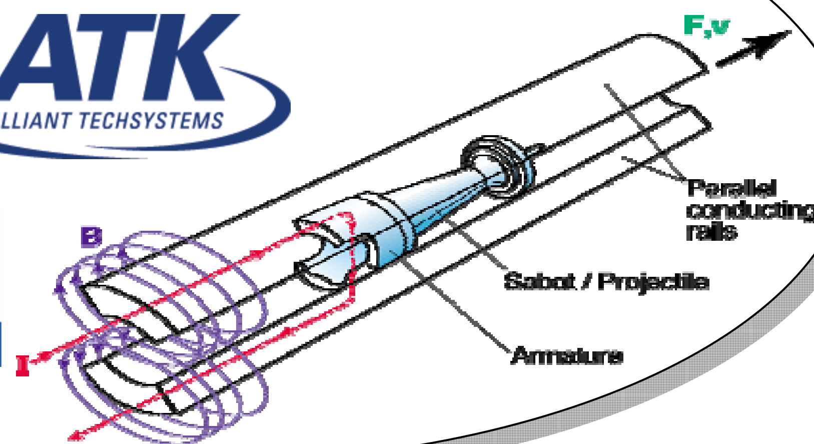
41st Annual Armament Systems:
Gun and Missile Systems Conference & Exhibition
March 27-30, Sacramento, CA

Development and Testing of High Explosive (HE) Projectiles for Electro-Magnetic Gun Army Tech Objective (ATO)

GENERAL DYNAMICS
Ordnance and Tactical Systems

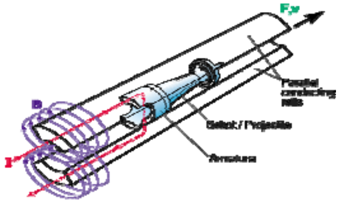
ATK
ALLIANT TECHSYSTEMS

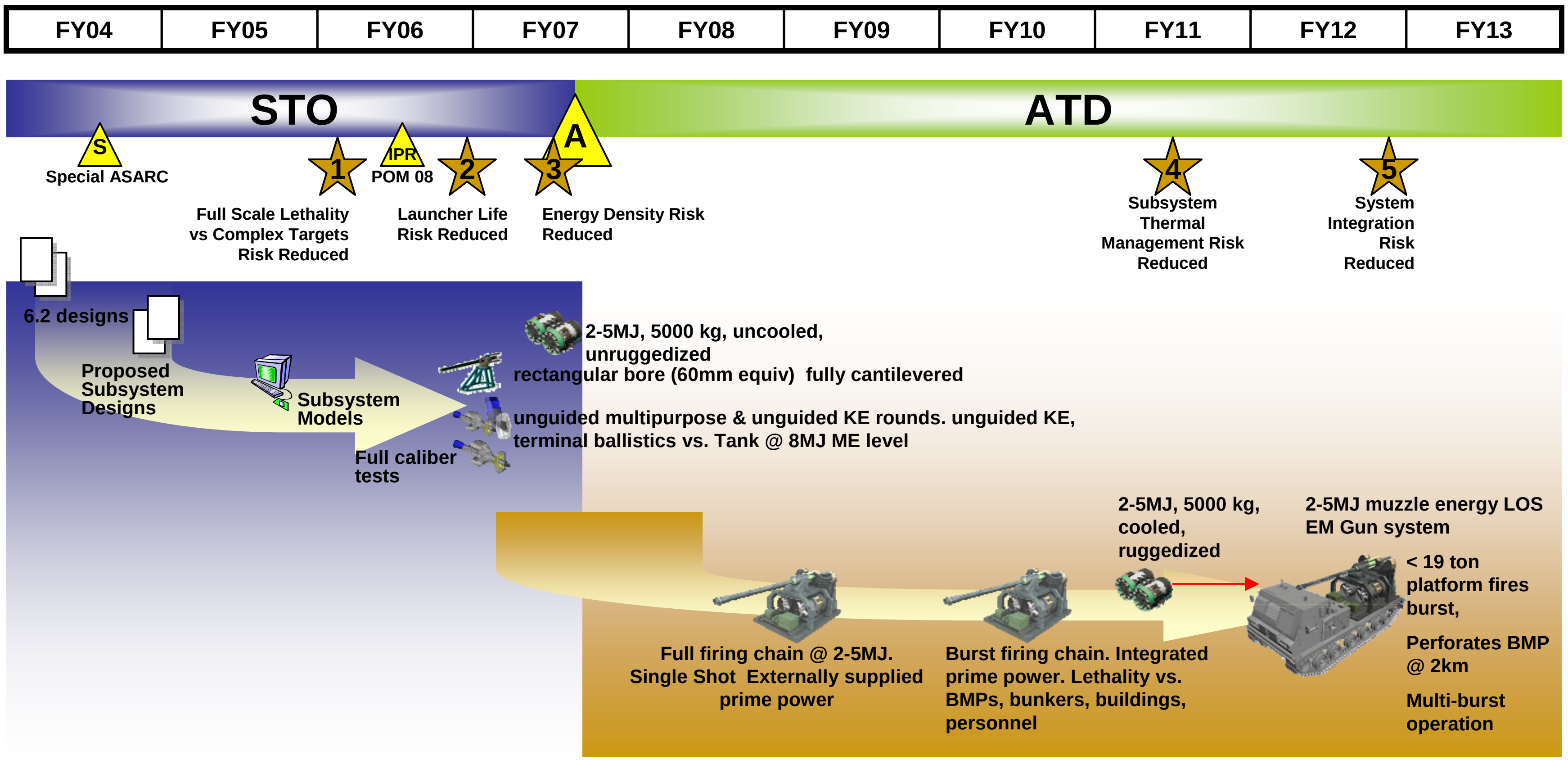


Presenter:
Dave Okken
RDECOM-ARDEC
Picatinny, NJ

Authors:
ARDEC: **Manfredi Luciano,**
David Okken, Samuel LaFontaine
Justin Rhodes, Robert Bryan, John Grau, Vinod Nagori
ARL: **Alex Zielinski**
GD-OTS: **Karl R. Linde**
ATK: **Eric Quist**

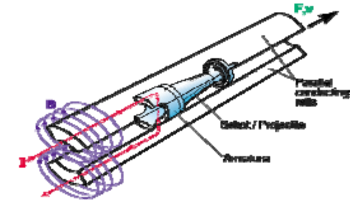
Army Program
First EM Technology Spiral



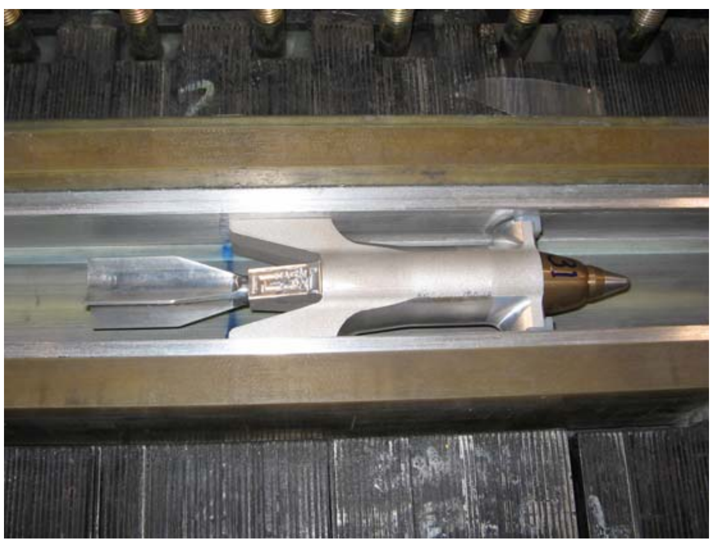


Special ASARC approved this ATD approach

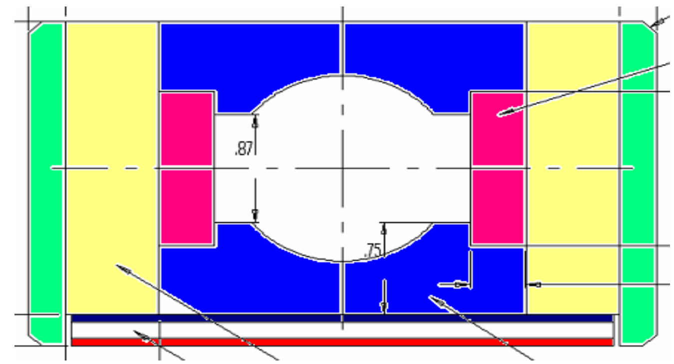
Test Vehicle:
ARL ½-MJ EM GUN

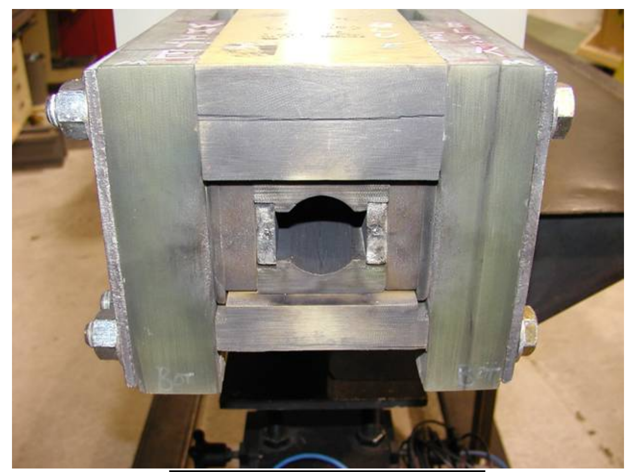


- *Max Muzzle Energy = ½ MJ*
- *Peak Current = 1MA*
- *Gun Length = 2.8 m*
- *Gun Cross Section = 22mm x 44 mm*
- *Scalloped Insulation Cross-*
  Section area = 38 mm (diameter)
- *Achieved seven shots on one set of rails*



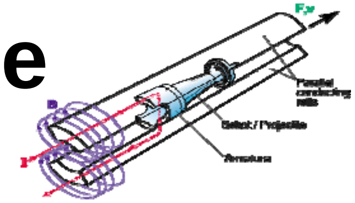
Test Launcher w/ ILP





Muzzle View

HE Integrated Launch Package (ILP)

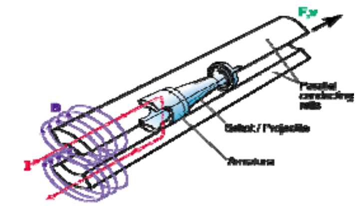


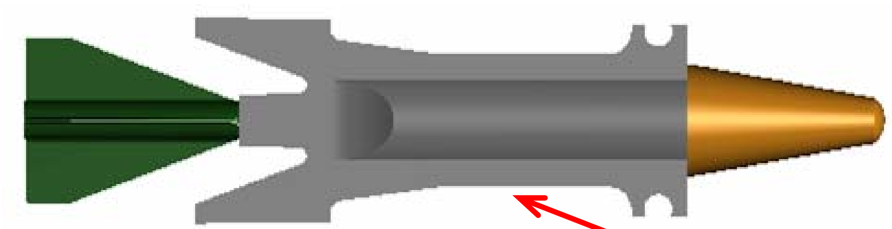
- **Objective:**
  - Demonstrate a HE ILP from an EM Gun, Achieving TRL-5.
    - Integrate a sabot/armature, flight body, fuze, and HE for a 2 km demo

- **Approach:**
  - Test from ARL ½ MJ Electro-Magnetic Gun
  - Task order contracts to GD-OTS & ATK for Hardware Mfg
  - Team intellectual collaborative effort between government and Industry
    - Maturing general EM technology
    - No competition between parties; non-tactical bullet

- **Technology Challenges:**
  - Can large body, fin stabilized sub-projectiles be launched with significant lateral loads and high current environment?
  - Can high explosive & fuze survive the high current, and magnetic fields in this environment?

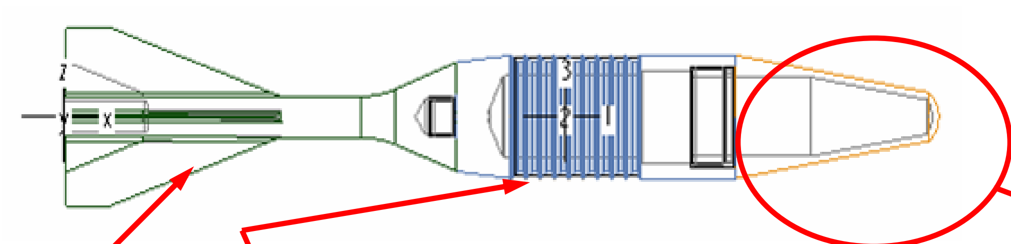
HE ILP Initial Design





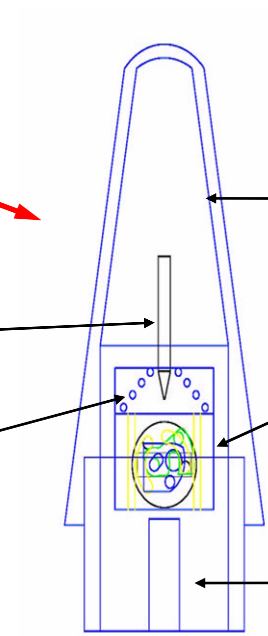
Integrated Launch Package: Integrates Sup-Projectile, Sabot, & Armature

Armature for EM Launch



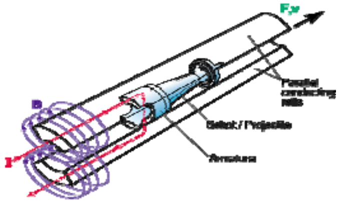
Body & H.E. Based on M792 (25mm HEI-T)

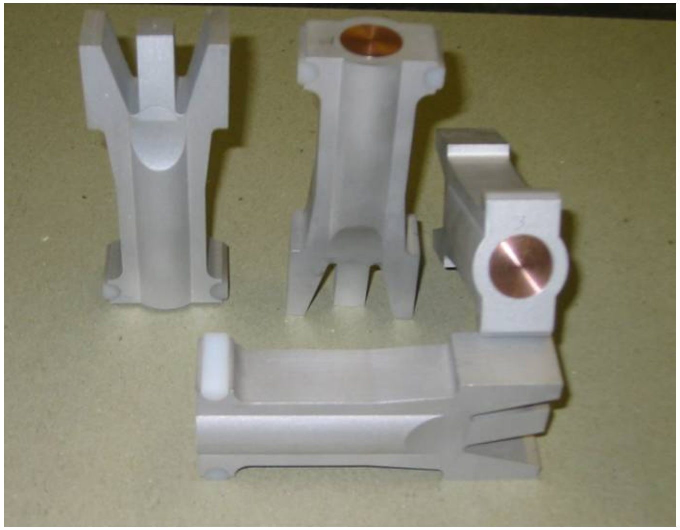
No Spin Environment
- **-Requires Boom/Fin for Stability**
- **- Clipped Delta, Four Bladed**
- **-Requires 2nd Fuze Arming Mechanism**



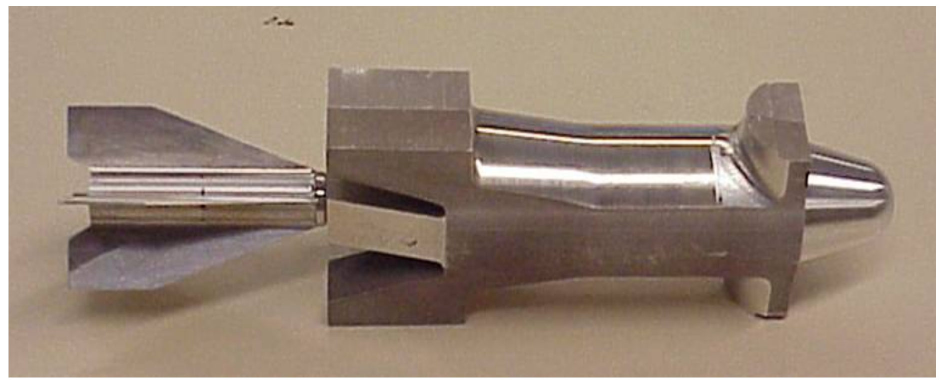
Dual Arm Fuze: Setback & EM

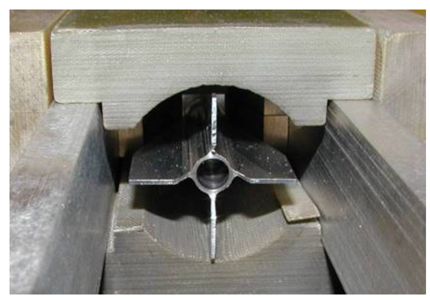
Test Results:
Slug & First ILP Test





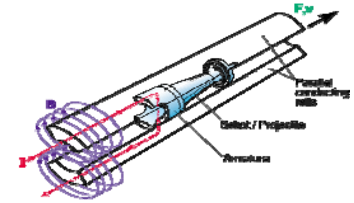
- Four slugs tested
- First shot at lower current, lower Gs
- Armature legs broke at muzzle exit





- Six ILP's tested at SOD conditions
  - 90/45 fin orientation
- Two out of six were successful
- Fin blades and fin-hub failures
- Results a function of:
  1. Acceleration
  2. Transition Current
  3. Muzzle Current

First ILP Flight Test, X-Rays



<u>Shot # 1</u>

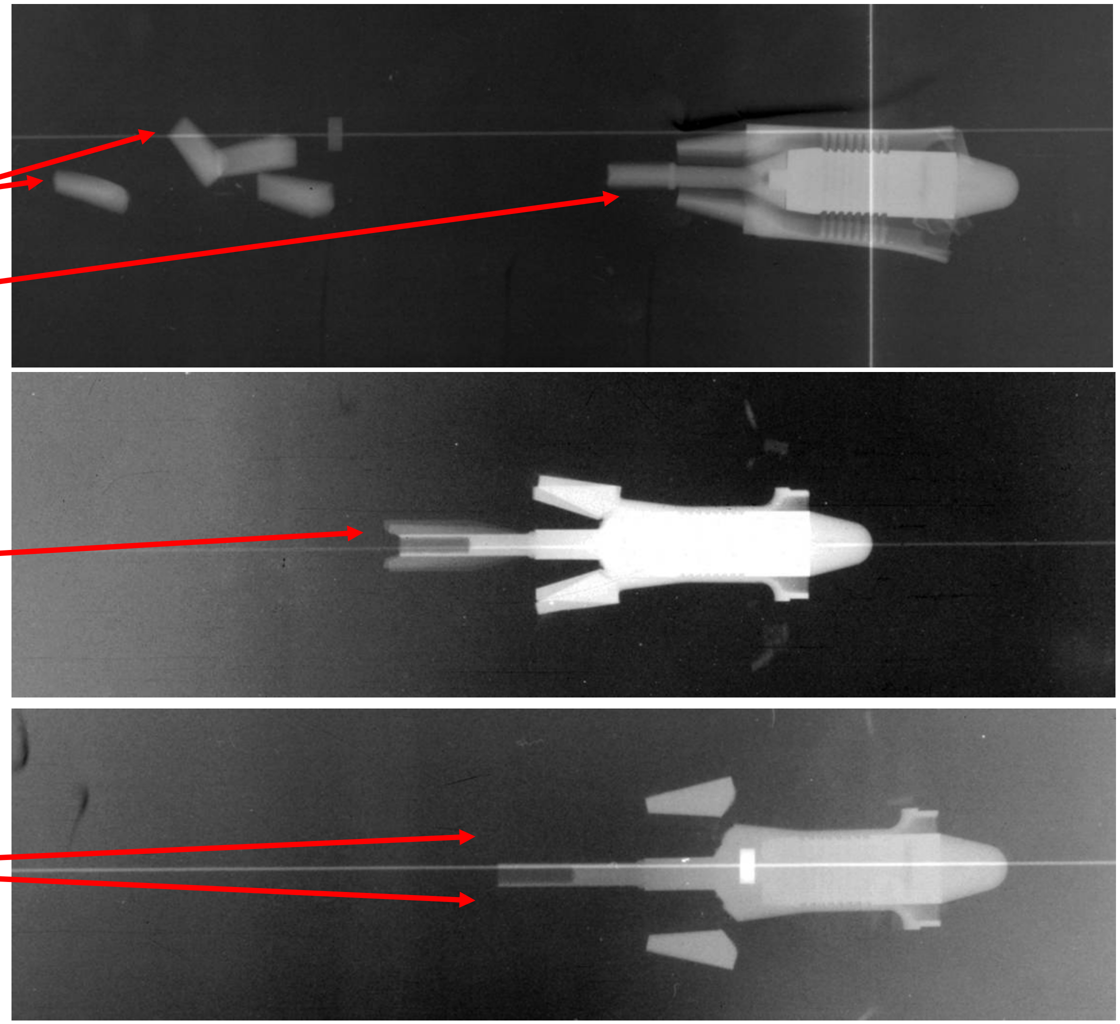
- **Armature Legs Fractured On Muzzle Exit**
- **Fin Blades and Hub fractured**

<u>Shot # 3</u>

- **Fins & Fin-Hub Intact**

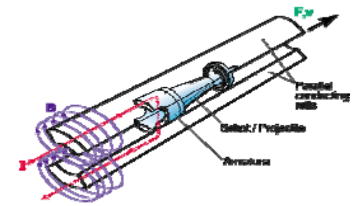
<u>Shot #6</u>

- **Fins Missing**
- **Fin-Hub Intact**

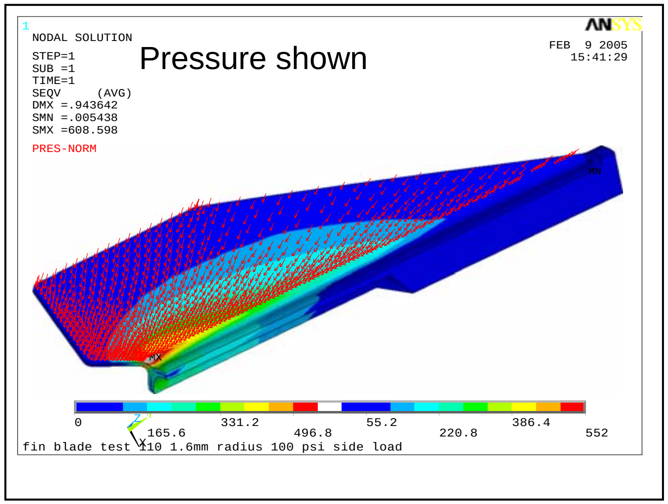


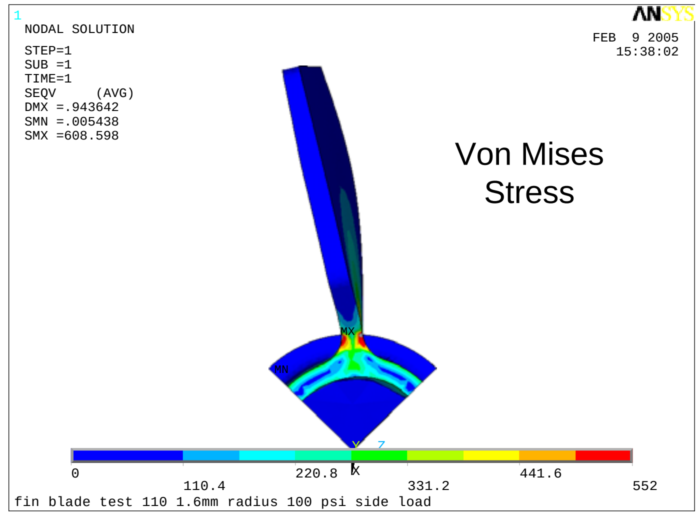
22" from Muzzle

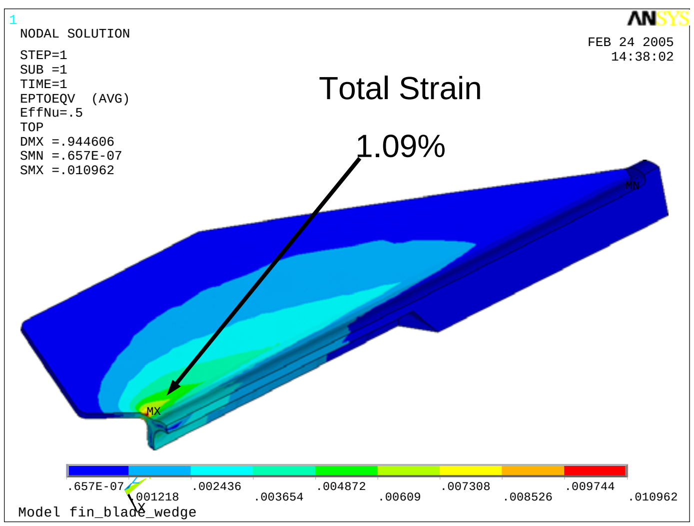
Fin Stress Analysis



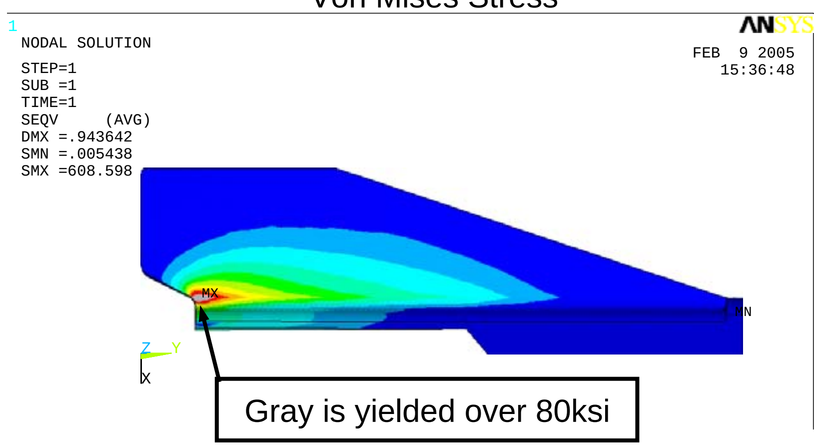
First Flight Test, Fin @ 100psi side load



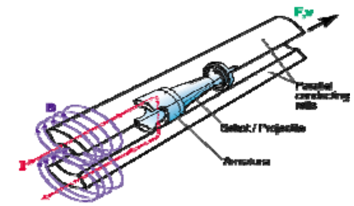




Von Mises Stress



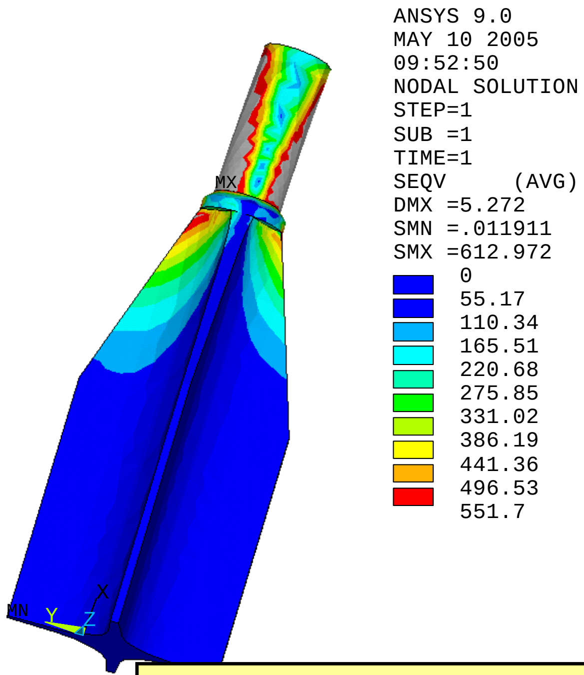
Boom Bending Analysis



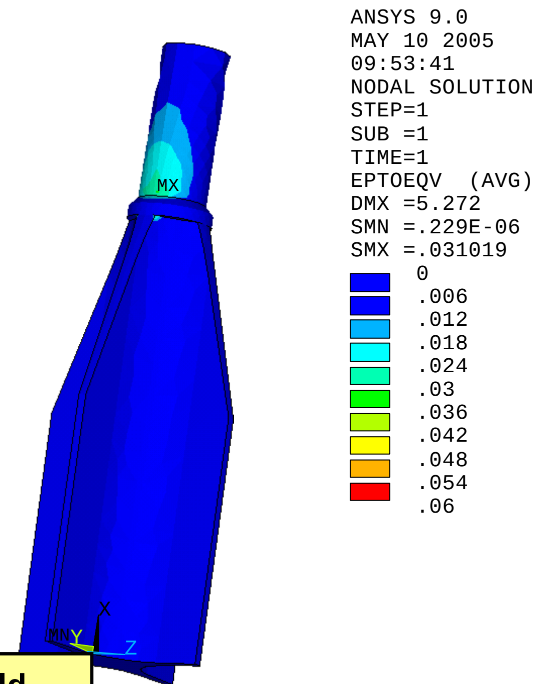
Test 120 Type A1 Alum 7075 Fin

Estimated Transition Loading (30000axial,11000Transverse g’s)

Von Mises Stress



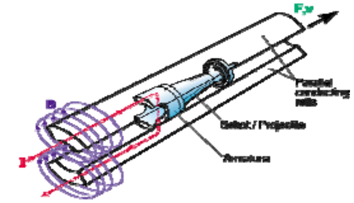
Strain

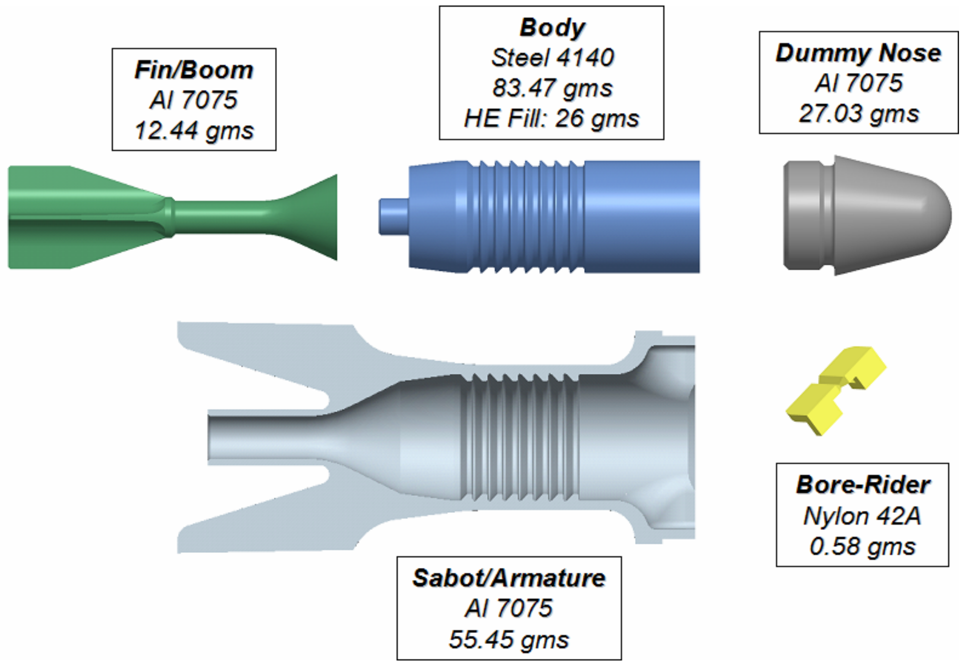


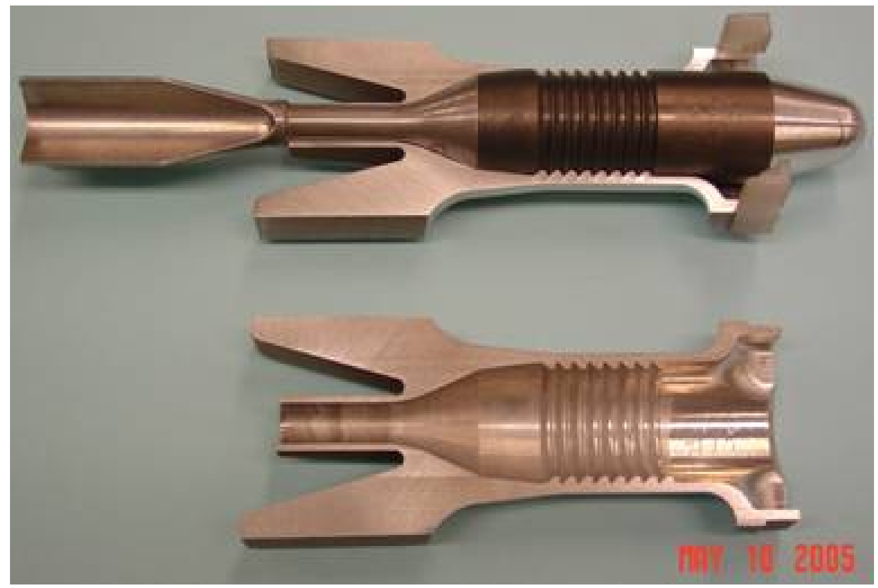
Stress & Strain show yielding but would survive these loads.

Red Lion EM ILP Test120 Fin Alum 30kg's axial, 11kg's trans May 10 05 Test120 Fin Alum 30kg's axial, 11kg's trans May 10 05

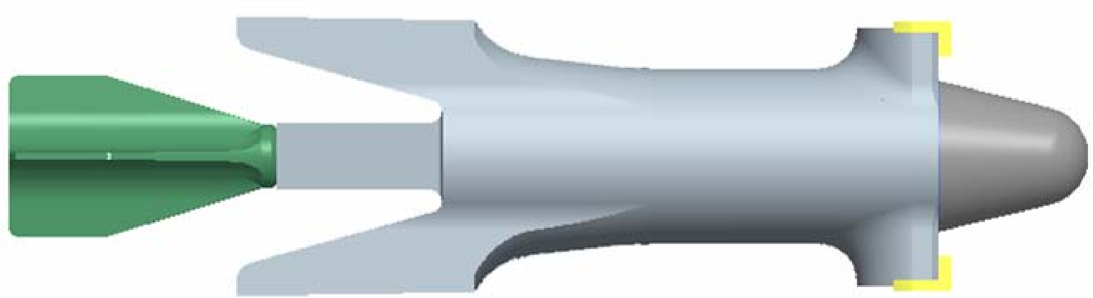
ILP Design & Assembly



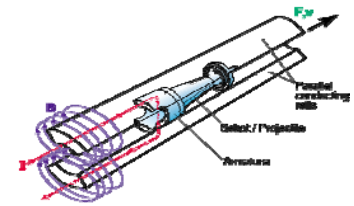




Actual Hardware

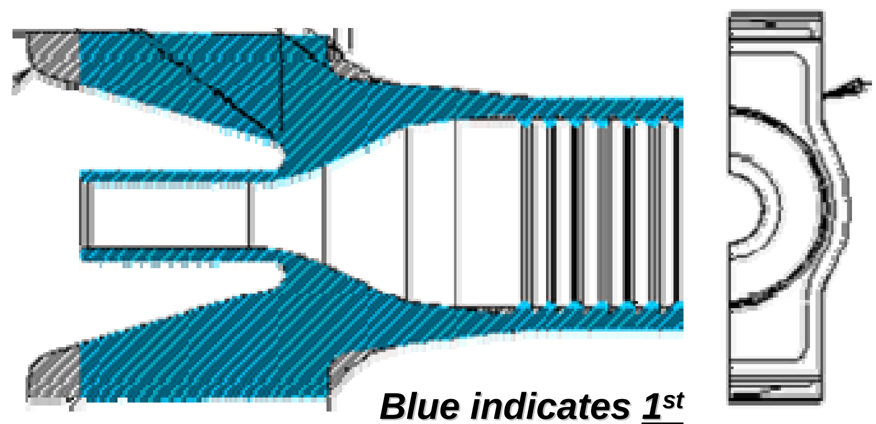


Second ILP Test Summary

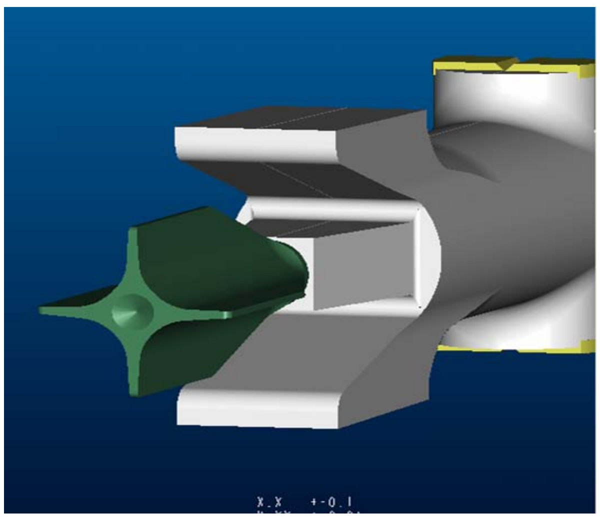


Design Changes:

- Increased armature length/mass
- Thicker chevron
- Reduced Fin span, increased root radius



Blue indicates <u>1st</u> armature iteration

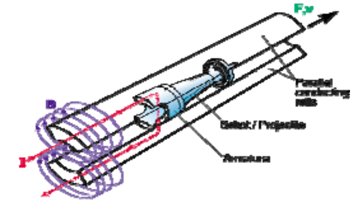


Achievements:

- *8 Successful Shots up to 63.7 KGs*
- Survivable Fin/Fin-Hub
- Minimize Transition Loads
- Minimize Muzzle Exit Dynamics

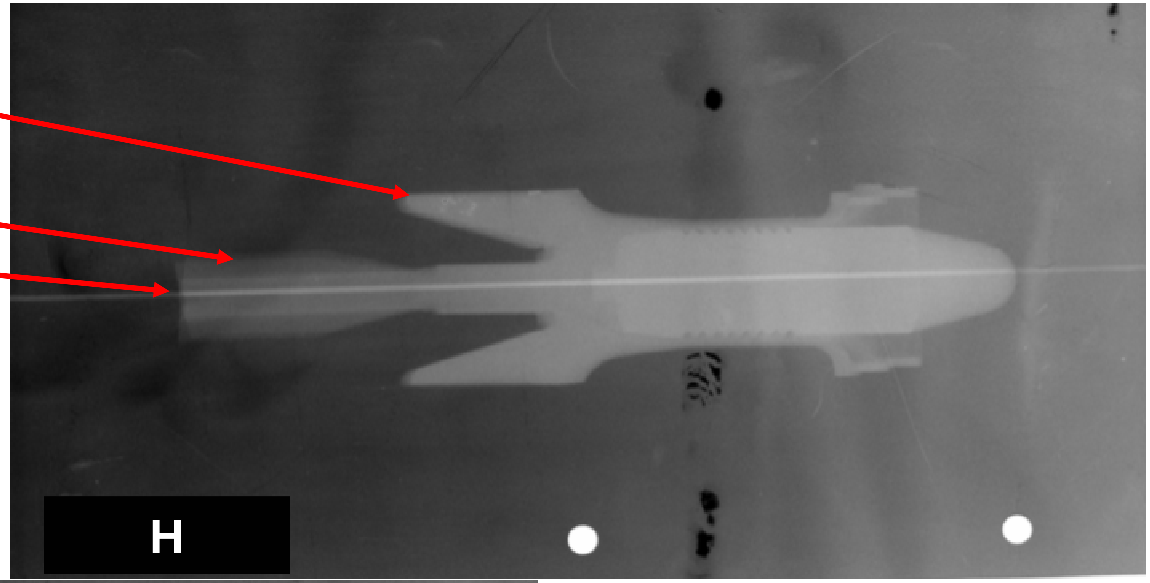
Designed correctly for axial loads
Designed for lateral loads 20% of axial – 12.7 KGs
Successfully managed large balloting loads and muzzle exit dynamics

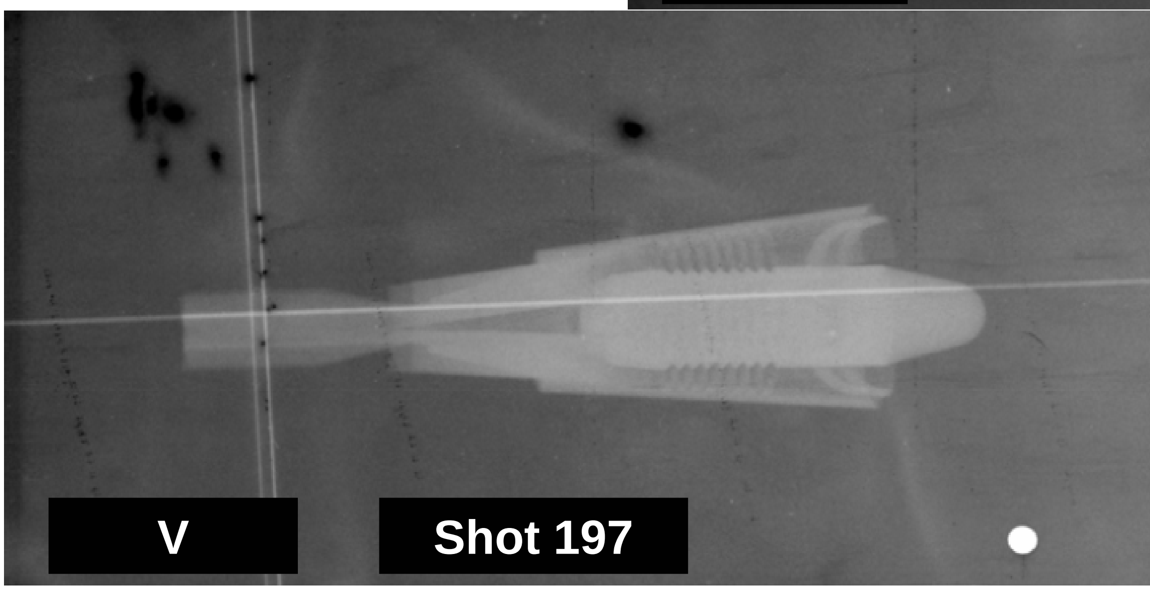
Second ILP Test X-Rays



- Armature Legs
- Fins
- Fin-Hub

Intact

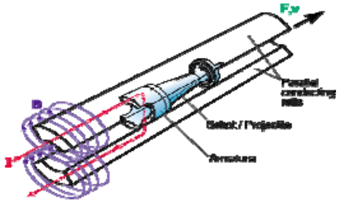


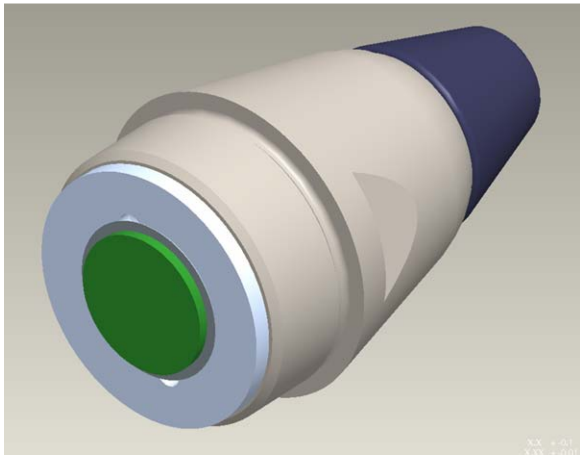


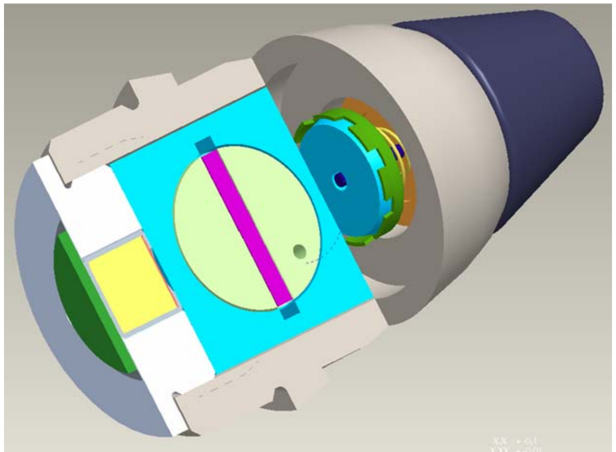
Even Discard

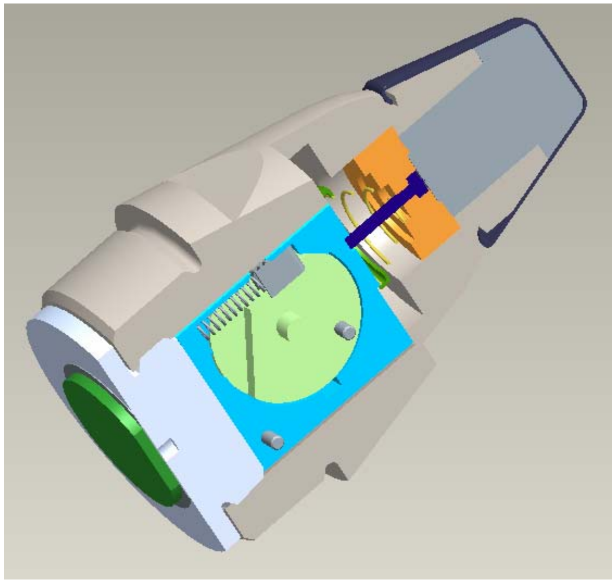
Minimal Yaw

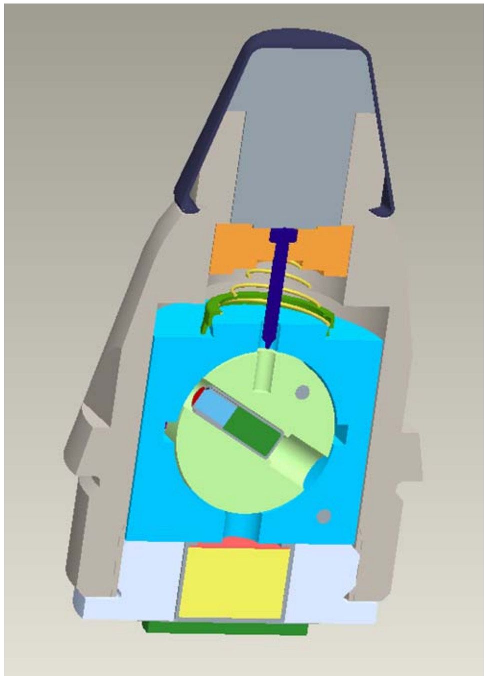
EM ILP Fuze Concept









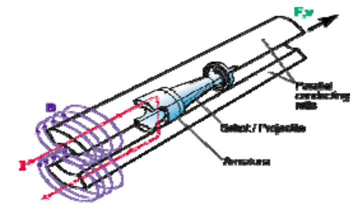


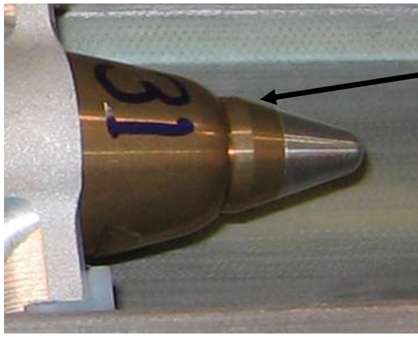
Dual Arm S&A:

1. ***Setback Pin/Spring***
2. ***Magnets Polarized from EM Field***

For More Info: **2006 NDIA Fuze Conference Paper**

Fuze Soft Recovery





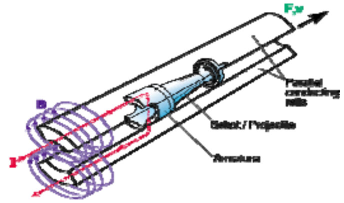
Pre-shot
Hardware

Recovered
Hardware

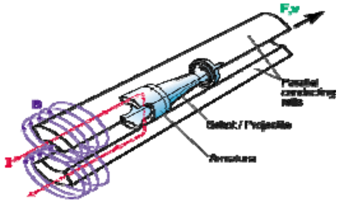
- Fired seven ILP’s fired with fully functional inert fuzes
- Nose modified to minimize blunt impact

- Target of foam and fiber board in a plywood frame
- All seven fuzes showed minimal impact damage
- Results of fuze function show further development needed

Live High Explosive



First time live HE fired from Electromagnetic Gun



Summary

- ILP is structurally sound
  - Three test iterations
- Live HE fired from EM Gun environment without incident
- Fuze development to continue
- System integration
  - Integrate live fuze with ILP containing HE