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Joint Armaments Conference, Exhibition & Firing Demonstration

"21st Century Weapon Systems – Providing the Right Response"

Dallas, TX

17 – 20 May 2010

Agenda

Monday, May 17, 2010

TUTORIALS

- DOD Instruction 5000.2, Ms. Karen Byrd, LCSC Learning Assistant Program Manager, DAU
- International Traffic in Arms Regulations, Government and Corporate Perspectives:
  1. Mr. Larry Christensen, Member Miller & Chevalier Chartered
  2. Mr. Moses E. Lewis, Executive Consultant to EME
- De Mystifying Intellectual Property and Data Rights: Government & Industry Perspectives, Mr. Tim Ryan, Technology Transfer Program Manager ARDEC

Tuesday , May 18, 2010

KEYNOTE ADDRESS

- BrigGen Michael M. Brogan, USMC, Commander, Marine Corps Systems Command
- BG Peter N. Fuller, USA, Program Executive Officer (PEO) Soldier

DISTINGUISHED SPEAKER

- Mr. George Solhan, SES, Deputy Chief of Naval Research (ONR 30)

DISTINGUISHED SPEAKER

- Mr. Michael Mulligan, President, General Dynamics Armament & Technical Products (ATP)

DISTINGUISHED SPEAKER

- Mr. Jay Tibbets, Senior Vice President, Business Development, ATK

DISTINGUISHED SPEAKER

- Mr. Hans Hoeneveld, Senior Program Manager Ammunition, Netherlands Defense Materiel Organization

BREAKOUT SESSIONS

SMALL ARMS SYSTEMS

9880 – Joint Service Small Arms Synchronization Team (JSSAST) Panel

- COL Scott Flynn, USA, Chairman
- LTC Tom Henthorn, USA
- CDR Thomas Gajewski, U.S. Navy
- Mr. Randy Roth, USAF

- LtCol Mark Brinkman, USMC
- CAPT Michael Price, USCG
- Mr. Kevin Swenson, Joint Non-Lethal

PM SOLDIER WEAPONS

- COL Tamilio, PM Soldier Weapons

PM LEGAL ISSUES

- 10194 - ITAR: The International Trade in Arms Regulation: Changes and Updates Relevant to the Small Arms Community, Mr. Jason Wong, Firearms Law Group
- 10199 - International Efforts to Regulate or Prohibit Military Small Arms Ammunition, Mr. Hays Parks, DoD OGC (1A)

GUN & MISSILE SYSTEMS

PRECISION WEAPONS

- 10034 - Mortar Guidance Kit (MGK), Ms. Kelly Hanink, ATK
- 10146 - Precision Guidance Kit (PGK), Mr. Tom Bybee, ATK
- 10174 - Improving the Accuracy of Precision Guided Munitions with a GPS Ephemeris & Ionospheric Correction Sharing Service (GEISS), Mr. Charles Johnson, NAVSYS Corporation

KEYNOTE: *F-35 Weapon System Overview*

- Mr. Doug Hayward, Deputy Director F-35 Vehicle Systems, Lockheed Martin

PLATFORMS

- 9899 - MK 51 Modular Advanced Weapon System (MAWS), Mr. Steven Cannon, NSWC PHD Det Louisville
- 10595 - Gun Tube Wear Reduction for 105mm Artillery, Mr. Thomas Boncompain, General Dynamics, Ordnance and Tactical Systems Canada
- 10153 - Indirect Fires Precision and Lethality Enhancements through Digitization of Artillery and Mortar Weapon Systems, Mr. Victor Galgano, U.S. Army ARDEC
- 10190 - JSF Missionized Gun System, Mr. Douglas Parker, General Dynamics ATP
- 10235 - EFV 30mm Ammunition Feed System, Ms. Kim Perkins, General Dynamics ATP
- 10640 - Gun / Ammunition Acquisition Strategy for the EFV Program, Major Ian McDuffie, USMC, Head of Guns and Ammo APM-Mechanical Systems, PM AAA

REQUIREMENTS & PROGRAM TRENDS

- 10171 - Making Affordability Work, Mr. David Panhorst, U.S. Army ARDEC
- 10219 - Propulsion System Design in a Low Pressure Gun System, Mr. Carlton Adam, U.S. Army ARDEC

Wednesday, May 19, 2010

LUNCHEON WITH SPEAKER - Landmark CD BRIGADIER GENERAL STEPHEN VINCENT BENET (1827-1895) - HIS LIFE AND TIMES

- Dr. Stephen Small, JSSAP RDAR-EIJ, Picatinny Aresenal, NJ

BREAKOUT SESSIONS

SMALL ARM SYSTEMS

WEAPONS

- 10137 - Small Arms Weapon Integration on the Ramp of the V-22 Osprey, Mr. James Buechler, NSWC Crane
- The Kongsberg Common Remotely Operated Weapons Station: An Evolution in Capability for the Small Arms of Today to the Medium Cannon of Tomorrow, Mr. Westley “Bo” Barbour, Kongsberg Defence Systems
- 9915 - Advanced Remote/Robotic Armament System (ARAS), Mr. Robert Testa, U.S. Army ARDEC
- 9861 - Strategic Tripartite. Historic Opportunities for US and NATO Ground Combatants, Mr. Jim Schatz, Consultant

- 9863 - The Next Generation: The Case for a New NATO Rifle and Machine Gun Cartridge, Mr. Anthony Williams, Consultant

INTERNATIONAL

- 10690 - Is There a Problem With the Lethality of the 5.56 NATO Caliber, Mr. Per Arvidsson, NATO Weapons & Sensors Working Group
- 10000 - Grenade Launchers in China, Ms. Juanjuan Yang, China R&D Academy of Machinery
- 10055 - K11, Dual-Barrel Air-Burst Weapon, Dr. In Woo Kim, Agency for Defense Development, Korea
- 10136 - R&D Activities in Support of the Canadian Small Arms Replacement Project, Mr. Paul Harris, Defence Research and Development, Canada
- 10202 - Enhanced Warfighter Capability with Direct and Indirect Small Arms Ammunition, Mr. Jarl Eirik Straume, Nammo Raufoss AS, Norway
- 10201 - Developing IfraRed (IR) (Dim) Tracer Compositions for Reduced Signature, Mr. Peter Hedsand, Nammo Vanäsverken AB, Sweden
- 10200 - Developing Reduced Range Ammunition for Training and Urban Combat, Mr. Fredrik Erninge, Nammo Vanäsverken AB, Sweden

MODELING & SIMULATION

- 9898 - Application of IWARS in Small Arms Development, Mr. Alex Lee, U.S. Army ARDEC
- 9909 - Small Arms Modeling and Simulation, Mr. Clinton Fischer, U.S. Army RDECOM-ARDEC

NON-LETHAL

- 10070 - Advancements in Personnel Incapacitation Methodologies for Multiple Projectile Cartridges, Mr. Stephen Swann, Army Research Laboratory
- 10226 - Testing Non-lethals: Finding the Right Tools for the Job, Mr. Pascal Paulissen, TNO Defence, Security and Safety

AMMUNITION

- 9684 - Lethal Limited Range Round, Mr. Stephen McFarlane, U.S. Army
- 10004 - Small Caliber Propellant Solutions for the U.S. Military, Mr. Steve Faintich, St. Marks Powder, A General Dynamics Company
- 10149 - DARPA SCORPION Program Transition to Army Advanced Technology Objective Program: A Success Story, Mr. Andre Lovas, Georgia Tech Research Institute
- 10213 - Lightweight Small Caliber Ammuntion (LSCA) Lessons Learned From Prototype Fabrication to Full Production Rates, Mr. George Feghali, General Dynamics OTS-Canada, Inc. & Mr. Bill Dittrich, Fleximation, Inc.
- 10172 - Aluminum 5.56 Case Development: Continued Success with an Advanced Lightweight Material, Mr. Christopher Still, ATK
- 10170 - Case Weight Variation Reduction and Subsequent Ballistic Dispersion Improvements in M118LR, Ms. Dionne Dillon, ATK Small Caliber Systems
- 10183 - .50 Caliber Steel Case Development: Design and Development of a Lightweight Case Compatible with Modernized Production Processes at the Lake City Army Ammunition Plant, Mr. Christian Miller, ATK Small Caliber Systems
- 10195 - Effects of Barrel Length on Sound Measurement, Bore Pressure, and Bullet Velocity, Dr. Philip Dater, Gemtech
- 10186 - MEMS S&A for Munitions, Mr. Dale Spencer, Kaman Precision Products
- 10650 - Developments in Short Range Training Ammunition, Mr. Luis de Sousa, General Dynamics OTS, Simunition Operations

GUNS & MISSILE SYSTEMS

EMERGING TECHNOLOGIES

- 9894 - Design of an Intelligent Round Counter for Monitoring Ballistic Events Experienced by a Gun Barrel, Mr. Cory Mettler, American Science and Technology
- 10231 - The Rarefaction Wave Gun (RAVEN) Program, Mr. Mike Bixler, ARES, Inc.
- 9936 - “Lightening Strike”– An Indirect Fire Concept Utilizing Combustion Light Gas Gun (CLGG) Technology to Achieve Extreme Ranges, Mr. David Kruczynski, UTRON Inc. & Mr. Stephen Floroff, U.S. Army ARDEC
- 10135 - Hypersonic Plasma Particle Deposition Coating… Making 21st Century Weaponry Last into the 22nd, Mr. Daniel Fox, Rushford Hypersonic, LLC
- 10150 - Exo-atmosphere Propulsion for Hypersonic Projectiles, Dr. Wayne Sawka, DigitalSolid State Propulsion, LLC
- 10220 - Extended Area Protection and Survivability (EAPS) 50mm Cannon, Mr. Arthur Aeberli, U.S. Army ARDEC
- 10222 - Advanced Gun Barrel Technology Program, Background and Results, Mr. Bill Vezina, BAE Systems
- 10033 - Selectable Effects Warhead Technology Demonstration, Mr. Eric Volkmann, ATK

- 10151 - Ultrasonic Characterization of Explosively-Bonded Concentric Tubes, Mr. Chris Jerred, South Dakota State University
- 9910 - Magnelok™ Technology – Achieving High Torque-densities with a Novel Electromagnetically Actuated Band-brake, Mr. Scott Miller, LORD Corporation
- 9720 - Miniaturized ESAD Development, Mr. Ed Cooper, L-3 Fuzing and Ordnance Systems
- 9974 - Technology Trends in Fuzing and Munitions Power Sources, Mr. Oliver Barham, U.S. Army RDECOM-ARDEC
- 10143 - Low Volume, Negligible EMI Advanced Guided Bullet and Mortar Flight Control Actuators, Dr. Ron Barrett, University of Kansas

ENERGETICS

- 9878 - Unique Partnership to Provide Precision and Lethality to Tomorrow's Warfighter, Ms. Kelly Moran, ATK
- 9990 - High Performance BKNO3 Igniter Formulations, Dr. Eugene Rozumov, U.S. Army ARDEC
- 10006 - Medium and Large Caliber Propellant Solutions, Mr. Robert Pulver, St. Marks Powder, A General Dynamics Company
- 10176 - Development of a Solventless Propellant for Use in 120mm Tank Training Rounds, Mr. Jim Wedwick, ATK
- 10001 - Ageing Effects on Performance of Small and Medium Calibre Ammunition, Mr. Chris Van Driel, TNO Defence, Security and Safety
- 10229 - The 155MM M795 Artillery Shell Loaded with IMX-101, Mr. Anthony DiStasio, U.S. Army ARDEC & Mr. Michael Ervin, BAE Systems

DIRECT & INDIRECT FIRES

- 9848 - 25mm Non-Energetic Fragmenting Cartridge, Mr. Rick Wright, General Dynamics
- 9857 - 120 MM XM360 Gun Program – Test & Evolution, Mr. David Smith P.E., U.S. Army Benet Laboratories
- 9862 - Howitzer Digitization Engineering Issues, Mr. William Key, IXSEA, Inc.
- 9869/10148 - Modeling of Composite Wrapped Cannon Barrel/Non-Destructive Inspection & Design, Dr. Zhong Hu, South Dakota State University & Dr. Jikai Du, South Dakota State University
- 9945 - Super 40mm to 30mm Ammunition Comparison – Performance/Lethality, Mr. Rick Wright, General Dynamic
- 10032 - The Advance Case System (ACS) program for 120mm Tank Training Ammo, Mr. Jeff Berg, TK
- 10225 - Warfare Has Changed: Investigation of the Performance of Ammunition in Maritime & Urban Environments, Mr. Martin van de Voorde, TNO Defence, Security and Safety
- 10157 - Modular Design of Direct Fire Medium Caliber Gun Systems for Joint Operations, Mr. Andrew Bradick, Consultant

MODELING & SIMULATION

- 9708 - Simulation of Cellulose Nitration Reaction, Mr. Mohamed (Mo) Elalem, U.S. Army ARDEC
- 10179 - Automated Projectile Design Software, Mr. Mark Steinhoff, Arrow Tech Associates, Inc.
- 10158 - Pyrotechnic Shock Loading of the M82 Percussion Primer in the M777 Light Weight Howitzer Magazine Assembly, Ms. Kathryn Hunt, Marine Corps Systems Command
- 9908 - Numerical and Experimental Comparison of Muzzle Brake Impulse Reduction on a 120mm Cannon System, Mr. Robert Carson, Benet Laboratories, U.S. Army ARDEC
- 10350 - Scalable Lethality: 'Dial-a-Yield' Approach to Greater Precision Engagement, Mr. Henry Kerwein, U.S. Army ARDEC
- 9707 - Modeling of Fluid Energy Milling Process, Mr. Mohamed (Mo) Elalem, U.S. Army ARDEC

Thursday, May 20, 2010

SMALL ARMS SYSTEM

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Session Chair: Chris Grassano, PM MAS

PM MAS

- An Overview of Non-Standard Ammunition, LTC Robert Dionisio
- Training Ammunition Safety Initiatives, LTC Robertson, Product Director
- 40MM Ammunition: Evolving and Emerging Requirements, MAJ Marc Meeker, Assistant Product Manager, Medium Caliber Ammunition
- Small Caliber Ammunition: Enhancing Capabilities, LTC Jeffrey Woods, Product Manager, Small Caliber Ammunition

JSSAP

- 9855 - Lightweight Small Arms Technologies, Mrs. Kori Phillips, U.S. Army ARDEC
- 10188 - JSSAP Futures 2012-2020, Dr. Barton Halpern, U.S. Army ARDEC

- 9895 - National Small Arms Center Update, Mr. Frank Puzycki, JSSAP Office, U.S. Army ARDEC
- 10193 - Advanced Lethal Armament Technology for Small Arms, Mrs. Sabbian Registe, ARDEC-RDECOM
- 9916 - Advanced Fire Control Technology for Small Arms Army Technology Objective (ATO), Mr. Terence F. Rice, U.S. Army ARDEC

GUNS & MISSILE SYSTEM

Distinguished Speaker: Mr. Edgar Fossheim, Nammo AS, Norway

TACTICAL MISSILES & ROCKETS

- 9714 - Demonstration and Validation of Lead-free Ballistic Modifier for Rocket Propellants, Dr. Sarah Headrick, ATK
- 10074 - Advanced Precision Kill Weapons System II, LCDR Nick Green, USN, Direct and Time Sensitive Strike Weapons PMA-242

JOINT INTEREST

- 10142 - Hovering Precision Weapons (HPW): Enabling Precise Surgical Strike and Collocated Close Air Support from Tactical to Strategic Distances, Dr. Ron Barrett, University of Kansas
- 10228 - CROWS II Vehicle Integration, Mr. Joseph Scheneck, PE, U.S. Army ARDEC
- 9827 - Environmentally Acceptable Alternatives to Lead Azide and Lead Styphnate, Dr. Michael Williams, Pacific Scientific EMC
- 10593 - Non-Incendiary Artillery Marking and Illumination Solutions, Mr. George Kurzik, General Dynamics – Ordnance and Tactical Systems & Mr. Ed Schmidt, Cyalume Technologies

NDIA
National Defense Industrial Association

PROMOTING NATIONAL SECURITY SINCE 1919

JOINT ARMAMENTS
CONFERENCE, EXHIBITION & FIRING DEMONSTRATION

"21st Century Weapon Systems - Providing the Right Response"

COMBINED PROGRAM ANNOUNCEMENT



GUN & MISSILE SYSTEMS

Precision and Lethality in Medium and Large Caliber

& SMALL ARMS SYSTEMS

Technology and Systems Sustaining and Evolving Small Arms Capability

HYATT REGENCY DALLAS ▸ DALLAS, TX

MAY 17-20, 2010

WWW.NDIA.ORG/MEETINGS/0610

EVENT #0610

MONDAY, MAY 17, 2010

8:00 am - 3:00 pm Exhibitor Move-in - Marsalis Hall

8:00 am - 6:30 pm Registration Open - Landmark Circle

1:00 pm - 2:45 pm **TUTORIALS**

- *Session Chair: Bob Glantz, ATK*

Cumberland A	Cumberland B
DOD Instruction 5000.2 *Ms. Karen Byrd, LCSC Learning Assistant Program Manager, DAU*	WSESRB Overview *Mr. Jim Gerber & Mr. Gary Vargo, NOSSA*

3:00 pm - 4:45 pm **TUTORIALS**

Cumberland A	Cumberland B
International Traffic in Arms Regulations, Government and Corporate Perspectives *Mr. Larry Christensen, Member Miller & Chevalier Chartered* *Mr. Moses E. Lewis, Executive Consultant to EME*	De Mystifying Intellectual Property and Data Rights: Government & Industry Perspectives *Mr. Tim Ryan, Technology Transfer Program Manager ARDEC, Mr. Carlton Chen, VP Compliance & Regulatory Affairs, Colt*

5:00 pm - 6:30 pm **RECEPTION IN MARSALIS HALL**

TUESDAY, MAY 18, 2010

7:00 am - 5:30 pm Registration Open - Landmark Circle

7:00 am - 8:00 am Continental Breakfast - Landmark Ballroom Foyer

8:00 am - 8:30 am **WELCOME & ADMINISTRATIVE ANNOUNCEMENTS** - Landmark AB

- MG Barry Bates, USA (Ret), *Vice President, Operations, NDIA*
- Mr. David Broden, *Broden Resource Solutions; NDIA Armaments Division Chairman*
- Mr. Brian Tasson, *Director of Mechanical Design, ATK; Gun & Missile Committee Chairman*
- Mr. Brian Berger, *Vice President and General Manager, General Dynamics-OTS Canada; Small Arms Committee Chairman*

8:30 am - 9:00 am **KEYNOTE ADDRESS**

- MG Michael S. Repass, USA, *Commanding General, USASFC (Airborne) - Cancelled*

9:00 am - 9:45 am **KEYNOTE ADDRESS**

- BrigGen Michael M. Brogan, USMC, *Commander, Marine Corps Systems Command*
- BG Peter N. Fuller, USA, *Program Executive Officer (PEO) Soldier*

9:45 am - 10:15 am Morning Break in Marsalis Hall

10:15 am - 10:45 am **DISTINGUISHED SPEAKER**

- Mr. George Solhan, SES, *Deputy Chief of Naval Research (ONR 30)*

10:45 am - 11:15 am **DISTINGUISHED SPEAKER**

- Mr. Michael Mulligan, *President, General Dynamics Armament & Technical Products (ATP)*

11:15 am - 11:45 am **DISTINGUISHED SPEAKER**

- Mr. Jay Tibbets, *Senior Vice President, Business Development, ATK*

11:45 am - 12:15 pm **DISTINGUISHED SPEAKER**

- Mr. Hans Hoeneveld, *Senior Program Manager Ammunition, Netherlands Defense Materiel Organization*

12:15 pm - 1:30 pm **AWARDS LUNCHEON** - Landmark CD

- CHINN AWARD presented to Mr. Frank Puzycki, U.S. Army ARDEC
  Presented by Mr. Joel Goldman, U.S. Army ARDEC
- HATHCOCK AWARD presented to Mr. Jeff Hoffman
  Presented by Mr. Brian K. Sain on behalf of American Snipers
- NDIA PROFESSIONAL SERVICE AWARD presented to Mr. Hays Parks
  Presented by Mr. Brian Berger, General Dynamics
- TRIFILETTI AWARD presented to Mr. Frank Bone
  Presented by Mr. Brian Tasson, ATK

1:30 pm - 2:50 pm **BREAKOUT SESSIONS**

- Joint Service Small Arms Synchronization Team (JSSAST)
  Session Chair: COL Karl Scott Flynn, USA, Chairman, JSSAST
- Precision Weapons
  Session Chairs: Rob Brewer, NAVAIR & Jeff Siewert, Arrow Tech Associates, Inc.
- Platforms
  Session Chairs: Anthony Gabriele, U.S. Army, RDECOM-ARDEC & Matt Diehl, General Dynamics
- Requirements & Program Trends
  Session Chairs: Mark Serben, U.S. Army RDECOM - ARDEC & Steve Kelly, BAE Systems

	Small Arms Systems	Gun & Missile Systems		
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	JSSAST			
1:30	9880 - JSSAST Panel • *COL Scott Flynn, USA, Chairman* • *LTC Tom Henthorn, USA* • *CDR Thomas Gajewski, U.S. Navy* • *Mr. Randy Roth, USAF* • *LtCol Mark Brinkman, USMC* • *COL James Smith, USSOCOM* • *CAPT Michael Price, USCG* • *Mr. Kevin Swenson, Joint Non-Lethal*		**Keynote:** F-35 Weapon System Overview *Mr. Doug Hayward, Deputy Director F-35 Vehicle Systems, Lockheed Martin*	
		Precision Weapons	**Platforms**	**Requirements & Program Trends**
2:10		9886 - Characterizing Performance of Precision Projectiles *Mr. Jon Peoble, Raytheon Missile Systems*	9899 - MK 51 Modular Advanced Weapon System (MAWS) *Mr. Steven Cannon, NSWC PHD Det Louisville*	
2:30		9896 - NavFire Guidance System – Integrated GPS and Mission Computer for Future Navigation Solutions *Mr. Walter Trach Jr., Rockwell Collins*	10595 - Gun Tube Wear Reduction for 105mm Artillery Mr. Thomas Boncompain, *General Dynamics, Ordnance and Tactical Systems Canada*	10171 - Making Affordability Work *Mr. David Panhorst, U.S. Army ARDEC*

2:50 pm - 3:30 pm Afternoon Break in Marsalis Hall

3:30 pm - 5:30 pm **BREAKOUT SESSIONS**

- PM Soldier Weapons
  Session Chair: COL Douglas Tamilio, USA, PM Soldier Weapons
- PM Legal Issues
  Session Chairs: Charles Buxton, Small Arms Ammunition and Testing (JXNN)
- Precision Weapons
  Session Chairs: Rob Brewer & Jeff Siewert, Arrow Tech Associates, Inc.

- Platforms
  Session Chairs: Anthony Gabriele, U.S. Army, RDECOM-ARDEC & Matt Diehl, General Dynamics
- Requirements & Program Trends
  Session Chairs: Mark Serben, U.S. Army RDECOM - ARDEC & Steve Kelly, BAE Systems

	Small Arms Systems	Gun & Missile Systems		
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	PM Soldier Weapons	Precision Weapons	Platforms	Requirements & Program Trends
3:30	**Panel Discussion** *COL Tamilio, PM Soldier Weapons* *LTC Chris Lehner, Individual Weapons Update* *LTC Michael Ascura, Crew Served Weapons Update*	10034 - Mortar Guidance Kit (MGK) *Ms. Kelly Hanink, ATK*	10021 - Remote Guardian System(TM) Defensive Weapon System *Mr. Adrian Gorsline, BAE Systems*	10219 - Propulsion System Design in a Low Pressure Gun System *Mr. Carlton Adam, U.S. Army ARDEC*
3:50		10049 - 5-Inch Long Range Land Attack Projectile (LR-LAP) *Mr. Brandon Engle, BAE Systems*	10153 - Indirect Fires Precision and Lethality Enhancements through Digitization of Artillery and Mortar Weapon Systems *Mr. Victor Galgano, U.S. Army ARDEC*	
4:10		10146 - Precision Guidance Kit (PGK) *Mr. Tom Bybee, ATK*	10190 - JSF Missionized Gun System *Mr. Douglas Parker, General Dynamics ATP*	
	PM Legal Issues			
4:30	10194 - ITAR: The International Trade in Arms Regulation: Changes and Updates Relevant to the Small Arms Community *Mr. Jason Wong, Firearms Law Group*	10174 - Improving the Accuracy of Precision Guided Munitions with a GPS Ephemeris & Ionospheric Correction Sharing Service (GEISS) *Mr. Charles Johnson, NAVSYS Corporation*	10235 - EFV 30mm Ammunition Feed System *Ms. Kim Perkins, General Dynamics ATP*	
4:50	10199 - International Efforts to Regulate or Prohibit Military Small Arms Ammunition *Mr. Hays Parks, DoD OGC (1A)*		10640 - Gun / Ammunition Acquisition Strategy for the EFV Program *Major Ian McDuffie, USMC, Head of Guns and Ammo APM-Mechanical Systems, PM AAA*	

5:30 pm - 7:00 pm **RECEPTION IN MARSALIS HALL**
Promotional Partner: ATK

WEDNESDAY, MAY 19, 2010

7:00 am - 5:10 pm Registration Open - Landmark Circle

7:00 am - 8:00 am Continental Breakfast - Landmark Ballroom Foyer

8:00 am - 9:20 am **BREAKOUT SESSIONS**

- Weapons
  Session Chair: Rick Adams, FNH USA LLC
- Ammunition
  Session Chair: Bruce Webb, Nammo Talley, Inc.
- Emerging Technologies
  Session Chairs: Jay Brannam, ATK & Michael Thornton, NSWC
- Direct & Indirect Fires
  Session Chairs: Dave Wallestad, Wallestad & Associates, LLC & Joe McPherson, USMC

	Small Arms Systems		Gun & Missile Systems	
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	Weapons	Ammunition	Emerging Technologies	Direct & Indirect Fires
8:00	10137 - Small Arms Weapon Integration on the Ramp of the V-22 Osprey *Mr. James Buechler, NSWC Crane*	9684 - Lethal Limited Range Round *Mr. Stephen McFarlane, U.S. Army*		9848 - 25mm Non-Energetic Fragmenting Cartridge *Mr. Rick Wright, General Dynamics*
8:20	10144 - The 0.50 Caliber Multi-Mode Machine Gun and Family of Enhanced Ammunition: A Complete Weapon System for Remote Mounts, Fighting Vehicles and Aircraft *Mr. Brian Sullivan, PMP, American Rheinmetall Munitions, Inc.*	10004 - Small Caliber Propellant Solutions for the U.S. Military *Mr. Steve Faintich, St. Marks Powder, A General Dynamics Company*	9894 - Design of an Intelligent Round Counter for Monitoring Ballistic Events Experienced by a Gun Barrel *Mr. Cory Mettler, American Science and Technology*	9857 - 120 MM XM360 Gun Program – Test & Evolution *Mr. David Smith P.E., U.S. Army Benet Laboratories*
8:40	10084 - GAU-21 CDWS Platform Integration *Mr. Bruce Richards, NSWC Crane*	10149 - DARPA SCORPION Program Transition to Army Advanced Technology Objective Program: A Success Story *Mr. Andre Lovas, Georgia Tech Research Institute*	10231 - The Rarefaction Wave Gun (RAVEN) Program *Mr. Mike Bixler, ARES, Inc.*	9862 - Howitzer Digitization Engineering Issues *Mr. William Key, IXSEA, Inc.*
9:00	The Kongsberg Common Remotely Operated Weapons Station: An Evolution in Capability for the Small Arms of Today to the Medium Cannon of Tomorrow *Mr. Westley "Bo" Barbour, Kongsberg Defence Systems*	10213 - Lightweight Small Caliber Ammuntion (LSCA) Lessons Learned From Prototype Fabrication to Full Production Rates *Mr. George Feghali, General Dynamics OTS-Canada, Inc.* *Mr. Bill Dittrich, Fleximation, Inc.*	9936 - "Lightening Strike"– An Indirect Fire Concept Utilizing Combustion Light Gas Gun (CLGG) Technology to Achieve Extreme Ranges *Mr. David Kruczynski, UTRON Inc.* *Mr. Stephen Floroff, U.S. Army ARDEC*	9869/10148 - Modeling of Composite Wrapped Cannon Barrel/Non-Destructive Inspection & Design *Dr. Zhong Hu, South Dakota State University* *Dr. Jikai Du, South Dakota State University*

9:20 am - 10:00 am Morning Break in Marsalis Hall

10:00 am - 12:00 pm **BREAKOUT SESSIONS**

Ammunition Breakout Session Promotional Partner

10:00 AM – 11:00 AM



- Weapons
  Session Chair: Rick Adams, FNH USA LLC
- Ammunition
  Session Chair: Bruce Webb, Nammo Talley, Inc.
- Emerging Technologies
  Session Chairs: Jay Brannam, ATK & Michael Thornton, NSWC
- Direct & Indirect Fires
  Session Chairs: Dave Wallestad, Wallestad & Associates, LLC & Joe McPherson, USMC
- International
  Session Chair: John Edwards, U.S. Army ARDEC

	Small Arms Systems		Gun & Missile Systems	
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	Weapons	**Ammunition**	**Emerging Technologies**	**Direct & Indirect Fires**
10:00	9915 - Advanced Remote/ Robotic Armament System (ARAS) *Mr. Robert Testa, U.S. Army ARDEC*	10172 - Aluminum 5.56 Case Development: Continued Success with an Advanced Lightweight Material *Mr. Christopher Still, ATK*	10135 - Hypersonic Plasma Particle Deposition Coating… Making 21st Century Weaponry Last into the 22nd *Mr. Daniel Fox, Rushford Hypersonic, LLC*	10140 - 30mm x 113mm Traced Target Practice (TP-T) Munition *Mr. Kyle Nerison, ATK Integrated Weapon Systems*
10:20	9861 - Strategic Tripartite. Historic Opportunities for US and NATO Ground Combatants *Mr. Jim Schatz, Consultant*	10170 - Case Weight Variation Reduction and Subsequent Ballistic Dispersion Improvements in M118LR *Ms. Dionne Dillon, ATK Small Caliber Systems*	10150 - Exo-atmosphere Propulsion for Hypersonic Projectiles *Dr. Wayne Sawka, Digital Solid State Propulsion, LLC*	9945 - Super 40mm to 30mm Ammunition Comparison – Performance/ Lethality *Mr. Rick Wright, General Dynamics*
10:40	9863 - The Next Generation: The Case for a New NATO Rifle and Machine Gun Cartridge *Mr. Anthony Williams, Consultant*	10183 - .50 Caliber Steel Case Development: Design and Development of a Lightweight Case Compatible with Modernized Production Processes at the Lake City Army Ammunition Plant *Mr. Christian Miller, ATK Small Caliber Systems*	10160 - Use of Non-metallic Materials in Gun-Launched Artillery Projectiles *Mr. John Tilling, QinetiQ*	9946 - The 30mm x 173 PELE: The Single Shot Solution for Combat Vehicles and Surface Combatants *Mr. Stephan Kerk, American Rheinmetall Munitions, Inc.*
	International			
11:00	10690 - Is There a Problem With the Lethality of the 5.56 NATO Caliber *Mr. Per Arvidsson, NATO Weapons & Sensors Working Group*	10195 - Effects of Barrel Length on Sound Measurement, Bore Pressure, and Bullet Velocity *Dr. Philip Dater, Gemtech*	10220 - Extended Area Protection and Survivability (EAPS) 50mm Cannon *Mr. Arthur Aeberli, U.S. Army ARDEC*	10032 - The Advance Case System (ACS) program for 120mm Tank Training Ammo *Mr. Jeff Berg, ATK*
11:20	10000 - Grenade Launchers in China *Ms. Juanjuan Yang, China R&D Academy of Machinery*	10186 - MEMS S&A for Munitions *Mr. Dale Spencer, Kaman Precision Products*	10222 - Advanced Gun Barrel Technology Program, Background and Results *Mr. Bill Vezina, BAE Systems*	

	Small Arms Systems		Gun & Missile Systems	
11:40	10055 - K11, Dual-Barrel Air-Burst Weapon *Dr. In Woo Kim, Agency for Defense Development, Korea*	10650 - Developments in Short Range Training Ammunition *Mr. Luis de Sousa, General Dynamics OTS, Simunition Operations*	10141 - LW25 High Explosive Dual Purpose (HEDP) Munition *Mr. Kyle Nerison, ATK Integrated Weapon Systems*	9905 - 25mm x 137 APEX Aircraft Ammunition *Ms. Eva Friis, Nammo Raufoss AS, Norway*

12:00 pm - 1:30 pm **LUNCHEON WITH SPEAKER -** Landmark CD
BRIGADIER GENERAL STEPHEN VINCENT BENET (1827-1895) - HIS LIFE AND TIMES
- Dr. Stephen Small, *JSSAP RDAR-EIJ, Picatinny Arsenal, NJ*

1:30 pm - 2:50 pm **BREAKOUT SESSIONS**
- International
  Session Chair: John Edwards, U.S. Army ARDEC
- Energetics
  Session Chair: Enrico Mutascio, Esterline Defense Technologies & Matt Solverson, General Dynamics
- Emerging Technologies
  Session Chairs: Jay Brannam, ATK & Michael Thornton, NSWC
- Direct & Indirect Fires
  Session Chairs: Dave Wallestad, Wallestad & Associates, LLC & Joe McPherson, USMC
- Modeling & Simulation
  Session Chairs: Mike Stankus, EG&G Technical Services, Inc. & Steve Piper, Piper Pacific International

	Small Arms Systems	Gun & Missile Systems		
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	International	Energetics	Emerging Technologies	Direct & Indirect Fires
1:30	10136 - R&D Activities in Support of the Canadian Small Arms Replacement Project *Mr. Paul Harris, Defence Research and Development, Canada*	9878 - Unique Partnership to Provide Precision and Lethality to Tomorrow's Warfighter *Ms. Kelly Moran, ATK*	10033 - Selectable Effects Warhead Technology Demonstration *Mr. Eric Volkmann, ATK*	10225 - Warfare Has Changed: Investigation of the Performance of Ammunition in Maritime & Urban Environments *Mr. Martin van de Voorde, TNO Defence, Security and Safety*
1:50	10202 - Enhanced Warfighter Capability with Direct and Indirect Small Arms Ammunition *Mr. Jarl Eirik Straume, Nammo Raufoss AS, Norway*	9990 - High Performance BKNO3 Igniter Formulations *Dr. Eugene Rozumov, U.S. Army ARDEC*	10151 - Ultrasonic Characterization of Explosively-Bonded Concentric Tubes *Mr. Chris Jerred, South Dakota State University*	10157 - Modular Design of Direct Fire Medium Caliber Gun Systems for Joint Operations *Mr. Andrew Bradick, Consultant*
				Modeling & Simulation
2:10	10201 - Developing IfraRed (IR) (Dim) Tracer Compositions for Reduced Signature *Mr. Peter Hedsand, Nammo Small Arms Division, Sweden*	10006 - Medium and Large Caliber Propellant Solutions *Mr. Robert Pulver, St. Marks Powder, A General Dynamics Company*	9910 - Magnelok™ Technology – Achieving High Torque-densities with a Novel Electromagnetically Actuated Band-brake *Mr. Scott Miller, LORD Corporation*	9708 - Simulation of Cellulose Nitration Reaction *Mr. Mohamed (Mo) Elalem, U.S. Army ARDEC*

	Small Arms Systems	Gun & Missile Systems		
2:30	10200 - Developing Reduced Range Ammunition for Training and Urban Combat *Mr. Fredrik Erninge, Nammo Vanäsverken AB, Sweden*		9720 - Miniaturized ESAD Development *Mr. Ed Cooper, L-3 Fuzing and Ordnance Systems*	10179 - Automated Projectile Design Software *Mr. Mark Steinhoff, Arrow Tech Associates, Inc.*

2:50 pm - 3:30 pm Afternoon Break in Marsalis Hall

3:30 pm - 5:10 pm **BREAKOUT SESSIONS**

- Small Arms Modeling & Simulation
  Session Chair: Mr. Matthew Cilli, U.S. Army ARDEC
- Non-Lethal
  Session Chair: Mr. Kevin Swenson, NLWS Directorate, MCSC, Quantico
- Energetics
  Session Chairs: Enrico Mutascio, Esterline Defense Technologies & Matt Solverson, General Dynamics
- Emerging Technologies
  Session Chairs: Jay Brannam, ATK & Michael Thornton, NSWC
- Gun & Missile Modeling & Simulation
  Session Chairs: Mike Stankus, EG&G Technical Services, Inc. & Steve Piper, Piper Pacific International

	Small Arms Systems	Gun & Missile Systems		
Time	Landmark B	Cumberland A-C	Landmark A	Reunion GH
	Modeling & Simulation	Energetics	Emerging Technologies	Modeling & Simulation
3:30	9961/9962 - 40mm Low & Medium Velocity Munitions *Mr. Cheng Hok Aw, Singapore Technologies Kinetics*	10176 - Development of a Solventless Propellant for Use in 120mm Tank Training Rounds *Mr. Jim Wedwick, ATK*	9974 - Technology Trends in Fuzing and Munitions Power Sources *Mr. Oliver Barham, U.S. Army RDECOM-ARDEC*	10158 - Pyrotechnic Shock Loading of the M82 Percussion Primer in the M777 Light Weight Howitzer Magazine Assembly *Ms. Kathryn Hunt, Marine Corps Systems Command*
3:50	9898 - Application of IWARS in Small Arms Development *Mr. Alex Lee, U.S. Army ARDEC*	10001 - Ageing Effects on Performance of Small and Medium Calibre Ammunition *Mr. Chris Van Driel, TNO Defence, Security and Safety*		9908 - Numerical and Experimental Comparison of Muzzle Brake Impulse Reduction on a 120mm Cannon System *Mr. Robert Carson, Benet Laboratories, U.S. Army ARDEC*
4:10	9909 - Small Arms Modeling and Simulation *Mr. Clinton Fischer, U.S. Army RDECOM-ARDEC*	10229 - The 155MM M795 Artillery Shell Loaded with IMX-101 *Mr. Anthony DiStasio, U.S. Army ARDEC & Mr. Michael Ervin, BAE Systems*	10143 - Low Volume, Negligible EMI Advanced Guided Bullet and Mortar Flight Control Actuators *Dr. Ron Barrett, University of Kansas*	10350 - Scalable Lethality: 'Dial-a-Yield' Approach to Greater Precision Engagement *Mr. Henry Kerwien, U.S. Army ARDEC*
	Non-Lethal			
4:30	10070 - Advancements in Personnel Incapacitation Methodologies for Multiple Projectile Cartridges *Mr. Stephen Swann, Army Research Laboratory*		10224 - Warfare Has Changed – So Should Have Methods: Experimental Investigation of the Performance of Modern Medium and Large Calibre Ammunition in Urban Terrain *Mr. Theo Verhagen, TNO Defence, Security and Safety*	9707 - Modeling of Fluid Energy Milling Process *Mr. Mohamed (Mo) Elalem, U.S. Army ARDEC*

	Small Arms Systems	Gun & Missile Systems		
4:50	10226 - Testing Non-lethals: Finding the Right Tools for the Job *Mr. Pascal Paulissen, TNO Defence, Security* and Safety			

5:10 pm **CONFERENCE ADJOURNED FOR THE DAY**

THURSDAY, MAY 20, 2010

7:00 am - 11:00 am Registration Open - Landmark Circle

7:00 am - 8:00 am Continental Breakfast - Landmark Ballroom Foyer

8:00 am - 9:40 am **BREAKOUT SESSIONS**

- PM MAS
  Session Chair: Chris Grassano, PM MAS
- JSSAP
  Session Chair: Joel Goldman, U.S. Army ARDEC
- Tactical Missiles & Rockets
  Session Chairs: Ed DePasqual, Nammo Talley, Inc. & John Bednarz, Raytheon Company
- Joint Interest
  Session Chairs: Doug Wong, PM MAS & Mike Stankus, EG&G Technical Services, Inc.

	Small Arms Systems	Gun & Missile Systems	
Time	Landmark B	Landmark A	Reunion GH
	PM MAS		
8:00	• An Overview of Non-Standard Ammunition *LTC Robert Dionisio*	Distinguished Speaker: *Mr. Edgar Fossheim, Nammo AS, Norway*	
8:30	• Training Ammunition Safety Initiatives *LTC Robertson, Product Director* • 40MM Ammunition: Evolving and Emerging Requirements *MAJ Marc Meeker, Assistant Product Manager, Medium Caliber Ammunition* • Small Caliber Ammunition: Enhancing Capabilities *LTC Jeffrey Woods, Product Manager, Small Caliber Ammunition*	Distinguished Speaker: *Mr. Patrick (Kevin) Peppe, Vice President, Naval Weapon Systems, Raytheon Company*	
	JSSAP	Tactical Missiles & Rockets	Joint Interest
9:00	9855 - Lightweight Small Arms Technologies *Mrs. Kori Phillips, U.S. Army ARDEC*		10142 - Hovering Precision Weapons (HPW): Enabling Precise Surgical Strike and Collocated Close Air Support from Tactical to Strategic Distances *Dr. Ron Barrett, University of Kansas*

	Small Arms Systems	Gun & Missile Systems	
9:20	10188 - JSSAP Futures 2012-2020 *Dr. Barton Halpern, U.S. Army ARDEC*	9714 - Demonstration and Validation of Lead-free Ballistic Modifier for Rocket Propellants *Dr. Sarah Headrick, ATK*	10228 - CROWS II Vehicle Integration *Mr. Joseph Scheneck, PE, U.S. Army ARDEC*

9:40 am - 11:00 am **BREAKOUT SESSIONS**

- JSSAP
  Session Chair: Joel Goldman, U.S. Army ARDEC
- Tactical Missiles & Rockets
  Session Chairs: Ed DePasqual, Nammo Talley, Inc. & John Bednarz, Raytheon Company
- Joint Interest
  Session Chairs: Doug Wong, PM MAS & Mike Stankus, EG&G Technical Services, Inc.

Time	Small Arms Systems	Gun & Missile Systems	
	Landmark B	Landmark A	Reunion GH
	JSSAP	Tactical Missiles & Rockets	Joint Interest
9:40	9895 - National Small Arms Center Update *Mr. Frank Puzycki, JSSAP Office, U.S. Army ARDEC*	*Morning Break - Landmark Ballroom Foyer*	
10:00	10193 - Advanced Lethal Armament Technology for Small Arms *Mrs. Sabbian Registe, ARDEC-RDECOM*	10074 - Advanced Precision Kill Weapons System II *LCDR Nick Green, USN, Direct and Time Sensitive Strike Weapons PMA-242*	10175 - Experimentation in Integrated Weapons Solutions for Unmanned Systems – Getting Past the Demonstration *Mr. Paul Balutis, iRobot*
10:20	9916 - Advanced Fire Control Technology for Small Arms Army Technology Objective (ATO) *Mr. Terence F. Rice, U.S. Army ARDEC*		9827 - Environmentally Acceptable Alternatives to Lead Azide and Lead Styphnate *Dr. Michael Williams, Pacific Scientific EMC*
10:40	9539 - Integrated Rifle Barrel Reference Sensor with Position Compensating Reticle *Mr. Slobodan Rajic, Oak Ridge National Laboratory*		10593 - Non-Incendiary Artillery Marking and Illumination Solutions *Mr. George Kurzik, General Dynamics – Ordnance and Tactical Systems* *Mr. Ed Schmidt, Cyalume Technologies*

11:00 am - 6:00 pm **CONTRACTOR FIRING DEMONSTRATION** **Promotional Partner:** LaRue Tactical

- *Session Chair: Sal Fanelli, U.S. Marine Corps*

11:00 am - 11:30 am Board Buses for Firing Demonstration - Hotel Lobby

11:30 am - 12:40 pm Buses En Route for Firing Range

12:40 pm - 1:40 pm Texas BBQ Lunch Provided by LaRue Tactical

1:40 pm - 4:30 pm Firing Demonstration - Spartan Tactical

3:30 pm - 4:45 pm Buses En Route for Hotel (first bus departs at 3:30 pm; last bus departs at 4:45 pm)

POSTER PRESENTATIONS

The following posters will be displayed in Marsalis Hall throughout the conference. Authors will be available for discussion during morning and afternoon breaks, as listed in the agenda. Posters will be displayed in numerical order.

- *Session Chairs: Mr. Steve French, BAE Systems & Mr. Matt Ohlson, ATK*

9893 - Development of a Nondestructive Testing Field Inspection Vehicle Designed to Scan Cylindrical Structures
Mr. Cory Mettler, American Science and Technology

9925 - Case Studies for Improved Sustainment of Bullet and Bullet Assembly Machines
Mr. Michael Coventry, Bliss Clearing Niagara Technical Services

10005 - Fire Control Systems for Heavy Machine Guns: Winning the Current Fight while Simultaneously Modernizing for the Future
Mr. Richard Hollen, VingTech Corporation

10100 - Liquid Ceramic Coatings for Signature Reduction in Small Arms
Dr. Leah Leavitt, NIC Industries, Inc.

10126 - New Power, Lightweight Materials, and Sustainable Design Tools for Small Arms Systems
Mr. Blase Leven, Kansas State University

10128 - Using Triboluminescence to Detect Impacts for Defense Applications
Dr. William Hollerman, University of Louisiana at Lafayette

10138 - FEM Analysis of a Barrett M99 0.50 Caliber Rifle Barrel
Dr. Gary Anderson, South Dakota State University

10145 - Determining Residual Stress of Ta Alloy Gun Tube
Dr. Tao Huang, South Dakota State University

10155 - Characterization of the Emergent Flame and Transient Pressure History of the M299 Ignition Cartridge at 70°F and -50°F
Mr. Jon Conner, National Technical Systems (NTS)

10168 - Individual Airburst Weapon System (IAWS)
Mr. Ryan Hurt, ATK

10192 - Miniature Integrated Capacitive Discharge Unit for Detonation and Ignition
Mr. Frank Duva, Novacap, Inc.

10236 - Analysis of Requirements for Engaging Defilade Targets with 40mm Grenades
Dr. Kevin Massey, Georgia Tech Research Institute

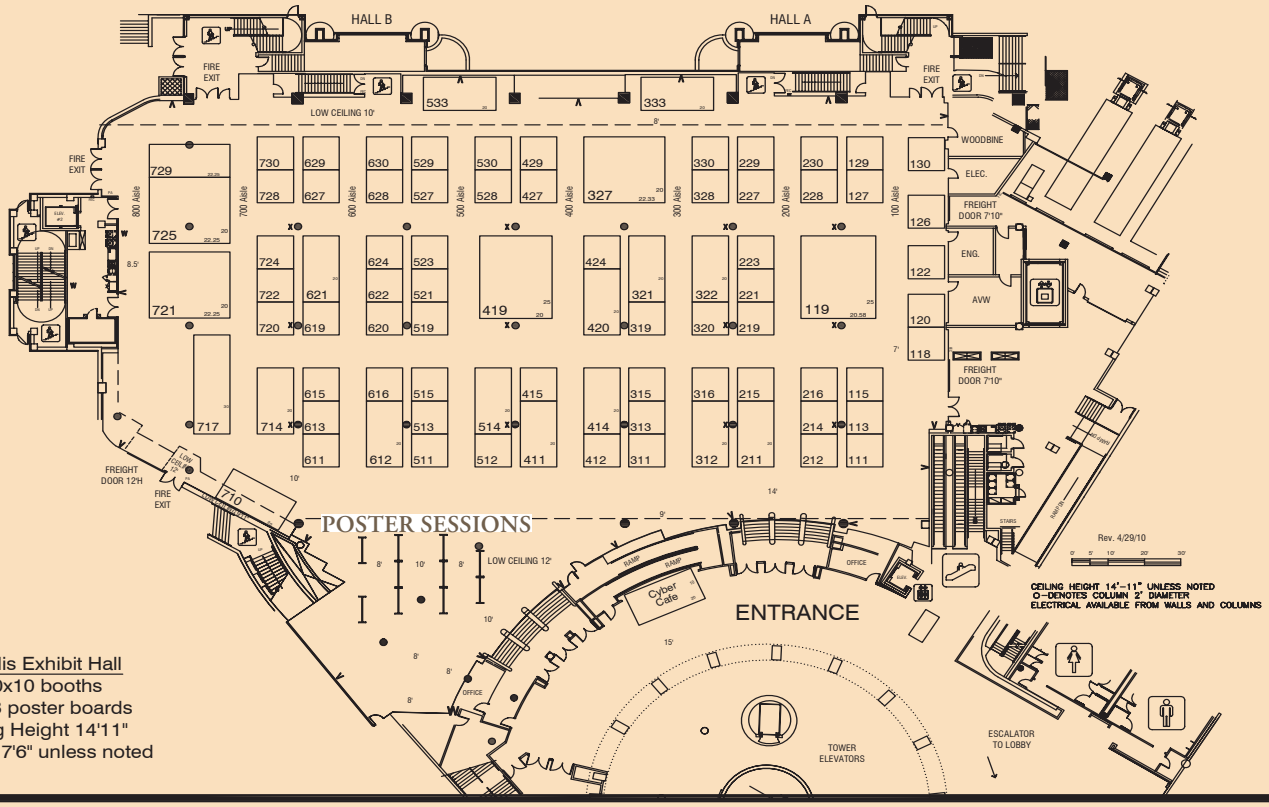
10482 - Small Arms Mounted Radar Sensor for Improving Aiming Accuracy
Dr. Ram Narayanan, The Pennsylvania State University

10578 - Small Caliber Dispersion Modeling
Mr. Jeff Siewert, Arrow Tech Associates, Inc.

EXHIBIT INFORMATION

Booth Number	Company Name
427	AAI Corporation
319	Advanced Armament Corporation
514	Aerojet
228	Aimpoint, Inc.
528	Alcoa Defense
412	American Rheinmetall Munitions, Inc.
513	Anniston Army Depot
725	ARDEC
530	Ares, Inc.
523	Arrow Tech
419	ATK
722	Barrett
612	Bulldog Tactical Equipment
321	Colt Defense, LLC
424	Combined Systems, Inc.
320	Competitive Edge Gunworks
333	Contract Fabrication & Design
529	Cornervision
512	Dayton T. Brown, Inc.
126	DTI Associates
710	ELCAN Optical Technologies
628	EMA Tactical
415	ENSINGER

Joint Armaments Conference, Exhibition & Firing Demonstration
May 17-20, 2010
Hyatt Regency Dallas
Dallas, Texas



Marsalis Exhibit Hall
117-10x10 booths
10-4x8 poster boards
Ceiling Height 14'11"
Aisles 7'6" unless noted

119	FNH USA, Inc.
219	GEMTECH
621	General Dynamics Amphibious Systems
327	General Dynamics Armament and Technical Products
322	General Dynamics-OTS
316	GLOCK, Inc.
527	Heckler & Koch
115	Hogue, Inc.
118	Institute for Advanced Technology at the University of Texas
328	ITT Enidine, Inc.
717	Joint Service Small Arms Program
313	Kistler Instrument Corporation
216	Knight's Armament Company
627	L-3 Fuzing & Ordnance Systems
227	Lancer Systems
622	LaRue Tactical
212	Laser Devices, Inc.
122	Lasermax
724	Magpul Industries Corporation
730	Manroy USA
130	Martin Electronics, Inc.
511	MAST Technology, Inc.
629	Metal Storm, Inc.
720	MILKOR USA, Inc.
429	MSC Software Corporation
411	Nammo Talley, Inc.
521	National Technical Systems Corporation
613	NNSA's National Secure Manufacturing Center
414	Nobles Manufacturing, Inc.
315	Olin-Winchester
311	Otis Technology
619	PCB Piezotronics
214	Pelican Products
728	Platt Mounts - USA, Inc.
721	PM Soldier Weapons
211	Remington Arms
519	Ringfeder Corporation
129 & 215	RUAG Ammotec
533	S&T Daewoo
111	Sabre Defence Industries, LLC
113	Samson Manufacturing
611	Schmidt & Bender GmbH
330	Sierra Bullets
127	Sig Sauer
229	Small Arms Defense Journal
515	Smith & Wesson
120	Spa-Defense
630	Streamlight, Inc.
615	Sturm, Ruger
230	SureFire
223	Taser International
420	Trijicon
616	US Army Aberdeen Test Center
729	US Army RDECOM
312	US Ordnance
624	UTRON, Inc.
620	Vectronix, Inc.
714	VingTech Corporation
221	Wilcox Industries

Exhibit Hours:
Monday, May 17:
5:00pm - 6:30pm Opening Reception

Tuesday, May 18:
9:00am - 5:30pm
5:30pm - 7:00pm Reception

Wednesday, May 19:
9:00am - 3:30pm

Save the Date!!!!

46th Annual Armament Systems: Gun & Missile Systems Conference & Exhibition
April 11-14, 2011
Miami, FL
www.ndia.org/meetings/1590

International Infantry & Joint Services Small Arms Systems Symposium
May 23-26, 2011
Indianapolis, IN
www.ndia.org/meetings/1610

ATK is a premier aerospace and defense company with approximately $4.8 billion in annual sales, more than 17,000 employees, and operations in 21 states and internationally. We bring non-traditional approaches to the market, with speed and innovation. ATK has signature expertise in delivering timely, advanced and affordable capabilities with reliable performance – in many cases economically upgrading current inventories with force multiplier affect.

ATK continues to expand its business as a leading provider of enhanced lethality and survivability solutions with core competencies in facility and supply chain management; small-and medium-caliber ammunition design and manufacture, medium-caliber gun system design and manufacture, and advanced propellant and energetics production. We are the technology leader in law enforcement, hunting and shooting sports ammunition, accessories and reloading supplies.

Our product line spans the breadth of individual and crew-served applications, from conventional and special-mission pistol and rifle ammunition, to 30mm and large-caliber for air, land and sea platforms. We have extended our supply chains to include not only U.S. and NATO specification ammunition, but non-standard products as well.

We are pioneering the development of enhanced tactical ammunition, including air bursting munitions, next generation energetics, and advanced propellants that will increase performance.

ATK offers an affordable 70mm precision system, Guided Advanced Tactical Rocket (GATR), which uses a semi-active laser guidance package to achieve extreme accuracy against both stationary and moving targets. GATR is a lock-on before or after launch system that supports integration on fixed/rotary wing and Unmanned Aircraft Systems platforms and is compatible with existing 2.75-inch launcher hardware.

ATK continues to enter new international markets supporting U.S., NATO, and allied forces with affordable, interoperable solutions in support of freedom. These offerings include mission-critical tactical systems and personal protection equipment, including load-bearing vests, hydration packs, holsters, bags, and slings.

ATK brings unmatched reliability and lethality in integrated weapon systems. We offer added value with fully integrated electronics and fire control capabilities supporting our innovative chain gun technology and medium-caliber ammunition systems, presenting a complete lethality package for today's ground and air platforms.

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

GENERAL DYNAMICS
Armament and Technical Products

General Dynamics Armament and Technical Products, located in Charlotte, N.C., provides a broad range of system solutions for military and commercial applications.

The company designs, develops and produces high-performance weapon and armament systems, defensive armor, countermeasure systems and aerospace composite solutions, as well as off-road axle and suspension systems. It is also a leading U.S. producer of biological and chemical detection systems.

Contact Info:

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2118 Water Ridge Parkway
Charlotte, NC 28217
Phone: 704-714-8291
Fax: 702-714-8212

LaRue Tactical

Located in Leander, TX, LaRue Tactical was founded as Austin Precision Products, Inc. (APPI) in 1980 as a precision machine shop servicing the technical markets, including microprocessors and the computer industry. In the early 90's, LaRue Tactical emerged from APPI, servicing the sniper community, and then quickly branched into design and production that supports all branches of the U.S. military world-wide. "LaRue" is now synonymous with Sniper Targets and Quick-Detachable Mounting Systems for every optic, laser and NVD used by our soldiers. Our facilities house a large array of CNC work-centers, assembly, testing, inventory, and shipping areas. We are co-located with an underground shooting / testing range.

LaRue is known for providing the Warfighter the finest hardware available at the best value. Our specific niche is speed and agility in the production and delivery of field-worthy prototypes, integrating our patented Quick-Disconnect Speed Lever design into a variety of MIL-STD-1913 related products and accessories. The "repeatable" attributes of our manufactured hardware, even under the harshest conditions and most rigorous abuse have given LaRue an idustry leadership reputation.

LaRue also designs and manufactures highly-accurate and dependable weapons systems, including the new 7.62 Optimized Battle Rifle (OBR), The OBR is an accurized gas-impingement AR-platform rifle that is available with 16", 18" or 20" barrels. Almost every part of the OBR is manufactured in-house, providing the ultimate in quality control that yeilds a consistent, sub-MOA rifle.

LaRue Sniper Targets are used by the sniper community world-wide. These robust steel targets are available in auto-resetting and remote-resetting models for calibers ranging from 5.56 through 50BMG. LaRue also provides several designs that are free-standing, reactive targets.

MEGGiTT
smart engineering for extreme environments

Meggitt Defense Systems Inc. (MDSI), specializes in the design, development and production of state-of-the-art medium caliber Linear Linkless ammunition handling systems and large caliber compact autoloaders in support of the United States military and her allies.

MDSI has a solid track record in meeting design-to-production requirements for increased capacity, reliability, and volumetric storage efficiency for ammunition handling systems.

MDSI provides a wide range of medium caliber Linear Linkless systems, all of which have been battle-proven. These include: AC-130U Gunship - 25mm, 3,000 rounds; Apache helicopter - 30mm, 1,200 rounds and 250 rounds (Combo PAK); Blackhawk helicopter - two 30mm magazines, 1,200 rounds and 660 rounds; Phalanx Reloader – 20mm, 1,500 rounds; and LALS Reloader – 20mm, 2,100 rounds. Additionally, development programs are underway for 30mm Mk44 Linkless feed systems, 35mm systems, and 40mm systems. Further, a new 20mm Linkless system is now in production, replacing the existing linked system on the Cobra helicopter.

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

MDSI has developed large caliber Compact Autoloader and magazine systems for 105mm, 120mm, 140mm and 155mm. They are electrically or hydraulically-driven, fully automatic battlefield robotics systems. Examples range from prototypes for Main Battle Tanks to today's Stryker Mobile Gun System and to next-generation combat platforms

As the technology leader in ammunition handling and storage systems, Meggitt Defense Systems Inc. is proud to be a sponsor for the NDIA Joint Armaments Conference.

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ALCOA DEFENSE

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BAE SYSTEMS

GENERAL DYNAMICS
Armament and Technical Products

LaRue Tactical

MEGGITT
smart engineering for extreme environments

K11 Dual-Barrel Air-Burst Weapon

In-Woo Kim, Dong-Hyun Kim, Eui-Jung Choe, Je-Wook Chae, Joon-Ho Lee

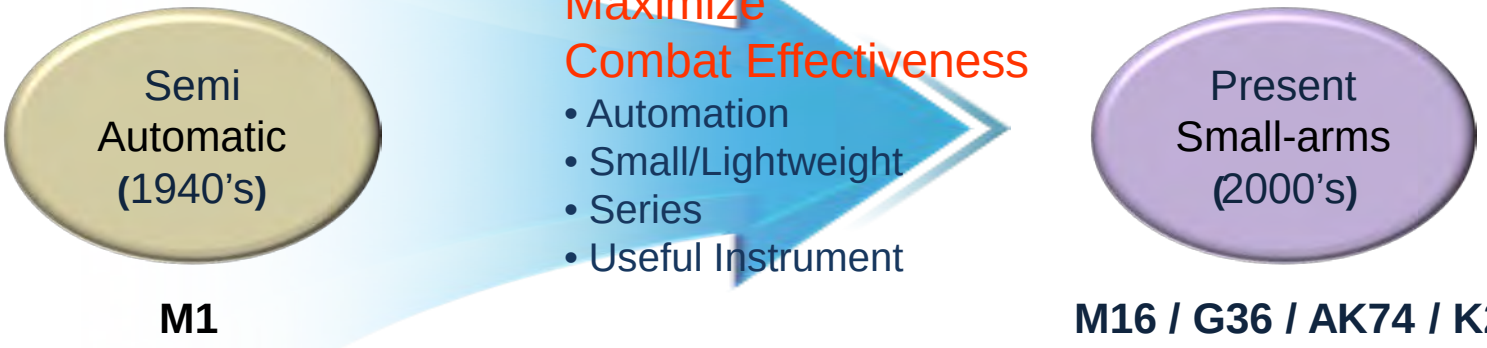
국 방 과 학 연 구 소
AGENCY FOR DEFENSE DEVELOPMENT

Contents

- Background & Introduction
- Key Technology
- Conclusions
- Demonstration Video

Background

Trend of Small-arms



Defect of Present Small-arms

- Distinction of accuracy between training and real Combat situation
- Incompetency to a defiladed target
- Necessity of supplementary night vision at night time

Introduction

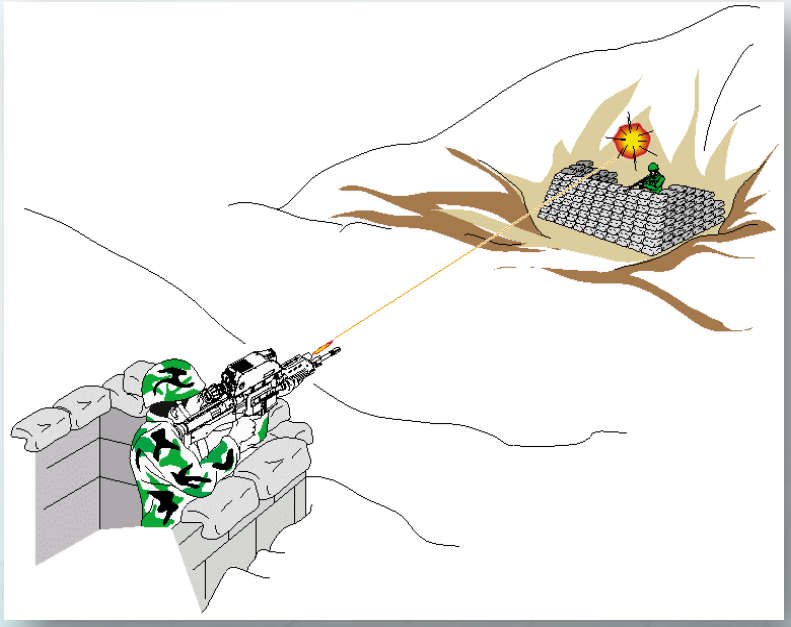
New attempt in the world (1994~2004)

Smallarms	Characteristics	Conclusion
4.7mm G11 Caseless (Germany)	3 Burst, High firing rate	Fail to Double up The Combat Effectiveness ⇩ Quit the Development Program
5.45 AN94 (Russia)	2 Burst, High firing rate	
5.56mm Double Bullet (USA)	Shot gun	
5.56mm Flechette (USA)	Flat Ballistics	
OICW (USA) PAPOP (France)	Dual Barrel, Air Bursting	

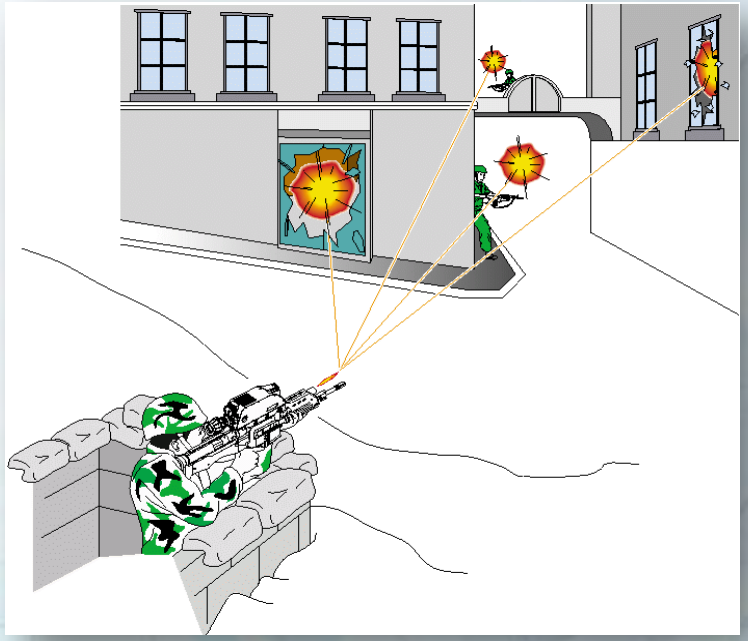
- Maximize Combat effectiveness considering New concept and technology
  - ➢ Precise Air Bursting against Defiladed Targets
  - ➢ Fire Control System at Day & Night, and All-Weather Conditions
  - ➢ Lightweight Rifle System

Requirements of Army

- Increase in Lethality and Precision Firing at Day & Night, and All-Weather Conditions
- Effective on Defiladed Targets and linked with Future Soldier System
- High Reliability, Availability, Maintainability and Durability



Field Operation



Urban Operation

Technical Approach



System integration

Fire Control System



Laser Range Finder



Integrated Controller





Complex Optical Modules



Thermal Image Generator



Battery





HE(20mm) Module

Fuse Setter
Bolt Action
5 Rds. Magazine



Air-Bursting Ammo



Fragmentation Warhead



Programmable Electronic Fuse



KE(5.56mm) Module

Complex Trigger System
Gas Operated
20/30 Rds. Magazine

Key technology

Ultra Precision Electronic Fuse

- MEMS-Based Smart Multi-Option Fuse
- Turns Count Sensor by Using Geomagnetism

Fragmentations of HEAB Ammunition

- High Performance and Low Vulnerability Propellant
- Applied to Small Ammunition under Volume and Weight Limitation
- Controlled Dual Fragmentation Structure → Epochal Increase of Lethality (Increased Effective Fragmentations)

Lightweight triggering Mechanism

- Lightweight Material Developed by Korean Science and Technology

  : Weight Reduction of More than 20% by Using Ti Alloy and High Strength Al Alloy Containing Scandium.

- 2.5 Times Increase of Barrel Life by Developing TiN Surface Treatment Method

- Highly Reliable Creative Mechanisms : Complex Trigger System, Link Type Percussion Lock

Simulation & Optimization

- Simulator for System Test and Evaluation to Reduce Development Period and Cost
- Pre-Evaluation of System Performance by Simulator at Early Stage of Full Scale Development
- Optimization of Operation Menu of FCS and Analysis on Combat Effectiveness
- Optimal Design by Human Parameter Analysis on Various Firing Postures
- Dynamic Analysis of Rifle/Human Integrated System for Ergonomic Design

Lightweight Fire Control System

- Apply Functions of Tank FCS (Day and Night Target Detection, Range Finding and Ballistic Trajectory Calculation) to Firearm
- Instant High Power Supply by Optimal Power Control
- Improved Ballistic Trajectory Calculation by Cant/Tilt and Temperature Sensors
- Low Power Laser Range Finding, Image Synthesis Using Micro Display

Operation Procedure



Conclusions

- Development of K11 dual-barrel air-burst weapon with indigenous technology.

- Key Features
  - Gives flexibility for urban engagement
  - Proved to be very accurate

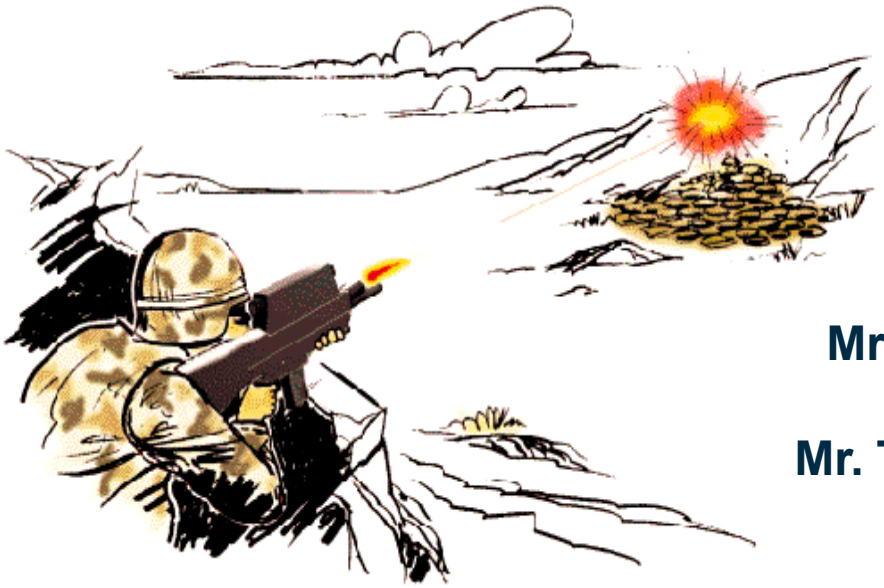
- Future plans
  - To be delivered to ROK Army by 2010
  - Technical support for mass production and export

Contact Information

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- Phone Number : +82-42-821-3100
- Company : ADD, Korea

  (Agency For Defense Development)
- Email : kiw111@chol.com

DARPA SCORPION Program Transition to Army Lethality ATO Program: A Success Story

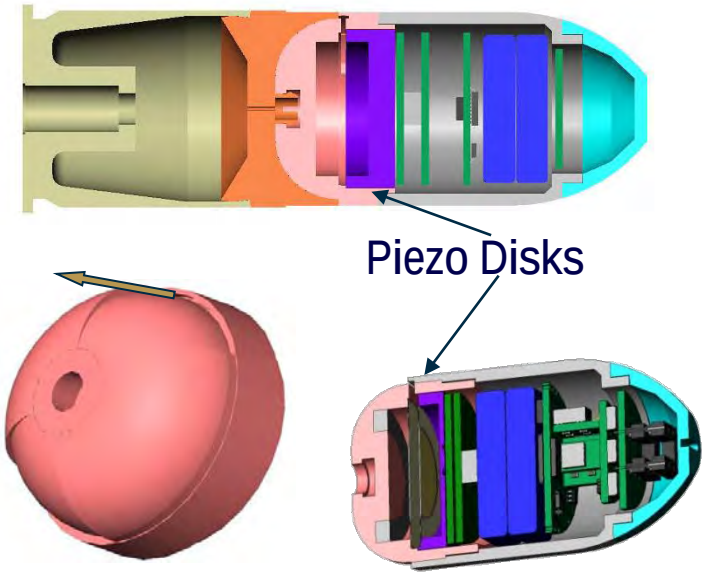


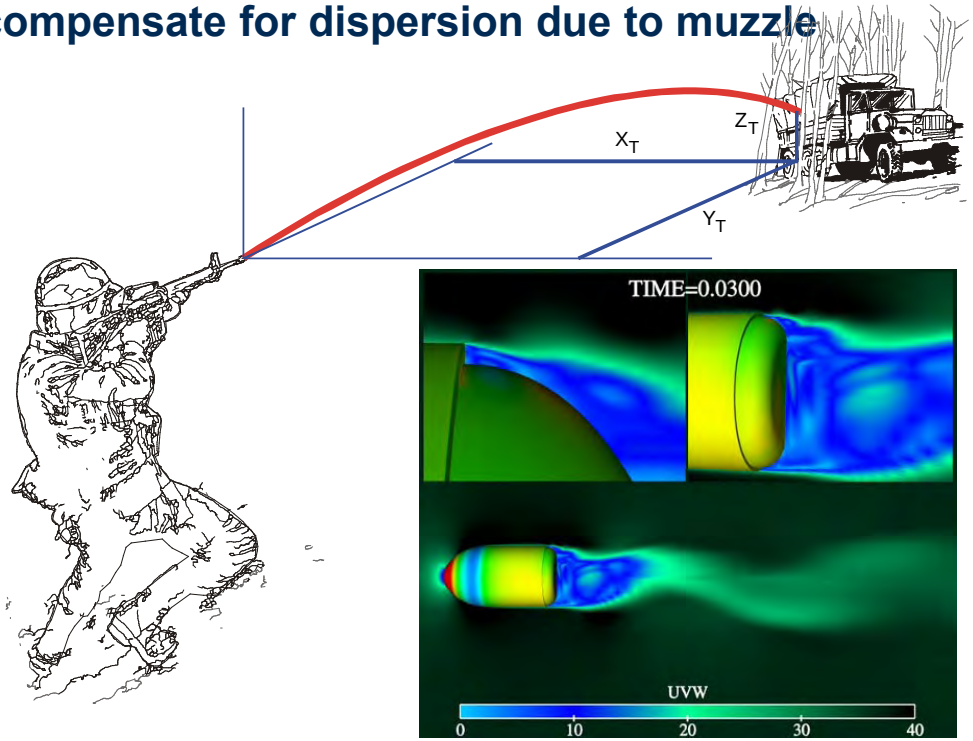
Mr. Andre Lovas, Dr. Kevin Massey,
Dr. Mike Heiges *GTRI*
Mr. T. Gordon Brown, Mr. Tom Harkins
US Army Research Laboratory

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SCORPION Program

- **DARPA supported *Self-Correcting Projectile for Infantry Operation* *--(2001 to 2007)***
- **Participants: Georgia Tech Research Institute, Georgia Institute of Technology and U.S. Army Research Laboratory**
- **Demonstrated controlled flight of a 40 mm projectile with steering forces generated by piezo-based actuators sufficient to compensate for dispersion due to muzzle velocity variations.**



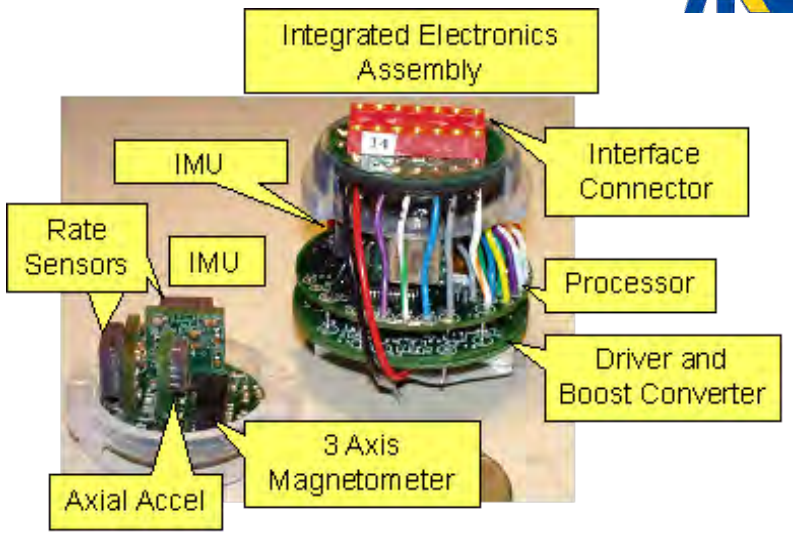


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SCORPION Electronics

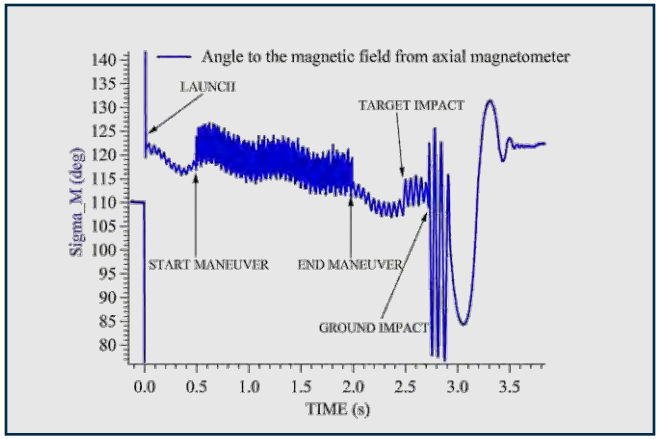
Onboard Sensors include:

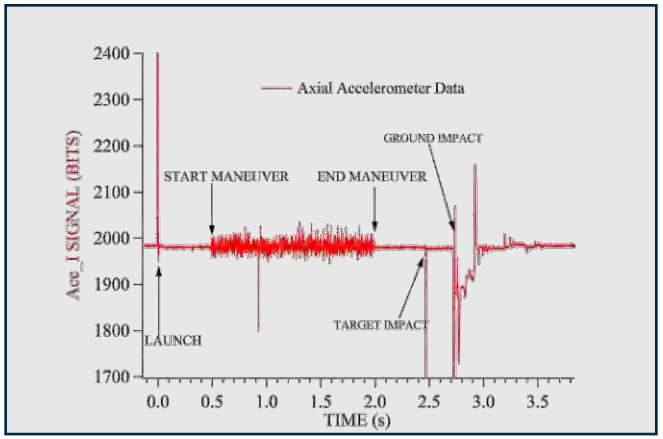
- **Axial and 2-axis Radial Accelerometer (3Components of Translational Accelerations)**
- **3-axis Magnetometer (Along Projectile Principal Axes – Same as Accelerometers)**
- **Pitch and Yaw Rate Sensors**
- **2 Centripetal Acceleration Sensors (Roll Rate)**



The inertial sensors respond to the projectile dynamics of launch and flight and provide measurements needed for projectile guidance.

The sequence of events in a typical maneuvering Scorpion flight are readily apparent in the sensor data.





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SCORPION Transition Plan

- During SCORPION program, an IPT was formed to explore transitioning DARPA program
- IPT membership included USAIC DCD, US Marines, SOCOM, JSSAP/ARDEC, PM-Soldier Weapons, PM-MAS, US ARL, GTRI, DARPA and OSD
- IPT engaged the user community including US Army Infantry School, SOCOM and US Marines
- IPT briefed Army PM's, ARDEC and ONR to determine interest and support

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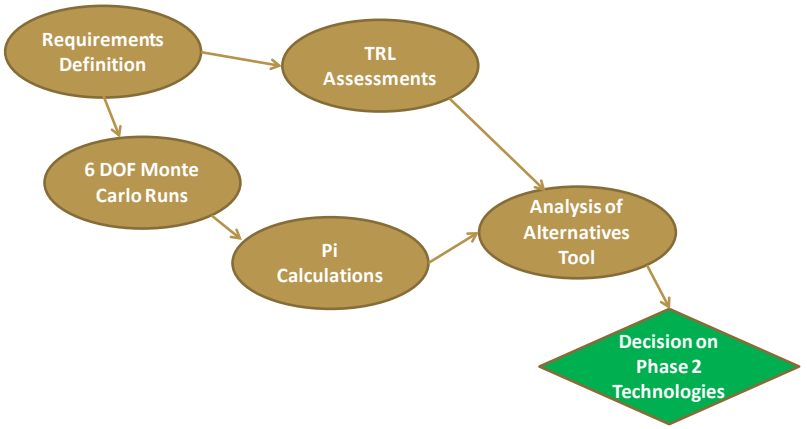
Precision 40 mm Grenade Program

- Three Phase Program—2009 to Present
  - Phase I – Concept Study, 9 months
  - Phase II – System Design, 9 months
  - Phase III – Integration and Test, 12 months
- Integration of Maneuver Technology with
  - Range Estimation
  - Trajectory Correction
  - On-Board Sensors and Processing

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Precision 40 mm Grenade Program Phase 1

- Looked at contribution of error sources to dispersion
- Assessed the application of different technologies to reduce dispersion
- Evaluated technologies on basis of technical maturity and risk and dispersion reduction
- Analysis flow included requirements definition, simulation, Pi calculations, TRL assessment and Alternatives Analysis



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Sources of Error and Effect

- Different sources of error stack up to produce inaccuracy at long range
- If we knew all of these we could have perfect aiming

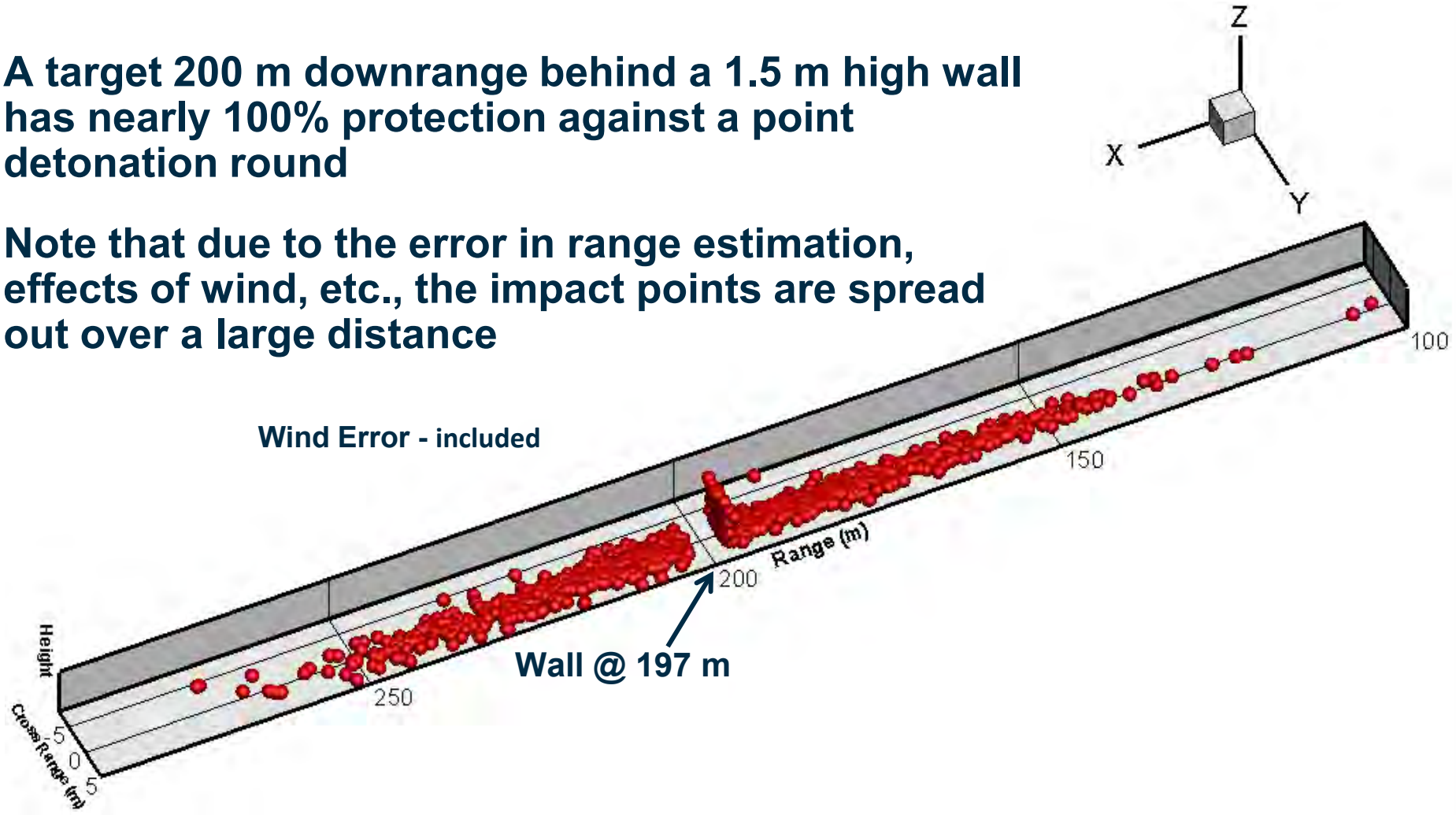
Pointing (Az and El)	Muzzle Exit Conditions	Environmental Factors	Range to Target
Gunner inability to hold weapon steady	Muzzle velocity variation	Changes in density affect drag and wind affects flight	Error in gunner estimate of range

Physical Properties of Round	Round to Round Variations can affect drag coefficient, mass, stability, muzzle jump

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Monte Carlo Analysis for Standard Grenade

- A target 200 m downrange behind a 1.5 m high wall has nearly 100% protection against a point detonation round
- Note that due to the error in range estimation, effects of wind, etc., the impact points are spread out over a large distance



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Technology Improvements

Technology	Effect on Error
Range Finder	Ranging Error → ± 0.5%
Feedback Elevation to Gunner	Pointing Error El → ± 0.6%
Active Pointing Error Correction	Effective QE → ± TBD%
Muzzle Velocity Compensation	Muz Vel Error → ± 0.6%

Information from Fire Control

QE, Az, Temp & Pressure Sensors
Provides gun orientation and density measurement

Aiming Aid
Provides QE feedback to shooter

Range Finder
Provides range to target

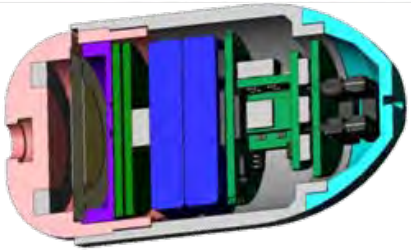


Muzzle Velocity
Magnets produce a local field measured by on-board magnetometers

Communications
Initializes round with gun orientation, target range

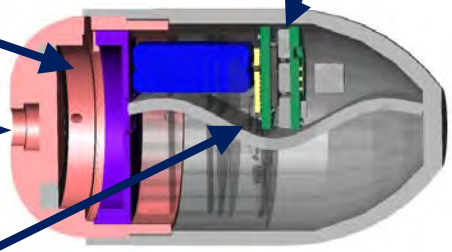
Course Correction, Fuze Timing, and Sensor Suite
Pointing error compensation, muzzle velocity correction, Senses orientation of round Calculates time for fuze

Maneuver Actuator
Synthetic Jet



SCORPION Round

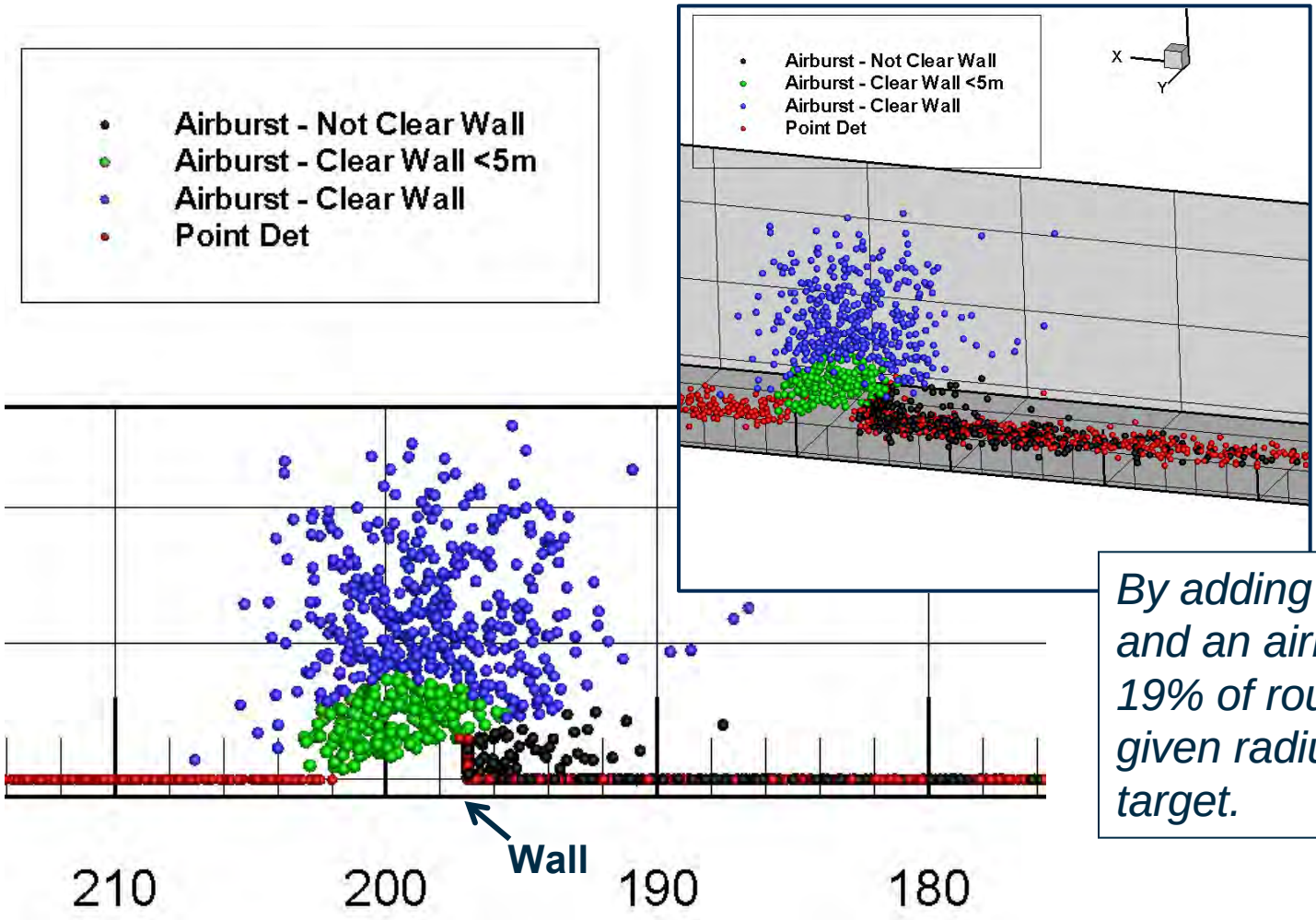
Electronics
Reduced volume for payload integration



Precision 40 mm Technology Demonstrator

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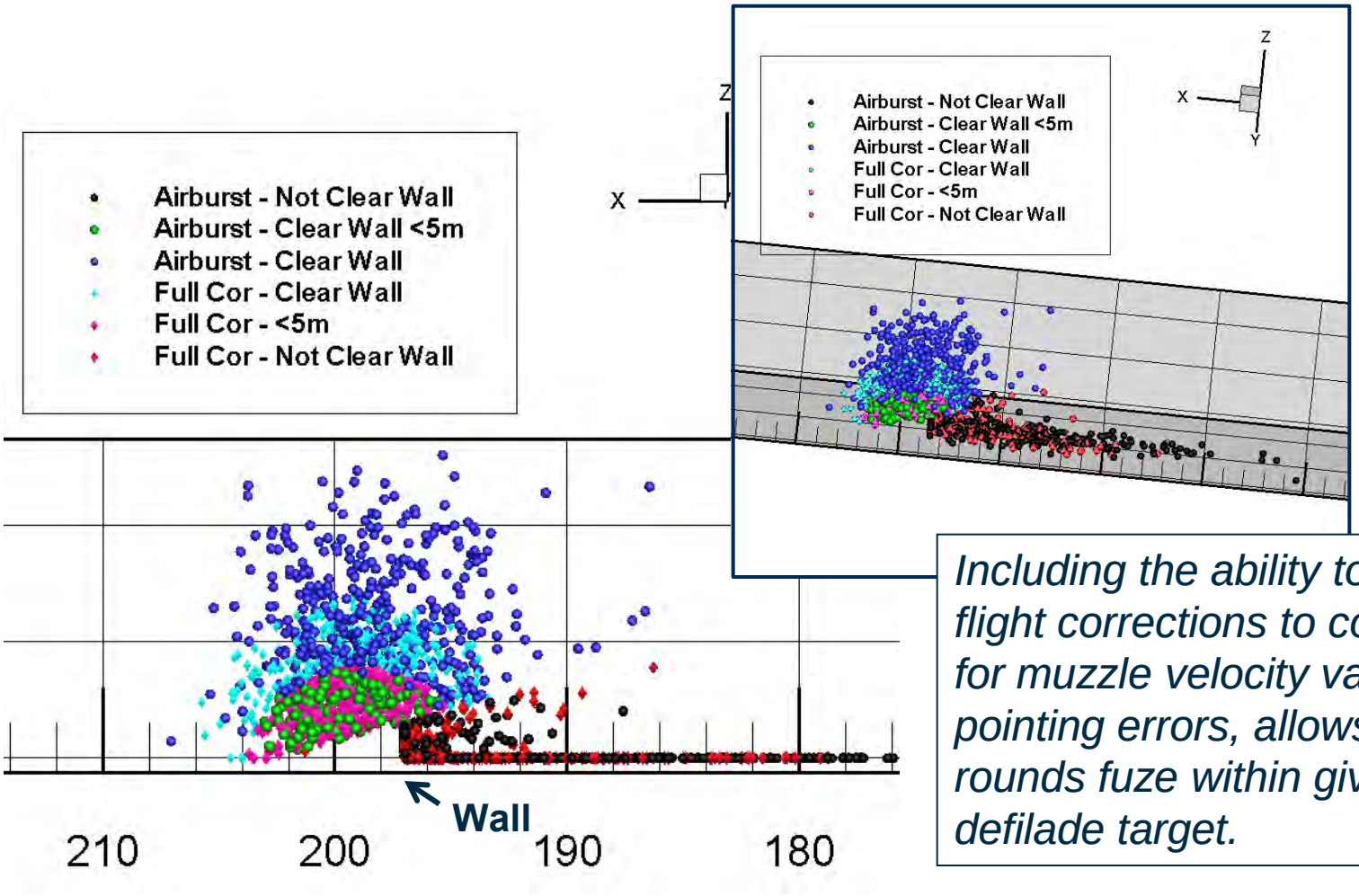
Effect of Including Range Finder and Airburst



By adding a range finder and an airburst capability, 19% of rounds fuze within given radius of defilade target.

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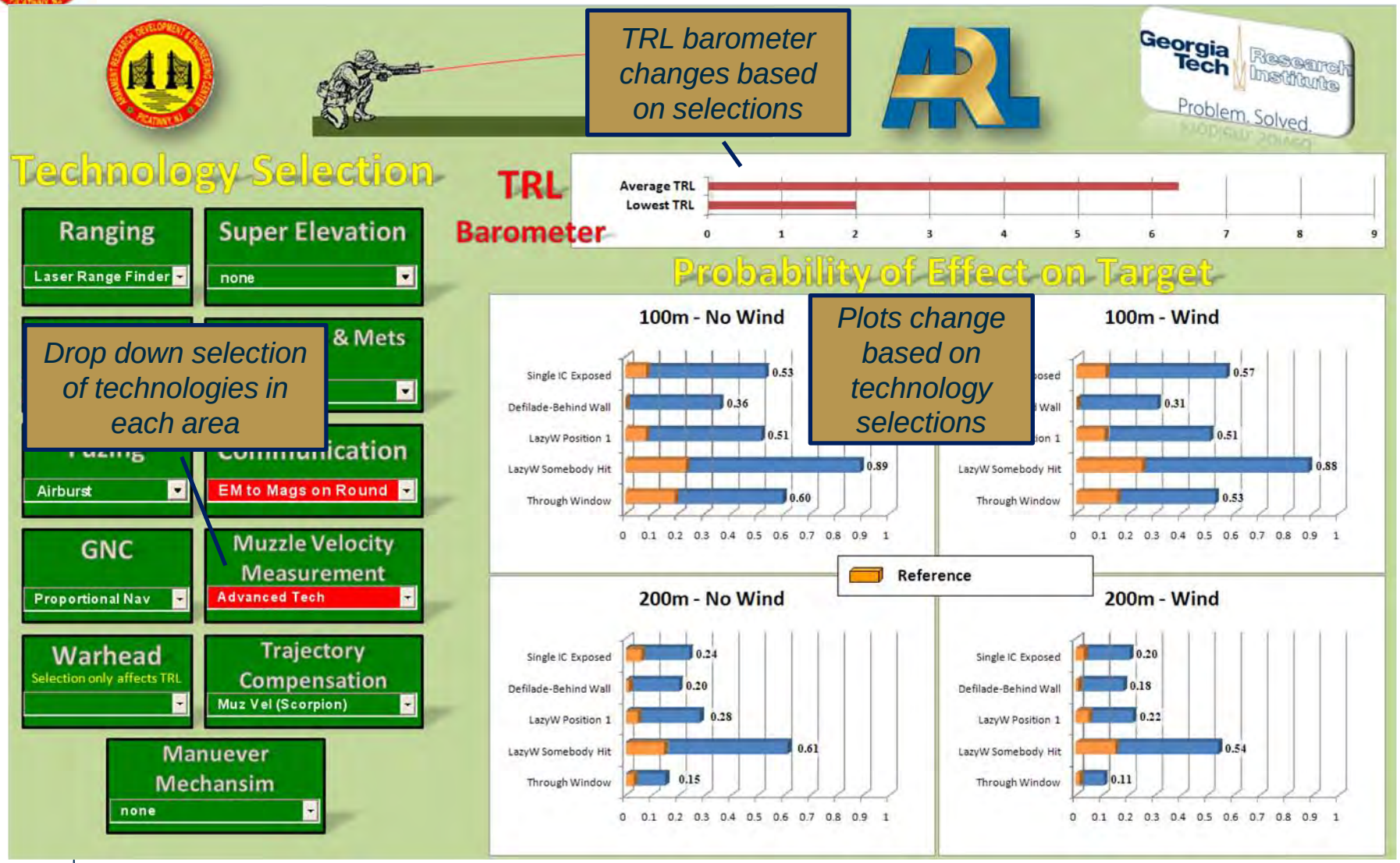
Effect of Compensating for Muzzle Velocity and Pointing Errors



Including the ability to perform in flight corrections to compensate for muzzle velocity variations and pointing errors, allows 34% of rounds fuze within given radius of defilade target.

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Analysis of Alternatives Tool



Summary

- **The current 40 mm systems could be enhanced for increased effectiveness.**
  - **A series of technological improvements to the grenade and launcher system would enable a system to be effective against targets in defilade.**
  - **The combination of Monte Carlo error modeling and 6-DOF simulations provides a useful way to explore the benefits of each technology.**
  - **An Analysis of Alternatives tool allows for rapid comparison of the different technology combinations.**
  - **Technologies to be carried forward in Phase 2 include airburst, gunner aiming aid and active compensation.**

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Acknowledgments

- Work sponsored by U.S. Army ARDEC JSSAP Advanced Lethality Armament ATO Program under U.S. Army Contract W15QKN-09-C-0087
- Authors would like to recognize the assistance and support of the following contributors:
  - GTRI—Dr. Jim McMichael
  - U.S. Army Research Laboratory—Dr. Peter Plostins, Mr. Ed Bukowski, Mr. Tim Brosseau, Ms. Mary Arthur, Mr. Moshe Hamaoui

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U. S. ARMY COMMON LOW-COST INSENSITIVE MUNITION PROGRAM
IMX-101 REPLACEMENT FOR TNT EXPLOSIVE

155mm M795 IM Projectile

Mike Ervin*, Virgil Fung, Brian Alexander, Alberto Carrillo
BAE SYSTEMS Ordnance Systems, Holston Army Ammunition Plant

Anthony Di Stastio*, Philip Samuels, Sanjeev Singh
ARDEC, Picatinny Arsenal, NJ

Charlie Patel
OPM - Combat Ammunition Systems, Picatinny Arsenal, NJ

U. S. Army CLIMEx Program Strategy and Goals

Common Low-cost Insensitive Munitions Explosive (CLIMEx)

Program Strategy

To accelerate candidate explosive fill formulations and compositions that satisfy the selection criteria into test material using representative manufacturing facilities.



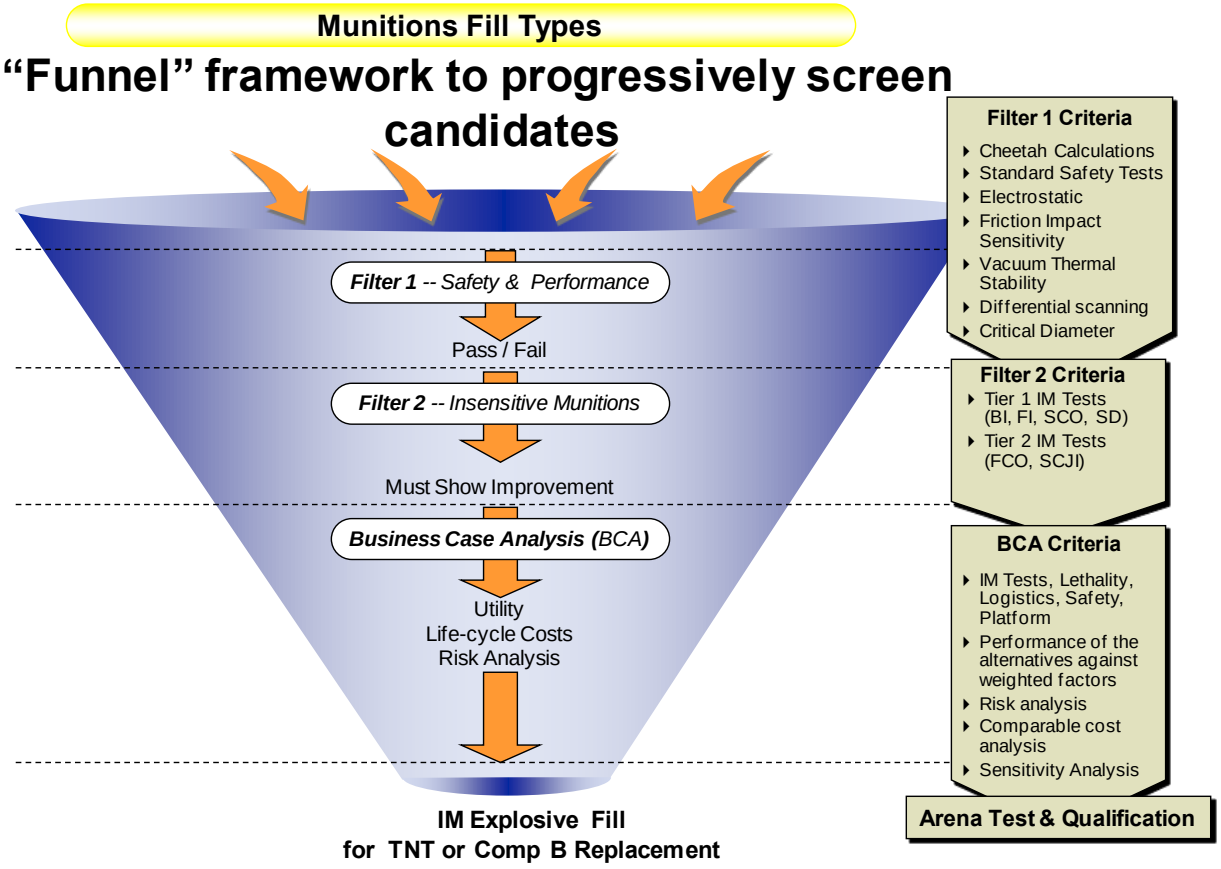


Program Goals

1. **Selection of one single common explosive fill for all artillery and mortar products.**
2. **Selection of two explosive fills, one that is common for replacement of TNT and another that is common for the replacement of Composition B.**

CLIMEx Program – Selection of IM Explosive

Execution of the CLIMEx Program by PM CAS involved the evaluation of multiple explosive technologies (melt-cast, cast-cure, and cast-cure injection) and numerous IM candidate explosives from the Industrial Base and foreign sources.



CLIMEx Program – Selection of IM Explosive

- **M795 155mm Artillery Munition selected as the initial test vehicle for identifying a common IM replacement for TNT in artillery systems.**



- **CLIMEx Criteria for candidate IM explosive fills:**
  - **Must be significantly less sensitive than TNT explosive , if not fully IM compliant.**
  - **Must maintain lethality, as compared to the TNT baseline, with minimal or no degradation.**
  - **Overall IM solution needs be affordable.**
  - **Must be producible within the National Technology & Industrial Base to include ingredients, formulation, and LAP. *Ideally a "drop-in" replacement for TNT in LAP activities.***

CLIMEx Program – Selection of IMX-101 Explosive

IMX-101 Explosive

- Selected as IM replacement to TNT in U. S. Artillery systems
- Developed and produced by BAE Systems at Holston AAP
- Utilizes standard LAP infrastructure for melt-cast explosives
- LAP of M795 Rounds performed at Picatinny Arsenal & Iowa Army Ammunition Plant
- Subjected to comprehensive IM and performance test criteria to include BI, FI, SCO, FCO, SD, SCJI (50mm & 81mm), etc

Energetics Material Qualification Completed for IMX-101



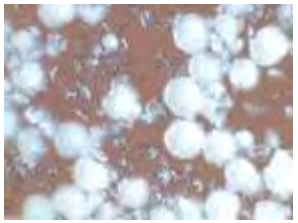
Molten IMX-101

Flaked Final Product



Making the IM Mission Possible

- Achieving the IM Mission Required New Technologies
- Energetic and Critical Materials for IM / EM Applications
  - DNAN
  - NTO
  - TATB
  - High Bulk Density NQ
  - FEM RDX and HMX
  - DMDNB
  - “Special Grade” RDX
  - R8002 Energetic Plasticizer



NTO Crystals



Nutsches of TATB



Incorporation of DNAN in IMX-101



2,000 gallon Glass-lined Reactor

- All Materials Produced on a True Production Scale at HSAAP

IM Melt Cast Explosives from Holston AAP

IMX-101	DNAN & NTO based formulation. Selected by the Army as the common TNT replacement. Applications include 105mm, 120mm, & 155 mm munitions.
IMX-104 (aka OSX-7)	Contains DNAN, NTO, and RDX in various grades. Selected by the Army as the common Comp B replacement in IM Mortar systems (60mm, 81mm, & 120mm) and various submunitions.
OSX-8	Contains DNAN, NTO, and HMX in various grades and provides excellent IM and energetic performance properties. Being evaluated in 60mm Mortar (Europe) and 120mm HET Tank Ammo (FMS).
OSX-12	An aluminized version of IMX-104 which offers excellent IM properties combined with high blast energetic output.
PAX-21	DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army 60mm Mortar system.
PAX-41	DNAN based melt-cast explosive which is currently qualified and fielded in the U. S. Army Spider Munitions system.

M795: System Enhancements for IM

Venting Technology for Cook-off Environments

- IM explosive alone cannot meet cook-off criteria in 155mm Artillery
- Total system analysis and design will provide complete **IM Solutions**

Evaluated and Incorporated Venting Solutions



Standard Lifting Plug Will *Not* Pass (Type III)



Partial Venting (Type IV)



Meltable Fuze Plug (Type V)

IM Test Results: Fast Cook-Off (FCO)

Test Conditions: Mil-Std-2105C, Liquid Fuel Fire, Witness Plate & Pressure Gauge





IMX-101 Passed with Type V Response

V

IM Test Results: Slow Cook-Off (SCO)

Test Conditions: Mil-Std-2105C, Precondition Temp at 145F, Heating Rate of 50F / Hr, Witness Plate & Pressure Gage







SCO Test Set-up

IMX-101 Passed with Type V Response

V

IM Test Results: Fragment Impact (FI)

Test Conditions: Mil-Std-2105C, Impact Velocity of 6,000 ft/sec, Army Fragment, Witness Plate & Pressure Gage



FI Test Set-up



IMX-101 Passed with Type V Response

V

IM Test Results: Bullet Impact (BI)

Test Conditions: Mil-Std-2105C, .50 Caliber AP Bullet, Witness Plate & Pressure Gage



BI Test Set-up



IMX-101 Passed with Type V Response

V

IM Test Results: Sympathetic Detonation (SD)

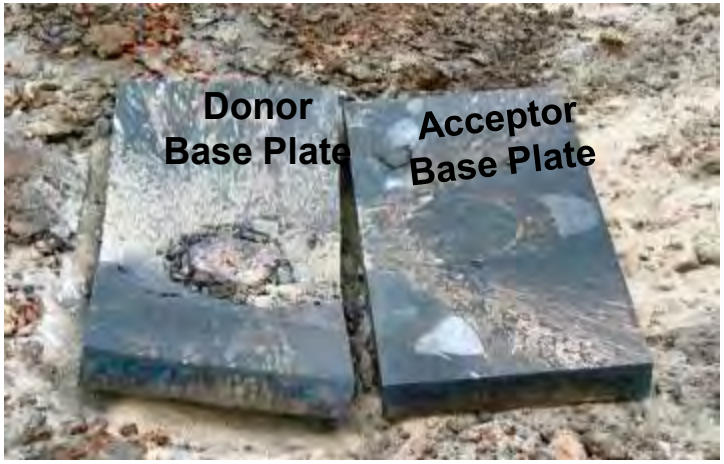
Mil-Std-2105C, Diagonal Configuration, Witness Plate & Pressure Gages



IMX-101
Passed with
Type III Response

III







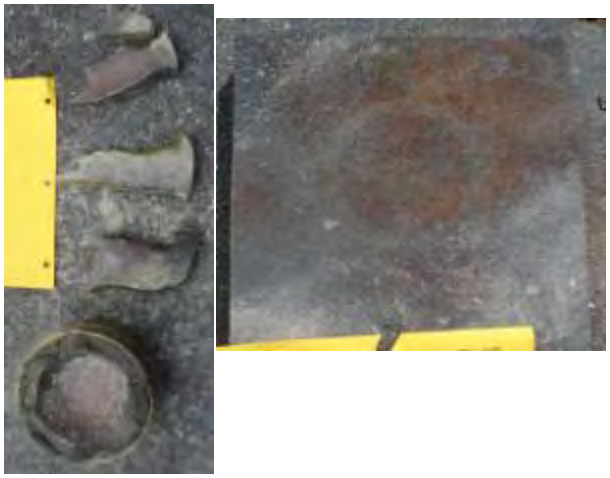
IM Test Results: Shaped Charge Jet Impact (81mm)

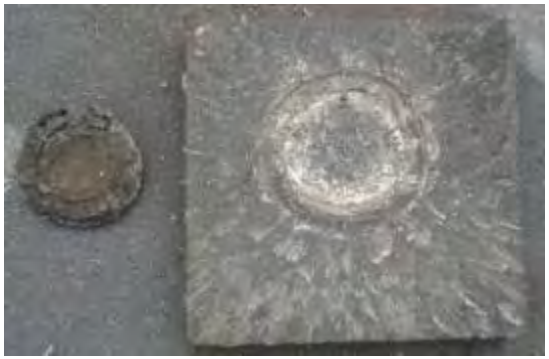
Mil-Std-2105C, Unconditioned Jet, Witness Plate & Pressure Gages





Test Set-up with 81mm SCJ





Example





IMX-101 Passed III

NO Detonation III

High-order Detonation I

Summary of IM Test Results

M795 Filled with IMX-101 Demonstrated Full IM Compliance!!

Passed SD
Passed SCJI

	VI No Sustained Reaction	V Burn	IV Deflagration	III Explosion	II Partial Detonation	I Detonation
IM Test:	**FCO**	**SCO**	**BI**	**FI**	**SD**	**SCJI**
Passing Criteria	V	V	V	V	III	III
M795 Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
IMX-101	PASS	PASS	PASS	PASS	PASS	PASS

Maturity of M795 IM Design

- **Safety Confirmation from Development Test Command**



- **Produced 132K lbs of IMX-101**
- **Loaded over 1,000 M795 projectiles**
- **Transition to production for FY10 Army procurement**

Test	Qty
Initial firing tests	√
12m Drop	√
Initial Safety Test	√
Sequential Environmental Safety & Performance	√
Shock Attenuating Lifting Plug	√
Worn Tube	√
Explosive Ordnance Disposal (EOD)	√
High Humidity & Temperature (16) / Fungus (8)	√
Solar Radiation	√
Long Term Storage - Uncontrolled	√
Final Reduced Qty Firing Table Confirmation	√
Arena Testing (Fragmentation)	√
Initiation Reliability	√
IM Testing (BI/FI/SCO/FCO/SD/SCJI)	√

Conclusions

- U. S. Army CLIMEx program was successful in identifying IMX-101 Explosive as a common insensitive replacement for TNT.
  - IMX-101 qualified by US Army as main charge explosive
- IM M795 155mm Munitions demonstrated far superior IM properties in all test categories with no barriers (BI, FI, SCO, FCO, SD, SCJI).
  - Formal IM tests completed – scores expect to be presented at IM&EM in October 2010
- Initial explosiveness & fragmentation performance of the IM M795 with IMX-101 indicates equivalency to the legacy TNT filled M795.
  - Arena tests completed – Analysis in process
- LAP of M795 Rounds using standard processing equipment was successfully developed and demonstrated with excellent cast quality.
  - Safety Confirmation for projectile from DTC

Conclusions (cont.)

- **IMX-101 explosive is effectively a "drop-in" replacement for TNT in melt-cast LAP operations.**

- **BAE Systems at Holston AAP has robust manufacturing processes and essentially unlimited capacity for both the IM ingredients (i.e. DNAN, NTO, etc) and melt-cast formulations.**

- **The marvelous achievement of the CLIMEx program is a strong testimony of the dedication and teamwork of PM-CAS and its industry partners.**

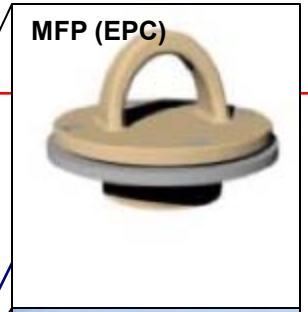


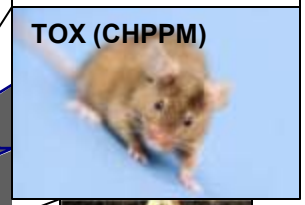
M795 Joint Program









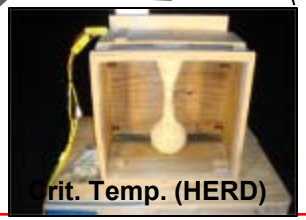


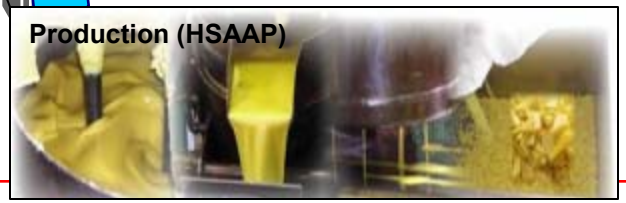












On-going Activities

- **Finalizing Technical Data Package for the IM M795 Munitions (FY-2010)**
- **Production and fielding of the IM M795 Munitions (FY-2011)**
- **Evaluation of IMX-101 Explosive in 105mm HE Ammunition**
- **Qualification of IMX-104 Explosives as a common replacement for Comp B in various mortar and artillery systems.**







Questions

Highlights of Other Testing - IM M795 Munitions

- Successful loading trials at Picatinny Arsenal (>150 projectile in recent LAP with “Zero” defects in cast quality).
- Completed firing trials at top service charge under extreme service conditions.
- Firing Table confirmation tests completed which validated a ballistic match to the legacy, TNT filled M795 Munitions.
- Completed Safety Test Series [ITOP 4-2-504(1)] to include drop tests in various orientations, tactical vibration sequence, and temperature extremes followed by confirmation of cast quality.
- Firing of the “abused” M795 Munitions evaluated in the Safety Test series under extreme service conditions.

Lightweight Case History

Bill Dittrich
Fleximation, Inc.

Lightweight Case History

- Aluminum case R&D:
  - Frankford, 1890's for 30-40 Krag.
  - 7.9mm used by Germans in 1919
  - Cals.30-.45 tested @Frankford in 1926, 1933
  - 5.56mm, 7.62mm, cal.50, 1958-1972
  - Present:ATK
  - ❑ Problems:

    -Burn-through experienced at high pressures

    -Liners, coatings, ablative materials unsuccessful in resolving problems thusfar

Lightweight Case History

- **Plastic case R&D**
  -1950's Frankford, Borg Warner, NOL, Dave Dartik's "Tround"
  -60's-70's Frankford, AAI, Dynamit Nobel, etc.
  -Recent work with improved plastics
  - **Problems:**
    -Extreme temperature operation
    -Base seal failures
- **Caseless R&D**
  -Frankford, AAI, others 1950's -1970s
  - AAI Recent
  - **Problems:**
    -Handling
    -Breech sealing
    -Weapon cooling
- **Stainless R&D**
- **NSAC Contract, including:**
  -ARDEC, GD OTS CANADA, Clickbond, Fleximation, etc. 2005-present

Innovation ... Delivered.

Mr. Chris Still
Principle Investigator
ATK Small Caliber Systems
Lake City Army Ammunition Plant

Mr. Mark Leng
Project Manager
US Army ARDEC
Picatinny Arsenal

OSR Approval #: 10-S-1445

Research And Development Effort: Fabricate A 5.56mm Aluminum Cartridge Case

- Latest In Aluminum Alloys
- Advanced Coating Technologies
- Advanced Lubrication Technologies
- Use Both New And Existing Metal Forming Capability

- Reduce Ammunition Weight
- Develop An Alternate Material For Cartridge Cases
- Reduce Sole Dependence On Brass



Lighter Ammunition For Today's Warfighter

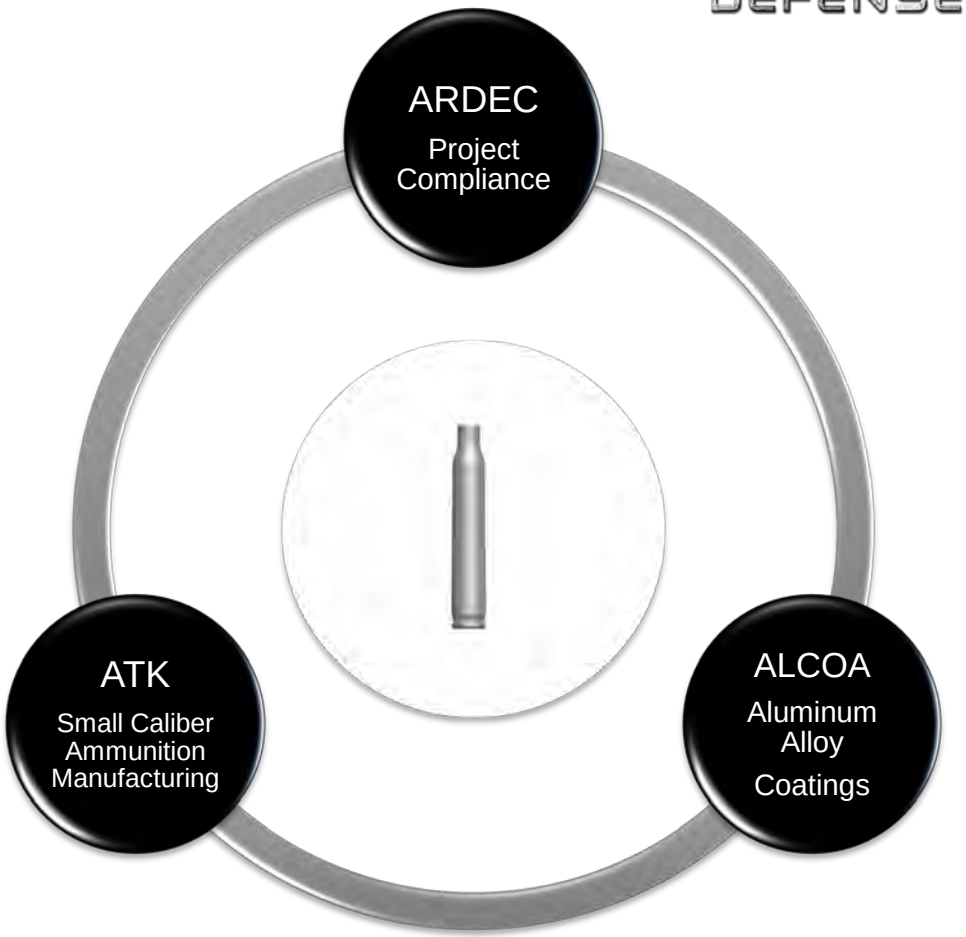
Requirements

- Review Technical Papers (1956 through 2004)
- Design A 5.56mm Aluminum Alloy Case
- Design & Analyze Tooling And Processes For Case Forming
- Test, Evaluate And Select Coatings And Sealants
- Test And Select The Best Alloy
- Evaluate The Implementation Of Case Production Process
- Report Recommendations Based On Scope Of Work

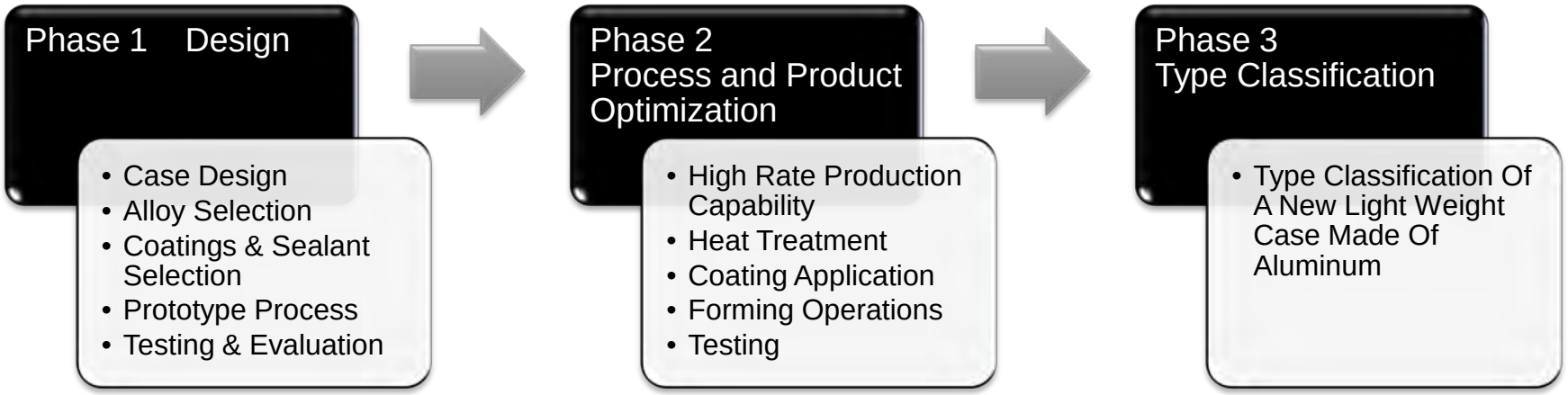


Research, Design, Build, Test, Report

Project Team



Project Phases

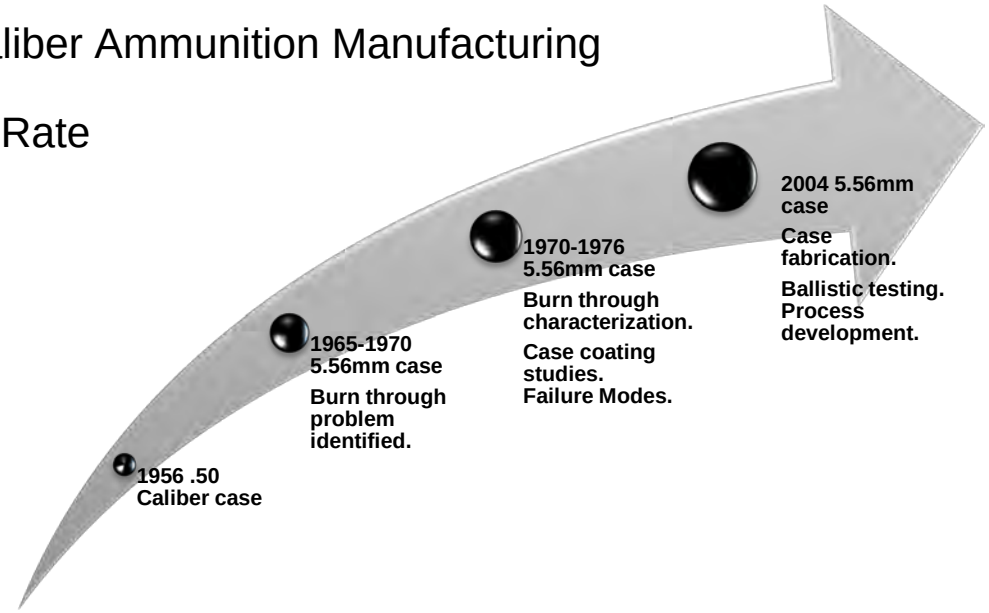


Advancing Technology

A premier aerospace and defense company

Fabrication Of An Aluminum Case Using ATK Small Caliber Systems Capabilities

- Knowledge Of High Rate Small Caliber Ammunition Manufacturing
- Metal Forming At High Production Rate
- Application Of Coating & Sealant
- Forming Tool Design
- Low Rate Lab Production
- Ballistic Test Facilities
- FEA Simulation
- Heat Treatment Process Knowledge



Gradual Advancement of Technology and Knowledge Base For Production Of Aluminum Cased Combat Ammunition

We Have a Knowledge Base

Supporting The Design, Development And Production

Of A 5.56mm Aluminum Case

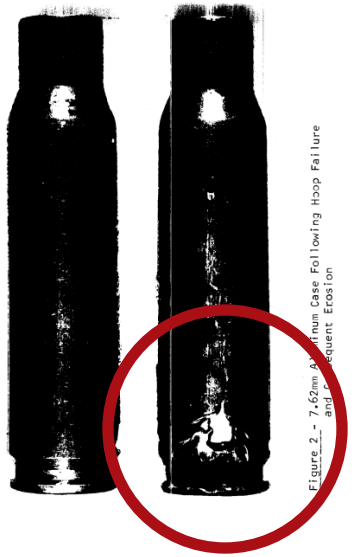


Learn From The Past To Move Forward

Burn Through Problem – Frankford Arsenal

Effort

- Early Work Indicated Burn Through As An Obstacle
- Burn Through Is The Erosion Of The Aluminum Caused By Hot Gases Reacting To A Compromised Surface
- Further Work Showed A Reaction To Oxygen And Aluminum



Conclusions

- Proposed a Weapon/Ammunition System Solution To Isolate The Problem

1. Modify The ***Weapon*** Chamber Design To Seal The Chamber
2. Modify The ***Case*** Design to Seal The Chamber

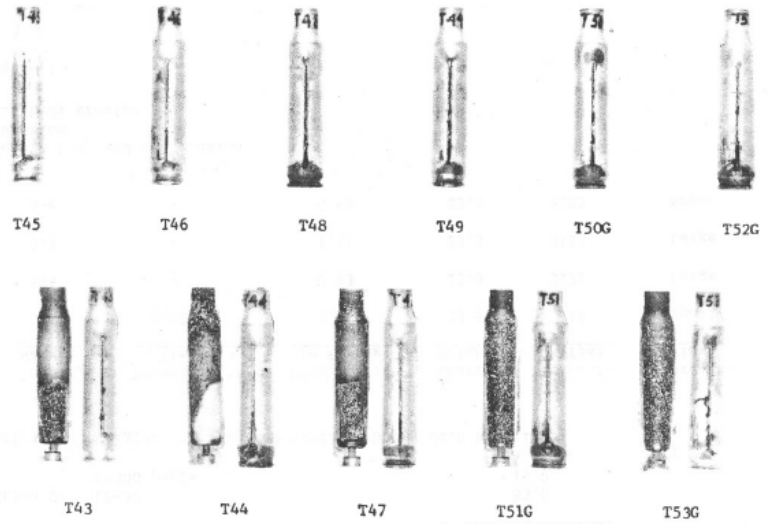
Systematic Approach To Design - Isolation And Means Of Elimination

Effective Inhibitors – Thiokol Chemical Corporation 1972-1973

A premier aerospace and defense company

Effort

- Tests Performed On Six Coatings To Find Inhibitor To Burn Through
  - Toughness
  - Thermal Stability
  - Elasticity
  - Insulation Capability
- Test Samples Damaged To Simulate Field Failures
- Ammunition Was Fired And Results Analyzed



Conclusions

- Identified Proprietary Formulation Composed Of A Polysulfide As Best Coating
- Suggested Polysulfide Pre-Form Cylinder Inserted Into Case Before Loading

Use Internal Coatings Prevent Burn Through

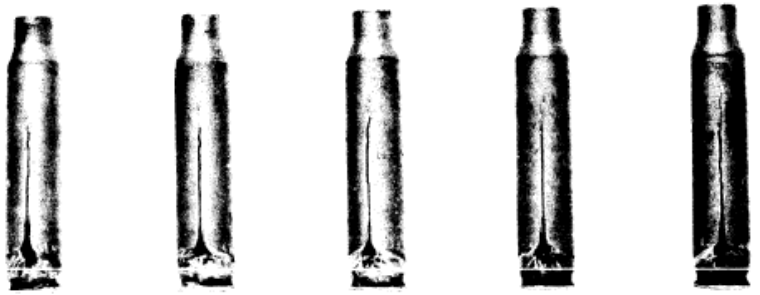
Failure Mechanisms – Frankford Arsenal 1976

A premier aerospace and defense company

Effort

- Studied Failure Mechanisms Of Burn Through
  - Not Caused By Interior Surface Burning Through

    To The Outside Of The Case
  - Burn Through Is A Result Of A Gas Path During Firing
  - Duplicated By Drilling A Hole In The Case Head
  - Duplicated By Creating A Scratch On the Outside Of The Case
  - Initiated By Oxidation Of Aluminum Vapor By CO_2 And H_2O Created By Propellant Burn



Failure Mechanisms of Simulated Burn Through

Conclusion

- Gas Path Caused By A Mechanical Defect Such As A Structural Flaw Or Insufficient Strength Of The Case Material
- Burn Through Inhibited By A Rubber Liner

Burn Through Caused By A Gas Path - Duplicated The Problem

Case Concept – ATK 2004

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Effort

- Designed a 5.56mm Aluminum Cartridge Case
- Fabricated Forming Punches And Dies.
- Developed A Cartridge Case Manufacturing Process
- Fabricated Samples For Testing In M249 And M16A2
- Performed Ballistic Tests
- Identified Coatings As A Solution To Burn Through



Identified Areas For Improvement

- Improve Case Design
- Improve Vacuum Test Results
- Improve Bullet Extraction

Process Development – Case Production

Technical Challenges

1. Burn Through
   - Erosion Of Case Caused By Hot Gases Reacting To Compromised Surface
     - Solution Method: Identify Coatings Capable Of Eliminating Burn Through
2. Long Production Cycle Times
   - Aluminum Case Production Requires Additional Heat Treat Requirements
     - Solution Method: Identify Most Effective Method Of Heat Treat To Meet Performance Cost And Ease Of Fabrication
3. Various Advanced Alloys Available
     - Solution Method: Test, Evaluate And Down-Select to Meet Cost, Performance, and Feasibility Criteria

Burn Through, Heat Treat Cycle Time, Alloy Selection

Use Coating And Sealant To Prevent Burn Through And Meet Specification Requirements

Internal and External Coatings

- Corrosion Resistance
- Wear Resistance
- Heat Resistance

Wicking Grade Sealants

- Improve Bullet Extraction
- Seal Primers
- Seal Case Mouth



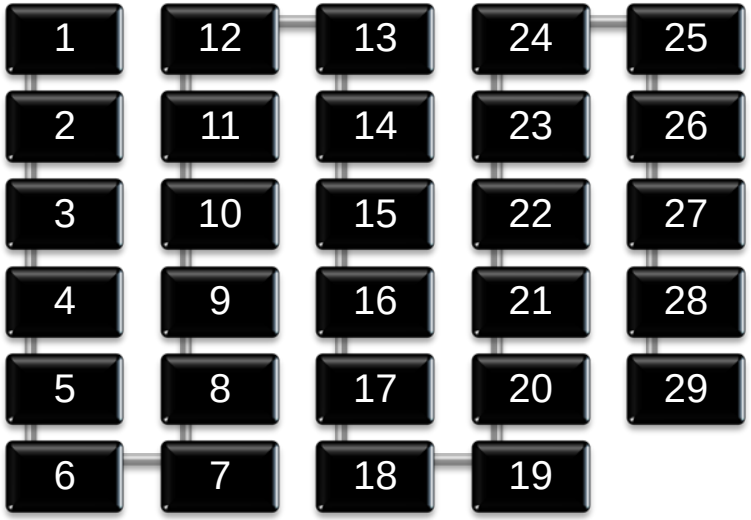
.50 Caliber Externally Applied Case Mouth Waterproofing

Leveraging Experience From Previous Technological Advancements

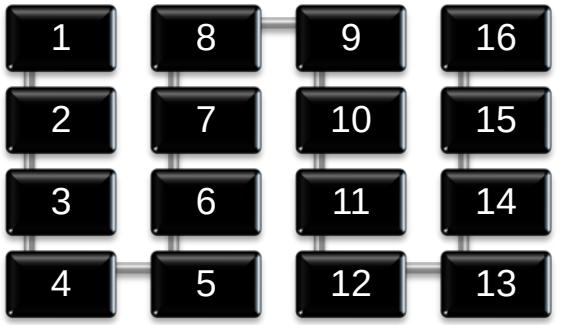
Cycle Time Constraint

- May Require Up To 25 Hours Of Heat Treatment
- Many Process Steps
- Batching Not Desirable In A Continuous Flow Production Environment

Aluminum Case
Multiple Process Steps
Lengthy Heat Treatment Time



Brass Case
Fewer Process Steps
Highly Automated1200 Parts Per Minute



Cycle Time A Constraint To High Rate

Alloy Selection

Alloy A

- Commercially Available
- Has A Balance Of Strength, Toughness And Resistance To Corrosion
- Has A Low Quench Sensitivity

Alloy B

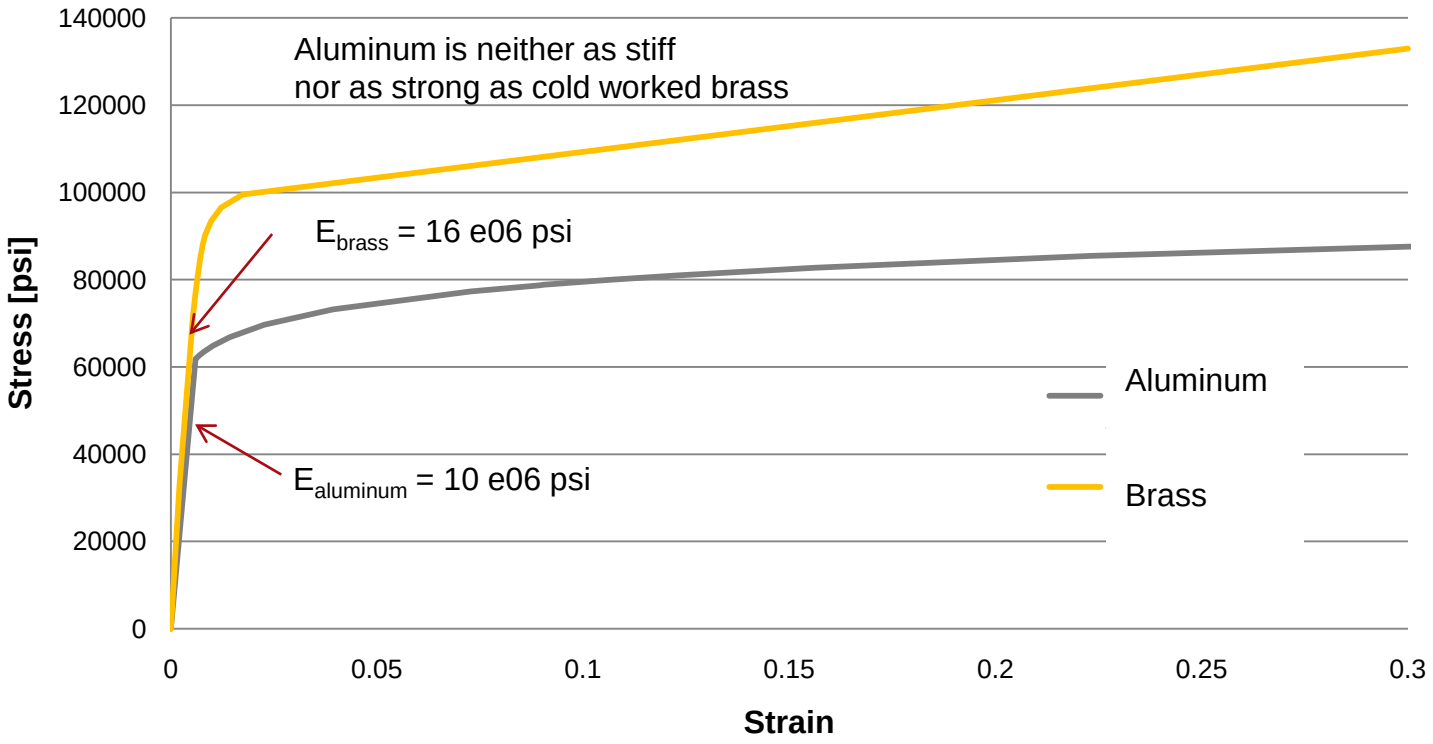
- Commercially Available
- Moderate Strength
- Good Strength After Temperature Exposure



ALCOA DEFENSE

Two Aluminum Alloys Under Evaluation

FEA Material Models



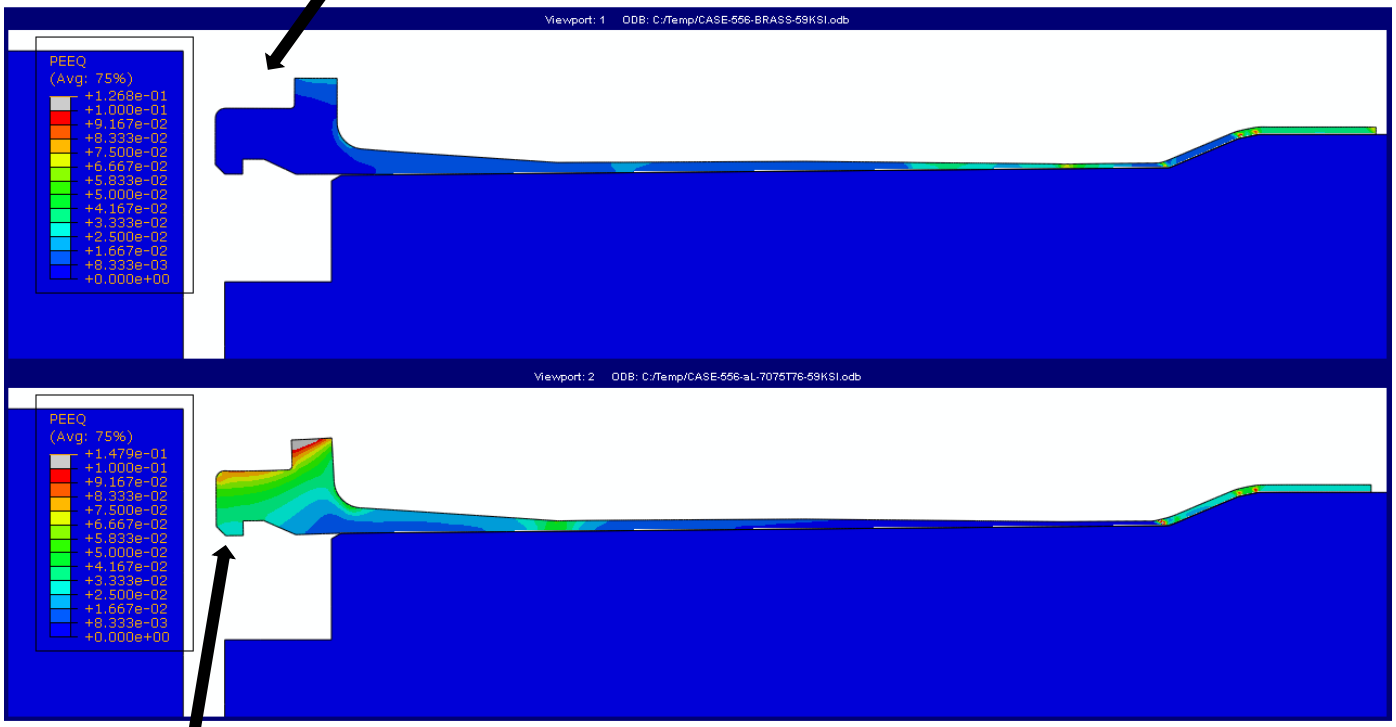
Cold Work Brass Versus Aluminum

FEA Plastic Strain Results

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Color Contours Indicate Plastic Strain After Applying Firing Pressure

Brass Case Is The Design Basis For Aluminum Case



Aluminum Case Must Be Thicker To Achieve Performance Of Brass

Firing Pressure Strain

Summary

- Past Efforts Investigated Aluminum Alternatives To Brass For Cartridge Cases
- Design Time Reduced By Lessons Learned From Past Efforts
- Objective - Develop Solutions To Burn Through Problem
- Objective - Design Production Process For LCAAP
- Test And Evaluate Two Aluminum Alloys
- Reduce Cycle Time Constraints To High Rate Production

References

1. *The Aluminum Cartridge Case "Burn-Through" Problem – Characteristics – Isolation and Means of Elimination. Donnard, Grandy, Skochko, Squire. Department of the Army Frankford Arsenal. Philadelphia, PA*

2. *Prevention of 5.56mm Aluminum Cartridge Case Burn-Through. Marziano, Vriesen, Thiokol Chemical Corporation, 1975.*

3. *A Critical Assessment of the Aluminum Cartridge Case Failure Mechanism. Squire, Donnard, Frankford Arsenal, Report no. FA-TR-76011, 1976.*

4. *Aluminum Cartridge Case Concept. Tasson, Alliant Techsystems, 2004.*

Contact Information

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Innovation ... Delivered.

.50 Caliber Steel Case Development

Presented to:

NDIA Joint Armaments Conference

Christian Miller

ATK Lake City Ammunition

OSR Approval #: 10-S-1445

Develop A New Design .50 Caliber Steel Cartridge Case

OBJECTIVES

- Utilizing Modern Steel Alloy Options
- Existing & New Production Forming Processes
- Enhanced Lubrication Formulations
- Optimize Tooling Designs
- Customized Heat Treatment Profiles
- Advanced Coating Technologies

GOALS

- Reduce Cartridge Case Weight



- Establish An Alternate Material For Cartridge Case Manufacturing
- Eliminate Sole Dependence on Brass Alloys

Lighter Ammunition For Today's Warfighter

Development Overview

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- *Research*
- *Brainstorm, Analyze, & Identify*
- *FEA Analysis*
- *Down Select*

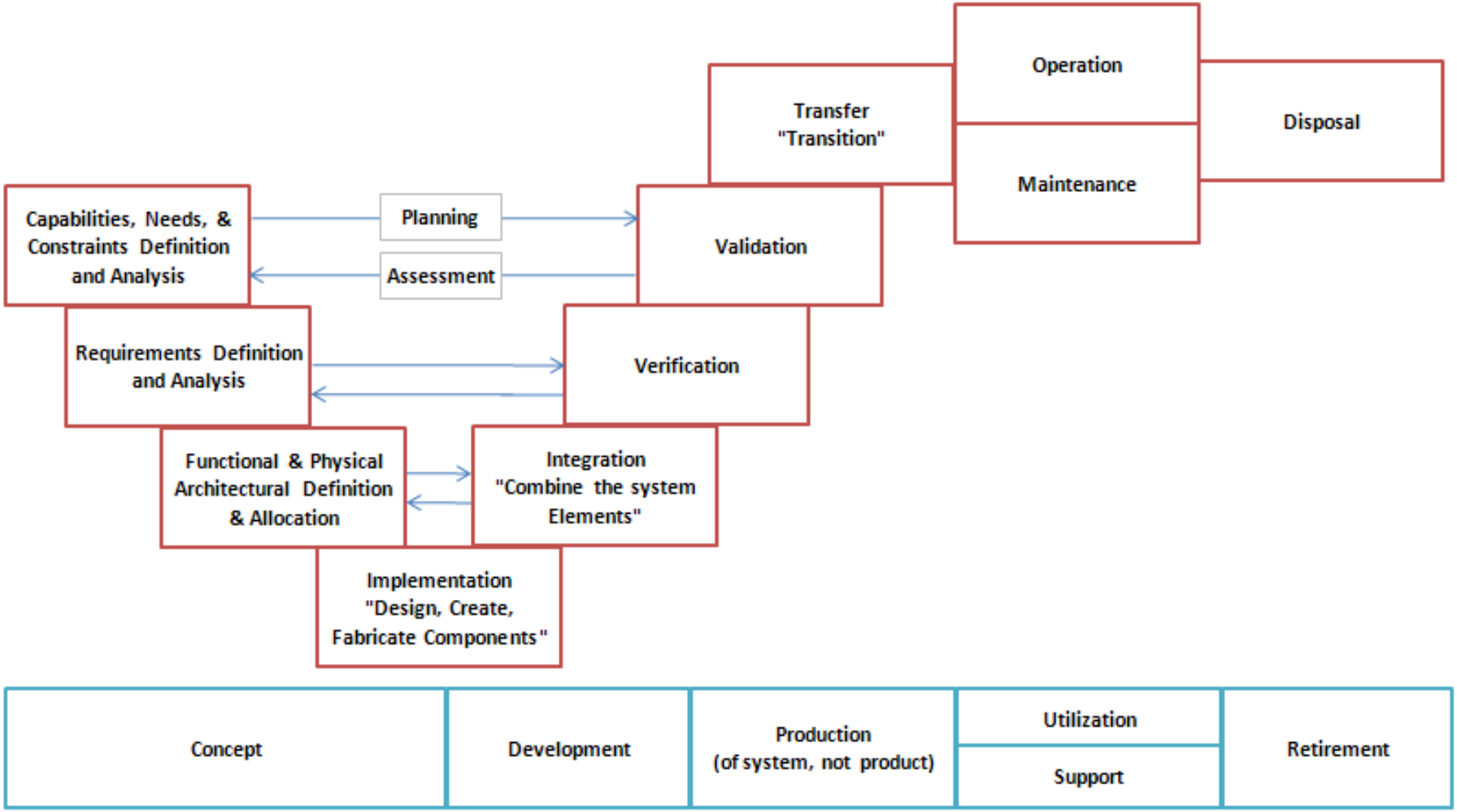
- *Evaluate Mfg Forming*
- *Apply Lubrication Technologies*
- *Develop Heat Treatment Profiles*
- *Build & Evaluate Prototypes*

- *Advanced Coating Techniques*
- *Prepare Producibility Studies*
- *Define Process Flow*
- *Perform Energy Cost Analysis*
- *Create Implementation Road Map*

Research, Design, Build, Test, & Report

Systems Engineering Approach

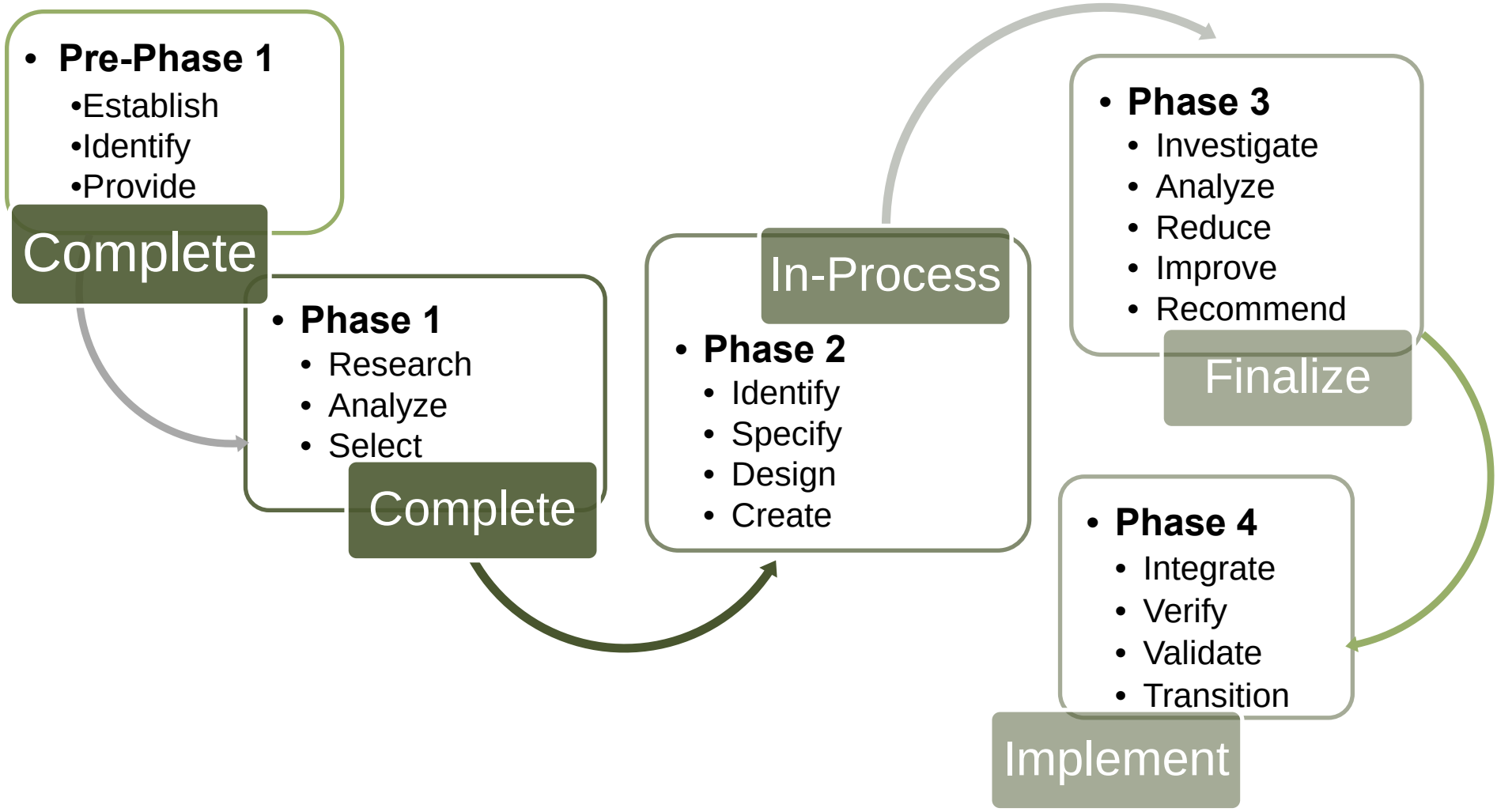
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Structured Toward Success

Project Phases

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Development Progress

Technical Challenges

Steel Alloy Selections

- Stiffness, Impact Strength At Low Temperatures, Rate of Strengthening, Yield Strength, Machinability

  •Research – Analyze –Test - Down Select To Optimize Formability, Performance, And Cost Efficient Manufacturability

Corrosion Coatings

- Steel Alloys Require Additional Processing To Prevent Corrosion
  - Identify Coatings Capable Of Eliminating Corrosion As Well As Possessing Impact/Handling Protection

Alloy Selection And Corrosion Coatings

Technical Challenges

Production Cycle Time

- Number Of Forming Operations To Achieve Final Draw And Overall Heat Treatment Requirements
  - Develop The Draw Forming Process To Minimize Overall Steps
  - Customize Heat Treatment Profiles To Reduce Extended Cycling

Process Tooling

- Tooling Design, Base Material, And Coatings
  - Evaluate Present Tooling Configuration For Interchangeability
  - Optimize Tooling Base Material And Coatings

Production Cycle Time And Tooling

Alloy Selection – Frankford Arsenal

Historical Evaluations

- Past Efforts Focused On Six (6) Specific Low-Medium Carbon Alloy Types In Two Conditions.
  - *Casualties Observed – Split Neck, Split Body, Rupture, Rim Shear, & Leaky Primer*
- Extended Development Efforts Focused On Varying The Alloy Chemistries And Observing The Structural Effects Realized Through Multiple Heat Treatment Profiles.

Conclusions

- Identified Three Top Steel Alloy Candidates And Recommended Structural Conditions For Each.

Constraints

- Recommendations Were Made Based Upon Using One Specific No. Of Draw Forming Steps.

Earlier Efforts Established Good Baseline

Corrosion Coatings – Frankford Arsenal

Historical Evaluations

- Three (3) Proprietary Chemically Activated Base Finishes Were Tested In Addition to Three (3) Electro-Plating Options.
    - *Functional Characteristics Evaluated– Corrosion Resistance (Std Salt Spray), Abuse Resistance (Typical Handling Evaluations), Stretches (Condition After Firing), Chamber Build-Up (Gun Chamber Accumulation), Stoppages (Failure of the Gun To Operate)*
- Follow-up Developments ,Tested Combination Finishes And Coatings In Attempts To Achieve Maximum Protection And Wear Resistance.

Conclusions

- This Was The Most Difficult Challenge And Has Remained Relatively Un-Solved.

Constraints

- Limited Coating Technologies Available, Hindered By Contact And Respiratory Poisoning Hazards Present With Coating And Finishing Options Utilized.

Limited By Technological Advances

Production Cycle Times – Frankford Arsenal

Historical Evaluations

- The Number Of Overall Draw Steps Initially Established To Achieve Final Form Was Five (5); One (1) To Blank And Four (4) To Final Draw Configuration. Heat Treatment Cycles Employed Were Conducted Using A Gas Fired Furnace.
    - *Observations– More Draw Steps Required to Final Form Than Brass Case Manufacturing. Varied Heat Treatment Cycles To Achieve Several Different Structures*
- Efforts Focused On Reducing The Draw Steps To Final Draw Configuration As Well As Hopes To Establish An Optimal Heat Treated Case Structure.

Conclusions

- Reduced Overall Draw Steps To Achieve Final Form From Five (5) to Four (4)…..One Being The Blank Step, Yielding Final Form In Three (3) Steps. Recommended One Specific Heat Treatment Structure To Achieve For Conducting Draw Operations.

Draw Reduction Improvement/Heat Treat Not Optimized

Historical Evaluations

- Evaluations Were Conducted On All Tooling Used In Brass Case Production While Processing Steel Cases Through To Final Taper.
  - *Observations – Established Tool Mortality Chart Comparison To Document Overall Tooling Performance*

Conclusions

- The Comparison Data Was Used To Illustrate Tooling Life Expectancy With The Present Designs And Tooling Materials Employed At That Time. The Data Was Used To Justify Tooling Material Changes For Several Tools As Well As Several Configuration Differences For Each Operation.

Establish Tooling Baseline And Improve

Alloy Selection – ATK Present Day

Present Evaluations

- Initially Identified Four (4) Specific Low Carbon Alloy Steel Types.
  - *Actions Taken – Developed Samples, Analyzed, Evaluated Using FEA Modeling Techniques, Compared Characteristic Profiles To Expectations, Down Selected, Produced Samples For Testing, And Introduced Into Production For Manufacturing Evaluations.*
- Ongoing Development Efforts Are Focused On Customizing The Heat Treatment Profiles To Optimize The Initial And Intermediate Structural Condition Of The Case.

Conclusions

- Down Selected To Two (2) Steel Alloys
- Testing And Evaluation Under Way To Establish Feasibility And Manufacturability Using Existing And New Mfg Processes.
- Validating Heat Treatment Profiles For Optimized Structural Condition

Lessons Learned Established Initial Direction

Production Cycle Times– ATK Present Day

Present Evaluations

- Efforts Are Directed At Reducing The Number Of Forming Steps To Achieve Final Form Configuration In Two (2) Steps As Compared To The Previously Established Three (3) Step Draw Operations Utilized.
    - *Actions Taken – Produced Samples For Testing And Introduced Into Production For Manufacturing Evaluations.*

Conclusions

- Initial Testing Yielded Successful Case Samples Through Final Draw Form In Two Draw Operations
- Evaluating Final Draw Formed Cases Using The New & Existing Mfg. Back End Processes

Goal

- Continue Mfg Testing to Support The Heat Treatment Profile Optimization Evaluations And Document Interactions Throughout Production Processes.

Continue Cycle Time Evaluations To Improve

Process Tooling – ATK Present Day

Present Evaluations

- Continuous Tooling Improvements Implemented Throughout The Years In Production Have Yielded Very Good Tooling Configurations Through All Forming Operations.
    - *Observations – Present Tooling Used In Brass Production Are Providing Good Overall Tooling Performance During Our Initial Testing & Evaluations Using Steel Alloys.*

Conclusions

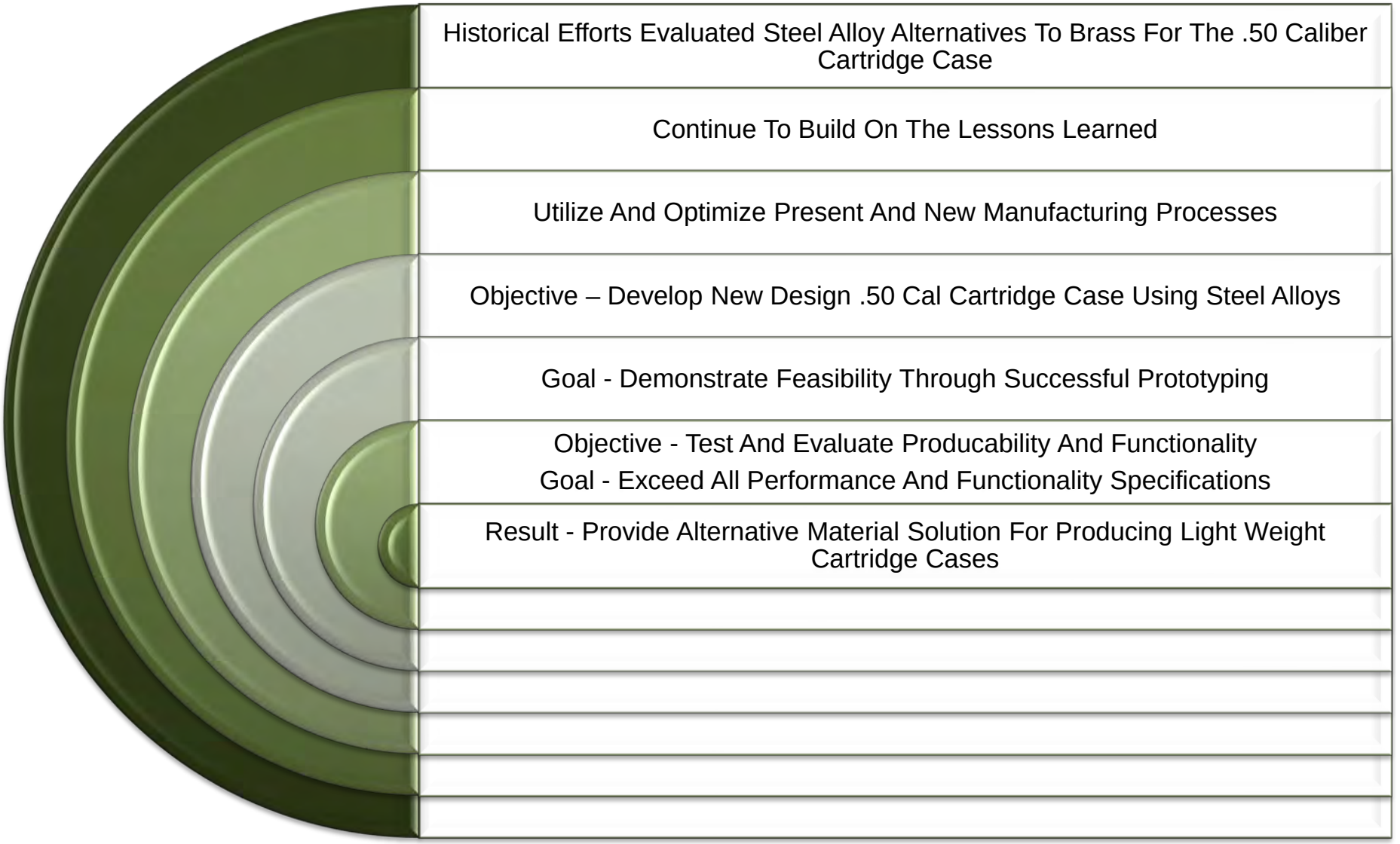
- Continue To Evaluate And Identify Wear Areas As Observed
- Specify Improved Coatings And / Or Base Materials To Further Enhance Durability And Toughness

Goal

- Use Same Tooling Configuration For Brass And Steel Alloys
    - Change Only Tooling Profiles To Establish Light Weight Case Characteristics

Continue Tooling Improvements

Summary


Historical Efforts Evaluated Steel Alloy Alternatives To Brass For The .50 Caliber Cartridge Case
Continue To Build On The Lessons Learned
Utilize And Optimize Present And New Manufacturing Processes
Objective – Develop New Design .50 Cal Cartridge Case Using Steel Alloys
Goal - Demonstrate Feasibility Through Successful Prototyping
Objective - Test And Evaluate Producability And Functionality
Goal - Exceed All Performance And Functionality Specifications
Result - Provide Alternative Material Solution For Producing Light Weight Cartridge Cases

References

1. *Cal .50 Steel Case Blank-Cup-and-Draw Process_ March 1944_Department of the Army Frankford Arsenal Philadelphia, PA.*

2. *Progress Report On The Caliber .30 And Caliber .50 Steel Case Program _ December 1942_Department of the Army Frankford Arsenal. Philadelphia, PA*

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Ageing Effects on Performance of Small and Medium Calibre Ammunition

Chris van Driel, Wim de Klerk
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TNO | Knowledge for business



NDIA Joint Armaments Conference, Dallas, May 2010

Introduction

- Ammunition in Out of Area operations: accelerated ageing due to external forces
  - Vibrations
  - Pressure
  - Temperature
  - Shock
  - Etc.



- Aim: qualitative insight in performance change

- Focus: ageing of propellant due to high temperature stress



Investigated ammunition

.50 BALL
- Total height: 138.5 mm
- Total weight: 110 gram
- Powder: 15 gram
- Muzzle velocity: 890 m/s





25mm APDS-T
- Total height: 223 mm
- Total weight: 454 gram
- Powder: 100 gram
- Muzzle velocity: 1345 m/s





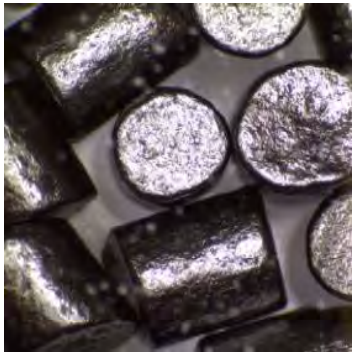
Artificial ageing

- Propellant removed from cartridges

- Ageing of propellant only
  - 4 weeks @ 71ºC *)
  - 8 weeks @ 71ºC

  *) MIL-STD-331A Test 112.1
  'Extreme Temperature Storage'

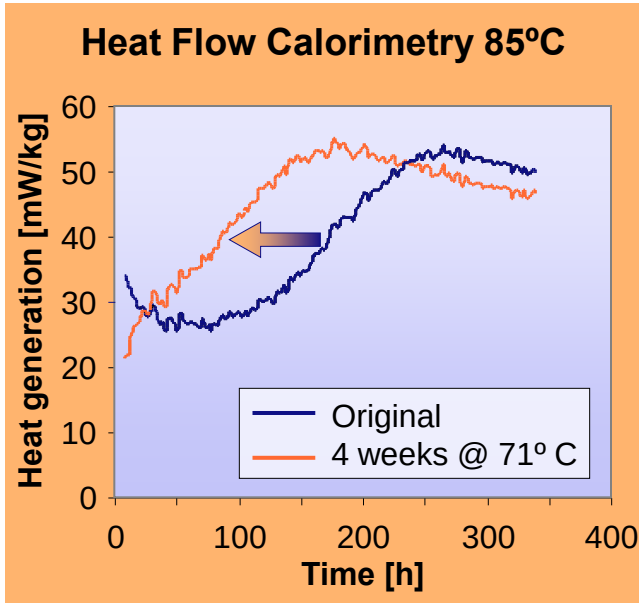
  → relatively short in comparison to expeditionary activities



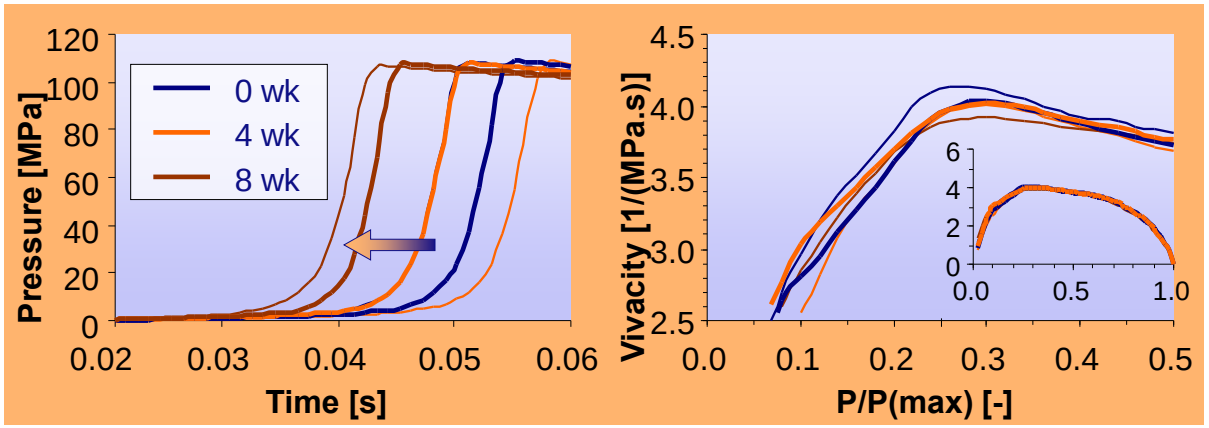


Change of propellant characteristics

- Chemical: usual changes like stabiliser depletion
- Thermal: usual patterns
  (Heat Flow Calorimetry, HFC)
- Decrease calorific value negligible
- Ballistics: theoretically expected:
  migration deterrent:
  → Propellant becomes faster
  → Ignition time decreases
  → Pressure in weapon increases
  → Projectile velocity increases
  → Propellant becomes more erosive



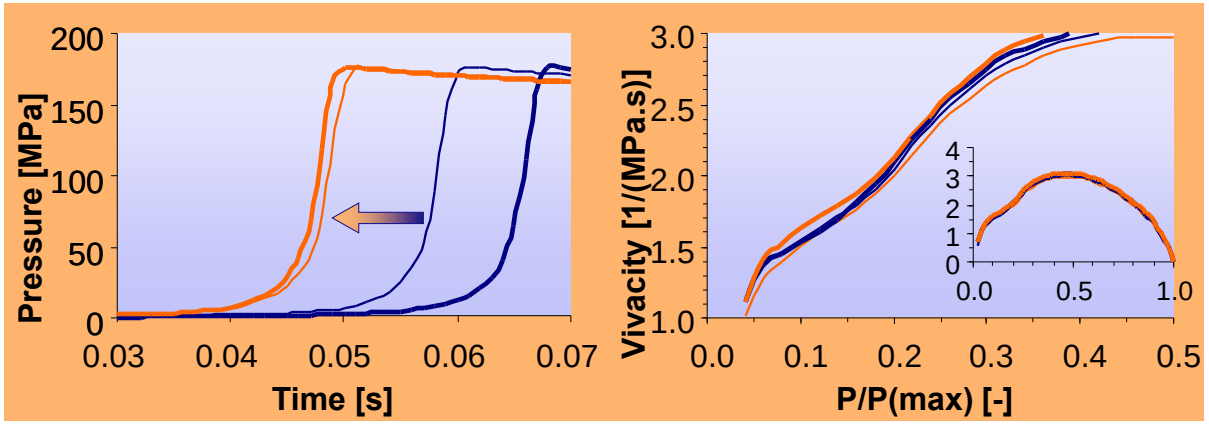
Ballistics: closed bomb tests



.50



deterrent: DBP



25mm



deterrent: camphor

Ballistics: closed bomb tests

Both .50 and 25mm:

- Slight reduction of maximum pressure (reduction of energy content due to ageing)
- No change of vivacity
- Significant reduction of ignition delay



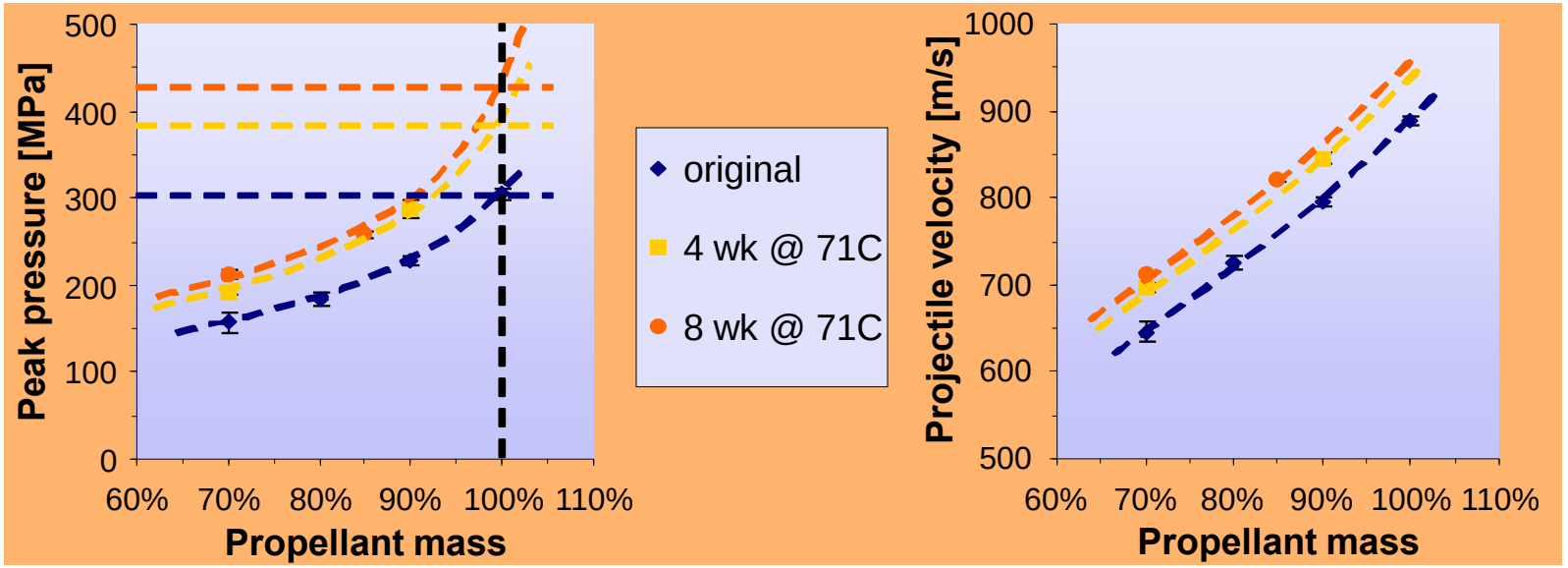


Firing tests .50

- Tests: variation propellant mass (safety reasons)
- Ambient temperature

→ Significant increase of gas pressure after propellant ageing



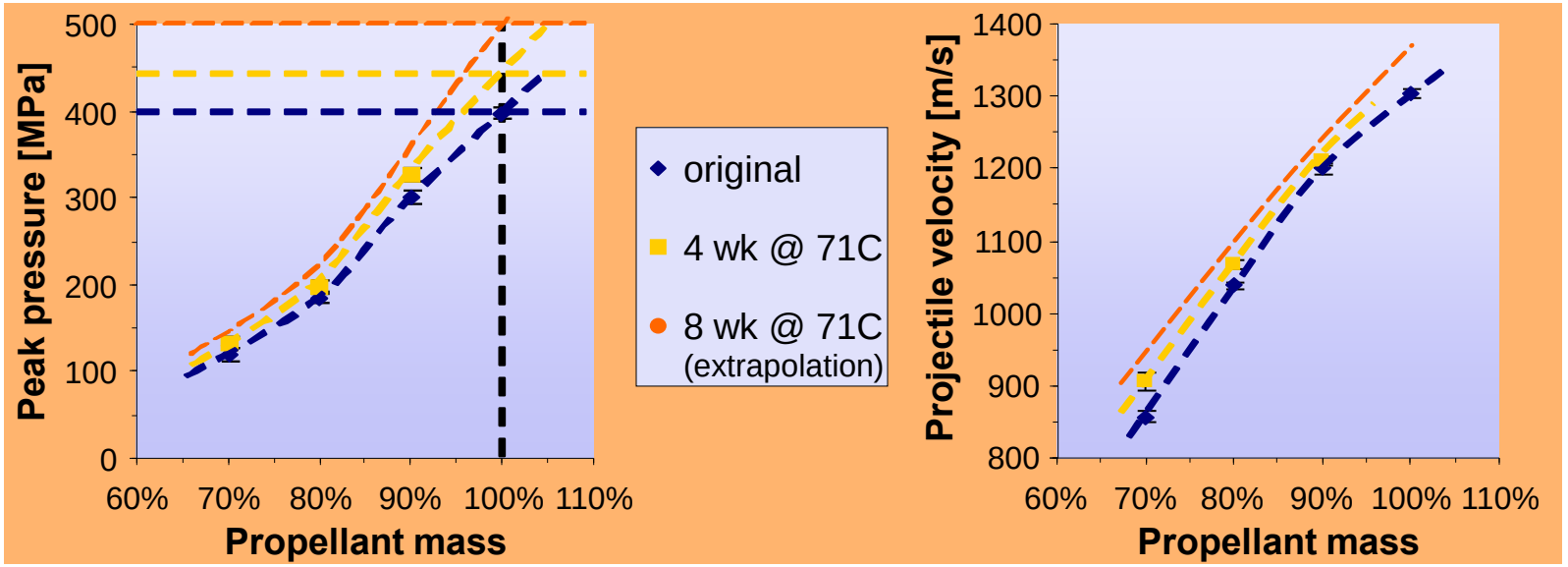


Firing tests 25mm (1)

- Tests: variation propellant mass (safety reasons)
- Ambient temperature

→ Significant increase of gas pressure after propellant ageing





Firing tests 25mm (2)

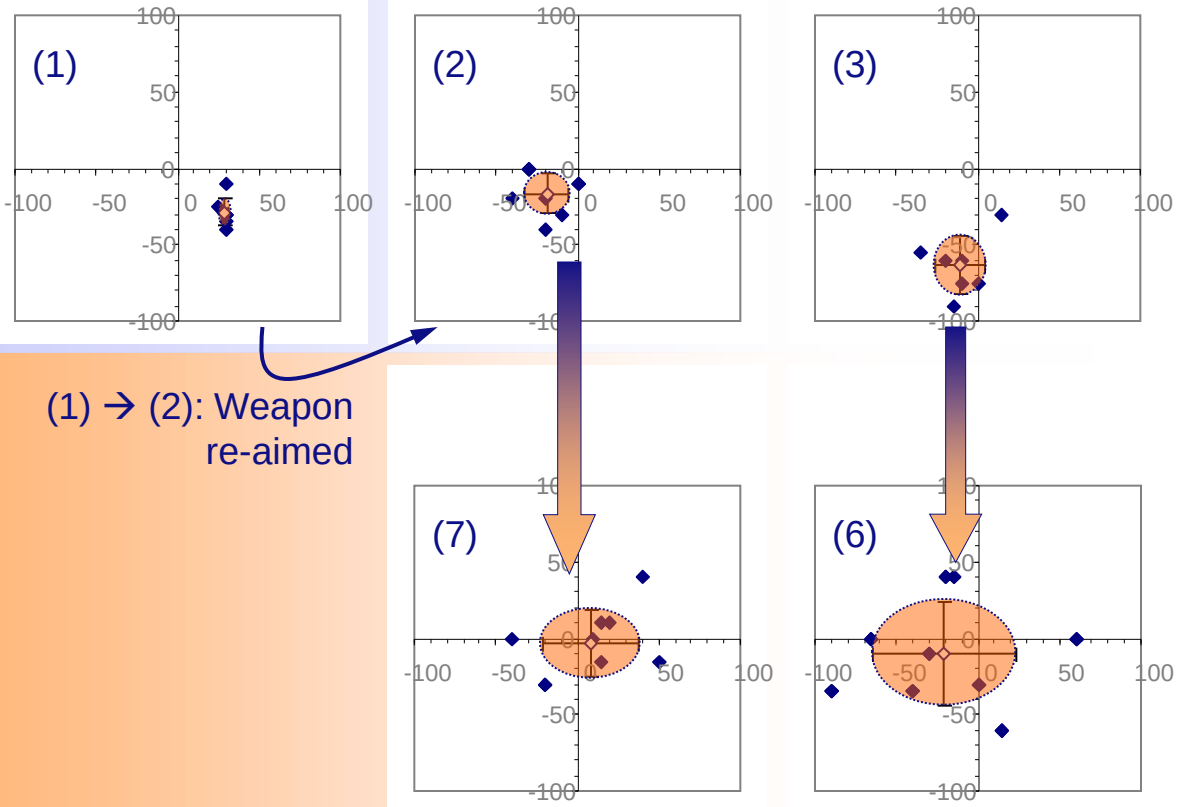
original

aged
(4 wk 71°C)

100% charge mass

90% charge mass

80% charge mass



(1) → (2): Weapon re-aimed

25mm



: 95% reliability

(1) – (7): firing sequence

No measurement of:
(4): 70% original prop.
(5): 70% aged prop.

Barrel erosion

- Not investigated in here, but known to occur:
  Barrel erosion more severe with aged ammunition
  - → higher pressures
  - → higher flame temperature (?) after prolonged ageing (migration deterrent)



- Result: further decrease of hit accuracy
  (added to observed effect of ageing)

- Possible effects on projectile orientation

Discussion

- Changes in peak pressure and projectile velocity though:
- No change in energy content and vivacities

→ Performance changes related to decrease of ignition delays: faster ignition affects flame spreading process resulting in higher pressures



- Decreased ignition delays impose …
  - irregularities of the flame spreading process, causing …
  - less defined engraving of projectile, causing …
  - increased radial projectile movement during translation in the barrel, resulting in …

    → decreased hit accuracy

Conclusion

Ageing of ammunition (4 / 8 weeks @ 71ºC) results in:



- Significant increase of peak pressures → **safe use**
- Possibly increase of barrel erosion
- Decrease of hit accuracty due to ageing + barrel erosion → **performance**
- Possibly: change of projectile orientation

Recommendations

- Substantiate observations by using a larger test set-up for better statistics

- Investigate effects on
  - barrel erosion
  - projectile orientation



Acknowledgement

- The authors are grateful to the Netherlands MoD for funding this project and for the practical support



Pictures: www.defensie.nl; TNO



Ageing Effects on Performance of Small and Medium Calibre Ammunition

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TNO | Knowledge for business



NDIA Joint Armaments Conference, Dallas, May 2010

MEMS S&A FOR MUNITIONS

To:

JOINT ARMAMENTS CONFERENCE

EXHIBITION & FIRING DEMONSTRATION

Small Arms Session

MAY 19, 2010

Dale Spencer

Kaman Precision Products

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  - EDF-11
- **Kaman Precision Products:**
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  - Project Management
- **Draper Laboratory:**
  - MEMS Design & Analysis Engineering
- **MicroFabrica: MEMS Manufacturer**
  - MEMS Foundry

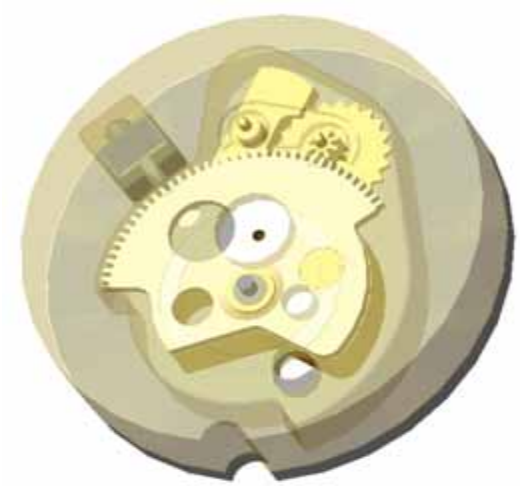
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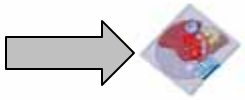
Kaman MEMS Overview

- **Concept:** Demonstrate the ability to produce a Runaway (Verge Escapement) Safe and Arm device with a self assembled, In-Situ, Micro-Electro Mechanical System. Thereby demonstrating the feasibility of MEMS S&As for Munition Applications.

Devices shown to relative scale



40mm S&A ~Ø32 mm



MEMS S&A ~5x5 mm

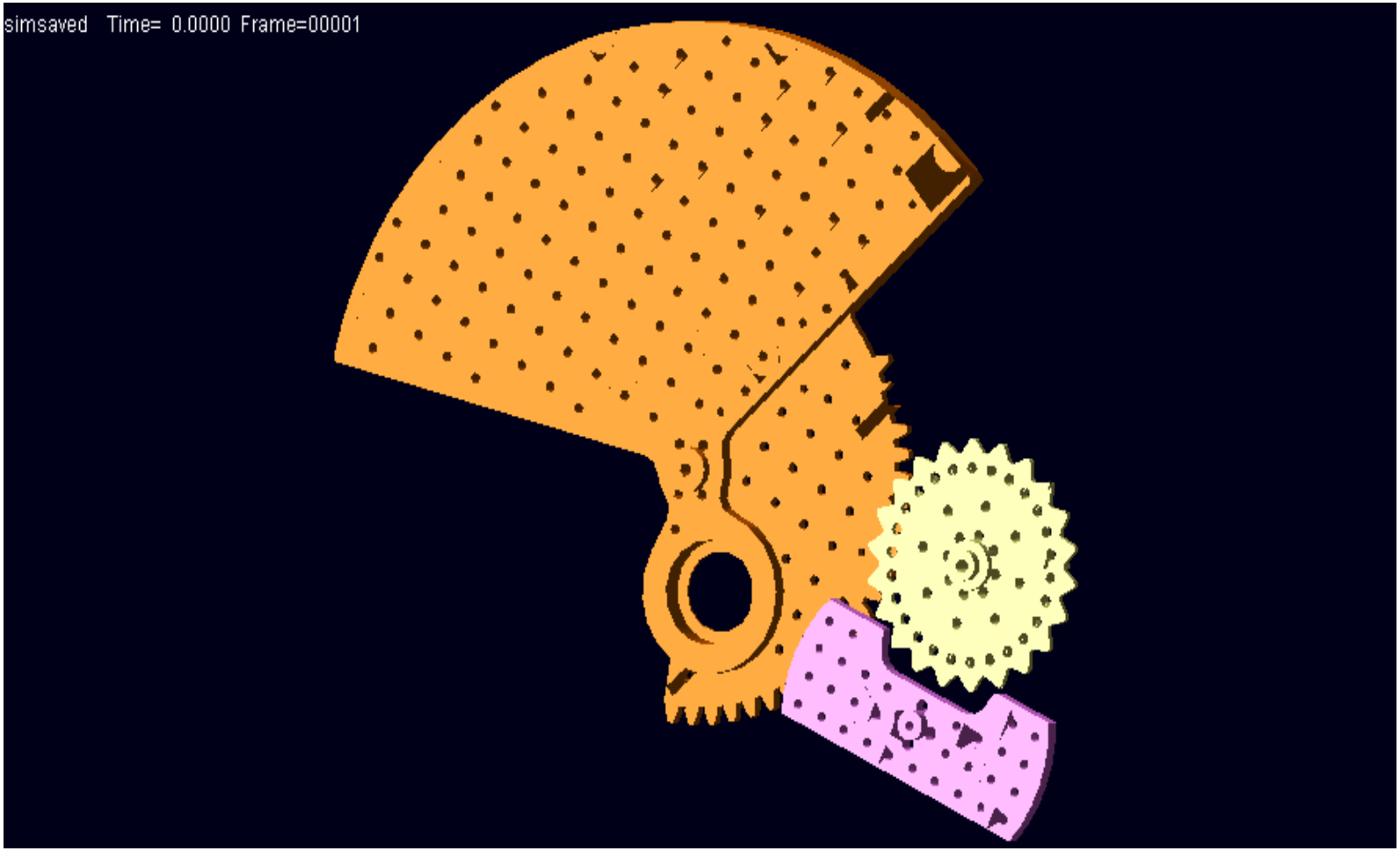
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Verge Escapement Simulation



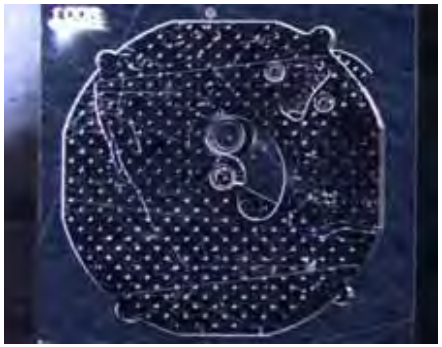
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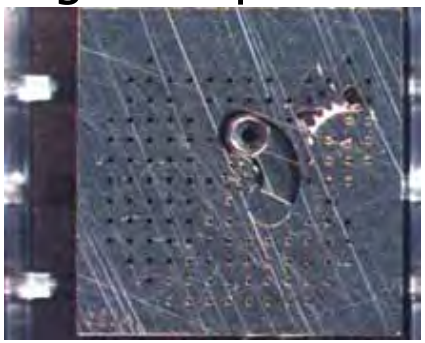
Self-Assembled (In-Situ) MEMS S&A Development History

P1 Demonstrated Moving Parts



P1 CY 2006

P2 Demonstrated Verge Escapement



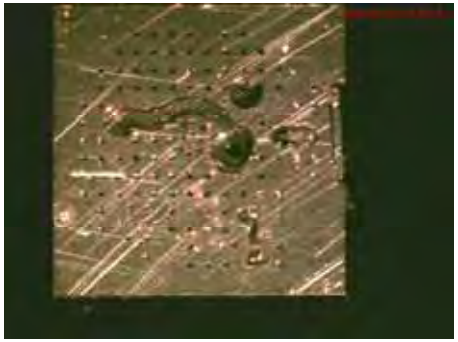
P2 CY 2007

P3 Demonstrated Spin Lock



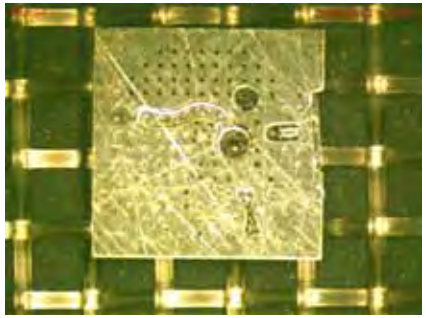
P3 Q1 CY 2008

Loaded w/EDF-11



P4 Set-Back Lock

Tested Q2 CY 2009



P5 In Fabricated 11/09

Out-of-Line Exp Train

Update Set-Back Lock

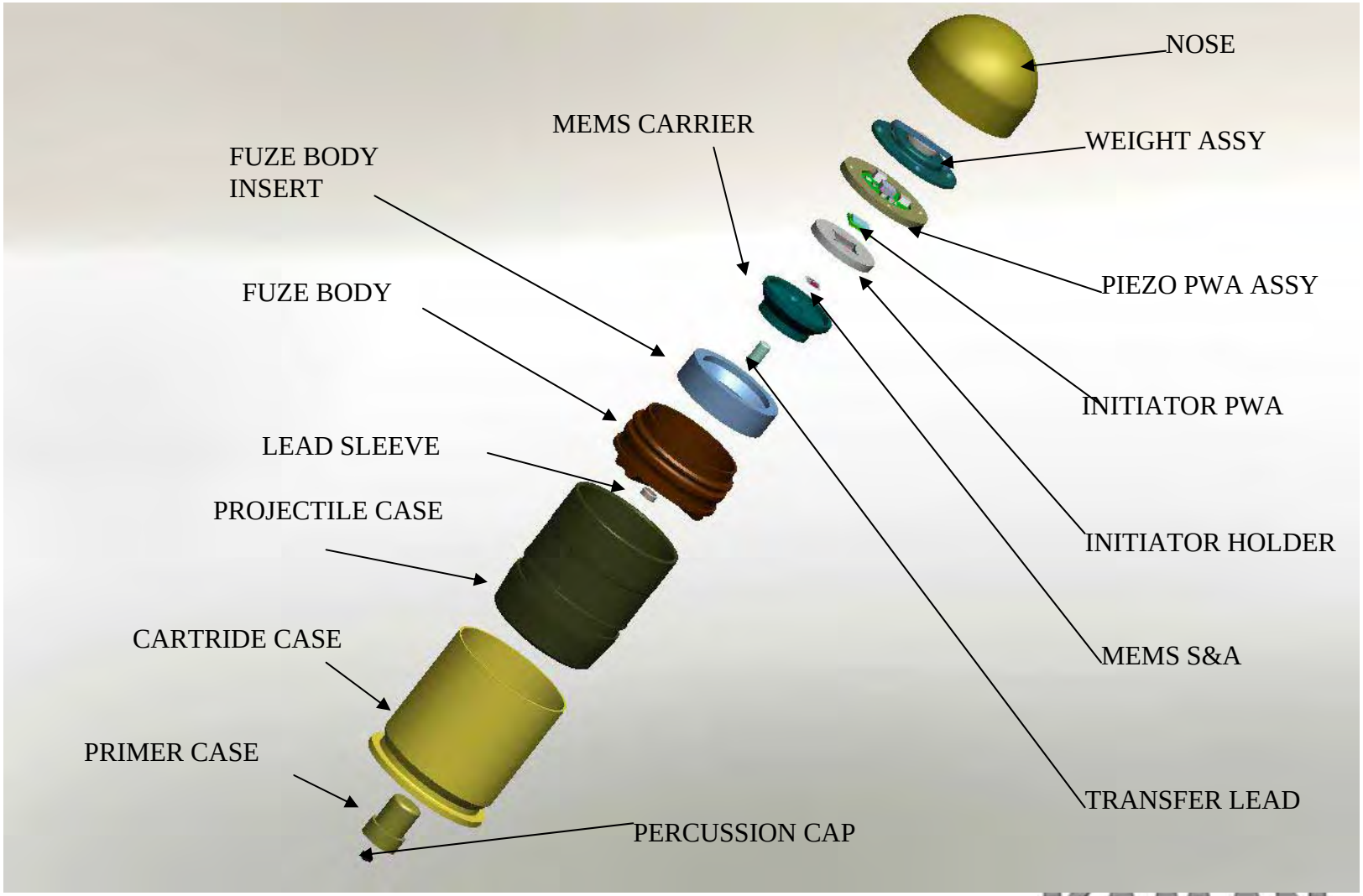
Rotor Armed Lock

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Current Concept for TOSA-159 Demonstration

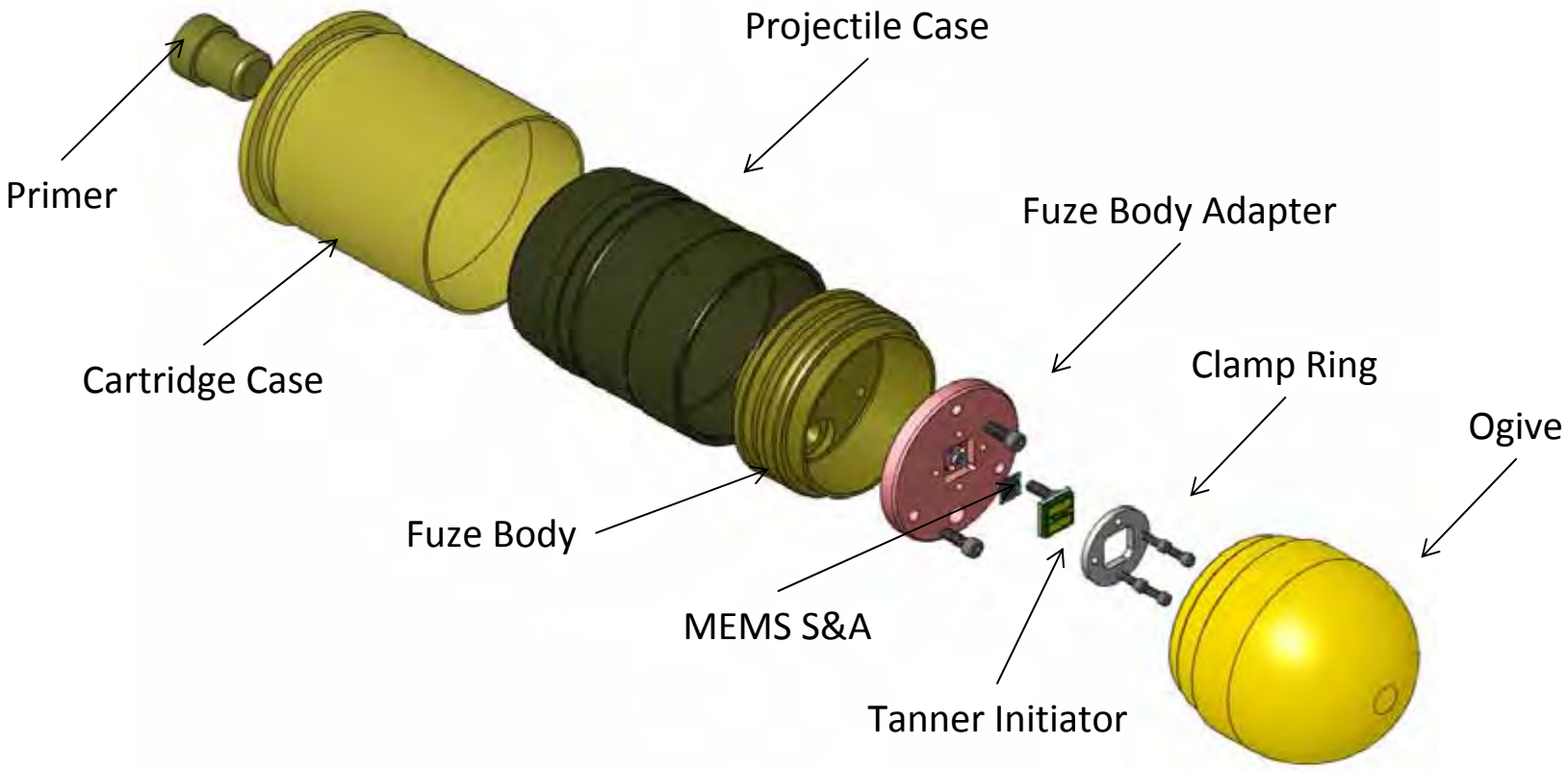


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Actual Demonstration Conducted in Dec 09



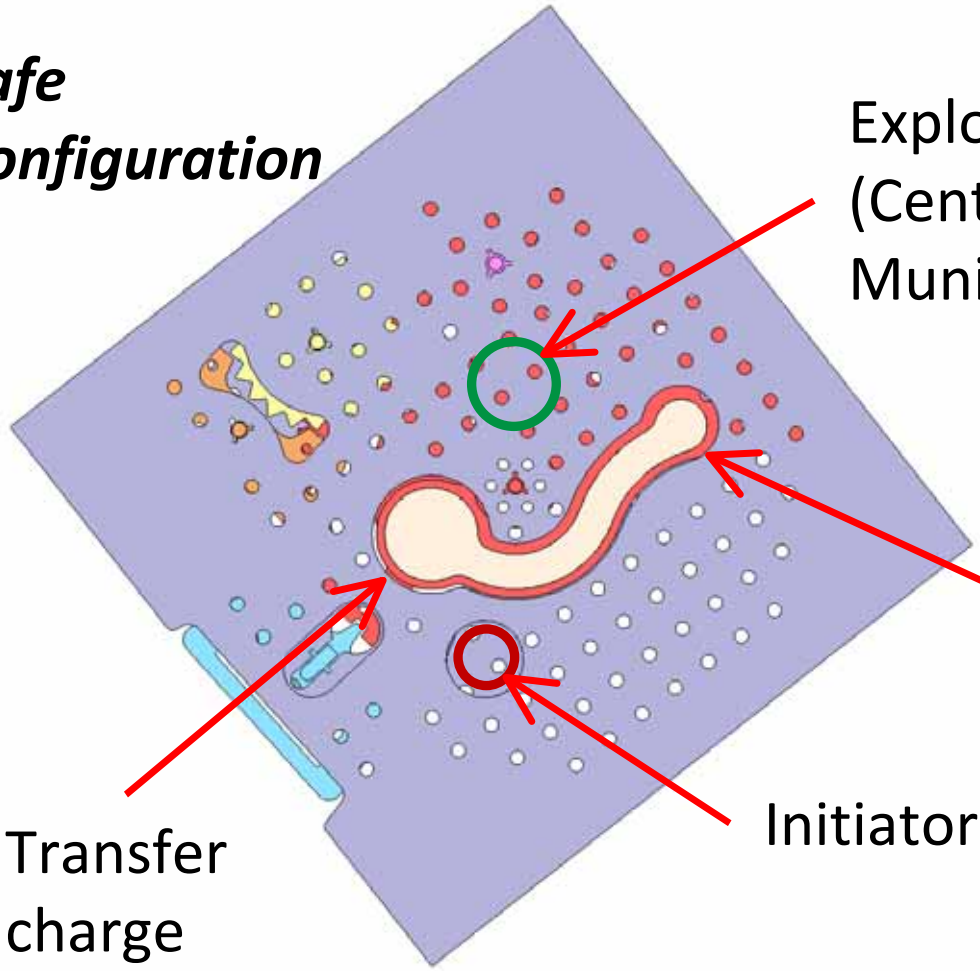
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MEMS S&A Out-of-Line
" Safe" Configuration

Safe Configuration



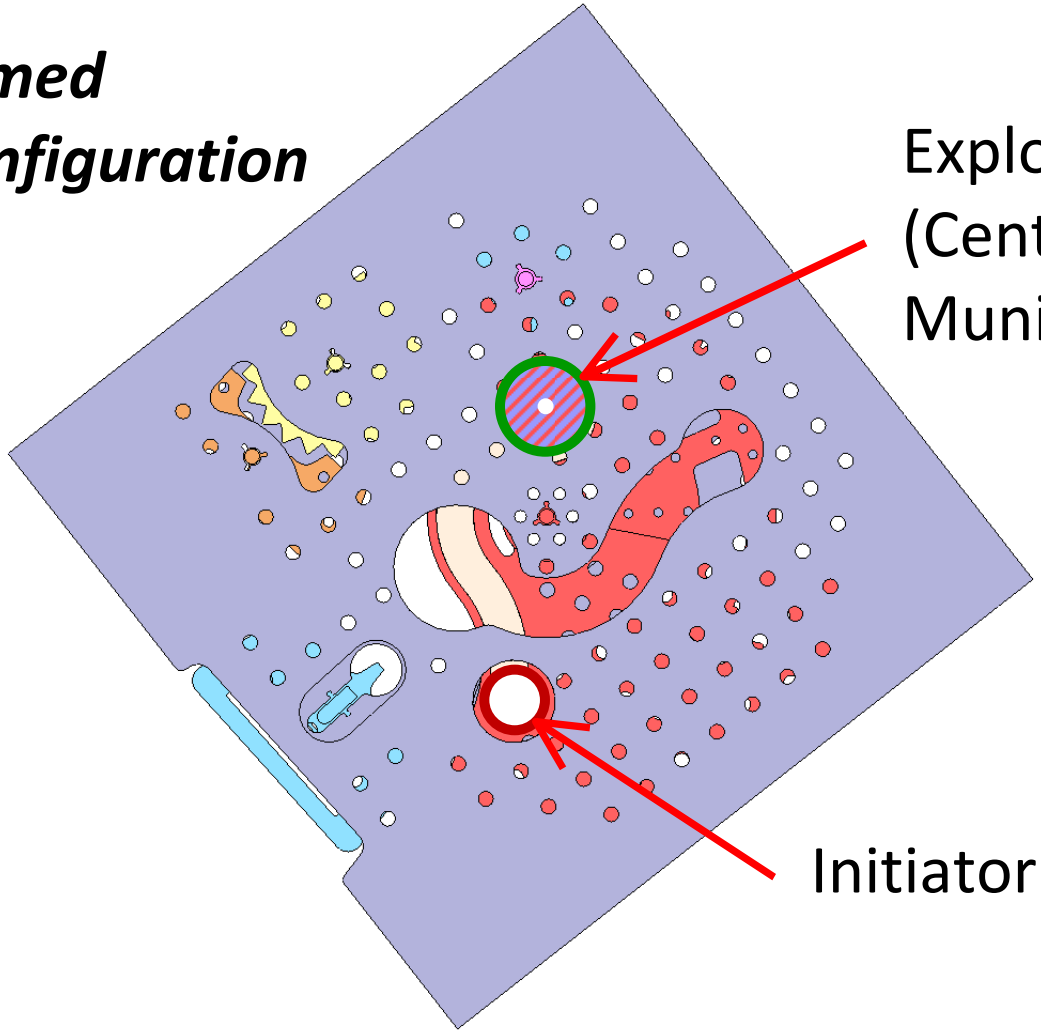
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MEMS S&A Out-of-Line "Armed" Configuration

Armed Configuration



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What the benefits are (versus existing funded efforts)

- Size
  - Present 5mm x 5mm x0.5mm = 12.5 mm3
  - Exclusive of Detonator of ~ same size
  - Thought to be the smallest 2 environment sensing S&A in World.
- Reliability -- Fully Self-Assembled
- Arming Accuracy – Exceeds Close in Arming distance requirement in Lab Tests
- Broad Application -- Medium Caliber, Small Caliber potential, Cannon Fired Sub-Munitions, Rockets, Small Missiles, Spinning and Non-Spinning
- Cost – Ultimately a lower cost approach

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TOSA 159 Studies

- **TOSA 159 Studies**
  - **Sensitivity Study** -- MEMS Verge Escapement design of interest has a good sensitivity
  - **Non-Spinning Munition** -- **MEMS Verge Escapement** suitable
  - **De-Spun Munition** -- MEMS Verge Escapement based device could be constructed that would act after sensing De-Spin
  - **Volume Requirements** -- **Two orders of magnitude reduction in comparison to Mortar Fuze Rotor assembly ~0.5 Cubic inches reduced to ~.008 Cubic inches**

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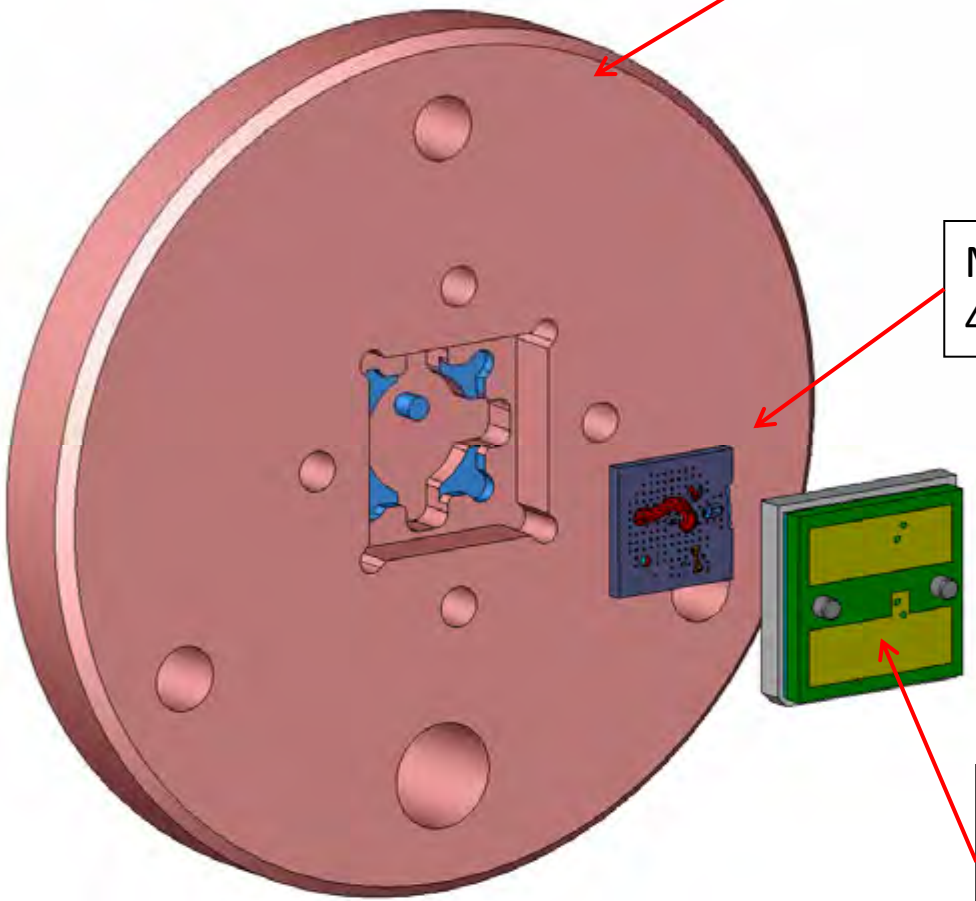
Preliminary Testing -- Test Objectives

- Demonstrate Feasibility of:
  - ☒Micro-Detonator Explosive Transfer to EDF-11 Loaded Explosive Transfer Charge
  - ☒Demonstrate Transfer via MEMS Explosive Transfer channel of EDF-11 detonation to MEMS Explosive Output Cup
  - ☒Demonstrate Explosive Output from Explosive Cup
  - ➢Demonstrated Out-of-line sufficiency for design with N5 lead pellet, a safety requirement

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Exploded View of Assembly

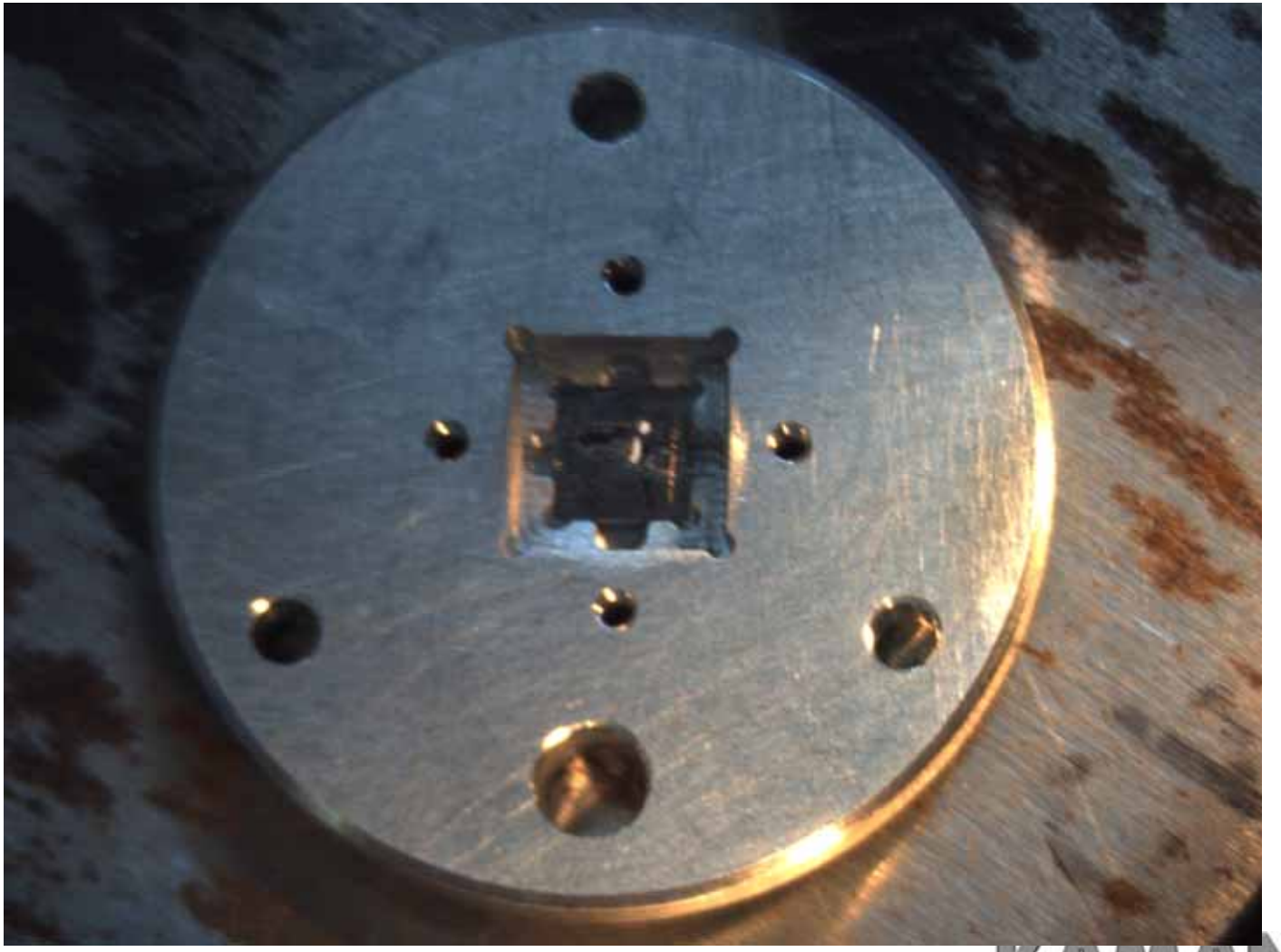


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Loaded Armed MEMS Device in Carrier

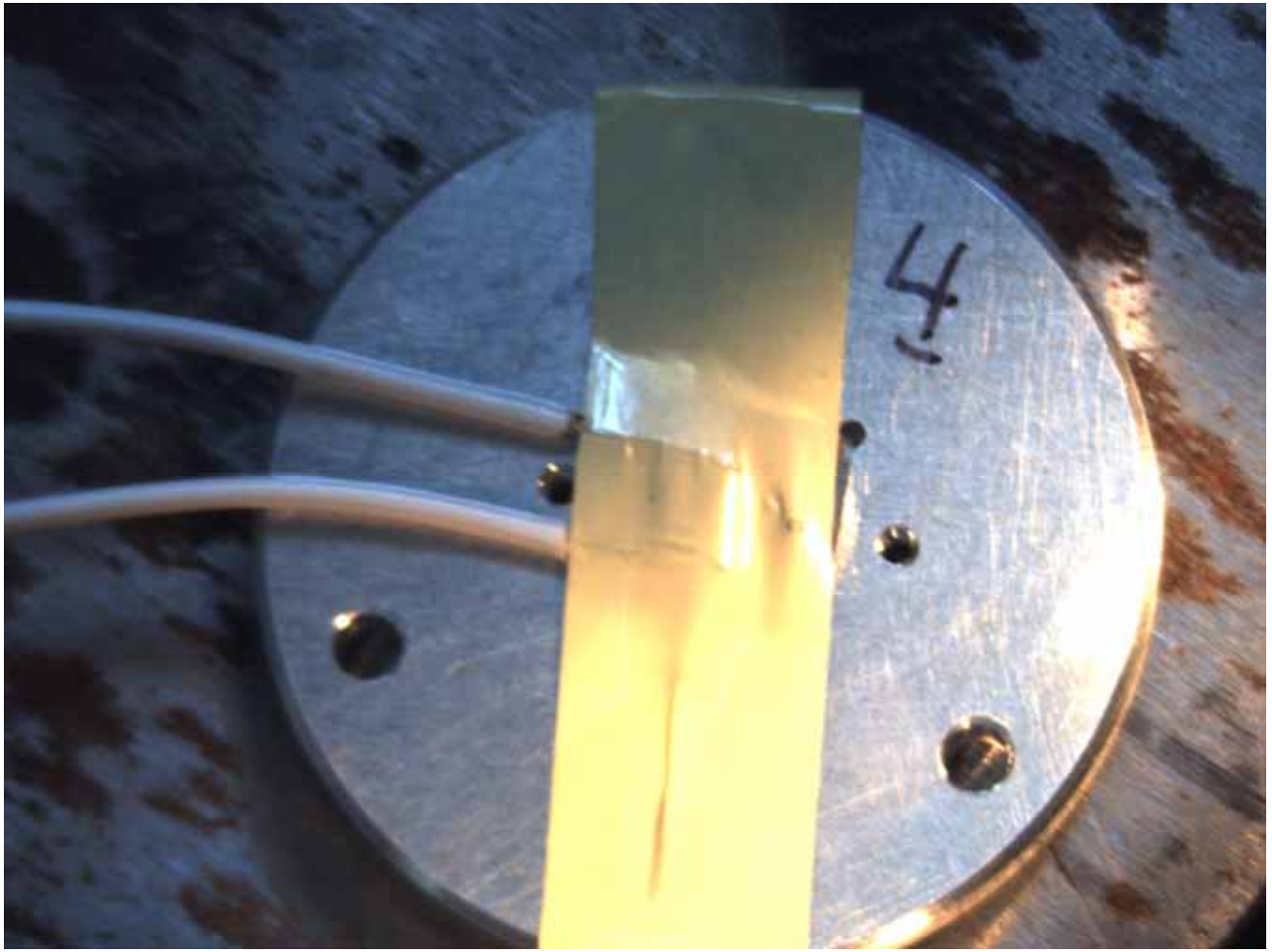


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MEMS Device w/ Initiator Ready for Firing Test



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Close-up of Carrier after Explosive Test

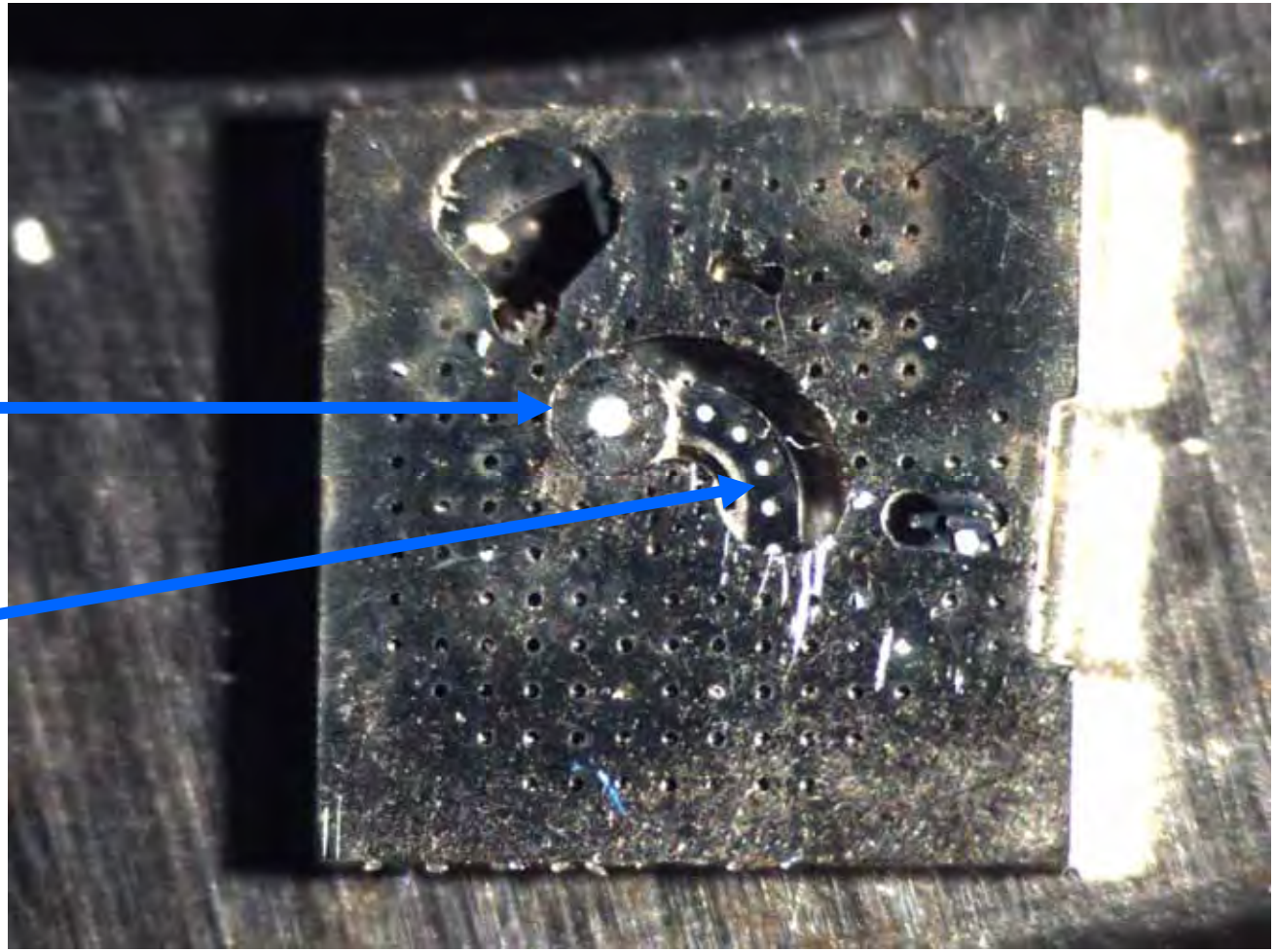


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Output side of MEMS Device in Armed Condition (Set Back Lock Removed)



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Close-up on Witness Dent

Close-up on Witness Dent



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Undamaged N5 Booster Pellet



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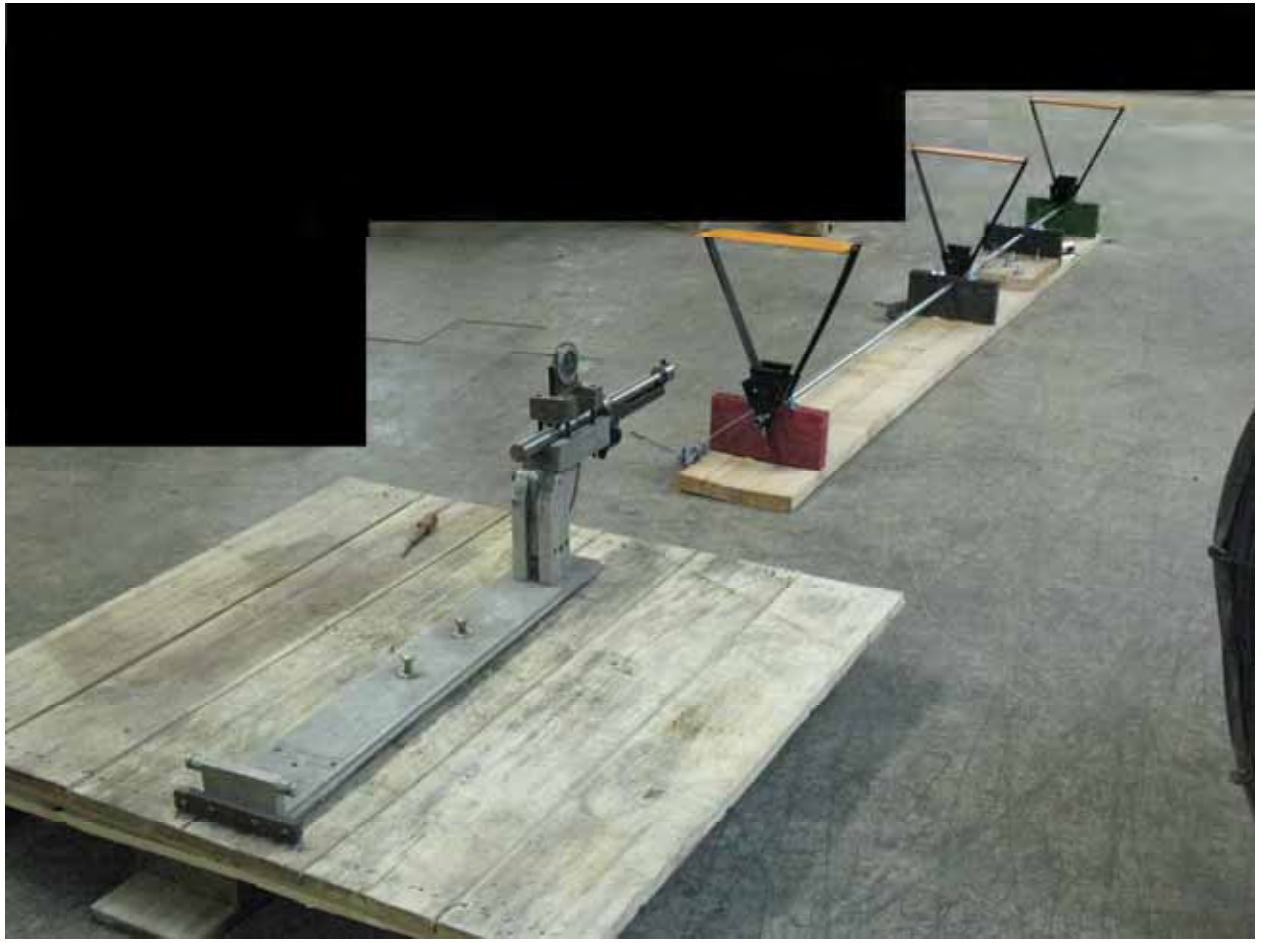
Results

- Demonstrated Micro-Explosive Train propagation from Micro-Det across to Explosive Output Cup, and then high order output of cup via flyer plate into aluminum holder. ~33% first round P4 ~50% second round P5
- Demonstrated Out-of-line sufficiency for design with N5 lead pellet, a safety requirement.

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40mm Gun Demo Set Up



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KAMAN PRECISION PRODUCTS FUZING

M203 Demo Preliminary Firing

- Objectives
  - Demonstrate the integrity of the Test Round, especially MEMS fixturing in Test Vehicle
  - Demonstrate survivability of MEMS S&A, Micro-Detonator and Micro-Explosive Train
  - Demonstrate Range set up
  - Demonstrate Suitable Ballistics of Test Vehicle
  - Demonstrate Arming in Flight and Post Firing Detonation

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M203 Demo Preliminary Firing

- 9 rounds Fired
  - Three Type A Set-Back Lock
  - Six Type B Set-Back Lock
  - All rounds fired, disassembled, inspected, reassembled, subjected to firing stimulus
- First two (9 and 8) took out velocity screens
  - Ogive collapsed
  - No test, gunners error

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M203 Test Firing, Con't.

- Next seven fired and soft recovered succesfully, no velocity data
  - Round 6, armed in flight detonator fired no transfer to lead charge
  - Round 5, not fully armed in flight, armed on lathe and successfully detonated high order
  - Remaining rounds were neither fully armed in flight nor successfully detonated.

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2010 Plans

- Program Continuing
  - Presently funded under Kaman IR&D
  - P6 MEMS and Micro-Detonator Build
  - Awaiting 2010 Sponsor funding
- 2010 Goals
  - Explosive Train Demo of better than 90%
  - Improved Gun fired demonstration

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Case Weight Variation Reduction and Subsequent Ballistic Dispersion Improvements in M118LR

Ms. Dionne Dillon
Manager, Manufacturing Engineering ,7.62mm and Cal .50
ATK Small Caliber Systems
May, 2010

OSR Approval #10-S-1445



Current Condition

- Demand For M118LR Increased 900% Between 2001 And 2009

- Considerable Field Experience Yielded Helpful User Feedback
  - Overall Quality And Performance Very Good
  - Accuracy And Consistency Typically Exceeds Specifications

- Some Users Requested Improvements
  - Improve Consistency Between Sublots
  - Reduce Need For Re-zero Between Sublots

Users – “Reduce Variation Between Sublots”

ARDEC / ATK Continuous Improvement Project

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Project Objective:

Identify Process-Related Measures that Can Be Implemented at the Lake City Army Ammunition Plant To Improve Average Extreme Horizontal and Vertical Spreads and Reduce the Need to Re-zero Between Sublots

Continuous Improvement Philosophy

M118LR Case Requirements

- M118LR Case Is Essentially Identical To An M80 7.62 Case Except For:
  - Primer Pocket Diameter
  - Head-stamp Requirements
  - Note 10 On M118LR Drawing

"Unit wt: 190-20 Grains. Case Weight Variation For Each Cartridge Sublot Shall Not Exceed 2 Grains After Taper."



M118LR Cases Nearly Identical to M80 Cases

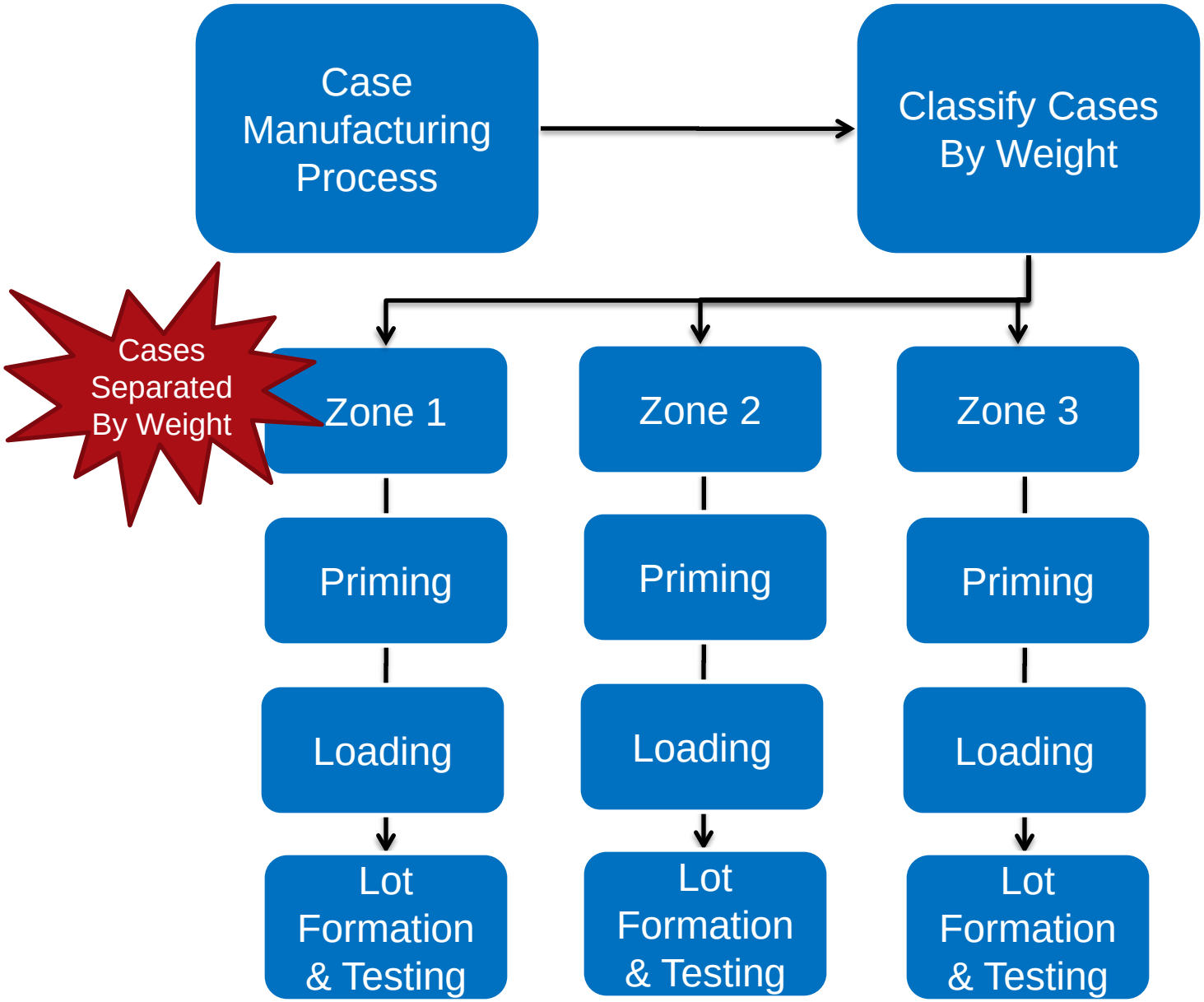
Why Is Note 10 There?

- Studies Show Relationship Between Case Volume, Pressure & Accuracy
- Minimize Case Volume Variation To Achieve The Best Accuracy
- Case Volume Can Be Correlated To Case Weight
- Case Weight Is Inherently Easier To Measure At High Production Levels
- Result Was Case Weight Variation Requirement

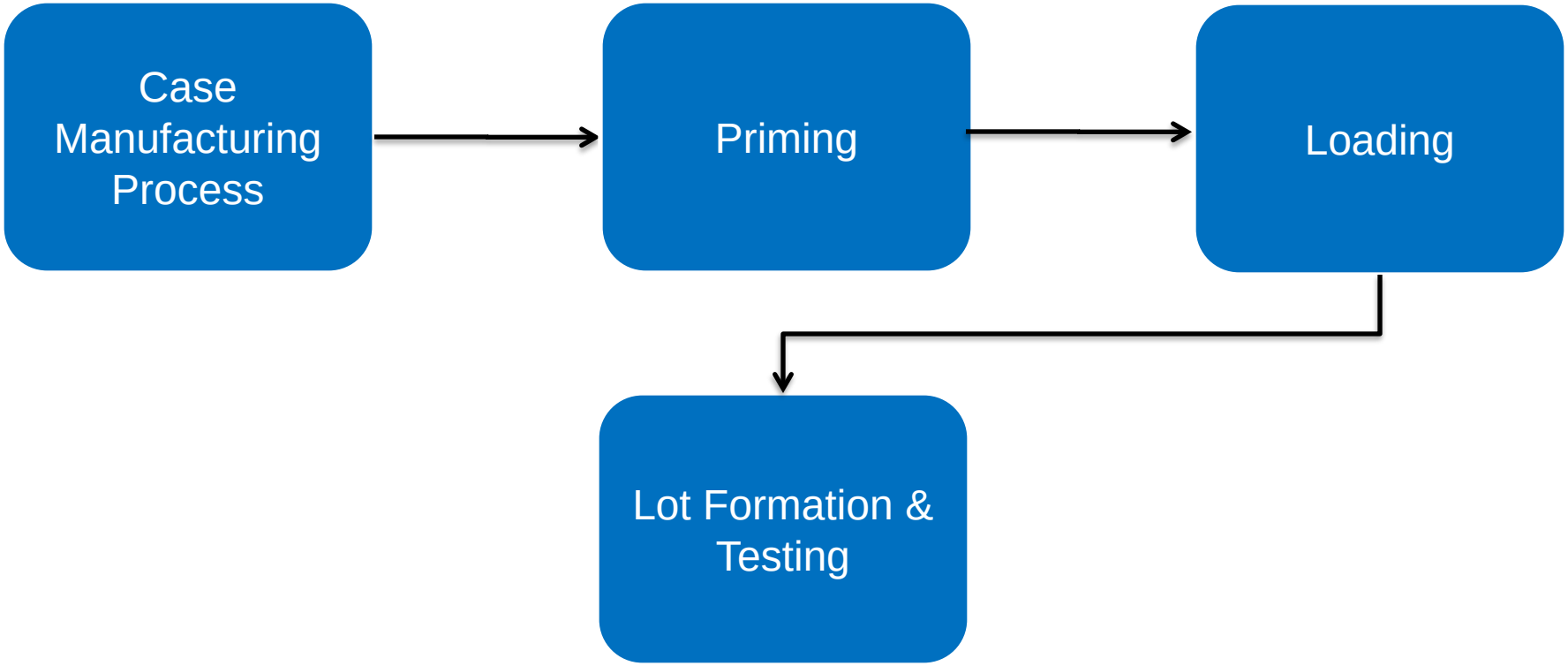
Control Case Weight For Best Performance

M118LR Case Manufacturing Process

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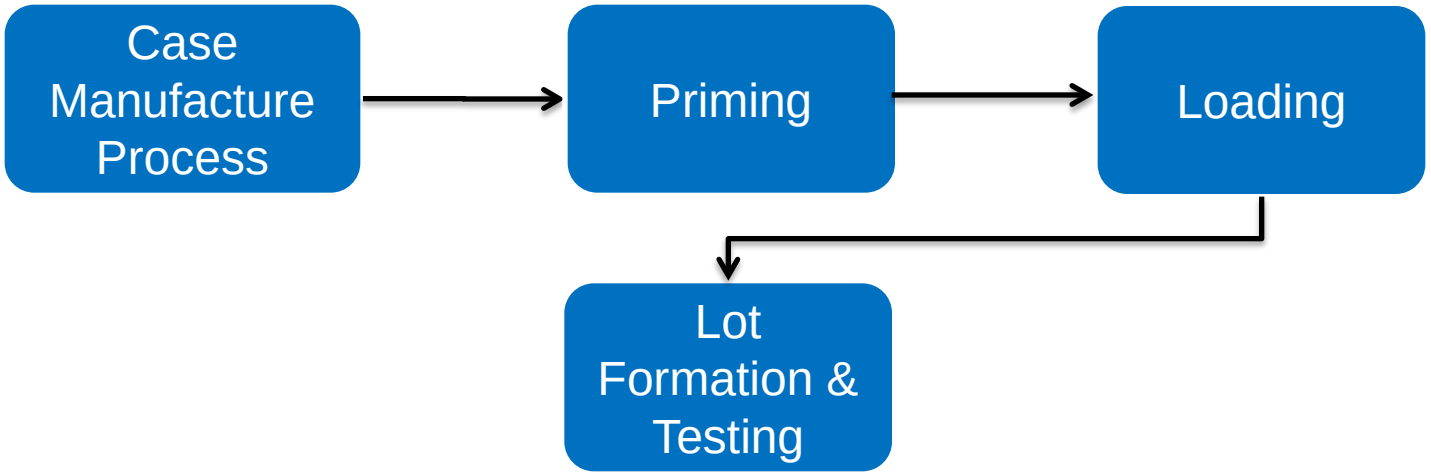
M80 Case Manufacturing Process



Could M118LR Cases Be A Subset of M80 Cases?

M80 Case Weight Study

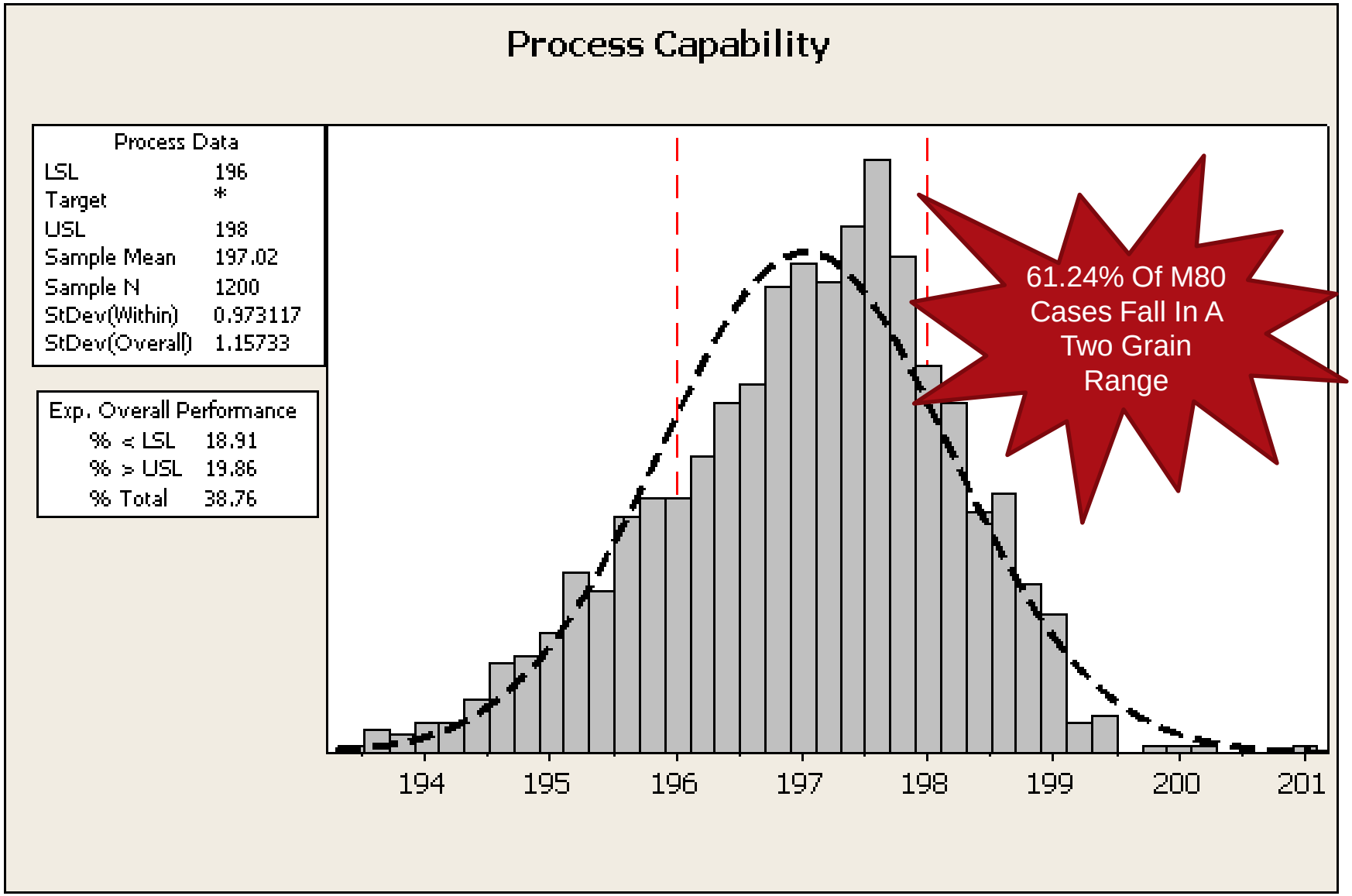
- Weigh Random Samples Of M80 Cases
- Over A Long Period Of Time, Capture Differences In Brass Strip Gauge Variation
- Calculate The Proportion Of M80 Cases That Fall Into The Desired Weight Range



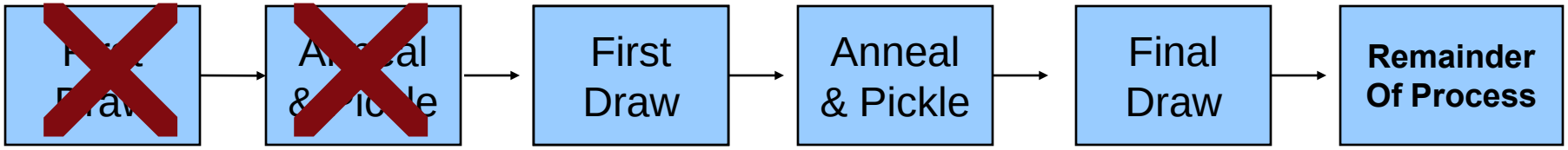
SPC Utilized To Measure Current M80 Process

M80 Case Weight Study Results

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Conclusions and Actions For Improvement



- Data Collection And SPC Analysis Supported Changes
  - Different Raw Material Dimensions
  - Elimination Of 1 Draw, 1 Anneal, & 1 Trim Operation
  - M118LR And M80 Cases Are Now Manufactured Using The Same Process

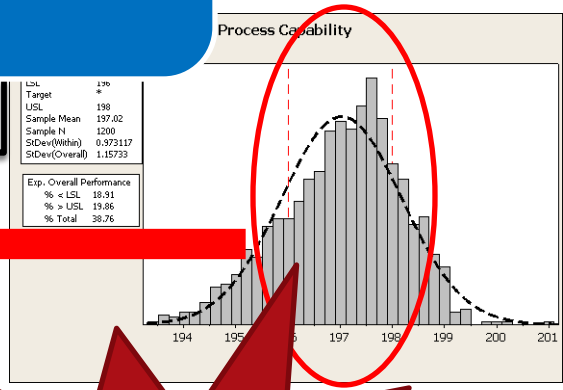
M118LR Process Mimics Proven M80 Process

M118LR and M80 – Unified Process Flow

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Drawing Operations

Case Weigh



NATO

Priming

Loading

Lot Formation & Testing

M118LR

Priming

Loading

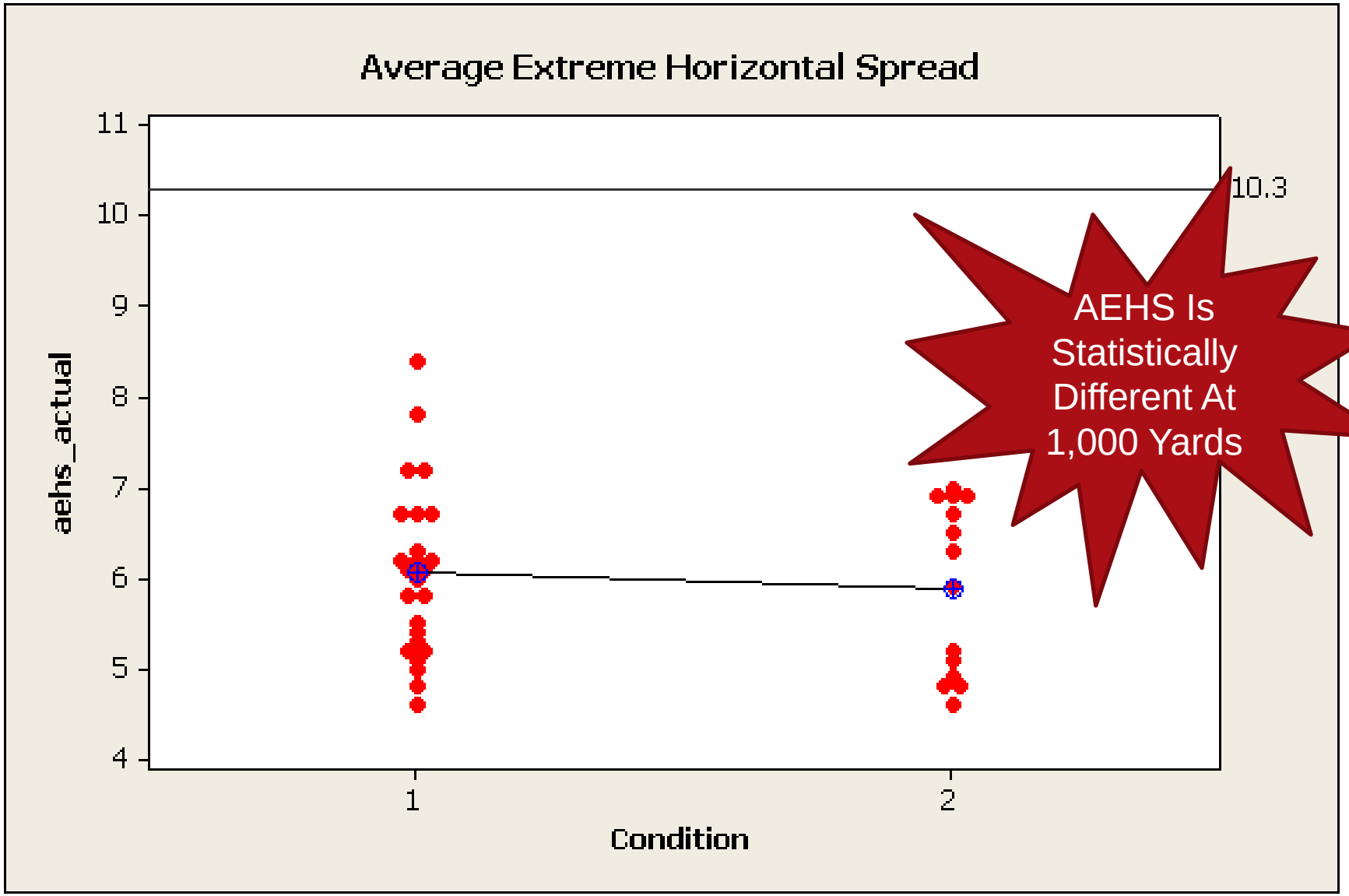
Lot Formation & Testing

M118LR Cases Are The Same Weight In Every Sublot

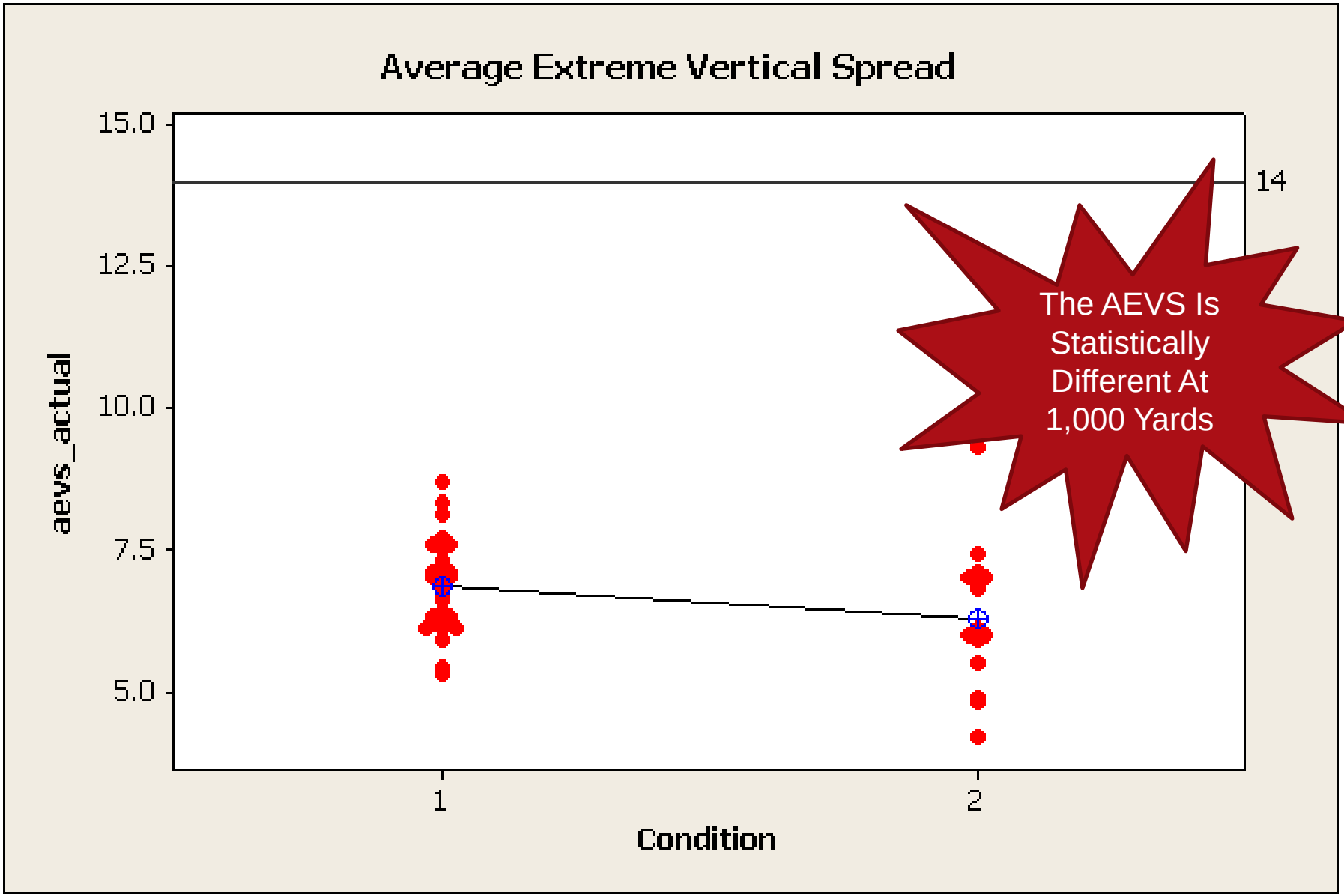
LR Cases Come From The Center Of The Case Process

Horizontal Spread

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Vertical Spread – A Better Measurement



Summary

- M118LR Accuracy Was Improved
  - Reduced AEHS From 6.06 To 5.89
  - Reduced AEVS From 6.85 To 6.29

- Contributing To Less Variation In Point Of Impact Between Sublots



A More Consistent Product For The User

Contact Information

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RDECOM

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High Performance $BKNO_3$ Igniter Formulations

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

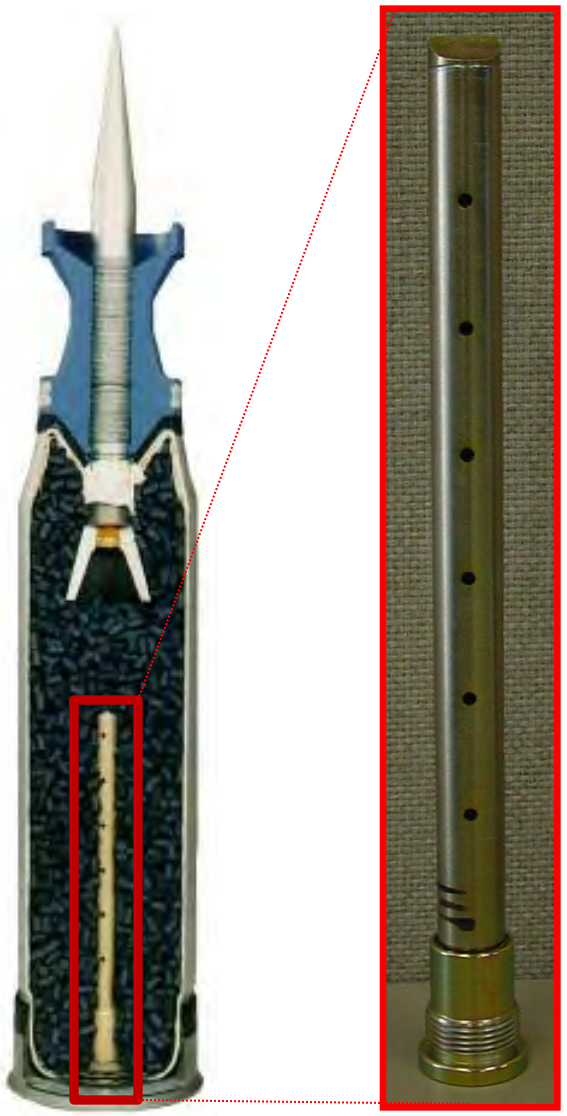
Dr. Eugene Rozumov, D. Park, T. Manning, J. O'Reilly, J. Laquidara, E. Caravaca, D. Thompson

NDIA
May 2010
Dallas, Texas

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Presentation Outline

- Problem/Challenge
- Background
- Technical Approach
  - Cheetah Modeling of $BKNO_3$ combustion
  - Sensitivity Testing
  - Small Scale Performance
  - Adjustable Static Fire Test Fixture
    - Benite analysis
    - $BKNO_3$ powder analysis
- Conclusions/Future Work



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High Performance Igniter

Challenge:

- Create an igniter formulation that has:
  - **Excellent and consistent performance**
  - **Exhibits no flare back**
  - **Is more energetic than Benite.**
  - **Is less sensitive than Benite.**





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Mechanism of Igniter Action

- First step of Propellant ignition is endothermic.*
- Highly unstable products of this 1st step are reactants for the subsequent exothermic combustion reactions.
- Ignition of Nitrate Ester Propellants is self-propagating once surface temperature reaches 170°C.
- Raising surface temperature accomplished by use of igniters that transfer heat via two distinct processes.

- Convection
  - Gases generated travel across propellant surfaces at a high velocity and transfer their heat (energy) to the propellant.
  - Slow process.
  - Can be affected by propellant temperature.
- Conduction
  - Condensed Phase material.
  - Direct contact with propellant.
  - Can cause over ignition and the formation of pressure waves.

*R.A. Fifer; **S.A.** Uebman; **P.J.** Duff; K.O. Fickle; **M.A.** Schroeder. *Proceedings of the 22nd **JANNAF** Combustion Meeting*, **CPIA** Publication **432.** Vol. **II,** October, **1985.**

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Technical Approach

- **Add commercially available ingredients to $BKNO_3$ to improve Oxygen Balance.**
- **Alter the Boron : KNO_3 ratio to improve Oxygen Balance**
- **Add various binders to $BKNO_3$.**
  - Will allow for extrusion of igniters into strands
  - Lower processing cost than pelletization.

$BKNO_3$

- 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)

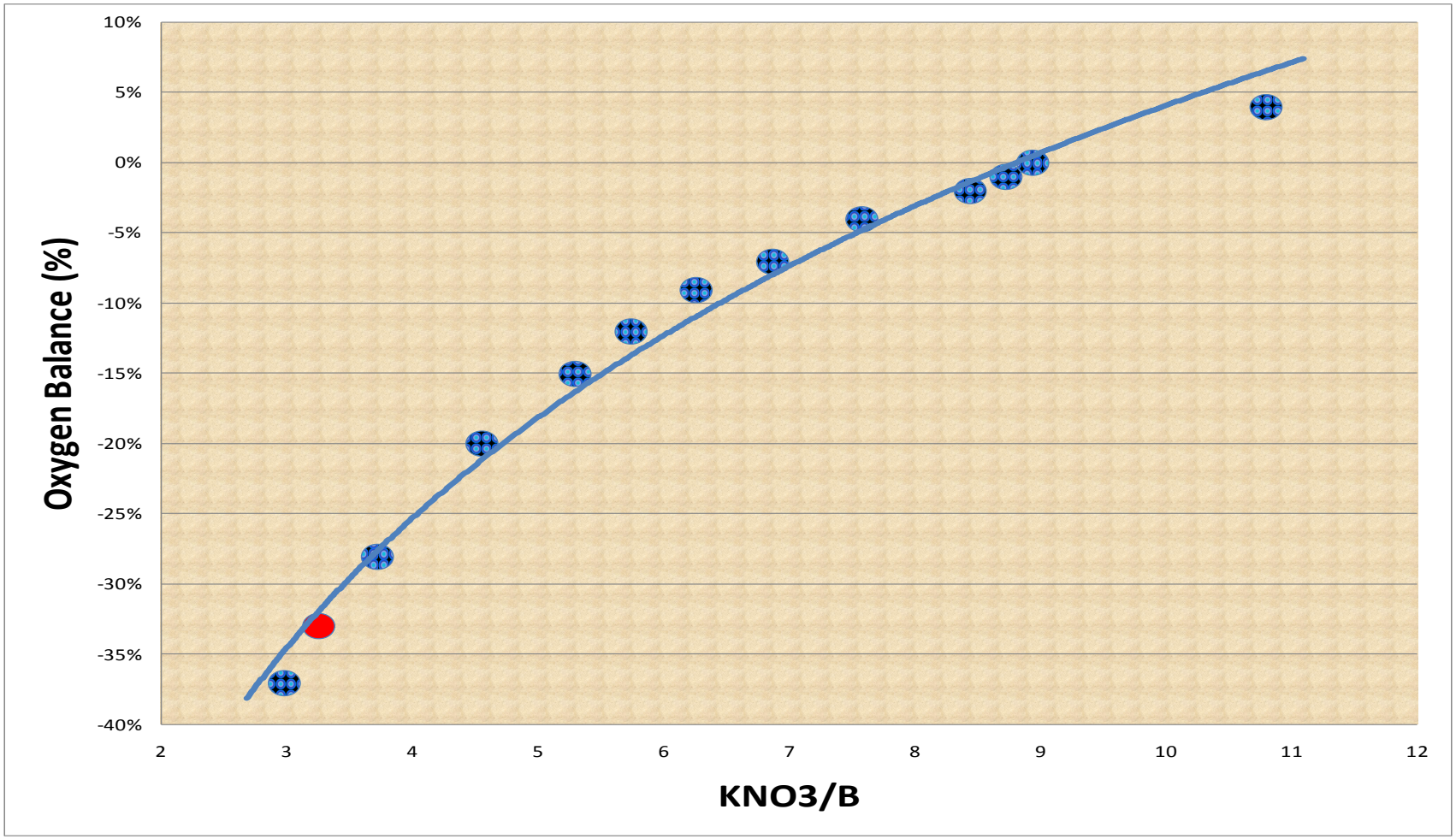
Benite

- 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.

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$BKNO_3$ Combustion: Oxygen Balance

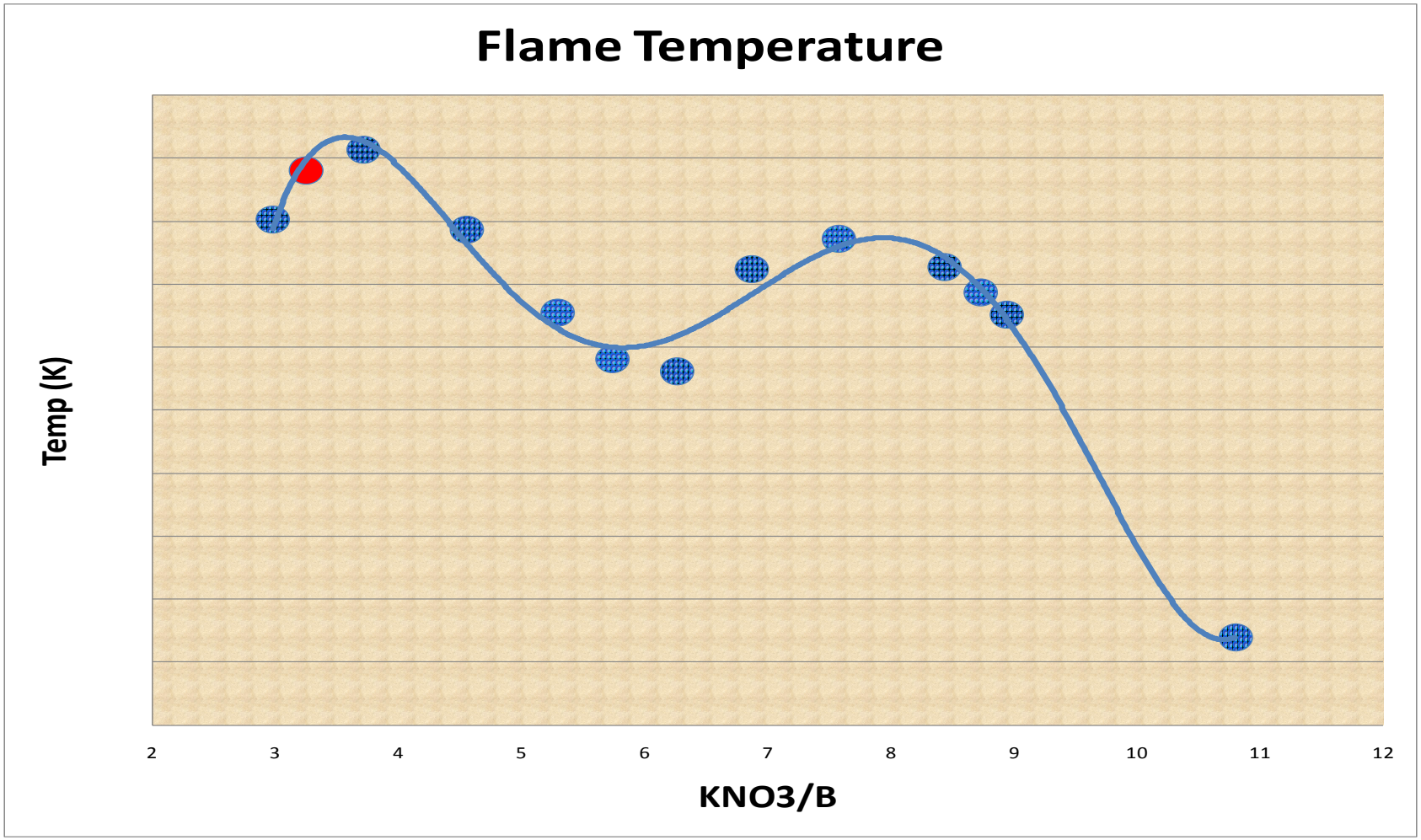


- Cheetah 5.0 modeling analysis

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$BKNO_3$ Combustion: Flame Temperature

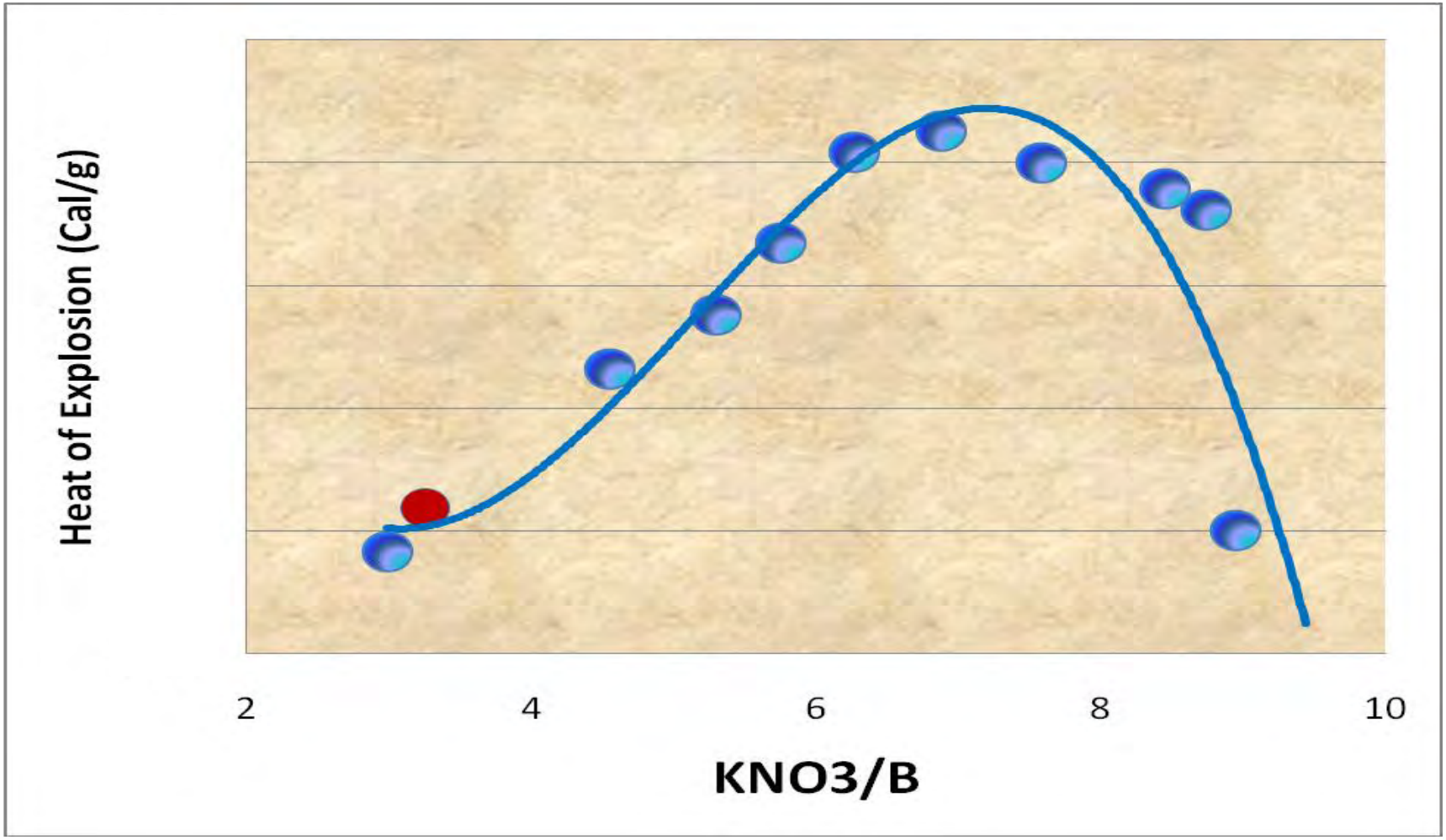


- Cheetah 5.0 modeling analysis

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$BKNO_3$ Combustion: Heat of Explosion

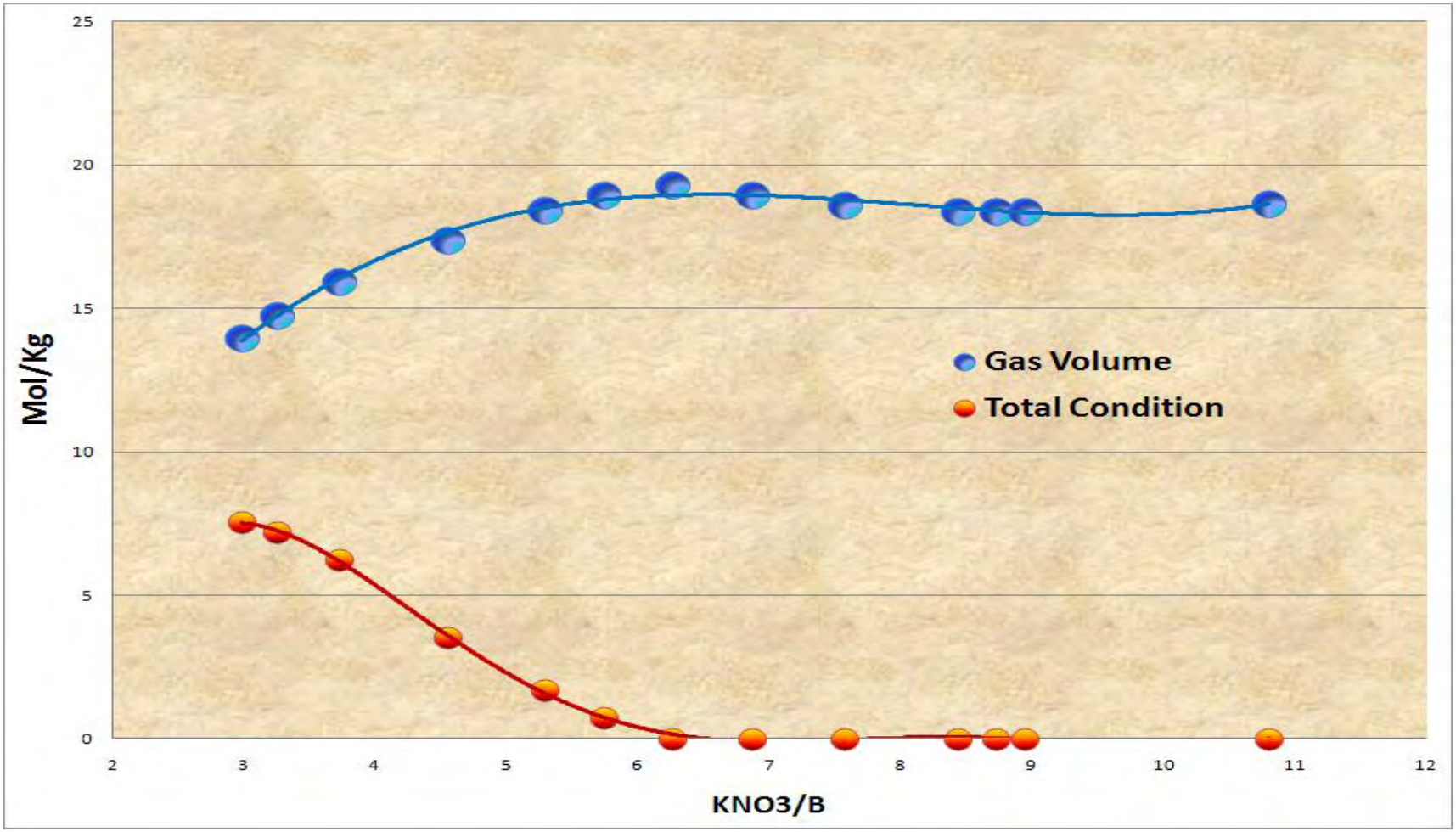


- MCVEPP modeling analysis

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$BKNO_3$ Combustion Products

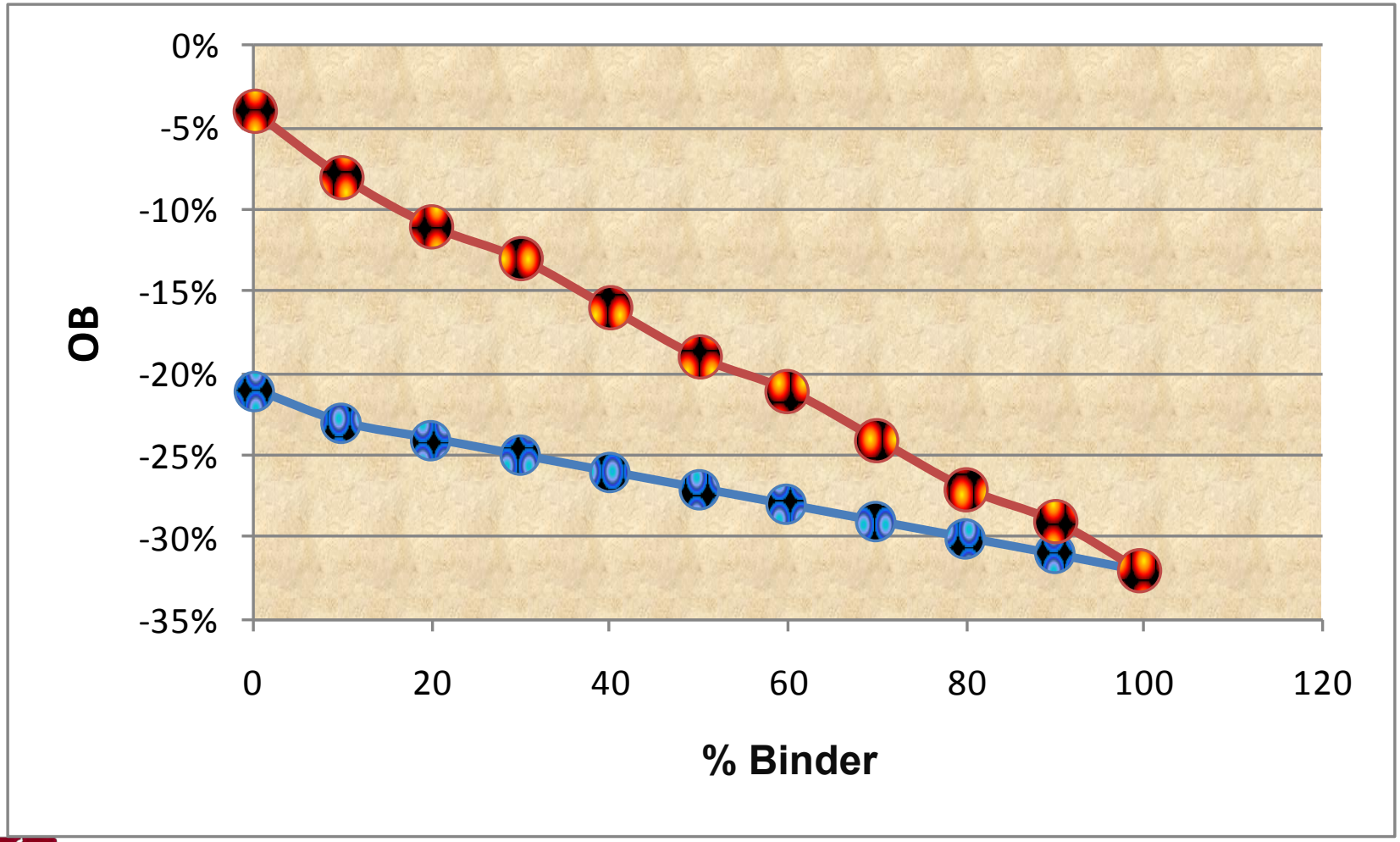


- Cheetah 5.0 modeling analysis

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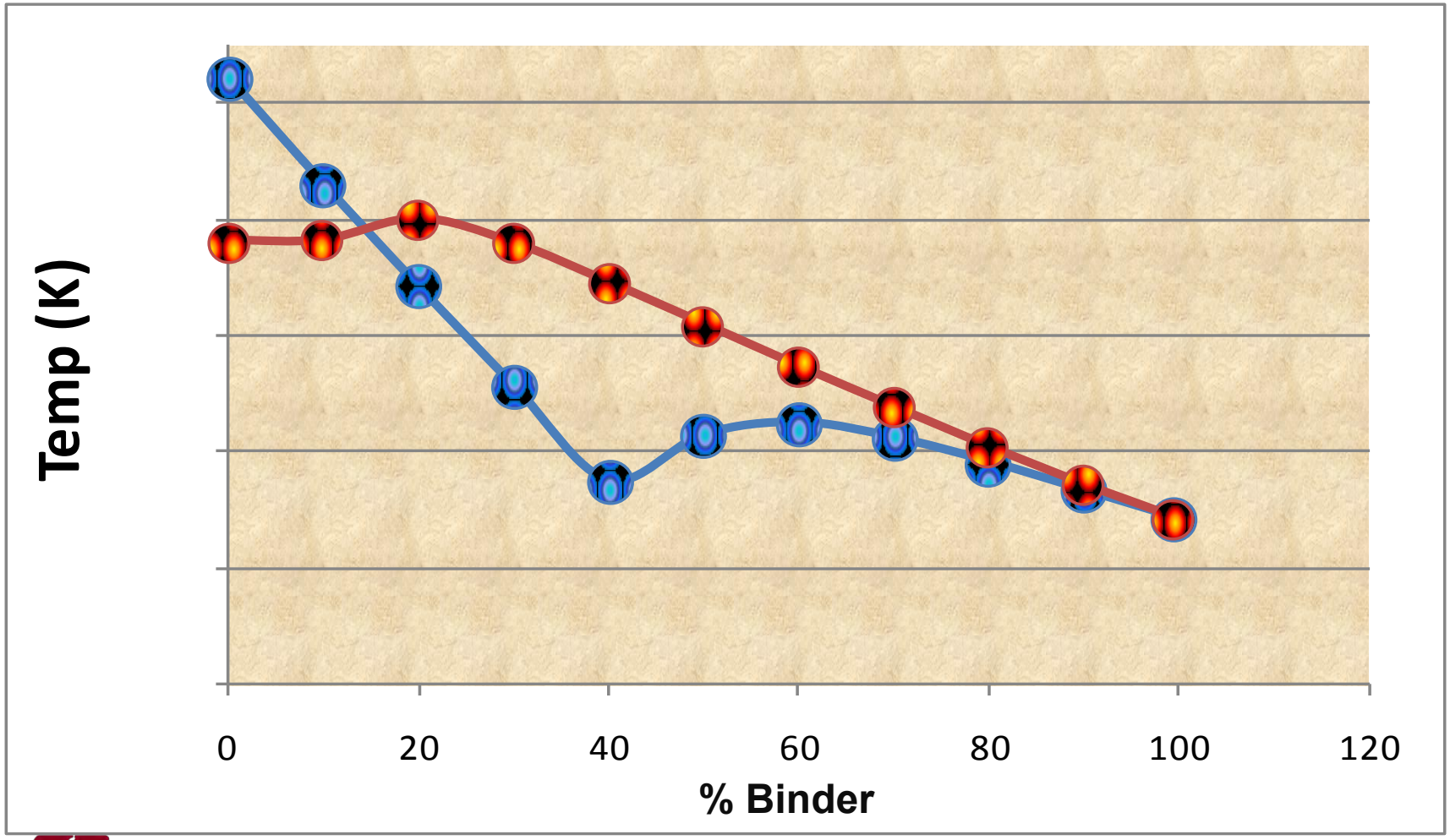
OB as a Function of Binder Content



- Cheetah 5.0 modeling analysis

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B382, Picatinny Arsenal, NJ 07806-5000.

Flame Temp as a Function of Binder Content

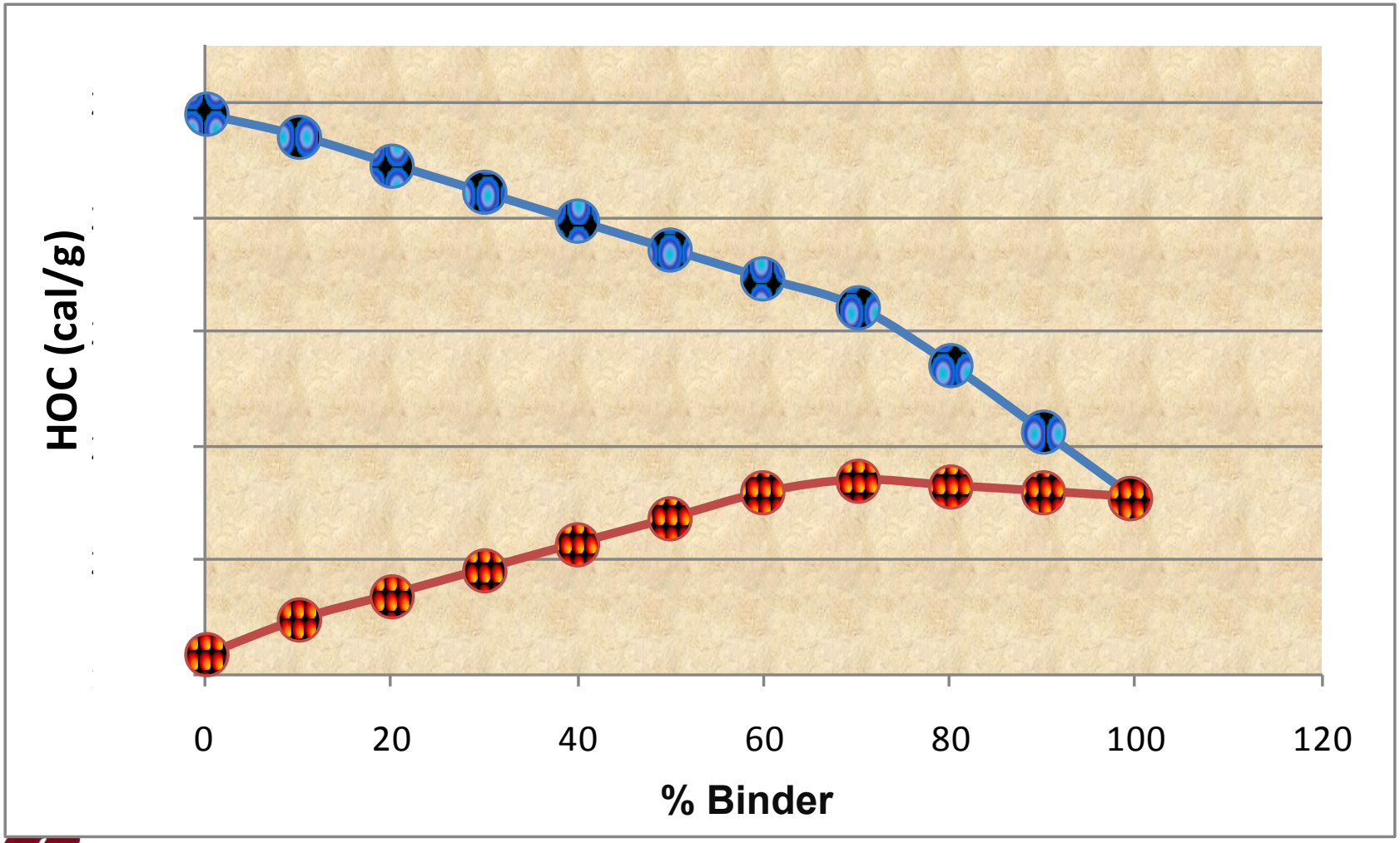


- Cheetah 5.0 modeling analysis

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Heat of Combustion as a Function of Binder Content



- Cheetah 5.0 modeling analysis

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Predicted Performance of Initial Formulations

Formulation	Igniter Sensitivity			Predicted Performance		
	Impact ERL (cm)	BOE	Friction (GO / No GO) (N)	Impetus (J/g)	Flame Temp (C)	HOE (cal/g)
Benite	18.8	6 of 10	288 / 252	488	2361	824
$BKNO_3$	23.2	10 of 10	> 360	419	3603	580
PAI-8552	>100	0 of 10	240 / 216	739	3313	401
PAI-8553	>100	0 of 10	240 / 216	710	3285	413
PAI-8550	16.8	10 of 10	168 / 144	738	3427	802
PAI-8554	22.3	10 of 10	288 / 252	595	3211	517
PAI-8555	18.9	9 of 10	288 / 252	679	2727	696
PAI-8556	22.4	7 of 10	240 / 216	613	2720	641
PAI-8557	24.6	5 of 10	324 / 288	594	2224	540
PAI-8558	>100	0 of 10	252 / 240	481	2018	360

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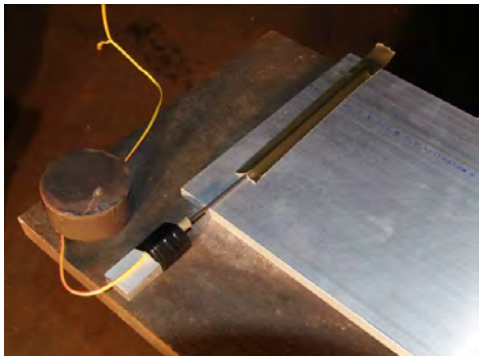
Table 1: Critical Diameter results

Critical Diameter Testing

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

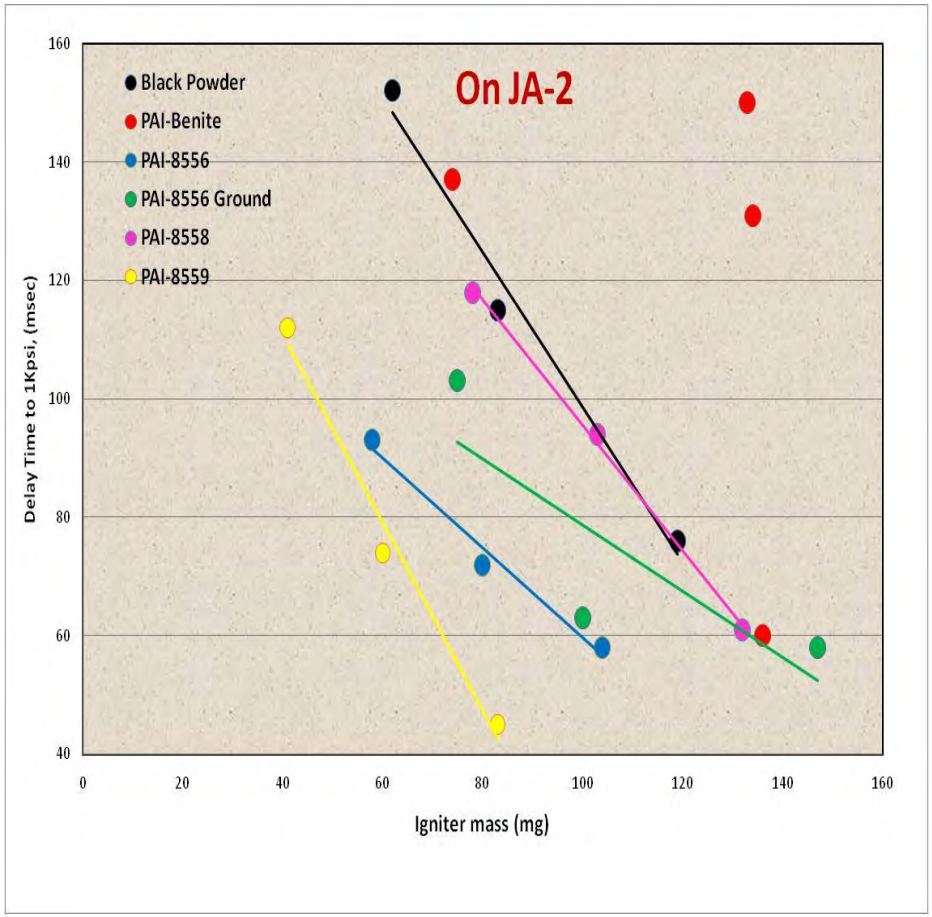
Small Scale Burn

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

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Subscale Performance Analysis

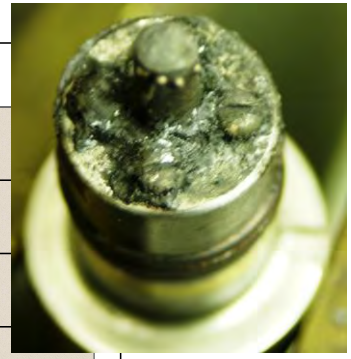


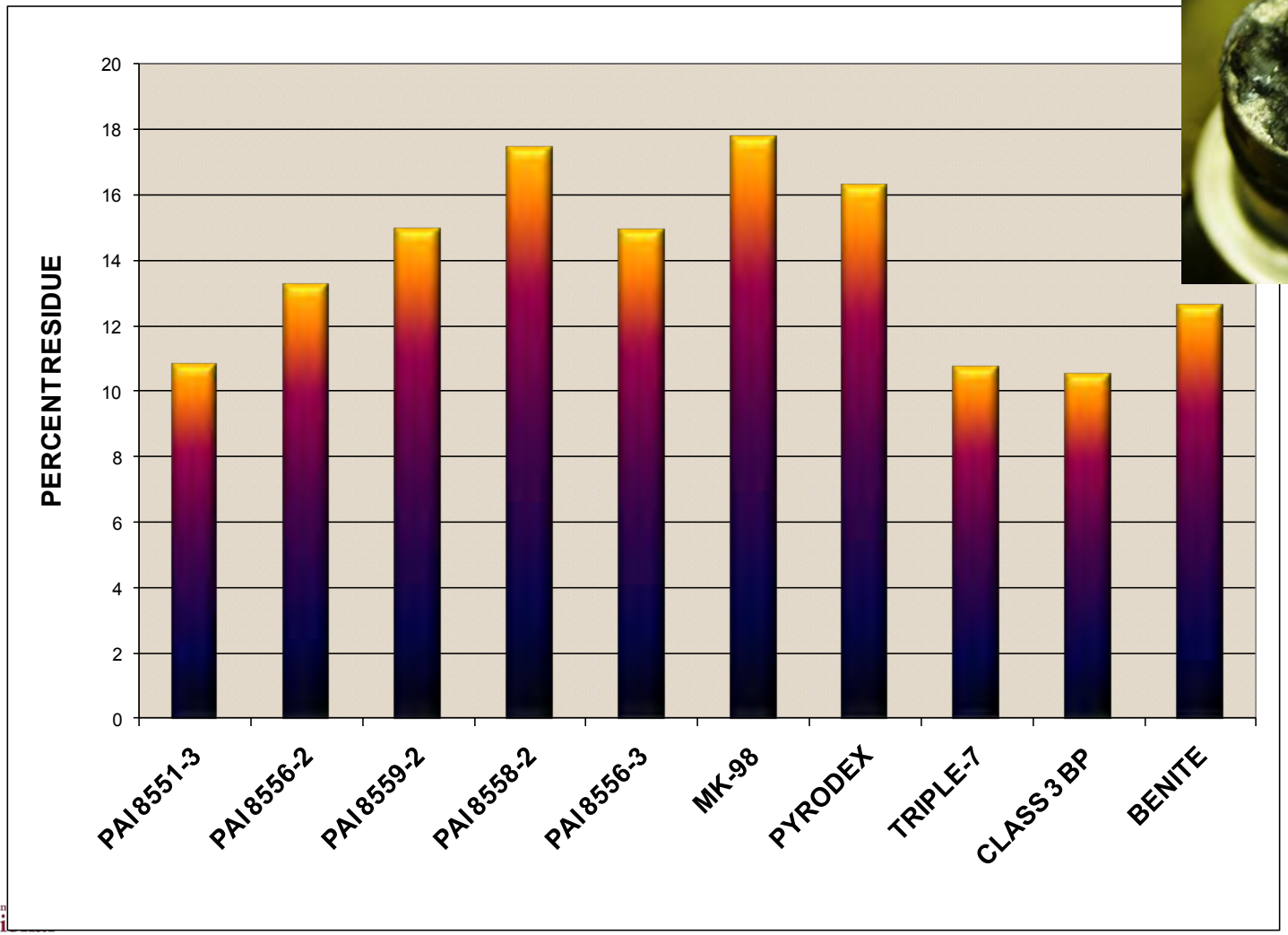
- BP & PAI-8558 behave very similarly.
- PAI-Benite very erratic behavior.
- BP, PAI-8558, & PAI-8559 are very sensitive to their mass (large negative slopes)
  - BP & CAB containing Igniters

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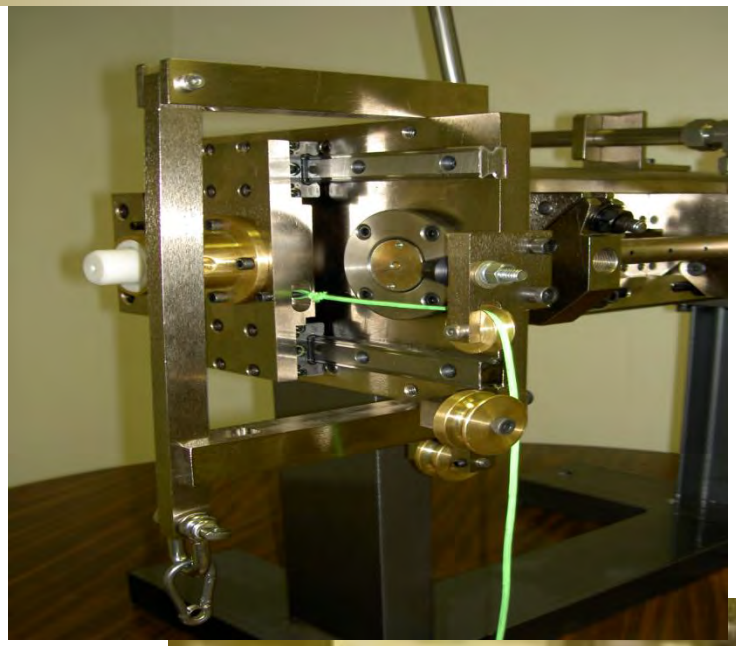
Residue Concerns





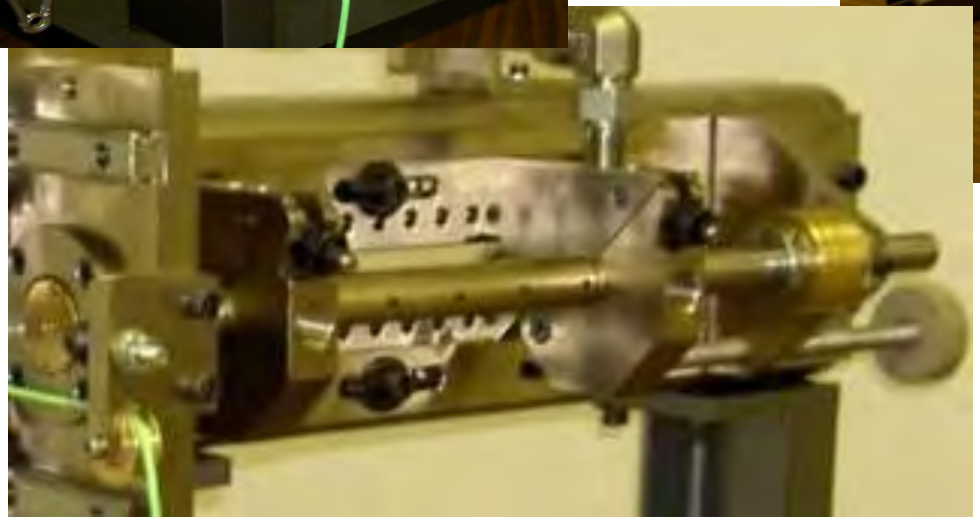
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Static Igniter Test Fixture





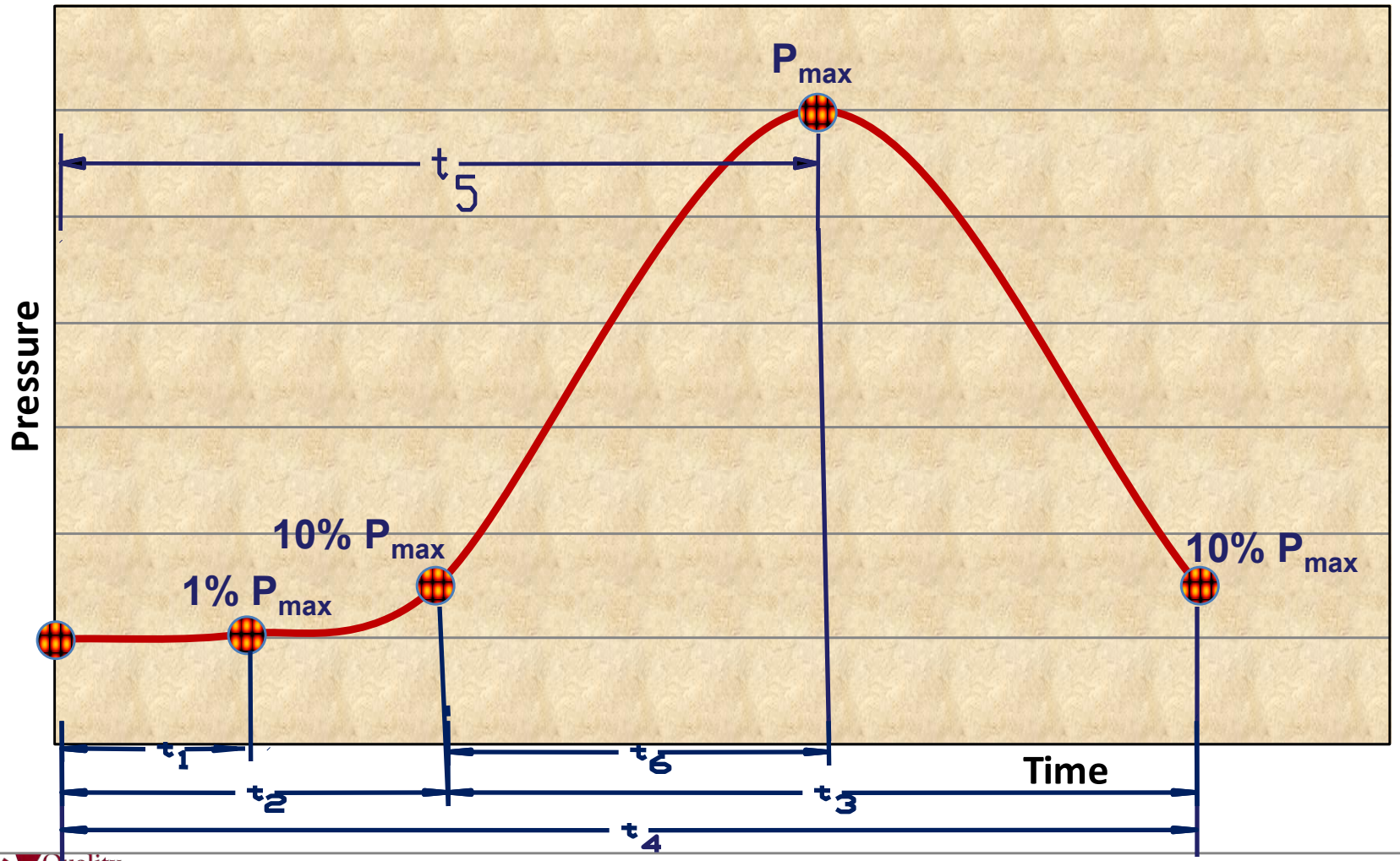




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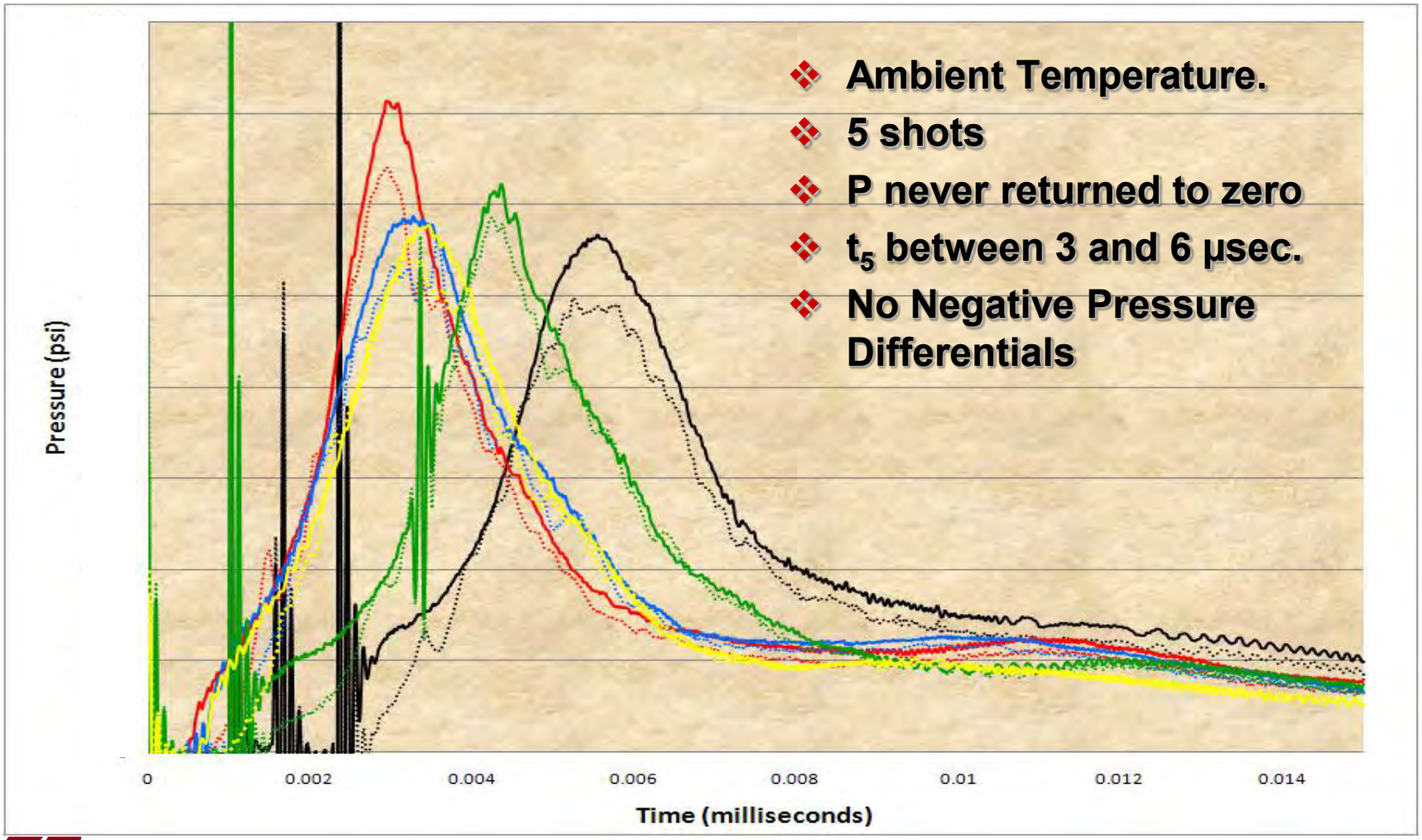
Expected Data



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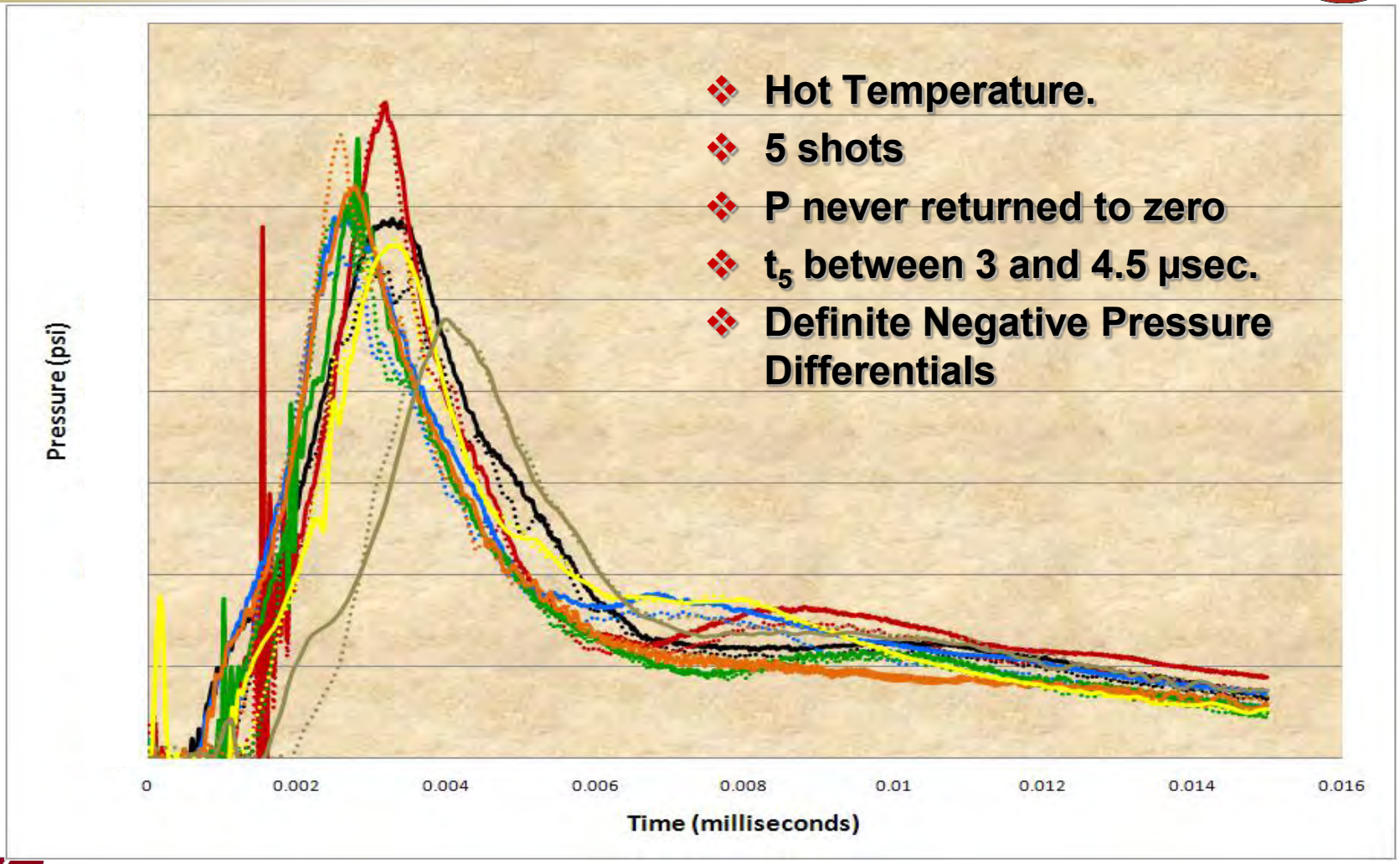
Benite at Ambient Temperature



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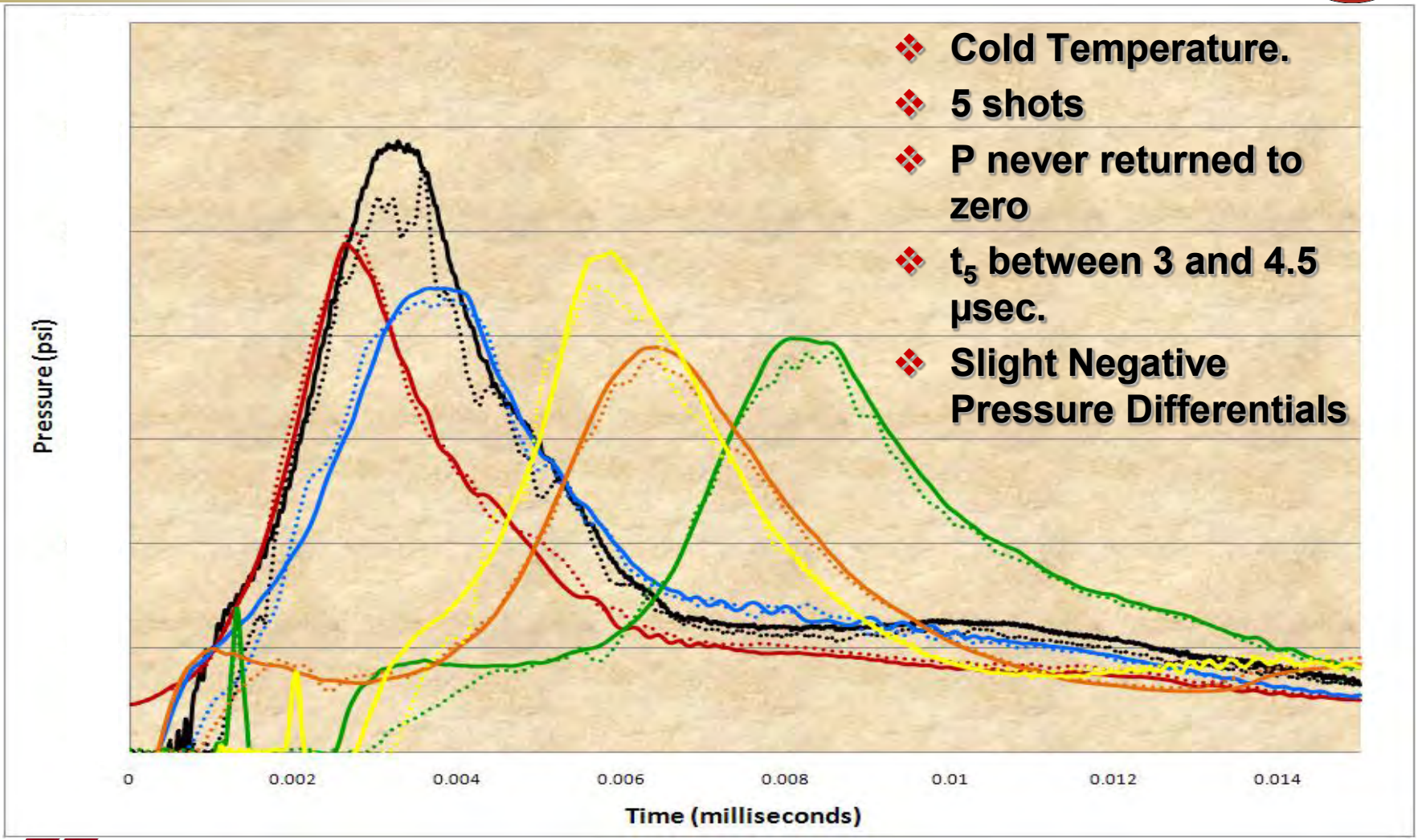
Benite at 63°C



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Benite at -32°C

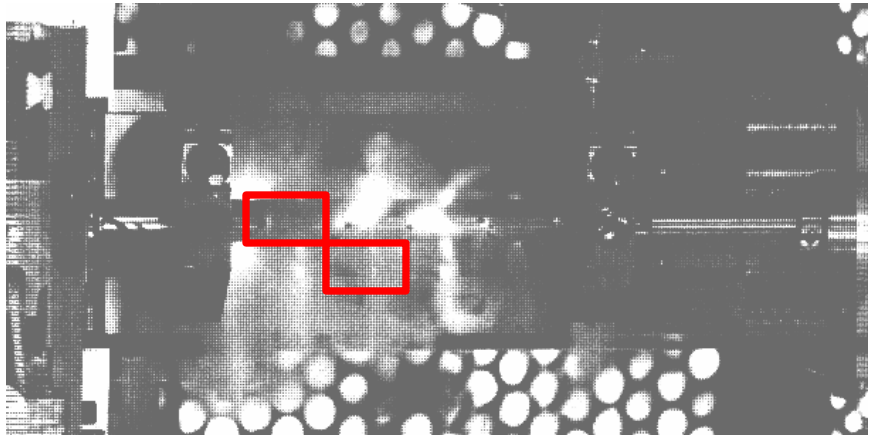


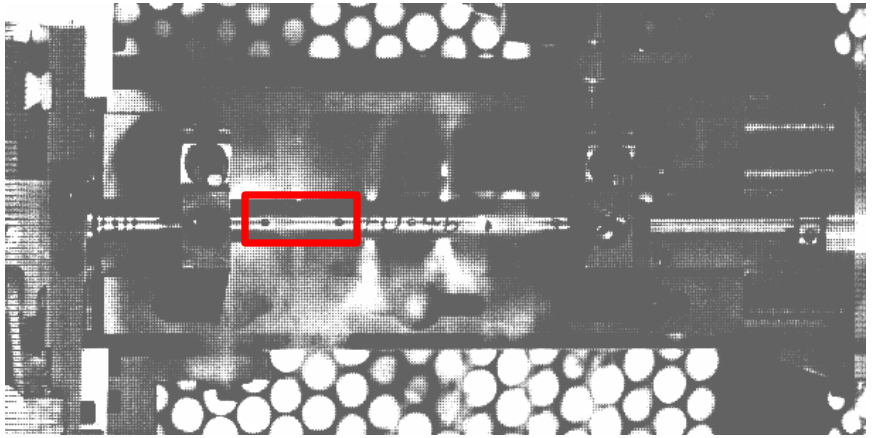
- Cold Temperature.
- 5 shots
- P never returned to zero
- t_5 between 3 and 4.5 µsec.
- Slight Negative Pressure Differentials

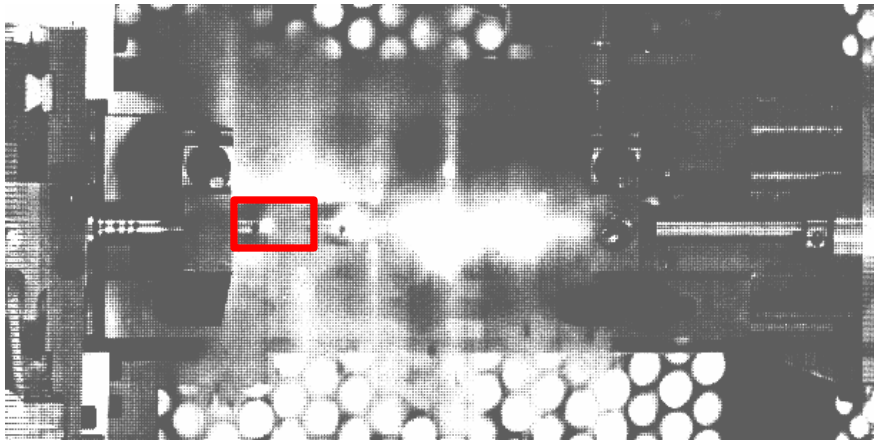
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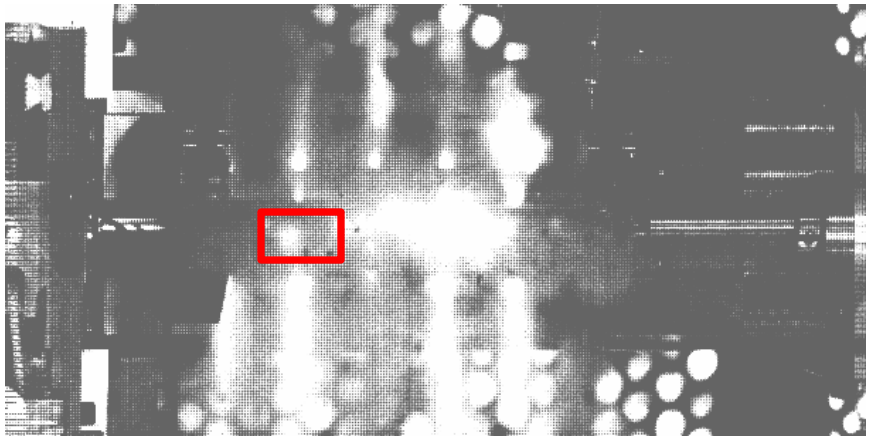
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High Speed Video Stills of Benite Igniter at Ambient Temperature





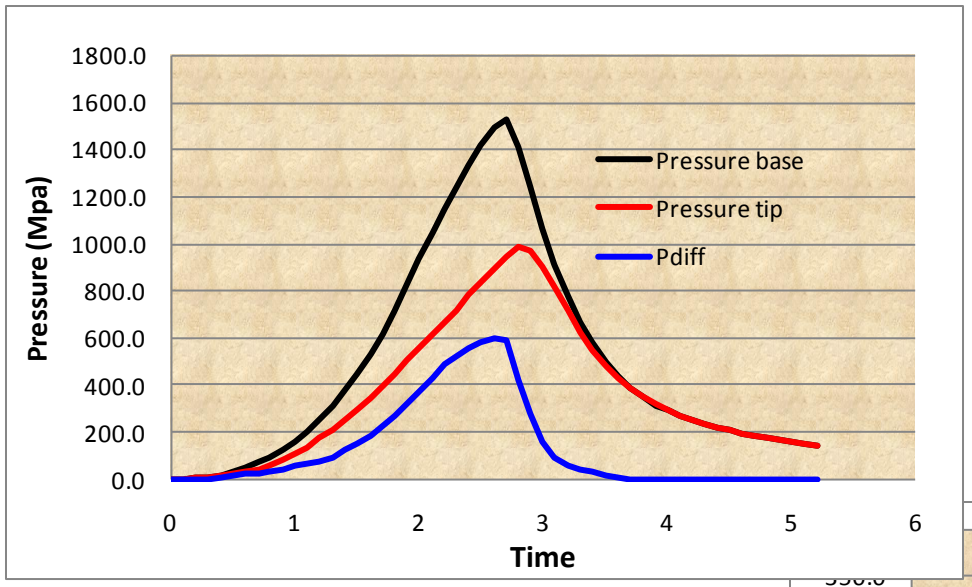




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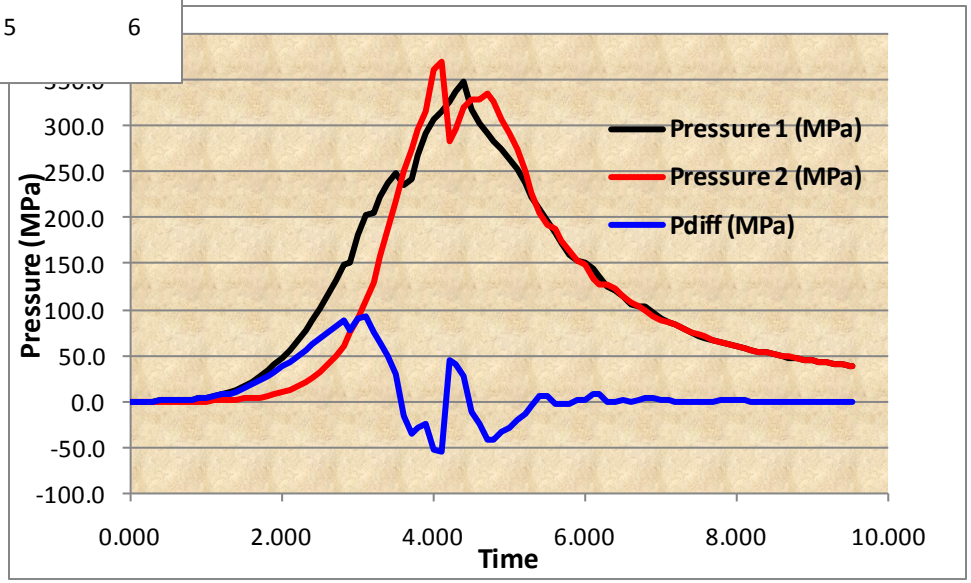
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FNGUN Analysis



- 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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Summary/Conclusions

- PAI-8556, 8557, and 8558 demonstrated excellent performance and reduced sensitivity characteristics.
- An adjustable igniter static test fire fixture was designed, built, and tested.
  - Benite was examined in this fixture and found to have significant shot to shot variability in terms of pressure and time, except at hot temperatures.
  - When $BKNO_3$ unsieved powder was examined in this fixture, it exhibited very consistent ignition delay and rise times, but did demonstrate the formation of pressure waves.
- Combustion of $BKNO_3$ was found to be very reliant upon oxygen balance, which itself is dependent upon the ratio of fuel to oxidizer.
- $BKNO_3$ analogues containing binder and other combustion enhancing additives were examined for their thermo-chemical properties and have been produced.

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Future Work

- Other commercially available $BKNO_3$ grains/pellets, namely IB, IIC, and IE, will be examined in the fixture.
- Convert the 125mm electrical igniter fixture to accept 105mm percussion ignition primers.
- The igniters that have been produced will be tested for their performance and further optimization of the formulations will be performed.
- Once the effects of the additives are ascertained, they will be employed in $BKNO_3$ analogues that do not employ any binder, and will be pelletized.
- PAI-8558 and PAI-8557 formulations are awaiting performance analysis in the Navy 40mm gun as well as fragment impact testing.
- To improve Benite's sensitivity, several formulations are being examined where the Binder is replaced with a more IM compliant binder.

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Contact Info

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- US Army ARDEC
- RDAR-MEE-W
- Propulsion Research & Engineering, Direct Fire Branch
- Picatinny, NJ 07806
- (973) 724-4535
- eugene.rozumov@us.army.

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ALWAYS ON target

National Defense Industrial Association Small Arms Symposium

Lightweight Small Caliber Ammunition

Lessons Learned from Prototype Fabrication to Full Production

George Feghali
Bill Dittrich
Mark Leng

May 2010

GENERAL DYNAMICS
Ordnance and Tactical Systems–Canada

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LSCA Programs

- Objective
- Partnership
- Concept
  - Concept Transfer
- Work Progress
- Manufacturing Process
- Manufacturing Challenges
- Risk Assessment
- Conclusion







Objective

To develop a functional alternatives for combat & training cartridges

- Offers a weight savings of 20%
- Meets current ballistic performance in unmodified weapon systems
- Manufactured using standard industrial techniques
- Assembled on conventional ammunition loading machinery
- Broadens the manufacturing base for military ammunition manufacturing
- Cartridge case produced and loaded at normal production rates





Partnership

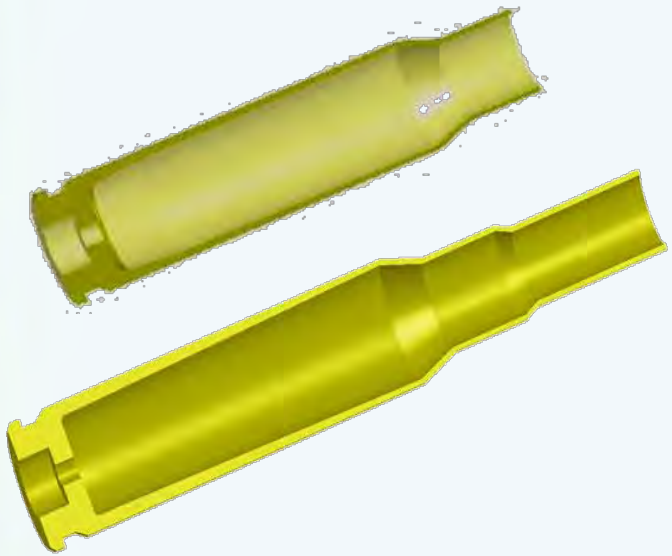
- **Fleximation** – Thin Wall Steel Concept
- **ARDEC** – Metallurgical Expertise & Computer Modeling and Simulation Capability



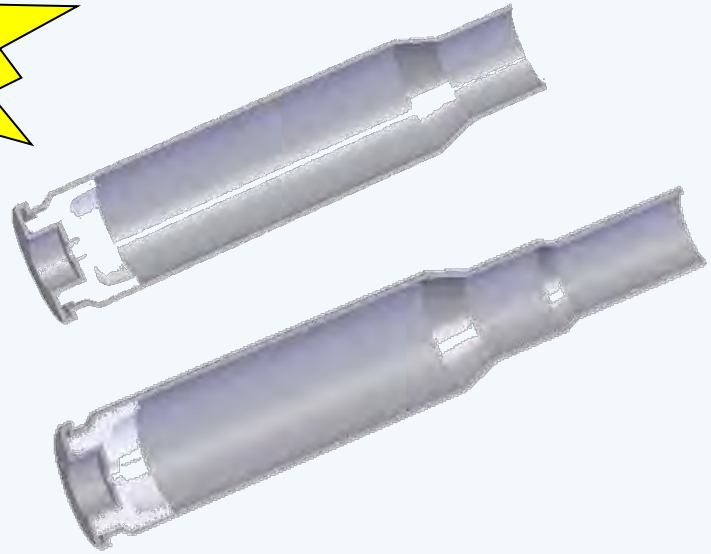
- **GD-OTS Canada** – Expertise in Ammunition Design & Production
  - **NATO test facility**
- **US Stamping Industry** – Expertise in Commercial Metal Stamping Processes

Concept – 7.62mm Ball

- Accomplished by thinwall steel replacing current brass case
  - Reproduces brass spring back
  - Capable of supporting ballistic pressure without splitting
- Aluminum plug is used in the base to provide structural support
  - Properties are suitable to accomplish component's functional requirements



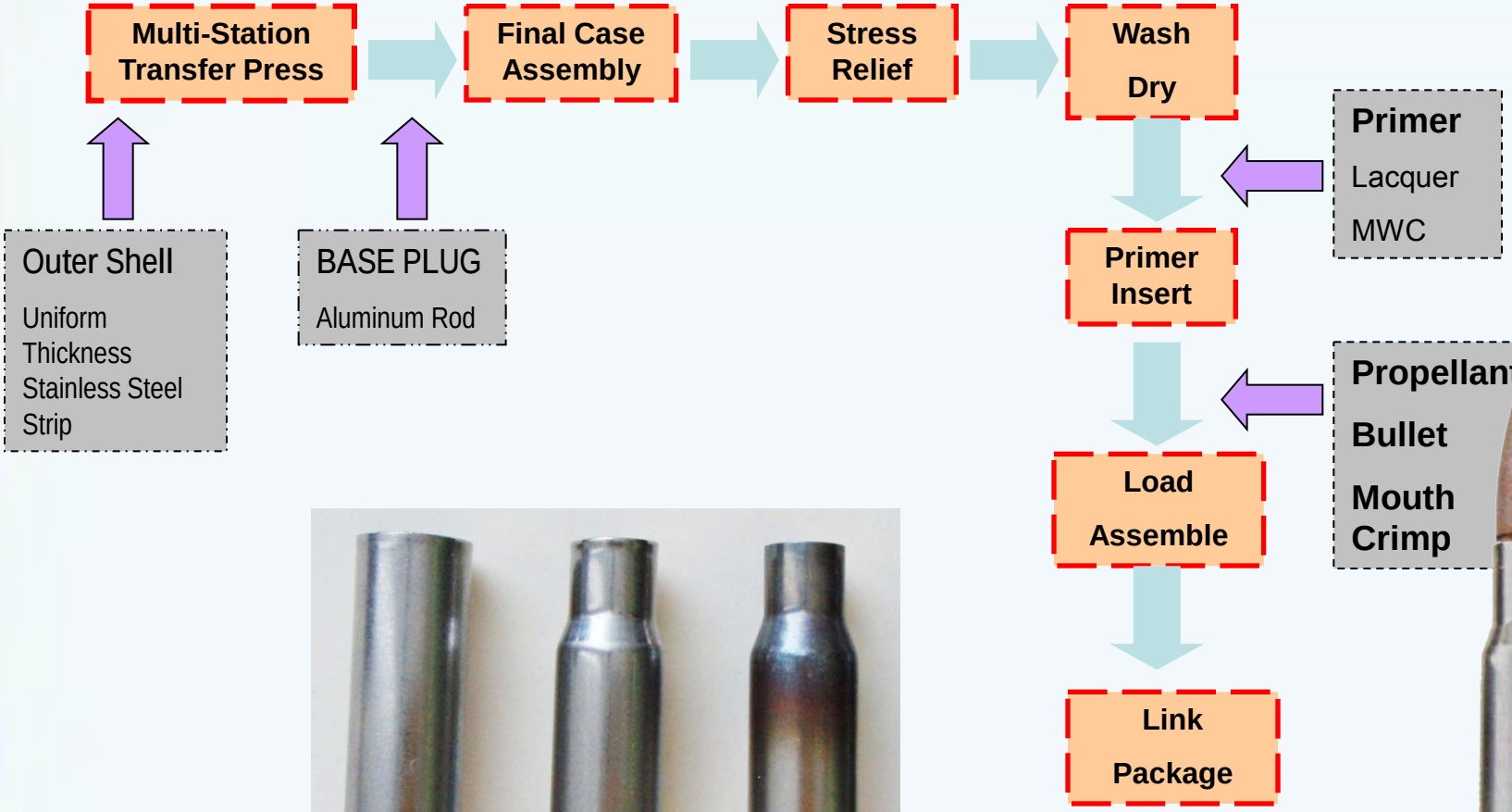




Work Progress

- Feasibility – Computer Modeling
- Phase 1 – Applied Research & Concept Demonstration (Ball and Tracer)
- Phase 2 – Development & Limited Production
- **Phase 3 – Pilot Production For Government Testing**
- **Develop other calibers / configurations**
  - 5.56mm and 7.62mm
  - Blank and Tracer Ammunition

Cartridge Manufacturing Process

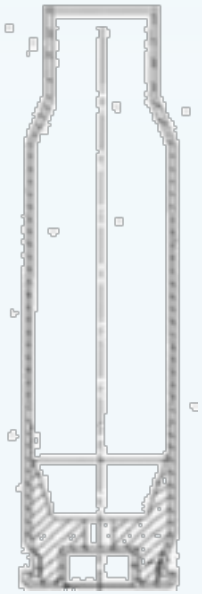






Manufacturing Challenges

(P) Failure Mode & Effects Analysis



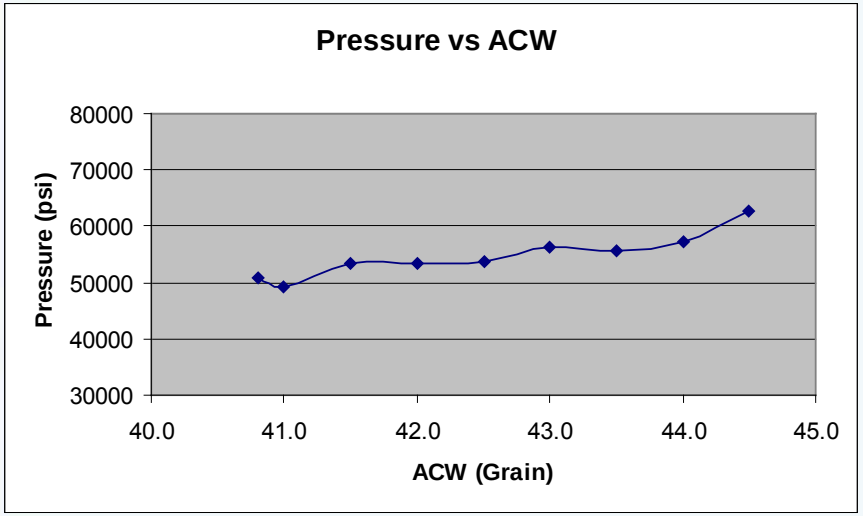
- **Manufacturing Challenges**
  - Raw Material Variations
  - Tool Wear
  - Trimmer Wear
  - Tooling Break-In
  - Cleaning Process
  - Cold Heading Aluminum Plug
  - Meeting DDI Requirement
  - Inspection & Manufacturing Controls

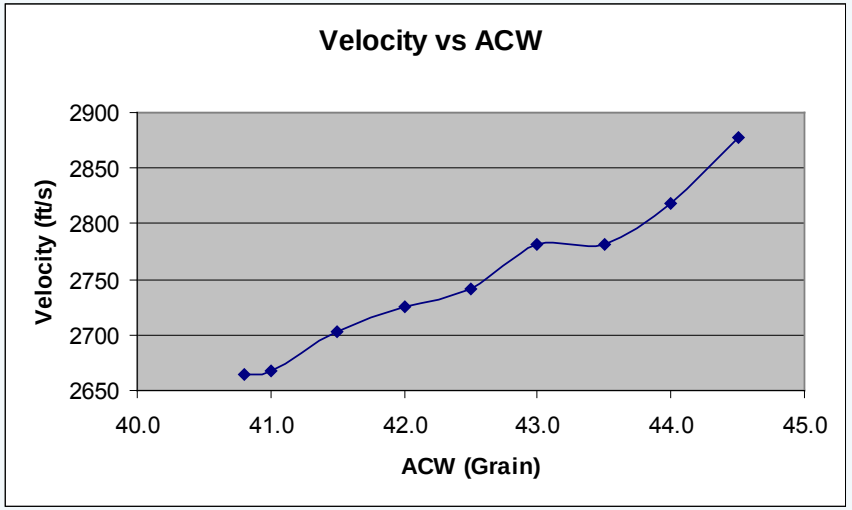


Risk Assessment

Risk Analysis

- Ensure that the product and the process are safe
  - EPVAT
  - Primer Sensitivity
  - Overpressure Test
  - Case Burst Effects





Conclusion

- **Accomplishments**
  - Weight reduction objective met
  - Demonstrated F&C with M240 Machinegun in Ball, Tracer & Blank configurations
  - Ballistic performance complies with MIL Specs
  - Compatible with standard cartridge components
  - Compatible with conventional loading equipment
  - Form, fit and function similar to brass-cased ammunition
  - Material cost advantage over brass alloy
  - Simplified manufacturing process steps



Further Information

GENERAL DYNAMICS
Ordnance and Tactical Systems–Canada

GD-OTS Canada	***Location***	***Phone Number***
George Feghali	Le Gardeur, Quebec	450-581-3080
Pierre Lemay (PM)	Le Gardeur, Quebec	450-582-6361

ARDEC (Picatinny Arsenal)	***Office***	***Phone Number***
Mark Leng (APO)	RDAR-MEM-I	973-724-5688
Lucian Sadowski (COR)	RDAR-WSW-F	973-724-2555
Audrey Shabazz (PMSW)	SFAE-CDR-CSW	973-724-6884



M1002

Development of a Solventless Propellant for use in 120 mm Tank Training Rounds

The National Defense Industrial Association's Joint Armaments Conference, Exhibition, & Firing Demonstration

19 May 2010

Dr. Shawn Osborn
Propellant Development Engineer
ATK Energetic Systems

Dr. Thelma Manning
U.S. Army TACOM-ARDEC Picatinny Arsenal



M865

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10



Outline

M14 Replacement in 120 mm Tank Training Rounds

- Program Summary
- Background
- Program Requirements
- Solventless Propellant Production Process
- Previous Accomplishments with PAP8386 Propellant
- Current M14 Replacement Approach
  - DEGDN-free PAP8386
  - Modified PAP8386
- Formulations and Closed Bomb results for DEGDN-free PAP8386
- Future Work
- Conclusions

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Program Summary

- **Sponsor: PM MAS**
- **Customer: JMC/ARDEC**
  - **End User (Army and USMC)**
- **Funding Source: Army and USMC**
- **Contracts:**
  - **JMC → ATK AW → ATK ES**
- **Objective: Per request of PM Large Caliber Ammunition, develop a solventless propellant that meets the M865 and M1002 ballistic requirements, and can be used with the suite of 120 mm future rounds**
  - **Optimize solventless formulation**
  - **Optimize propellant web**
  - **Demonstrate desired ballistics of M14 replacement propellant**

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Background

M14 Propellant Characteristics

Ingredient, wt. %	M14
NC, 13.15% N	90.0 2.0
DNT	8.0 2.0
DBP	2.0 1.0
DPA (added)	1.05 0.15
Graphite (added)	0.06 0.04
Residual Solvent	0.7 Max
Moisture	0.6 0.2
Flame Temp., [K]	2774
Force, [J/g]	995
Abs. Density, [g/cc]	1.60



M865 TPCSDS-T

Projectile Weight = 5.50 kg
MV (21 C) = 1700 20 m/s
MV (52 C) = 1740 20 m/s
MV (-32 C) = 1620 30 m/s
Pressure (63 C) <= 5900 bars
M14 Charge Weight = 7.2 kg



M1002 MPAT-TP-T

Projectile Weight = 10.55 kg
MV (21 C) = 1375 10 m/s
MV (52 C) = 1404 10 m/s
MV (-32 C) = 1335 10 m/s
Pressure (63 C) <= 6400 bars
M14 Charge Weight = 7.6 kg

M14 Propellant Drawbacks

- Damaged cartridges may vent residual solvent (diethyl ether)
- DNT, DBP and DPA are environmentally undesirable
- IM Properties poor compared with tactical ammunition

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Program Objectives

1. Eliminate (or reduce) residual solvents.
2. Meet existing ballistic requirements for the M865 and M1002.
   - **Min. M1002 velocity** at -32 C
   - **Meet velocity tolerance** from -32 C to +52 C
   - **Average max. pressure** at +63 C at least 3 Std Dev. below the fatigue limit of the M256 gun tube (7000 bars)
   - **Meet negative delta p requirements** of ITOP 4-2-504(2) and not affect safety or structural integrity
   - **Meet ballistic requirements** per DTL 14000022
3. IM standards equivalent or better for each round.
4. Affordable solution relative to existing M14 costs.
5. Environmentally friendly formulation and process.
6. Producible at the quantities required to meet near term cartridge needs.
7. Propellant compatible with existing cartridge materials.
8. Propellant shall not negatively impact barrel/gun tube life.
9. Propellant storage life and hazard classification meet existing requirements.

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Solventless Propellant Manufacturing Process

A premier aerospace and defense company

Solventless process eliminates risk of damaged cartridge venting ether



Solventless propellant manufacturing process at the Radford Army Ammunition Plant

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Previous Work With PAP8386 Propellant



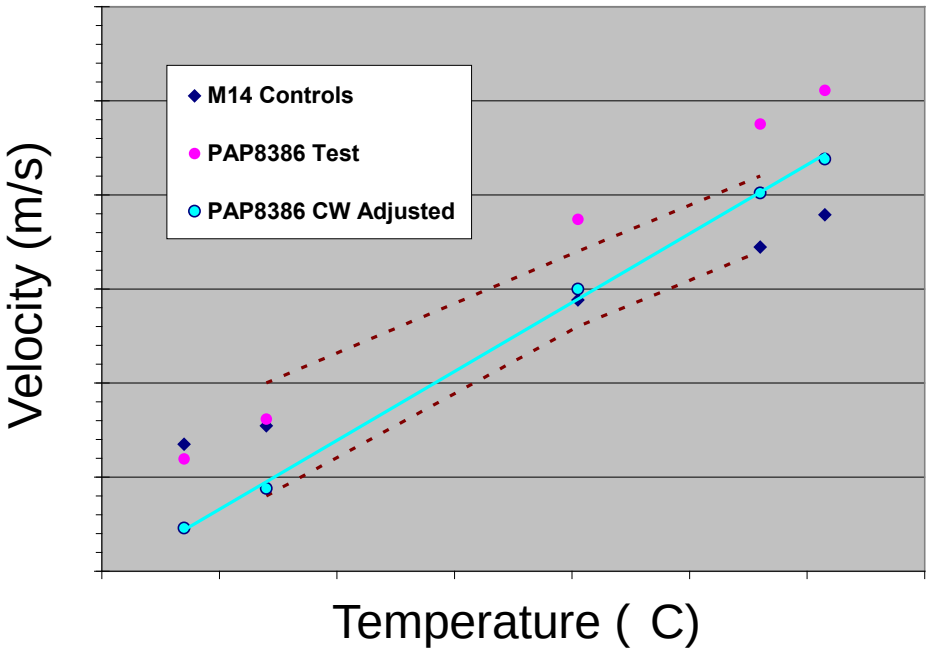
Thermochemical Parameter	Value
Flame Temperature, [K]	2948
Force, [J/g]	1063.6
Gas Molecular Weight, [g/gmol]	23.049
Covolume, [cc/g]	1.042
Frozen Gamma	1.244

- **Solventless Manufacture**
  - Completely Eliminates Potential of Solvent Vapor Ignition Within Round
- **Material Properties Similar to JA2**
  - Improved Impact Sensitivity
- **Environmentally-Friendly Formulation**
  - Eliminates DNT, DPA, DBP, and all VOC's
- **Same Ingredients as JA2 and RPD-380**
  - Compatible with existing systems
  - 1.3c Hazard Classification
  - Similar Storage Life
- **Flame Temperature < 3000 K**
  - Low barrel Erosion

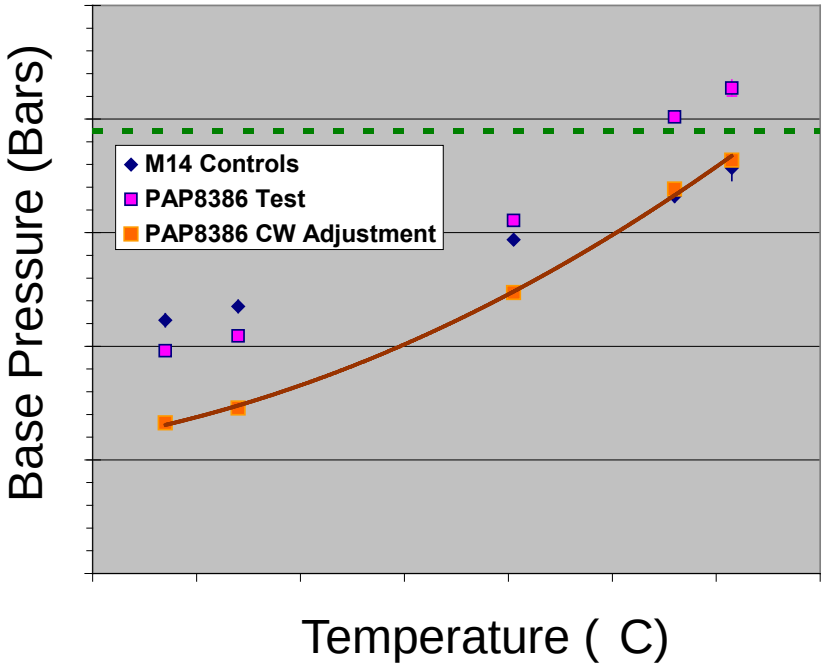
Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

M865 Performance Using PAP8386 Propellant

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PAP8386 met M865 performance requirements for muzzle velocity

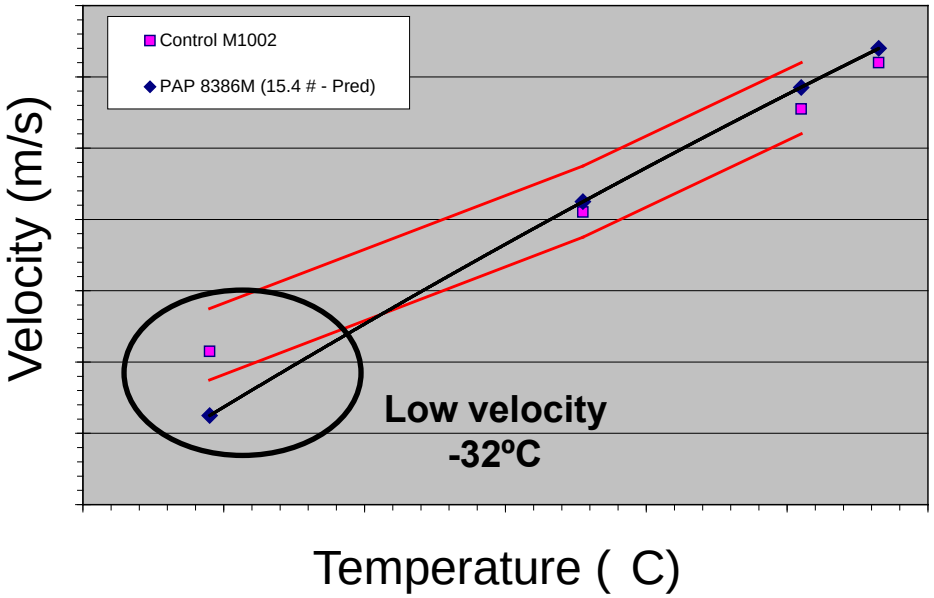


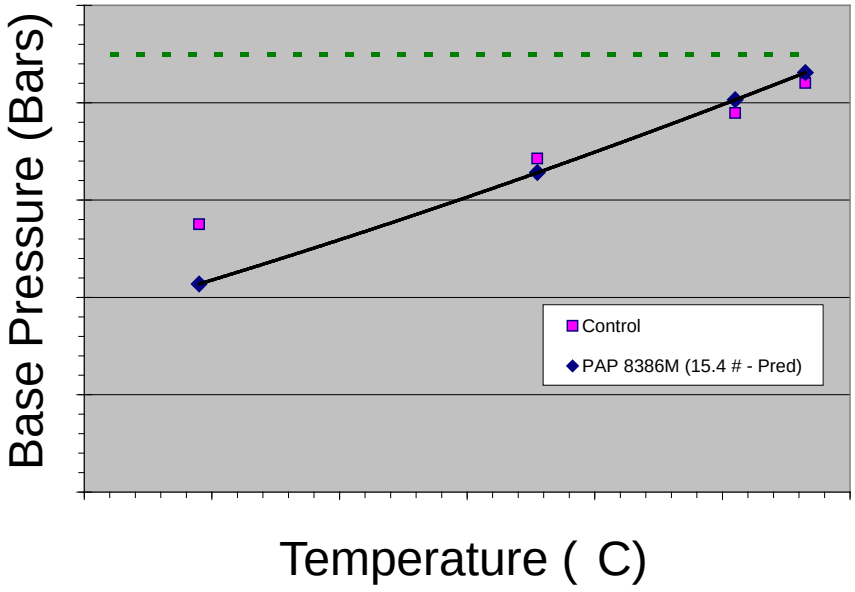
PAP8386 peak pressure is comparable to existing round

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

M1002 Performance Using PAP8386 Propellant

A premier aerospace and defense company





Muzzle velocity falls just below the performance window at -32 C. Further optimization is necessary.

PAP8386 pressure levels are equivalent to existing round

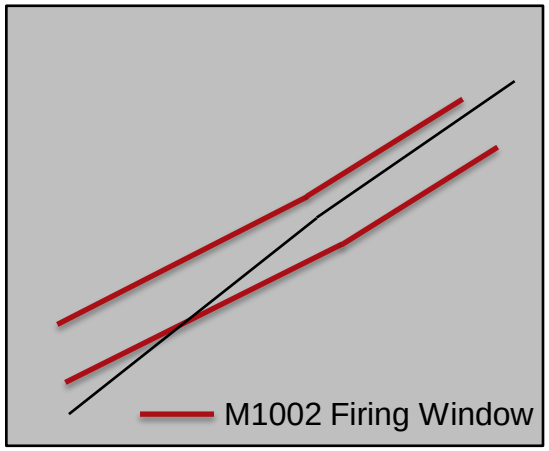
Results Shown are Predicted 15.4 lb Charge Weight Adjusted Based on February 2006 Firing Data At Aberdeen Test Center with a 15.6 lbs

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Dual path

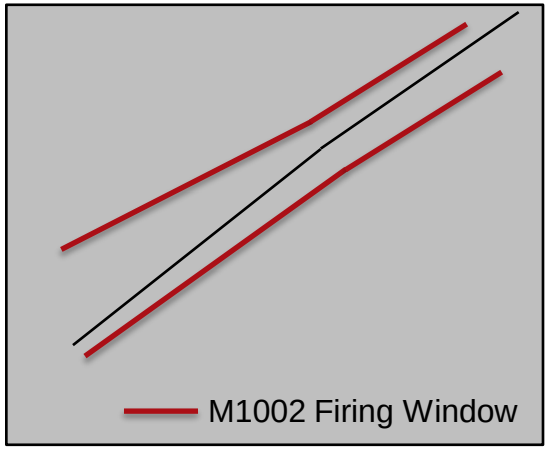
- **Preferred Path -- Replace DEGDN in PAP8386**
  - ✓ Higher technical risk, lower potential per pound cost for formulation
- **Alternate Path -- Build on previous PAP8386 work**
  - ✓ Lower technical risk, higher potential cost per pound for formulation (but less expensive than original PAP8386)
  - ✓ May require a change to the firing tables

Previous Work



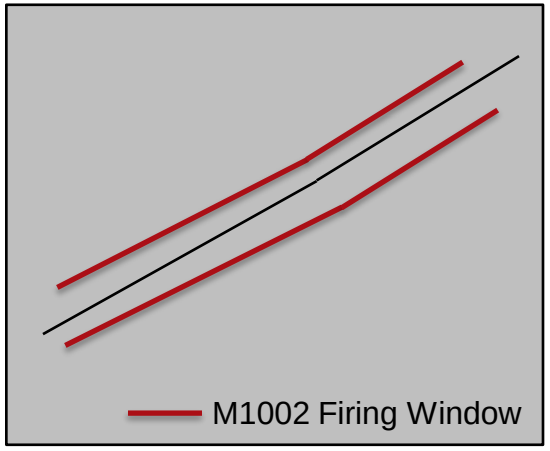
Original PAP8386

Alternate Path



Shift firing table to meet PAP8386 ballistics

Preferred Path



Novel inert plasticizer to manipulate propellant ballistics

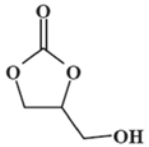
Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Preferred Path to M14 Replacement

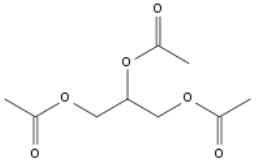
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- **Replacing DEGDN in PAP8386**
  - Combination of NG and inert plasticizer to mimic ballistic potential of PAP8386
  - Inert plasticizers chosen based on literature as well as melting point, boiling point, density, and solubility

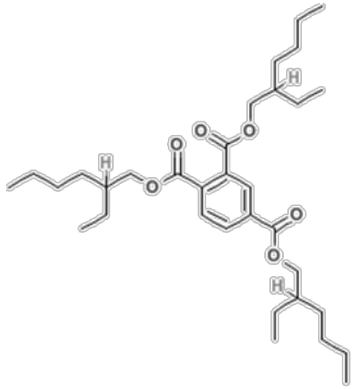
Inert Plasticizers



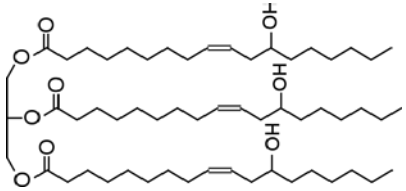
Glycerol Carbonate



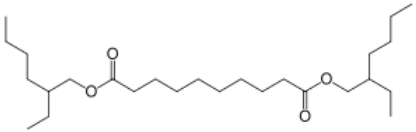
Triacetin



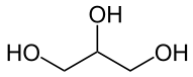
Trioctyl Trimellitate (TOTM)



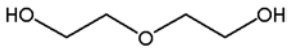
Castor Oil



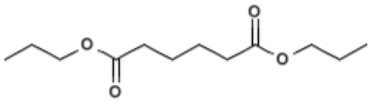
Dioctyl Sebacate (DOS)



Glycerol



Diethylene Glycol



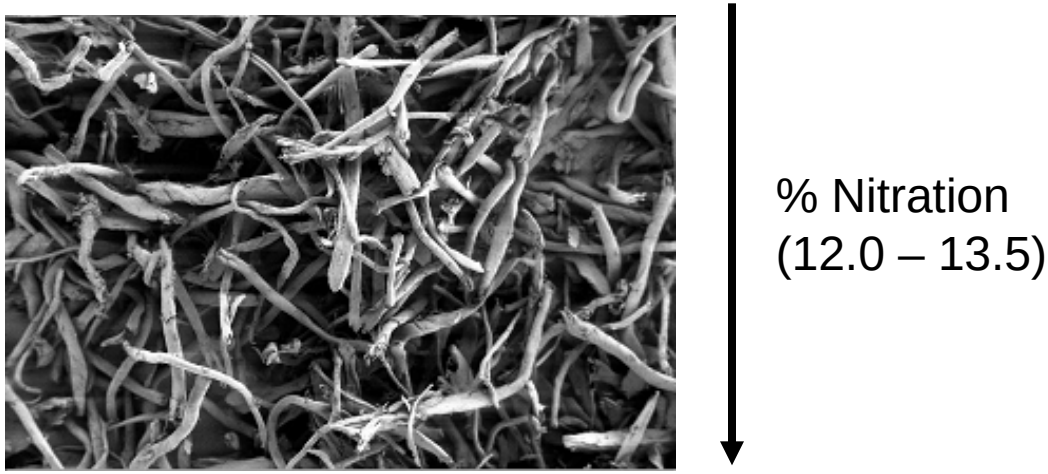
Dipropyl Adipate (DnPA)

Inert Plasticizer	Melting Point (°C)	Boiling Point (°C)	Density (g/cc)	Solubility in Water
Castor Oil	-14	313	0.958	insoluble
Diethylene Glycol (DEG)	-10	245	1.118	soluble
Di n-Propyl Adipate (DnPA)	-15	273	0.975	insoluble
Dioctyl Sebacate (DOS)	-48	256	0.910	insoluble
Glycerol	18	290	1.261	soluble
Glycerol Carbonate	-69	105	1.400	1-10% in water
Glycerol Triacetate (Triacetin)	-78	259	1.155	6% in water
Trioctyl trimellitate (TOTM)	-50	414	0.989	insoluble

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Preferred Path to M14 Replacement

- **Replacing Lint NC in PAP8386**
  - Utilizing wood pulp NC for affordability and possible processing benefits
  - Various NC nitration combinations (influences processability and mechanical properties)



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Evaluation 1 – Replacing DEGDN in PAP8386

11 Formulations (NG and inert plasticizer to replace DEGDN)

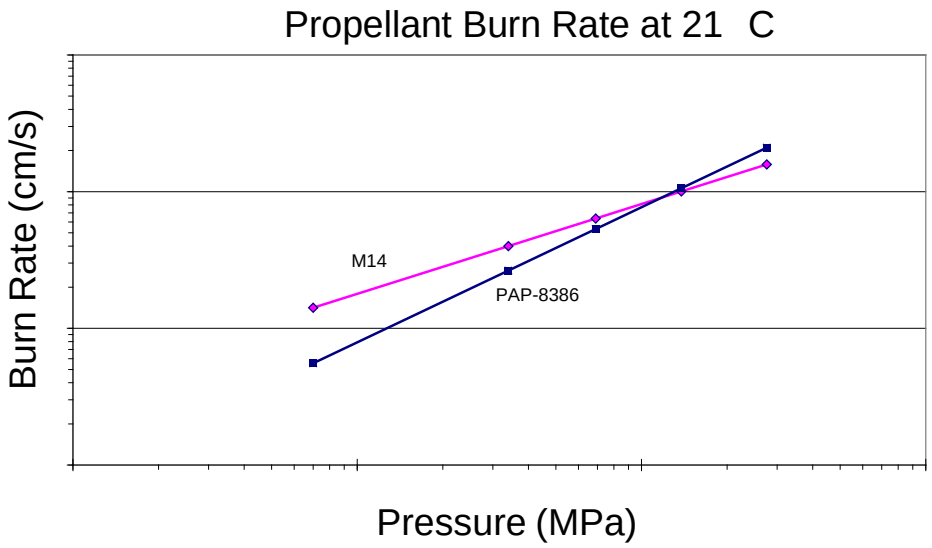
- 7 processed, 4 did not process
- Formulated to PAP8386 ballistic potential
- Formulated toward a desired plasticizer/binder ratio
- High level of success processing various types of nitrocellulose
  - Wood pulp and cotton linters (12.0 – 13.5 %N)
- Two plasticizers processed well
- Four plasticizers yielded unprocessable propellant sheets
- Completed closed bomb analysis on sheetstock of successful formulations

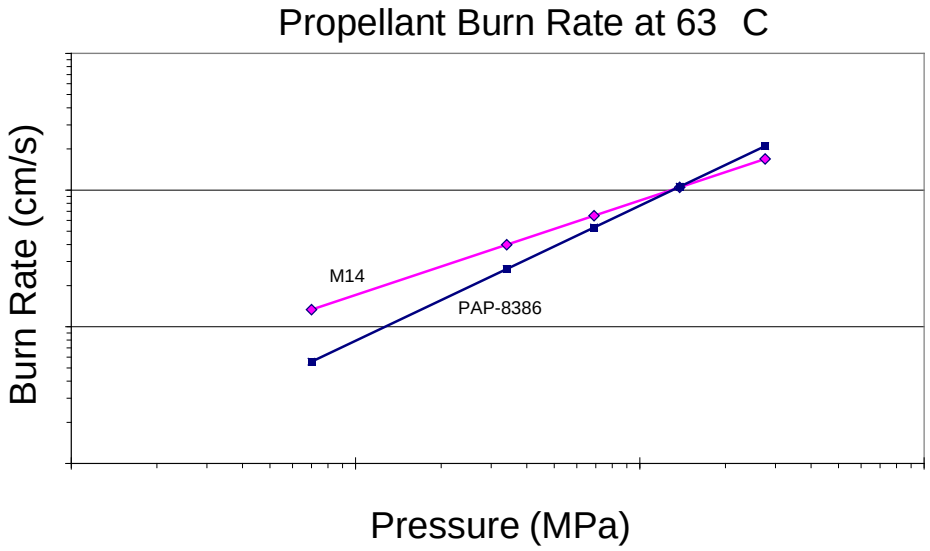
Successfully processed alternative to PAP8386 propellant

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

M14 and PAP8386 Propellant Burn Rate Behavior

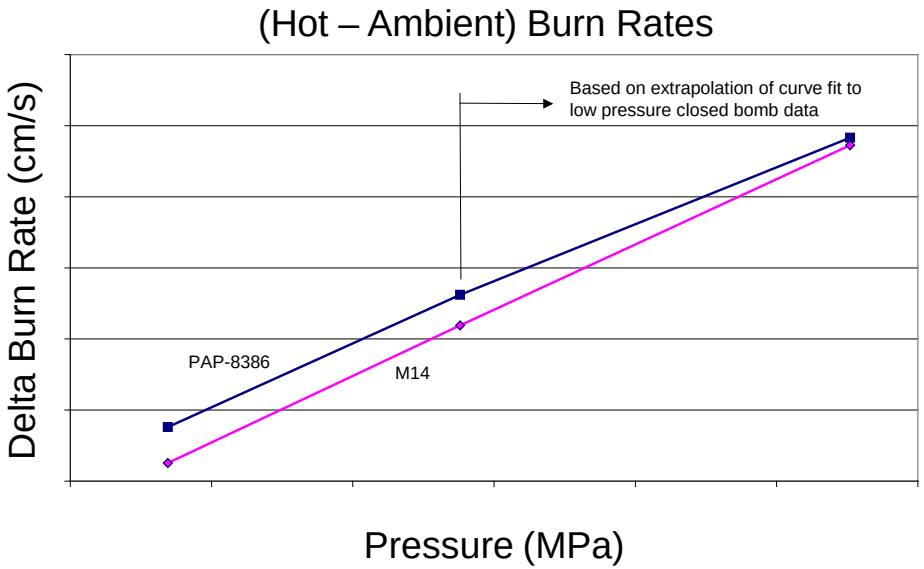
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PAP-8386 burn rate pressure coefficient (B) higher than M14

$$b_r = B(P)^n$$

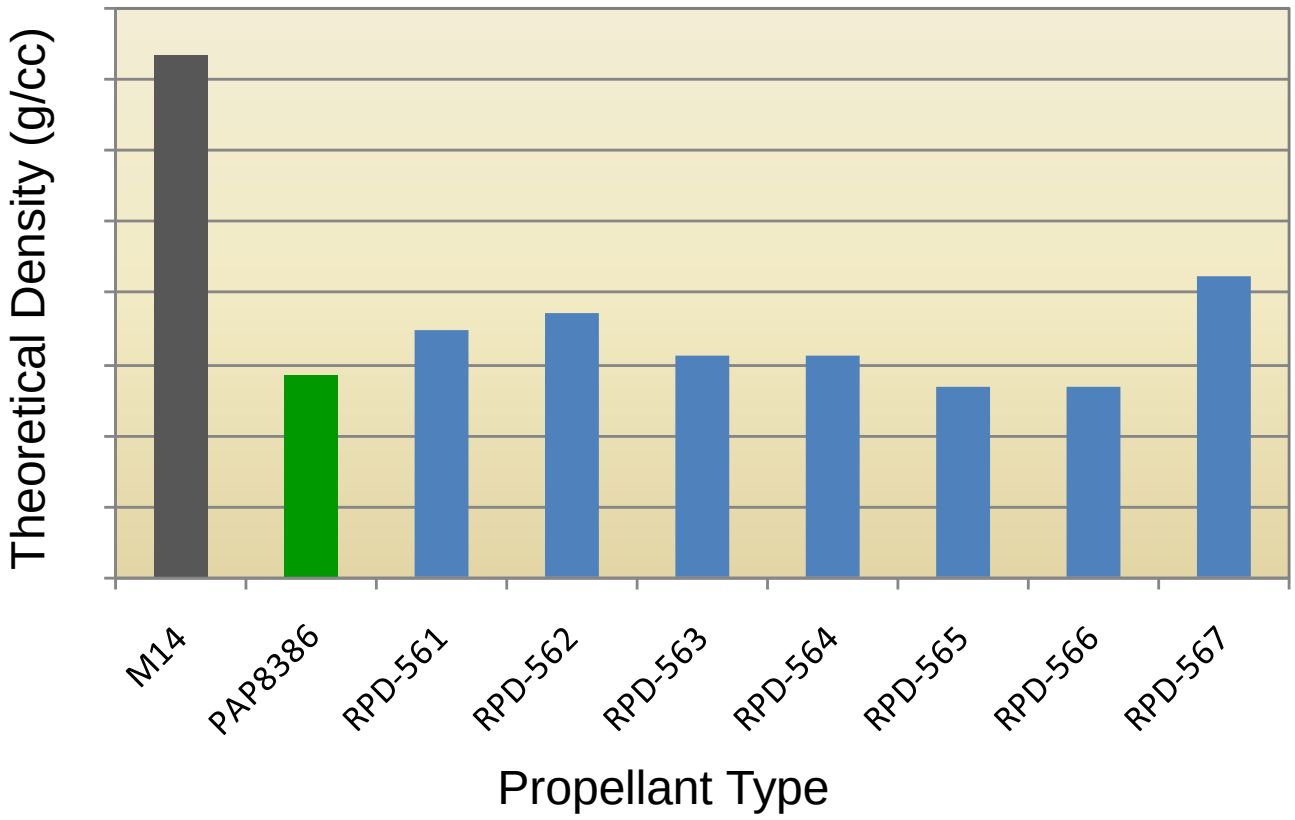


Cold M14 Data not available

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Theoretical Density of M14 Replacement Propellants

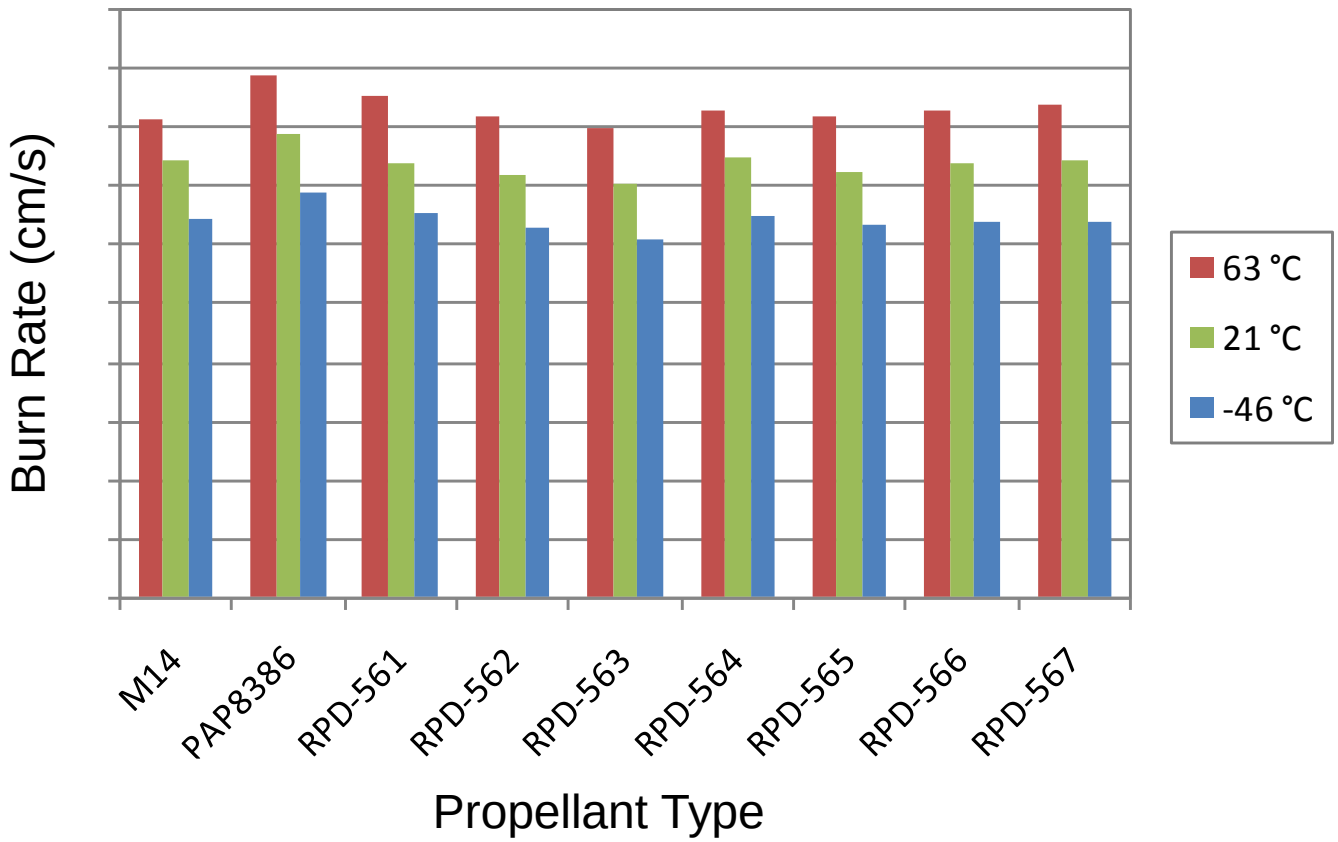
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- Solventless propellants exhibit lower theoretical densities
  - Most inert and energetic plasticizers are less dense than Nitrocellulose
  - More plasticizers are necessary to process solventless propellant

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Propellant Burn Rate at 200 MPa

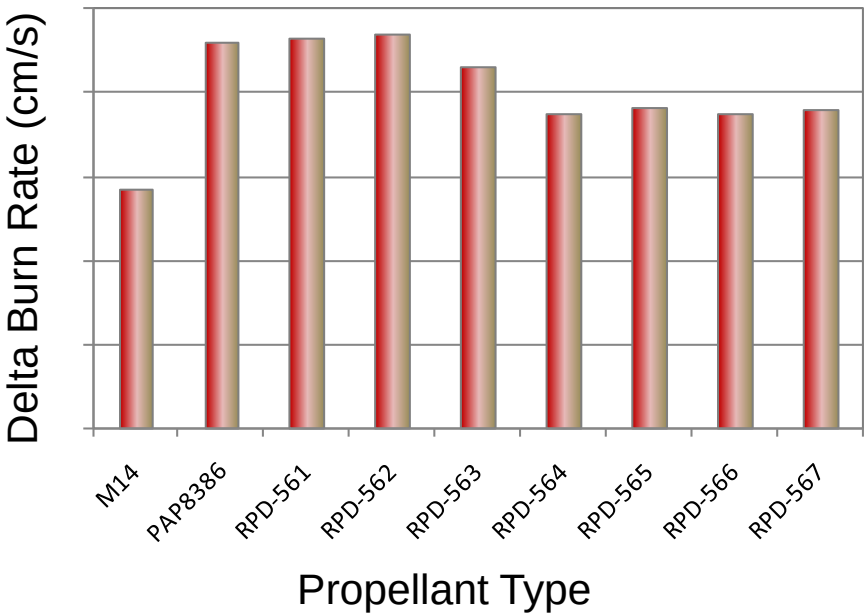


- RPD-561 through 567 have similar burn rates to PAP8386
  - Changes to the final grain geometry would be necessary to reach or exceed PAP8386 burn rates
  - 120 mm gun data is essential in determining the optimal propellant formulation

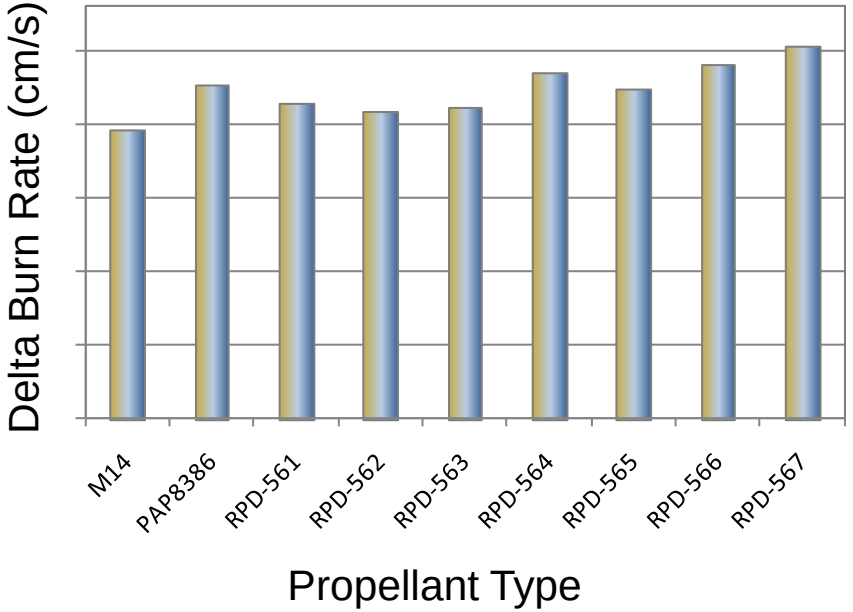
Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Temperature Sensitivity of M14 Replacement Propellants

(Hot – Ambient) Burn Rates at 200 MPa



(Ambient – Cold) Burn Rates at 200 MPa



- Temperature sensitivities are similar between all propellants
  - RPD-561 through 567 could be feasible PAP8386 replacements

Change in burn rates between temperatures is higher than M14 propellant

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Evaluation 2 – Replacing DEGDN in PAP8386

14 Formulations (NG and inert plasticizer to replace DEGDN)

- Formulated to PAP8386 ballistic potential
- Examined processing NC at various nitration levels (11.95-13.15 %N)
- Formulated with a fixed plasticizer/binder ratio
  - Lower ratio to aide processing of inert plasticizers
- 1 processed, 13 did not process
- One plasticizer processed acceptable propellant sheets
- Five plasticizers yielded unprocessable propellant sheets
- Awaiting closed bomb analysis on sheetstock of successful formulation

Plasticizer/binder ratio plays a significant role during processing

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Conclusions and Future Work

Conclusions

- Examined various novel inert plasticizers for solventless propellant development
- Successfully developed a cost effective version of PAP8386
  - Closed bomb results indicate propellants with similar burn rate characteristics

Technical Risks

- Meeting M1002 minimum velocity at -32 C
- Exceeding M1002 pressure requirement at 63 C
- High pressure cold due to propellant breakup

Future Work

- Perform additional evaluations
- Downselect two propellants for ballistic testing
- Charge establishment and charge verification
- Initial ballistic evaluation of M865 and M1002 rounds
- Propellant web optimization study
- Ballistic test of final propellant at temperature extremes



Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

Acknowledgements

- **The authors would like to thank the following:**
  - PM MAS for funding
  - Major Patrick Baker for presentation comments and suggestions
  - ATK - Advanced Weapons for technical input and assistance
  - Jeremy Smith, Curtis Rupe, Jim Wedwick, and Dr. Steve Ritchie of ATK – Energetic Systems for assistance in propellant manufacture

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 502-10

QUESTIONS???

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Principal Engineer – M14 Replacement

ATK– Energetic Systems

540-639-8690

shawn.osborn@atk.com





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Unique Partnership to Provide Precision and Lethality to Tomorrows Warfighter



Teaming for Performance

US Army, Alliant Techsystems and Rheinmetall Nitrochemie

2010 Joint Armaments Conference
Guns and Missile Systems - 17-20 May 2010
Presenter: Kelly Brown Moran kelly.moran@atk.com

ATK

RHEINMETALL NITROCHEMIE

Bringing Advanced Propellants to the US DOD Market

A premier aerospace and defense company

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 largest propellant production facility











Advanced Products – Plan to Transition

A premier aerospace and defense company

Manufacturing License provides the exclusive ability to transition production of the following advanced propelling solutions: EI, ECL, SCDB, R-Type and Combustible Cartridge Cases

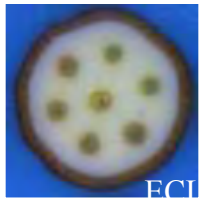
EI







ECL









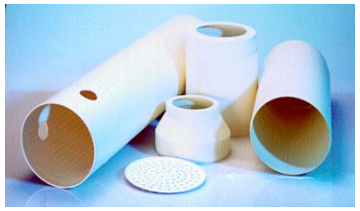


SCDB



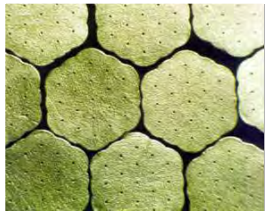


CCC





R Type







Current Projects with DOD

120mm Mortar Extended Range + Igniter Improvements

- Lead by Howard Shimm, ARDEC, Picatinny Arsenal
- Demonstrated range to 8.2 km; currently demonstrating non-NG igniter

XM350 – Combining the M67 and M200 charges into single charge round

- Lead by Nguyen Tran, ARDEC, Picatinny Arsenal
- Combining the M67 & M200 systems into single cartridge

LW30 Qualification Program

- Lead by Andy Lewis, PM MAS, Picatinny Arsenal
- Demonstration and Qualification of Improved LW30 propellant

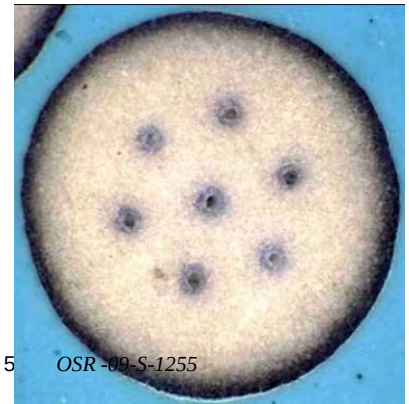
Next Generation 120mm Tactical Tank

- Lead by ATK – Advanced Weapons
- Demonstration of flat temperature response in the 120mm tactical tank

Advantages of ECL Across All Systems

A premier aerospace and defense company

Improved Characteristic's of ECL®	Translates to…
High energy density formulations High thermal conversion Tuneable performance and force	Improved ballistic performance and efficiency Flat, tuneable ballistic profile across temperatures Improved dispersion, repeatability
No mobile plasticizers, non-nitrogylcerin	No migration of NG into cases Improved system compatability Improved safety during manufacture
Enhananced IM properties	Higher cook off temps - improved crew survival Less sensitive/no reaction to impact
Non-toxic, "green" formulation	Better for the environment Better for the user/manufacturer
Chemical stability Ballistic stability	Ammunition can be deployed to extreme climates with no degredation in performance Longer service life for ammunition







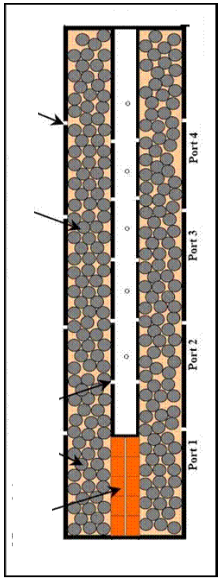


Future Path of Mortar Propellants – Synergy of System

Requirements for Future Fight Scenarios:

Mortars are becoming the weapon of choice due to mobility

- **Ability to compensate for heavier projectiles**
  - ➢ **ECL® provides energy density necessary for precision guided rounds**
- **Potential for extension of battle space ranges**
  - ➢ **ECL® has the potential to extend range out to 12 km**
- **Reduction in number of rounds fired to eliminate target**
  - ➢ **ECL® demonstrates consistent ballistics & improved dispersion**
- **Safe use / storage in hot climatic zones + no NG, no toxic ingred**
  - ➢ **ECL® provides reduced life cycle costs, reduced demil costs**
  - ➢ **Ideal candidate for improved celluloid cases**







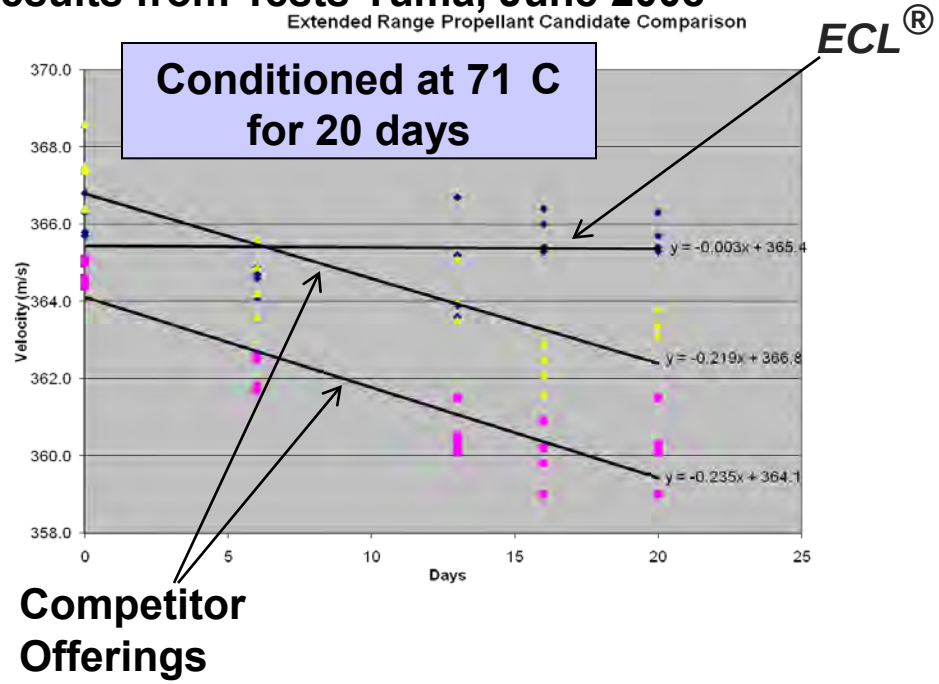


ECL® Propellant Demonstrates Stability and Range

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ECL® ➢ Excellent Ballistic Stability and Performance

Results from Tests Yuma, June 2008



ECL®	+70 F	+145 F
Velocity	8190 m	8460 m
ToF	43.9 s	44.8 s
Pressure	14.4 kpsi	17.1 kpsi
Range	8.2 km	8.5 km

- ECL® exhibits *NO CHANGE* in velocity compared to competitors
- Provides *CONSISTENT BALLISTICS* after hot temperature storage

- 8.2 km range achieved with 80% bulk fill of case
- Perfect candidate for future extended range mortar solutions

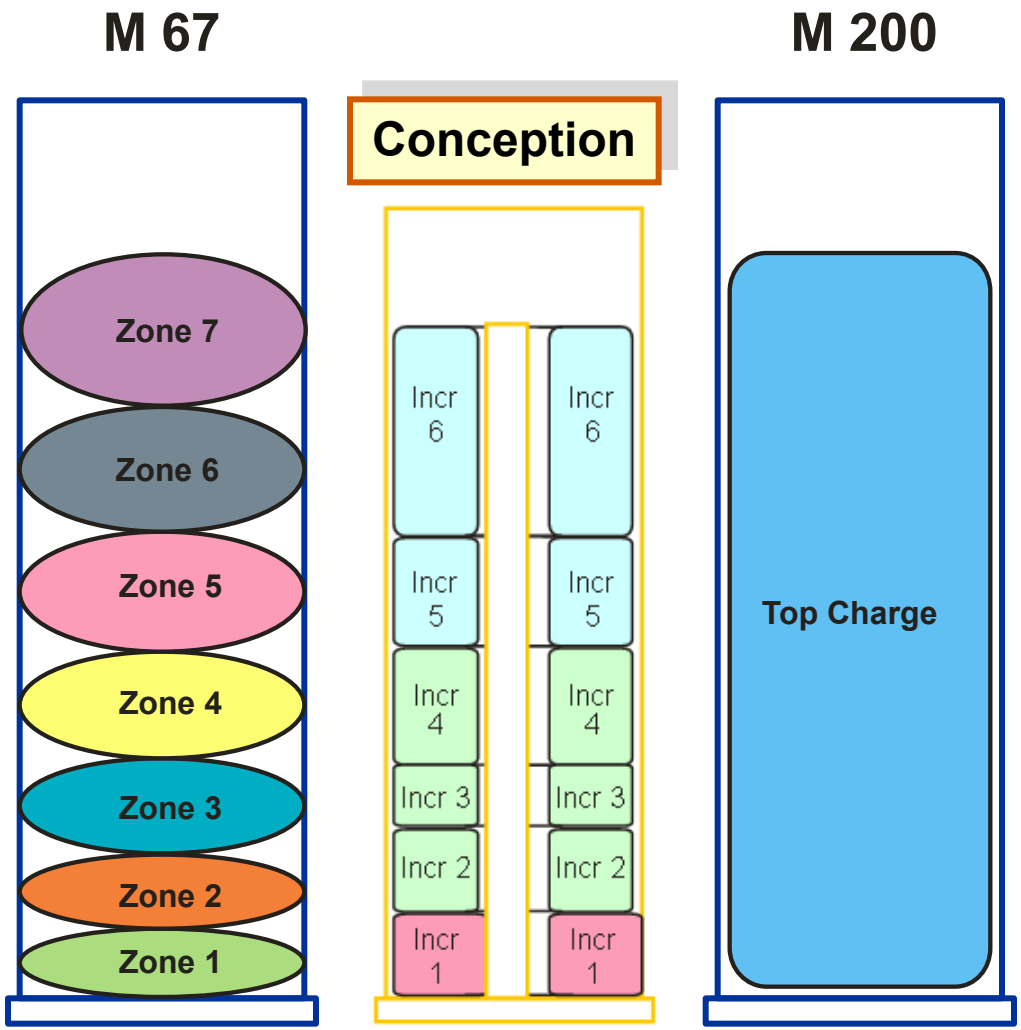
XM350 – Concept 2009

A premier aerospace and defense company

Gun
- M119A2

Propellant
- M1 (DNT, DBP, DPA)

Range
- 11,5 km

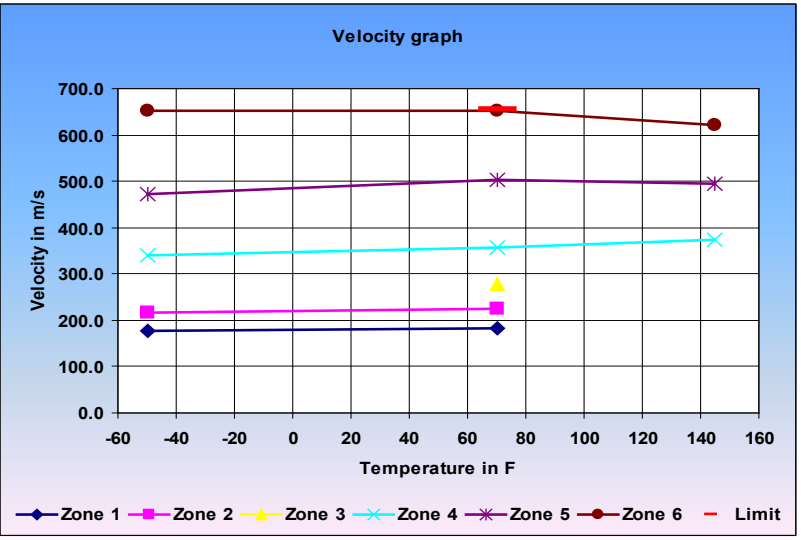


Gun
- M119A2

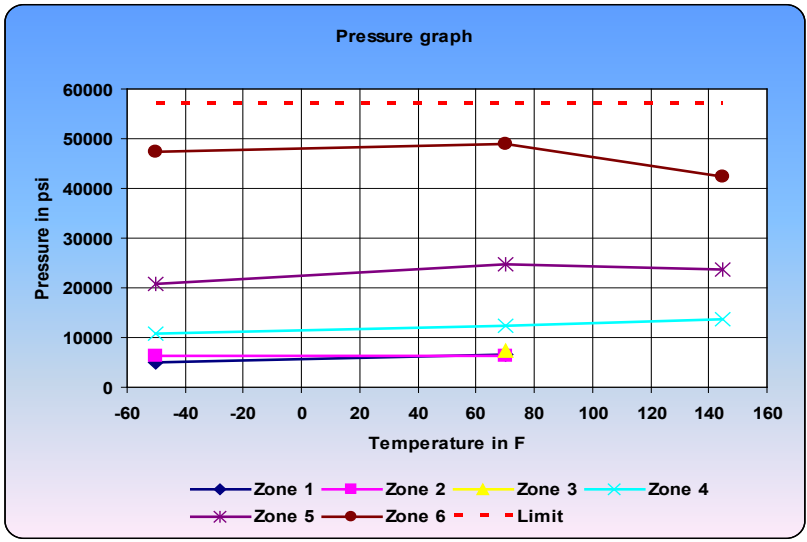
Propellant
- M30 (NG, NQN)

Range
- 14 km

Results of Velocity Measurements – Yuma PG



Zone	Goal	Actual
1	185	190
2	225	225
3	279	280
4	353	355
5	498	500
6	656	652



Highest pressure at ambient, pressure drop at hot!

Future Efforts include:

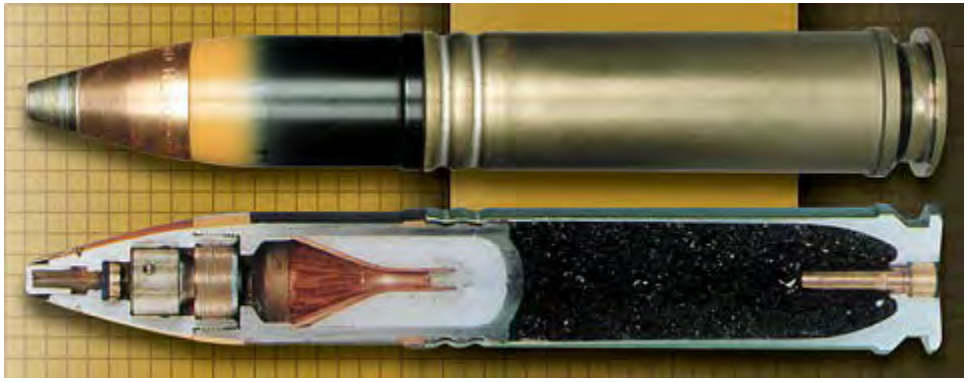
- Modelling of propellant design (coating and process parameters)
- Slight correction of temperature behaviour for highest zone
- Evaluate advantages of a 7 Zone solution
- Work towards Qualification Program

Failures in Field Lead to New Propellant Qual

Current LW-30 Ammunition Family

- M789 HEDP/ M788 TP
- Fired from the M230 on the AH-64 Apache
- Propulsion: PA520 primer + 3 FT pellets + WC 855 BALL POWDER®





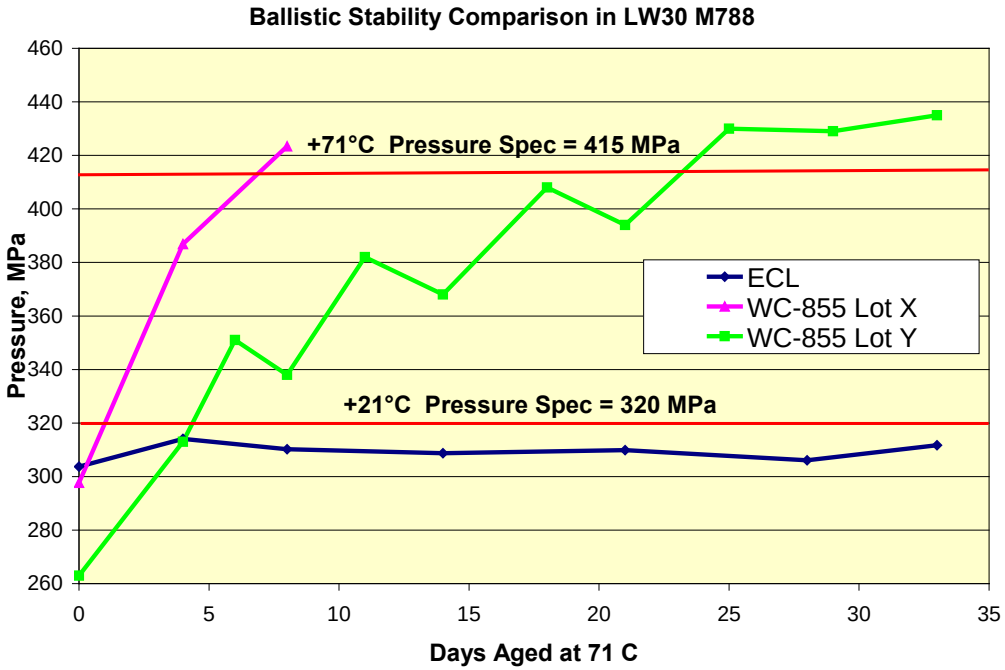
Investigation identified propulsion system weaknesses as one root cause for hang fire signature

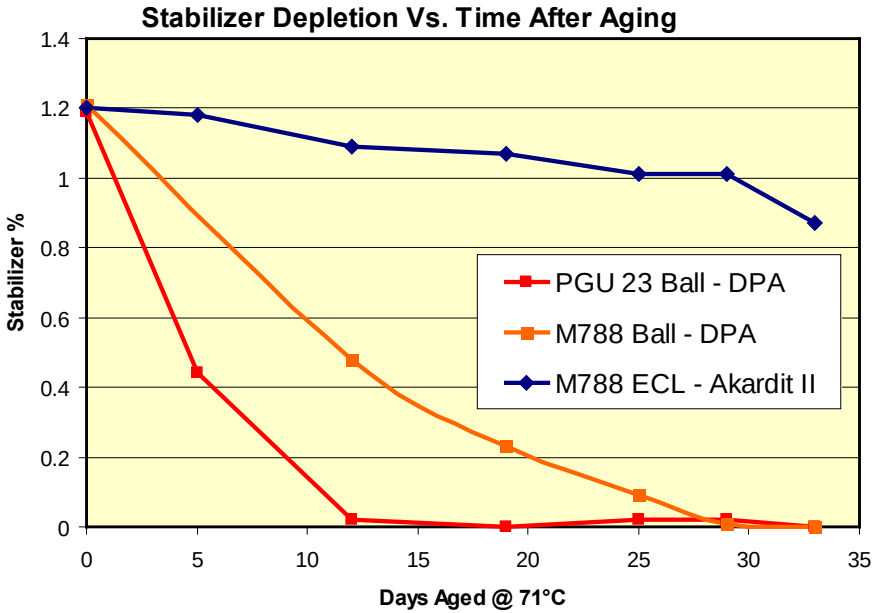
- Propellant Aging– propellant becomes chemically and ballistically unstable
- Ignition System – nitrocellulose lacquer seal failure



ECL® Propellant Superior Stability Response

A premier aerospace and defense company





- **Large variation in ballistic stability response for WC-855 after hot temp storage**
- **Propellant lot 'X' reaches upper spec limit for pressure after 7 days at 71 C**

- **Ball propellant analyzed 0% stabilizer after 18 days at 71 C**
- **ECL propellant analyzed 1.1% stabilizer after 18 days at 71 C**

Safety Concern for User!

No change in ballistic performance of ECL after 33 days at 71 C!

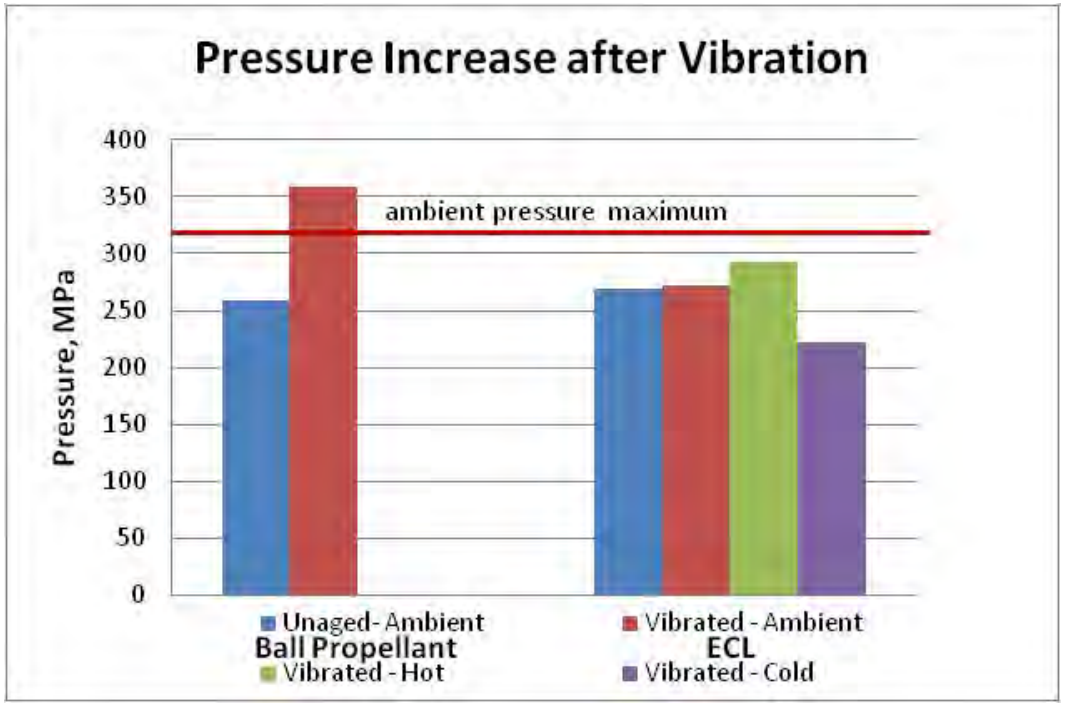
After 33 days, ECL analyzed with 83% primary stabilizer

LW30 Vibration Testing



- **Extreme pressures (> 500 MPa) measured with ammunition that suffered from ignition failure coupled with propellant**
- **To demonstrate superiority of ECL, M592 ammo container loaded with 20 rounds (ball propellant) and 90 ECL rounds subjected to vibration testing**
- **Vibration testing consisted of 500+ hours of vibration across 3 axes coupled with over 350 hours of temperature cycling (-40 to +65 C) in the M592 container**

- **ECL rounds tested at ambient, hot +71 C and cold -54 C**
- **Ball propellant rounds only tested at ambient due to high pressure ~ Pressure increase of approximately 40%**



LW30 PVAT Advantages

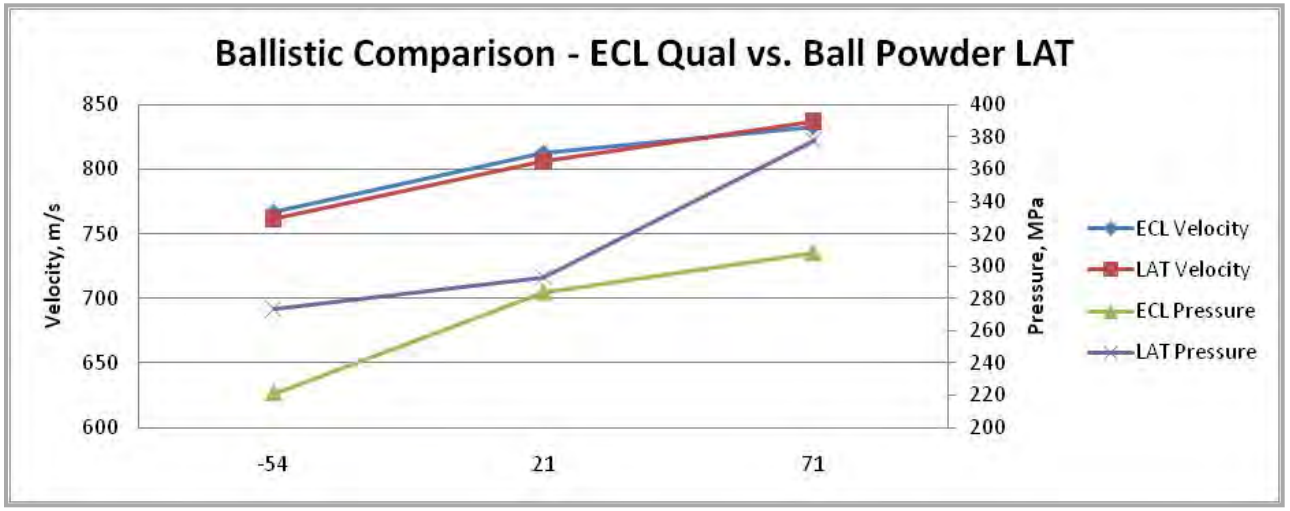
ECL® Exceeds Ballistic Performance of Ball Powder WC 855:

- ✓ Lower Charge Weight ~ -5%
- ✓ Higher Velocity ~ +15 m/s
- ✓ Reduced Pressure ~ -20% at hot

Extra Efficiency of ECL Translates to:

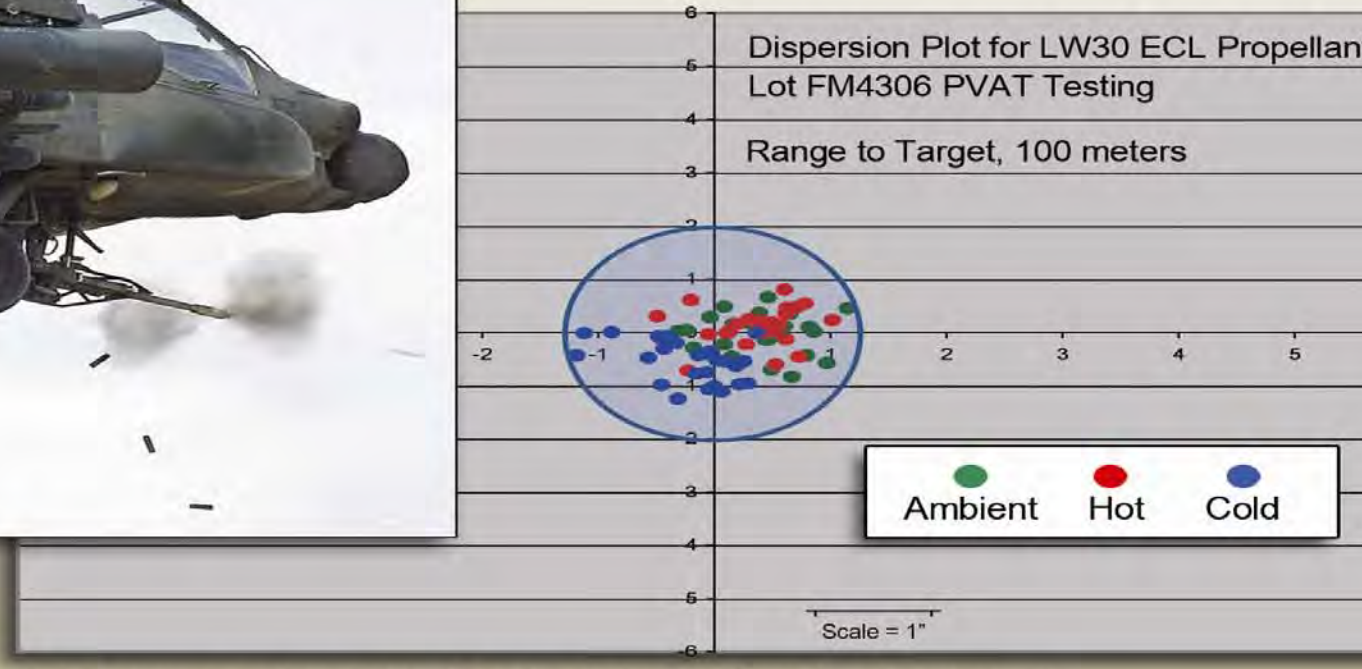
- ✓ Extended Range
- ✓ Increased Lethality
- ✓ Cost Savings
- ✓ Ballistic Margin





Innovation ... Delivered.





ECL is currently undergoing qualification testing for 30mm Apache ammunition.

RHEINMETALL NITROCHEMIE

Photo courtesy of the U.S. Army

Extruded Composite Low-sensitivity (ECL) gun propellant allows 30mm Apache ammunition to provide low dispersion at cold, ambient and hot operating temperatures. ATK.

www.atk.com

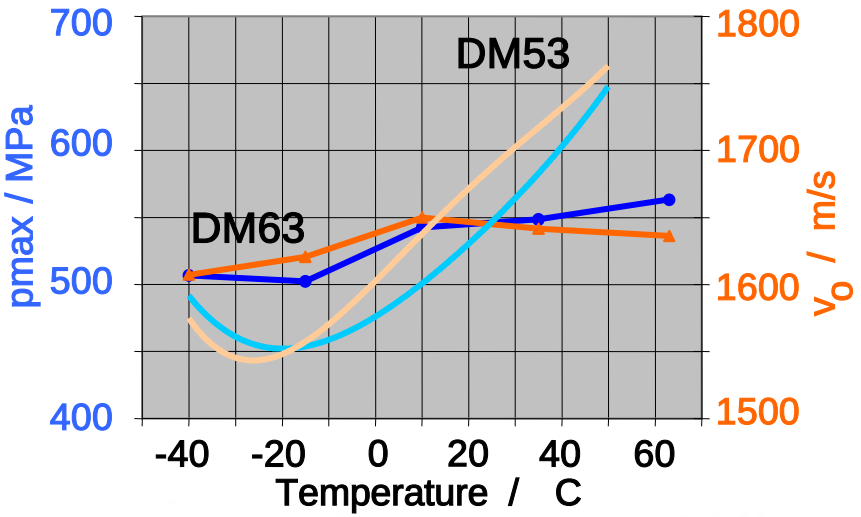
ATK

SCDB – Future for Advanced Tactical Tank

A premier aerospace and defense company

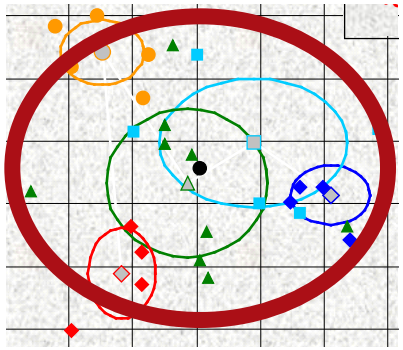
Same high performance as predecessor DM53 but SCDB offers:

- 3 times lower gun barrel wear
- Temperature-independent peak pressure, velocity, projectile acceleration, and projectile trajectory
- Perfect for all climatic regions: full function from -46 C to +63 C
- Lower dispersion / higher hit probability
- Reduced peak pressure and recoil impulse
- Excellent IM properties due to optimized formulation and surface coating
- Qualified and in series production since 2005; introduced in Germany, Netherlands, Finland, Denmark, Austria, Canada, Turkey

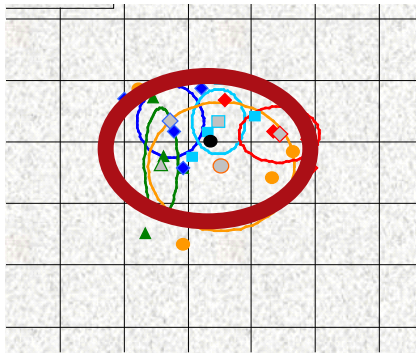




conventional



DM 63



Thanks and Questions?

A premier aerospace and defense company



Thanks for your attention!

Questions???



For Sales and Technical Assistance, please contact the program offices:

Outside North America	North American Market
Nitrochemie	ATK
Martin Wenger	Douglas Messner
Wimmis, Switzerland	Radford Army Ammunition Plant
41 33 228 1022	540 639 8514
martin.wenger@nitrochemie.com	douglas.messner@atk.com

Developments in Short Range Training Ammunition

ALWAYS ON target

National Defense Industrial Association Small Arms Symposium
May 2010

Author: Luis de Sousa
luis.desousa@can.gd-ots.com

GENERAL DYNAMICS
Ordnance and Tactical Systems–Canada

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GD-OTS Canada SRTA Developments



- Project Objectives for 5.56mm and .50cal SRTA
- Current 7.62mm SRTA
- Concept for 5.56mm and .50cal SRTA
- Performance
  - Simulations
  - Test Data
- Applications/Benefits
- Summary

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Short Range Training Ammunition (SRTA) Project Objectives

- **To develop a 5.56mm and .50 cal SRTA**
  - Eliminate need for weapon adaptors/ancillary equipment
  - Increase effective ballistic match and training range of current SRTA
  - Maximum range limited to approx 10% to 20% of ball
  - Increase functioning reliability on respective weapon systems
  - Increase performance with respect to current SRTA:
    - **M862 (5.56mm SRTA)**
    - **M858 Ball and Tracer M860 (.50 cal SRTA)**





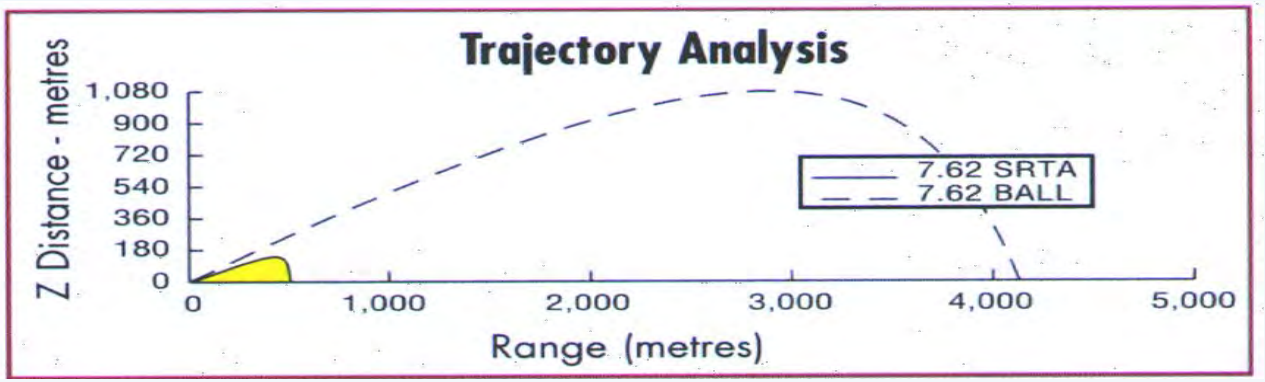


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Current Product
SHORT STOP® 7.62 mm SRTA

- 7.62 mm SHORT STOP® training round
- Available in 4B/1T configuration
- Now in Production for DoD as M973 & M974











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SHORT STOP® 5.56 mm SRTA Development

- **5.56mm SRTA Requirements:**
  - No weapon modification (conversion bolt)
  - Max range of 600 m (at any elevation)
  - Trajectory match up to 100m within ±2mils (threshold)
  - 10 rds dispersion@100m ≤7.0cm (average mean radius)
  - Full functional capability in M4/M16/M249

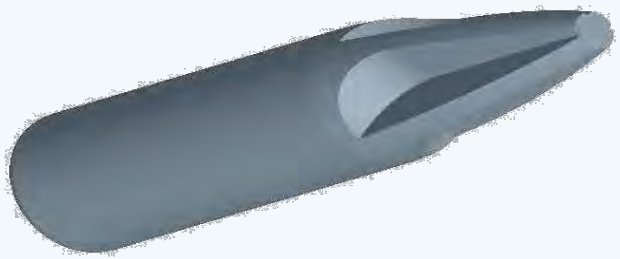
    from -4°F to 104°F



© 2[illegible]al Dy[illegible]rdna[illegible]actical Systems-Canada inc.

5.56mm SRTA Concept

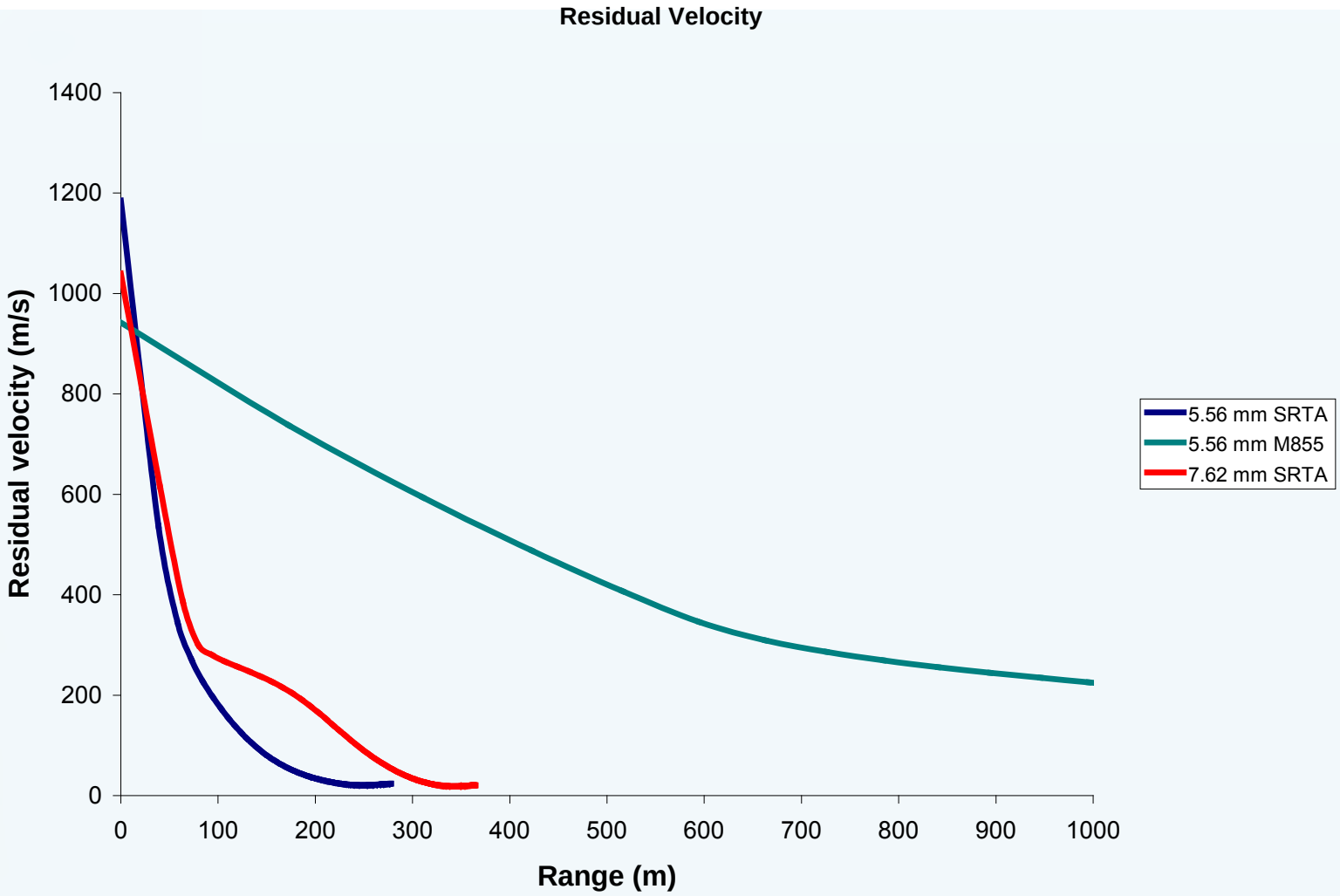
- **The 5.56mm SRTA Cartridge:**
  - Lightweight molded compound projectiles (approx 2.25gr);
  - Frangible lead free projectile;
  - Forward fins design;
  - Low environmental impact
    - Material: No toxic/heavy metals;
    - Reduced terminal effects;
    - Reduced max range;



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SRTA Ballistic Simulation

Comparison of velocity decay (PRODAS)

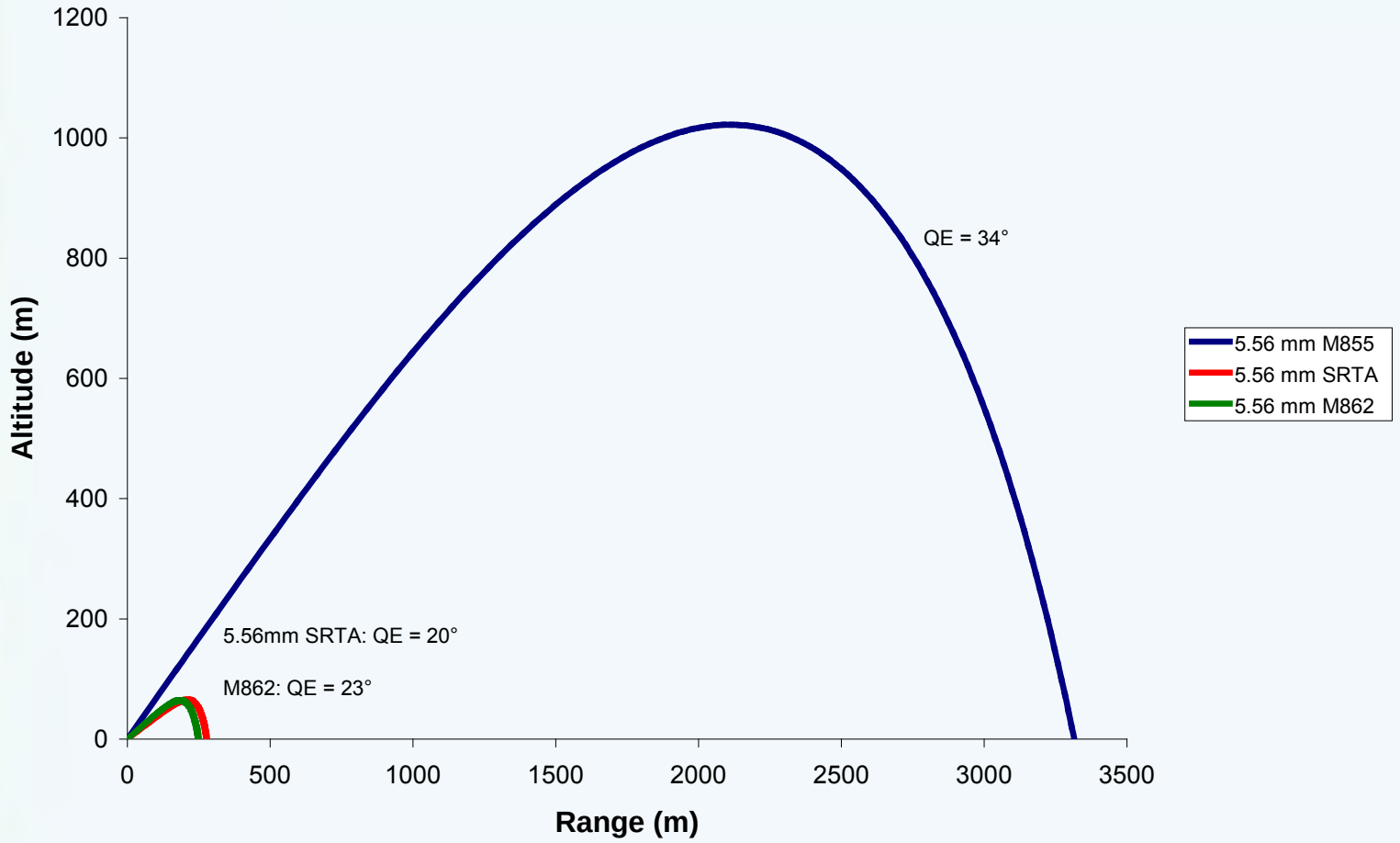


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SRTA Ballistic Simulation

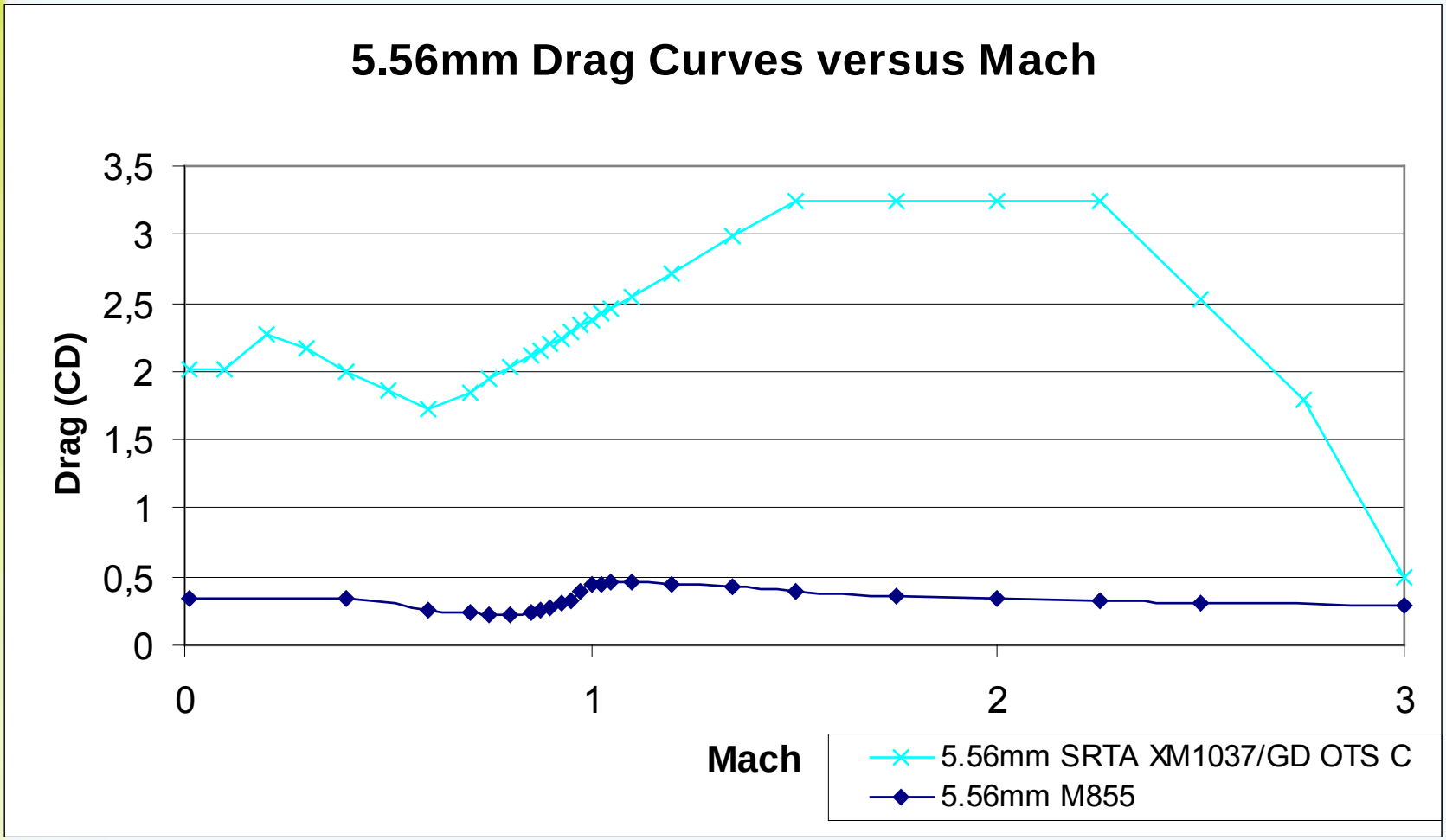
Comparison of max range (PRODAS)

Trajectory with 5.56 mm caliber



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SRTA Ballistic Simulation



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SRTA Ballistic Live Fire Results

Performance Summary

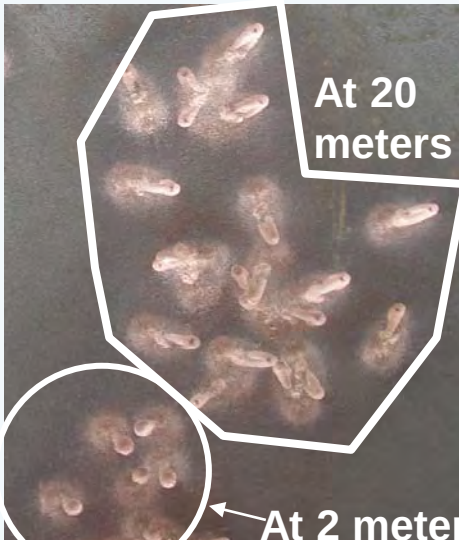
Ammunition	Distance (m)	5.56mm SRTA	
		GD XM1037	M862[1]
			
Dispersion Mean radius in accuracy barrel	25	.29 in	.30 in
	100	2.64 in	NA
Vertical Match at target located X meters from the weapon vs operational ammunition- accuracy barrel	25	.16 in	.79 in
	100	5.12 in	NA
Maximum training range	approx	100 m	25 m
Functioning in M4		YES	NA
Functioning in M16		YES	As per spec
Functioning in M249		YES	NA
Maximum range		600 m[2]	250 m

Note 1: Maximum value taken from MIL-C-70725A (AR)
Note 2: Maximum range measured was **434m**

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5.56mm SRTA Next Step

- **Delivery of 160K rounds to US Govt to conduct Design Verification Testing at APG (Phase III contract delivered June 2009);**
  - Majority of tests completed;
  - Environmental testing and analysis ongoing
- **Limited production by GD OTS C fall 2010**



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SHORT STOP® .50cal SRTA Development

- **.50cal SRTA Original Requirements:**
  - No modifications of M2 machinegun
  - Improved ballistic match with M858 & M860 (T)
  - Reliable functioning from –20 to +50ºC
  - Lead free projectile
  - Max range of 700 m (objective), 1000m (threshold)
  - No splashback beyond 25 m (Target at 50m)
  - Improved performance vs. M858



GD OTS C .50cal SRTA



M858

.50 Cal SRTA Voice of Customer

Conclusions

- Key Customer Requirements
  - Projectile Must not make use of any recoil amplifiers and/or buffer devices
  - Surface Danger Zone (SDZ) requirements have precedence over ballistic match
  - Projectile should not exceed 700m (Objective) and 1000m (Threshold). Revised threshold max range 700m.
  - Projectile should provide effective training range up to 300m ± 50m on identified targets
  - Should have similar functionality/reliability/availability /maintainability/ barrel wear performance as ball
  - Tracer Projectile should be visual throughout the useful training range
  - Yaw at target not an issue.
  - Projectile must sink (Navy requirement)



.50 cal SRTA Concept

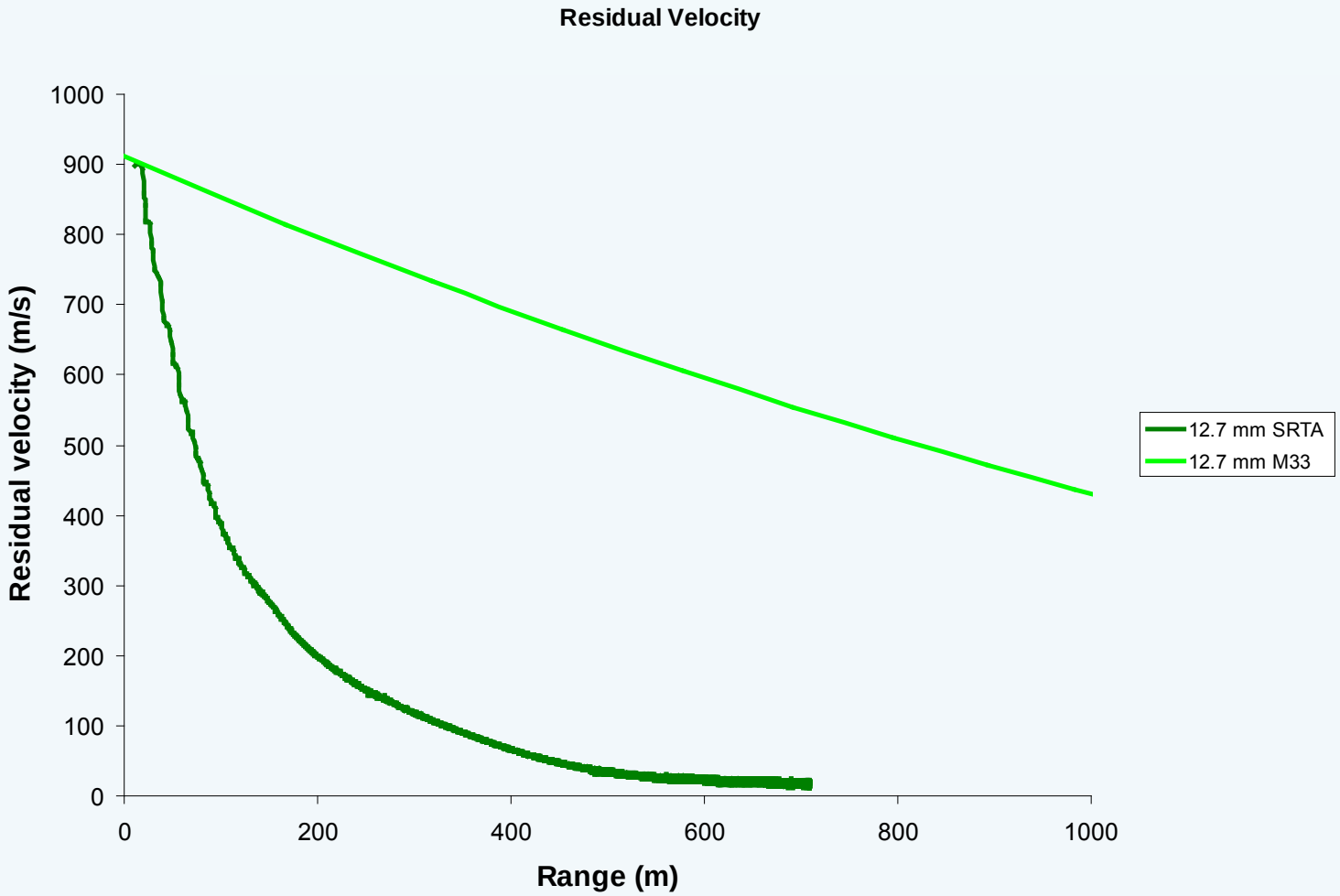
- **The .50 cal SRTA has:**
  - Several projectile concepts under study
  - Forward fins with controlled spin technology to limit range
    - Fins introduce a "reverse" spin/drag, opposing rotation
    - The projectile quickly becomes dynamically unstable
  - Very good accuracy due to consistent ballistic performance
  - Frangible lead free projectile seems to be most promising concept at this time



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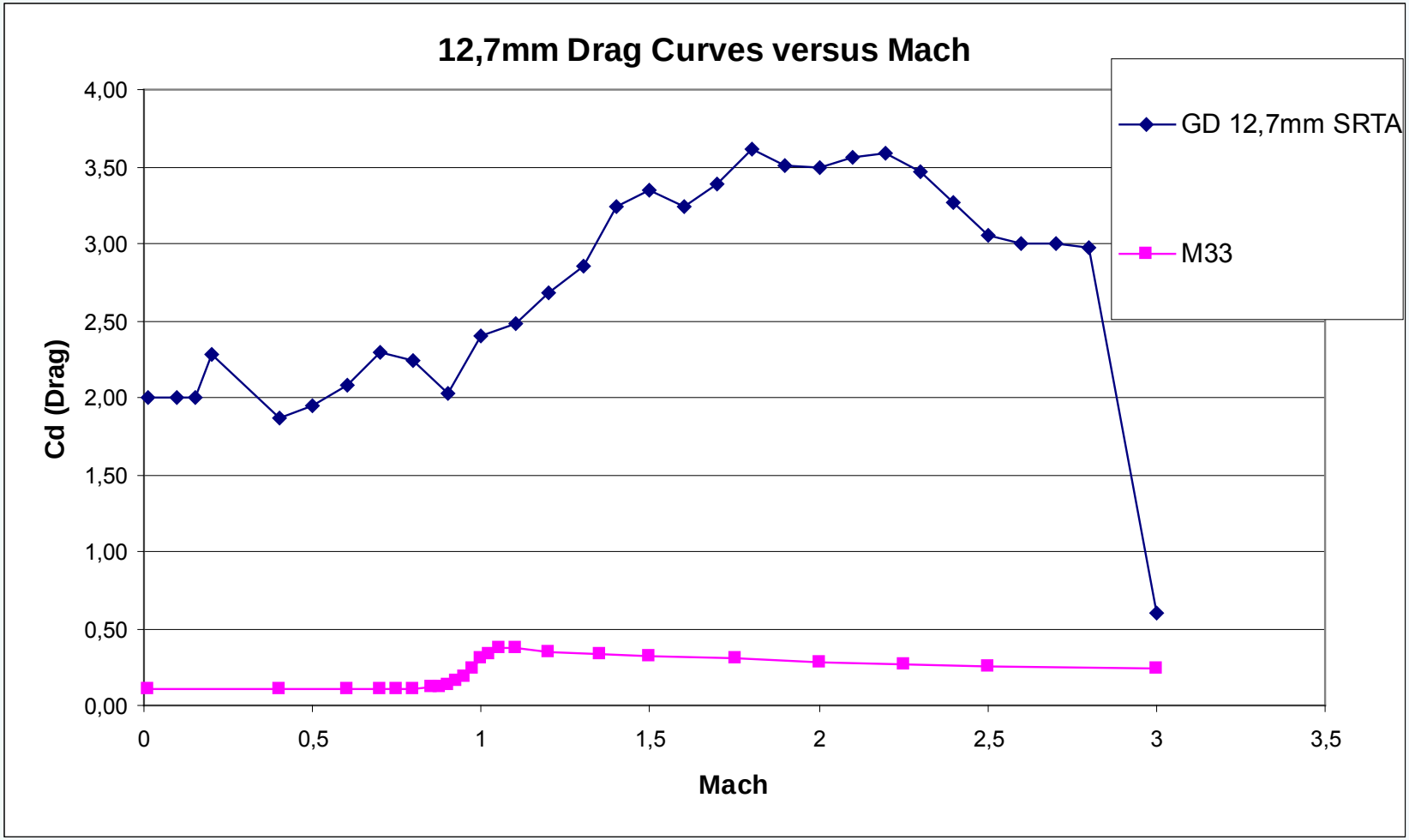
.50 cal SRTA Ballistic Simulation

- Velocity decay vs. M33 simulation with PRODAS



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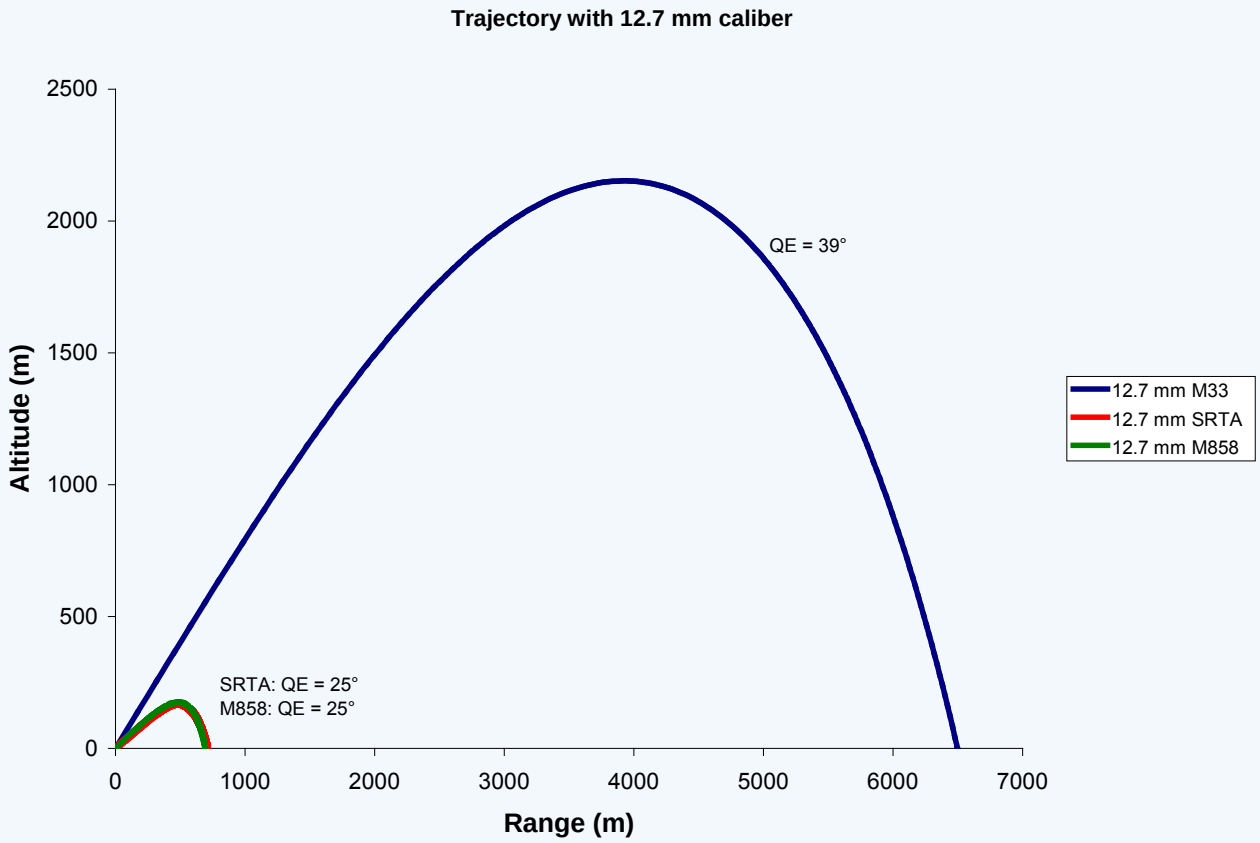
.50 cal SRTA Ballistic Testing



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.50 cal SRTA Ballistic Simulation

- **Maximum range simulation with PRODAS**
  - Upcoming concept: less than 700 meters



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.50 cal SRTA Measured Performance

		12,7mm SRTA	
Ammunition	Distance (m)	GD SRTA	M858[1]
Dispersion Mean radius in accuracy barrel	100	1.6 in	approx. 8 in
	300	5.8 in	
Vertical Match at target located X meters from the weapon verses operational ammunition- accuracy barrel	100	.9 in	-
	150	4.7 in	no specified match
Maximum training range		300 m[2]	150 m
Maximum range		720 m[2]	700 m

note 1: Maximum value taken from MIL-C-70723 (AR)

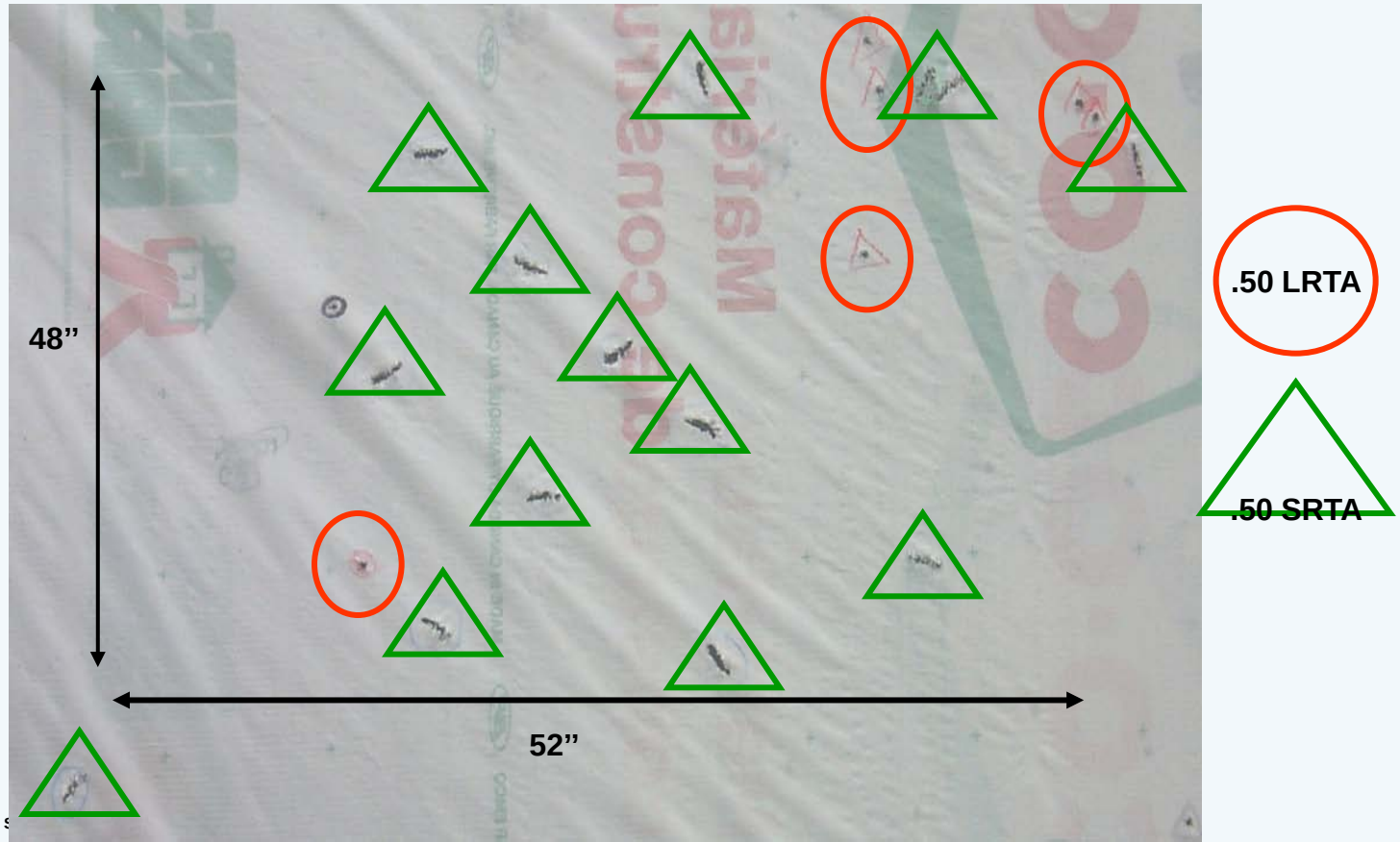
note 2: As tested



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.50 cal SRTA Ballistic Testing

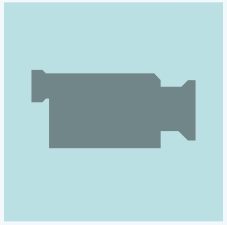
- **300 Meter Ballistic Match and Accuracy Testing Oct 09**
  - Tripod mounted machine gun (not an accuracy barrel)
  - Dispersion grouping of 52x48 inches (M2 HB MG – tripod)



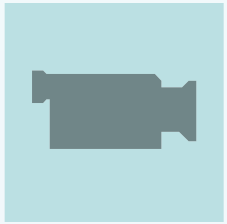
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SRTA Ballistic Testing

- Weapon cycling video



5.56mm SRTA



.50cal SRTA

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5.56mm and .50cal SRTA Summary



- **SUMMARY**
  - The new family of small calibre SRTA lead free, frangible concept represents an advance in SHORT RANGE small arms training technology
  - The 5.56mm and .50 cal SRTA is currently an in-house R&D project
  - The new family of small calibre SRTA will optimize the use of range training resources due to its significantly reduced danger-template

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Developments in Short Range Training Ammunition

Questions?

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RDECOM

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

7.62mm, Lethal Limited Range Round For USCG

Informational Brief for **NDIA 2010**

19 May 2010

Project Overview & Objectives

Overview

- JSSAP funded effort for USCG
- 7.62mm Lethal Limited Range Round
- For use in harbor security applications.

Objectives

- Reduced maximum range
- Engage and defeat





Customer Requirements

- Defeat 1/4 inch of mild steel at 200 meters, at a 45-degree angle
- Match trajectory of M80 out to at least 400 meters.
- Capable of defeating soft target out to at least 400 meters.
- Maximum range of 2000 Meters (1500 Meters desirable)
- Capable of being fired from an M14 rifle and M240 Machine Gun

M80



L2R2



Value to Warfighter

- Operational environment close to civilian populace
- Lethal force often necessary to accomplish missions
- Use of Small Arms at times is restricted due to potential risk to civilians
- Reduced range ammunition will enable USCG to engage targets



Summary From 2008



2007



2008

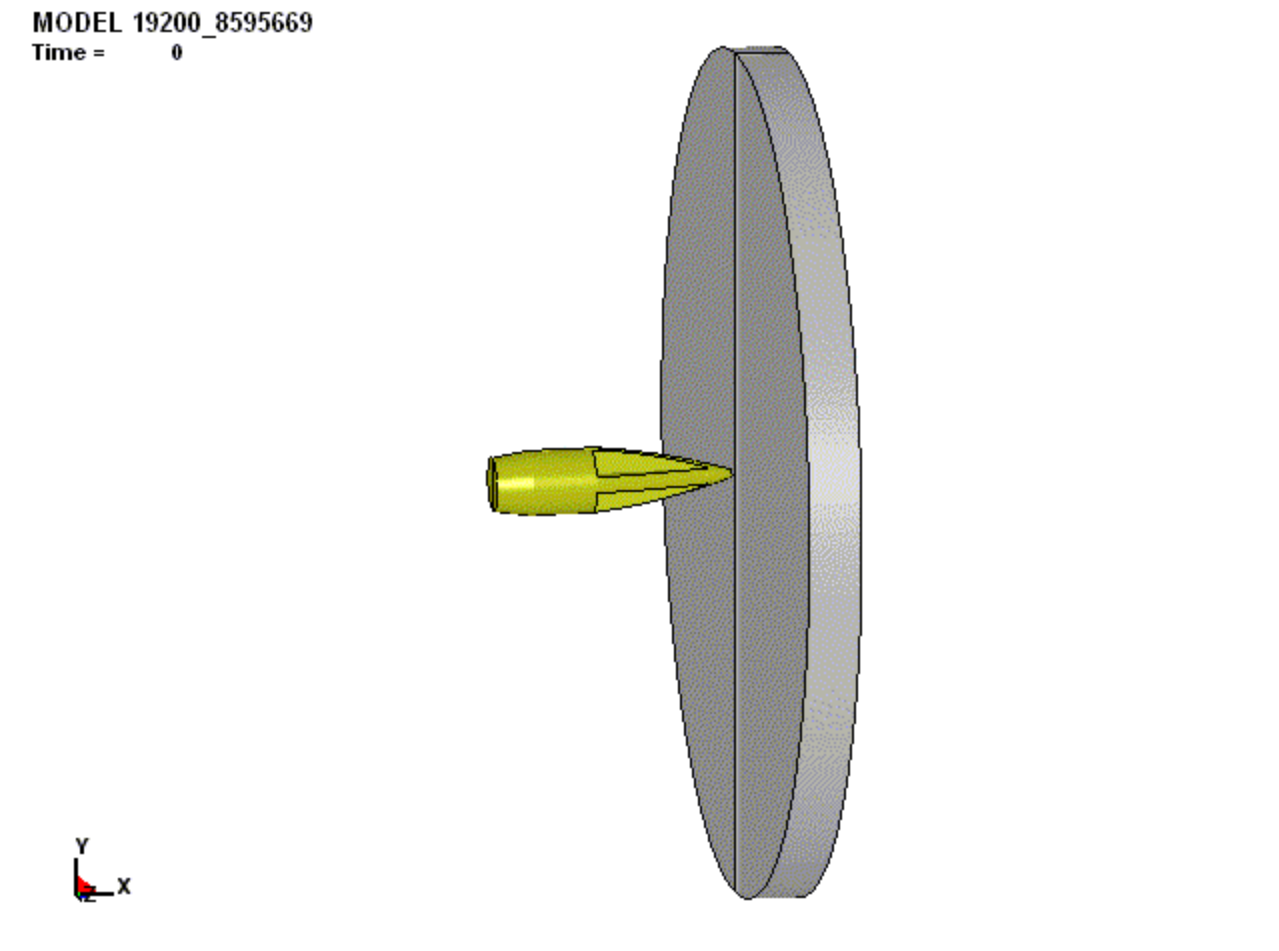


2009

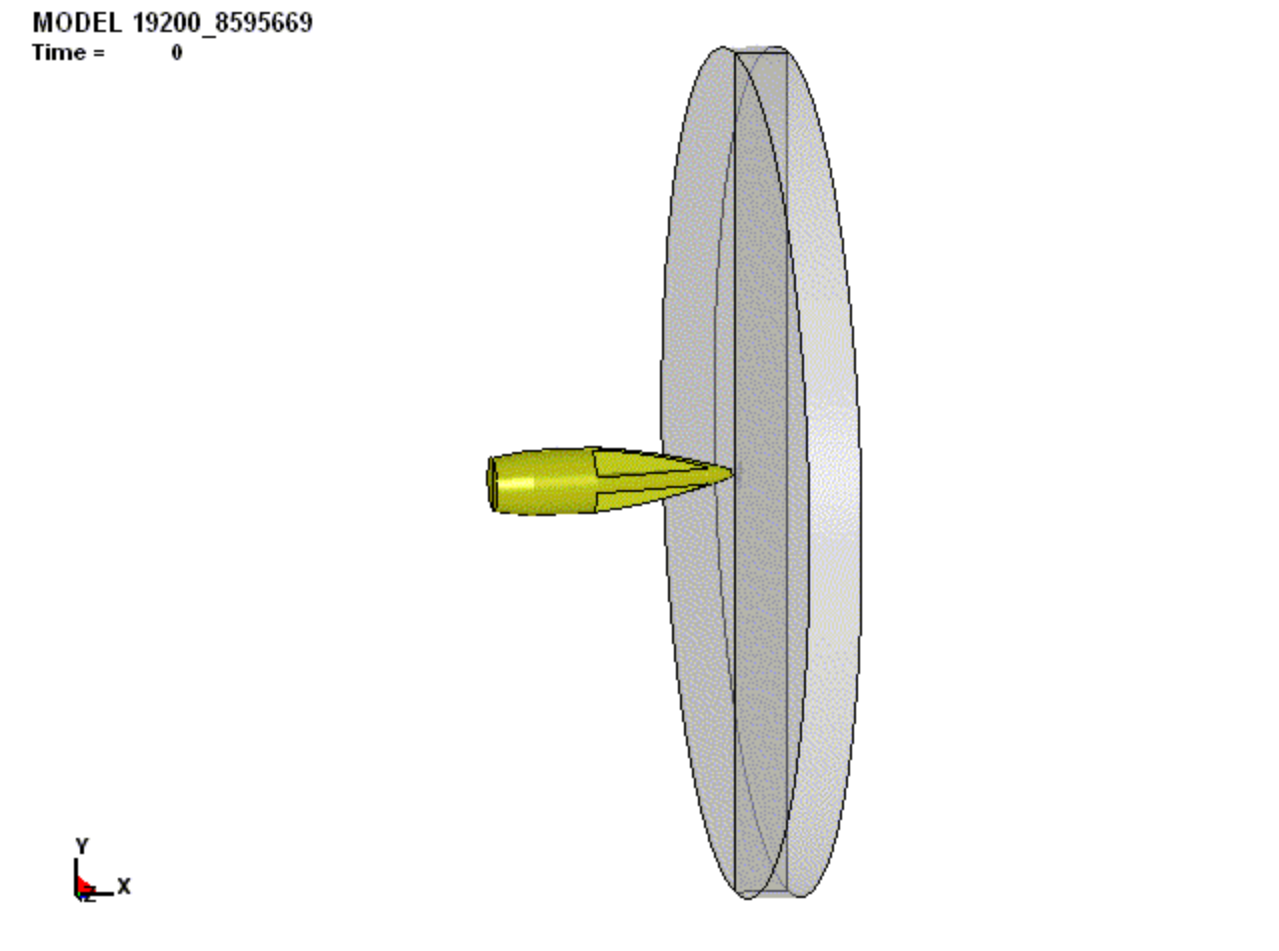


- Brass M80 with forward facing fins
  - Pro
    - Low dispersion
  - Con
    - Poor target penetration
- Future Tasks
  - Model and Simulate projectile target penetration
  - Redesign for penetration and improved dispersion
  - Dispersion test at 400m
  - Radar test for max range

Penetration Simulation
1820 ft/s



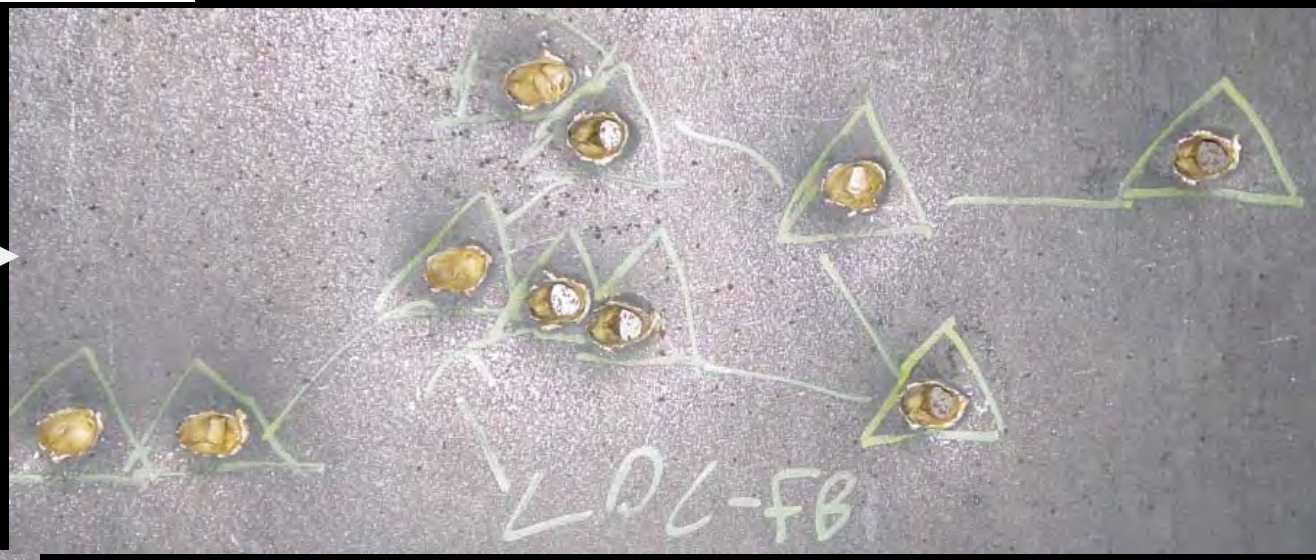
Penetration Simulation
2230 ft/s



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Target Penetration 45 Deg Obliquity

Design LDC-FB
50% Perforation





Design LC-FB
100% Perforation

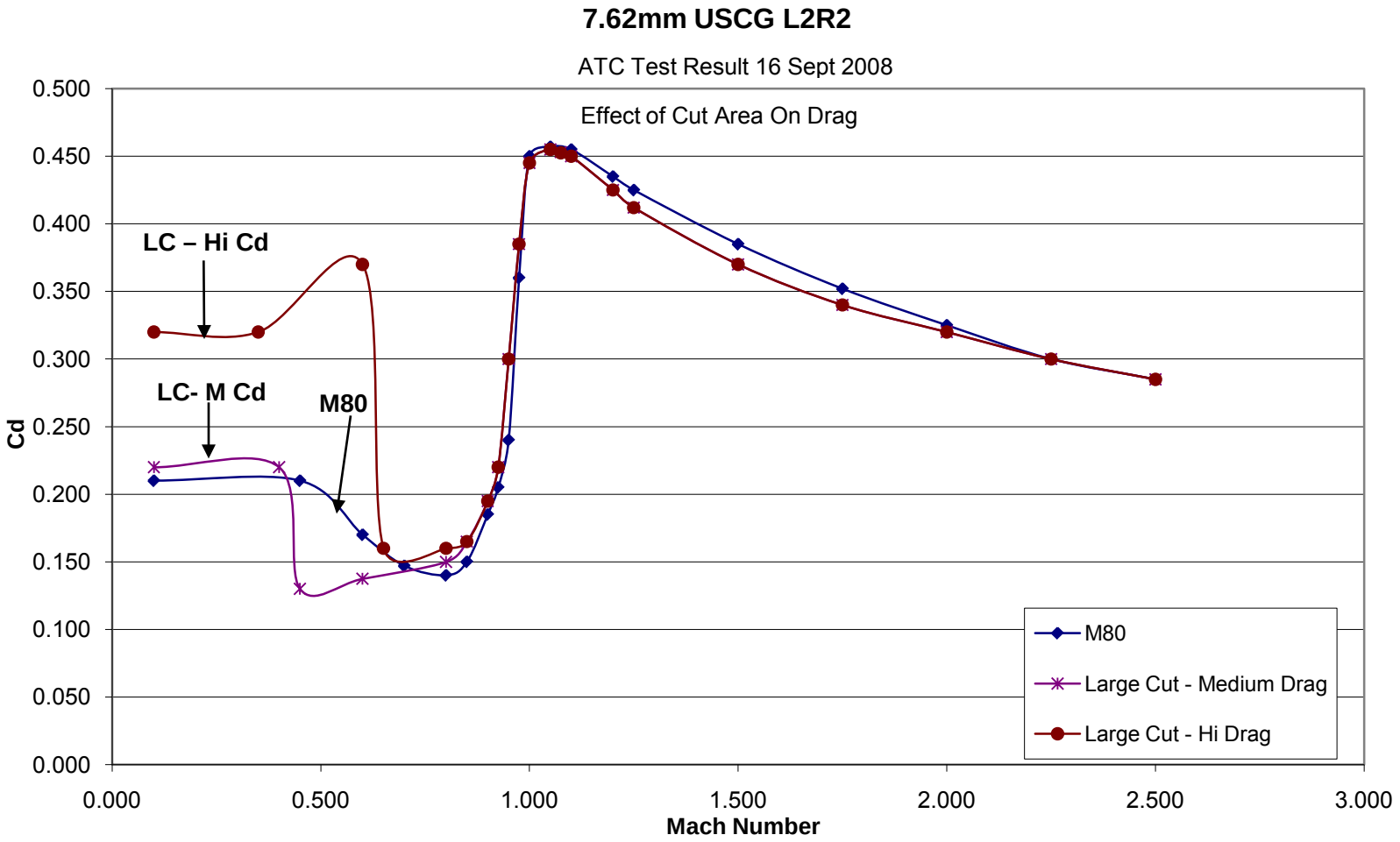
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Target Penetration 45 Deg Obliquity



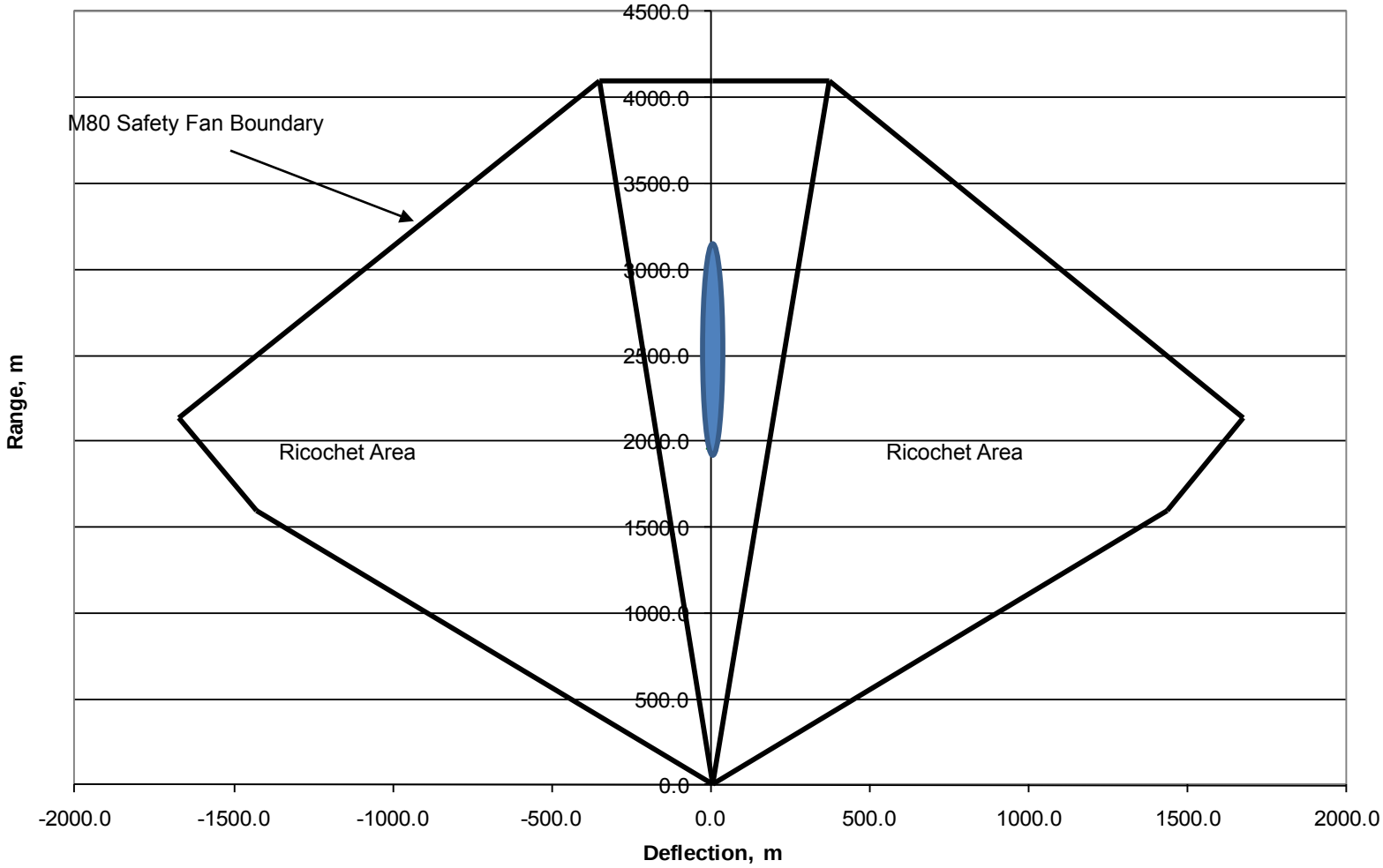
M80 Ball
80% Perforation

Mach vs. Drag LC-FB



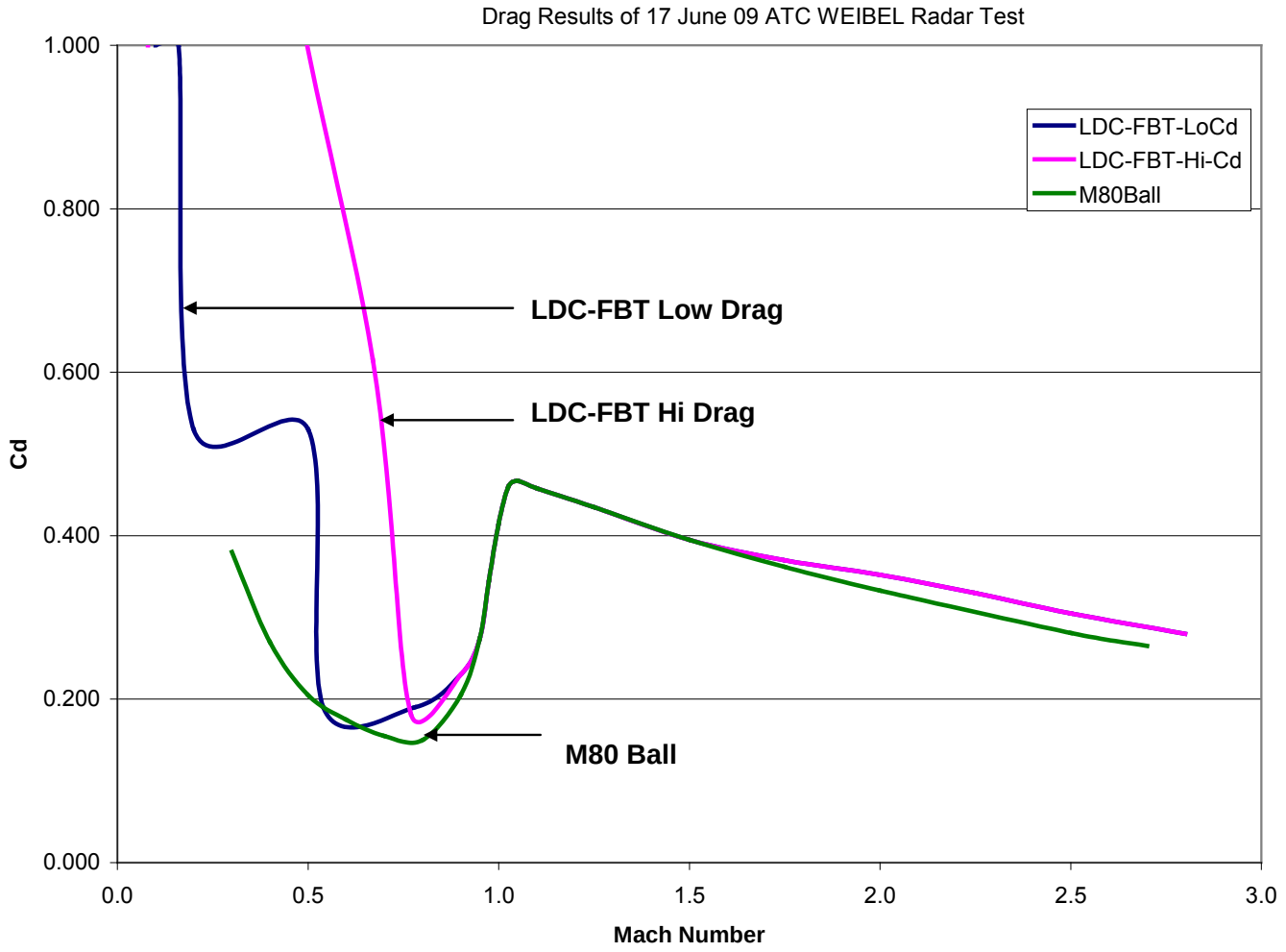
LC-FB Impact Locations on M80 Safety Fan

LC-FB fired from M240B at 10° & 30° QE

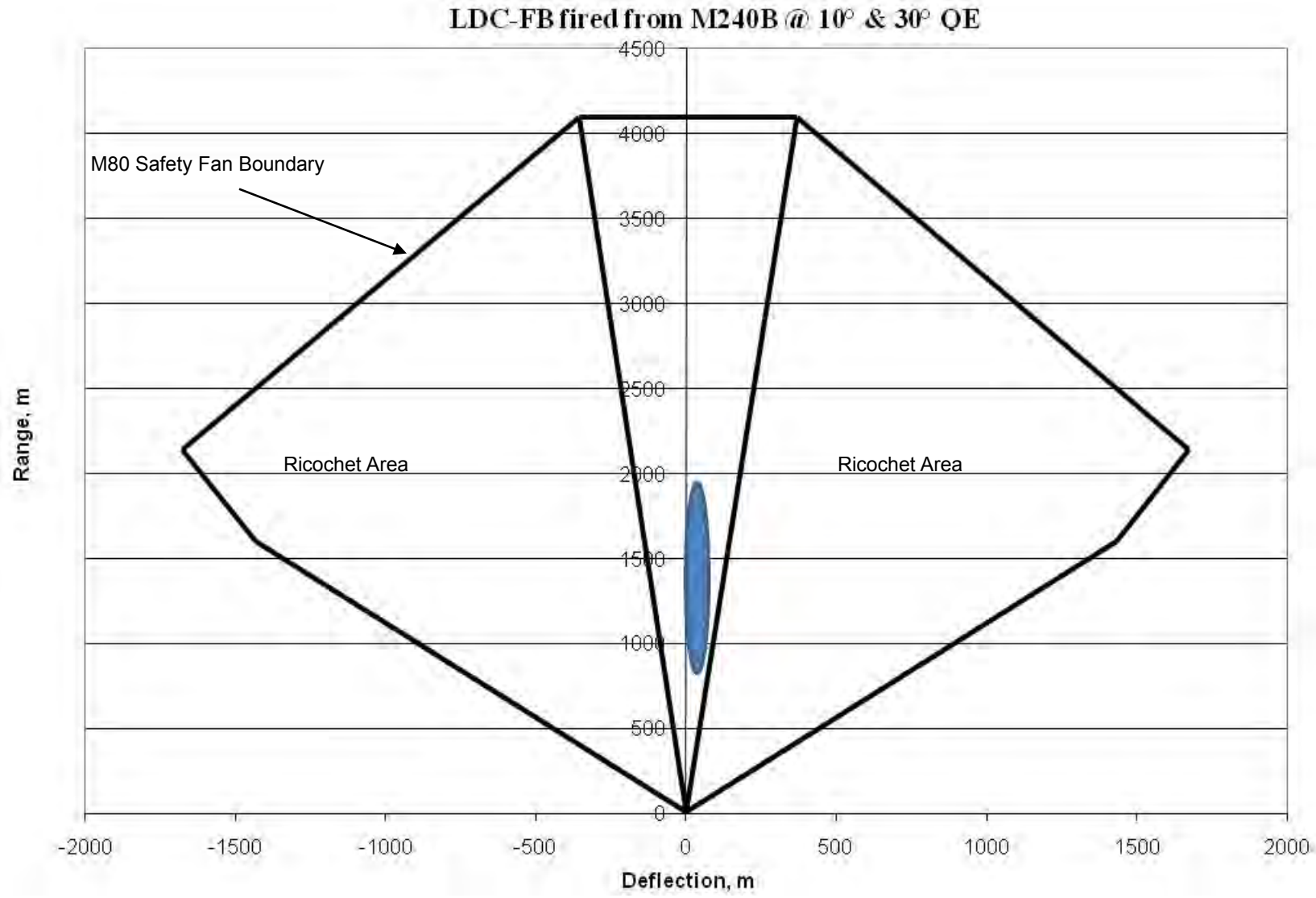


Mach vs. Drag LDC-FB

7.62 mm USCG L^2R^2



LDC-FB Impact Locations on M80 Safety Fan



M80 Ball vs. LC-FB vs. LDC-FB

KPPs	M80 Ball	LC-FB	LDC-FB
≈ Max Range, 10° QE (m)	2765	2390	1865
≈ Max Range, 30° QE (m)	3715	3283	1967
Function M240B	Y	Y	Y
Perforate Steel Target @ 200m at 45° angle	Y	100%	50%
Defeat Soft Target @ 400m	Y	Y	Y
Match Trajectory of M80 @ 400M	—	N	N



M80

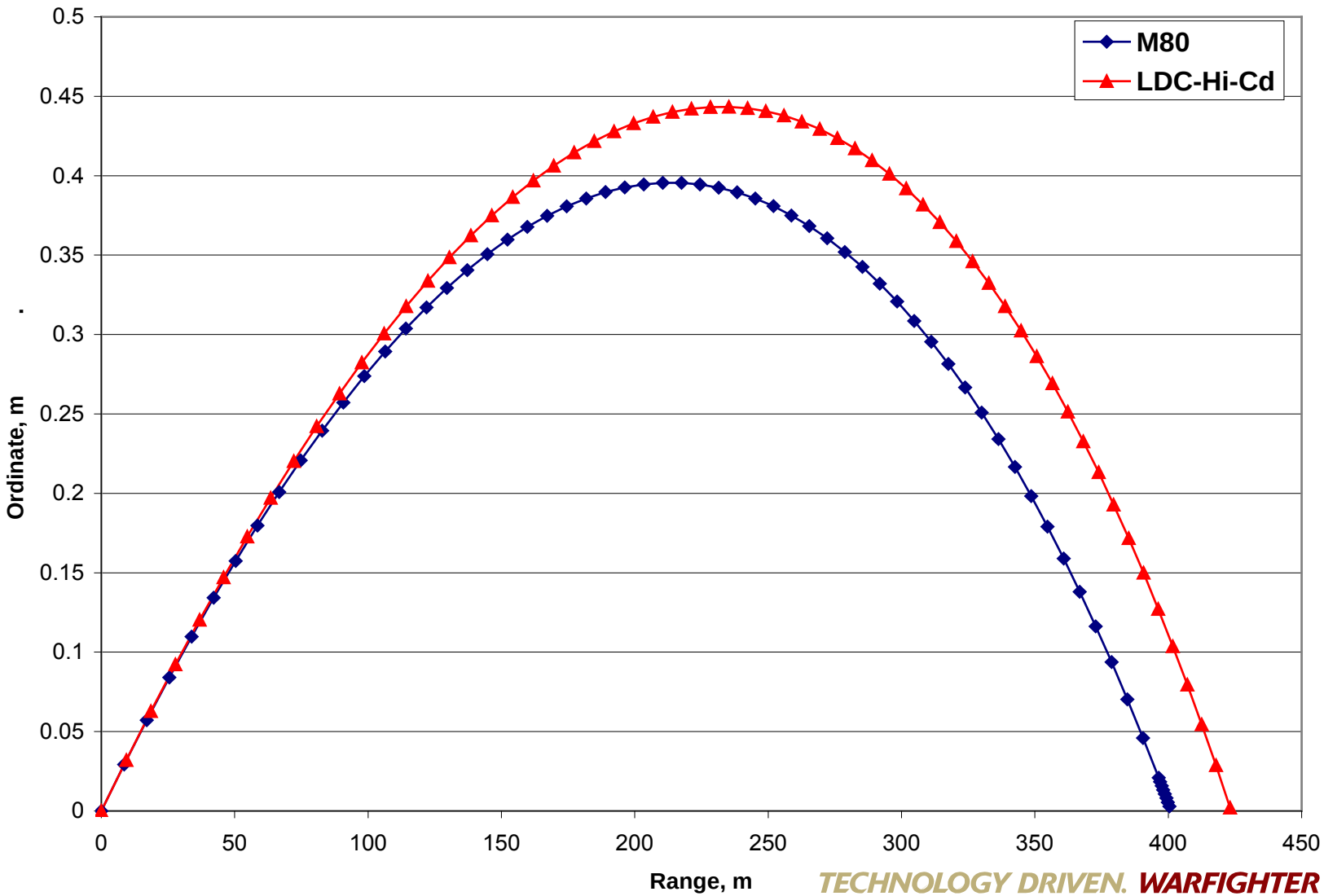


LC-FB

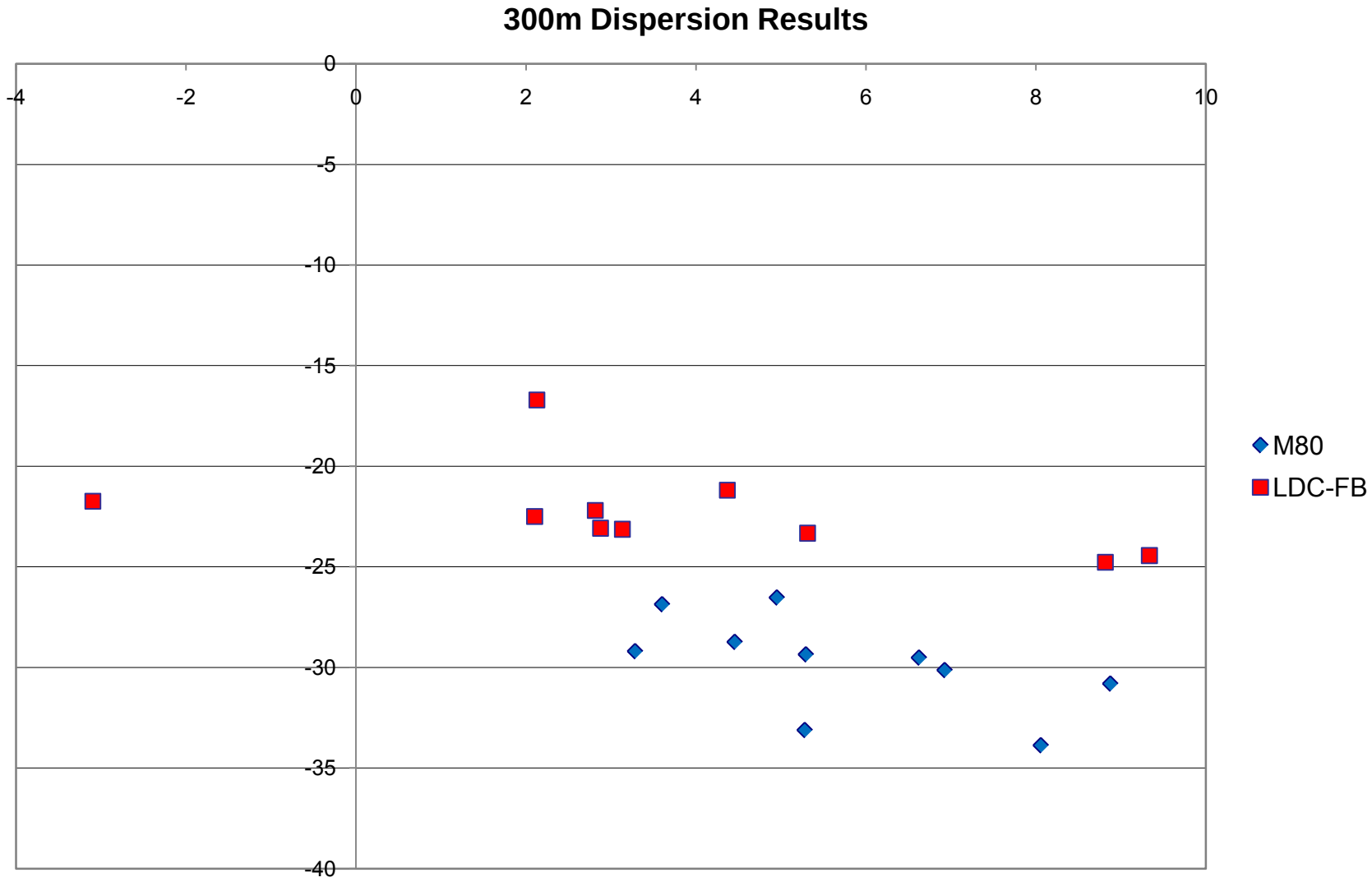


LDC-FB

Trajectory Comparison

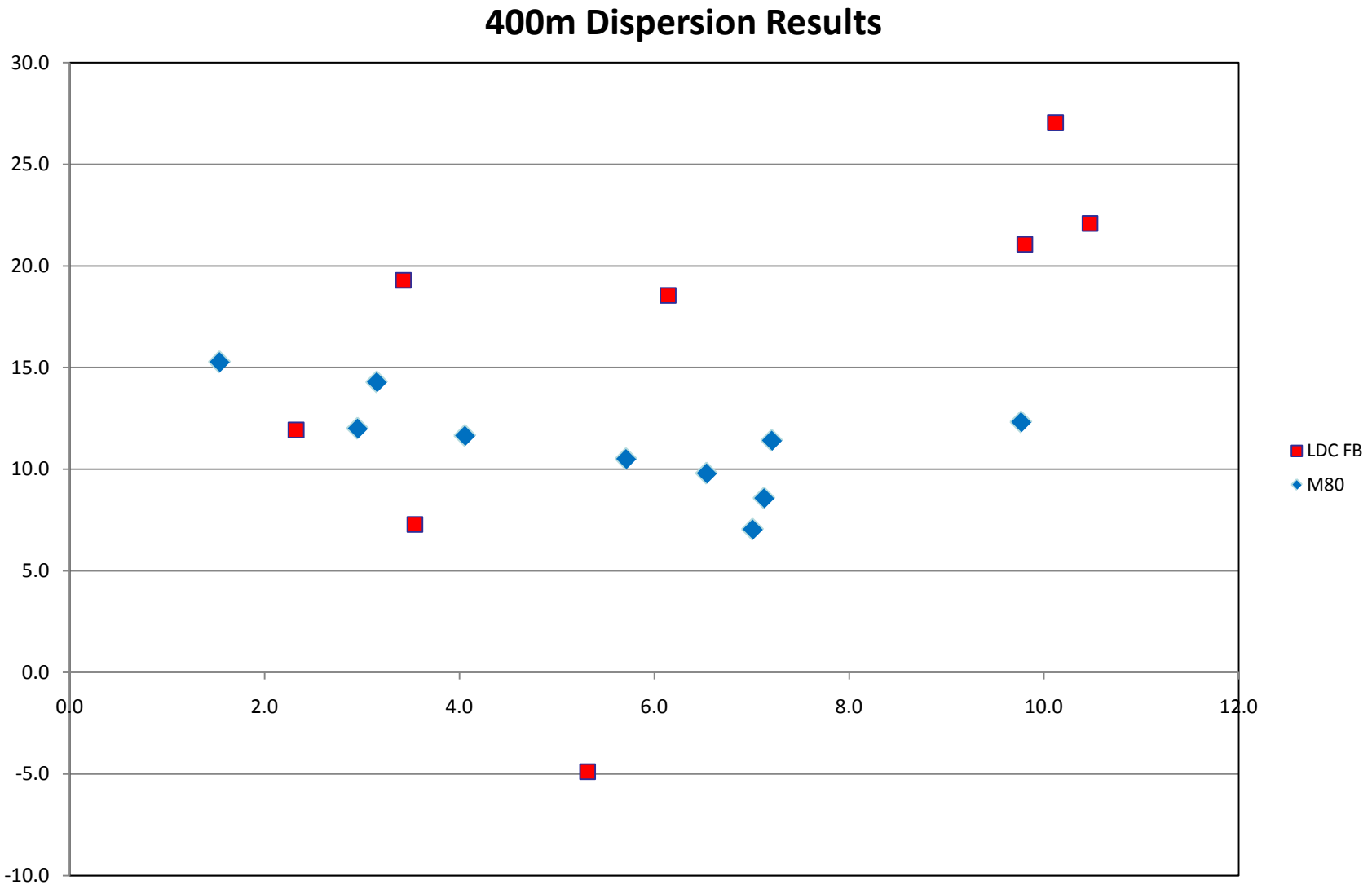


300m Dispersion Test Results



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

400m Dispersion Test Results



M240B Machine Gun Functioning



VIDEO

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

M14 EBR Rifle Functioning



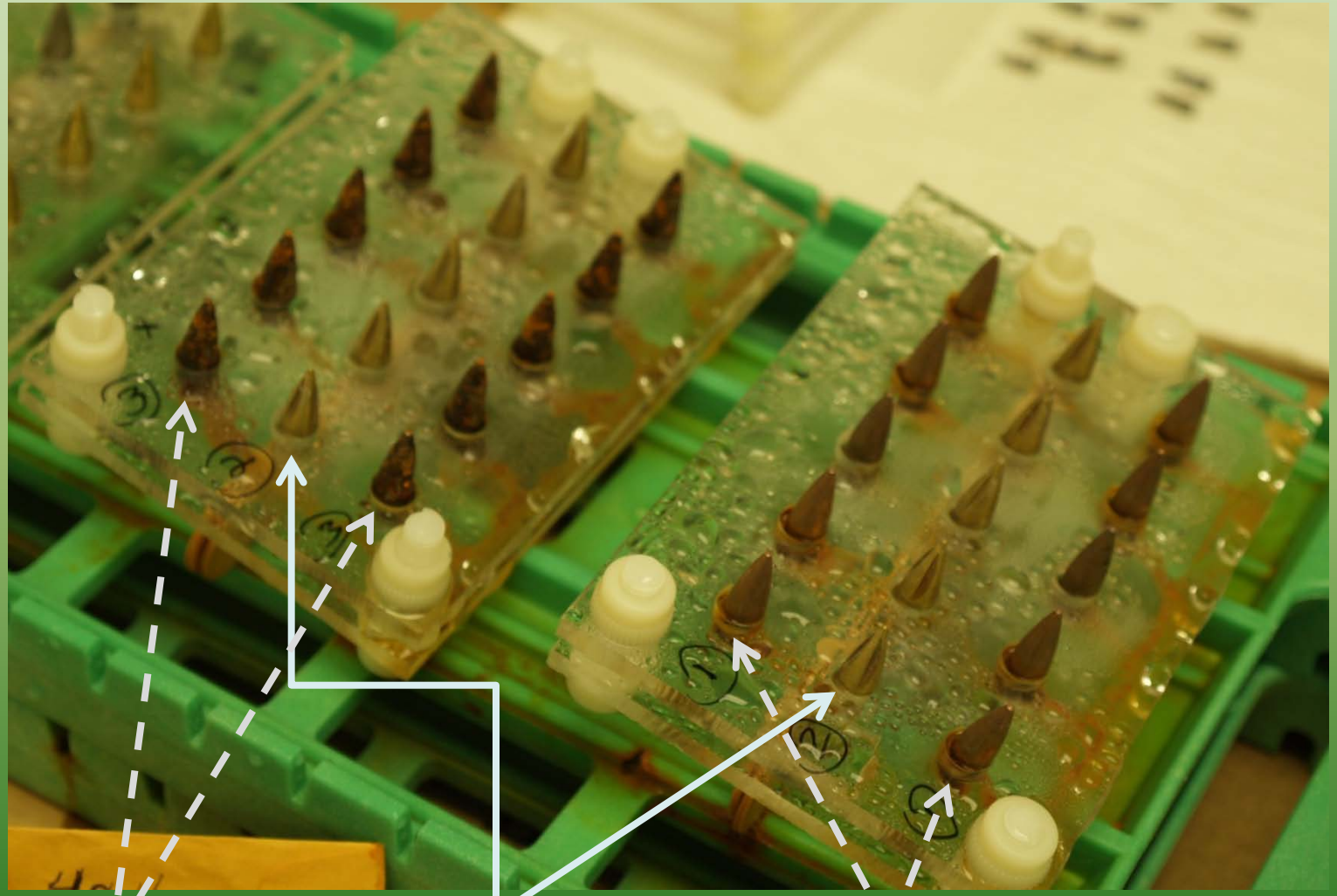
VIDEO

Salt-Fog-Humidity Chamber



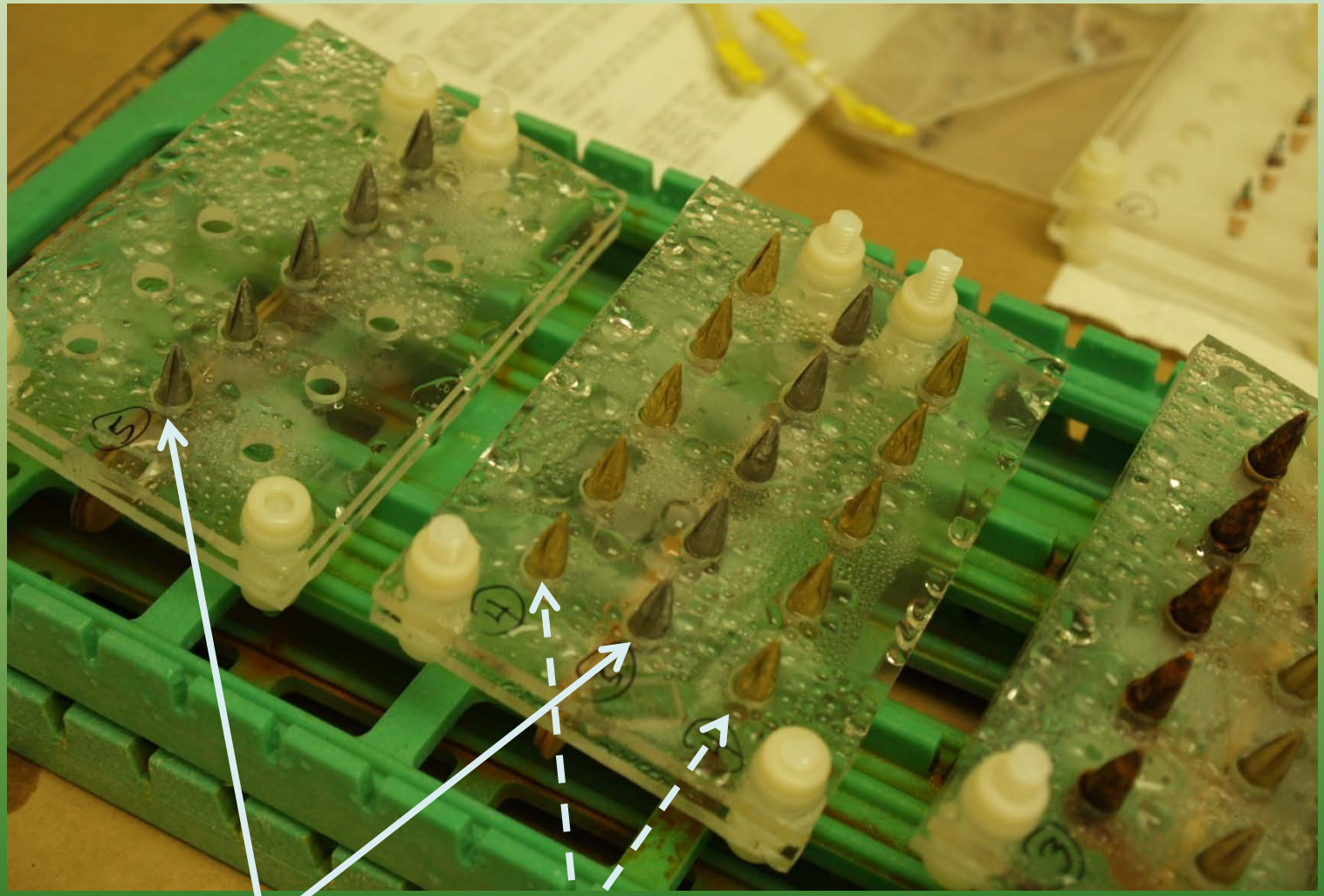
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Salt-Fog-Humidity Results



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Salt-Fog-Humidity Results



Summary & Future Tasks



- Penetration 50%
- Threshold Max Range Requirement met
- Function requirement met
- 400m trajectory comparable to M80
- Brass Projectile better suited for Oceanic environment than M80
- Future Tasks
  - Find industry partner that is able to manufacture and load projectiles on a large scale
  - Evaluate Key Performance Parameters on larger scale

Questions?

Stephen McFarlane

Project Engineer

Small Caliber Munitions Division

Tel#: 973-724-7326

Fax#: 973-724-7095

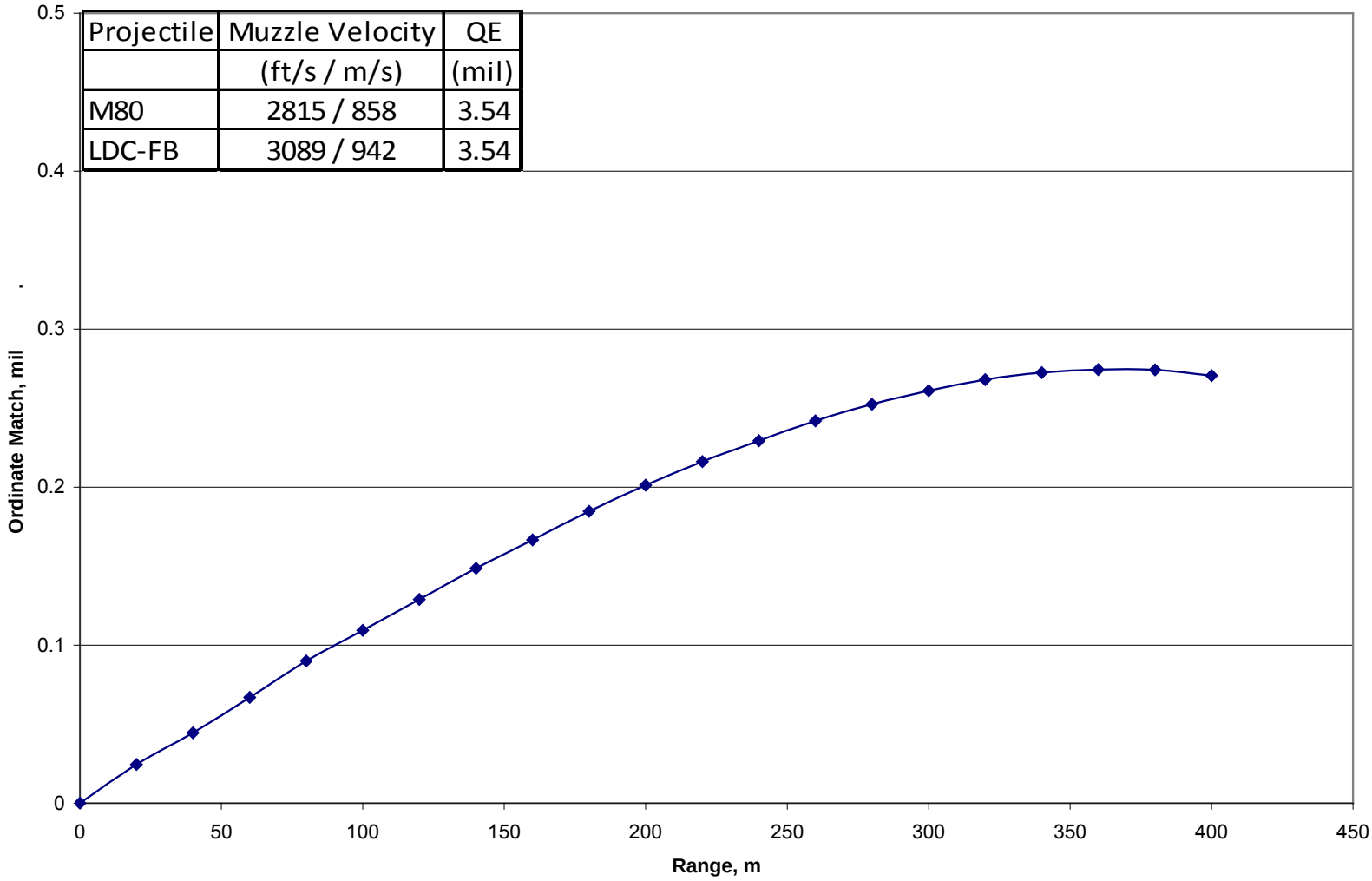
stephen.mcfarlane@us.army.mil

Ordinate Match Between LDC-FBT and M80 Ball

USCG L^2R^2

Ordinate Match Between LDC-FBT and M80

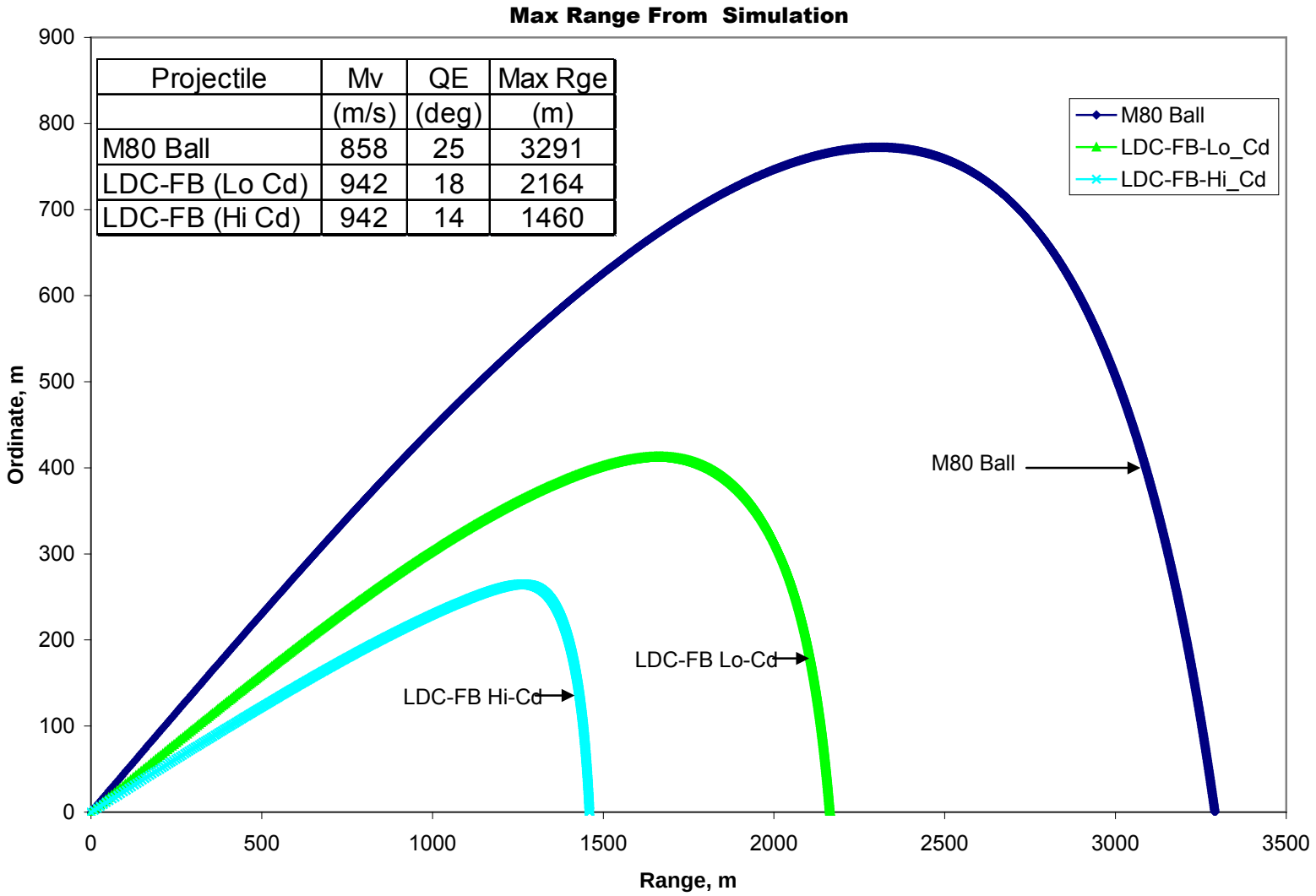
Projectile	Muzzle Velocity (ft/s / m/s)	QE (mil)
M80	2815 / 858	3.54
LDC-FB	3089 / 942	3.54



Maximum Range Simulation

USCG L²R²

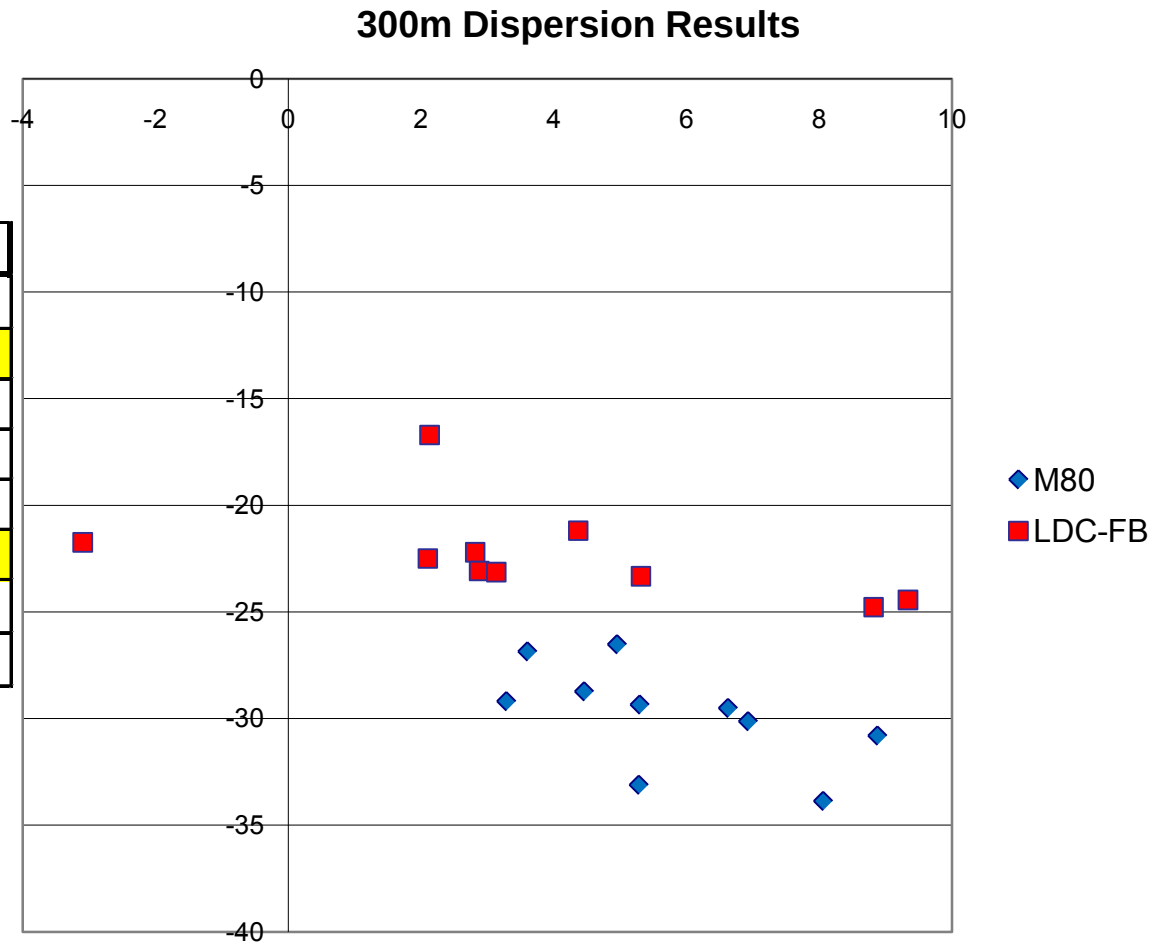
Projectile	Mv (m/s)	QE (deg)	Max Rge (m)
M80 Ball	858	25	3291
LDC-FB (Lo Cd)	942	18	2164
LDC-FB (Hi Cd)	942	14	1460



Note actual data from safety fan chart indicates that LDC-FB design meets max range requirement.

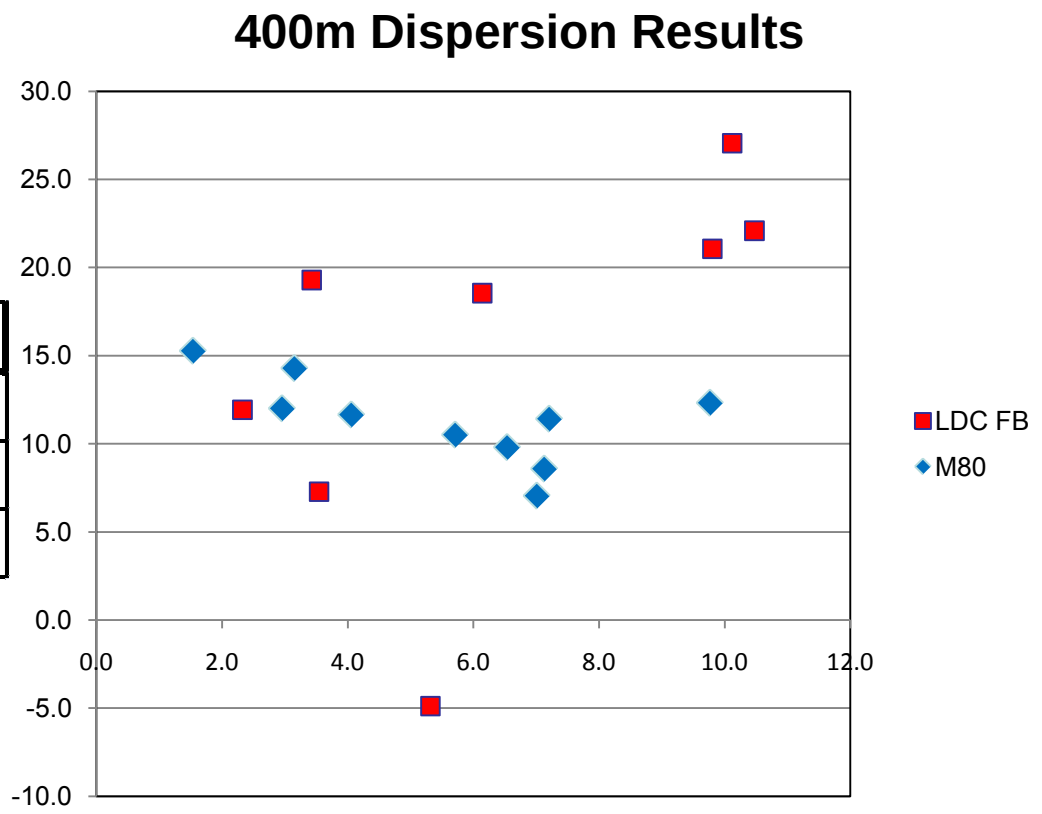
300m Dispersion Test Results

300m Dispersion Results		
Projectile	Mean Radius (in)	Mils
M80	2.53	0.22
M80 Brass	4.35	0.38
LDC-LF	8.03	0.69
LDC-NB	9.62	0.83
LDC-FB	3.23	0.28
LC-NB	5.82	0.50
LDC-SF	4.42	0.38



400m Dispersion Test Results

400m Dispersion Results		
Projectile	Mean Radius (in)	Mils
LDC-FB	8.6	0.75
M80	3.0	0.26



EFFECTS OF BARREL LENGTH ON BORE PRESSURE, PROJECTILE VELOCITY and SOUND MEASUREMENT

Philip H. Dater, MD
GEMTECH
Boise, ID

Jason M. Wong
Firearms Law Group
Seattle, WA

©2010 Philip H. Dater

BARREL LENGTH and BORE PRESSURE



There is increasing interest in M16-type weapons having progressively shorter barrels to make highly maneuverable entry weapons. As barrel lengths decrease, weapon reliability decreases while sound and flash increase.

BARREL LENGTH and BORE PRESSURE



One of our compact stainless suppressors was exhibiting swelling of the outer tube over the entrance chamber, but only after significant full auto fire on a 10.5 inch barreled M16, but not on a 14.5 inch barreled M4.

This prompted performing actual entrance chamber pressure measurements, with interesting results.

BARREL LENGTH and BORE PRESSURE



*100 rounds full auto will raise the suppressor temperature to 800F where the yield strength of 300 series stainless steel is approximately 62% of the strength at room temperature.

M855	10.5” BBL	14.5” BBL
Entrance chamber pressure	2,990 psi	1,978 psi
Hoop Stress	15,635 psi	10,343 psi
Safety Factor	1.92	2.90
Safety factor after 100 rds F/A*	1.19	1.8

Yield 300 series stainless steels is 30,000 psi

BARREL LENGTH and BORE PRESSURE



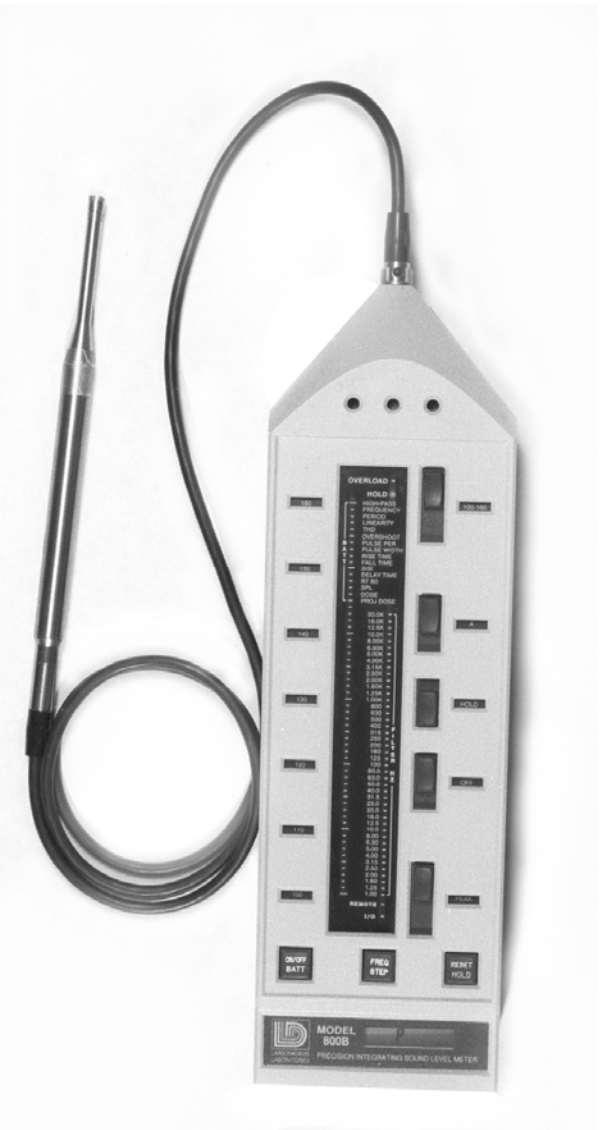
We became curious about pressure gradients in the bore throughout the 5.56mm barrel using M855 ammunition.

There are numerous studies about temperature gradients, but we could not find any relating to pressure.

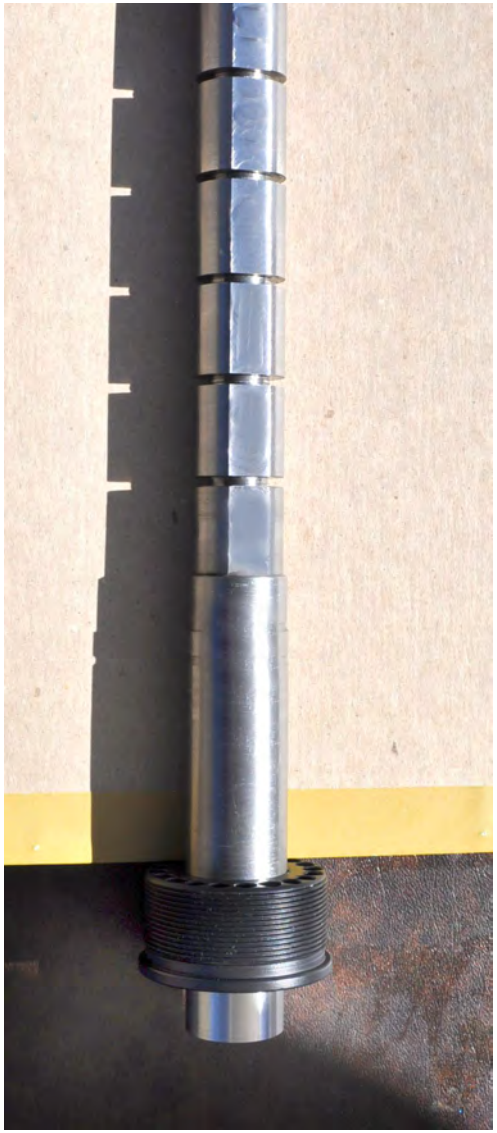
BARREL LENGTH and BORE PRESSURE



So we devised our own study. Since we were going to measure bore pressure, we might as well measure velocity and sound pressure levels at the same time.



BARREL LENGTH and BORE PRESSURE



We felt that direct port pressure measurement with a piezoelectric transducer was more accurate than pressures from a strain gauge.

A new 24 inch AR15 barrel was scored at 1 inch intervals down to 5 inches from the bolt face.

We used a barrel without a gas port, making the rifle a single shot weapon

BARREL LENGTH and BORE PRESSURE



If the port and sensor were at the end of the barrel (1/2 inch from the muzzle), the highest pressure measured would be the bore pressure at the moment of bullet exit (uncorking)

A series of 2mm ports were drilled and tapped for pressure measurements.

BARREL LENGTH and BORE PRESSURE



All but the port closest to the muzzle were plugged with a 3/8 inch setscrew.

After each test, 1 inch was cut from the barrel and the sensor moved back to the next port.

BARREL LENGTH and BORE PRESSURE



The Kistler 6215 direct measuring piezoelectric pressure sensor was screwed into a special fitting that screwed into the threaded holes in the barrel.

Measurements were made using a Kistler 5015 charge meter/amplifier.

BARREL LENGTH and BORE PRESSURE



Rifle was stabilized in a machine rest. Three parameters were recorded in each 5-round string.



1. Bore pressure at uncorking
2. Velocity at 2 meters from muzzle
3. Sound pressure level per MIL-STD-1474D

BARREL LENGTH and BORE PRESSURE



For consistency, ammunition was all LC-2009 M855 ball and from the same lot.

Ambient air temperature varied throughout the day. Ammunition was kept in a cooler until loaded for firing to reduce variability from ammunition temperature.

BARREL LENGTH and BORE PRESSURE



Bore pressure, velocity (at 2 meters), and sound pressure level were recorded for each shot. There was more shot-to-shot variation in pressure and velocity than anticipated.

BARREL LENGTH and BORE PRESSURE

Results in table are 5 (or more) round averages.



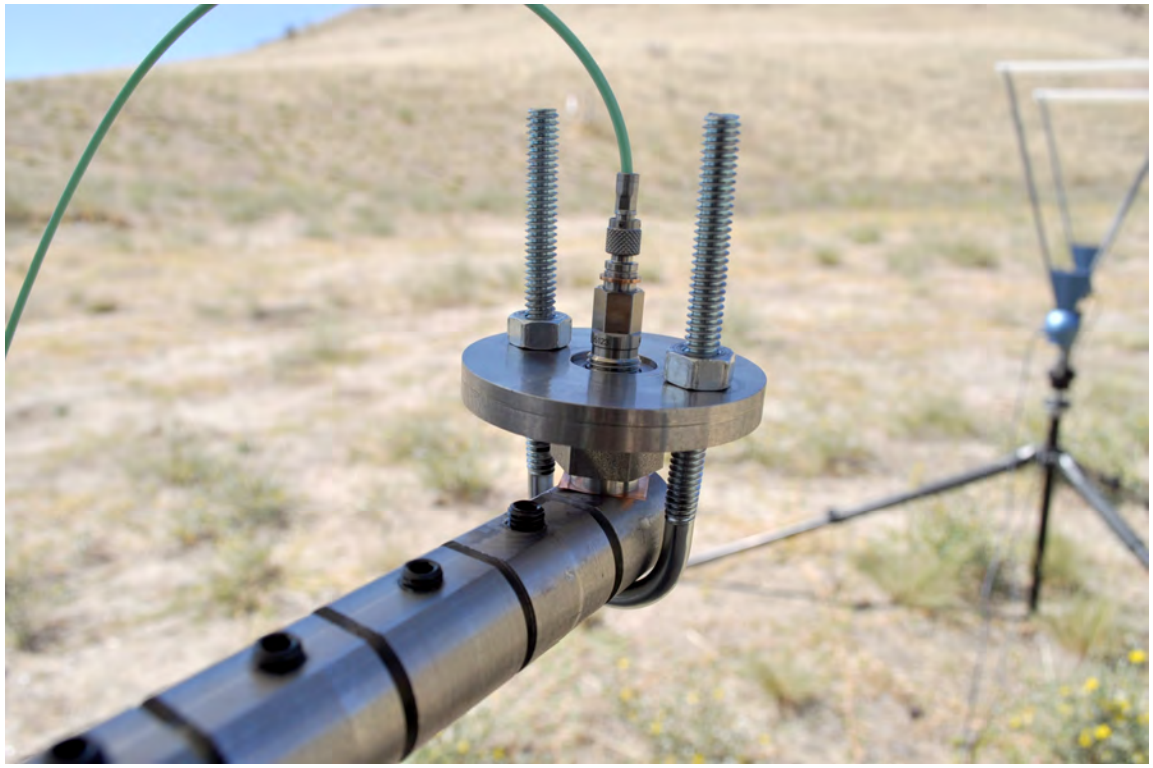
Barrel Length (in)	Pressure (psi)	Velocity (f/s)	SPL [dB(A)]
24	4800	2964	162.5
23	5050	2951	162.7
22	5150	2873	162.7
21	5380	2849	162.7
20	5717	2979	162.9
19	5780	2921	163.1
18	6600	2889	163.1
17	7788	2835	163.6
16	7430	2786	163.3
15	7878	2729	163.4
14	8487	2686	163.6
13	8858	2649	164.0
12	9814	2626	164.6
11	10540	2643	164.2
10	12140	2575	164.3
9	13567	2446	164.7
8	15860	2357	164.7
7	17040	2204	164.8
6	20760	2034	164.5
5	25042	1823	165.1

BARREL LENGTH and BORE PRESSURE

As an example of the variation in pressures, below are the measured pressures for the 6 rounds used when the barrel was cut to 15 inches.

Note: Sometimes more than 5 rounds were measured because the chronograph may have missed one shot.

7670
8110
7810
7760
8040
7000



The average was 7,878 psi and the standard deviation 396

BARREL LENGTH and BORE PRESSURE



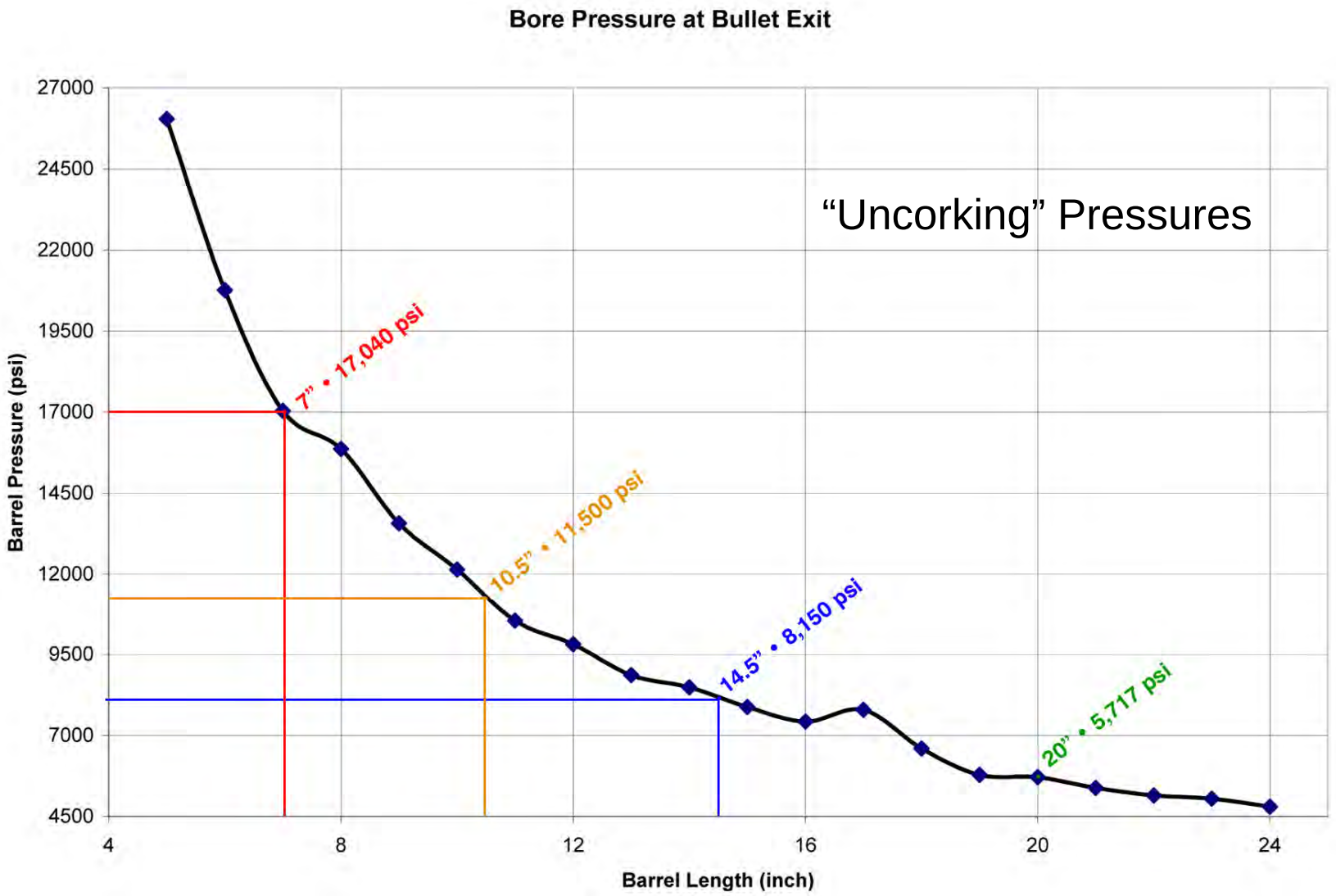
Unable to measure actual chamber pressure, we drilled a 2.5mm port at 3” from the bolt face and measured port pressure.

The SAAMI maximum chamber pressure for commercial .223 is listed as 55,000 psi.

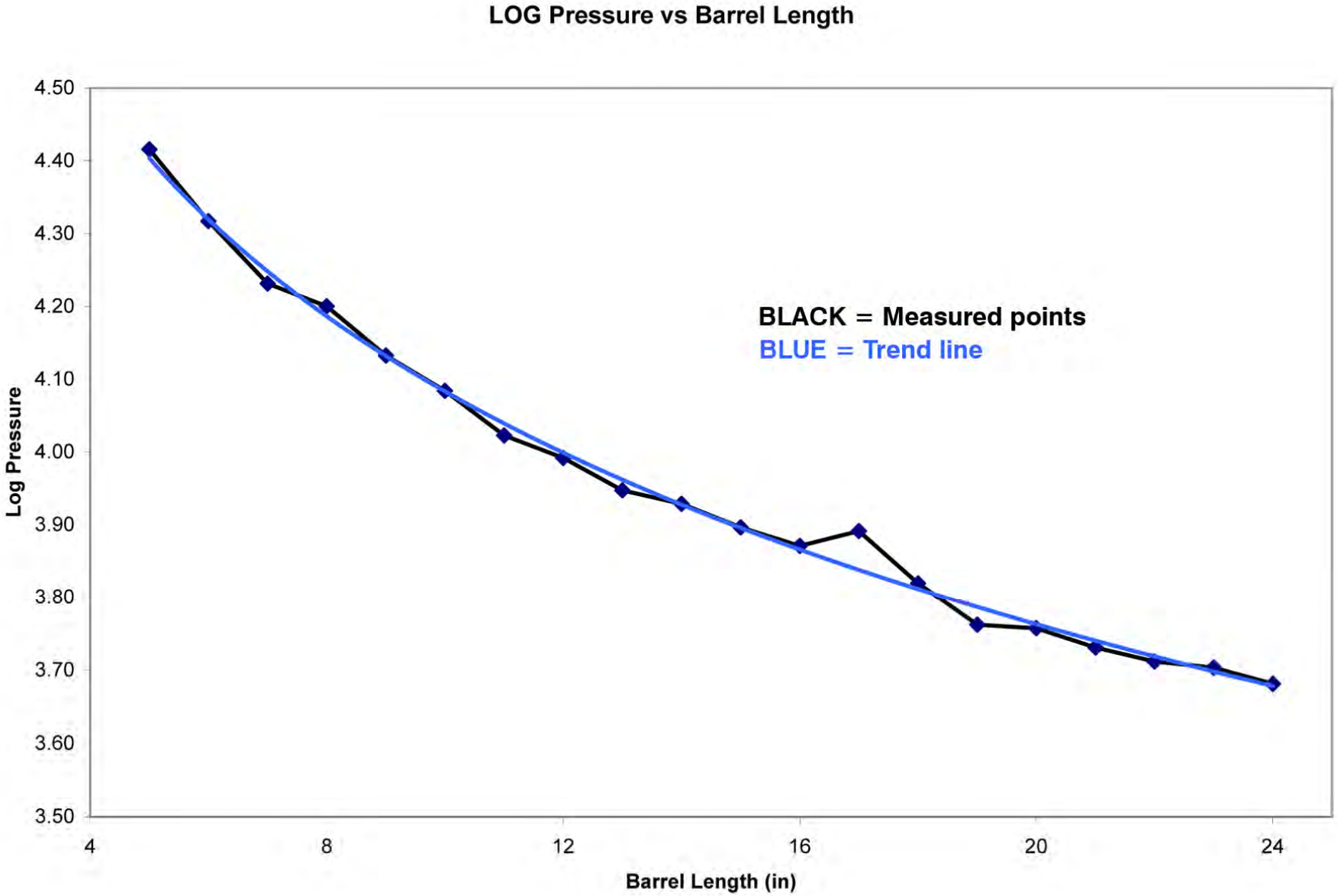
The 3 inch port pressure we measured was 55,744 psi using M855 (average of 9 rounds).

The measurements varied from a low of 52,500 psi to a high of 57,600 psi

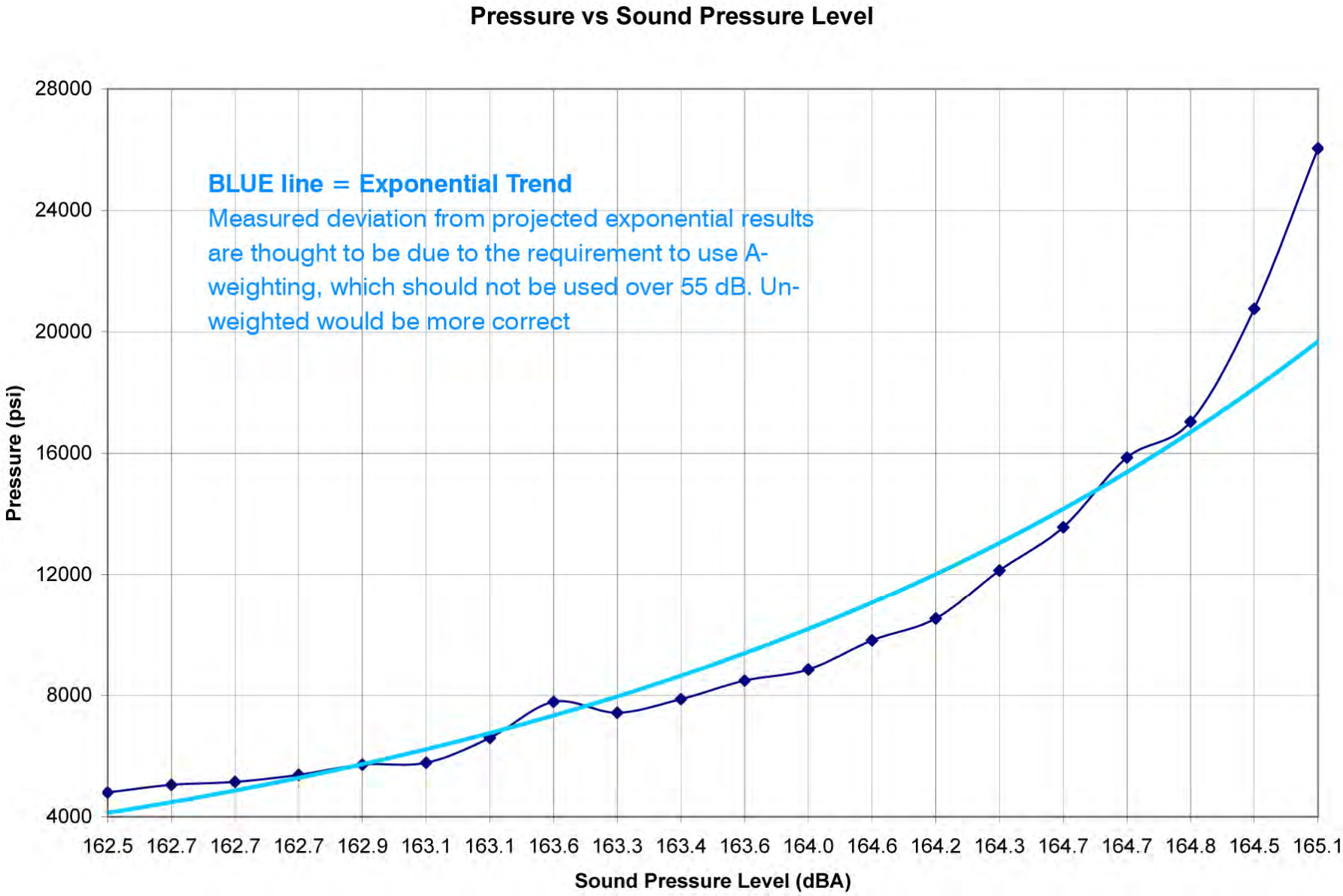
BARREL LENGTH and BORE PRESSURE



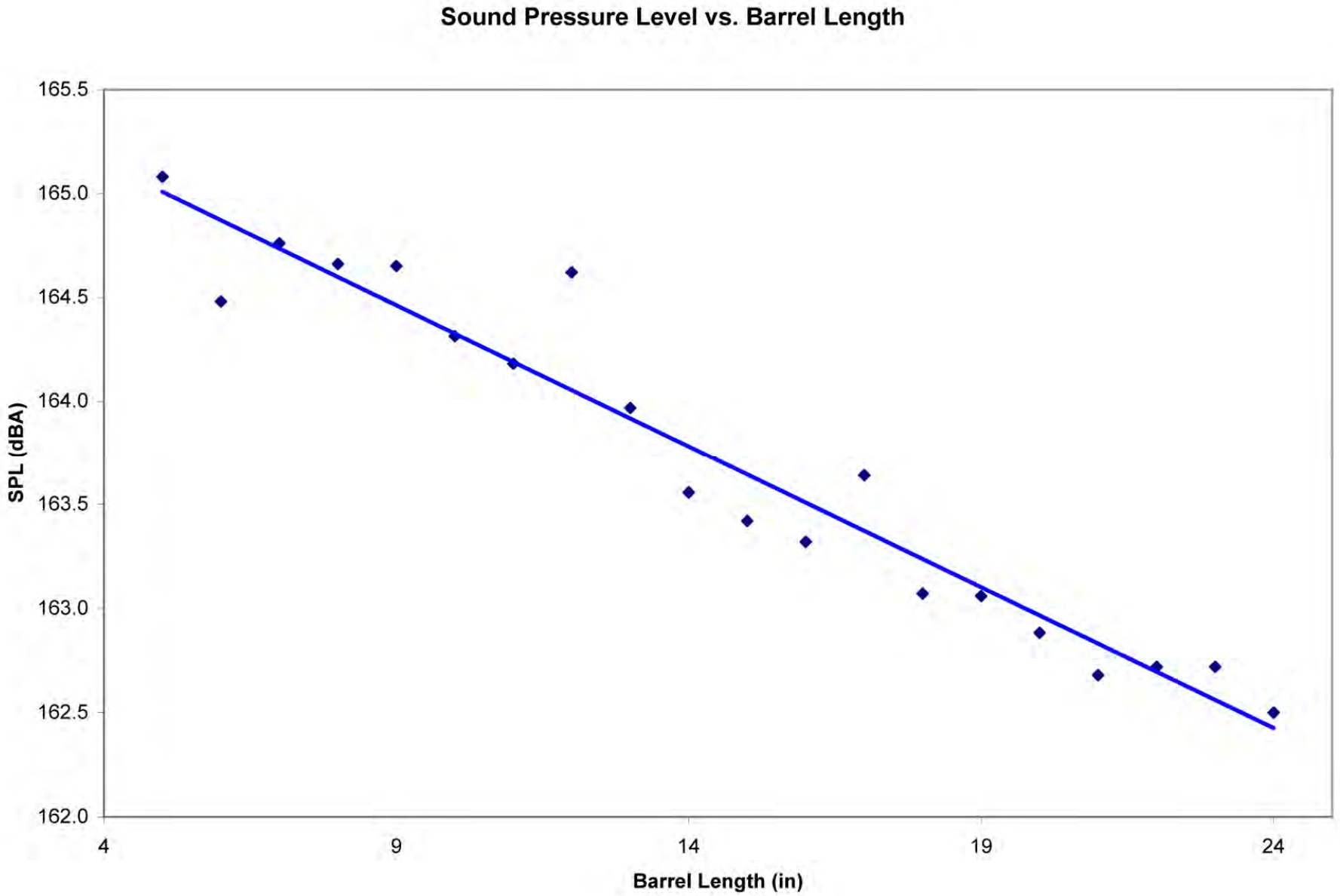
BARREL LENGTH and BORE PRESSURE



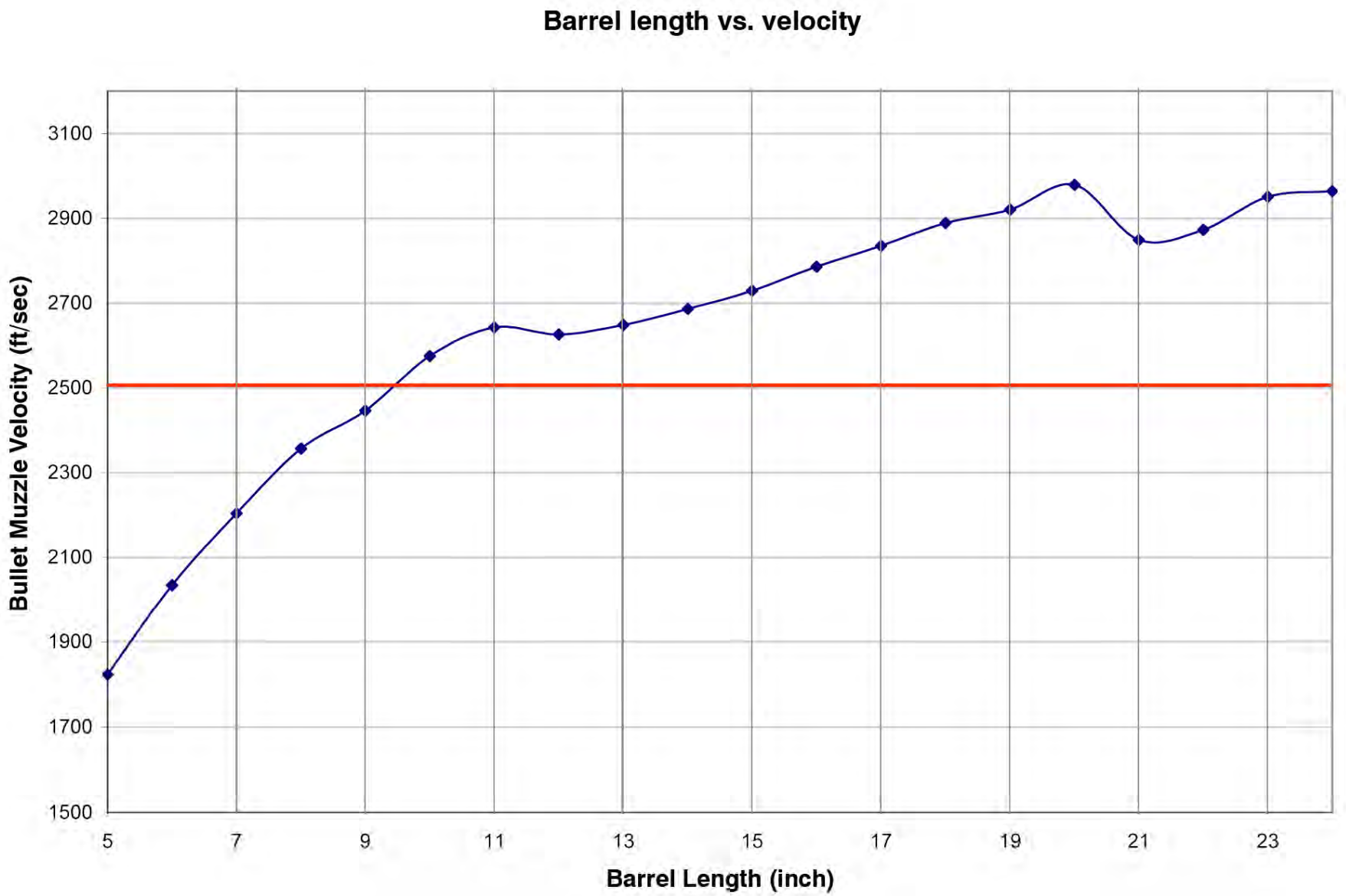
BORE PRESSURE and S.P.L.



S.P.L. and BARREL LENGTH



BARREL LENGTH and VELOCITY



CONCLUSIONS

1. Pressure in the bore (uncorking pressure) increases exponentially with decreasing barrel length.
2. Non-suppressed sound pressure level increases exponentially with decreasing barrel length.
3. Pressure in a suppressor's entrance chamber appears to increase proportionately with uncorking bore pressure (based on previous studies).
4. Maximum velocity is in a 20 inch barrel. Barrels at or less than 10 inches may not have adequate velocity (2,500 ft/sec) for a lethal wound channel at other than point-blank range with M855 ammunition.

GENERAL DYNAMICS
Strength on Your Side

Medium and Large Caliber Propellant Solutions

May 19, 2010

Bob Pulver – St. Marks Powder

Frederick Paquet - Valleyfield



GD-OTS Propellant Capabilities



GD-OTS St. Marks Powder

Producing Propellant Since 1970
1974 Acres,
# of Buildings - 137
# of Employees - 350



GD-OTS Canada Valleyfield

Producing Propellant Since 1941
1112 Acres,
# of Buildings – 180
# of Employees - 420



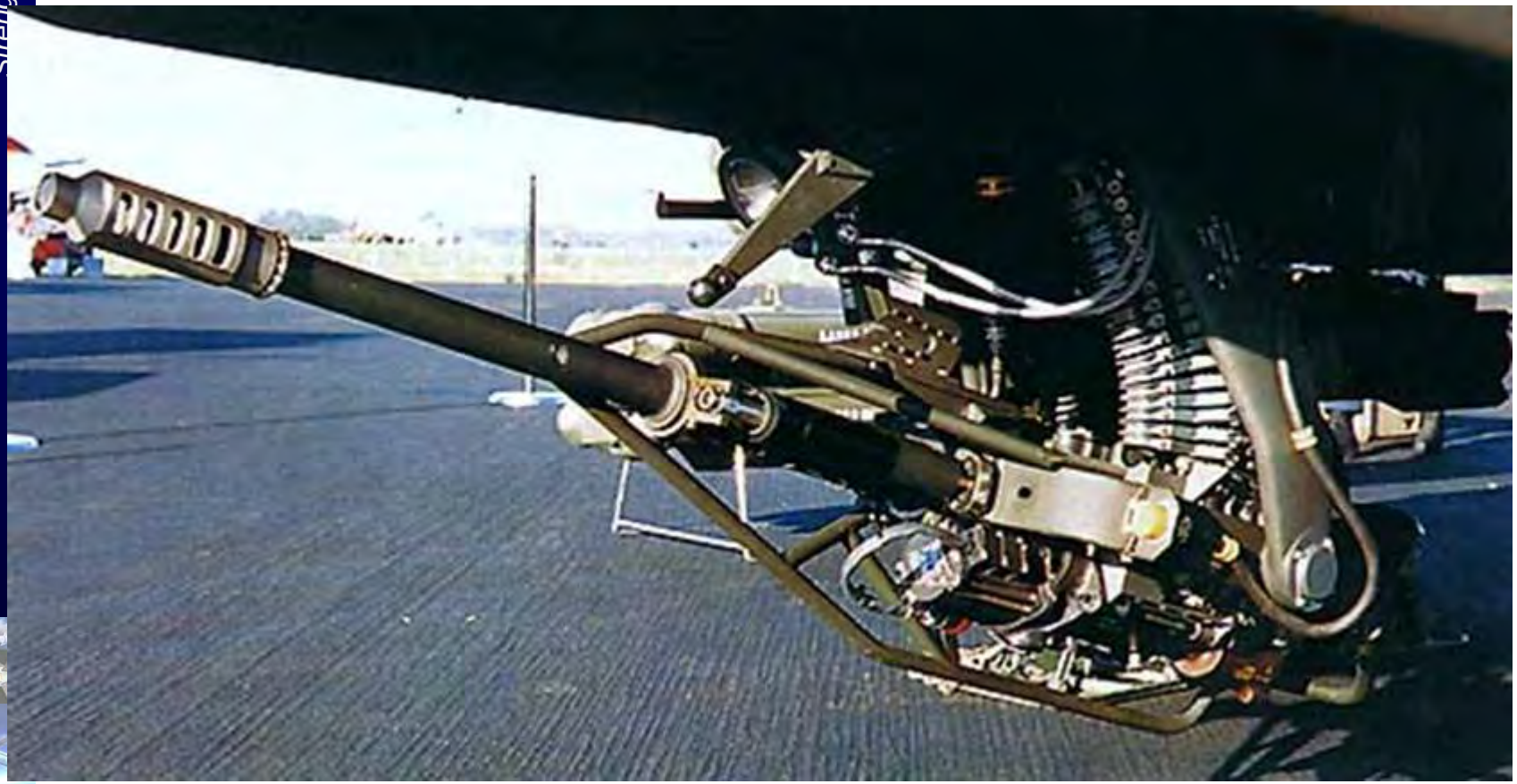


Medium and Large Caliber Propellant Solutions

- **St. Marks Powder HYBRID Propellant for 30mm Lightweight Ammunition**
- **St. Marks Powder and Valleyfield Extruded/BALL POWDER® Propellant Mixed Charge Concept**
- **Valleyfield M-14 Replacement Effort for 120mm Tank Trainer Ammunition**



The Army has experienced numerous M230 Chain Guns failures with 30mm M789 HEDP ammunition when exposed to hot temperatures over extended periods of time



The Apache's 30 mm x 113 automatic M230 chain gun

30mm Lightweight Improved Hot Temperature Storage

Overview

- GD-OTS St. Marks Powder is currently developing a single perf, HYBRID propellant to replace WC 855 BALL POWDER® Propellant to with improved hot temperature storage properties (ballistic stability)
  - Meets interior ballistic specifications
  - Meets fire control goals
  - Expected to have very good barrel wear/life



HYBRID Propellant for 30mm M788/M789

The State-of-the-art in Propellant Technology for Small, Medium and Large Caliber Ammunition

Ultimate ballistic efficiency achieved by combining perforated geometry with burn rate modifiers (deterrents)

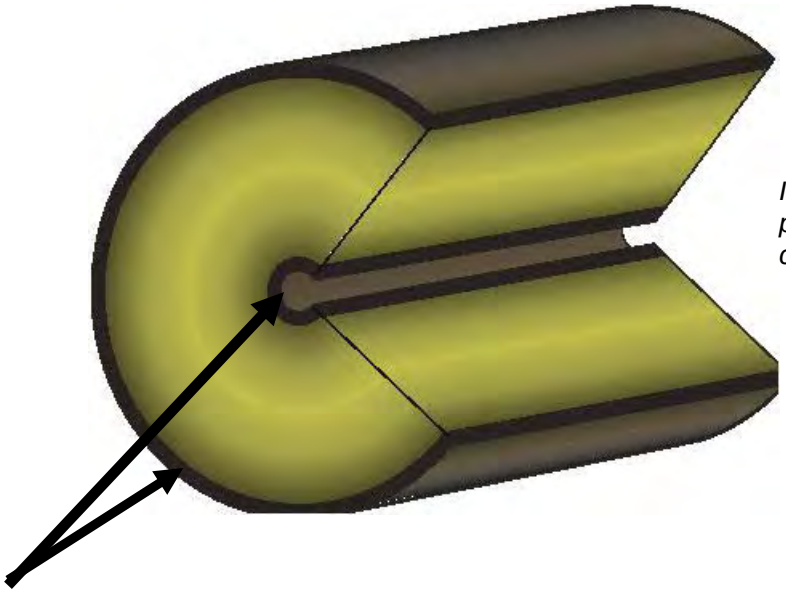


Illustration of a propellant grain cross section

Deterrent Layer - applied to tailor the burn rate for specific applications to optimize ballistic efficiency

Deterrent Layer – Lowers overall flame temperatures and provides a relatively cool burning outer layer



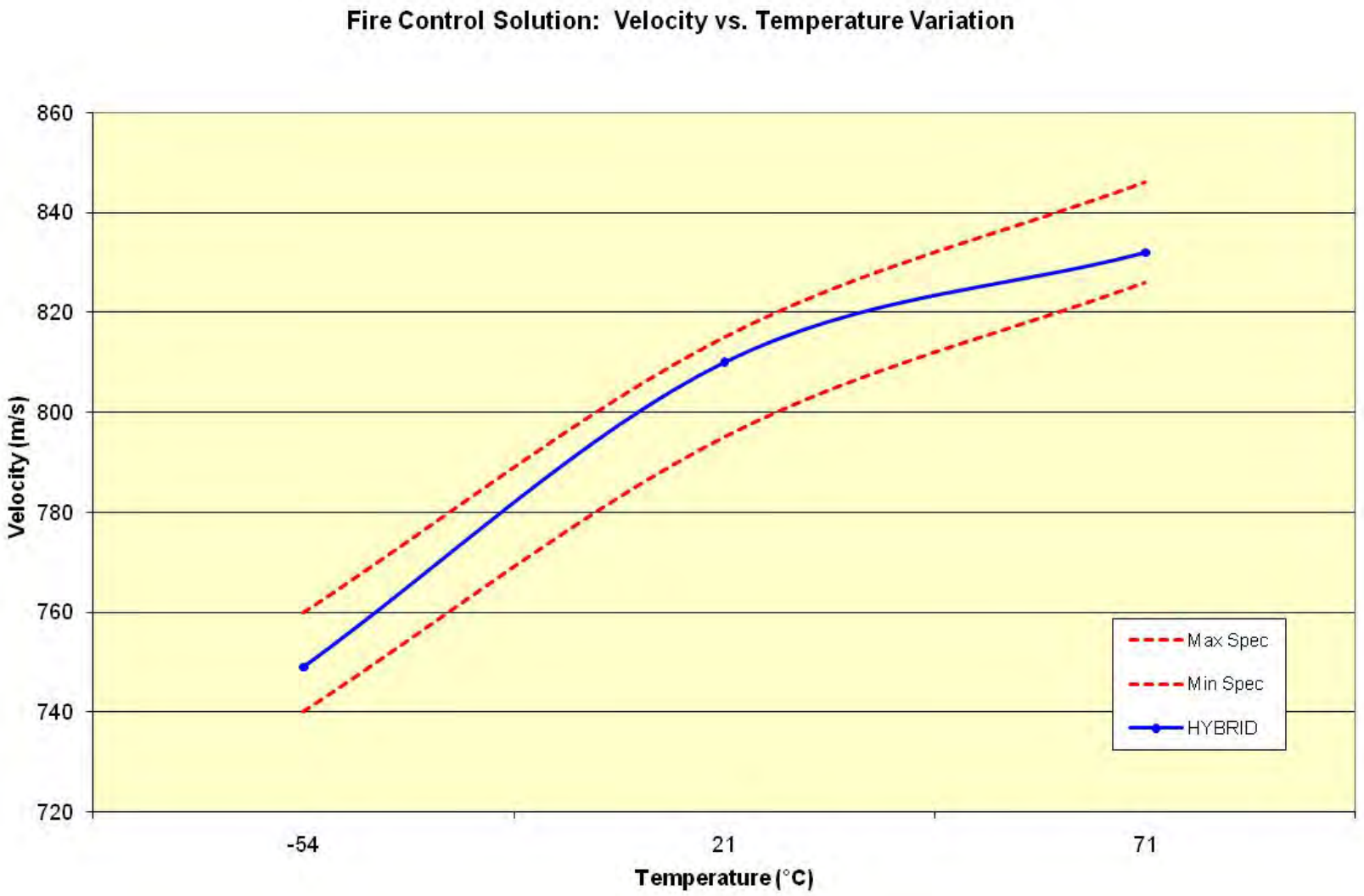
Addresses Needs for 30mm M788/M789 Ammunition

- **Superior Robustness to Hot Temperature Exposure**
  - Excellent High Temperature Storage Results
  - No increase in peak pressure after conditioning
    - Dual Stabilizers used, including Akardite II for long shelf life

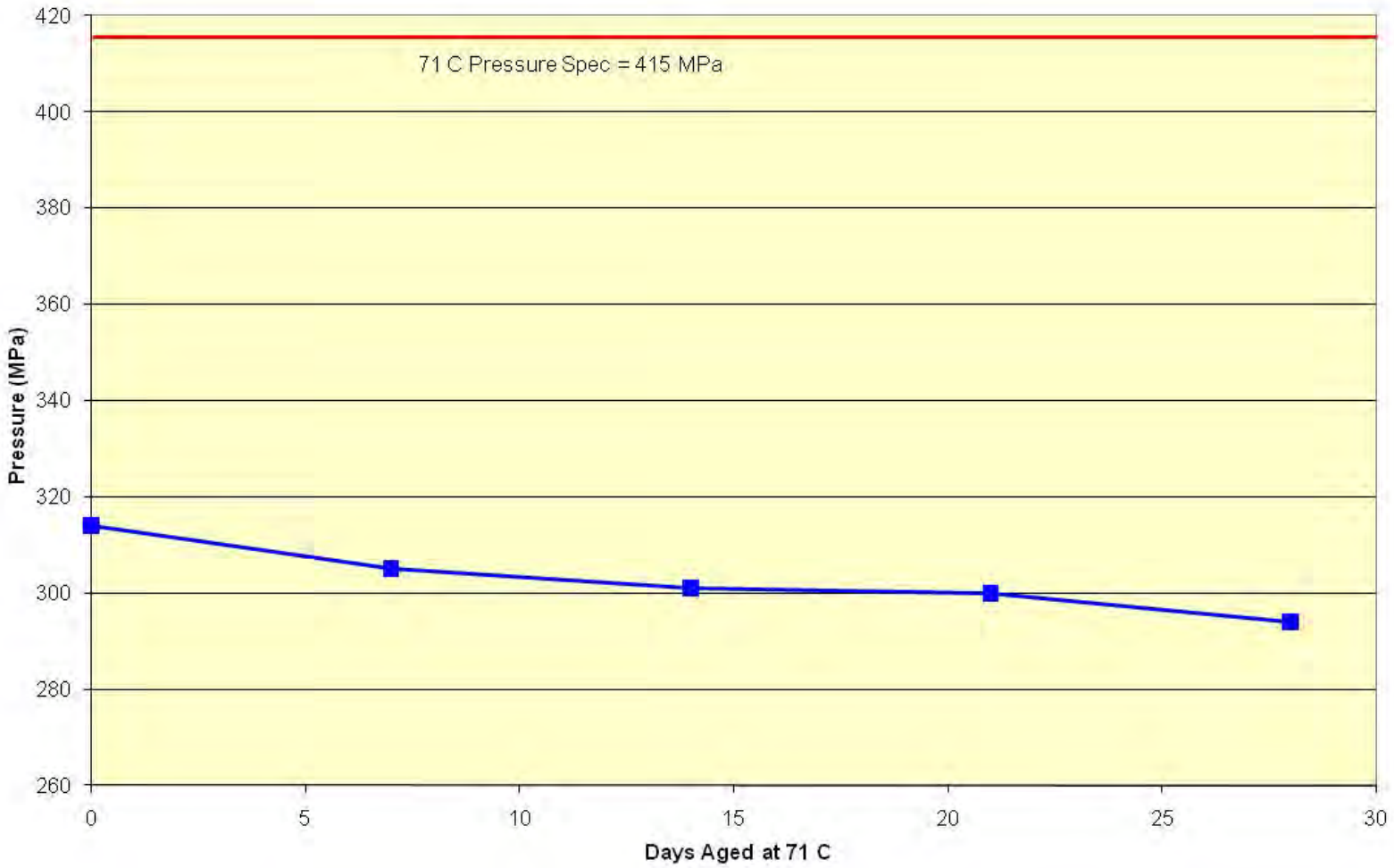
- **Current off-the Shelf Product ("Drop-In Replacement")**
  - Commercial variant of SHP 831 already in production
  - Economical - using conventional processes and low cost materials
  - Excellent temperature sensitivity
  - Excellent ignition properties
  - Excellent IM properties



30mm Lightweight HYBRID Data



HYBRID Propellant Operating Pressures in LW 30mm after Extended High Temperature Exposure at 71°C (160°F)



Improved Propellant: HYBRID SHP 831

- HYBRID SHP 831 propellant represents an economical state-of-the-art propellant
- Currently in production for commercial applications
  - Loading rate between BALL POWDER® and Extruded Propellants (little if any impact on ammunition loading equipment or capacity)
- St. Marks Powder HYBRID propellants are domestically produced in existing production facilities



St. Marks Powder and Valleyfield Extruded/BALL POWDER® Propellant Mixed Charge Concept



High Performance Propellant Technology

High Loading Density
+ Ballistic Efficiency

= High Performance

The ability to achieve higher charge weights combined with the appropriate burn progressivity (ballistic efficiency) will yield higher performance capabilities



Mixed Propellant Charge - Objective

- Valleyfield and St. Marks Powder Objective: Demonstrate this concept in ammunition to achieve improved ballistic performance
  - Chose 30mm GAU-8/A PGU-15 /B TP ammunition as a Baseline
  - In 2009, Valleyfield started with a 7-Perf, surface deterred, extruded propellant
  - Blended in a small diameter, surface deterred, BALL POWDER® propellant
  - Loaded with vibration

Achieved 17% charge weight increase with excellent ballistic efficiency, very good standard deviations and low flame temperature



Mixed Propellant Charge

- In 2010, Valleyfield tested a 19-Perf, surface deterred, extruded propellant
  - Blended in a small diameter, surface deterred, BALL POWDER® propellant
  - Loaded with vibration

Achieved 19% charge weight increase



Mixed Charge Propellant Concept



7-Perf Extruded and
BALL POWDER® Propellant



19-Perf Extruded and
BALL POWDER® Propellant

30mm Ballistic Results - Projected

Baseline @ 145 grams = 3,340 fps

1st Iteration Mixed Charge @ 170 grams = 3,623 fps

Represents an 18% increase in Kinetic Energy +283 fps

Planned Iteration Mixed Charge @ 188 grams = 3,730 fps

Represents a 25% increase in Kinetic Energy +390 fps



Mixed Propellant Charge – Future Work

Future Work

- Maximize charge weights
  - *Geometry and Loading Studies*
- Maximize ballistic efficiency with deterrent technology
- Optimize standard deviations and temperature sensitivity
  - *Propellant chemistry (Compatibility)*
  - *Ignition system*
- Ensure excellent long-term, hot temperature ballistic storage
- Ensure excellent IM properties



Valleyfield M-14 Replacement Effort for 120mm Tank Trainer Ammunition



Introduction

- The main processing solvent of M14, diethyl ether, has a strong affinity for NC.
- Diethyl ether is also known for its high flammability
- A number of tank fires in training exercises have put in question the use of M14 propellant in 120mm training ammunition.



Residual solvent reduction

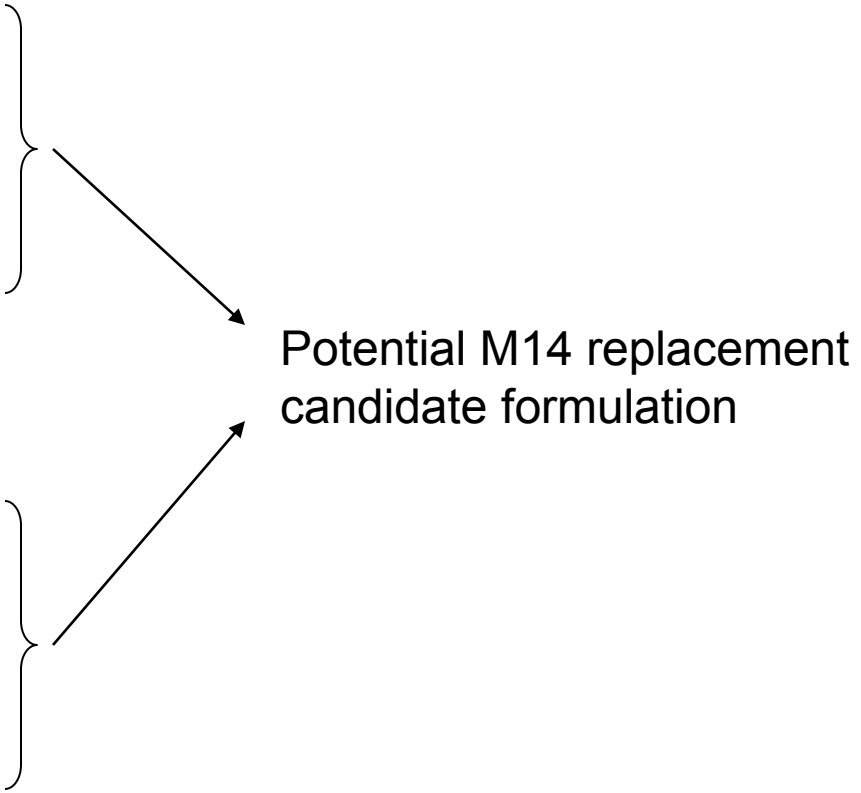
Double base formulation

Easier solvent removal

NG free formulation

Better insensitivity

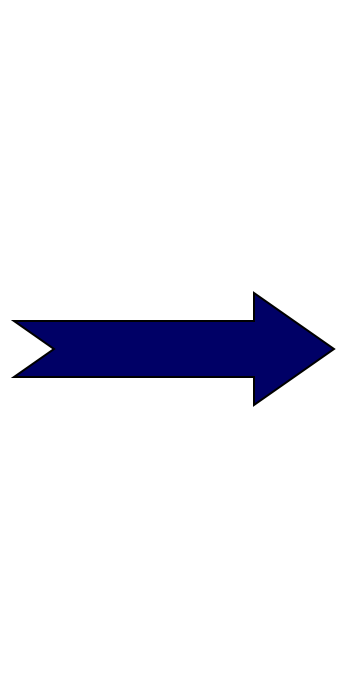
Lower flame temperature





TMDB formulation

- "T"EGDN
- "M"odified
- "D"ouble
- "B"ase



An NC based formulation that is plasticized with tri-ethylene glycol dinitrate (TEGDN)



TEGDN

- Extremely insensitive (impact sensitivity almost 100 times less then DEGDN).
- Better thermal stability then NG and DEGDN.
- Not a vasodilatator.
- Better gelatinizing agent to NC then NG.
- Less mobile then DEGDN and NG.



Meyer R, Köhler J, Homburg A, Explosives, 5th Revised Edition, Wiley-VCH, 2002.
Urbanski T, Chemistry and Technology of Explosives, Pergamon Press, 1984.
Fedoroff B T, Sheffield O E, Kaye S M, Encyclopedia of Explosives and Related Items, Picatinny Arsenal.
Lewis R J, SAX's Dangerous Properties of Industrial Chemicals, 9th Edition, Van Nostrand Reinhold, 1996.

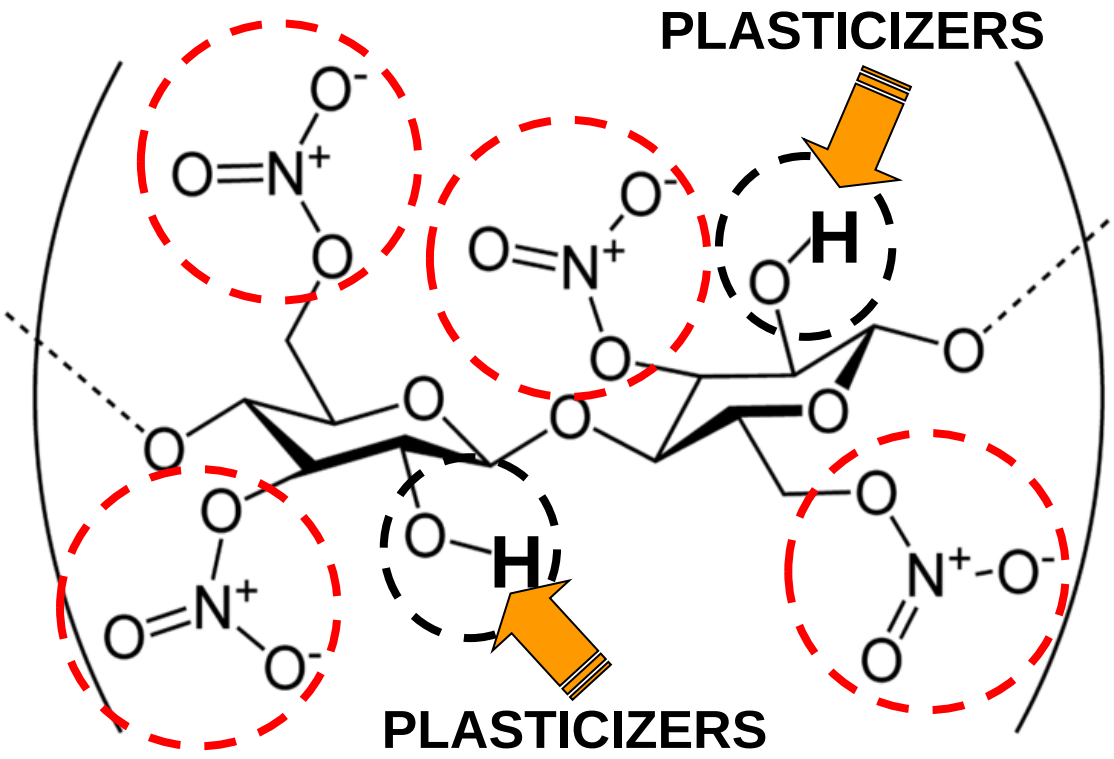
Processing solvents

- A mixture of acetone and ethanol is used in the manufacturing process. These solvents are much safer than the usual diethyl ether used in M14 manufacturing.

Characteristics	Diethyl ether	Acetone	Ethyl Acetate
LEL, % V/V	1.9	2.5	2.2
Explosivity range (UEL-LEL), % V/V	34.1	10.3	9.3
Flash point, °F	-49	0	24.8
Vapour pressure, mm Hg	440	180	75

- Given that the TMDB formulation contains 30% of plasticizer, the amount of required solvent in the process is reduced by 50% to 70% (10-15% at extrusion instead of 30-35% for M14).

Residual solvents



CH_3-CH_2-O-H

CH_3-CH_2-O-CH_2-CH_3

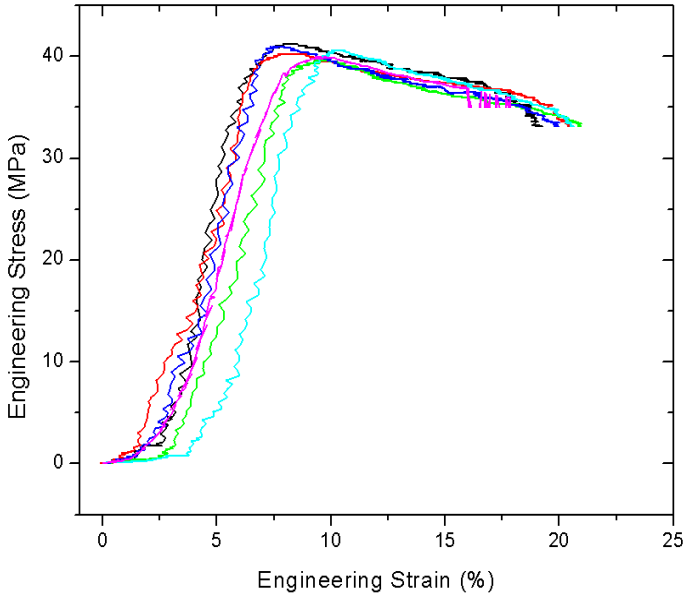
With TMDB propellant, the hydrophobic plasticizer (TEGDN) will block the hydroxyl groups and drive off the solvents

Mechanical properties

Grain Type	Compressive Modulus
	(Gpa)
TMDB	**1.01 ± 0.18**
JA2	0.722
M14	2.79
M30A2	1.638
XM39	3.07 ± 1.27



Mechanical properties are similar to JA2



Insensitivity testing

- A shape charge jet attack test yielded a Type III reaction on a 105mm tank cartridge with 9.9 Lb of TMDB propellant





- An 84mm (Carl Gustav) shape charge jet and a brass cartridge case were used

TMDB configurations

19 Perforations hexagonal rosette



1 Perforation cylindrical





7 Perforations cylindrical

Surface moderation has also been applied to these geometries when necessary in order to increase the ballistic efficiency.

Ballistic testing

- All testing was done as part of the original M14 replacement effort between 2005 and 2007.
- TMDB has been tested successfully in the 120mm M865 tank cartridge.
- In the case of the 120mm M1002, the right temperature slope was obtained but the geometry has to be optimized in order to decrease the pressures.



Future efforts

- As part of the current M14 replacement program, TMDB will be used as a potential solution.
- The goal is to confirm the previous M865 success and lower the pressures in the M1002 application through a change of geometry.
- All candidates shall have a residual solvent level lower then 0.1%.
- All testing for the first phase of this program is scheduled to be completed by August 2010.



GENERAL DYNAMICS
Strength on Your Side

Small Caliber Propellant Solutions for the U.S. Military

St. Marks Powder
A General Dynamics Company

May 19, 2010



GENERAL DYNAMICS
Ordnance and Tactical Systems

A Leading Supplier Of Propellants For Military Applications

- BALL POWDER® Propellant Loaded in over 95% of U.S. Military small arms ammunition





- Loaded Internationally in over a dozen countries for their Small Caliber Military Applications

- Ability to develop and deliver propellants specifically tailored to customer requirements.

St. Marks Powder
Research and Development



Resources

- Dedicated pilot plant
- Analytical and process Laboratories
- Ballistic test ranges
- Modeling and simulation capabilities

Activities

- Product and Process development and optimization
- Technical services to customers
- Support to operation: process, products and materials
- Contract R&D

The St. Marks Quality Program: Designed to Drive Continuous Improvement in Performance

Customer focused
Team management approach
Closed-loop design

Comprehensively integrated:

- **Strategic planning**
- **Employee training and development**
- **Product design and development**
- **Supplier quality assurance**
- **Production**
- **Testing**
- **Customer service**
- **Performance review/improvement**



DET NORSKE VERITAS

MANAGEMENT SYSTEM CERTIFICATE

ST. MARKS POWDER, INC.

ISO 9001:2008

THE DESIGN, MANUFACTURE AND SUPPLY OF SOLID GUN PROPELLANTS AND RELATED TECHNOLOGIES FOR MILITARY AND COMMERCIAL MARKETS

ISO 9001 certified since 1994.
ISO 14001 and OHSAS 18001 certified in 2004.

Flash Reduced Pistol Ammunition for the U.S. Military

45 ACP

Applications – Ball, Frangible, Green Primer, Green Bullet

45 ACP M1911 Ballistic Specifications

Velocity 855 +/- 5 ft/s, Pressure 16,500 CUP max. avg.

- St. Marks Powder has developed a BALL POWDER® Propellant which meets 45 ACP specifications
- 45 ACP BALL POWDER® Propellant is designed to be clean burning with reduced flash



45 ACP Flashed Suppressed BALL POWDER® Propellant

St. Marks Powder has developed propellant additives which reduce flash for 45 ACP ammunition



Baseline



St. Marks BALL POWDER®
Flash Suppressed Propellant

Flash Reduced Pistol Ammunition for the U.S. Military

9mm NATO M882

- The currently fielded WPR® 289 St. Marks BALL POWDER ® Propellant used in the 9mm NATO M882 cartridge is designed to be clean burning with reduced flash



St. Marks Powder Flash Testing in 9mm MANN Barrel

St. Marks Powder IR&D effort in short barrel 5.56mm

5.56mm BALL POWDER® Propellant

Standard 5.56mm M855 Projectile, 62.0 grains – IR&D testing in various length MANN Barrels

Barrel Length	Propellant Development Candidate	Velocity @78 feet (ft/s)	Mouth Pressure (psi)	Port Pressure (psi)
20"	WC 844 (5.56mm M855 Baseline)	3,022	56,370	16,387
20"	WCR 845®S/SMP® 843	3,017	54,822	16,373
20"	SMP® 842	3,087	59,221	16,064
14.5"	WC 844 (5.56mm M855 Baseline)	2,752	55,756	16,487
14.5"	WCR 845®S/SMP® 843	2,756	54,855	16,582
14.5"	SMP® 842	2,825	58,830	16,204
11.5"	WC 844 (5.56mm M855 Baseline)	2,624	56,262	23,767
11.5"	WCR 845®S/SMP® 843	2,610	53,698	24,156
11.5"	SMP® 842	2,691	58,747	24,059

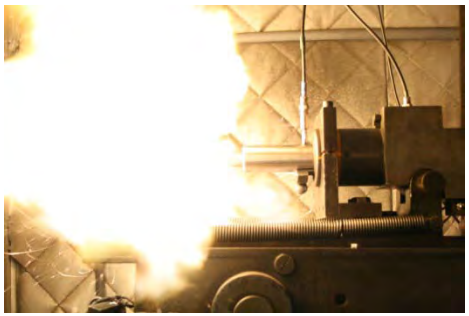




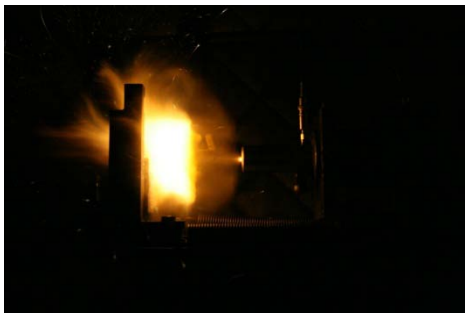
St. Marks Powder IR&D effort in short barrel 5.56mm

- St. Marks Powder has developed optimized BALL POWDER® Propellant solutions for reduced flash in short barrel applications

Propellant Development work in a 11.5” Mann Barrel without a Flash Suppressor



WC 844 (Baseline Propellant for 5.56mm M855 Ammunition)



WCR 845®S/SMP® 843 Reduced Flash (Propellant Development Candidate)

5.56mm Subsonic Propellant Research & Development Effort

5.56mm Subsonic/Flash Suppressed

Tested in HK416 Weapon @ 21.0 grns.

Propellant	Temp	Velocity (ft/s)
SHP 771 X7081	**150°F**	**1,167**
	70°F	**971**
	- 20°F	**834**
	-65°F	**824**



- All rounds functioned in a HK416 Weapon at all Temperatures
- Need to reduce velocity at 150°F to achieve subsonic velocity at all temperatures

7.62mm M118 BALL POWDER® Propellant

7.62mm M118 Long Range/Flash Suppressed

Projectile 175 grns., Propellant Charge 42.3 grns., 22" barrel

Propellant	Temp	Velocity (ft/s)	Presure (psi)
SMP® 768	**160°F**	**2,624**	**64,000**
	70°F	**2,603**	**58,800**
	-65°F	**2,603**	**53,700**

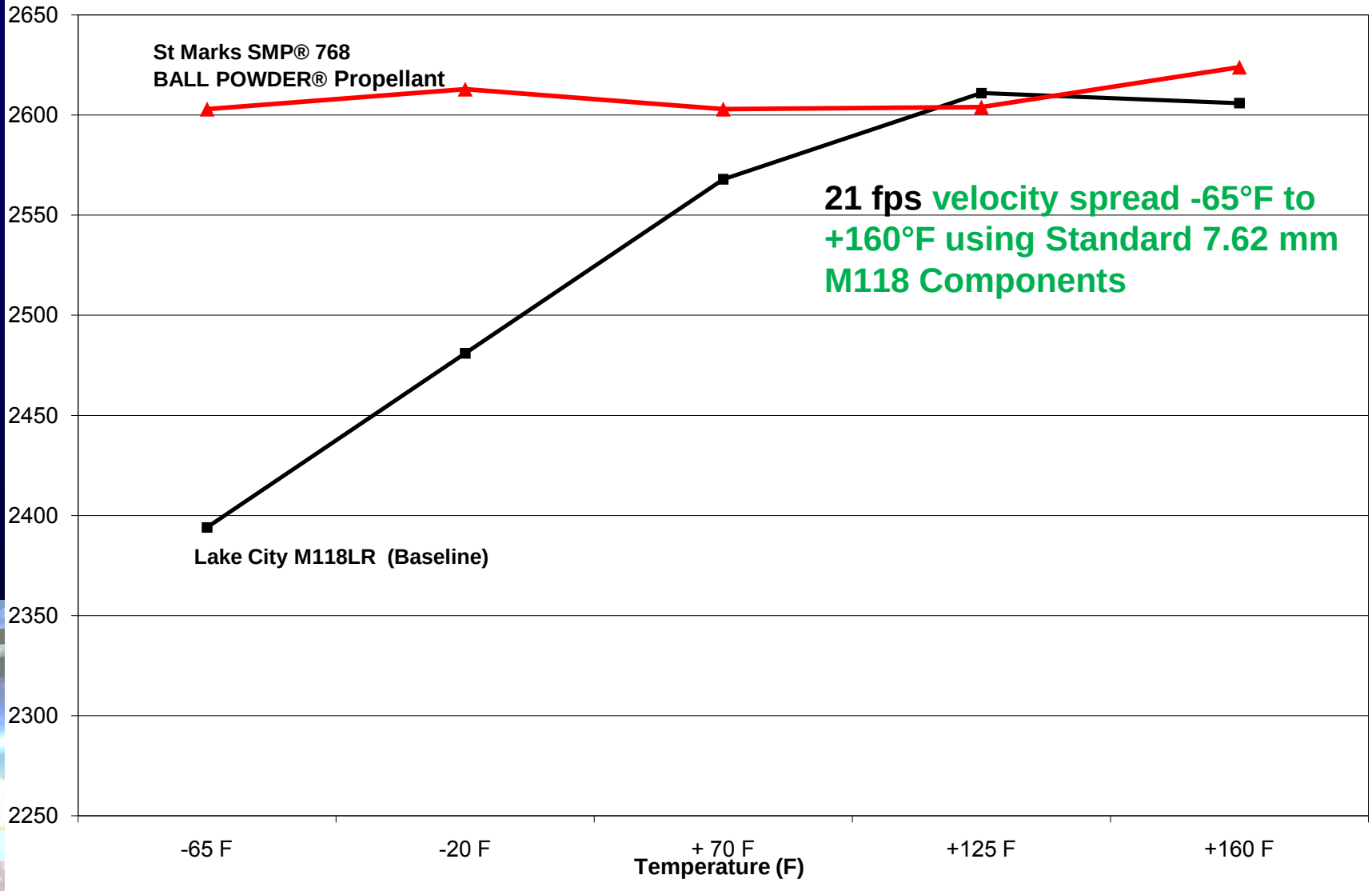
- SMP® 768 has enhanced Temperature Sensitivity over conventional propellants with excellent long term, hot temperature storage properties





7.62mm M118 BALL POWDER® Propellant

Velocity and Storage Data of 7.62mm Rounds at Temperatures



7.62mm M118 BALL POWDER® Propellant

- Excellent Storage Properties

SMP® 768		
Storage Data	Velocity (ft/s)	Pressure (psi)
30 Days +70°F	2592	58700
30 Days +150°F/+70°F	14	-300
30 Days -40°F/+70°F	4	-200
Temperature Cycling	-10	-200



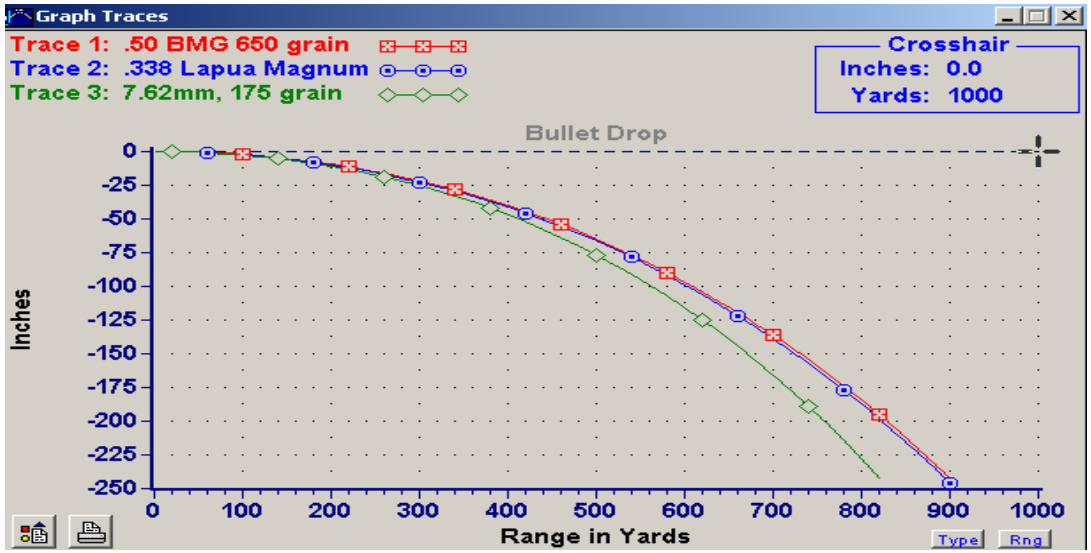
.338 Lapua BALL POWDER® Propellant Commercial Ammunition

.338 Lapua Enhanced Performance

Projectile 300 grns., Propellant Charge 98.5 grns., 24" barrel

Propellant	Velocity (ft/s)	Presure (psi)
OBP® 715	**2,750**	**65,000**

- > 90 ft/s increase in velocity over factory rounds with BALL POWDER® Propellant
- Enhanced .338 Lapua has similar trajectory as 50 Cal., 650 grain commercial ammunition





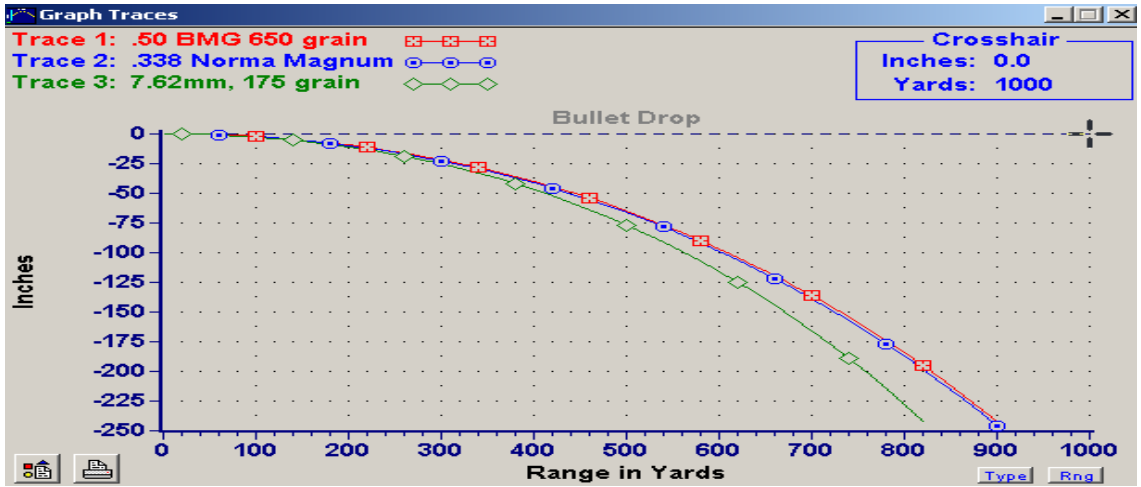
.338 Norma BALL POWDER® Propellant Commercial Ammunition

.338 Norma Enhanced Performance/Flash Suppressed

Projectile 300 grns., Propellant Charge 94.5 grns., 24" barrel

Propellant	Velocity (ft/s)	Presure (psi)
OBP® 715	**2,750**	**64,000**

- St. Marks Powder sets the standard in velocity for this cartridge. No other propellant can match the energy, velocity and accuracy
- Enhanced .338 Norma has similar trajectory as 50 Cal., 650 grain commercial ammunition





.50 Cal. BALL POWDER® Propellant Commercial Ammunition

.50 Cal. Enhanced Performance/Flash Suppressed

Projectile 650 grains., 36" barrel

Propellant	Velocity (ft/s)	Presure (psi)
WC 869	**>3110**	**60,000**

- > 200 ft/s increase in velocity over commercial .50 Cal., 650 grain ammunition using WC 869 (>14% increase in K.E.)



Conclusion

- St. Marks has fielded propellant technology to enhance performance and reduce muzzle flash for a variety of applications.
- St. Marks has a dedicated Research and Development group that is available to resolve technical issues.
  - Working on next generation of Small Arms Propellants for Increased Lethality, Improved Barrel Wear and Reduced Flash







RDECOM









RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Extended Area Protection and Survivability (EAPS) 50mm Cannon

Presented By:
Arthur Aeberli
Systems Engineer
Medium Caliber Weapons Team

Agenda

- Basic 25mm Bushmaster Cannon
- Bushmaster Cannons
- Extended Area Protection and Survivability (EAPS)
- EAPS 50mm Cannon Requirements
- 50mm Cannon Current Performance.
- Future Work on Cannon



M242 Bushmaster Chain Gun



- Designed as the main armament for the Bradley Fighting Vehicle.
  - •Validation contract award was May 1972
  - •Type Classified Standard Dec 1979
  - •Full Material Release Mar 1983

- •M242 25mm Chain Gun Performance:
  - •Externally powered cannon.
  - •Reliability 20,000+ of rounds between stoppages.
    - •Primary targets: Area Targets
    - •Secondary targets: Lightly Armored Vehicles
    - •Fired mixture of HEI-T and APDS-T Rounds
    - •Very field maintainable.
    - •Dispersion of .44 Mils
    - •Fired in a single shot mode and 200 shots per minute mode
    - •Light weight.

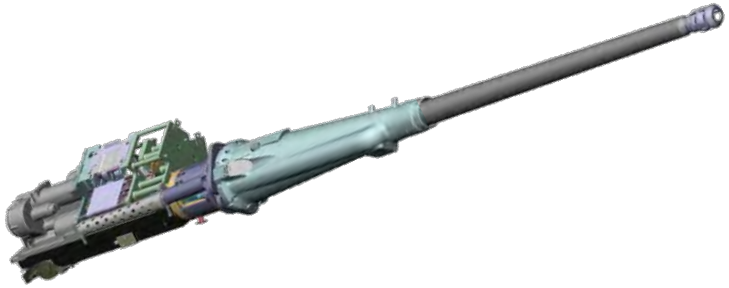
Other Bushmaster Chain Guns

- 30mm Bushmaster II Automatic Cannon
- 30/40mm Mk44 Bushmaster Automatic Cannon
- 35/50mm Bushmaster III Automatic Cannon
- 40mm Bushmaster IV Automatic Cannon
- Lightweight 25mm Bushmaster Chain Gun
- 50mm EAPS Automatic Cannon



Extended Area Protection and Survivability (EAPS)

- ***EAPS is an Advanced Technology Demonstrator (ATO-D) Program. The purpose of this program is to develop inner tier gun based air defense technologies that will bridge the gap between the initial C-RAM capability and the Objective EAADS capability for providing a 360 degree hemispherical extended area protection from RAM threats.***



Results:

- ***Key developmental technologies include:***
  - ***50mm Automatic Cannon***
  - ***Course Corrected Ammunition***
  - ***Advanced Forward Fragmentation Warhead***
  - ***Ammunition Tracking System (ATS) Radar***



Payoff:

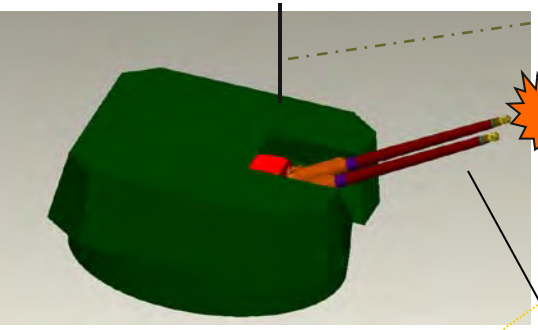
- ***Extended Engagement Range***
- ***Lower Cost per Kill***
- ***10 Round Bursts- less Collateral Damage***



EAPS Concept



50mm EAPS Cannon





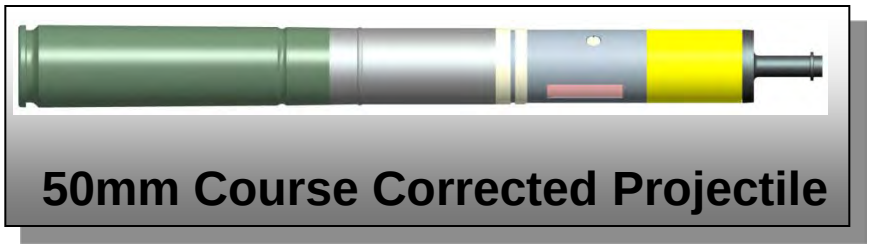
RF Data Link

Radar Track

10 Round Burst

Mid-Flight Course Correction

Forward Fragmentation Warhead Detonation



50mm Course Corrected Projectile

Malcolm Baldrige National Quality Award 2007 Award Recipient

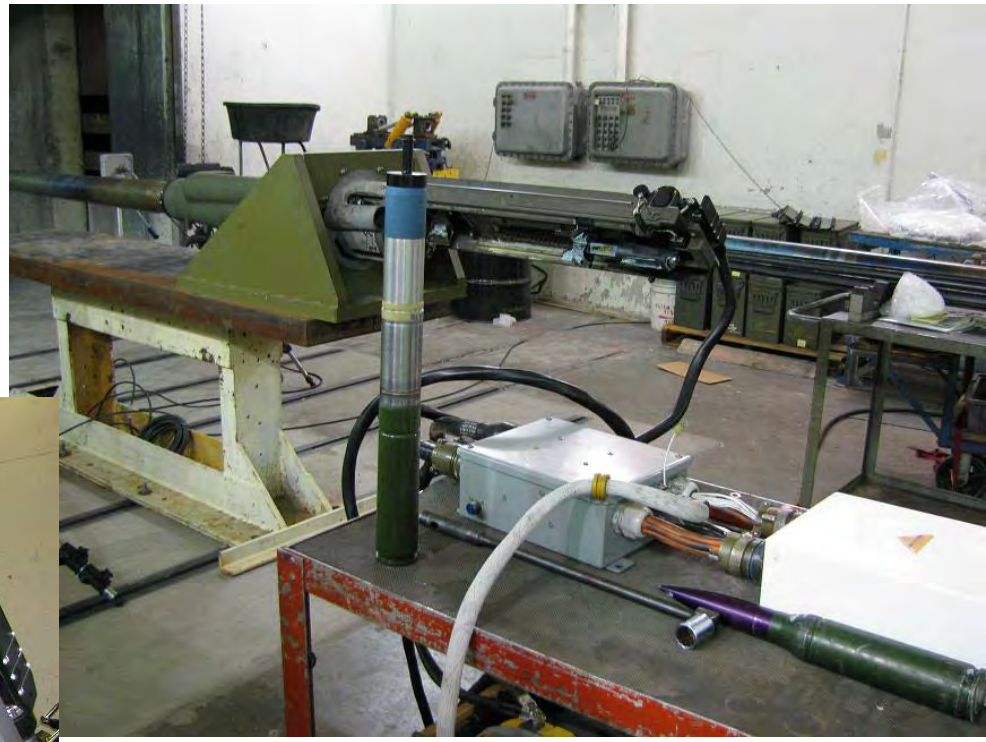
Rational for a 50mm Chain Gun

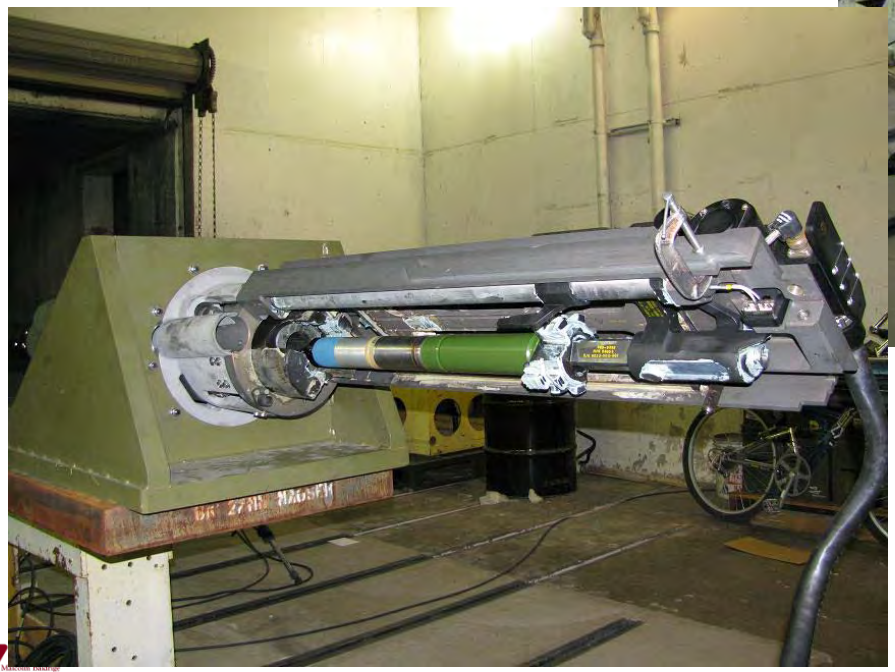
- Caliber needed to be in the range of 50 to 60mm
- Proven Scalability
- Accurate
- Light Weight
- Short Lead Time
- Case Availability
- High Firing Rate



50mm EAPS Cannon

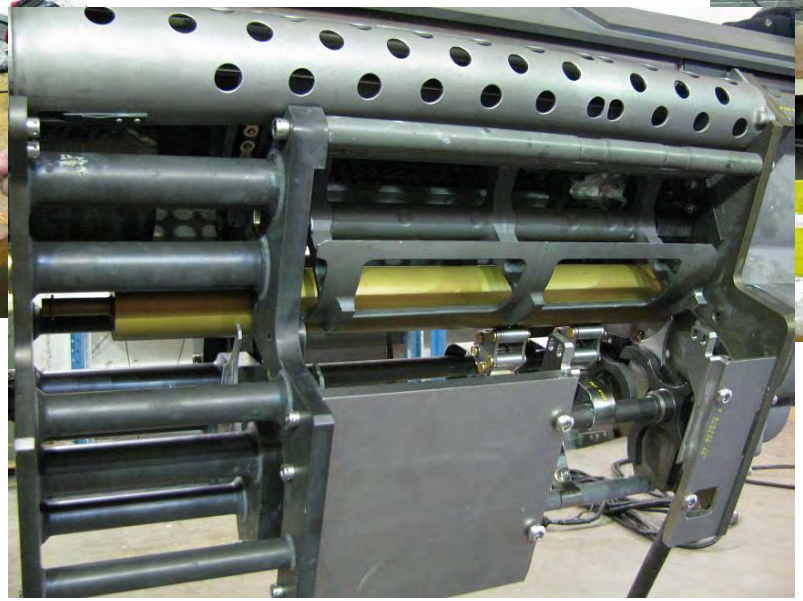
- Fired 17 tests rounds with no weapon failure.
- Have achieved firing rates of 120 shots per minute
- Dispersion appears to be in the appropriate range.





Functioning of the Upper Receiver







50mm EAPS Cannon

EAPS Cannon firing video



BD EAPS Video NOT RELEASED email version.wmv

Future Work on Cannon

- Increase firing rate to 200spm
- Increase durability and reliability
- Verify dispersion.

Summary

- 50mm Cannon Program on Track for EAPS Program

- Represents largest of all Chain Gun Designs

- Initial Performance Indicates High Probability of Success

Advanced Gun Barrel Technologies (AGBT)

Background and Results

NDIA Joint Armaments Conference, 2010

Presented by: Mr. Bill Vezina
BAE Systems, Inc. Land & Armaments
william.vezina@baesystems.com
(763) 572-4898

Office of Naval Research
Program Manager: Mr. Dan Simons
Technical Direction Agent: Mr. Paul Conolly

BAE Systems, Land & Armaments
Program Manager: Dr. Amir Chaboki
Technical Lead: Mr. Mike Hermanson

Outline

- AGBT program background
- Development approach
- Technology selection and screening
- Subscale development and testing
- Full scale firing demonstration
- Summary and conclusion
- Questions

Advanced Gun Barrel Technologies

ONR Future Naval Capabilities Program

Objectives

- Identify & develop Gun Barrel Technologies that enable upgrades to existing barrel capabilities for Naval gun propulsion missions
  - *50% increase in Gun Barrel Erosion & Fatigue Life*
  - *Reduced Life Cycle Cost*
  - *Improved Gun Barrel Thermal and Ballistic Performance*

Payoffs

- Increased Gun System Availability
- Improved Ballistic Capability (Higher KE for increased range)
- Lower Life Cycle Cost

Transition

- Demonstrate Improved Barrel Life and Ballistic performance over AGS Baseline for Transition into DDG 1000

Large Caliber Naval Guns



- **MK 45 / Mod. 2**
- Bore: 5-inch (127mm)
- Length: 54cal, 22.5 ft (6.9m)
- Operating Pressure: 55 kpsi (380 MPa)
- Range: 13 Nmi
- Volume of Fire: 16-20 rnds/min (20 round ready service)
- **Barrel Life: 8000 rnds**
- Thermal Mgmt: Air Cooling
- Mark 67 charge with various projectiles
- Muzzle energy: 10 MJ



- **MK 45 / Mod. 4**
- Bore: 5-inch (127mm)
- Length: 62cal, 25.8 ft (7.9m)
- Operating Pressure: 63 kpsi (435 MPa)
- Range: 41 Nmi
- Volume of Fire: 8-10 rnds/min (10 round ready service)
- **Barrel Life: 1,500 rnds**
- Thermal Mgmt: Air Cooling
- ERM Projectile/Propelling Charge (under development)
- Muzzle Energy: 18 MJ



- **Advanced Gun System (AGS)**
- Bore: 155mm (6.1 in)
- Length: 62cal, 31.5 ft (9.6m)
- Operating Pressure: 53 kpsi (365 MPa)
- Range: 83 Nmi
- Volume of Fire: 10 rnds/min Sustained
- **Barrel Life: 3,000 rnds (Req.)**
- Thermal Mgmt: Liquid Cooling
- Long Range Land Attack Projectile/Propelling Charge
- Muzzle Energy: 27 MJ

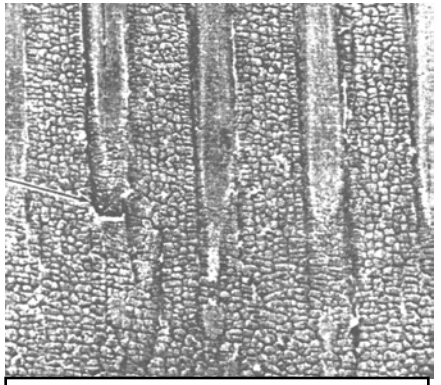
Trend toward higher performance guns using more aggressive propellants

Increased performance levels result in barrel life becoming a logistics cost driver

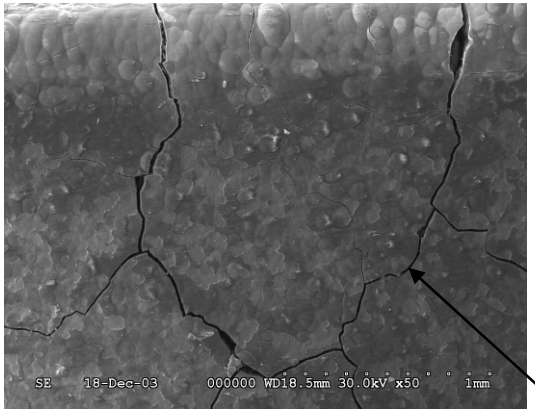
Current Technology: Hard Chrome

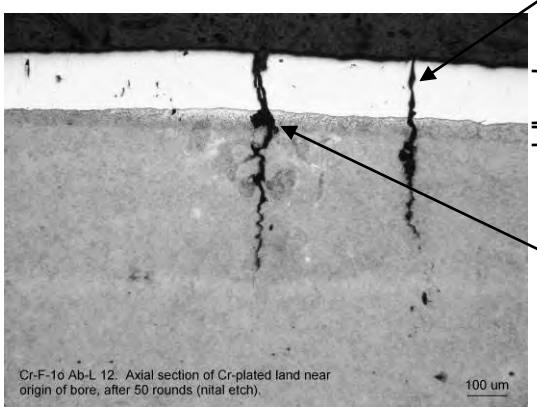
Root Problem: Chrome Plated Barrel Wear and Erosion

- Thermally induced stresses create heat check cracks during firing
- Underlying substrate is thermally altered (HAZ)
- Subsequent chemical attack of steel from combustion gasses undermines chrome
- Chrome “islands” are jeopardized until they break free and leave steel substrate exposed.
- Steel substrate is rapidly eroded by high velocity combustion gasses and accelerated chemical attack at high temperatures.



Bore scope view of heat checks at origin of rifling





Heat Check Cracks

Chrome Plate

Heat Affected Zone (HAZ)

Chemical attack at high temperature undermines chrome

AGBT Development Approach

- Identify existing technologies that have the potential to improve the service life of large caliber gun barrels and can be developed into full scale (155mm) process capability within the time frame of the program
- Screen these technologies using actual gun firings rather than vented combustors or other accelerated wear tests
- Select the most promising technologies for additional evaluation in a high rate of fire environment
- Identify the single best performing technology and demonstrate its performance in full scale 155mm test firings

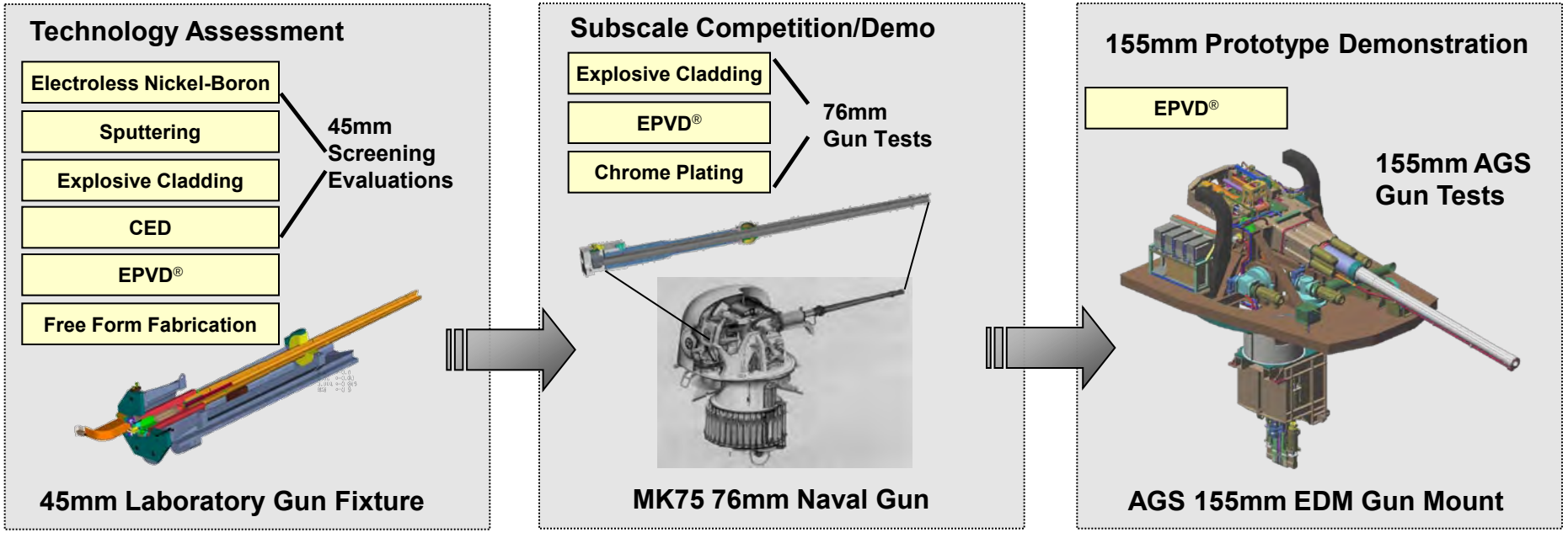
AGBT Development Approach

Primary Program Phases

I. Identify currently available technologies that offer the potential to extend the life and performance of large caliber gun barrels. Screen these technologies through firing tests in a “scaled down” large caliber gun environment.

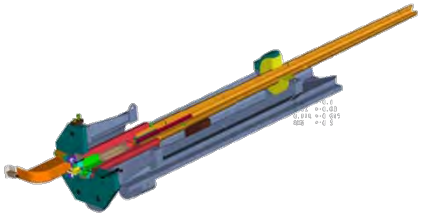
II. Select the two most promising technologies for a competitive “shoot-off” in a medium caliber high rate of fire environment.

III. Select the best technology and demonstrate its performance in a full scale 155mm high rate of fire environment.



Technology Selection and Screening

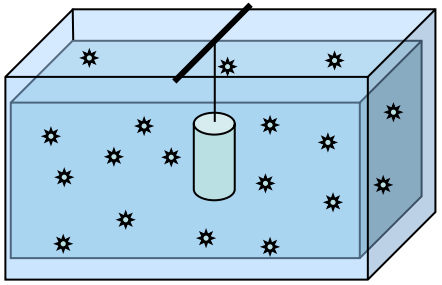
45mm Testing Phase



- Various coating technology vendors were identified
- Vendors of promising technologies were selected to perform under sub-contract
- Vendors applied their coating technology to an insert that was assembled into the shot start region of the 45mm test gun
- Each insert was subjected to a 50 shot test series
- Adhesion results compared to a chrome plated insert ‘baseline’ using micrographic analysis

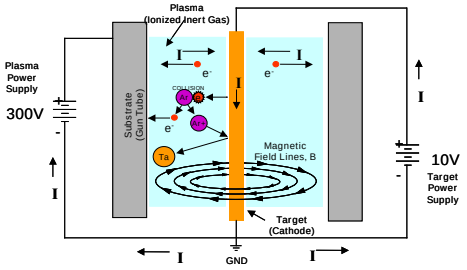
Candidate Coating Technologies

Electroless Nickel-Boron



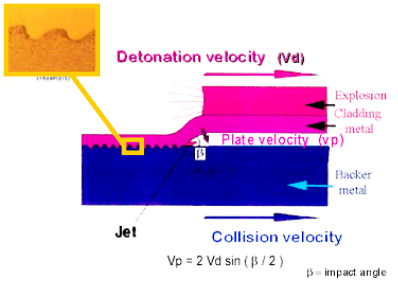
Catalytic plating process produces extremely uniform coating even on complex geometries

Sputtering



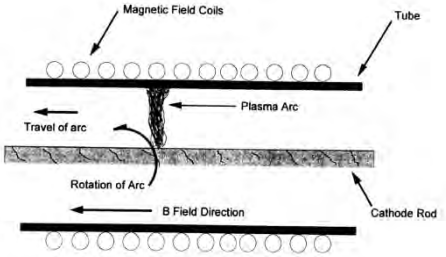
Material is sputtered, from a coaxial target, uniformly over the inside diameter of the barrel

Explosive Cladding



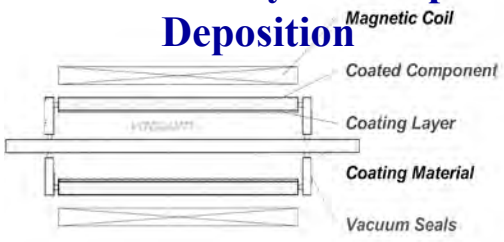
Tube of cladding material is mechanically bonded with the gun barrel in a collision driven by an explosive detonation

Coaxial Energetic Deposition



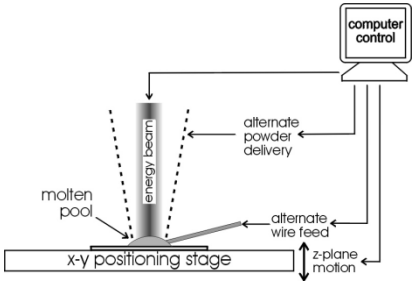
Plasma arc rotates around center conductor and travels along its length depositing material

Electromagnetically Enhanced Physical Vapor Deposition



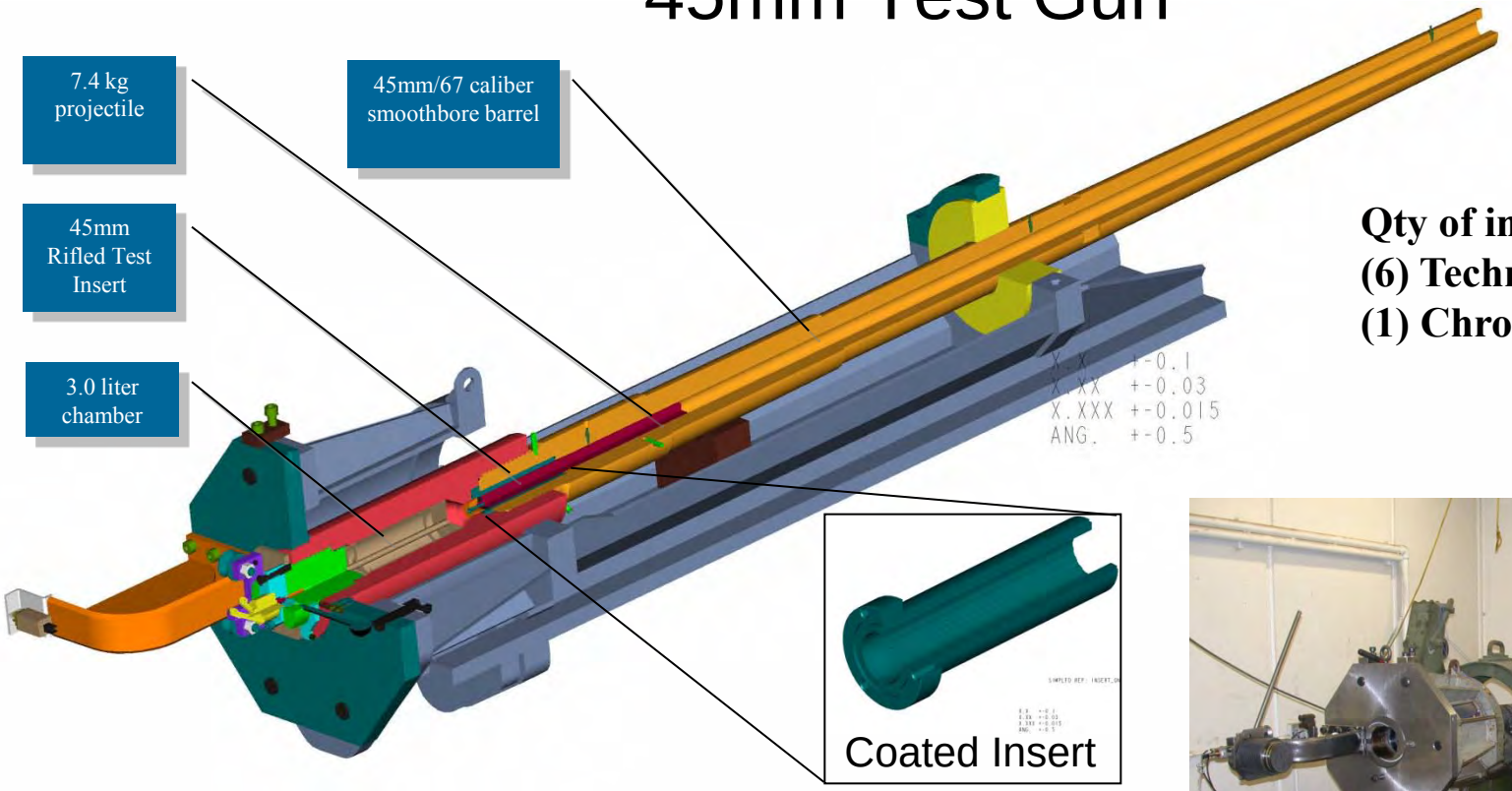
Electrically controlled magnetic fields enhance the plasma environment of the physical vapor

Solid Free-Form Fabrication



Engineered material is created by alloying of powdered and/or wire-fed metals

Technology Screening Platform
45mm Test Gun



Qty of inserts screened:
(6) Technology candidates
(1) Chrome baseline

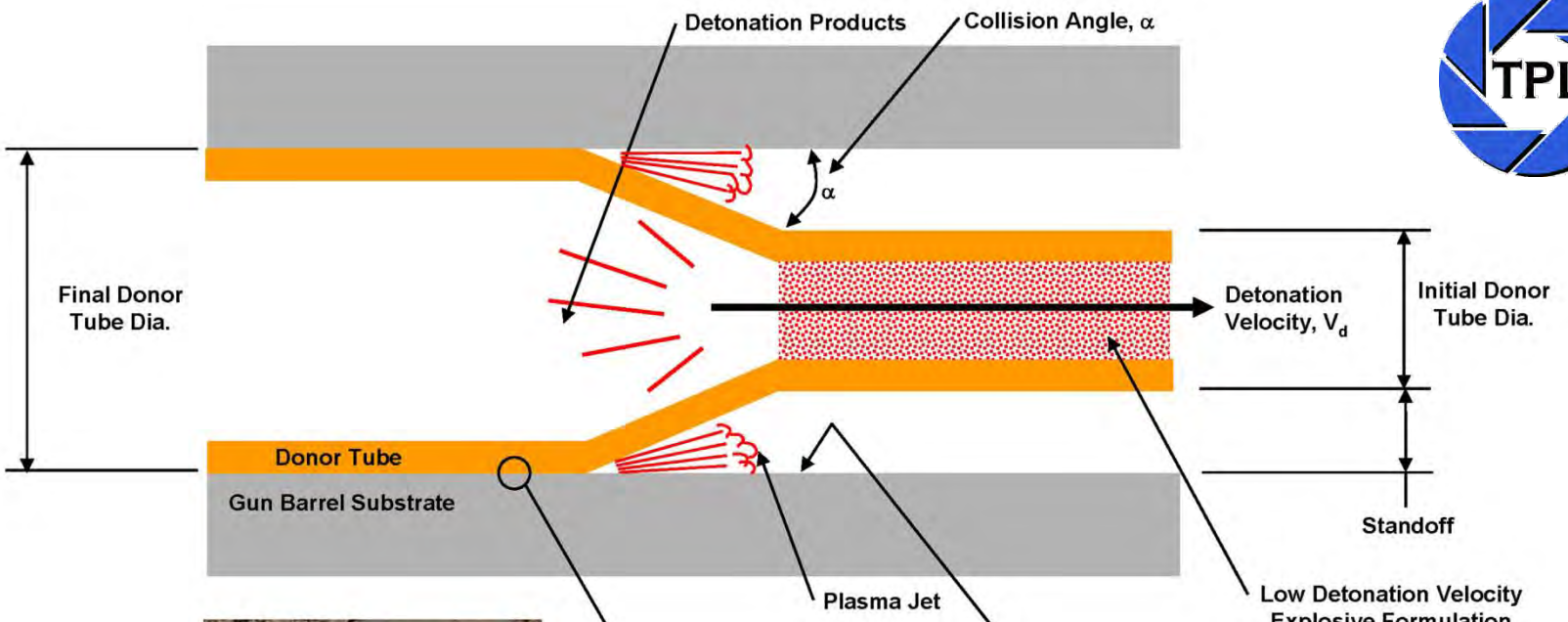


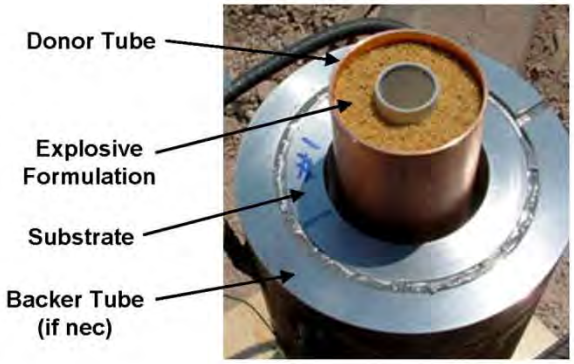
45mm gun in place at BAE Systems test range

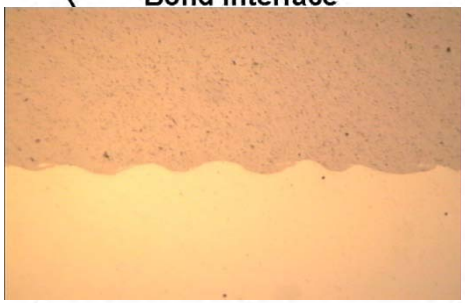
- **Coated insert assembled at shot start region of gun**
- **45mm ballistics designed to reproduce thermal, chemical and mechanical environment of a large caliber gun**
- **50 shot test sequences used to evaluate coating adhesion and integrity**
- **Screening Test Winners: Explosive Cladding and EPVD®**

Provided a cost effective method for evaluating coatings prior to large caliber gun evaluation

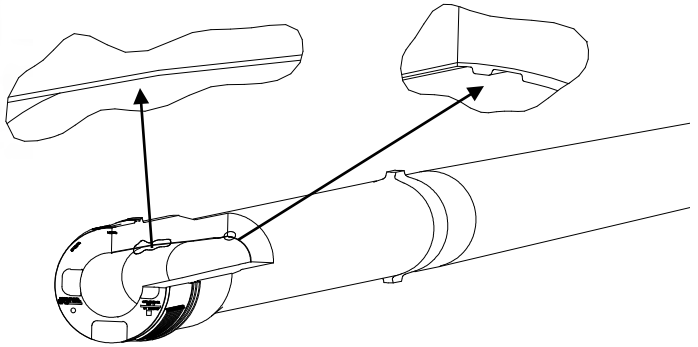
Explosive Cladding Process





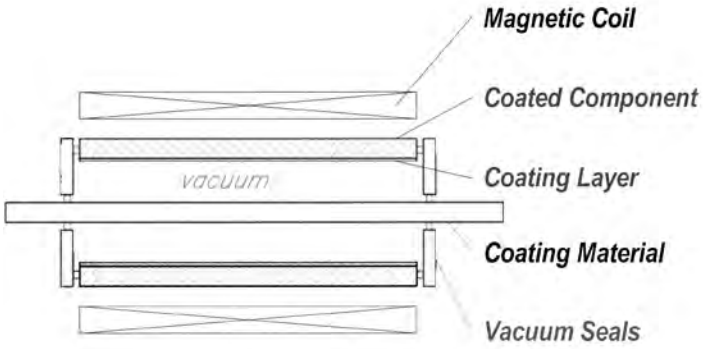


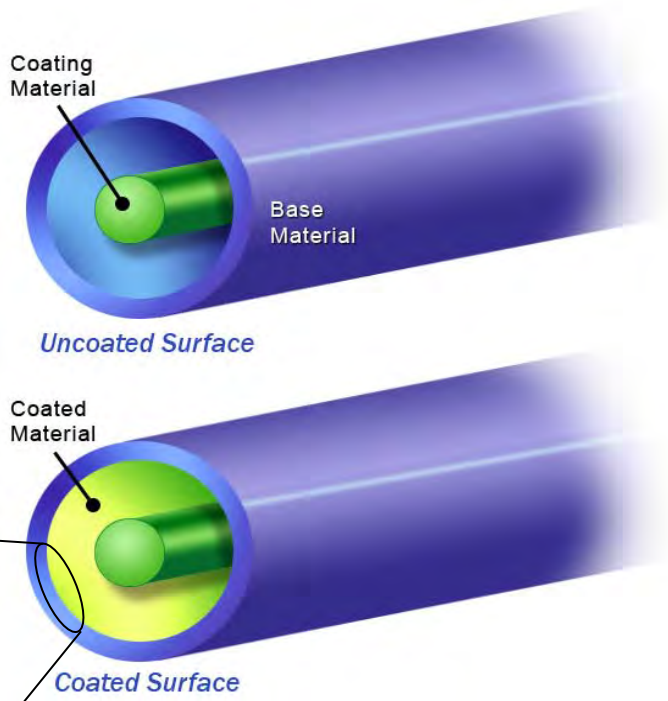




EPVD® Process
(Electromagnetically Enhanced PVD)

Electromagnetically Enhanced Physical Vapor Deposition (EPVD®)





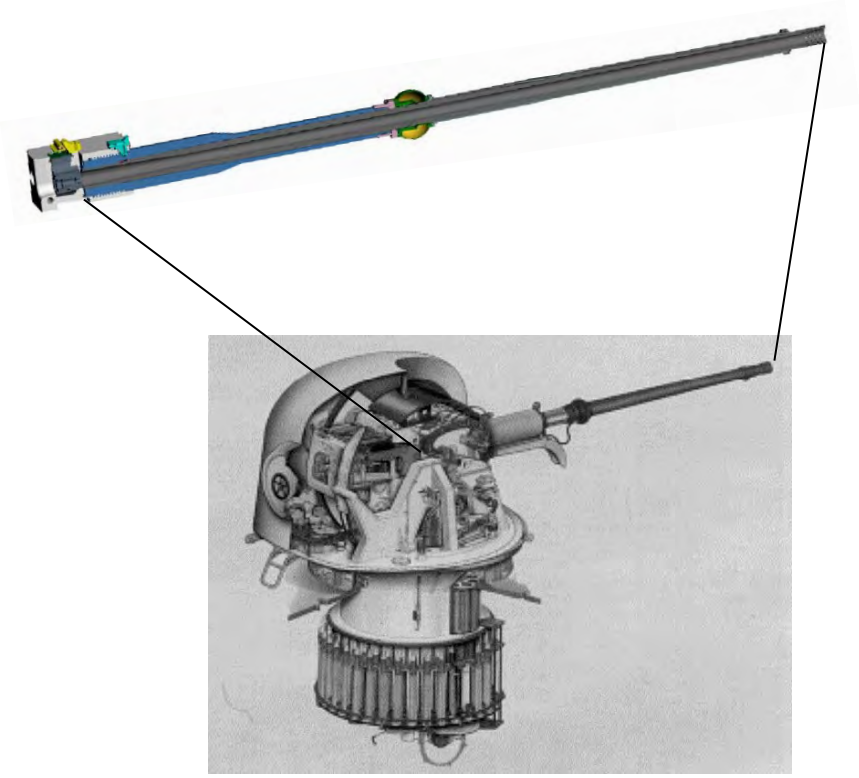
Uniform thickness on lands and grooves

Paradigm Shift Technologies Inc.

76mm Medium Caliber Testing

- 76mm platform selected for similar match to the AGS near bore thermal profile
- Historical 76mm service records indicated that measurable wear and erosion would occur within 400 rounds fired
- Technologies were applied to the bore of MK 75 gun barrel liners for firing at rate for a total of 400 rounds each. A chrome plated 'baseline' liner was subjected to the same test.
- 76mm tests were conducted at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD).

Prototype Barrel Assembly For Mk 75 76mm Gun



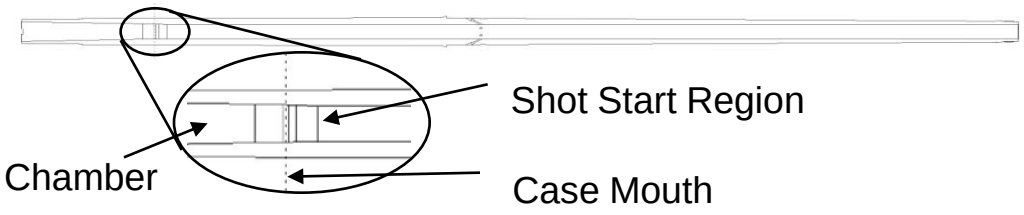
76mm Rapid Fire Testing

- Explosive clad liner experienced problems in manufacturing that were not recoverable within the time frame of this program and therefore effort was ceased
- Chrome Baseline and EPVD® coated liner were subjected to 400 rounds each, at max rate of fire in Mk 75 Naval gun
- Each liner was subjected to ten 40 round bursts at ~90 rounds per minute
- Detailed inspections conducted every 80 rounds

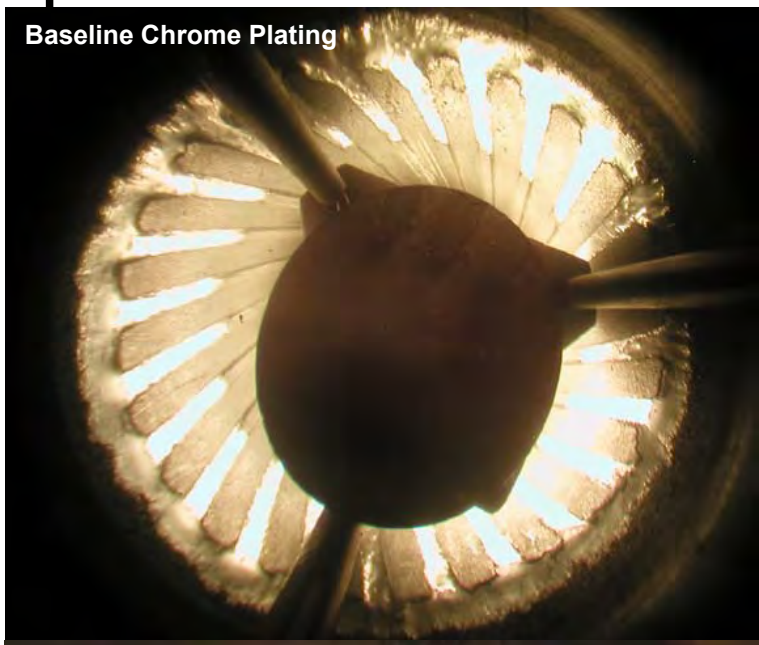


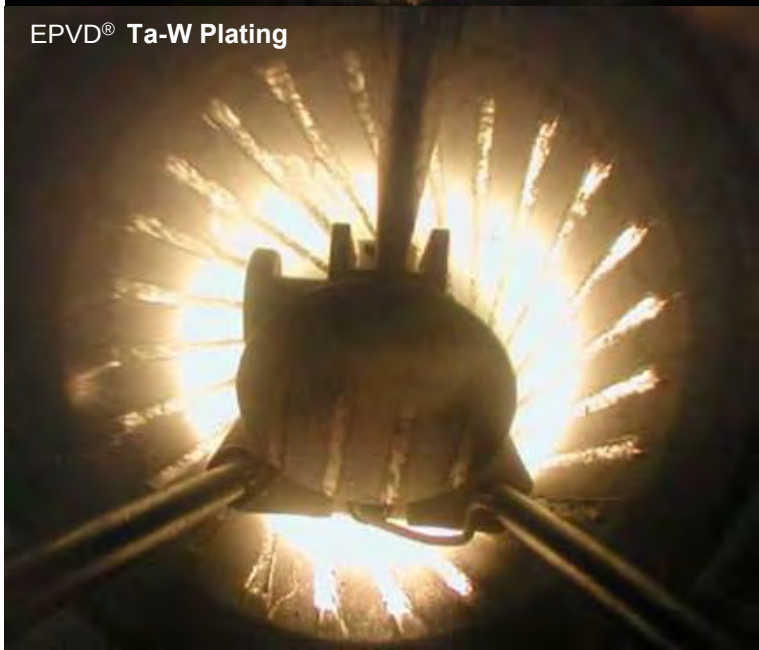


76mm Post Test Inspection



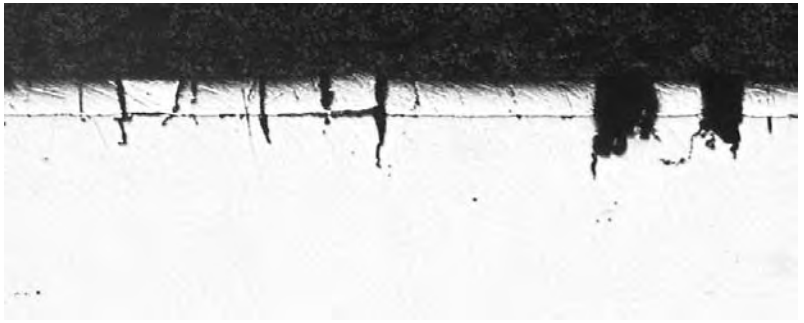
- NSWCDD bore scope reports at conclusion of test
  - Baseline Chrome
    - "Heavy erosion is present in the origin of bore and origin of rifling area"
  - EPVD® Ta-W
    - "Moderate erosion exists in the Origin of Bore area"
- *In both cases, coating removal from lands is due to engraving loads of gilding metal rotating bands*.
- EPVD® erosion much less than Chrome



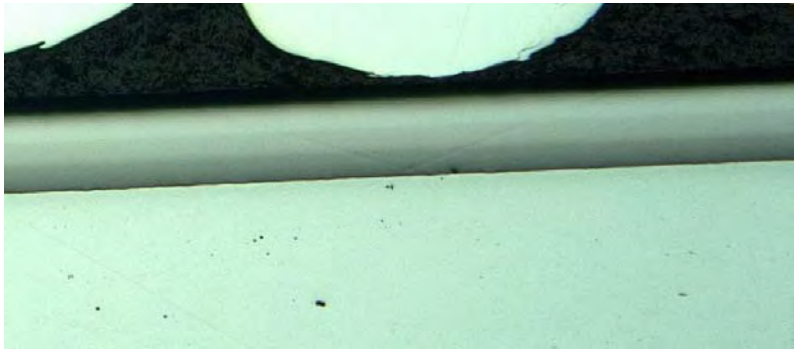


Micrographic View of Coatings

- Chrome plating shows significant heat check damage with cracks extending up to 1mm deep in substrate



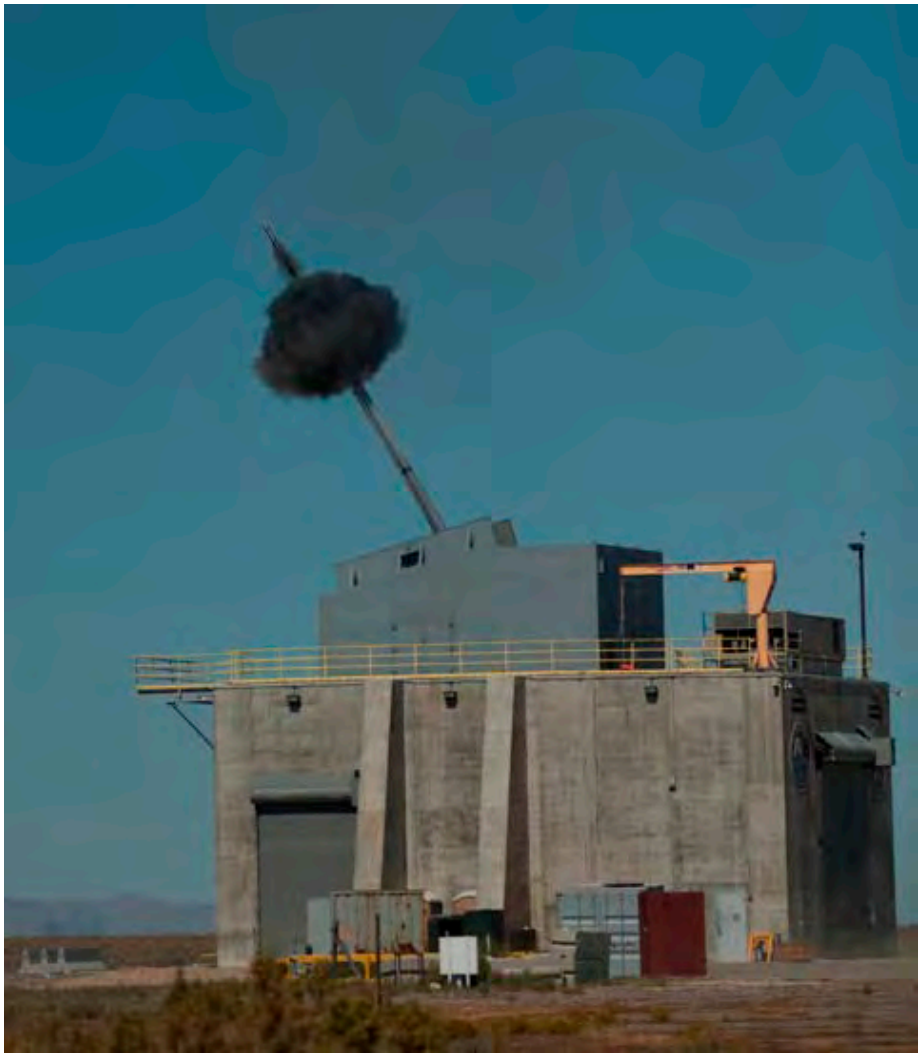
- EPVD® shows a thicker coating layer without apparent cracking or obvious heat affected zone



EPVD® applied Ta-W coating was well adhered and provided excellent thermal and chemical protection

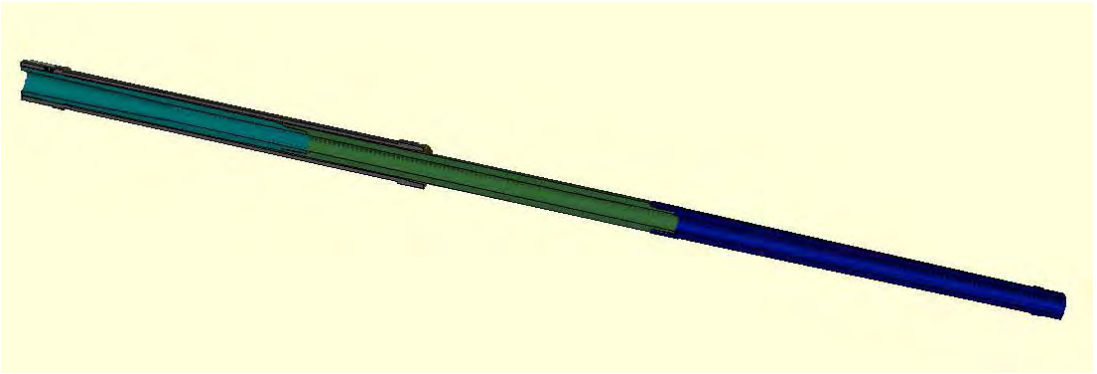
Full-Scale 155mm Demonstration

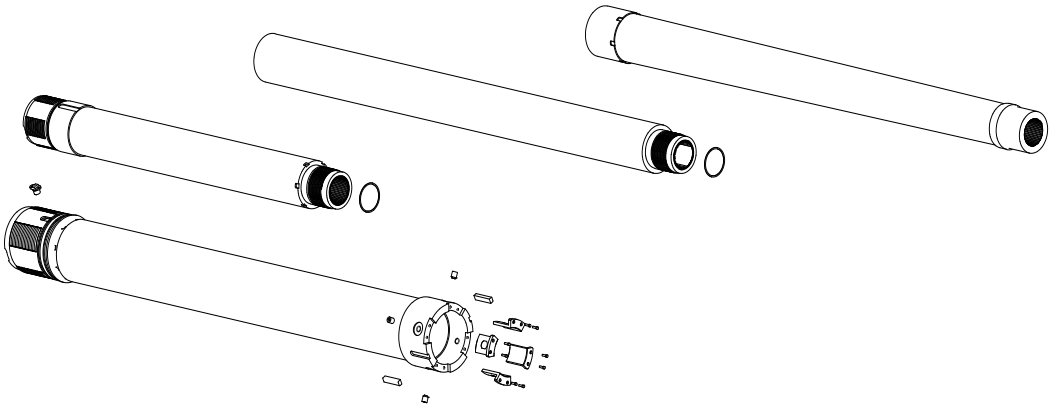
- Full scale tests conducted using the BAE Systems Advanced Gun System (AGS) Engineering Development Model (EDM) mount at Dugway Proving Grounds, Utah
- A multi-piece 155mm barrel was used for AGS rapid fire testing
- Barrel was subjected to Proof shots as well as extended firing at 10 rounds per minute



Tube and Liner Barrel Assembly

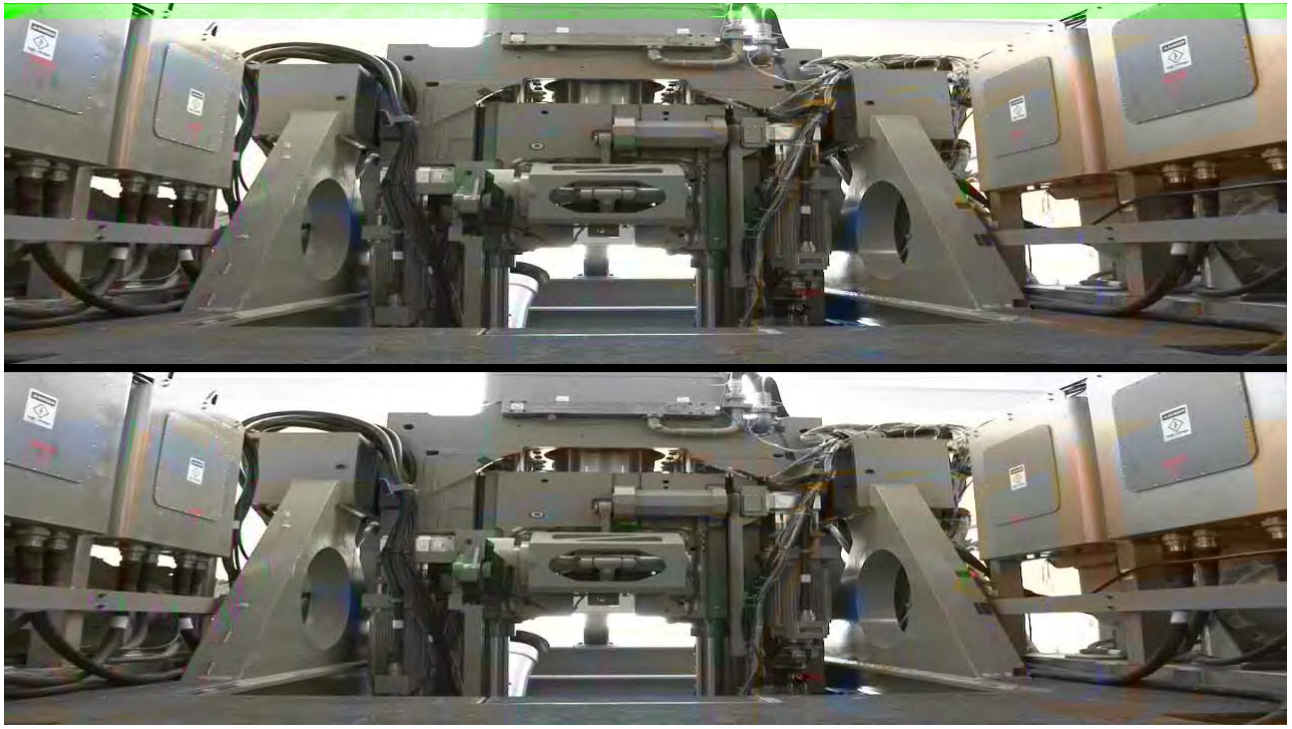
- AGBT test barrel is a tube and liner assembly
- Liner is a multi-piece subassembly
  - Allowed barrel to be fabricated from available assets
  - Allowed barrel to be coated using existing equipment
- Integrates with the EDM mount using existing cooling hardware





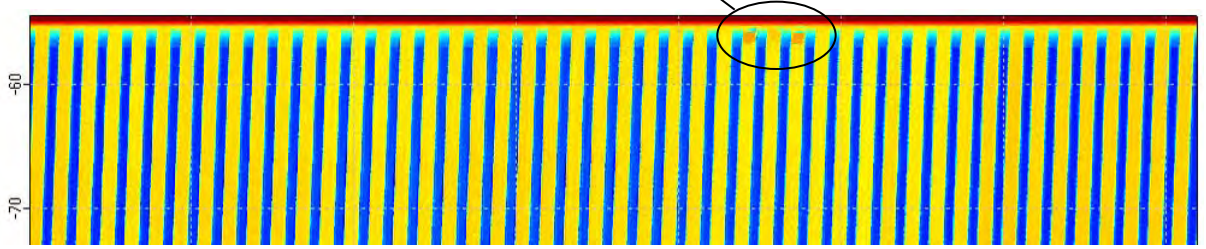
155mm Development

- Advanced Gun System (AGS)
  - 155mm (6.1”) 62 cal.
  - 10 rounds/min.
  - Vertical load
  - Liquid cooled
  - All electric drives
  - Fully Automated Magazine
- 61 total shots fired in AGBT test series



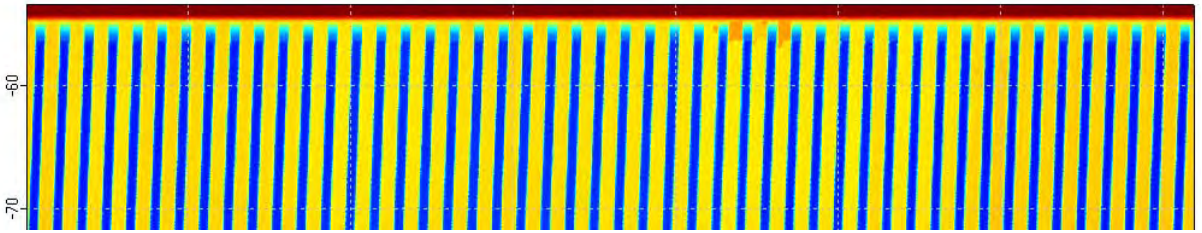
Laser Scan data of Shot Start Region

Note: area of delamination



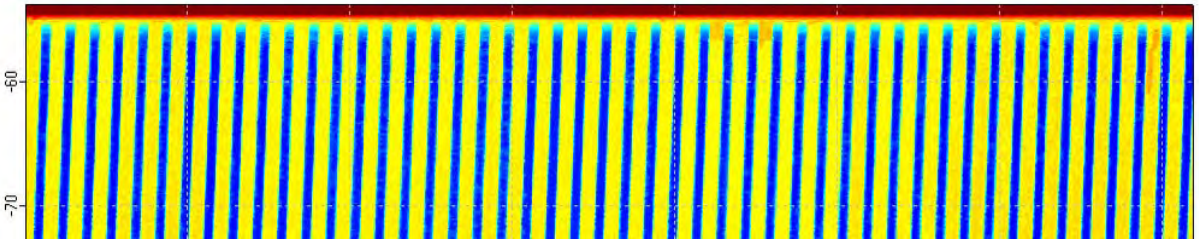
Shot 0

Coating delaminated in noted area prior to firing



Shot 8

At conclusion of proof series, delaminated area grew slightly

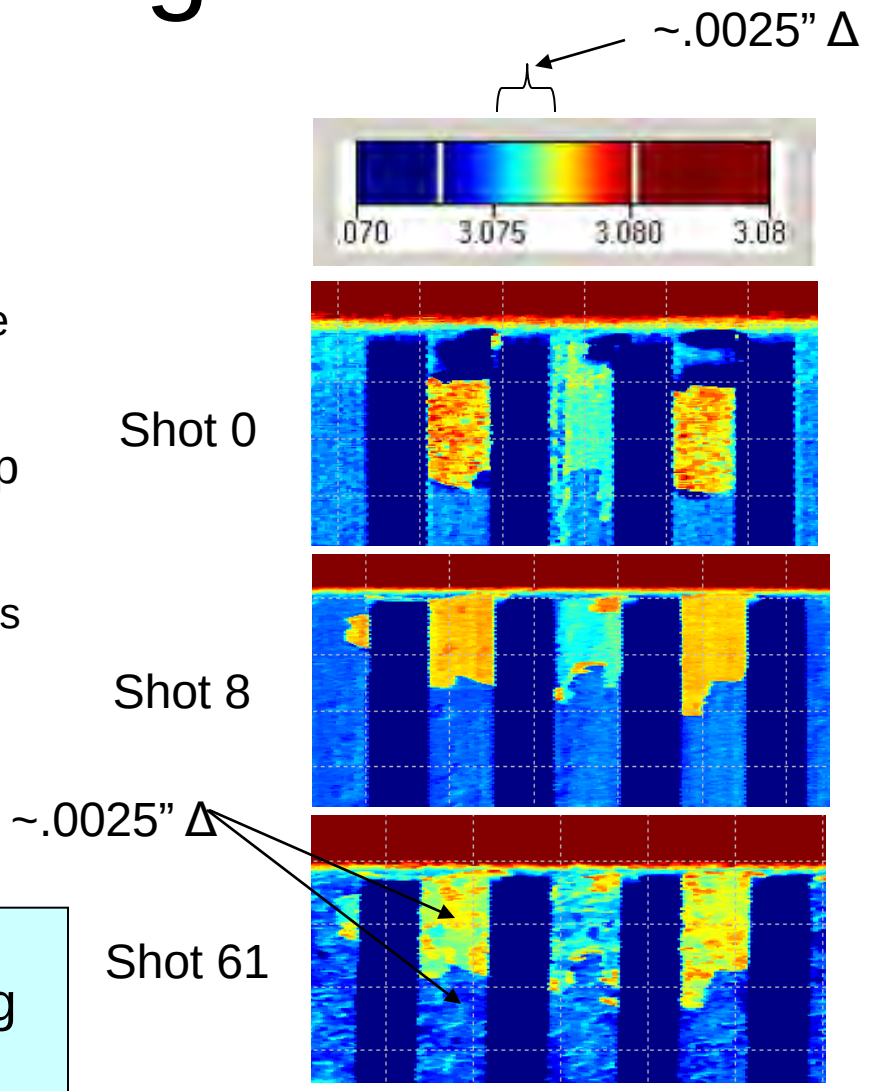


Shot 61

At conclusion of rapid fire series, minimal additional grown.

Degree of coating loss

- Localized area at origin of rifling shows loss of the upper most layer(s) of the coating in three adjacent grooves prior to firing.
- Damaged area does not grow appreciably during the firings
- Laser based profilometry used to determine depth of features. Accuracy: +/- .0005”
  - Full depth of coating is .005” thick
  - Coating delamination: ~.0025” deep
- Substrate is not exposed, damage appears limited to top layer(s)
- Barrel not removed for micrographic analysis of coating.



Conclusion: EPVD® coating adhesion to barrel substrate held-up during firing tests. Work still needed to address inter-coating delamination

Summary and Conclusions

- AGBT Program successfully met objectives
- Selected technology: EPVD®
- Improvements in coating composition needed to tolerated mechanical engraving loads of gilding metal rotating bands
- Improvements in processing needed to address interlaminar adhesion
- Application of EPVD® technology for gun barrel use is relatively new. Potential for different compositions of various materials exists
- BAE Systems is currently working with the U.S. Navy to transition this technology for fleet use

Questions

For additional information, please contact:
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Land and Armaments
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Ultrasonic Characterization of Explosively-Bonded Concentric Tubes

Presented by: Chris Jerred

Acknowledgements: Dr. Fred Delfanian, Dr. Jikai Du, & Dr. Tao Huang

Materials Evaluation and Testing Laboratory (METLab)
Mechanical Engineering Department, Box 2219 SCEH 214
South Dakota State University, Brookings, SD 57007-0294
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Presentation Outline

- Background
- Purpose
- Machining
- Microscopy
- Ultrasound techniques
- Conclusions
- Future work

Background

- Concentric tubes used in military applications
- Wear resistance liner (donor tube)
- Tubes bonded explosively
- Many factors in process, affect bond quality
- Ends of composite tube are scrapped
- Bond quality difficult to ascertain

Aim

- Find inspection method for material interface
- Non-Destructive Test (NDT) is preferred
- Assess overall bond quality
- Serve as QC or life monitoring tool
- Correlate NDT and destructive methods

EB Specimen

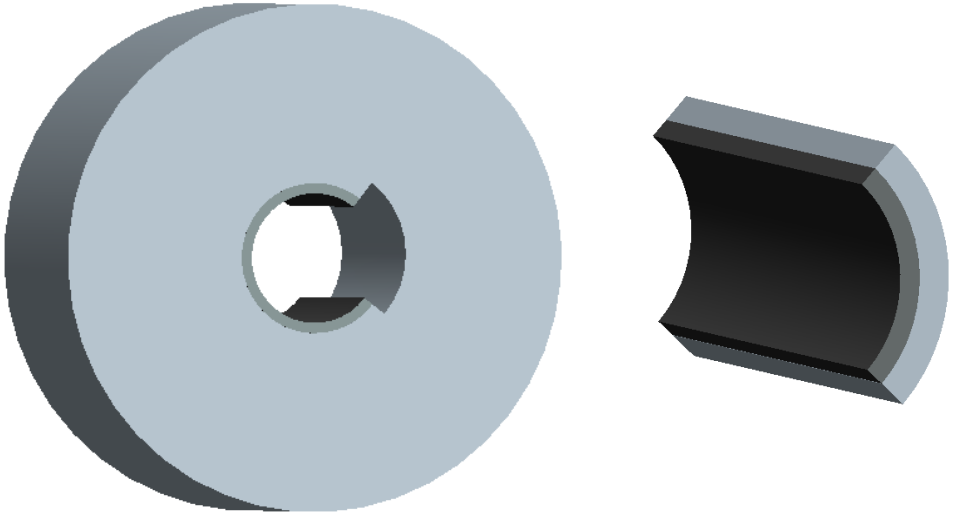
- Steel major tube
- Alloy donor tube
- ~ 3” length
- ~ 4” OD, 1” ID

- 1 “poor” - PEBS
- 1 “good” - GEBS



Machining

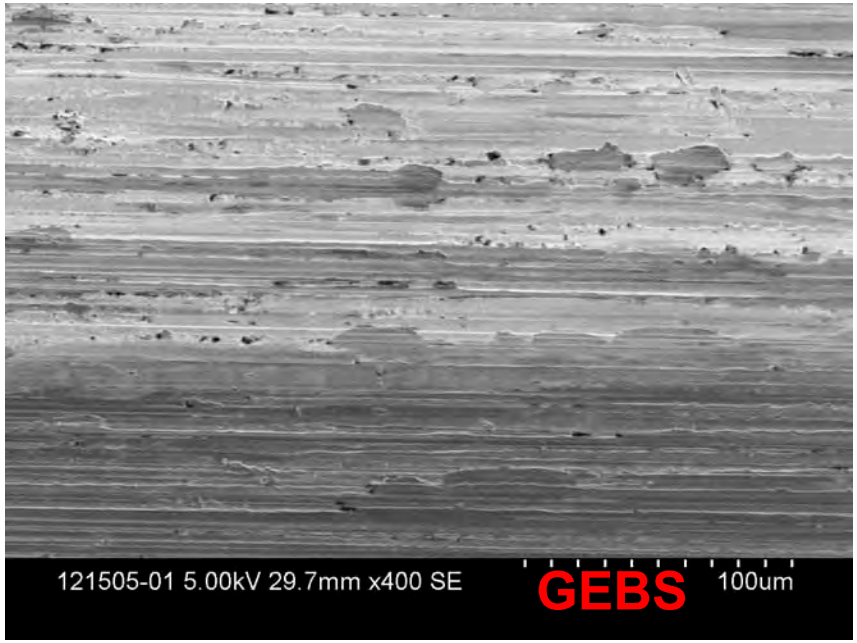
- EDM samples
  - Destructive tests
  - Microscopy
  - Hardness tests
  - Alloy analysis

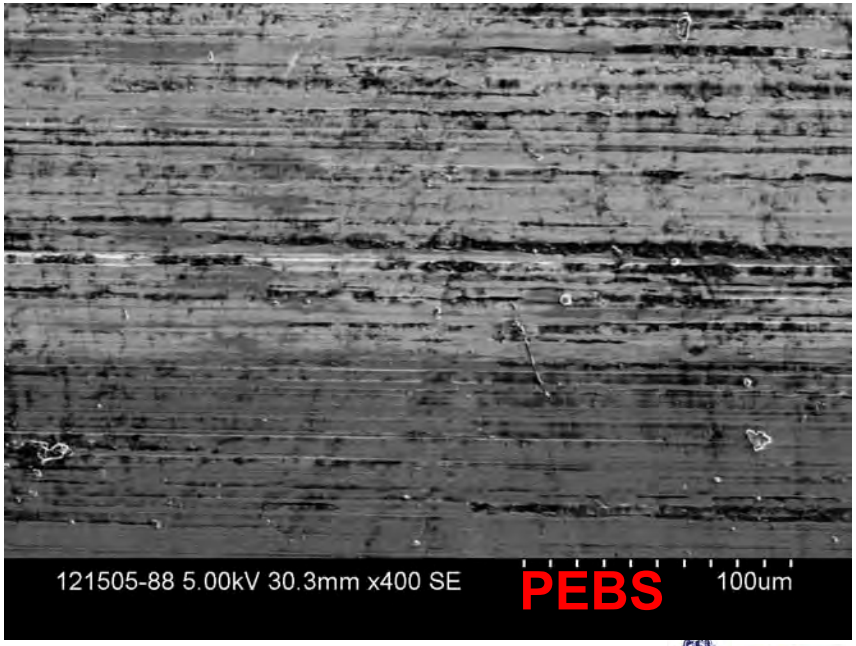


Microscopy



- SEM
  - Destructive, time consuming, small sampling area
  - Looking for “wavy interface” and “material mixing”

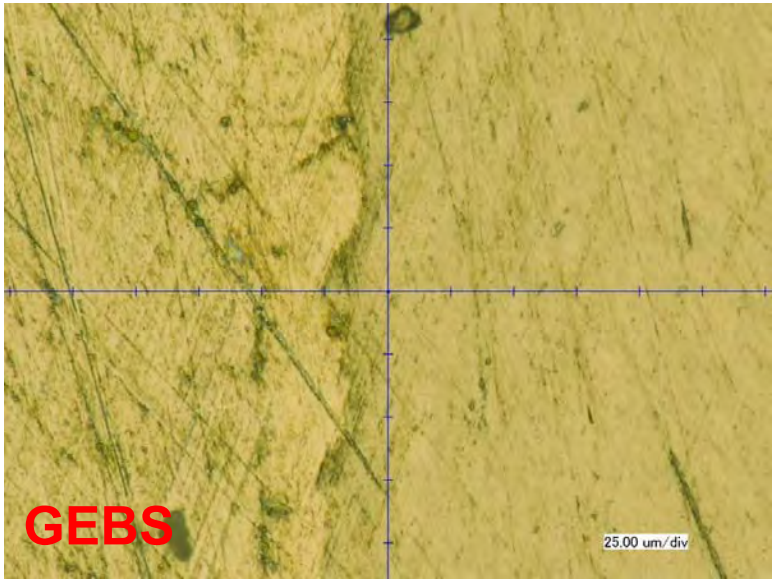


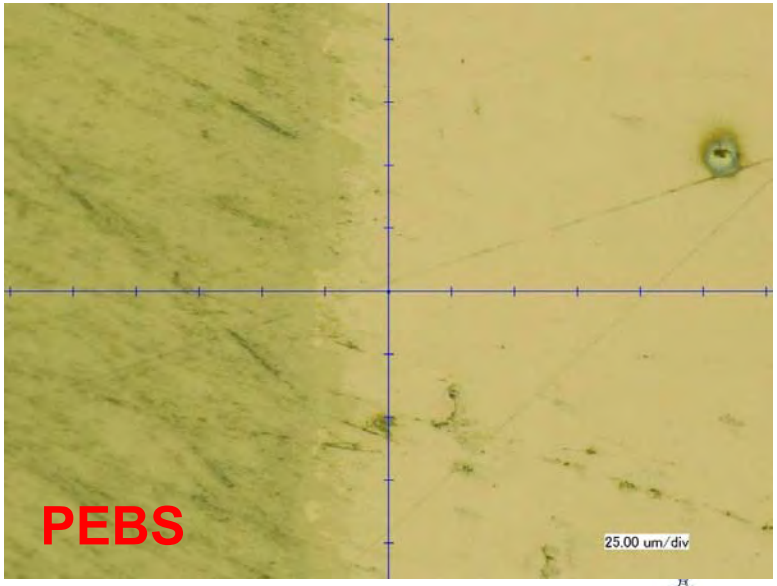


Microscopy

- Digital Microscope
  - Quick, little preparation, color

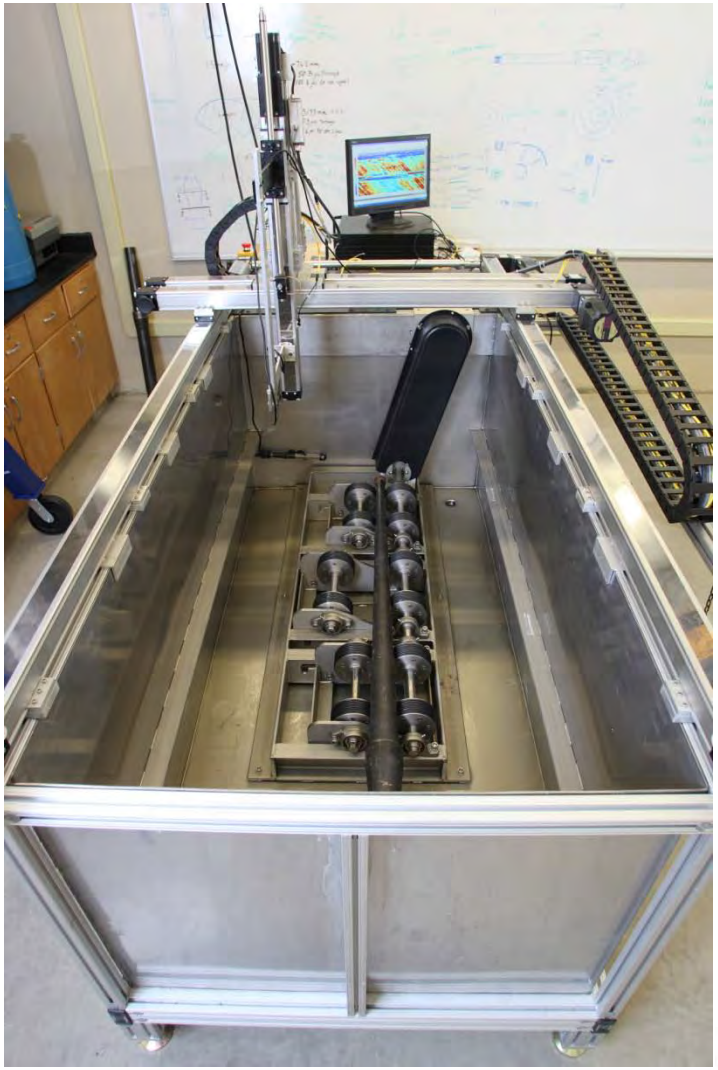






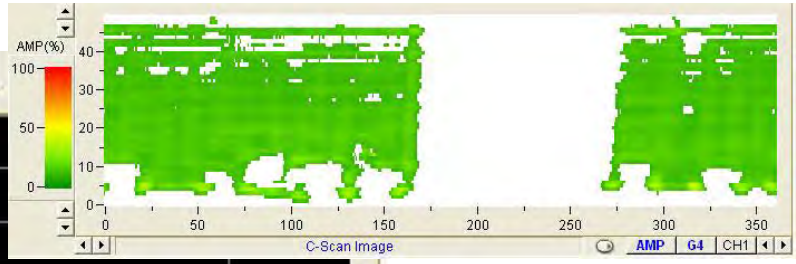
Ultrasonic Methods

- Physical Acoustics
  - Immersion Scanner
- Resolution 0.0001”
- Max 20 in/sec
- 2,000 lbs max load
- 3-10” diameter tubes
- Up to 5’ length



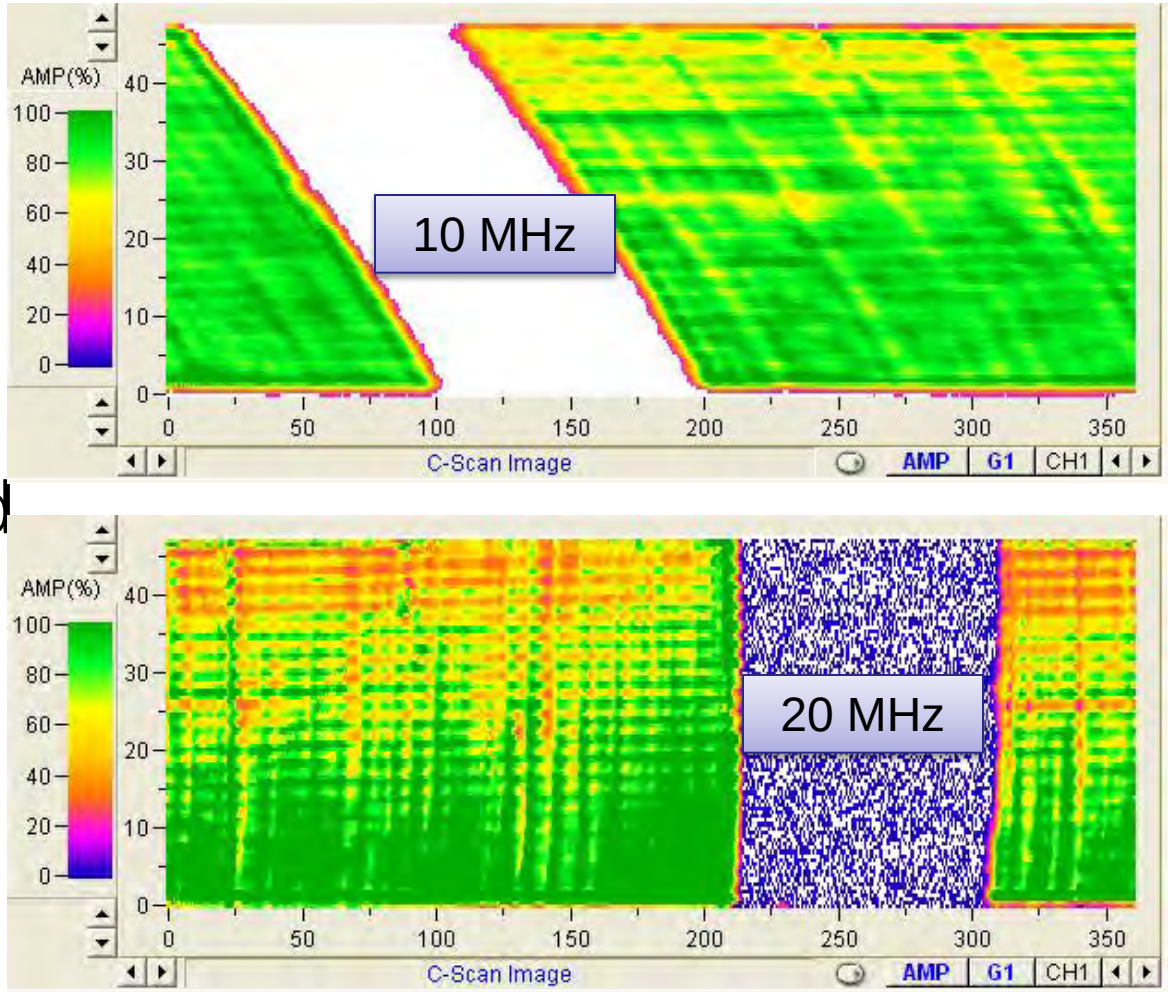
Bond Focusing





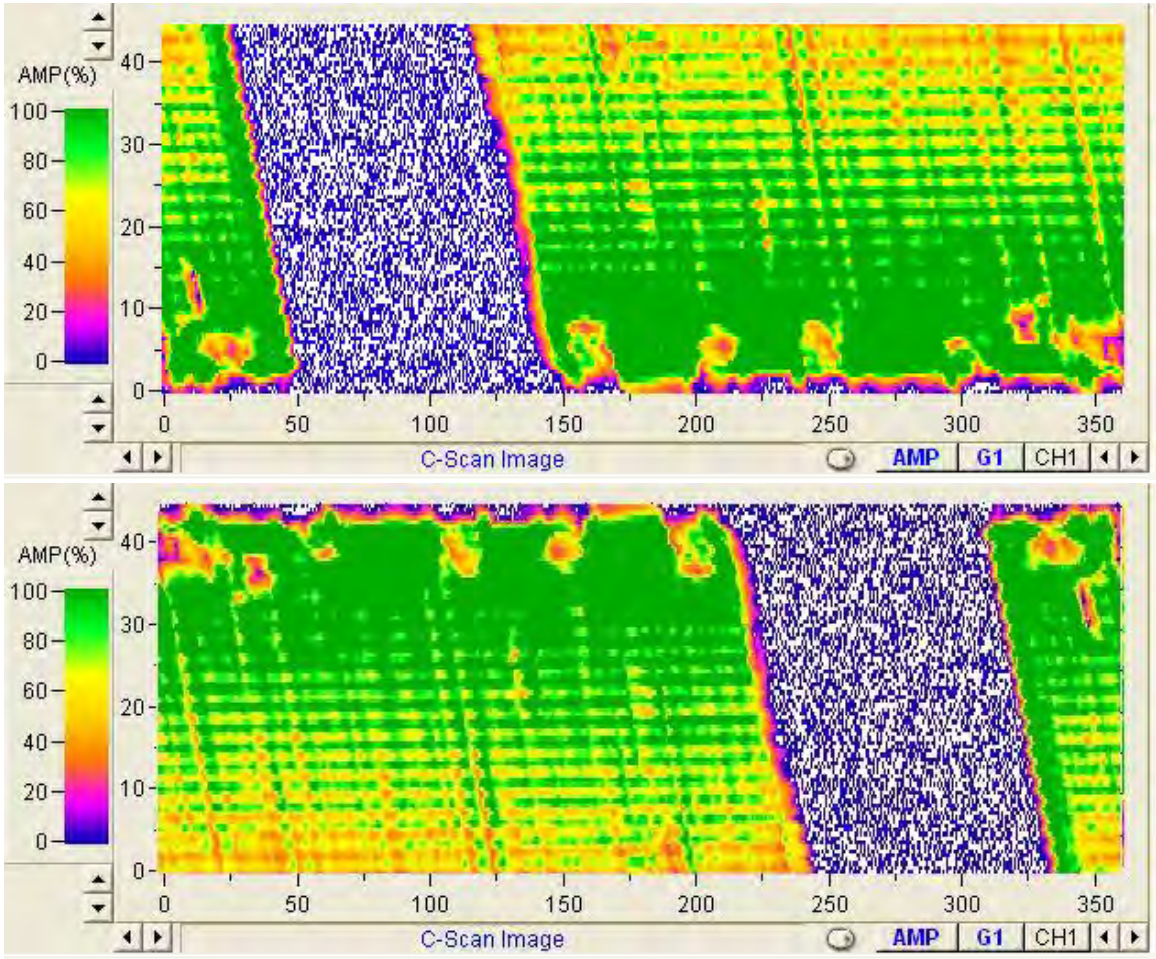
Frequency Optimization

- High frequency
  - Inc. resolution
  - Same settings
- 20 MHz selected
  - On hand
- Gap = Removed
- Slant = Tuning



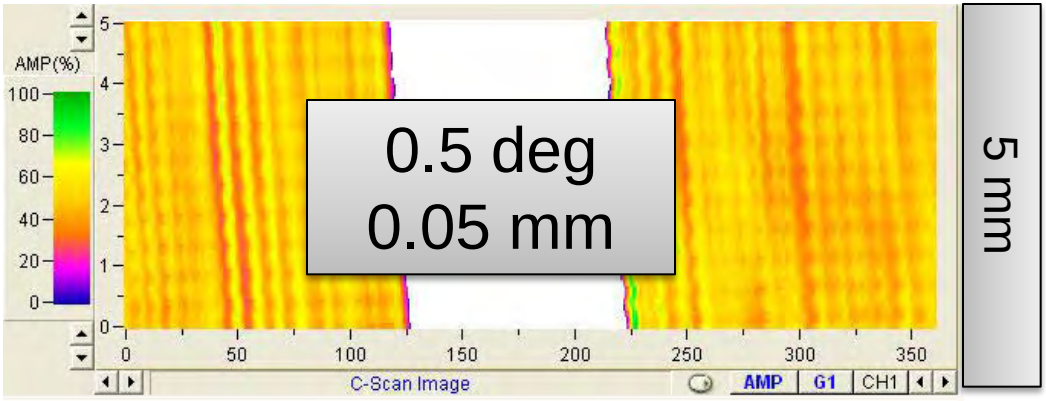
Gradient

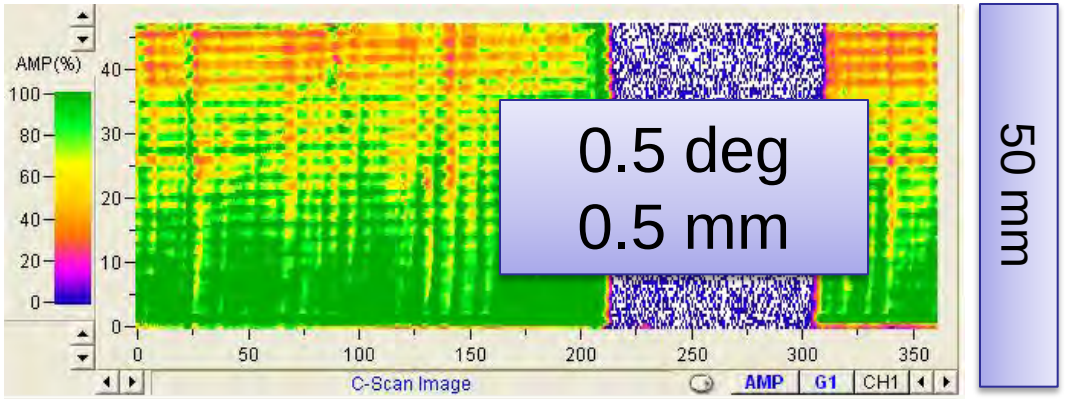
- Caused by ?
  - Δ bond
  - Scan method
- Reversed part
  - Same scan
  - Same trend
- Δ bond is cause
- Less obvious GEBS



Stripes

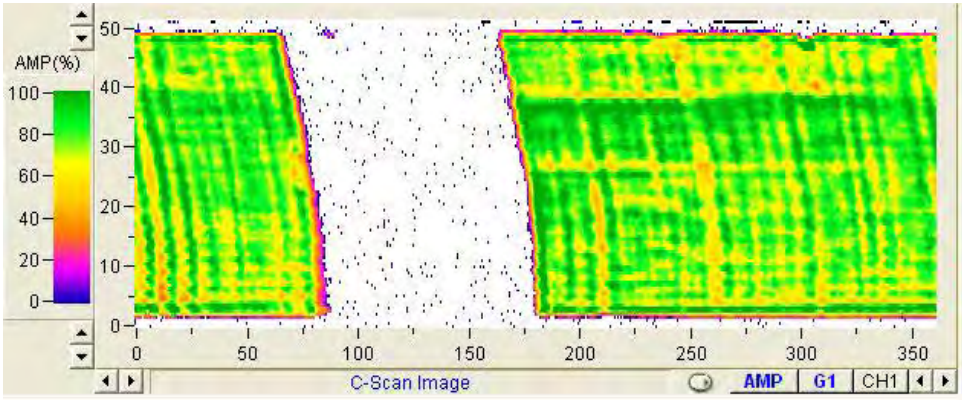
- Caused by ?
  - Wavy axial bond
  - Scan method
- Changed step size
  - Same results
- Scan method

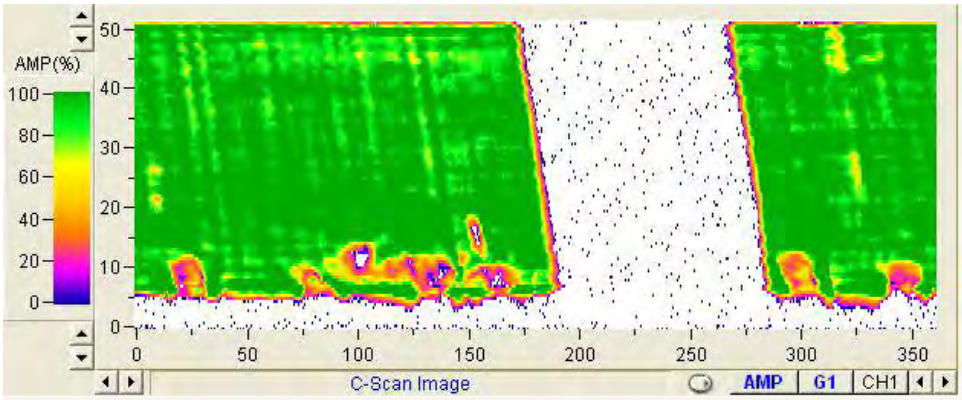




Good vs. Poor

- GEBS
  - Lower reflection amp.
- PEBS
  - Higher reflection amp.
- Good bond provides easier transmission of acoustic energy





Conclusions

- Semi-Quantitative
  - Need reference tube as standard

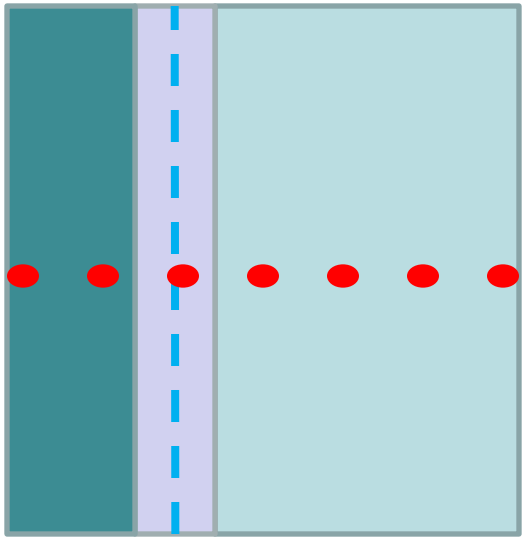
- Poor vs. Good — Distinguishable
- Observed Gradient — Due to bond
- Frequency Effects — Higher (20MHz) is Better
- Stripes — Due to scan method

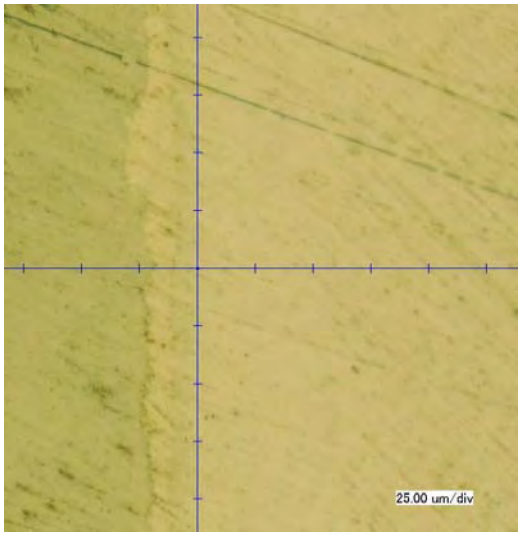
Future Work

- Reference specimen

- Hardness vs. alloy composition
  - Micro hardness tester
  - Alloy analyzer

- Correlate to NDT-UT & destructive results





Questions?

- Chris Jerred
- Materials Evaluation and Testing Laboratory (METLab)
- Mechanical Engineering Department, Box 2219 SCEH 214
- South Dakota State University, Brookings, SD 57007-0294
- Phone: (605) 688-4300, Fax: (605) 688-5878, http://www.sd-metlab.org

Design of an Intelligent Counter to Monitor Fatigue Events Experienced by a Gun Barrel (#9894)

Cory Mettler & Chris Mouw
American Science and Technology

Joint Armaments Conference
Dallas, TX May 17-20, 2010

Outline

- Background, Objective, and Requirements
- FOS Overview
- Transducer Selection
- Housing & Mounting
- Storage Requirement
- Power Requirement
- Live Fire Testing Results
- Future Work

Background

- As mechanical systems age, lifetime fatigue causes wear and eventually system failure
- In order to predict ‘end-of-life,’ the FOS was developed to monitor and record fatigue on a weapon barrel
- Currently, fatigue monitoring is often done by manually recording events in a log book by the warfighter.
  - Prone to errors
  - Time consuming
  - No electronic record keeping
- Focus on large caliber direct line of site weapon systems

- All research was performed on an AST-owned .50cal

Objective

Design a system which will detect and count fatigue events on weapon barrel

- Improve event counting accuracy
- Reduce soldier's burden
- Increase soldier's safety
- Lead to a more accurate determination of "end-of-life"
- Provide an electronic inventory and maintenance record

Differentiate round families

- Round Family: round types which induce similar amounts of fatigue

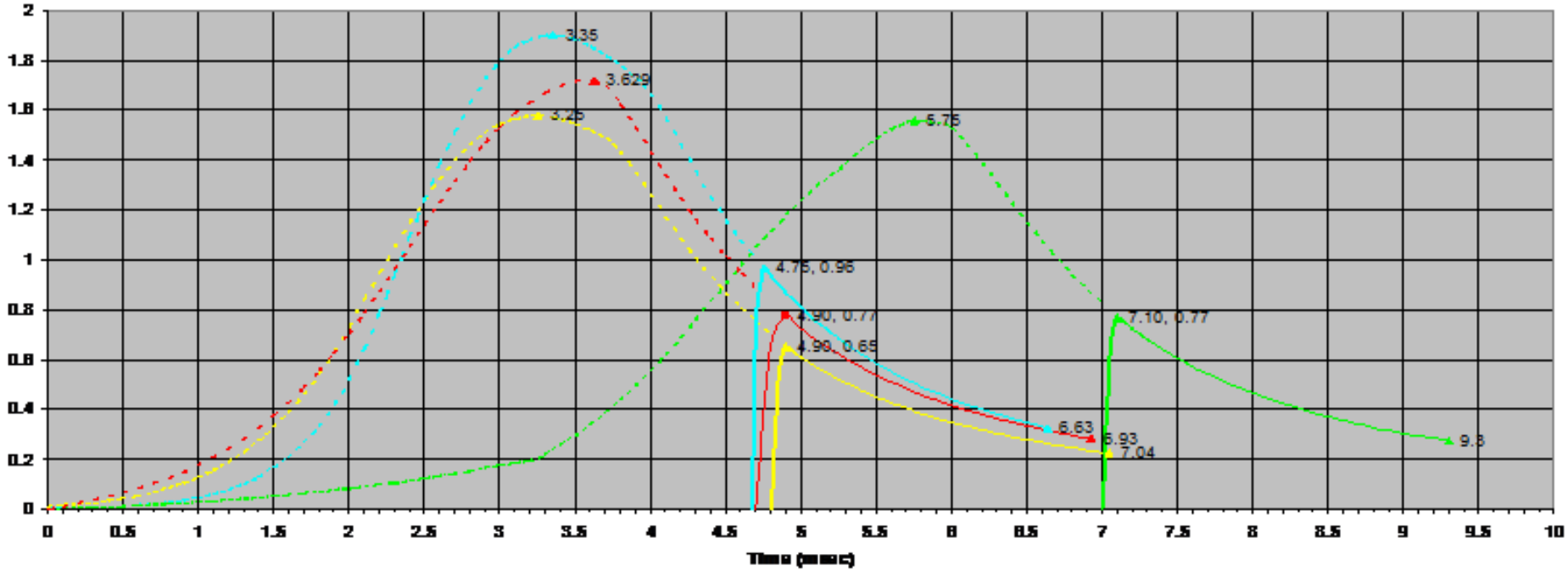
The FOS is only the first stage of improvement, leading to a more accurate count. Once that count has been reached a secondary project has been completed which will individually scan the system for flaws (see AST's poster on the Field Inspection Vehicle).

Requirements for Primary Test Platform

1. Count up to 20 rounds per minute
2. Detect and count rounds with an allowable deviation of +2% (no undercounting)
3. Prevent false counts in the system due to external sources of shock and vibration not due to a firing event
4. Sustain and operate at a 300^{o}F barrel surface temperature for “short” periods of time (<1hr sustained)
5. Perform wireless data transfer (but only upon demand)
6. Be capable of storing information from at least 10,000 rounds along with life time maintenance records
7. Be self-powered for up to 30 years (i.e., the life of the device) without the need for battery replacements

FOS Overview

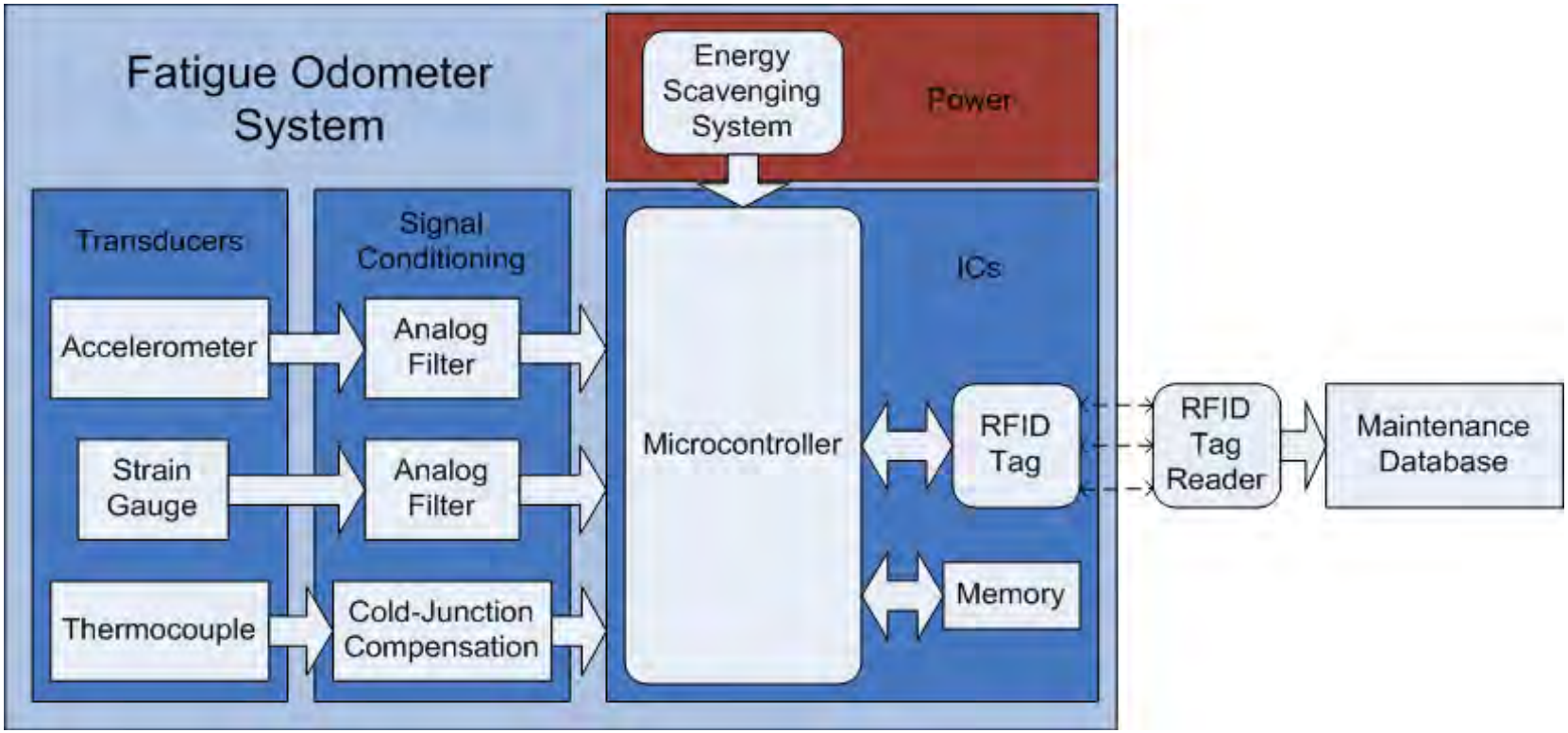
(theoretical design justification)



Generic simulation of recoil acceleration and hoop strain on a cylindrical structure when measured at mid-point of a weapon barrel for 4 different round types

FOS Overview
(System block diagram)

- System will measure recoil acceleration, hoop strain, and outer barrel temperature
- Signal filtering and data conditioning prevents ‘false’ round counts
- System controlled by low power microcontroller
- Data capable of being uploaded to a central database through RFID tag



Transducer Selection

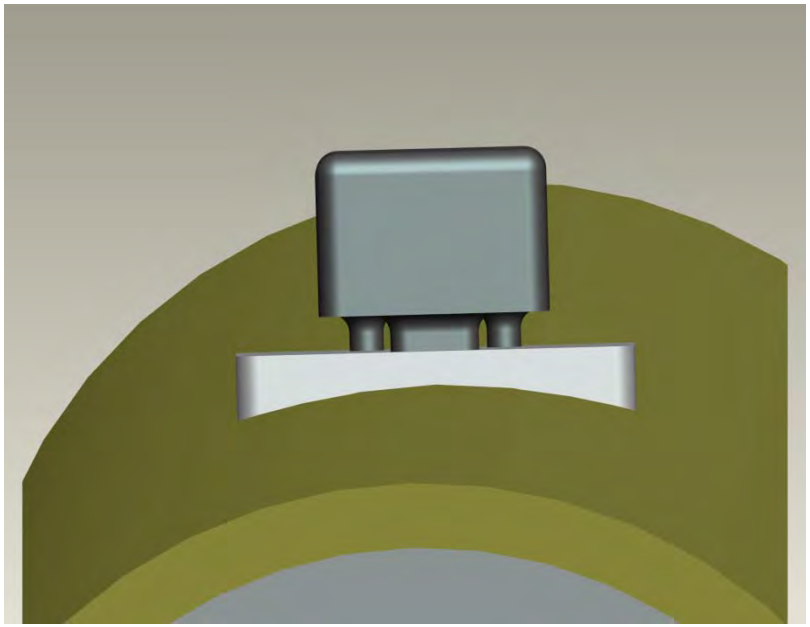
- Monitored signals using passive sensors and low power circuitry in order to keep power consumption to a minimum

- Recoil Acceleration
  - Passive piezoelectric accelerometer
  - Low-power analog filtering
- Hoop Strain
  - Passive, piezoelectric strain-rate sensor
  - Low-power analog filter

- Temperature
  - Required for strain sensor compensation
  - Thermocouple (passive)
  - Cold-Junction compensation for accurate measurement

Housing & Mounting

- Issue: Circuitry can only withstand 185°F but barrel can reach 300°F
- Two-stage housing with ¼" air-gap to thermally isolate circuitry
  - Thermo-isolating PEEK base plate
  - Rapid prototyped housing (needs to be studied for robustness)
  - Verified to 300°F in lab tests (circuitry only reached 175°F)
- Base plate mounted to barrel using high-temperature adhesive



Storage Requirement
(data storage of 10,000 rounds)

- Primary Data Storage
  - Memory built into RFID tag can hold 500 rounds worth of data as well as maintenance logs
    - Will upload data from Micro to Tag after every round is fired
  - It is expected that data will be downloaded from FOS to database every few 100 rounds
  - The on-tag data allows for faster data download by user and does not require power from the FOS but does not meet requirement
- Lifetime Data Storage
  - Data is also uploaded onto on-board EEPROM after every shot fired
  - In the event all previous data has been lost or corrupted in database, backup of 10,000 rounds of data stored on FOS can be retrieved
    - This is a slow process and consumes a considerable amount of power directly from the FOS
    - But, would only be used in emergency situations

Power Requirement

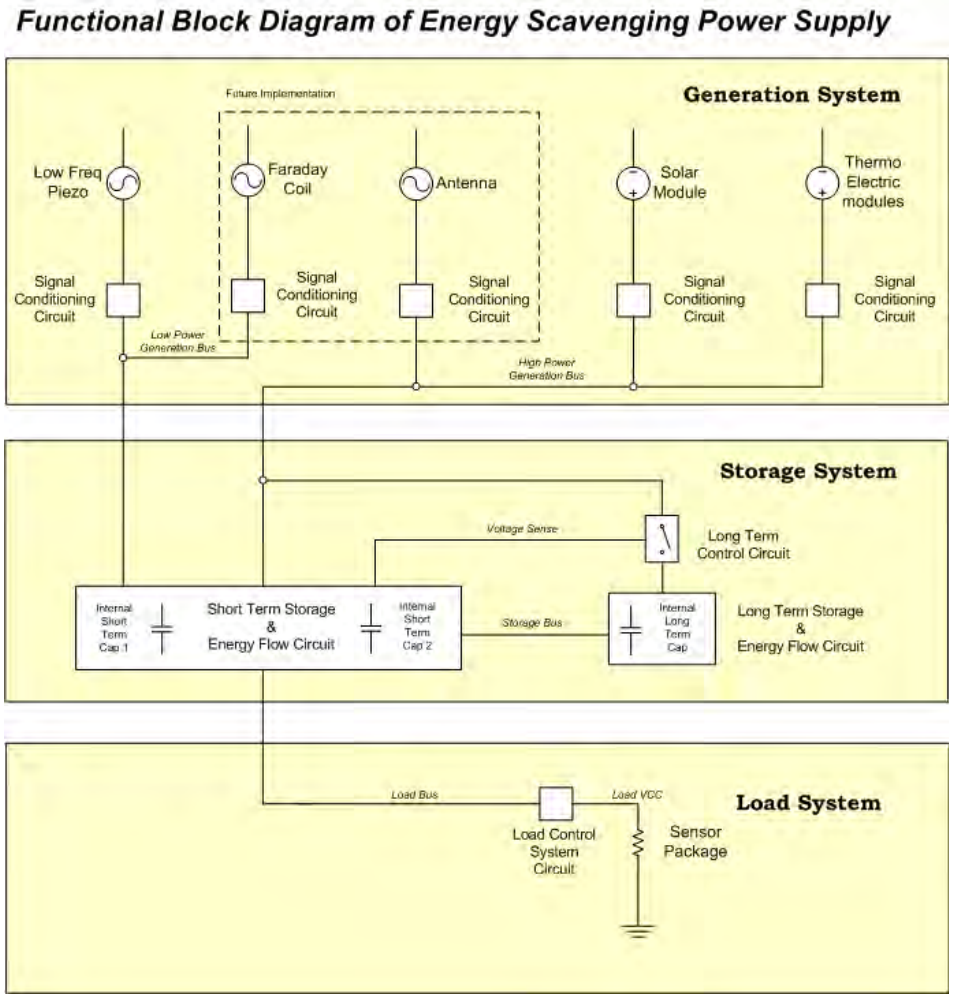
(maintenance free for 30 years)

- How do you power a sensor for 30 years without replacing batteries or plugging into power source???
  - FOS, located on a system, often doesn't have access to a power source
  - Battery technology would not meet the 30-year requirement
- Development of an Energy Scavenging Power Supply
  - Uses capacitive energy storage system which can be recharged 'indefinitely' rather than conventional chemical battery system
    - Can store at least 100 Joules at prototype level
- Relies on a number of renewable energy sources
  - Solar – Photovoltaic cell provides ample power during sunny conditions
  - Motion – Piezoelectric cantilevers produce short bursts of energy during periods of vibration (traveling)
  - Thermal – Thermal Electric Device (TED) converts heat from weapon barrel to electricity
- Investigating new sources of energy
  - Recoil – Faraday coil to capture recoil energy
  - Electromagnetic – Scavenging radio waves for energy

Power Requirement

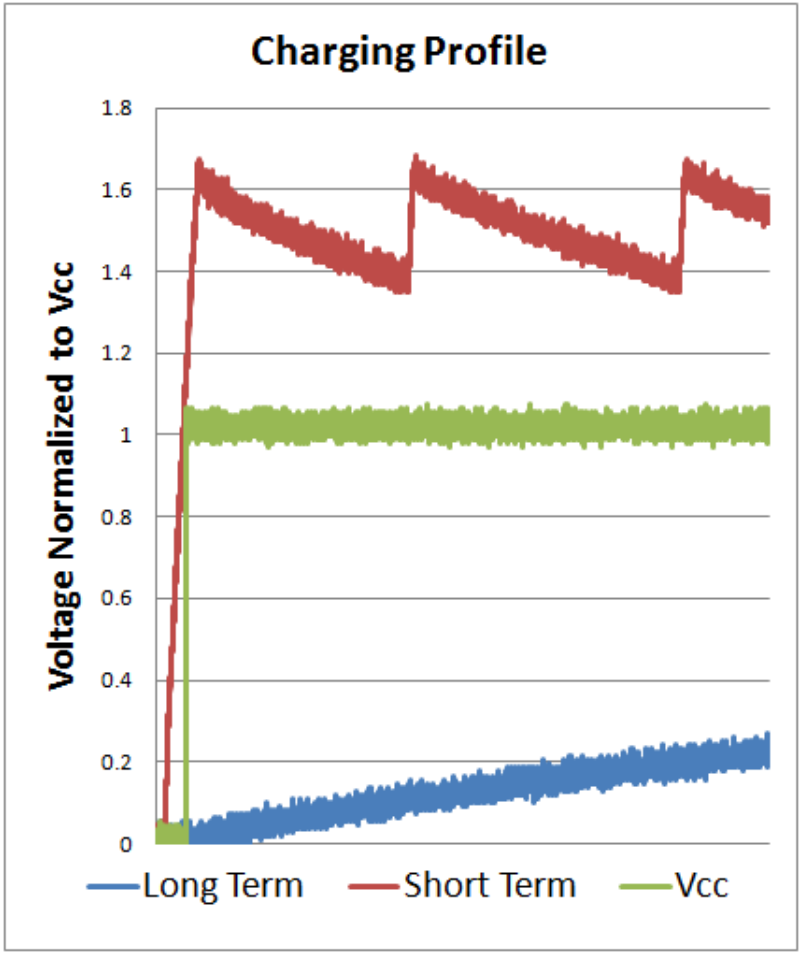
Block Diagram

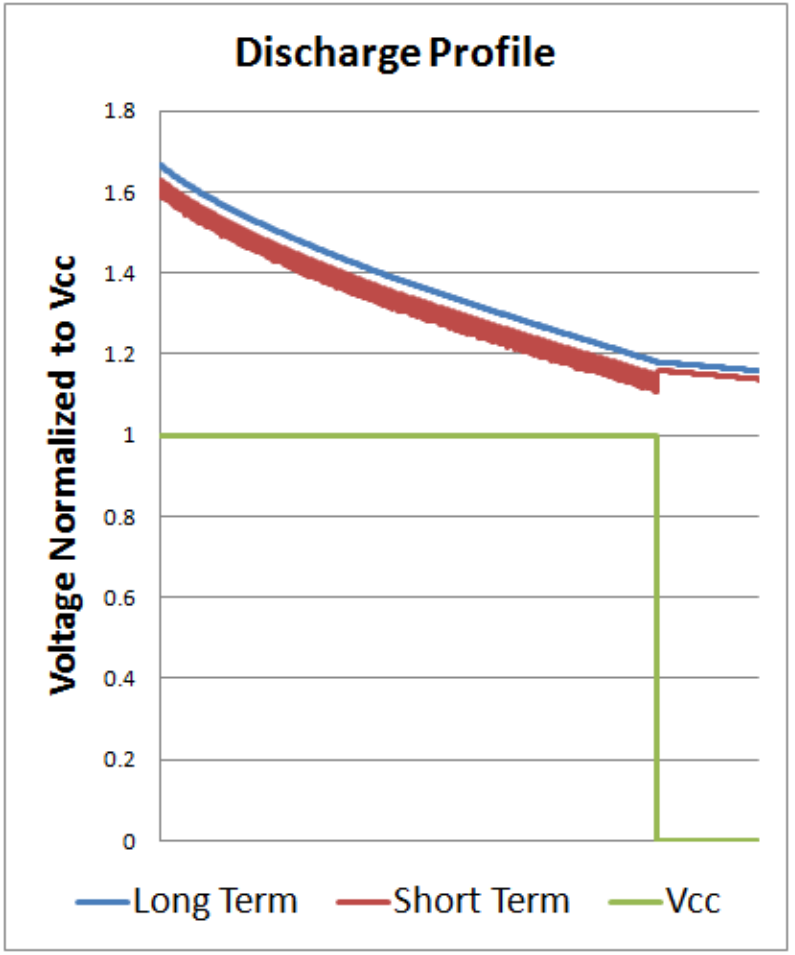
- Three-stage system
  - Generation System: Energy is collected and conditioned
  - Storage System: Two part
    - Short term: quick charging system which provides power to the load (FOS)
    - Long term: charges after short term is charged and provides power to the short term for extended periods
  - Load System: DC output voltage is conditioned to meet load requirement



Power Requirement

Test Results





Power Requirement

Summary

- ESPS currently in development stage
  - Initial prototype ~2” x 2” x 4”
  - ESPS will power the FOS from a full charge for 93 hours without the need for external energy
  - ESPS can be recharged from complete depletion to power the FOS within 5 minutes or less depending on environmental conditions
  - ESPS can be fully recharged in 4 hours
  - Stable output power
    - Either V_{CC} or 0V
    - Solid on/off with no rapid switching
- ESPS can be adapted to power almost any low-power electronic system

Live Fire Tests

- Field tested on smaller-barrel weapons
  - Barret .50 cal as well as 25 mm
- Verified transducer operation, accurate round count, and wireless communication
- Powered with lithium inorganic high-temperature battery
- Tested round identification algorithm in the field



Final Live Fire Test Results

- Nine rounds of .50 BMG ammo fired by multiple users
  - APIT-M20 619gr
  - Summit Tracer-M17 643gr
  - Summit AP-M2 700gr
- FOS was able to:
  - Accurately count each round
  - Identify round type fired
  - Communicate data wirelessly via RFID
  - Perform a memory dump in lab and verify data

Event	Shooter	Type Fired	Identified As
1	A	700	700
2	B	643	643
3	A	643	643
4	B	619	619
5	A	700	700
6	B	619	619
7	A	700	700
8	B	643	643
9	A	619	619

Future Work

- Field test FOS on larger caliber weapons
  - 105 mm, 120 mm, etc.
- Transducer upgrades
  - Transition to surface-mount accelerometer
    - ½ size of previous sensor
    - Eliminates cabling to further decrease FOS volume
  - Adapt analog filtering to larger calibers
    - Adjust analog scaling for different signal magnitudes
- Incorporate energy scavenging power supply
- Package Upgrades
  - Decrease housing volume
  - Test new housing materials



Questions?

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Rushford

HYPERSONIC

A CUTTING EDGE NANOTECHNOLOGY COMPANY

NDIA
Joint Armaments Conference

Presentation

19 May 2010

Rushford HYPERSONIC
A CUTTING EDGE NANOTECHNOLOGY COMPANY

I. Rushford Hypersonic (Overview)

II. Hypersonic Plasma Particle Deposition (HPPD)

III. Applications

IV. Open Forum

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Rushford Hypersonic

Hypersonic was founded in October of 2007 and was facilitated and supported by:

- *The Rushford Institute for Nano Technology*
- *Rushford, MN - Economic Development Authority*
- *Southern Minnesota Initiative Foundation*
- *U of MN – Office of Technology Commercialization*

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Location - Rural S.E. Minnesota

- The work force is well educated and posses a strong work ethic!
- Manufacturing floor space, utilities and labor are much lower than in major metropolitan areas! It is estimated that Hypersonic has saved in the range of $1.5 - $2.2 million to date due to the lower costs in a small community vs. locating in a major metropolitan area and less turnover of labor force.

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Rushford Hypersonic (Overview cont.)

Hypersonic was founded to utilize the University of Minnesota's *Patented - Hypersonic Plasma Particle Deposition (HPPD)* and *Focused Beam (FIB)* processes (which Hypersonic has *exclusive rights*) to coat and or modify high wear surfaces such as Gears, Bearings, Compressor wheels, Rotor-Blade Wear strips, Cutting tools and Implantable medical devices, etc… with the focus on

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Rushford Hypersonic (Overview cont.)

***Increasing** the **M**ean **T**ime **B**etween **F**ailure*

thus *Reducing the end cost* of the product by:

- Extending the useful life span of the part or tool
- Reducing change over time
- Increased Service Life
- Less Scrap due to increased life span and reduced dimensional and thermal changes during operation of the part or tool

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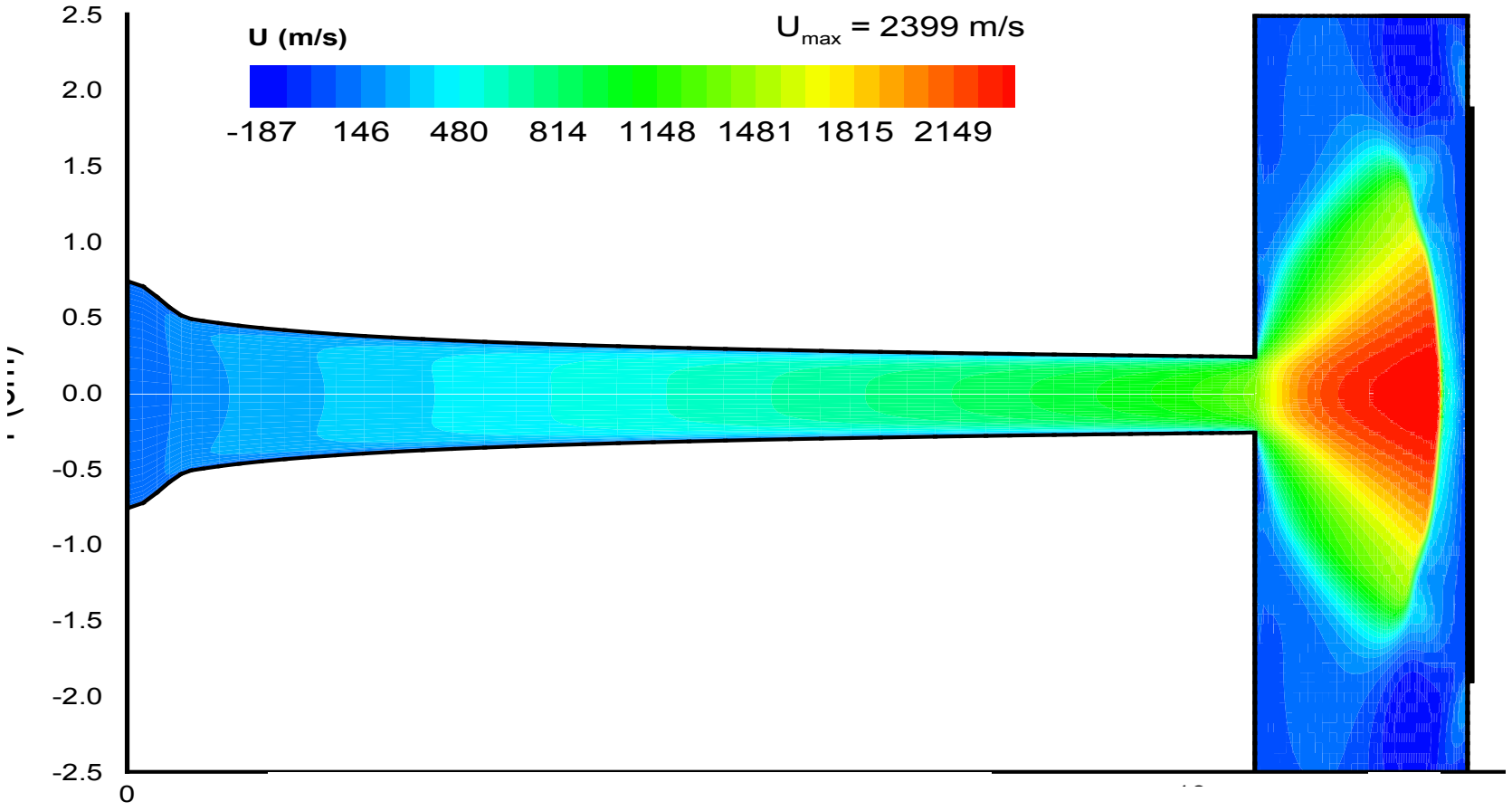
Hypersonic Plasma Particle Deposition

(HPPD)

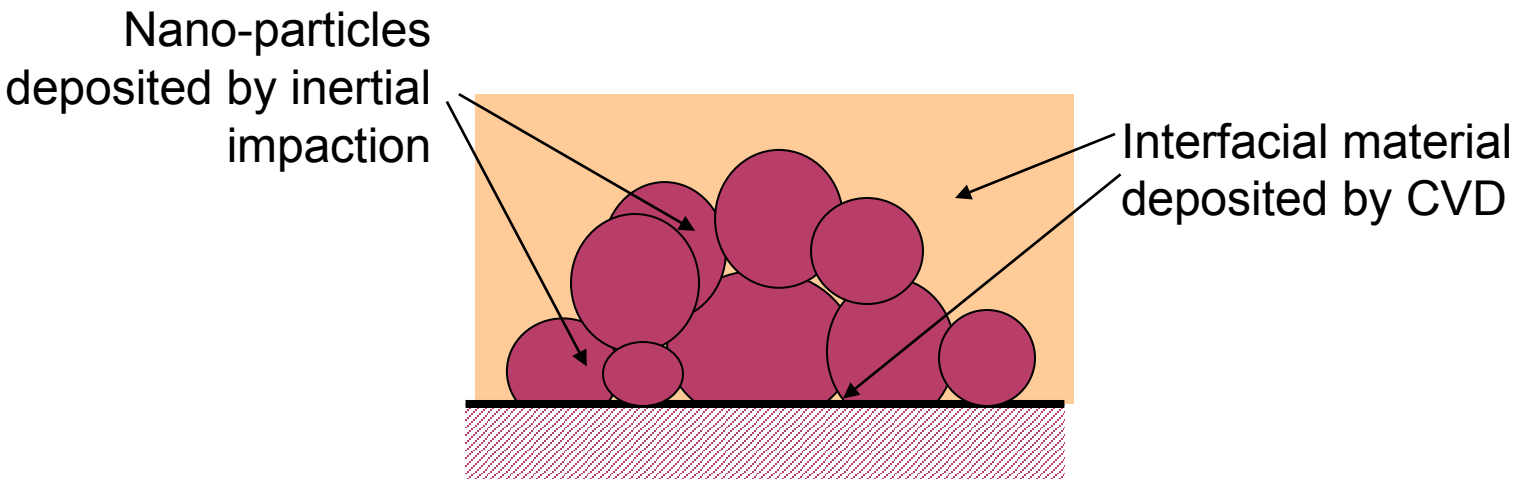
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- The *Patented* HPPD process is a "Innovative process in which Hypersonic particle impaction is crossed with a thermal plasma CVD.
- In this process we add various reactant materials and then disassociate them into their atomic elemental states in a reactor *(Intellectual Property)* which operates between (4,000 – 10,000$^{o}K^{+/-}$).
- We then reassemble the elements into nano-particles ranging from ~2nm – 20nm in size and of the material composition we have designed for the specific application.
- The particles are then accelerated and impact the substrate at hypersonic velocities of Mach 8^{+} in which they go thru a phase-change upon impaction with the substrate and form a chemical weld in addition to the cut impaction of ~3 - 5 nm.

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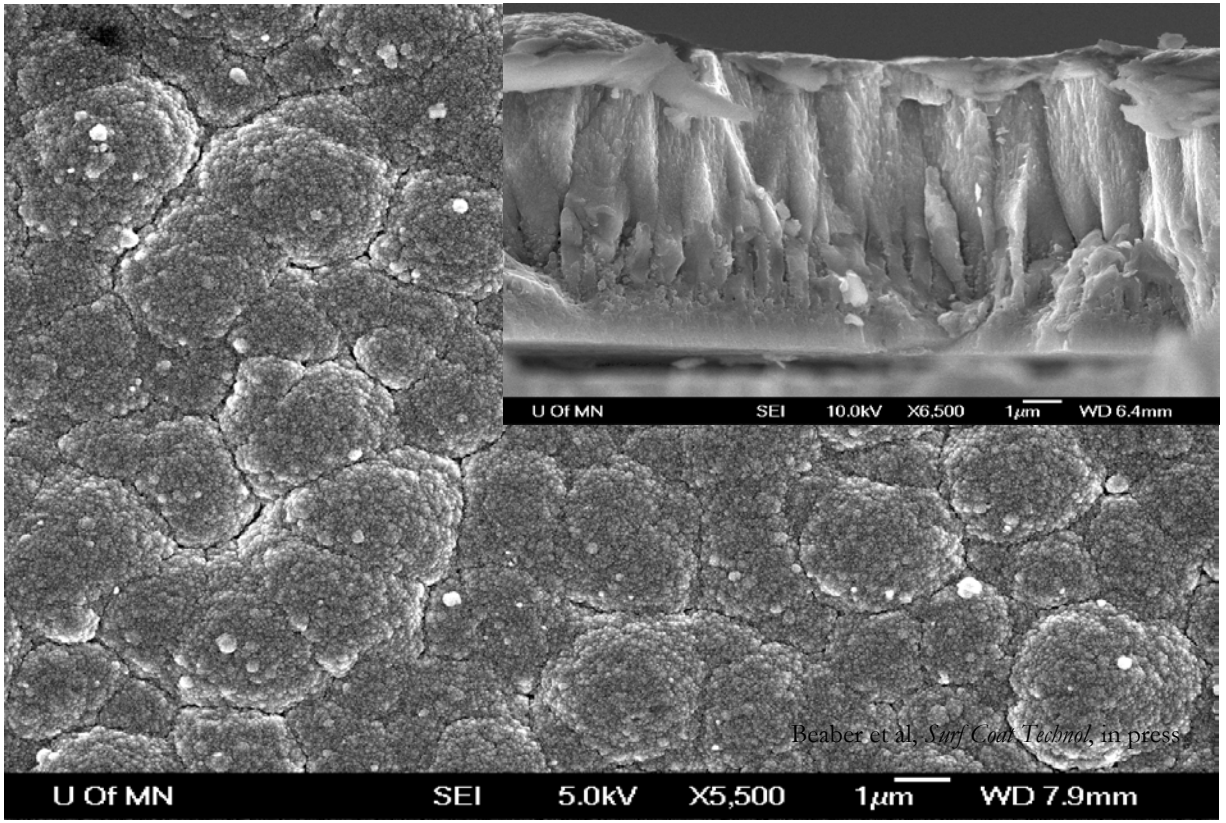


Rushford HYPERSONIC
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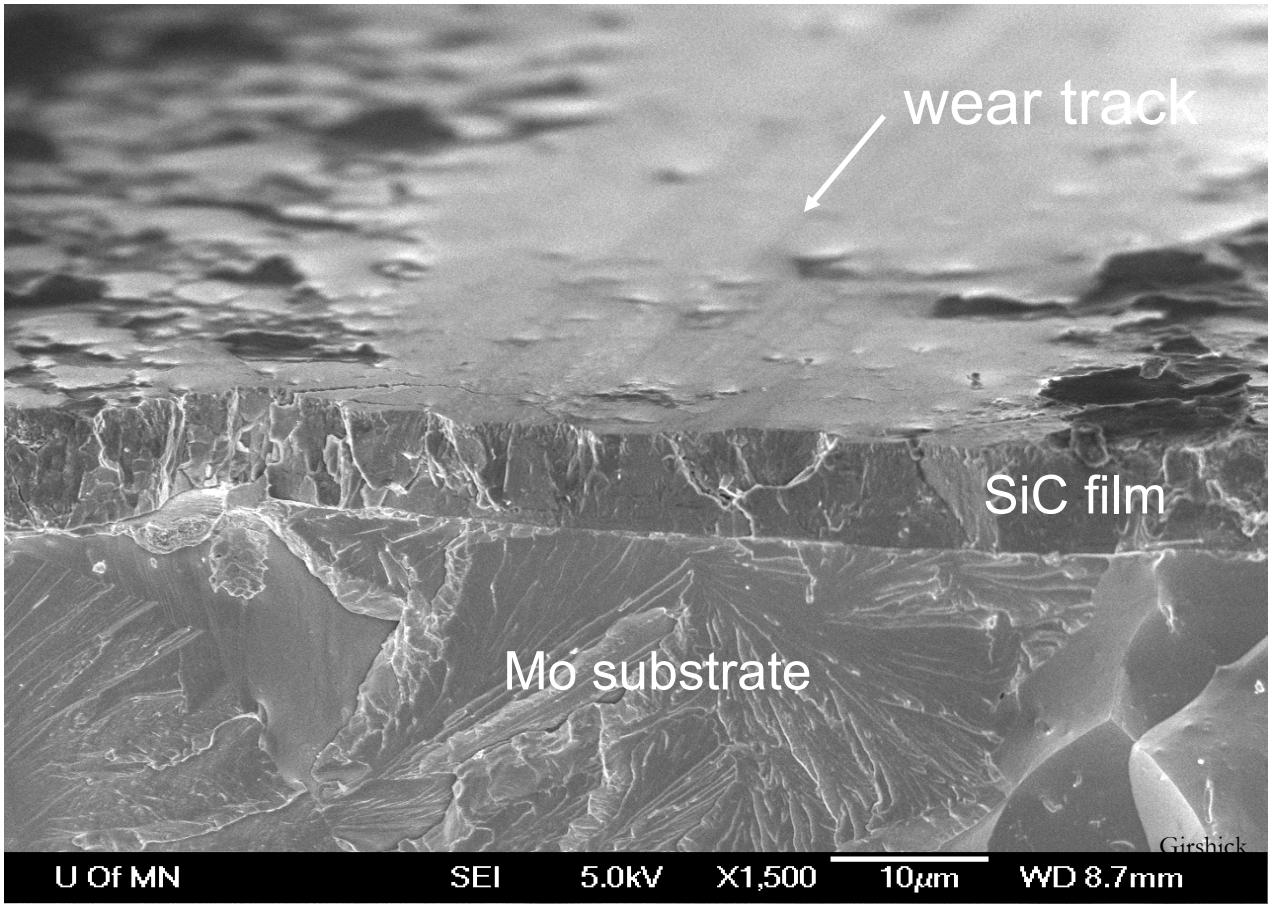
Inherent CVD then fills in pores left by nano-particle impact

SiC film morphology



Beaber et al, *Surf Coat Technol*, in press

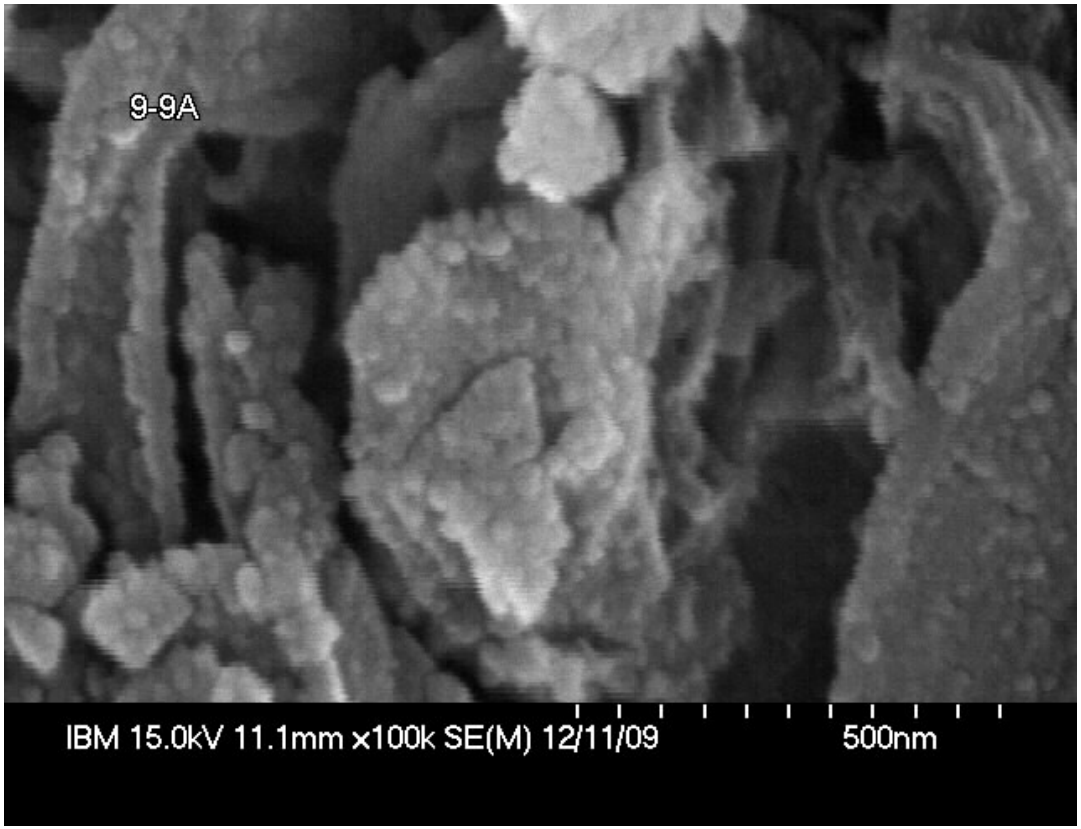
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Pin-on-disk wear track at r = 6 mm

Qualitatively, wear resistance appears excellent

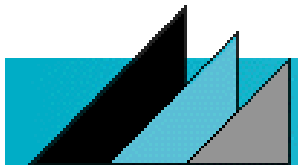
SiC film morphology



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University of Minnesota

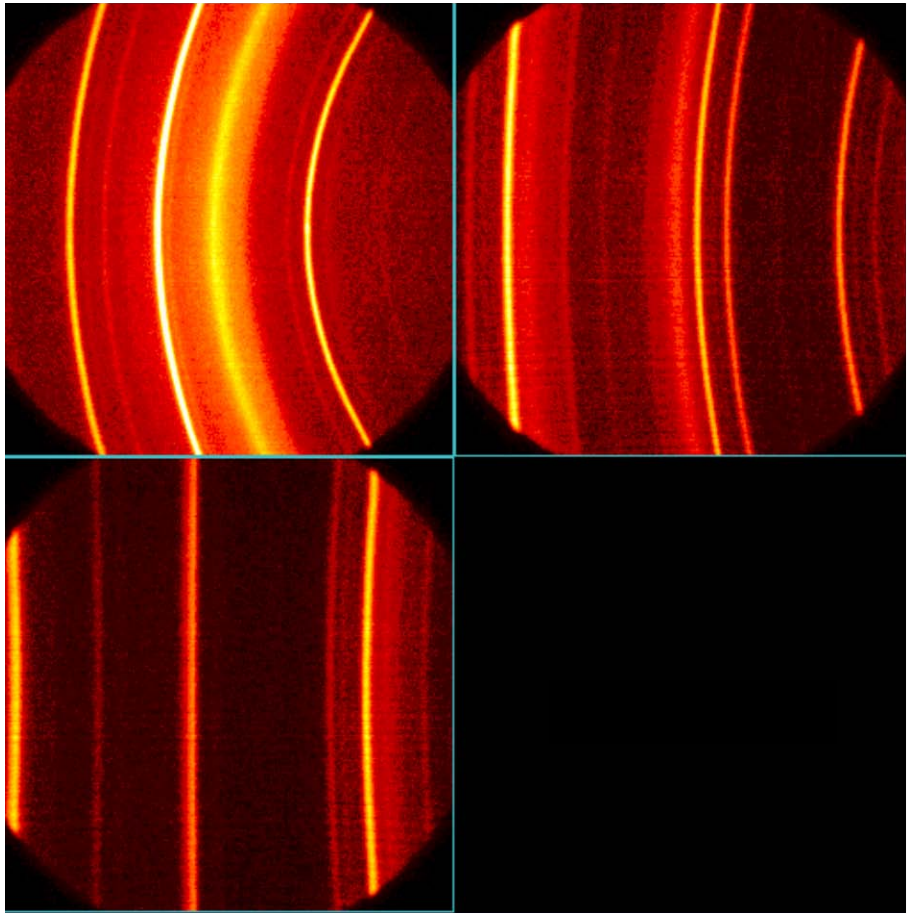


Characterization Facility

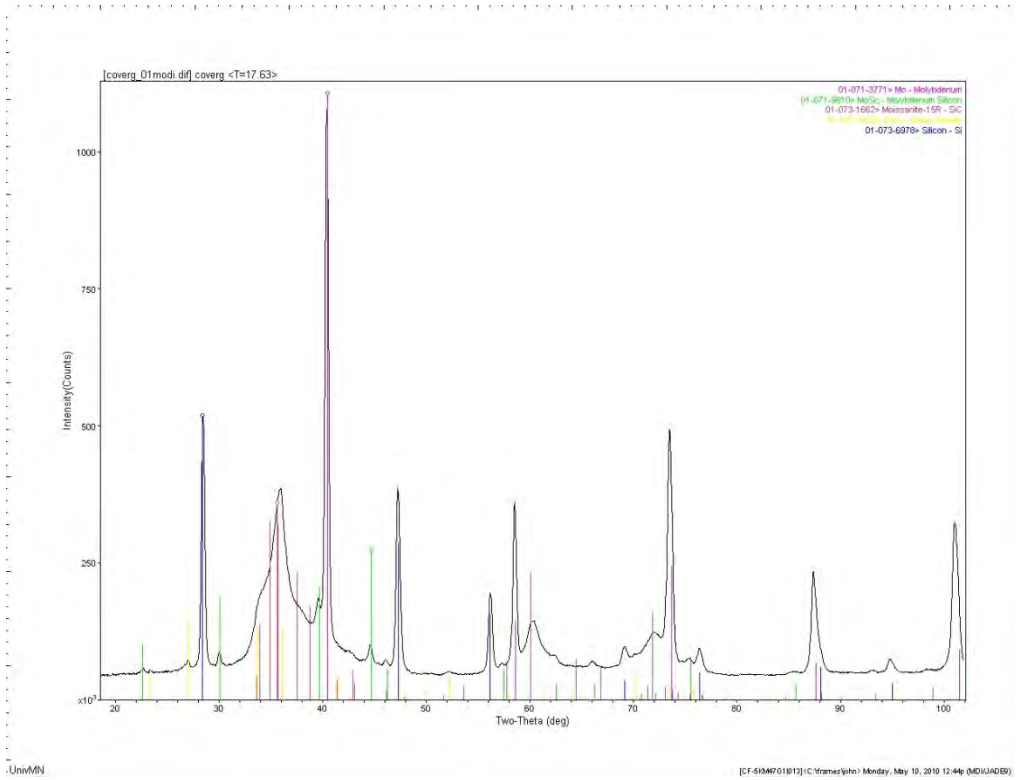
X-ray Scattering Lab

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Mo sample with thick coating

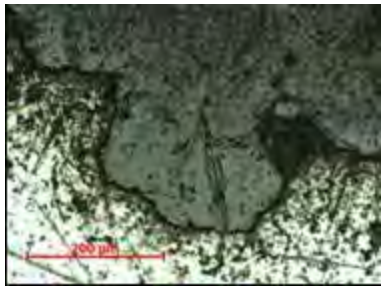


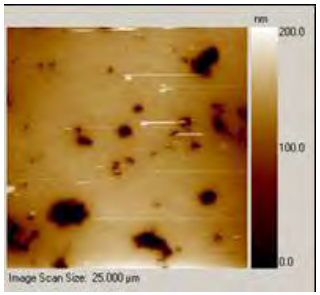
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…The SiC is moissanite, the hardest material known and the ideal coating.

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Sample #	E_r (GPa) *Ave ± StDev*	H (GPa) *Ave ± StDev*
4	254.7 ± 11.2	37.01 ± 1.95

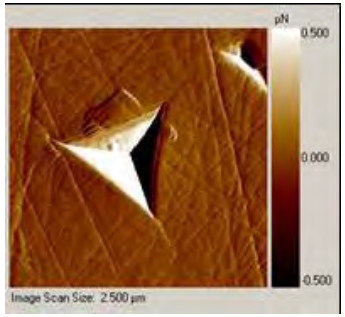


Table 1. Results from fracture toughness tests

Test #	Peak Load (mN)	Crack Lengths (µm)				K_c (MPa*m$^{1/2}$)
		1	2	3	Ave	
1	30.00	0.97	0.93	0.82	0.90	3.29
2	30.00	0.97	0.98	0.93	0.96	3.02
3	30.00	0.90	0.93	0.84	0.89	3.37
4	30.00	1.06	1.04	0.77	0.96	3.02
					Ave	**3.17**

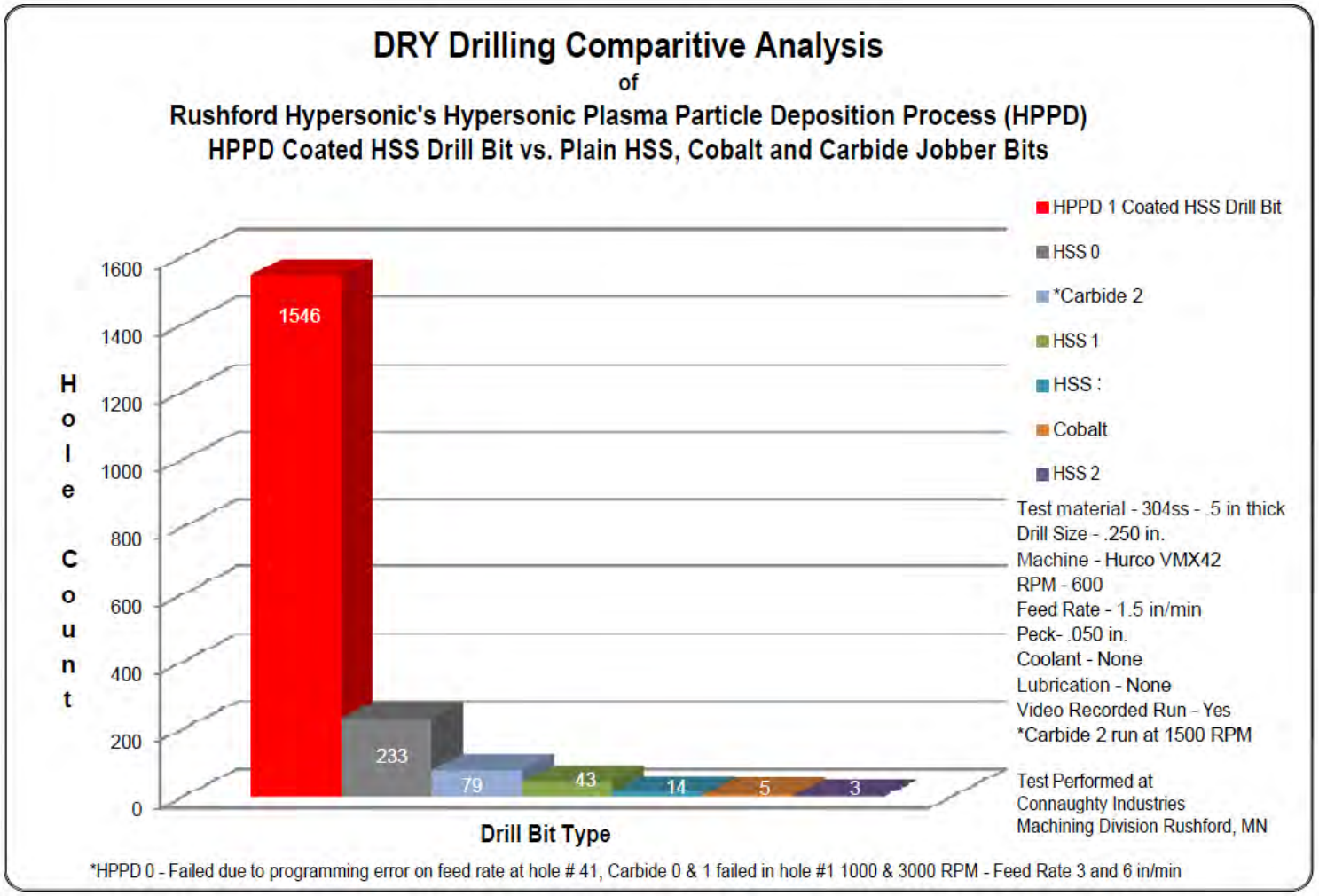
Why HPPD is Different!

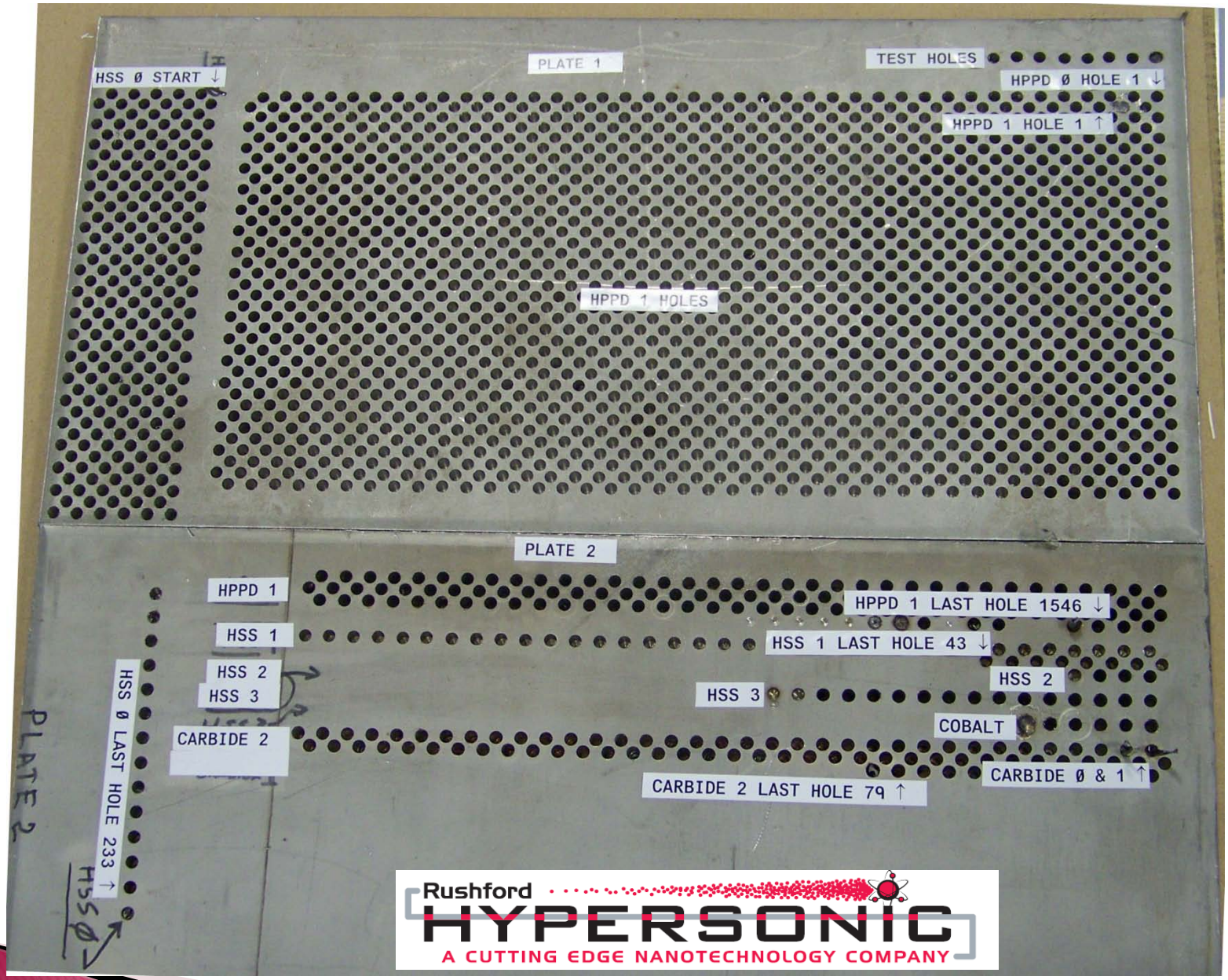
1. ***HPPD deposition material is 30-50% harder*** than the most industrial Ceramic Carbide material in use >**<u>36GPa.</u>**
2. The ***HPPD coating produced is up to 100% more fracture resistant*** than current materials going from ~ 3MPa $m^{1/2}$ to 6^{+}MPa $m^{1/2}$
3. Superior Wear Resistance
4. Deposition of HPPD process is up to 1000x faster than current CVD Processes
5. HPPD coatings are chemically welded to the substrate vs. just being a coating

- Rushford Hypersonic LLC has Licensed exclusive rights from U of MN for HPPD and FIB technology

Connaughty Industries
In house analysis run
of
Rushford Hypersonic LLC's
HPPD coated Drill bits vs. HSS - Carbide and Cobalt

Dry Drilling Analysis




PLATE 1
HSS Ø START ↓
TEST HOLES
HPPD Ø HOLE 1 ↓
HPPD 1 HOLE 1 ↑
HPPD 1 HOLES
PLATE 2
HPPD 1
HPPD 1 LAST HOLE 1546 ↓
HSS 1
HSS 1 LAST HOLE 43 ↓
HSS 2
HSS 3
HSS 2
HSS 3
COBALT
CARBIDE 2
CARBIDE Ø & 1 ↑
CARBIDE 2 LAST HOLE 79 ↑
HSS Ø LAST HOLE 233 ↑
PLATE 2
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Customer / Collaboration Base

FASTENAL

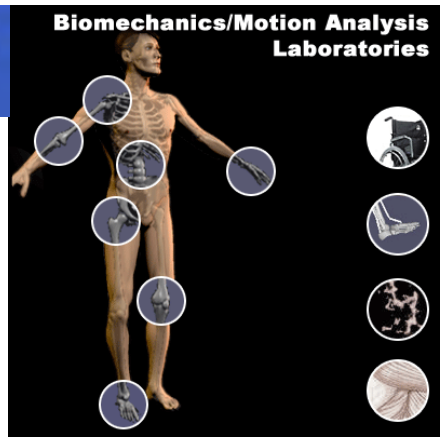
PYRAMID ABRASIVES
Manufacturer of:
SHARXTOOTH WoodMaster Angelfeet

UK AERO, INC.



HIGH-TEK TUBE CORP.

MAYO CLINIC



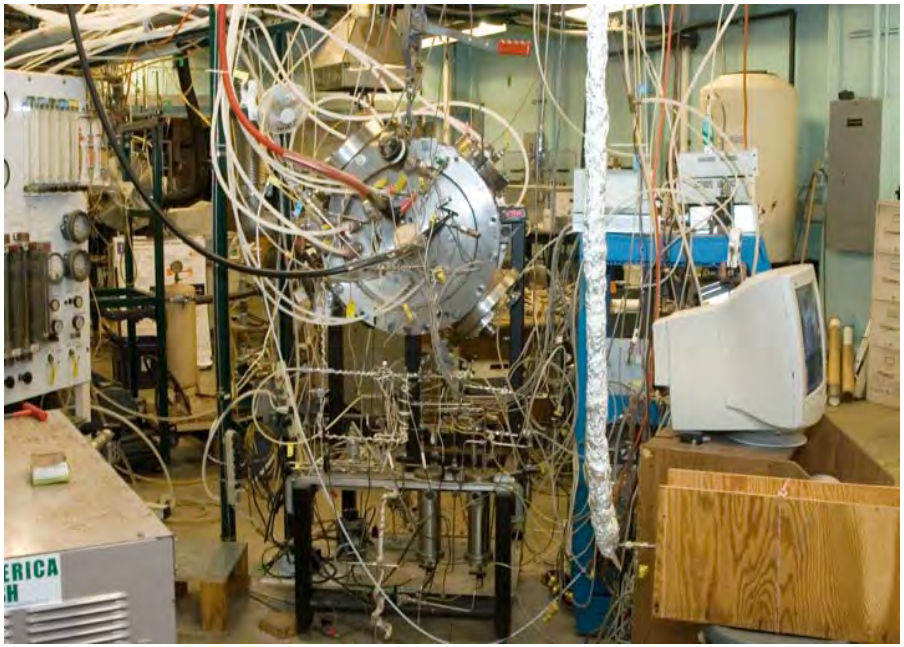
Centennial Carbide

Reiland's Hair Clinic, Inc.

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University of Minnesota HPPD Lab Machine



Hypersonic's HPPD-001 Deposition Chamber

Contact Information

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“Lightening Strike” – An Indirect Fire Concept Utilizing Combustion Light Gas Gun (CLGG) Technology to Achieve Extreme Ranges

David Kruczynski
Stephen G. Floroff

Workings of a Combustion Light Gas Gun



$2H_2 + O_2 \rightarrow 2H_20$ - *Classic Hydrogen Reaction*

$2H_2 + O_2 + xH_2 \rightarrow 2H_20 + xH_2$ – *Typical CLGG Reaction*

In the CLGG;

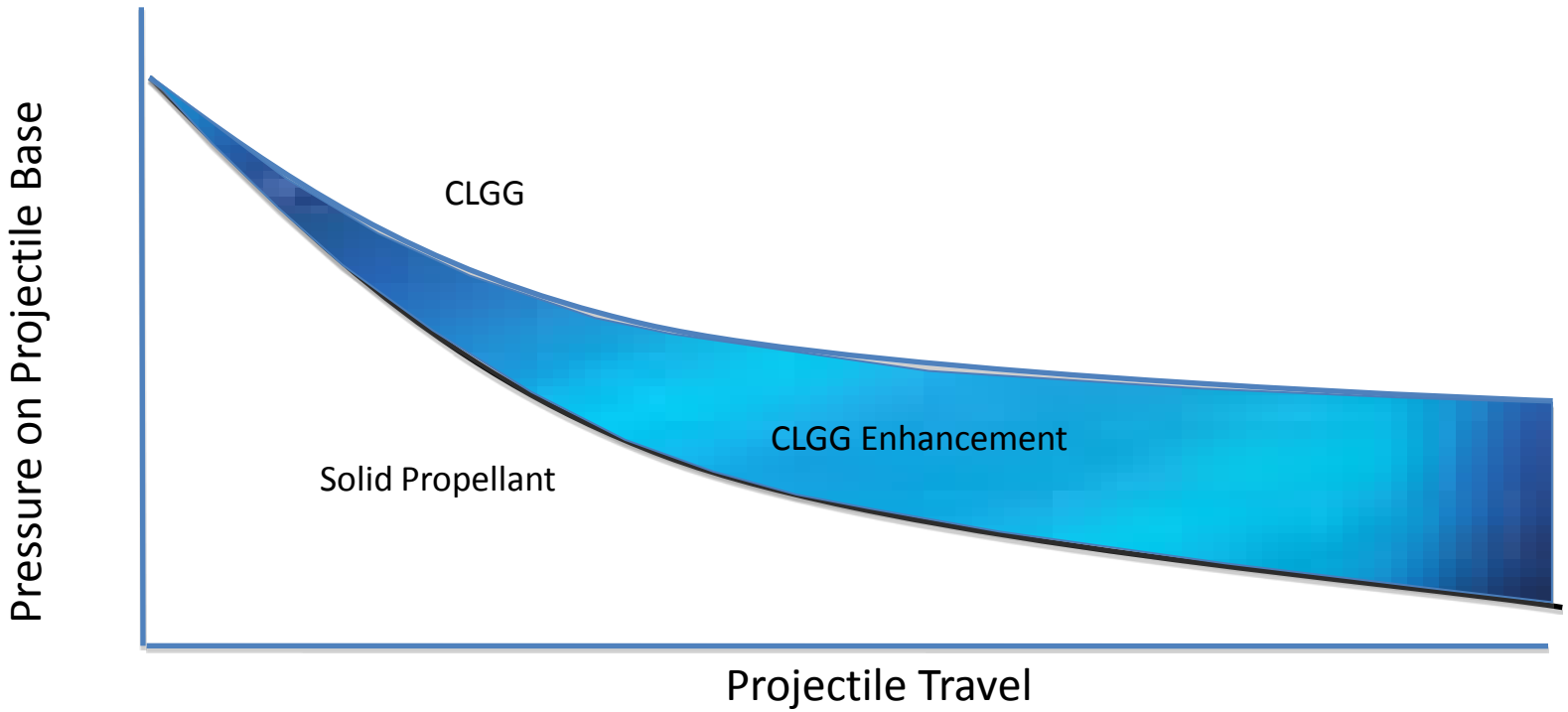
Oxygen quantity controls the available energy

Hydrogen serves both as a propellant and diluent

Hydrogen quantity controls the;

Sound Speed
Combustion Temperature
Molecular Mass

Key CLGG Benefits



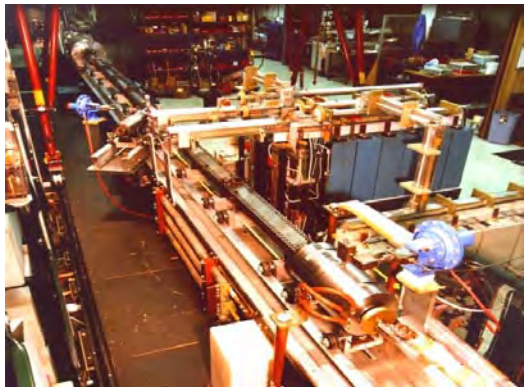
- Higher velocity and/or muzzle energy
- Zoning control
- Ability to produce propellant onsite

CLGG HISTORY

1993 -
16-mm ELGG - CLGG

1995 -
45-mm CLGG

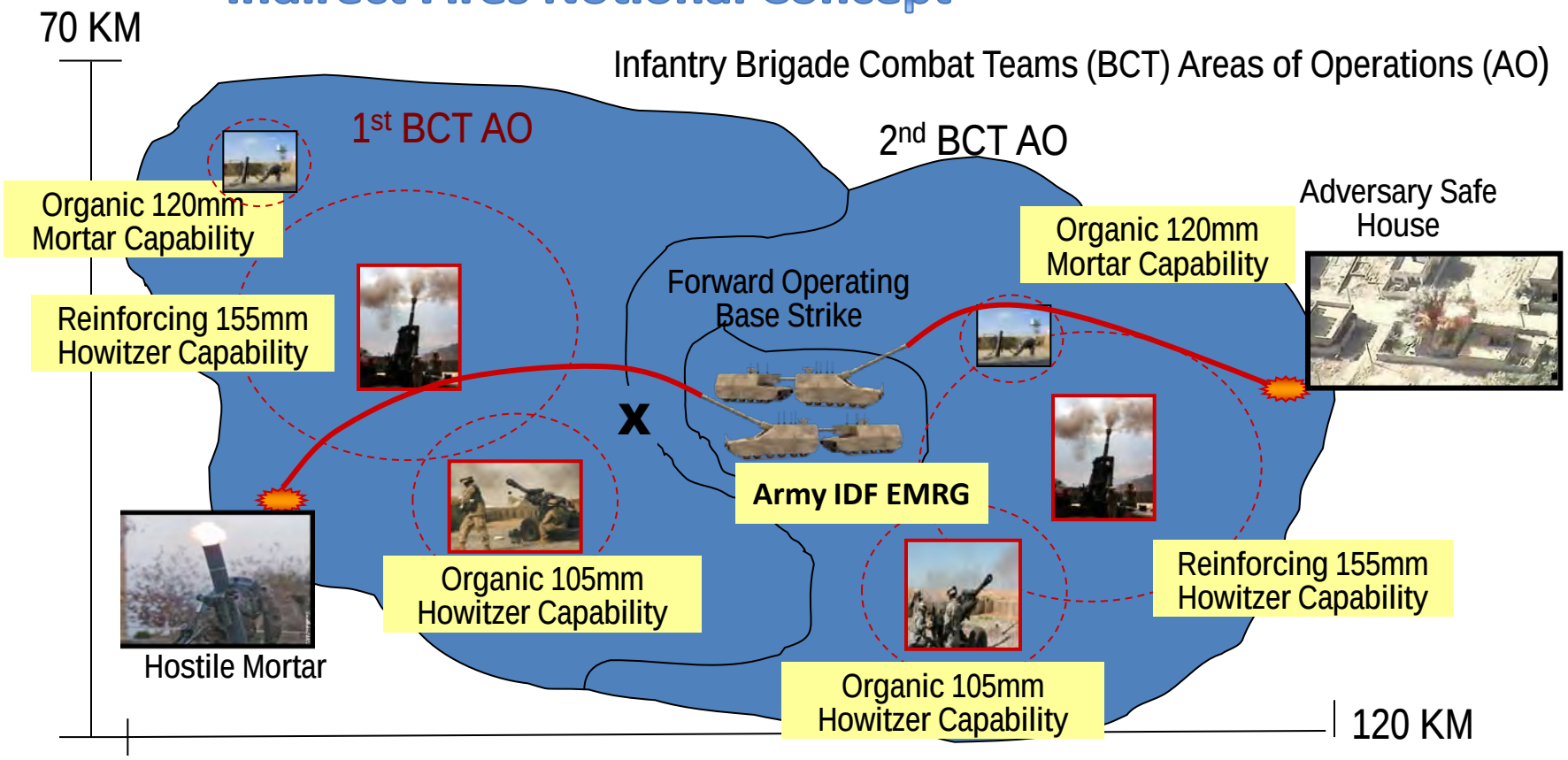
2007 -
155-mm CLGG







Indirect Fires Notional Concept



- **Here's a notional concept of how we might change and expand the capabilities of indirect fires with EMRG.**
- **Shown are two U.S. Army infantry brigade combat teams areas of operation not unlike what we see in Afghanistan today**
- **The 105mm howitzer represents the range capability of that system. Today we place these units in sub-optimized pairs to allow coverage for the most critical areas of operation.**
- **There are obviously logistics and force protection challenges with each of these operating bases we are required to establish.**
- **The 120mm mortar has an even smaller area of coverage.**
- **Next we have shown what reinforcing 155mm howitzers add in terms of range capability.**
- **In the center of the area deployed on forward operating base Strike, a pair of Army indirect fire ERMGs are providing extended range, precision fires to the entire area to attack an enemy mortar firing in the east and an enemy safe house in the west.**
- **All of this from a very secure area that is easily sustainable.**
- **I hope this provides a snap shot of how EMRG can drastically change indirect fire capability in the future.**

Artillery Technology Environment

Assumptions:

- Course correcting technology will become cheap and ubiquitous.
  - While one may debate how soon, how accurate and how cheap – this will occur over the course of the coming decade or two.

- Long range, time sensitive target location technology will come. It will include organic, local and inorganic i.e. global.
  - While many targets will undoubtedly remain elusive, dispersed and time critical communication of target location over vast areas will become common place over the coming decade or two.

- Scalable lethality will come. It will be demanded.
  - Flexibility with regard to the trade between lethality of effects and collateral damage will be achieved.

ARMY Use of CLGG Technology – Safety and Vulnerability

UTRON and others have extensively studied hydrogen and oxygen safety and vulnerability. Bottom line, is that these materials can be made as least as safe as the propellants and motors, which they replace, by well-understood engineering practices.



Hydrogen Car on Left, Gasoline Car on Right
Both Tanks Punctured



Fuel Ignited



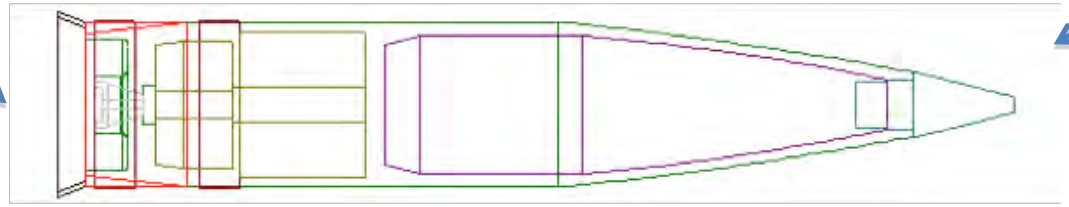
ARMY Use of CLGG Technology – Projectile Considerations

CLGG technology is backward compatible with some projectiles in the current inventory such as the M549A1 round with minor modifications however, rounds specifically designed for higher velocity flight are suggested.

Add pusher, seal, and iron rotating band

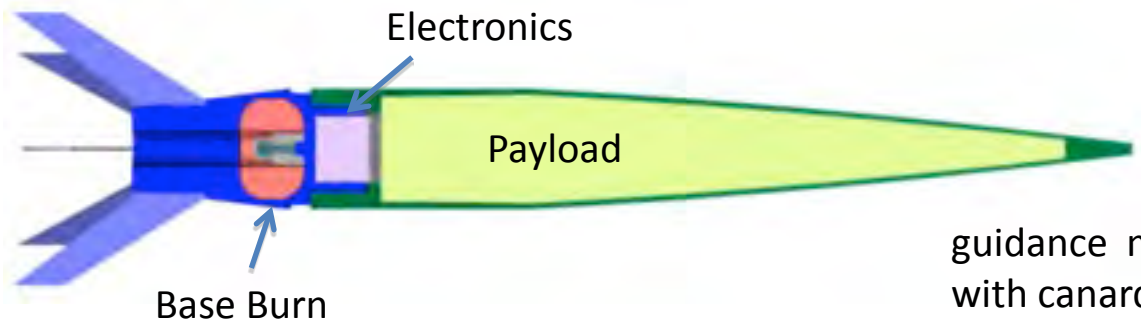
Use fuse/canard guidance and controls

M549A1



High speed concept round

Folding fins (8)



ARMY Use of CLGG Technology – Logistics

CLGG propellants are currently available from an established industrial base in the US and elsewhere. The ability to produce CLGG propellants onsite adds additional flexibility in logistics.

Major H_2 production sites in U.S.



Industrial production and use of H_2

Area	Hydrogen gas Trillions ft^3	If Liquid Billions Gal
U.S.	4.2	35
Worldwide	25	210



In addition onsite production Is available as needed



ARMY Use of CLGG Technology – Concepts

A 155mm tracked vehicle equipped with a 52 caliber long CLGG is capable of launching a 45 kg projectile to ranges up to 100 km.

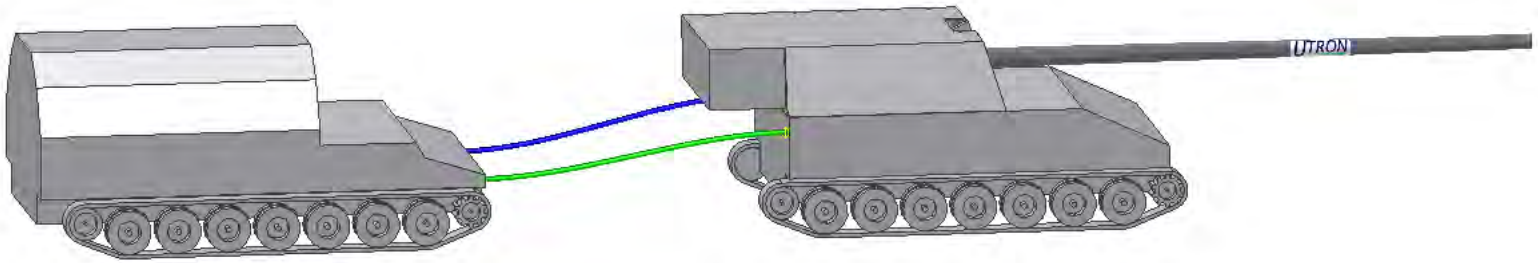


Paladin with 52 caliber CLGG



FAASV with CLGG Propellants

FAASV resupplying CLGG equipped Paladin



CLGG – Future (near term)

- ✧Build Tracked Based CLGG Demonstrator
- ✧Continue Logistics Studies
- ✧Perform Onsite Production Demonstration



155-mm bore CLGG Firing



L-3 Fuzing & Ordnance Systems

Miniaturized Electronic Safe & Arm Device Development

Joint Armaments Conference
May 19, 2010

Presented By
Ed Cooper, Director, Technology Development

This presentation consists of L-3 Corporation general capabilities information that does not contain controlled technical data as defined within the International Traffic in Arms (ITAR) Part 120.10 or Export Administration Regulations (EAR) Part 734.7-11.



Agenda

- Need for smaller ESADs
- Example of size reduction realized to date
- Enabling Technologies
- What is necessary for further size reduction

The information in this presentation is of general capabilities and open for public release



Need for smaller ESADs

- Customer Requirements
- Armed UAVs
- Better safety features for handheld weapons
- Further proliferation of ESADs into new areas

The information in this presentation is of general capabilities and open for public release

First ESAD (ATACMS)

- Volume: ~56 cubic inches

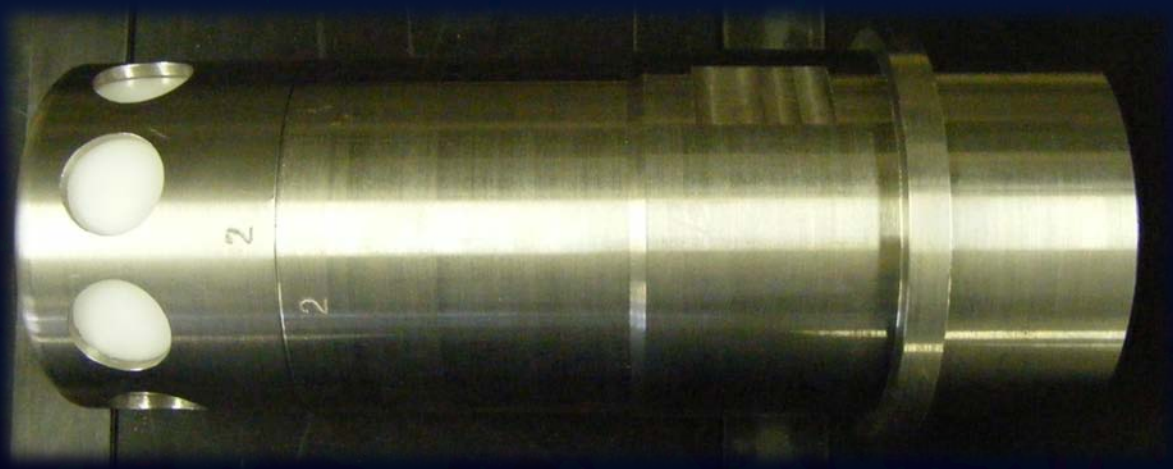


The information in this presentation is of general capabilities and open for public release



Typical 3” Bomb Fuze

- Volume: ~40 cubic inches (without booster)
- 29% smaller than ATACMS



The information in this presentation is of general capabilities and open for public release



Miniaturized ESAD

- Volume: 1.8 cubic inches
- 97 % smaller than ATACMS
- 96 % smaller than 3” bomb fuze



The information in this presentation is of general capabilities and open for public release



Miniaturized ESAD

- Volume: 1.16 cubic inches
- 98 % smaller than ATACMS
- 97 % smaller than 3” bomb fuze



The information in this presentation is of general capabilities and open for public release



Comparison to Computer Industry

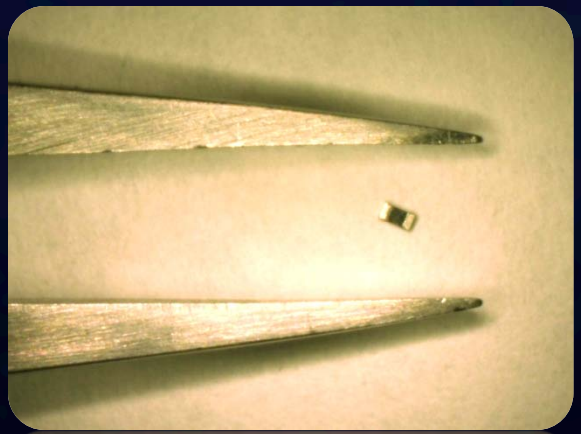
- Computer industry has realized ~99.999998 % volume reduction (ENIAC to smart-phone)
  - *660,000 smart-phones needed to fill up volume of ENIAC*
  - *Due to tight integration of different parts and discrete part size reduction*
- L-3 FOS has realized ~98 % fuze volume reduction
  - *48 miniaturized ESADs needed to fill up volume of ATACMS*
  - *Driven by customer requirements, realized by smaller components*
  - *So far, not much integration of different parts for fuzing applications*
- Aggressive fuzing specific component integration needed to further drive down ESAD size.

The information in this presentation is of general capabilities and open for public release

Small Passive Components

- Passives take up significant percentage of board space.
  - *Smaller passives have been facilitator of size reduction in the past.*

- Passives are about as small as they can get
  - *Smallest readily available passives are 0201 size*
  - *Approximately 20 mil length x 10 mil width x 9 mil height*



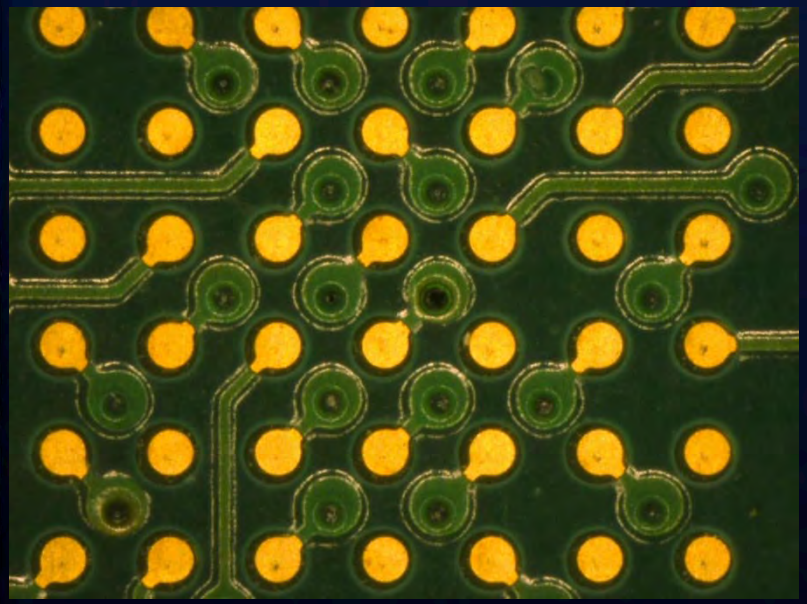
Tweezers and 0402 size resistor

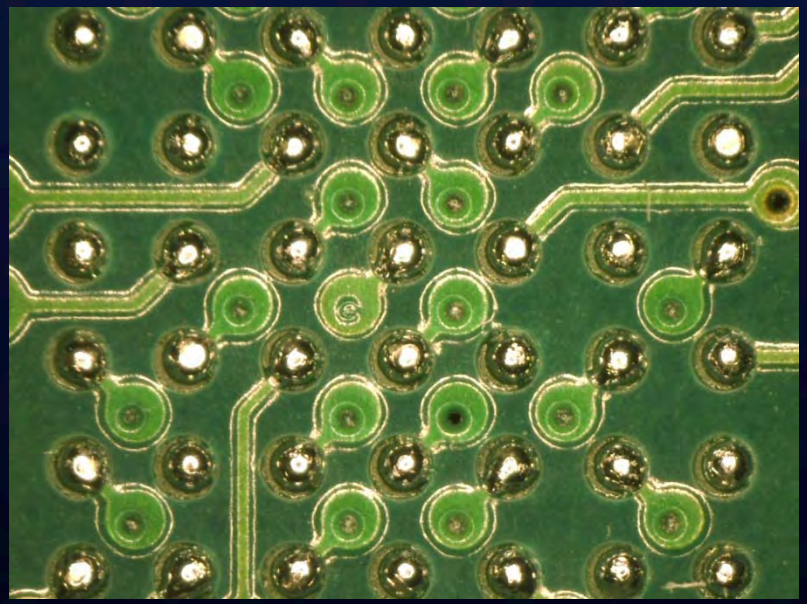
The information in this presentation is of general capabilities and open for public release



Printed Circuit Board Finish

- ENIG boards offer very flat surface
  - *Flat surface required to reliably solder small components*
  - *Left: ENIG (electroless nickel immersion gold)*
  - *Right: HASL (hot-air solder level)*





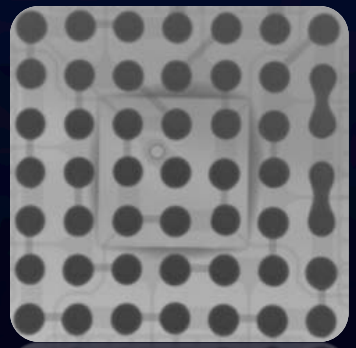
The information in this presentation is of general capabilities and open for public release

Useful Equipment

- Surface mount assembly line
  - *Solder paste masking*
  - *Pick & place*
  - *Reflow oven*
- Semi-automated re-work equipment
  - *Camera assisted part placement*
  - *Localized IR reflow*
- X-Ray BGA Inspection







The information in this presentation is of general capabilities and open for public release



Enabling Technologies

- **Smaller Components**
  - *Ball Grid Array (BGA) IC packages*
  - *Surface-mount transformers*
  - *Very small passive components*
- **ENIG Printed Circuit Boards**
  - *Electroless Nickel Immersion Gold*
  - *Flatter surface required for small components*
- **Automated assembly equipment**
  - *Higher reliability assembly for small components*

Commercial industry driven

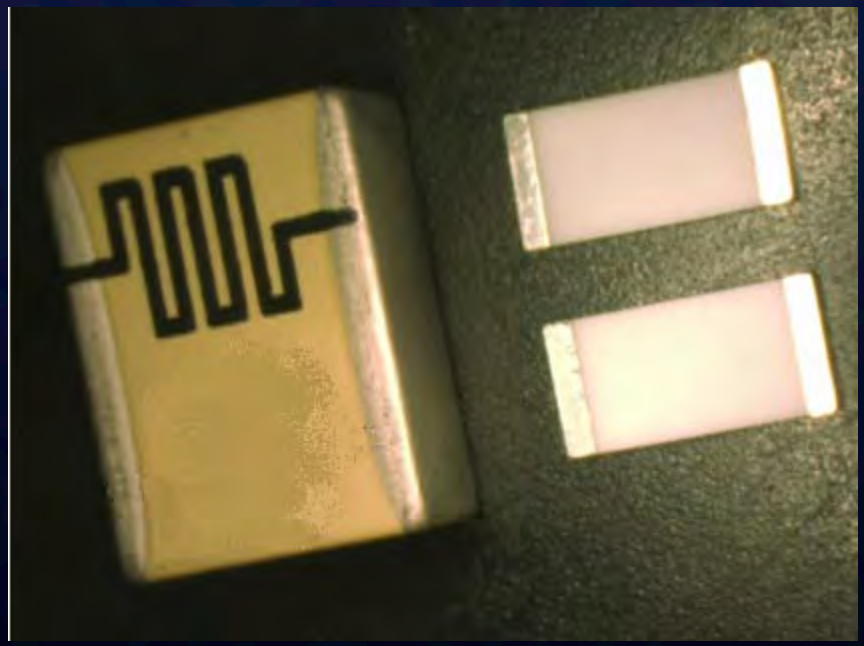
- **Fuze-specific component integration**
  - *Fire cap with integrated bleed resistors*

Fuze industry driven

The information in this presentation is of general capabilities and open for public release

Fuze-Specific Component Integration

- Capacitor with integrated bleed resistors
  - *Approximately 50% of the area of a layout with discrete bleed resistors*
  - *Equivalent bleed resistors shown at right*



Source: NOVACAP

The information in this presentation is of general capabilities and open for public release



Fuze-Specific Component Integration

- This is where future space savings will be realized

Large Components	Integrated?
Bleed Resistors	✓
High voltage capacitor	✓
Fire Switch	
Safety Logic	
Voltage Regulators	
Transformer	
Small Passive Components	
Environment Sensors	

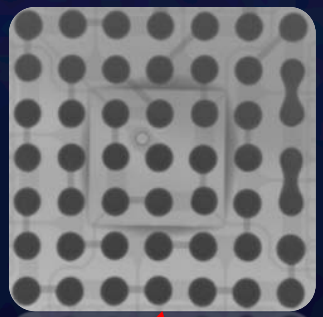
The information in this presentation is of general capabilities and open for public release

L-3 FOS Capabilities

- L-3 FOS has invested in necessary equipment and has the experience needed to produce state-of-the-art miniature ESADs



Two miniature ESADs in development/DVT



X-Ray BGA solder inspection



Surface-mount prototyping & assembly

The information in this presentation is of general capabilities and open for public release

2010 Joint Armaments Conference, Dallas, Texas, 17-20 May 2010

Selectable Effects Warhead Technology Demonstration

19 May 2010

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Selectable Effects Background

High output bombs/missiles cannot be used on ROE-restricted missions or near friendly troops

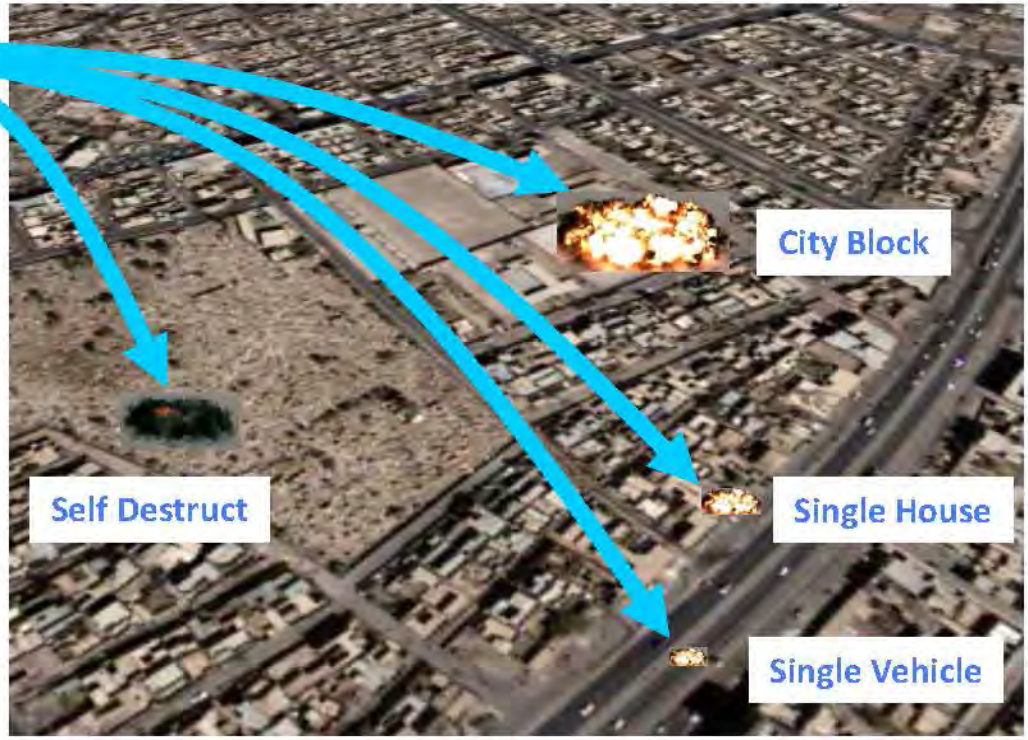
Current DoD solution: separate weapon for low collateral damage mission

- Focused Lethality Munition for Small Diameter Bomb
- BLU-126 Low Collateral Damage 500-lb Bomb



Better Solution = Single "Dial-A-Yield" Warhead

- ✓ Flexible
  - One bomb, many missions
- ✓ Adaptable
  - In-flight re-targeting option
- ✓ Safe
  - No hazardous duds



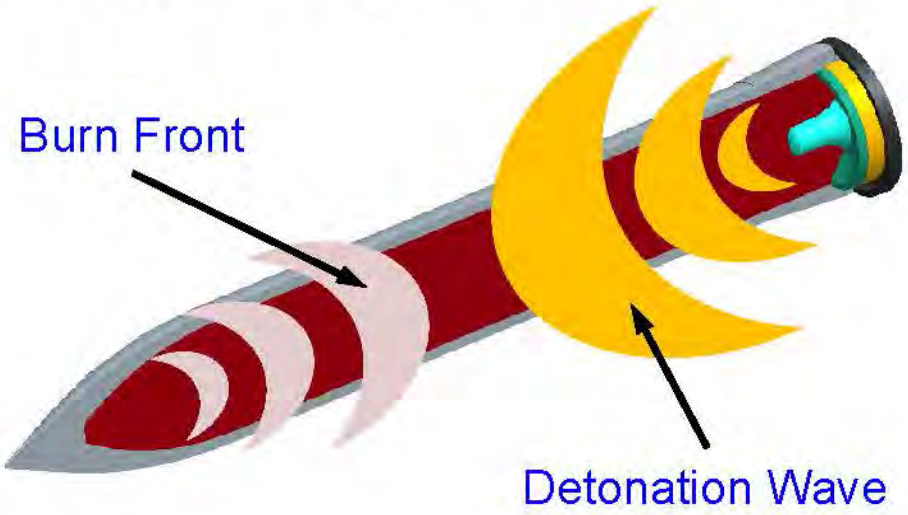
Approved for public release 22 CFR 125.4(b)(13)applicable. OSR #10-S-1993 dated 18 May 2010.

Battelle
The Business of Innovation

Dial-A-Yield Bi-Modal Warhead Concept

A premier aerospace and defense company

- **Initiation Based - Partially burn/Partially detonate explosive charge**
  - **Time delay between burning initiation & detonation initiation**
- **Compatible with MIL-STD-1316 approved fuzing systems**
- **Cockpit or in-flight selectable with data link**





High Speed Video

Scalable to 105mm and Greater Size Munitions

Initiator Timing Control Demo

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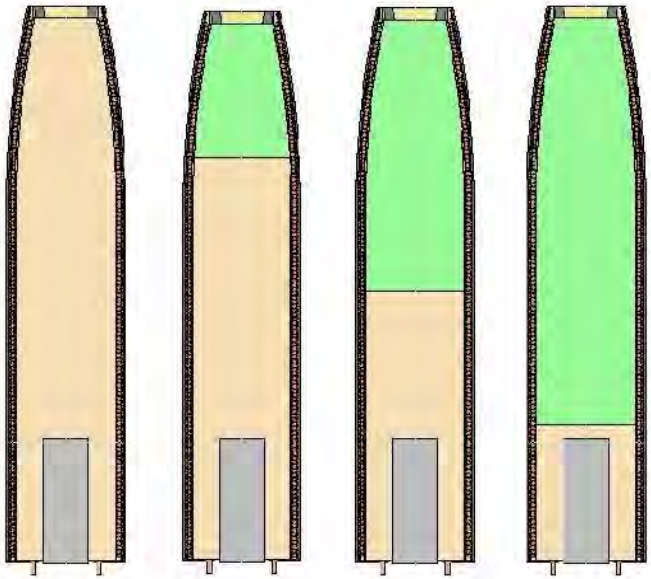
Battelle
The Business of Innovation

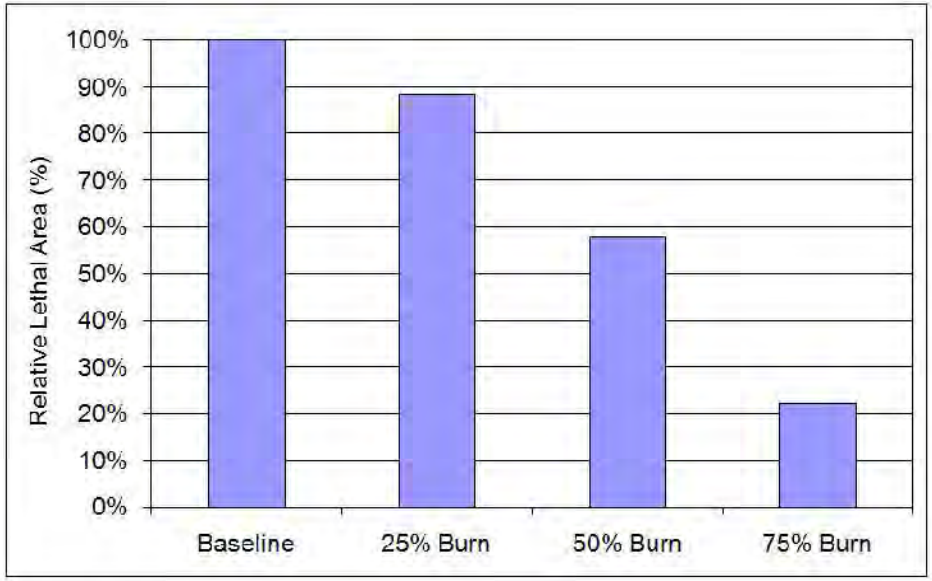
Preliminary Lethality Analysis

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CTH Simulations of generic warhead shape to estimate fragmentation

JMEM software to calculate relative lethal area





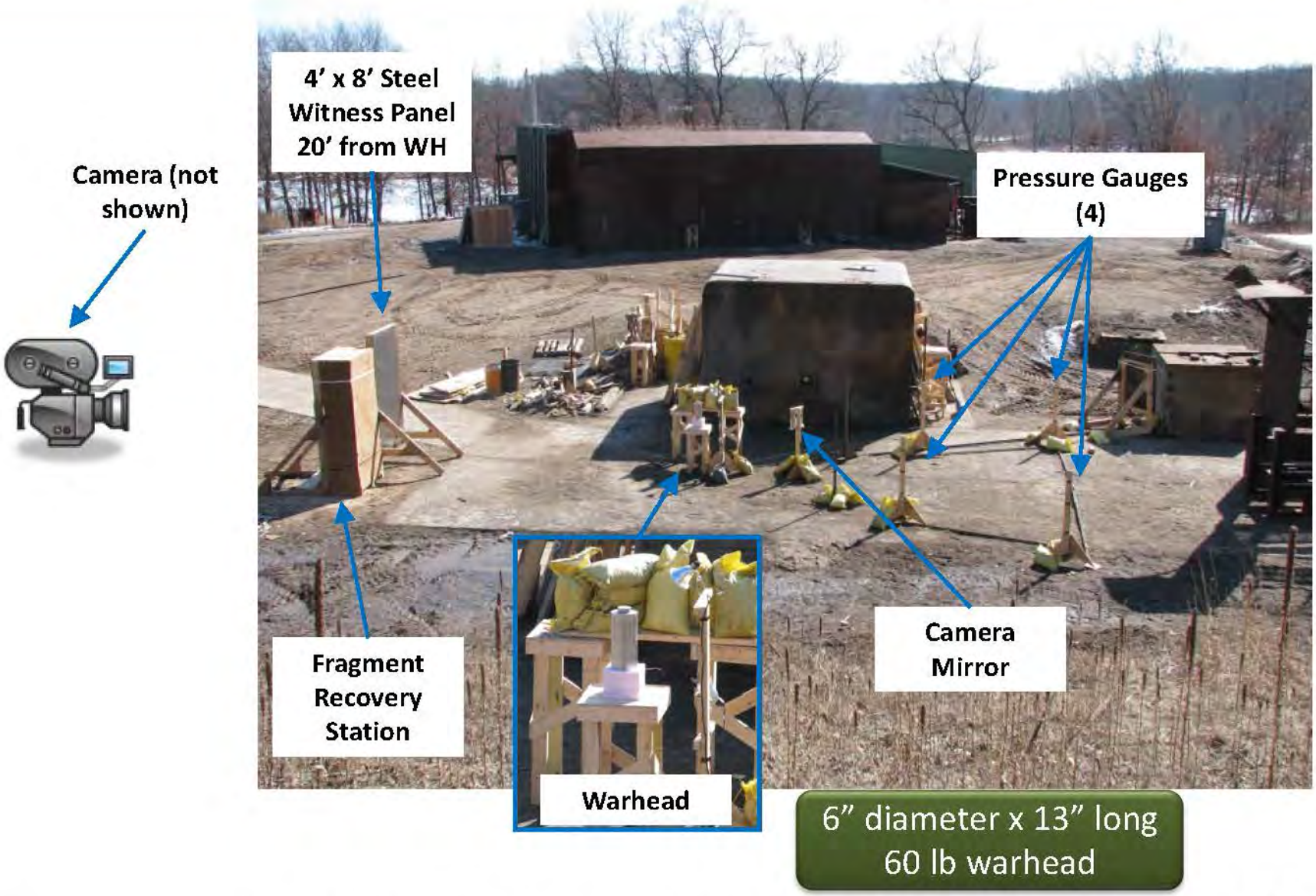
More burned explosive = lower collateral damage

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March 2009 ATK IR&D Demo Test Setup

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High Speed Videos

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Three Warhead Tests

- ✓Full Output Baseline
- ✓Bi-modal low collateral damage
- ✓Deflagration-only self destruct

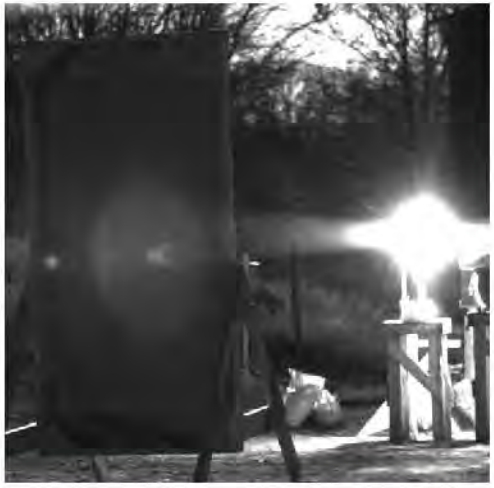
Baseline



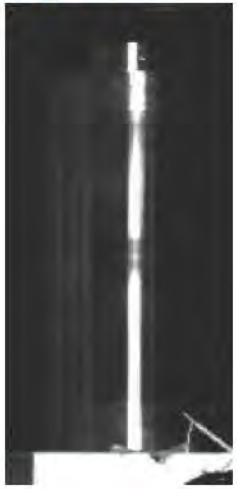


Bi-Modal





Deflagration





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Battelle
The Business of Innovation

Test Results

Test	Relative Fragment Velocity	# Witness Panel Holes
Baseline	100%	30
Bi-modal	68%	20
Deflagration	9%	0

← > 40% Reduction In Lethal Area

← Didn't break a mirror 5 ft away

Back-Lit Witness Panels



Baseline | Bi-Modal | Deflagration

Technology Ready for System Integration

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Summary

ATK Team Selectable Effects (Dial A Yield) capability

- Initiation-based
- Adaptable to any warhead system

ATK Demo Test Series

- Successfully demonstrated initiator timing control
- Successfully demonstrated the bi-modal technology
  - Full output mode
  - Low collateral damage mode
  - Self-destruct mode

Ready for DoD system integration

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The Rarefaction Wave Gun Program

A Government and Industry Collaboration to Develop 21st Century Cannon Systems

Presented by :
Mike Bixler, ARES, Inc.
(419) 635-2175
mike.bixler@aresinc.net

21st Century Cannon Systems

- LW vehicles w/ large caliber guns
  - Considerable momentum and kinetic energy imparted to system
- Engineering barriers
  - Mitigate recoil
  - Reduce weight
- RArefaction waVE guN (RAVEN)
  - Army After Next project (1999)
  - Dr. Eric Kathe - doctoral thesis (2001)
  - Engineering & demo. (2005 – 2010)





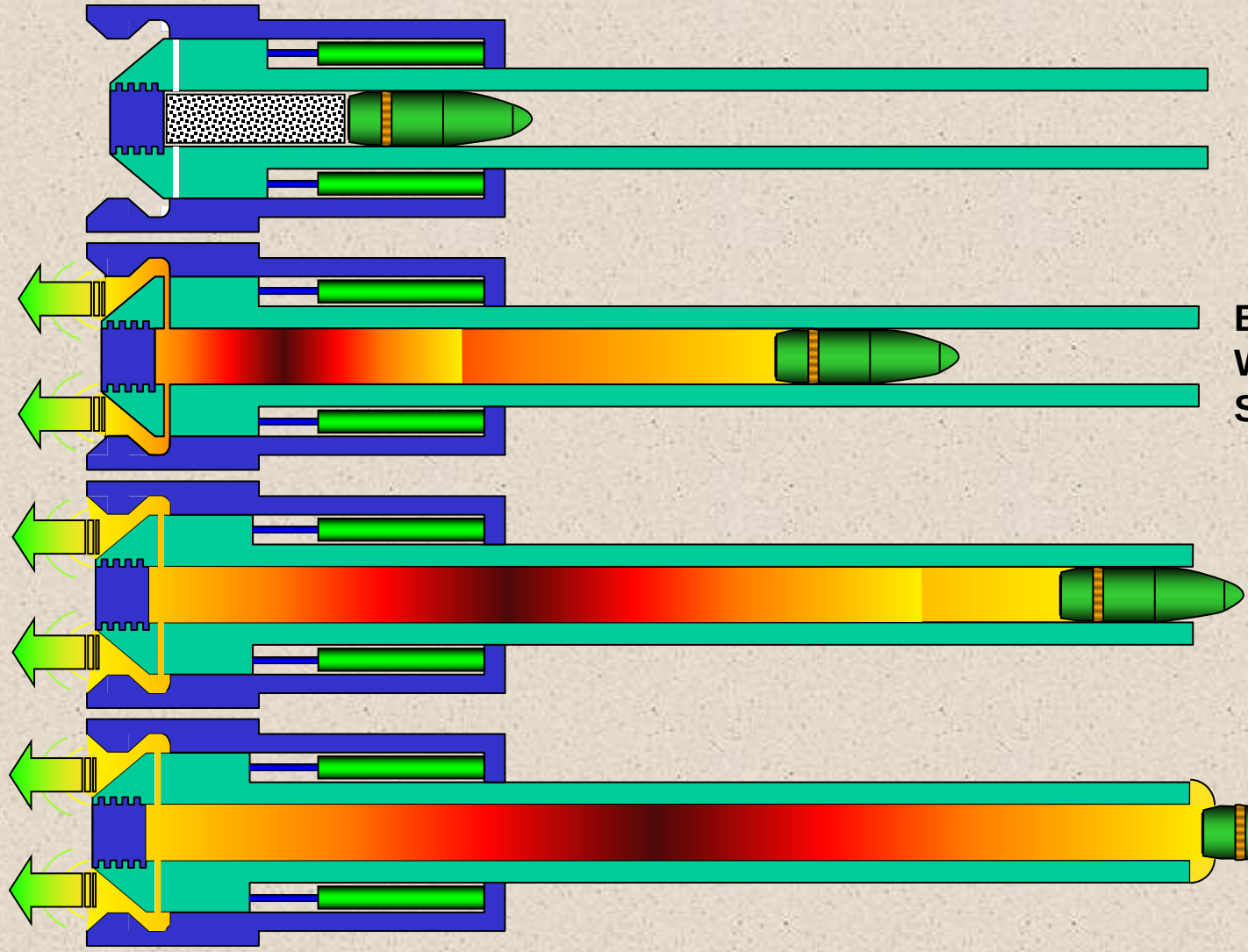
RAVEN Propulsion – Objectives

- High lethality weapons on lightweight vehicles
- Mitigate recoil
  - Recoilless early venting achievable
- Reduce thermal load
  - Reduced gas density
  - Reduced gas temperature
  - High rate-of-fire capability
  - Sustainable fire
- Maintain ballistic efficiency
- Maintain muzzle velocity
- Minimize impact to vehicle
- Lightweight materials to reduce system weight



Notional RAVEN Cannon Mounted upon a Lightweight Robotic Vehicle

RAVEN Propulsion – Operation



Ignition

Breech Vent Opens While Projectile is Still In-Bore

Synchronized Rarefaction Wave Catches Projectile At the Gun Muzzle

No Velocity Loss

RAVEN Propulsion - Challenges

- Vent method and mechanics
  - Blow-back bolt
  - Recoil actuated
  - Rupture disk
- Back blast
  - Overpressure
- Ammunition loading
- Gun system integration



Notional 45mm RAVEN Automatic Cannon Mounted upon a RIPSAW Robotic Vehicle

RAVEN Program – Accomplishments

- Proof-of-Principle
  - 35mm demonstrator
    - RAVEN propulsion validation
    - Vent mechanics experimentation
- System Advancements
  - 105mm demonstrator
    - Converted FCS_MRAAS cannon w/cased telescoped ammunition
    - Inertial breech vent
    - Ammunition handling system
  - 45mm demonstrator
    - Converted COMVAT automatic cannon
    - Blow back bolt & ammunition based vent
    - Ammunition development

RAVEN Program – Accomplishments

- Firing Tests
  - 105mm Demonstrator
    - Synchronized rarefaction wave demonstrated
  - 45mm Demonstrator
    - Closed breech baseline
    - Pre-synchronized venting (recoilless operation)



Accomplishments – 35mm Demonstrator

- Design
  - Based on Oerlikon KD series 35mm anti-aircraft gun
- Vent Method
  - Ammunition-based rupture disk
    - Intentionally ‘uncorks’ the breech
  - Blow-back bolt
    - Propelled rearward by impulse from propellant gases
  - Timing
    - Driven by same propellant gases as bullet
    - Governed by bolt mass bolt and distance to ‘uncork’

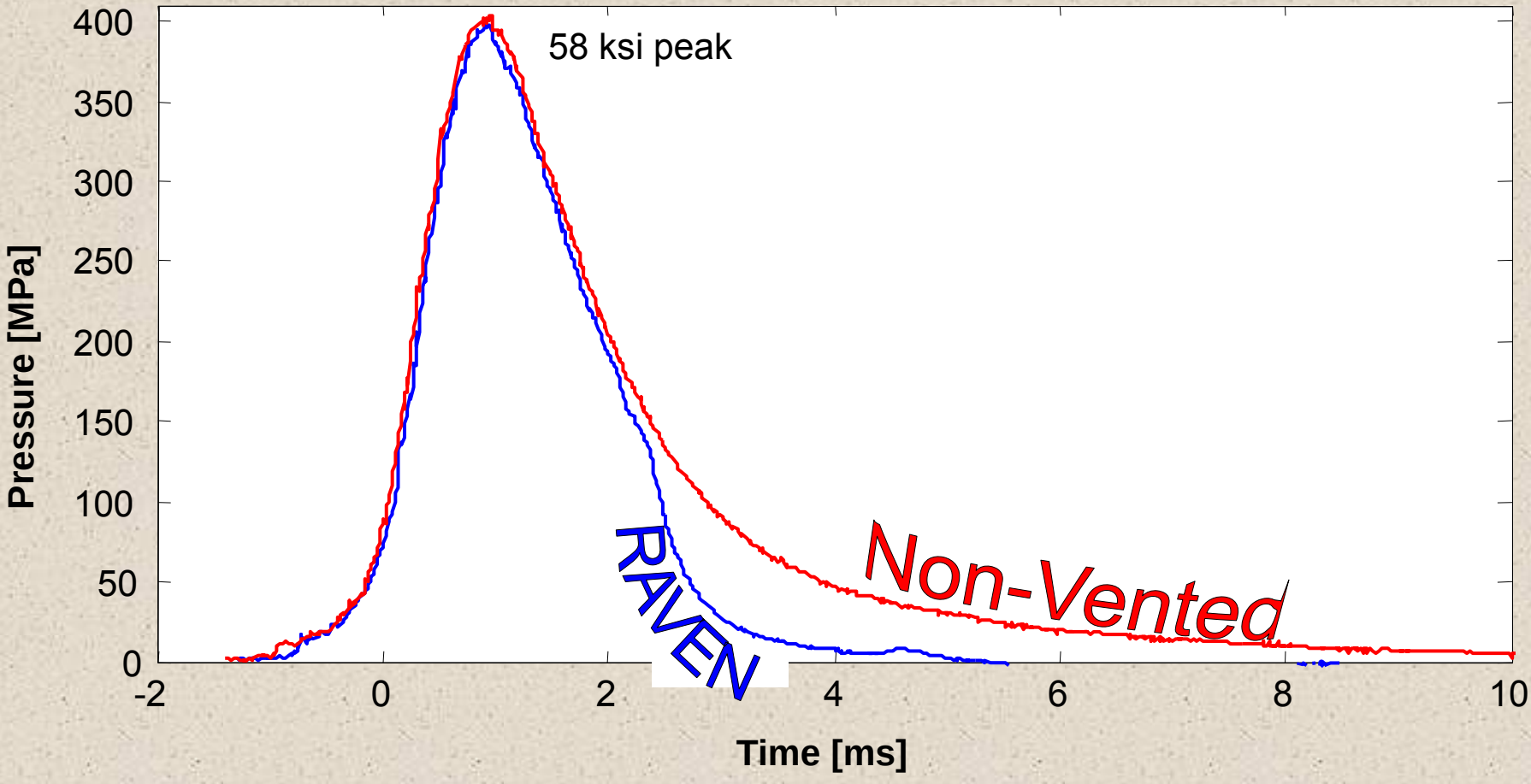


Accomplishments – 35mm Demonstrator

- Proof-of-principle tests
  - Synchronized & pre-synchronous venting (60 shots)
    - Maintained muzzle velocity when synchronized
    - Recoilless when pre-synchronous
    - Significant reductions in
      - Barrel heating
      - Recoil momentum
  - Experimental results

Measurement	Units	Closed Breech Baseline	RAVEN Results	% of CB Baseline
Muzzle Velocity	m/s	1,135	1,131	100%
Barrel Heating (ΔT)	K	3.61	2.13	59%
Momentum	N-s	1,031	402	39%

Accomplishments – 35mm Demonstrator



Chamber Pressure Data

Vented and Non-vented Rounds w/ Same Muzzle Velocity

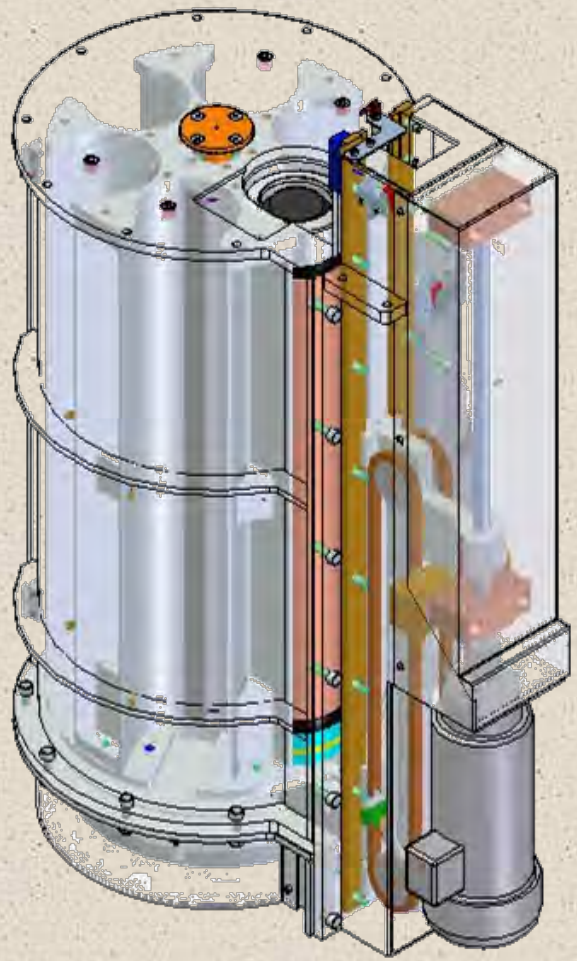
Accomplishments – 105mm Demonstrator

- Design
  - FCS_MRAAS 105mm smooth bore swing chamber cannon
- Vent method
  - Bolt face nose, integrated blow-back bolt, and exhaust nozzle
    - Impulse acts on bolt face
    - Combined inertia of bolt and exhaust nozzle delay venting
  - Timing
    - Governed by mass of inertial breech and required travel distance of bolt face seal to vent



Accomplishments – 105mm Demonstrator

- Ammunition Handling System
  - Design
    - Based on 75mm XM274 autoloader
  - Vertical carousel
    - 6 rounds
    - Rotary motor driven Geneva indexing mechanism
  - Feeder
    - Ball screw driven
  - Rate of fire
    - 15-20 shots/min (targeted range)
    - 17 shots/min (designed)



Accomplishments – 105mm Demonstrator

- Firing tests
  - Synchronized & pre-synchronous vent (14 shots)

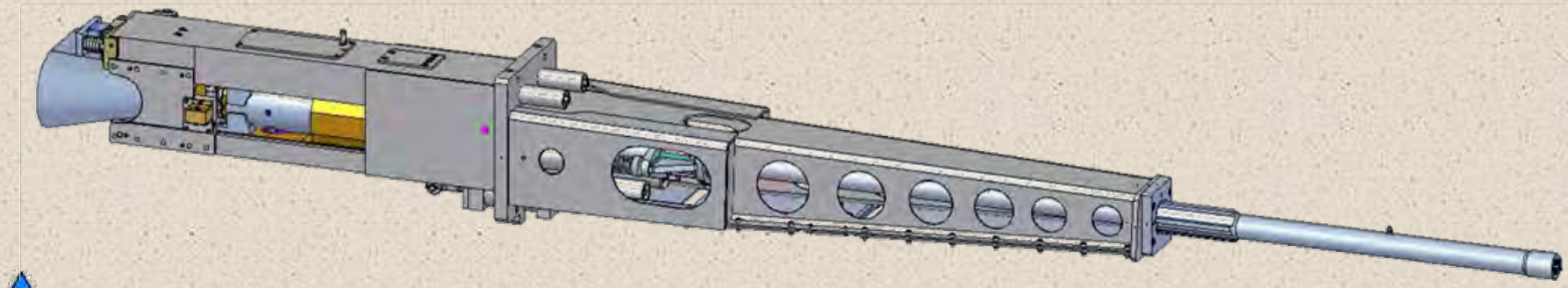


  - Experimental results

Measurement	Units	RAVEN Results	
		Predicted	Actual
Muzzle Velocity	km/s	1.49	1.37
Momentum	kN-s	14.0	12.7

Accomplishments – 45mm Demonstrator

- Design
  - 45mm COMVAT automatic CTA cannon
- Venting Method
  - Ammunition rupture disk
    - Consumable exhaust throat
  - Inertial bolt with brake
    - Controls vent displacement over time
  - Timing
    - Governed by material properties and geometry of rupture disk and bolt mass



Accomplishments – 45mm Demonstrator

- Ammunition development
  - Converted from percussion primer
  - Challenges
    - Integrating electric ignition train into cartridge
    - Maintaining high pressure seals



45mm RAVEN Cartridge

Accomplishments – 45mm Demonstrator

- Firing tests
  - Closed breech baseline (21 shots)
  - Pre-synchronous vented recoilless (4 shots)
    - Unimpeded baseline vent, bolt brake not included
    - Impeded vent, bolt brake included
  - Experimental Results

Measurement	Units	Closed Breech (CB) Baseline	RAVEN (no brake)	% of CB Baseline	RAVEN (w/ brake)	% of CB Baseline
Muzzle Velocity	ft/s	3,636	2,326	64%	2,837	78%
Chamber Pressure	ksi	54	45	83%	49	91%
Barrel Heating (ΔT)	°F	79	21	27%	37	47%
Recoil Travel	in	3.49	0.10	3%	0.16	5%

RAVEN Program – Objectives

- Demonstrate RAVEN Propulsion Objectives
  - Reduce recoil impulse, thermal loads, and system weight
  - Maintain ballistic efficiency and velocity for synchronized venting
  - Demonstrate repeatability
    - Accurate vent timing predictability
- Model validation
  - Confirm interior ballistic performance
  - Verify heat transfer predictions
  - Verify gas discharge behavior
- Integrate RAVEN into lightweight vehicle platform
- Demonstrate minimum impact on vehicle dynamics
  - Vehicle movement

RAVEN Program – Task Schedule

Jun-Aug 2010

Synchronization Tests

- 45mm & 105mm
  - Fire single shots
  - Achieve synchronized vent

Sep-Dec 2010

Development Tests

- 45mm & 105mm
  - Install AHS
  - Demonstrate rapid–fire with RAVEN propulsion

Jan-May 2011

Vehicle Integration

- 45mm & 105mm
  - Build platform modifications
  - Install demonstrators onto lightweight vehicles

Jun-Jul 2011

Vehicle Firing Tests

- 45mm & 105mm
  - Fire single shots
  - Demonstrate vehicle response

RAVEN Program – Collaboration Benefits

- Government: WSEC, ARDEC, RDECOM
  - Obtains knowledge in 21st century weapon systems development
  - Gain access to ARES expertise
    - Case Telescoped Ammunition (CTA) design
    - Transitioning prototype designs to mature firing systems
- Industry: ARES, Inc.
  - Upgrades capabilities
    - Design and analysis
    - Manufacturing
    - Testing
  - Expands personnel and expertise



The Rarefaction Wave Gun Program



Acknowledgements

Dr. Robert Dillon, ARDEC, Science Advisor

Mr. Gary Moshier, ARDEC, 45mm COMVAT System

Mr. Thomas Louzeiro, ARDEC, 105mm CTA

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT, & ENGINEERING CENTER (ARDEC)

Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Technology Trends in Fuze and Munitions Power Sources

May 19th 2010

Mr. Oliver Barham

DISTRIBUTION STATEMENT A.
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RDECOM

Outline

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER
PICATINNY ARSENAL

- ARDEC Fuze Division Introduction
- OSD Joint Fuze Technology Program Introduction
- ARDEC Fuze Capabilities and Technology
  - Micro Electro-Mechanical Systems (MEMS)
  - Proximity Fuzing
  - Electronic Safing and Arming Devices (ESADs)
  - Munition Power Sources

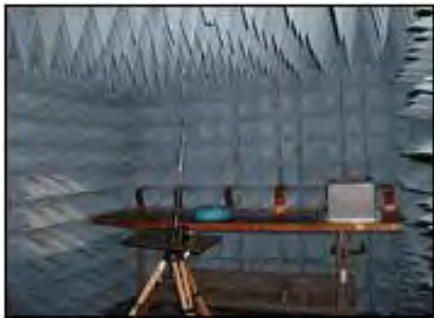
Fuze Division Mission

- Fuze RD&E Life Cycle
  - Fuzes
  - Safe & Arm Devices (Mechanical and Electronic)
  - Related Technologies
    - Advanced Sensors
    - Low Cost, Small, Gun Rugged Electronic and
    - Mechanical Devices (MEMS)
    - Electronic Fuze Setters
  - E3 Munition Assessments
  - Munitions Power Sources
- National and International Fuze Related Committees
- Army Fuze Safety Review Board
- DoD + NDIA Fuze Committees

Fuze Division Facilities

- Picatinny Arsenal, NJ
  - Building A (temporary)
    - Office Space for ~70 employees
  - Building B
    - Electronics Laboratory
  - Building C
    - Fuze Development Center
  - Building D
    - Electromagnetic Environmental Effects Test and Evaluation Laboratory
- Co-located with ARL Adelphi Lab Center, MD
  - Office space for ~45 employees
  - Lab facilities
    - RF Proximity, electronic mechanical
    - Prototype machine shop







BRAC Consolidation at Picatinny with $17M state -of- the- art facilities construction

Joint Fuze Technology Program (JFTP)

- **JFTP is an OSD funded 6.2/6.3 national program established (FY10 start) to develop and mature technologies for improving future fuzing performance, survivability, and reliability.**
- **JFTP governance and process is modeled after the Joint Munitions Program (JMP) and the Joint Insensitive Munitions Technology Program (JIMTP).**
- **Program will leverage and be synergistic with projects in JMP, JIMTP and individual Service S&T Programs**

Joint Fuze Technology Program (JFTP)

OUSD(AT&L)/ PSA/LW&M

Technical Advisory Committee

JOINT FUZE TECH PANEL OVERSIGHT COMMITTEE

PROGRAM MANAGERS
Charles Kelly, Lawrence Fan, Phil Gorman, Tim Tobik

FUZE AREA TECHNOLOGY GROUPS

FATGI – Hard Target / Survivable Fuzing	**FATGII – Tailorable Effects**	**FATGIII – High Reliability Fuzing**	**FATGIV – Enabling Fuze Technologies**
Chair Dr. Howard White (AF)	Chair Gene Henderson (Army)	Chair John Hendershot (Navy)	Chair Chris Janow (Army)
Co-Chairs John Kandell (Navy) Danny Hayles (DTRA) Bill Konick (Army)	Co-Chairs Daniel Lanterman (Navy) Dr. Eric Welle (AF)	Co-Chairs Steve Smith (AF) Tom Crowley (Army) Danny Hayles (DTRA)	Co-Chairs Matt Bridge (AF) Bruce Hornberger (Navy)
SME Participants	SME Participants	SME Participants	SME Participants

Fuze Area Technology Groups

FATG I – Hard Target / Survivable Fuzing	FATG II – Tailorable Effects	FATG III – High Reliability Fuzing	FATG IV – Enabling Fuze Technologies
1.1 Improved M&S 1.2 Fuze Environment 1.3 Next Generation Fuzing Hardware	2.1 Initiation and multi-point technologies 2.2 ESAD Based Multi-point Initiators 2.3 MEMS Based Multi-point Initiators 2.4 Smart Fuzing: Algorithms, fuzing timing and control	3.1 Fuzing Architecture 3.2 Fuzing Components 3.3 UXO reduction features	4.1 Common / Modular Fuze Architecture 4.2 Components Technologies 4.3 Proximity Sensors 4.4 Weapons Effects & Damage Assessment 4.5 Fuzing Power Sources

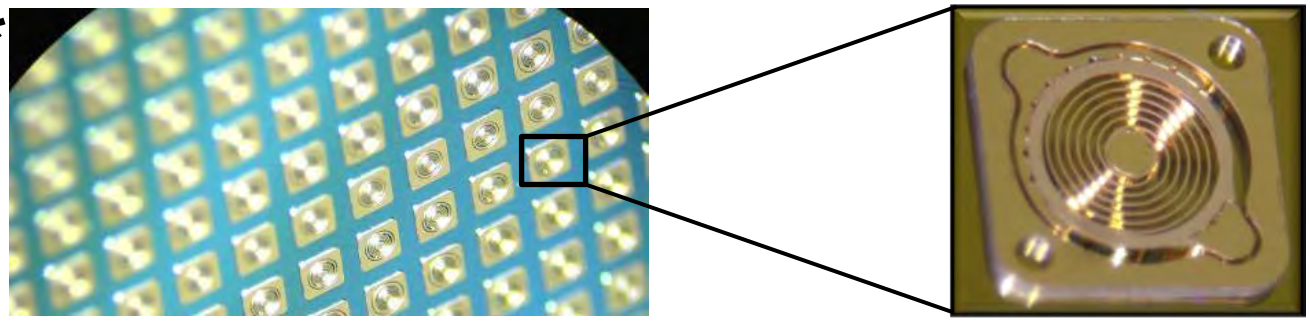
Micro Electro-Mechanical Systems (MEMS)

ARDEC S&T Investment: MEMS

2002-2008 S&T Development:

- High-aspect ratio (HAR) *metal* MEMS fabrication*
- MEMS omnidirectional g-switch*
- MEMS S&A and Micro-Scale Firetrain (MSF)
- Explosive inks and direct-write loading of MSF
- Electromagnetic and piezoelectric setback generators

*



40mm HEDP MEMS Program Description

Implement MEMS mechanical S&A device and direct-write explosive ink loading technology to improve the fuzing system & explosive train of the M433 & M430 40mm HEDP cartridges

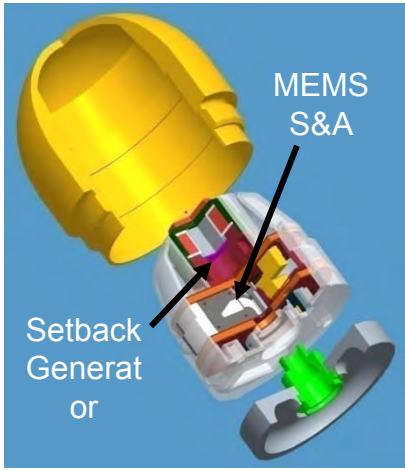
MEMS = micro-electro-mechanical systems

HEDP = high-explosive, dual-purpose



M430

- New fuze architecture
- Electronic initiation vs. stab detonator
- Command-arm-enable
- Self-destruct capability (reduce UXO)
- More accurate arming distance
- Improved reliability on soft targets & graze
  - MEMS G-switch array
- Drop-in replacement for current fuzes



Program Objectives:

- Demonstrate 40mm MEMS fuze, May 2010
- Fuze & cartridge integration and test, FY10-11
- Cartridge Qualification and TDP, FY12-13

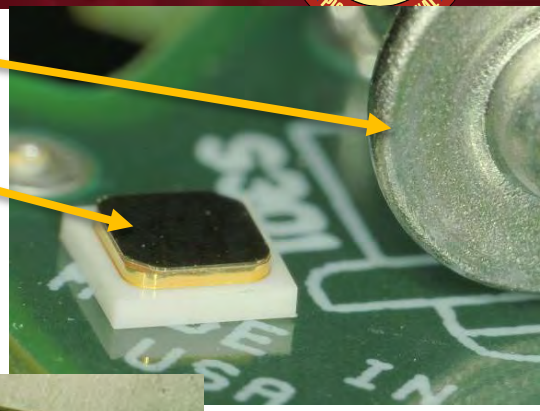


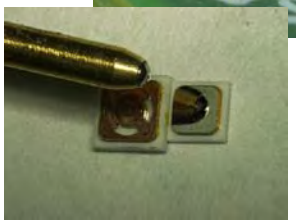
Mk19

RDECOM

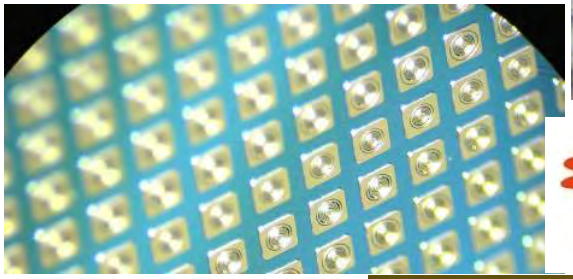
MEMS G-Switch (Impact Sensor)

- MEMS Inertial Sensor
  - Surface-mount to standard PCB
  - All metal on ceramic substrate
  - Packaged at the wafer level with hermetic bonds
- Normally-open switch
  - 95% volume reduction from “Lucey” switch
  - Omni-directional sensitivity
    - Independent directional contacts, ±x, ±y, ±z
    - Independent radial spin sensitivity
    - Setback soft/hard impact, spin, graze
    - Robust in overshock
  - 50- to 10,000-Gs range thresholds
  - Tested to 45-kGs at BP, 75-kG at ATK
- Potential for transition to multiple programs
- Customer Interest:
  - ATK, 3800 ea. for XM25,30mm STAR ATO
  - ARDEC 900 ea., MK19 HEPD 40mm- M918

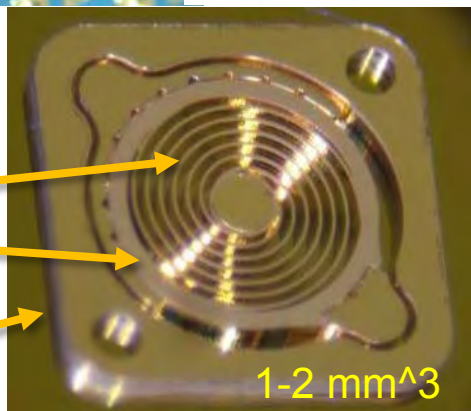








htmicro



40mm MEMS DEMO – May 2010



Metal MEMS Device Application Trends

Large- & Med-Cal S&A and Micro-scale Firetrain Integrations

- 105mm and 155mm, ARDEC Fuze & Power ATO
- 50mm, Enhanced Area Protection System
- 40mm, 40mm MEMS Fuze
- 30mm, STAR (scalable technology for adaptive response) ATO
- 25mm

Non-spin S&A Applications

- Hand Grenade, replace M228 fuze
- 50mm, Enhanced Area Protection System

Inertial Mechanical Switches

- Omnidirectional g-switch
- High-current uni-axial g-switch
- Integrating g-switch

New Platforms

- AFRL Cyborg moth project
- Other lightweight/small platform integrations

Proximity Fuzing Technology

JFTP Next Generation Proximity Effort



- Develop a next-generation low cost sensor technology with:
  - Enhanced battlefield performance
  - Improved Electronic Counter-Measure (ECM) resistance
  - Better immunity to reverse engineering

- Use a tri-service Integrated Product Team (IPT) to select the best technology for a wide array of applications
  - Adaptable for a wide array of systems and target types
  - Software defined Height of Burst (HoB)

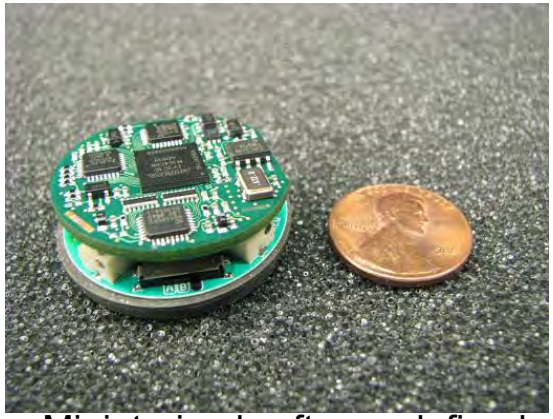




- Address concerns of the DoD Fuze IPT and Project Manager Combat Ammunition Systems (PM CAS) regarding the existing state of proximity sensor technology

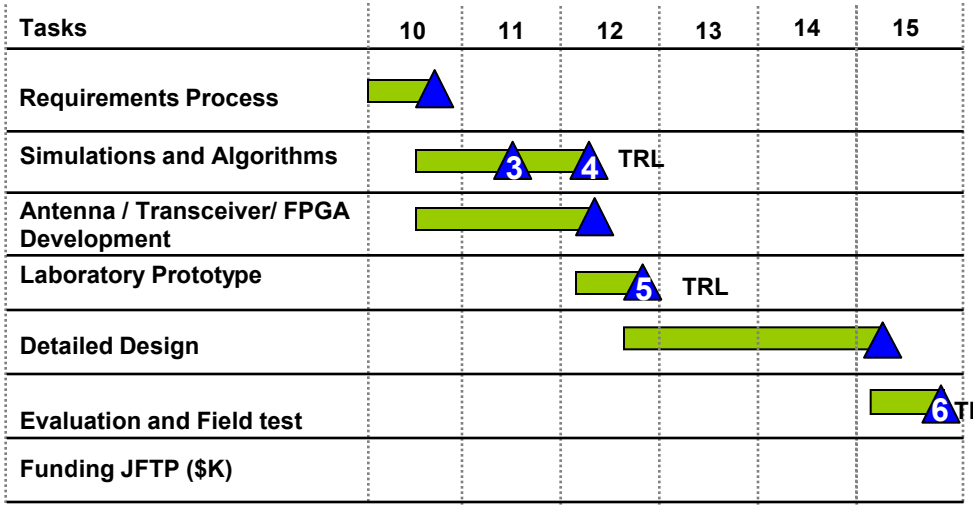
- Maintain the US lead in proximity sensor technology

JFTP Next Generation Proximity Effort



Miniaturized software defined proximity sensor

Technology Investment Schedule (FY)



Objective

This program addresses the Department of Defense (DoD) need to develop a next-generation proximity fuze technology to replace the current Frequency Modulated Continuous Wave - Directional Doppler Ratio Ranging (FMCW-DDR) proximity sensors.

Current Year Milestones

- *M1: Joint Proximity Sensor Requirements*
- *M2: QFD Technology Down Select*
- *M3: Refined Task Allocations*
- *M4: Frequency Allocation*

Technical Approach

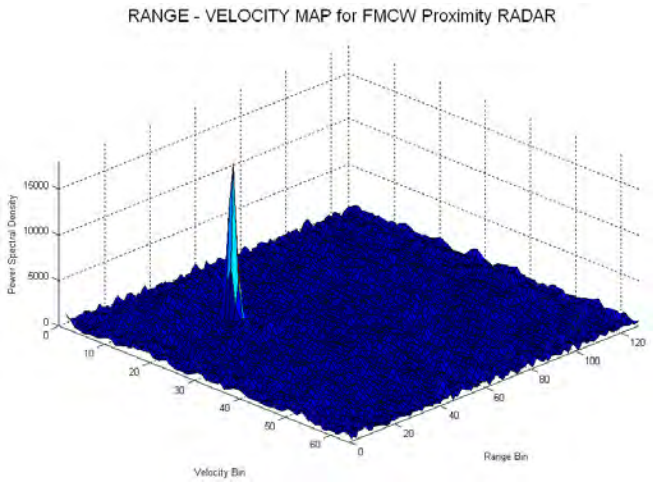
- *Tri-Service IPT down select to highest payoff technology approach*
- *Advanced antennae, transceivers, and signal processing algorithms capable of frequency agility*
- *Low cost anti-tamper techniques for improved reverse engineering protection*
- *Software defined proximity sensors with selectable standoff and improved electronic countermeasure protection*

Leveraging and Transition Opportunity

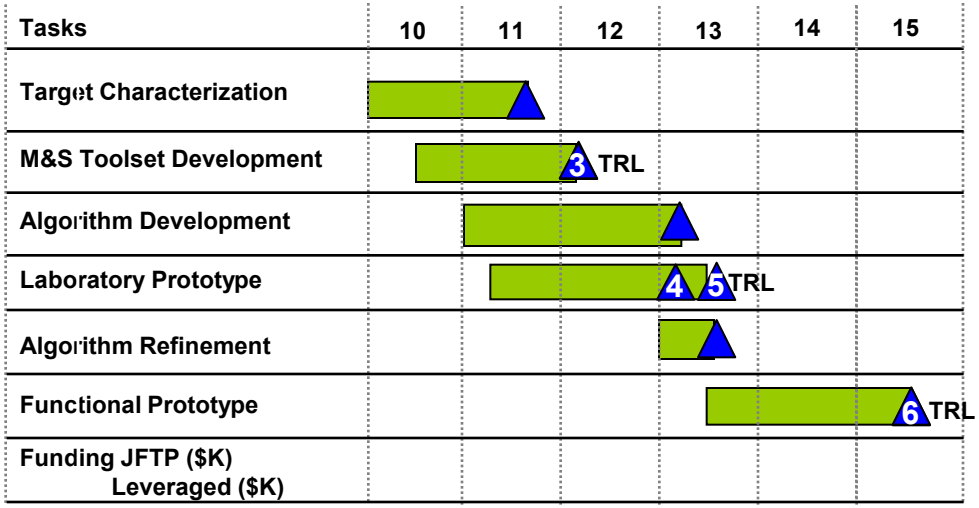
- *Technology leveraging from Fuze and Power Army Technology Objective Program*
- *Endorsed by Project Manager for Conventional Ammunition systems (PM CAS)*
- *Potential insertion into XM1156 Precision Guidance Kit (PGK), M782 Multi-Option Fuze for Artillery (MOFA), M734A1 Multi-Option Fuze for Mortars (MOFM)*

TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**

Prox. Sensor for Tailorable Warheads



Technology Investment Schedule (FY)



Objective

- Develop a sensor system to crudely identify primary features of different target scenes in the end-game encounter
- Provide information to make smart decisions on "how" and "when" to initiate tailorable warheads

Current Year Milestones

- M1: Target Set Selection – Mar10
- M2: Fuze Sensor Data Acquisition System –Jun10
- M3: Baseline Simulation toolset – Oct10

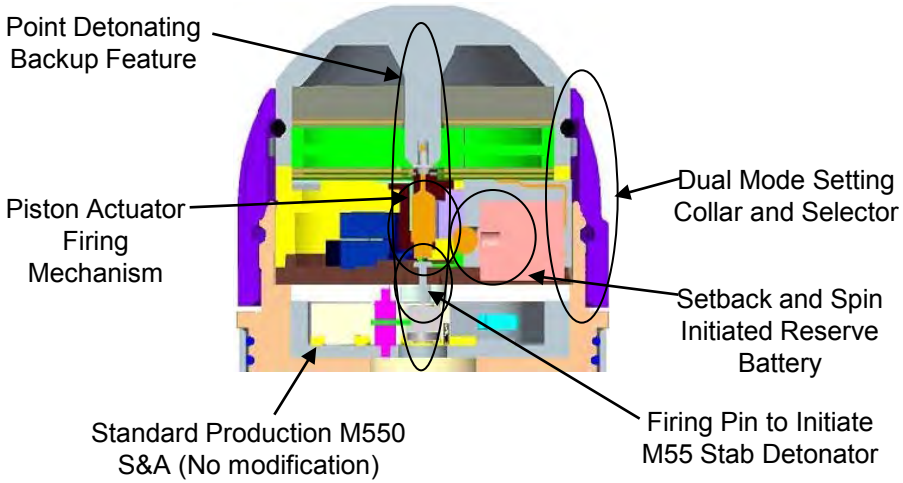
Technical Approach

- Development and validation of M&S toolset to aid in the design of signal processing techniques capable of producing end-game target classification data and accurate standoff measurements
- Design of miniaturized low noise analog, digital, and RF sensor circuitry
- Implementation of advanced DSP algorithms in commercial FPGA/DSP devices

Leveraging and Transition Opportunity

- 105mm Precision Munition (PEO Ammunition)
- Very Affordable Precision Projectile (VAPP)
- Scalable Technology for Adaptive Response ATO
- Sensor, Warhead and fuze Technology Integrated for Combined Effects ATO
- Mortar & Artillery Proximity Fuzes (PM Conventional Ammunition Systems)

Airburst Non-Lethal Munition (ANLM)



- Airburst Non-Lethal Munition (ANLM) is a non-lethal low velocity 40mm grenade fully compatible with existing M203/M320 weapon platforms.
- User settable fuze – two modes: 5m proximity and 5m proximity with delay (room clearing).
- Ability to employ non-lethal effects lasting up to 30 seconds, in a complementary non-lethal manner to enhance combined- arms battlefield effectiveness by minimizing mass physical destruction of people, materiel, infrastructure, and the environment.
- Allow tactical commander the option to tailor a response to situations when a lethal response in not the best option.

30mm Apache Gun System Prox. Fuze

Problem:

M789 HEDP round utilizes an impact mechanism that does not function fast enough when fired at personnel targets in soft or sandy soils. Most of the warhead fragments are absorbed by the ground.

Objective:

Develop a proximity sensor capability confined with the M759 fuze envelope utilizing the existing S&A.

POC: David Errera/Steve Stephey, ARDEC Fuze Division

User/Customer: PM-MAS

Benefits to the Warfighter:

Improve effectiveness of 30mm Apache gun system against personnel targets.

Tasks (FY10/11)

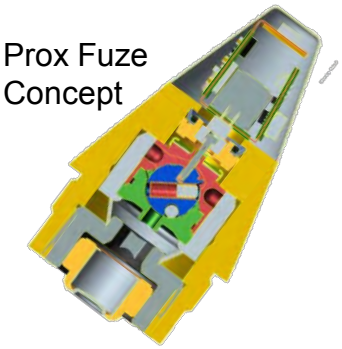
- Evaluate prox sensor using TM projectile.
- Continue tactical fuze design & integration
- Award ATK support contract
- Identify/develop custom components
- Fab, assemble, test sub-assy & demo hardware
- Conduct 30mm demo test

Schedule (FY10/11)





M789 HEDP 30mm round with M759 Fuze

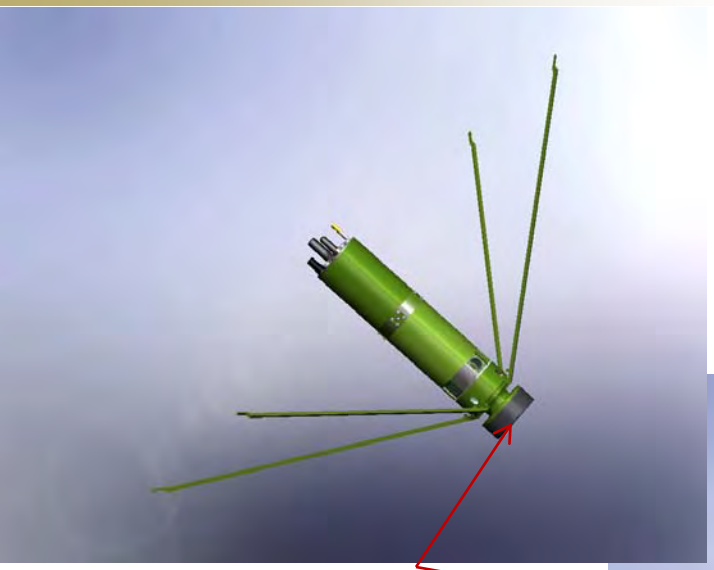


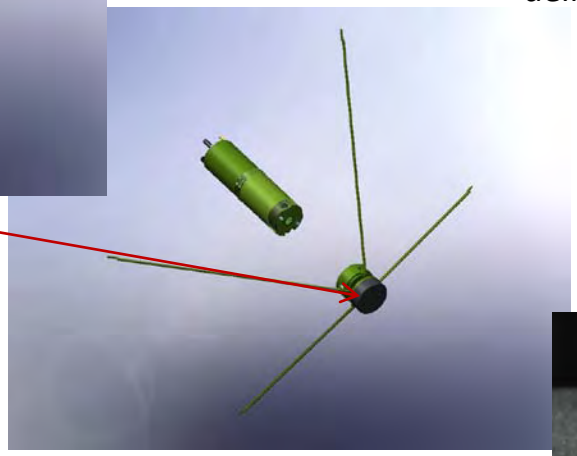
Prox Fuze Concept

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RDECOM

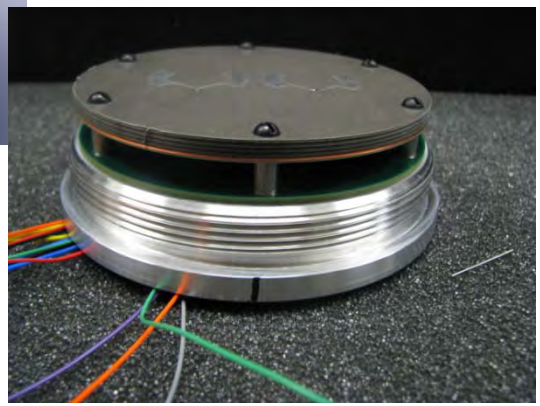
ORIOLE Medium Altitude Prox. Sensor





Location of
Proximity Sensor

Nominal Standoff: 150m
Accuracy: +/- 20%
Target Type: HoB on Dense Tree Canopy
-Software defined proximity sensor using commercially available devices
-Sensor output used to deploy parachute for soft delivery of the ORIOLE system



Customer: Army Research Laboratory

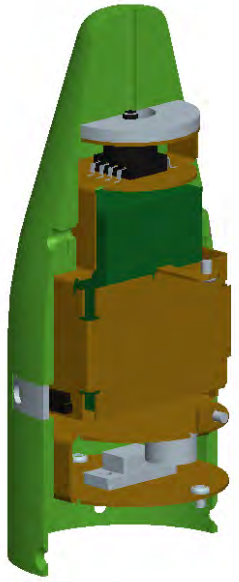
Designed, Fabricated, and Characterized in house at ARDEC

Prox. Sensors for UAVs

ARDEC is designing and building proximity hardware for a variety of UAVs and UAV munitions









Electronic Safing and Arming Devices (ESADs)

RDECOM

Electronic Safing and Arming Devices



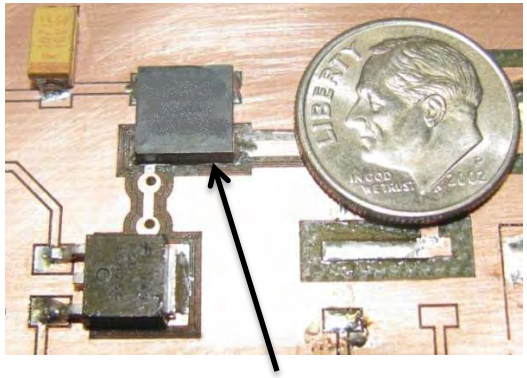




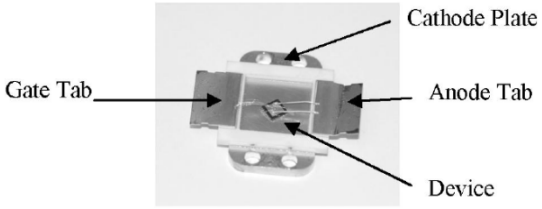
- All Electrical
- No moving parts
- No primary explosives
- High current / voltage devices
- High reliability
- High cost
- Example applications: Rockets, Missiles, Recoverable UAVs

Proposed ESAD Cost/Size Reduction

- JFTP Proposed Program
- Model and analyze transformer loading during setback events. Develop test fixturing to provide alternate mounting configurations for transformers. Develop underfill and assembly methods for mounting transformers to allow survival of artillery setback and prevent the failure of its brittle materials.
- Incorporate SiC switches from multiple manufacturers into ESAD firesets. Work with manufacturers to reduce packaged size for ESADs.
- Low Energy Exploding Foil Initiators (LEEFI) bridge substrates to be developed leveraging previous initiator work. Strict process control to minimize variation of bridge structures is necessary to maintain consistent initiation times



Transformer



ARL SiC Device

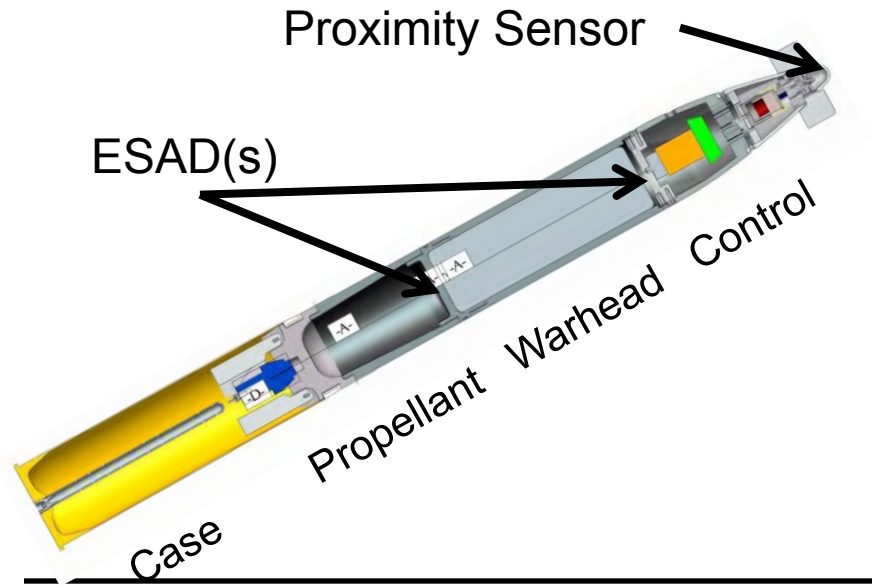
ESAD: Non-Proximity Application

- ARDEC is designing and building ESADs for UAV applications, and others that do not employ proximity sensors





ESAD: STAR ATO 105mm Fuze Development



METC/ARDEC In-House Effort

Height of burst sensor
- System Design
- Schematic Capture / Physical Layout
- Algorithm Architectures
- Firmware Implementations

ESADs
- Safety System Development
- ESAD Laboratory Prototypes
- Firmware Development
- Fireset Design/Development
- Environmental Sensors (Setback Switch / Spin Switches)

Description:

-One of three thrust efforts under STAR ATO
-Increased lethality for Precision 105 mm (VAPP) while minimizing collateral damage
-Efficient thermal battery for Fuze and GNC
-Innovative warhead initiation schemes
-Hardened fuze for penetration
-Optimized HOB sensor for precision engagement

Customer: PM CAS

Requirements: TRADOC PAM 525-66: FOC 05-01, 05-02, 09-01; CNA 08-13 Future Force Capability Gaps Analysis for lethality overmatch; Future Force O&O and FCS ORD

Funding Source: (ASA(ALT)) Core

POC: C. Sanchez, 973-724-5495, camilo.sanchez@us.army.mil

Contracted/OGA Efforts

Electronic Development Corporation (EDC)
- ESAD prototyping
- Electronics integration

U of Florida – Electronics Communications Lab (ECL)
- HOB Sensor Algorithm Support
- HOB Modeling & Simulation

L3-Fuze Ordnance Systems (L3-FOS)
- Setback Sensor Development

ARL - Adelphi, MD
- Environmental Testing

ARL - Blossom Point, MD
- Field Test Support

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

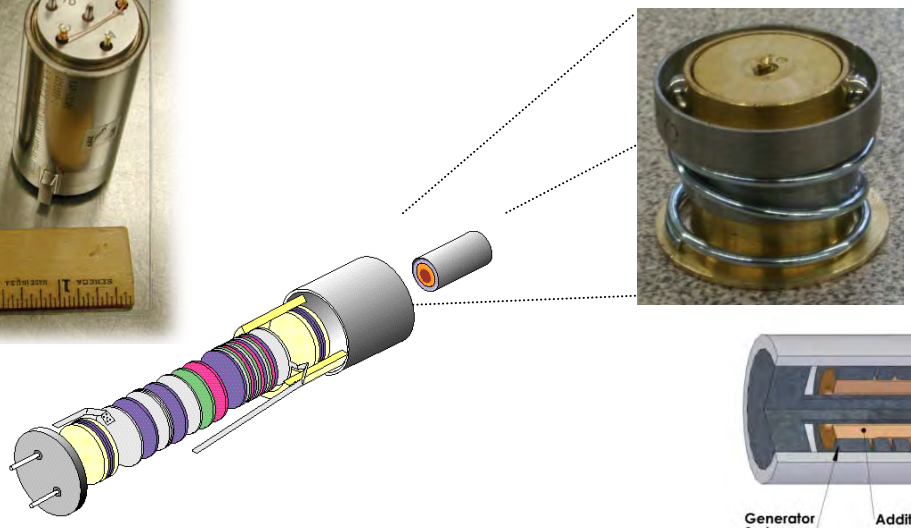
Munitions Power Sources

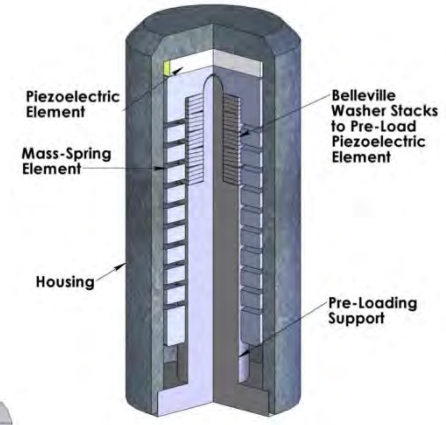
Munitions Power Sources

Objective:

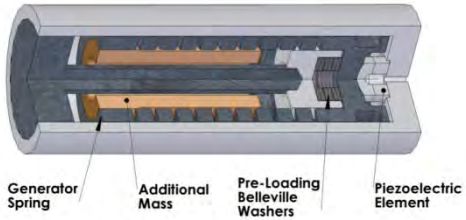
To develop advanced, affordable, on-board gun-fired munitions power source technologies with increased energy and power densities, reduced volume and weight, increased mission time & improved extreme temperature performance for a portfolio of munitions.







Axial Piezoelectric Harvesters

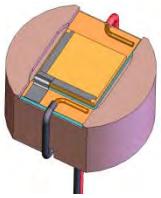


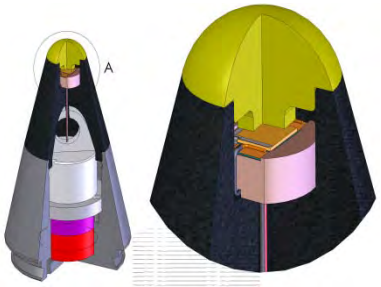
Lateral Piezoelectric Harvesters

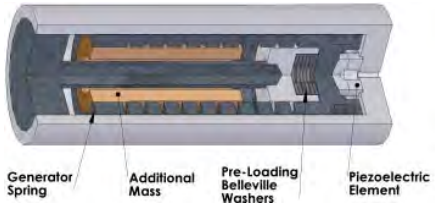
Munitions Power Sources

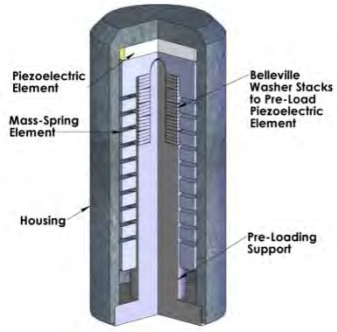
Hybrid Energy Systems *SBIR and Science & Technology Programs*

- Develop new types of energy harvesters to supplement and reduce the dependence on batteries ("Hybrid Energy Systems")
- Convert and combine energy in various forms that is resident in the ballistic environment of gun fired munitions
- Built & tested various types of energy harvesters, several types of designs to be mounted axially and radially for flight tests
  - Piezo-electric based Energy Harvesters
  - Thermophotovoltaic Power Generation for Supersonic Munitions









Axial Piezoelectric Harvesters

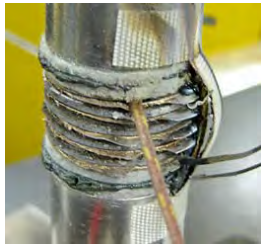
Munitions Power Sources

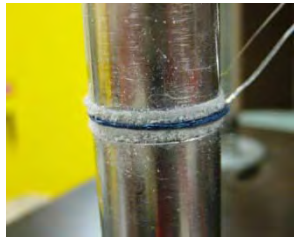
Thermal Battery Technology

- Miniature Ignition Systems *SBIR, Science & Technology Program, Army Commercialization Pilot Program*
  - Develop battery systems with higher energy densities in a smaller volume that meets munitions' performance requirements
  - Increased power source reliability, safety & performance



- Thin Film Thermal Battery Technology *SBIR Program*
  - Manufacture geometrically conformal & high performance thermal batteries to provide a more affordable & producible power source also enabling in a higher energy density
- Nanofoil for Thin Film Thermal Battery *DoD JFTP Program*
  - Develop a thin film heat source, needed to realize the potential of thin film thermal battery





Liquid Reserve Battery Improvements

Problem:

The liquid reserve battery for the M762A1 electronic time (ET) artillery fuze contains a corrosive, moisture sensitive electrolyte that impacts producibility.

Objective:

As a risk reduction effort, develop a producible and affordable liquid reserve battery for the electronic time (ET) artillery fuze that eliminates the corrosive electrolyte, allows a higher production throughput, maintains performance requirements at low temperature and satisfies a 20 year shelf life.

POC: Karen Amabile, ARDEC Fuze Division

User/Customer: PM-CAS/ PEO-AMMO

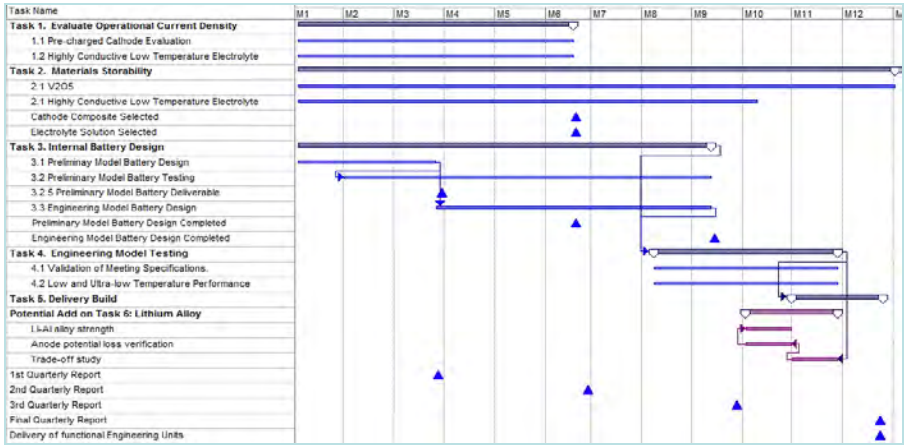
Benefits to the Warfighter:

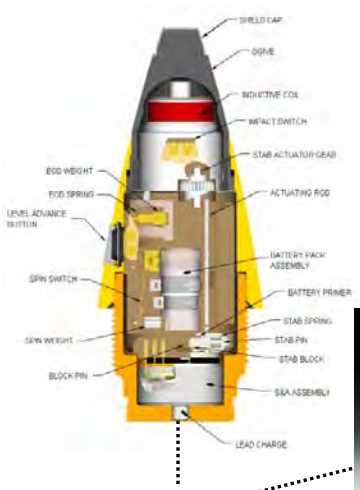
Provides an environmentally friendly and affordable power source for the M762A1 electronic time artillery fuze allowing PEO Ammunition to meet its current production requirements for war reserve quantities as well as future requirements for the M767, M721, M853A1, M816, M819, M930 & M983 mortar rounds.

Tasks (FY10)

- **Optimization of baseline cell ($Li/LiBF_4/\gamma$-BL/DME/V_2O_5)**
- **Component stability**
- **Temperature & performance tests**
- **Build optimized hardware**
- **Deliver hardware**

FY10 Schedule





M762A1 Artillery Fuze



XM785

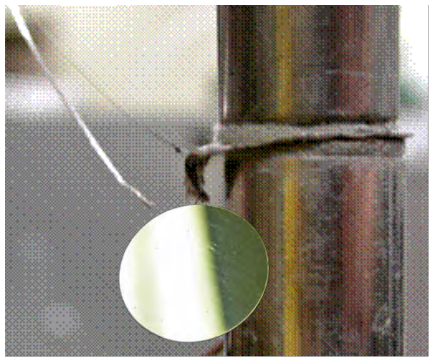


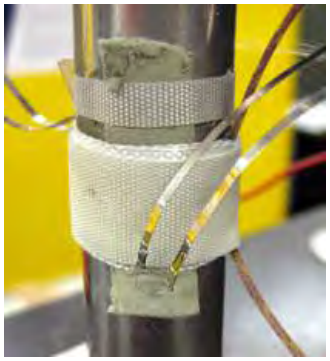


XM784

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

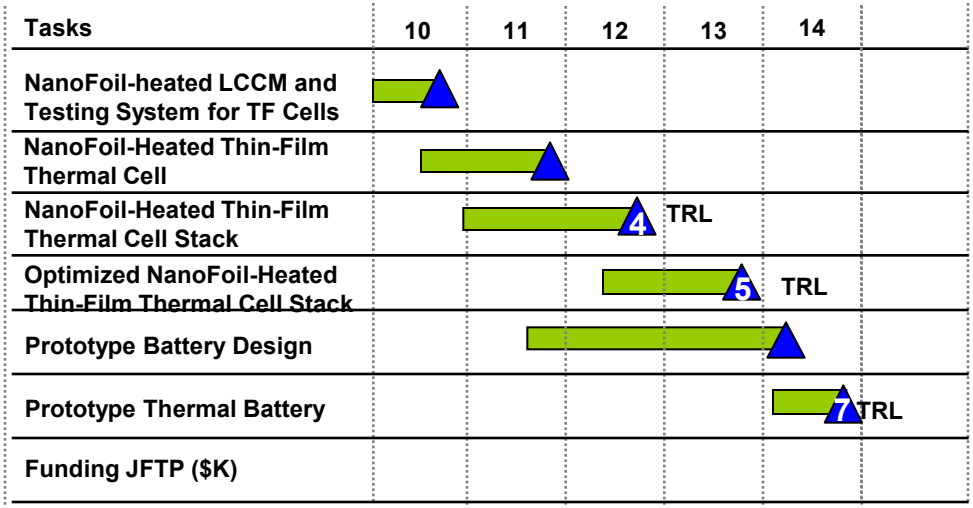
NanoFoil-Heated Thin-Film Battery





A NanoFoil disc for peak temperature test and a NanoFoil-heated pellet-based 4-cell thermal battery stack ready to be initiated and tested

Technology Investment Schedule (FY)



Objective

This project is aimed at producing a prototype NanoFoil-heated thin-film thermal battery made of thin layers of anode, electrolyte, cathode, and heat source components, capable of fast rise, high power and energy, and flexible form factor, and conducive to continuous production.

Current Year Milestones

- *M1: NanoFoil-heated LCCM thermal battery*
- *M2: Test system for thin-film thermal cells and cell stacks*

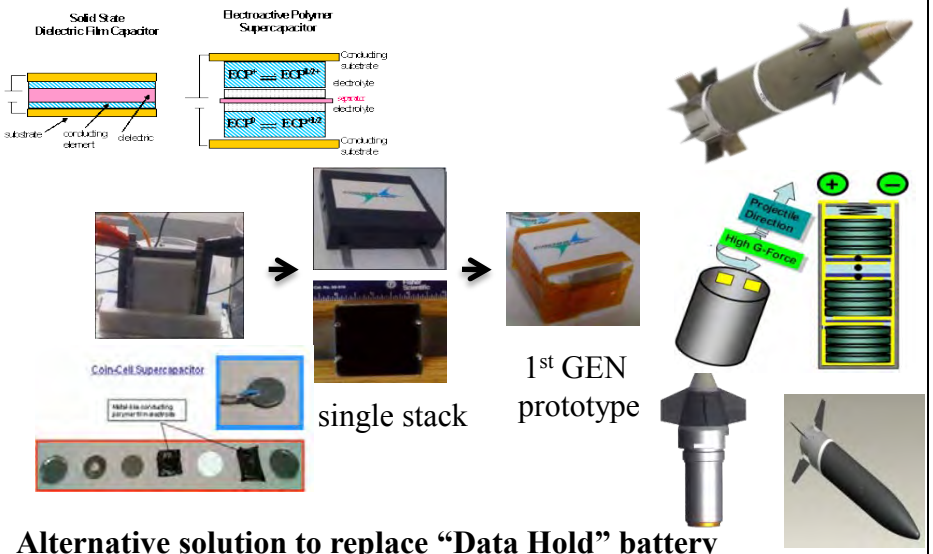
Technical Approach

- *NanoFoil will be used as the heat source layer composed of thousands of alternating layers of aluminum and nickel each only a few dozen nanometers thick, made by physical vapor deposition.*
- *Anode, cathode, and electrolyte layers will be produced by commonly available methods such as spray-coating or tape-dipping.*
- *Fast reaction of NanoFoil in combination with the other thin components leading to a fast-rise, high power and energy, and flexible form factor thermal battery.*

Leveraging and Transition Opportunity

- *Leveraging Sandia National Laboratory's effort on thin-film thermal battery*
- *Leveraging Prior and current ARL-ARDEC efforts on NanoFoil R&D*
- *Leveraging Affordable Precision Components Technology ATO*
- *Potential transition to use in small and medium caliber munitions, artillery and mortar projectiles, rockets, and missiles; the Army's Extended Aerial Protection System; and the Army's PRAXIS; and the Common Smart Sub-munitions Program (CSS)*

Conductive Polymer-Based Super-Cap



Alternative solution to replace "Data Hold" battery

Customer: Potential customer is PEO-AMMO

- Endorsement by OPM-CAS as of Mar 04, 2010
- Transition potentials:
  - Excalibur, PGK, VAPP(155), STAR(105), APMI, VAPM, and other artillery & mortar rounds
  -potential direct-fired rounds

Leverage:

- DoD-JFTP (6.2 and possible 6.3 follow-on)
- Affordable Precision Component ATO
- Others

Objectives

To advance the development of novel supercapacitor device for fast charging time, function over military temperature range, and high energy/power density needed to extend Army's munitions' capability for current and/or new generation of Munitions and Fuzes.

Challenges

Existing COTS supercapacitor exhibit technological shortfall & gaps :

- Functional over a wide temperature range
- Performance in term of charging time, ESR, energy/power density
- Large scale manufacturing and processing of materials as films for cost effective production
- Extended shelf-life (up to 20 years)

Approaches

- Optimize synthesis of conductive material & film by enhanced functionality of the side chains and dopants.
- Process the conductive polymer systems to create fibers/films that allow highly ordered lamellae and sheet-like structure and enhance performance
- Investigate & develop electrolyte with improved ionic conductivity to satisfy extreme temperature performance and 20 years shelf life
- Mature supercapacitor iteratively throughout R&D cycle

Impacts

- Enhance Warfighter mission flexibility by eliminating the needs to expend the projectile after initialization due to re-usage and effectively infinite operating life of this supercapacitor.
- Ensure availability and technological enabler for alternative, reliable, cost-effective, and common used power source to store mission data
- Potential transition to PM offices for next block upgrade and/or product improvement

APO: Hai-Long Nguyen; 973-724-1543; hailong.nguyen@us.army.mil

Power Sources TCG

- **Power Sources Technical Coordinating Group is a new (2010) DoD/DOE group focused on developing power systems technology to improve munitions and transform national capability through collaborative research**
- **The TCG is implemented to support the Joint Munitions Program (JMP), created by Congress, and managed out of the Office of Land Warfare & Munitions, Office of the Under Secretary of Defense, (Acquisition, Technology and Logistics)**

Questions?

Low Volume, Low Power, Low Cost Advanced Guided Bullet and Mortar Flight Control Actuators

Professor Ron Barrett
Director of the Adaptive Aerostructures Laboratory (AAL)
Aerospace Engineering Department
The University of Kansas, Lawrence, Kansas USA

AAL ...Backroom for the Innovation-Driven Aerospace Organizations of the world...

Joint Armaments Conference, Exhibition and Firing Demonstration
Dallas, Texas 19 May 2010

Outline:



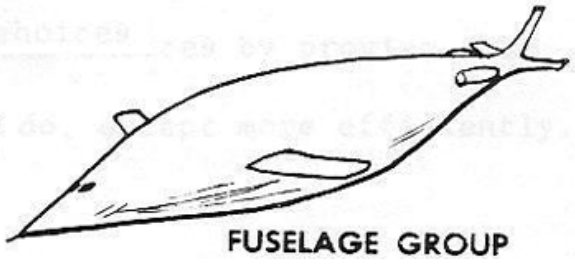
I. Brief Introduction to Adaptive Materials & History

II. New Classes of Adaptive Actuators

III. Summary of Adaptive FCS Properties and Designs

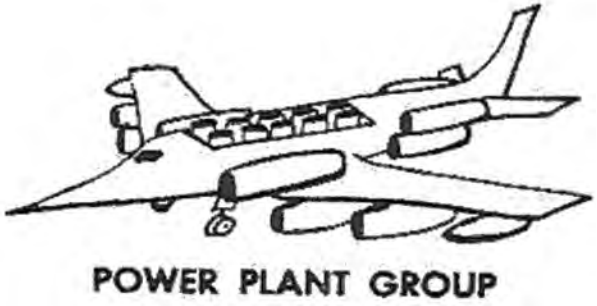
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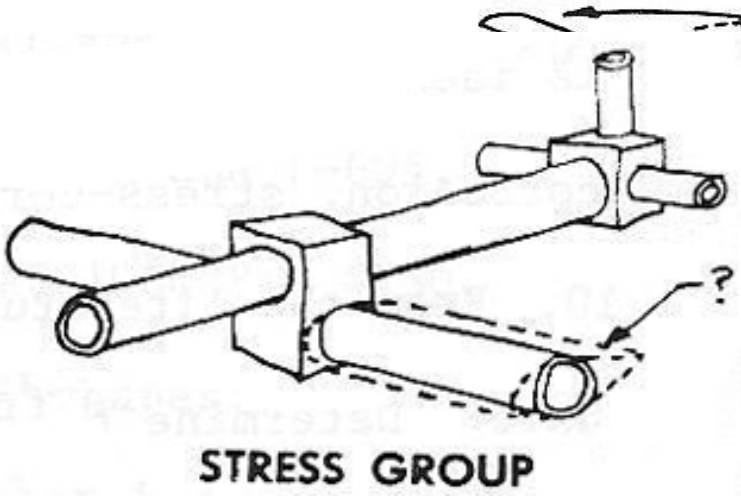
Adaptive Materials

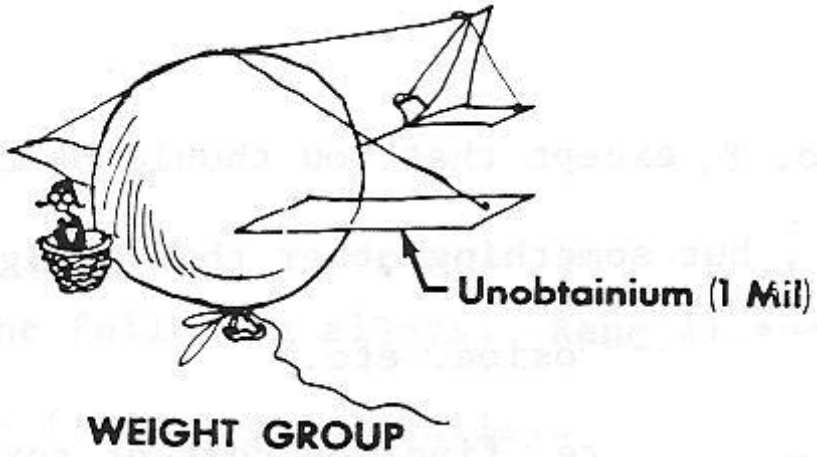


Old Paradigm:

Structural deformations indicate that a given loading state is occurring and must therefore be accommodated.







be comm

used to enha

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Adaptive Aerostructures
A (Very) Brief Introduction



Most Useful Classes of Adaptive Materials:

- **Shape-Memory Alloy -**
  High Deflection, Slow, Lots of Power

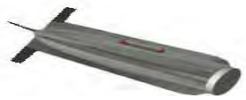


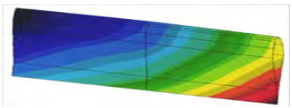
- **Piezoceramics -**
  Very Fast, Low Power

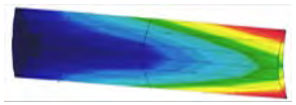
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First 20 years of Programs with Lineage to Flying Adaptive UAVs

		Project	Modeling Technique		Test Techniques			Sponsor
			Closed or CLPT	FEM	Bench	Stand or Tunnel	Flight	
21	'94-95	Aeroservoelastic Flexspar Fin	3	3	3	3		AAL
22	**'95-96**	**Solid State Adaptive Hiller Servopaddle Rotor (Gamara)**	**3**		**3**	**3**	**3**	**NSF**
23	**'94-97**	**Flexspar Micro Aerial Vehicle Stabilator (Kolibri)**	**3**		**3**	**3**	**3**	**DoD CDTO**
24	'95-97	Barrel-Launched Adaptive Munition (BLAM)	3		3	3		AFOSR
25	'95-97	Smart Compressed Reversed Adaptive Munition (SCRAM)	3		3	3		WL/MNAV
26	'95-97	Monolithic Rotationally Active Linear Actuator (RALA)	3		3	3		WL/MNAV/Boeing
27	'97-98	Pitch-Active Torque-Plate Wing	3		3	3		AAL
28	'98-99	Range-Extended Adaptive Munition (REAM)	3		3	3		DARPA
29	'98-00	Hypersonic Interceptor Test Technology (HITT)	3		3	3		SMDC/Schafer
30	**'98-00**	**Coleopter MAV Flexspar Stabilators**	**3**		**3**	**3**	**3**	**DARPA**
31	**'00-01**	**Pitch-Active SMA Wing**	**3**		**3**		**3**	**AAL**
32	'00-01	Light Fighter Lethality Fin MicroFlex Actuator	3		3	3		TACOM/ARDEC
33	'01-02	Pitch-Active Curvilinear Fin Actuator	3		3	3		AMCOM
34	'01-03	Shipborne C'measure Range-Ex. Adaptive Munition (SCREA	3		3	3		TACOM/ARDEC
35	'00-03	Thunder Multilaminate RALA Fin	3		3			WL/MNAV
36	'00-03	Centerline Precompression Multilaminate RALA Fin	3		3			WL/MNAV
37	'02-03	Center Pivot Flexspar Fin	3					ARL
38	**2003-**	**StAB**	**3**	**3**	**3**	**3**	**3**	**TUD/TNO**
39	**2003-**	**Coleopter PBP Grid Fin**	**3**	**3**	**3**	**3**	**3**	**TUD**
40	**2003-**	**Coleopter PBP Turning Vane Flap**	**3**	**3**	**3**	**3**	**3**	**TUD**
41	**2003-**	**Twist-Active Wings for Extended-Range Gravity Weapon**	**3**	**3**	**3**	**3**	**3**	**WL/MNAV/Boeing**

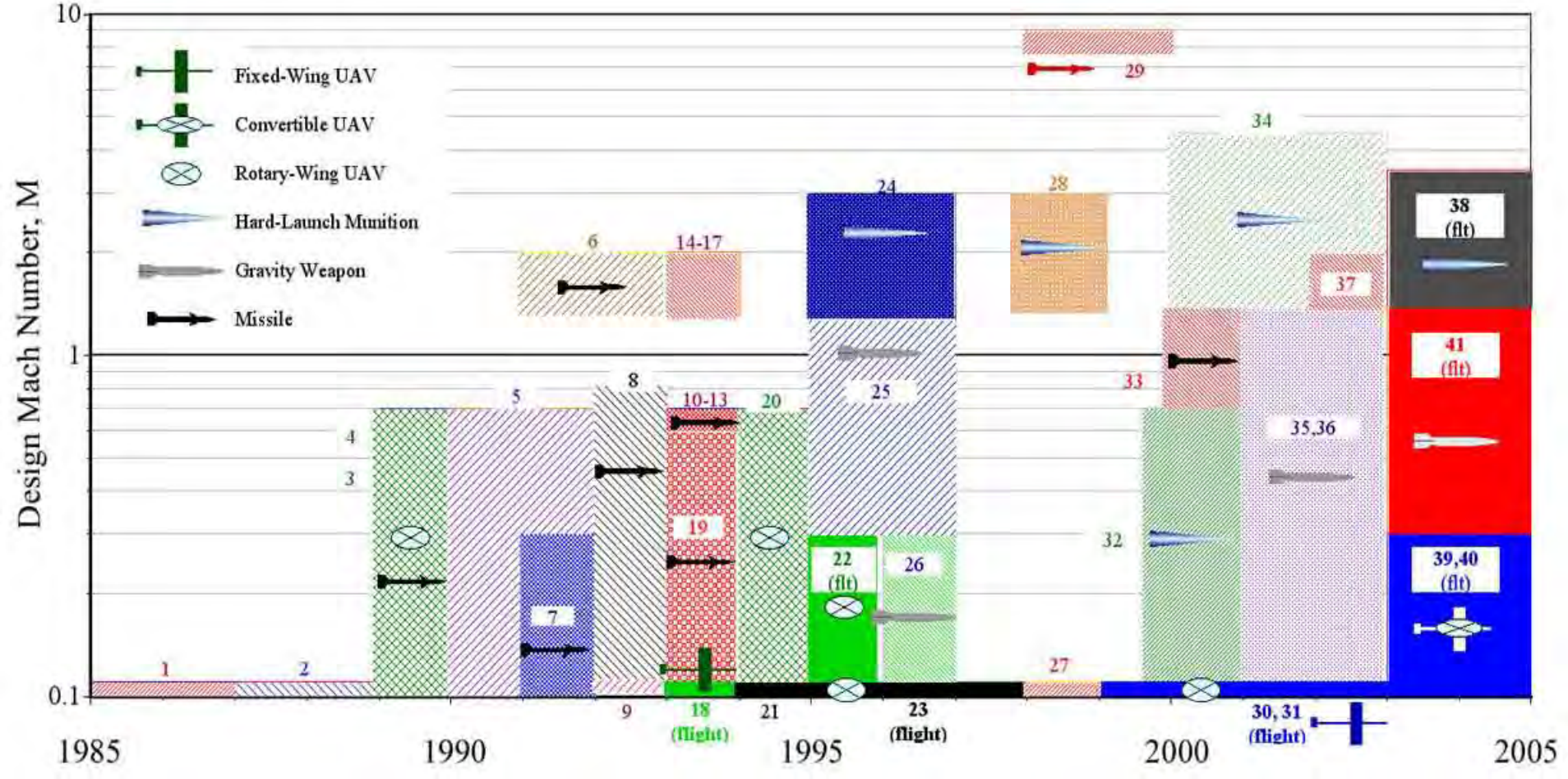








Overview of Programs with Lineage to Flying Adaptive UAVs



R. M. Ba

Brief Guided Round History

M712 Copperhead 1975











XM 982 Excalibur & ERGM

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Guided Round History



What's needed in a low caliber FCS actuator?

What is needed in such a flight control actuator???

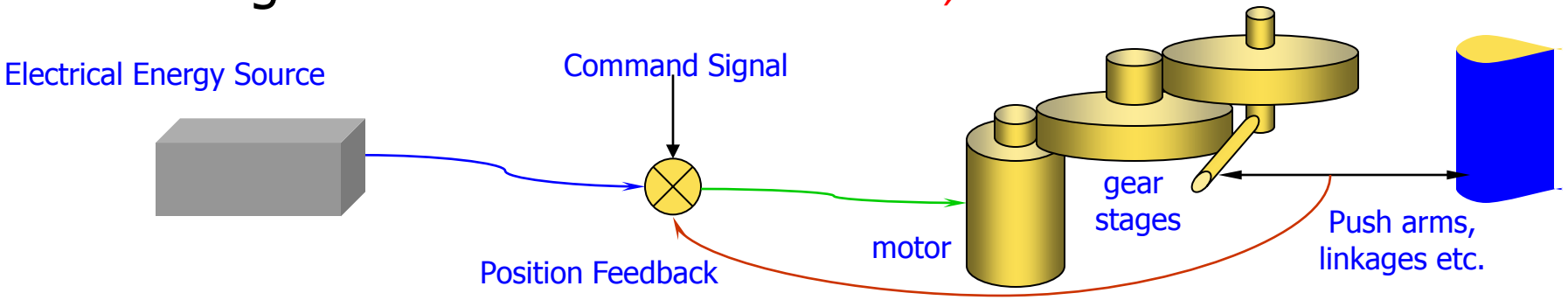
- Setback tolerance: 5,000 - 200,000g's
- Balloting, setforward, ringing impervious
- Compatible with supersonic control effectors
- Not affected by atmospherics (rain, dust, dirt, snow, etc.)
- 20 yr storage life
- -40 to +145° F
- Lightweight (<1g), Low Volume (<1cc), Low Power (10's of mW)
- High bandwidth (>200 Hz)
- Production shipset costs in single dollars... at most

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Flight Control Technologies

Electromagnetic

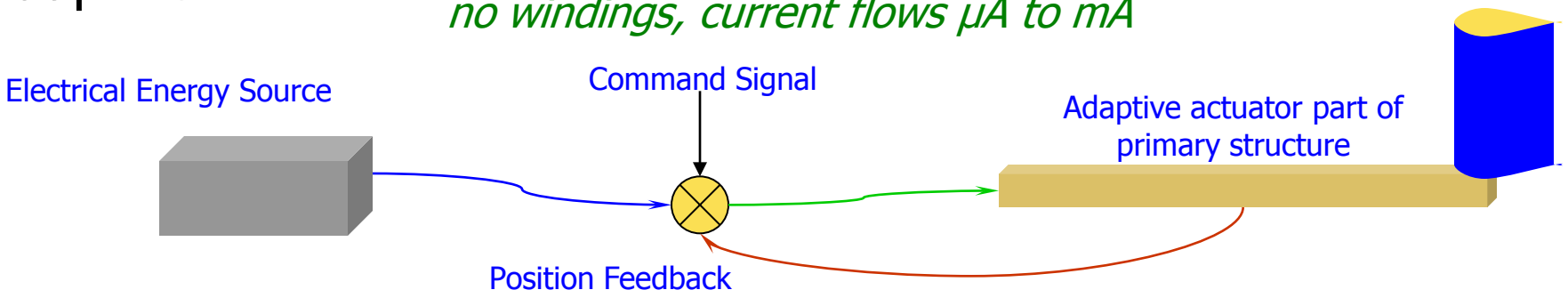
dozens to hundreds of turns, current flows A to 10's of A



Magnetic Field α no. of windings x current

Adaptive

no windings, current flows μA to mA



All information from public sources
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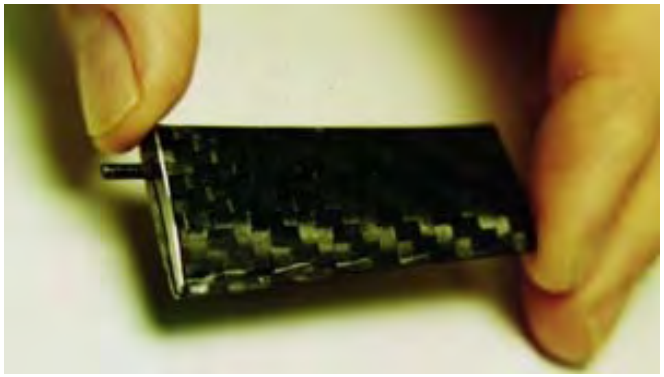
The First MAV… Driving Adaptive FCS

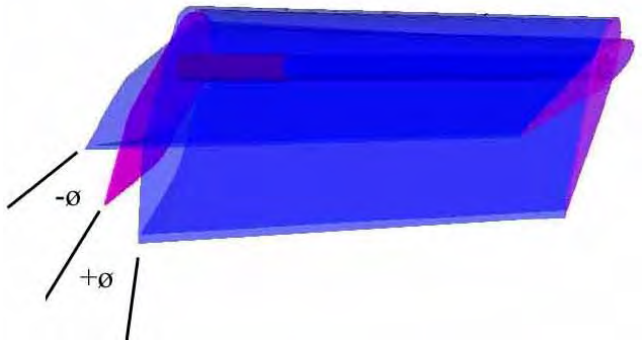
Conventional Electromagnetic



36 components, 830μT @10cm

Adaptive Stabilators





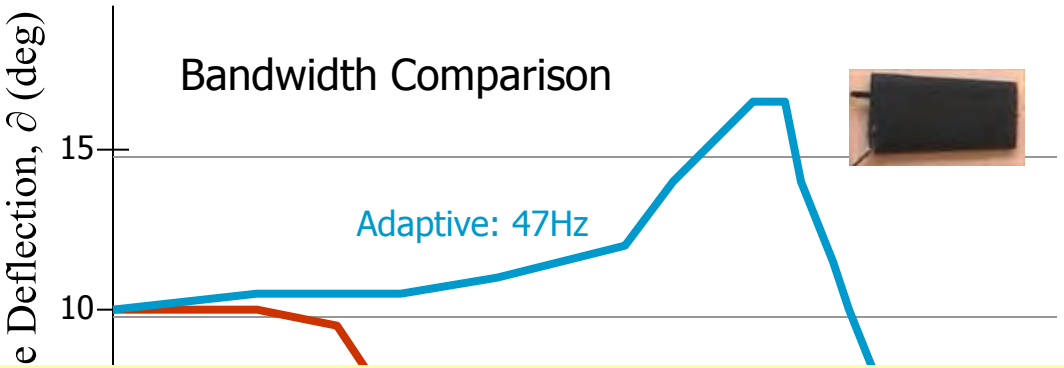
5 components, 0.6μT @10cm

Earth's Magnetic Field: 30 – 60 μT

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Advanced UAVs:

Driving the need for Adaptive Actuators -- faster, lighter, stronger



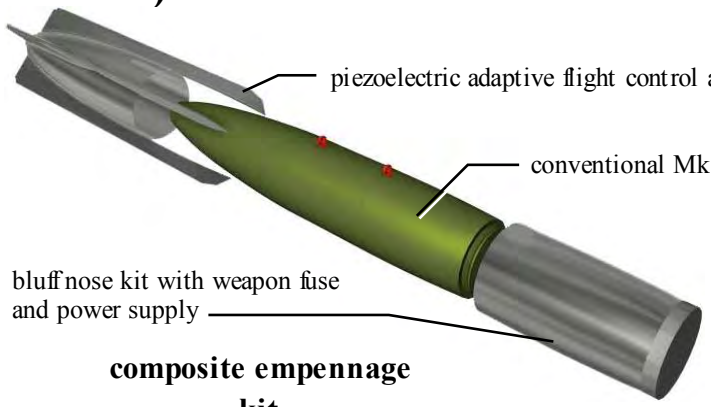
Adaptive Surfaces vs. Conventional Servos

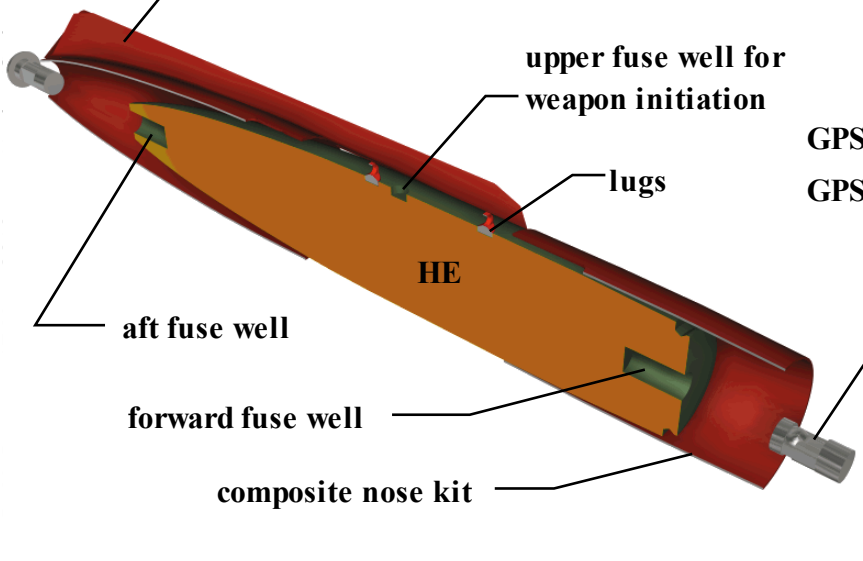
- 96% reduction in power consumption
- 16x increase in bandwidth
- 99.2% decrease in slop
- OM reduction in part count
- 12% OWE savings

Gravity Weapons

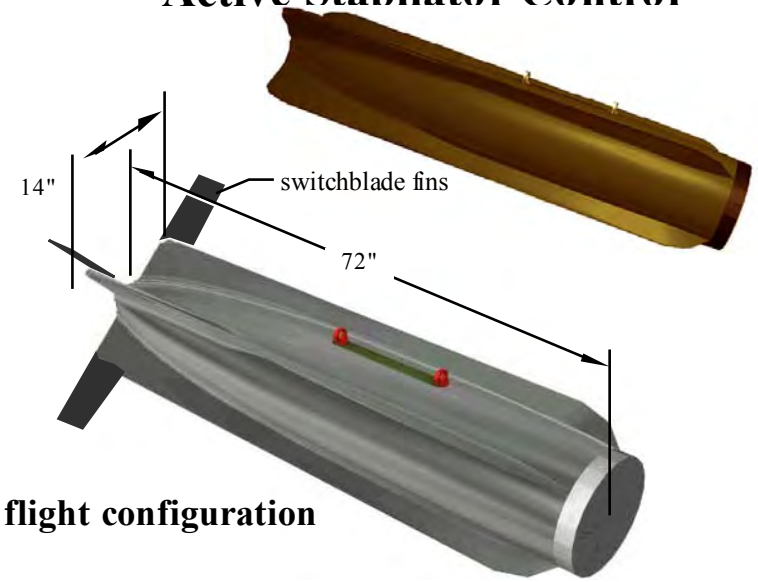
Weapon Compression

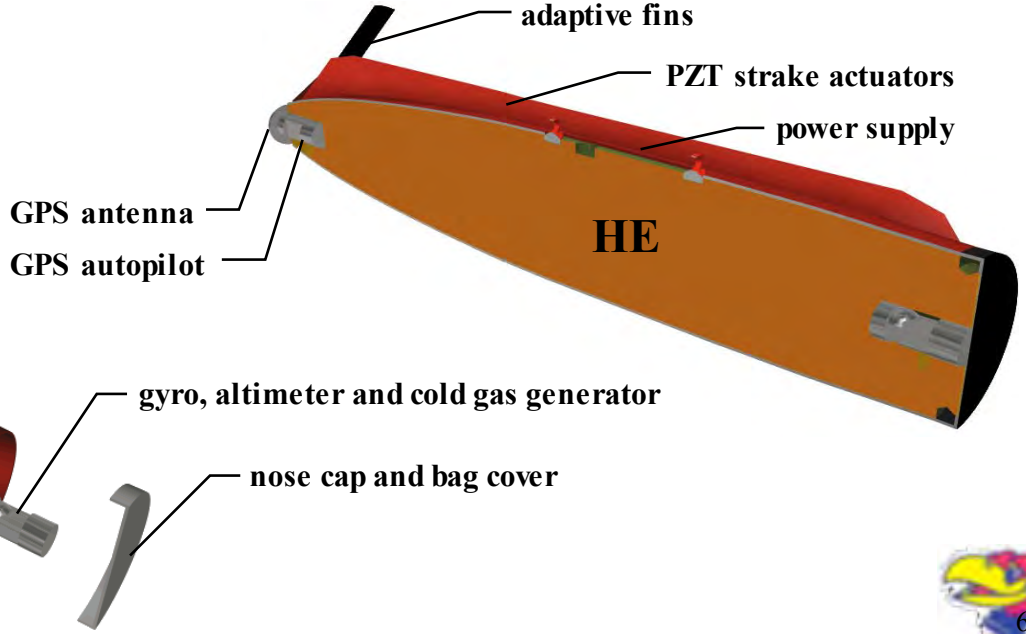
Smart Compressed Reversed Adaptive Munition (SCRAM)





Active Stabilator Control





All information from public sources

Interceptors

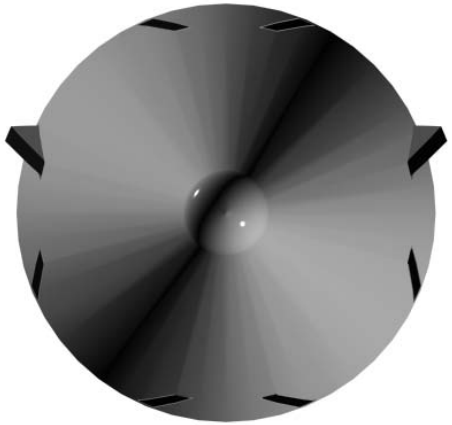
SMDC HITT Program 1997 - 2000

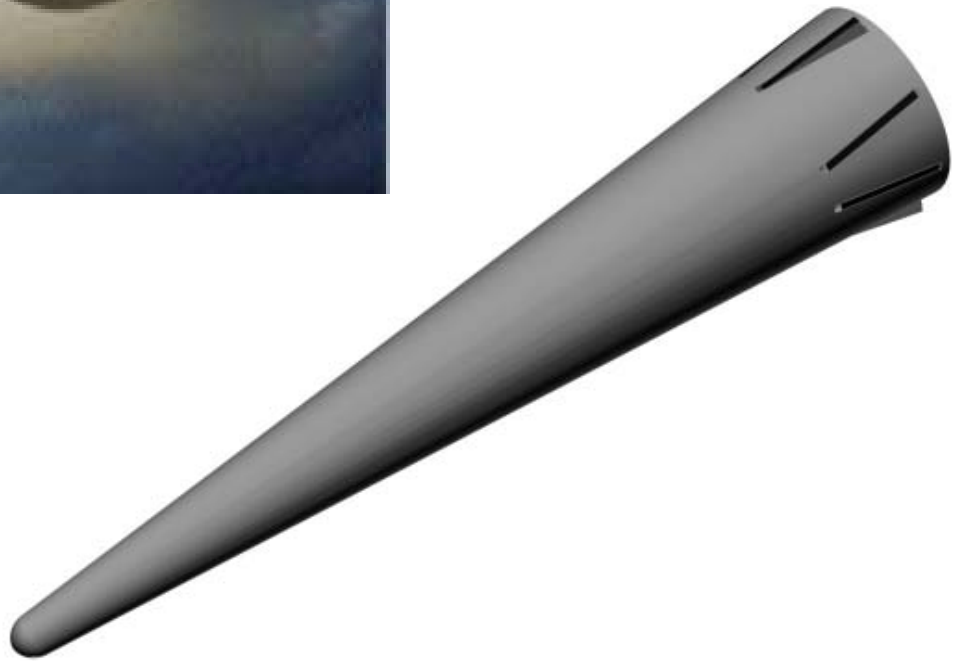


Hypersonic

5ms Fully Proportional Response

Pitch, Roll, Yaw control



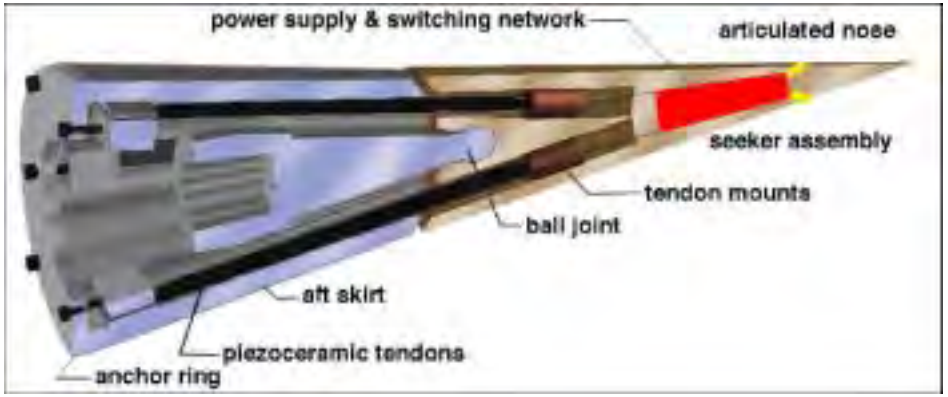


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Guiding Lower Caliber Rounds… More History

Barrel-Launched Adaptive Munition (BLAM) Program 1995 - ‘97

USAF/AFRL-MNAV



- Aerial Gunnery (20 - 105mm)
- Extend Range
- 2g maneuver

(Eglin AFB tests ‘97)

(Mach 3.3 tests ‘96-’97)

- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction

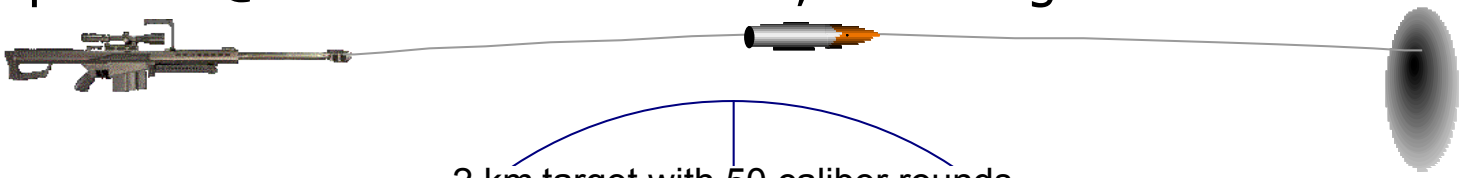
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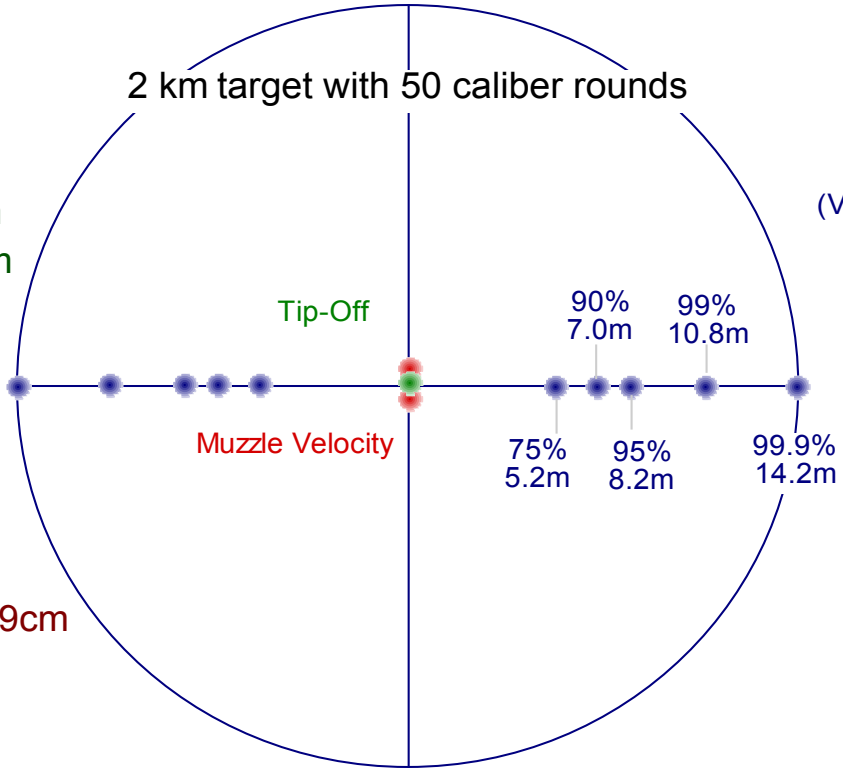
Guiding Small Arms Rounds… More History

Range-Extended Adaptive Munition (REAM) Program 1998 - '99

TACOM-ARDEC (Picatinny-APG) Phase I SBIR

- Guide 50 cal sniper rounds against targets moving up to 100km/hr
- 10cm dispersion @2km under 99% winds, variable grade to 10%





Tip-Off Rate:
4 rad/s error ~ 25cm
12 rad/s error ~ 75cm

Muzzle Velocity
1% change error ~ 99cm

Crosswinds
(Von Kárman Spectrum)

$V \sim \chi^2(\nu)$

Vav = 4.03 kts
75th%: 5.21 kts
90th%: 6.95 kts
95th%: 8.15 kts
99th%: 10.7 kts
99.9%: 14.2 kts

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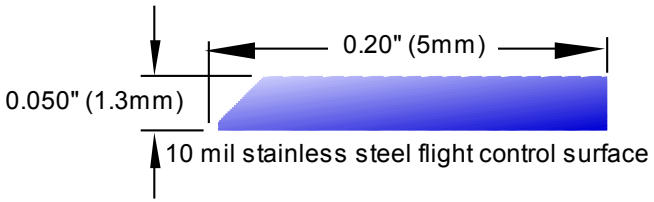
Guiding Small Arms Rounds… More History

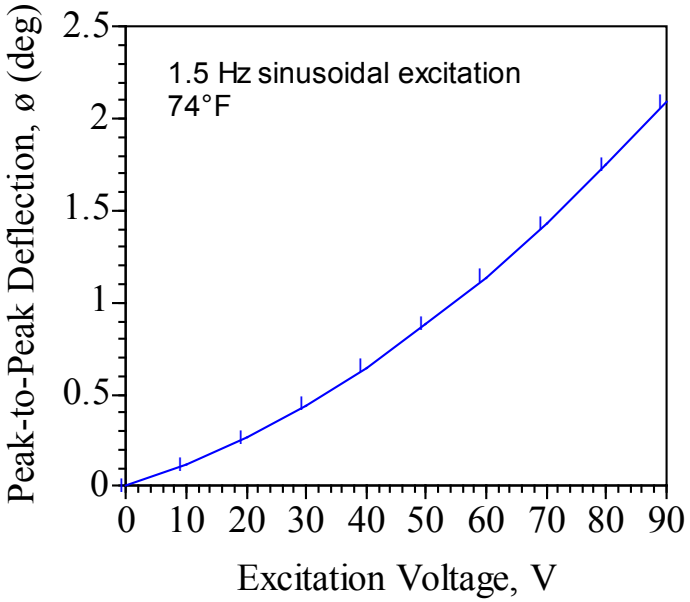
Range-Extended Adaptive Munition (REAM) IRAD 1999 - 2001

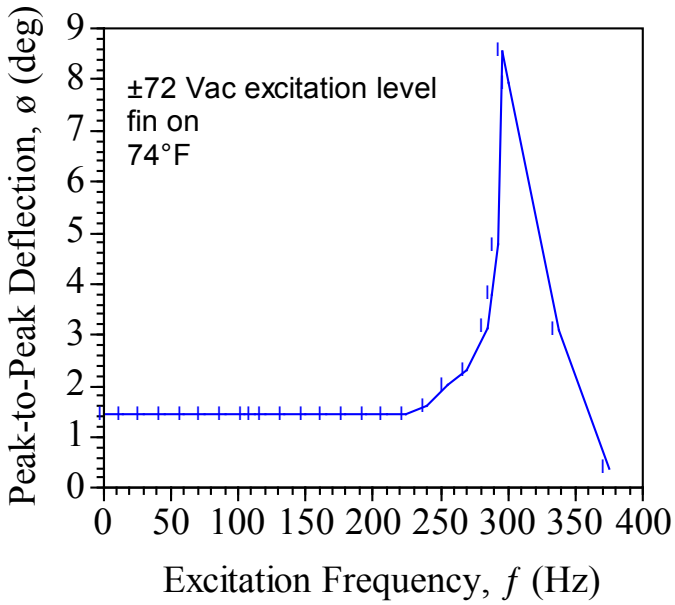
BAT-Lutronix Corp. developed supersonic piezoelectric FCS actuators

Flight Control Surface and Actuator Performance

Max Power Consumption: 28 mW
Nominal Power Consumption: 3.5 mW
Static Power Consumption: < 1μW
Design Mach Range: 0.8 - 4.5, STP
Design Accelerations: 25k g's







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Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II

- Change from sniping to countering high jinking rate sea-skimming missiles
- Change from 0.50 caliber to 40mm
- Change from ~2g's of maneuver authority to many tens of g's
- Entire FCS passed 41,000g shock table testing





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Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II



SCREAM Actuator Challenges:

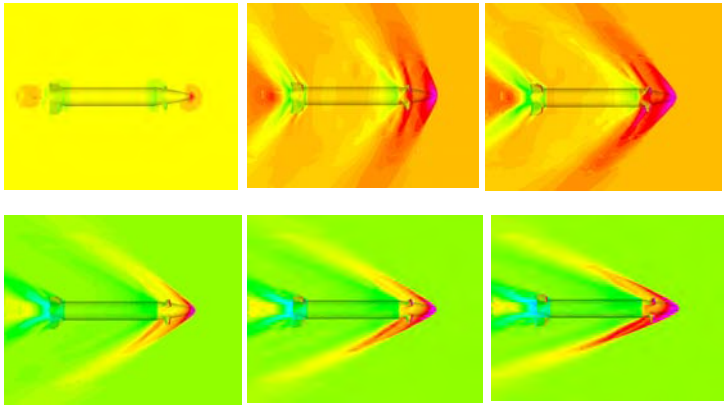
- Long actuator bay length
- Difficulty pushing beyond 50,000g's
- Low deflection -- ~ok for sniper, not ok for SCREAM

Hmmm…

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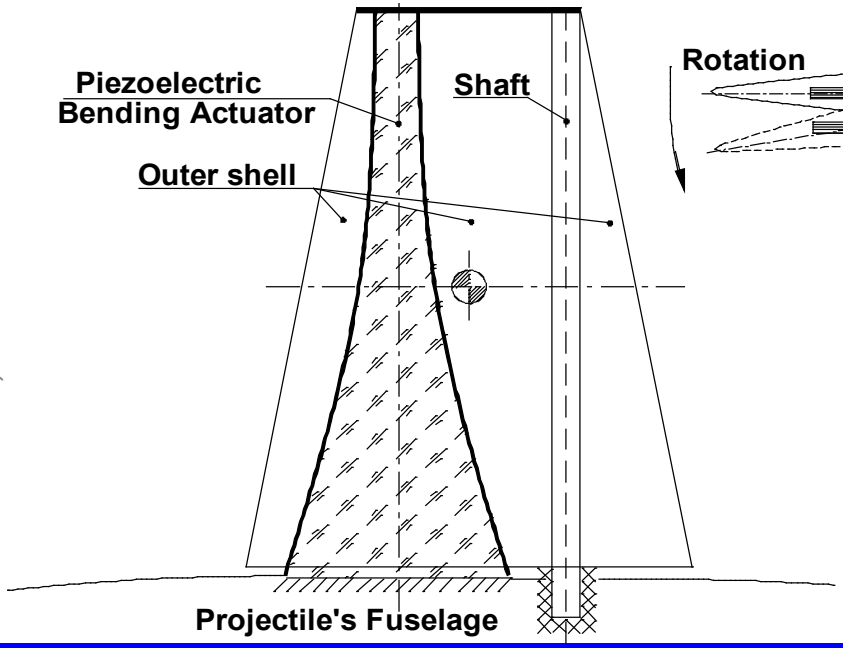
Other Adaptive FCS Efforts

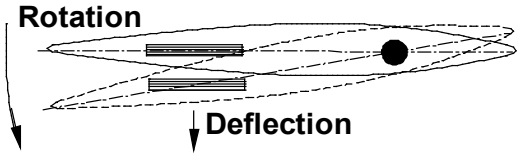
Rabinovitch & Vinson 2000 - present

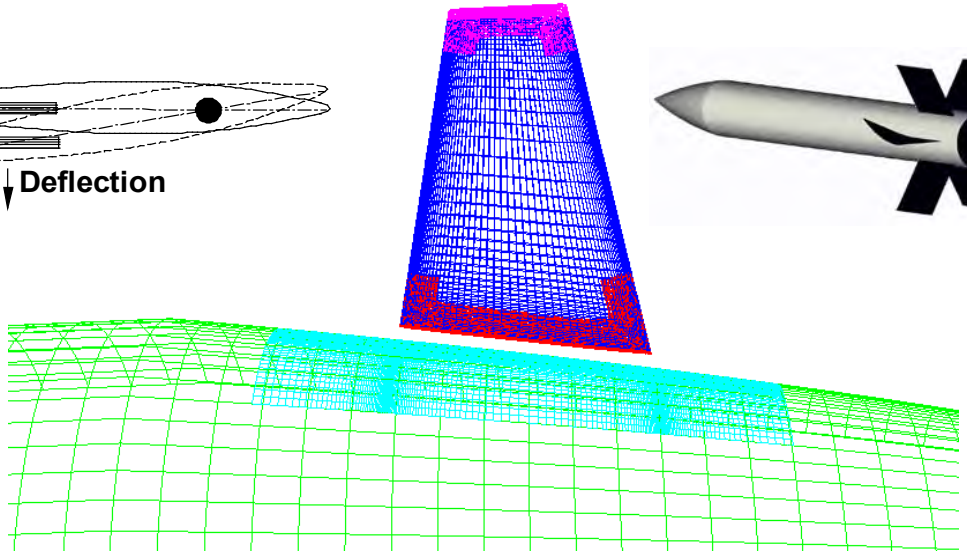


again... low authority
can't survive balloting, setback unsteady aero...

Now Where???



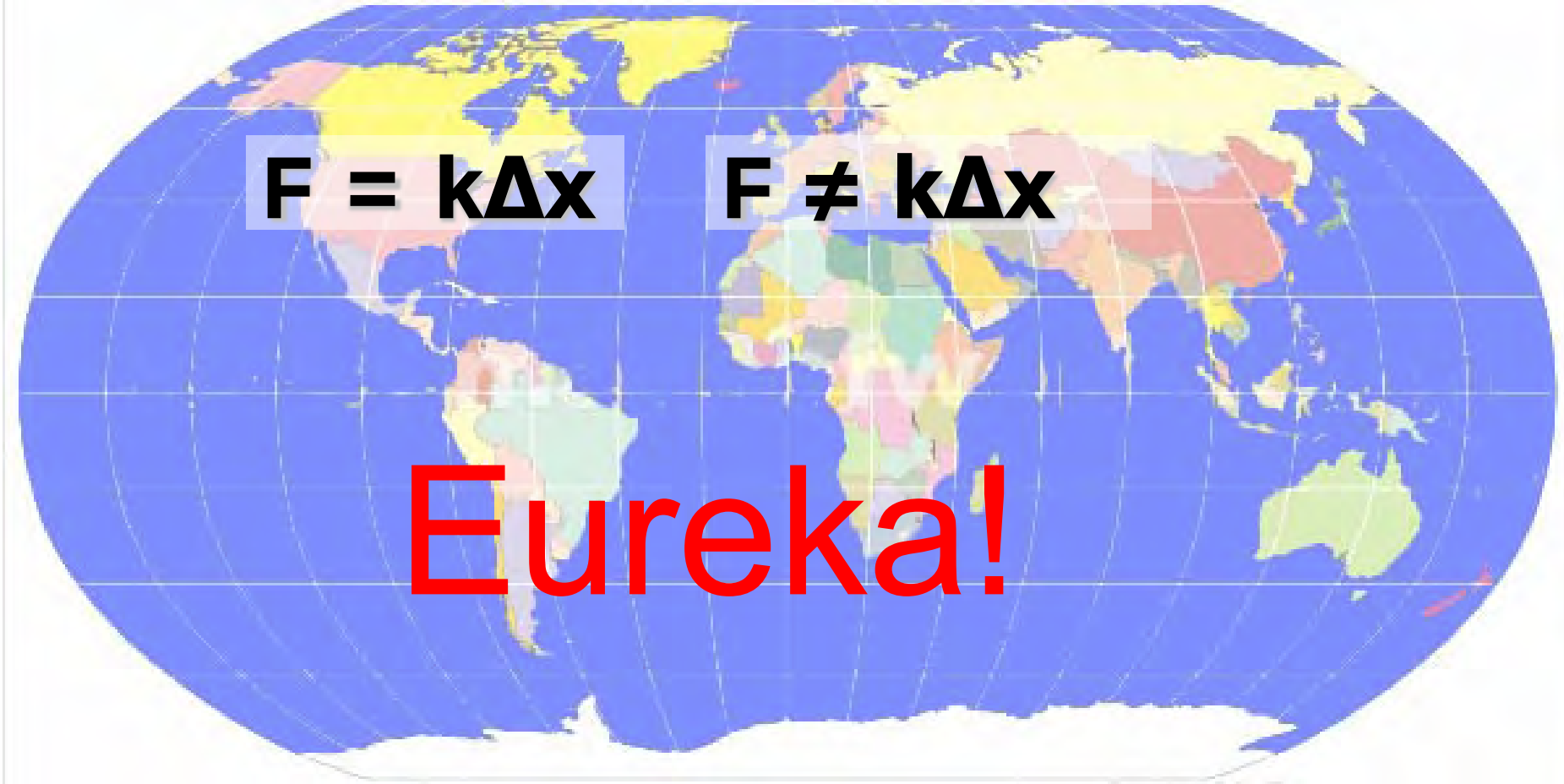




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Guiding Hard-Launched Rounds… The Ephphany!

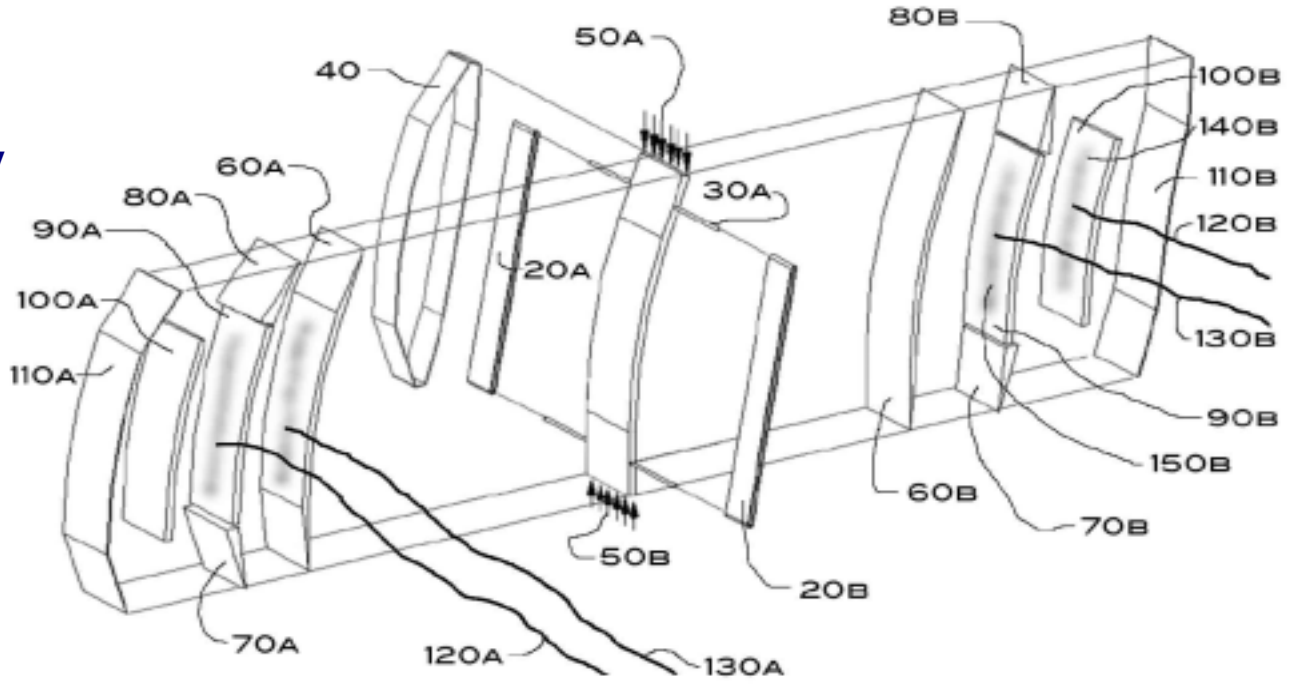
Discoveries from Europe… 2003 - 2004



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PBP Actuators: The FCS Solution

- Fraction of the weight, size & power consumption of US Actuators (i.e. much smaller actuator bays)
- 300+% deflection increases with full force/moment capabilities
- Higher bandwidth
- Lower g-sensitivity
- Lower cost

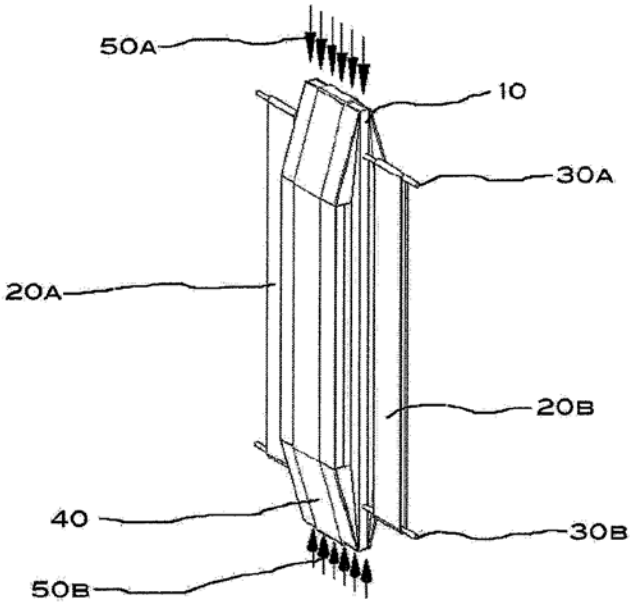


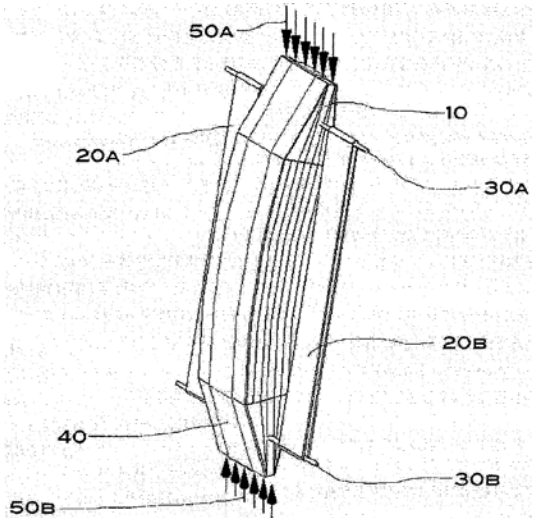
Worldwide patent application: 18 Jan. 2005

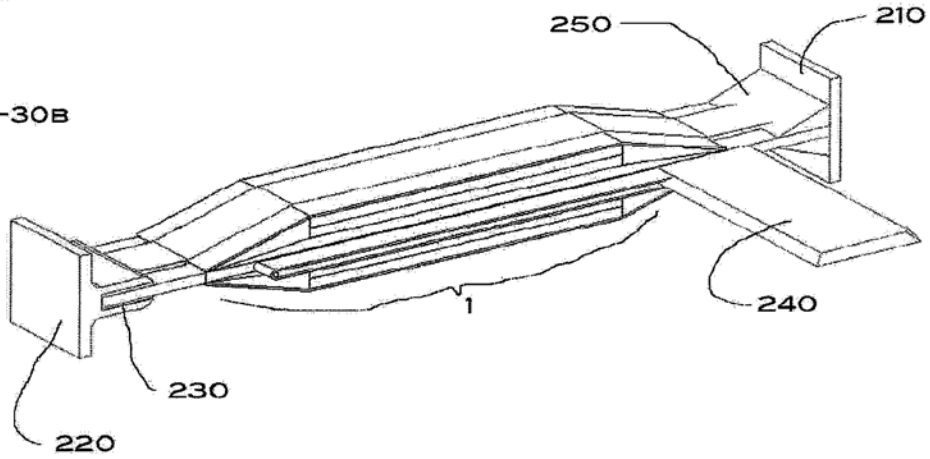
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PBP Actuators: Actuator Layout

Assembled, functioning actuator:



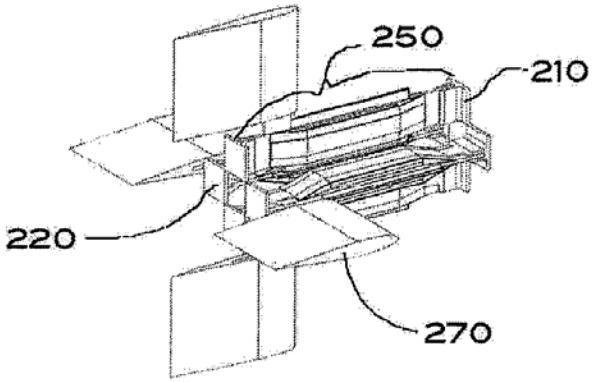


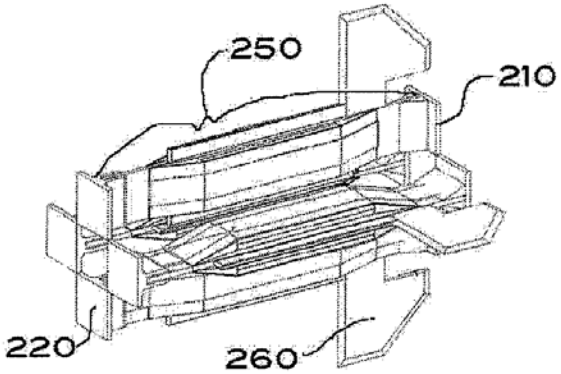


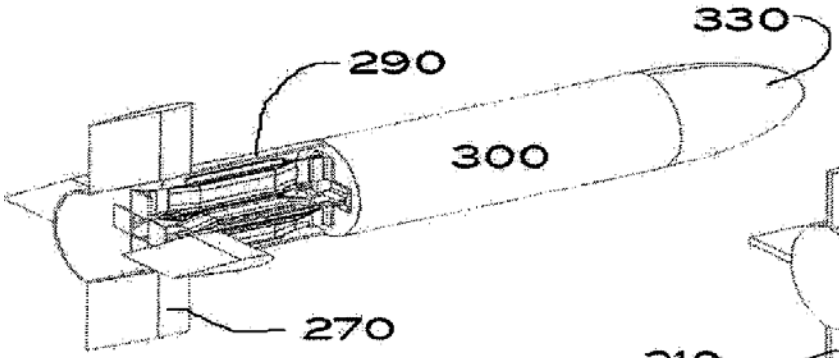
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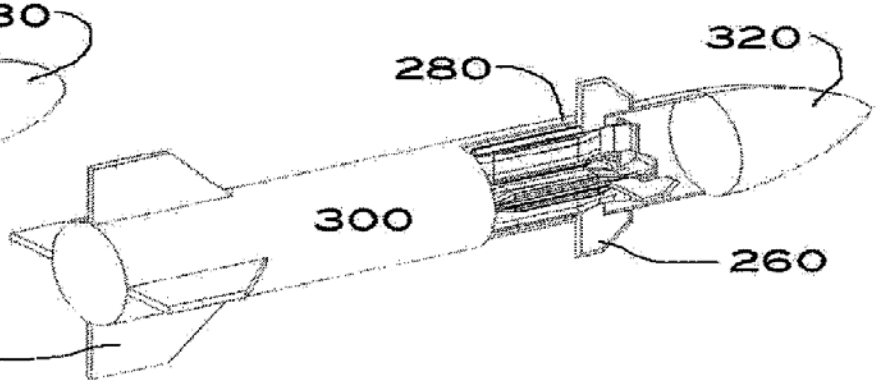
PBP Actuators: Assemblies

Assembled Hard-Launch Capable Actuator FCS Units:







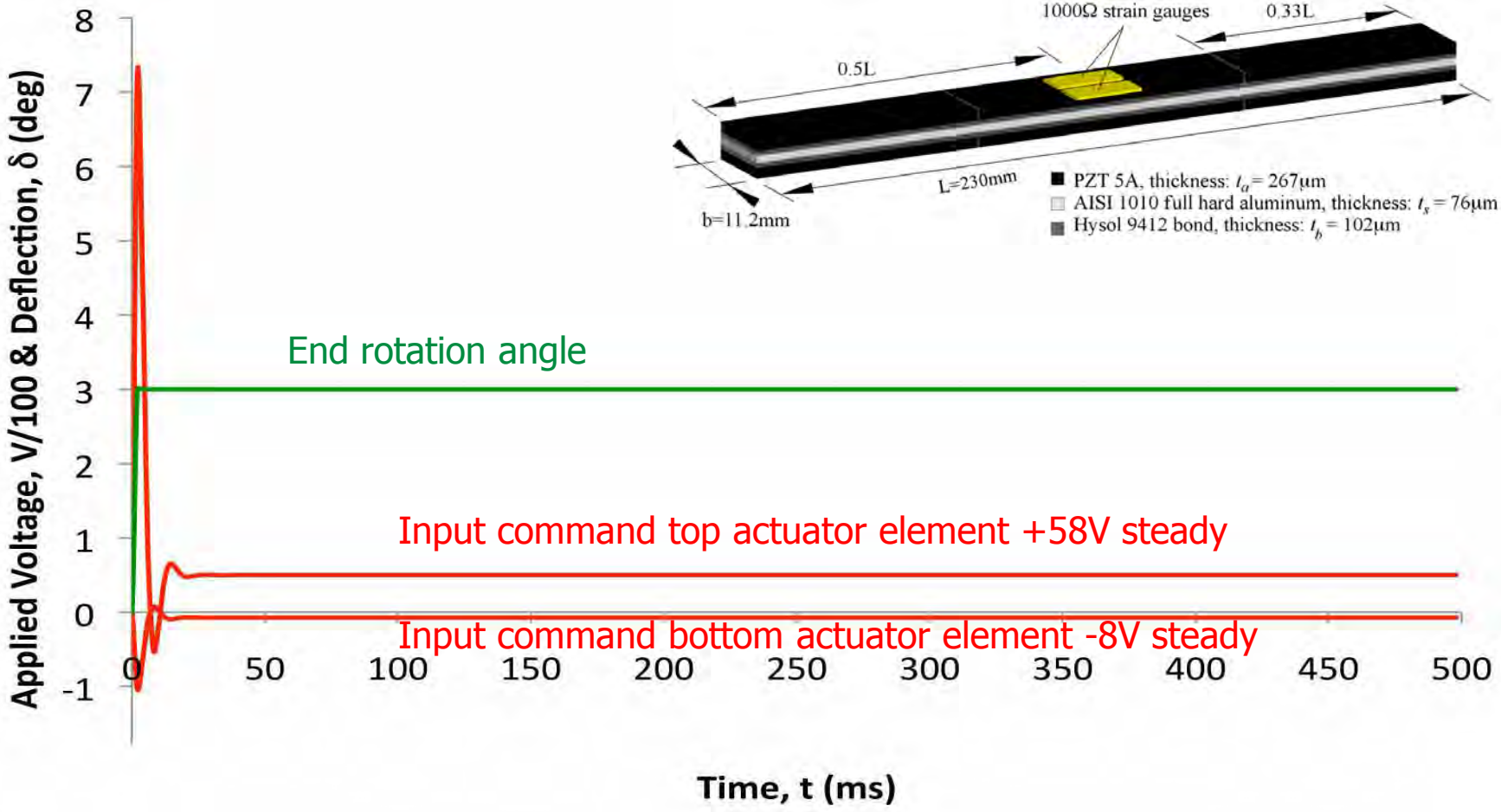


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PBP Actuators: Fastest around…

Best performance in the adaptive structures industry:

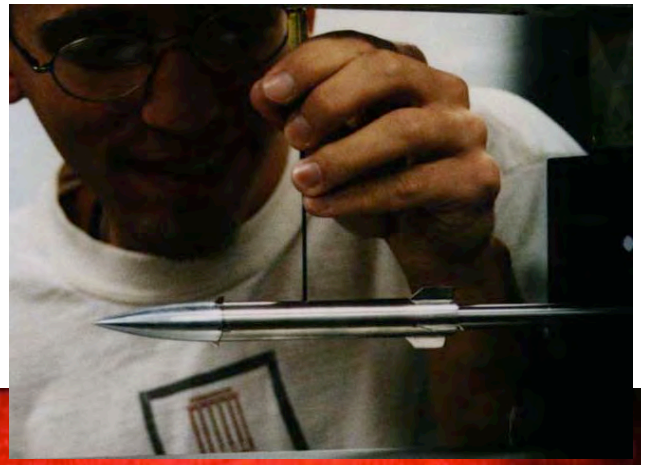
- **1kHz equivalent bandwidth**
- **Driving 0.40/.50 cal Mach 4.5 canards**

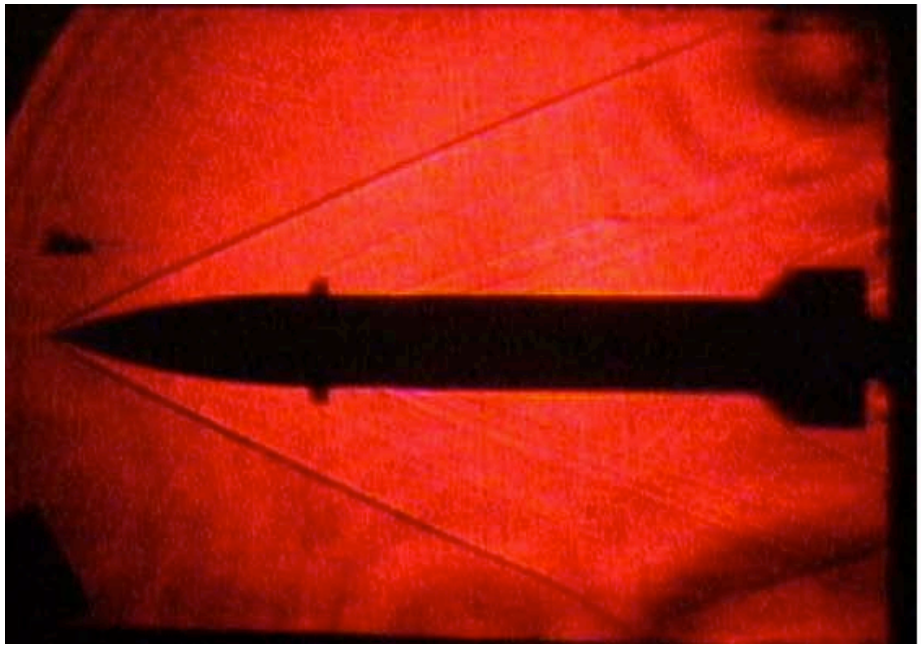


R. M. Barrett 17 May 2010 Unclassified All information from public sources

PBP Actuators: Real Performance!

Mach 3 Testing – FCS works well!



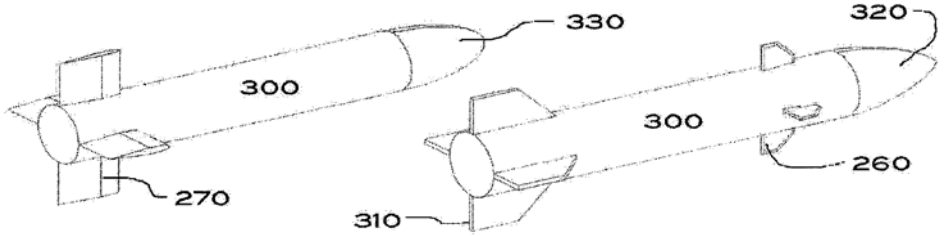


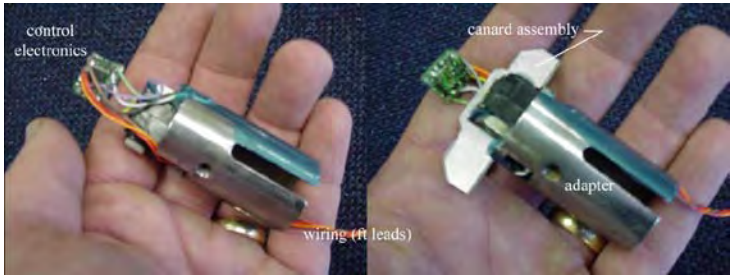


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PBP Actuators: Munitions Comparisons

Smaller, Lighter, Cheaper – the Name of the Game



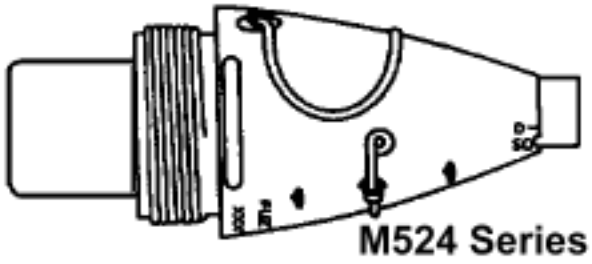


	Conventional Electromagnetic FCS	Adaptive / PBP FCS
Volume	14cc	5.1cc
Mass	69g	4.2g
Peak Power	148W	2.6W
Deadband/Slop	±0.38°	±0.002°
Bandwidth	22 Hz	189Hz
Acquisition Cost (100,000 shipsets)	$187 ea.	$12.30

All information from public sources
Unclassified
R. M. Barrett 17 May 2010

PBP Actuators: Moving up in caliber to fuses – Easy!

Mortar Fuses





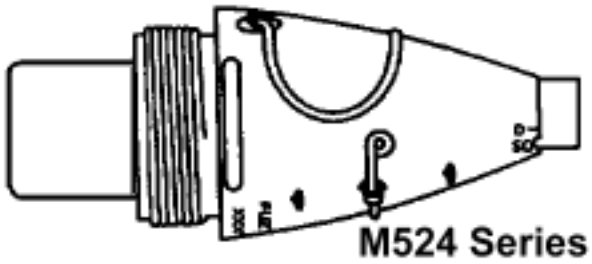
Howitzer Fuses



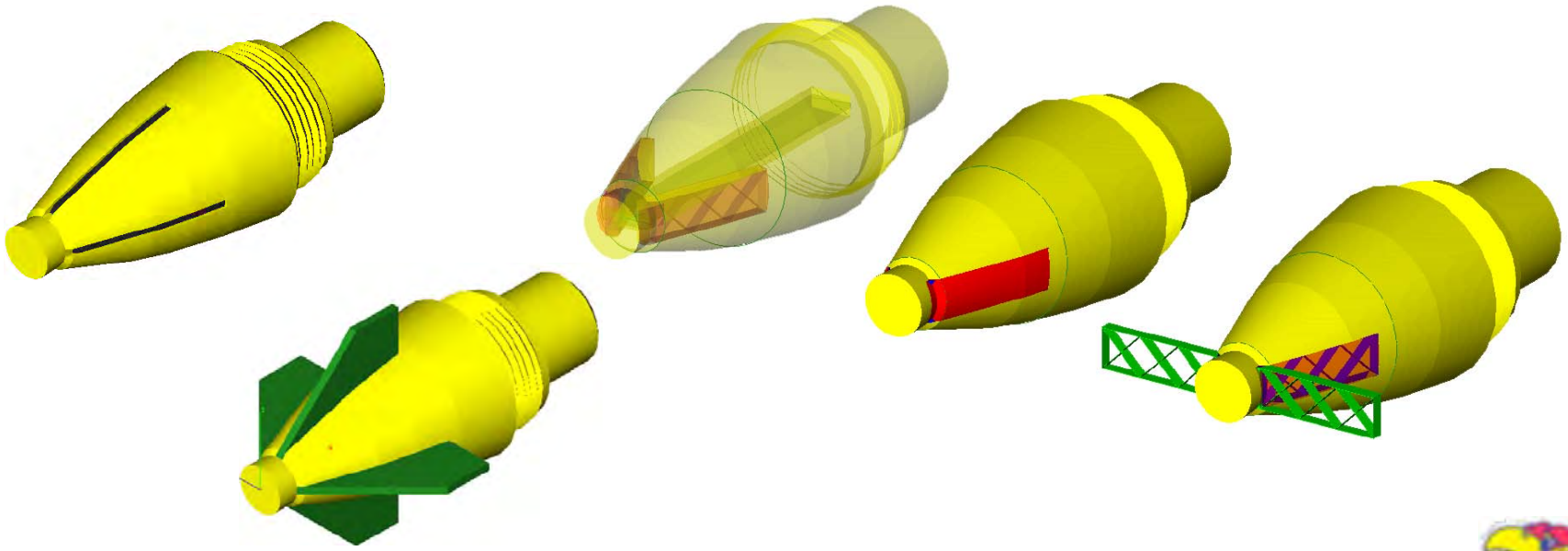
R. M. Barrett 17 May 2010 Unclassified All information from public sources

PBP Actuators: Moving up in caliber – Easy!

Fuse PBP FCS Designs



Designs to drive both blade and grid-fin control surfaces full pitch, roll & yaw from apogee for ~8cc volume, through 100 Hz, <1W



R. M. Barrett 17 May 2010 Unclassified All information from public sources

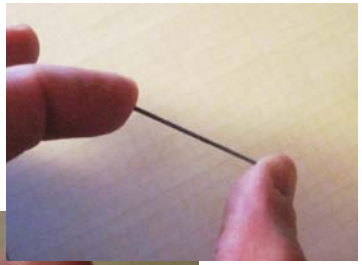
PBP Actuators: The Next Challenge

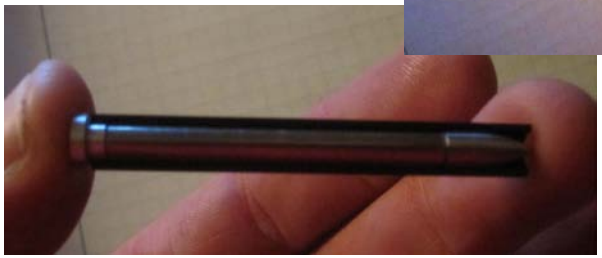
Bring 0.50 Cal. Sniper Performance to a Weapon with an M-16 Form





- **M-16 form factor**
- **Tight Dispersion @ meaningful ranges**
- **Impervious to 99% atmospherics**
- **Flat trajectory**





$13.81/round (lots of 100,000)

Industrial & Government Partners

All information from public sources
Unclassified
R. M. Barrett 17 May 2010

Adaptive Materials and Aerostructures for Missiles, Munitions and UAVs

Short Course for:
Program Managers &
Practicing Engineers

R. M. Barrett 17 May 2010 Unclassified All information from public sources

Open/Unrestricted Course

(all materials from public documents, can be taught worldwide)
2 – 14 hrs, on site, up to 2 days

1. Nomenclature
2. History of the Field
3. Adaptive Material Properties and Modeling Techniques
4. Electrical Interface and Control
5. Aircraft Applications and Programs
6. Missile & Munitions Fundamentals & Programs thru early 2000's
7. Helicopter & UAV
8. Limitations
9. Future Directions



ITAR/EAR Restricted Course

(materials from restricted sources, proof of US citizenship req'd)
2 – 21 hrs, on site, up to 3 days

1. Nomenclature
2. History of the Field
3. Adaptive Material Properties and Modeling Techniques
4. Electrical Interface and Control
5. Aircraft Applications and Programs
6. Missile & Munitions Fundamentals & Programs thru today w/advanced weapons concepts
7. Helicopter & UAV
8. Limitations
9. Future Directions

Questions?

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Safe Electric Solid Propellants

Wayne Sawka, Ph.D.
President

Digital Solid State Propulsion, LLC
Reno, NV

Small Satellite Conference
Utah State University
Logan, UT Aug. 13-16, 2007

Navy Opportunity Forum
Washington, DC
June 2009

Energetics Safety & Performance

Essential to Navy Programs

- Energetics continue to be dangerous to manufacture, transport and use
- Few weapons able to meet current Mil Stds for shipboard safety
- Controllable solid rocket motors are complex, heavy and expensive



*Accidents are still occurring**

Jalalabad, Afghanistan, 10 Aug 02

26 killed, 90 injured

Spin Boldak, Afghanistan, 28 Jun 02

32 killed, 70 injured

USS Nimitz, 26 May 81

14 killed, 48 injured. $79M in losses: Sparrow Missile

1960s

USS Oriskany, USS Enterprise and USS Forrestal

206 killed, over 600 injured *and*
$321M in losses

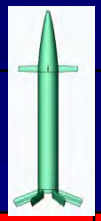
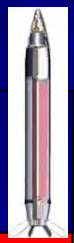


** More recent incidents information is restricted*

5” Rocket Propelled Projectiles:

Longer Range but More Hazardous

RED is a NO PASS

MIL-STD-2105C Tests	ERGM 	BTERM 	LRLAP 
Slow Cook-Off	Rocket Motor	Rocket Motor	Pass
**Fast Cook-Off*	Rocket Motor	Rocket Motor	Rocket Motor
**Bullet Impact*	Rocket Motor	Rocket Motor	Rocket Motor
Fragment Impact	Warhead & Rocket Motor	Warhead & Rocket Motor	Warhead & Rocket Motor
Shape Charge	Warhead & Rocket Motor	Warhead & Rocket Motor	Warhead
Sympathetic Detonation	Warhead & Rocket Motor	Warhead & Rocket Motor	Pass

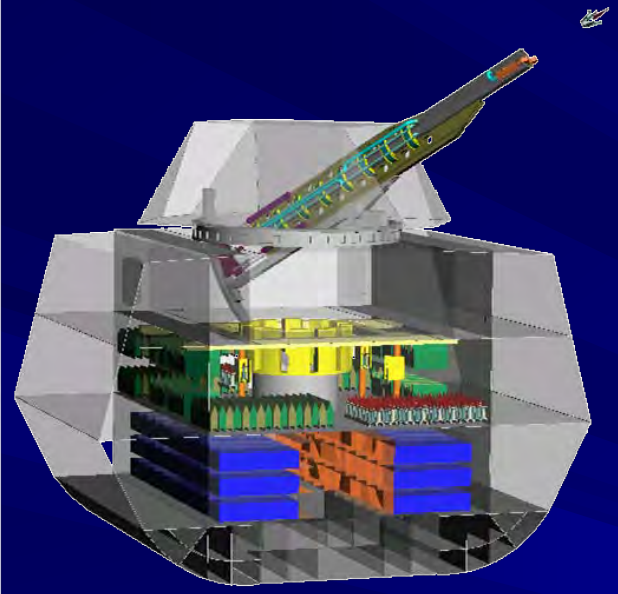
* videos

Baseline Technologies

Some 50 years old…..

- Solid propellants contain sensitive ingredients like nitroglycerin and perchlorates
- Liquid rocket motors are not easily stored and use toxic materials such a hydrazine
  - *Not acceptable on Navy ships*
- Controllable solid rocket motors
  - *Very low mass fractions*
  - *Mechanically complex*
  - *Very expensive*

Customer Need



- New long range projectiles will require exo-atmospheric adjustments/targeting
  - Can only be done with thrusters
  - Must withstand *extreme* G-loading
  - Low cost is essential
- Missile systems need longer ranges and flexible multi-mission roles
- ACS and DACS need longer operation times and higher mass fractions
- Nano-satellites need a viable propulsion option



Our Solution:

A New Class of Energetic Material

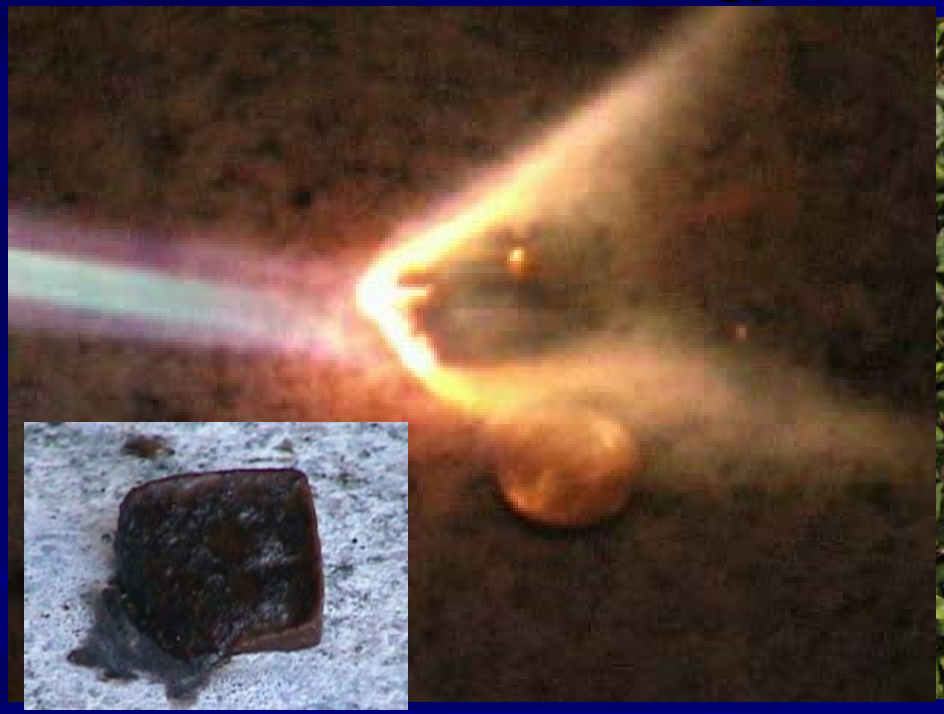
"ELECTRIC SOLID PROPELLANTS"

- **World's first "Smart" energetic materials**
  - **Safe, CANNOT be ignited by spark/flame**
  - **CAN BE electrically switched off/throttled with NO moving parts**
  - **Manufacturing/Shipping is safer & easier**
    - **No high shear mixing**
  - **Non-toxic exhaust & environmentally safe to manufacture**

First-of-Its-Kind:

"Smart Energetic Material"

Safe, Nontoxic Byproducts-
Green Technology



Electronics Manufacturing with Energetics



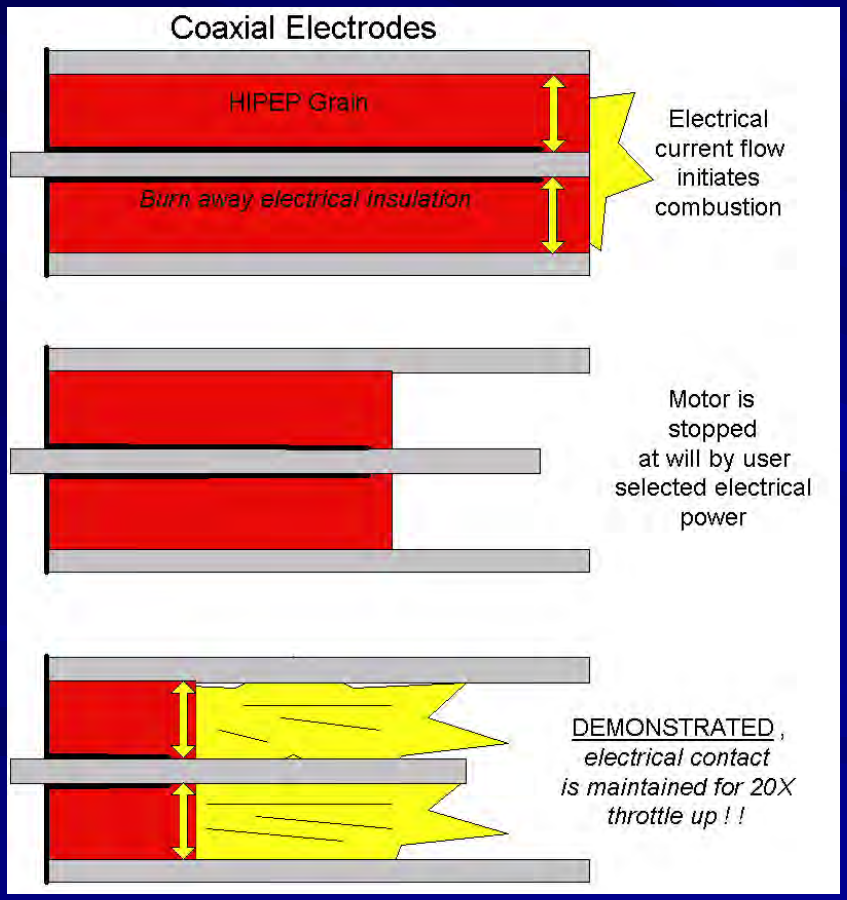
Safer to Manufacture and Use

ESP Functions



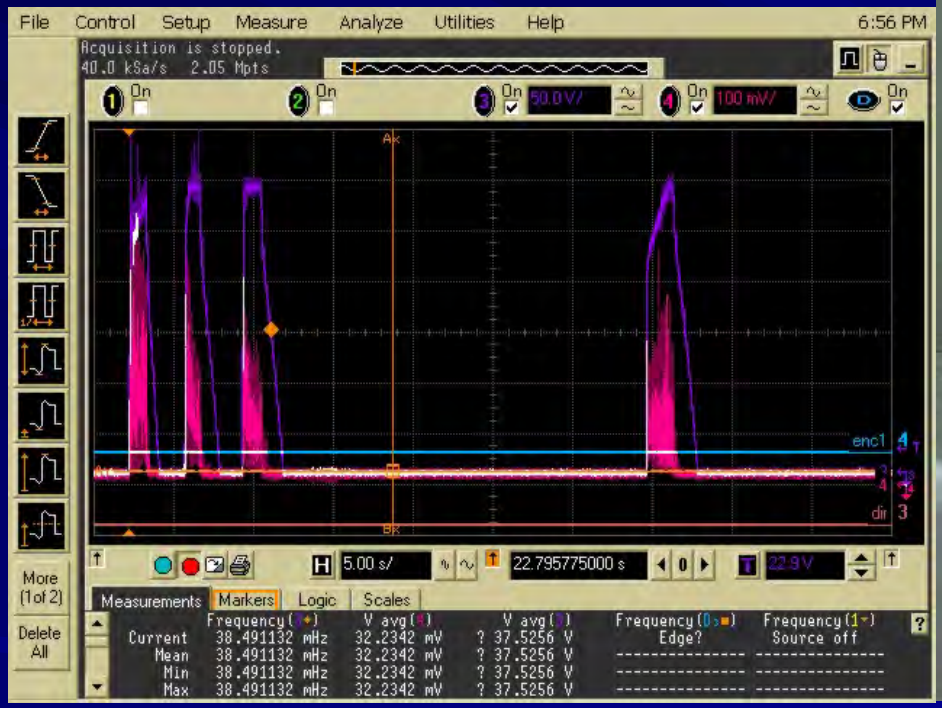
- **Throttle 6-20x**
  - Proportional to electrical power supplied
- **Extinguishment**
  - User selected pulse widths/on-off cycles
- **No Moving Parts**
  - Low part count

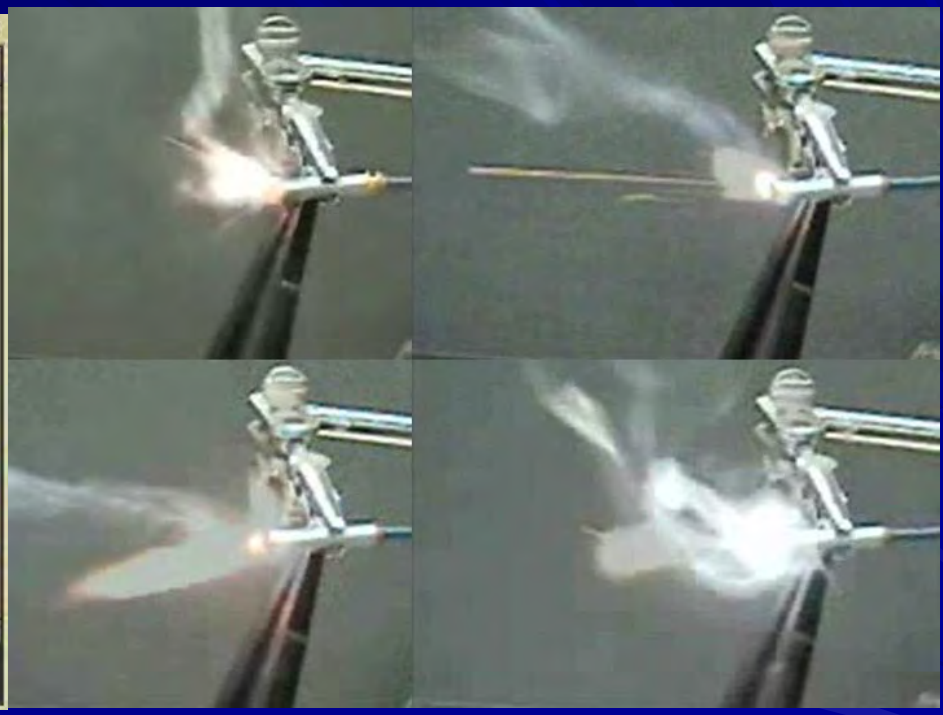
ESP Coaxial Grain Burn Away Insulation



- Insulation
  - Central electrode only
  - Directs electrical power to burning surface
  - Recesses ahead of burning propellant maintaining contact

Electric Solid Propellant Provides Discrete Pulse Widths





Clusters Balance Electrically and Ignite Simultaneously



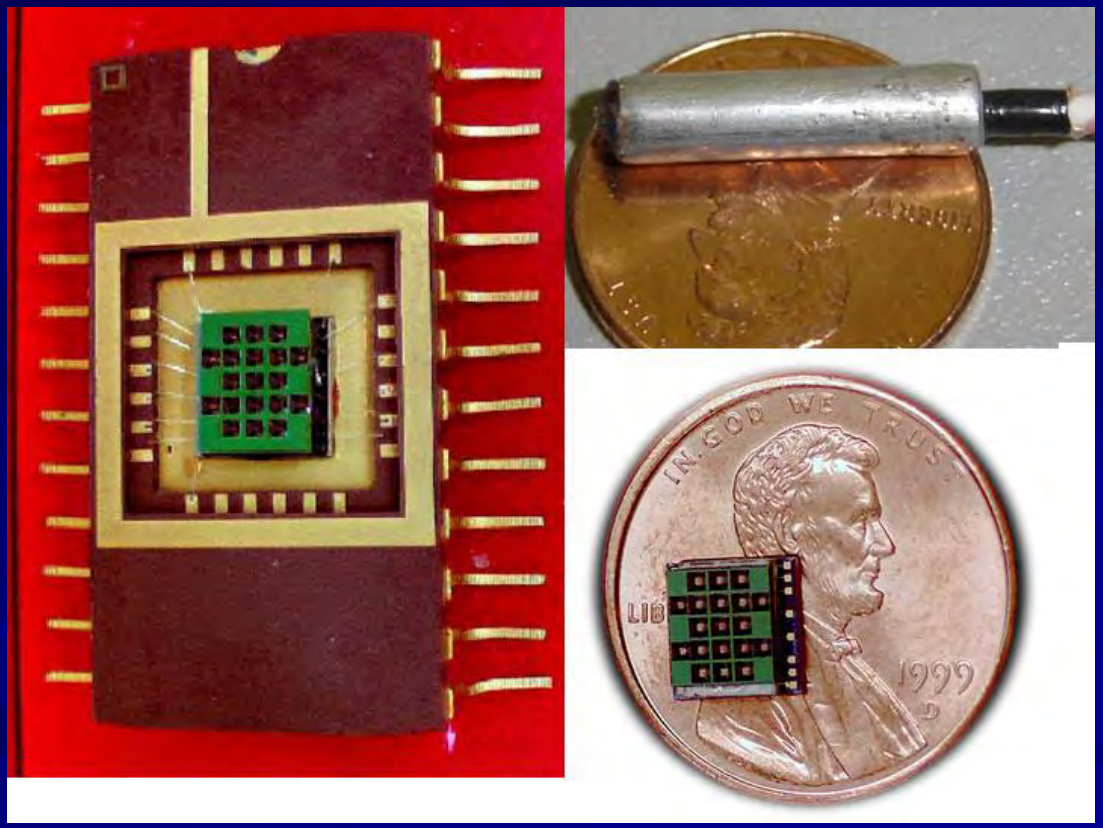
Electric Solid Propellants are Safer To Use and Can Be Controlled

Cannot easily be ignited with spark or flame

Insensitive to high velocity tracer bullet impact

Solid state on-off-on electric control

DSSP Coaxial ESP
Better, Faster, Cheaper than a DARPA Chip Thruster



- Higher mass fraction
- Lower part count
- Variable thrust
- Fewer wires
- Lower powder

Why Are Electric Solid Propellants So Much Better?

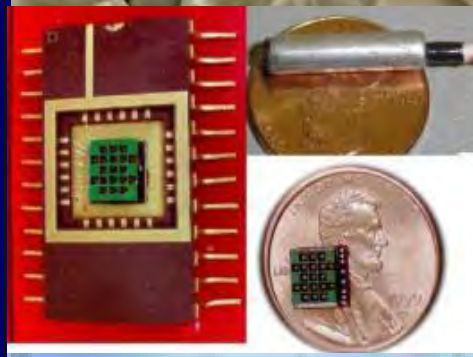
Feature	Advantages	Benefits
Propellant Controllability	Many applications *Even explosives….*	Lower cost Better smart weapon systems
Green Safe Propellant Class 1.4S *(pending)*	Fewer accidents and less hazmat handling disposal	Lower cost: manufacturing, transportation, and storage
High Performance*	About the same current solid propellants	Higher mass fractions for longer missions

** ITAR Restricted*

Current State of Development

- **DOD Development Programs**
  - **Navy: Miniaturized ACS for Exo-atmospheric Projectiles**
    - **IM Testing being accelerated via CRADA w/ NAVAIR China Lake**
  - **MDA: Mil Std. 1901A Compliant Ignition Systems**
  - **MDA: Igniterless Rocket Motors**
  - **MDA: Advanced DACS**
- **Commercial Development**
  - **Oil Service:** "2009 Top Ten Inventions" by *Oil and Gas Innovation*
- ***7 Patents and Counting….***









Further Applications

- Multi-fire igniters for solid and liquid rockets
- Advanced gun propellants
  - Dial in range: non-lethal to lethal
- True variable yield explosives



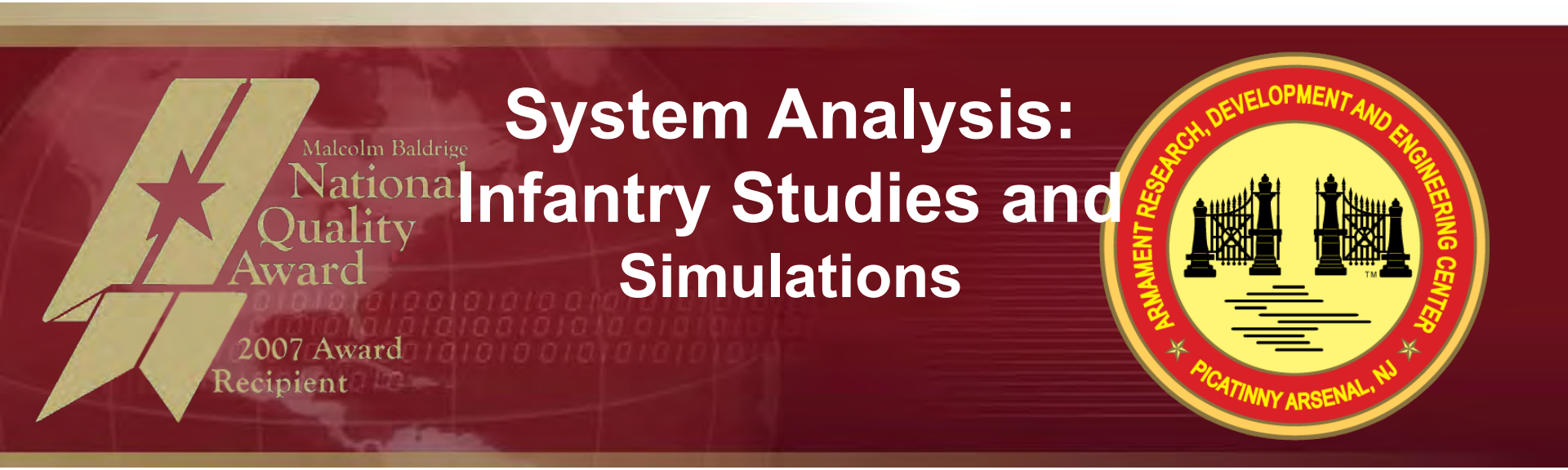



Further Information On ESPs



- **JANNAF Conference Papers in:**
  - 2005 Monterey, CA
  - 2007 Denver, CO
  - 2009 Las Vegas, NV
    - Distribution C
- **Small Satellite Conference 2007**
  - Logan, UT
    - Distribution A
- ***Acknowledgements***
  - MDA and Navy SBIR Programs
  - ONR, Fires Program





System Analysis: Infantry Studies and Simulations

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Timothy Fargus, Michael Wilson, and Alexander Lee
System Analysis, ARDEC
Timothy.fargus@us.army.mil, michael.c.wilson@us.army.mil, alexander.lee5@us.army.mil

5/19/10

RDECOM

Overview

1. Background
2. M&S tools
3. M&S work w/ new technology
4. Other work

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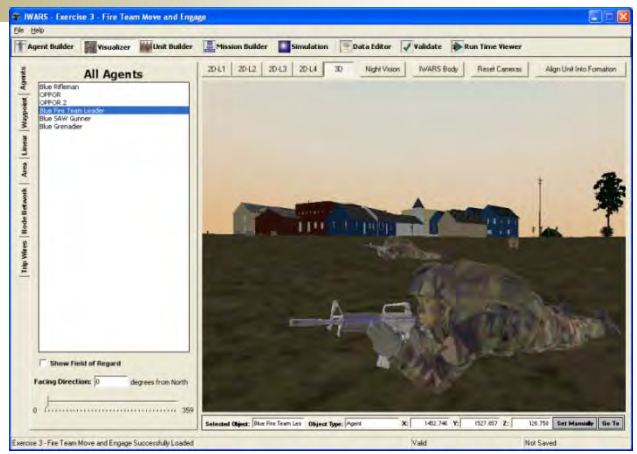
1. Background

How does System Analysis Modeling and Simulation improve the world of infantry technology and doctrine?

- **M&S answers the following questions:**
  - HOW MUCH improvement can the technology/doctrine provide?
    - Survivability
    - Lethality
    - Mission Success
  - How do we optimize a certain technology to accomplish the goal?
  - How do we compare existing technologies to new technologies to achieve a certain goal?
- **M&S saves money.**
- **Results help point the direction for development of small arms technology**
  - Controlled experiments obtain statistical results

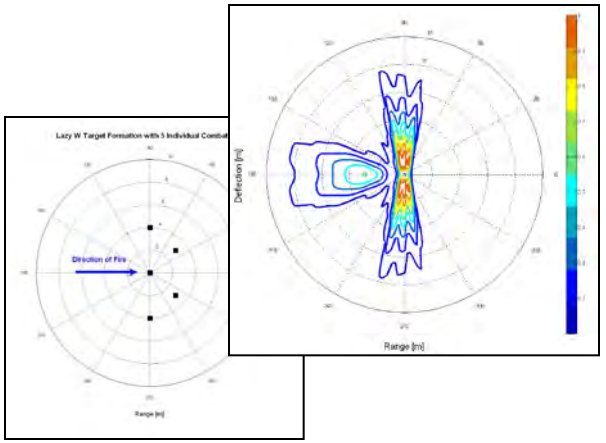
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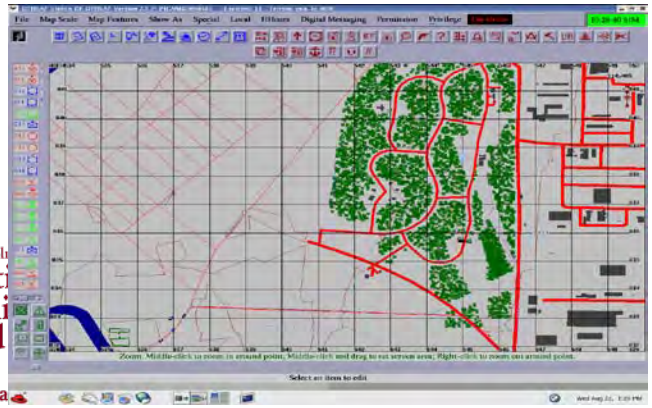
2. M&S Tools



1. IWARS – Infantry Warrior Simulation

2. CASRED & FBAR – fragmentation and delivery accuracy of a bursting warhead





3. OTB – Distributed force on force simulation

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

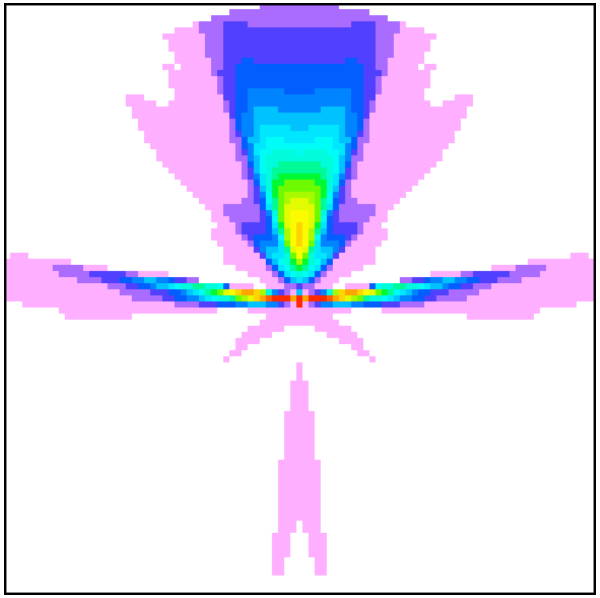
3. M&S work w/ new technology

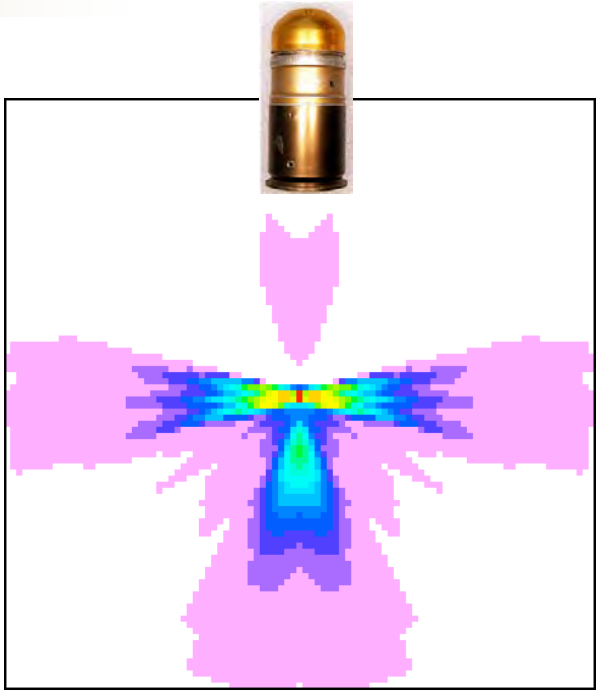
- M&S can be applied to analyze a multitude of technologies.
- The following are examples of work that have been recently completed or are in progress.

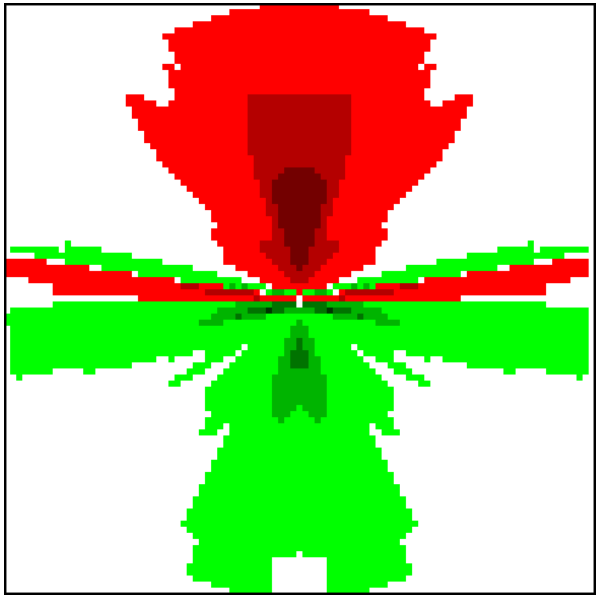
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3. M&S work w/ new technology: Comparisons of 40mm Concepts

40 mm concepts







New Concept | Baseline | Difference

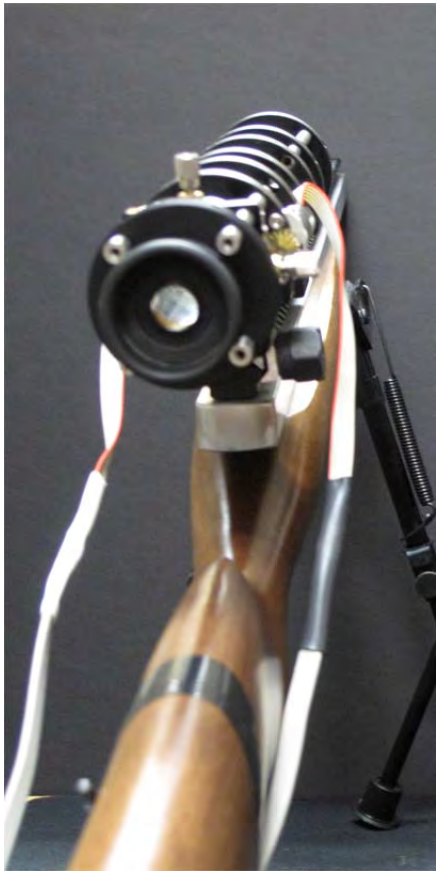


- This tool allows us to directly compare polar plot lethality data between two different rounds, giving us a direct picture of where a notional warhead gains and loses lethality in comparison with the baseline warhead, or with other notional concepts.
- Red indicates improvement over baseline.
- Green indicates degradation over baseline.

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

3. M&S work w/ new technology: IWARS in RAZAR study



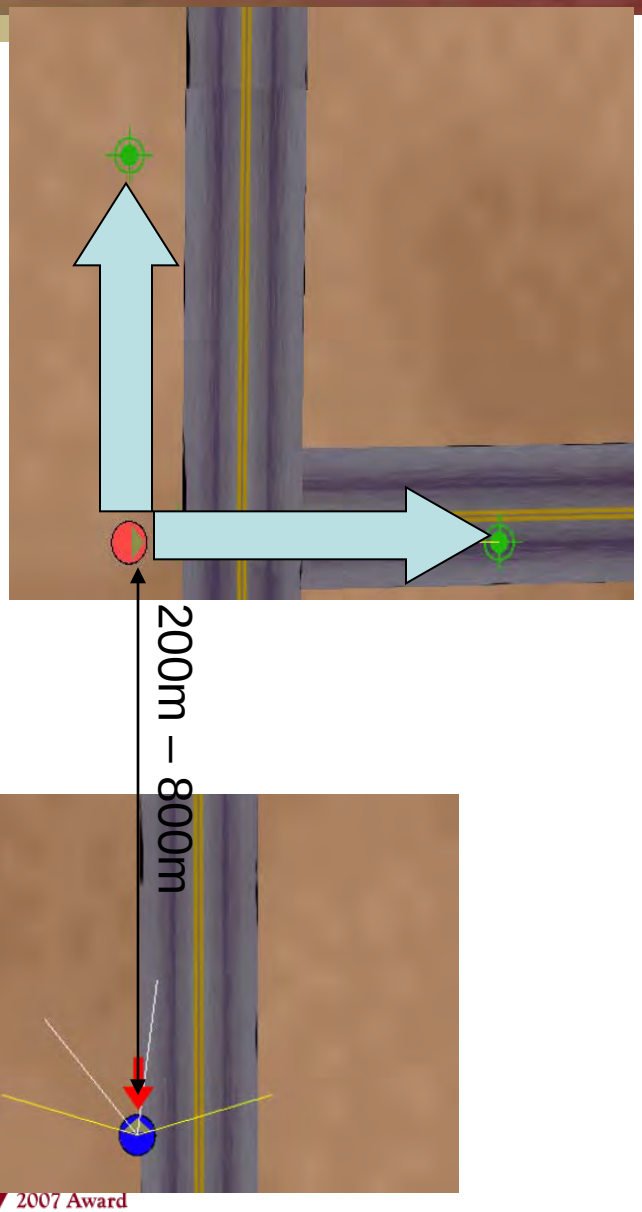
Technology:

Rapid Adaptable Zoom for Automatic Rifle

- Allows rapid target acquisition compared to manual scopes
  - Recognition and identification will allow faster target engagements

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3. M&S work w/ new technology: IWARS in RAZAR study



Simulation:

Blue agent attempts to acquire the target using his eyes and then uses the RAZAR scope.

- Observer to target range: 200m to 800m

  Experiments conducted in 50m increments

- Magnifications and Field of View:
  - 2X @ 12 degrees
  - 4X @ 6 degrees
  - 6X @ 4 degrees
- Vignettes - Red target either:
  - travels short distance horizontal
  - walks the same distance farther downrange

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3. M&S work w/ new technology: IWARS in RAZAR study

Findings:

Overall, RAZAR allowed further acquisitions needed for engagement of target over unaided eye

- 2X –up to 3 times (@ 700m)
- 4X – up to 2.27 times (@ 700m)
- 6X – up to 2 times (@ 800m)

Further experiments will be performed

- RAZAR aiming
- RAZAR time for acquisition

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3. M&S work w/ new technology: IWARS in LSAT study

Technology:







- Lightweight Small Arms Technology implements caseless (right) and cased telescopic ammunition (left), providing a foundation for lighter rifles, carbines, and machine guns.
- Current study involves comparison of M249 LMG to the LSAT LMG

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3. M&S work w/ new technology: IWARS in LSAT study





Simulation:

- Reduced ammunition weight will have effects on warfighter mobility and ammunition capacity
- Experiments will test the energy burned and additional kills given increased ammunition capacity
- Scenarios will start with single agent and expand to squad level battles

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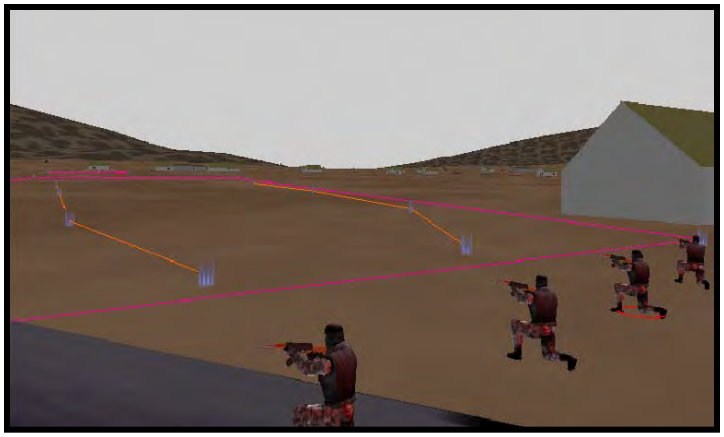
4. Other Work

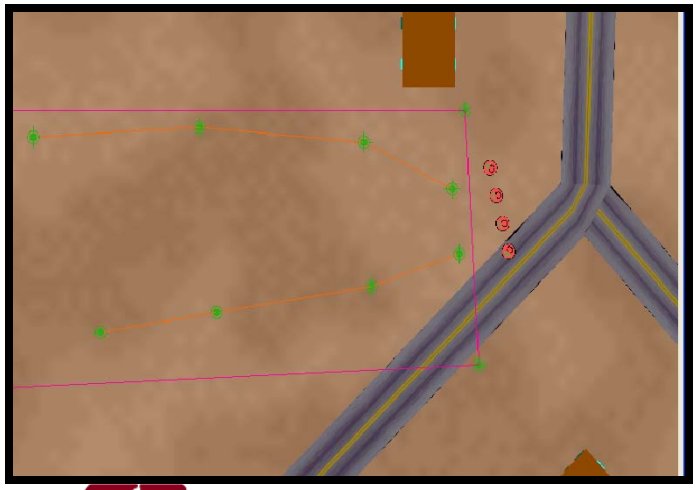
Laying the Groundwork

Anticipating future work and needs of the warfighter, we have taken the initiative to establish new scenarios and tools to perform experiments and other work for emerging technologies.

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4. Other Work: Fire and Maneuver





Fire and Maneuver Scenario

- One Red Opforce FT will attempt to fire and maneuver while another Red FT will provide firing cover, overwhelming a Blue FT under normal circumstances.
- The Blue FT will implement an improved capability such as improved acquisition or aiming.
- Stochastic shields will provide the Red force cover and concealment.
- Blue force will be in prone position.

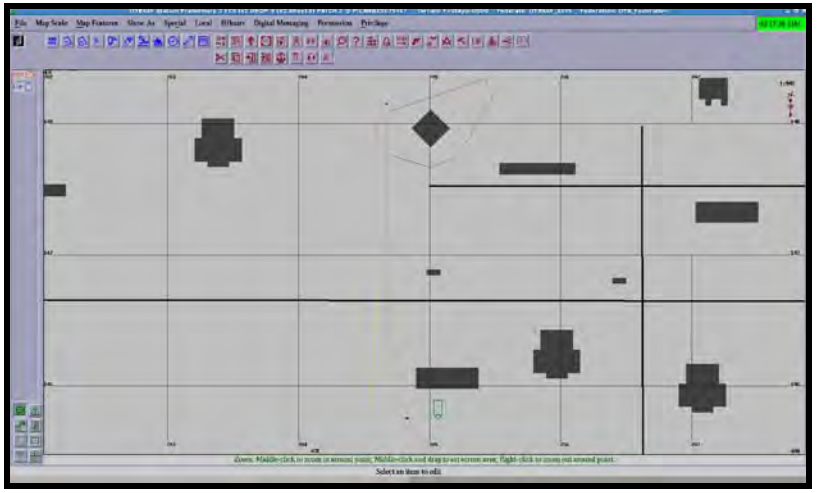
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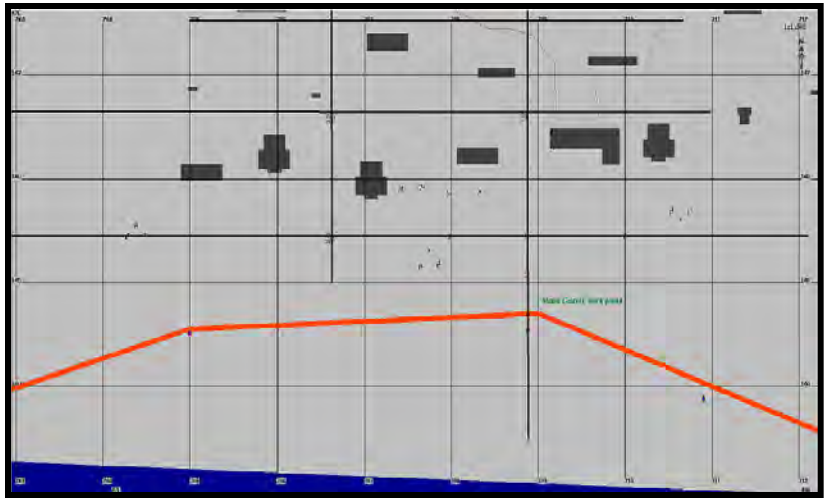
RDECOM

4. Other Work: OTB

Truck Bomb scenario

- Will be used as a foundation to test new capabilities





•Blue with M4 vs. Red with M4
- •~240 meters apart
- •Red does not shoot
- •Red runs for cover behind building
- •Exposed for about 3-5 seconds

•Group of civilians head to checkpoint to cause distraction
•Blue forces converge onto checkpoint in support
•Red, to west, drive into unguarded section of gate with truck bomb
•Red soldiers on foot enter hole in gate
•Blue force retaliates

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Infantry Study Outlook





- Continue analysis of 40mm and 25mm concepts to optimize fragmentation on target
- Implementation of RAZAR in realistic team battles
- Implementation of LSAT in realistic team battles

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Questions????

Contact information

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ARDEC
973 724-9710
Alexander.lee5@us.army.mil

Malcolm Baldrige National Quality Award 2007 Award Recipient

NDIA Joint Armaments Conference May 2010

THE NEXT GENERATION

The case for a new NATO rifle and machine gun cartridge

ANTHONY G WILLIAMS
Independent Ammunition Consultant

THE LESSONS OF AFGHANISTAN

Characteristics:

- Precise targeting required with limited effects
- Collateral damage must be minimised
- Focus on infantry and their weapons

Key ammunition question:

Are the 5.56 mm and 7.62 mm cartridges optimal for the next generation of small arms?

THE RANGE PROBLEM



Biting the Bullet



By

Nicholas Drummond
Independent Strategy Consultant
and Former Infantry Officer

and

Anthony G. Williams
Independent Ammunition Consultant
and Co-editor of Jane's Ammunition Handbook

Why the time has come to acknowledge the significant limitations of 5.56 mm ammunition in British and NATO service and reconsider the case for replacing it with a larger, intermediate calibre – a solution regarded as ahead of its time when originally proposed by Britain more than 50 years ago.

BRITISH 5.56mm GUNS AND EFFECTIVE RANGES



L86A2 LSW

25in / 65cm barrel

300-400 metres

L85A2 rifle

20in / 52cm barrel

c.300 metres

L110A1 LMG

14in / 35cm barrel

c.200 metres

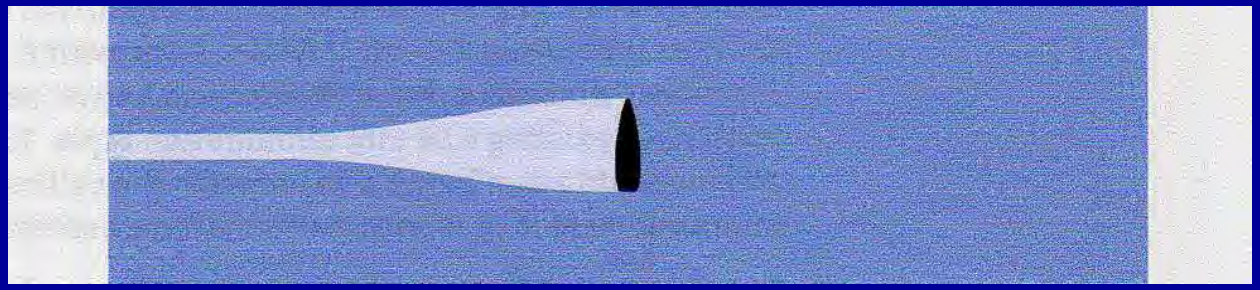


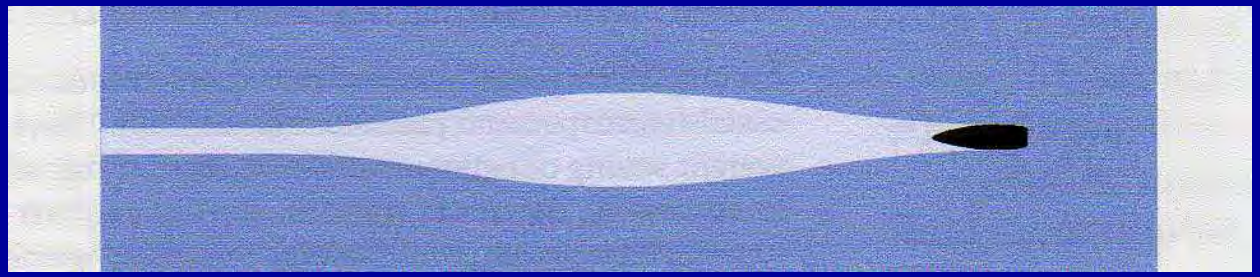
PROBLEMS WITH 5.56mm AMMUNITION

- More than 50% of engagements beyond effective rifle range (70% with short-barrelled guns)
- Inadequate suppressive effect (fire ignored)
- Unreliable terminal effectiveness (erratic yaw)
- Lack of barrier penetration (easily stopped or deflected)

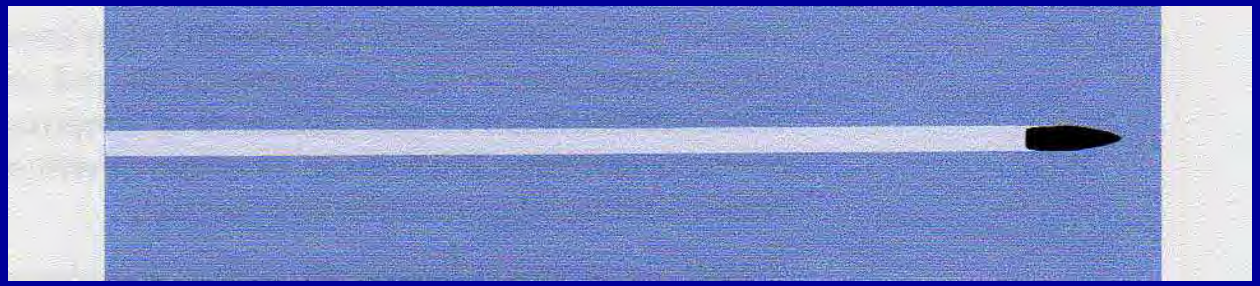
To maximise terminal effectiveness, the bullet needs to yaw rapidly on impact (as shown in the first three diagrams).







If bullet fails to yaw, it makes only a small wound channel



Time for a Change

U.S. Military Small Arms Ammunition
Failures and Solutions

NDIA Dallas, TX
21 May 2008

Gary K. Roberts, LCDR, USNR

Increasing Small Arms Lethality in Afghanistan: Taking Back the Infantry Half-Kilometer

A Monograph
By
Major Thomas P. Ehrhart
United States Army



School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas

AY 2009

INCREASED USE OF 7.62mm WEAPONS

L7A2 GPMG (right)

L129A1 (below)





DO WE NEED A NEW CARTRIDGE?

5.56 x 45

7.62 x 51



	Cartridge weight grains/gm	Bullet weight grains/gm	Muzzle velocity* fps/mps	Muzzle energy* ft lbs/joules
5.56mm M855	185/12	62/4.0	3,050/930	1,285/1,730
7.62mm M80	370/24	147/9.5	2,700/823	2,392/3,217

* From 20 inch (508mm) barrels

DO WE NEED A NEW CARTRIDGE?

5.56mm for urban fighting, 7.62mm for open terrain?

PROBLEMS:

1. Combat ranges may change rapidly
2. Mixed calibres in a squad reduces firepower
3. Doesn't help 5.56mm effectiveness & barrier penetration
4. Doesn't reduce weight & recoil of 7.62mm ammunition

WHAT DO WE NEED SMALL ARMS TO ACHIEVE?

REQUIREMENTS:

1. Reliable incapacitation
2. Good barrier penetration characteristics
3. Effective range to match full-power 7.62mm weapons
4. Lightest weight and lowest recoil consistent with 1-3

Ammunition selection is the key to achieving these

AMMUNITION OPTIONS

1. Retain the 5.56 and 7.62, but introduce an improved 5.56 loading

2. Return to using the 7.62, with an improved loading

3. Replace the 5.56 with a more effective short to medium range cartridge, retaining the 7.62 in DMRs and LMGs

4. Replace both existing rounds with a new intermediate cartridge with good long-range performance

AMMUNITION OPTIONS ASSESSED

1. 5.56mm too small; improvements use open-point bullets
2. 7.62mm inefficient; too much weight and recoil
3. 6.8mm Rem replaces 5.56mm, but can’t replace 7.62mm

RECOIL OF 5.56mm, 6.8mm, 7.62mm

Recoil of HK416/ 6.8 (middle) much closer to 5.56mm HK416 than to 7.62mm HK417



AMMUNITION OPTIONS ASSESSED

1. 5.56mm too small; needs open-point bullets
2. 7.62mm inefficient; too much weight and recoil
3. 6.8mm Rem replaces 5.56mm, but can't replace 7.62mm
4. The right calibre, bullet and ballistics can deliver a new general-purpose intermediate cartridge with a long-range performance good enough to replace 7.62 as well as 5.56

AMMUNITION OPTIONS HISTORY

.30’06 (1906+)
150gr / 9.7gm @ 2,700 fps / 823 mps

.276 Pedersen (c.1930)
125gr / 8.1gm @ 2,520 fps / 768 mps

7 x 43 British (c.1950)
140gr / 9.0gm @ 2,415 fps / 736 mps

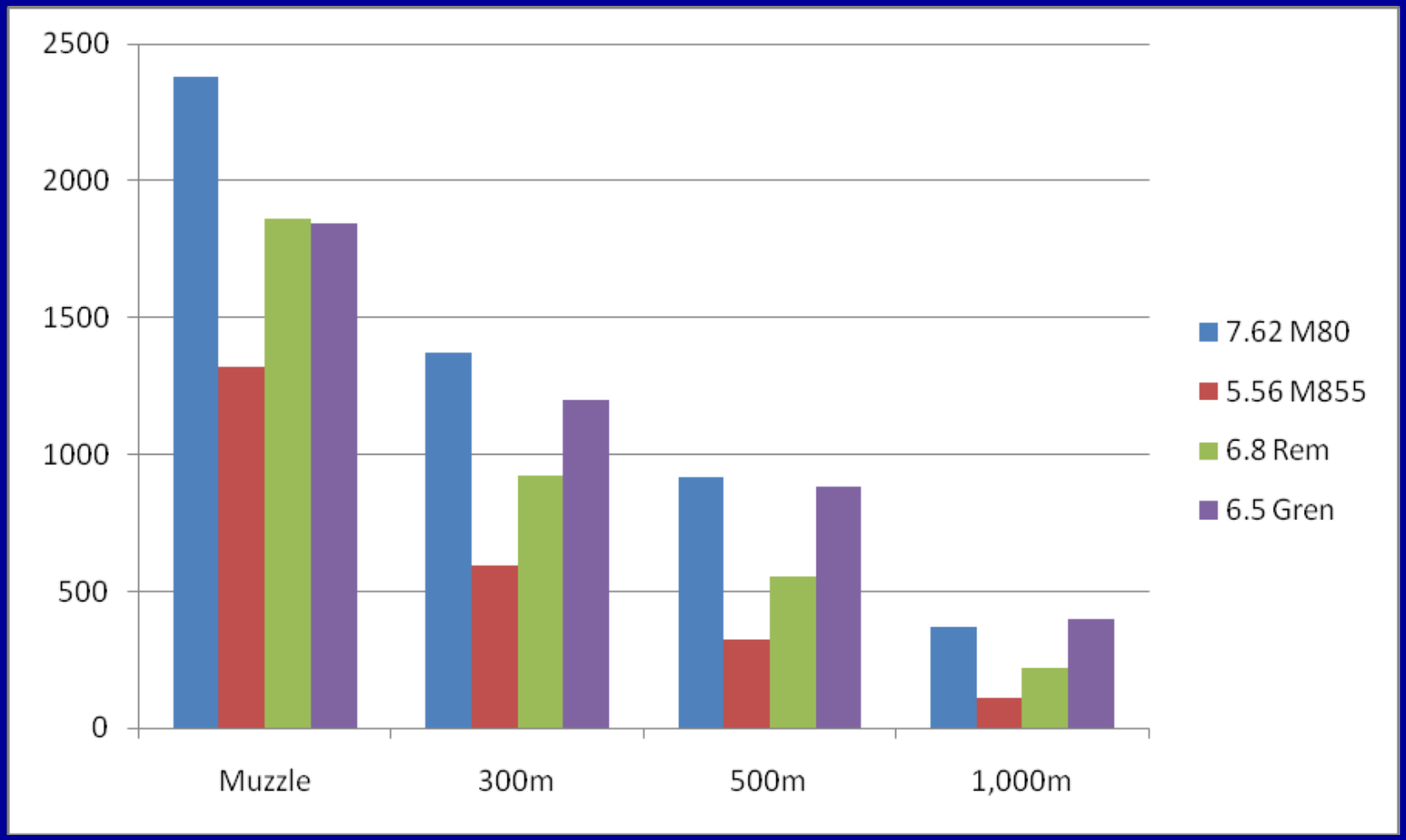
6.25 x 43 British (c.1970)
100gr / 6.5gm @ 2,680 fps / 817 mps

6 x 45 SAW (c.1970)
105gr / 6.8gm @ 2,520 fps / 768 mps

6.5mm Grendel (2000s)
123gr / 8.0gm @ 2,600 fps / 790 mps



BULLET ENERGY LOSS (ft/ lbs) WITH RANGE



CURRENT RIFLE ROUNDS & BULLETS



Left to right:

7.62x51 M80

5.56x45 SS109

6.8x43 Rem SPC 115 gr

6.5x38 Grendel 123 gr



AMMUNITION CHARACTERISTICS

1. Calibre between 6.5mm and 7mm
2. Low-drag bullet fired at medium velocity
3. Muzzle energy, weight & recoil midway between 5.56mm & 7.62mm
4. Performance at 1,000 metres to be comparable with 7.62mm M80
5. Anti-personnel effectiveness vital: rapid and reliable yaw on impact
6. Good barrier penetration characteristics
7. Must have FMJ option for universal use
8. Leave armour penetration to a specialised design

SOME POSSIBLE OPTIONS FOR A GENERAL PURPOSE CARTRIDGE

20 inch (508mm) barrels	Bullet weight grains/gm	Muzzle velocity fps/mps	Muzzle energy ft lbs/joules
7.62x51	147 / 9.5	2,700 / 823	2,392 / 3,217
5.56x45	62 / 4.0	3,050 / 930	1,285 / 1,730
6.5mm GPC	115-123 7.45-8.0	2,690-2,600 820-790	1,855 / 2,500
6.8mm GPC	127-135 8.2-8.75	2,560-2,480 780-755	1,855 / 2,500
7mm GPC	133-142 8.6-9.2	2,500-2,420 760-740	1,855 / 2,500

Similar to the 6.5mm Grendel at the bottom of the range, the 7x43 British at the top

CURRENT AND POSSIBLE FUTURE ROUNDS



7.62x51 5.56x45 6.5x45? 6.8x45? 7x45?

The 6.5 x 45, 6.8 x 45 and 7 x 45 are photo mock-ups to give a visual impression of some of the possible options.

They are all based on a slightly extended 6.8 x 43 case.

ADVANCED AMMUNITION CONCEPTS

- Primary concern with bullet performance
- Issues raised equally applicable to conventional ammunition and advanced types
- If LSAT or other advanced types adopted, we should take the opportunity to investigate the optimum calibre rather than copy what we already use

OBJECTIONS TO A NEW CARTRIDGE

1. The ammunition's OK – improve the training
2. There is no such thing as a golden bullet
3. Small arms irrelevant at long range
4. It would cost too much
5. Afghanistan is not typical
6. The USA must get involved

RESPONSES TO OBJECTIONS

1. Training is vital but can't compensate for everything
2. The smaller the cartridge, the more likely it is to fail
3. Heavy fire support may not be available or usable
4. New round phased in as weapons replaced
5. Afghanistan may be typical of the future: but ammo better than 5.56mm and lighter than 7.62mm always useful
6. The USA must get involved!

PROPOSAL

Small-scale research & development project to:

1. Determine the optimum calibre and ballistics
2. Produce conventional options for thorough testing
3. Provide input to LSAT and other advanced technologies
4. Provide a conventional back-up in case it's required

Very low costs and risk, but high potential benefits

Let's get it right next time!

Anthony G Williams

Independent Ammunition Consultant

http://www.quarry.nildram.co.uk/

tony.williams@quarry.nildram.co.uk



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Small Arms Modeling and Simulation

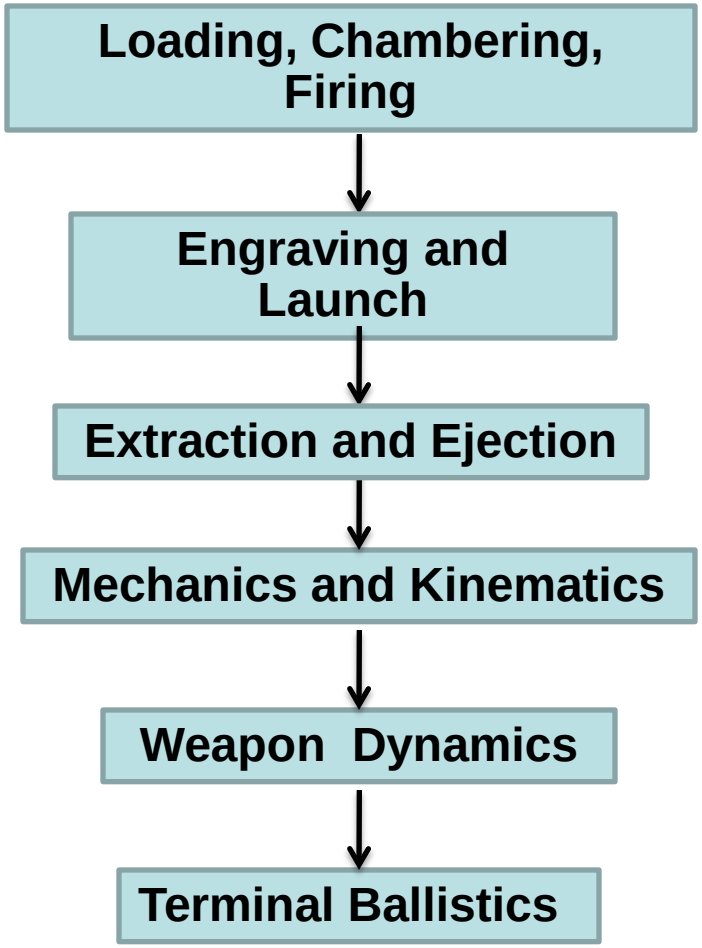
Clint Fischer
Weapons Technology Branch
Weapon Systems & Technology
Picatinny Arsenal RDECOM-ARDEC

TOPICS COVERED

- Review of Small Arms Modeling: Tools, Capabilities, and Goals
- Update on Computational Fluid Dynamics Models
- Conclusions
- Future Plans

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Goal : Virtual analysis of all aspects of weapon operation



- Saves Time / Money – reduces live fire
- Some aspects cannot be obtained in live fire

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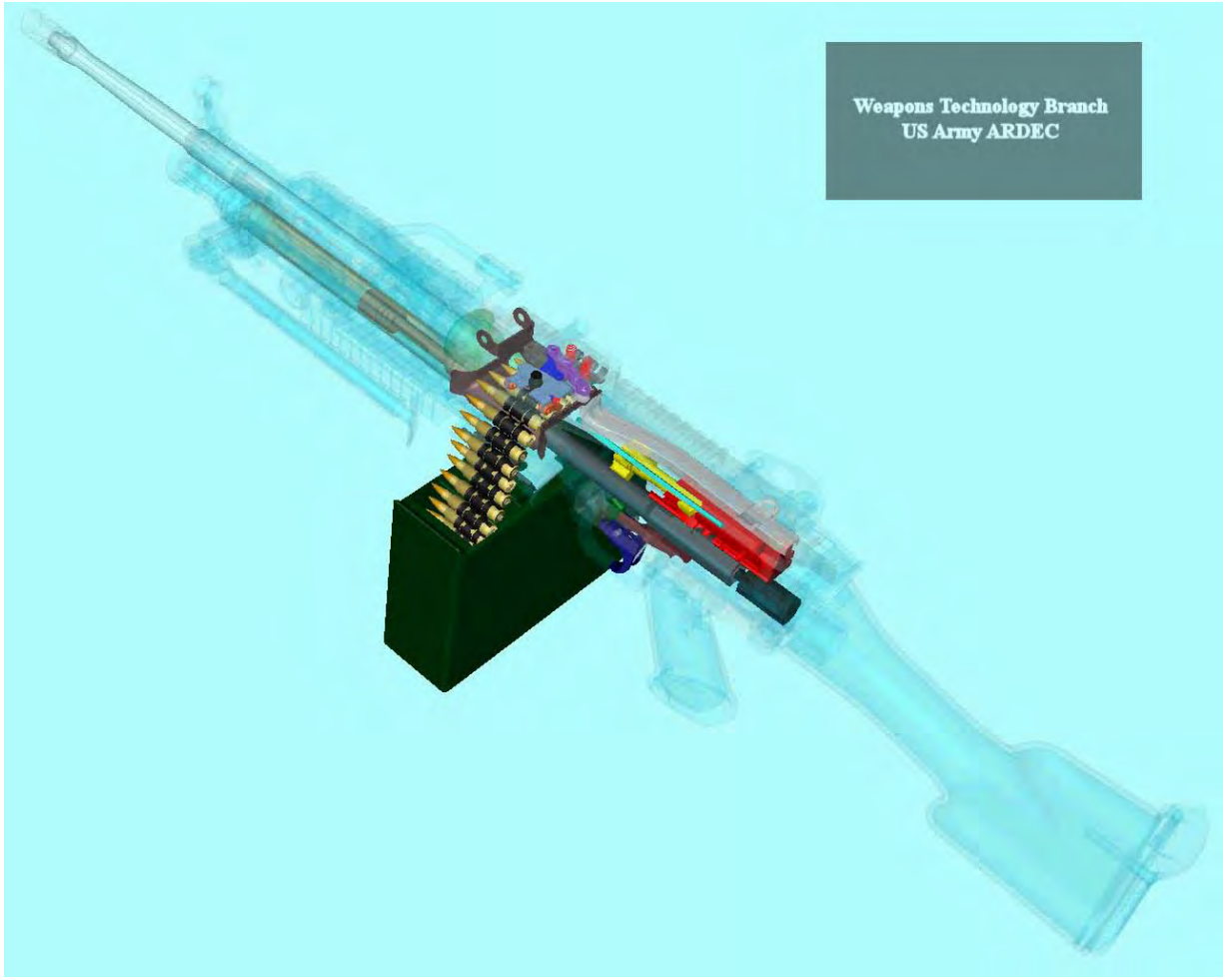
ANALYSIS TOOLS

Computational and Empirical Methods

- Physical Geometry
- Dynamics/Kinematics
- Finite Element Analysis
- Computational Fluid Dynamics

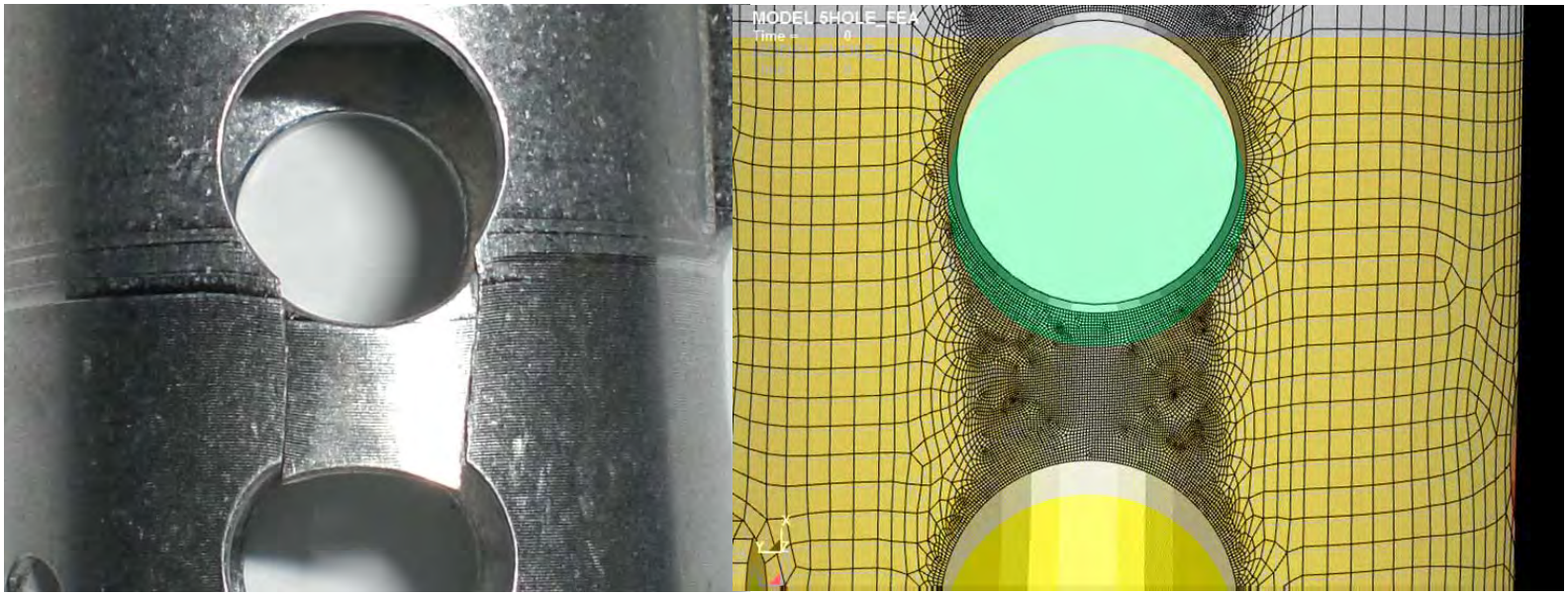
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DYNAMIC ANALYSIS



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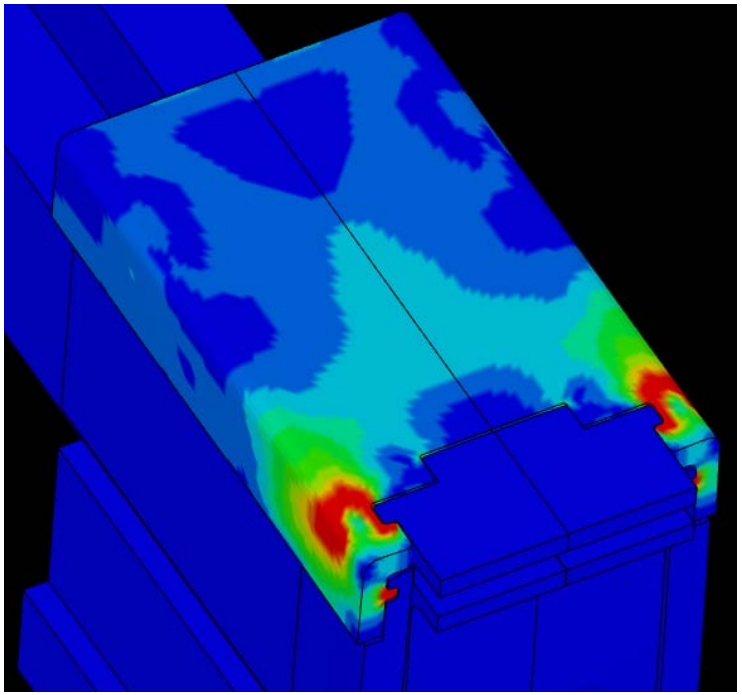
FEA - WEAPON



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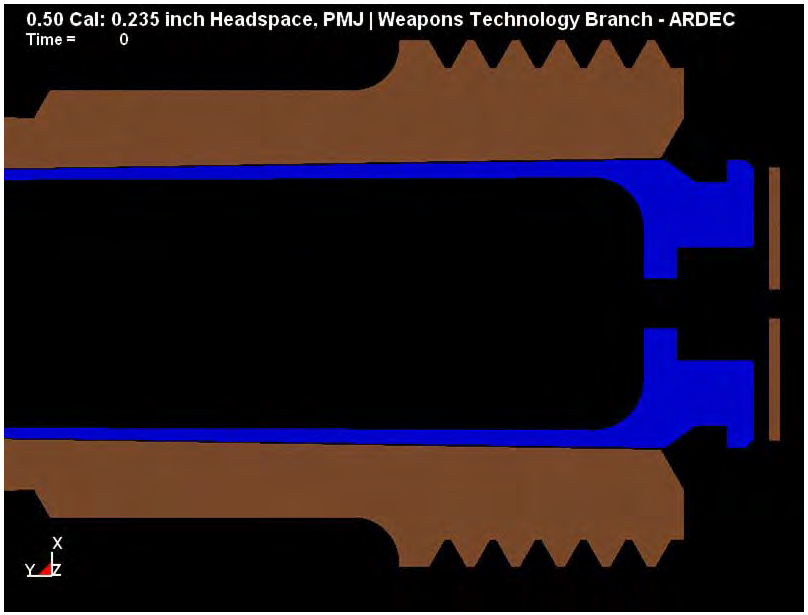
Fatigue - WEAPON

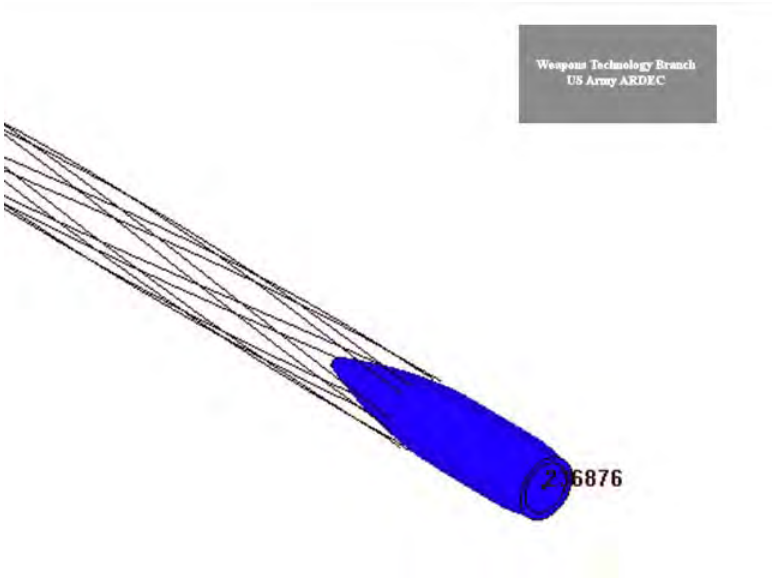




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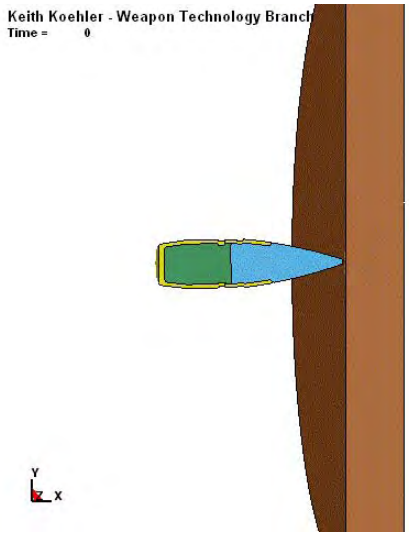
AMMUNITION

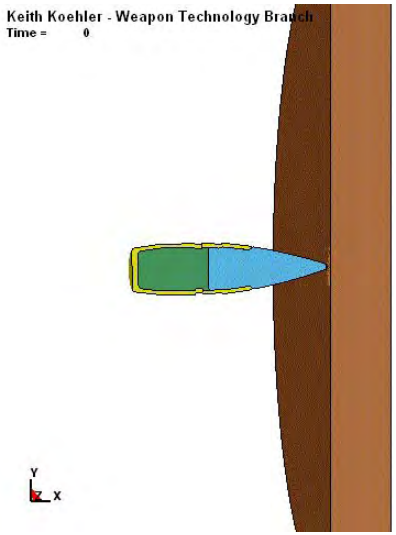


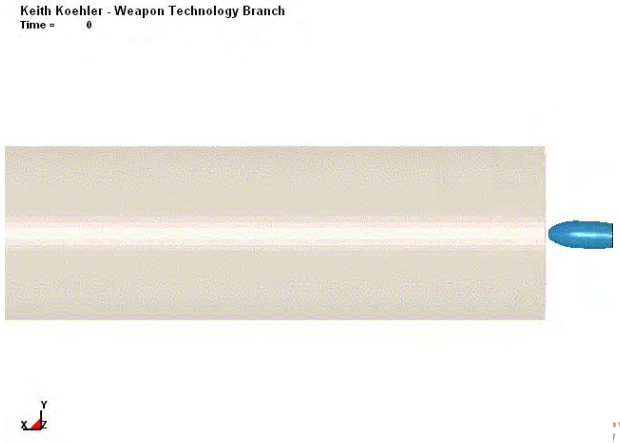


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FEA – TERMINAL BALLISTICS

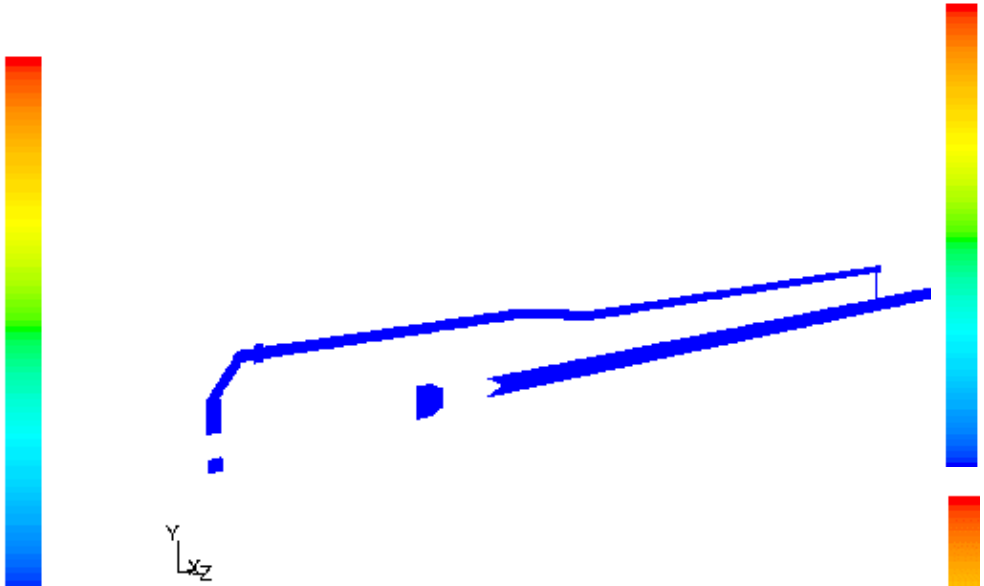




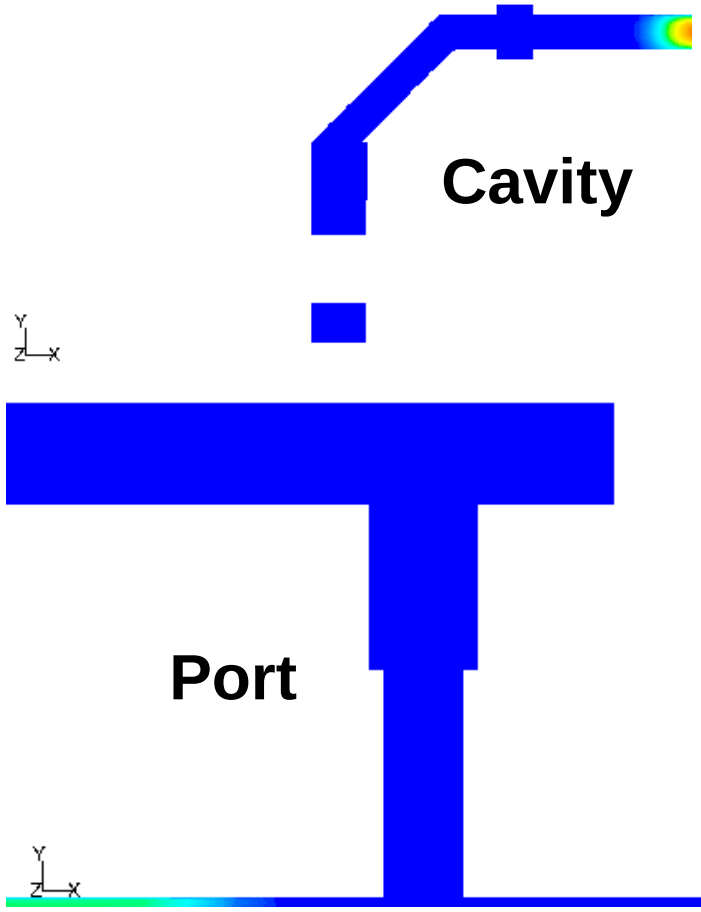


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CFD – WEAPON & AMMUNITION



Bullet Motion/gas bleed-off



Velocity Contours

Malcolm Baldrige National Quality Award

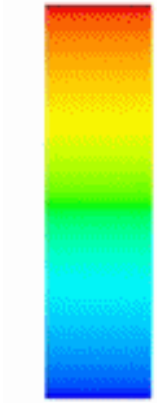
CFD MODELING UPDATE

- Barrel heating
- Internal particle flow carried with gas and particle impact based erosion
- Muzzle flow

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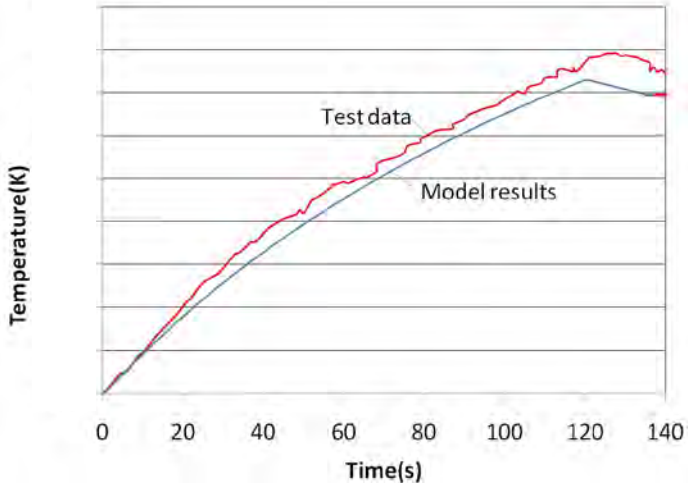
Modeling & Simulation Capabilities
CFD – Barrel Heating

- Predicts system temperatures for multiple shots
- Based on single shot heat input
- Accounts for effects of cartridge insertion and extraction and magazine change
- Investigates effect of firing rate





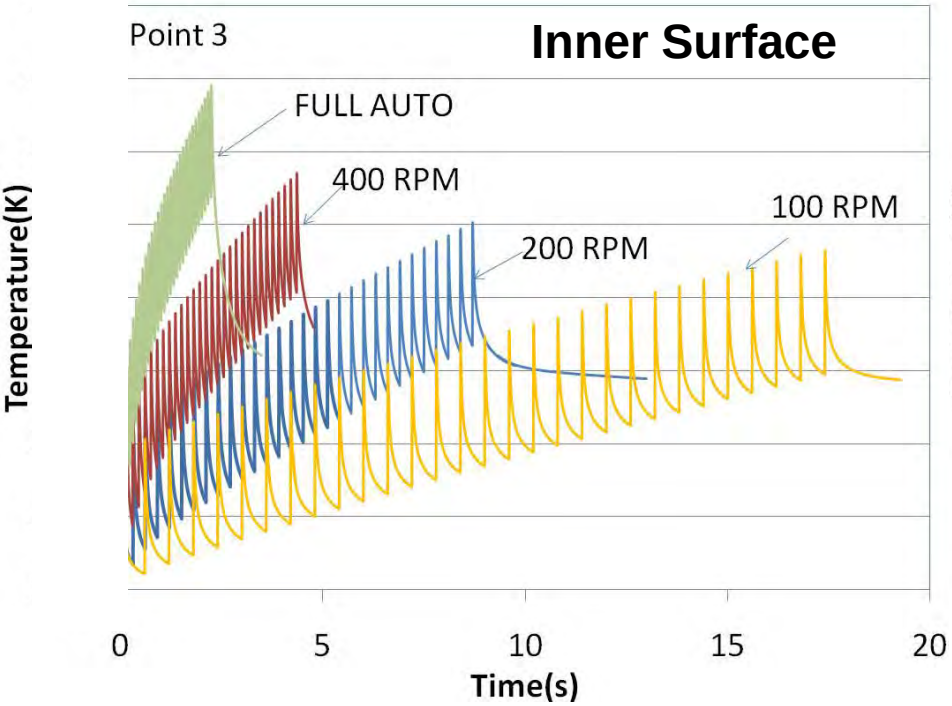
Temperatures

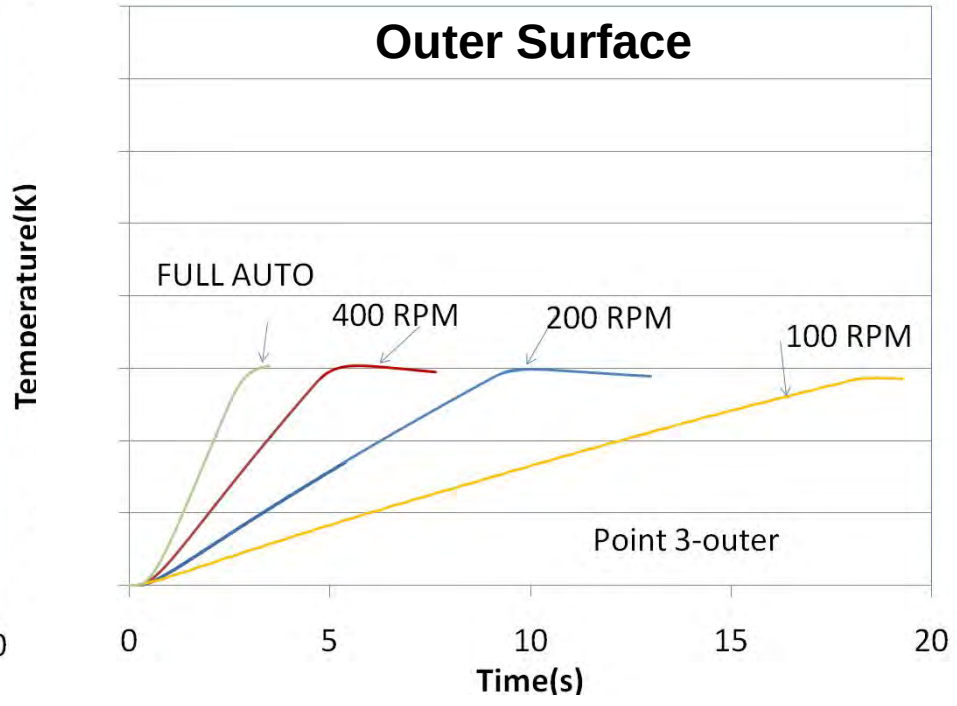


Comparison to experiment – outer barrel surface at muzzle

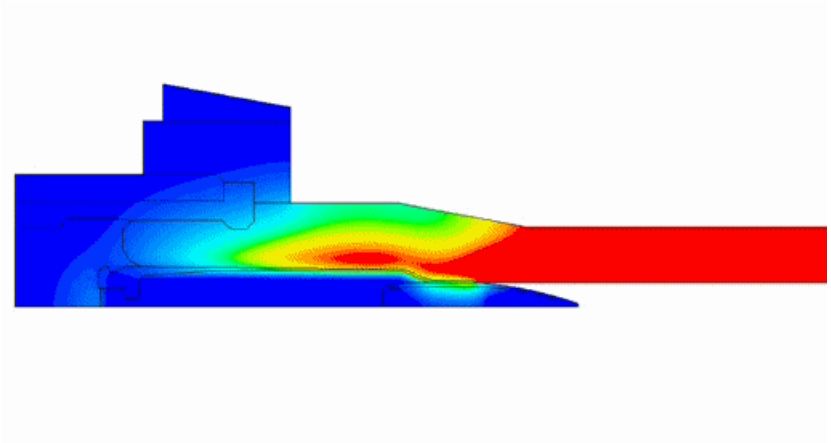
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Modeling & Simulation Capabilities
CFD – Heat Transfer





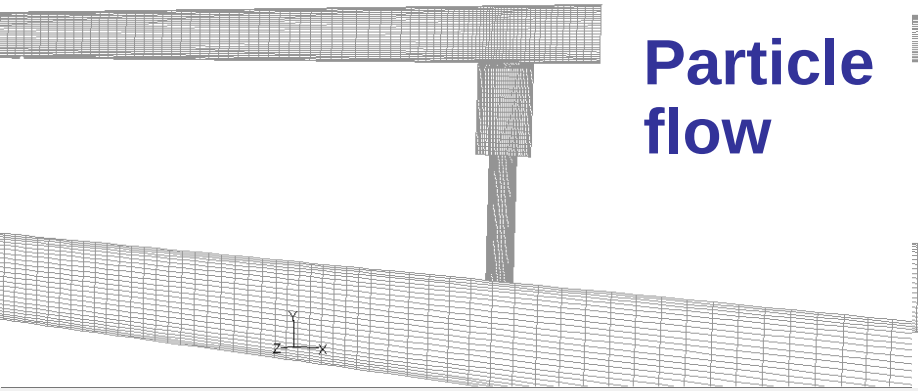




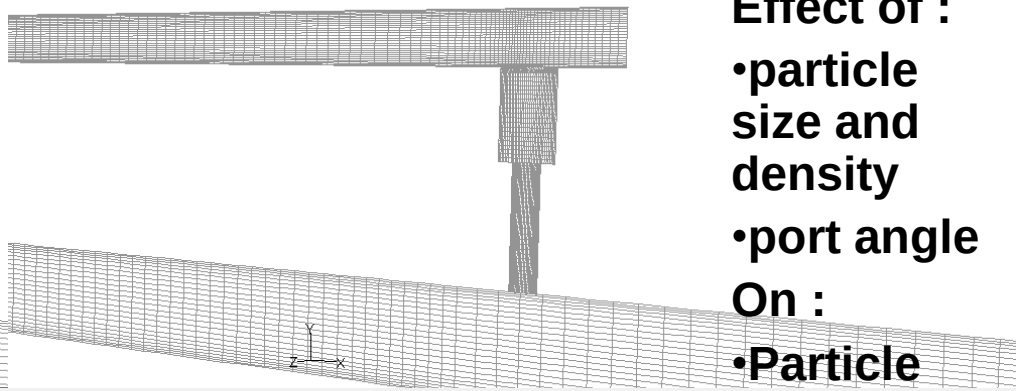
Temperatures of round inserted into heated barrel

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Modeling & Simulation Capabilities
CFD – Particle Flow



Particle flow



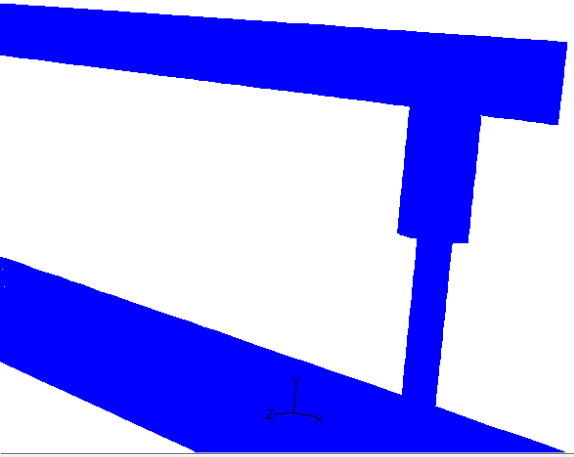
Small and light | **Large and heavy**

Effect of :

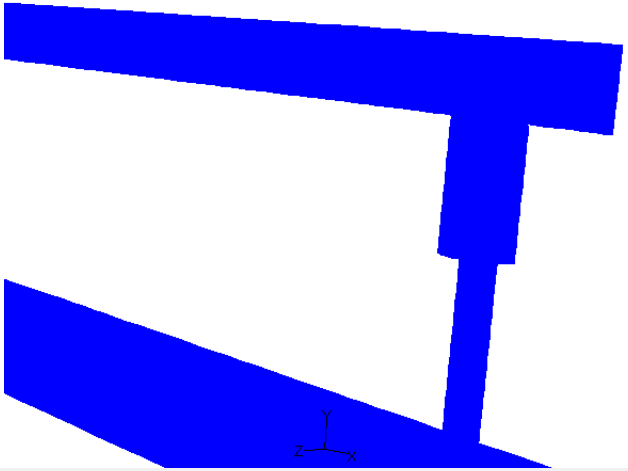
- **particle size and density**
- **port angle**

On :

- **Particle motion**
- **Particle impact based erosion**



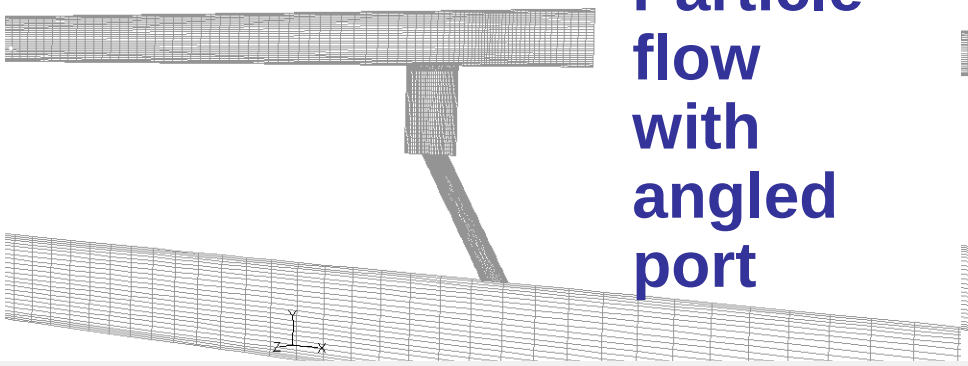
Particle impact based erosion

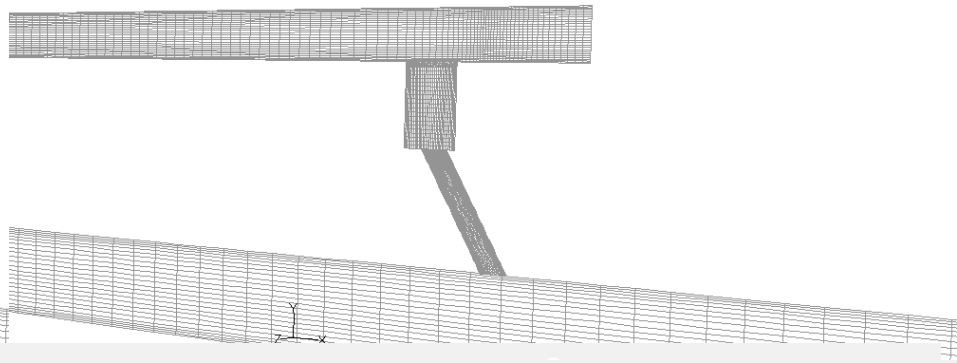


Small and light | **Large and heavy**

Modeling & Simulation Capabilities
CFD – Particle Flow – Angled Port

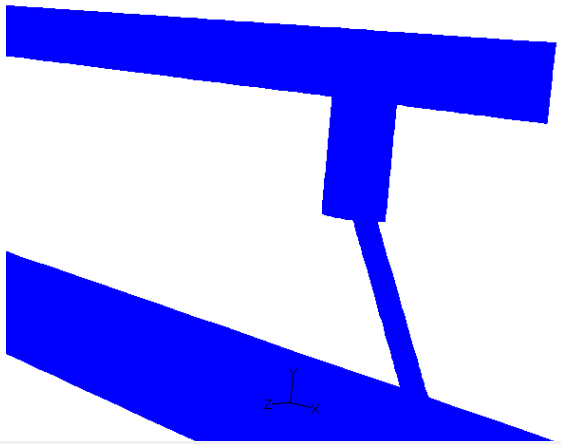
Particle flow with angled port

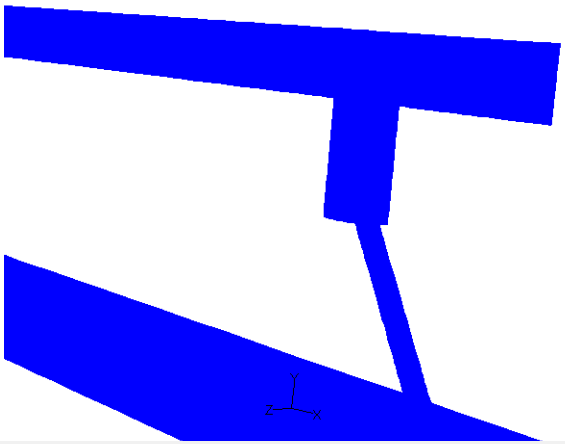




Small and light | **Large and heavy**

Particle impact based erosion



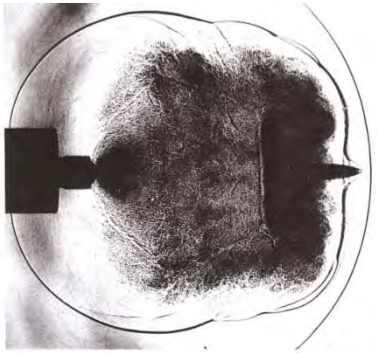


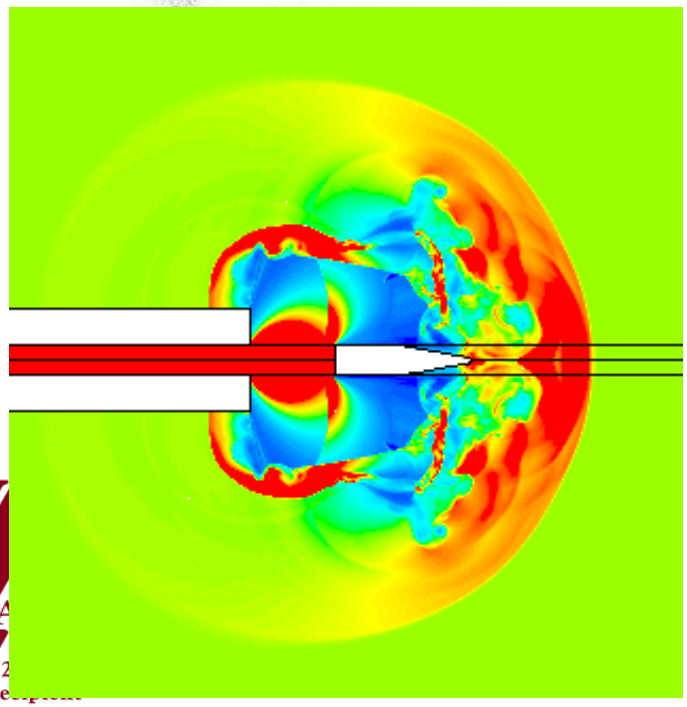
Small and light | **Large and heavy**

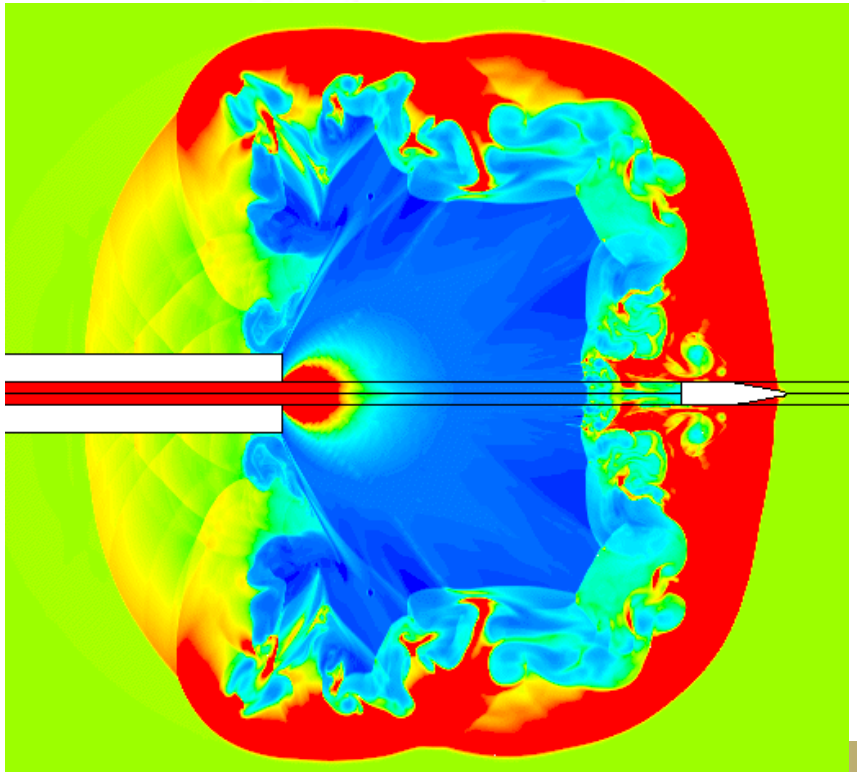
Modeling & Simulation Capabilities
CFD – Bare Muzzle – Shadowgraph

- Predict exiting flow patterns
- Compare muzzle device performance

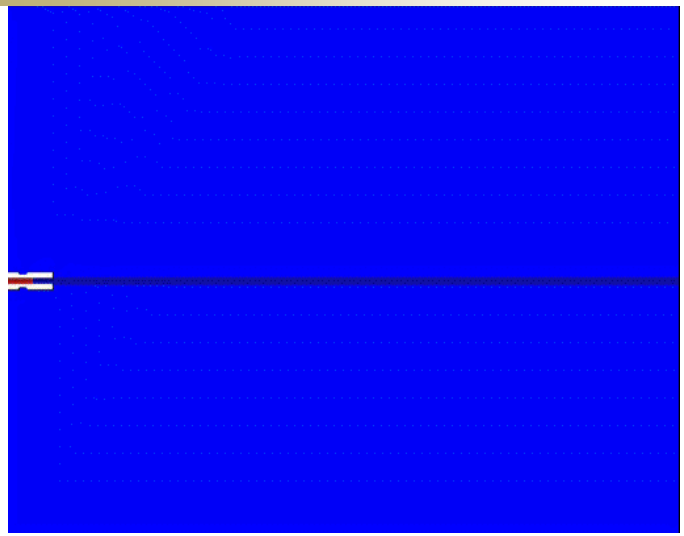




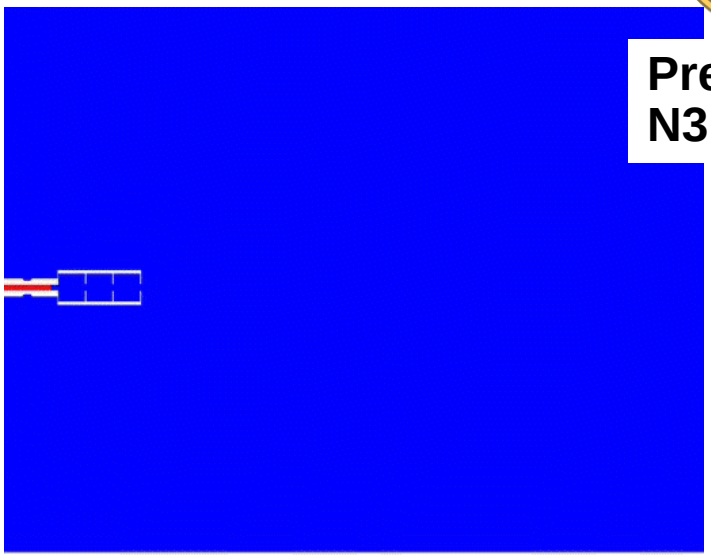




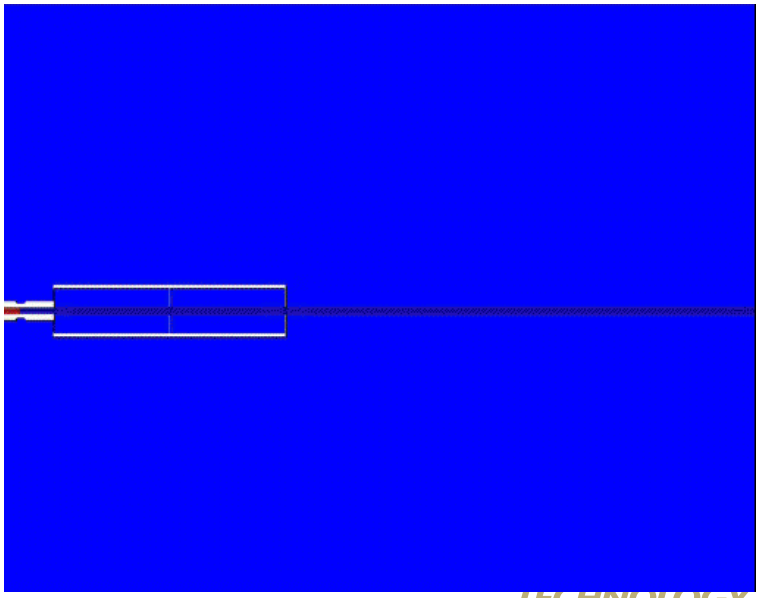
Modeling & Simulation Capabilities
CFD – Pressure Distributions

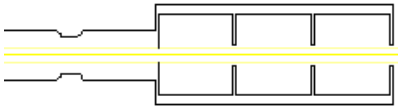


Pressure
Bare



Pressure
N3





Pressure
N2



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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

CONCLUSIONS

- Modeling and simulation :
  - Requires level of expertise and knowledge to properly simulate the weapon operation
  - Provides information not easily obtainable in physical testing
  - Can assist in identifying potential causes of issues
  - Can improve efficiency and effectiveness of the design process

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FUTURE PLANS

Along the modeling and simulation capabilities “roadmap”

- Further refinement and improvement of modeling techniques for more robust models
- New development areas :
  - Wear
  - Reliability
  - Materials
  - Chemistry
  - Particle-particle interaction
- Coupling of Dynamic, FEA, CFD modeling

CONTACT INFORMATION

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REDUCED RANGE (RR)

AMMUNITION

2010
MAY 19

FOR TRAINING AND URBAN COMBAT

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Nammo

2010

NAMMO VANÄSVERKEN AB

LOCATION



ZOOM : LOCATION 170 %
SWEDEN

Nammo
Vanäsverken AB

RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

2010

TOPICS

DEVELOPMENT OF 7.62 RR

[Reduced Range Ball Ammunition]

- Customer Requirements
- Projectile Development
- Tuning Characteristics
- Summary

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7.62 **RR**

- CUSTOMER REQUIREMENTS

- **Need for ammunition with reduced safety template**
  - Training
  - Combat
- **Maximum Range ≤ 1500 m** (1640 yds)
- **Trajectory match Nato reference @ 200 m** (220 yds)
- **Accuracy compared to Nato reference @ 100 m** (110 yds)
- **Meet relevant STANAG requirements**
  - Terminal effects
  - Weapon function in complete temperature intervall
- **Non Toxic (lead- and heavy metal free)**

- **Price competitive**
  - Possible to produce with standard machinary

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TRAINING & COMBAT OPERATIONS

2010

- **Training**
  - MOUT training
  - Firing ranges near populated areas
  - Firing from moving vehicles

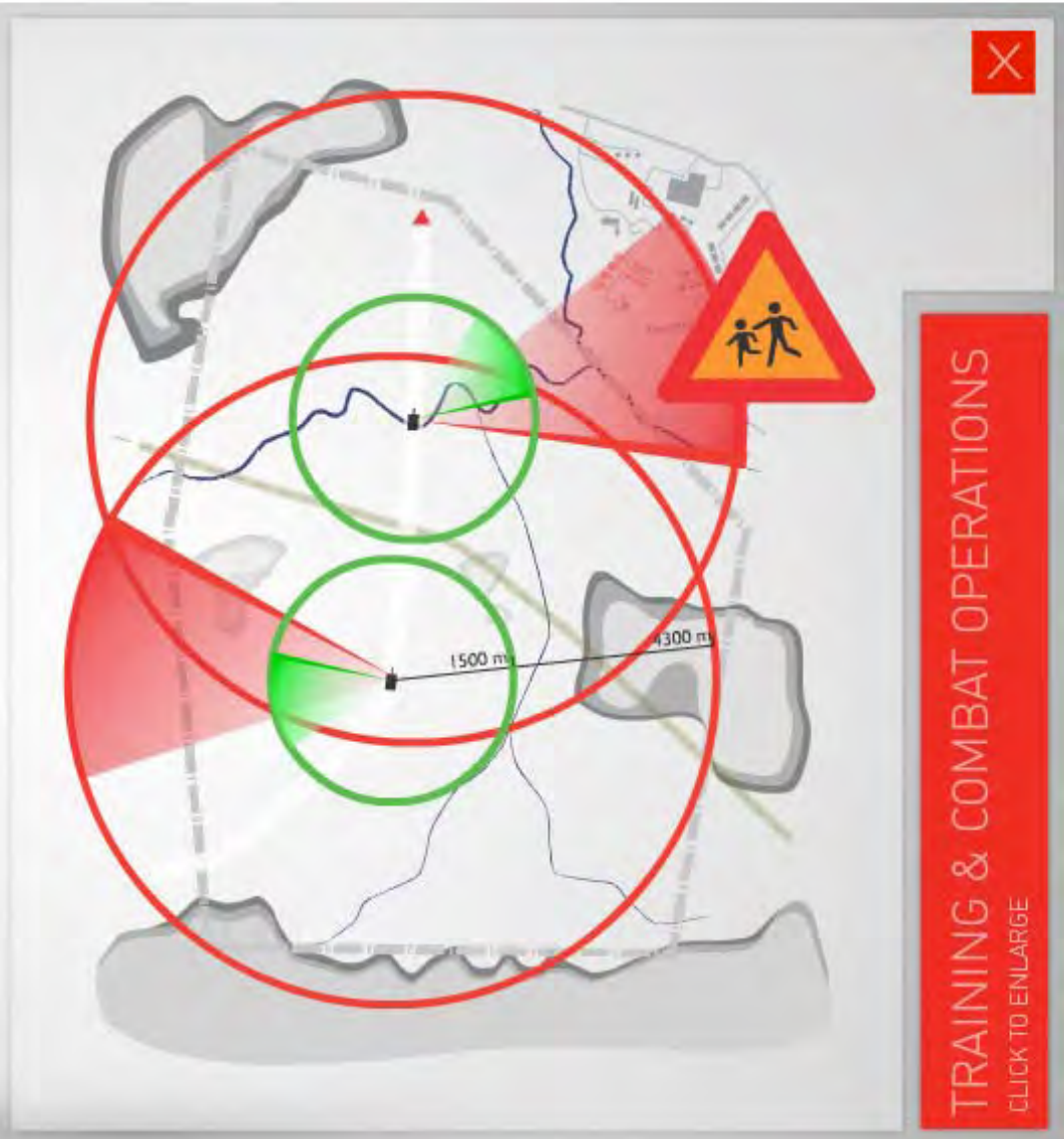
- **Urban Combat Operations**
  - Typical maximum range =
    200 m (220 yds)
  - Typical average fighting distances =
    15-35 meters (~15-40 yds)
  - 360 Degree awareness, hemispherical (Convoy)



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RR 7.62
Reduced Range
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TRAINING & COMBAT OPERATIONS
CLICK TO ENLARGE

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REDUCED RANGE

BASED ON NAMMO NON TOXIC DESIGN

- All Swedish and Norwegian standard ammunition is Non-Toxic
- Non-Toxic = Lead/heavy metal free (primer, propellant & projectile)
- 5.56, 7.62 and 9 mm
  - Ball & Tracer
  - Produced since 2000
- Four Non-Toxic cartridges Nato Qualified



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

Nammo

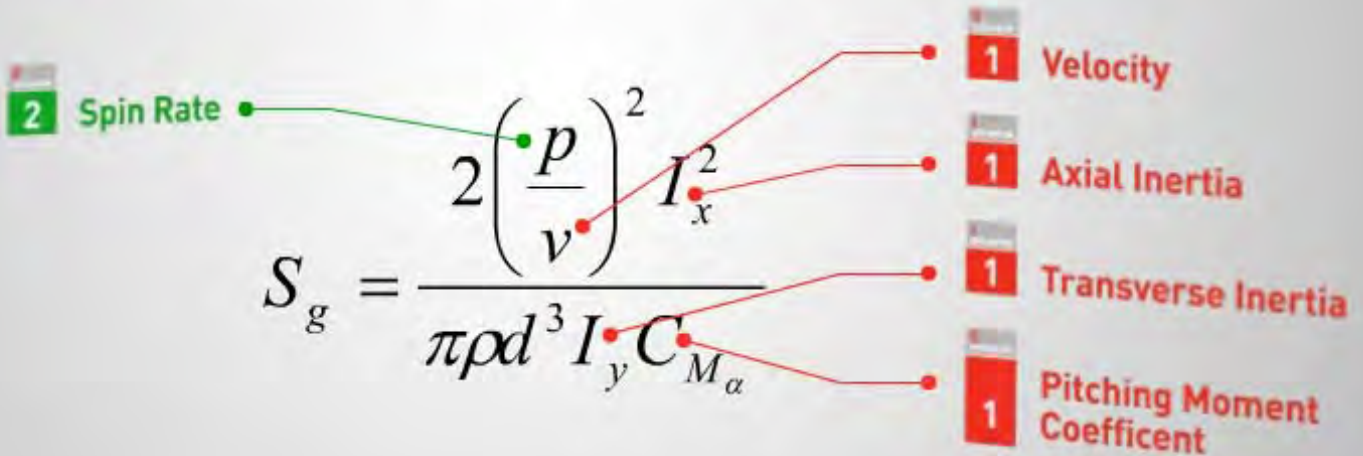
REDUCING

THE MAXIMUM FLIGHT RANGE

- Reduce the projectile stability
- S_g – Gyroscopic Stability Factor

1 Reduce muzzle exit stability compared to standard ammunition

2 Reduce stability downrange at a defined distance



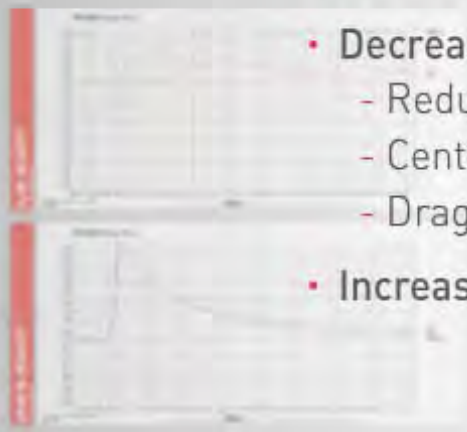
RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

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MUZZLE EXIT STABILITY

- BASIC DESIGN

- Different projectile profiles evaluated with Prodas simulation programme
- Decreased stability caused by:
  - Reduced weight & density (Transverse & Axial inertia)
  - Center of Gravity pushed towards tail
  - Drag Center of Pressure pushed forward
- Increased Drag value



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

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2010

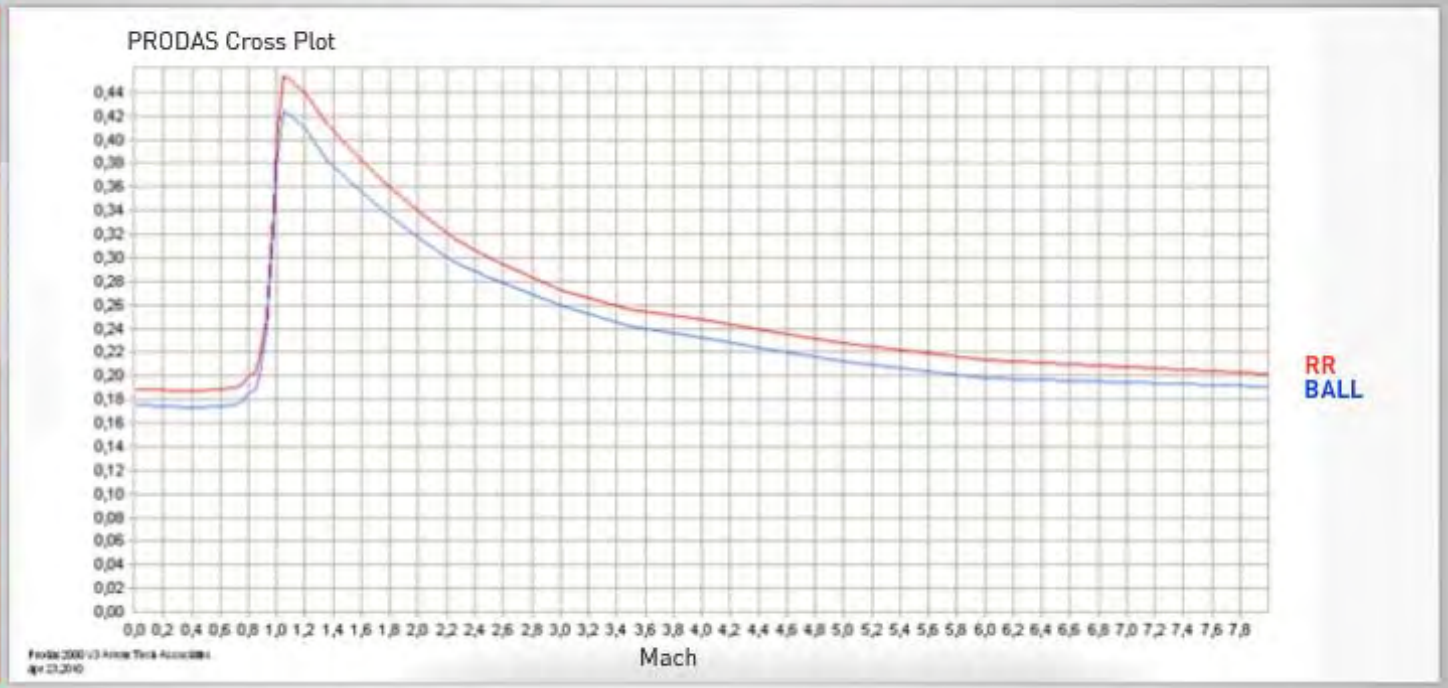
MUZZLE EXIT STABILITY

- BASIC DESIGN



DRAG VS. VELOCITY

CLICK TO ENLARGE



RR 7.62

Reduced Range

SMALL ARMS AMMUNITION

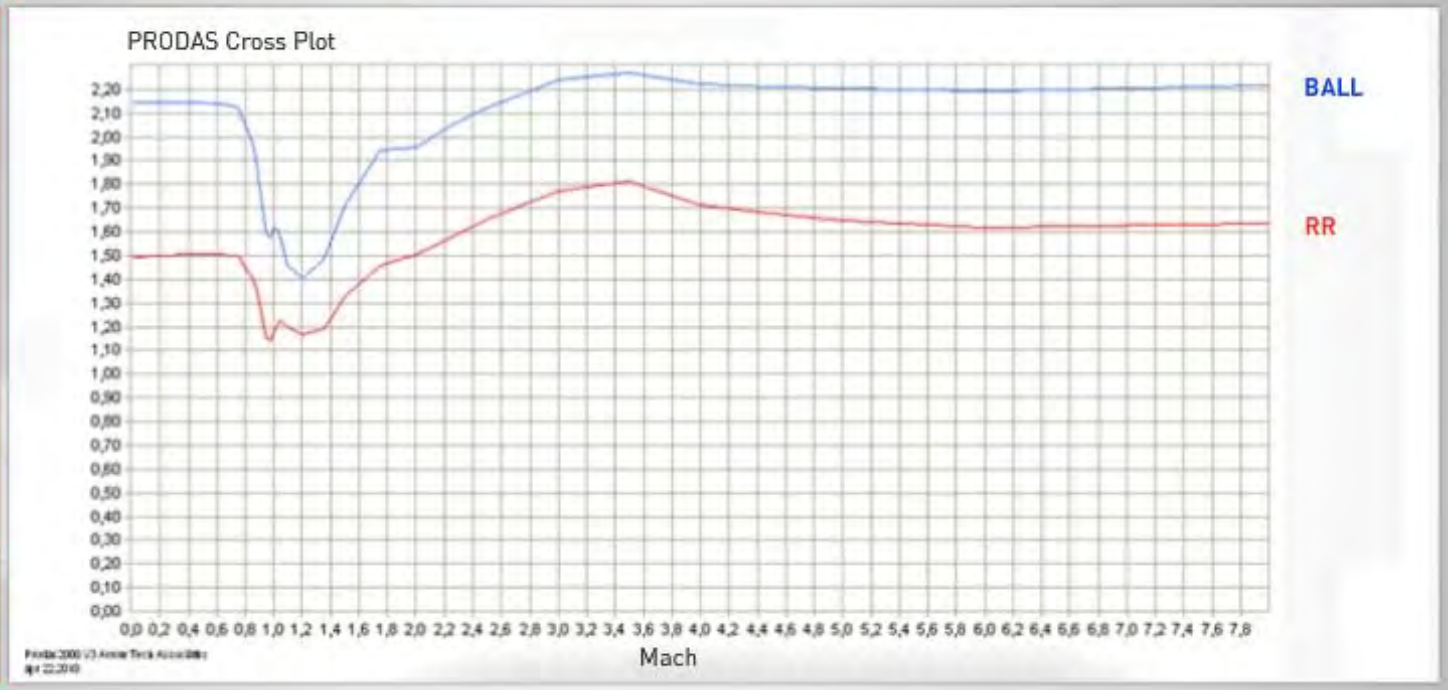
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MUZZLE EXIT STABILITY

- BASIC DESIGN

Sg VS. VELOCITY



RR 7.62

Reduced Range

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DOWNRANGE STABILITY

- REDUCING SPIN

- Reduce spin by air braking flutes
- Position, number and basic geometry of flutes were optimized
  - First developed with 12.7mm (.50cal)
  - Test firings with Doppler radar measurements
  - Adapted for 7.62 mm
- Design Conclusions:
  - Flutes on projectile tip
  - Three flutes more stable and manufacturable than 4 or 5
  - Flute length maximized for portion outside cartridge case



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

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2010

DOWNRANGE STABILITY

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  - First developed with 12.7
  - Test firings with Dopple
  - Adapted for 7.62 mm
- **Design Conclusions:**
  - Flutes on projectile tip
  - Three flutes more stabl
  - Flute length maximized





MODEL 01

MODEL: 02

CLICK TO ENLARGE



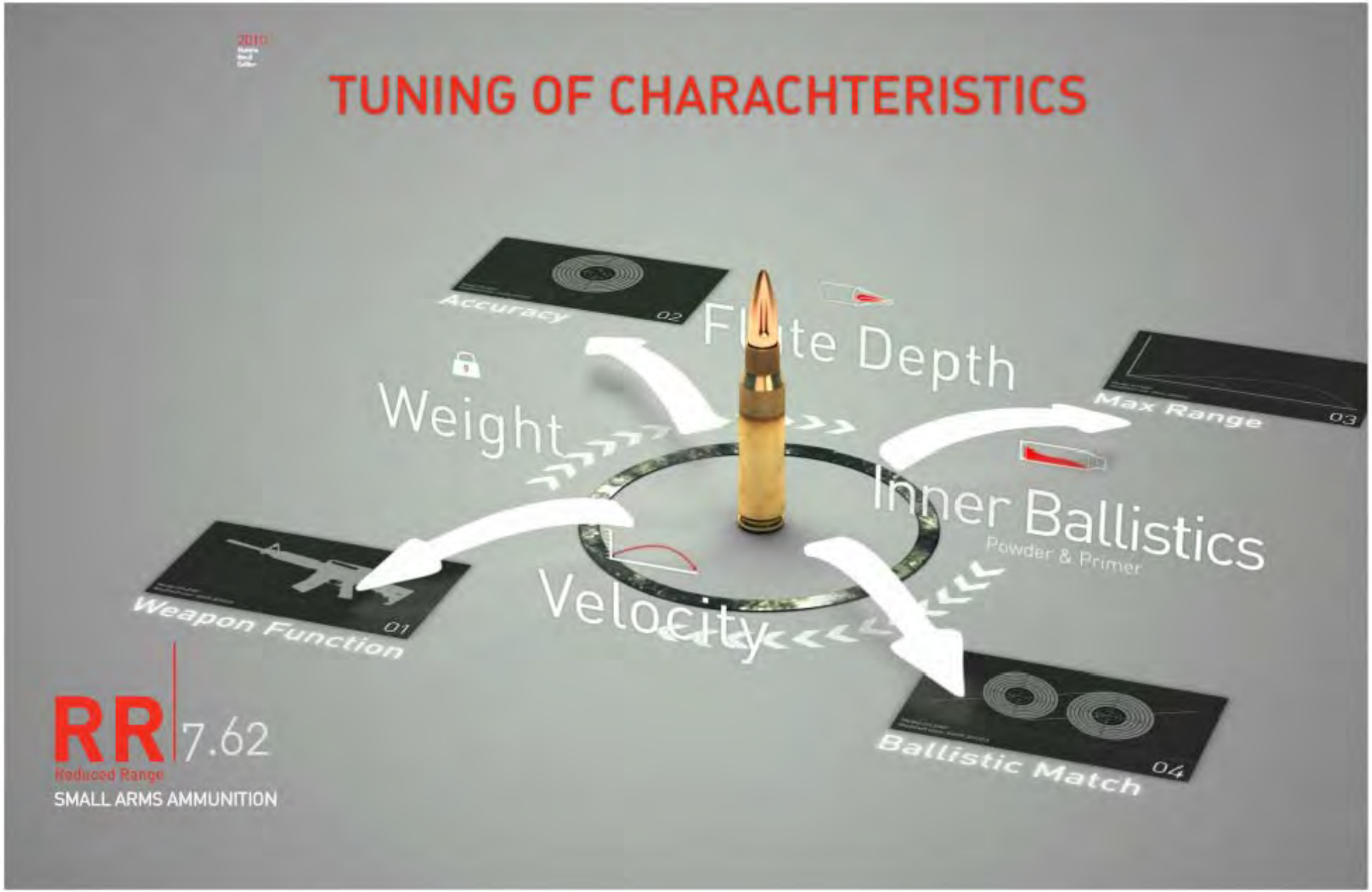
MODEL 03

RR 7.62

Reduced Range

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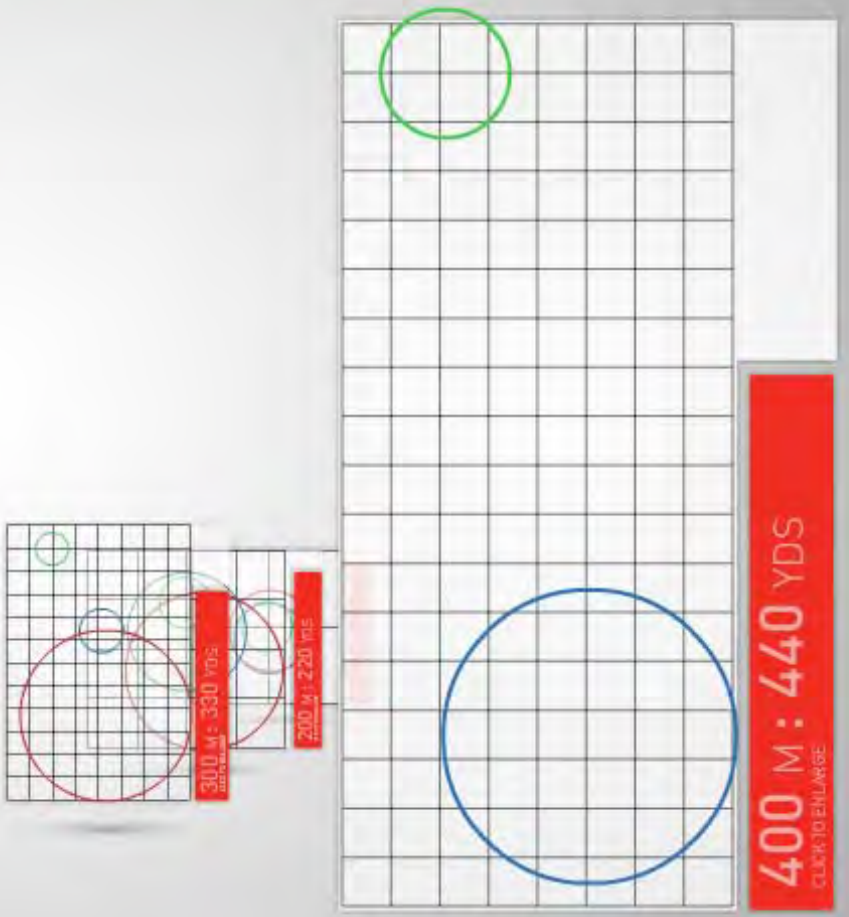

TUNING OF CHARACHTERISTICS
Accuracy
02
Flute Depth
Max Range
03
Weight
Inner Ballistics
Powder & Primer
Weapon Function
01
Velocity
Ballistic Match
04
RR 7.62
Reduced Range
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TRAJECTORY & ACCURACY

2010

- Live Firing Tests
- Mean point of impact and Extreme spread
- The square pattern has the side 100 mm (~4 inch)

Ball [reference]
RR [1]
RR [2]



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

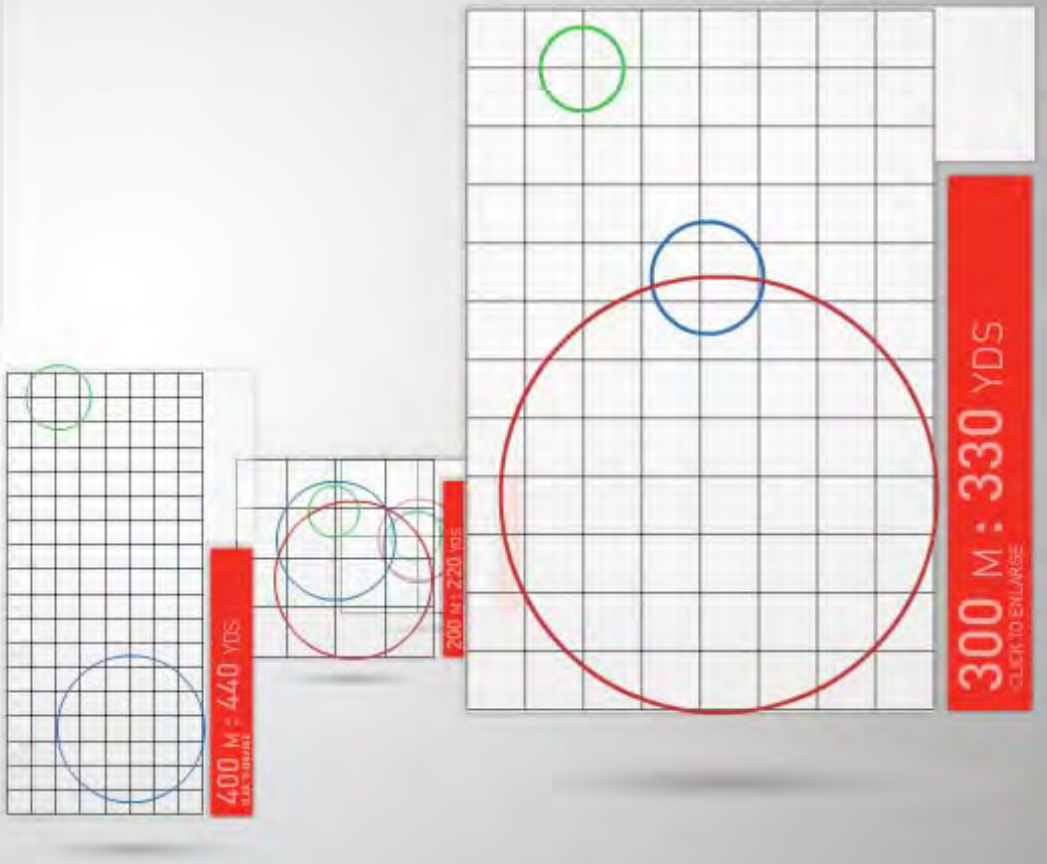
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TRAJECTORY & ACCURACY

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RR 7.62
Reduced Range
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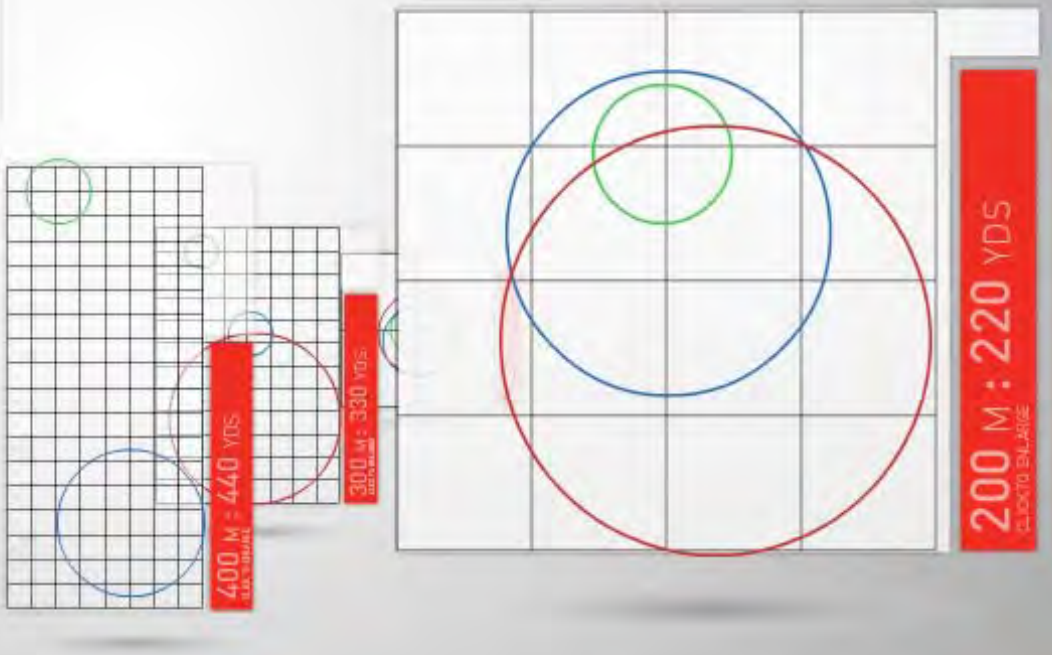
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TRAJECTORY & ACCURACY

2010

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RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

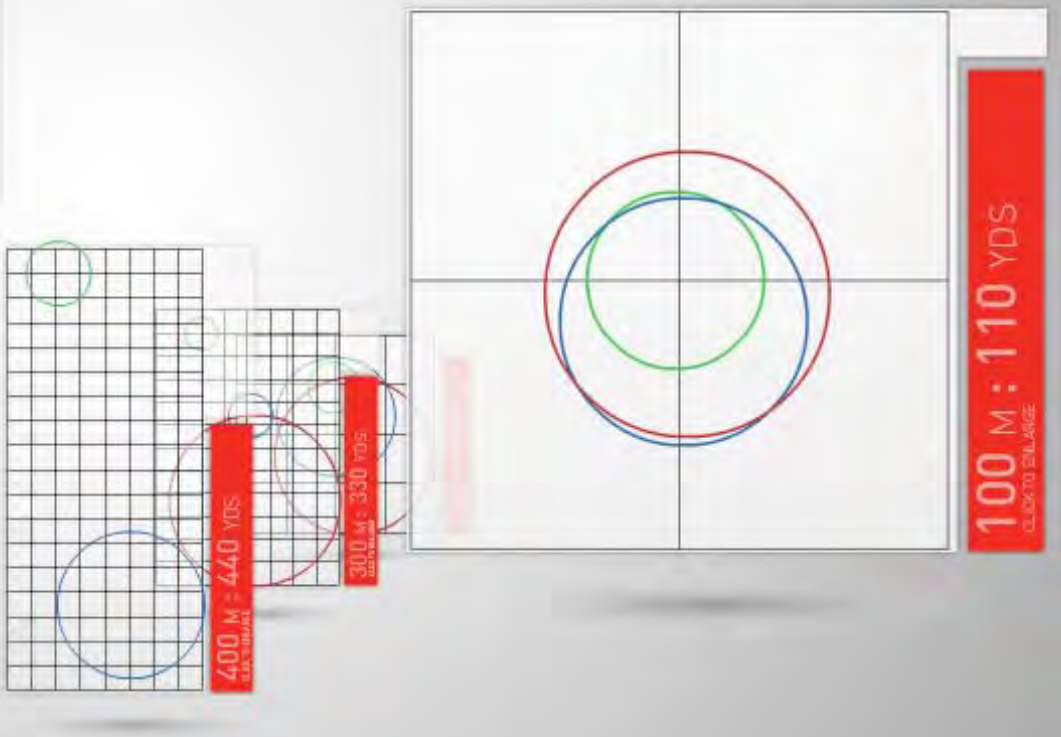
Nammo

TRAJECTORY & ACCURACY

2010

- Live Firing Tests
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Ball [reference]
RR [1]
RR [2]



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

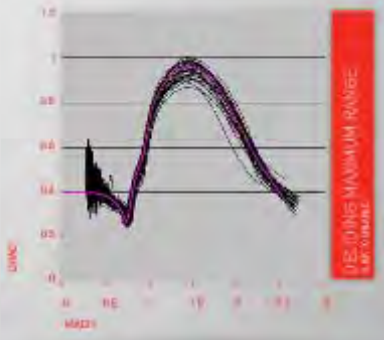
Nammo

2010

DECIDING MAXIMUM RANGE

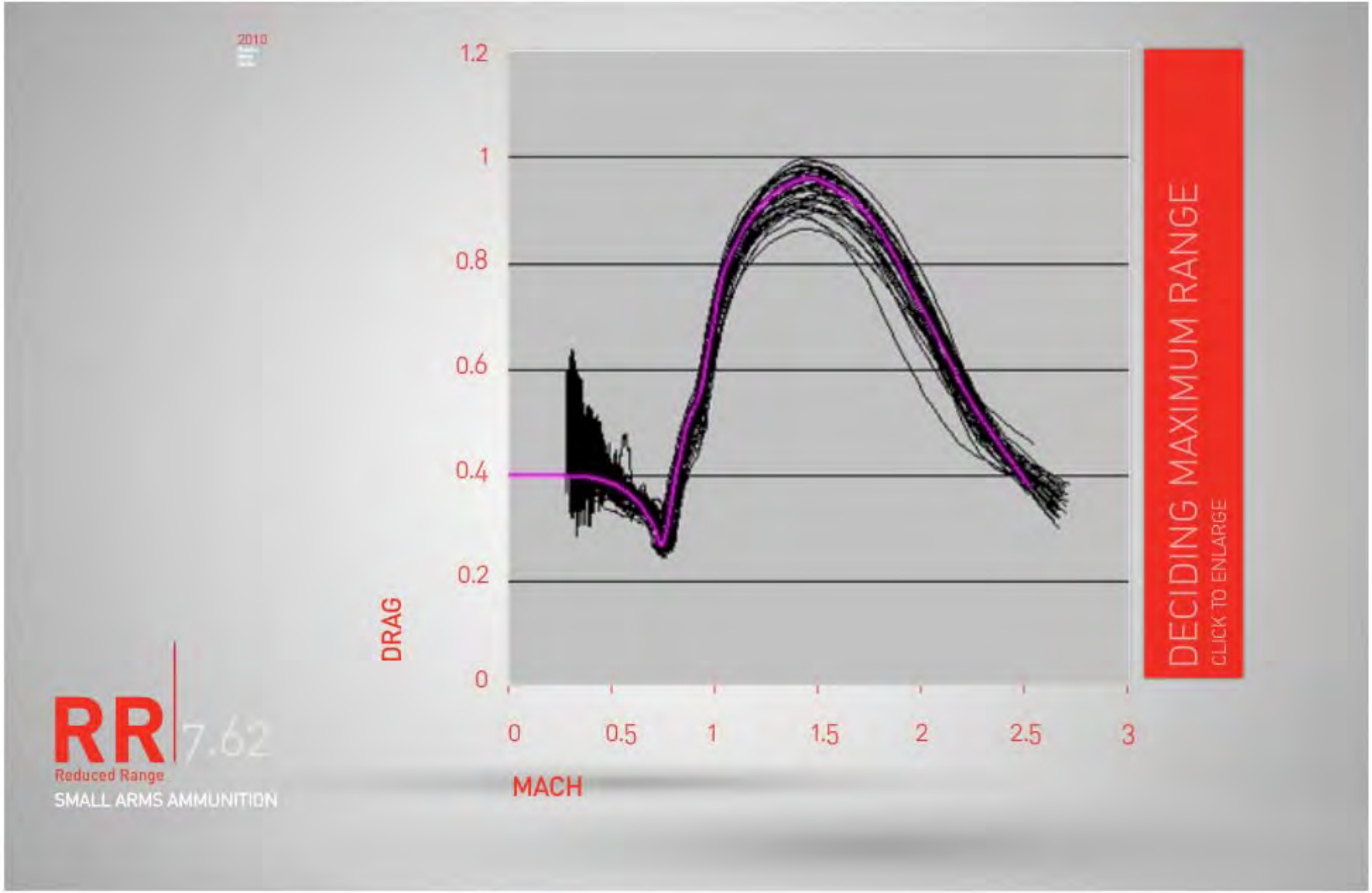
- **Maximum Range calculated with a Prodas model**
- **Non rotation symetric geometry**
  - Physical parameters from CAD model
    - Transverse Inertia
    - Axial Inertia
    - Center of Gravity

- **Drag values from shootings with doppler radar measurements**
  - Different elevation angles (15-30°)
  - Different projectile velocities
  - Consistent drag values measured (black lines)
  - Drag value in Prodas adapted (purple line)



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

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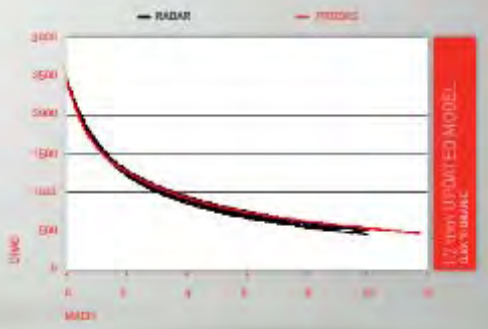

2010
1.2
1
0.8
0.6
0.4
0.2
0
DRAG
0
0.5
1
1.5
2
2.5
3
MACH
DECIDING MAXIMUM RANGE
CLICK TO ENLARGE
RR 7.62
Reduced Range
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2010

SPIN DECAY

- Evaluated by test firings with Doppler radar measurements
- V-shapen spin slot
  - Spin signals detected by radar
- Spin decay form factor added to Prodas and compared to radar data
- Pitching moment coefficient, CM_{α}, form factored

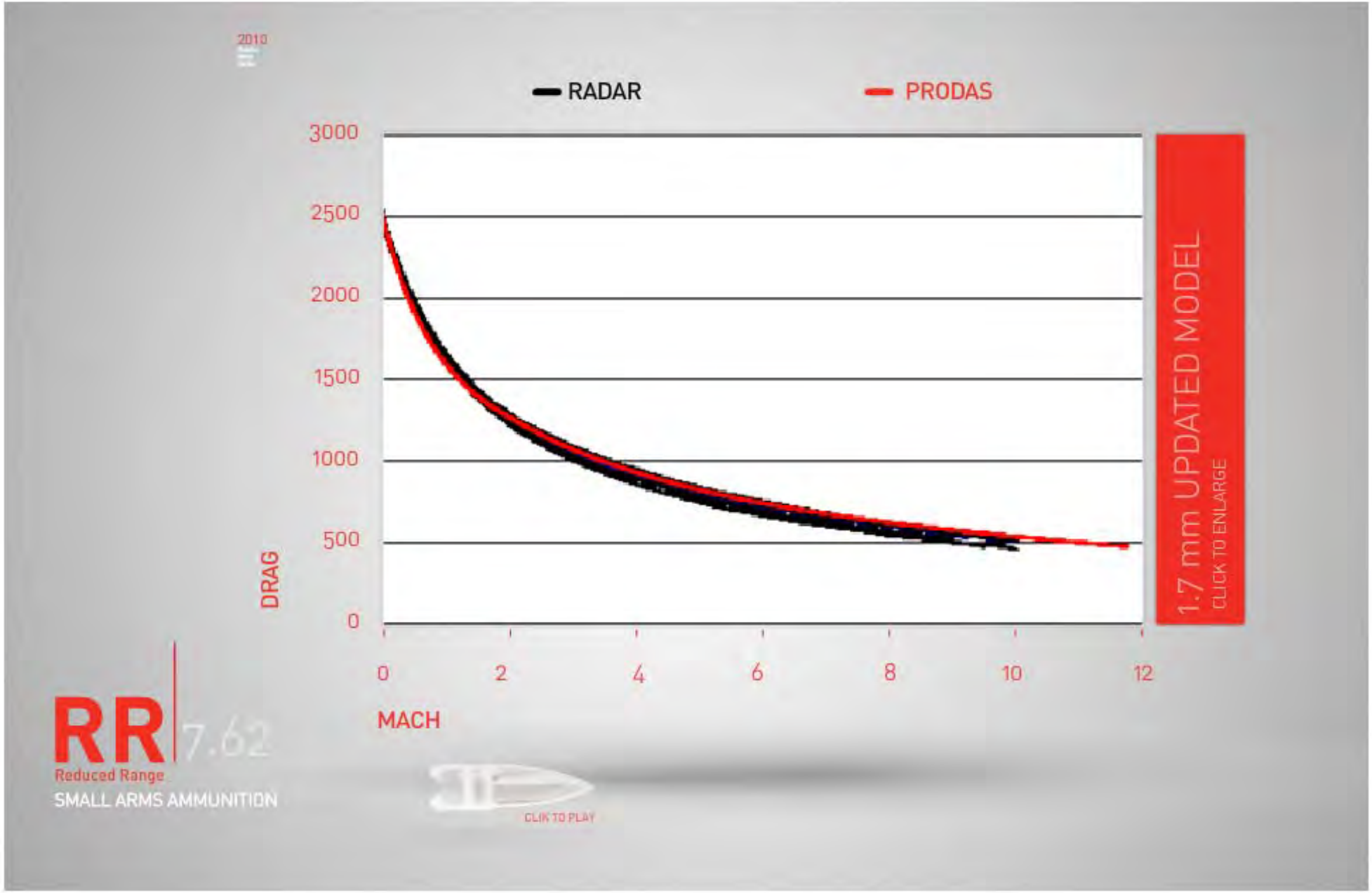




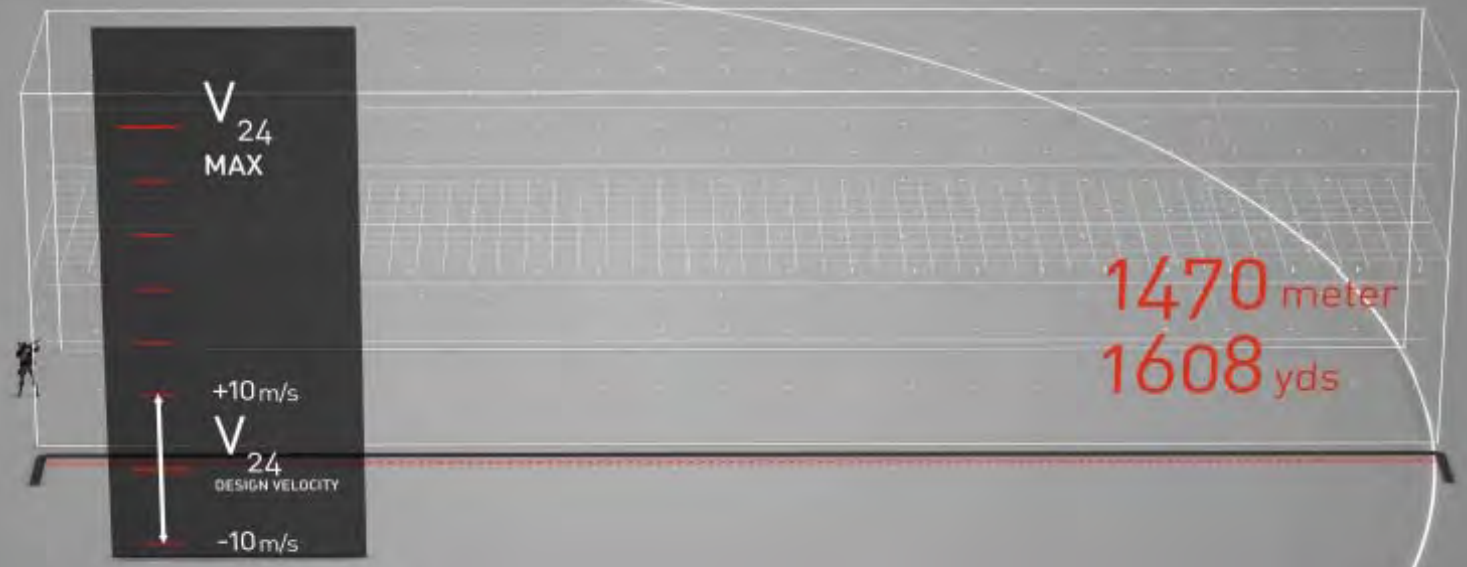
RR 7.62
Reduced Range
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RADAR
PRODAS
3000
2500
2000
1500
1000
500
0
DRAG
0
2
4
6
8
10
12
MACH
1.7 mm UPDATED MODEL
CLICK TO ENLARGE
RR 7.62
Reduced Range
SMALL ARMS AMMUNITION
CLIK TO PLAY

MAXIMUM RANGE CALCULATION



RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

STANDARD ATMOSPHERIC CONDITIONS
No wind
Temperature +15°C (+59°F) @ sea level
Air Pressure 1.013 bar @ sea level

back next

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COMBAT USE



CAM SPEED 25 000 fps

1 speed 2 speed 3 speed

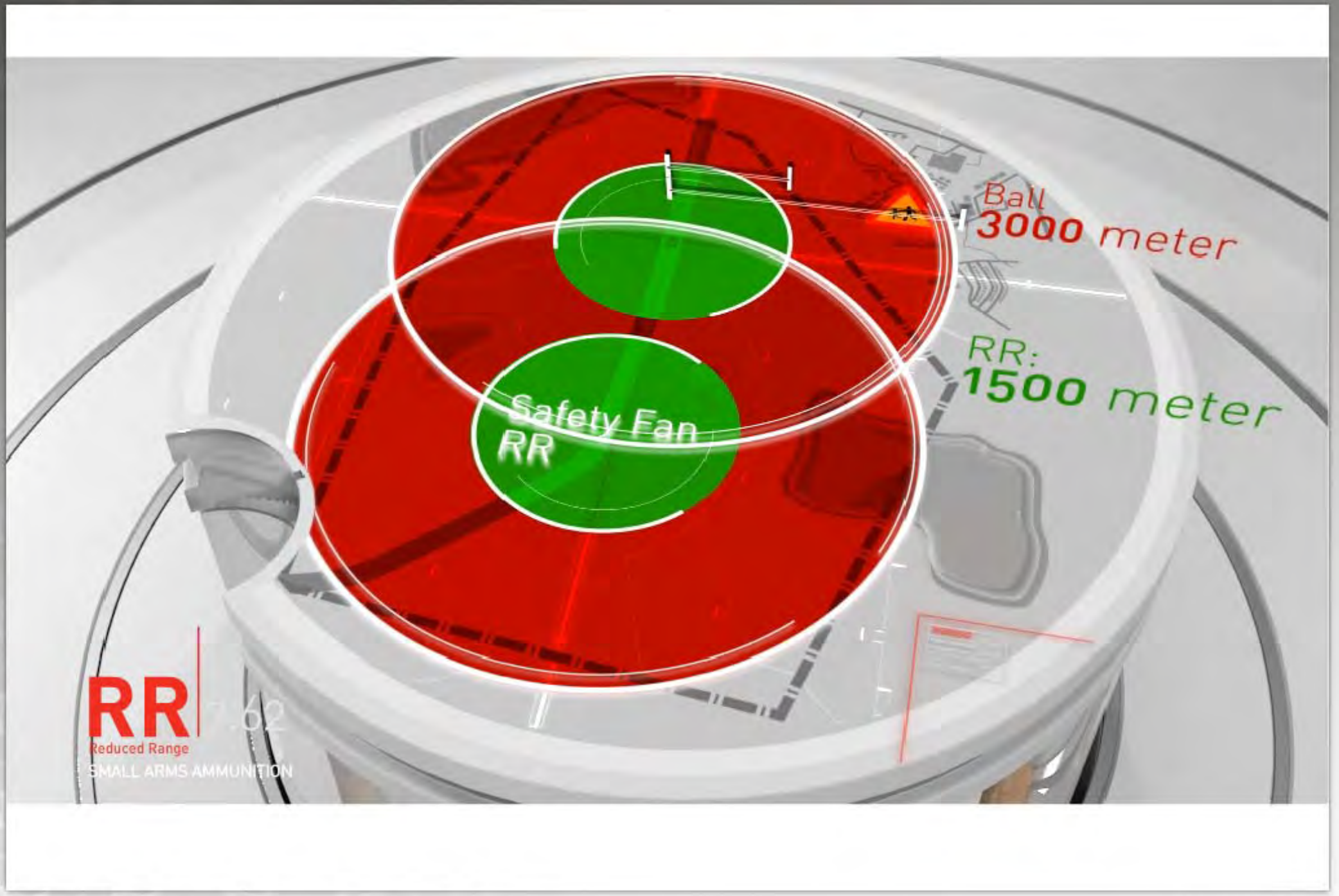


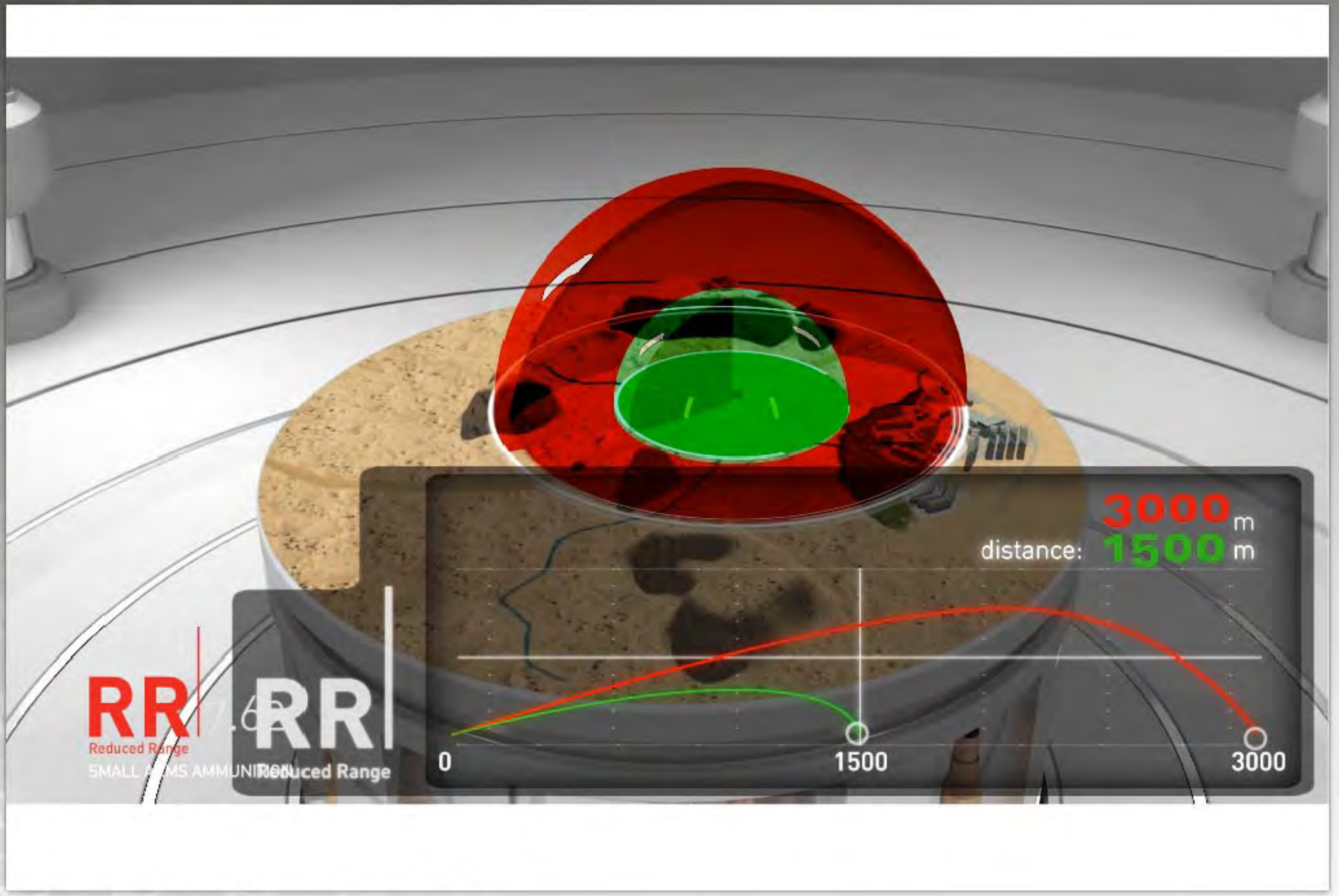
RR 7.62

Reduced Range

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Ball
3000 meter
RR:
1500 meter
Safety Fan
RR
RR
Reduced Range
SMALL ARMS AMMUNITION


3000 m
distance: 1500 m
0
1500
3000
RR
Reduced Range
RR
Reduced Range

7.62 **RR**

- CORE CUSTOMER REQUIREMENTS



- **Need for ammunition with reduced safety template**
  - Training
  - Combat
- **Maximum Range ⩽ 1500 m** (1640 yds)
- **Trajectory match Nato reference @ 200 m** (220 yds)
- **Accuracy compared to Nato reference @ 100 m** (110 yds)
- **Meet relevant STANAG requirements**
  - Terminal effects
  - Weapon function in complete temperature intervall
- **Non Toxic (lead- and heavy metal free)**

- **Price competitive**
  - Possible to produce with standard machinary

RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

1 facts 2 facts 3 more

SUMMARY

- CARTRIDGE DESIGN



- Cartridge Case: Standard Brass
- Primer: Boxer Non Toxic
- Propellant: Extruded double base Non Toxic
- Projectile: Steel plated jacket covering a steel core

- CHARACTERISTICS

- Significantly reduced safety template
  - Max range < 1500 meters (1640 yds)
- Trajectory match within 0.3 Mils to
- NATO reference @ 200 m (220 yds)
- Accuracy s < 30 mm (1.2 inch) @ 100 m (110 yds)
- Meets all relevant STANAG requirements
- Cost effective design

- A Non-Toxic alternative for training and/ or special tactical tasks

RR 7.62
Reduced Range
SMALL ARMS AMMUNITION

1 2 3


bullet
#X-ray# : view front
shelf
#X-ray# : view front
RR 7.62
Reduced Range
SMALL ARMS AMMUNITION
1 facts
2 facts
3 more


RR 7.62
Reduced Range
SMALL ARMS AMMUNITION
RR

2010

QUALIFICATION STATUS

- .50cal Ball RR – Qualified October 2009, In production
- .50cal Tracer RR – Qualified October 2009, In production
- .50cal Dim Tracer RR – Qualified October 2009, In production

- 7.62x51 mm Ball RR – Qualification Q3 2010
- 5.56x45 mm BallL RR – Qualification Q4 2010
- 5.56 and 7.62 mm Tracer & Dim Tracer RR – Qualification 2011

RR 7.62
Reduced Range
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QUESTIONS



AP 7.62
Armor Piercing
SMALL ARMS AMMUNITION

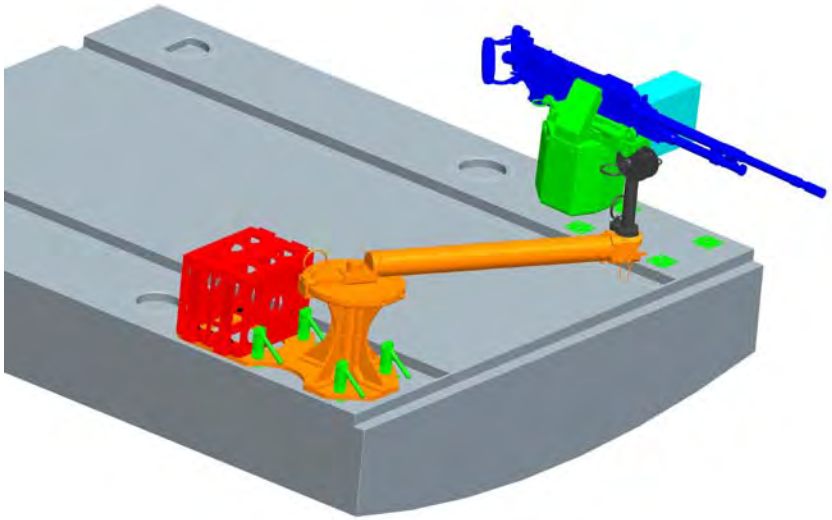
RR 7.62
Reduced Range
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IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

BALL 7.62
Non Toxic
SMALL ARMS AMMUNITION

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V-22 Ramp Mounted Weapon Systems



Naval Surface Warfare Center

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james.buechler@navy.mil

May 2010

Unclassified

Distribution Statement A: Approved for public release; distribution unlimited

Task Description/Timeline



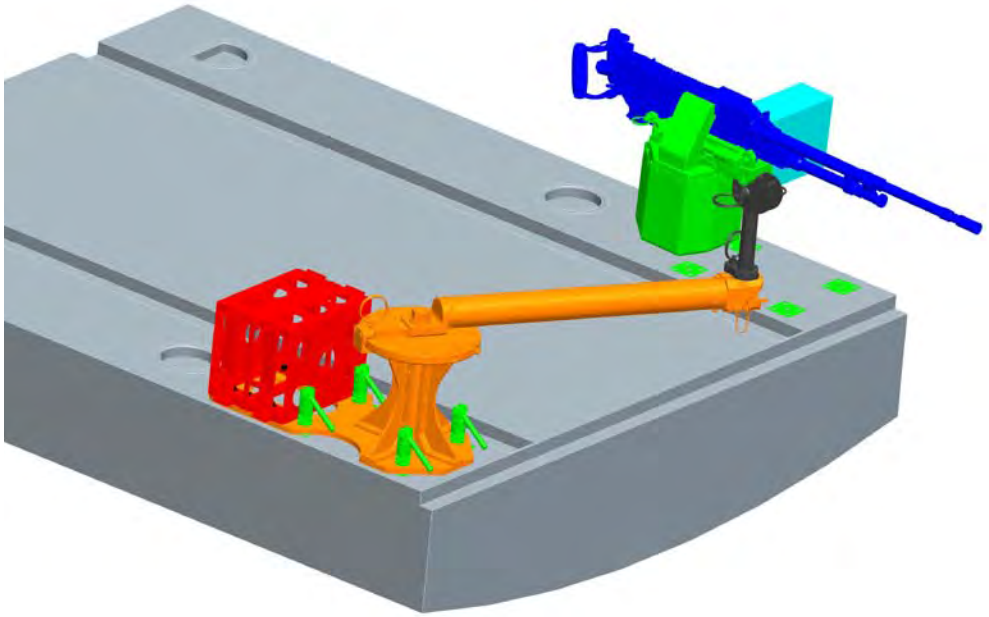
- 2005 – NSWC Crane tasked by NAVAIR to develop an M240 Ramp Mounted Weapon System.
- 2006 – Started fielding M240 Ramp Mounted Weapon Systems for Marines & Air Force.
- 2008 – Tasked to integrate GAU-16/18 (.50 Cal) system on Ramp.
- 2009 – Started fielding .50 Cal Ramp Systems.
- 2010 – Continue to field .50 Cal/M240 Ramp Mounted Weapon Systems.

Distribution Statement A: Approved for public release; distribution unlimited

NSWC Crane M240 Ramp Mount

Current Design:

- Shows installed on Port side of Ramp
- Always fired with ramp level.



Distribution Statement A: Approved for public release; distribution unlimited

M240D Weapon



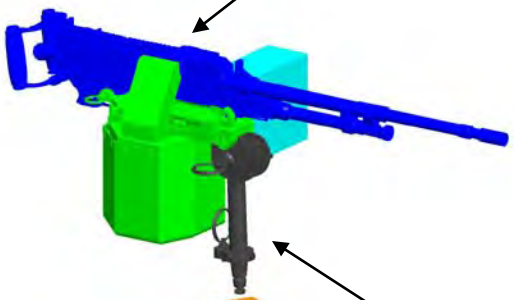
- FN-designed
- Weight: 26 lbs.
- Length: 49 inches
- Gas-recoil operated system (non-electric)
- Cyclic Firing rate: 650 – 950 rpm
- 7.62 mm ammo (standard ammo)
- Maximum effective range: 1,200 meters

Distribution Statement A: Approved for public release; distribution unlimited

NSWC Crane M240 Ramp Mount

Design Consists of:

- Subassemblies shown
- Aluminum/SST Materials



M240D Weapon

Pintle/Cradle

Baseplate/Swing Arm

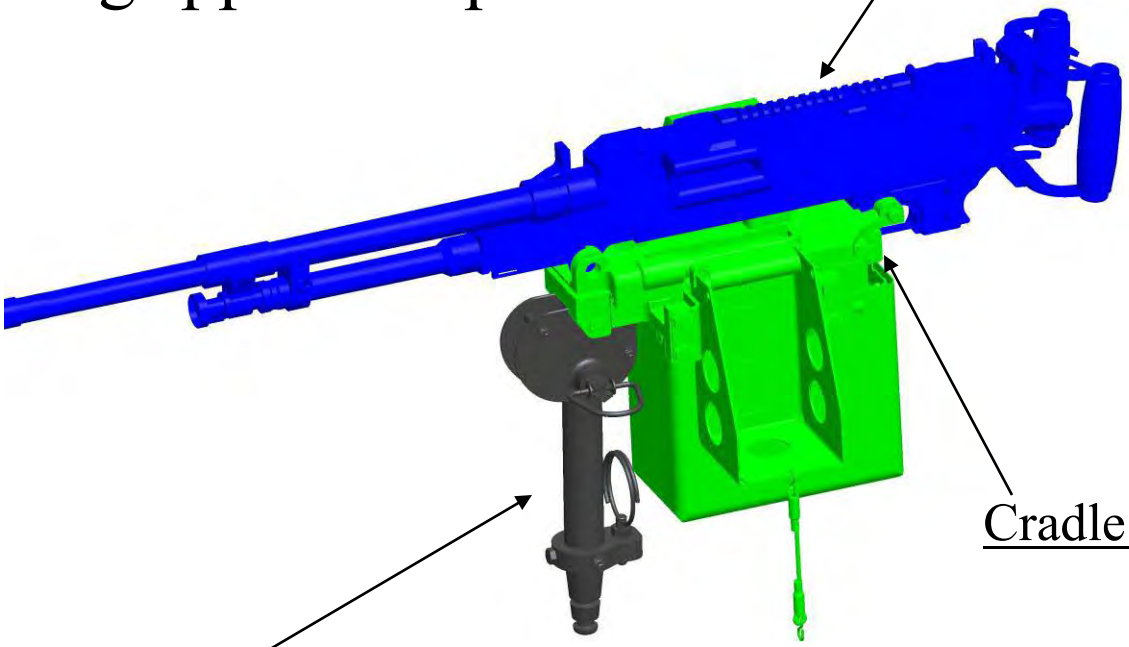
Ammunition Rack

Distribution Statement A: Approved for public release; distribution unlimited

Pintle/Cradle Assembly



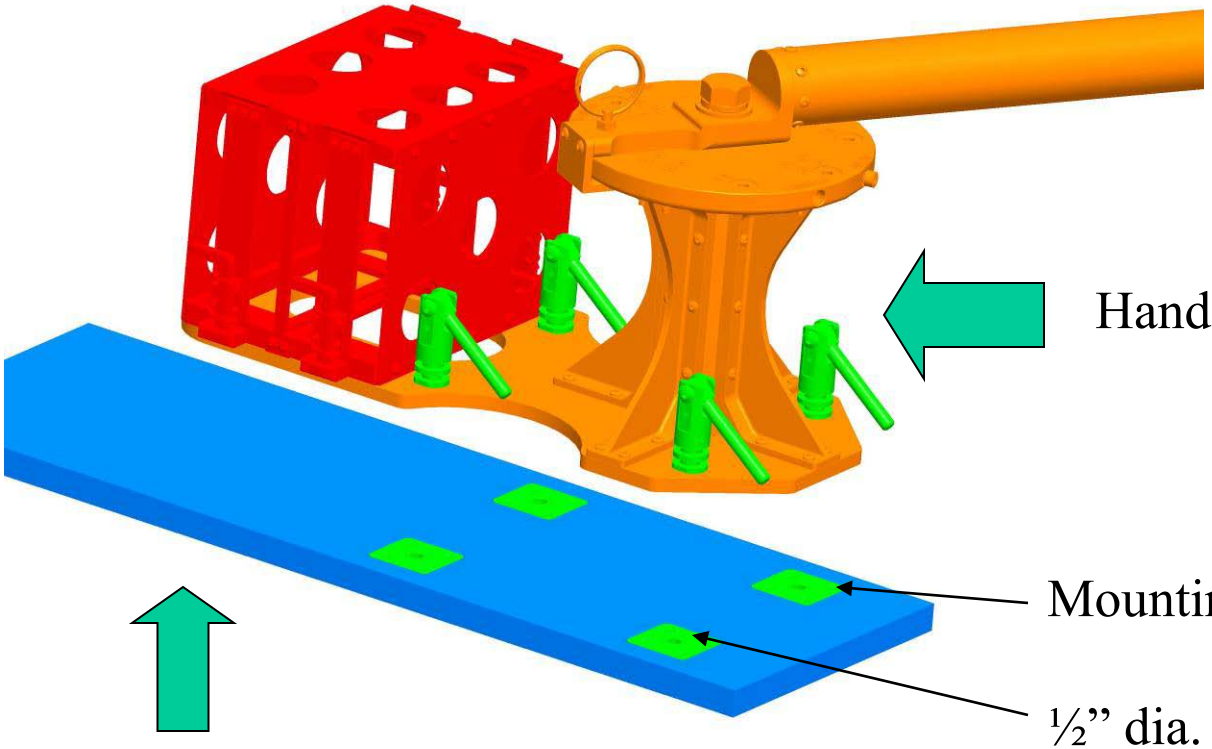
- Soft-mounted to reduce recoil.
- Spade-gripped weapon



Distribution Statement A: Approved for public release; distribution unlimited

Quick-Disconnect Handles





Handles (Qty: 4)

Mounting Receptacle

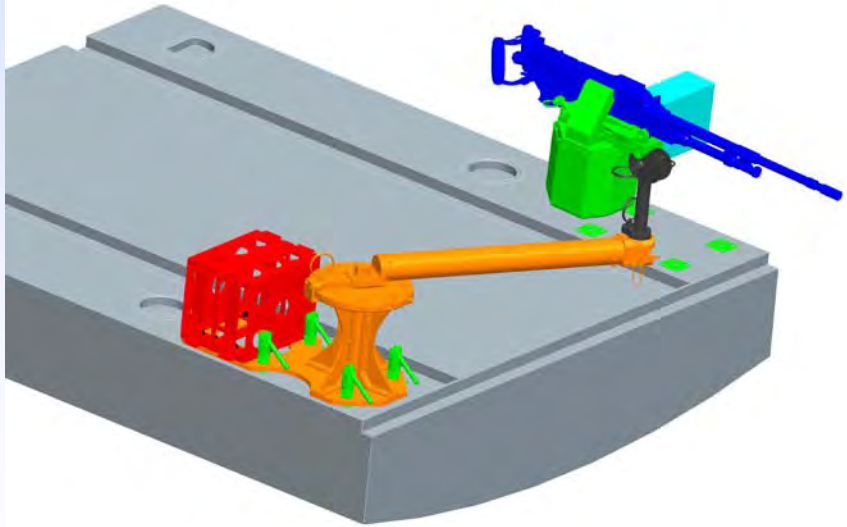
½” dia. Setscrews installed here when Mount not in use.

V-22 Aircraft Ramp Panel

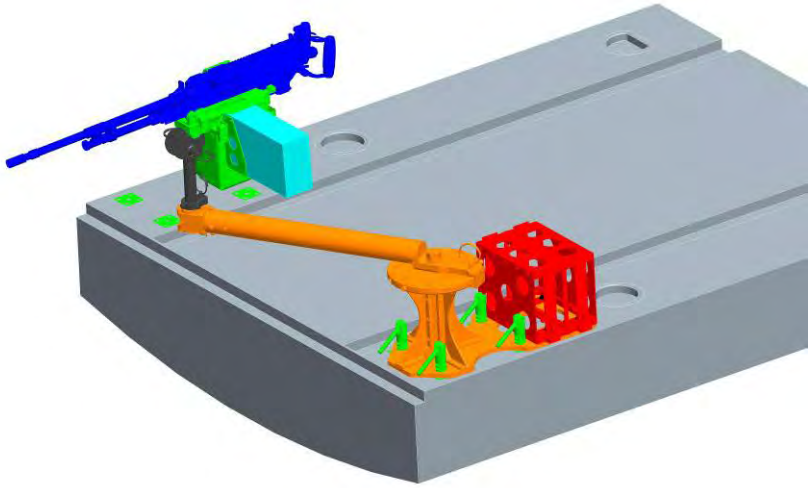
Distribution Statement A: Approved for public release; distribution unlimited

Port/Starboard Installation

- Ramp Mount can be installed on either the Port or Starboard side.



Port Side

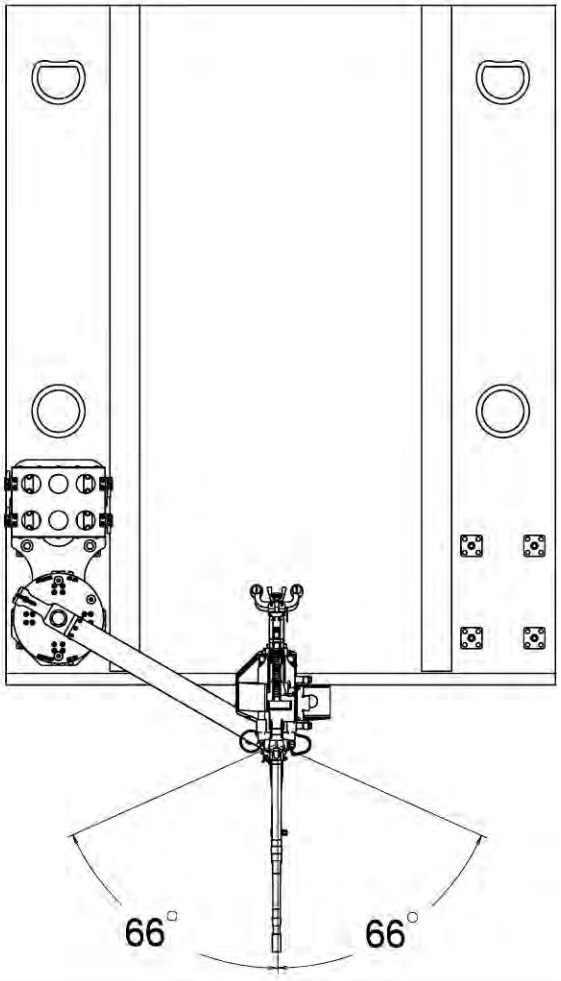


Starboard Side

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Azimuth Angles





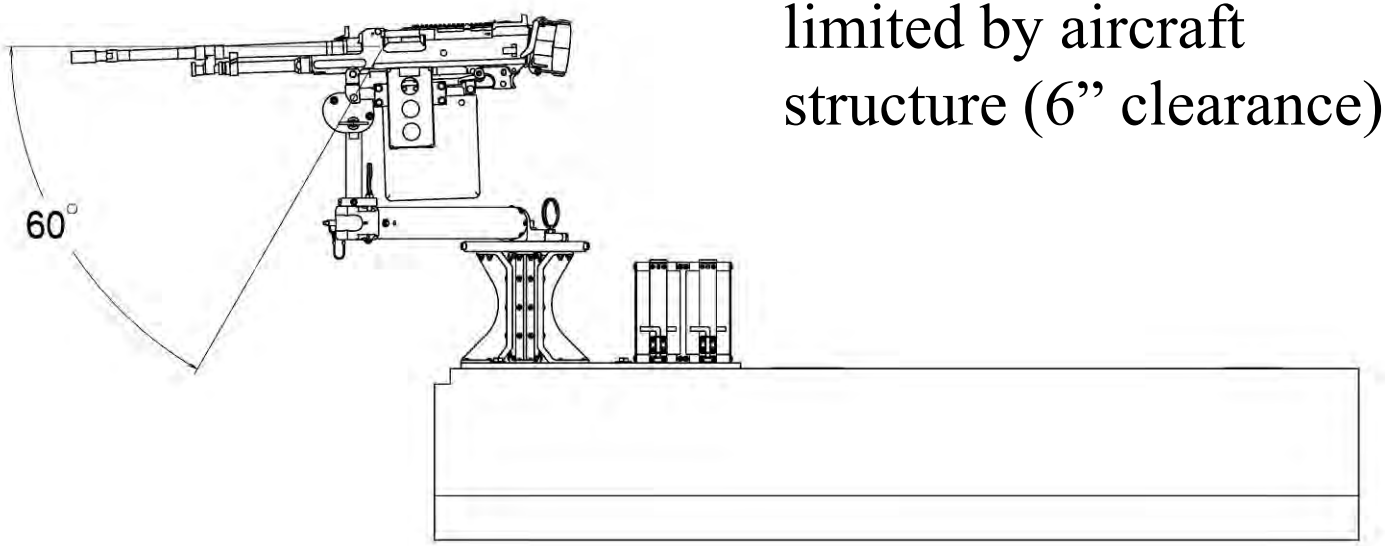
- Good aft field-of-fire.
- Azimuth fields-of-fire limited by aircraft structure (6” clearance).

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Depression Angle



- Significant Depression
- Elevation field-of-fire limited by aircraft structure (6” clearance).

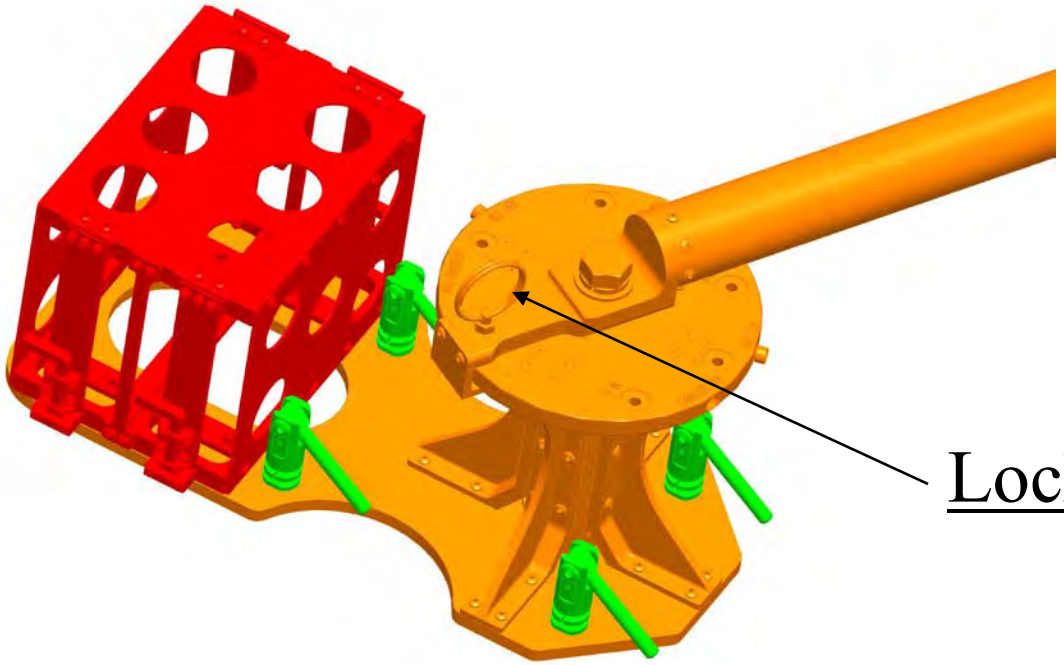


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Swing Arm Lock-in Pin



- Lock-in pin used to rotate Swing Arm
  - firing position
  - inboard stow position



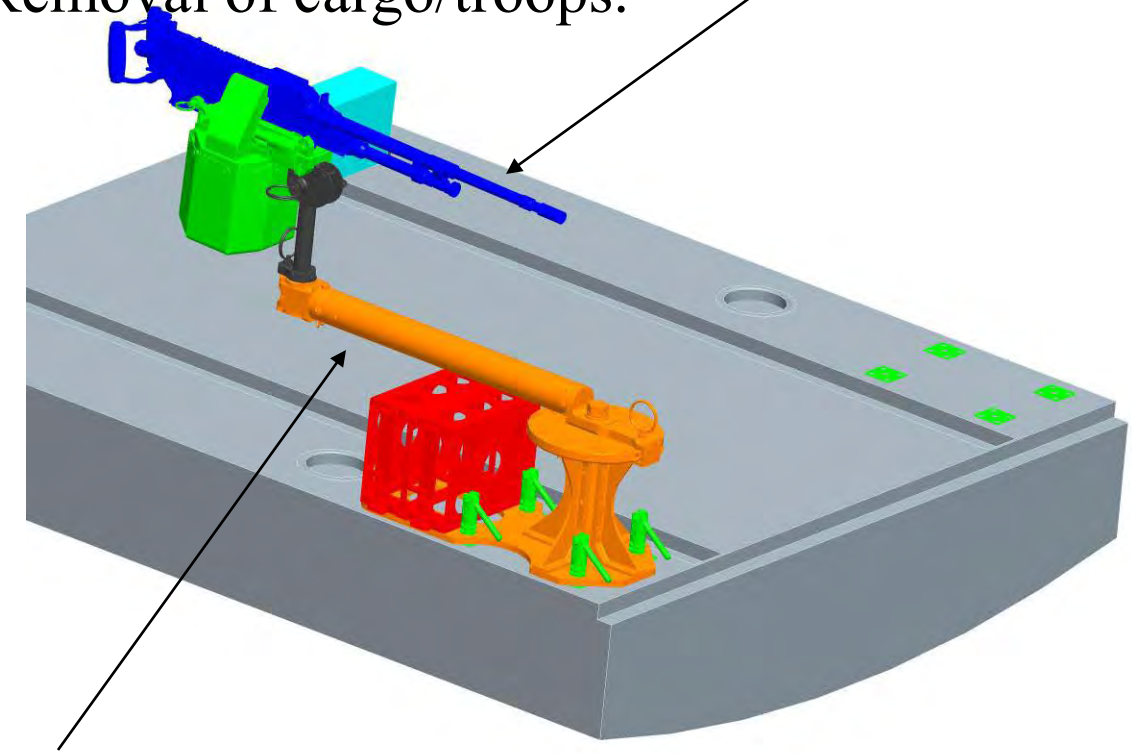
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NAVSEA
WARFARE CENTERS
CRANE

Inboard Stow – Port Side



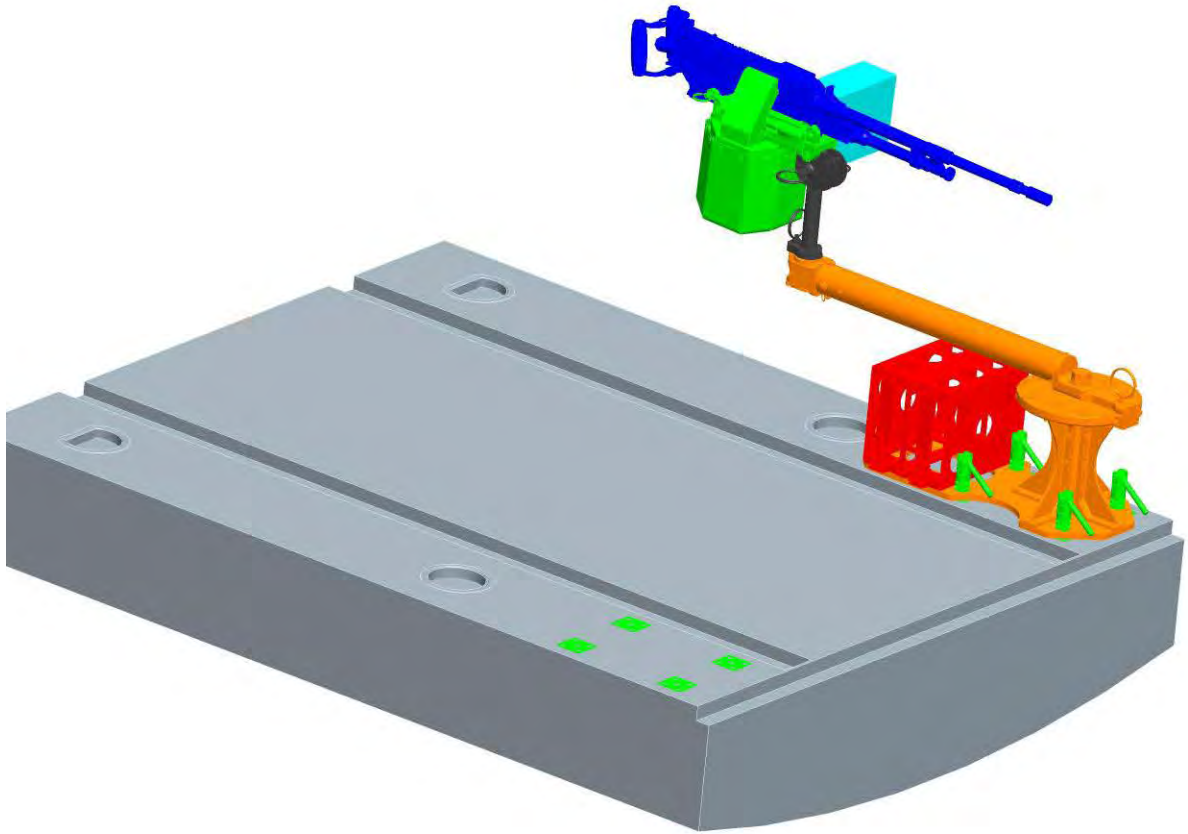
- Allows ingress/egress of personnel.
- Loading/Removal of cargo/troops.



Distribution Statement A: Approved for public release; distribution unlimited

NAVSEA
WARFARE CENTERS
CRANE

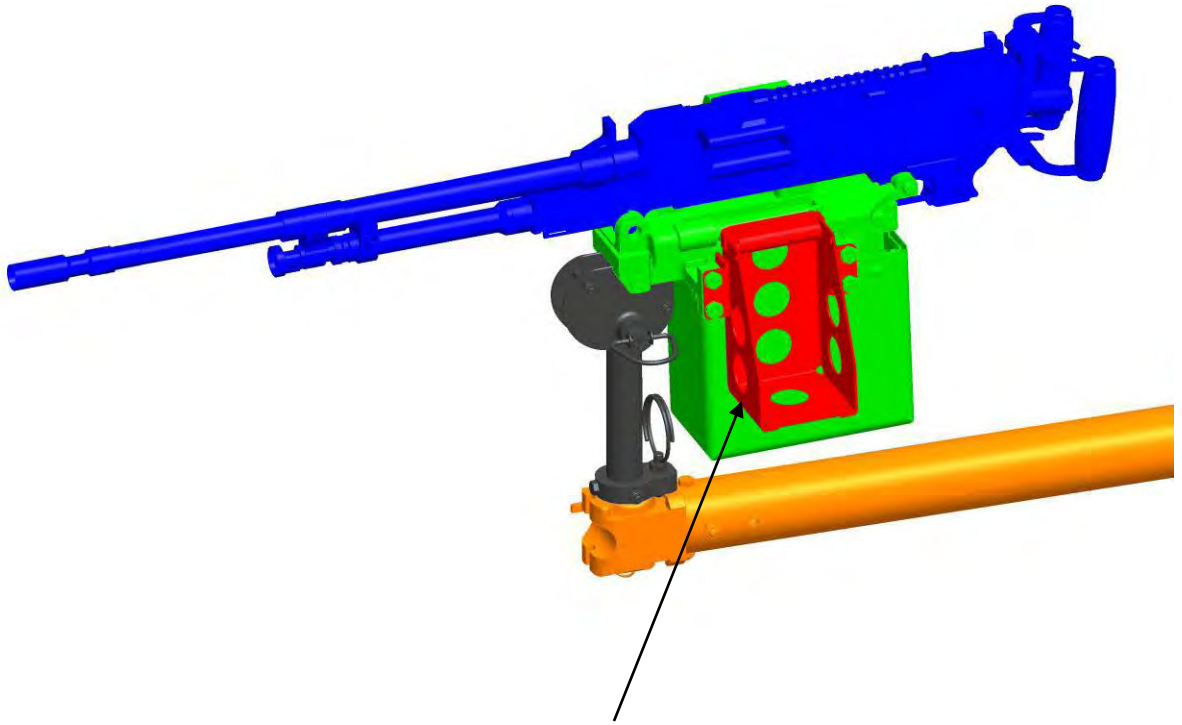
Inboard Stow – Starboard Side



Distribution Statement A: Approved for public release; distribution unlimited

Ammunition Tray on Mount

- Holds 1 standard can of 7.62 mm ammo
- 200 rounds
- Used on UH-1N, -H46, & H60



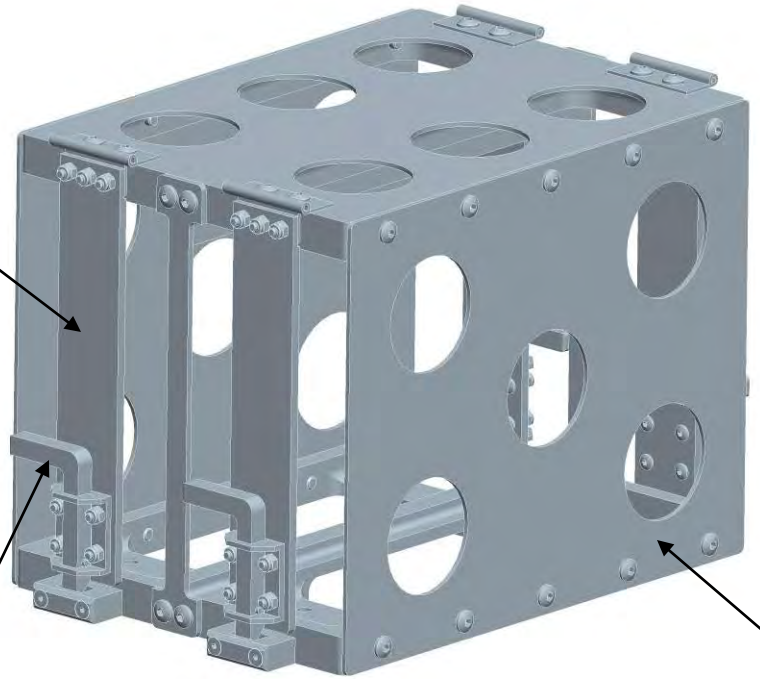
Ammunition tray

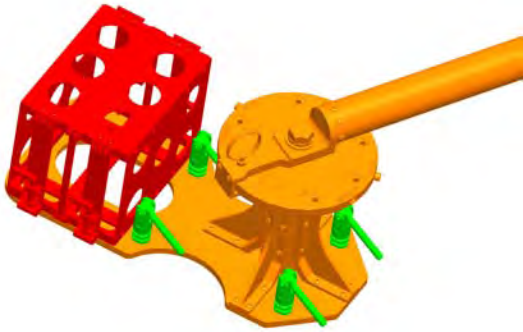
Distribution Statement A: Approved for public release; distribution unlimited

Ammunition Rack



Hinged latch plate that swings up





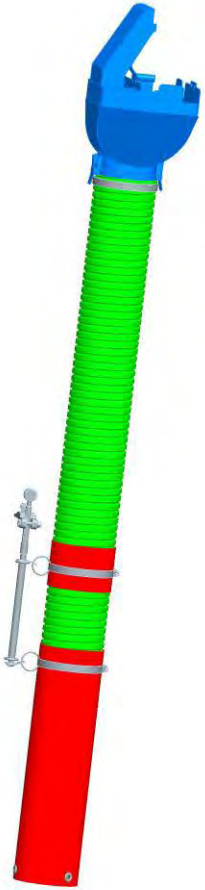
Spring-loaded latches

Ammo Rack holds two cans of ammo (400 rnds)

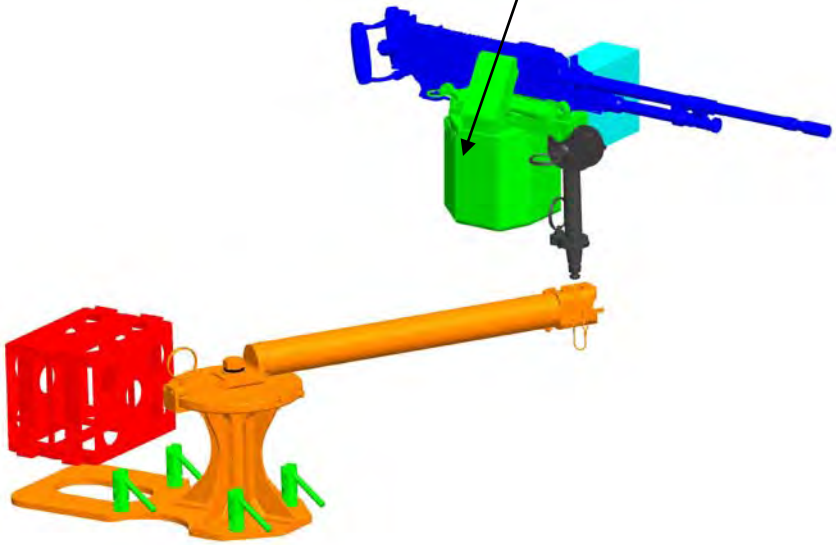
Distribution Statement A: Approved for public release; distribution unlimited

Brass/Link Ejection Systems





Brass/Link Catch Bag



Ejection Chute System

Distribution Statement A: Approved for public release; distribution unlimited

NAVSEA
WARFARE CENTERS
CRANE

Picture of Ejection Chute System

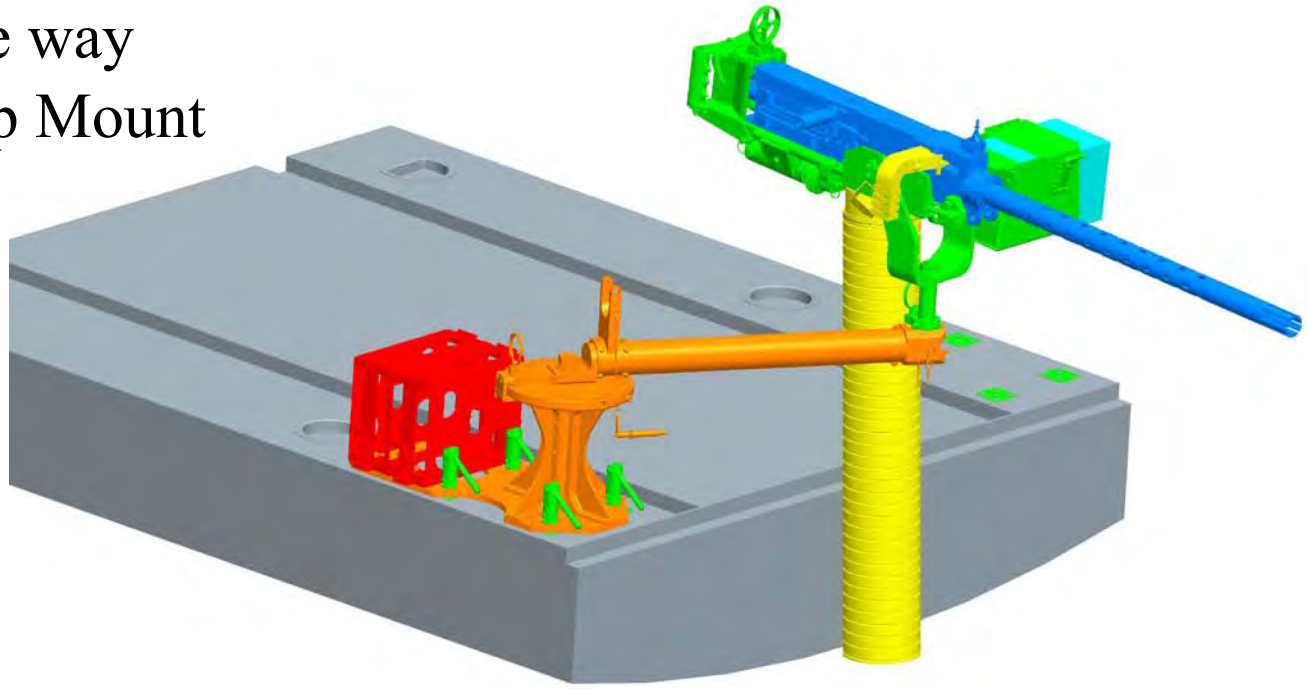


Distribution Statement A: Approved for public release; distribution unlimited

NSWC Crane .50 Cal Ramp Mount

Current Design:

- Attaches same way as M240 Ramp Mount



Distribution Statement A: Approved for public release; distribution unlimited

NAVSEA WARFARE CENTERS CRANE

GAU-16/GAU-18 Weapon

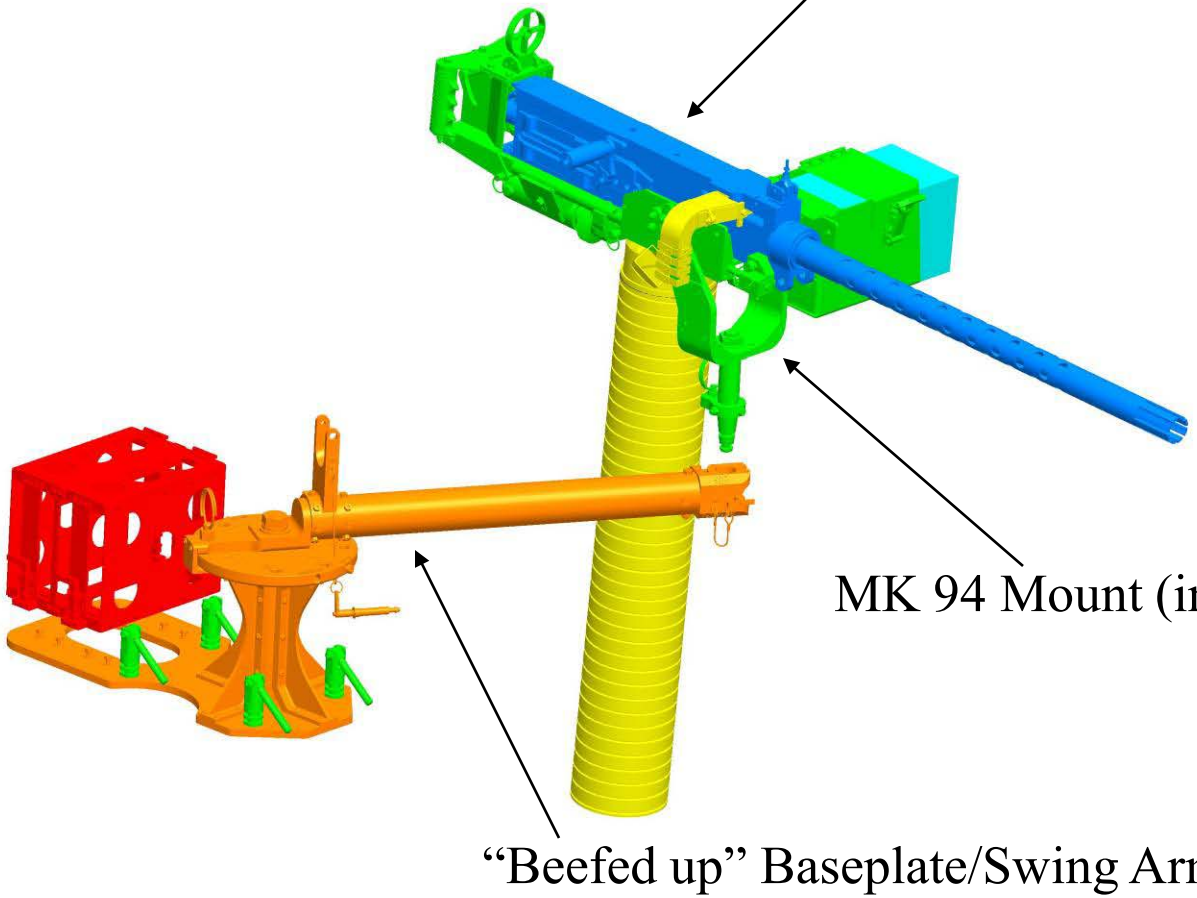


- Weight: 65 lbs.
- Length: 56 inches
- Gas-recoil operated system (non-electric)
- Cyclic Firing rate: 750 – 850 rpm
- .50 cal ammo (standard ammo)
- Maximum effective range: 2,000 yards

Distribution Statement A: Approved for public release; distribution unlimited

NSWC Crane .50 Cal Ramp Mount

- GAU-16 Weapon – Marine
- GAU-18 Weapon – A/F

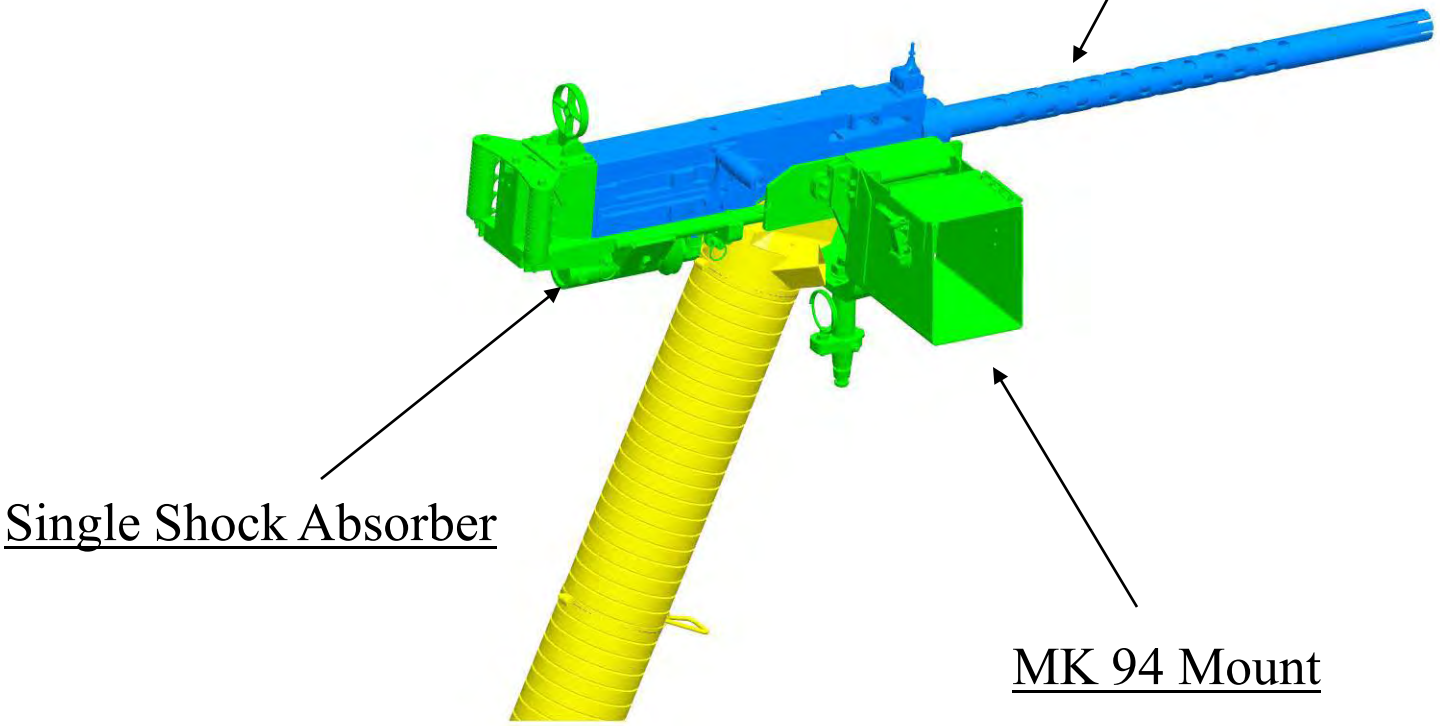


Distribution Statement A: Approved for public release; distribution unlimited

MK 94 Mount



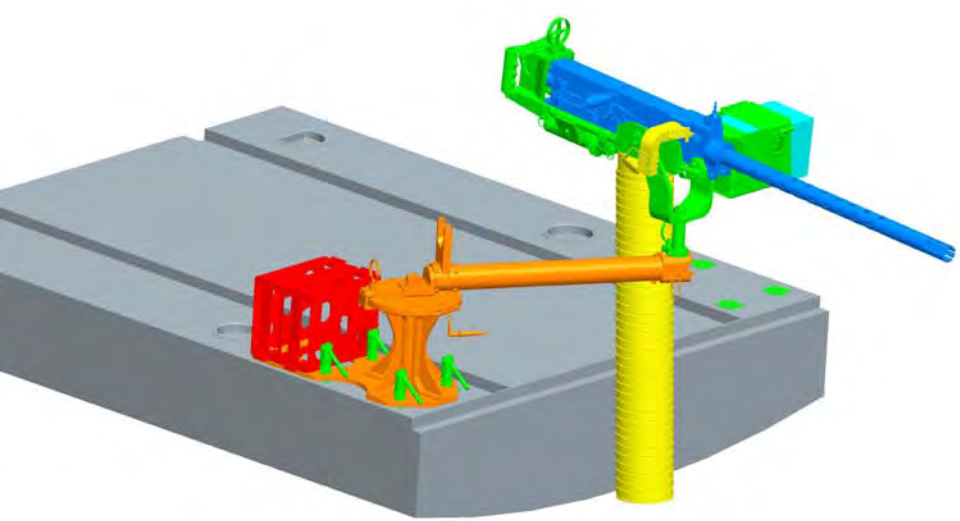
- Soft-mounted to reduce recoil.
- Trigger Housing rotates down
- Used on H60 aircraft



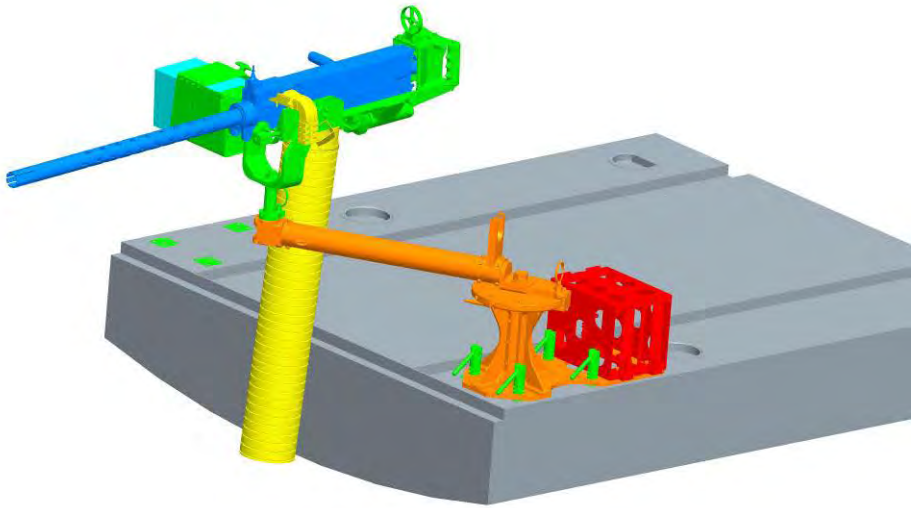
Distribution Statement A: Approved for public release; distribution unlimited

Port/Starboard Installation

- .50 Cal Ramp Mount can be installed on either the Port or Starboard side.



Port Side



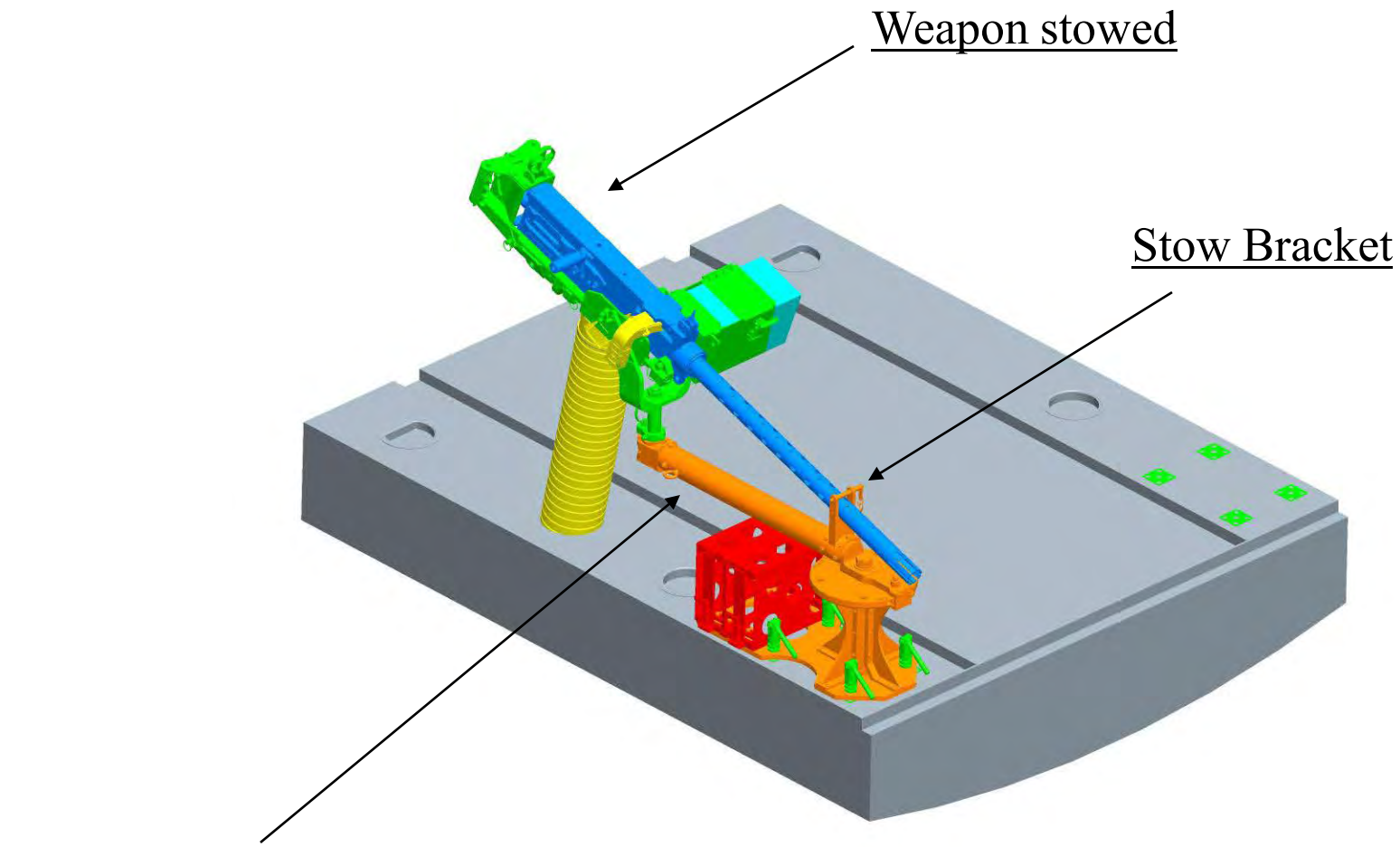
Starboard Side

Distribution Statement A: Approved for public release; distribution unlimited

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Inboard Stow – Port Side

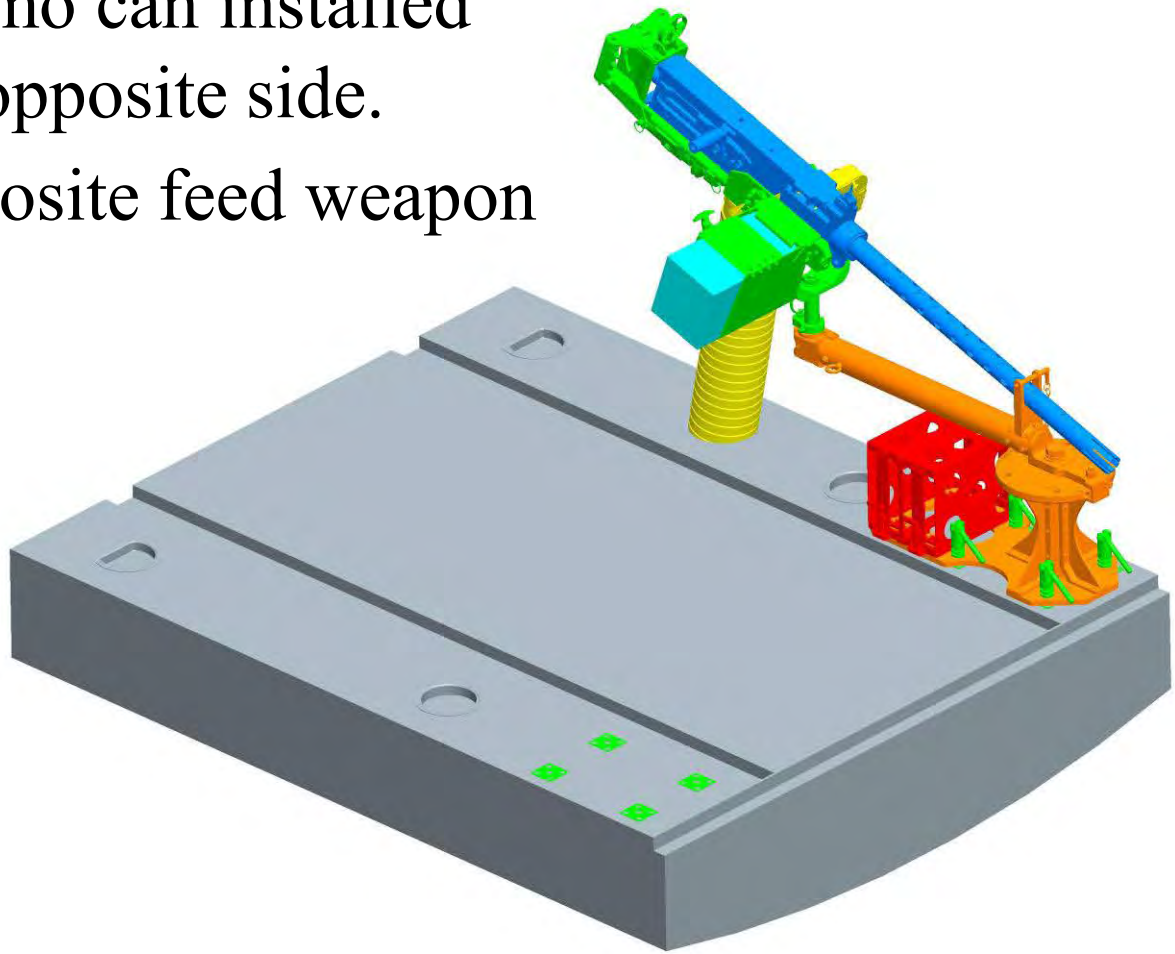




Distribution Statement A: Approved for public release; distribution unlimited

Inboard Stow – Starboard Side

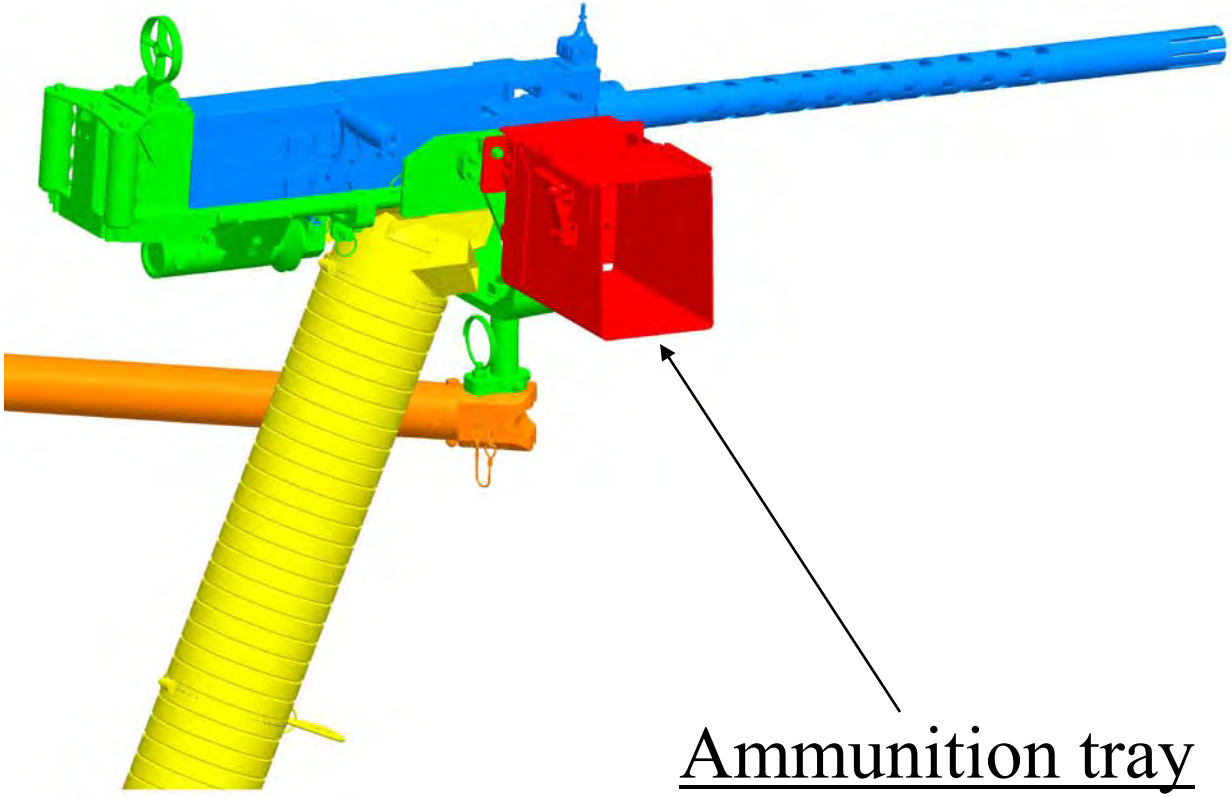
- Ammo can installed on opposite side.
- Opposite feed weapon



Distribution Statement A: Approved for public release; distribution unlimited

Ammunition Tray on Mount

- Holds 1 can of standard .50 cal ammo
- 100 rounds



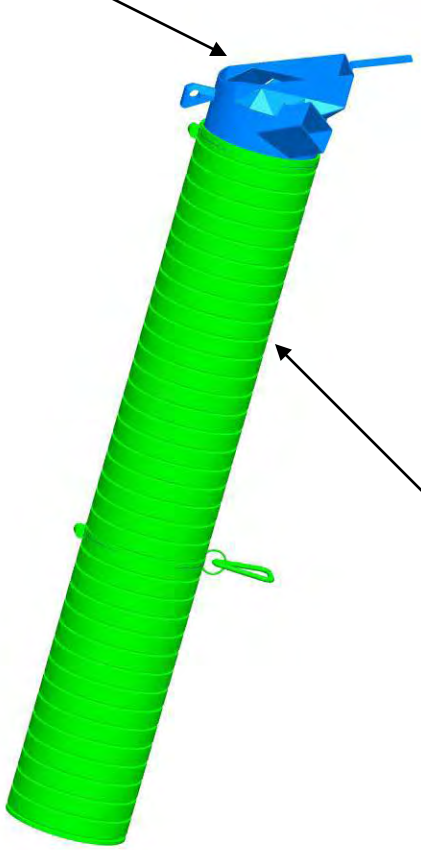
Distribution Statement A: Approved for public release; distribution unlimited

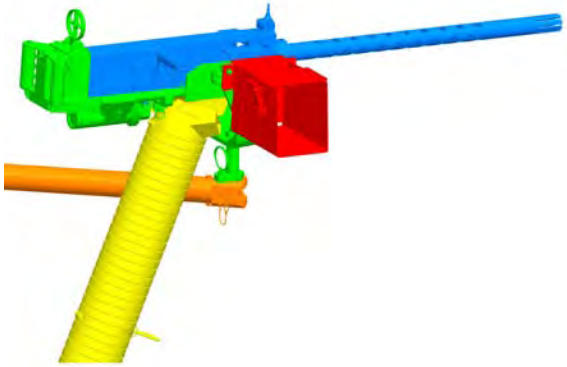
NAVSEA WARFARE CENTERS CRANE

Ejection Chute Assy



Metal hopper





6” Flexible hose

Distribution Statement A: Approved for public release; distribution unlimited

Weights of Ramp Mount System



	M240	.50 Cal
- Weapon:	26 lbs.	65 lbs
- Ammo (400 rnds):	34 lbs.	128 lbs.
- Mount/Swing Arm:	70 lbs.	99 lbs.
Total Weight:	**130 lbs.**	**292 lbs.**

Distribution Statement A: Approved for public release; distribution unlimited

NAVSEA
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CRANE

Future Deliveries of Ramp Mount Systems



- Thru 2020 – in conjunction with deliveries of production aircraft.

Distribution Statement A: Approved for public release; distribution unlimited

Point of Contact Information



- Name: Jim Buechler
- Company: NSWC Crane
- Section: Small Arms Platform Integration
- Phone: (812)854-5744
- Email: james.buechler@navy.mil

Distribution Statement A: Approved for public release; distribution unlimited

Enhanced Warfighter Capability with Direct and Indirect Small Arms Ammunition

NDIA Joint Armaments Conference 2010

Jarl Eirik Straume
Director Marketing and Sales
Nammo Raufoss

Nammo

Overview

- 12,7mm (.50 cal)
- 40mm x 53

PRECISION PEOPLE TECHNOLOGY

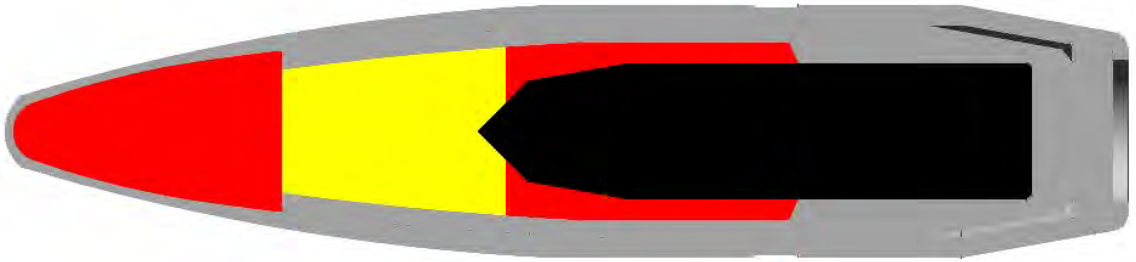
The Nammo 12,7mm (.50cal) Family



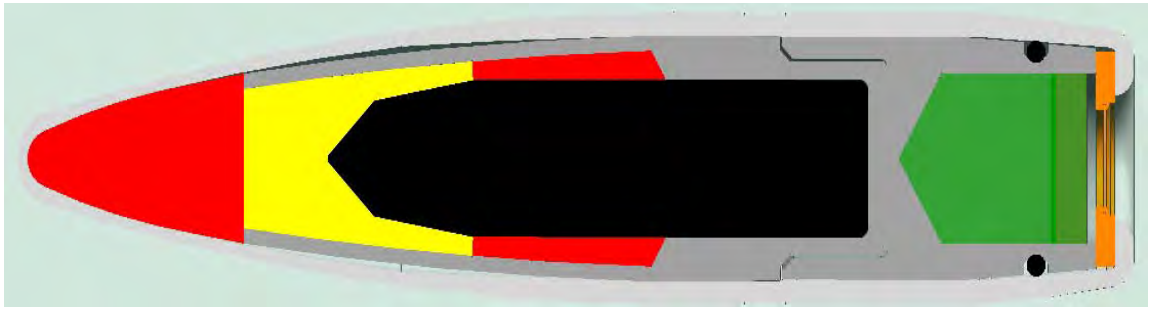
PRECISION PEOPLE TECHNOLOGY

The Multipurpose

12,7mm MP NM140/Mk211



12,7mm MP-T NM160 and MP-DT



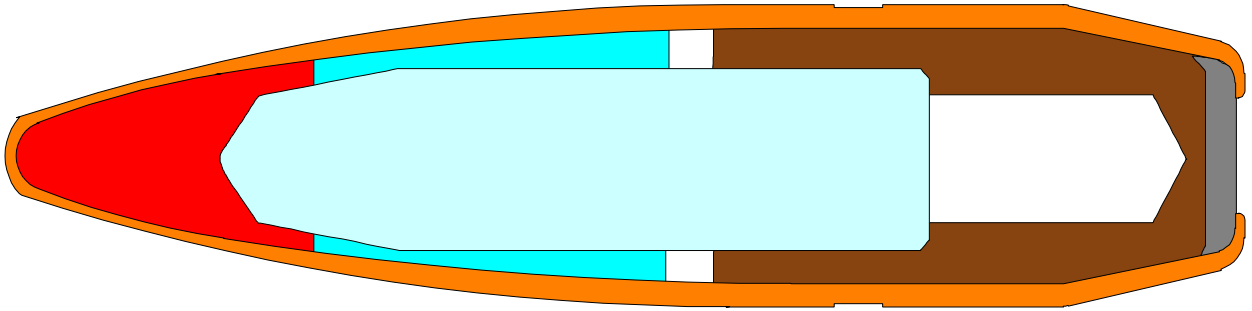


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Nammo

The Armour Piercing Super

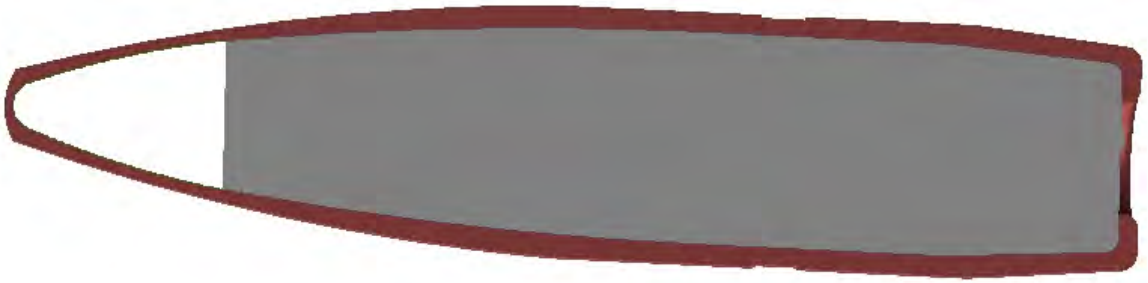
AP-S NM173 (API) and NM185 (AP)



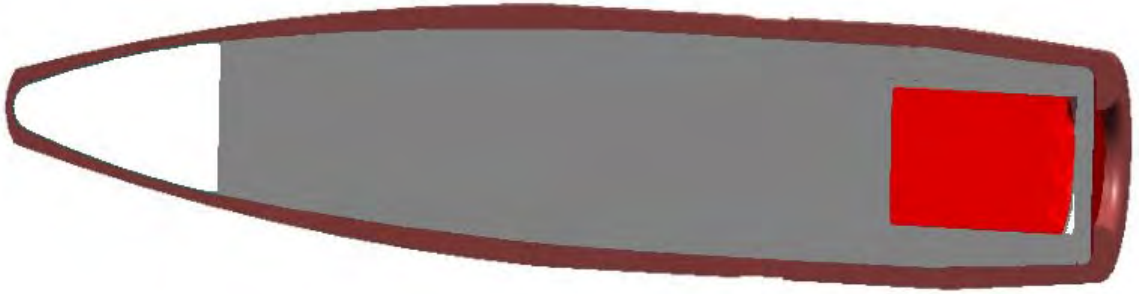


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The Special Grade



12,7mm SG



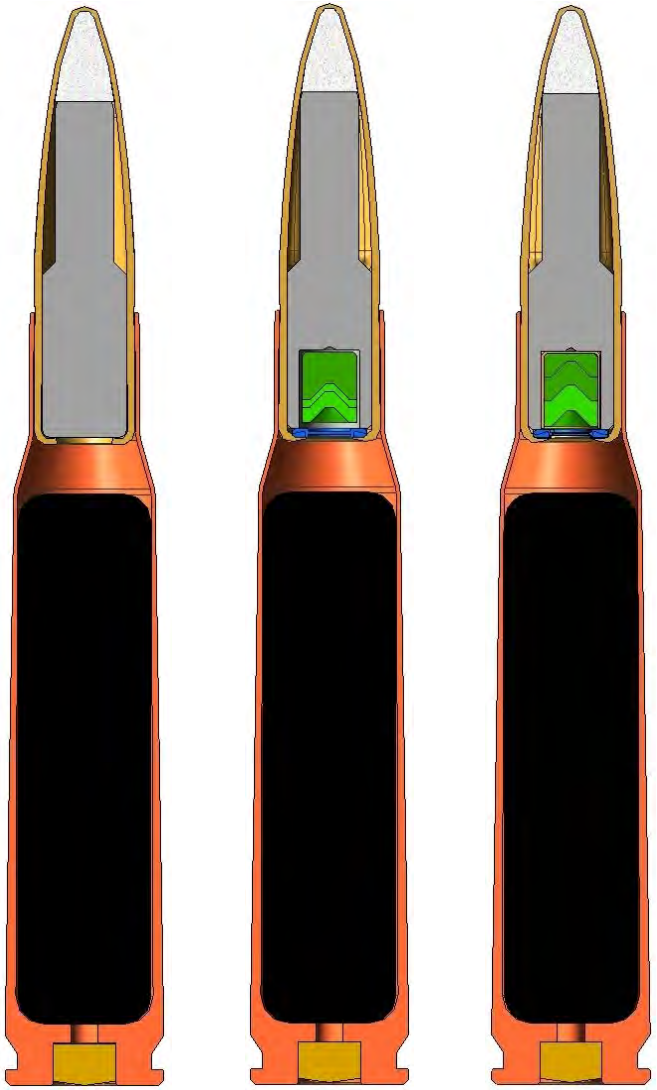
12,7mm SG-T and SG-DT



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Nammo

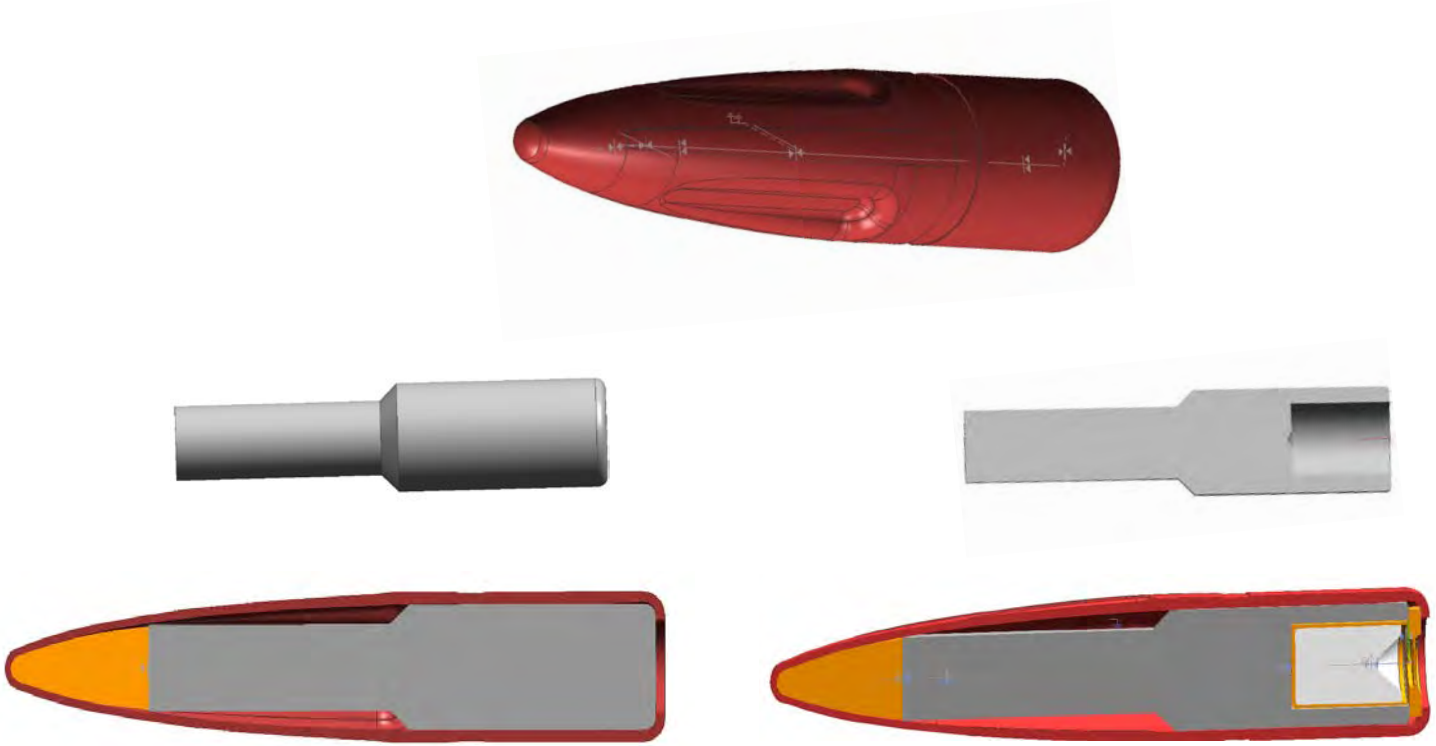
The Reduced Range





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The Reduced Range



12,7mm RR

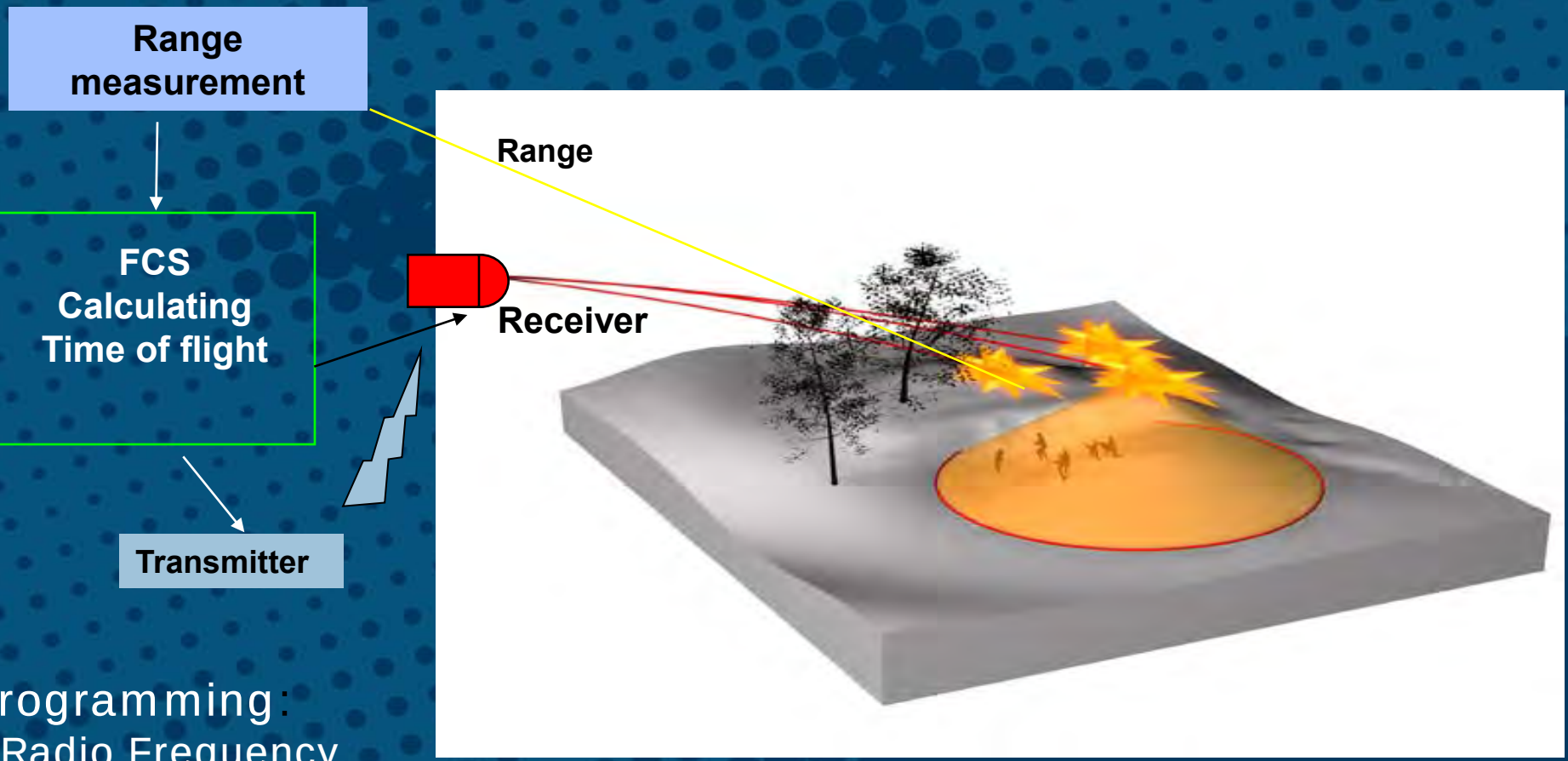
12,7mm RR-T and RR-DT



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Nammo

Airburst Principal



Programming:

- Radio Frequency
- Galvanic contacts (only MK47)

Nammo

PPHE Ammunition (US MK 285)

- Electronic Programmable Time Fuze
- Air-Burst Function (electronic)
- Point Detonating (mechanical)
- Self-Destruct (electronic)
- Mechanical Safe & Arm (US MK91)
- Prefragmented Shell
- IM Properties



Nammo

PRECISION PEOPLE TECHNOLOGY

40mm RF Round

- Electronic Programmable Time Fuze
- Air-Burst Function (electronic)
- Point Detonating (mechanical)
- Self-Destruct (electronic)
- Mechanical Safe & Arm (US MK91)
- Prefragmented Shell
- IM Properties



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Nammo

40mm RF

- Wireless programming
- Easy integration to existing weapon platforms



PRECISION PEOPLE TECHNOLOGY

IHV-HEDP

- M430A1 (HEDP) Product Improvement Program (IHV-HEDP)

- SD function (Mechanical)
- IM properties
- Reduce safety zone (Back-plug)

- Two versions:
  - Standard (MK315)
  - Air-Burst (MK314)



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Nammo

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Nammo Raufoss AS
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Strategic Tripartite
Historic Opportunities for US and NATO Ground Combatants

by Jim Schatz

NDIA Joint Armaments Conference
19 May 2010
Dallas, Texas USA

051110



Introduction, Caveats



This paper represents the educated opinions of the presenter

- As an independent consultant the presenter has no affiliation with nor does he receive any compensation what-so-ever from any small arms, ammunition or ancillary equipment manufacturer or provider

- The presenter has been a member of the small arms community since 1977 in most roles to include end user, trainer, developer, support provider for more than 150 US and foreign friendly organizations, and an advocate for the small arms end user



Content



A "snap shot" look at three topics that would greatly benefit the ground combatant, small arms end user, NATO, the small arms industrial base and the tax payer *today and always*

Part I The US Carbine Upgrade and new Individual Carbine (IC) programs – Explore the state-of-the-science currently available

Part II A Joint NATO Small Arms and Ammunition Development/Fielding Program – The merits and benefits of

Part III The User Small Arms and Ammunition Advisory Panel (USAAAP) – The need for

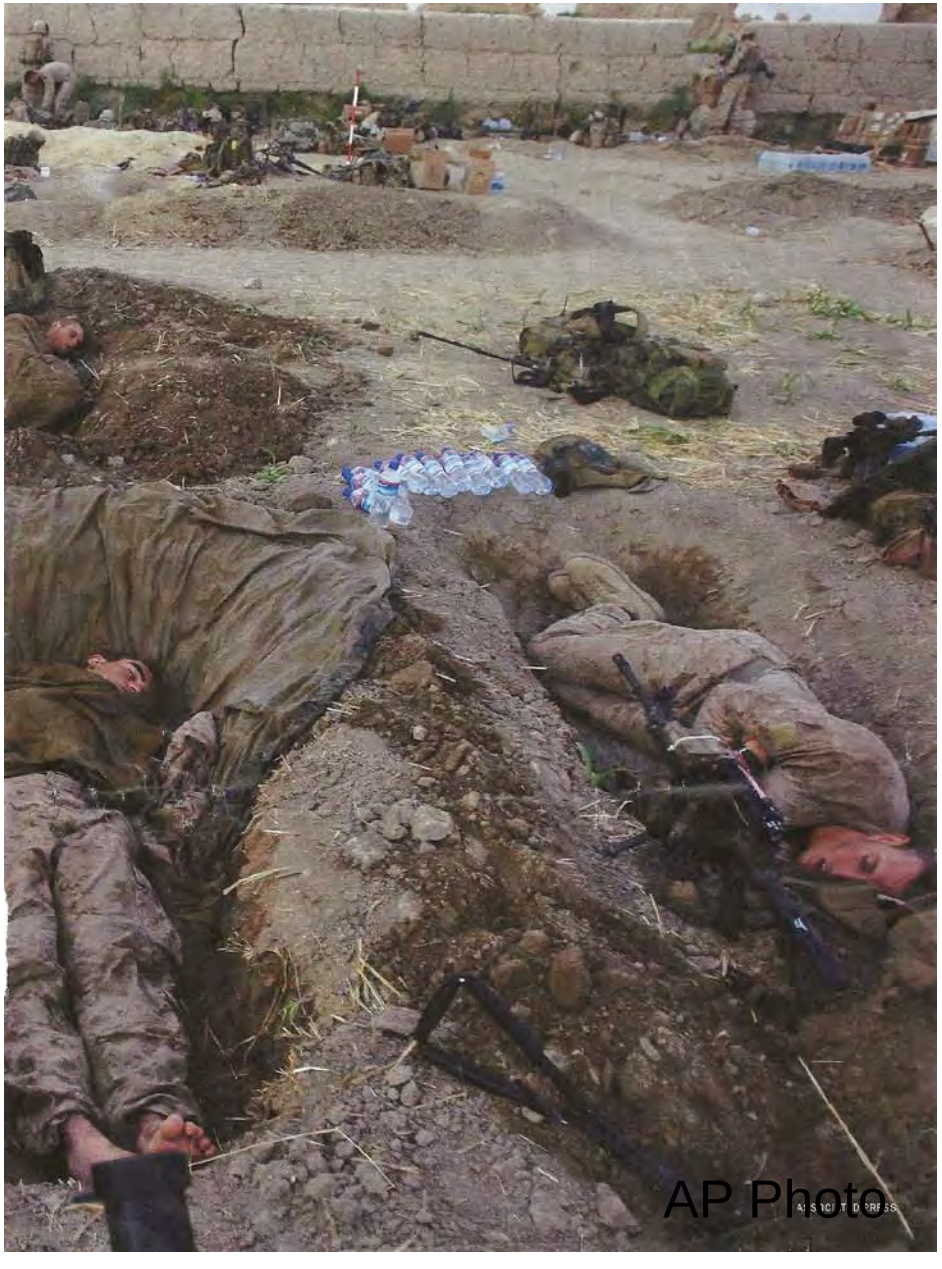


Purpose



1. **Explore historically strategic <u>but fleeting</u> opportunities to exploit substantial and available incremental and/or evolutionary improvements in small arms and ammunition performance for US and NATO ground combatants.**
2. **Capitalize on parallel programs within NATO with similar goals, requirements and challenges:**
   - **Not since US AR-15/5.56mm adoption (1960's)**
   - **Not since the 1977-1980 NATO trials**
3. **Exploit the Low Risk Benefits of "the 90% solution".**
4. **Discuss the advantages of a NATO common modular/ user-configurable rifle system & optimized cartridge.**
5. **Give the Small Arms End User a seat at the decision making table.**

Where did you sleep last night?



We owe these brave men and women, who engage with and destroy the enemy with small arms the very best *now and always!*

Men of the 1st Battalion, 5th Marines, Helmand province, Afghanistan 8 July 2009 resting after marching for 6 hours in 135 degree F heat with 120 pounds of equipment.



Part I
US "Individual Carbine" Initiatives



- **Substantial advances in rifle technology have been realized since the mid-1990's:**
  - **NLT 35 Op Rod Carbines since 2003**
  - **Improved magazines, barrels, piece parts, mounts**
  - **Numerous new rifle rounds/projos since 9/11**
  - **"Blind-to-Barrier" rifle ammunition**

- **Business and New Product Development has flourished since/as a result of 9/11, OIF/OEF and 2008 US election "Panic Buying". *Industry is ready!***

- **As a result Industry IR&D and Select Govt Programs (JCP, MSR/PSR, SCAR, XM8, MURG, SOST, etc.) have advanced the state-of-the-science not only in rifles but in handguns, LMG's, AGL's, also.**



Historic Opportunities



1. "Individual Carbine" (IC) Competition
   - The first since the M1 Carbine competition in 1940.
   - Will/may explore the long-standing issue of 5.56mm/M855 terminal effects IF industry responds with solutions to the enhanced terminal effects requirements
   - Sadly not looking for a "modular family of weapons"

2. Carbine Upgrade Effort
   Carbine Upgrade (and IC competition) efforts – 20 or more competent, mature, responsive submissions likely

Both MUST be Merit Rated to avoid selection of the Best Value/ Low Bidder that meets Threshold-Only specifications

Approved Requirements meet a Well Prepared Industry!



Common Requirements - IC & Legacy Carbine Enhancements



"Incremental" Improvements - The "90% solution", Available as COTS/NDI, modified COTS. Significant advantages for *the end user!*

- **Reliability:** 4 - 7X, 18K MRBS/F (cold-hammer forged barrels, high reliability mags)
- **Service Life:** 3 – 4X (optimized materials, piece parts, coatings)
- **Improved Accuracy:** 30 - 50% increase/Sub 2 MOA (optimized design/ergonomics, enhanced ammo/projos, improved sights, enhanced training). Critical with Carbine "Pure Fleeting" and the OEF Long Range war
- **Increased Terminal/BTB Effects, Effective Range:** Optimized intermediate cartridge (6-7mm x 45/51mm), improved propellants, SOST/TOTM, M855A1, Barnes TSX, other?
- **Safety:** OTB (0 vs. 6 sec. drain time), Increased (60%+) Cook Off (210-240 vs.120-150 rounds), SBFA (catch live projectiles during blank firing)
- **Improved Sustained Fire Capability:** 540/70 vs. 900, 90 vs. AKM 120/150 (Wanat), IAR 660 rds/1.5 minutes (440 rpm), 60% > 36 rpm spec possible (12/15 M16A2)

Example:
Improved Sustained Fire Capability

Excerpts from 2009 Army Combat Studies Institute, Fort Leavenworth, KS
(available at www.battlefieldtourist.com/content/battle-of-wanat-historical-analysis-rough-draft-release/)

There were three vehicles that could still fire from the COP, the two squad HMMWVs on the northern segment of the perimeter, both armed with Mk 19 40mm automatic grenade launchers, and the Platoon HMMWV with a .50 cal at the CP. The TOW HMMWV was now merrily burning to the ground, and was well and truly out of action. The Marine ETTs also had a single M240 Machine Gun manned by Corporal Jones, described by the paratroopers as "the big Marine with a moustache." This gun's presence was fortunate as both the 2nd Platoon's M240 Machine Guns were located at OP Topside. The insurgents so aggressively pushed their advance that their positions were within the minimum arming range of the 40mm grenades. Additionally, their small arm fire was so devastating that one of the grenade launchers was struck with a bullet through the feed tray, permanently disabling it. The other Mk 19 grenade launcher jammed, which they are prone to do. Thus, the American defenders at the main COP had only a single .50 caliber machine gun, the Marine M240 Medium Machine Gun, and their own small arms to repel the assault. It is to the credit of the Chosen soldiers that they maintained at least fire parity from the COP. To achieve this, the 2nd Platoon soldiers were firing their weapons "cyclic," on full automatic at the highest possible rates of fire. As a result, numerous soldiers experienced weapons malfunctions, just as Staff Sergeant Phillips had faced at the mortar pit. One young specialist fighting at the COP Kahler later complained, "…I ran through my ammo till my SAW would not work anymore despite the 'Febreze' bottle of CLP I dumped into it."[clxvii] Another Sergeant described the desperate struggle at the COP when the 2nd Platoon QRF departed to reinforce OP Topside:

System Recommendations

There were repeated and recurring failures of small arms firing at "cyclic" rates of fire (high volume of fire for extended duration) during this engagement. Weapon systems that experienced failures include M-4 rifles, SAW automatic weapons, and MK19 grenade launchers. The failure of weapons at OP Topside degraded the defense of that post at a critical moment in the engagement, and contributed to the penetration of that position by the ACM. Some GWOT and U.S. Army veterans queried by the author have suggested that this could have been caused by improper weapon cleaning. However, numerous Chosen Few NCOs interviewed for this study have been vehemently adamant in stating that weapons were meticulously and regularly cleaned, and rigorously and routinely inspected by the chain of command. Other GWOT veterans consulted have noted that the high rates of fire sustained during the two hour intense engagement phase at Wanat could possibly have contributed to these failures. However, numerous weapons failed relatively early in the engagement (particularly a number of M-4 rifles and at one SAW at the mortar pit), and in any event the maintenance of cyclic rates of fire was critical to restore fire superiority, and to prevent positions (particularly at OP Topside) from being overrun by determined, numerous, and hard pressed insurgent assaults. The U.S. Army Project Manager-Soldier Weapons needs to investigate the reason(s) behind the repeated failures of multiple weapons at sustained cyclic rates of fire, and initiate appropriate measures to address such failures.

The Battle of Wanat
COP Kahler, Afghanistan
13 July 2008

- **9 US soldiers killed, 27 wounded when their fighting positions were partially overrun**
- **Numerous Carbines, SAW's AGL's failed – due to high SRF**
- **Sustained Rate of Fire (SRF) Comparison (Rounds/Minute)**
  - **Carbine = 90**
  - **AK-47/AKM = 120 - 150**
  - **Modern COTS Alternatives = >150 (USMC IAR >300)**

Thing is we knew of this issue as early as 1990! **(AMC tests)**



Cpl. Pruitt Rainey's coffin was carried from his funeral in July 2008 in Burlington, N.C. He was one of nine American soldiers killed in a firefight that month in Wanat, Afghanistan.



Common Requirements (cont.)
IC & Legacy Carbine Enhancements



- **Weight Reduction:** =/> 20% (PCAP's, Add-on Rails vs. full RAS, ISM's, Dynamic Flowform Inconel/Cobalt Barrels?)
- **Modularity - User Configurable Caliber, Barrel, Stock Conversion:** SCAR Common Receiver (5.56mm-7.62mm), Rem. ACR/MSR, Beretta ARX-160, HK XM8/USP, SIG516 Gen II, Czech Republic CZ805A, etc.
- **Parts Commonality:** 82% between 5.56mm, 6.8mm and 7.62mm (SCAR)
- **Reduced Maintenance (User, Maintainer):** 72% less cleaning time (any Op Rod system), "Lubeless" finishes
- **Reduced Procurement Costs:** (complete weapons, barrels, piece parts)
- **Reduced Life Cycle Costs:** 45 - 75%
- **Unique Capabilities:** Advanced penetrator technology, "Blind to Barrier" projectiles, LV 40mm ABMS, fielded/emerging threat capabilities



COTS Incremental Advances Waiting to be Exploited



Modular, User Configurable Rifle Systems are now available that would allow on-the-fly user reconfiguration to support changing missions, threats for:

- **Transition from Iraq to the Long Range War of OEF & the need for long range accuracy & terminal effects**
- **Improved terminal performance from short-barreled weapons for personal protection, vehicle use**
- **To meet as of yet unanswered but approved user requirements for:**
  - **M4-style SDMR's**
  - **Medium Caliber MURG's**
  - **Automatic Rifles**
  - **7.62x51mm Rifles, SDMR's**
  - **Personal Defense/Subcompact Weapons**

A modular "Lego" system configurable by the user

Available Modular Weapons
New since 2009

User Exchangeable (without tools, special tools):
-Barrels (lengths, types) -Feed Systems
-Stocks (assorted) -Calibers

Beretta ARX-160
Fully modular w/o tools. 5.56mm, 7.62 x39mm, 6.8x43 mm. In service w/ Italian Army.







FN SCAR
"Common Receiver"
5.56mm – 7.62x51mm
In final development.

Remington ACR
Fully modular w/o Tools. 5.56mm, 6.5mm G and 6.8mm, 7.62x39mm. In production 2010.



Taiwan T97 conver-tible from 9mm – 7.62x51mm. Fielding expected 2012-2013





CZ 805 A
Fully modular w/o tools.
Entering series production.

Incremental Advantages Waiting to be Exploited

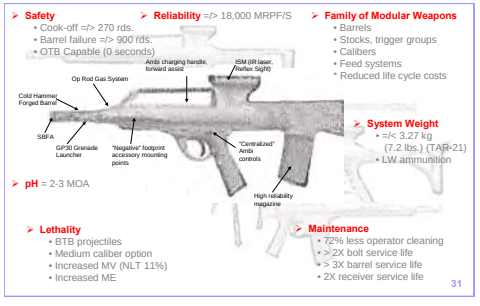
- **Safety**
  - Cook-off =/> 270 rds.
  - Barrel failure =/> 900 rds.
  - OTB Capable (0 seconds)
- **Reliability** =/> 18,000 MRPF/S
- **Family of Modular Weapons**
  - Quick-Change barrels, stocks, trigger groups
  - Caliber Convertible
  - Convertible Feed System
  - Reduced life cycle costs



- **System weight**
  - =/< 2.8 kg (6.1 lbs.)
  - LW ammunition
- **pH** = > 2 MOA

Same Advantages for a Bullpup Configuration

- **Terminal Effects ("Lethality")**
  - BTB projectiles
  - "Medium Caliber" options
  - Increased Terminal Effectiveness against unprotected and protected targets
- **Maintenance**
  - 72% < operator cleaning
  - > 2X bolt service life
  - > 3X barrel service life
  - 2X receiver service life



Sadly the US is not seeking a Modular Carbine or Family of Weapons



Part I Summary



If allowed to run its full course, important and available incremental improvements will be realized

- **US IC and Carbine Upgrade efforts will provide welcome data to 8+ similar NATO programs**
- **The US should be seeking a modular user reconfigurable family of weapons to meet assorted user needs**
- **Strong Congressional support exists and is engaged**
- **This same assessment process must be applied to other aged legacy weapon categories (handgun, rifle, SAW/LMG, AGL)**

Part II
Joint US/NATO Programs – What if?

What if we collaborated on the joint, shared "team" development, testing, fielding, support, PIP's of a NATO common "suite" of small arms and enhanced ammunition for the benefit of the joint international war fighters?

How can we?

Who should be the Lead?

What are the Obstacles?

Who pays for it?



US Marine Sergeant and British Army Major in Helmand Province Afghanistan

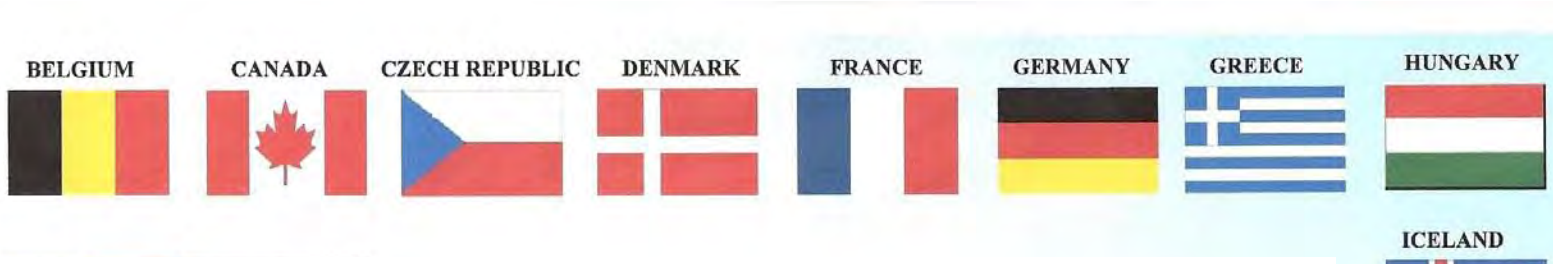
If it can be imagined, it can be accomplished

The United States

All can be breached

We share the costs

NATO Overview



28 Independent Member Countries: @ 3.8M Personnel

- 18 Countries "Seeking Membership": @ 1.7M Personnel
- Total Personnel: @ 5.6M Armed Personnel
- **That is some serious buying power!**
- Currently using 19 + 3 different rifles/carbines and 15 + 2 LMG's/LSW's in 2 + 4 calibers.
- **Why?** For the most part we fight the same enemy, in the same locations and in the same manner.







NATO Small Arms, Ammunition Replacement Programs – 2010-2022



Weapon Type	Programs (Approximate Start Dates)	Value (USD)	Comments (Partial List only!)
Handguns (1) Estimates based on $400 unit cost x active personnel	US M.H.S. (2010) UK (2010-2012) Canada (2012-2015) (3)	208M 8M	(3) Part of 1B Canadian dollar "SARP 2" (Small Arms Replacement Program - 2012-2022)
Rifles/Carbines (2) Estimates based on $1K unit cost x active personnel	US M4 Upgrade, I.C. (2012) UK (2020) Canada (2018-2020) (3) Czech Republic (ongoing) (4) France Italy (ongoing) (4) Romania (2010-2013) Sweden Turkey (ongoing)	1B 240M 67M 8M/57M 259M 230M 90M 34M 514M 2.49B	Also non-NATO countries of Australia, India (2-3M/$1.5-2B!), Norway (ongoing), Switzerland (4) User-convertible caliber, barrels, etc.
Cartridge/Caliber	US (I.C. Competition) UK (ongoing studies) Canada (under consideration)		5.56mm, 7.62mm NATO PIP's (M855A1/SOST), UK CTA, US LSAT, "Medium Caliber"



NATO Trails - Last Time We Partied Together



Caliber/Cartridge

- 1949 to 1953: 7.62x51mm NATO Standardization
- 1977 to 1980: Tested 5.56mm, 4.85mm, 4.7mm Caseless
  SS109 selected as the 2nd NATO Cartridge

- **Rifles**
  - 1977 to 1980: 6 tested. No NATO Standard Rifle selected.
    There are only "NATO Nominated" rifles.

- **Other Weapon Categories** – NATO PDW Tests 2000-2003

Combine the talents, resources, facilities, funding, technology, experience and economies of scale for the benefit of the war fighters of participating countries at a time of shrinking defense budgets throughout NATO



NATO Trails - Last Time We Partied Together (cont.)



It CAN be done!

The Warsaw Pact/Communists did it (twice)!

(7.62x39mm AK-47/AKM, 5.45x39mm AK-74)

- **NATO/EDA "Common Module Program"**
  - **9 NATO countries participating - Austria, Finland, France, Germany, Italy, Portugal, Romania, Spain, Sweden**
  - **7 subsystems to include weapons/sensors integration, C4I, power supply, training, vehicle integration, survivability and sustainability**
  - **Schedule:**
    - *** 2010 Common Staff Requirement to Industry**
    - *** 2013 to 2014 Technology Demonstration**
    - *** 2015 – Initial Operating Capability**
  - **Jointly Funded by National Defense Budgets**



Benefits



Maximized System Performance for all Joint NATO War Fighters (weapon, sights, ammo terminal effects, MER)

- Leverage appreciable incremental advancements developed since @ 1995

- **Access to a true "Optimized" Intermediate Assault Rifle, LSW/LMG Cartridge for the first time in history!**

- **True NATO Interoperability and Interchangeability (weapons, ammo, accessories, sights, parts, tools)**

- **Common "Manual of Arms", Training, Documentation**

- **Universal/Worldwide User Access to Spares, Tools, Repair Facilities, Accessories, Compatible Ammo**



Benefits (cont.)



- **Friend versus Foe ID – Reduced Fratricide**
  (Example: MK16/17 outline ID'ing US SOF operators)

- **Reduction of Threat Weapons Sales/Proliferation**
  (N. Korea, PRC, Iran – 100K/$8.3M AK's to India in 1995)

- **Wider Range of Technical Solutions and Materials available to all during development**
  (Examples: Dynamic Flowform barrels, LSAT polymer CTA ammo, BTB projectiles [SOST], special coatings, modular architecture)

- **Access to Non-NATO Technologies**
  (Novel mechanisms e.g. AN-94, exposed tip AP & CPT ammo)



Cost Benefits
Do something for the beleaguered Taxpayers!



- **Economies of Scale/Increased Price Competition**
  - Reduced Unit Costs (weapons, ammo, parts, sights, accessories, tools/gauges, etc.) **Slides 27 & 28**
- **Shared/Reduced Production Tooling Costs**
- **Benefits of common PIP's throughout NATO fleet versus new and complete replacement programs (with a true modular/user-convertible weapons system)**
- **Industry focus on 1 or 2 RFP's versus 20 or 30 in various countries, languages, currencies and with radically different, non-compatible requirements**

Motivated by Money? (or the lack thereof?)

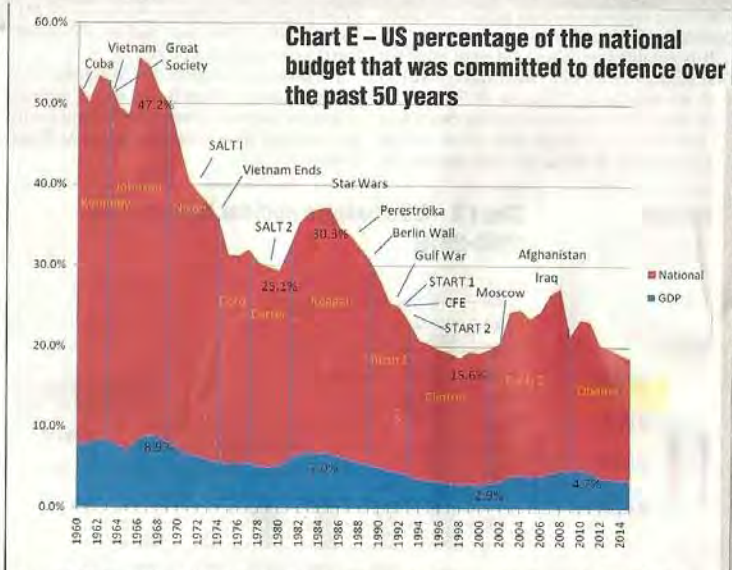
February 8, 2010 www.defensenews.com

Pentagon Dodges Budget Bullet

6 DefenseNews March 15, 2010 ★ www.defensenews.com

WORLD NEWS

Budget Cuts Affecting Canadian Defense Programs



Sources: DGDP and national budget data derived from the Department of Defense and the President's FY2011 Budget Submission. Author Ron Hertenstein: 136938

22 DefenseNews April 19, 2010

EUROPE

Turkey, Greece Pledge Defense Cuts; Doubts Remain

Spending cuts threaten Austrian projects

Defence budget cuts threaten Czech assault rifle

Cuts to the defence budget may force the Czech Ministry of Defence (MoD) to postpone or cancel a programme to select a new standard-issue assault rifle for the Army of the Czech Republic (ACR).

It was expected that the MoD would announce the selection of a new standard-issue family of assault rifles at the beginning of 2010. Czech small arms maker Ceska zbrojovka Uhersky brod unveiled the new rifle, the CZ S 805, at the IDET 2009 Def... in May.

The MoD expect... the defence budge... (USD1.3 billion) o... procurement.

"Further develo... on the proposed d...

10 • 31 March 2010 • JDW • jdw.janes.com

THE AMERICAS

US mulls future balance as budgets shrink

INTERNATIONAL DEFENCE DIGEST

Economic downturn signals a change of pace for SMPs

And what often gets cut first?



Motivated by Money? (or the lack thereof?) (cont.)



- "NATO already faces shortfalls of hundreds of millions of Euros"
  – US Defense Secretary Robert Gates (February 2010)
- Canadian PM Harper plans to cut 2.5 billion Canadian dollars ($2.4B USD) in defense spending between 2012 and 2015
- Spain's 2010 budget of around EUR 7.35B (10B USD) is EUR 489.8M (6.2%) below the figure for 2009 and is set to fall an additional EUR 141.1M.
- "On the Pentagon's current plan, defense spending is set to fall from 4 percent now to 3.2 percent of GDP in 2015 and 2.6 percent of GDP in 2028" – Congressional Budget Office
- French and German soldier modernization programs are seeing cuts of up to 50% in funding since 2009.
- In 2009, China's defense budget rose by 14.9% compared with 2008 & have posted dbl digit increases every year since 1989.

Can we afford NOT to share available resources?

Production Sites

Multiple/Joint Production Teams/Locations (Industry, Arsenals) Each Licensed by NATO/Design Holder to produce and test the weapons and ammunition in accordance with strict NATO specifications (AC/225)

Multiple Contract Awards for a handful of Like Weapons increases Production Efficiency and Output

Work with NATO Test Centers (2 Regional, 12 National)





Sample NATO Modular Weapon Contract Composition/CLINS



CLIN/Item Description	Caliber	Barrel (OL/Type)	Comments
1. Carbine, Conventional, cpl.	5.56mm	14.5”/Standard	One
2. Carbine, Conventional, cpl.	7.62mm	16.0”/Standard	Common
3. Carbine, Conventional, cpl.	OC (1)	15.0”/Standard	Receiver?
4. Carbine, Bullpup, cpl.	5.56mm	18.5”/Standard	One
5. Carbine, Bullpup, cpl.	7.62mm	20.0”/Standard	Common
6. Carbine, Bullpup, cpl.	OC (1)	19.0”/Standard	Receiver?
1.A.- 6.A. Barrel Assemblies, cpl.	All	CQB, Carbine, Rifle, SDM, AR	Operator install-able w/o tools/ special tools
1.B.- 6.B Magazines, cpl.	All	10, 20/30, Hi Capacity Magazine	
1.C.- 6.C. Accessories	All	Grenade Launcher, Sound Suppres-sor, Bayonet, Sights, Slings, etc.	
1.D- 6.D Kits, Caliber Conversion	All	Includes bolt, barrel, magazine	
1.E.- 6.E Spare Parts	All		
1.F.- 6.F Tools, Gauges	All	To include Manuals	

(1) Optimized Cartridge (Intermediate Caliber) OL - Overall Length (in.) Cpl. - Complete



Cost Benefits

Economies of Scale/Increased Price Competition



- Assault Rifles/Carbines only. Does not consider spare mags, parts, tools/ gauges, sights, accessories *OR* shared development, testing, logistical support, documentation, tooling costs, etc.
- Assumes all Active Duty personnel are assigned a rifle/carbine.

Qty	Unit Price (USD)	Total Procurement Cost (USD)	Dis-count (%)	Cost Savings (USD)	Supplemental Purchases Possible (Qty)	Comments "Free" guns for: NATO Member Seeking Membership
100K	1,000	100M	0	0	0	Iceland (0)
250K	1,000	250M	1	2.5M	2,500	Switzerland
500K	1,000	500M	2	10M	10,000	Albania, Ireland
1M	1,000	1B	4	40M	40,000	Belgium, Bulgaria, Croatia/Denmark, Finland/Moldova, Uzbekistan, Portugal
1.7M (3)	1,000	1.7B	5	85M	85,000	(3) Potential Future NATO Membership. Belarus, Romania, Netherlands/ Luxemburg, Lithuania/ Latvia, Slovenia/ Switzerland



Cost Benefits (cont.)

Economies of Scale/Increased Price Competition



Qty	Unit Price (USD)	Total Procurement Cost (USD)	Dis-count (%)	Cost Savings (USD)	Supplemental Purchases Possible (Qty)	Comments "Free" guns for: NATO Member Seeking Membership
2M	1,000	2B	8	160M	160,000	Canada/Poland, Spain
3M	1,000	3B	12	360M	360,000	1/4 US Army + US Navy, Germany/Czech Rep./ Georgia, France/ Poland, UK/Poland/ Slovakia
3.9M (4)	1,000	3.9B	15	585M	585,000	(4) Current NATO Members. Entire US Army + Polish military. Total population of Wash. DC or the state of Wyoming. Turkey/Sweden/Turk-menistan/Tajikistan/ Estonia
5.6M (5)	1,000	5.6B	20	1.12B	1,120,000 (5) Current/Future NATO Members US Army/Navy/USAF + 77% of USMC, Russia/Venezuela, Entire populations of East Timor, Las Vegas/Portland or Kaufman Co. Texas!	



Part II Summary



<u>This opportunity is fleeting</u> – should begin ASAP using common requirements/specs (AC/225)

- **The United States should take the lead with NATO LCG-1 SG/1. Most agree and history has shown that NATO is unlikely to proceed unless America is on board, <u>especially on new caliber selection</u>**

- **Greater order potential (quantities purchased) drives innovation, industry IR&D and thus reduces unit costs while increasing performance for the benefit of all involved**

- **State-of-the-science weapons/ammunition available from a global inventory for all NATO small arms end users**

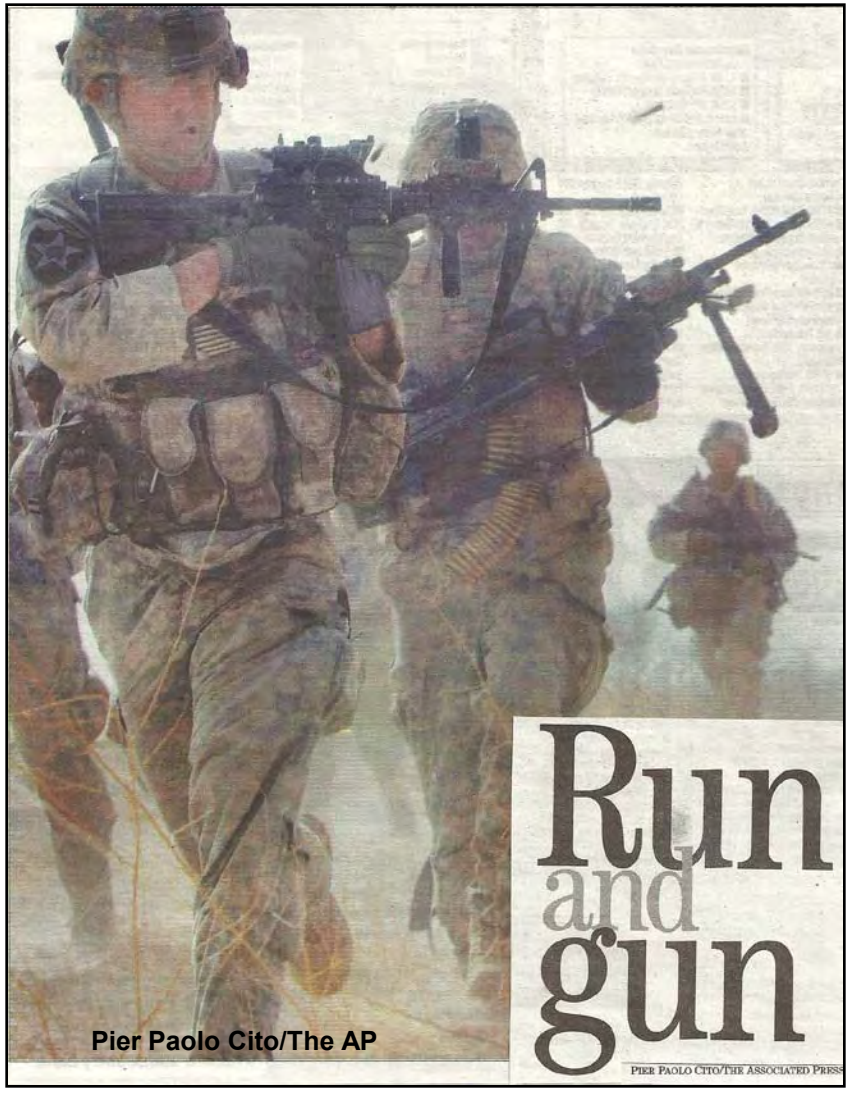
If not through NATO, how?

Part III
The USAAAP

User Small Arms and Ammunition Advisory Panel (USAAAP) "U Sap"

Giving the experienced small arms end users/ground combatants a seat at the decision making table.

A say in what they fight with! (and sometimes die with)





The "Lost" User Requirements



Too often valid and/or urgent <u>AND UNIT CG APPROVED</u> user requirements never survive "the process"

- **Army Infantry Divisions and XM8 for OIF**
- **M4-style DM Carbine – 82nd ABN DIV**
- **CASCOM Convoys, 10th SFG(A) – 10" 5.56mm Uppers**
- **5th SFG(A) – PMOD, 6.8mm MURG, .45 ACP Pistols**
- **.300 WINMAG M24's – 20+ years later**
- **New Handgun (4 false starts)**
- **QCB/Fixed Headspace M2HB's – 25+ years later**
- **Multi-cam versus UCP (ACU) – known deficient in 2005. A $5B+ mistake the USAAAP would not have made.**



The USAAAP model already exists…..and works well



- **Select US units have replaced 9/10 US standard weapons with incrementally superior COTS weapons <u>by involving end users in the process</u> - *the properly executed "90% solution"***
  - **In near term (< 2 years)**
  - **Few if any R&D dollars spent – low risk to vendors**
  - **Advanced and unique capabilities fielded – *<u>ALL COTS!</u>***

> FN Minimi before M249
> MAG58 before M240
> MK19 in Navy Spec War in 1960's
> .50 caliber Sniper Weapons before M107
> SR-25 before M110
> AG-416 before M320
> .40 S&W caliber handguns years before JCP/CP/MHS
> PDW caliber weapons and ammo
> HK416/417, GMG, SCAR/EGLM, others
> .300 WINMAG sniper rifles before M24 PIP
> .338 caliber and Modular Sniper Rifles before the PSR program
> Multi-shot 40x46mm Grenade Launchers before the US Army, USMC (M32)
> Also Uniforms, visual augmentation, protective gear, etc.

Many fielded with limited US Govt R&D spending, *<u>if any!</u>*

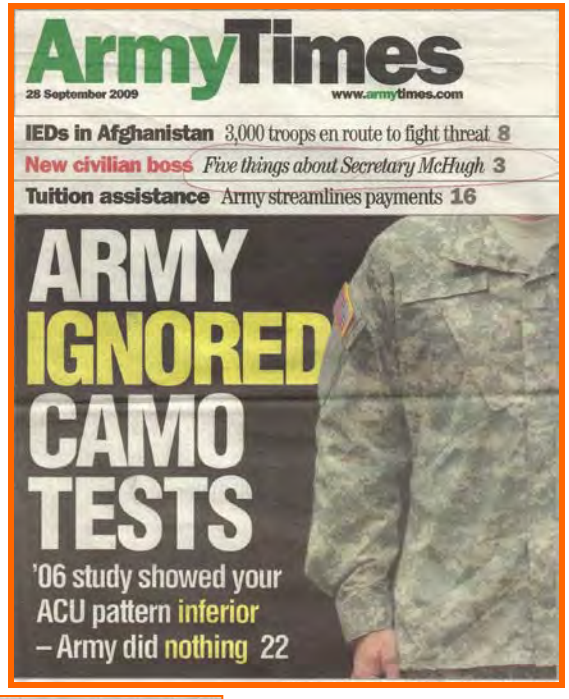
- **Multi-Cam combat uniforms before UCP/ACU's**

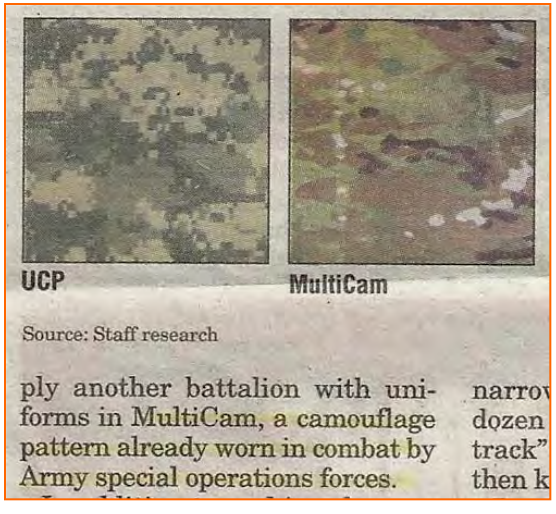
The USAAAP could have prevented a $5,000,000,000+ mistake

We would not have invested @ $5B on substandard Army ACU (UCP) uniforms and UCP camo pattern equipment if we had followed the lead of these units.

The 2009 Natick report raises questions as to why PEO Soldier overlooked the Marine desert digital, MultiCam and Desert Brush patterns in 2004 and chose the UCP for its Army Combat Uniform, a decision that resulted in $5 billion in uniform and equipment costs.

report, the first Natick study, called "Computerized Visual Camouflage Evaluation," conducted between November 2005 and July 2006, found that "MultiCam performed significantly better than the UCP in most conditions."





- **Model small arms acquisition that *can and should be replicated for all US military war fighters***
- **User driven, tested, selected**
- **Realistic requirements!**
- **Pushing the envelope of COTS**
- **Intelligent use of Limited Combat Evals**
- **Less cost to the tax payer**
- **Enhanced warfighter confidence, safety, survivability, enemy fear (respect) of our ground combatants**

Camo Uniform of The Week?

And why does each service need a different camouflage pattern/uniform?

How does that make any sense at all?



Pick the best patterns (desert, woodland, etc.), tag them by service and issue them to all – and save money through economies of scale!



The USAAAP

(User Small Arms and Ammunition Advisory Panel)



- **Real Users, Select US Unit representation**
- **Proven incremental fielding representation**
- **Self-vetting - No PEO's, PM', AO's, other**
- **Report to both Congressional ASC's, SECDEF**
- **Directs, approves actions of system on:**
  - **Current Product Performance**
  - **New item assessment, testing**
  - **Major Contract Awards and Extensions**
  - **R&D Program Funding (current and new)**

The system truly working for the real end user!



The USAAAP (cont.)

(User Small Arms and Ammunition Advisory Panel)



•Purpose

- To address the pronounced absence of the front line combat small arms end user on issues and decisions concerning US DoD small arms and ammunition performance, development, selection, assessment, fielding, sustainment and training to insure the US war fighter always has and is properly trained on the very best small arms, ammunition and ancillary equipment available to the United States.

•Description

- The USAAAP will be comprised of no more than twenty five (25) select current individual end users and subject matter experts from the US DoD and industry small arms and ammunition communities. Representative slots on the USAAAP will be allocated as follows:

- DoD, OGA Sub-Panel [(1)] (Total 14)
- 2 - US Army (Infantry)
- 1 - US Air Force
- 2 - US Marine Corps (Infantry)
- 1 - US Army AWG
- 2 - USSOCOM
- 1 - US Coast Guard
- 1 - US Navy
- 2 - JSOC
- 1 - NGIC
- 1 - CIA

- SME Sub-Panel (Total 11)
- 1 - Test community
- 1 - Logistics community
- 1 - Contracting community
- 3 - Incremental Fielding Experts
- 3 - Small Arms Experts
- 2 - Other (as required)

[(1)] Specifically members of the DoD Panel of the USAAAP will be or represent the actual small arms end user units/personnel and will not be current General Officers, PEO's, Acquisition Officers, Proponent Representatives, Program/Project Managers, or persons currently occupying positions within the current US DoD small arms acquisition infrastructure. USAAAP members will not be employed by the small arms, ammunition or ancillary industry in any capacity.



USAAAP Skill Identifiers



Skill Identifiers (background, panel qualifications)

- **A – Army Acquisition History/Dysfunction**
- **CA – Caliber, Wound Ballistics**
- **C – Contracting (contracts, cost analysis)**
- **E – Expert (Subject Matter)**
- **EN – Engineering (design, materials, technology)**
- **G – Gunsmith**
- **IF – Incremental Fielding (recent success)**
- **IN – Inside Knowledge**
- **L – Logistics**
- **LG – Legal (Hague, Geneva, ICRC compliance)**
- **M – Media Representative (NDA required!)**
- **P – Political**
- **PM – Program Management**
- **PR – Production**
- **PS – Performance Specs**
- **U – User (present, past)**
- **R – RDT&E**
- **S – Sensitive Organization *(protect information!)***
- **T – Testing**
- **TH – Threat (threat capabilities, countering the threat)**
- **TR - Training**



The USAAAP (cont.)

(User Small Arms and Ammunition Advisory Panel)



•Reporting

- **The USAAAP will report jointly and directly to the SASC/HASC and OUSD for AT&L or DoD Joint Staff.**

•Chairmanship

- **Chairmanship will be joint with one Co-Chairman from each of the two Sub-Panels.**

•Selection

- **Selection for Chairmanship and participation in the USAAAP will be determined by recommendations and approvals from the panel members by majority vote.**

•Duties

General Duties

- **The USAAAP will be responsible for reviewing, directing, coordinating and approving all small arms and small arms ammunition development (up to and including 40x53mm and .50 BMG caliber) and acquisition activities within the US DoD annually based specifically upon the expressed needs of the small arms end users each member represents.**



The USAAAP (cont.)

(User Small Arms and Ammunition Advisory Panel)



- **Specific Duties**

- Receive and collect end user requirements documents for small arms, ammunition and ancillary equipment and training
- Coordinate an annual end user summit to collect user feedback on existing equipment and training, threat capabilities, and to discuss new and urgent requirements
- Coordinate and receive semi-annual threat briefings and updates
- Review and direct small arms development and fielding
- Review and direct small arms ammunition development and fielding
- Review and direct small arms ancillary equipment development and fielding
- Review and direct small arms user training development, implementation
- Review, modify and approve new requirement documents (from proponents) for small arms, ammunition and ancillary equipment
- Review, modify and approve all Performance Specifications for small arms, ammunition and ancillary equipment
- Review, modify and approve new R&D initiatives for small arms and ammunition and ancillary equipment
- Review, modify and approve new contract initiatives (awards, delivery orders, recompetes, extensions, major modifications, etc.)
- Review, modify and approve solicitations for small arms and ammunition and ancillary equipment
- Coordinate joint efforts, requirements within the US DoD community
- Brief and provide direction to the OUSD for AT&L, the DoD Joint Staff, SASC/HASC and the ammunition support infrastructure on USAAAP decisions, directives



The USAAAP (cont.)

(User Small Arms and Ammunition Advisory Panel)



- **Activities**
  - Meet Quarterly, or as required to review specific duties listed above.
  - Meet Annually;
    1. To assess the current performance of all legacy (existing) US DoD small arms and ammunition and ancillary equipment.
    2. To direct the US DoD Small Arms Support Infrastructure to assess select new "Incrementally Superior" COTS/near COTS candidate small arms and ammunition and ancillary equipment items that offer improved performance and capabilities over existing (legacy) items for fielding 1-3 years out.
    - Every three (3) years meet to review and direct the US DoD Small Arms Support Infrastructure on "Future Programs" for small arms and ammunition and ancillary equipment items that offer improved performance and capabilities over existing (legacy) items for fielding 3-5 years out.
    - Every five (5) years meet to review and direct the US DoD Small Arms Support Infrastructure on "R&D Programs" for small arms and ammunition and ancillary equipment items that offer improved performance and capabilities over existing (legacy) items for fielding 5-10 years out.

- **Funding**

  Funding to support the activities of the USAAAP, to include US Govt personnel travel and SME contractor labor and travel expenses, and full time administrative support will come from the OUSD for AT&L and will be incorporated into the permanent DoD budget.

Notes:

1. No contract will run longer than 5 years without being recompeted.
2. Contract recompetes will occur only with updated Performance Specifications and Purchase Descriptions based on USAAAP review.
3. No Small Arms or Small Arms Ammunition R&D program will run longer than 10 years.



3-year Incremental Fielding Cycle



On a three-year cycle the USAAAP

- **Reviews (every 3rd year)**
  - USG and COTS System Performance and Specifications, PIP's, Threats, etc.
  - R&D Programs (current, new)
- **Tests (every 4th year)**
  - Solicits Industry for and tests incrementally superior systems
- **Contract Award (every 5th year) NTE 6 years**



Part III Summary



The proposed USAAAP will provide the means to give the real small arms end users a "seat at the decision making table" on the development and selection of the very small arms and ammunition they fight and die with!

- **Will provide Top Level visibility on the state of US small arms and ammunition from the vantage point of the end users and SME's.**
- **Focus attention were needed in real time**
- **Expedite Incremental Fielding of Urgently needed items and prevent "distractions" and waste**
- **Reduce disjointed, parallel and sometimes unnecessary efforts**
- **Help better spend limited funds**
- **Exploit the talents of the existing support structure**

Form and empower the USAAAP Now!



Parting Thoughts



Decreasing US and NATO defense budgets and increasingly challenging global priorities dictate a need to combine efforts, talents, funding and resources in a truly joint environment.

- Direct end user involvement, visibility and oversight will make better use of available resources and deliver state-of-the-science materials more rapidly, more often and more affordably than the current top-down driven process.

- The existing support system truly working to address the real time needs of the ground combatant.

- Better equipment saves lives and wins battles!

Dedicated to the memory of

US Army Specialist Stephen Lee Mace
3 SQD, 61 CAV REG (4BCT), 4ID
from Purcellville, Virginia





A fallen soldier returns home. Leesburg Virginia airport

Killed in action on October 3rd, 2008 at Combat Outpost Keating, Nuristan province Afghanistan

In Memoriam





Thank you for your time and attention!

Contact Information

Jim Schatz

Email: schtred@aol.com

Grenade Launchers in China

(Upper)



Juanjuan Yang, Xinlong Li, Bin Yang,
Yi Ren, Junli Wang

China R&D Academy of Machinery

May 15 , 2010

Content



- Introduction
- Looking Back on China’s Grenade Launchers
- China’s Automatic Grenade Launchers
- China’s Jet Shot Grenade Launchers
- Summary

1、Introduction



Grenade launchers are used to kill & wound living targets, penetrate light armored targets and provide firepower supporting to infantry, which have become one of the most important small arms in modern wars.

China's Grenade Launchers



The Grenade Launchers made in China include automatic grenade launcher, jet shot grenade launcher and under-slung grenade launcher. All these can be equipped with iron sights, white light sights, low-level-light sights or infrared sights. They can launch different ammunitions, such as anti-personnel, anti-armor, smoke, incendiary, training, etc.



China’s Jet Shot Grenade Launcher



China’s Under-Slung Grenade Launcher

Characteristics



The grenade launchers independently developed by China are ones with light weight, high firepower, high precision, simple operation, good safety and low manufacturing cost features.

2、Looking Back

At the beginning of 1980s, China began to develop automatic grenade launcher. The first problem was to select the caliber for the weapon. The caliber would influence the weight 、power and mobility of the weapon.







Considering the fact that the terrain of China is of many mountains and walking was one of the main maneuvering ways for Chinese infantry, small arms R&D agency in China decided to develop 35 mm caliber automatic grenade launcher. In the specifications for the weapon, good mobility and capability of light armor piercing were highlights of the requirements



After years of arduous efforts, China finalized the design for its 35 mm automatic grenade launcher at the beginning of 1990s and designated the weapon as Type QLZ87 35mm ATL and then the weapon entered service in China. At the same time, other kinds of grenade launchers, such as jet shot ones, were developed in China.

In a short period of less than 40 years, China has made great progress in the area of grenade launchers. From nothing to serialization and from military employment to security application, Chinese grenade launchers have shown their unique capabilities in national defense and public security.



3、China's 35 mm ATL



QLZ87 ATL is the first generation grenade launchers for squad service in Chinese army, which filled the blank of ATL weapon in China and was a milestone for the development of Chinese grenade launchers. It's a kind of infantry weapon capable of direct & indirect firing 、 killing and light armor-piercing.

QLZ87 ATL has light configuration and heavy configuration. The light configuration is mainly used in a direct range of 600 m by a single soldier while the heavy configuration includes the light one plus tripod and could also be operated by a single man.

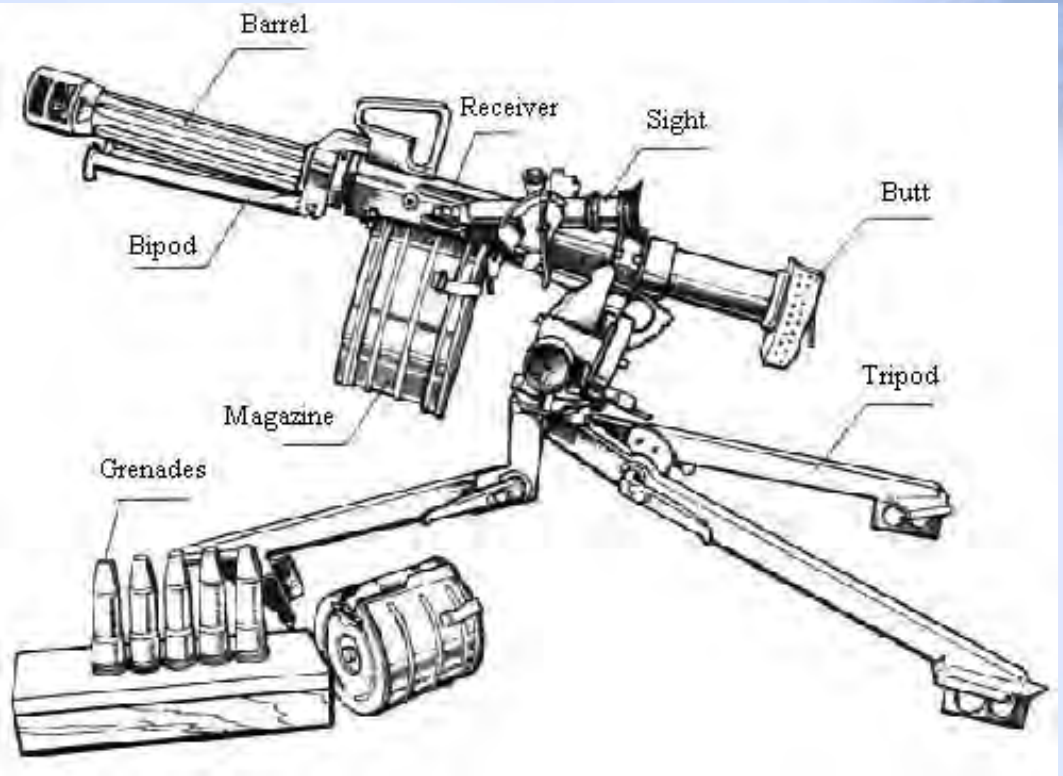


Light Configuration of Type QLZ87 ATL



Heavy Configuration of Type QLZ87 ATL

Structure



The Structure of QLZ87 ATL

QLZ87 ATL consists of barrel/receiver, automat，transmitter, butt, optical sight, magazine, tripod, etc. The weapon is of tubular structure for main assemblies including fluted barrel, receiver, frame and butt. This structure makes the motion axis of moving parts coincided with axis of the weapon, eliminating turning moment caused by non-coincidence between the two axes. The weapon embraces such characteristics as stable firing, easy manufacturing, compact structure and small size.

Magazine

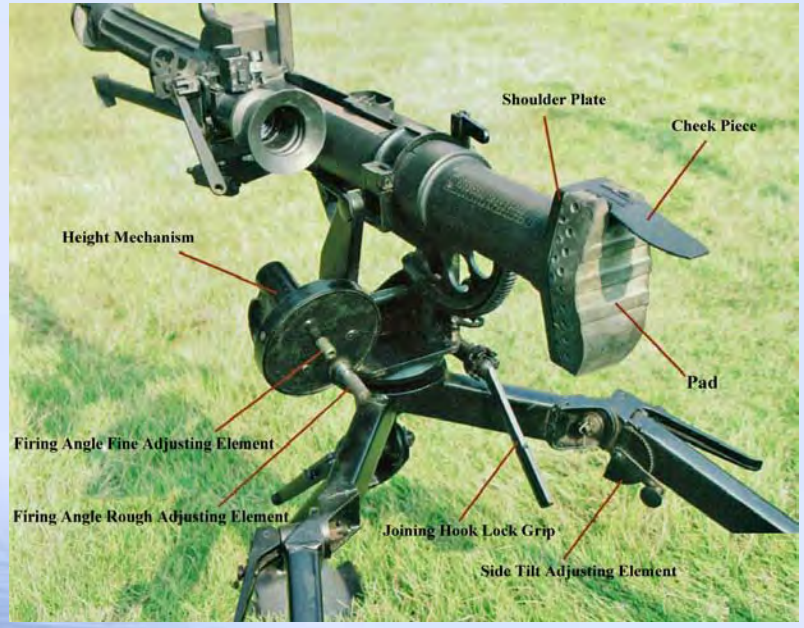
QLZ87 ATL is fitted with 6 or 15-round drum magazine at the bottom of the launcher, providing a clear FOV above the launcher for shooter's observation and aiming



Magazine of Type QLZ87 ATL

Tripod

The heavy configuration of QLZ87 ATL is supported by tripod . The elevation range for it is -10° - + 70° and traverse range is 360°



Sight

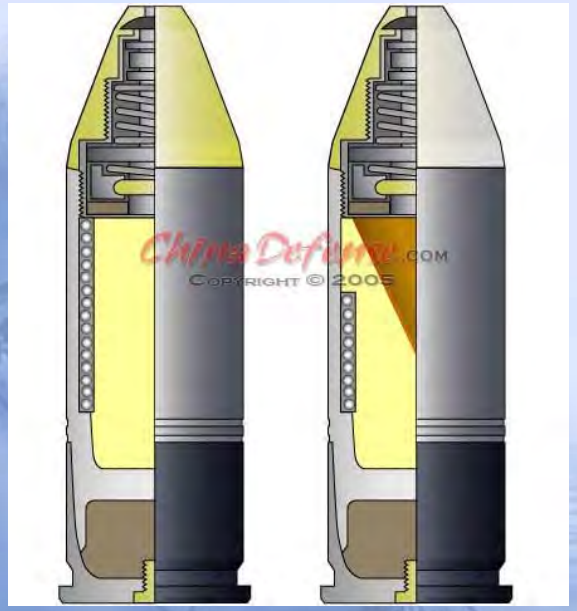
Sights for QLZ87 ATL include optical sight and iron sight. The FOV for the optical sight is 11° and the magnification for it is 3×.





Ammunition

QLZ87 ATL fires 35×32 mm SR grenades. Types of ammunition for it include DFS87 anti-personnel grenade, DFJ87 armor-piercing grenade, DFR87 incendiary grenade, DFN87 anti-personnel incendiary grenade, DFD87 smoke marking grenade, etc.



Anti-personnel Grenade and Armor-Piercing Grenade

Specifications

Caliber: 35 mm
The total weight for the weapon
Light configuration (including optical sight): 12 kg
Heavy configuration (including optical sight、tripod): 20 kg
The total length for the launcher
Light configuration: 1040 mm
Heavy configuration: 1300 mm
Weight of tripod: 8 kg
Weight of sight: 0.9 kg
FOV of sight: 11°
Magnification of sight: 3×
Weight of 6-round drum magazine without/with ammunition: 1.3 kg/(2.8 kg)
Weight of 15-round drum magazine without/with ammunition: 2.3 kg/(6 kg)
Weight of grenade: 0.25 kg

Specifications

Ammunition: HE, HEAT
Elevation: - 10° - + 70°
Traverse: 360°
Muzzle velocity: 190 m/s
Maximum range: 1750 m
Range for iron sight: 600m
Firing mode: single, burst
Rate of fire
Single mode: 15~20 shots/minute
Burst mode: 30~40 shots/minute
Blasting radius: 11 m
Armor penetration: 35 mm/ 60°, 80 mm/0°
Action: air cooling, gas operation

Review

The function and performance of QLZ87 has satisfied the requirements made by Chinese army. It has a weight of 12 kg for light configuration and 20 kg for heavy configuration, which is tailored for tactical doctrine of stressing maneuverability by Chinese army. QLZ87 is mainly used to suppress enemy firepower in range of 800 m, kill and wound living targets in open and covered area in range of 1750 m, penetrate light armored targets in range of 600 m and burn combustible materials in warehouses、camps、vehicles、equipments and military facilities in range of 1750 m.

Upgrades

To improve its burst firing capability and other performances, China furthermore developed Type QLZ04 ATL which is belt fed with much better burst firing capability and many new improvements.



Type QLZ04 ATL

4、China's Jet Shot Grenade Launchers

China began its development of jet shot grenade launcher at the beginning of 1980s and finalized the design at the beginning of 1990s. The jet shot grenade launcher designated as Type QLT89 has already entered service in China.



Type QLT89 50 mm Jet Shot Grenade Launcher

Structure

QLT89 consists of directional assembly, seat assembly, trigger assembly and belt. It embraces such characteristics as small volume, light weight and easy operation which make it suitable in employment in mountain or forest.





Aiming Unit

The aiming unit consists of rear sight and firing-angle marks on the belt. The aiming of the weapon is provided through rear sight, belt and the tip of grenade.





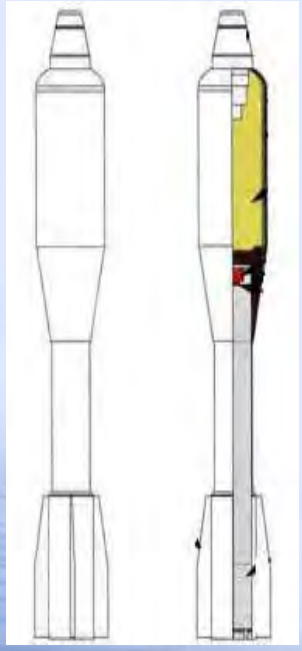


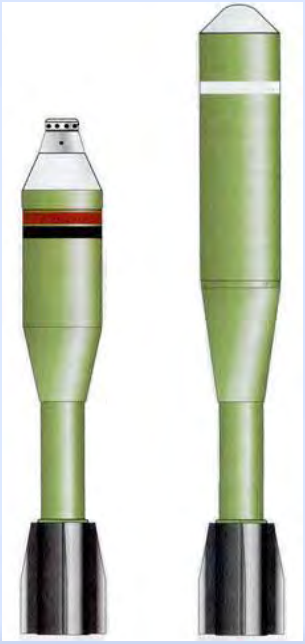


Aiming Method of QLT89

Ammunition

50 mm anti-personnel grenade is the main ammunition for QLT89. 800 fragments will be released when exploded with killing zone radius of 16 m. Apart from anti-personnel grenade, 50 mm smoke incendiary grenade and illumination grenade are available.





Specifications

Weight of launcher: 4.1 kg
Length of launcher: 600 mm
Life of launcher: 6000 shots
Caliber of grenade:50 mm
Weight of grenade:700 g
Length of grenade: 330 mm
Effective range: 200-800 m

Review

QLT89 is a kind of close range small arms portable by single soldier, which is fired indirectly with area lethality capability. It's mainly equipped into company or platoon unit. Generally it embraces such characteristics as small volume, light weight and easy operation. It's capable of suppressing enemy firepower, killing and wounding living targets behind covers and destroying fieldworks. In range of 200-800 m, it can provide firepower support for infantry units.

Upgrades

The rough aiming method is not convenient in operation and considerable training is required for high accuracy. In addition, QLT89 is mainly designed for field operation which isn't suitable for urban fighting. Aiming at the above problems, china R&D agency has made some improvements to QLT89 .



Type QLT89A 50 mm Jet Shot Grenade Launcher

5、Summary

From blank to generalization、serialization and standardization, China's grenade launchers have experienced a span development in short time. For the development of grenade launchers in China, on the one hand, advanced technologies in the world should be studied to make further improvements and updates. On the other hand, stemming from the concept of defense & self guard, China also needs to consider its own requirements to find a way with Chinese characteristics.

Purpose of Arms



Dagger of Ancient China

Philosophy

Through the development of Chinese grenade launchers, we can have a look at china's defense strategy of "Defense and Self-Guard ", which reflects one of Chinese military philosophy from very ancient time, that is "Hold Dagger to Stop War with final purpose of Beating it into plowshares" .

Thank You !

May 19, 2010



Testing non-lethals: Finding the right tools for the job

NDIA Joint Armaments, 17-20 May 2010

TNO | Knowledge for business



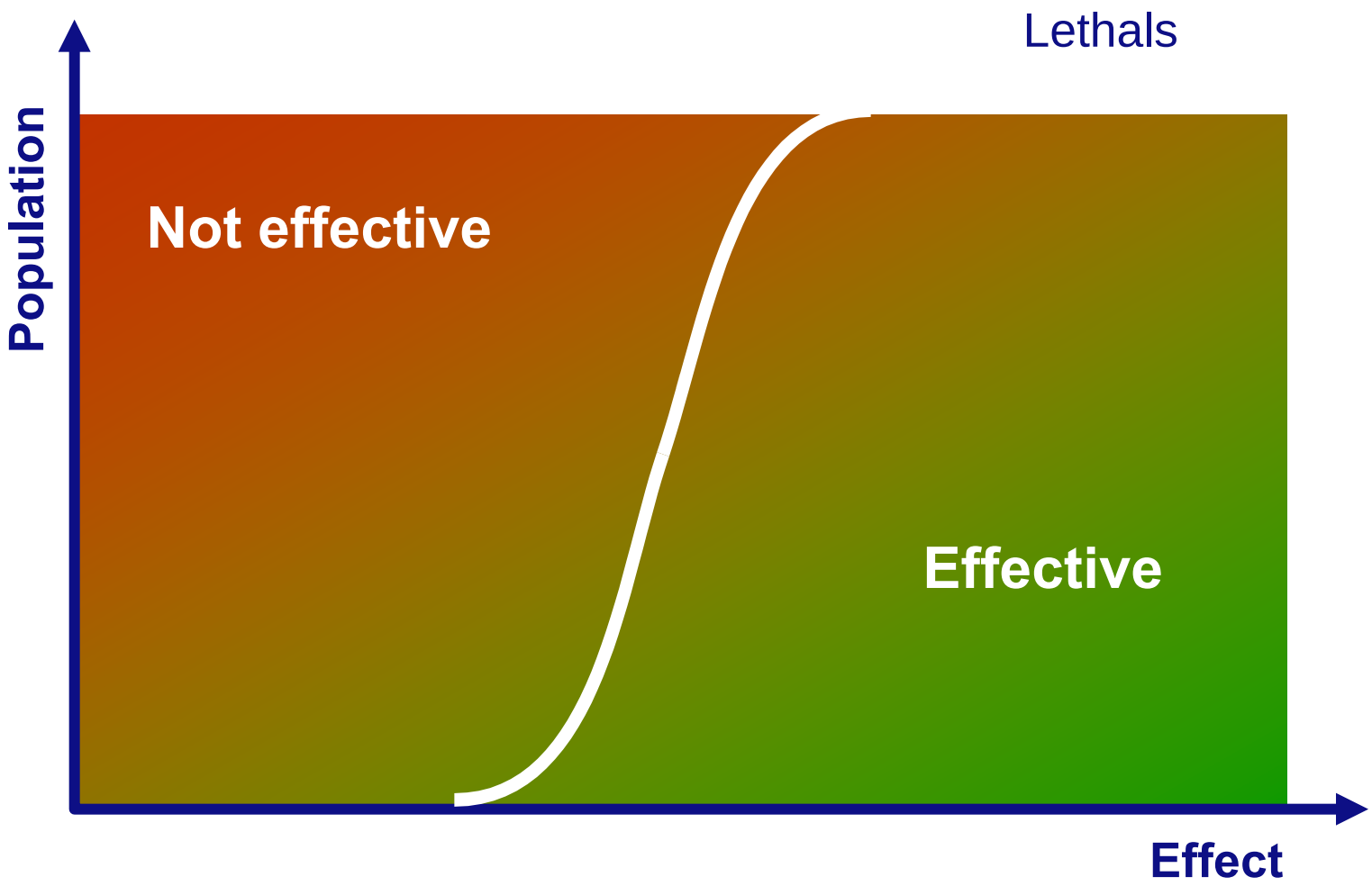
Pascal Paulissen

What are non-lethals?

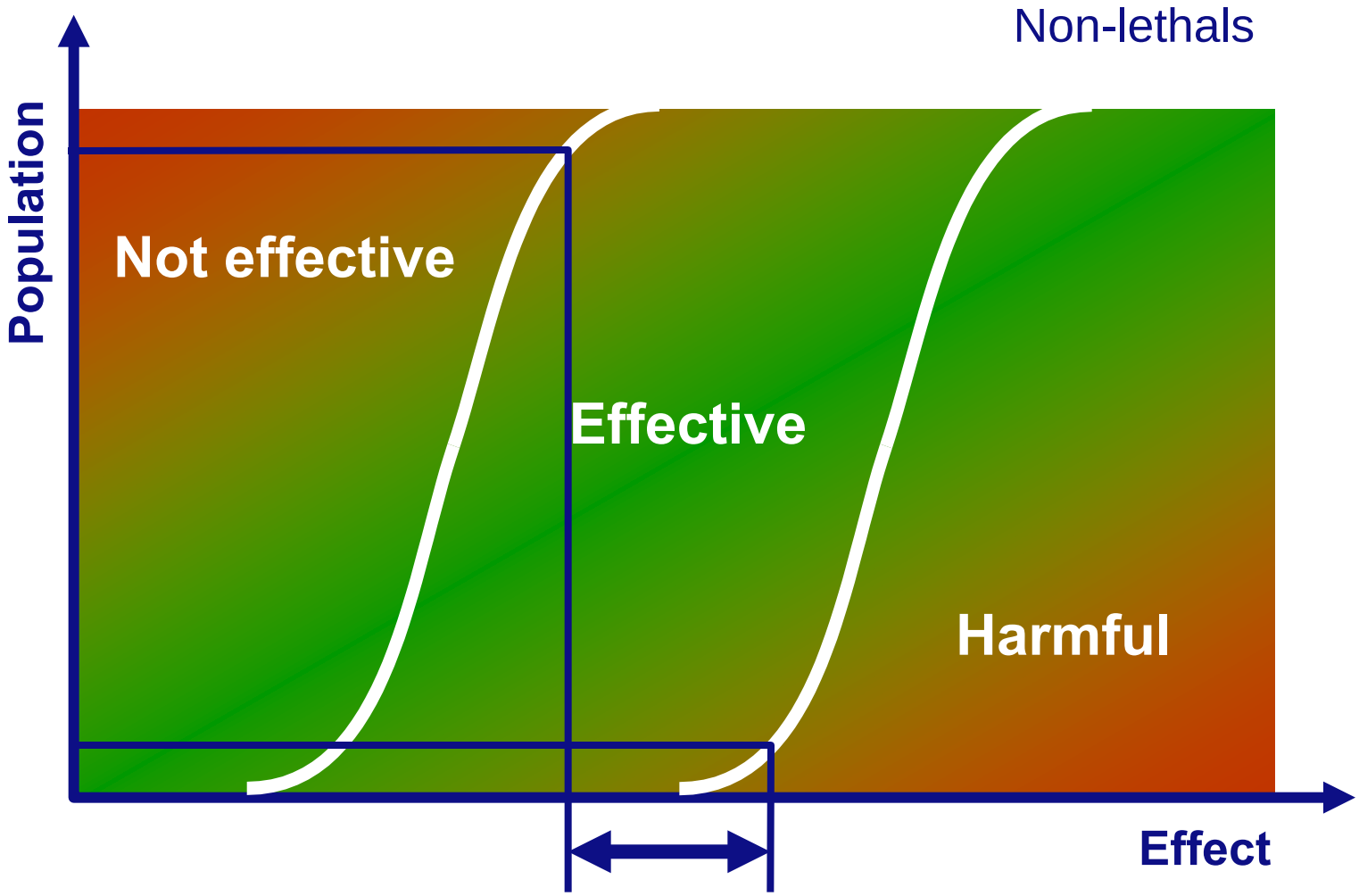
“Non-lethal weapons are weapons which are explicitly designed and developed to incapacitate or repel personnel, with a low probability of fatality or permanent injury, or to disable equipment, with minimal undesired damage or impact on the environment.”

NATO NLW Policy document C-M(99)44, 28 September 1999

What makes them different? (1/2)



What makes them different? (2/2)



A multitude of options...

Regarding military effects:

Warn
Divert
Disrupt
Disperse
Disorient
Deny
Repel
Incapacitate
....

Regarding means to achieve effects:

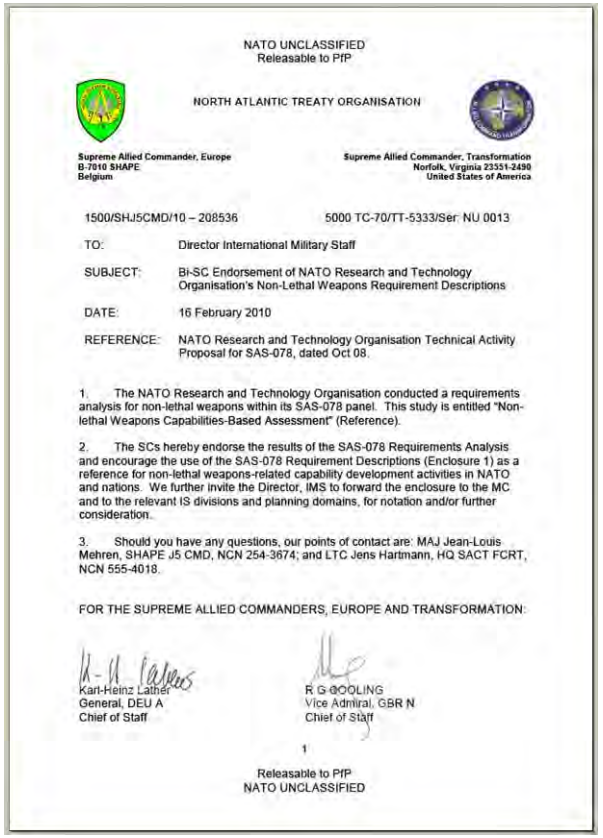


How the find the right one?

- It is all about effectiveness, bounded by risk
- Effectiveness starts with employment options (scenarios)

Crowd and riot control
Checkpoint operations
Force protection
Room entry
Covert operations
Combat operations
....

Requirement descriptions



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NORTH ATLANTIC TREATY ORGANISATION

Supreme Allied Commander, Europe
B-7010 SHAPE
Belgium

Supreme Allied Commander, Transformation
Norfolk, Virginia 23551-2490
United States of America

1500/SHJ5CMD/10 – 208536 5000 TC-70/TT-5333/Ser: NU 0013

TO: Director International Military Staff

SUBJECT: Bi-SC Endorsement of NATO Research and Technology Organisation's Non-Lethal Weapons Requirement Descriptions

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3. Should you have any questions, our points of contact are: MAJ Jean-Louis Mehren, SHAPE J5 CMD, NCN 254-3674; and LTC Jens Hartmann, HQ SACT FCRT, NCN 555-4018.

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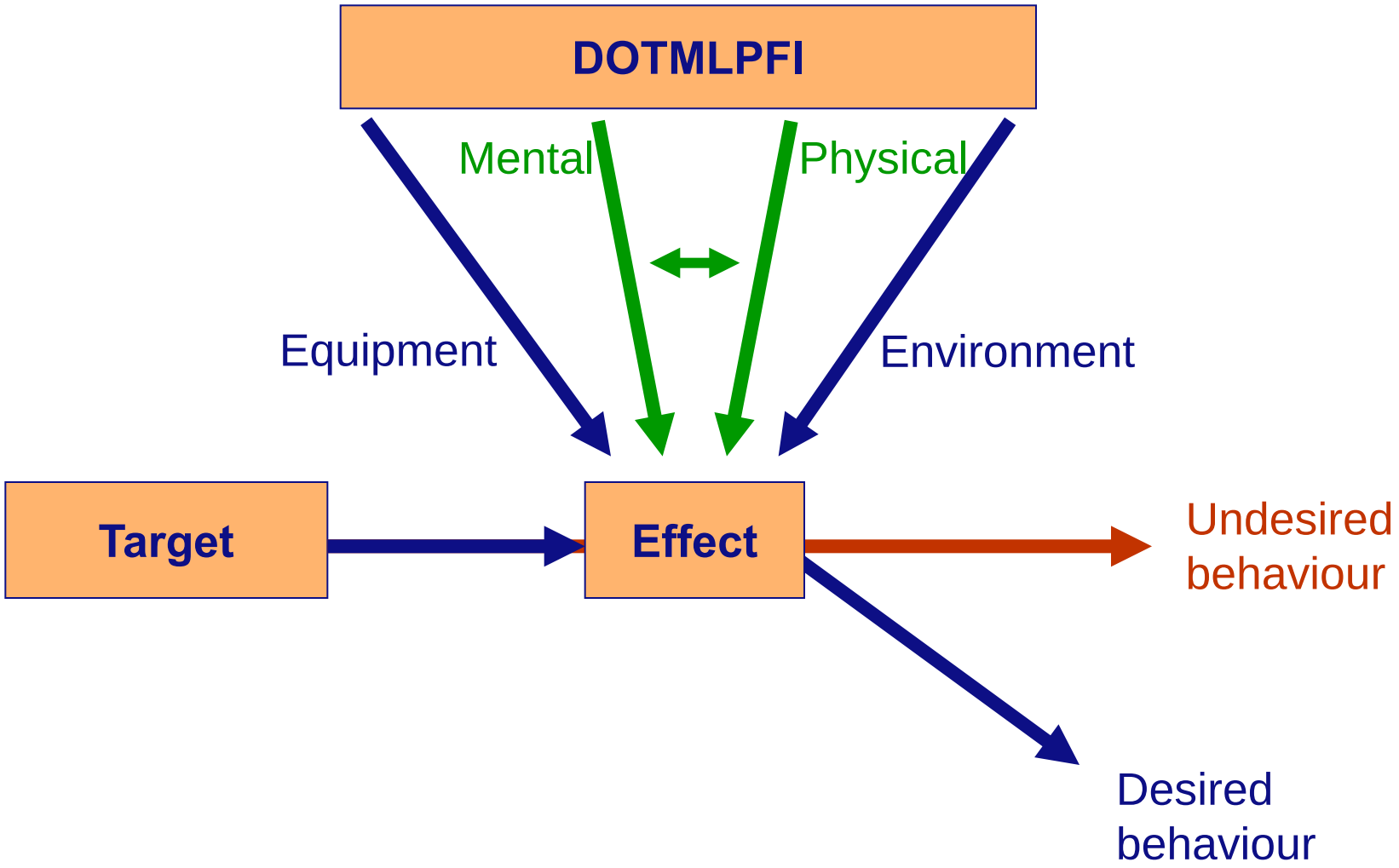
Karl-Heinz Lather
General, DEU A
Chief of Staff

R G COOLING
Vice Admiral, GBR N
Chief of Staff

1

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Employment framework



"Each person is, in certain respects, like all other persons, like some other persons, and like no other person." [Larsen, R.J., Buss, D.M., Personality psychology]

International co-operation (1/3)



- **Essential!**
- NATO arena
  - NAAG TG/3
  - DAT PoW Item 11 (DAT-11)
  - RTO SAS-078
- Bilateral agreements
- Civil-military co-operation
- …

NATO OTAN

NLW EWG

WAYNE STATE UNIVERSITY

POLITIE

AIR FORCE RESEARCH LABORATORY

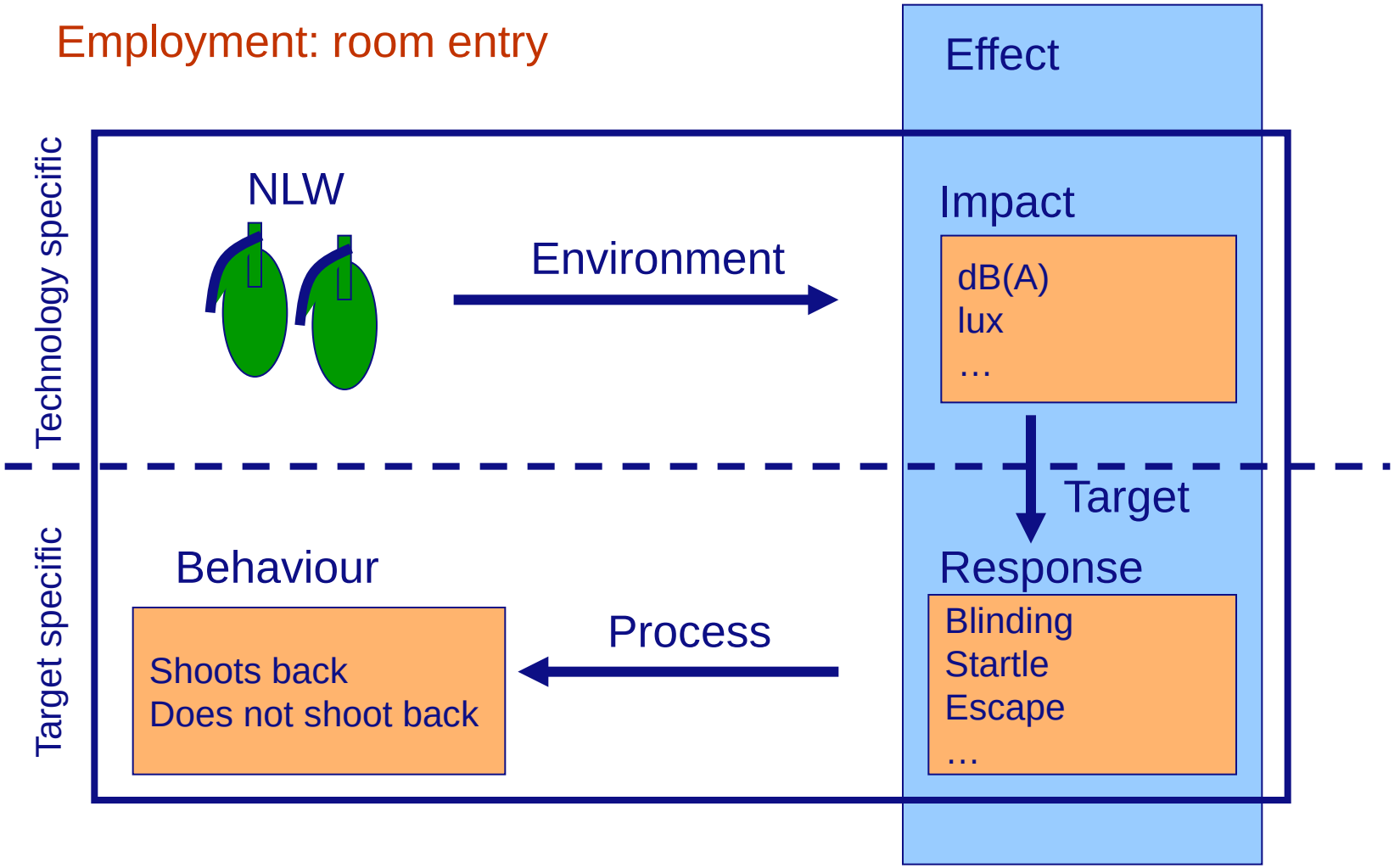
FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY ARSENAL, NJ

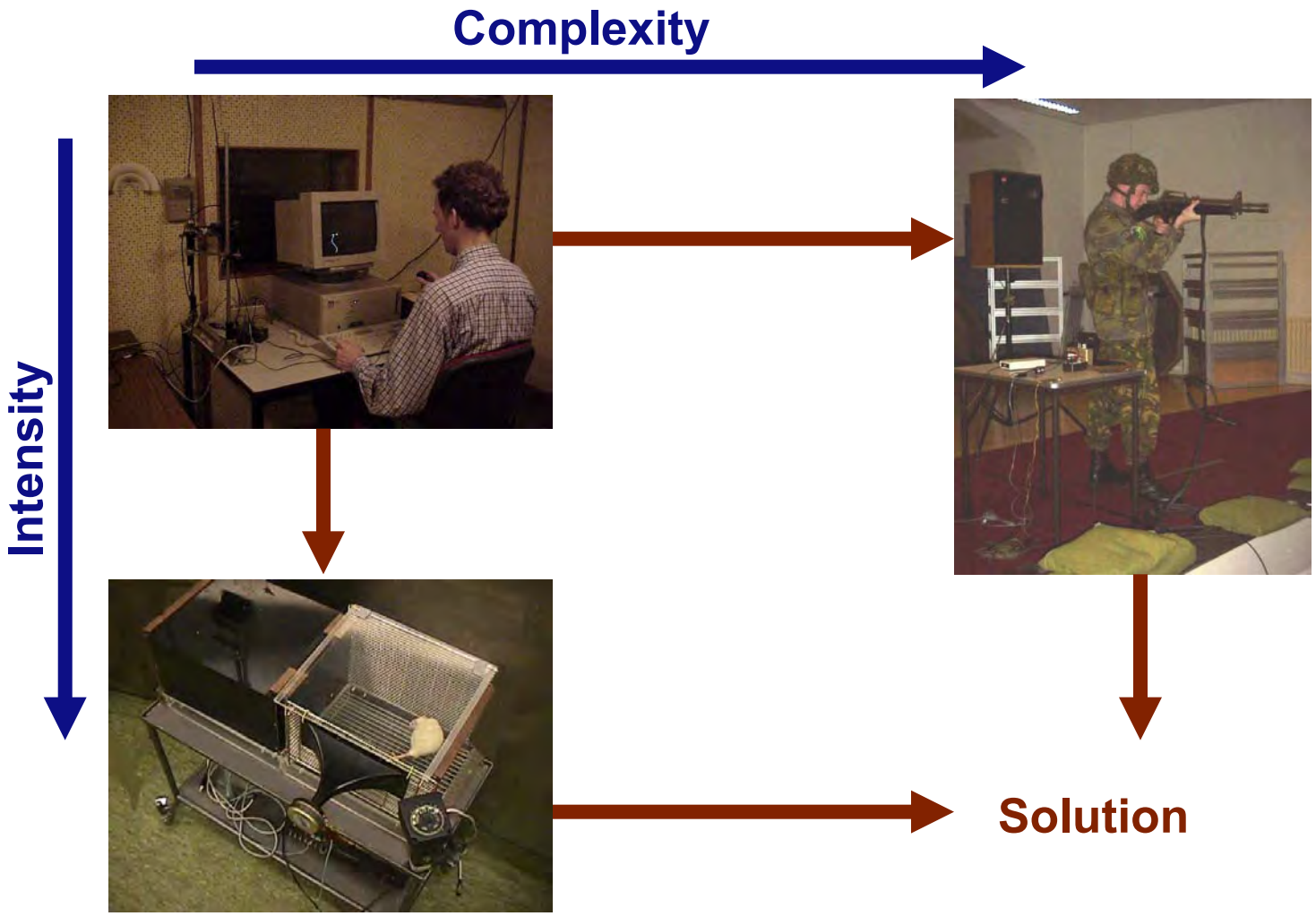
Wehrtechnische Dienststelle
für Schutz- und Sondertechnik

Case: flash-bang effectiveness (1/3)

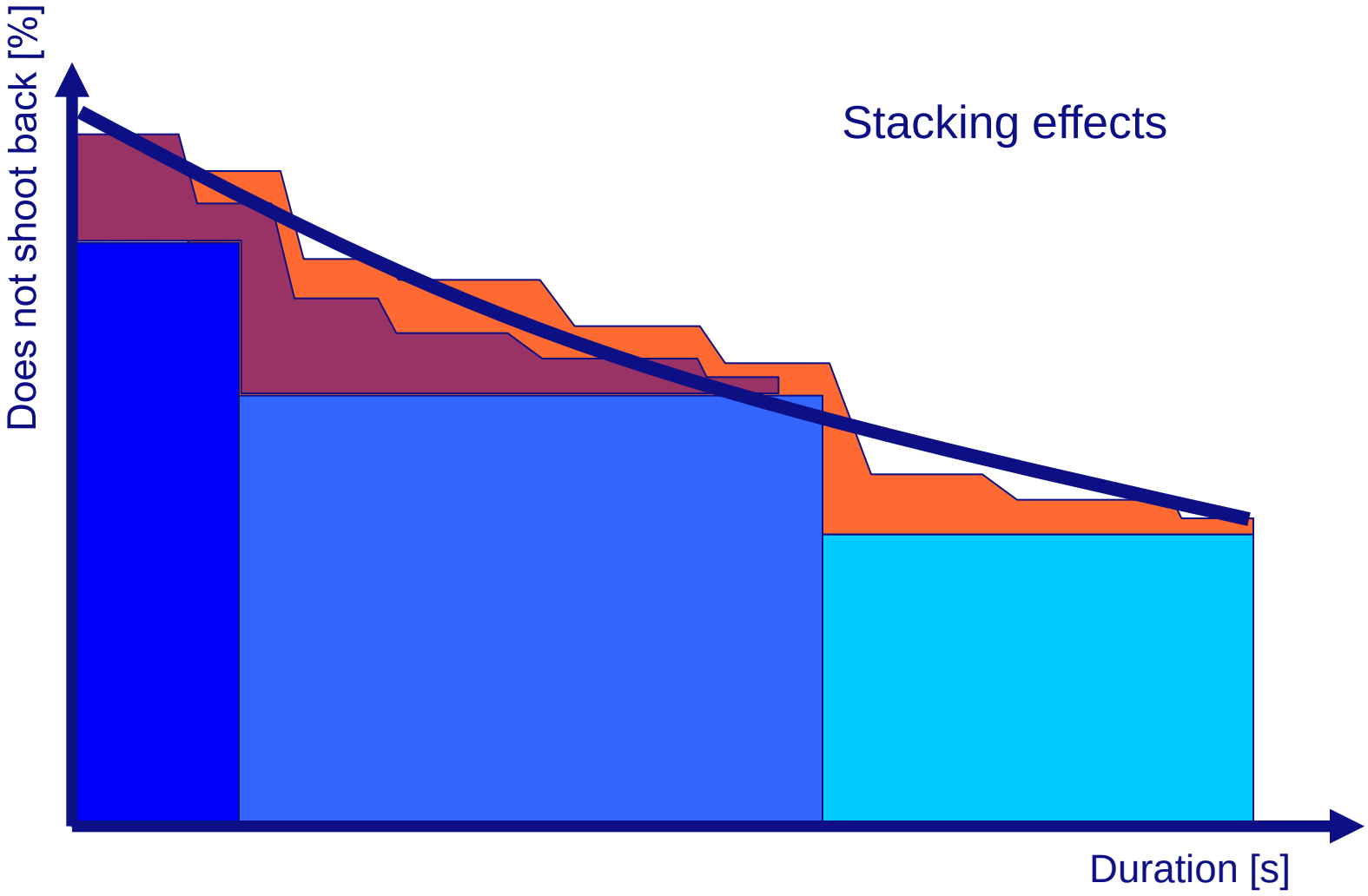
Employment: room entry



Case: flash-bang effectiveness (2/3)



Case: flash-bang effectiveness



Case: impact projectiles risk (1/3)

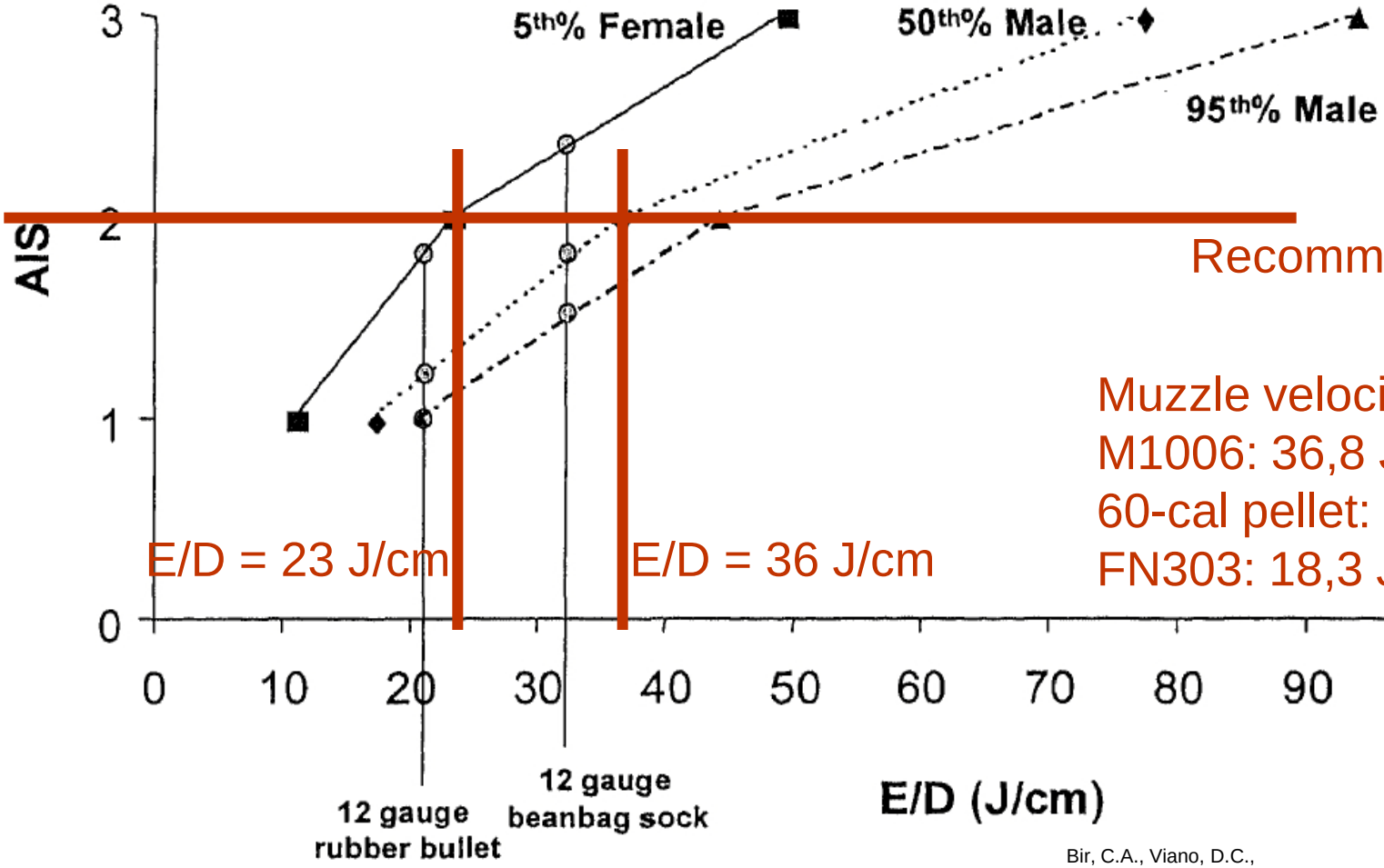
Employment: CRC

- Skin penetration thresholds:
  - Army Research Laboratory: 79 J/cm^2 (“serious injury”)
  - Walter Reed: 16-22 J/cm^2
  - US Marines Corps: 6 J/cm^2 (“pain”)
  - Wayne State University: 26 J/cm^2 (“50% upper thigh”)
  - Wayne State University: 24 J/cm^2 (“50% anterior rib”)

Recommended threshold: 22 J/cm^2

Case: impact projectiles risk (2/3)

Internal injury thresholds



Muzzle velocities:
M1006: 36,8 J/cm
60-cal pellet: 6,0 J/cm
FN303: 18,3 J/cm

Bir, C.A., Viano, D.C.,
Design and injury assessment criteria for blunt ballistic impacts
Journal of trauma injury, infection and critical care
Vol.57 No.6, December 2004.

Case: impact projectiles risk (3/3)

- Development of biomechanical tests:
  - Skin penetration
  - Chest impact
  - Abdomen impact
  - Head impact

???



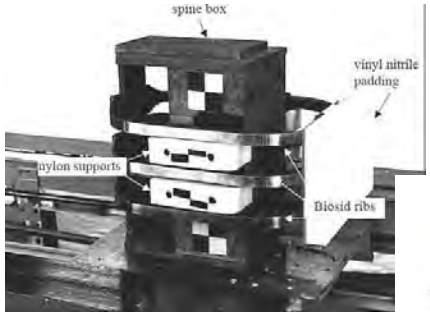




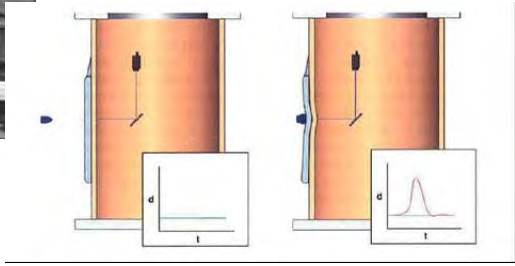
FOCUS
NOCSAE
Hybrid III
BABT







3RCS
BTTR

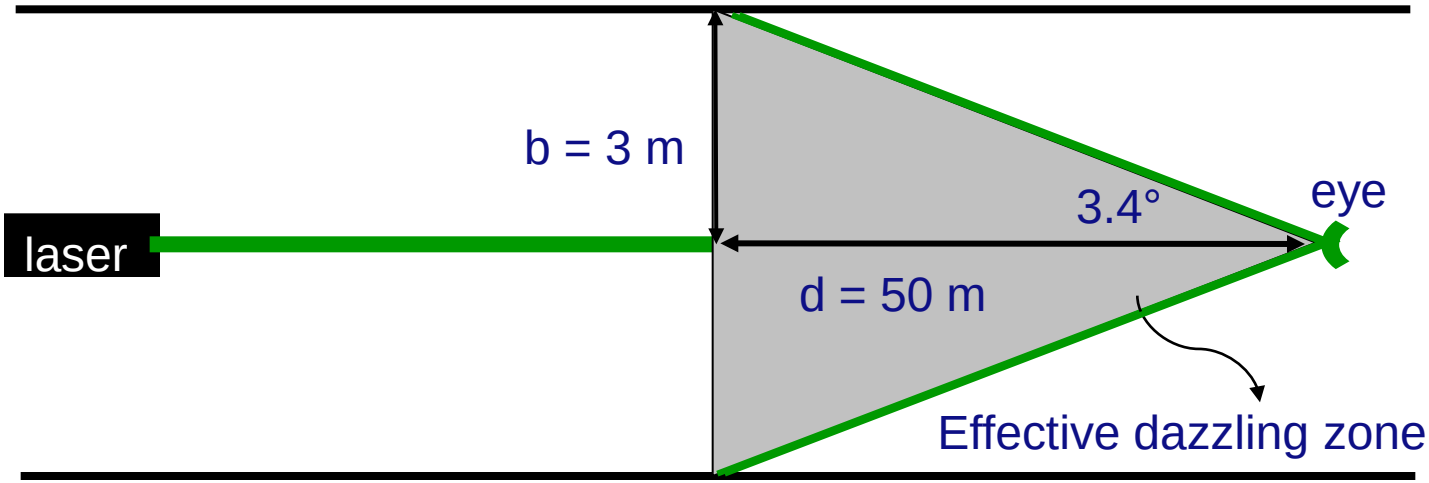


A test for desired effects (e.g. pain) still needs to be developed...

Case: eye-safe laser effectiveness (1/2)

- Safeness according to standard IEC60825-1
- Dazzling deemed effective when:
  - Glare luminescence of source > background luminescence
  - Vision impaired over sufficiently large FOV angle

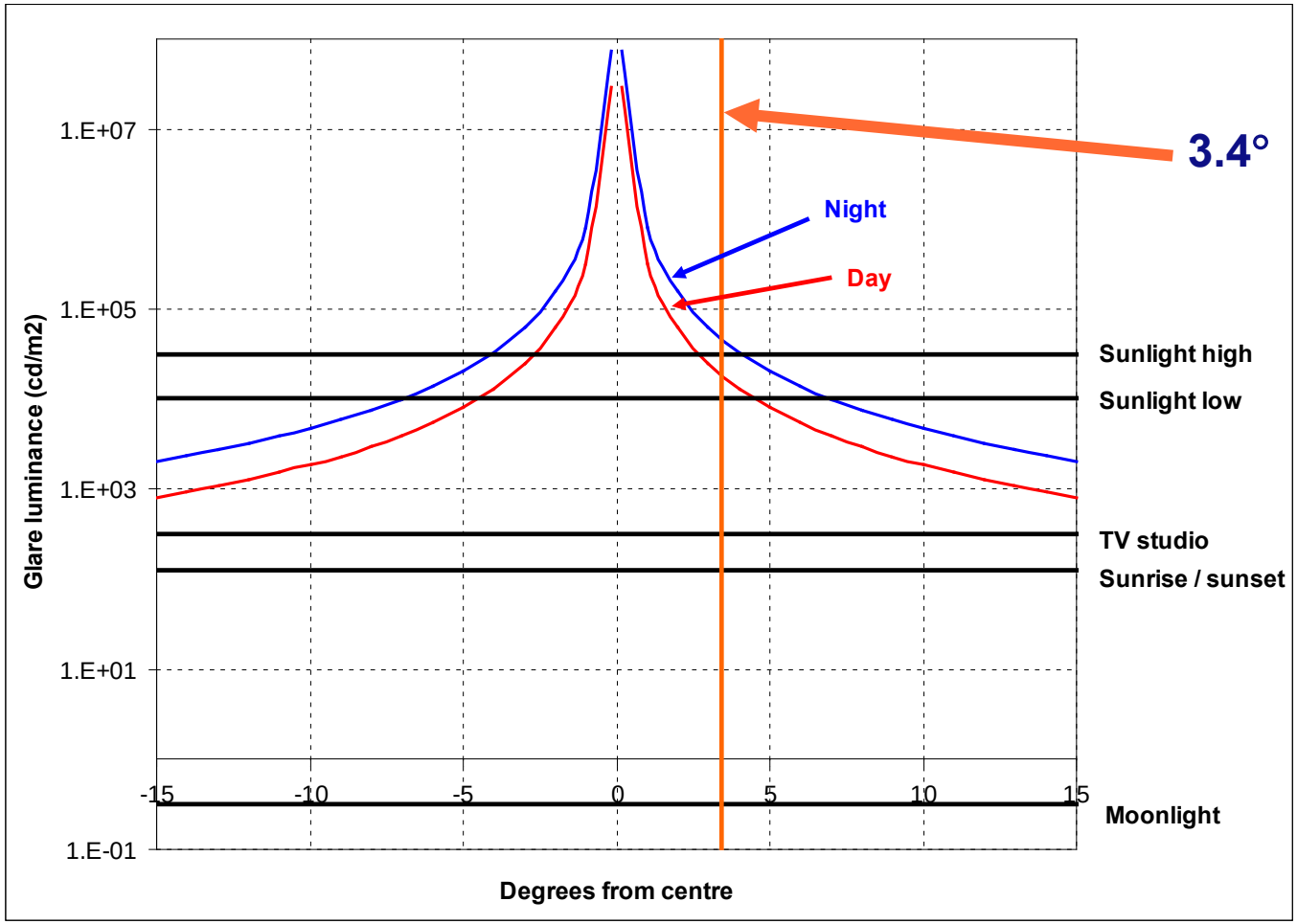
Employment: checkpoint operations



Case: eye-safe laser effectiveness (2/2)



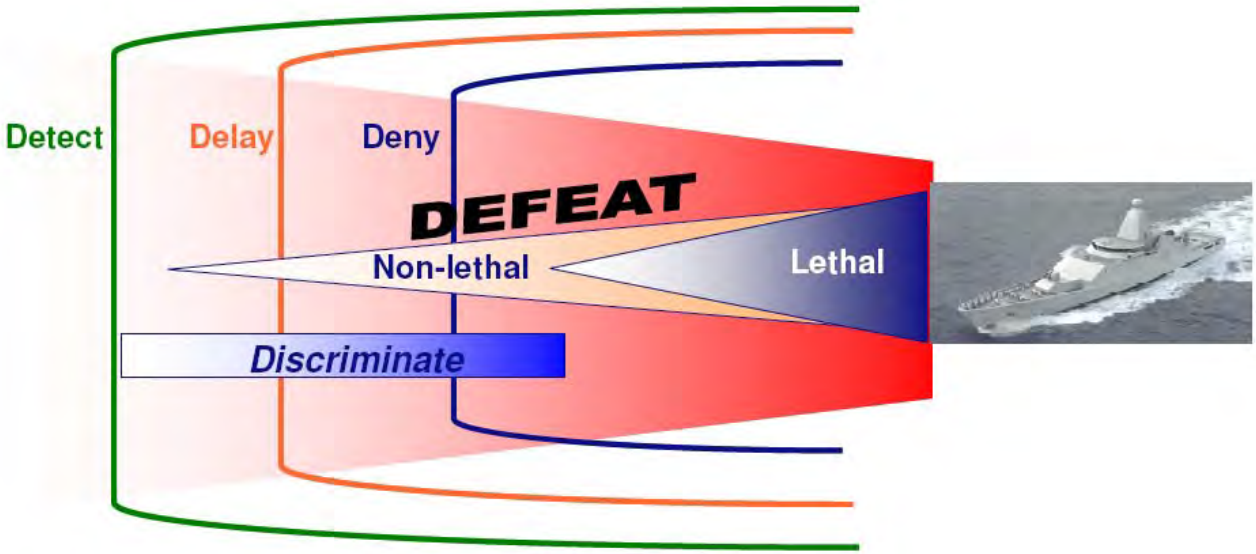
In this case:
No dazzling without eye safeness risk on a sunny day

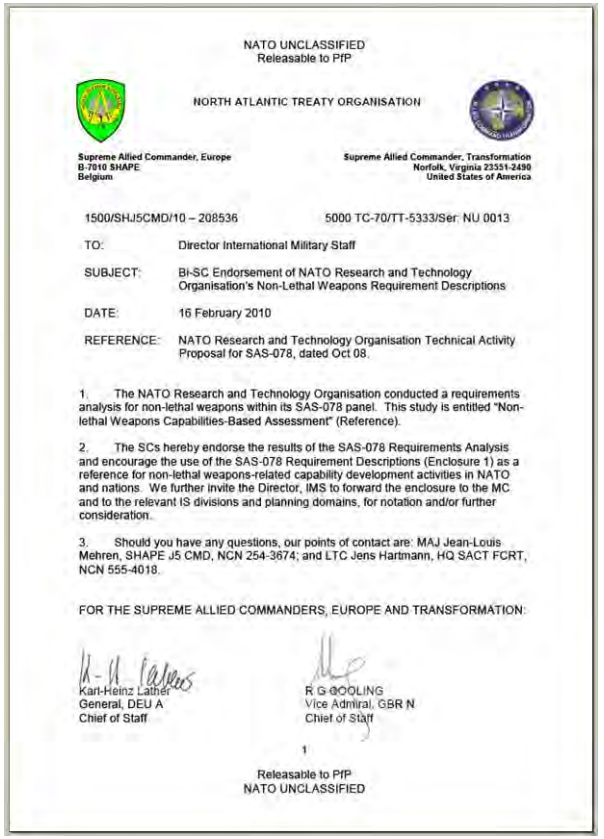


Case: vessel stopping/deterrence (1/2)

Employment: maritime security

- Non-lethals are a potential solution in force protection concept
- Target are manned vessels (fast, small)
- Intent is often unclear





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NORTH ATLANTIC TREATY ORGANISATION

Supreme Allied Commander, Europe
B-7010 SHAPE
Belgium

Supreme Allied Commander, Transformation
Norfolk, Virginia 23551-2490
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Chief of Staff

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Concept + Requirements + Means = Candidates

Case: vessel stopping/deterrence (2/2)

- Short-term solutions
  - Identified
- Range issue:
  - Stand-off or carried
- Response issue:
  - Behavioural modeling

Tests required here









International co-operation (2/3)

- Many tests, mostly on weapon functioning and risk
- Few tests on intended effects

- Non-lethal Capability Based Assessment underway (SAS-078)
- Including work on experimentation:



"To substantiate claimed effectiveness in the Capability Based Assessment"

International co-operation (3/3)

- Joint experimentation framework established 2009
  - 1st dimension: impact – response – behaviour - effectiveness
  - 2nd dimension: specificity and generalizability
- Tests from nations to be put in joint framework (2010/2011)
  - Peer review from nations
  - Establishing best practice for range of non-lethals
  - To be consolidated in experimentation guidebook
- Basis for future standardization (STANAG/ITOP) within NATO

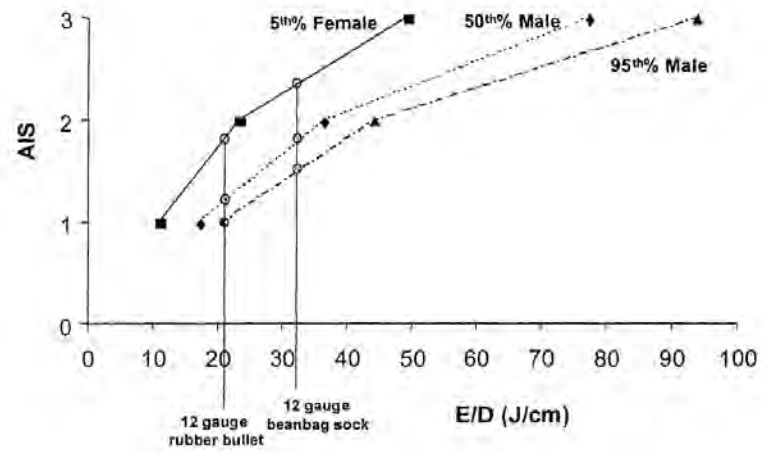
To date, there is no internationally agreed test for qualifying non-lethals

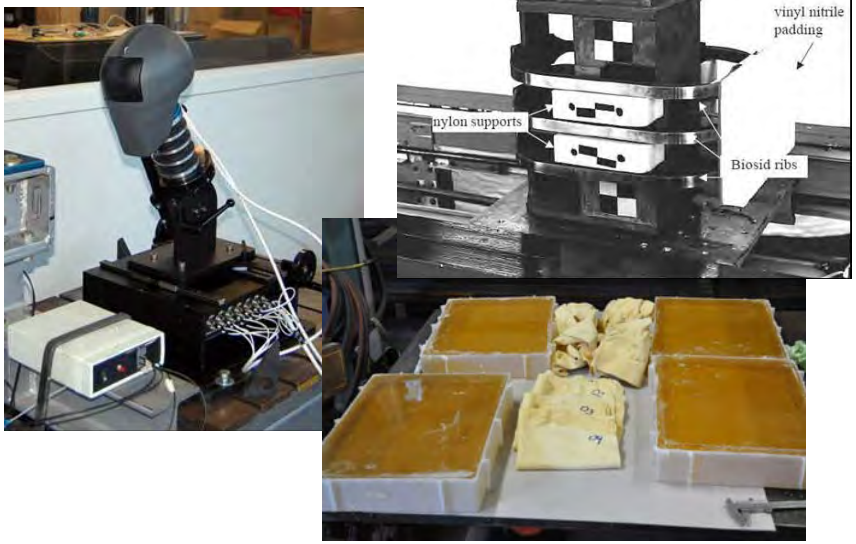
In summary (1/2)



- Military value of non-lethals depends on:
  - Knowing risk of unintended effect
  - Knowing effectiveness of intended effect

- Risk related tests are technology-specific
- Risk related tests do not predict mission success

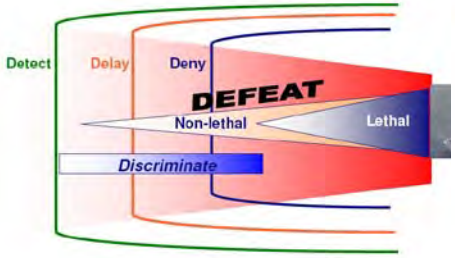




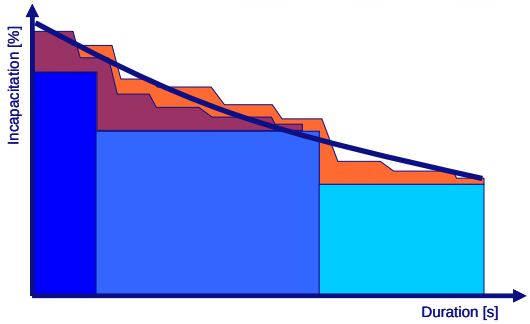
In summary (2/2)



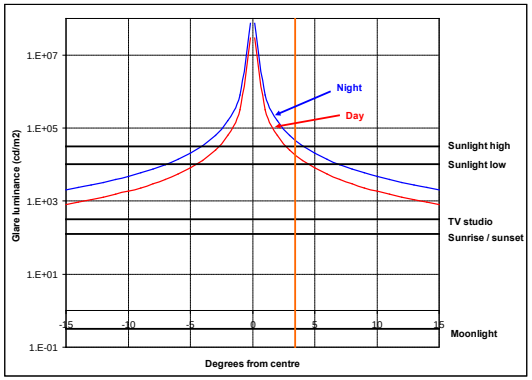
- So, how to find the right tools for the job?
- Know your environment



- Know your task
  - Effectiveness is defined by objective
  - Effectiveness follows from impact – response - behaviour



- Know your non-lethal
  - Limitations
  - Types of effects it can produce



Let’s get started!



DEFENCE R&D DÉFENSE

S&T Activities in Support of the Canadian Small Arms Replacement Program

Mr. Paul Harris, Mr. Paul Lemay, Mr. Gilles Pageau, Dr. Vincent Tanguay, Dr. Frank Wong,
Mr. François Lesage, Dr. Philips Laou, Mr. Daniel Bourget, Dr. Amal Bouamoul,
Major Bruce Gilchrist, LCol Mike Bodner, LCol. Luc Angiolini

National Defense Industrial Association
Joint Armaments Conference, Exhibition & Firing Demonstration
Annual Symposium
May 2010

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

Canadian Forces Soldier System Vision

The Soldier as an integrated weapons platform: a "System of Systems"



Environmental Clothing System

Mobility Systems





Ballistic Protection System

Head Borne Systems





Battle Management Systems





Navigation Systems







Weapon Systems



Comms Systems





Sensors Systems

UGS



Micro-UAV



Personal



Power Sources



Small Arms Replacement Program

- Acquisition valued at over $1.0 B
- Aim:
  - To ***replace*** or ***modernize*** CF small arms inventory and associated ammunition and fire control systems
  - To deliver a modern, networked, integrated direct fire, multi-effect, portable anti-personnel and anti-material capability that includes weapons, fire control, munitions, training systems and logistic support for the CF in the 2012 to 2022 period (CF SRB 21 Sept 2007)
- Timeline:
  - Project 1 – Acquisition of pistols, Canadian Ranger's rifle, Weapon sights, Weapon accessories
  - Project 2 – Acquisition of a Personal Defence Weapon (PDW), Tactical Shotgun, Grenade Launcher System, Naval boarding party weapons, breaching systems and hand grenades; and
  - Project 3 – Modernization / replacement of the CF Individual Combat Weapon capability

Major S&T Activities Supporting Small Arms Replacement Program

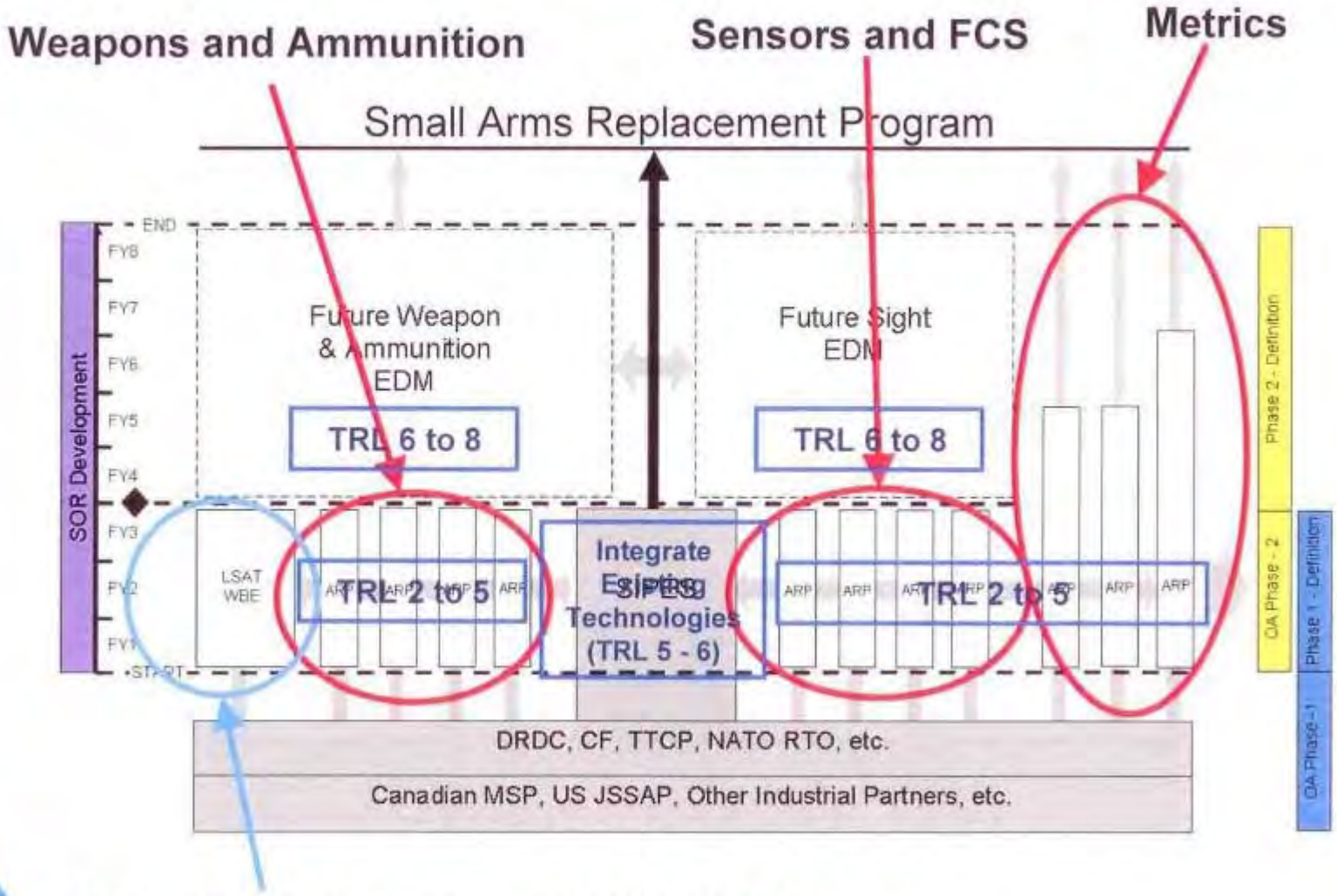
Statement of Operational Requirements (SOR) Development Effort

- Objectives
  - Develop science-based operational requirements for CF man portable future direct fire capability (FDFC) as part of the Small Arms Replacement Program
- Components
  - Soldier Integrated Precision Effects System (SIPES) Technology Demonstration Project to explore system integration issues (***financed***)
  - Applied Research Projects (ARP) to build up knowledge and technology base
  - Engineering Development Models (EDM) to integrate the results of SIPES, ARP, and SSTRM in TRL 8 level systems

Soldier Systems Technology Road Map (SSTRM)

- Objectives
  - To develop a comprehensive technology roadmap (TRM) that will support the Canadian Forces soldier modernization effort using Industry Canada TRM framework: a fair and transparent process open to all stakeholders (***financed***)
  - Much larger than soldier weapons

Small Arms Replacement Program
SOR Development Effort

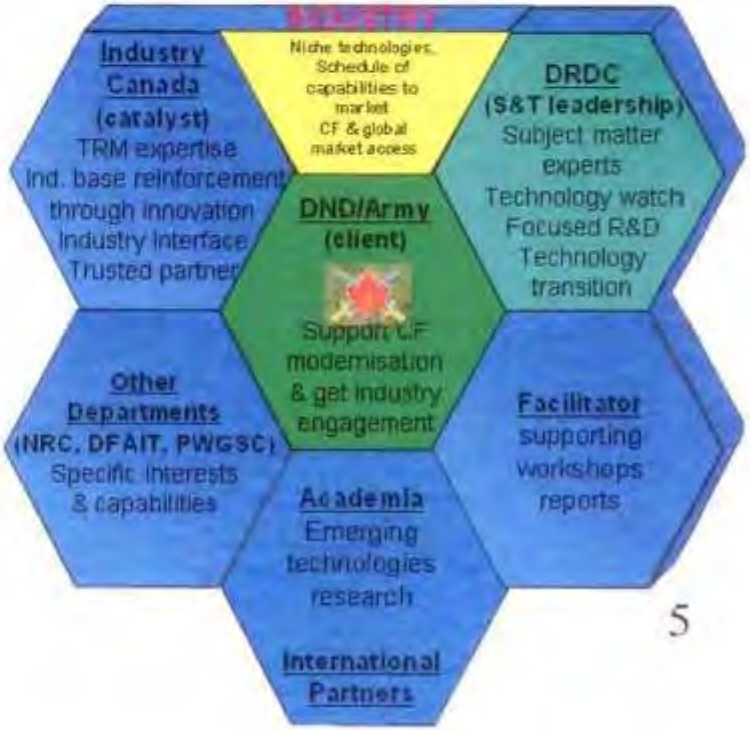


Potential Partnership with US LSAT Program

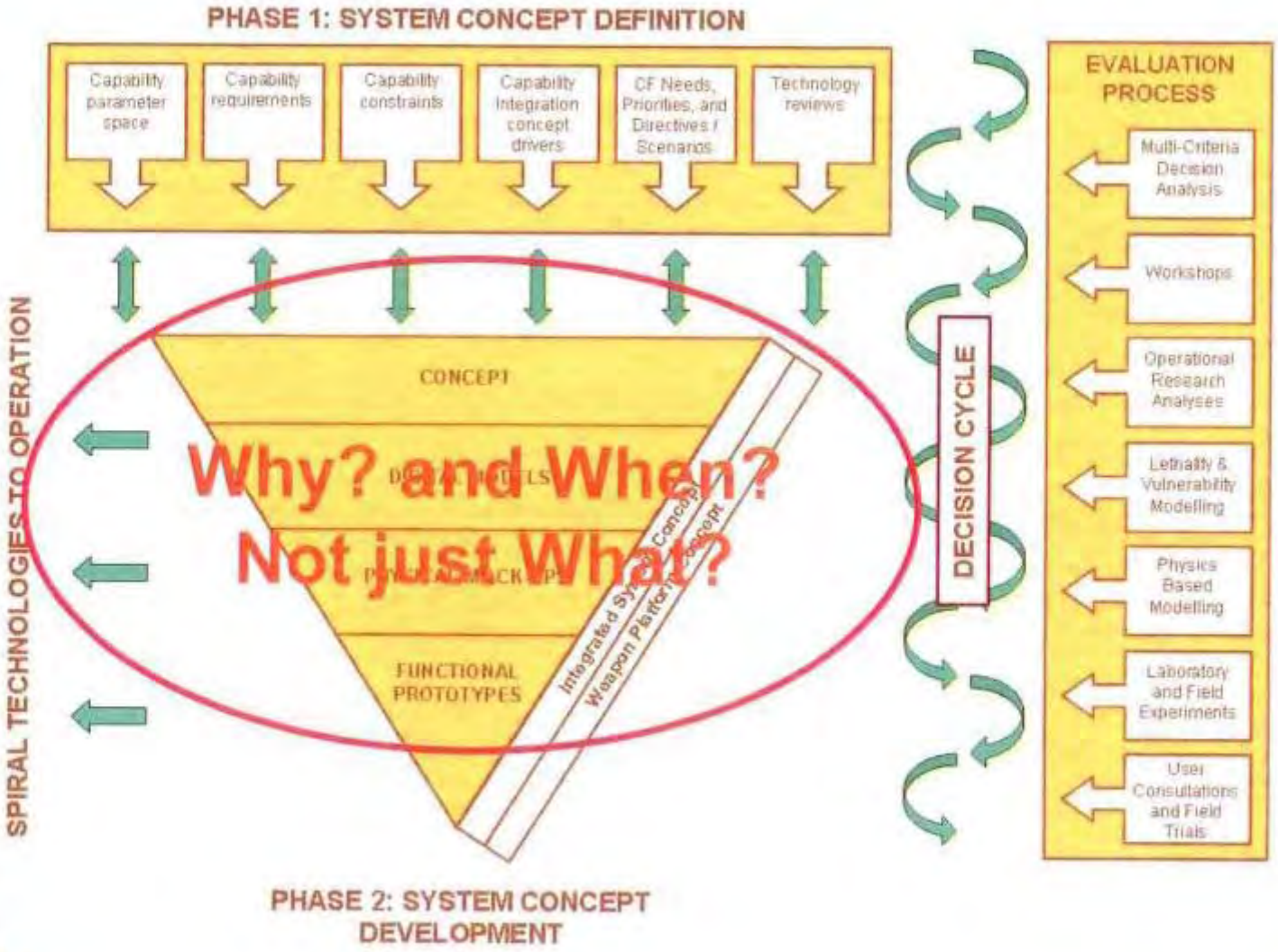
Soldier Systems Technology Roadmap Project

- **Government Role**
  - To provide Industry and Academia with an equal opportunity to be aware, understand and discuss future DND needs
- **Industry/Academia Role**
  - To provide DND insight on novel technologies maturing in 3-15 year and leading to potential important increases in soldier capabilities
  - Industry plays an integral role in the TRM process
- **Soldier Systems TRM Process**
  - Visioning and technical workshops
    - 6 including lethal and non-lethal weapons
  - Novel Collaboration Tool (ICee)
    - Innovation Collaborative Exchange Environment
    - Public/Password controlled data base / Wiki
      - "http://soldiersystems.collaboration.gc.ca"
  - R&D projects aligned with identified priorities

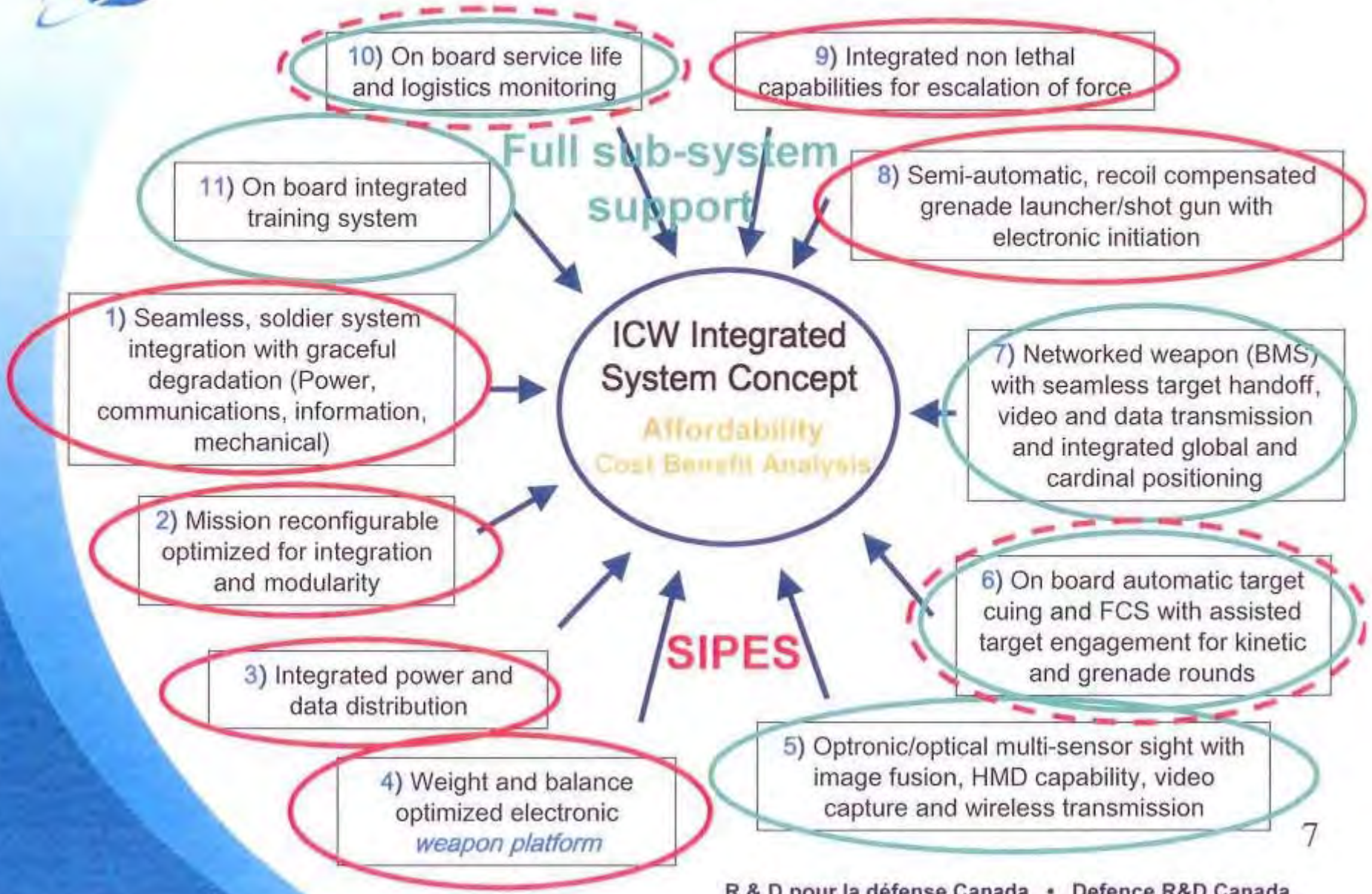




SIPES Technical Strategy

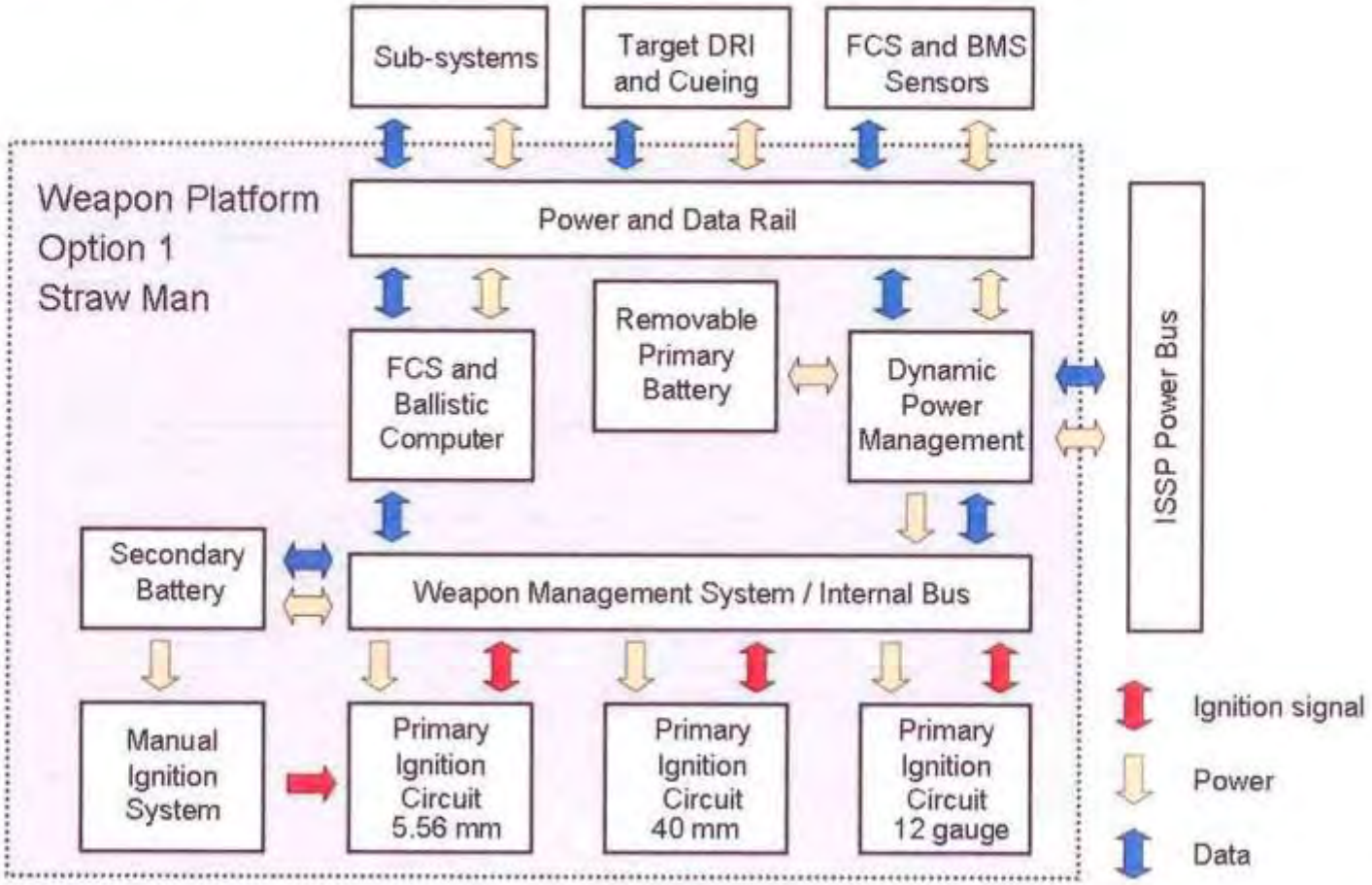


SIPES ICW Integrated Weapon System Concept



SIPES ICW Platform Concept

Electrical and Data System Architecture



SIPES ICW Platform Concept

Operational Objectives

- Increased mission effectiveness through
  - Weapon configuration flexibility (mission configurable)
  - Integrated escalation of force
  - Soldier networking
  - Optimized usage of electrical power
- Increased lethality through
  - Increased accuracy
  - Increased fragmenting round capability
- Increased usability through
  - reducing total carriage
  - optimizing weapon system handling

A weapon platform with the capability to maximize the use of future technological innovations

Overview of SIPES Plan

Primed by Colt Canada

- Canadian Partners: GD-OTS Canada and HSI Inc
- Potential International Partners: Caseless Technology AG, Metal Storm

Task Description	FY 1				FY 2				FY 3				FY 4				FY 5			
	Apr 09-Mar 10				Apr 10-Mar 11				Apr 11-Mar 12				Apr 12-Mar 13				Apr 13-Mar 14			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Phase 1 - System Concept Definition																				
Phase 2 - System Concept Development																				
Preliminary Design of Weapon Platform																				
Characterization of key enabling technologies																				
Conceptual design of configurations																				
Human factors analyses																				
Electronic achitecture																				
Sub-system integration																				
Prototype Design and Analysis																				
Prototype Build and Testing																				
Fabrication of prototypes																				
Unmanned testing and limited man certification																				
Capability demonstrations																				
Weapon power bus / soldier system connectivity																				
ATC / ATE functionality																				
LSAT CL ammunition (electronic ignition)																				

Selected Thoughts from Phase 1 of SIPES

The Issue of Weight and Balance

- Weight constraints
  - Total carriage
  - Weapon system effectiveness
- Total Carriage
  - Average soldier carries 10.8 kg ***over*** maximum allowable (26.2 kg)
  - Weapon and ammunition accounts for 24% of total weight (8.9 kg)
- Weapon System Effectiveness
  - NATO RTO studies indicate that
    - ***5.35*** kg is completely acceptable
    - ***6.83*** kg is somewhat acceptable depending on CG
  - Present weight of C7 + 2 Mags + C79 is ***5.09*** kg
  - Present weight of C7 + 2 Mags + C79 + M203 + Ammo is ***7.42*** kg
- Weight is an issue for a future weapon system with increased capability

The Argument for Electronic Ignition

- Kinetic Round
  - Increased control of automatic/burst fire with more rounds on the target
  - Increased accuracy under all conditions with automatic target cuing and assisted target engagement
- Fragmenting Round
  - More and faster delivery of rounds on target
    - With minimum weight penalty (innovative technological approach)
    - Without taking eyes off target
  - Firing from behind cover through seamless connectivity between launcher and FCS
- System
  - Enhances level of system integration
  - Provides flexibility in weapon configuration
  - Provides potential technical solutions for caseless ammunition
    - Chamber sealing (firing pin)
    - Cook-off (temperature sensors)
    - Light percussion

Characterization of Electronically initiated caseless ammunition

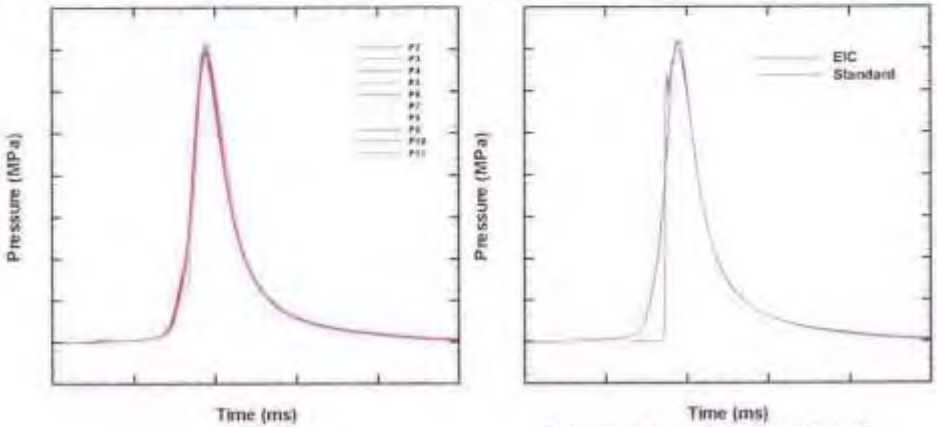
Objective

- Determine whether available electronically initiated caseless (EIC) ammunition technology is acceptable for a weapon platform prototype
- Evaluate key parameters applicable to weapon system design – chamber pressure profile, lock time, action time, accuracy, cook-off, …

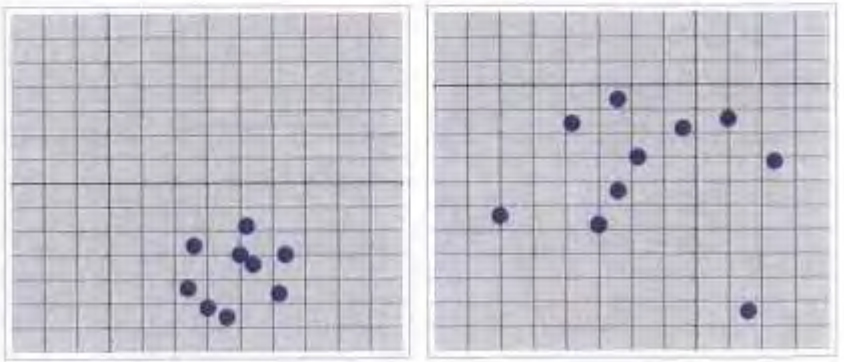
Results for non-telescoped rounds

- Muzzle velocity variation: $\sigma_{EIC}/\sigma_{Stnd} = 0.7$
- Consistency: $\sigma_{EIC}/\sigma_{Stnd} = 0.5$
- Lock time + action time: $t_{EIC}/t_{Stnd} = 0.45$
- Still need to evaluate telescoped ammunition





EIC Standard and EIC
Chamber Pressure Profile



EIC Standard
Dispersion at 80 m

Automatic Target Cueing (ATC) and Assisted Target Engagement (ATE)

Objective

- Reduce the effect of soldier stress on shot accuracy through assisting the soldier to fire at the optimal time

Concept Exploration

- Preliminary concept demonstration
  - VEC-91 rifle, MOTS TWS, frame-grabbing and thermal target
- ATC-ATE Mod 1
  - Purpose designed TWS with no FCS to be demonstrated on SIPES weapon platform
- ATC-ATE Mod 2
  - Addition of FCS

AN/PAS-13B



AN/PAS-13C



VEC-91





Assisted Target Engagement Concept Analysis

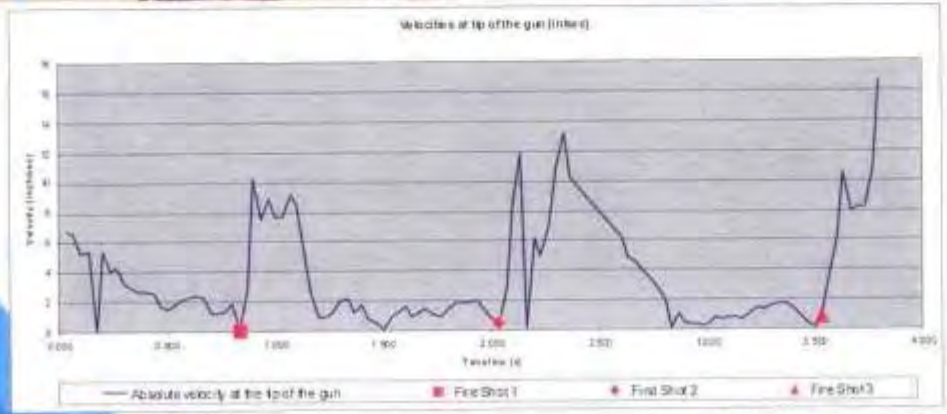
Objective

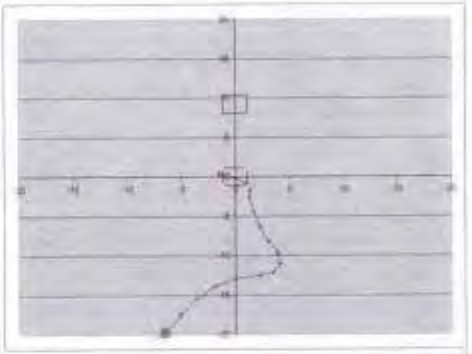
- Characterize rifle slew rate, shot delay and general aiming behavior of soldiers to provide design and analysis input for the ATE concept
- Data analyzed was thru sight video from NATO RTO trials using US Marines (significant Canadian participation)

Range of 25 m

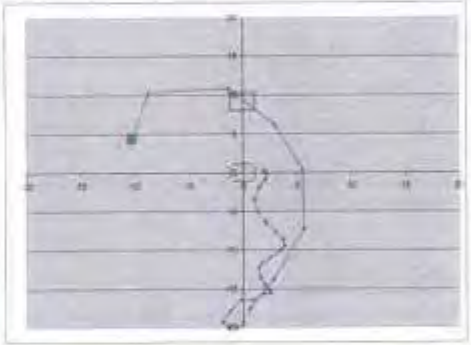




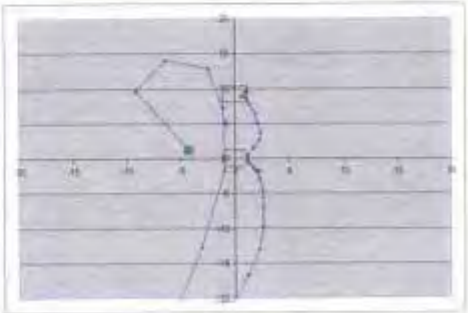




Shot 1



Shot 2



Shot 3

Characterization of Bullet Lethality

Present Effort

- Development of a methodology to experimentally characterize the flight dynamics of bullets
- Development of a methodology to experimentally evaluate the terminal effect of bullets on human surrogates
- Development of a methodology to numerically model the terminal effect of bullets on human surrogates

Canadian version of work done by Joint Services Wound Ballistics IPT

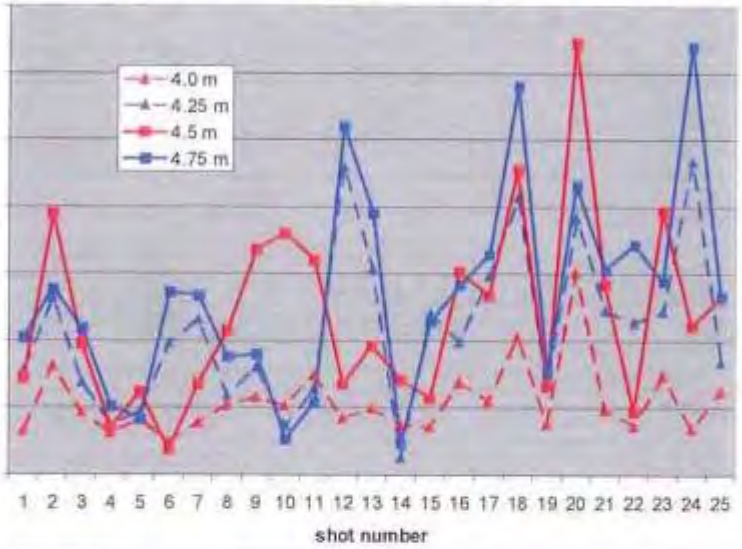
A Methodology to Characterize Bullet Flight Dynamics

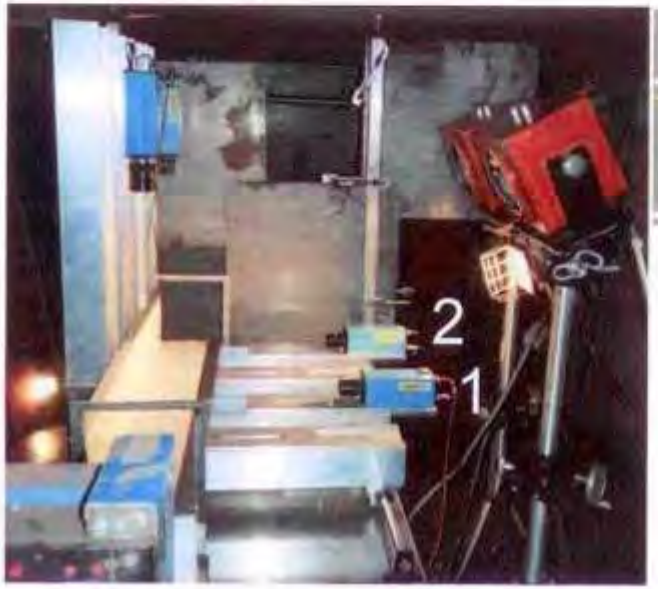
Objective

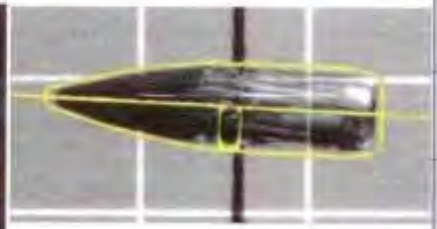
- Develop a measurement methodology and perform preliminary characterization of the the yaw behavior of C77 rounds fired under various conditions

Observations

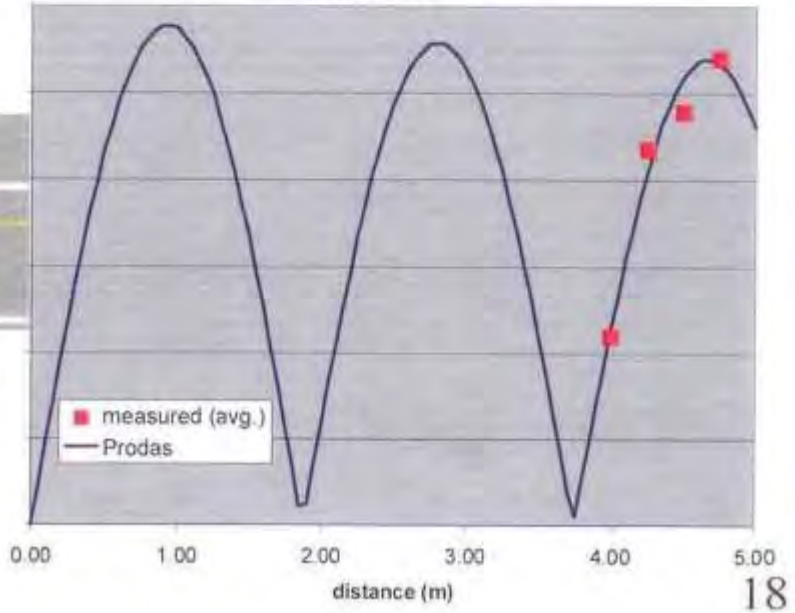
- Significant round-to-round variations
- Cyclical variation with distance confirmed
- Yaw dependence on barrel temperature
- Yaw dependence on barrel type (Mann barrel)







Two orthogonal camera stations

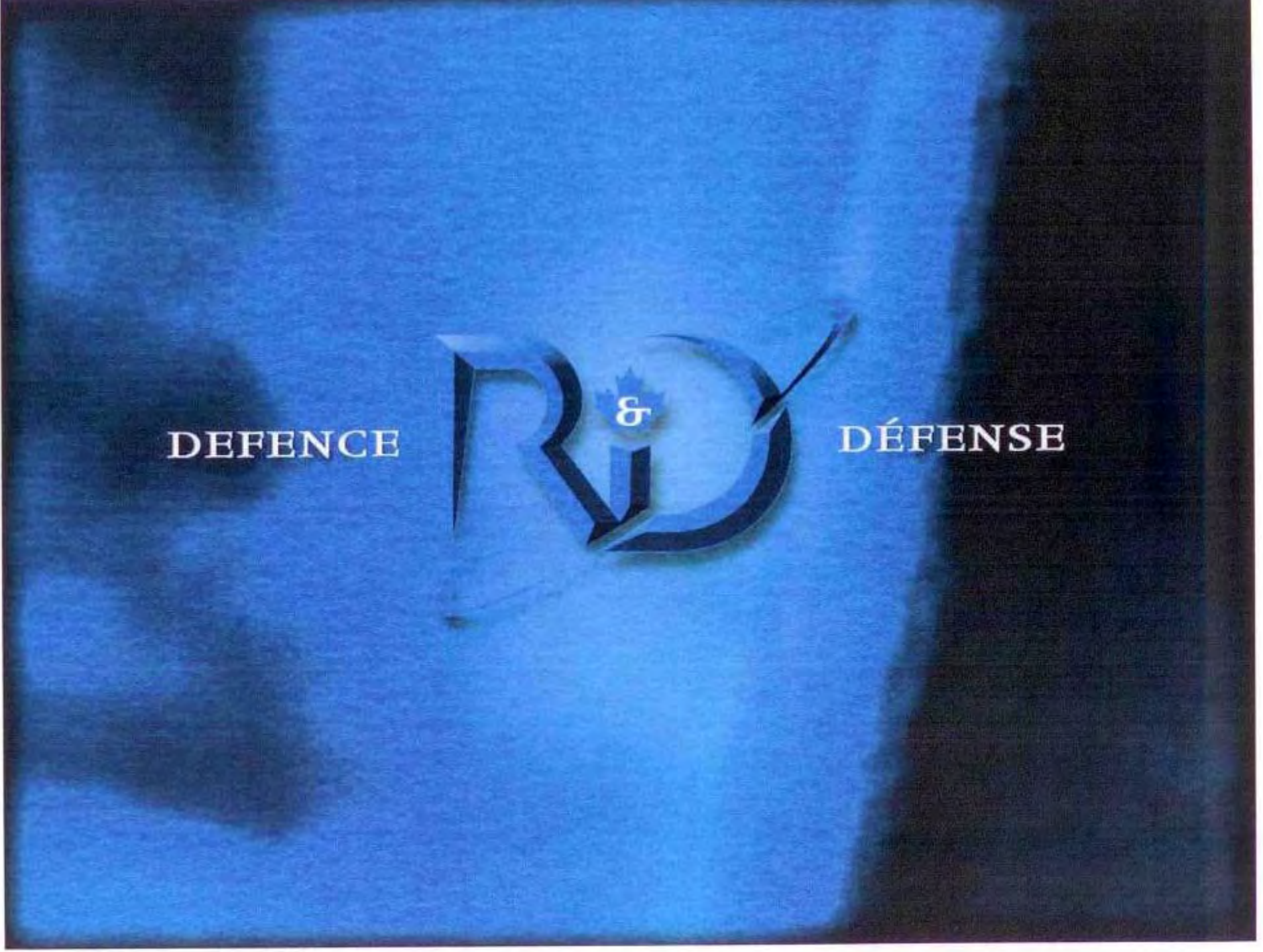


Summary

- The Canadian small arms replacement program is being supported by two major S&T initiatives
  - SOR Development Effort, government directed
  - Soldier Systems Technology Roadmap, industry focused

Contact Information

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DEFENCE
R&D
DÉFENSE

NATO OTAN

NATO Army Armaments Group

Is there a problem with the lethality of the 5.56 NATO caliber?

Per G. Arvidsson

Chairman

NATO Weapons & Sensors Working Group

Direct: +46-8-782 4181, Mobile: +46-70-682 6412

E-mail: per.arvidsson@fmv.se

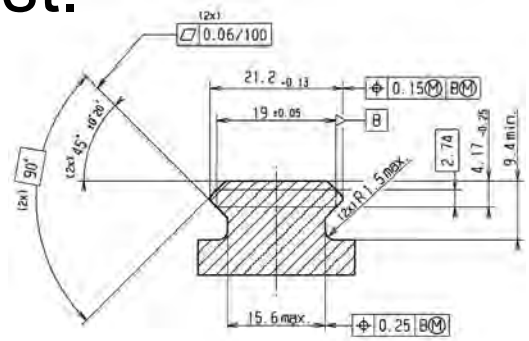
No!

Our Terms of Reference

- We are responsible for all issues related to dismounted soldier's weapon systems.
- We have two main missions:
  - Exchange of information and lessons learned.
  - Promote technical standardization.
- STANAG 4694 “NATO Accessory Rail” was approved by the NAAG in May -09, and has been sent out on a ratification request.

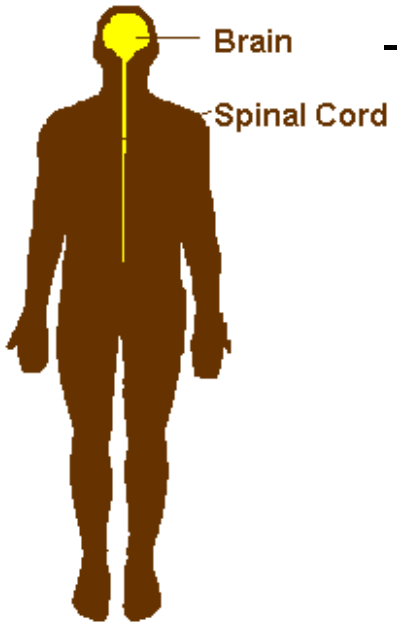


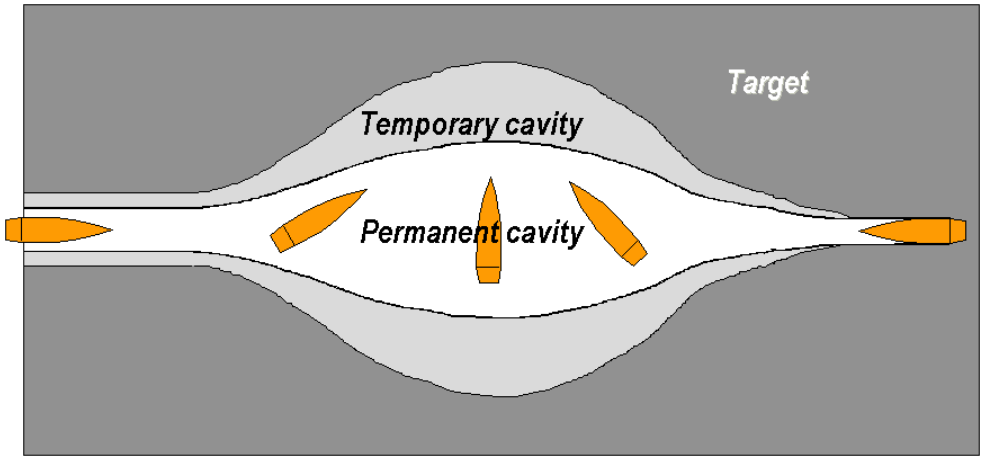




Two ways to incapacitate

1. Hit to the central nervous system.
   - Immediate incapacitation regardless of caliber or type of projectile!
2. Loss of blood pressure by massive bleeding.
   - Incapacitation can take time!





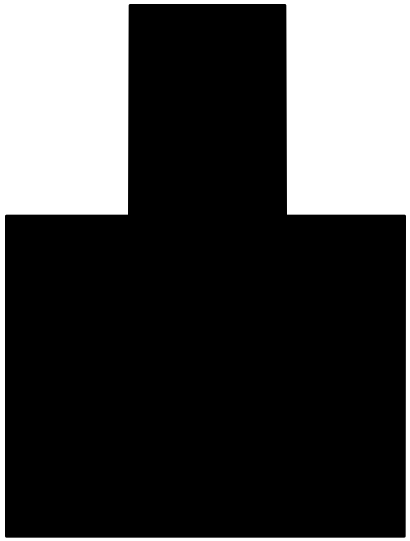
Small Arms Lethality

- GBR hosted a two day ”NATO Workshop on Small Arms Lethality” in February -09 at the Defence Academy of the United Kingdom in Shrivenham.
- The conclusion was that ***shot placement*** is the most important parameter.
- This is achieved through good and realistic training.



New Swedish pop-up target

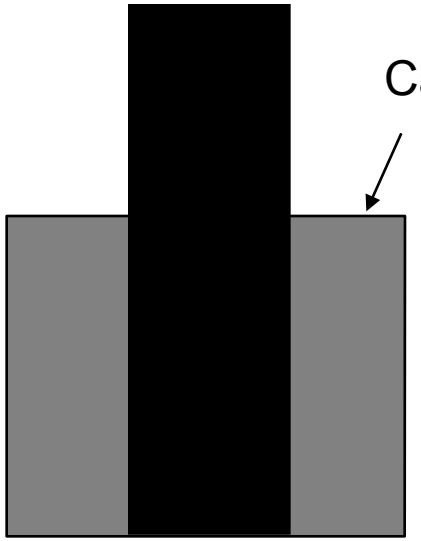
Sheet metal



Original target

Sheet metal (w=120mm)

Cardboard



Modified target



Two main problems with current and future soldier systems

Weight



Power supply



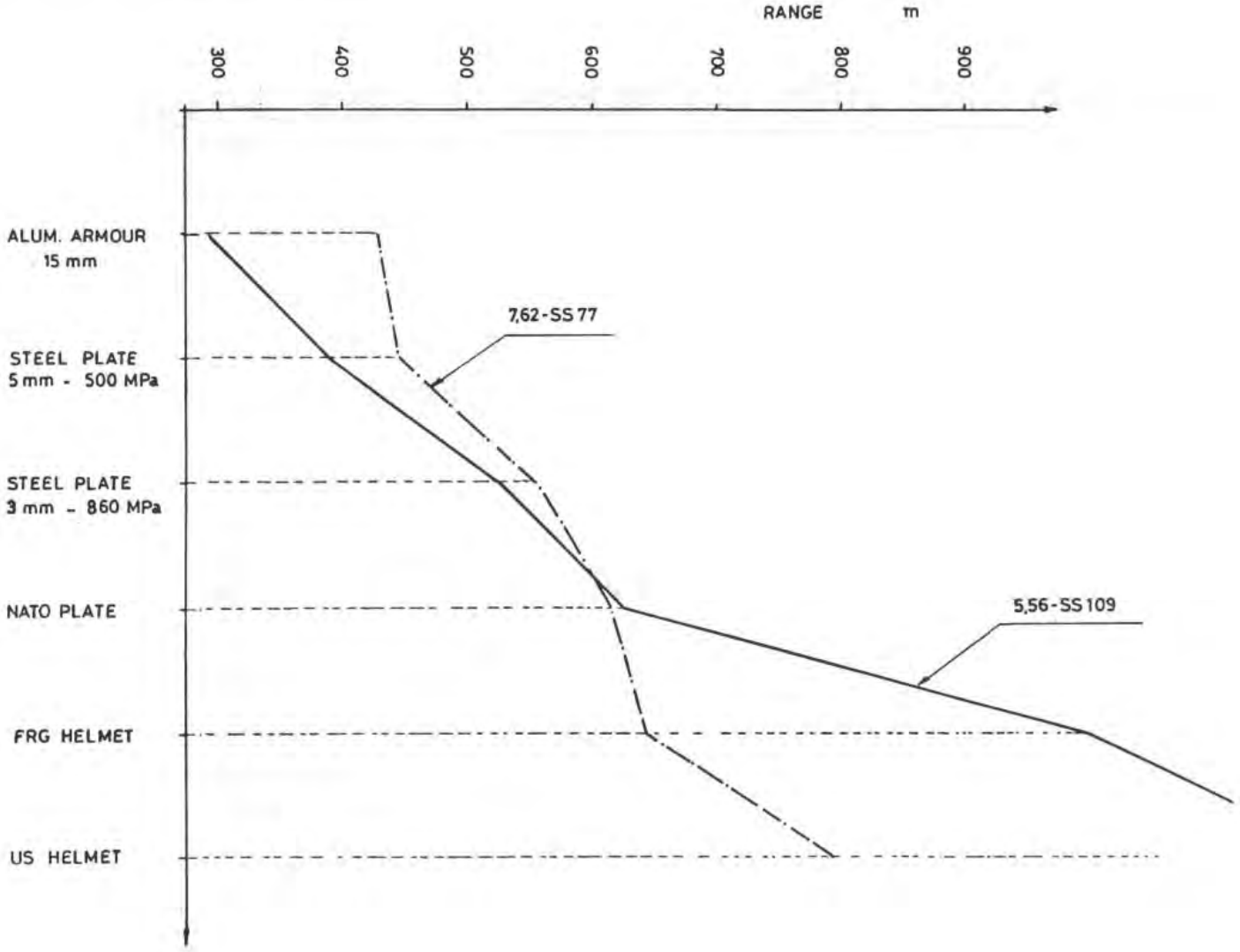
1.5V AAA | 1.5V AA | 3V 123A

NATO Rifle Calibers



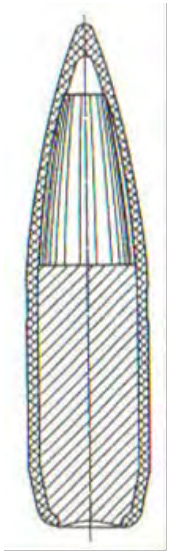
	7.62 x 51 NATO	5.56 x 45 NATO
STANAG	2310	4172
Cartridge length (mm)	71.0	57.0
Cartridge weight (g)	24.0	12.7
Bullet weight (g)	9.5	4.0
Bullet diameter (mm)	7.82	5.70
Muzzle velocity (m/s)	830	930
Muzzle energy (J)	3270	1730
Core material	Lead	Steel/Lead
Rifling twist	1/12” (305 mm)	1/7” (178 mm)
Penetration of 3 mm steel plate at (m)	800	1300
Penetration in RHA at 100m and 0° NATO of APHC projectile	18mm	12mm

Compared performance of NATO rounds



Development of 5.56mm SS109 round

- FNH developed a weapon family in the mid 70's consisting of the FNC rifle and the Minimi LMG.
- To increase the range for the LMG a round that could penetrate the NATO plate (3.5mm mild steel) out to 600m was developed.
- It had a dual core (steel tip and lead rear).
- It was named SS109.
- It required a 1/9" rifling twist.
- There were no requirements to penetrate body armor.







History of 5.56 NATO

- In 1970 NATO decided to try to standardize a common rifle and a second rifle caliber.
- During 1977-1980 NATO therefore performed tests with rifles and ammunition.
- The calibers tested were:
  - 5.56mm rounds with increased penetration from BEL and USA.
  - GBR 4.85mm round.
  - DEU 4.7mm caseless round.
- No weapon could be agreed upon.
- The BEL SS109 round was found to be the best, and was standardized as NATO's second rifle caliber in 1980.



USA 5.56 XM777 **GBR 4.85** **DEU 4.7** **BEL 5.56 SS109**

Benefits of 5.56 over 7.62

- Equal lethality.
- Half the mass (12g – 24g).
- Half the volume.
- Reduced recoil and signature (noise and flash).
- Better penetration in thin metal plates.
- Flatter trajectory and shorter ToF out to 700m
- Lighter weapons.
- Higher hit probability.





Swedish experience



- In SWE we realized already back in the early 80's that you must "train as you fight".
- A dynamic shooting training was therefore introduced in 1985.
- There are three levels of "Marksmanship badges" that are worn by soldiers and officers.
- When SWE introduced the 5.56 ak 5 rifle in 1986, the score had to be increased because otherwise everybody qualified as a Marksman.
- The same thing happened when we introduced the ak 5C with its red-dot sight.





7.62 ak 4 (G3)



5.56 ak 5 (FNC)



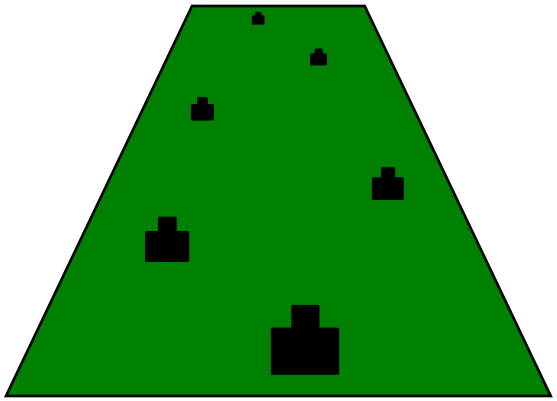
5.56 ak 5C + sight

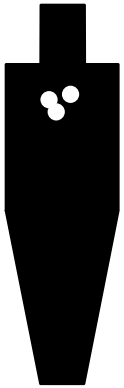
NATO Workshop on Marksmanship Training

- Spain hosted a marksmanship training workshop in March -10.
- The results showed that only a few nations teach shooting beyond 200-300m to ordinary infantry soldiers.
- Nations are using from 150 rounds during 28h engaging targets out to 200m up to 1000 rounds during two weeks engaging targets out to 400m.
- SWE and CAN requirement: Prone or kneeling position, 3-5 rounds at 100m max dispersion 150mm.

Long range shooting

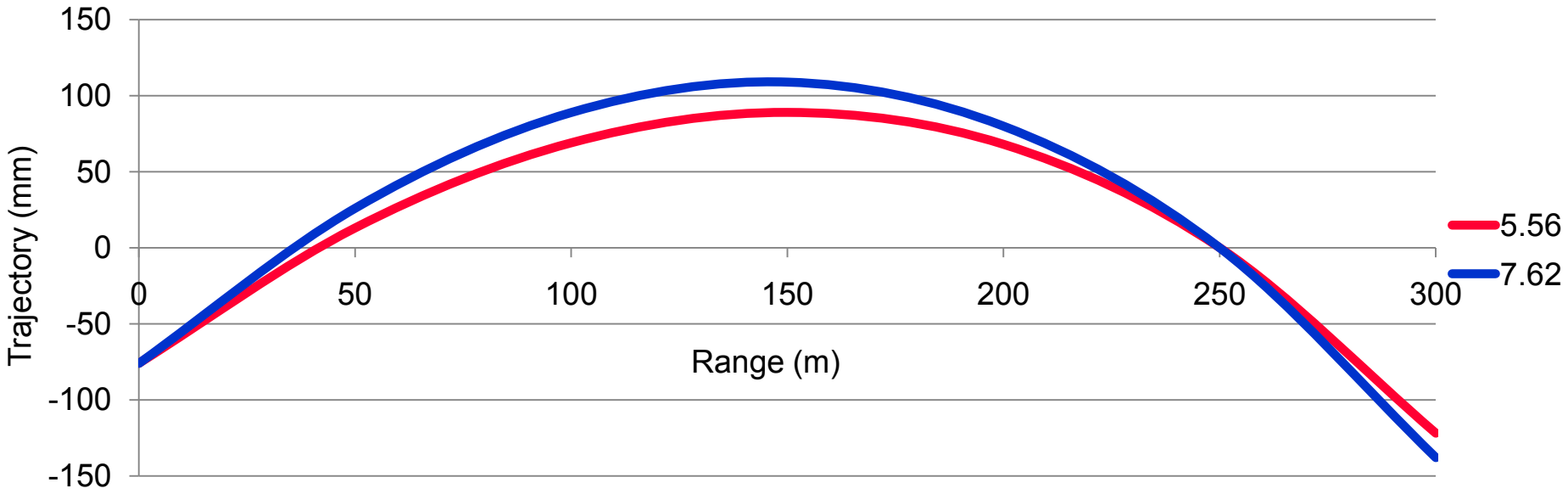
- It is very difficult to hit at longer range due to:
  - Shooters dispersion
  - Moving targets
  - Unknown range
  - Wind drift
- Swedish units in ISAF rely on 12.7mm (.50 cal) machine guns for long range…







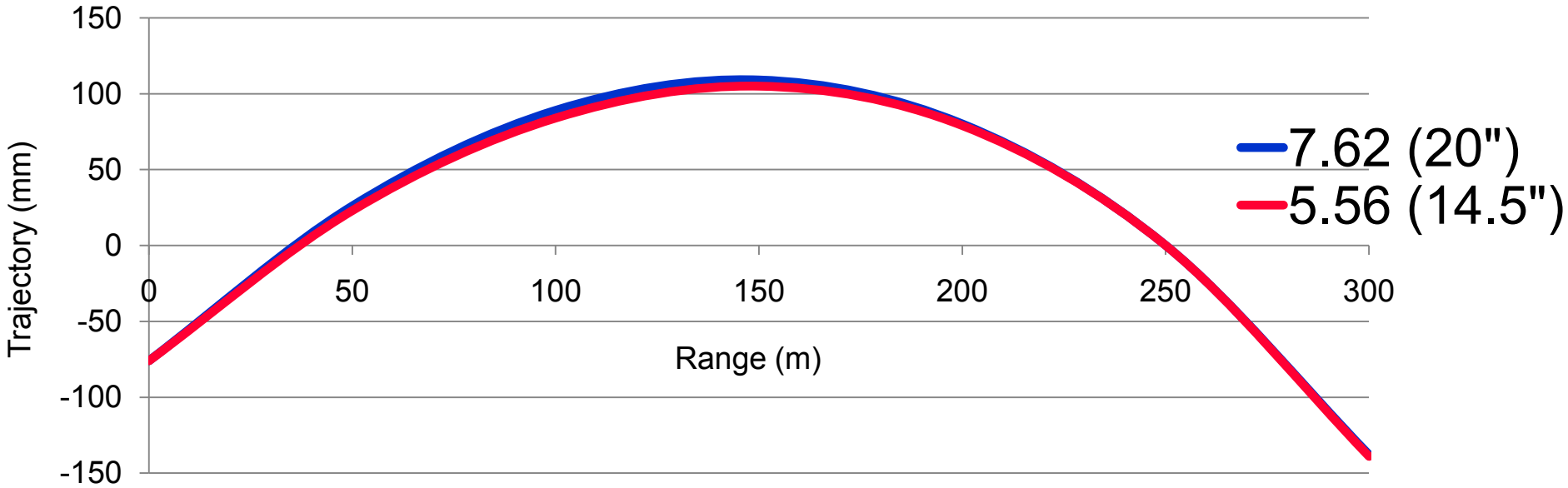
Comparison between 5.56 and 7.62 with equal barrel lengths (20”=508mm)



20" barrel	0	50	100	150	200	250	300
5.56	-76	13	69	89	68	0	-122
7.62	-76	26	89	109	80	0	-138

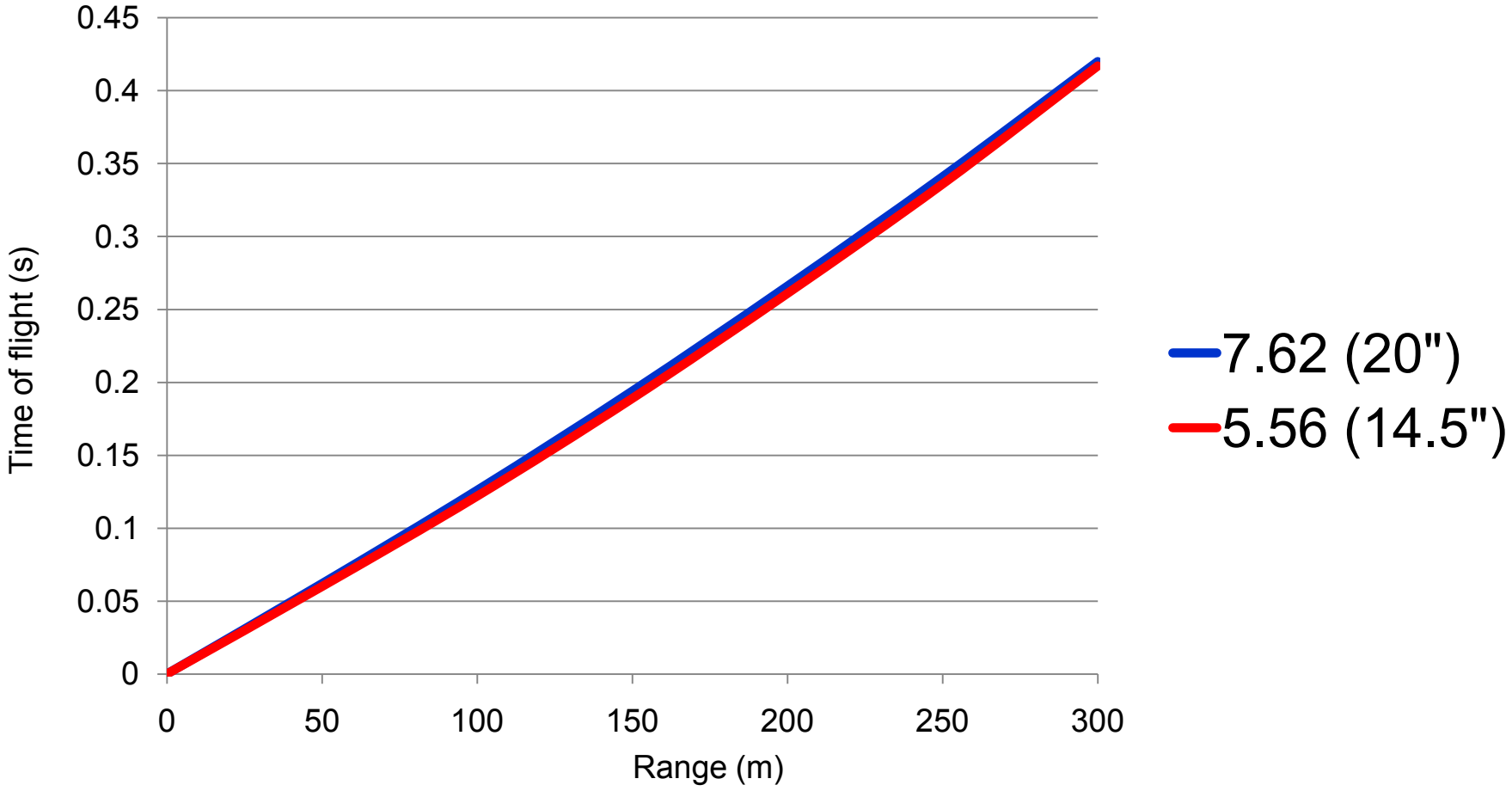
Rifles with optical sights. NATO standard air temperature (+15°C).

Comparison between 5.56 with short barrel and 7.62 with long barrel



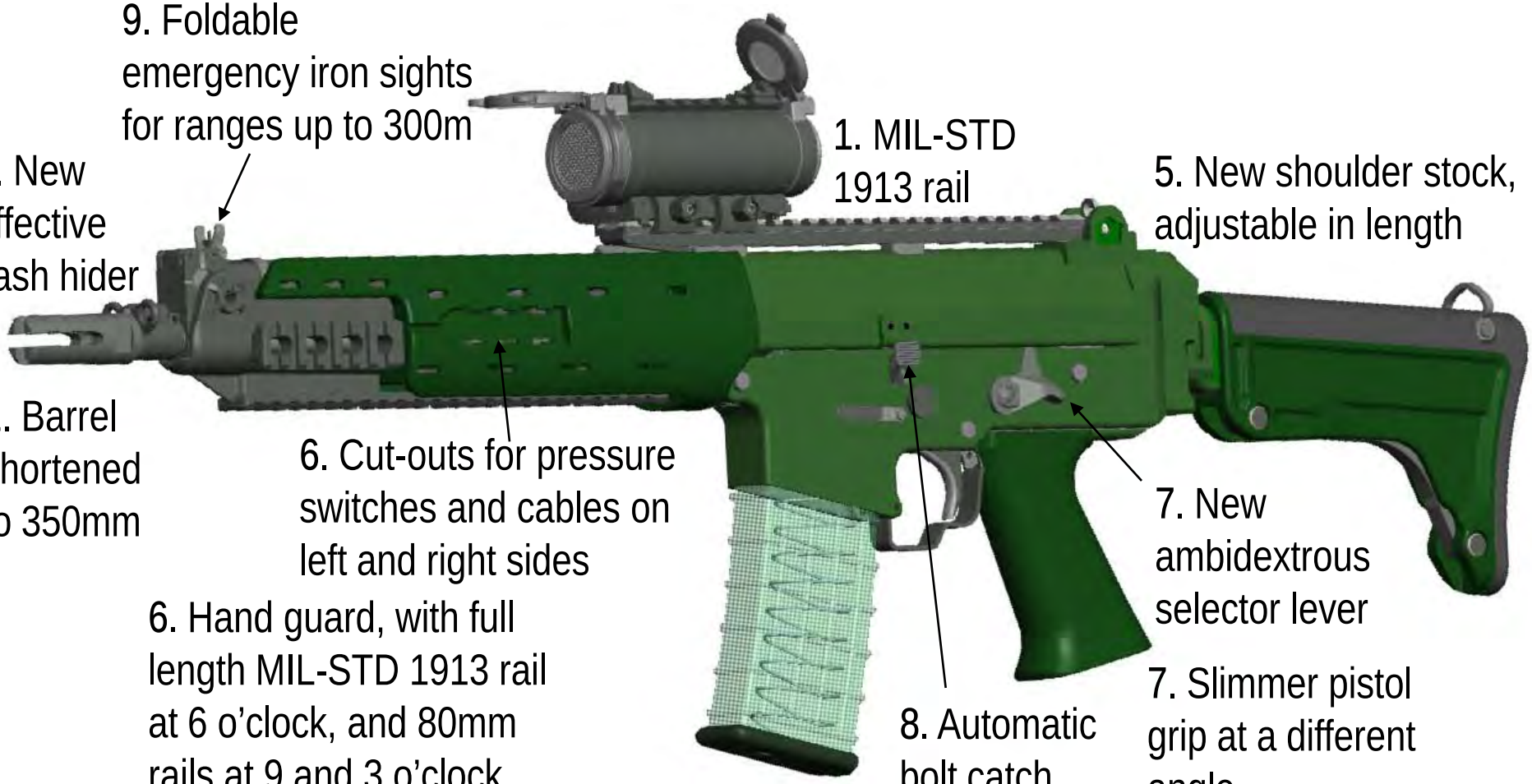
Rifles with optical sights. NATO standard air temperature (+15°C).
20”=508mm. 14.5”=368mm.

Time of Flight



Rifles with optical sights. NATO standard air temperature (+15°C).
20”=508mm. 14.5”=368mm.

User priorities on SWE ak 5C



9. Foldable emergency iron sights for ranges up to 300m

1. MIL-STD 1913 rail

5. New shoulder stock, adjustable in length

2. New effective flash hider

2. Barrel shortened to 350mm

6. Cut-outs for pressure switches and cables on left and right sides

7. New ambidextrous selector lever

6. Hand guard, with full length MIL-STD 1913 rail at 6 o'clock, and 80mm rails at 9 and 3 o'clock.

8. Automatic bolt catch

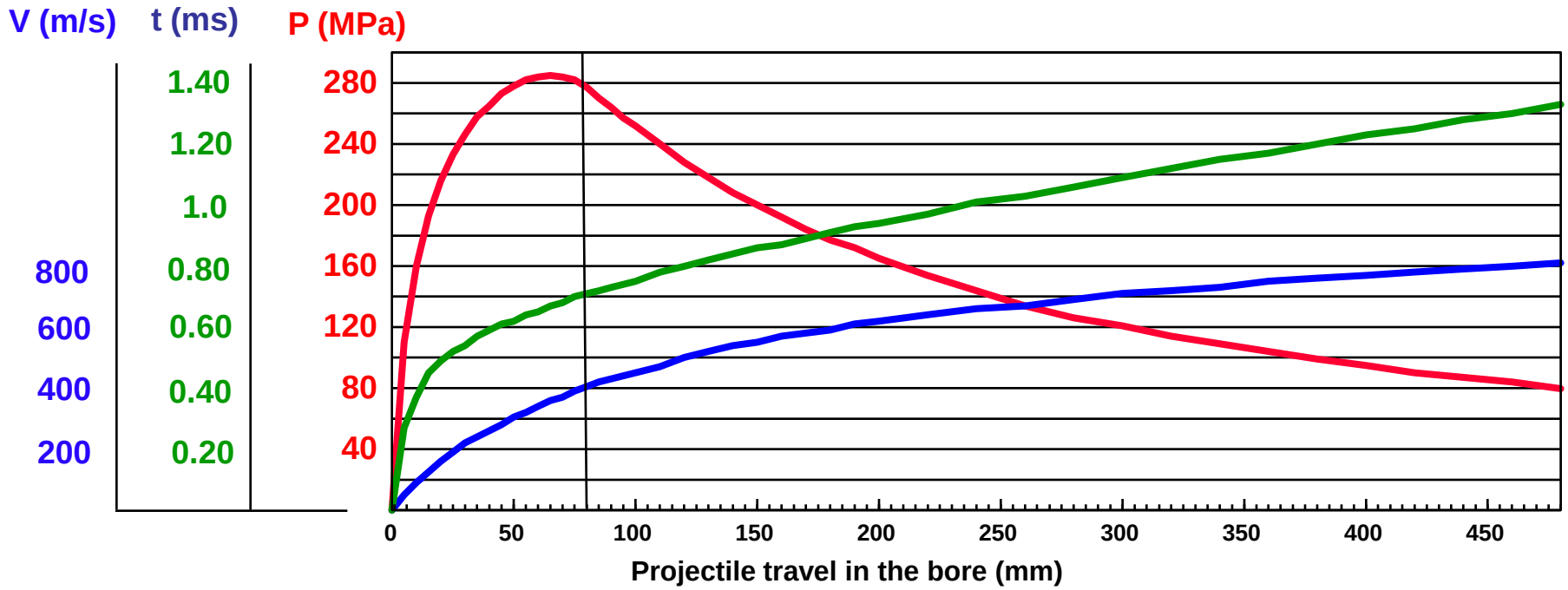
7. Slimmer pistol grip at a different angle

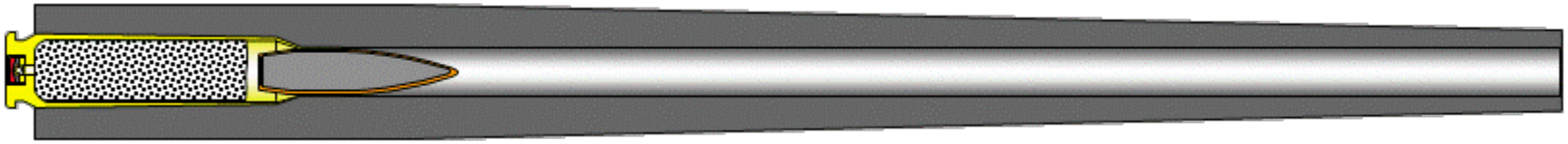
3. Weight max 3.8kg.

4. MRBS >2000.

10. Transparent plastic magazines

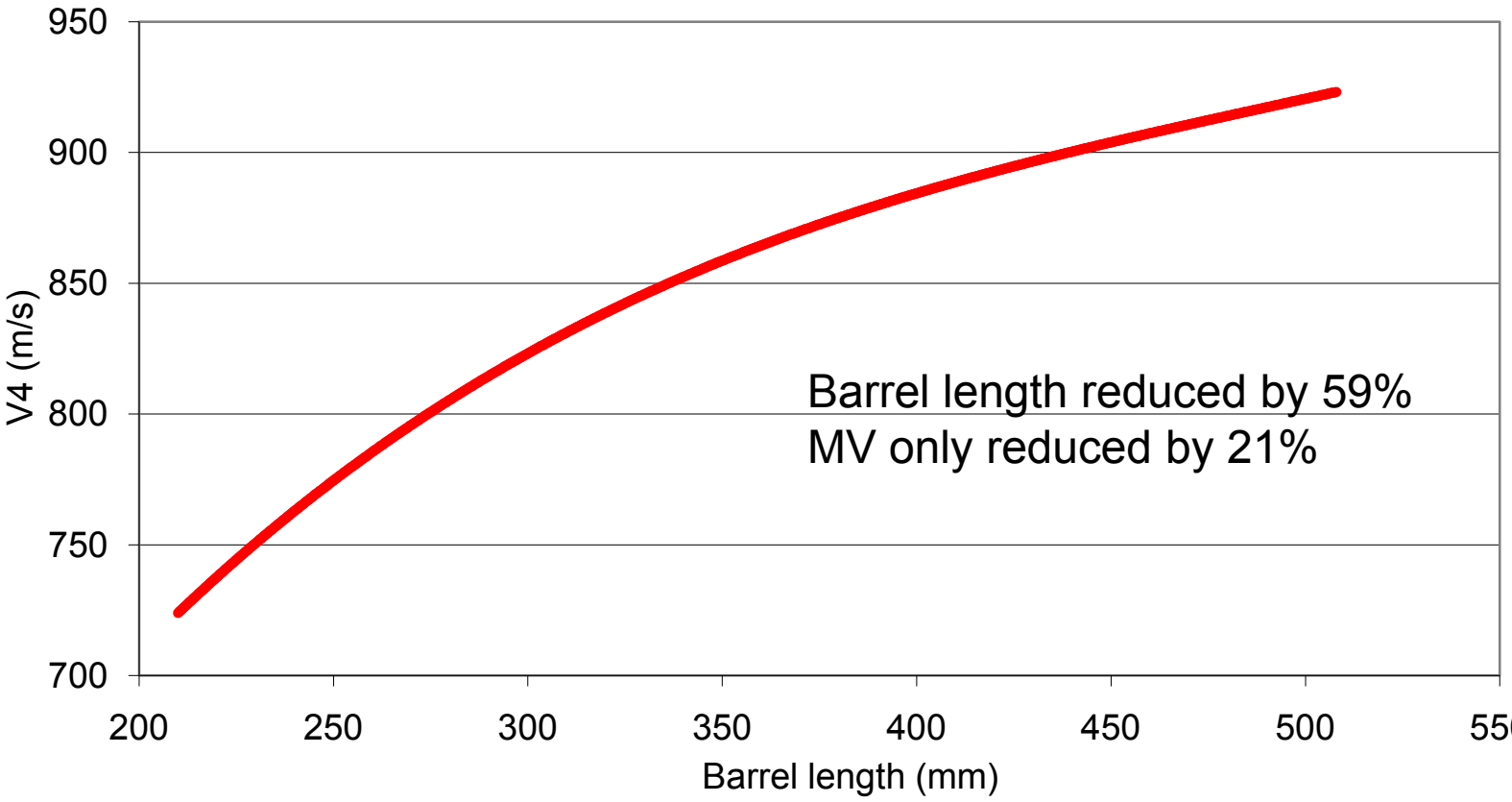
7.62mm inner ballistics





50% of V_0 within 80mm!

Barrel length / Muzzle velocity
5.56 NATO Ball

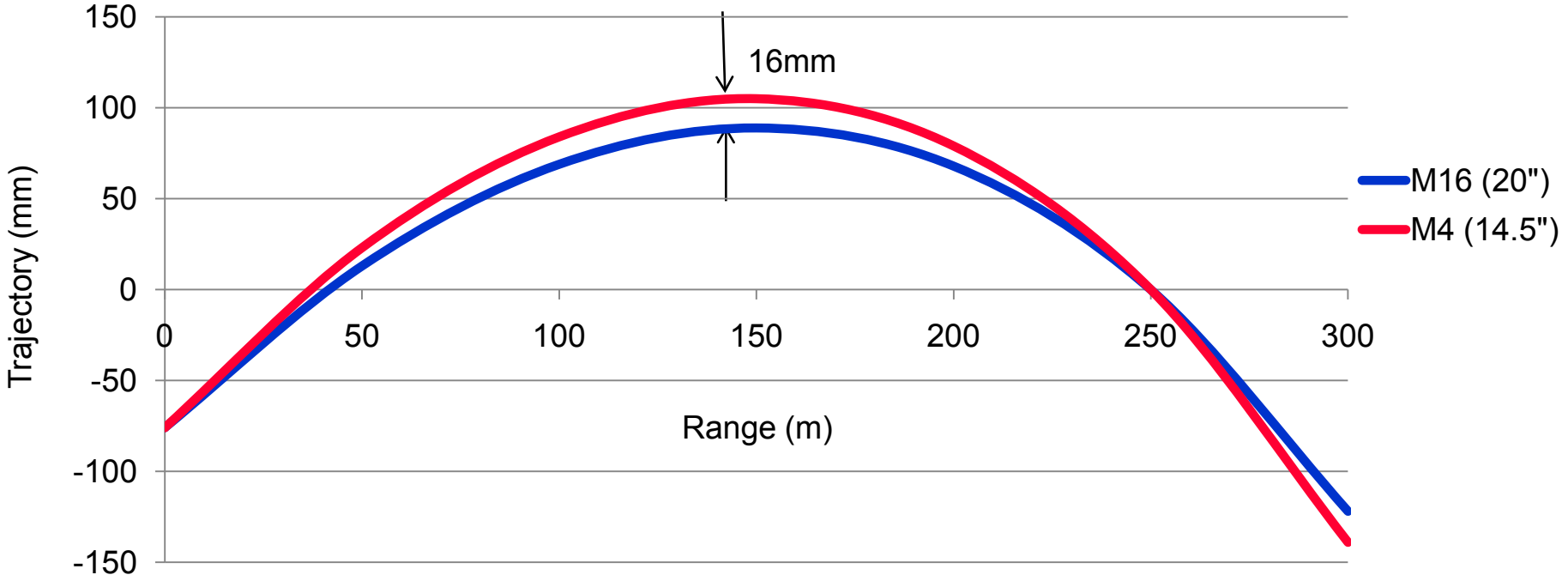


Length (mm)	V_4 (m/s)
210	723
240	764
270	796
300	825
330	843
360	866
390	878
420	892
450	906
480	915
508	922

Length (inch)	V_{13} (fps)
8,3	2372
9,4	2507
10,6	2612
11,8	2707
13,0	2766
14,2	2841
15,4	2881
16,5	2927
17,7	2972
18,9	3002
20,0	3025

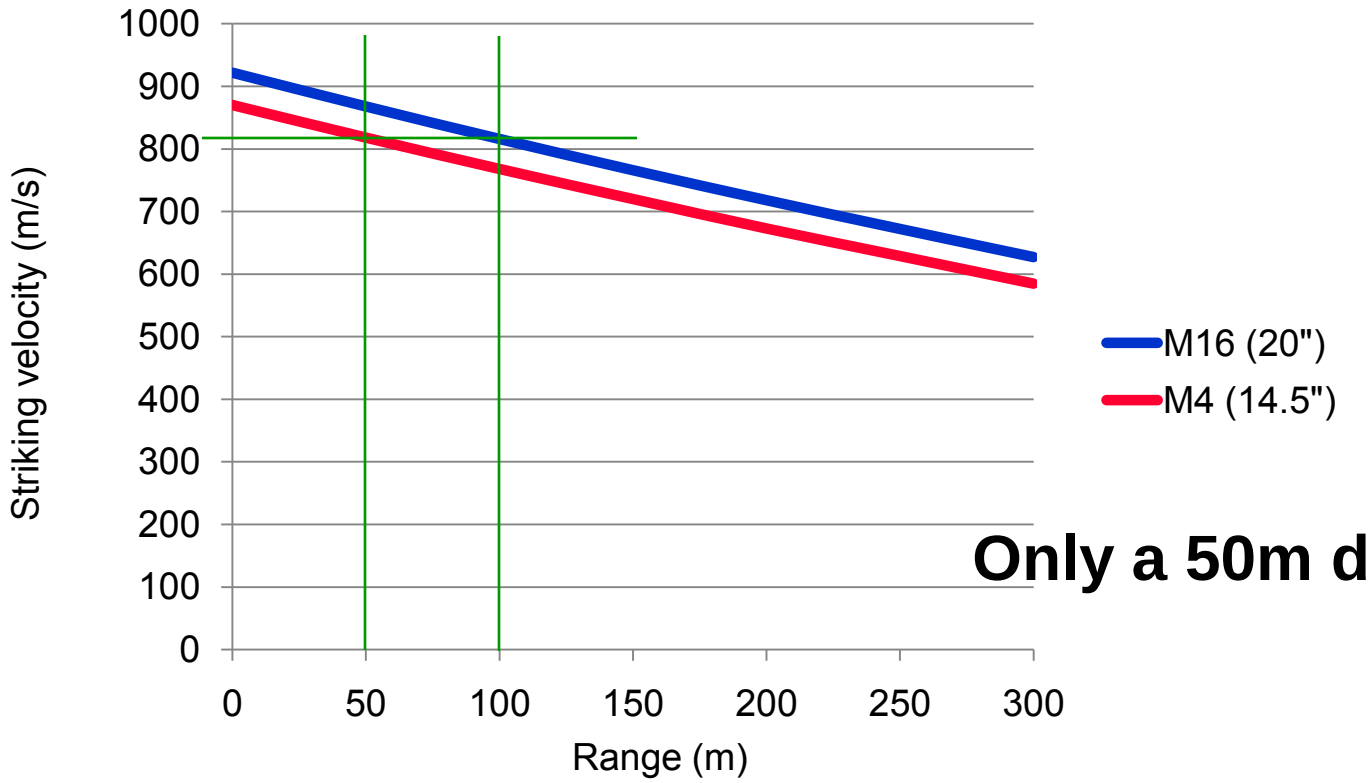
Colt M16A2. NATO reference ammo. NATO standard ammo temperature (+21°C).

The effect of a long barrel is often greatly exaggerated



Rifles with optical sights. NATO standard air temperature (+15°C).
20”=508mm. 14.5”=368mm.

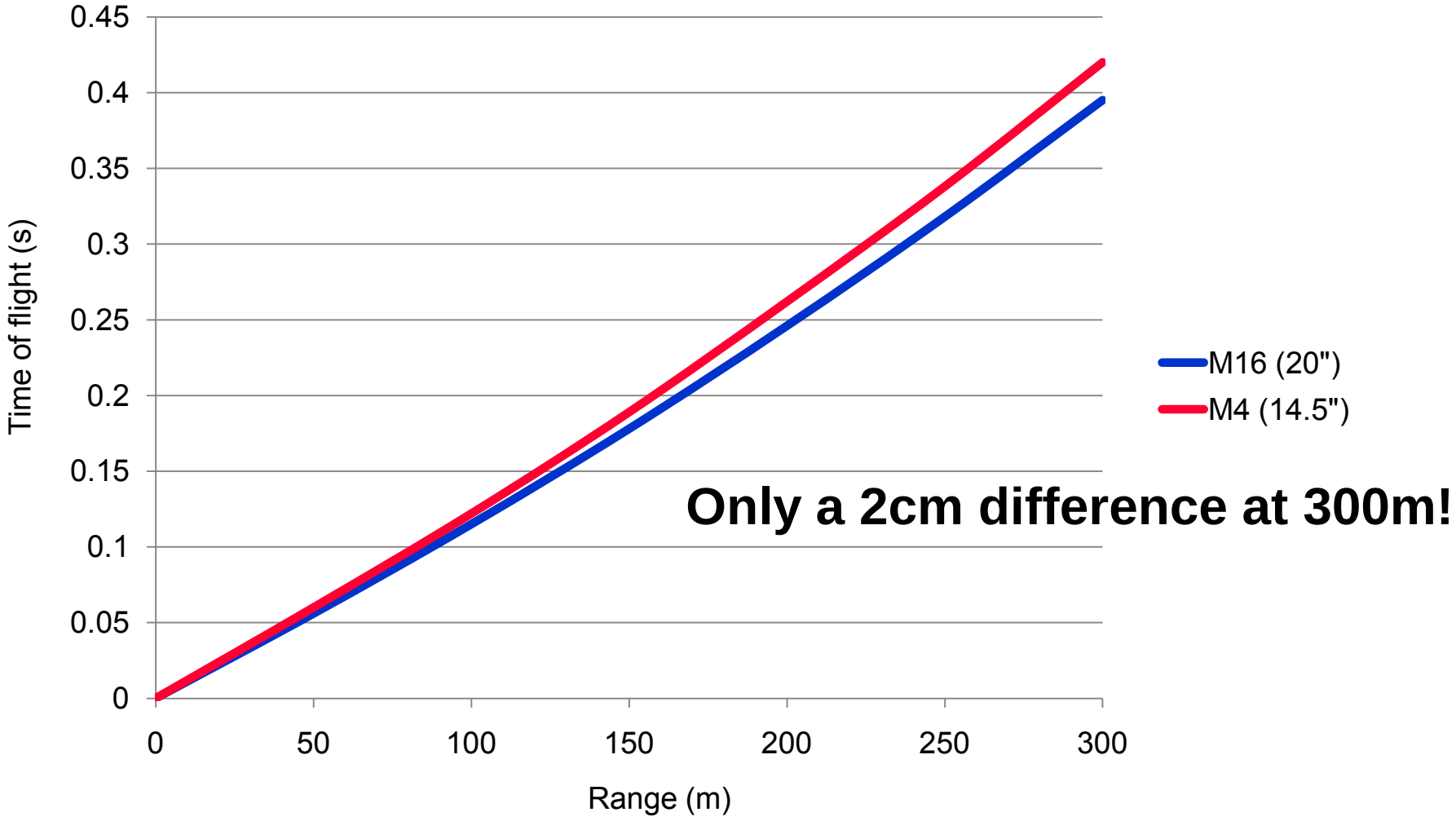
Striking velocity of 5.56 NATO Ball



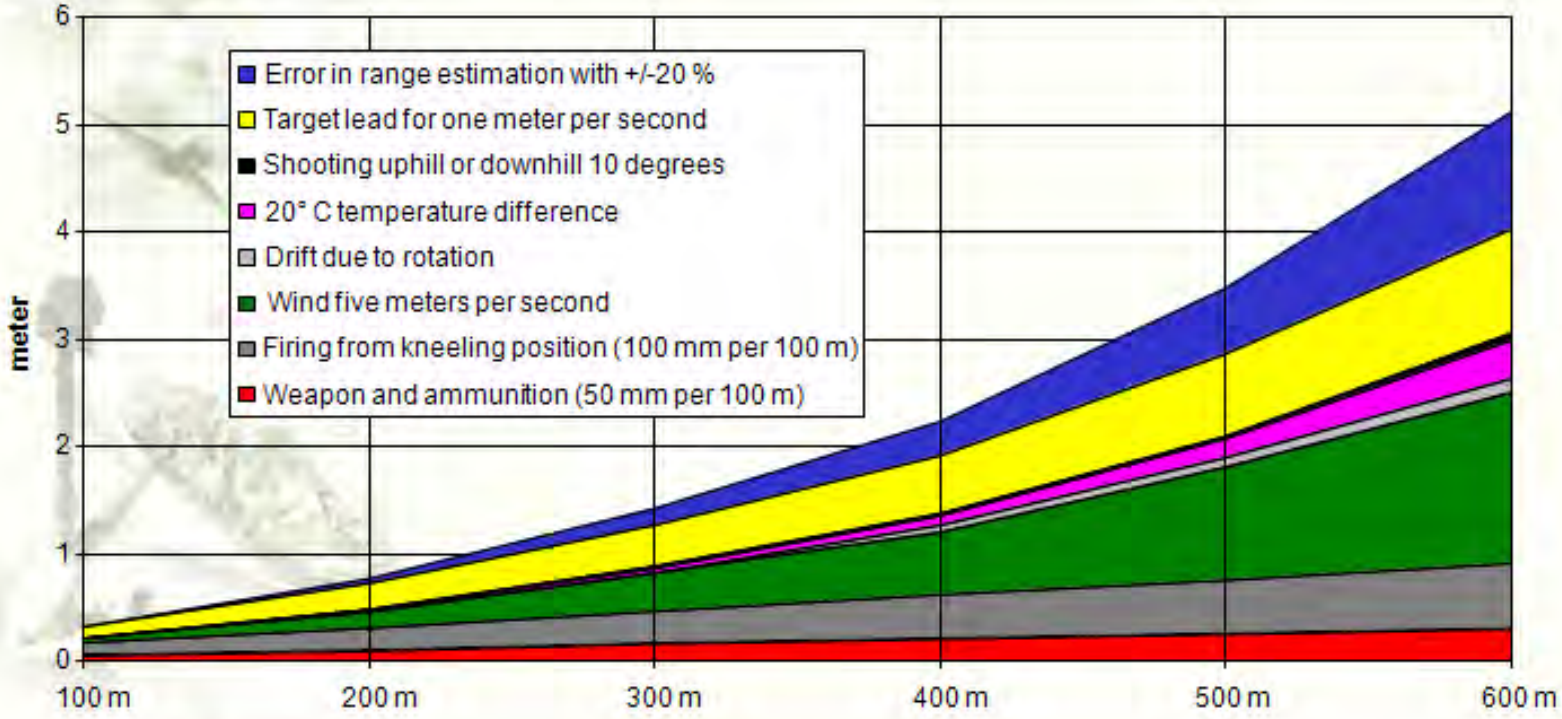
Only a 50m difference!

	0	50	100	150	200	250	300
M16 (20")	922	870	820	772	725	680	637
M4 (14.5")	870	820	772	725	680	637	595

Time of flight for 5.56 NATO Ball

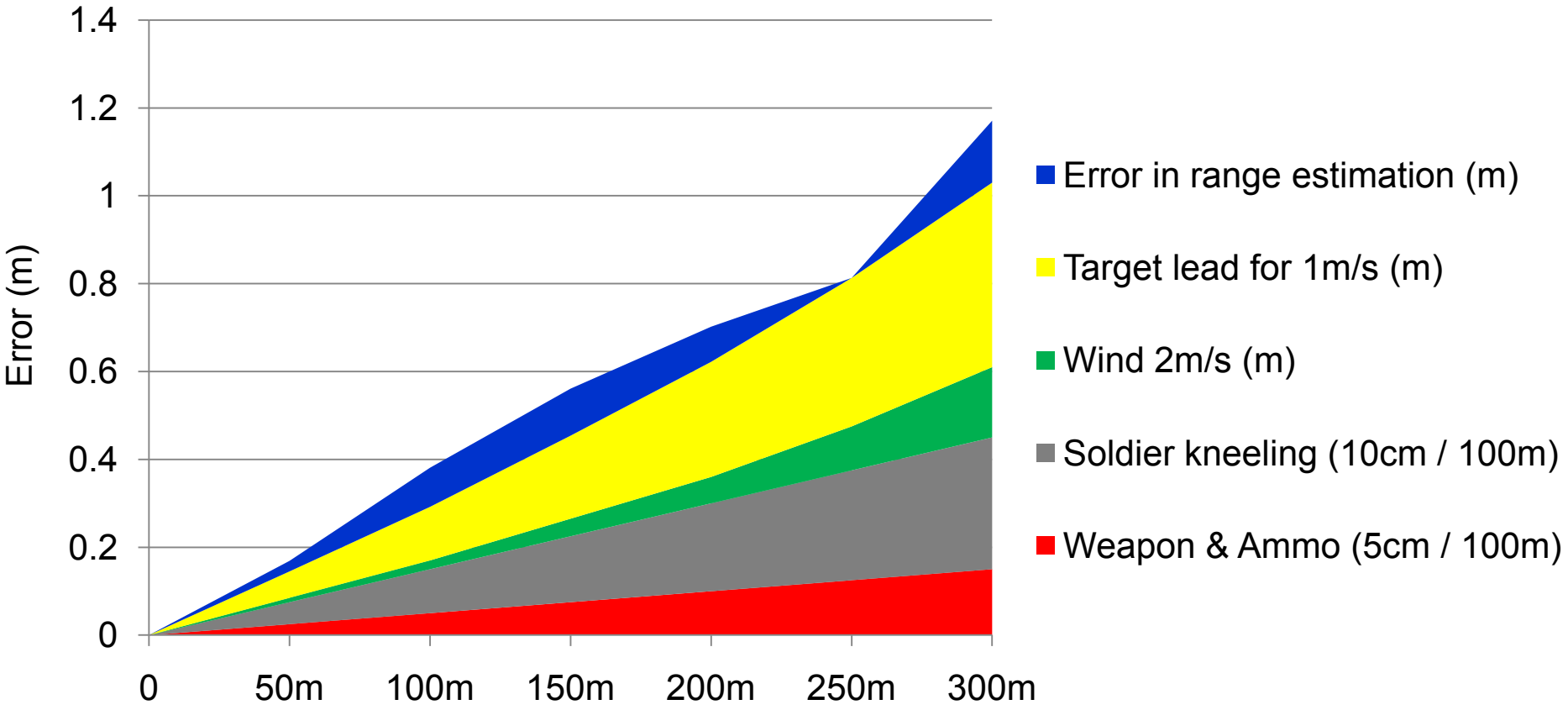


5.56 NATO Error Budget

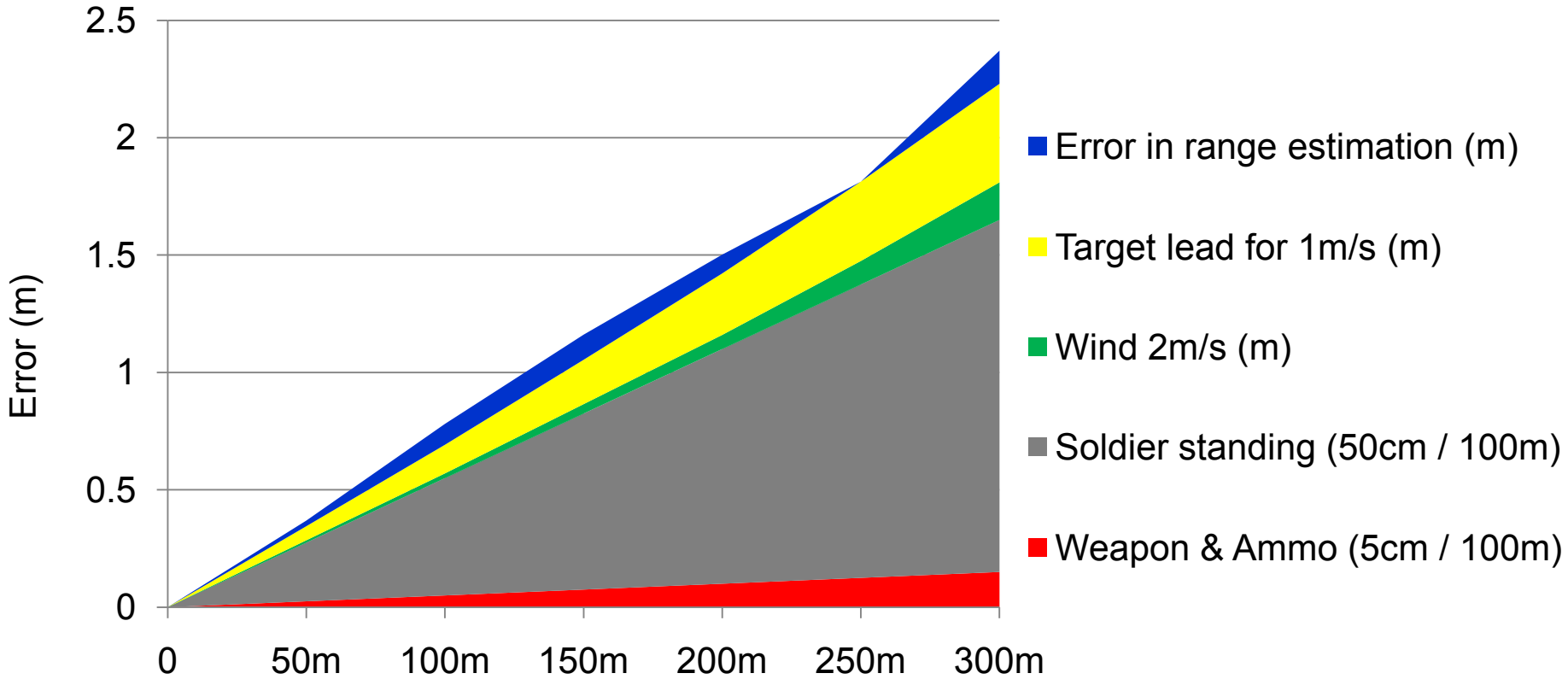


FMV

Error budget, kneeling, no stress



Error budget, standing, stress

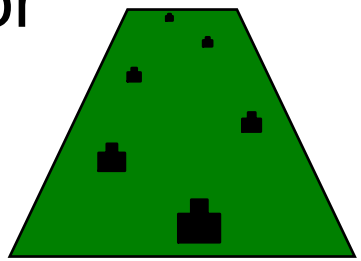


“Internet rumors”

- Rumors about 5.56mm:
  - “Ineffectiveness at long range”
  - “Inconsistent wounding effect”
  - “Poor intermediate barrier penetration”
  - “Ease of deflection”
- There are no official documents that 5.56mm has failed in any NATO Army.
- Most NATO nations agree that the next generation of small arms weapons will also use the 5.56mm NATO caliber.

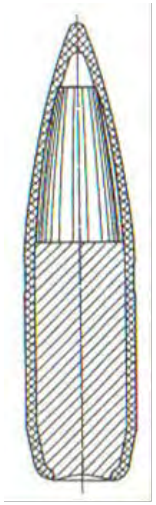
Summary

- There is no problem with the lethality of the 5.56 NATO caliber!
- Most NATO nations are confident with the lethality of their 5.56 and 7.62 rounds!
- To increase small arms lethality, nations must better train their soldiers!
- Soldiers must “train as they fight!”
- If nations want to engage targets at long range, then it is not about rifle caliber, projectile or barrel length, it is all about ***training!***
- Or use the 12.7mm (.50 cal) HMG…





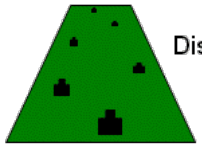
Questions?





Shot placement





Distance



Target

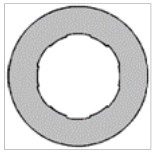
Ammunition

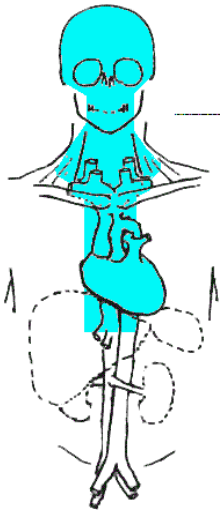


Weapon



Caliber







deanlight
production: www.deanlight.se

Nammo

DEVELOPMENT OF
NAMMO IR-Dim Tracer

- Nammo Vanäsverken AB started to study the IR - Dim Tracer concept in the middle of the 90:ies when Night Vision Devices hade become more available.

- **The design targets for the 5.56 mm round were;**
  - IR-emission near to visible IR (NIR) 0.7-0.8 µm
  - IR trace distance at least 600 meters (>1.5 sek)
  - Full performance in temperatures -54°C to +52°C
  - Reduced muzzle flash/signature
  - Meeting applicable STANAG and MOPI requirements

- **In addition;**
  - Suitable for mass production with existing equipment
  - Compatible with standard tracer cartridge components and existing tracer ignition composition without shelf life deterioration

IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

DEVELOPMENT OF
NAMMO IR-Dim Tracer
- COMPOSITION

- A pyrotechnical solution was the preferred choice to meet the design requirements.
- The first concept was based on a Boron/Potassium composition
  - Emissions of visible light
  - Short IR trace
  - Halo effect in Night Vision Devises

  This type of composition are used in IR flares when you need a lot of IR radiation for illumination of greater areas.

- The second concept was based on a Oxide/Resin composition
  - The selected IR composition meet all design requirements and with some improvements exceeded the design requirements in respect to low level of visible emissions and trace distance.

IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

QUALIFICATION

OF SELECTED IR COMPOSITION

2010

- **The selected IR-Dim Tracer composition has been thoroughly scrutinised with respect to;**

  - Stability and compatibility with other cartridge components.
  - Electrostatic spark, chock and friction testing.
  - Resulting in the IR composition is considered to be non explosive.
  - Ignition temperature and differential scanning calorimetry
  - 5.56x45 Dim Tracer 4 qualified by US Navy Mod. Mk301

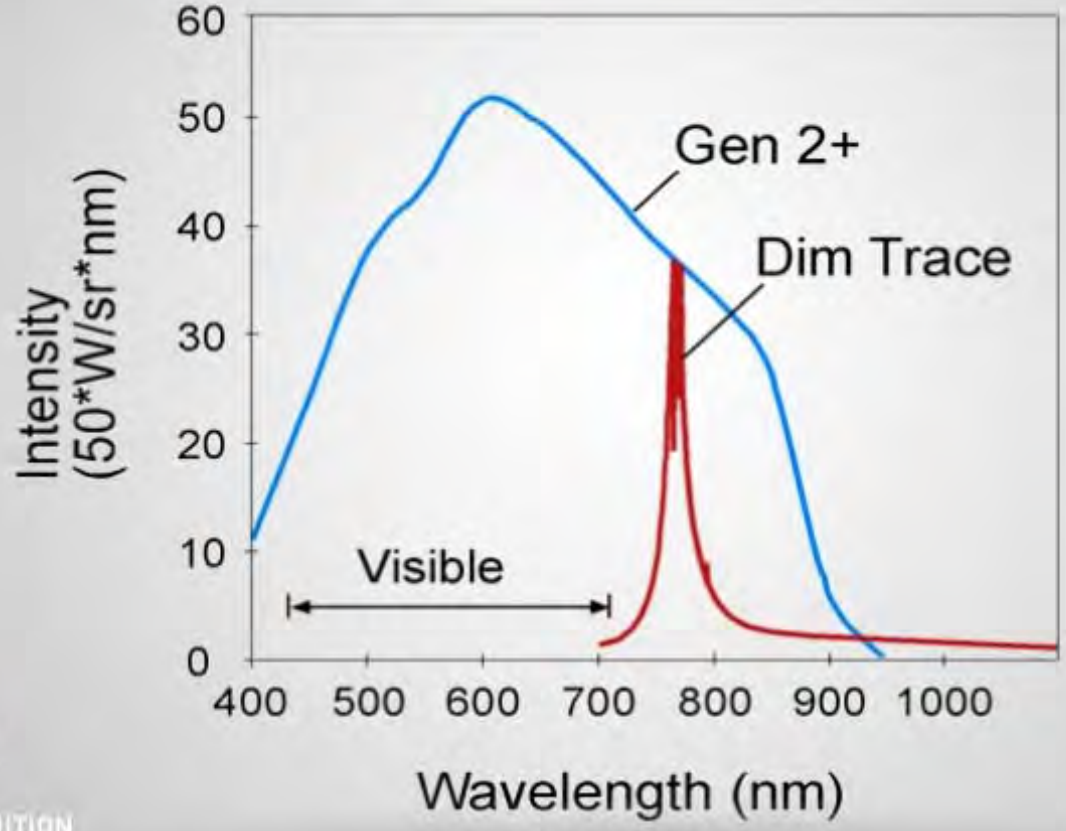
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

2010

IR - DIM TRACE

EMISSION & NVD SENSITVITY



IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

IR - DIM TRACER

PROPERTIES

2010

- General cartridge requirements based on respective STANAG 4172 for 5.56 mm and 2310 for 7.62 mm
- Minimal emission in visible spectrum
- Main emission near to visible IR (NIR) with wavelength 0.7-0.8 nm
- Minimal muzzle flash
- Trace distance with Gen 2+ NVD
  - 5.56 mm – Min 600 m Average 750 m
  - 7.62 mm – Min 775 m Average 1000 m
- Fully ignited IR trace from 50 m

IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

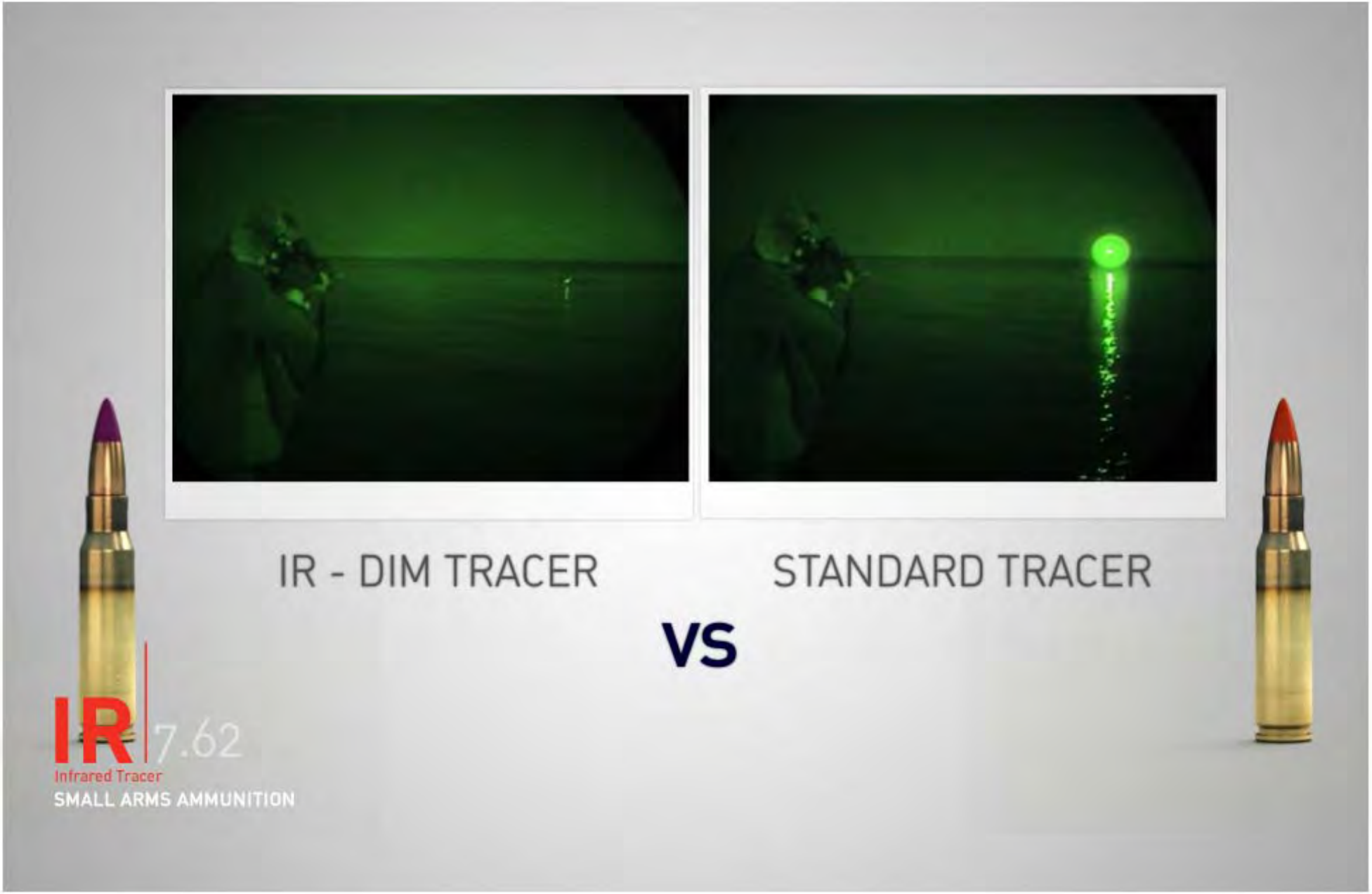
IR - DIM TRACER

ADVANTAGES v. CONVENTIONAL TRACER

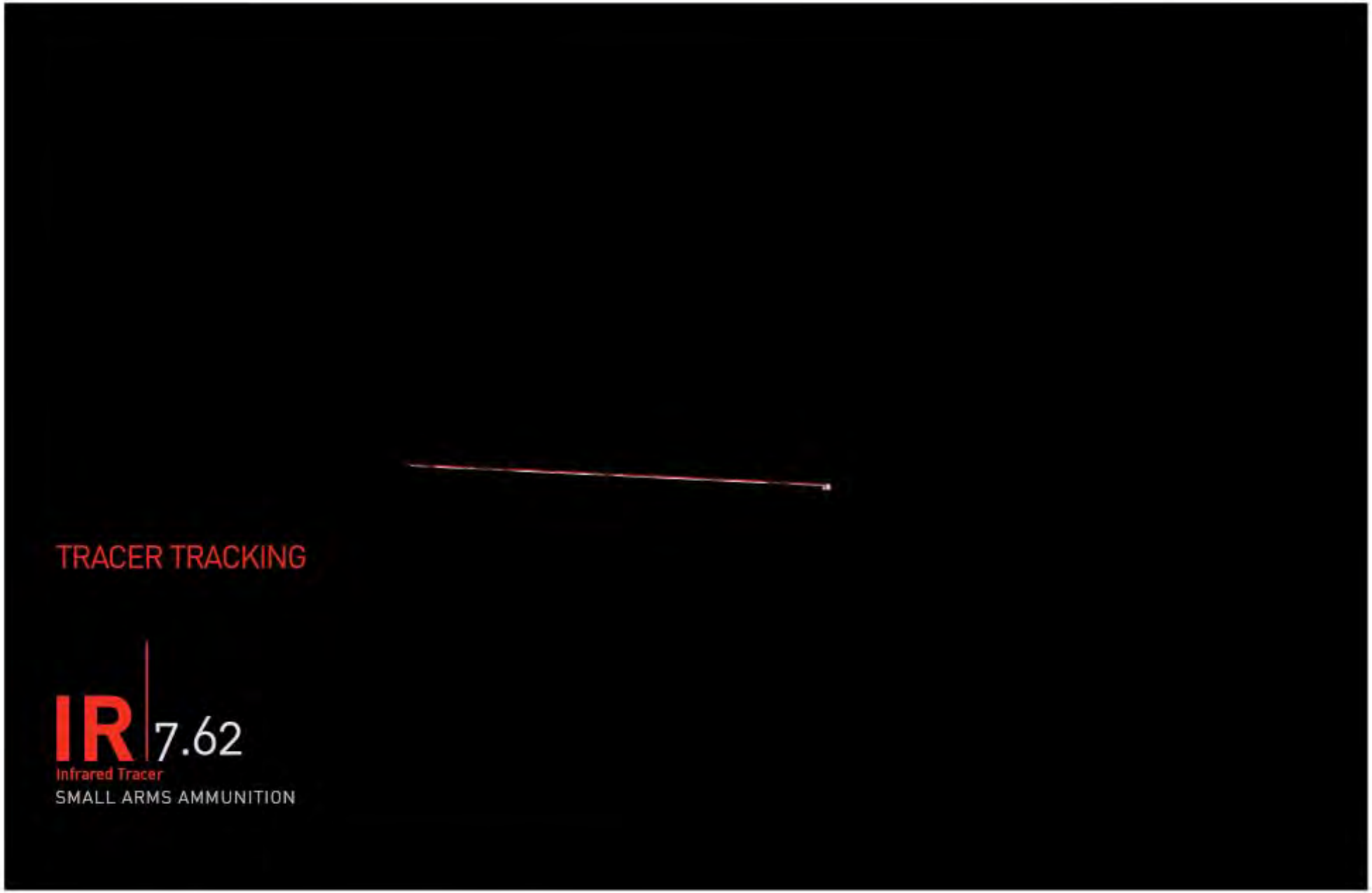
- **Dim Tracer**
  - Opening of fire – Surprise effect
  - Target location – Also after opening of fire
  - Minimal disturbance – Own observers
  - Minimal exposure – Own unit
- **Conventional Tracer**
  - Muzzle flash
  - "Fireballs" at the target
  - Illumination backwards
  - Tracer light track
- **Resulting in**
  - Lower hit probability
  - Exposure of own unit

IR | 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo


IR - DIM TRACER
STANDARD TRACER
VS
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION
Nammo


STANDARD TRACER vs DIM TRACER
[Gen III NVD]
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION


TRACER TRACKING
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

DIM [IR] TRACER

IR 7.62

Infrared Tracer

SMALL ARMS AMMUNITION

Namm


STANDARD TRACER
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION


IR TRACER
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

7.62 IR - DIM TRACER

PROPERTIES



- General cartridge requirements based on respective STANAG 4172 for 5.56 mm and 2310 for 7.62 mm
- Minimal emission in visible spectrum
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- Minimal muzzle flash

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- Fully ignited IR trace from 50 m

IR | 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

1 facts 2 facts 3 more

Nammo


bullet
#X-ray# : view front
shelf
#X-ray# : view front
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION


IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION
1 facts
2 facts
3 more


bullet
#X-ray# view front
IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION
1 facts
2 facts
3 zoom

Nammo

2010

NEW IR -TRACER PROGRAMS

- 5.56x45 **mm IR Tracer: Qualified as Mk 301.** [In production]
- 7.62x51 **mm IR Tracer** [In production]
- .50**cal** [In production]
- **Development of** 5.56 **mm and** 7.62 **mm Reduced Range IR-Dim Tracer** [Design and Qualification during 2010]
- **Development of 9 mm IR-Dim Tracer** [Study]
- **Development of 4.6 mm IR-Dim Tracer** [Study]

IR 7.62
Infrared Tracer
SMALL ARMS AMMUNITION

Nammo

NDIA Joint Armaments Conference:

21st Century Weapon Systems

Advanced Remote/Robotic Armament System (ARAS)

Presented by: Bob Testa, Brian Hoffman, Bill Burgermeister
ARDEC Weapon Systems and Technology (WS&T)

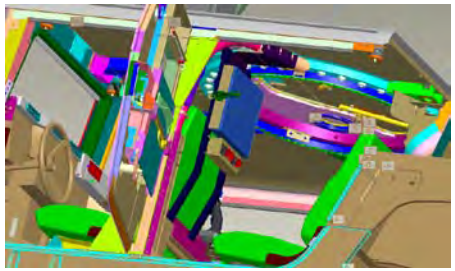
Bob Testa, 973.724.3620,
robert.testa1@us.army.mil

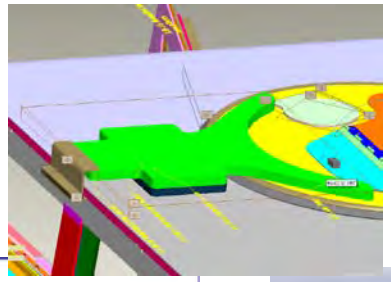
19 May 2010

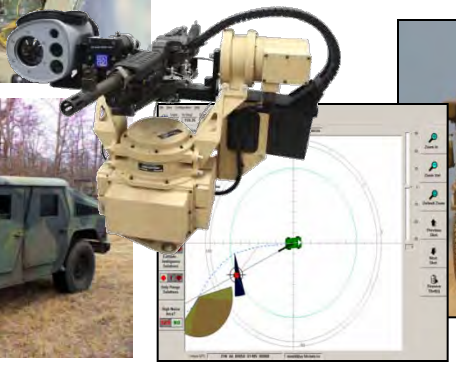
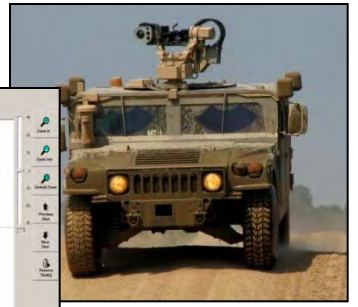
US ARMY RDECOM

Advanced Remote/Robotic Armament System (ARAS)






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2007 Award Recipient

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Remote Weapons

What is wrong with this picture?



Mk19 40 mm GMG



.50 Cal M2 MG



M240B, 7.62 mm Medium MG



M249 Squad Automatic Weapon
5.56 mm MG

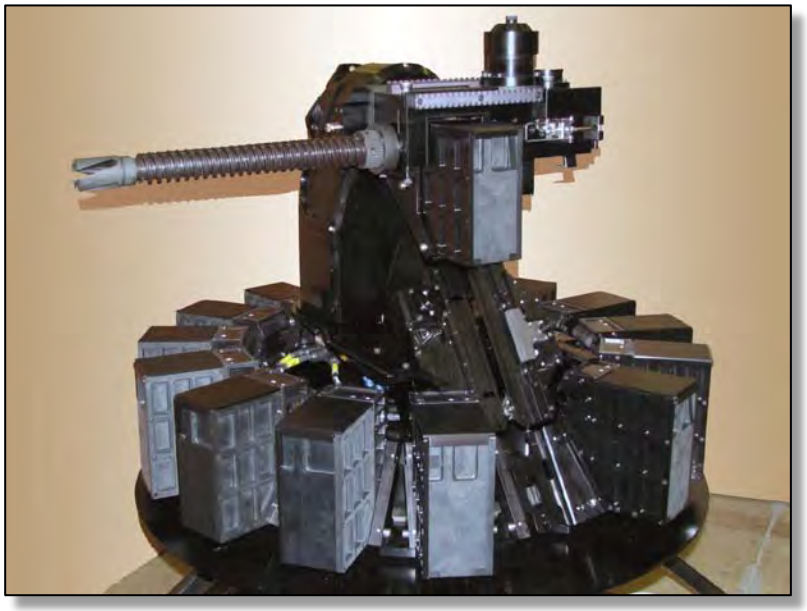
Advanced Remote/Robotic Armament System (ARAS)

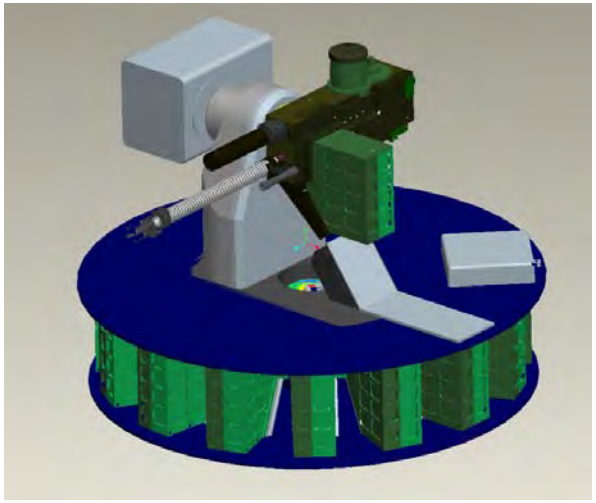
Our development objectives are based on our understanding of the 'problem'

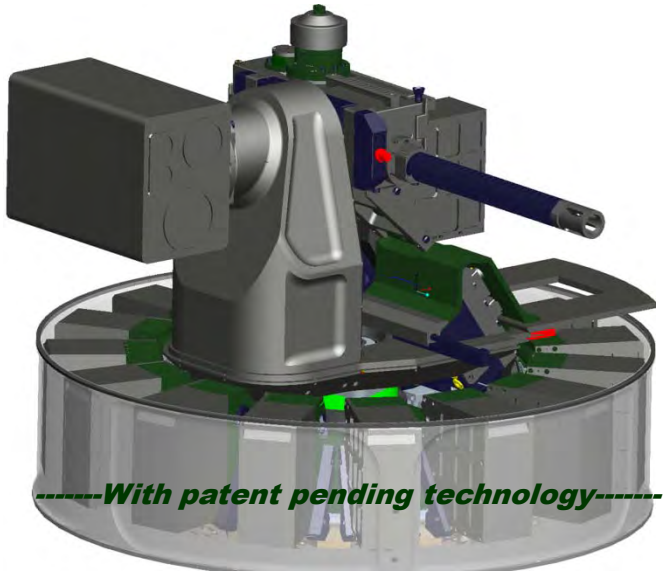
ARAS CAPABILITIES:

- ✓ Electrically actuated weapon firing standard linked ammunition
- ✓ High stabilization and pointing accuracy
- ✓ Reload from UNDER ARMOR
- ✓ Change Ammunition type from UNDER ARMOR
- ✓ Full ammunition inventory
- ✓ Non-lethal capability
- ✓ Real time operating system for critical subsystem performance
- ✓ Minimize reload or ammo type change time: ~6sec
- ✓ Theft/Tamper resistant weapon and ammunition
- ✓ Up to 90 degree elevation from low silhouette mount

Advanced Remote/Robotic Armament System (ARAS)







ARAS Development:

FY05/06 – early concepts and internal marketing
FY07/09 – Baseline 7.62mm development
FY09/10 – Prototype 7.62mm fabrication
FY10/12 – 50cal ARAS development and fabrication

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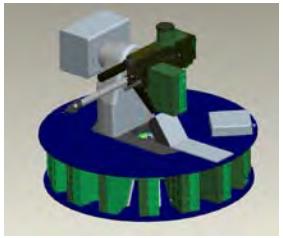
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Advanced Remote/Robotic Armament System (ARAS)

How we did it:

- ARDEC management buy in; allowed us to work behind the curtain
- We kept our goals achievable: no modification of physics required
- We developed a strong multi-organizational team with supervisor buy in
- We understood key capabilities and added new requirements carefully
- We intentionally avoided specific platforms or applications

ARAS Concept



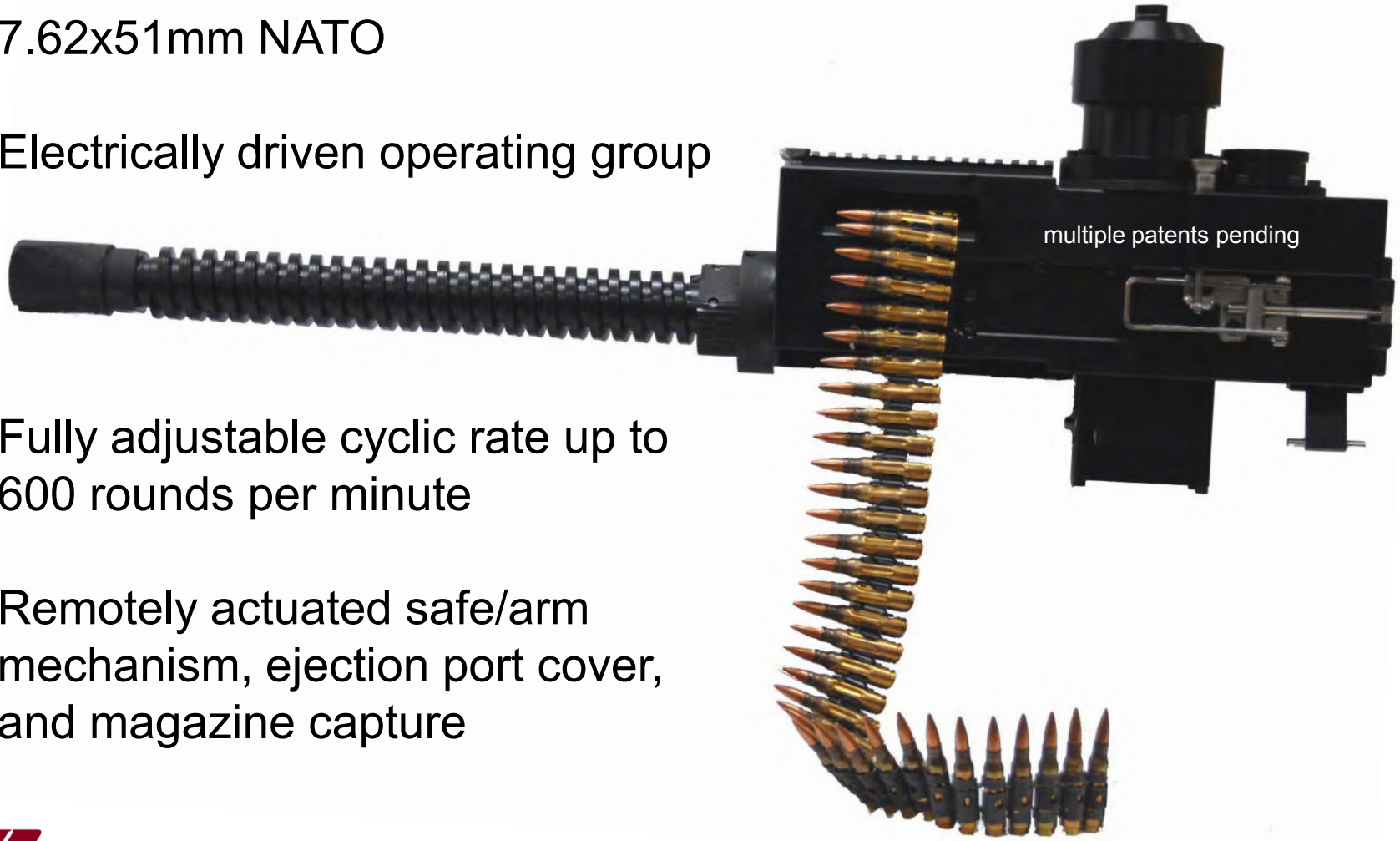


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ARAS Weapon Subsystem

7.62x51mm NATO

Electrically driven operating group



Fully adjustable cyclic rate up to 600 rounds per minute

Remotely actuated safe/arm mechanism, ejection port cover, and magazine capture

Design Goals and Challenges

#1 Mission modularity with single weapon capabilities that span multiple conventional battlefield roles

#2 High reliability when firing lethal and non-lethal ammunition

#3 Scalable effects and ability to interchange lethal and non-lethal munitions on the fly and without hardware modifications

---

#4 Compact physical envelope with favorable inertial properties

---

#5 Barrel survivability (worst case payload dump of 1500 rounds in under 5 minutes)

#6 KISS

Addressing Design Goals #1-3
(mission modularity, reliability, scalable effects)

External Power

Percussion Firing Mechanism

Software Control

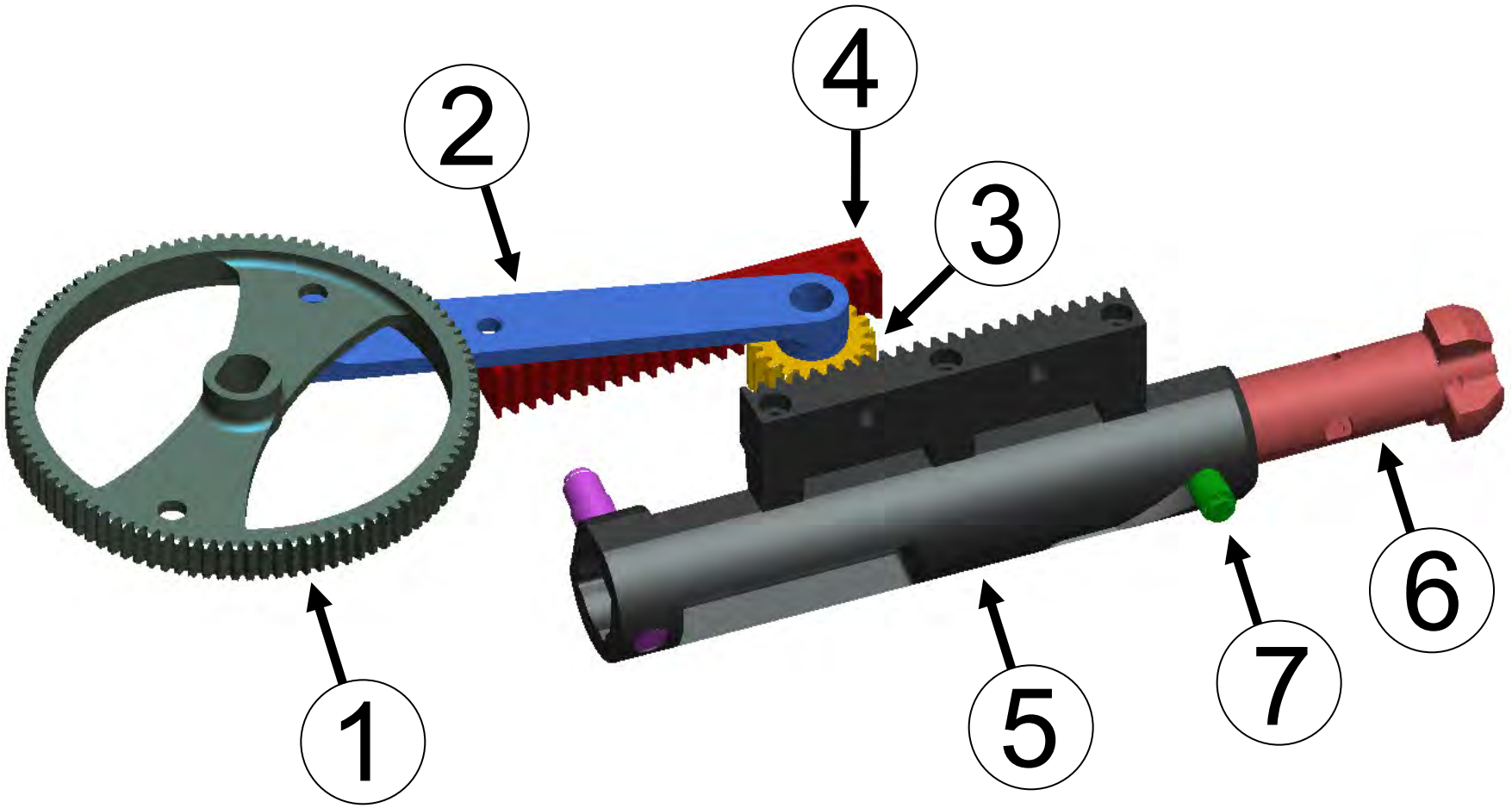




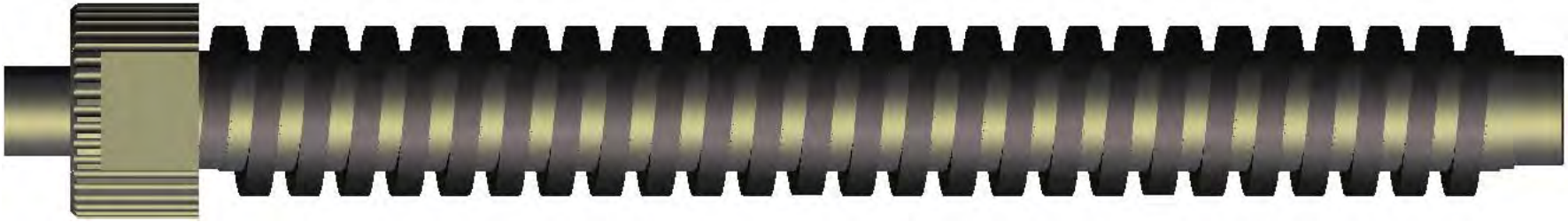
sample code

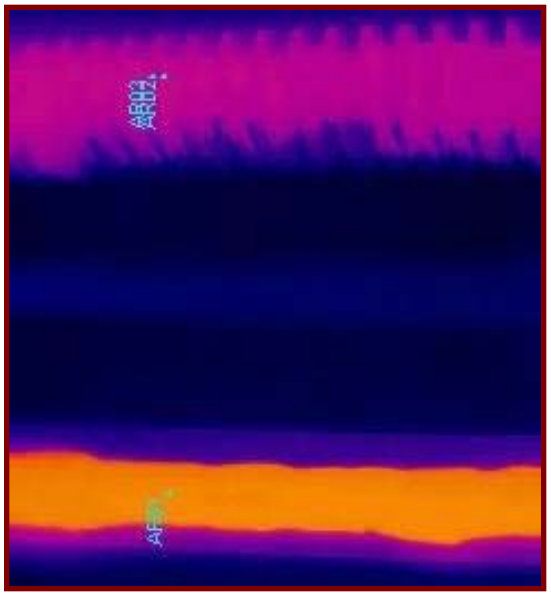
```
X=burst length;
If (firing rate>400), X=10;
//set burst length to 10 rds
//for firing rates exceeding 400 rds/min
```

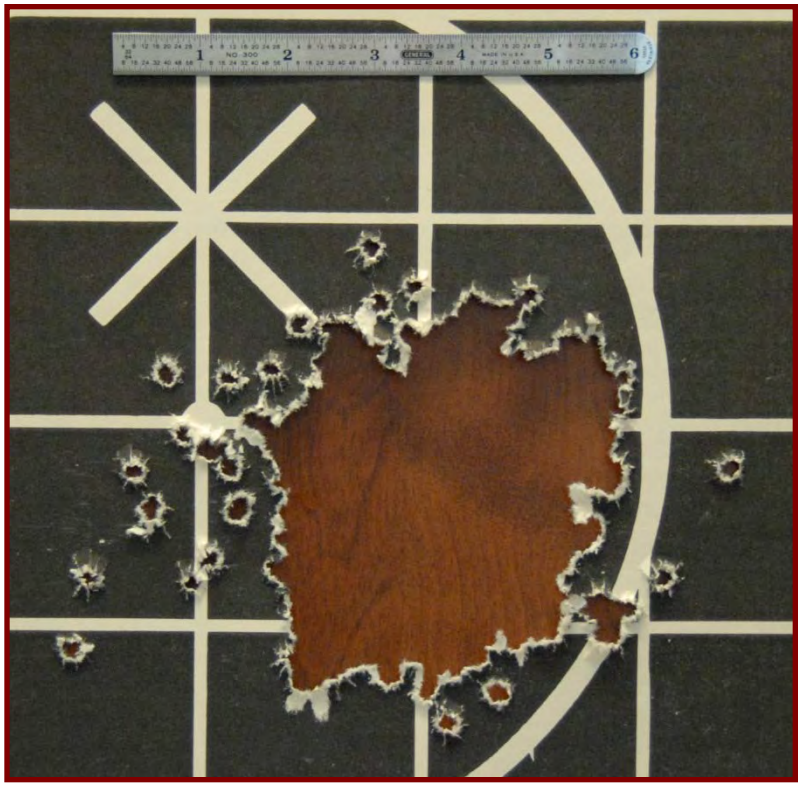
Addressing Design Goal #4
(compact with favorable inertial properties)



Addressing Design Goal #5
(barrel survivability)







Addressing Design Goal #6
(KISS)

FIXED HEADSPACE

FIXED TIMING

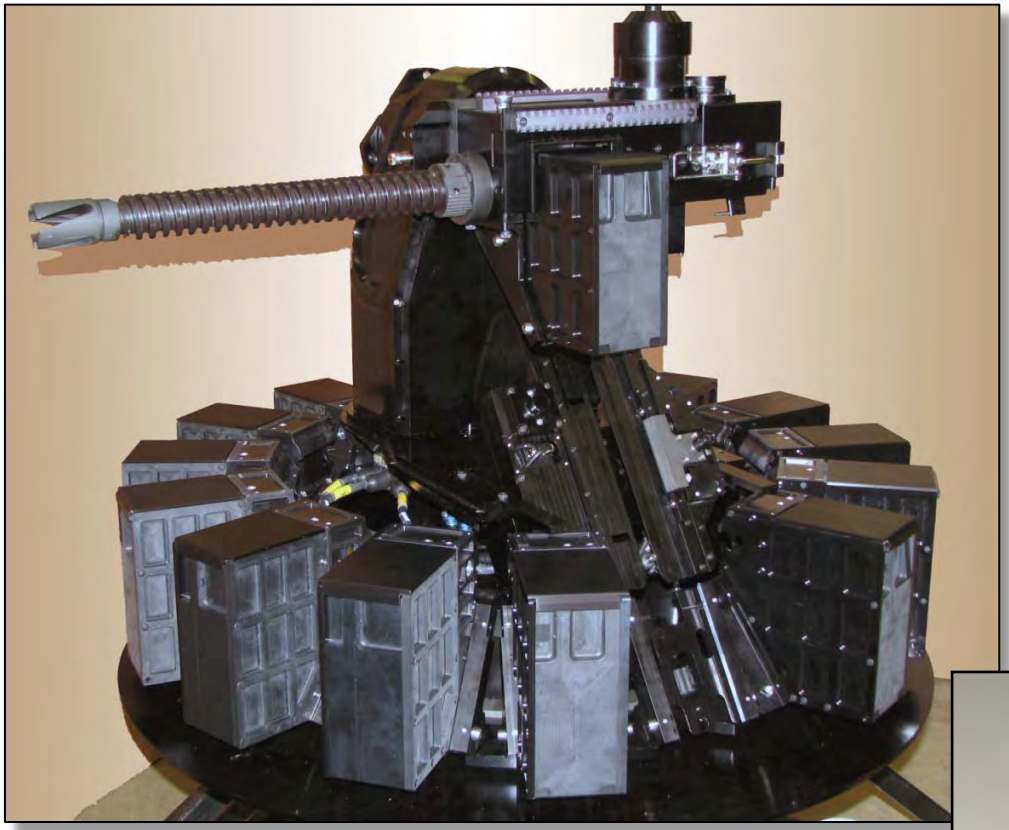
TOOL LESS USER FRIENDLY FIELD STRIP AND REASSEMBLY

NO BARREL CHANGE DURING PAYLOAD EXPENDITURE

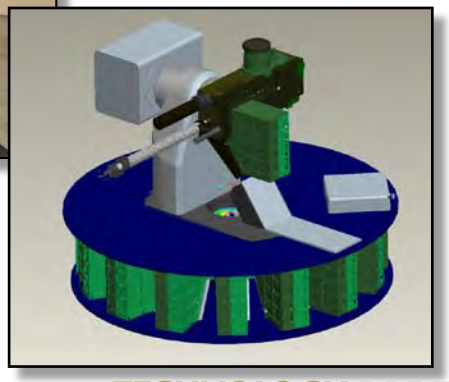
INTERNAL CABLING WITH TRANSPARENT CONNECTION WHEN ATTACHING THE WEAPON TO THE TURRET ARM

Design Goals and Challenges

Ammo Handling & Turret Design

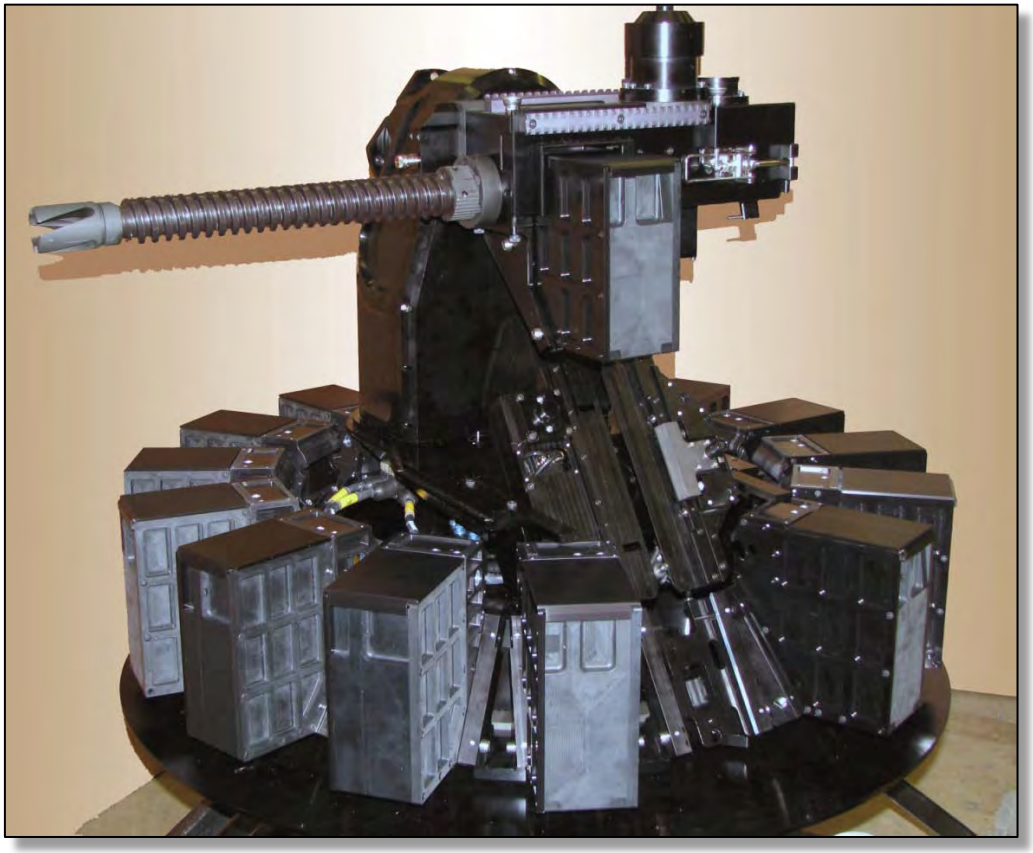


- Automated reload/switch ammo type under armor
- Reliably transport and lock magazine to weapon
- 360 ° continuous azimuth, 90° elevation -30° depression angle
- Ability to store and select different ammo types for mission flexibility and scalable effects



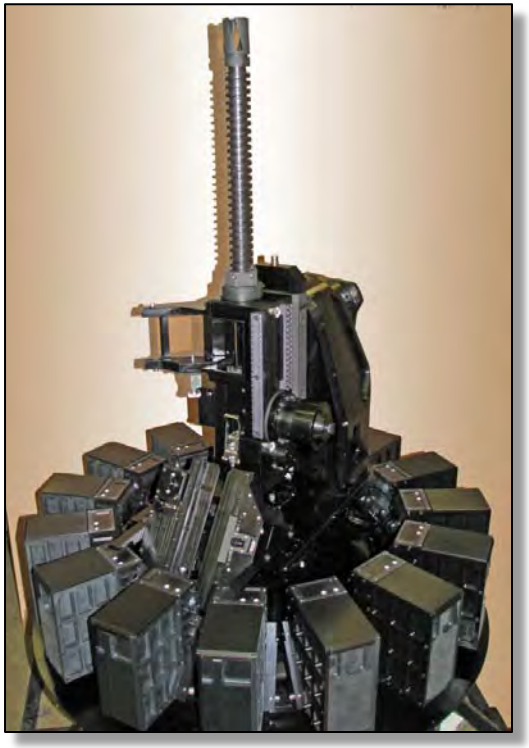
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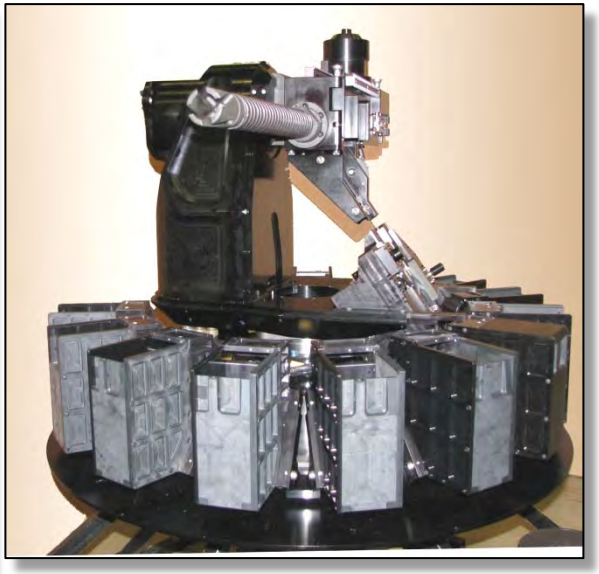
Design Goals and Challenges (continued)

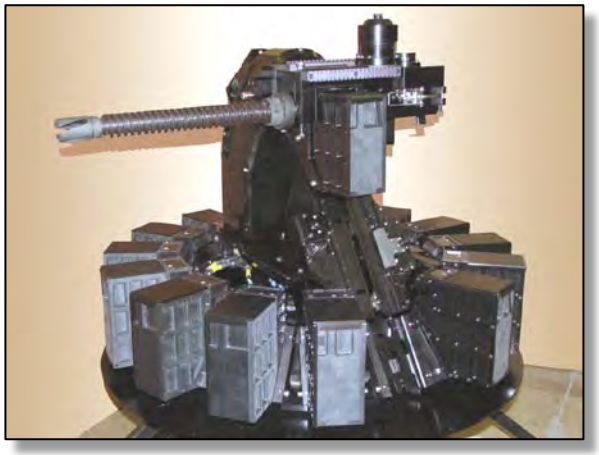


- First round select
- Internal Cable routing
- Lightweight and small footprint/swept volume
- High performance slew rate to facilitate stabilization and external systems (PDQ, GDS, Network centric handoff…)
- Rigid turret system to improve weapon accuracy and round dispersion
- Fast reloading, target retention during loading.

Turret and Carousel design





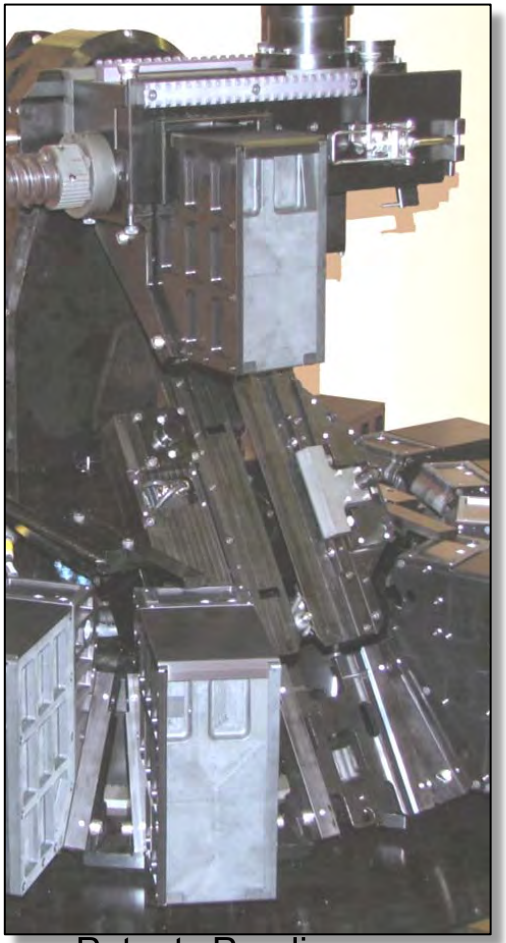


System Level approach in concurrent engineering of ammo handling, turret and weapon

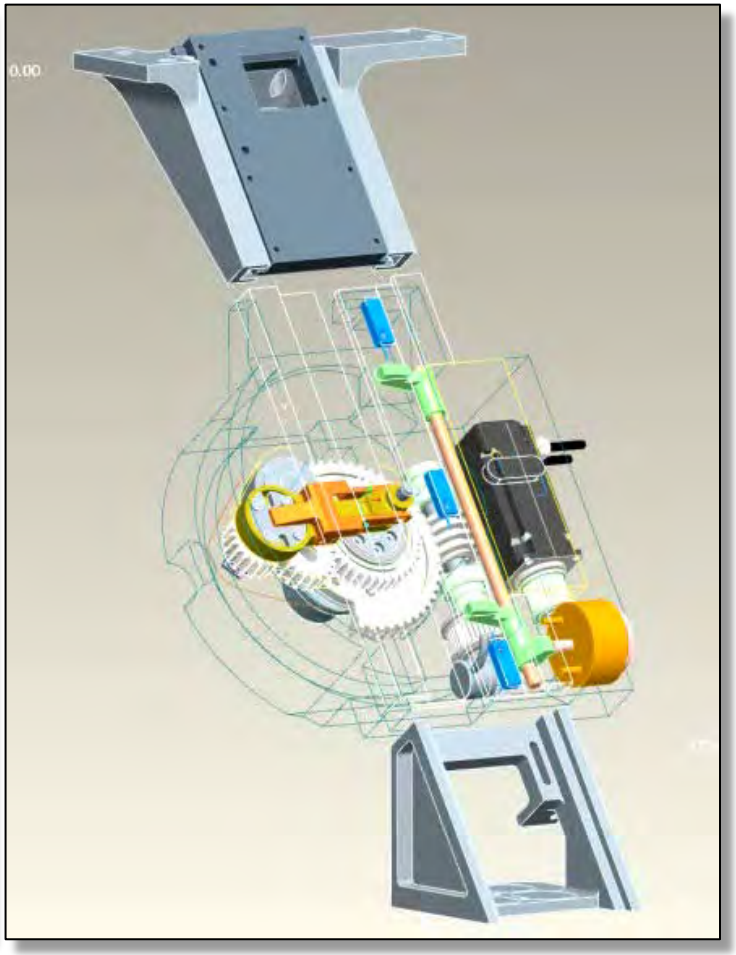
- One arm turret accommodates ammo handling
- Weapon designed from onset to interface with ammo handling
- Magazine shuttle mechanism traverses with turret, carousel has separate axis, for fast reload capability and target retention
- Ability to select any ammo magazine in carousel
- Ammo magazines are environmentally protected

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Shuttle Design



Patents Pending



Provides a robust method to transport Ammo Magazine between Weapon and Carousel

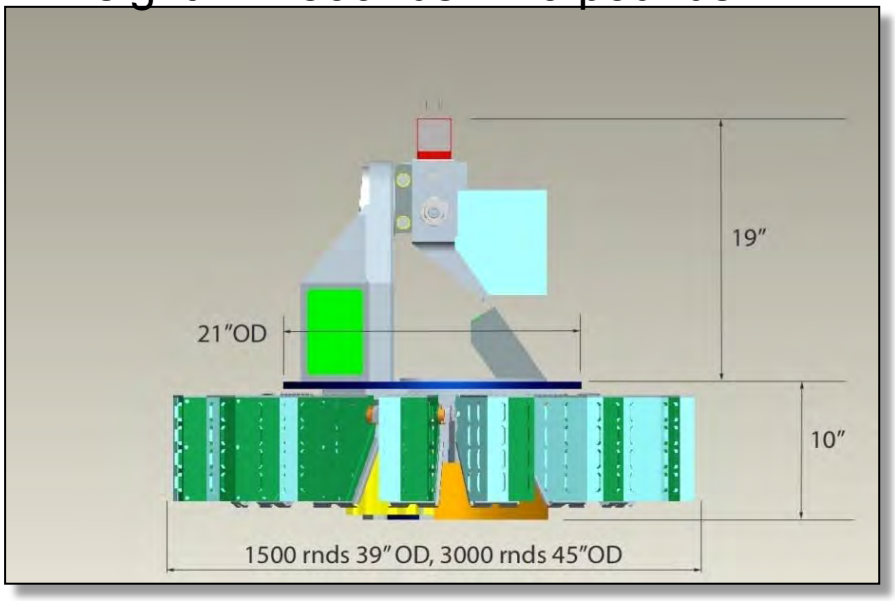
- Fault tolerant design in case of control sequence malfunction
- Extended stoke length
- No intrusion into weapon or carousel swept volumes in home position
- Utilizes peak mechanical advantage at ends of stoke to latch ammo magazines to weapon and to carousel storage slots

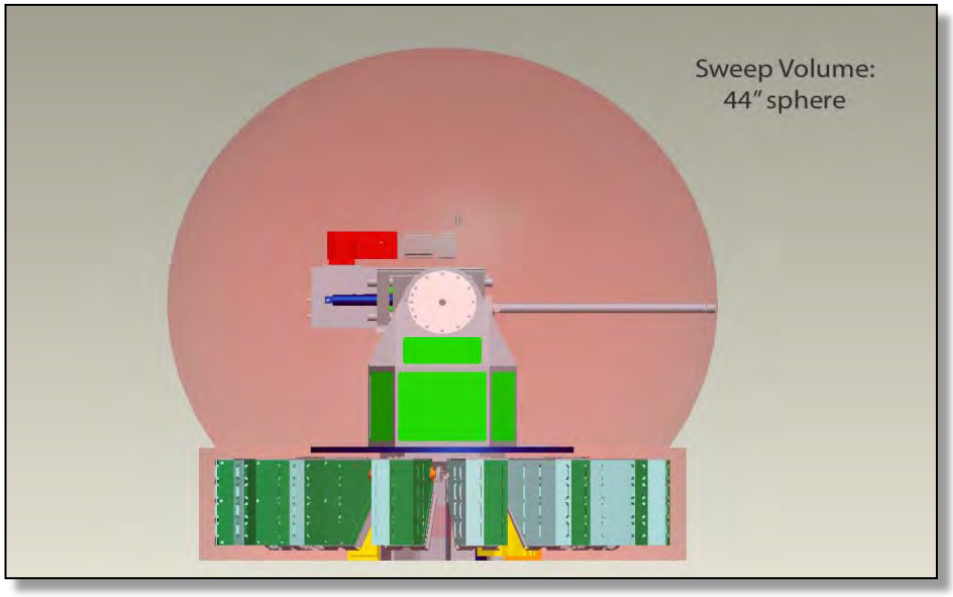
Malcolm Baldrige National Quality Award 2007 Award Recipient

ARAS Specification

ARAS

Weight w/ 1500 rds: 410 pounds





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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



U.S. Army Research, Development and Engineering Command

Advancements in Personnel Incapacitation Methodologies for Multiple Cartridge Projectiles (MPCs)



NDIA – Joint Armaments: Conference, Exhibition, and Firing Demonstration

19 May 2010

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Stephen P. Swann

U.S. Army Research Laboratory
Survivability/Lethality Analysis Directorate

Outline

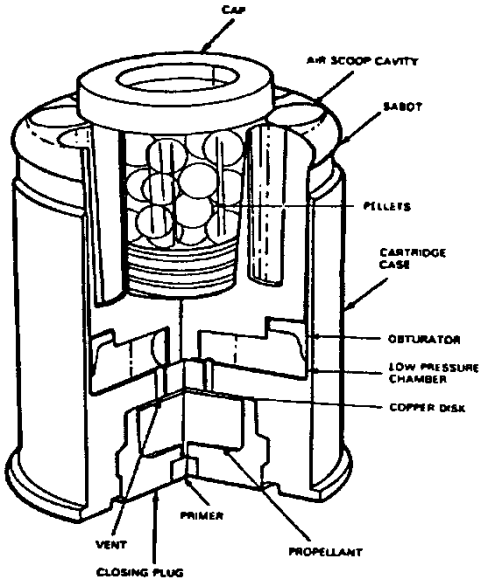
- Background – Close-In Anti-Personnel (CIAP) Study
- Modeling methodology
  - Overview
    - Delivery
      - MUVES-S2
      - Modeling MPCs
      - ORCA
    - Damage
      - Dispersion patterns
    - Incapacitation
      - Target profile
- Analysis example
  - Modeling an individual shot configuration
  - Modeling a single pellet
  - Optimization observations
  - Optimization methodology/analysis
- Operational modeling
- Questions

Background – CIAP Study

- The intent of the CIAP program is to replace the current 40mm Multiple Projectile (M576) cartridge with modern alternative.

- ARL conducted a 3 phase effort to assist in the design:
  - Phase 1 – Characterize the M576
  - Phase 2 – Characterize the Mossberg 590A Tactical Shotgun System w/ standard configuration
  - Phase 3 – Concept evaluation and optimization

- Each phase considered:
  - Pellet mass/velocity/quantity
  - Pellet shape and in shot dispersion
  - In addition, as a part of phase 2, ARL evaluated and compared the Probability of Incapacitation (P(I) =1) values of the M576 and the 590A



Cutaway View of the M576



Mossberg 590A

All modeling and simulation were performed with ARL-SLAD's MUVES/ORCA software

Overview of Modeling MPCs

Modeling is composed of three stages:

- Delivery
- Damage to target (injury)
- Incapacitation (assessment of target's reduced capability to accomplish tasks)

Hit a Target



Target posture
Aim point
Aim error
Trajectory
Velocity decay
Air drag
Dispersion

Delivery

Injury

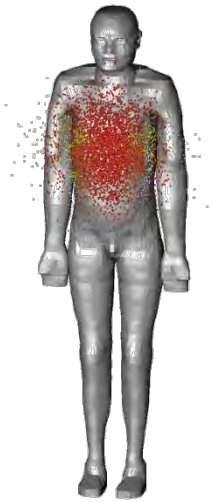
Hit location
Shot line in target
Striking velocity
Fragmentation effects
Anatomical model
Deleterious processes
Tissue retardation
Resulting hole sizes





Damage to Target

Task-based Assessment



Assess target's reduced ability to accomplish tasks, using Operation Requirement based Casualty Assessment (ORCA)

Incapacitation

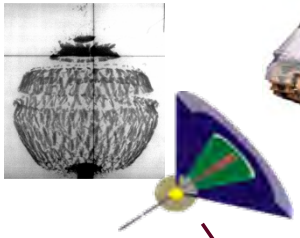
MUVES-S2 with Embedded ORCA

A Survivability/Lethality/Vulnerability (SLV) computer model capable of analyzing the effects of one or more munitions against aircraft, ground-mobile targets and/or personnel

ORCA Methodology allows for:

- discrete shot lines through anatomy based on orientation of threat trajectory to personnel
- projectile penetration mechanics through various anatomic structures
- velocity retardation of threat through wound track
- injury description by type, severity, and frequency
- in-depth description of operational effectiveness

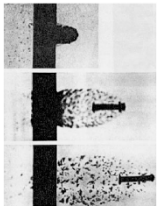
Threat Characterization



Target Geometry



Behind-Armor Debris



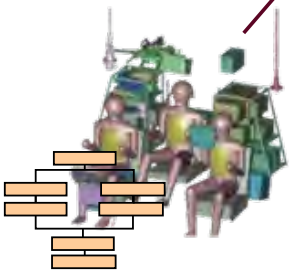


Crew Casualty

Vehicular SLV Analysis

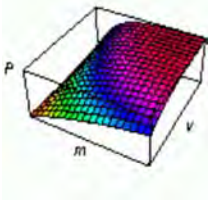
Analysis Outputs

- personnel injury and incapacitation
- system-level kills / loss of function
- residual penetration & velocity
- component damage
- subsystem capabilities
- remaining system utility
- user-defined criteria
- tabular & graphical products



Criticality Analysis of Components and Subsystems

Component Defeat Criteria





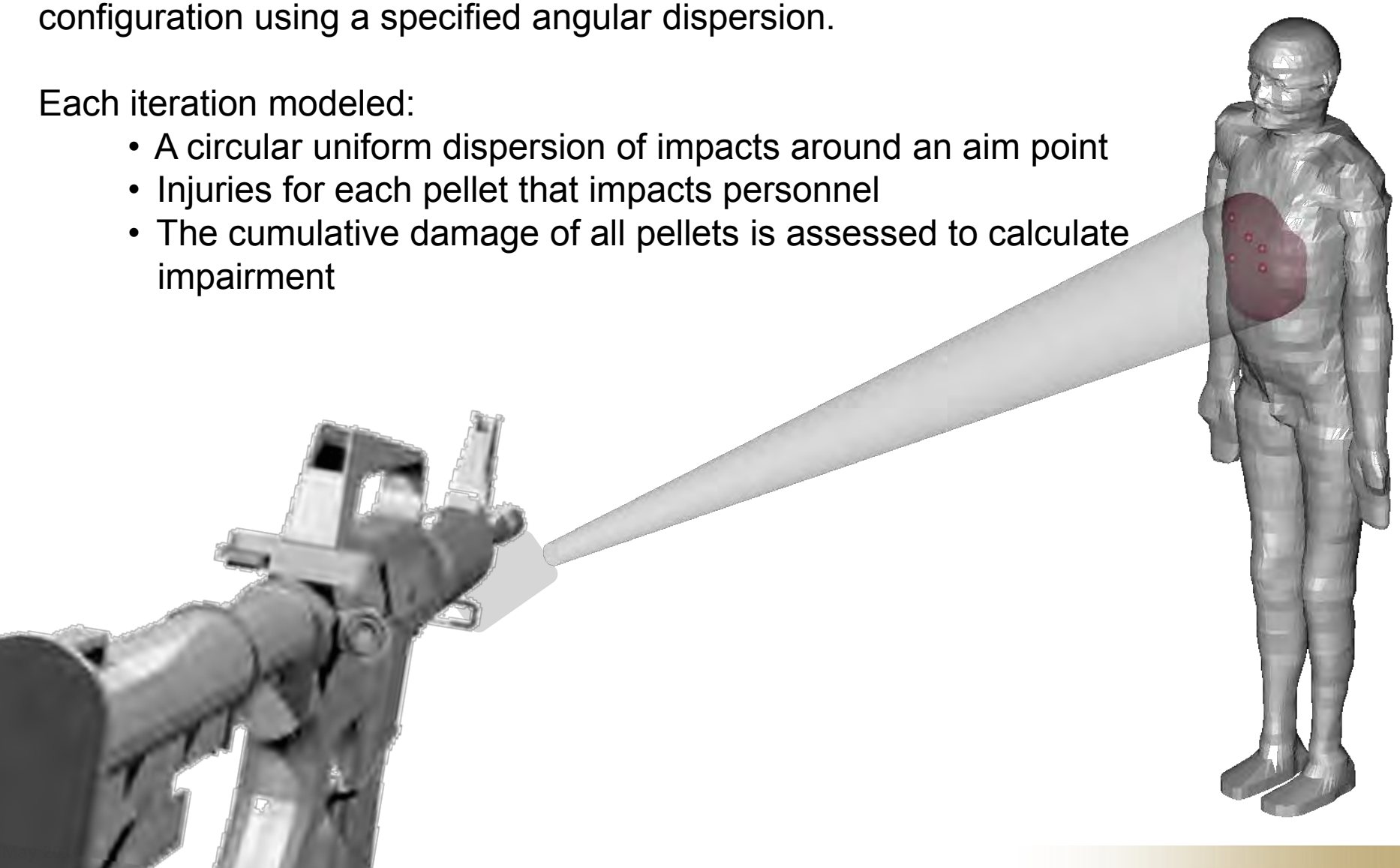
Engagement Conditions

How MPC's are modeled in MUVES-S2

Each run within MUVES-S2 modeled 250 iterations of a unique shot configuration using a specified angular dispersion.

Each iteration modeled:

- A circular uniform dispersion of impacts around an aim point
- Injuries for each pellet that impacts personnel
- The cumulative damage of all pellets is assessed to calculate impairment



Operational Requirement-based Casualty Assessment (ORCA)

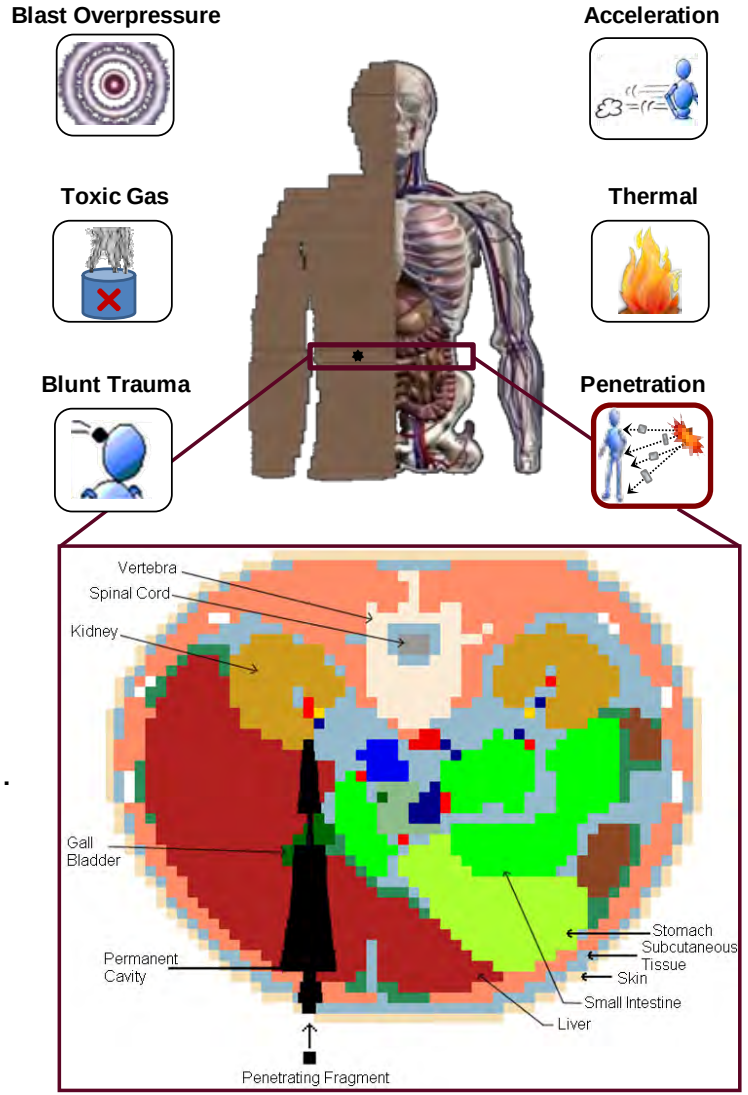
- ORCA is a high-resolution computerized human vulnerability model that is used to assess the impact of various casualty-causing insults on personnel.

- ORCA calculates several injury severity trauma metrics that may be used to characterize both an individual injury as well as multiple injuries to a single person.

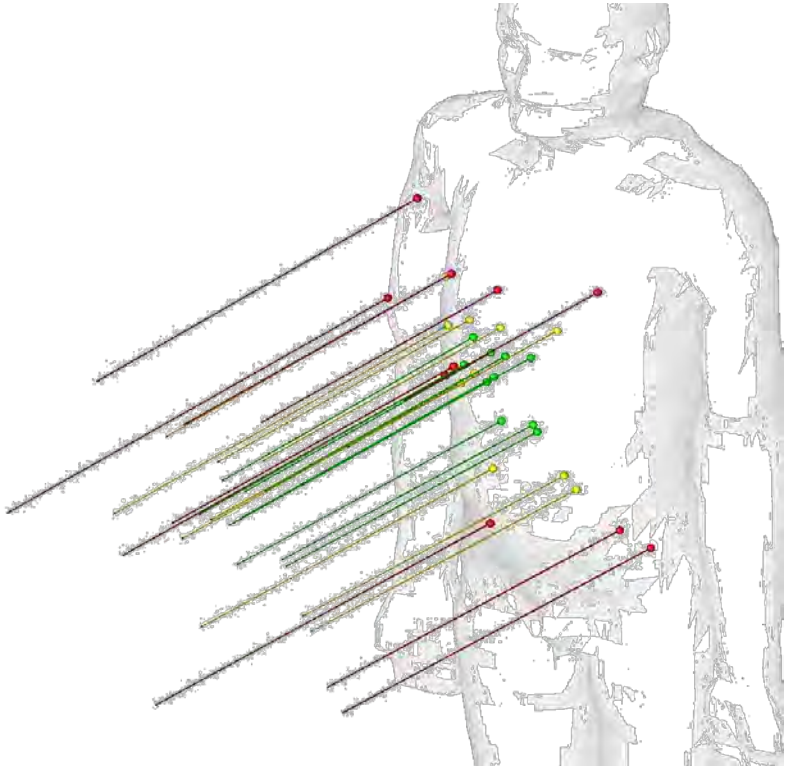
- Incapacitation:
  - The inability to perform, at a level required for combat effectiveness, a predefined combat role at a specific time after wounding:
    - Physical capabilities
    - Mental capabilities

  - A combat role is a specific list of individual tasks that personnel must be able to perform at a pre-designated level.

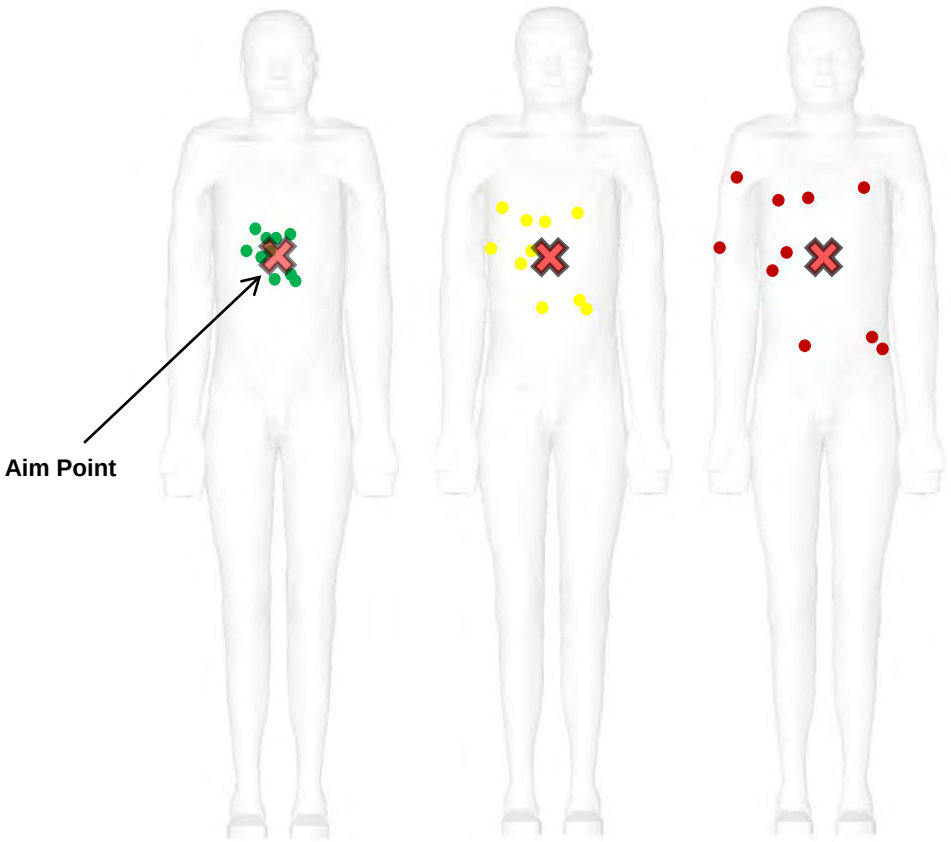
  - Personnel are considered incapacitated if they cannot perform their given combat role at the minimum capability level, and are considered an **Operational Casualty.**



Sample Dispersion Patterns



Dispersion provides the means for MPCs to affect damage to multiple critical tissues at once but diminishes the incapacitation potential of a cartridge when it causes an insufficient number of projectiles to impact the target.



Potential dispersion patterns at given ranges

Example of a Target Profile

Target Profile: Insurgent
Armor: Light to none
Environment: Close quarters
Capabilities:

- Stand
- Aim
- Shoot

Time Period of Interest: ≤1 second

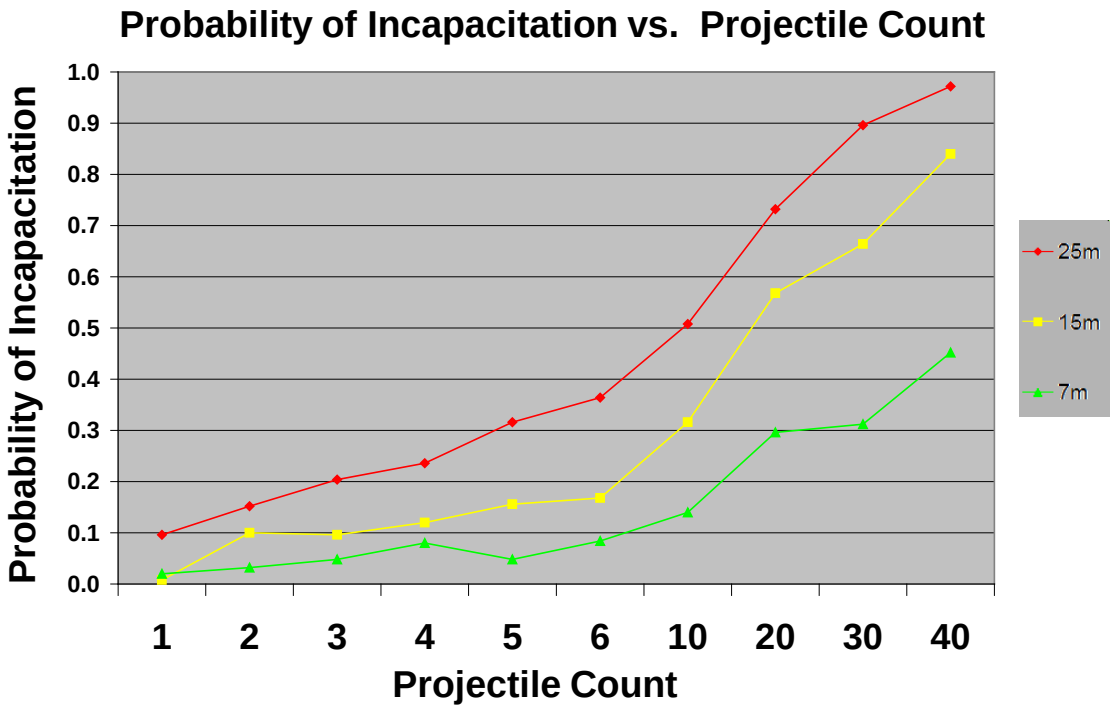
Job Description Chosen: Armed Adversary

- Most difficult job to incapacitate
  - Pro: Provides worst case scenario
  - Con: May underestimate incapacitation potential of a given round



– Incapacitation is achieved by damaging the central nervous system, cardiovascular system, and the skeletomuscular system
– This job description was approved by Director of Combat Development, Infantry Center
– It was used by ARL in lethality and small arm characterization studies (FY09-Present)

Characterizing a Sample Shot Configuration



Projectiles	1	2	3	4	5	6	10	20	30	40
25 m	.10	.15	.20	.24	.32	.36	.51	.73	.90	.97
15 m	.01	.10	.10	.12	.16	.16	.32	.57	.67	.84
7 m	.02	.03	.05	.08	.05	.08	.14	.30	.31	.45

Probability of P(I) = 1 for given projectile count @ given ranges

Shot Configuration Variables

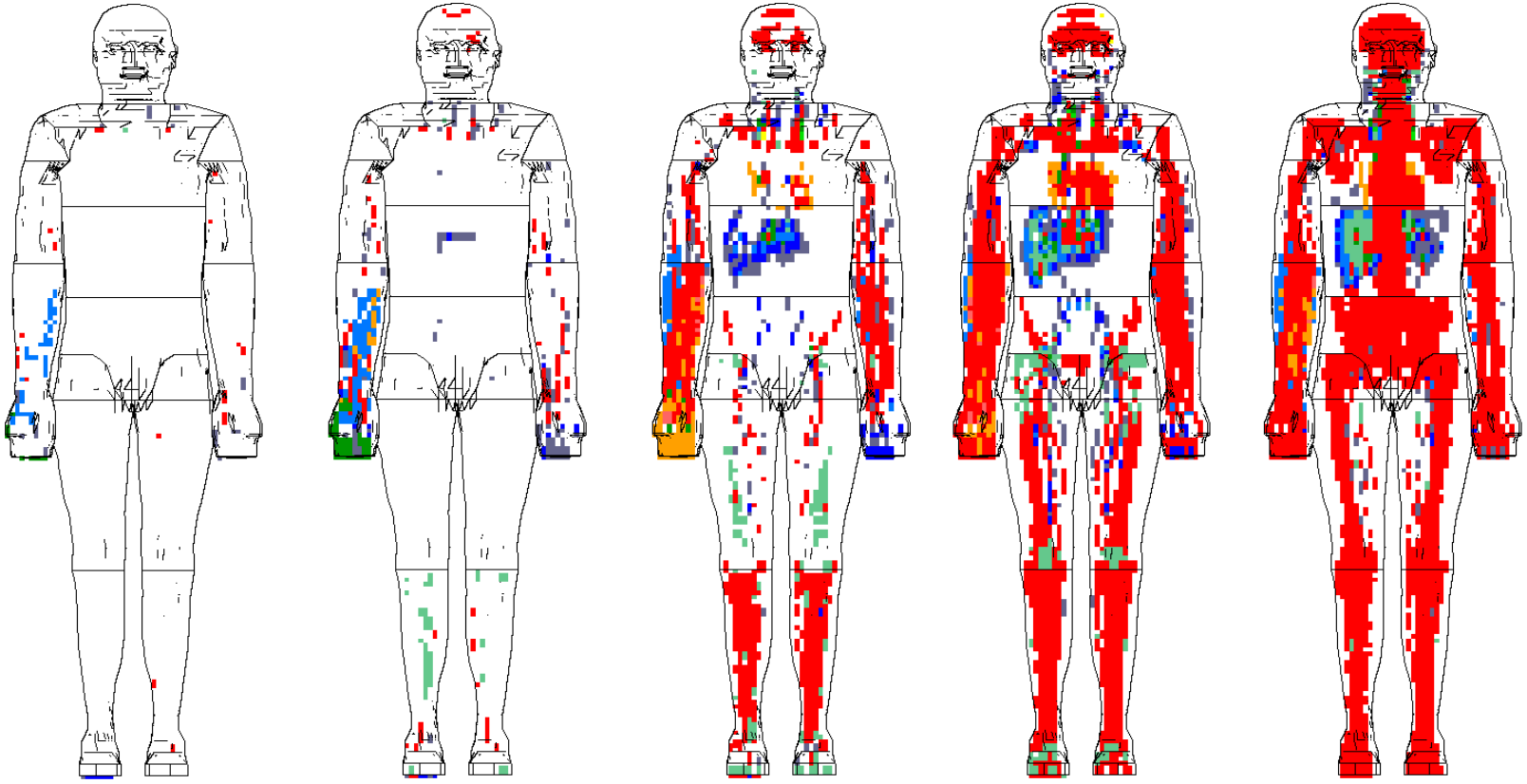
- Mass
- Shape
  - Sphere
  - Cube
  - Cylinder
- Velocity
- Count
- Dispersion Angle
- Material
  - Steel
  - Lead
  - Tungsten

Target Configuration Variables

- Range
- Posture
- Armored vs. Armored
- Job Description

Characterizing a Single Pellet

- These incapacitation plots were modeled using a single projectile from a given shot configuration.
- Uniform grid of shot lines in a front-only view with zero degrees azimuth and elevation.



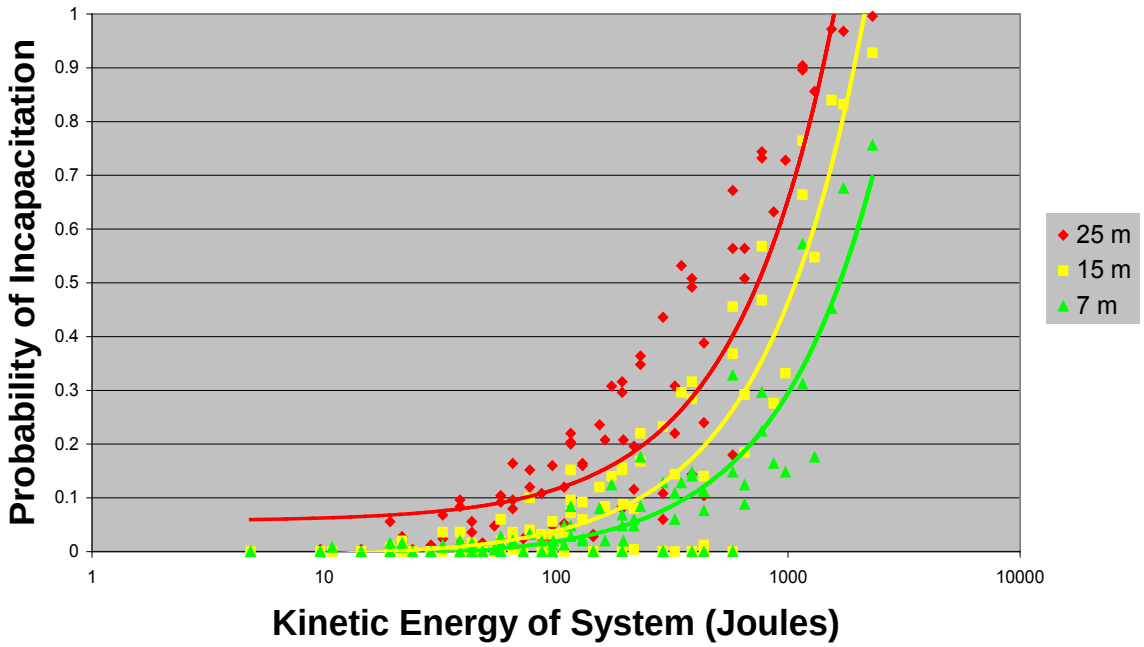
Velocity A | Velocity B | Velocity C | Velocity D | Velocity E

0.0 **1.0**

Probability of Incapacitation

Optimization Observations

Probability of Incapacitation vs. Kinetic Energy of System



Summary

Without sufficient penetration, an increase in dispersion/pellet count will result in a minimal increase in incapacitation. However, as range increases, dispersion and pellet count amplify a MPC's ability to incapacitate by damaging more than one physiological region at once.

Observations

- Driving factors of incapacitation:
  - Penetration/tissue damage (KE of the system)
  - Hit location (dispersion)
  - Quantity of tissues damaged (pellet count)
- Without sufficient penetration, incapacitation is unlikely regardless of hit location
- With an increase in dispersion, pellet count is a greater factor
- A high energy, optimally dispersed system with the maximum number of projectiles provides the greatest potential for complete incapacitation

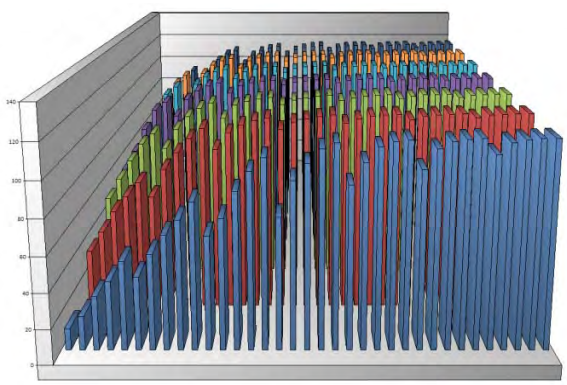
Optimization Analysis

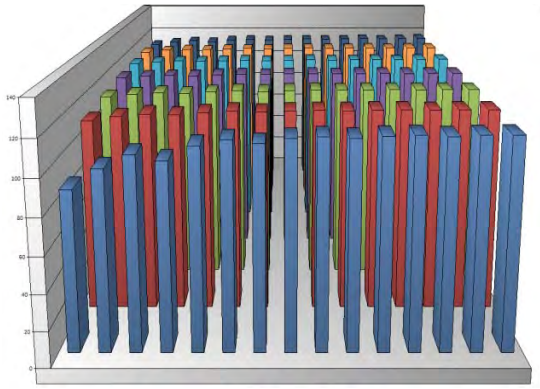
245 Mass/Velocity/Dispersion Configurations

Optimization Methodologies:

- **Trend analysis via frequency histograms**
- **Legacy constraints:**
  - **Velocity**
  - **Mass**
  - **Dispersion**
- **Geometric optimization**

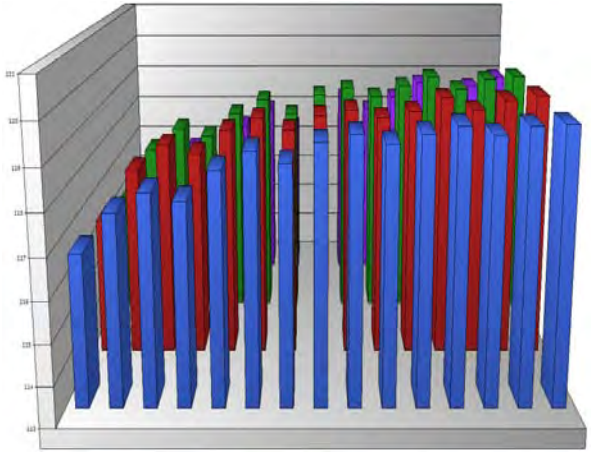
Results: 8 final configurations

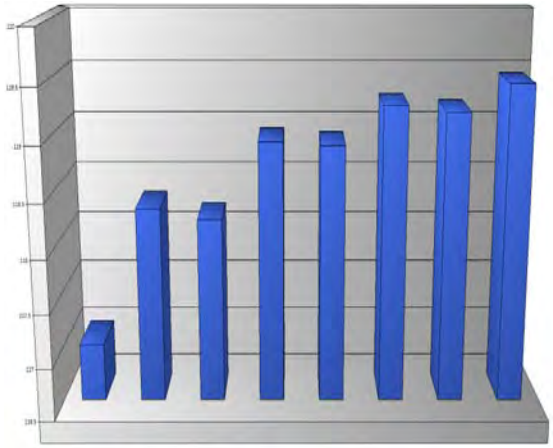




Configurations: 245 → 105

Constraint: Projectile Velocity/Mass





→ 45 → 8

Dispersion

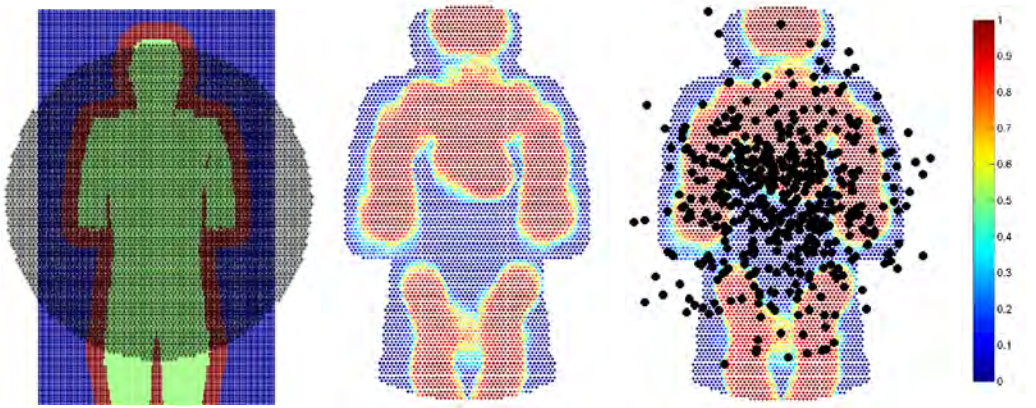
Geometric Optimization

Operational Modeling

MUVES-S2/ORCA provides inputs for dynamic modeling software such as The Infantry Warrior Simulation (IWARS)

Tailored to the specific analysis:

- Scope
  - System based
  - Single projectile based
- Casualty based P(I) values
  - Entire body
  - Per body region
  - With or without aim error



Images provided by ARL/WMRD

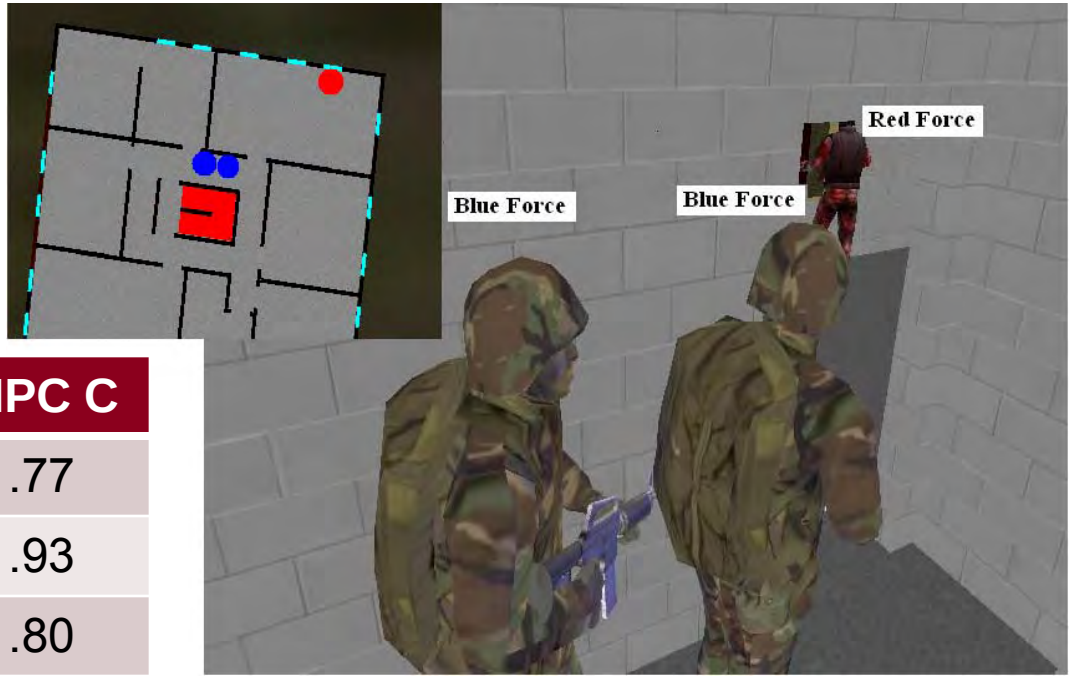


Image provided by ARL/WMRD

Range	MPC A	MPC B	MPC C
7 meters	.57	.99	.77
15 meters	.69	1	.93
25 meters	.86	1	.80

Questions

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KONGSBERG

CROWS

Stabilization and Accuracy for today's Warfighter

Bo Barbour

Kongsberg Protech Systems

WORLD CLASS – through people, technology and dedication









KONGSBERG

-The history of KONGSBERG
-Background of the RWS
-Stabilization and Accuracy
-Key Performance Parameters
-The Future of RWS

WORLD CLASS – through people, technology and dedication

The History of Kongsberg

KONGSBERG

- The city of Kongsberg founded in 1624 by King Christian IV based on the discovery of silver in the area.
- The silver mine was the biggest industry in Norway and i constituted about 20 % of the income. In 1814 the Kongsberg weapons factory was founded.
- The Krag Jørgensen rifle was introduced in 1892, and became soon a big hit for the weapon factory. The US Army bought about 500 000 rifles, and it soon became one of the biggest export products for Norway.
- Kongsberg Weapons factory played a major role in post war recovery in Norway, after World War-2 renamed the Norwegian Defence Industry, and as we know it today, KONGSBERG.
- US manufacturing facility for CROWS II opened in 2008 in Johnstown PA, 90 % US parts.

First International Success

KONGSBERG

Krag-Jørgensen

The **Krag-Jørgensen** is a repeating bolt action rifle designed by the Norwegians Ole Herman Johannes Krag and Erik Jørgensen in the late 19th century. It was adopted as a standard arm by Denmark, the United States and Norway.

The Krag-Jorgensen Rifle in Rimmed .30 Army round found use in the Boxer Rebellion, the Spanish-American War and the Philippine-American War. In this later war the rifle was referred to in a song popular with U.S. troops with a verse running:

Damn, damn, damn the Filipinos!
Cut throat murdering ladrones!
Underneath the starry flag,
Civilize them with a Krag,
And return us to our beloved home.



Why a Remote Weapon Station

KONGSBERG











KPS- Kongsberg Protech Systems

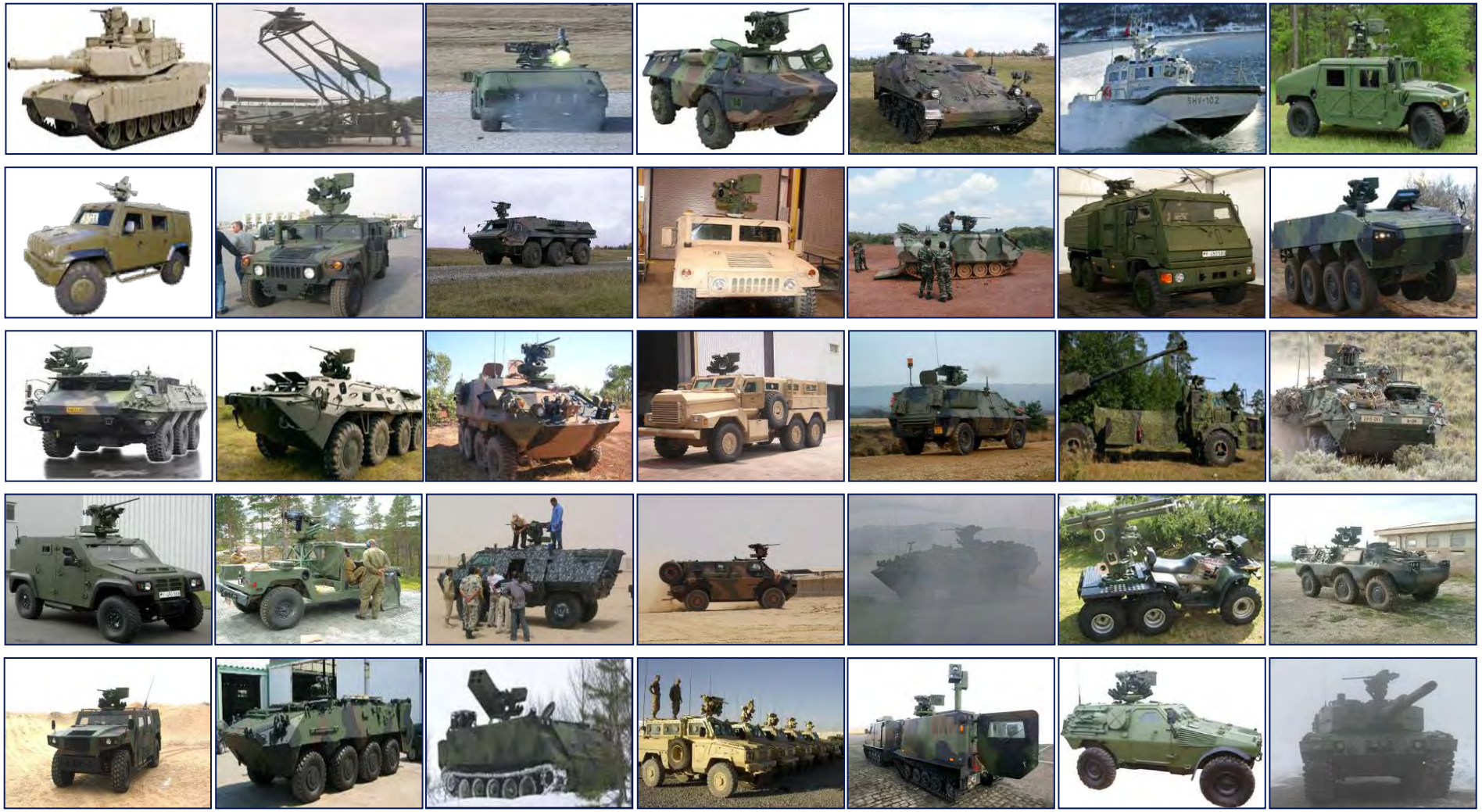
KONGSBERG

- **The Main Focus of Protech Systems:**
  - PROTECTOR Family of Remote Weapon Station (RWS)
  - Common Remotely Operated Weapons System (CROWS)
  - PROTECTOR Medium Caliber Remote Weapon Station (MC RWS)
  - M151 PROTECTOR
  - XM153 PROTECTOR CROWS
  - PROTECTOR Lite
  - PROTECTOR Super Lite



Vehicle Integrations

KONGSBERG



RWS Family

KONGSBERG



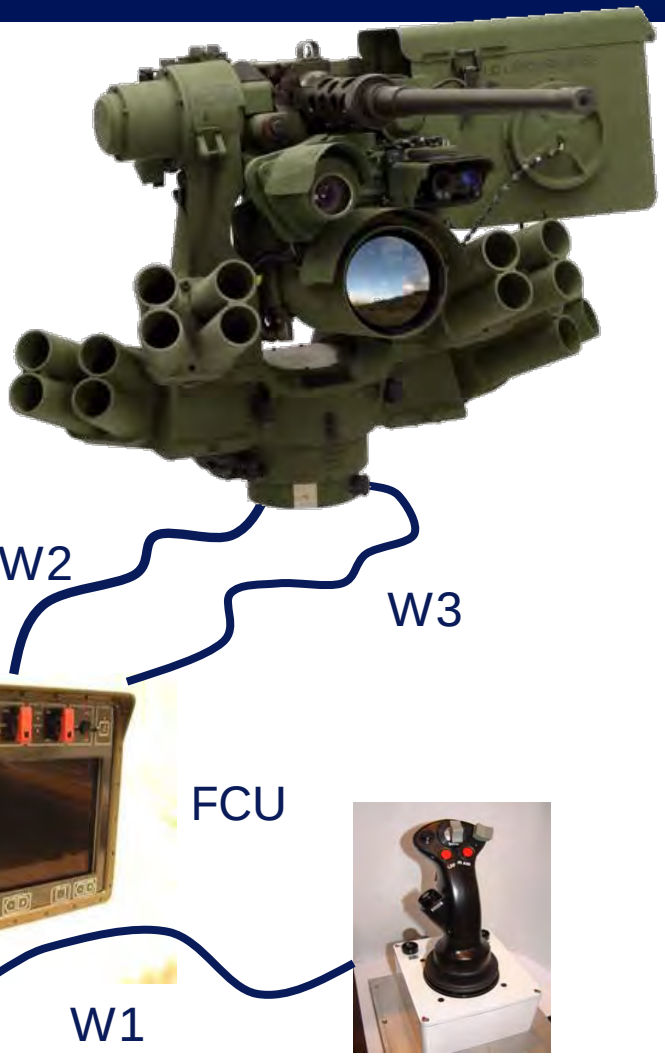
What is the Remote Weapon System (RWS)?

KONGSBERG

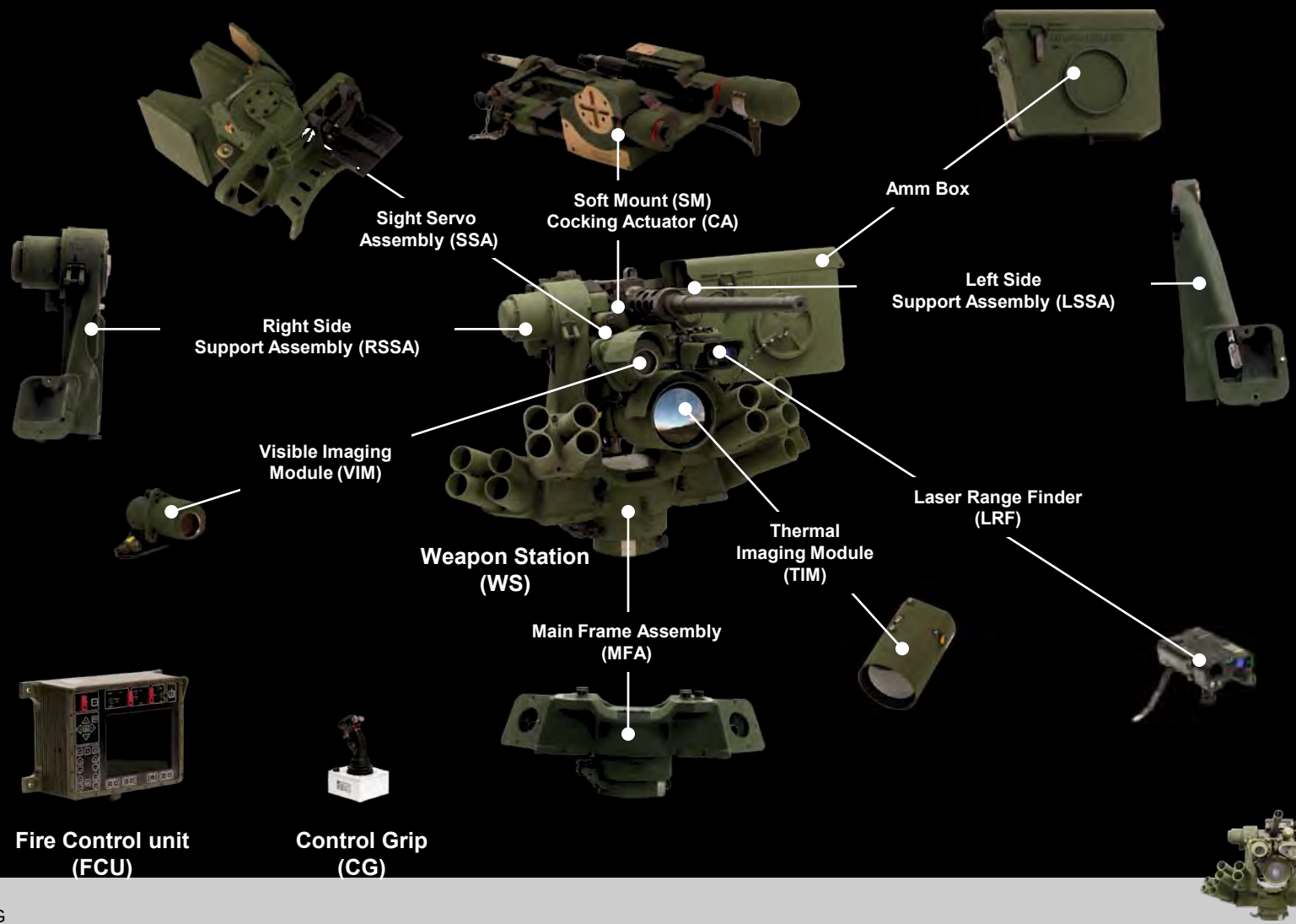
- The RWS is designed to be mounted on top on a variety of combat vehicles and is remotely operated by an operator located inside the vehicle compartment, giving complete armored protection from direct enemy fire.
- The remote operation of the RWS is carried out by two operating components,
  - **Fire Control Unit (FCU)**
  - **Control Grip (CG).**
- The system also has remote weapon charging capability for cocking of the weapon as well as firing.
- The tracking and control capabilities of the RWS provide a high first-round hit probability against stationary and moving targets.
- The RWS can also be operated manually if required.
- Integrated Machine Guns:
  - **MK-19 40mm**
  - **M-2 .50 Cal**
  - **M-240 7.62mm**
  - **M-249 5.56mm**

Main Parts

- RWS consists of following main parts:
- Weapon Station (WS)
- Fire Control Unit (FCU)
- Control Grip (CG)
- Connection Cables
- (**W1**) Power and signal cabel from FCU to CG
- (**W2**) Data signal cabel from FCU to WS
- (**W3**) Power and video cabel from FCU to WS



Line Replacement Units (LRU)



Principal Factors in Stabilization and Accuracy

KONGSBERG

- Machine gun barrel condition – temperature and wear
- Soft recoil mount – attenuates recoil
- 4 axis servo system
- Stabilization on the move
- Lead angle compensation– determines lead on the move
- Fire Control unit – ballistic solution software
- Hand Control – man machine interface

Bore Sighting

- Bore sighting is the procedure of defining the position of the sight where the axis of bore and the line of sight are perfectly aligned.
- This position is stored by the system in the non-volatile memory of the FCU. At later start-ups, the system reads this position from that memory.
- Default values are used at power-up when no position is stored in the memory.
- This position is used as the basis for positioning the weapon according to the calculated ballistics for the defined target range and current ammunition.
- **NOTE!**
  Whenever a new weapon is mounted or a new FCU is connected, the bore and the line of sight must be aligned by performing the bore sighting procedure.
- **NOTE!**
  If one of the sensors is bore sighted, it is not necessary to do the same with the other sensors.



XM153 CROWS II – The Next Evolution

KONGSBERG





KONGSBERG

QUESTIONS ?

WORLD CLASS – through people, technology and dedication

Joint Armaments Conference

Dallas, Texas

May 17-20 2010

JOINT FAMILY OF WEAPONS

- **35MM Revolver Cannon**
  &
  AHEAD Air Bursting Ammo

- **Mission Area:**
  SUW/SHORAD/MOUTS/Force Protection

•Fully developed NDI end items.
•NATO qualified.

The Millennium GDM-008 Naval Gun System



Operational Capability:

- Scalable Lethality capability in one weapon
- Operational range 300M to 5 KM
- Unmanned/Modular/No thru deck penetration
- Rapid Reload 252 Ready Service Rounds on Mount

Skyshield 35 Short Range Air Defence Weapon System



Operational Capability:

- Area- and point-defence against air threats,including low RCS & C-RAM
- Continuous full hemisphere surveillance >20 km
- Short reaction time Automatic (TEWA),

SkyRanger



Operational Capability: Defeat Ground Targets - Air Defence Counter Mortar (RAM) - Infantry Flank Protection - Urban Warfare - Scalable Lethality

Ahead Air Burst Munition - One Round for all Missions



Summary of Advantages - Part 1

- Multi mission = C-RAM/ SHORAD/ Camp protection/Force Protection/Counter Swarm/
- Light weight + Modular design = Air Transportable
- Mature technology - NDI
- Open Architecture
- No auxiliary systems = lower maintenance
- Linkless feed system = Reload 250 rds ~ 9 min
- Optimized health monitoring = <MTBR
- Off-board diagnostics = reduced manning
- On-mount local reference system
- Low power requirement < 2KVa
- Network Enabled

Summary of Advantages Part 2

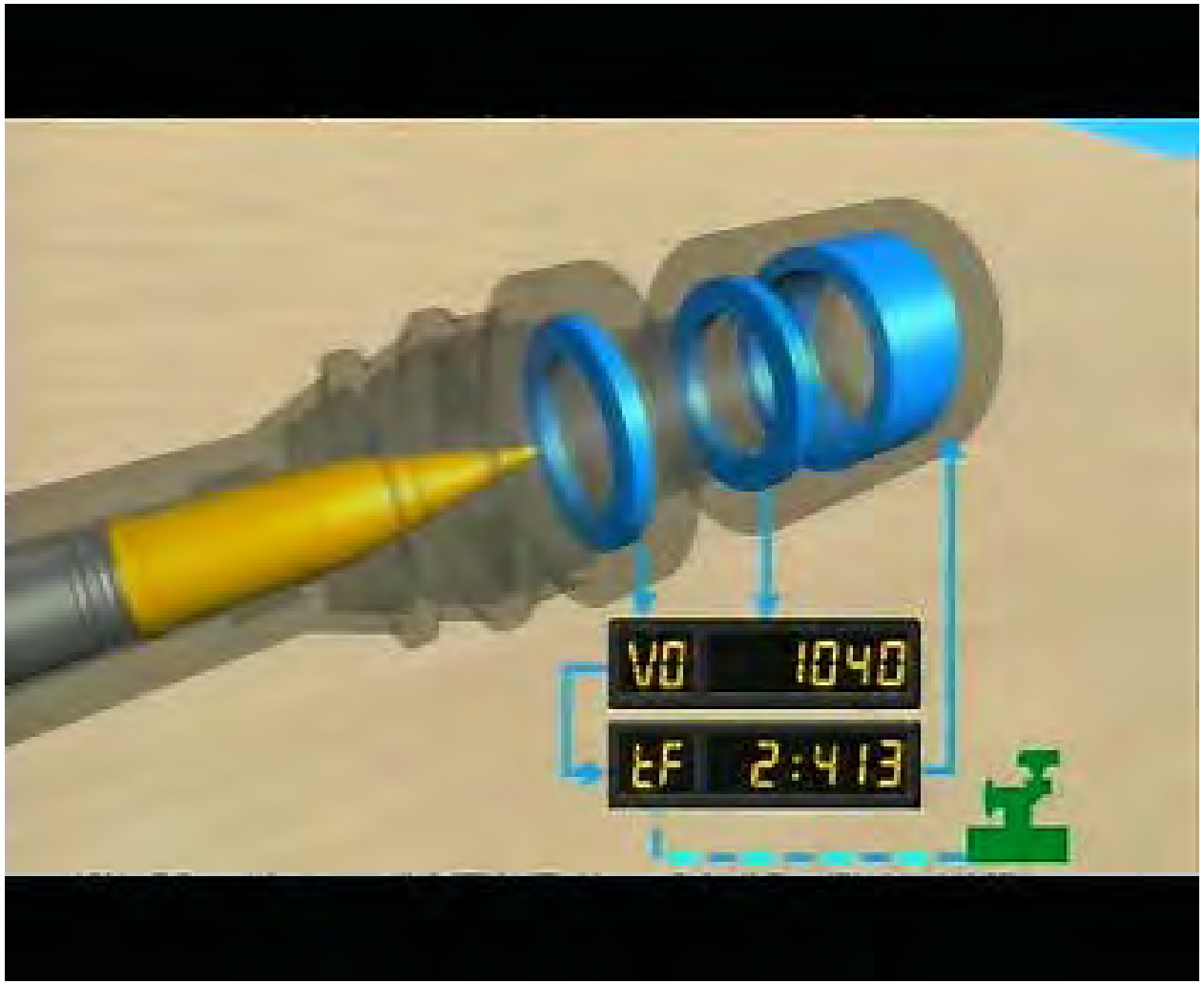
- Engage all air & ground targets +85 to -15
- Self contained casualty power
- 250 rounds on mount = 10 - 20 engagements
- Selectable Rate of Fire 1000 RPM/200 RPM/single shot
- Fully stabilized
- Unmanned Gun System
- No hot gun issues
- Common parts & fasteners = less spares
- Minimum tool set - one 5mm & one 8mm wrench
- One round for all missions
- Safe ammo - no H.E.
- Lowest TOC

Summary of Advantages Part 3 Naval version specific

- Light weight 3.6t to 5.2t depending on configuration
- Minimum Structure to install
- No auxiliary systems = lower maintenance
- Modular design = 30 min swap out
- On-mount local reference system = easy cross decking

"Personality" card in the on-mount GCM = easy cross decking

AHEAD Lethality Mechanism



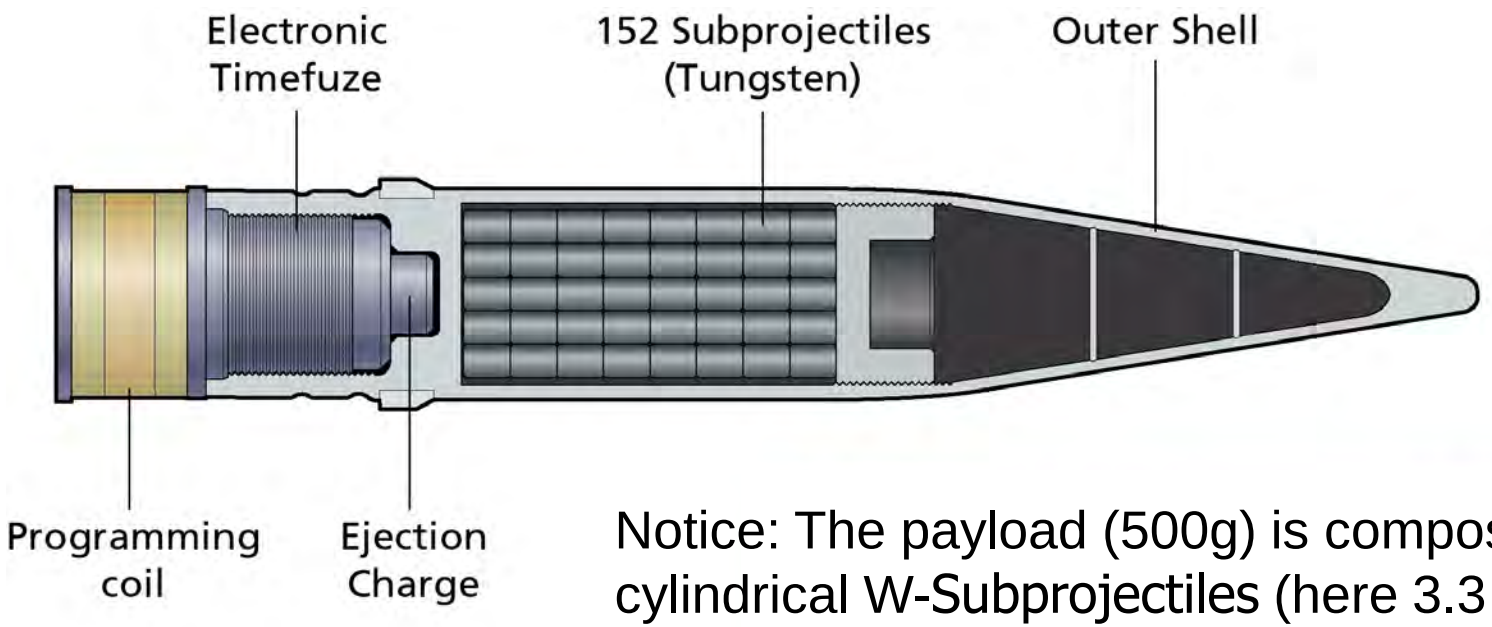
Selectable Firing Rates

Single Shot - 200spm - 1000spm



35mm Air Burst Munition

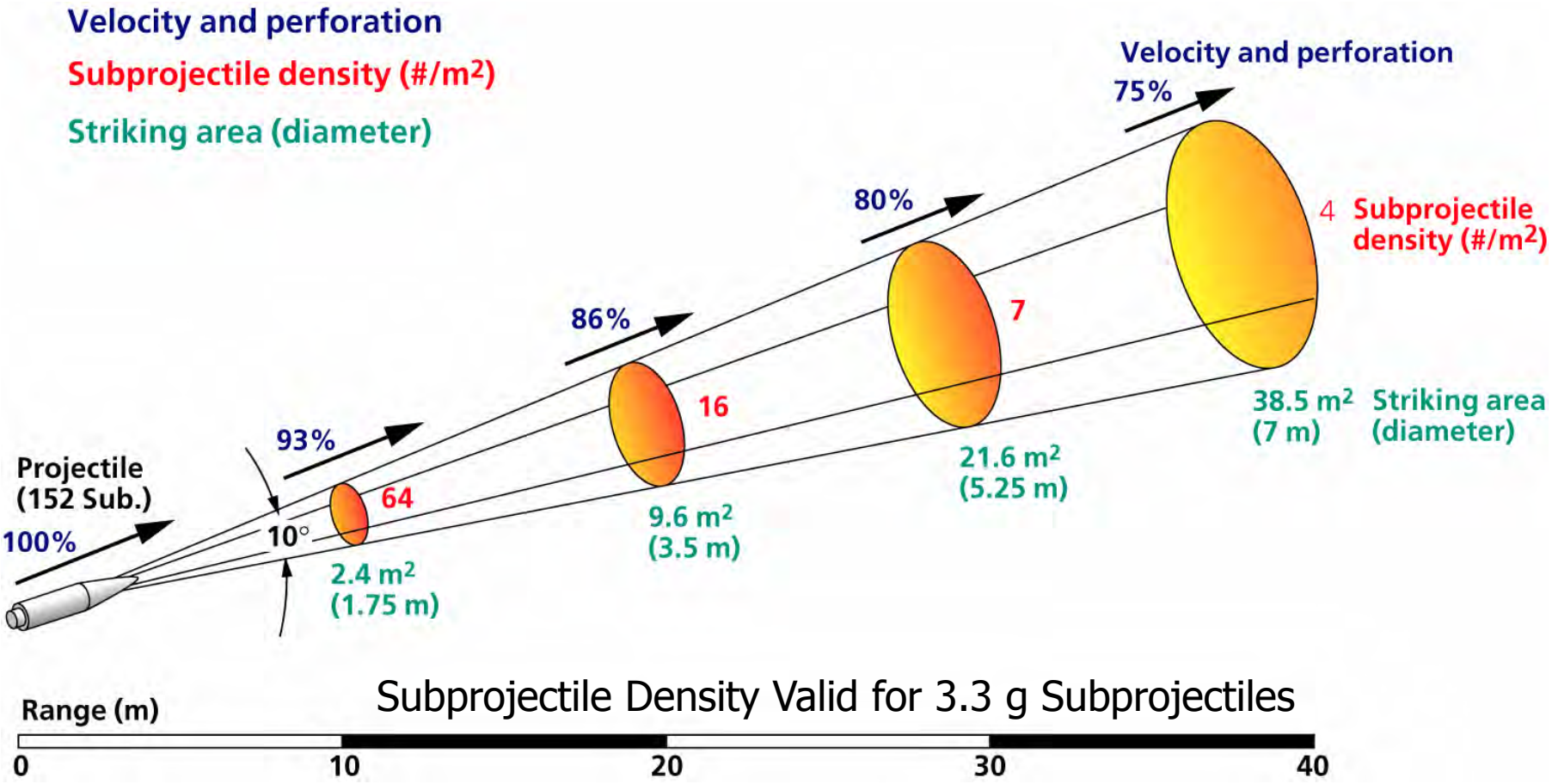
Kinetic Energy Time Fuze (ABM-KETF)



Notice: The payload (500g) is composed of cylindrical W-Subprojectiles (here 3.3 g each). For engagements other than AA (e.g. G-to-G) the mass of the subprojectiles can be reduced accordingly (e.g. 1 to 1.5 g)

AHEAD 35 mm ABM

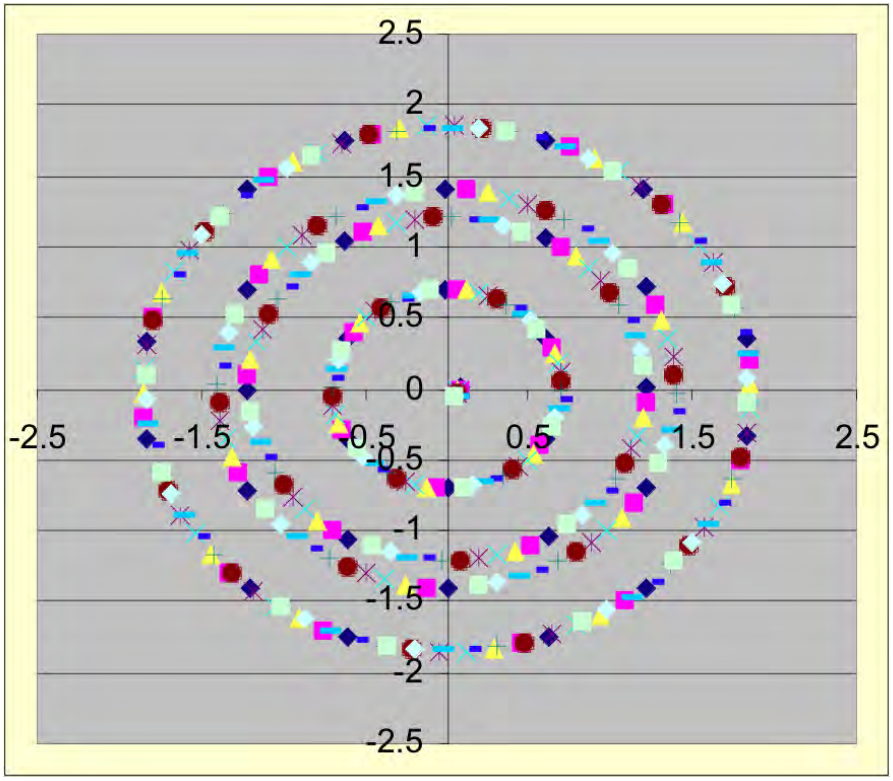
Subprojectile Dynamic Parameters



Payload Foot-Print



35 mm ABM (Ahead):
152 subprojectiles of 3.3 g



35 mm ABM:
341 subprojectiles of 1.5 g

On-line Compensation of Muzzle Velocity Variation

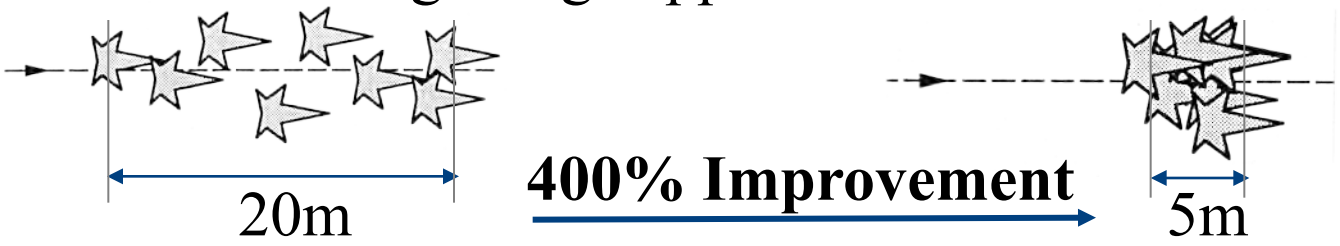
Fixed Time Programming



On-LineΔVo - Compensation



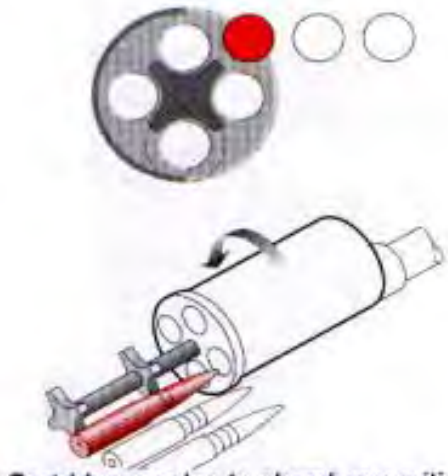
Firing Range approx. 1600m



Muzzle Velocity Correction



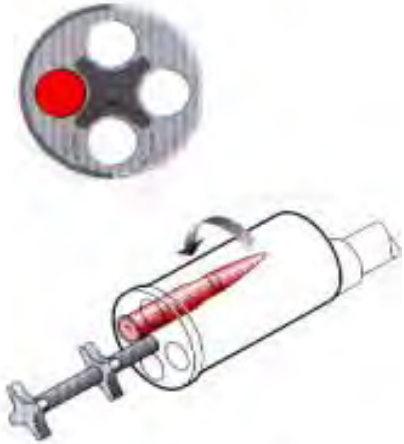
Four Chamber Revolver Cannon



Cartridge moving to chamber position



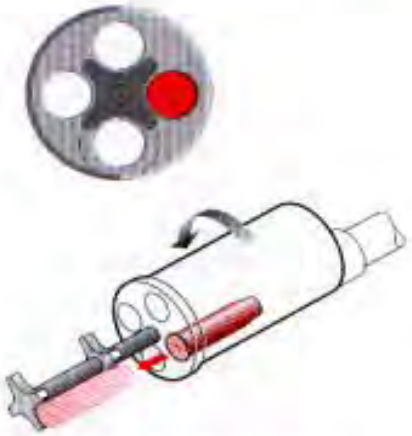
Cartridge half in chamber



Cartridge fully in chamber



Chamber and cartridge in line with barrel – firing position



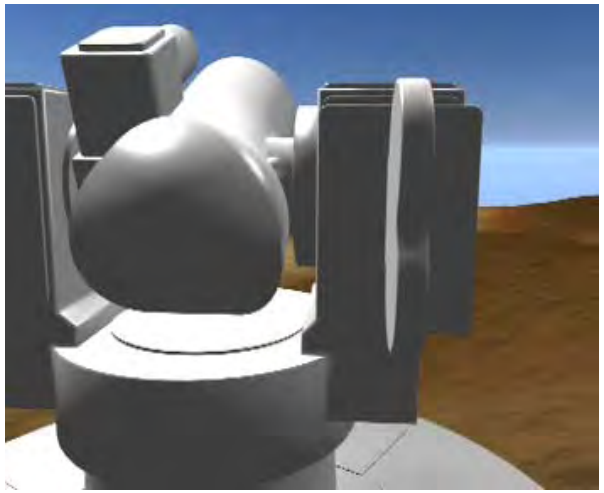
Ejection of cartridge case

Sample Target Sets

1. Boghammer



2. UAV 12' wingspan



3. Periscope



4. 2" Armor Plate



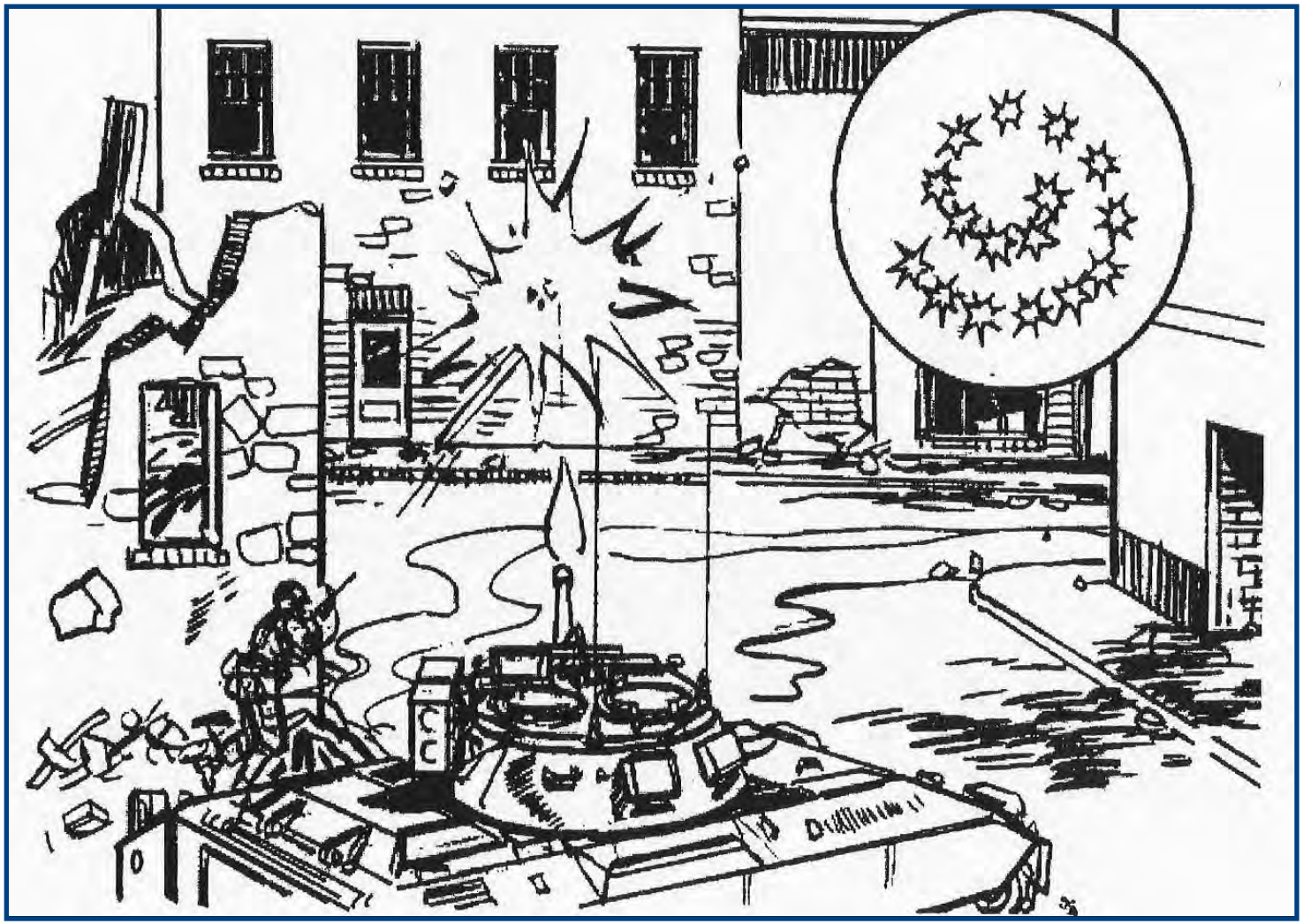
Helicopter Target (UH-1, Static)

- 2 Shots
- Range:1500 m
- Entry Side
- Ref.: APG/Oct. 98



F2 15225 BB

U.S. Army Breeching Technique



Breeching Fire

8” Concrete Wall

Double Steel-Structure Reinforced





Video: M1 15962BA

F2 15562 BA

Neutralizes Heavy Armor



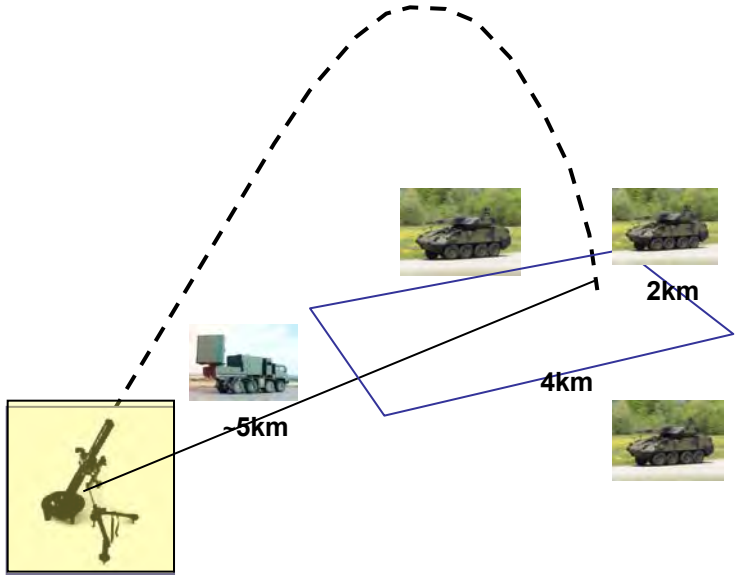




F2 16494 A3

Base Defence – Counter Mortar

Demonstrated 12.2004





Effective Against ATW Positions







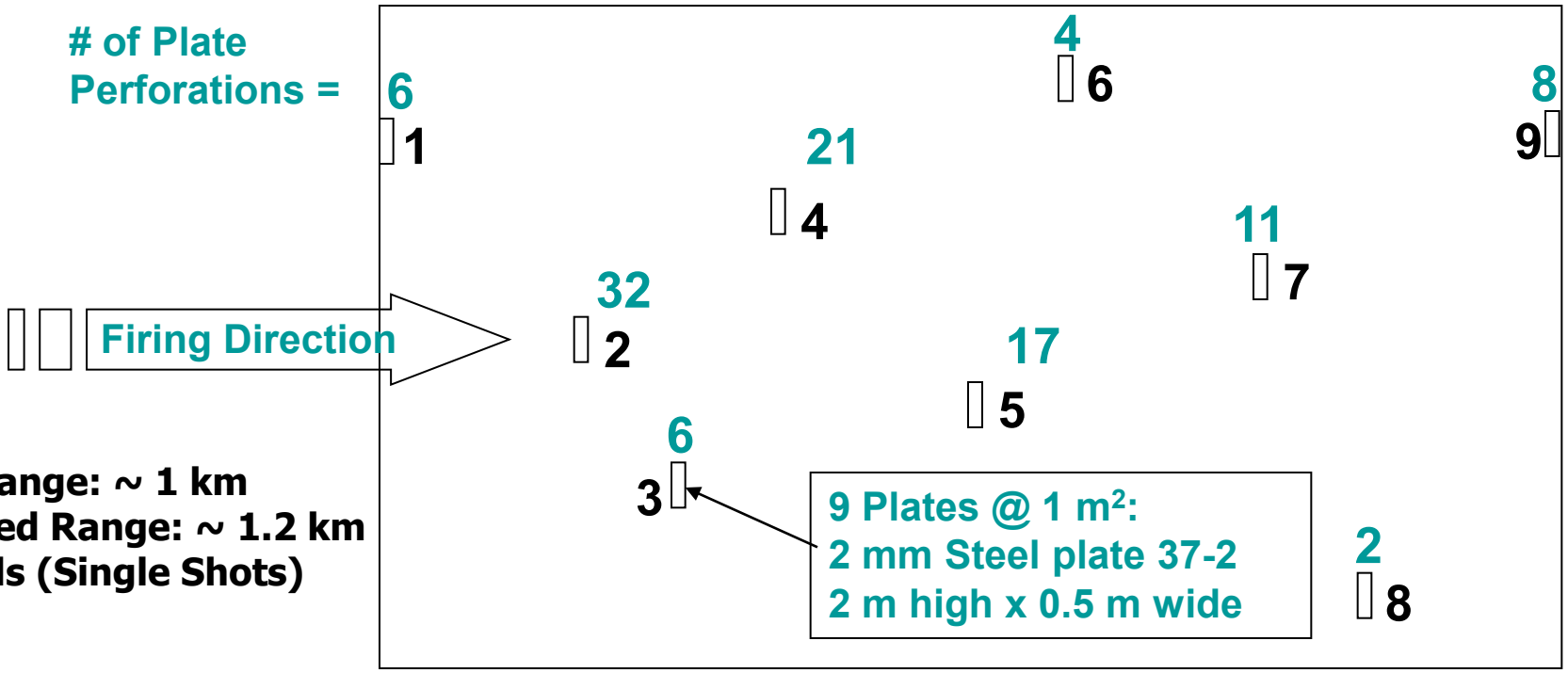




Dismounted Troops

4 Rds @ 135 Subprojectiles = 540 SP

Total: 107 Plate Perforations (~ 20%)

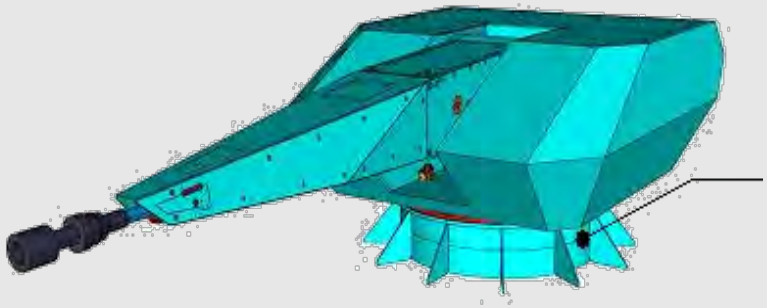


Firing Range: ~ 1 km
Simulated Range: ~ 1.2 km
4 Rounds (Single Shots)

Target Area: 10 (width) x 30 (depth) m

The target area is 27 m higher than the gun muzzle

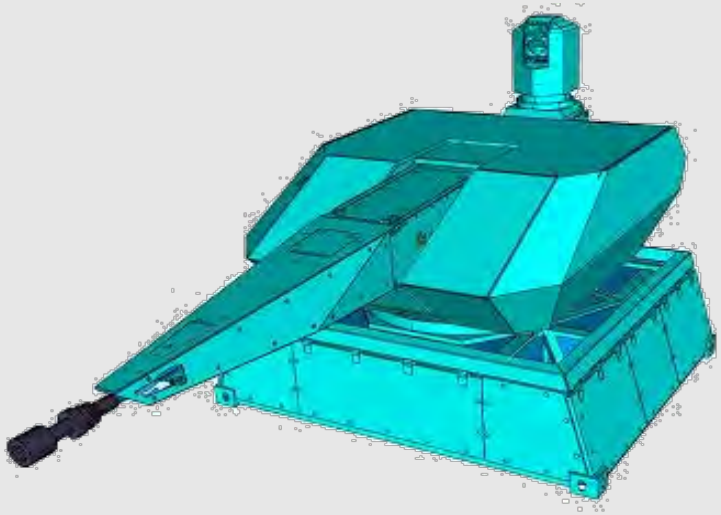
Naval Version Modular Options



Fixed installation 4.2 tons



Modular (ISO) Installation 5.3 tons



Modular Install w/ Optional EO/IR FCS



Skyranger – Turret Version

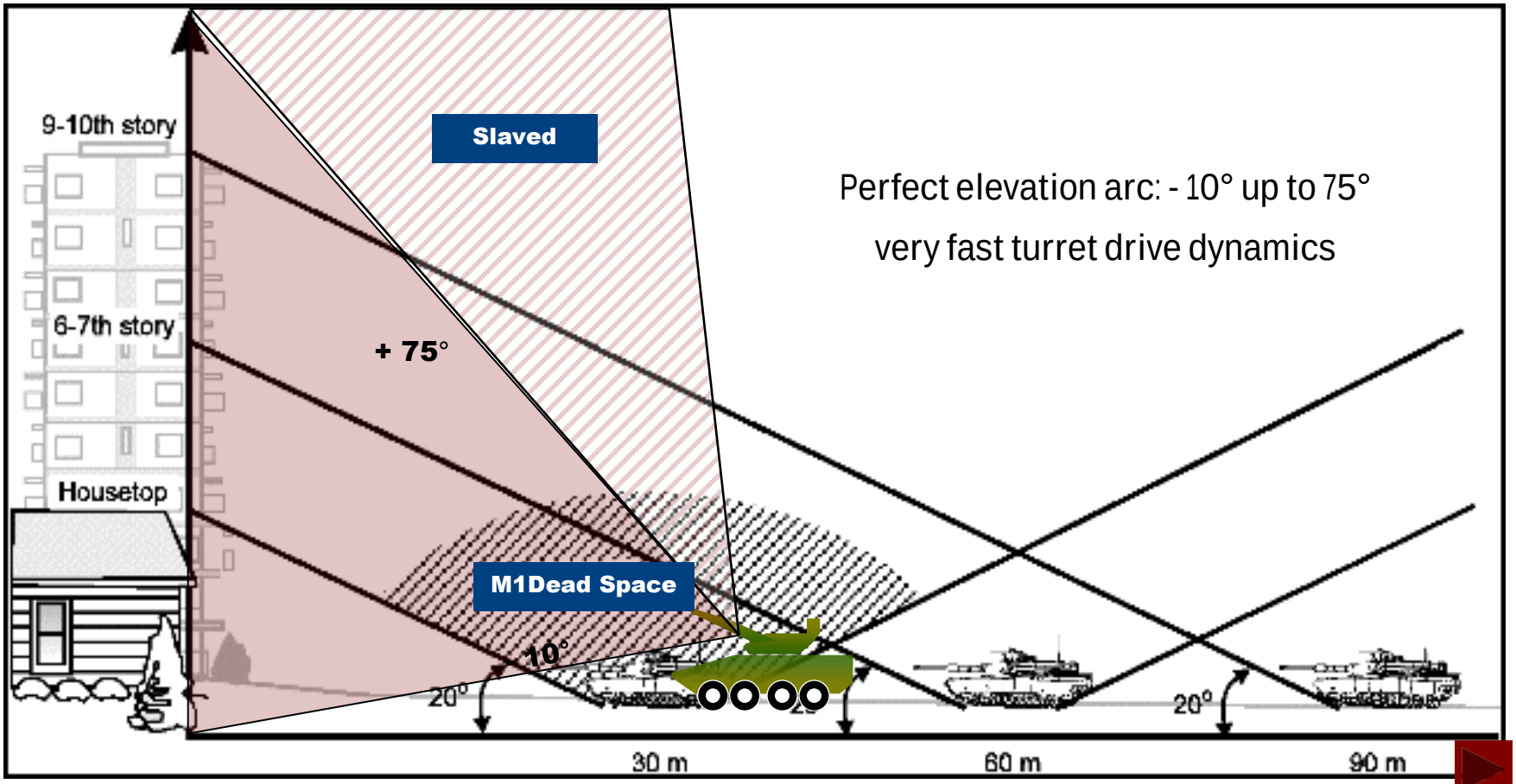


- Compatible with: Pirahna III/IV, Stryker,etc
- Design Basis for Millennium Gun
- On Mount EOD
- Capable of Netcentric Operation
- Capable of Independent Operation

Turreted Gun Version

Advantages

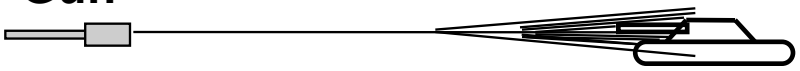
STRYKER elevation +15, Depression -5
M1/M1 A2 elevation +20, Depression -10
BFV elevation +60, Depression -10



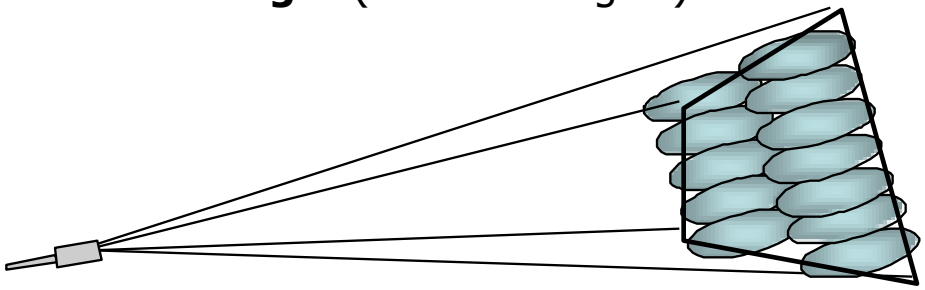
Ground Operation Modes

Point Target (incl. ATGW-Bunker, Prone & Covered Troops, MBT, Helicopter):

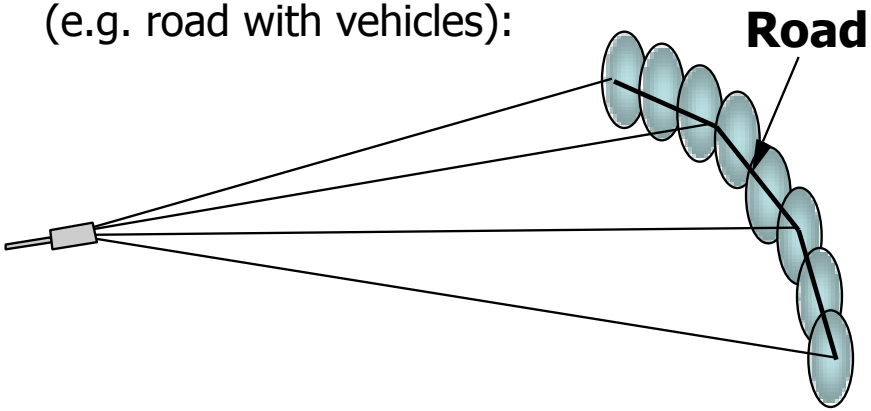
Gun



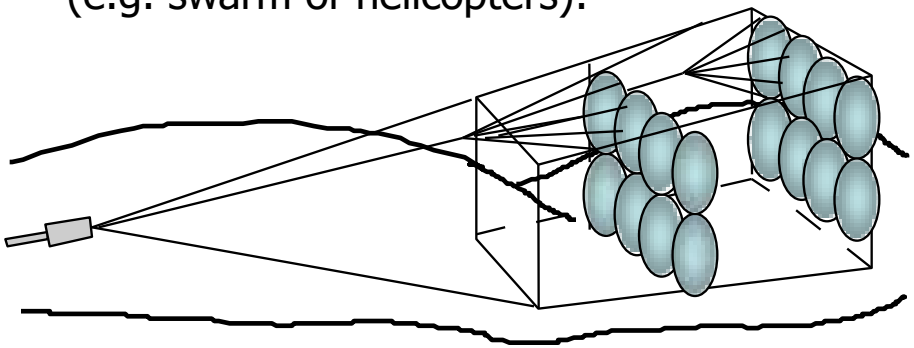
Area Target (Diffused Targets):



Linear Target
(e.g. road with vehicles):



Pre-Determined Air Space
(e.g. swarm of helicopters):



Summary of Advantages - Part 1

- Multi mission = C-RAM/ SHORAD/ Camp protection/Force Protection/Counter Swarm/
- Light weight + Modular design = Air Transportable
- Mature technology - NDI
- Open Architecture
- No auxiliary systems = lower maintenance
- Linkless feed system = Reload 250 rds ~ 9 min
- Optimized health monitoring = <MTBR
- Off-board diagnostics = reduced manning
- On-mount local reference system
- Low power requirement < 2KVa
- Network Enabled

Summary of Advantages Part 2

- Engage all air & ground targets +85 to -15
- Self contained casualty power
- 250 rounds on mount = 10 - 20 engagements
- Selectable Rate of Fire 1000 RPM/200 RPM/single shot
- Fully stabilized
- Unmanned Gun System
- No hot gun issues
- Common parts & fasteners = less spares
- Minimum tool set - one 5mm & one 8mm wrench
- One round for all missions
- Safe ammo - no H.E.
- Lowest TOC

Summary of Advantages Part 3 Naval version specific

- Light weight 3.6t to 5.2t depending on configuration
- Minimum Structure to install
- No auxiliary systems = lower maintenance
- Modular design = 30 min swap out
- On-mount local reference system = easy cross decking

"Personality" card in the on-mount GCM = easy cross decking

Questions?

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DISTRIBUTION STATEMENT A: Unlimited Distribution



U.S. Army Research, Development and Engineering Command
Benét Laboratories



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

120mm XM360 Primary Weapon Assembly
XM1202 Mounted Combat System (MCS) of Future Combat System (FCS)
Briefing to NDIA Joint Armaments Symposium
18 May 2010

ARDEC Program Officer (APO): David Smith
Chief Engineer: Edward Hyland

Manned Ground Vehicle (MGV) Fleet

Three (3) of the systems have large caliber main guns:

NLOS - M – Non Line Of Sight Mortar Carrier

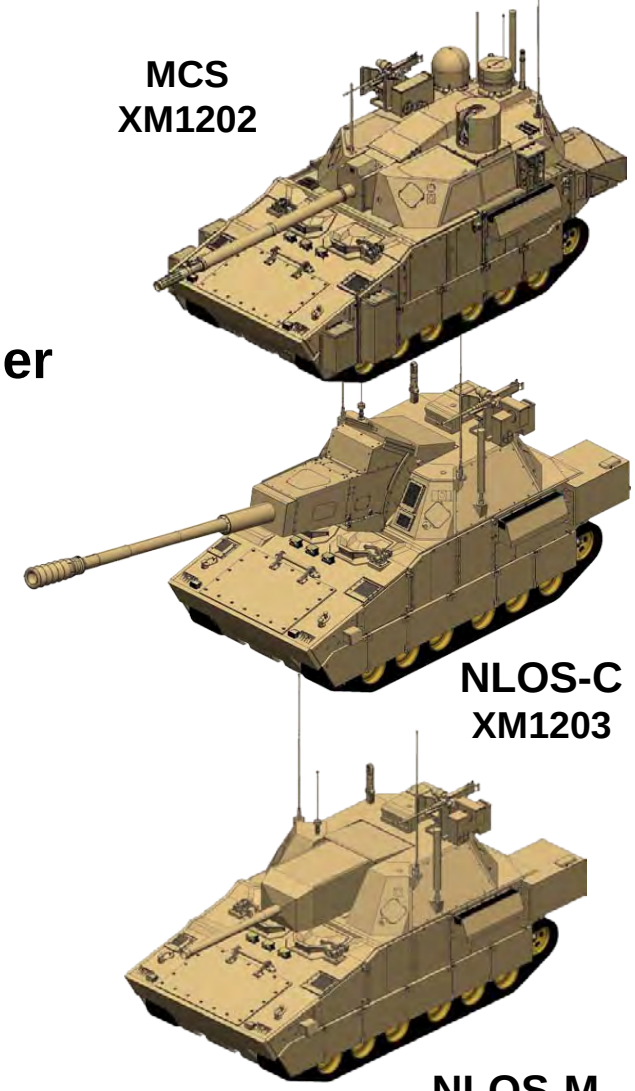
- 120 MM Mortar

NLOS – C – Non line of sight cannon

- 155 MM Gun

MCS - Mounted Combat System

– 120 MM Gun

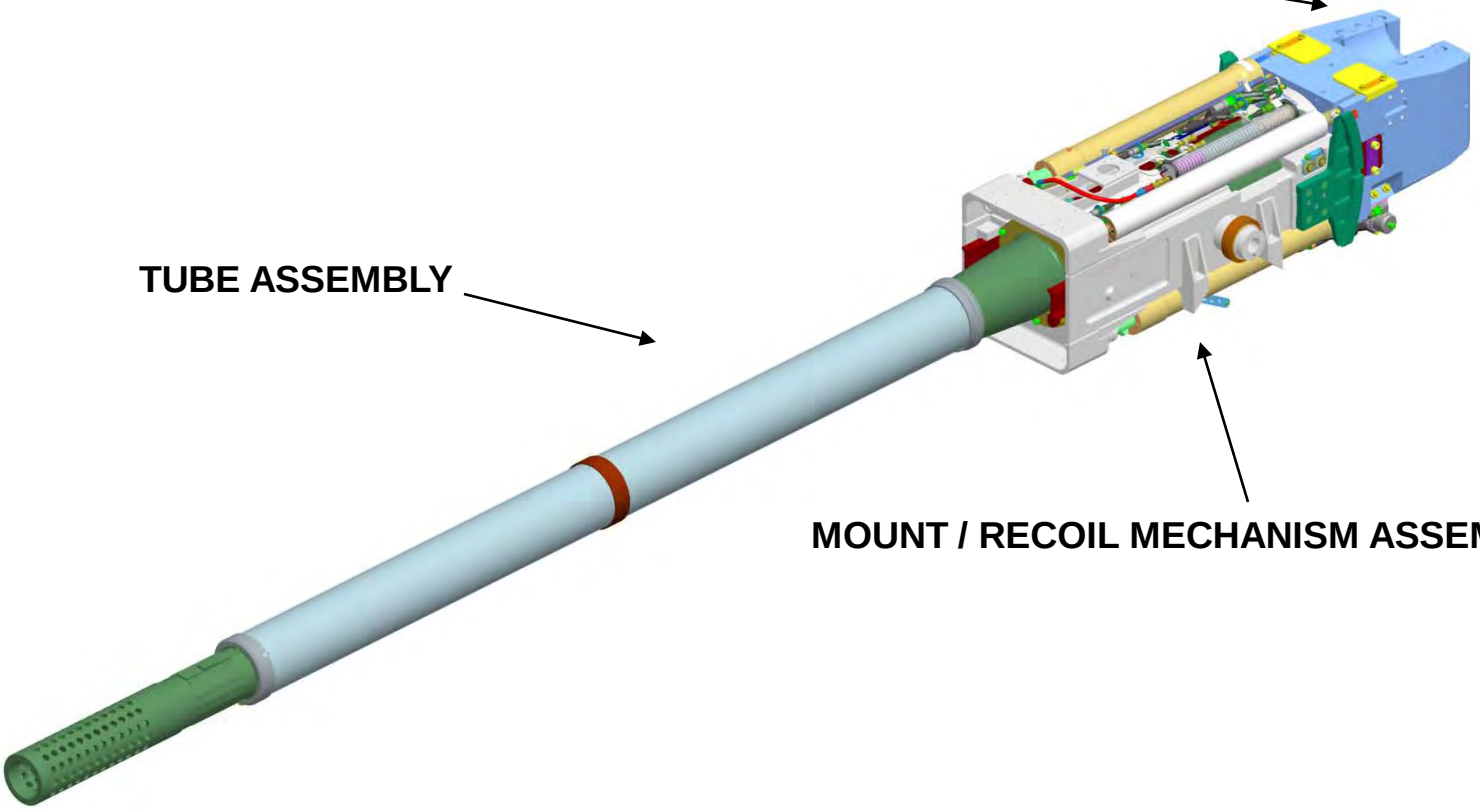


MCS
XM1202

NLOS-C
XM1203

NLOS-M
XM1204

120mm XM360 Gun Assembly



XM360 Primary Weapon Assembly Accomplishments

- Completed delivery of 3 gun assemblies
- Completed integration of 1 Gun Assembly into XM1202 Firing Platform Turret
- Completed two (2) Tube Pre-Fatigue Firing Tests
- Completed two (2) Tube Laboratory Hydraulic Fatigue Tests
- Completed one (1) Breech Laboratory Hydraulic Fatigue Tests
- Completed Durability (simulated damage) Test of Composite Tube Section
- Completed one (1) Gun Mount Durability Firing Tests
- Completed phase 1 of Extreme Temperature Firing Tests
- Completed Scavenger Headwind Testing
- Completed Bore Clear Camera Testing
- Completed Breech Actuator/Mechanism Durability Cycling test
- Tube Frequency Response Testing
- Supported XM360 on XM1202 Firing Platform
  - Integration
  - Shock – Vibration – Road Simulator
  - Firing Tests

XM360 Primary Weapon Assembly Tube Fatigue Test Results

- Two (2) Tubes Completed Fatigue Tests
  - Pre-fatigue Firing
  - Hydraulic Cycling
- Tested 5 critical sections
  - Chamber
  - Origin
  - Composite Wrap (2)
  - Muzzle (MRS)
- Materials Properties taken of tube sections after failure



RESULTS – XM360 Tube Met Life Requirements

XM360 Primary Weapon Assembly Tube Fatigue Test Results

- One (1) Breech Test in process (>50% complete)
  - Hydraulic Lab Cycling



RESULTS – XM360 Breech on track to meet Fatigue Life Requirements

XM360 Primary Weapon Assembly DurabilityTest of the Composite Wrap Material

- Gun Tube Composite Wrap TRL-6 Testing (Mar. 2006 to Dec. 2006) Firing Damage applied to a Composite Tube Section – Non-Autofrettaged Zone
  - Gun Fired 250 Rounds (198-M829A3, 37-M831A1, 5-M865)
  - Applied 10,000 lab Fatigue cycles to Muzzle end section. No fatigue damage noted.
  - Firing Damage applied to tube @ APG (7.62mm armor piercing round) – "Glancing Blow"
  - Fatigued Tested 200 cycles – No Fatigue damage noted.





RESULTS – XM360 Composite Damage not a significant hazard

XM360 Primary Weapon Assembly Extreme Temperature Testing

- XM360 Installed in Aberdeen Test Center Climate Chamber:
  - Completed Hot, Cold Test Firing
  - Completed extreme elevation tests





RESULTS – XM360 met Climatic Extreme Requirements

XM360 Primary Weapon Assembly Mount Durability Test

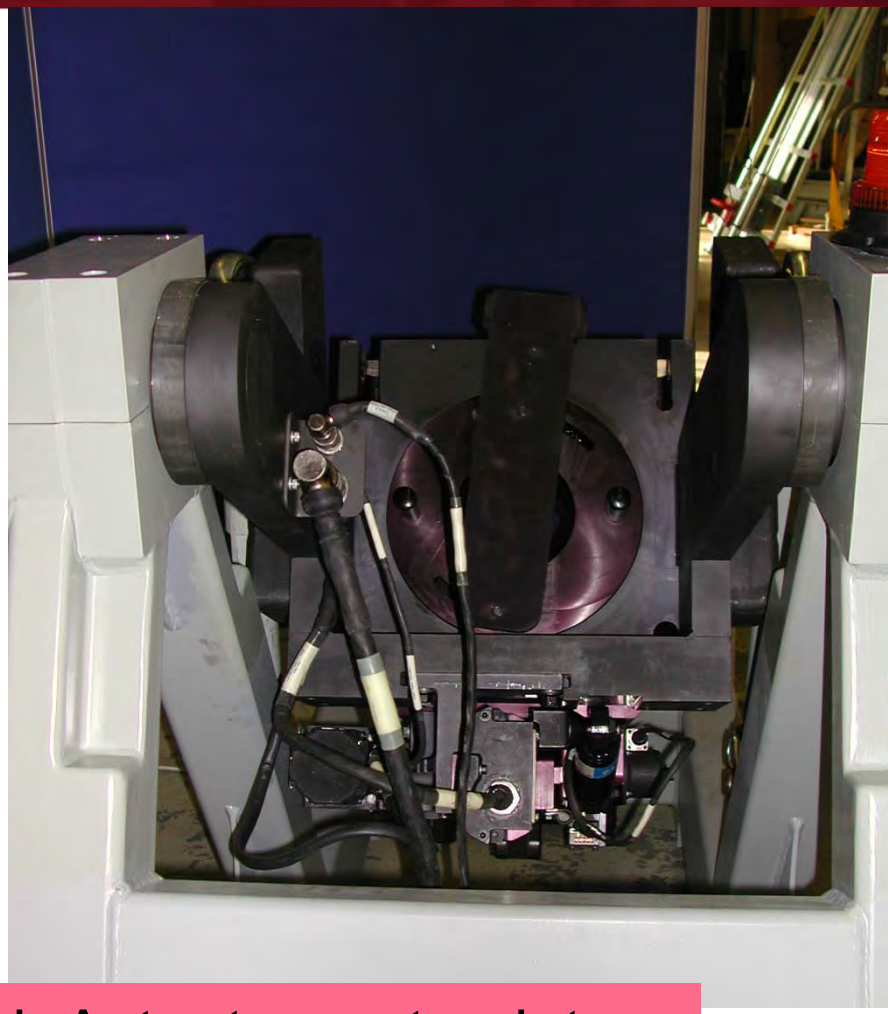


- XM360 Gun Mount fixtured in Impact Simulator at Rock Island Arsenal and cycled 20 times prior to firing tests to check function and performance.

RESULTS – XM360 Mount Performance met Requirements

XM360 Primary Weapon Assembly Breech Mechanism Cycling Test





- Breech Actuator & Mechanism fixtured in test stand & actuator cycled at various elevations
- Completed 18,557 cycles without stoppage

RESULTS – XM360 Breech Actuator on track to meet Reliability Requirements

XM360 Primary Weapon Assembly Breech Mechanism Test Results

- During Firing Tests – some mechanism housing structural failures occurred
- Subsequent Investigation found unique firing loads being transferred from tube into mechanism & exciting the housing
- Analytical models were developed to duplicate the event and used to redesign the housing
- FEA modal resonant freq – 400Hz Strain measurements at ATC – 356Hz





RESULTS – XM360 Mech Housing redesigned & tested - strain gages verified lower stresses

XM360 Primary Weapon Assembly Systems Engineering - Integration

- ARDEC/Benet Labs partnered closely with vehicle developer – GDLS – and ammunition developers to ensure early:
  - Integration across sub-systems & interfaces
  - Performance of all subsystems optimized

RESULTS – XM360 Gun Assembly Integrated with gun drives very early in design process:
•Software tuned in early
•Interfaces Optimized



XM360 Primary Weapon Assembly System Level Testing

- XM360 Mount in XM1202 Turret with autoloader, active gun & turret drives (video)



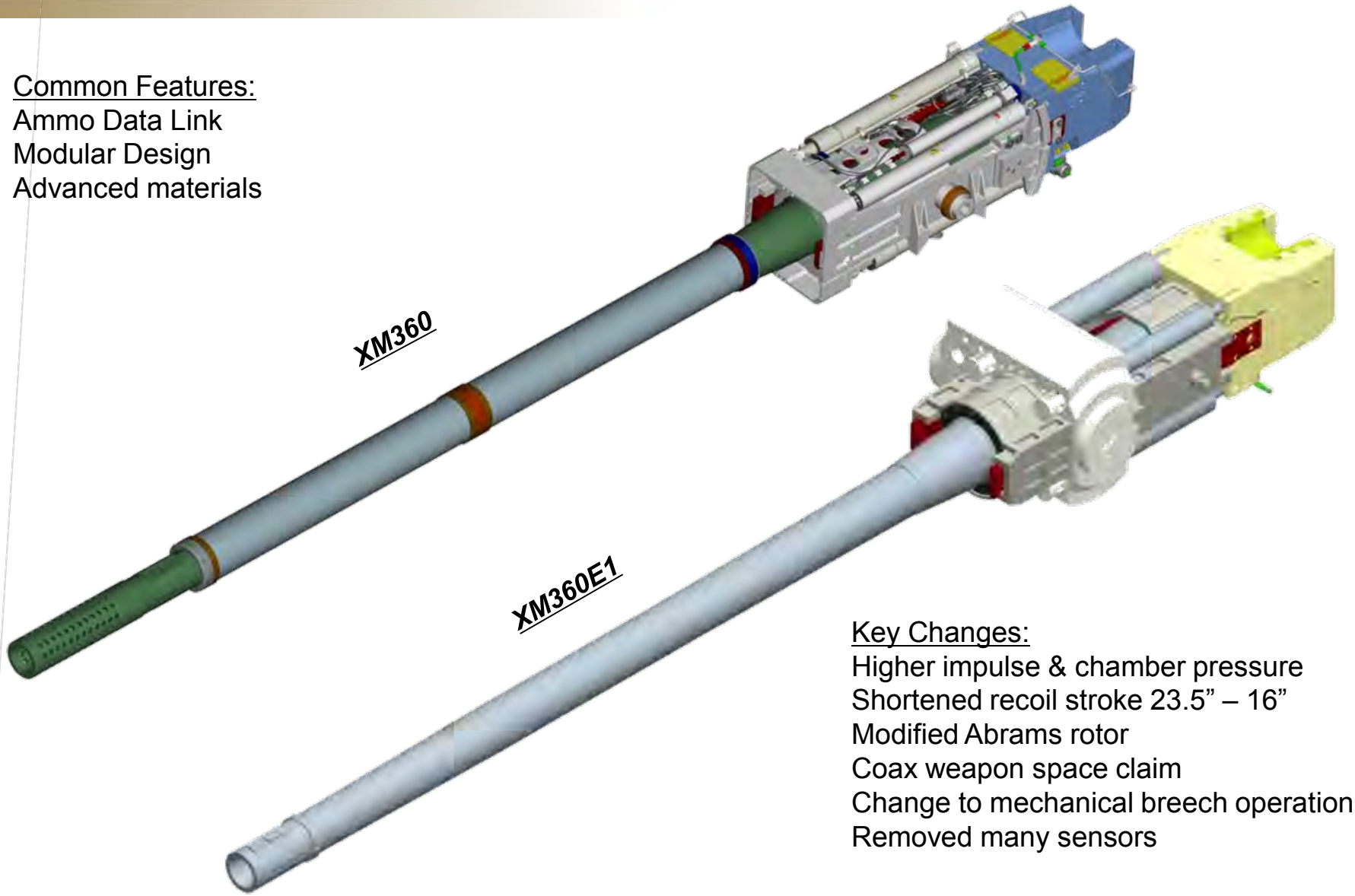
XM360 Primary Weapon Assembly (PWA)

- Original FCS Requirements:
  - Provide the firepower of the M256 cannon on the M1A2 in a light weight, compact package - fire all current & developmental 120mm ammunition
  - Provide reduced impulse to a 20 ton class vehicle (muzzle brake) – provide remote actuation and operation (600vdc electric supplied)
- NEW REQUIREMENTS:
  - Provide increased firepower in a light weight, compact package - fire all current & developmental & next generation 120mm ammunition
  - Provide capability of firing on M1 series Tank with hatches open (no muzzle brake)
  - Provide mechanical breech operation



XM360E1 Concept Development

Common Features:
Ammo Data Link
Modular Design
Advanced materials



Key Changes:
Higher impulse & chamber pressure
Shortened recoil stroke 23.5” – 16”
Modified Abrams rotor
Coax weapon space claim
Change to mechanical breech operation
Removed many sensors

Summary

- From 2004 – 2009, combined results of Government sponsored Tech Base Work and XM360 PWA SDD Program a total of 1,952 rounds fired (1,182 rounds SDD Program)
- Four (4) complete design iterations were completed
  - Vehicle Dynamic Response Demonstrator (joint PM MAS – GDLS – Army Tech Base)
  - Advanced Technology Demonstrator (Army Tech Base)
  - Lightweight Armament Enhancement Program (Army Tech Base)
  - FCS Primary Weapon Assembly (GDLS CRADA)
- Most key requirements were verified by test:
  - Weight
  - Accuracy
  - Ammunition Compatibility
  - Tube Fatigue Life
  - Breech Fatigue Life
  - Integration in lightweight turret
- Post FCS – the XM360 is being re-developed into the XM360E1 variant for the next M1 Abrams Tank upgrade – Abrams Evolutionary Design (AED)

Point Of Contact

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Watervliet, NY 12189

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Phone: 518-266-4741
Email: david.c.smith2@us.army.mil

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT, & ENGINEERING CENTER (ARDEC)



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Henry Kerwien

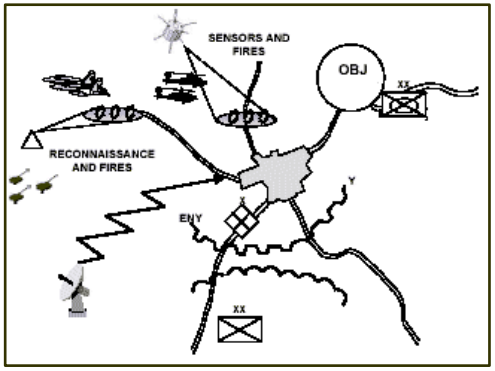
Scalable Lethality: 'Dial-a-yield' approach to greater precision engagement

17-20 May 2010

Distribution A: *Approved for public release.*

Scalable Lethality
Bottom Line Up Front

- Scalable Lethality provides more engagement options
  - Improves Weapon Effectiveness
  - Reduces Collateral Damage
- Enables Military Operations in Complex Environments (MOUT, Defilade, Wooded Terrain, In the Open)
- Applicable to a range of munition calibers (Missiles, Artillery, Medium Caliber)
- Requires Integrated Advanced Component Technologies (multi-purpose energetics, reactive materials, advanced fuzing & lethal mechanisms)







Key User-Identified Need

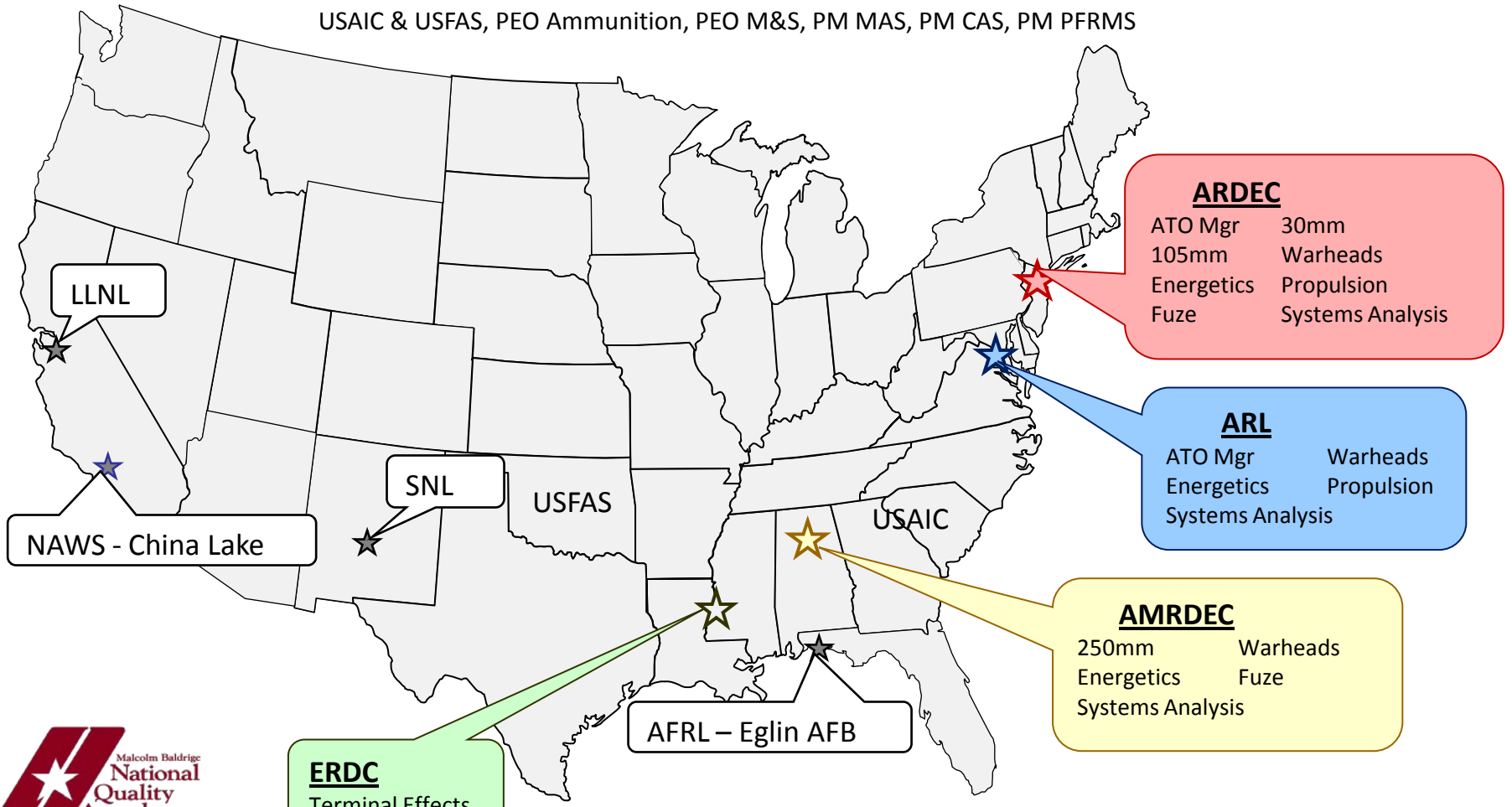
Malcolm Baldrige National Quality Award 2007 Award Recipient

Distribution A – *Approved for Public Release*

STAR IPT

ARDEC, AMRDEC, ARL & ERDC Core IPT Members
LLNL, AFRL, SNL & China Lake are Shell IPT Members

Demonstration objectives and requirements are coordinated with
USAIC & USFAS, PEO Ammunition, PEO M&S, PM MAS, PM CAS, PM PFRMS



Malcolm Baldrige National Quality Award 2007 Award Recipient

Engagement in Close Proximity with Low Collateral Risks

Current Munitions

Collateral Region

Lethal Region

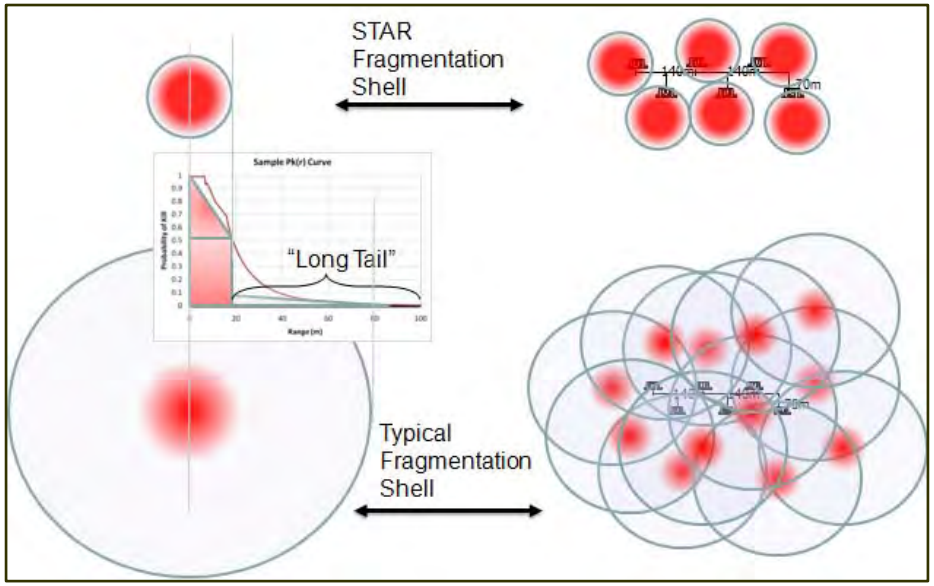
Scalable Munitions

Control Collateral Region

Enhance Lethal Region

Focused Effect

Large/Small Area Effect



Provides Increased Effectiveness with Reduced Logistics

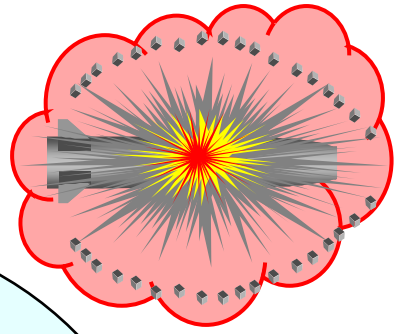
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Distribution A – *Approved for Public Release*

How We Achieve Scalable Lethality



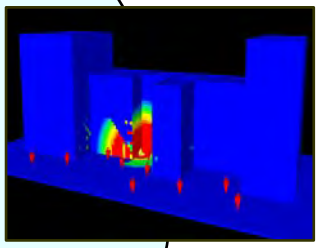
Controlled Fragmentation
(Lethal Mechanisms & Fuze)



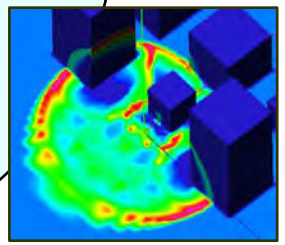


Scalable Lethality

Scalable Explosives
(Energetic Materials)



Combined Effects
(Blast & Fragment)





Effectiveness Assumes Precision Delivered

Malcolm Baldrige National Quality Award 2007 Award Recipient

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How We Achieve Scalable Lethality

Advanced Energetics

- Combined Effects/Scalable Explosives
- Reactive Materials – IM Performance & Increased Controlled Energy Output
- Dual Purpose Energetics/Rocket Assist

Warheads

- Directional/Selectable/Preformed Fragmentation
- Liners/Composites
- Reactive Materials - Output Energy, IM Compatibility, Reactive & Consumable Fragments

Fuze & Power

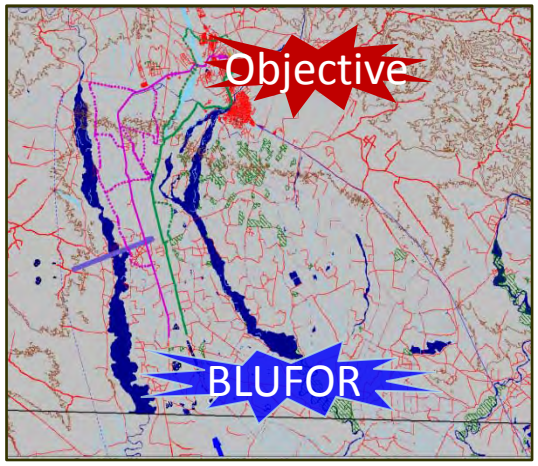
- Height of Burst Algorithms (HOB)
- Initiation Train
- Hybrid Power Sources/Thermal & Liquid Reserve Batteries

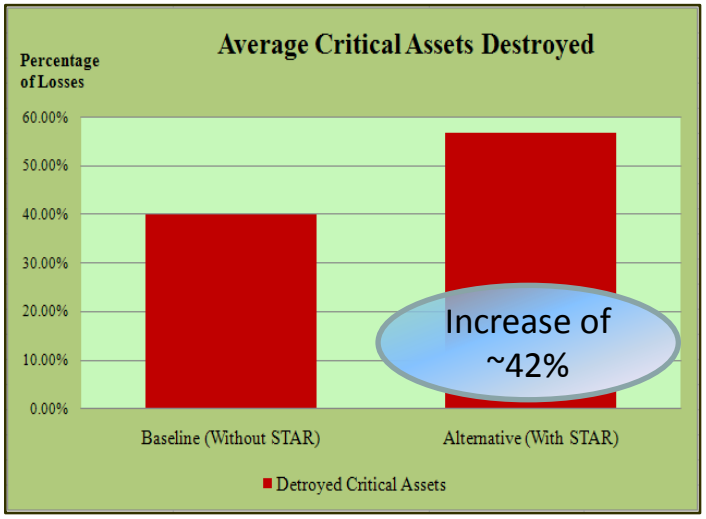
Advanced Propulsion

- Coated Single Base or Hybrid Propellant
- Ballistic Efficiency/Flat Temp Profile
- Increase MV/Range
- Cooler Flame Temp
- Deterrent Migration/Shelf Life/Cost
- Advanced Igniters



Modeling & Simulation to Optimize Effectiveness in the Urban Environment





- Force Level Effectiveness Analysis
  - RDECOM Modeling Architecture for Technology, Research, and Experimentation (MATREX)
    - Virtual Test Bed utilizing ARDEC Armaments Server

85% Fewer Individual Combatant Losses
17% Fewer Aircraft Losses
6% Fewer Ground Platform Losses

154% More OPFOR Individual Combatant Losses
34% More OPFOR Ground Platform Losses
30% More OPFOR Air Defense Losses

- Scalable Lethality Enabled Engagement of Targets in Collateral Damage Sensitive Sites
- Attacks on otherwise protected targets forced relocation of critical OPFOR assets and prevented OPFOR from returning fire
- Destruction of OPFOR Air Defense Systems Enabled BLUFOR Aircraft to Participate in Battle and Identify & Engage Targets

The Entire Force Benefits from Scalable Lethality

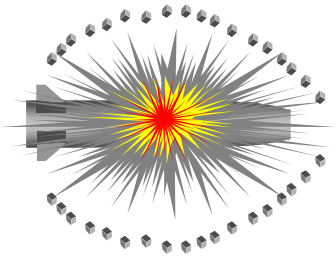
Malcolm Baldrige National Quality Award 2007 Award Recipient

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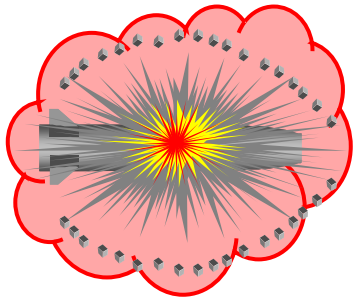
All in the Same Weapon

- Warfighter selects lethality based on target type
  - Fragmentation for Personnel & Materiel
  - Blast against Structures
  - Hardened for Penetration of Bunkers & Structures
  - Focused Effects – Point Target

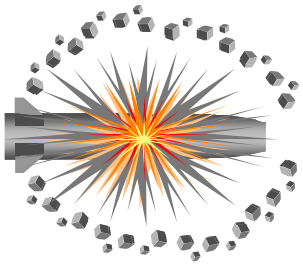
All in 1 round



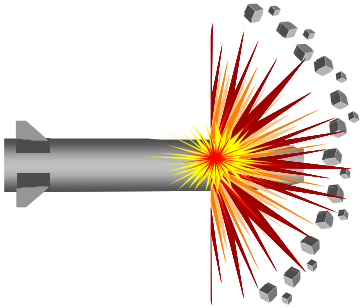
Fragment Types



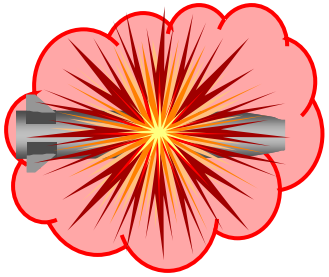
Fragments + Blast



Small and/or Big Fragments



Directional-Focused, Variable Velocity Fragments



All Blast
No Fragments

Dial-A-Yield Capability

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All in the Same Weapon

Demonstrations in 2011

Capabilities to Demonstrate



250mm (GMLRS)



- Scalable Explosives – Deflagrate-to-Detonate
  - Effective against structures and personnel in complex environments where collateral damage is a concern

105/155mm Artillery





- Controlled Fragmentation & Blast
- Hardened against Structures
- Advanced Fuzing & Power Sources
  - Effective against structures and personnel in complex environments where collateral damage is a concern

30mmx173mm Medium Cannon Caliber





Summary

- Scalable Lethality provides more engagement options
  - Improves Weapon Effectiveness
  - Reduces Collateral Damage
- Enables Military Operations in Complex Environments (MOUT, Defilade, Wooded Terrain, In the Open)
- Applicable to a range of munition calibers (Missiles, Artillery, Medium Caliber)
- Integrated Advanced Component Technologies



42% More Effective than Conventional Munitions

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Questions

Contact Information

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(973) 724-4447
DSN 880-4447



M1002

120 mm Tank Ammunition
Advanced Case System (ACS)

Presented At
The National Defense Industrial Association's Joint Armaments Conference, Exhibition, & Firing Demonstration

19 May 2010

Jeff Berg
Principal Engineer
120mm Training Ammunition
ATK



M865

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10



Agenda

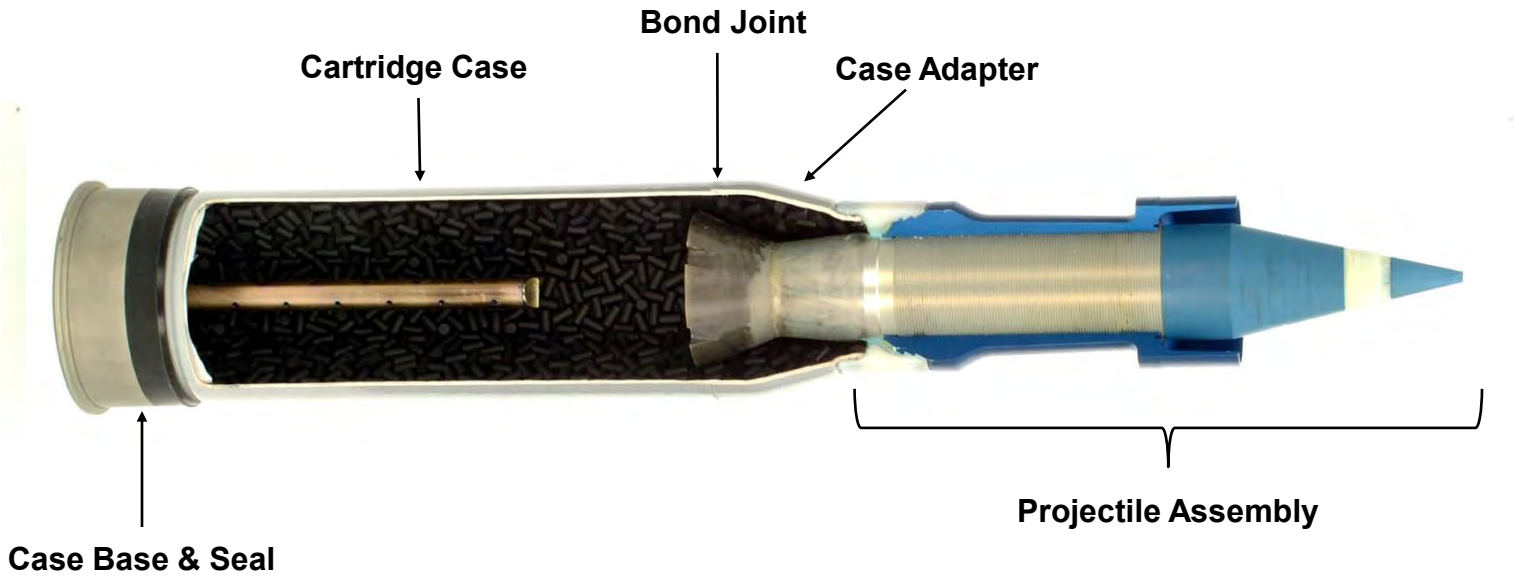
120 mm Tank Ammunition Advanced Case System (ACS)

- Background
- Program Summary
- ACS Design Options
- Double Wall Joint vs. Skive Joint
- Technical Challenges – Bond Joints
- Analysis and Solutions
- Conclusion

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10

M1002 Cartridge (current case design)

A premier aerospace and defense company



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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 Group, American Ordnance**

- **Objective: Provide a re-designed cartridge solution 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 Design Options

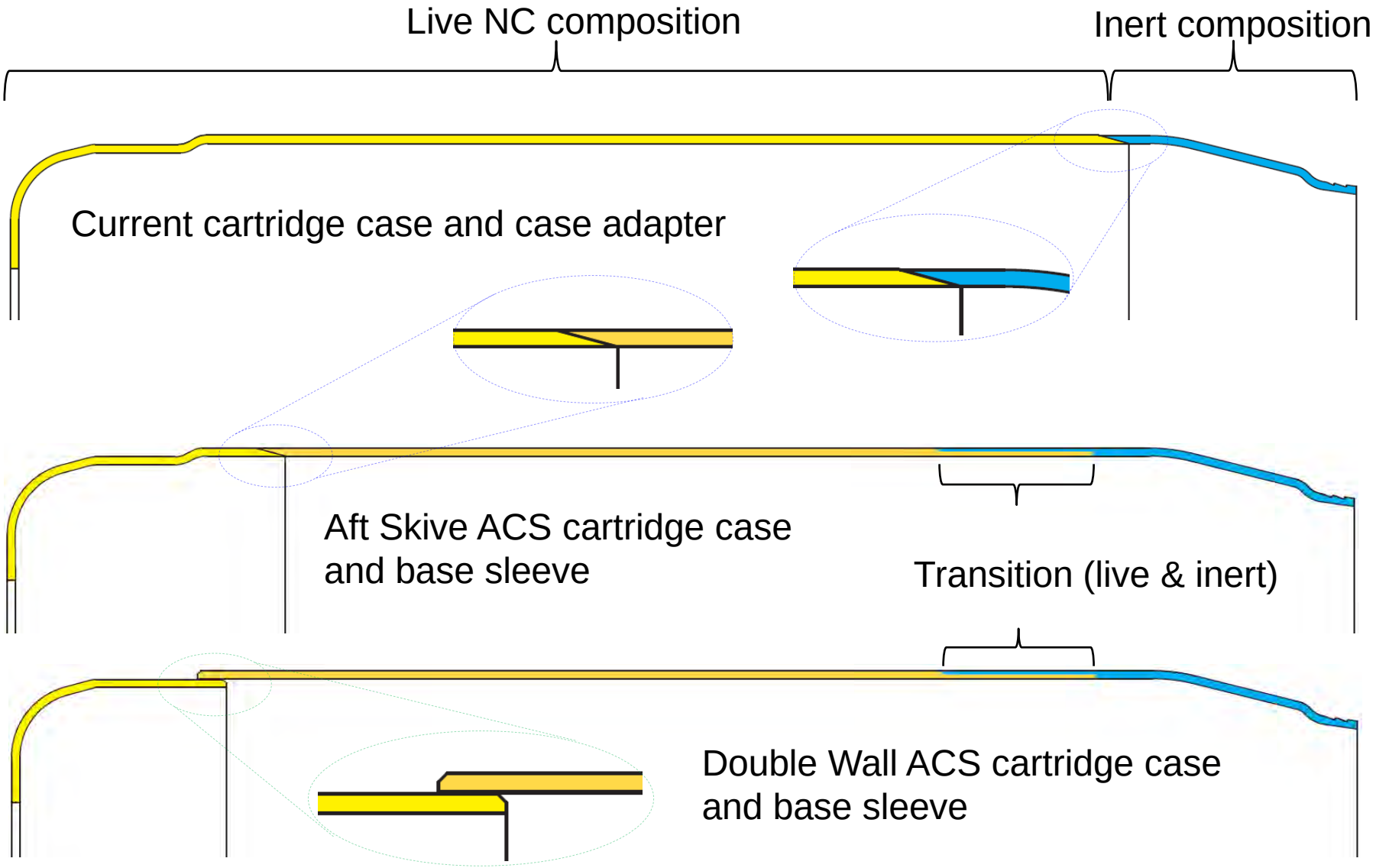
ACS Design

- Joint: Double Wall, Skive, Single Wall
- Adhesive: Green two-part epoxy or Red NC based adhesive
- Propellant Bag: Tailored or Tied

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ACS Design Options – Cartridge Joint

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Double Wall vs. Aft Skive Joint

	Double Wall Joint	Aft Skive Joint
Pros	•Manufacturing process simpler. •Joint is more robust •Joint has better protection	•Producibility – similar to current design.
Cons	•Ballistic concerns: •Increased risk for residue. •Restricts seal performance (joint too strong). •Diametric repeatability risk (adhesive). •Trimmed end of case difficult to paint.	•Component manufacturing more complex (same as current design). •Cartridge bonding process more difficult. •Joint is more exposed.

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Aft Skive Joint - Technical Challenges

Aft Skive Joint:

- Cartridge alignment (straightness): joint location allows for misalignment.
  - Early concern that has since been resolved.
- Aft skive joint is more exposed than double wall.
  - Preliminary qualification results demonstrate aft skive location is superior compared to the current design.
  - Actual protection is quite good due to proximity to case base.

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Double Wall Joint -Technical Challenges

Double Wall Joint:

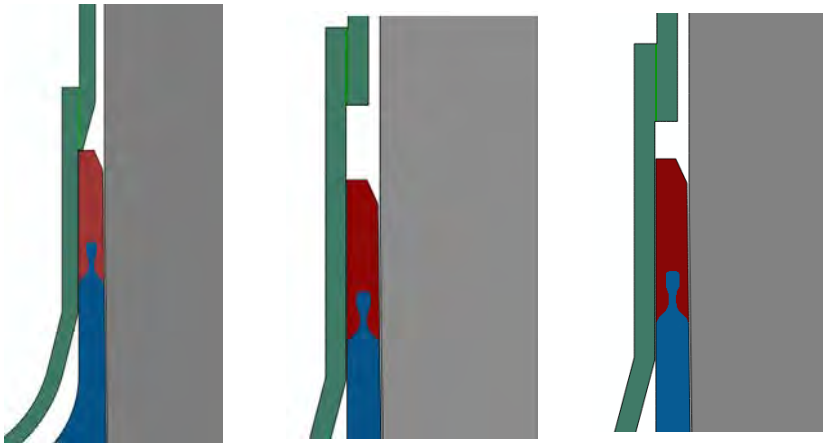
- Case base seal performance
  - Occasional gas leakage aft of case base seal.
  - Modeling was able to repeat the condition.
  - Design modifications investigated and modeled to correct.
  - Testing successfully validated the model results.
- Design Modifications lead to increase risk of energetic exposure
  - Continue to evaluate solutions.
  - Objective – no more risk than current design

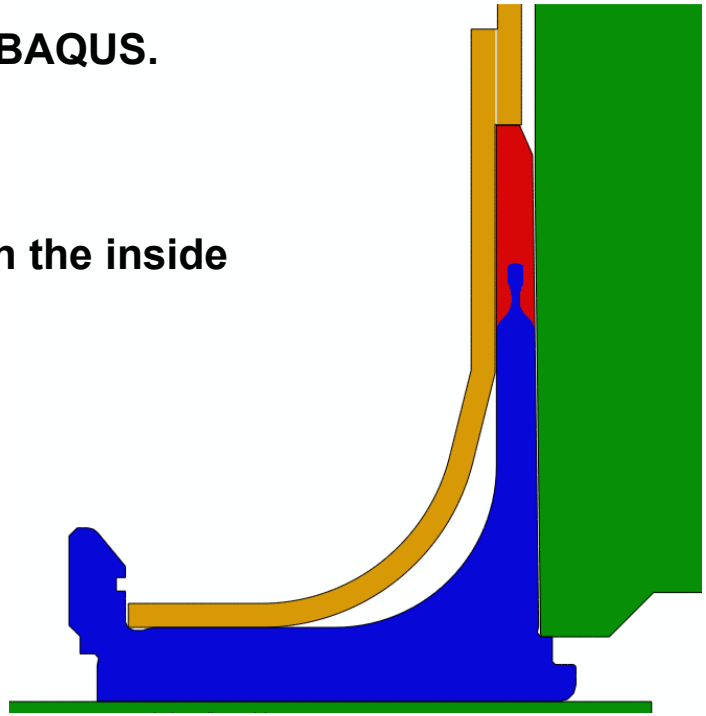
Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10

Comparative Analysis of ACS Double Wall and Current Case System

MODEL ASSUMPTIONS:

- Explicit dynamic analysis performed in ABAQUS.
- Axi-symmetric analysis performed.
- Up to 200 psi uniform pressure applied on the inside of the case.



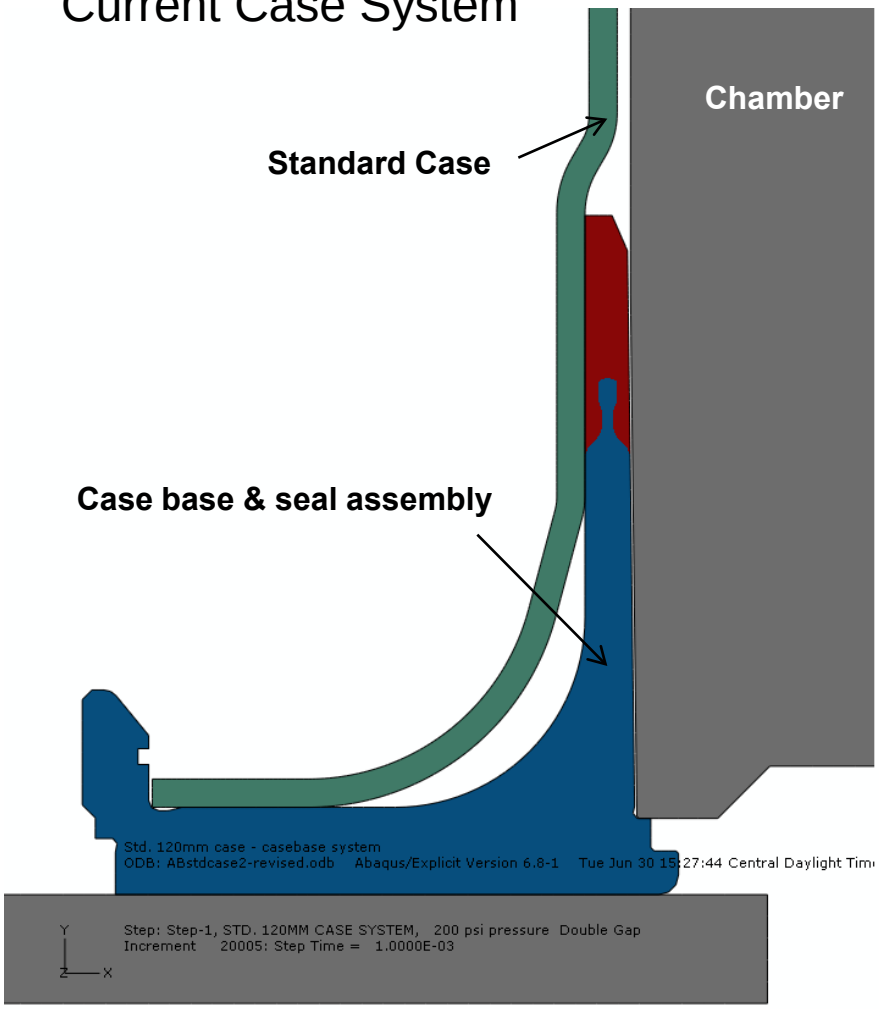


Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10

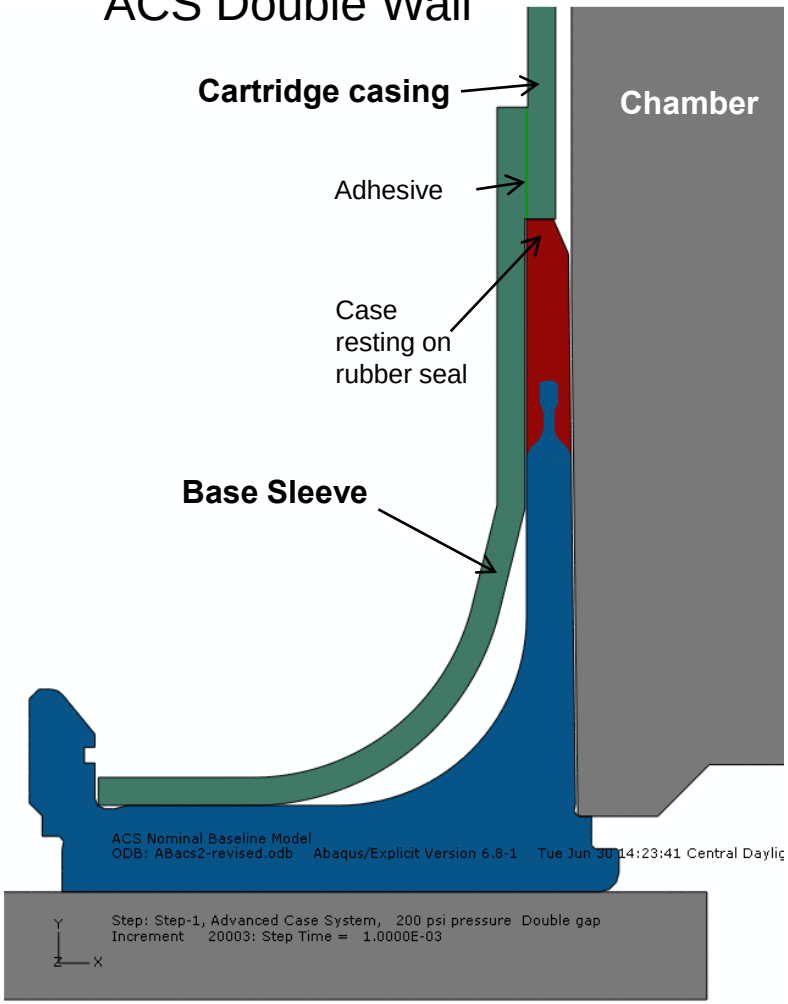
Comparative Analysis

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Current Case System



ACS Double Wall

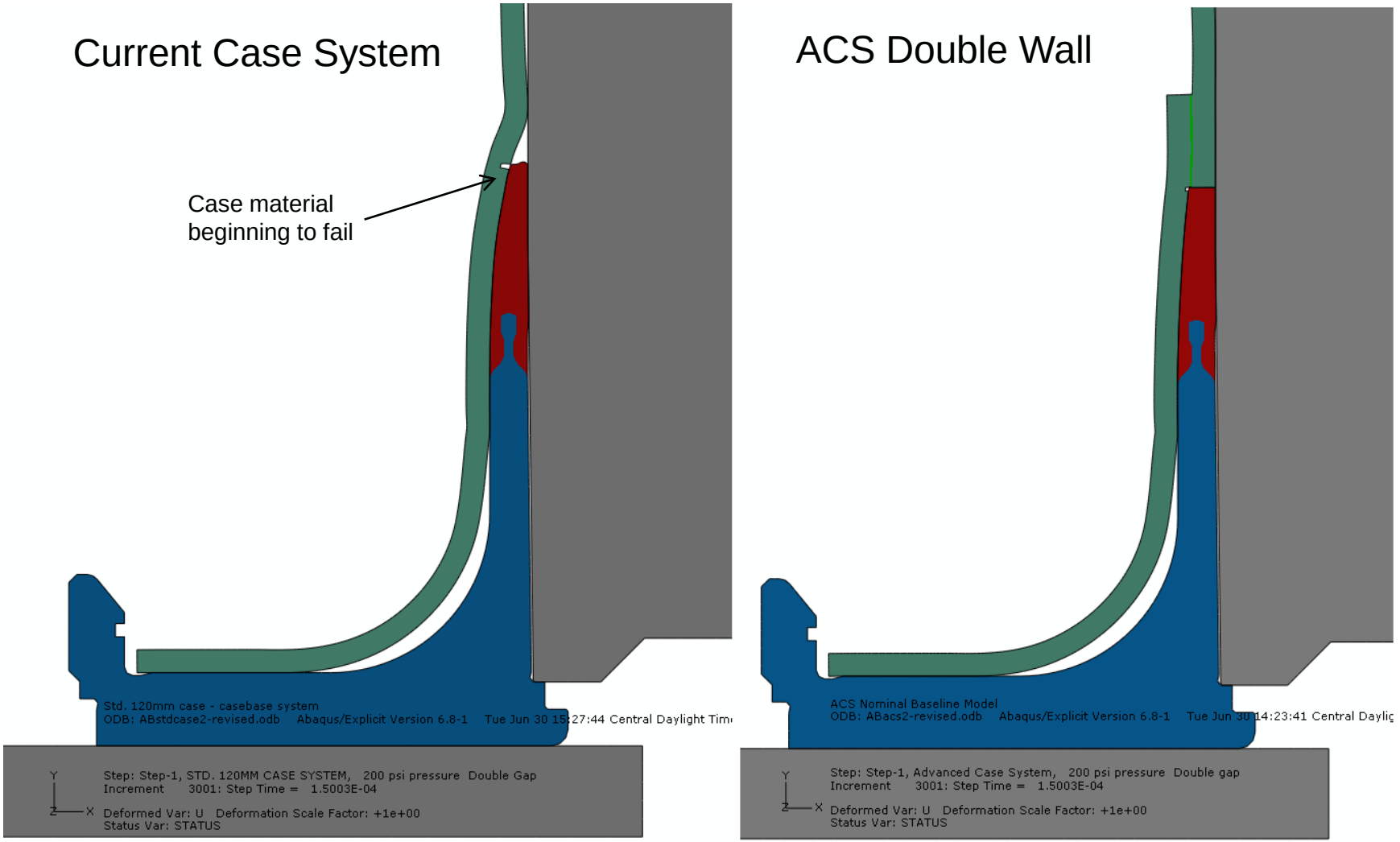


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Current Case vs ACS Double Wall

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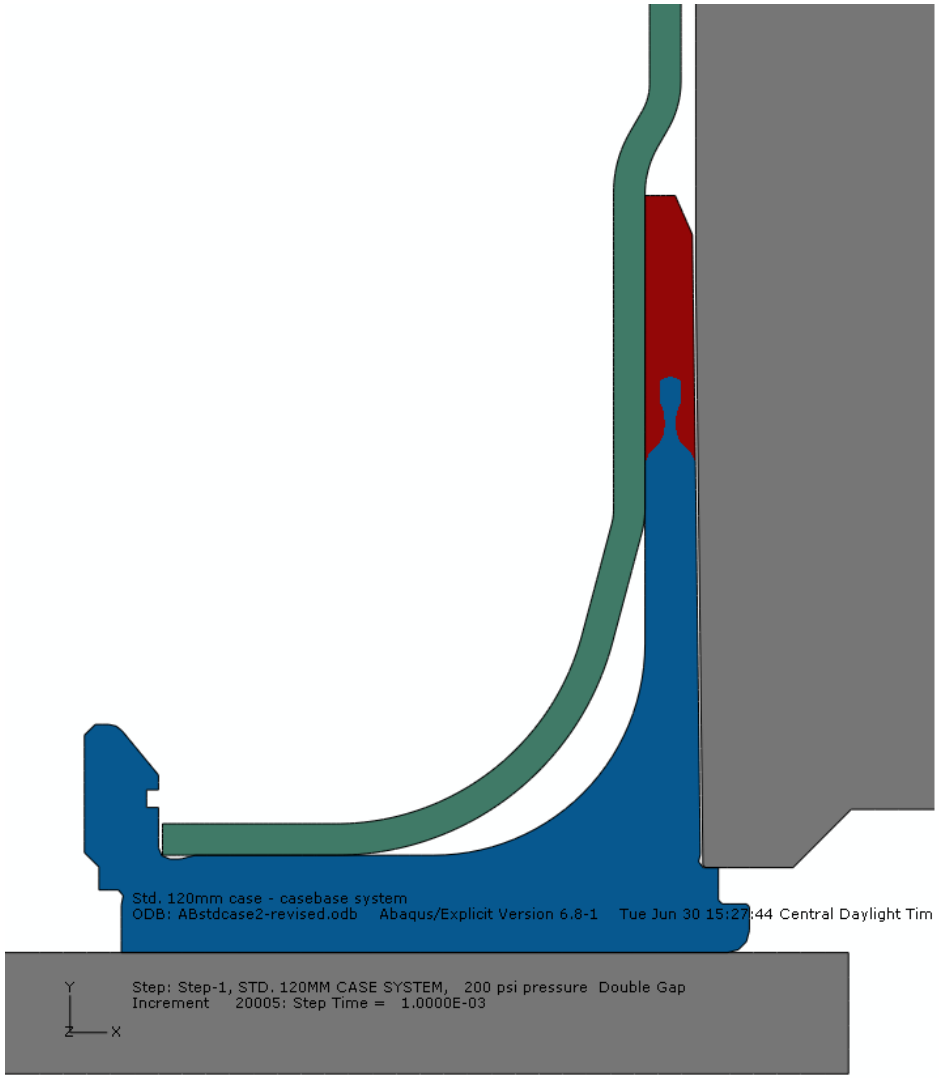
30 psi uniform pressure on case

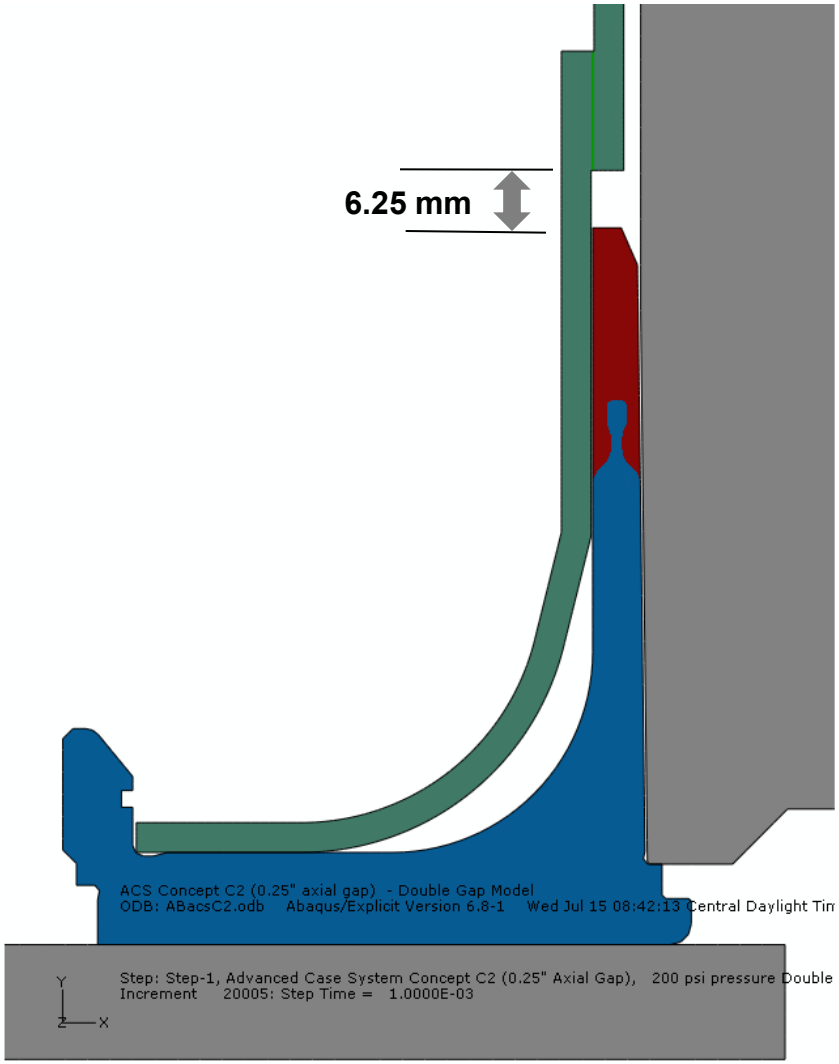


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Improved Double wall with 6.25 mm gap

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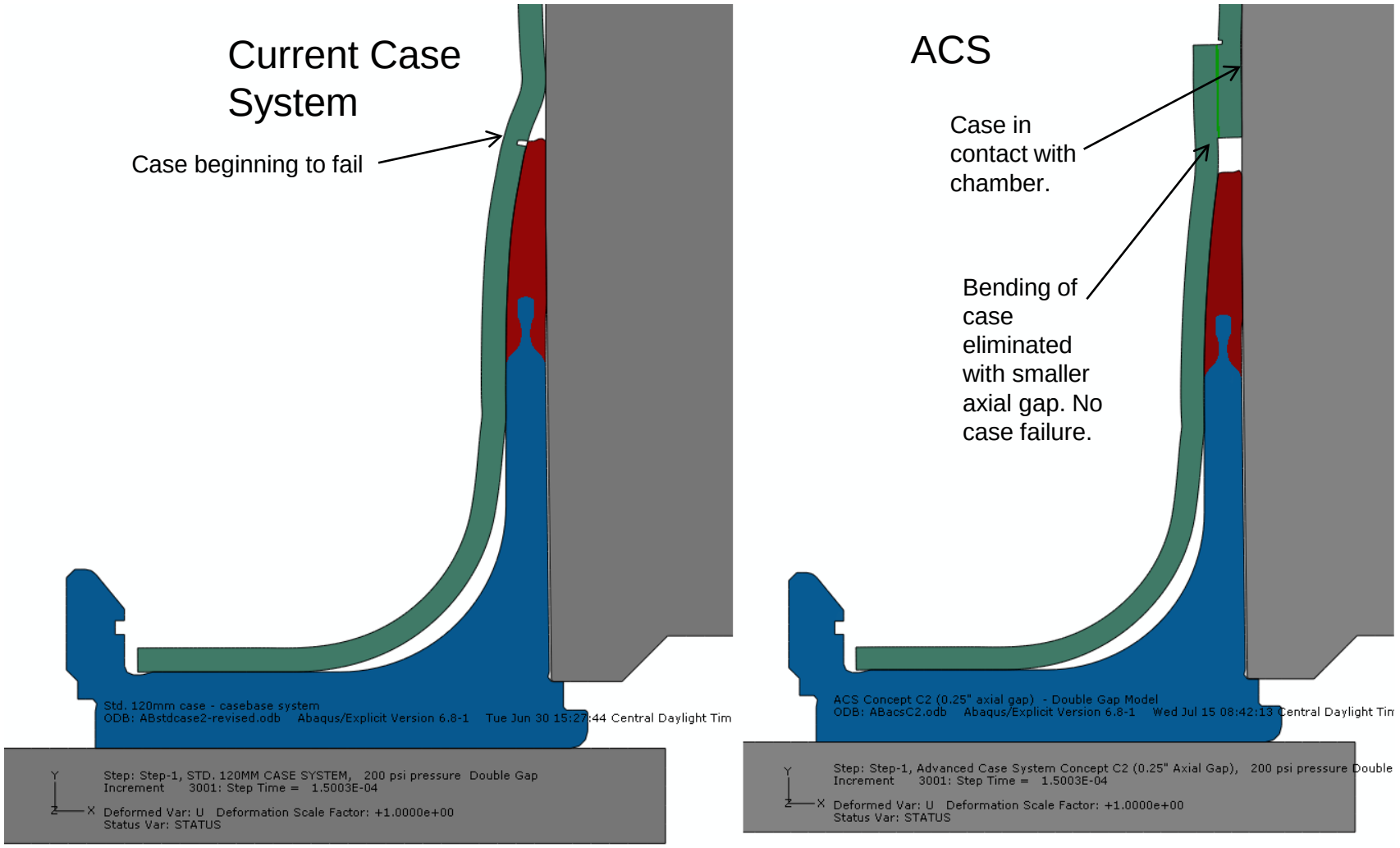


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Current Case vs ACS Improved Double Wall

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30 psi uniform pressure on case



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Model Conclusions

- **Model of improved double wall with 6.25 mm axial gap showed good sealing.**
  - **Seal performance was comparable to the current case system.**
  - **Of all ACS double wall designs models, the 6.25 mm gap had the best results.**
- **Ballistic testing completed to validate results.**
- **ACS qualification program proceeding with both the ACS double wall and skive joints.**
- **Down-select to a single joint anticipated upon completion of qualification tests.**

Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10

QUESTIONS???

Jeff Berg

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Approved for public release 22 CFR 125.4(b)(13) applicable. PAO Log# 503-10

Non-Destructive Inspection of Composite Wrapped Thick-Wall Cylinders

Jikai Du, John Feldhacker, Christopher Jerred and Fereidoon Delfanian

May 17-19, 2010
Joint Armaments Conference, Exhibition and Firing Demonstration

Materials Evaluation and Testing Laboratory (METLab)
Mechanical Engineering Department, Box 2219 SCEH 214
South Dakota State University, Brookings, SD 57007-0294
Phone: (605) 688-4300, Fax: (605) 688-5878, http://www.sd-metlab.org

Introduction

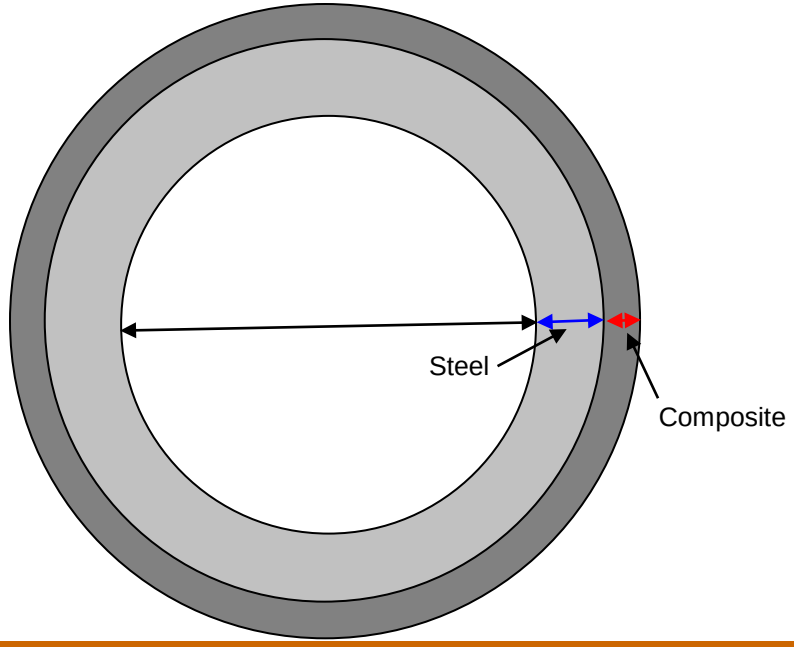
- Compared to all-steel cylinder, composite wrapped cylinder can reduce weight.
- Appropriate evaluation techniques are necessary for the evaluation of cylinder's structural integrity, especially the property of composite layer and the interface condition between composite and steel layer.
- Our research work focus on the experimental and theoretical study of various ultrasound techniques for the inspection of such multilayer cylindrical structures.

How Ultrasound Works

- Ultrasound is acoustic wave with frequency higher than 20 KHz.
- Ultrasound is mechanical wave that can travel in solid media. Its traveling velocity and attenuation are related to material properties such as density and elastic constants.
- When ultrasound propagates in materials, reflection and refraction may occur at acoustic discontinuities such as delaminations and inclusions.

Challenges of the Acoustic Evaluation

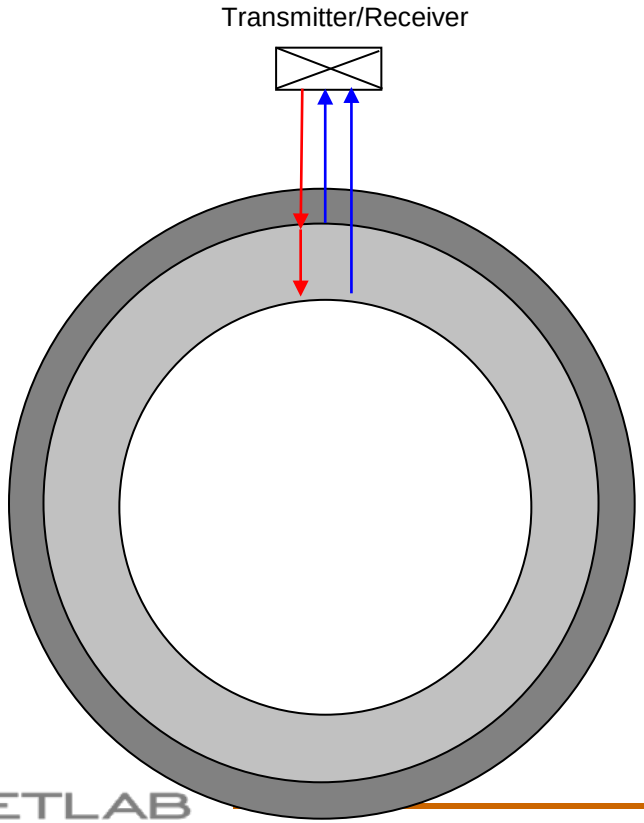
- High acoustic attenuation caused by the thick composite layer.
- The complexity of the acoustic propagation in multilayer cylindrical structure.
- Various types of defects: steel layer, composite layer, and steel/composite interface.



Ultrasound C-Scan Technique

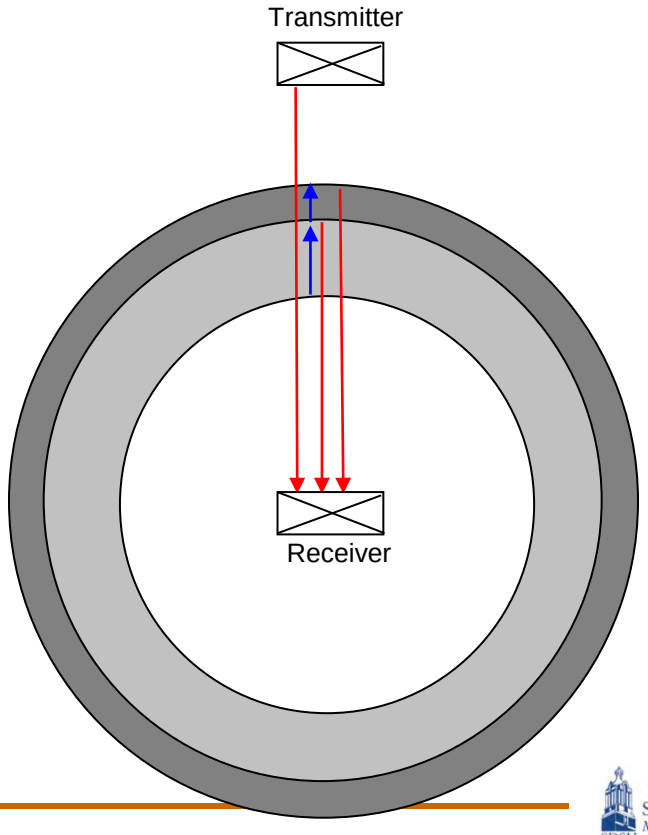
Reflection Mode

- Pros: simple system setup and easy signal analysis.
- Cons: high attenuation.

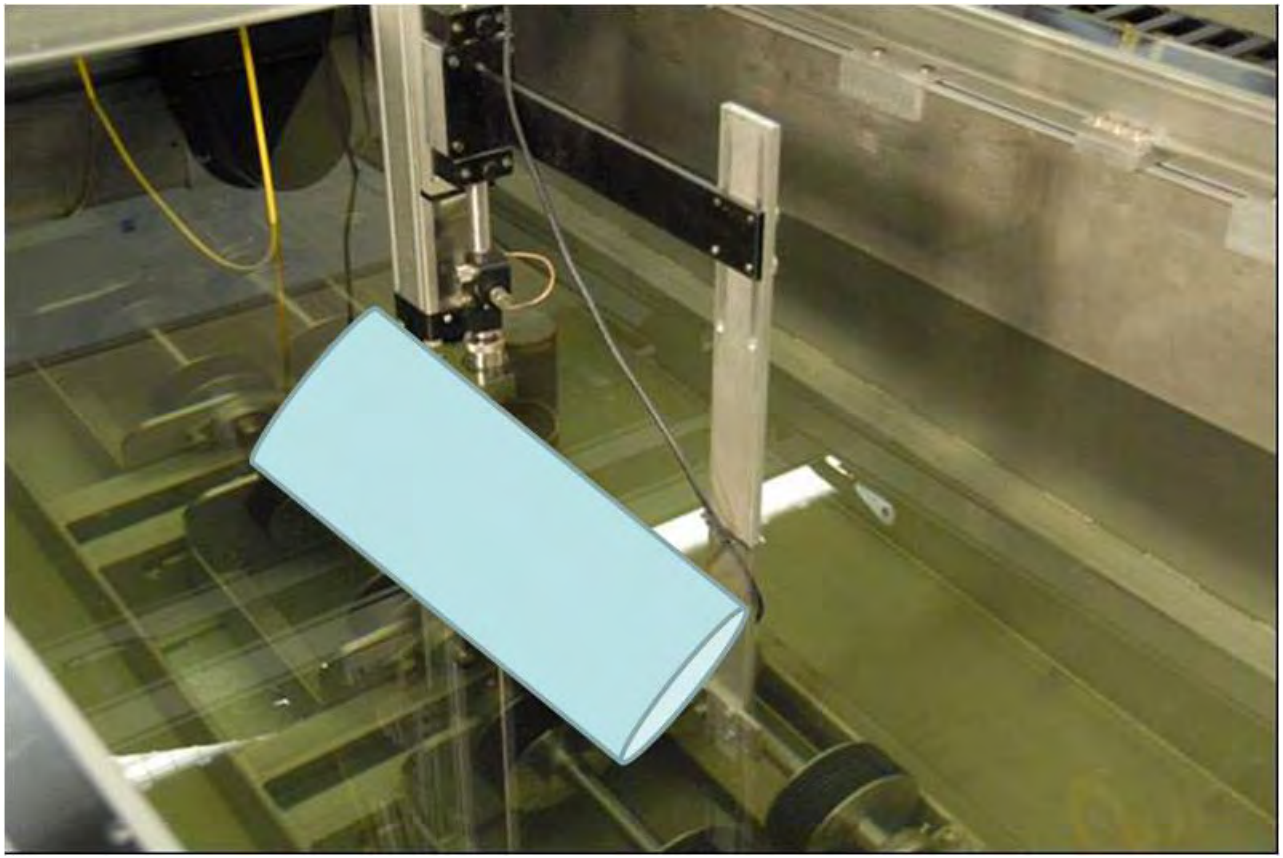


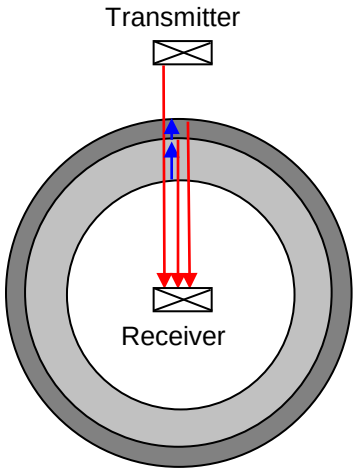
Transmission Mode

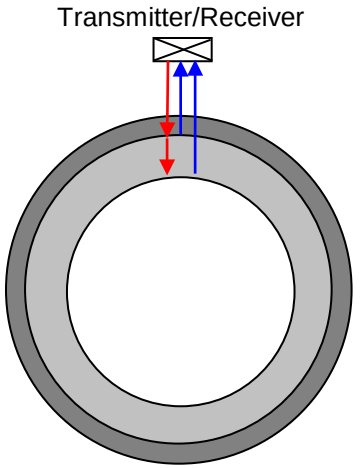
- Pros: low attenuation.
- Cons: Complex system setup and difficult signal analysis.



Ultrasound C-Scan System

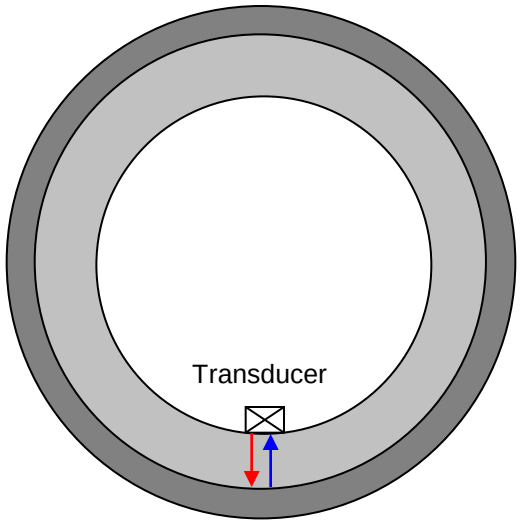


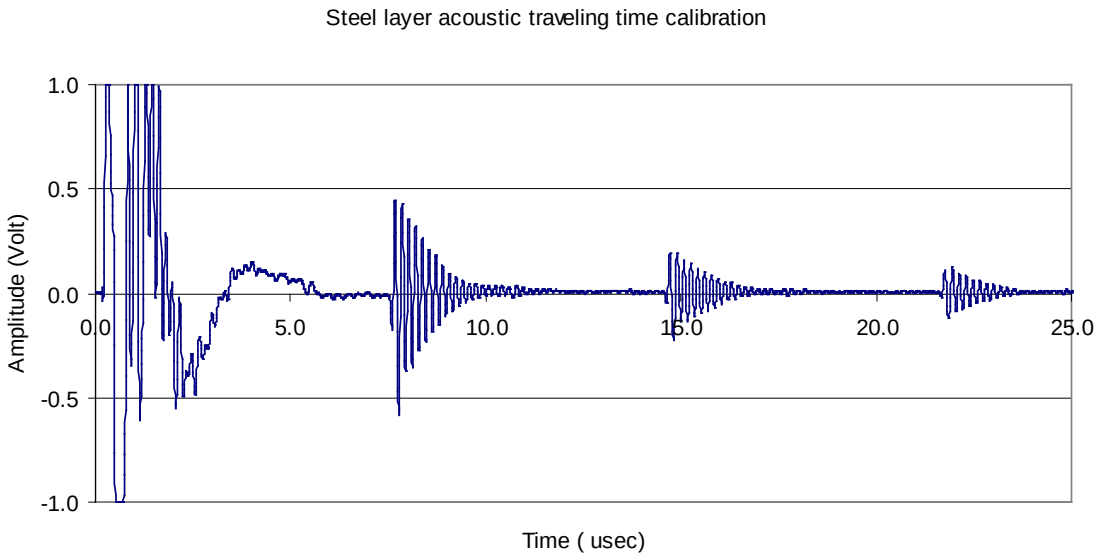




Steel Layer Ultrasound Signal Calibration

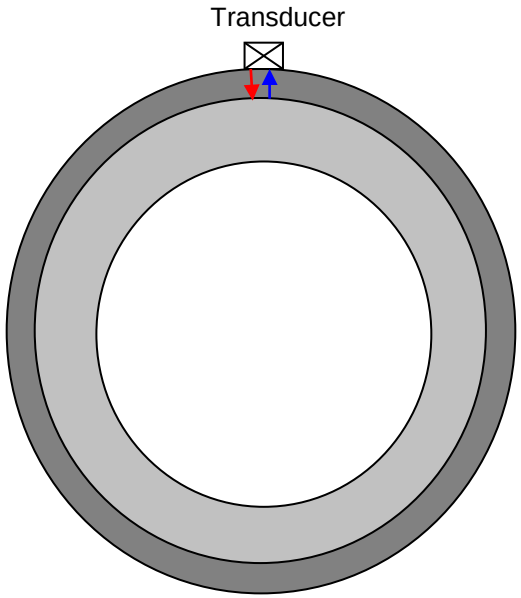
- Transducer: Freq. 10 MHz, dia. 0.25”, contact.
- Ultrasound velocity: 0.235 in/μsec.

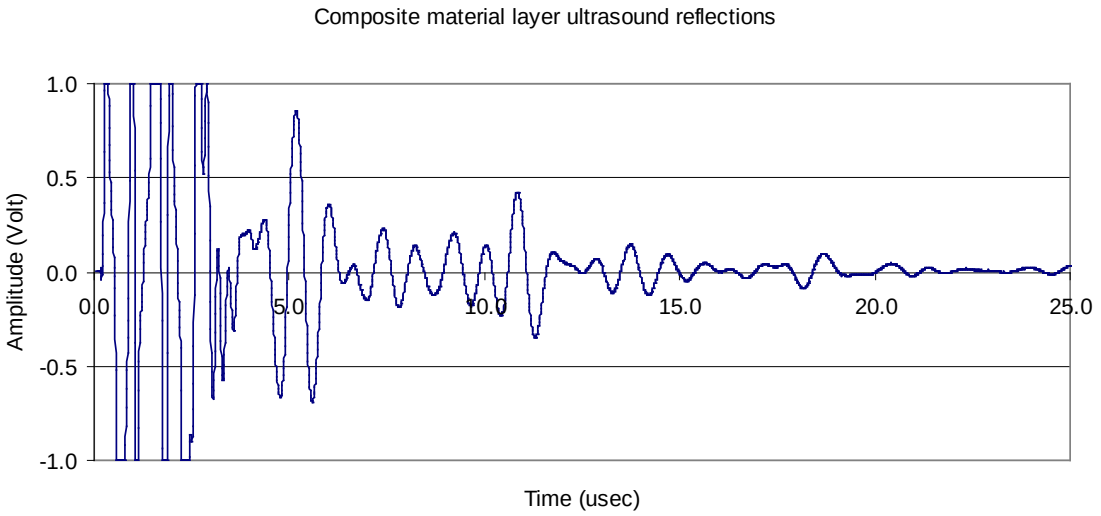




Composite Layer Ultrasound Signal Calibration

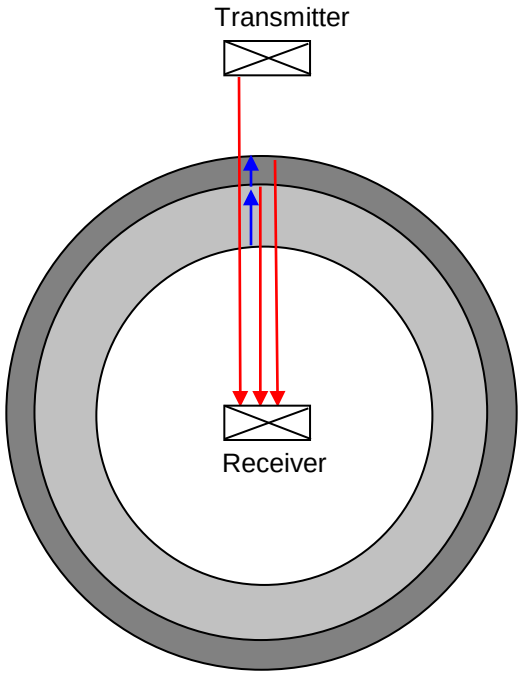
- Transducer: Freq. 0.5 MHz, dia. 0.75”, unfocused.

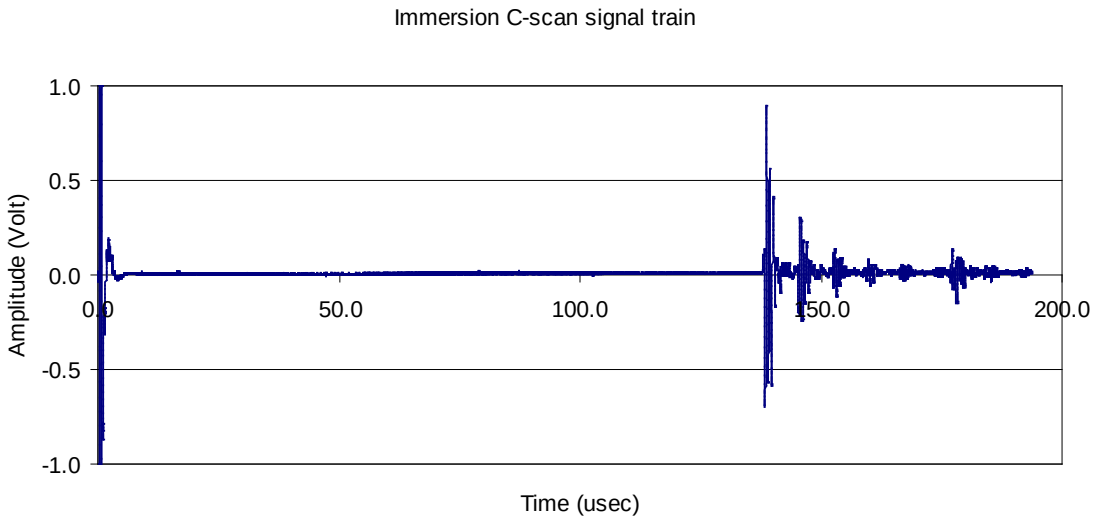




C-Scan Transmission Mode System Setup

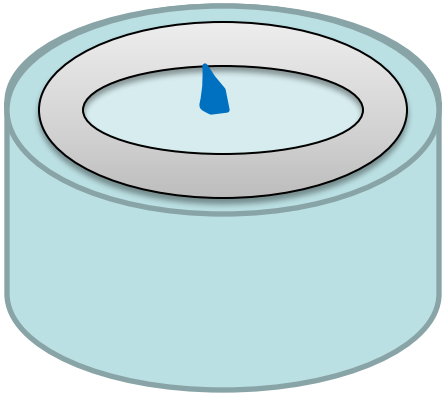
- Transmitter: Freq. 1.0 MHz, dia. 1.125”, unfocused.
- Receiver: Freq. 0.5 MHz, dia. 0.75”, unfocused.
- Distance between transmitter and receiver: optimized experimentally.

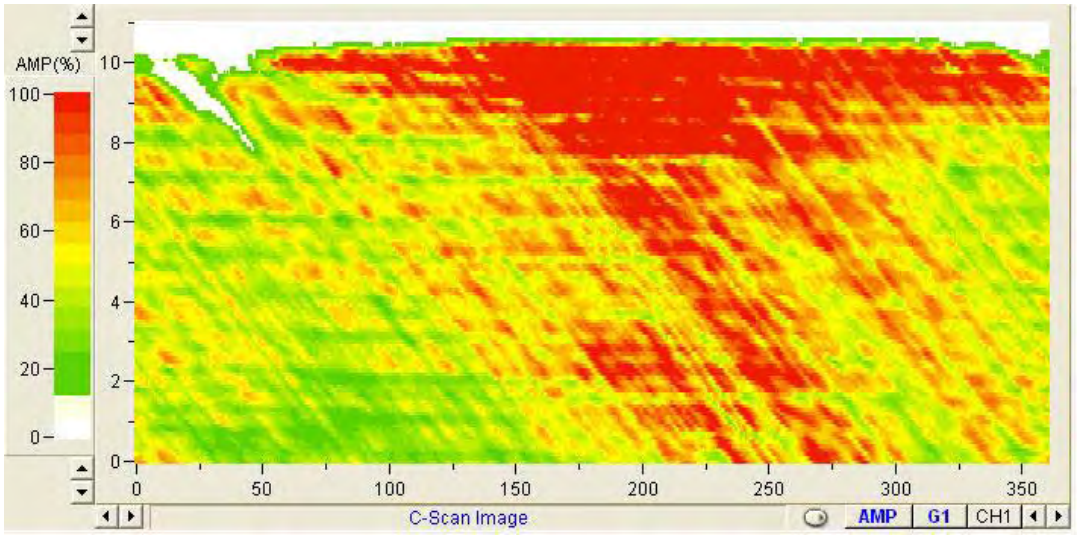




C-Scan Transmission Mode of Known Defect in Steel Layer(1)

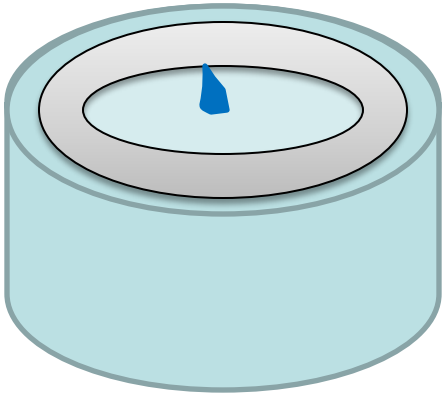
- Defect can be seen in the inner steel layer at the end of the cylinder (see picture).
- The first transmitted acoustic signal was used for imaging.
- C-Scan image size is 360 degrees by 11 inches (about half the length of the cylinder).

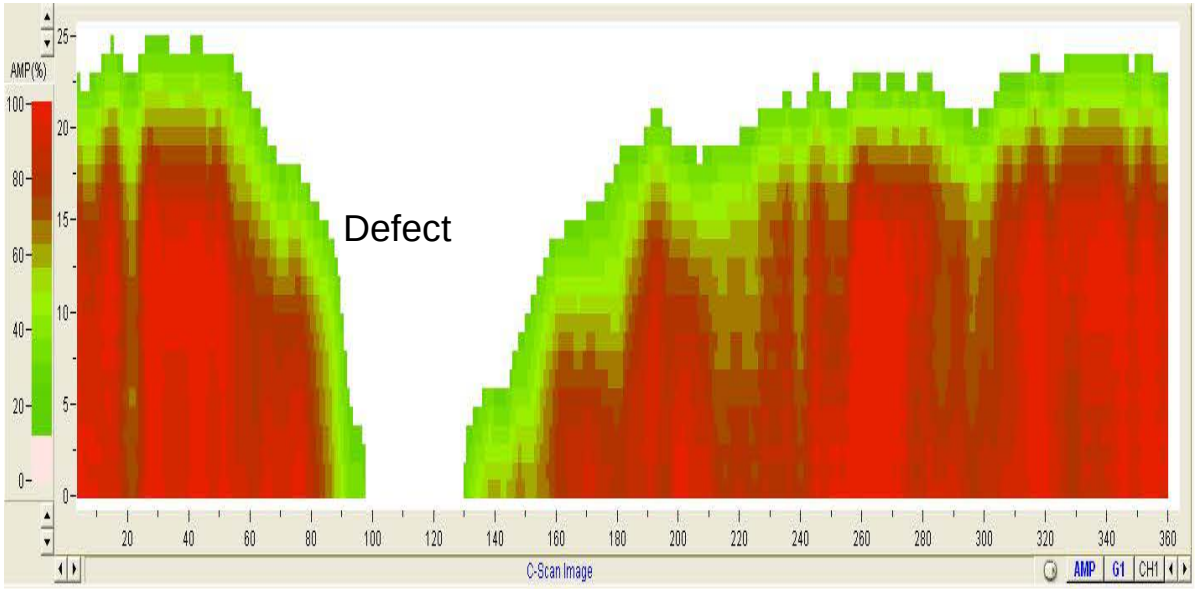




C-Scan Transmission Mode of Known Defect in Steel Layer (2)

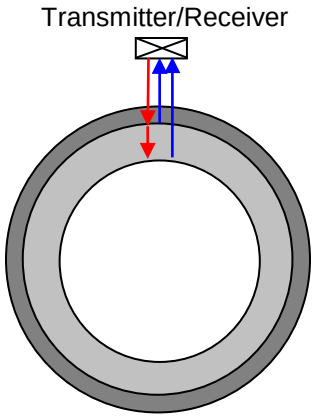
- Image size: 360 degrees by about 25.0 mm.

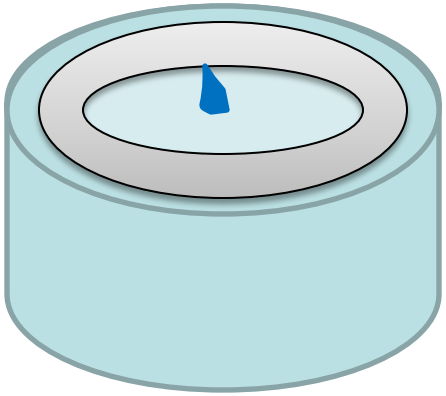


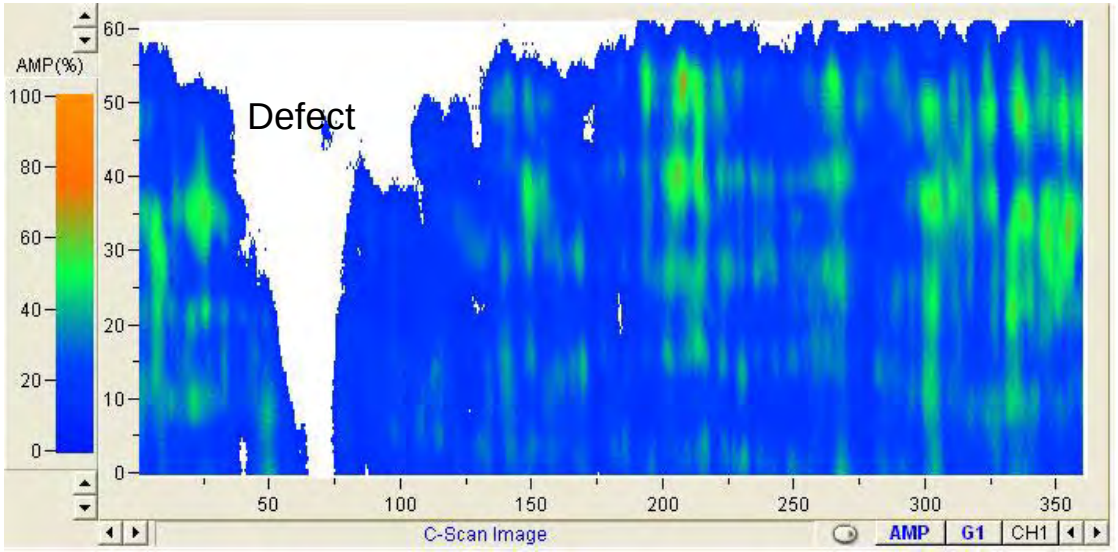


C-Scan Reflection Mode of Unknown Defect in Composite Layer

- Reflection mode: 0.5 MHz, dia. 0.75”, unfocused.
- Image size: 360 degrees by about 60.0 mm.
- Defect in composite layer can be detected.

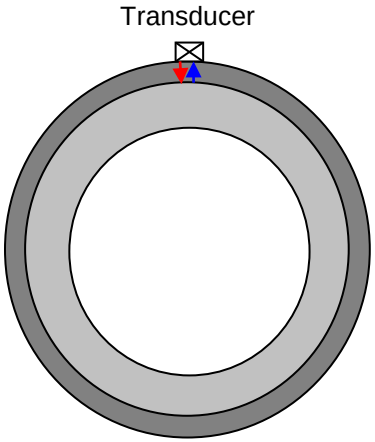


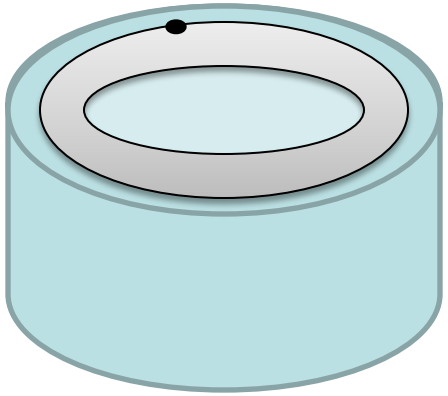


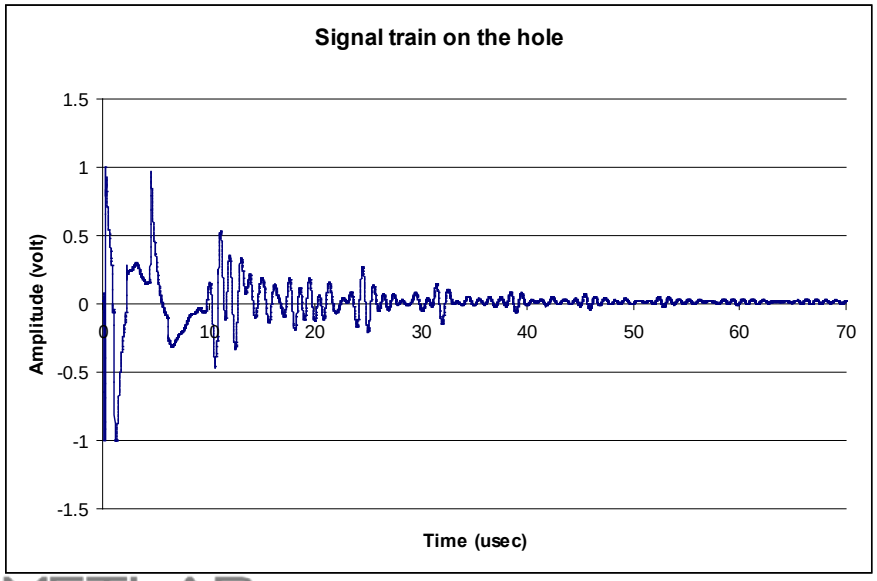


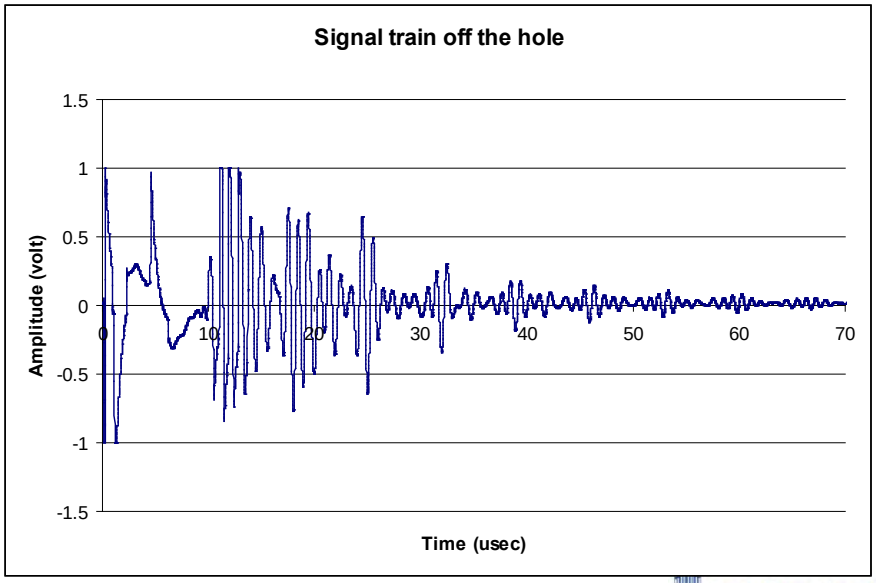
Inspection of Composite/Steel Interface

- Drilled hole: diameter 2.5 mm and depth 25.0 mm
- Transducer: Freq. 0.5 MHz, dia. 0.75”, unfocused.



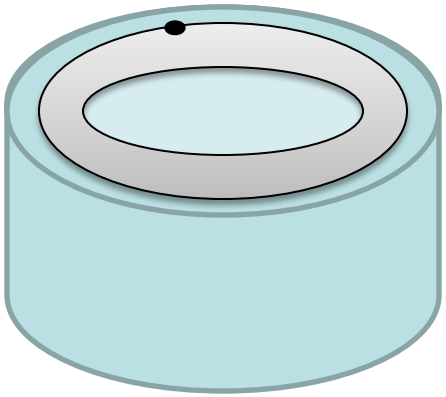


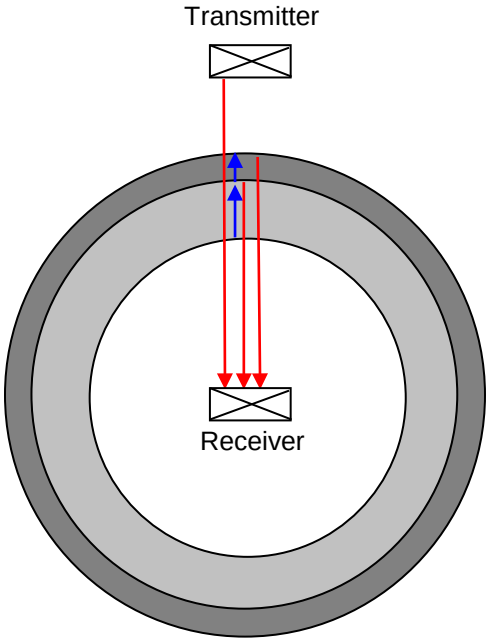


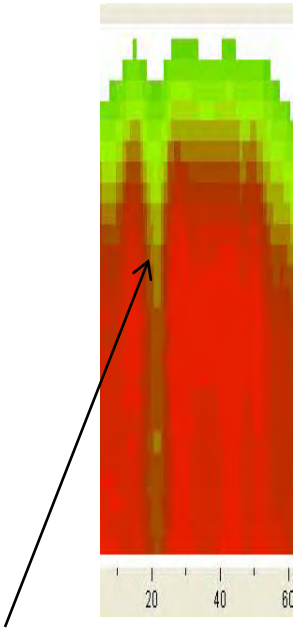


C-Scan Imaging of Composite/Steel Interface (1)

- The drilled hole can be imaged by ultrasound C-scan transmission mode.



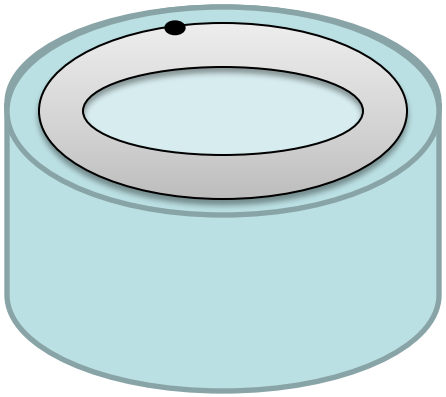


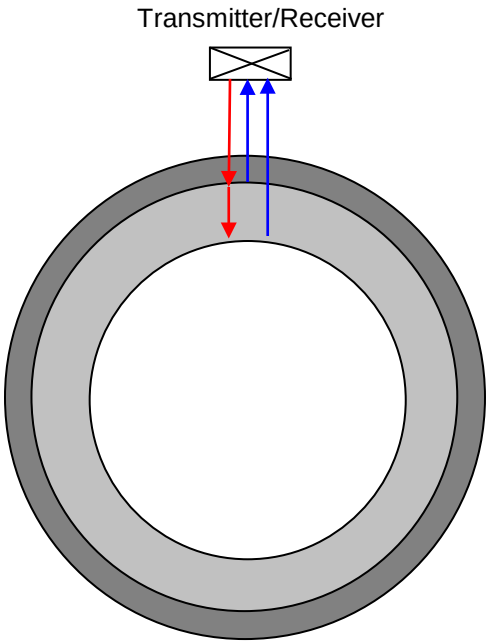


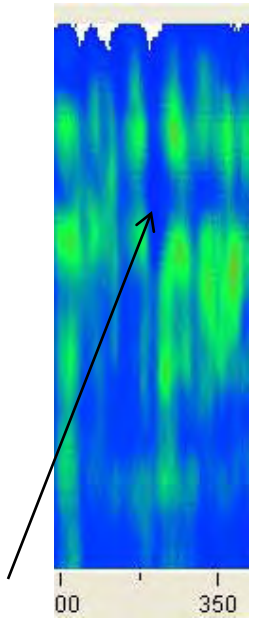
Hole

C-Scan Imaging of Composite/Steel Interface (2)

- The drilled hole can be barely detected with reflection mode.



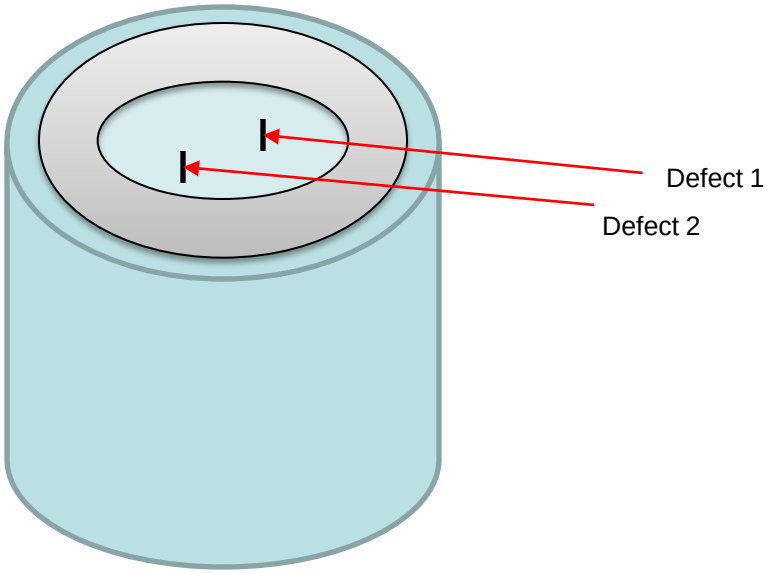




Hole

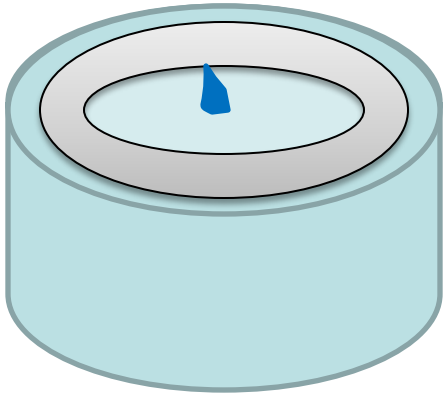
Ultrasound Guided Wave for Steel Surface Inspection

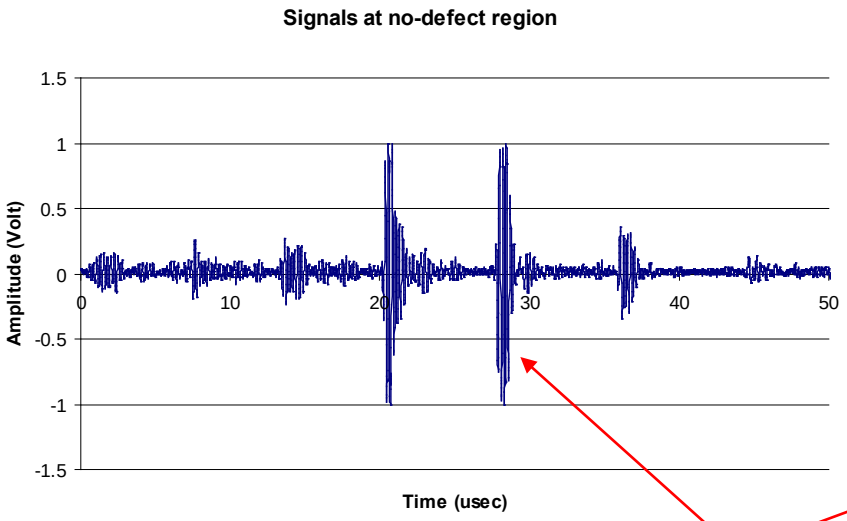
- The above C-scan technique failed to detect two small steel surface defects: defect 1 at 70 mm from edge and defect 2 at165 mm from edge.
- Ultrasound guided wave technique with angle beam transducer is applied.
- Various frequencies and incident angles were tested.

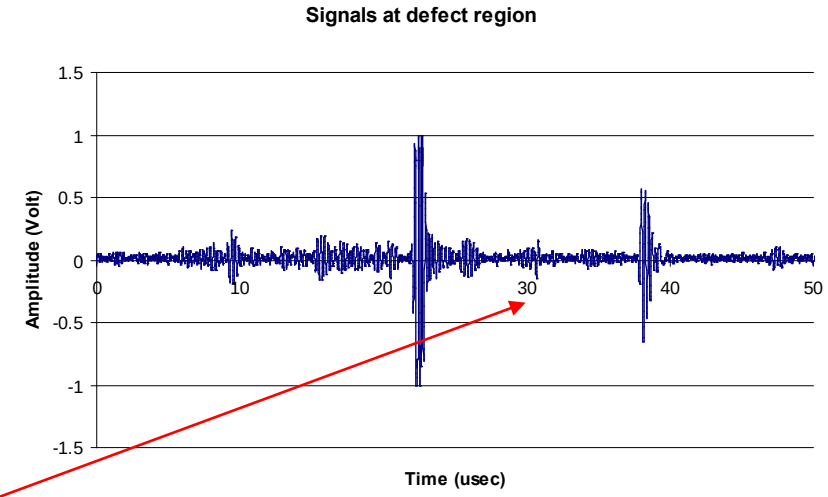


Ultrasound Guided Wave for Known Defect

- Ultrasound system: Pocket UT^{TM} system
- Transducer: 3.5 MHz
- Wedge: 60^0
- Detection direction: axial direction



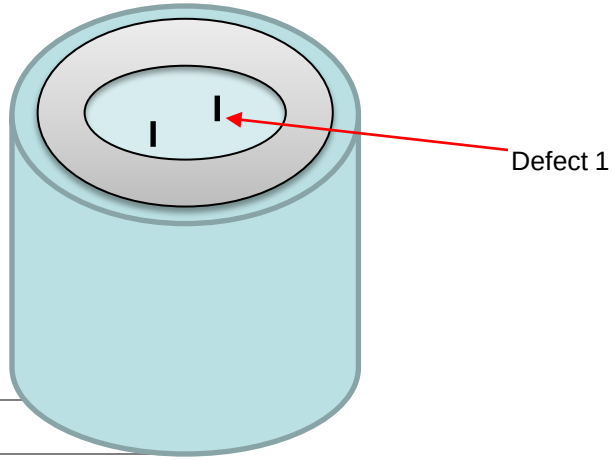


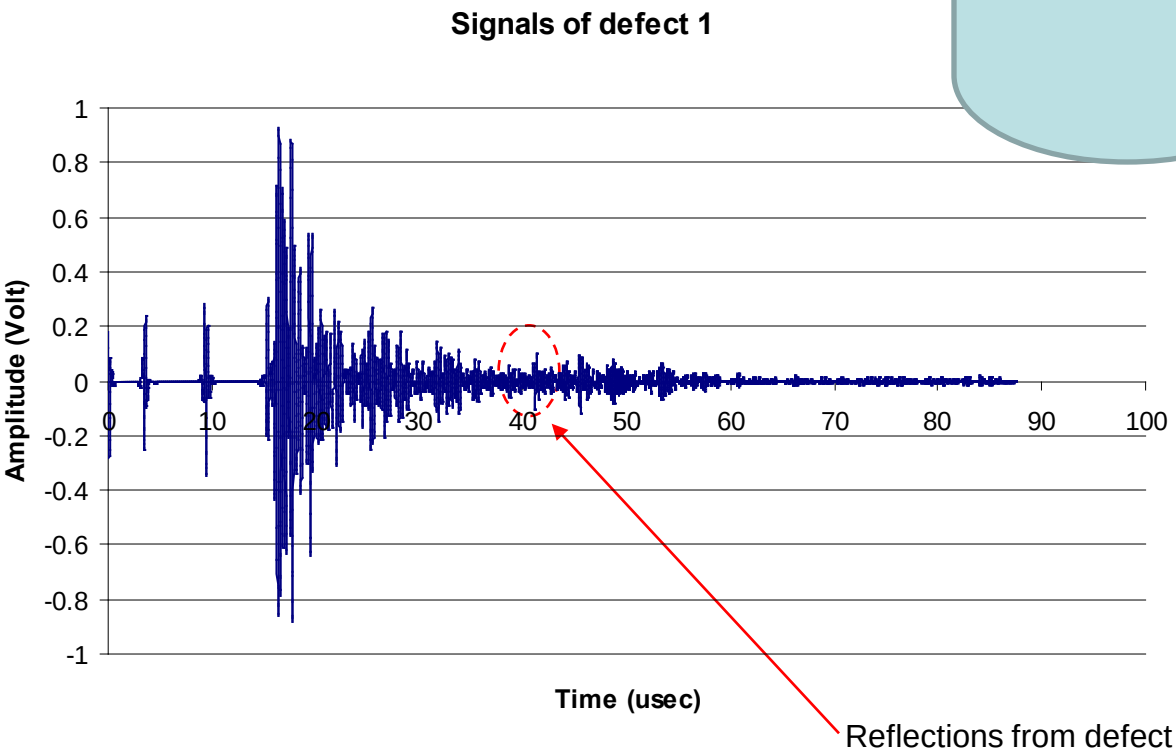


Difference

Ultrasound Surface Wave for Surface Defect (1)

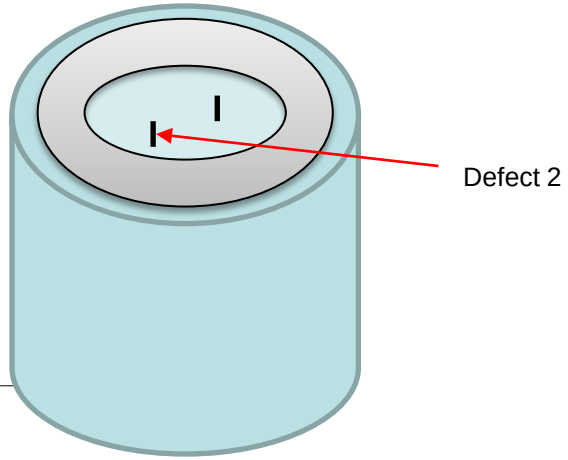
- Ultrasound system: Pocket UT^{TM} system
- Transducer: 3.5 MHz
- Wedge: 90^0
- Detection direction: axial direction

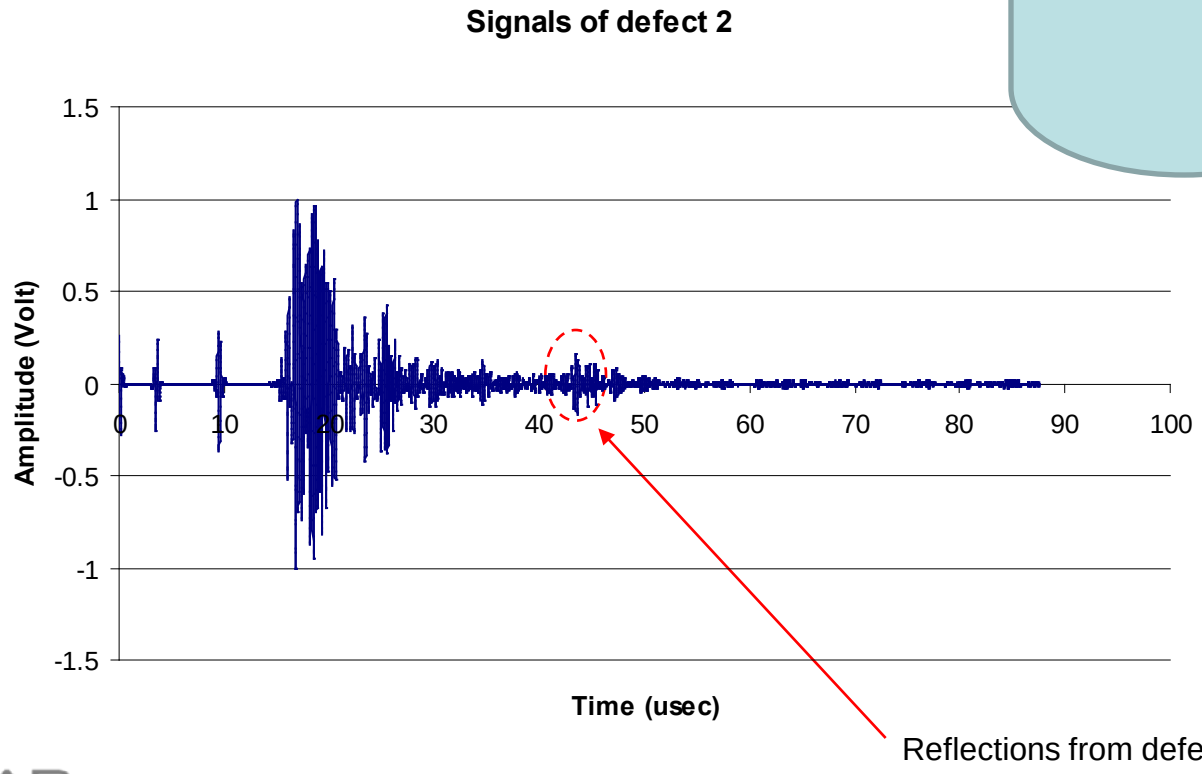




Ultrasound Surface Wave for Surface Defect (2)

- Ultrasound system: Pocket UT^{TM} system
- Transducer: 3.5 MHz
- Wedge: 90^0
- Detection direction: axial direction



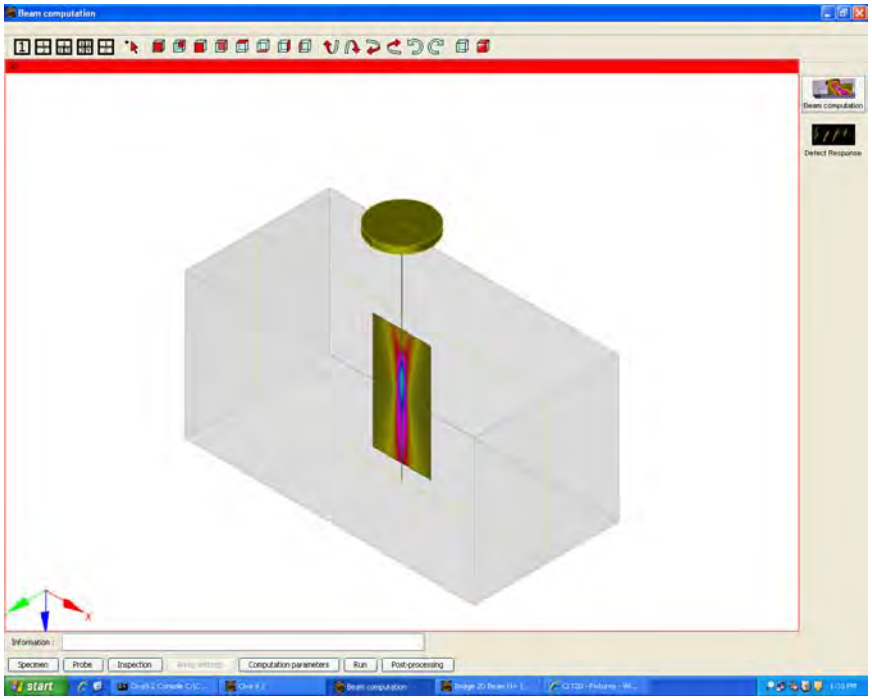


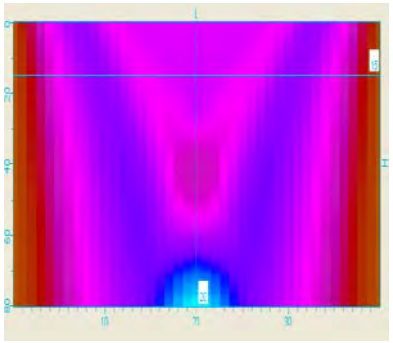
Summary of Experimental Results

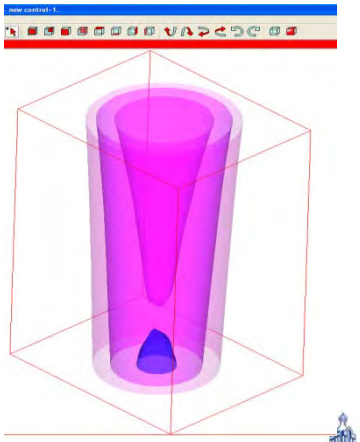
- Defects in both steel layer and composite layer can be imaged by ultrasound C-scan technique.
- Dia. 2.5mm drilled hole can be imaged with ultrasound C-scan transmission mode, but cannot be detected with ultrasound C-Scan reflection mode.
- Because of the high acoustic attenuation caused by the composite layer, ultrasound frequency at about 1.0 MHz is applied.
- Ultrasound guided wave with 60^0 angle beam transducer is suitable for detecting defects from long distance.
- Ultrasound surface wave with 90^0 angle beam transducer is sensitive to surface small defects which may be difficult for C-Scan imaging technique.

Ultrasound Simulation with CIVA

- CIVA is an ultrasound simulation software that can simulate acoustic wave propagation and its interaction with flaws.
- CIVA can simulate with both single element acoustic sensor and phased array acoustic sensors

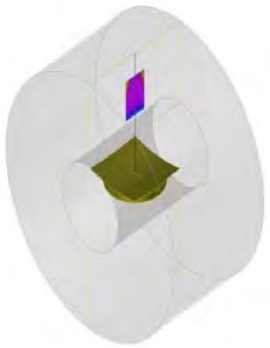


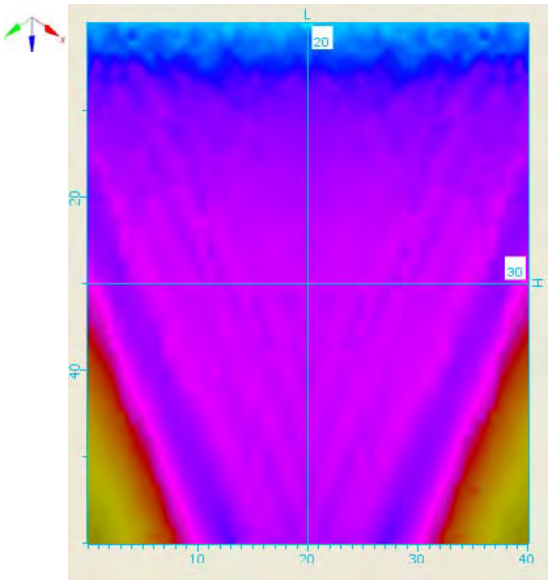


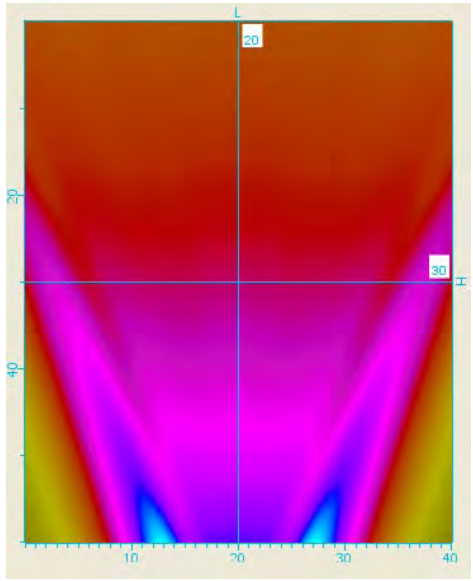


Ultrasound Simulation with Cylindrical Structure (1)



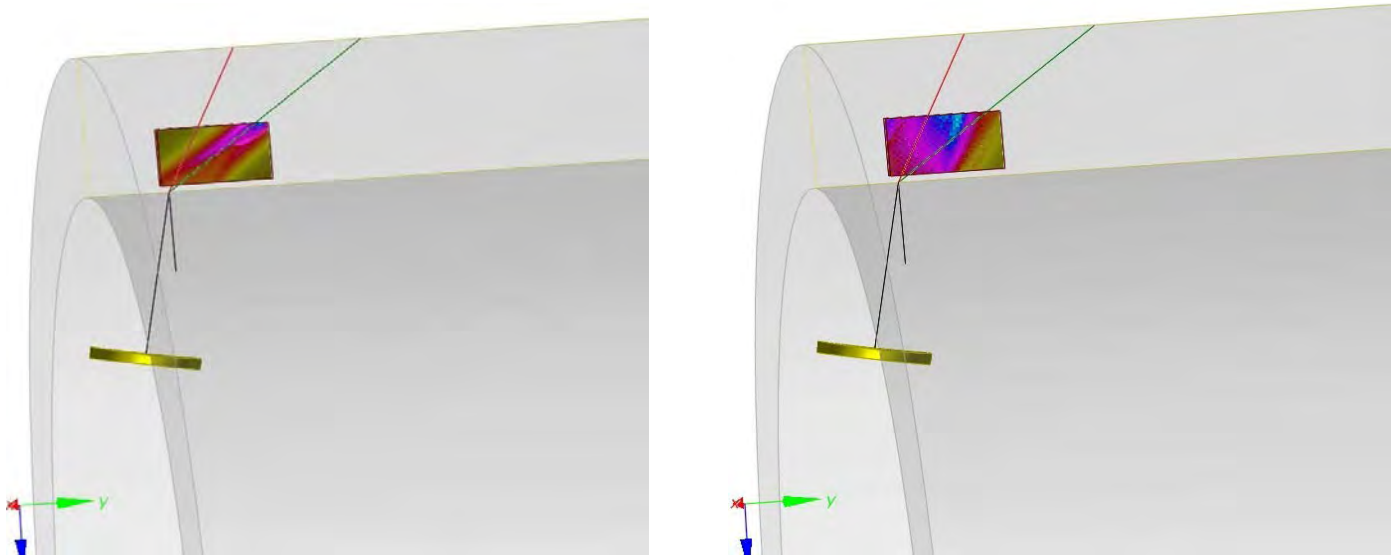




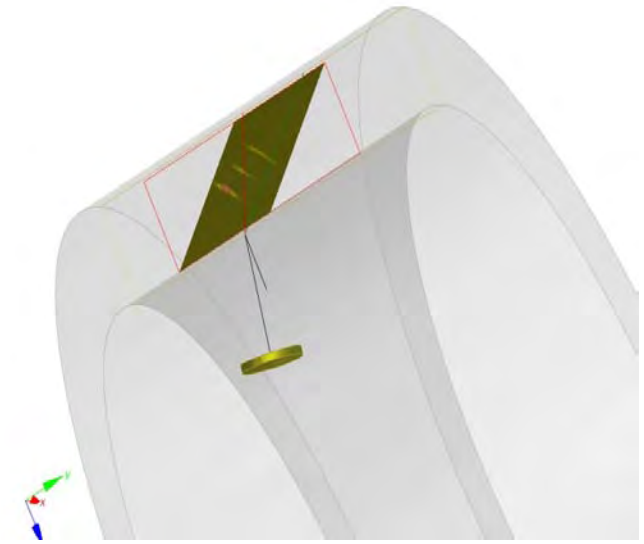


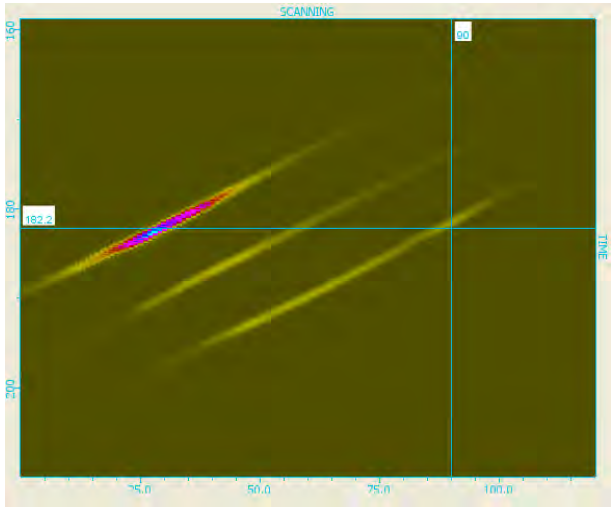
Ultrasound Simulation with Cylindrical Structure (2)

- Longitudinal and shear wave test configuration for a cylindrical structure



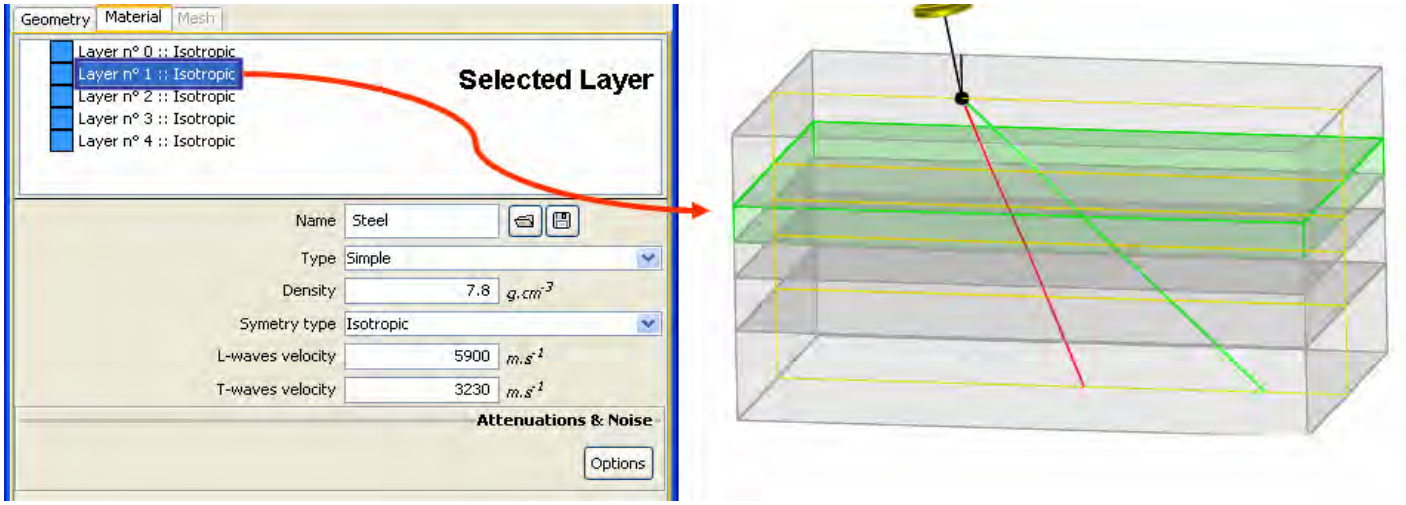
Ultrasound Simulation of Flaw Responses





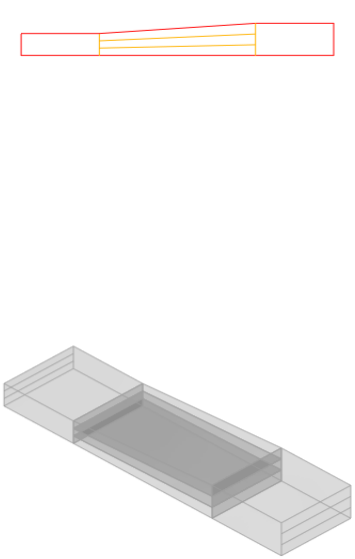
Ultrasound Simulation with Composite Materials (1)

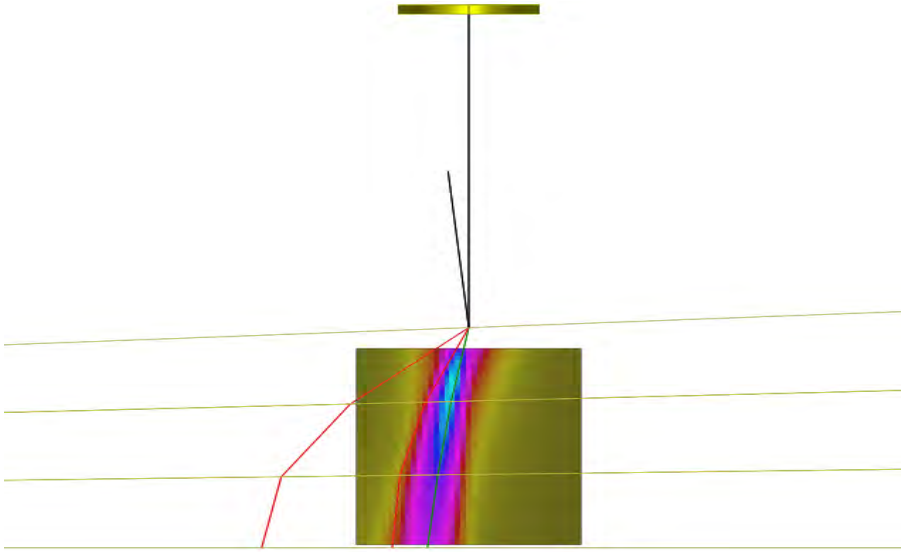
- Orientation and elastic properties of each composite layer can be determined.



Ultrasound Simulation with Composite Materials (2)

- Acoustic attenuation and beam bending can be simulated.

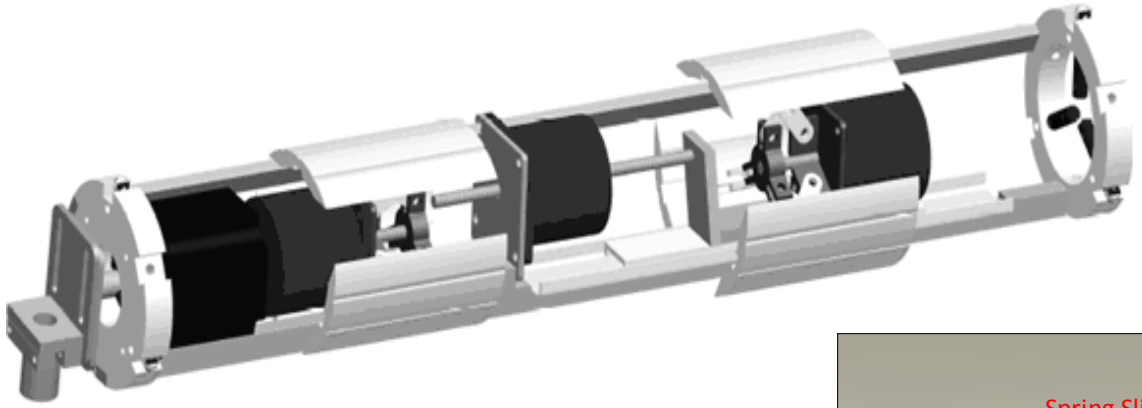


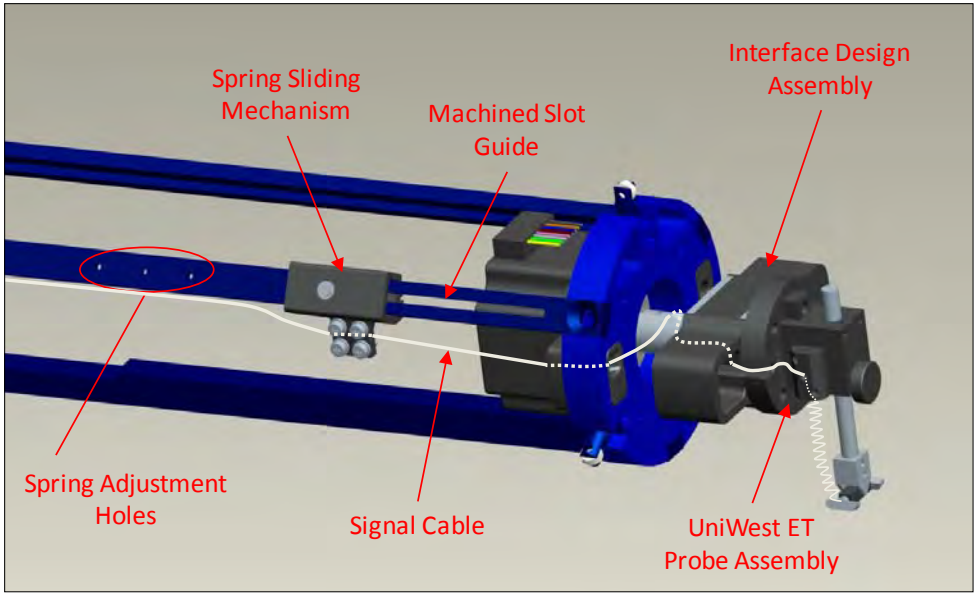


Conclusions

- Various ultrasound techniques have been applied for the evaluation of various types of defects in composite wrapped cylinder.
- The high acoustic attenuation caused by composite can be improved by low ultrasound frequencies, but this needs to be further studied.
- CIVA theoretical simulation may help to understand the ultrasound propagation in cylinder, and to optimize experimental parameters.
- Further quantitative comparison of CIVA simulation and experiments is necessary to improve the sensitivity of ultrasound inspection.
- Other NDE techniques, such as eddy current technique and ultrasound phased array technique, also have the potential for on-site evaluation of cylinders.

Portable Inspection System





Thank You!

Pyrotechnic Shock Loading of the M82 Percussion Primer in the M777 Light Weight Howitzer Magazine Assembly

Presented to the NDIA Joint Armaments Conference May 2010

Co-Authors

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- Kathryn Hunt, Chemical Engineer, USMC MARCORSYSCOM, PM Ammo
- Mr. Victor Hugo, Mechanical Engineer, NSWC Crane, Detachment Fallbrook, ESED
- Mr. Jon Conner, Senior Scientist, National Technical Systems, Dana Point, CA
- Mr. Caleb Bell, Program Manager, National Technical Systems, Camden, AR

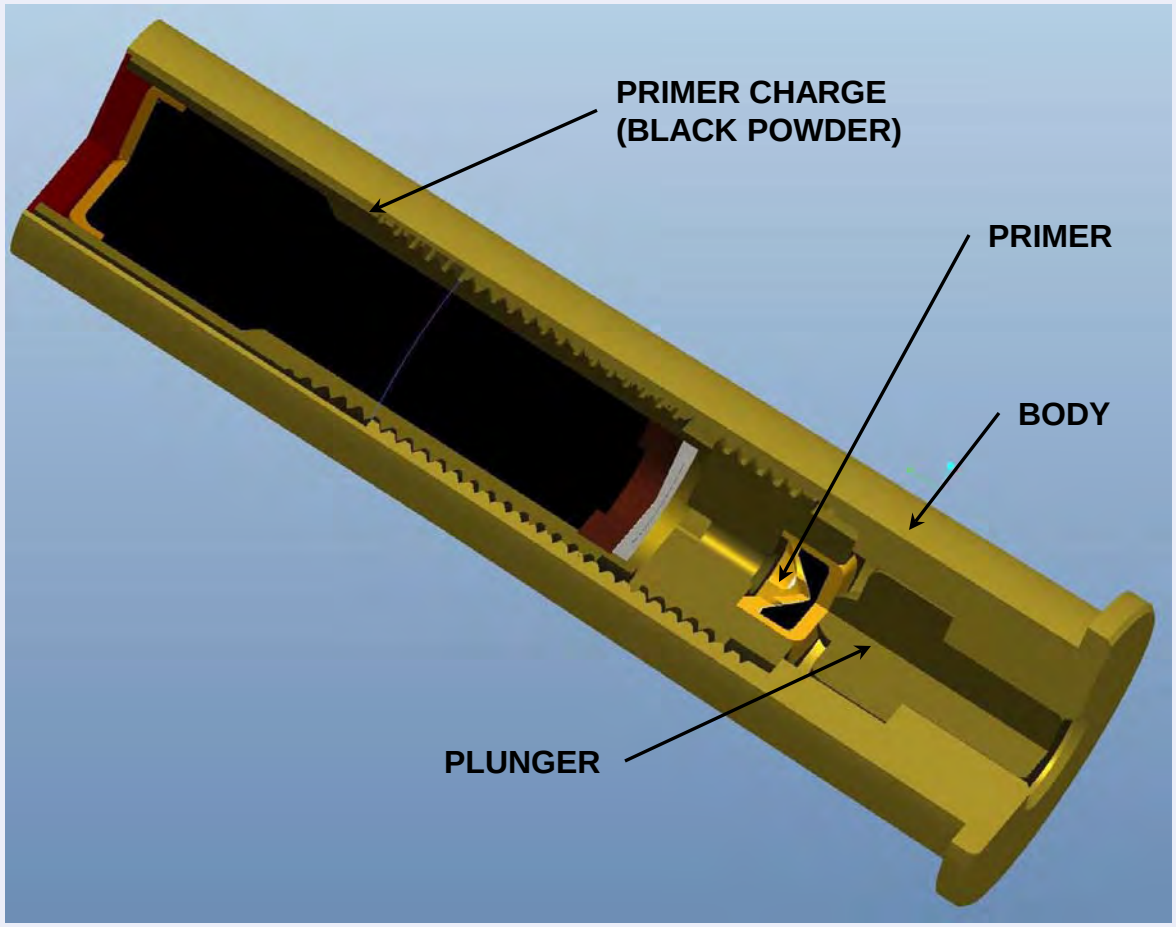
Pyrotechnic Shock Loading of the M82 Percussion Primer in the M777 Light Weight Howitzer Magazine Assembly

- Background
  - M82 Percussion Primer Description and Design
  - M777 Primer Feed Mechanism
  - Premature Primer Functioning Observations
  - Test Design and Objective
- Evaluation of Operational Loading of M777 Magazine Assembly
  - Instrumentation Description
  - Field Test Firing Schedule
  - Data Reduction/Signals Analysis
- Simulation of Operational Loading with Laboratory Shock Tests
  - Baseline Sensitivity Test
  - Pyrotechnic Shock
  - Sine Burst
  - Drop Shock
- FEA and Test Results
- Summary and Conclusions

M82 Percussion Primer Description

- US Army and Marine Corps standard primer for the initiation of all 155mm Howitzers
- During functioning, black powder output ignites propelling charge
- On earlier Howitzers the primer was hand loaded into breach
- New Howitzer designs incorporate a mechanical loading assembly

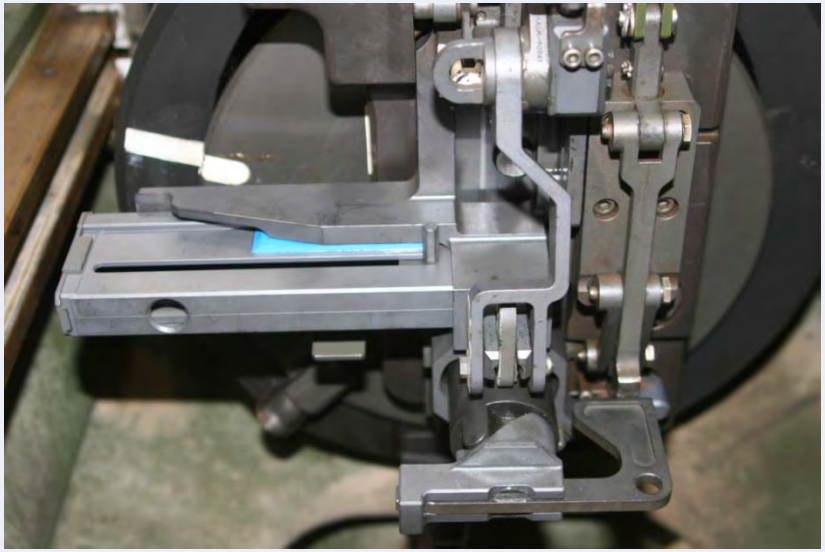
M82 Percussion Primer Design



M777 Howitzer Primer Feed Mechanism Description



PRIMER FEED AT
BREACH ASSEMBLY



PRIMER MAGAZINE
AND TRAY ASSEMBLY

Premature Primer Functioning

- During initial weapon testing, multiple primers functioned in the magazine during firing
- Field malfunctions associated with functioning of primers during chambering
- Primer is subjected to extreme forces associated to M777 firing
- Primer not designed to withstand these types of forces

Test Design and Objective

Understand the impact of M777 firing on the M82 primer

- **Measure forces associated with M777 firing**
- **Simulate these forces**
- **Condition M82 Primers to simulated forces**
- **Verify their functional performance and sensitivity**

Instrumentation Description

- 3 Each Endevco 2225M5A Piezoelectric Accelerometers (100,000 g's)
- Installed on Tri-axial Mounting Block
- Mounting Block Bolted to Top of Primer Magazine Assembly
- Cables Tied Down and Routed to Side of Gun System
- Endevco 133 Charge Amplifier
- LDS Genesis Digital Data Recorder
  - 125 kHz Sampling Rate



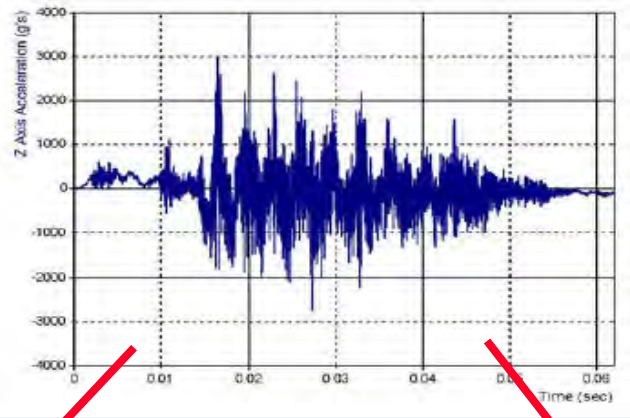


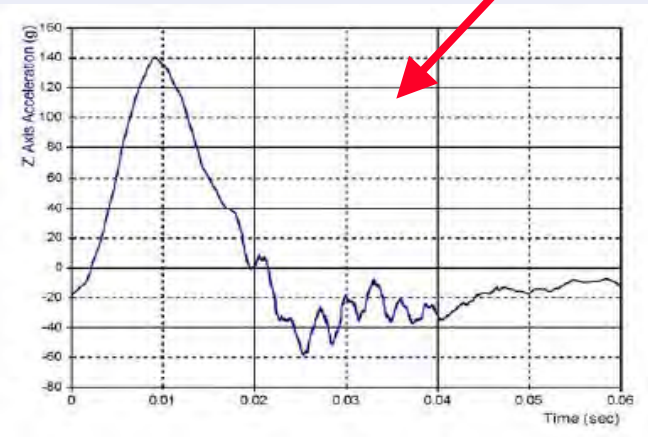
Field Test Firing Schedule

Round Numbers	Projectile	Fuze	Propelling Charge
1-4	M795 HE	M739A1	MACS at Increment 5
5-8	M795 HE	M739A1	M203A1
9-12	M107 HE	M739A1	M4A2 White Bag - Charge 7

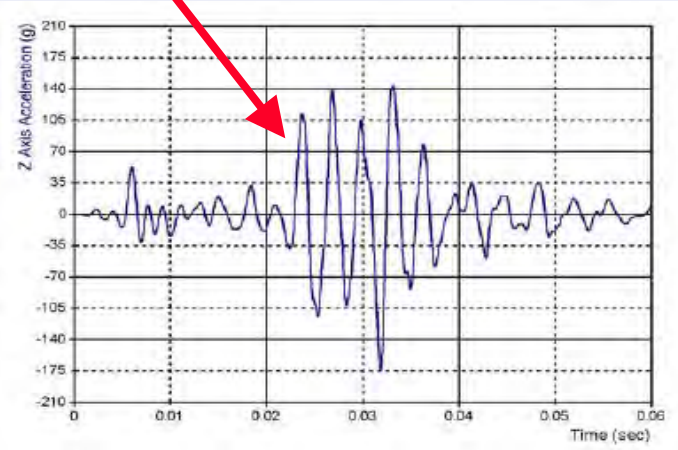
Data Reduction/Signals Analysis

Raw Accel Data – Z Axis



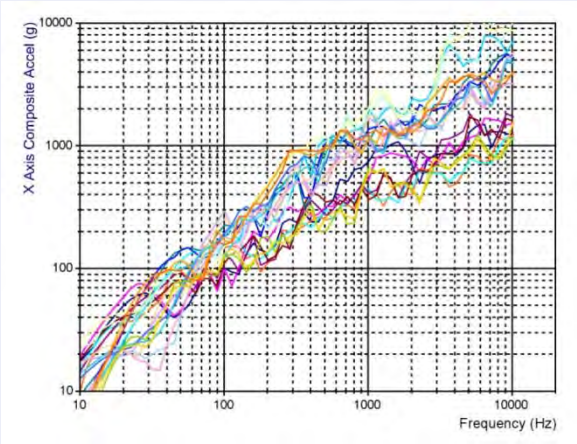


Smoothed

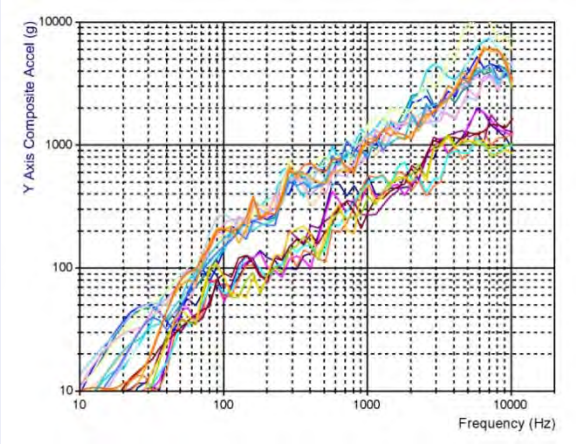


Band Pass Filter

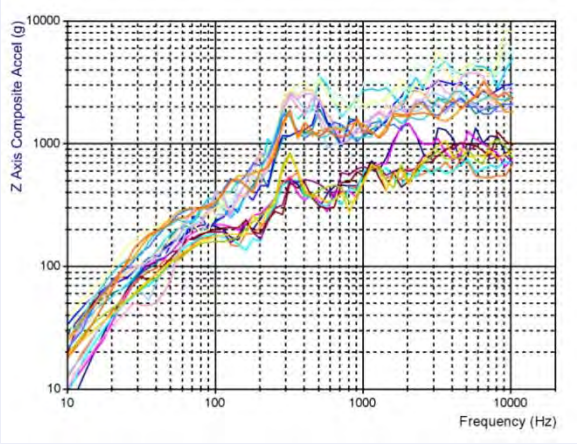
Composite Acceleration Shock Response Spectra



X Axis



Y Axis



Z Axis

Data Reduction/Signals Analysis Summary

- **Forces compromised of 3 distinct phenomena**
  - **Shock associated with propellant combustion**
  - **Harmonics associated with projectile travelling down barrel**
  - **Recoil force**

Data Reduction/Signals Analysis - Conclusions

- **Laboratory simulation requires three techniques**
  - **Pyrotechnic Shock**
    - **Simultaneous in all 3 axes**
    - **Based on Composite SRS**
  - **Electro-Dynamic Shaker**
    - **250 Hz, 200 g Sine Burst in Z axis**
  - **Drop Test**
    - **200 g, 10 msec Half Sine Pulse in Z axis**

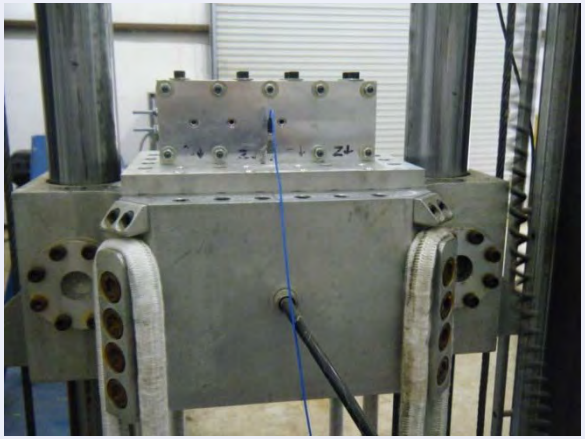
Simulation of Operational Loads – Test Methodology

- **Sensitivity Testing**
  - **Establish Baseline M82 Percussion Primer Lot Sensitivity**
  - **Evaluate Impact of Sequential Shock Testing on Sensitivity**
- **Shock Testing w/Test Fixtures to Replicate Tactical Magazine Interfaces**
  - **100 Primers Total**
  - **Replica Magazine Test Fixture Holds 10 Primers**
  - **9 Shock Replications Applied to Each Group Sequentially**
    - **Drop Shock**
    - **Pyrotechnic Shock Tests**
    - **Sine Burst Tests**

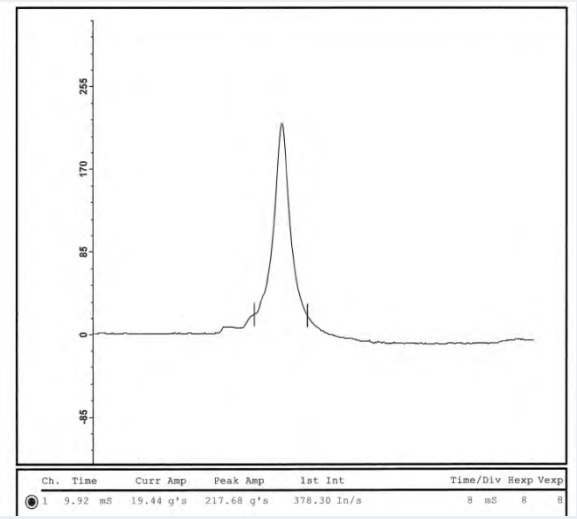
Drop Shock Testing



M82 Primers in Magazine Fixture

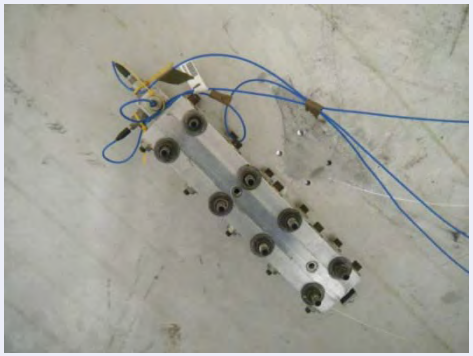


Drop Shock Test Setup

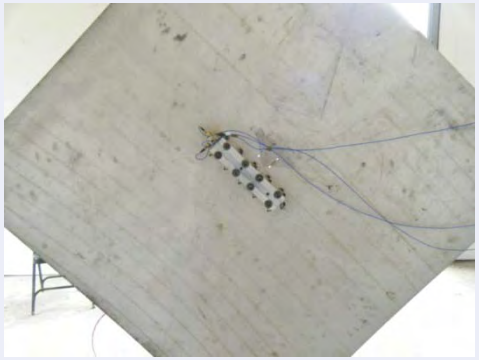


Accel Data – Z Axis

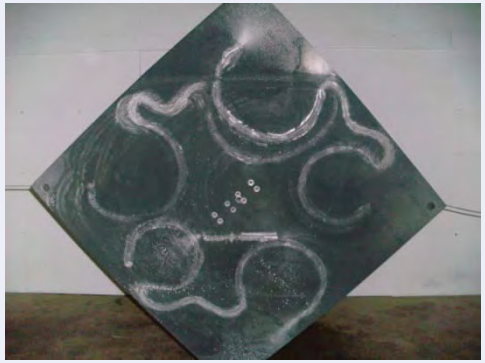
Pyrotechnic Shock Testing



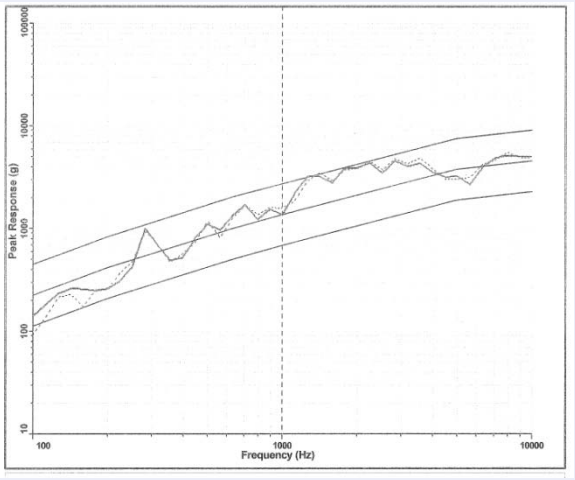
Magazine Fixture w/Accels



Magazine Fixture Mounted to Resonating Plate



Det Cord Patters for Pyroshock



Example +/- SRS Response Curve

Pyrotechnic Shock Testing
Premature Function of M82 Primer



Group 5 Pre-Test



Group 5 Post-Test

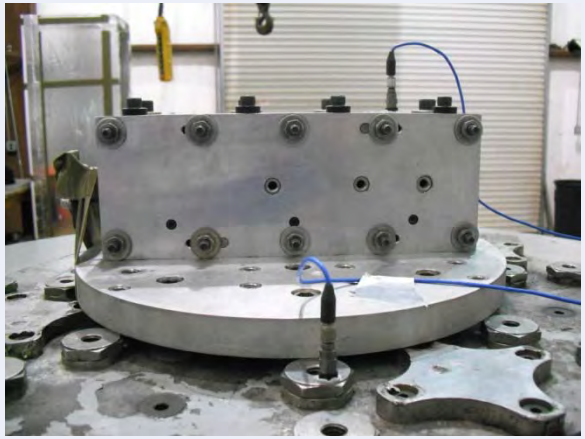


Group 5 SN 1 Premature Function
(overstress of force)

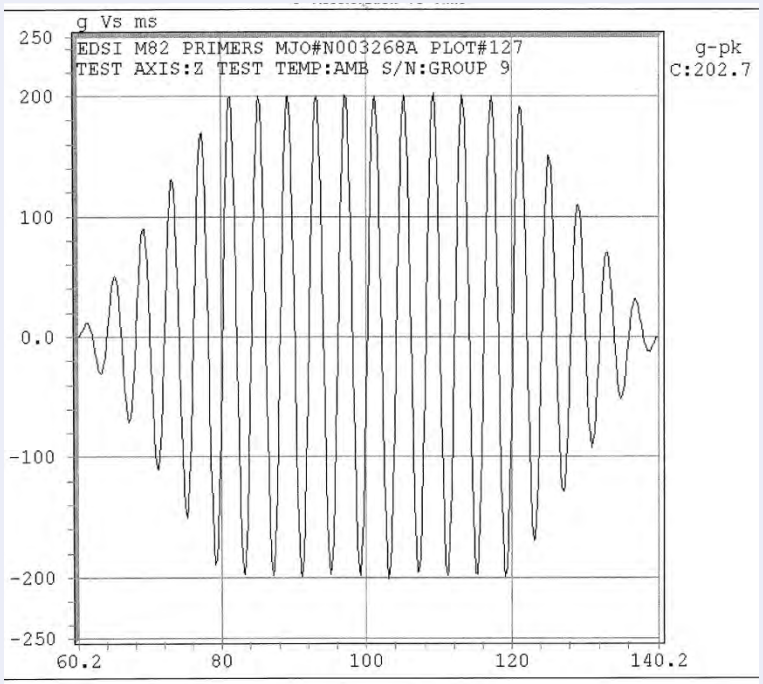
Sine Burst Shock Testing



Group 10 Pre-Test

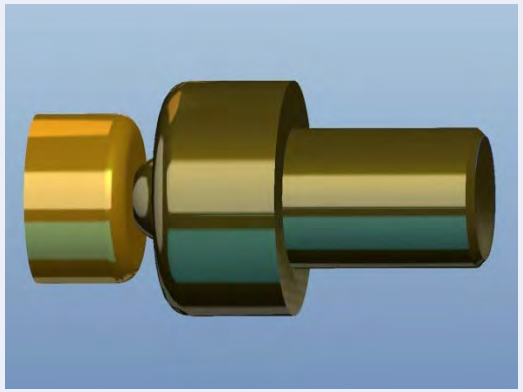


Electro-Dynamic Shaker Test Setup

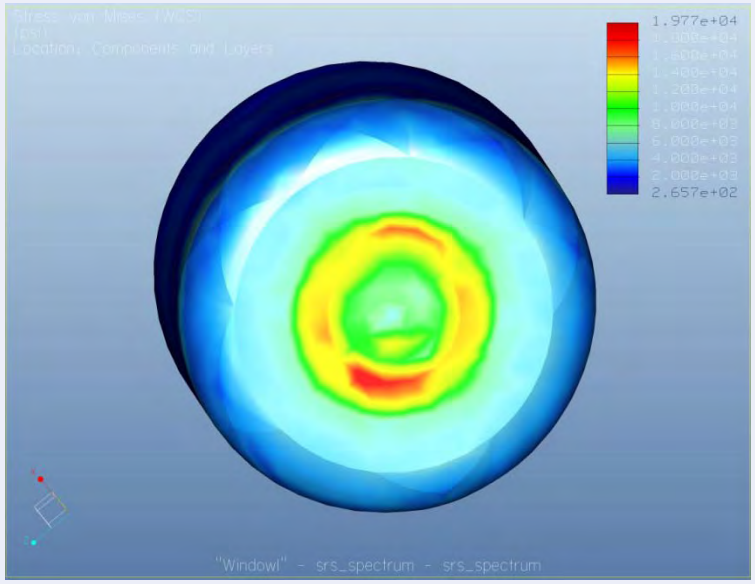


Example Response Accel Output

Dynamic FEA Analysis Results



Plunger/Primer Only Model:
Primer Cup Material Yield Strength Approx 17 ksi



Dynamic Shock Load	Max Von Mises Stress in Primer Cup (ksi)
Z Axis Pyroshock SRS	19.8
Z Axis Drop Shock	0.136
Z Axis Sine Burst	0.235

Summary and Conclusions

- Operational Loading of M82 Percussion Primers During M777 Firings Evaluated for Various Maximum Charge Configurations
  - Loading consists of three aspects: pyrotechnic shock, 250 Hz harmonic burst, and recoil shock
- Pyrotechnic Shock Loading is Most Severe Aspect of Operational Loads Based on Lab Tests and Dynamic FEA Analysis
  - Overstress induced premature function of primers
- Sensitivity testing of conditioned primers in progress

Automated Projectile Design Software

Mark Steinhoff
Arrow Tech Associates



Projectile Design

- Ballistic Projectile Design
  - Performance Specs
  - System Interface
  - Candidate Design
    - Mass Properties
    - Aerodynamics
    - Ballistic Effectiveness
    - Payload Effectiveness

Projectile Design

- Ballistic Projectile Design
  - Performance Specs
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  - Candidate Design
    - Mass Properties
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    - Ballistic Effectiveness
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- Guided Projectiles
  - Same as ballistic plus
  - Control mechanisms
  - Sensors
  - Autopilot
  - Guidance strategy

Mission

- Ballistic Mission
  - How often will you hit the target (P_h)
  - When you hit it, what is the likelihood of a kill ($P_{k/h}$)

Mission

- Ballistic Mission
  - How often will you hit the target (P_h)
  - When you hit it, what is the likelihood of a kill ($P_{k/h}$)
- Guided
  - Same as Ballistic, plus
  - Remove system errors
  - Trajectory shaping
    - Glide for extended range
    - Dive to clear obstacles or for lethality

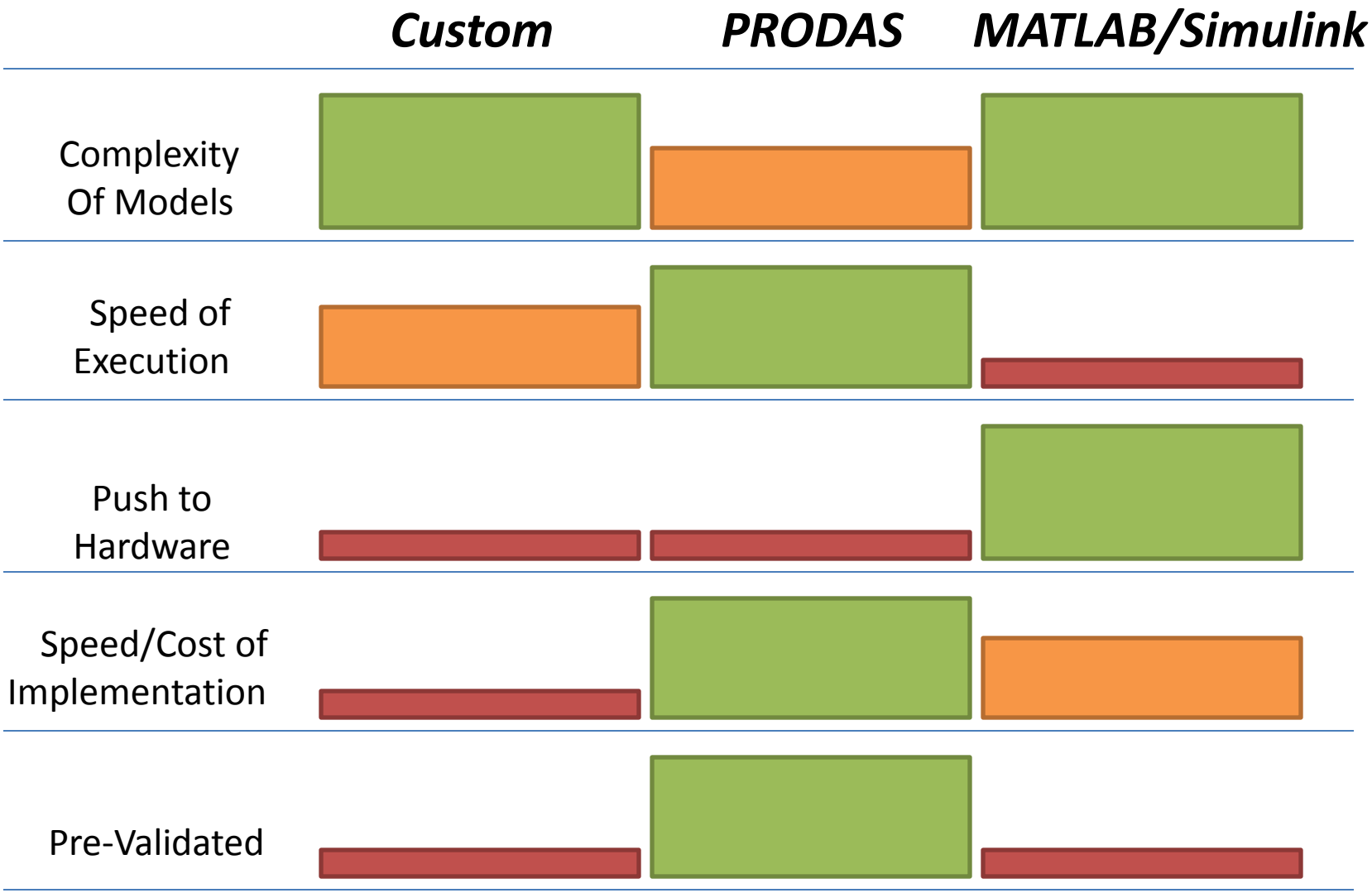
Bottom Line

- You now have to:
  - Design the projectile
  - Decide on a control mechanism
  - Design the auto pilot
  - Implement a Guidance strategy

Commercial/Military Projectile Design Tools

- Custom/Proprietary Software
  - Developer uses different analysis modules handing off data from one to the other
  - Stand alone modelers
    - Model building (PRO-E or Solid Works)
    - Aerodynamic estimation (CFD, Missile DATCOM, MILS3 or AP)
  - Simulation codes
    - Hand coded custom solutions
    - Typically Project A evolves into Project B evolves into Project C
- PRODAS
  - Legacy codes embedded into an integrated software system
  - Validated simulations
  - Macro language
- MATLAB/Simulink
  - Like Legacy Simulation codes except within an environment
  - Pre-built simulation blocks and integration engines

Software Metrics

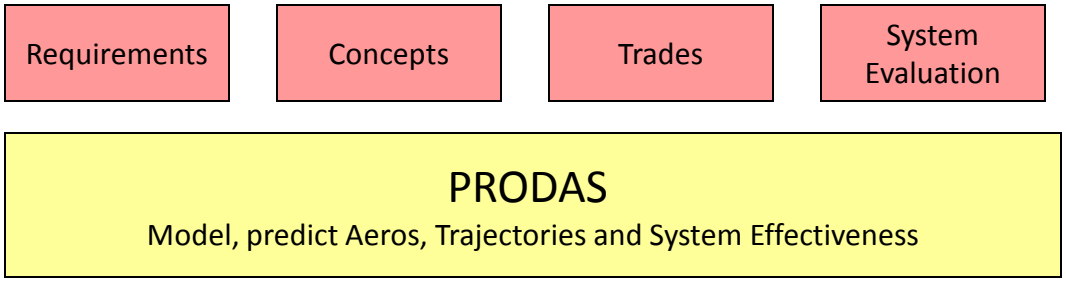


Smart Weapon Development Levels

- First Level - Conceptual Design Studies (Proposal)
  - For a Given Projectile, What Improvements in Performance Can be Obtained IF a Control Force and/or Moment is Available?
  - Simple to model and assess the Benefit of a Flight Control System
- Second Level - Detailed Design Studies (Design)
  - Perform Parametric Trade Studies to design the details of the Control Mechanism
  - Assess the Performance of a Smart Weapon
- Third Level - Final Detailed Design (Test)
  - At this Stage, Detailed Models of the Sensor Suite and Control Law are Included in Analysis
  - Models will include real time loop rates
  - Model should generate C code for embedded processors

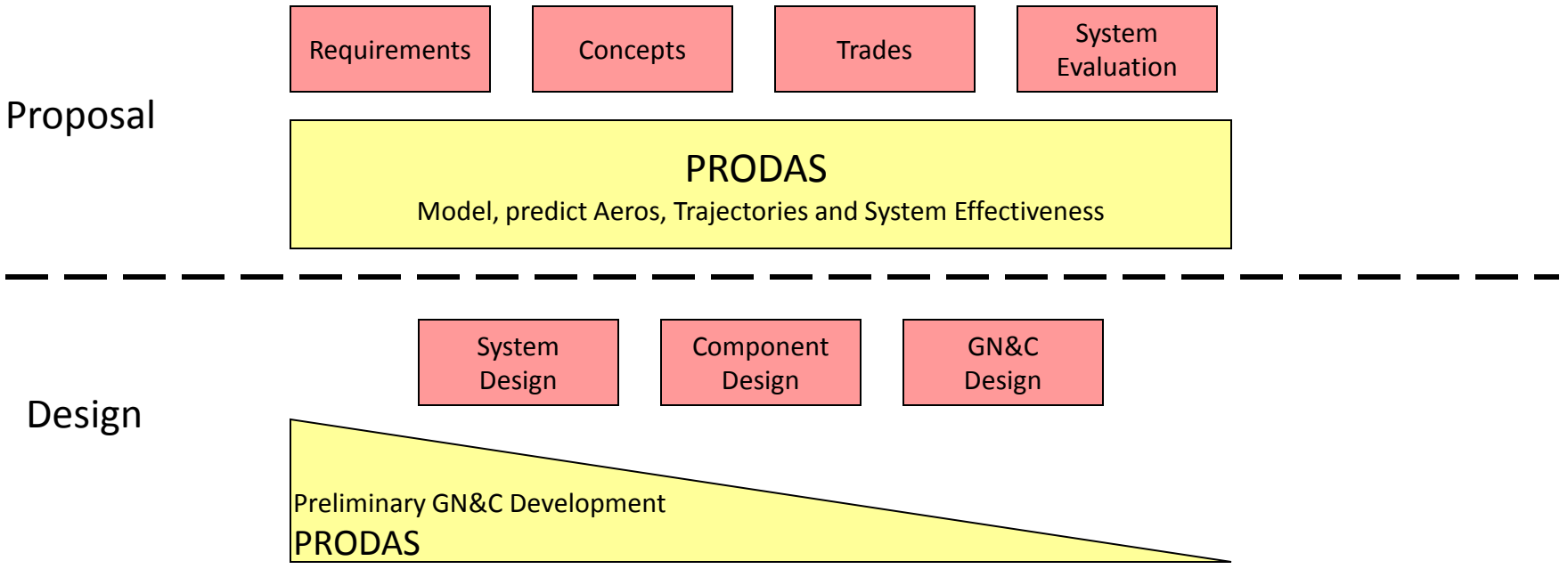
Guided Projectile Development Cycle

Proposal



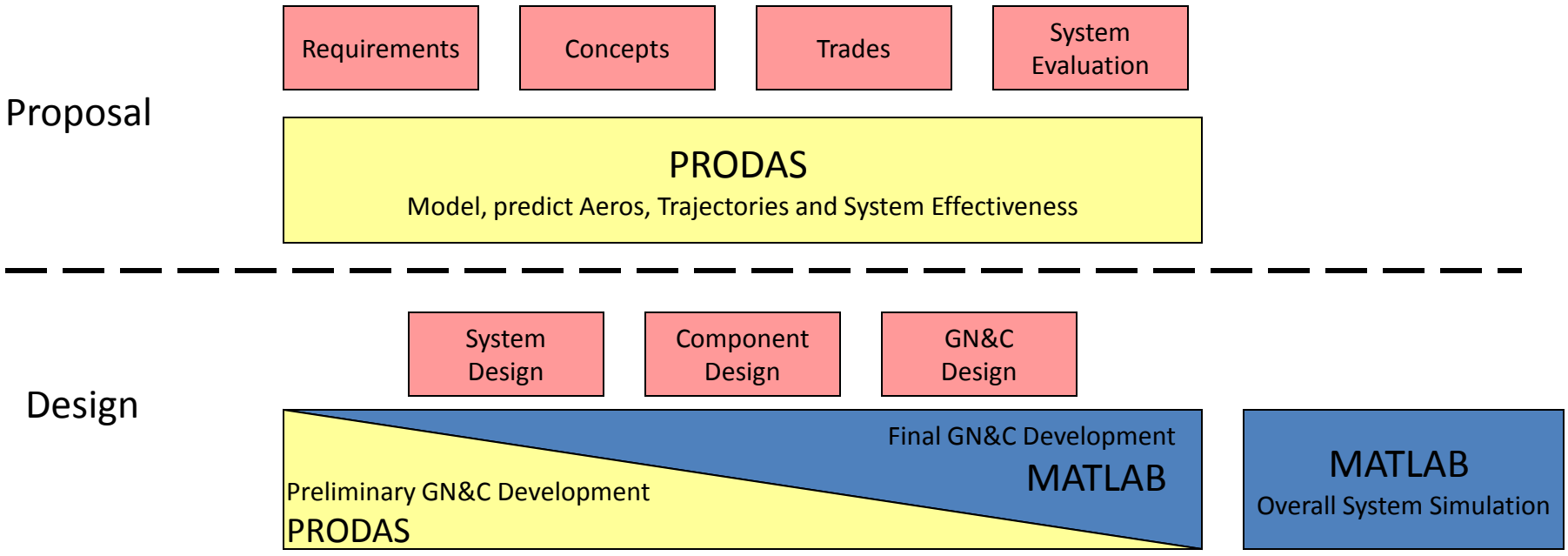
ARROW TECH

Guided Projectile Development Cycle



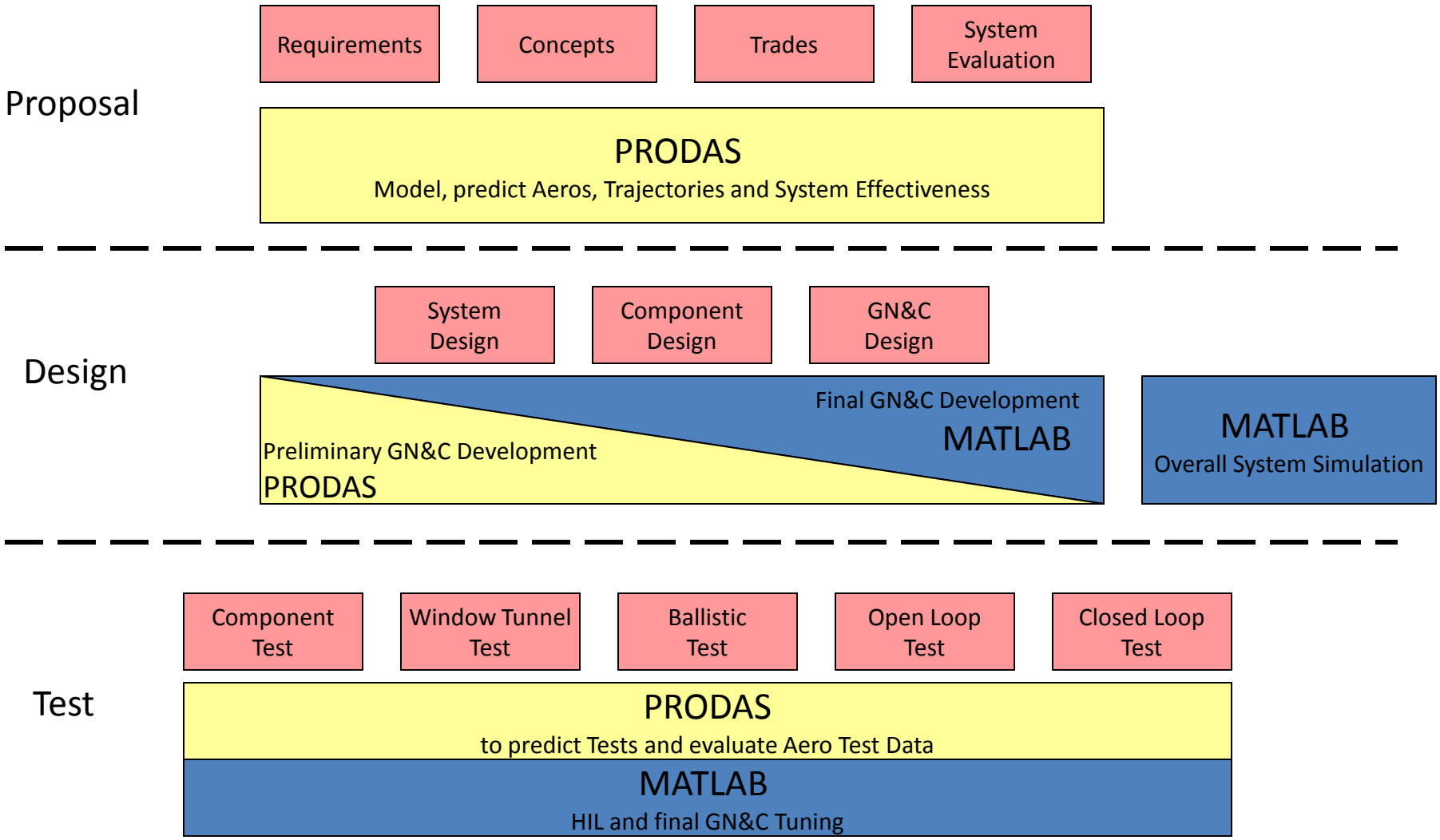
ARROW TECH

Guided Projectile Development Cycle



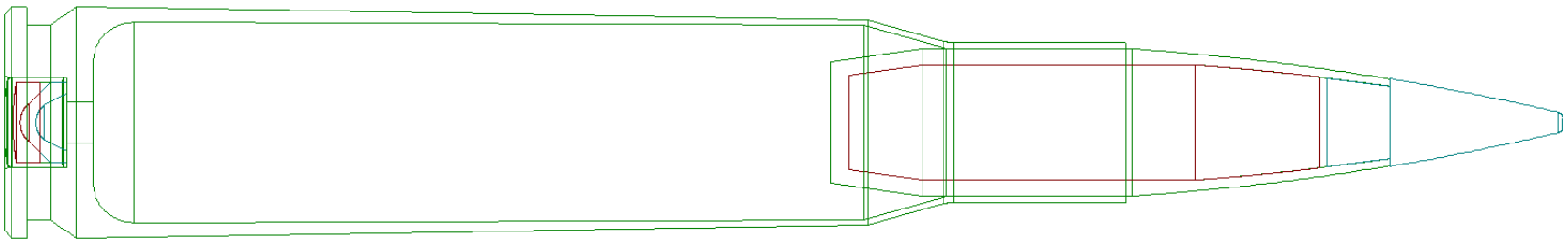
ARROW TECH

Guided Projectile Development Cycle



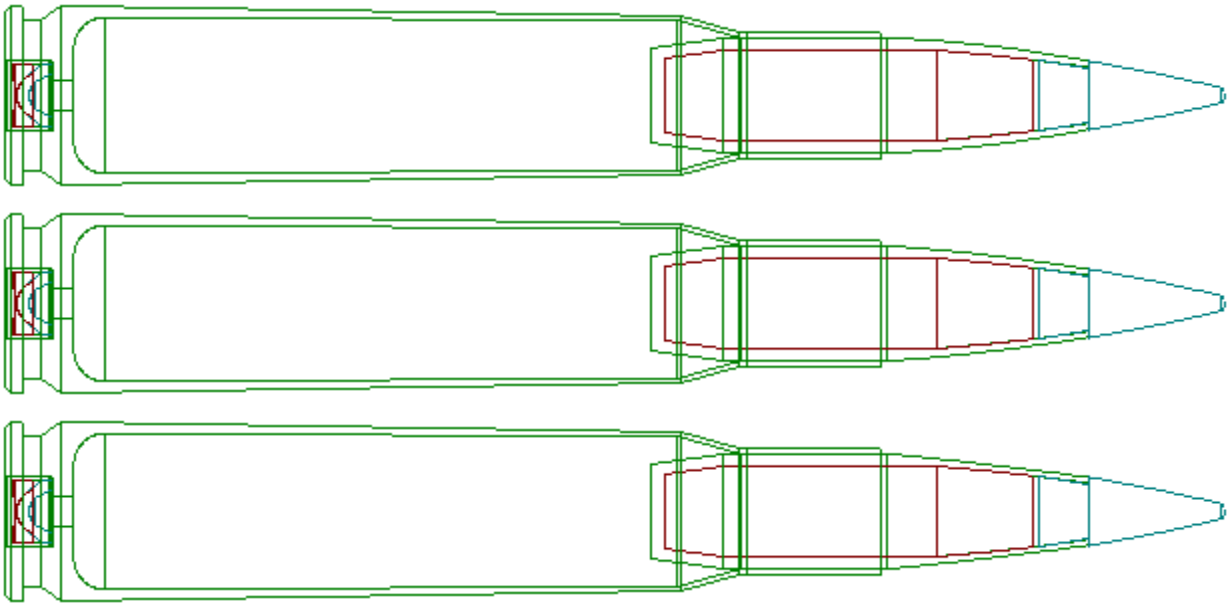
Example #1 Ballistic Projectile

- Design a 50 caliber projectile that will minimize wind sensitivity at 1000m
  - Start with basic shape
  - Vary boat tail length and Ogive length and shape



ARROW TECH

Subtle Changes to Ogive Shape



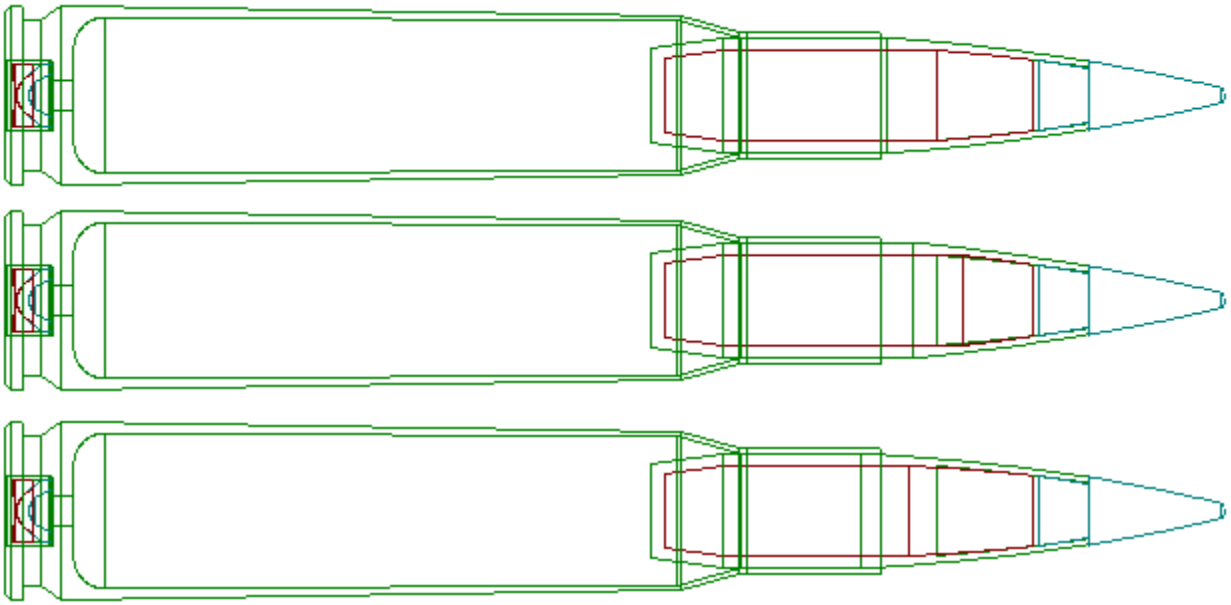
154mm radius

254mm radius

664cm radius

ARROW TECH

Not So Subtle Changes to Ogive Length



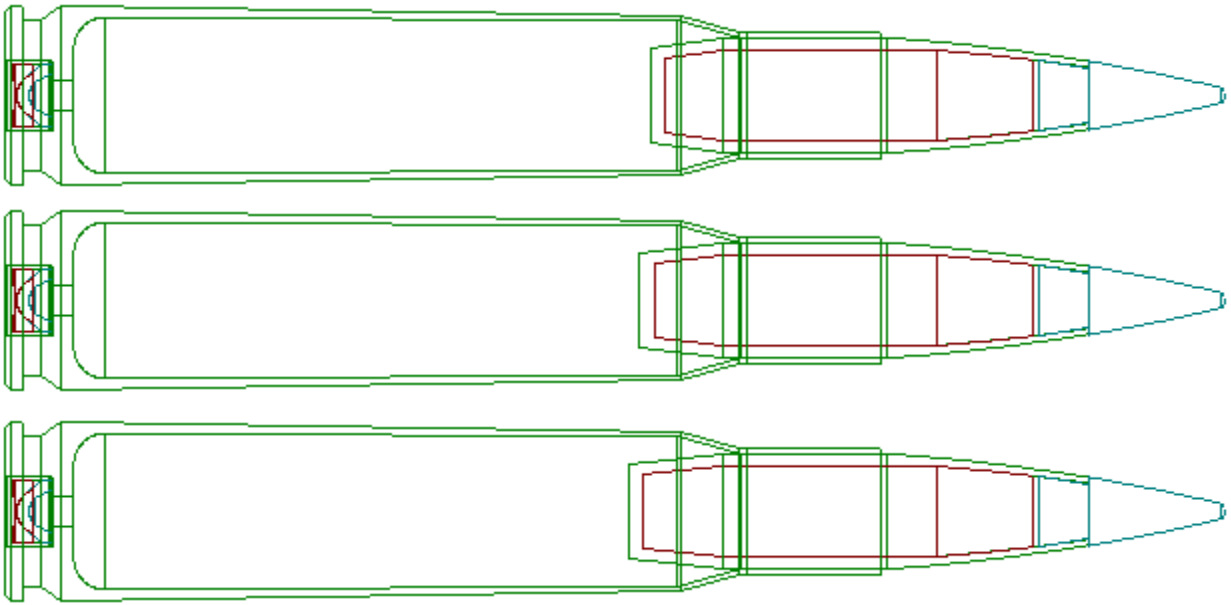
Standard

-3mm

+3mm

ARROW TECH

Not So Subtle Changes to Boat Tail



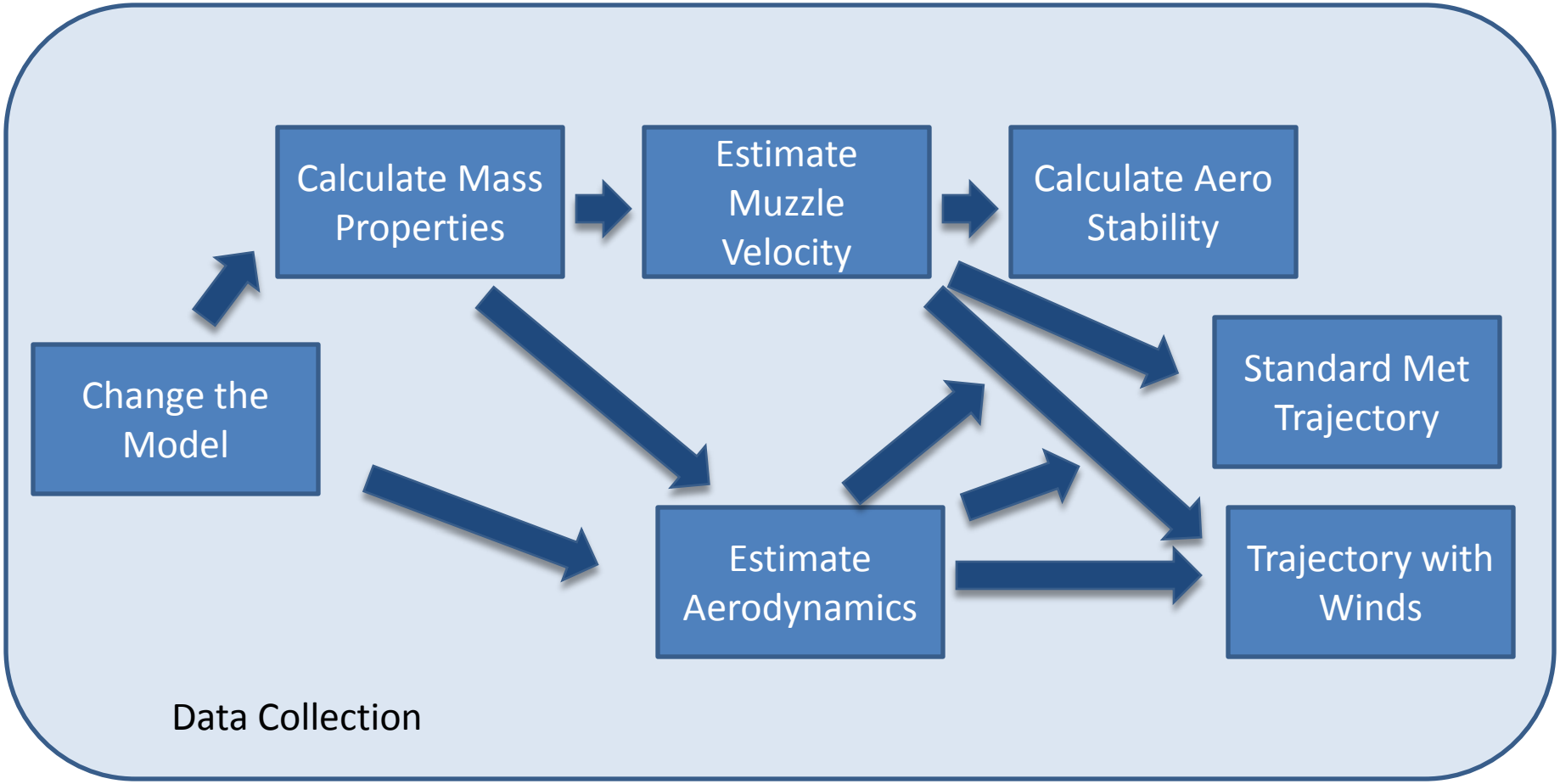
Standard

+15%

+30%

ARROW TECH

Analysis Map



ARROW TECH

Example #1 Metrics

- 27 designs evaluated
- 7 analysis modules executed
- 50 seconds run time
- 200 lines of PRODAS macro code
- 4 hours to develop
- 1 Excel file of results

- Results:
  - Decreased wind sensitivity by 7.6%
  - Some configurations increased by as much as 10%

Example #1 Extended Metrics

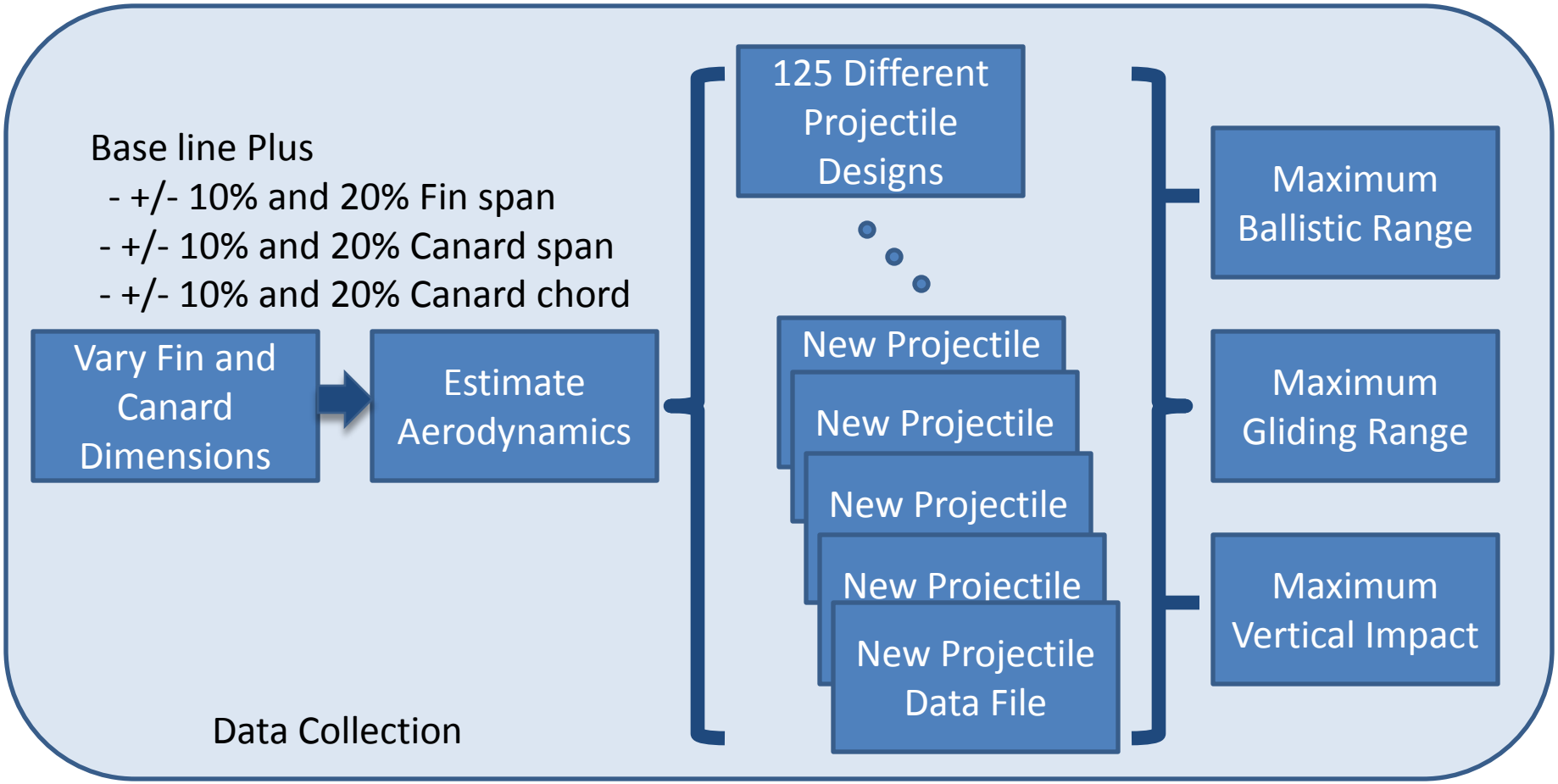
- Started with previous macro
- 125 designs evaluated
- 7 analysis modules executed
- 4 minutes run time
- 212 lines of PRODAS macro code
- 2 minutes to modify
- 1 Excel file of results

- Results:
  - Decreased wind sensitivity by 7.8%
  - Some configurations increased by as much as 25%

Example #2 Guided Projectile

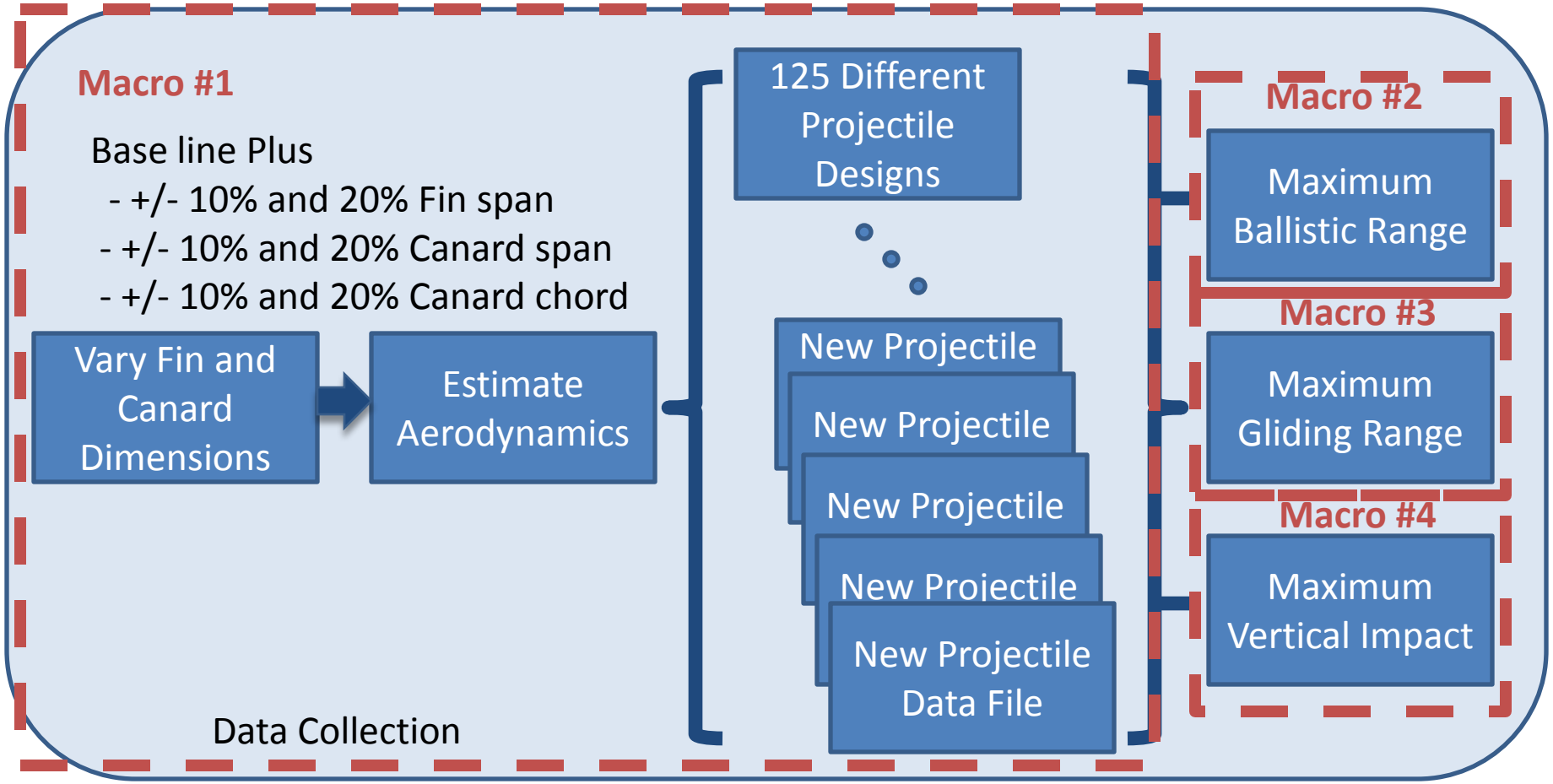
- Basic design of mortar body is fixed, evaluate different fin/canard designs to meet multiple requirements.
  - Find maximum ballistic range
  - Find maximum gliding range using open loop control
  - Find maximum target range with vertical impact using open loop control

Analysis Map



ARROW TECH

Macro Map



ARROW TECH

Guided Flight Macros

- Simple open loop canard controller embedded in the GN&C Prototype tool
- Maximum Gliding Range Macro
  - Macro to iterate these design variables:
    - Quadrant elevation
    - Time Glide on
    - Canard application level to limit total AOA
- Maximum Range with Vertical Impact
  - Macro to iterate these design variables:
    - Quadrant elevation
    - Time Glide on
    - Time Dive on
    - Canard application level to limit total AOA

Example #2 Results

- About half of the configurations unstable
- 40% met the ballistic requirement
- 15% met the extended range
- 8% met all the requirements

- Iterated this analysis with three different air frames

ARROW TECH

Conclusions

- Thorough ballistic development is tough
  - Automation lessens the burden
  - Guided projectiles are even worse
- Match the tool to the job
  - Where are you in the development cycle?
  - Fast or Detailed?
  - Do you have to validate the sims?

- Tools are readily available

Warfare has changed:

Research into performance and use of weapon systems and ammunition in Maritime Environment

NDIA Joint Armaments Conference (May 2010)

TNO | Knowledge for business



Outline

- Warfare has changed: operations in littoral areas
- Change in demands within RNLN: new ship classes
- Research topics
- Summary

Warfare has changed:
Transition from in the open ('Cold War role') …



Hunting Warschaupact Subs







CIWS



Warfare has changed:

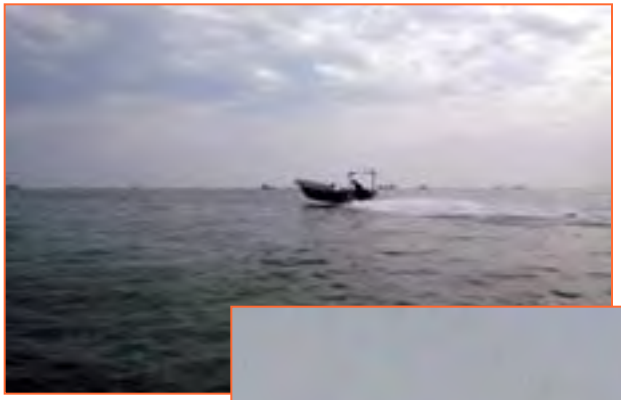
… to operations in littoral areas

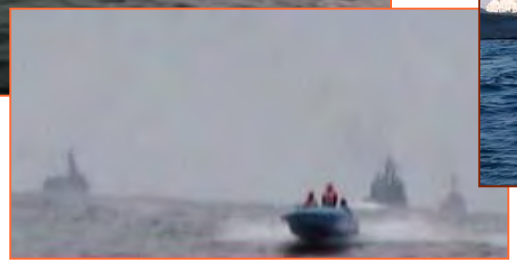














Anti Piracy



Coast guard & security

As a result: a change in requirements to the fleet

Introduction of two new ship classes in RNLN

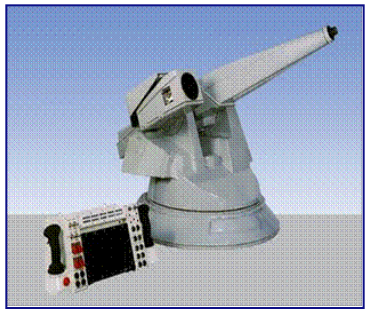
Off Shore Patrol Vessel
- 4 ship class
- low intensity conflicts
- **asymmetric** threat
- (2010 – 2012)

Joint Support Ship
- 1 ship class
- full violence spectrum with
- **asymmetric** component
- (2014)



As a result: a change in requirements to the fleet (II)

OPV : 1 * 30mm WS & 2 * .50 WS per ship
JSS : 2 * 30mm WS & 4 * .50 WS per ship


.50 WS

<u>Requirements for RCWS</u>

- Specific threat set
- 30 mm – preferable dual feed
- TV / IR / LRF
- Controls integrated in CMS


30mm WS

<u>Contract OPV</u> signed July 2008

- OTO Melara (It): 30mm MARLIN WS with Mk44
- Systems JSS as options

Task of platform

present → new

Weapon system / Ammunition type

present → new



















Research topics

1. Choice of Ammunition *vs* asymetric threat

<u>short term advice</u>

- Advice on first buy operational ammo
  - ✓ Off-the-shelf ammunition
  - ✓ No system modifications
- Limited budget & Quick
  - ✓ Use existing research data
  - ✓ Expert judgement

<u>long term advice</u>

- Full operational potential
  - ✓ Current & near future ammunition
  - ✓ System modifications allowed
- Bigger budget
  - ✓ detailed study
  - ✓ use of international agreements for data exchange

2. Self Defence Capability *vs* asymetric threat

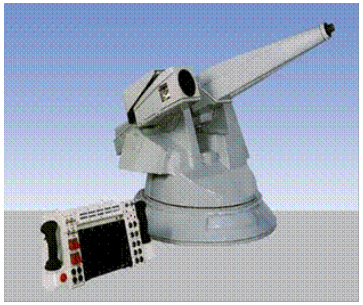
Advice on:

- Tactical guidelines
- Control from CMS
- Optimal allocation of tasks

Initial choice of ammunition for Offshore Patrol Vessels



- Objective: ‘ranking’ of ammunition type performance for possible use in 0.50” and 30mm WS of OPV.



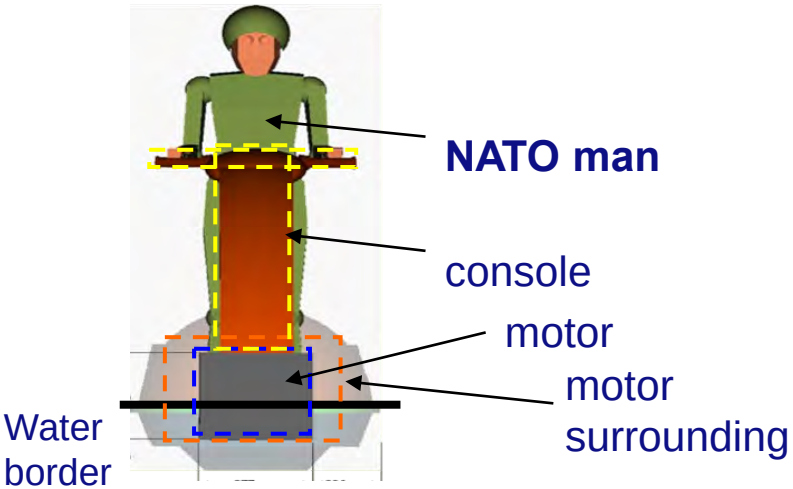
- Ranking based on:
  - SSPK (single shot probability of kill)
  - Burst (average # of rounds to achieve succes)
- Restrictions / Freedoms of choice
  - Ammunition (Availability, no modification on gun configuration)
  - Target set & range: what when to expect what kind of kill !!!
    - *mobility kill*
    - *catastrophic kill*.
  - Time schedule & budget

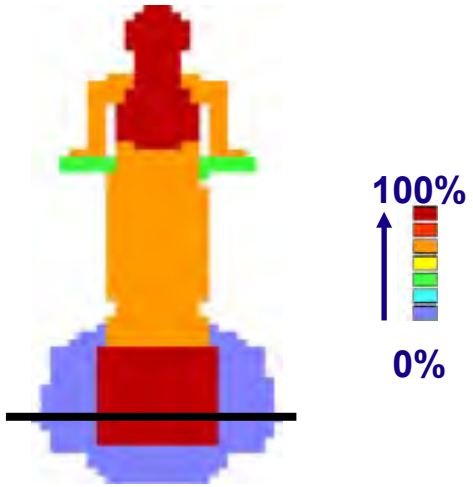
Quick scan methodology

- Build up of ~~detailed~~ target model(s)
  - Transformation in geometric models using Google Sketch-up
  - Introduction of critical components

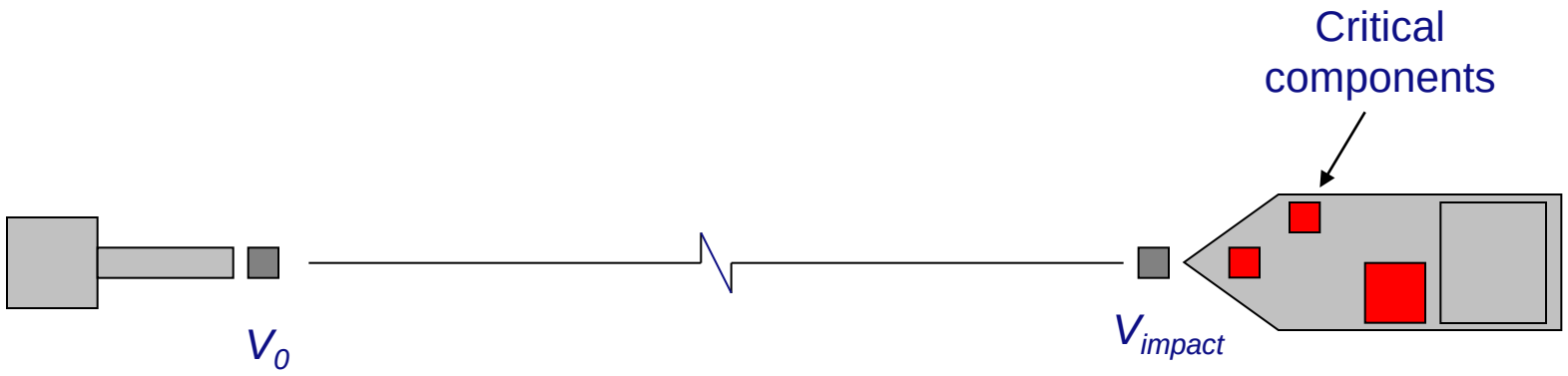
- ~~build up of detailed~~ ammunition model(s)
  - direct translation into expected effect on component level (Pk/c)

- computations with standard software

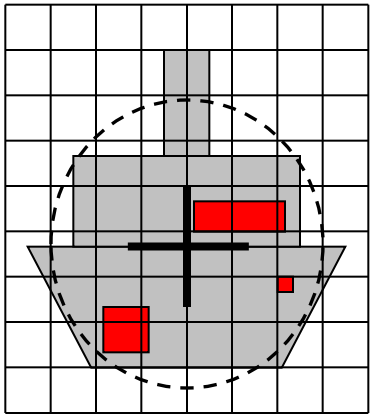




Sketch of quick scan methodology



Gun and ammunition dispersion determine the hit probability (*Ph,s*) of each critical component.

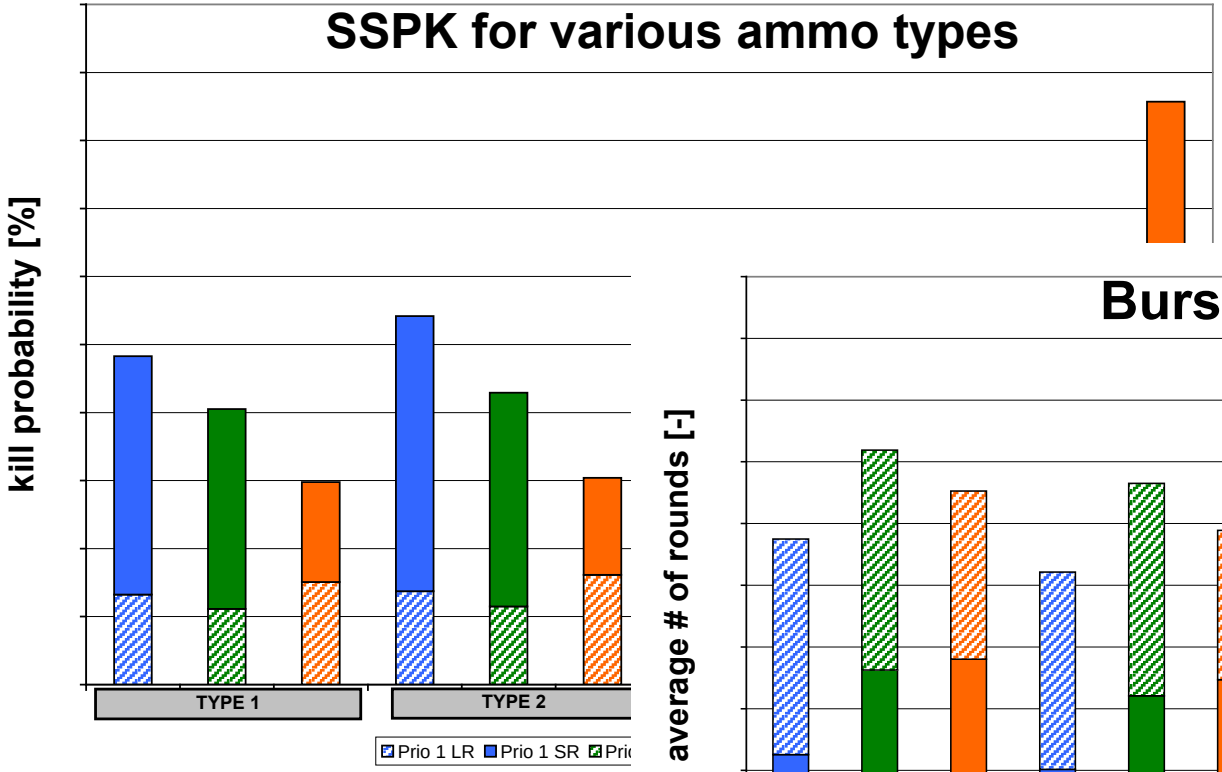


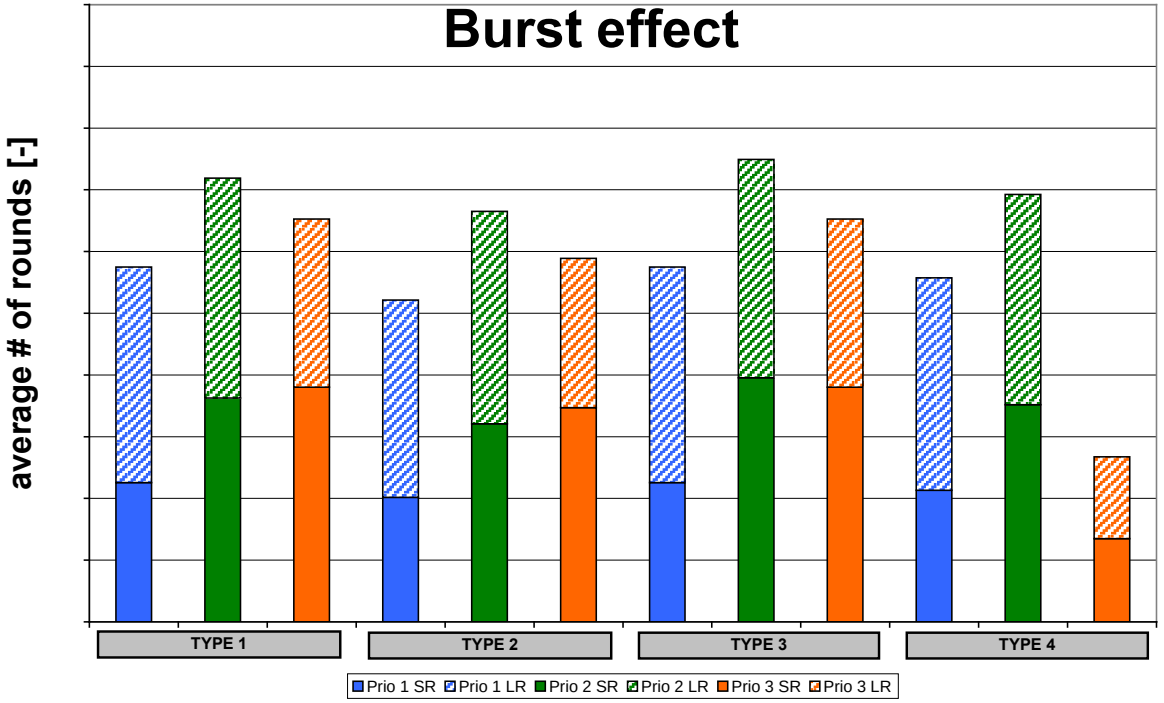
Ammuntion type, V_{impact}, impact angle and target information result in perforation capacity and damaging effect

Kill probability ($P_{k,s}$) is the sum of individual *Pk,h x Ph,s f*or each component.

!No cummulative damaging effect is taken into account for burst calculations!

Results





- Target 1 at long range
- Target 2 at short range
- Target 3

Long term solution



- Objective:
  selection of optimal ammunition type for 30 mm gunsystem

Normal methodology:

- build up of detailed target model(s)



- build up of detailed ammunition model(s)

PELE trial regarding incendiary effect and modelling



- numerous simulations with TARVAC software

Single PELE round on ‘short target’, simulated distance @ 1 km



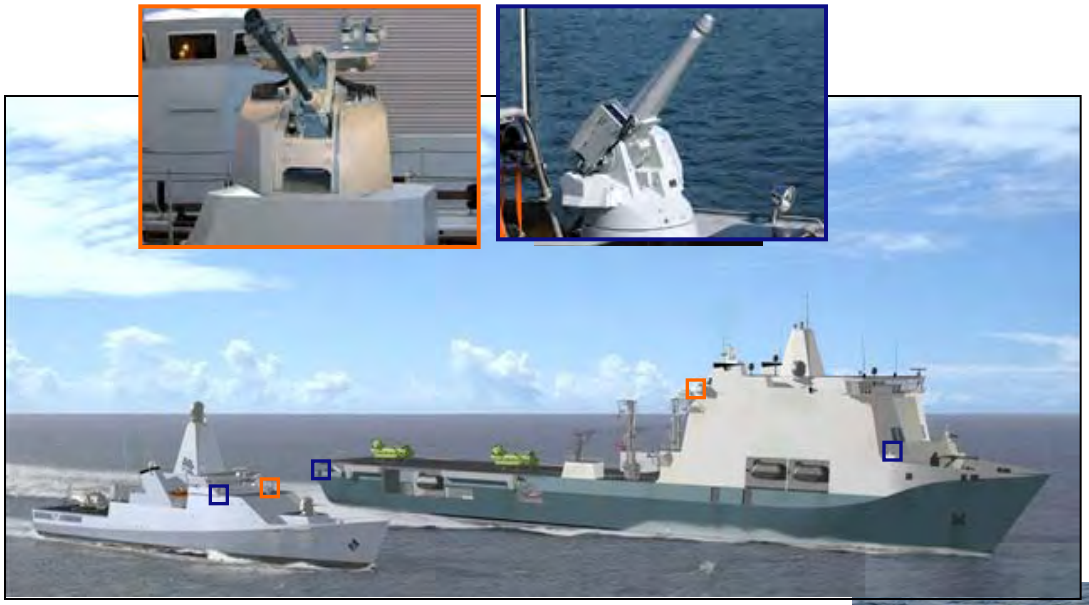
- Single PELE **Zr** round on ‘short target’, simulated distance @ 2 km



- Burst of PELE rounds on ‘deep target’, simulated distance @ 1 km



Self defence capability of ship with RCWS against Asymmetric Threats



Advice on:

- Tactical guidelines
- Control from CMS
- Optimal allocation of tasks

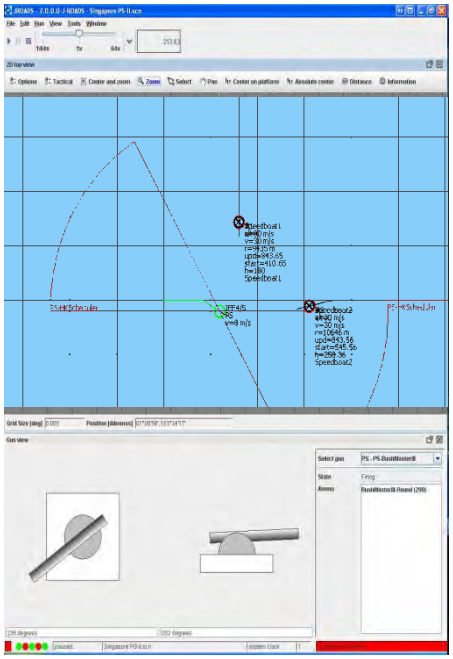


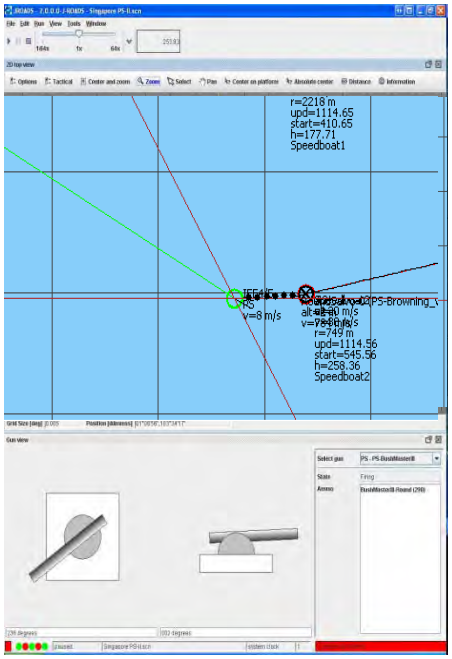
Immobilised target



Self defence capability
(Tactical guidelines)

Modelling ship (components), targets, interaction and scenario





Analysis based on computational Monte Carlo runs

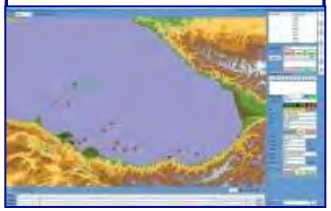
Engagements result with guns at platforms

Gun name	Target name	# ammo	# hits	% hits	% kills	Avg kill time	Avg kill range	Avg first launch range	part 1	part 1 # hit	part 2	part 2 # hits
PS-050_1	SuicideBoat1	3	1	33.33	100	288.9	865.78	865.78	289.97			
PS-30mm	SuicideBoat1	180	21	11.67	90	232.18	1508.82	1860.45	SuicideBoat1-Hull1	17	SuicideBoat1-Hull2	4
PS-050_1	SuicideBoat2	18	1	5.56	0			956.02	339.24			
PS-30mm	SuicideBoat2	180	26	14.44	88	243.64	1445.92	1805.45	SuicideBoat2-Hull1	21	SuicideBoat2-Hull2	5
PS-30mm	SuicideBoat3	484	19	3.93	77.78	320.22	855.49	1429.01	SuicideBoat3-EngineBox	6	SuicideBoat3-Hull2	19
PS-050_2	SuicideBoat4	30	1	3.33	0			985.32	344.2			
PS-30mm	SuicideBoat4	495	19	3.84	70	299.73	1061.43	1861.32	SuicideBoat4-Hull2	19	SuicideBoat4-EngineBox	3

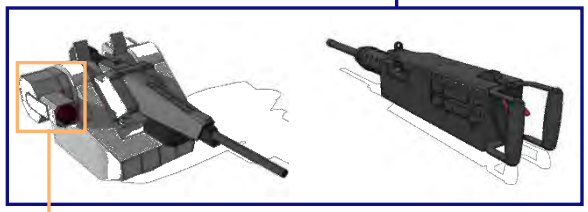
SPECIMEN

Self defence capability (Allocation tasks)

Guns & Sensors

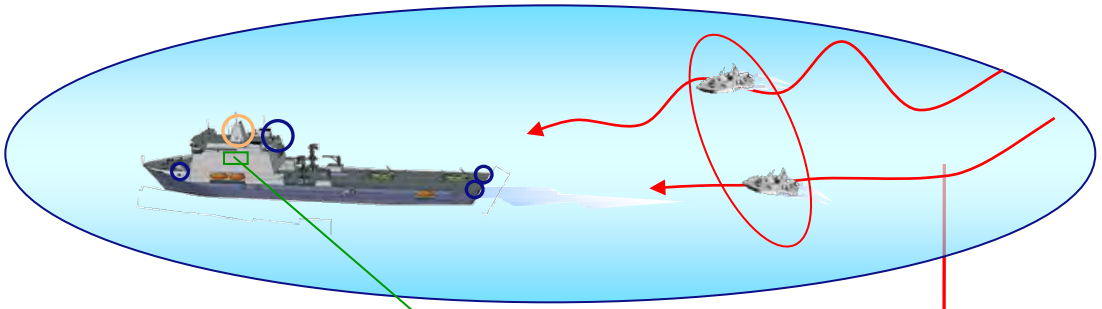






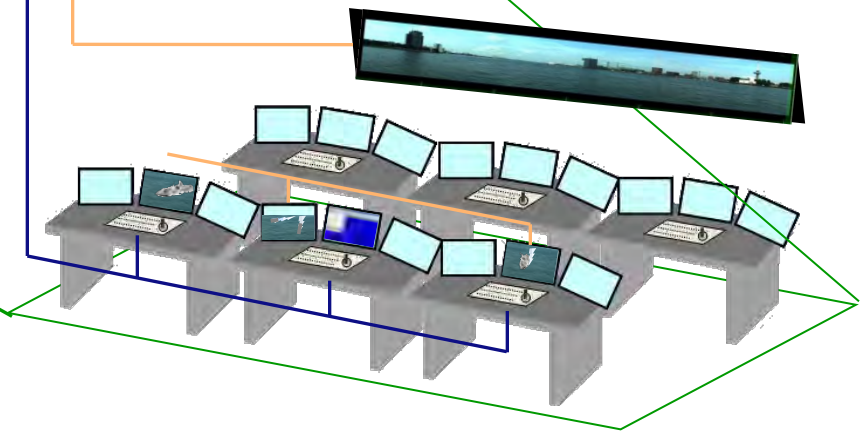
3D visual





Man Machine Interface





Comp. Generated Forces



ACE study:
Human in the Loop

Task of platform

present → new

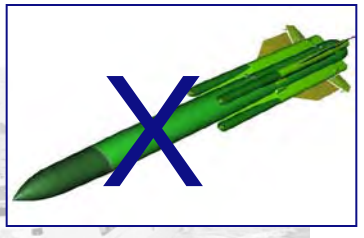
Weapon system / Ammunition type

present → new





















Non lethal solutions

Summary

- Warfare has changed: operations in littoral areas
- Change in demands within RNLN: new ship classes
- Research topics
  - Choice of ammunition
    - ✓ Short term solution
    - ✓ Long term solution
    - ✓ Non lethal solution
  - Self Defence Capability of ship



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RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Analysis of a Fluid Energy Mill (FEM) by Gas-Solid Two Phase Flow Simulation

Presented by : Mohamed Elalem (ARDEC)
Dr. Ming-Wan Young, Dr. Linjie Zhu, Zheng Qian (PPI)

National Defense Industrial Association Conference
May 17-20 , 2010

Acknowledgements

- Dr. Ming-Wan Young — PPI
- Dr. Lingie Zhu — PPI
- Dr. Peng Wang — PPI
- Zheng Qian — PPI
- Peter Bonnett — ARDEC
- Leslie Ben'Ous — ARDEC
- Fee Lee — ARDEC
- Mica McGhee-Bey — ARDEC

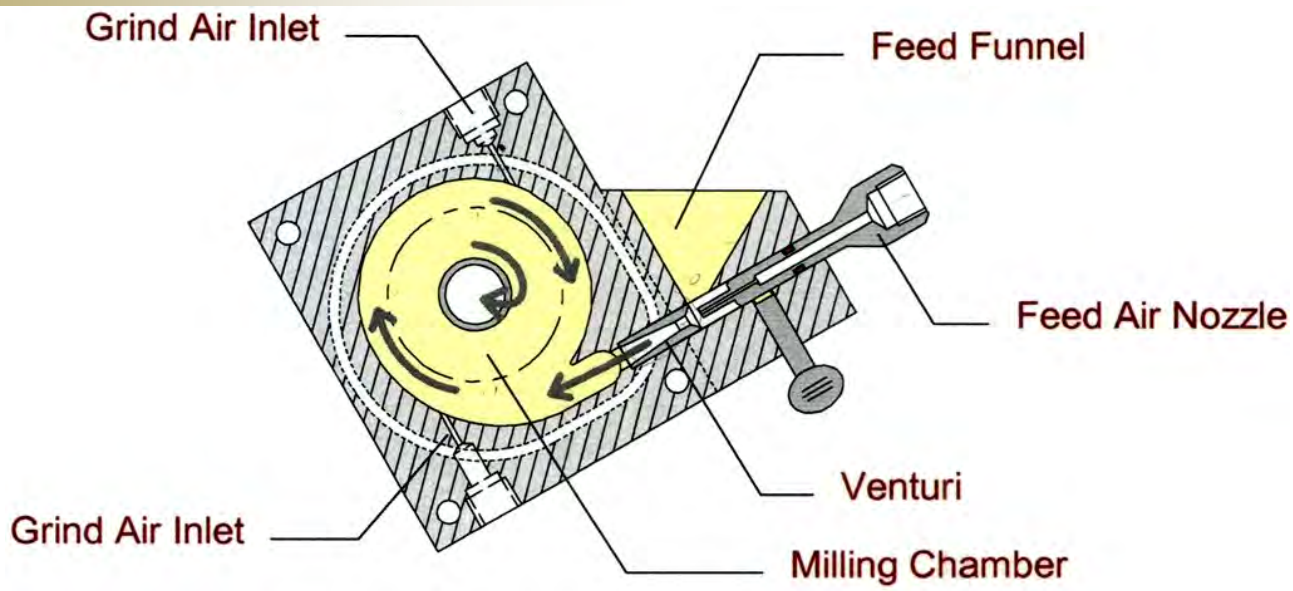
Outline

- Introduction
- Theoretical Model
- Simulation Setup
- Simulation Results
- Conclusion
- References

Introduction

- The size reduction in the Fluid Energy Mill is achieved by intensive particulate collisions inside the gas-solid two-phase flow.
- This study focuses on the two-phase flow inside the FEM.
- The three-dimensional particulate motions and collisions inside a FEM were simulated by coupling the Discrete Element Method (DEM) and Computational Fluid Dynamics (CFD), where particle-particle interactions were taken into consideration.

Experiment Setup



The cross-section view of the Sturtevant Qualification FEM.

	KCl	Steel
Poisson's Ratio	0.5	0.31
Shear Modulus (*Pa*)	6.24E+09	7.30E+10
Density (kg/m^3)	1990	7750

Material properties for the DEM-CFD coupling simulations

Theoretical Model

- Gas Phase (CFD)
  - FLUENT (Ansys Inc. Canonsburg, PA), a widely used commercial Computational Fluid Dynamics (CFD) software.
  - The Reynolds Averaged Navier-Stokes equations.
  - The κ - ε turbulent model.
- Solid Phase (DEM)
  - Discrete Element Method (DEM).
  - EDEM (DEM Solutions (USA) Inc., Lebanon, New Hampshire).
- DEM-CFD Coupling
  - Including the transfer of the momentum but excluding the heat transfer.
  - Employing the Lagrangian model due to the computation load and the low particulate volume fraction.

Simulation Setup

- Single-phase gas flow was simulated under five different operating conditions, as listed in the following Table.

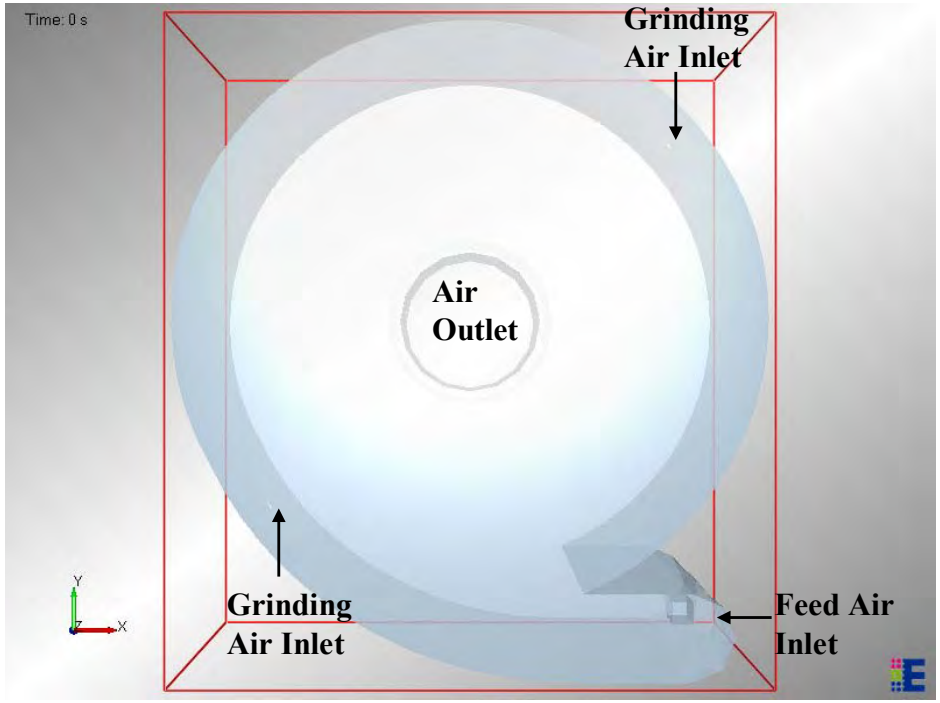
Case	Grind Air Pressure (*kPa*)	Feed Air Pressure (*kPa*)
1	137.8	137.8
2	206.8	206.8
3	275.8	275.8
4	344.7	344.7
5	413.7	413.7

Five different operating conditions investigated in this study

Simulation Setup

- Three air inlet nozzles were not considered in the coupling simulation and only the main chamber was investigated.

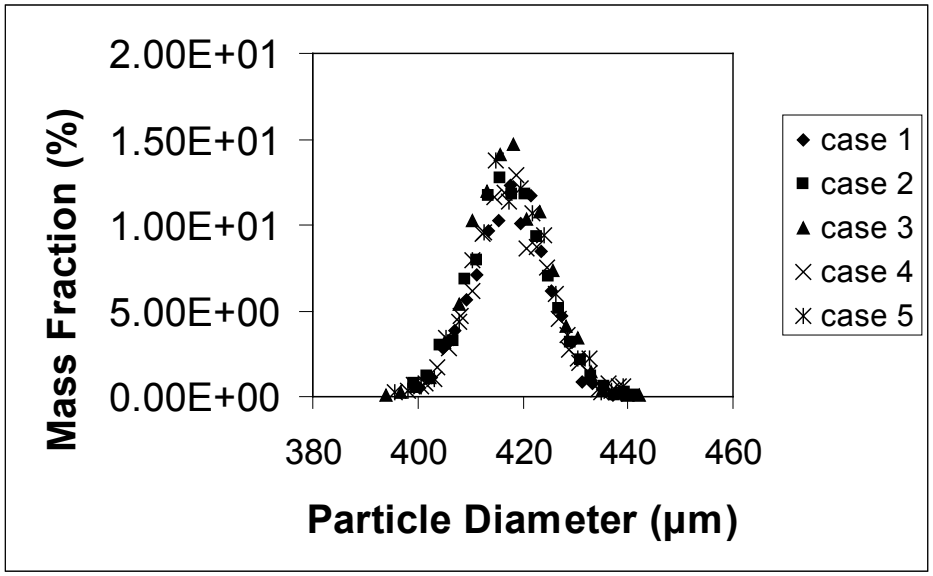
- The cubic box at the entrance of the feed air is a virtual geometry used to generate particles with the mean particle size of 420 μm.



Geometry of the grinding chamber for two-phase simulation.

Simulation Results

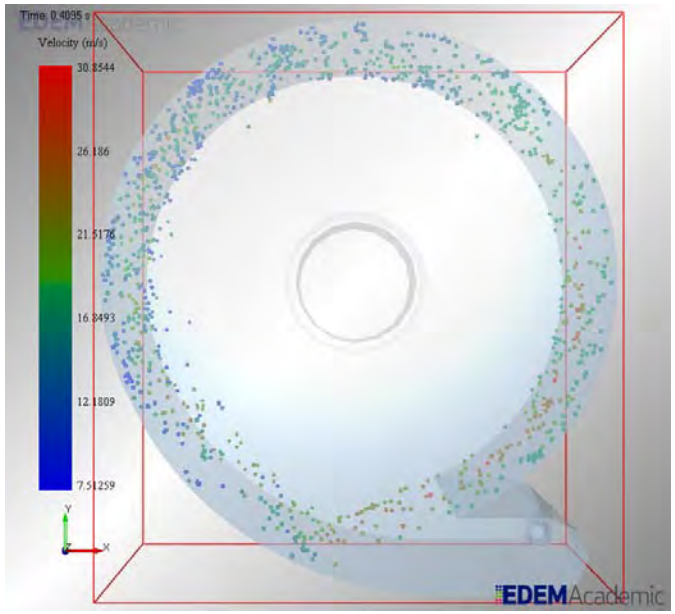
- Particle Generation
  - 1,000 spherical KCl particles were generated at a rate of 10,000 per second.
  - The KCl particles were set to have a mean particle size of 420 μm and follow a normal distribution.



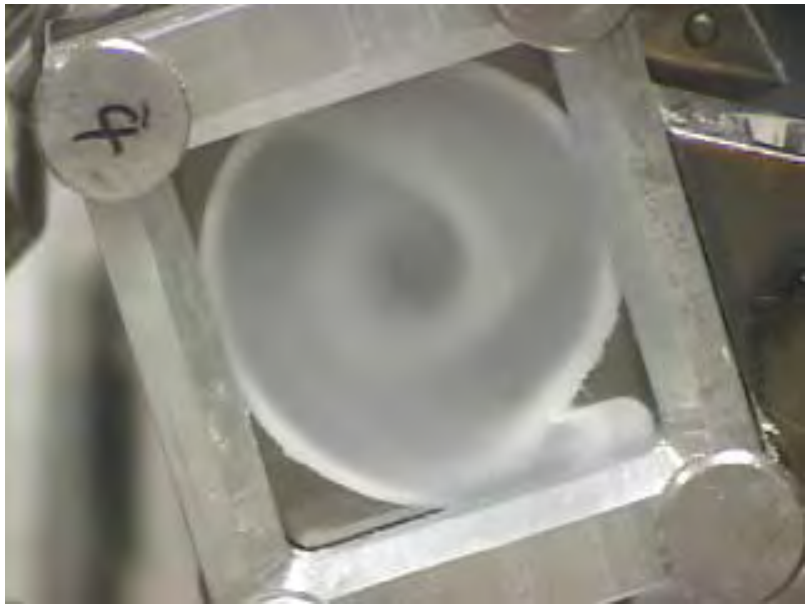
Size distributions of the particles used in the five cases.

Simulation Results

- Particle Motions
  - The particles were driven to the peripheral wall.



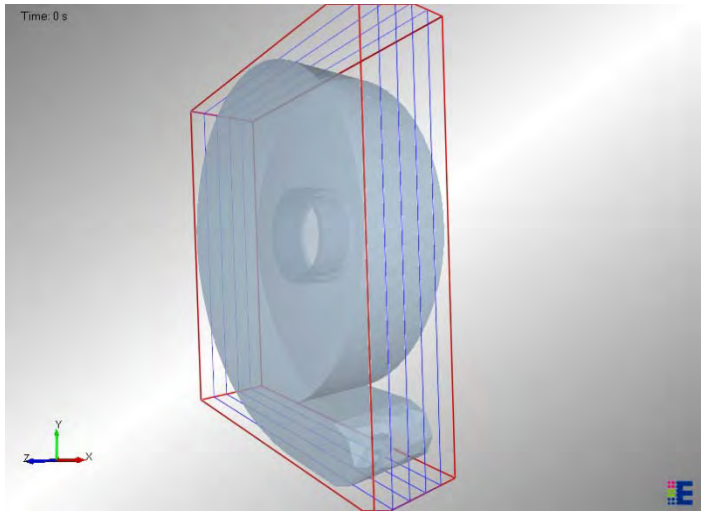
Particle flow pattern after the particle generation under the condition of Case 2.



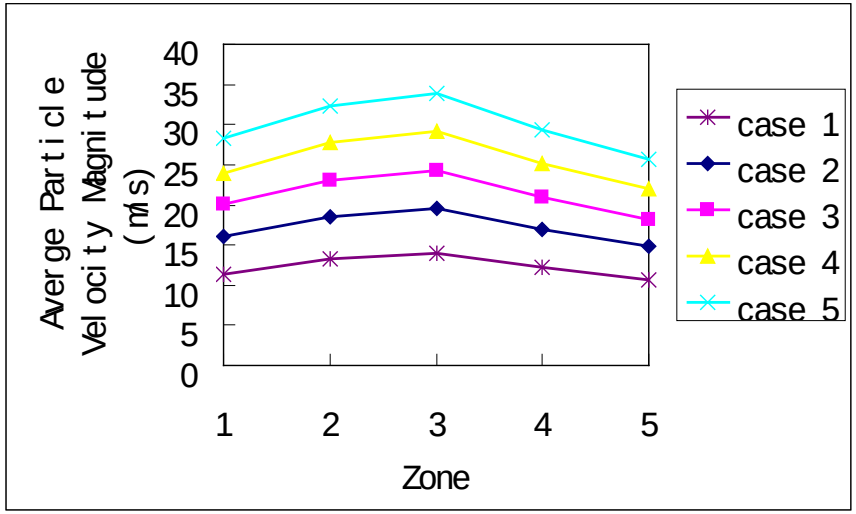
Inside view of the grinding process at steady state.

Simulation Results

- The grinding chamber was evenly divided into five zones along Z direction.
- Zone 3 has the maximum average particle velocity, independent of the operation pressure.



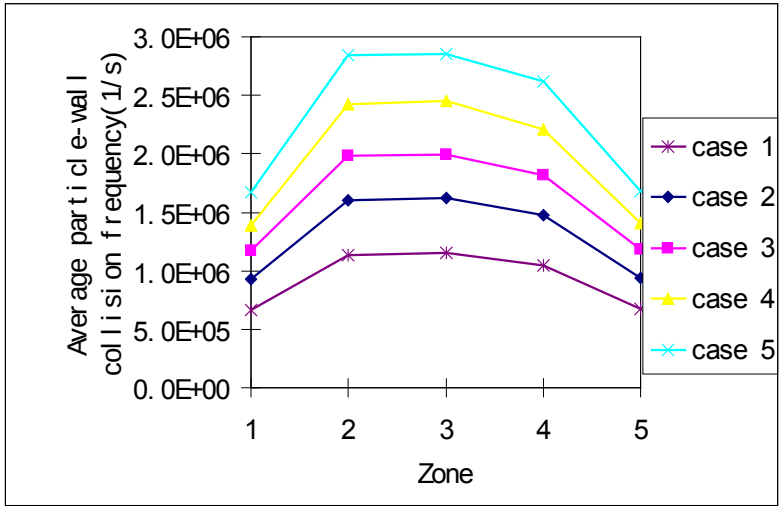
Five zones along the Z direction.

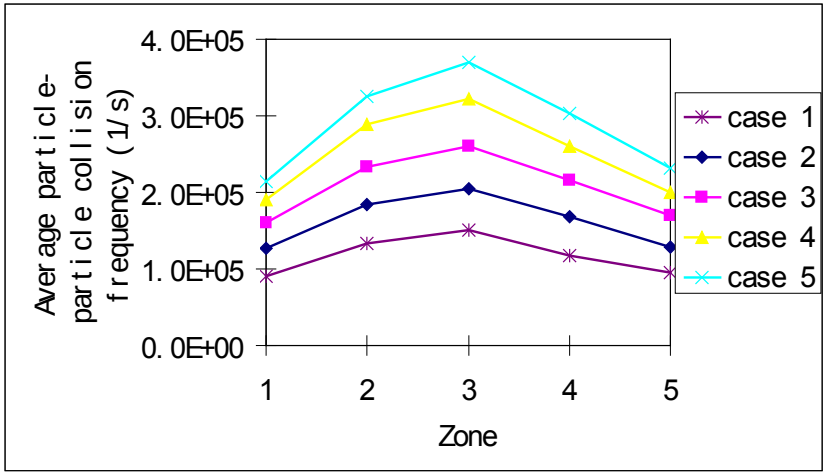


Average particle velocity magnitude in each zone under different cases. (“Average” means average in *both* number and time. And time average is taken from 0.2*s* to 0.45*s*.)

Simulation Results

- Particle Collisions
  - Zone 3 has the largest collision frequencies.

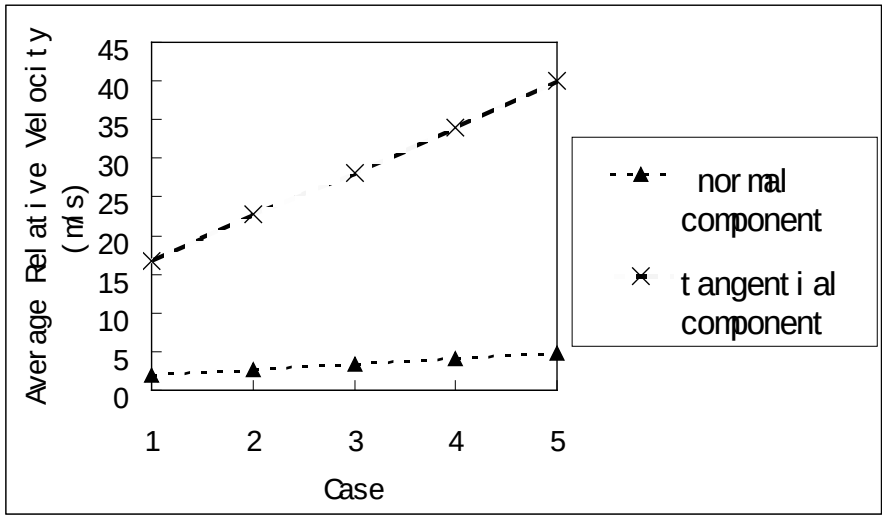




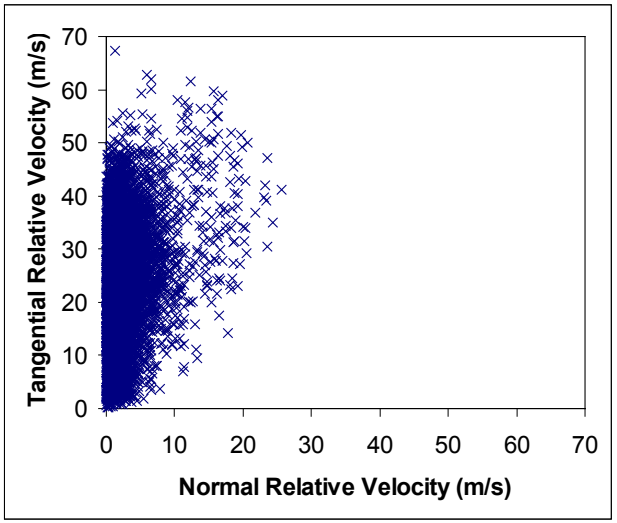
Average collision frequency between the particle and wall and average collision frequency between the particles ("Average" is the time average from 0.2*s* to 0.45*s*.).

Simulation Results

- The ratio of the normal to the tangential component of the relative velocity of particle-particle collisions is about 1:8.3.
- The collisions between the particles can be considered in the majority as "*sideswipe collisions*".



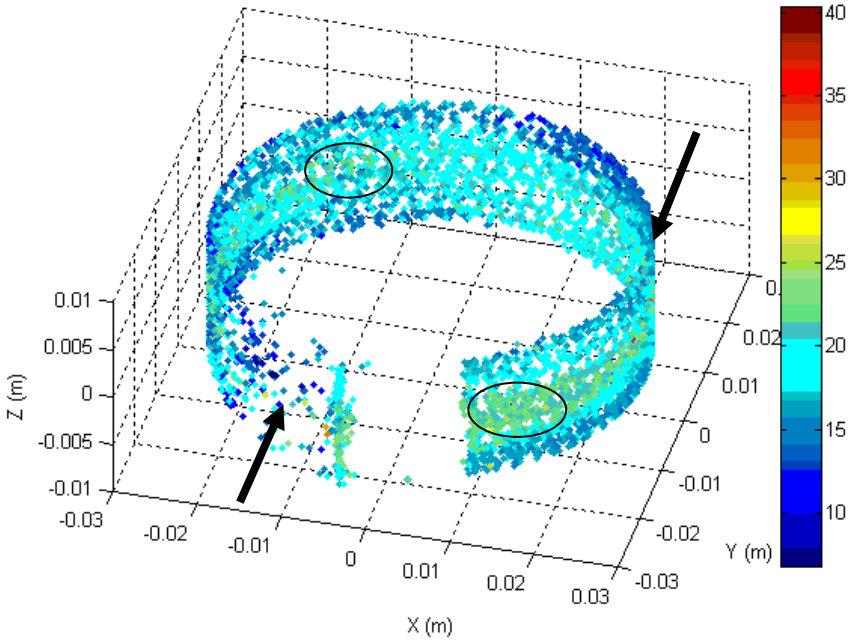
Comparison of the normal and tangential components of the average collision speed for particle-particle collision.



Scatter plot of the normal relative velocities vs. the tangential relative velocities of the collisions between the particles in the Case 2.

Simulation Results

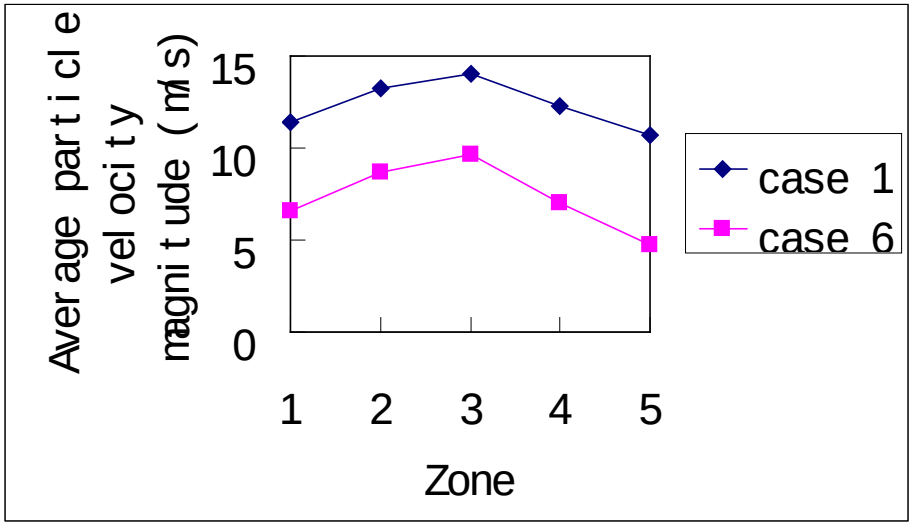
– The particle-wall collisions occur most intensively and frequently at the positions opposite to the two grinding nozzles (marked with circles in Figure).



3-D illustration of the particle-wall collisions in the Case 2. (Duration: 0.001*s*, from 0.44*s* to 0.441*s*).

Simulation Results

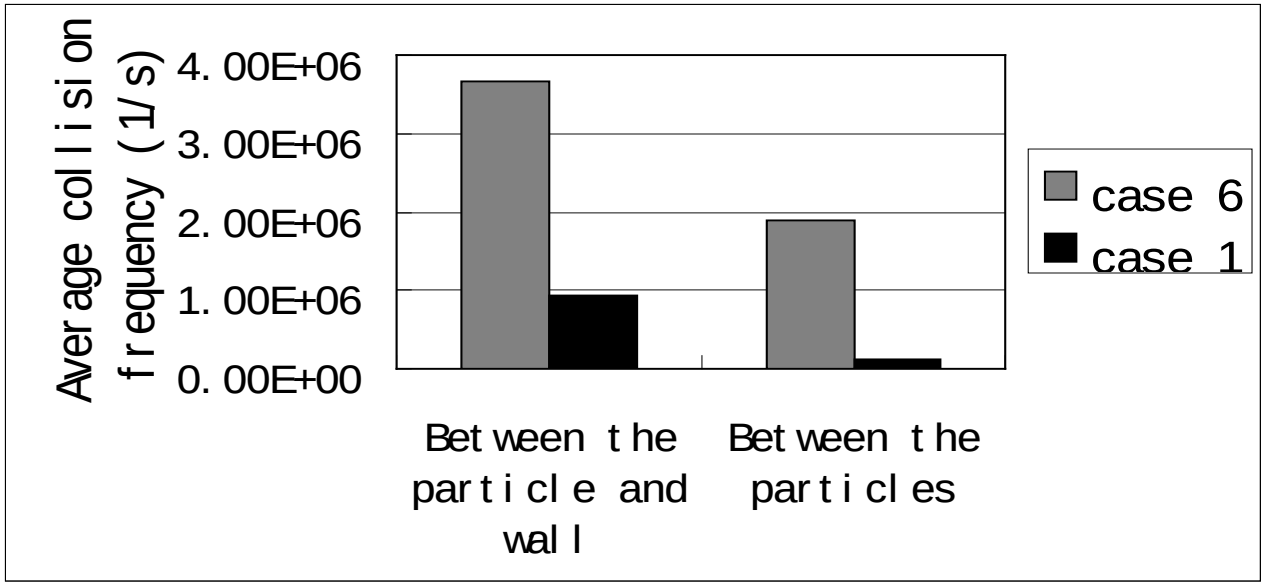
- The Effect of the Number of the Particles
  - 7000 particles were used in the simulation under the operating condition of the Case 1, which is referred as Case 6.
  - The average particle velocity in Case 6 is about one half of that in Case 1.



Comparison of the average particle velocity between Case 1 and Case 6.

Simulation Results

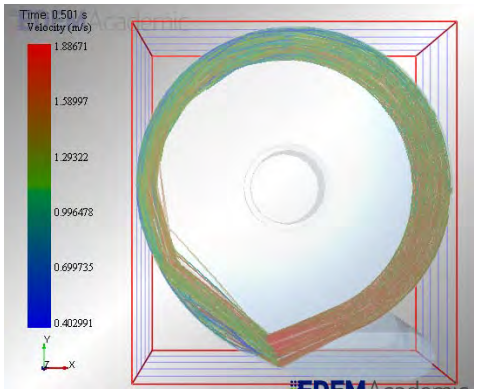
- The collision frequencies increase significantly for Case 6.
- The particle-particle collision frequency increases faster with the number of the particles than the particle-wall collision.
- The ratio of particle-particle collision to particle-wall collision is 1:3 and 1:8, respectively, for case 6 and case 1.



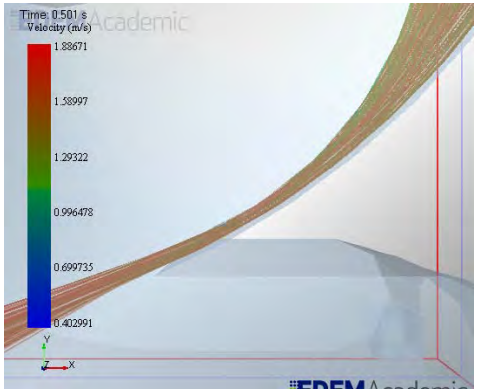
Comparison of average collision frequency between Case 1 and Case 6. ("Average" is the time average from 0.2*s* to 0.45*s*.)

Simulation Results

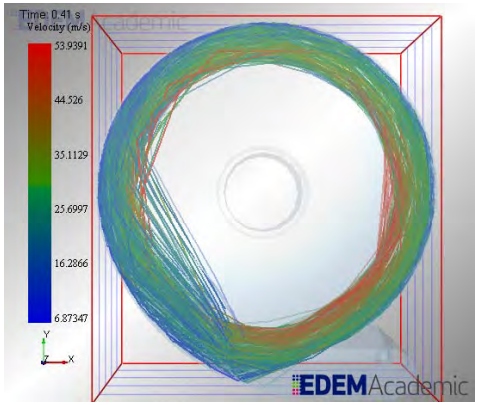
- Streamlines of the Particle Motions



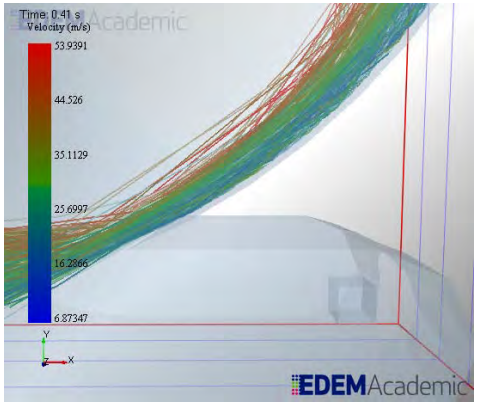
(a)



(b)



(c)



(d)

Comparison of the particle motions with grinding air and without grinding air (in (a) and (b), only FP=344.7*kPa*; in (c) and (d), FP=GP=344.7*kPa*.).

Conclusion

- The particles are driven to the peripheral wall forming a circulating particle layer.
- Those particles located near the grinding air nozzles are accelerated to higher velocities by two grinding air streams compared to other particles. Those high-speed particles are more likely to hit the wall, or collide with other particles due to the velocity difference.
- The distribution of the particle velocities becomes broader with the increasing of the operating pressures, leading to a higher probability of the establishment of the relative velocities and higher relative velocities to some extent.
- Both the particle-particle collisions and the particle-wall collisions play an important role in the particle size reduction.
- Particle-particle collisions can be considered to be “sideswipe collisions” in majority, and mainly lead to particulate abrasion, instead of cleavage or fracture.
- The feed air stream is not as efficient and effective as the grinding air stream in terms of facilitating particle breakage.

Thank You !

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SIMULATION OF CELLULOSE NITRATION PROCESS UNDER ACID-EXCESS CONDITIONS

Presented by : Mohamed Elalem (ARDEC)

National Defense Industrial Association Conference
May 19 , 2010

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Acknowledgements

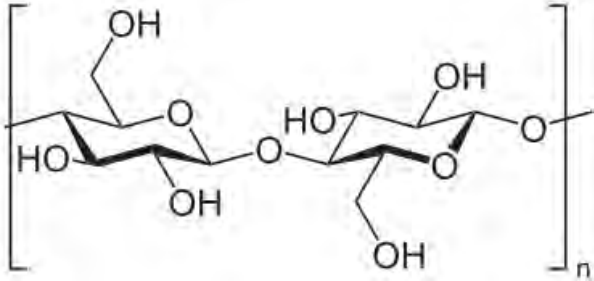
- Dr. Ming-Wan Young — PPI
- Dr. Lingie Zhu — PPI
- Dr. Peng Wang — PPI
- Bin Lin — PPI
- Peter Bonnett — ARDEC
- Joseph Palk — ARDEC
- Mica McGhee-Bey — ARDEC

Outline

- Introduction
- Experimental Studies
- Model Formulation
- Modeling Results
- Conclusion
- Future Work
- References

Introduction

- **Cellulose**
  - Organic compound $(C_6H_{10}O_5)_n$ consisting of polymeric carbohydrate structures (linked glucose units)
  - Different cellulose sources are different in:
    - **Cellulose Percentage**: Softwood Pulp, Hardwood Pulp<Sisal Fiber<Cotton Fiber (cotton: 93~95% cellulose; wood such as Fir/Pine/Aspen: 40~55% Cellulose)
    - **Molecular weight** (n=100~14000)
    - **Impurity; Specific Surface Area; Macro-scale Porosity: (affecting acid diffusion/absorption and, consequently, reaction rate and uniformity; product stability)**





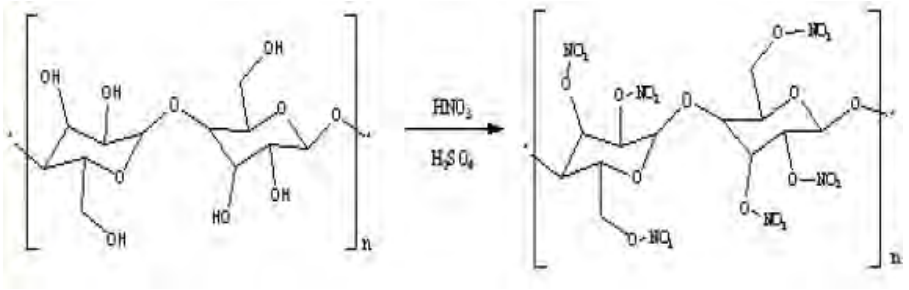


Introduction

- **Cellulose nitration**
  - Reacting cellulose in the presence of mixed sulfuric and nitric acid.
  - Esterification process:
    - $3HNO_3 + [C_6H_{10}O_5]_n \rightarrow [C_6H_7(NO_2)_3O_5]_n + 3nH_2O$

	Mononitrocellulose	Dinitrocellulose	Trinitrocellulose
% Nitrogen	6.75	11.11	14.14

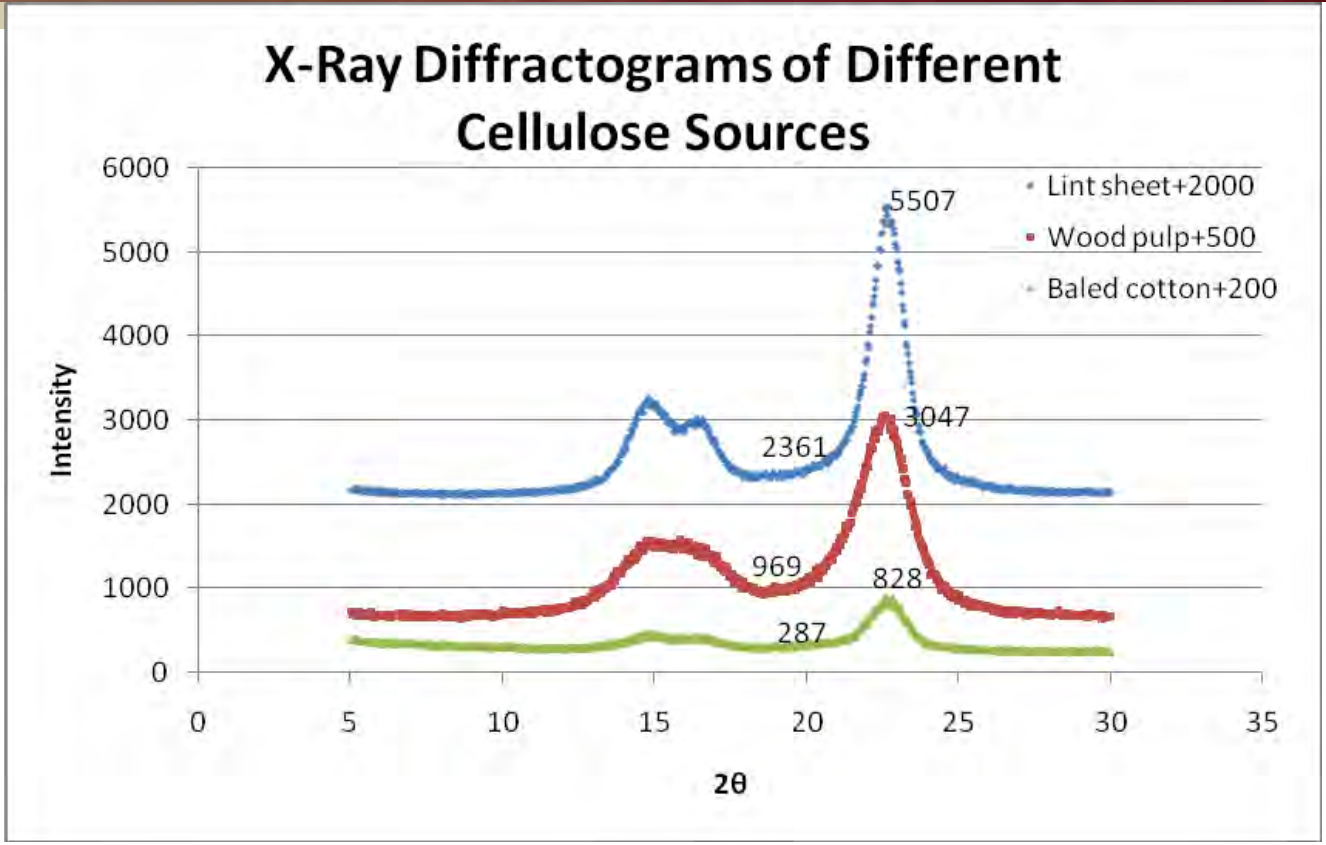
  - Propellants and gunpowder applications: nitrogen content ranges from 12%-13.8%



Factors Affecting Acid Absorption and Diffusion

- Surface area of the fibers
- Porosity of the fibers
- Cellulose crystallinity
  - Rigid anhydroglucose rings
  - Hydrogen bonding capacity-laterally ordered
- Moisture uptake
- Fiber Impurity

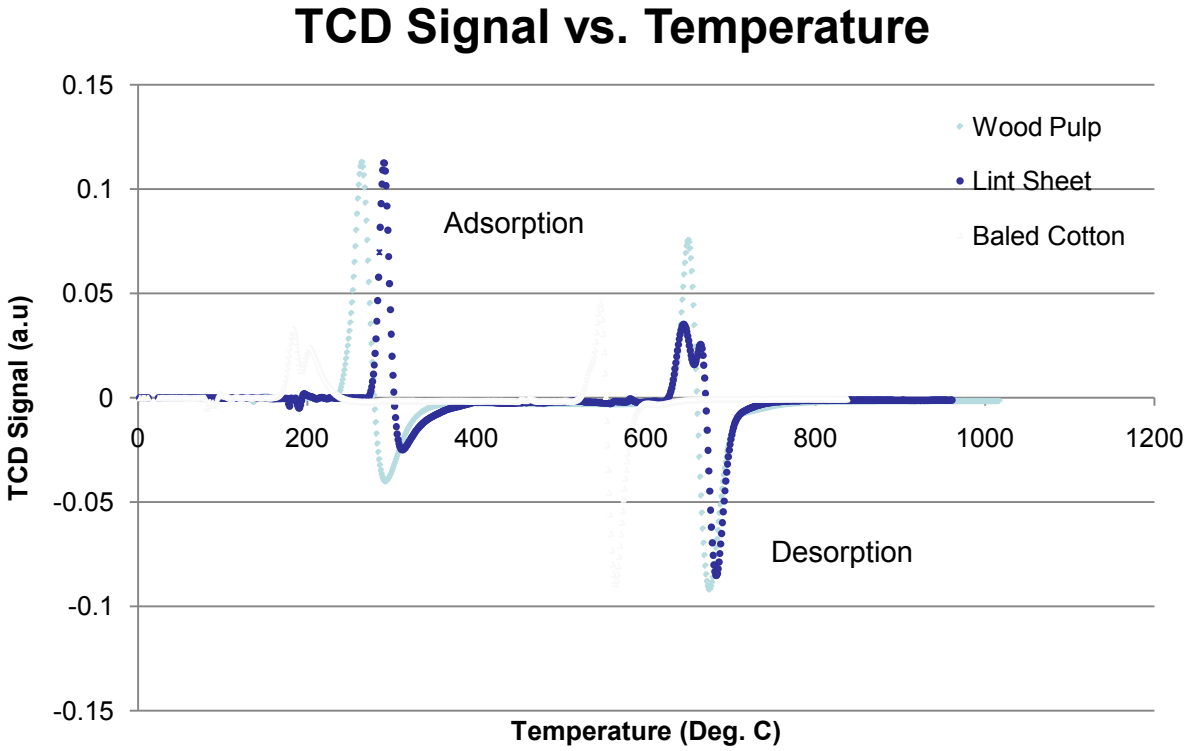
X-ray Diffraction



Cellulose Types	Crystal Size (nm)
Wood pulp	3.47
Lint sheet	5.66
Baled cotton	5.14

Surface Area of Fibers: BET Analysis

- Gas flow technique for surface area (SA) measurement
- Nitrogen as adsorbate
- Stronger binding for lint and wood pulp sheets



Surface Area of Fibers: BET Analysis

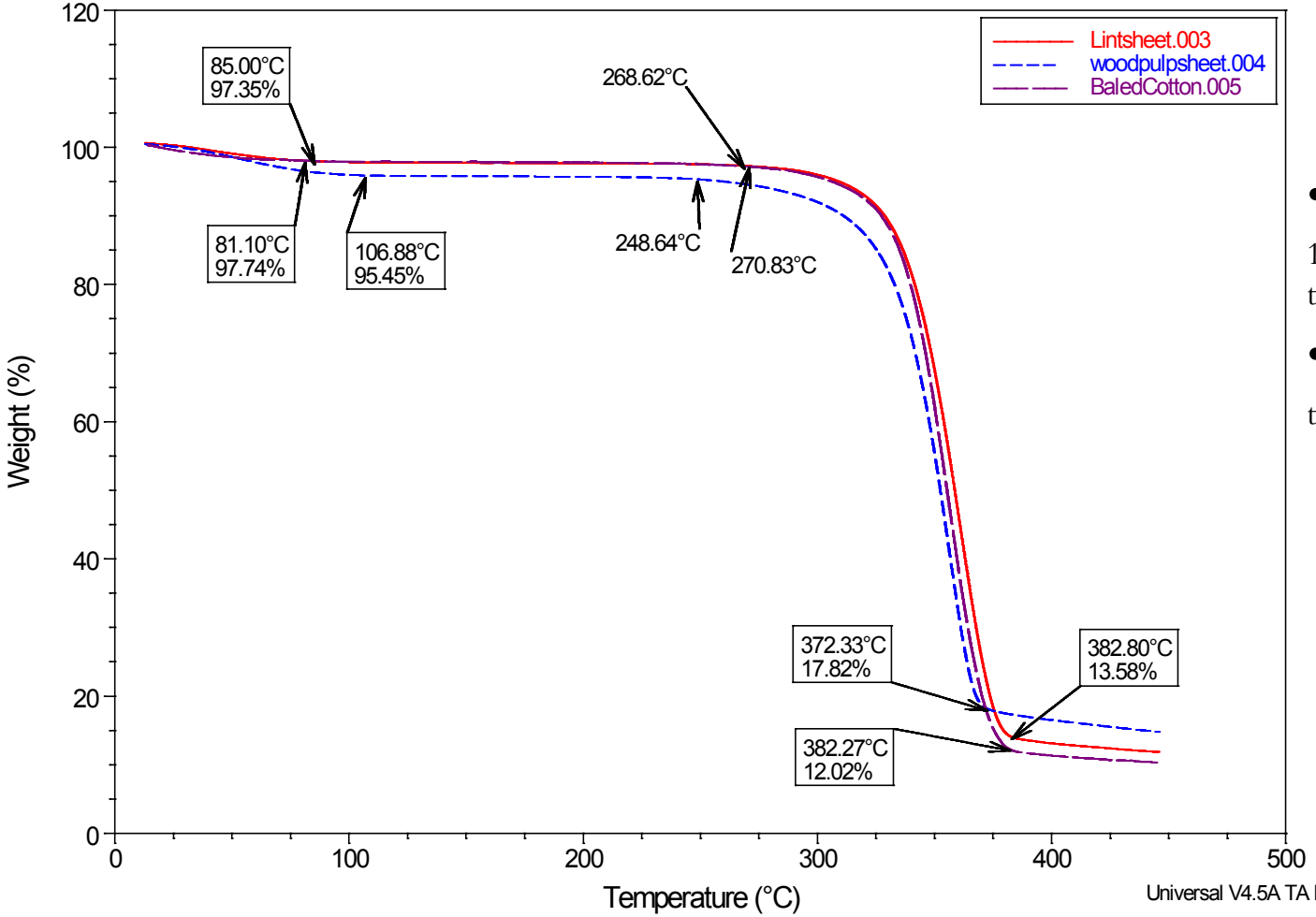
- Higher surface area (SA) causes moisture increase as comparing wood pulp and lint sheet
- Consistent with XRD results

$$B_i = \frac{\left(\frac{P}{P_o}\right)_i}{\left(1 - \left(\frac{P}{P_o}\right)_i\right) V_{ads}} \qquad SA = \frac{A_{N2} * (6.02 * 10^{23})}{22414 cm^3 * \left(\frac{10^{18} nm^2}{m^2}\right) * (m + Y_{int})}$$

Cellulose Types	BET Surface Area (m^2/g)
Lint Sheet	5.0845
Wood Pulp	5.9328
Baled Cotton	6.4392

Moisture Content Analysis: TGA Results

Lint-(97.35%)
Baled Cotton-(97.74%)
Woodpulp-(95.45%)



- Temperature ramping at 10 °C/min from room temperature to 450 °C
- Water loss was observed from the TGA thermographs

Moisture Content Measurement: Results and Discussion

- Wood pulp
  - Contains the most water
  - Least stable out of all the cellulose types in the experiment
- Baled cotton and lint sheet have shown to have similar water content
  - Similar onset of degradation
  - More extreme degradation than wood pulp
- Consistent with BET results

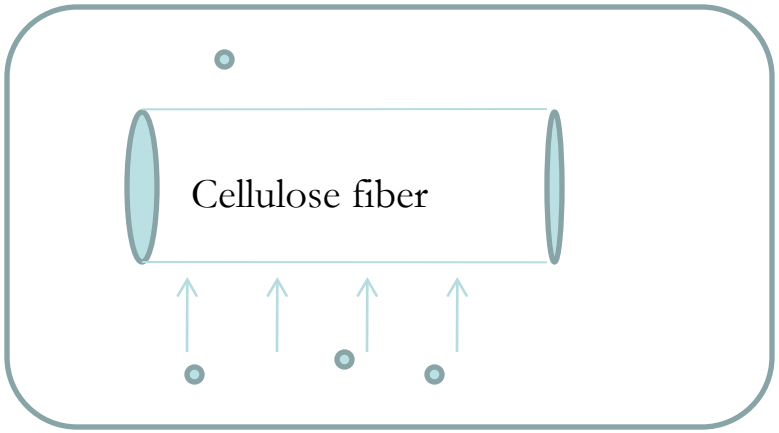
Cellulose Types	Water Content (%)	Onset of Degradation (° C)
Wood pulp	4.55	248.64
Lint sheet	2.65	268.62
Baled cotton	2.26	270.83

Model Formulation

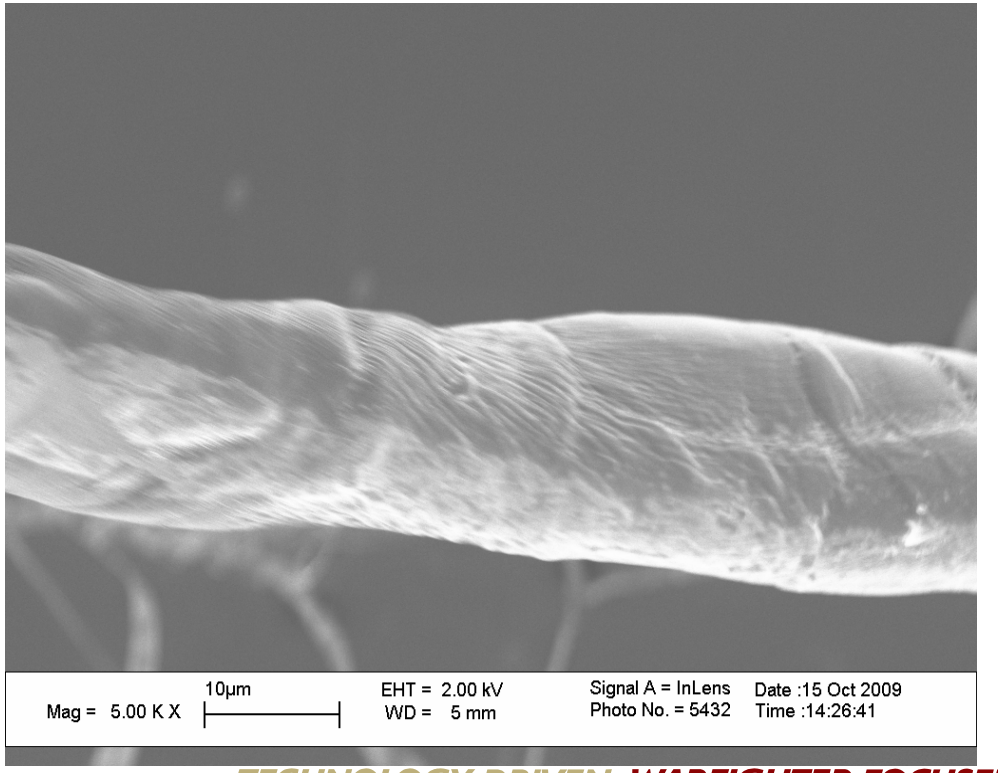
1) Simulation of reaction

$$3nHNO_3 + [C_6H_{10}O_5]_n \rightarrow [C_6H_7(NO_2)_3O_5]_n + 3nH_2O$$

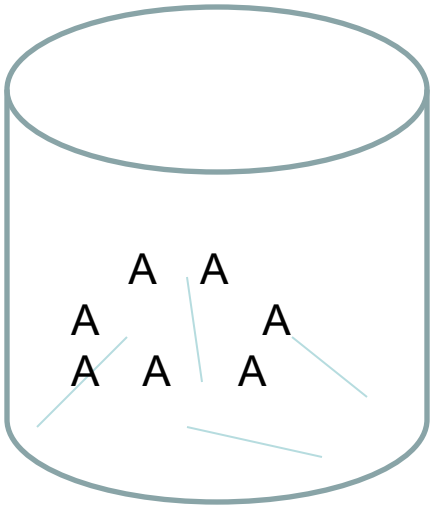
Layer by layer diffusion and reaction



Diameter of the fiber is roughly 10μm from the SEM image



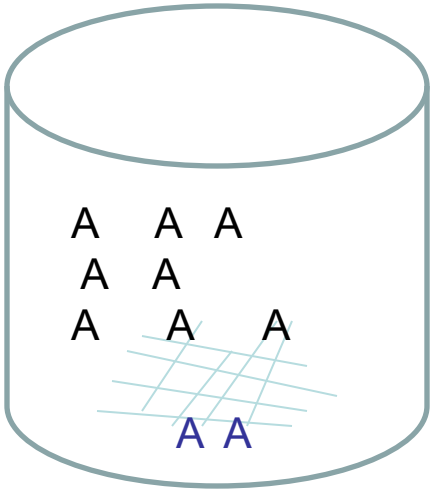
Model I: Dilute Fibers



A-Nitric Acid Fibers

- Nitric acid is in excess of what the reaction needs
- Constant acid concentration at the fiber surface

Model II: Fiber Entanglements



A-Nitric Acid Fibers

- Fibers are bundled into sheets
  - Presence of acid concentration gradient
  - Non constant acid concentration at the surface

Model Formulation

For convenience of subscripts and symbols, the nitration reaction is rewritten in a general form as shown below: $3A+B \Rightarrow C+3D$, where A-nitric acid, B-cellulose, C-nitrocellulose, D-water.

Assumptions:

1) Fibers are perfect of "infinite" length;
2) Liquid phase is perfectly mixed;
3) Nitric acid diffuses into the fiber and reacts with the cellulose.
4) Fibers are suspended uniformly in a nitric acid rich medium

$$\frac{\partial C_A}{\partial t} = \frac{D_{AB}}{r}\frac{\partial\left(r\frac{\partial C_A}{\partial r}\right)}{\partial r} - kC_AC_B$$

$$\frac{\partial C_B}{\partial t} = -\frac{1}{3}KC_AC_B$$

$$\frac{\partial C_C}{\partial t} = \frac{1}{3}KC_AC_C$$

where CA,CB and CC are the concentration of the nitric acid, cellulose and nitrocellulose, respectively; DAB is the diffusion coefficient of the nitric acid inside the fiber; k is the reaction rate constant of nitration; r is the radial direction of the fiber.

Model Formulation

$$C_C(r,t) = C_{Bo} - C_B(r,t)$$

Instead of expressing the nitrocellulose concentration in a differential form, it can be rewritten in the following form according to stoichiometry from the chemical equation:

- B.C 1: Constant surface

$$\frac{\partial C_A(r=0,t)}{\partial r} = 0 \quad C_A(r = 10\mu m, t) = 0.00222 \frac{mol}{cm^3}$$

- Initial conditions:

$$C_A(r, t=0) = 0 \qquad C_B(r, t=0) = 0.00863$$

Equations in Dimensionless Form

$$\frac{\partial C_A^*}{\partial \tau} = \frac{1}{x}\frac{\partial}{\partial x}\left(x\frac{\partial C_A^*}{\partial x}\right) - \phi C_A^* C_B^*$$

$$\frac{\partial C_B^*}{\partial \tau} = -\frac{1}{3}\phi\gamma C_A^* C_B^*$$

where $t = \frac{R^2\tau}{D_{AC}}, x = \frac{r}{R}$ $C_A^* = \frac{C_A}{C_{Ao}}$ and $C_B^* = \frac{C_B}{C_{Bo}}$

B.C: $\frac{\partial C_A^*}{\partial x}(x = 0, \tau) = 0$ $C_A^*(x = 1, \tau) = 1$

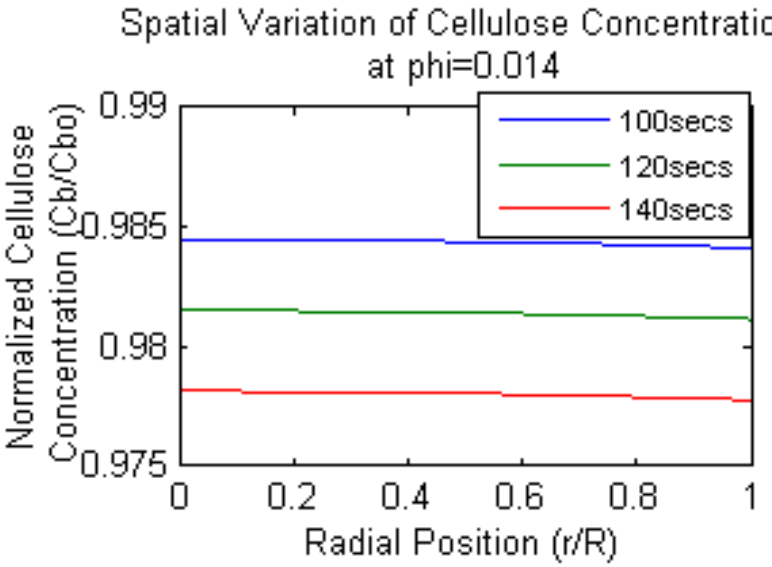
I.C: $C_A^*(x, \tau = 0) = 0$ $C_B^*(x, \tau = 0) = 1$

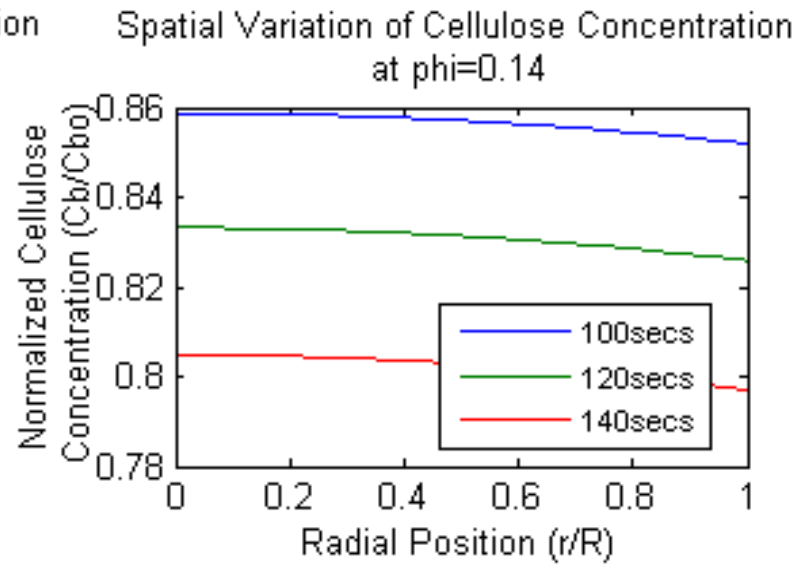
The coupled partial differential equations are dimensionalized, where φ is the Damkohler number that characterizes the strength of chemical reaction and γ is the saturation ratio of acid concentration with respect to cellulose.

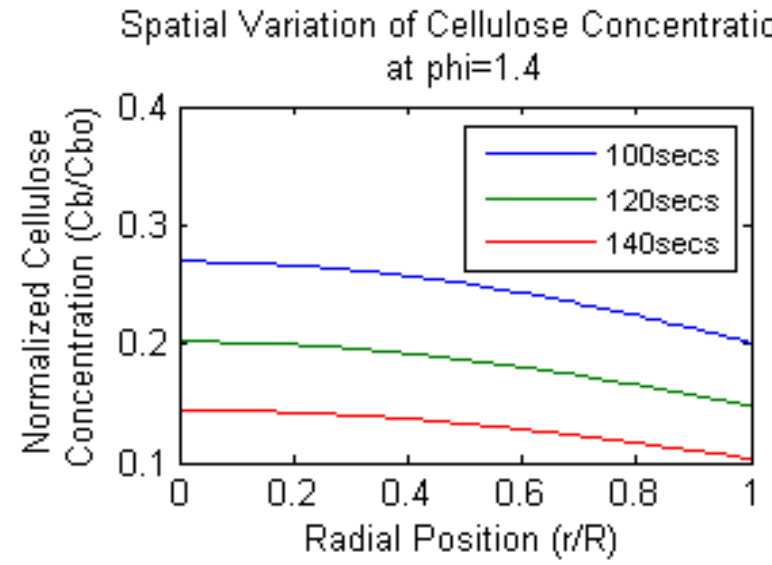
$$\phi = \frac{R^2 K C_{Bo}}{D_{AC}}$$

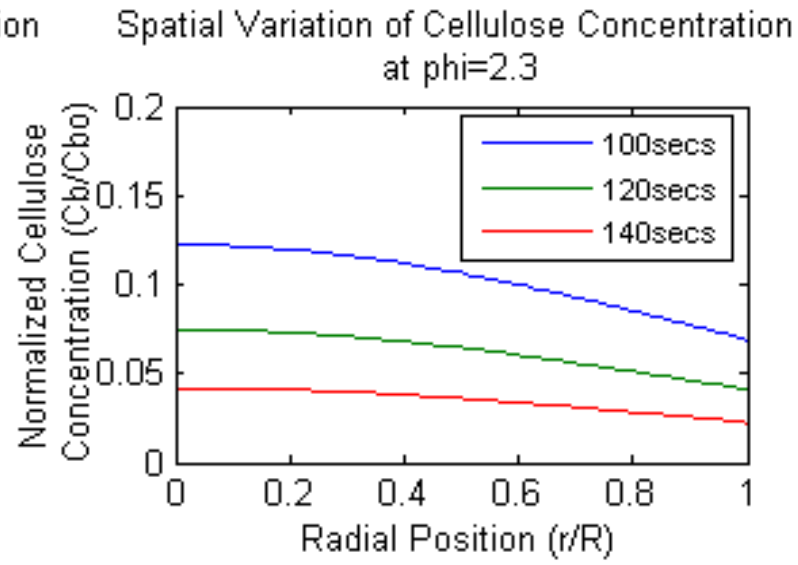
$$\gamma = \frac{C_{Ao}}{C_{Bo}}$$

Results: Variation of Damkohler Number (Phi)

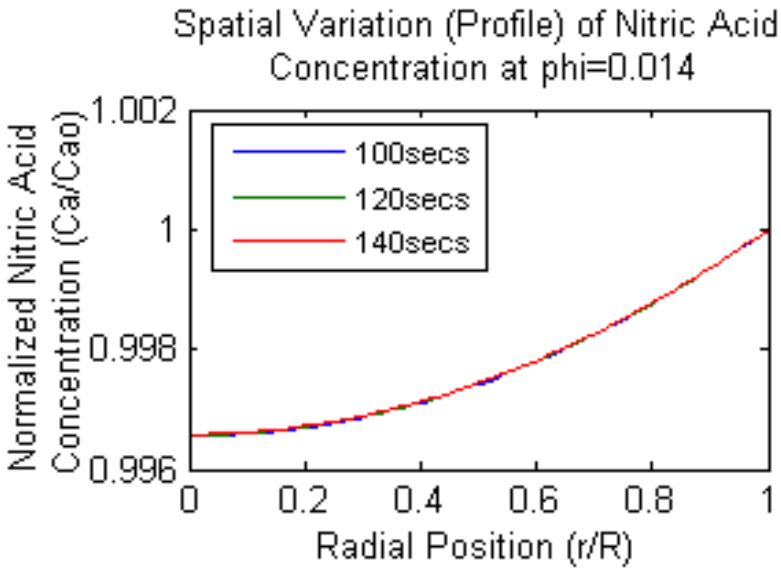


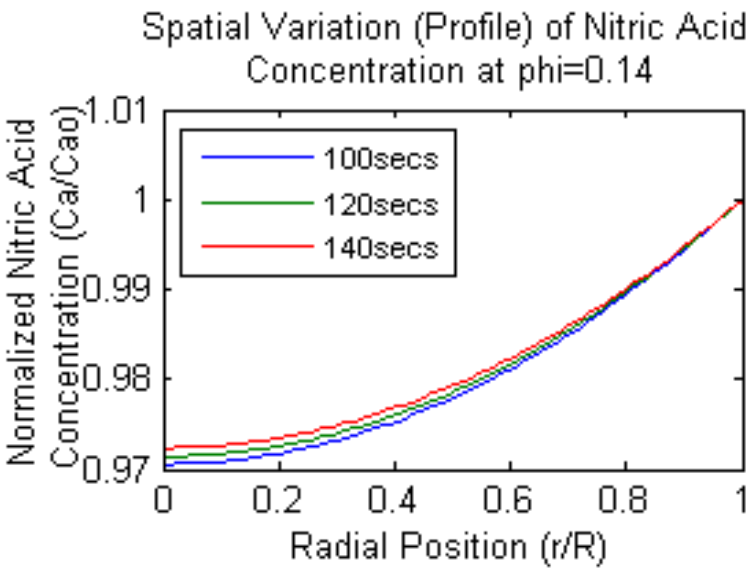


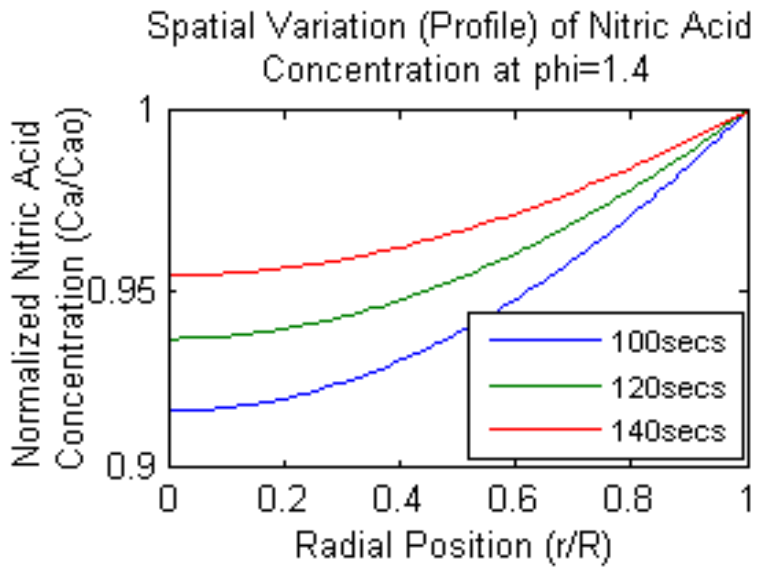


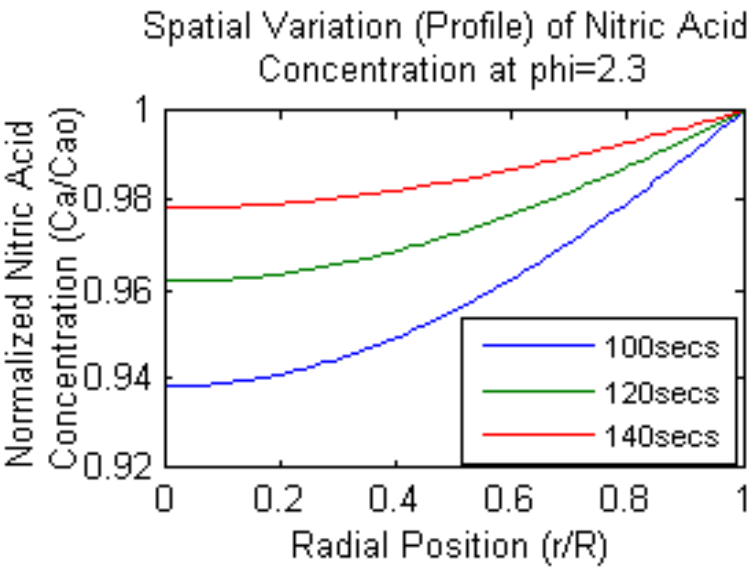


Results: Variation of Damkohler Number (Phi)



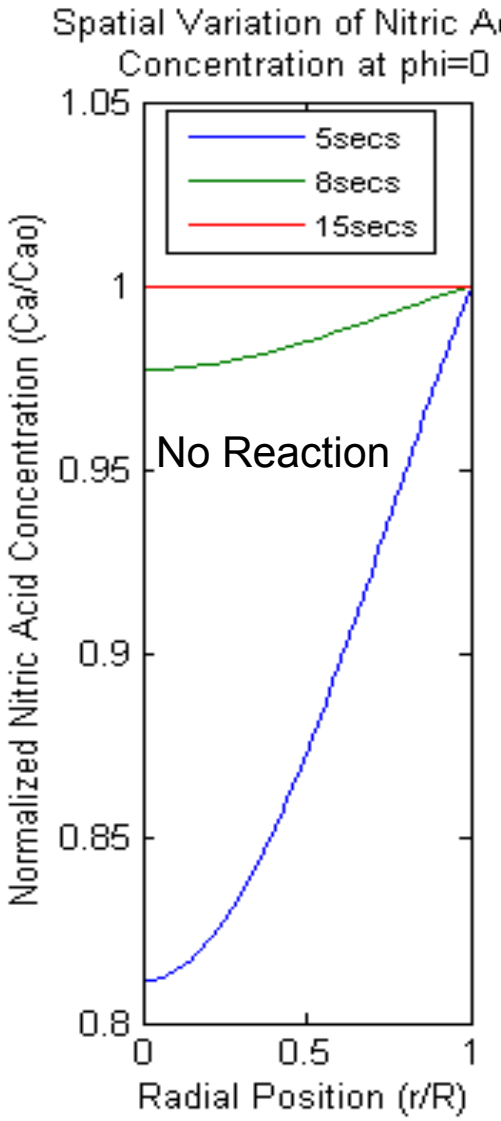


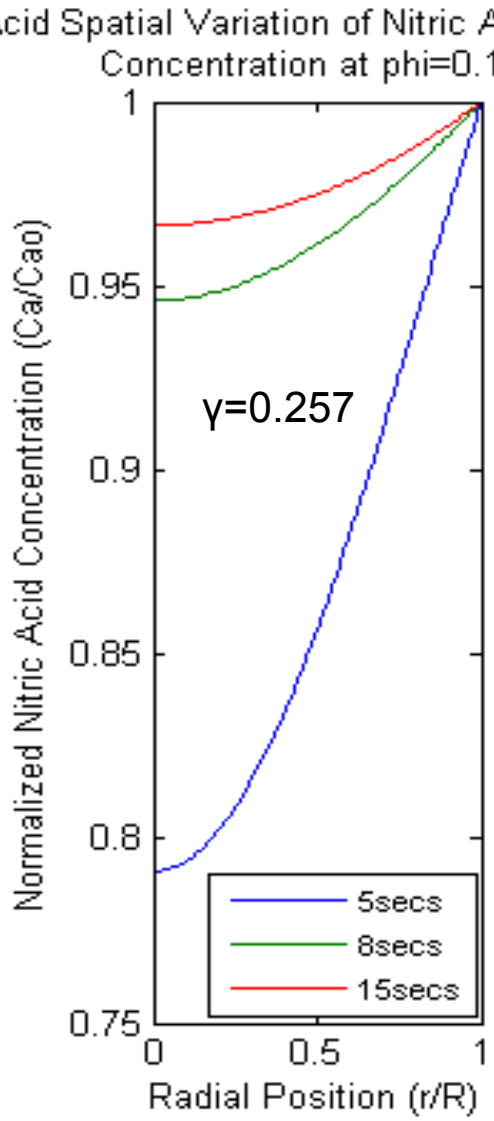


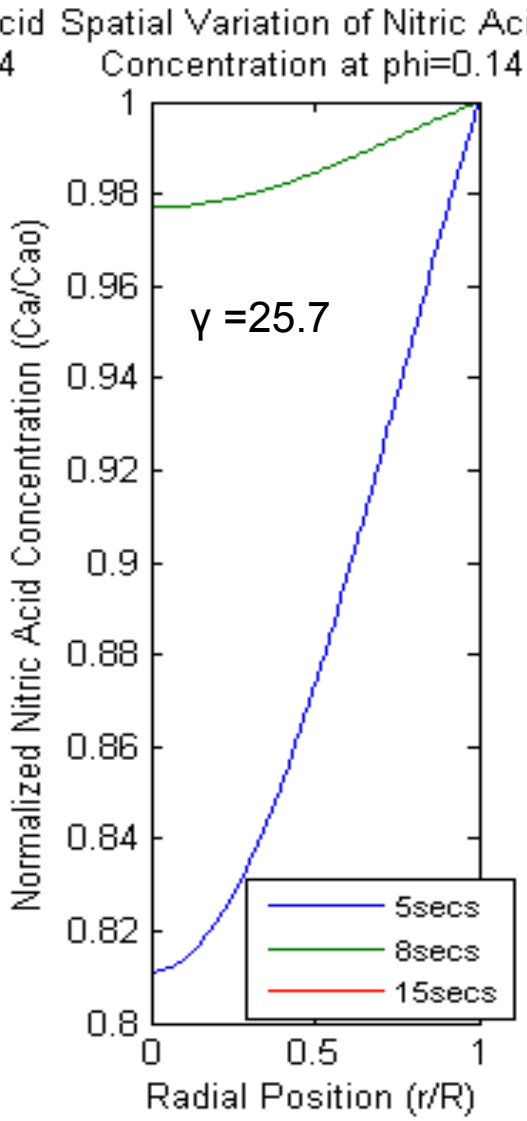


SED.

Effect of Saturation Ratio on the Nitric Acid Concentration



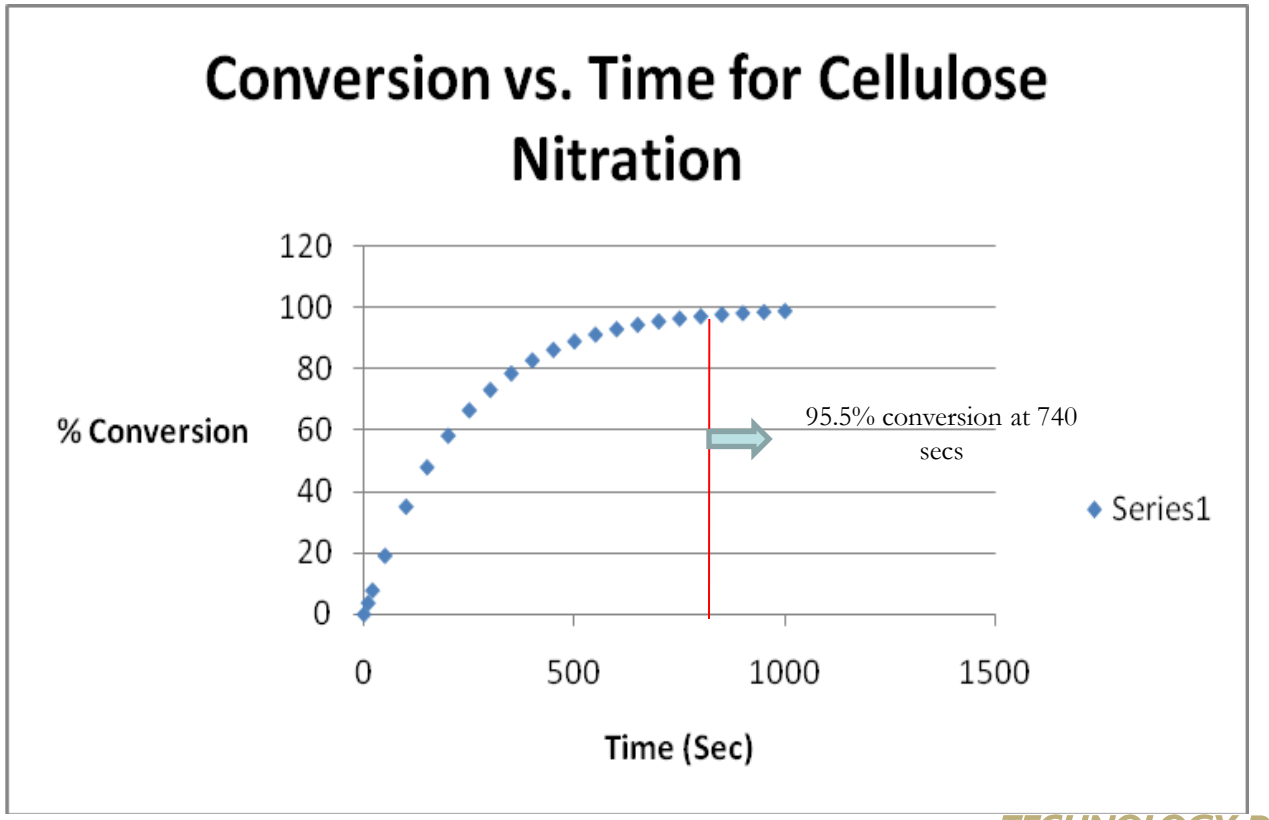




D.

Cellulose Conversion

- Manufacturing data
  - Reactor residence time is roughly 740 seconds
  - 96% conversion from cellulose to nitrocellulose
- 95.5% conversion was obtained from the model



Cellulose Conversion

$$X(r,t) = 1 - \frac{C_B(r,t)}{0.008634}$$

Mean Conversion

$$\bar{X}(t) = \frac{\int_0^{2\pi}\int_0^R X(r) r\,dr\,d\theta}{\int_0^{2\pi}\int_0^R r\,dr\,d\theta}$$

Conclusion

- Various characterization techniques are formulated to analyze properties and characteristics of cellulose fibers that can potentially affect the nitration process
- Cellulose concentration at the center of the fiber is typically lower than its surface due to the delay with acid diffusion.
- The diffusion of nitric acid into the cellulose fibers increases with increase in the diffusion coefficients. On the contrary, acid concentration decreases with increase in the rate constants up to a point when reaction is nearly at its completion.
- In the case of slow diffusion, the nitration reaction tends to occur predominantly at the fiber surface.
- Decrease in the reaction rate constant changes the nitration kinetics to reaction-controlled, leading to a more uniform nitration degree inside the fiber.
- Cellulose concentration decreases with time due to reaction while nitric acid increases because equilibrium of nitric acid is never achieved between the surface and the center of fibers whenever there is acid consumption

Thank You !

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GENERAL DYNAMICS
Ordnance and Tactical Systems



Event #0610
May 17 - 20, 2010
Dallas, Texas

"21st Century Weapons Systems – Providing the Right Response"

GD-OTS' 25mm Non-Energetic Fragmenting (NEF) Cartridge (Enhanced 25mm PGU-20)



GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20

Joint developement by:



General Dynamics –
Ordnance and Tactical Systems (GD-OTS)
Marion, Illinois
and
the Army Research and Development Engineering Center (ARDEC)
Picatinny, New Jersey



GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20



F-35
Lightning II

Delivering Lethality to Target

- Air-to-Air ➡ thin-skinned targets
- Air-to-Ground ➡ armored targets

25mm NEF
Cartridge



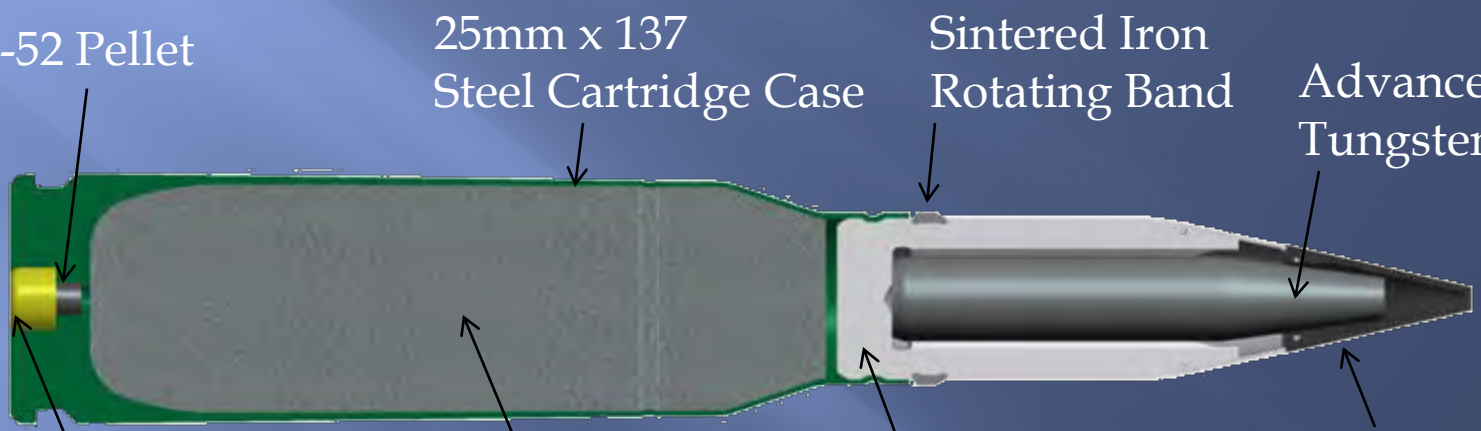
25mm
GAU-22A
Cannon





GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20









GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20

Armor Penetration (Air-to-Ground Combat)

- Advanced Tungsten Core – developed by ARDEC to provide significant improvements to standard tungsten alloys.
- V50 Data and Performance Capabilities are classified.
- The 25mm NEF Cartridge ("Enhanced PGU-20") easily exceeds the Joint Strike Fighter requirements.



More Penetration = Lethality
Against More Targets





GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20



Fragmentation (Air-to-Air Combat)

- Two-Piece Nose Cap – specially designed for transfer of forces to body and core.
- Projectile Body – incorporates features to promote separation and fragmentation of body upon impact with thin-skinned targets.
- Advanced Tungsten Core – provides a large pattern of high density fragments creating damage within the target.



High Density Fragments = More Damage = More Kills





GENERAL DYNAMICS
Ordnance and Tactical Systems

25mm NEF Cartridge – Enhanced PGU-20

The 25mm NEF Cartridge ("Enhanced PGU-20") provides the JSF war fighter lethality on target whether it is in the air or on the ground.



GENERAL DYNAMICS
Ordnance and Tactical Systems

GENERAL DYNAMICS

Ordnance and Tactical Systems

45th Annual Armament Systems: Gun and Missile Systems
Conference & Exhibition
Event #0610
May 17-20, 2010
Dallas, Texas

"Precision and Lethality in Medium and Large Caliber"

Super 40mm Ammunition – Performance/Lethality



S40mm MK44 Ammunition

- Why S40mm ammunition?
- Lethality of S40mm over 30mm
- Brief S40mm ammunition history
  - US Army Contract Efforts
  - Internal Research and Development (IRAD) Efforts
- S40mm Ammunition Family
  - Armor Piercing Fin Stabilized Discarding Sabot with Tracer (APFSDS-T)
  - Multi Purpose Air Burst with Tracer (MPAB-T)
  - Target Practice with Tracer (TP-T)
- Summary



Why 540mm ammunition?



S40mm - Introduction

Why S40mm Ammunition?

The up gunned S40mm MK44 weapon and ammunition solution is ready for U.S. Army study and test

- The 30mm MK44 weapon is a battle proven system with a complete family of qualified ammunition ranging from target practice, armor piercing and high explosive cartridges
- The proven MK44 weapon contains growth provisions for S40mm cartridges
    - Increasing lethality over 30mm where…bigger is better
    - Minimal up-gun cost impacts due to a combination of MK44 weapon part commonality and interchangeability

30mm to S40mm Projectile Growth Placing more Lethality on Target



30mm and S40mm with the MK15 Link

S40mm - Introduction

Why S40mm Ammunition?

It is a solution that meets the Army's future fighting capability growth objective:

- To maintain lethality overmatch against the most common/capable threat
- Leverage existing 30mm cartridge technologies and qualified explosive items
- Existing and established US supplier base currently implementing growth objective needs
- Common 30mm MK44 and S40mm MK44 weapon parts
- Common MK15 cartridge link for 30mm and S40mm
- Nearly common cartridge packaging system for 30mm and S40mm

30mm and S40mm commonalities = Lower weapon system costs

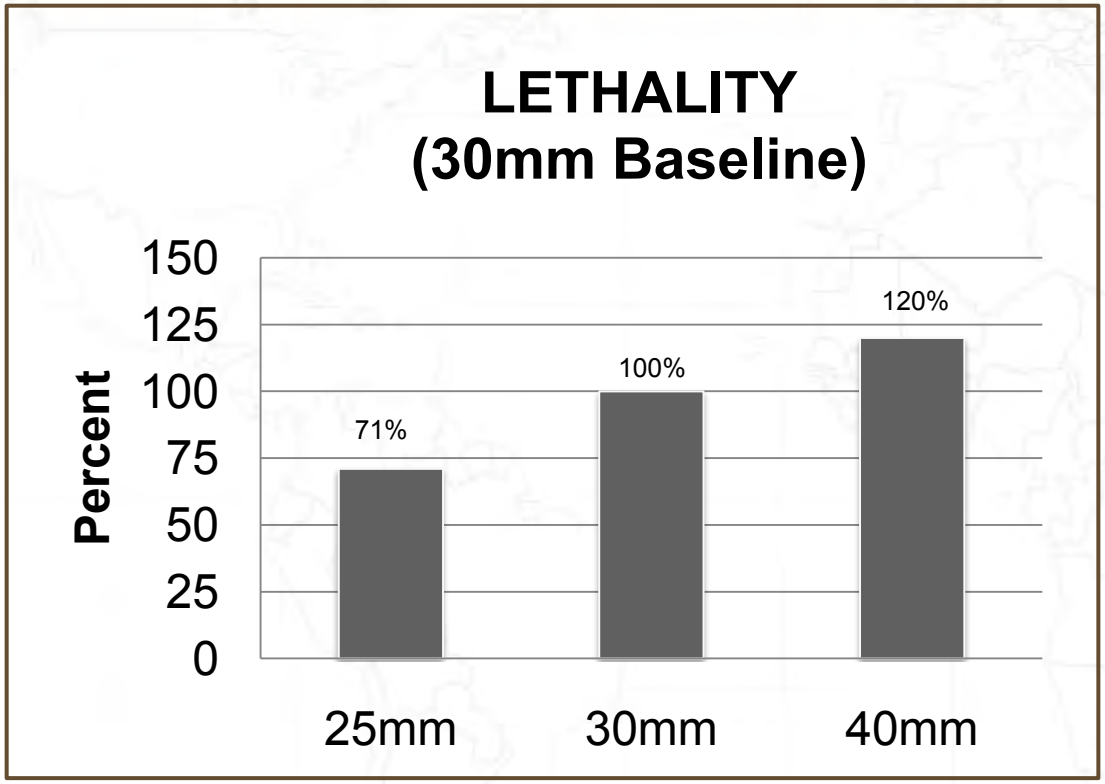


Lethality of S40mm over 30mm





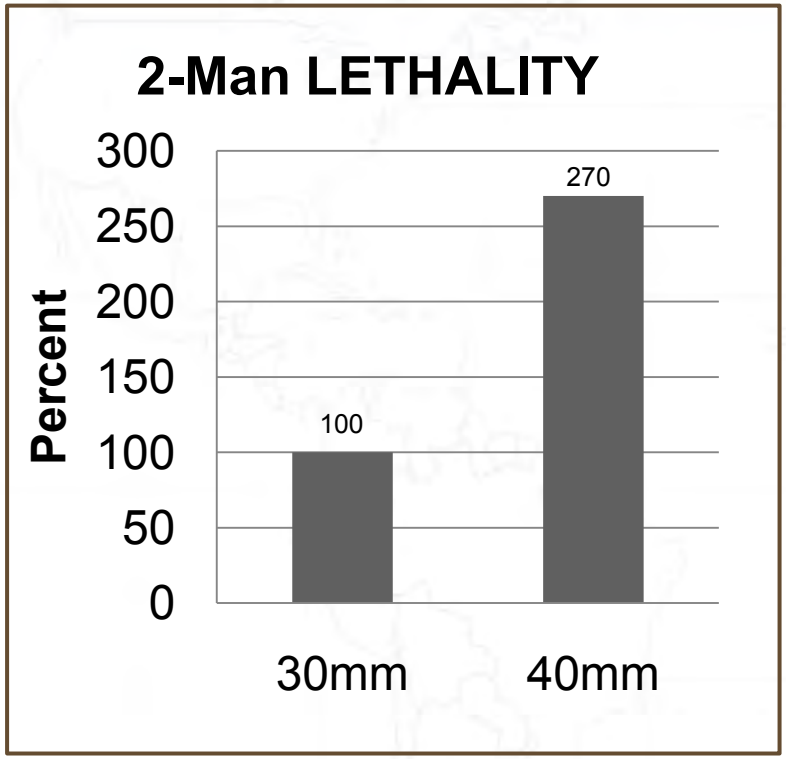
APFSDS-T Caliber Comparisons

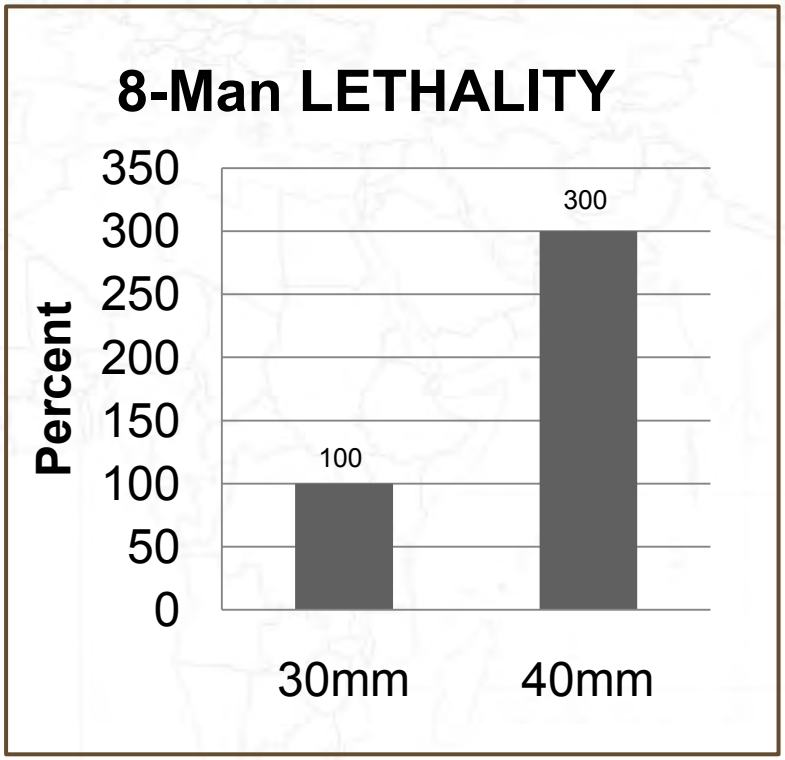


25mm – DU
30mm – Tungsten
40mm – Tungsten

S40mm APFSDS-T offers up to 20% more lethality over the 30mm APFSDS-T while allowing the same number of stowed rounds

MPAB-T Requirements





S40mm Air Burst offers up to 3 times the lethality of the 30mm Air Burst while allowing the same number of stowed rounds

Brief S40mm ammunition history

- US Army Contract Efforts
- Internal Research and Development (IRAD) Efforts



540mm – US Army Contract Efforts

2001-2005 – US Army Contract for the Advanced Light Armaments Combat Vehicle (ALACV)

- Propellant development for:
  - Armor Piercing Fin Stabilized Discarding Sabot with Trace (APFSDS-T)
  - Multi Purpose Air Burst with Trace (MPAB-T)
  - Target Practice with Trace (TP-T)
- Cartridge development:
  - 540mm x 218 APFSDS-T
  - 540mm x 165 MPAB-T
- Live fire demonstrations at High Rate Bursts (HRB) out of the MK44 mounted in a Bradley Fighting Vehicle
- Successful APFSDS-T ballistic penetration performed
- Successful MPAB-T ballistic function demonstrated



S40mm–Internal Research and Development (IRAD) Efforts

2001-Present –IRAD

- Common S40mm x 180mm case design, development, tooling and manufacture complete for S40mm ammunition family
- S40mm APFSDS-T Cartridge Design:
  - Successful aluminum sabot ballistic testing with common case
  - Composite material sabot solution in process
  - Propellant solutions from GD-OTS St. Marks and GD-OTS Canada within 10% of goal at ambient temperature
- S40mm MPAB-T Cartridge Design
  - Induction or contact set fuze with
    - PD/PD delay
    - Self destruct
    - Selectable short/long fuze arming ranges
- S40mm TP-T Cartridge Design
  - Simple two piece metal projectile design for low cost production



S40mm Ammunition Family



S40mm Ammunition Family

- APFSDS-T for armor targets. Features include:
  - Cobalt free penetrator
  - Composite sabot assembly
- MPAB-T for urban and troop targets. Features include:
  - PD/PD delay
  - Short or long selectable arming ranges
  - Airburst function
  - Self destruct function
  - Induction or contact communication fuze
- TP-T for training. Features include:
  - Simple two piece projectile construction for low cost production



MPAB-T TP-T APFSDS-T

540mm Armor Piercing Fin Stabilized Discarding Sabot with Tracer (APFSDS-T)



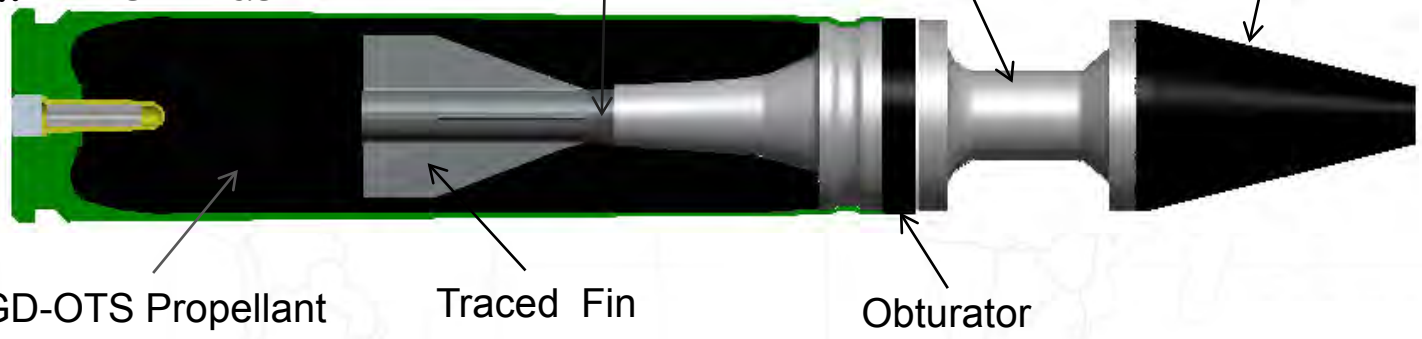
S40mm APFSDS-T – Design Characteristics

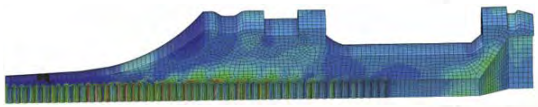
Projectile Features:

- S40mm provides ~50% higher flight weight (penetrator, fin, and windscreen) than the 30mm APFSDS-T
- Muzzle velocity consistent with the 30mm APFSDS-T at 1430mps
- This yields an ~ 20-25% increase in penetration capability over the 30mm and >145% more kinetic energy on target at 2,000m

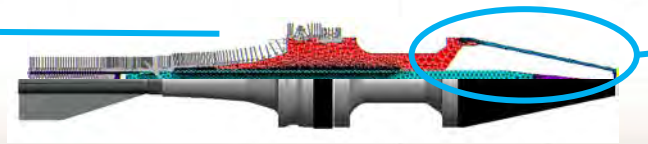
APFSDS-T Cartridge

S40mm x 180 Case

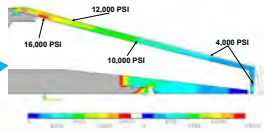




Composite Sabot FEA



Projectile Launch Loads



Nose Cap/Penetrator Tip FEA

S40mm APFSDS-T - Penetrator



S40mm penetrator comparison placing more lethality on target over current 25mm and 30mm solutions

S40mm Challenges and Solutions

Challenge: Muzzle velocity goal of 1430m/s

Solution:

- GD-OTS propellant solutions:
  - SHP831 Hybrid Propellant produced by St. Marks Powder
  - Mixed propellant from:
    - St. Marks Powder, SHP831 Hybrid
    - GD-OTS Canada, Extruded SPDN
- Transition from aluminum to composite sabot decreasing projectile mass



Propellant Example



Composite Sabot Assembly Example

Status:

- Current velocity breakthrough with General Dynamics St. Marks SHP831 Hybrid propellant at ambient temperature
  - Within ~10% of the ambient velocity goal with aluminum sabot
  - Loose fill propellant pour
- Additional testing planned with composite sabot later in 2010 to reach velocity goal

S40mm APFSDS-T – Demonstrated Performance

Spin, yaw, dispersion, penetration, trajectory, and autogun testing have been successfully performed









Back Side of 2" Armor Plate (3km equivalent)

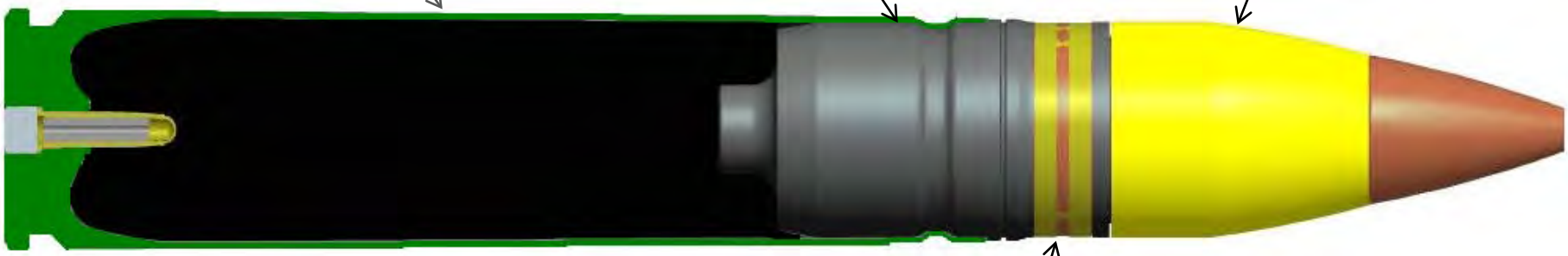


4" Back-up Plate

540mm Multi Purpose Air Burst with Tracer (MPAB-T)



540mm MPAB-T Cartridge

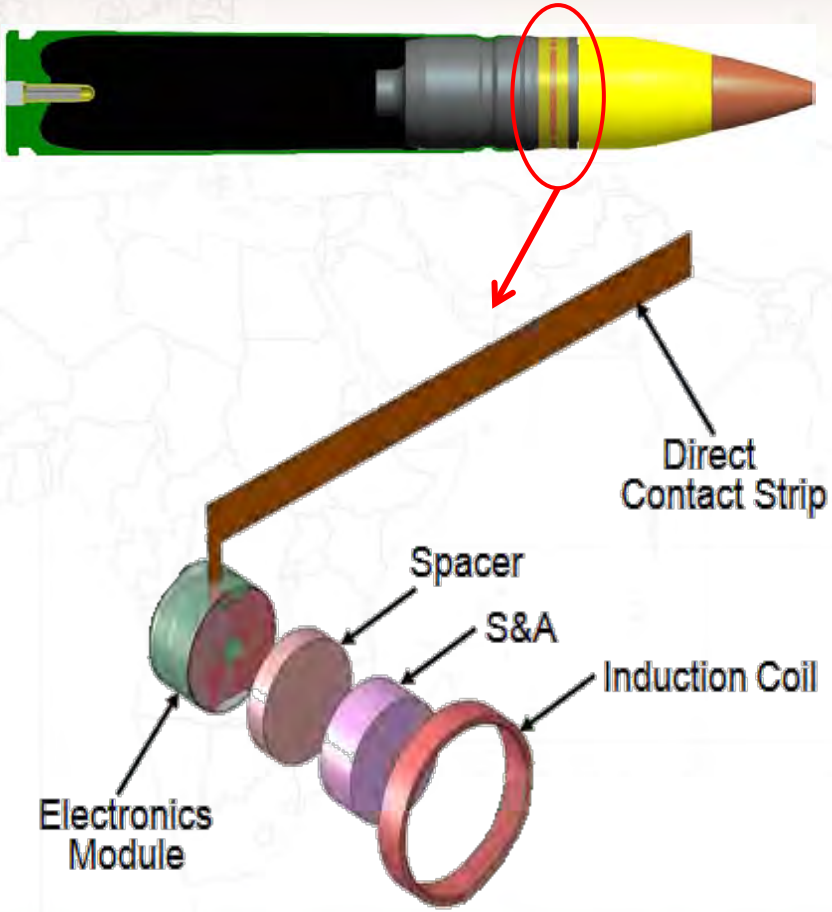


MPAB-T Cartridge

540mm x 180 Case

540mm Air Burst – Fuze Characteristics

- Inductive or contact set, time-based, programmable electronic fuze
- Airburst function
- PD/PD Delay feature to:
  - Increase capability of the ammunition and eliminate the need for HEI PD ammunition
  - Defeat light materiel targets
  - Provide PD function in the unlikely event that an air burst communication signal fails
- Selectable arming: allows user to select an arming range of short or long
- Self destruct function



Induction/Contact Airburst Fuze

S40mm Air Burst – Demonstrated Performance









One 3-rd burst hit 12 of 12 mannequins and perfed vests/helmets 7 times (2 mannequins) @ 600m

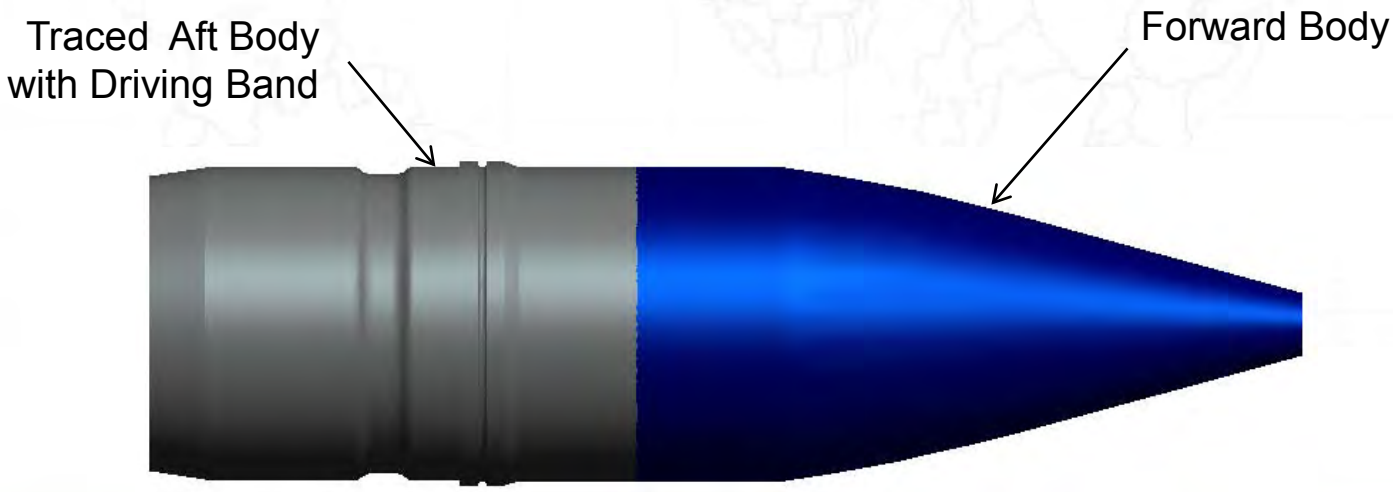
540mm Target Practice with Tracer (TP-T)



540mm TP-T

Projectile Features:

- Simple two piece metal projectile design for low cost production
- Ballistic match to the MPAB-T
- Qualified tracer configuration: PGU-30 trace igniter and M793 trace sustainer



Summary

- The S40mm cartridges offer greater lethality than 30mm without reducing the number of stowed rounds:
  - Developed link and linkless MK44 feed systems have provisions for S40mm ammunitions
  - APFSDS-T design provides ~20-25% more penetration than 30mm
  - MPAB-T design is up to 3 times more lethal than 30mm

Storage Volume
30mm = 40mm

- APFSDS-T sabot and GD-OTS propellant development will yield goal muzzle velocity by end of 2010
- The S40mm APFSDS-T and MPAB-T munitions have been successfully demonstrated out of the MK44 cannon



MK44 Weapon

S40mm Family



MPAB TP KE

NDIA – 2010
Numerical Prediction of Large Caliber Cannon Impulse



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

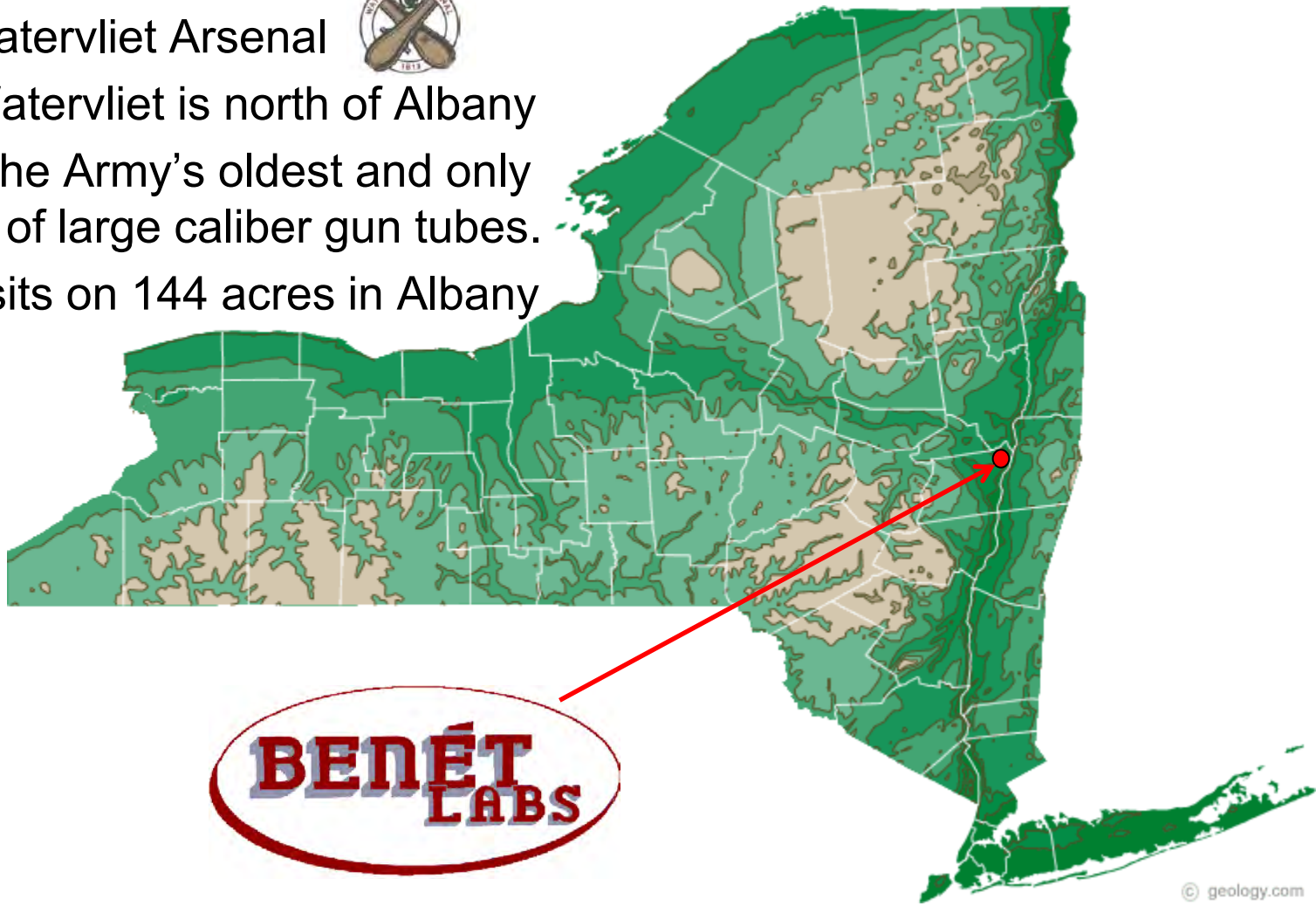
Bob Carson
Mechanical Engineer
Fluid Dynamics Analyst
Date: 19 May 2010

AGENDA

- Where is Benet Laboratories?
- What is a Large Caliber Cannon?
- What is a Cannon Muzzle Brake?
- Why is this Relevant?
- Results of Analysis
- Conclusions and Ongoing Work

OUR LOCATION

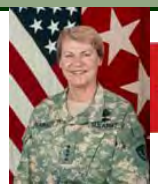
- Located at Watervliet Arsenal
- The City of Watervliet is north of Albany
- Watervliet is the Army's oldest and only manufacturer of large caliber gun tubes.
- The Arsenal sits on 144 acres in Albany County.

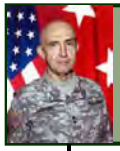


ORGANIZATIONAL HIEARCHY

DEPARTMENT OF THE ARMY

ARMY MATERIEL COMMAND
(AMC)
GEN ANN DUNWOODY
Wash, DC





RESEARCH, DEVELOPMENT, & ENG'G COMMAND
(RDECOM)
MAJ GEN NICKOLAS JUSTICE
Ft. Belvoir, VA



ARMAMENT RD&E CENTER
(ARDEC)
DR. JOSEPH A. LANNON
Picatinny, NJ



TACOM LIFE CYCLE MGMT COMMAND
(TACOM-LCMC)
MAJ GEN SCOTT G. WEST
Detroit, MI



Mr. Lee Bennett

Benet Laboratories
developer of
Army and USMC Large Caliber Cannon

Watervliet Arsenal
producer of
Army & USMC Large Caliber Cannon



Col. Scott Fletcher

Joint Manufacturing and Technology Center at Watervliet (JMTC-WV)
Watervliet, NY

- Research & Engineering Division of Watervliet Arsenal renamed Benét Laboratories in 1962
- Became part of the US Army Armaments RD&E Center (ARDEC) in 1977
- Benét Laboratories' cannons have been produced at Watervliet Arsenal since 1887.

MISSION

Plan, program, budget, manage, and execute the technology base, life cycle engineering, manufacturing technology development & implementation, production support, and field support and sustainment for:

- ***Large Caliber Cannon*** (conventional and electromagnetic)
  - Howitzer Cannon (indirect fire)
  - Guns (direct fire)
  - Mortar Cannon, BiPods & Baseplates
- ***Large Caliber Direct Fire Gun Mounts***
- ***Large Caliber Direct Fire Vehicle Turret Components***

Mission Items

Large Caliber Cannon CRADLE-To-GRAVE

Armament Technology - Design & Development – Manufacturing Technology Development @ WVA
Production Support - Field Support & Sustainment – Industrial Base Support

Benet Laboratories -Watervliet Arsenal Cannon Product Line

Technology- Design- Development- ESIP- Field Sustainment


120mm M256 Cannon
M1A2 ABRAMS System


155mm M284 Cannon
M109A6 PALADIN System


81mm M253 Mortar Barrel
M252 Medium Mortar System


120mm M298 Mortar Barrel
M120 Heavy Mortar System


105mm M68A2 Cannon
Stryker System


155mm XM776 Cannon
M777 System


60mm M225 Mortar Barrel
M224 Mortar System


81mm M253 Mortar Barrel / M252 Mortar System
on
USMC LAV Carrier-mounted Mortar Vehicles


155mm M199 Cannon
M198 System


120mm M298 Mortar Barrel / M121 Mortar System
on
M1064 Carrier-mounted Mortar Vehicles


105mm M20A1 Cannon
M119 System


105mm M137 Cannon
M102 System


105mm M137 Cannon
AC-130 Gunship

XM360 Cannon System

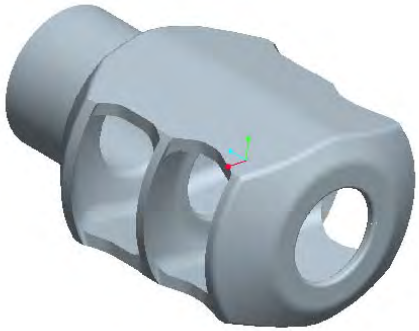
- Future Combat Systems (FCS) 2003 – 2009.
  - Goal - strategically deployable, tactically superior and sustainable force
- Mounted Combat System (MCS)
  - Lighter and more easily transportable
  - Reduced crew requirements
- 120 mm smooth bore cannon
- Fires kinetic energy rounds
  - Anti-tank round

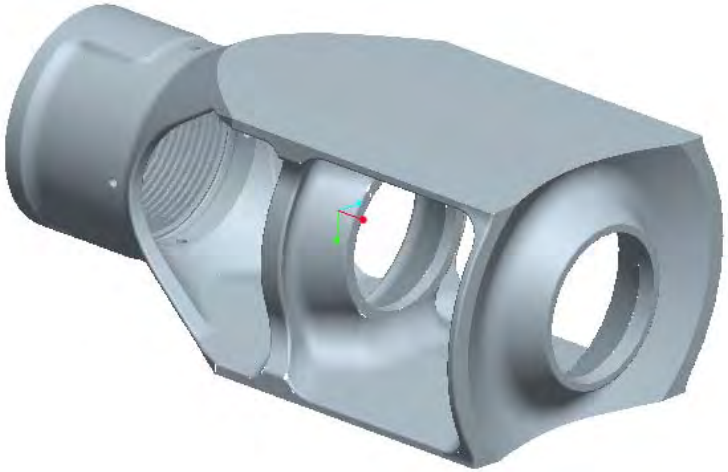


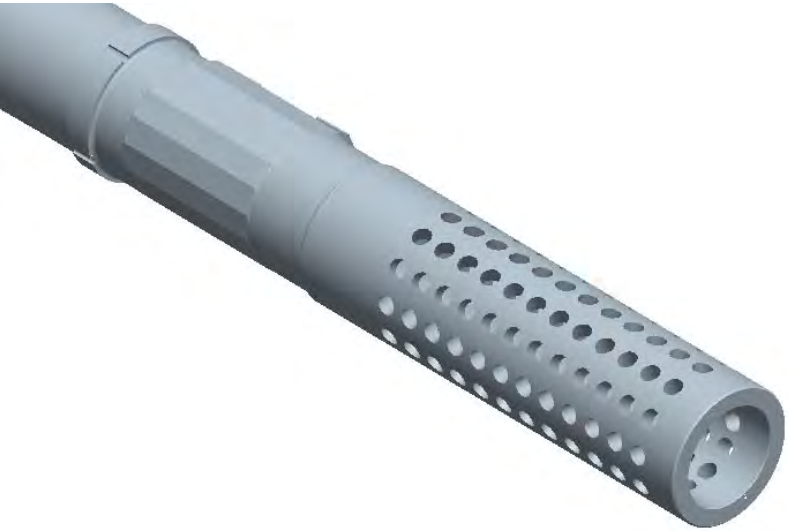


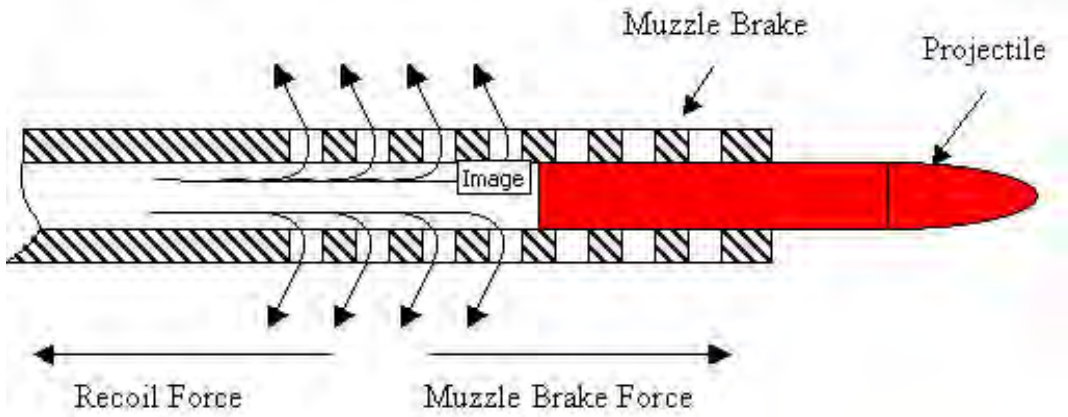
Muzzle Brake Technology











Muzzle Brake Relevance

"Lethality of the 120 with impulse of 105."





- M1A2 Abrams Battle Tank
- 70 ton class
- 120 mm Cannon

- FCS MCS
- 20 ton class
- 120 mm Cannon

Interior Ballistics of the XM360

- Breech pressures consistent with Hot round.
- High velocity at muzzle exit.
- Tube length around 5.5 m.
- Propellant mass was matched.
- Patched pressure vs time, velocity vs time and temperature using custom field functions.





Measuring the Efficiency

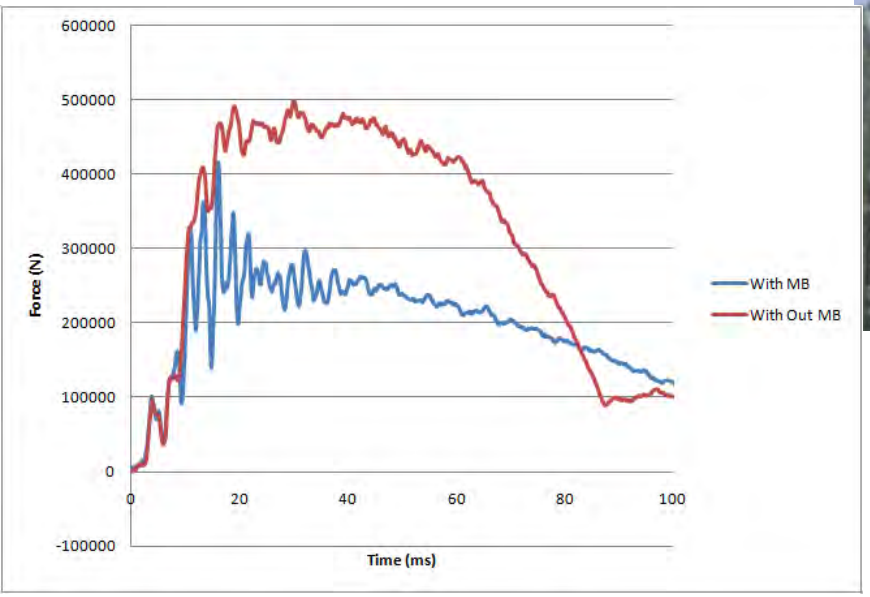
- Overall Efficiency

$$\psi = \frac{I_{wo} - I_w}{I_{wo}}$$

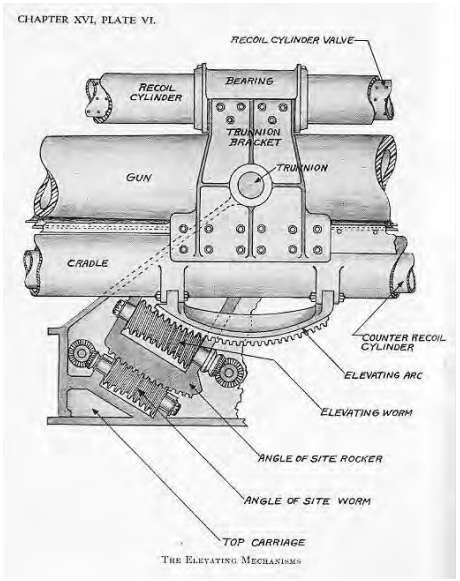
- Gas Dynamic Efficiency

$$\beta = \frac{\Delta recoil_a}{\Delta recoil_s} \longrightarrow \beta = \frac{I_{wo} - I_w}{I_{wo} - m_p V_e}$$

Test Results for the Impulse



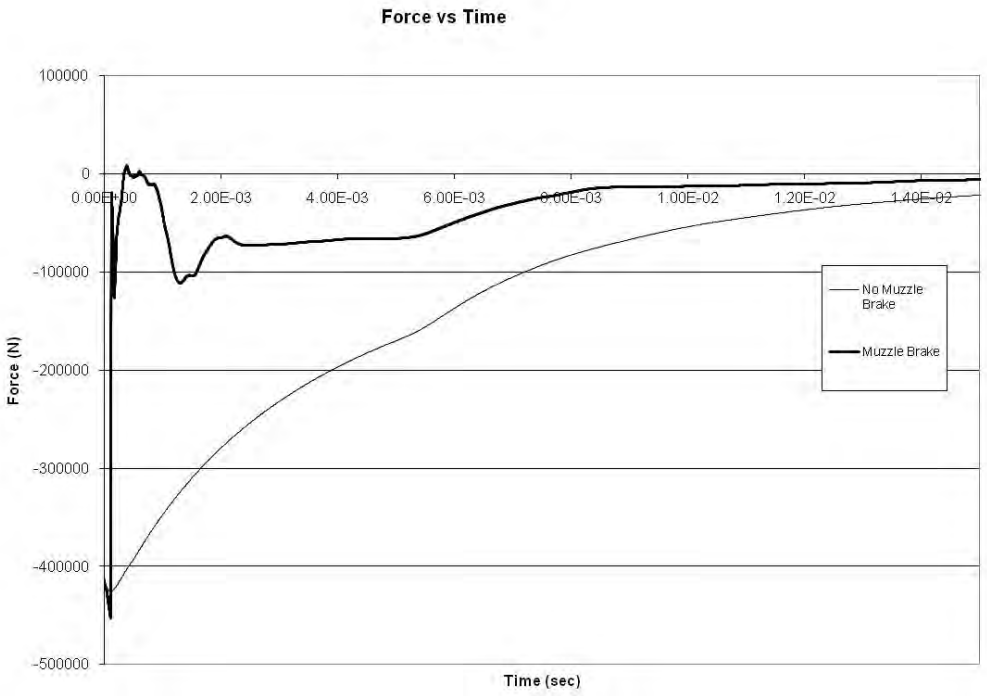




- Overall Efficiency – 24.8%
- Gas Dynamic Efficiency – 49.0%
- Max Force is 355,000 N

$$I = \int F dt$$

Modeling the Impulse



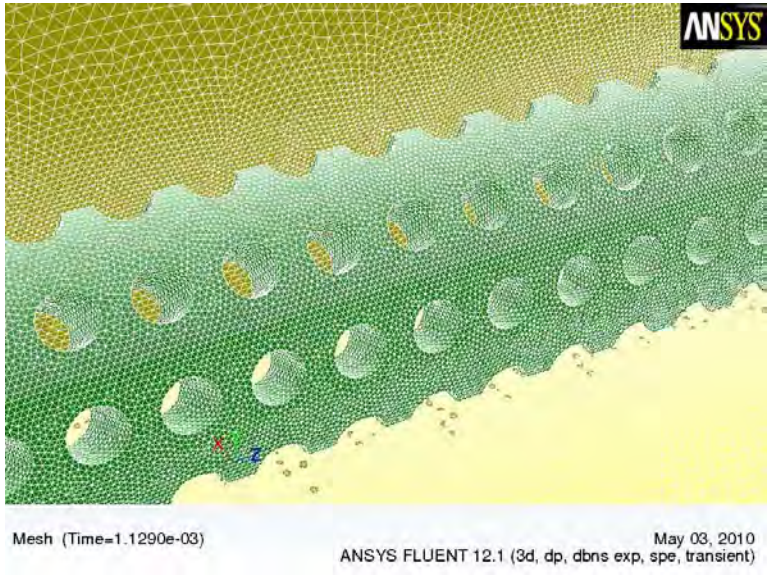
- Impulse

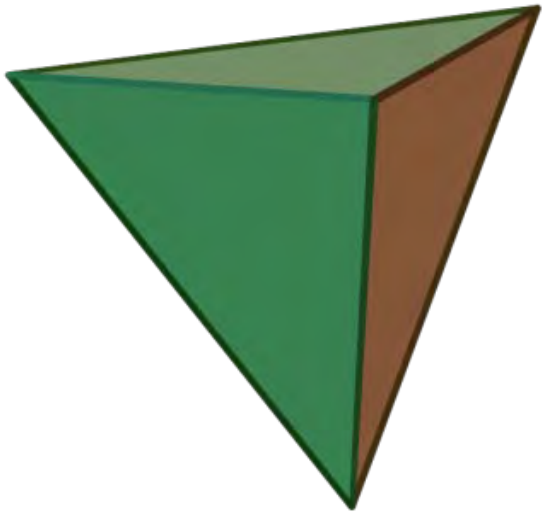
$$I = \int F dt$$

- ANSYS Fluent models the fluid flow.
- Force in the x Direction
- The Force curve is then integrated wrt time during the blown down of the muzzle brake

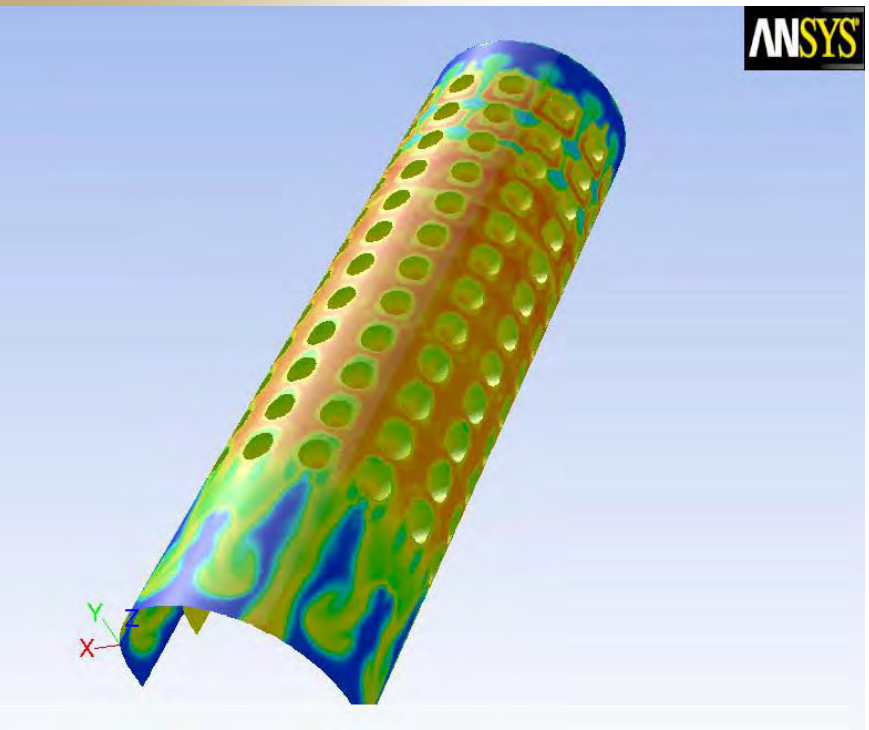
Modeling the Impulse – Sim1

- Simulation 1
- Utilized 3D 1/8 model
- No projectile in simulation
- Fully Tet pave mesh with control around the muzzle brake for size.
- Fine mesh in muzzle brake holes.
- Tube interior and muzzle brake from Pro-E models

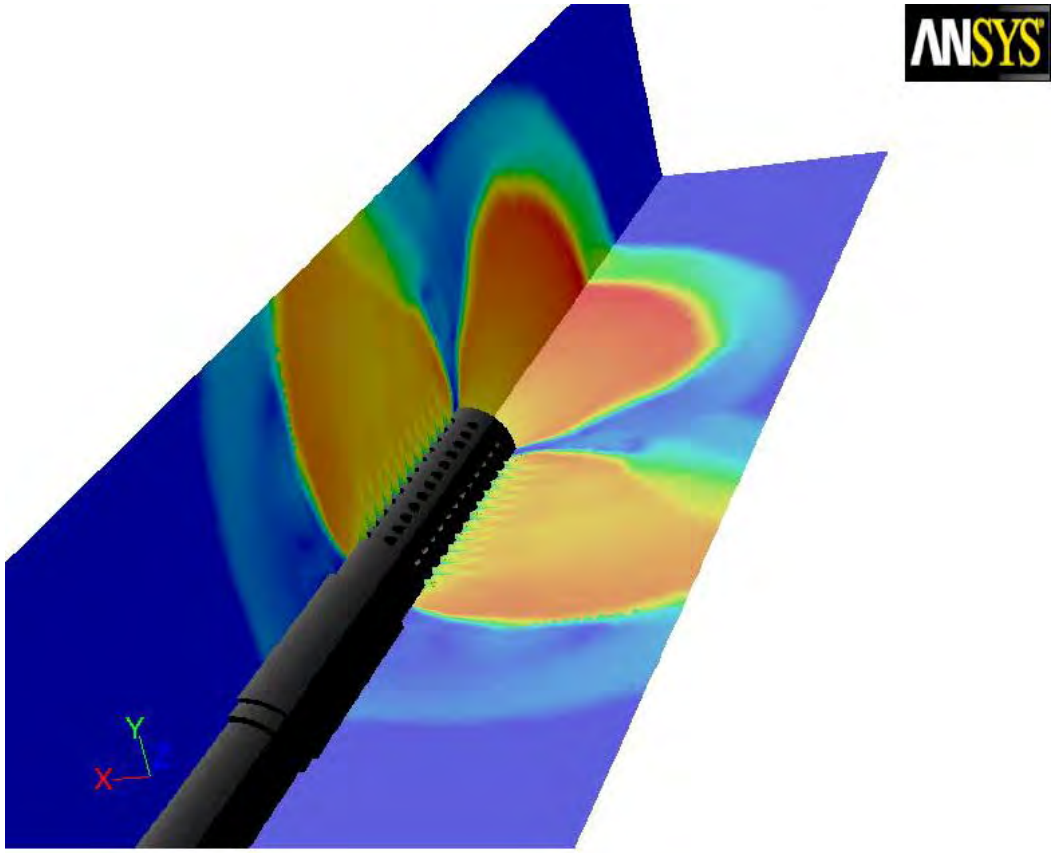




Modeling the Impulse – Sim1

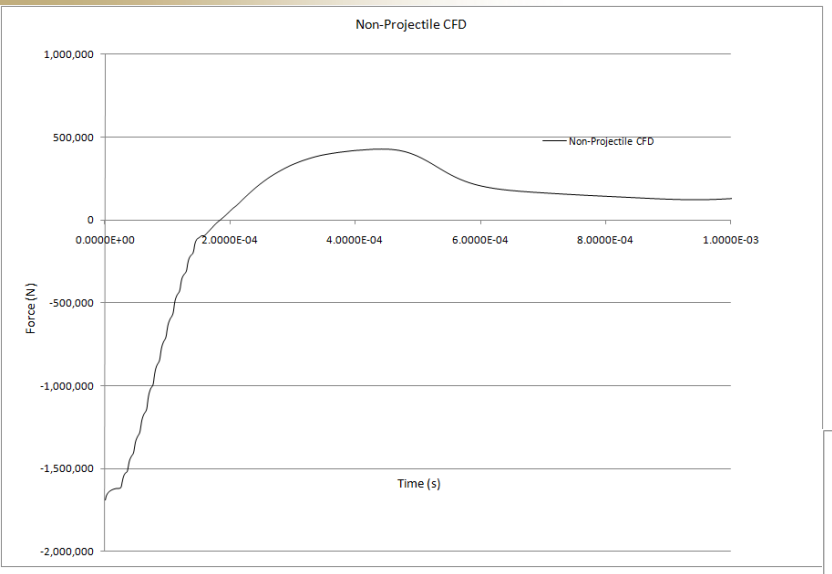


Static Temperature
Time – 0.5 ms



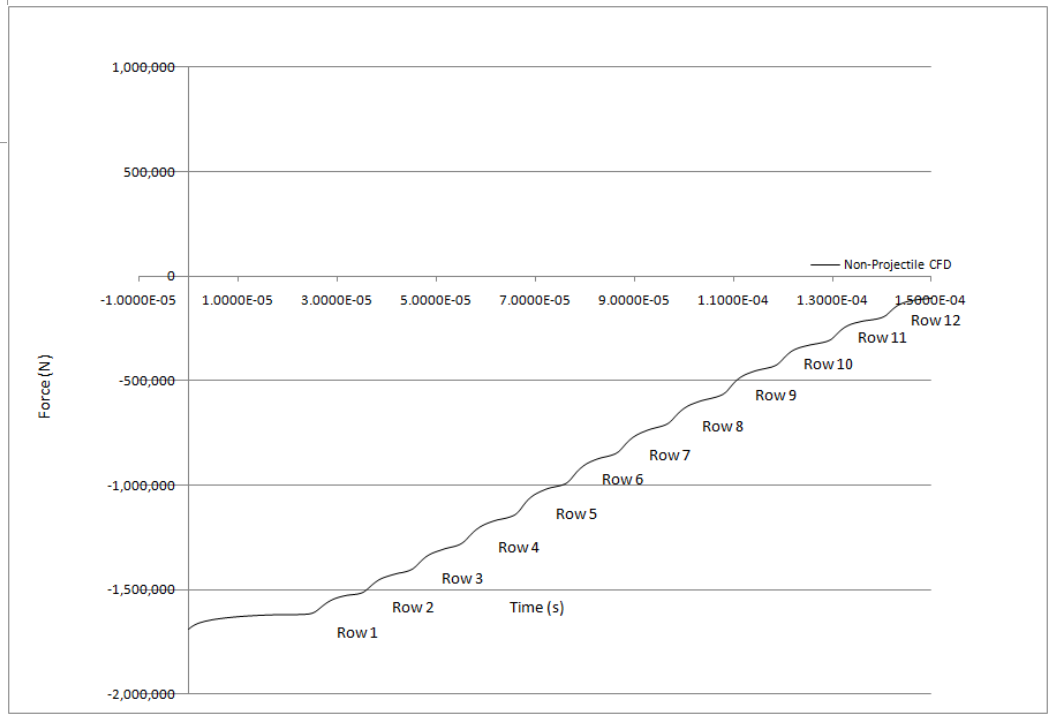
Velocity
Time – 0.5 ms

Modeling the Impulse – Sim1





- Force in the rearward direction peaks at around 450,000 N.

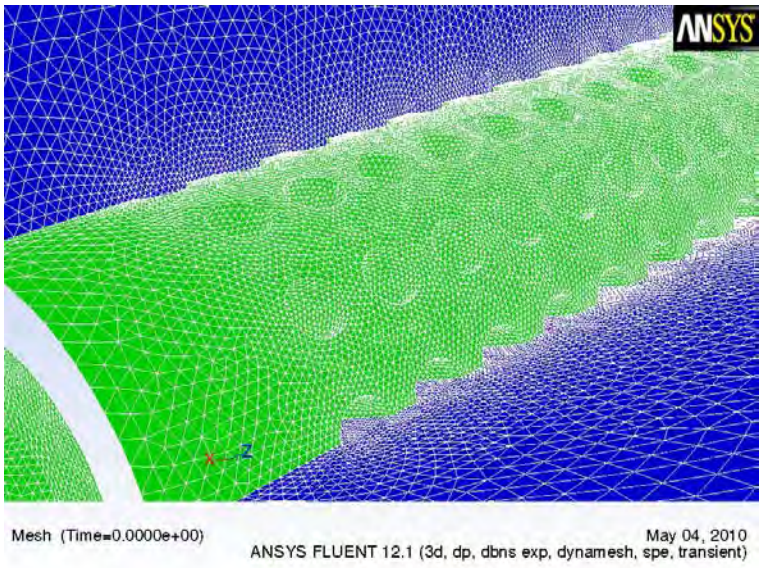


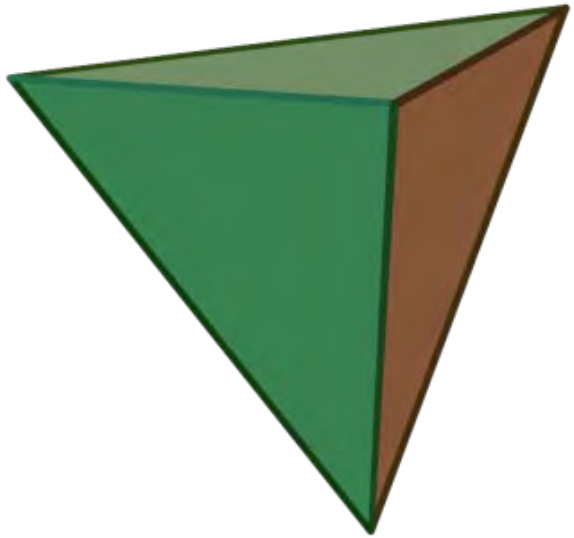
Modeling the Impulse – Sim1 vs Test

- Simulation 1
  - Runtime approximately 2.5 days on 16 processors
  - Overall Efficiency – 26%
  - Gas Dynamic Efficiency – 52%
  - CFD Prediction of Impulse – 1.7% high
- Test
  - Overall Efficiency – 25%
  - Gas Dynamic Efficiency – 49%

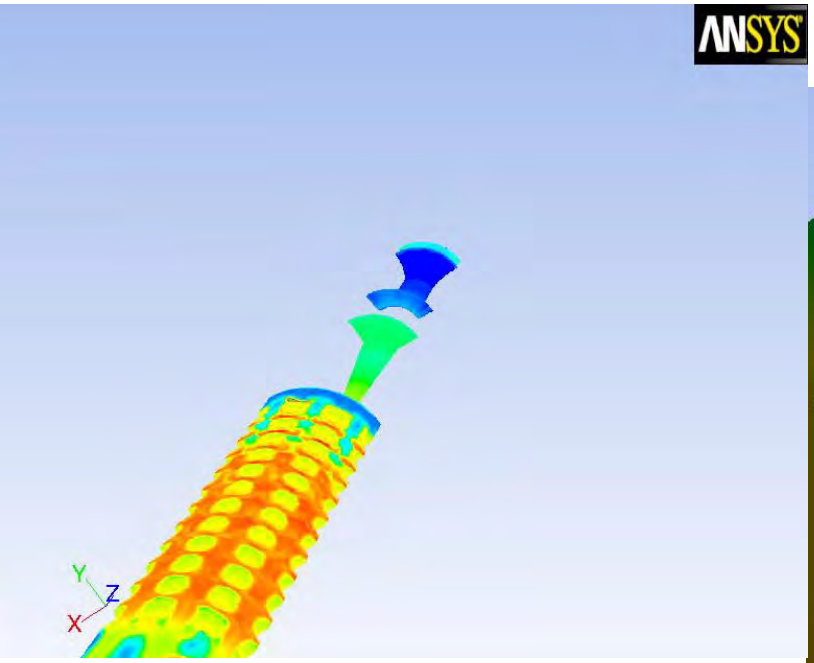
Modeling the Impulse – Sim2

- Simulation 2
- Utilized 3D 1/8 model
- 120mm projectile in simulation
- Tetrahedral (four sided) dominate mesh with control around the muzzle brake for size.
- Fine mesh in muzzle brake holes.
- Tube interior and muzzle brake from Pro-E models

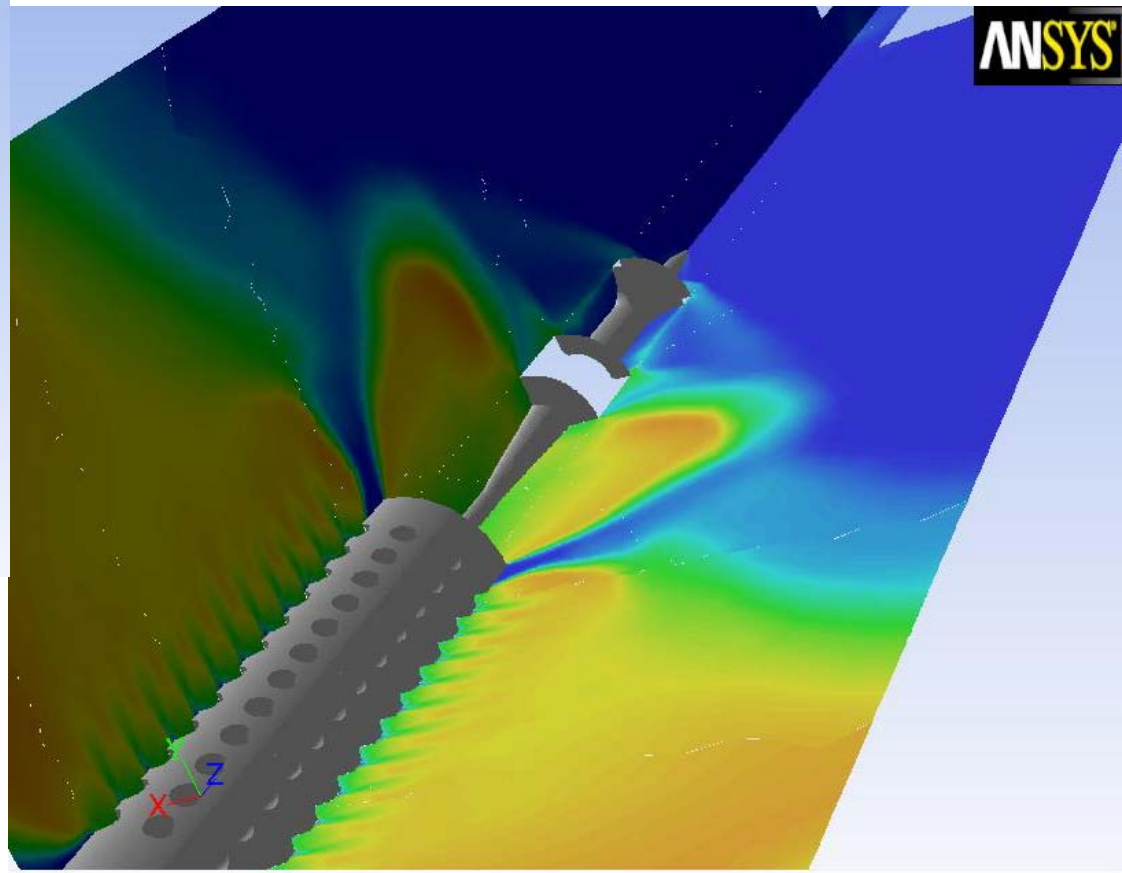




Modeling the Impulse – Sim2

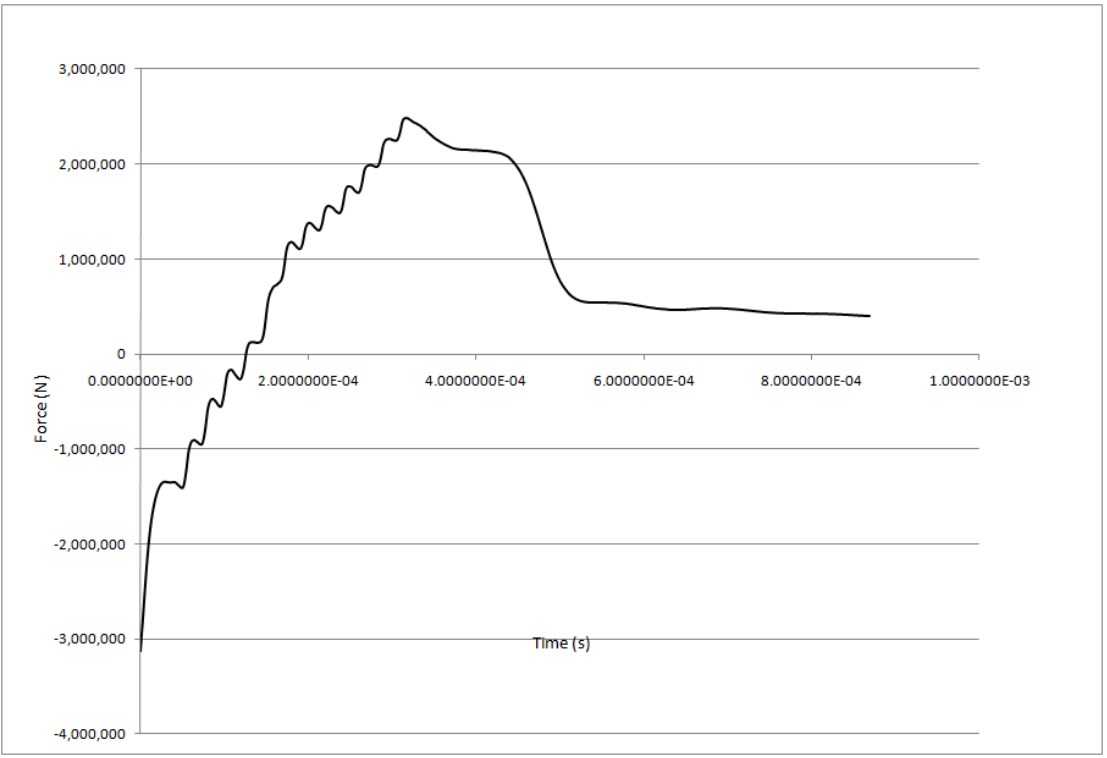


Static Temperature
Time – 0.5 ms



Velocity
Time – 0.5 ms

Modeling the Impulse – Sim2





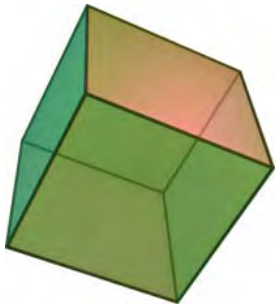
- Force in the rearward direction peaks at around 2,500,000 N.

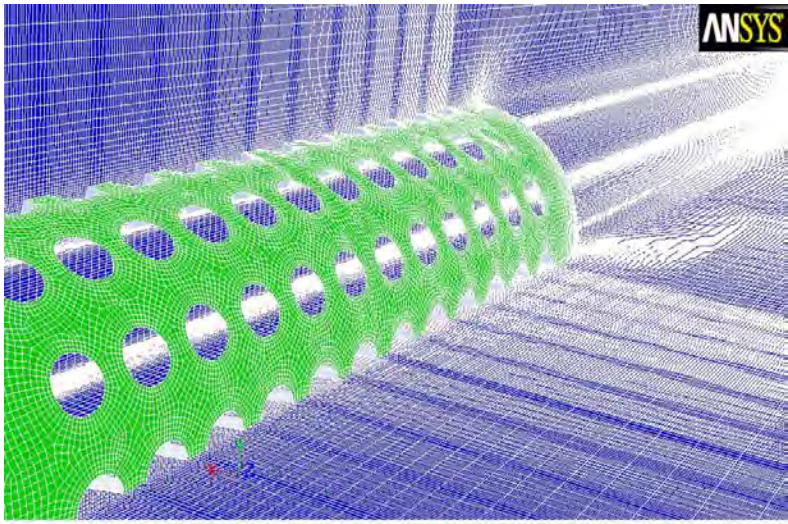
Modeling the Impulse – Sim2 vs Test

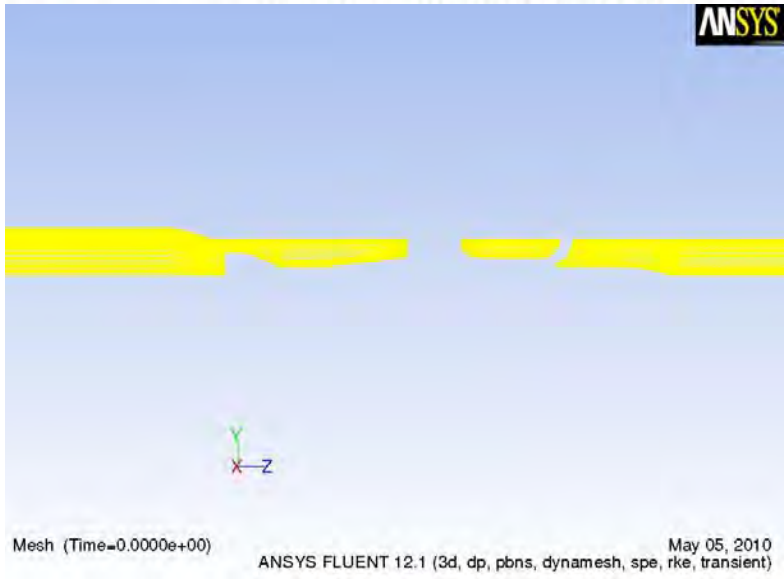
- Simulation 2
  - Runtime approximately 1 month on 32 processors.
  - Overall Efficiency – 28%
  - Gas Dynamic Efficiency – 55%
  - CFD Prediction of Impulse – 4.2% high
- Test
  - Overall Efficiency – 25%
  - Gas Dynamic Efficiency – 49%

Modeling the Impulse – Sim3

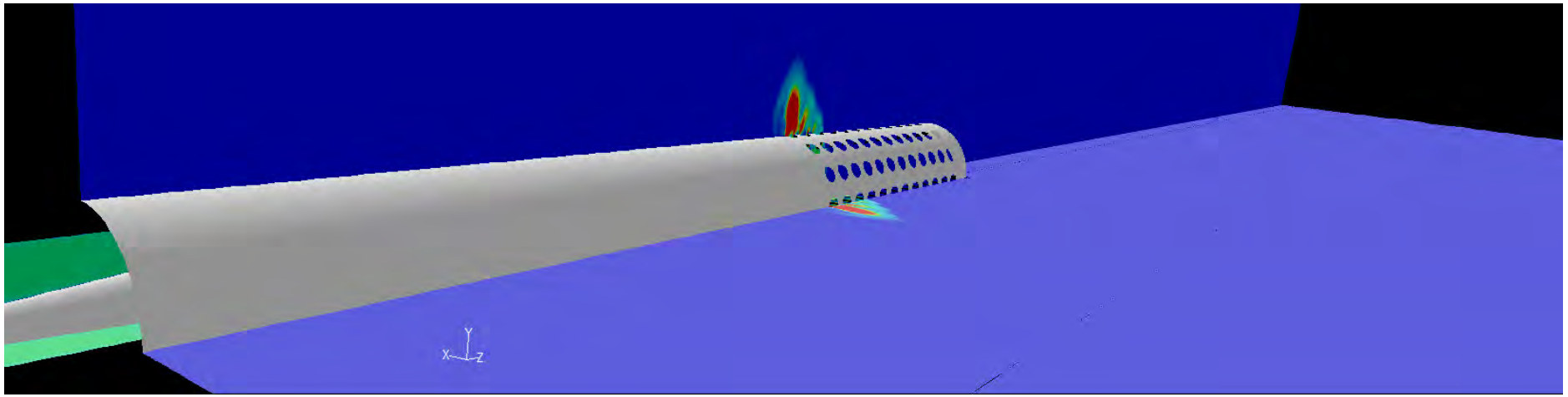
- Simulation 3
- Utilized 3D 1/8 model
- 120mm projectile in simulation
- Hexahedral (six sided) dominate mesh with control around the muzzle brake for size.
- Fine mesh in muzzle brake holes with significant domain deconstruction.
- Tube interior and muzzle brake from Pro-E models







Modeling the Impulse – Sim3



- Precursor shot due to projectile motion more accurately models the realistic effect of firing.
- Simulation running approximately 3 weeks on 48 processors.

Modeling the Impulse – Sim3 vs Test

- Simulation 3
  - Runtime approximately 1 month on 48 processors.
  - Overall Efficiency – UNKNOWN
  - Gas Dynamic Efficiency – UNKNOWN
  - CFD Prediction of Impulse – UNKNOWN
- Test
  - Overall Efficiency – 24.8%
  - Gas Dynamic Efficiency – 49.0%

Summary of Results

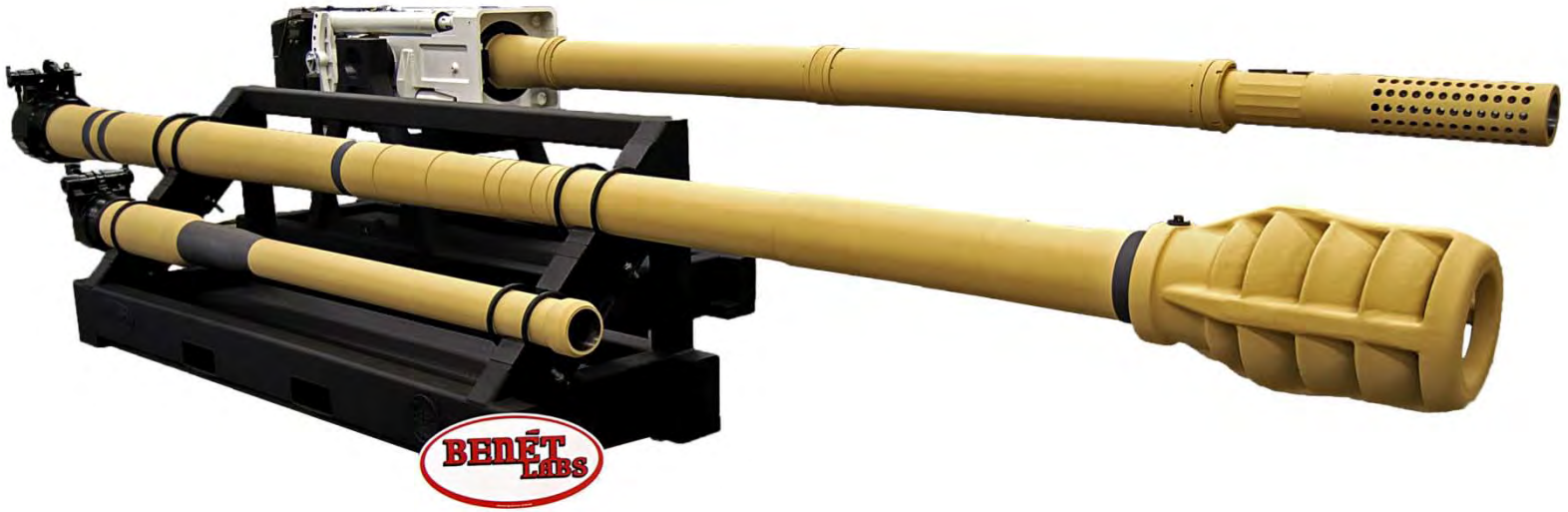
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- Simulation 2
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- Simulation 3
  - Runtime approximately 1 month on 48 processors.
  - Overall Efficiency – UNKNOWN
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- Test
  - Overall Efficiency – 24.8%
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Concluding Remarks

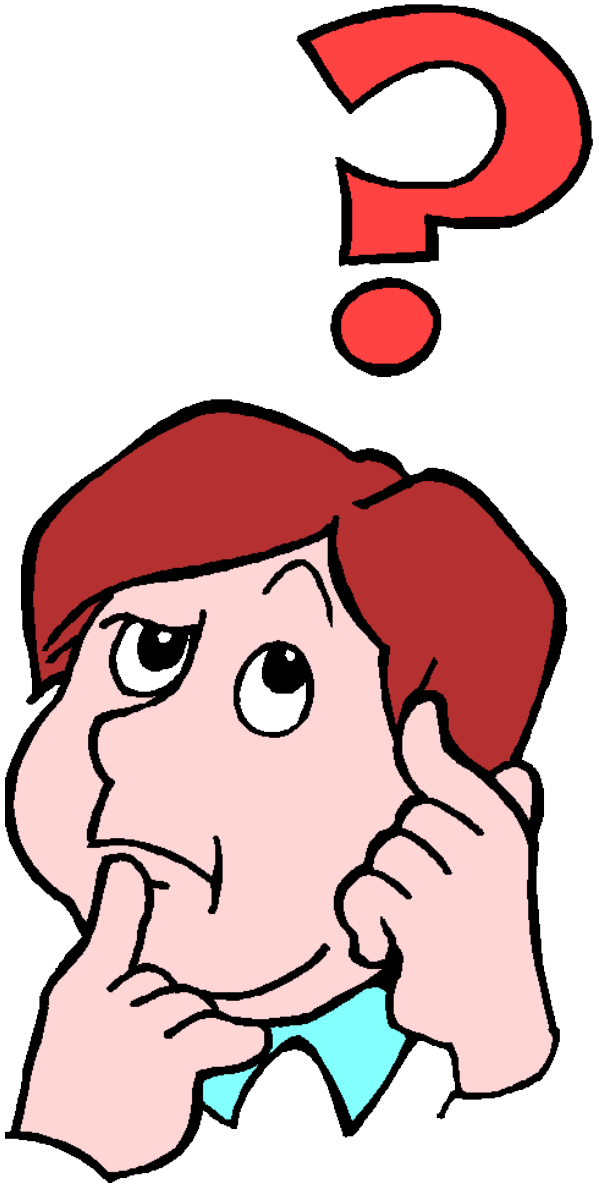
- Inconclusive on whether the incorporation of a projectile has a significant impact on impulse modeling.
- Grid plays a major role in the refinement of the solution.
- Current results show the non-projectile case produces best results but expectation is that the hexahedral dominate mesh will produce superior results.
- Impulse prediction is adequately close in all simulations and can be used as a tool for design.
- CFD application can be extended beyond large caliber.

Concluding Remarks

- Advantages to M&S reduce the test cost and development timeframe.
- Display of Benet designed FCS equipment currently at NDIA 2010.



Questions?





HOWITZER DIGITIZATION

William Key and Yves PATUREL

Joint Armaments Conference

Digitization of a Howitzer

- Installation of INS Based Digital Orientation System
- Provides Barrel Orientation Parameters Constantly and Accurately
- Provides Howitzer Position
- Presents Operator Friendly Data to the Gun Crew

TOWED GUN M105



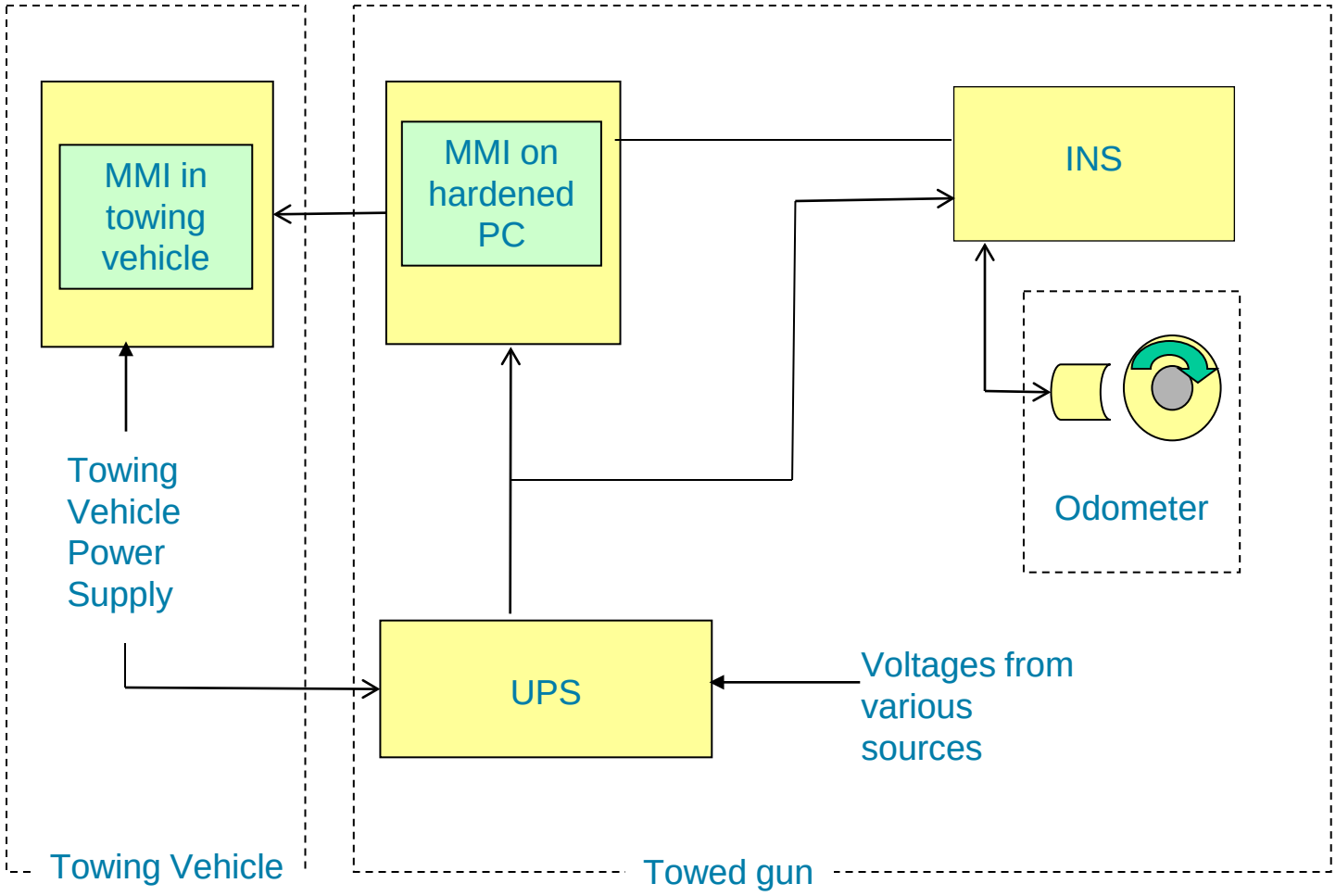
Digitization of a Howitzer

- Enables Fast operation :
  - Quick alignment
  - Knowledge of position
- Enables Quick angular positioning :
  - Elevation
  - Bearing
- Bottom Line
  - More rounds per minute on Target

Digitization Package

- INS Based Navigation System
- Power Supply pack with batteries
- Hardened PC
- Smart User Interface (MMI)

Typical Digitized Gun



Digitization Package Functional Requirements

- Performance (minimum)
  - Heading: 0.1 deg (secant latitude),
  - Attitude: 0.1 deg roll, pitch
- No moving parts
  - Fiber Optic Gyro (FOG) or Ring Laser Gyro (RLG) Sensor
  - Optical
- Very low weight components (less sensitivity to shocks)
  - FOG or RLG INS
  - Similar Weight

Digitization Package Functional Requirements

- Power Supply Pack
  - Gun Mounted Power Source
  - 12 hour operation min without external power
- Electronics
  - Low Power Consumption
  - Shock Hardened
- Temperature management
  - Extreme Temperature Range High and Low
  - No External Cooling Fans

Digitization Package Functional Requirements

- Hardened Computer
  - Shock resistance (shock mounted)
  - >400 g in 4 millisecond nominal
- Waterproof
  - IP 66 Waterproof Requirement Minimum
  - 30 min direct spray without leaking
- Display
  - Readable in direct sun conditions
  - Touch Screen MMI

Digitization Package Functional Requirements

- No limited lifetime components
  - “Use Before Date”
  - Acronym “USD”
- Definition of USD
  - Failure of Key Component prior to Computed MTBF
  - Unscheduled Failure
- MILHB 217 MTBF Example
  - MTBF FOG and RLG similar - 40,000 hrs nominal
  - USD RLG IMU 7,000 to 10,000 hrs operational
  - USD FOG IMU >85,000 hrs operational

Digitization Package Operational Requirements

- Good Shock Management
- High Reliability (hundreds or thousands of rounds will be fired)
- Full Performance Before and After Firing
- No Long or Complex Setup
- Operator Friendly

Shock Management Functional Requirements

- Shock Survivability
  - System Must Not be Disabled by Shock
  - Survive Unlimited number of Shocks
- Inertial system
  - Retain Position Memory
  - Ready to Shoot After Recoil
- Orientation System Mounted Directly on Gun
  - Subjected to very high shocks (> 400 g)

Shock Management Issues

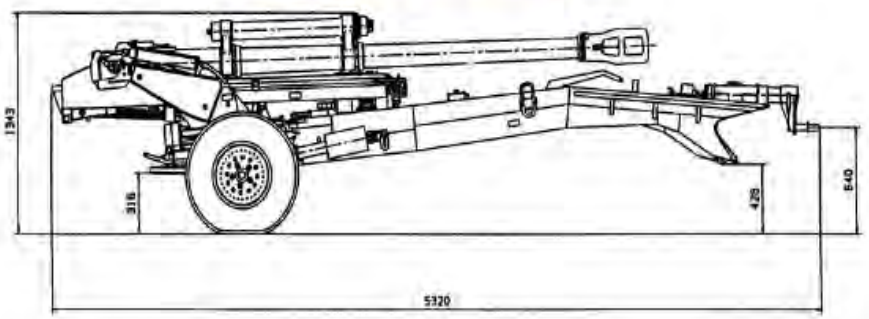
- COTS Solution
  - Mounting trays with Isolators
  - Maintain shock to lower levels
- Compliant Isolators
  - Limit Shock Loading
- Isolators must be stable
  - No Variability after Repeated Shocks and/or Time

Digitization of a 105 mm howitzer - Example

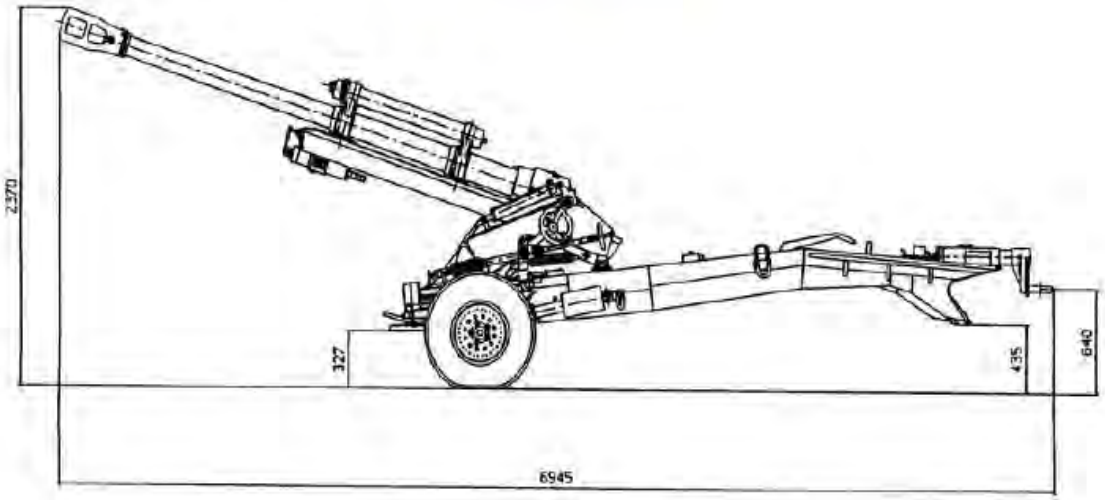
- Program Sponsor
  - Nexter SAS (France)
    - (www.nexter-group.fr)
- Howitzer
  - Nexter SAS
    - 105 mm Lightweight Howitzer
- Orientation System
  - IXSEA SAS (France) www.ixsea.com
    - ADVANS LYRA FOG Inertial Navigation System (INS)
    - Hardened PC
    - LI Ion batteries

NEXTER Lightweight 105 MM Howitzer

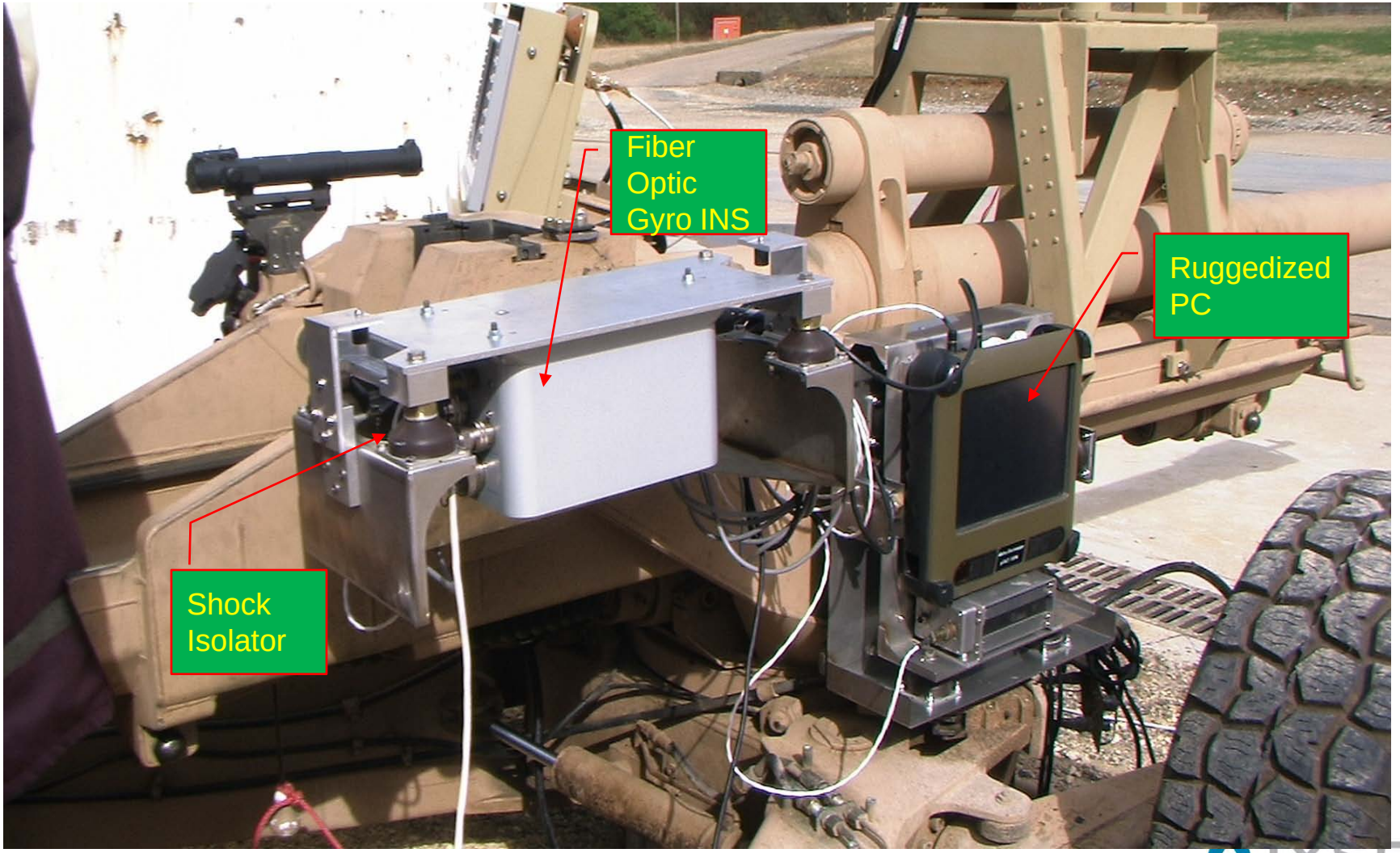
Normal Travel Mode (folded)



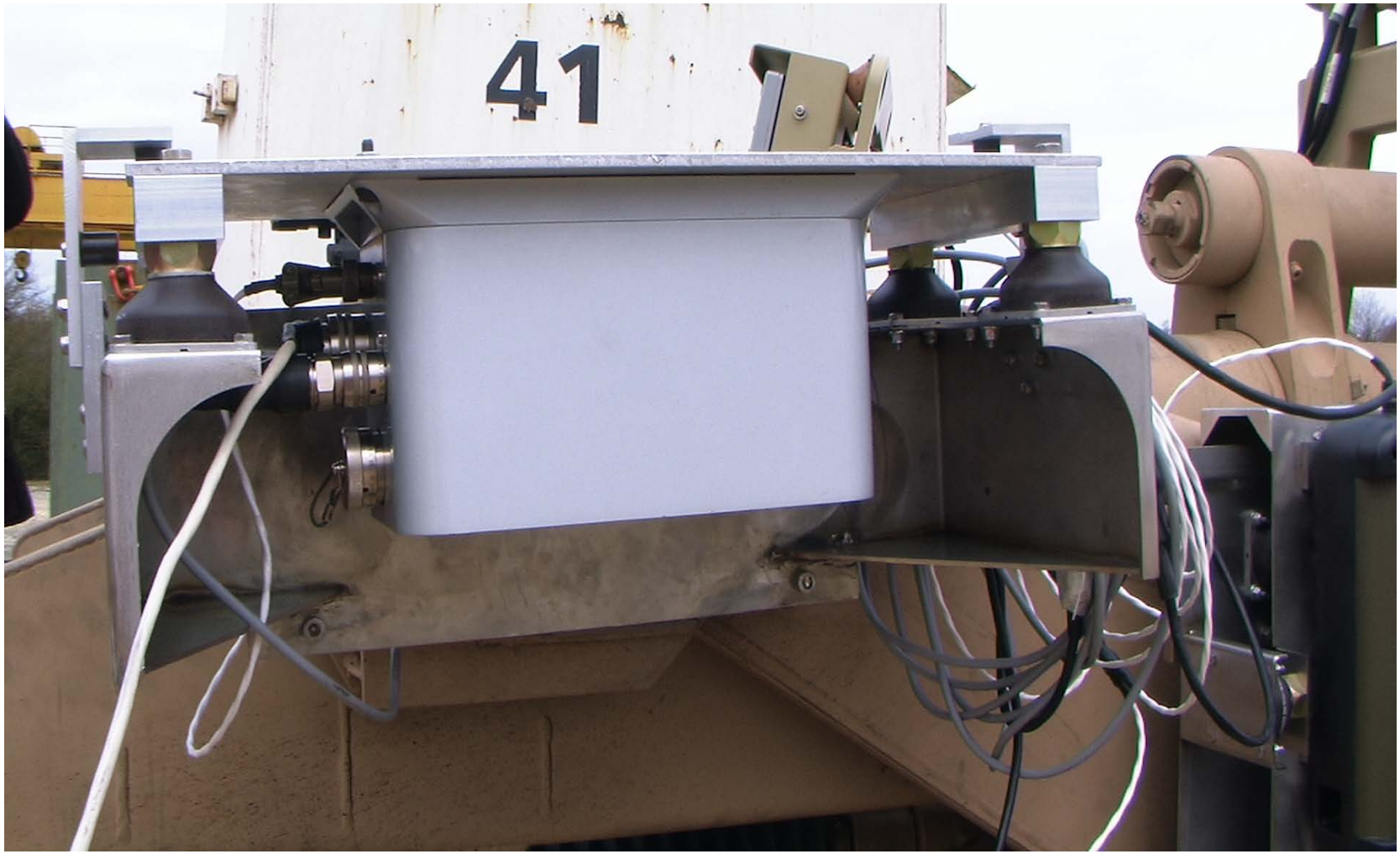
Emergency Travel Mode



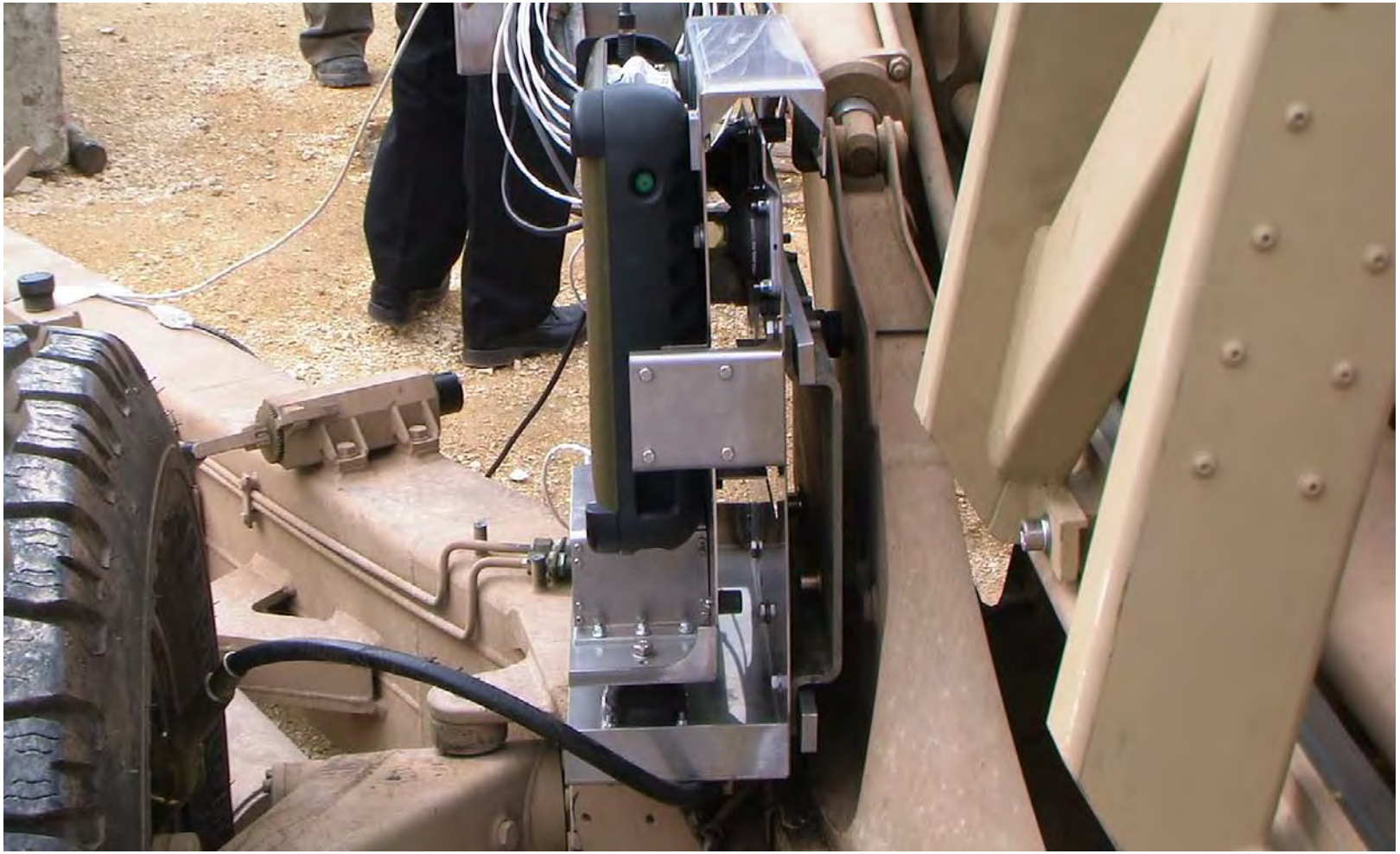
Nexter 105 mm Installation for Validation Trials



Fiber Optic Gyro (FOG) Shock Mount Installation



Ruggedized PC Shock Mount Installation



Ruggedized PC Man Machine Interface (MMI)



- Mounted on Shock Mounted Fixture
- Contains Wi-Fi Interface
- High Light Power for Full Sunlight Readability
- Cover for UV Protection when Not in Use

Firing Trials

- Gun Outfitted with Orientation System
  - Shock Mounted Equipment
  - Compliant Mounts
- Three Types of Proof Firings
  - Normal Ammunition
  - Overspeed Ammunition
  - Overpressure Ammunition
- Execution of Trials
  - Field Conditions
  - Multiple Firings
  - Each Type Ammunition

Firing Trials

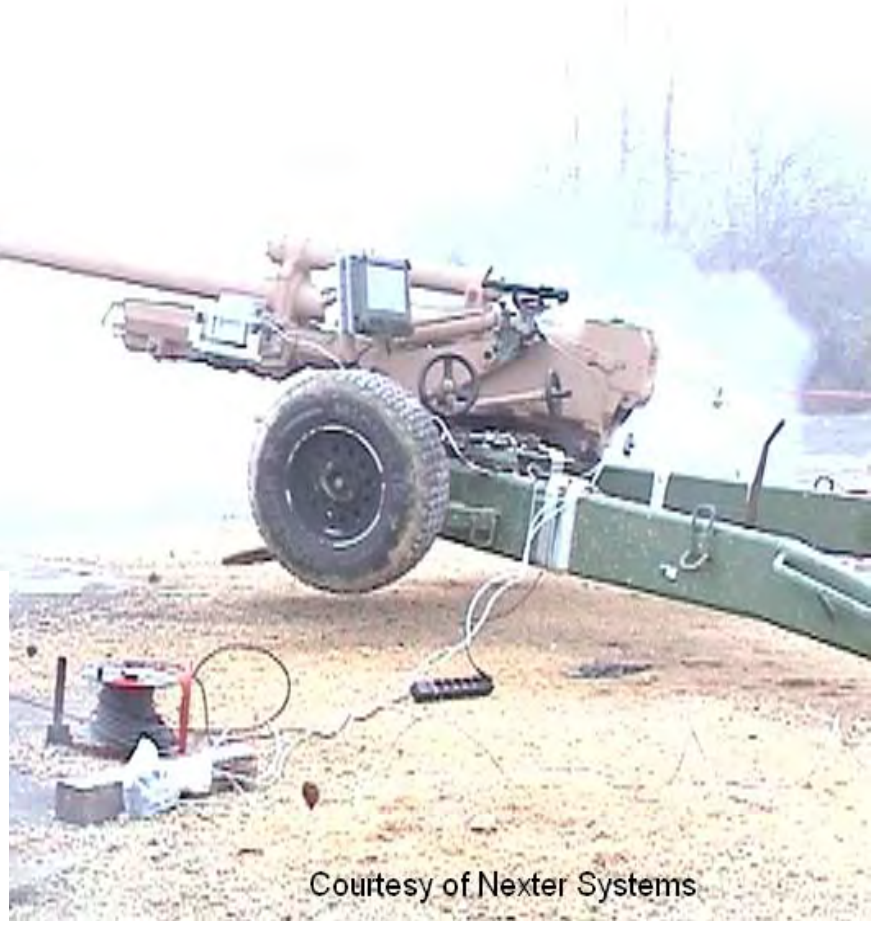


Nexter 105 mm in Towed Configuration



IXSEA Man Machine Interface

Firing Trials Installation



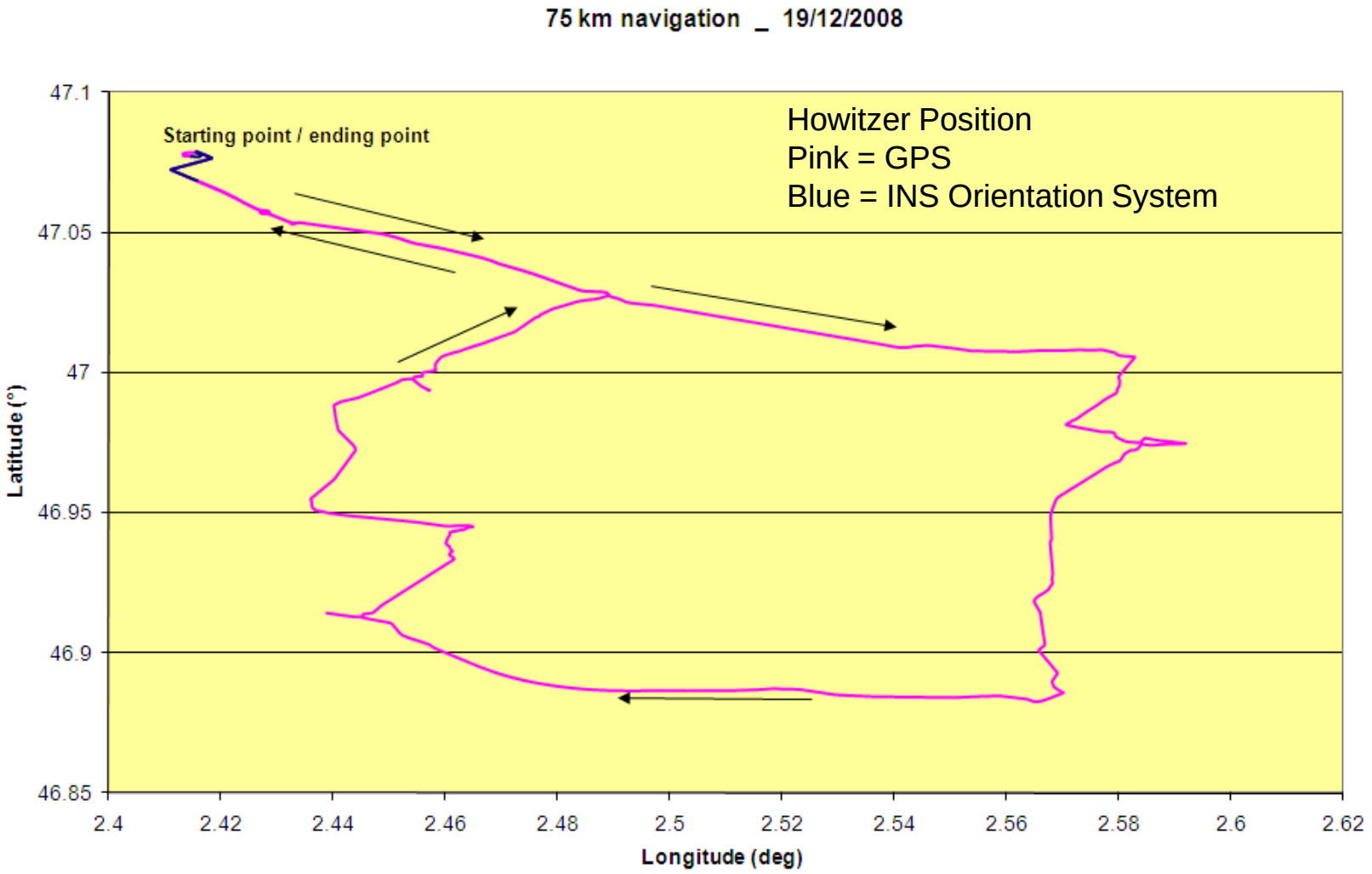
Firing Trials Results

- Performance
  - No interruption of Function During Firing
  - Immediate Readiness for New Firing or move After Firing
  - No Position or Accuracy Degradation Full Rate Fire

- Position and Attitude/Heading Reference Accuracy
  - At Gun Placement
  - Full accuracy available

- On-the-Move Position Data
  - Available to Towing Vehicle at all times

Navigation Tests : INS/GPS Comparison



Conclusions

- Howitzer Digitization Not Easy
  - No Explanation Required
- Skilled Engineering Required
  - Understanding of the Environment Necessary
- Appropriate Selection of Components
  - Absolutely Necessary
- Test Results
  - System qualified for Howitzer Application
  - Selected Technologies Appropriate for Application

A Star To Steer By

High Performance Positioning Products

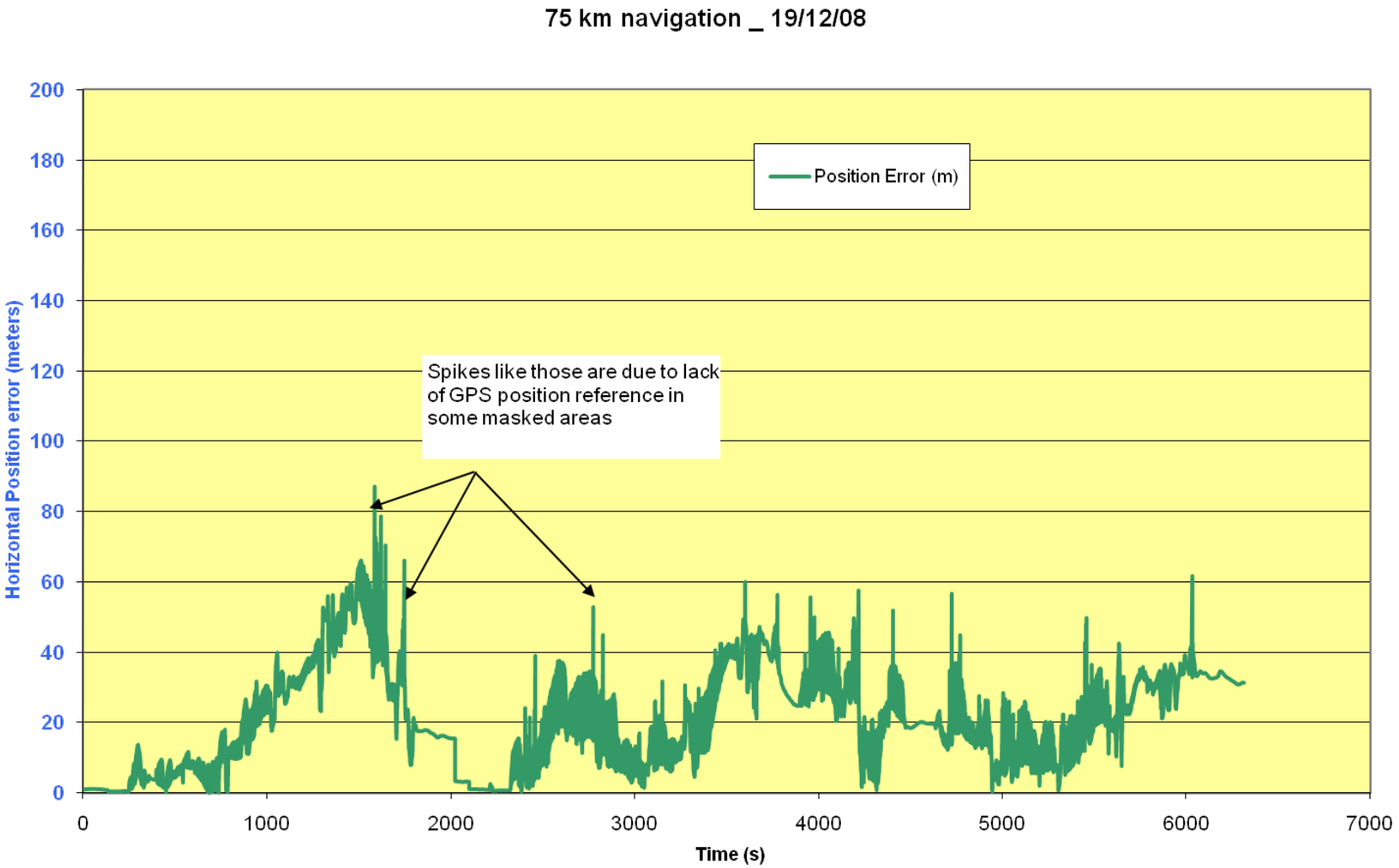
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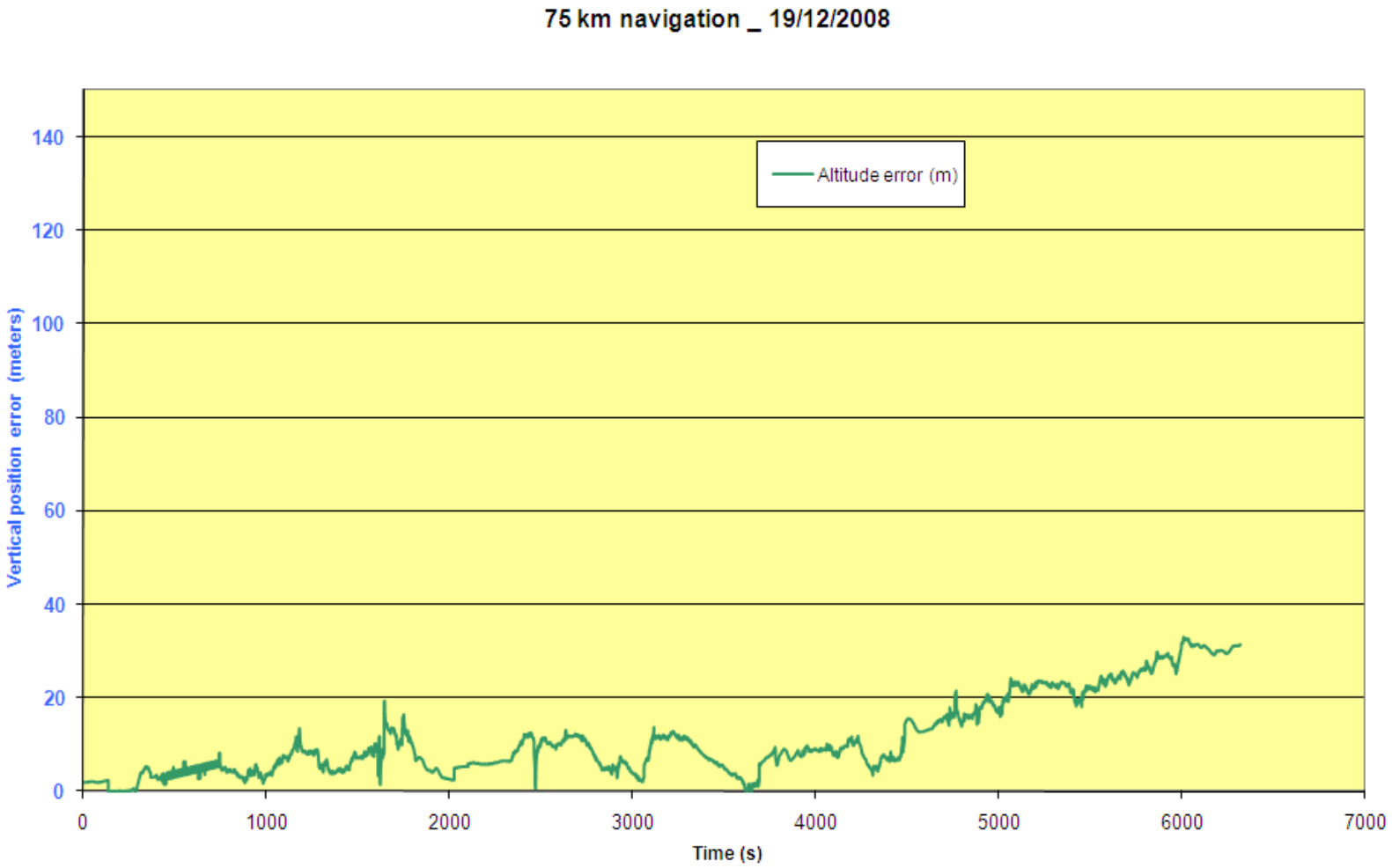
BACKUP DATA

Navigation Tests : Horizontal Position



6000 sec = 100 hrs

Navigation Tests : Altitude



6000 sec = 100 hrs

DESIGN AND MODELING OF INTERNALLY PRESSURIZED THICK-WALLED CYLINDER

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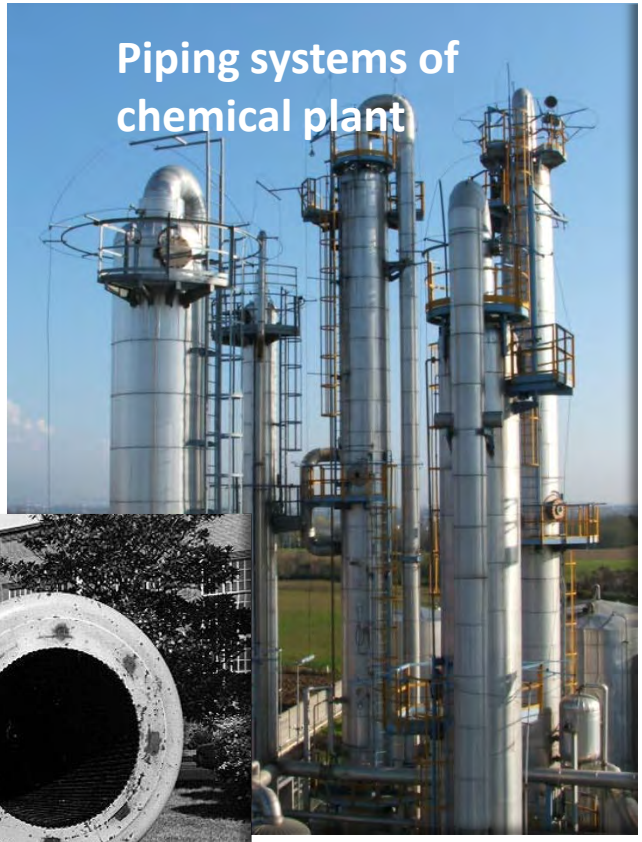
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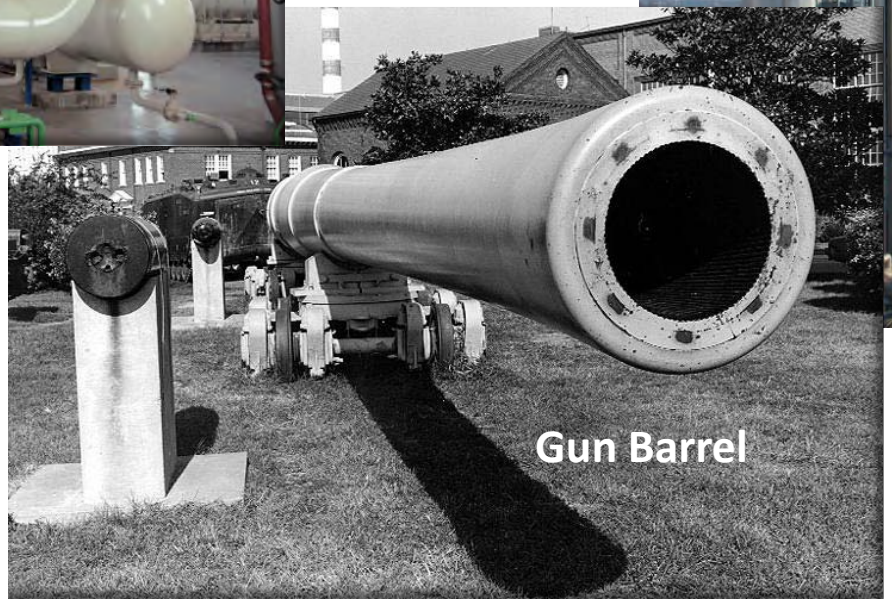
OUTLINE

1. Introduction
2. Basic Concepts OF A Pressurized Thick-Walled Cylinder
3. Stress Analysis of A Single-Layer Pressurized Thick-Walled Cylinder
4. Stress Analysis of A Double-Layer Pressurized Thick-Walled Cylinder
5. Stress Analysis of A Composite-Wrapped Pressurized Thick-Walled Cylinder
6. Conclusions
7. Acknowledgements

1. INTRODUCTION

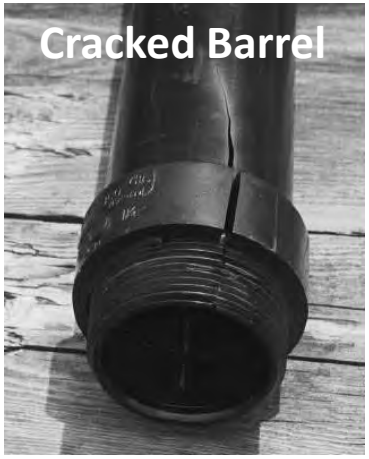




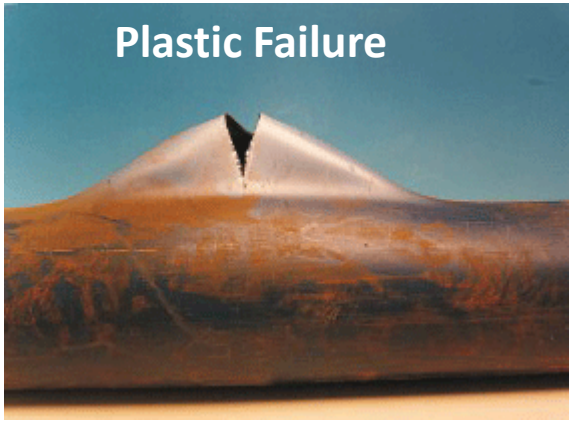


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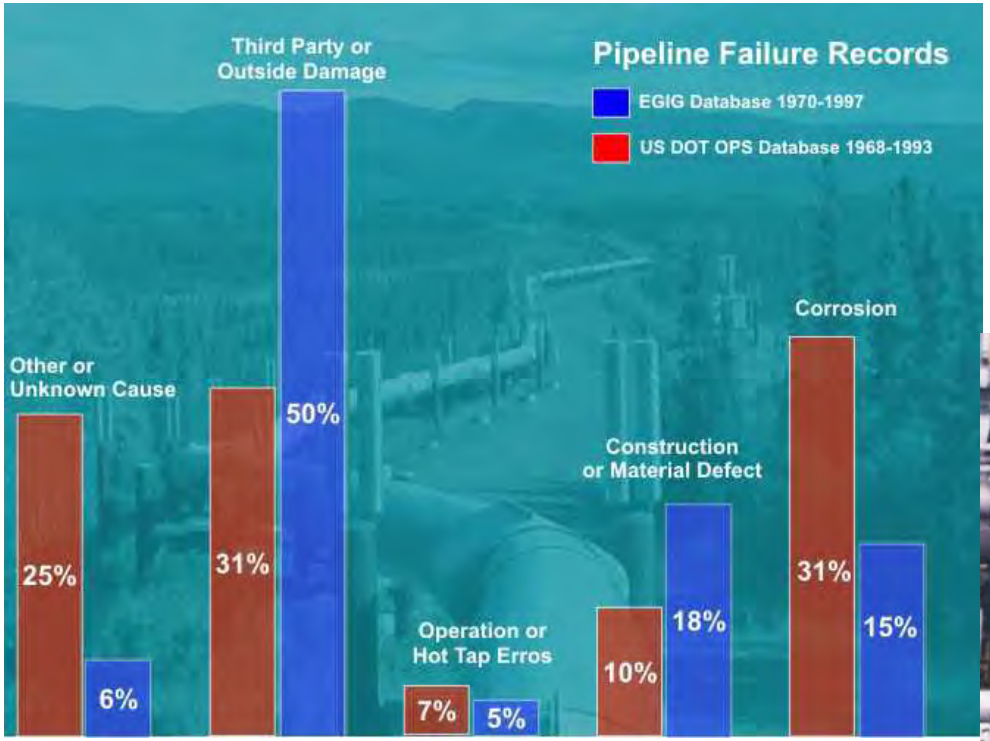
1. INTRODUCTION – CONT.

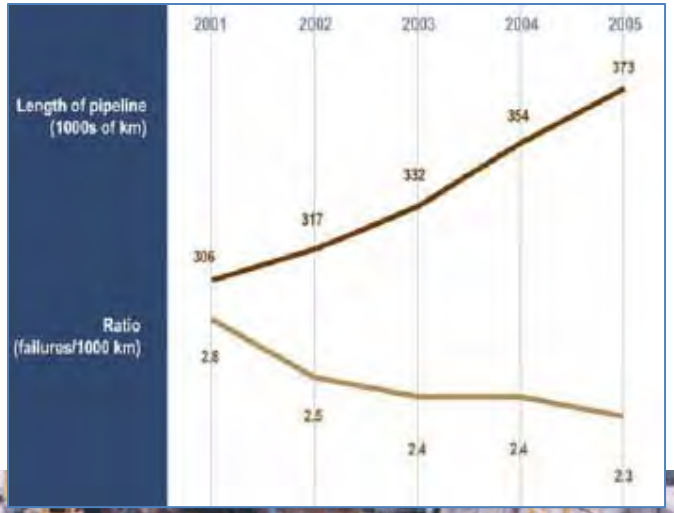






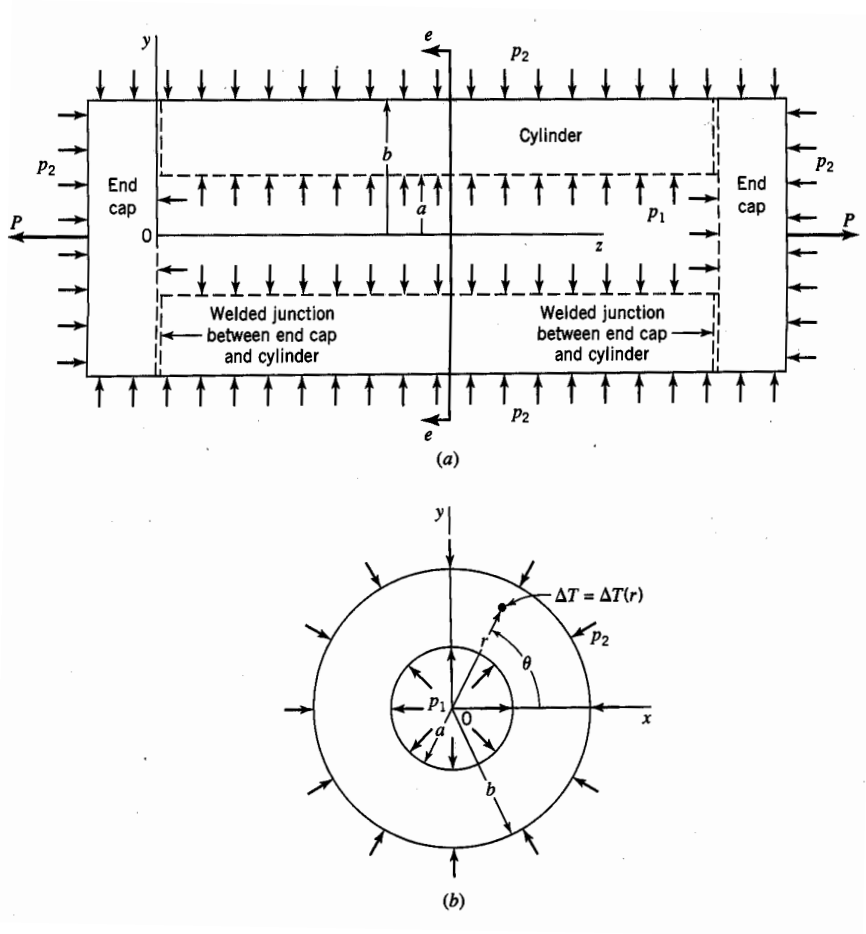
1. INTRODUCTION – CONT.





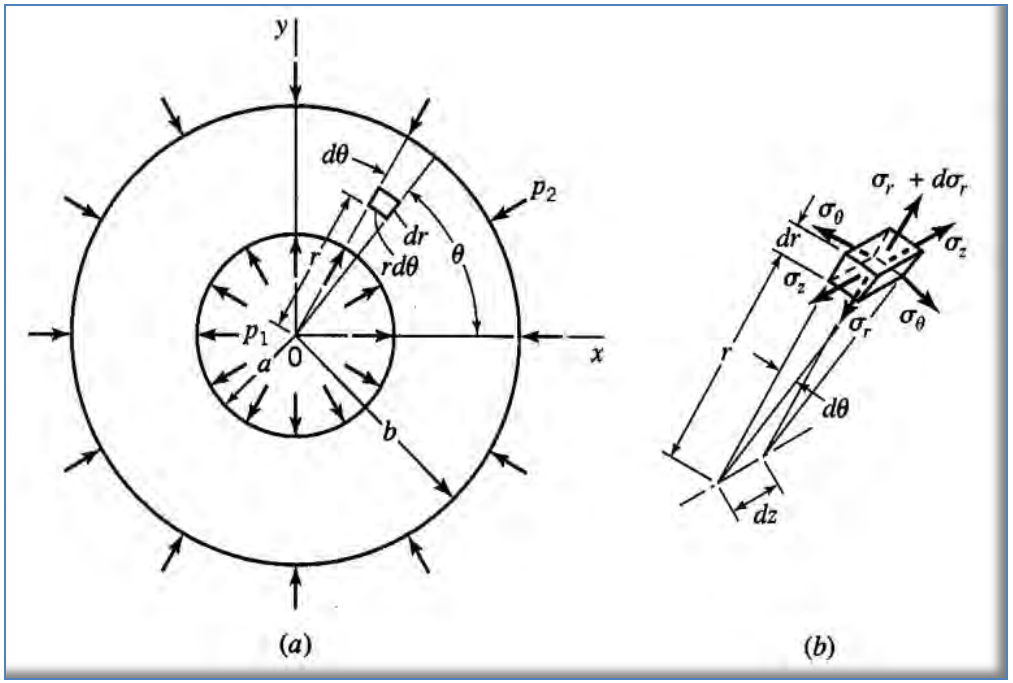


2. BASIC CONCEPTS OF A PRESSURIZED THICK-WALLED CYLINDER



Closed cylinder with internal pressure, external pressure, and axial loads. (*a*) Closed cylinder. (*b*) Section *e*-*e*.

3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER



Stresses in thick-wall cylinder. (*a*) Thin annulus of thickness dz. (*b*) Cylindrical volume element of thickness dz.

Basic Assumptions:

(1). Static loads
(2). Isotropic and homogenous material
(3). Constant temperature
(4). Elasto-plastic and small deformation
(5). Ignoring axial load (stress)
(6). Cross section keeping plane after deformation

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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Elastic Analysis:

Equilibrium Equation

$$\sigma_\theta = \sigma_r + r\frac{d\sigma_r}{dr} = \frac{d}{dr}(r\sigma_r)$$

Strain-Displacement Relations

$$\epsilon_r = \frac{\partial u}{\partial r}, \epsilon_\theta = \frac{u}{r}, \epsilon_z = \frac{\partial w}{\partial r} = constant$$

Strain Compatibility Condition

$$\epsilon_r = \epsilon_\theta + r\frac{d\epsilon_r}{dr} = \frac{d}{dr}(r\epsilon_\theta)$$

Hooke's Law (stress-strain relations)

$$\epsilon_r = \frac{1}{E}[\sigma_r - \upsilon\sigma_\theta]$$

$$\epsilon_\theta = \frac{1}{E}[\sigma_\theta - \upsilon\sigma_r]$$

$$\epsilon_z = \frac{1}{E}[-\upsilon(\sigma_r + \sigma_\theta)]$$

Stress Components under Internal and External Pressure

$$\sigma_r = \frac{p_1a^2 - p_2b^2 + (p_2 - p_1)(ab/r)^2}{b^2 - a^2}$$

$$\sigma_\theta = \frac{p_1a^2 - p_2b^2 - (p_2 - p_1)(ab/r)^2}{b^2 - a^2}$$

$$\sigma_r + \sigma_\theta = 2\frac{p_1a^2 - p_2b^2}{b^2 - a^2} = constant$$

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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Stress Components under Internal Pressure Only

$$\sigma_r' = \frac{p_1 a^2 (1 - b^2/r^2)}{b^2 - a^2}$$

$$\sigma_\theta' = \frac{p_1 a^2 (1 + b^2/r^2)}{b^2 - a^2}$$

$$\sigma_r'' = \frac{p_2 b^2 (a^2/r^2 - 1)}{b^2 - a^2}$$

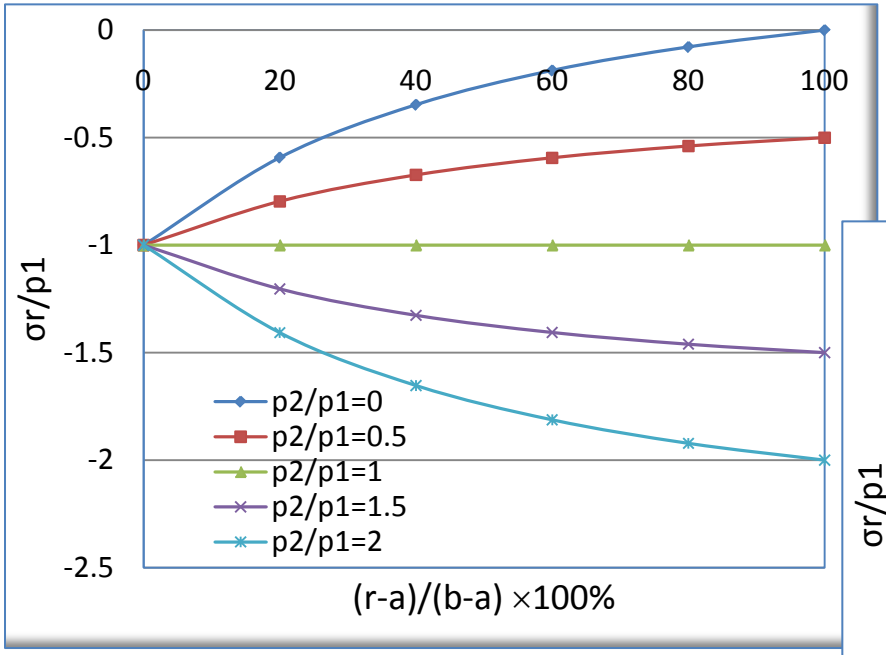
$$\sigma_\theta'' = -\frac{p_2 b^2 (a^2/r^2 + 1)}{b^2 - a^2}$$

Radial Displacement under Internal and External Pressure

$$u = \frac{r}{E(b^2 - a^2)}\left[(1 - 2v)(p_1 a^2 - p_2 b^2) + \frac{(1+v)a^2 b^2}{r^2}(p_1 - p_2)\right] \quad (10)$$

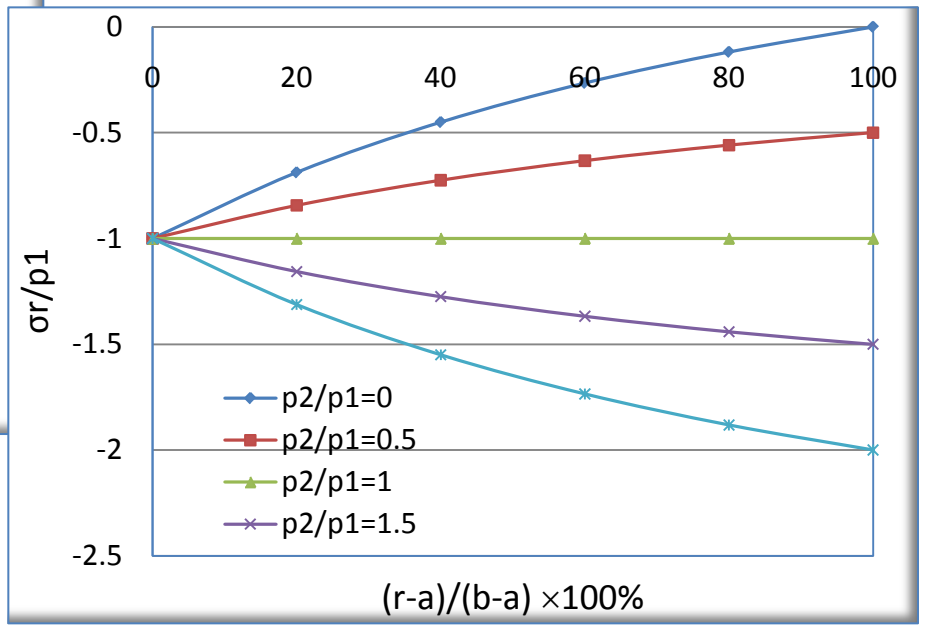
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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.



b/a = 2

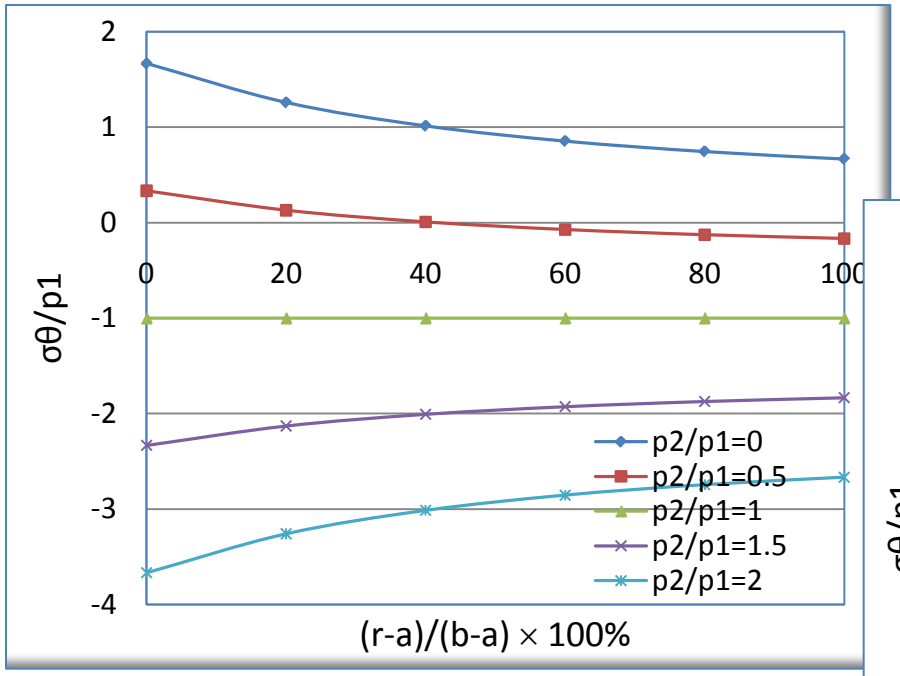
b/a = 1.5



Radial Stress, σ_r, Distribution in A Single Layer Thick-Wall Cylinder.

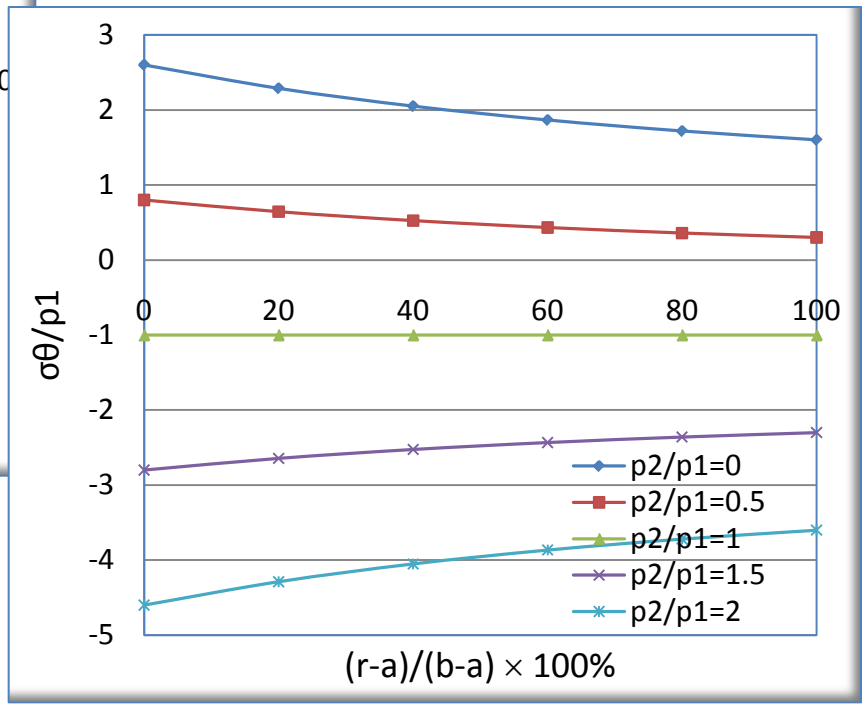
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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.



b/a = 2

b/a = 1.5

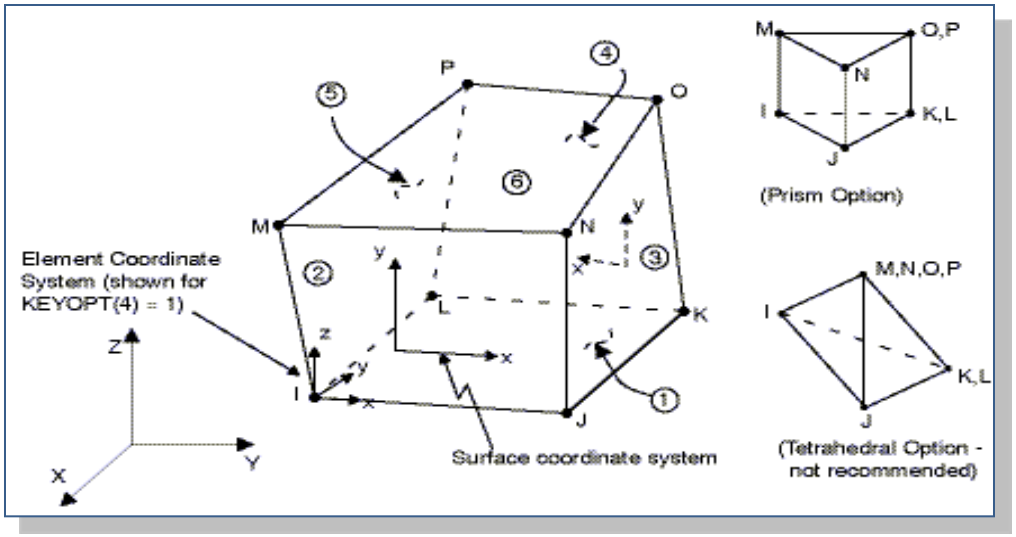


Hoop Stress, σ_θ, Distribution in A Single Layer Thick-Wall Cylinder.

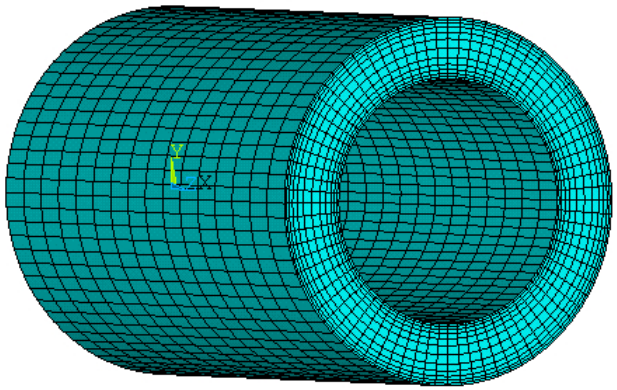
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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

3-D structural solid element

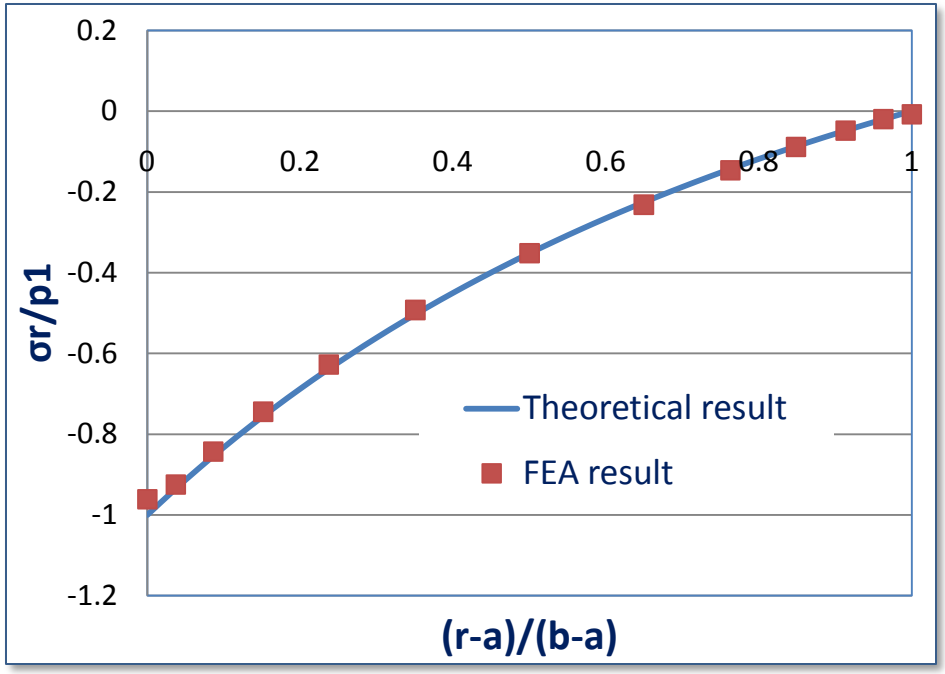


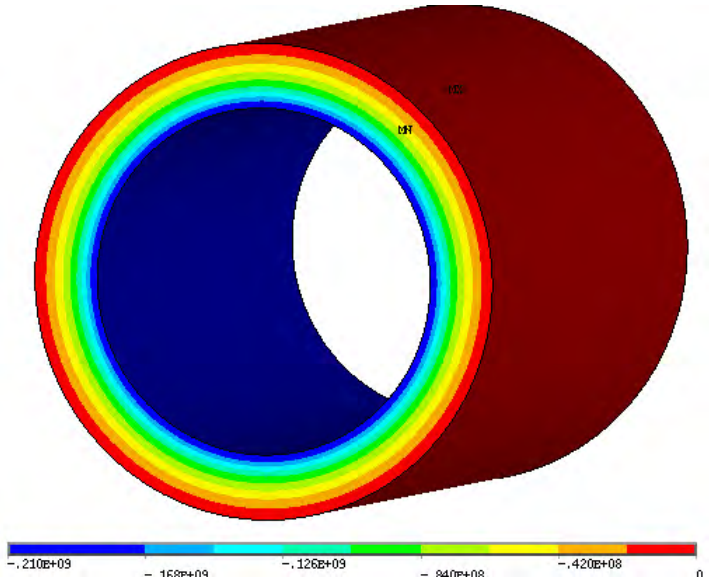
Finite Element Model



3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Comparison of the analytical results with FEA results of an internally pressurized thick wall cylinder.

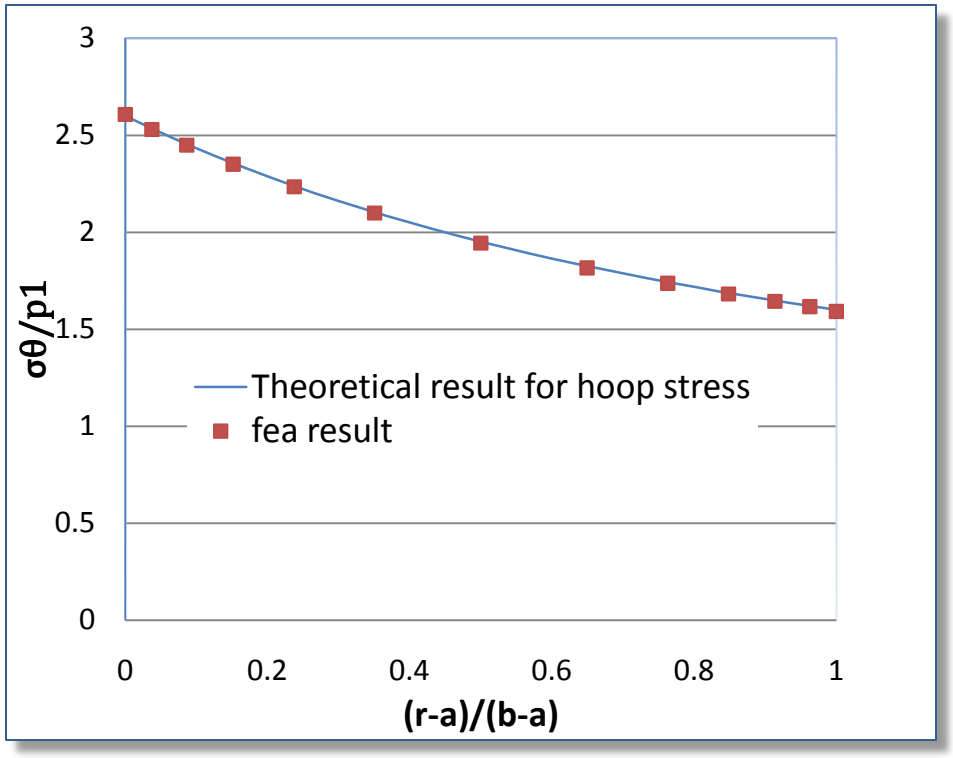


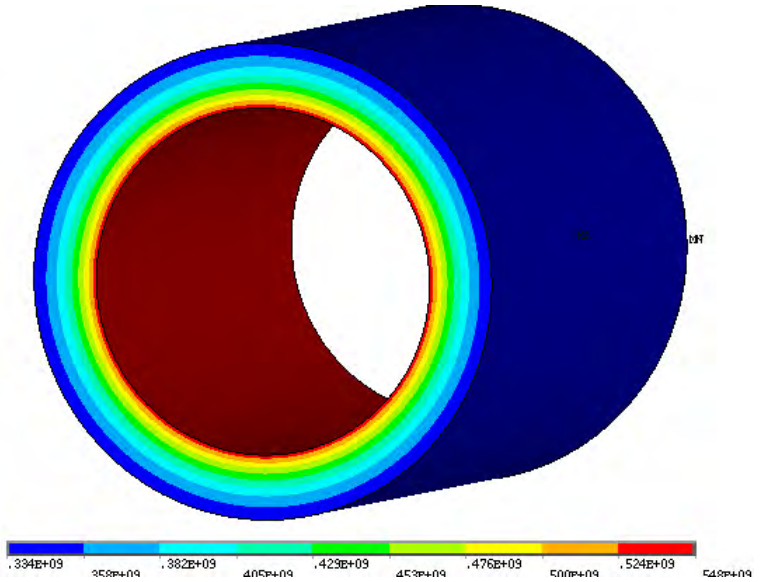


Radial Stress

3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Comparison of the analytical results with FEA results of an internally pressurized thick wall cylinder.

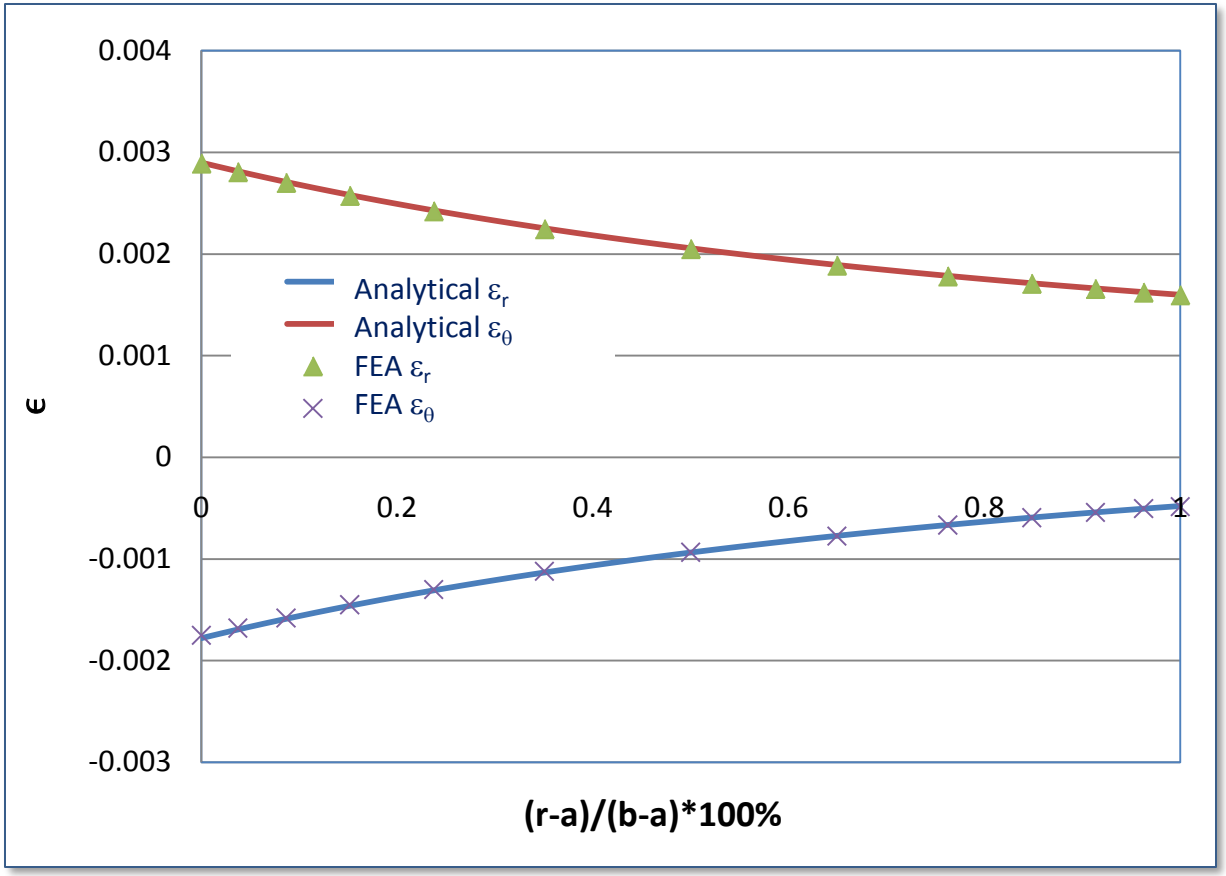




Hoop Stress

3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Comparison of the analytical results with FEA results of elastic strains in an internally pressurized thick wall cylinder.



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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Elasto-Plastic Analysis of Autofrettage

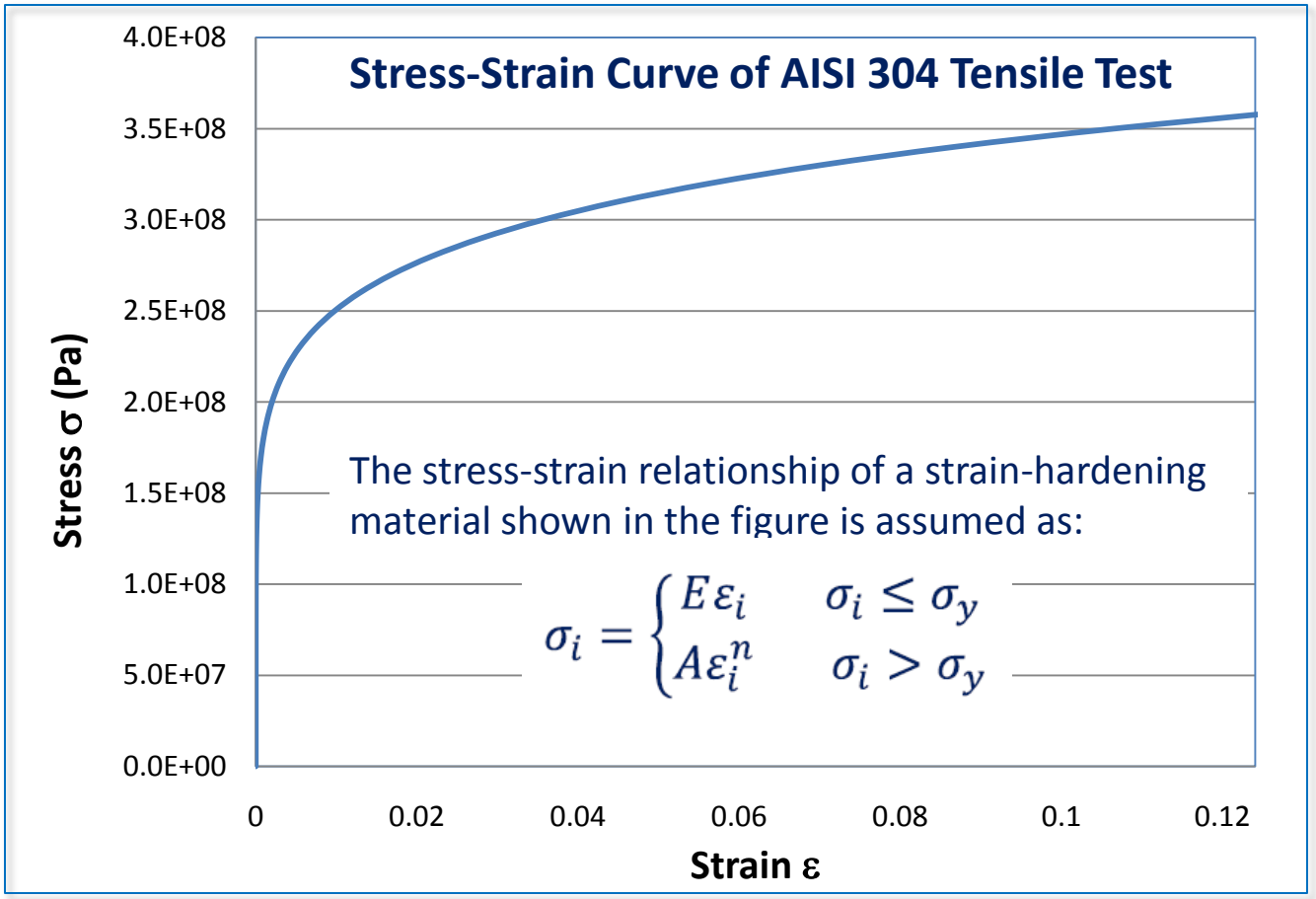
From Wikipedia:
Autofrettage is a metal fabrication technique in which a pressure vessel is subjected to enormous pressure, causing internal portions of the part to yield and resulting in internal compressive residual stresses. The goal of autofrettage is to increase durability of the final product. The technique is commonly used in manufacturing high-pressure pump cylinders, battleship and tank cannon barrels, and fuel injection systems for diesel engines. While some work hardening will occur, that is not the primary mechanism of strengthening.

When autofrettage is used for strengthening cannon barrels, the barrel is prebored to a slightly undersized inside diameter, and then a slightly oversized die is pushed through the barrel. The amount of initial underbore and size of the die are calculated to strain the material past its elastic limit into plastic deformation, sufficiently far that the final strained diameter is the final desired bore.

The technique has been applied to the expansion of tubular components down hole in oil and gas wells. The method has been patented by the Norwegian oil service company, READ, which uses it to connect concentric tubular components with sealing and strength properties outlined above.

3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Elasto-Plastic Analysis of Autofrettage



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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Elasto-Plastic Analysis

It can be assumed that the elastic zone of vessel is a cylinder of inner radius ρ and outer radius b which is subjected to internal pressure p_ρ

$$\sigma_\theta = \frac{p_\rho \rho^2}{b^2-\rho^2}\left(1+\frac{b^2}{r^2}\right), \quad \sigma_r = \frac{p_\rho \rho^2}{b^2-\rho^2}\left(1-\frac{b^2}{r^2}\right)$$

Where p_ρ in plane-strain and plane-stress conditions is obtained as:

$$p_\rho = \frac{\sigma_y}{\sqrt{3}}\left(1-\frac{\rho^2}{b^2}\right), \quad p_\rho = \frac{\sigma_y (b^2-\rho^2)}{\sqrt{(3b^4+\rho^4}}$$

The elastic-limit pressure p_e and the plastic-limit pressure p_y are:

$$p_e = \frac{\sigma_y}{\sqrt{3}}\left(1-\frac{a^2}{b^2}\right), \quad p_y = \frac{\sigma_y}{\sqrt{3}}\frac{1}{n}\left(\frac{b^{2n}}{a^{2n}}-1\right)$$

The relation between internal pressure and the radius of the elastic-plastic boundary in plane-strain and plane-stress condition is determined as:

$$p_i = \frac{\sigma_y}{\sqrt{3}}\left[\left(1-\frac{\rho^2}{b^2}\right)+\frac{1}{n}\left(\frac{\rho^{2n}}{a^{2n}}-1\right)\right],$$

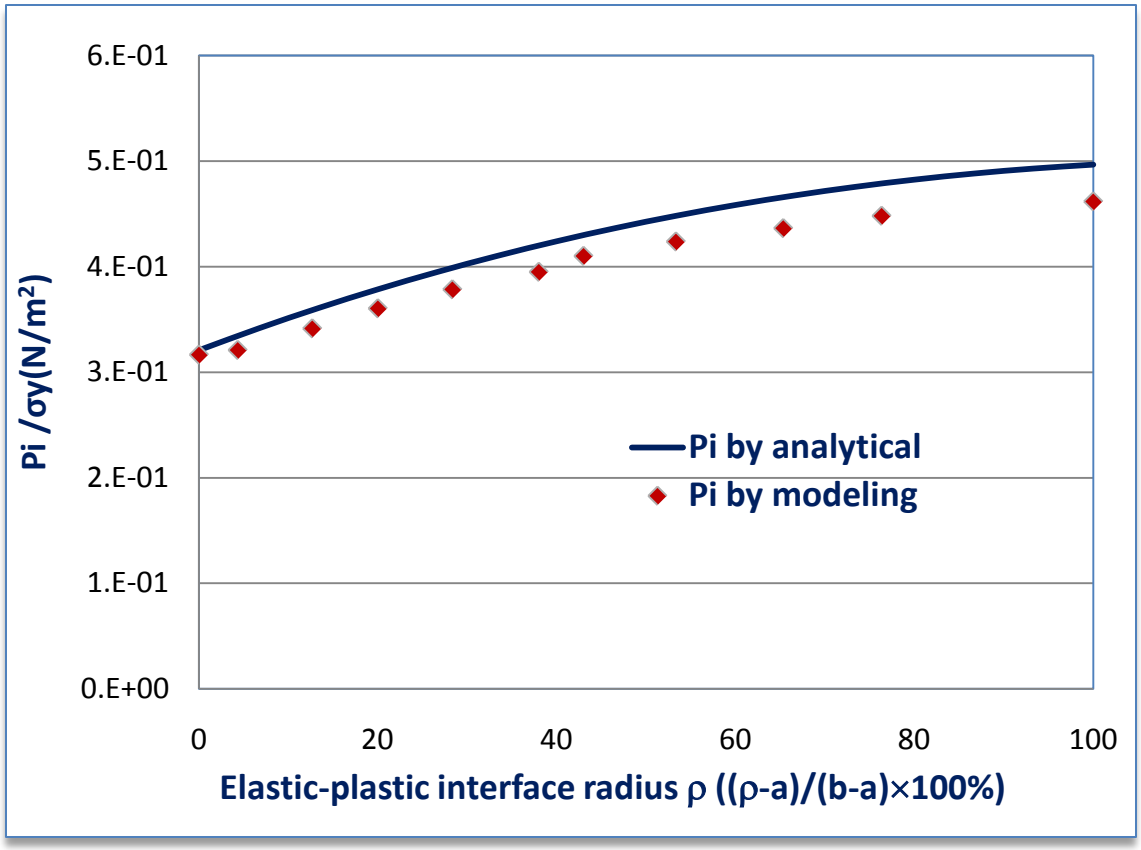
$$\begin{cases} \frac{p_i}{\sigma_y} = \frac{2}{\sqrt{3}}\left|\frac{\cos(\phi_\rho+\phi_n)}{\cos(\phi_a+\phi_n)}\right|^{(3n^2+n)/(3n^2+1)} \\ \quad \times \exp\left[\frac{\sqrt{3}n(n-1)}{3n^2+1}(\phi_a-\phi_\rho)\right]\cos\phi_a, \\ \rho = a\sqrt{\frac{\sin(\phi_a+\pi/6)}{\sin(\phi_\rho+\pi/6)}}\left|\frac{\cos(\phi_\rho+\phi_n)}{\cos(\phi_a+\phi_n)}\right|^{2n/(3n^2+1)} \\ \quad \times \exp\left[\frac{\sqrt{3}}{2}\frac{1-n^2}{3n^2+1}(\phi_\rho-\phi_a)\right], \\ \phi_\rho = \cos^{-1}\frac{\sqrt{3}}{2}\frac{(b^2-\rho^2)}{\sqrt{(3b^4+\rho^4)}}, \end{cases}$$

where ϕ_n is defined as $\cos^{-1}(\sqrt{3}n/\sqrt{3n^2+1})$

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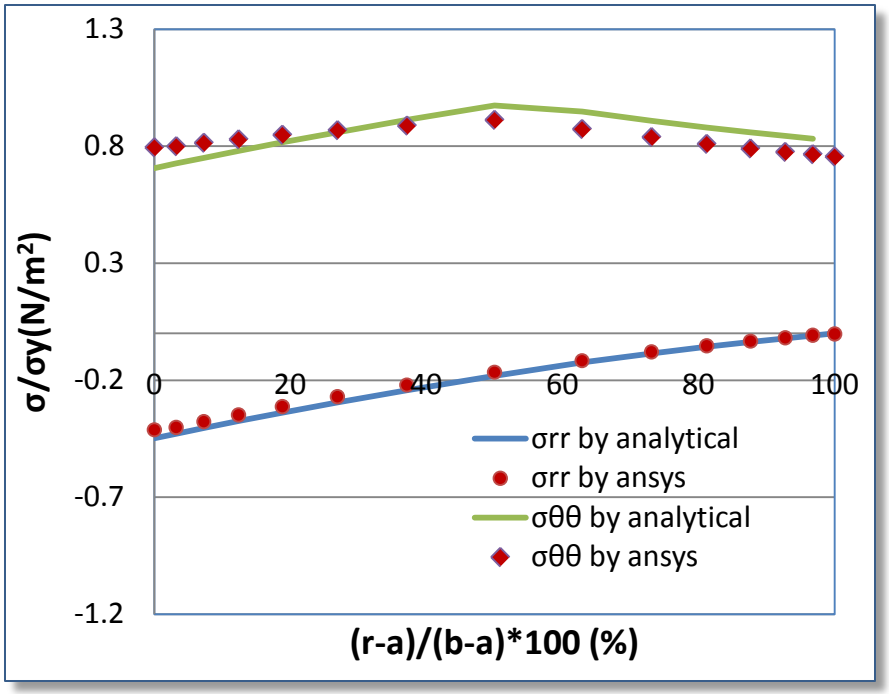
3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

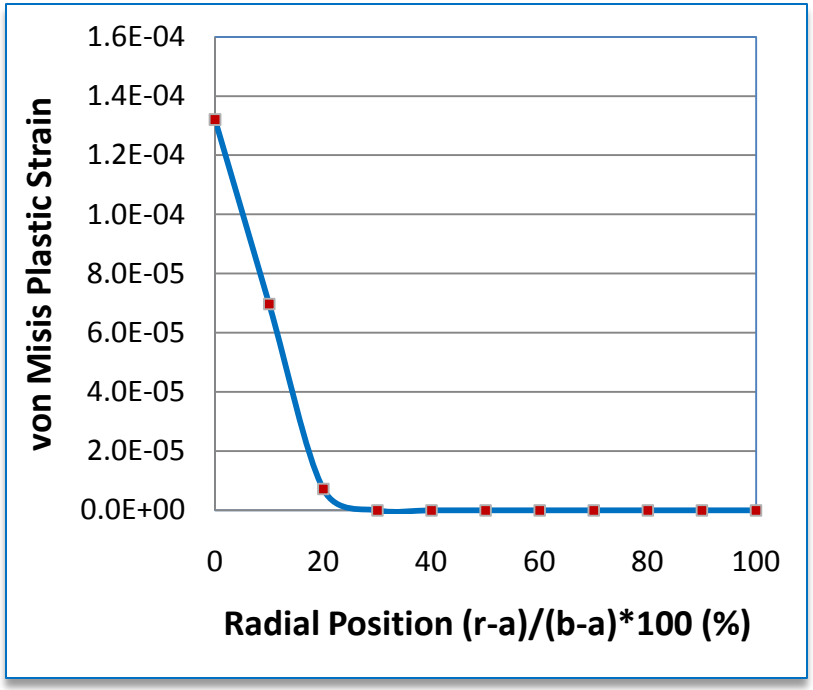
Comparison of the analytical results with FEA results of the elastic-plastic interface radius vs. the internal pressure.



3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Comparison of the analytical results with FEA results of the strain and stress during pressuring process





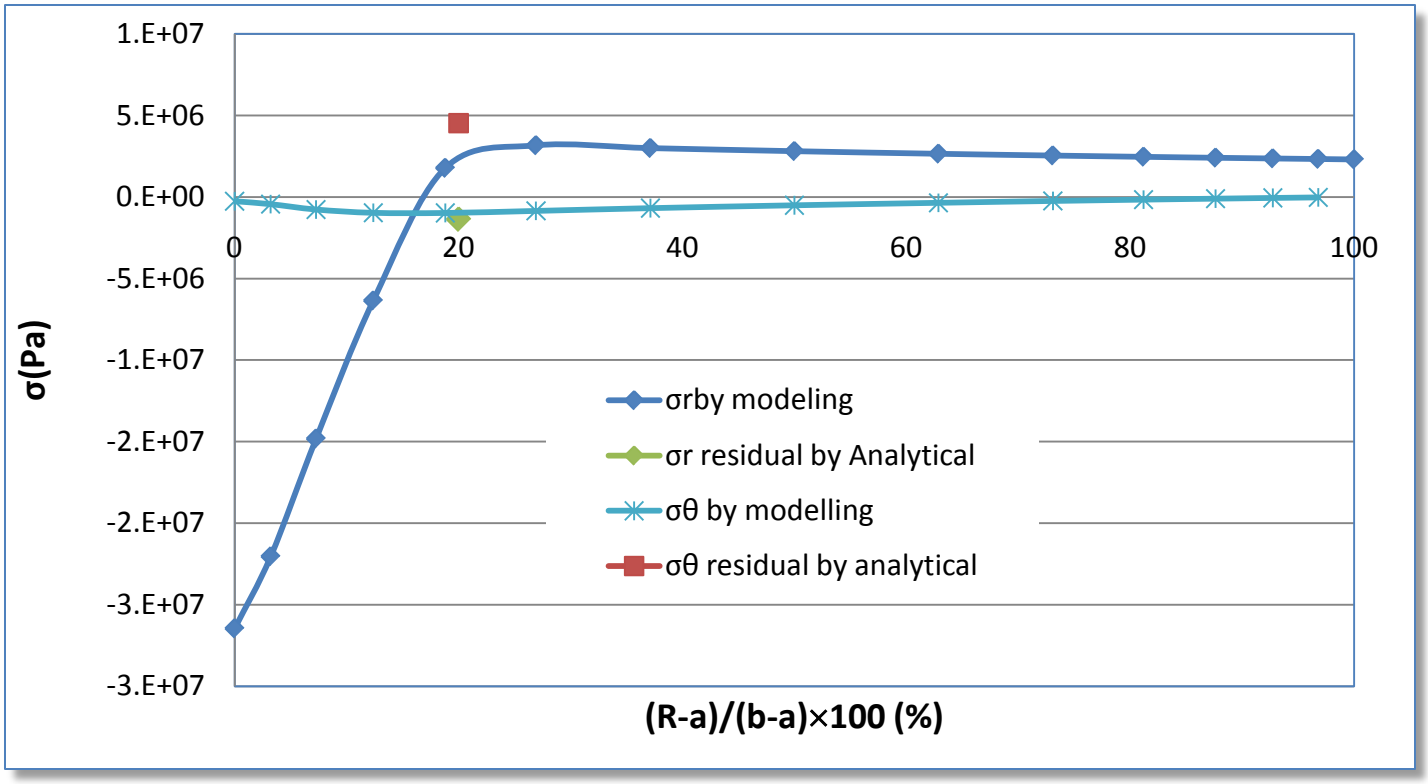
Stresses at pi=86.9 MPa and ρ=53.33%

Strain at pi=65.8 MPa and ρ=21.15%

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3. STRESS ANALYSIS OF A SINGLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

FEA results of residual stresses of autofrettaged cylinder



Residual stresses of autofrettaged cylinder (pi=7.39 MPa and ρ=20.0%

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4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER

Elastic Analysis:

During Assembling, the radial displacement of the inner layer(p_1=0):

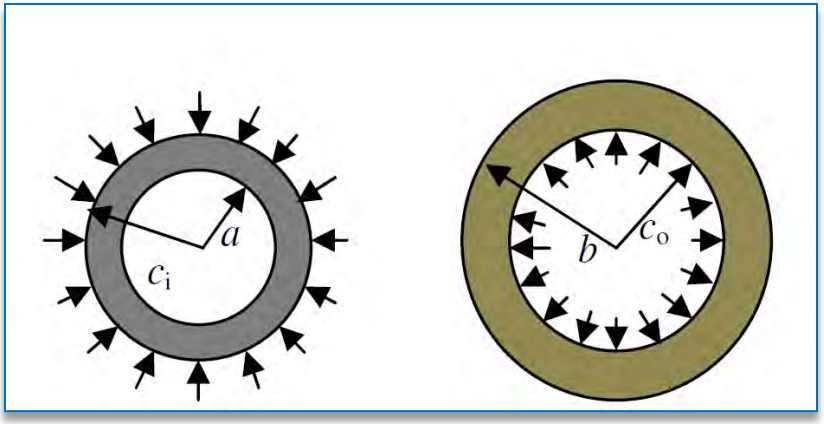
$$u_i' = \frac{-rp_i c_i^2}{E(c_i^2 - a^2)}\left[(1-2v) + \frac{(1+v)a^2}{r^2}\right]$$

During assembling, the radial displacement of the outer layer (p_2=0):

$$u_o' = \frac{rp_i c_o^2}{E(b^2 - c_o^2)}\left[(1-2v) + \frac{(1+v)b^2}{r^2}\right]$$

$$u_i' + c_i = u_o' + c_o = c$$

Initial geometric condition of the composite cylinders before assembly ($\Delta = c_i - c_o$).



During pressuring ($p_1 \neq 0$) after assembling, the radial displacement of the outer and inner layer are:

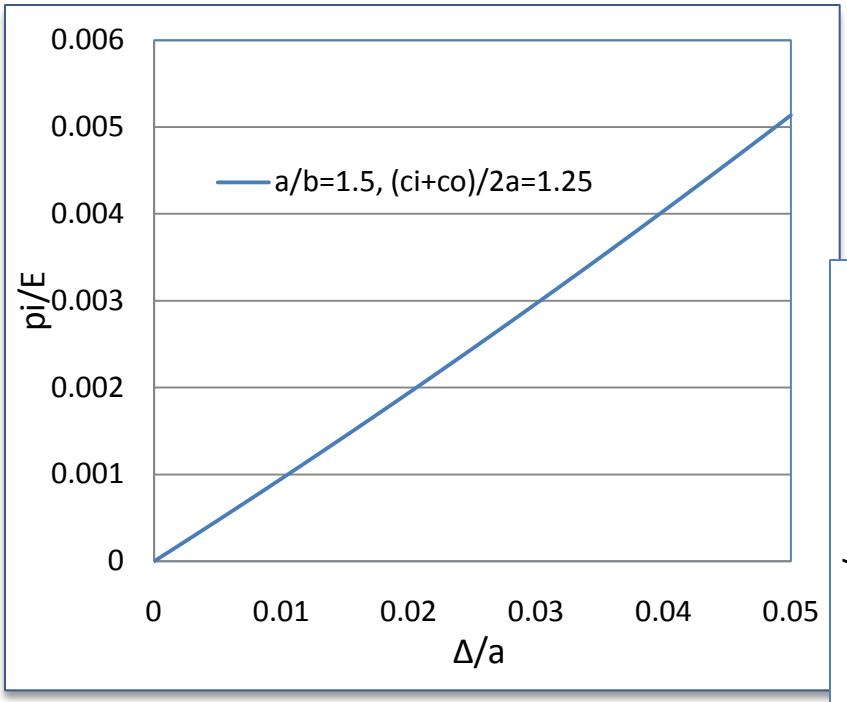
$$u_o = \frac{r}{E(b^2 - c_o^2)}\left[(1-2v)(p_i c_o^2 - p_2 b^2) + \frac{(1+v)c_o^2 b^2}{r^2}(p_i - p_2)\right]$$

$$u_i = \frac{r}{E(c_i^2 - a^2)}\left[(1-2v)(p_1 a^2 - p_i c_i^2) + \frac{(1+v)a^2 c_i^2}{r^2}(p_1 - p_i)\right]$$

$$\Delta = \frac{c_o p_i}{E(b^2 - c_o^2)}[(1-2v)c_o^2 + (1+v)b^2] + \frac{c_i p_i}{E(c_i^2 - a^2)}[(1-2v)c_i^2 + (1+v)a^2]$$

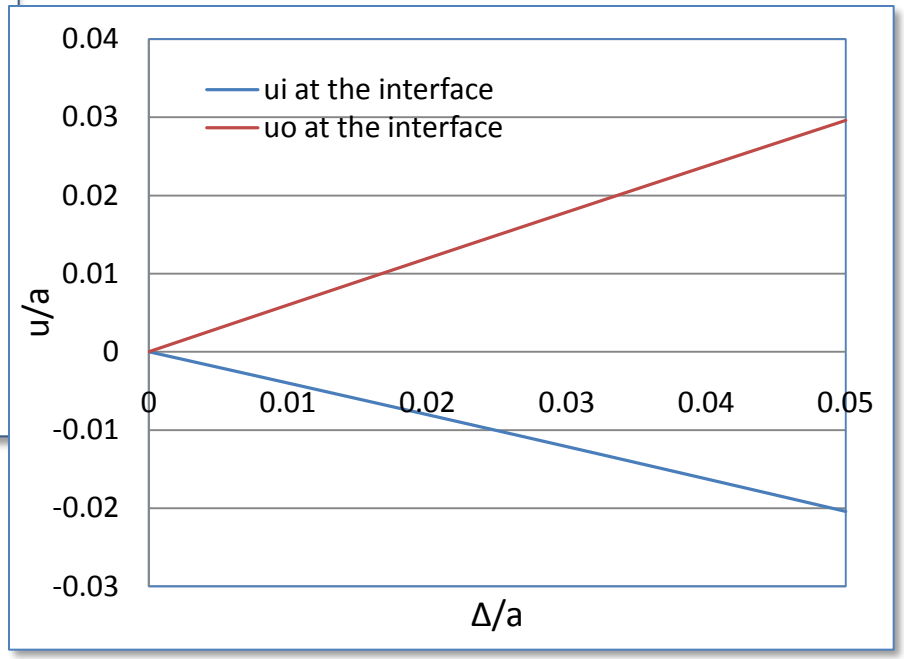
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4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.



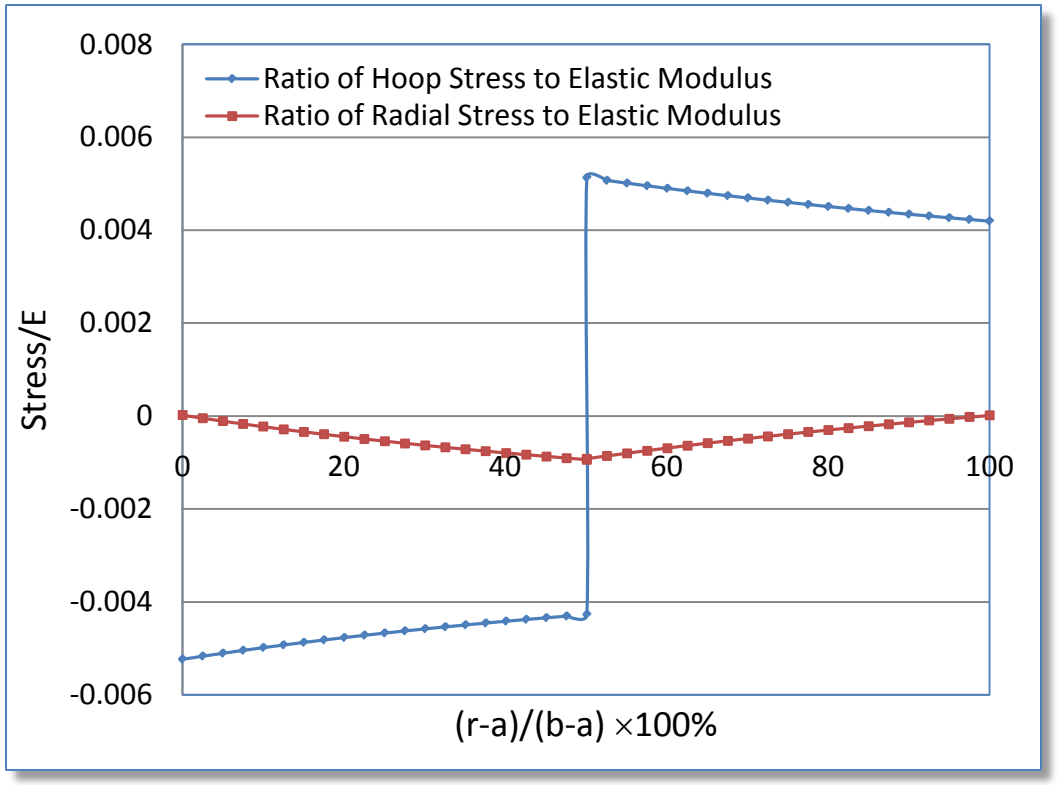
Relationship between the difference of Δ/a and p_i/E (b/a=1.5 and $(c_i+c_o)/2a$=1.25, and υ=0.3).

Relation between Δ and *u*.



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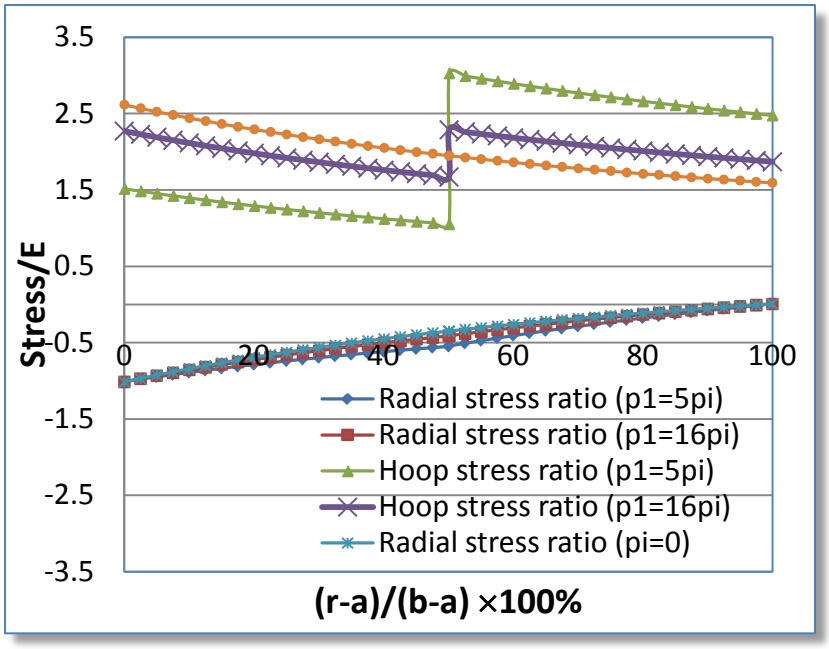
4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

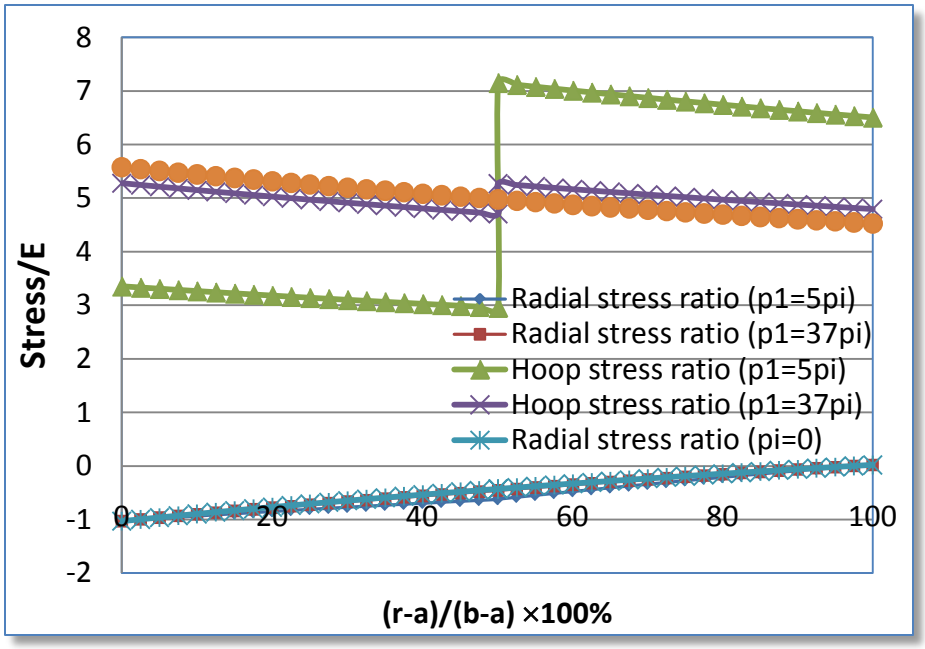


The radial and hoop stress distributions by prestressed assembly (b/a=1.5 and $(c_i+c_o)/2a$=1.25, and υ=0.3).

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4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.





The radial and hoop stress distributions by internal pressure p_1 and the assembly pressure p_i (b/a=1.5 and $(c_i+c_o)/2a$=1.25, and υ=0.3).

The radial and hoop stress distributions by internal pressure p_1 and the assembly pressure p_i (b/a=1.2 and $(c_i+c_o)/2a$=1.1, and υ=0.3).

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4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Coulomb friction model, two contacting surfaces can carry shear stresses up to a certain magnitude across their interface before they start sliding relative to each other. The state is known as sticking. The Coulomb friction model is defined as:

$$\tau_{lim} = \mu P + b \text{ and } |\tau| \le \tau_{lim}$$

where:

τ_{lim} = limit shear stress;
τ = equivalent shear stress;
μ = frictional coefficient;
P = contact normal pressure;
b = contact cohesion, providing sliding resistance even with zero normal pressure.

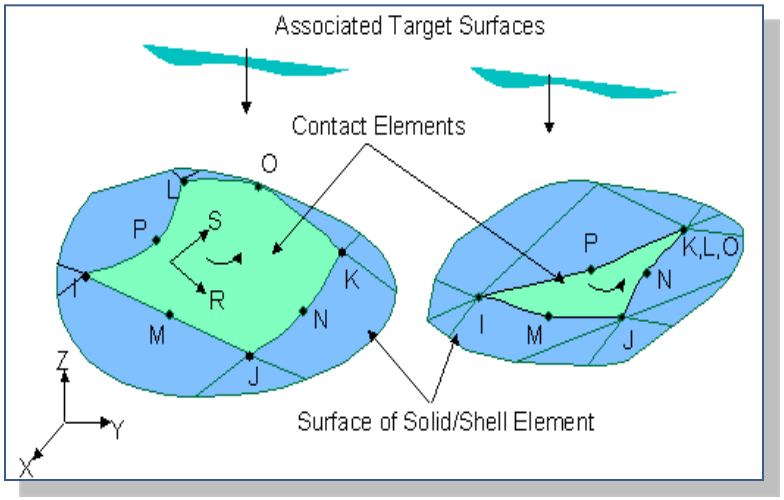
An exponential friction model can be used to smooth the transition between the static coefficient of friction and the dynamic coefficient of friction

$$\mu(\upsilon) = \mu_d + (\mu_s - \mu_d)e^{-c|\upsilon|}$$

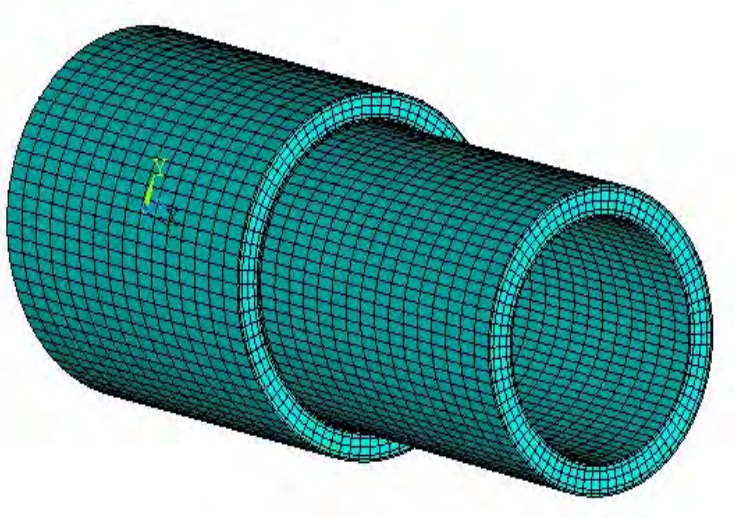
where:

c, υ = decay coefficient and slip rate, respectively;
μ_d = dynamic friction coefficient;
μ_s = static friction coefficient.

Contact Model



4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER – CONT.



- **Two layer cylinder tapered in dimension so that one can slide into another.**
- **Dimension- inner cylinder to outer cylinder in the model is 0.06-0.09 m**
- **Element Type- Solid45, Conta174,Targe170**
- **Total elements= 17920,**

  ET1= 15360, ET2&3=1280

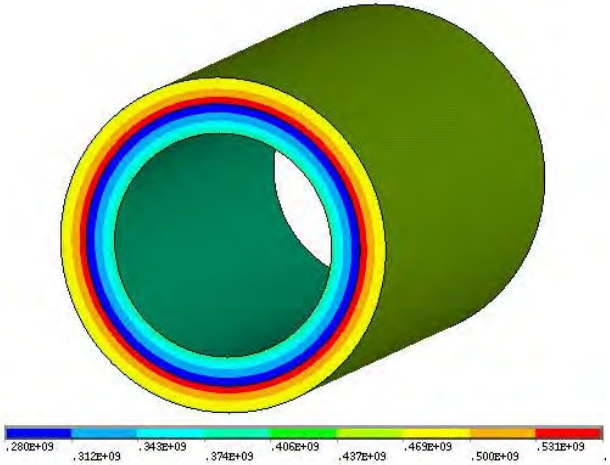
  Total nodes = 19040

Model is in transient condition with the first 10 sub steps used for assembly and the next 10 sub steps used to apply internal pressure

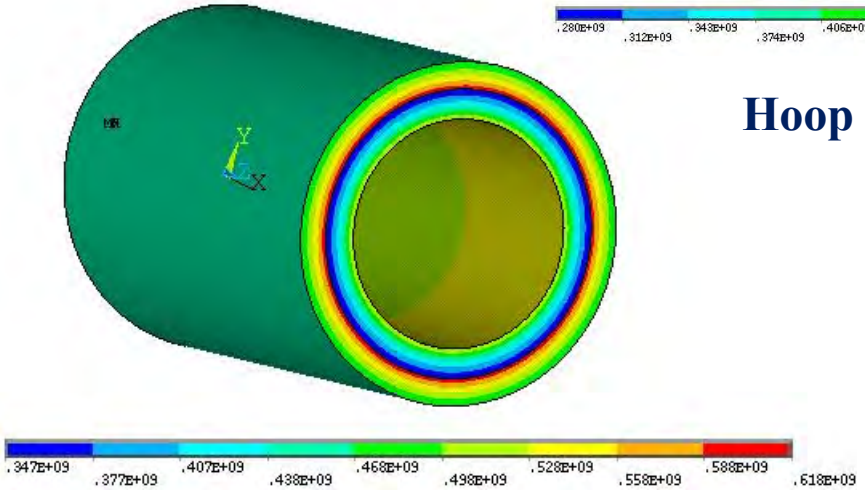
SDSU

4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Modeling Results - Stresses

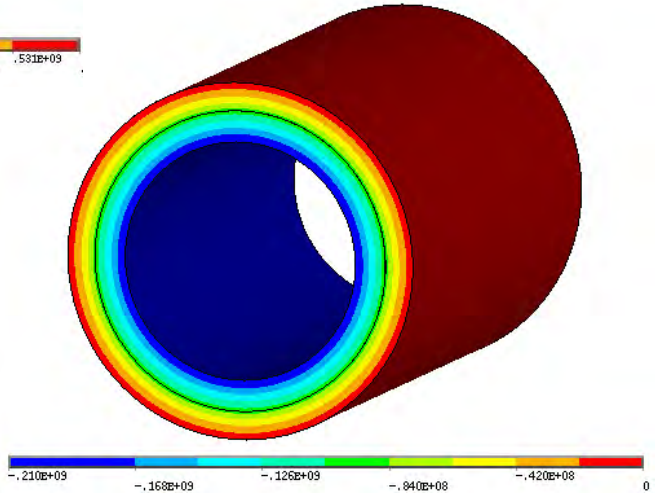


von Mises Stress



Hoop Stress

Radial Stress

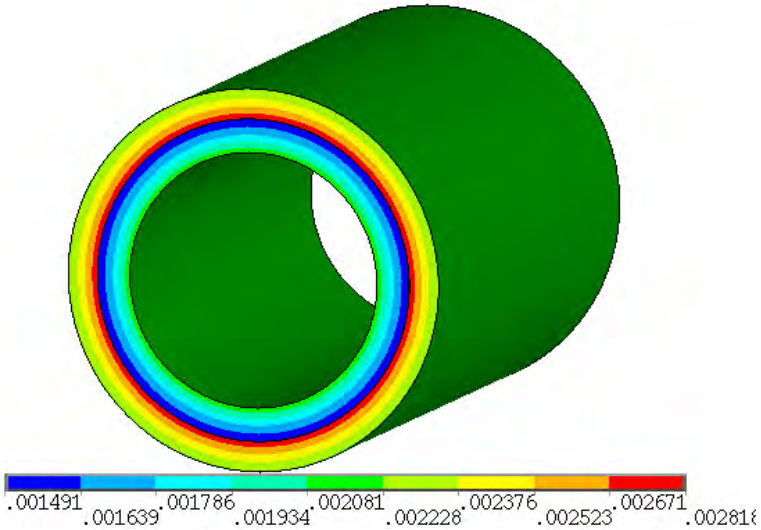


Isotropic, elastic deformation with uniform pressure of 2.1e8 Pa

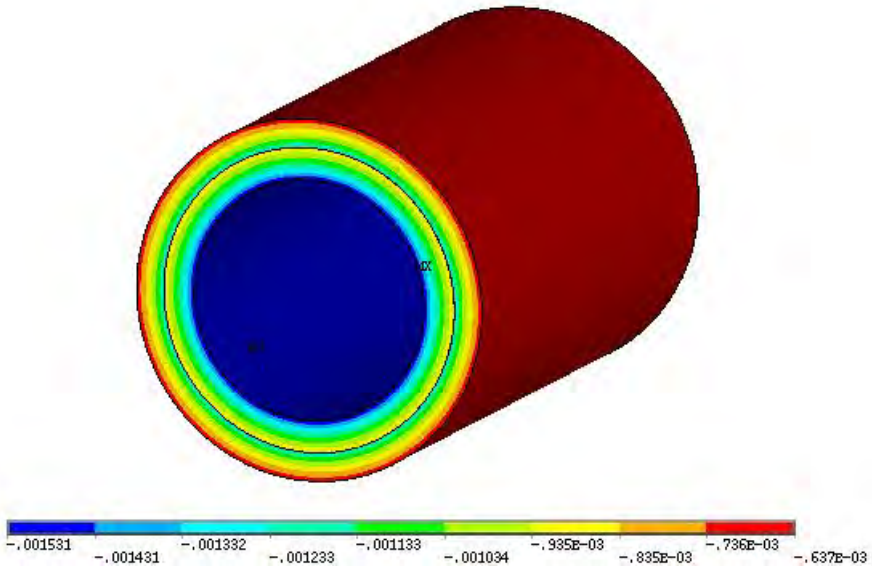
SDSU

4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Modeling Results - Strains



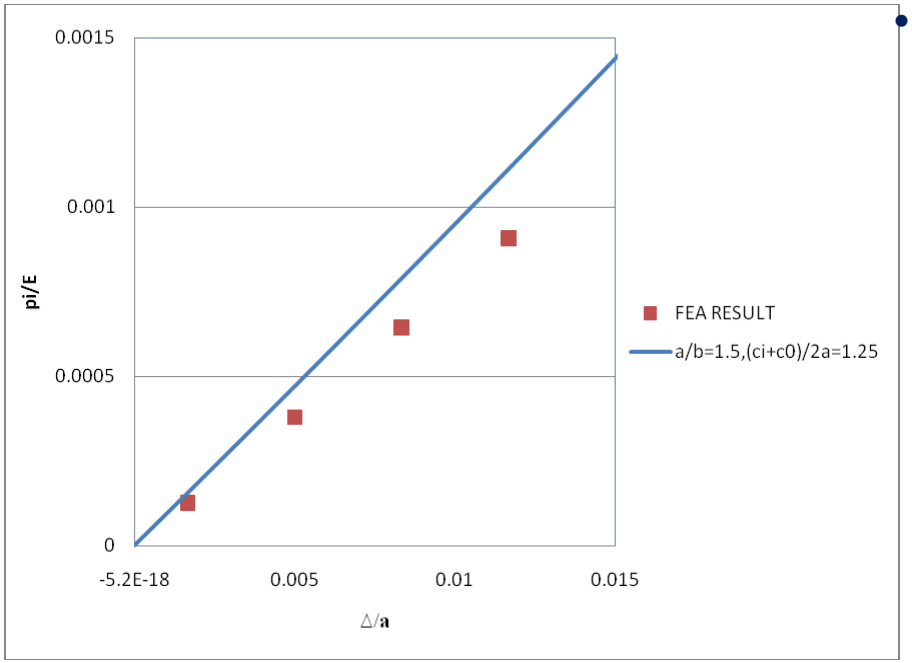
Hoop Strain



Radial Strain

4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

Relationship between pi/E and Δ/a

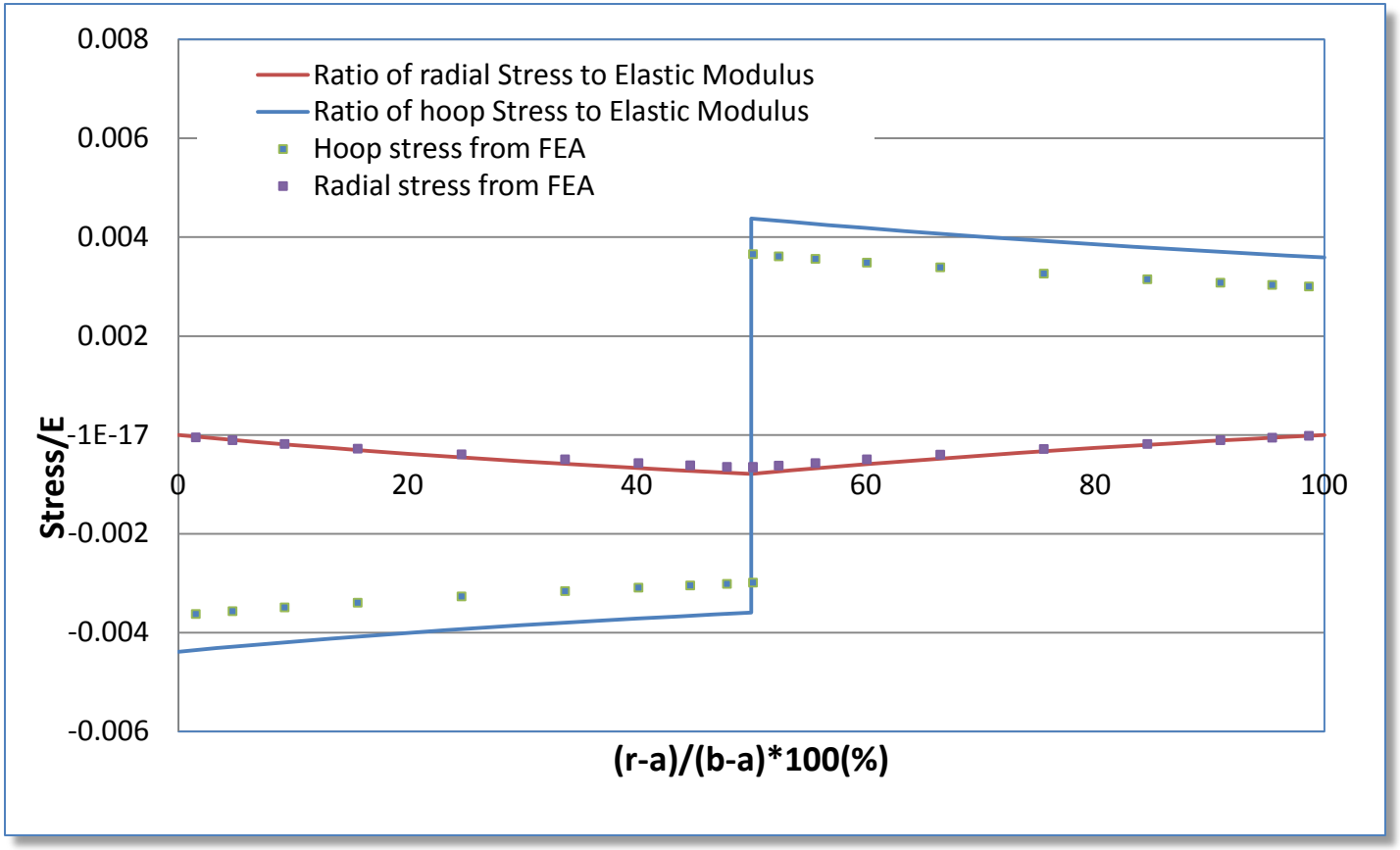


- **Relationship for dimensionless radii Δ/a & dimensionless pre-pressure after assembly pi/E.**
- **To generate more residual stress, more overlapping between the interface- more pressure**

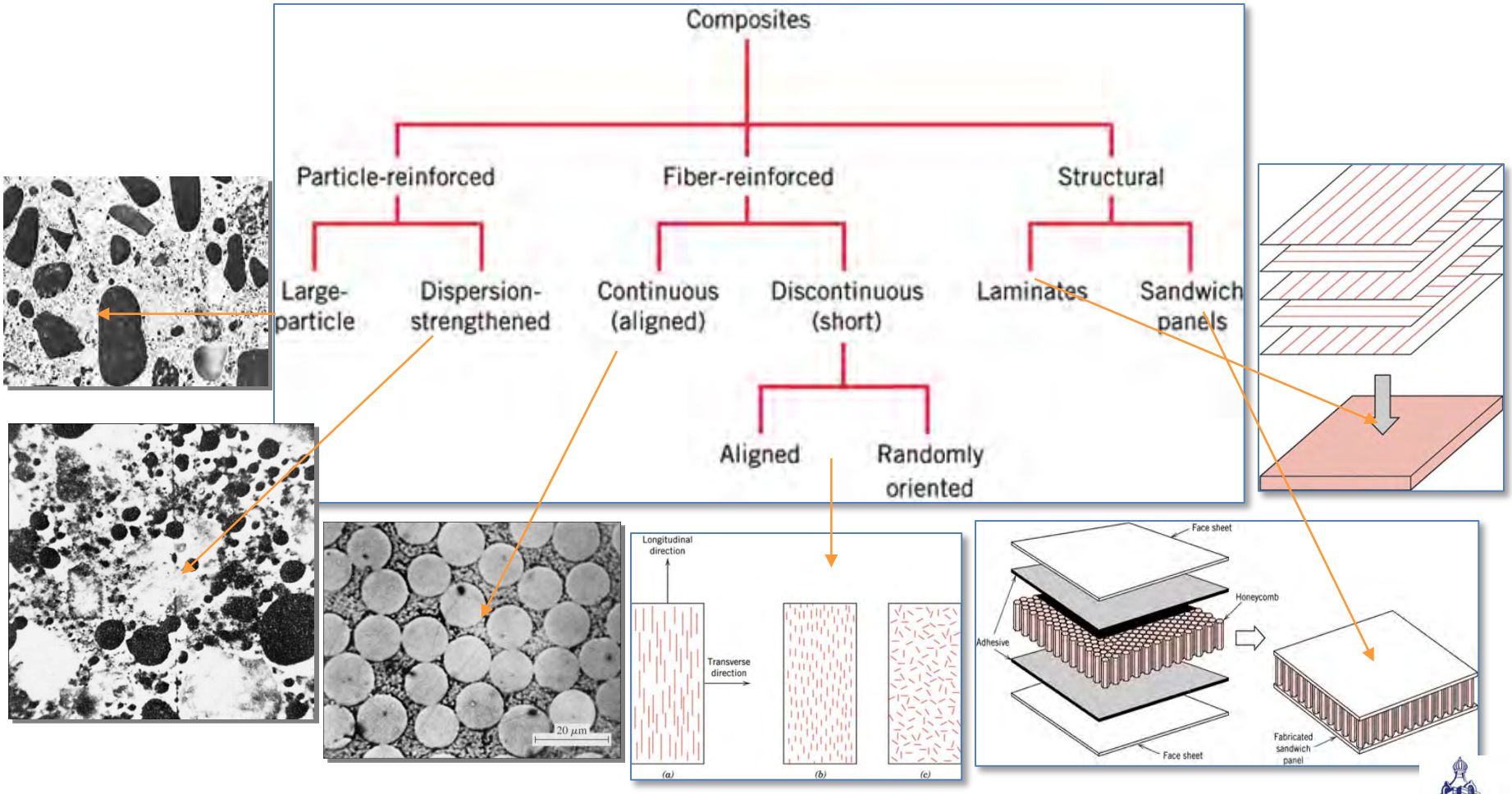
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4. STRESS ANALYSIS OF A DOUBLE-LAYER PRESSURIZED THICK-WALLED CYLINDER - CONT.

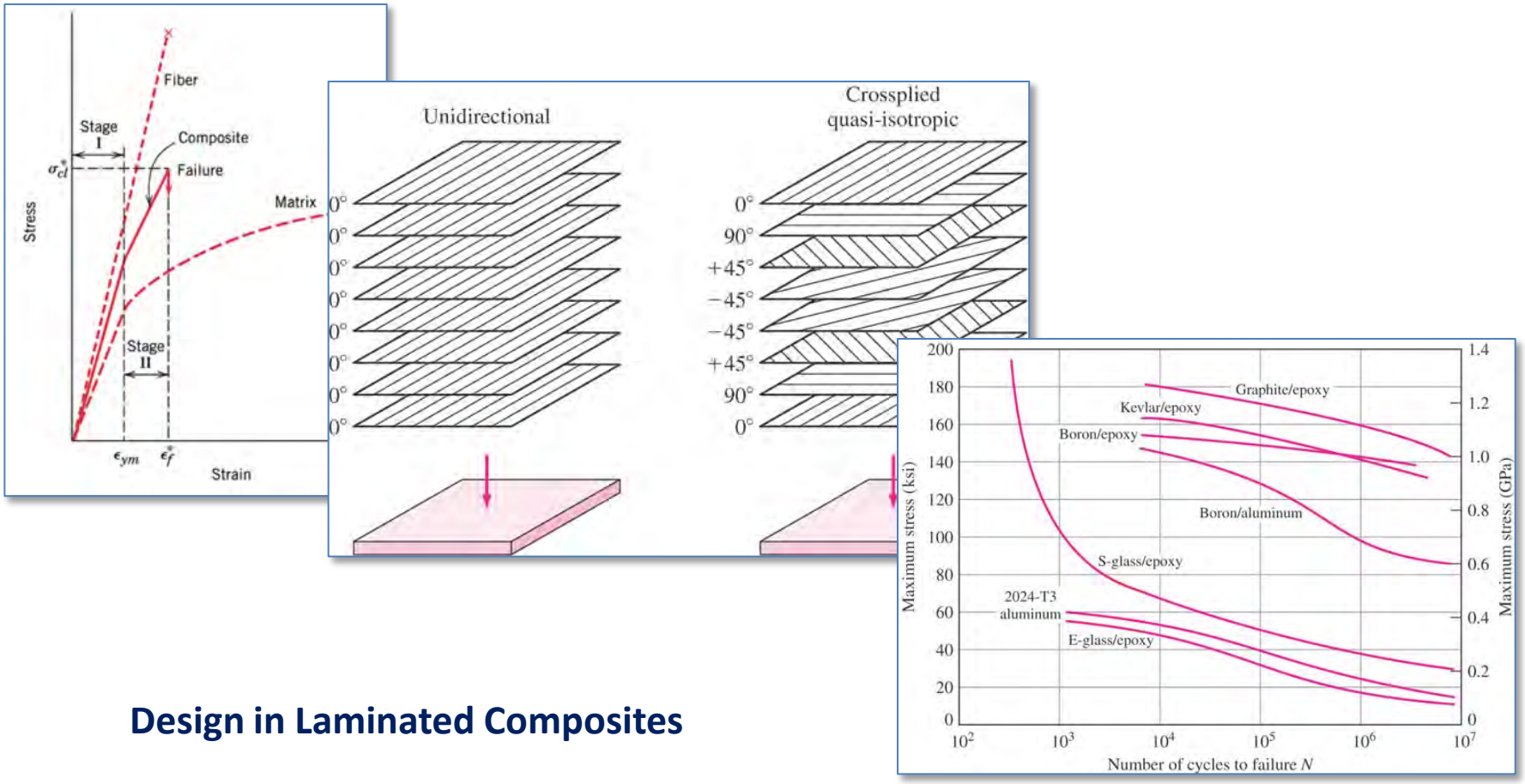
Radial and hoop stress distributions by prestressed assembly



5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER



5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.



Design in Laminated Composites

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5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.

The elastic material property matrix $[D]_j$ for the layer j

$$[D]_j = \begin{bmatrix} BE_{x,j} & B\nu_{xy,j}E_{x,j} & 0 & 0 & 0 & 0 \\ B\nu_{xy,j}E_{x,j} & BE_{y,j} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & G_{xy,j} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{G_{yz,j}}{f} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{G_{xz,j}}{f} \end{bmatrix}$$

where:

$$B = \frac{E_{y,j}}{E_{y,j} - (\nu_{xy,j})^2 E_{x,j}};$$

$E_{x,j}$ = Young's modulus in layer x–direction of layer j;

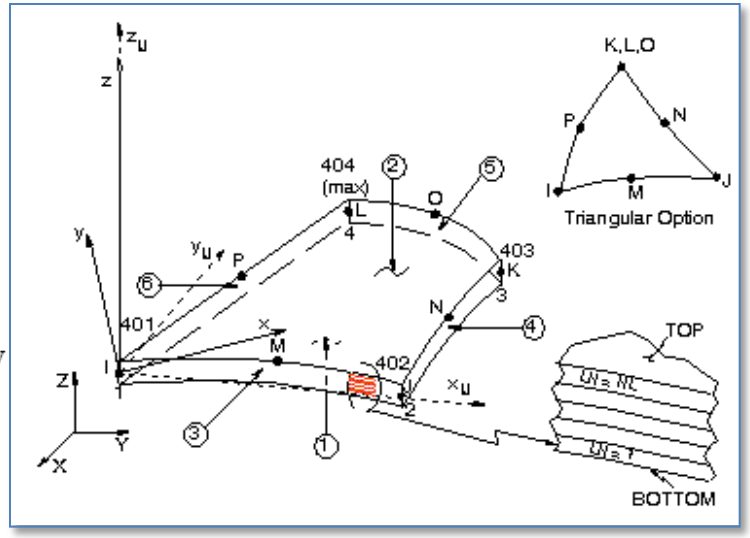
$\nu_{xy,j}$, $G_{xy,j}$ = Poisson's ratio and shear modulus in layer x–y plane of layer j, respectively;

$$f = \left\{ \begin{matrix} 1.2 \\ 1.0 + 0.2\frac{A}{25t^2} \end{matrix} \right\}, \text{ whichever is greater;}$$

A = element area (in s–t plane);

Governing Equations

Nonlinear Finite Strain Shell



5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.

Governing Equations

$$\frac{\partial \sigma_x}{\partial x}+\frac{\partial \sigma_{xy}}{\partial y}+\frac{\partial \sigma_{xz}}{\partial z}=0\,,\quad \frac{\partial \sigma_{yx}}{\partial x}+\frac{\partial \sigma_y}{\partial y}+\frac{\partial \sigma_{yz}}{\partial z}=0$$

Rewriting these in incremental form,

$$\Delta\sigma_{xz}=-\Delta z\left(\frac{\Delta\sigma_x}{\Delta x}+\frac{\Delta\sigma_{xy}}{\Delta y}\right),\ \Delta\sigma_{yz}=-\Delta z\left(\frac{\Delta\sigma_{yx}}{\Delta x}+\frac{\Delta\sigma_y}{\Delta y}\right)$$

Setting these equations in terms of layer j,

$$\Delta\sigma_{xz,j}=-t_j\left(\frac{\Delta\sigma_{x,j}}{\Delta x}+\frac{\Delta\sigma_{xy,j}}{\Delta y}\right),\ \Delta\sigma_{yz,j}=-t_j\left(\frac{\Delta\sigma_{yx,j}}{\Delta x}+\frac{\Delta\sigma_{y,j}}{\Delta y}\right)$$

where:

$$\Delta\sigma_{x,j}=\left(\sigma^2_{x,j}+\sigma^3_{x,j}-\sigma^1_{x,j}-\sigma^4_{x,j}\right)/2.0$$
$$\Delta\sigma_{xy,j}=\left(\sigma^3_{xy,j}+\sigma^4_{xy,j}-\sigma^1_{xy,j}-\sigma^2_{xy,j}\right)/2.0$$
$$\Delta\sigma_{yx,j}=\left(\sigma^2_{xy,j}+\sigma^3_{xy,j}-\sigma^1_{xy,j}-\sigma^4_{xy,j}\right)/2.0$$
$$\Delta\sigma_{y,j}=\left(\sigma^3_{y,j}+\sigma^4_{y,j}-\sigma^1_{y,j}-\sigma^2_{y,j}\right)/2.0$$

$\sigma^3_{x,j}$ = stress in element x direction in layer j at integration point 3.

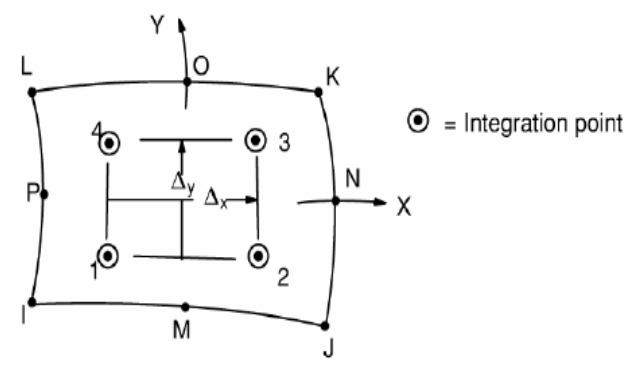


Fig.3 Integration point locations.

Δx and Δy are shown in Fig.3. Thus, the interlaminar shear stress is:

$$\tau^k_x=\sum_{j=1}^{k}\Delta\sigma_{xz,j}-S_x\sum_{j=1}^{k}t_j\,,\quad \tau^k_y=\sum_{j=1}^{k}\Delta\sigma_{yz,j}-S_y\sum_{j=1}^{k}t_j$$

where:

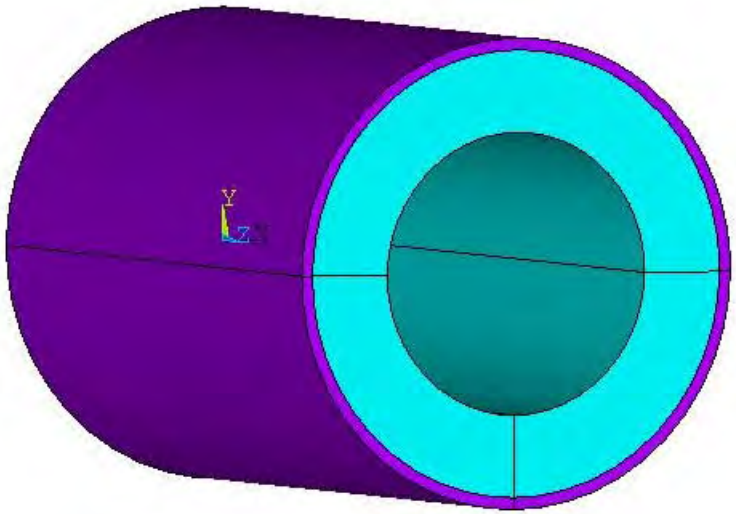
τ^k_x = interlaminar shear stress between layers k and k+1;

$S_x=\sum_{j=1}^{N_l}\Delta\sigma_{xz,j}\Big/t$ (= correction term);

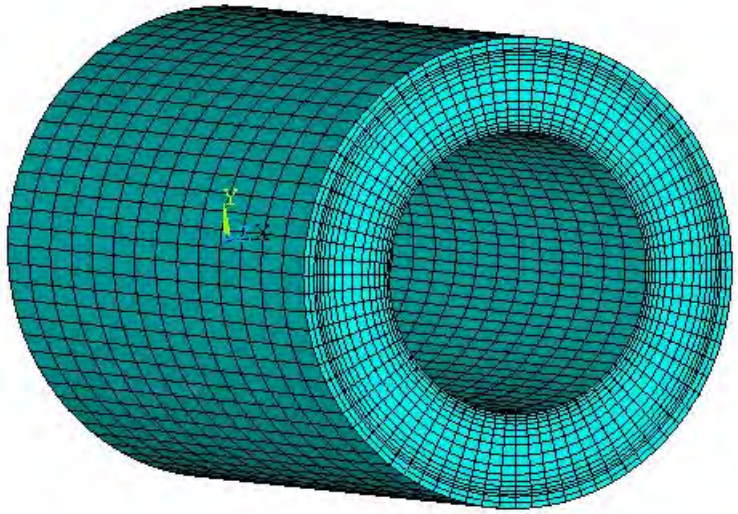
t = total thickness.

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5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER



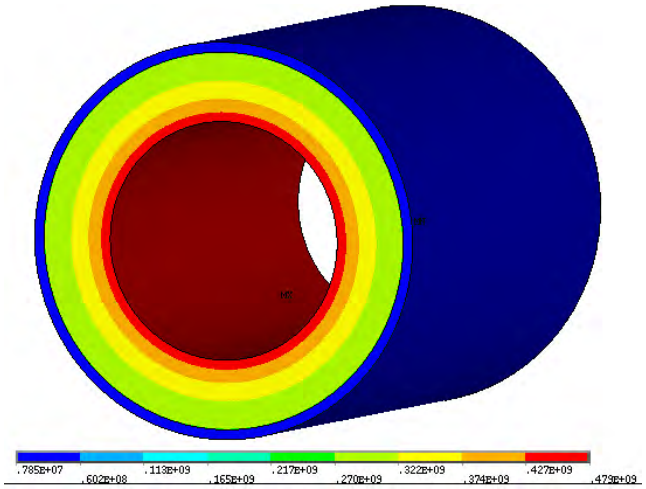
Solid Model



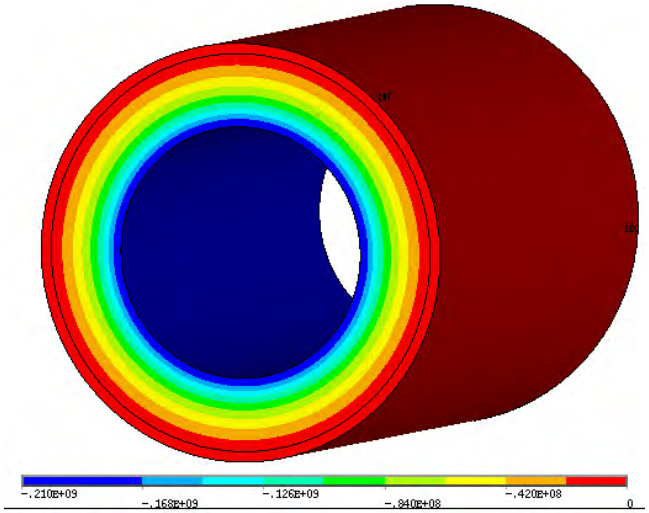
Meshed Model

Different orientations were selected, such as (0/90/0/90), (0/90/45/135), (0/90/30/120/60/150)

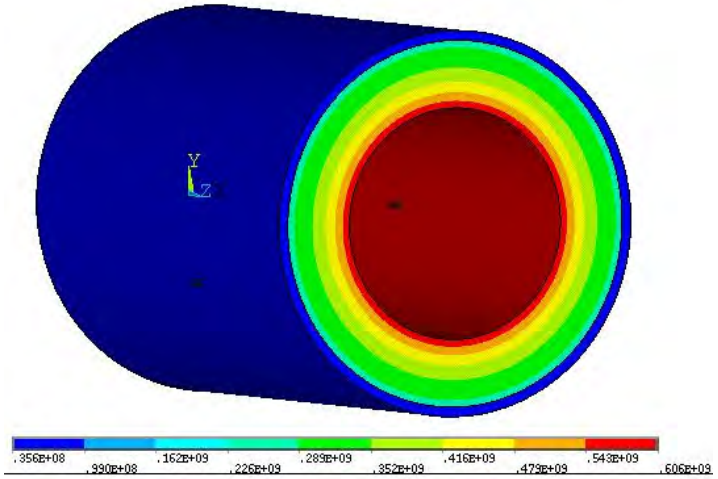
5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.



Von Mises Stress



Hoop Stress



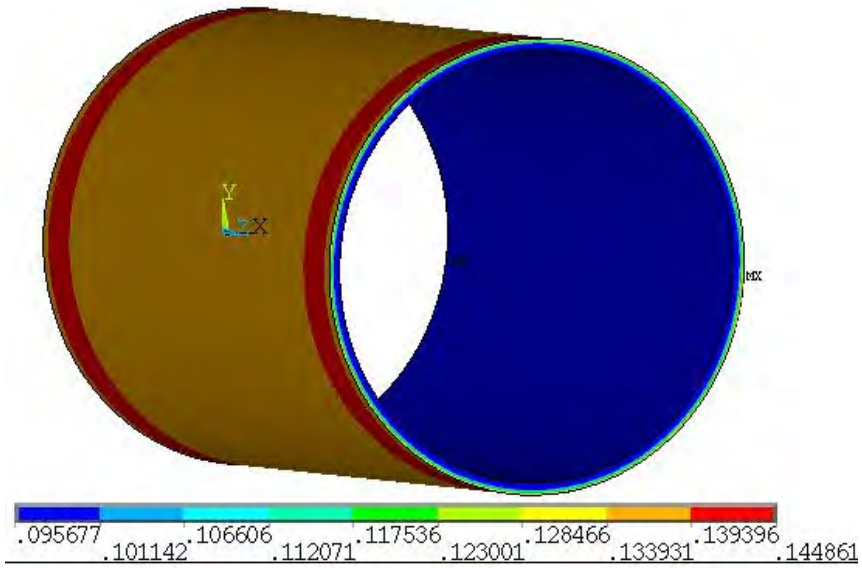
Radial Stress

Isotropic, elastic deformation with uniform pressure of 2.1e8 Pa

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5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.

FAILURE CRITERIA



- Failure criteria are curve fits of experimental data that attempt to predict failure under multi-axial stress.
- Failure criteria is defined as $I_f = \frac{stress}{strength}$
- Failure is predicted when $I_f \geq 1$
- Considering failure for maximum stress criterion.

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5. STRESS ANALYSIS OF A COMPOSITE-WRAPPED PRESSURIZED THICK-WALLED CYLINDER - CONT.

COMPARISON

SINGLE LAYER THICK WALL CYLINDER	von Mises Stress 0.671e9
DOUBLE LAYER THICK WALL CYLINDER	0. 618e9
COMPOSITE WRAPPED THICK WALL CYLINDER	0. 606e9

Best orientation for this model was (0-90-45-135)

Acknowledgement

This work was inspirited by the DoD projects in METLAB at South Dakota State University and supported by the Department of Mechanical Engineering at SDSU. Calculation data contributed by Manjunath Gurumallappa and Sudhir Puttagunta is gratefully acknowledged.

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Questions ?

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Mechanical Engineering Department

South Dakota State University

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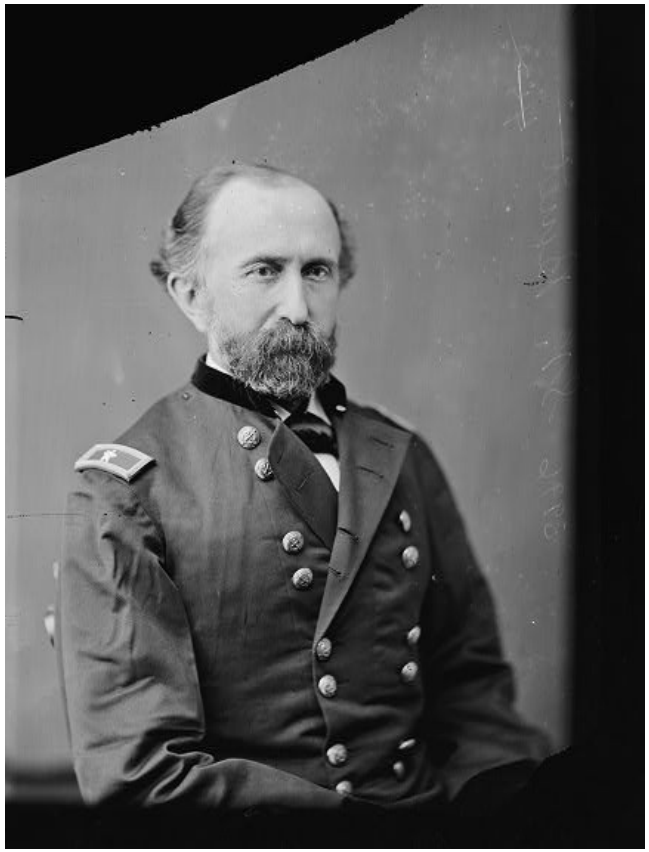
E-mail: Zhong.Hu@sdstate.edu

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NDIA

Joint Armaments Conference, Exhibition, & Firing Demonstration - 2010

"Brigadier General Stephen Vincent Benet (1827 – 1895) - His Life and Times"

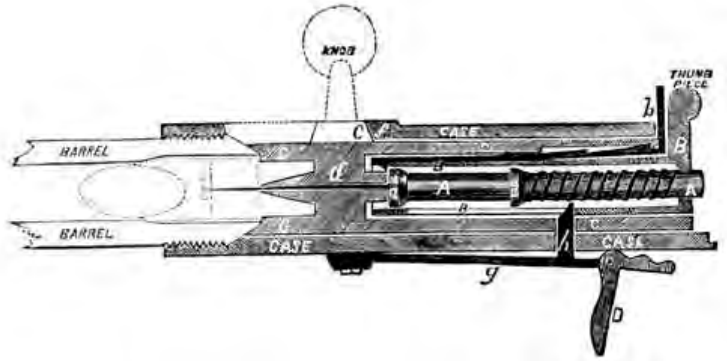


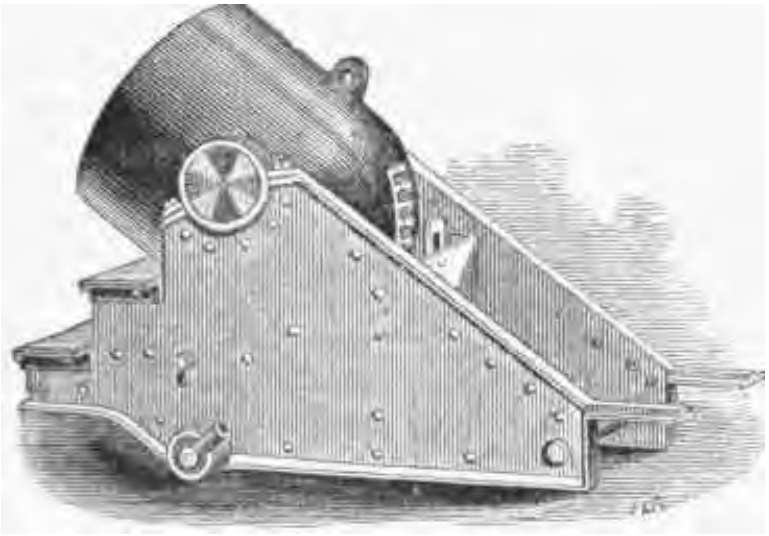
By Stephen C. Small, PhD

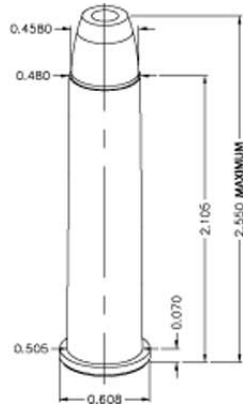
As of 1030hrs – 7 May 10

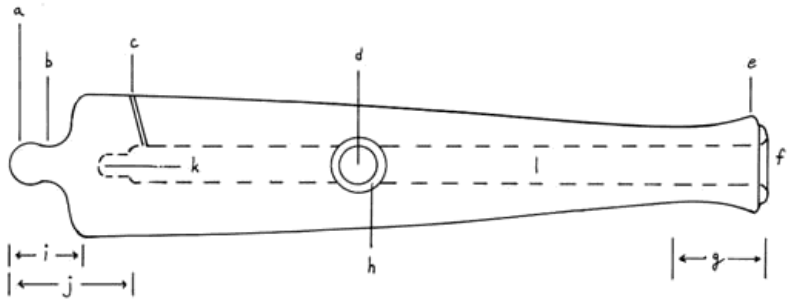
Agenda

- Military Career
- The Late 19th Military
- Homeland Defense and Insurgencies
- Arms and Armament
- Benet's Legacy
- Postscript









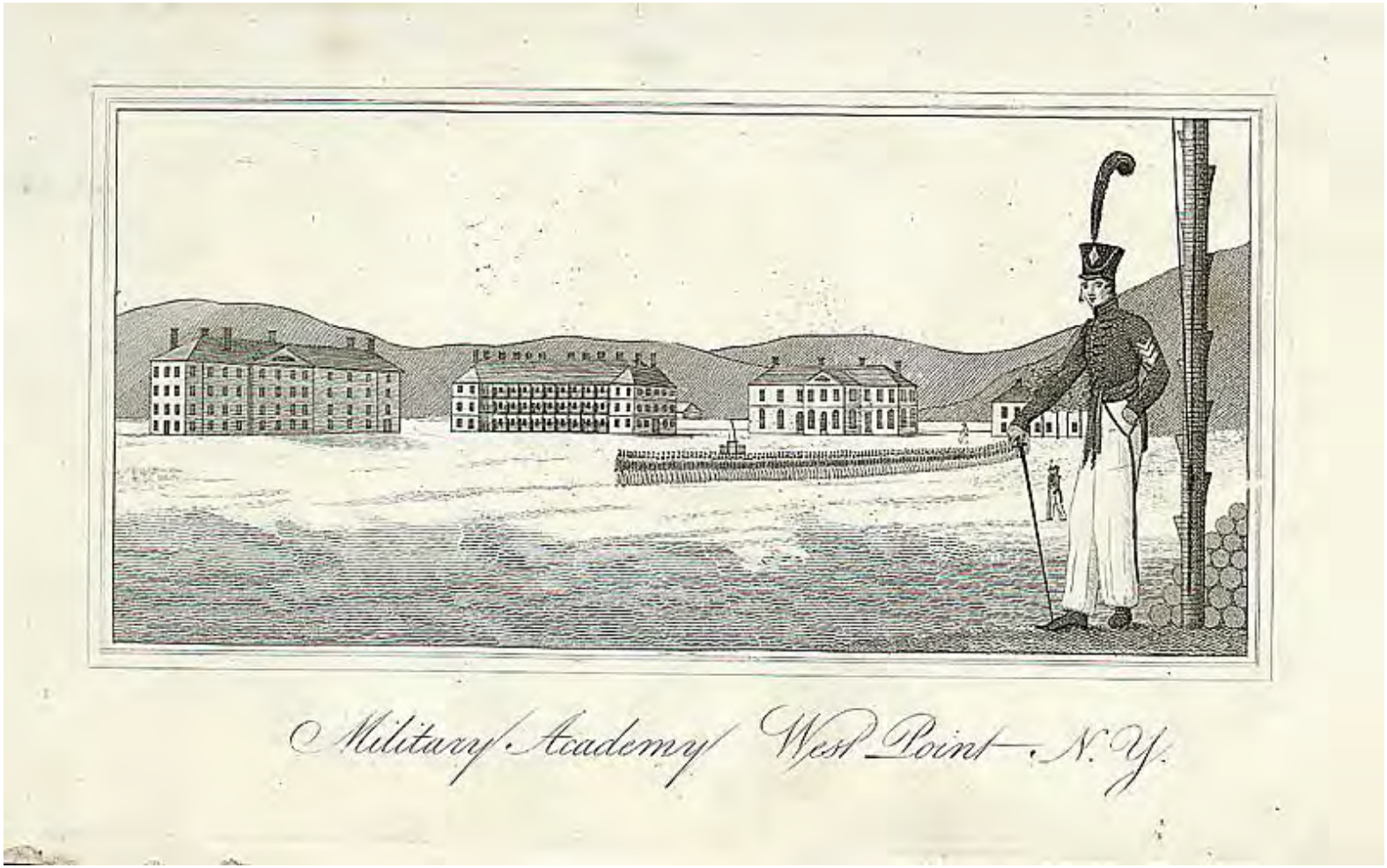
Military Career

Early Life

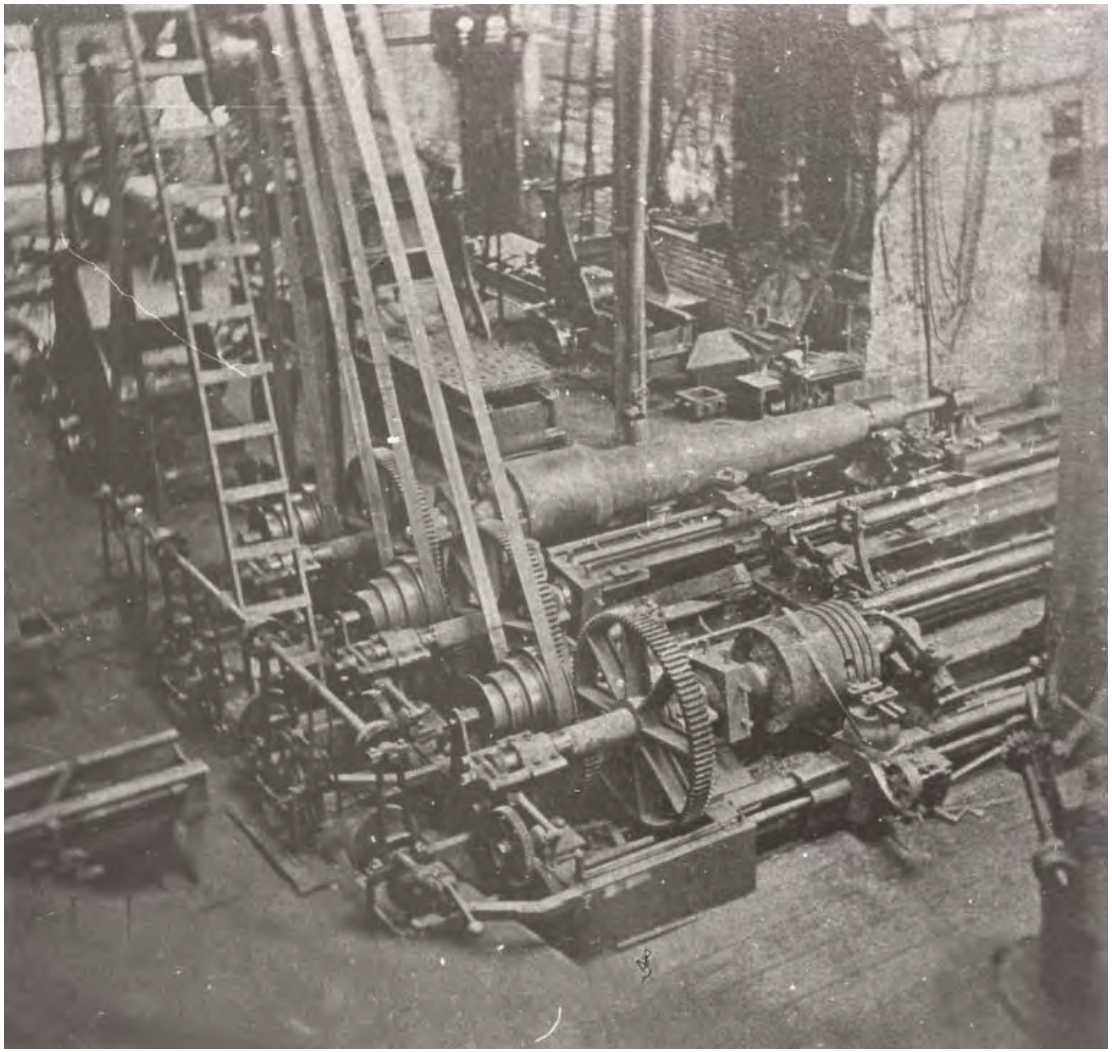
West Point

Chief of Ordnance

USMA West Point – 1849



Ordnance Department



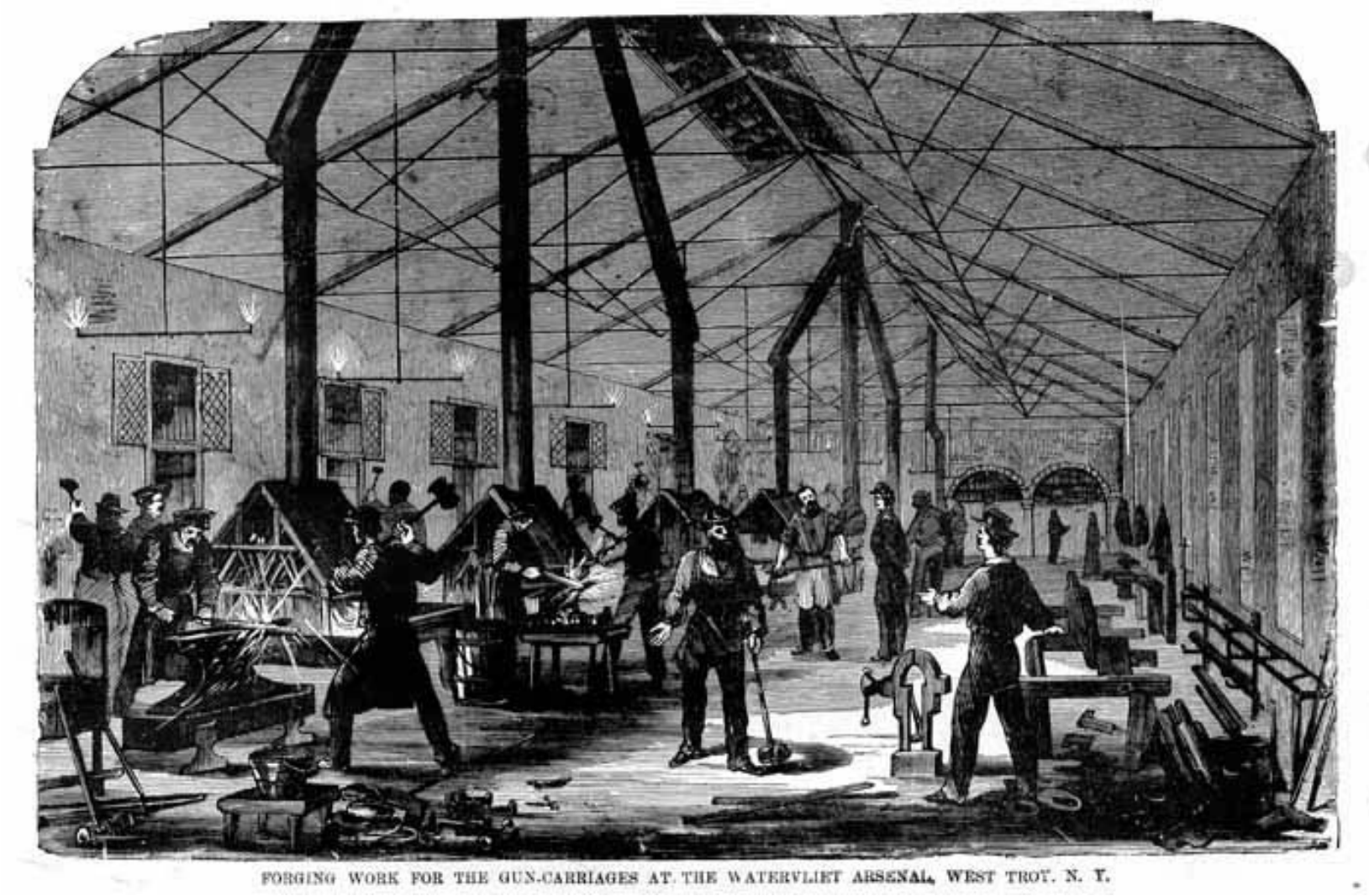
Frankford Arsenal







Watervliet Arsenal



FORGING WORK FOR THE GUN-CARRIAGES AT THE WATERVLIET ARSENAL, WEST TROY, N. Y.

West Point Military Academy Professor



Chief of Ordnance,
Brigadier General Stephen Vincent Benet

June 1874 – January 1891





The Late 19th Century U.S. Military



Underpaid

Overworked

Well Equipped?



The Army



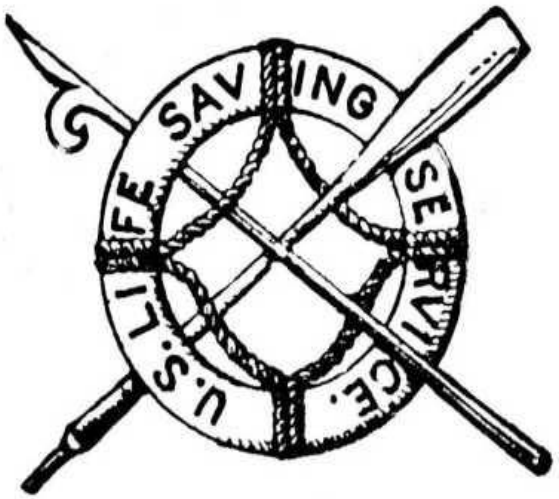
The Navy

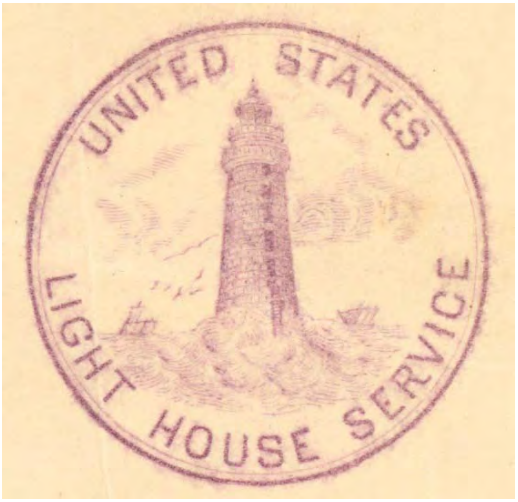


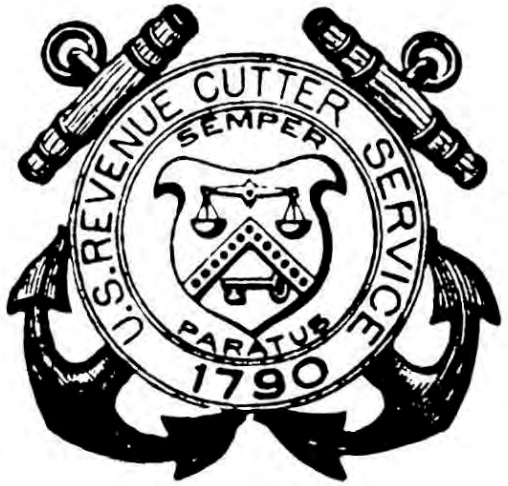
The Marines



Three Lifesaving Services

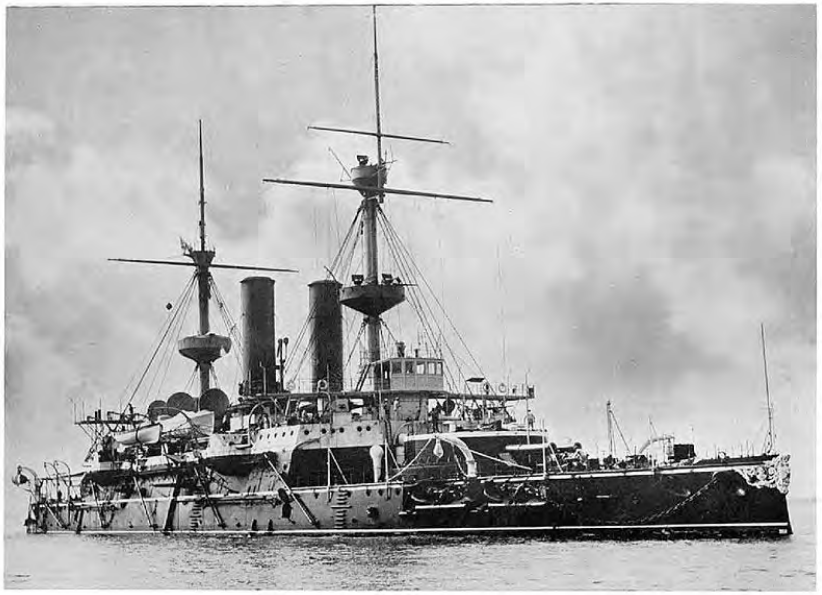






Homeland Defense

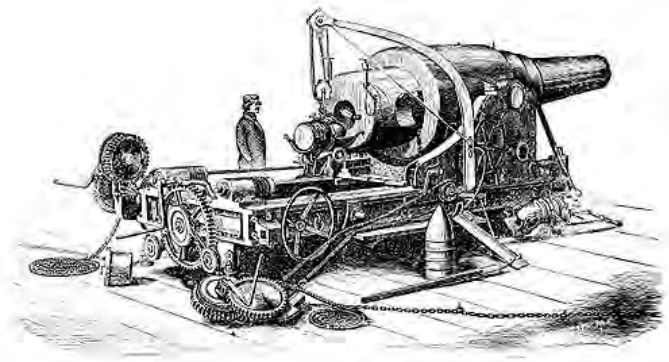






Homeland Defense

The Battleship Raid



Insurgencies





Indian Insurgents





Little Big Horn Battle
1876





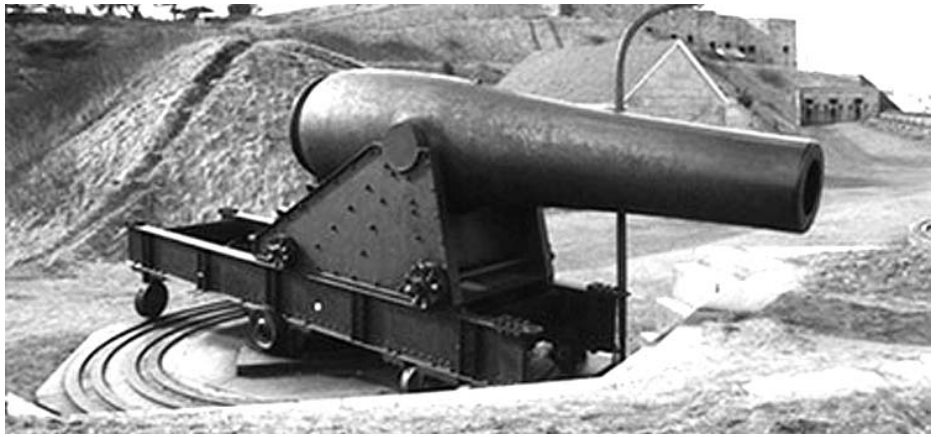
1890 – Wounded Knee





Arms and Armaments

1874 – 1891



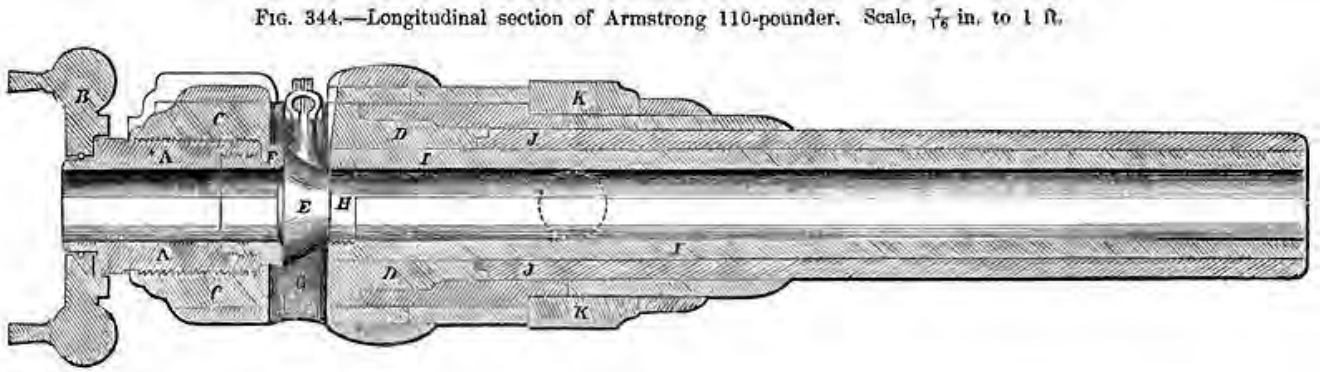


Fig. 344.—Longitudinal section of Armstrong 110-pounder. Scale, $\frac{1}{16}$ in. to 1 ft.

Seacoast Guns



Coastal Defense

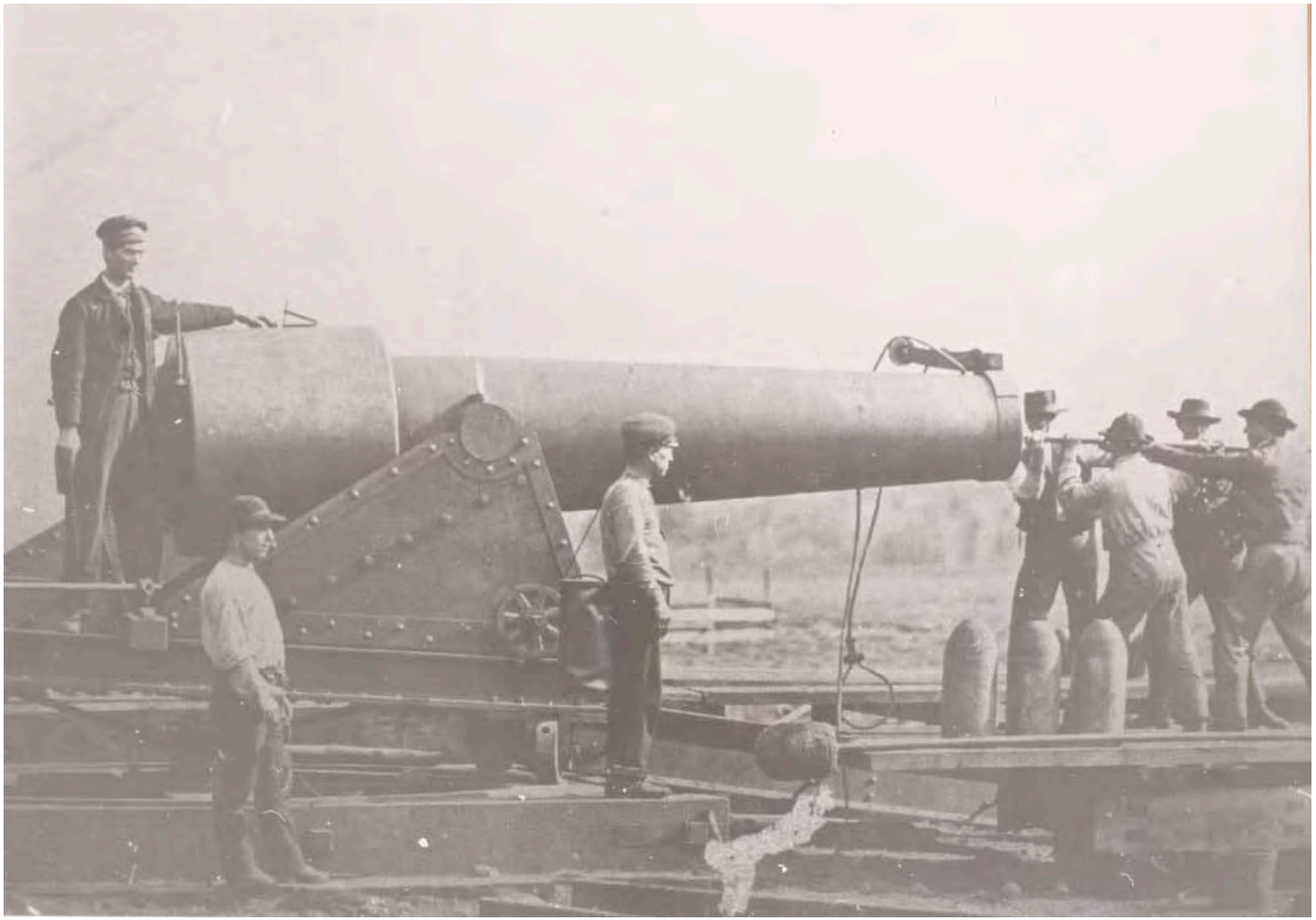


Seacoast Artillery

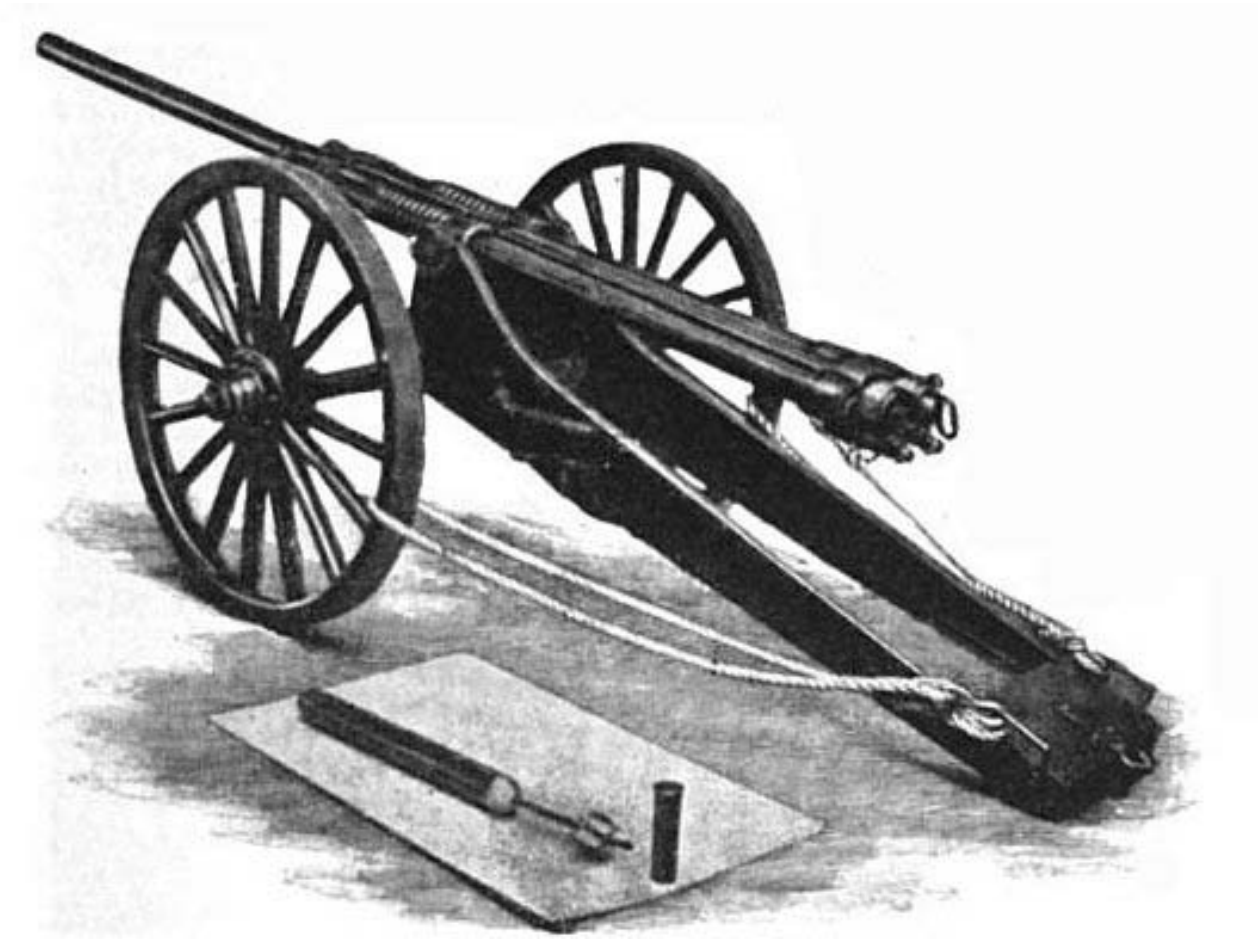
The “Columbiad”



The Parrot Rifled Shell Gun



Testing the Dynamite gun



Testing the Dynamite gun



USS Vesuvius







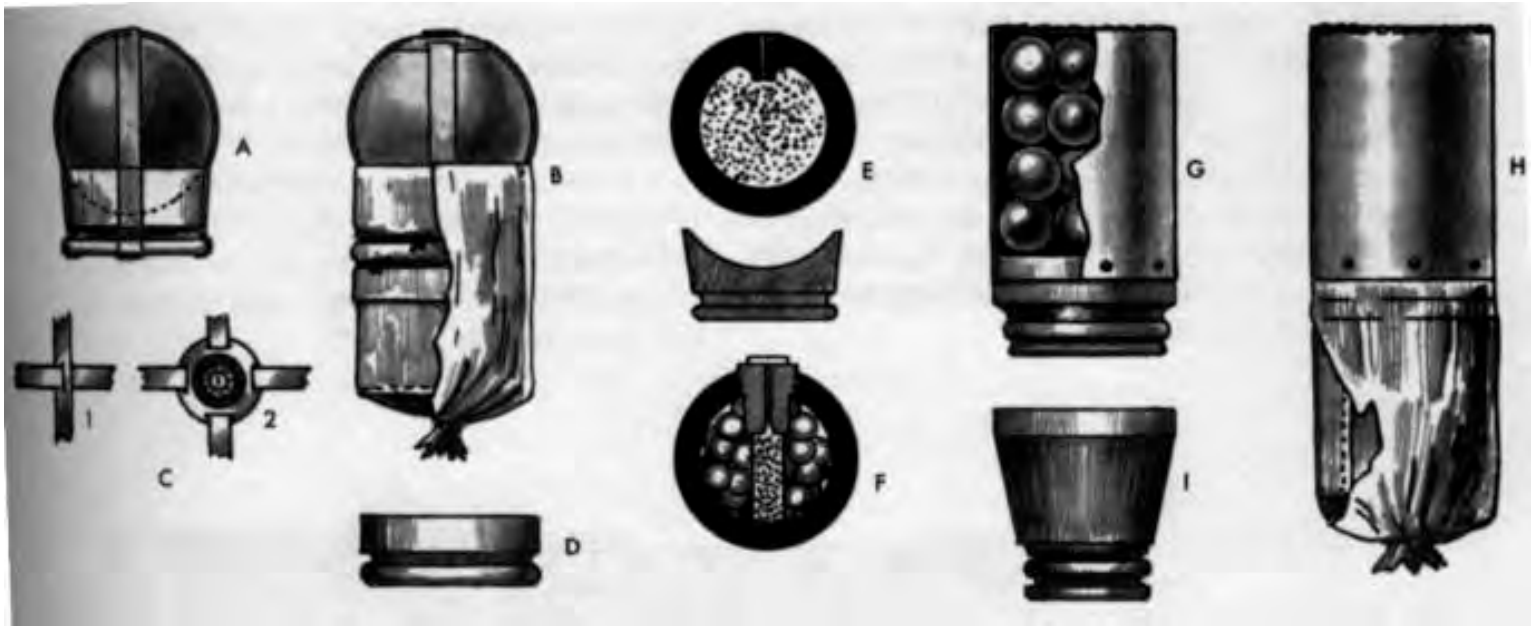
Field Artillery

Mostly Legacy Systems

Field Artillery

Model	Caliber (Inches)	Length of Tube	Max. Range
3-in. Ordnance Rifle	3.00	69 Inches	1830 yards
M1841 6-pounder smoothbore	3.67	60 Inches	1523 yards
10-lb. Parrot Rifle	3.00	74 Inches	1619 yards
12-lb. smoothbore	4.62	78 Inches	1663 yards
12-lb. Howitzer	4.62	53 Inches	1072 yards
M1857 12-lb. Napoleon	4.62	66 Inches	1619 yards
20-lb. Parrot Rifle	3.67	84 Inches	1900 yards

Artillery Smoothbore Ammunition



The 3 Inch Hotchkiss Mountain Gun

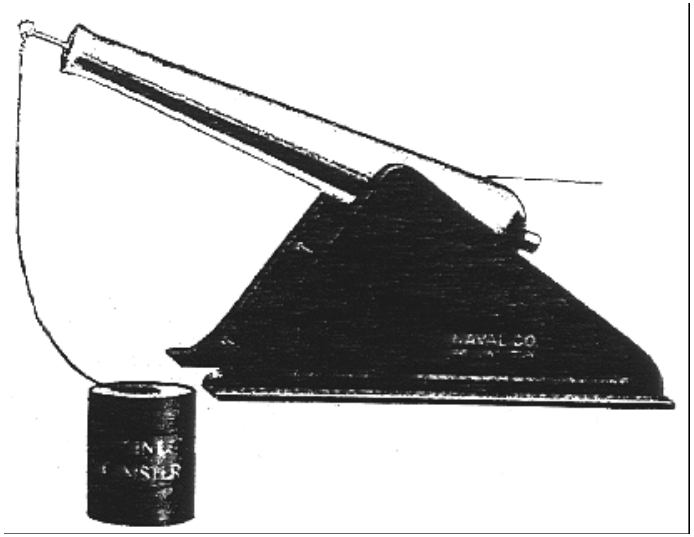
“Rifled” Projectile





The Lifesaving Lyle Gun











Small Arms

Mostly Legacy Systems



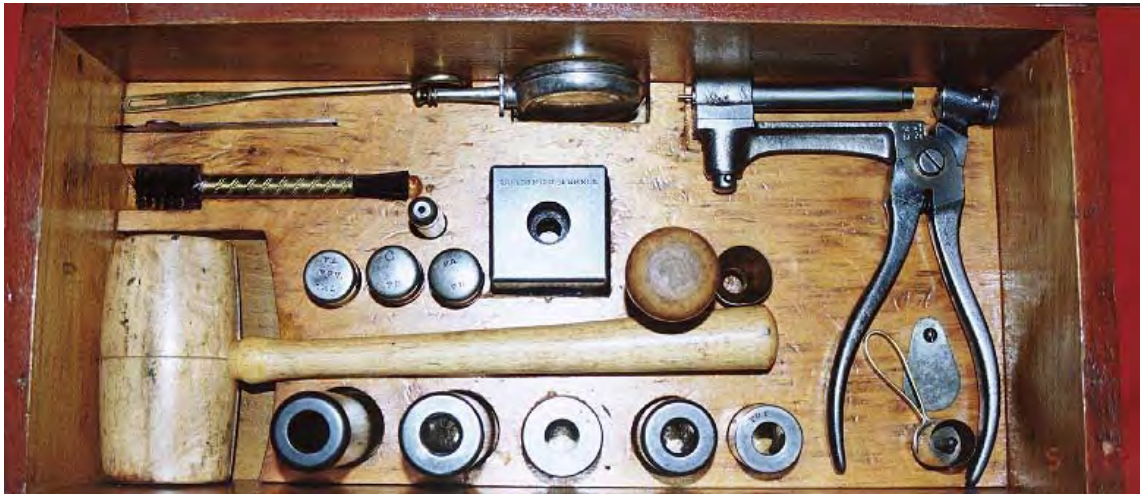
The Service Rifle and Carbine
1866 – 1892

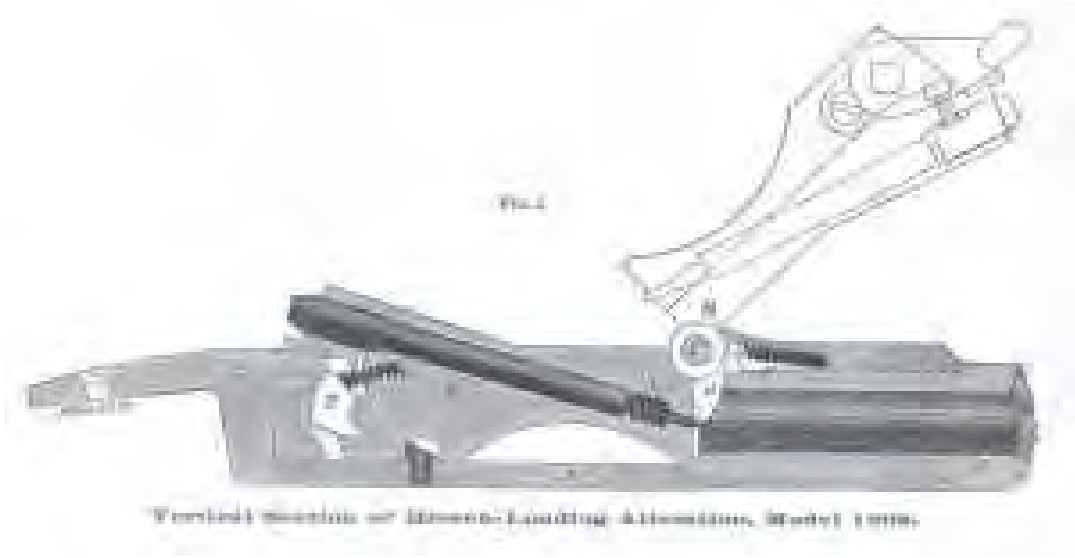


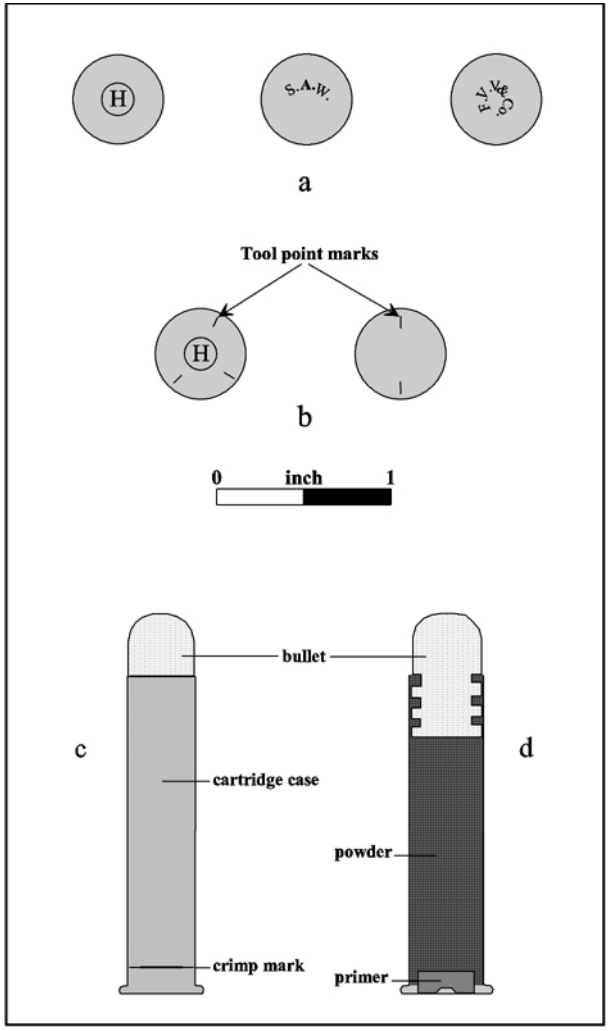




45-70 Caliber



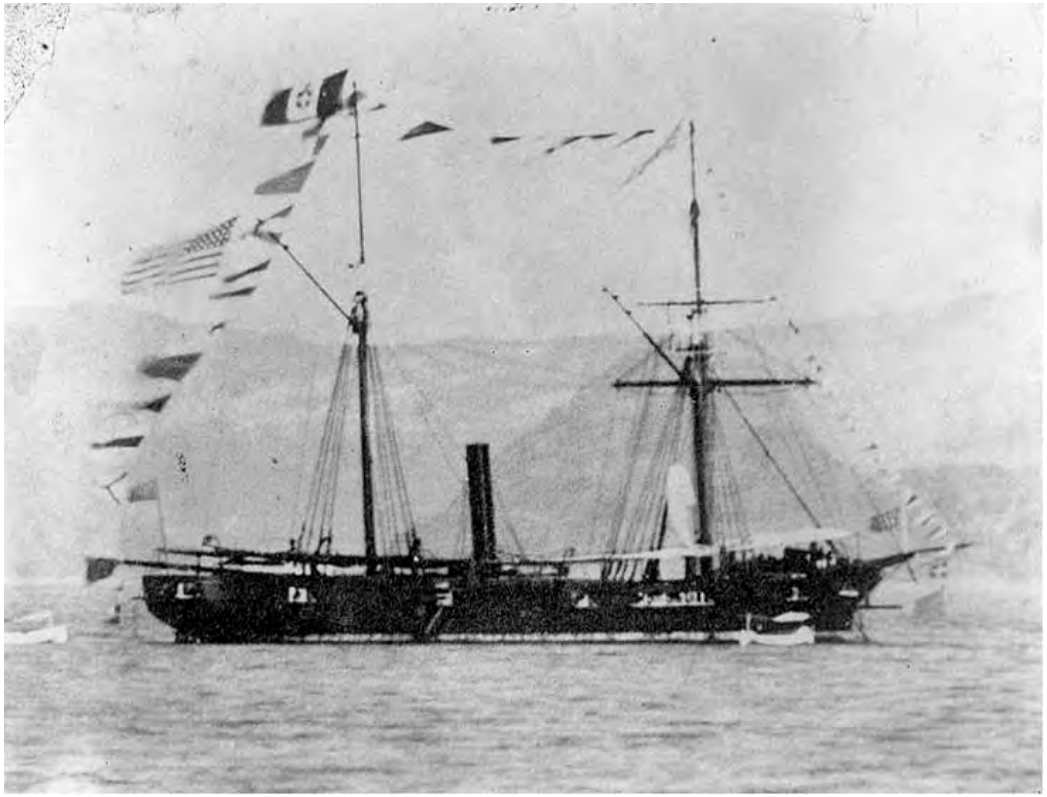




U.S. Navy Model 1869

Remington Rolling-block



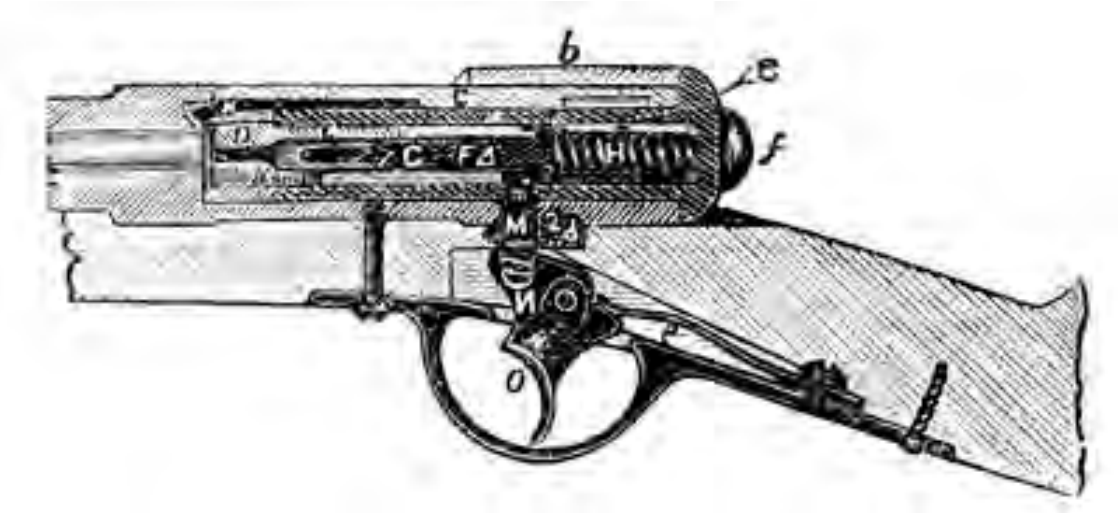


Ward-Burton Bolt-Action Rifle



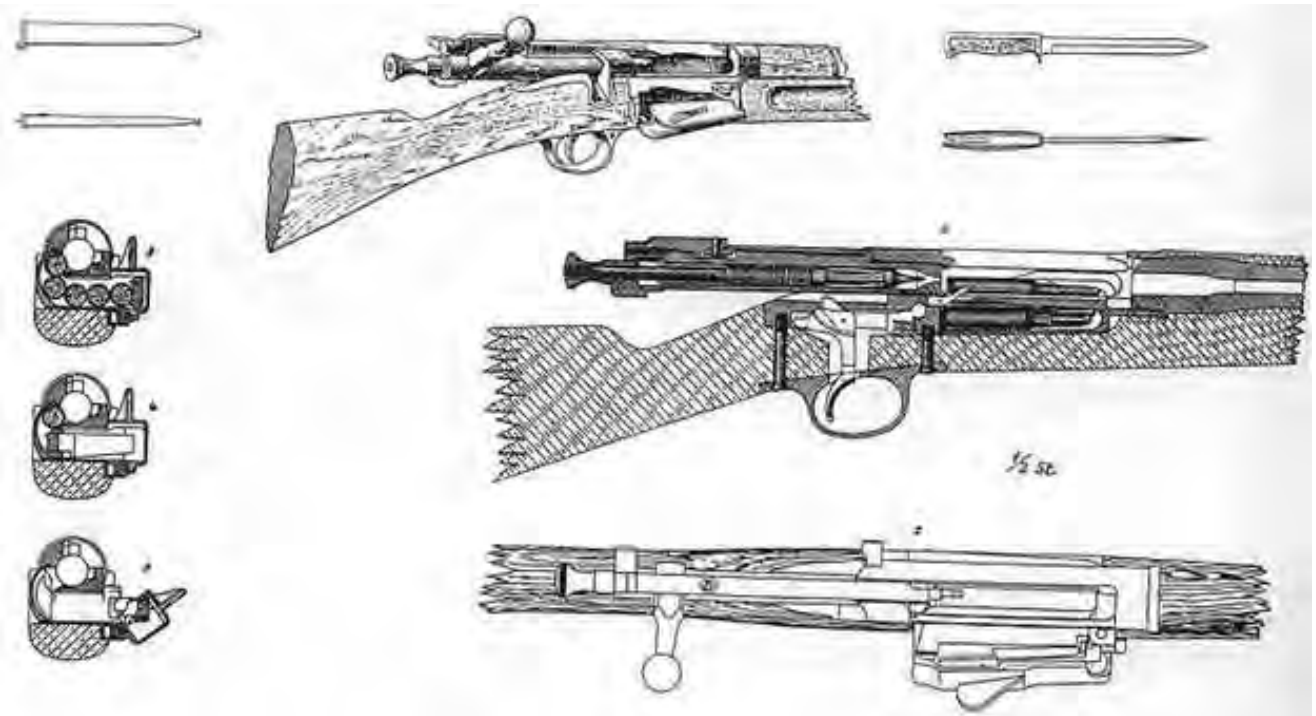


Ward-Burton Bolt-Action Rifle





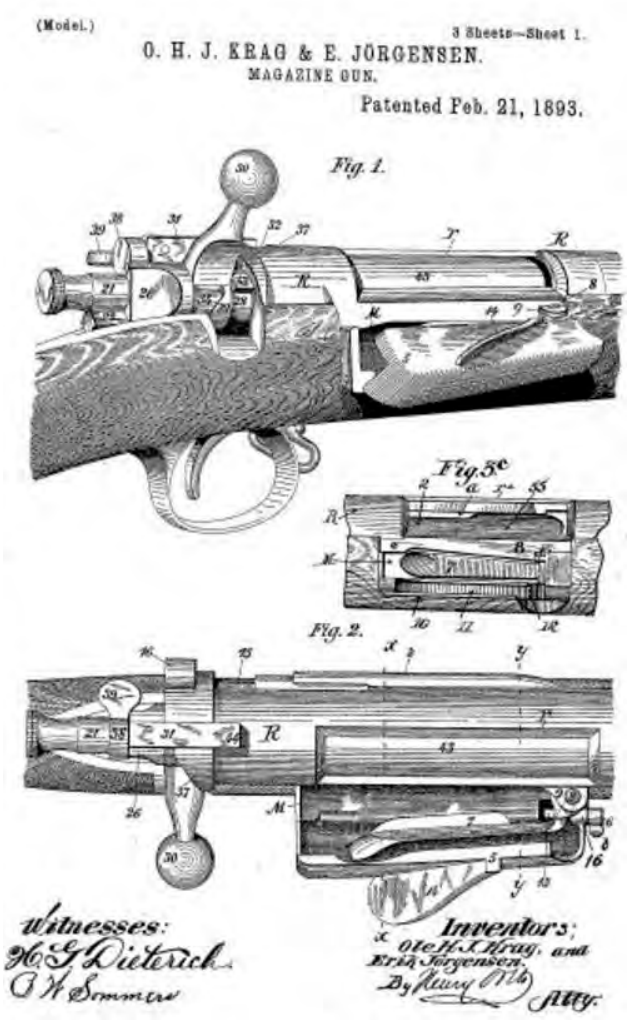
1890 – Magazine Rifle Board of Officers





Krag .30-40 –Lighter, Smaller, Faster





(Model.) 3 Sheets—Sheet 1.

O. H. J. KRAG & E. JÖRGENSEN.

MAGAZINE GUN.

Patented Feb. 21, 1893.

Fig. 1.

Fig. 3c

Fig. 2.

Witnesses:
H. G. Dieterich
C. H. Sommers

Inventors;
Ole H. J. Krag, and
Erik Jörgensen,
By Henry Orth
Atty.

Model 1873 Single-Action Colt .45

- Caliber .45” 250-255 gram lead ball
- Capacity six
- Muzzle Vel 860 Muzzle
- Sights Fixed – 25 yards



Double-Action Revolvers



.45 Colt Model - 1878



.38 Smith & Wesson Hammerless Safety - 1889

Benet's Legacy



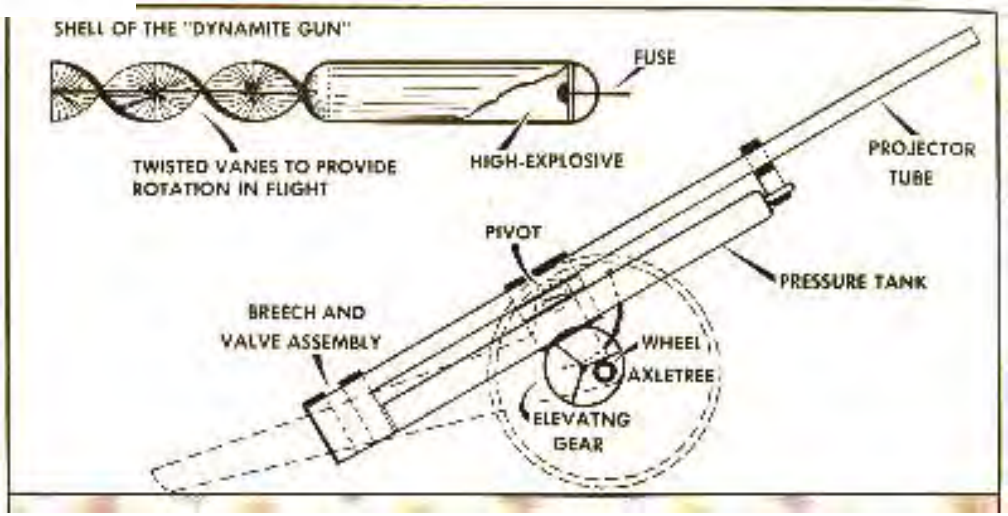
Benet's Legacy





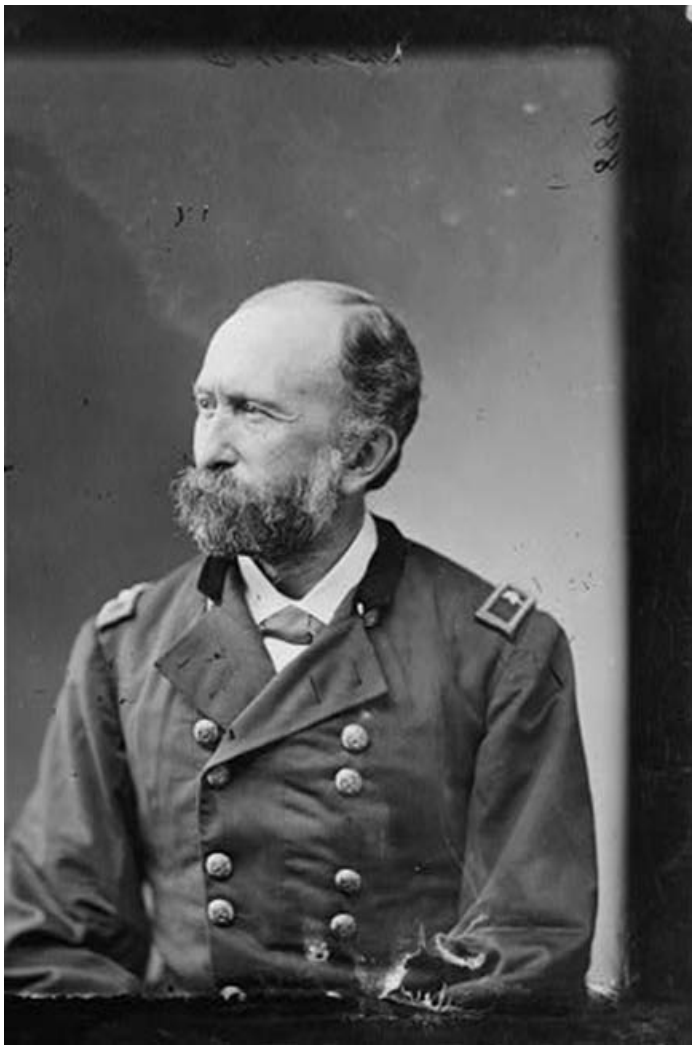






Benet's Grandson





Questions



