MSIAC

Munitions Safety Information Analysis Center

Supporting Munitions Safety

Insensitive Munitions Technology: Career Reflections and International Perspective

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OVERVIEW

- My Career
- NATO MSIAC
- IM: US vs. International Policy
- NATO IM Test Standard Update
- IM Success Examples
- Harmonization of IM and Safety
- Technology Gaps
- Conclusion

Present and Past

NATO Munitions Safety Information and Analysis Center (MSIAC)

- 1 June 2016
- Technology Specialist Officer for Warheads
- Support the 15 MSIAC member nations

US Army Armament Research, Development and Engineering Center

- Retired May 31 2016 after 31 years
- Senior Research Scientist (ST) for Insensitive Munitions
- Support the US DoD, Army and ARDEC

Strong interest in energetic materials from a young age

TECHNICAL COMMUNITY

I hugely benefited through technical interactions

- ARDEC
- DoD (JIMTP)
- DOE (JMP)
- Industry
- Academia
- International

Technical interaction outside of your organization is vital for both personal and technical community development

I am a product of the technical community

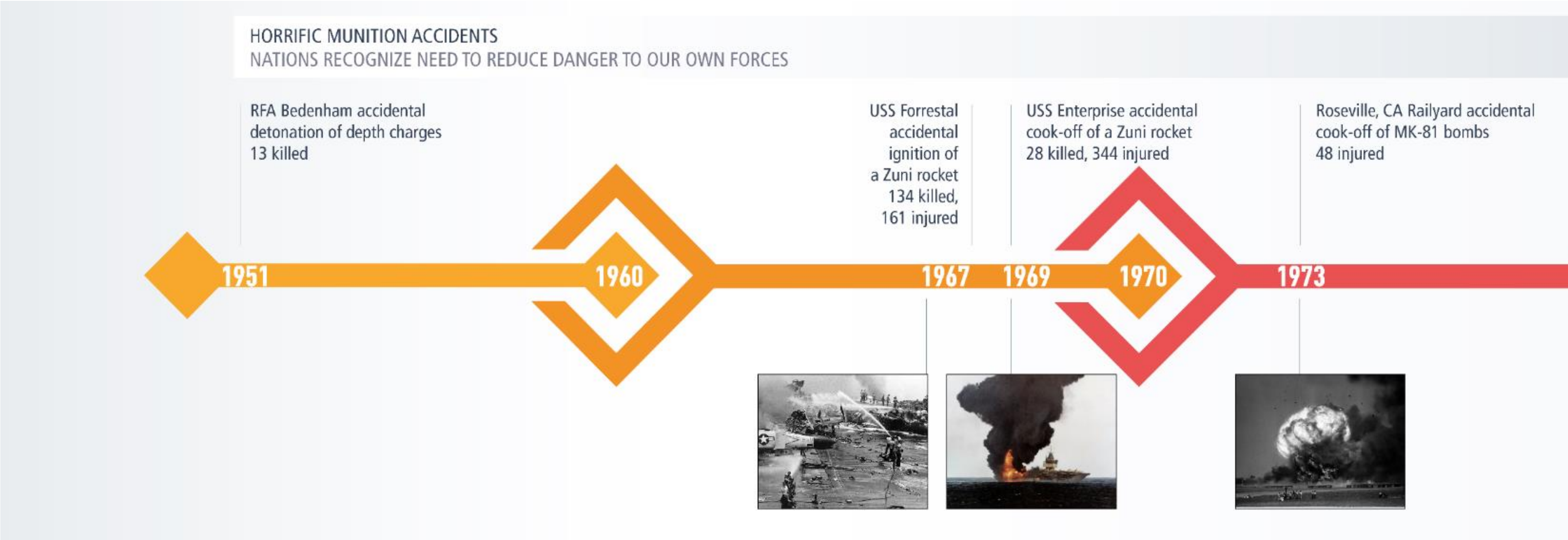
MSIAC History

History of NIMIC/MSIAC is linked to history of IM

- Need arose from horrific accidents of 1960 and 1970s

25th MSIAC 1991-2016

Time Line


HORRIFIC MUNITION ACCIDENTS
NATIONS RECOGNIZE NEED TO REDUCE DANGER TO OUR OWN FORCES
RFA Bedenham accidental detonation of depth charges 13 killed
USS Forrestal accidental ignition of a Zuni rocket 134 killed, 161 injured
USS Enterprise accidental cook-off of a Zuni rocket 28 killed, 344 injured
Roseville, CA Railyard accidental cook-off of MK-81 bombs 48 injured
1951
1960
1967
1969
1970
1973

Technical Information & Analysis Center Focusing on Munitions Safety

- NATO Project Office
- Independently Funded by its Member Nations

MSIAC Strategic Goal:

Eliminate Hazardous Consequences due to Unintended Reactions of Munitions and Energetic Materials Throughout their Lifecycle

MSIAC Staff

PROJECT MANAGER
Mr. Charles Denham

OFFICE MANAGER
Diane Vanoverstraeten

TECHNICAL SPECIALISTS

- MUNITIONS SYSTEMS — *Matt Ferran*
- STORAGE & TRANSPORT — *Martijn van der Voort*
- ENERGETIC MATERIALS — *Chris Hollands*
- WARHEAD TECHNOLOGY — *Dr Ernie Baker*
- PROPULSION TECHNOLOGY — *Christelle Collet*
- MATERIALS TECHNOLOGY — *Dr Kevin Jaansalu*

IT SUPPORT

- SYSTEM SUPPORT — *Dimitris Tsoukalos*
- DATA SPECIALIST — *Trinh Vo*

Trainees

Christian Li (FRA)
Hugo Chelabi (FRA)
Pierre-Louis Spychala (FRA)

Stokes Fellow

(MSIAC Funded Training Fellowship)
Dr Georgios Zografakis (UK, GRC)

Knowledge & Access to Community of Technical Experts Across our Member Nations

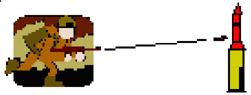
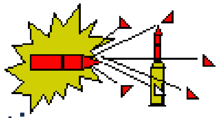
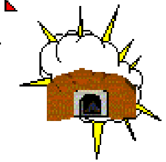
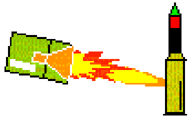
NATO and MSIAC Drivers

- Want to minimize the risk from our own munitions
- Understand and demonstrate benefits of munitions safety throughout the lifecycle
- Improve and standardize munitions safety risk assessment methodologies
  - better understanding of benefits and relative costs of munitions safety measures and methods
- Harmonize munitions safety policies to achieve greater sharing of munitions safety evidence
- Provide world leading scientific and technical analysis, and advice to support decisions on munitions safety and risk management
- Standardize approach to safe storage and use of munitions in operational theatres

US VS. INTERNATIONAL

US DoD Insensitive Munitions: MIL-STD-2105D

- Refers to NATO Standards (STANAGs)
  - STANAG 4240: Fast Cook-Off (FCO), in a fire
  - STANAG 4382: Slow Cook-Off (SCO), near a fire
  - STANAG 4241: Bullet Impact (BI), rifle attack
  - STANAG 4496: Fragment Impact (FI), mortar or artillery attack
  - STANAG 4396: Sympathetic Reaction (SR), prevent mass detonation
  - STANAG 4526: Shaped Charge Jet Impact (SCJI), RPG attack

International

- NATO: Policy for Introduction and Assessment of Insensitive Munitions (IM), STANAG 4439 covering AOP-39 Edition D Version 1 (20 Nov 2018)
  - *All NATO IM policy and test standards have been recently updated!*
- However different countries have different national policies
- Several NATO and some MSIAC countries do not have national IM policies

IM Test Standards Update

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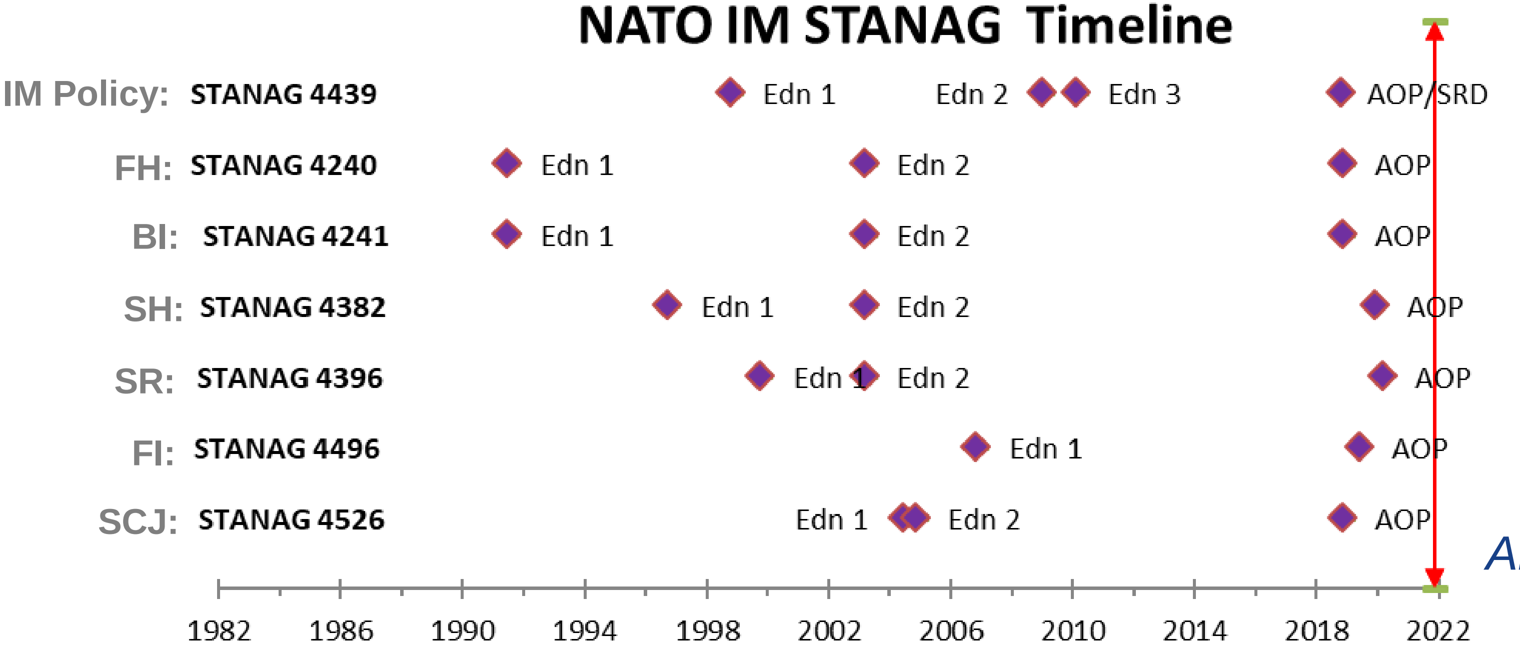
- Last coordinated publication of IM Test STANAGs April 2003
- STANAG 4439 revised twice since last Test STANAG
  - Resulting inconsistencies
- Changing organization and structures
- Opportunity with transition of Test STANAGs to AOPs

AC/326, SG/B

NATO IM STANAG Timeline



All documents updated!

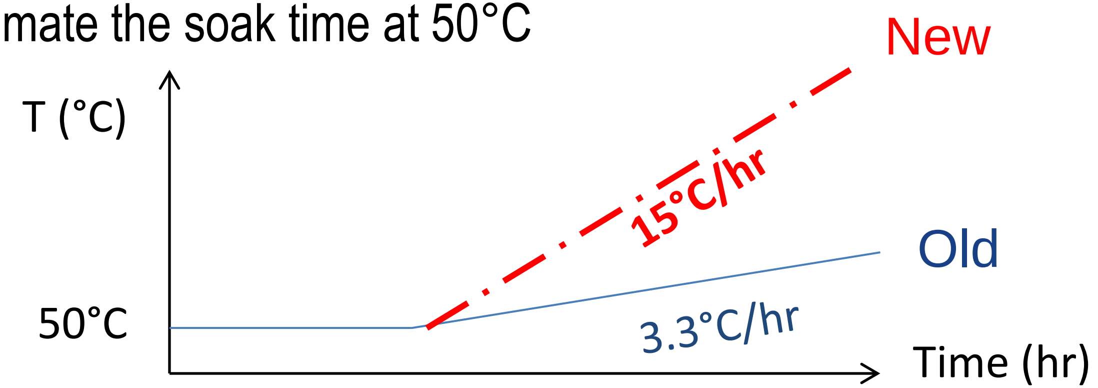
AOP-4240: Fast Heating

- Test procedures – *Modified*
  - Procedure 1: Large pool fire
  - Procedure 2: Mini pool fire
  - Procedure 3: Fuel burner fire **NEW**
- Themocouples – *Modified*
  - Minimum 6 TC: (40-60 mm) fore, aft, starboard, port, above and below
- Conformity – *Modified*
  - Taverage > 800°C measured by all TC
  - 550°C under 30 s measured by all TC

US NSWCDD 3.7 m square propane burner

AOP-4382: Slow Heating

- **Test procedures – *Modified***
  - Procedure 1: Preconditionning at 50 ± 3°C until thermal equilibrium of the test item, then Heating Rate **15°C/hr** until reaction occurs
  - Procedure 2: Another HR determined by THA
  - Procedure 3 (UN HC): 3,3°C/hr until reaction occurs – possibility to precondition at Treaction – 55°C (estimated)
- **Thermocouples – *Modified***
  - **6** required TC at 40-60 mm around the test item, rather than 4
- NEW **Annex A:** Methods to estimate the soak time at 50°C



AOP-4241: Bullet Impact

- **Test procedures –** ***Modified***
  - Procedure 1: 3 12.7 mm AP M2 projectiles at 850 ± 20 m/s (600 ± 50 rounds/min)
  - NEW Procedure 2: 1 12.7 mm AP M2 projectile at 850 ± 20 m/s
  - Procedure 3: 1 or several projectiles – projectile and velocity determined by THA

NEW

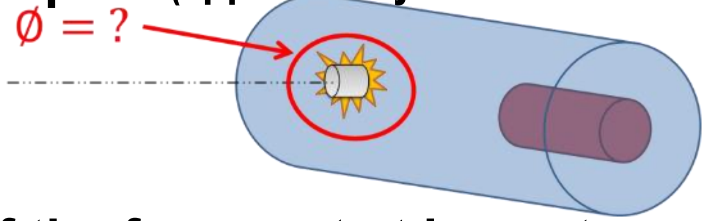
- Annex A: Recommendations aiming point and target area
- Annex B: Specifications 12.7 mm AP projectiles

AOP-4496: Fragment Impact

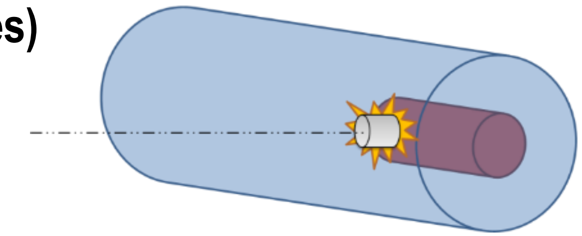
- **Test procedures –** ***Unchanged***
  - Procedure 1: 2530 +/- 90 m/s
  - Procedure 2: 1830 +/- 60 m/s

NEW

- **Accuracy at impact (approved by National Authorities)**

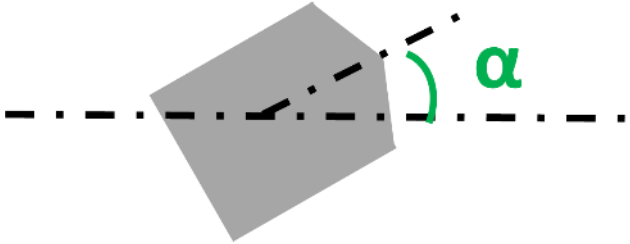


Small items: Hit the targeted area



NEW

- **Orientation of the fragment at impact**
  - Recommendation ± 10°



- **Brinell Hardess of the fragment –** ***Modified***
  - **190 < HB < 270**

AOP-4396: Sympathetic Reaction

- **Test methods (donor initiation)**
  - If designed to detonate, detonate the donor munition in the design mode – ***Unchanged***
  - For munitions which are not designed to detonate, initiate the donor munition(s) with a credible threat that produces a worst-case response (for example, shaped charge jet) – ***Modified***
  - Sand not to be used for inert munitions or confinement – ***Modified***

NEW

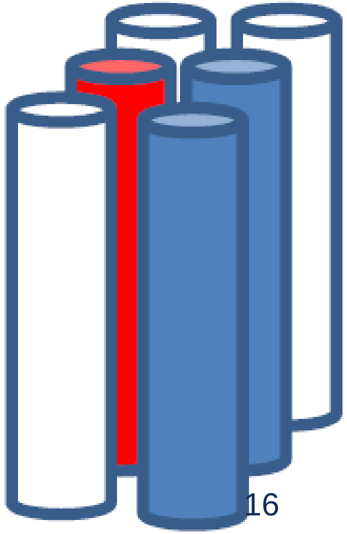
- **Baseline test:** recommendation to perform a baseline test in order to determine the blast, fragmentation and penetration signature of the donor test item(s), and the fragmentation and spatial distribution of inert acceptors.

NEW

- **Additions in SRD AOP-39.1**
  - SR configuration examples
  - Clarification of what is the test item in SR tests

NEW

- **Addition of definitions for donor/acceptor munition in official NATO terminology**



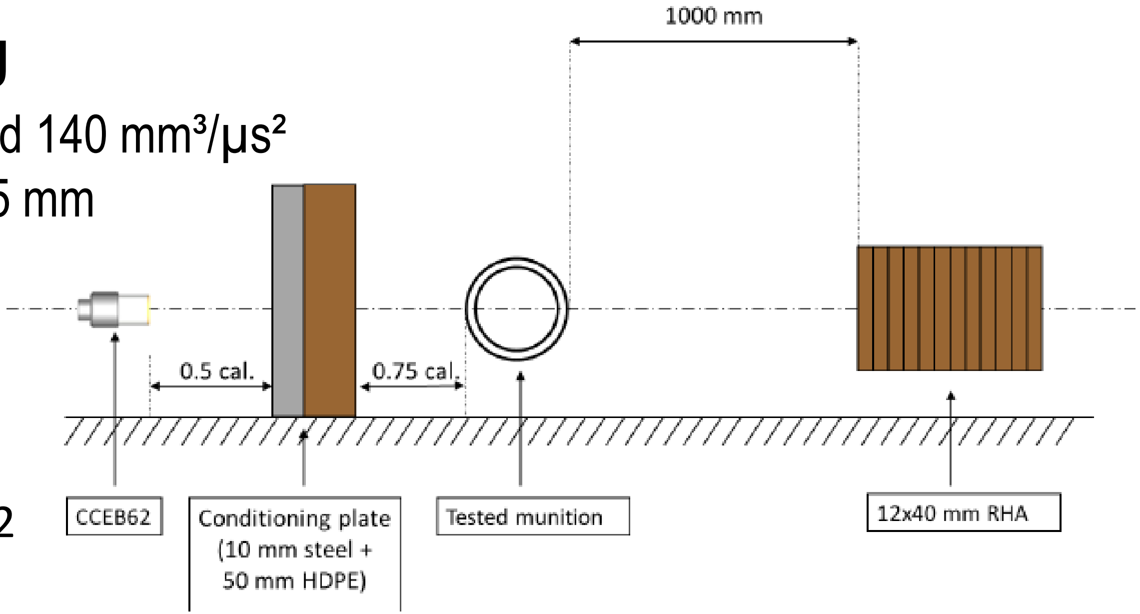
AOP-4526: Shaped Charge Jet

NEW

- **Test procedures – *Modified***
  - Procedure 1: SCJ characteristic of RPG-7 (Rocket Propelled Grenade)*
  - Procedure 2: SCJ supported by means of a THA

NEW

- **Characterization of the SCJ**
  - V^2d at the target between 120 and 140 $mm^3/\mu s^2$
  - Jet diameter between 2.5 and 3.5 mm



Previous: STANAG: Rockeye 50 mm
New: SC 81 mm LX-14 (USA); France : CCEB62

155-mm M795 High Explosive Projectile

Performance Comparisons

- Matches TNT Performance

	Conventional	IMX-101
Formulation	TNT	DNAN/NTO/NQ
Density	1.65	1.75
VoD	6960	6960
Gurney Velocity	2300	2300

Type IV response to SCJ

IM Technology

- IM High Explosive: IMX-101 with Large Critical Diameter (66mm)
- Supplementary charge
- Not fuzed –Meltable fuze lifting plug adaptor

IM Benefits (cost analysis)

- Melt Cast Formulation
- Choice of EM results in small cost increase per unit round

IM Signature

	FCO	SCO	BI	FI	SR	SCJ
M795 (TNT)	III	III	IV	IV	I	I
M795 (IMX-101)	V	V	IV	V	Pass	IV

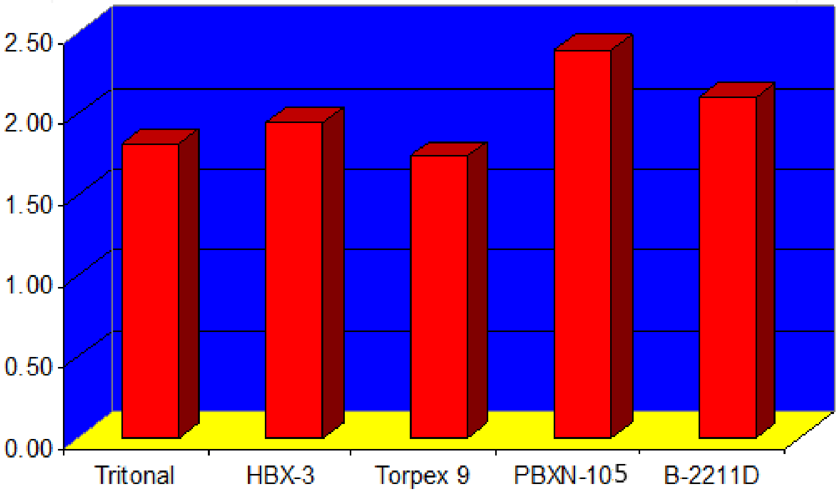
Customers

- U.S. Army, U.S. Marine Corps

Heavy Torpedo (F21)

Performance Comparisons

- Dual purpose torpedo
- Relative Bubble Energy

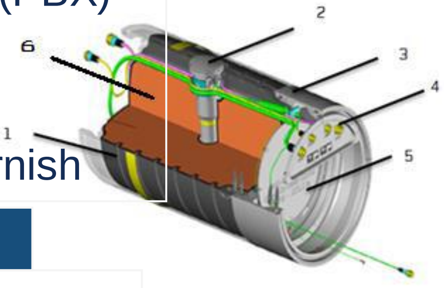


Customers

- French Navy

IM Technology

- EIS High Explosive: 250 Kg B-2211D (PBX)
- AP/Al/I-RDX®/HTPB (43/25/20/12)
- Thermal Protection and Fuze Varnish
  - Delayed ignition for fire fighting
  - Controlled ignition due to fuze varnish



IM Benefits (cost analysis)

- Heavy Torpedo Unit Cost: >US$ 2.5M
- Low Cost Ingredients, WH HE cost < 1% total torpedo cost

IM Signature

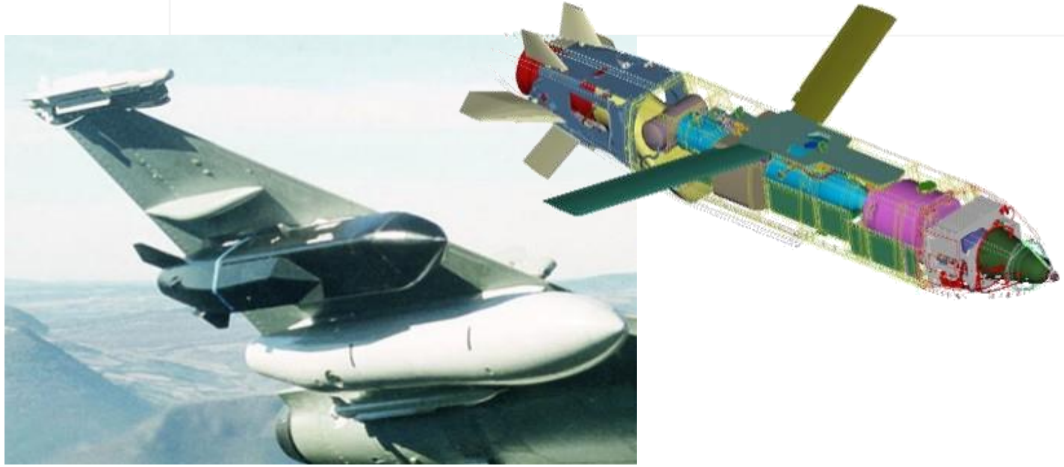
	FCO	SCO	BI	FI	SR	SCJ
HBX/Torpex					>III	
TP-2000	V	IV	V	V	III	IV

*Specific stowage configuration (head to tail) and a metal protection plate

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)

- UKNot Relevant as this family of large penetrator missiles is IM only
- MoD classified as NATO 1.2.3

IM Signature

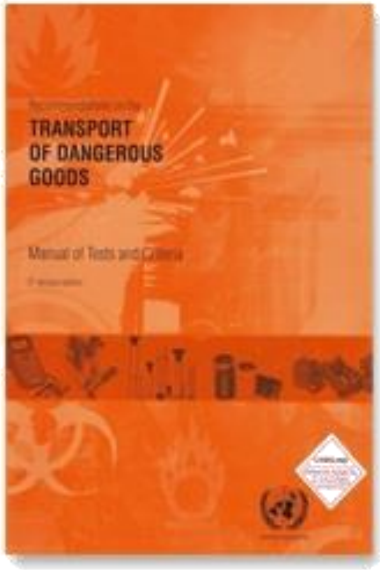
	FCO	SCO	BI	FI	SR
Mk-83	I	I	I	I	I
BLU-110	IV/V	IV/V	V	V	I
Storm Shadow	V	V	V	V*	IV**

* By analysis, ** In logistics container

HARMONIZATION OF IM AND HC

Ongoing working group (WG) to investigate further harmonizing IM and hazard classification (HC) testing and assignment procedures.

- Working to combine STANAG 4439 & AOP-39 with STANAG 4123 & AASTP-3.
- Harmonize IM and HC testing beyond NATO: Use UN test series 7 for hazard division 1.6 (rarely used)



What keeps me up at night?

- Cook-off and sympathetic reaction
  - Large bomb sympathetic reaction: been working this issue for over 25 years
  - Rocket motors: introduction of reduced response rocket motors has been difficult
- Medium caliber explosives: small critical diameter, reduced sensitivity and cost effective
- Is gap test data reliable and predictive? ***NATO working group formed in 2019!***
- Large caliber gun launch of new energetic materials: lack of ignition understanding and physics based fill acceptance criteria: How does laboratory setback testing relate to actual gun launch? ***NATO working group formed in 2017!***
- Slow cook-off rate: Are we working a problem that doesn't exist? At what cost? ***Issue resolved: NATO working group resulted in an updated STANAG!***

WORST DAY: AMERICAN ORDNANCE EXPLOSION

Fatal explosion occurred on 12 June 2006 killing two.

Justin Friedrichsen (24) , Steven Upton (48)

BEST DAY: INSENSITIVE MUNITIONS SUCCESS

Insensitive Munitions saves lives!

SPC Ng visits US Army PEO Ammunition on 5 OCT 2009

MRAP exterior view

MRAP interior view

Collected unexploded shell bodies and separated fuzes

12 SEP 2009: Specialist Ng was travelling in a Mine Resistant Ambush Protected (MRAP) vehicle when it was hit by a very powerful Improvised Explosive Device (IED). The IED ruptured the vehicle’s hull and fuel tank, which engulfed the vehicle interior in flames-to include sixteen M768 60mm mortar cartridges that were carried inside the cabin with the seven-man crew. Although several soldiers were seriously injured in the ambush, all survived. Specialist Ng credited the Insensitive Munitions (IM) features of the M768 cartridges with averting a much greater disaster.

Questions?