Insensitive Munitions State of the Art

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What the Customer Wants

Department of Defense

DIRECTIVE

NUMBER 5000.01
May 12, 2003
Certified Current as of November 20, 2007

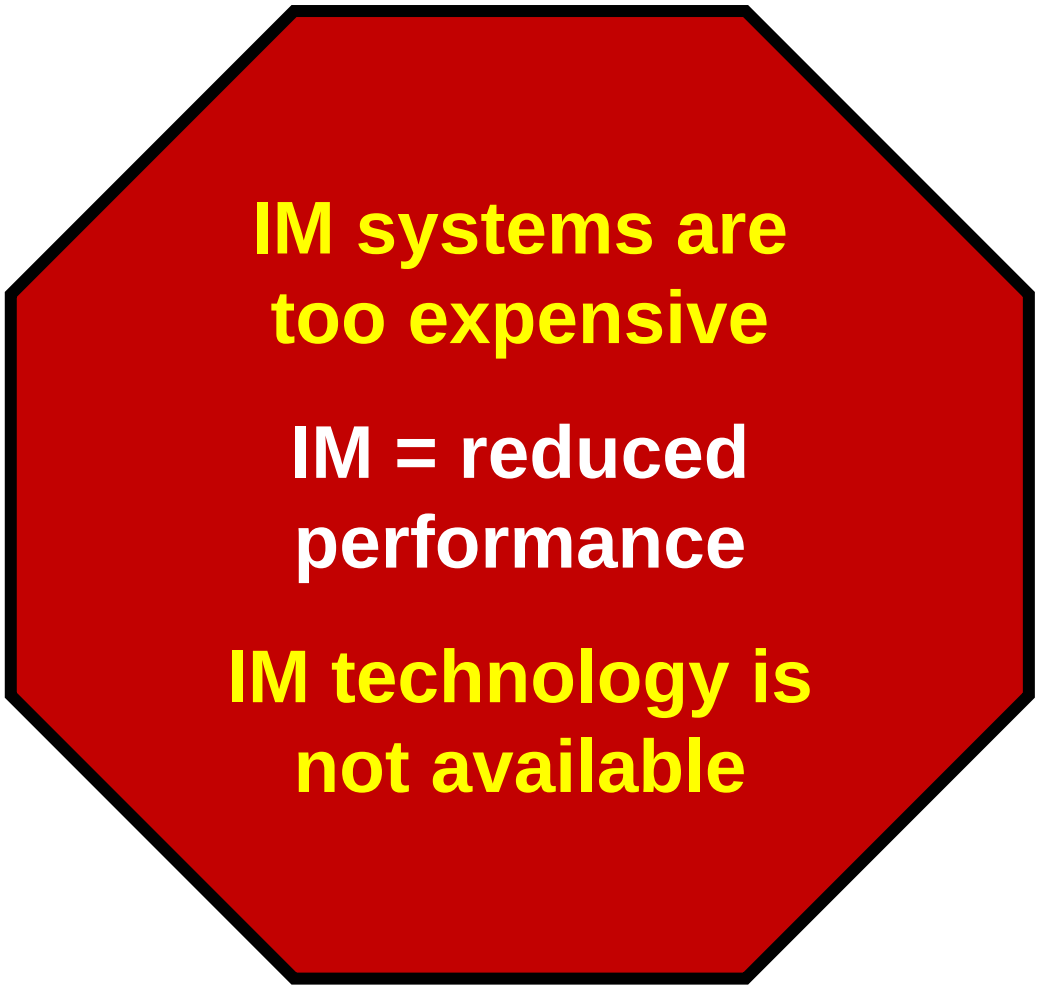
USD(AT&L)

SUBJECT: The Defense Acquisition System

E1.1.23. Safety. Safety shall be addressed throughout the acquisition process. Safety considerations include human (includes human/system interfaces), toxic/hazardous materials and substances, production/manufacturing, testing, facilities, logistical support, weapons, and munitions/explosives. All systems containing energetics shall comply with insensitive munitions criteria.

USS COLE

Common misconceptions



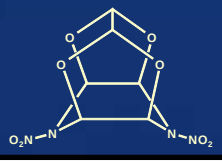
MSIAC is attempting to change these perceptions!

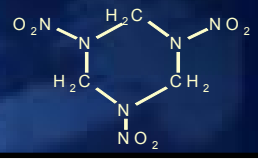
Implementation – A Systems Approach

- Aspects to be considered:
  - Energetics (first point of call)
  - Design & Construction
  - Packaging
  - Stacking
  - Platform integration (ship magazines)
  - Other measures, barriers etc

- Not ‘safe’, just less violent
- Testing in accordance with Stanag 4439 gives us a signature with which we can judge progress.

TEX v RDX





	TEX	RDX
• Data		
Sensitivity		
– Autoignition:	282 °C	205 °C
– Friction:	>353 N	120 N
– Impact:	23 -25 Nm	7.5 Nm
– ESD:	6 – 8 J	????
– Critical Diameter@ density	21 mm	2 mm
• Detonation Performance calculated with Cheetah 1.36		
– Detonation velocity	8160 m s^{-1}@1.99g cm-3	8750 m s^{-1} @1.76 g cm-3
– Detonation pressure	31.4 GPa	35.2 GPa
– Gurney Energy	2510 ms^{-1}	2830 ms^{-1}

- Price Index 10 **(will decrease significantly when produced on larger scale)**1

  - ATK, EXPLOSIA, RAFAEL
  - The patents mostly belong to ATK and Rafael.

Insensitive Munitions (who started it?)

- Birth of the Insensitive Munition Program
- Nobel
  - Dynamite
- USS Forrestal, (134 Killed, 161 Injured)
- USS Oriskany (44 Killed, 156 Injured)
- More recently Camp Dohar, 3 killed in the clean up, 49 injured 102 vehicles damaged or dstroyed

Legend

Colour coding for FCO, SCO, BI and FI results			
Colour code	Response Type	Response	Result
	V or NR	Burning or no response	Pass
	IV	Deflagration	Fail
	III	Explosion	Fail
	I or II	Detonation or Partial detonation	Fail

Colour coding for Sympathetic Reaction (SR)			
Colour code	Response Type	Response	Result
	III, IV, V, or NR	Burning to no response	Pass
	I or II	Detonation or Partial detonation	Fail

Colour coding for Shaped Charge Jet (SCJ)				
Colour code	Response Type	Response	V^2D ($mm^3/\mu s^2$)	Result
	III, IV, V or NR	Explosion, Deflagration, Burning or no response	Above 200	Pass
	III, IV, V or NR	Explosion, Deflagration, Burning or no response	Below 200	Pass
	I or II	Detonation or Partial detonation		Fail

30 mm (NAMMO Raufoss, Mauser, ATK, Alliant, Primex)

Performance Comparisons

- **No reduction in performance**
- **Armour Piercing**: MK 258 MOD 0 and MK 268 MOD 0 (APFSDS-T) & NM30 (MPDS)
- **High Explosive Incendiary**: MK 238 MOD 0 (HEI-T w/M758 Fuze), MK 266 MOD 0 (HEI-T w/FMU-151/B Fuze),
- **Multi-Purpose**: MK 267 MOD 0 (MPLD) and MK 264 MOD 0 (MPLD-T)



Programme Phase

•IM Improvement plan



IM Technology

•MPLD-T: PBXN-5
•HEI-T: PBXN-5
•M592 Ammo container vent

IM Benefits (cost analysis)

•No cost benefit information available although greater survivability and reduced loss of stockpile inevitable.

IM Signature

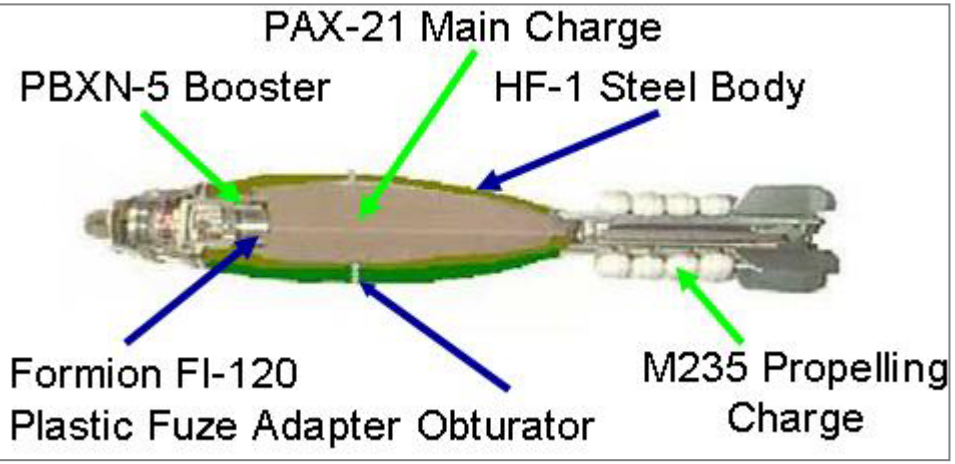
	FCO	SCO	BI	FI	SR	SCJ
APFSDS-T	III	III	III	III	>III	
MPLD-T	III	III	III	III	>III	
HEI-T	III	III	III	I	>III	

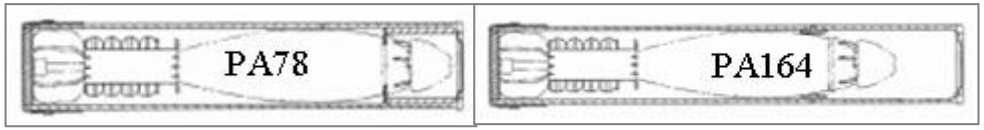
APFSDS - Armour piercing, fin stabilised, discarding sabot
MPLD - Multi purpose, low drag, HEI – High explosive, Incendiary

60-mm M720E1 HE Mortar Cartridge

Performance Comparisons

- 25% average increase in lethality above current configuration (1340 steel against HF-1 steel) despite 5% loss in Performance Dent Depth between PAX-21 and Comp B





Customers

- US Army

IM Technology

- IM High Explosive - PAX-21 (melt-cast)
- IM Fuze Booster - PBXN-5
- Gun propellant - no IM modifications
- Venting – Plastic Fuze adapter, obturator
- Logistic Packaging design (PA164 &PA124)
  - Round orientation: Fuze up
  - No fire A18NV Intumescent coating
  - Longer fibre tube

IM Benefits (cost analysis)

- Comp B – 6-8 USD/lb, PAX-21 – 10-12 USD/lb
- Mitigation cost 18-20 USD/round

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Comp B	I/II	III	I	I	II	I
PAX-21	V	IV	V*	III	III	III

* PA124 Ammunition (Metal) Container,
Wire bound box (16 live rounds=2 X PA124)

105-mm DPICM (M915)

Performance Comparisons

- Ageing – no degradation in performance

Customers

- US Army (high rate production - 30,000 parts per 10-hour shift)

IM Technology

- High Explosive – PAX-2A with 0.5% flow additive (756 g for 42 grenades)

IM Benefits (cost analysis)

- Manufacturing process compatible with Comp-A5 equipment
- Cost of Comp-A5 is 30% of PAX-2A (USD$30/lbs for HSAAP)
- Extra-cost for system should be < 2%

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Comp A5		I	I		I	
PAX-2A		III*	V*		IV*	

* With inert fuze and propellant in PA117 shipping containers

Note: previous version of 105 DPICM was involved in Camp Doha accident in 1991.

Reactive Tile Armour for Armoured Fighting Vehicle (AFV)

Performance Comparisons

- LBR6 when compared to C4 as the energetic in Explosive Reactive Armor trial produced a similar reduction in penetration result.

Customers

- US Army for Bradley, Abrams and Stryker

IM Technology

- Explosive : Low Burning Rate 6 (LBR6)
- NATO 1.2.3 (US DoD Classification) therefore has passed FCO, SCO, BI and SR.
- Must react to SCJ to be effective
- Rafael product
- Contains RDX with an inert fire retardant and an inert binder

IM Benefits (cost analysis)

- US DoD classified NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Tile Armor	*	*	*		*	

* Assumed results because of 1.2.3 assessment

Excalibur 155mm guided projectile (XM982)

Performance Comparisons

- Precision munition, high angle of attack (near vertical)
- Packaged HE Projectile: HD 1.3 compliant during storage and transportation
- First operational firing May 2007

Radial vent holes

Customers

- US Army (725 Rounds in 2007)

IM Technology

- High Explosive : PBXN-9
- Pressed Booster:
- Flexible shell liner HDPE
- Modified packaging
- A number of vent plugs, located around the warhead body, which are also designed to melt at a lower temperature than the temperature at which the round reacts.

IM Benefits (cost analysis)

- Initial costs ~ $100K USD, reducing to ~ $30K USD in full production

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
XM-982	V	V	V	V		

* In packaging

120-mm APFSDS (M829A3)

Performance Comparisons

- New higher energy propellant (multiplex stick charge – RPD-380)
- DU penetrator

Customers

- Currently undergoing type classification (expected to be assigned NATO 1.2.3)
- US Army

IM Technology

- New container: PA-171
- 2 single Pane Windows
- Fiberglass reinforced PE ionomer
- 90 degrees offset and 79 in^2 Vent Area

IM Benefits (cost analysis)

- Container cost increase is marginal

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
PA – 116[1]	III	III	III	II	II	II
PA – 171[2]	V	V	V	IV	III	III

1. M829A2
2. M829A3

155/52 Artillery shell: 155 LU 211-IM

Performance Comparisons

	Comp B	XF-13333
Formulation	RDX/TNT (60/40)	NTO/TNT/Al/Wax
Density	1.67	1.75
VoD	7860	7150

Customers

- French Army – 5,000 rounds in 2004 plus 20,000 in 2006

IM Technology

- IM High Explosive: XF-13333
- NTO 48%,TNT 31%, Al 14%, Wax 7%
- Embedded booster (V-350)
- Storage pallet 20-round configuration (95% of life cycle)

Not fuzed –Plugged

IM Benefits (cost analysis)

- Hexal / XF-13333 (NTO cost sensitive)
- Increased Unit Cost shell: ~ 6 %

IM Signature

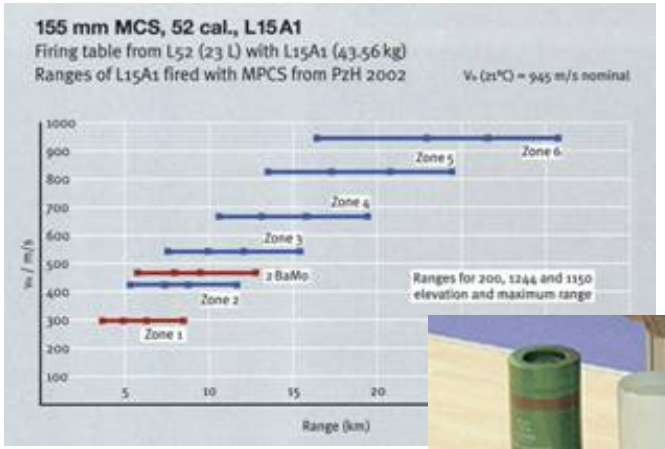
	FCO	SCO	BI	FI	SR	SCJ
Hexal	I	I	I	I	I	I
LU211-M	IV	V	V	IV *	IV	III
LU211-IM	V	V	NR	NR	IV	NR

*Heavy Fragment Impact 250 g – 2000m/s: type III MURAT ** (Latest results suggest ***)

Modulares Treibladungssystem (DM72/92)

Performance Comparisons

- Full agreement with specification for muzzle velocity, maximum pressure, temperature coefficient and pressure waves for zone 6



IM Technology

- R5730/R5733 solvent less triple base propellant with RDX
- Packaging container with vents

IM Benefits (cost analysis)

- Five modules cost no more than a US M203 unitary (NATO Zone 8) charge and are cheaper to buy than the equivalent L10 charge

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
M203A1	IV/V				≥III	
DM72/92*	V	V	V		NR	IV

* In logistics container

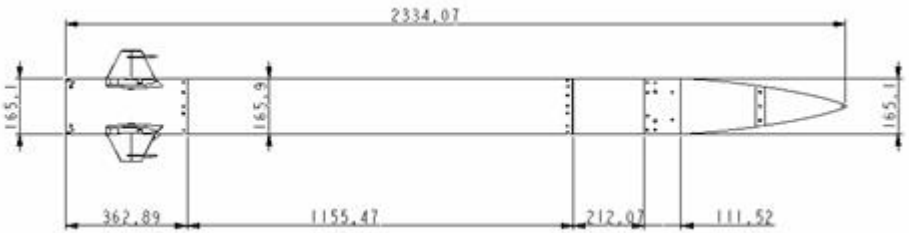
Customers

- 5 NATO countries (>1.5M units shipped)

Air Defence Missile (VT1 01)

Performance Comparisons

- Maximum effective range: 11 km
- Altitude: 6 km
- Lethal blast radius : 8 m



Customers

- France, Greece, Finland, Oman

IM Technology

- Warhead: HBU88A
- Slapper initiation
- Rocket Motor: TPH-8313
- Graphite epoxy case with Carbon Fibre Reinforced Plastics

IM Benefits (cost analysis)

- No information

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
Warhead		V	V			
RM			IV			
VT1	IV	IV	III*		III	

* Assessment – MURAT 1*

Anti-Personnel Obstacle Breaching System (APOBS)

Performance Comparisons

- Improvement in deployment characteristics
- and packaging (130-pound two-man portable) over the intensive manpower M1A2 Bangalore Torpedo demolition kit
- 1 APOBS = 3 Bangalore
- Capabilities (45 m - 98% effectiveness) similar to the much larger M58 Mine Clearing Linear Charge
- Reduction in system weight

Customers

- US Army, US Marine Corps (Production)

IM Technology

- 108 grenades with PBXN-10 main charge and booster explosive
- PBXN-8 detonating cord
- Packaging design

IM Benefits (cost analysis)

- Cost of PBXN-10 is 1/3 that of PBXN-9
- Palletized load weight has been reduced

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
PBXN-9	V	V	I/III	I/III	I	
PBXN-10	V	V	V	V	>I	

In shipping package configuration

Demolition Block No.4 Mk1

Performance Comparisons

- Penetrates 1” steel (Armor) plates
- Operating Temperatures: -54C to +71C
- TNT equivalent: 1.6
- Service life over 20 years

Customers

- Germany, Norway, Switzerland, Malaysia, Italy

IM Technology

- PX-139 RDX/HTPB (87/13)

IM Benefits (cost analysis)

- No information

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
C4			III			
PX-139	V	V	NR	NR*	V**	

* Rafael test – EFP - Cu 16.2 g, 1500 m/s
** Minimum 60mm air gap

SPIDER (XM7) (Formerly XM155)

Performance Comparisons

- RDX/DNAN based melt cast
- Comp B replacement

Customers

- US Army

IM Technology

- Energetics PAX 41 main charge
- Low Energy Exploding Foil Initiator
- RSI 007 (CL20 based) initiation
- Venting of plastic material around GIM
- Packaging design – venting of box seal
- Use of polythene foam for shock attenuation

IM Benefits (cost analysis)

- Cost of PAX 41 is low
- Grenade initiation Module (GIM) has twice the output at ½ the cost of traditional Fuze and booster

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
C4			III			
PAX 41	*	*	*	*	*	*

* Reported as a pass/fail however response not specified

Evolved Sea Sparrow Missile (ESSM)

Performance Comparisons

- **Rocket Motor**: As well as superior IM performance, the HTPE propellants offer comparable energy density and equivalent/superior physical properties.
- Warhead: KS-33 (90% HMX) –VoD 8480 ms^{-1}
- PBXN-4 (94%DATB) – VoD 7200 ms^{-1}
- PBXN-3 (86% HMX)

Customers

- US Navy, Norway, Germany, Australia, Netherlands, Denmark, Canada, Spain, Italy, Turkey, Greece, Belgium and Portugal

IM Technology

- IM High Explosive (15kg) – KS-33
- Dual HTPE propellant grain (119 kg)
- Laser Arm and Fire Device as Ignition System for the rocket
- Composite Case being considered for the next generation (PI)
- Al/polystyrene foam sandwich casing for the container

IM Benefits (cost analysis)

- KS-33 is cast-cured whilst PBXN 3 & 4 are pressed HE. Cost difference by HMX

IM Signature

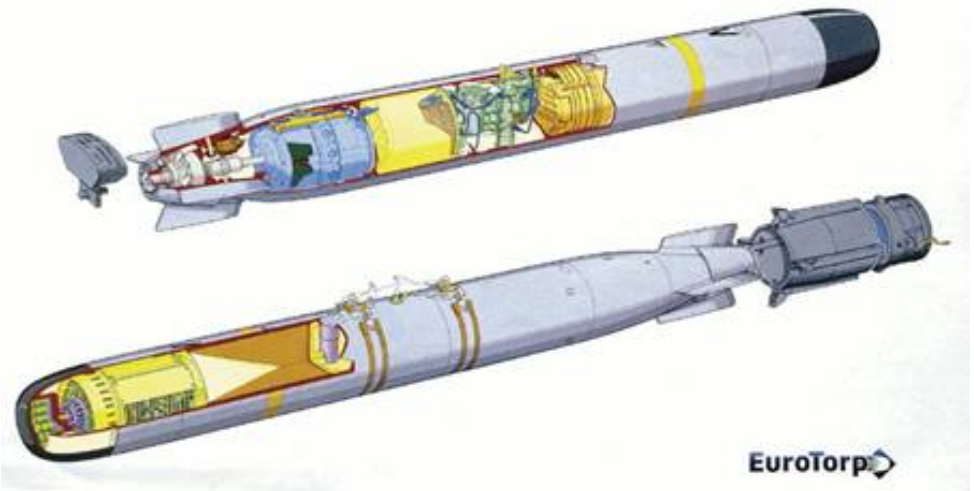
	FCO	SCO	BI	FI	SR
KS-33 warhead	V	V	V*	V	>II
Rocket motor[1]	III	III	V*	IV	

*In launch canister. [1] Baseline motor, steel case

Lightweight Torpedo (MU90)

Performance Comparisons

- Tip velocity 8925 ms^{-1}



Customers

- Denmark, France, Germany, Italy, Poland, Australia, New Zealand

IM Technology

- IM High Explosive: V-350 (Isostatic pressed)
- Booster V-350
- Logistic container with a sandwich barrier

IM Benefits (cost analysis)

- MU 90 Cost: TATB-Minimal effect on unit cost

IM Signature

	FCO	SCO	BI	HFI	SR
Octol (HMX/TNT)					
MU-90	V	V	V	IV	NR*

* In logistics container

Naval Strike Missile (NSM)

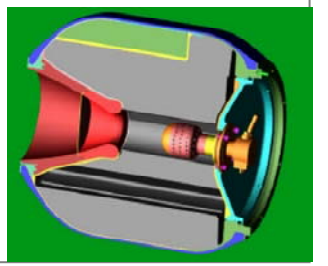
Performance Comparisons

•Hard target penetrator
•Fuze Counts voids/ (hard) layers w/ back-up timer.
Weight: approx. 400 kg. Range: in excess of 150 km. Designed for littoral waters as well as open sea scenarios. (The advanced design allows the missile to fly around and over landmasses.)

Warhead: Navel strike missile (NSM)

IM Technology

- IM High Explosive: KS22a
  (67 % RDX)(15 % Plastic Binder)(18% Al)
- Boost Motor Carbon fiber reinforced plastic casing
- Turbofan sustainer



IM Benefits (cost analysis)

- Cost difference of IM over non IM would be insignificant

Customers

- Norwegian Navy
- Platforms: Ships
- Also planned for Patrol Boats, trucks, armoured vehicles, and airborne weapon carriers.

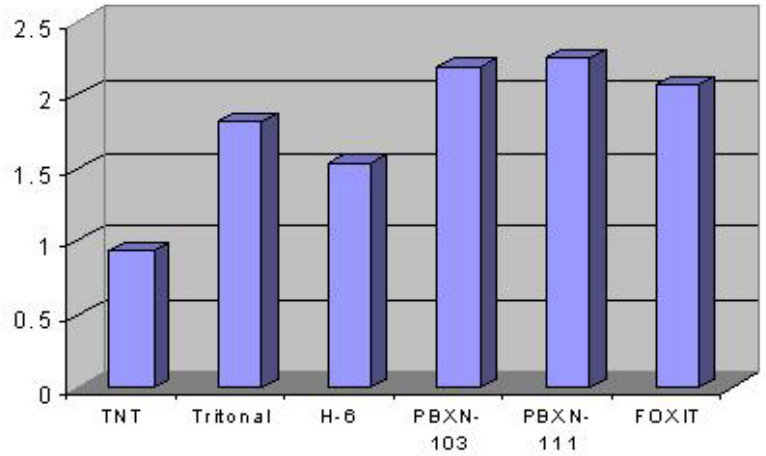
IM Signature

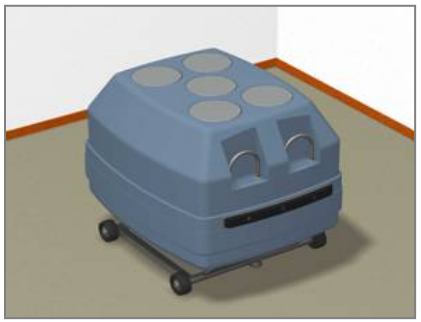
	FCO	SCO	BI	FI	SR	SCJ
Warhead	IV	IV	V	V	IV	
Boost Motor	V	III	V	IV	IV	

Sea Mine 2000

Performance Comparisons

- Relative bubble energy





Customers

- Finland

IM Technology

- EIDS High Explosive FOXIT (AP/Al/RS-RDX/HTPB: (38/28/20/14))
- IRDX – different crystallisation to normal RDX
- Case: Special composite material

IM Benefits (cost analysis)

- Ingredient cost (RDX cost-driven factor) FOXIT < H6
- Process cost : Cast-cured > melt-cast

IM Signature

	FCO	SCO	BI	FI	SR
Torpex					>III
FOXIT	V		V		III*

* Air gap > 50 cm

AGM-158: JASSM

Performance Comparisons

- Requirements:
  - Blast and fragmentation similar to Mk-82 and Mk-83 (AFX-757 e.g. 2.54 kJ/cm3)
  - Hard-target case (hard steel alloy > 2 cm)

Customers

- US Air Force
- Australia

IM Technology

•EIDS High Explosive (AFX-757)
•Venting fuze booster (PBXN-9)
•Aft closure, thermally reactive retaining ring
•Logistic container

IM Benefits (cost analysis)

•240 lbs HE in the warhead (~ BLU-110)
•JASSM Unit Cost ~ USD $0.7 M
•US DoD Classified as NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR
Mk-83 (H6 fill)	I	I	I	I	I
BLU-110	IV/V	IV/V	V	V	I
JASSM	V	V	V	V	III*

*Only in the logistics container

STORM SHADOW / SCALP EG

Performance Comparisons

- All western countries precision-guided cruise missiles are IM to a certain extent and used similar HE formulations (PBXN-109 type)

Customers

- France
- Greece
- Italy
- UK

IM Technology

- High Explosives:
  - PBXN-110 (Precursor Charge)
  - PBXN-109 (Follow-Through Bomb)
- Booster Explosive: Rowanex 3601
- Logistic Container

IM Benefits (cost analysis)

- Not Relevant as this family of large penetrator missiles is IM only
- UK MoD classified as NATO 1.2.3

IM Signature

	FCO	SCO	BI	FI	SR
Mk-83	I	I	I	I	I
BLU-110	IV/V	IV/V	V	V	I
Storm Shadow	V	V	V	V*	IV**

* By analysis, ** In logistics container

IRIS-T (SHORT RANGE AIR to AIR)

Performance Comparisons

- Improved rocket motor
- 50g turns reported

IM Technology

- Warhead
  - Energetics and construction classified
- Motor
  - Thermal Initiated Venting System (trialed)
  - HTPB/AP/AL composite
  - Reduced smoke

IM Benefits (cost analysis)

- IRIS-T unit cost approx $270,000

Customers

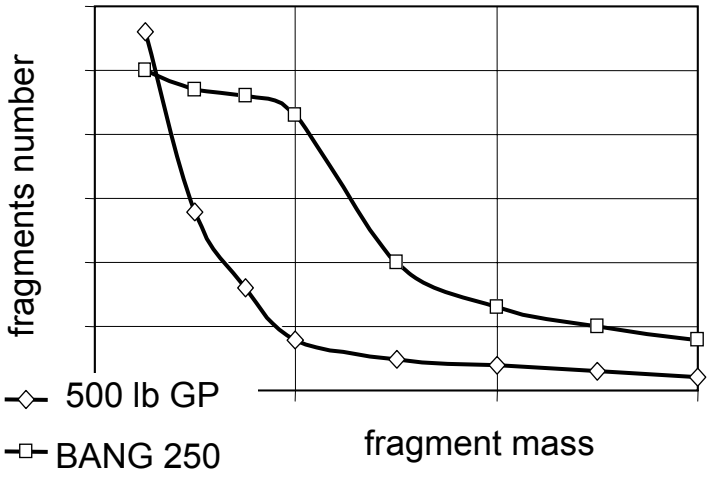
- Germany
- Greece
- Italy
- Norway
- Spain
- Sweden

IM Signature

	FCO	SCO	BI	FI	SR
AIM-9M	V	III	IV		III
Warhead	V	V	V		
Motor Unit	V	IV	IV	III	III

CBEMS/BANG 125 kg

Performance Comparisons

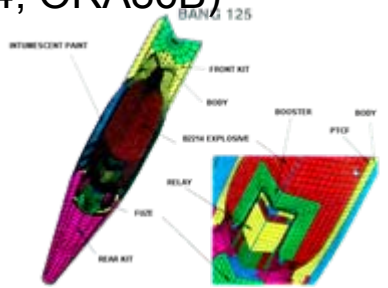


Customers

- French Naval Air Force (production)

IM Technology

- IM High explosives (B2214, ORA86B)
- Discharge of combustion gas by the liner towards the end
- Intumescent paint
- Logistic pallet geometry
- Venting devices in rear frame



IM Benefits (cost analysis)

- For the all up round (including Paveway II guidance kit), ratio between IM version and non-IM version is 1.13

IM Signature

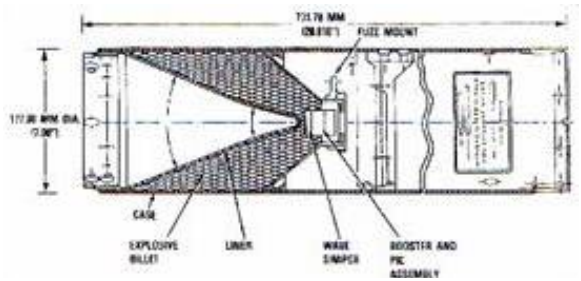
	FCO	SCO	BI	FI	SR
Mk82 mod 2 TP	I	I	I	I	I
CBEMS/BANG	V	V	V	V	III

4 palletized bombs without the fuze MURAT **

HELLFIRE II WARHEAD (AGM-114K)

Performance Comparisons

- Design adaptation studies:
  - explosive pressing, weight reduction, and liner adaptation
- At 7 CD stand-off same performance
- Over 70 tests



Customers

- US Army
- US Marines
- UK Army (Apache, Cobra Helicopters)
- France

IM Technology

- K variant incorporates an IM High explosive (PBXN-9) to improve Helicopter survivability
- IM booster
- 2" thick buffer aluminum

IM Benefits (cost analysis)

- Explosive weight reduced (<14 pounds)
- No hardware modification
- Similar loading and assembling method
- No more wave shaper

IM Signature

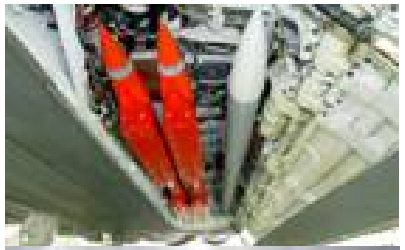
	FCO	SCO	BI	FI	SR*
LX14	V	V	I/III	I/III	I/III
PBXN-9	V	V	V	I/III	III

*All missiles in shipping containers

SMALL DIAMETER BOMB (SDB) (GBU-39B)

Performance Comparisons

- Nominal range ~100 km
- Warhead mass ~48 kg Net Explosive Weight
- Current and planned launch platforms include F-15E, B-1, B-2, F-16, F-18, F-22 and F-117.



Customers

- Production approved in April 2005
- USAF plans to purchase 24,000

IM Technology

- Boeing GBU/39B, 250lb class munition
- EIDS high explosive (AFX-757)

IM Benefits (cost analysis)

- Total program cost ~US$2.59 billion including development
- 24,000 phase 1 units and 2000 carriages
- Reported USAF target price is <US$50K/bomb
- USA DoD classified NATO 1.2.3 and UN HD1.2

IM Signature

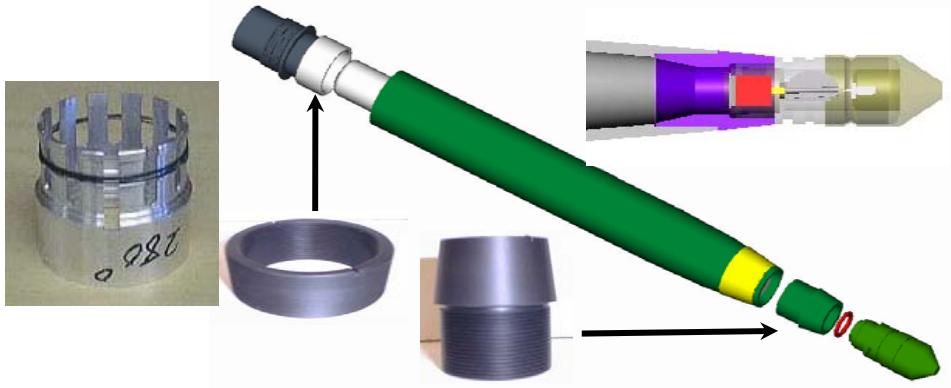
	FCO	SCO	BI	FI	SR
GBU-39	V	V	V		III

GBU-39B SDB was only the second munition to be given SsD 1.2.3 (following JASSM) which means the above signature has been achieved. SR is Type III or better.

2.75” ROCKET SYSTEM

Performance Comparisons

- Mk-146 Mod 0: larger lethal area and greater fractional casualties/damage than the M229 (Mk-151) Warhead, at all ranges and all targets:
  - Standing and Prone Personnel: ~20%
  - Light Trucks: ~9%
  - Straight Flush Radar:~5%



Customers

- Mk-146: Scheduled to be introduced to production in FY04

IM Technology

- Insensitive explosives in Mk-146 Mod 0 Warhead (PBXN-110) and fuze (Lead-in charge: PBXN-5 and booster charge: PBXN-7)
- Venting on both warhead ends to improve Cook-off reaction (Polymer adapter)
- Nitinol (shape memory) ring , vented motor tube and ejectable warhead adapter for motor section

IM Benefits (cost analysis)

- None available

IM Signature

	FCO	SCO	BI	FI	SR
Mk-151 CompB	II	I	IV	I	I
Mk-146 Mod 0	V *	V *	V	I	I
RM Mk-66 Mod 5	IV/V*				

*In LAU-6CA launcher or Mk-706 mod 0 container

US IM Strategic Plan

- Complete munitions portfolio for the Program Executive Office (legacy, developmental, production, awaiting production, Advanced Technology Demonstration, Foreign Comparative Testing, inventory)
  - For each munition:
    - Research Development Test, Evaluation and procurement profiles
    - Baseline and predicted IM performance
    - Ongoing and planned technology integration efforts with identified funding
- IM investment priorities and prioritization criteria
- Standardized detailed IM Plan of Action and Milestones for each priority program
- Service-specific and Joint IM investments
- Unfunded IM requirements
- Technology shortfalls

Albania 15th March 2008 - The End