

# MULTI-ROLE ARMAMENT & AMMUNITION SYSTEM (MRAAS) CANNON

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## **ABSTRACT**

*This paper will describe the Cannon portion of the MRAAS concept. The MRAAS is a concept for a highly flexible weapon system, extremely adaptable and well suited to support joint operations. The system concept calls for a single cannon capable of providing direct fire, indirect fire, and air defense missions from a single platform within the weight limits of modern lightweight wheeled combat vehicles. This paper will briefly discuss the integrated development of the launcher, mount, and ammunition from a systems perspective in the first part. The second part of the paper will focus on the final weapon system assembly and test firing. The performance of numerous advanced technologies, such as composite support elements, composite cannon tube, integral muzzle brake, and swing chamber configuration will be reviewed. Video clips and graphics will help describe the performance relative to the original design goals. Future possible spiral development approaches will be explored. The conclusions will highlight the adaptability of this system to meet many diverse missions, utilizing lightweight vehicle platforms.*

## **1.0 BACKGROUND**

### **1.1 BACKGROUND**

The Multi Role Armament and Ammunition System (MRAAS) was a unique armament system developed as a technology base program oriented around the goals of the Future Combat System (FCS): The FCS was defined in the following text:

“The Future Combat Systems will be a multi-functional, multi-mission re-configurable system of systems to maximize joint inter-operability, strategic transportability and commonality of mission roles including direct and indirect fire, air defense, reconnaissance, troop transport, counter mobility, non-lethal and C2 on the move. [1]

The MRAAS was intended to show a ‘multi-role’ armament system is capable of fulfilling the first three (3) mission roles. While originally intended as a cannon based armament system, it is fully expected if the demonstration program were to receive sponsorship to move into later development, missile

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## **Multi-Role Armament & Ammunition System (MRAAS) Cannon**

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launch capability would be added in all roles.

### **1.2 Terminology**

### **1.3 Previous Experience – Large Caliber Cannons on Light Vehicles**

Blos: beyond line of sight, los: line of sight

Sto: science & technology objective

Trl: technology readiness level

Mast: mcs ammunition system technology

Eti/etc: electrothermal ignition/electrothermal-chemical

## **2.0 OBJECTIVES**

### **1.1 Overall Program Objectives:**

The objectives of the MRAAS program, as defined by the Program Manager, Manuever Ammunition Systems (PM MAS), was to assist the US Army in determining material needs and associated requirements for its Future Combat System (FCS) and to identify and advance pacing armament & ammunition technologies that will help meet FCS material needs and requirements

### **2.2 Cannon System Objectives:**

The performance objectives of the MRAAS Gun, as defined by the PM MAS and Benet Laboratories were to demonstrate a multi-role capability (direct & indirect fires), while firing-on-the-move, and to demonstrate ranges of 0 - 4 km (in direct fire mode and 2 – 50 km (in indirect fire mode). The cannon must be capable of elevating from -10 to + 55 degrees, attaining a burst rate of fire of 15 – 20 rounds per minute, and in general to be compatible with a lightweight vehicle, defined as the entire system weighing less than 18 tons (U.S.)

## **3.0 AMMUNITION:**

While the subject of this paper is not the ammunition, the ‘leap ahead’ technologies developed at Picatinny Arsenal and ARMTEC, Inc and incorporated into the ammunition enabled the cannon to demonstrate ‘leap ahead’ technologies as well. A short description will enable the reader to visualize the cannon more clearly. The overall concept developed was a cased telescoping approach with a programmable, steerable round. See Figure 1. This right circular cylinder allows easy autoloading and handling. This approach also eliminated the need for zoning since the smart projectile and gun pointing will allow for range correction and Multiple Round Simultaneous Impact (MRSI) missions. This could also extend effectiveness by allowing the cannon to point at some angle away from the target and allow the round to approach the target from the flank (side). The ammunition development team also examined

## Multi-Role Armament & Ammunition System (MRAAS) Cannon

innovative integration approaches to combine the packaging and cartridge into a plastic cased round that would be ejected after use. This would result in a recyclable, autoloading, more environmentally-friendly unit. An optional approach would be to utilize a more conventional combustible case with rigid end caps and a conventional shipping separate container.



Figure 1: MRAAS Cased Telescoped Cartridge.

## Multi-Role Armament & Ammunition System (MRAAS) Cannon

### 4.0 OVERALL CANNON CONCEPT

The basic concept chosen, after a down select, was a swing chamber breech mechanism, similar to the ARES guns developed in the 1980's. See Figure 2. While the original parametric studies indicated that a 110 mm bore would be optimal, a 105 mm size was chosen due to availability of tooling and forging blanks. The chamber was sized to be similar to current 120 MM Cannon chamber volumes [2]. The tube travel was set at 5400 mm based on ballistic studies and modelling to balance current tank gun lethality capability and a 50 km indirect fire range. In addition to this, the cannon was designed for complete remote actuation with high reliability. Wherever a system incorporated some element of risk, a back up or secondary capability was planned. For example, the electric swing drives for the chamber were designed to allow dual drives – but one (1) drive motor could operate the breech in a slower mode. This breech also incorporated additional electrical actuation of the seal elements within the breech and ElectroThermal Chemical ignition. The breech element utilized a composite tube support that formed the rear part of the environmental shroud. The tube concept included an advanced bore coating, a composite jacket for stiffening, an environmental signature reduction shroud, and an integral muzzle brake.

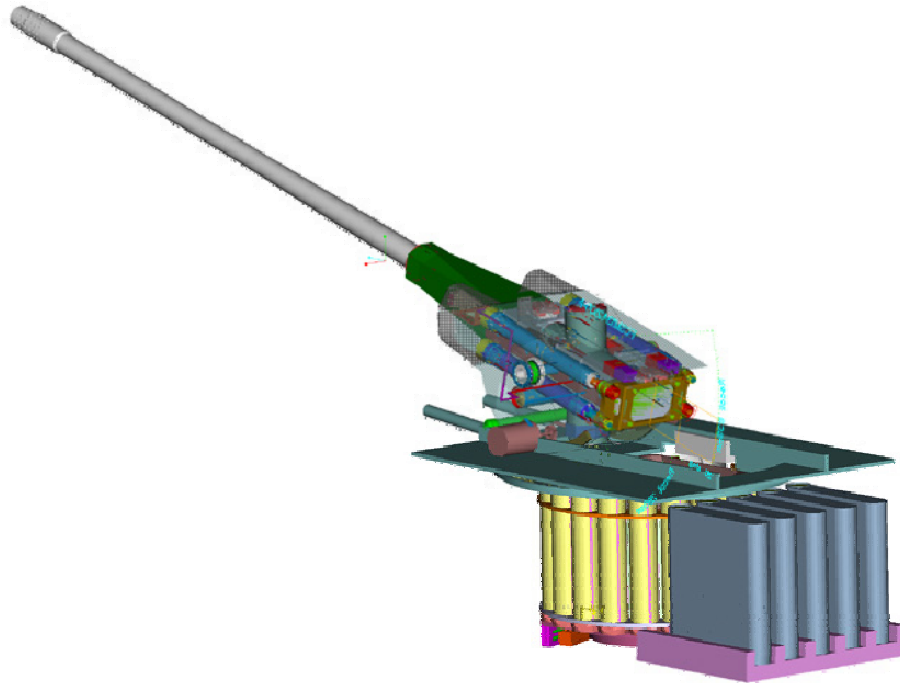


Figure 2: MRAAS System Concept Showing Potential Autoloader Configuration

## 5.0 TECHNOLOGY THRUSTS

### 5.1 Integral Muzzle Brake:

The concept of an integral muzzle brake has been around for nearly 100 years. It is only recently that it has been applied to large calibre cannons. In the mid 1980's through the mid 1990's, Benet Labs has applied this technology to various cannons. It has numerous advantages over separate brakes, including lower cost, better exit stability for the projectile, and reduced flash potential. Numerical models have been developed that estimate the impulse reduction and tube stress. Only limited models are available that would predict the blast fields. The MRAAS program pioneered the use of extensive computational fluid dynamic models to estimate forces and blast fields utilizing solid models. This allowed the designers to examine an number of geometries to minimize effect on light vehicles and the tube elements. This could also allow for future design of lightweight environmental and survivability shrouds

### 5.2 Composite Tube Support:

In normal gun systems, a sleeve or rails support the breech and tube as an assembly. In this case, to minimize width, the breech would attach to the recoil elements and would support the tube. To prevent the threaded connection between breech and tube from being the only load transfer point, a concept for support and stiffening of the tube to breech connection was required. A tube support element was developed that would utilize the large forward surface of the breech to provide a base, and a support structure that would reach out to support the tube at approximately 1 meter from the breech. To keep the weight imbalance low, the item would be made of composites, the first time that Benet has used a composite element as a support element in a gun assembly. Note that this item differed from the composite tube in that it had no pressure to withstand. The final concept utilized titanium end frames and carbon fiber shell. Its shape was optimized to become part of future survivability suite with the shroud. The tube interface utilized the standard Benet tube interlock that allows tube dilation without restriction. See Figure 3.



Figure 3: 105 MM MRAAS Tube with Composite Overwrap

## Multi-Role Armament & Ammunition System (MRAAS) Cannon

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### 5.3 Composite Tube:

The key area for weight reduction in any gun system is the cannon tube. Normally, weight reductions here are traded off against tube stiffness and pressure capability and recoil mitigations. Benet Labs has been designing and building composite tubes for over 20 years, and utilizing this experience, we have been able to eliminate the first two (2) areas from trade off. The MRAAS composite tube weights 15% less than a steel tube of equivalent stiffness and pressure capability, resulting in a system level weight reduction when balancing the muzzle brake and its recoil mitigation. In addition, this design improved gun balance by shifting the center of gravity closer to the trunnions. The design of the composite improved the dynamic strain mitigation that could be achieved by an all steel design. As part of the concept, the tube stiffness remained unchanged from an all steel version to ensure a direct comparison of accuracy and other parameters. During the design, it became clear that, in the future, the stiffness could be increased while still preserving weight savings

### 5.4 Titanium Components:

As part of the concept and drive to save weight, the costs and benefits of non-traditional gun materials were examined. It was surmised that extensive use of titanium components to save weight would be cost effective. The historical barriers to the use of titanium include cost, questionable performance in gun fatigue environments, and formability. The first factor is being overcome by the increased system desire to save weight. The second factor was addressed by improved modelling and in-house testing that addressed fatigue characteristics of titanium used in critical structural elements. The final issue is being addressed throughout industry as rapid prototyping and casting have become commonly used. Benet Labs utilized in house Stereo Lithography mold development and direct model transfer to casting vendors to speed development of parts. Following this, new cutting tools and computer numerical control programs reduced the final cutting time of the parts. See Figures 4 and 5.

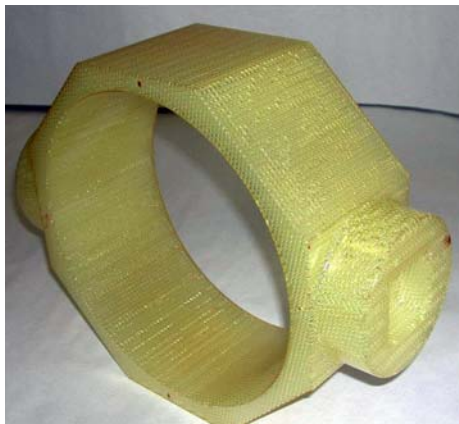


Figure 4: SLA Blank Trunnion Block



Figure 5: Cast Titanium Block

## **5.5 Recoiling Electrical Components:**

Most modern large calibre gun systems incorporate a separate gun control system and sensors. In the MRAAS, to facilitate remote operation and high reliability, the number of sensors and actuators were increased and made as rugged as possible. Here, Benet Labs leveraged the 'make-break' connectors and logic developed for the XM297 Crusader Gun System and expanded the sensors and electrical capacity on the recoiling parts while eliminating the need for recoiling cables. On the MRAAS, the seal drives utilized compact linear motors for breech seal actuation on recoiling breech and utilized rotary motors to adjust brakes for variable recoil on cradle. Electrically actuated clutches engaged non-recoiling motors through the trunnions to swing the breech open and closed. All of the systems and sensors employed redundancy whenever possible. A Standard Army Vetronics Architecture (SAVA) compatible local bus system allowed for the easy insertion and removal of design elements. Cable check circuits were utilized to allow built in system test capability.

## **5.6 Variable Length Recoil Brakes:**

The gun mount elements were primarily developed by a team at Picatinny Arsenal. They worked closely with the cannon elements to ensure a carefully balanced recoil system design. One key element incorporated here as a rotary electric motor built into the mount that adjusted brake recoil stroke. By actuating control elements in the brake modules, the recoil length could be varied based on elevation and ammunition. During the demonstration firing, indirect fire at  $-3^{\circ}$  to  $+55^{\circ}$  elevation recoil strokes would be set at 482.5 mm (19 inches) and the direct fire at  $-10^{\circ}$  to  $+20^{\circ}$  elevation would be set at 635 mm (25 inches). This would enable gun recoil envelopes to be adjusted for vehicle and ammunition parameters.

## **5.7 High Strength Steel:**

Recent industry developments have resulted in a number of new processes and alloys in the steel industry. A new high strength steel used in the MRAAS system allowed a minimum of a 10% increase in yield strength, with no decrease in toughness from current steel alloys used in gun design. This allowed higher pressures and thinner cross sections to be used in this design. Performance was verified by fatigue testing and analysis conducted on samples that indicate good performance in cannon environment

## **6.0 TECHNICAL COMPATIBILITY**

A number of elements or technologies were planned for fabrication or compatibility with the MRAAS system, but could not be included in the firing demonstrator due to time or expense. The MRAAS system was specifically designed to ensure that these elements would be compatible with the basic design, should the need arise to incorporate them. These items include:

- ElectroThermal Chemical/ElectroThermal Ignition (ETC/ETI): A concept to utilize a high energy

## **Multi-Role Armament & Ammunition System (MRAAS) Cannon**

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electrical plasma and special ignitor to initiate the conventional propellant bed.

- RAREFACTION WAVE VENTING (RAVEN) COMPATIBLE (1<sup>st</sup> Level): A patented technology to vent combustion gases out the rear of a cannon to reduce recoil.
- Fire-Out-Of-Battery (FOOB): A recoil system that allows the cannon to be pulled out of battery, released to travel into battery, fired, and the firing loads to push the cannon back into battery.
- Hybrid Muzzle Brake (External And Integral): The use of an external muzzle brake with an internal muzzle brake to increase brake efficiency and to re-direct gases.
- Survivability/Environmental Shroud: A shroud to both equalize thermal and environmental effects that affect tube straightness and to provide signature reduction capability to the tube.
- Advanced Bore Coatings: While the tube was Hard Chrome (HC) plated – it was compatible with Low Contractile (LC) Chrome or Tantalum.

## **7.0 MODELING AND SUBCOMPONENT TESTS**

### **7.1 Modeling:**

Extensive modelling of gun systems have been employed in recent years to reduce development schedules and costs. The MRAAS utilized extensive modelling including Finite Element Analysis (FEA) of all pressure vessel components and mount structure, numerical and fluid dynamic analysis of the integral muzzle brake, MATLAB ® system modelling of swing chamber dynamics, and numerical analysis of brake and recuperator models 1.

### **7.2 Subcomponent Testing:**

To complement modelling, an analysis of key risk elements was conducted. This identified key elements whose failure could cause major system impacts. Laboratory testing of these elements were conducted to reduce risk and prove design assumptions. Some of the testing included cycling breech drives to confirm mechanical element performance and software, pressure testing of seals in fixtures, static deflection of tube under load, and cycling of the mount system in a gymnasticator.

## **8.0 TEST FIRING**

In the spring and summer of 2003, the MRAAS launcher was transported to Aberdeen Test Center and installed in facility mount. Eleven rounds were fired during the early summer. Both direct and indirect fire modes were demonstrated. See Figures 6 and 7.

## **9.0 TEST RESULTS**

During firing, over 90 channels of data collected during each round. Among other parameters, strain at



**Multi-Role Armament & Ammunition System (MRAAS) Cannon**

various locations on the tube and breech were measured, muzzle velocity and peak pressure readings were taken, muzzle velocity and range were measured, tube deflection and whip examined, and blast overpressure fields were measured.



**Figure 6: MRAAS Firing in Direct Fire Mode**



**Figure 1: MRAAS Firing in Indirect Fire Mode.**

## 10.0 CONCLUSIONS

The MRAAS Gun System successfully demonstrated:

- Muzzle velocity to attain a 2-50 km range.
- Large caliber swing chamber cannon configuration feasibility
- Large caliber cased telescoped ammunition.
- 3rd generation composite wrapped large calibre gun tube
- Titanium and composite structural elements
- High strength steel in gun applications
- Integral muzzle brake
- Recoiling linear electric motors.



**Multi-Role Armament & Ammunition System (MRAAS) Cannon**

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- [1] FCS Public Briefings presented on US Army Tank Automotive Command (TACOM) Industry Day, Ypsilanti, MI on January 11, 2000 By GEN Eric Shinseki.
- [2] NATO Standardization Agreement 4385: 120 MM X 570 MM Ammunition For Smooth Bore Tank Guns