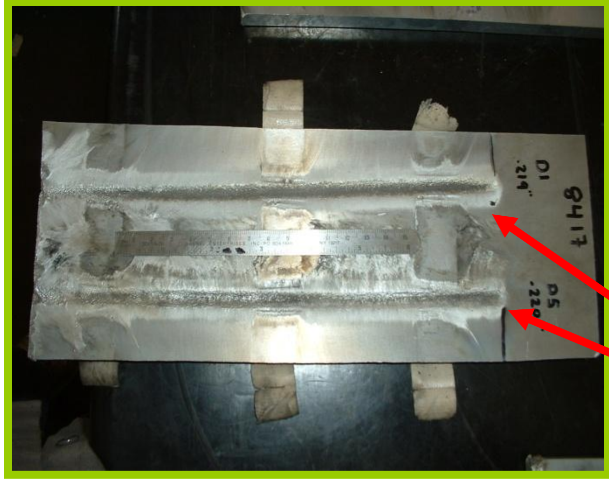
RESULTS: Shock Sensitivity

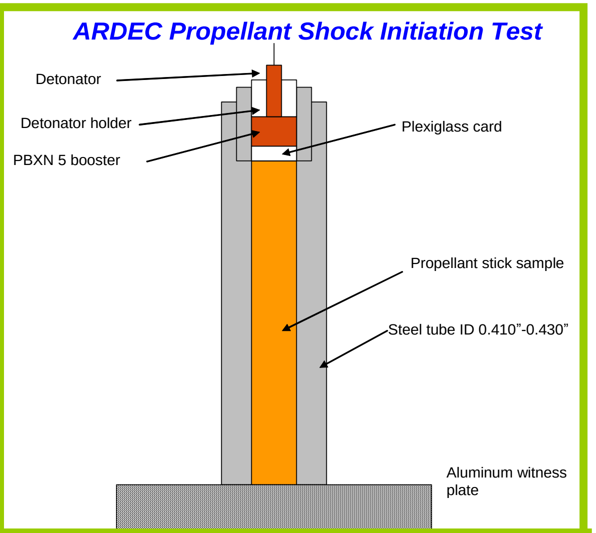
Critical Diameter and Shock Initiation

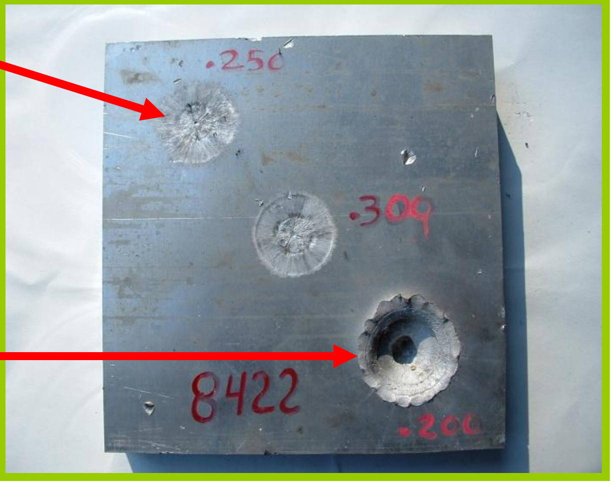
Critical Diameter Setup





Shock Initiation Setup





Not detonated

Dent from detonated samples

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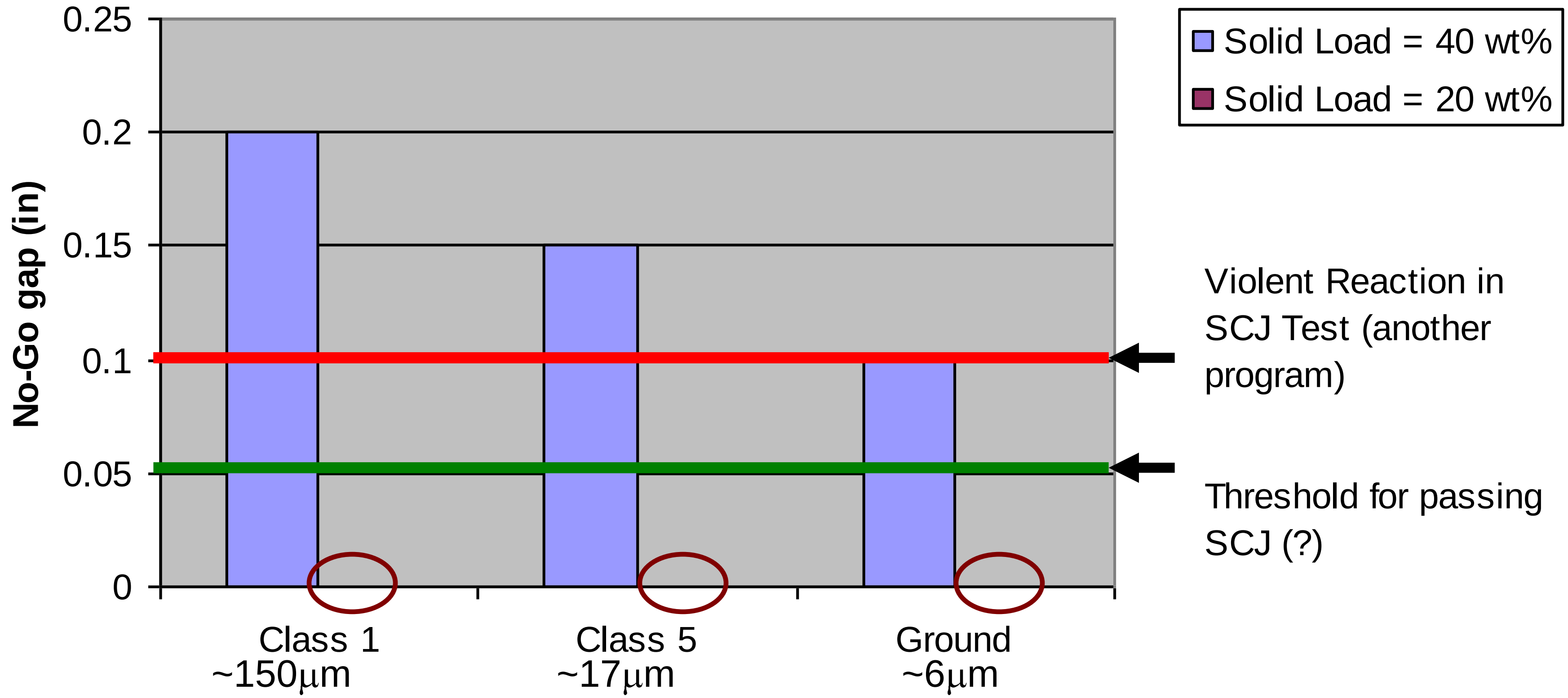
RESULTS: Shock Sensitivity (Cont.)

Shock Sensitivity of iRDX Based Propellants



As particle sized decreased the sensitivity decreased

As solid load decreased (total E) the sensitivity decreased

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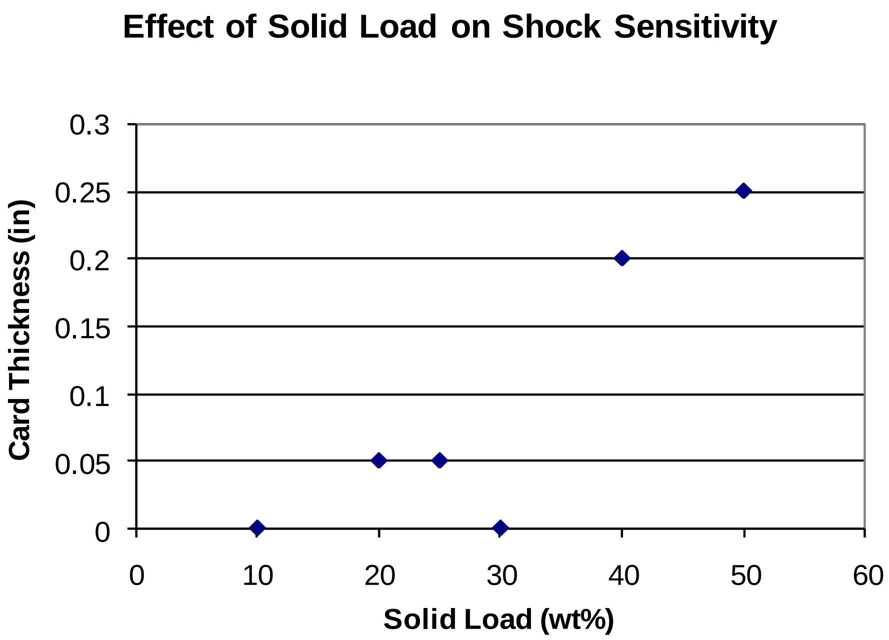
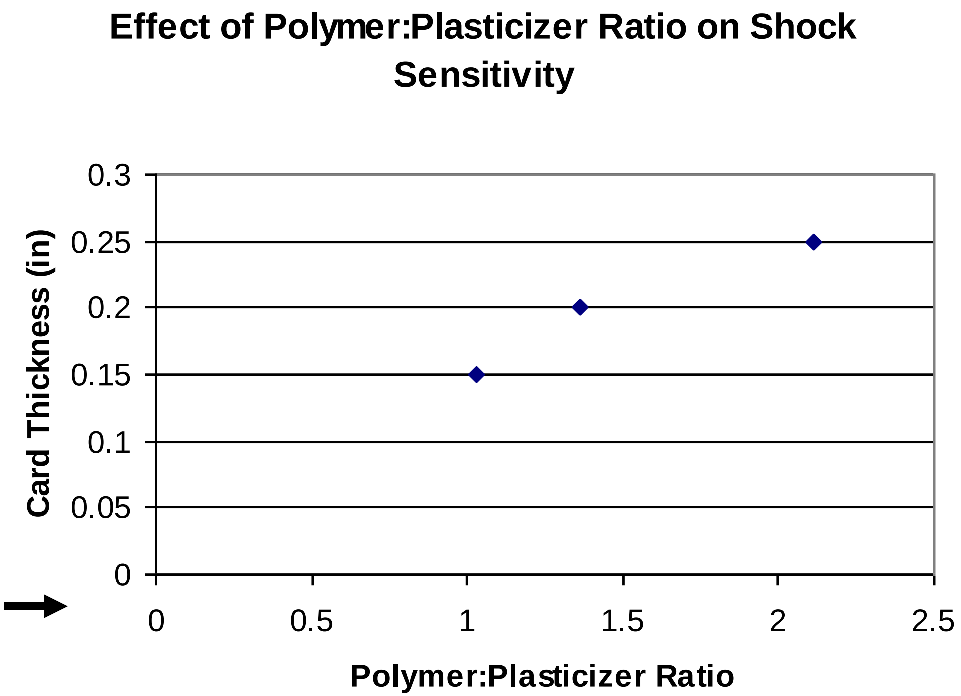
RESULTS: Shock Sensitivity (Cont.)



Polymer:Pasticizer Ratio = 1.36



Solid Load = 40wt%

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RESULTS: Mechanical Properties

Trends in Mechanical Properties

Polymer: Plasticizer Ratio	Mech. Prop.	Solid Load (wt%)
1.03	Best	40
1.36	Good	40
2.11	Accept.	40
1.5	Best	0
4	Accept.	0

Solid Load (wt%)	Mech. Prop.	Polymer: Plasticizer Ratio
0	Best	1.5
10	Good	1.36
20	Good	1.36
30	Good	1.36
40	Good	1.36
50	Good	1.36

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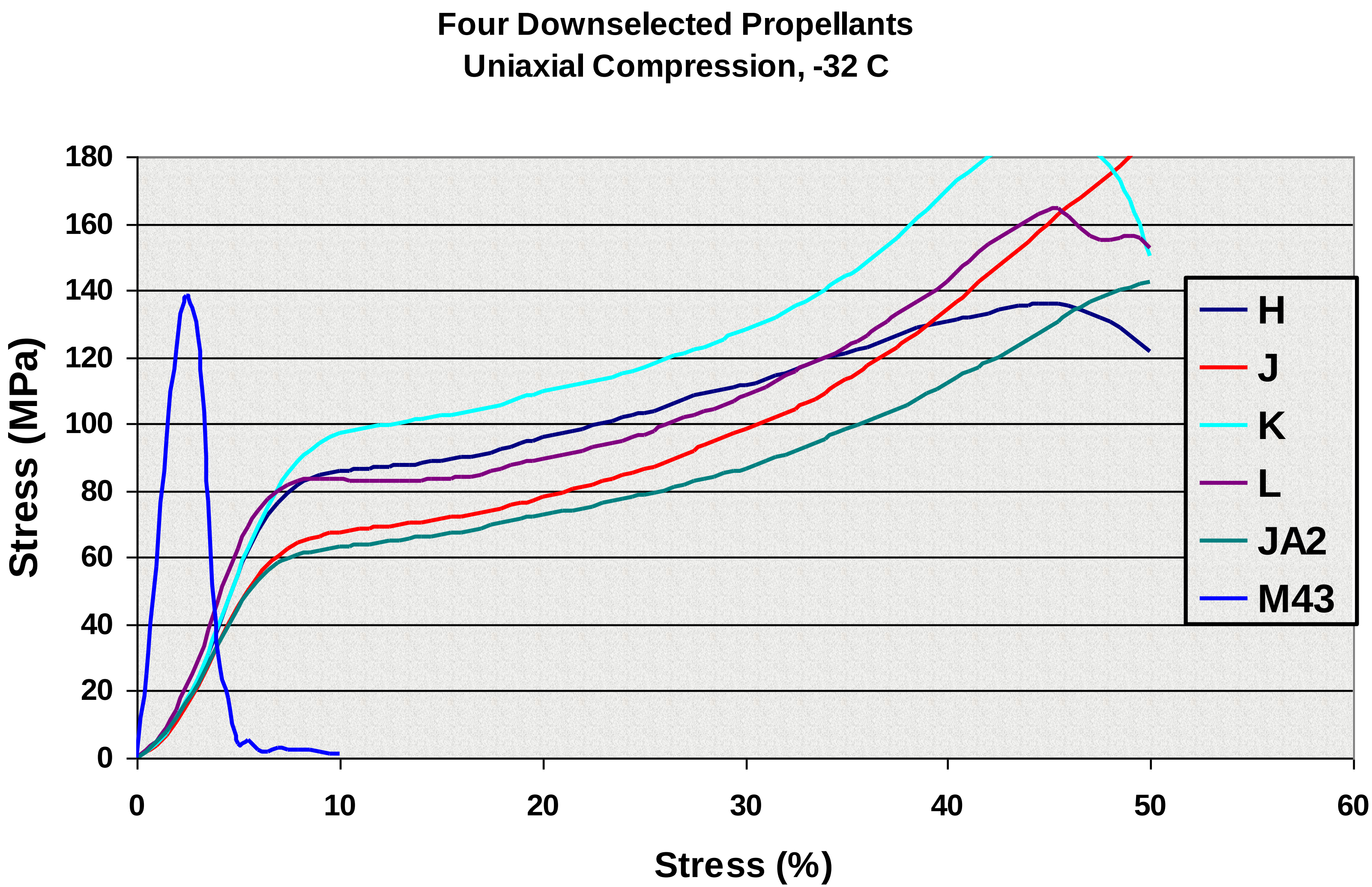
RESULTS: Young's Modulus

Uniaxial Compression (Mechanical Properties)



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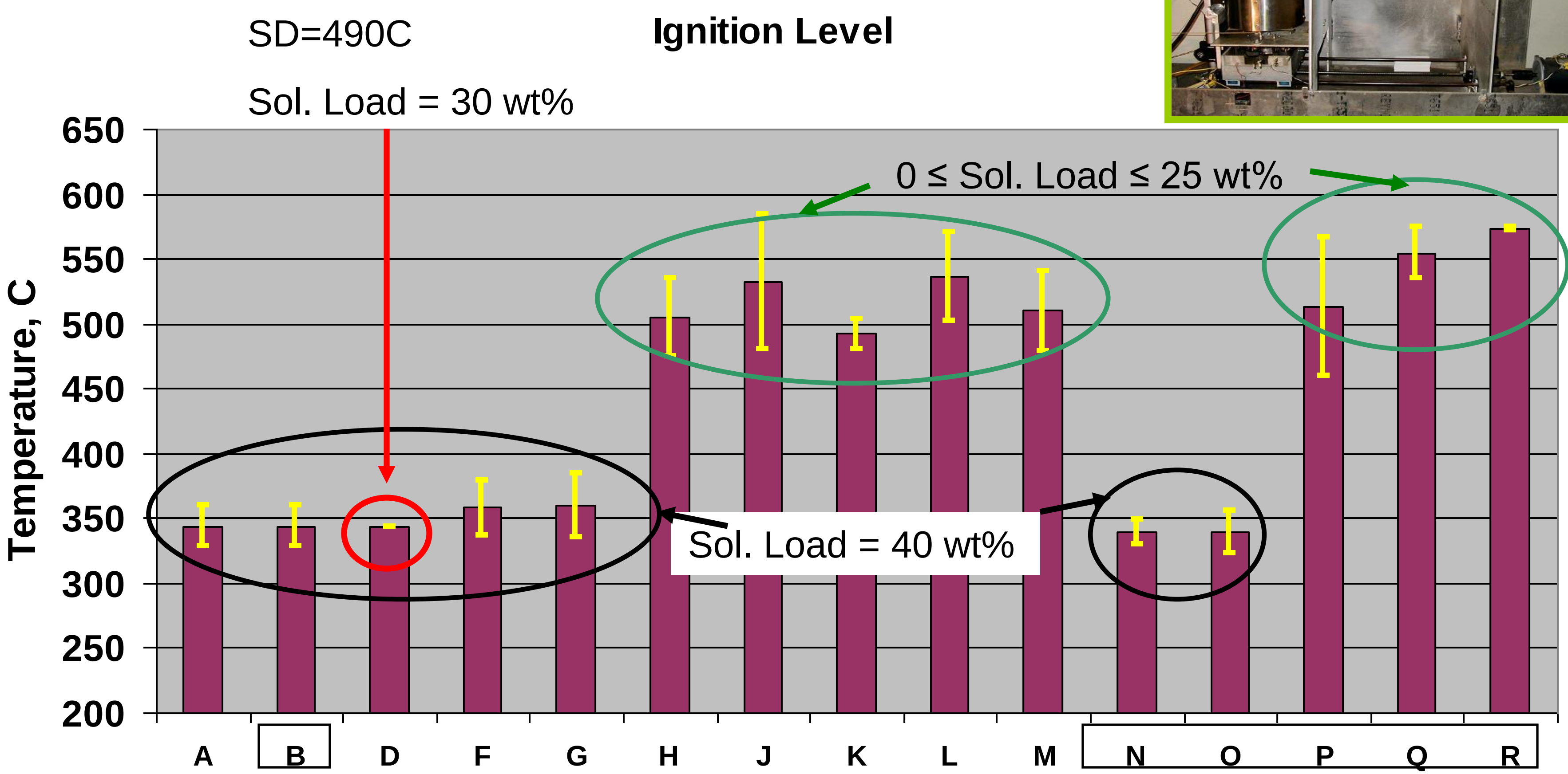
RESULTS: Thermal Sensitivity

Hot Fragment Conductive Ignition



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RESULTS: Downselection

Ranking for Downselection

Formulation	Vel. Ranking	Erosiv. Ranking	Shock Init. Ranking	HFCI T_{ig} Ranking
JA2	**10**	**13**	**-**	**-**
A	2	10	10	8
C	1	12	11	-
D	6	7	1	9
E	3	11	11	-
F	4	9	9	7
G	5	8	8	6
H	8	6	6	4
I	7	5	1	-
J	12	1	1	2
K	9	4	6	5
L	11	2	1	1
M	13	3	1	3

•Formulations H, J, K, and L were downselected

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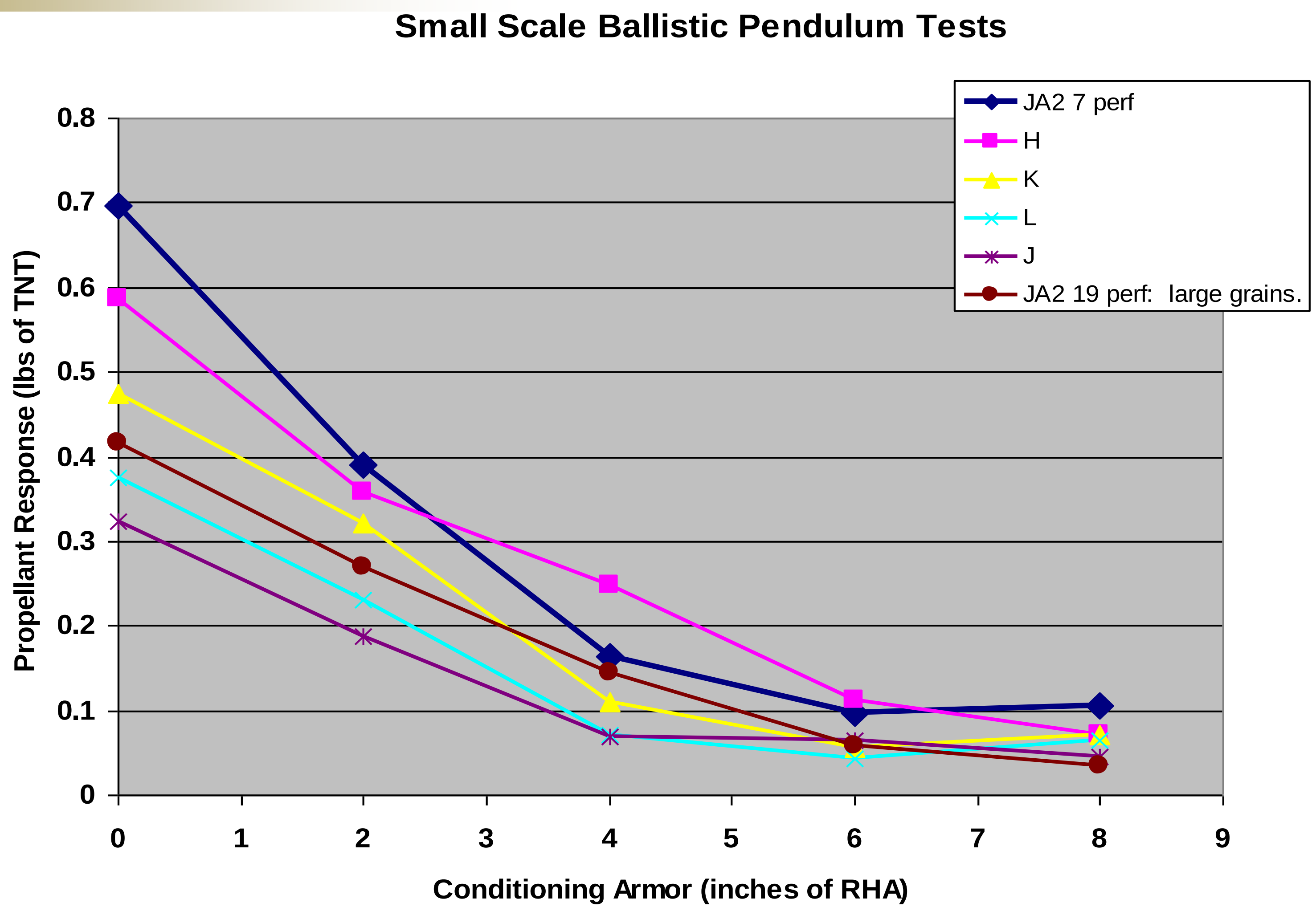
RESULTS: Small Scale SCJ Test

Small Scale SCJ Ballistic Pendulum Test Setup

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RESULTS: Small Scale SCJ Test



No Detonation Observed

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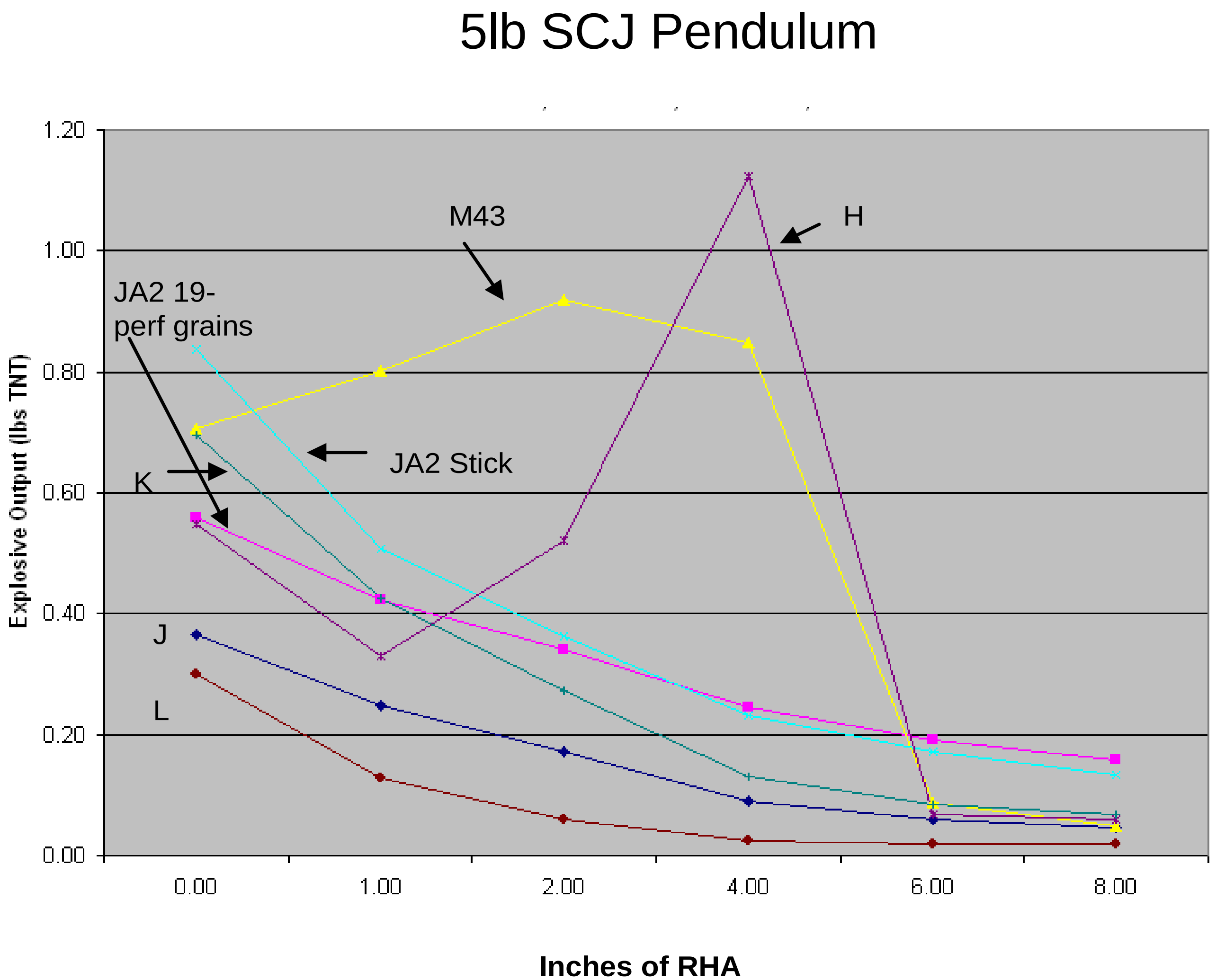
RESULTS:
5lb SCJ Pendulum Test



Detonation was Observed for H at 4" RHA

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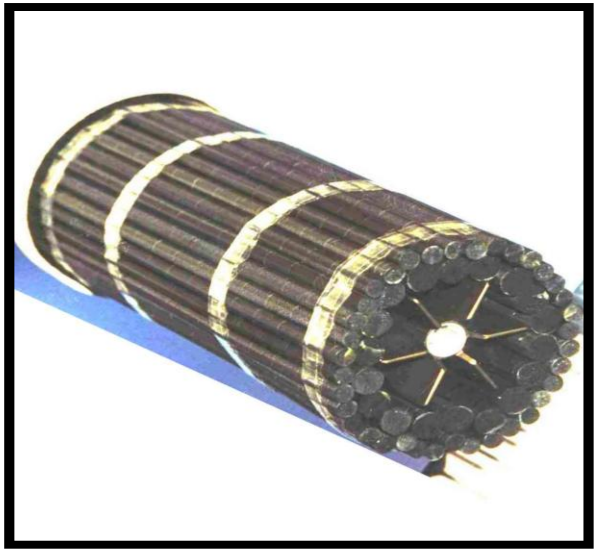
RESULTS: Shock Sensitivity of End Item

5lb SCJ Pendulum Test Sample vs End Item Loading Configuration

Propellant Sticks loaded in 6 in x 6 in Cardboard Tube

Source: Boyd, K. et. al., ARL, MD (Aug 2006)



Tank KE Charge Configuration

Source: ATK, Radford, VA

- Formulation H has lower critical diameter of bed than JA2
- It may not react violently in actual charge configuration due to space made by projectile
- Further testing is needed to confirm this

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RESULTS: Gun Firing

60mm Gun Firing

- One slot became available in Novel Energetics Material ATO
- Formulations H was selected to test (before 5lb SCJI pendulum test data was available)
- 60mm Gun:
  - sub-scaled from 120mm
  - Base pad electrothermal-chemical (ETC) igniter
- Formulation H performed better than JA2 as expected
- Formulation K was not test fired but should have similar performance as JA2
- Some shots displayed high negative delta P
  - Data under further evaluation
  - Blocked pressure ports on several shots

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SUMMARY and CONCLUSIONS

- Eighteen IM gun propellant formulations were thoroughly characterized in this program
  - One formulation **met performance** requirement and had **better IM** properties than JA2
  - One formulation **exceeded performance** requirement and had **better IM** properties than JA2 **except against SCJ** – critical diameter of the bed is smaller than that of JA2
    - This formulation also had higher ballistic efficiency than JA2 in the 60mm sub-scale gun firing
  - Two formulations had **slightly lower performance** than required but had **much better IM** properties than JA2
  - All Four formulations mentioned above have **much lower erosivity** than JA2

Patent Pending

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AKNOWLEDGMENTS

- Dr. Pai Lu – Consultations and mentoring
- Dr. Brian Fuchs, Ms. Amy Wilson, and Mr. Gerard Gillen for Critical diameter, Shock initiation, and other safety testing
- Dr. Avi Birk and Mr. Steve Aubert’s Team for HFCI and Small scale SCJ pendulum testing
- Mr. Charlie Leveritt and Dr. Stephanie Piraino for erosion calculations and good technical exchange
- Drs. Rob Lieb and Stephanie Piraino for Uniaxial compression test and SEM
- Dr. Barrie Homan for Closed bomb and Strand burn testing
- Mr. Ken Klingaman for Closed bomb and Critical diameter testing
- Mr. Kevin Boyd for 5lb SCJ Pendulum testing
- Dr. Jim Luoma for 60mm gun firing
- Mr. Joe Colburn for 30mm gun firing
- Dr. Pat Baker and Ms. Nora Eldredge for program management and funding

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ONR

Revolutionary Research . . . Relevant Results

46th Annual NDIA
Gun & Missile Systems Conference
Non-Traditional Weapons I

Development of a Large Caliber Naval EM Railgun

Mr. Roger Ellis / Mr. Ryan Hoffman
Office of Naval Research

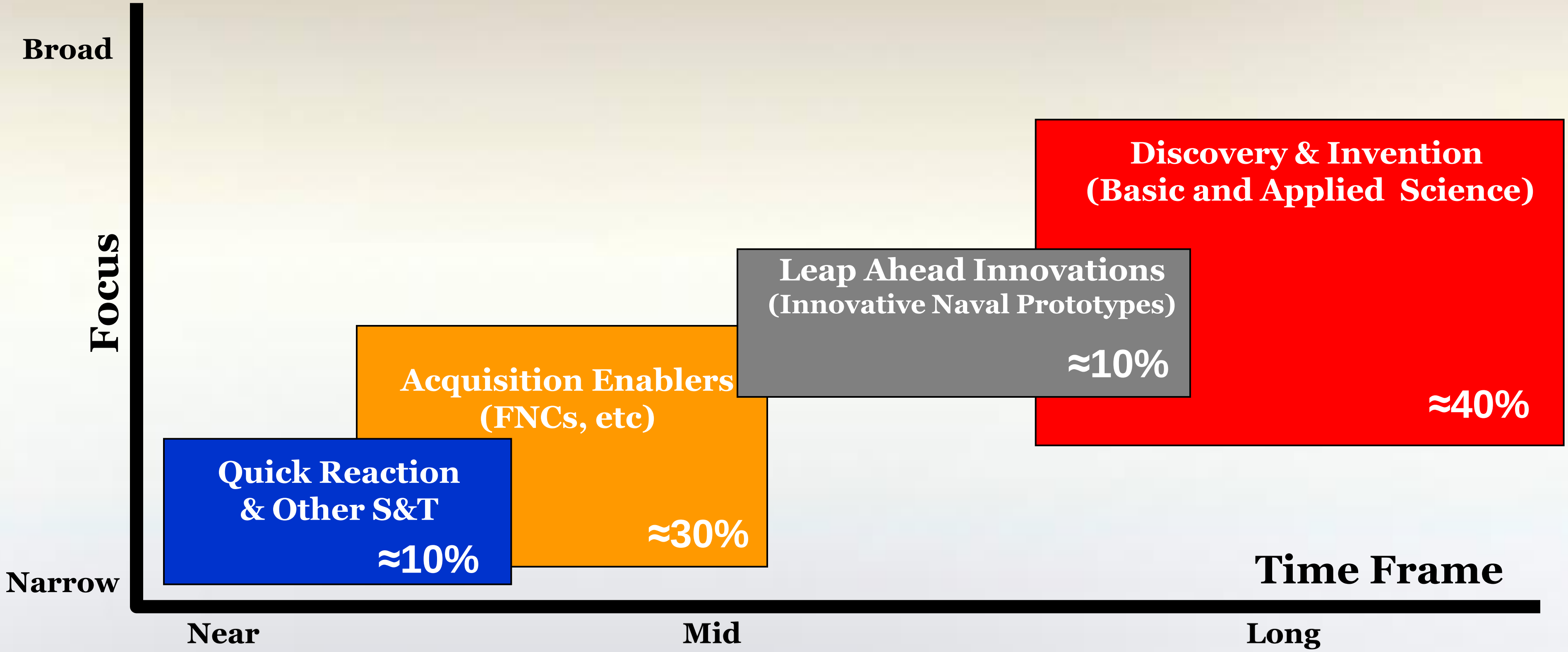
DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited

Is this what you think of when you hear RAILGUN?

80 cm German Gun "Dora" circa 1942

THINK AGAIN!!

ONR Shaping S&T Investment



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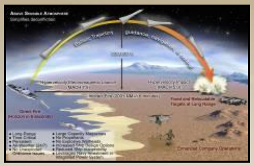
Innovative Naval Prototypes

INP Objective

- Explore high-risk, game-changing technologies
- Provide a venue to experiment with innovative technologies to advance the capabilities of the Warfighter
- Reduce the acquisition risk of disruptive technologies and capabilities

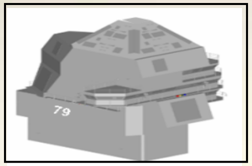


EMRG

PLUS

SBE

FEL



INTOP

Technical Approach

- Transition investments within 4 to 8 years
- Leverage previously untapped D&I investments
- Force function on the basic and applied research community
- Move the risk from acquisition ($B) back to S&T ($M)
- Accept higher technological risk than FNCs
- Cultivate significant high level interest (Executive Steering Committees from SECNAV, OPNAV, SYSCOM and S&T communities)
- Useable prototype available at completion
- Deputy PMs from acquisition PEOs to facilitate transition

Primary S&T Focus Areas

- Affordability, Maintainability, and Reliability
- Information, Analysis, and Communications
- Survivability and Self Defense

Current INP Projects

- Electromagnetic Railgun
- Sea Base Enabler
- Tactical Satellites
- Persistent Littoral Undersea Surveillance
- Free Electron Laser
- Integrated Topside

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Conventional Weapons
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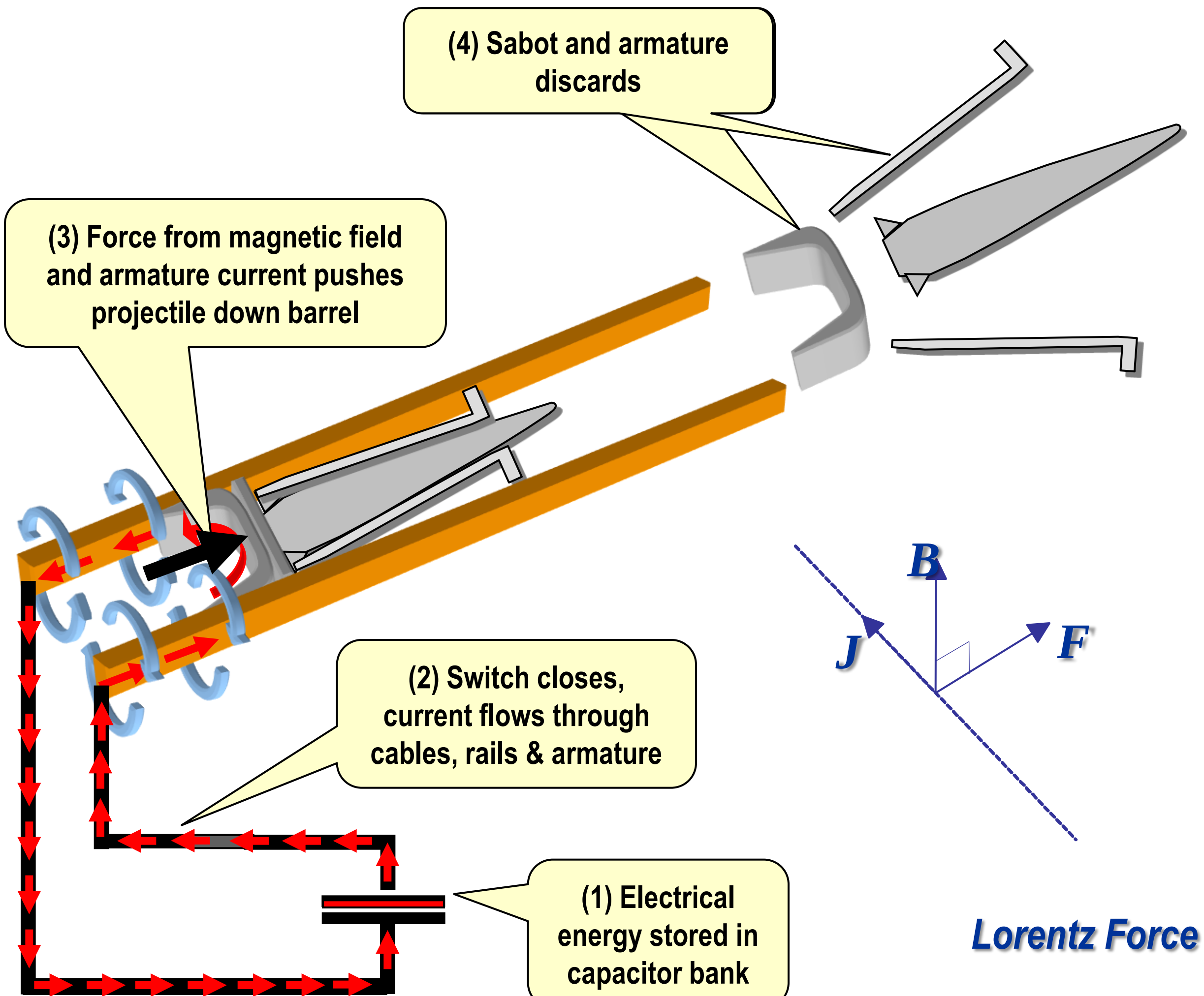
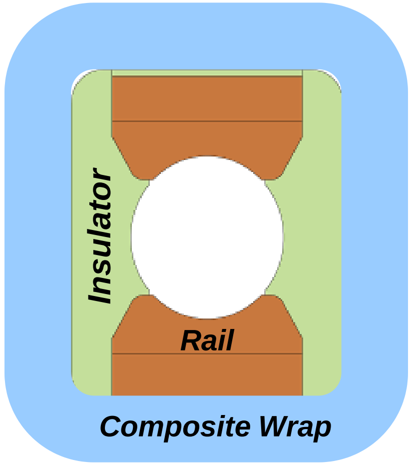
Revolutionary Research . . . Relevant Results

How Railgun Works

Operating Principle



Cross-Section

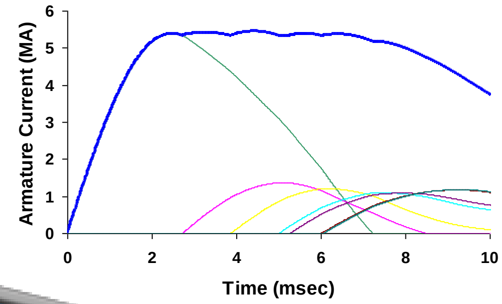


Lorentz Force = Current (J) X Magnetic Field (B)

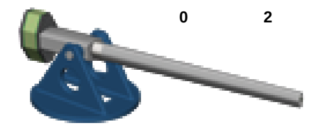
or

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

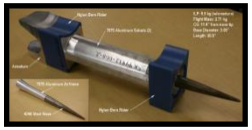
What's Non-Traditional About Naval Railgun

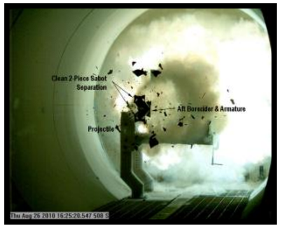


- Electrical energy vs. chemical propellants for projectile launch
  - Enables variable velocity
  - Optimized in-bore acceleration profile

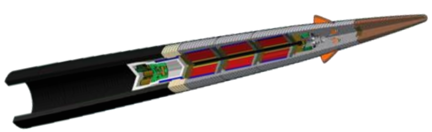


- Non-electrical conducting barrel structure
- Greater launch velocities than conventional (2.5km/sec)
- Greater ranges (200+nm)



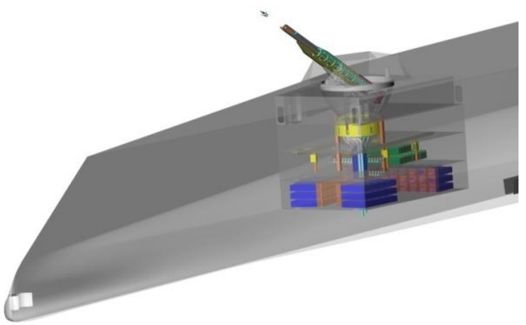


- Enables non-round bore geometries
- Ballistic trajectory with guided projectile correction
  - Endo-exo-endo
  - Aerodynamic profile



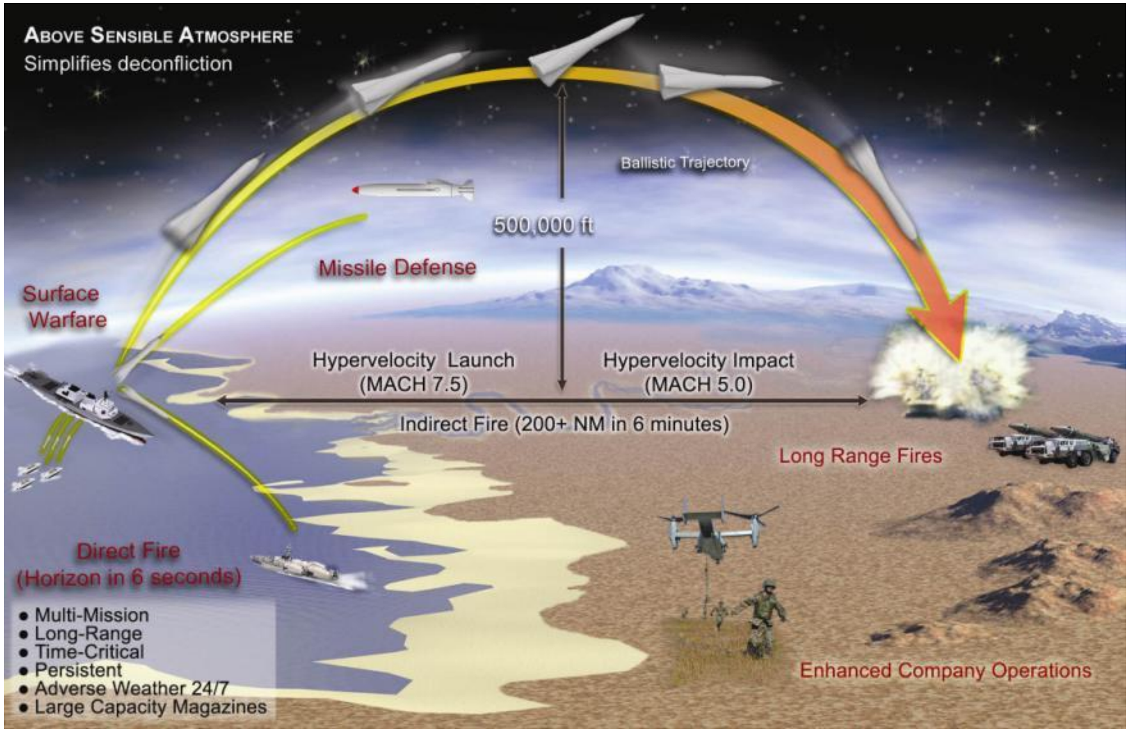
- Kinetic energy kill through dispensed fragments variable height of burst

- Enables greater ship platform modularity



Railgun Operational Impact

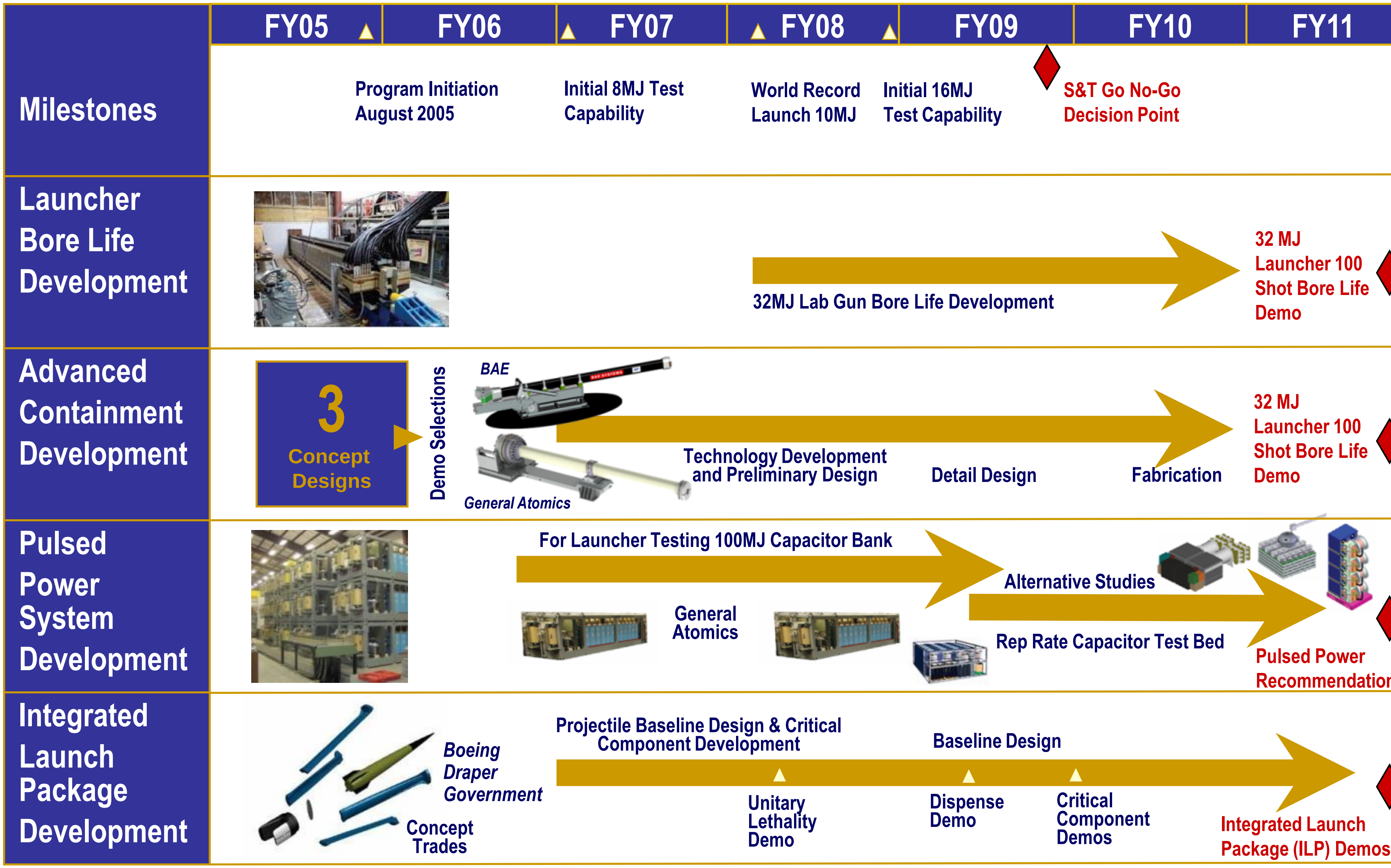
- *Wide Area Coverage*
  - Increased speed to target
  - 200+ NM
- *Accelerates operational tempo*
  - Faster attrition of enemy personnel and equipment
  - Operation timeline shifts left
- *Reduces Cost per Kill*
  - Lower Unit Cost
  - Lower handling cost
- *Enhances Safety*
  - No risk of sympathetic detonation
  - Simplified storage, transportation and replenishment
  - Reduced collateral damage
  - No unexploded ordnance on battlefield
- *Reduces Logistics*
  - Eliminates gun powder trail
  - Deep magazines



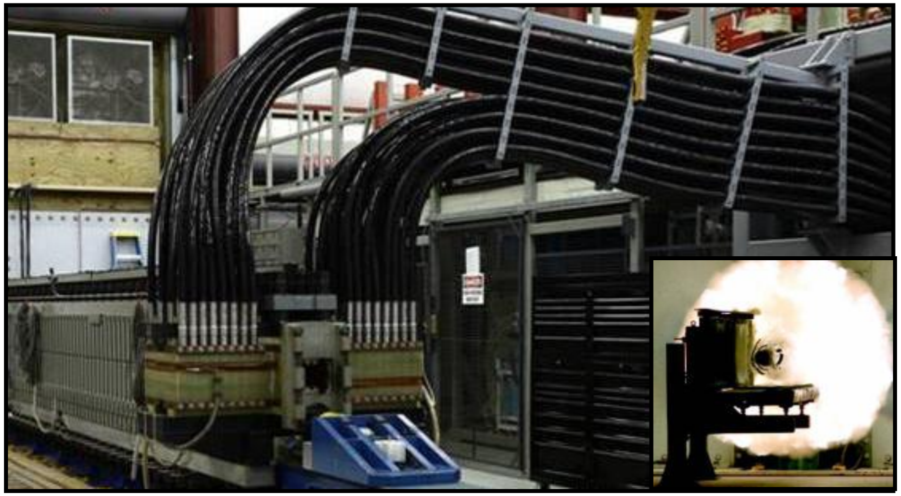
- *Multi-Mission Capability*
  - *Surface Warfare*
  - *Missile Defense*
  - *Long Range Fires*
  - *Direct Fire*
  - *ASuW*

Multi-Mission Capable for Offense and Defense

EM Railgun INP Phase I



Progress FY05 – FY11

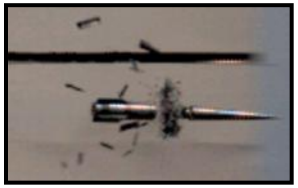


Lab Launcher

GA Med-Cal Blitzer (IRAD)

Rep-Rate Test Bed

BAE 5M Prototype



Dispense Test

- Muzzle energy:
  - From 6MJ to 32MJ
- Bore Life
  - From 10s to 100s
  - Multiple configurations & materials
- Industry Launcher Prototypes
  - From concept to hardware
- Pulsed power
  - From single shot
  - To multi-shot capable design
- Projectile
  - From slugs & sand catch
  - To instrumented and dispensing flight bodies on open range
- Mission
  - From Land Attack
  - To Multi-Mission Initiative

Advanced Containment Launchers

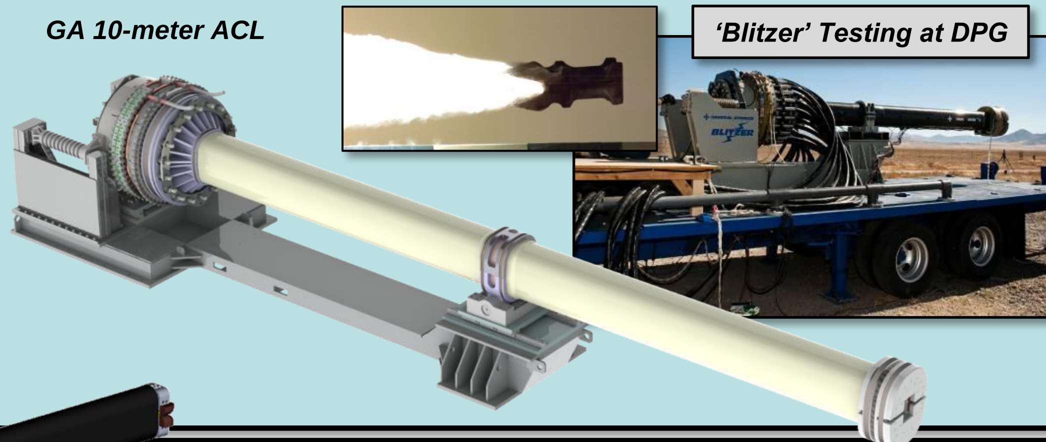
The industry developed Advanced Containment Launchers (ACLs) detailed designs are competition sensitive and each include unique materials, however they both share the following attributes:

- Advanced composite containment designs
- Advanced insulator materials

GENERAL ATOMICS

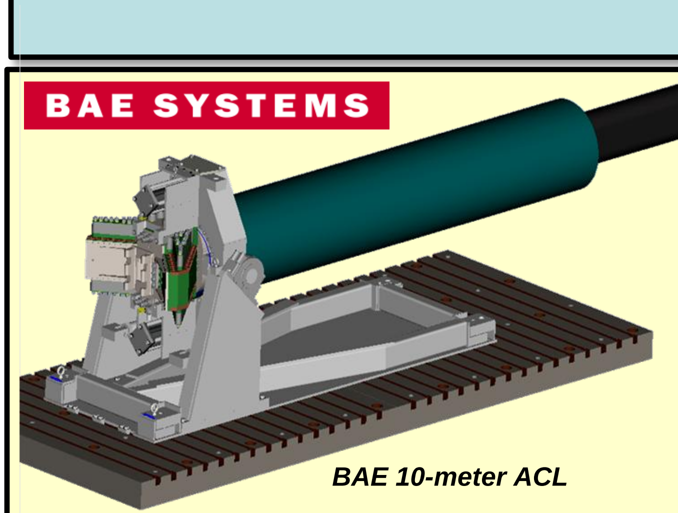
- Subscale ACL launcher ('Blitzer') built by GA to provide risk reduction. Multiple test series have been completed at Dugway Proving Grounds (DPG), Utah
- Full-scale 10-meter ACL in production
- GA 10-meter ACL scheduled to be delivered to the Electromagnetic Launch Facility (EMLF) at NSWC Dahlgren and complete testing during the 1st quarter of FY2012

GA 10-meter ACL



'Blitzer' Testing at DPG

BAE SYSTEMS



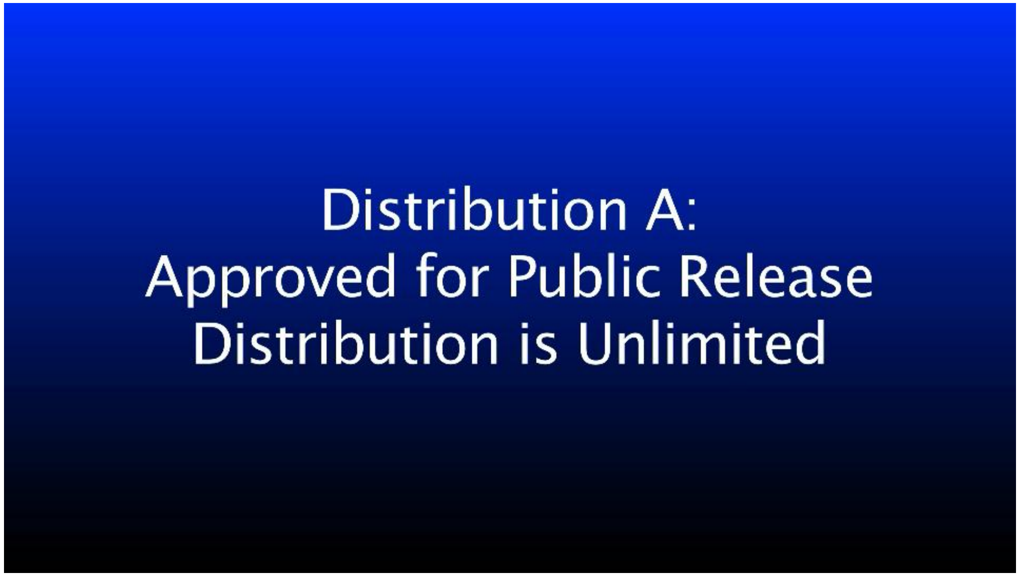
BAE 10-meter ACL

5-meter ACL Testing at EMLF

- 5-meter version of 10-meter ACL recently tested at EMLF (1/2011) with full-scale bore (cross-section), breech, muzzle and mount.
- Full-length ACL in production.
- BAE 10-meter ACL scheduled to be delivered to the Electromagnetic Launch Facility (EMLF) at NSWC Dahlgren and complete testing during the 4th quarter of FY2011

Videos


Gun Launch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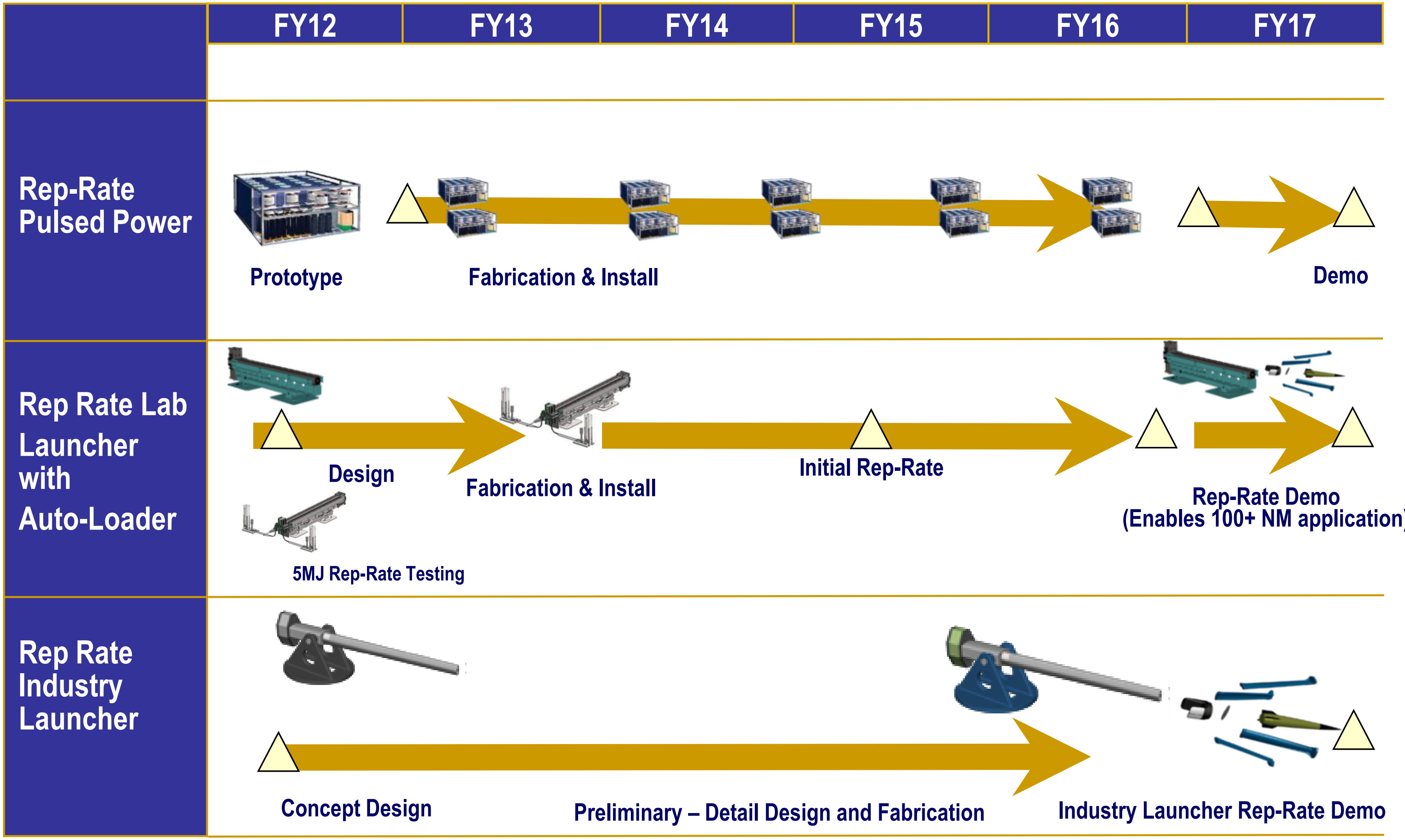
Distribution is Unlimited


Distribution Statement A:
Approved for Pubic Release.
Distribution is Unlimited.

EM Railgun INP Phase II



INP II Focused on Rep-Rate and Thermal Management

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Electromagnetic Railgun, A Multi-Mission Weapon System

by
Alan Kull
and Thomas Hurn
General Atomics





46th NDIA Gun and
Missile Systems Conference

August 30, 2011

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

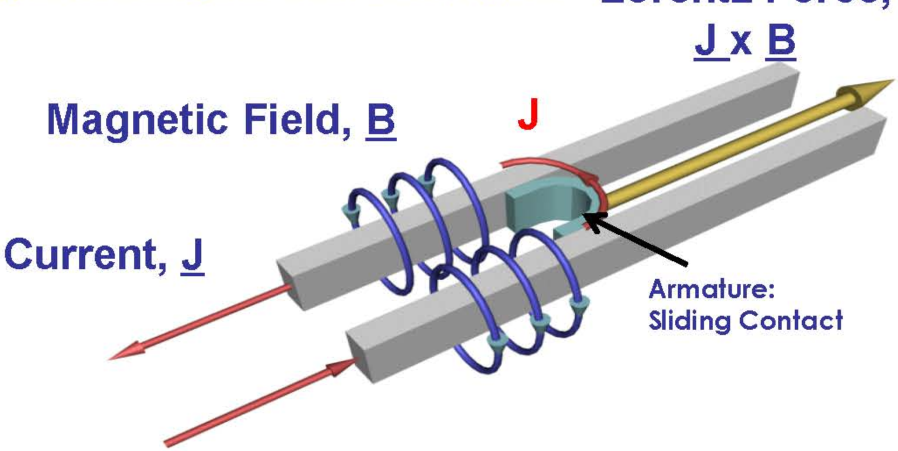
Briefing Outline

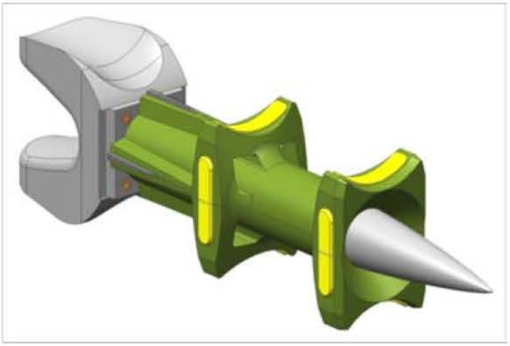
- Introduction to electromagnetic railguns
- General Atomics' role in ONR program
- Application of railguns to multiple missions
- Testing of Blitzer ™ prototype system

GENERAL ATOMICS

Introduction to Physics of Railguns

Railgun: Electromagnetic Force drives projectile

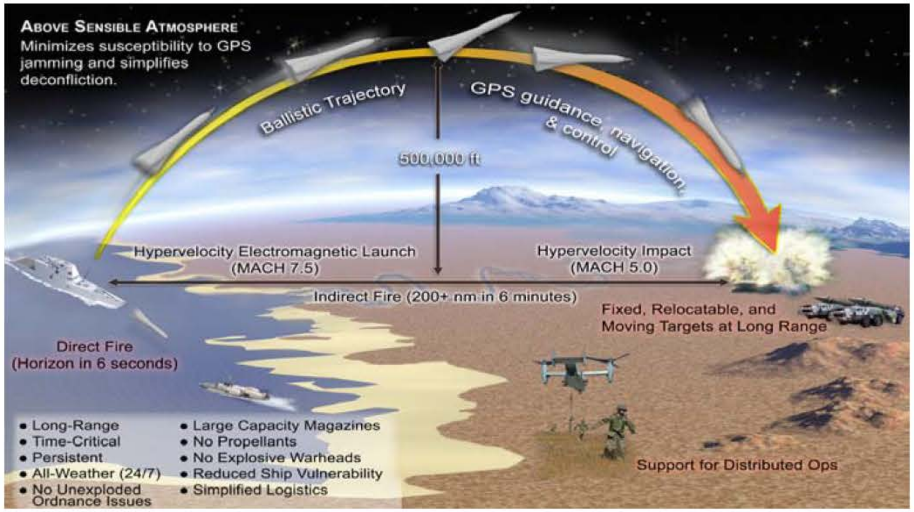


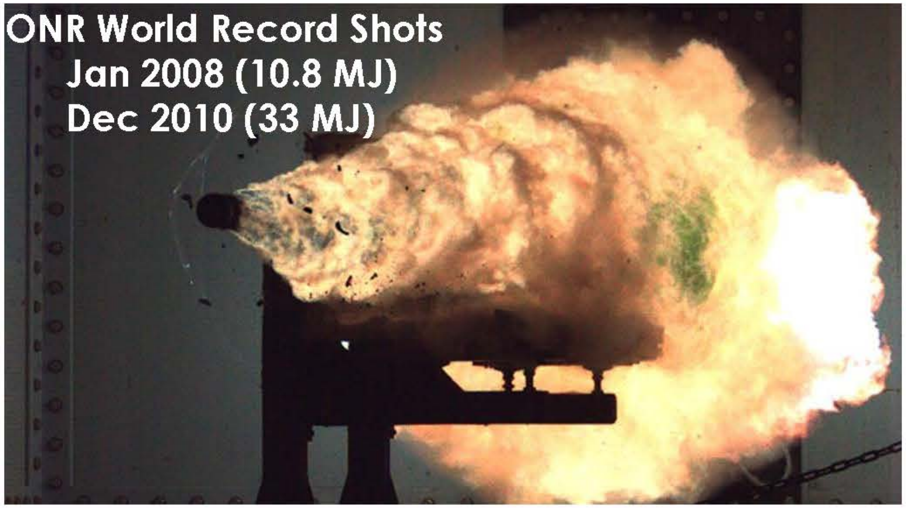


Launch Package
- Armature
- Sabot with
- Bore riders
- Flight body

- **MJ of electrical energy stored in capacitors instead of propellant**
  - **Propulsion from Mega-Ampere level currents discharged through rails in milli-seconds**
  - **Acceleration 20 – 100 k-gee**
- **High muzzle velocity: 2–2.5 km/sec (Mach 6-7.5)**
  - **Long range**
    - Extends inner tier of ship defense to horizon
    - Mostly exo-atmospheric flight for indirect fire missions
  - **Fast time to target**
    - 7 seconds to horizon at sea level
    - 30-40 seconds from sea level to 100,000 feet
  - **High Lethality from kinetic energy**
- **No onboard propellant**
  - **Simplifies logistics**
  - **Improves ship survivability**

GA is Providing Tactical Launcher Development and Pulsed Power for ONR's Railgun Program





GA Pulsed Power for NSWCDD Railgun Facility

- 81 MJ Laboratory Modular Capacitor Bank
- All units delivered and operating reliably

GA Advanced Containment Launcher

Develop and demonstrate tactically relevant launcher at full muzzle velocity and half muzzle energy (32 MJ)

- System under construction for testing 1st Qtr of CY12

GENERAL ATOMICS

Railguns Have Potential to Dramatically Improve Ship Defense Against Emerging Air and Surface Threats

Problem: Rapid proliferation of low cost cruise & ballistic missiles

- Overwhelm our ship defense system through swarm attack
- Denies access to key regions
- Cost to defeat threat many times higher than threat cost

Ballistic Missile

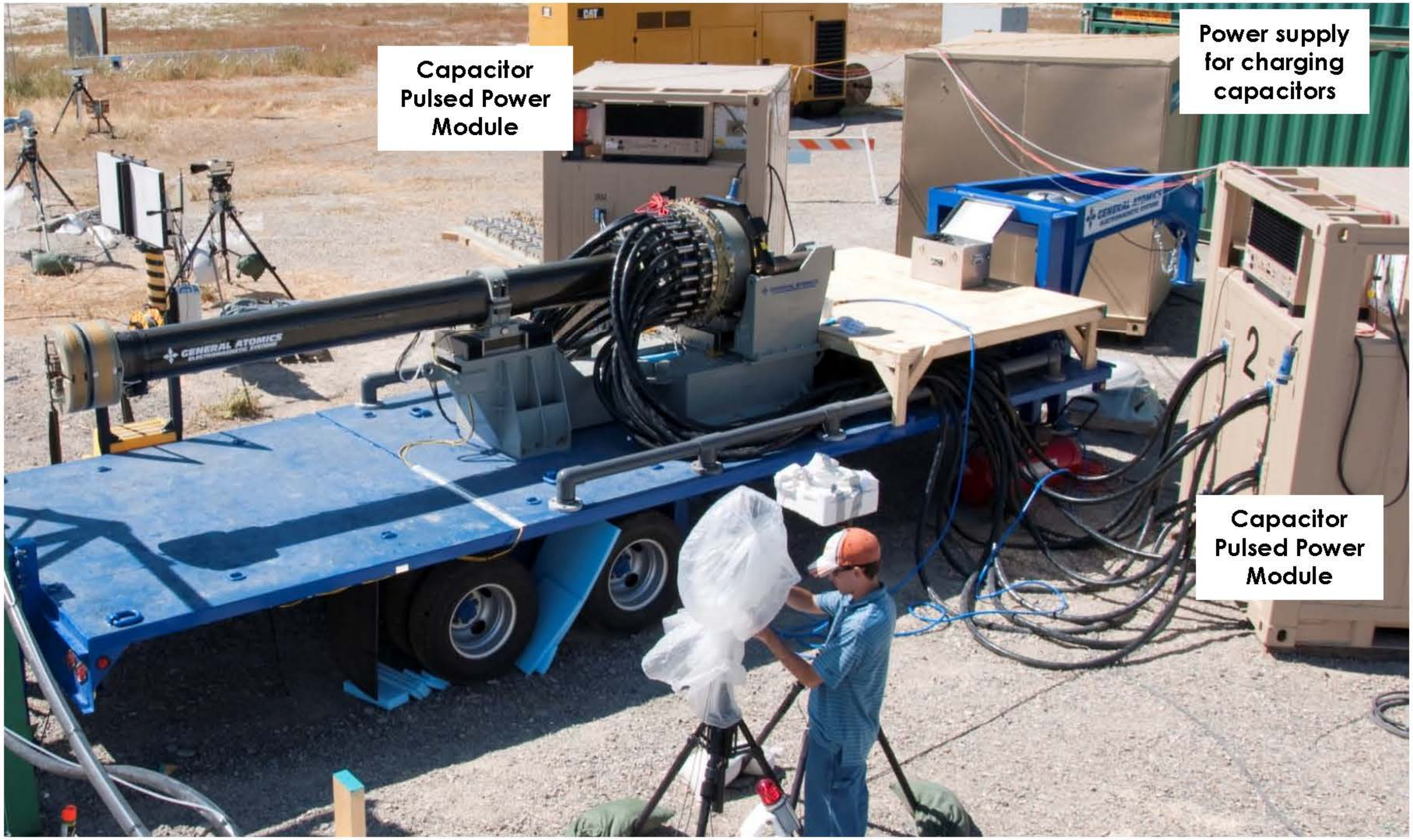
Supersonic sea skimming cruise missiles can travel at Mach 3 (1 km/sec)

High Performance, Low Cost Solution: Multi-Mission Blitzer Railgun

- > 2x muzzle velocity of current guns
- Faster time to target
- Greater range
- Higher lethality at range
- No onboard propellant
- Smaller rounds, deeper magazines

GENERAL ATOMICS

Blitzer Railgun System: Developed to Demonstrate Technical Maturity and Practicality of a Smaller Scale Railgun System



System was built for testing in a Proving Grounds environment

GENERAL ATOMICS

Blitzer Testing at Dugway Proving Grounds Provides a Significant Demonstration of Railgun Maturation


2 MJ Blitzer EM Gun


Mobile Pulser


Testing at Dugway


Launch Package in Flight

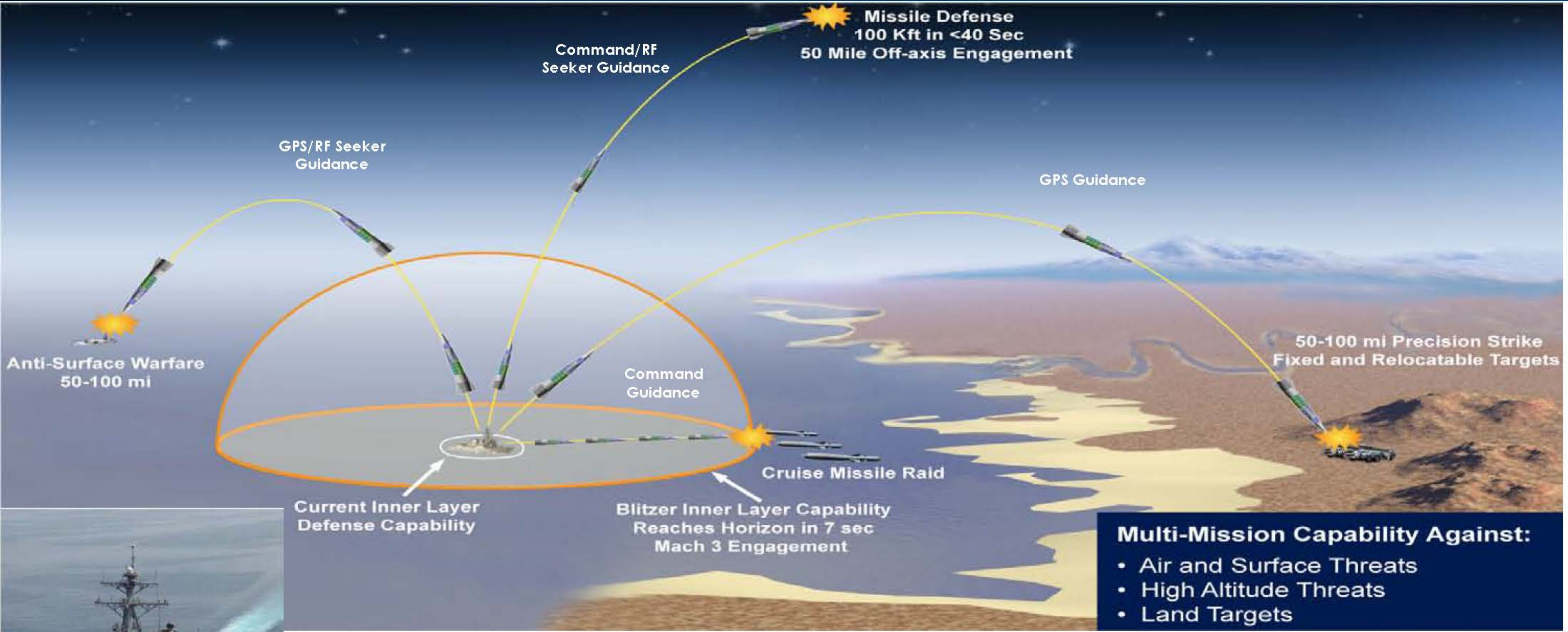
- Launcher and mobile pulsed power system developed on internal GA funds
- Testing on ONR funds provided through support from UT delegation
- 71 rounds fired to date (9 tests with ¾ scale aerodynamic projectile)
- Minimal bore wear; significant increase in state of the art

PEAK PERFORMANCE TO DATE	
Parameter	**Performance**
Velocity (km/sec)	2.0
Gun Energy (MJ)	1.8
Peak Current (MA)	2.12
Peak Voltage (kV)	2.8

Demonstration validates major elements of the Blitzer System

GENERAL ATOMICS

Blitzer Railgun Provides a Lower Cost, Deep Magazine, Multi-Mission Solution on Surface Combatant



Multi-Mission Capability Against:
- Air and Surface Threats
- High Altitude Threats
- Land Targets

- **Replacement of Mk45 5” Gun**
- **Variable muzzle energy, lower for air defense targets requiring high firing rate (5 MJ); higher for Ballistic Missile Defense and Precision Strike (up to 20 MJ)**
- **Using battery energy storage, ship prime power requirement reduced to current available power**

One launcher firing a family of projectiles to accomplish multiple missions

GENERAL ATOMICS

Excellent Progress Being Made on Railgun Development

- **ONR program and GA's Blitzer ™ efforts have significantly matured railgun technology**
- **Rapid advances in railgun technology motivate near term applications on surface combatants**
- **A 20 MJ Blitzer multi-mission railgun system on today's surface combatants appears viable**
  - Using today's technology
  - Substantially improve defense of our fleet against rapidly emerging threats
- **Navy leadership showing significant interest**

The rapid pace of technology maturity and evolving threats are accelerating the drive toward railgun deployment

IM in the Field – Experience of Reduced Sensitivity Mortar Cartridges to Actual Combat Threat Stimuli
April 2011

Presented by:

Pamela Ferlazzo

Idea Catalyst - RDECOM-ARDEC

120mm M120 / M121

I-81mm
M252

60mm
M224

RDECOM-ARDEC Malcolm Baldrige
National Quality Award - 2007 Recipient

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

IM Design Features Incorporated into 60mm HE Ammo (M720A1 & M768)

➢PBXN-5 Explosive Fuze Booster

- ➢ Improved thermal response than former COMP A5 explosive - Burning / pressure rupture vs. partial detonation in Variable Confinement Cook-off tests (VCCT) .
- ➢ Approved in-line explosive (MIL-STD-1316).
- ➢ Already utilized in M734A1 and M783 Fuzes (lead charge).

➢Plastic Fuze Adapter

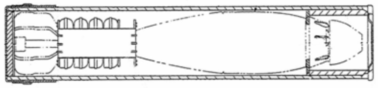
- ➢ Provides warhead venting.
- ➢ Prevents internal pressure buildup and acceleration of a burning reaction to a deflagration / explosion (upon auto-ignition / cook-off of explosive fill in a fire or exposure to thermal stimuli).

➢PAX-21 Explosive Main Charge

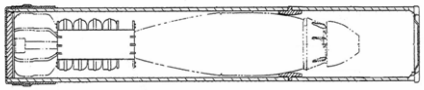
- ➢ Less shock sensitive than former COMP B explosive fill – 165 cards vs. 208 cards NOL gap tests (LSGT).
- ➢ Improved behavior in burning reactions.
- ➢ Non-TNT based, melt-pour explosive
- ➢ Minimal impact on existing loading facilities.

IM Design Features Incorporated into Packaging for 60mm M720A1 & M768 HE Mortar Ammo

- **Fibertube Container**
  - Eliminated metal packing clip (inserted into fuze wrench slots) - Cartridge presently supported on projectile body by a new plastic ring / fiberboard sleeve system.
  - Longer container to provide additional space for fuze separation and optimal warhead venting.



PA78 FIBER TUBE
W/ METAL FUZE SUPPORT CLIP



PA164 FIBER TUBE
W/ PLASTIC PROJECTILE BODY SUPPORT RING

- **Metal Ammo Container**
  - Taller can for longer PA164 fibertubes.
  - Intumescent paint coating eliminated due to unresolved durability problem (i.e. cracking / de-lamination during rough handling tests at extreme cold environment).

Developmental IM Testing (Fast Cook-off)

Non IM- 60mm M720
HE Cartridges

Projectile Body Fragments and Unconsumed COMP B Explosive (TYPE II Response)

Developmental IM Testing (Fast Cook-off)

IM Enhanced - 60mm M720A1 / M768 HE Cartridges

Burned-out Projectiles (TYPE V Response)

Mine Resistant Ambush Protected (MRAP) Vehicles

Afghanistan (September 2009)

- **MRAP vehicle hit by an Improvised Explosive Device (IED).**
- **IED ruptured the vehicle's hull and fuel tank, which engulfed the vehicle in flames.**
- **Seven-man crew and 60mm M768 HE mortar ammunition were inside the cabin.**
- **Although several soldiers were seriously injured, all survived.**
- **<u>Insensitive Munitions (IM)</u> features of 60mm M768 HE cartridges credited with averting a greater disaster.**

Response to Actual Combat Threat (IED) Stimuli

Exterior of MRAP

Burned out projectile

Interior of MRAP after IED attack and resulting fire.

Burned-out 60mm M768 projectiles recovered from MRAP

Mortar Ammunition IM Enhancements

- Real Benefits
  - Increased Soldier Survivability
  - Reduced Collateral Damage
  - Enhanced Safety
  - Logistics (Improved Ammo Storage)
- Additional (Ongoing) Design Improvements
  - IMX-104 Explosive Fill
  - PBXW-14 Fuze Booster Explosive

Time for an Upgrade in US Propellant Manufacturing

Teaming for Performance

Alliant Techsystems and Rheinmetall Nitrochemie

2011 NDIA Guns and Missiles Conference

Miami, FL   30 August – 1 September 2011

Presenter:

Operational Environment

WW II	Korea / Vietnam	Gulf War	GWOT
Volume (Quantity over Quality)	Increased investment in technology	Introduction of precision weapons	Precision
Large number or formations	Enemy: Soviet Sponsored States	Stand down of Armor units	Point Targets Elimination of Collateral Damage
Area denial		Expectation of quick victories	Reduced reliance on Artillery Reduced reliance on Armor
Area targeting		Enemy: Rouge States	Increased reliance on drones
Enemy: Large State Actors		Increase in simulation	Enemy: Rouge States and Non State Actors
10% of the population in Uniform			Less than 1% in Uniform

Propellant Requirement

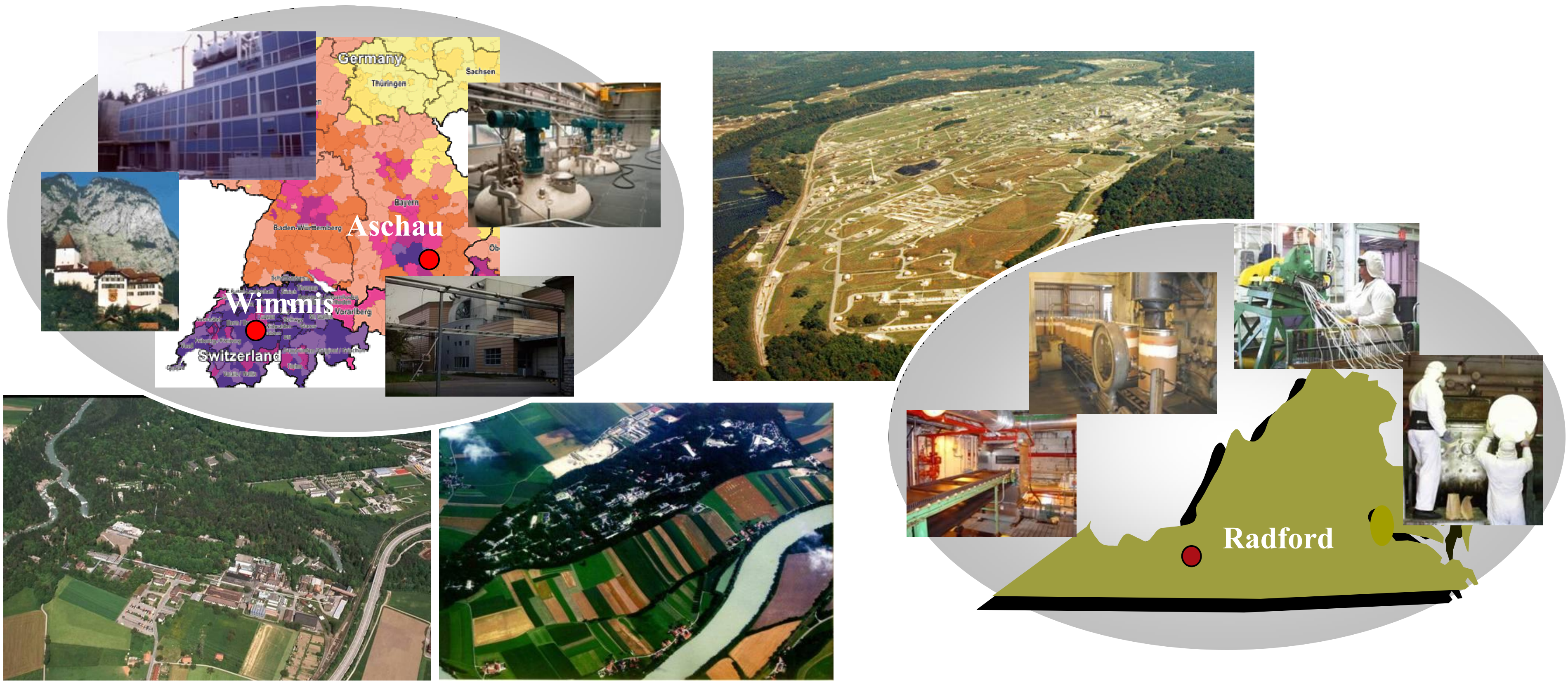
Large volumes
Not Sensitive to Variation

Lower volumes
Consistency

Sensitive to Variation
Repeatable

Combining Nitrochemie’s Advanced Technology with ATK’s High Volume Manufacturing to Provide our DOD Customers with Key Requirements

Combining Nitrochemie’s modern world class propellant production capabilities with the US Army’s propellant production facility



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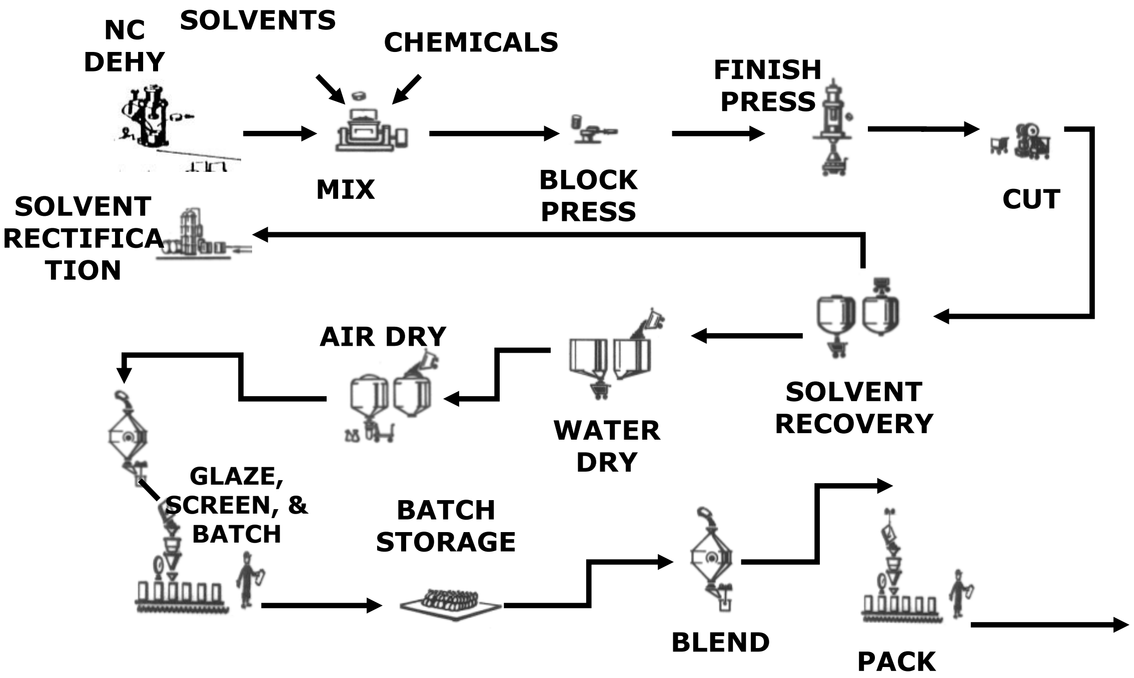
Reducing the Footprint

Maintaining the current US GOCO infrastructure is costly: electricity, steam, water, roads, buildings, equipment

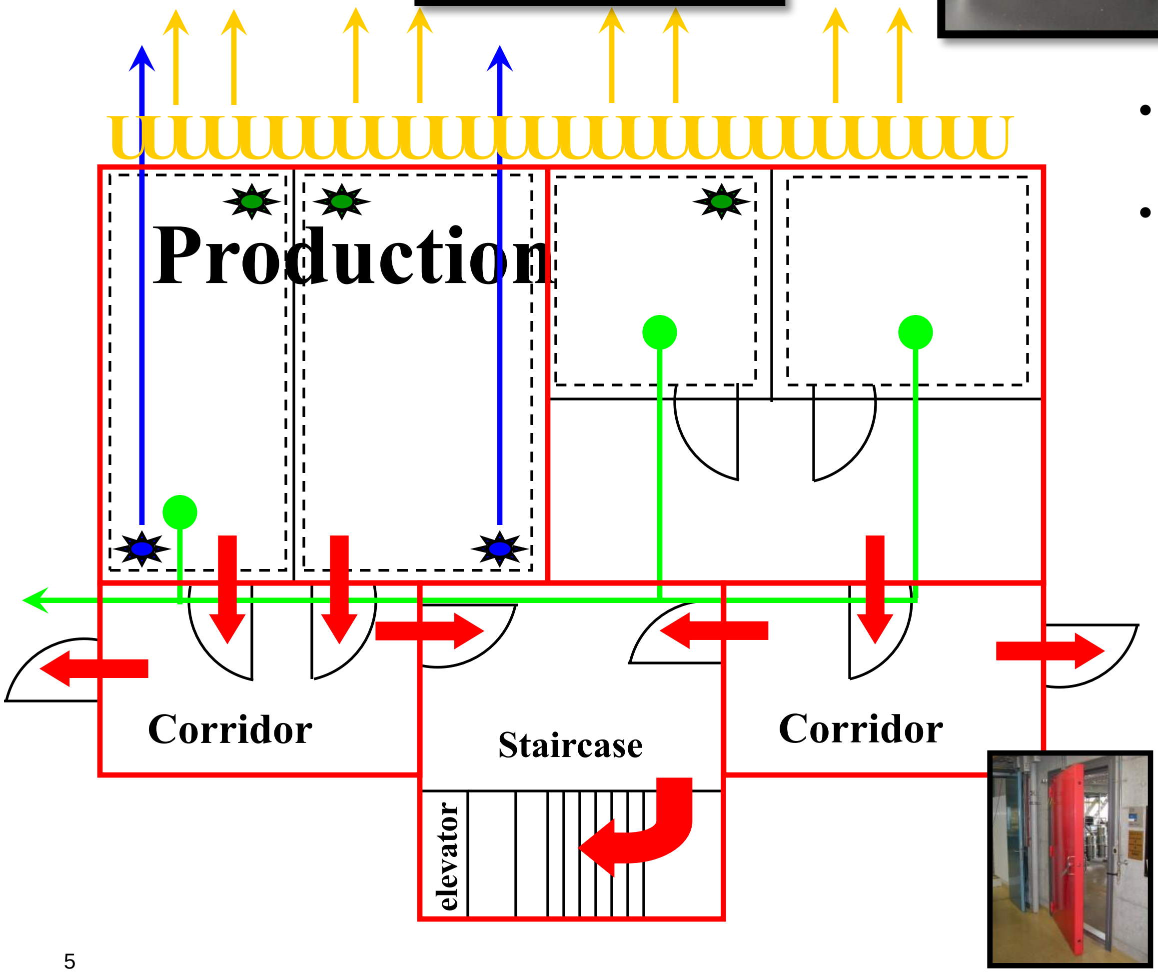
By reducing the footprint, one can also reduce the environmental and utility impact

By implementing advanced safety technologies, energetics processing can be consolidated and co-located

Modernization Goals: safe, flexible, scalable, environmentally responsible with low operating costs, high quality product



Safe, Clean, Reproducible, Efficient



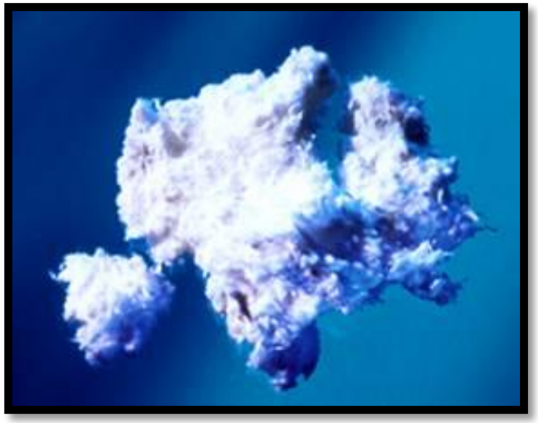
- **Separate operator from product**
- **No detonation**
  - **Separation of production rooms from infrastructure**
  - **Light walls**
  - **Fast acting fire detection and deluge**
  - **Solvent detection and emergency ventilation**
    - **Ventilation of rooms and at source**

Nitrocellulose Improvements

•Current US manufacture of NC up to a month

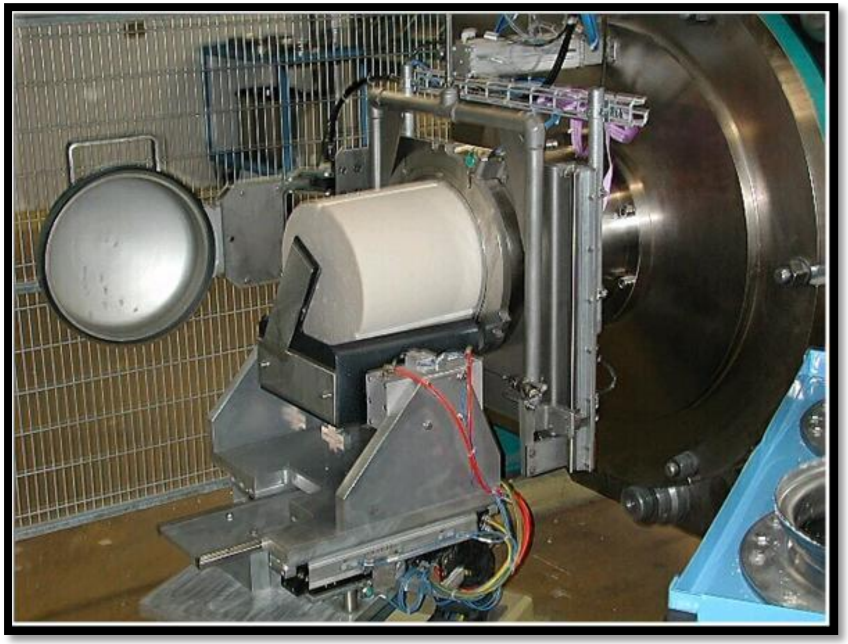
•By implementing pressure boiling, process times can be reduced by 70% with a similar reduction in utilities

•Ability to handle alternative pulp sources – various tree types, various nitration levels



Automated, Instrumented Mixing and Blocking

- Bar coding to prevent formulation errors
- Sealed mixing capability and robot addition of ingredients
- Advanced safety controls
- 80% reduction in man hours



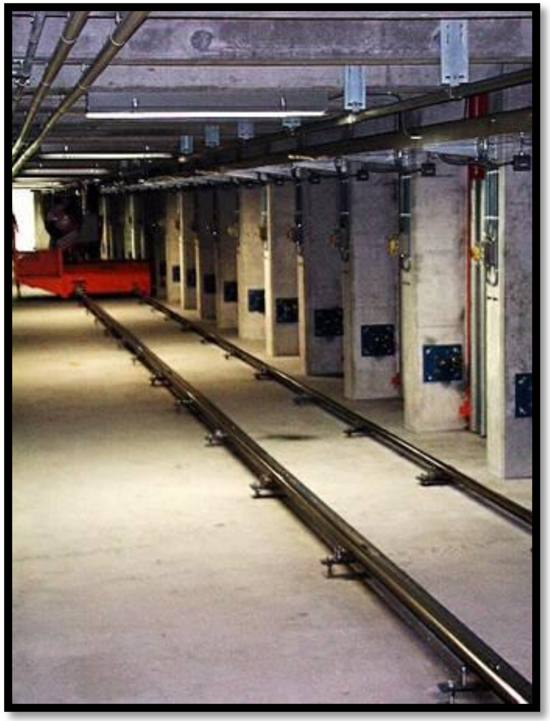
Solvent Equilibration and Pressing

Strand Collection and Cutting

A premier aerospace and defense company

- Introducing automation and high speed cutting reduce labor costs by 80%

Reduction in Costs - Finishing



Modernization is on the horizon for the US Industrial Base

A successful modernization effort will focus on :

- **Reducing the foot print and upgrading the infrastructure**
  - Maintaining the level of safety and security
- **Designing low cost/low labor processes**
  - Operations that are scalable and flexible
- **Implementing modern environmental practices**
- **Building a facility that manufactures a high quality product at a competitive price in the market**

Thanks and Questions?

Thanks for your attention!

Questions???

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