A METHODOLOGY FOR EVALUATING POTENTIAL THREAT HAZARDS TO MILITARY MUNITIONS

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ABSTRACT

In the documents concerned with safety/hazard assessment testing of munitions such as MIL-STD-2105B for US, OB Pillar Proc 42657 for UK, I No 0260 DGA/IPE for FR and Draft STANAG 4439, it specifies that a hazard analysis should be completed. However, none of these documents proposes a procedure for conducting such an analysis. To cater for this need, a methodology for evaluating potential threats and hazards to military munitions during peacetime and military operations is presented so that the level and range of IM tests, necessary for assessing the degree a munition has achieved reduced vulnerability, can be prescribed.

The methodology involves using a logical Threat Hazard Tree to cover the range of threats and hazards to which a military munition is likely to be exposed to during all possible life cycle environmental profiles, and suggests how this Threat Hazard Analysis Tree procedure could be used for munitions likely to be used by Army and Marine Forces However, the same process could be adapted and implemented for munitions used on Naval Ships or Military Aircraft depending on the users needs. This logical approach identifies qualitatively the potential threats from perceived accident and combat scenarios. It highlights the stimulus level, but suggests that the characteristics of duration or likelihood of occurrence should be determined from other sources. Using a theoretical munition as an example and by justifying the range of threats from a series of threat matrix tables, the paper demonstrates how the user can be provided with a complete overview of all the potential threats and hazards the munition is likely to be exposed to. In addition it will allow the user to rationalize into a tailored programme of tests the most appropriate and relevant IM and safety tests necessary to assess these threats, and consider mitigation techniques to protect against these threats.

To use this procedure effectively as a decision aid, the document recommends that the logic process should be presented in the fond of a computer programme in which the associated software describes the logic process along with detailed notes and instructions for any of the decision boxes. The programme to be written by NIMIC will be based on the logic described in this paper, but with the capacity to add, modify or delete the set-up to suit individual needs.

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BACKGROUND

Munitions by their very nature are hazardous items, and therefore the hazards associated with munitions will always be of concern to the user during their life cycle environmental profile, sometimes referred to as the "cradle to grave" sequence. To guard against introducing into service increasingly hazardous munitions and to decrease the probability of explosive related accidents or events, nations are developing munitions which when subjected to unplanned stimuli will minimize the violence of a reaction and subsequent collateral damage. These munitions are tended Insensitive Munitions (IM). Although they are designed not only to reduce any hazards, they will still be required to reliably fulfil their performance, readiness and operational requirements on demand. To evaluate the improvements in safety by having an IM inventory, it is necessary to assess the response of these munitions to suitable tests which represent credible accidents or combat threats. These tests, along with their associated IM requirements, are described in various national documents such as: MIL-STD 2105B for US, OB Pillar Proc 42657 for UK, I No 0260 DGA/IPR for FR, DI(G)LOG07-10 for Australia and now Draft STANAG 4439 for NATO nations. However, before conducting any of these IM tests, all the above documents specify that a hazard analysis should be completed to determine the range of threats a munition is likely to experience during its life cycle environmental profile. So far none of the above documents propose a procedure for conducting such an analysis, and therefore this paper presents how a formalized process for determining these potential threats to a munition could be developed.

2. <u>Purpose</u>. The purpose of this paper is to propose a methodology for evaluating potential threats and hazards to military munitions during peacetime training and military operations, in order that the level and range of IM tests, necessary for assessing the degree a munition has achieved reduced vulnerability, can be prescribed.

INFORMATION

3. <u>General</u>. In this paper, the methodology procedure for evaluating the potential threats and hazards which munitions are likely to experience is restricted to those munitions which are likely to be incorporated on weapon systems used by Andy or Marine forces (Military Munitions. The procedure adopted in this paper could also be implemented for munitions carried on Naval Ships or Military Aircraft, but for these weapon platforms a different scenario of threats would have to be considered. Although it is not a definitive solution to rationalizing all the perceived threats, as nations may have different conceptions of identifying these threats, the methodology hereafter is very general. It involves using a logical Threat Hazard Tree to cover the range of threats and hazards to which a military munition is likely to be exposed to during all possible life cycle environmental profiles in both peacetime training and military operations. The assessment of these threats, includes threats posed by adjacent or friendly munitions, hostile munitions, accidents, handling and also environmental threats (lightning, BMP and Electromagnetic Radiation Hazards (EMRH)). An example of such a logical Threat Hazard Tree to evaluate the threats likely to be experienced by military munitions used by Andy or Marine forces is shown in Annex A. For the purposes of this paper these munitions will always be referred to as military munitions.

4. Scope. By adopting the process of using a Threat Hazard Analysis Tree, a qualitative description of the range of predicted threats and hazards to a munition is obtained. From these threats and hazards, the programme of IM tests, including Lightning, EMP and EMRH tests, will be determined so that the degree to which a particular munition has achieved the required level of safety and reduced vulnerability can be assessed. This process has the following benefits:

a. It allows both the explosive hazard requirements for transportation and storage and munition safety assessment requirements to be considered as one programme of tests. For instance, the data and results from these munition safety assessment tests could also be used where applicable by nation's transport and storage committees in their evaluations for determining the UN hazard classification for a particular munition.

b. It will suggest for a particular IM test what the munition packaging configuration will be so that the most vulnerable threat scenario is evaluated.

c. It will assist designers of munitions to consider at an early stage in the development programme what protection is necessary from packaging or mitigation devices, so that hazards which may evolve from the range of threats applicable to a particular munition might be reduced.

d. It provides an opportunity to consider the sequence in which these IM and safety tests are conducted in order that useful data and information from a particular test can be used as inputs for subsequent tests. Therefore, by conducting these tests in an appropriate sequence and analysing the results, a better understanding of the response characteristics to particular threats will be obtained early on in the test programme. As a result this process may result in a re-assessment of the need to conduct all the IM tests deemed necessary from the initial Threat Analysis.

e. It provides the user with a complete overview of all perceived potential threats and hazards that are considered relevant for a particular military munition in a prescribed scenario.

5. The use of this Threat Hazard Tree logical approach is that it identifies qualitatively potential hazards from potential accident and combat threat scenarios. It determines the stimulus level, but not the characteristics of duration or likelihood of occurrence. These quantitative considerations (ie duration and likelihood) which are a combination of the probabilities of a munition being in a specific scenario, its exposure to that scenario along with the probabilities of the threat stimulus occurring and that stimulus interacting with the munition have to be evaluated as a separate exercise using data provided by operational analysts. A procedure for evaluating these probability factors from a range of tables, assumptions and calculated predictions, using as an example a well characterized US Navy tactical missiles given in Reference A. Although quantitative technical data is available for these probability factors, it is emphasized that consideration should be given to the reliability of the data and any constraints on the use of that data. Therefore, any Threat Hazard

Assessment will probably include subjective assumptions which will result in subjective conclusions. In assigning potential threats to particular scenarios for military munitions in the Threat Hazard Tree example defined in Annex A, a subjective approach, based on user experience, has been applied along with familiarity with the operational roles of these weapon systems plus discussions and comments with the military and Defence Safety Approving Authorities.

6. Potential Threats. The threat damage mechanisms associated with the potential threats and hazards to any munitions are comprised of the following:

a. Thermal environments produced by hydrocarbon fuel fires, wood fires, and combustible structural materials durig transportation; combustion of energetic materials, structural material and bush fires durig storage; shipboard fires or any other accidental induced thermal incidents.

b. The shocks/impacts due to detonation of an adjacent weapon.

c. Impact and perforation by bullets, fragments, shaped charge jets and spall produced by the interaction of such high speed projectiles.

d. Electro-magnetic effects produced by lightning, EMP and electronic radiation hazards.

e. Severe drop on flat surfaces or sharp edge protrusions.

Whilst some of the threats and hazards identified above are common to all types of munitions, others are dependent on exposure of the munition to specific operational environments, logistic cycles or munition design features. To evaluate the range of these threat scenarios, it will be necessary to have inputs from relevant authorities who are aware of the operational requirements of the munition, military users of the munition, munition project managers and logistic managers.

7. A summary of these potential threats and hazards to which military munitions are likely to be exposed to and the tests that are assigned to simulate these threats and hazards are listed below. The validity of these tests is a different issue and is one of the subjects being studied by NIMIC in a number of other reports.

	Threat	Test
a.	Fire in Magazine, Store, or Road/Rail, Naval and Air transport carrier.	Fast Cookoff
b.	Combustion from energetic material and torching	Fast Cookoff

c.	Fire in adjacent store, Naval Magazine or Steam leak	Slow Cook Off
d.	Heat source removal from munitions which have been heated to elevated temperatures, and which may remain at temperatures and times for critical conditions to be reached.	Slow Cookoff
e.	Hostile or terrorist small arms attack.	Bullet Impact
f.	Hostile attack from Bombs, Missiles, Artillery Shells and Hand grenades.	Fragment Impact
g.	Explosion in Store/Magazine, Detonation/Functioning or Road/Rail transport carrier.	Sympathetic
h.	Attack of Armoured vehicles	Spall Impact
J.	Anti-Tank Guided Weapon/ shaped charge weapons (in particular Bomblet Attack)	Shaped Charge Jet Impact
k.	Transport Accident or Mishandling	Safety Drop
l.	Electrical Stones	Lightning
m.	Radio/Radar Emission Hazards	Radiated and Conducted Susceptibility tests
n.	Nuclear weapon effects	EMP

8. The Threat Hazard Tree Procedure. The Threat Hazard Tree procedure proposed in this paper consists of a series of levels or steps at each of which a number of questions are asked relating to the munition's use, handling, storage, deployment and disposal. The answers to the questions at any one level determine the questions to be asked in subsequent levels. Using the example given in Annex A, the first question is to identify the role of the munition. For military munitions, can it be identified as artillery ammunition, tank ammunition, a free-flight rocket, infantry/gun ammunition, a demolition device or a guided weapon? The next step is to determine whether the munition contains a material whose response in its design

configuration to any foreseeable threats will be no more than a bunting reaction. This will involve a preliminary hazard analysis of the munition's design, the explosive material and the confinement of the explosive material. If the munition does satisfy this above condition, then a judgement could be made to not conduct any of the IM tests because the desired response criteria will be no more severe than a bunting reaction. However, there will still be a need for safety reasons to possibly conduct safety drop tests, lightning, EMP and EMRH tests on the munition in either its packaged or unpackaged configuration. Military munitions that may fall into this category are pyrotechnic stores, smoke and illuminating rounds of artillery and mortar ammunition. If the munition does contain an explosive material whose response will be more severe than burning, then the next step is to consider under what conditions the munition is going to be used during peacetime conditions of training and military operations. For this exercise, the tend military operations is used to define all levels of conflict from peacekeeping/peacemaking operations to a status of warfare.

9. Under the scenarios of peacetime and military operations, the next stage is to determine how the munition is to be transported (Air, Sea, Road and Rail), stored, deployed, used and finally disposed of durig its life cycle environmental profile. For peacetime conditions, it is assumed that the munitions will be packaged in their logistic packs, whereas during military operations and when the munitions are deployed to their weapon systems the munitions are likely to be in a field packaging configuration or unpackaged. To each of these above profiles, the user can then assign a range of perceived threats it considers the munition may experience. In addressing the munition's deployment and use, this paper considers 6 separate categories of weapon systems that are likely to use military munitions. and these are as follows:

a. Armoured Vehicles

b. Guns and Rocket Launchers.

c. Infantry Weapons.

d. Helicopter Launched Weapons.

e. Guided Weapons.

f. Mines and Demolition Stores (Engineer Stores).

10. Depending on the answers given as to how the munition is going to be deployed or used during its environmental and combat profiles along with the associated perceived threats, a qualified judgement can then be made on the threat probability and the munition's most vulnerable scenario before attributing tests or evaluations needed to assess these threats. The justification for considering these likely potential threats to particular logistic and weapon scenario profiles is considered below.

11. <u>Using The Threat Hazard Tree As a Decision Aid</u>. By using the Threat Hazard Logic

Tree procedure described above, the user is now provided with a complete overview of all the potential threats and hazards a particular munition is likely to be exposed to and also a means of deciding the most appropriate and relevant IM and safety tests necessary to assess these threats. However, to use this procedure effectively as a decision aid it is considered that the logic process should be presented in the fond of a computer programme. As a result, an associated software programme describing the logic process along with detailed notes and instructions for each of the decision boxes should be written. The programme could be based on the example given in Annex A, and within the programme users should have the capacity to add, modify or delete any presented set-up to suit their needs. For example, if in its deployment and use the munition can not be associated with the 6 categories of weapon systems described above, then a new category can be created and associated threat profiles be prescribed. This flexibility within the programme will also allow the user to modify the programme from one for military munitions to aircraft launched munitions and naval launched munitions using as a guide the logic tree process suggested in Annex A.

l2. <u>Justification For Peacetime Threats</u>.

a. <u>Transportation</u>. Once military munitions have completed manufacture, it will be necessary to move these munitions to a pre-prepared peacetime storage facility, either a bunker or igloo which will have been specially designed and inspected to receive that munition's specific hazard classification. In the majority of cases this initial movement transportation will be by Road/Rail, and with the munitions non-ally packaged in logistic containers. Even if these munitions are to be subsequently transported either on Naval ships or as Air cargo as military stores, then the munitions are still likely to remain packaged in logistic containers and be transported by Road/Rail to the port or airport.

(l) <u>Threats Road/Rail</u>. During transportation by Road/Rail, the principle hazards to military munitions are likely to be accidents involving handling and impacts, the threats from Fires, EMRH, Lightning and Sympathetic Functioning of adjacent munitions which might include terrorist bombs. In the case of fires these might be caused by bunting liquid fuel from vehicles, wood in rail box cars or any other combustible material associated with the means of transportation and combustion of energetic material such as torching from adjacent munitions. Also associated with the fire threat is the situation when a heat source has been removed from munitions which have been heated to elevated temperatures, and which may remain at temperatures and times for critical conditions to be reached. For certain classes of munitions such as small arms ammunition or sub-calibre ammunition the hazards from these threats may be minimal because any explosive events initiated in the store may be confined by the packaging material. Therefore if it is shown that this is the case from trials, then the need for conducting sympathetic functioning tests could be considered unnecessary. Also the logistic packaging may be so designed that it acts as a Faraday cage and protects the munition from the hazards of EMRH and Lightning, and therefore the need for conducting these tests would have to be considered on a case by case basis.

(2) Threats in Naval Ships. Most military munitions carried in Naval Ships for peacetime training will be used by Marine forces or any other amphibious units. Whilst in this scenario, these munitions will likely remain packaged in their logistic containers and only broken down into field packaging conditions when required for training purposes on dry land exercises. Therefore the threats will be similar as for Road and Rail except that the drop heights will be greater and should include impacts on to sharp edges (Spigot Intrusion), the fire threats will need to be expanded to cover the situation of fires in an adjacent ship magazine, Slow Heating, and the parameters of the EMRH will need to be increased to allow for the hazards created by ships radars and other electromagnetic sources. Also the same rationale, as described for munitions transported by road and rail, will apply for not necessarily conducting certain tests on particular store configurations and test outcomes when certain stores are transported in Naval ships.

(3) Threats in Transport Aircraft/Helicopters. For military munitions transported in miliary aircraft or as underslung loads from helicopters, the munitions will be packaged in their logistic containers and also will have to comply with the requirements of STANAG 3854 Edition II, (Ref C) (Policies and Procedures Governing The Air Transportation of Dangerous Goods). Fulfilling these requirements will help to reduce the hazards from handling accidents, but never eliminate them. However, certain threats such as Sympathetic Functioning and Lightning will be less of a concern. With Lightning, the aircraft by its design should act as Faraday Cage and prevent Potential Differences being created on the skin of the aircraft. Also the regulations and requirements will be such that no munition should by itself detonate because the hazards will be catastrophic regardless of the considerations of Sympathetic Functioning. The threats from fire and impacts which might result from the aircraft or helicopter crashing and the hazards from EMRH will be similar to those described for Road and Rail.

b. Storage. Under Peacetime conditions, military munitions will be stored in specially prepared purpose built storage sites. These storage sites will be either igloos or bunkers and will have been designed to meet the requirements of STANAG 4440 (Ref D) (Safety of The Storage of Military Ammunition and Explosives). The munitions will be stored in their logistic containers and whilst in storage strict regulations will be enforced. Therefore in this environment the threats and hazards will be somewhat reduced. The buildings will be protected from Lightning, and the hazards from EMRH should be eliminated through the on- site rules governing use of electrical appliances in these buildings. The threats from fires would likely result from burning of energetic material (torching on to adjacent munitions), bunting of structural material and Bush Fires around the storage site, Fast Heating scenarios. The hazards from Drops and the threat from Sympathetic Functioning would be similar to Road and Rail.

c. <u>Disposal</u>. In peacetime conditions it can be assumed that when munitions have to be replaced or reach their end of storage life, there will be requirement to carry out necessary disposal of these munitions. This action will either involve separating and reclaiming certain ingredients, burying the munitions in deep holes or carrying out a destruction at a predetermined site. The normal process for such an exercise will be to move these munitions from the storage site by Road and Rail to the disposal location. The threats and hazards will be no different from when the munitions were initially transported from manufacture to the storage site, except that through lifetime storage these munitions may have become more hazardous. Therefore, before movement is agreed it will be necessary to inspect and certify these munitions as being safe for transportation.

l3. <u>Justification For Threats and Hazards Dunn- Military Operations</u>. The main difference from peacetime threats to threats during military operations is that the threats which existed in peacetime to military ammunition have to be expanded to cover threats from hostile action. These additional threats will involve the following:

a. Bullet impact from small ants ammunition (SAA) up to and including 30mm.

b. Fragment attack from grenades, mortar shells, bombs, fragmenting warheads and artillery shells.

c. Shaped charge jet attack from bomblets, Anti Tank Guided Weapons (ATGW), Anti Ship Guided Weapons (ASGW).

d. Fires resulting from ignitions of energetic material by any of the above stimuli.

l4. <u>Threats During Transportation</u>. In Military Operations, the norm will be to outload military munitions from the peacetime storage sites and move these stores by Rail/Road to operational field storage sites. In some cases this may involve movement by sea or air in Naval support ships or Military aircraft e.g. Cl30 or Chinook. As in Peacetime, these munitions will remain in their logistic containers durig transportation until they are broken down into their field packaging for deployment to their respective weapon systems.

a. <u>Threats Road/Rail</u>. Whilst being transported by Road/Rail the hostile threats will include variations of weapon attack depending on the level of the threat. In wartime, attack by weapons can be expected from the air by bombs, rockets (light fragments) and SAA (20-30mm) and from the ground by mortar and artillery fire (small fragments), attack by SAA up to 30mm and shaped charged jet attack from ATGW and air delivered bomblets. Even with all the above hostile threats, certain classes of munition such as small arms ammunition will not create a hazard because any explosive events initiated in the store may be confined by the packaging material. However, when the munition is in its logistic container it is not necessarily in its most vulnerable state to these attacks. The EMRH and Lightning threats will be no different from peacetime, but a further threat which should be considered is Electromagnetic

Pulse (EMP) from nuclear weapon effects. In addition to all these perceived threats and hazards, consideration must be given to fires which may result from ignition of energetic material by any of these stimuli.

b. <u>Threats in Naval Ships</u>. The threats to military munitions when carried in Naval ships will need to be expanded to include hostile threats from various forms of weapon attack relevant to the level of the threat. In wartime the attack from the air will include the same range of weapons used to attack road and rail transportation. However the munitions exposure to this fond of attack will depend on whether these munitions in their logistic containers are stored above or below the deck. Generally, the main form of hostile attack from sea or air will come from weapons which produce heavy fragments, as the principle intention is to destroy the ship. Some of these weapons might be of a "directed energy" type, which might produce fast heavy slugs rather than the long thin jets which are produced from a standard shaped charge jet attack. These slugs can be considered comparable to heavy fragments. As above, consideration must be given to fires which may result from ignition of energetic material by any of these stimuli.

c. <u>Threats in Transport Aircraft and Helicopters</u>. Threats to military munitions when transported in aircraft or underslung as logistic loads from helicopters will need to be expanded to include hostile threats from air and ground weapons relevant to the level of the threat. The principle forms of attack will be by SAA up to 30mm and fragmenting warheads (light fragments). Lightning and EMP will only be of concern if munitions are being transported underslung from Helicopters. Finally the threats from fires created by any of these stimuli must also be considered.

15. <u>Threats in Open Storage</u>. Durig Military Operations, military munitions are likely to be temporarily stored in open storage sites with very little protection. Although the munitions will generally be packaged in their logistic containers, it can be expected that in these storage sites all classes of munitions with their respective hazard classifications will be stored collectively. Even in Military Operations, certain precautions are required when storing munitions in open storage along with regulations stipulating the separation distances necessary between respective munition stockpiles. The hostile threats are likely to come from attacks similar to those described for munitions transported by Road and Rail. EMP, and fires which may be created by any of the attributed stimuli will also have to be considered.

16. <u>Threats Dunne: Deployment</u>. When military munitions are deployed to their respective weapon systems as defined in Para 9, these munitions are likely to be in their most vulnerable state because they will be either in an unpackaged condition e.g artillery shells or in some form of field packaging e.g guided weapons. Some munitions, such as Tank ammunition or ammunition issued to Armoured Personal Carriers (APC) will be provided with a degree of protection to bullet and fragment attack by the thickness of armour. However, in a number of tactical deployment situations it will be the bare munition which is exposed. Particular examples will be munitions carried on Helicopters, artillery and mortar ammunition at gun

and mortar positions and SAGW. For particular weapon systems, the following threats and hazards to their respective munitions should be considered:

a. **Armoured Fighting Vehicles (AFV)** - Shaped Charge, Spall and kinetic energy rounds plus fires created by any of the above stimuli or caused by burning hydrocarbon fuel and electrical circuitry in the vehicle (FCO).

b. **Guns and Rocket Launchers** - Bullet Impact, Light Fragment Impact, Shaped Charge Jet, Sympathetic Functioning, Lightning, EMRH and EMP plus fires that may be created by any of these stimuli.

c. **Infantry Weapons** - Although the munitions used with these weapons are likely to be small calibers, Bullet Impact, Light Fragment Impact, Shaped Charge Jet, Sympathetic Functioning, Lightning, EMRH and EMP remain a concern plus fires that may be created by any of these stimuli.

d. **GW Systems** - As munitions for these weapon systems may be both ground mounted or vehicle borne either as a bare munition or in some fond of launch tube, then the attack threats and hazards will be similar to those for munitions deployed to Infantry weapons, Guns and Rocket Launchers. The only difference being that Sympathetic Functioning could be less of a concern and EMRH, Lightning and EMP could be more of a concern.

e. **Helicopter Weapons** - Since these munitions are specific to a particular weapon launch platform, the hostile attacks will be no different from the situation of helicopter transportation durig Military Operations, see Para l4.c. Sympathetic Functioning will not be a concern, but EMRH, Lightning and EMP will be need to be addressed. Also the threat from fires will need to include fires created by any of the attack stimuli and from burning Hydrocarbon Fuel.

f. **Engineer Demolition Stores.** - These munitions are mainly mines and explosive demolition stores. The nature of their deployment and packaging will be similar to infantry weapon munitions, but in some cases these munitions will be carried in launch vehicles. As a result, the hostile attacks, hazards and reasoning for testing against certain threats will be the same as for munitions deployed to Infantry weapons and artillery ammunition described in Paras l6.b. and l6.c.

17. <u>A Worked Example Using The Threat Tree Procedure</u>. To demonstrate use of the above procedure for a particular munition, a High Velocity Surface To Air Missile is given as an example. For this example, certain assumptions will have to be made to its deployment and operation to make this exercise viable, and these are described as follows:

a. The missile is transported on a lightly armoured vehicle and deployed at predetermined fixed site locations during hostilities.

b. It is packaged in a logistic container for transport by road/rail and in military operations will be carried by air, where it is envisaged it will be as an underslung load.

c. It is unlikely to be carried in Naval Ship magazines.

d. It has an HE Warhead and a solid propellant Rocket Motor and the missile will be fired durig peacetime on suitable ranges.

e. It has a shelf life of 20 years in temperate climate conditions

18. Using the analysis procedure in the Threat Hazard Tree from the above information, it can be determined that the munition will be used for both peacetime training and military operations, and that the explosive materials are likely to respond with a reaction greater than burning when subjected to mechanical shocks or then~al threats. The munition will be transported by road/rail in peacetime and military operations, and during military operations underslung from helicopters. It is assumed that during peacetime the munition will be stored in a specially prepared storage site and durig military operations held in a field storage site unprotected. After 20 years it is anticipated that the munition will undergo some form of demilitarization. Therefore by following the logic process described in paragraphs 8 and 9 and the logic tree of Annex A, the threats and associated tests applicable to this munition under the above conditions and scenarios will be those shown below in the matrix tables of Fig l, Fig 2, Fig 3, Fig 4, Fig 5, Fig 6 and Fig 7 along with any relevant or consequential notes.

AN EXAMPLE OF THE RANGE OF THREAT MATRIX TABLES FOR
A THEORETICAL SURFACE TO AIR GUIDED WEAPON (SAGW)

Fig 1
PEACETIME TRANSPORTATION BY ROAD/RAIL IN LOGISTIC CONTAINERS.

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	EMRH & LIGHTNING	SD
ROCKETS & GW	X	X	X	(1)	(2)
TESTS	FCO	MODELLING	DROP	EMRH & LIGHTNING	SD

Fig 1: PEACETIME TRANSPORTATION BY ROAD/RAIL IN LOGISTIC CONTAINERS.

Notes:

(1) If logistic packaging acts as a Faraday cage, then the need for EMRH and lightning tests will have to be examined on a case by case basis.

(2) If any explosive events from the above testing of certain munition configurations are confined within the packaging material, then the need for conducting SD tests may be considered an unnecessary exercise.

Fig 2
PEACETIME STORAGE IN LOGISTIC CONTAINERS.

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	EMRH & LIGHTNING	SD
ROCKETS & GW	X	X	X	(3)	(2)
TESTS	FCO	MODELLING	DROP	EMRH & LIGHTNING	SD

Fig 2: PEACETIME STORAGE IN LOGISTIC CONTAINERS.

Notes:

(2) If any explosive events from the above testing of certain munition configurations are confined within the packaging material, then the need for conducting SD tests may be considered an unnecessary exercise.

(3) If the buildings are protected against lightning and the on-site regulations governing the use of electrical appliances eliminate the hazards from EMRH, then testing against these threats may not be necessary.

Fig 3
PEACETIME DISPOSAL IN LOGISTIC CONTAINERS.

THREATS	PRE INSPECT	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	EMRH & LIGHTNING	SD
ROCKETS& GW	(4)	X	X	X	(1)	(2)
TESTS		FCO	MODELLING	DROP	EMRH & LIGHTNING	SD

Fig 3: PEACETIME DISPOSAL IN LOGISTIC CONTAINERS.

Notes:

(1) If logistic packaging acts as a Faraday cage, then the need for EMRH and lightning tests will have to be examined on a case by case basis.

(2) If any explosive events from the above testing of certain munition configurations are confined within the packaging material, then the need for conducting SD tests may be considered an unnecessary exercise.

(4) Threats will be no different from when initially transported by Road and Rail, therefore before movement is agreed it will be necessary to inspect and certify these munitions as being safe for transportation prior to conducting any of the above testing.

Fig 4
MILITARY OPERATIONS TRANSPORTATION BY ROAD/RAIL IN LOGISTIC CONTAINERS

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	LIGHTNING & EMRH	BI UP TO 30 MM	FI	EMP	SC	SD
ROCKETS & GW	X	X	X	(5)	X	X	(5)	X	(2)
TESTS	FCO	MODELLING	DROP	EMRH & LIGHTNING	50 CAL BI	LIGHT FRAGMENT	EMP	SC	SD

Fig 4: MILITARY OPERATIONS TRANSPORTATION BY ROAD/RAIL IN LOGISTIC CONTAINERS

Notes:

(2) If any explosive events from the above testing of certain munition configurations are confined within the packaging material, then the need for conducting SD tests may be considered an unnecessary exercise.

(5) If logistic packaging acts as a faraday cage, then the need for EMRH, lightning and EMP tests will have to be examined on a case by case basis.

Fig 5
MILITARY OPERATIONS TRANSPORTATION BY TRANSPORT AIRCRAFT/HELICOPTERS IN LOGISTIC CONTAINERS

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	LIGHTNING & EMP	BI UP TO 30 MM	FI	EMRH
ROCKETS & GW	X	X	X	(6)	X	X	(6)
TESTS	FCO	MODELLING	DROP	EMP & LIGHTNING	50 CAL BI	LIGHT FRAGMENT	EMRH

Fig 5: MILITARY OPERATIONS TRANSPORTATION BY TRANSPORT AIRCRAFT/HELICOPTERS IN LOGISTIC CONTAINERS

Notes:
(6) If logistic packaging acts as a Faraday cage, then the need for EMRH and Lightning tests will have to be examined on a case by case basis. Also Lightning and EMP tests will only be deemed applicable if the munitions are to be underslung from helicopters.

Fig 6
MILITARY OPERATIONS STORAGE IN LOGISTIC CONTAINERS

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	LIGHTNING & EMRH	BI UP TO 30 MM	FI	EMP	SC	SD
ROCKETS & GW	X	X	X	(5)	X	X	(5)	X	(2)
TESTS	FCO	MODELLING	DROP	EMRH & LIGHTNING	50 CAL BI	LIGHT FRAGMENT	EMP	SC	SD

Fig 6: MILITARY OPERATIONS STORAGE IN LOGISTIC CONTAINERS

Notes:

(2) If any explosive events from the above testing of certain munition configurations are confined within the packaging material, then the need for conducting SD tests may be considered an unnecessary exercise.

(5) If logistic packaging acts as a faraday cage, then the need for EMRH, lightning and EMP tests will have to be examined on a case by case basis.

Fig 7
MILITARY OPERATIONS: MUNITIONS DEPLOYED TO GUIDED WEAPON SYSTEMS

THREATS	FIRES	HEAT SOURCE REMOVAL	LIGHTNING & EMRH	BI UP TO 30 MM	FI	EMP	SC	SD
GW (7)	X	X	X	X	X	X	X	(8)
TESTS	FCO	MODELLING	EMRH & LIGHTNING	50 CAL BI	LIGHT FRAGMENT	EMP	SC	SD

Fig 7: MILITARY OPERATIONS: MUNITIONS DEPLOYED TO GUIDED WEAPON SYSTEMS

Notes:

(7) Munitions are likely to be in an unpackaged state.

(8) If the munitions are deployed to a vehicle or launch platform, then Sympathetic Functioning can be eliminated as a threat because the raison d'être for doing the test in itself would be catastrophic.

19. From the results of the above tables, the analyst can derive the following conclusions:

a. The range Of threats are Fast Heating Fires, Removal of a Heating Source, Drop Impact, EMRH, Lightning, EMP, Sympathetic Functioning, Bullet Impact up to 30 mm, Light Fragment Impact and Shaped Charge Jet Attack.

b. The munition, when packaged in its logistic container, will be vulnerable to all the threats in Para 19a, and when deployed unpackaged, to all the threats in Para 19a, less Drop Impact and Sympathetic Functioning.

c. EMRH, lightning and EMP tests should be conducted on the unpackaged munition and also on the packaged munition if the packaging does not act as a Faraday Cage.

d. Fast Heating Tests, Modelling of Heat Source Removal, Drop Impact, Bullet Impact, Light Fragment and Shaped Charge Jet Attack Tests should be conducted with the munition in its most vulnerable condition. Therefore, generally this will be packaged for Fast Heating and Drop Impact and unpackaged for Bullet Impact, Fragment Impact and Shaped Charge Jet Attack.

e. The tests to be conducted in Para 18.d. should be completed before doing the Sympathetic Detonation Test because if these tests demonstrate that any explosive events are confined within the packaging material, then a Sympathetic Detonation Test may be deemed unnecessary.

20. As a result of the above conclusions, a complete matrix table of the threats and hazards likely to pertain to this theoretical SAGW is established along with the relevant IM and safety tests necessary to assess these threats. For the example SAGW, this is shown below with any associated notes regarding testing.

THREATS AND ASSOCIATED TESTS FOR THE SAFETY ASSESSMENT OF A THEORETICAL SURFACE TO AIR GUIDED MISSILE

THREATS	FIRES	HEAT SOURCE REMOVAL	DROP IMPACT	LIGHTNING & EMRH	BI UP TO 30 MM	FI	EMP	SC	SD
THEORETICAL SAGW	X	X	X	X	X	X	X	X	X
TESTS	FCO (1)	MODELLING (1)	DROP (1)	EMRH & LIGHTNING (2)	50 CAL BI (3)	LIGHT FRAGMENT (3)	EMP (2)	SC (3)	SD (4)

Notes:

(1) These tests and any modelling should be conducted with the munition in its packaged configuration.

(2) These tests should be conducted with the munition both packaged and unpackaged, but if the packaging is proven to act as a Faraday cage, then the tests should be done only on the unpackaged munition.

(3) The tests should be conducted on the unpackaged munition.

(4) This test should conducted as the last in the sequence, and pending the outcome of the other tests results the requirement for testing will have to be reviewed.

THREATS AND ASSOCIATED TESTS FOR THE SAFETY ASSESSMENT OF A THEORETICAL SURFACE TO AIR GUIDED MISSILE

CONCLUSIONS

21. Although this methodology is considered to be fairly general, it is not a definitive solution to rationalizing all the perceived threats as the user may have different conceptions of how these threats are identified, Consequently, the procedure for conducting this methodology can be modified within a computer programme to suit the needs of the user, and give the analyst the flexibility of identifying qualitatively the potential hazards from likely accident or combat threat scenarios. Any quantitative considerations (ie duration and likelihood) which involve probability considerations will still have to be evaluated as a separate exercise.

22. By adopting this logical approach, the programme of tests or modelling considerations assigned to evaluate the identified threats and hazards will allow the opportunity to assess both mumtion safety as well as its explosive hazard; provided, data from munition safety testing is used by national transport and storage safety committees. Also within the programme of tests, it will suggest for a particular test, what is the most vulnerable condition for the munition when it is exposed to a particular threat ie packaged or unpackaged, and the sequence in which tests should be conducted so that data from one test can be used as inputs for subsequent tests.

23. Besides providing the user with a complete overview of all the perceived threats and hazards that are considered relevant for a munition in a prescribed scenario, it will assist munition designers to consider early in development the level of protection necessary to reduce these threats and hazards. Therefore, this methodology can be used both as a tool for rationalizing the IM test programme and improving the design safety of the munition.

24. Finally, the proposed IM STANAG 4439. in its agreement, states that:

> a. "Whenever it is feasible t() do 50, Insensitive Munitions shall be developed and introduced into service".
>
> b. The results of threat hazard assessn~ents, test result assessinents and tests to evaluate Insensitive Munitions (MURAT) performed in accordance with this document shall be provided by the developing nation".

The methodology developed in this paper provides a means to achieve the Threat Hazard Assessment required in this STANAG.

REFERENCES

A. Insensitive Munitions Threat Hazard Assessment: Methodology and Examples by Andrew C. Victor dated May 1993

B. Proceedings of the 1993 MMIC Workshop on Cookoff held at NATO Headquarters, Brussels, Belgium dated 23-25 June 1995

C. STANAG 3854 - Policies and Procedures Governing the Air Transportation of Dangerous Goods

D. STANAG 4440 - Safety of the Storage of Military Ammunition and Explosives

E. CINO Report No. 64/90/5 - Cost Benefit Analysis of the Introduction of Less Sensitive Mumtions for the CVS Class dated September 1992

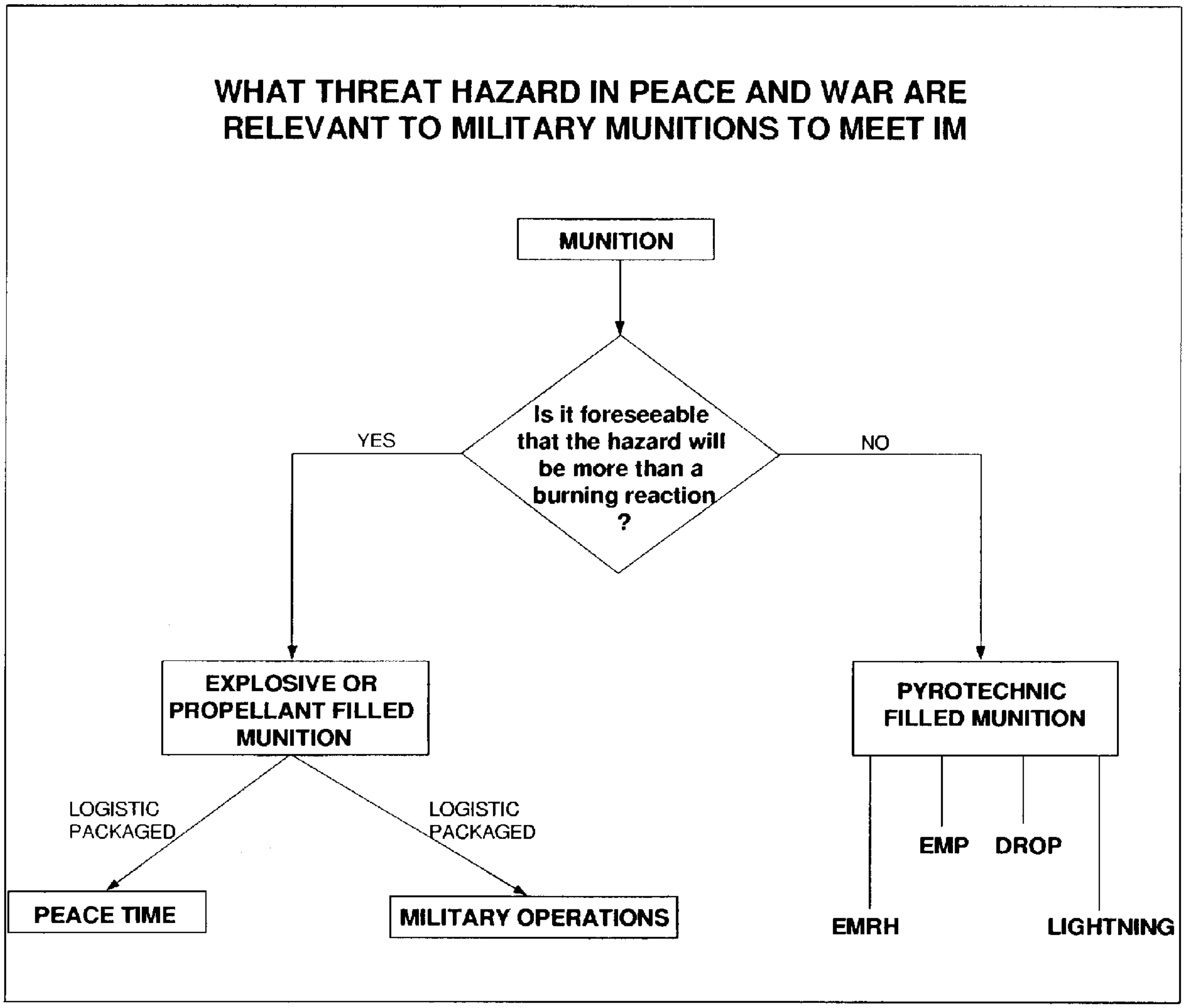
F. NIMIC-JFS-86-93 - NIMIC Comments to US Arn~y Supplement to MILSTD2105A(Navy) dated 11 March 1993

G. MIL-STD2105B - Hazard Assessment Tests for Non-Nuclear Munitions dated 27 October 1993

H. DGA/IPE Instruction No. 0260 - French National Doctrine with Regard to Less Hazardous Munitions dated July 1993

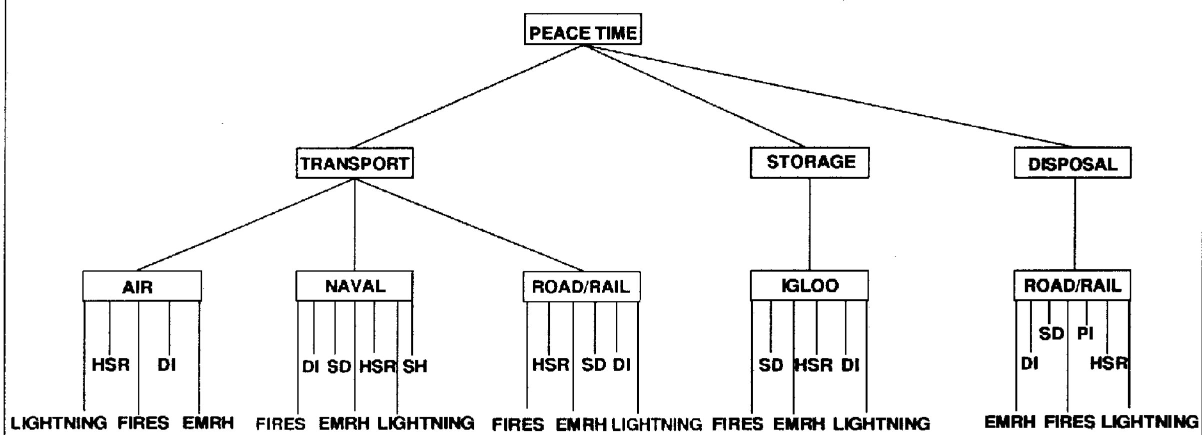
I. OB Pillar Proc 42657 - Insensitive Munitions Pillar Proceeding dated 25 September 1990

ANNEX A1



WHAT THREAT HAZARD IN PEACE AND WAR ARE
RELEVANT TO MILITARY MUNITIONS TO MEET IM
MUNITION
Is it foreseeable that the hazard will be more than a burning reaction ?
YES
NO
EXPLOSIVE OR PROPELLANT FILLED MUNITION
PYROTECHNIC FILLED MUNITION
LOGISTIC PACKAGED
LOGISTIC PACKAGED
PEACE TIME
MILITARY OPERATIONS
EMP
DROP
EMRH
LIGHTNING

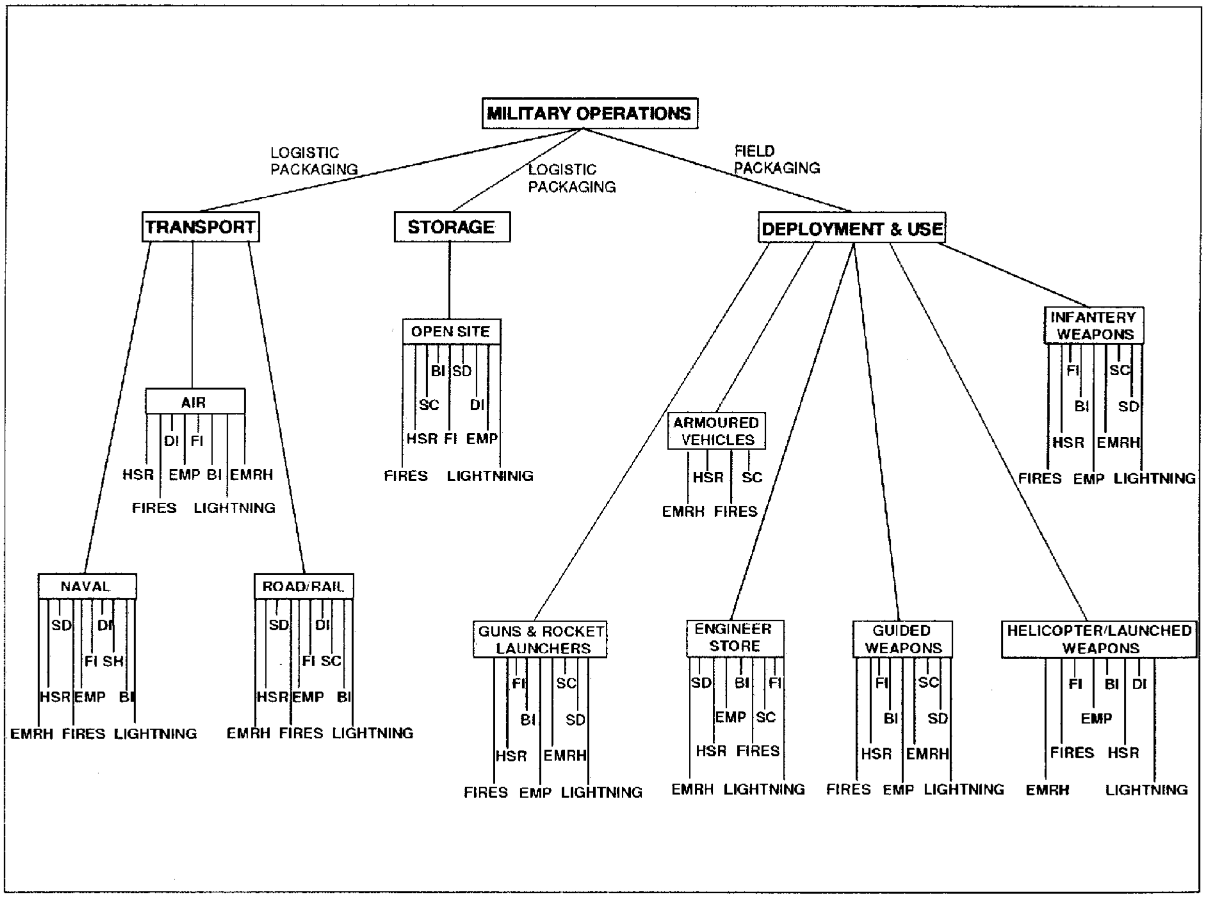
ANNEX A2



KEY

BI: BULLET IMPACT UP TO 30mm
DI: DROP IMPACT
EMP: ELECTRO MACNETIC PULSE
EMRH: ELECTRO MAGNETIC RADIATION HAZARD
FI: FRAGMENT IMPACT
HSR: HEAT SOURCE REMOVAL
PI: PRE INSPECT
SC: SHAPED CHARGE
SD: SYMPATHETIC DETONATION
SH: SLOW HEATING

ANNEX A3



MILITARY OPERATIONS
LOGISTIC PACKAGING
LOGISTIC PACKAGING
FIELD PACKAGING
TRANSPORT
STORAGE
DEPLOYMENT & USE
AIR
DI FI
HSR EMP BI EMRH
FIRES LIGHTNING
OPEN SITE
BI SD
SC DI
HSR FI EMP
FIRES LIGHTNIG
NAVAL
SD DI
FI SH
HSR EMP BI
EMRH FIRES LIGHTNING
ROAD/RAIL
SD DI
FI SC
HSR EMP BI
EMRH FIRES LIGHTNING
ARMOURED VEHICLES
HSR SC
EMRH FIRES
INFANTERY WEAPONS
FI SC
BI SD
HSR EMRH
FIRES EMP LIGHTNING
GUNS & ROCKET LAUNCHERS
FI SC
BI SD
HSR EMRH
FIRES EMP LIGHTNING
ENGINEER STORE
SD BI FI
EMP SC
HSR FIRES
EMRH LIGHTNING
GUIDED WEAPONS
FI SC
BI SD
HSR EMRH
FIRES EMP LIGHTNING
HELICOPTER/LAUNCHED WEAPONS
FI BI DI
EMP
FIRES HSR
EMRH LIGHTNING