# 120 MM XM360 Gun Technology Base Transition into Future Combat System (FCS) System Design & Development (SDD) Program


TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

BRIEFING TO THE GUNS & MISSILES SYMPOSIUM
23 APRIL 2008

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

US Army ARDEC Weapon Systems & Technology Directorate
BENÉT LABORATORIES

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- BACKGROUND – AS EARLY AS 1999, THE US ARMY PM MANEAUVER AMMUNITION SYSTEMS, PM LETHALITY, PM FUTURE COMBAT SYSTEM RECOGNIZED A NEED FOR A HIGHLY LETHAL GUN SYSTEM TO PROVIDE COMBAT FIREPOWER FOR THE MOUNTED COMBAT SYSTEM.
- COMBINING FORCES WITH GENERAL DYNAMICS LAND SYSTEMS, ARDEC WS&T BENET LABORATORIES DEVELOPED A LIGHTWEIGHT 120 MM GUN ASSEMBLY THAT UTILIZED THE PROVEN 120 mm FAMILY OF AMMUNITION, AND COULD BE INSERTED INTO A LIGHTWEIGHT ARMOURED VEHICLE.
- BENET LABORATORIES DEMONSTRATED THIS SYSTEM IN 2004
- BENET UNDERTOOK AN INDEPENDANT TECHNOLOGY BASE PROGRAM TO MATURE THIS SYSTEM TO TRL 6 AND DESIGNATED IT THE XM360 120 MM GUN ASSEMBLY
- IN 2004 – GDLS RECOGNIZED THE CLEAR ADVANTAGE OF THIS SYSTEM AND SELECTED IT FOR USE ON THE MOUNTED COMBAT SYSTEM – IN OCTOBER 2005 – GDLS & BENET LABORATORIES SIGNED A CRADA FOR BENET TO DESIGN DEVELOP AND DELIVER THIS GUN IN A SYSTEMS DESIGN & DEVELOPMENT PROGRAM
- FROM 2005-2007 BENET INDEPENDANTLY PURSUED ADDITIONAL LARGE CALIBER ENHANCEMENTS FOR ALL FCS PROGRAMS AND TRANSITIONED THEM INTO THE XM360 AND THE XM324 PROGRAMS

# XM360 LAEP
# SCHEDULE & APPROACH



| MILESTONE | FY03 | FY 04 | FY05 | FY06 | FY07 | FY08 | FY09 | FY10 | FY11 |
|---|---|---|---|---|---|---|---|---|---|
| VDRD DEMONSTRATOR | | | | | | | | | |
| TECH BASE - ATD | | | | | | | | | |
| LAEP 120-7 TEST | | | | | | | | | |
| LAEP 120-8 TEST | | | | | | | | | |
| XM360 MCS EVENTS | | | | △ SFR | | △ PDR | △CDR | | |
| XM360 GUNS | | | | | △ | FF△ FTR | | MCS VEHICLES | |
| TESTS | | | | | | FF | FTR | IQT | |
| IPF | | | | | | | | | IPF |
| | | | | | | | | | |
| FUNDING | | | | | | | | | |
| TECH BASE | X | X | X | X | | | | | |
| PM UA | | | X | X | | | | | |
| GDLS CRADA | X | | | X | X | X | X | X | X |

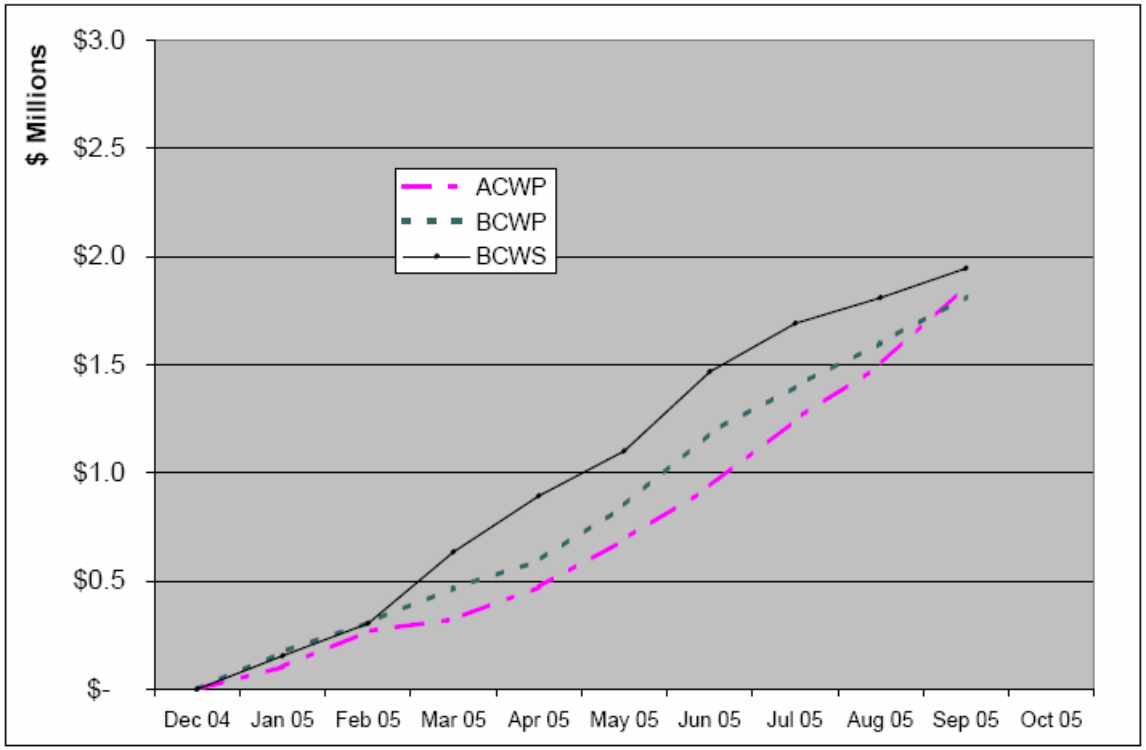
- **APPROACH - STRATEGY:**
  - CREATE THE ANALYTICAL TOOLS REDUCE TESTING COSTS
  - PARTNER WITH INDUSTRY, WATERVLIET ARSENAL, ROCK ISLAND ARSENAL, ARMY RESEARCH LAB, MANUFACTURING TECHNOLOGY PROGRAMS TO ENSURE IDEAS WORKED TOGETHER
  - DEMONSTRATE NOT JUST THE TECHNOLOGY BUT THE MANUFACTURING PROCESSES AS WELL
  - WORK WITH INDUSTRY PARTNERS TO TRANSITION THIS TECHNOLOGY INTO THEIR PRODUCTS

# XM360 LAEP Milestones



| | |
|---|---|
| • LAEP Program Start | 20 Jan 05 |
| • ATD Test Phase 2/3 Complete at ATC | 08 Aug 05 (Revised) |
| • LW 120-6/7 Preliminary Design Review | 12 Dec 05 |
| • ATD Test 4A HW Delivered to ATC | 10 Aug 06 (Revised) |
| • ATD Test 4A Complete | 31 Aug 06 (Revised) |
| • ATD Tube 5 Fabrication Start | 01 Jun 05 |
| • Critical Design Review – LW 120-6/7 | 31 Apr 06 (Revised) |
| • ATD Tube 5 HW Delivered to ATC | 07 Feb 06 |
| • ATD Tube 5 Test Complete | 14 Jun 06 |
| • UHSS Steel Forgings Delivered | 23 Jan 06 |
| • LW120-6/7 Fabrication Start | 24 Jan 06 (Revised) |
| • LW120-6/7 Hardware Delivered to ATC | 28 Mar 07 |
| • LW120-6/7 Test Complete | 15 May 07 |

| EARNED VALUE MANAGEMENT WORKSHEET - LIGHTWEIGHT ARMAMENT ENHANCEMENT PROGRAM | PERIOD ENDING | 30 Sep 05 | 10/10 |
|---|---|---|---|




| CUMULATIVE PERFORMANCE | | |
|---|---|---|
| WBS | CPI | SPI |
| 1 | 0.734 | 0.879 |
| 2.1 | | |
| 2.1.1 | 0.862 | 0.950 |
| 2.1.2, 3.8 | 0.939 | 0.975 |
| 2.1.3, 3.9, 4.1.2 | 0.903 | 0.831 |
| 2.1.4, 3.11 | 1.790 | 1.336 |
| 2.1.5,3.10,3.26,4.1.9 | 0.840 | 0.493 |
| 2.1.6 | 1.454 | 1.000 |
| 2.1.10 | 0.000 | 1.000 |
| 2.2, 4.2 | 1.049 | 0.917 |
| 2.3, 4.3 | 1.110 | 1.035 |
| 3.4 | | |
| 3.27 | 0.451 | 0.500 |
| 4.4.7, 4.4.8 | 0.910 | 1.000 |
| | | |
| | | |
| 4.4.8 | | |
| 3.1 | 1.581 | 0.908 |
| 3.23, 3.24 | | |
| 3.2 | 0.000 | 0.436 |
| 4.4.1 | 0.456 | 1.000 |
| 4.4.2 | | |
| 3.25 | | |
| 3.3 | | |
| OVERALL | 0.973 | 0.939 |

| | | | |
|---|---|---|---|
| ESTIMATE AT COMPLETION (FY05) | $ | 1,973,583 | |
| BCWS | $ | 1,931,174 | (what progress we should have made) |
| ACWP | $ | 1,864,424 | (what we spent) |
| BCWP | $ | 1,813,379 | (what progress we have made) |

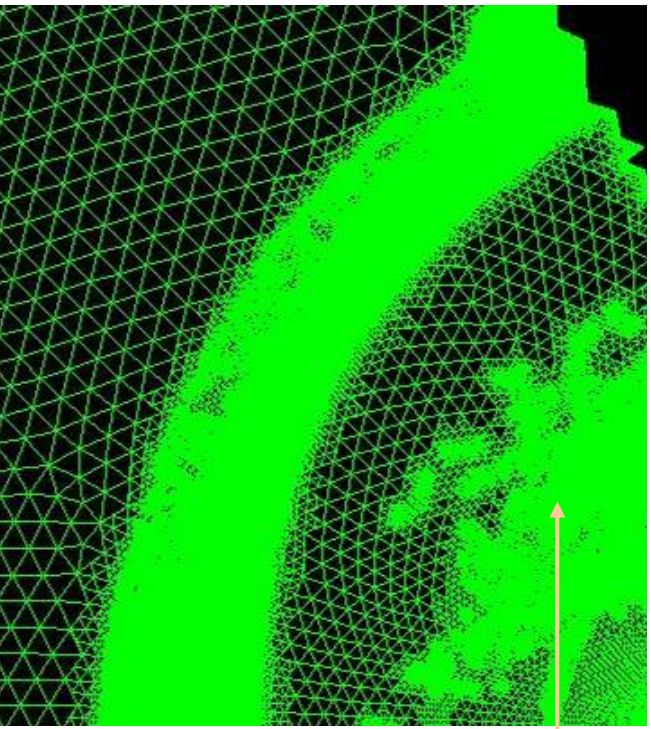
| ACTUAL SURPLUS | | $ 103,429 |
|---|---|---|

COMMENTS: Final Report
Some Unliquidated funds left
FY06 EVMS will include other measures earlier in year to identify problem areas

- **Project is complete**
  - Completed Final Report for the Sympathetic Detonation Barrier (SDB) effort.
  - 2 Major Patents Resulted
    - Multiple Autofrettage
    - Blast Wave Identification Protocol (BWIP)
  - Major Design Software Tool validated (BWIP)
    - Potential Commercial Software Licensing (BWIP)
    - Other CRADA work has been generated
- **Partnership of Tech Base programs with customer funded efforts was helpful**
- **Continuing gun/cannon Tech Base work is critical to maintaining CRADA funded programs and future business**

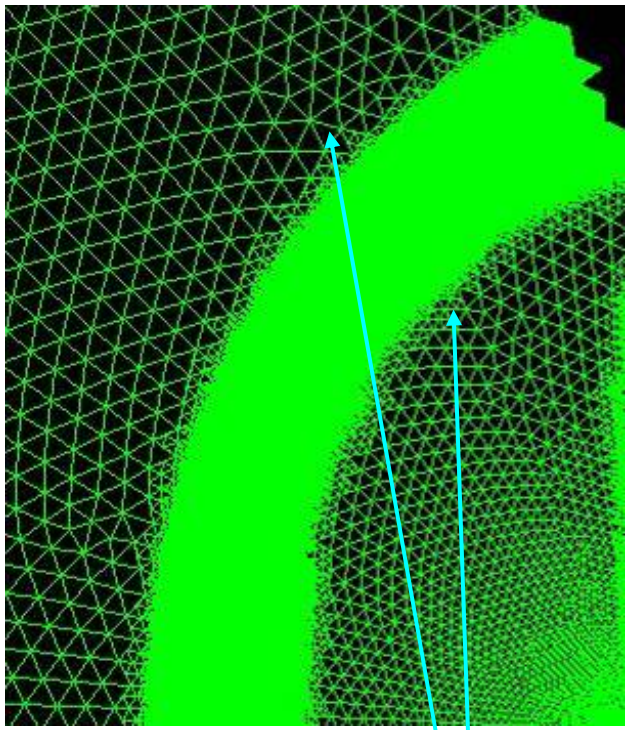
# FLUENT SOFTWARE MESH ADAPTION COMPARISON

## Original Technique



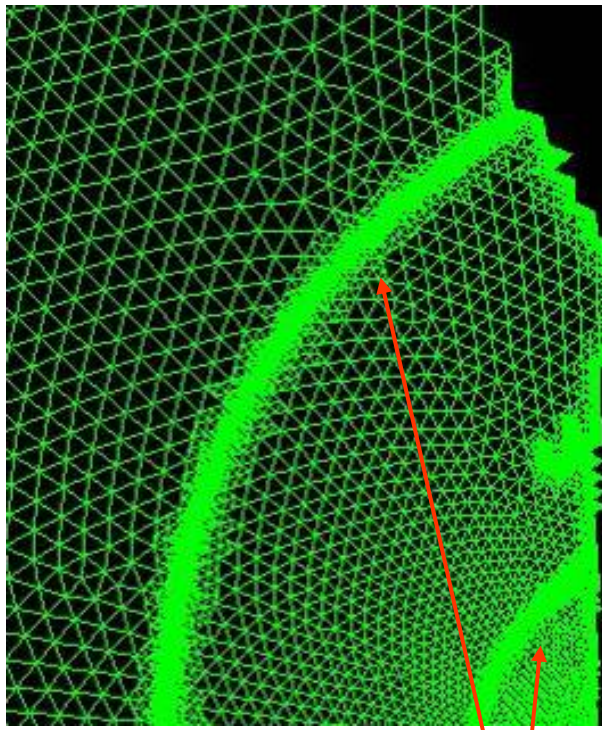
Unnecessary Adaption Behind Blast Wave

## Modified Technique



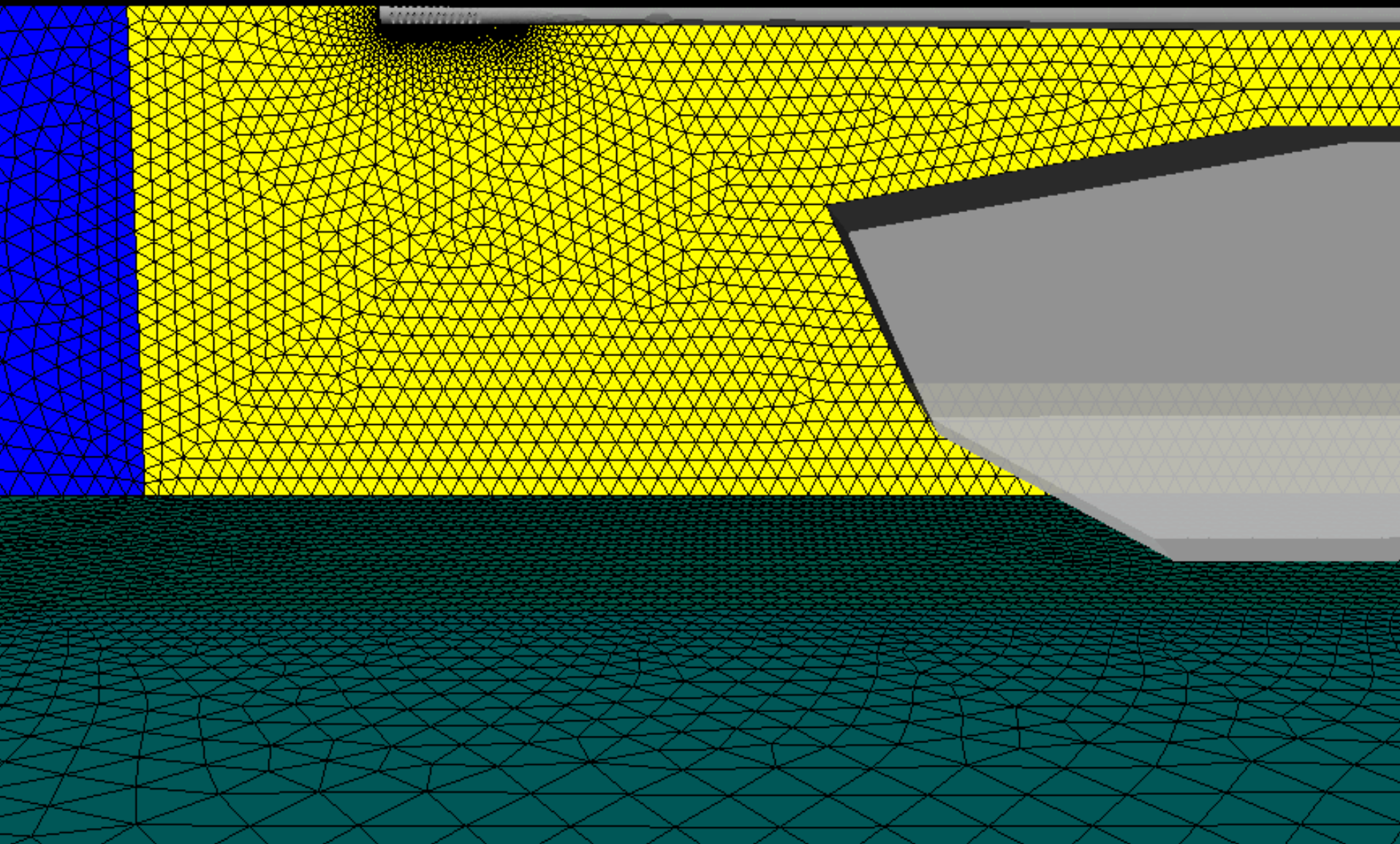
Better Identification Equals Adaption at Blast Wave Only

## New Technique

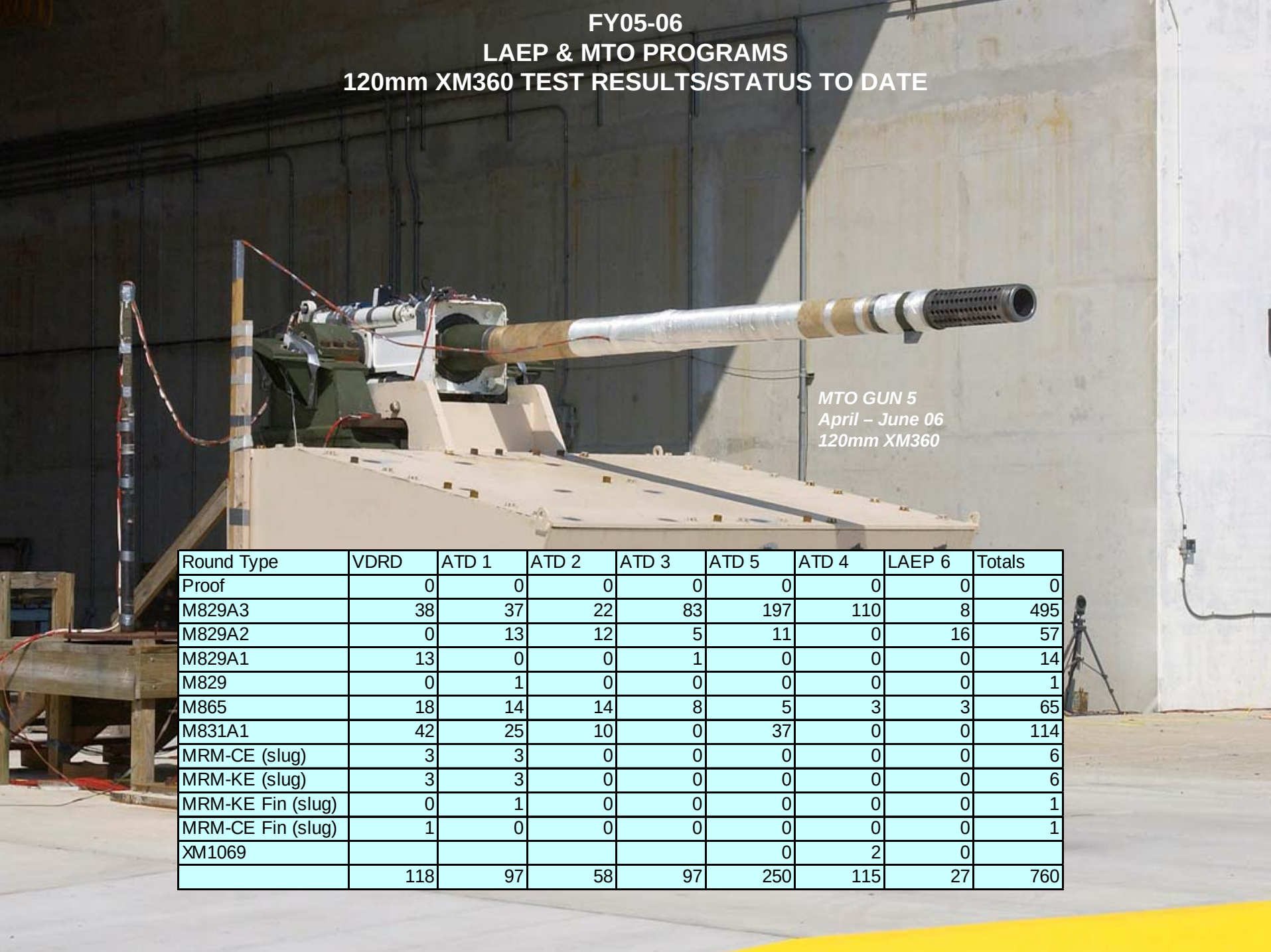


Filtering better identifies shock wave boundary (s)

# WS&T/BENET LABORATORIES
# LEVEL 3 REVIEW
# LIGHTWEIGHT ARMAMENT ENHANCEMENT PROGRAM
# (LAEP)



# FY05-06
# LAEP & MTO PROGRAMS
# 120mm XM360 TEST RESULTS/STATUS TO DATE

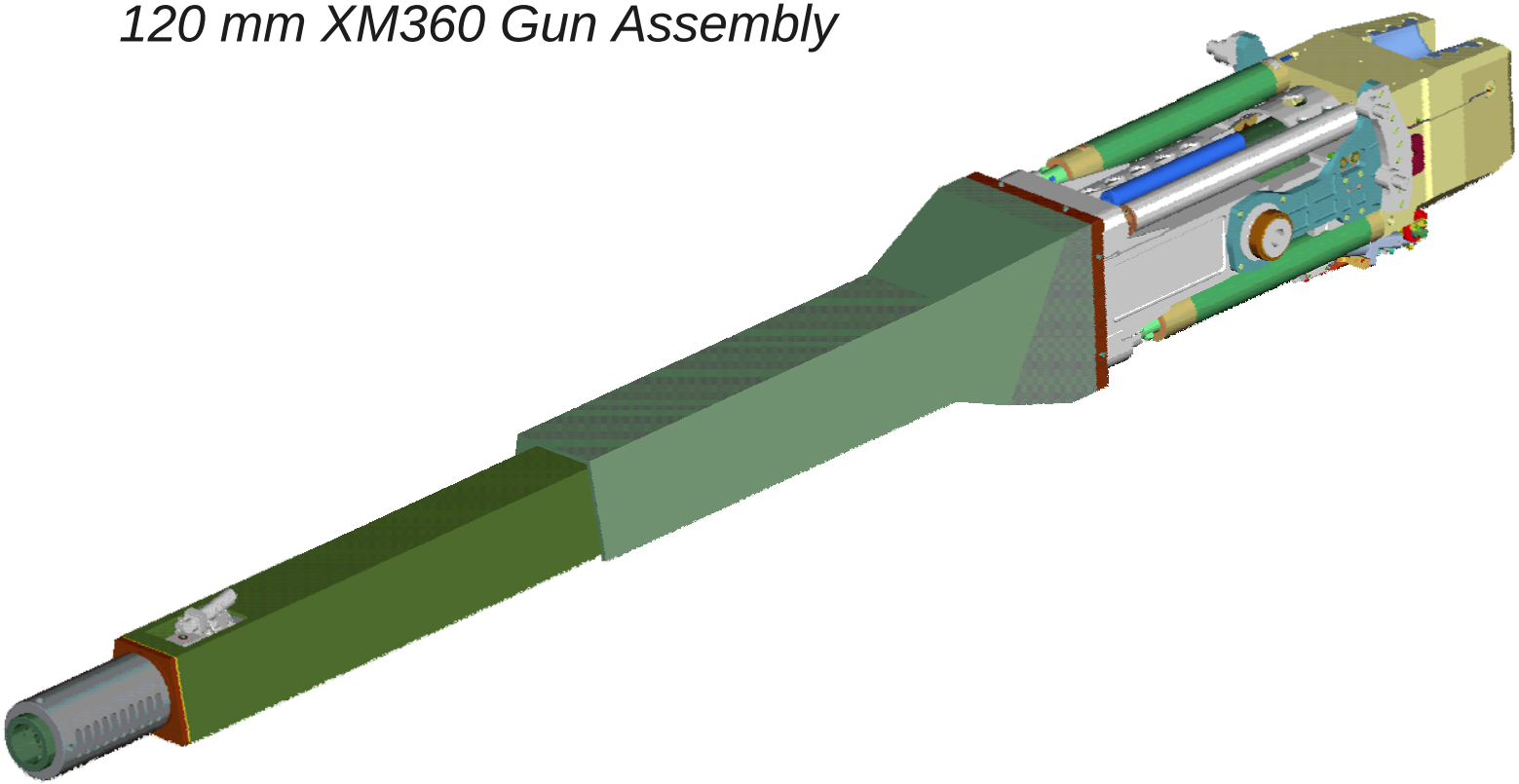


*MTO GUN 5*
*April – June 06*
*120mm XM360*

| Round Type | VDRD | ATD 1 | ATD 2 | ATD 3 | ATD 5 | ATD 4 | LAEP 6 | Totals |
|---|---|---|---|---|---|---|---|---|
| Proof | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M829A3 | 38 | 37 | 22 | 83 | 197 | 110 | 8 | 495 |
| M829A2 | 0 | 13 | 12 | 5 | 11 | 0 | 16 | 57 |
| M829A1 | 13 | 0 | 0 | 1 | 0 | 0 | 0 | 14 |
| M829 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| M865 | 18 | 14 | 14 | 8 | 5 | 3 | 3 | 65 |
| M831A1 | 42 | 25 | 10 | 0 | 37 | 0 | 0 | 114 |
| MRM-CE (slug) | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 6 |
| MRM-KE (slug) | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 6 |
| MRM-KE Fin (slug) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| MRM-CE Fin (slug) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| XM1069 | | | | | 0 | 2 | 0 | |
| | 118 | 97 | 58 | 97 | 250 | 115 | 27 | 760 |

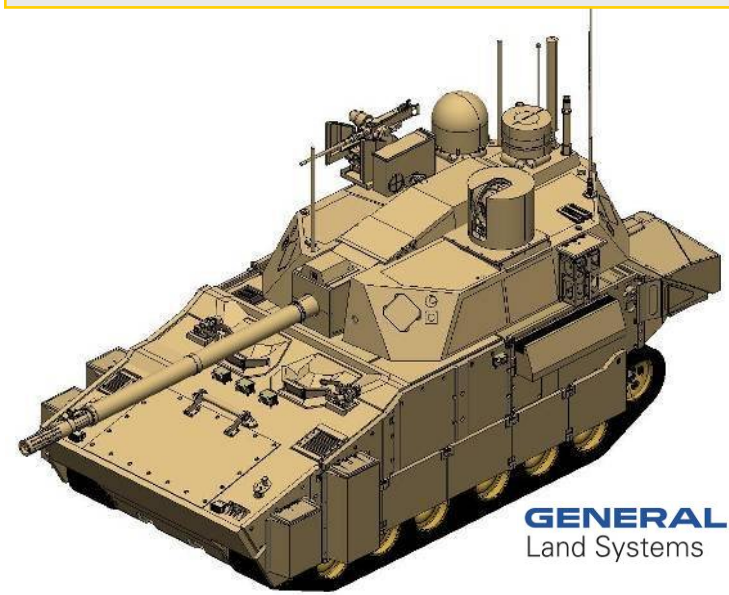
**300+ LBS WEIGHT REMOVED FROM XM360 GUN SYSTEM WHILE MAINTAINING SAME IMPULSE LEVEL, INCREASING ITS ACCURACY, AND REDUCING BLAST OVER PRESSURE**

*Lightweight Armament Enhancement Program*
*120 mm XM360 Gun Assembly*



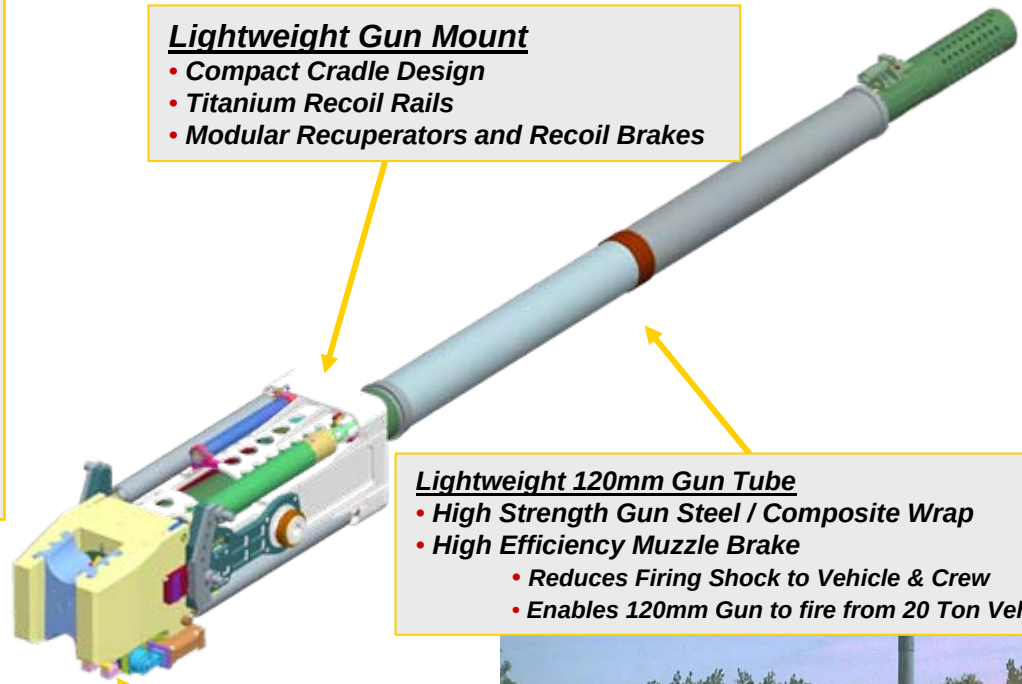
## *Primary Weapon for Mounted Combat System*

- *Provides direct fire in support of forces in the Unit of Action (UA).*
- *Beyond Line-of-Sight (BLOS) capability to 12 km with Medium Range Munitions (MRM).*
- *All the Performance of Current 120mm Cannon in a Light Weight, Compact Design*
- *Over 2,000 lbs lighter than 120mm Gun used on Abrams Tank*
- *Muzzle Brake & Recoil System Design Enables a 120mm Gun to fire from a 20 Ton Vehicle.*



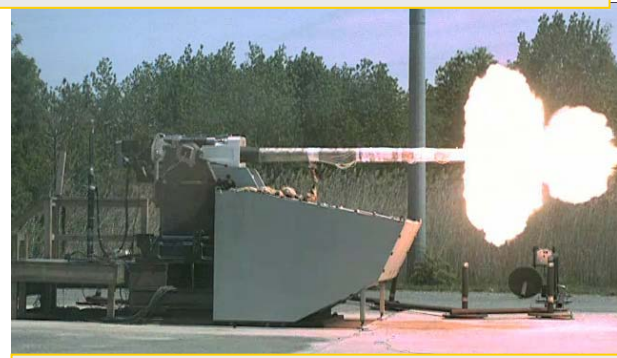
GENERAL DYNAMICS
Land Systems

***Lightweight Gun Mount***
- *Compact Cradle Design*
- *Titanium Recoil Rails*
- *Modular Recuperators and Recoil Brakes*



***Lightweight 120mm Gun Tube***
- *High Strength Gun Steel / Composite Wrap*
- *High Efficiency Muzzle Brake*
  - *Reduces Firing Shock to Vehicle & Crew*
  - *Enables 120mm Gun to fire from 20 Ton Vehicle*

***Multi-Lug Breech Mechanism***
- *Long Life, Compact, Light Weight*
- *600VDC Electrically Actuated*
- *Ammo Data-Link Enables Communication to Smart Rounds*



*•Gun Technology Demonstrated on Over 866 Rounds of Live Fire Testing*

## Mission

The XM360 is a 120mm high performance gun assembly being developed as the Primary Weapon Assembly for the Mounted Combat System of the Future Combat System. The mission of the XM360 is to provide lethality to defeat targets in the Line-of Sight (LOS) and Beyond Line of Sight (BLOS) areas. In simple terms the XM360 is being designed to provide the firepower of the M256 cannon assembly in the current M1A2 tank in a package over a ton lighter in weight. It also adds BLOS capability that the current system does not offer. The 360 will be able to fire all current US fielded 120mm ammunition plus all of the new 120mm rounds currently under development. This includes the new Mid Range Munition (MRM).

## Features

The XM360 gun assembly features a modular recoil system with embedded instrumentation to monitor gun performance in the unmanned turret of the MCS. It is designed to provide all necessary interfaces to the turret to facilitate the gun elevation and pointing electric drives. The 360 utilizes 600 VDC electric breech operation, and utilizes muzzle brake to reduce impulse to the MCS vehicle platform. The gun also includes a new ammunition data link. This feature allows communication of the fire control system with a bullet that is loaded in the gun. This allows passage of target location information to that bullet just before actual firing. Safety certification of the XM360 gun assembly has been initiated and will continue over the next few years.

## Background

The XM360 Primary Weapon Assembly (PWA) is being developed under a Cooperative Research & Development Agreement (CRADA) between General Dynamics Land Systems and ARDEC. After an extensive world wide search of available gun technology the XM360 PWA design and ARDEC were selected as being the most mature and capable gun design for the main armament of the Mounted Combat System of FCS .

# Milestones – XM360 Primary Weapon Assembly



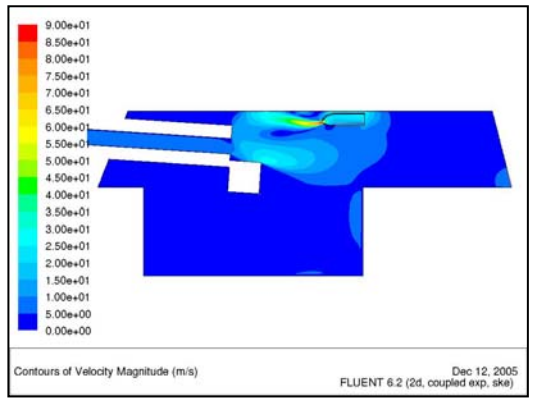
| | |
|---|---|
| • Started formal SDD for MCS PWA (Primary Weapon Assembly) | Oct 05 |
| • Delivery of PWA Emulator to GDLS SIL | Sep 07 |
| • Delivery of 1st PWA for turret integration and hardstand testing | Oct 07 |
| • PWA successfully passed proof firing and baseline accuracy firing | Nov 07 |
| • Blast overpressure and thermal bending test also conducted | Nov 07 |
| • GDLS & subs mate the gun, autoloader, fire control – Firing Fixture | Feb 08 |
| • Planned Testing at TACOM Motion Base Simulator | Jun 08 |
| • GDLS Firing Fixture goes to APG for firing tests | late 08 |
| • Testing of PWA 2 to be used to test for ISFL | Mar 08 |
| • Testing of PWA 3 to be used to test for ISFL | Jun 08 |
| • XM360 PWA Interim Safety Release | Mar 09 |
| • Delivery of 4 PWA for Final Safety Release | Nov 08 - Feb 09 |
| • Delivery of 6 PWA's for Vehicle Integration | Aug 09 - Feb 10 |

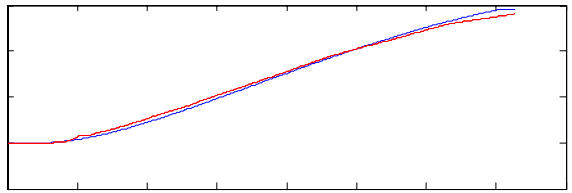
- Total Delivery: 15 PWA, 4 additional cannon, 2 spare tubes

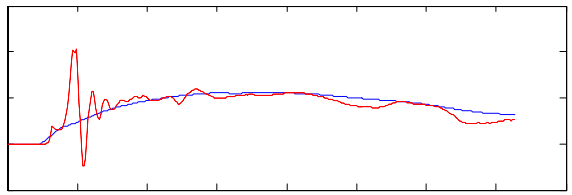
- Developer: US Army ARDEC - Benét Laboratories
- CRADA to: General Dynamics Land Systems
- Caliber/Type: 44 Caliber plus muzzle brake / High Pressure direct fire cannon
- Length: 5930 mm
- Range: 0 to 12 KM with Mid Range Munition
- Weight: 1865 kg
- Electric ignition/ breech operation
- Ammunition: All current 120mm US inventory & developmental

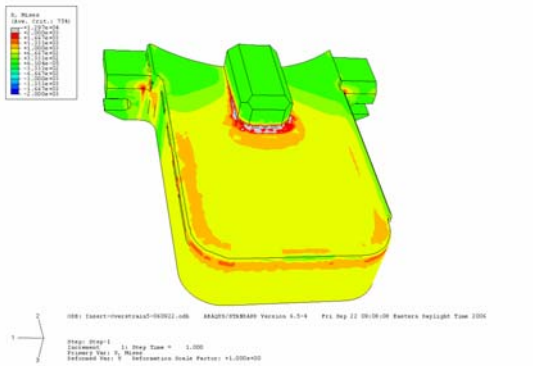
## *Examples of M&S To Reduce Development Time*

- **Computational Fluid Dynamics-**
  - Muzzle Break
  - Bore Purge
- **Finite Element Analysis-**
  - All major and critical components
- **MatLab-**
  - Breech Controls
- **Virtual Lab-**
  - Breech Mechanism



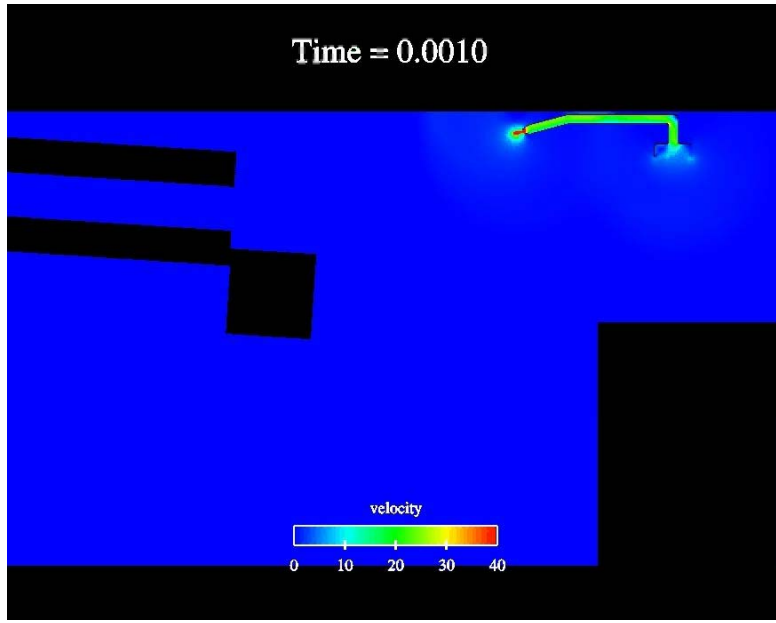



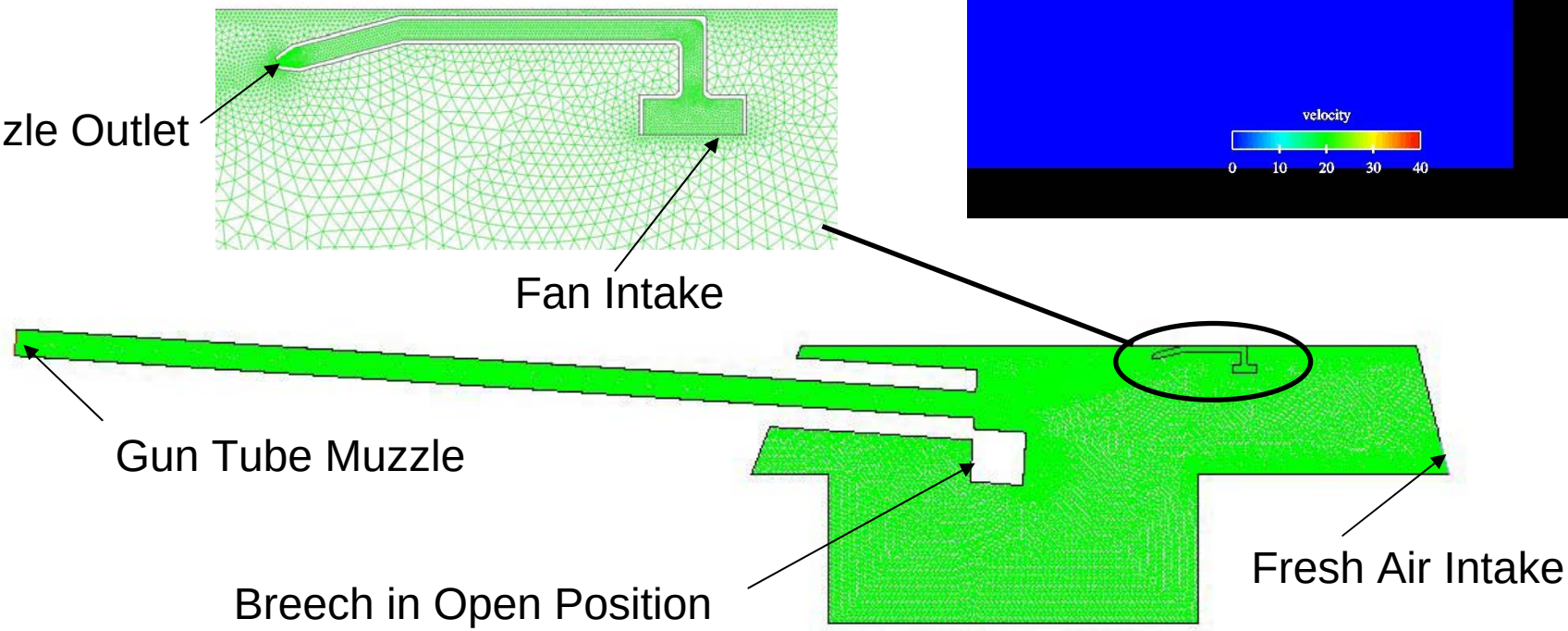


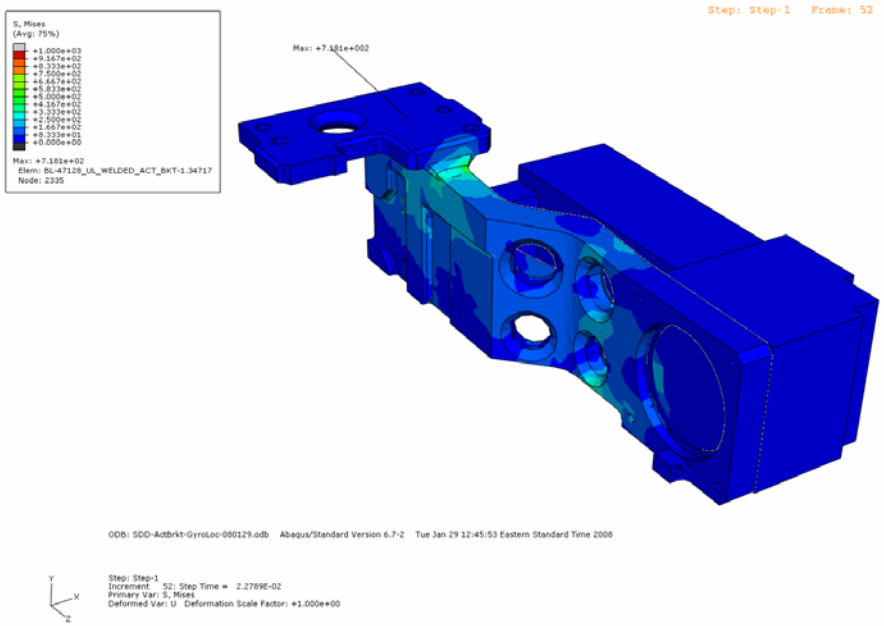


# Computational Fluid Dynamics

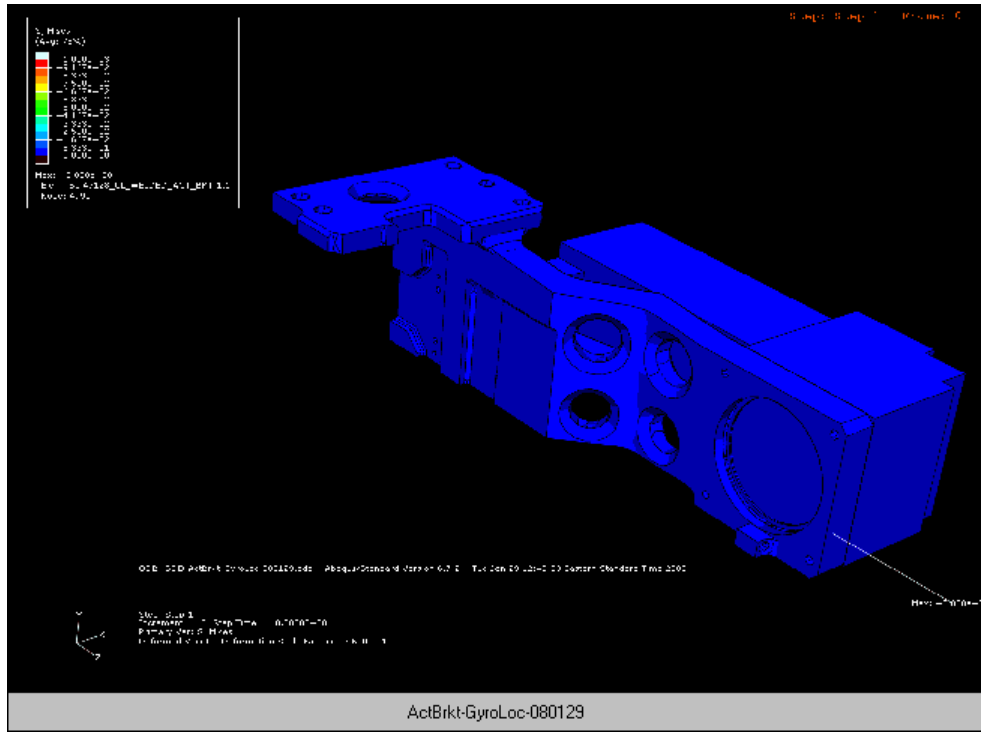
- **Fluent® 2-D CFD model of turret, basket, breech, barrel, nozzle, piping, fan system and fresh air intake.**
- **Steady-state, coupled-explicit, ideal gas model with k-epsilon turbulence model.**
- **Dynamic model without turbulence.**

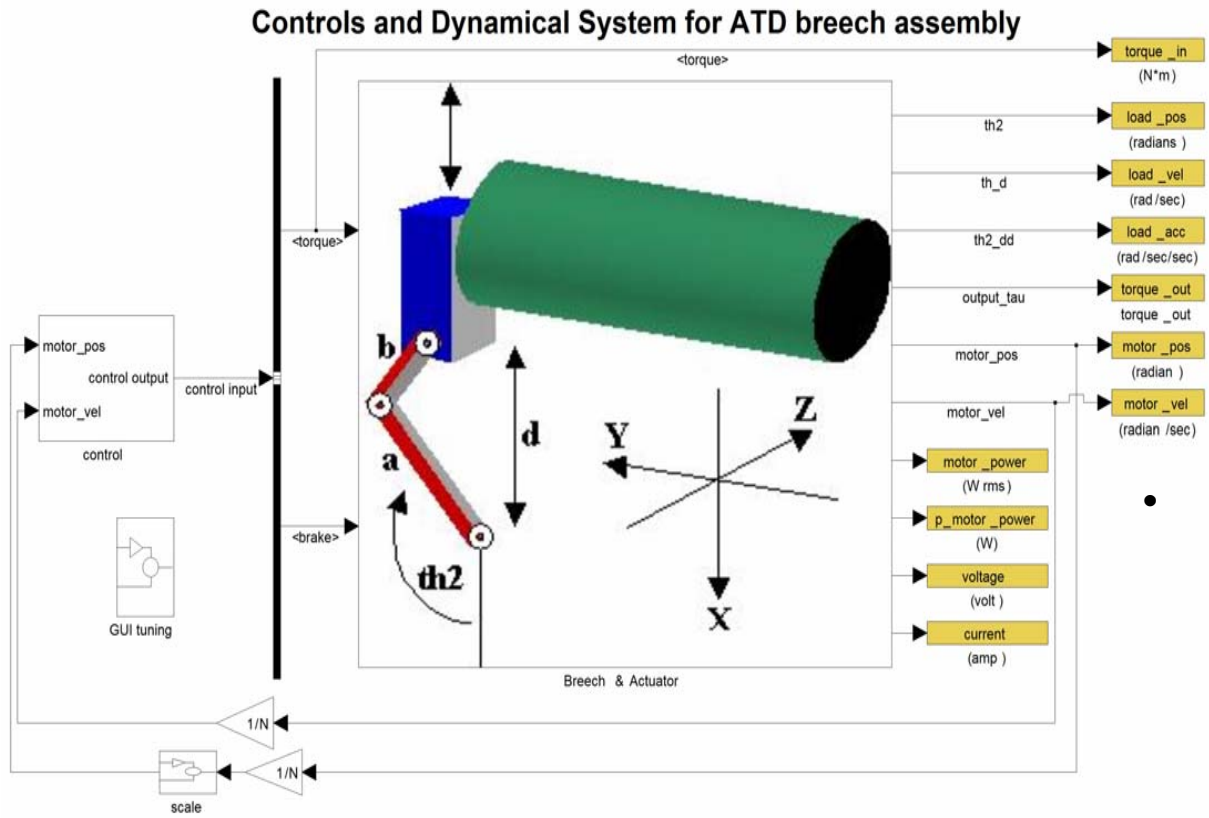


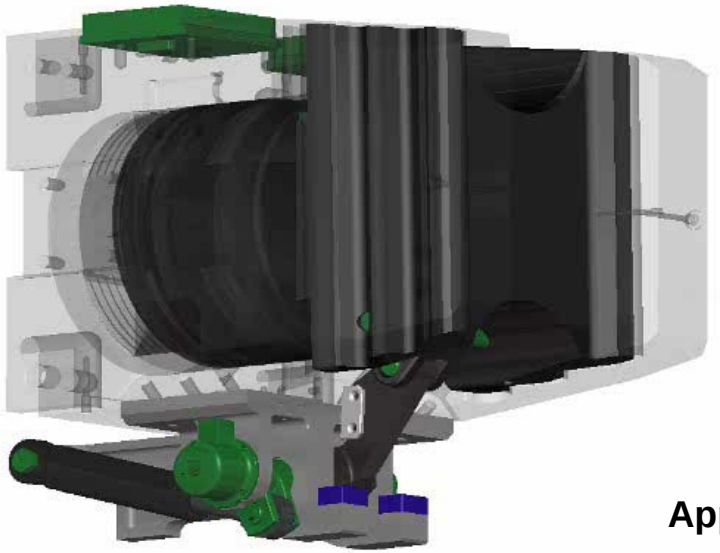


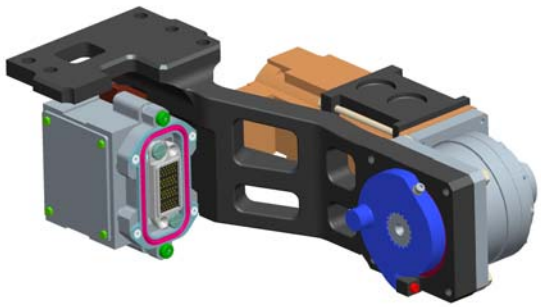

Breech Actuator FEA using accelerometer data taken during Baseline firing test of SDD01 Gun at APG.






- **Control design began in Matlab® using a hand coded dynamics model for an Advanced Technology Demonstrator (ATD) system.**
- **This allowed better prediction regarding changes in the actuation system.**





## LMS Virtual.Lab®

- Simulate realistic motion and loads of multi-body mechanical systems.
- Virtual.Lab® Standard Motion
  - Rigid body analysis
- Mechanical elements include spring, friction, contact forces, and an extensive list of joint and constraint features
- Dassault Systems: CATIA®, ABAQUS®

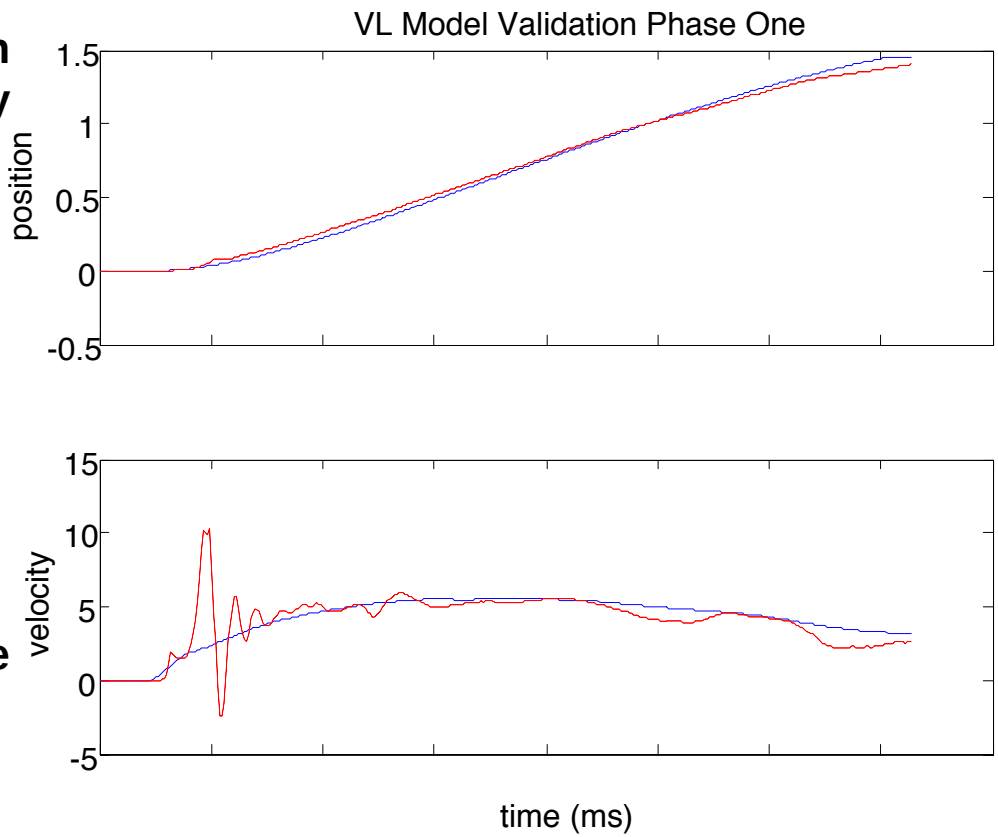
**Application Process**

- **Import Pro-E® part/assembly files**
- **Identify and apply joints at all interfaces**
- **Apply material densities for dynamic loading**
- **Apply external forces (i.e. gas spring preload and gravity)**
- **Apply constraints**
- **Apply motion parameters**
  - Coefficient of friction (steel on steel stiction and dynamic)
  - Crank travel angle for opening and closing
  - Time of 0.4s to complete half a cycle (open or close)
  - Gas Spring data from dynamic test on an MTS machine.

- **Virtual prototyping of the ATD breech mechanism that later transformed into the XM360 breech mechanism allowed design changes to be considered in a way not otherwise possible.**

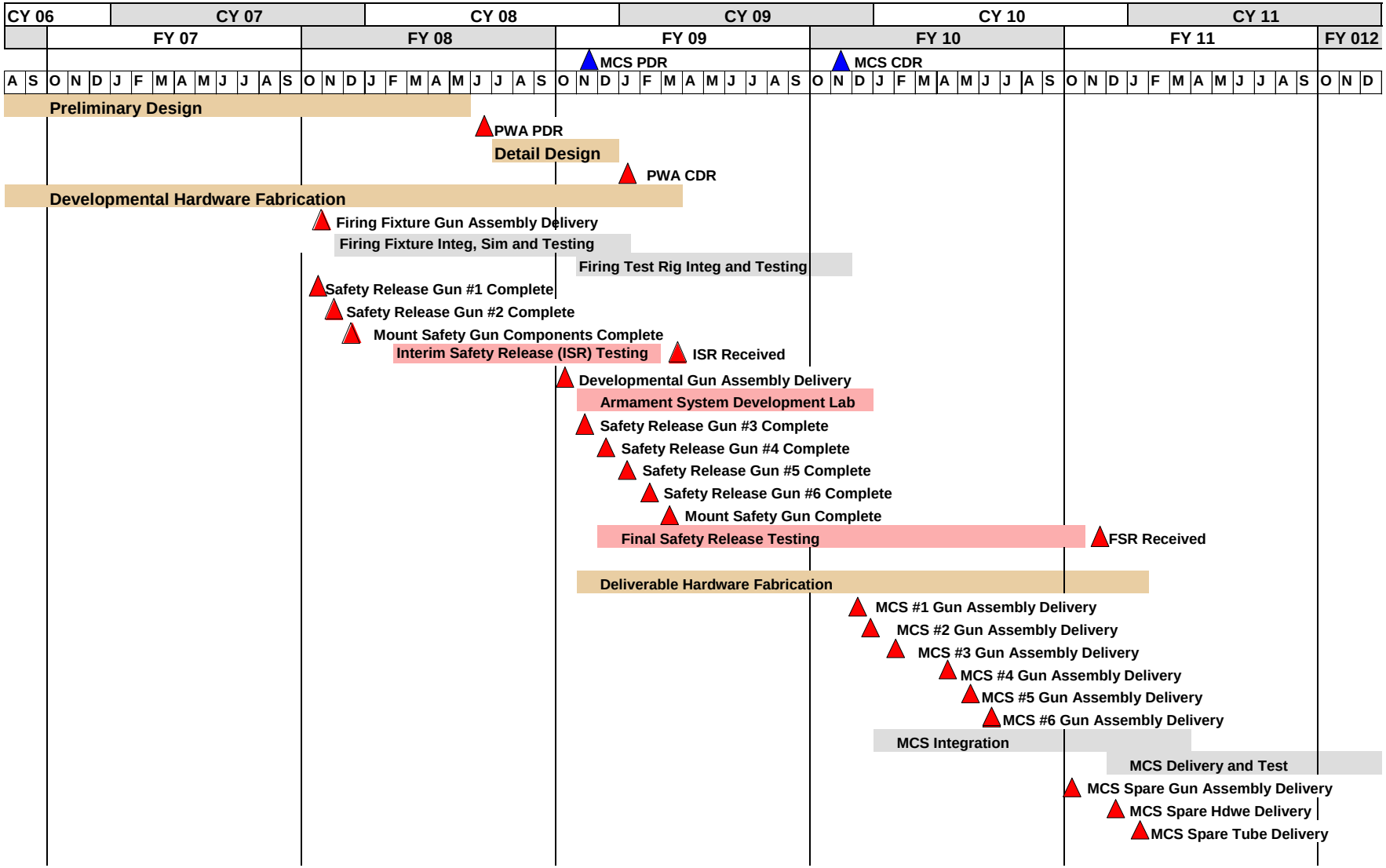
- **The validation process of virtual prototypes was and is indispensable, allowing accurate modeling using validation for the most uncertain design aspects.**

- **Across the design a more concurrent design was made more accurate, requiring fewer design iterations to meet system requirements.**



# PWA Overall Schedule





# XM360 PWA Summary