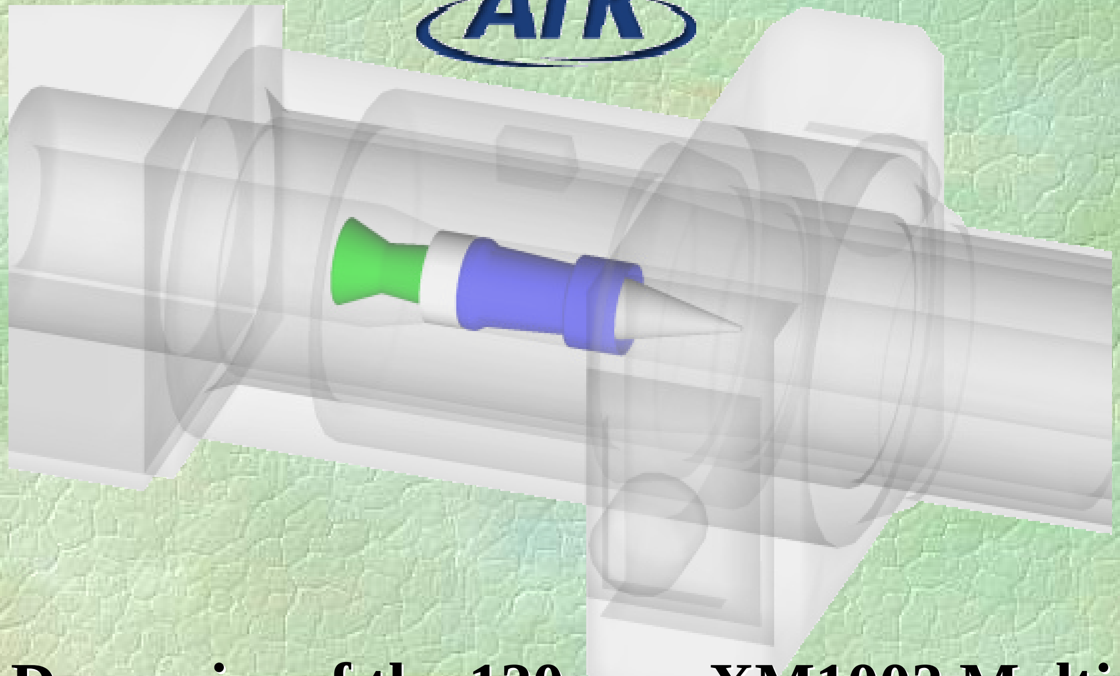


Launch Dynamics of the 120-mm XM1002 Multi-Purpose Anti-Tank (MPAT) Training Projectile

J. F. Newill, Ph.D. and J. Garner,
U.S. Army Research Laboratory

Rollie Dohrn,
Alliant Techsystems Inc.

Anthony Farina,
U.S. Army Armament Research, Development, and Engineering Center

37th Annual Gun and Ammunition Symposium and Exhibition

16-17 April 2002

Acknowledgements

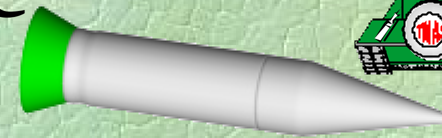
- Dick McDanolds (OPM-TMAS) Program Manager
- John Kostka (ARDEC) Technical Manager
- Jim Persoon (Alliant Techsystems) Program Manager

- DOD's High Performance Computing (HPC) Initiative
  - ARL's Major Shared Resource Center (MSRC)
    - 1 of 4 in DOD
  - Providing the computers for the study

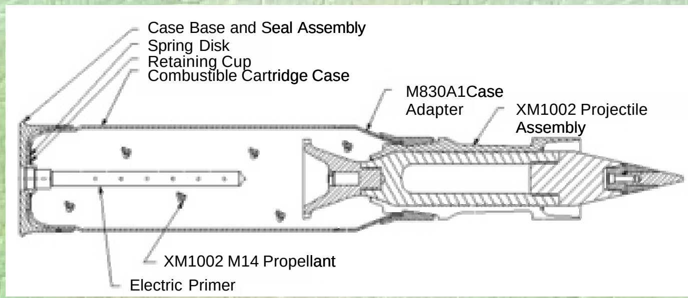
Contents

- XM1002 Projectile
- Development Strategy
- Gun/Projectile Dynamic Simulations
- XM1002 Models
- Dynamics of Launch
- Sensitivity to Tube Shape and Defects
- Conclusions

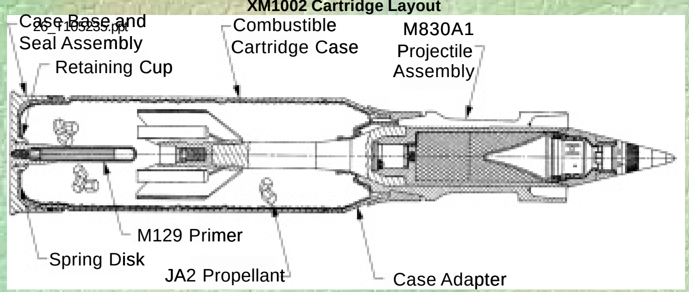
XM1002 Projectile



Training projectile for the M1A1/M1A2 Abram M256 120-mm Cannon's M830A1Multi-Purpose Anti-Tank (MPAT) projectile



XM1002 Cartridge Layout



29_T105235.ppt

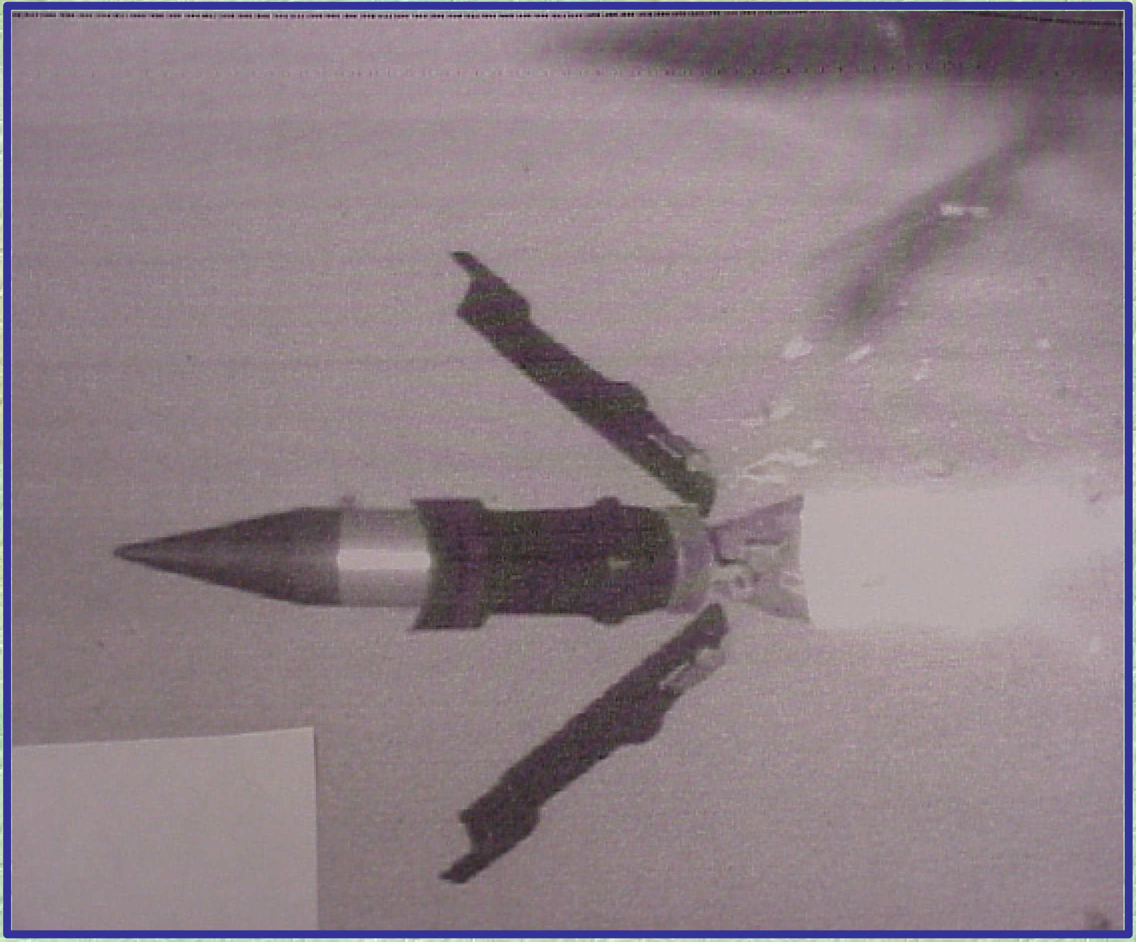
M830A1 Cartridge Layout

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

Preliminary Design Concept Utilizes TACOM-ARDEC Design

Minor Modifications to Improve Structural Margin & Jump Sensitivity

XM1002 EXITING GUN TUBE

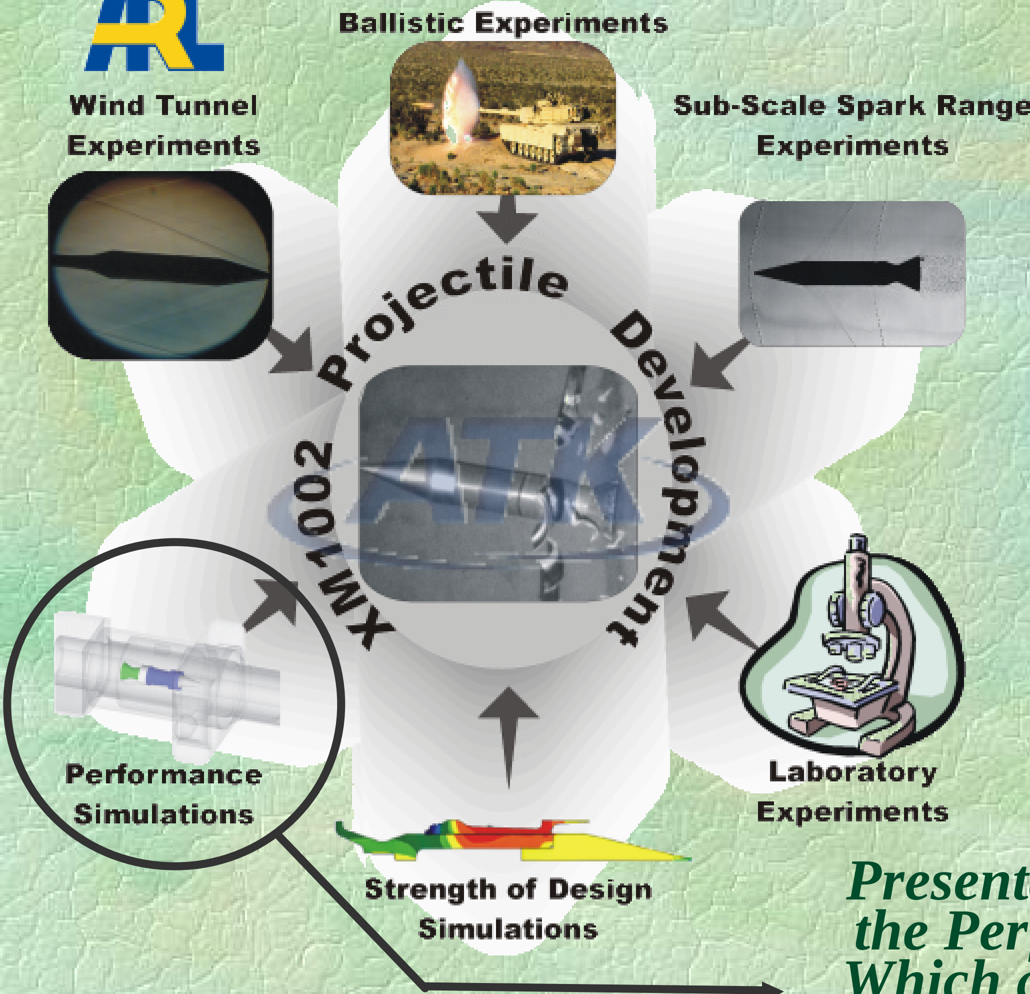


XM1002 – M830A1 Trainer ORD

Key Requirements (JUL 98)

- Max Range 8 KM (10^{o} Gun Elevation)
- Dispersion < 0.3 mils
- Visual Appearance ~ M830A1
- Ballistics Similar to 3000m (Requires FC Solution)
- Checking / Setting Capability of Dummy Air / Ground Switch
- Tracer Visible To 3000m
- Tracer Different Color than M865
- Weight(+0/-6 Pounds) Compared to M830A1
- Cartridge Center Of Gravity (+/- 3 Inches) Compared to M830A1

Development Strategy



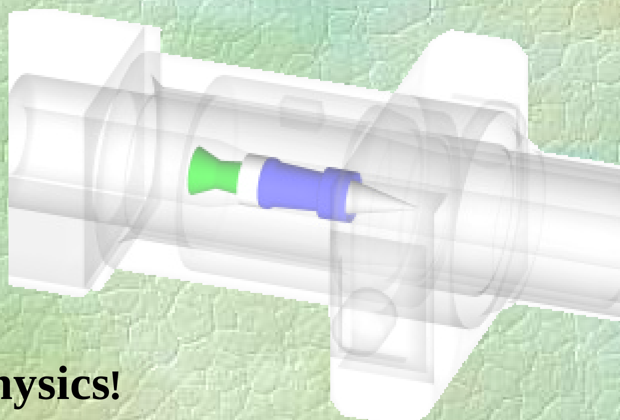
- Low Cost Development
  - Fewer Full Scale Rounds Available for Ballistic Testing
- Required Integrated Approach With More Up Front Experiments and Simulations To Insure Success
  - Subscale Ballistic and Wind Tunnel Experiment
  - Bench Laboratory Experiments
  - Extensive Use of Simulation

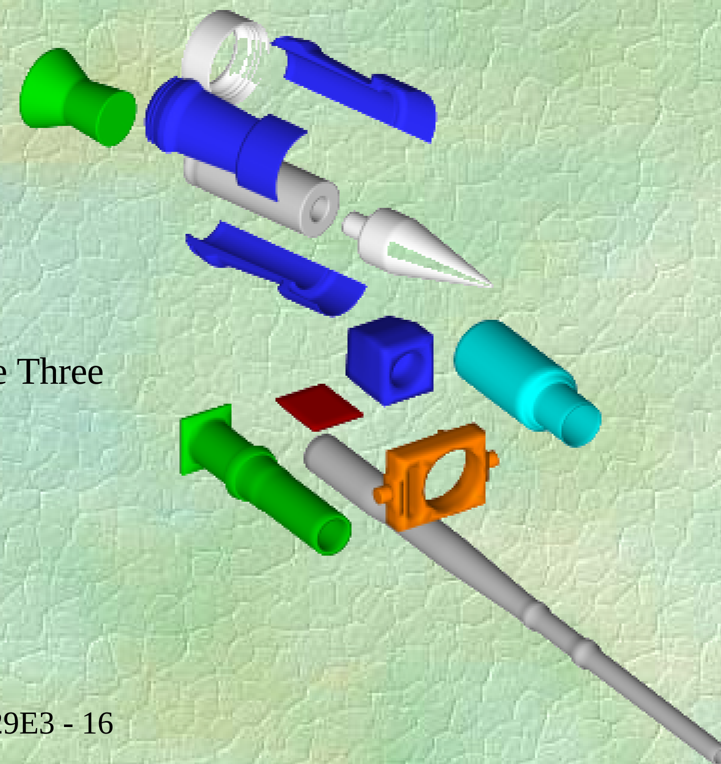
Presentation Will Focus on a Some of the Performance Simulations Results Which are Typical of the Extent of the Work Done in All the Areas

Gun Dynamics Simulation

- Gun Dynamics Simulation Technology Yields:
  - ***DIRECT INSIGHT*** Into the Behavior of the Projectile in Bore
    - No Other Method Available!
  - ***INTERACTIONS*** Between the Gun System and the Projectiles
    - **Dynamic Path**
  - Projectile ***MODIFICATIONS*** Assessment Without Building Hardware (Virtual Prototyping)
    - Faster and Cheaper Method of Design and Preliminary Testing
  - ***FOCUSES*** Experiments
    - Reduces Cost of Experiments
    - Increases Odds of Success

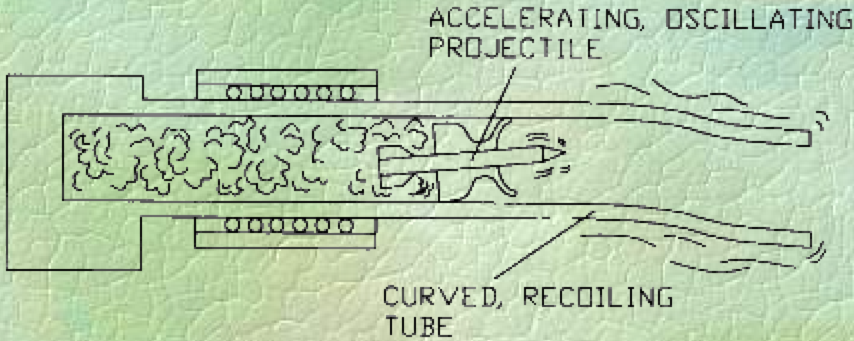
How Is It Done?

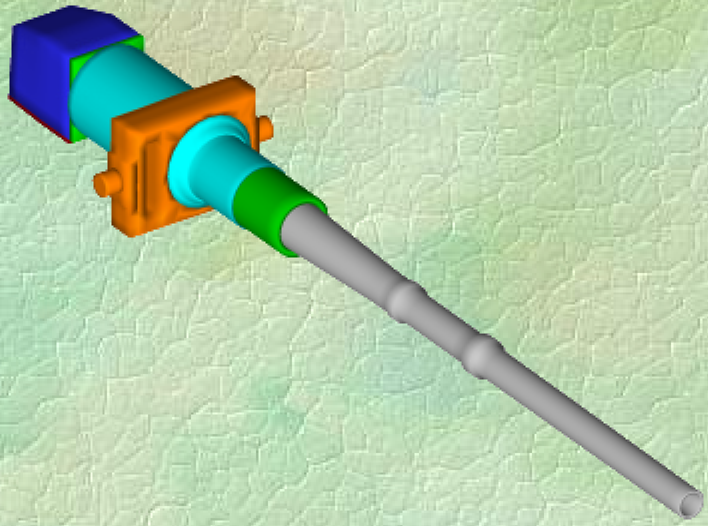




- **Physics!**
  - Continuum Mechanics Is Used to Formulate the Three Dimensional Transient Problems
  - Solution Done Using Lawrence Livermore's Hydrocode DYNA3D Modified at ARL for Application to Current Projectile Technology
- What Has Been Done
  - M1's M256 Gun System
    - Kinetic Energy (M829, M829A1, M829A2, M829E3 - 16 Types, M865, M865E3)
    - Heat Rounds (M830A1, M831A1)
  - Artillery Shells (SADARM Shell and Electronics Module)
- Method Well-Suited to Model Ballistic Phenomena

How Is It Done?



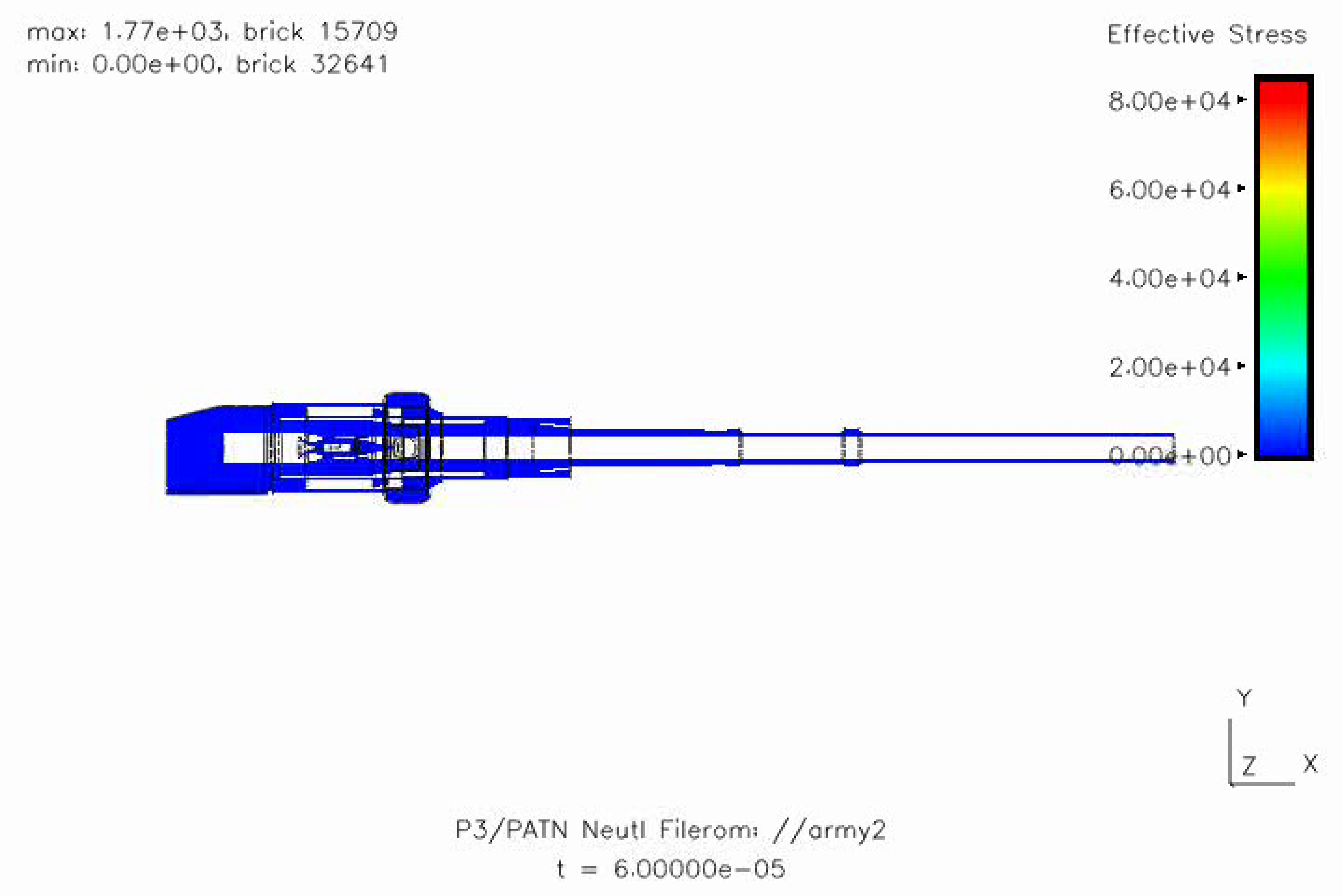


- Models "Numerically Manufactured" in Components
- Components Are Assembled
- Interfaces Between Parts Are Defined

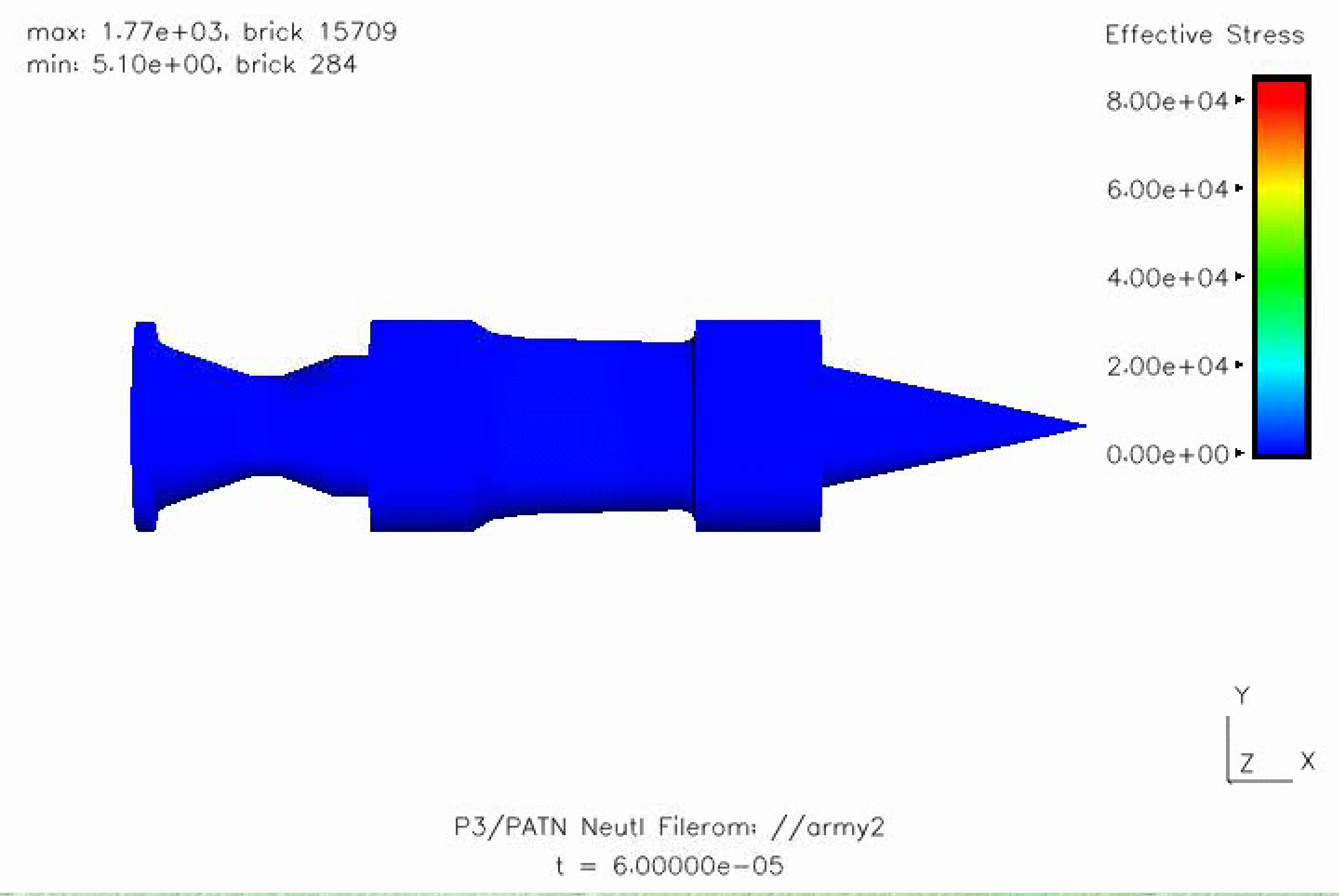
- The M256 Gun System
  - System Is Modeled Back to the Trunions
  - System Includes Recoil
  - Gun Tube Models Are Modeled From Measurements Made of Tubes in the Inventory
    - Every Tube Is Different
    - Uniform Profile (Wilkerson, Held, and Bundy)

- Typical Simulation takes ~ 10-12 Hours
  - Over 4000 simulations have been done
  - ~ 5 CPU Years of Computer Time Utilized

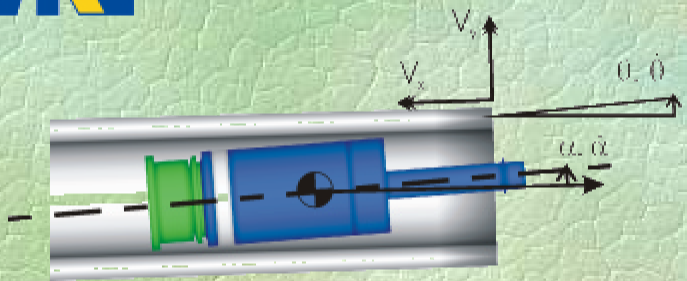
Launch Simulations

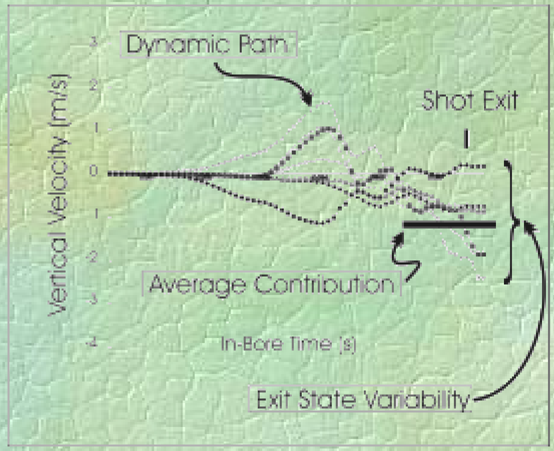


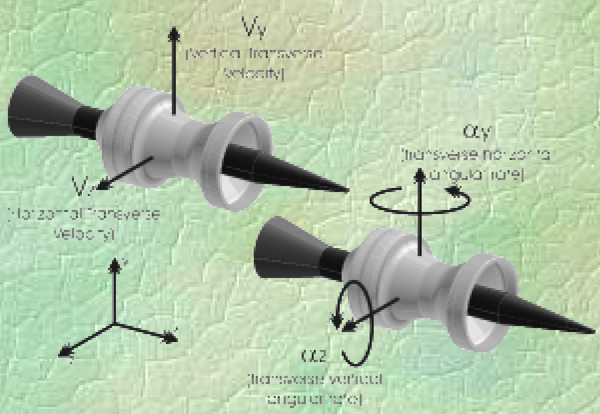
Dynamic Loading of the Projectile During Launch



Factor of Merit: Muzzle Rates



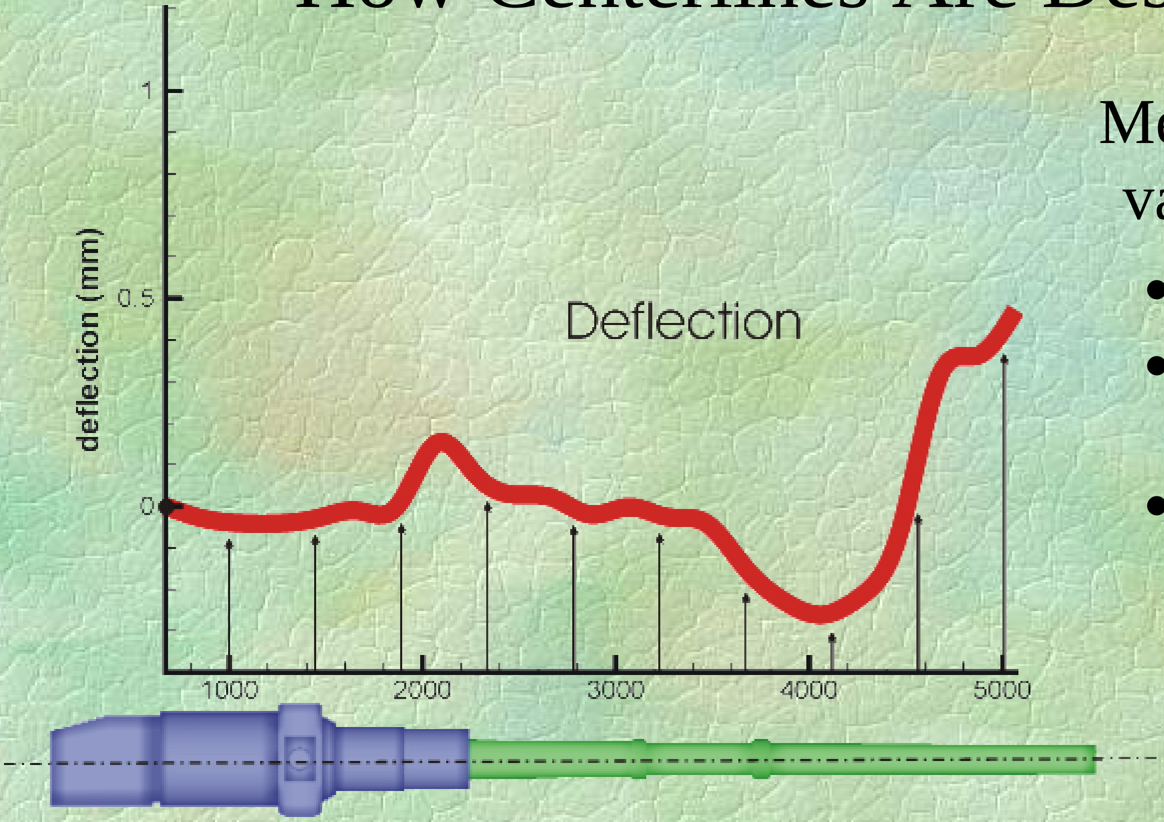




- Plot Shows CG Transverse Velocity vs. Time (Similar Plots for CG Angular Rates)
- Projectiles Evaluated for Several Factors of Merit
- Results are Converted to Jump at the Muzzle

Gun Tube Influences

How Centerlines Are Described

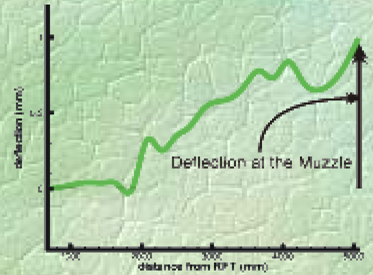


Measurements come from a variety of sources

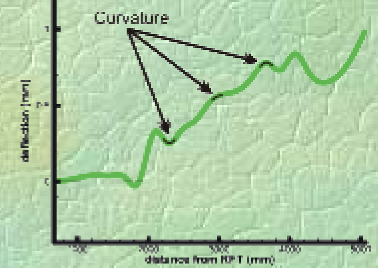
- Original optical system
- Benet developed laser system (better accuracy)
- BRI developed SMX laser system (accurate to 0.1 mm)

Types of Shape Issues

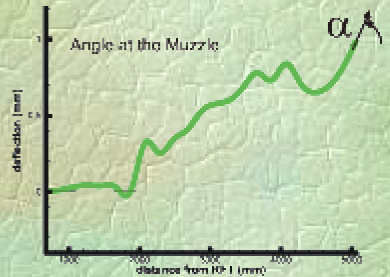
- Deflection at the Muzzle



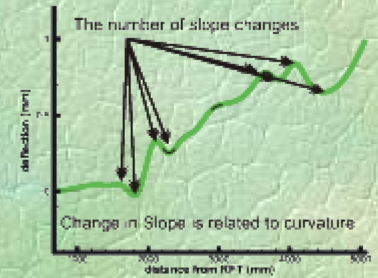
- Curvature



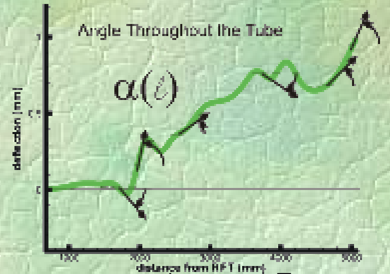
- Angle at the Muzzle



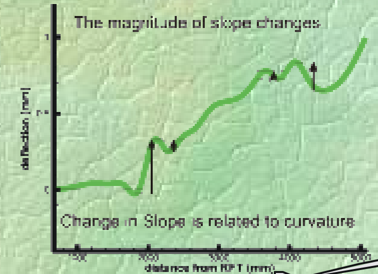
- Number of Slope Changes



- Angle



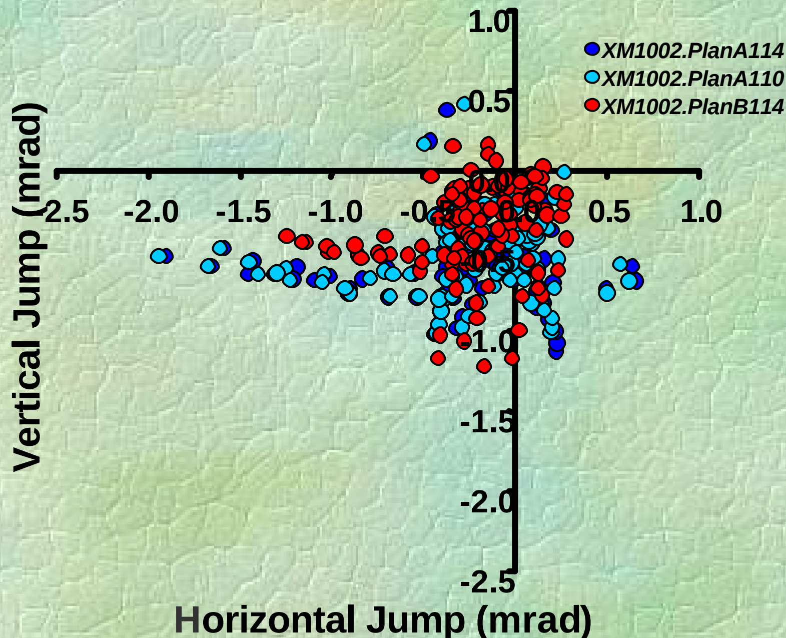
- Magnitude of Slope Changes

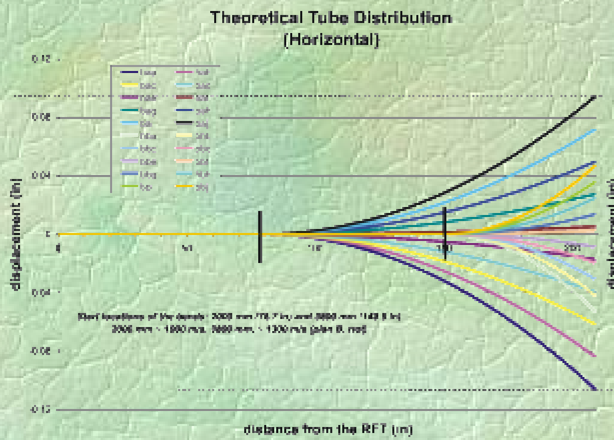


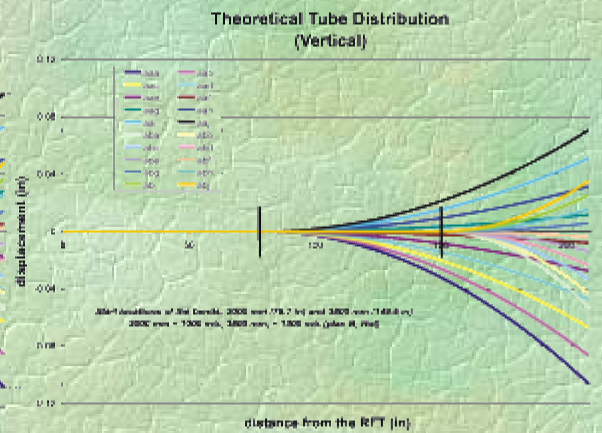
Ideal Tube Shape

- Based on the overall envelope of the shapes in the database
- Smooth bends, no other types of defects
- Two starting locations, 2000 and 3800 mm
  - Based on shape distributions
- Magnitudes of shapes derived from fleet database information

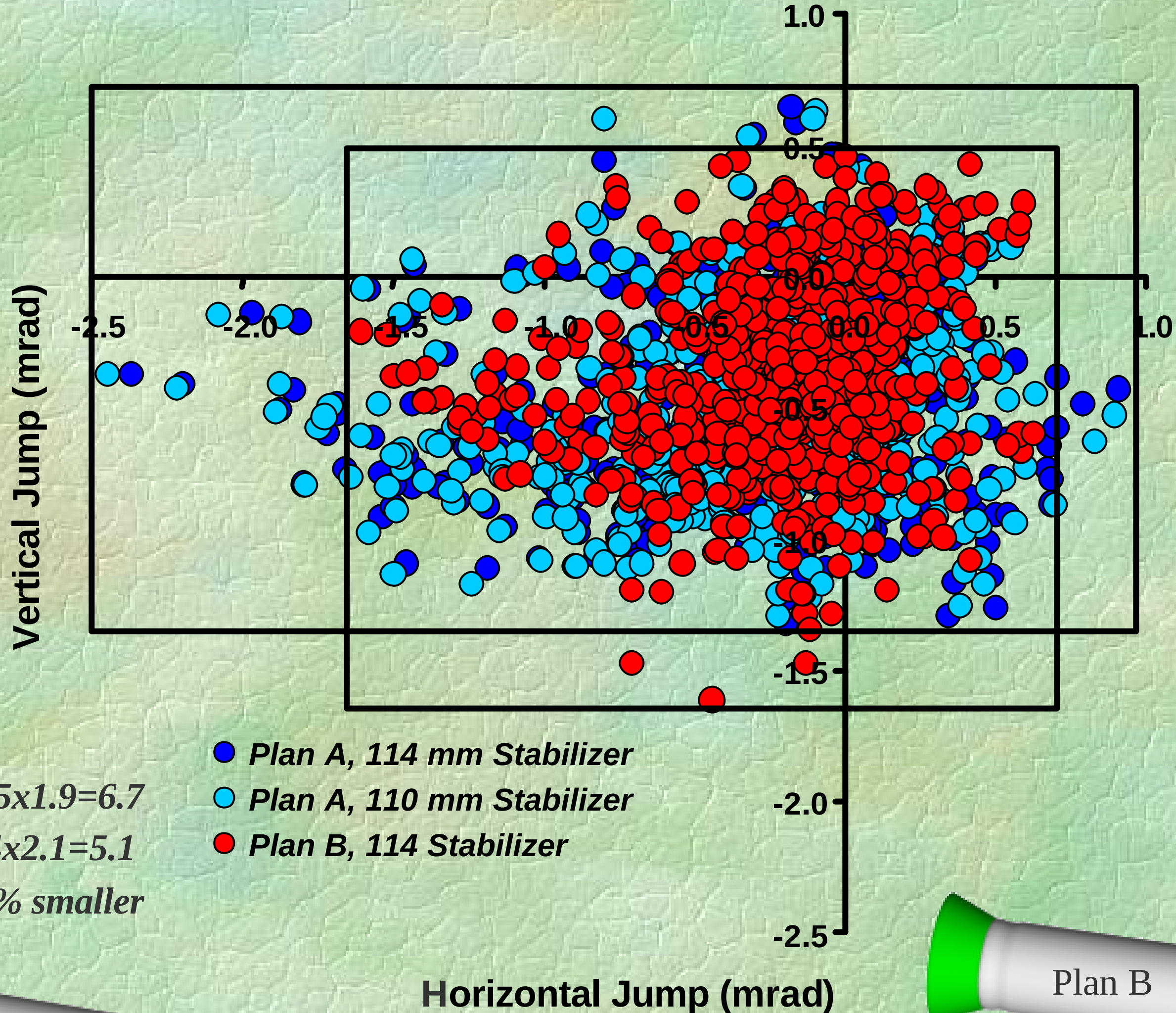
Ideal Tube Shape Total Jump COI







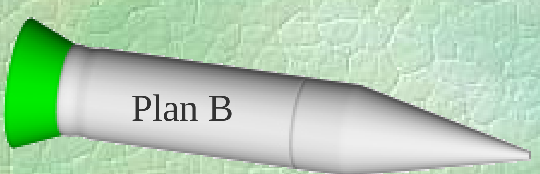
Ideal Tube Shape Total Jump
Individual Shot



Areas: Plan A -> 3.5x1.9=6.7

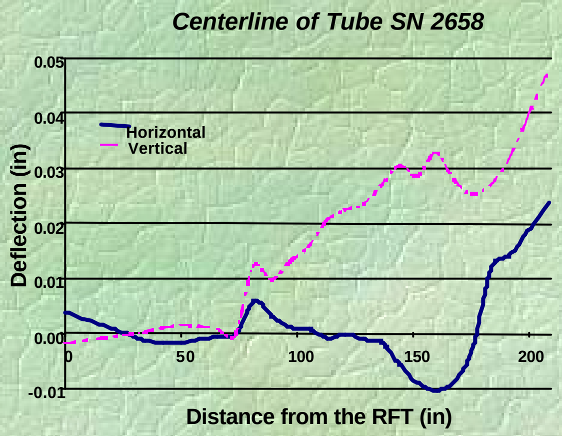
Plan B -> 2.4x2.1=5.1

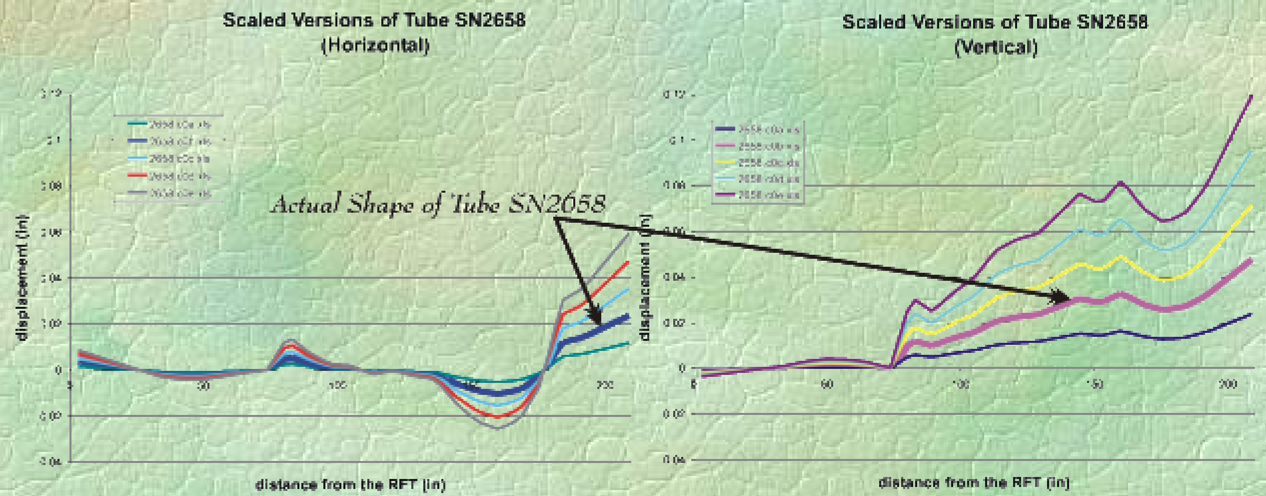
Plan B's area ~ 24 % smaller



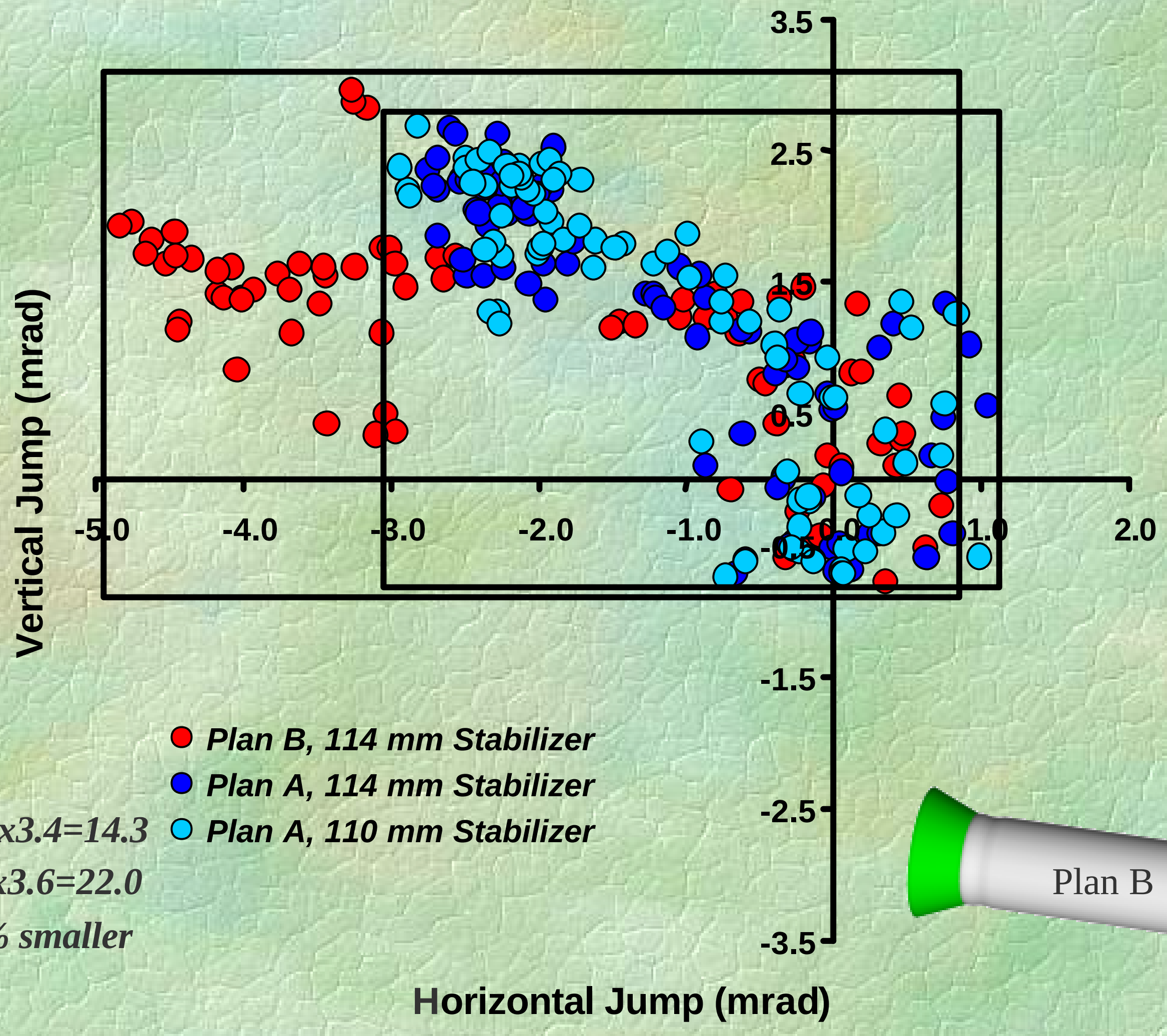
Tube Shapes Based on SN2658

- One of the worst tubes in the database
- Used to create a series of torturous path tubes
- Magnitude ranges from 0 to 2.5 times the actual magnitude of the tube

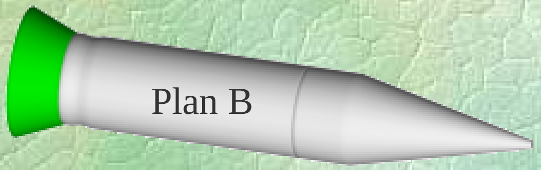


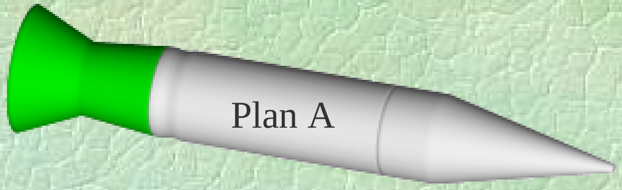


Total Jump for the Tubes Based on SN2658

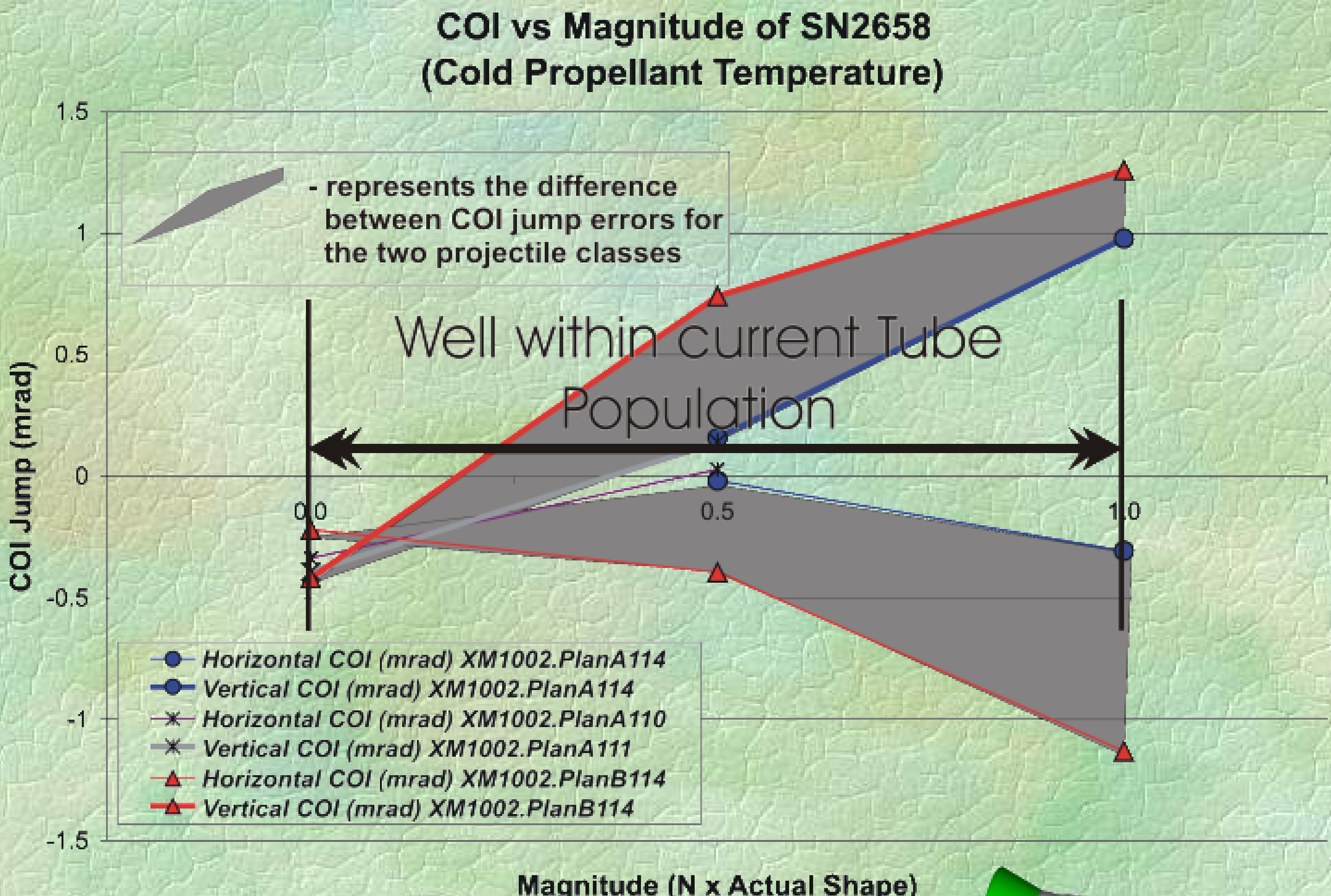


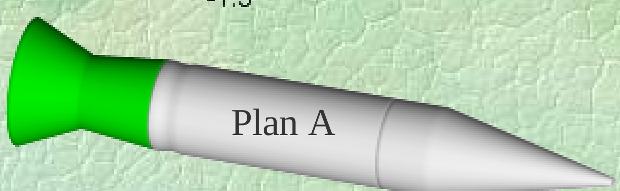
Areas: Plan A -> 4.2x3.4=14.3
Plan B -> 6.1x3.6=22.0
Plan A's area ~ 35 % smaller





Differences Between the Projectile





Conclusions

- These methods can be used to distinguish differences in the launch performance of various projectile versions
- Primary difference in the two versions of the projectile is the transverse moment of inertia (I_{yy})
- The lower I_{yy} projectile performed with less variability in ideal, smoothly shaped tube, ***BUT***
- When subjected to a more realistic environment, the projectile with the higher I_{yy} resulted in less jump variability
- This jump variability manifests itself in occasion to occasion error
- Working on Validation