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New Army XM1002 TPMP-T Cartridge Design Performance Assessment and Selection Process *

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TACOM-ARDEC

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Alliant Techsystems Inc.

*** The Development of the XM1002 (MPAT) Trainer is Managed by Project Manager – Maneuver Ammunition Systems (PM-MAS, Picatinny Arsenal, NJ)**

26 March 2003

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- Dick McDanolds (OPM-MAS) Program Manager
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- Jim Newill (Army Research Laboratory) Computational Structure Dynamics, Team Leader

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Contents

- XM1002 Projectile
- Key Requirements
- Development Strategy
- Gun/Projectile Dynamic Simulations
- Dynamics of Launch
- Example of Gun/Projectile Dynamic Simulations
  - Sensitivity to Tube Shape and Tube Defects
- Success Criteria Evaluation
- Current Project Status

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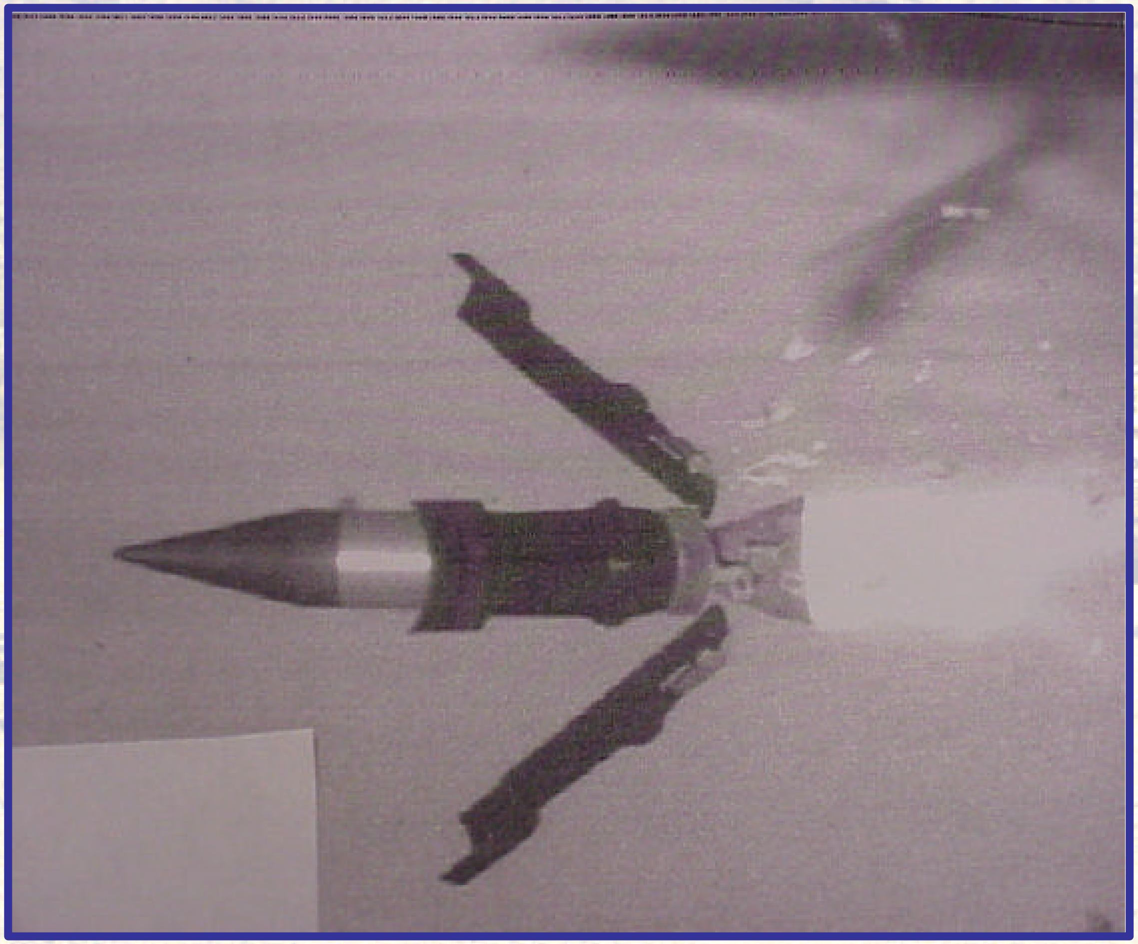
XM1002 EXITING GUN TUBE



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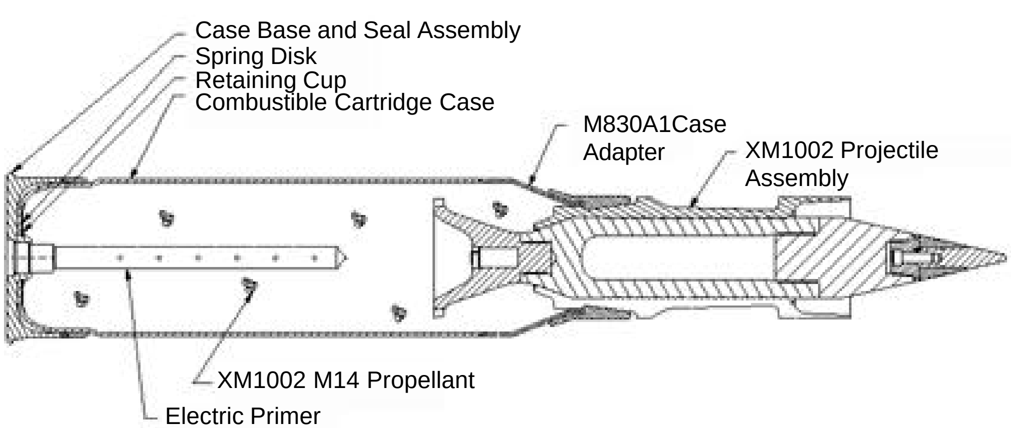
XM1002 - Training for M830A1



XM1002 Cartridge Layout

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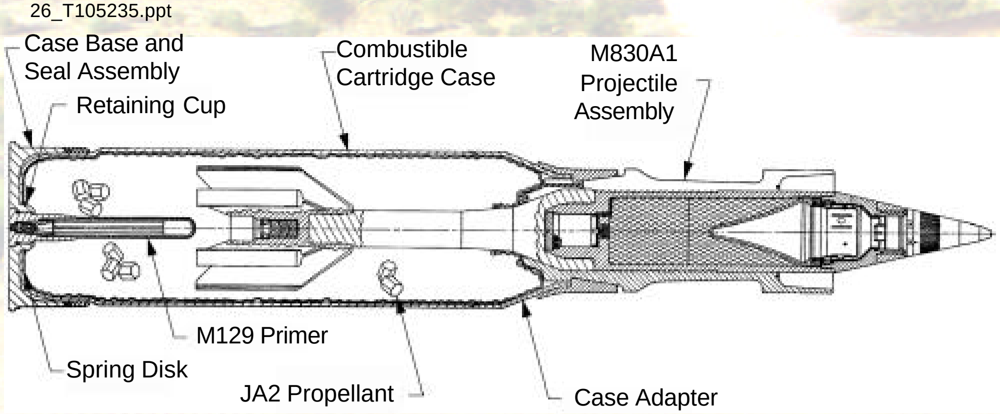

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M830A1 Cartridge Layout

- **XM1002 External Geometry Identical to M830A1**
- **Weight & CG Location Similar to M830A1**
- **Conical Flare to Stabilize and Drag Down**
- **M14 Propellant to Achieve Cost Objective**
- **Consistent Flight Characteristics (Low TID)**

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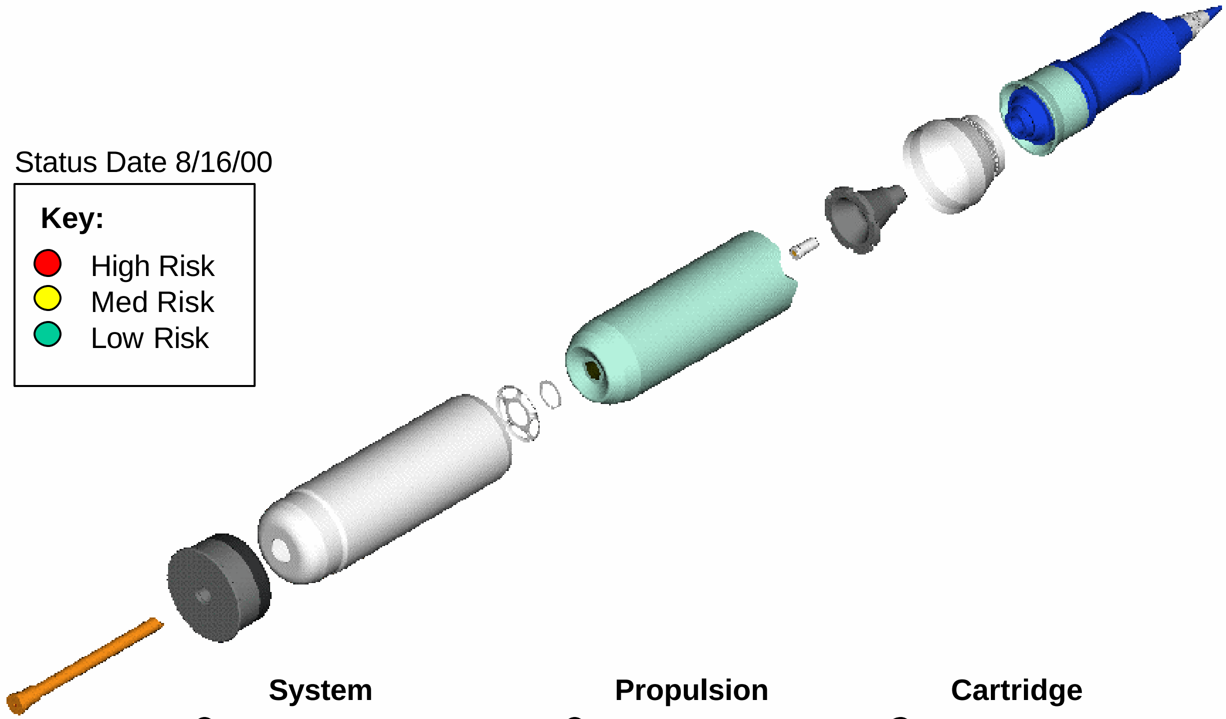
XM1002 – M830A1 Trainer ORD

<u>Key Requirements (JUL 98)</u>

- **Max Range 8 KM (10^o Gun Elevation)**
- **Dispersion ~ at 3 km**
- **Visual Appearance ~ M830A1**
- **Ballistics Similar to 3000m (Requires FC Solution)**
- **Checking / Setting Capability of Dummy Air / Ground Switch**
- **Tracer Different Color than M865 & Visible To 3000m**
- **Cost Comparable to Current Training Cartridges**
- **Weight(+0/-6 Pounds) Compared to M830A1**
- **Center Of Gravity (+/-3 Inches) Compared to M830A1**

XM1002 Key Requirements



Status Date 8/16/00

Key:
- High Risk
- Med Risk
- Low Risk

System
- TID
- Max Range
- Strength of Design
- Tracer Color/Visibility
- Crew Survivability
- Tube Service Life
- Hangfire

Propulsion
- Muzzle Velocity
- Pressure
- T4 Time
- Negative DP
- Misfire

Cartridge
- Appearance
- Air Ground Switch
- Weight and CG
- Robustness
- UPC

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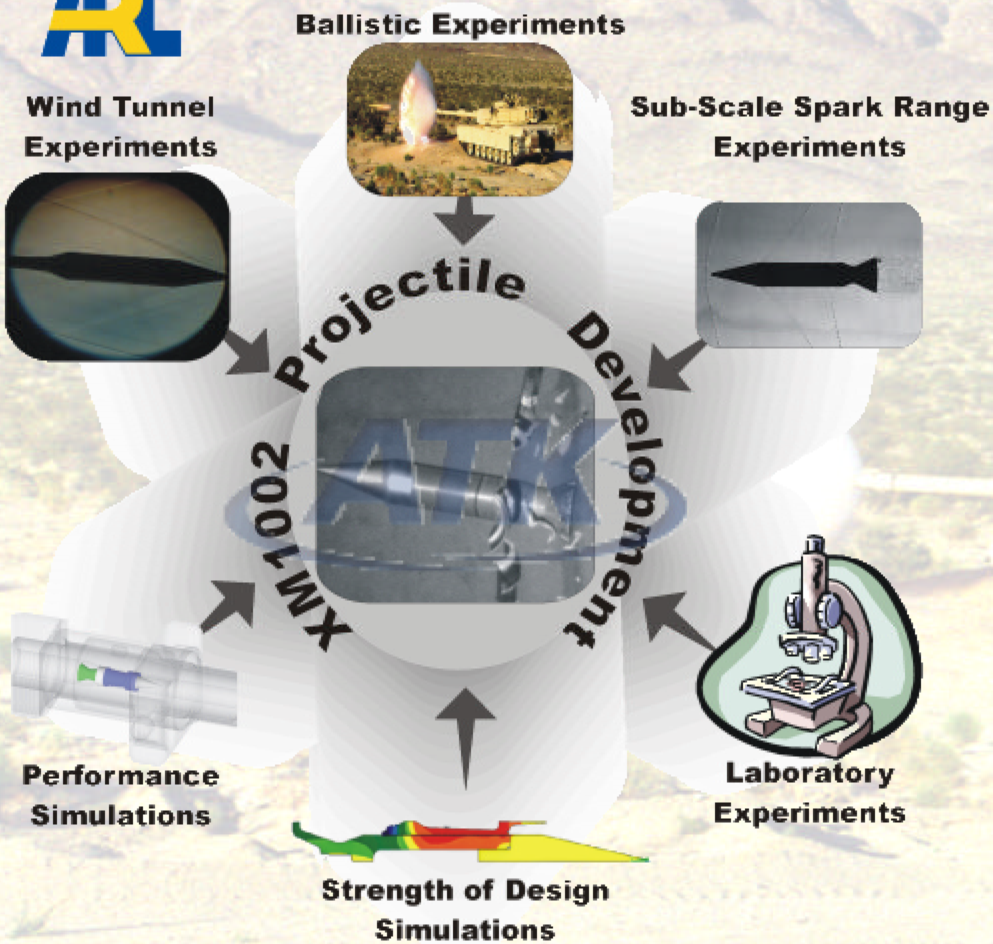
Development Strategy



- Low Cost Development
  - Fewer Full Scale Rounds Available for Ballistic Testing
- Required Integrated Approach With More Up Front Experiments and Simulations To Insure Success
  - Subscale Ballistic and Wind Tunnel Experiment
  - Bench Laboratory Experiments
  - Extensive Use of Simulation

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ATK XM1002 Design
Modified TACOM-ARDEC Enhances Structural Margin

Iteration #1: Develop Database for Analysis and Design Selection

9 Configurations

Wind Tunnel Test

Evaluate Effect of:
- Flare Configurations (Diameter, Slots, Flange)
- Body Geometries (Diameter, Groove/Thread)
- Nose Configurations (Geometry)

Sub-Scale Spark Range Test

- 3 Configurations Incorporating Wind Tunnel Data
- Free Flight Aerodynamic Coefficients for Modeling

Propellant Charge Establishment

Establish Propulsion System
- Charge Weight
- Pressures, Etc.

Target Impact Dispersion (TID-1)

Evaluate Performance of Design Options
- Flight
- Propulsion
- Launch

Analysis & Laboratory Testing

Analysis & Lab Testing Supports Design
- 6 DOF Modeling (TRAJ7, PRODAS)
- Structural Analysis (ANSYS)
- Laboratories (Chemical & Mechanical)

Iteration #2: Incorporate Design Enhancements using Iteration #1 Database Evaluate Robustness

2 Configurations

Target Impact Dispersion (TID-2)

Evaluate Performance Enhancements of Design Options
- Flight
- Propulsion
- Launch

Transportation Handling & Drops

Verify Candidate Designs meet Robustness Requirements

Analysis & Laboratory Testing

Analysis & Lab Testing Supports Design
- Test Readiness & Confidence
- Verify Performance Requirements Not Directly Tested

Iteration #3: Finalize Design and Confirm Key Requirements

1 Configuration

Target Impact Dispersion (TID-3)

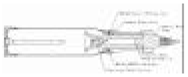
Confirm Final Design Performance
- Flight
- Propulsion
- Launch

Strength of Design, Maximum Range & Tracer Visibility

Verify Candidate Designs meet Safety Requirements

Analysis & Laboratory Testing

Analysis & Lab Testing Supports Design
- Producibility Investigations
- Requirements Verifications



ATK XM1002 Shoot-Off Design
ATK Delivers 210 Cartridges for Shoot-Off Testing & Analysis Confirms Performance & Producibility Requirements Achieved

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XM1002 Approach to Reduce TID

Gravity Drop:

- **Reduce Propellant Variability**
- **Reduce Time of Flight**

Aerodynamic Jump:

- **Increase Stability (Cp Back, CG Forward)**
- **Reduce Jump Factor, Decrease Transverse MOI**
- **Reduce Asymmetries**

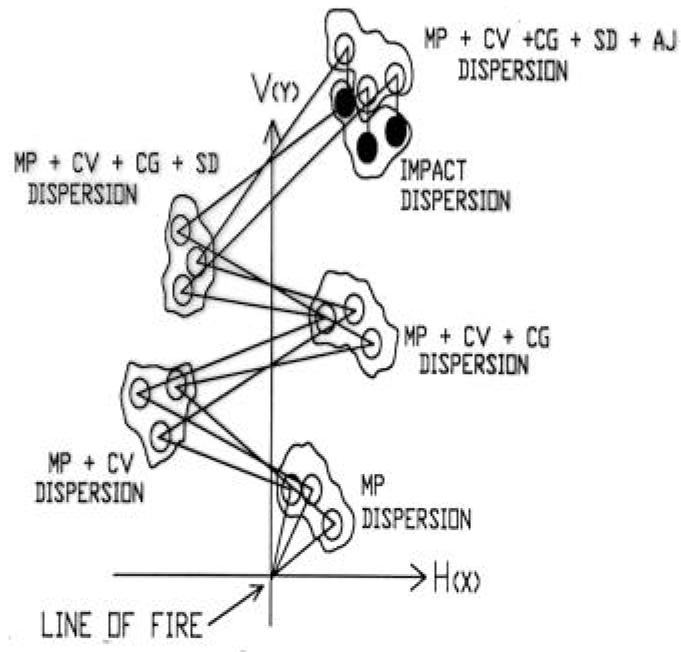
Sabot Discard:

- **Move Pivot Near Cp, Reduce Sabot Weight Ratio**

Center of Gravity/Crossing Velocity/Muzzle Pointing Angle

- **ARL In-Bore Analysis and Transonic Range Testing**

Jump Variability



$$DISPERSION = MP + CV + CG + SD + AJ + GD + CORRELATIONS$$

$$\sigma^2 = \sigma_{mp}^2 + \sigma_{cv}^2 + \sigma_{cg}^2 + \sigma_{sd}^2 + \sigma_{aj}^2 + \sigma_{gd}^2 + 2\sigma_{cgaj}$$

- Gravity Drop
- Aerodynamic Jump
- Sabot Discard
- Center of Gravity
- Crossing Velocity
- Muzzle Pointing Angle

TID = Variability in Jump

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Major Influences on Jump

- Gun Motion
- Gun Tube Centerline Shape
- Projectile Structure (Mass Properties, Bourrelet Configuration, Tolerances, etc.)
- Projectile Flight Characteristics
- Propellant (Consistency,Temperature, etc.)

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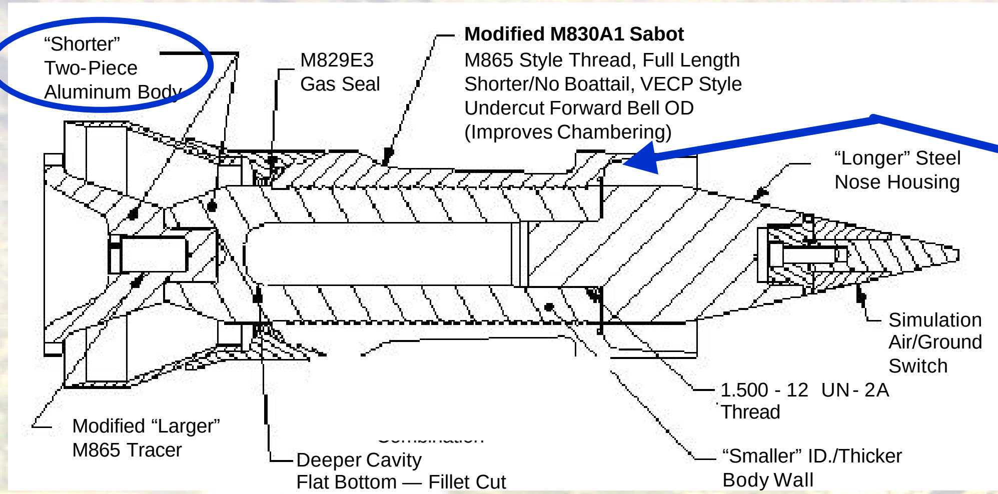
XM1002 Enhancements

Three Tail Cone Concepts all have "short" 5mm boom.



Threaded Grooves Reduces Cost

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Aerodynamic:

- **Heavy Nose – CG Moves Forward Improving Stability**
- **Thicker Body & Increased Grooves – Reduces Plastic Deformations**
- **Stabilizer – Optimize Stability & Jump Factor**

Sabot Discard:

- **Sabot Pivot Near Cp – Reduces Impulse From Sabot Discard**
- **Truncated Sabot – Reduced Sabot Weight Ration Reduces Impulse**
- **M829E3 Obturator – Proven Obturation**

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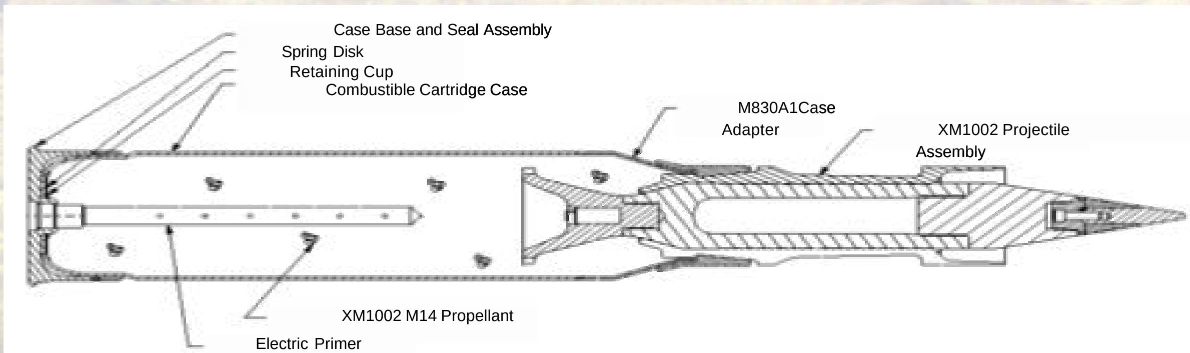
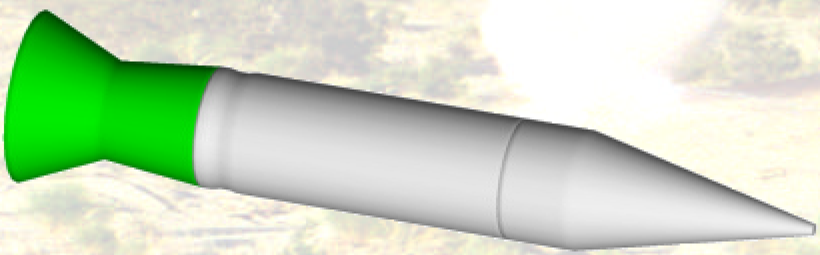
XM1002 Cartridge

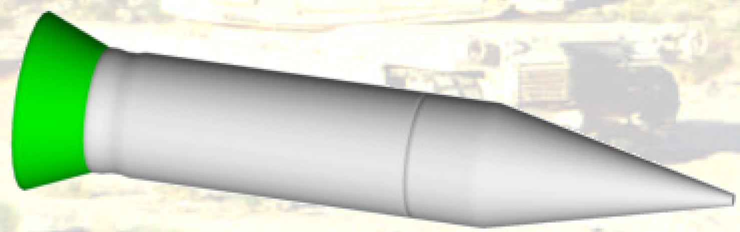
Training projectile for the M1A1/M1A2

Abrams M256 120-mm Cannon





Plan A



Plan B

Preliminary Design Concept Utilizes ARDEC Design

Modifications to Improve Structural Margin & Jump Sensitivity

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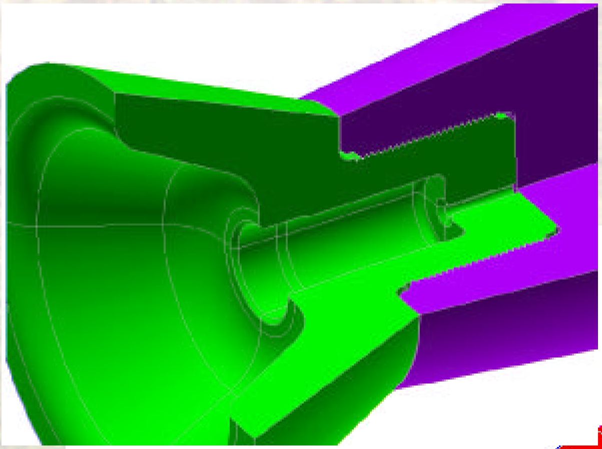
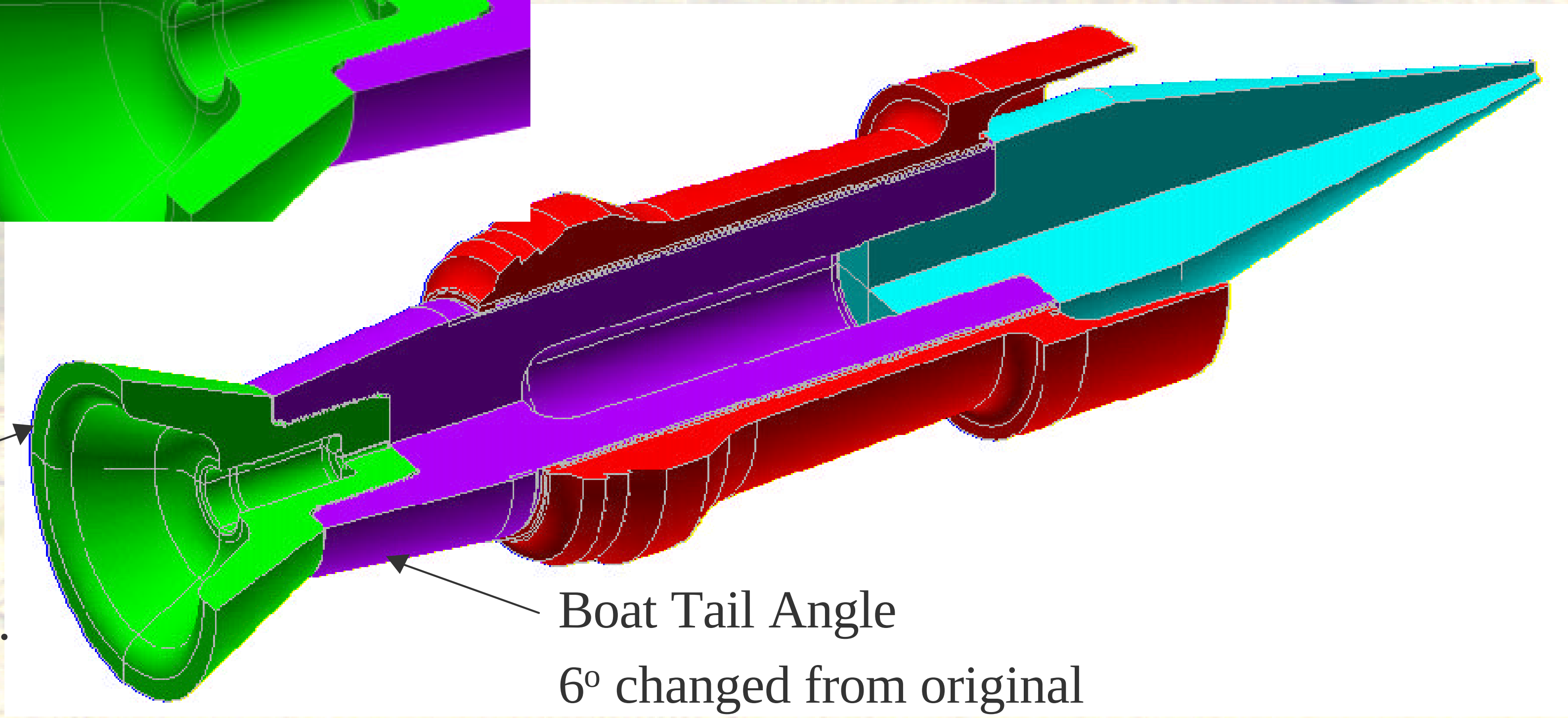
Plan A -"Modified Boat Tail"





Slot Angle Reduced to 5° from 30°.

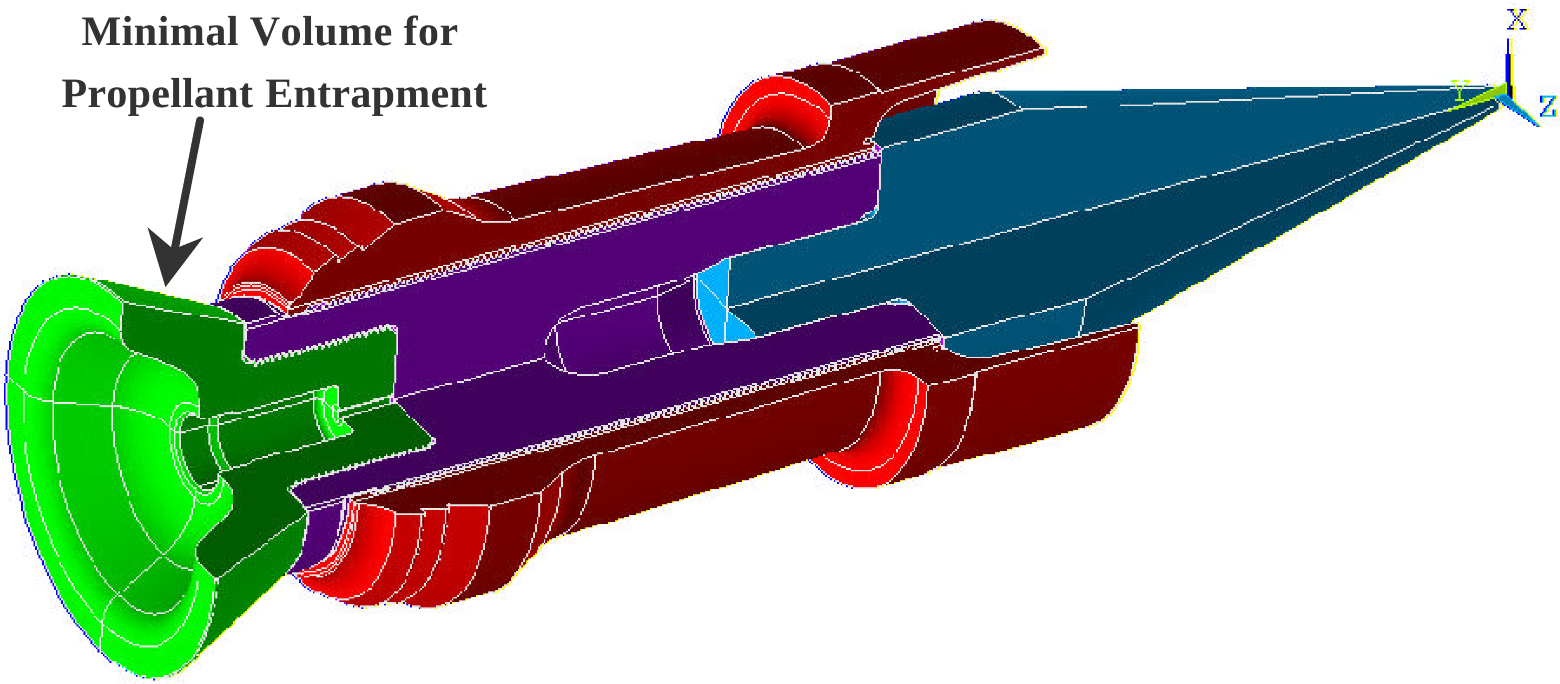
Plan B slot angle is 10°.

Boat Tail Angle

6° changed from original

20° Boat Tail

Plan B



Eliminate Trapped Propellant by Pushing the Tail Cone Forward

Use of Gun/Projectile Dynamic Simulations

- Overview of Techniques
- Data Obtained from the Simulations
- Projectile Dynamics
- Gun Tube Shape Effects
- Ideal Tube Shape Results
- Tortuous Path Results

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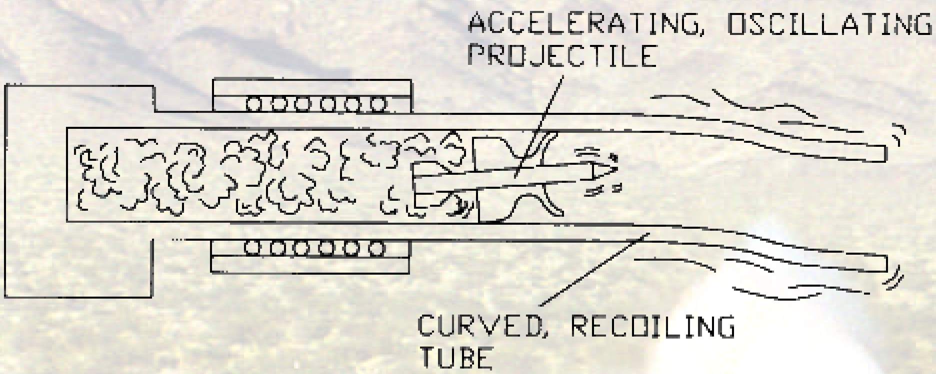
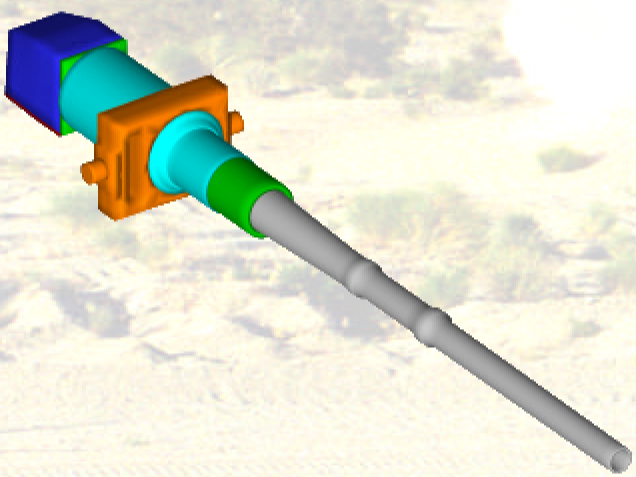
How Is It Done?





- Models “Numerically Manufactured” in Components
- Components Are Assembled
- Interfaces Between Parts Are Defined
- The M256 Gun System
  - System Is Modeled Back to the Trunions
  - System Includes Recoil
  - Gun Tube Shapes Are Taken From Measurements Made of Tubes in the Inventory
    - Every Tube Is Different
- Typical Simulation takes ~ 10-12 Hours
  - Over 4000 simulations have been done
  - ~ 5 CPU Years of Computer Time Utilized

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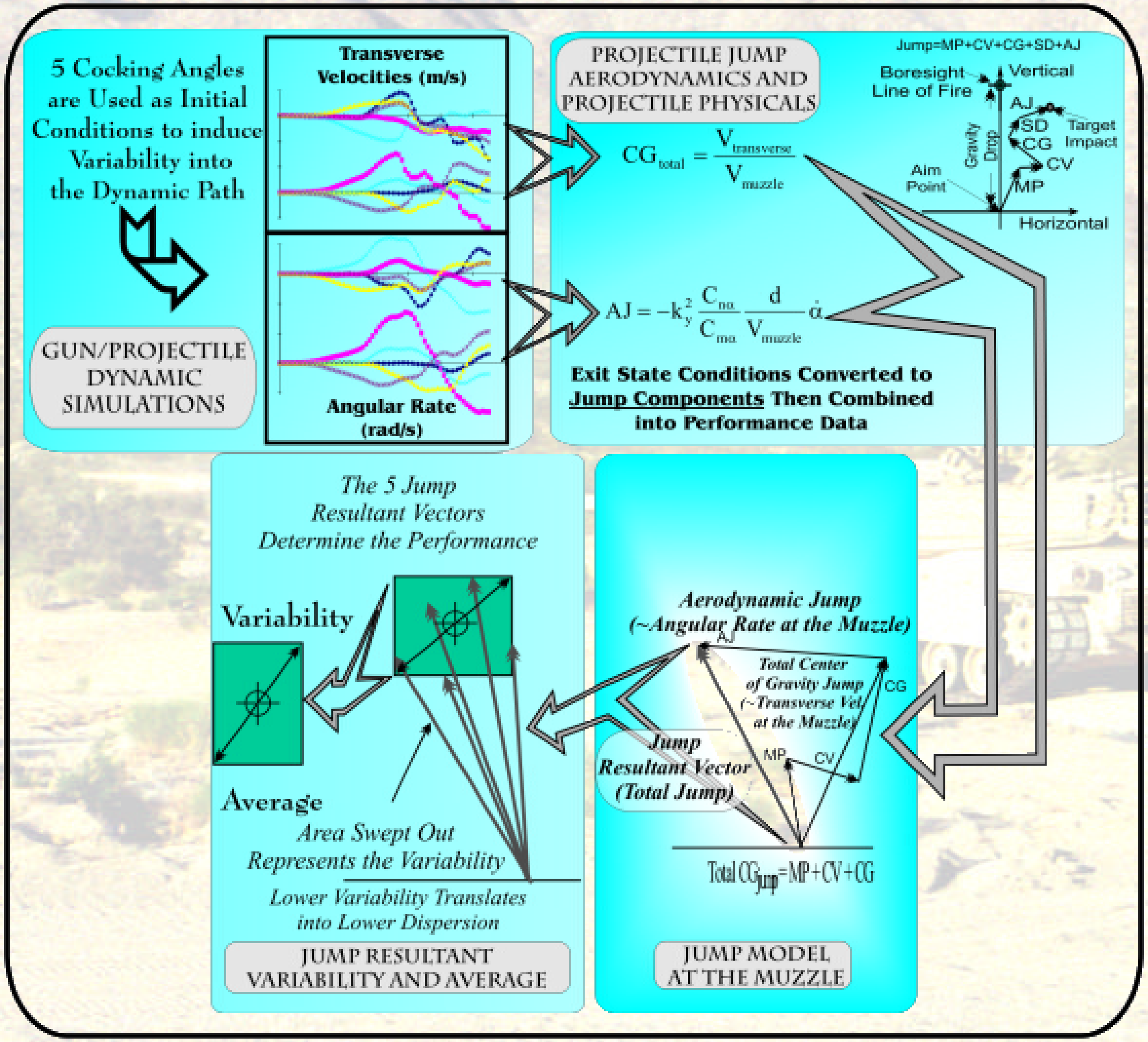
Data Obtained from the Simulation



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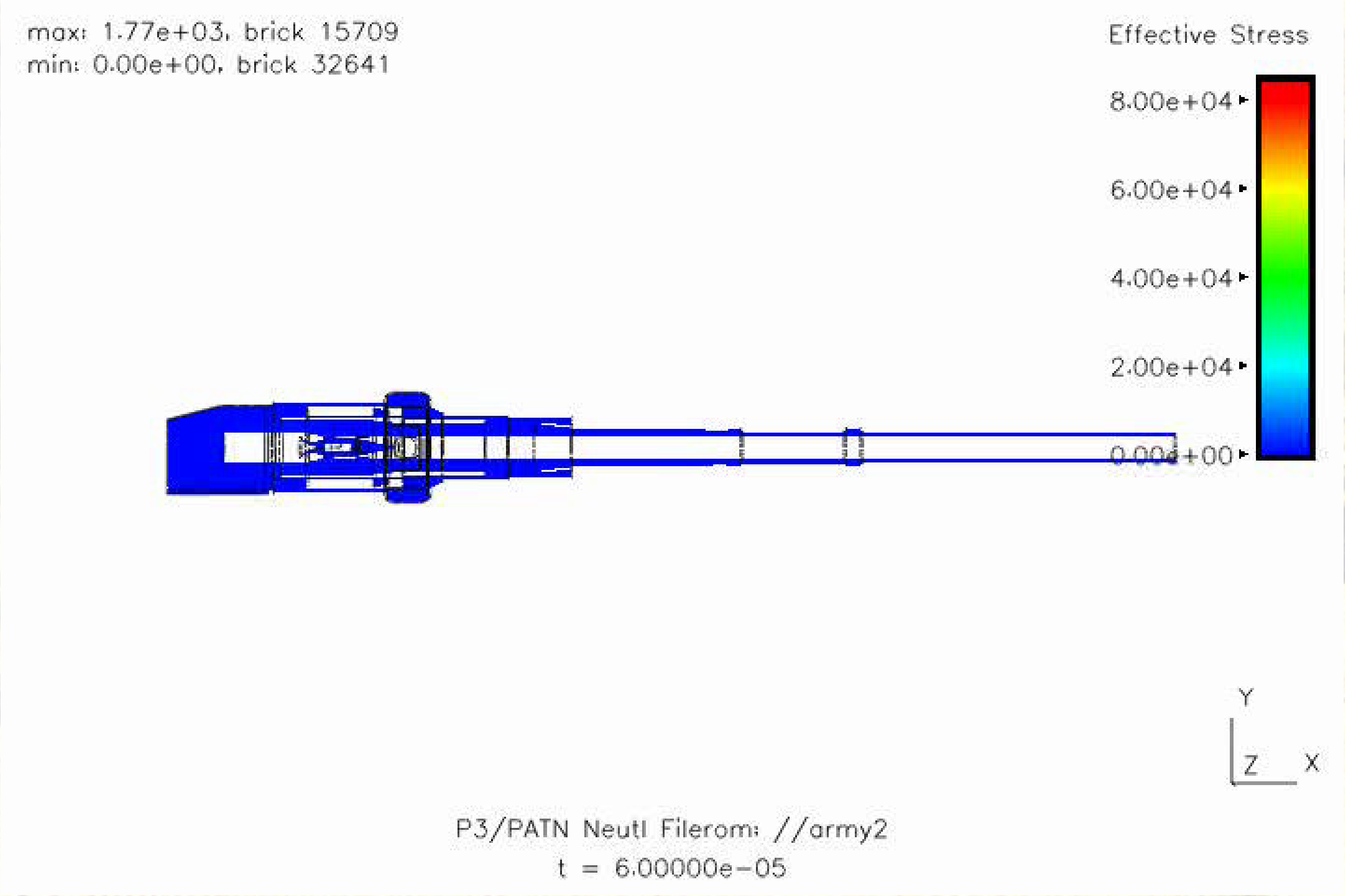
Launch Simulations



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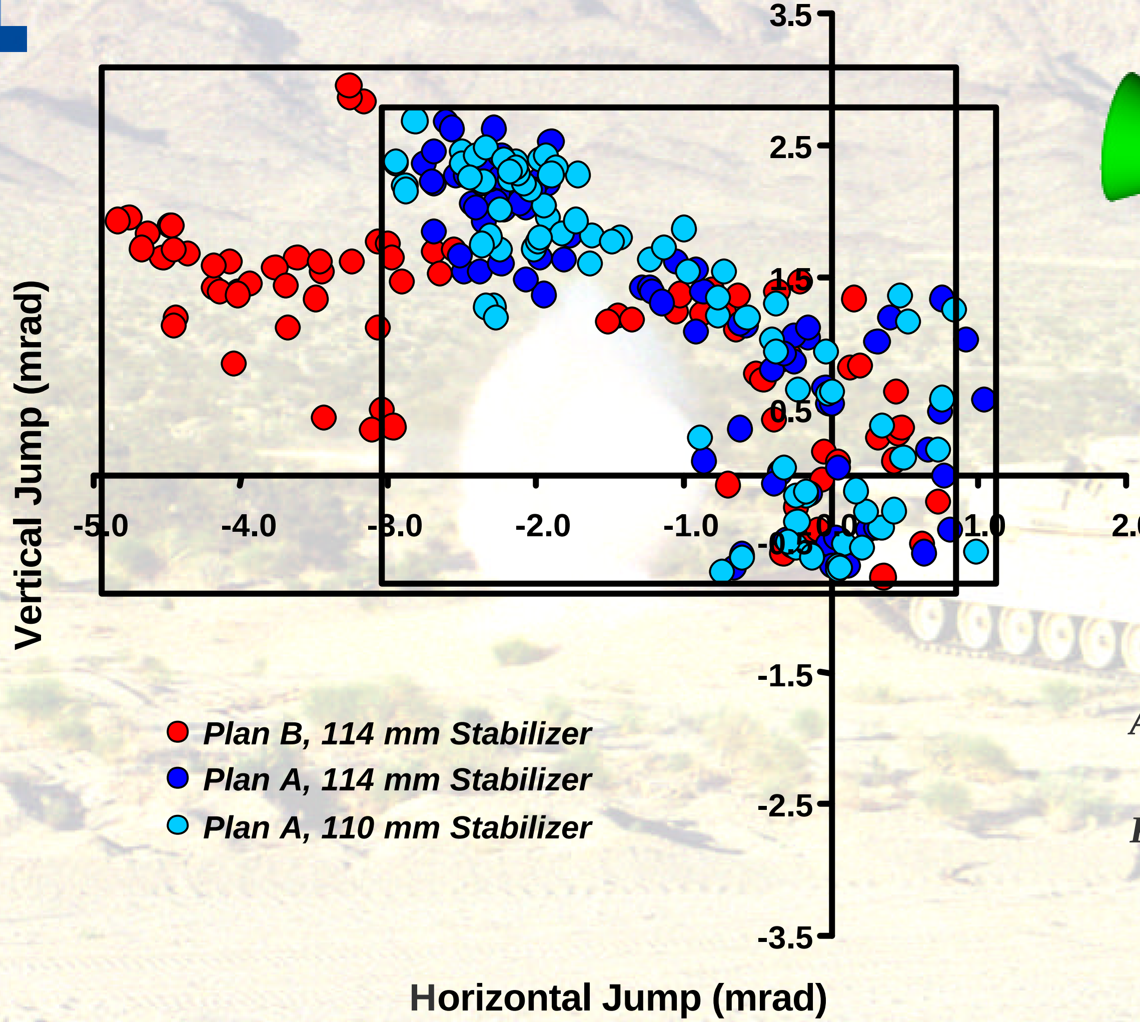
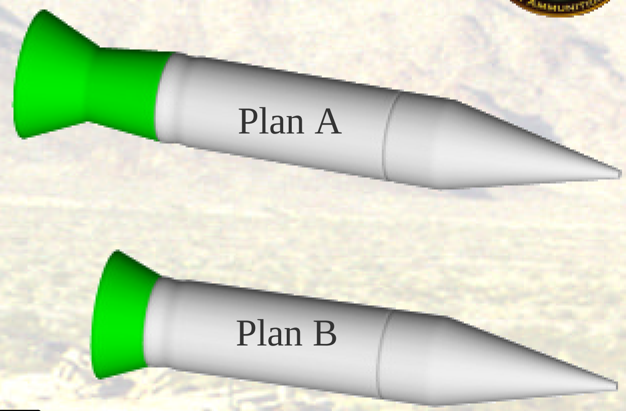
Total Jump for the Tubes Based on SN2658





Areas: Plan A -> 4.2x3.4=14.3
Plan B -> 6.1x3.6=22.0
Plan A's area ~ 35 % smaller

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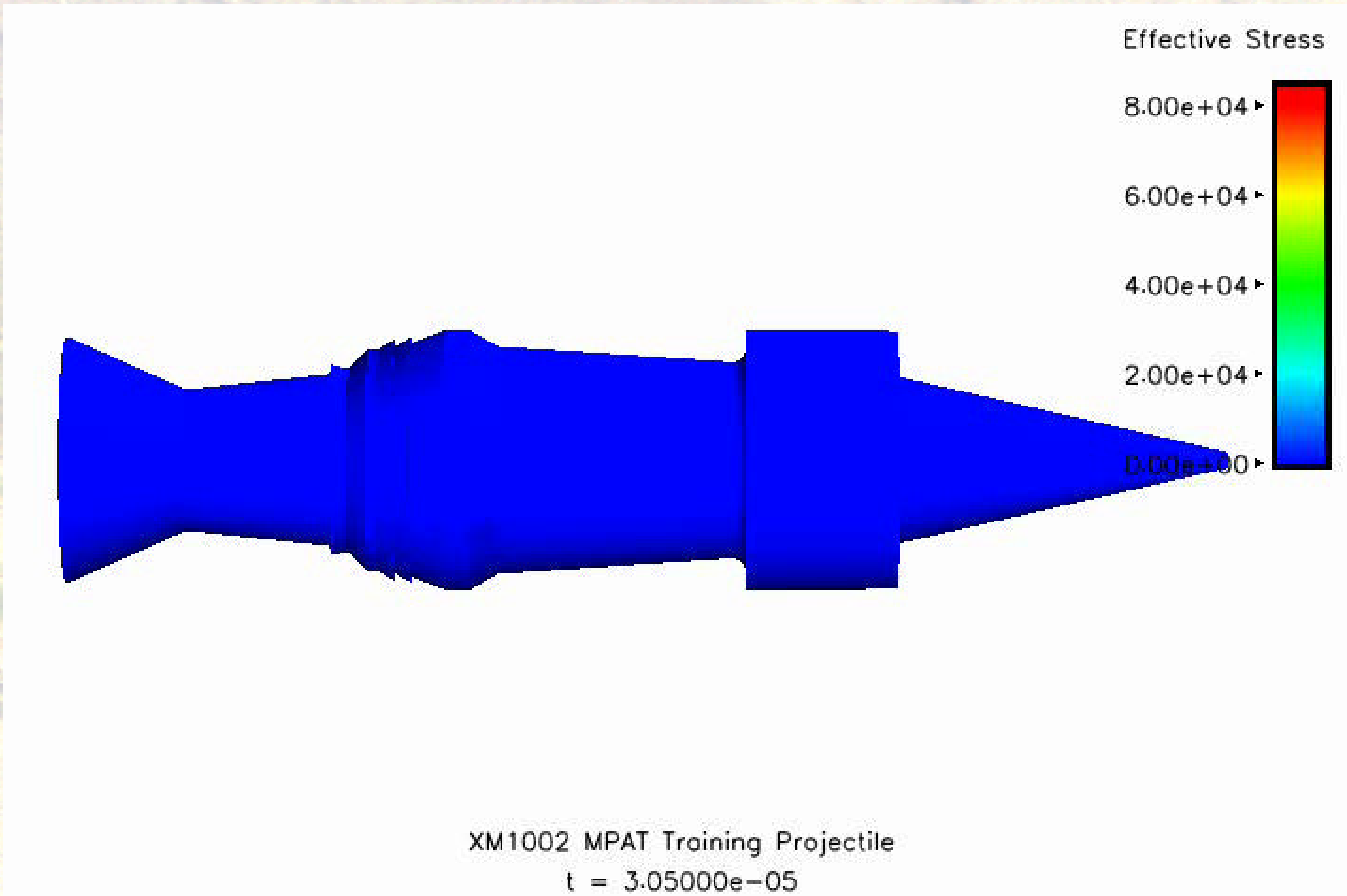
Dynamic Loading of the Projectile During Launch



Launch Dynamics Conclusions

- Projectiles showed different launched behavior
- In realistic gun systems the Plan A Projectile launch with lower disturbance
- Difference in launch disturbance attributed to differences in projectile's transverse moment of inertia
- $I_{tranverse}$ expected to affect discard in a similar manner

	Plan A	Plan B
Stabilizer Dia. (mm)	114	114
CG (mm)	247.080	219.610
CG (Cal)	3.089	2.745
Mass (kg)	8.053	7.596
Ixx (kg mm^2)	6091	5616
Iyy (kg mm^2)	138500	88740

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Success Criteria Evaluation

Producibility Criteria (DTUPC)

Risk Criteria

8 Design Threshold Requirements

- 3 Km TID
- Maximum Range
- Peak Pressure
- Negative Delta Pressure
- Maximum Range
- Cartridge Mass
- Center of Gravity
- T4 (Action Time)
- 3 Km Tracer Visibility
- 4 Km Tracer Visibility

Weighted Comparative Performance Evaluations

- 6 Primary Performance Criteria
  - 3 Km Horizontal TID @ 3 Temperatures
  - 3 Km Horizontal TID Pooled
  - 3 Km Vertical TID @ 3 Temperatures
  - 3 Km Vertical TID Pooled
  - Accuracy (Predicted)
  - Aerodynamic Static Margin
- 4 Secondary Performance Criteria
  - Muzzle Velocity Standard Deviation
  - Crosswind Sensitivity (Calculated)
  - 4 Km Gravity Drop Standard Deviation
  - Negative Delta Pressure

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Today's Program Status and Plans

- Have Down-Selected to Plan A Design
- Have Modified Propellant Grain Design
  - Produced new pilot lot
  - Completed characterization tests at 5 temperatures
- Verified TID Performance at 3 Temperatures
- Increased Adapter-Obturator Joint Strength
- Performing SCV Pre-look Testing
- Nearing Completion of EMD-1 (PPQT) Hardware Manufacture
- EMD-2 (PQT) Hardware Manufacturing Completion Scheduled for June 2003
- TC/LRIP Release Planned for November 2003