Insensitive Munitions European Manufacturers Group

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Ageing Expert Working Group (Chair)

FOR SAFER MUNITIONS AND TACTICAL ADVANTAGE

Assumptions

“The most important things to say are those which often I did not think necessary for me to say - because they were too obvious.”

André Gide

IMEMG MURAT
EUROPEAN MANUFACTURERS GROUP

Nato define Insensitive Munitions as….

“Munitions which reliably fulfil specified performance, readiness, and operational requirements on demand, but which minimize the probability of inadvertent initiation and violence of subsequent collateral damage to the weapon platform (including personnel) when subjected to unplanned stimuli.”

FOR SAFER MUNITIONS AND TACTICAL ADVANTAGE

How do we ACHIEVE IM?

Manufacturers have developed IM solutions through a combination of advanced technologies which mitigate violent reactions.

Examples include:-

(1) Energetic formulation based on low-sensitivity energetic molecules
(2) Optimised system architectures
(3) New types of logistic packaging

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How do we ASSESS IM?

- **By testing in accordance with STANAG 4439/AOP-39 which is the NATO regulation policy for the introduction and assessment of IM.**
- **Six tests are used to simulate the potential threats which an munition could encounter during its whole lifecycle and the level of reaction is assessed.**
  - ***Assessment ranges from no reaction to full detonation.***
- **The munition is considered IM compliant if it meets a pre-defined level of insensitiveness.**

NATO Regs. STANAG 4439/AOP-39

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Six tests

Munition Test Procedures

Stimuli		STANAG / AOP	
	FH	4240	Fast Heating
	SH	4382	Slow Heating
	BI	4241	Bullet Impact
	SR	4396	Sympathetic Reaction
	FI	4496	Fragment Impact
	HFI	•	Heavy Fragment Impact
	SCJI	4526	Shaped Charge Jet Impact

REPRESENTATION OF THE IM REQUIREMENTS 2023

STANAG 4439 • AOP-39 • AOP-39.1

Threat	Test Procedures: Stimuli	Test Procedures: STANAG / AOP	IM requirements	AASTP-1 (SsD 1.2.3)	DSA 03.OME Part 1, Chap. 11	FüSK II 2	DG-AT IM Guidelines 2000: Φ	DG-AT IM Guidelines 2000: ΦΦ	DG-AT IM Guidelines 2000: ΦΦΦ	Instruction n° 211893 21 July, 2011: ★	Instruction n° 211893 21 July, 2011: ★★	Instruction n° 211893 21 July, 2011: ★★★[1]	HD 1.2 Unit Risk INSP 30 S-CAT	MIL-STD-2105E
Magazine / store fire or aircraft / vehicle fuel fire	FH	4240	V	V	V	V	V	V	V	IV[2]	V[3]	V[3]	IV	V
Fire in adjacent magazine, store or vehicle	SH	4382	V	V	V	V	V	V	V	III	V	V	III	V
Small arms attack	BI	4241	V	V	V	V	V	V	V	III	V	V		V
Most severe reaction of same munition in magazine, store, aircraft or vehicle	SR	4396	III	III	III	III	III	III	III	III	III	III	III	III
Fragmenting munitions attack	FI	4496	V		V	V		I[4]	V		V	V	IV	V
	HFI							I[4]	V		III[5]	III[5]		
Shaped charge weapon attack	SCJI	4526	III		III	III		I[4]	III		III	III		III

[1] Only MEPS (ST-SG-AC10-11 Serie7 Tests) [2] No-Propulsion [3] After five minutes [4] Type I or more, as per THA [5] France: S-CAT N° 13146

STANAG 4439 • AOP-39 "Policy for Introduction and Assessment of Insensitive Munitions (IM)"

SRD AOP-39.1 provides guidance on the organisation, conduct and documenting of full-scale testing.

The IM Signature is assessed for any particular configuration of a munition during its life cycle.

Range of reactions

VI	No Reaction
V	Burn
IV(F)	Deflagration
IV(P)	Propulsion
III	Explosion
II	Partial detonation
I	Detonation

Table from MSIAC TSO consensus assessment based on fielded systems in 2016 for warheads.

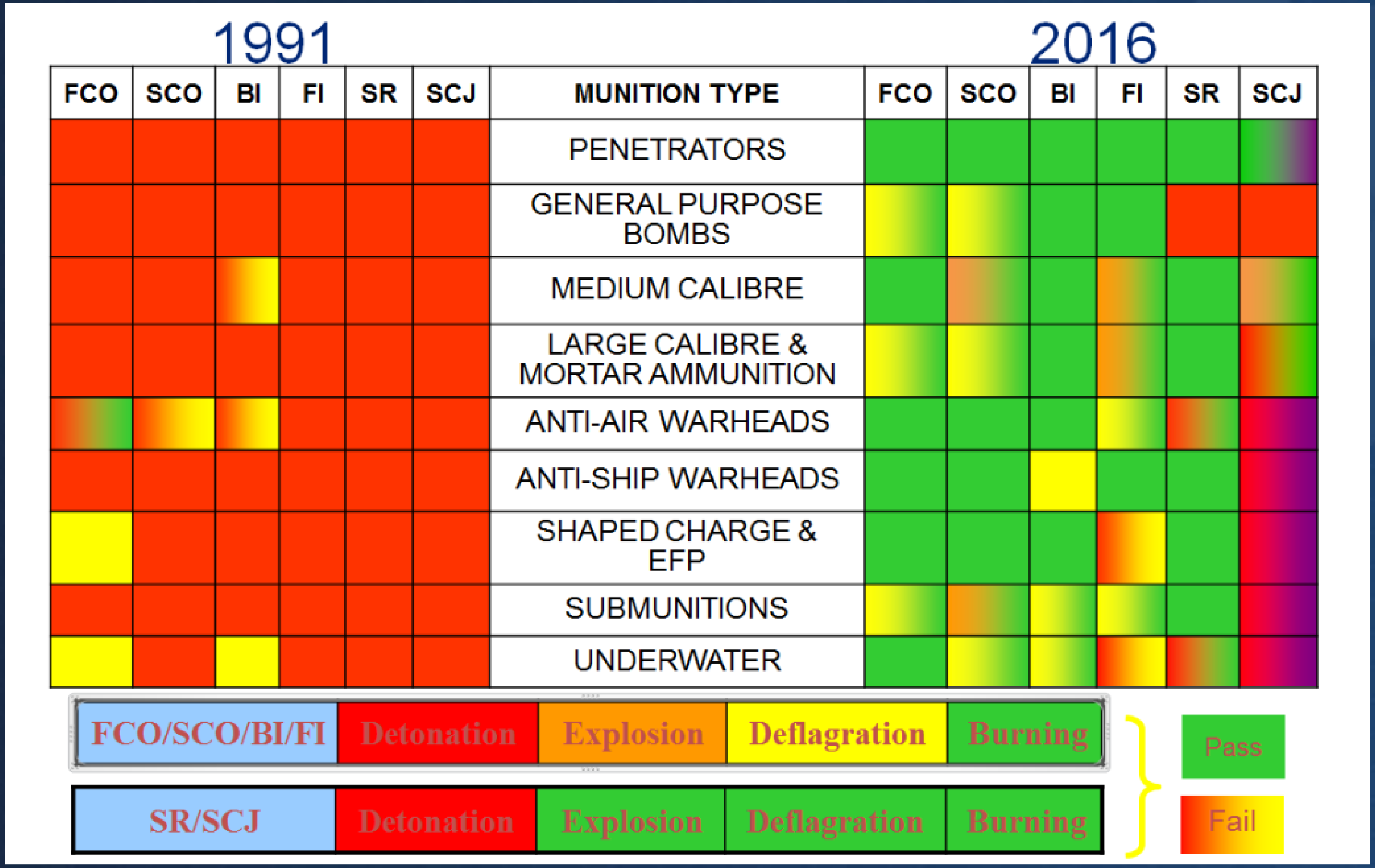
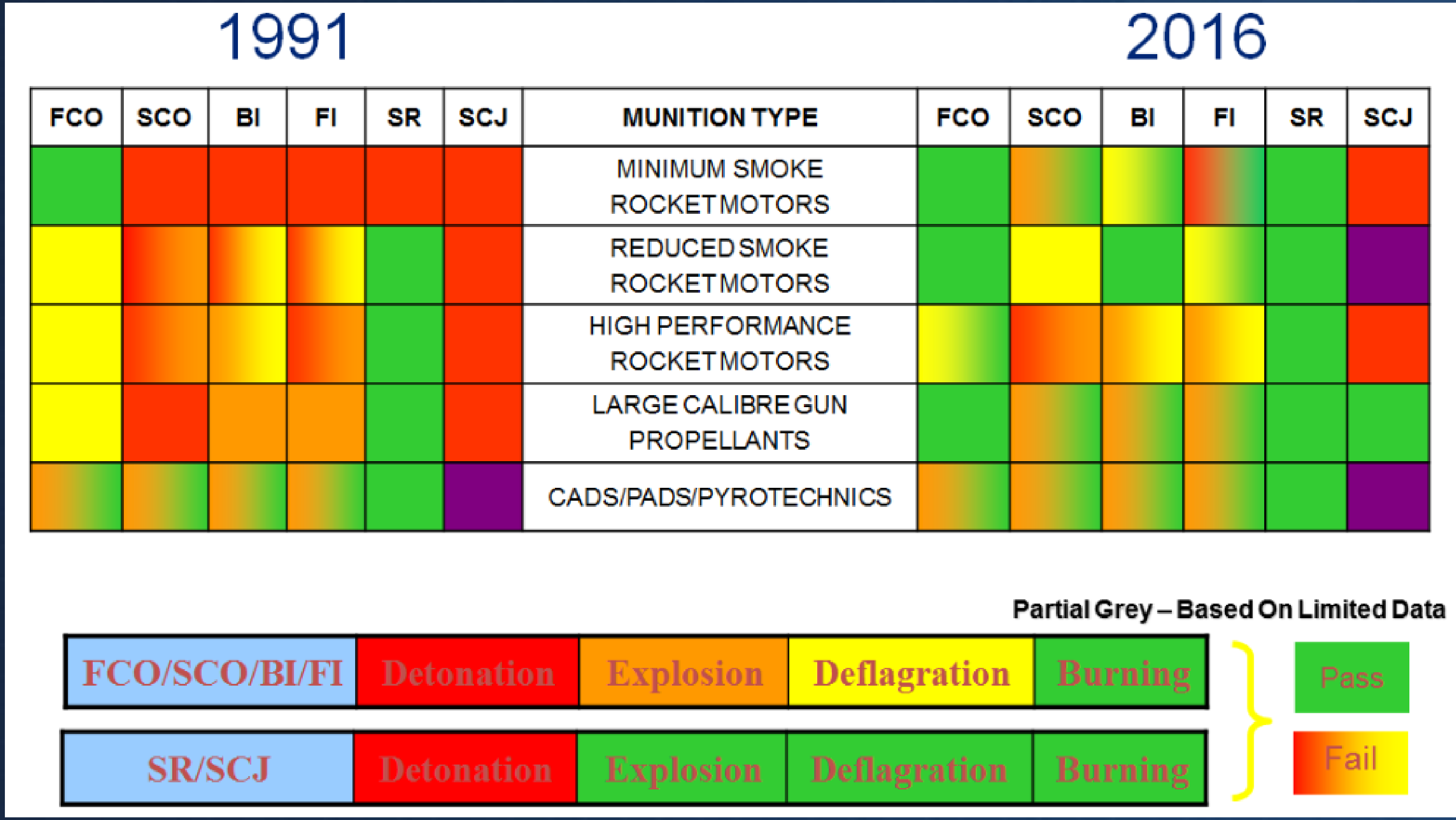


Table from MSIAC TSO consensus assessment based on fielded systems in 2016 for propulsion/pyrotechnics.



Benefits/selling points of IM?

- Reduces front line risk
- Increases platform survivability
- Makes logistics and storage safer
- ALARP - aids safety case assessments

- Reduces Whole Lifecycle Cost of Ownership
  - By addressing “cradle to grave”
  - Prolongs service life
  - Reduces environmental impact
  - Design for disposal

IMEMG Vision and Objectives

FOR SAFER MUNITIONS AND TACTICAL ADVANTAGE

Vision "The European IM industry focus and voice for IM"

Objectives

1. Support the development of harmonised international IM policies and regulations.
2. Facilitate the development and implementation of harmonised international IM standards for IM products during their whole life cycle.
3. Promote and share the benefits of IM technological progress.

AIM

Increase the operational benefits for the Armed Forces through the use of Insensitive Munitions

IMEMG History

FOR SAFER MUNITIONS AND TACTICAL ADVANTAGE

MEMBERSHIP
12 member companies
3 countries

MEMBERSHIP
22 member companies
8 countries

2001
IMEMTS
France

2003

2006
IMEMTS
UK

IM Day
Brussels, Belgium
2009

2010
IMEMTS
Germany

IM Day
London, UK
2013

2015
IMEMTS
Italy

IM Day
Amsterdam, Holland
2017

2019
IMEMTS
Spain

IM Day
Graz, Austria
2022

2024
IMEMTS → EMTWG
Norway





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IMEMG Member Companies

23 companies from 8 countries

EURENCO
arianeGroup
Roxel
THALES
nexter
MBDA MISSILE SYSTEMS
DE LA RECHERCHE À L'INDUSTRIE cea

DIEHL Defence
TDW an MBDA company
RHEINMETALL DEFENCE
JUNGHANS Defence

LEONARDO
RWM ITALIA SPA
MBDA MISSILE SYSTEMS

Chemring Energetics UK
Roxel
BAE SYSTEMS
AWE
MBDA MISSILE SYSTEMS

Nammo

SAAB

hirtenberger Defence Systems

EXPAL

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Effects of Ageing
Dr Gaynor Olliver
MBDA UK

Hazard Assessment & Classification
Carole Fournier
Eurenco France

Expert Working Groups

IMEMG Expert Working Groups

Overview

EWG 1: FAST COOK OFF (FCO) TEST PROCEDURES

- Harmonisation and improvements to the test procedure for FCO (STANAG 4240). **CALIFLUX**

EWG 2: COMPUTER MODELS FOR IM PERFORMANCE

- A review of Computer Models to aid the design and assessment of IM performance.

EWG 3: HAZARD ASSESSMENT AND CLASSIFICATION

- The harmonisation of International test procedures and acceptance criteria.

EWG 4: EFFECTS OF AGEING

- The effects of ageing on IM response or on the properties of energetic materials which could influence IM response.

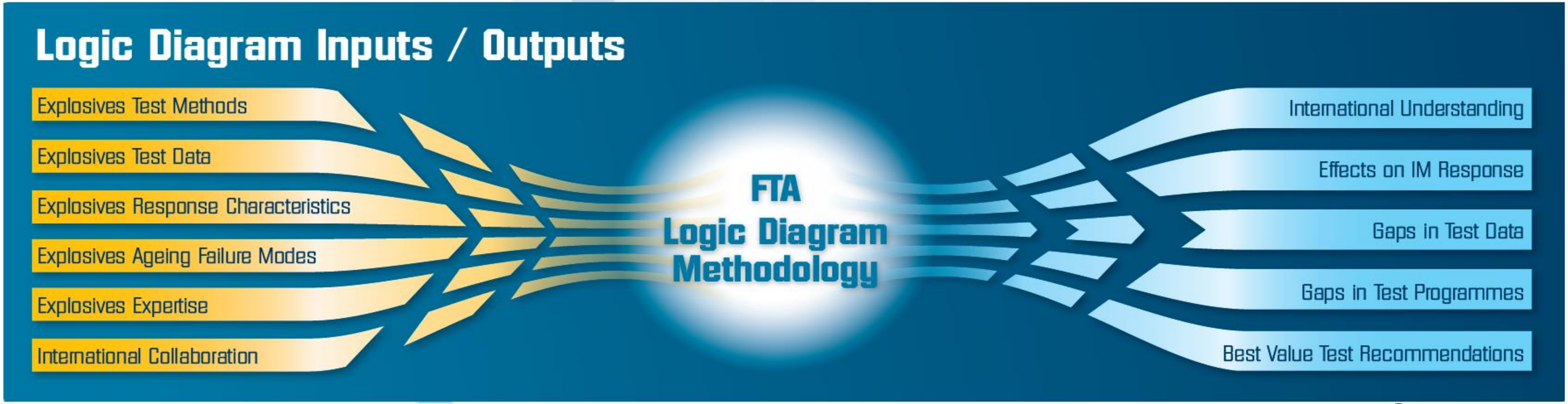
EWG 5: COST / BENEFIT ANALYSIS

- To promote and establish the state of the art of IM Cost Benefit Analysis. **ASSIM**

EWG 4: EFFECTS OF AGEING

Approach taken - on range of energetic materials

- **Expert meetings: sharing experiences to build Fault Trees.**
- **Fault Tree considers relationship between:-**
  - Explosive response mechanisms and appropriate tests
  - Munition IM response

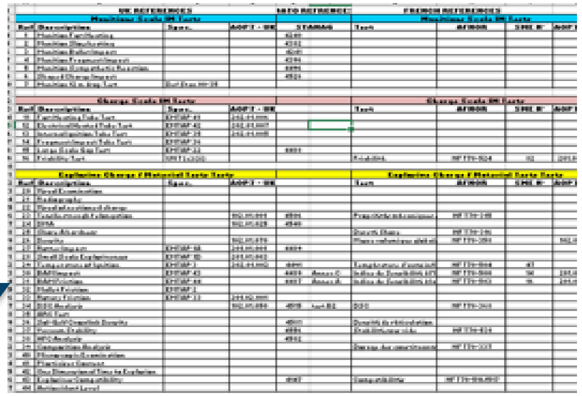


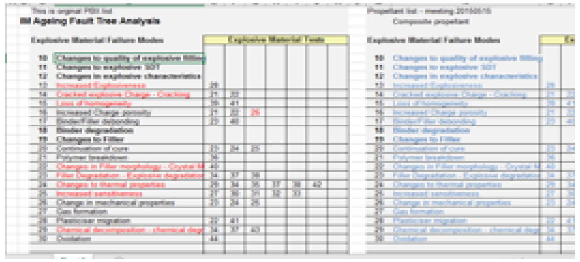
EWG 4: EFFECTS OF AGEING

Approach – 3 working documents used to generate FTAs

- **To generate the logic diagrams for the different generic formulations types three working documents are populated:**

1. **<u>Test methods</u> including reference numbers for the different nations.**
2. **<u>Table linking the relevant test methods to possible failure modes.</u>**
3. **<u>Generic comparison table of material properties</u> to help identify key differences between generic types.**

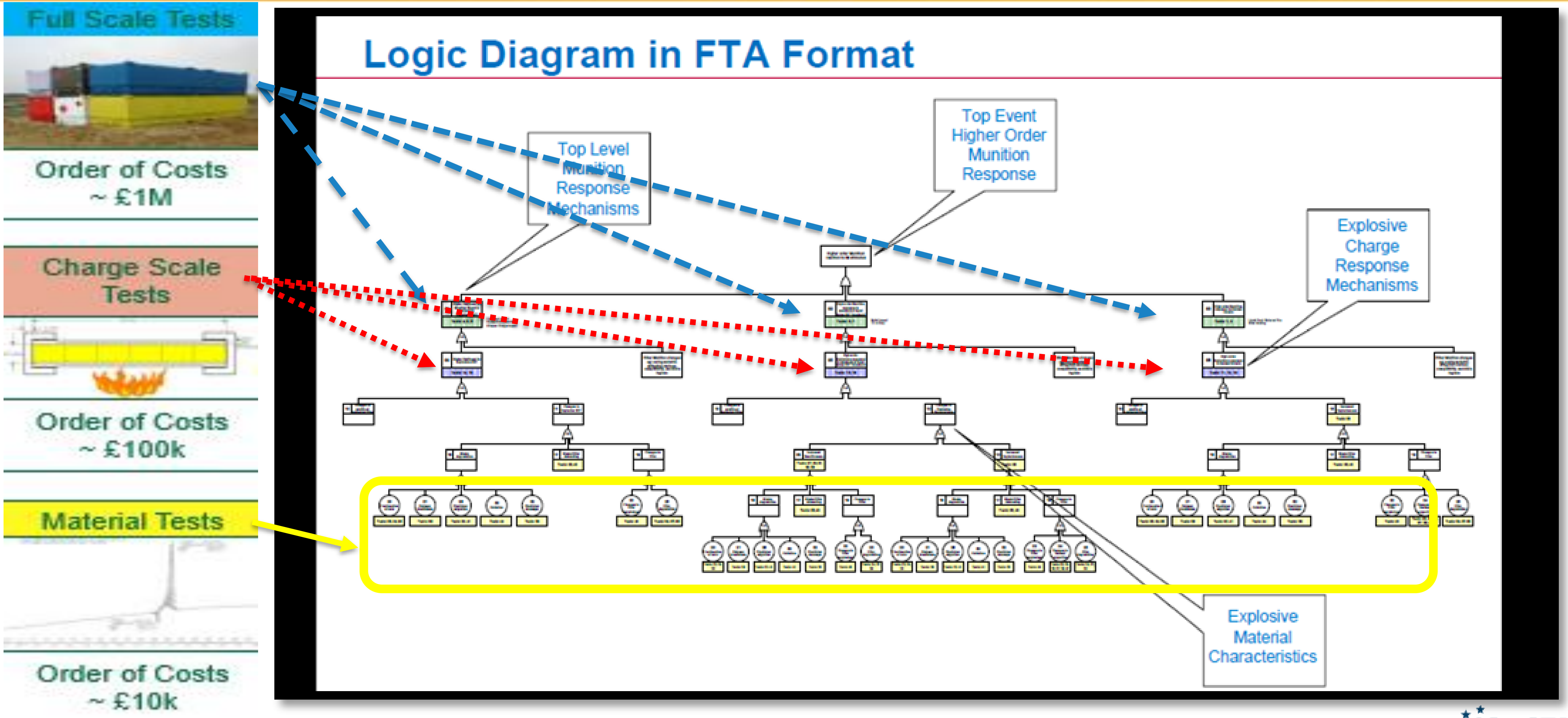




Cast PBX	IM Melt Cast	Propellant Composite
Homogeneity as cast good	Needs controlled cooling/ stress relief	Homogeneity as cast good
Good mechanical properties	Prone to cracking	Good mechanical properties
Rubbery – good tensile properties	Brittle – good compressive properties Re-inforcement possible	Rubbery – good tensile properties
Exudation/migration of plasticiser	Exudation/migration of binder/synthetic bi-products	Exudation/migration of plasticiser toward liner or thermal insulation
Binder usually non-energetic	Energetic binder	Binder usually non-energetic and energetic binders
Binder/filler adhesion poor without bonding agent	Binder/filler adhesion good	Bonded agent with AP based are possible
Low glass transition point	Mechanical properties limited by melting point of binder	No impact of glass transition temperature on mechanical properties as glass temperature is outside of in-service temperature range

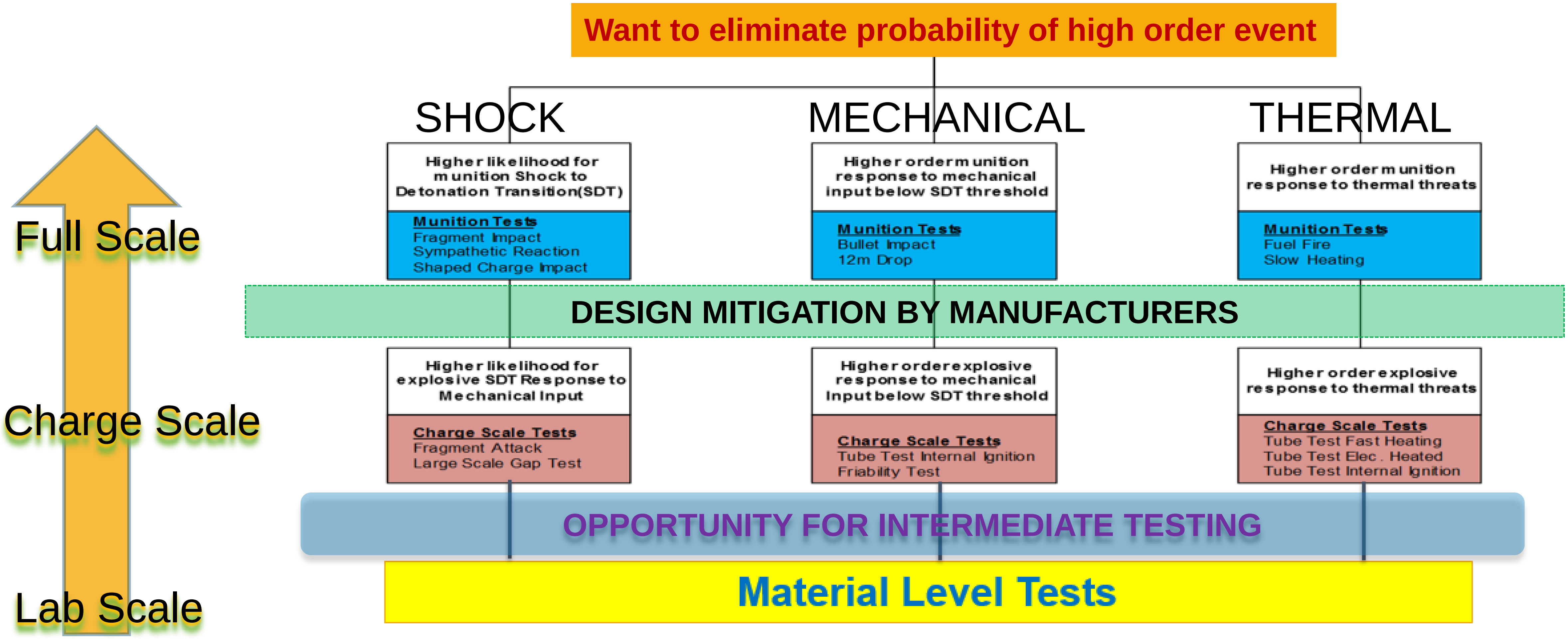
EWG 4: EFFECTS OF AGEING

Approach taken – Full/Charge/Lab Scale



EWG 4: EFFECTS OF AGEING

Approach taken – Full/Charge/Lab Scale



EWG 4: EFFECTS OF AGEING

Technical Status on FTA - Potential Applications…

- **Demonstrated it provides an overview of effects of EM properties on IM response.**
- **Has ability to be tailored to suite range of energetic formulations and *multiply applications..*** examples
  - Applicable to Material Qualification, In-Service Surveillance & Life Extension.
  - Helps identifies gaps in test programmes and test data.
  - Aid justification as to why new methods are required in specific areas.
  - Ensure programmes focus on tracking potential failure modes.
- **Can identify which tests offer the most value (most frequent in logic diagram).**
  - Could be used to scope out most appropriate tests when *developing new formulations*.

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EWG 4: EFFECTS OF AGEING

Technical Status on FTA - Potential Applications…

- **Illustrates how available test data fits the big picture**
  - Shows links in scale which have the *potential to educate early careers/new starters*.
- **Could also be used to assess effects of energetic ingredients or process changes, in addition to ageing –** *reduce re-qualification programmes.*
- **Develop into useable tool for everyone – multiply applications**
  - Employ traffic light system.
- **Used to demonstrate implications at system level if you want projects to take notice and fund additional work**
  - Black and white approach needed as project leaders not interested in the detail.
- **Output could help identify technical areas which need further development**
  - Gaps – research into SMARTER Certification methods

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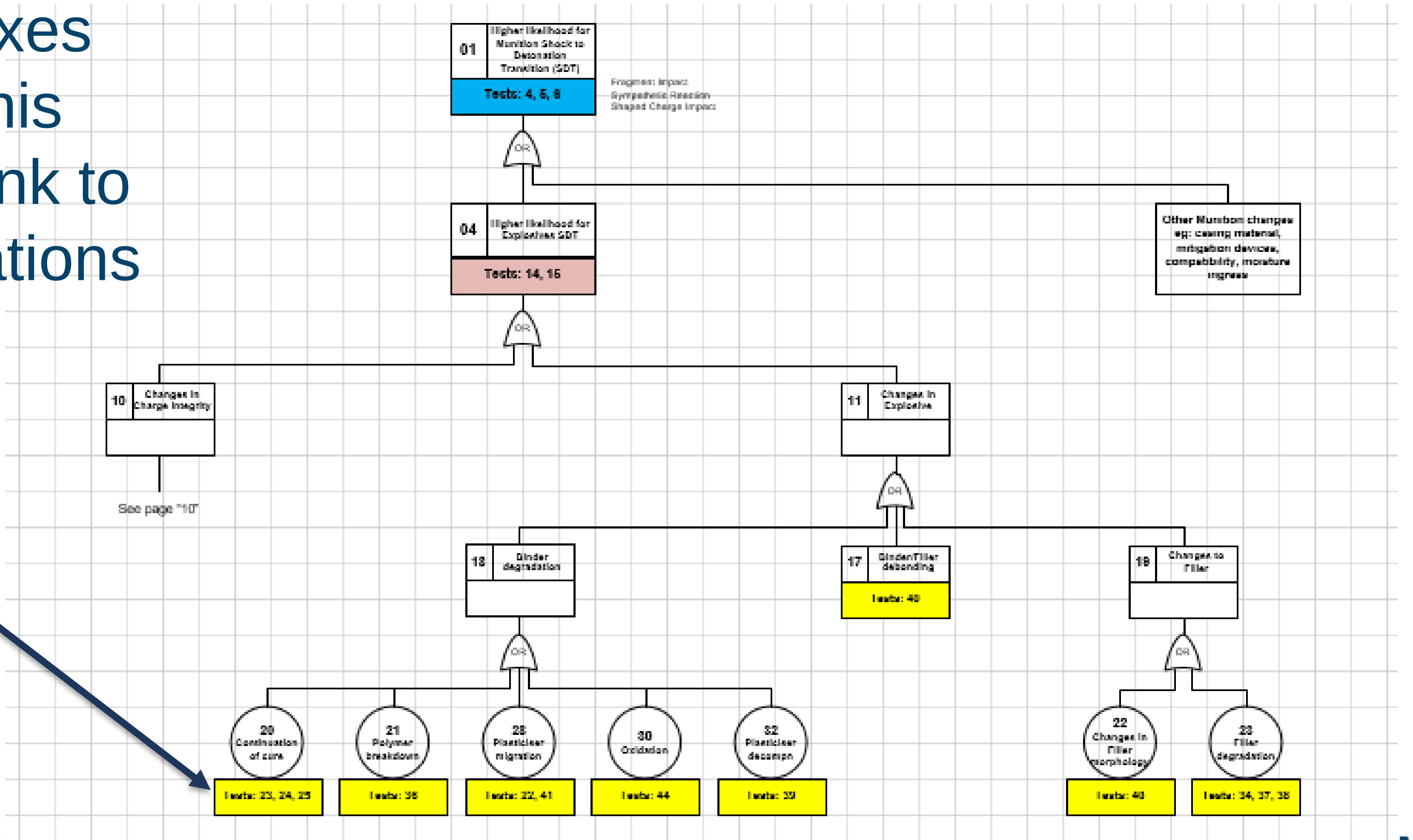
EWG 4: EFFECTS OF AGEING

Fault Tree Analysis Visual Example

Colour code test boxes based on results. This would show direct link to system level implications

Risk	
Monitor	
Acceptable	
Outstanding	
Not requested	



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EWG 4: EFFECTS OF AGEING

Summarised outputs

	Explosive Material Failure Modes	Explosive Material Tests						
10	**Changes to quality of explosive filling**							
11	**Changes to explosive SDT**							
12	**Changes in explosive characteristics**							
13	Increased Explosiveness	28						
14	Cracked explosive Charge - Cracking	21	22					
15	Loss of homogeneity	39	41					
16	Increased Charge porosity	21	22	26				
17	Binder/Filler debonding	23	40					
18	**Binder degradation**							
19	**Changes to Filler**							
20	Continuation of cure	23	24	25				
21	Polymer breakdown	36						
22	Changes in Filler morphology - Crystal Morphology	40						
23	Filler Degradation - Explosive degradation	34	37	38				
24	Changes to thermal properties	29	34	35	37	38	42	
25	Increased sensitiveness	27	30	31	32	33		
26	Change in mechanical properties	23	24	25				
27	Gas formation							
28	Plasticiser migration	22	41					
29	Chemical decomposition - chemical degradation	34	37	43				
30	Oxidation	44						
32	Plasticiser decomposition	39						

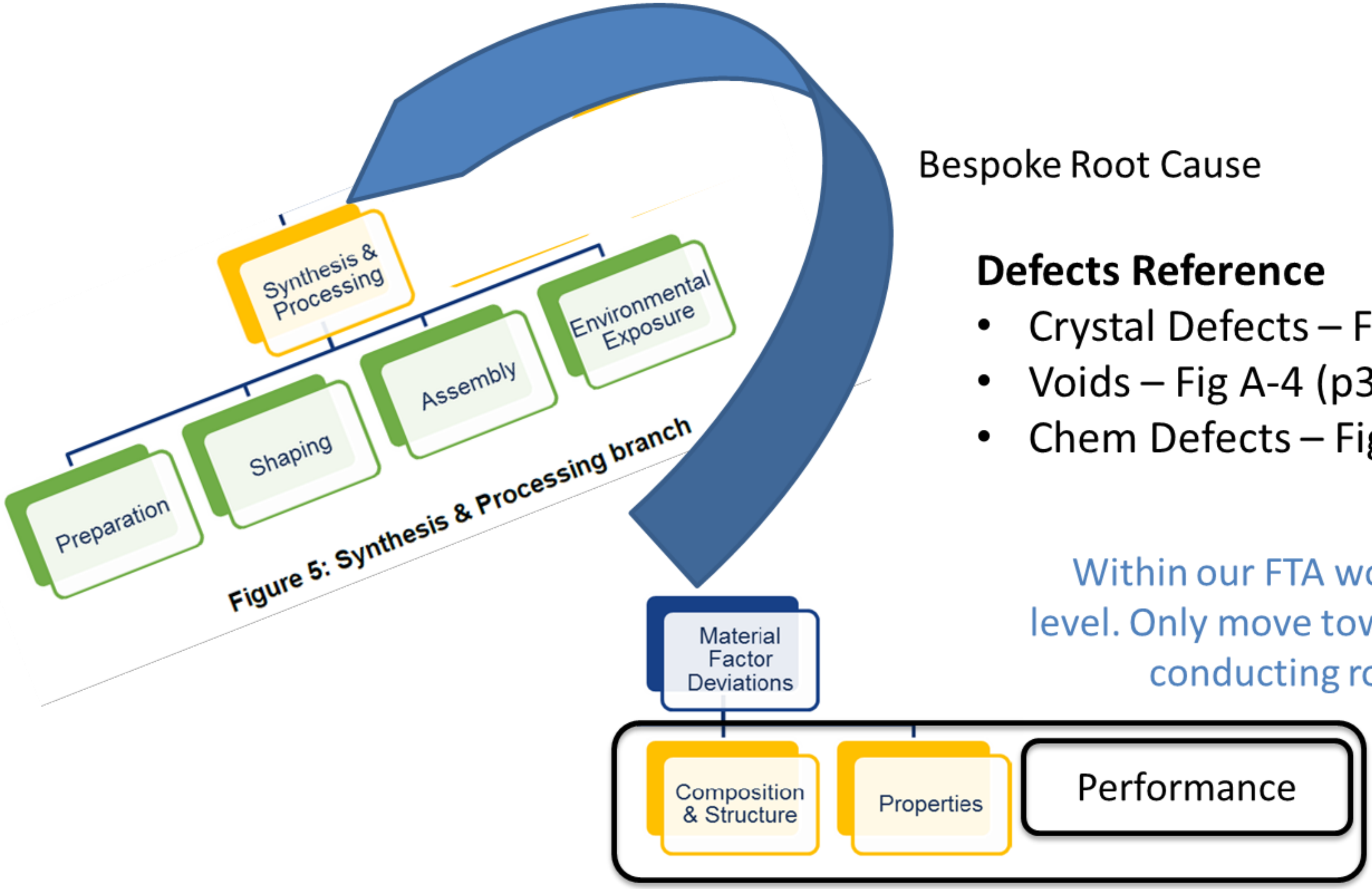
	Explosive Material Tests	
21	Radiography	
22	Inspection of Sectioned Charge	
23	Tensile Strength / Elongation	STANAG 4506
24	DMA	STANAG 4540
25	Shore A Hardness	
26	Density	
27	Impact Sensitiveness	STANAG 4489
28	Small Scale Explosiveness	EMTAP 1D
29	Temperature of Ignition	STANAG 4491, Annex
30	BAM Impact	STANAG 4489, Annex
31	BAM Friction	STANAG 4487, Annex
32	Mallet Friction	EMTAP 2
33	Rotary Friction	STANAG 4487, Annex
34	DSC Analysis	STANAG 4515
35	ARC Test	
36	Sol content / Cross link density	STANAG 4581
37	Vacuum Stability	STANAG 4556
38	HFC Analysis	STANAG 4582
39		
40		
41		STANAG 4581
42		
43		STANAG 4147
44		

Risk	Red
Monitor	Amber
Acceptable	Green
Outstanding	Light blue
Not requested	Dark grey

Colour code boxes based on real data

EWG 4: EFFECTS OF AGEING

More Recently - Fitting Defects to FTAs?



Bespoke Root Cause

Defects Reference

- Crystal Defects – Fig A-3 (p31/41)
- Voids – Fig A-4 (p31/41)
- Chem Defects – Fig A-5 (p32/41)

Within our FTA work keep descriptions to top level. Only move towards lower level descriptors if conducting root cause investigation.

Any Question?

Save the Date

Energetic Materials Technology Working Group (EMTWG)

(Previously known as the Insensitive Munitions and Energetic Materials Technology Symposium – IMEMTS)

13th to 16th May, 2024
Clarion Hotel The Hub, Oslo, Norway

“Preparing advanced Energetic Materials & Insensitive Munitions for high intensity warfare”

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National Armaments Consortium NAC Innovation Through Collaboration

MSIAC Munitions Safety Information Analysis Center