The Effect of Energetic Materials Ageing on System IM Response

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And all EWG participants

Presented by:

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Agenda

- Objectives of the EWG
  - **Evidence of Ageing effects on critical properties**
- Memberships
- EWG progress
  - **Literature review**
  - **Classes of interest**
  - **Fault Tree Analysis**
- Conclusion and perspectives

Evidence of Ageing Effects on Critical Properties

- IMX104 Characterisation for DoD Qualification, L.Zunino *et alii*, IMEMTS_2012
  - **Reports an increase in shock sensitivity after ageing (e.g. 106/120 LSGT cards to 135 cards after 3 months @ 70°C)**
- Irreversible Growth of DNAN based formulation, P.Samuels *et alii*, IMEMTS_2012
  - **Reports a significant increase in shock sensitivity for IMX 101 and TNT after 30 thermal cycles**
- Aging Evaluation of Certain RS RDXs.., S.Singh *et alii*, IMEMTS_2006
  - **Reports that wax formulations based on some recrystallised Bachmann RDX show an increase in shock sensitivity after ageing for 6 months @ 60°C**

- Objectives of the EWG

EWG - Objectives

- Identify potential changes due to ageing of the energetic material that may affect IM response
  - **Analyse how energetic material degradation can affect munition IM response**
  - **Establish state-of-the-art with respect to ageing of energetic materials & review international standards**
  - **Identify data with which to validate the proposed failure modes**
  - **Identify gaps in our knowledge**
  - **Write a final report and make recommendations for future work**

EWG - Meetings

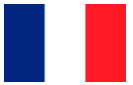
- Experts Working Group (EWG) first proposed in 2011
  - **The Effects of Ageing on the Properties of Energetic Materials which could Affect IM Response**
  - **Sponsor Fabio Sgarzi, Rheinmetall Italia**
- EWG has had 7 meetings:-

#1	January 2012	Quai Henri IV, Paris, France	Eurenco
#2	February 2012	Stirling Square, London, UK	GCSM – BAE Systems
#3	April 2012	MBDA - UK, The Strand, London, UK	MBDA - UK
#4	September 2012	MBDA - F, Le Plessis Robinson, France	MBDA - F
#5	December 2012	Eurenco Head Office, Paris, France	Eurenco
#6	March 2013	RWM Italia S.p.A., Ghedi, Italy	RWM Italia S.p.A.
#7	June 2013	MBDA - UK, The Strand, London, UK	MBDA - UK

- Memberships

EWG - Membership

- EWG membership:-

Paul Deacon (Chair)	AWE	UK	
Ron Hollands	BAe Systems	UK	
Peter Milner	MBDA-UK	UK	
Michel Vivès	MBDA-Systems	France	
Christophe Coulouarn	Nexter Munitions	France	
Raymond Coleno	Roxel France	France	
Bernard Mahé	Eurenco	France	
Bruno Nouguez	Eurenco	France	
Richard Wild	DIEHL BGT	Germany	
Stefan Borg	SAAB Dynamics	Sweden	
Fabio Sgarzi (Sponsor)	RWM Italia	Italy	
David Jordan	RWM Italia	Italy	

- EWG progress

EWG Progress – Review Standards

- Establish state-of-the art
  - **Review International standards**
    - » **STANAG 4666 for PBX Ageing, STANAG 4170 for Qualification, NATO AAS3P-10 "Safety & Suitability for Service Including Lifecycle", AOPs, MSIAC guidance**
  - **Collate energetic materials tests data (chemistry, kinetics etc)**
  - **Exploit members' expertise & experience**
- STANAG 4666
  - **Draft NATO standard for cast-cure PBX ageing**
  - **STANAG 4666 is extensive but certain tests omitted (e.g. density, composition)**
  - **6 months ageing at 60°C**
  - **Unclear application of microscopy & thermal analysis**
  - **No clear mechanism for IMEMG to provide feedback to NATO SG1**

EWG Progress – KS-32 Ageing

- A successful international collaboration on KS-32 ageing was reviewed
  - **UK, France, Germany, The Netherlands**
  - **Cast-cured PBX; 85% HMX, 15% HTPB binder**
- KS-32 was aged at 3 institutions
  - **Shown to be very stable at T < 80°C**
  - **Inhomogeneity noted; uncoated HMX surfaces**
  - **Shock sensitivity increased very slightly in the most aged samples**
- Papers published at 2009 ICT conference
  - **Papers V5 – V8**
- This study contributed to philosophy of STANAG 4666 and experimental methods therein

Energetic Materials - Classes of Interest

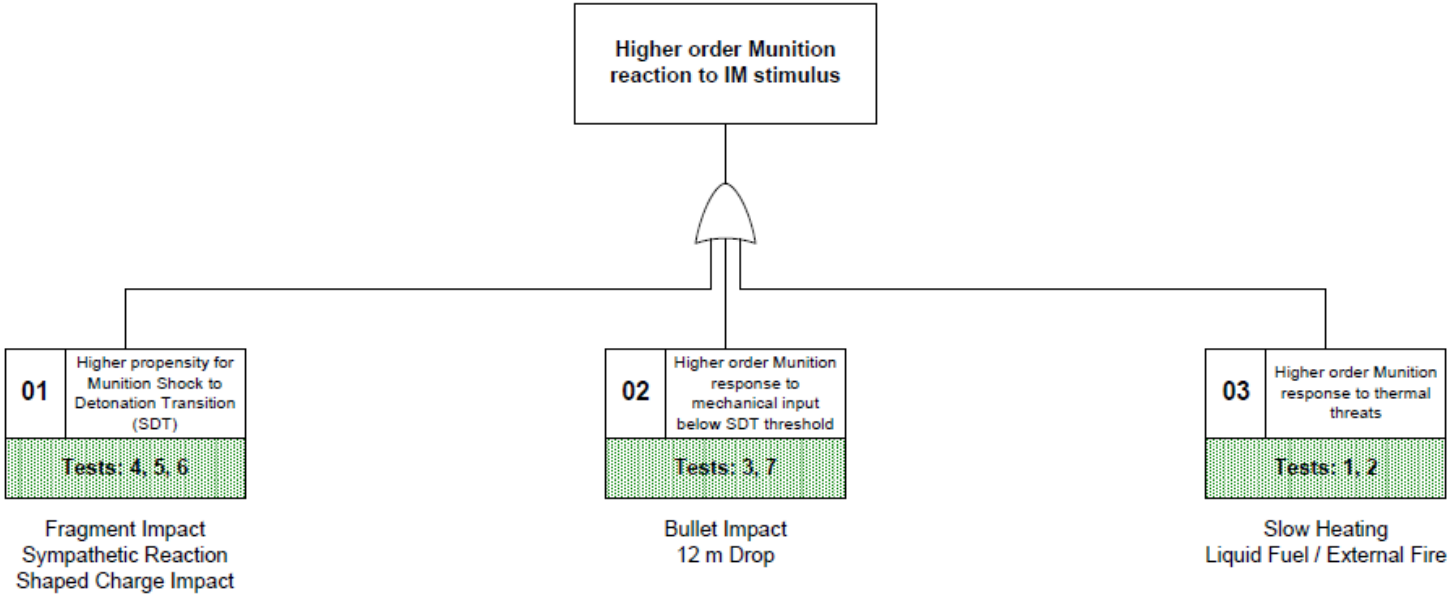
- Various classes of energetic materials should be considered
  - **Cast-cured PBXs**
  - **Composite propellants**
  - **Melt-cast IM formulation (TNT based)**
  - **Pressed compositions**
  - **Gun propellants**
- Certain classes will be excluded from investigation
  - **Primary explosives**
  - **Double based propellants**
- Initial efforts have focused on cast-cure PBXs

EWG Progress - Analysis

- The EWG drafted a logic diagram in fault tree format
  - **Tailored to suite cast-cured PBXs**
  - **Identified overall effect to munition, i.e. higher order reaction to IM stimulus**
  - **Identified charge-scale effects, e.g. SDT, DDT**
  - **Identified material-scale effects, e.g. cracked explosive, changes to binder system**
- The links between munitions/charge-scale tests & explosive charge/energetic materials tests are made
- Noted that cast-cure PBXs were developed to be chemically & physically stable
  - **Dramatic changes in PBX required to affect IM response!**

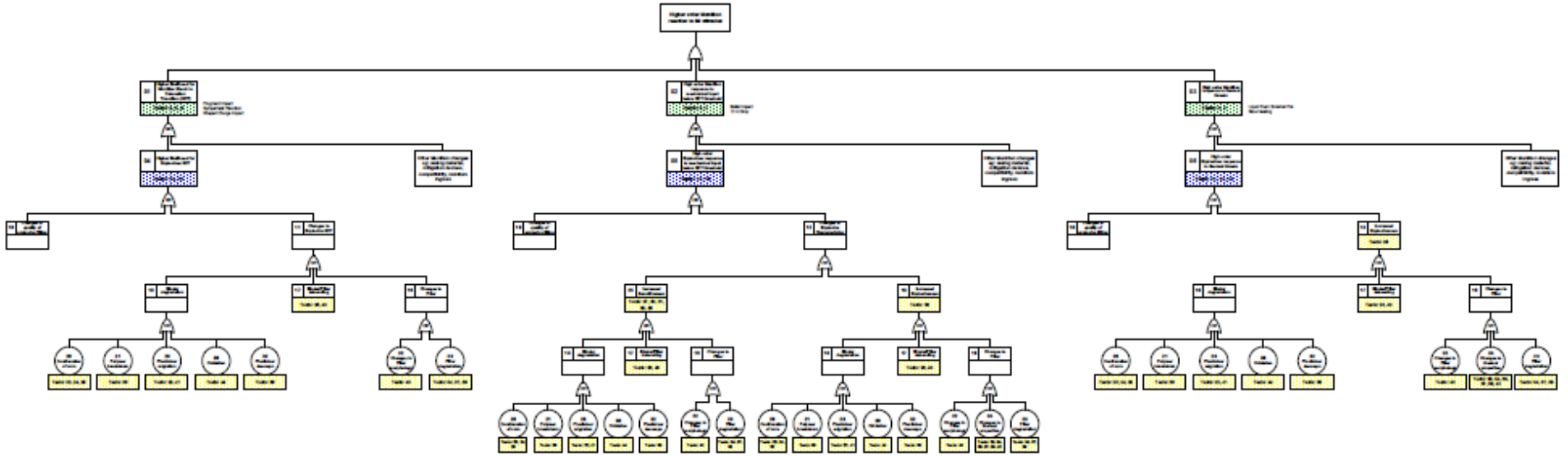
EWG Output - 'Logic Diagram'

- Higher order response to IM stimulus
  - **Increased likelihood of SDT**
  - **Increased response to mechanical input below SDT threshold**
  - **Increased thermal response**



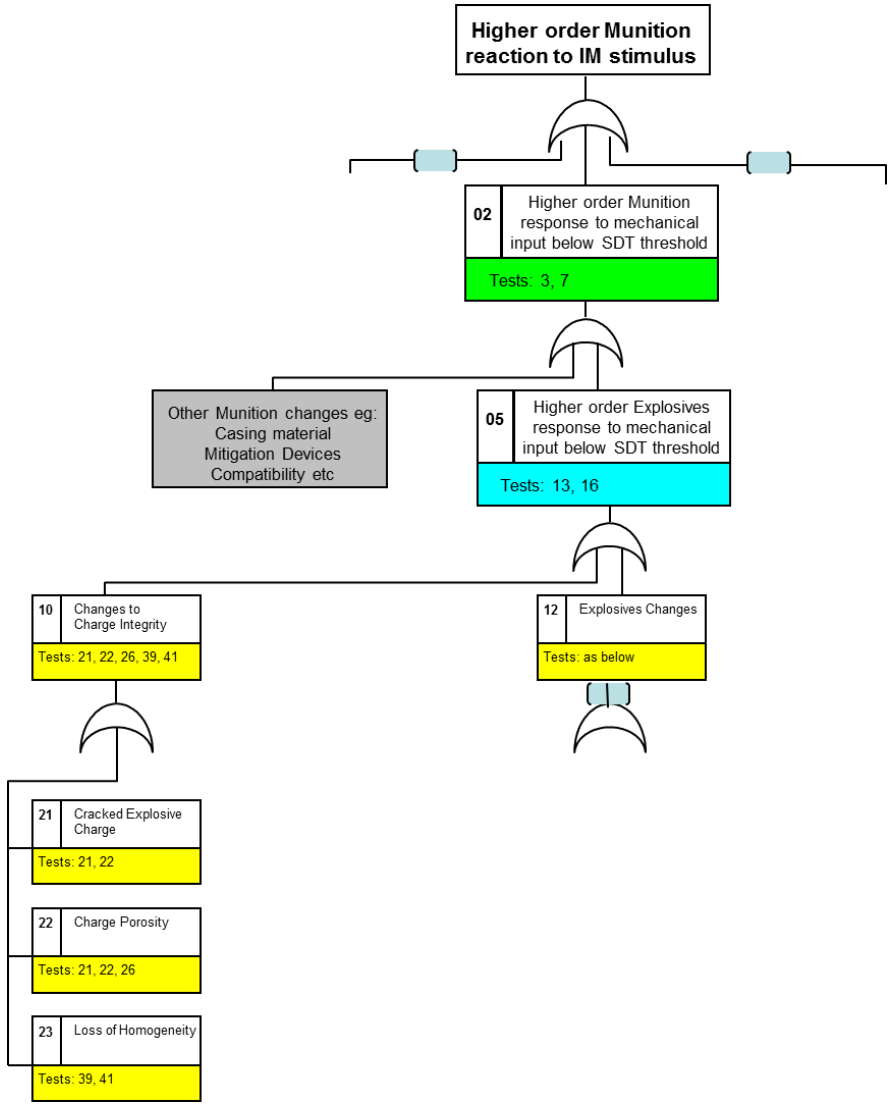
EWG Output - 'Logic Diagram Analysis'

- Unbiased hierarchy of likely failure modes
  - **Probability of individual events occurring was not considered**
- 'Logic diagram' became complex!



‘Logic Diagram’ - Extract

Test Type	Test Number	Description	Standard
Full-scale Munition *[Expensive, limited availability]*	3	Bullet Impact	STANAG 4241
	7	12m Drop	UN Test 4(b) (ii)
Charge-scale IM	13	Tube Test – Internal Ignition	EMTAP 35
	16	Friability Test	UN Test 7 (c) (ii)
Explosive Material *[Inexpensive, quicker, widely available]*	21	Radiography	-
	22	Inspection of Sectioned Charge	-
	26	Density	-
	39	Composition Analysis	STANAG 4581
	41	Plasticiser Content	-



Logic Diagram - Benefits

- Provides an overview of effects of EM properties on IM response
- Collates International test methods and specifications
- Can identify which tests offer the most value (most frequent in logic diagram)
- Could Influence test programmes for life extension and ISS
- Illustrates how available test data fits the big picture
- Identifies gaps in test programmes and test data
- Could also be used to assess effects of explosives ingredient or process changes, in addition to ageing

- Conclusion and perspectives

Conclusions

- Approach is generic & it can be applied to other classes of energetic materials
  - **Melt-cast & pressed PBXs, composite propellants**
- 'Logic diagram' makes the links between properties of energetic materials & system level IM response
  - **Links are further made to the tests that are performed**
  - **Tests that significantly 'add value' to surveillance programmes can be identified**
- Failure modes can be identified which would cause IM properties to change
  - **'Fault Tree' can be used to prioritise mitigating action against certain failure modes**
- Cast-cure PBXs are known to be very stable
  - **Difficult to envisage a situation where a cast-cure PBX would cause IM response to change dramatically**

Acknowledgements

- Members of the EWG & their respective organisations
- Hosts for the EWG meetings
- IMEMG