NDIA Armaments Systems Forum

Novel Mortar Blast Attenuation

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Novel Mortar Blast Attenuation thru Augmented PrecursOr Low impuLse nOise- APOLLO

Background:

- The goal of the effort is to reduce 120mm Mortar Blast Overpressure (BOP) imposed on the crew without the use of undesirable Blast Attenuation Devices (BAD).
- Research on a novel approach to BOP, or impulse noise mitigation, shows promising results by incorporating propellant flow channels in the bore of the mortar tube with minimal performance degradation.
- BOP or impulse noise imparted on the crew is the main driver for establishing the Daily Allowed Number of Rounds (ANOR). Reduction in BOP results in an increase in ANOR and ultimately system lethality.

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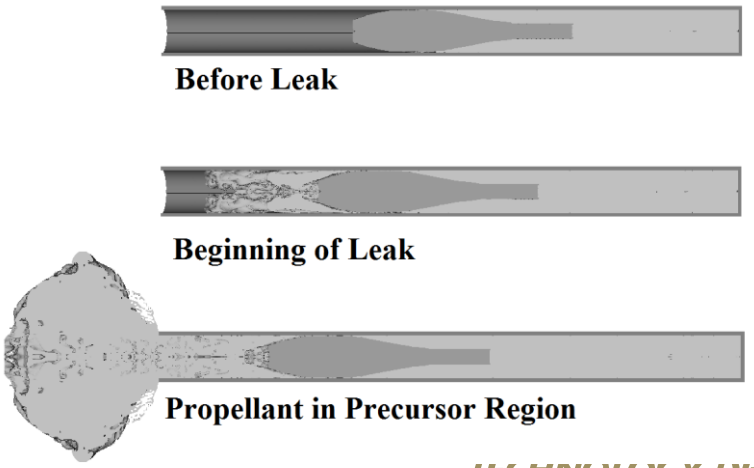
Background Continued:

- This effort focuses on validating the extensive analytical modeling conducted in 2012 as part of an ARDEC Science Fellowship project. Necessary components were developed and fired (planned) as a means of validating extensive applied research conducted on propellant gas flow phenomena using a Computational Fluid Dynamics (CFD) approach. (See 2014 NDIA Joint Armaments Forum- ***Multifaceted Gun Fluid Flow Modeling and Experimentation at ARDEC***)
- Initial analytical studies show a BOP decrease of up to 55% depending on mortar elevation and round conditioning.
- Provisional Patent Application Serial No. 61/726,709 has been filed on the approach.
- If successful this concept has application to future mortar systems including the notional 120mm Extended Range Mortar. Extended range will require higher firing pressures which will increase current BOP values. This approach will help mitigate any reduction in ANOR caused by an increase in BOP.



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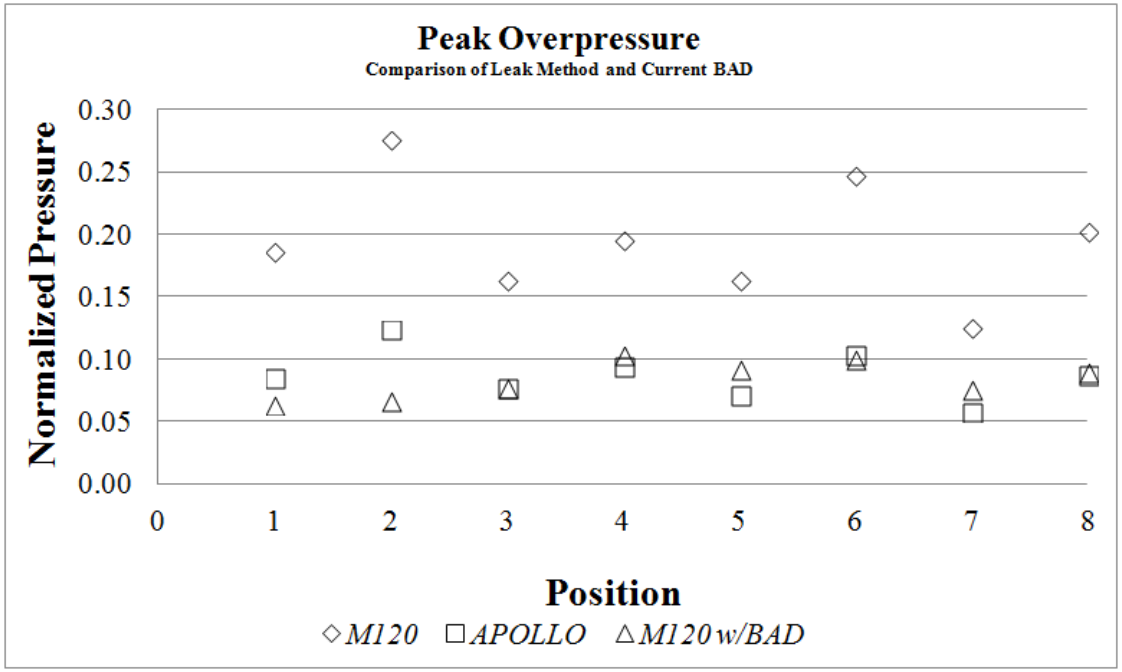
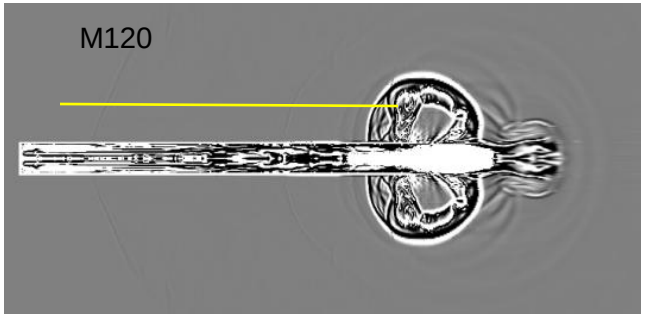
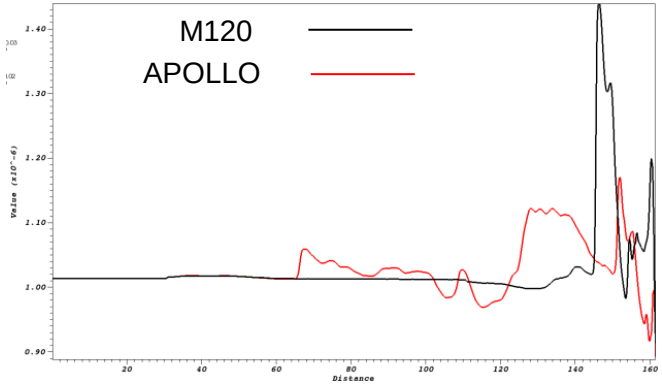
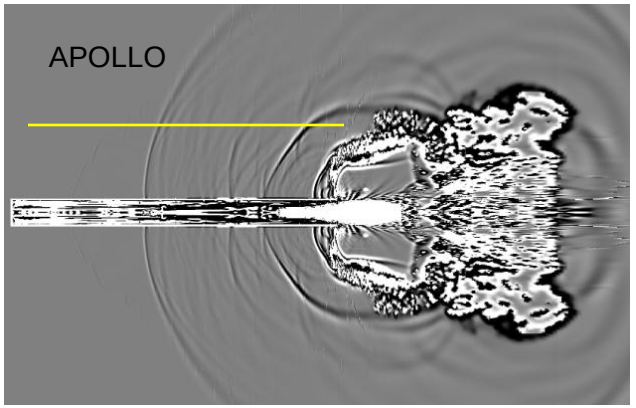
2012 M&S Using ALE3D
2013 Junior ARDEC Science Fellowship
2014 Senior ARDEC Science Fellowship



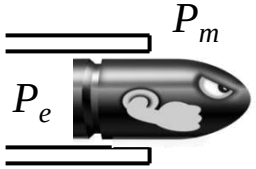






$$PR = {}^{P_e}/_{P_m}$$

	PR
M120	**232**
APOLLO	**7**



Malcolm Baldrige National Quality Award 2007 Award Recipient

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Objective:

This SC&T effort will involve the development of a 120mm Mortar tube that includes features called "flow channels" to enable a small amount of pressure to leak ahead of the projectile thereby reducing the pressure ratio of the system. These features were designed and optimized utilizing CFD modeling and simulation under a FY12 SAG M&S and ARDEC Fellowship project with Bob Carson.

Deliverables:

- *Manufacture of a Proof of Principle (PoP) 120mm Mortar*
- *Firing Test of PoP with BOP and Projectile sensors*
- *TDP for manufacture of an objective APOLLO120mm Mortar*
- *Report to include design, analysis, and test results of effort.*

Customer:

This effort was requested by and is endorsed by PM-GPMMS (Product Manager - Guided Precision Munitions and Mortar Systems), Mr. Ted Greiner, 973-724-5524/DSN 880-5524, theodore.g.greiner.civ@mail.mil

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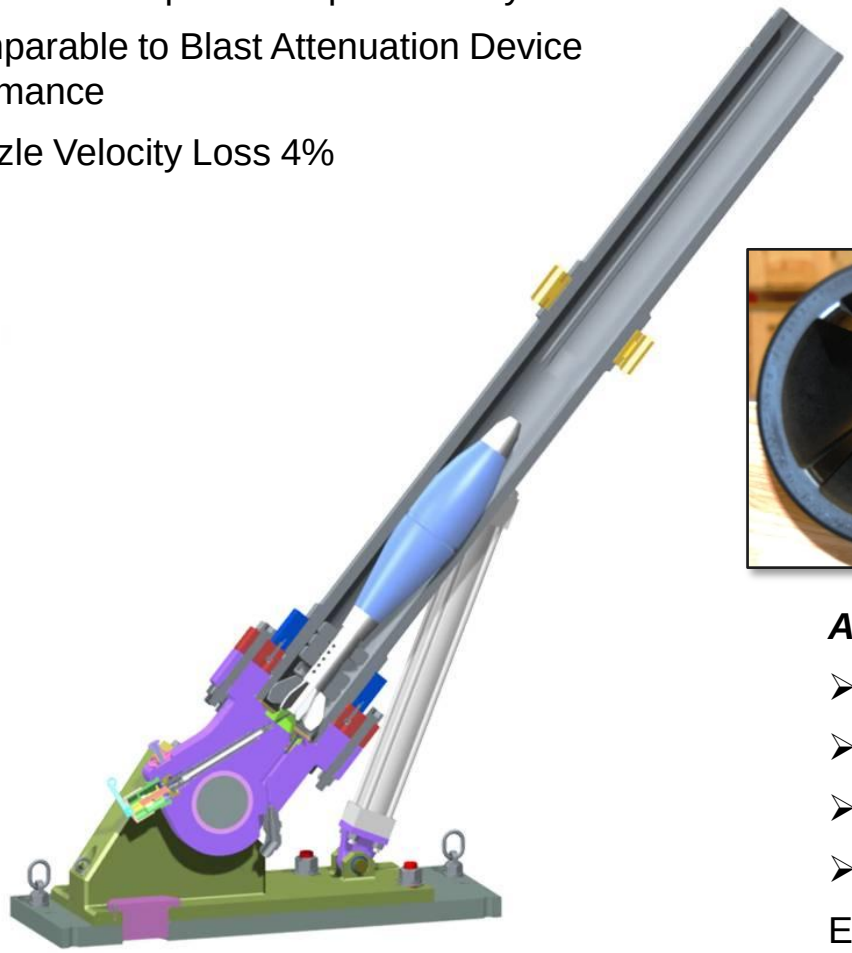
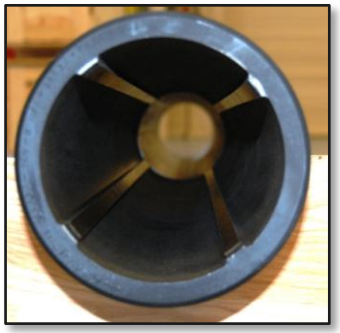
Blast Attenuation Features:

- Controlled leak of propellant into precursor
- Attenuation of peak overpressure by 50%
- Comparable to Blast Attenuation Device performance
- Muzzle Velocity Loss 4%





APOLLO Proof of Principle Tube Features:

- 120mm PoP tube based on ER Ballistic Test Platform.
- Can Mount BAD.
- Utilize HS Steel Forging
- Firing test to coincide with ER Ballistic Testing.

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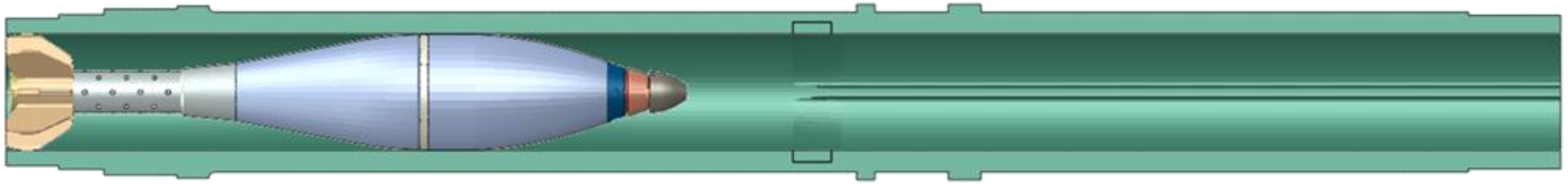
ARDEC Munitions Engineering Technology Center (METC)
Ammo Performance Analysis of PoP APOLLO Mortar
Contributed by Adrian Blot, ARDEC METC

- Goals:
  - To compare the performance of a 120mm projectile operating in an equivalent baseline barrel and the Apollo barrel to ensure the system performance is not degraded.
- Scope:
  - Modeling the in bore dynamics with blow-by of the M934A1 120mm Mortar in a baseline equivalent barrel and the Apollo barrel.
  - Initially work with BCFD coupling to Abaqus for preliminary in-bore modeling. Completed
  - Transition modeling for FSI coupling to Star-CCM+ to better model in-bore pressures around the projectile and to model the transient behavior during muzzle exit. Planned



Ammo Performance Analysis of PoP APOLLO Mortar- Adrian Blot, METC

Assumptions

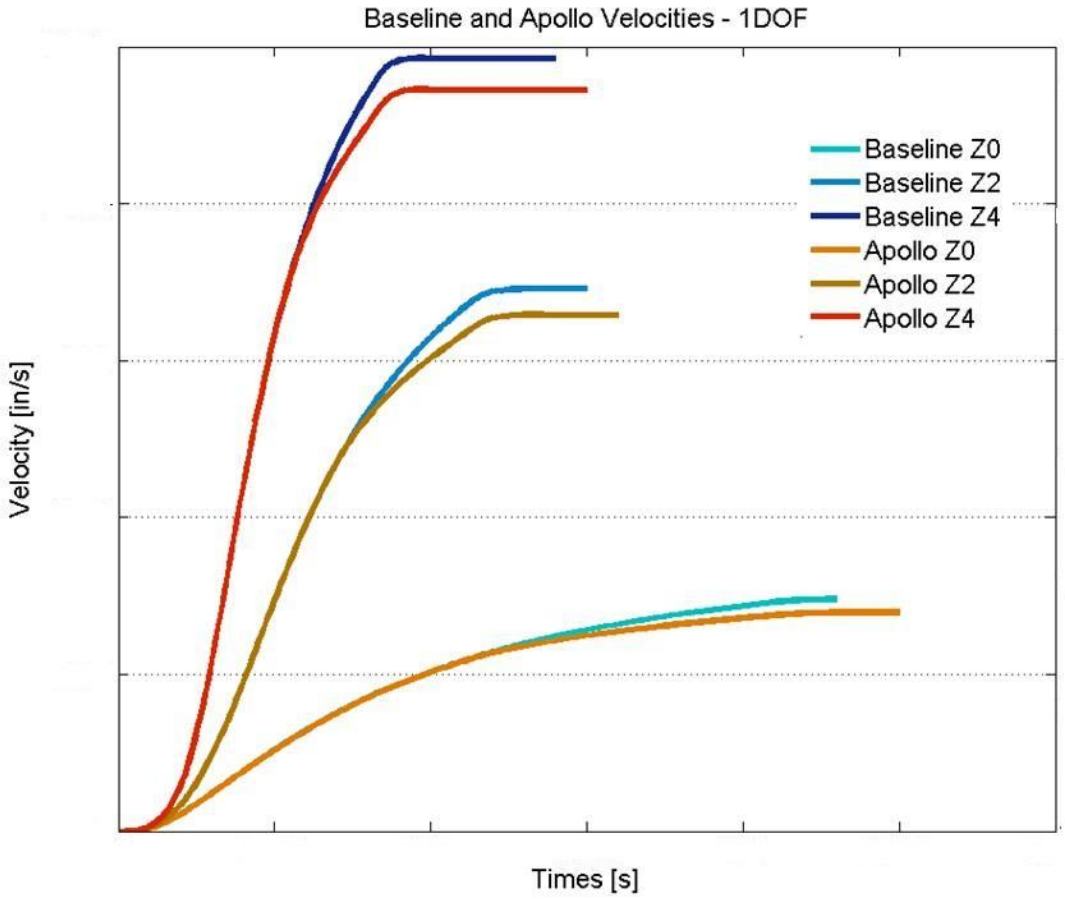
- Currently modeling ignition from trigger fire. Starting position of the mortar is at the bottom of the tube perfectly centered.
  - Mortars are typically dropped onto the firing pin. The ignition pressures may vary compared to the trigger mode operation due to the dynamics of the free volume behind the projectile when it is allowed to bounce from the drop. This will require additional analysis.
- Modeling rigid body projectile and barrel.
- QE=800 mil and (45deg and 80deg from horizontal), gravity included
- Global friction coefficient of 0.5 used.
- Neglecting barrel recoil

Preliminary Conclusions

- The models are producing good results, but still requires some refinement.
- In the Apollo models once the projectile reaches the sudden barrel expansion the pressures around the projectile rapidly reduce but then recover with a more gradual pressure distribution along the length of the body. The additional pressure loads could potentially pose an issue to components in the fuze.
- The interior ballistics model has been validated to ensure that the results match pressure curves and exit velocities.
- Preliminary results comparing projectile balloting and pitch and yaw out of the barrel indicates some changes in stability with APOLLO tube. Model refinement in process.

Ammo Performance Analysis of PoP APOLLO Mortar- Adrian Blot, METC

1DOF analysis with no band interaction with barrel. The velocities match until the point the projectile enters the expansion region at which point there is a reduction in acceleration due to lower base pressure and higher blow-by pressure.



Analysis Velocities	
Apollo Z0	-5.6%
Apollo Z2	-4.7%
Apollo Z4	-4.0%

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Ft Benning Live Fire Exercise November 2014.

- Mr. Kamimori,research Physiologist, Walter Reed and LT. Olagheredasilva ,Naval Medical Research Centers studying the effects of blast over pressure on Soldiers firing Mortars.
- Instrumented soldiers to understand how they are developing TBI and how the blast pressure impacts their internal organs and hearing.
- Infantry Mortar Leaders Course (IMLC) Live Fire Exercise 19 November.
- Approx. 300 rounds fired the 120mm Ground Mounted Platform.
- Ft. Benning POC Leon Junk, First Sergeant, MTC 1-19IN, 198th ITB
- ARDEC POC @ Ft. Benning Michael Campolieto

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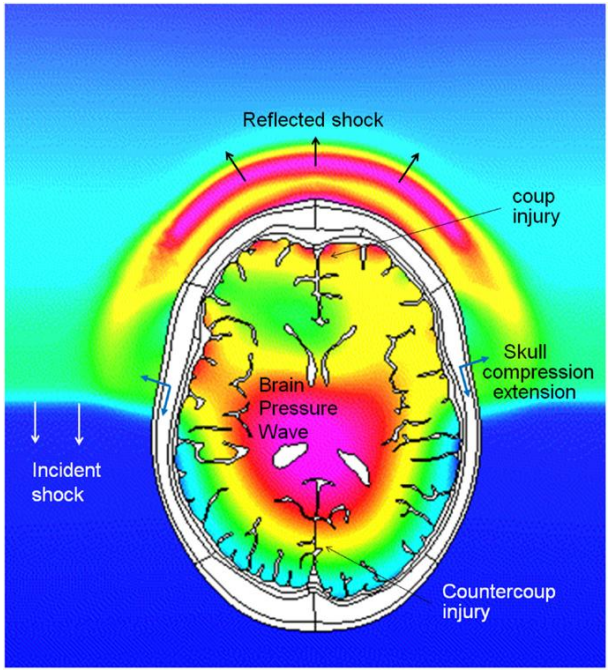
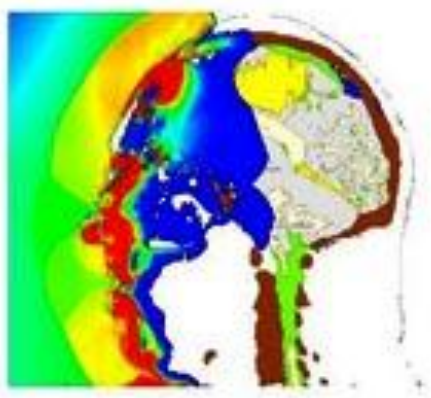
Ft Benning Live Fire Exercise November 2014 Continued.

- Test results show current Over Pressure (OP) values exceed threshold for hearing protection in some cases. Most concerned about OP role in brain injuries.
- 5 year medical research effort is focusing on the physiological effects of Overpressure on the brain with repeated occasions on short term basis and over longer periods of time.
- Broad scope of effort includes large scale explosives to small arms and everything in between.
- POC LT. Olagheredasilva ,Naval Medical Research Center





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Manufacturing Challenge:

- The internal bore Flow Channels require a internal feature machining process.
- Traditional machining of rifled cannon requires expensive broaching.
- Watervliet Arsenal Electrical Discharge Machining (EDM) capability limited to Wire EDM which would required the cannon be manufactured in sections.
- Utilizing a Plunge EDM process, Reliable EDM, of Houston Texas, manufactured the flow channel features into a finish machined tube produced at Watervliet.
  - Concern over the EDM Recast Layer leads us to desire alternate processes.
  - Costly tooling is consumed during machining process.

APOLLO Proof Of Principle Mortar Tube Internal Flow channels with Plunge EDM process

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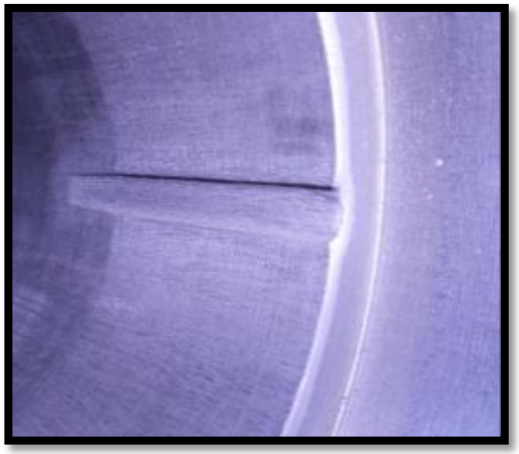
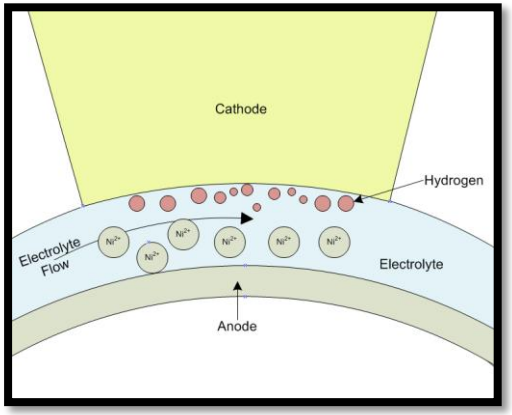
ARDEC Benet Labs is currently developing a Electrical Chemical Machining (ECM) process for large caliber cannon's.

- Electrochemical Machining (ECM) - A non-conventional machining method that uses controlled metal removal by anodic dissolution in an electrolyte cell.
  - An electrolyte flows between the electrode gap while a high current at low voltage is passed between the gap ionizing the tube surface. Metal ions are removed from the surface effectively machining the surface to the desired shape.
- Complex shape fabrication, superior surface finish, and no induced residual stress provides a cost effective and attractive manufacturing method for defense applications.
- Current high strength gun steel is very tough, thus making it difficult & costly to machine, increasing the risk of dimensional deficiencies on complex critical components.
- A non-contact machining method will not suffer from the limitations imposed by the high strength material condition.
  - Electrochemical machining is a non-contact machining method used in the aerospace industry to machine difficult to machine materials.
  - Unlike conventional machining processes, Electrochemical machining is not affected by material strength, hardness, or toughness.
  - Reusable customized tooling reduces costs by 90% over broaching.
  - No resulting re-cast layer eliminates fatigue life concerns.





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2015 Plans

- Perform firing test utilizing ER Ballistic test setup @ YPG
- Test Data Analysis
- Complete Design of Objective Mortar to asses structural issues and determine weight impact.
- Assess Fatigue & Fracture impact
- Complete analysis of projectile performance- METC
- Report

QUESTIONS?