RDECOM

Malcolm Baldrige National Quality Award 2007 Award Recipient

Extended Area Protection and Survivability (EAPS) ATO

Fire Power Presentation

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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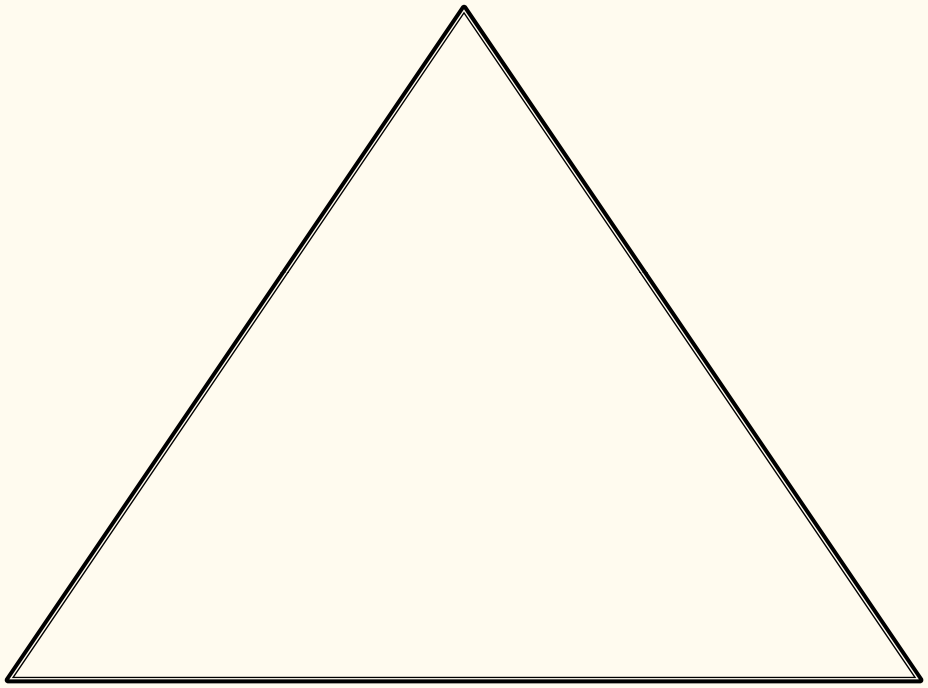
EAPS ATO Manager

10 June 2009

Briefing Themes

EAPS Development



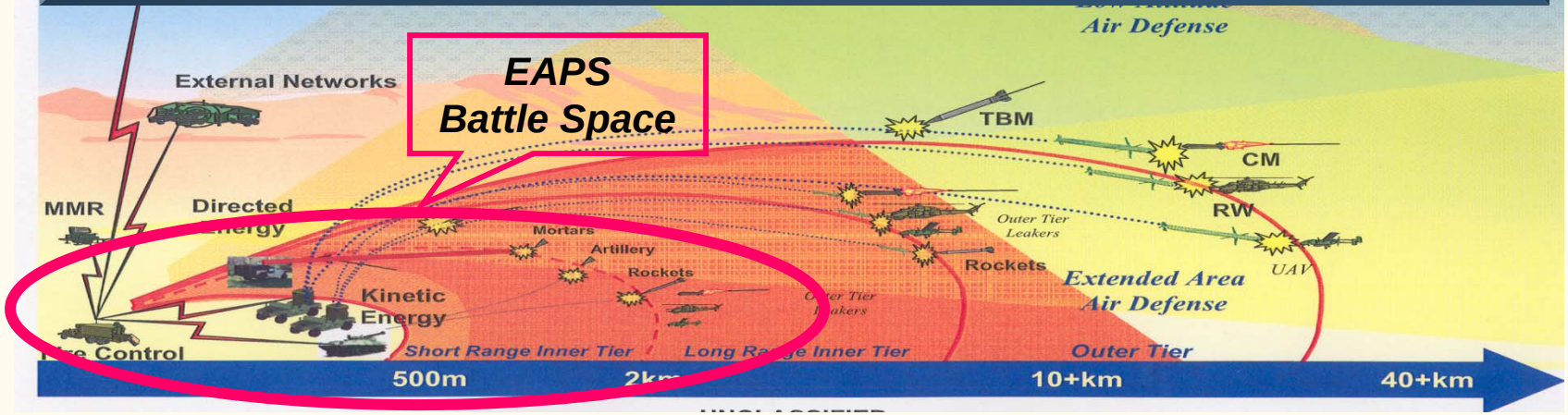
Air Defense

Command Guided
Direct Fire Ammo

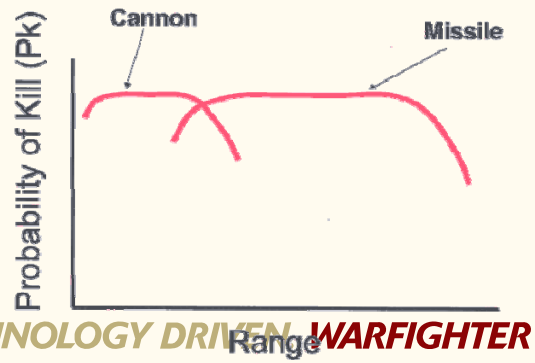
Special Thanks For Parts of This Briefing To:
Gary Moshier, Dan Ericson, & Lucian Sadowski

Program Goal and EAPS Battle Space

Develop and Demonstrate Critical Technologies for Bridging the Gap Between the Initial C-RAM Capability and the Objective EAADS Capability for Providing Mobile, 360-Degree Hemispherical Extended Area Protection from RAM Threats



- New Start Joint ATO with AMRDEC: FY09-13
- Goal is to Develop Technologies for 360 Degree Mobile Air Defense Against Rockets, Artillery and Mortars (RAM)
- ARDEC Pursuing Gun Based Solution for Short Range Inner Tier



EAPS Integrated Product Team

CONTRACTORS
- **ATK Mission Systems**
- **ATK Ammunition Systems**
- **Technovative Applications**

ARDEC
Assoc Dir Tech Base
Ms. Barbara Machak

PIO Office
C. Perazzo

CUSTOMERS
- **PM C-RAM: Mr. Van Rassen**
- **USAADA: Mr. Mike Cochran**
- **ASA(ALT): Ms. Mary Miller**
- **AMRDEC: Mr. Bill Nourse**
- **PM MAS: Mr. Ken Insco**

EAPS APO
M. Luciano
D. Tappe (ATK)

Systems Engineering IPT
SEL: D. Mao (Acting)
Systems Analysis:
D. Ericson and M. Knuteson
Planning: J. Martocci

EAPS DEL
G. Fleming
M. Danielson (ATK)

Weapon IPT
IPT Lead: Gary Moshier
ATK MCS COTR: A. Aeberli
(ATK): B. Glantz
Turret Design: B. McHugh,
Brian Forsberg
QA: Jorge Ruiz

Radar / FC IPT
IPT Lead: R. Shipe
(TA): D. Miller
Electronics: S. Khan
FC Consultant: M. Barbarisi
Instrumentation: J. Struck

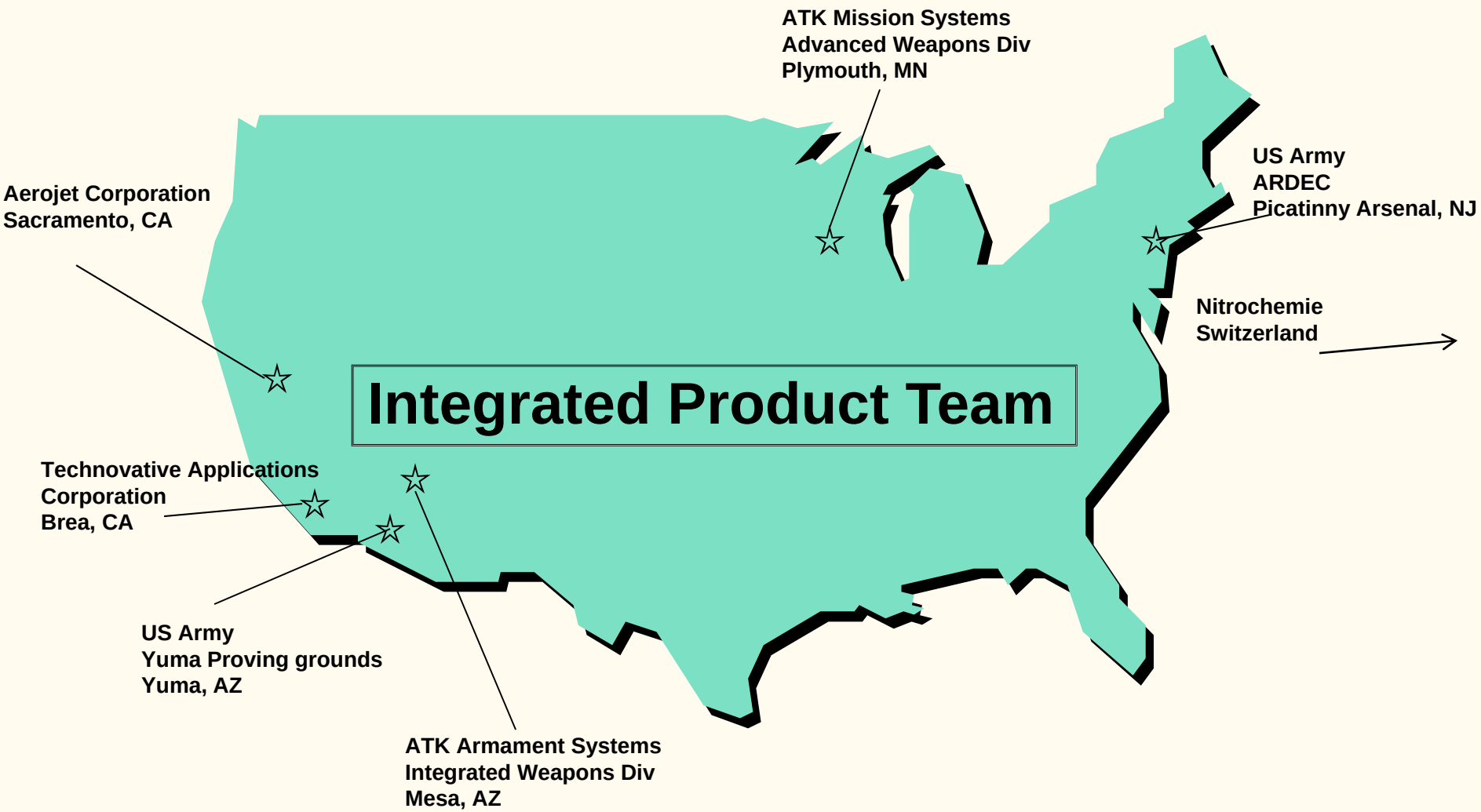
Projectile Design and
Warhead Integration IPT
IPT Lead: Phil Brislin
(ATK): J. Reynolds
Projectile Design: M. Ellis,
Fuze: A. Chebishev
Warhead Dev: S. Tang & J. Pincay
Propulsion Dev: D Keyser
Configuration Mgr: J. Wasserman

Course Correction IPT
IPT Lead: R. Bryan,
(TA): D. Miller
(ATK): J. Yost
Electronics: L. Vo
Telemetry: B. Flyash
C/C Consultant: L. Sadowski
Aeroballistics: J. Grau
Thruster Design: M. Horvath

Ammunition IPT Members:

Safety : C. Muhammad
QA (Mech): C. Brandt
QA (Elect): N. Eid
IHCs : A. Shankle
Pkg: G. Farbanish

EAPS Team Members



EAPS ATO Program

FY06	FY07	FY08	FY09

ARDEC Non ATO & MAAST C.C. ATO

EAPS ATO-R

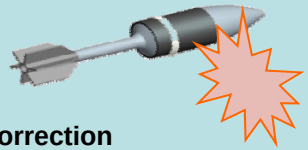
EAPS ATO-D

System Study

Proposed Subsystem Designs

MAAST Course Correction ATO

Development Tests
Warhead Performance
Course Correction
Maneuver
Command Communication
Radar & Fire Control
Integration



Command Course Correction Projectile

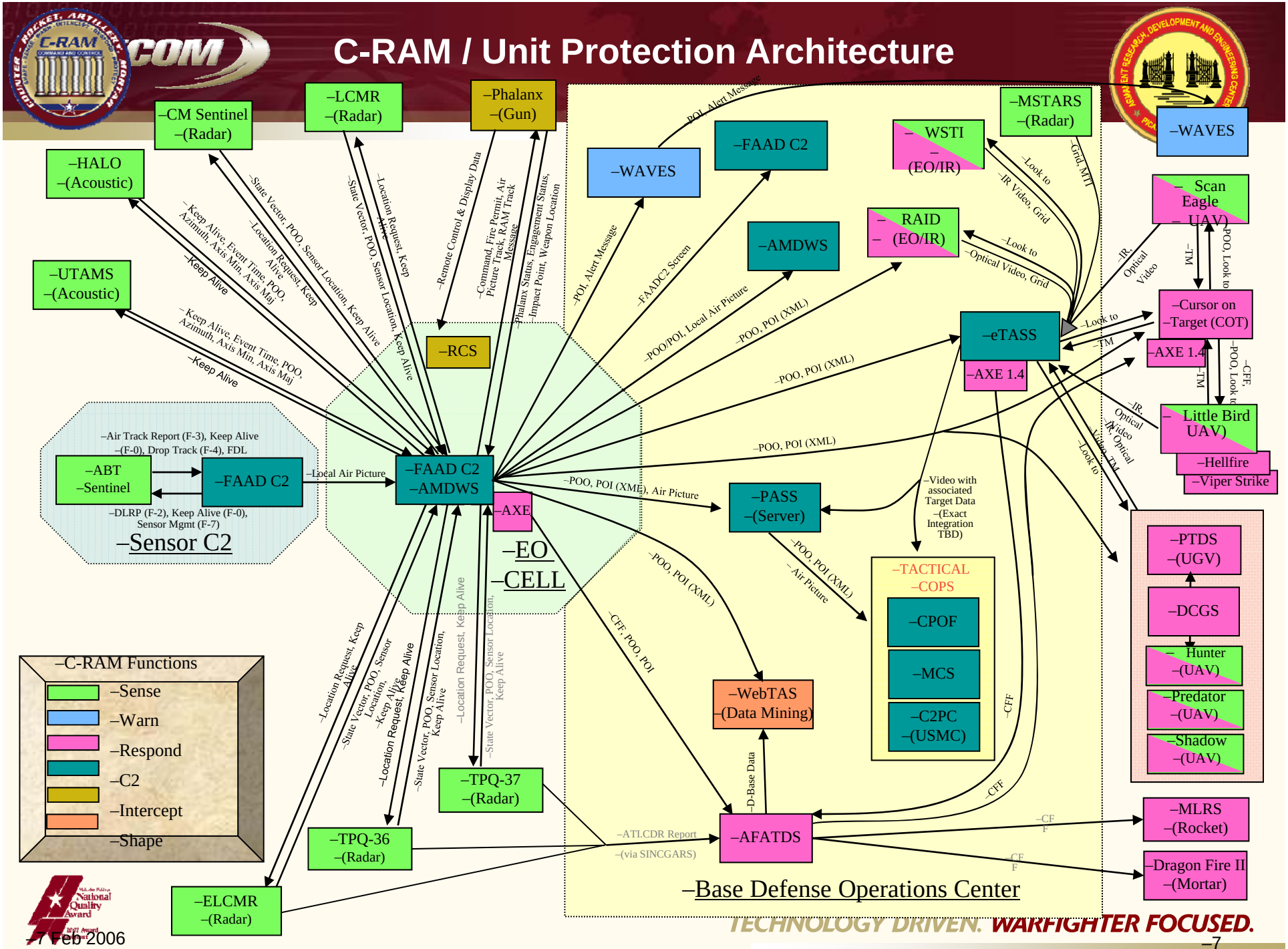
Ballistically Launched Defeat of Static Target

$17 M Total MAAST/EAPS for FY06 - 09

Demonstrate 50mm Auto Cannon on Hardstand Mount Firing EAPS Ballistic Simulants (Currently UFR)

Mid FY09 Demo

C-RAM / Unit Protection Architecture



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Army's Recent Air Defense Systems

1960s-1970s

–M163 VADS
–Vulcan Air Defense System

1980s

–M247 Sergeant York
–DIVADS

1990s-2000s

–Avenger Pedestal Mounted Stinger

1990s-2000s

–M6 Bradley Linebacker

2005

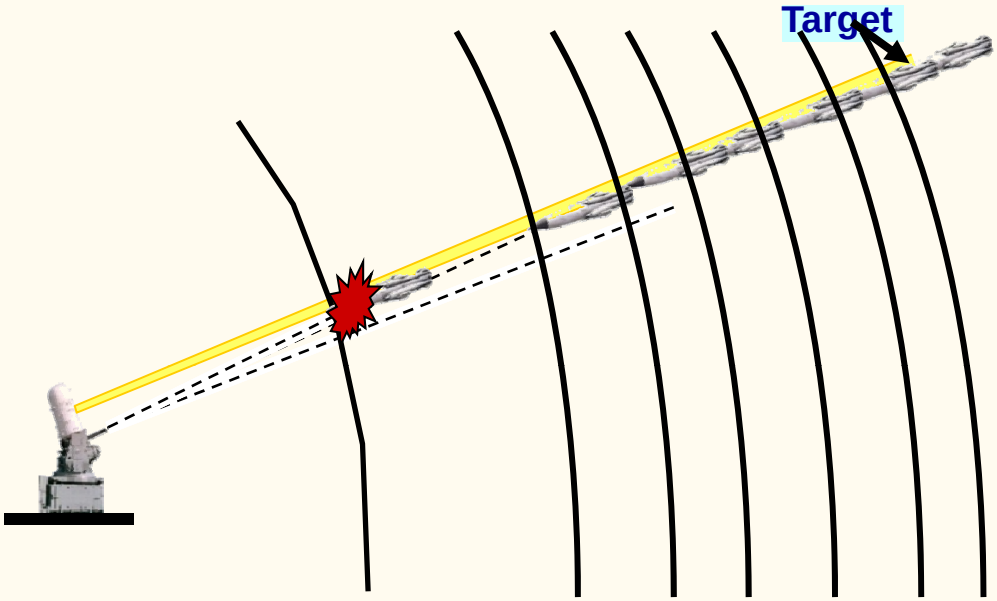
–Phalanx 20mm CIWS
–Adopted for C-RAM

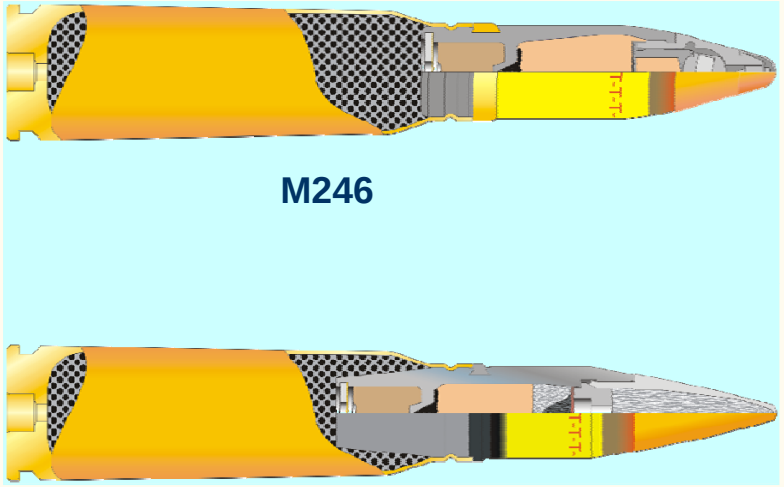
2014?

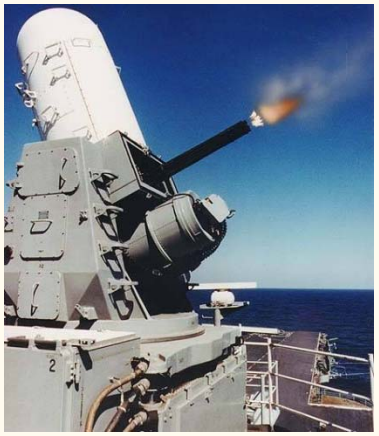
–?

–EAPS

Phalanx Weapon System







20mm M61A1 Gatling Gun, 6 Barrels
M246 and M940 Self-Destruct rounds
Up to 4500 rounds per minute
A Continuous Spray of Lead

Up To 400 Rounds Per Engagement

Threat Target Challenges

- Small Presented Areas
- Low RCSs
- Thick, Hard Warhead Cases
- Short Times of Flight
- High Rates of Fire
- Dual Purpose Improved Conventional Munitions (DPICMs)
- Helos, Lows and Slows, UAVs

Interceptor Lethality Criteria:

High Order Detonation Of Payload (Primary)

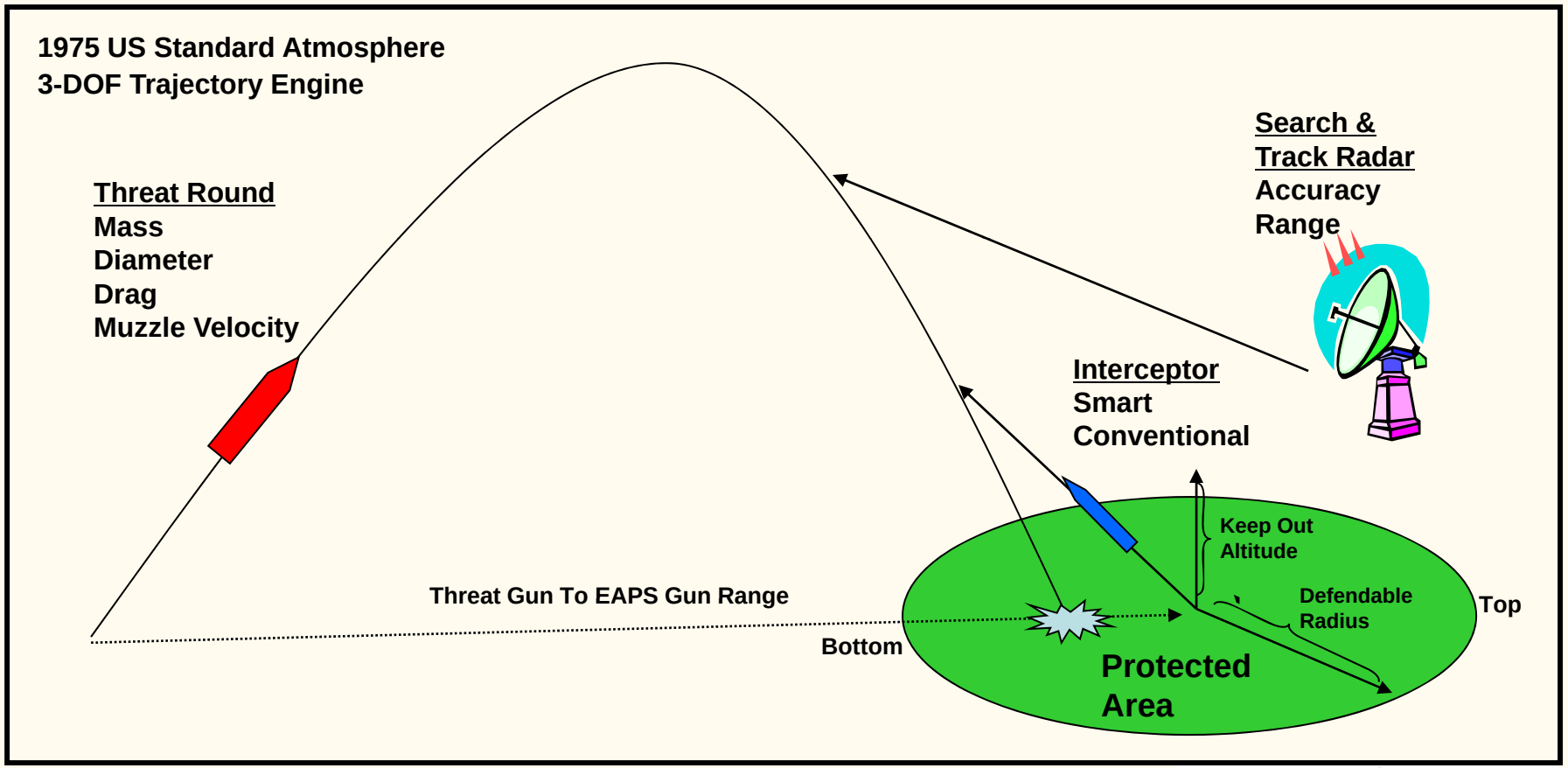
Destruction of Fuze (Secondary)

Target List

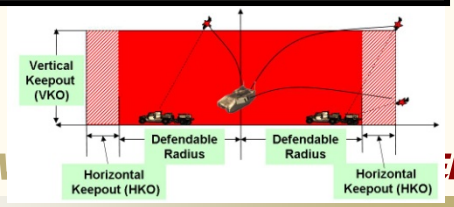
- **Mortars: 60 mm – 120 mm**
- **Rockets: 107 mm-240 mm**
- **Artillery: 122 mm-152 mm**

EAPS.F FORTRAN Gun Simulation

Basic Idea Is To Model The Event Timeline, Accuracy, & Lethality In Explicit Detail



Simulation Models A One (Or Many) On One Engagement Of Incoming Threat Round With EAPS Gun (Acoustics, Radar, Fire Control, Gun, Bullet)



Engagement Options

Rapid Fire- Hit to Kill

- C-RAM Type Engagement
- 20-30mm Caliber
- High Rate of Fire
- KE or HEPD Kill
- Lowest Cost Ammo
- High Expenditure Rate
- Issues: Collateral Damage and Cost

Precision Fire- Burst to Kill

- 35-82mm Caliber
- Low- Mod Rate of Fire
- Advanced Warhead
- Prox/Advanced Fuzing
- Moderate Cost Ammo
- Issues: Adequate Ph and Lethality

Precision Fire- Guide to Hit

- 30-35mm Caliber
- Low- Moderate Rate of Fire
- Command Guided Course Correction
- KE Kill
- No Warhead, Fuze or S&A
- High Cost Ammo
- Issues: Burst Size, Cost and SD

Precision Fire- Guide to Burst

- 50-82mm Caliber
- Low Rate of Fire
- Command Guided Course Correction
- Advanced Warhead
- Prox/Advanced Fuzing
- Very High Cost Ammo
- Issues: Cost, Complexity, Size

Trade Study Results -
Characterization of Trade Space

Warhead	Guidance	20mm	25mm	35mm	50mm	75mm	82mm
KE-Sabot	No	PR~0.3R 40XShots	PR~0.3R 15X Shots	ROF Too Low	Similar To Smaller Calibers ROF Too Low		Velocity Too Low
	Yes	Too Small		PR ~0.6R >2x Shots	ROF Issues		
HE-Nat	No	PR~0.3R 40XShots	Not Done	Not Done – Appears to Have Low Promise Results Similar to KE Sabot			
	Yes	Too Small					
HE-PFF	No	Too Small			Not Done	PR > R ~0.6X Shots	PR~0.1R 0.4X-Shots
	Yes				Not Done	PR >R ~0.3X Shots	Not Done
CE-Unitary	No	Not Done – Appears to Have Low Promise Results should be similar to KE Sabot					Too Slow Likely To Be Ineffective
	Yes						
HE-EFP	No	Too Small			Not Done – Appears to Have Moderate Promise Results Should Be Similar To HE-PFF		
	Yes						
KE-Subs	No	Too Small		PR~0.2R >4X Shots	PR~0.6R ~3X Shots	PR~0.6R ~0.8X Shots	Too Slow Likely To Be In
	Yes			Too Small	PR~R ~X Shots	PR~0.9R ~0.8X Shots	
CE-Subs	No	Not Done – Appears To Be Too Small (Insufficient Number Of Submunitions)				Not Done – May Have Some Promise In Larger Calibers	
	Yes						

What Works
Required PR

Approach
Cost/Kill: <$10K
Weight/Kill: 31 lbs
Time/Kill: ~2 sec

Fuze Risk Too High

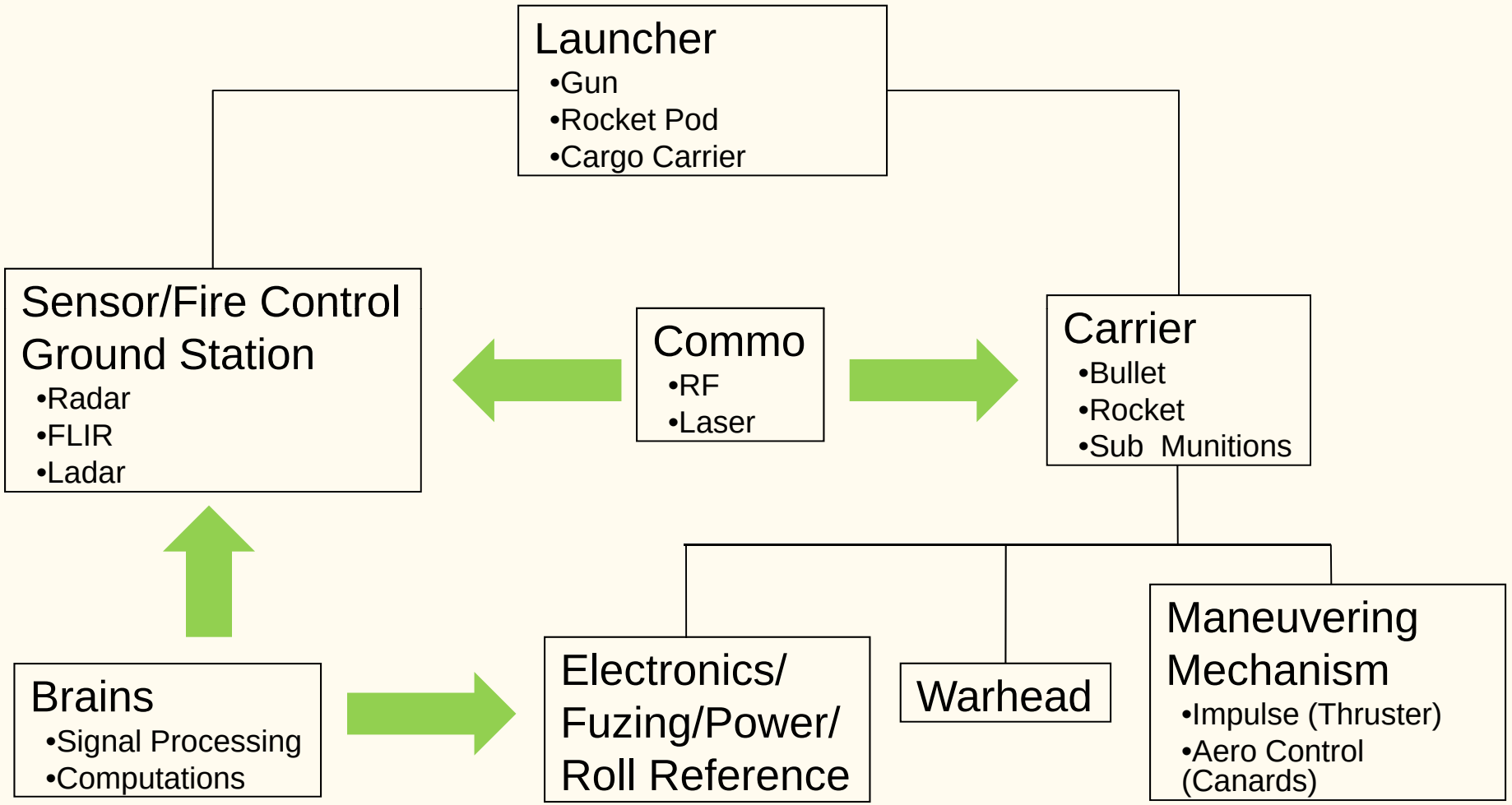
Logistic Burden Too High

Used M&S To Determine Technical Approach To EAPS

- Recommended Development of A Demonstrator Incorporating:
  - External Surveillance Radar With At Least Phalanx Range Capability
  - PTS/ATS Fire Control Radar For Tracking And Communication Link
  - 50mm Bushmaster III/IV Twin Guns for 400 rpm Rate
  - Interceptor Using Course Correction Technology From MAAST STO (Single Thruster, Guidance Instruments)
  - Transceiver Compatible With PTS/ATS Radar
  - Command Fuzed Forward Fragmenting Warhead Using Multiple EFPs

Launched EAPS Gun and Interceptor Development Using These Rough Guidelines As Most Likely Technical Approach To Meet C-RAM Needs

Command Guided, Direct Fire Basics



Command Guided, Direct Fire History

Tube-Launched, Optically-Tracked, Wire-Guided (TOW) (1957-)

Launcher	Carrier	Sensor	Brains	Commo	Roll Ref	Maneuvering Mech
Rocket Tube	Rocket	FLIR	Ground Station	Wire Link	N/A	Canards

Cannon Cal Maneuver Munitions, Ford Aerospace (1979-84)

Launcher	Carrier	Sensor	Brains	Commo	Roll Ref	Maneuvering Mech
40mm Gun	Bullet	Radar	Ground Station	Radio Freq	Magnetometer	RAM Air Control

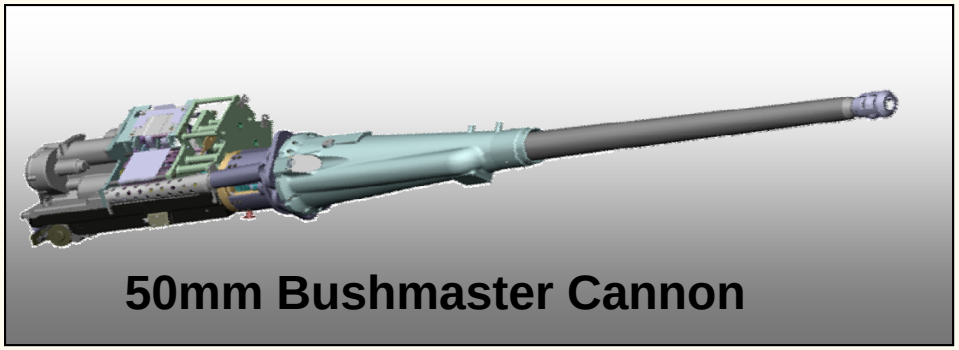
Command Adjusted Trajectory (CAT), LTV/Vought (1981-85)

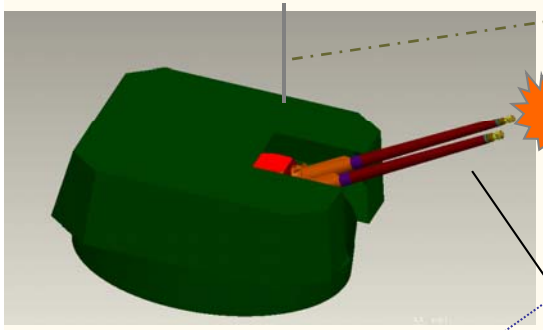
Launcher	Carrier	Sensor	Brains	Commo	Roll Ref	Maneuvering Mech
40mm Gun	Bullet	FLIR	Ground Station	Radio Freq	Magnetometer	Squibs

MAAST Course Correct, Gen Dynamics, ATK (2003-06)

Launcher	Carrier	Sensor	Brains	Commo	Roll Ref	Maneuvering Mech
120mm Gun	Bullet	FLIR	Ground Station	Radio Freq	Magnetometer	Thruster

EAPS Baseline Concept





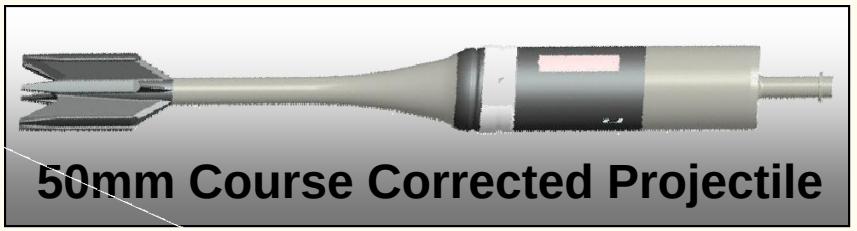
RF Data Link

Radar Track

Forward Fragmentation Warhead Detonation

Mid-Flight Course Correction

10 Round Burst at 500 Shots per Minute

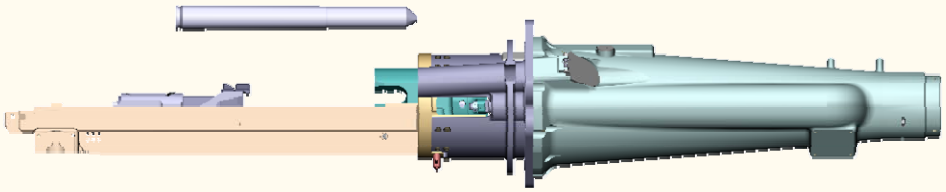


50mm Bushmaster Cannon

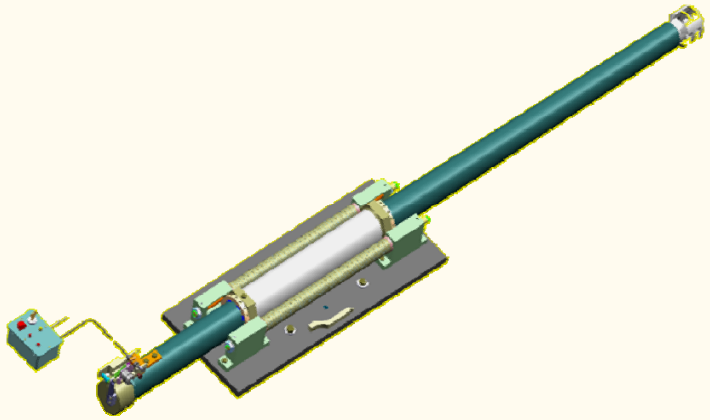
- Hybrid Bushmaster Cannon
- Accommodates EAPS 50mm Caliber and 538mm Cartridge Length
- No New Development Required
- Approx Cost: $400K for Modified BMIII Weapon and Conversion Kit
- Twin Guns in Common Turret for 400 SPM

50mm Bushmaster Specs

- **Caliber: 50mm**
- **Cartridge Length: 538mm (21”)**
- **Firing Rate: SS/200 spm**
- **Weight: 510 lbs**
- **Recoil Force: 14,000 lb**
- **Power Req’d: 3 HP**
- **Dispersion: .35 mils**
- **Manufacturer: ATK Med Cal Sys**



BMIV AFT RECEIVER with BMIII BREECH & FWD RECEIVER
Will accommodate up to 150.8 mm additional cartridge length
537.8mm vs. 387mm max overall cartridge length



MANN Barrel Test Fixture

PROJECTILE TRACKING SYSTEM (PTS)
NLOS-C RADAR

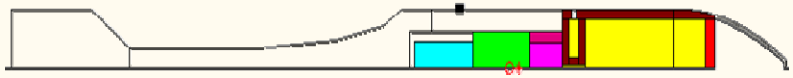
Interferometry is Most Accurate Technique Known for Measuring Angle of Arrival of a Radio Signal

- **Operating frequency: 15.7 – 16.2 GHz**
- **Active Electronically Scanned Antennas**
- **Transmit power 500W**
- **Angle accuracy (x,y,z) < 0.3 mils @ 20dB SNR**
- **Range accuracy < 0.2 meters**
- **Doppler accuracy v(t) < 0.02 m/sec**
- **Tracking range: Muzzle to 40000 meters**
- **Muzzle velocity determination < 0.05%**
- **Impact Prediction accuracies ~ 6 meters @ 20 Km**
- **Projectile communication capability**
- **Tracked six (6) long range projectiles > 10km simultaneously**

Modeling: Ongoing Process

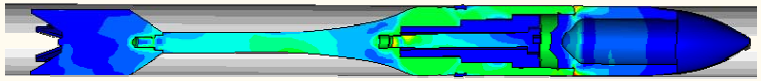
50mm System Study

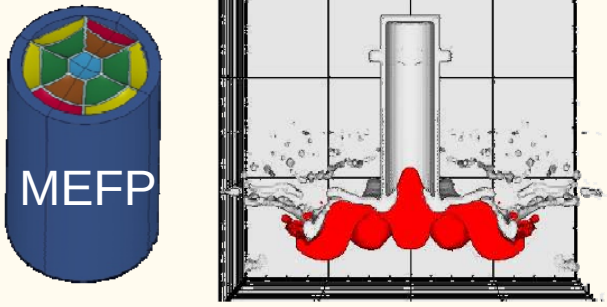
Projectile Configuration Study



M&S Design Loop

Detailed Modeling & Analysis



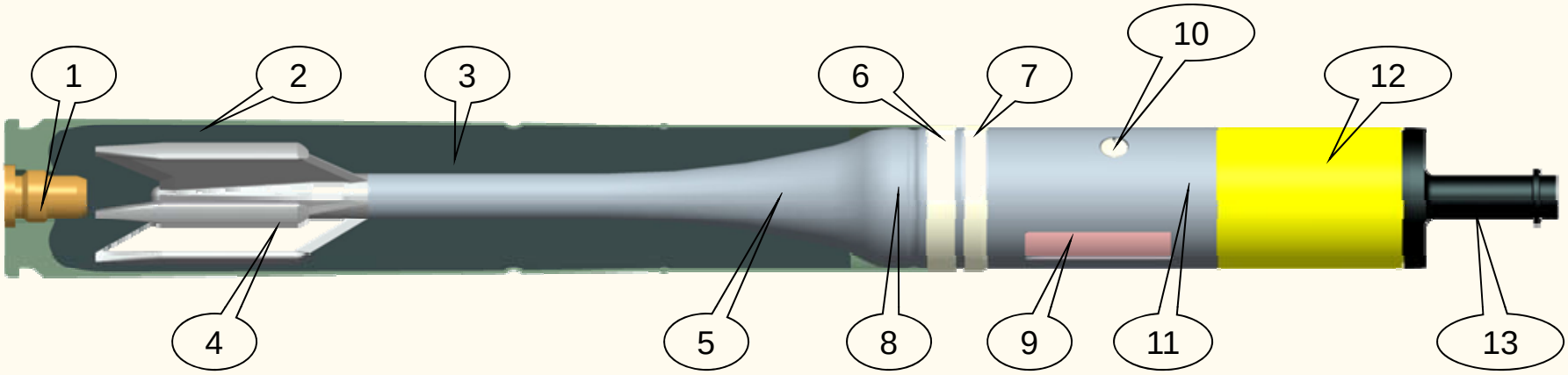


Test Data

Zone 1 Zone 2 Zone 3

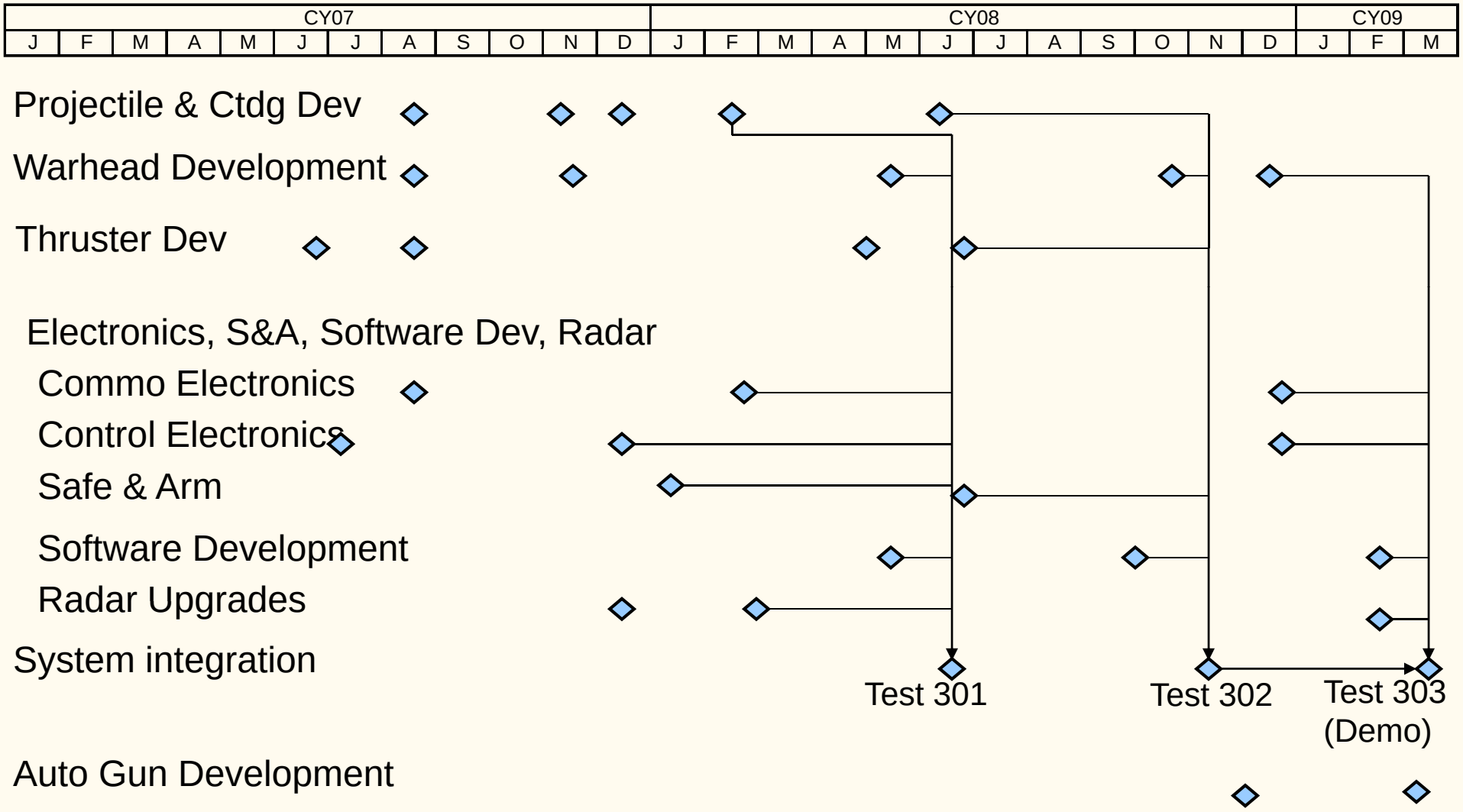
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

EAPS Tactical Concept
"Demo Configuration"

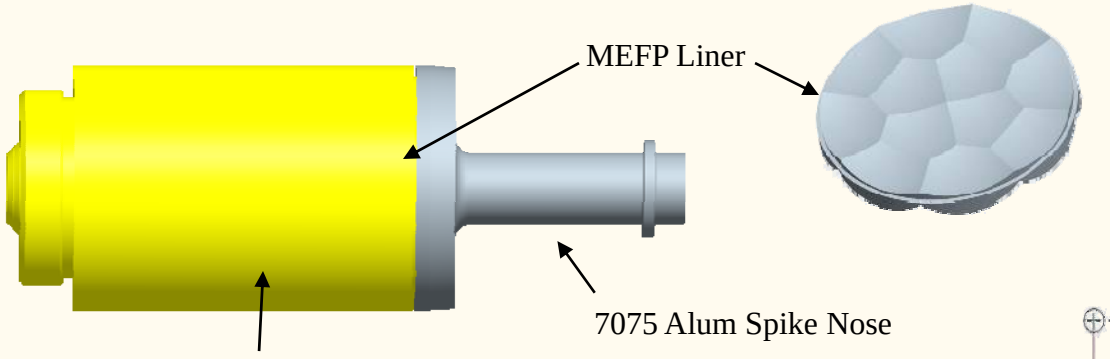


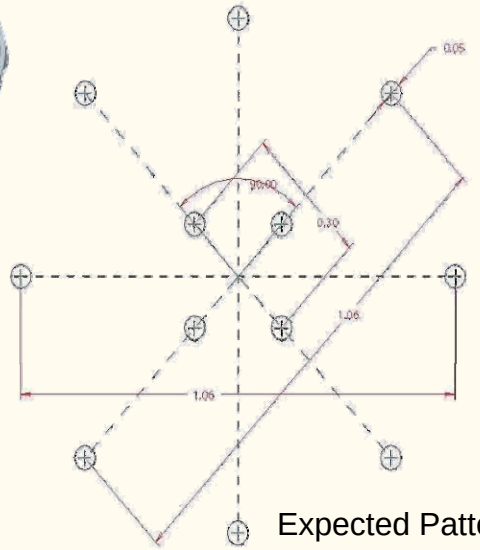
1. Primer
   M115 percussion primer
   Black powder flashtube
2. 328mm steel cartridge case
3. Nitrochemie ECL propellant
4. Aluminum 6 vane fin
5. 7068-T6 aluminum aft-body
6. Nylon obturator
7. Nylon rotating band
8. Set-back initiated battery
9. Electronics package
   TA transceiver
   ATK fuze electronics
10. Course correction divert thruster
11. ATK safe and arm device
12. Warhead
    4340 Steel body
    140g PAX-2A HE charge
    PBXN-5 booster
    Tantalum-tungsten 12 MEFP liner
13. Aluminum spiked nose

Program Development Plan

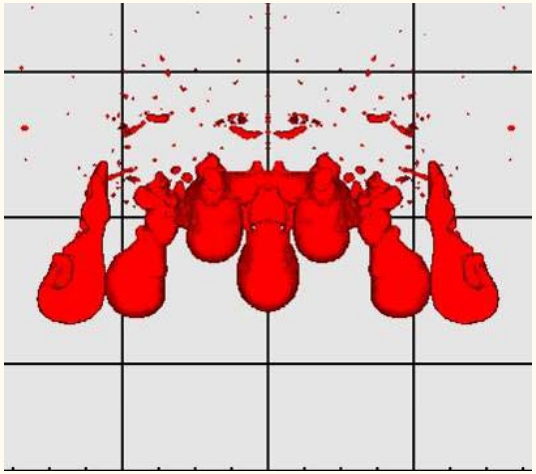


Tactical EAPS Warhead Design & Test
12 MEFP Design

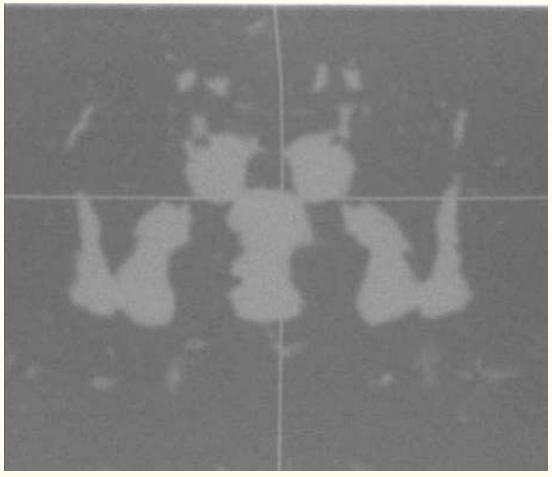




Expected Pattern & Velocity

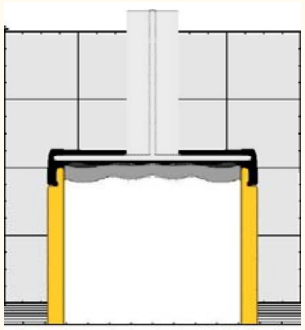


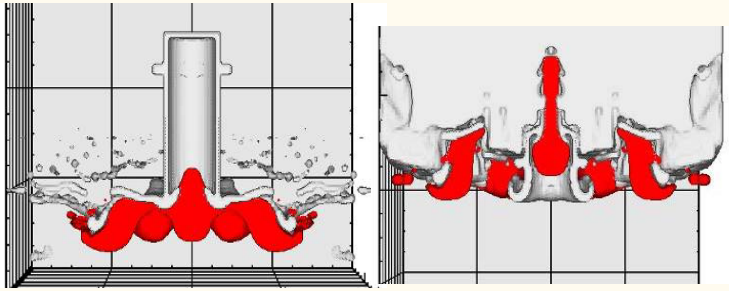
Modeled MEFP Formation

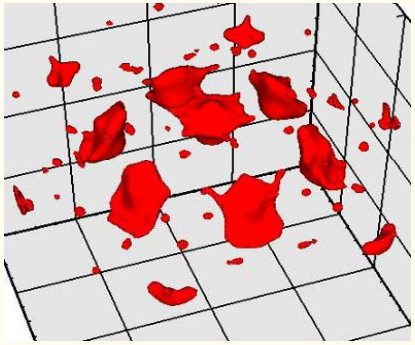


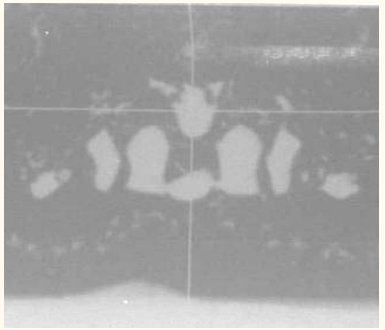
Bench Test X-Ray MEFP Formation

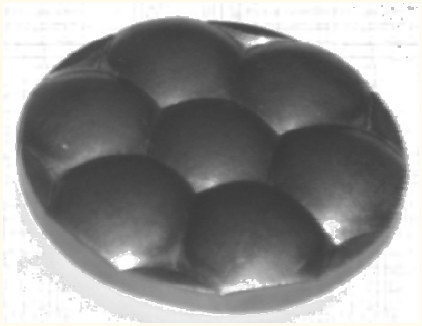
Warhead Development Summary











7 MEFP Liner

Thruster Development Summary

2007				2008					
May/Jun	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec

Chg Est

Impulse#1

Heavy Wt

Welding Process Development
Clam Shell Design

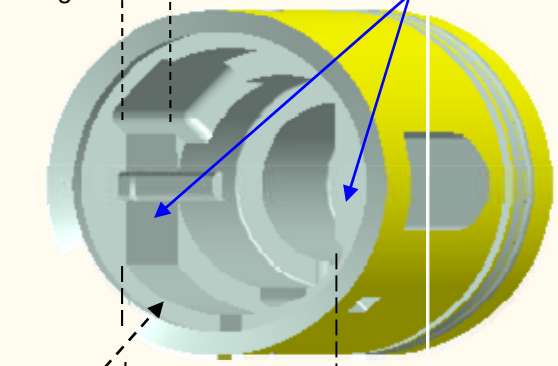
Threaded Design

Burst Integrity

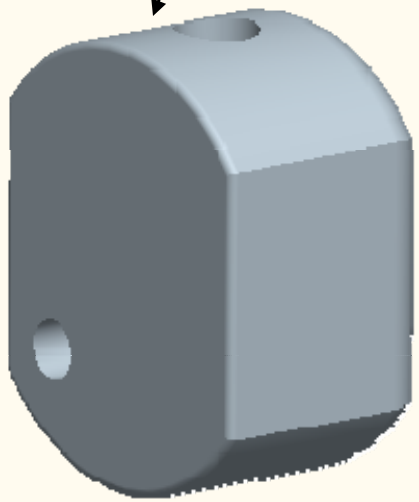
Impulse #2

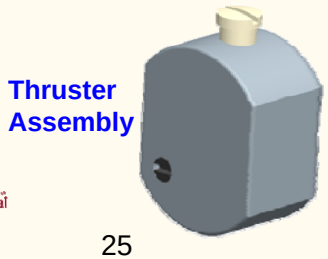
Tactical

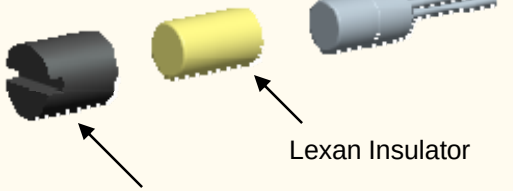
302



Thruster Assembles into Aft Body







TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

EAPS XCVR Design Verification

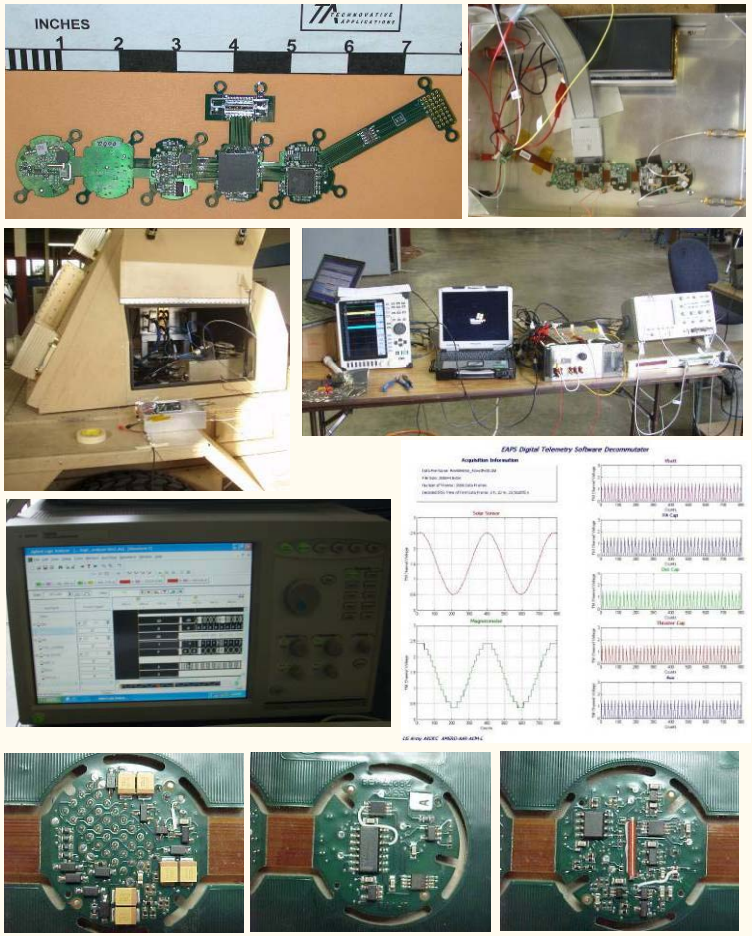
- **Design**

- **Verify Commo Hardwired**
  - a. Basic Commo
    - ✓ Up Link
    - ✓ Down Link
  - b. Mission Data
    - ✓ Up Link
    - ✓ Down Link

- **Verify Como Open Air Close Range**
  - a. Basic Commo
    - ✓ Up Link
    - ✓ Down Link
  - b. Mission Data
    - ✓ Up Link
    - ✓ Down Link

- **Verify Como Open Air Tactical Range**
  - a. Mission Data
    - ✓ Up Link
    - ✓ Down Link

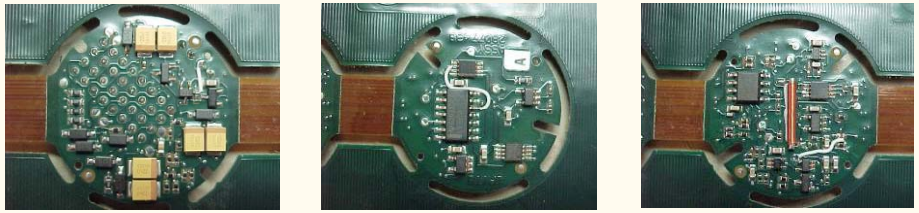
- **Integration (X-cvr With Fuze/Control Electronics)**
  - ✓ Basic Interface – Flat Boards
  - ✓ Mission Data Exchange – Flat Boards
  - ✓ Mission Data Exchange – Potted Units



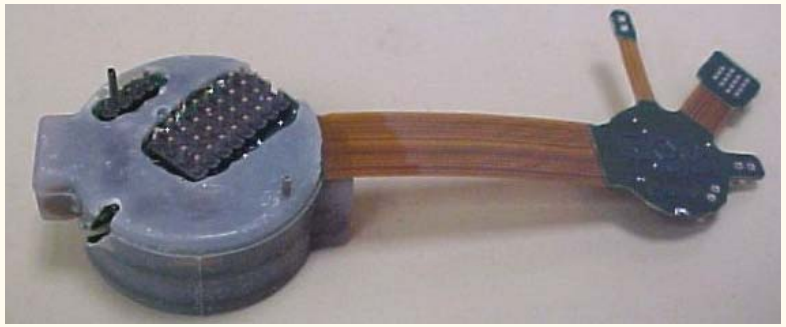
Control Electronics

Implemented Revised fuze electronics PCB

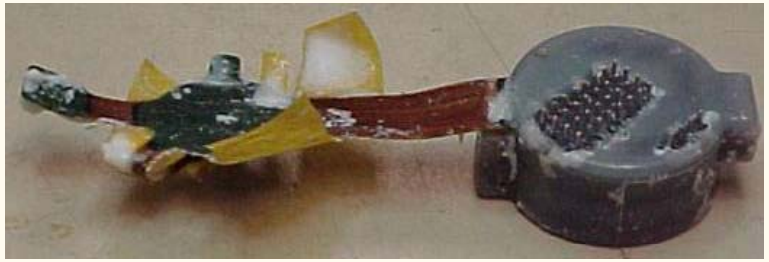
1) 2) 3)

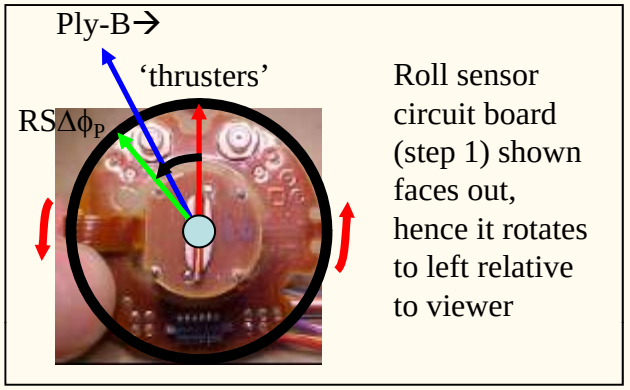


- Potting Rev-A Fuzes



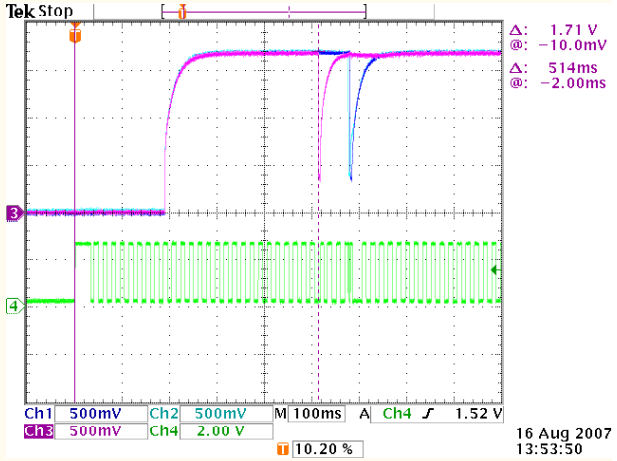
- Mated Rev-A fuze serial #1 with TA xcvr #3 for air-gun testing with good results





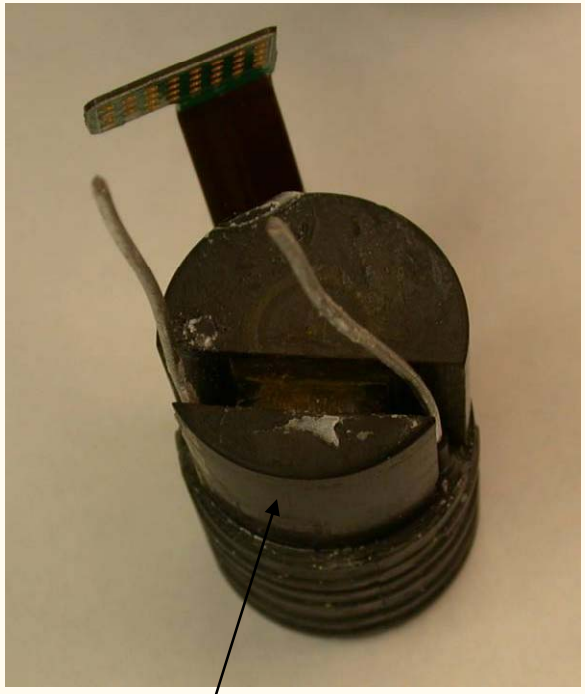
Roll sensor circuit board (step 1) shown faces out, hence it rotates to left relative to viewer

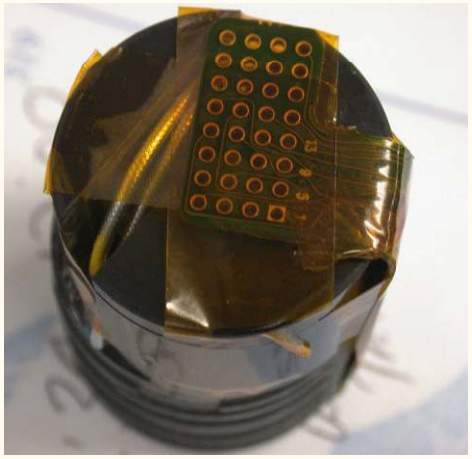
Magnetometer & Roll Sensing



Post Air Gun Test Results

Commo & Control Electronics Interface





- Spool support to wrap coaxial cable around (4” length of cable)
- Provides additional support to the cable even when potted in wax
- Loose wrap allows generous bend radius which when potted in wax eliminates sever bends and damage

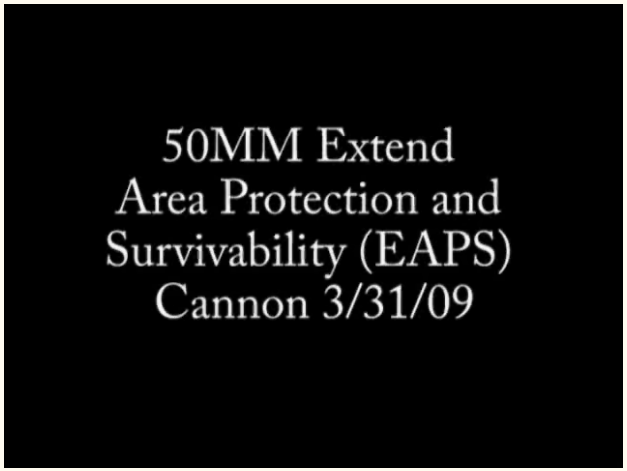
EAPS Test Videos

–EAPS Feasibility Demonstration

Test Plan:
Four Rounds for Command Course Correction
Five Rounds for Command Warhead Detonation
Six Rounds for Integrated Command C.C & W.D.

50mm Auto Cannon Test

- Alliant Tech systems – Medium Caliber Weapons Division (Mesa, AZ)
  - 50mm Cannon Designer
  - Contract W15QKN-07-C-0160
  - Proof round fired through cannon March 09
  - Feeder assembly completed 24 March 09
  - Dry cycle dummy rounds 26 March
  - Single shot firing of control rounds 30 March
  - Burst firing of 50mm control rounds 31 March
  - Addition test assets available for cannon reliability assessment



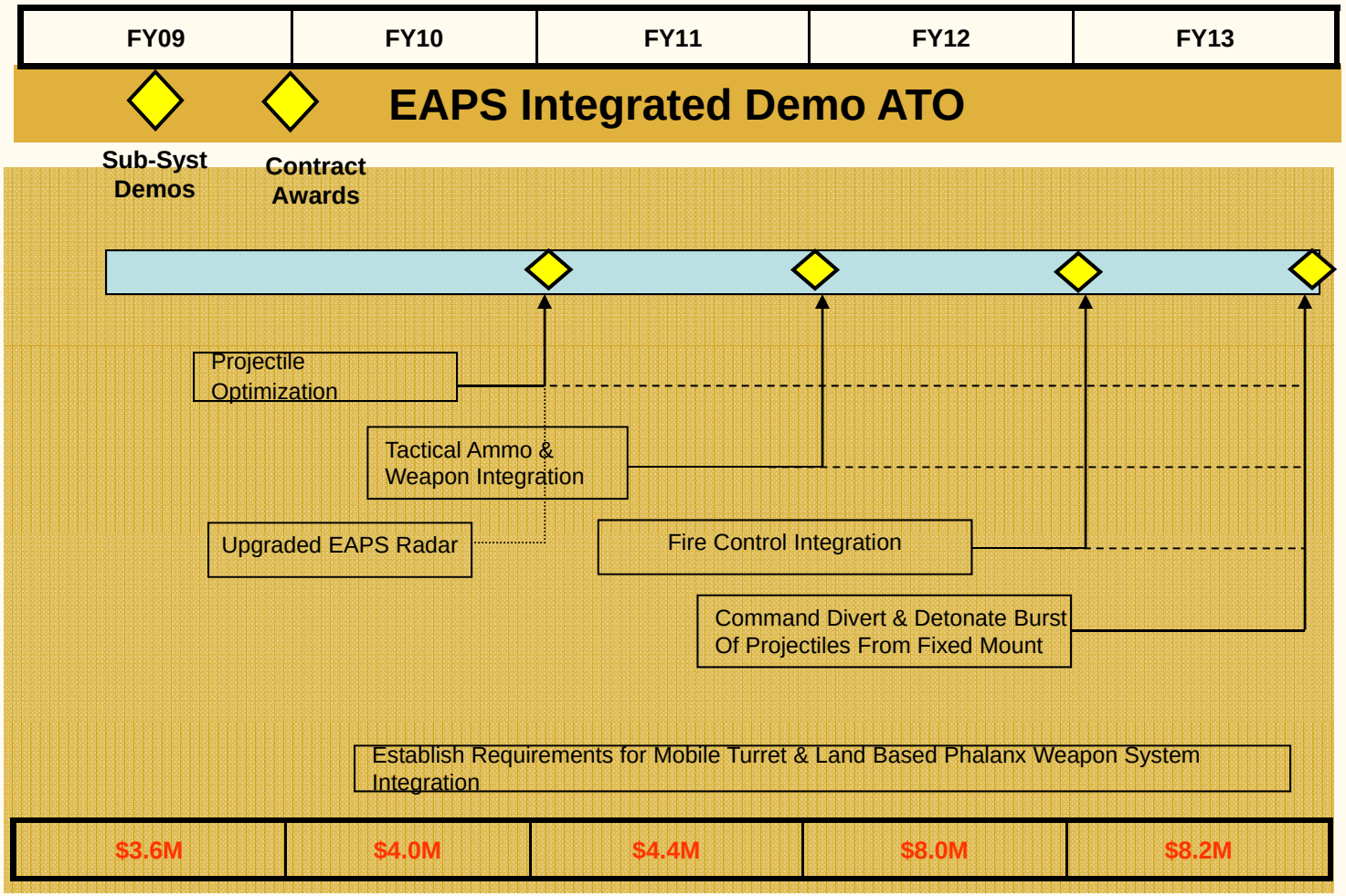
Program Goals and Objectives

- EAPS Phase 1 (ATO-R) Closeout Demonstrations (Sep 08):
  - ✓ EAPS Projectile Gun Launch, Interior Ballistic, and Exterior Ballistic Feasibilities.
  - ✓ Command Divert of a Course Correct Projectile.
  - ✓ MEFP Warhead Bench Test Functionality.
- EAPS Concept Demonstrations (March 2009):
  - ✓ Prototype EAPS 50mm Automatic Cannon on Hardstand Mount
  - ✓ 50mm Lethality “A” Round (Command Warhead Detonation)
  - ✓ 50mm Course Correction “B” Round (Command Course Correct)
  - ✓ ATS Radar Integration for Tracking and RF Communication
  - ✓ Component Level Tests to Demonstrate Fuzing, Warhead Lethality, Course Correction and Engagement Accuracy Against Static Targets to Demonstrate Performance

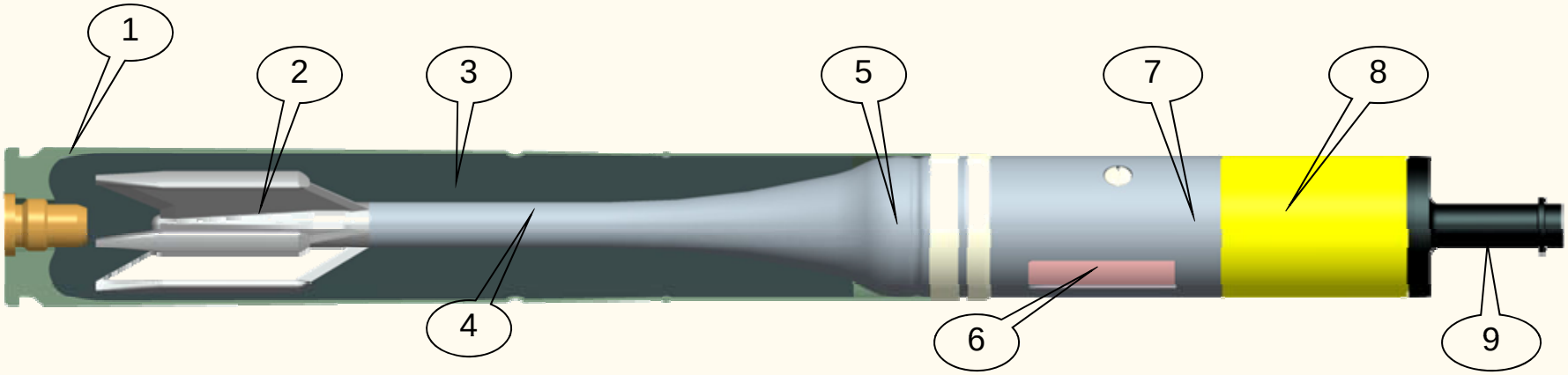
Exceeded Goals:

Demonstrated Integrated Lethality “A” & Course Correct ““B” Round

EAPS ID Road Map



Follow On Technologies Maturation – Optimized Projectile

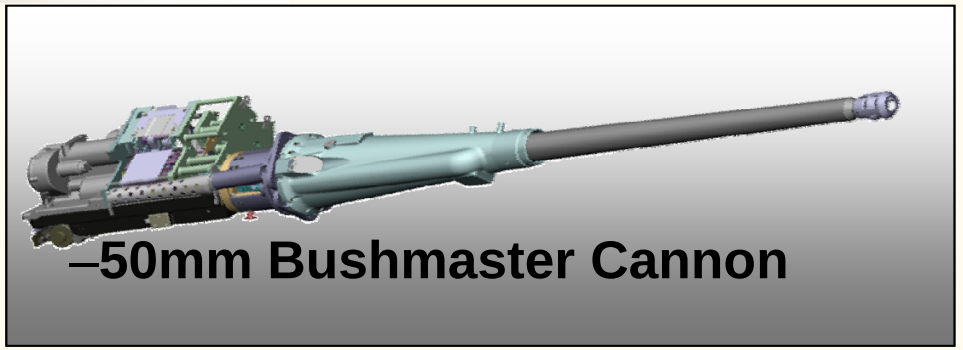


1. One piece cartridge case
2. Reduce fin cost
3. Propellant performance increase
4. Boom size reduction
5. Smaller thermal battery
6. Electronics size reduction and manufacturing improvements
7. Integration of MEMS S&A
8. Warhead explosive volume increase
9. Lower drag spike nose

Overall System Refinement Goals

- **Increase strike velocity on target**
- **Reduce frangible component size to limit collateral damage**
- **Increase producibility and lower cost**
- **Refine assembly procedures**

–Follow On Technologies
–Maturation of Autogun



–50mm Bushmaster Cannon

Goals and Objectives:

- Improve Gun Mounting
- Design and Develop a dedicated Feeder
- Increase Firing Rate & Reliability (mean rounds between stoppages)
- Conduct Dispersion Testing (Single Shot & Burst Fire)

Weapon Status		
Performance Parameter	Current	Completion of FY11
Firing Rate	112 spm	200 spm
Capacity	3 rounds	min of 10 rounds
Reliability	unknown	min of 1000 mrbs
Rd –to-Rd Dispersion (burst)	unknown	0.5mils
Feed System	Dual Feed	Single Feed

Follow On Technologies
Upgraded Radar

- **Power upgrade for multiple tracks & communication**
- **Antennas for E-Scan**

Summary

- Command Guided, Direct Fire Munitions Have Made Significant Advances Based On EAPS Feasibility Demonstration
- EAPS Gun Concept Is A Go Forward Technology for Future Air Defense Options
- Exploring Other Possible Applications