

40th Annual Armament Systems: Guns - Ammunition - Rockets - Missiles
Conference & Exhibition
"Translating Lessons Learned into Systems Requirements"

25 -28 April 2005

Agenda

Tuesday, 26 April 2005

General Session:

- Weapons Systems and Explosives Safety in a Joint Warfighting Environment, Mr. David C. Schulte, Executive Director, Naval Ordance Safety & Security Activity
- The Future of Small Missiles, Dr. James C. Bradas, Associate Director for Missile Technology, AMERDEC

Session: Modeling & Simulation

- Accuracy Modeling of the 120mm M256 Gun as a Function Of Bore Centerline Profile, Mr. David Smith for Dr. Ronald Gast, Benet Laboratories
- Opening New "DOORS" to Managing JSF Gun System Requirements, Ms. Renee I. Bellack, General Dynamics Armament and Technical Products
- Optimized Trajectory Shaping Guidance for an Air-to-Ground Missile Launched from a Gunship, Mr. Shane Sorenson, Naval Surface Warfare Center
- Estimating Ballistic Limits of Skin and Clothing for Projectiles, Mr. Henry E. Hudgins, US Army ARDEC
- A Review of The Insensitive Munitions Design Technology Workshop, Mr. M. Pascal Marchandin, NATO-MSIAC

Luncheon:

- Super Weapons – An Analysis, LTC Simon R. West, British Army, United Kingdom Defence Academy

Session: Medium Caliber System

- Oerlikon Ammunition for New Defense Environment, Mr. Allan N. Buckley, BTECH Oerlikon Contraves Pyrotec AG
- Multi Mission Vehicle Armament & Air Burst Munition for Expeditionary Warfare Force Protection, Mr. Andrew Bradick, Lockheed Martin
- 25mm Gun Systems for theF-35 Joint Strike Fighter (JSF), Mr. Douglass C. Parker, General Dynamics Armament and Technical Products
- Optimized Gun Barrel Targeting Investigation, Mr. Jeff A. Siewart, Arrow Tech Association
- Mk 110 Mod 0 / 57mm Naval Gun & Ammunition Certification Process, LT Timothy J. Hackett, USCG, US Coast Guard Deepwater Sponsors' Representative
- GAU-19/A Barrel Life Study, Mr. James J. St. Germain, General Dynamics Armament & Technology Products
- RNLA IFV Firepower: 30 mm versus 35 mm - 35 mm KETF Firing doctriney, Mr. Eelko van Meerten, TNO Defence, Safety & Security
- OMk44 Gun/Ammo IPT, Maj Kirk D. Mullins, USMC, DRPM AAA
- O30mm Airburst Development - Translating Lessons Learned into System Requirements, Mr. Paul A. Reynolds, General Dynamics - OTS

Wednesday, 27 April 2005

General Session:

- ATEC Update, BG(P) James R. Myles, USA, Commanding General, US Army Test & Evaluation Command
- Raytheon Missile Systems: A Global Perspective, Mr. Robert Salyer, Director, Business Development Raytheon Missile Systems
- Acquisition and Sustainment Program, COL Lloyd E. McDaniels, USA, Project Manager, CCWS Project Office

Session: Weapon Systems

- Weapon System Concepts for a Future Gunship, Mr. Michael M. Canaday, Naval Surface Warfare Center
- Royal Navy Small Calibre Gun Research to Defeat the Small Boat Threat, Mr. Johnathan Watkins, Defence Scientific Technology Laboratory
- Mini-Typhoon Remote Operated Small Arms Mount (ROSAM), Mr. Benjamin J. Hardie, General Dynamics Armament and Technical Products
- Update on Picatinny High Speed Turret, Mr. Mr. Richard Ciekurs, US Army RDECOM-ARDEC
- 40mm CTWS Supporting UK and France, Mr. Michael Duckworth, CTA International

Session: Missles & Rockets

Abraham Overview, Mr. Robert Daunfeldt, Bofors Defence
- Summary Overview of an Advanced 2.75 Hypervelocity Weapon, Mr. Larry Bradford, CAT Flight Services, Inc
- APKWS Flight Test Results, Mr. Larry Ingram and Mr. Dean Slocum, General Dynamics Armament & Technology Products
- APKWS Block II Demonstration Program , Mr. Milton E. (Gene) Henderson, Jr., US Army RDECOM-AMRDEC
- Missile Systems Lethality Enhancement Through the Use of a Conducting Aerosol Plasma Warhead, Mr. Allen H. Stults, US Army RDECOM-AMRDEC
- Next Generation Adaptable RF Seekers for Precision Munitions, Dr. Cory Myers, BAE Systems IEWS
- Technology for the Smart Rocket Launcher: The System Enabler For The 21st Century, Mr. Donald E. Davis, US Research, Development & Engineering Command
- Development of a Unique Penetrator Warhead for Rocket or Missile Delivery, Mr. Roger W. Melin, Lockheed Martin Missiles and Fire Control

Session: Large Caliber

- Development of the M1028, 120mm Anti-Personnel Tank Round, Mr. Hugh MacMillan, US Army Armaments Research, Development & Engineering Center and Mr. Neal Hylton, General Dynamics – Ordnance and Tactical Systems
- Metallic Materials & Processes Enabling Lightweight System Initiatives, Mr. Jeff Lehner, Director, Military Programs, Alcoa/Howmet Corporation
- Advanced Modular Gun Demonstrator: Redefining – "Faster Than A Speeding Bullet", Mr. Steve Coladonato, Applied Ordnance Technology, Inc.
- The Modified Tank Ammunition IMI M152/6 HEAT-AP- T, Mr. Danny Schirding, Chief Systems Engineer Tank Ammunition Directorate - IMI Ammunition Group
- A105/120/125 mm PELE Firing Results, Dr. Lutz Börngen, Rheinmetall Wafe Munition
- Line Of Sight/Beyond Line Of Sight (LOS/BLOS) Advanced Technology Demonstrator (ATD), Mr. David C. Smith, P.E., USA Benet Laboratories

Session: Energetics

- Development, Evaluation and Lifetime Prediction of Medium and Large Caliber Ammunition, Mr. Gert Scholtes, TNO
- Concepts and Practices in Finding and Applying Lessons Learned, Mr. David F. Fair, US Army ARDEC
- Propellant Replacement for the 105-mm M67 Propelling Charge, Ms. Adriana L. Eng, US Army ARDEC
- Lead Azide Replacement Program, Mr. John M. Hirlinger, US Army RDECOM-ARDEC
- Modeling Efforts for Autorotation Delivery System Concept Development, Mr. David C. Rutledge, Ph.D., Staff Engineer, United Defense

Thursday, 28 April 2005

General Session:

- Direct Fire Ammunition Lessons Learned: "More Than Just Impacts on Bullets", COL Mark Rider, USA, Project Manager, Maneuver Ammunition Systems
- U.S. Army ARDEC Overview & Special Weapon Observation Reconnaissance Direct-Action System (SWORDS), Mr. Anthony Sebasto, Associate Director for Technology & Business Development, AETC
- National Defense Industrial Association (NDIA) Armament Division - 2005 Division Status, Mr. Dave Broden, Chairman, Armaments Division, NDIA

Session: Technology & Manufacture

- Automated Ammunition Identification, Mr. David F. Pouliot, United Defense L. P.
- Design for Manufacturing & Assembly (DFMA), Mr. Steve Watts, US Army RD&E Command
- ARDEC Business Development Process, Mr. David L. Burkhardt, Director, Strategic Communications, US Army ARDEC
- MEMS IMU – Common Guidance, Dr. Vicki C. LeFevre, US Army RDECOM-AMRDEC and Mr. David W. Panhorst US Army ARDEC, US Army ARDEC
- Development and Testing of High Explosive (HE) Projectiles for Electro-Magnetic Gun Army Tech Objective (ATO), Mr. Manfredi Luciano, US Army ARDEC
- Metal Injection Molding of Wing/Flaperon, Mr. Jerry C. LaSalle, Director of MIM Operations, Polymer Technologies, Inc (PTI)
- TBX Evaluation Testing in the M151 (2.75") Warhead as Risk Reduction for the APKWS, Mr. Jason C. Gilliam, US Army RDECOM-AMRDEC
- Archer Artillery Program, Mr. Ulf Einefors, Bofors Defence
- Improvements to Airborne Ladar Man-in-the-Loop Operations, Mrs. Sarah J. Hard, RDECOM-AMRDEC

Session: Mortars & Artillery

- M865 TID Improvement Study, Mr. Jason W. Gaines, General Dynamics
- Lessons Learned from the Development of the U.S. Navy 5-Inch Force Protection Projectiles, Mr. Sanford (Luke) Steelman, III, Naval Surface Warfare Center
- Advanced Gun Barrel Technologies, Dr. Amir Chaboki and Mr. Allen Boutz, United Defense
- Defining Homogeneity for Medium Caliber Ammunition and Small Grain Propellant Lots, Mr. Scott Carney, ATK
- Precision Fires for the Field Artillery, Mr. John Halvey, Raytheon, and Stefan Blomgren, Bofors Defence
- Low Cost Course Correction (LCCC) Demonstration Program, Mr. George Barnych and Mr. Daniel Davis, Ordance and Tactical Systems Division
- XM395 Precision Guided Mortar Munition (120mm PGMM): Responsive, Standoff Precision Lethality for Highly Deployable and Mobile Forces, Mr. James Terhune and Mr. Anthony Pezzano, OPM Mortars
- Precision Guided Miniature Munitions, Mr. Mark Carlson, BAE Systems
- The 81mm Non Lethal **Mo**rtar **Ca**rrier **P**rojectile (MoCaP), Mr. Seungeuk Han, Mr. Andrew Ponikowski, and Mr. Raymond Trohanowsky, US Army RDECOM-ARDEC
- Commercial Disposal of Explosive Wastes, Mr. Mark M. Zaugg, EBV Explosives Environmental Company

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

"Translating Lessons Learned into Systems Requirements"

40th Annual Armament Systems: Guns - Ammunition - Rockets - Missiles Conference & Exhibition

April 25 - 28, 2005

Sheraton New Orleans Hotel
New Orleans, LA



Monday, April 25 2005

10:00 a.m. On-site Registration

Noon Exhibit Move-In

5:00 p.m. - 6:30 p.m. Reception in the Exhibit Hall

6:30 p.m. Adjourn for the Day

Tuesday, April 26, 2005

7:00 a.m. On-site Registration / Continental Breakfast

7:45 a.m. Opening Remarks

8:00 a.m. ***Mr. David C. Schulte***, Executive Director, Naval Ordnance Safety & Security Activity

8:30 a.m. ***Dr. James C. Bradas***, Associate Director for Missile Technology, AMRDEC

9:00 a.m. **Session: Modeling & Simulation**

Accuracy Modeling of the 120mm M256 Gun as a Function of Bore Centerline Profile
Mr. David Smith for Dr. Ronald G. Gast, Benet Laboratories

Opening New DOORS to Managing JSF Gun System Requirements
Ms. Renee I. Bellack, General Dynamics Armament and Technical Products

Optimized Trajectory Shaping Guidance for an Air-to-Ground Missile Launched from a Gunship
Mr. Shane Sorenson, Naval Surface Warfare Center

9:30 a.m. Exhibit Hall Opens

10:00 a.m. Break in the Exhibit Hall

10:30 a.m. Conceptual Weapon System Design for the Defense of Naval Vessels from the Swarming Small Boat Threat
Mr. John E. Bibel, Naval Surface Warfare Center Dahlgren Division

Warhead Penetration Dynamics - Warhead Body, Fuze, and Target Interaction
Mr. Richard Ventura, Talley Defense Systems

Ballistic Limits of Skin and Clothing for Lethality Estimates of Projectiles Wound Ballistics
Mr. Henry E. Hudgins, US Army ARDEC

A Review of the Recent NIMIC IM Design Technology Workshop
Mr. M. Pascal Marchandin, NATO - MSIAC

11:50 a.m. Luncheon: Super Weapons From a Historical and Psycological Basis
LTC Simon R. West, British Army, United Kingdom Defence Academy

1:10 p.m. **Session: Medium Caliber Systems**

Ammunition for the New Infantry Battelfield Environment
Mr. Allan N. Buckley, BTECH Oerlikon Contraves Pyrotec AG

Force Protection - Multi Mission Vehicle Armament & Air Burst Munition for Expeditionary Warfare
Mr. Andrew Bradick, Lockheed Martin

F-35 Joint Strike Fighter Gun Overview and System Update
Mr. David L. Maher and ***Mr. Douglass C. Parker,*** General Dynamics, Armament and Technical Products

Phalanx Targeting Investigation
Mr. Jeff A. Siewart, Arrow Tech Association

3:00 p.m. Break in the Exhibit Hall

3:30 p.m. **Session: Medium Caliber Systems (Continued)**

Mk 110 Mod 0 / 57mm Gun Test & Certification Process
LT Timothy J. Hackett, USCG, US Coast Guard

GAU-19/A Barrel Life Study
Mr. James J. St. Germain, General Dynamics Armament & Technology Products

Calibre Choice for the Dutch IFV
Mr. Eelko van Meerten, TNO Defence, Safety & Security

The Expeditionary Fighting Vehicle, How Operational and Combat Lessons Learned Apply to the EFV and the 30MM Mix of Tomorrows Warfighter
Maj Kirk D. Mullins, USMC, DRPM AAA

30x173mm HEAB-T Development and Lessons Learned
Mr. Paul A. Reynolds, General Dynamics - OTS

5:30 p.m. - 7:00 p.m. Reception in the Exhibit Hall

7:00 p.m. Adjourn for the Day

Wednesday, April 27, 2005

7:00 a.m. On-site Registration / Continental Breakfast

7:45 a.m. Opening Remarks

8:00 a.m. ***BG (P) James R. Myles, USA***, Commanding General, US Army Test & Evaluation Command

8:45 a.m. ***Mr. Robert Salyer***, Raytheon

9:10 a.m. Acquiring and Sustaining US Army Missiles
COL Lloyd E. McDaniels, USA, CCWS Project Office

9:30 a.m. Exhibit Hall Opens

9:45 a.m. **Session: Medium Caliber Systems (Continued)**

Recent Developments of the M230 30MM Chain Gun
Mr. Lawrence A. Mason, ATK Ordnance & Ground Systems

MK44 Automatic Cannon Update
Mr. Mark McMillian, ATK Ordnance Systems

10:30 a.m. Break in the Exhibit Hall

Concurrent Sessions

10:50 a.m. **Session: Weapon Systems**

AC-130U Gun System Production Re-Start
Mr. John G. Fletcher, General Dynamics Armament and Technical Products

Weapon System Concepts for a Future Gunship
Mr. Michael M. Canaday, Naval Surface Warfare Center

Royal Navy Small Calibre Gun Research to Defeat the Small Boat Threat
Mr. Johnathan Watkins, Defence Scientific Technology Laboratory

11:50 a.m. - Lunch

1:00 p.m. **Session: Weapon Systems (Continued)**

Remote Operated Small Arms Mount (ROSAM)
Mr. Benjamin J. Hardie, General Dynamics Armament and Technical Products

Placing Gunner's Behind the Proctective Armor of Vehicles
LTC Kevin P. Stoddard, USA, PM Soldier Weapons

Picatinny High Speed Turret (PHIST)
Mr. Richard Ciekurs, US Army RDECOM-ARDEC

Session: Missiles & Rockets

Critical Asset Defense - ABRAHAM Rocket Assisted Projectile
Mr. Robert Daunfeldt, Bofors Defence

Hypervelocity Propulsion System Substantially Improves 2.75 Rocket Lethality, Safety, Survivability
Mr. Larry Bradford, CAT Flight Services, Inc.

APKWS Flight Test Results
Mr. Larry S. Ingram, General Dynamics Armament and Technical Products

APKWS Block II Demonstration Program
Mr. Milton E. (Gene) Henderson, Jr., US Army RDECOM-AMRDEC

Lunch

Session: Missiles & Rockets (Continued)

Missile System Lethality Enhancement Through the Use of Pulsed Power and Plasma Conduction
Mr. Allen H. Stults, US Army RDECOM

Next Generation Adaptable RF Seekers for Precision Munitions
Dr. Cory Myers, BAE Systems

The Smart Rocket Launcher as the Key Enabler for the Rocket System of the Future: The Technology Developments Needed for the Next Generation Rocket Laucher to Carry 70mm Rockets into the 21st Century
Mr. Donald E. Davis, US Army Research, Development & Engineering Command

	Session: Weapon Systems (Continued)	**Session: Missiles & Rockets (Continued)**
	Recent Activities Involving 40mm CTWS in Support of UK and France ***Mr. Michael Duckworth***, CTA International	Development of a Unique Penetrator Warhead for Rocket or Missile Delivery ***Mr. Roger W. Melin***, Lockheed Martin Missiles and Fire Control
	The Marine Corps Expeditionary Fire Support System (EFSS): A Systems Overview ***Mr. Jason Burkett***, General Dynamics	Determining the Army Aviation Rocket and Missile Mix for the Future Fight ***Mr. William M. Mulholland***, Whitney, Bradley & Brown
2:40 p.m.	Break in the Exhibit Hall ***(Last Opportunity to Visit Exhibits)***	Break in the Exhibit Hall ***(Last Opportunity to Visit Exhibits)***
3:00 p.m.	Exhibit Hall Closed	Exhibit Hall Closed
3:10 p.m.	**Session: Large Caliber**	**Session: Energetics**
	Development of the XM1028, 120mm Anti-Personnel Tank Round ***Mr. Hugh MacMillan***, Armaments Engineering and Technology Center, ***Mr. Peter Georgantzis***, US Army ARDEC, and ***Mr. Neal Hylton***, General Dynamics-OTS	Advanced Propelling Solutions Complying with Demands (FCS) ***Dr. Beat Vogelsanger***, NITROCHEMIE Wimmis AG
	Titanium Investment Casting Weapon System Application ***Mr. Jeff Lehner***, Director, Military Programs, Alcoa/Howmet Corporation	Development, Evaluation and Lifetime Prediction of Medium and Large Caliber Ammunition ***Mr. Gert Scholtes***, TNO
	Advanced Modular Gun Demonstrator - XLT Test Gun ***Mr. Steve Coladonato***, Applied Ordnance Technology, Inc.	Concepts and Practice in the Application of Lessons Learned ***Mr. David F. Fair***, US Army ARDEC
	The Modified Ammunition, Equipped with the "Fuzaman": The IMI 105-mm Heat-AP-t Cartridge M152/6 ***Mr. Danny Schirding***, Israel Military Industries, Ltd	Propellant Replacement for the 105-mm Artillery Propelling Charge ***Ms. Adriana L. Eng***, US Army ARDEC
	105/120/125 mm PELE Firing Results ***Dr. Lutz Borngen***, Rheinmetall Waffe Munition	Environmentally Benign Substitute Compounds for Lead Azide ***Mr. John M. Hirlinger***, US Army RDECOM-ARDEC
	Lightweight Gun Development and Testing for the Future Combat System ***Mr. David C. Smith, P.E.***, USA Benet Laboratories	Modeling Efforts in Support of PKERS Concept Development ***Mr. David C. Rutledge, Ph.D.***, Staff Engineer, United Defense
5:15 p.m.	Adjourn for the Day	Adjourn for the Day

Thursday, April 28, 2005

7:00 a.m. On-site Registration / Continental Breakfast

7:45 a.m. Opening Remarks

8:00 a.m. ***COL Mark Rider, USA***, Project Manager, Maneuver Ammunition Systems

8:30 a.m. ***Mr. Anthony Sebasto***, Associate Director for Technology & Business Development, AETC

9:00 a.m. ***Mr. Dave Broden***, NDIA Armaments Division Status Overview, Chairman, Armaments Division, NDIA

9:20 a.m. Break

Concurrent Sessions

9:40 a.m.

Session: Technology & Manufacture

Automated Ammunition Identification
Mr. David F. Pouliot, United Defense L. P.

Deep Digger Weapons System Concept
Mr. David W. Burns,US Army ARDEC

Development of Composite Launch Tubes for Shoulder Fired Weapons through Applied Science, Planning and Teamwork
Mr. Thomas P. Jacobson, Talley Defense Systems

Design for Manufacture & Assembly (DFMA)
Mr. Steve Watts, US Army RD&E Command

Technology and Manufacturing Initiatives
Mr. Dave Burkhardt, Enterprise Management Office, US Army ARDEC

Session: Technology & Manufacture (Continued)

Army MEMS Common Guidance Program
Mr. David. W. Panhorst, US Army ARDEC and ***Dr. Vicki C. LeFevre***, AMRDEC

Development and Testing of HE Projectiles for EM Gun - STO
Mr. Manfredi Luciano, US Army ARDEC

Session: Mortars & Artillery

Tank 120mm Training Ammunition: MB65 Target Impact Dispersion Study
Mr. Jason W. Gaines, General Dynamics-OTS

Lessons Learned from the Development of the U.S. Navy 5-inch Ship Self Defense Projectiles
Mr. Sanford L. Steelman, III, Naval Surface Warfare Center

ONR's Advanced Gun Barrel Technology Program
Mr. Allen Boutz, United Defense

Structural Margin Improvement on the M829A3 Projectile
Mr. Scott Carney, ATK

Session: Mortars & Artillery

Excalibur: Turning the Field Artillery into a Long Range Precision Attack Weapon System
Mr. Stefan Blomgren, Bofors Defence

Low Cost Course Correction (LCCC) Demonstration Program
Mr. George B. Barnych, General Dynamics Ordnance and Tactical Systems Division

Session: Technology & Manufacture (Continued)

Advanced Metal Injection Molding Technology Applications to Defense Industry
Mr. Jerry LaSalle, Polymar Technologies

11:40 a.m. Lunch

1:00 p.m. **Session: Technology & Manufacture (Continued)**

TBX Evaluation Testing in the M151 (2.75") Warhead as Risk Reduction for the APKWS
Mr. Jason C. Gilliam, US Army RDECOM-AMRDEC

Advanced Precision Kill Weapon System
Mr. Ulf Einefors, Bofors Defence

Test Results of an Imaging LADAR Seeker for Small Missiles
Mrs. Sarah J. Hard, RDECOM-AMRDEC

Session: Mortars & Artillery (Continued)

Applying Six Sigma Principles to Implementation of the PGMM Training Concept
Mr. Anthony Pezzano, OPM Mortars

Lunch

Session: Mortars & Artillery (Continued)

Precision Guided Miniature Munitions
Mr. Mark Carlson, BAE Systems

Development of a Non-Lethal Mortar Delivery System
Mr. Seungeuk Han, US Army RDECOM-ARDEC and ***Mr. Andrew Ponikowski***, US Army, RDECOM-ARDEC

Explosive Waste Recycle and Disposal
Mr. Mark M. Zaugg, EBV Explosives Environmental Company

3:00 p.m. **Conference Adjourns**

GENERAL DYNAMICS
Armament and Technical Products

Opening New "DOORS" to Managing JSF Gun System Requirements

Renee I. Bellack
26 April 2005

Opening New "DOORS" Outline

- Entrance – Evolution of Systems
- Previous Programs
- Current Challenge
- DOORS
- JSF Approach
- Exit – Benefits / Lessons Learned



ENTRANCE - Evolution of Systems

- Systems Engineering and Design
- Requirements
- Interfaces and Product Integration
- Design and Sourcing Approach

Comparison - Then to Now

AV-8, GEPOD

- Legacy specifications had few lower level specifications
- Traceability to other documents and impact assessments done manually
- “Product Manufacturer” - Product designed and manufactured in-house

JSF Gun Systems

- Requirements flowed to lower level configuration item specifications
- Traceability and impact assessments achieved through use of automated tool
- “System Integrator” – Product designed and manufactured with subcontractors as an integrated team

Requirements

- Legacy Programs
  - HOW - Design-based requirements
  - Referenced MIL-STDs as requirements
- JSF
  - WHAT - Performance-based requirements
  - Industry best practice
  - Reference DoD and other documents as “Guides”

DEVELOPMENT SPECIFICATION	# PAGES	# REQMTS (SHALLS)
AV-8B	29	195
JSF - CTOL	91	170
GPU-5/A (GEPOD)	46	228
JSF - MISSIONIZED	125	206

Current Challenge

- Larger requirements documents
- Intertwined and interdependent requirements
- Verification of requirements, especially unique requirements (e.g. chem bio)
- Flow down and allocation of requirements to sub systems
- Flow down of requirements to subcontractors (system integrator vs. sole designer/mfr)

Adjusting How We Manage Requirements

- Requirements have been developed and managed using a “document centered” approach
  - Separate requirements, design and test documents are developed by different organizations and stored in different locations
  - Requirement information is duplicated in many different documents to accommodate tracing and allocating requirements
  - Document management and maintenance effort is extensive and is sometimes the focus

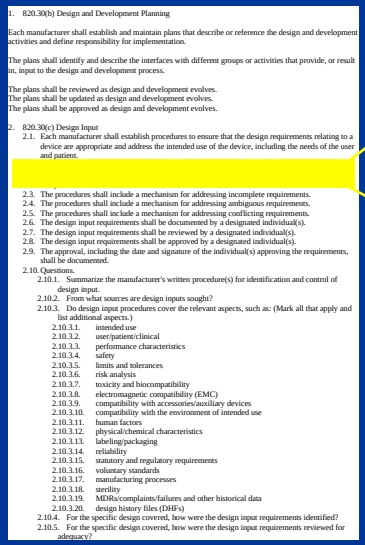
Adjusting How We Manage Requirements

- Developing and managing requirements has evolved to a “database centered” approach
  - Dynamic Object Oriented Requirements System (DOORS) is tool of choice
  - Single database, accessible to all users, contains all requirements and related documentation
  - Requires a transition from the use of traditional word processors in order to capitalize fully on DOORS functionality

Traceability

DOORS Links Provide for Traceability

User Requirements → Technical Requirements → Design Elements → Test Cases



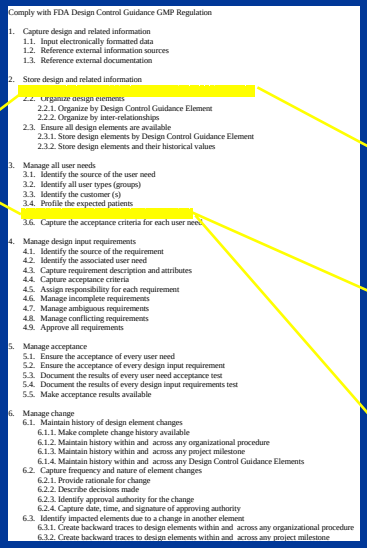
1. 820.30(b) Design and Development Planning

Each manufacturer shall establish and maintain plans that describe or reference the design and development activities and define responsibility for implementation.

The plans shall identify and describe the interfaces with different groups or activities that provide, or result in, input to the design and development process.

The plans shall be reviewed as design and development evolves.
The plans shall be updated as design and development evolves.
The plans shall be approved as design and development evolves.

2. 820.30(c) Design Input
   2.1. Each manufacturer shall establish procedures to ensure that the design requirements relating to a device are appropriate and address the intended use of the device, including the needs of the user and patient.
   2.3. The procedures shall include a mechanism for addressing incomplete requirements.
   2.4. The procedures shall include a mechanism for addressing ambiguous requirements.
   2.5. The procedures shall include a mechanism for addressing conflicting requirements.
   2.6. The design input requirements shall be documented by a designated individual(s).
   2.7. The design input requirements shall be reviewed by a designated individual(s).
   2.8. The design input requirements shall be approved by a designated individual(s).
   2.9. The approval, including the date and signature of the individual(s) approving the requirements, shall be documented.
   2.10. Questions.
      2.10.1. Summarize the manufacturer's written procedure(s) for identification and control of design input.
      2.10.2. From what sources are design inputs sought?
      2.10.3. Do design input procedures cover the relevant aspects, such as: (Mark all that apply and list additional aspects.)
         2.10.3.1. intended use
         2.10.3.2. user/patient/clinical
         2.10.3.3. performance characteristics
         2.10.3.4. safety
         2.10.3.5. limits and tolerances
         2.10.3.6. risk analysis
         2.10.3.7. toxicity and biocompatibility
         2.10.3.8. electromagnetic compatibility (EMC)
         2.10.3.9. compatibility with accessories/auxiliary devices
         2.10.3.10. compatibility with the environment of intended use
         2.10.3.11. human factors
         2.10.3.12. physical/chemical characteristics
         2.10.3.13. labeling/packaging
         2.10.3.14. reliability
         2.10.3.15. statutory and regulatory requirements
         2.10.3.16. voluntary standards
         2.10.3.17. manufacturing processes
         2.10.3.18. sterility
         2.10.3.19. MDRs/complaints/failures and other historical data
         2.10.3.20. design history files (DHFs)
      2.10.4. For the specific design covered, how were the design input requirements identified?
      2.10.5. For the specific design covered, how were the design input requirements reviewed for adequacy?



Comply with FDA Design Control Guidance GMP Regulation

1. Capture design and related information
   1.1. Input electronically formatted data
   1.2. Reference external information sources
   1.3. Reference external documentation

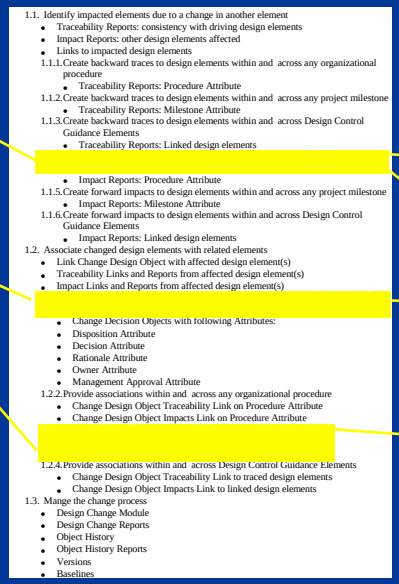
2. Store design and related information
   2.2. Organize design elements
      2.2.1. Organize by Design Control Guidance Element
      2.2.2. Organize by inter-relationships
   2.3. Ensure all design elements are available
      2.3.1. Store design elements by Design Control Guidance Element
      2.3.2. Store design elements and their historical values

3. Manage all user needs
   3.1. Identify the source of the user need
   3.2. Identify all user types (groups)
   3.3. Identify the customer (s)
   3.4. Profile the expected patients
   3.6. Capture the acceptance criteria for each user need

4. Manage design input requirements
   4.1. Identify the source of the requirement
   4.2. Identify the associated user need
   4.3. Capture requirement description and attributes
   4.4. Capture acceptance criteria
   4.5. Assign responsibility for each requirement
   4.6. Manage incomplete requirements
   4.7. Manage ambiguous requirements
   4.8. Manage conflicting requirements
   4.9. Approve all requirements

5. Manage acceptance
   5.1. Ensure the acceptance of every user need
   5.2. Ensure the acceptance of every design input requirement
   5.3. Document the results of every user need acceptance test
   5.4. Document the results of every design input requirements test
   5.5. Make acceptance results available

6. Manage change
   6.1. Maintain history of design element changes
      6.1.1. Make complete change history available
      6.1.2. Maintain history within and across any organizational procedure
      6.1.3. Maintain history within and across any project milestone
      6.1.4. Maintain history within and across any Design Control Guidance Elements
   6.2. Capture frequency and nature of element changes
      6.2.1. Provide rationale for change
      6.2.2. Describe decisions made
      6.2.3. Identify approval authority for the change
      6.2.4. Capture date, time, and signature of approving authority
   6.3. Identify impacted elements due to a change in another element
      6.3.1. Create backward traces to design elements within and across any organizational procedure
      6.3.2. Create backward traces to design elements within and across any project milestone



1.1. Identify impacted elements due to a change in another element
- Traceability Reports: consistency with driving design elements
- Impact Reports: other design elements affected
- Links to impacted design elements

1.1.1. Create backward traces to design elements within and across any organizational procedure
- Traceability Reports: Procedure Attribute

1.1.2. Create backward traces to design elements within and across any project milestone
- Traceability Reports: Milestone Attribute

1.1.3. Create backward traces to design elements within and across Design Control Guidance Elements
- Traceability Reports: Linked design elements
- Impact Reports: Procedure Attribute

1.1.5. Create forward impacts to design elements within and across any project milestone
- Impact Reports: Milestone Attribute

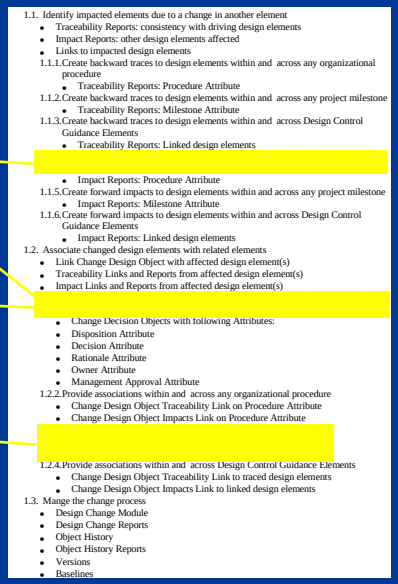
1.1.6. Create forward impacts to design elements within and across Design Control Guidance Elements
- Impact Reports: Linked design elements

1.2. Associate changed design elements with related elements
- Link Change Design Object with affected design element(s)
- Traceability Links and Reports from affected design element(s)
- Impact Links and Reports from affected design element(s)
- Change Decision Objects with following Attributes:
- Disposition Attribute
- Decision Attribute
- Rationale Attribute
- Owner Attribute
- Management Approval Attribute

1.2.2. Provide associations within and across any organizational procedure
- Change Design Object Traceability Link on Procedure Attribute
- Change Design Object Impacts Link on Procedure Attribute

1.2.4. Provide associations within and across Design Control Guidance Elements
- Change Design Object Traceability Link to traced design elements
- Change Design Object Impacts Link to linked design elements

1.3. Mange the change process
- Design Change Module
- Design Change Reports
- Object History
- Object History Reports
- Versions
- Baselines



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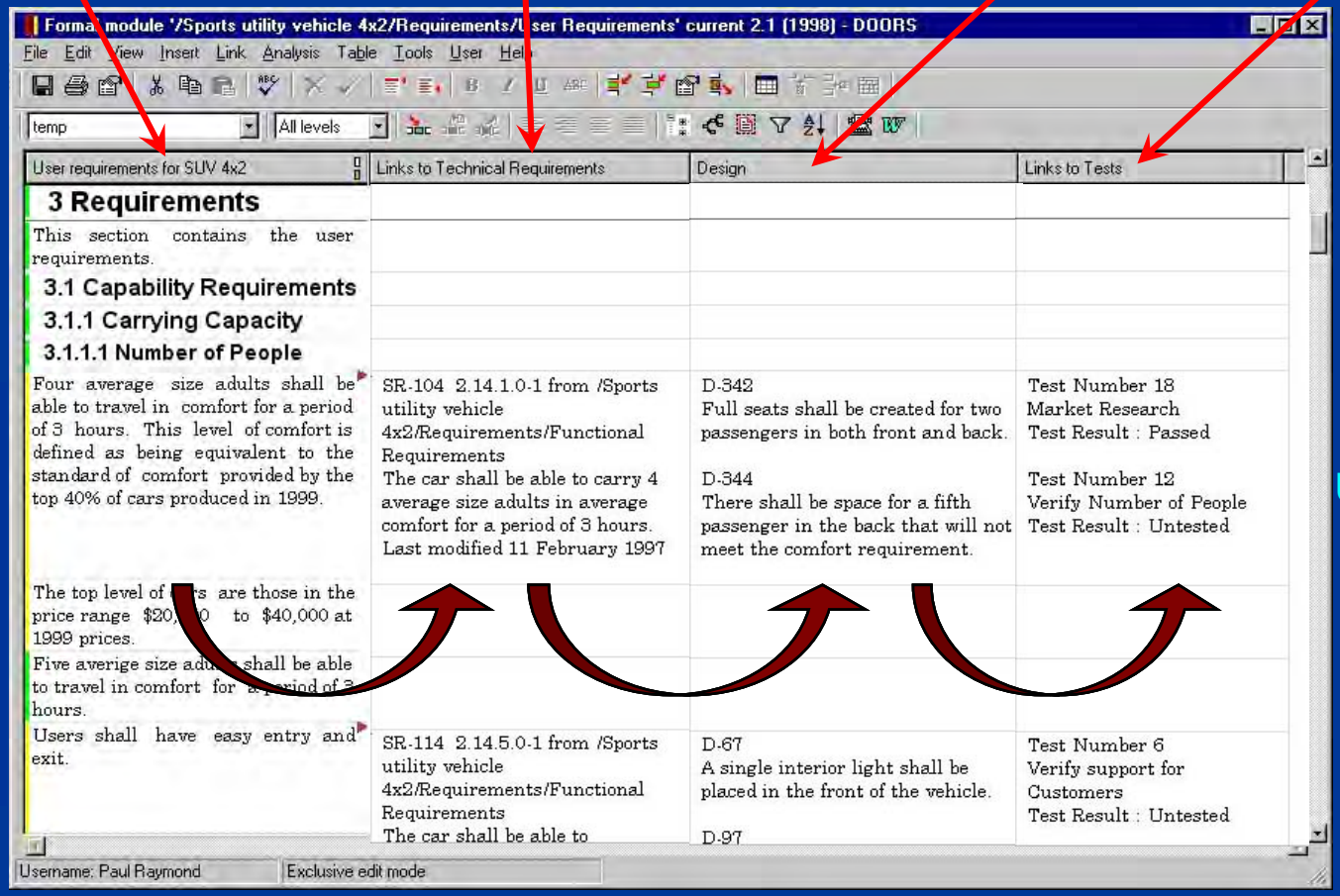
1.3. Mange the change process
- Design Change Module
- Design Change Reports
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- Object History Reports
- Versions
- Baselines

Impact analysis is the first step towards determining the cost of a change

Understand the change before you make it

DOORS View With Multiple Documents

User Requirements | Technical Requirements | Design Elements | Test Cases

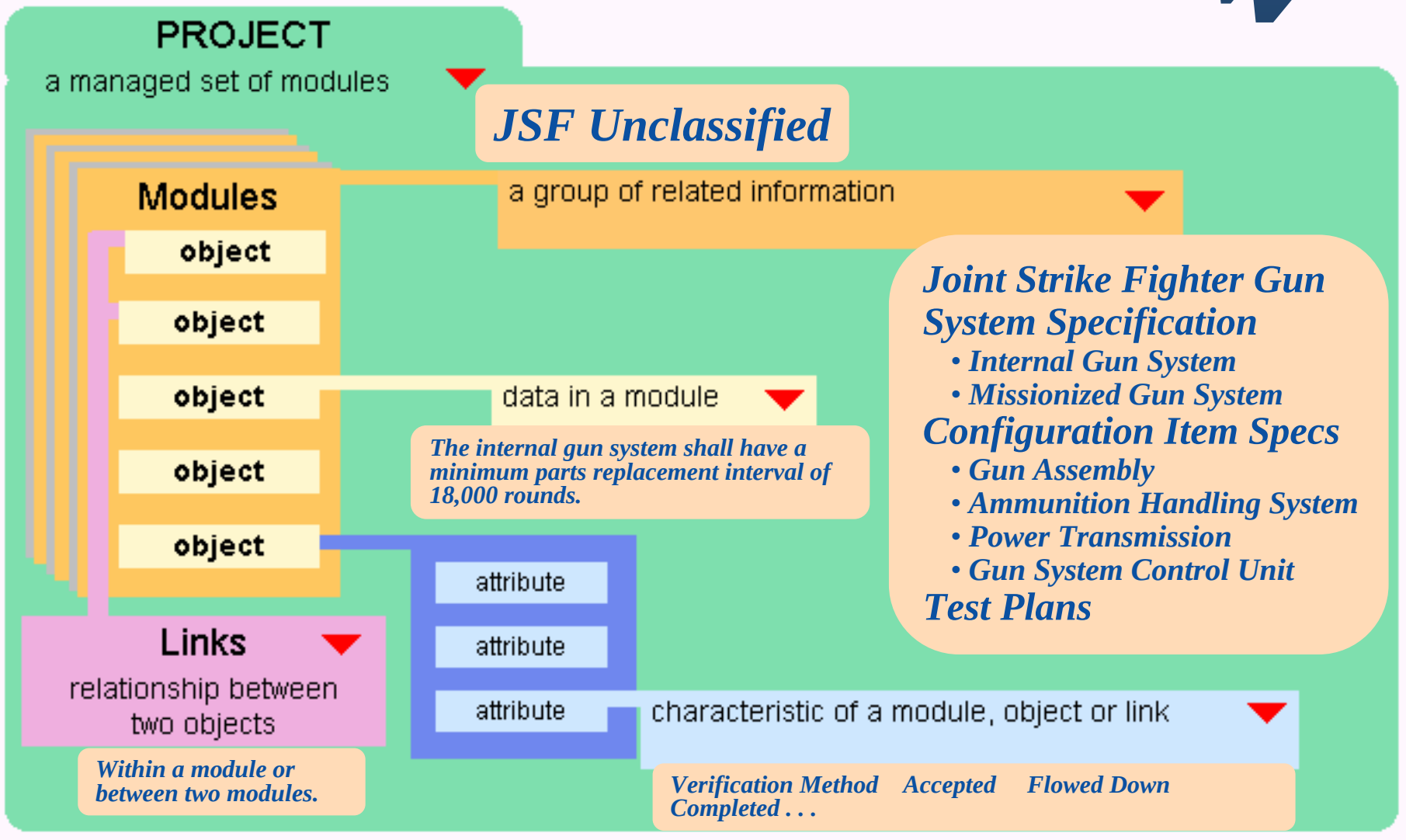


Impact analysis is the first step toward determining the cost of a change

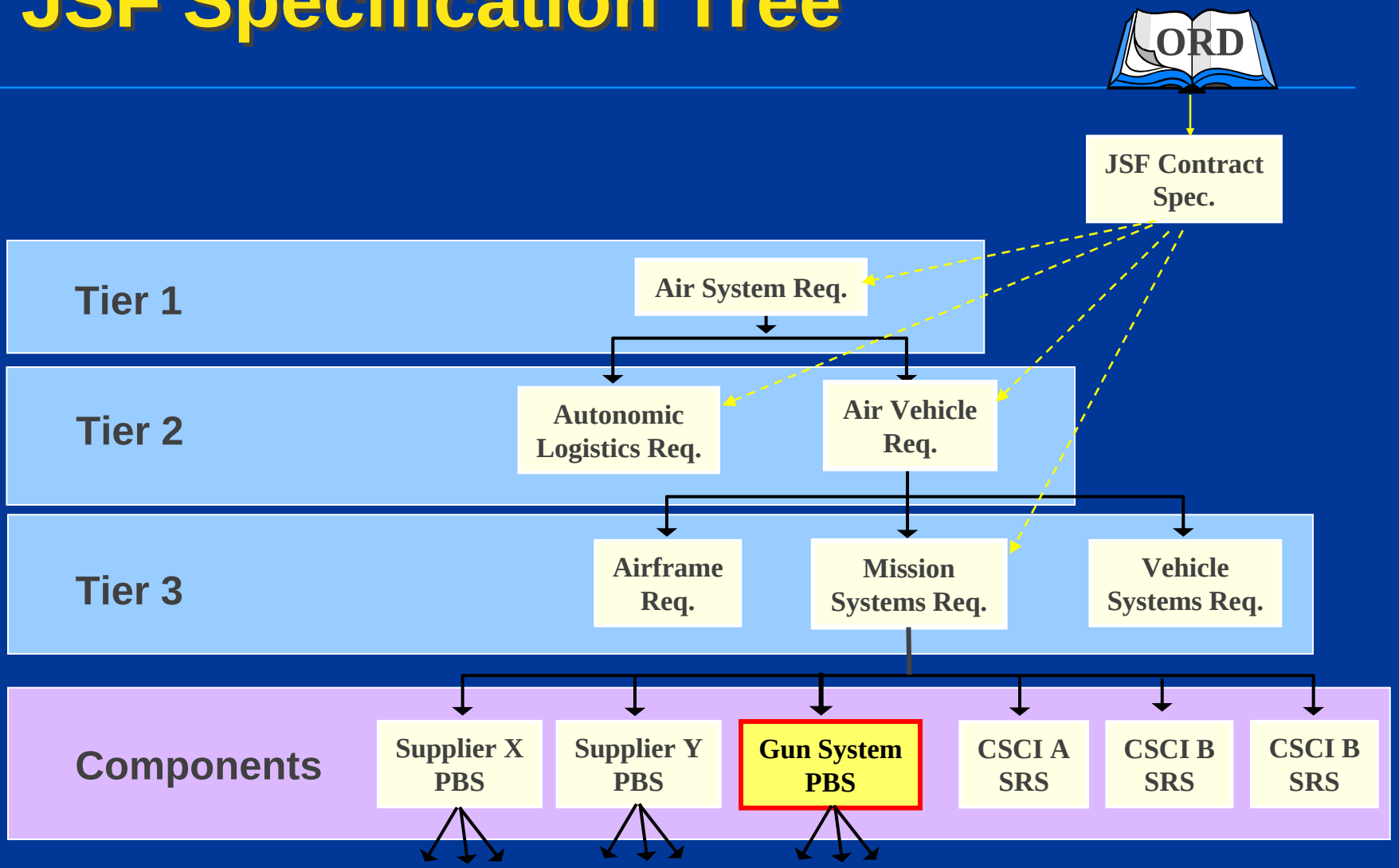
Understand the change before you make it

End-to-end visual validation in a single view

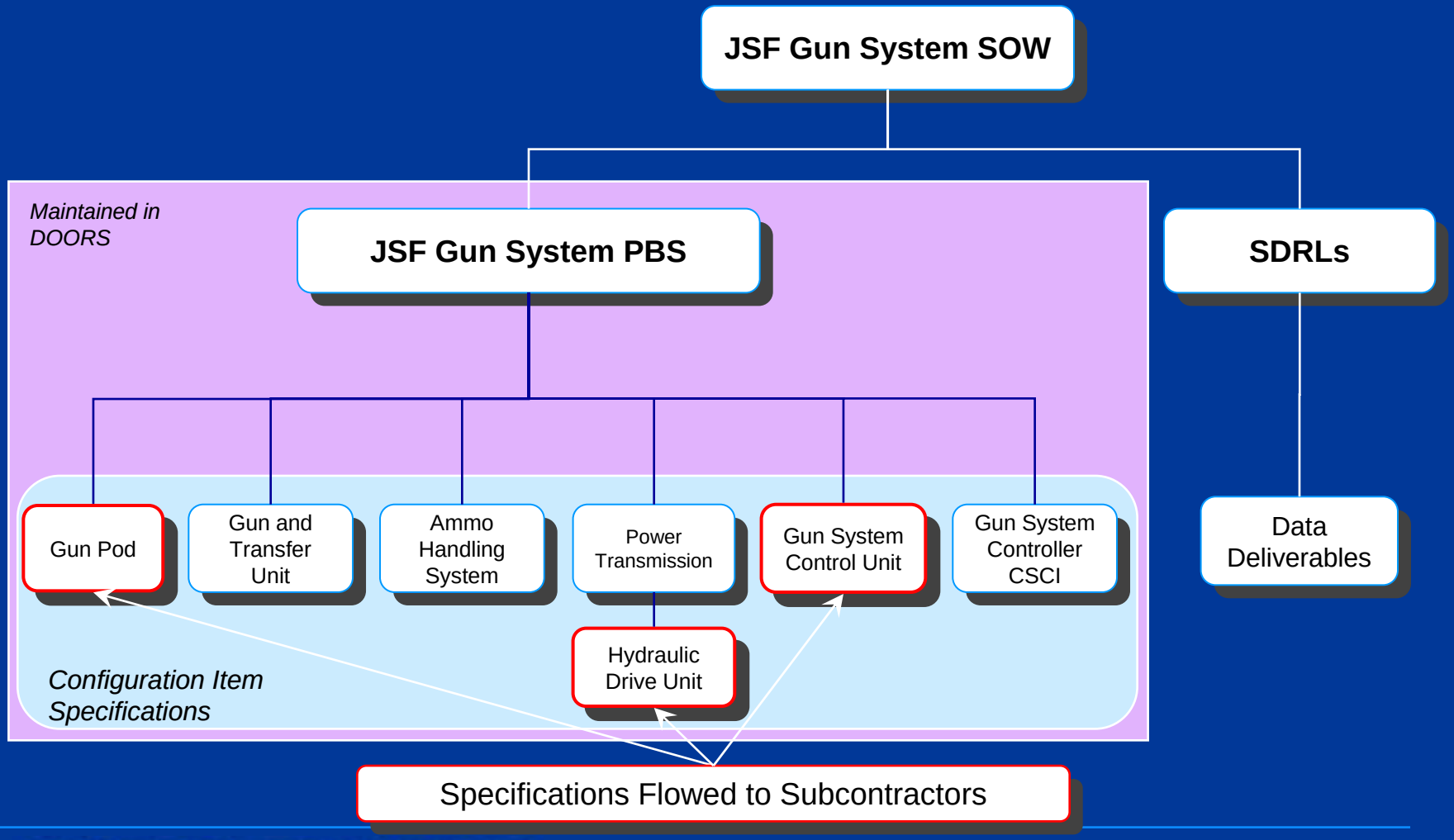
JSF DOORS Structure Summary



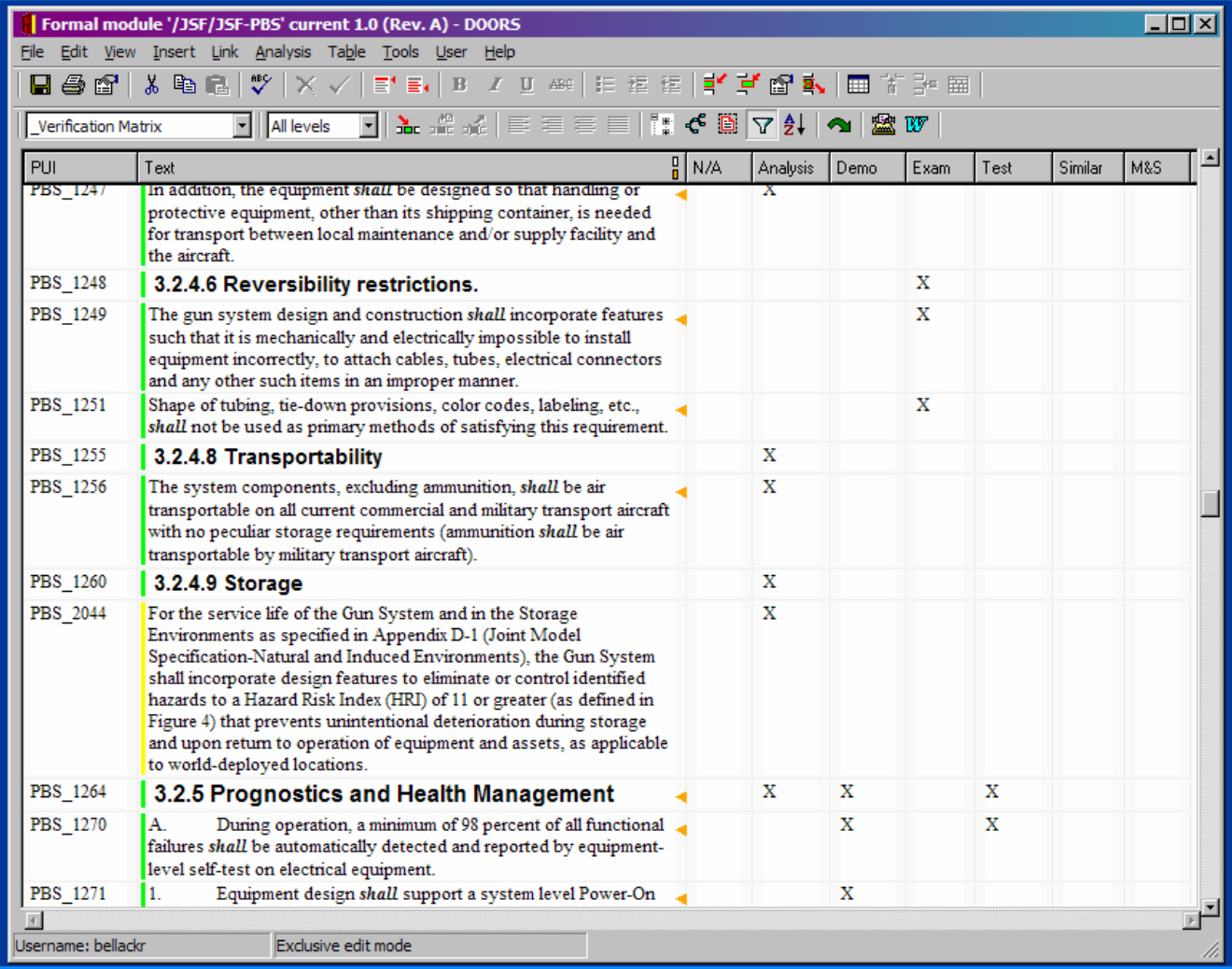
JSF Specification Tree



JSF Gun System Requirements Flow Down

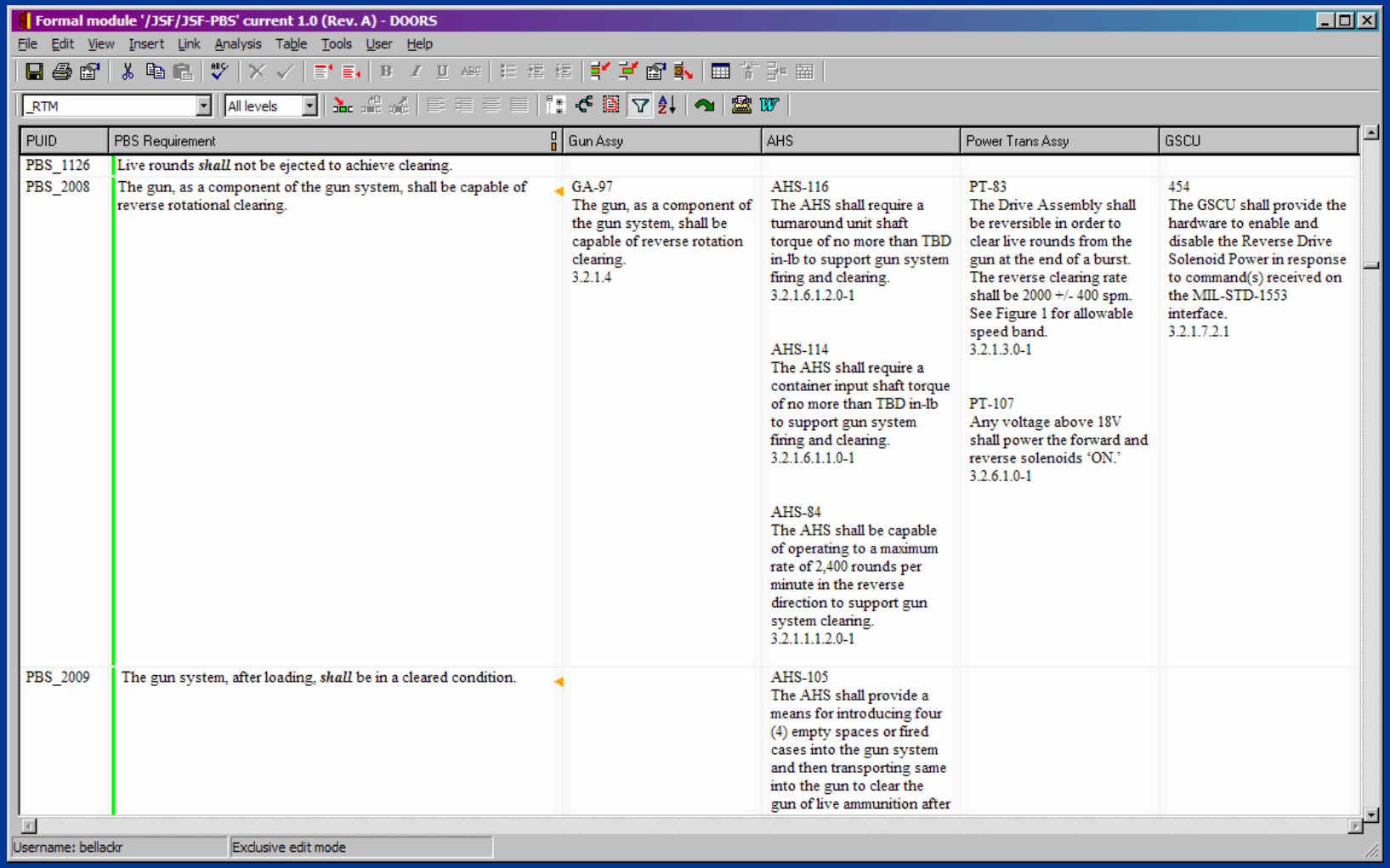


Verification Matrix



PUI	Text	N/A	Analysis	Demo	Exam	Test	Similar	M&S
PBS_1247	In addition, the equipment ***shall*** be designed so that handling or protective equipment, other than its shipping container, is needed for transport between local maintenance and/or supply facility and the aircraft.		X					
PBS_1248	**3.2.4.6 Reversibility restrictions.**				X			
PBS_1249	The gun system design and construction ***shall*** incorporate features such that it is mechanically and electrically impossible to install equipment incorrectly, to attach cables, tubes, electrical connectors and any other such items in an improper manner.				X			
PBS_1251	Shape of tubing, tie-down provisions, color codes, labeling, etc., ***shall*** not be used as primary methods of satisfying this requirement.				X			
PBS_1255	**3.2.4.8 Transportability**		X					
PBS_1256	The system components, excluding ammunition, ***shall*** be air transportable on all current commercial and military transport aircraft with no peculiar storage requirements (ammunition ***shall*** be air transportable by military transport aircraft).		X					
PBS_1260	**3.2.4.9 Storage**		X					
PBS_2044	For the service life of the Gun System and in the Storage Environments as specified in Appendix D-1 (Joint Model Specification-Natural and Induced Environments), the Gun System shall incorporate design features to eliminate or control identified hazards to a Hazard Risk Index (HRI) of 11 or greater (as defined in Figure 4) that prevents unintentional deterioration during storage and upon return to operation of equipment and assets, as applicable to world-deployed locations.		X					
PBS_1264	**3.2.5 Prognostics and Health Management**		X	X		X		
PBS_1270	A. During operation, a minimum of 98 percent of all functional failures ***shall*** be automatically detected and reported by equipment-level self-test on electrical equipment.			X		X		
PBS_1271	1. Equipment design ***shall*** support a system level Power-On			X				

Traceability to CI Specifications



PUID	PBS Requirement	Gun Assy	AHS	Power Trans Assy	GSCU
PBS_1126	Live rounds ***shall*** not be ejected to achieve clearing.				
PBS_2008	The gun, as a component of the gun system, shall be capable of reverse rotational clearing.	GA-97 The gun, as a component of the gun system, shall be capable of reverse rotation clearing. 3.2.1.4	AHS-116 The AHS shall require a turnaround unit shaft torque of no more than TBD in-lb to support gun system firing and clearing. 3.2.1.6.1.2.0-1 AHS-114 The AHS shall require a container input shaft torque of no more than TBD in-lb to support gun system firing and clearing. 3.2.1.6.1.1.0-1 AHS-84 The AHS shall be capable of operating to a maximum rate of 2,400 rounds per minute in the reverse direction to support gun system clearing. 3.2.1.1.1.2.0-1	PT-83 The Drive Assembly shall be reversible in order to clear live rounds from the gun at the end of a burst. The reverse clearing rate shall be 2000 +/- 400 spm. See Figure 1 for allowable speed band. 3.2.1.3.0-1 PT-107 Any voltage above 18V shall power the forward and reverse solenoids 'ON.' 3.2.6.1.0-1	454 The GSCU shall provide the hardware to enable and disable the Reverse Drive Solenoid Power in response to command(s) received on the MIL-STD-1553 interface. 3.2.1.7.2.1
PBS_2009	The gun system, after loading, ***shall*** be in a cleared condition.		AHS-105 The AHS shall provide a means for introducing four (4) empty spaces or fired cases into the gun system and then transporting same into the gun to clear the gun of live ammunition after		

EXIT – JSF Gun System Benefits / Lessons Learned



- Traceability effort has been dramatically reduced with proper tools. DOORS database:
  - Contains entire document and associated trace information
  - Avoids updating multiple documents to the current requirements' baseline
  - Eliminates the need to correct consistency errors
- Requirement status, comments, or any other information can be readily associated with each requirement
- Through linking, relationships between requirements, design information, and test information are dynamically managed

GENERAL DYNAMICS

Aviation and Missile Research, Development, and Engineering Center

The Future of Small Missiles



Presented by

Dr. James C. Bradas

April 2005

Associate Director for Missile Technology
and
Director, Weapons Sciences Directorate

Aviation and Missile RD&E Center
U.S. Army RDECOM

First, A Bit of History

- *Many of the Army's Current Inventory of Tactical Missiles Were Designed or Envisioned During the Cold War*

- *Many Tactical Missiles Were Designed to Defeat Main Battle Tanks (TOW Family, HELLFIRE/LONGBOW, Javelin)*

- *Guidance Techniques Have Evolved –*

  TOW – Command Guidance (1960's)
  HELLFIRE – Semi-Active Laser Guidance (1970's)
  LONGBOW – LOBL / LOAL RF Active Terminal Homing (1980's)
  Javelin – LOBL Fire-and-Forget Passive Terminal Homing (1990's)
  Joint Common Missile – Tri-Mode Seeker Terminal Homing (2000+)

Truly Autonomous, "Fire-and-Forget" Weapons Able to ID Targets
Not Yet Do-Able
Without Significant Risk of Fratricide / Collateral Damage

How Successful ?

- ***Desert Storm I***

  HELLFIRE Viewed as Very Successful Although "Overkill" on "Highway of Death" Retreat from Kuwait

- ***Operation Enduring Freedom (Afghanistan)***

  PREDATOR UAV + HELLFIRE Combination Very Successful

- ***Operation Iraqi Freedom***

  HELLFIRE with Mod K Warhead

  TOW 2A / TOW "Bunker Buster" Warhead

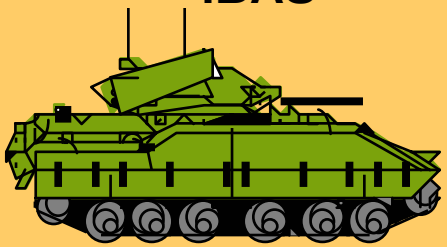
  Javelin – Battle of Debecka Pass by Special Forces

10 – 40 Year-Old Technology Proven Very Effective

As Far as Army S&T Is Concerned - We Want to Get There -

Today's Tactical Missile Capability

IBAS





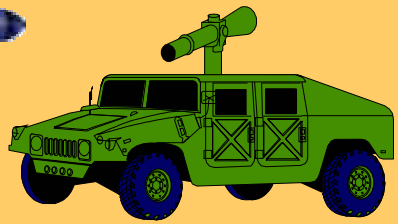


TOW 2A

TOW 2B

TOW Bunker Buster

ITAS



AT4





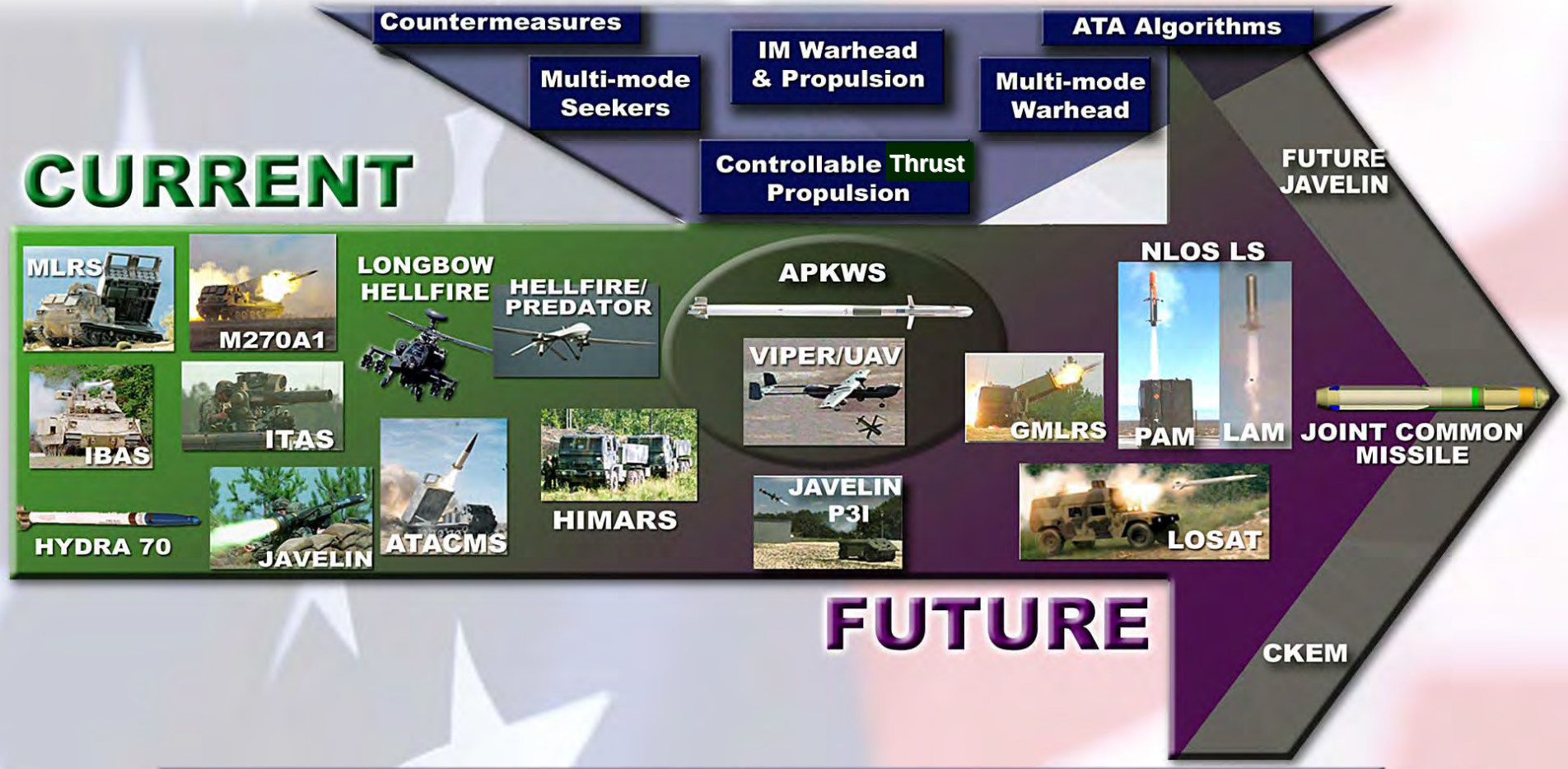
Javelin

The Question Is – Where Are We Going?

EVOLVING ARMY TRANSFORMATION

Current to Future Force – Accelerate fielding of select Future Force capabilities to enhance Effectiveness of Current Force, Army Transformation is part of constant change.

AMRDEC
STRENGTH THROUGH TECHNOLOGY



Developing the Future Force while Simultaneously Spiraling Future Capabilities into the Current Force

-- "The Way Ahead"

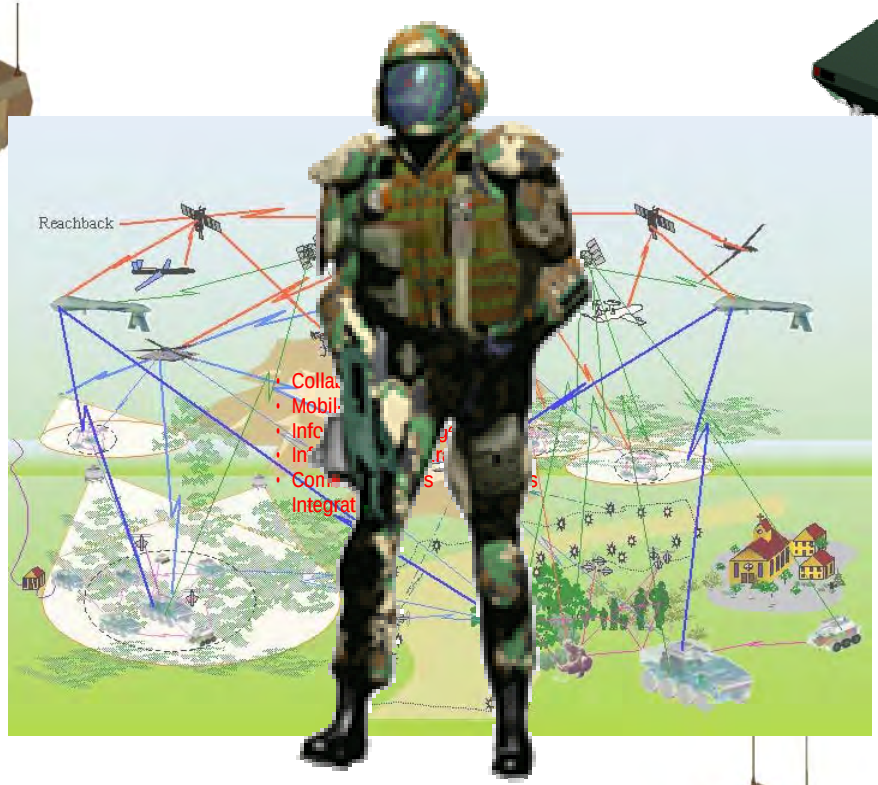
Is This Where We're Going?

Future Combat Systems (FCS)

NLOS-LS
PAM & LAM

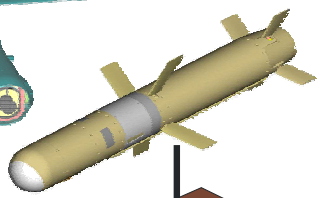


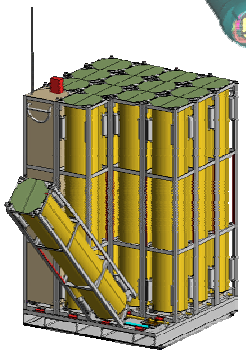


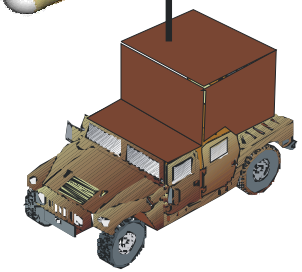


















CKEM









DoD View of Changing World Threat

IRREGULAR

Those seeking to erode U.S. influence and power by employing unconventional methods, such as:

- **Terrorism**
- **Insurgency**
- **Civil War**
- **Emerging concepts such as "unrestricted warfare"**



Likelihood: very high

Vulnerability: moderate, if not effec ely checked

CATASTROPHIC

Those seeking to paralyze U.S. leadership and power by employing weapons of mass Destruction or WMD-like effects in surprise attacks on symbolic, critical or other high-value targets, such as:



- **Sept 11, 2001**
- **Terrorist use of WMD**
- **Rogue missile attack**

Likelihood: moderate and increasing

nerability: unacceptable; single event uld alter American way of life

More likely

Less likely

Lower vulnerability

Higher vulnerability

TRADITIONAL

Those seeking to Challenge U.S. power by military operations, such as:



- **Conventional air, sea and land attacks**
- **Nuclear forces of established nuclear powers**

Likelihood: decreasing (absent pre-emption) due to historic capability-overmatch and expanding qualitative lead

Vulnerability: low, if transformation is balanced

DISRUPTIVE

Those seeking to usurp r and Influence ng breakthrough capabilities, such as:



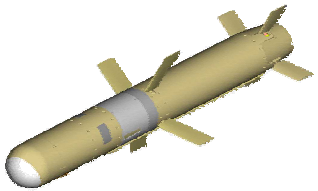
- **Sensors**
- **Biotechnology**
- **Miniaturization on the molecular level**
- **Cyber-operations**
- **Space**
- **Directed-energy and other emerging fields**

Likelihood: low, but time works against U.S.

Vulnerability: unknown; strategic surprise puts U.S. security at risk

NLOS-LS

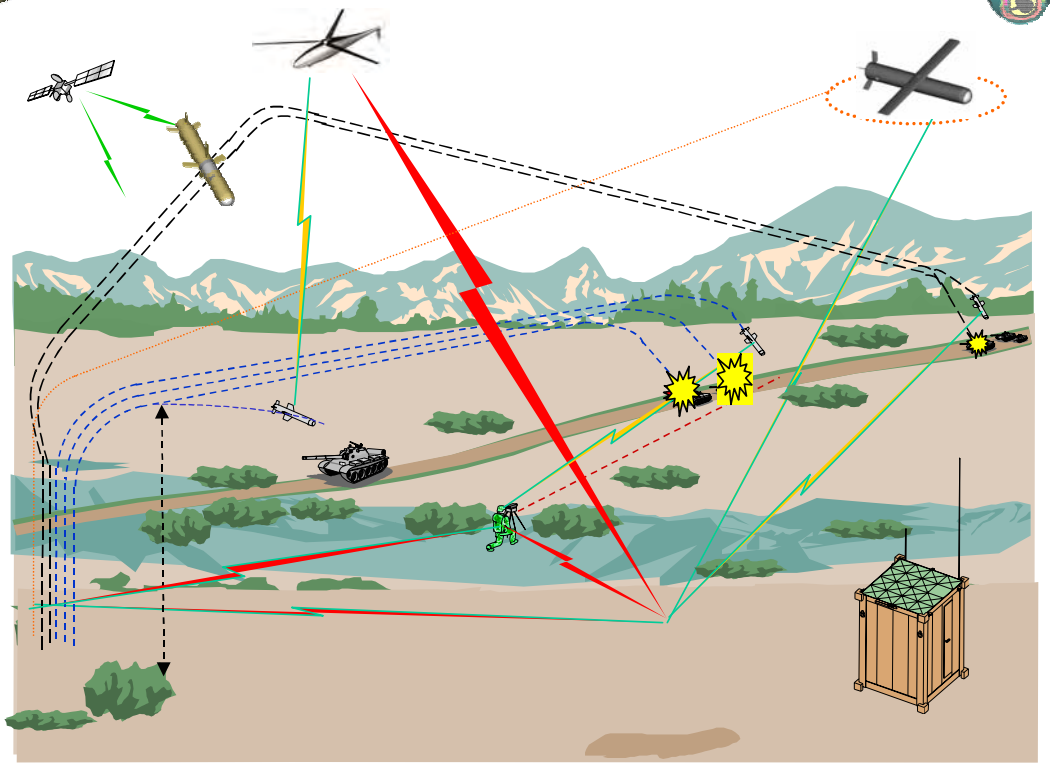
Networked Lethality – Very Dependent on Networked Sensors

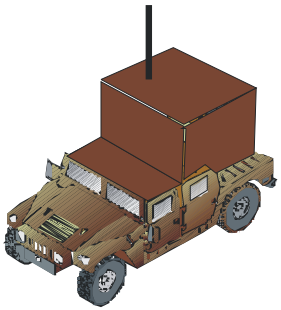


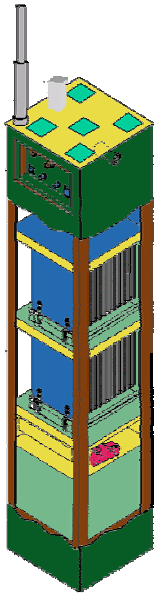


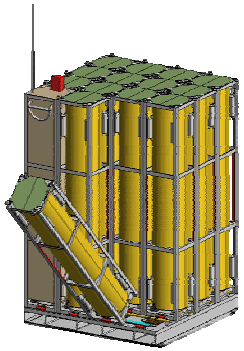












Precision Engagement Options: From Sledgehammer to Scalpel



Joint Air to Surface Strike Missile (JASSM)
2250 pounds, 14 Feet Long
Big Platforms



Hellfire Longbow
108 Pounds, 5.75 Feet Long
Medium/Small Platforms

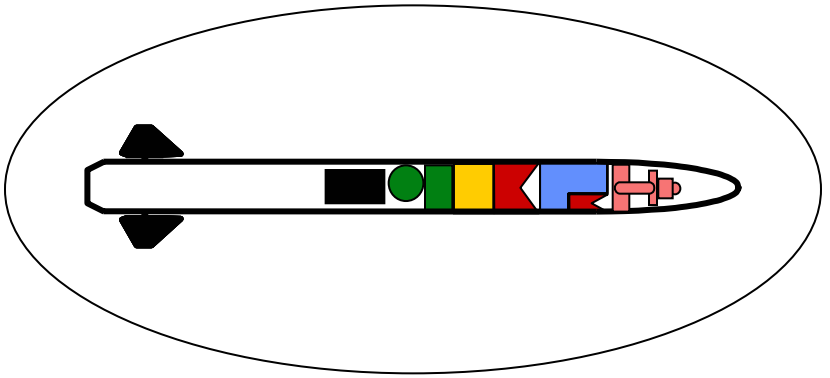


TOW
50 Pounds, 4 Feet Long
Crew-Served



Javelin
35 Pounds, 3.5 Feet Long
Manportable

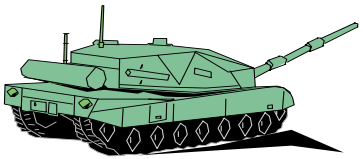
The 21st Century Missile

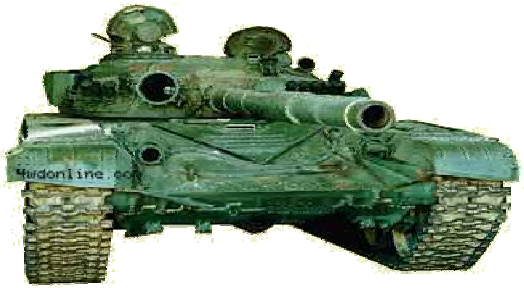


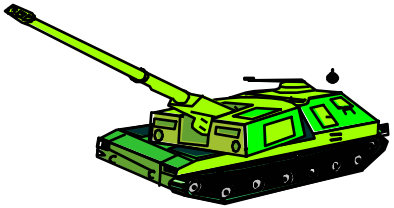
- ***How Small?***
- ***How Much Range?***
- ***BLOS / NLOS?***
- ***What Target Set?***
- ***How Autonomous?***
- ***How Much Will It Cost?***

Target Sets Are Changing

From This -







To This -



Light Armor

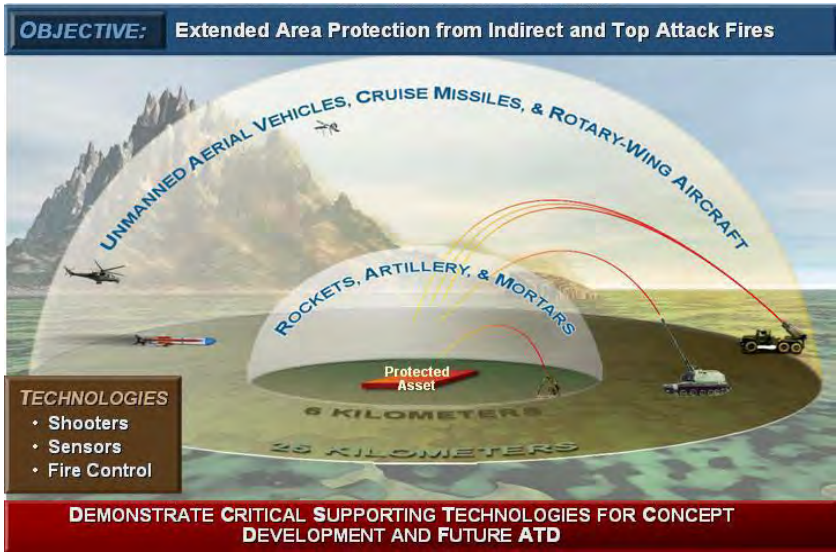


Earth and Timber Bunker



8” Reinforced Concrete and 12” Triple Brick

Survivability is a BIG Focus

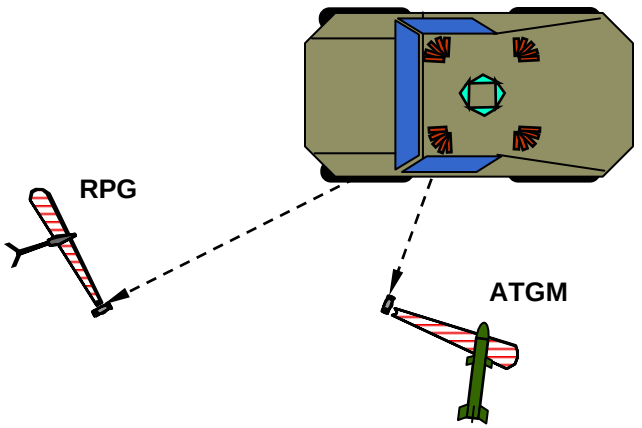


Extended Area Protection System

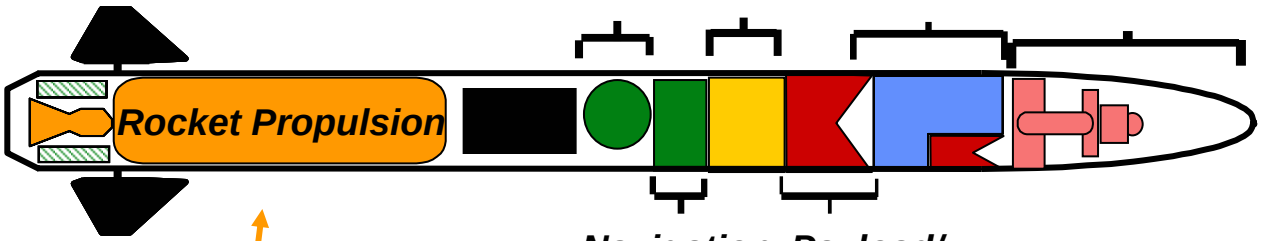
- *Layered Protection from Top-Attack from Rockets / Artillery / Mortars*
- *Area Protection vs. Point Protection*
- *Guided Bullet & Missile Interceptors*

Close-In Active Protection System

- *Protection Against ATGMs & RPGs*
- *Prototypes Being Integrated on Stryker Vehicles*
- *Next Generation Technology for Smaller & Reduced Fratricide*



Key Technology Component Investment Areas



Batteries*

NLOS-LS Comms

Chip-Level Electronics Integration
Auto Target Acquisition

Uncooled IR
Gimbal-Free in SAL, RF
Improved Resolution (EPAM)
Very-Low-Cost Seekers
LADAR

Power Datalink Processing Seeker

Actuators & Controls

Navigation Payload/ Warhead(s)

Insensitivity (IM)*
Throttlable Propulsion*

MBARS
Hi-g MEMS*

Insensitivity (IM)*
Multipurpose Fuzes*
Multipurpose Warheads*
Smaller Warheads*

* Mostly Joint with Army Research Lab and/or Armaments RDEC

Trends

Shorten the engagement cycle (detect, track, identify, assign, engage, BDA)

- ***Decrease the number of people in the cycle***
- ***Speed the connections between the people in the cycle***
- ***"One shot, one kill" (…or more)***
- ***Perpetually "on station"***
- ***Available (it works "all" the time)***
- ***Few war-winning targets; many war-losing targets. ("regret avoidance" is key)***
- ***Improved target ID / Friend-Foe-Neutral***

Key Technology Enablers

- ***Reduce Cost (both incremental reductions and fundamentally cheaper guidance technologies)***
  - ***Make Technologies "Easier to Build" for More Vendors – Including Less Hi-tech***
  - ***Common Components (given a good business case)***
  - ***More Open Hardware and Software Architectures, Standards***
- ***Reduce Weight and Size***
- ***Autonomous Target Recognition / ID / IFF***
- ***Improve adverse-weather and MOUT capabilities (IIR, RF, MMW, etc.)***
- ***Increase Reliability***
- ***Retain few-meter accuracy***

The Future of Missiles?

- ***Multi-Mission***
- ***Multi-Effects Warheads (Including Non-Lethal)***

  With Intelligent Sensing / Fuzing
- ***Beyond Line-of-Sight / Non Line-of-Sight***
- ***Autonomous / Smart***
- ***Cargo Carriers / Payload Deliverers***
- ***VERSATILE***
- ***AFFORDABLE***

SkyRanger

Multi Mission
Vehicle Armament &
Air Burst Munition
for
Expeditionary Warfare
Force Protection

Conflict Management Dynamics



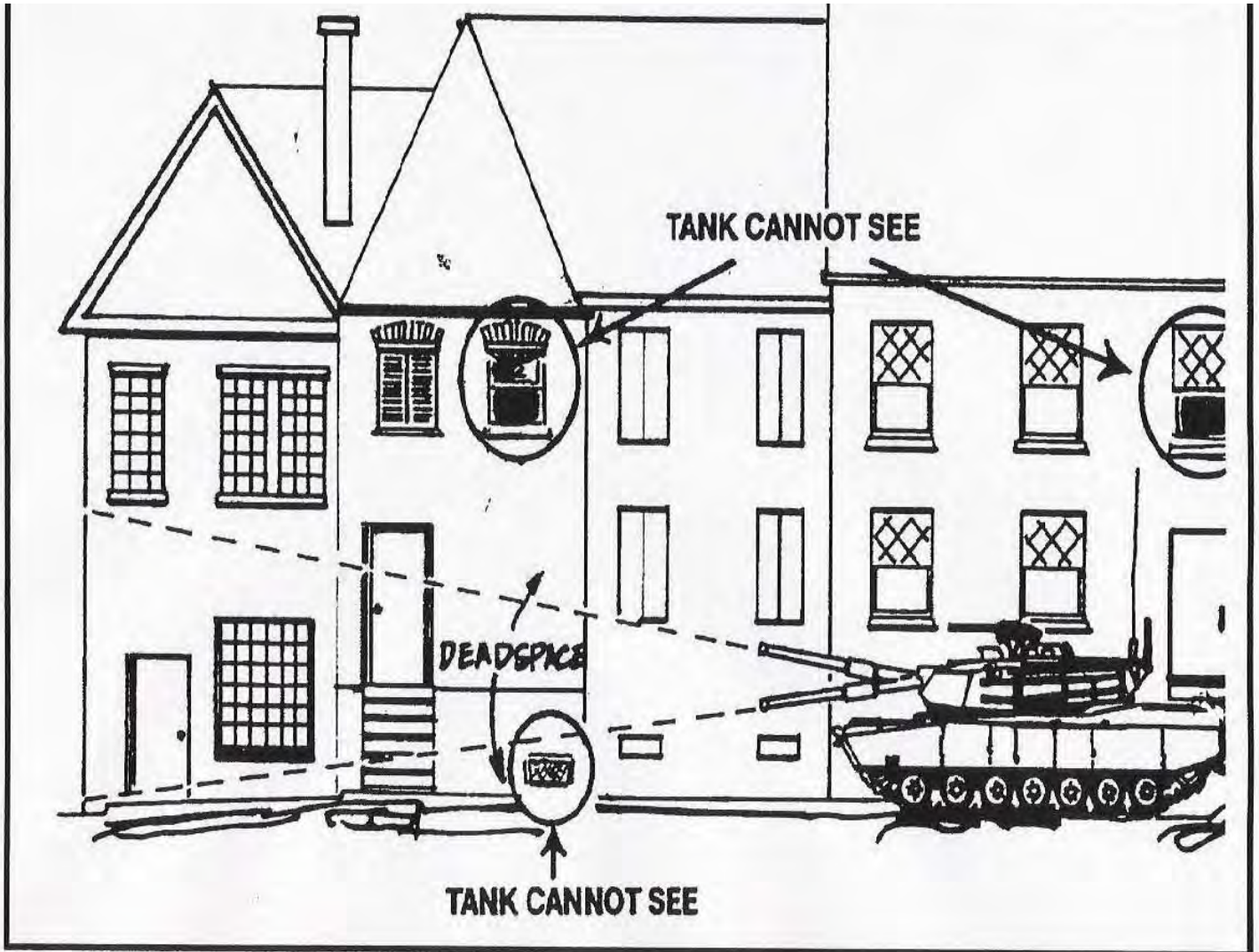
Cold War
--Clear Rules
--Doctrines
--Plans



Hot War
--Three Block War
-- Asymmetric & Symmetric Threats
-- Expeditionary
-- Rapid Deployment
-- Dynamic Planning

Turreted Gun Limitations

STRYKER elevation +15, Depression -5
M1/M1 A2 elevation +20, Depression -10
BFV elevation +60, Depression -10



SkyRanger Gun System

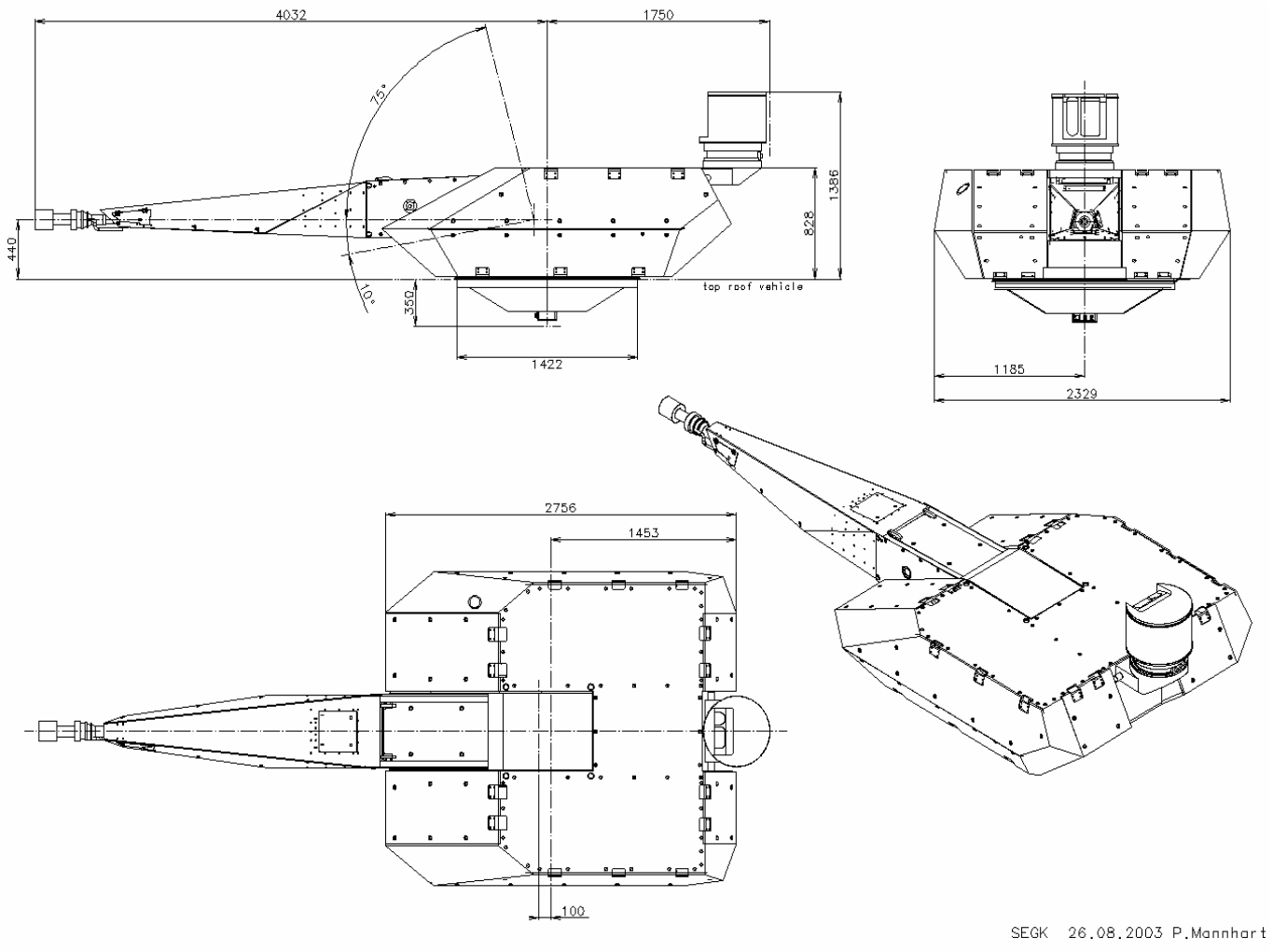


Example of Installation

Typical Layout

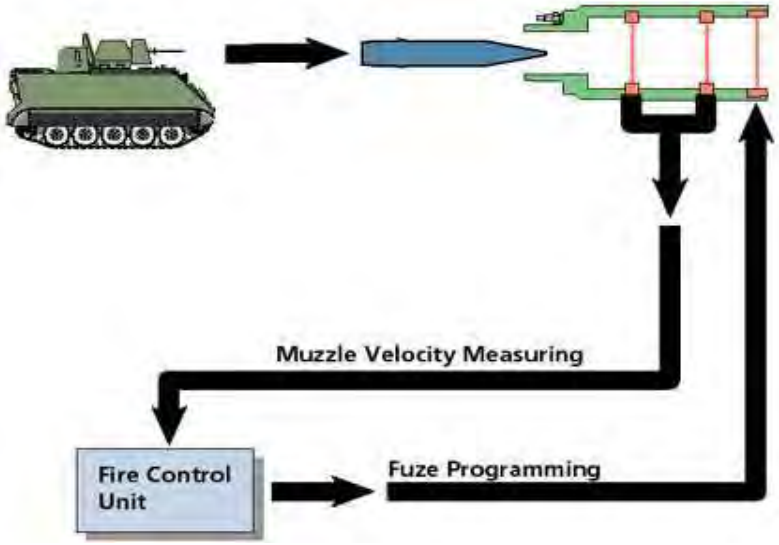


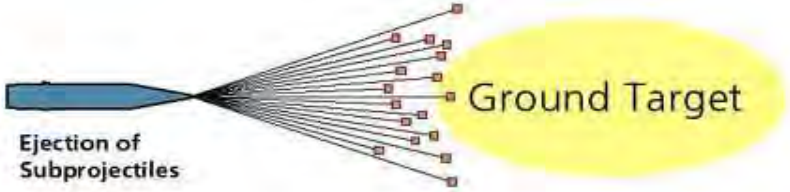
35mm Ahead Turret

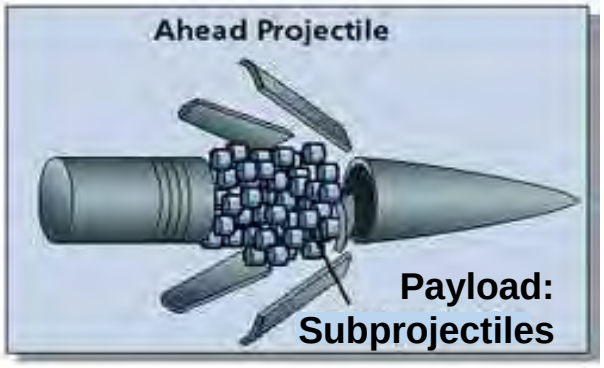


35 mm Revolver Cannon & Ahead Ammunition



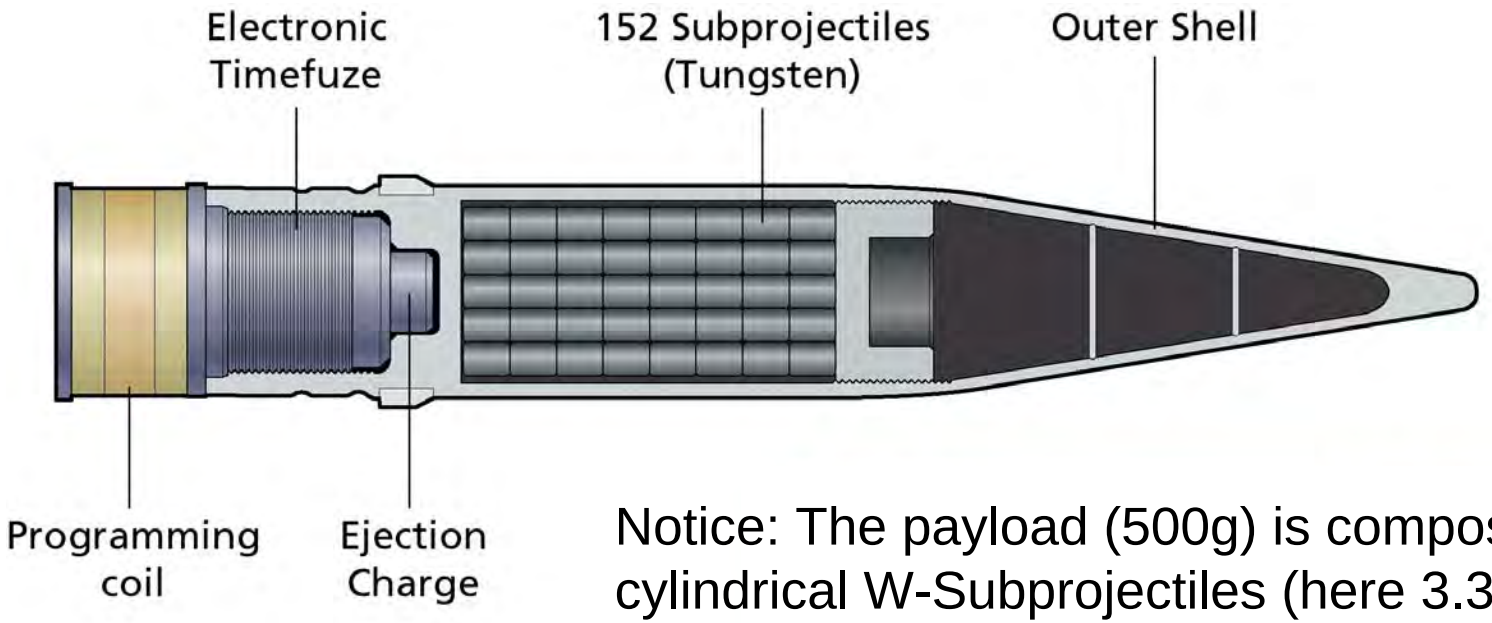






35mm Air Burst Munition

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)

Effective against UAVs & Helicopters





China Lake NAWS July 2004

Helicopter Target (UH-1, Static)

Effectiveness of 35 mm Ahead Ammunition

- **2 Shots**
- **Range:1500 m**
- **Entry Side**
- **Ref.: APG/Oct. 98**



Effectively Neutralizes Heavy Armor







Effective against ATW Positions



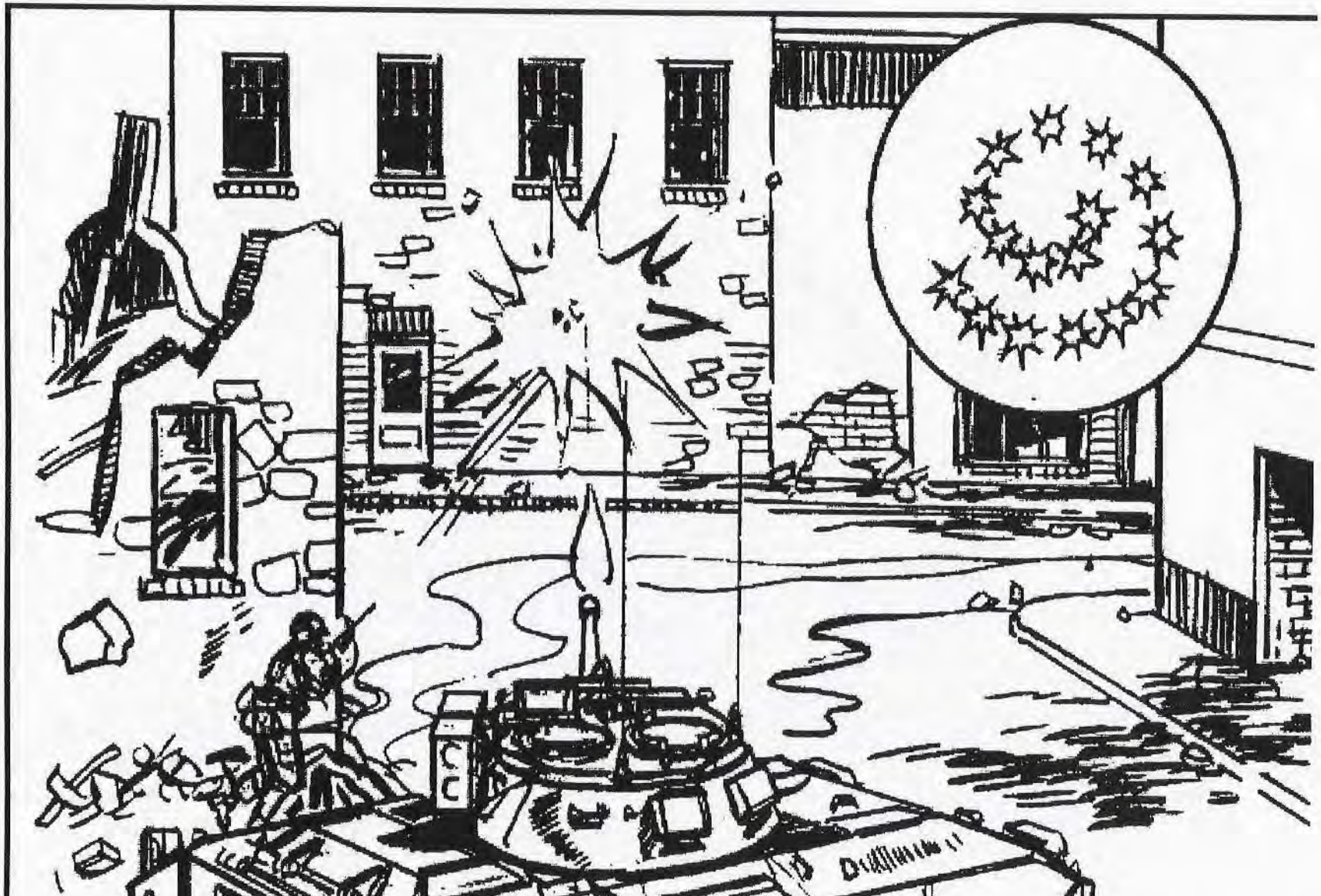






OERLIKON CONTRAVES

U. S. Army Breeching Techniques



Breeching Fire

8” Concrete Wall

Double Steel-Structure Reinforced

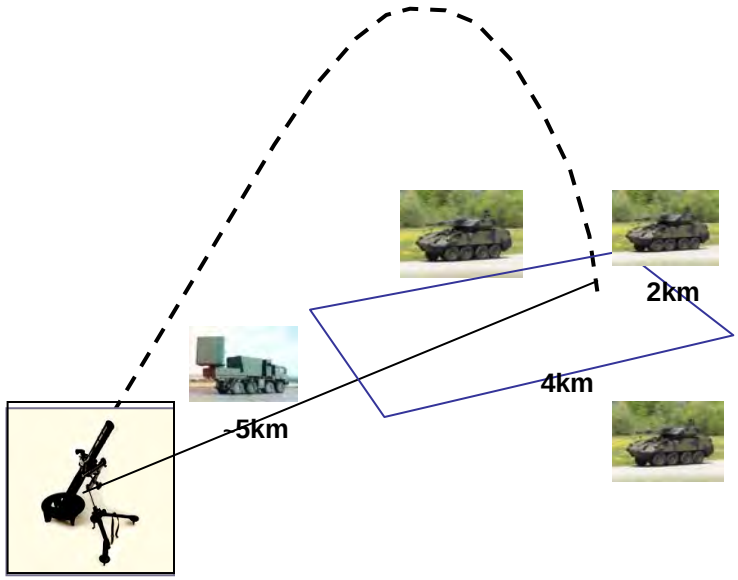




Video: M1 15962BA

Base Defence – Counter Mortar

Demonstrated 12.2004

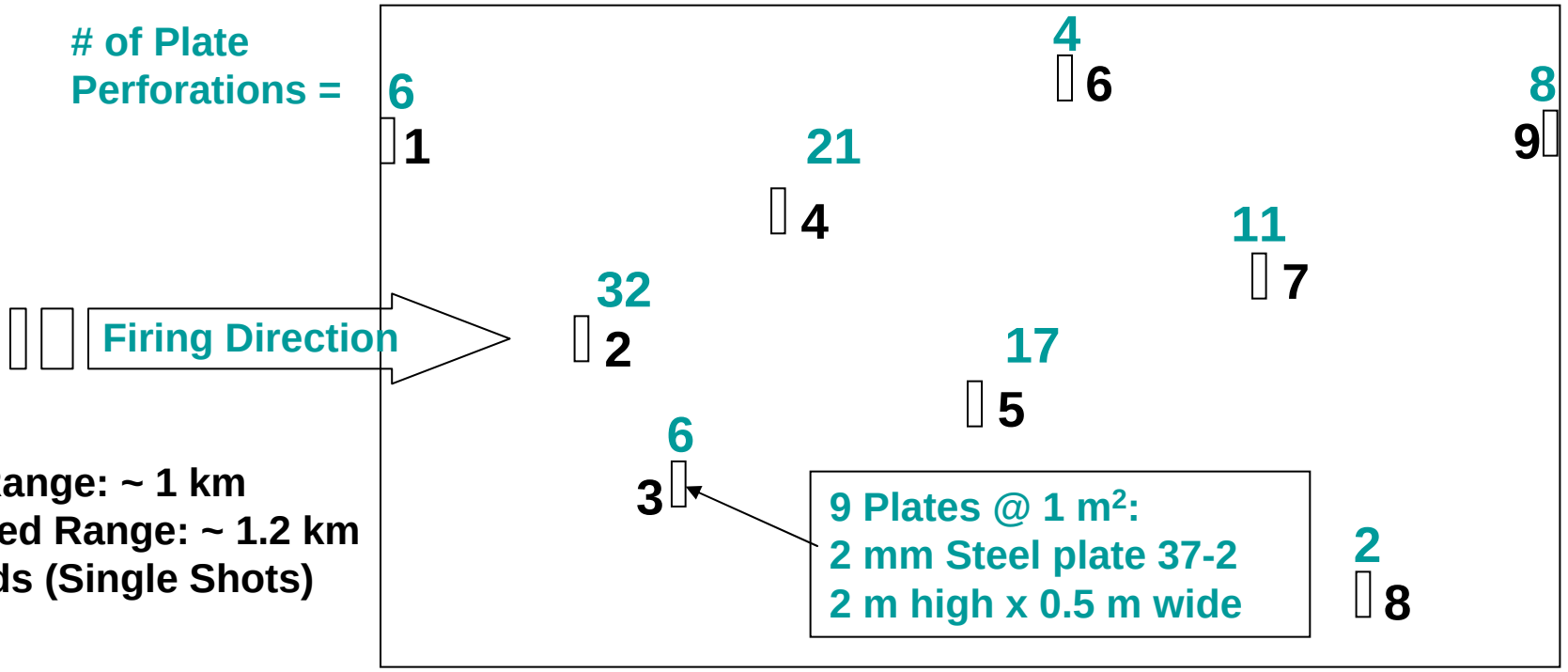


QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Ahead Lethality – 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)

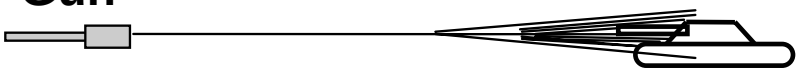
Target Area: 10 (width) x 30 (depth) m

The target area is 27 m higher than the gun muzzle

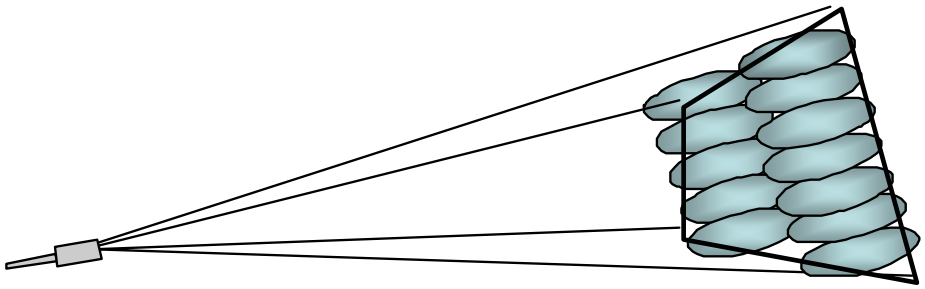
ABM Ground Operation Modes

Point Target (incl. ATGW-Bunker, Prone & Covered Troops, MBT, Helicopter):

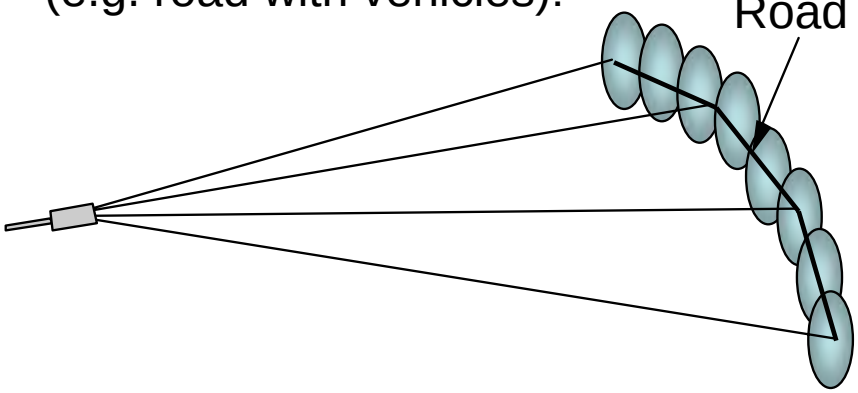
Gun



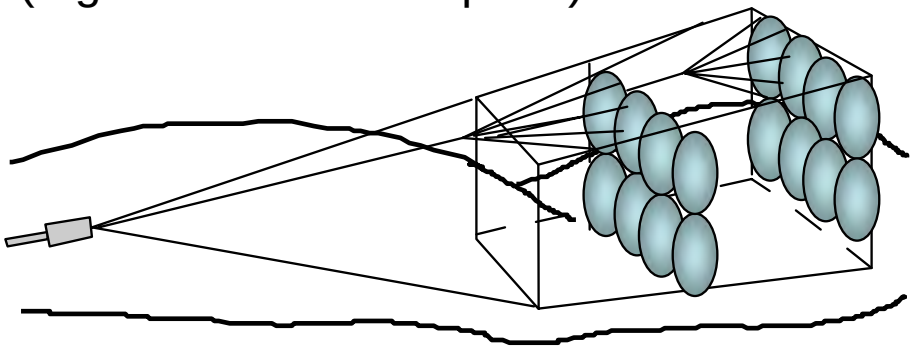
Area Target (Diffused Targets):



Linear Target
(e.g. road with vehicles):



Pre-Determined Air Space
(e.g. swarm of helicopters):



SkyRanger Capabilities

- Automatic target detection and tracking
- 35mm Revolver Cannon (1000 rds/min.)
- Independent line of sight
- Air and ground target engagements
- Small target engagement capability
- 200 rounds ready to fire ammo
- Dual feed
- Rapid single shot (200 rds/min.)
- Unmanned turret
- Navigation system
- Battery powered
- Low mass / Turret: 3.4 + 0.8 inside equipment (tons)

Questions?

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Suite 210
McLean Va 22101
Tel 703 448 1947 Fax –1961 email
abconsult@yahoo.com

RHEINMETALL
WAFFE MUNITION

Oerlikon Ammunition for New Defense Environment



NDIA 40th Annual Armament Systems
New Orleans, LA - April 25-28, 2005

Presented by:
Allan Buckley
Director Product Management
RWM Schweiz AG
CH-8050 Zurich / Switzerland
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Lessons Learned & Implemented

AMMUNITION		
System	**Issue**	**Solution**
Aircraft	Safety	FAP
Gun Ship	Diffused Ground Target	ABM
Vehicle	Multiple Threat	ABM, FAPDS; APFSDS
Naval	Asymmetric Threat	ABM, FAPDS
GB Air Defense	Missile-, RAM-Threat	ABM, FAPDS

FAP: Frangible Armor Piercing (Frap Technology)
FAPDS: Frangible Armor Piercing Discarding Sabot (Frap Technology)
APFSDS: Long Rod
ABM: Air Burst Munition (Ahead Technology)

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WAFFE MUNITION

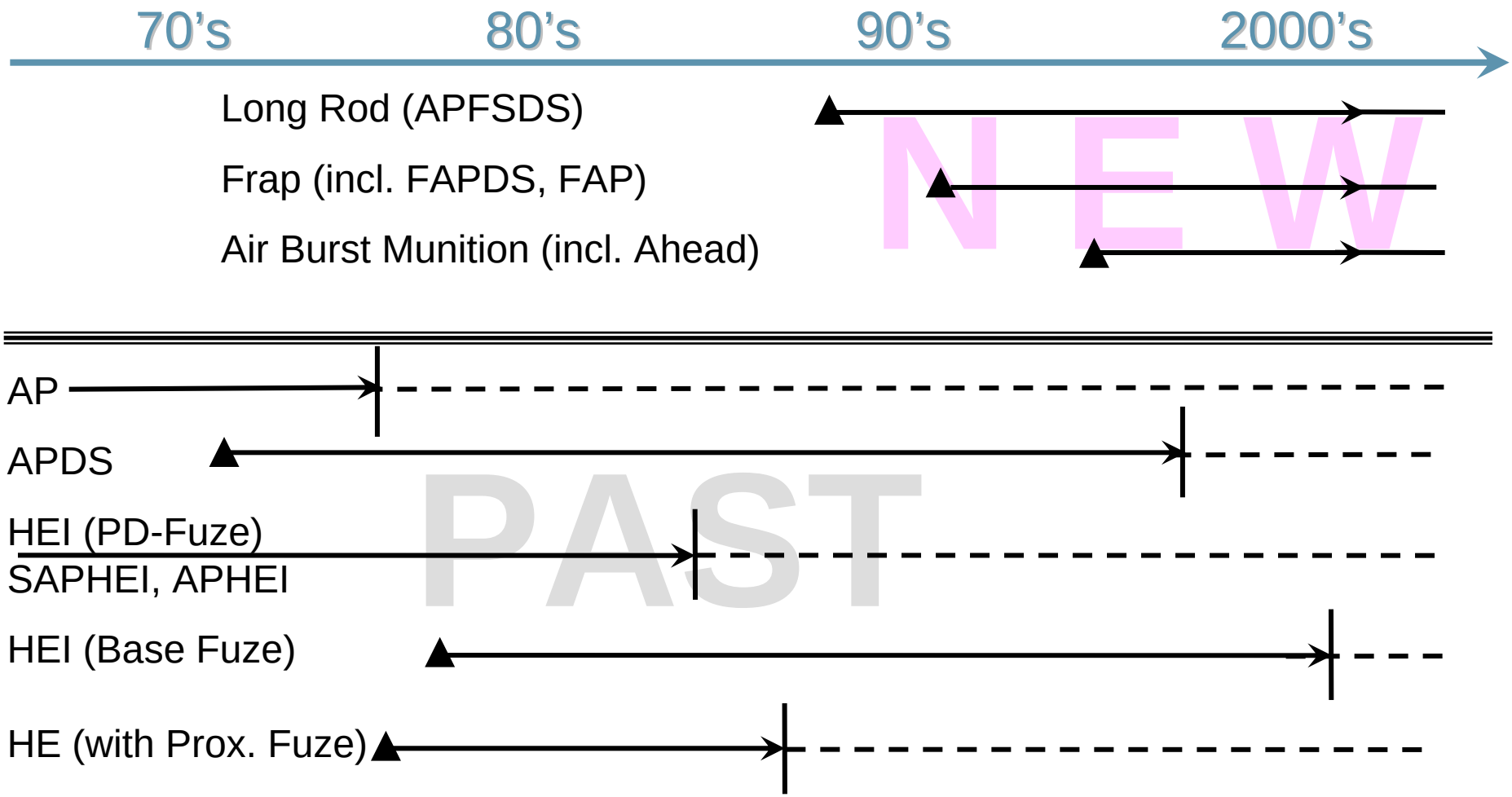
Threat Spectrum



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Evolution of Medium Caliber Ammo Types
Paradigm-Shift (Quantum Leap)

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WAFFE MUNITION

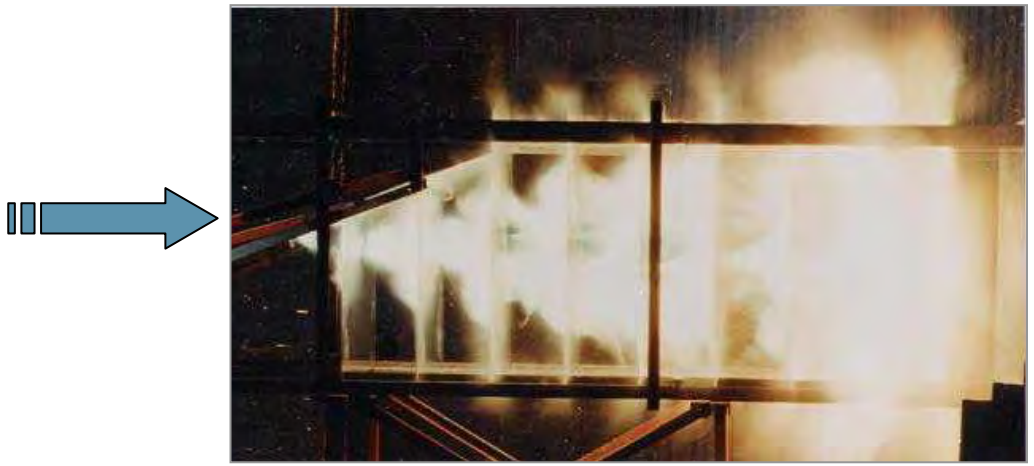


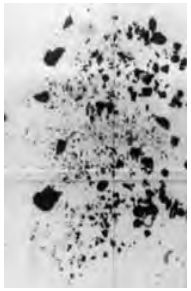
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Frap (Fragmenting Payload) Definition

Frap is a generic term defining a KE ammunition with an inert payload designed to fragment and release its energy after target penetration, thereby creating devastating in-depth and lateral secondary effects (fragments, blast, incendiary).





Heavy Metal Fragment Cloud

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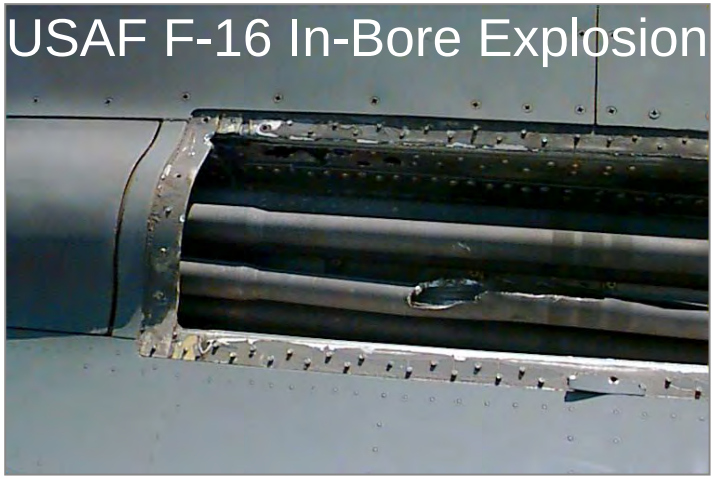
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Safety Issue
with High Explosive Aircraft Ammunition

Swiss F/A-18 “Early Burst”



USAF F-16 In-Bore Explosion



USNavy F/A-18
Gun Barrel
Rupture



Ref.: www.google.com:

Search: PGU-28/B

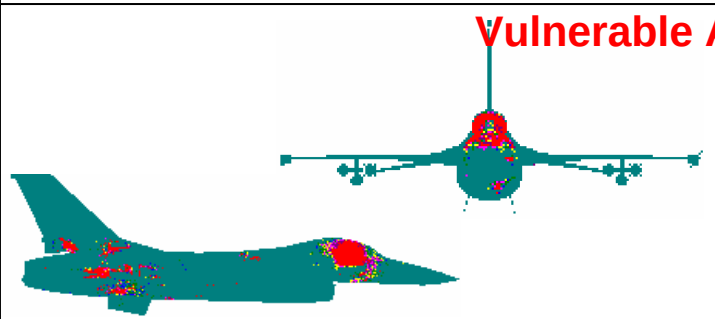
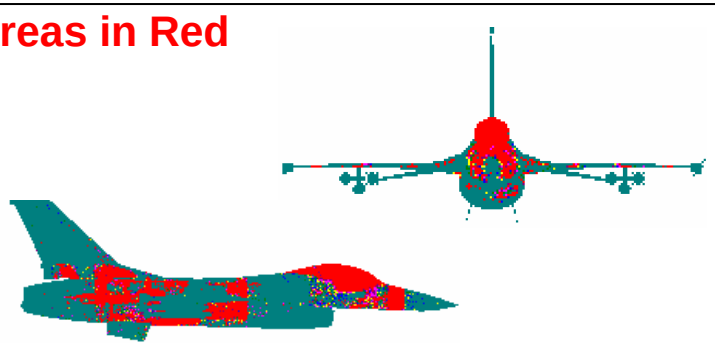
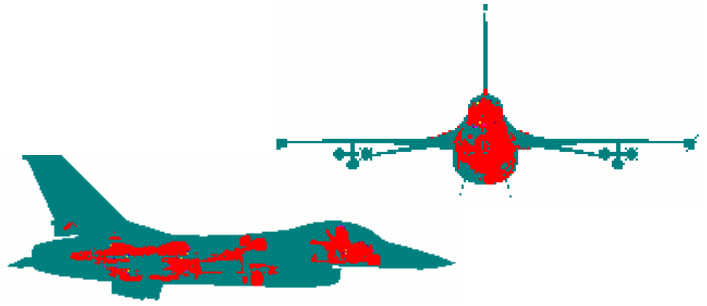
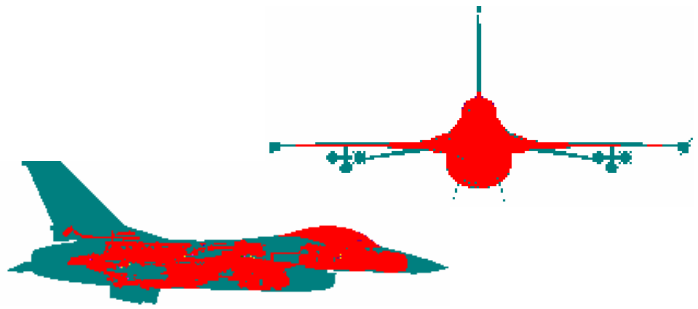
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WAFFE MUNITION

Solution: FAP Ammunition
Lethality of 20mm x 102 FAP & HEI



TARVAC Vulnerability Assessment
Code run by TNO/NL

	Attrition Kill	Mission Abort
HEI		
FAP		

Vulnerable Areas in Red

Range: 900 (m), Side & Head-on attack

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WAFFE MUNITION

Urban Targets
Solution: FAPDS Ammunition (e.g. 25mm x 137)

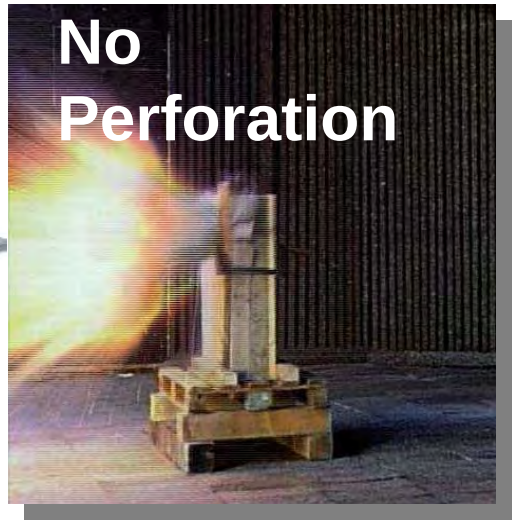


HEI-T





SAPHEI-T



Target: 20 cm (2 x 10 cm) Concrete Wall with double steel-structure reinforcement at a range of 1500 m



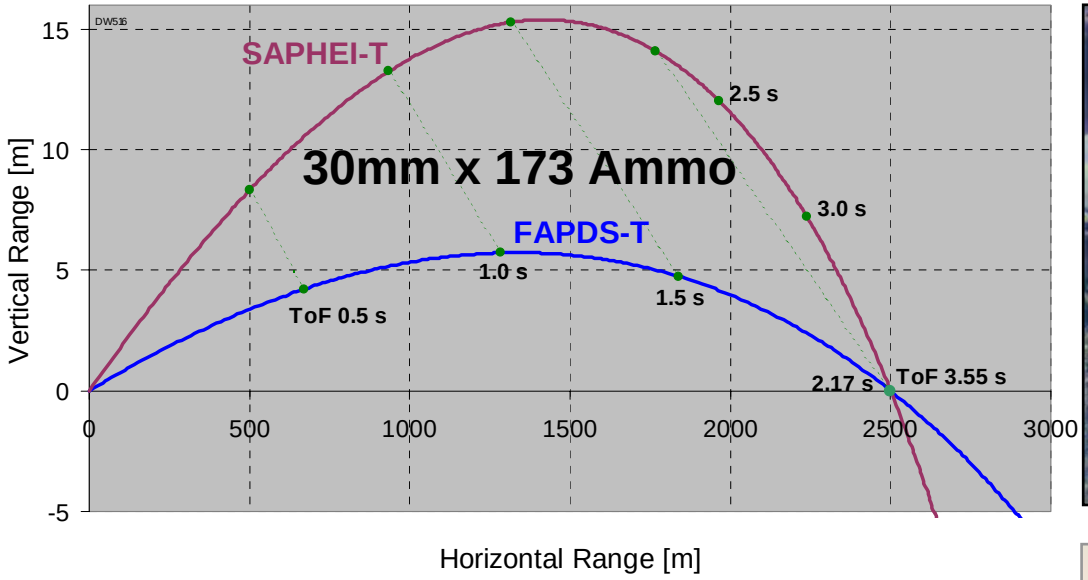
FAPDS-T



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WAFFE MUNITION

‚Soft' Targets
Solution: FAPDS Ammunition







FAPDS Main Characteristics:

- Higher Hit Probability (shorter ToF)
- Higher Lethality
- Lower Vulnerability (no HE-Filling)
- Lower Life Cycle Costs

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WAFFE MUNITION

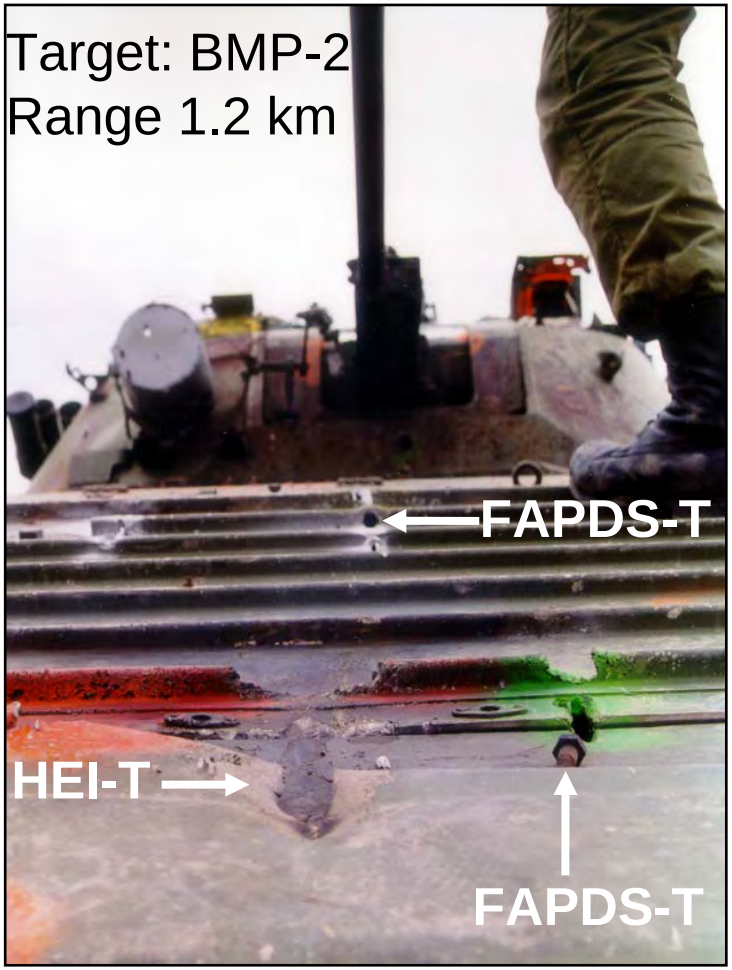
‚Hard' Targets
Solution: FAPDS Ammunition (e.g. 25mm x 137)



Results:

HEI-T:
no penetration
of main armour

FAPDS-T:
full penetration
of main armour



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Armoured Targets
Solution: APFSDS-T (Long Rod) Ammunition (e.g. 30mm x 173)

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WAFFE MUNITION







- 2 hits with full penetration through the turret side, in the area of the ammo storage, angle of impact 45° and 60°NATO
- 1 hit on engine cover with angle of impact >70°NATO

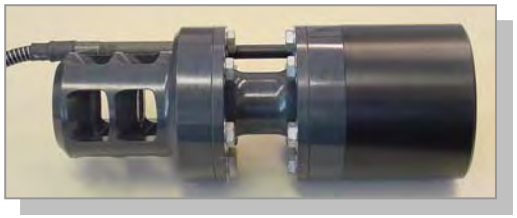
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Vehicle & Naval Craft
Solution: ABM Ahead System - Principle

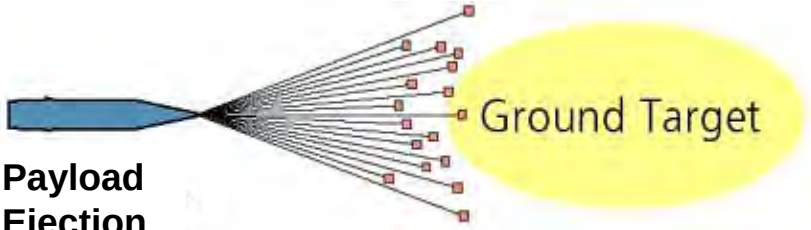
Examples:

Ground Vehicles
Puma / DE (30mm)
CV9035 / NL
Skyranger / OCAG





Programmer



Payload Ejection

Naval Crafts:
35mm: GDM-A07 & Millennium
30mm: MK44; DS30B

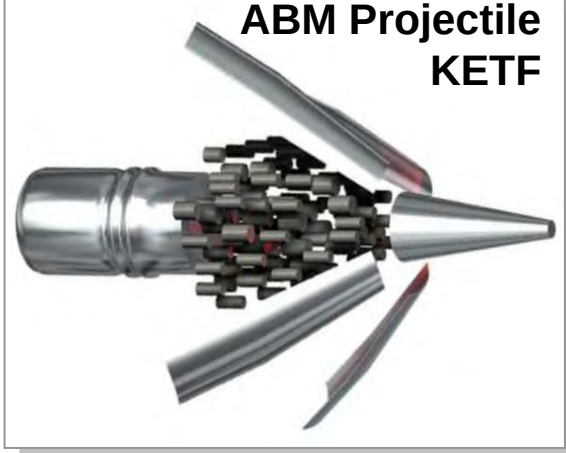
Vo Measuring

Fire CS

ABM Electronics

Fuze Programming

ABM Projectile KETF



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ABM-Ahead Ammunition 30 & 35mm for Modern Vehicle Armament (Examples)

RHEINMETALL WAFFE MUNITION



ABM Fire Power against incl. MBT (neutralise), Mi-24 Hind-D, Personnel (covered in Foxhole & dispersed Infantry Soldiers), Urban Targets.











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ABM-Ahead Ammunition 35mm for Navy Applications (Examples)

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Surface Threat: incl. Fast Intruder Attack Craft (e.g. Boghammar, Jet Ski), Submarine-Periscope.

Air Threat: incl. ASM, AGM







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WAFFE MUNITION

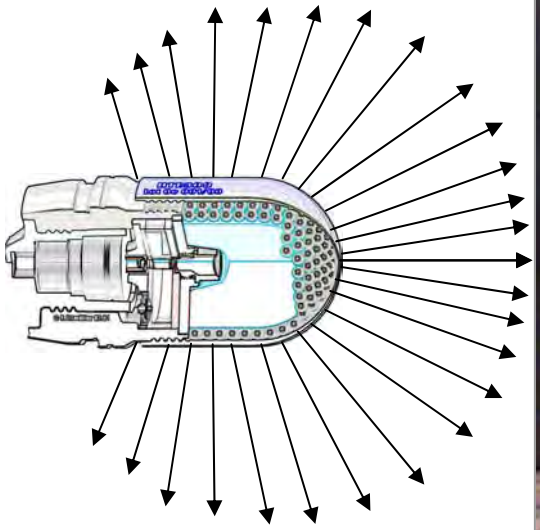
Infantry
Solution: ABM 40mm x 53 Calibre (AGL)

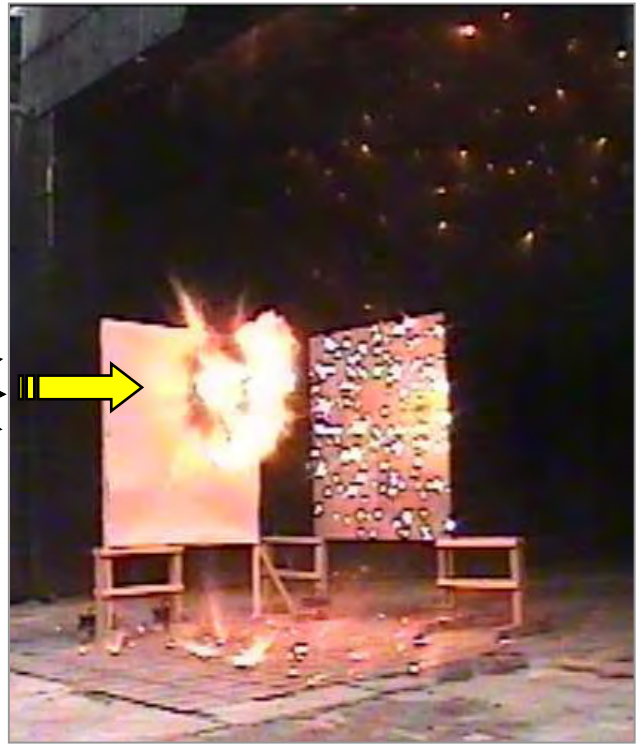
AGL: Automatic Grenade Launcher

Air Burst Munition (Ahead-HETF)

Any AGL System
incl. LWAGL, MK19







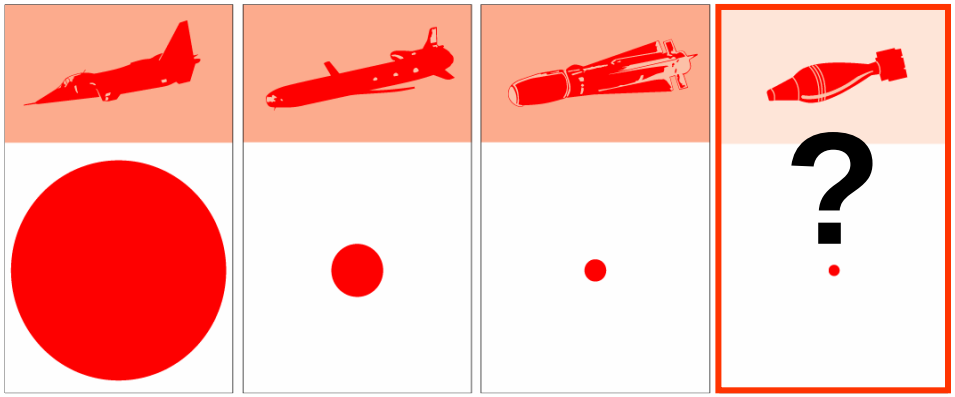
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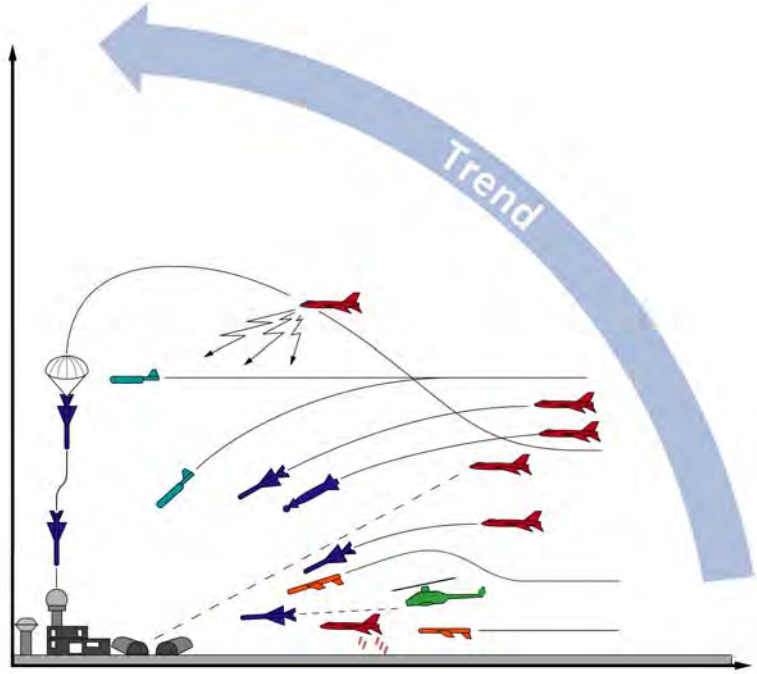
RHEINMETALL
WAFFE MUNITION

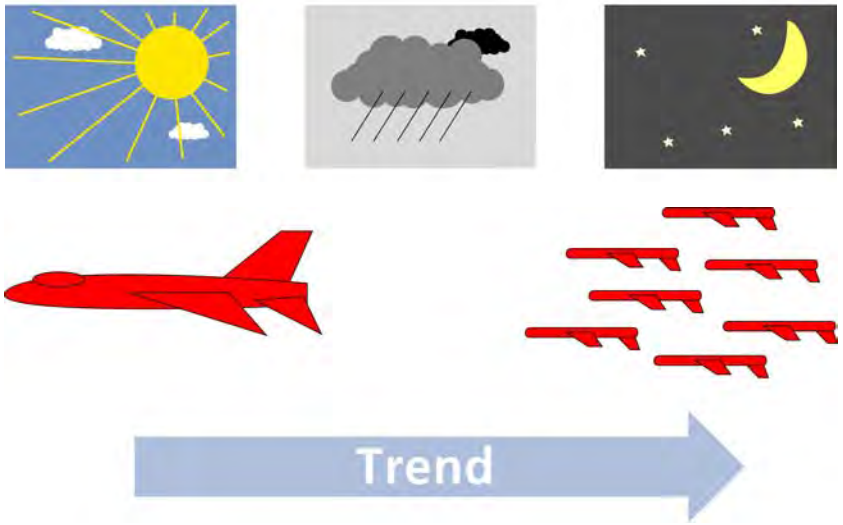
Trends in Air Threat

Difficult to

- **Detect, Track, Engage, Hit, Kill**

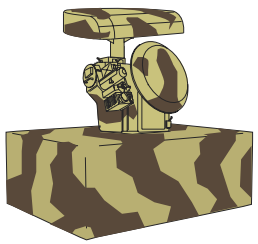






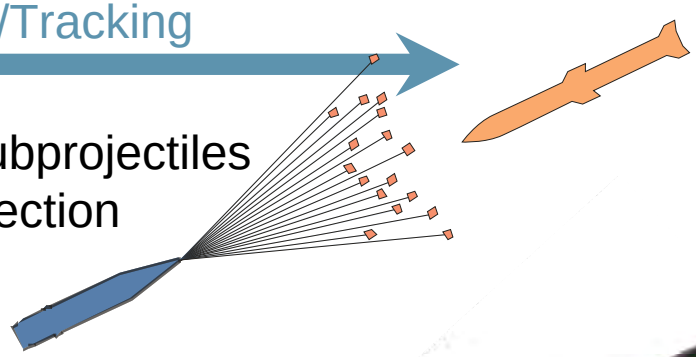
Solution: GB Air Defense Skyshield 35mm Ahead

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WAFFE MUNITION

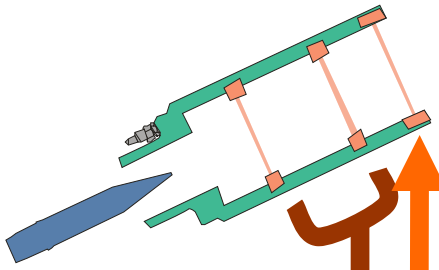


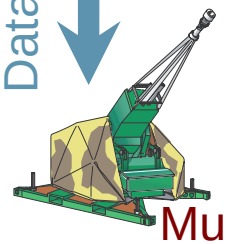
Detection/Tracking

Subprojectiles
Ejection



Data Transmission





Muzzle Velocity Measuring

Gun
Computer

Fuze Programming



Muzzle Base with
Programmer

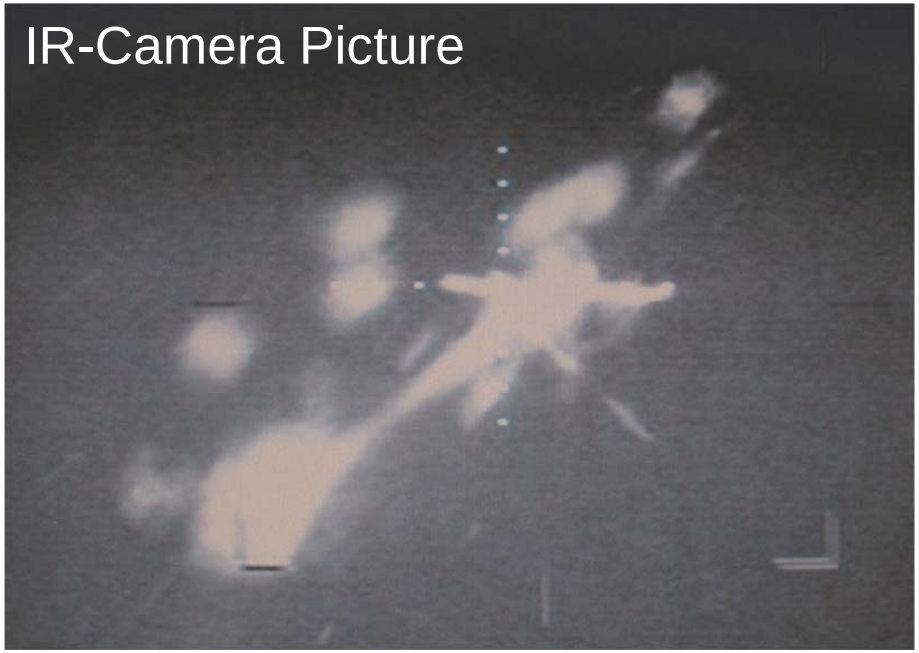
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UAV's & Missiles
Solution: Skyshield 35mm Ahead



U.S. Army Test,
NAWS China Lake, July 2004



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New Threat: Rockets, Artillery, Mortars (RAM)











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Solution: Counter RAM (Rocket Artillary & Mortar) for Military Camp Protection

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Skyshield 35mm Ahead:
Tests in Todendorf (Germany, Dec. 04)





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35 mm ABM Ahead Technology: C-RAM Defense Potential demonstrated

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Target: 120mm Mortar destroyed



Skyshield Tests in Todendorf (Germany, Dec. 04)

Detonation caused by Ahead (Bursts of 18 to 36 Rds)



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ABM-Ahead Technology:
Versatile Solution to Defense Problems

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The Space-Time Programmable Ammunition:
For **ANY Defence Role** & **TARGET Engagement**

- **Armies**
- **Navies**
- **Air Forces**
- **Peace Keeping & Enforcement Forces**

TARGET Engagement

- **Hard to Soft**
- **Dispersed to Concentrated**
- **Open to Hidden**
- **Lethal to Less-Than-Lethal**

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Example of a Modern Med. Cal. Ammo Family: 30mm x 173 New Oerlikon Ammunition

RHEINMETALL WAFFE MUNITION

		Vo
Air-Burst ABM		1100 m/s
Long-Rod APFSDS-T		1405 m/s
Frangible FAPDS-T		1405 m/s
Training TPFDS-T		1465 m/s

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ACCURACY MODELING OF THE 120MM M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

BRIEFING FOR THE GUNS, AMMUNITION, ROCKETS & MISSILES SYMPOSIUM - 25-29 APRIL 2005

Providing America Advanced Armaments for Peace and War



RONALD G. GAST, PhD, P.E.

SPECIAL PROJECTS TEAM, WEAPONS, SYSTEMS AND TECHNOLOGY DIRECTORATE

ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

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BACKGROUND AND MOTIVATION FOR THE CONDUCTION OF THIS STUDY

It is a well known fact that the centerline profile of the bore affects the in-bore dynamics and exit conditions of the projectile.

The exit state of the projectile serves as initial conditions to the projectile's flight path to its intended target.

A relatively accurate and quick running model of this would be beneficial to assess accuracy, especially for the newer, lightweight ordnance weapons.

Since simulations are just mathematical models of reality, validation is an extremely important aspect of their use.

The subject weapon has a plethora of field generated experimental data regarding accuracy and dispersion for several unique gun tubes.

We are submitting a validation effort of our modeling techniques through the attempted reproduction of this data using dedicated models and statistics knowing full well that replication of field generated data is most difficult.

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M1A2 TANK IN DESERT CAMOFLAUGE



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DESCRIPTION OF THE ANALYSIS MODELS

Simulation of Barrel Dynamics (SIMBAD)

A quick running finite element code, which employs beam elements for the gun tube and a variety of options for modeling the projectile, mount and cradle.

Designed to predict the motion of the gun barrel and projectile during the firing phase, ultimately passing the exit conditions of the projectile to the flight prediction model.

Barrel employs three dimensional beam finite element structural representation using an Euler-Bernoulli formulation.

Shot is represented as a two piece flexible structure consisting of a projectile and sabot, both of which employ beam finite element formulation.

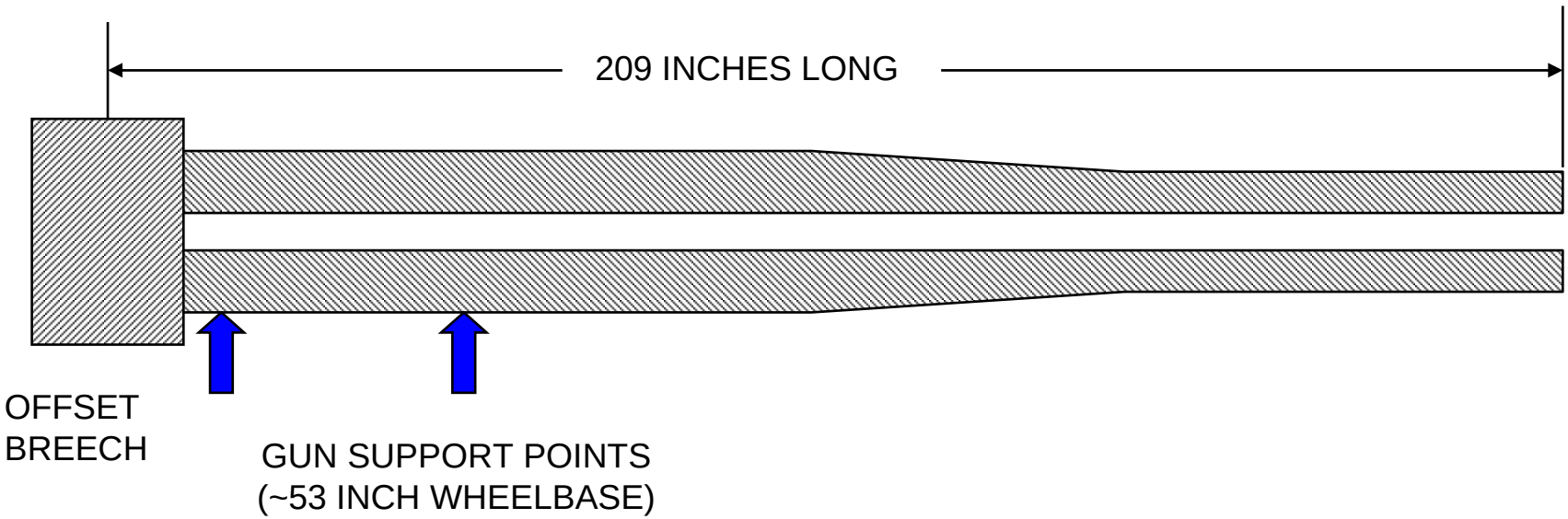
The dynamic equations for barrel, sabot and projectile are cast in a standard matrix form.

Since this type of problem is highly non linear, a modified Runge-Kutta time marching integration technique is employed.

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GUN BARREL MODEL IN SIMBAD

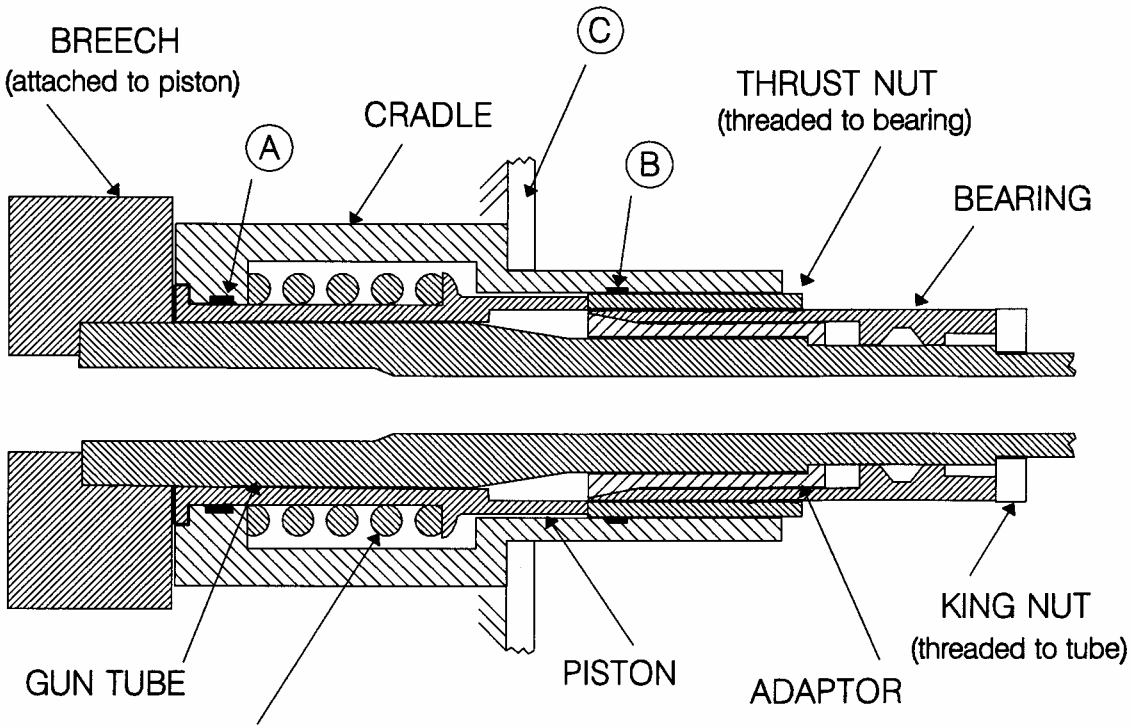


SIMBAD FINITE ELEMENT MODEL: 40 NODES; 41 ELEMENTS

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120mm M256 CANNON and MOUNT

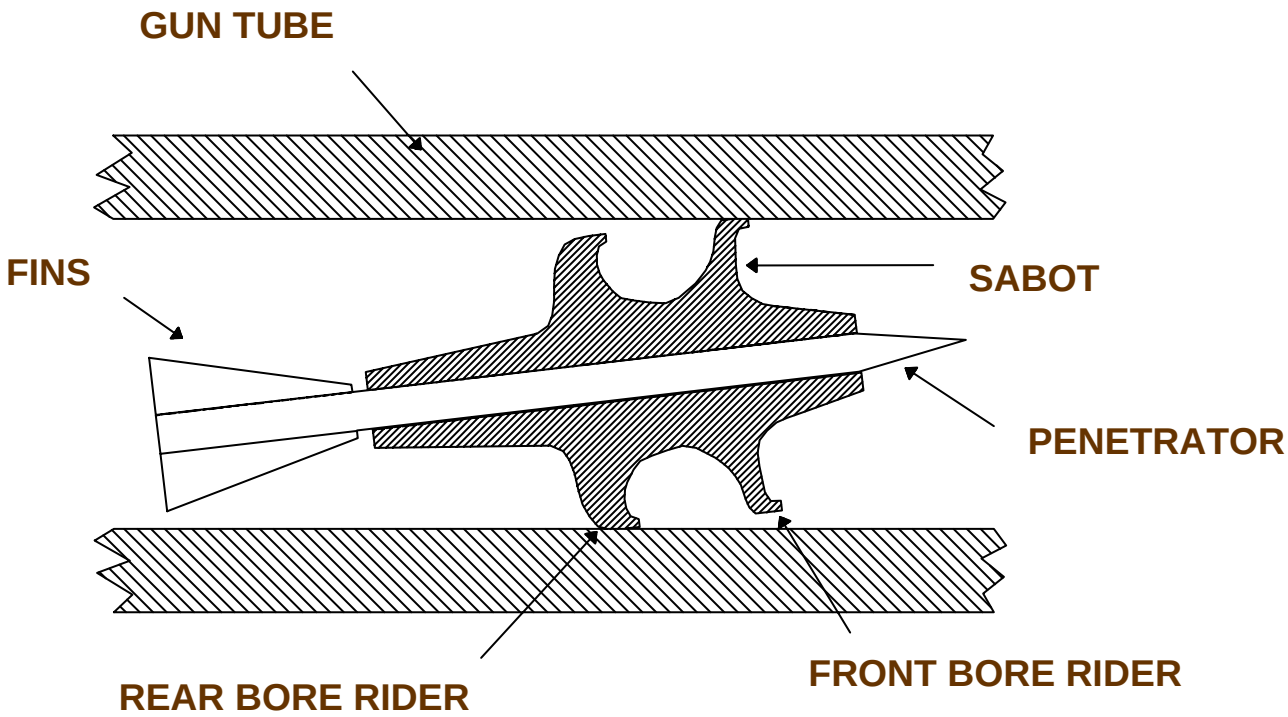


For Clarity the radial scale is exaggerated and numerous features are not shown.

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PROJECTILE MODEL IN SIMBAD



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DESCRIPTION OF THE ANALYSIS MODELS

BOOM

A six degree of freedom (dof) rigid body aerodynamics code used to predict the external flight path of ordnance projectiles.

The six dof's are comprised of three body inertial position coordinates as well as three Euler angle body attitudes.

The dynamic equations are written with respect to body a frame coordinate system.

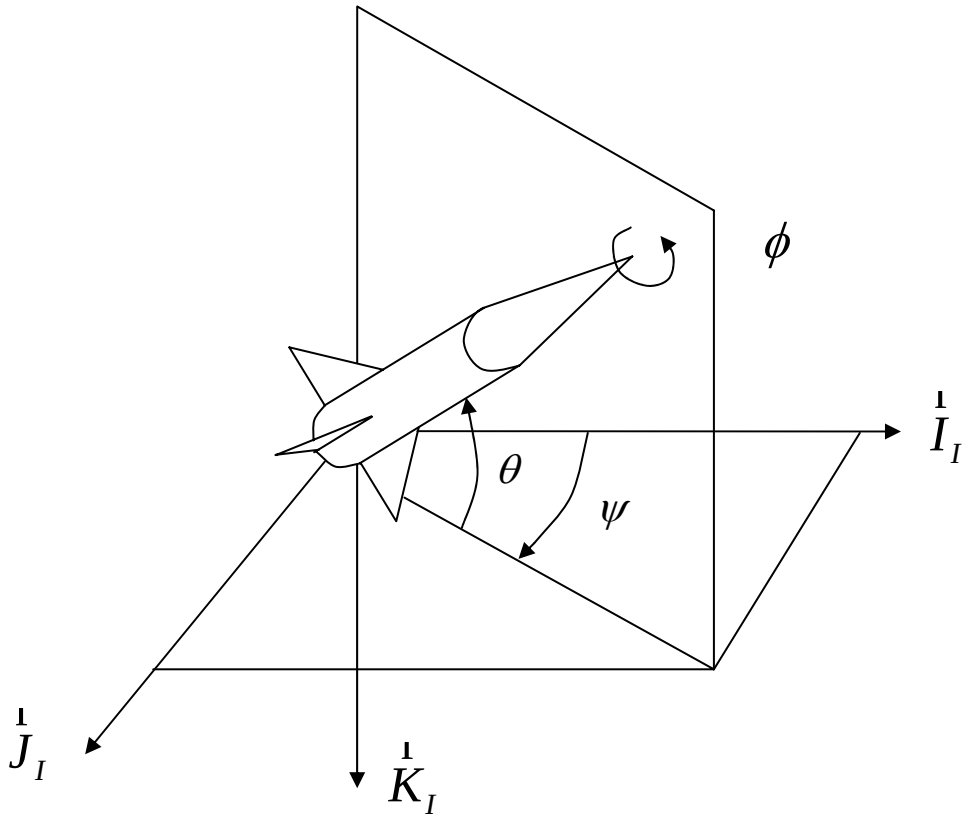
The total applied force is composed of weight and body aerodynamic force terms (lift, drag, etc).

A considerable amount of empirical data (which is projectile dependent) used for lift and drag calculations has been generated at the Army Research Lab Test Center.

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RIGID PROJECTILE MODEL IN BOOM



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DESCRIPTION OF THE ANALYSIS MODELS

TRANSFER OF DATA FROM SIMBAD TO BOOM

Each of the computer codes are stand-alone employing their own coordinate systems.

An interface routine was developed through a coordinated effort among Benet Labs and the developers of the two codes.

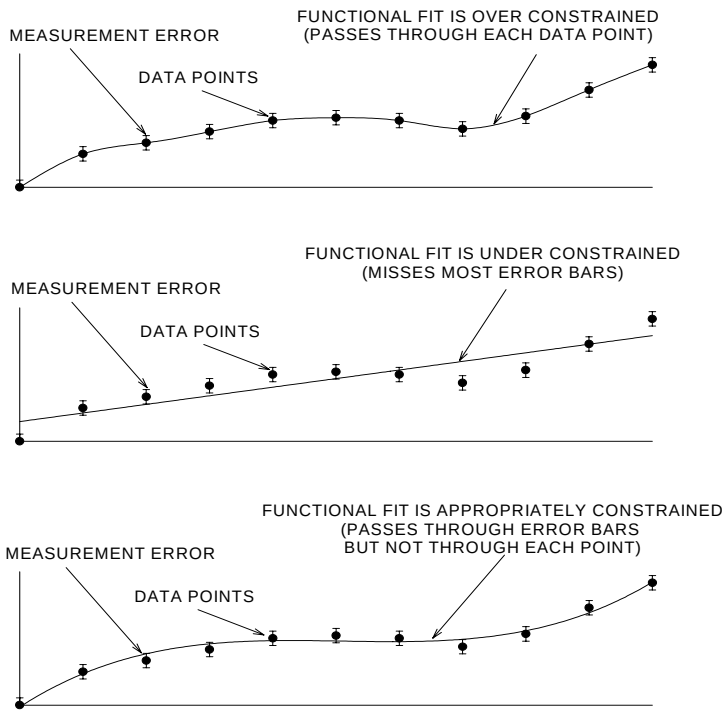
This routine employs several matrix equations to transfer projectile's exit conditions (i.e. displacement, velocity, etc) from the SIMBAD coordinate system into the coordinate system used by BOOM.

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STATISTICAL METHODS FOR GENERATION OF SIMULATION DATA

BORE PROFILE FUNCTION



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ESTIMATION OF THE BORE CENTERLINE PROFILE

Bore profile centerline is derived from the inspection measurements taken during manufacture. There are usually 23 points (x_i , y_i) along the gun tube for which measurements are taken.

These measurements are used as the 'data' for a least squares polynomial fit (p_n) per the following equation:

$$p_n(x) = a_o + a_1x + a_2x^2 + a_3x^3 + \ldots\ldots + a_{n-1}x^{n-1} + a_nx^n$$

Several polynomial fits are generated (i.e. n = 2,…,14)

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ESTIMATION OF THE BORE CENTERLINE PROFILE

The coefficients for each polynomial order is determined by minimizing the residual (defined below) for each fit.

$$\sum_{i=0}^{22}[y_i - p_n(x_i)]^2$$

The change in residual from one order to the next is compared.

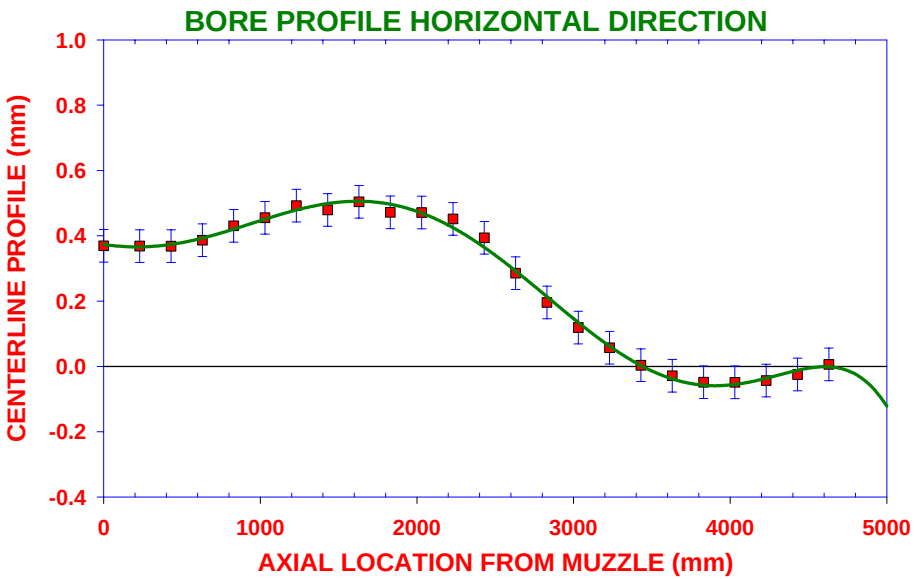
To determine which polynomial order yields the appropriate fit an F-test is conducted.

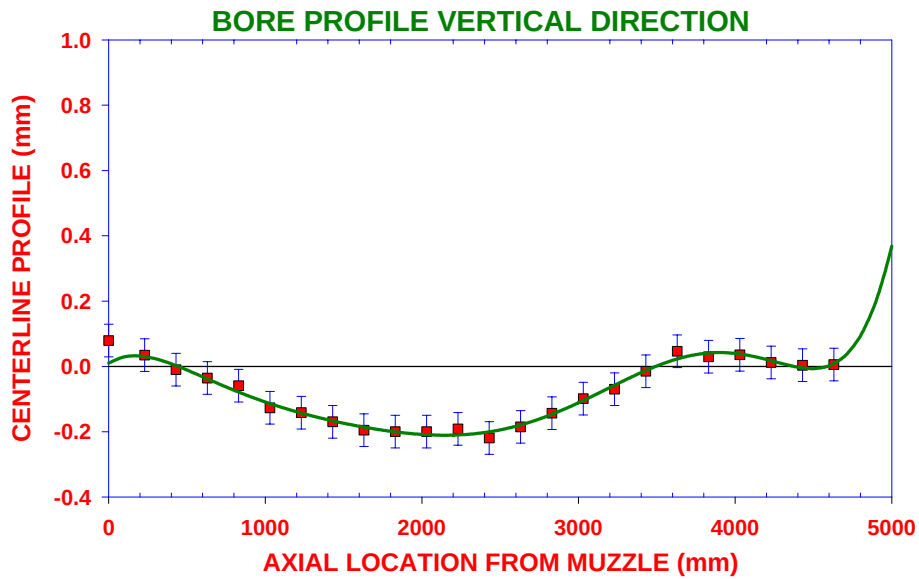
When the improvement from consecutive orders does not change significantly (using a 10% significance level) the lower order polynomial is chosen and the testing is terminated.

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BORE CENTERLINE PROFILE DATA AND POLYNOMIAL FIT FOR TYPICAL GUN TUBE





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STATISTICAL METHODS FOR GENERATION OF SIMULATION DATA

BALLISTIC PRESSURE AND MUZZLE VELOCITY

Peak pressure and muzzle velocity was recorded for each round in the test.

Each round type and bore profile configuration was fired 3 times on 3 occasions.

This provided the basis for developing a random array of muzzle velocity scale factors applied to the ballistic driving force for each simulated shot.

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STATISTICAL METHODS FOR GENERATION OF SIMULATION DATA

PROJECTILE STIFFNESS AND CLEARANCE

The front and rear bore rider diameters have nominal dimensions with tolerance values as do any other engineered part.

A normal distribution of the diameters was assumed with the nominal value set at the midpoint of the diameter range.

The standard deviation of the distribution was set at one-third of the tolerance which would keep nearly all of the random diameter values within the tolerance range.

We had no way of knowing the actual values of these diameters.

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COMPARISON OF TEST DATA TO SIMULATED RESULTS

The simplest method of comparing simulations to test data is in the form of 'target' plots indicating the angular offset from the aim point of the data and simulations at the target location.

These 'target' plots employ a 2.00 milli-radian square window with the aim point shown as a green cross.

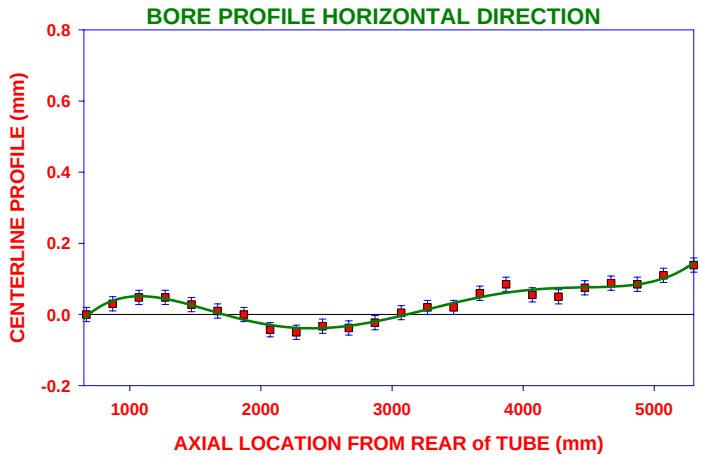
For each gun tube bore profile there are 3 sets of 3 shots each for the test data and a 10 shot simulation employing the statistical variances in the input values previously discussed.

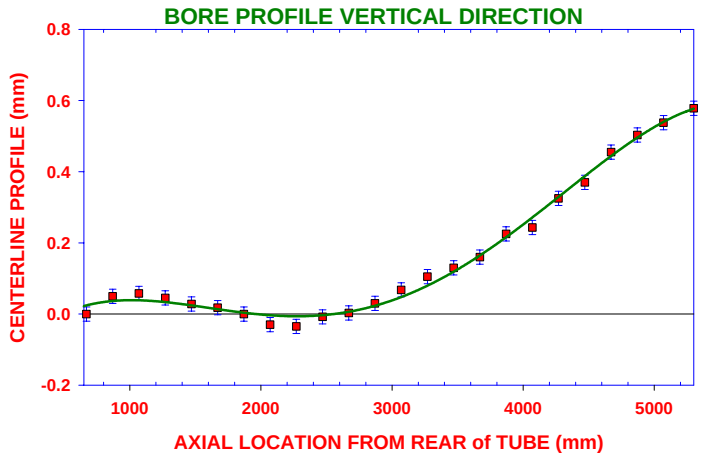
A total of 20 configurations were compared but only a few will be presented and discussed here.

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TUBE #1: PROFILE

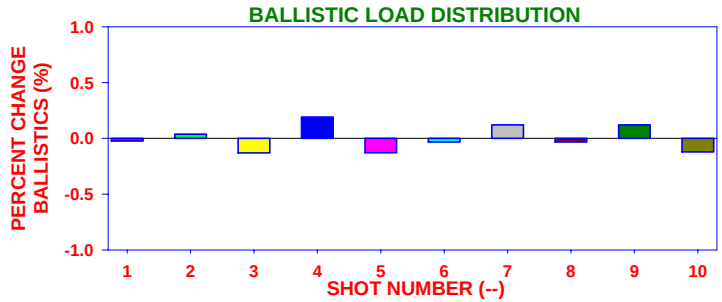


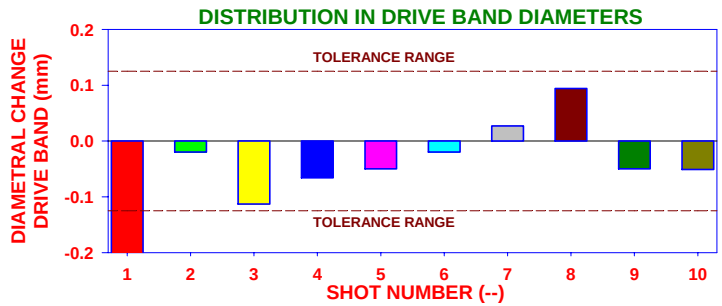


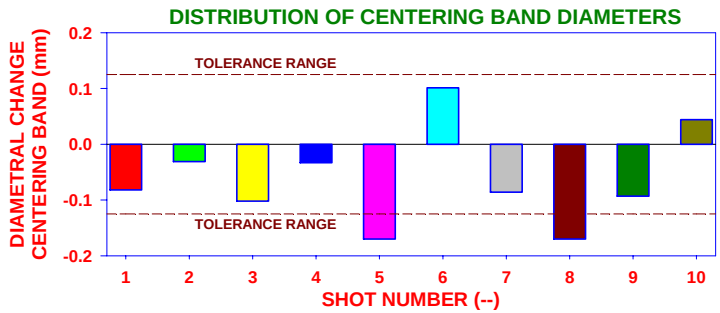
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TUBE #1: LOAD / PROJECTILE DISTRIBUTIONS

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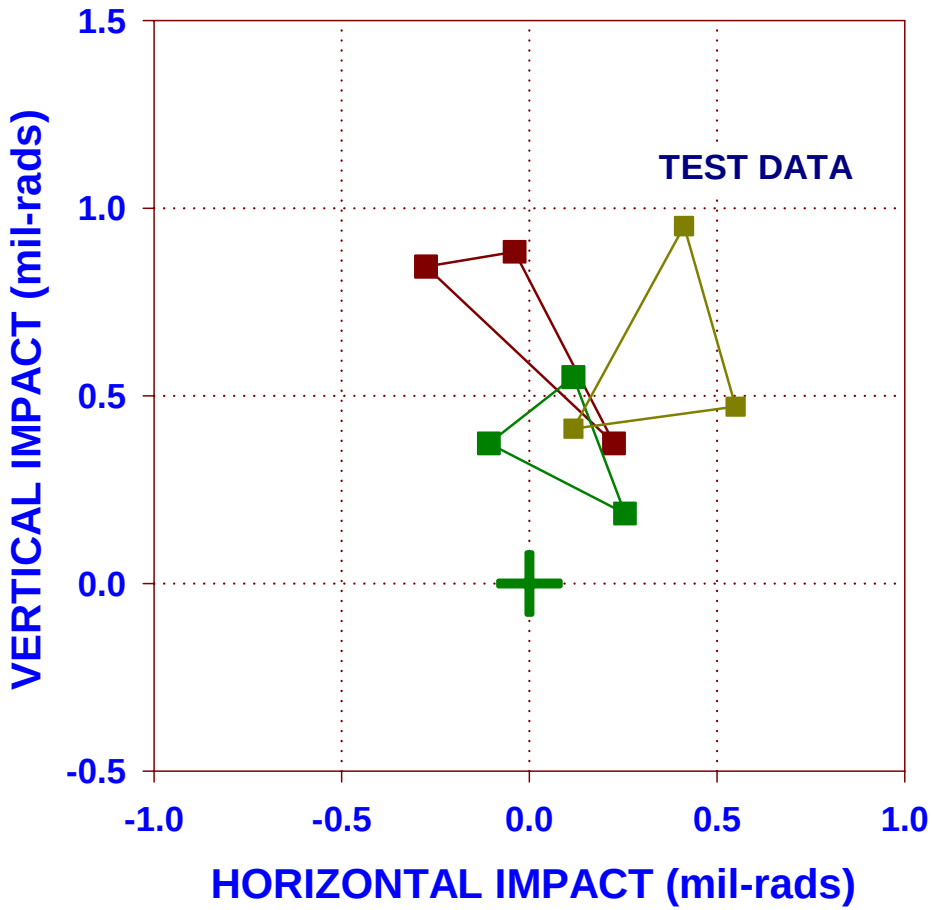




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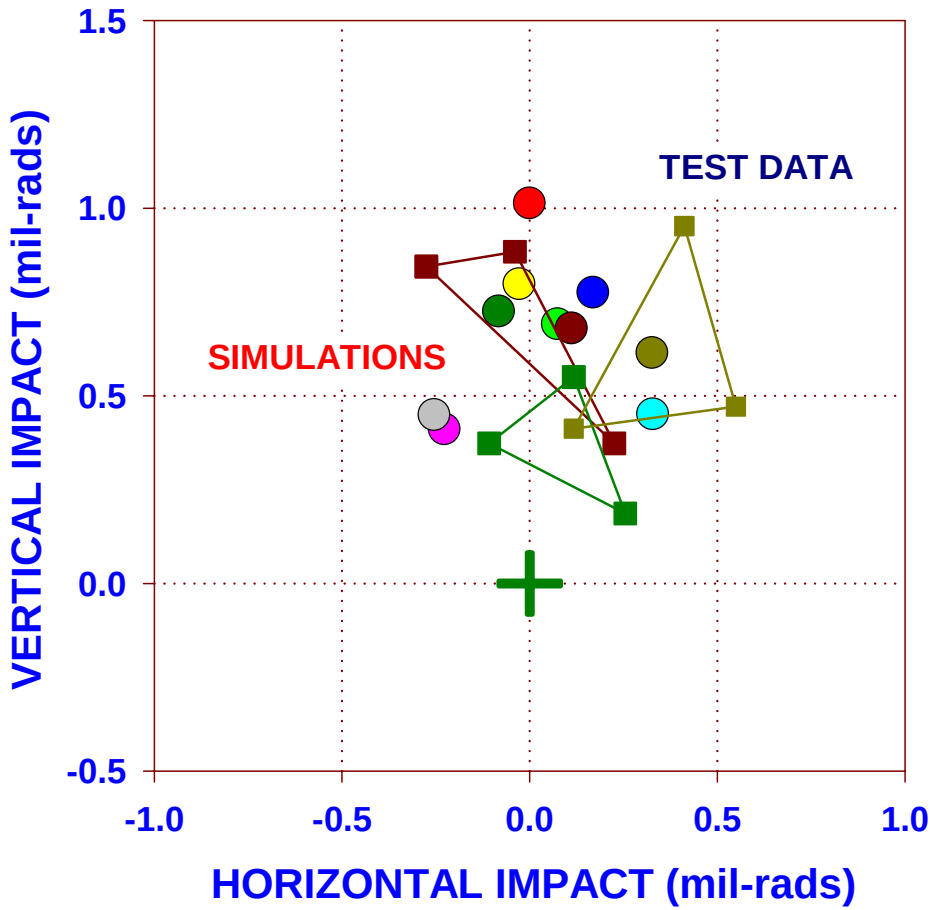
RESULTS for TUBE #1: DATA



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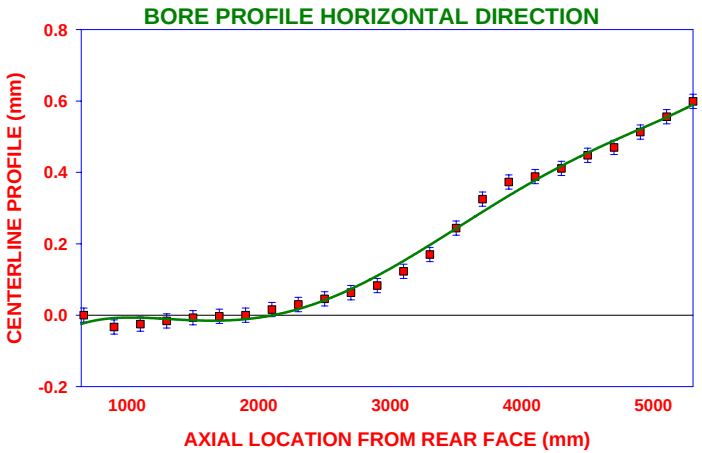
RESULTS for TUBE #1: DATA & SIMULATIONS

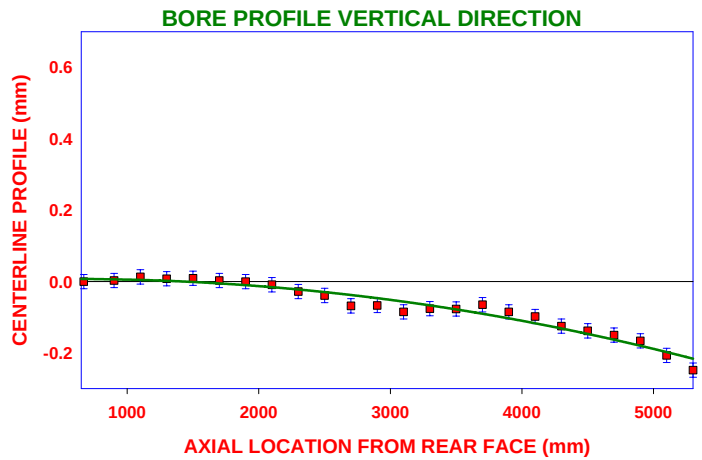


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TUBE #2: PROFILE

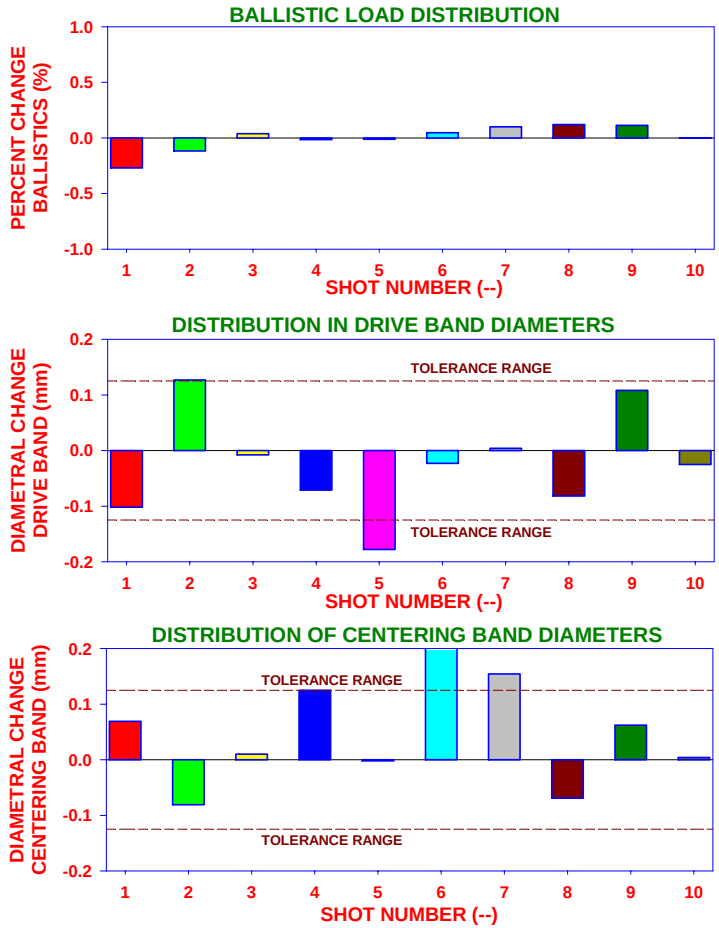




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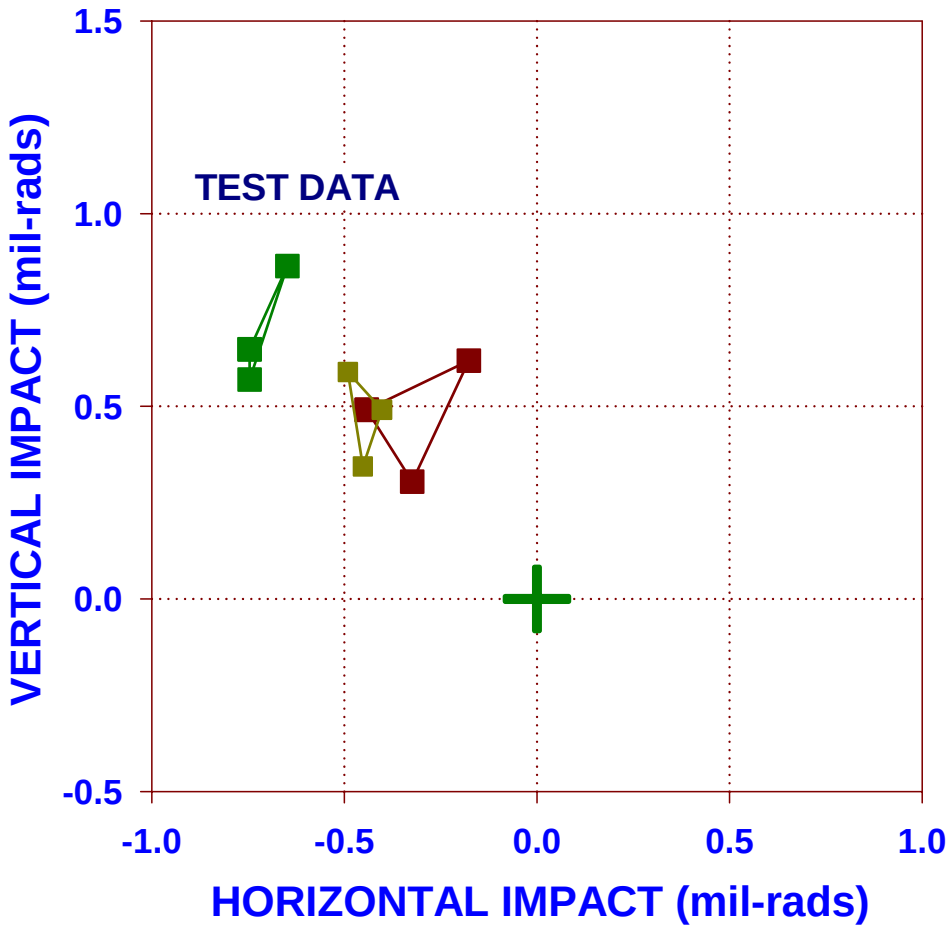
TUBE #2: LOAD / PROJECTILE DISTRIBUTIONS



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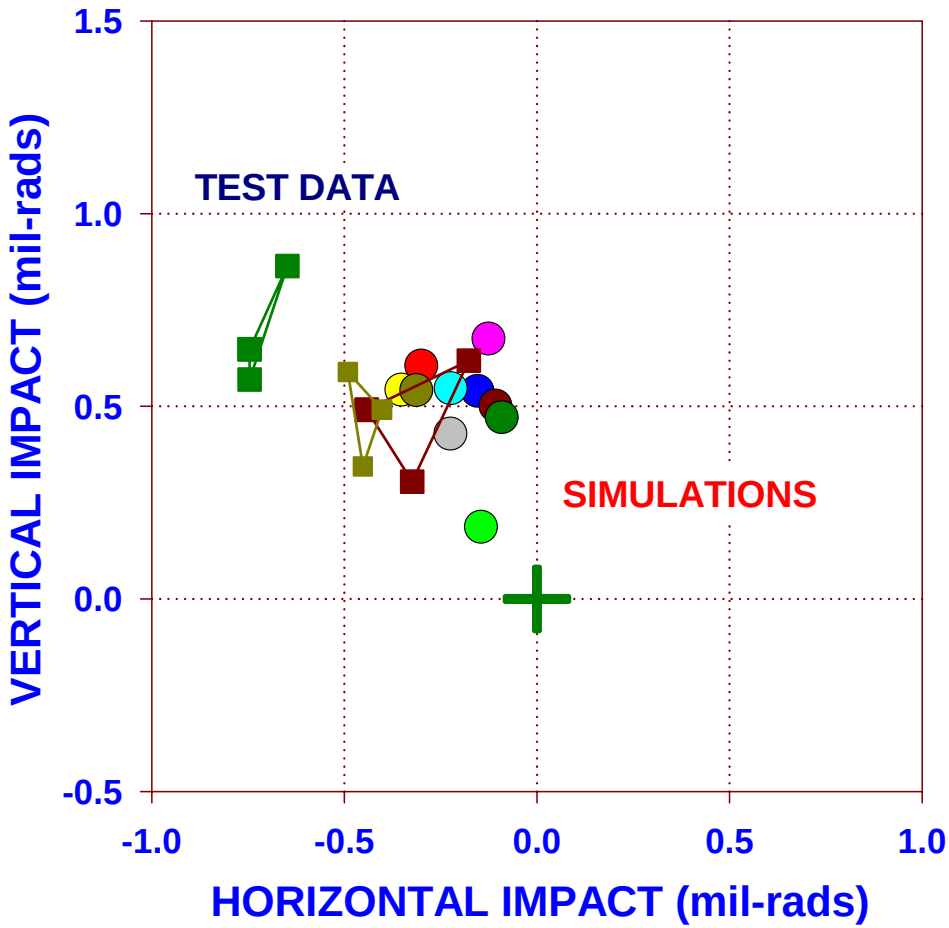
RESULTS for TUBE #2: DATA



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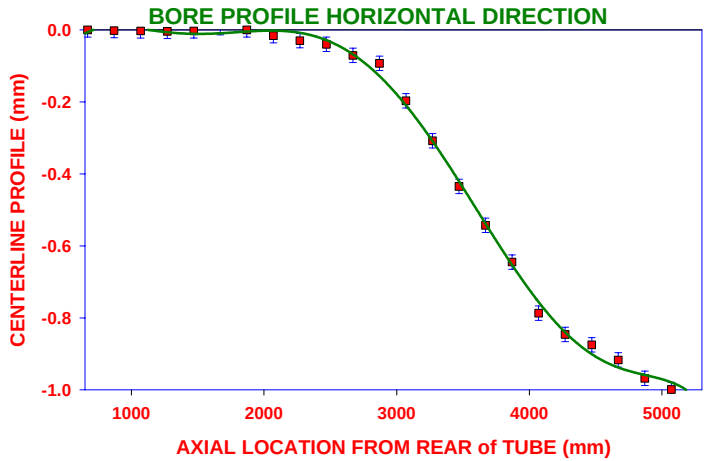
RESULTS for TUBE #2: DATA & SIMULATIONS

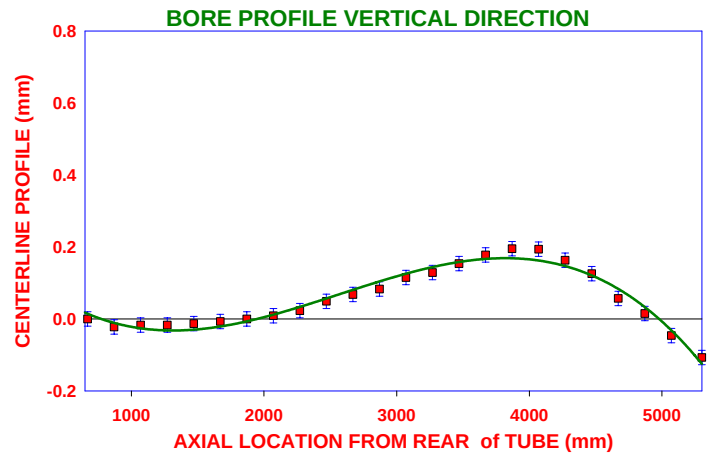


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TUBE #3 PROFILE

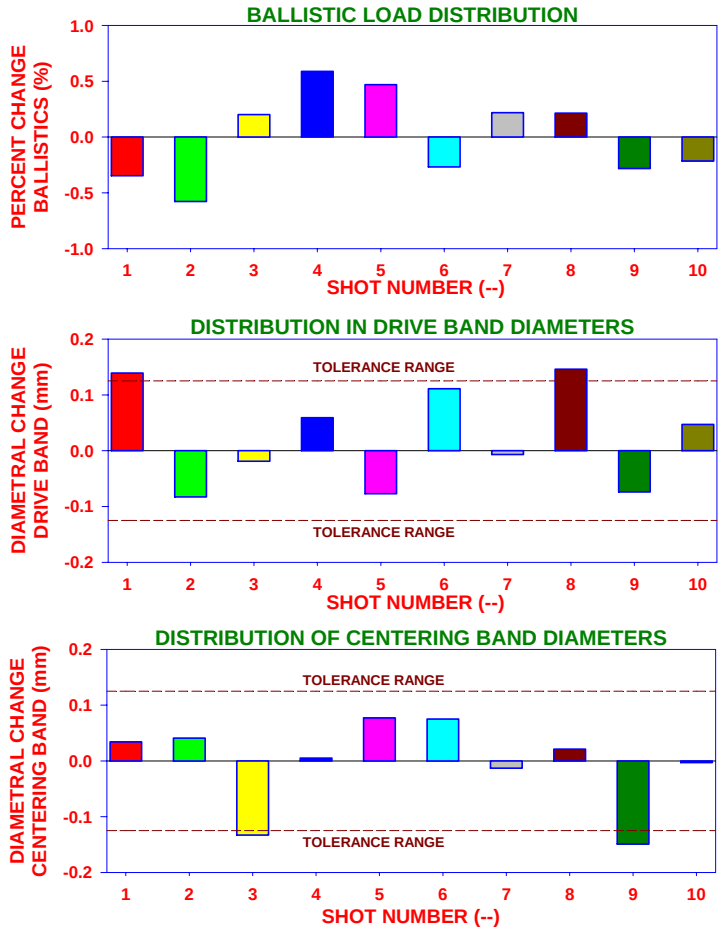




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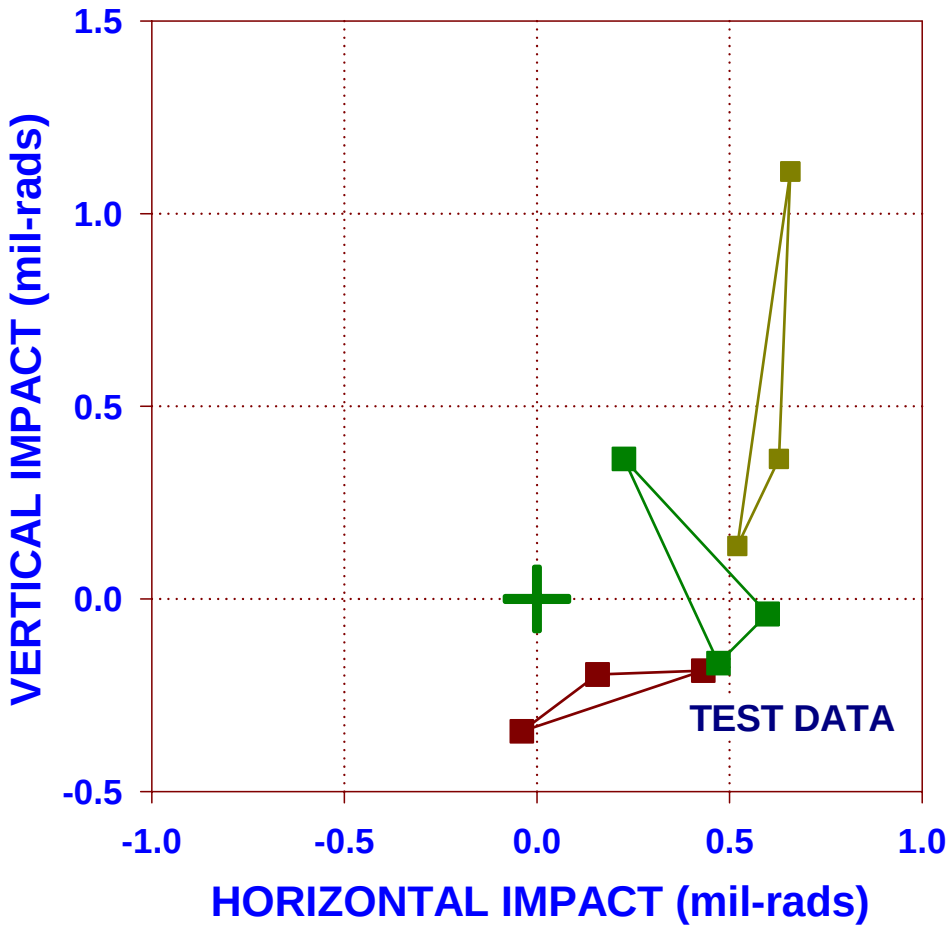
TUBE #3 LOAD / PROJECTILE DISTRIBUTIONS



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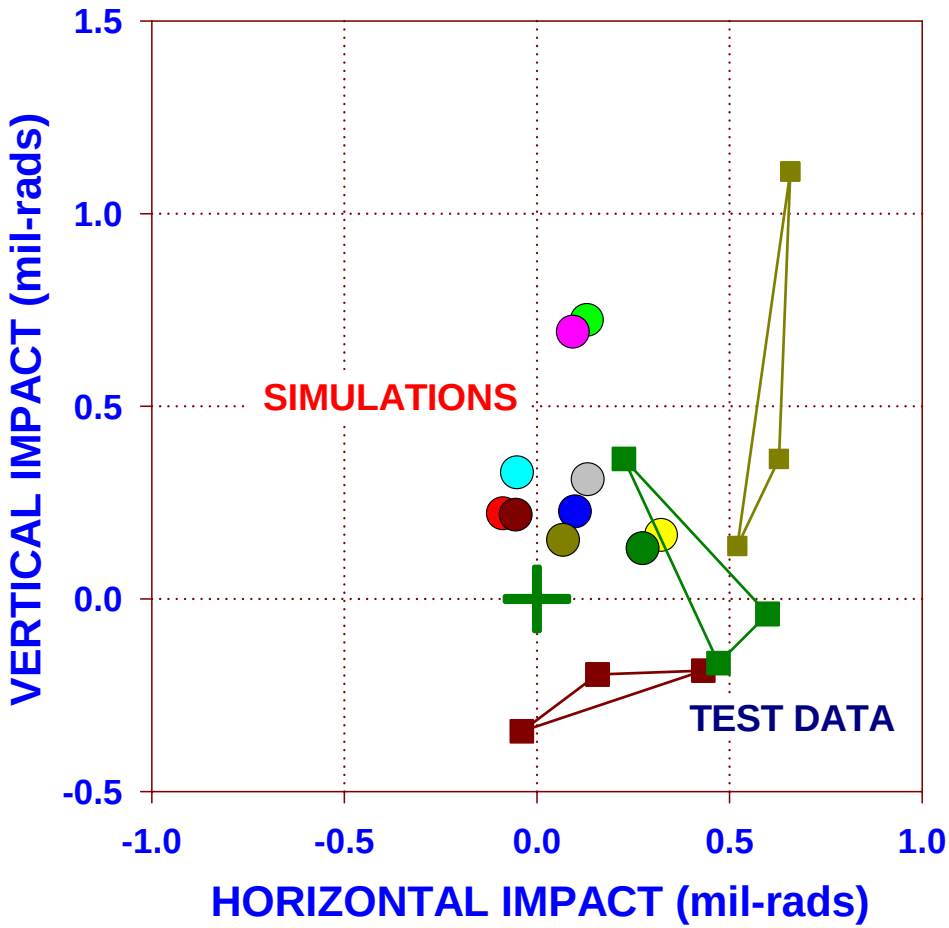
RESULTS for TUBE #3: DATA



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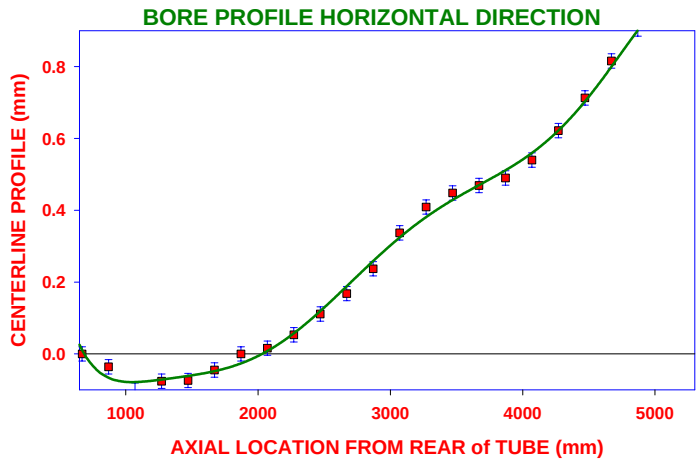
RESULTS for TUBE #3: DATA & SIMULATIONS

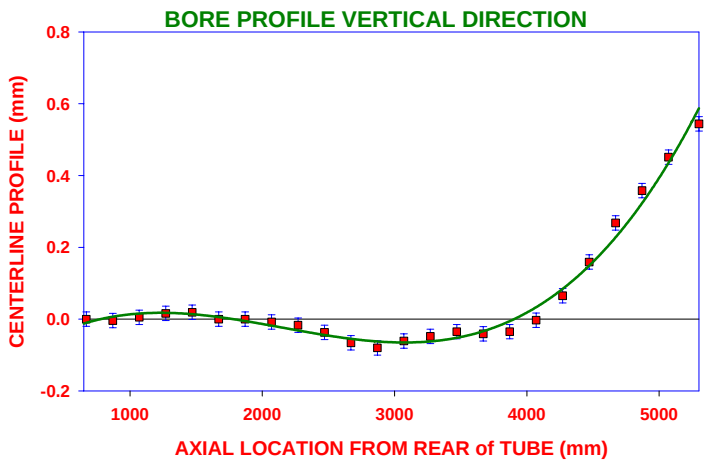


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TUBE #4 PROFILE

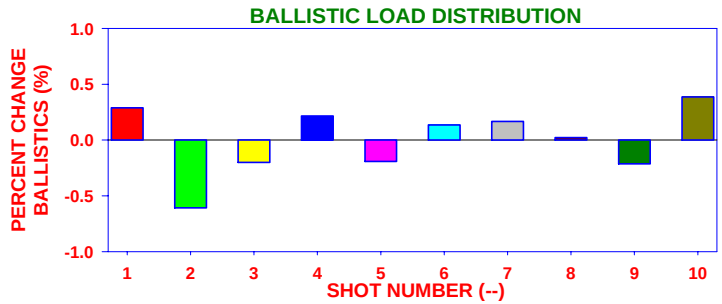


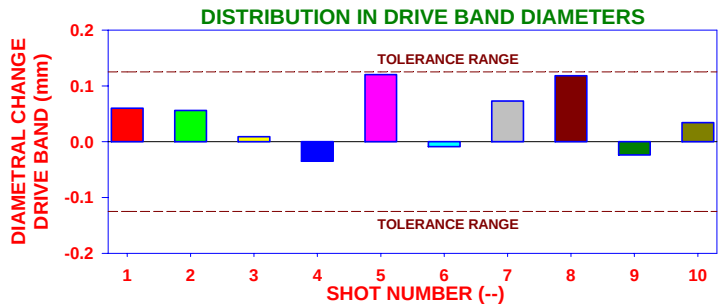


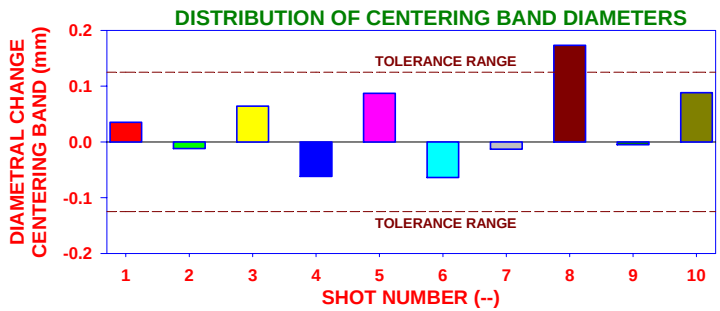
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TUBE #4 LOAD / PROJECTILE DISTRIBUTIONS



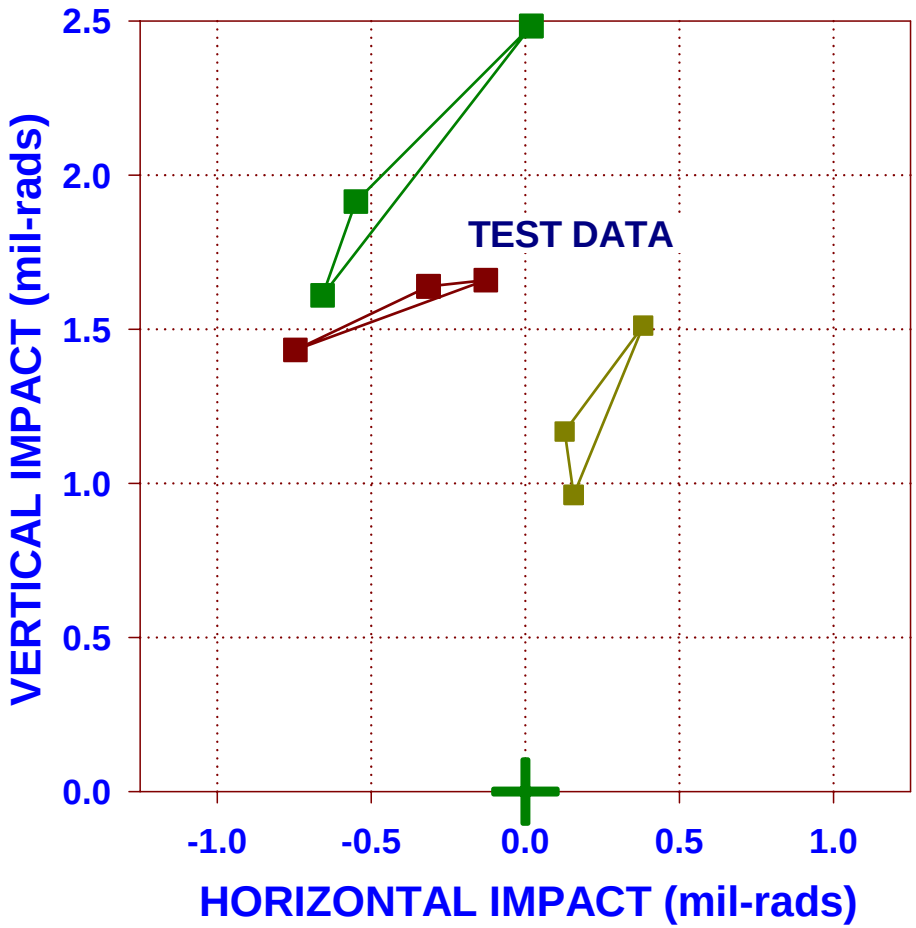




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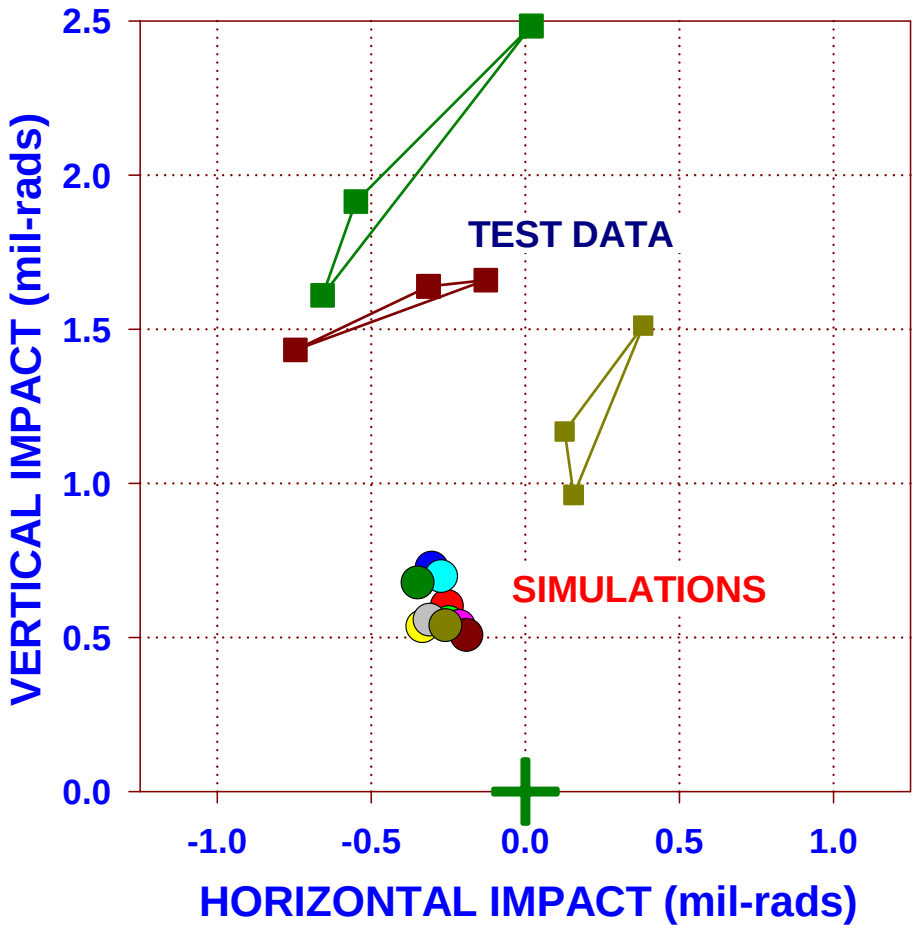
RESULTS for TUBE #4: DATA



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RESULTS for TUBE #4: DATA & SIMULATIONS



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SUMMARY OF INDIVIDUAL TUBE RESPONSES

These four cases span the best to the worst in regard to accurately simulating test results.

Reiterating considerable amount of data, which impacts the test is unknown.

Projectile specifications were ‘guessed’ using nominal values and tolerances.

As shown in the simulations, band diameters that are out of tolerance tend to indicate shot impact locations that reside on the outskirts of group distributions.

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STATISTICAL ANALYSIS OF PREDICTIONS AND TEST DATA

The analysis and discussion of these four cases does not allow one to claim the validity of the model.

It would be impossible to predict with a great degree of reliability any one shot, however, trends in shot patterns may offer more representative information.

To this end I suggest that we compare mean impact and dispersion values for the test and simulation groups.

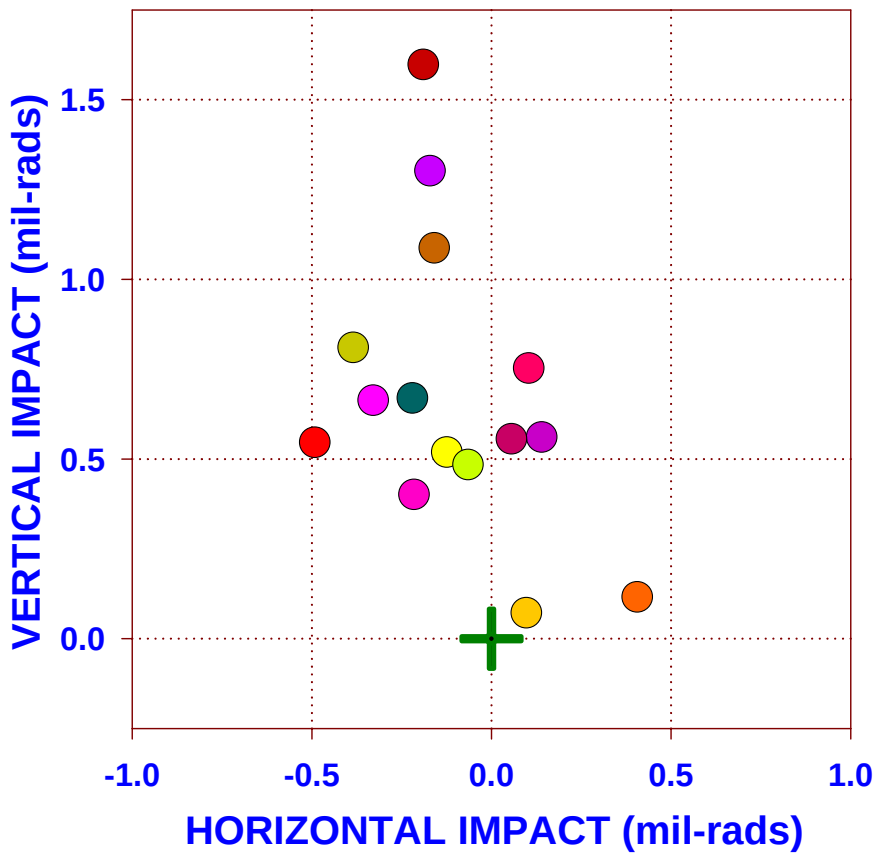
We have nearly 200 test and simulation shots to use in this averaging process.

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COMPILATION OF RESULTS FOR ALL 20 CASES

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MEAN IMPACT LOCATIONS FOR TEST DATA

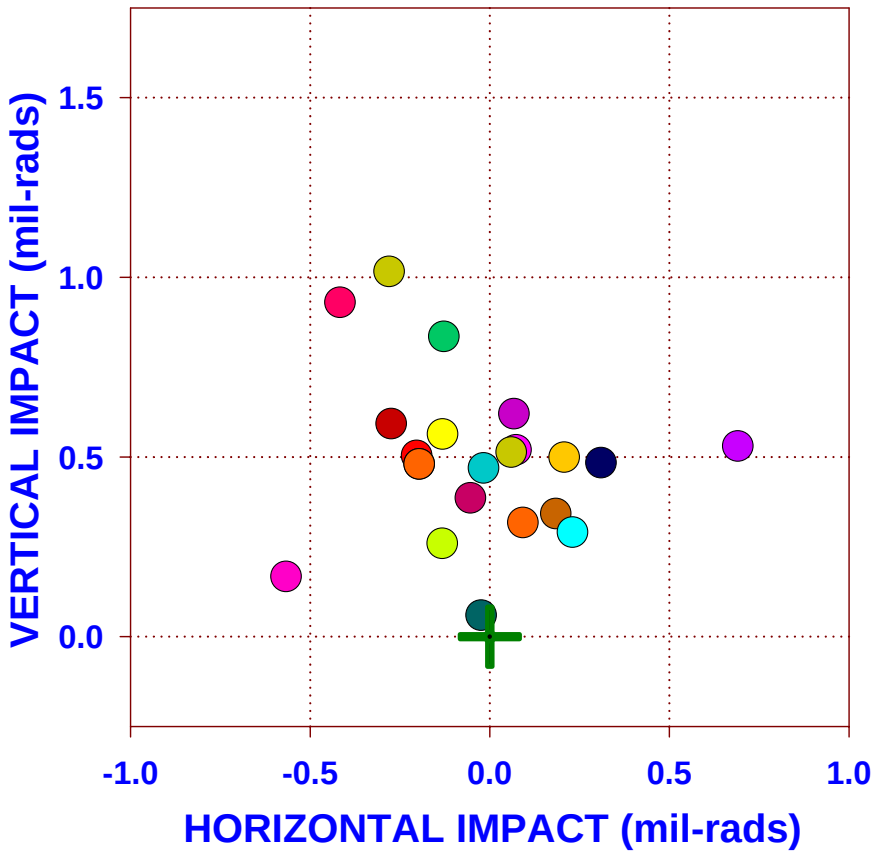


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COMPILATION OF RESULTS FOR ALL 20 CASES

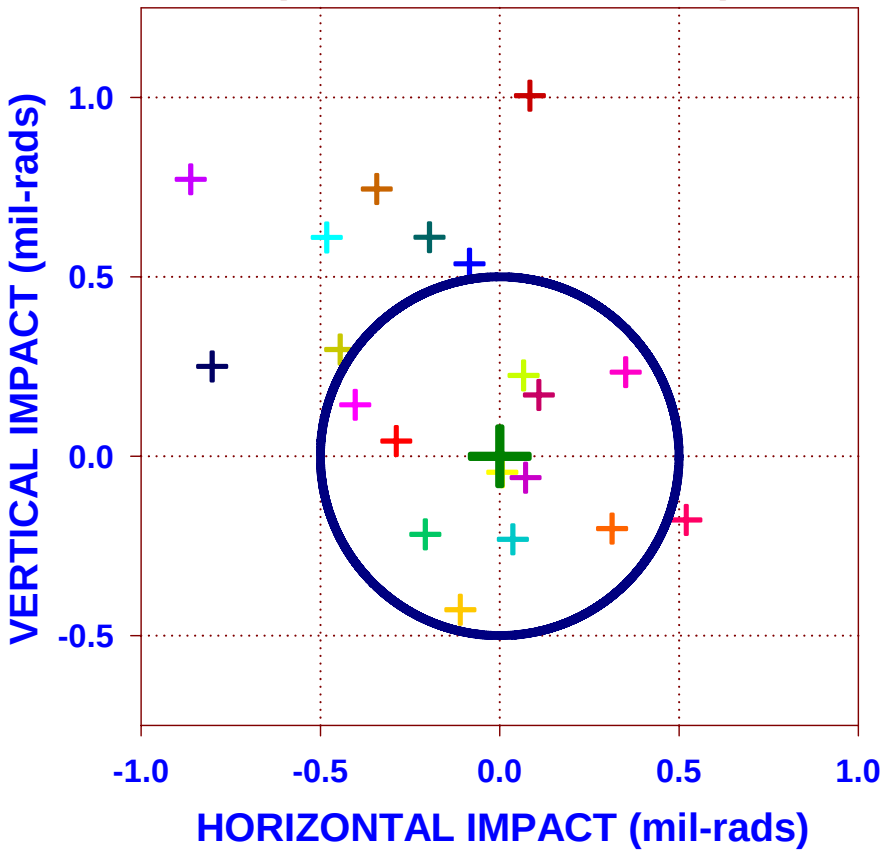
MEAN IMPACT LOCATIONS FOR SIMULATED RESULTS



ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

COMPILATION OF RESULTS FOR ALL 20 CASES

DIFFERENCE IN MEAN VALUES (TEST - SIMULATION)



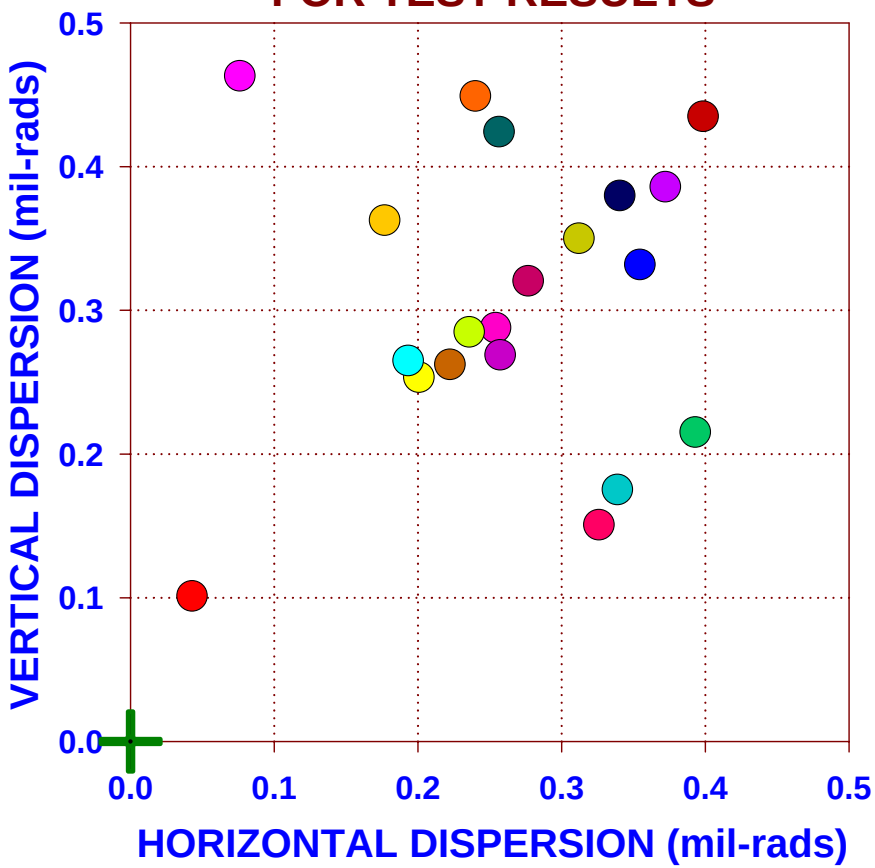
ISO 9001 Certified
FS15149

ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

ISO 9001 Certified
FS15149

COMPILATION OF RESULTS FOR ALL 20 CASES

DISPERSION VALUES FOR TEST RESULTS

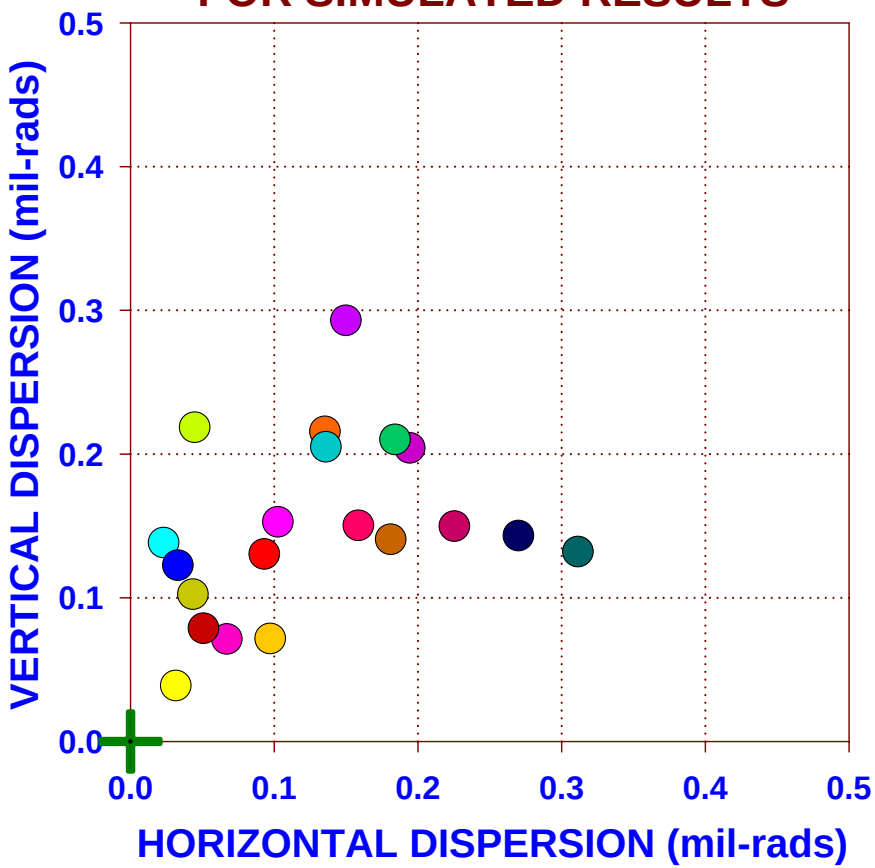


ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

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FS15149

COMPILATION OF RESULTS FOR ALL 20 CASES

DISPERSION VALUES FOR SIMULATED RESULTS

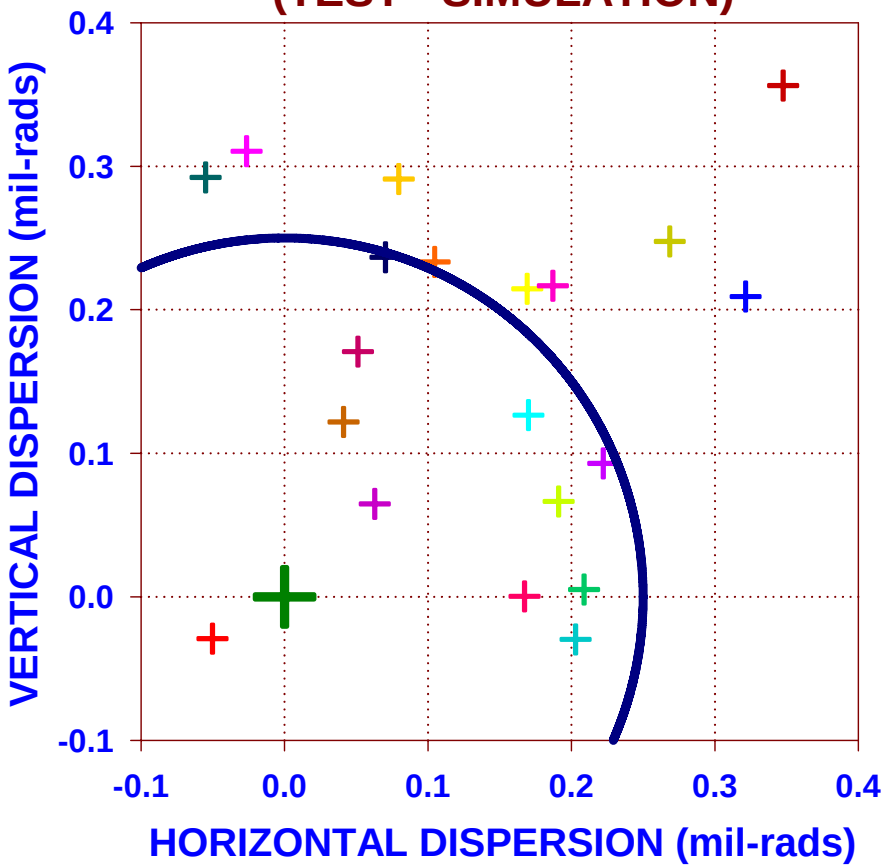


ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

ISO 9001 Certified
FS15149

COMPILATION OF RESULTS FOR ALL 20 CASES

DIFFERENCE IN DISPERSION
(TEST - SIMULATION)



ACCURACY MODELING OF THE 120mm M256 GUN AS A FUNCTION OF BORE CENTERLINE PROFILE

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DISCUSSION AND CONCLUSIONS

An attempt was made to validate coupled simulation routines for predicting projectile impact locations as a function of the bore profile of the gun tube.

Predictions were made for individual shots as well as an averaging method applied to groups of shots.

Mean and dispersion values were compared, the results of which indicated the following:

In 70 percent of the cases the difference between predicted and simulated mean values was equal to or less that 0.50mr

In 60 percent of the cases the difference between predicted and simulated dispersion was less than 0.25mr

Given the level of uncertainty of several parameters we feel that these results are quite good.



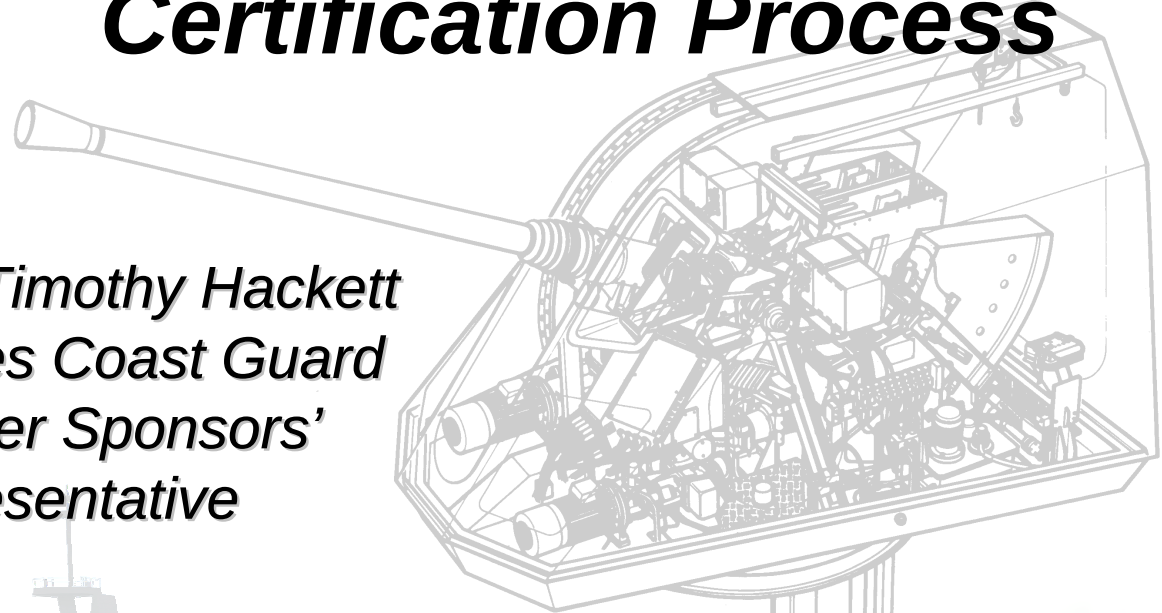


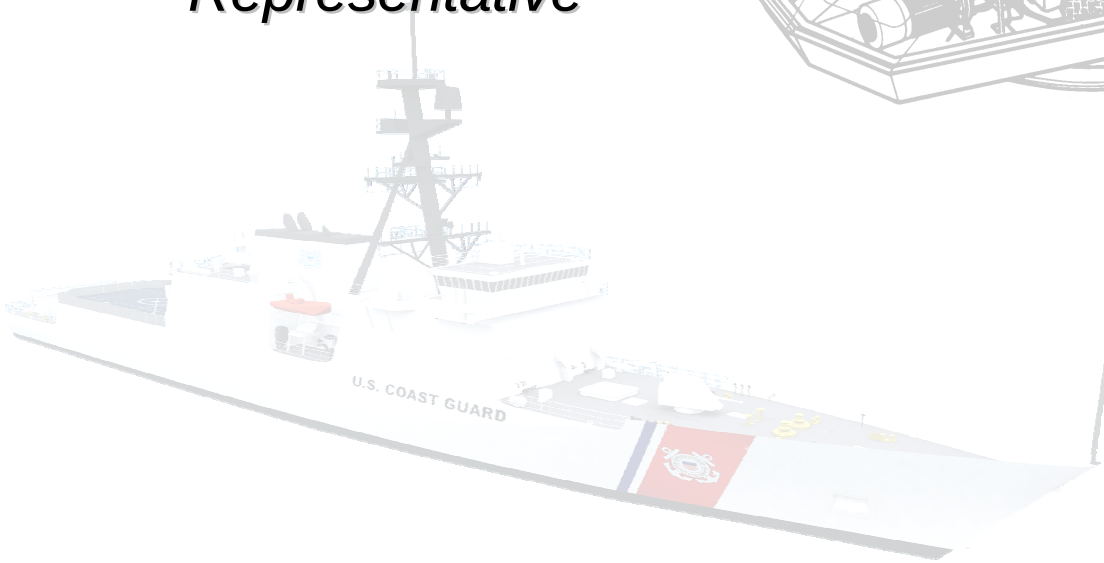
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rgast@pica.army.mil

Mk 110 Mod 0 / 57mm Naval Gun & Ammunition Certification Process

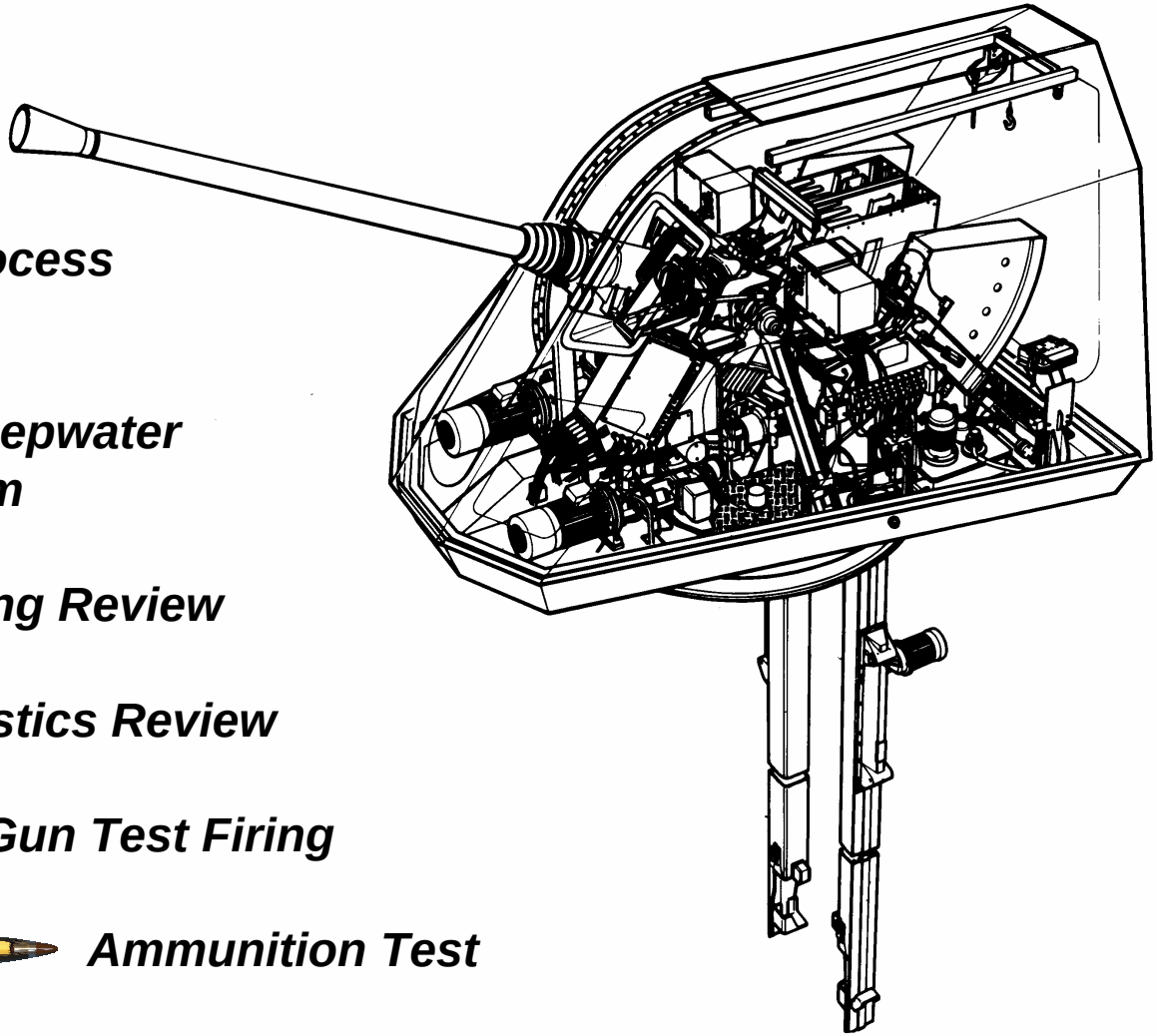
Lieutenant Timothy Hackett
United States Coast Guard
Deepwater Sponsors' Representative







Mk 110 Mod 0 / 57mm Naval Gun & Ammunition



Certification Process Includes:

- ***Review of Deepwater Program***
- ***Engineering Review***
- ***Logistics Review***
- ***Gun Test Firing***
- ***Ammunition Test***
- ***Teamwork***

USCG Deepwater Program



The Maritime Security Cutter, Large (WMSL) System Performance Specification identifies multiple requirements for limited general defense operations. The requirements include: operating in a low-threat environment, ability to fire warning and disabling shots against targets of interest, engaging surface threats achieving mission kill on high speed coastal patrol craft

Engineering & Logistics Review



57mm Mk 110 Mod 0 Gun in Test Stand @ Louisville, KY

57mm Gun Test Fire Series





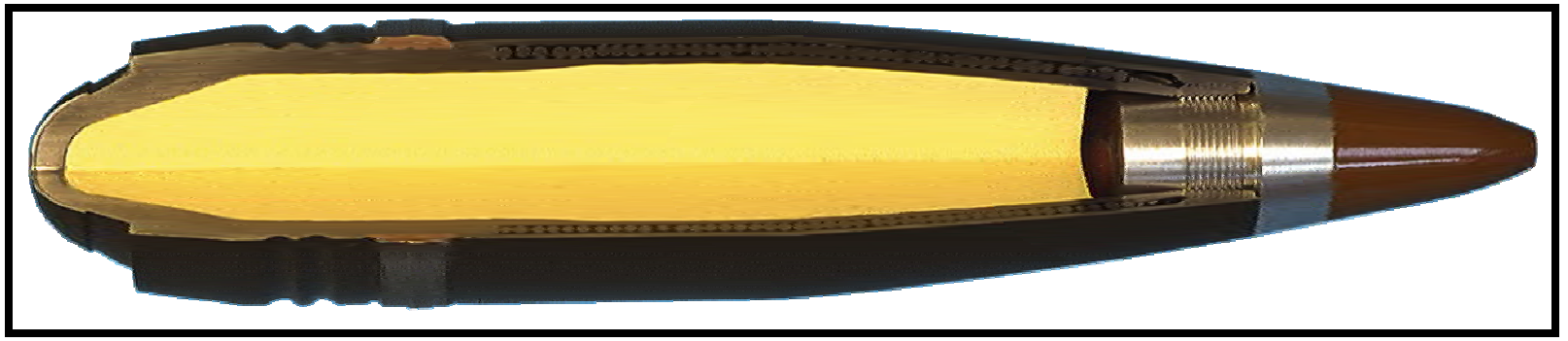




Test firings conducted on the Potomac River Test Range

57mm Ammunition









Ammunition Test

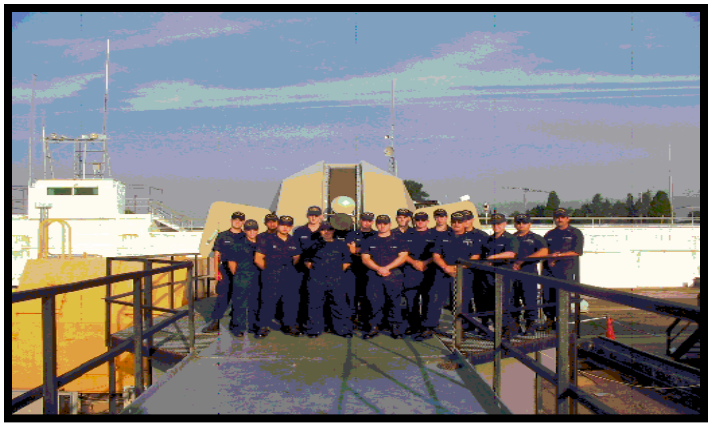




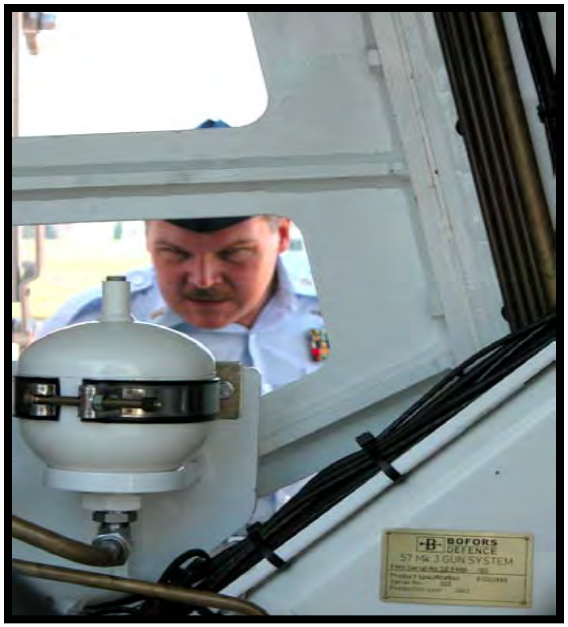




USCG / NAVSEA Teamwork











So What Did We Accomplish?

- *Complete understanding of the 57mm Gun*
- *Test Firing of over 2000 Rounds of Ammo*
- *Coast Guard Gunner's Mate Integration Test*
- *USCG / NAVSEA / Industry Teamwork*
- *Ready to present results to the USN's Weapon System Explosive Safety Review Board (WSESRB) ~ 09 May 2005 ~*

57mm Gun Video Presentation



Traver Sutton

Naval Surface Warfare Center Dahlgren

Gun Weapons System Branch (G-32)

Estimating Ballistic Limits of Skin and Clothing for Projectiles

PRESENTED BY:
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Introduction-1

- This paper reports the development of an accurate correlation function for the ballistic limit velocity (that velocity for which there is a 50% probability of target perforation, V_{50}) over a wide range of projectiles striking bare skin and skin covered by various amounts and types of clothing.
- Accurate determination of the ballistic limit of skin and skin covered with various clothing is essential to accurate estimates of incapacitation levels by all models for incapacitation.
- Projectiles that must meet a requirement of being less-than-lethal (the non-perforation of skin, covered or uncovered) are just as demanding of an equally accurate determination of their ballistic limits.

Introduction-2

- The determination of being less-than-lethal (no breaking of the skin) used by the U. S. Army's Office of the Surgeon General is based on not exceeding a specified value of the ratio (for any projectile) of its kinetic energy to its presented cross-sectional area. This is for bare skin only
- As will be shown here, this ratio does not remain a constant over the range of projectile and skin properties for which it is necessary to determine the velocity limit for the perforation of skin.

Discussion-1

- Applicable data from eight studies were found in References 1- 5. A major issue with most of these sources is they give a range of velocities for "penetration" without a definition of "penetration".
- Only Lewis *et al* (Ref. 5) reported the velocity and the perforation or non-perforation of the target skin and covering for each and every shot fired.
- This paper uses V_{50}, the velocity at which one-half of the tested projectiles will perforate the target and one-half will not, as the best estimate of the minimum velocity for perforation in the presence of velocity overlap.

Discussion-2

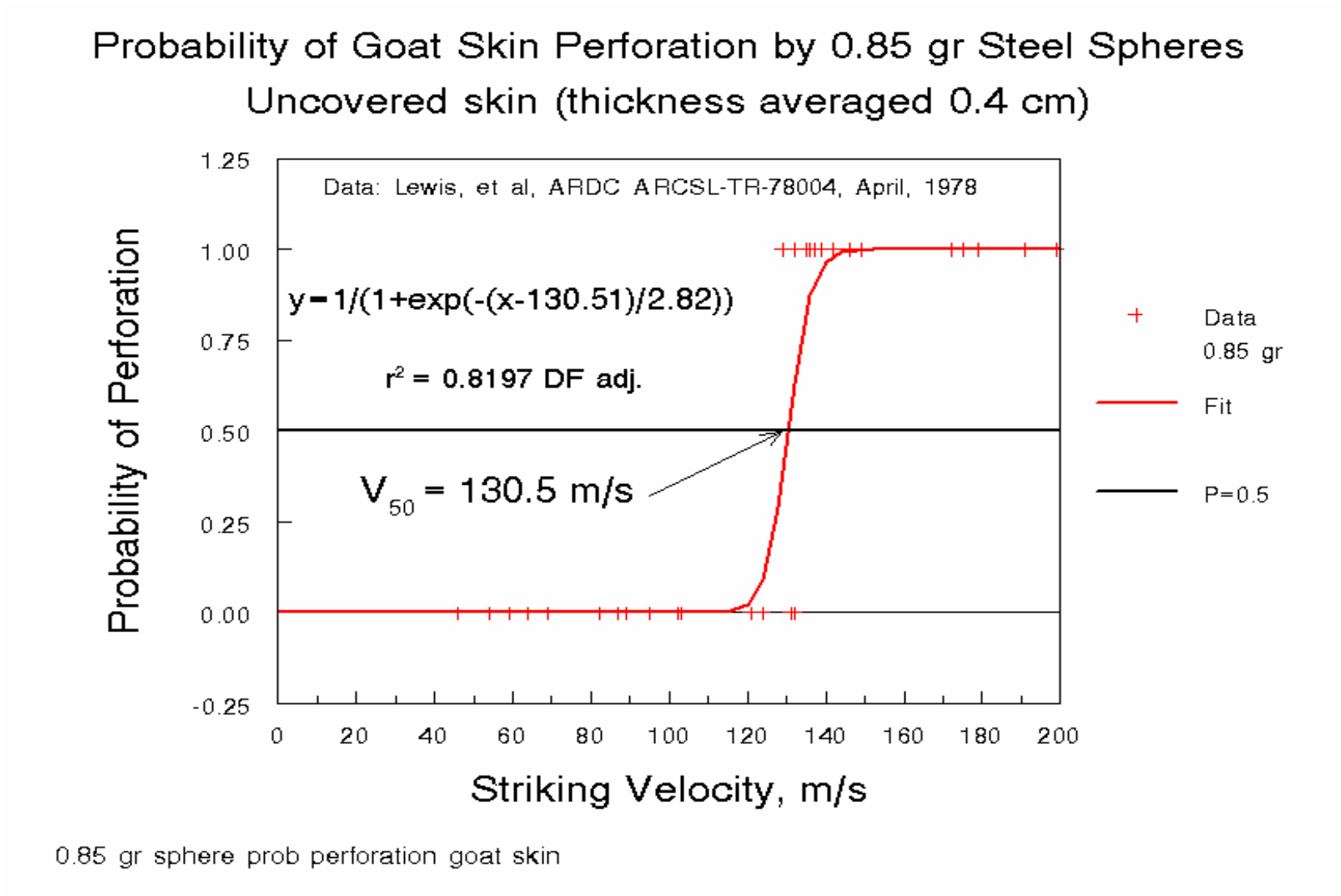


Fig. 1 Example of Probability of Perforation vs Striking Velocity

Discussion-3

- For the sources with only velocity spreads it was necessary to provisionally use the mean of the spread to approximate V_{50}. This provisional use was shown to be reasonable when the data from the sources and the data from Lewis *et al* for which the more exact method was used correlated equally well.
- MacPherson (Ref. 2) used sectional density as a correlation parameter and he showed good results for bare skin. The data in Kokinakis and Sperrazza (Ref. 3 and 4) and in Lewis, *et al* (Ref. 5) that include bare skin and various clothing layers could not be correlated using only projectile sectional densities.
- It is clear that target skin and covering properties also need to be included in the correlation parameter. The obvious starting point is to use a perforation parameter, analogous to the penetration parameter defined for flight,

Discussion-4

$$P \equiv 2m/(\rho t A_p)$$

where,

ρ = target density

m = projectile mass

t = target skin and covering thicknes

A_p = projectile average presented area

Discussion-5

- The average presented area of a stable projectile is the maximum cross-sectional area perpendicular to the flight axis, and it is the average presented area for an unstable projectile. It has been proven (e.g., Ref. 7) that for any shape composed of non-concave surfaces that the average presented area is given by:

$$A_p = \underline{\text{Total Surface Area}} \,/4$$

- The one exception found in the data used was for unstable cubes (Refs. 4 & 5). The differences in skin thicknesses used between Ref. 4 and Ref. 5 still allowed good correlation of all cube data, therefore, attention shifted to the effective area.
- Empirically, and **only for the case of bare skin**, dividing the cubes' average presented area by 3.37 brought the tumbling cubes back into line with the other shapes when perforating skin and with cubes perforating cloth-covered skin.

Discussion-6

- This suggests the needed area reduction is not due to an incorrect average area but it is the result of the cubes sometimes striking primarily with a point or edge. This creates very high stress concentrations in the bare skin.
- The fact that an area reduction is not needed when the skin is cloth-covered supports this hypothesis. Cloth pushed in front of the cube (even as loose pieces) effectively blunts edges and corners and reduces stress concentrations.

Modeling Clothing-1

- Clothing properties can often be input directly into the model as the product ρt is exactly the areal density usually used to describe the “weight” of clothing.
- The way to account for multiple clothing layers of different areal densities is to determine the effective areal density of all the layers, $(\rho t)_{eff}$.

Modeling Clothing-2

- Effective areal density is computed as:

$$(\rho t)_{eff} = \sum_{1}^{i} (\rho t)_i = \sum_{1}^{i} \rho_i t_i \square \square [$$

or combine the forms as required by the available data.

Fitting the Data-1

- The actual data points fitted are given in Table 1 and were computed from the values of skin thickness and density and clothing areal density reported, when available. When not available, average values of the reported data were used.
- Table 1 arranges the parameterized data by experimenter, type of projectile, and the makeup of the target covering (bare skin, skin plus 2-layer clothing (summer uniform), or skin plus 6-layer clothing (winter uniform). The final fit using a nonlinear method is described next.

Results-1

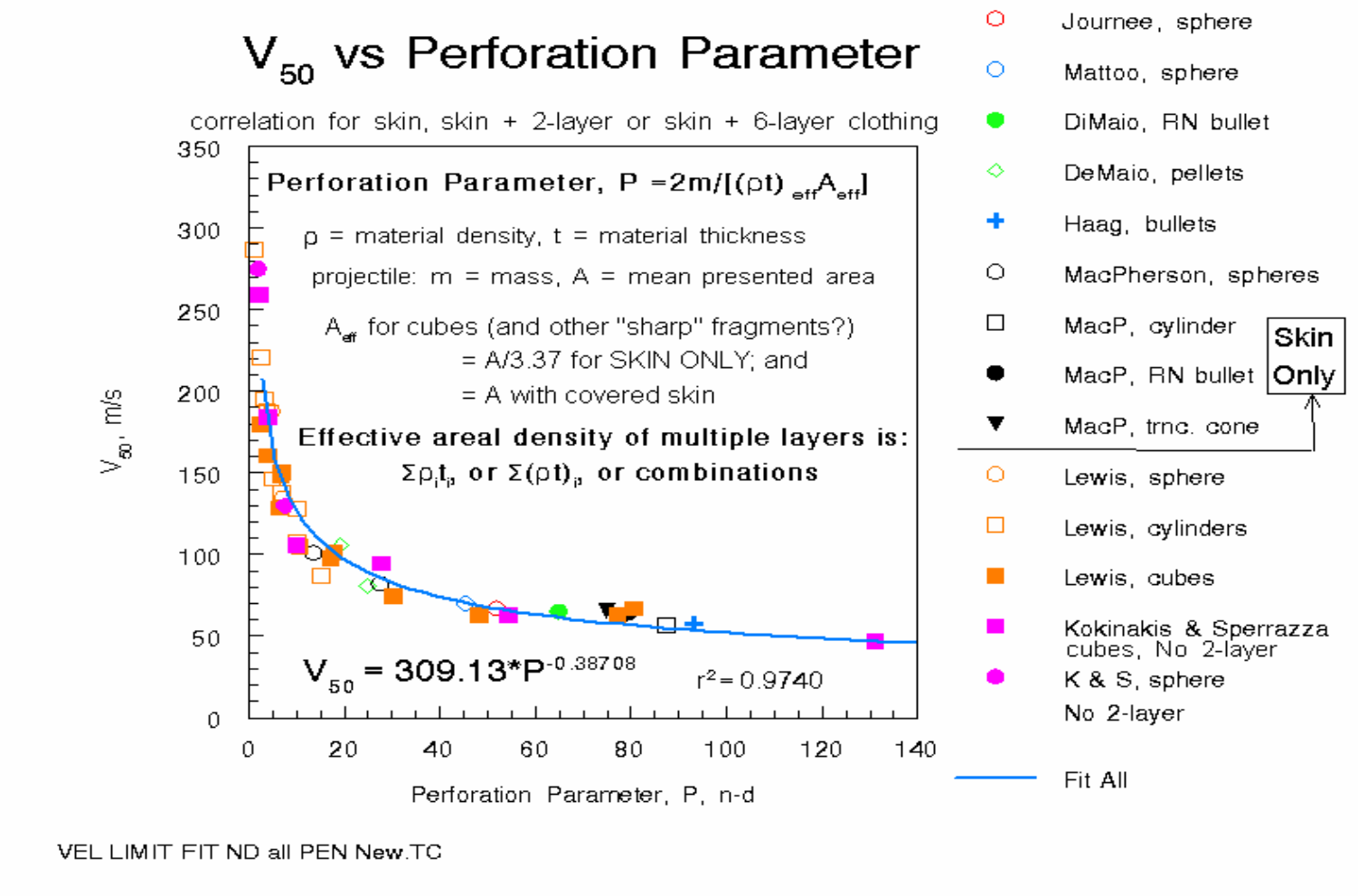


Figure 2. V_{50} vs Perforation Parameter

Results-2

- When densities, thicknesses, and/or areal densities are not available for the estimates that need to be made, use a skin density of 1.06 gm/cm^3 and a skin average thickness (based on all the sources) of 0.31 cm and the clothing areal densities from Lewis *et al* (Ref. 5).

Target Skin and Covering	Effective Areal Density, $(\rho t)_{eff}$
	gm/cm^2
skin	0.33
skin + 2-layer summer uniform	0.49
Skin + 6-layer winter uniform	1.30

Compare Correlation and Energy/Area-1

- Given this correlation equation, the approach using striking energy divided by projectile presented area is a constant that defines the ballistic limit can be shown to be less accurate even when accounting for target skin and covering properties.

Compare-2

- Using energy equals one half mass times velocity squared, the correlation equation yields the following:

$$E_{50} / A_{eff} = 2^{-(1-2b)}\ a^2\ (\rho t)_{eff}^{-2b}\ (m/A_{eff})^{(1+2b)}$$

where, a is the multiplier and b is the exponent of P in the fitting equation, $(\rho t)_{eff}$ is the effective areal density of the target skin and covering, and m/Aeff is the projectile's mass over its presented area. It is clear for any given target skin and covering E50/Aeff cannot be a constant when m/Aeff varies since b = -0.38708 and, therefore, (1+2b) is not zero. A constant ratio requires b = -1/2. A fit using this value was tried and yielded a poorer fit, as expected.

Conclusions-1

- It is necessary to include target skin and clothing areal density in the correlation parameter to allow the results from different layers and types of clothing to be collapsed into the same curve for predicting V_{50}.
- An excellent correlation has been found for V_{50} (ballistic limit) using a physically meaningful non-dimensional combination of projectile and target skin and covering properties (named here the perforation parameter).
- This correlation has been demonstrated for a wide range of projectile shapes, dimensions, and masses for bare skin and skin covered with multiple layers of differing clothing.

Conclusions-2

A power law very well fits this general new correlation.

$$V_{50} = 309.13 P^{-0.38708}$$

$r^2 = 0.9740$

Conclusions-3

- This fit has direct application with improved accuracy and generality for determining the safe limit for less-than-lethal projectiles for bare skin and skin covered with various clothing.
- It is also essential to determining levels of incapacitation. All incapacitation models must compute or be provided with the velocity variation with distance through the specified target.
- The velocity losses from clothing, etc. are required to provide the correct initial velocity condition.
- Now that the form of a good fit to the data is known, it also demonstrates that the quantity – striking energy divided by projectile presented area – cannot be made a constant without producing a poorer fit to the data, even when accounting for skin and clothing properties.

Recommendations-1

- It is recommended the perforation performance of unstable cubes and other unstable “sharp-edged” projectiles be investigated further to see if the “cutting” hypothesis proposed here for the skin only case can be confirmed or some other explanation found. Special attention should be given to the evidence that clothing appears to eliminate this effect.

Recommendations-2

- The sources used in this analysis supported the skin or covered skin target differently. Some did not specify how, others stretched the target in a frame, and still others backed up the target with a gelatin block. A test series with the same backing for all targets should be conducted.
- Since how V_{50} is best used to estimate the remaining velocity of a projectile that has excess striking velocity is still being debated, tests should be conducted without a support behind the target and the exit velocity measured. Parenthetically, the most common suggestion for estimating remaining velocity is based on energy: $V_{out} = \sqrt{(V_{in}^2 - V_{50}^2)}$.

References

1. Demaio, Vincent J. M., **Gunshot Wounds**, CRC Press, Boca Raton, FL, 1985
2. MacPherson, Duncan, **Bullet Penetration**, Ballistic Publications, Box 772, El Segundo, CA 90245, 1994
3. Kokinakis, William and Sperrazza, Joseph, *Criteria for Incapacitating Soldiers with Fragments and Flechettes,* BRL Report No. 1269, January 1965, Ballistic Research Laboratories, Aberdeen Proving Ground, MD 2101
4. Sperrazza, J. and Kokinakis, W., *Ballistic Limits of Tissue and Clothing,* BRL Technical Note 1645, January 1967, Ballistic Research Laboratories, Aberdeen Proving Ground, MD 21010
5. Lewis, James H., *et al, An Empirical/Mathematical Model to Estimate the Probability of Skin Penetration by Various Projectiles,* Technical Report ARCSL-TR-78004, April, 1978, US Army Armament Research and Development Command, Chemical System Laboratory, Aberdeen Proving Ground, MD 21010
6. Walker, S. H. and Duncan, D. B., *Estimation of the Probability of an Event as a Function of Several Independent Variables,* **Biometrika** *54*, 167-179 (1967)
7. Matney, M., *How to Calculate the Average Cross-Sectional Area,* **The Orbital Debris Quarterly News**, Vol. 8, Issue 2, pg 7, April 2004

Table 1-1. Ballistic Limit Velocity vs Perforation Parameter by Source, Type, and Target Skin and Covering

P_{n-d}	V_{50}, m/s								
	Journee	Mattoo	DiMaio		Haag	MacPherson			
	sphere	sphere	round nose bullet	BB pellet	various shaped nose bullets	sphere	cylinder	round nose bullet	truncated cone nose bullet
	skin	skin	skin	skin	skin	skin	skin	skin	skin
51.82	67.1								
45.33		70.1							
64.82			65.0						
24.82				81.0					
19.21				106.0					
93.18					57.3				
13.55						101.0			
27.48						82.0			
87.27							56.4		
79.30								64.0	
74.94									65.5

Table 1-2. Ballistic Limit Velocity vs Perforation Parameter by Source, Type, and Target Skin and Covering

P, n-d	V_{50}, m/s								
	Lewis, Coon, Clare, and Sturdivan								
	sphere 0.85 gr	sphere 0.85 gr	sphere 0.85 gr	cylinder 0.5 in length	cylinder 0.5 in length	cylinder 0.5 in length	cylinder 1.0 in length	cylinder 1.0 in length	cylinder 1.0 in length
	skin	skin + 2-layers	skin + 6-layers	skin	skin + 2-layers	skin + 6-layers	skin	skin + 2-layers	skin + 6-layers
7.15	134.6								
4.82		188.0							
1.82			259.1						
4.88				146.4					
3.29					195.3				
1.24						286.5			
10.12							107.2		
6.86								137.5	
2.57									220.5

Table 1-3. Ballistic Limit Velocity vs Perforation Parameter by Source, Type, and Target Skin and Covering

P, n-d	V_{50}, m/s								
	Lewis, Coon, Clare, and Sturdivan								
	cylinder 1.5 in length	cylinder 1.5 in length	cylinder 1.5 in length	cube steel 4 gr	cube steel 4 gr	cube steel 4 gr	cube steel 16 gr	cube steel 16gr	cube steel 16 gr
	skin	skin + 2-layers	skin + 6-layers	skin	skin + 2-layers	skin + 6-layers	skin	skin + 2-layers	skin + 6-layers
15.09	87.2								
10.16		127.8							
3.83			187.7						
30.20				74.8					
6.72					148.1				
2.54						180.0			
48.16							62.7		
10.65								104.7	
6.74									150.5

Table 1-4. Ballistic Limit Velocity vs Perforation Parameter by Source, Type, and Target Skin and Covering

P, n-d	**V_{50}**, m/s							
	Lewis, Coon, Clare, and Sturdivan						Kokinakis & Sperrazza, 1965	
	cube tungsten 16 gr	cube tungsten 16 gr	cube tungsten 16 gr	cube steel 64 gr	cube steel 64 gr	cube steel 64 gr	cube steel 2.1 gr	cube steel 2.1gr
	skin	skin + 2-layers	skin + 6-layers	skin	skin + 2-layers	skin + 6-layers	skin	skin + 6-layers
80.50	67.0							
17.88		101.3						
4.02			160.5					
77.14				62.9				
17.12					97.5			
6.45						128.4		
27.74							94.5	
2.09								259.0

Table 1-5. Ballistic Limit Velocity vs Perforation Parameter by Source, Type, and Target Skin and Covering

P, n-d	V_{50}, m/s					
	Kokinakis and Sperrazza, 1965				Kokinakis & Sperrazza, 1967	
	cube steel 16 gr	cube steel 16 gr	cube steel 225 gr	cube steel 225 gr	sphere steel 0.85 gr	sphere steel 0.85 gr
	skin	skin + 6-layers	skin	skin + 6-layers	skin	skin + 6-layers
54.38	62.8					
4.10		184.0				
131.11			47.2			
9.89				106.0		
7.61					129.9	
1.92						275.0

MSIAC

Supporting Munitions Safety

Munitions Safety Information Analysis Center

A Review of The Insensitive Munitions Design Technology Workshop

By Pascal Marchandin (MSIAC)

TSO Munitions Systems

Co-author: Ian J. Powell

2005*



Contents

- **Introduction:**
  - MSIAC
  - Insensitive Munitions
- **Workshop Outline**
- **Summary Of Final Output**
  - Key Factors
  - General IM Technology Status
- **Conclusion**



















Munitions Safety Information Analysis Center (MSIAC)

MSIAC (formerly NIMIC): a NATO Project funded by its member Nations

Answers to Technical Inquiries	50,000+ reports, journals, references, STANAGS; POC's
Software & Databases	Range of munition safety related topics
Technical Reports	Topics of interest, reviews, tutorials
Focused Training	Example: Short courses for Finnish services
Workshops & Tech. Meetings	Reaction mechanisms, testing, implementation…
Internet	E-groups, Open website, secure website

Insensitive Munitions: Why?

4 US Navy Aircraft Carrier Accidents: 1966 - 1981



Bien Hoa AF Base – 1965



Da Nang ASP – 1969



Killed: 251/99 (if IM)
Injured: 985/226 (if IM)

Roseville, CA 1973

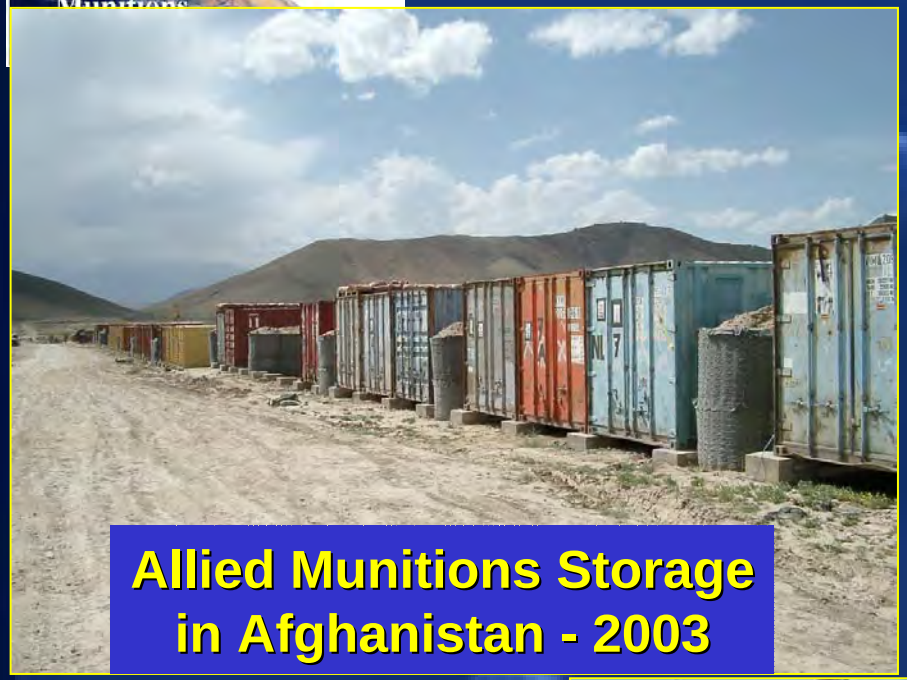


Camp Doha – 1991



IM Cost savings: US$ 2,340 M (FY-2004)

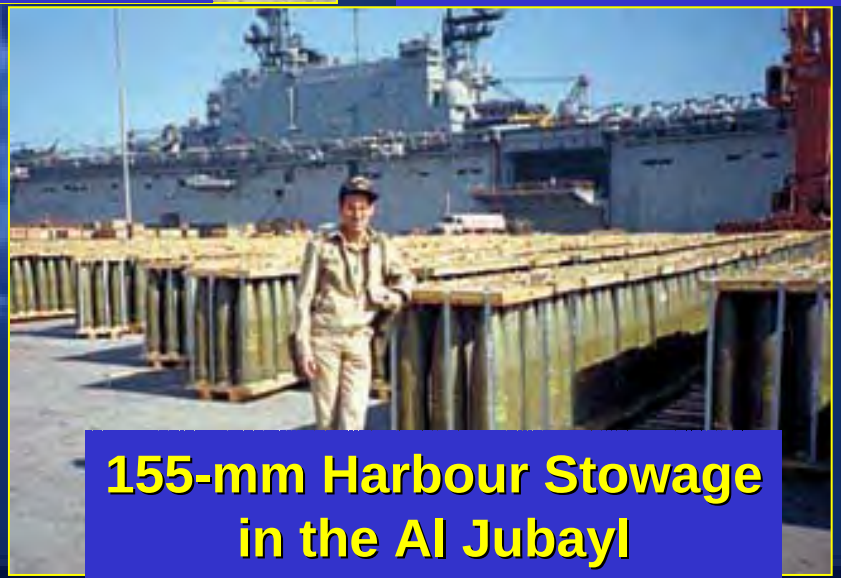
Insensitive Munitions: Recent Headlines



Allied Munitions Storage in Afghanistan - 2003



US Aircraft Carrier Deck: Armed Aircraft - 2003



155-mm Harbour Stowage in the Al Jubayl

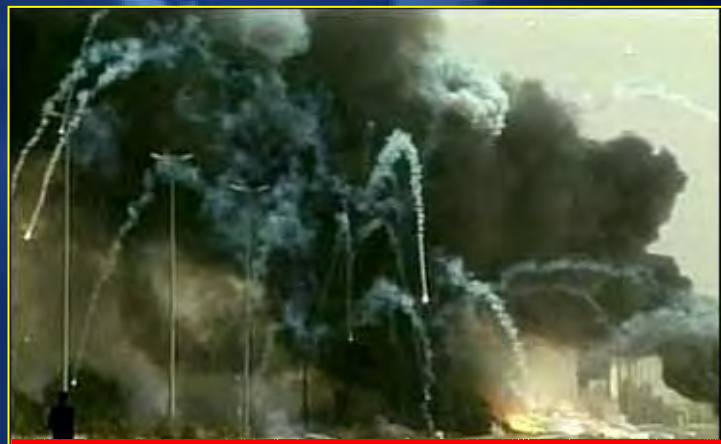
Insensitive Munitions: Recent Headlines

MSIAC
Supporting Munitions Safety

32 killed, 70 injured



Spin Boldak, Afghanistan, 28/06/02 – Attack



Fallujah, Iraq
19/10/03 – RPG Attack

6-14 killed, > 50 injured



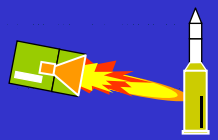
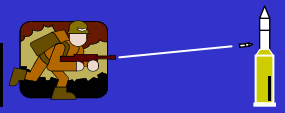
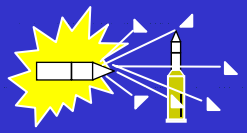
Zaafaraniya, Iraq, 26/04/03 – Attack

USAF Base, Kirkuk, Iraq
02/06/04 – Rocket Attack



Tests and Reaction Levels

Threats

- Shaped Charge Weapon Attack 
- Detonation in Magazine, Store, Aircraft or Vehicle 
- Magazine, Store, Aircraft or Vehicle Fuel Fire 
- Fire in Adjacent Magazine, Store, or Vehicle 
- Small Arms Attack 
- Fragmenting Munitions Attack 

Tests

- Shaped Charge Jet Impact
- Sympathetic Reaction
- Fast Cookoff
- Slow Cookoff
- Bullet Impact
- Fragment Impact

Responses

- **Type I Detonation**
- **Type II Partial detonation**
- **Type III Explosion**
- **Type IV Deflagration**
- **Type V Burning**

More Severe

Less Severe

NIMIC IMDT Workshop



- The NIMIC IM Design Technology workshop was held between 29th September and 2nd October 2003 at the Royal Military College of Science, Shrivenham, UK
- The UK DOSG provided sponsorship
- 92 Participants.

IMDT Workshop Final Output

MSIAC Restricted Document L-101:
Report on the State of the Art of IM Design Technology

Key Factors

Common
&
Specific

General IM Technology Status

- Payload
- Delivery Systems: Rocket Motors & Gun Propellant Charges
- Auxiliary Explosive Devices
- Packaging
- System Integration

MSIAC Limited Presentation:
IM SoA version 1.4 – Compendium of 29 “IM” Systems

Common Key Factors (1)

Material Properties ← **Casing** → **Configuration**

Heat transfer rate.

Attenuation of impacting bullets, frags, shock wave. Frag projection.



Thermal

Impact

Confinement (Venting).

Confinement (Venting). Shock attenuation (Case thickness).

Common Key Factors (2)

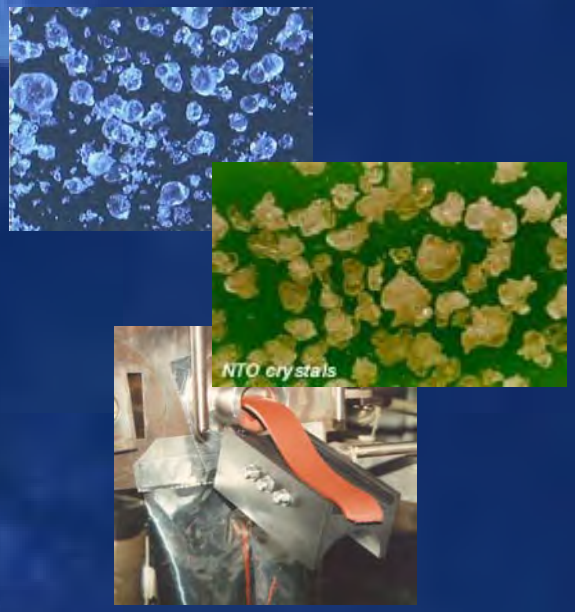
Energetic Material

Explosiveness

Sensitiveness

DDT/BVR Tendency.

DDT/BVR Tendency.



Thermal

Impact

Auto-ignition Temperature (Booster vs Main Charge). Chemical Stability.

Ignitability (mechanical properties, shock sensitivity, extinguishability etc.).

Specific Key Factors

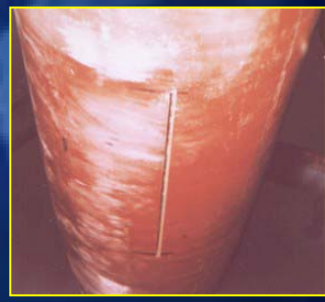
Propellant	Packaging	System Integration
Charge Configuration	Spatial Configuration	Mech. properties of degraded architecture
Propellant Cd vs Web.	Propagation (SR).	Venting systems.
DDT Tendency (Depends on geometry, bed density & distribution).	Thermal Impact	Barriers.

Payload: IM Technology Status

Payload Type	FCO	SCO	BI	FI	SR	SCJ
Penetrators	V	V	V	V	P^C	P
Fragmenting Warheads	V	V	IV/V	IV/V	F/P^C	F
Shaped Charge	V	V	V	I/IV	P^C	F

C=In Container/Stowage Configuration

- **Technology**
  - Explosives: Cast & Pressed Cast PBX (RDX, HMX, NTO, Al, AP)
  - Design/Mitigation: Intumescent paint, venting, internal liners
- **Technology deployment: HIGH**
- **Shortfalls**
  - Explosives with lower shock sensitiveness











Payload: IM Technology Status(2)



Payload Type	FCO	SCO	BI	FI	SR	SCJ
Guns & Mortar Ammunition	IV/V	IV/V	V	III/V	P[C]	P[C]
Submunitions	IV/V	III/V	IV/V	IV/V*	P[C]	F



*In carrier shell; C=In Container

- **Technology**
  - Explosives: Cast & Pressed PBX (RDX, HMX), Melt-cast (DNAN, Wax, NTO/TNT)
  - Design/Mitigation: Cook-off resistant boosters, Fusible fuze adaptors (Guns & Mortar Ammunition)
- **Technology deployment:**
  - Guns/Mortar = LOW; Submunitions = MEDIUM;
- **Shortfalls**
  - FI/SCJ resistant explosives
  - Guns/Mortar: Lower cost explosive filling (process/EM).







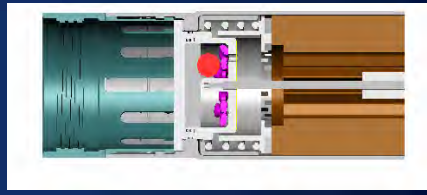
Delivery Systems: IM Technology Status

Rocket Motor Type	FCO	SCO	BI	FI	SR	SCJ
Minimum Smoke	V	III/V	IV/V	I/III	P[C]	F

C = In Container

- **Technology**
  - Propellant: Less sensitive nitrate esters, Reduce/eliminate sensitive nitramines, unfilled EMCDB
  - Mitigation: Case deconfinement (CFRP, SSL, KOA, Bonded end closures, Shear pins, Shape memory metal joints), Preferential insulation
- **Technology deployment: MEDIUM**
- **Shortfalls**
  - FI low shock sensitivity propellant with suitable performance
  - SCO mitigation devices
  - SCJ mitigation.











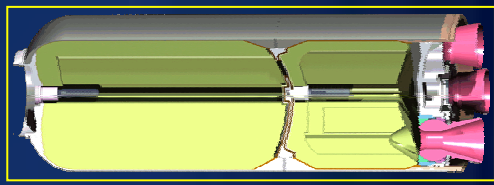
Delivery Systems: IM Technology Status

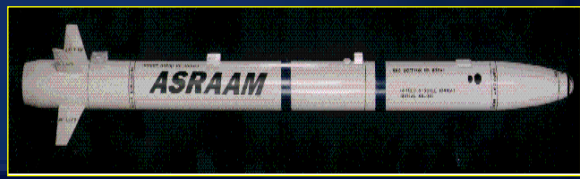
Rocket Motor Type	FCO	SCO	BI	FI	SR	SCJ
Reduced Smoke	V	IV	V	IV/V	P	NA
High Performance	IV/V	I/III	III/IV	III/IV	P	F

- **Technology**
  - Propellant: HTPE/Butyl-NENA binder, Partial replacement of AP with AN, Eliminate nitramines
  - Mitigation: Case deconfinement (CFRP, SSL, KOA, Bonded end closures, TIVS), Preferential insulation
- **Technology deployment:**
  - Reduced Smoke = HIGH
  - High Performance = LOW
- **Shortfalls**
  - SCO mitigation devices
  - BI, FI & SCJ mitigation.









Delivery Systems: IM Technology Status

Delivery System	FCO	SCO	BI	FI	SR	SCJ
Gun Propellant Charge System	V	IV/V	IV/V	III/V	P	P^C

C = In Container

- **Technology**
  - Propellant: Composite propellant (LOVA, LOVA/CAB)
  - Mitigation: Fusible parts in container, Combustible case
- **Technology deployment: LOW**
- **Shortfalls**
  - Low cost-lightweight packaging materials
  - Progression of next generation LOVA type propellants
  - SCJ mitigation
  - Reduced vulnerability high performance propellants (esp. direct fire).





Packaging: IM Technology Status

Type	FCO	SCO	BI	FI	SR	SCJ
Propelling Charges	V	IV/V	IV/V	III/V	P	NA
High Value Munitions	NA	NA	V	V	P	NA





- **Considerable progress in IM technology; wide range of materials available**
- **Technology deployment: HIGH**
- **Shortfalls**
  - **Suitable lightweight inexpensive materials (for low cost munitions)**
  - **Assessment of candidate materials**
  - **Materials to mitigate SCJ.**









MSIAC
Supporting Munitions Safety

Conclusions

Technology is **sufficiently mature** for the design of IM compliant (or near compliant) solutions for most munition types

Acceptable technical risks
Acceptable costs
Acceptable performance

Many munitions have been introduced into service that are IM compliant (or near compliant).

MSIAC

Supporting Munitions Safety

Questions?



FCO	SCO	BI	FI	SCJ	SD	CATEGORY FAMILY	FCO	SCO	BI	FI	SCJ	SD
						Bombs						
						Penetrators						
						Directed Energy						
						Submunitions						
						Anti-Air Missile Warheads						
						Anti-Ship Missile Warheads						
						Land Missile Warheads						
						Projectiles						
						Propelling Charges						
						Underwater Warheads						
						Min. Smoke Rockets Motors						
						Reduc. Smoke Rocket Motors						
						Booster Rockets						

1985

2002

- **Contacting MSIAC:**
  - **Address:** MSIAC / NATO HQ
    B-1110 Brussels, Belgium
  - **Phone:** +32.(0)2.707.54.16
  - **Fax:** +32.(0)2.707.53.63
  - **Email:** MSIAC@hq.nato.int
  - **Website:** http://hq.nato.int/related/msiac
  - **Secure Website:** https://msiac.hq.nato.int

Mk44

Gun / ammo ipt

NDIA, GARM Symposium, April 2005

Major K.D. Mullins, DRPM AAA











Mk44

Gun / Ammo IPT

- Government Members:
  - USMC DRPM AAA / Expeditionary Fighting Vehicle
    - Sponsor
  - USN LPD-17 / RAMICS
  - US Army / FCS
  - US Air Force / ACU-130
  - US Coast Guard / DWP

Mk44

Gun / Ammo IPT

- Industrial Partners:
  - ATK Gun Systems
  - ATK Ordinance
  - General Dynamics – Ordinance Tactical Systems
  - Oerlikon Contrives
  - NAMMO
  - Diehl
  - General Dynamics Amphibious Systems
  - UDLP / Boeing / SAIC

Mk44

Gun / Ammo IPT

- Additional Members:
  - ArrowTech
  - DSTL (MOD) United Kingdom

Mk44

Gun / Ammo IPT

"the future will be full of open and hidden dangers and U.S. Forces will have to be fully integrated and expeditionary, capable of achieving decision superiority and, of course, be lethal"

Defense Secretary Donald Rumsfeld

"Joint Operations Concepts"

Mk44

Gun / Ammo IPT

- **30mm x 173 Programmable Airbursting Munitions**
  - ***The challenge lies in the pursuit of a common technology/round that can be utilized on all platforms while meeting platform specific requirements.***
    - ***Timing War Reserve Purchase with Operational fielding of specific platforms weighed against performance maturity of NDI Solutions.***
    - ***Weighing NDI Solution performance against a broader spectrum of Platform Requirements.***

Mk44

Gun / Ammo IPT

- **Operational Assumptions made by the MK44 IPT.**
- ***Joint Operations in OIF/OEF, in battles such as Fallujah, where U.S. Marine and U.S. Army forces fought side by side, while U.S. Naval Combatants work the littoral regions require the MK44 IPT to work towards a common solution.***
- ***Interoperability of ammunition allows the War-Fighters to exchange in the heat of battle, while reducing the logistical burden placed upon our support forces.***

Mk44

Gun / Ammo IPT

- **Service Assumptions made by the MK44 IPT.**
- ***Common Technology / Ammunition will significantly reduce costs to each Service through Economy of Scales and lowering the War Reserve Support Requirements.***

Mk44

Gun / Ammo IPT

- **30mm x 173 Programmable Airbursting Munitions Joint Program.**
  - **FY05 US Navy, US Marine Corps, US Army, and US Coast Guard Developed Evaluation Test Plan fusing requirements into a single plan. (U.S. Air Force – Program of Interest)**
  - **FY05 Submitted for FY06 FCT / DACP (US Navy in the lead)**
  - **FY05 US Navy / DRPM AAA / US Army procuring candidate rounds.**
  - **FY06 Joint Evaluation of Candidate Rounds (Hawthorne Nevada)**
  - **FY06 Down Selection, providing a single round meets requirements.**
  - **FY06-FY08 Qualify Single Round**

Mk44

Gun / Ammo IPT

"Our Military Forces are on one Team-in the game to win regardless of who carries the ball"

General of the Army, Gen. Omar Bradley, U.S. Army

The MK44 IPT has been and will continue to be Joint Organization committed to working together, putting our Warriors first, in solving common MK44 and 30mm x 173 related issues.

GENERAL DYNAMICS
Armament and Technical Products

25mm Gun Systems for the F-35 Joint Strike Fighter (JSF)



Presented by:

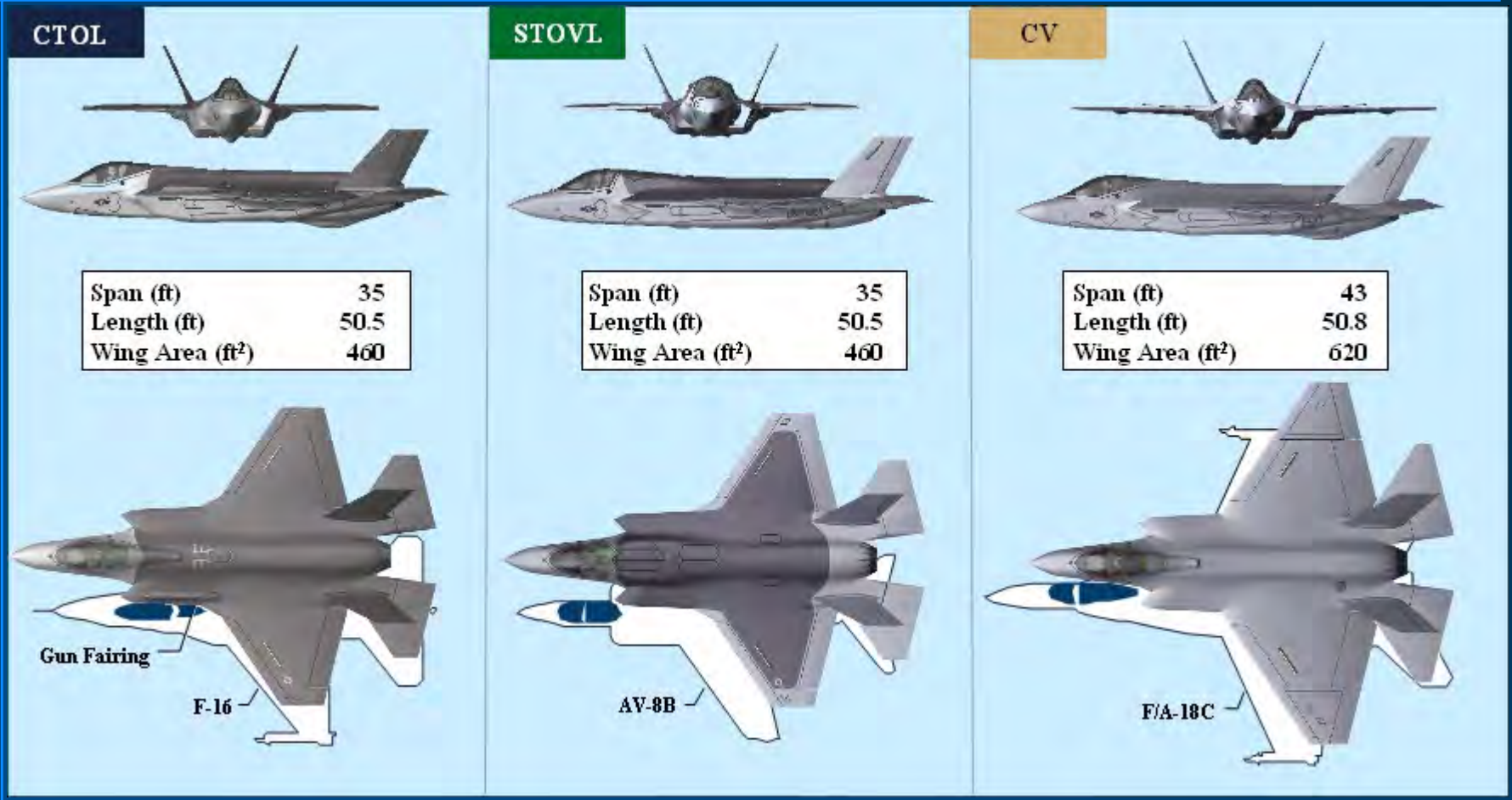
Douglas Parker
Lead Mechanical Engineer – Joint Strike Fighter Gun System
General Dynamics Armament & Technical Products
Burlington, Vermont USA

Presentation Outline

- JSF Program Overview
- Key System Requirements
- Technical Approach
  - ↗ Internal Gun System (CTOL)
  - ↗ Missionized Gun System (CV & STOVL)
- Risk Reduction Testing
- Program Status
- Path Forward



Lockheed Martin F-35 Variants



Major Program Changes

- Program was replanned due to Aircraft level weight initiatives at LM Aero in 2nd quarter of 2004.
- Gun system weight initiatives include:
  - New 4-barrel gun (implemented)
  - Titanium barrel clamps (under development)
  - Removal of Gun System Control Unit (GSCU) regulated power supplies (implemented)
  - CTOL aluminum access unit (implemented)
  - CTOL composite carriers (under parallel development)
- GDATP entered risk reduction testing with the 5-barrel CTOL system in the 4th quarter of 2004.

Major Technical Requirements

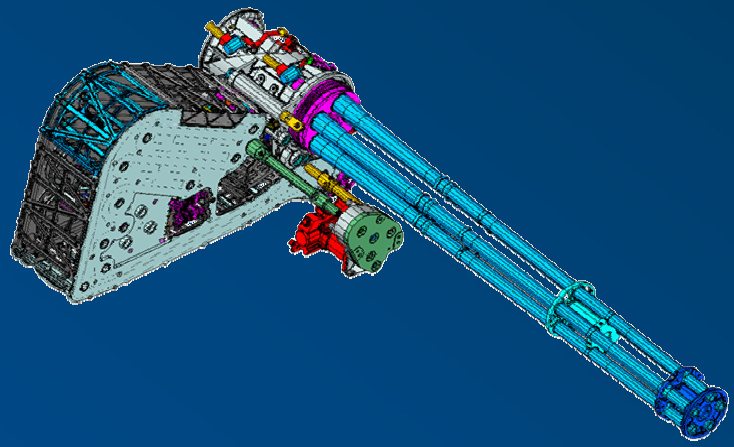


- 25mm 4-barrel gun firing at 3000 spm
- Compatible with the following ammunition:
  - PGU-23/U Target Practice (TP)
  - PGU-20/U Armor Piercing Incendiary (API)
- Linkless Ammunition Handling System
  - CTOL: 180 rounds, STOVL/CV: 220 rounds
- GSCU controls gun functions and operation of doors
- Reverse clearing gun
- 2-level maintenance
- Common loader interface for both system types

Gun System Overviews

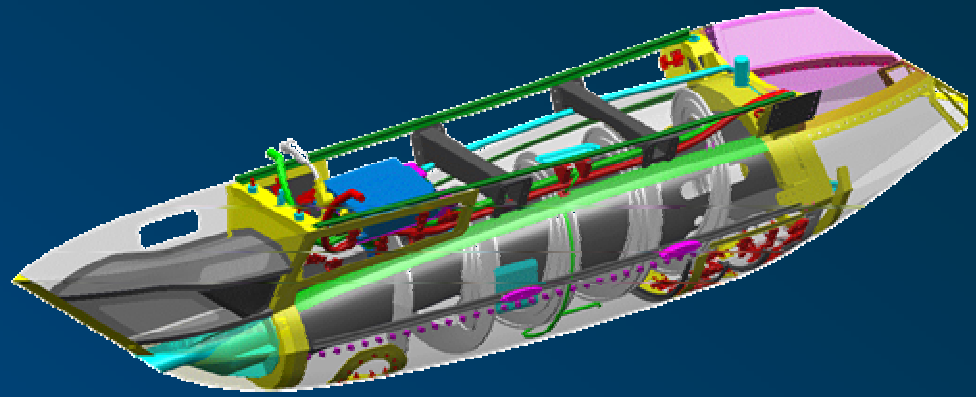


CTOL



- Components
  - Gun Assembly
  - Linear Linkless Ammo Handling System
  - Power Transmission/Hydrive
  - GSCU

STOVL/CV



- Components
  - Gun Assembly
  - Helical Ammunition Handling System
  - Power Transmission/Hydrive
  - GSCU
  - Gun Pod

Gun Heritage



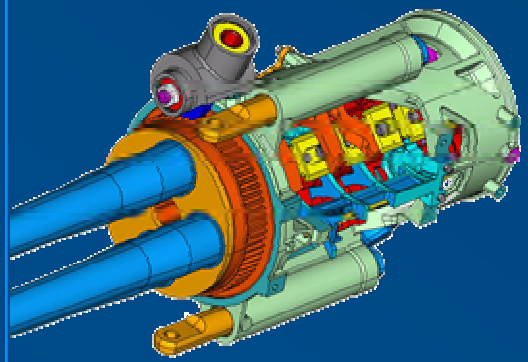
GAU-12U

- AV-8 gun system
- 25-mm, 4,000 spm system
- Supported at mid-barrel clamp

5-barrel derivative

- GAU-12 commonality maximized
- Remote safing incorporated
- Installation requirements
  - Support at muzzle
  - New gun housing

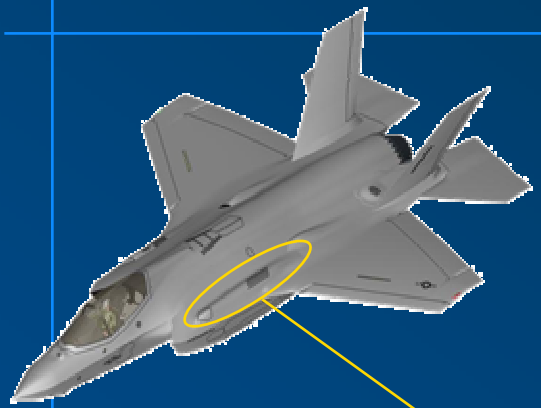


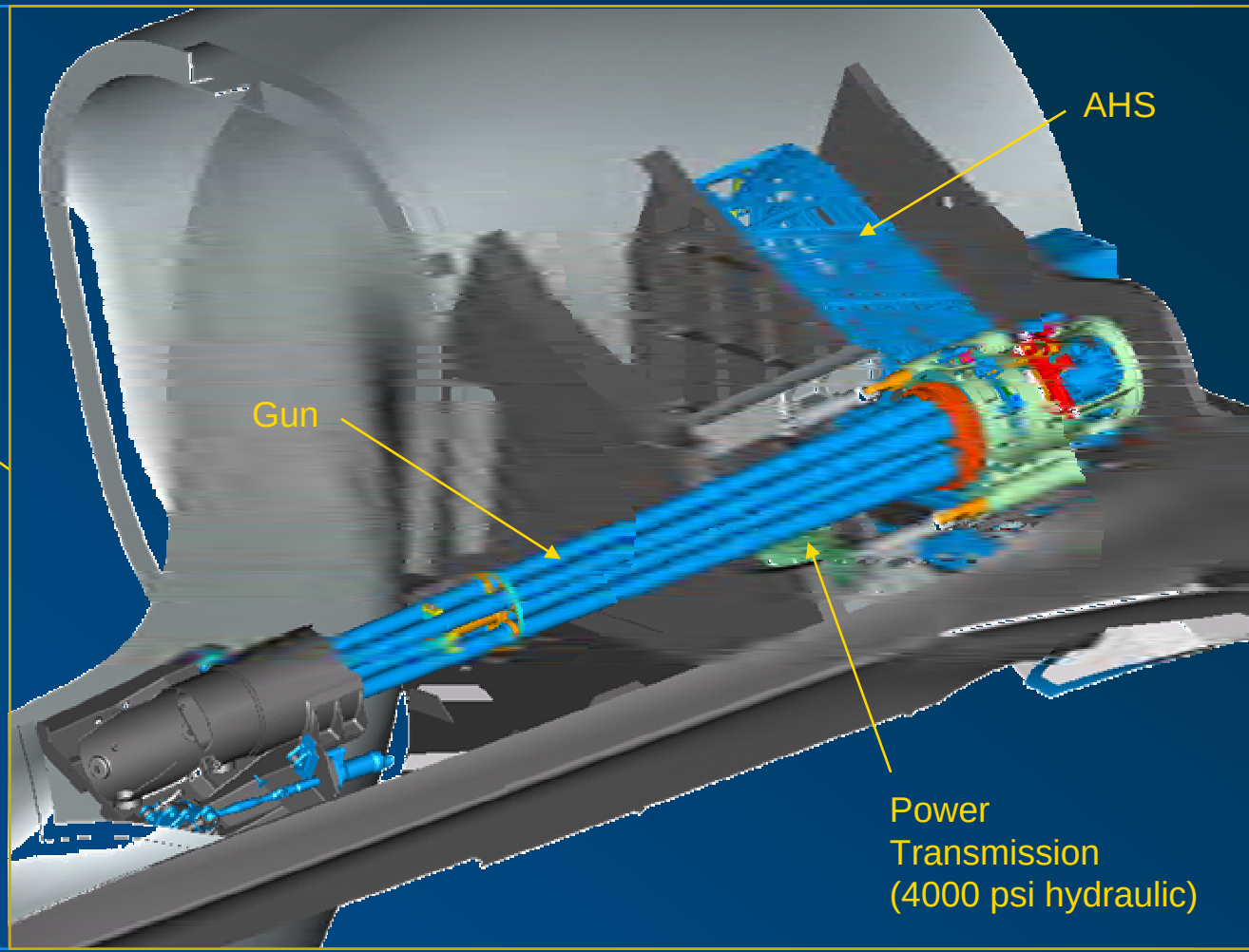


4-barrel derivative

- 3,000 spm system
- Entered design in March of 2004
- Gun mechanism principles retained
- Basic installation geometry retained
- 42 lb weight savings

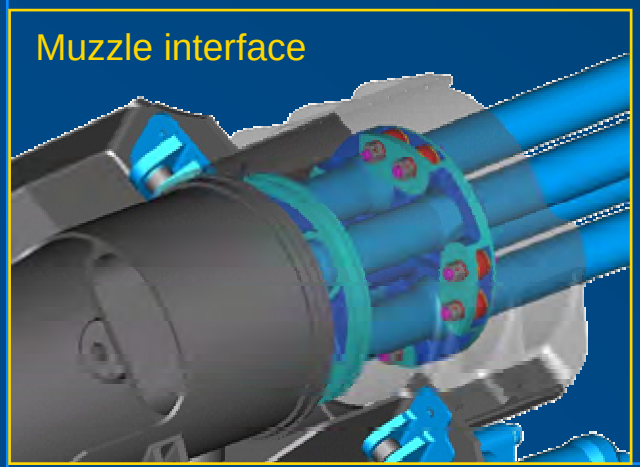
CTOL Gun System

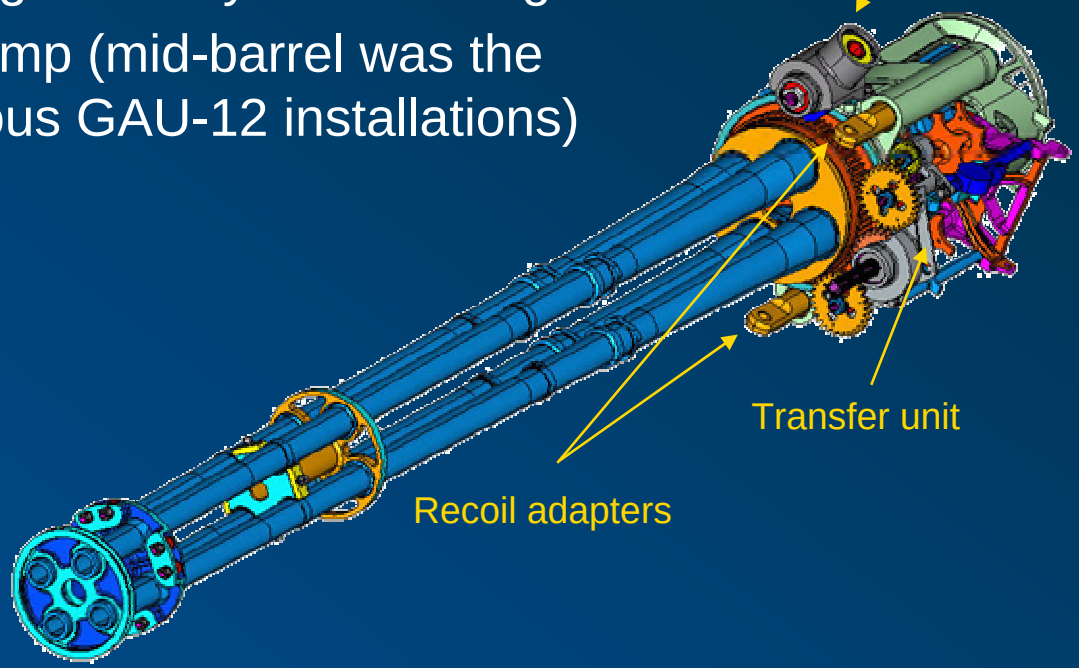




CTOL - Gun Installation

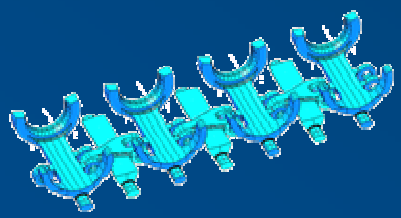
- GD425 (heavily based off GAU-12 to reduce risk)
- AV-8 derivative transfer unit (power through main rotor gear)
- Power input from Power Transmission through transfer unit
- Manual drive input at rotor gear for system loading
- A/C interface at muzzle clamp (mid-barrel was the interface used for all previous GAU-12 installations)



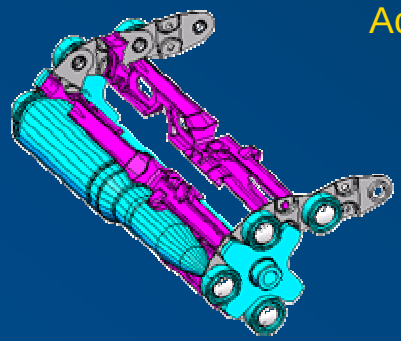


CTOL - Ammunition Handling System

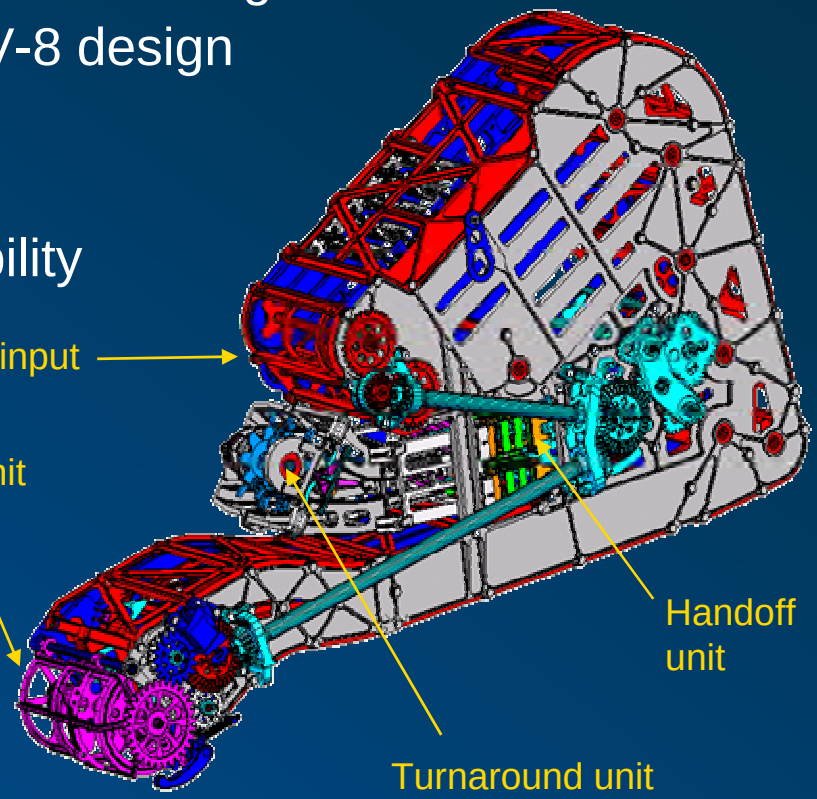
- Linear linkless system in serpentine arrangement – 180 round capacity
- Proven clamshell carrier based on F-15E Design
- Proven gun conveyor identical to AV-8 design
- Elliptically geared Handoff Unit
- Access unit based on AV-8 system
- Positive round control for high reliability



Gun conveyor

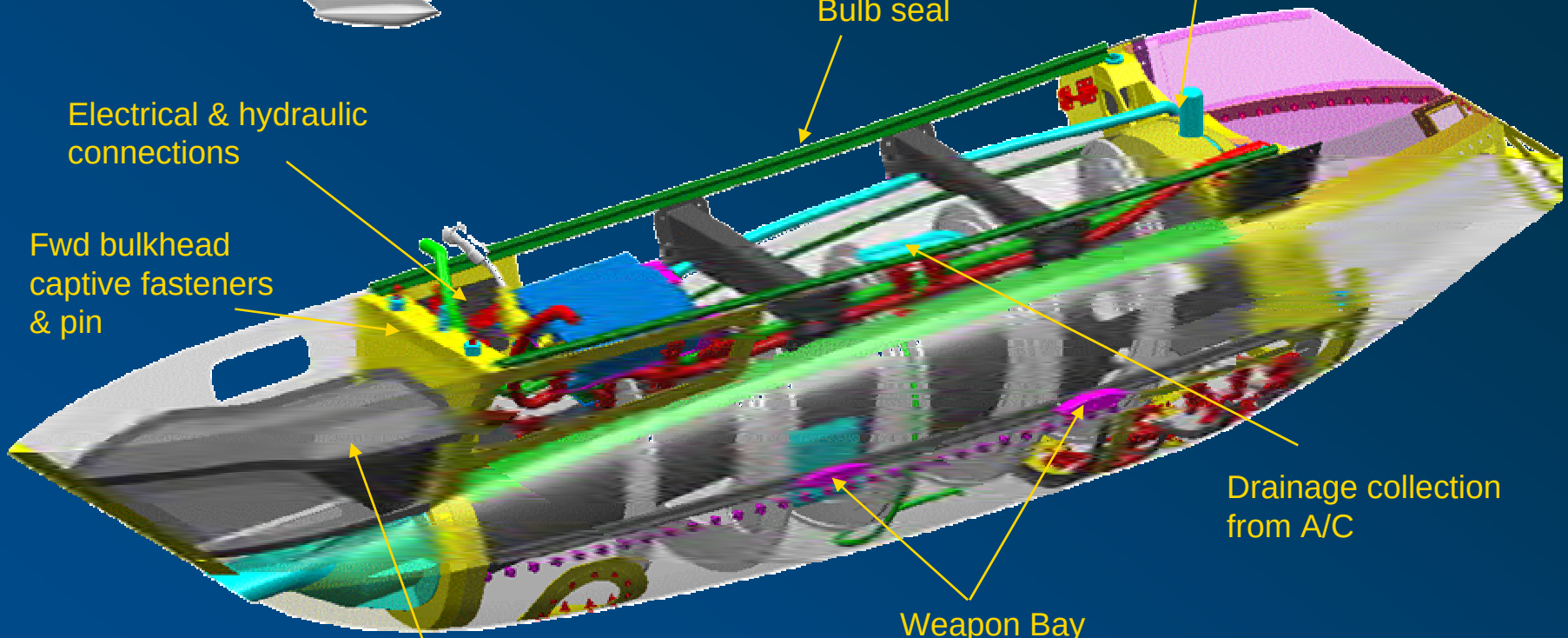


Clamshell carrier

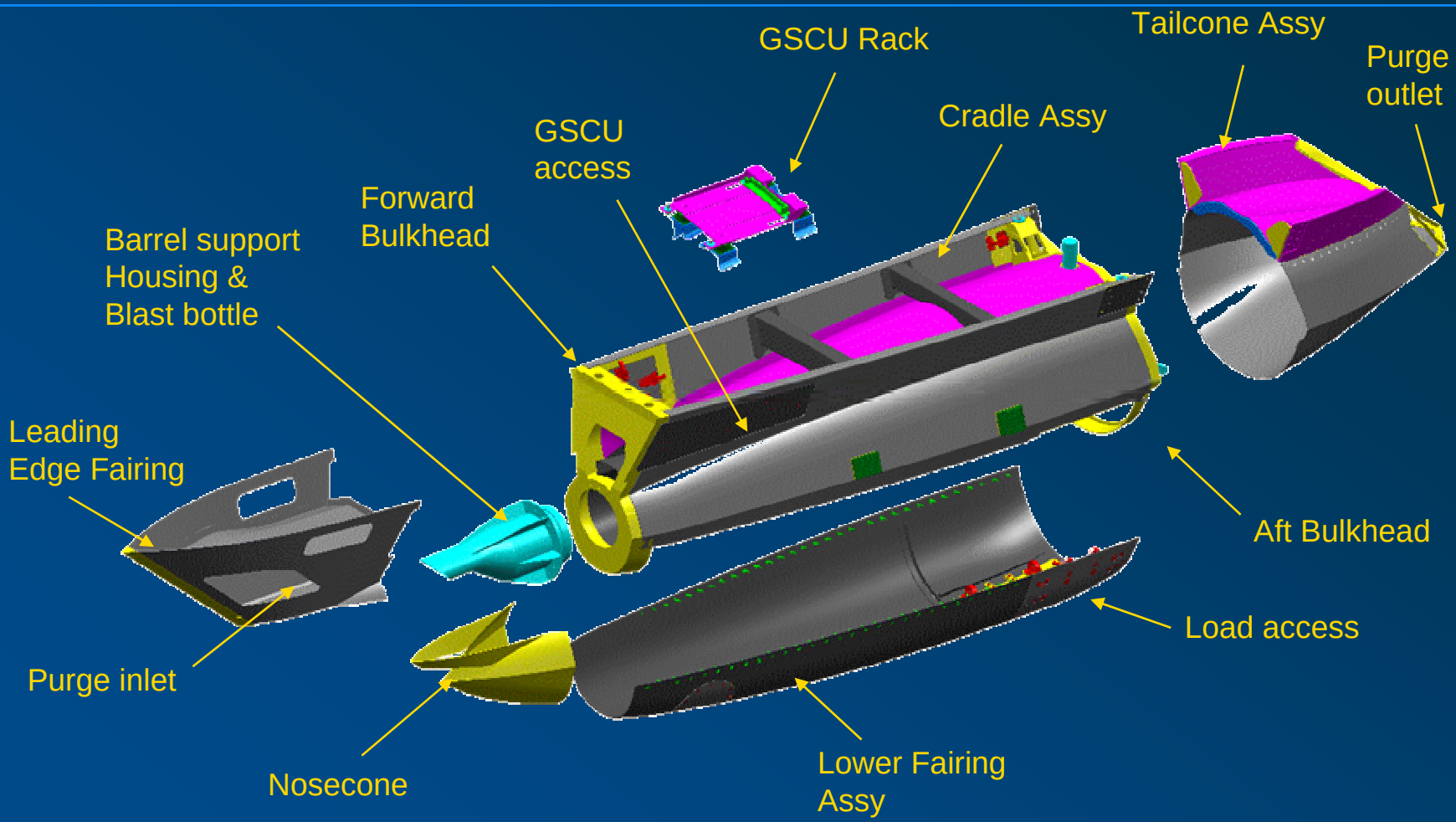


STOVL/CV Gun System





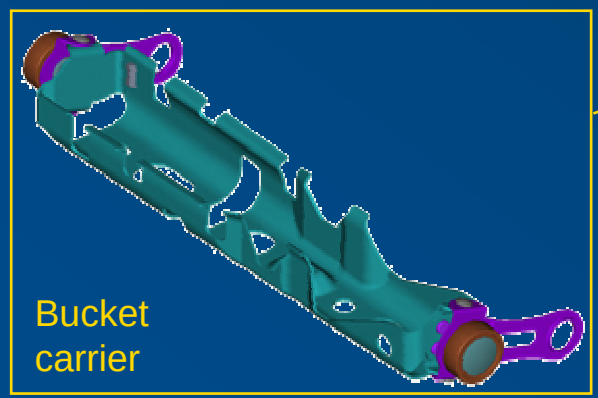
STOVL/CV – Pod Structure

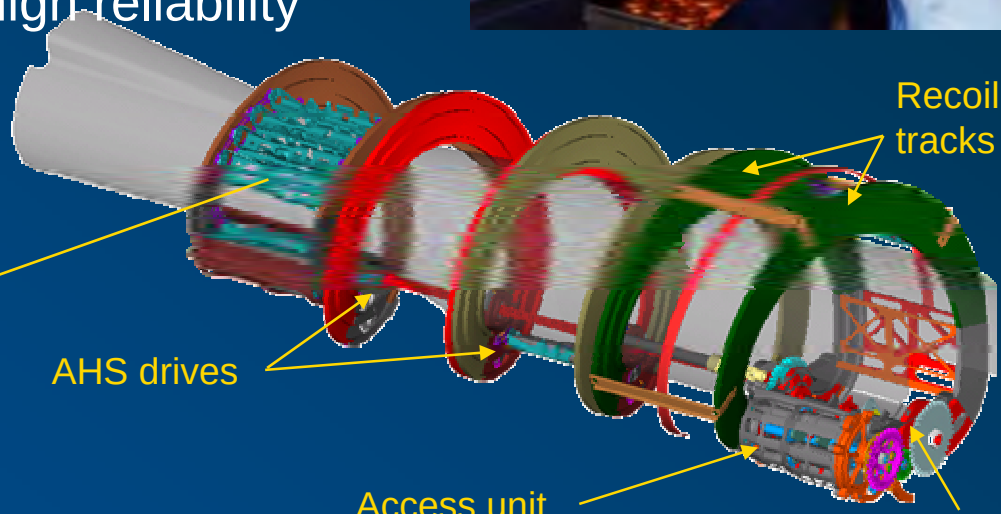


STOVL/CV - Ammunition Handling System

- GPU-5A architecture
  - Linear linkless system in helical arrangement
    - 220 round capacity
  - Proven aluminum bucket carrier design
- Access unit is a derivative of the AV-8B
- Positive round control for high reliability

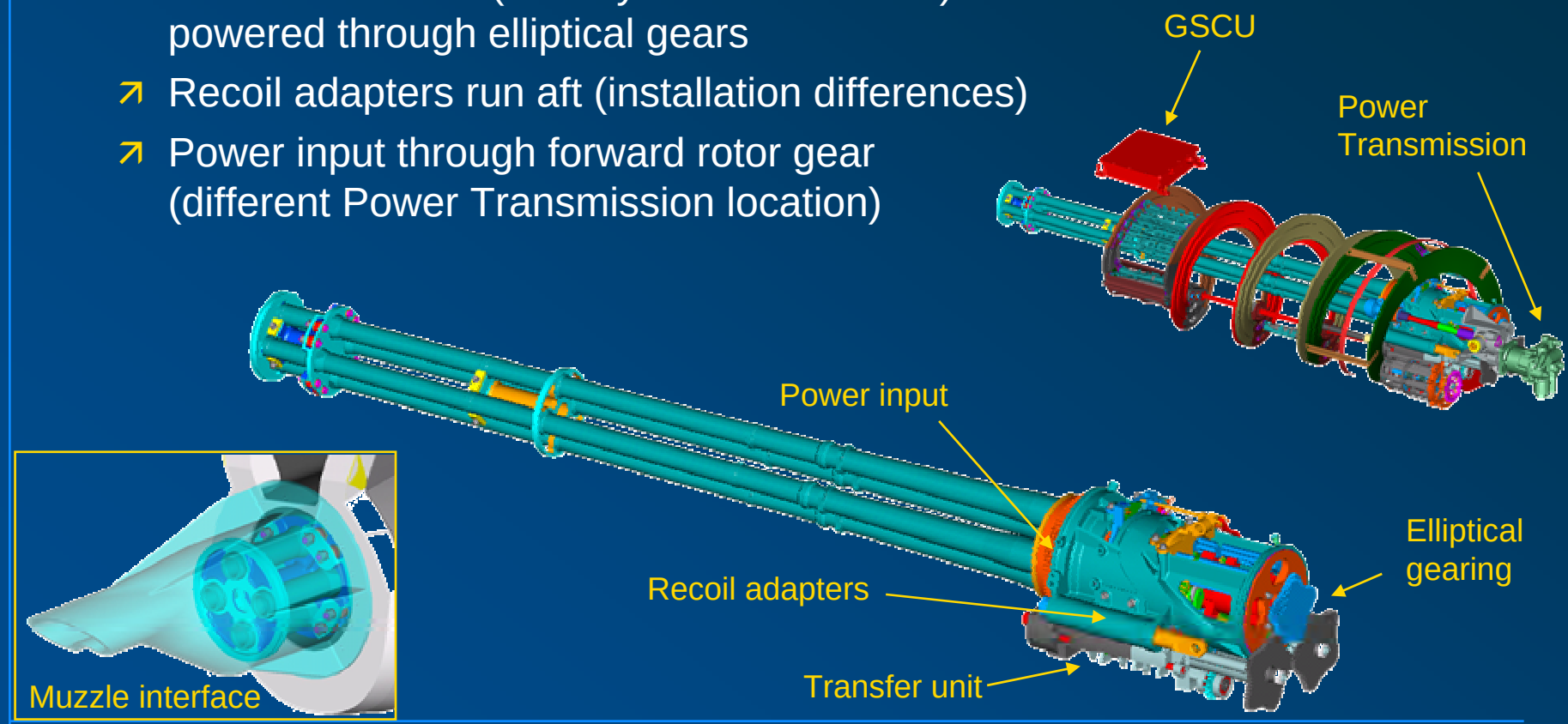






STOVL/CV - Gun Installation

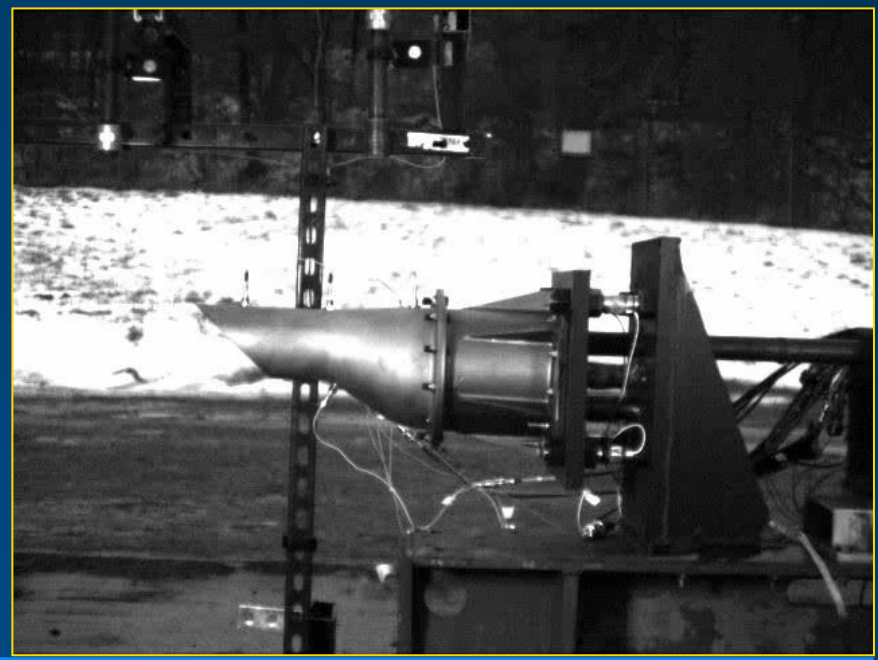
- 90% common with CTOL
  - New transfer unit (feed system differences) powered through elliptical gears
  - Recoil adapters run aft (installation differences)
  - Power input through forward rotor gear (different Power Transmission location)



Risk Reduction Testing

- CTOL fire test
- 5-barrel hydraulic drive qualification
- STOVL/CV blast bottle single shot testing
- STOVL/CV recoil track characterization (April/May 2005)





Challenges

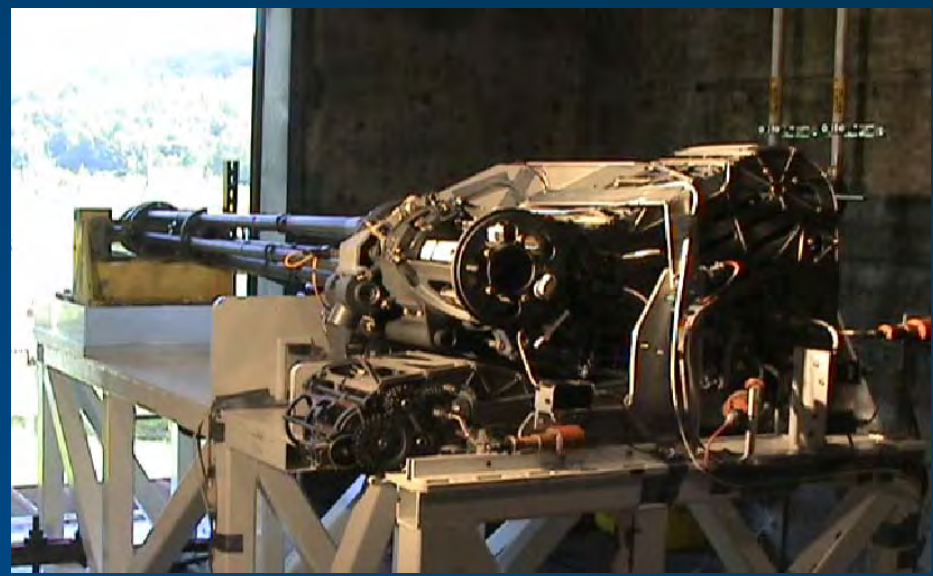
- Complex STOVL/CV Pod to gun system interfaces
- Short design cycle
  - Base on heritage designs where possible
  - Rapid prototyping for long lead castings
- Aggressive schedule for delivery
  - Release CTOL Units 3 & 4 before Engineering test is complete
- Overlap of CTOL and STOVL/CV schedules

JSF Gun System Master Schedule

Task Name	2005				2006				2007			
	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
CTOL													
Detailed Design													
Fabrication & Assembly													
5K Round Gun Engineering Test													
10K Round System Engineering Test													
30K Round System Qualification Test													
Environmental Test													
Delivery													
STOVL/CV Gun System													
Detailed Design													
Fabrication & Assembly													
5K Round Gun Engineering Test													
Gun Pod SDD #1 Delivery													
10K Round System Engineering Test													
30K Round System Qualification Test													
Environmental Test													
Delivery													

Path Forward Prior to the 2006 Guns & Ammo Symposium

- Complete
  - STOVL/CV Critical Design Review
  - 4-barrel Gun Engineering Test (10,000 Rounds)
  - CTOL 10,000 Round Engineering Test
- Begin
  - STOVL/CV 10,000 Round Engineering Test
  - CTOL 30,000 Round Qualification Test
  - CTOL Environmental Qualification





GENERAL DYNAMICS

GENERAL DYNAMICS

Ordnance and Tactical Systems

30mm Airburst Development

Translating Lessons Learned into System Requirements

40th Annual Guns and Ammunition Conference

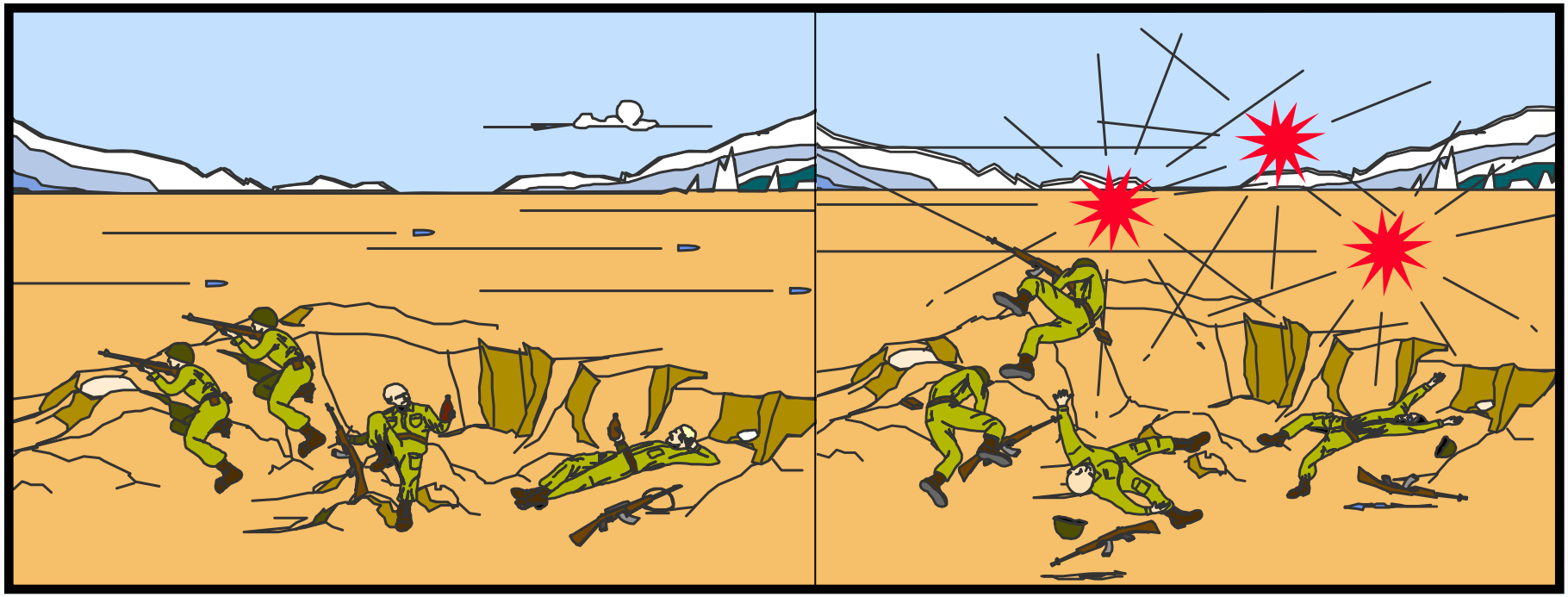
25-28 April 2005

New Orleans, LA

Paul Reynolds



Why Do We Need Air Bursting Munitions



KE Ammunition Can Only Suppress Personnel In Defilade

Air Burst Ammunition Kills

Why Do We Need Air Bursting Munitions

Emerging Threats

- Troop Personnel
- ATGM Sites
- Light Armored Vehicles
- Unarmored Vehicles
- Urban Structures
- Bunkers
- Watercraft

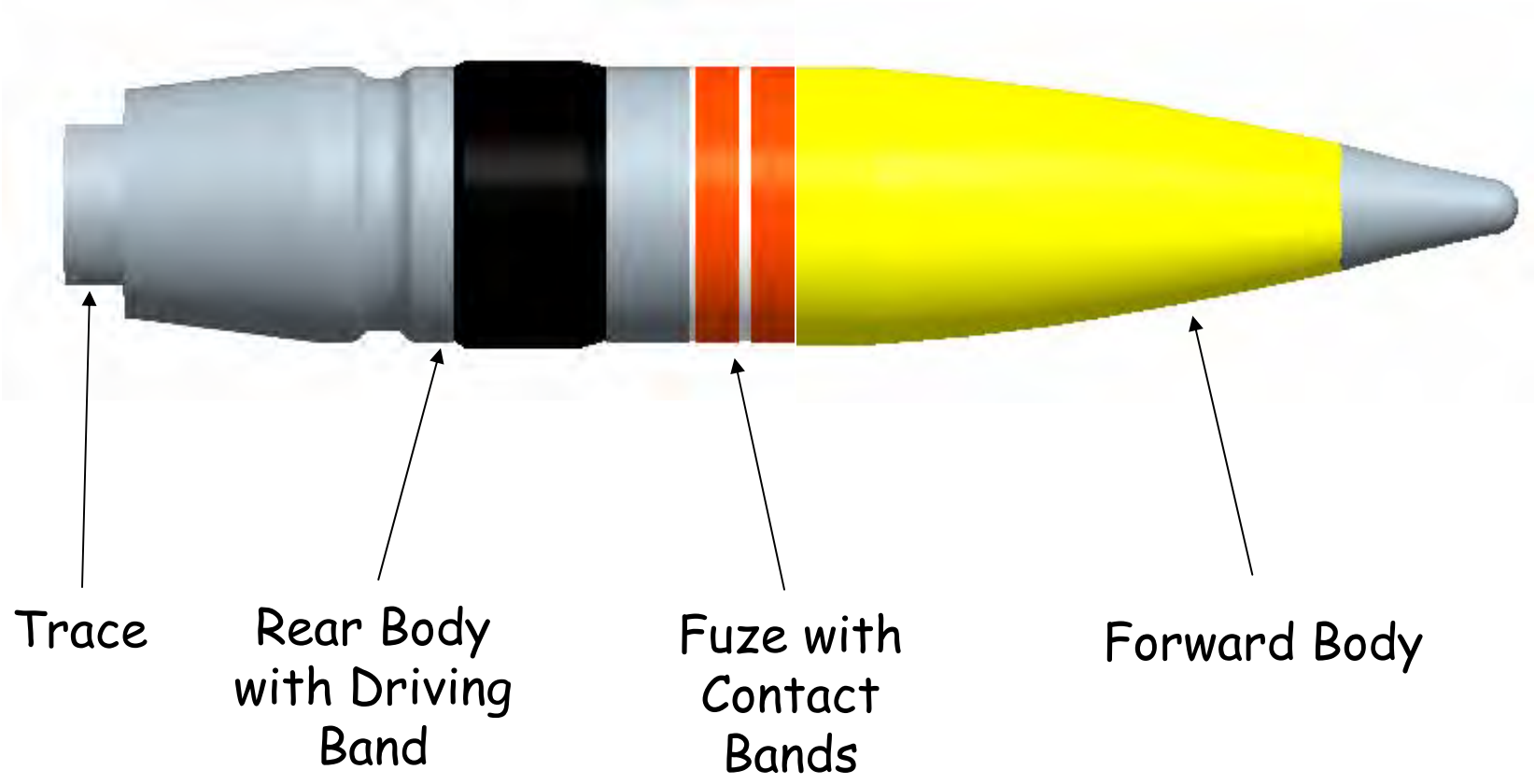








A 30mm Airburst Solution

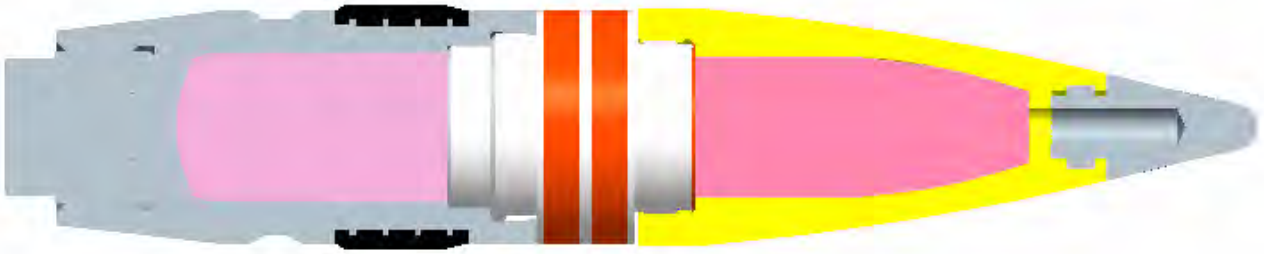


30mm Air Burst Fuzing Approach

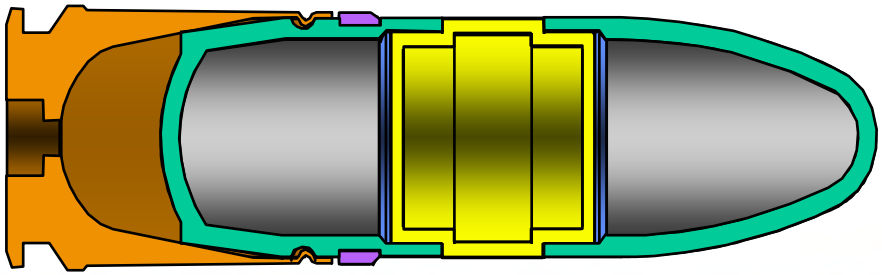
- Remote settable electronic time fuze
- Independent point detonating backup with super quick or delay
- Independent sterilization
- Precision air burst function
- Fuze powered and set in weapon feed system
- Fuze re-set each time a target is lased
- Contact communication system similar to that being qualified for 25mm Advanced Crew Served Weapon (ACSW)
- 25mm ACSW / 30mm Air Burst Commonality

30mm Air Burst Fuzing Approach

- Simple communication through contact bands eliminate the need for exotic materials.
- Significant development cost savings are realized by adapting the ACSW design to 30mm / 40mm HEAB munitions



30mm HEAB



25mm HEAB

30mm Air Burst Fuzing Approach

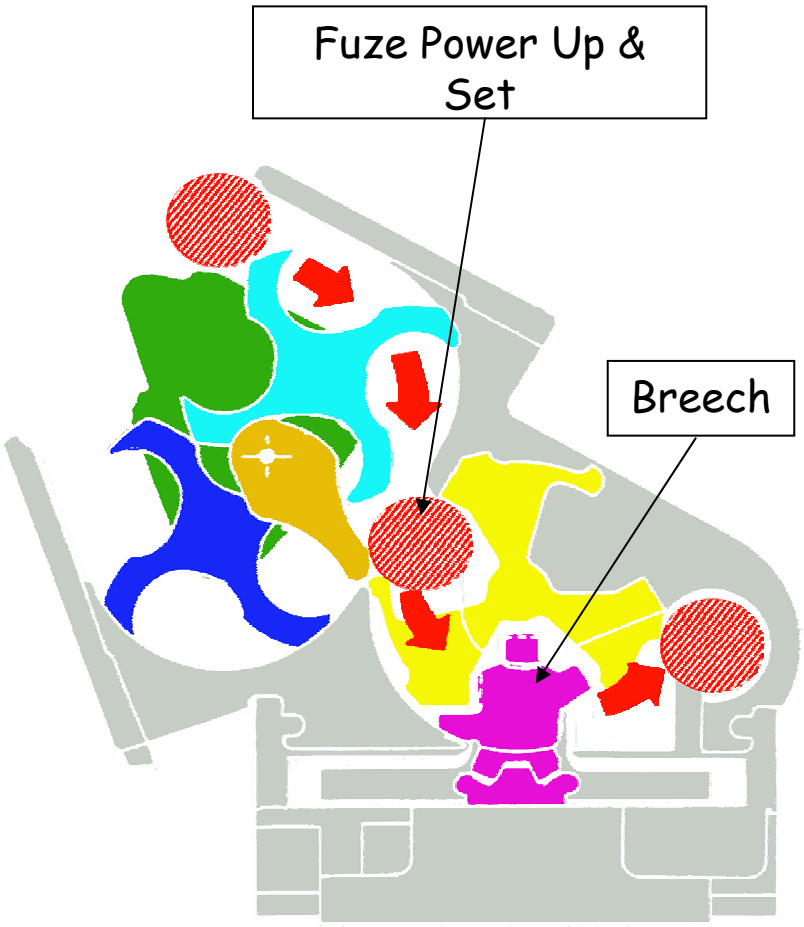
- Early in the ACSW program, the time of flight and direct contact communication was selected as the best choice
- Through testing we have developed confidence that this system will meet the needs for 30mm HEAB applications



30mm Airburst Lessons Learned

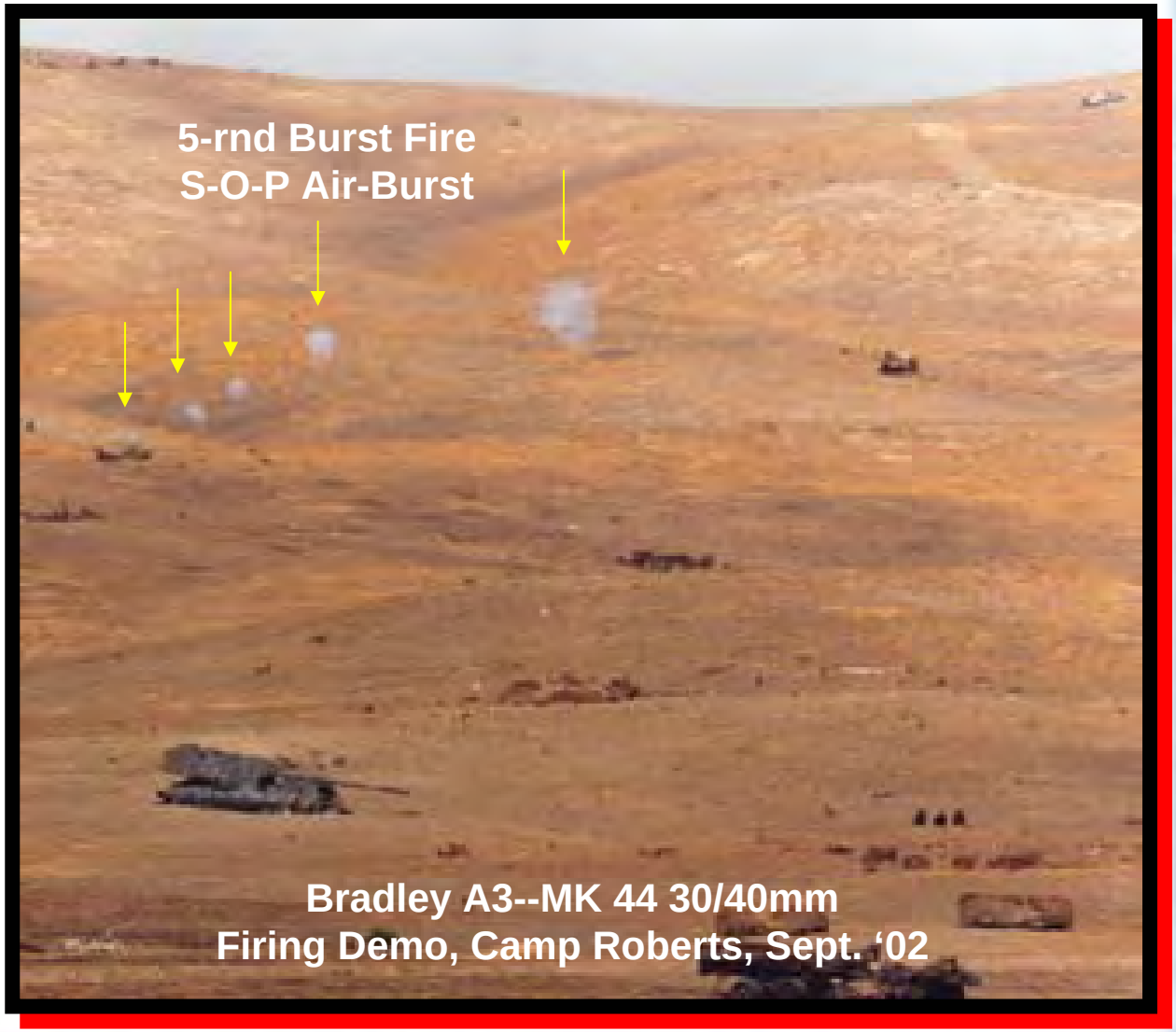
FUZE SETTING FLEXABILITY:

- Fuze can be set and reset multiple times before commitment by pulling the trigger. This enables the user to change targets as needed.
- Manual override is an additional capability in the event a range finder cannot lock on a target. The solution is a progressive or regressive string of pearls that can cover the target.



30mm Airburst Lessons Learned

String of Pearls Demonstration



30mm Airburst Lessons Learned

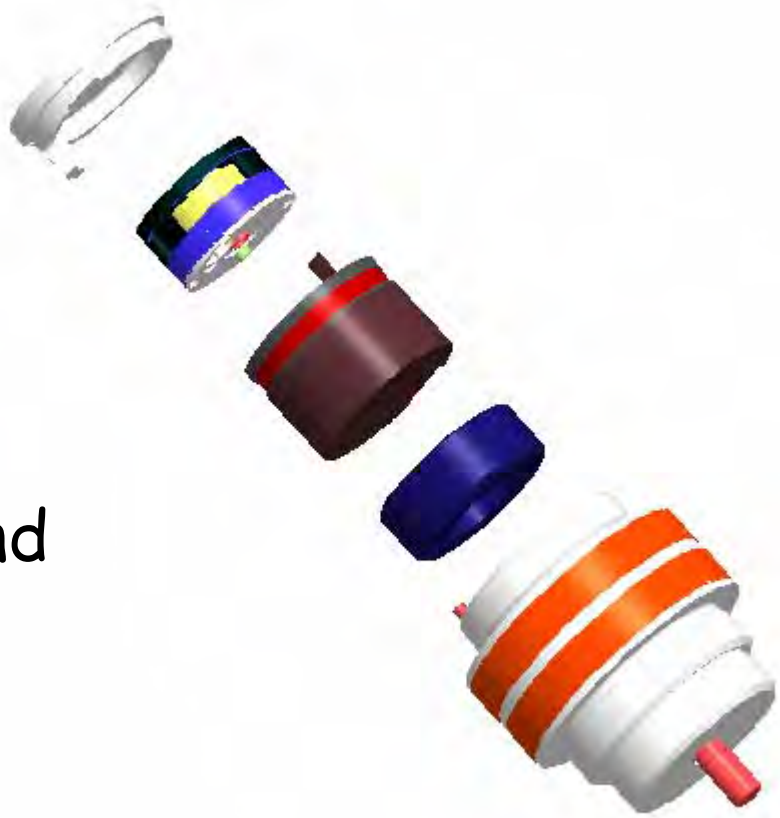
Demonstration of 30/40mm Air Burst

30mm Airburst Lessons Learned

30mm Airburst Lessons Learned

FUZE COMMONALITY:

Many fuze components are common with the ACSW configuration. This allows for lower cost, higher producibility, reliability, and availability as a result of higher manufacturing volumes.



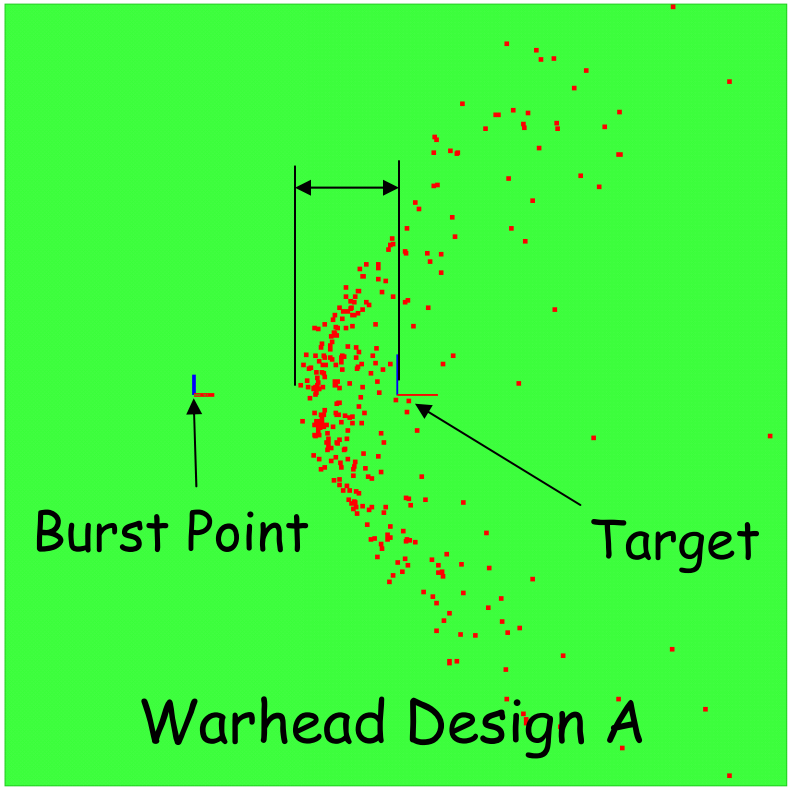
30mm Airburst Lessons Learned

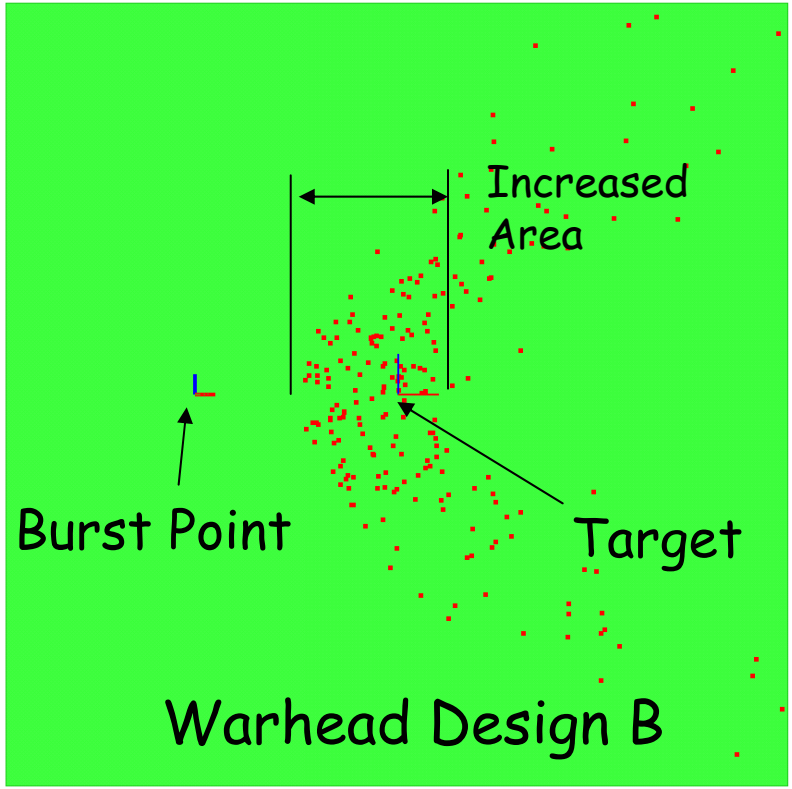
Based on Feedback from the user community the HEAB must contain a point detonating (PD) function to:

- Increase capability of the ammunition and eliminate the need for HEI PD ammunition
- Defeat materiel targets
- Have a functional round in the unlikely event that a airburst communication signal fails
- Provide round "Sterilization"



30mm Airburst Patterns on Target at 1000m
Simulated Warhead Designs





Warheads can be designed per user requirements using the same fuze configuration. Further increasing fuze commonality advantages.

30mm Airburst Lessons Learned

Summary

- A lethal 30mm air burst munitions exists today.
- The munitions has been successfully demonstrated out of the Mk44 cannon in both single and burst mode (200spm) at multiple ranges.
- The munitions have been demonstrated against mannequins in standing, prone, and behind sandbag barriers. Fragment patterns have been scored by the Eglin Vulcan System.
- Work continues on bringing ACSW advantages into 30mm.

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Weapons Systems and Explosives Safety in a Joint Warfighting Environment

Prepared for: National Defense Industrial Association
40th Annual Armament Systems: Guns-Ammunition-Rockets-Missiles Conference & Exhibition

26 April 2005

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Agenda

- Safety Importance to Navy/Marine Corps
- Safety: Common Sense?
- Weapon System Explosives Safety Review Board (WSESRB)
- Other Services' Boards
  - USA Materiel Release Board
  - USAF NNMSB
- Joint Staff: Safe Weapons Capabilities Review
- Where to Next?

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Safety Importance to the Navy/Marine Corps

- Nature of Expeditionary Mission
- All Weapons Carried to the Fleet
  - Initial Allocation
  - Sustaining Requirements
- Fuel
- Other Hazardous Materials

No Where To Escape, In Case of Incident



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Safety: Common Sense?

- **Common Sense isn't always common.**
- **Mishaps/Accidents both on and off duty have cost hundreds of USN and USMC lives and an average of $4B every 5 yrs**
- **Need for greater hazard awareness by all personnel at all times to preserve our greatest asset:**

PEOPLE

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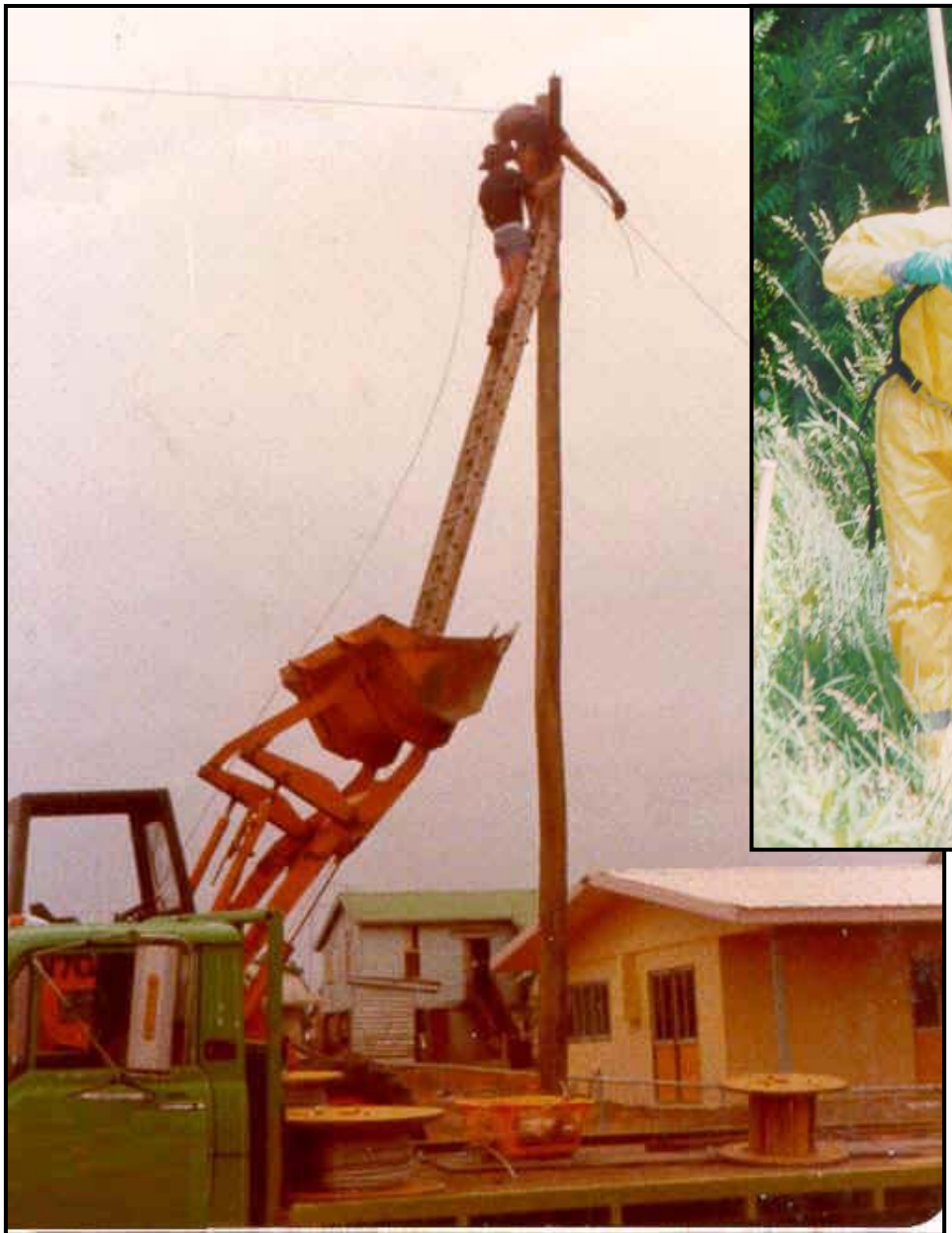
Safety: Common Sense?

Although a weapon system can be designed to maximize safety,

People <u>really can</u> make poor decisions without applying either risk management OR common sense ……

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Safety: Common Sense?





What is wrong with these pictures?

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Safety: Common Sense?






PHS&T
Approved
unit loads?

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….and “Risk Management” closer to home?!!



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Safety: Common Sense?



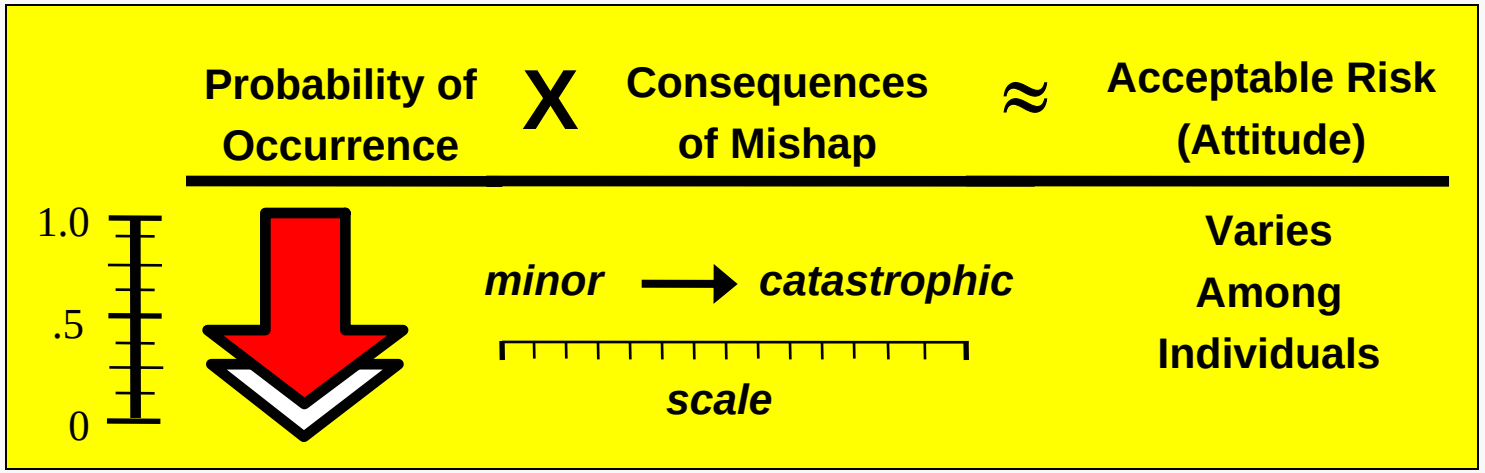
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WSESRB: Why?

WSESRB:

- established in 1968 as a result of mishaps aboard aircraft carriers
- provides independent oversight of weapon program safety effort to ensure maximum compliance with long standing weapon safety requirements.

Proper design up front to avoid mishaps during lifecycle



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WSESRB Authority

DODI 5000.2 Para E7.7

- *PM shall identify, evaluate and manage safety and health hazards*
- *Explains the process for accepting risk*

SECNAVINST 5000.2C

- *CNO may establish system safety advisory boards*

SECNAVINST 5100.10H

- *Directs CNO/CMC to establish safety programs*

OPNAVINST 8020.14/MCO P8020.11

- *Explosives Safety Policy*
- *Tasks COMNAVSEASYSCOM to establish WSESRB*

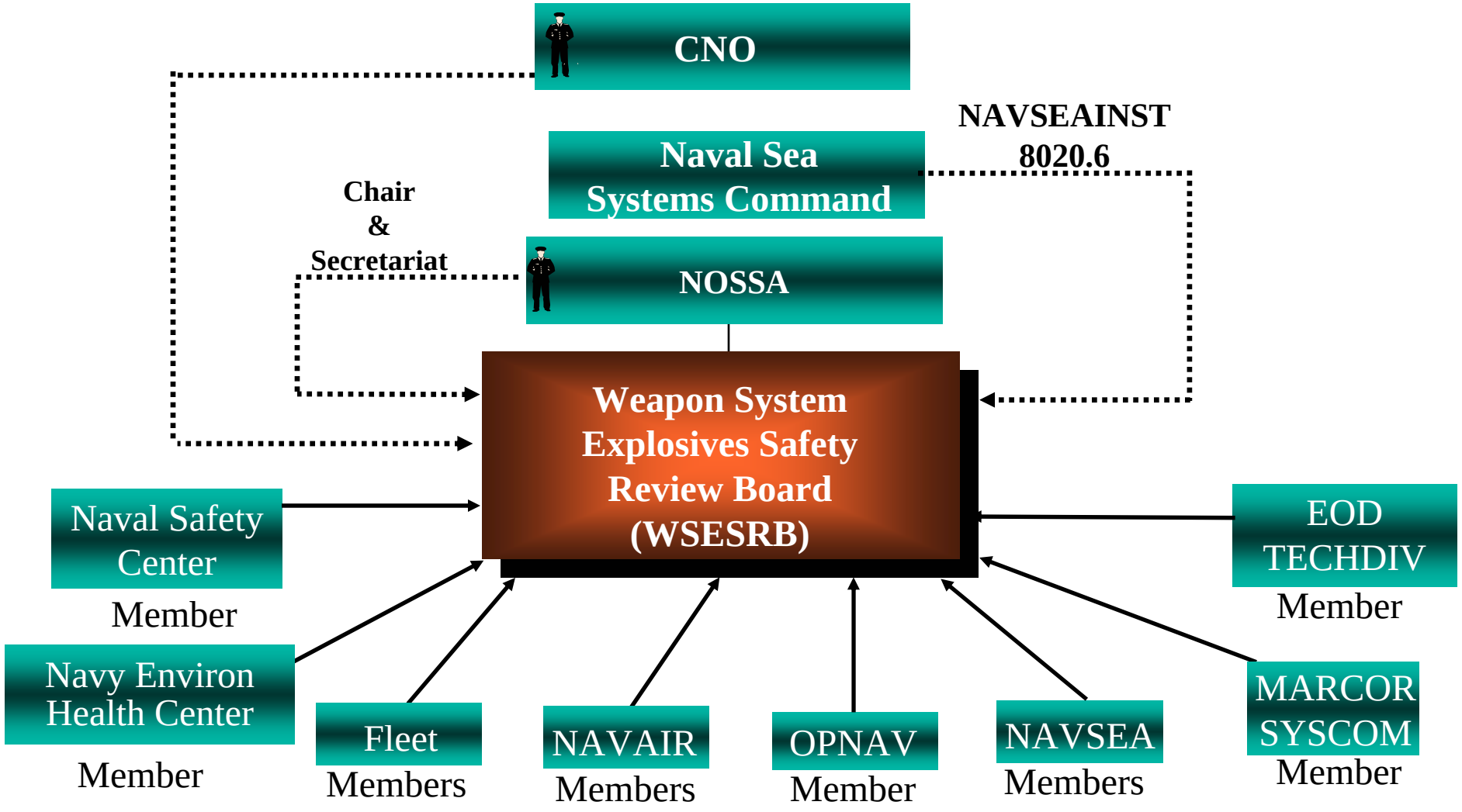
NAVSEAINST 8020.6D

- *Defines WSESRB process and procedures*

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WSESRB: Who?

Policy Flow and Membership



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WSESRB: What?

- **Reviews weapon and combat system acquisition programs, including Product Improvement Programs, for compliance with longstanding safety design requirements.**
  - PM identifies, evaluates and manages safety and health hazards
  - Focus on safety from an overall Combat System perspective
  - Emphasis on Human Systems Integration (HSI)
- **Provides concurrence or nonconcurrence with the design; makes recommendations.**
- **PM responds to the Board with the actions taken or planned.**
- **For those hazards that cannot be eliminated, risk is assessed, Board provides concurrence.**
- **PM must get any residual risk accepted at appropriate level.**
  - High risk = ASN (RDA)
  - Serious risk = PEO
  - Moderate/low risk = PM

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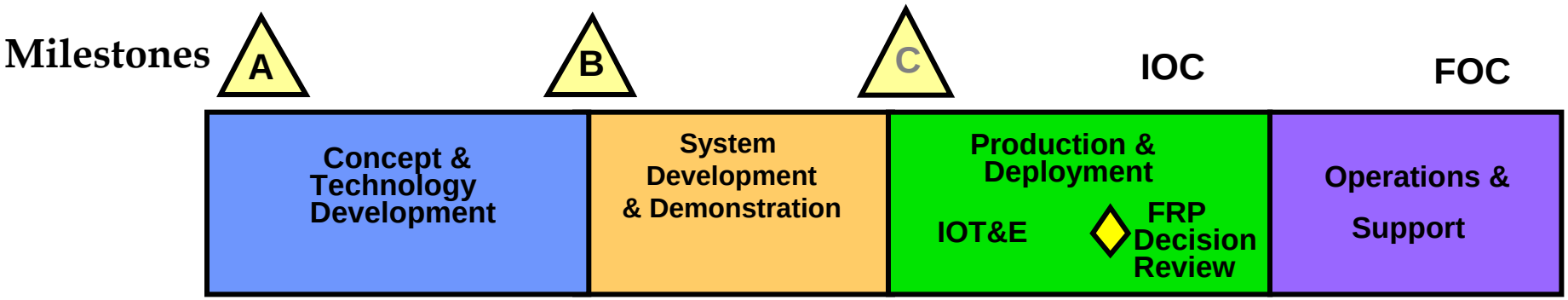
WSESRB: Why?

- **WSESRB works in partnership with Program Managers and the Fleet in identifying hazards**
- **Identify hazards**
- **Develop actions to mitigate the hazards**
- **Communicate any residual risks to Fleet operators**

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WSESRB: When?

Acquisition Events That Trigger WSESRB Reviews



- Acquisition Strategy
- Component Advance Development

- Pre-PDR
- Pre-CDR
- Developmental Tests
- Operational Tests
- Product Improvements

- LRIP
- Production
- Deployment

- Mishap
- QE Data

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Weapons Systems Safety



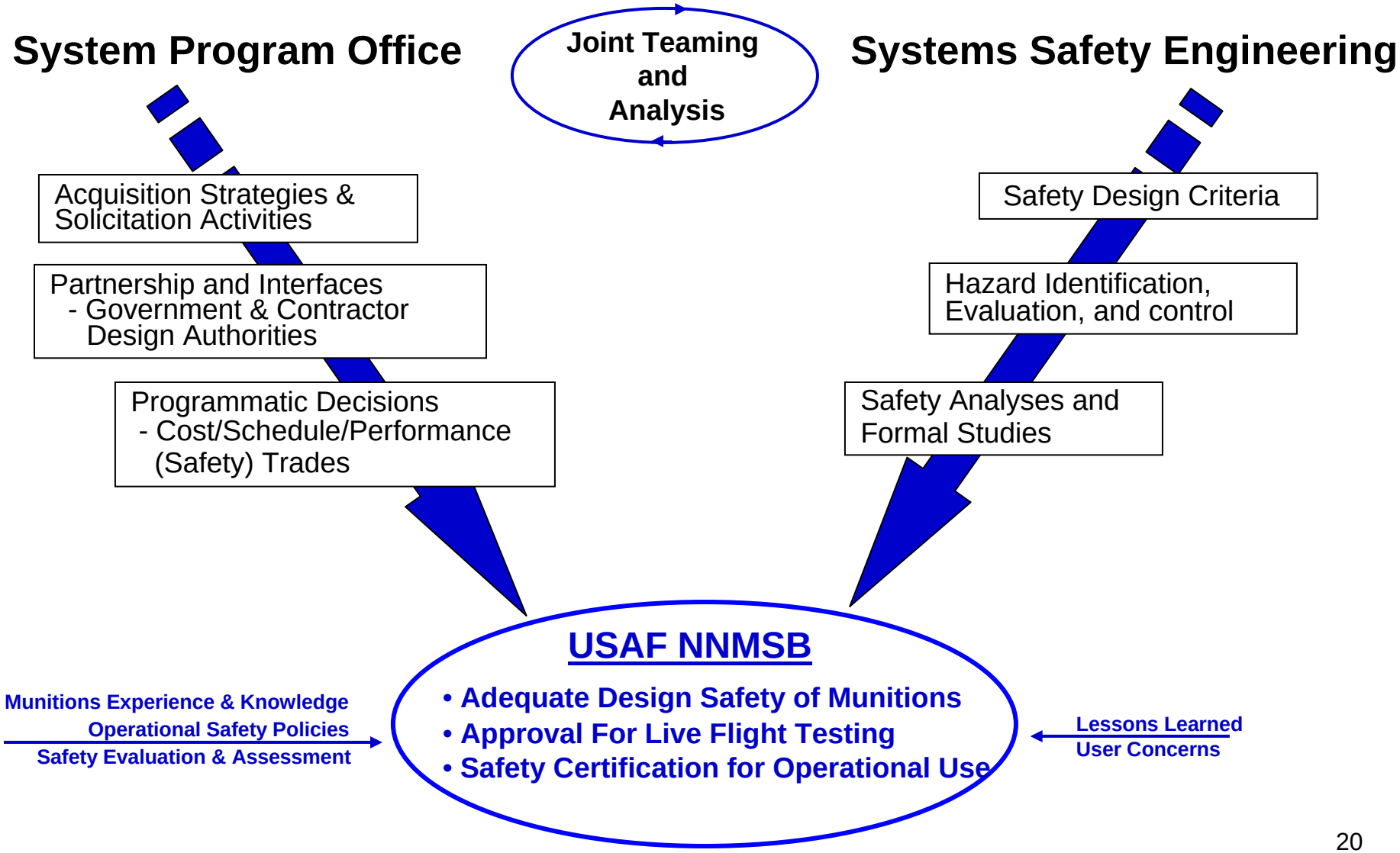
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USA: Safety Reviews

- Army Fuze Safety Review Board
  - Board of Technical and Safety Experts
  - Certify fuze design for Army munitions based on STANAGs 4157, 4187 and 4497 and associated AOPs
  - Fuze Board approval included in milestone decision review package
- Army Ignition System Review Board
- Materiel Release Board
  - Looks at a system's Safety, Supportability and Suitability
  - Final QA check
    - Unresolved safety hazards?
    - Meets approved capabilities document?

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USAF: Nonnuclear Munitions Safety Board (NNMSB)



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Current Drivers in DOD



Joint Operations Are Now the Norm

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Challenges to Safe Joint Environment

- Limited Joint Review of Safety Capabilities
- Increased Weapon System Complexity
- Weapon/Environment Incompatibilities
- Service Unique Design Requirements
- Implementation of Evolving and Varied Acquisition Strategies
- Technology Gaps
- Budget Pressures

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CJCS, J8 (DDFP) Action

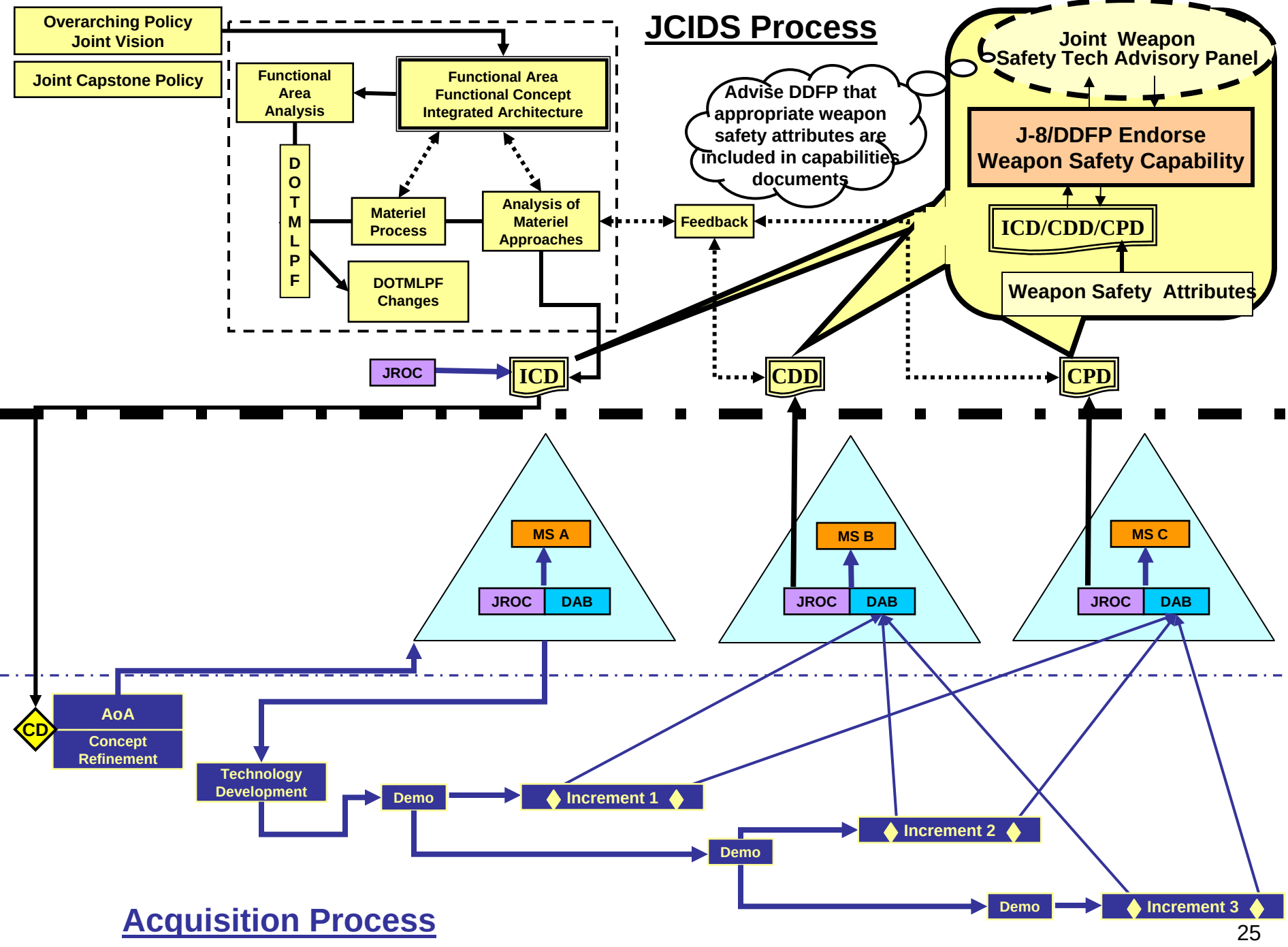
- **Supported Chartering Service Representatives to Explore Process to Ensure**
  - Safe Weapons in a Joint Warfighting Environment
- **Review Capability Documents**
- **Recommend Process**
  - CJCSI&M 3170 Changes
  - Charter
  - Process Development

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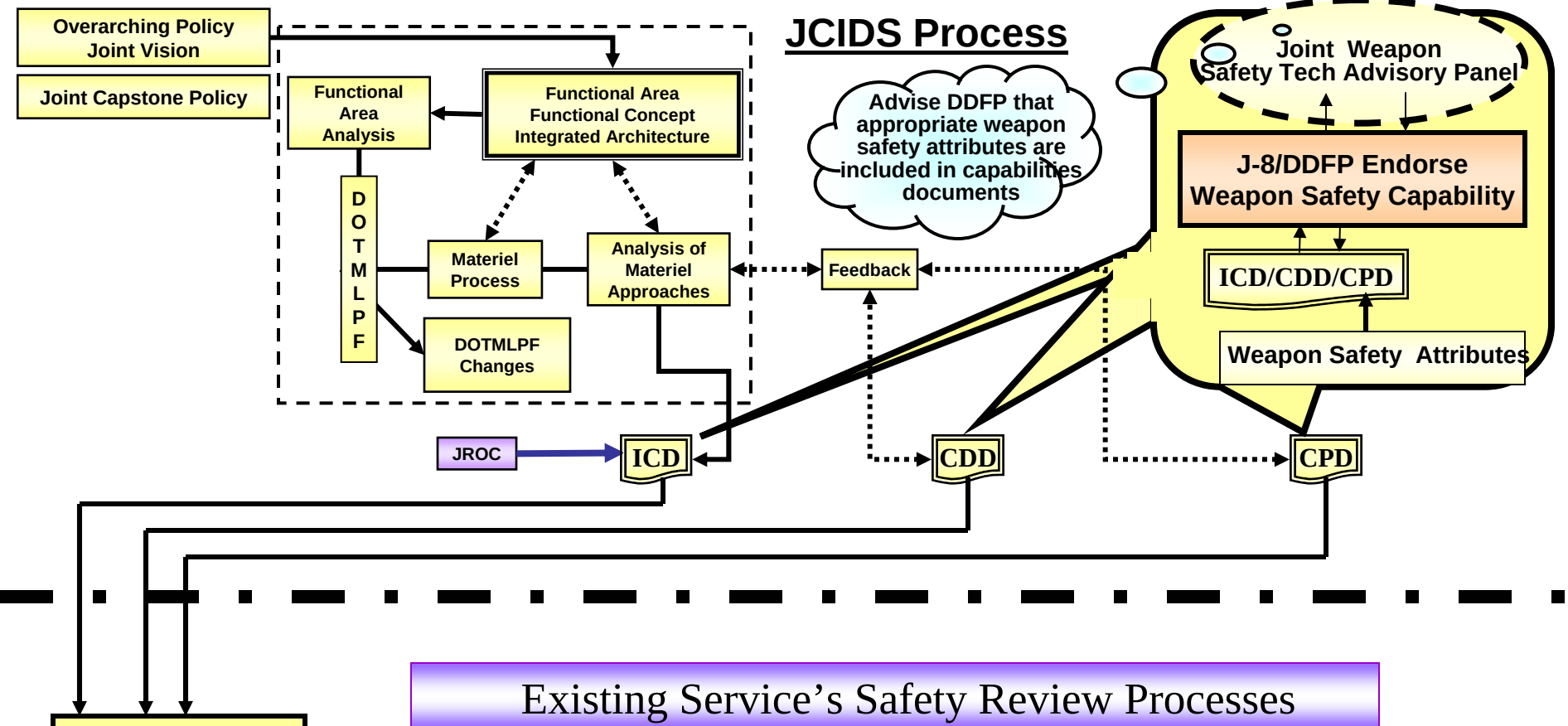
JCIDS Recommended Process

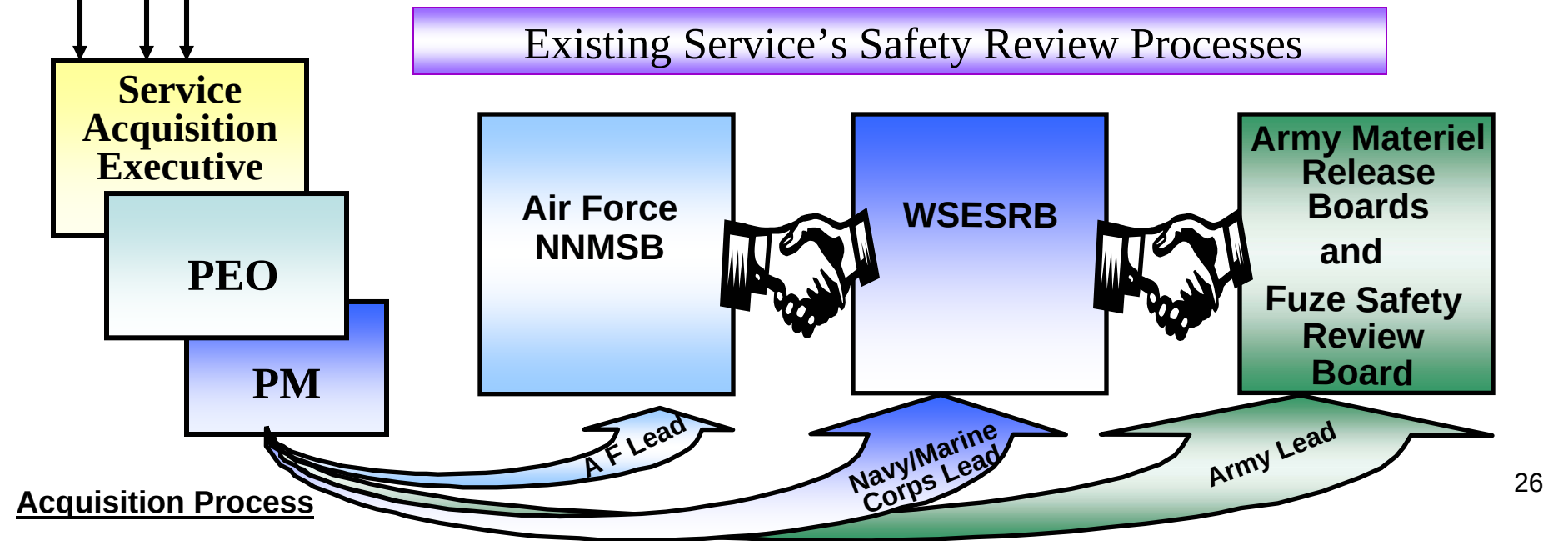
- ICD/CDD/CPD Required to Address Weapon Safety
  - ICD to Contain Weapon Safety Capabilities Statement
  - CDD and CPD to Address Specific Weapon Safety Attributes Needed for Joint Warfighting Environments
- DDFP Validates that the ICD/CDD/CPD Adequately Address Weapon Safety Attributes within the JCIDS Process
- J-8/DDFP Provides Weapon Safety Capabilities Endorsement, with Any Limitations Identified
- Joint Weapons Safety Technical Advisory Panel Council (JWSTAP) Created to Advise the DDFP and Sponsors in the Weapon Safety Capabilities Endorsement Process

JCIDS Process



Acquisition Process





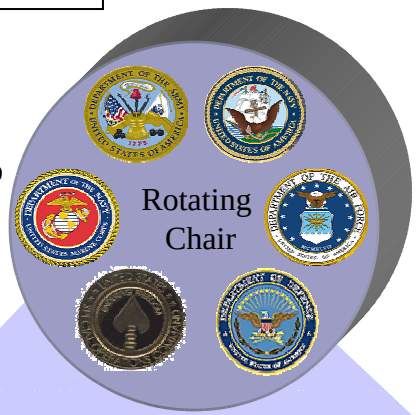
Acquisition Process

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Joint Weapon Safety Technical Advisory Panel

Working Within the Joint Capabilities & Integration Development Process

JWSTAP



JWSTAP Provides

Weapon Safety Capability Endorsement Recommendation to the J-8/DDFP Regarding ICD, CDD, CPD

Joint Warfighting Safety Requirements; Tailored From Existing Standards

Leverage Existing SME, With Warfighter Representation

Air Force
Nonnuclear Munitions Safety Board

Army
Materiel Release Boards
Fuze Safety Review Board

Navy **Marine Corps** **Coast Guard** **USSOCOM**
Weapon System Explosives Safety Review Board

Existing DoD 5000 Acquisition Process

Hardware/Software Safety Design Review and Approval

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Where Will This Take Us?

- **Toward Service Collaborative Reviews**
- **Toward More Universal Cross-Service Criteria**
- **Toward Single Safety Reviews**

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How Can You Help?

- **If the WSESRB is Remiss in Coordinating Reviews…**
  - **ask for coordinated review?**
- **Communicate Early in the Acquisition Process?**

Questions?

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Back-ups

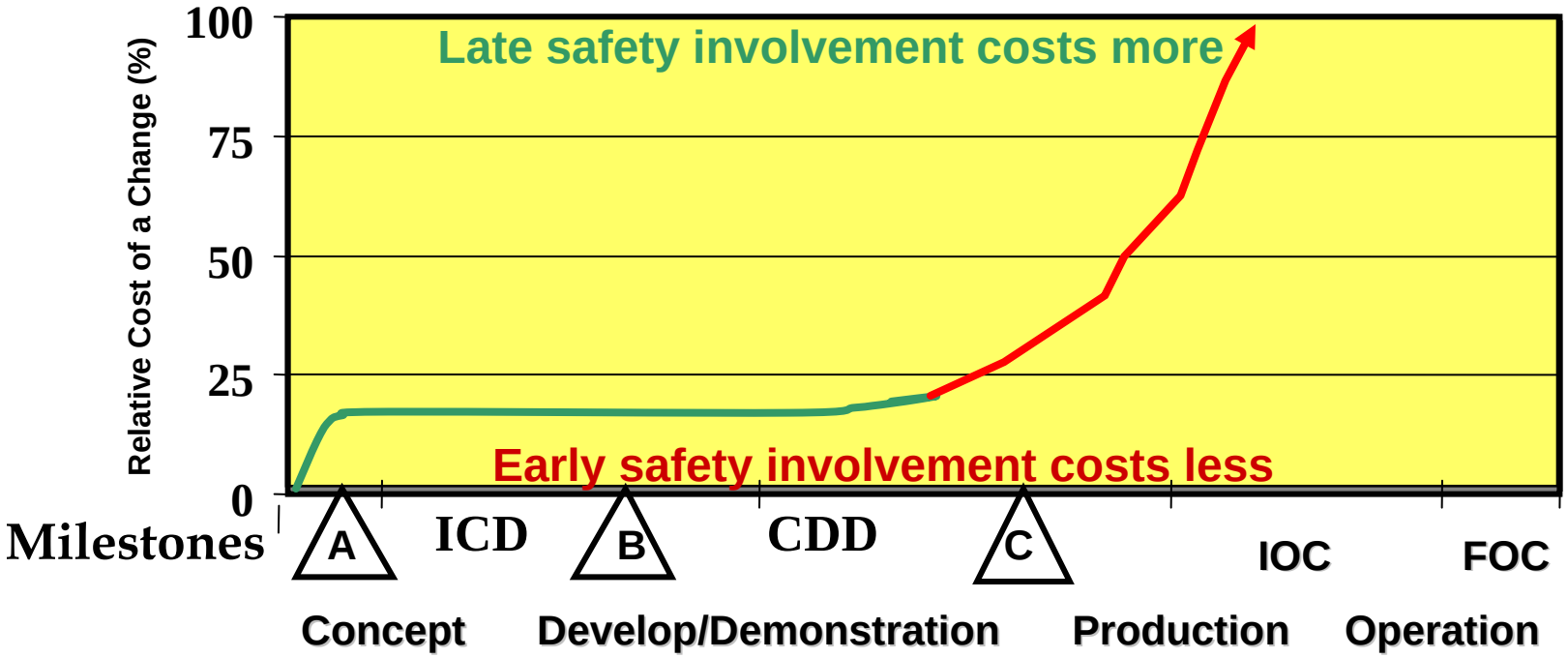
- **USAF NNMSB**
  - **Chart #5**

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Why a Weapon Safety "Certification" Process?

Over a program's lifecycle it costs less to integrate safety early

Curve adapted from NASA's Practice No. PD-AP-1314.



System Engineering/Acquisition Phases

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Joint Operations Example

- USS DWIGHT D. EISENHOWER September 1994
  - Embarked Army Contingent; 14 AH-1F Cobra, 13 MH-58 Kiowa and 26 MH-60 Blackhawk Helicopters
  - Examples of Issues
    - Shipboard Bow Whip Antennas Secured Until All Cobra Helicopters Departed
    - Hot tube loading of 2.75” Rockets Not Authorized
    - Thermite Grenades (NALC G900) Not Permitted, Exceeded Jettison Locker Capacity
    - Army Munitions on Wooden Pallets, Wooden Boxes; Shipboard Fire Issue

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Joint Operations Example

- USS KITTYHAWK, Fall 2001
  - Embarked Army SOF in Support of Enduring Freedom
  - Examples of Issues
    - HERO Unsafe, Untested, or Susceptible; Required Restrictive EMCON to be Set When Handling SOF Ordnance
      - Reduces Communications, Detections, and Tracking Capabilities of the Ship
    - Waiver Granted for Non-thermally Protected Ordnance Aboard Ship
    - Waiver Granted for SOF to Conduct Hot Tube Loading of 2.75 Inch Rockets
    - Identification, Compatibility, Segregation of SOF Ordnance

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Joint Operations Example

EMV Compatibility Issues

- Aircraft Susceptibility Issues Discovered During EMV Testing to the Army/Navy Joint Operation Electromagnetic Environment (Reports Available Dated July 1986, April 2001, February 2002)
  - Engine Instrumentation
  - Avionics Systems
  - Multifunction Display
  - Weather Radar
  - GPS System
  - HF and UHF Communication Set
  - Digital Electronic Control System

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Interim Workarounds

- Joint Shipboard Helicopter Integration Program (JSHIP)
  - 5 Year DoD JT&E Sponsored Program (1998-2003)
  - Ordnance was One Part of the JSHIP Effort
  - Attempt to Develop Procedures to Mitigate Risk
  - Cost: $22M
- Joint Shipboard Weapons/Ordnance Program (JSWORD)
  - 1 Year Quick Reaction Test Sponsored by DoD JT&E (12 May 03 – 31 March 05)
  - Sponsored by USSOCOM
  - Focused on Developing Shipboard Procedures for Hot Tube Loading of 2.75” Rockets On Army Helicopters
  - Cost: $1M

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Working Group Recommendations

- Establish a Weapon Safety Capability Certification Process for Joint Warfighting Environments
  - Not Modeled on Current CJCSI Certification Processes
  - Risk Identification and Acceptance Decision Process
  - Safety Is Risk Management, Not Compliance, Issue
- Identify Weapon Safety Capabilities in ICD/CDD/CPD Process
- Establish a Technical Advisory Committee to Review Capabilities Specified in the ICDs/CDDs/CPDs and Advise DDFP on Risks and Limitations, If Any

GENERAL DYNAMICS
Armament and Technical Products

PHALANX

ARROW TECH

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



Optimized Gun Barrel Targeting Investigation

Jeff Siewert
Arrow Tech Associates
Systems Engineer

NDIA GA&RM April 2005

Outline

- Requirements & Problem
- Diagnostic Tests
- Targeting Background & MPI Shift Sources
- Analyses & Measurements
- Firing Results
- Conclusions

- Thanks to Ms. JoAnn Kramer, GDATP Phalanx PM

OGB Targeting Requirements

Burst Dispersion – One Sigma

- Req'mt < 1.0 milr

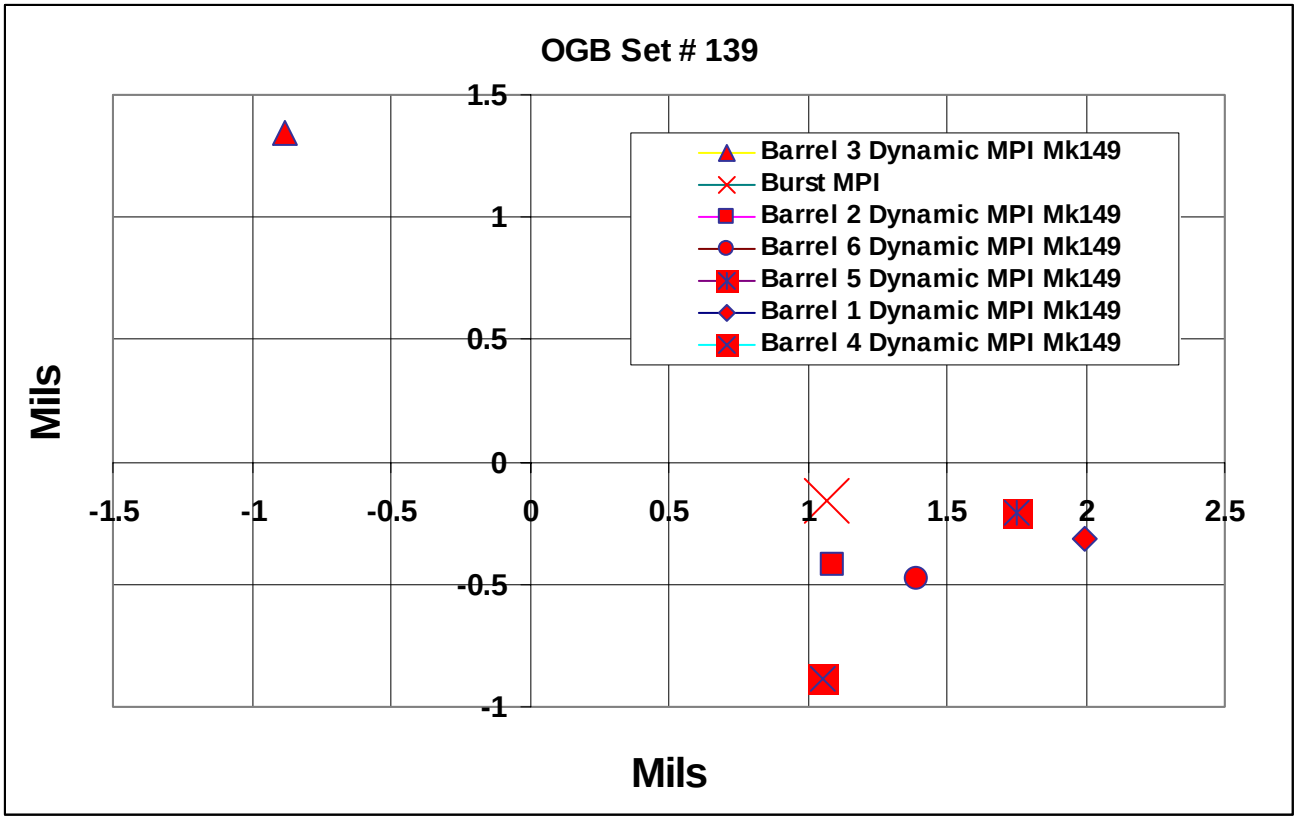
Max Individual Bbl MPI wrt Burst MPI

- Req'mt < 1.5 milr

Average Bbl MPI wrt Burst MPI

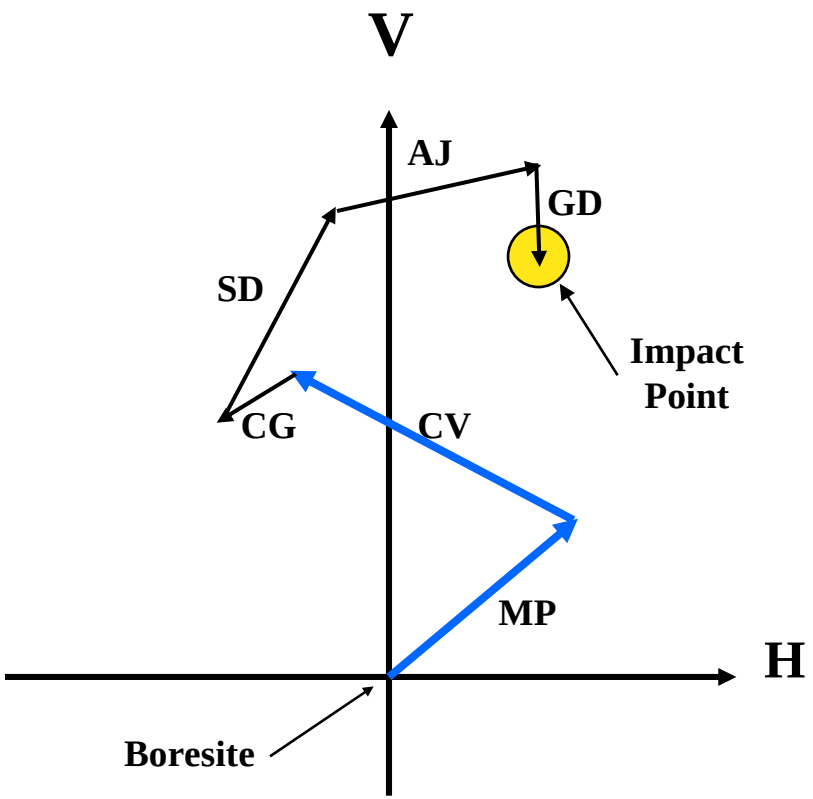
- Req'mt < 1.0 milr

Typical “Problem” Target



- MPI of one or more barrels fails to fall within 1.5 milr of average burst MPI
- Barrels meet TDP established during system qualification

Background: Jump Budget



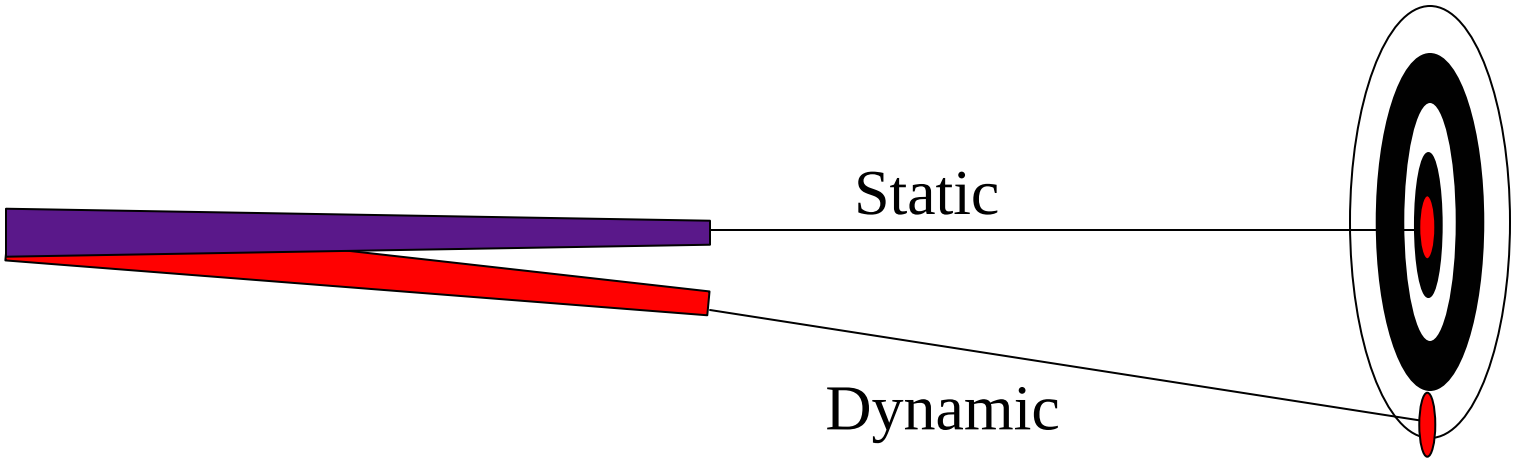
MP = Muzzle Pointing
CV = Barrel Cross Velocity
CG = Projectile CG Cross Velocity
SD = Sabot Discard
AJ = Aero Jump
GD = Gravity Drop

- Objective: Make MP & CV small, repeatable on a barrel-barrel basis

MPI Shift Sources

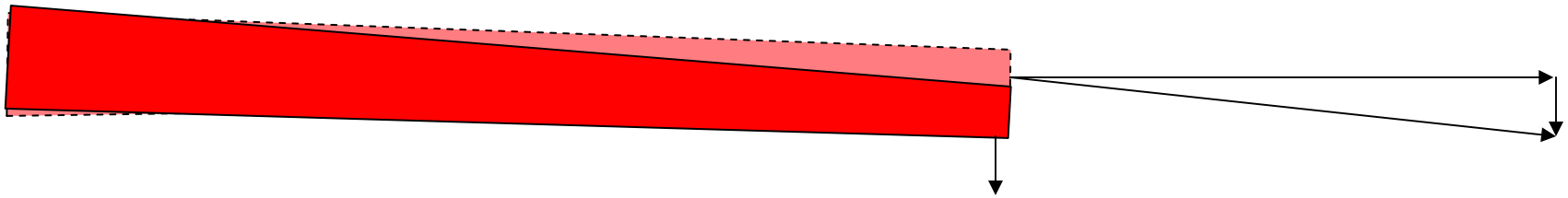
- Bore Straightness (pointing, x velocity, angular rate)
- Barrel Ring Length (pointing, bending stiffness)
- Chamber Run Out (initial condition bias)
- Gun Dynamics (pointing, x velocity, angular rate)
- External sources (e.g. Blast, Sabot Discard)

Barrel Pointing



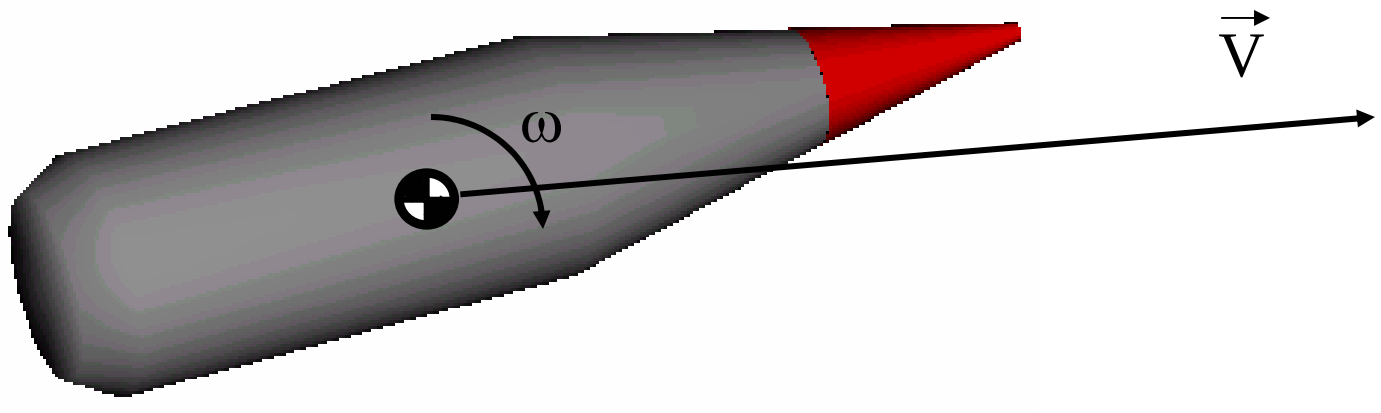
- **At muzzle exit, tube is not aligned with static boresite point**
  - ↗ **Symptoms: Impact not at boresite point, no yaw visible, tube motion during in bore travel**
- **Caused by: bore curvature, projectile-barrel interactions**

Barrel Cross Velocity



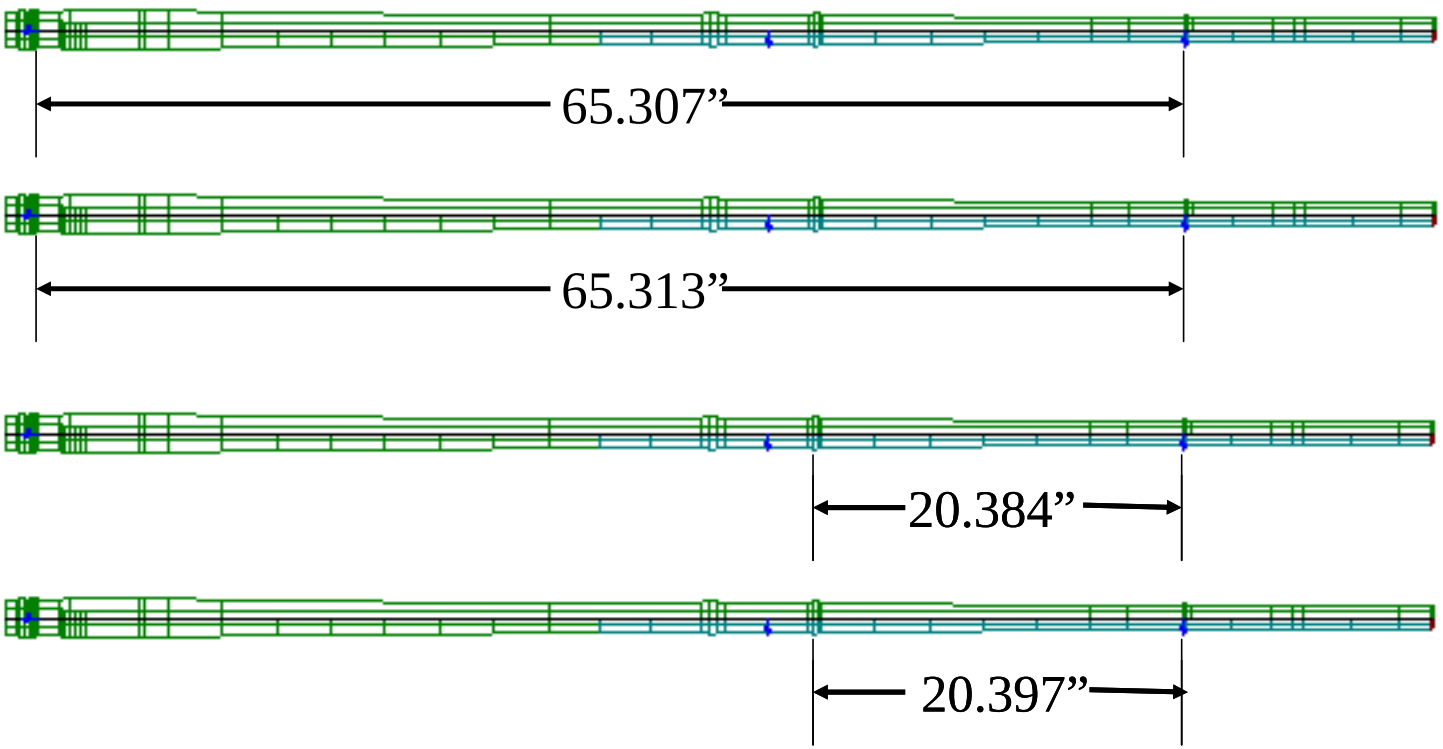
- At projectile release, velocity vector is imparted to the projectile perpendicular to muzzle velocity
  - ↗ Symptoms: Impact not at boresite point, no yaw visible, tube motion during in bore travel
- Caused by: Barrel run-out, bore curvature, L-G Run out, projectile CG offset, projectile-barrel interactions

Preferred Angular Rate



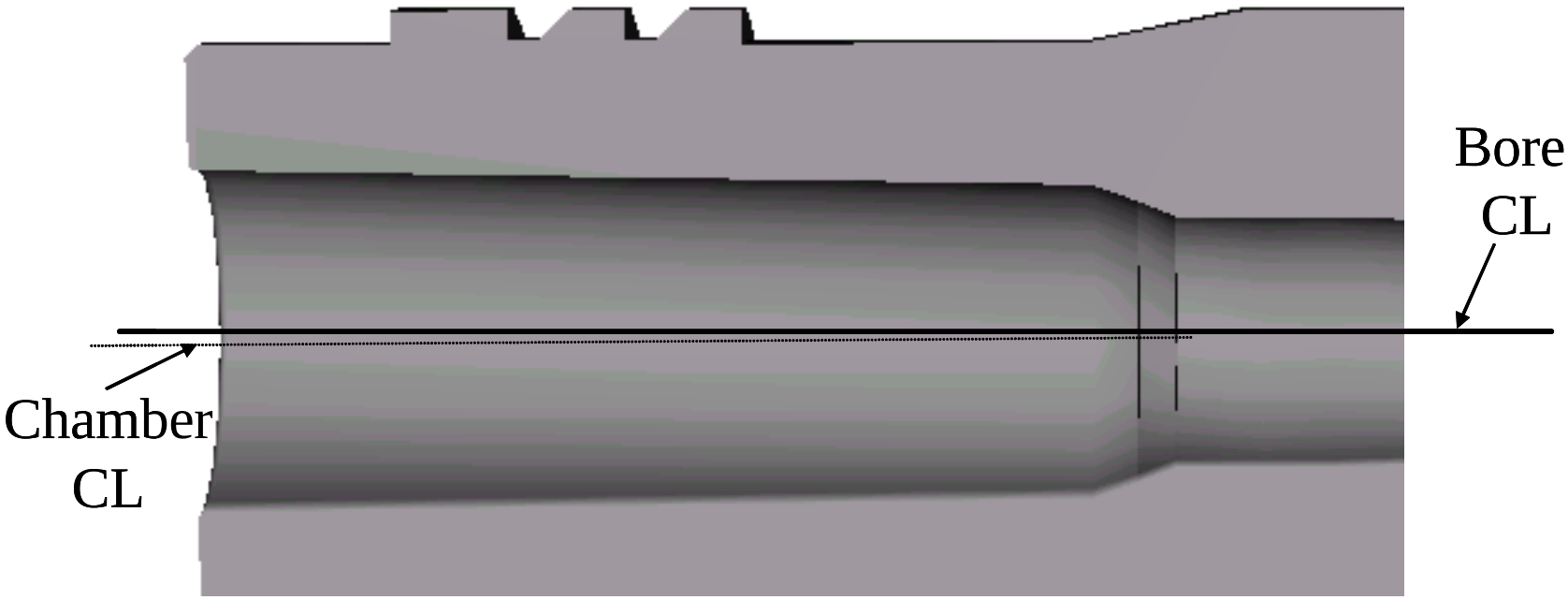
- **Moment applied to projectile at muzzle release**
  - ↗ **Symptoms: Yaw Visible, Preferred Orientation = MPI Shift; Random Orientation = dispersion**
- **Sources: In bore clearance x spin, projectile–barrel interactions, bore curvature, change in bbl cross velocity between fwd & aft bourrelet release, etc.**

Barrel “Ring” Length



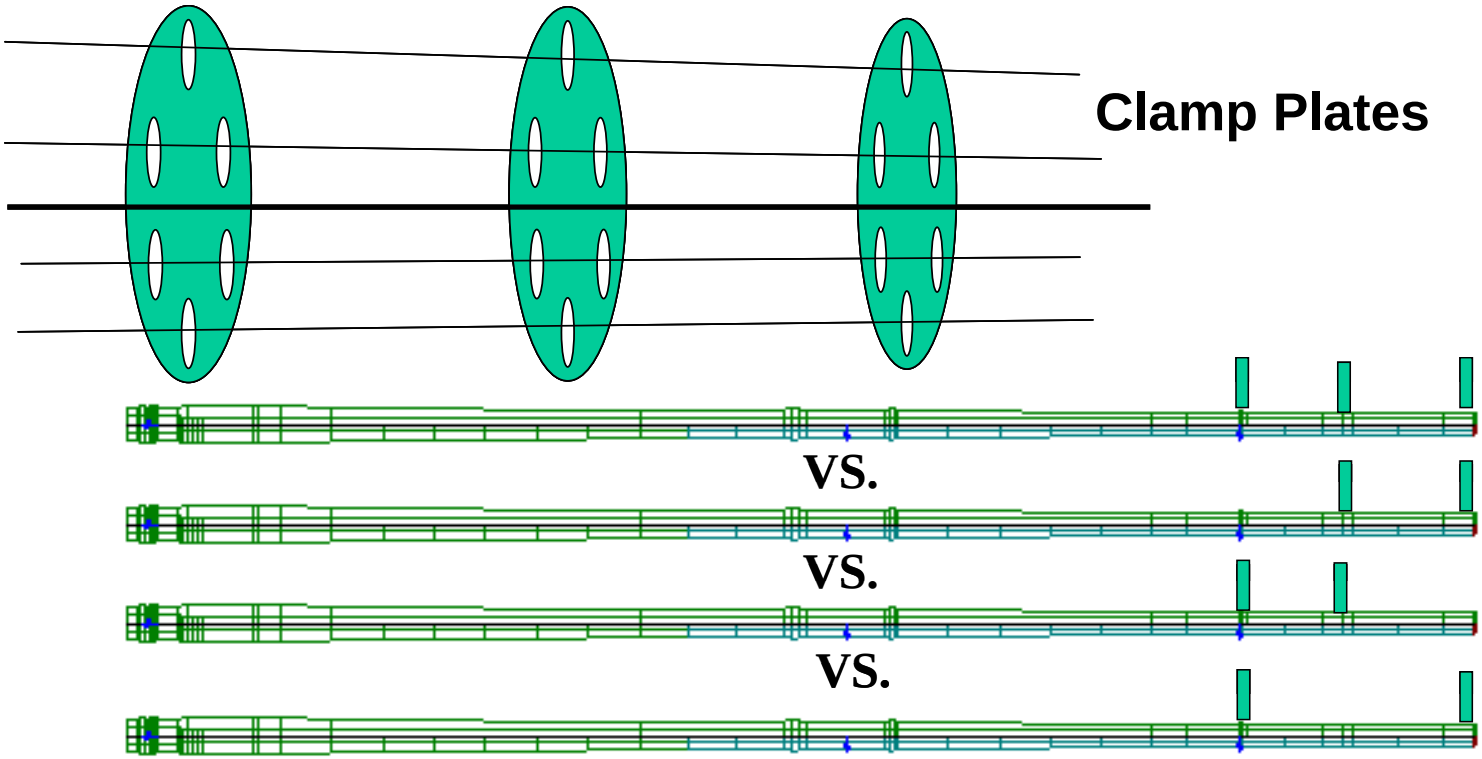
- Minor Effect on Pointing
- Potentially Large Effect on cluster bending stiffness
- Effect of mid bbl clamp & muzzle clamp axial gaps

Chamber Run Out



- Easily visible if present in forcing cone
- Not observed on “problem” barrels

Gun Dynamics: Clamping Variability

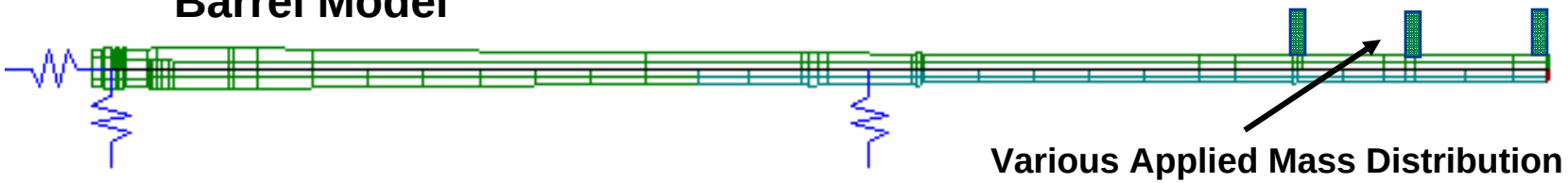


- Small changes barrel-barrel cause variations in boundary conditions (location of applied mass) for each barrel
- Interactions occur w/ bore straightness, projectile & barrel stiffness
- Can cause large changes in Mean Point of Impact

Gun Dynamics: Balloting Simulation

PHALANX

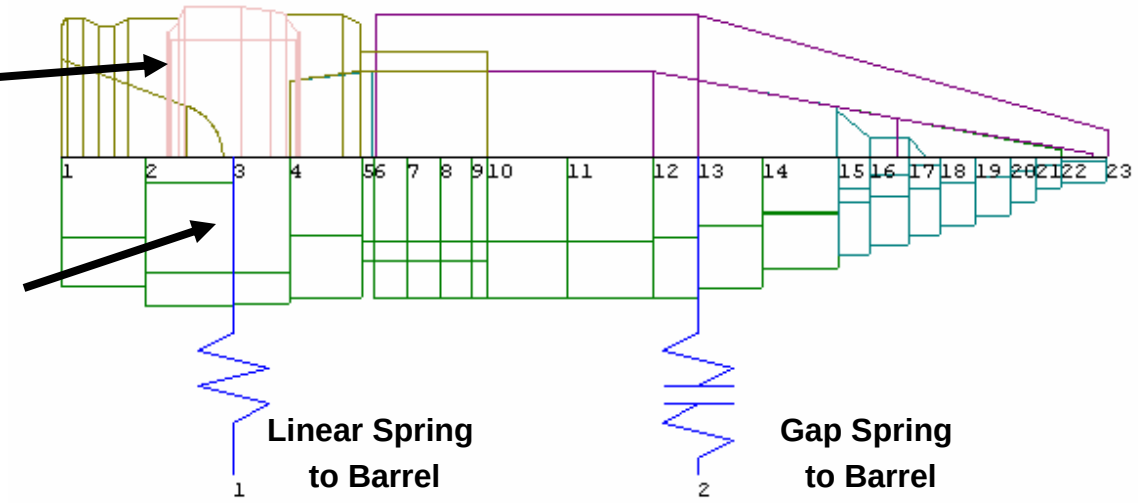
Barrel Model



Various Applied Mass Distribution

Projectile Geometry

Lumped Mass & Beam Element Projectile Model



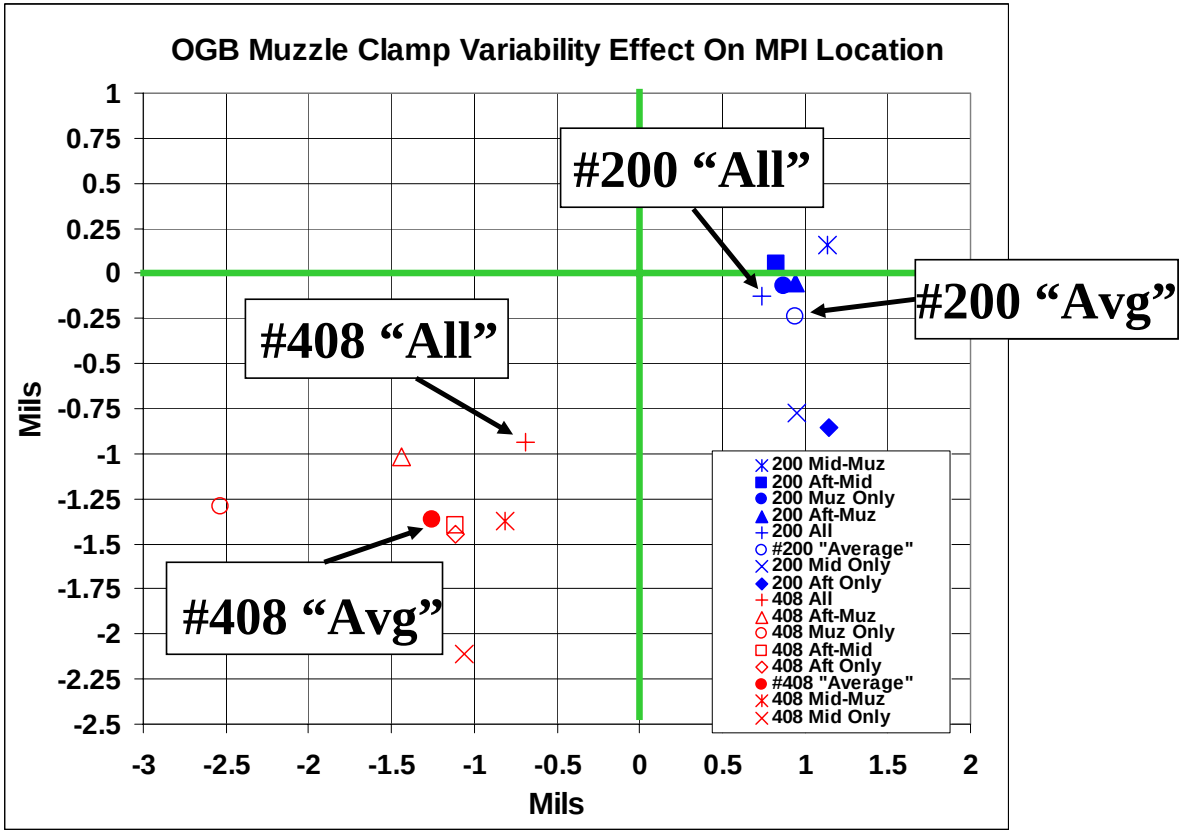
Linear Spring to Barrel

Gap Spring to Barrel

- Balloting Analysis Model of Barrel & Projectile
- 500 Runs in Monte Carlo Mode to Obtain MPI

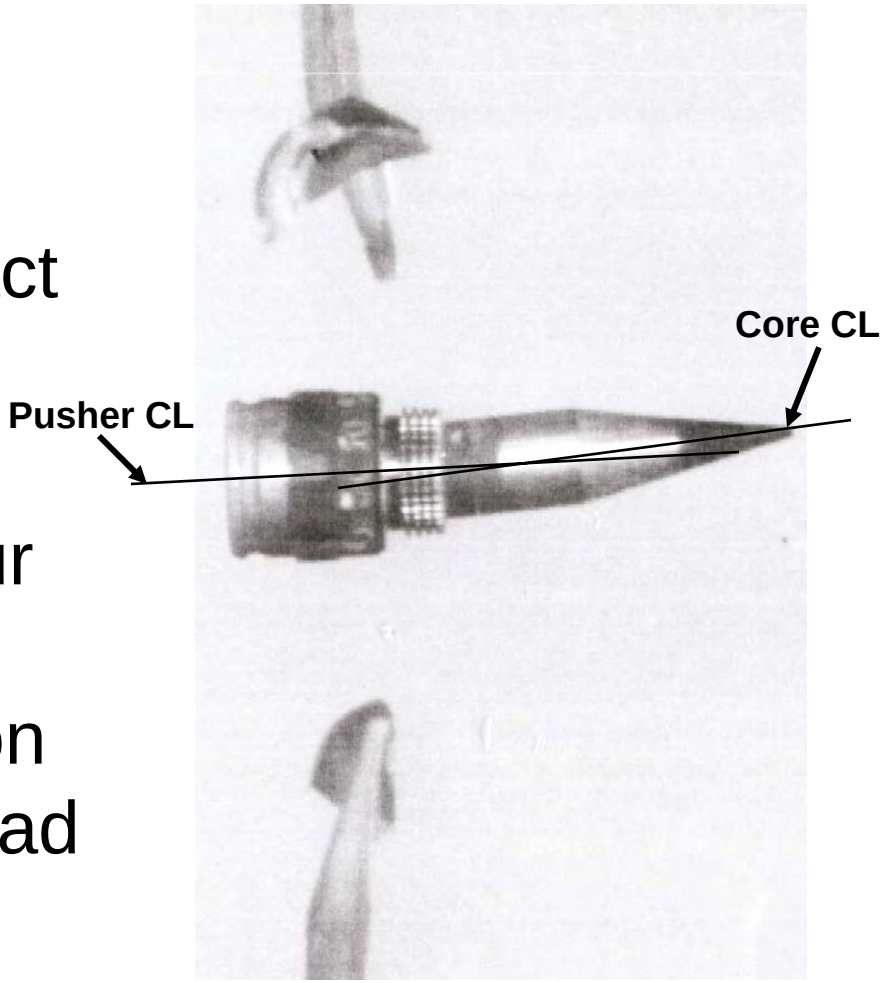
Clamping Variability Targeting Results

- Results of analytical treatment of balloting interaction between flexible barrel & projectile
- 500 simulations per predicted impact point
- #200 is “straight”, #408 has ~ 0.009” TIR change over last 3” of travel
- Illustrates need to make bore straight
- Illustrates need to make clamping consistent



Sabot Discard

- Mismatched yaw period of pusher & core guarantee impact w/ hi angular rates
- Large jump can occur for very small lateral impulse depending on location of applied load



Investigation Plan

Nov 2003

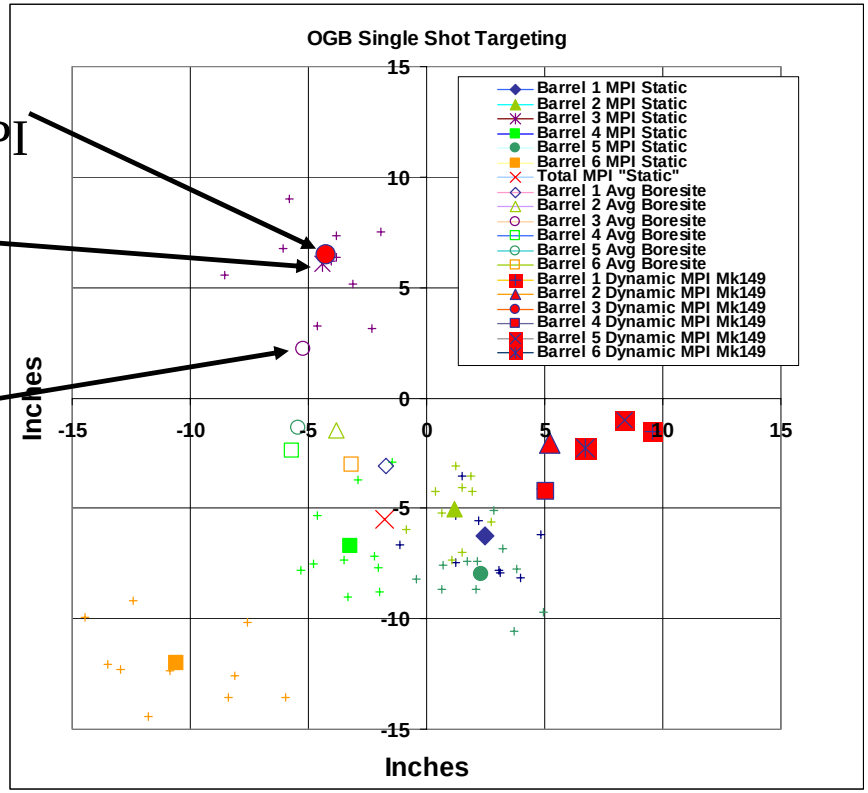
- Single Shot Firing of Barrels & Clamps comprising Kit # 139 w/ Mk-244 Ctgs.
- Purpose: Determine which barrel parameter affects targeting
- Compare static results w/ dynamic firing to isolate gun dynamic effects
- Trends visible useful for “screening”?

Diagnostic Test Target

BBL 408
Dynamic MPI

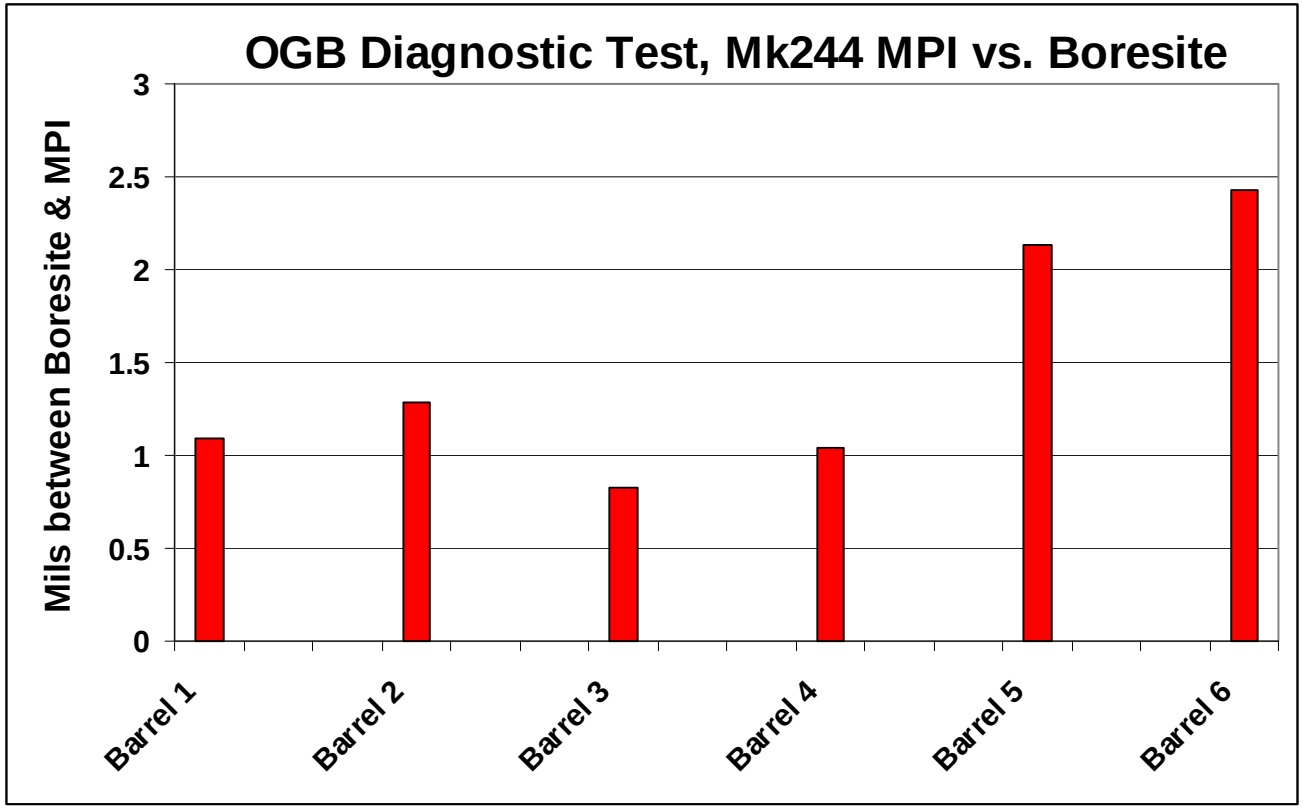
BBL 408
Static MPI

BBL 408
Boresite



- Kit 139, Autogun Fired in single shot mode
- Projectiles from bbl 3 (#408) & bbl 6 (#465) have yaw

MPI vs. Boresite



- Barrel 3 (#408, problem barrel) hits closest to boresite!!
- Why is Barrel 3 MPI so far from other barrels??

Single Shot Test Results

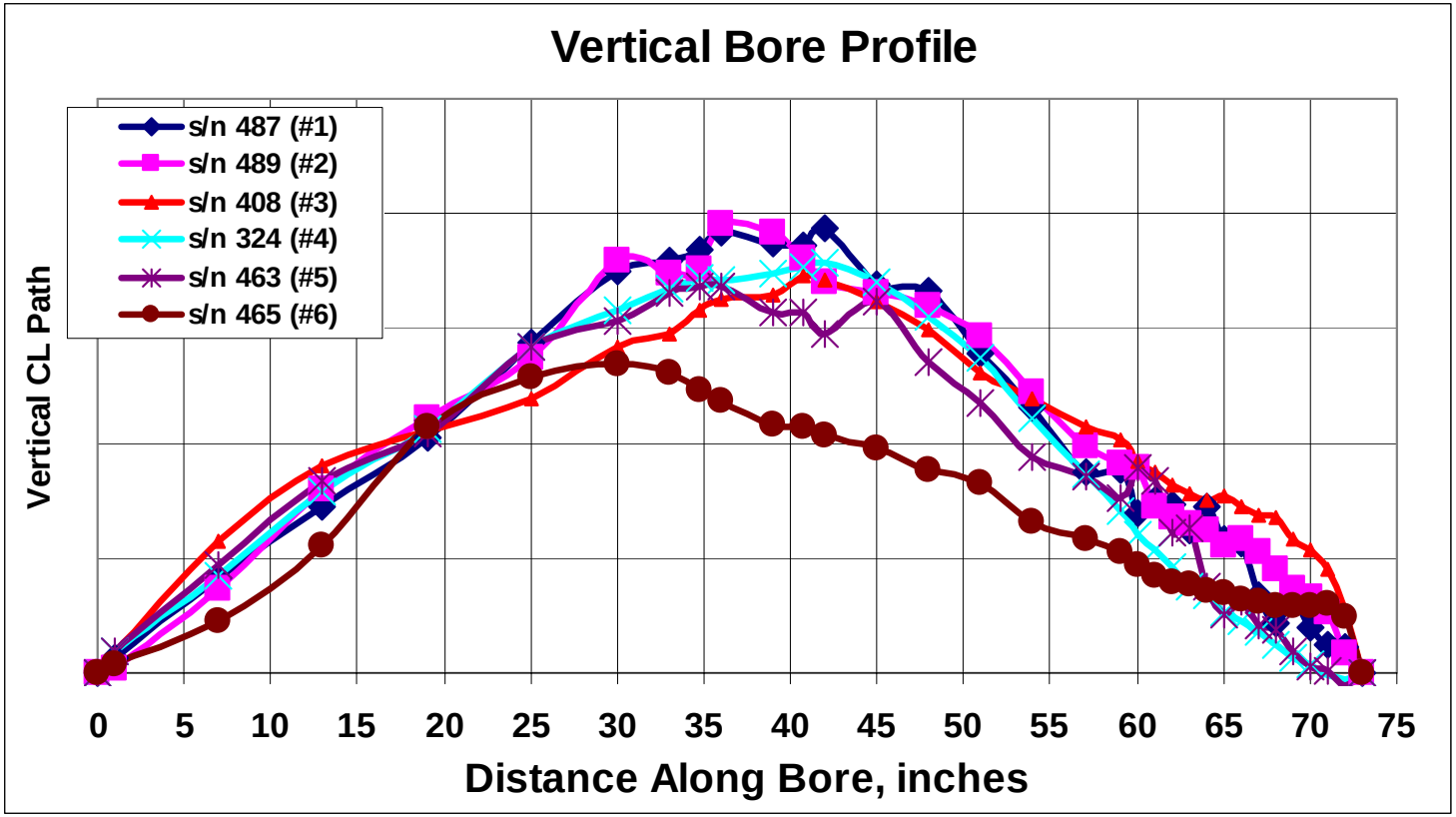
	Yaw Angle @ 400 ft Deg.	$\alpha^{\blacksquare}$ @ muzzle rad/sec.	Expected Jump Mils	Implied Clearance inches
Barrel #6	9.5	~200	~2.13	~0.026
	7.5	~160	~1.70	~0.021
	7.5	~160	~1.70	~0.021
	5.0	~105	~1.12	~0.014
	5.0	~105	~1.12	~0.014
	2.0	~ 42	~0.45	~0.005
Barrel #3	7.5	~160	~1.70	~0.021
	7.5	~160	~1.70	~0.021
	5.5	~116	~1.23	~0.015
	3.0	~ 63	~0.67	~0.008

- **Large yaw levels imply in bore disturbance**
- **Examine bore straightness**

Bore Straightness Investigation

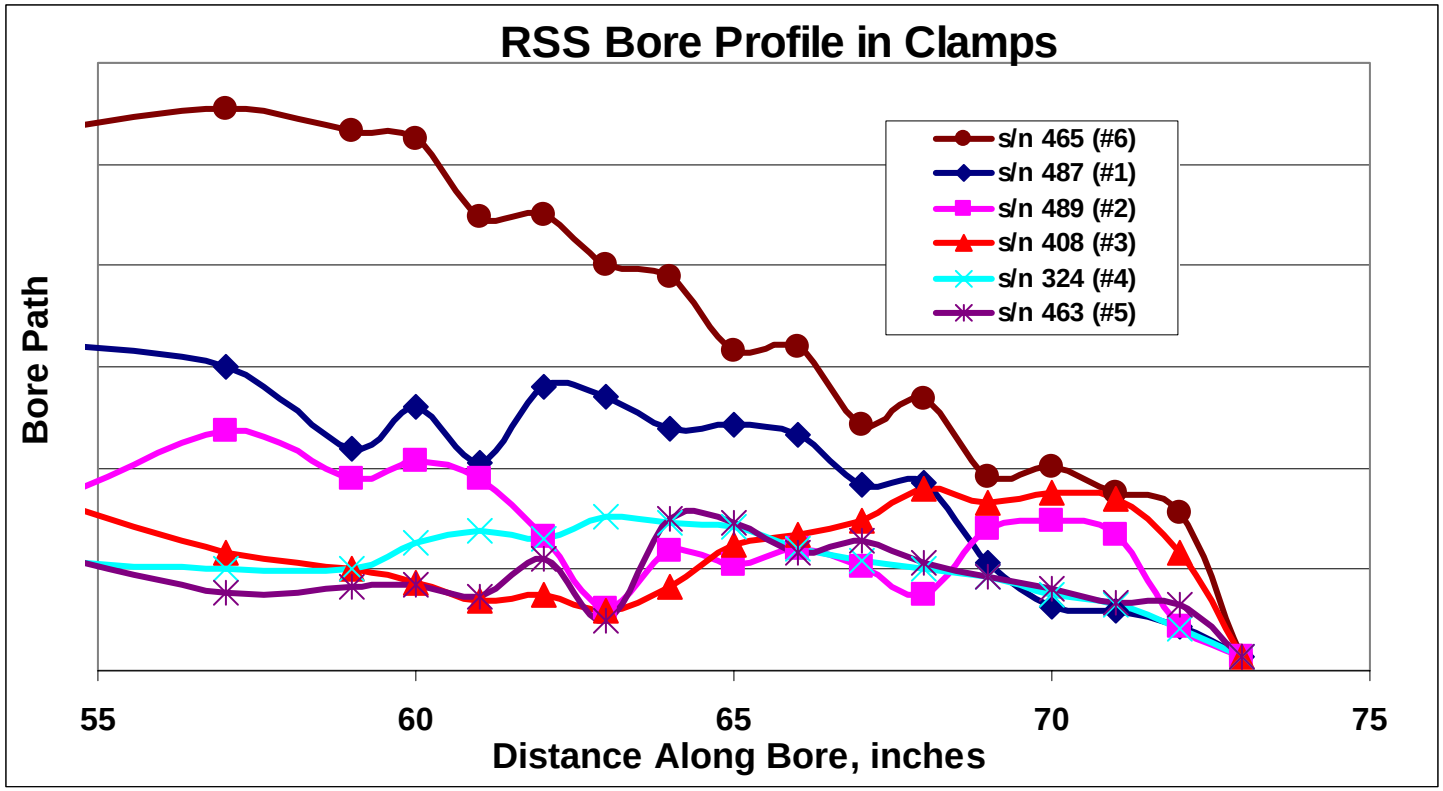
- Laser (optical) measurement of bore
  - Map entire bore profile
- Wiggler (mechanical) measurements of bore
  - Map muzzle end of bore

Bore Straightness in Clamps



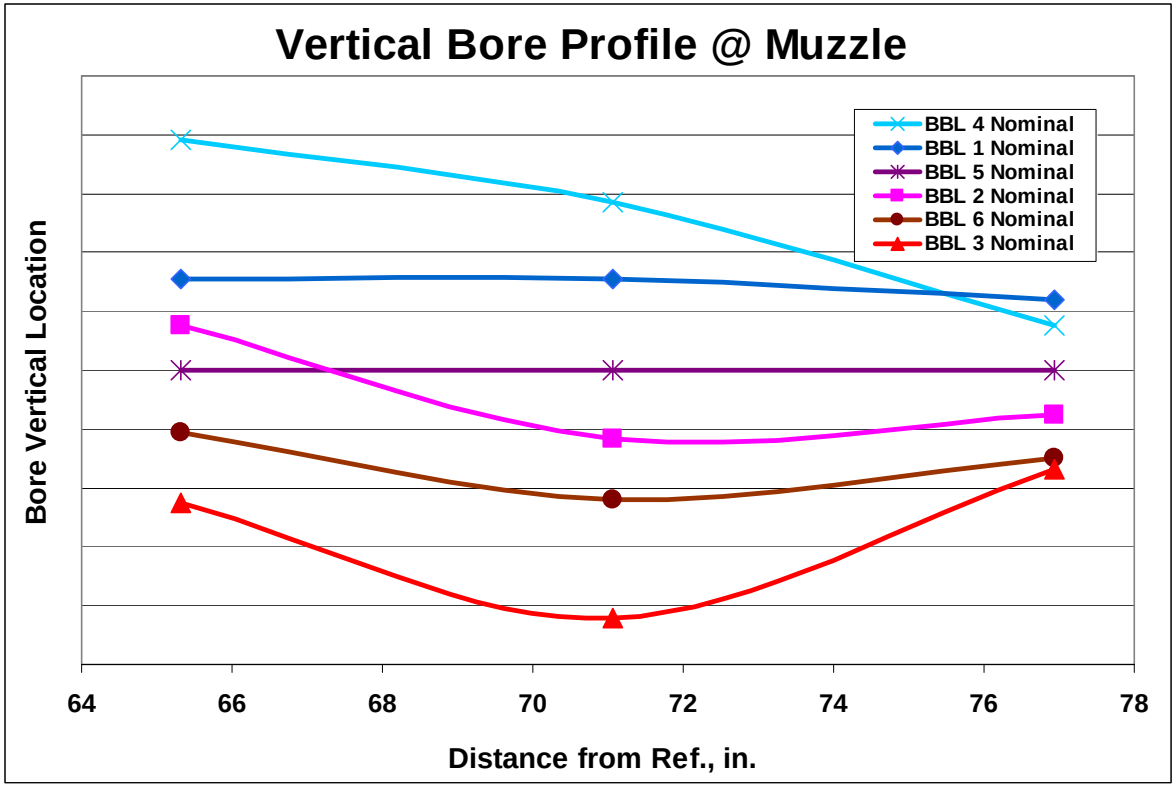
Barrels supported at aft & mid barrel (~ 39”)
Mathematically zeroed at breech & muzzle

Kit 139 Muzzle Close-up



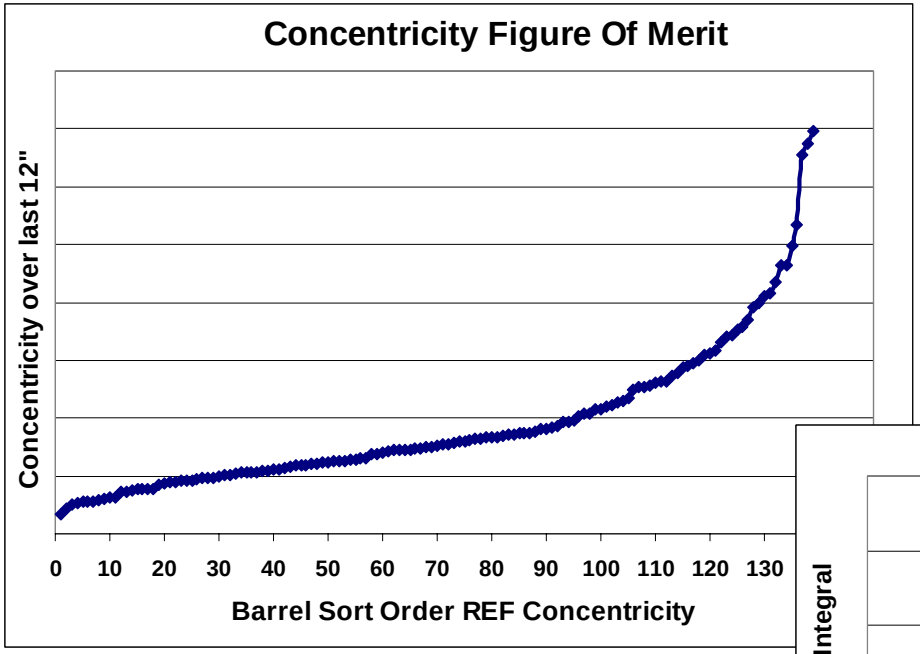
- Barrels w/ yawed projectiles also have straightness problem near muzzle!

Kit 139 Wiggler Measurement

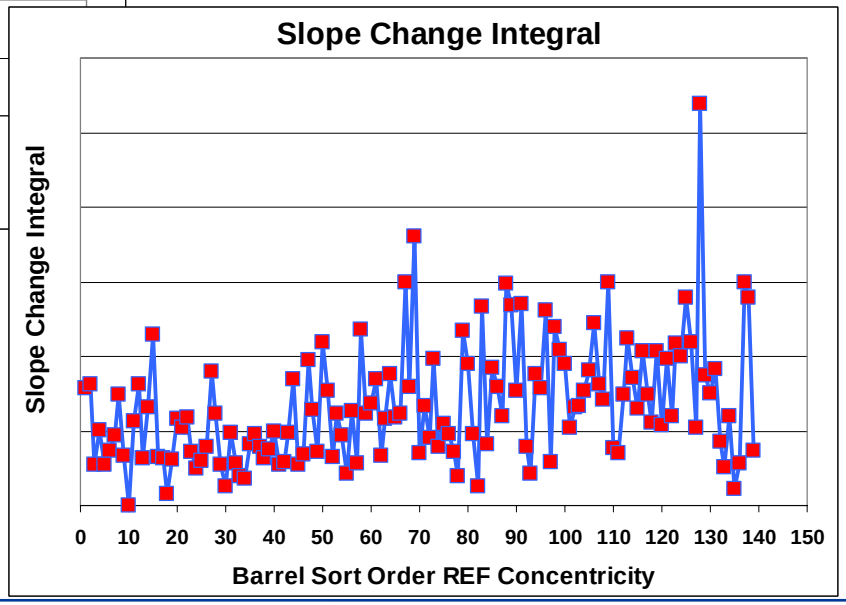


- Problem readily identified w/ either wiggler or laser

Bore Concentricity & Straightness



- Inspect 167 bbls on hand
- Sort by concentricity & straightness
- Group & Fire Test to find straightness limits



Firing Results

- Passed 45 of 46 acceptance tests
  - "Avg." Max Barrel MPI ~ 1.05 mils, σ ~ 0.28 mils
  - Avg. Cluster Dispersion ~ 0.72 mils, σ ~ 0.12 mils
  - Avg. Barrel MPI ~ 0.65 mils, σ ~0.17 mils

- Slave Performance:
  - "Avg." Max Barrel MPI ~ 0.77 mils, σ ~ 0.21 mils
  - Avg. Cluster Dispersion ~ 0.59 mils, σ ~ 0.11 mils
  - Avg. Barrel MPI ~ 0.50 mils, σ ~ 0.14 mils

- Pass probability for Max Barrel MPI ~ 94% (Gaussian)

Straightness Limits

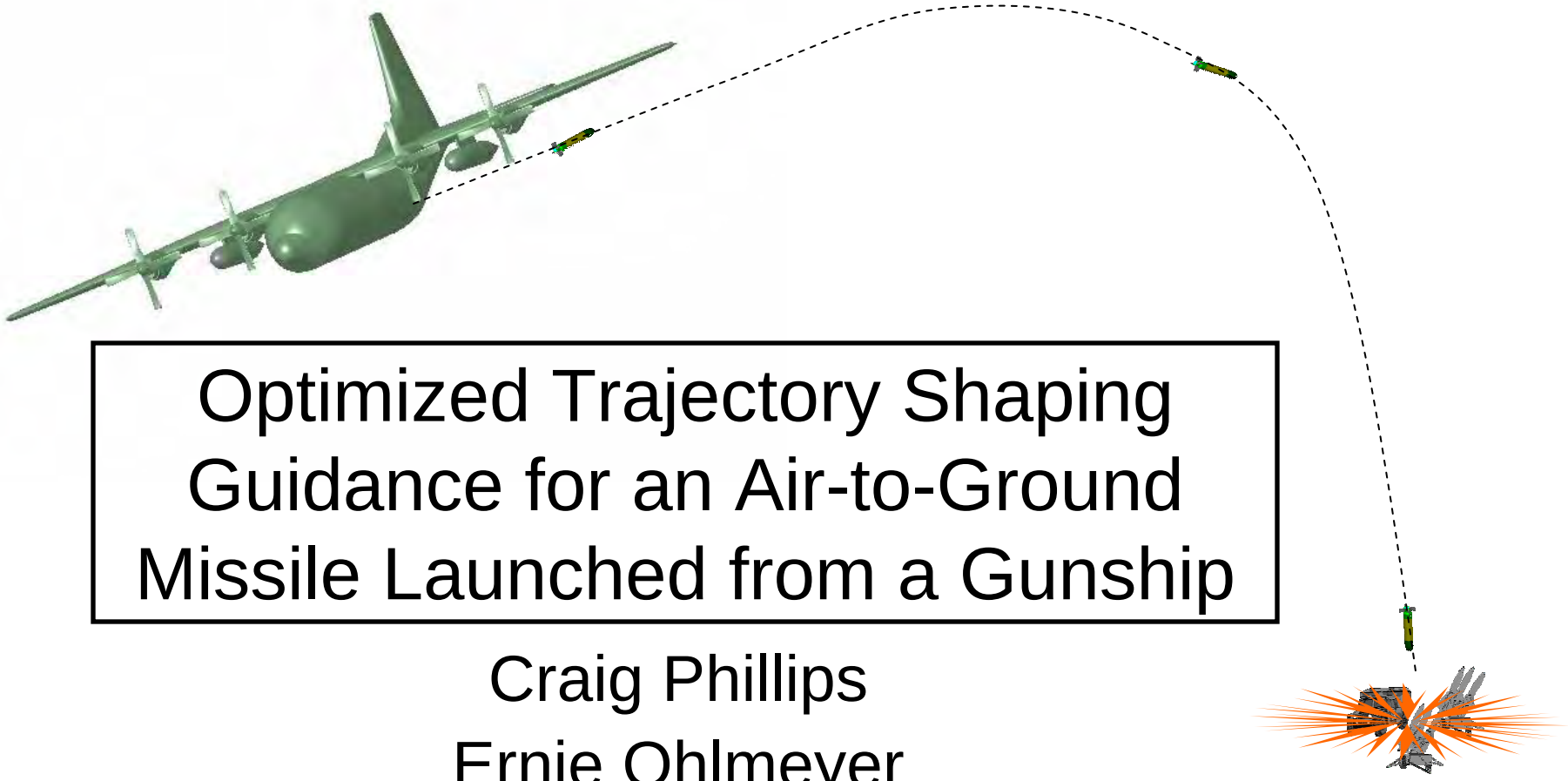
- Empirical TIR change limit determined of 0.0015”/1 inch and 0.0025”/2 inch over last 6” of barrel travel.

Conclusions

- **Monitoring bore straightness critical to targeting success.**
- **Process improvements underway to reduce straightness variability.**

Translating Lessons Learned into Systems Requirements

- **Bore straightness can be critical for low dispersion, multi-barrel systems.**
- **Bore straightness has implications for single barrel weapons with MPI vs. aim point requirements when barrels are changed.**
- **Bore straightness of single barrel guns will influence MPI difference for projectiles w/ significantly different action times (e.g. APFSDS-T vs. HE)**



Optimized Trajectory Shaping Guidance for an Air-to-Ground Missile Launched from a Gunship

Craig Phillips
Ernie Ohlmeyer
Shane Sorenson

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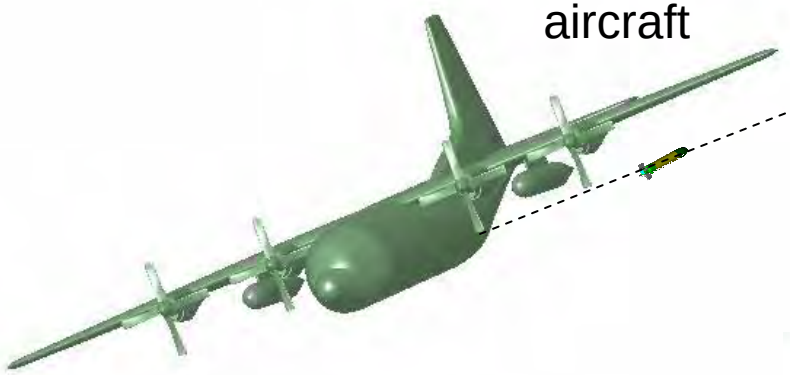
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Overview

- Mission Scenario
- Notional Munition Concept
- Guidance Laws
  - Generalized Vector Explicit Guidance
  - Composite Guidance
- Footprints
- Trajectories
- Conclusions

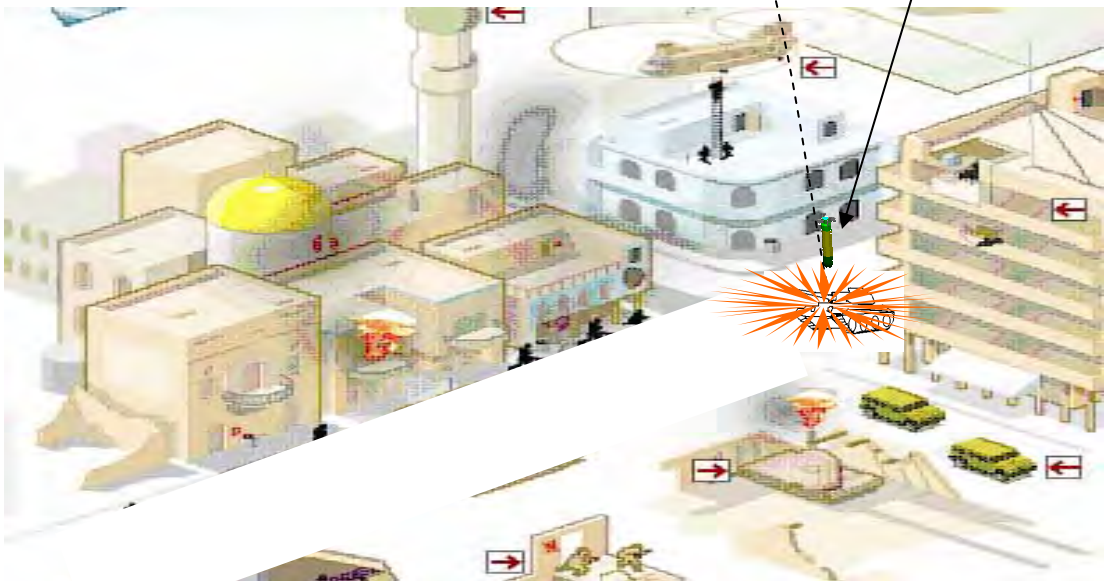
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Next Generation Gunship Mission Scenario



Munition launched from port side of aircraft

Vertical Impact Angle



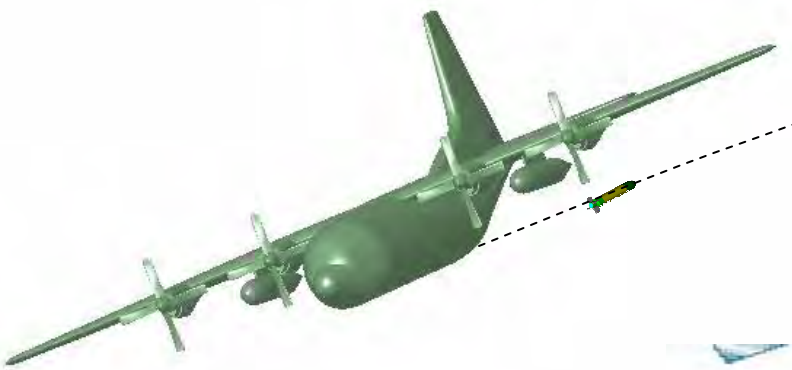
Munition will be able to reach extended ranges and have 360 degrees of coverage, which will help keep the gunship out of the range of an enemy's weapons.

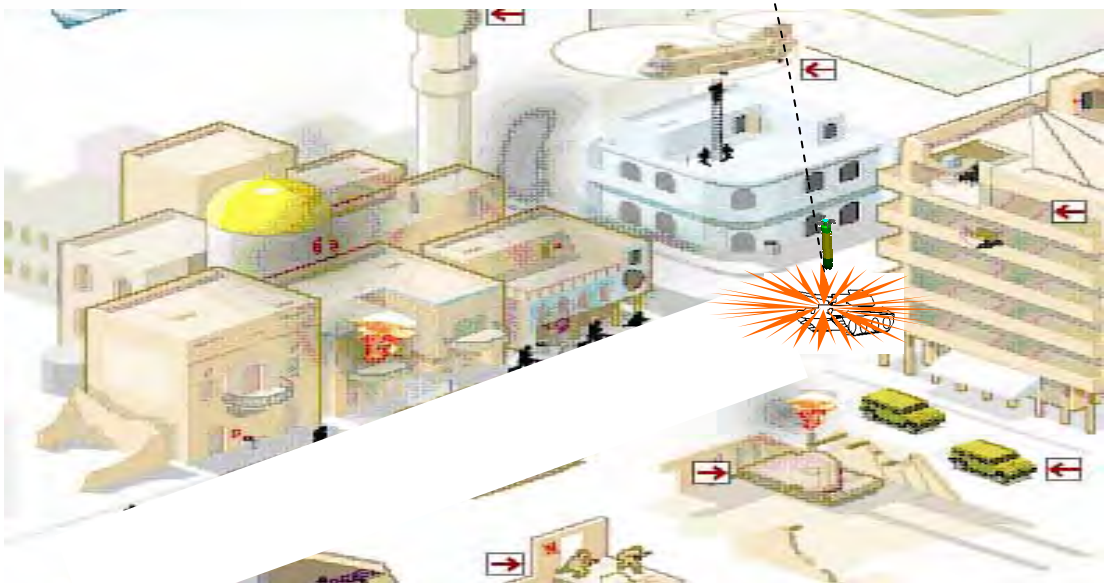
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Next Generation Gunship Mission Scenario

Munition must meet Military Operations on Urban Terrain (MOUT) requirements:

- Be able to attack in urban canyons
- Have low collateral damage

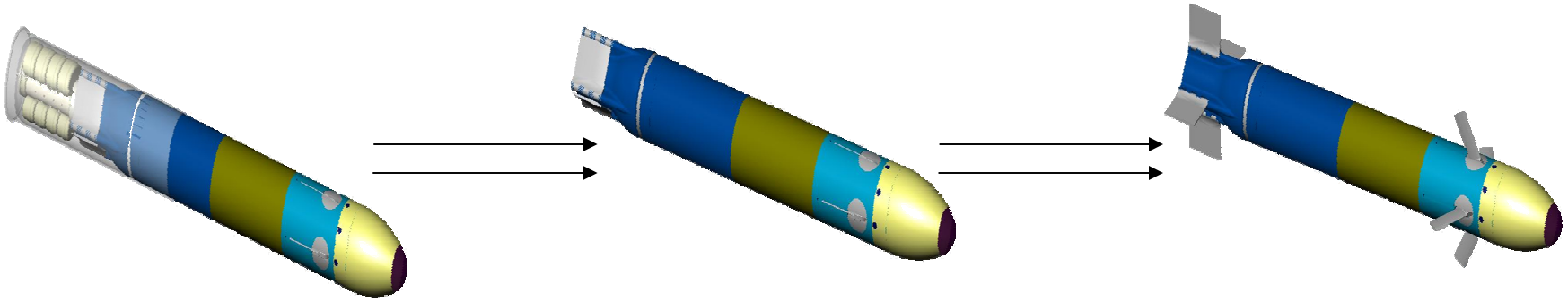




Trajectory shaping will help the munition reach these extended ranges, have 360 degrees of coverage, and meet MOUT requirements

Notional Gun-Launched Munition Concept

- Weight: 47.5 lb
  15 lb (Warhead)
  20 lb (Propellant)
- Length: 42.5 inches
- Diameter: 4.7 inches (120 mm)
- Thrust: 1350 lb (Boost)
  163.9 lb (Sustain)
- Burn Time: 2 sec (Boost)
  15 sec (Sustain)
- Total Impulse: 5158.5 lb*s



- Angle of Attack (Max): 20 deg
- Achievable Acceleration: 35 g's (Aerodynamic Limit)

Generalized Vector Explicit (GENEX) Guidance

$$u^* = \frac{1}{T^2}\left[K_1(\underbrace{y_f - y_M - \dot{y}_M T}_{\text{ZEM}}) + K_2(\dot{y}_f - \dot{y}_M)T\right]$$

u^* : Missile acceleration

T : Time-to-go

$y_M, \dot{y}_M$: Missile position and velocity

$y_f, \dot{y}_f$: Desired final missile position and velocity

ZEM : Zero Effort Miss wrt a specified final position

Define the gains as:

$$K_1 = (n+2)(n+3)$$

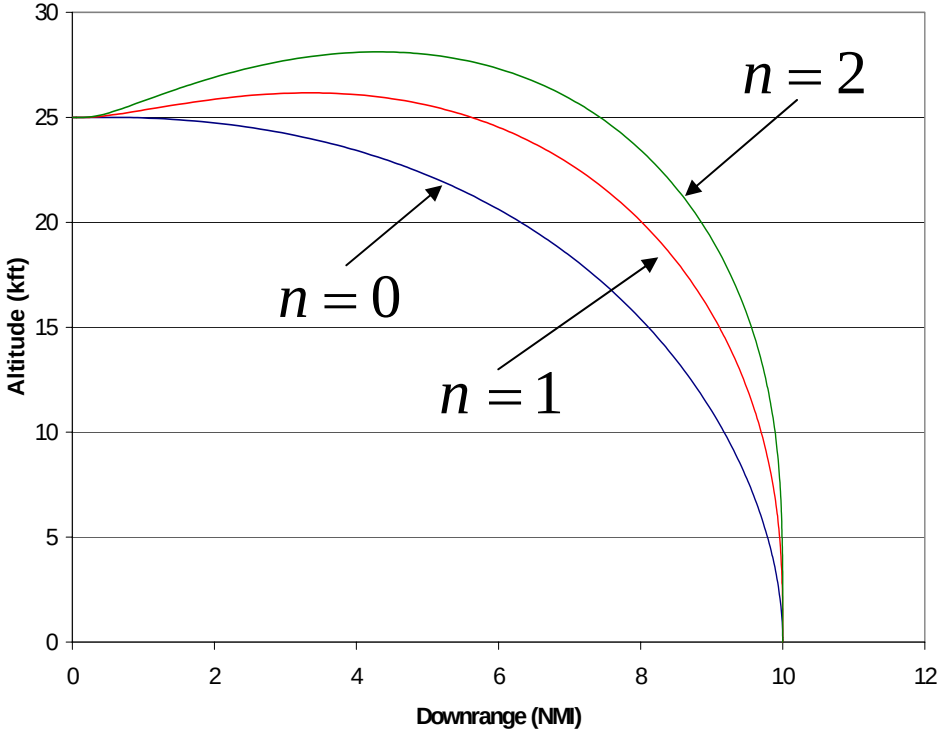
$$K_2 = -(n+1)(n+2)$$

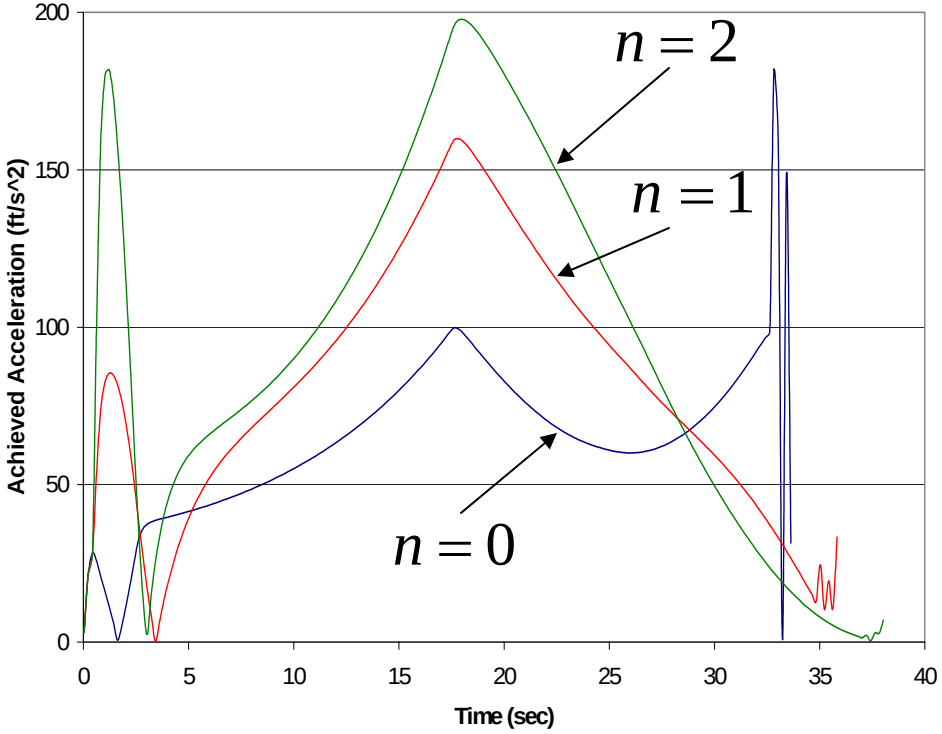
n = design parameter

- The optimum guidance consists of a PRONAV-like term with gain K_1 and a trajectory shaping term with gain K_2.
- The Generalized Explicit Guidance solution defines a family of guidance laws defined by the parameter n. The parameter n may be chosen to achieve specific performance objectives and to satisfy terminal constraints.
- In general, n may be used to modify the curvature of the trajectory, while enforcing a specified final position and final velocity orientation (impact angle).

Reference: Ohlmeyer, E. J., "Control of Terminal Engagement Geometry Using Generalized Vector Explicit Guidance," Proceedings of American Control Conference, Vol. 1, 2003, pp. 396-401.

Effect of Varying Design Parameter, n, in GENEX Guidance Law





Increased curvature as n is increased

For $n > 0$, large accelerations achieved earlier in flight to allow for smaller accelerations at terminal (e.g. smaller angle of attack)

Composite Guidance Law

$$\underline{a}_N = C(t)\underline{B} + \underline{u}\left[1 - C(t)\right] + \underline{g}_{Bias}$$

$\underline{a}_N$: normal acceleration commanded by guidance
$C(t)$: time-dependent composite index
$\underline{B}$: composite bias acceleration vector
$\underline{u}$: GENEX control term
$\underline{g}_{Bias}$: one g up bias term

The bias acceleration vector B, when added to GENEX, provides higher gains early in flight, increases the curvature of the trajectory, and extends the kinematic reach of the munition.

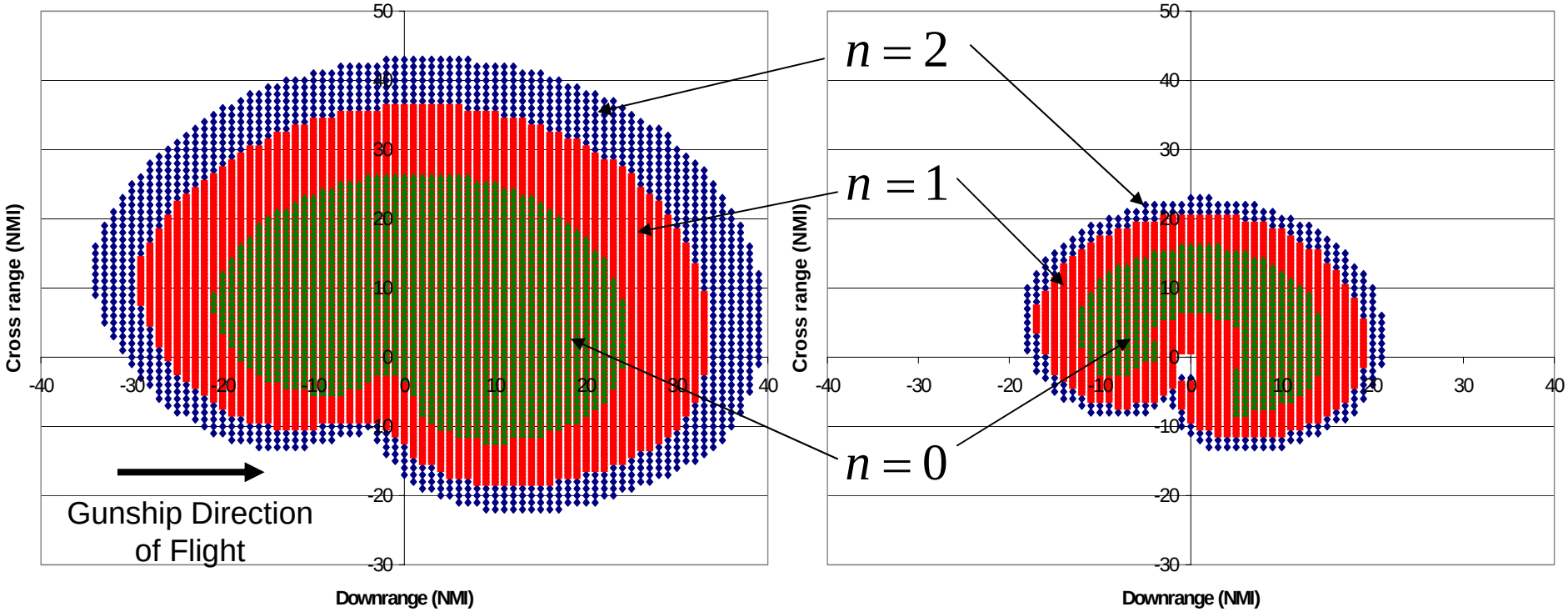
Level flight commanded for $t \le 0.5$ sec
For $0.5 < t \le 2.5$ sec, $C(t) = 1.0$
For $2.5 < t \le 7.5$ sec, $C(t) = 1.5 - (0.2t)$
For $t > 7.5$ sec, $C(t) = 0.0$
For $C(t) = 0.0$, above equation becomes GENEX equation

$C(t)$ picked to be linear for simplicity. $C(t)$ should be optimized for best results.

GENEX Footprints

25,000 ft Launch

10,000 ft Launch



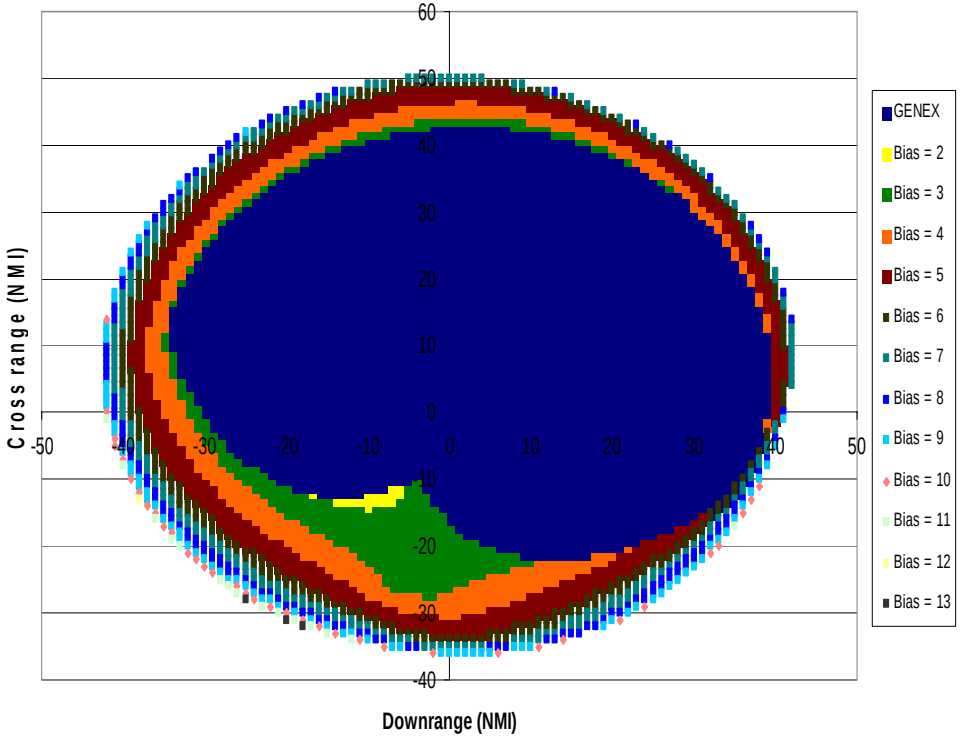
GENEX less effective with drop in launch altitude

Muzzle Velocity = 1100 fps
Gunship Velocity = 405 fps
Launch Angle = 0 deg

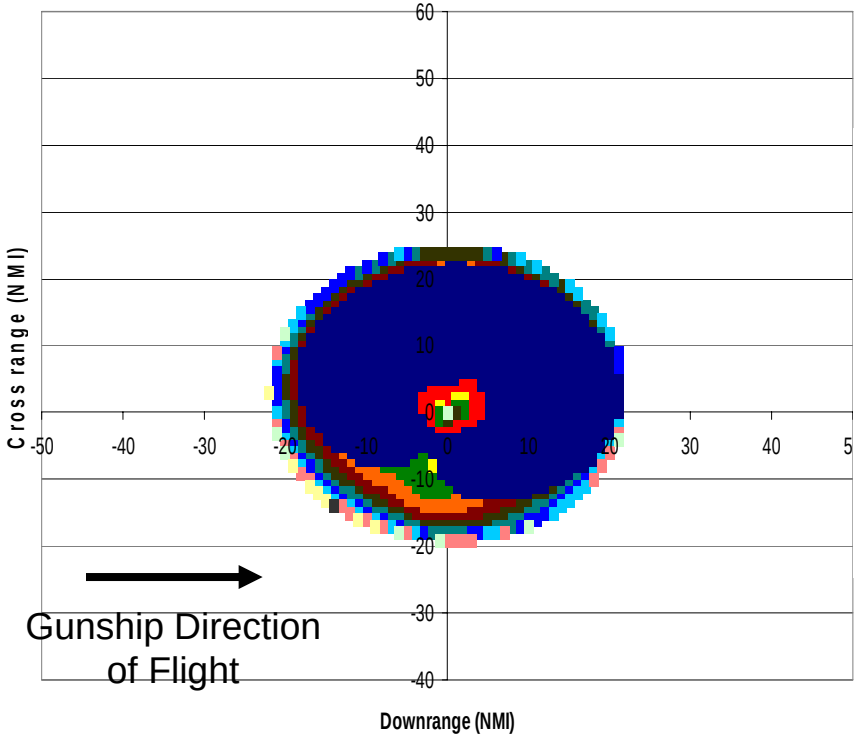
Hit Criteria:
- less than 5 ft Miss Distance
- within 10 deg of vertical impact angle

Composite Guidance Footprints

25,000 ft Launch
n=2



10,000 ft Launch
n=2



Composite Guidance increases the footprint significantly compared to GENEX only

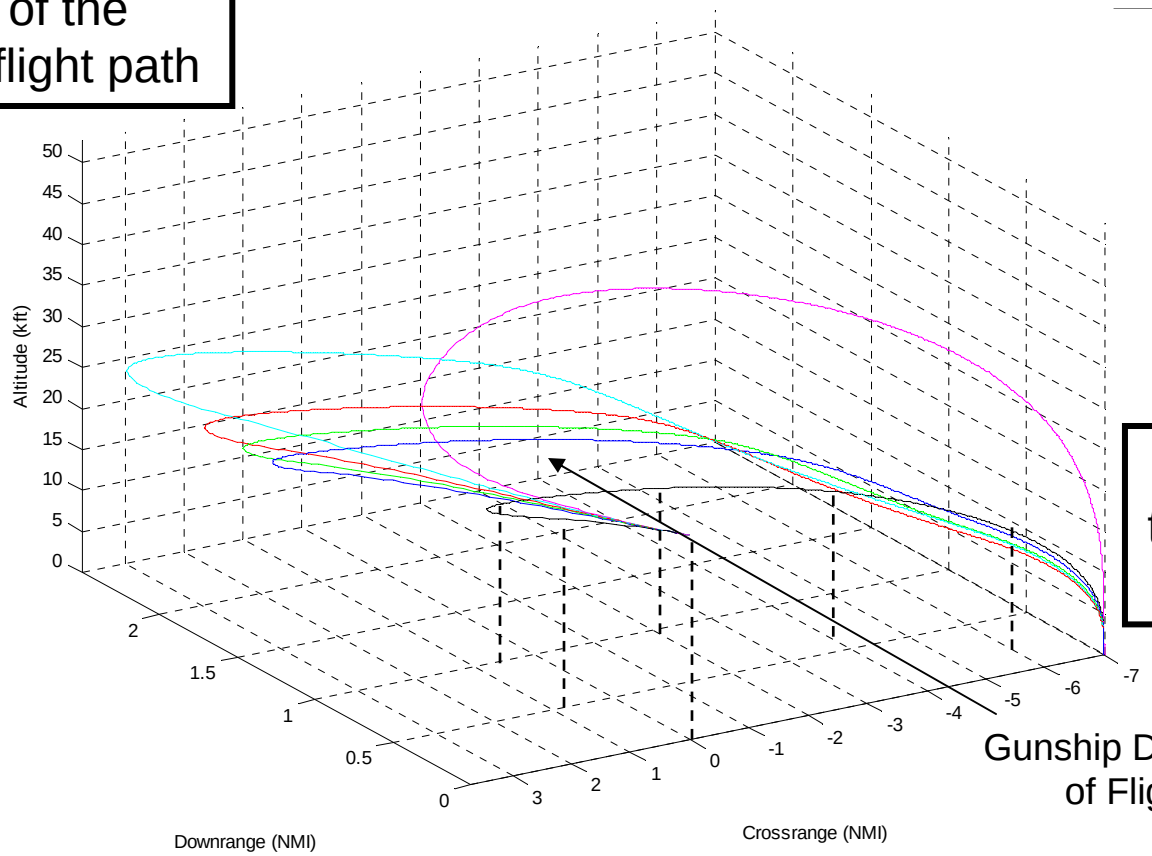
- 10-25 NMI farther for 25 kft launch
- 5-10 NMI farther for 10 kft launch

Like GENEX, Composite Guidance becomes less effective with drop in launch altitude

Trajectories

Target: Cross range = -7 NMI
25,000 ft Launch
$n = 2$

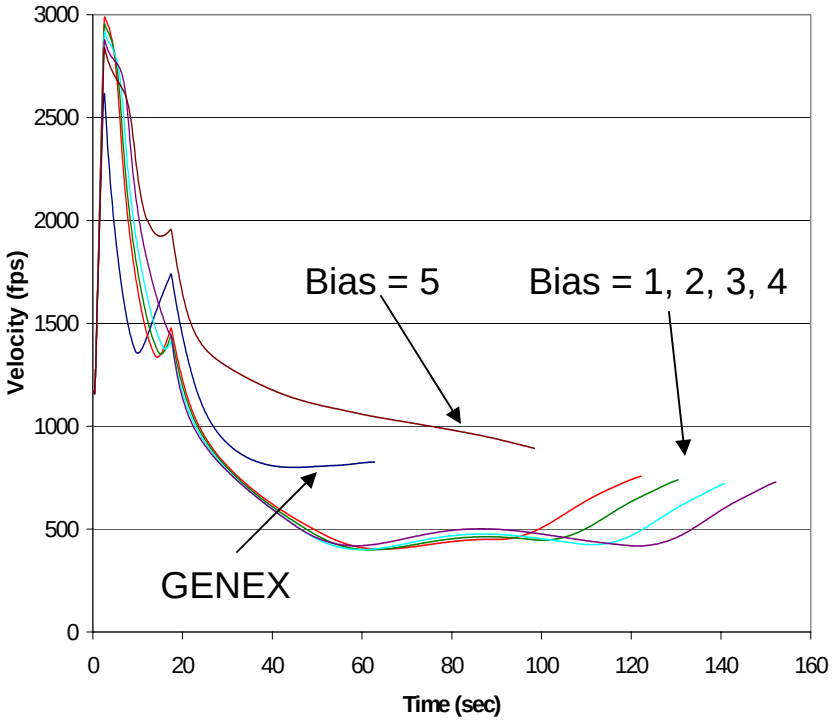
In all cases, the munition passes well in front of the gunship's flight path

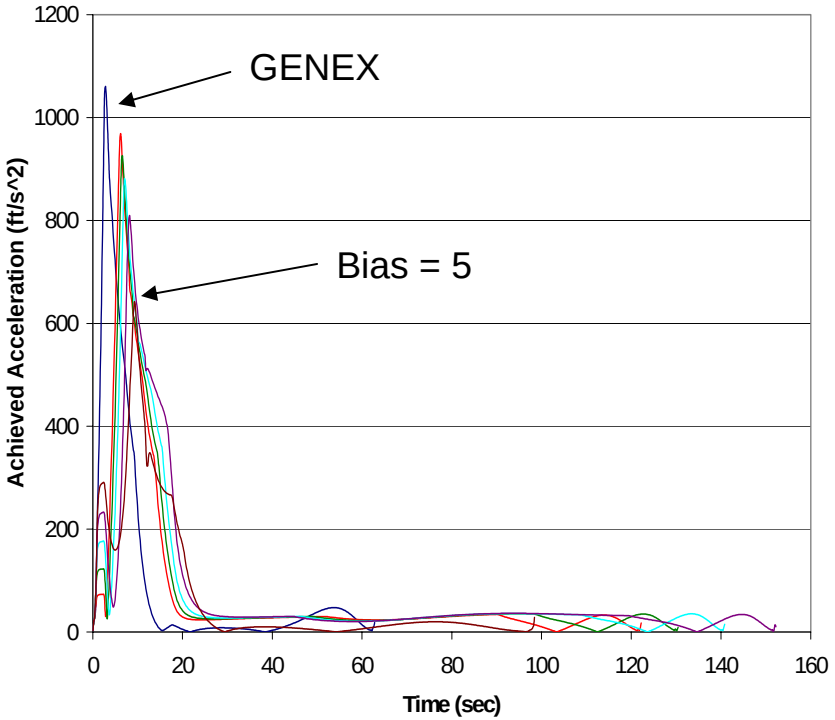


All cases hit the target with required impact angle

Velocities and Accelerations

Target: Cross range = -7 NMI
25,000 ft Launch
$n=2$



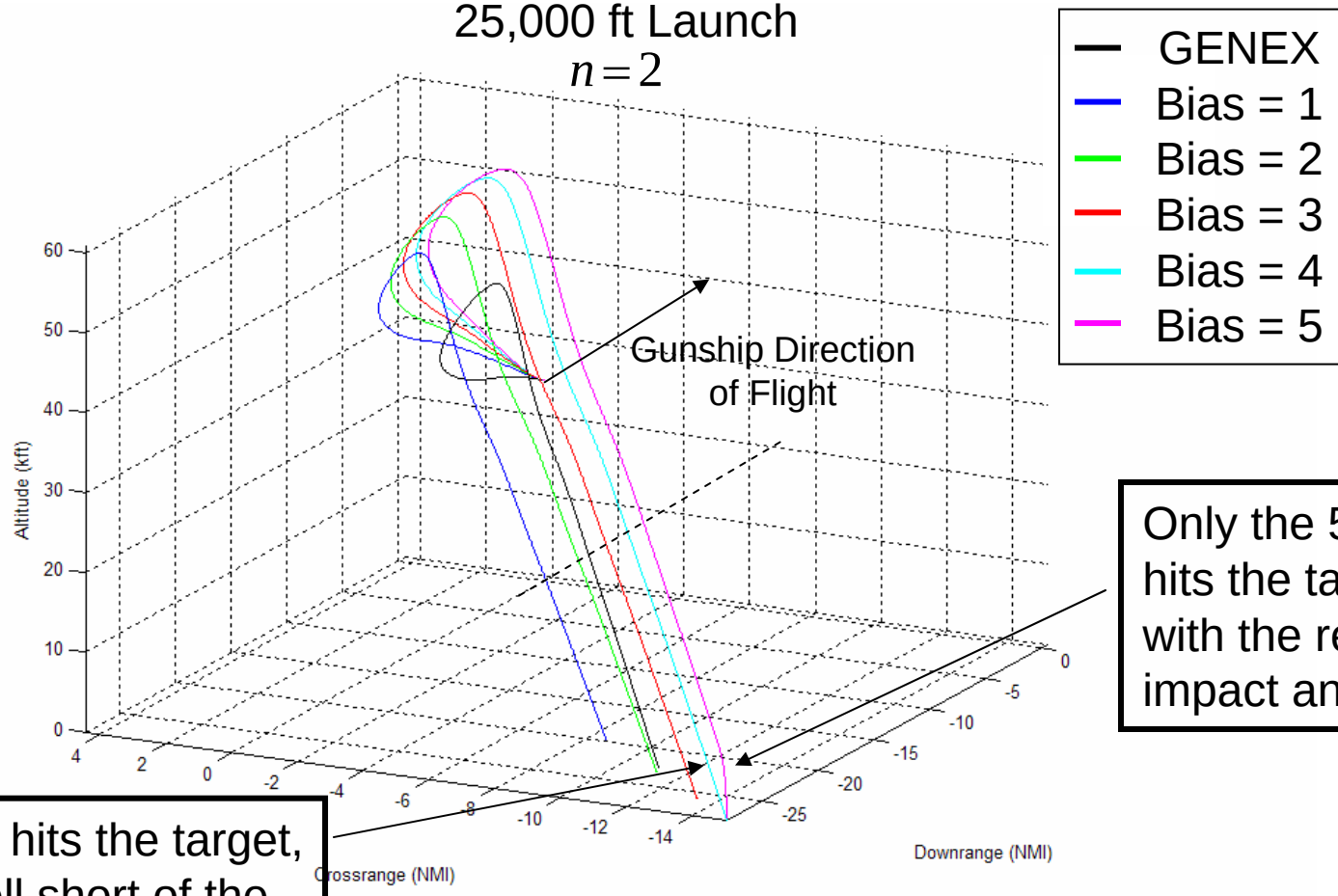


The 5 g Bias case gives a 40% reduction in max acceleration and still achieves approximately the same impact velocity

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Trajectories

Target: Downrange = -28 NMI, Cross range = -15 NMI
25,000 ft Launch
$n = 2$

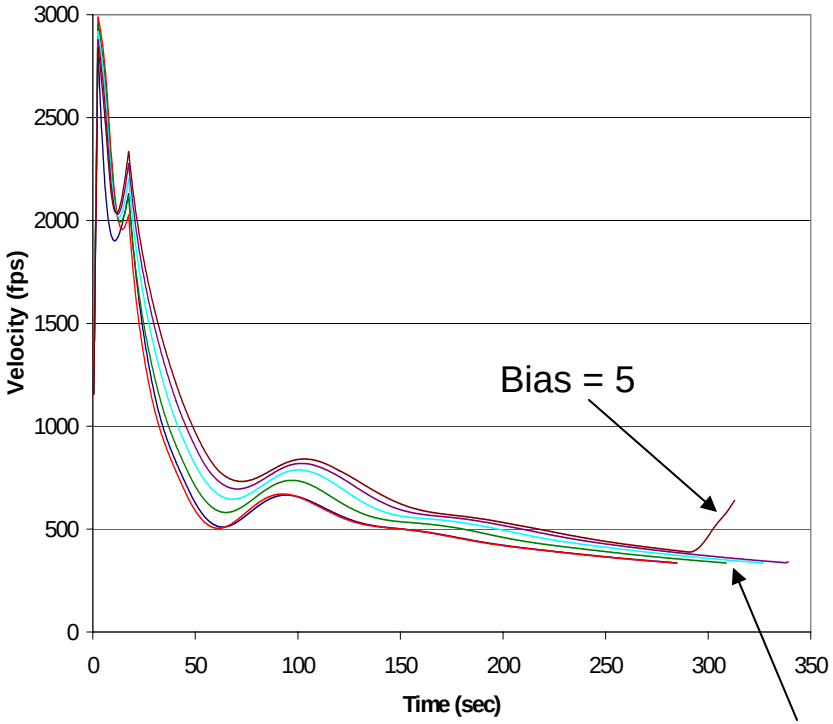


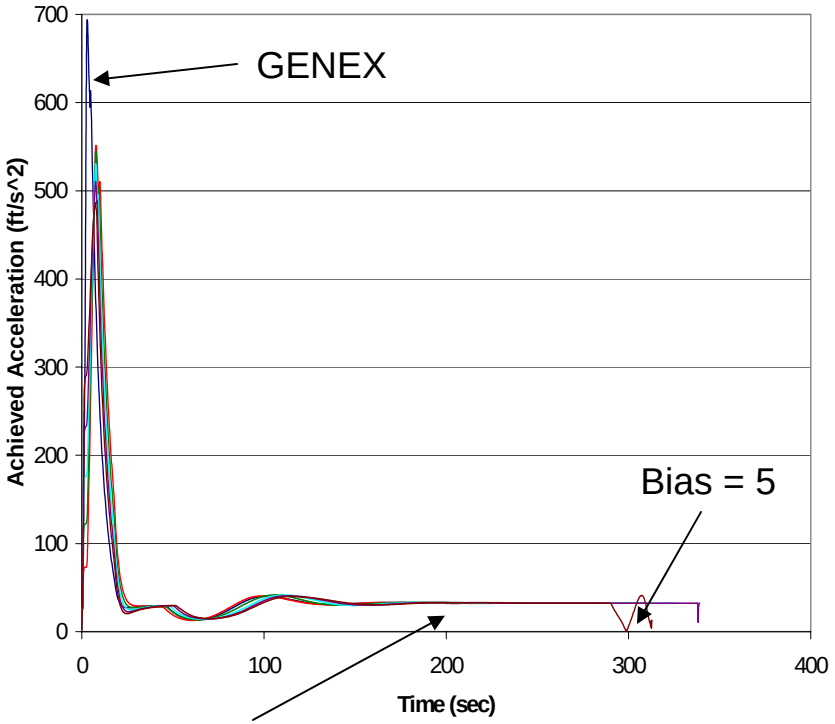
Only the 5 g Bias hits the target with the required impact angle

The 4 g Bias hits the target, but falls well short of the required impact angle

Velocities and Accelerations

Target: Downrange = -28 NMI, Cross range = -15 NMI
25,000 ft Launch
$n=2$





The munition expends too much energy to reach the target. Only the 5 g Bias case, with its increased curvature, is able to reach the target with the required impact angle.

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Conclusions

- Composite Guidance, a blending of GENEX guidance with a bias acceleration vector, provides a larger footprint than GENEX alone
- Composite Guidance extends the effectiveness of GENEX guidance
  - Allows the munition to reach 15-25 NMI farther on the starboard side and 10 NMI farther behind the gunship for a 25 kft altitude launch
  - Allows the munition to reach 5-10 NMI farther on the starboard side and 5 NMI farther behind the gunship for a 10 kft altitude launch
- Able to meet strict Military Operations on Urban Terrain (MOUT) requirements
  - Munition comes in vertically to allow an attack in urban canyons, simplifying mission planning
  - Small miss distance for low collateral damage

Backup Slides

Generalized Vector Explicit Guidance (GENEX)

Define a set of linear state equations and boundary conditions as:

$$\underline{\dot{X}} = A\underline{X} + \underline{b}u \qquad \underline{X}(t_0) = \underline{X}_0 \qquad \underline{X}(t_f) = \underline{X}_f = \underline{0}$$

where $\underline{X}$ is the state and u is the control (missile acceleration).

Select a cost function of the form:

$$J = \int_0^{T_0} \frac{u^2}{2T^n} dT = \int_0^{T_0} L(u,T) dT$$

where $T = t_f - t$ is the time-to-go, and n is an integer ≥ 0 .
The above equation comprises a family of cost functions parameterized by the index n.

Reference: Ohlmeyer, E. J., "Control of Terminal Engagement Geometry Using Generalized Vector Explicit Guidance," Proceedings of American Control Conference, Vol. 1, 2003, pp. 396-401.

Generalized Vector Explicit Guidance (GENEX)

Define the states as: $X_1 = z = y_f - y_M - \dot{y}_M T$

$$X_2 = \nu = \dot{y}_f - \dot{y}_M$$

subject to the terminal conditions $z = 0$ and $\nu = 0$ at $T = 0$.

z = zero effort miss with respect to a specified final position

ν = difference between current velocity and desired final velocity

$y_f, \dot{y}_f$ = desired final missile position and velocity

Define the gains as: $K_1 = (n+2)(n+3)$

$$K_2 = -(n+1)(n+2)$$

Reference: Ohlmeyer, E. J., "Control of Terminal Engagement Geometry Using Generalized Vector Explicit Guidance," Proceedings of American Control Conference, Vol. 1, 2003, pp. 396-401.

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Composite Guidance Rationale

Treat Guidance Command as composed of a set of basis functions

Increasing the number of degrees of freedom in the Basis Set increases flexibility and thus allows performance to equal or surpass lower order forms

$$\underline{a}_N(t) = a_1(t)\phi_1(t) + a_2(t)\phi_2(t) + a_3(t)\phi_3(t)$$

In comparison with Open-Loop Trajectory Optimization, GENEX forms have shown excellent match with the mid-trajectory regions

GENEX matching in regions of transition at initiation and termination of trajectories may be improved

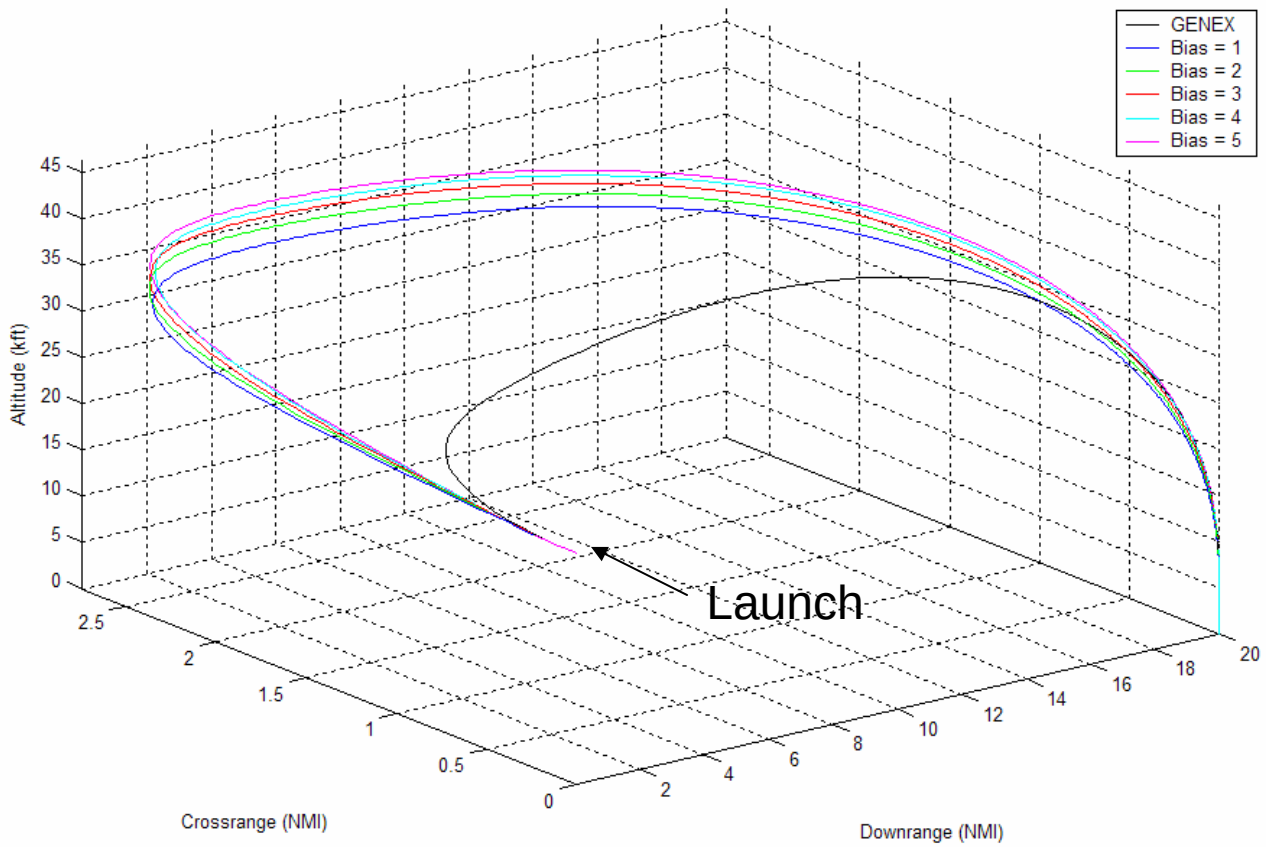
Thus, use GENEX as one of the basis functions

Add another function that is active only for initial phase (ramp)

Select Bias as simplest form for initial investigations

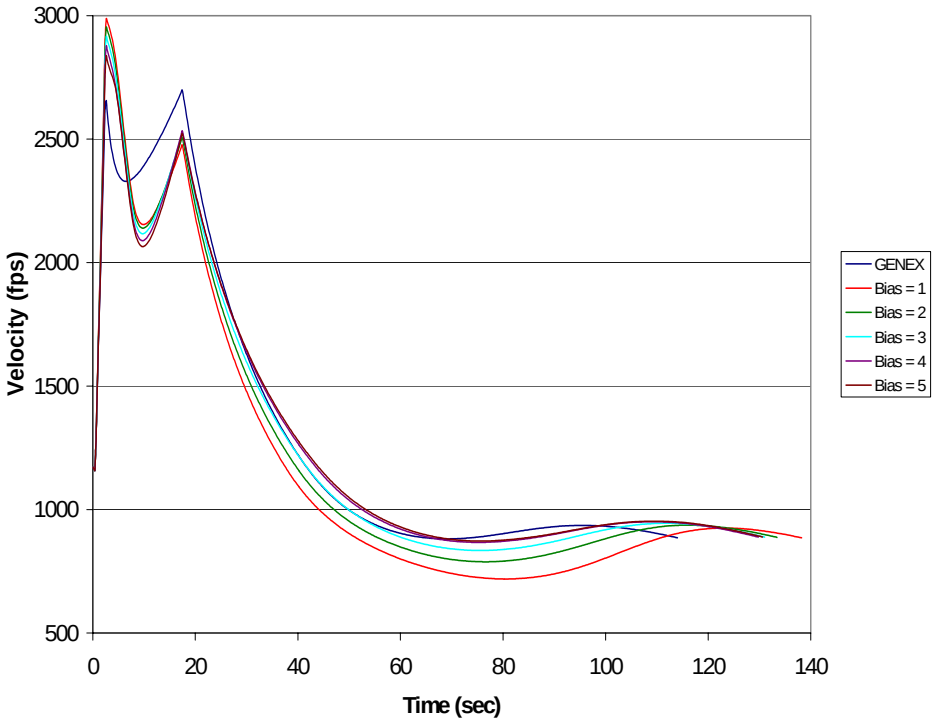
Trajectories

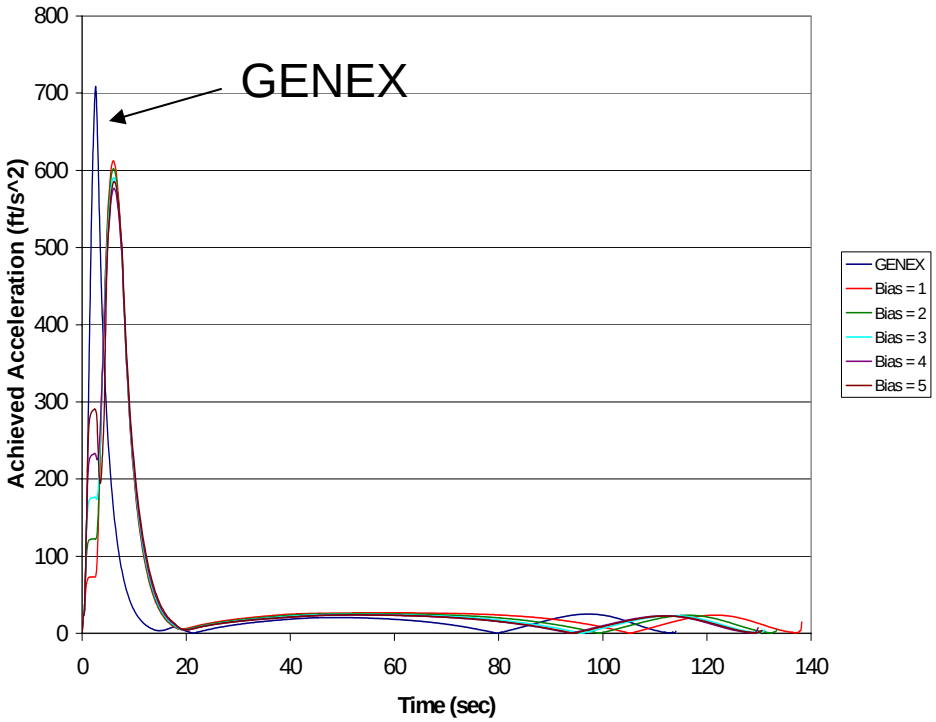
Target: Downrange = 20 NMI
25,000 ft Launch
$n = 2$



Velocities and Accelerations

Target: Downrange = 20 NMI
25,000 ft Launch
$n = 2$





Composite Guidance allows for smaller accelerations to hit target with approximately the same impact velocity

GENERAL DYNAMICS
Armament and Technical Products

GAU-19/A Barrel Life Study

James St. Germain

GAU-19/A Barrel Life Study Agenda

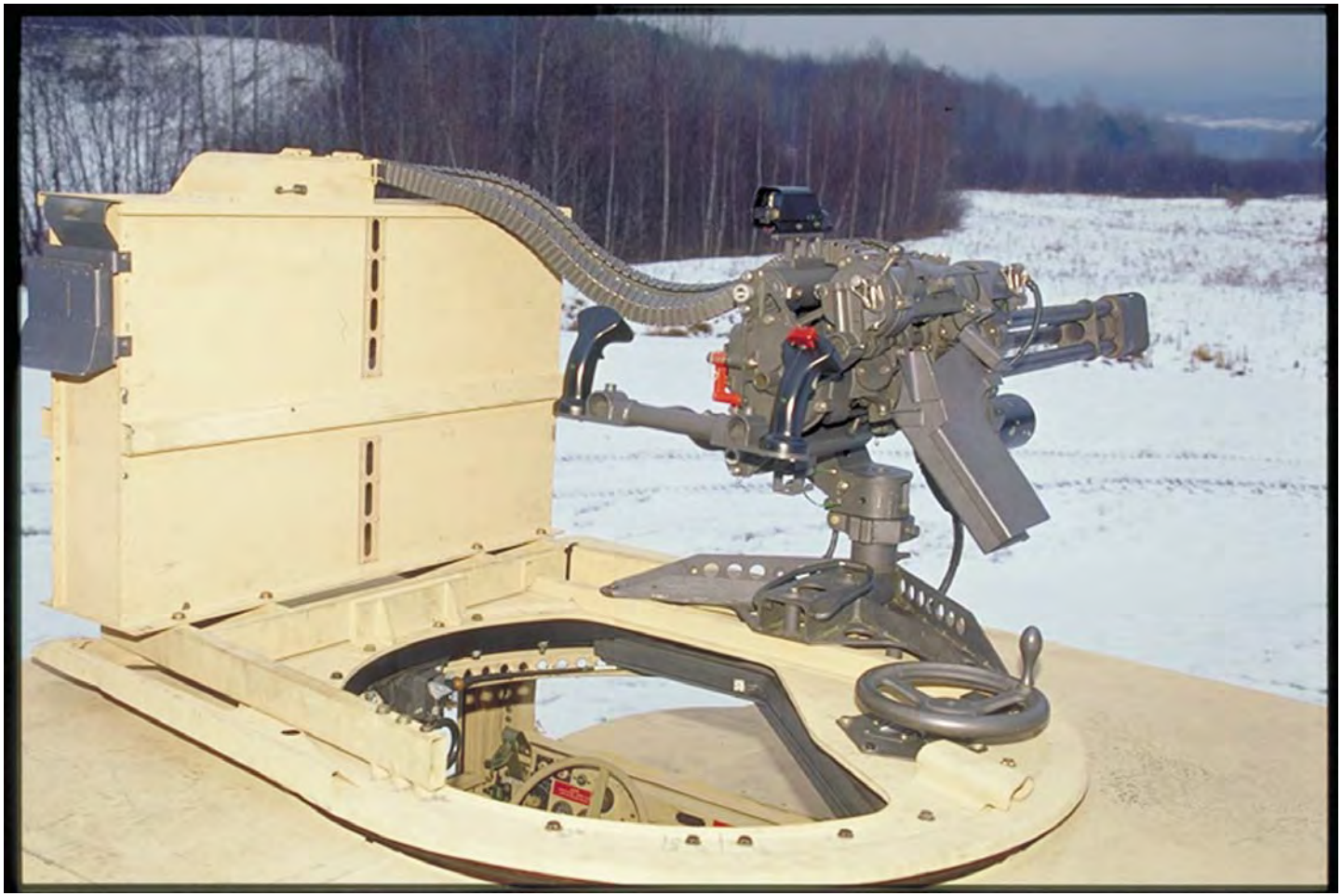
- GAU-19/A Description
- Barrel Design Parameters
- Customer Background
- Barrels Used in the Study
- Barrel Inspection & Results
- Barrel Testing & Results
- Conclusion

GAU-19/A Barrel Life Study
GAU-19/A Description

- Three-barrel 12.7mm externally powered Gatling gun
- Provides lightweight, lethal firepower to a variety of platforms:
  - Helicopters
  - Ground vehicles
  - Naval vessels
  - High speed patrol boats
  - Fixed Wing Aircraft



GAU-19/A Barrel Life Study
GAU-19/A Description



GAU-19/A Barrel Life Study
GAU-19/A Description

- Rate of Fire — 1000/2000 spm (1,300 spm HMMWV)
- Effective Range — 1800 Meters
- Maximum Range — 6000 Meters
- Max Dispersion — 5 mrads (80 % circle) = 5m at 1000m
- Weight — 138 Lbs (gun & feeder assembly)
- Reliability — 40,000 MRBF
- Average Recoil — 600 Lbs at 2000 SPM
- Maintenance — 30,000 rds.
- Barrel replacement — 50,000 rds. per set
- Sighting — Holographic, NVG compatible, Laser Pointer
- Uses entire range of .50 cal NATO / Mil Spec ammunition

GAU-19/A Barrel Life Study
Initial Barrel Design Parameters

- Crack Propagation Program utilized for barrel analysis
- Each barrel set must be capable of firing out a complete ammunition container load
- Target life expectancy of 35000 rounds per set used in analysis program

GAU-19/A Barrel Life Study
Barrel Physical Description

- Mat'l: CrMoV steel per A10505
- Bore: Chrome plated per A10374
- Exterior Finish: Solid Film Lubricant 119A2115
- 12.69 mm bore/12.98 mm groove diameter
- 8 land rifling: right-hand constant twist 1 turn in 30 calibers

GAU-19/A Barrel Life Study
Customer Background



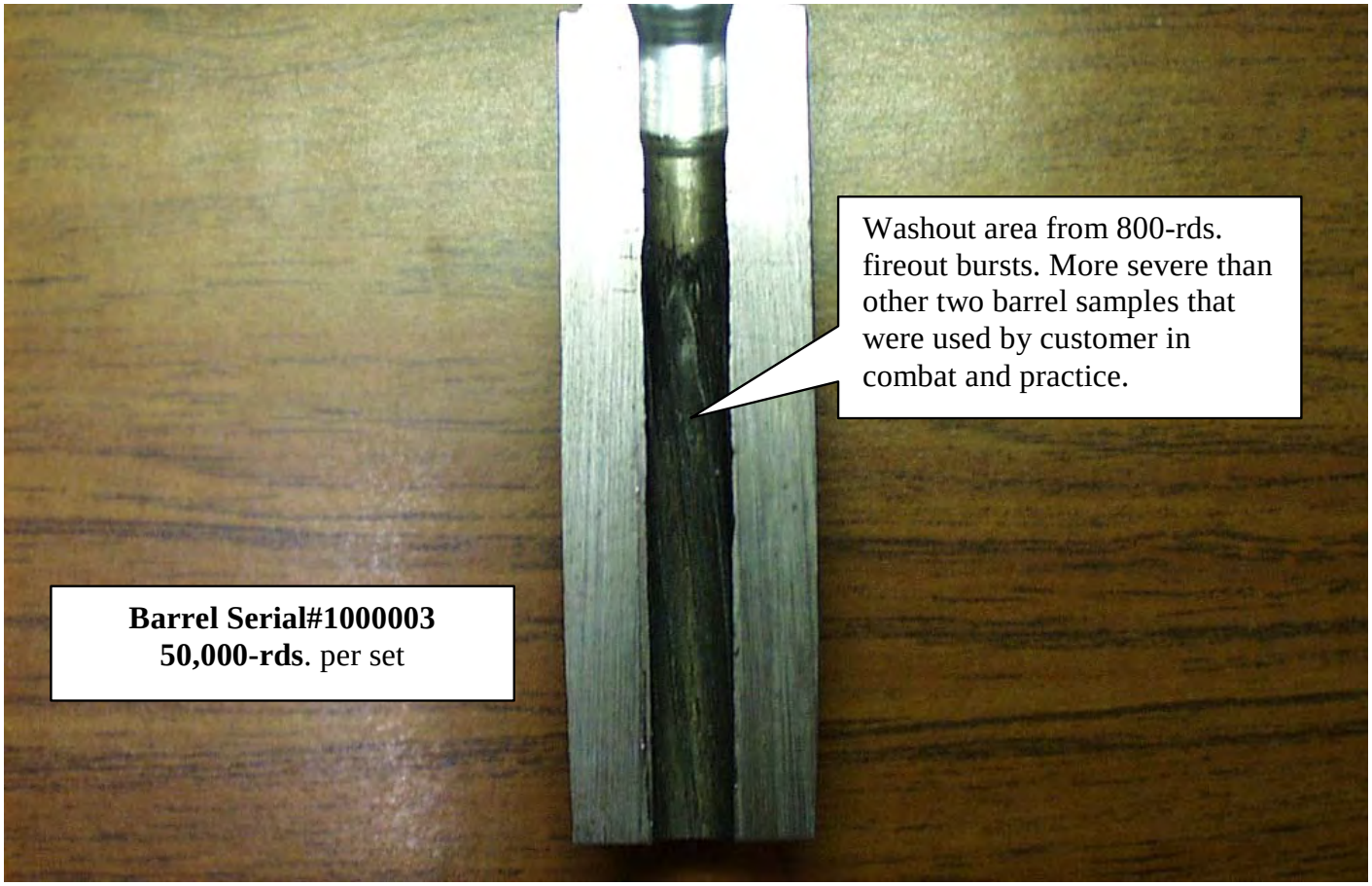
GAU-19/A Barrel Life Study
Barrels Used in Study

- Barrel sets from customers with 35,000 to 54,000 rounds
  - Typical firing cycles of 50 to 100 rounds
  - API ammunition
- Barrel set from GDATP with 50,000 rounds
  - Ten 800 round bursts with all others at 200 to 400 rounds
  - M33 Ball and M17 Tracer, 4:1

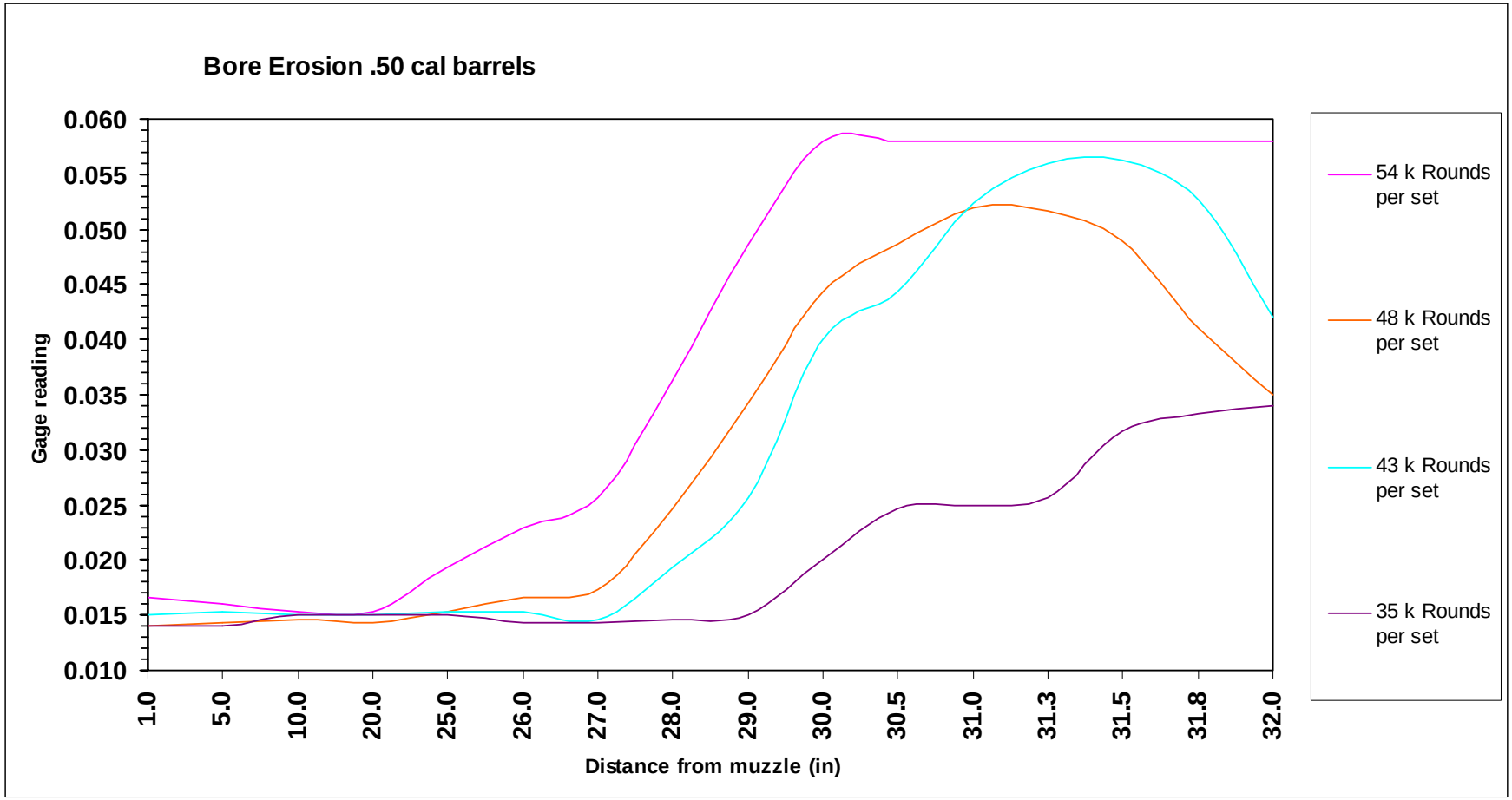
GAU-19/A Barrel Life Study Parameters Measured

- Inspection
  - Erosion
    - Indicator of velocity reduction
  - Crack Depth
    - Indicator of rounds to failure
- Test
  - Velocity
    - Indicator of barrel performance and resultant targeting

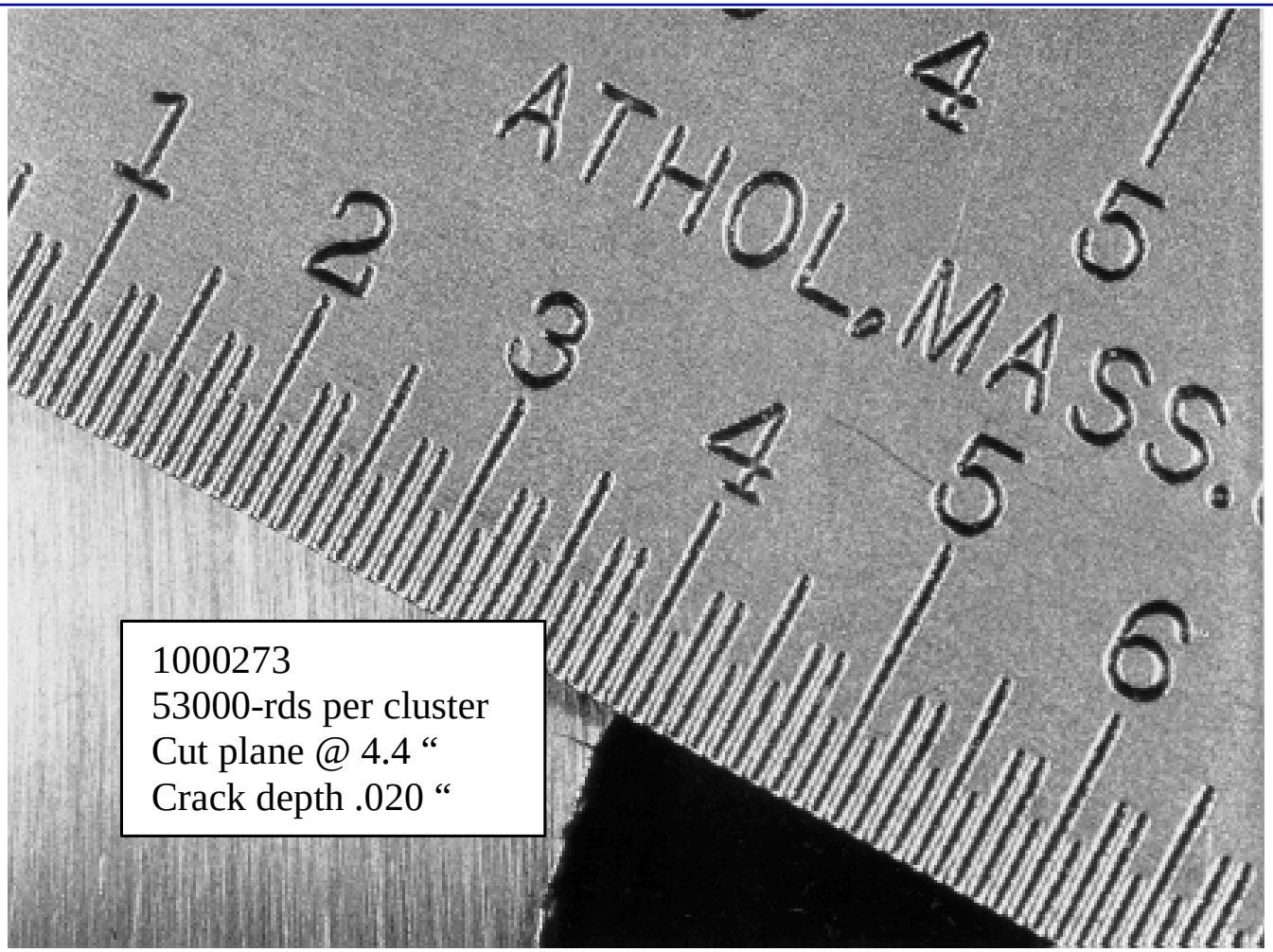
GAU-19/A Barrel Life Study
Parameters Measured – Barrel Erosion



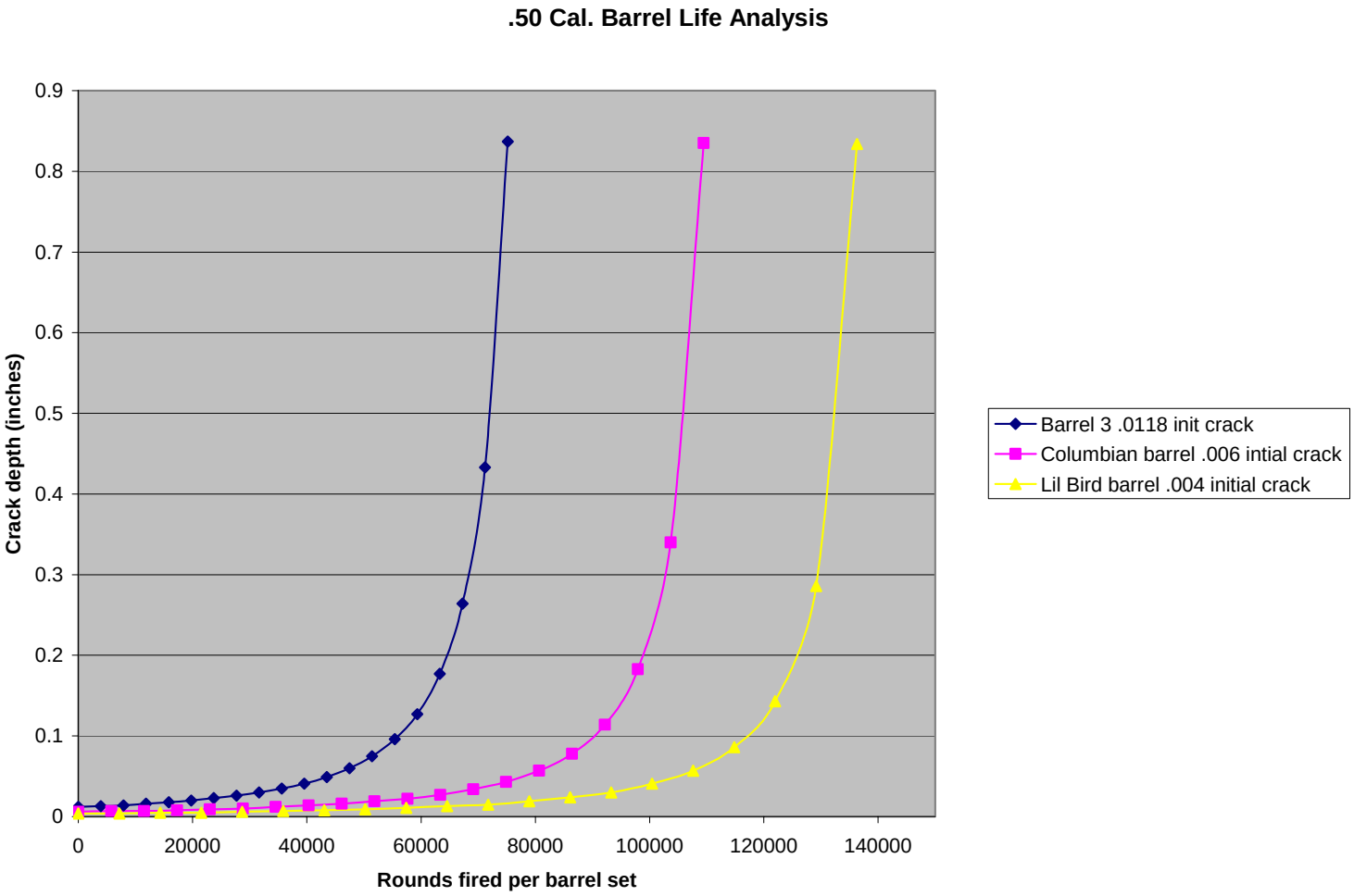
GAU-19/A Barrel Life Study
Parameters Measured – Barrel Erosion



GAU-19/A Barrel Life Study
Parameters Measured – Crack Propagation



GAU-19/A Barrel Life Study
Parameters Measured – Crack Propagation



GAU-19/A Barrel Life Study Parameters Measured - Velocity

ROUNDS AS RECEIVED (per barrel cluster)	VELOCITY (ft./sec.)	YAW RESULTS
4000	2800	No yaw
43250	2680	No yaw
45200	2655	No yaw
48405	2565	Two minor yaws, tracer only
53000	2210	Yaw present, tracer only
54000	2150	Yaw present, tracer only

GAU-19/A Barrel Life Study Conclusion

- At approximately 50,000 rounds
  - Significant velocity change
  - Yawing begins to occur in tracers affecting targeting
  - No danger of crack propagation causing failure
- BARREL REPLACEMENT PER ROUNDS FIRED CAN BE INCREASED FROM 35000 TO 50000 ROUNDS PER SET

RNLA IFV Firepower

30 mm versus 35 mm

35 mm KETF Firing doctrine

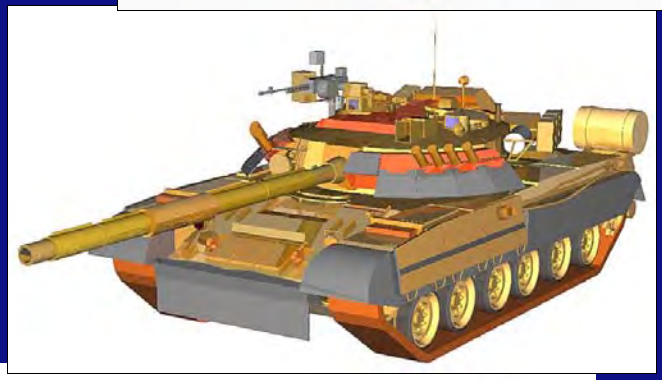
TNO | Knowledge for business



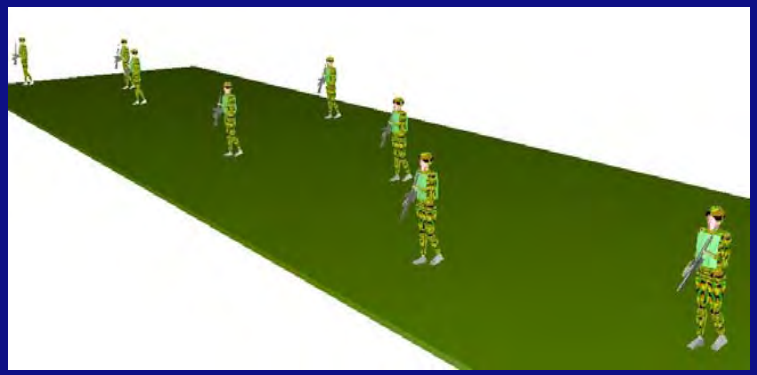
RNLA IFV Firepower

- Ammunition selection & modelling
- Caliber determination : 30 vs. 35 mm
- Ammunition optimization
- Firing doctrine











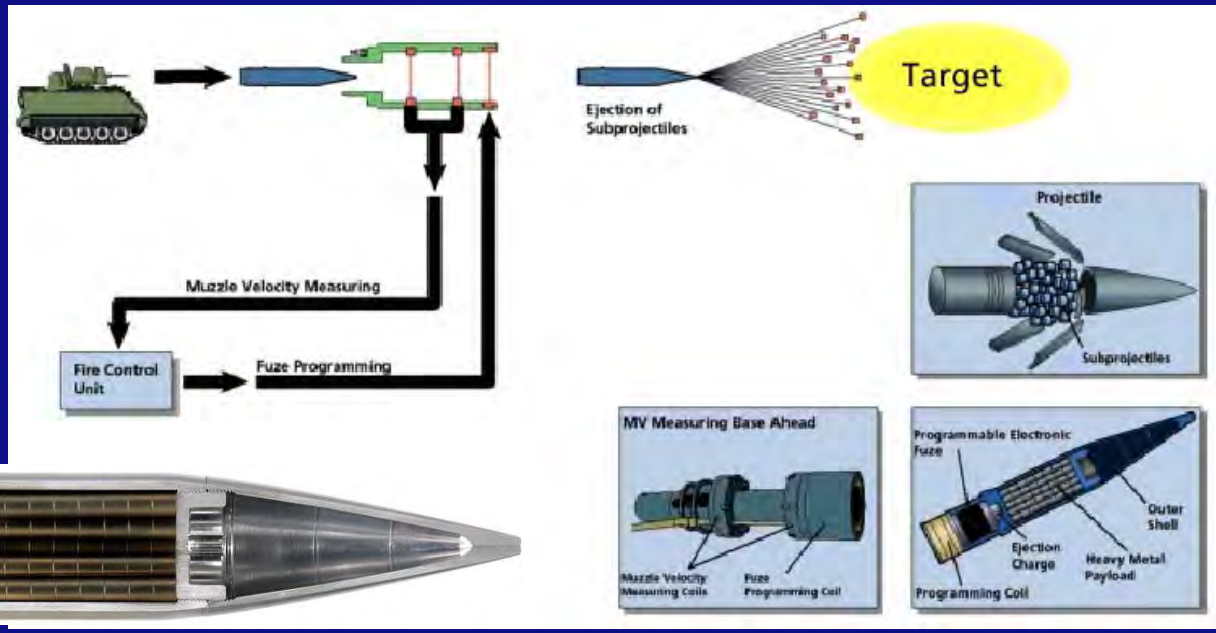
Ammunition selection

- **RFI review**

Air Burst Munition
HETF & KETF







APFSDS

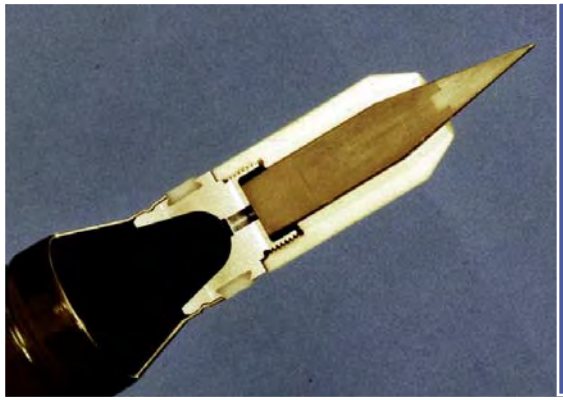




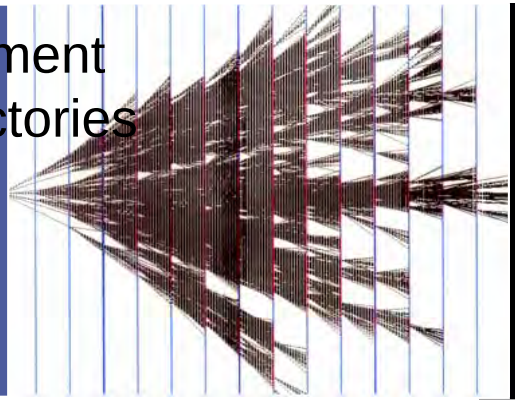
FAPDS/PELE



Frangible ammunition modelling



Fragment trajectories





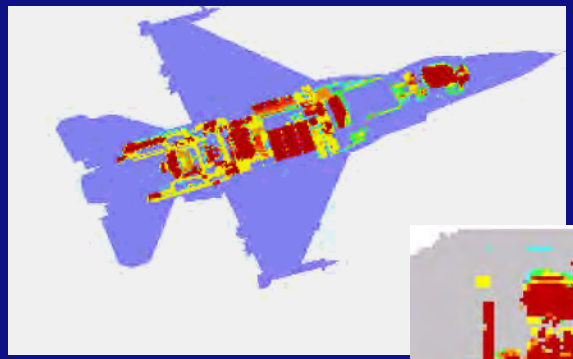
Experimental

- Plate - arrays
- Fragment Simulating Projectiles
- Flash X-ray
- Imax
- Real targets



Simulations

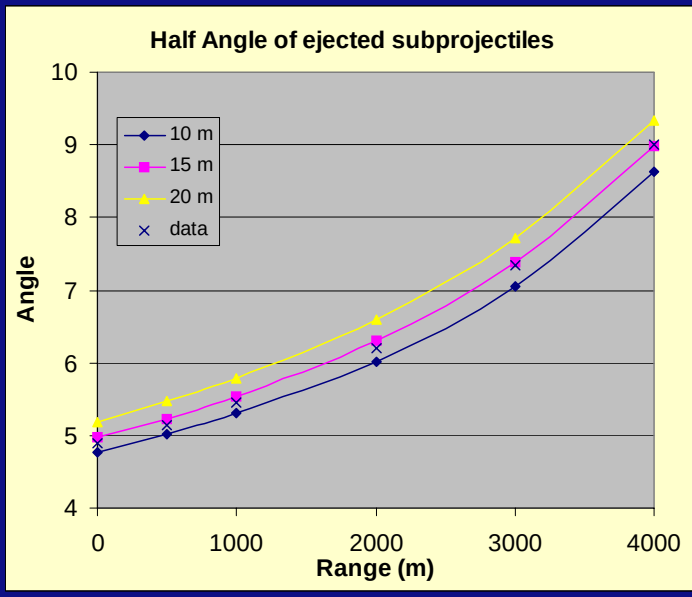
- Terminal ballistic model
- Lethality model



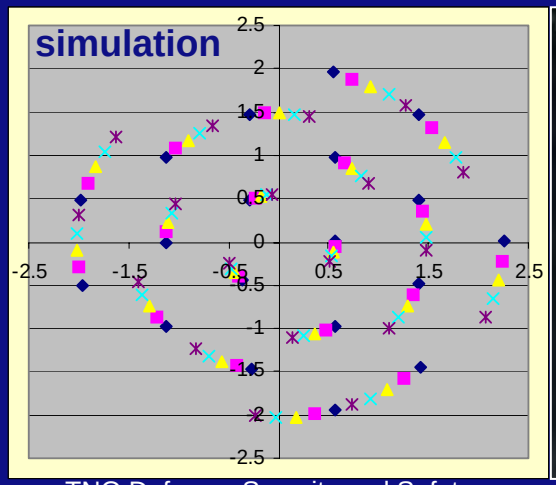


KETF modelling
subprojectile dispersion model

- **Required input:**
  - Ground firing table
  - Projectile spin as a function of the range
  - Shape of subprojectiles, drag



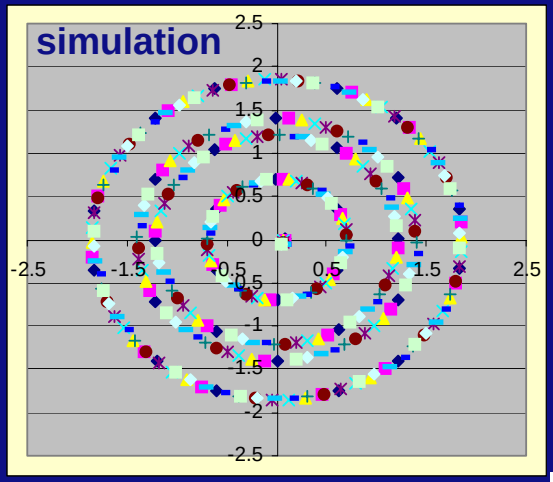
30 mm KETF with 135 subprojectiles of 1.5 gram





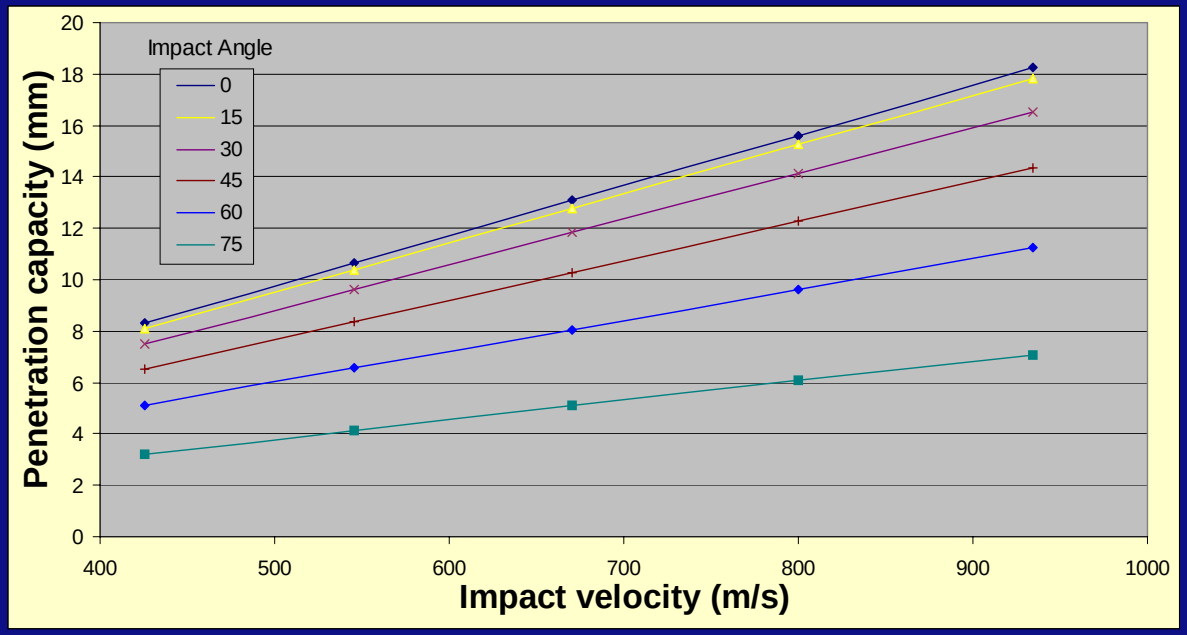
35 mm KETF with 341 subprojectiles of 1.5 gram

Note: this is not the existing 35 mm KETF!



KETF modelling
subprojectile penetration model

- **Penetration capacity in Aluminium of 1.5 gram subprojectile**

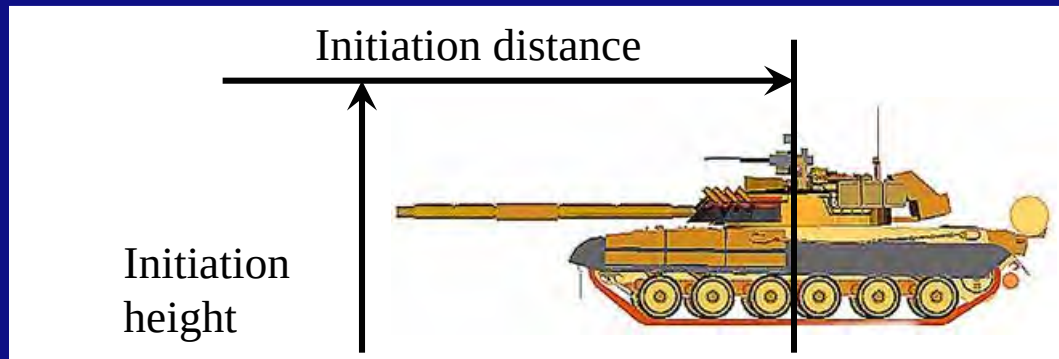


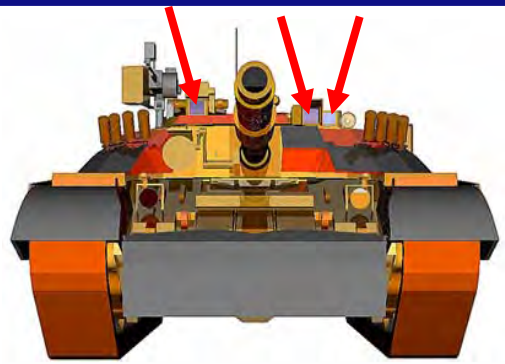
- **Penetration capacity in helmets and fragment resistant vests**
- **Penetration capacity in optical sights**

KETF ammunition vs T-80U

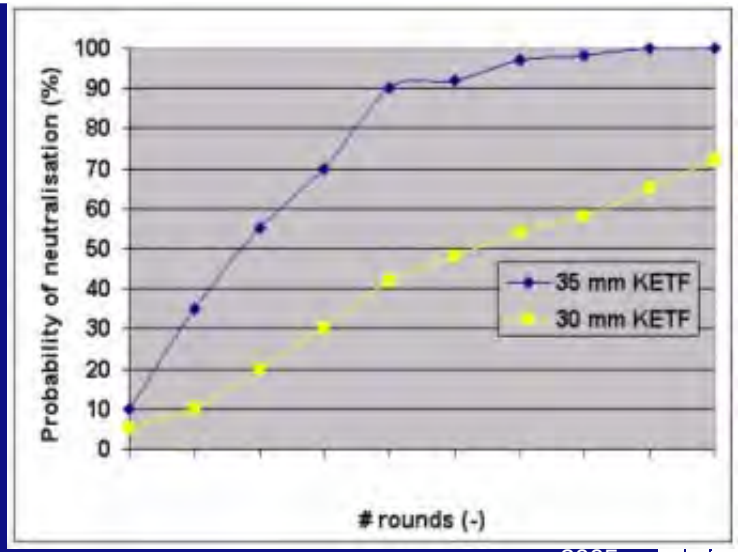


- **Neutralise T-80U by killing all optical sights as a function of the initiation distance and height and number of fired projectiles**





- **Conclusion: Compared to the 35 rounds, over twice as much 30 mm rounds have to be used to achieve the same effectiveness explained by the much larger number of subprojectiles**



KETF ammunition vs Foxhole

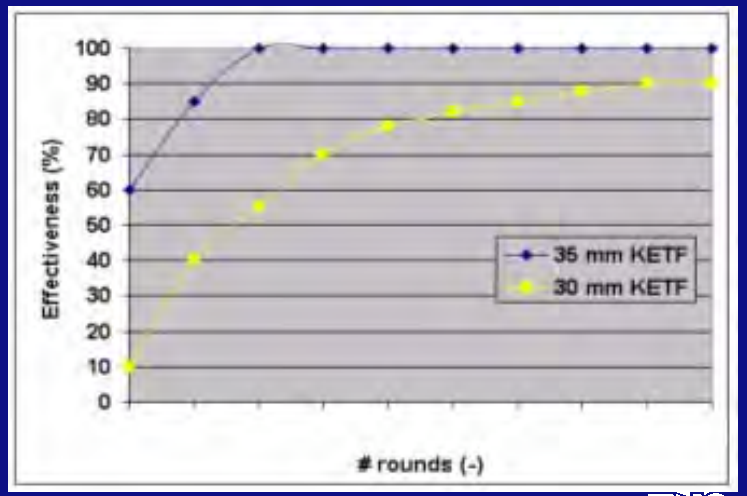


- Kill two men covered Foxhole as a function of the initiation distance and height and number of fired projectiles



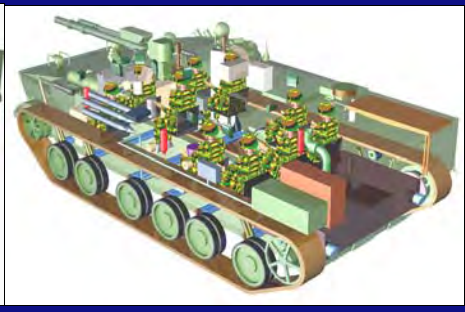


- Conclusion: Compared to the 35 rounds, over twice as much 30 mm rounds have to be used to achieve the same effectiveness explained by the much larger number of subprojectiles



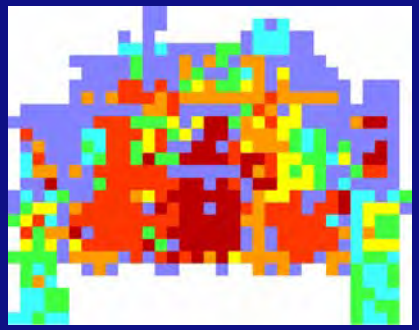
APFSDS ammunition



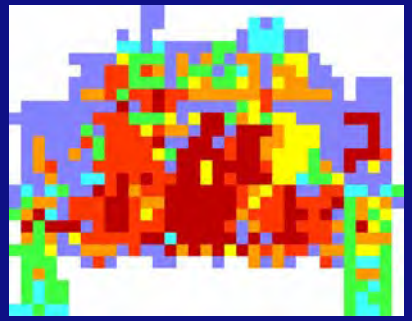


- BMP-3 (+ add-on armour)
  MorFinC kill
  (TARVAC simulation)

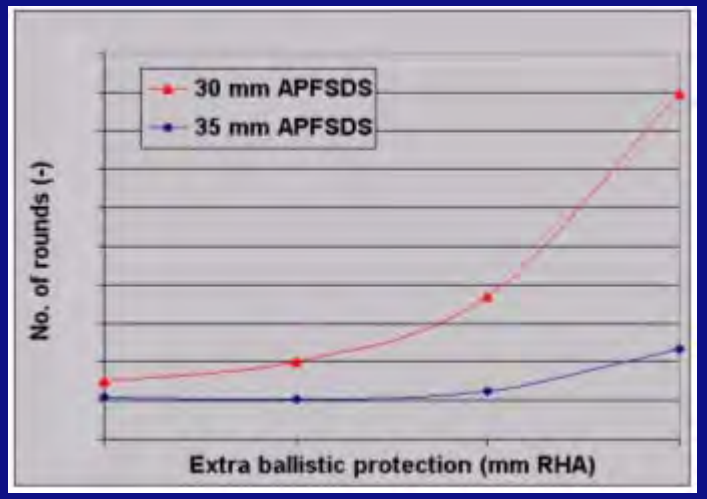
Frontal attack, no add-on armour



30 MM



35 MM



- Conclusion: 30 mm APFSDS is able to perforate the main armour of BMP-3, however with “add-on” armour (BMP-3+) the 30 mm APFSDS is stopped by the armour where the 35 mm APFSDS can easily perforate the armour

Conclusion

- **Based on requirements, effectiveness results, logistics, etc …… the RNLA selected the 35 mm caliber for the new Infantry Fighting Vehicle**

- **Next step:**
  - **KETF Ammunition optimization against infantry soldiers**
  - **KETF Firing doctrine against:**
    - T-80U
    - Mi-24 Hind
    - Foxhole
    - Dismounted soldiers

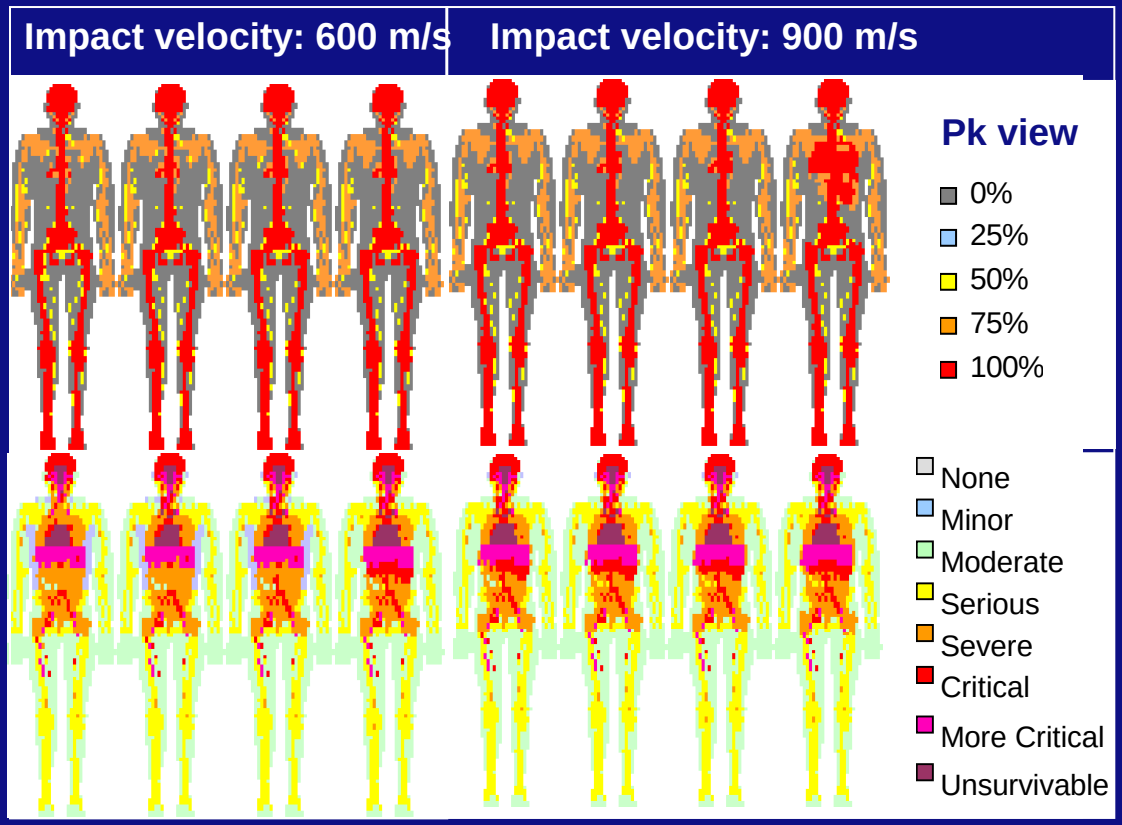
ABM subprojectile lethality

- Standing soldier, including helmet and vest, 30. sec assault
- Ballistic protection is based on experimental data

- Fixed total payload mass: heavier subprojectiles results in smaller density of fragment cloud
- TNO requested to find most optimal solution

- Result: 35 mm KETF prototype is redesigned by manufacturer on request of RNLA -> subprojectile mass: 1.24 gram

Increasing Subprojectile mass ->



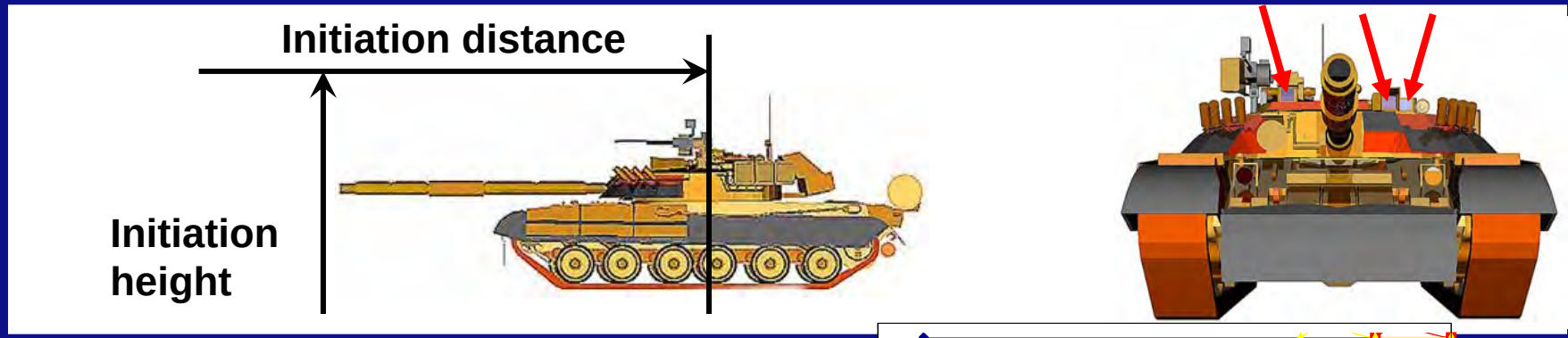
Injury indication view

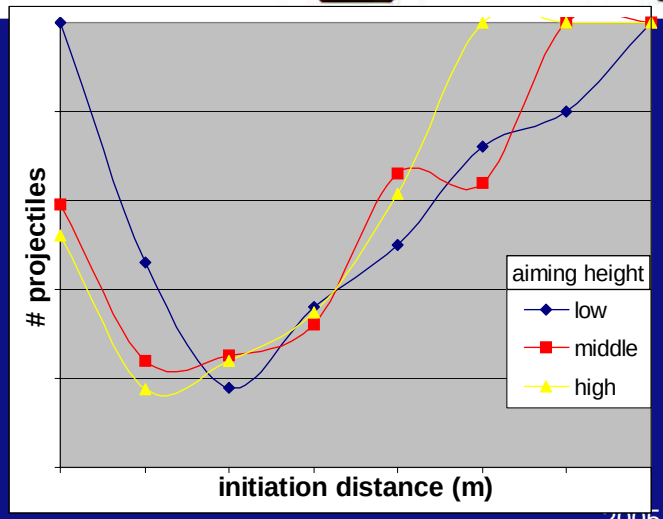
Conclusion KETF optimization

- All subprojectiles can be classified as heavy fragments in the anti-personnel role and very lethal
- With higher subprojectile velocities the soldier was completely perforated
- Difference in injuries is due to subprojectile dimensions
- Fragment resistant vest is always perforated
- At lower impact velocities the heavier subprojectiles result in higher kill probabilities
- Kill probability conclusions are based on standing soldier for a 30 sec. assault

Firing doctrine
35 mm KETF ammunition vs T-80U

- Neutralise T-80U by killing all optical sights as a function of the initiation distance and height and number of fired projectiles





- Conclusion: selection of initiation distance and height is very important to achieve best effectiveness for KETF

Firing doctrine
35 mm KETF ammunition vs Foxhole



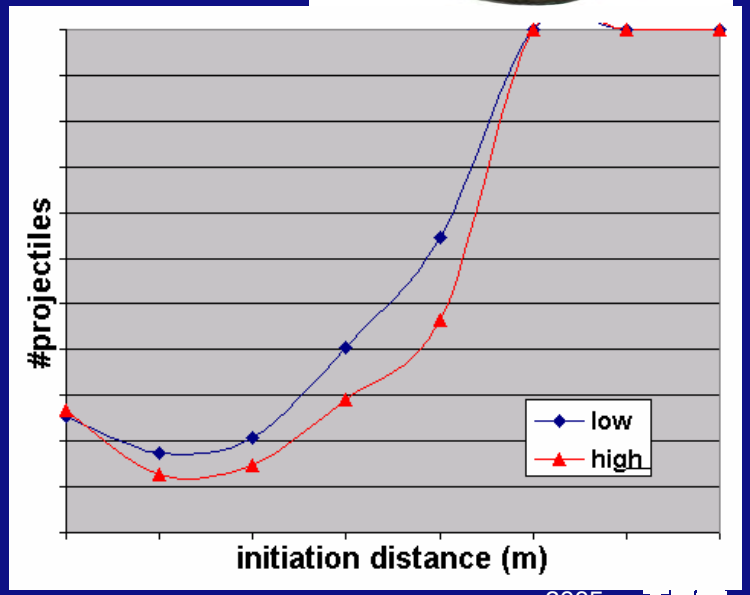
- Kill two men covered Foxhole as a function of the initiation distance and height and number of fired projectiles



Initiation distance

Initiation height

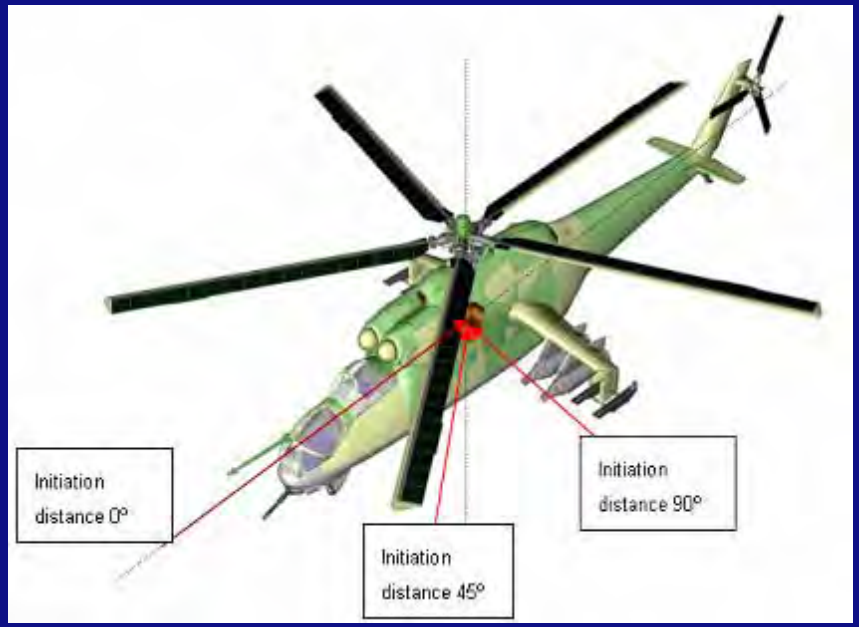


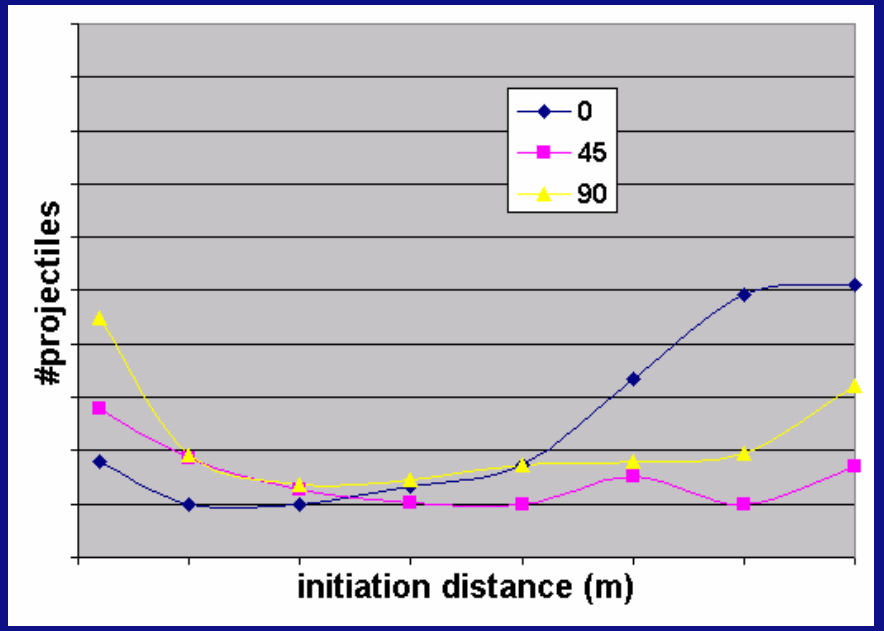


- Conclusion: selection of initiation distance and height is very important to achieve best effectiveness for KETF very effective against this target

Firing doctrine
35 mm KETF ammunition vs Mi-24 Hind

- Scenario: three azimuth angles, 2000 m range
- Kill category: K-kill, without manned control within 30 sec.

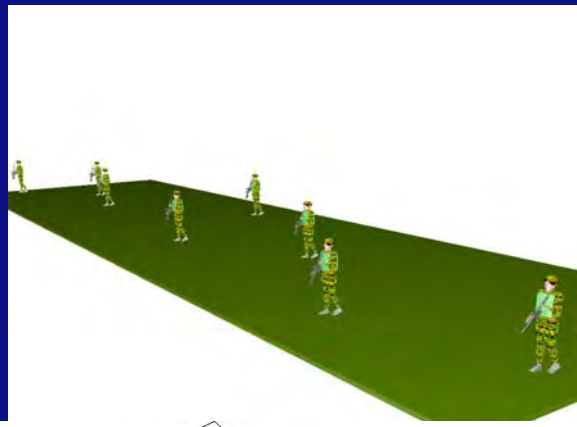




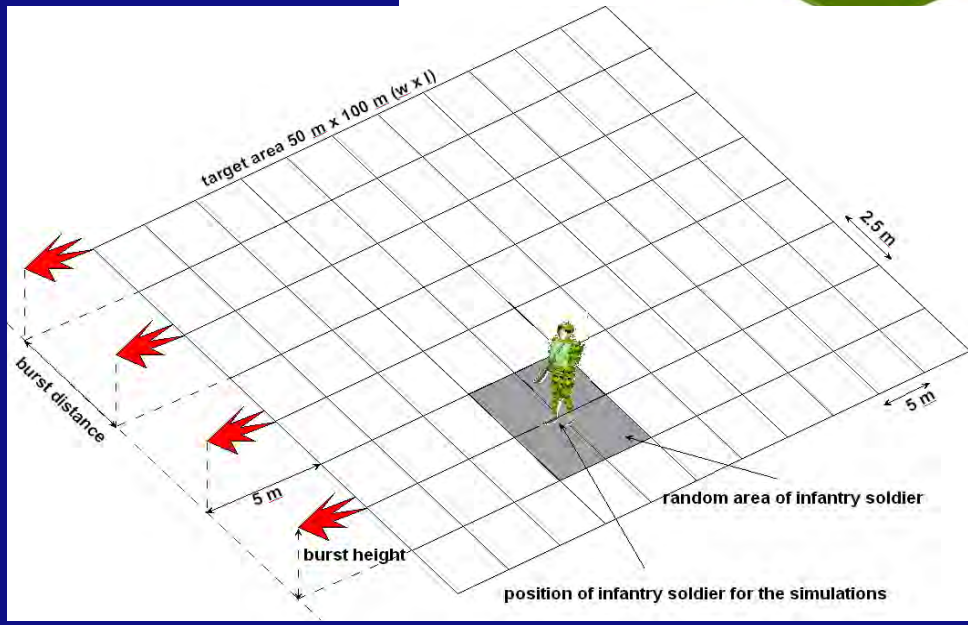
- Conclusion: for KETF the selection of initiation distance is very important to achieve best effectiveness and KETF is very effective against helicopter

KETF firing doctrine: dismounted soldiers in open field

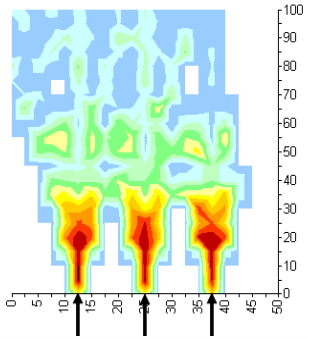
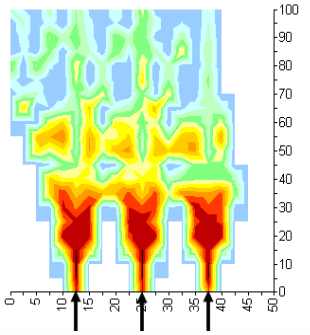
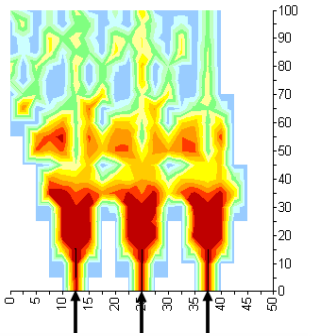
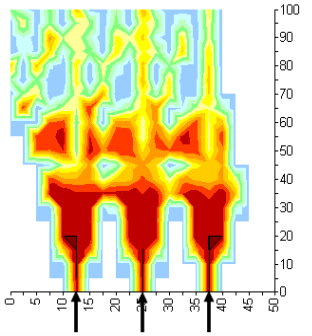
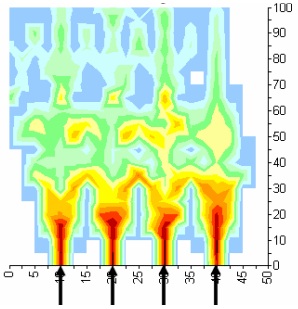
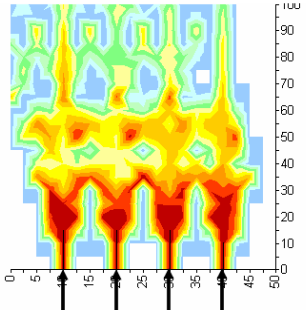
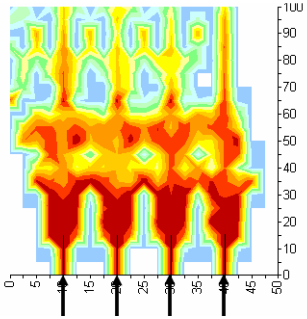
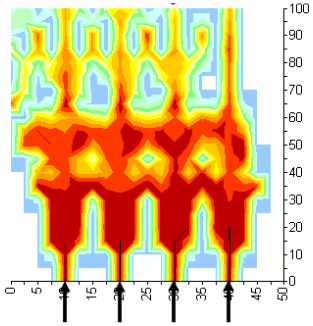
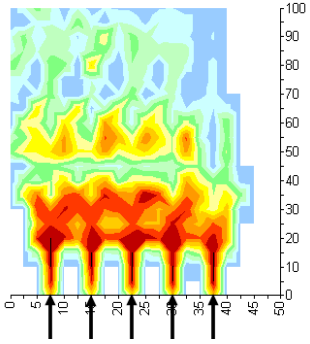
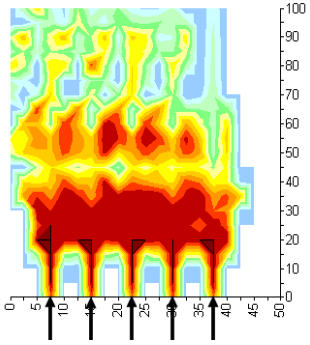
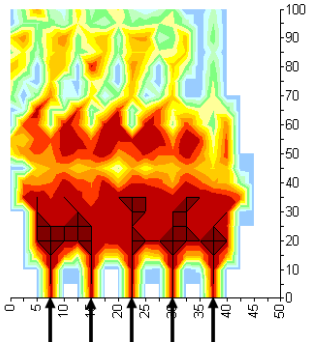
- Soldiers next to each other (line formation):
  8 men covering an area of 10 x 40 m
- Soldiers in column formation:
  5 men covering an area of 50 x 10 m



- Doctrine determined by variation in:
  - Initiation height
  - Initiation distance
  - Number of rounds in initiation point
  - Distance between initiation points



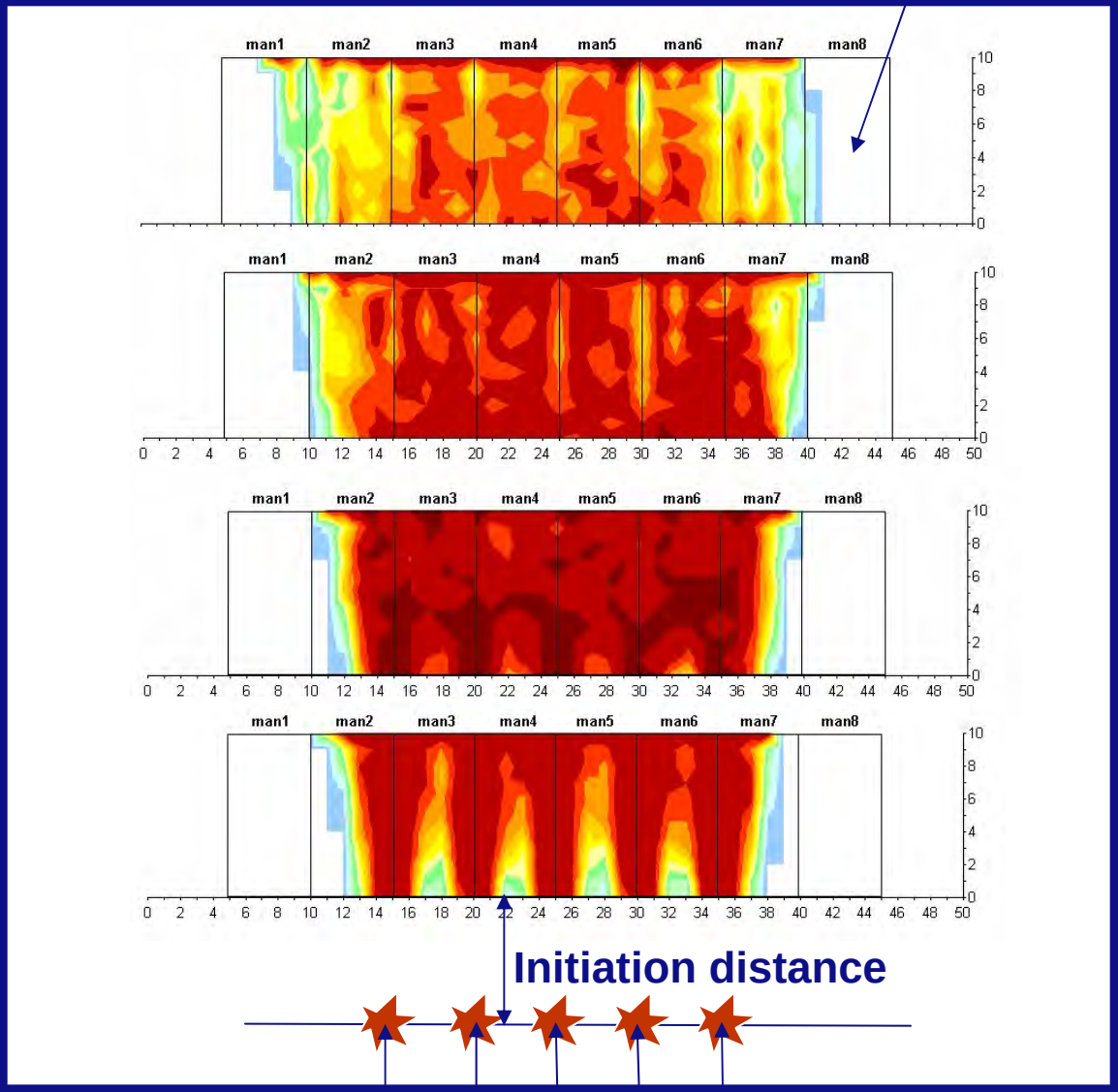
KETF versus dismounted soldiers

	1 proj.	2 proj.	3 proj.	4 proj.
3 aim Points				
4 aim points				
5 aim Points Pk =				 Infantry soldiers positioned in area of 50 m wide x 100 m deep.
	0-0.1 0.1-0.2 0.2-0.3 0.3-0.4 0.4-0.5 0.5-0.6 0.6-0.7 0.7-0.8 0.8-0.9 0.9-1			

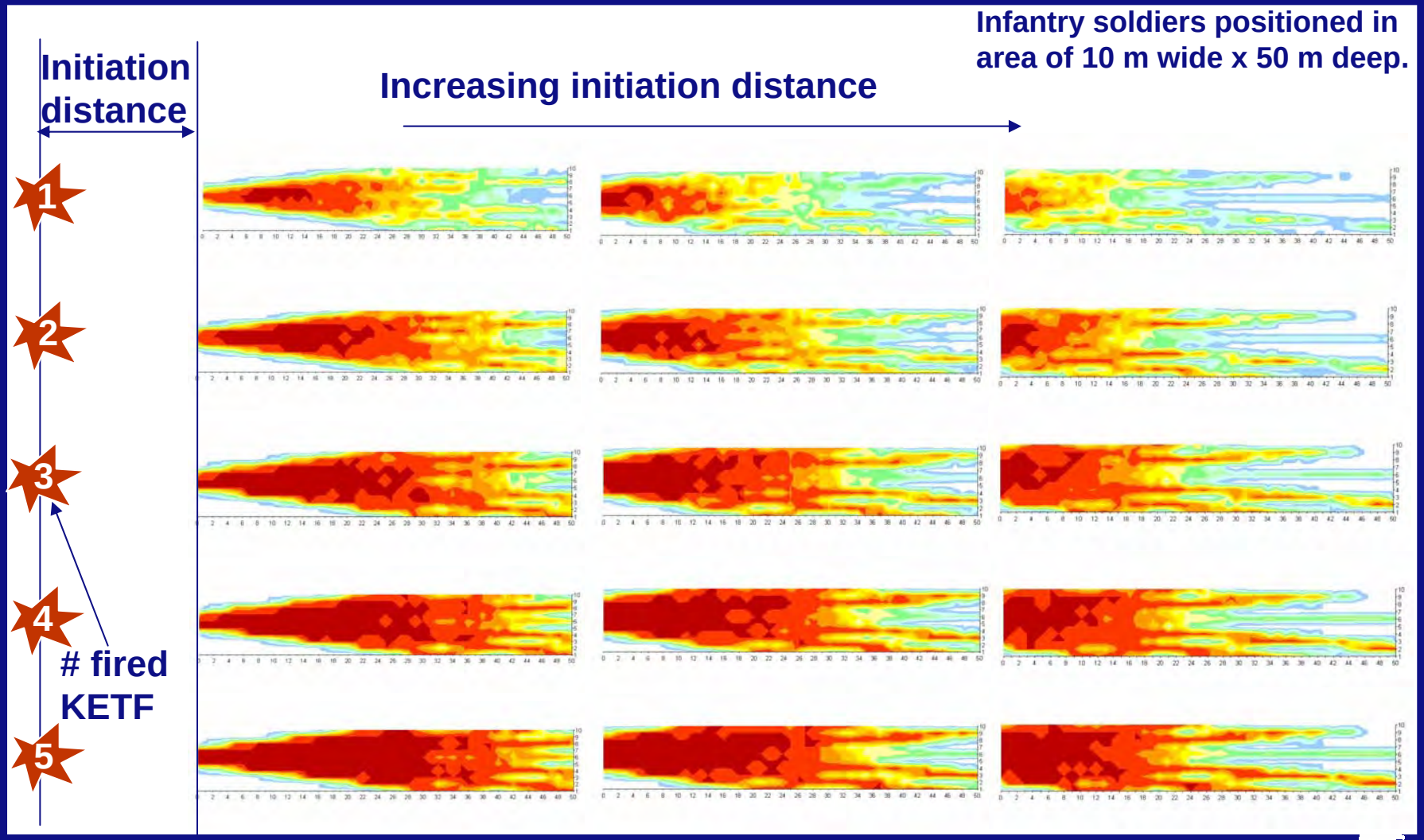
Firing doctrine
35 mm KETF vs line formation

Infantry soldier positioned in area of 5 x 10 m.

Increasing initiation distance



Firing doctrine
35 mm KETF vs column formation

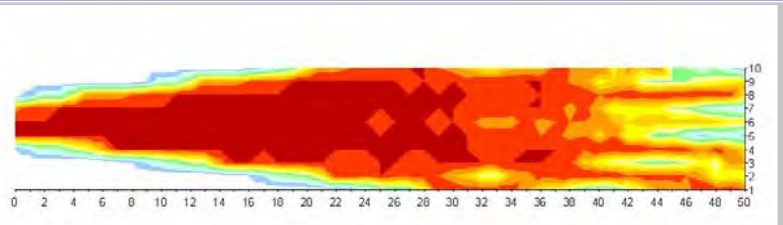


Firing doctrine
35 mm KETF vs column formation

1 aim point

Initiation distance

n



0.5n

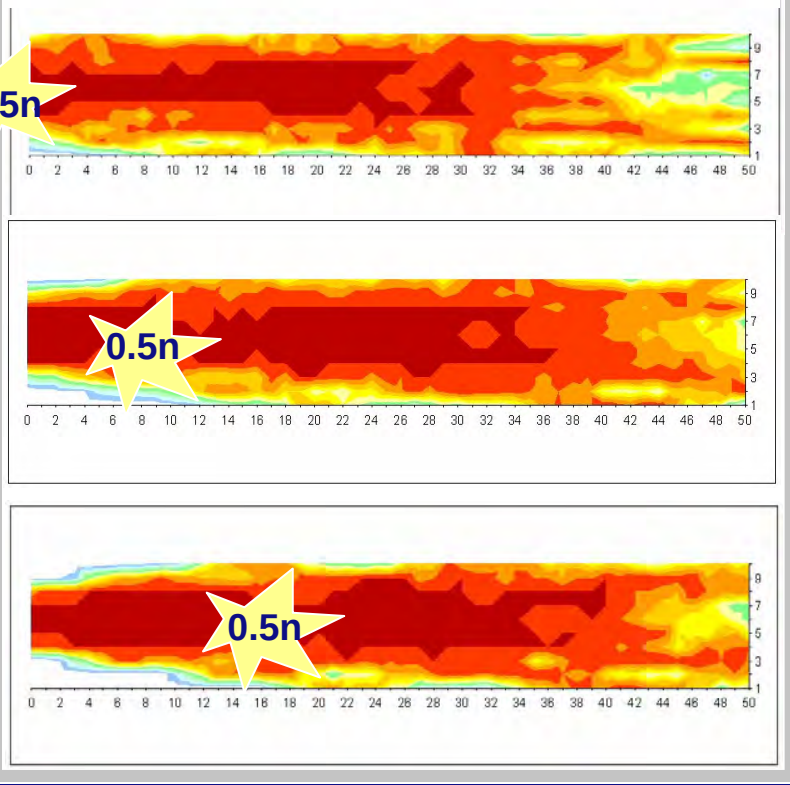
N = # fired KETF

0.5n

0.5n

2 aim points

Using different time settings



Infantry soldiers positioned in area of 10 m wide x 50 m deep.

KETF firing doctrine: dismounted soldiers in open field

- Conclusions:
  - The KETF is very effective against infantry soldiers
  - The effectiveness is influenced by:
    - number of rounds
    - initiation distance
    - initiation height
    - distance between initiation points
    - time setting of the fuze (“string of pearls option”)





Conclusion

- The 35 mm caliber was selected for the RNLA IFV to fulfil the Firepower requirements
- The ABM ammunition can be very effective against a range of targets
- To achieve the best effectiveness for the ABM ammunition the balance has to be found between:
  - The number of fired projectiles
  - Initiation distance
  - Initiation height
  - Distance between initiation points
  - Time setting of the fuze

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Warhead Penetration Dynamics- Warhead Body, Fuze and Target Interaction

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Outline

- Next Generation SFW Description
- Smart Fuze Definition (An Essential Component of Next Generation SFW)
- Description of a Fielded, Next Generation SFW- Utilizes First Generation Smart Fuze Technology
- Second Generation Smart Fuze Technology-Capabilities to Implement
- Second Generation Smart Fuze Technology-Implementation Approach
  - Electronic Fuzes
  - Target Definition Data
    - Warhead/Target Interaction Simulation
    - Experimental Validation of Warhead/Target Interaction Simulation
- Conclusion

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Next Generation SFW Description

- Infantry Forces are requesting a new generation of shoulder-fired weapons (SFW) that defeat a variety of urban structures at 100-300 meter standoff ranges
  - Urban environment target set examples (with each target having its own penetration requirement): metal security doors, windows, non-armored and light-armored vehicles, plywood and drywall on wooden studs, cinder block walls, brick walls (single or triple layer), adobe, sand, armored glass
  - Target defeat strategy:

    a) First, the warhead penetrates the target wall using its own KE

    b) Second, the warhead then continues to fly into the structure

    c) Finally, the warhead then functions once inside the structure in a high blast and/or fragmentation mode

    Note: Penetration event happens differently for different targets and hence warhead function timing is target dependent

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Smart Fuze Definition

- To field this next generation of shoulder-fired weapons with specific utility in urban warfare operations requires the development of a multi-target “Smart” fuze
  - Smart Fuze:

    Capable of calculating when to function the warhead based on its own determination of what kind of target is being penetrated without Gunner selection or action prior to firing

    or More Simply

    Ability to self discriminate targets on impact without Gunner intervention

1st Generation Smart Fuze Technology

- Marine Corps' SMAW-NE: The only currently fielded U.S. shoulder-fired weapon whose warhead has the ability to penetrate a target wall and then function once inside the structure
  - Team:
    - MARCORSYSCOM (Marine Corps' System Command)
      - PM, Anti-Armor Systems
      - PM, Ammo
    - NSWC-Indian Head, NSWC-Dahlgren, NSWC-Crane
    - Talley Defense Systems (TDS)
    - BAE Systems
  - Team received Marine Corps' Team Excellence Award
    - SMAW-NE taken from concept, through qualification, to delivery of 1000 units to Soldiers in Iraq in less than 1 year

1st Generation Smart Fuze Technology (cont'd)

- Marine Corps' SMAW-NE:
  - Warhead structure and internal components have been designed to withstand a penetration event and then function behind the target
  - Utilizes an enhanced blast explosive fill

1st Generation Smart Fuze Technology (cont'd)

- Marine Corps' SMAW-NE:
  - Incorporates a electro-mechanical Dual Mode Smart fuze that discriminates between hard and soft targets; no Gunner action is required to select attack mode
    - Hard Targets: triple layer brick, reinforced concrete and armor
      - Fuze detonates the warhead on the outside of the target on impact
      - Lethality Mechanism: Behind wall spall fragment affects
    - Soft Targets: earth and timber bunkers and single brick on ¾" plywood wall (a light clad target)
      - Fuze detonates the warhead only after the warhead has buried into the bunker wall or has flown through the single brick wall
      - Lethality Mechanism for earth and timber bunker: Heaving affects
      - Lethality Mechanism for single brick wall (light clad target): Behind wall heat and overpressure blast affects

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1st Generation Smart Fuze Technology (cont'd)

- SMAW-NE destroying a 2-story building (wall: single brick with plywood sheet backing)-target defeat strategy successfully implemented on a soft target



1st Generation Smart Fuze Technology (cont'd)- Snapshots of Building Defeat Animation

- SMAW-NE destroying a 2-story building (wall: single brick with plywood sheet backing)- target defeat strategy successfully implemented on a soft target



1st Generation Smart Fuze Technology (cont'd)

- SMAW-NE penetrating a single-brick plywood wall (behind the wall view)- target defeat strategy successfully implemented on a soft target



1st Generation Smart Fuze Technology (cont'd)- Snapshots of Behind Wall Function Animation

- SMAW-NE penetrating a single-brick plywood wall (behind the wall view)- target defeat strategy successfully implemented on a soft target



1st Generation Smart Fuze Technology

- The Dual Mode Smart fuze used in the SMAW-NE operates in a binary mode, either sensing a hard or soft target and incorporates a single delay time setting for proper detonation of the warhead when engaging soft targets
- Talley is ready to expand on this capability and move to 2nd generation fuze technology

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2nd Generation Smart Fuze Technology (cont'd)

- The 2nd generation smart fuze should expand on the current ability to defeat hard and soft targets and provide a warhead capability that is effective against a wider target set
  - The fuze should incorporate multiple delay time settings to enable the defeat of subtler targets
  - The fuze design itself should not inherently limit the number of targets that can be discriminated from one another
  - The fuze should have the ability to increase the array of targets that it can discriminate as warhead/target interaction physics for new targets becomes available

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2nd Generation Smart Fuze Technology- Implementation Approach

- Electronic fuzes capable of meeting 2nd generation smart fuze requirements
  - Currently capable of being programmed with multi delay time settings
  - Near term ability to carry onboard sensors to record data during warhead/target interaction and provide such data to onboard computing resources for the purposes of
    - target identification
    - selection of delay time required to defeat identified target
- Target definition data: Remaining facet still needed to provide electronic fuzes with the capability to discriminate multiple targets from one another
  - “Teach” electronic fuzes the differences in a warhead’s response to a variety of targets during the warhead/target interaction event
  - Fuze can utilize such differences to discriminate multiple targets from one another

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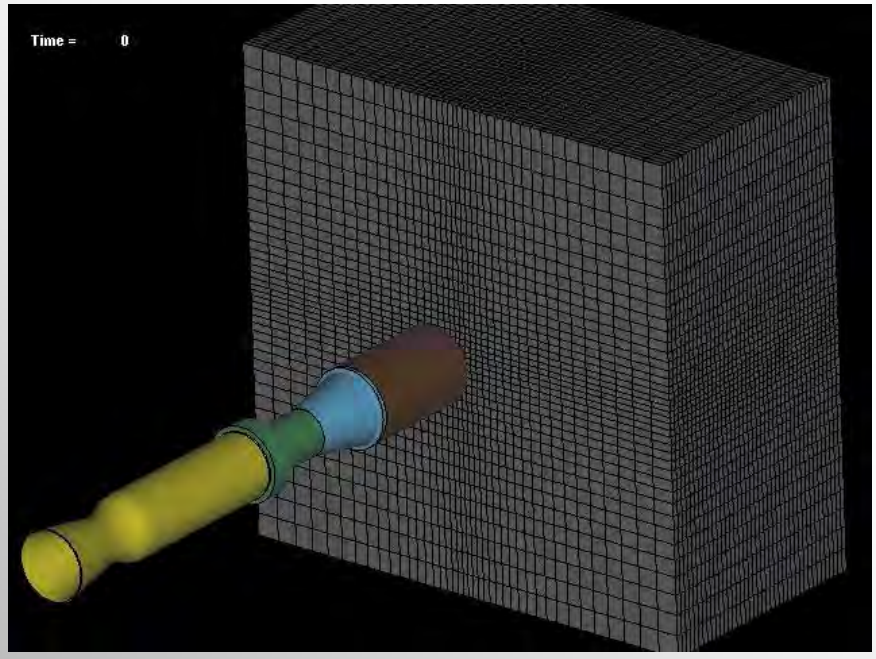
2nd Generation Smart Fuze Technology- Implementation Approach (cont'd)

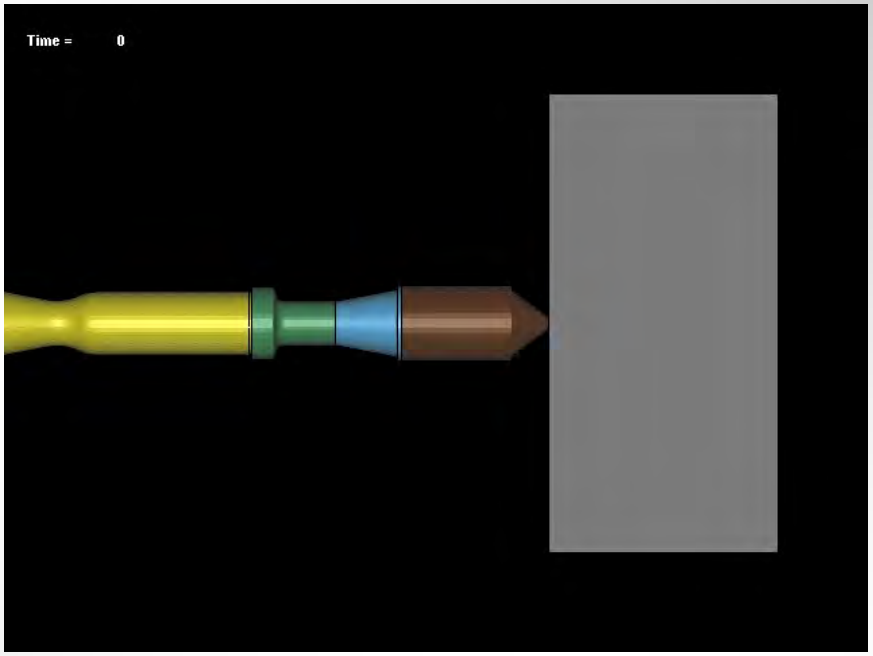
- The approach Talley will use to provide target definition data to the electronic fuze
  - Build analytical computer models of warhead and targets
  - Simulate the warhead impacting a given target; repeat for each target of interest
  - Validate the analytically predicted warhead/target interactions with experimental testing of inert warheads fired into targets
  - Use the interaction physics of experimentally validated warhead/target simulation models to provide target definition to the fuze

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Warhead/Target Interaction Simulation (cont'd)

- LS-DYNA simulation of warhead penetrating concrete (notice the shock/rarefaction wave-collision induced spalling behind the target on the right)

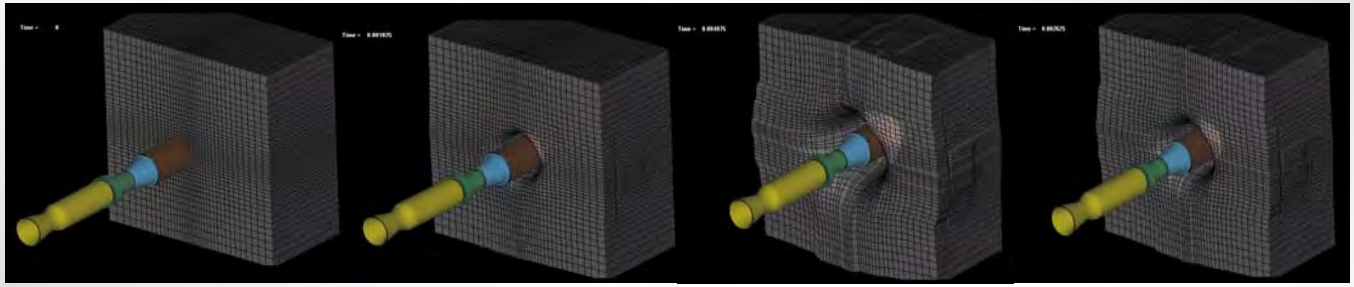


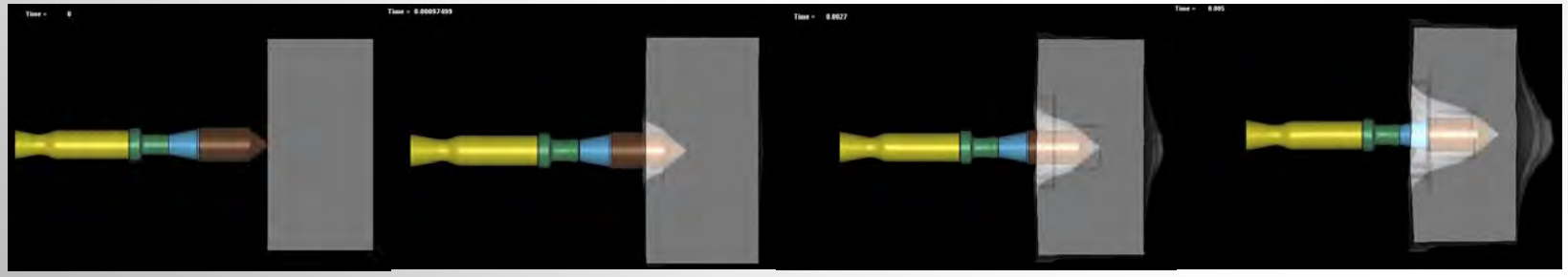


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Warhead/Target Interaction Simulation (cont'd)- Snapshots of Warhead Penetrating Concrete

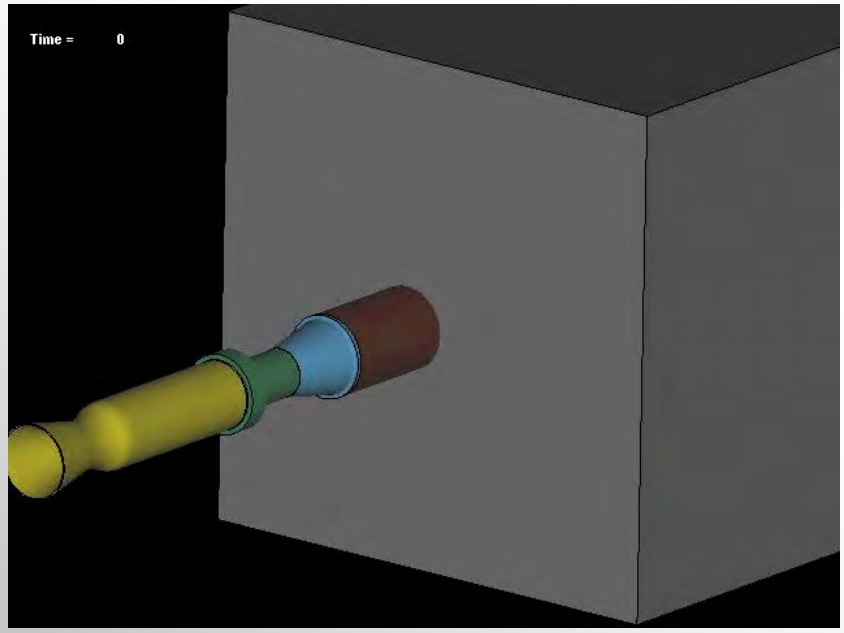
- LS-DYNA simulation of warhead penetrating concrete (notice the shock/rarefaction wave-collision induced spalling behind the target on the right)

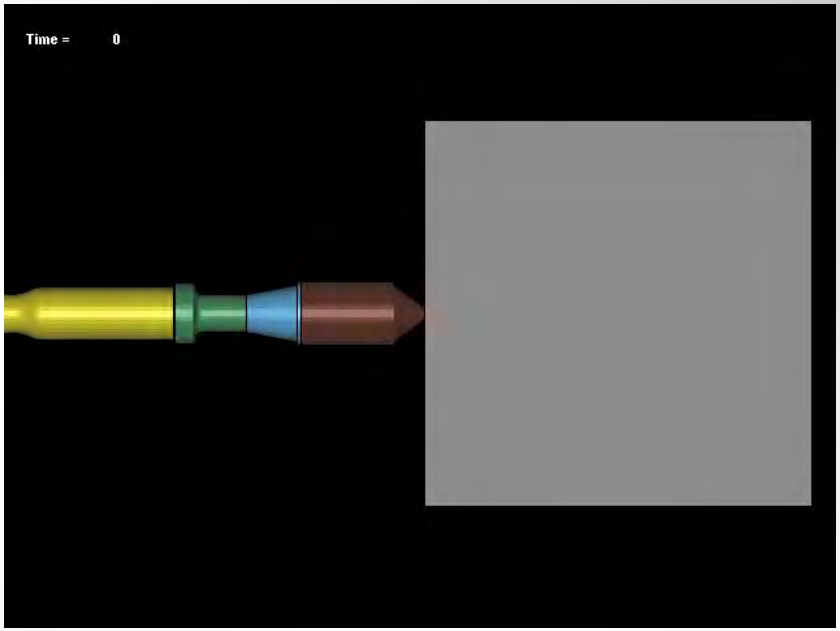




Warhead/Target Interaction Simulation (cont'd)

- LS-DYNA simulation of warhead penetrating sand (notice the shock cone)



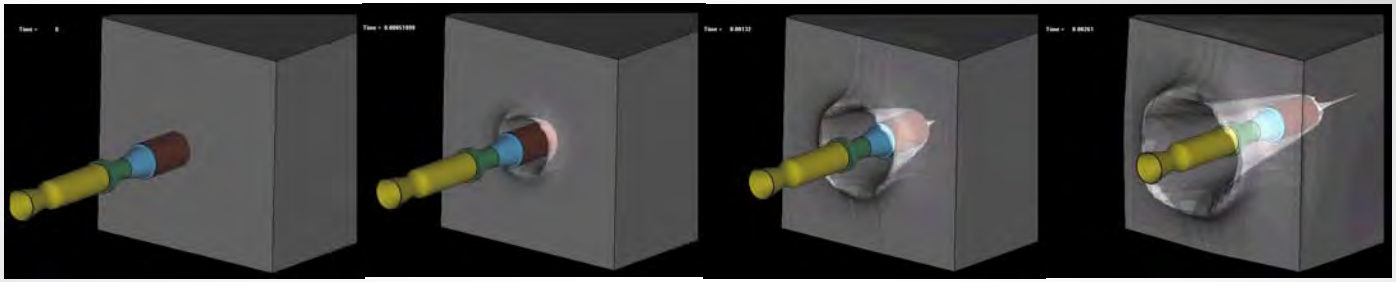


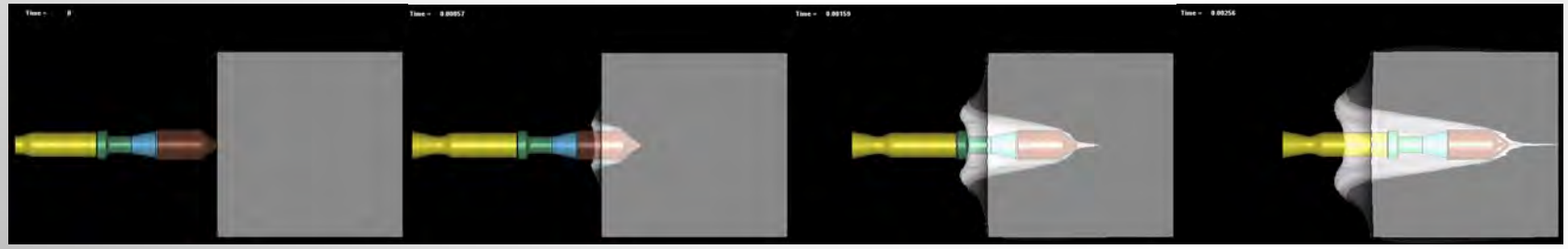
Talley Defense Systems

Warhead/Target Interaction Simulation (cont'd)-

Snapshots of Warhead Penetrating Sand

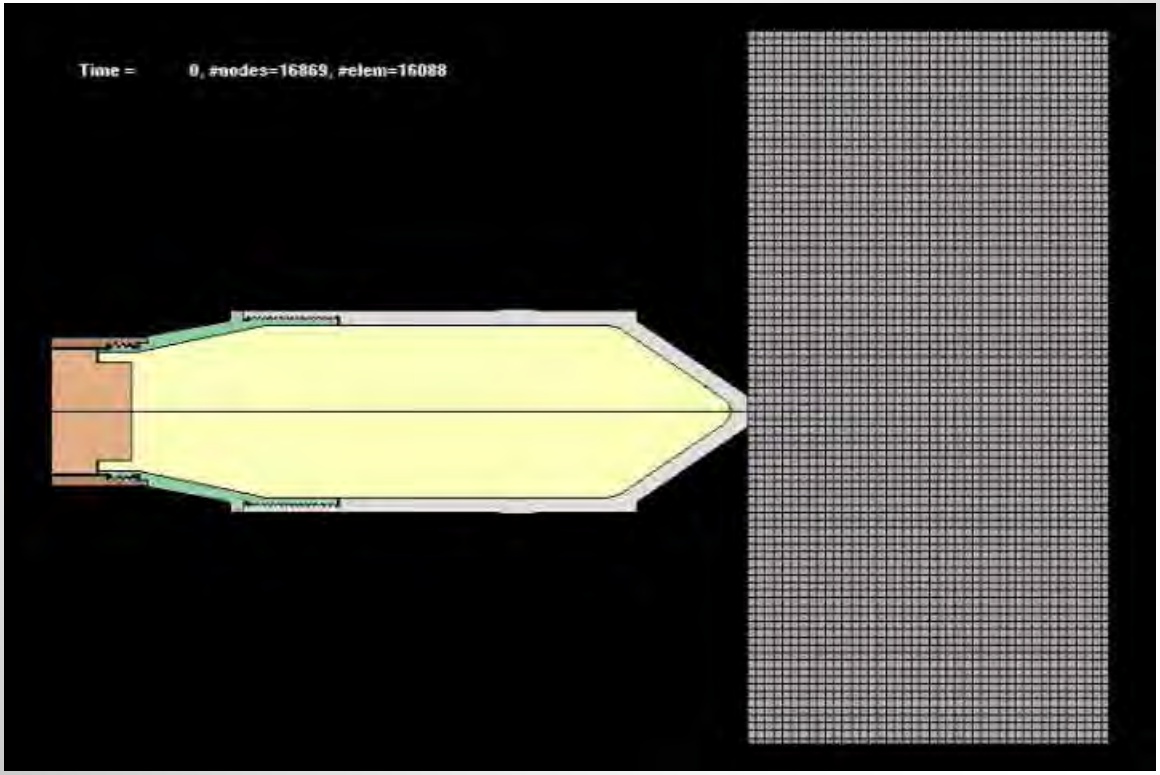
- LS-DYNA simulation of warhead penetrating sand (notice the shock cone)





Warhead/Target Interaction Simulation (cont'd)

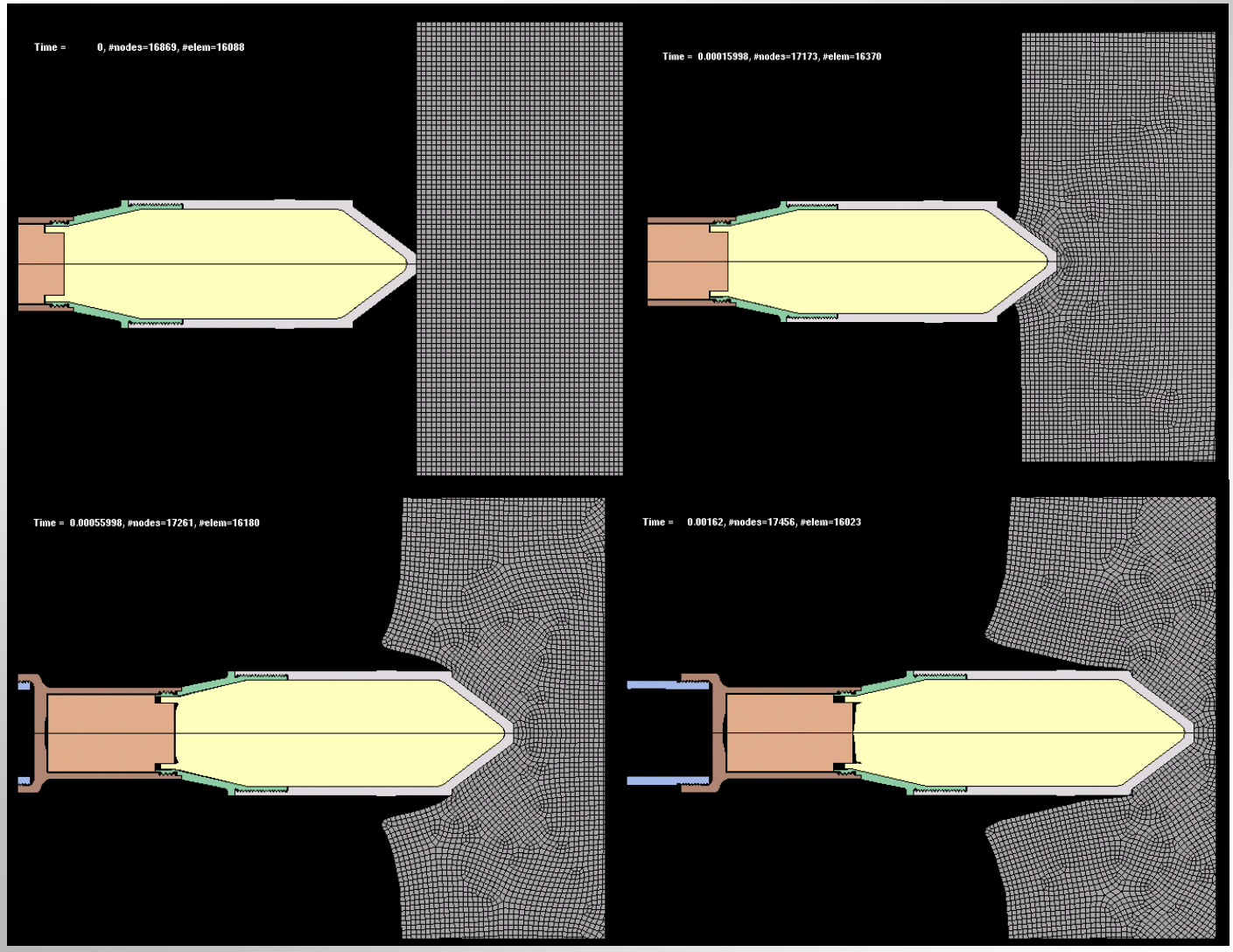
- LS-DYNA simulation of warhead penetrating brick



Warhead/Target Interaction Simulation (cont'd)-

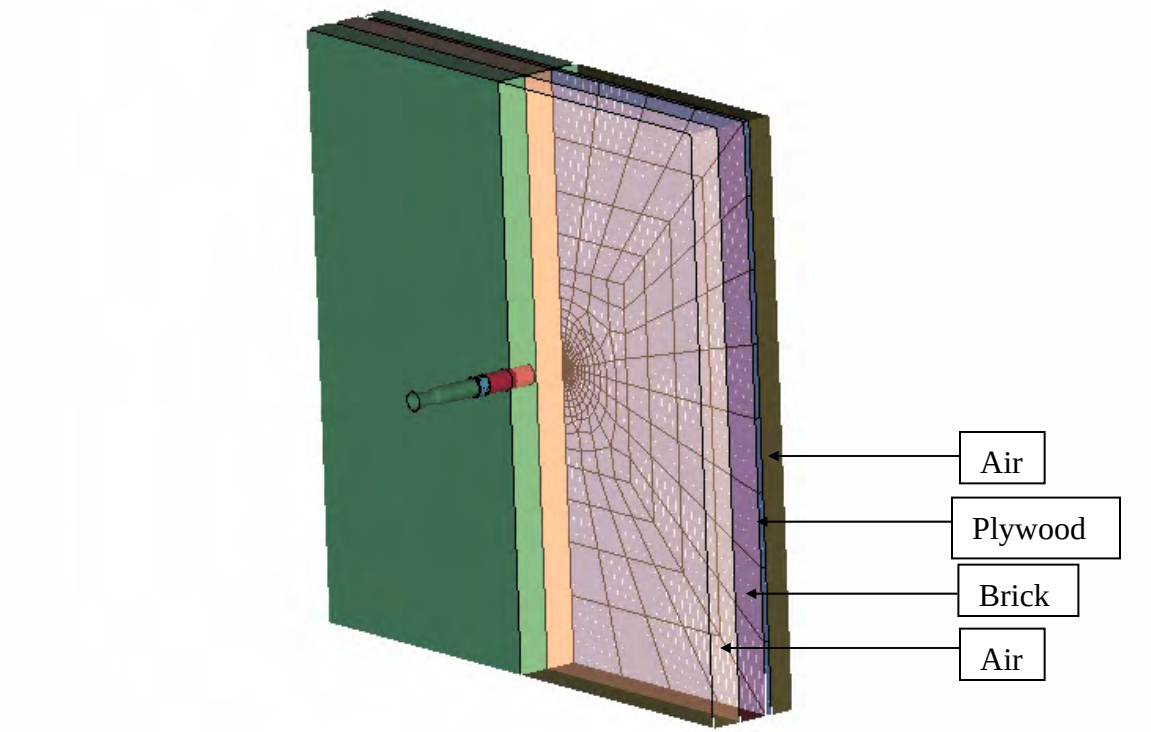
Snapshots of Warhead Penetrating Brick

- LS-DYNA simulation of warhead penetrating brick



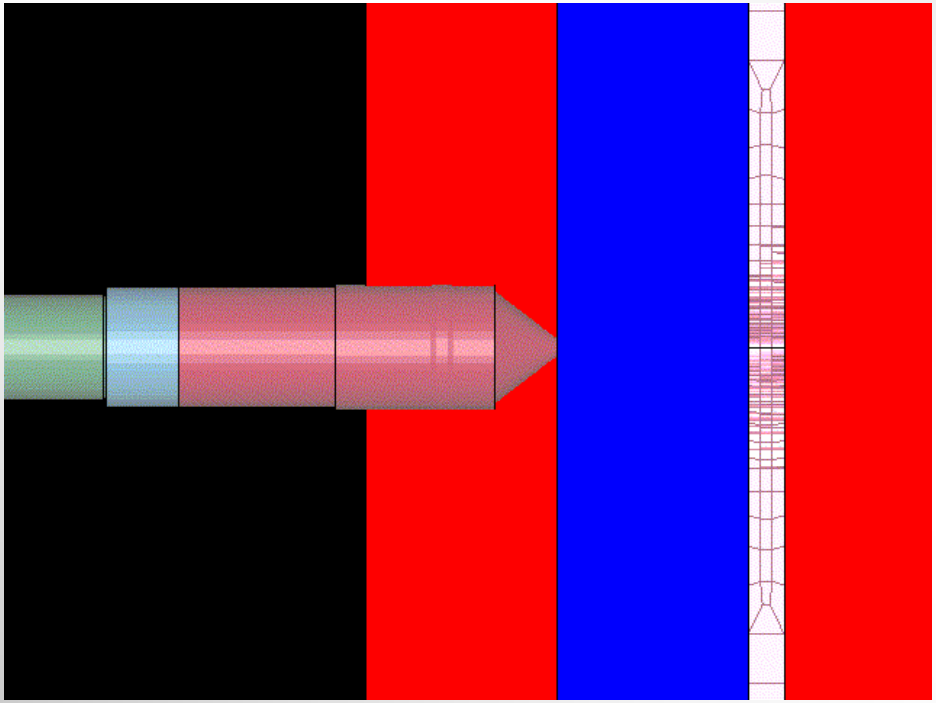
Warhead/Target Interaction Simulation (cont'd)

- LS-DYNA simulation of warhead penetrating single brick wall backed by plywood (Description of Plywood Backed Brick Wall Target)



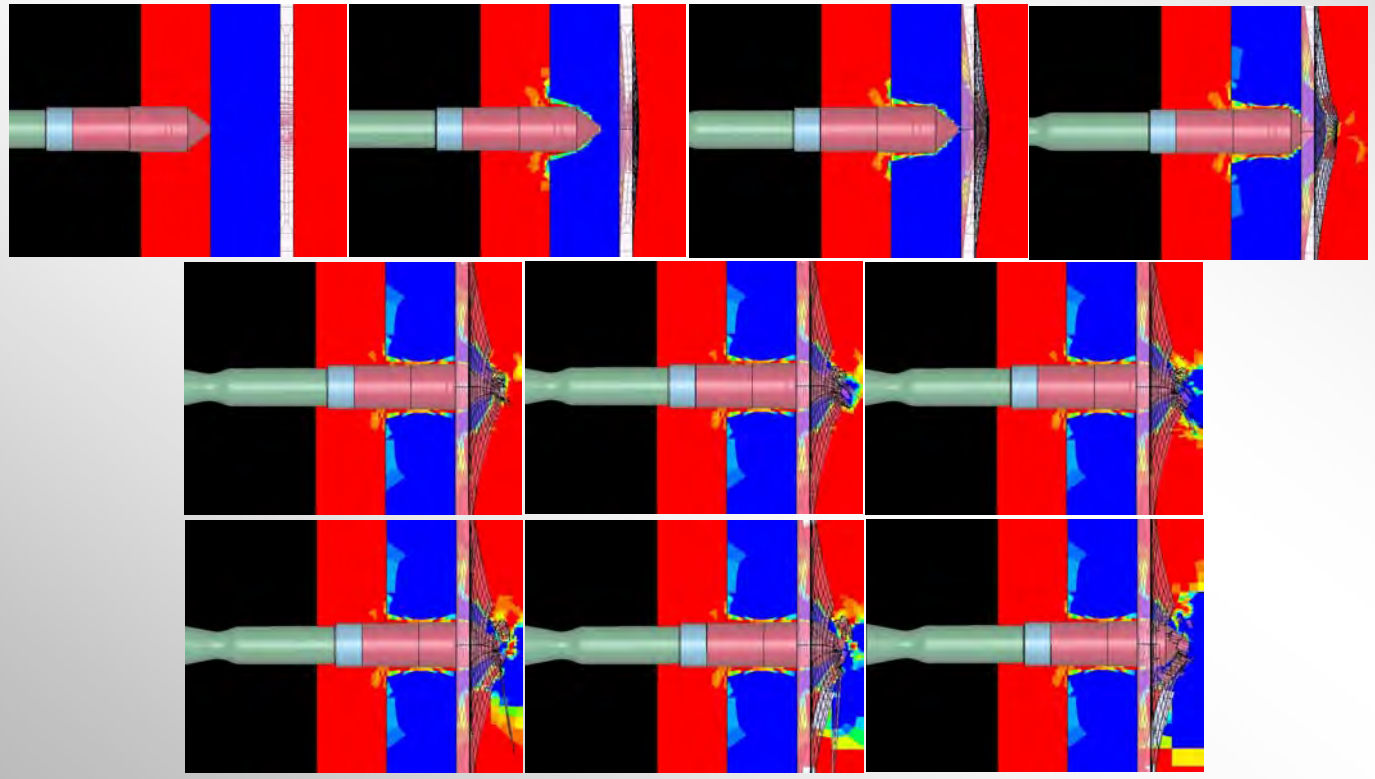
Warhead/Target Interaction Simulation (cont'd)

- LS-DYNA simulation of warhead penetrating a single brick wall backed by plywood
  - Notice the brick spall damaging the plywood before the warhead's ogive impacts the plywood)
  - Notice the brick spall passing through plywood after the plywood is ruptured



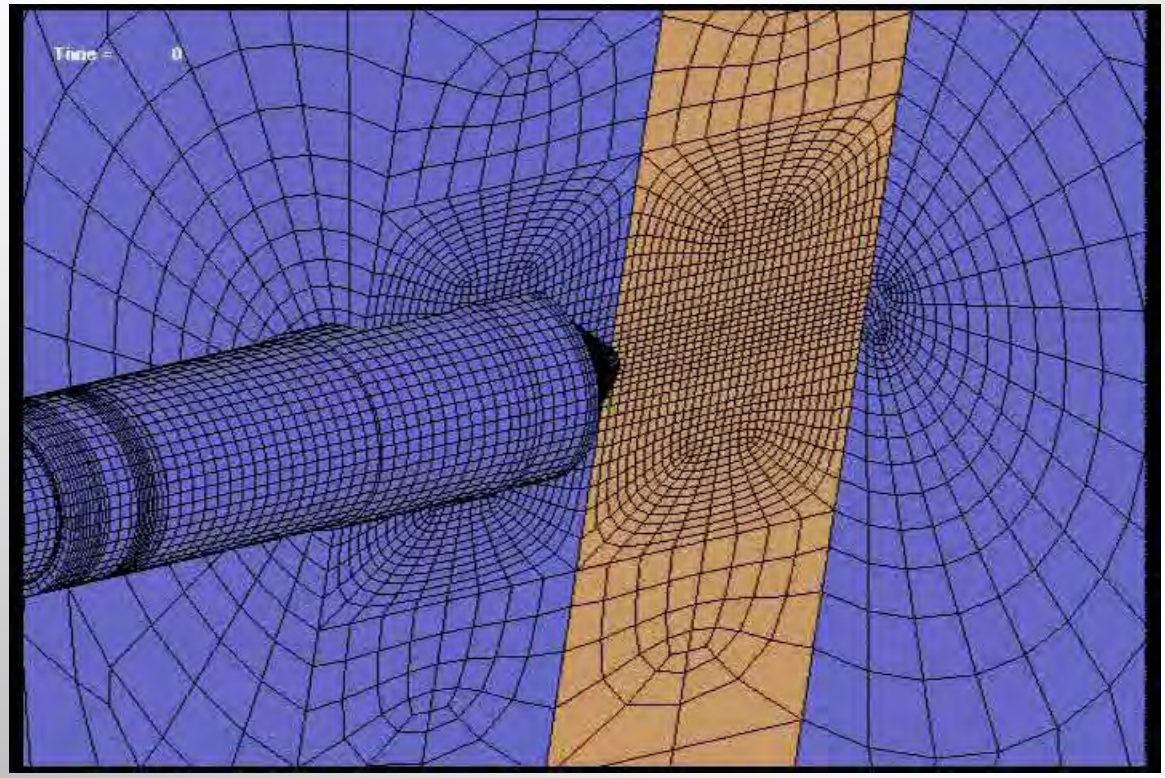
Warhead/Target Interaction Simulation (cont'd)-Snapshots of Warhead Penetrating Plywood Backed Brick Wall

- LS-DYNA simulation of warhead penetrating a single brick wall backed by plywood
  - Notice the brick spall damaging the plywood before the warhead's ogive impacts the plywood)
  - Notice the brick spall passing through plywood after the plywood is ruptured



Warhead/Target Interaction Simulation (cont'd)

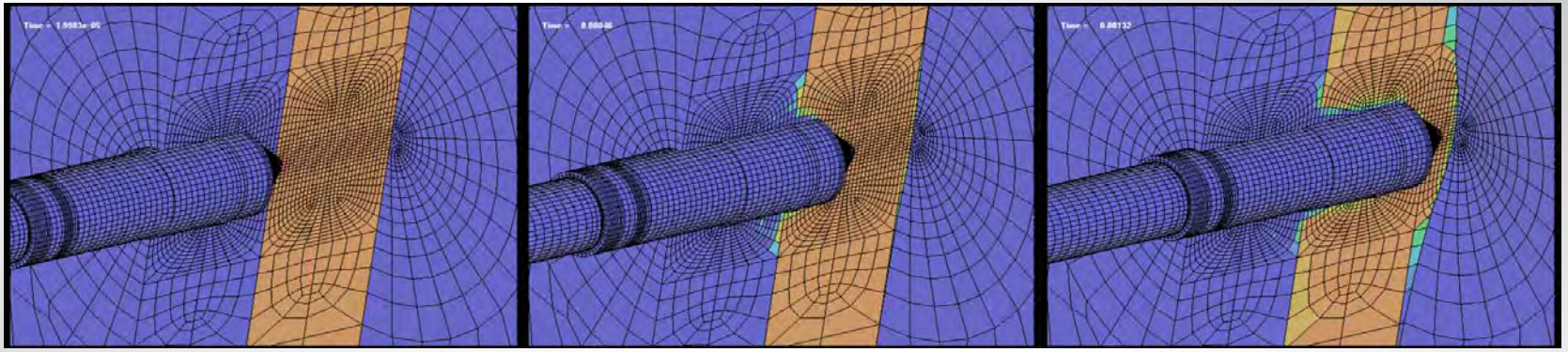
- LS-DYNA simulation of warhead penetrating a single brick wall backed by plywood (notice the brick spall damaging the plywood before the warhead's ogive impacts the plywood)

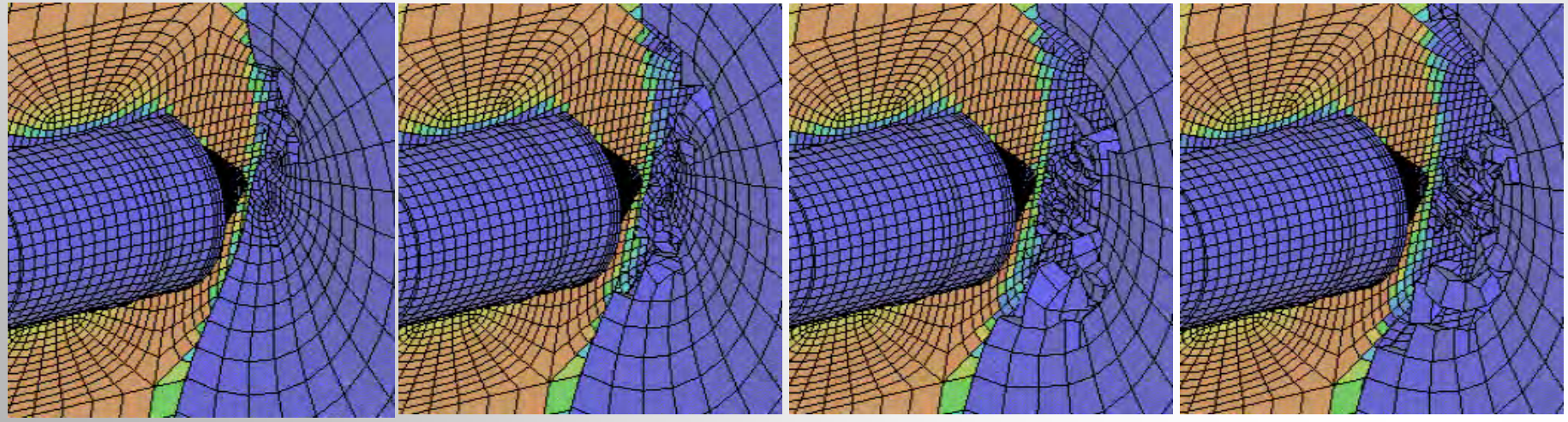


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Warhead/Target Interaction Simulation (cont'd)-Snapshots of Warhead Penetrating Plywood Backed Brick Wall

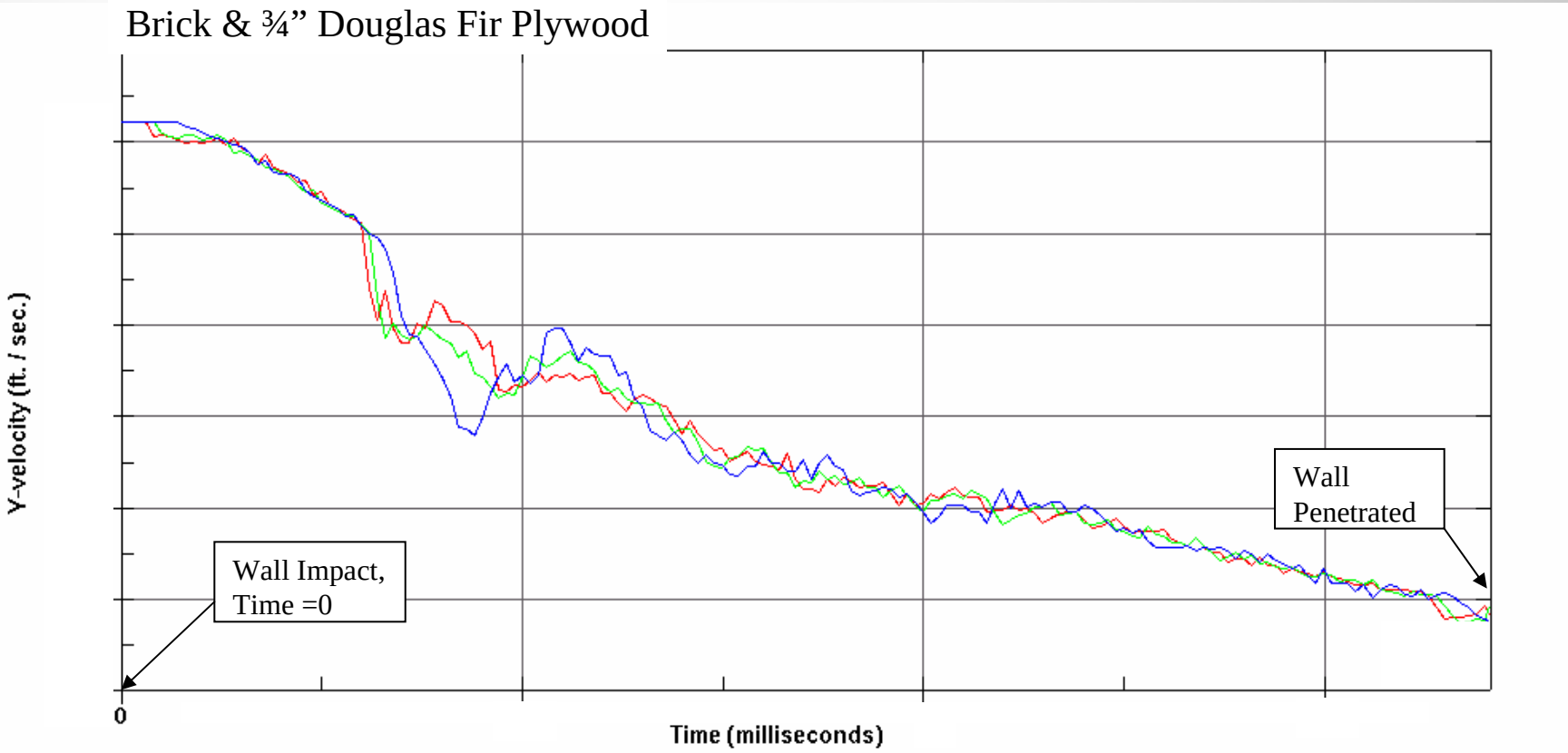
- LS-DYNA simulation of warhead penetrating single brick wall backed by plywood (notice the brick spall damaging the plywood before the warhead's ogive impacts the plywood)





Warhead/Target Interaction Simulation (cont'd)

- LS-DYNA predicted velocity traces of projectile components from the instant of impact to the moment after the plywood is perforated by brick spall



Typical Velocity Time Histories in Ogive, Closure and Rocket Motor Case During Impact

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Experimental Validation of Warhead/Target Interaction Simulation

- Experimentally predicted residual velocity of projectile at an instant after the projectile had completed penetrating the target was within 2 FPS of analysis predicted value



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Experimental Validation of Warhead/Target Interaction Simulation-Snapshots of Warhead Penetrating Plywood Backed Brick Wall

- Experimentally predicted residual velocity of projectile at an instant after the projectile had completed penetrating the target was within 2 FPS of analysis predicted value



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Conclusion

- Infantry Forces require shoulder-fired weapons that defeat a variety of urban structures at 100-300 meter standoff ranges by first penetrating the target and then functioning on the backside of the target

- 1st generation of Smart fuze technology is currently fielded (TDS Produced SMAW-NE) to meet this need for hard and soft targets

Conclusions (cont'd)

- Development is underway on the 2nd generation of Smart fuze technology to increase the array of targets that can be discriminated from one another
  - Electronic fuzes currently capable of being programmed with multi delay time settings
  - Electronic fuzes nearing the ability to carry onboard sensors that can be used to identify unique characteristics of targets during the warhead/target interaction event
  - Experimentally validated warhead/target interaction simulation approach is available to provide electronic fuze manufacturer qualitative distinctions between various targets during the warhead/target interaction event
  - Future electronic fuze testing is planned which incorporates target specification data obtained from warhead/target interaction simulation

SUPER WEAPONS – An Analysis

Lieutenant Colonel Simon West
Royal Artillery

Defence Academy of the United Kingdom

GARM – New Orleans

26 Apr 05

Defence Academy-Shrivenham

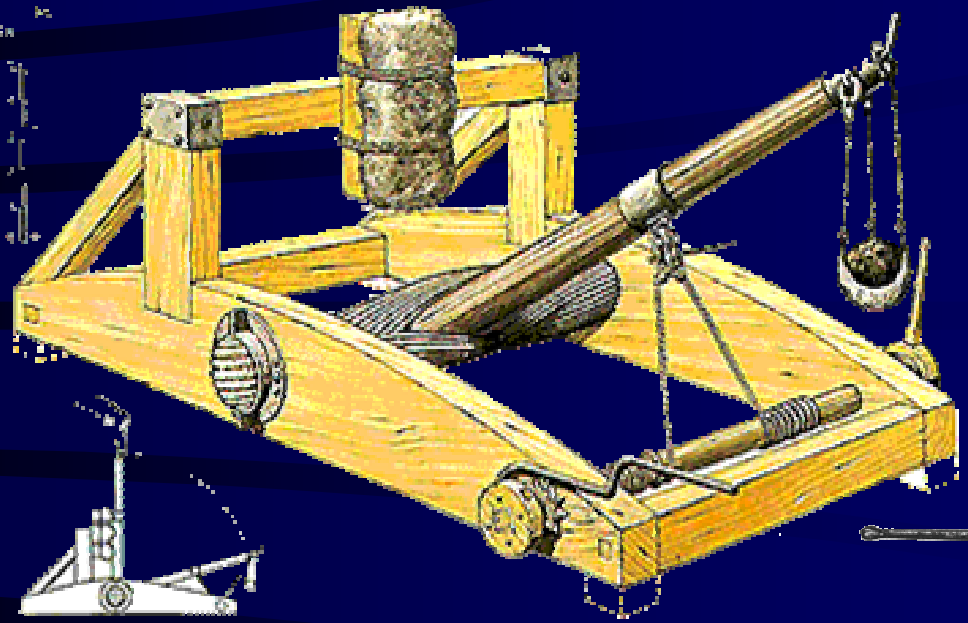


INITIAL DEFINITION

- A weapon designed to generate decisive military effect



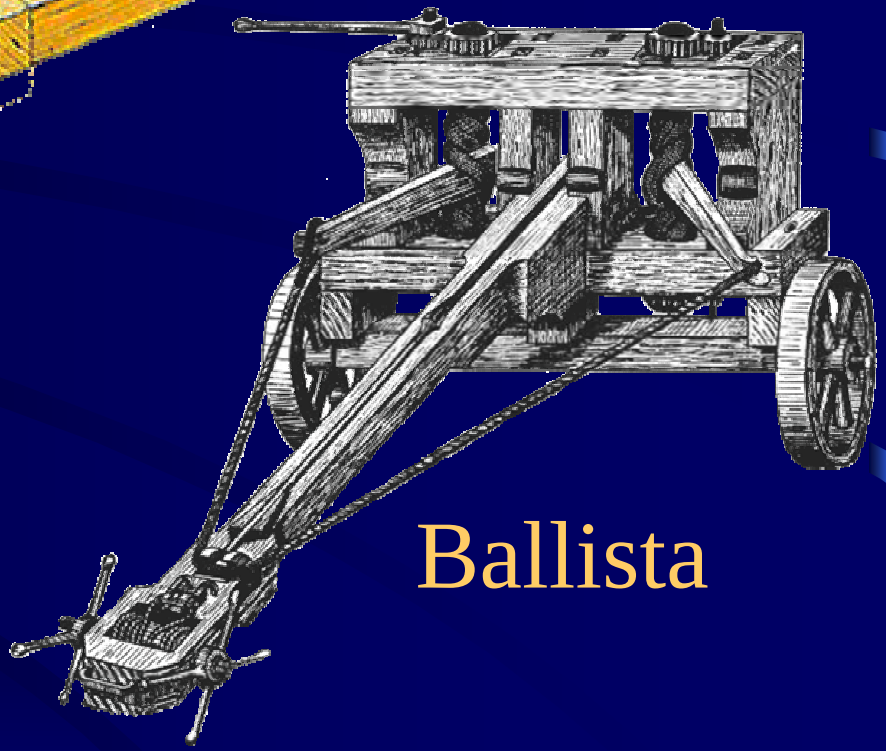




Onager

Trebuchet



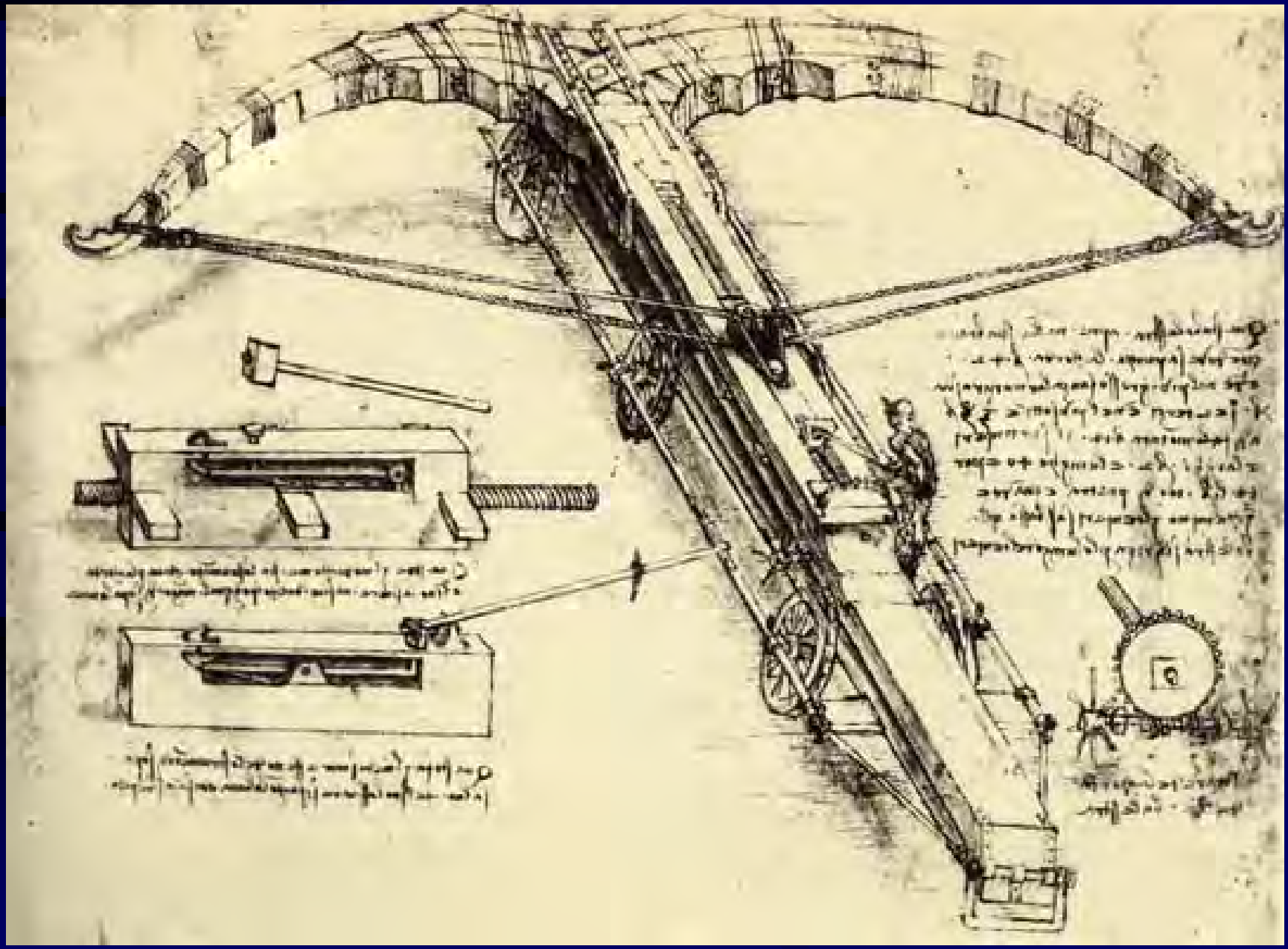


Ballista

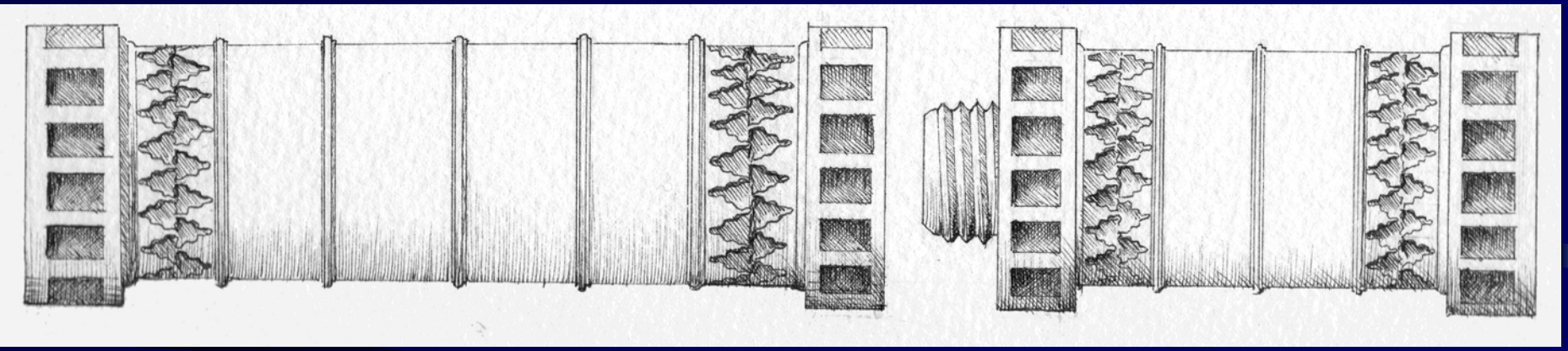
Crecy 1346







Constantinople 1453



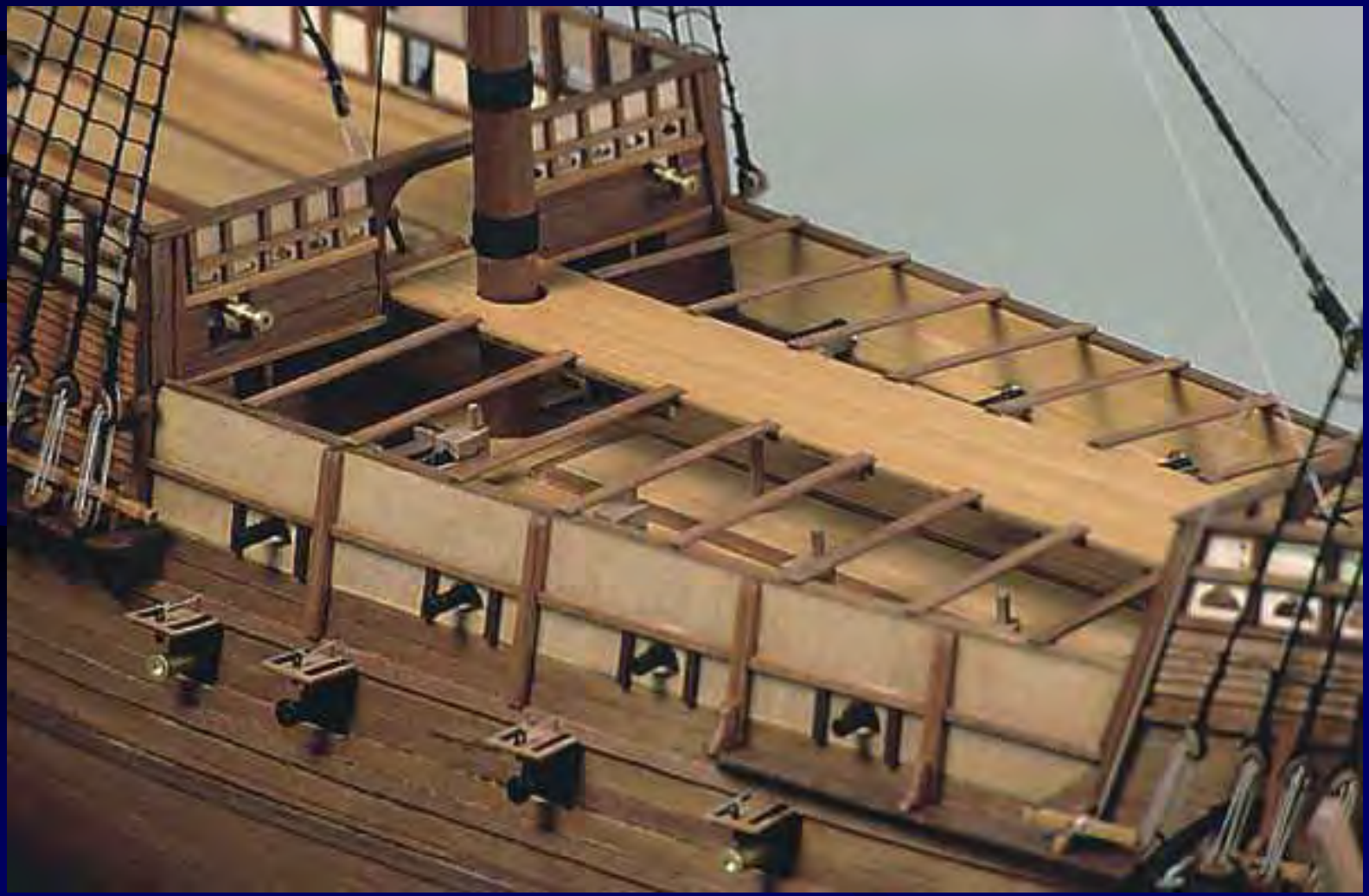
Mons Meg 1449



- Threave Castle



Mary Rose

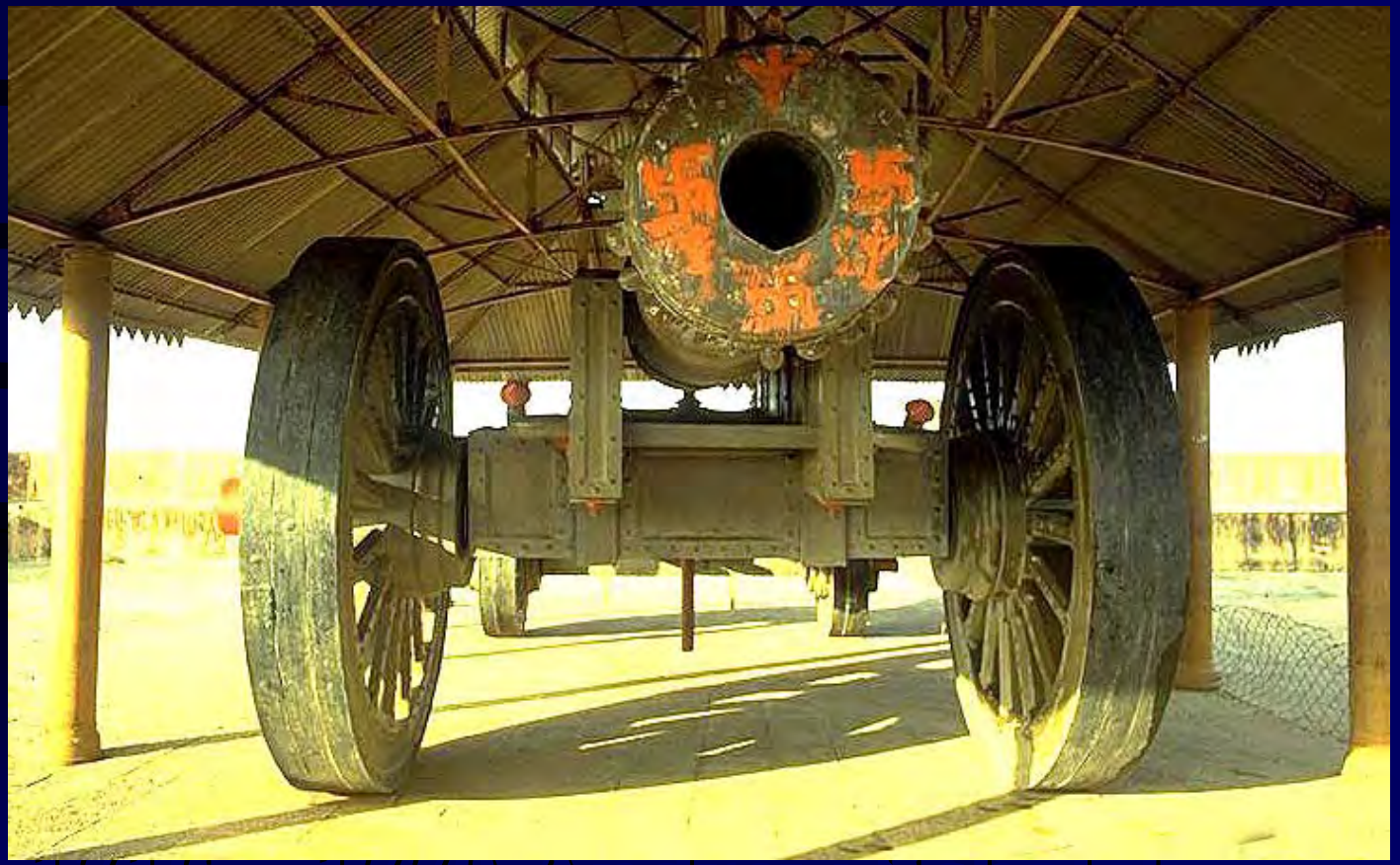


Tsar Cannon - Moscow



40 tonnes
890mm

Jaivana – Jaipur 1720



50 tonnes

1716 – 1770 Andrew Schalch

Mallet’s Mortar



914mm





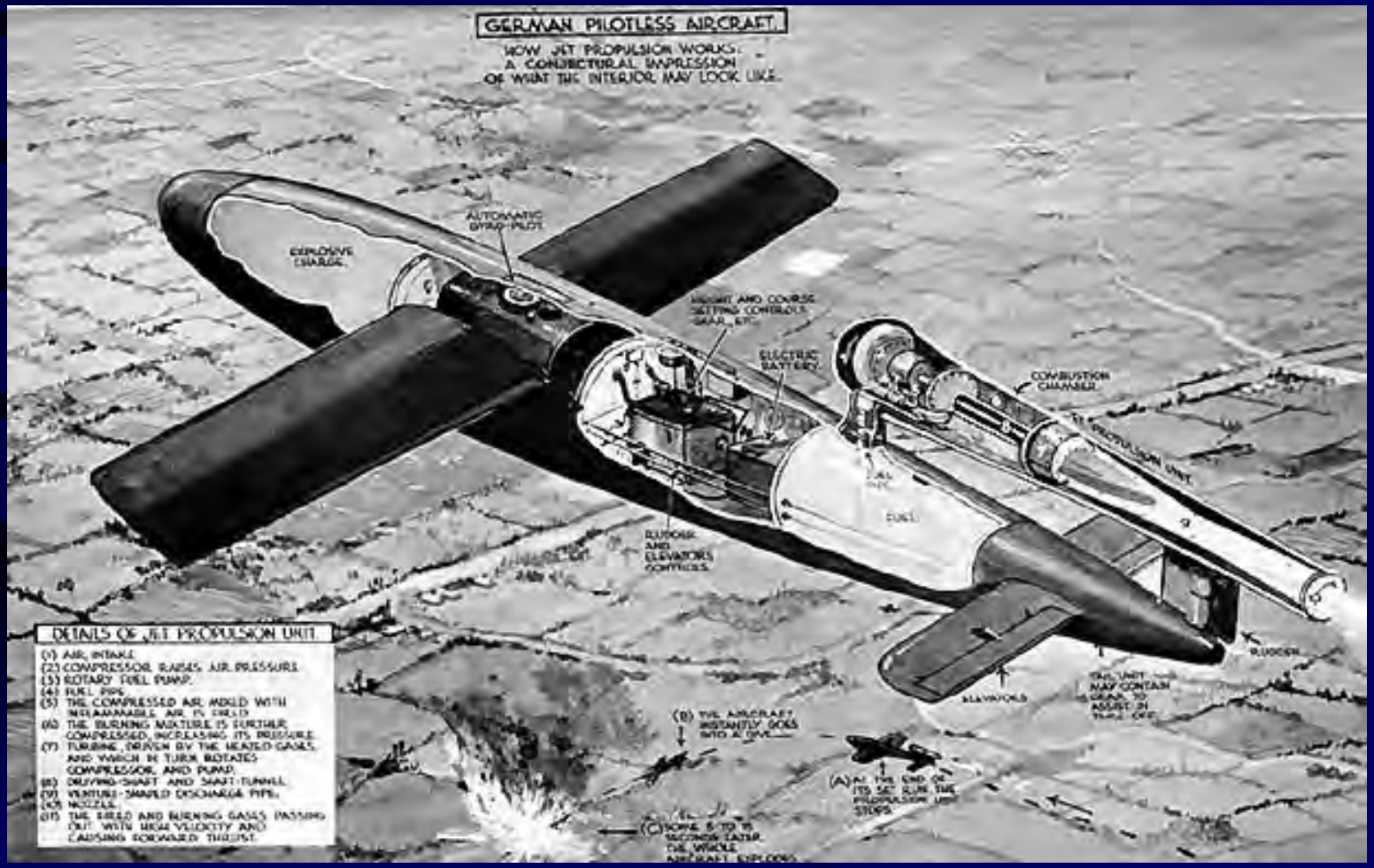
The Paris Gun

Gustav – 800mm



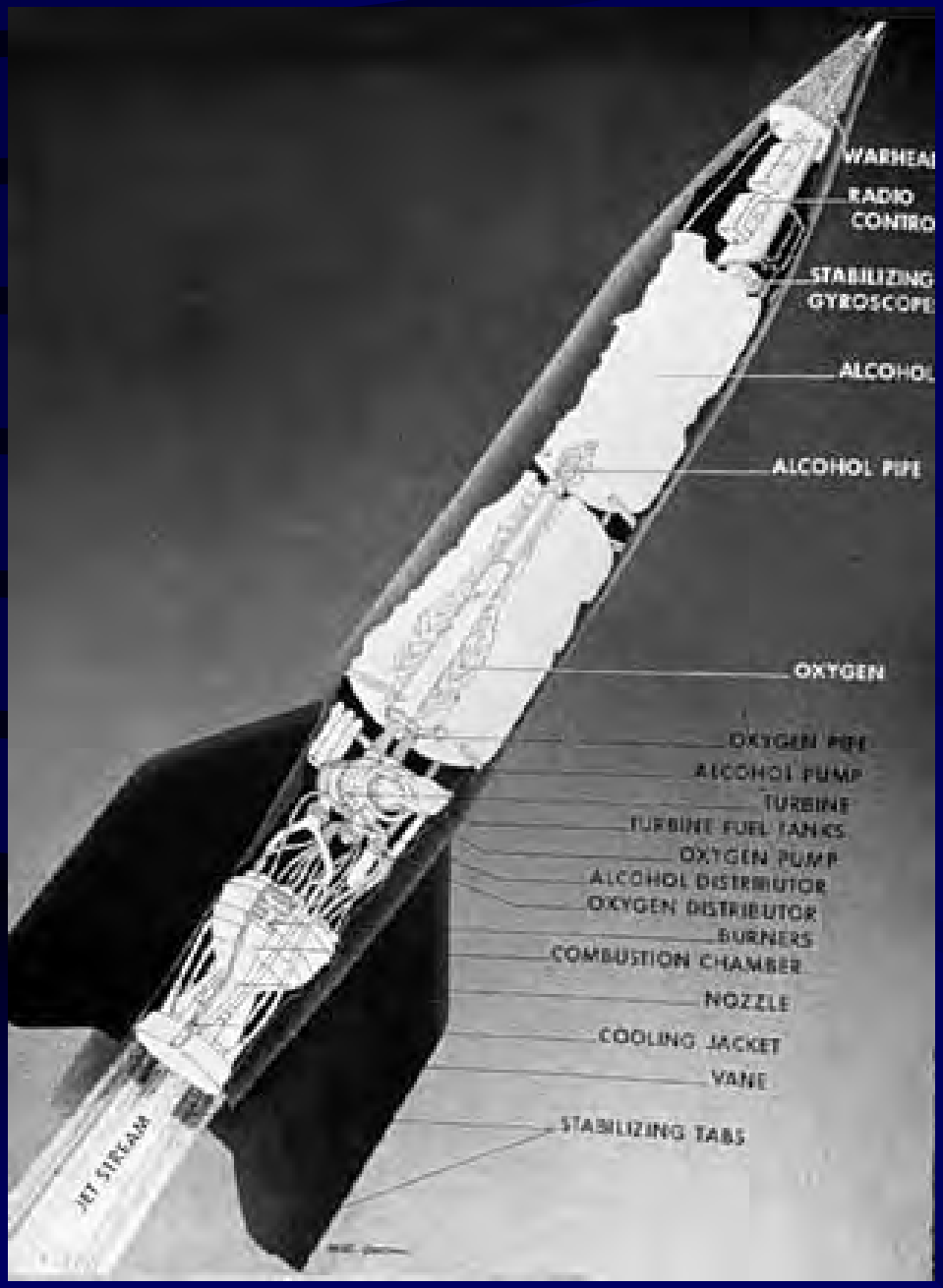


V1


GERMAN PILOTLESS AIRCRAFT.
HOW JET PROPULSION WORKS:
A CONJECTURAL IMPRESSION
OF WHAT THE INTERIOR MAY LOOK LIKE.
AUTOMATIC GYRO-PILOT
EXPLOSIVE CHARGE
ELECTRIC BATTERY
COMBUSTION CHAMBER
FUEL
RUDDER AND ELEVATORS CONTROLS
ELEVATORS
RUDDER
DETAILS OF JET PROPULSION UNIT.
(1) AIR INTAKE.
(2) COMPRESSOR, RAISES AIR PRESSURE.
(3) ROTARY FUEL PUMP.
(4) FUEL PIPE.
(5) THE COMPRESSED AIR MIXED WITH INFLAMMABLE AIR IS FIRED.
(6) THE BURNING MIXTURE IS FURTHER COMPRESSED, INCREASING ITS PRESSURE.
(7) TURBINE, DRIVEN BY THE HEATED GASES, AND WHICH IN TURN ROTATES COMPRESSOR AND PUMP.
(8) DRIVING-SHAFT AND SHAFT-TUNNEL.
(9) VENTURI-SHAPED DISCHARGE PIPE.
(10) NOZZLE.
(11) THE HEATED AND BURNING GASES PASSING OUT WITH GREAT VELOCITY AND CAUSING FORWARD THRUST.
(B) THE AIRCRAFT INSTANTLY GOES INTO A DIVE.
(A) AT THE END OF ITS SET RUN THE PROPULSION UNIT STOPS.
(C) SOME 5 TO 15 SECONDS LATER THE WHOLE AIRCRAFT EXPLODES.

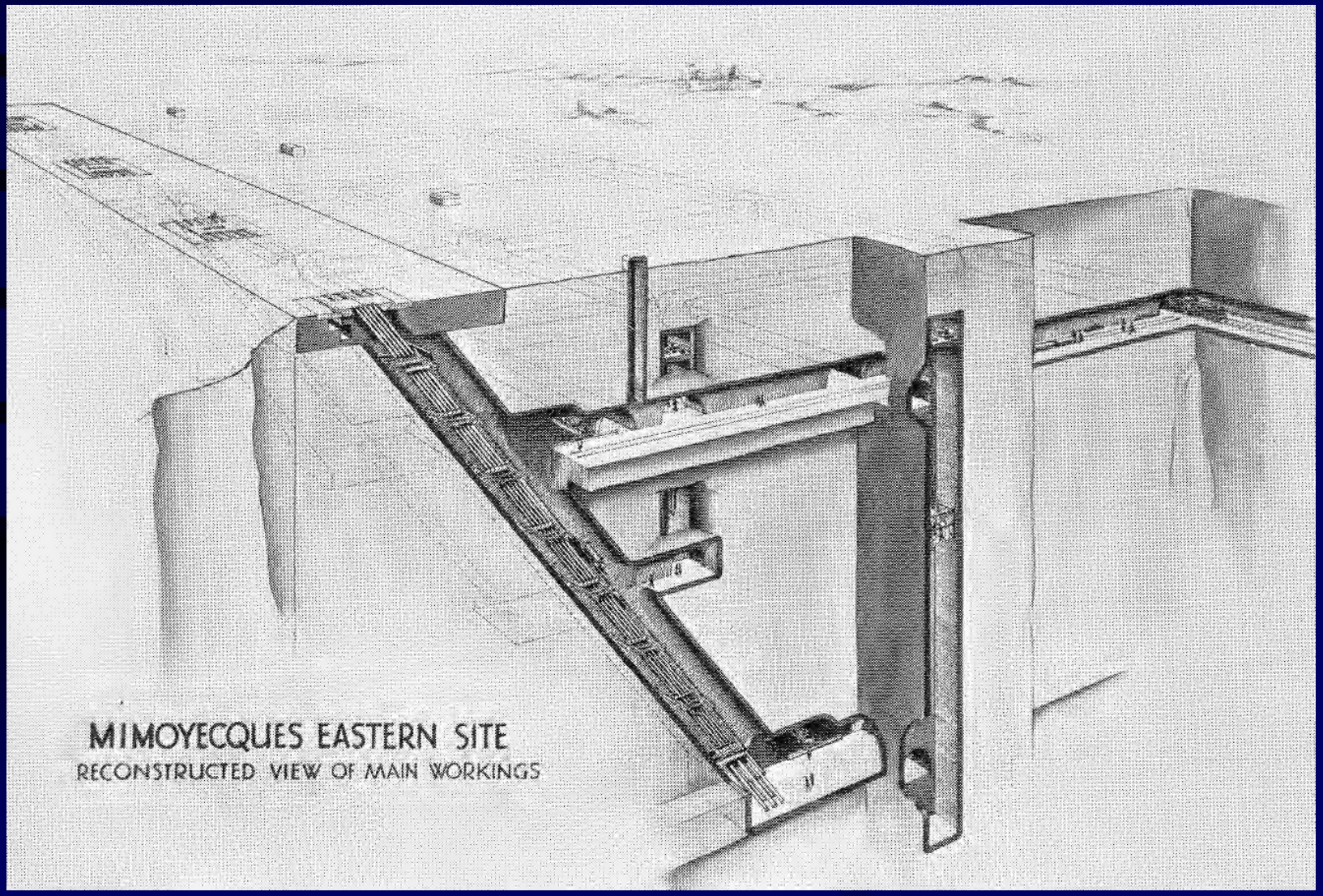


V2


WARHEAD
RADIO CONTRO
STABILIZING GYROSCOPE
ALCOHOL
ALCOHOL PIPE
OXYGEN
OXYGEN PIPE
ALCOHOL PUMP
TURBINE
TURBINE FUEL TANKS
OXYGEN PUMP
ALCOHOL DISTRIBUTOR
OXYGEN DISTRIBUTOR
BURNERS
COMBUSTION CHAMBER
NOZZLE
COOLING JACKET
VANE
STABILIZING TABS
JET STREAM


D4VE RESOURCE SITE
THE V2 ROCKET

V3 - MIMOYECQUES

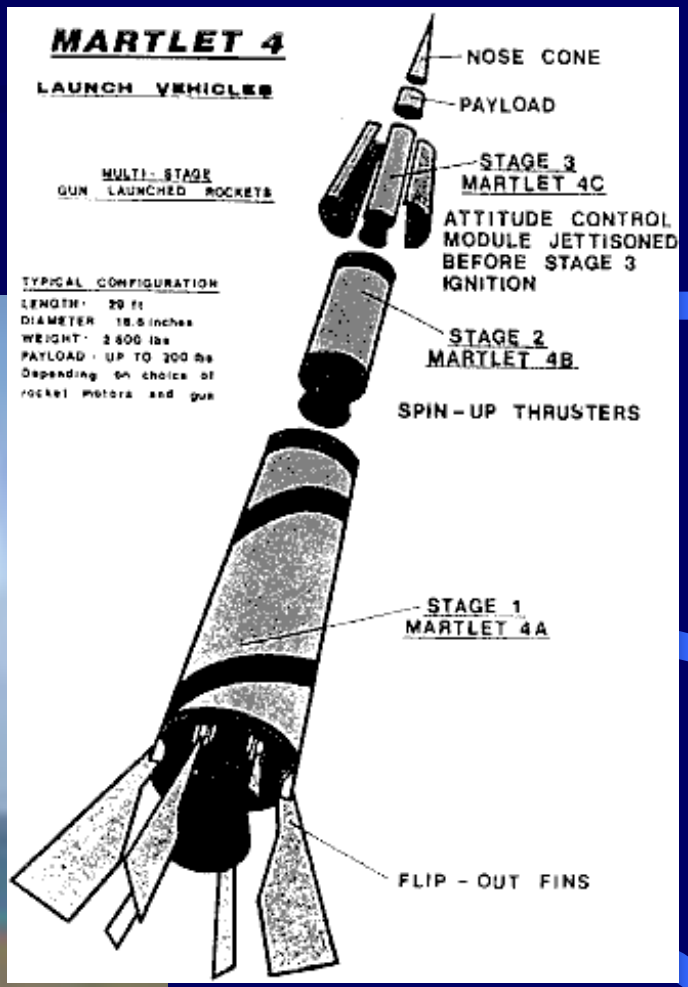






HARP - SRC




MARTLET 4
LAUNCH VEHICLES
MULTI-STAGE
GUN LAUNCHED ROCKETS
TYPICAL CONFIGURATION
LENGTH: 20 ft
DIAMETER 18.5 inches
WEIGHT: 2 600 lbs
PAYLOAD: UP TO 200 lbs
Depending on choice of
rocket motors and gun
NOSE CONE
PAYLOAD
STAGE 3
MARTLET 4C
ATTITUDE CONTROL
MODULE JETTISONED
BEFORE STAGE 3
IGNITION
STAGE 2
MARTLET 4B
SPIN-UP THRUSTERS
STAGE 1
MARTLET 4A
FLIP-OUT FINS

350mm BABY BABYLON



1000mm BABYLON GUN



The Deterrent

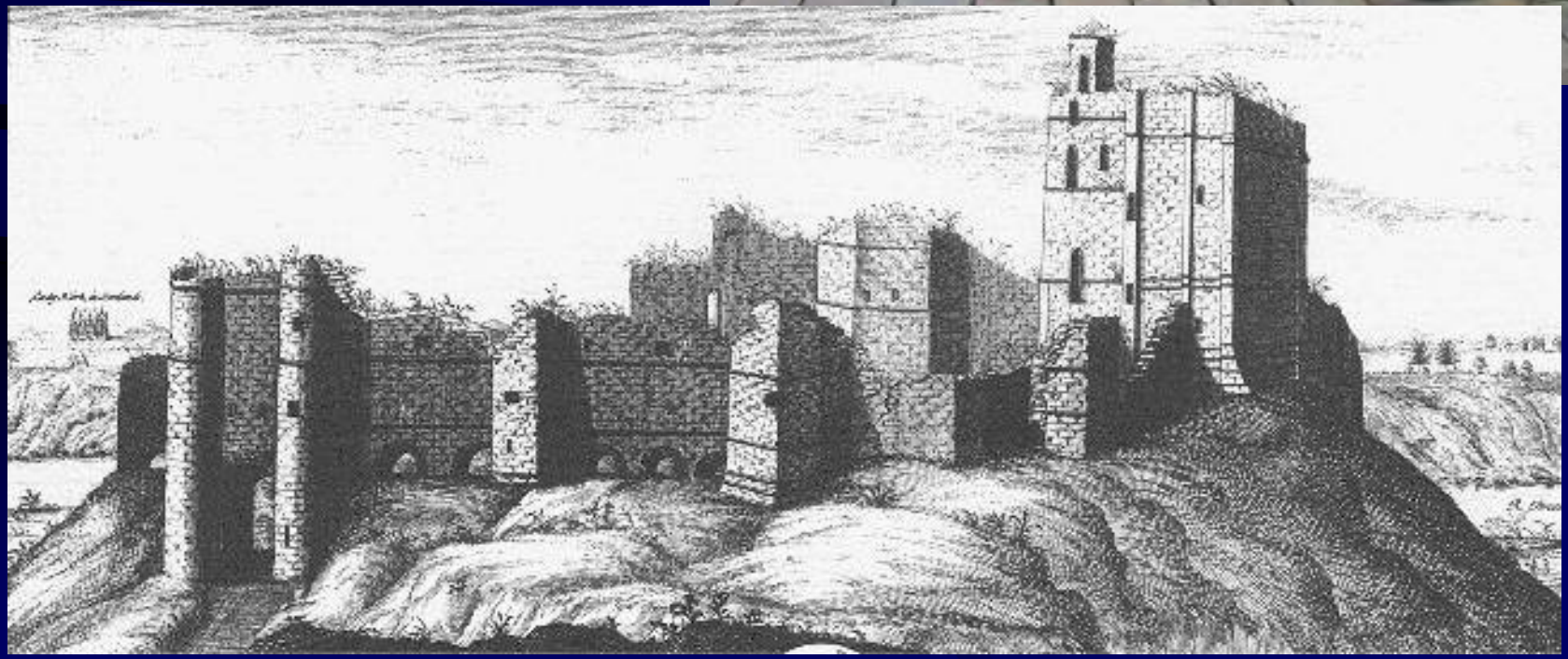



BUT



Norham 1497





1453 – The Truth



Mary Rose



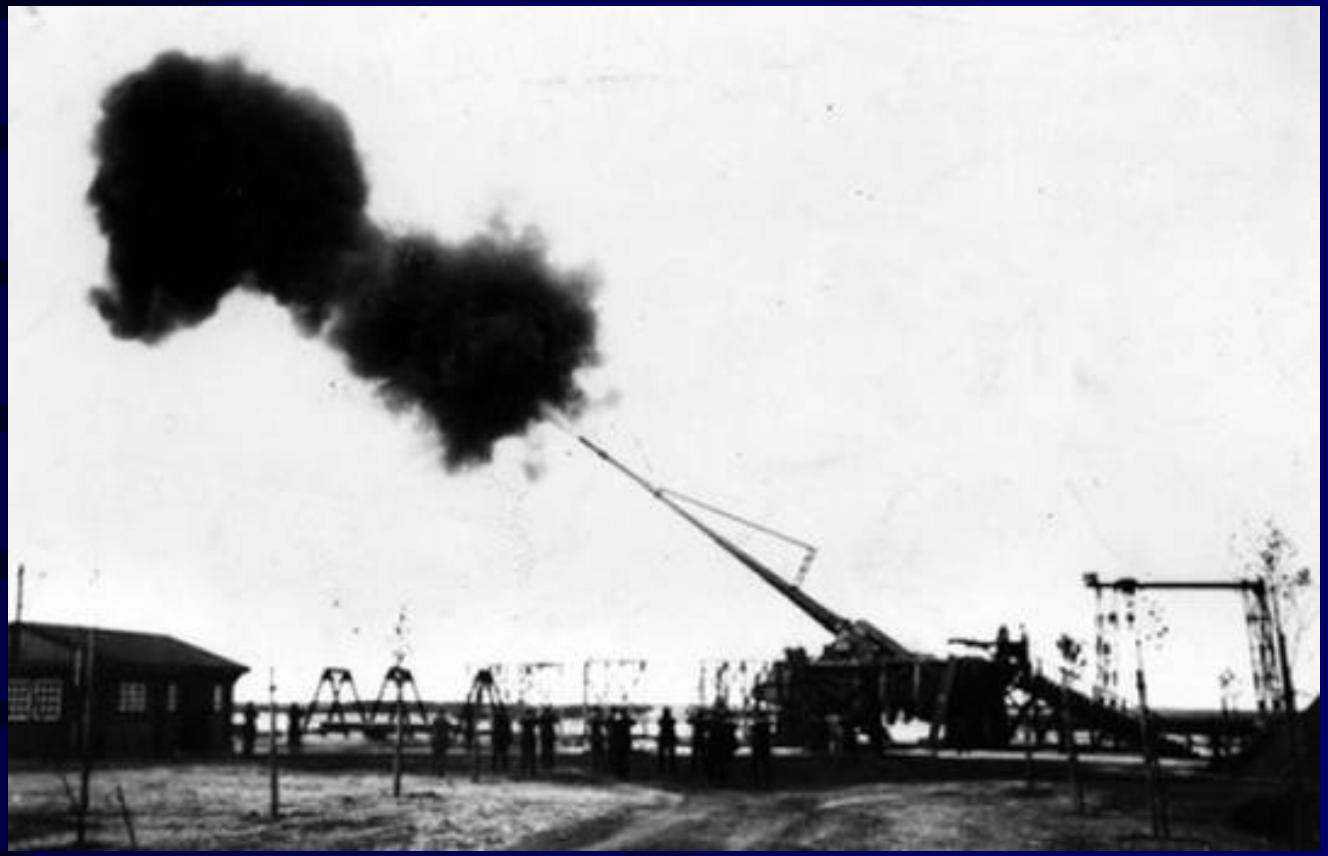




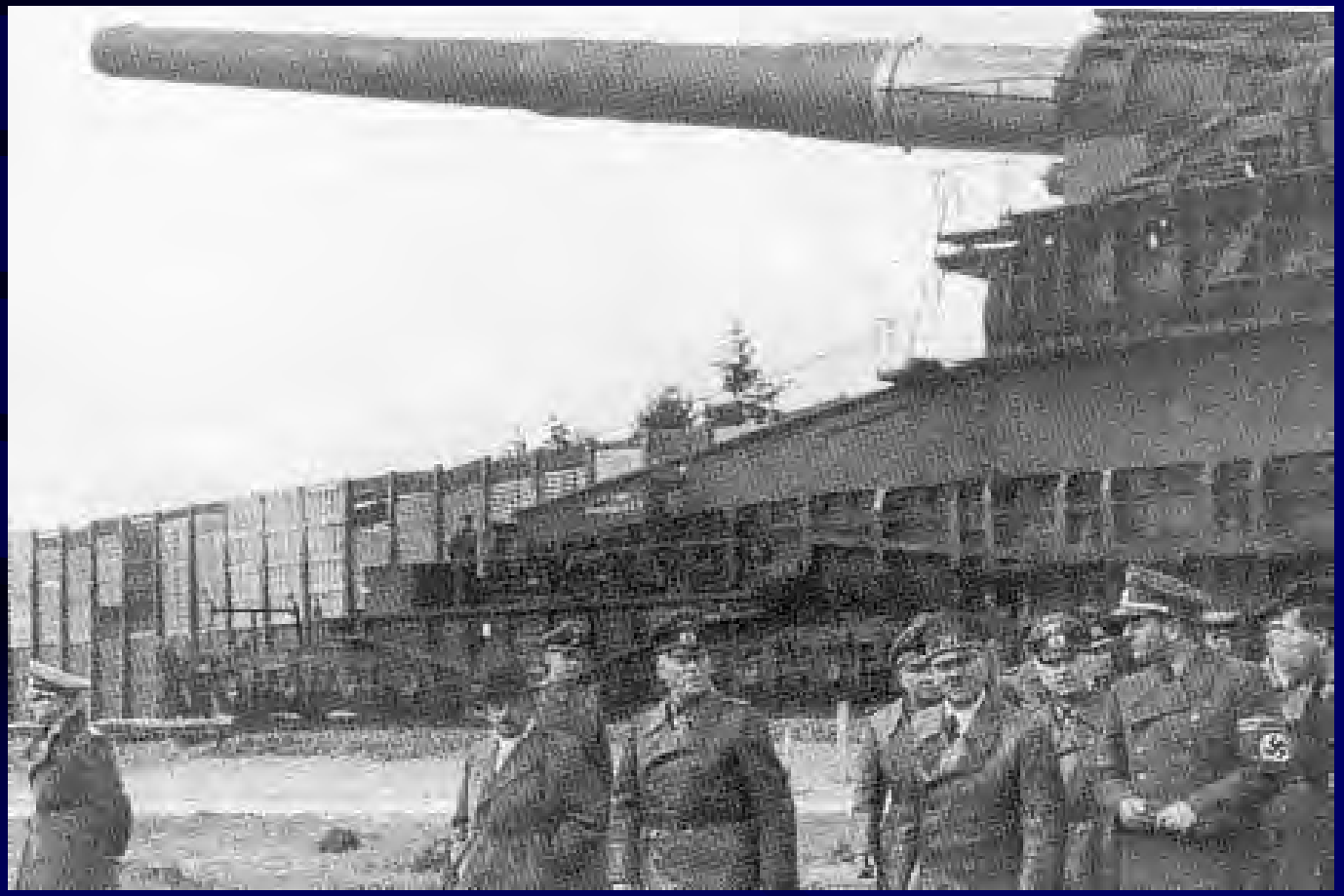
Sebastopol







Largest Ever…….







V3- Mimoyecques



Babylon to Brussels
1928 - 1990





POLAND
USSR
CZECHOSLOVAKIA
AUSTRIA
HUNGARY
ROMANIA
YUGOSLAVIA
BULGARIA
ALBANIA
GREECE
MEXICO
UNITED STATES
CANADA
CUBA
DOMINICAN REPUBLIC
ICELAND
GREENLAND (Denmark)
NORWAY
SWEDEN
FINLAND
GREAT BRITAIN
ATLANTIC OCEAN
INDIA
PAKISTAN
IRAN
IRAQ
TURKEY
SPAIN
PORTUGAL
AFRICA
INDIAN OCEAN
INDONESIA
AUSTRALIA
HAWAIIAN ISLANDS (USA)

NATO Nations
Other U.S. allies
Warsaw Pact nations
Other USSR allies

Characteristics

- Weapons that have soaked up a nation's resources beyond their apparent operational worth
- Strategic Battle
- Largely Indiscriminate



THE PSYCHOLOGY

POSSESSOR	TARGET
POWER	FEAR
Reach	No escape
Destruction	Helplessness
Influence	Servitude
Propaganda	Death
Dominance	Indiscriminate



Other Evidence of the Psychological Effect of Super Weapons

- Attacks on Japan WW2
- Cold War
- SDI – End of Cold War??
- “Shock and Awe”

The Whole System 1890



Precision Attack – More than a Super Weapon?












SFOR
SFOR