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HOW TO GET INSENSITIVE MUNITIONS BENEFITS ACCORDING TO HAZARD CLASSIFICATION

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ABSTRACT

IMEMG is the European Organisation assembling leading armament groups working with IM technologies. It aims at expressing the viewpoint of the armament industry with regards to relevant transnational regulations and requirements. This paper is the result of common work carried out by the Hazard Assessment & Classification EWG and the Cost & Benefit Analysis EWG. IM bring safety for soldiers and survivability for combat platforms enhancing battle winning capability and reducing consequences of peacetime accidental events. Logistic benefits due to the introduction of IM for armed forces can be taken through SSD1.2.3 safety distances. However, this is limited to military storage. How could this being extended? Civilian regulations overview is presented with examples of how they are applied in various European countries. Up to now, no practical correlation could be made between UN HD and IM standard. Consequently, today's' qualified IM in the inventory are still handled and stored by non-military as ordinary ordnance with no real benefit for logistics. In an attempt to solve this issue, a proposition for harmonisation of HD1.6 criteria with STANAG 4439 requirements was prepared by national experts. Then, HD 1.6 criteria amendment has been approved by UN Committee of Experts on 10 December 2010 and it has been published on 8 March 2011. The EIDS (become EIS) requirement is limited to the main charge. This is a significant step forward. Nevertheless, some unrealistic criteria are maintained and even new ones introduced! Therefore, HD1.6 would remain an unattainable standard for a long time onwards. However, even with existing regulation, explosives manufacturing industry can benefit from the use of safer explosive compositions in every day operations. Reduction of regulation constraints can be achieved through the reduction/elimination of accidental detonation risks; thus the accidental effects are limited to thermal flux. Finally, interests for the development of specific regulations for IM are underlined by some Cost Benefits Analysis (CBA) all along life cycle *from cradle-to-grave*. Tools dedicated to this aspect may help to quantify some cost evolutions provided by IM, step-by-step. IM enhance safety of peacetime phases (production, storage, transport …) as well as during military logistics operations. A better acknowledgment of these improvements into future regulations will be profitable to all.

1 INTRODUCTION

IMEMG is the European Organisation assembling leading armament groups working with Insensitive Munitions (IM) technologies. It represents a total of 17 companies from France, United Kingdom, Germany, Italy and Norway. It has been established for six years and can be traced back to the foundation of "Club MURAT" in 1991. It aims to express the viewpoint of the armament industry with regards to transnational regulations and requirements in the field of munitions safety. It is acting as a focal point of contact for members' domestic authorities, EDA and MSIAC. It has established several Expert Working Groups (EWGs) in order to explore technical topics. This paper is a result of common analysis work prepared by the Hazard Assessment & Classification EWG and the Cost & Benefit Analysis EWG.

Insensitive Munitions bring increased safety for soldiers and survivability for combat platforms, enhancing battle winning capability and reducing consequences of peacetime accidental events. Logistic benefits due to IM introduction in forces can be taken into account by reducing safety distances for SSD 1.2.3 (Sub-Storage Division), as has been illustrated by the IMEMG's paper [1]. Unfortunately, the SSD 1.2.3 is limited to military storage. Nevertheless, opportunities appear in some countries to take into account the risk reduction for industrial and civilian logistic phases. This paper also gives examples from various European countries of the benefits that may be gained from the application of civilian regulations to explosive storage.

The UN Orange Book (Recommendations for Transportation of Dangerous Goods [13]) is used as the basis for the Global Harmonised System (GHS) implementation. For explosive goods, tests and criteria have been duplicated from the Orange Book and it is promulgated in Europe through the Regulation on Classification, Labelling and Packaging (CLP) [2].

At present, IM products do not exist according to transportation rules because the HD 1.6 (Hazard Division) criteria do not take into consideration the performance of current state-of-the-art of IM technology. IM products, which pass the STANAG 4439 criteria and which bring considerable advantages in safety, cannot meet the HD 1.6 criteria because not all the energetic materials within an IM product can be classified as "Extremely Insensitive Detonable Substance (EIDS)".

Propositions for harmonisation of HD 1.6 criteria with STANAG 4439 requirements have been prepared by national experts led by the British. Then, HD 1.6 criteria amendment has been approved by UN Committee of Experts on 10 December 2010 and it has been issued on 8 March 2011 [14]. This amendment would solve the current, unrealistic EIDS requirement by limiting the requirement to meet the EIDS criteria to the main charge of the IM product. Nevertheless, at the same time some unrealistic criteria have been introduced and these are surprising stricter than for SSD 1.2.3.

For industry in some countries, possibilities / opportunities exist to achieve IM benefits resulting from the reduction of regulatory constraints due to the reduction / elimination of accidental detonation risks, the accidental effects being limited to lower order burning reactions. These examples shall be disseminated in order to share best practice.

Finally, benefits that may be achieved by the development of specific regulations for IM may be illustrated by the use of Cost Benefits Analysis (CBA) applied throughout the life cycle *from cradle to grave* (i.e. across the complete Manufacture to Target / Disposal Sequence (MTDS)). Tools dedicated to this aspect may be used to assist in quantifying the cost savings provided by IM at various stages of the MTDS. IM provides enhanced safety during peacetime phases of the MTDS (production, storage, transport etc.) as well as during military logistics operations. A better understanding of these improvements when preparing future regulations will be profitable to all. To provide this greater level of understanding is the main objective of this paper.

2 INSENSITIVE MUNITIONS SAFETY REGULATIONS

Logistic benefits due to the introduction of IM products into service can be achieved by reducing safety distances for NATO's SSD 1.2.3, as has been illustrated by the IMEMG's paper [1]. This sub-storage division is dedicated to Insensitive Munitions which are not fully compliant with UN HD 1.6.

Thus, these munitions are assigned to HD 1.2 despite not being capable of reacting violently (i.e. detonating) when exposed to the defined stimuli. Rather than detonating, IM products exhibit a burning reaction giving a Type V response to Liquid Fuel / External Fire, Slow Heating and Bullet Impact trials and a Type III response for Sympathetic Reaction.

The SSD 1.2.3 is limited to military storage only. It is not useable for transportation or by industry. Thus, for example, this sub-storage division is implemented in the United Kingdom through the document: ESTC Standard No. 15 [3].

In France, The HD 1.2 Unit Risk is used [4]. This means that only one item is able to detonate accidentally. So, munitions relevant to this HD 1.2 U.R. are the IM / MURAT ☆. Such munitions have the following IM signature (or better), Type IV reaction for Liquid Fuel / External Fire, and Type III for Slow Heating, Bullet Impact, and Sympathetic Reaction.

Quantity / Distances arcs for HD 1.2.3 or HD 1.2 U.R. are significantly reduced in comparison with HD 1.1 and HD 1.2. Such reductions bring some benefits for forces, such as:

- Additional quantity of IM stored within the same safety distances
- Reduced storage areas and/or fewer storage magazines for the same quantity of munitions
- Reduced number of security personnel to guard the same quantity of munitions.

Other opportunities appear in separate countries to take into account the reduced risk of IM products and materials during industrial phases. These opportunities are provided by domestic regulations for Industrial Risk Management.

For example, in France according to a Quantitative Risk Assessment (QRA) method, Plastic Bonded Explosive (PBX) manufacturing can be operated within the constraints of HD 1.3. Indeed, accidental risks are limited to lower order burning reactions. Neither mass explosion nor violent explosions are considered as credible events in an accident scenario. This has been demonstrated through extensive characterisations of PBX compositions, and also through the application of appropriate controls throughout the casting and curing processes.

Due to similar considerations in regards to industrial QRA, French regulations recognise than PBXs can be assigned to HD 1.3 if they pass the Friability Test (in addition to meeting the requirements of conventional test requirements such as Gap Test, Burning Velocity Test etc.) [5].

Unfortunately, such opportunities do not exist for transportation because the relevant rules are defined by the UN Orange Book [15]. The previous requirements for HD 1.6 were over prescriptive in that munitions that cannot be detonated in any credible storage and transport scenario are being excluded from HD 1.6. These munitions are being excluded from HD 1.6 because they contain explosives that are not classed as an Extremely Insensitive Detonating Substance (EIDS). Explosives are being denied EIDS status on the basis of an arbitrary gap test threshold, despite all other evidence indicating that they have very good hazard properties. Then, this comment has become partially obsolete since amendment publication on 10 March 2011 [14].

3 HAZARDS CLASSIFICATION DEVELOPMENTS

The UN Orange Book (Recommendations for Transportation of Dangerous Goods) is used as the basis for the Global Harmonised System (GHS) implementation. For explosive goods, tests and criteria have been duplicated from the UN Orange Book and, it is promulgated in Europe through the Regulation on Classification, Labelling and Packaging (CLP) which will come into force on December, 1^{st}, 2010 [2].

Development of these regulations is important because CLP gives the legal definition of hazard for the whole life cycle of substances. This means that CLP Hazard Classification will be applicable for manufacturing and storage. Therefore, it is not clear how the use of SSD 1.2.3 or HD 1.2 U.R. will continue as these sub-divisions are not defined in Orange Book. Thus, for IM, only HD 1.6 is available to recognise safety benefits brought by the use of low vulnerability explosives.

Thus, these developments reinforce the need for practical HD 1.6 criteria to be defined. As described previously, IM products, which meet the STANAG 4439 criteria and which bring considerable advantages in safety, cannot pass the HD 1.6 criteria because not all the energetic materials within current IM products can be classified as "Extremely Insensitive Detonable Substance (EIDS)". Fortunately, to solve this issue, a proposition for harmonisation of HD 1.6 criteria with STANAG 4439 requirements was prepared by national experts led by the British and related amendment is now published.

4 HD 1.6 CRITERIA DEVELOPMENTS

HD 1.6 criteria amendment would solve the current, unrealistic, EIDS requirement for whole embedded explosive substances. The EIDS are renamed EIS (Extremely Insensitive Substance) to take into account gun and rockets propellants which are not dedicated to detonate. Indeed, the EIS requirement is limited to the main charge of the IM article. The booster compositions have to meet a reduced set of criteria which are a part of the EIS criteria. This is justified because the mass of the booster is small compared to the mass of the main charge, and the booster, located close to the core of main charge, has a degree of protection from external stimuli. The fuse compositions have to be placed behind two barriers to provide a greater level of insensitiveness.

Nevertheless, at the same time some unrealistic criteria are maintained (or introduced). These points are discussed below.

The Fragment Impact Test with an 18.6g fragment and an impact velocity of 2530 m/s velocity is introduced. This test seems totally unjustified for the UN Tests and Criteria of Transport of Dangerous Goods. This is not representative of any credible threat presented during civilian transport or even for most of logistics defence. Indeed, this high fragment velocity can only be achieved by air to air warheads (but with much lighter fragments of 3 or 4 g) or through Explosively Formed Projectile (EFP) charges. In addition, the maximum demonstrated response to pass this test must be a Type V response, with response descriptors coming from the AOP 39 ed3. The national experts consider that a Type V response for the Fragment Impact Test is the counterbalance to the EIDS waiver for booster / fuse compositions. In addition, the fragment impact threat is not required for NATO's SSD 1.2.3, and then it would be coherent to do the same for UN HD 1.6. It is surprising that HD 1.6 is stricter than SSD 1.2.3 while safety objectives seem to be equivalent.

The "accidental scenario" connected with this Fragment Impact test appears highly unrealistic. If detonation of a munition is able to generate 18.6g fragments travelling at 2530 m/s, then a damage, both in terms of casualties and damage to structures, equipment etc, will be caused in the surrounding area due to the effects of the donor charge itself. Bursts of high energy will be projected in all cases beyond 15 meters by the donor charge. Thus, it is unimportant that the acceptor munitions response be either Type V or IV or III.

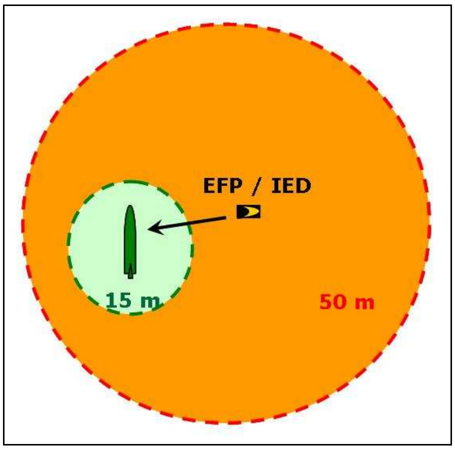

FIGURE 1:

Example to illustrate excessive severity of criteria

Primary Fragments Injuries Distance for 1kg Explosive Charge with 2mm thick case: 50m

In comparison with :

Maximum Projections Distance to pass Type V Response: 15 m

The Type V response requirement for Fragments Impact Test in order to satisfy the criteria of UN HD1.6 is very high. Apart for some simple types of ammunitions, this response will be very hard to attain for most Insensitive Munitions. This event scenario can be compared with sympathetic detonation, but for this trial the mandatory response is only Type III.

For the Bullet Impact Test, a similar concern appears. In the approved UN Manual of Tests and Criteria, a maximum Type IV reaction is mandatory. In the current proposal, this criterion moves to Type V. This seems unnecessarily severe in regard to Type V definition, especially for large munitions. Nevertheless, it is not unreasonable to specify the same reaction type as STANAG 4439.

Concerning the Type V response descriptors, problems have been identified with the new AOP 39 ed3. The main problem comes from the specified maximum projection energy which is limited to 20 joules. This energy level is very low and it has been demonstrated that a steel barrel filled with water subjected to fuel fire test could exhibit a response consistent with a hazard classification of HD 1.2 (or Type IV reaction according to AOP39). By the same reasoning, this configuration would also be classified as HD 1.2 according to UN Orange Book. This is due to the 2.5 kg cover plate of the steel barrel being propelled 22 meters.

In conclusion, the HD 1.6 criteria amendment is very interesting because it presents real improvements. But, at the same time, it would be necessary to adjust the Fragment Impact Test conditions to 1830 m/s and the maximum allowable reaction to a Type III or IV for current IM products to meet the criteria. It seems also possible to harmonise criteria with SSD 1.2.3.

5 EXAMPLES OF REGULATORY CONSTRAINTS REDUCTION

For industry in some countries, possibilities / opportunities exist to achieve IM's benefits resulting from the reduction of regulatory constraints due to the reduction / elimination of accidental detonation risks; the accidental effects being limited to lower order burning reactions. These examples shall be disseminated in order to share best practice.

5.1 EURENCO'S SORGUES PLANT

The Sorgues plant has produced military explosives for 95 years. The site is very densely populated with a large number of workshops. This resulted in the need to maintain minimum Quantity / Distances arcs preventing the construction of new buildings / workshops (illustrated in figure 2).

A QRA was conducted for a new workshop dedicated to PBX casting and curing for artillery shells. It has been shown that the accidental risks in case of fire are limited to low order burning responses. This is an acceptable approach given the insensitiveness of PBX materials being processed, the process control guaranteeing conformity of the explosive mix and the continuous process employed using the Eurenco bi-component technique

Thus, this activity has been classified as a HD 1.3 pyrotechnic operation. This classification has allowed the workshop to be constructed whilst maintaining the required quantity distance arcs. In addition it has achieved significant savings in the capital expenditure required for the construction of the new installation. This illustrates the potential cost savings that can be achieved with Insensitive Munitions manufacturing. The new installation has been producing insensitive shells (for mortar, artillery, and tank) for four years.

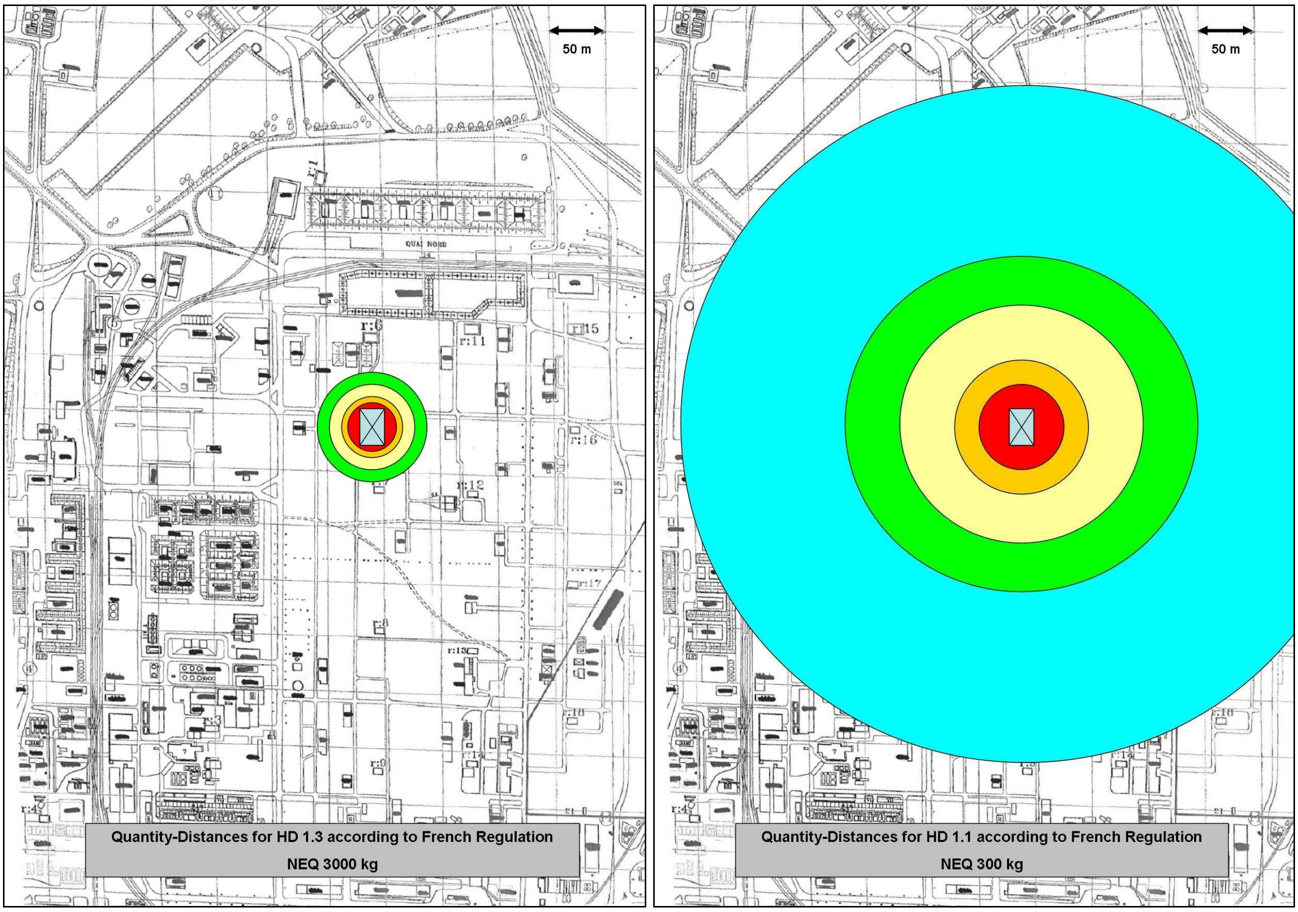

FIGURE 2: Example Regulatory Constraints Reductions for EURENCO's Sorgues Plant
"For 10 times less of Net Quantity Explosives, Quantity-Distances are 6 times larger for detonation risk"

5.2 NEXTER'S LA CHAPELLE PLANT

One of the flagships products manufactured by Nexter Munitions is 155 mm IM artillery shell named LU211. The LU211 is an explosive artillery shell interoperable with weapons of NATO-standard 39 caliber and 52 caliber according to the requirements of the interoperability agreement JBMoU (Joint Ballistics Memorandum of Understanding). This shell IM is loaded with XF® insensitive melt cast explosive. Even in case of aggression, the excellent behavior of the XF® composition allows the classification of the LU211 IM in Hazard Division 1.2 Unitary Risk and MURAT✰. In the case of a positive improvement of the regulation (see chapter 4), this shell could be a serious candidate for HD 1.6 classification. The same type of shell is also loaded in a version with the conventional comp. B explosive: a TNT/RDX mixture. Conventional shells are classified in Hazard Division 1.1. These both types of artillery shells generally follow the same industrial process and are manufactured in the same workshops. However, the use of insensitive explosive compositions allows substantial improvements, which are:

- Blast hazard areas reduction. Only one shell is taken into account for blast and fragment hazards. This advantage is due to the fact that no sympathetic reaction can occur with HD 1.2 Unitary Risk shells
- Increased capacity of existing storages, at each step of manufacturing. In most cases, when existing hardened building are used, the maximal number of shell that can be contained in the building is no more given by the NEQ. The number of shell is only limited by the available space inside the building.
- Reduction in the volume of internal transports. The short term buffer storages have very limited quantity for HD 1.1 articles. So, many transports are necessary between short and long term storages. These transports induce some costs and pollution, whose can be avoided for insensitive shells
- Gains in process flexibility. Some operations on conventional shells have to be necessary realized with remote control due to the detonation hazard. With insensitive shells, the same operation can be directly done, without remote control. It procures gains in flexibility, particularly with regard to treatment of eventual non conformities or breakdowns.

The figure 3 below shows the main workflow of 155mm artillery shells Nexter's production plant of La Chapelle. It summarizes the gains made by insensitive munitions regarding to conventional munitions.

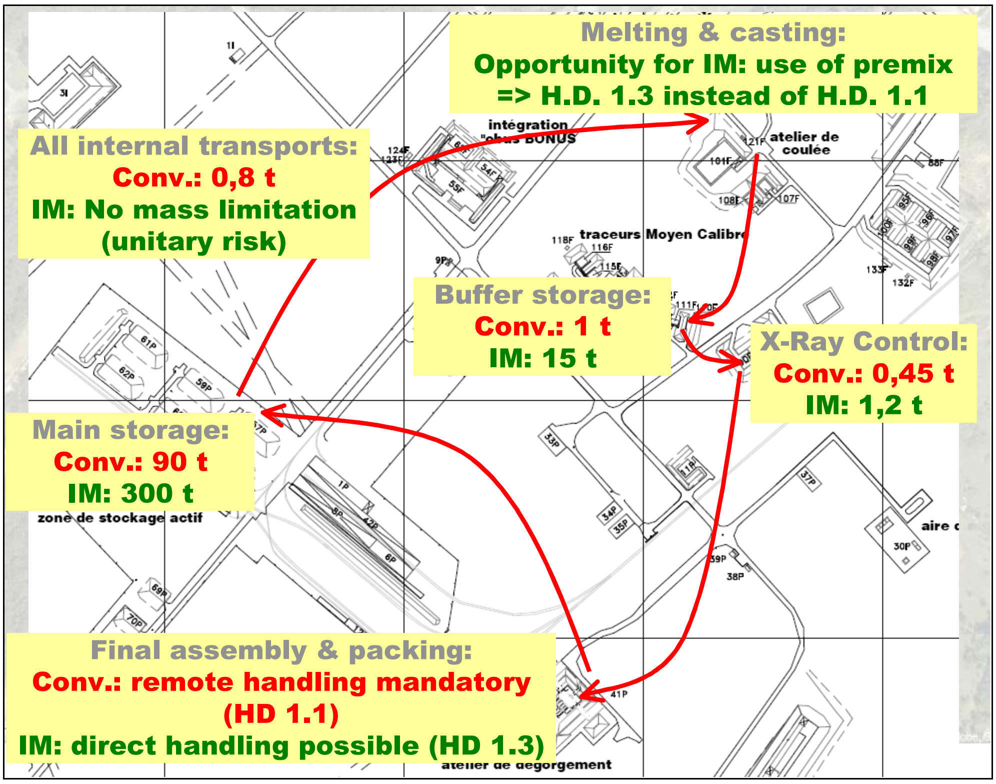

FIGURE 3: Example of industrial fluxes in Nexter's plant, the maximum acceptable weight of explosive is indicated for each workshop with comparison between conventional and IM shells.

In conclusion, main industrial workflows are simplified. This allows more flexibility in production and participates in costs reduction.

Another new opportunity is emerging for XF®: the use of premix composition in the filling workshop. It allows eliminating the conventional explosives in the filling phase. This would allow the classification of the filling workshop in H.D. 1.3 instead of H.D. 1.1. The internal capacity of the workshop could be increased and/or the architecture of the workshop could be seriously lightened.

6 COST AND BENEFIT ANALYSIS: WHAT FOR?

Industry and users need to improve their analyses for IM implementation. Cost and Benefit Analysis (CBA) is a major aspect to be considered by the community (MoD/DoD, Operational Forces and Services, Industry). The workshop organised by NIMIC/MSIAC in Rimforsa (2001) on this topic and the related documents [6][7][8] recall the importance of increasing understanding and awareness of IM. Indeed, the IM Day 2009 event sponsored by IMEMG in Brussels underlined that IM implementation is unavoidable today and does not need to be demonstrated. Nevertheless, as military budgets tend to decrease, it becomes vital to be able to justify the cost and the content of any new project. The methodology defined and provided by CBA contributes to consolidating the project by itself and positioning it regarding the competition. Any stakeholder in the defence market is interested in monitoring the CBA rules and the true outputs that can be expected.

UK was the first European country to take steps towards developing an IM Insertion Plan (IMIP). This IMIS/IMIP approach considers all the munitions in service but operational cost aspects of IM are not taken into account. The use of CBA could potentially help in assessing the potential benefits associated with enhanced platform survivability, a reduction in the collateral damage / number of platforms rendered un-serviceable following an accidental event and a greater suitability for service resulting from the introduction of IM. Other countries, like France, have shown an interest in CBA in order to provide additional evidence to support the case for developing IM products. A holistic approach is developing and the intention is to determine the IM signature for all munitions in service in the French Forces, in order to analyse the economic impact of their IM performance. On this subject, French DGA has launched a major study (MURAT ETO) for Land Defence munitions [9]. Some of the findings are as follows:

- Introduction of IM products has a significant influence in the costs' splitting,
- The CBA could help to establish the elements to be used to reduce the cost associated with the introduction of MURAT/IM (or in other words what are the important sources of costs).

To continue in Europe, munitions safety concept and IM policy are taken into account at the different levels of the German defence organisation [10]. The need to perform risk analysis for the munition life cycle, to specify IM signature and to define safety principles, rules and regulations for munitions in service, including IM aspects, is recognised.

7 TOOLS AND CBA: WHERE ARE WE?

It is well recognised that IM introduction reduces risk, increases platform survivability and improves the safety of munitions use during their whole life cycle. The idea to analyse and understand the costs in relation to IM introduction has quickly appeared. Estimates of the benefits that could be expected with IM insertion are of interest to many in the defence community but this requires particular efforts to put in place. Some methodologies have been proposed and developed into software to lead Cost and Benefit Analyses, the aim being always the same: to determine the key cost drivers comparing a non IM-solution with a projected IM version of the same munition. To put these methodologies in place, some computerised CBA tools were developed.

Recent literature gives examples of the interest generated by CBA. Some of them are dealing with the risk assessment and the determination of the munitions life cycle linked to this kind of analysis. At the beginning of the 2000s, a two part workshop was organised by NIMIC regarding risk assessment and C&B analysis (one for each). It was agreed that Risk Assessment was dependent upon the whole life cycle parameters to determine (threat leading to a stimulus, probability of the stimulus, leading response, probability of an event, effect of the event upon the surroundings etc.). To define a C&B Analysis methodology was also an issue; nevertheless, existing models/software on C&B analysis were identified (ACB, CBAM, COBEAN Cascade etc.).

COBEAN, developed by CINO/DOSG, was optimised for the naval environment and required some specialised data, probably known by experts of this domain. The tool seems to be more dedicated to assess the consequences of an initial event, the cost being a component of a more global approach. CBAM, developed by NIMIC/MSIAC, is not dedicated to a special armament corps and can be addressed to more general life cycles [12]. The common aspect for these two tools is the importance of collecting a significant amount of data but which allows a complete analysis to be conducted once collected. In addition to these tools, ACB from IMEMG (formerly Club MURAT) was also identified as being of interest because it featured the most important parameters agreed by the IM community for a C&B analysis, for example at first step level of an analysis. Consequently:

- Pilot NIMIC methodology (F. Möller) could be used as a basis,
- C&B analysis simulation has to consider the whole life cycle,
- The model must have the capability to simulate munitions with different levels of Insensitivity.

If a C&B Analysis is undertaken, 3 main phases should be observed:

1. To build the life cycle of the munition
2. To look for and to enter the data describing technical and economical parameters
3. To analyse the results and to validate data input.

In ACB Software, the description of a munition life cycle is proposed with an arborescence showing the various phases of the munition life and the relevant undesirable threats / incidents that may occur during each phase. This arborescence is subdivided into four levels:

- 1 - **The studied case**: The reference munition and its corresponding IM/Murat version in a given life cycle is considered. It is possible to deal with several cases in parallel, generally cases that are similar, for example, several munitions that differ in their IM profile levels with respect to the reference munition, or by incorporating different assumptions into the life cycle.

- 2 - **The sequence**: The munition life cycle is divided into separate operational phases which can be preceded or followed by storage periods on the national territory. Every sequence is characterized by a geographic zone of deployment, associated to a military status (peace, crisis or combat).

- 3 - **The elementary situation:** Every sequence is defined by a succession of storages, transportations and missions, which are theoretically unlimited in number (on identical or different platforms). Each individual storage, transportation or mission is referred to as an elementary situation, because it is not possible to subdivide it more.

- 4 - **The disaster:** Every elementary situation can be the subject of one or several accidental or deliberate threats, generating a typical disaster.

Within Club MURAT/IMEMG CBA software, every element of the arborescence, including every treated/studied case, every sequence, every elementary situation and every undesirable event, is also referred to as a node. Data is needed at each node.

The Möller formula is the core of the ACB software. It allows the application of the Cost Benefit Analysis to an IM/Murat munition case. It determines benefits which are dependent on earnings and cost differences, between referenced and planned munitions. The general formula can be expressed by:

$$CB = RP + PP - DAC$$

Cost Benefit = Total statutory Earning + Total potential Earning – Costs

- **CB**: Cost / Benefit of the IM program. CB is the balance of the cost-benefit and is given in the form of a table. It represents the sum of the logistic and potential earnings, minus the extra-costs of inserting into service and disposal, between the reference and planned munitions.

- **RP**: Regulatory Profits (storage and transport) or Logistic benefits are connected to the variation of the constraints (statutory or not) in the conditions of storage, transportation and during missions. They result from the accumulated variations of the costs of storage, transportation and missions, between the reference and the planned munitions.

- **PP**: Potential Profits (damage in case of accident) are connected to the variation of the risk associated with every elementary situation (the probability of occurrence and the severity of the disaster), and for every conceivable threat. They result from the accumulated cost difference of disasters between the reference and the planned version.

- **DAC**: Difference in Acquisition Costs is the difference between the reference and the planned munitions in their acquisitions cost, taking into account the number of munition needed in the study.

Whatever the software used, the difficulty lies in establishing the whole life cycle and in data collection.

In 1999, a cost benefit analysis was undertaken using ACB software as part of cooperative work performed by NIMIC/MSIAC and Club MURAT dealing with a 155mm artillery shell and a short range ground to air missile. This works demonstrated that collecting the data was difficult, even on a restricted / reduced life cycle. At that time, storage / logistic benefits were neither taken into account, nor identified, mainly due to the fact that it was difficult to take the legal advantages of the munitions improved IM performance.

Some years later, it is clear that HD 1.6 or SSD 1.2.3 may offer financial advantages in the field of storage by reducing the size of the storage area, allowing storage in differently constructed buildings or reducing the required safety distances. Over the last three or four years, several papers have highlighted this idea, for example [11].

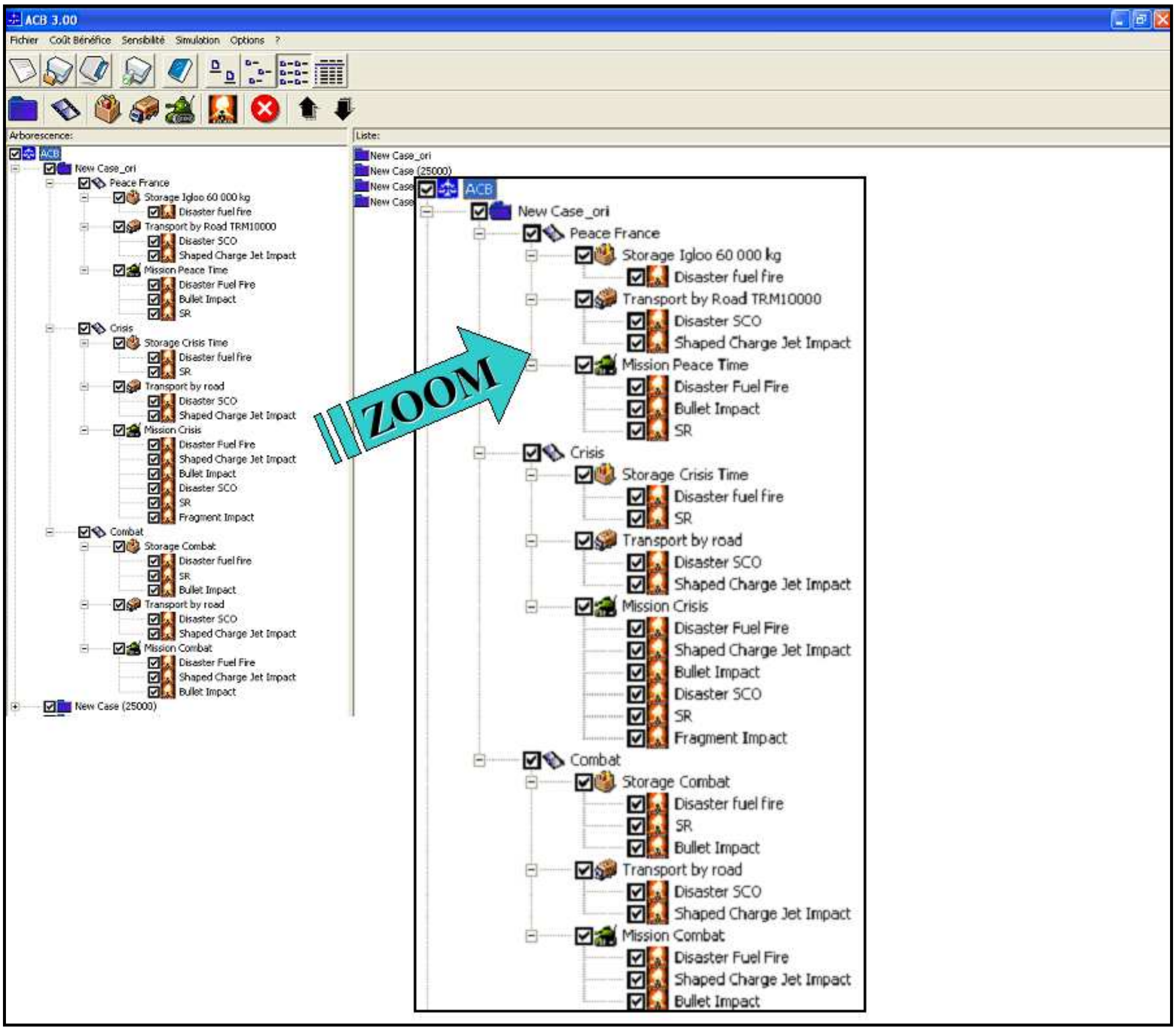

FIGURE 4: An example of ACB 3.0 Software life cycle:

To illustrate the regulatory benefits that may be gained by the introduction of IM, the CBA Working Group from IMEMG decided to revisit the previous 155mm artillery shell evaluation, without altering the original hypotheses investigated for the Potential Profits during the operational phase. The group also attempted to retain the spirit of the original approach whilst understanding quickly that the work to be performed was of high importance. It was decided to model a single node of the life cycle in relation to regulatory considerations. The peacetime storage node was chosen as this accounts for approximately 50% of the life cycle for typical artillery ammunition.

For an inventory of several thousand 155mm artillery shells, it was estimated that a 20% reduction of the cost of storage (depending on storage area reduction, cost increases over time, potential reduction of associated supporting functions etc.) could lead to an additional benefit estimated as being up to 10%. Additional benefit means the difference between the original result calculated with and without taking into account regulatory profits. Percentage values of additional benefits are only estimates but they help to illustrate that a small earning percentage at each node of the life cycle could lead to a more significant benefit over the whole arborescence.

This kind of approach for an artillery shell is compatible with previous advantages presented earlier in this paper. On the one hand, taking into account the advantages of regulatory profits provided by IM introduction can lead to an increase in the quantity of munitions able to be stored at the same place (realising that probably, other benefits associated with a reduction in the number of internal transports inside a plant could be assessed). On the other hand, it can also help to optimise the explosive limits of storage buildings.

On each node of the life cycle (peace, crisis or combat time phase), additional benefits may be found with respect to regulatory changes: They may be small but never negative. If the same exercise is performed with a short range ground to air missile, the estimated results introducing regulatory profit during peacetime are not significant. It is linked to the much smaller quantities of munitions within the inventory for missiles compared to artillery ammunition. It is probable that other benefits could be found at the storage building level itself. For a small missile, the advantage could be estimated by performing a calculation taking into account a lighter storage building construction (meaning reduced building costs) than heavier existing ones.

The previous discussion is mainly dedicated to demonstrating the peacetime benefits that can be assessed if hazard classification is taken into account (the subject of this paper). There exist other benefits during crisis time and operational phases. These (additional) benefits could be significant but it is obvious that the CBA approach needs to focus more on potential benefits related to operational phases, where greater benefits can be assessed.

8 CBA AND WHAT ELSE?

Finally, in addition to cost benefit considerations, it is also possible to consider the optimum compromise that can be offered to the customer by manufacturers in terms of the tradeoffs between terminal performance, IM profile and cost. Studying the whole munition life cycle, it would be also interesting to propose:

- The best IM signature with respect to the state of the art of the considered munition to achieve compliance (vulnerability techniques: technology maturity, energetic materials: properties and/or manufacturing processes and related investments to plan etc.)
- To identify the key cost drivers (disaster, sequence, phase etc.) to be compliant with the signature specified by the customer / stakeholders.

With this in mind, the IMEMG CBA Working Group is considering the idea of creating a tool which could help in assessing and specifying an IM signature. A common approach using this tool and ACB would be able to provide to assist in finding the best compromise between costs and IM introduction.

9 CONCLUSIONS

Logistic benefits due to the introduction of IM products into service can be achieved by reducing safety distances for SSD1.2.3 (Sub-Storage Division). Unfortunately, the SSD 1.2.3 is limited to military storage only. Nevertheless, opportunities appear in some countries to take into account the risk reduction for industrial phases.

Some possibilities / opportunities exist to achieve IM's benefits resulting from the reduction of regulatory constraints through the reduction / elimination of accidental detonation risks; the accidental effects are limited to low order burning events as defined through QRA. In this way, Insensitive Munitions generate cost reductions. Examples given in this paper should be disseminated for best practice sharing.

These opportunities exist for manufacturing and storage installations. But, for transportation, the classification rules are only based on the UN Orange Book. In addition, it becomes the basis for the Global Harmonised System (GHS) which is promulgated in Europe through the Regulation on Classification, Labelling and Packaging (CLP) [2].

At present, IM products do not exist according to transportation rules because the HD 1.6 criteria have not took into consideration the real performance of current state-of-the-art of IM technology. These requirements for HD 1.6 are over prescriptive. Munitions that cannot be detonated in any credible storage and transport scenario are being excluded from HD1.6.

Propositions for harmonisation of HD 1.6 criteria with STANAG 4439 requirements have been prepared by national experts led by the British. Then, HD 1.6 criteria amendment has been approved by UN Committee of Experts on 10 December 2010 and it has been issued on 8 March 2011 [14]. This amendment would solve the current, unrealistic EIS (Extremely Insensitive Sunstance) requirement by limiting the requirement to meet the EIS criteria to the main charge of the IM product. Nevertheless, at the same time some unrealistic criteria have been introduced and these are surprising stricter than for SSD 1.2.3. The Fragment Impact Test has been introduced with the highest fragment velocity fixed at 2530 m/s, and with Type V reaction required to meet the HD 1.6 criteria. This requirement is not consistent when compared with the Sympathetic Reaction Test where a Type III reaction required. At least, the fragment impact threat is not required for NATO's SSD 1.2.3, and then it would be coherent to do the same for UN HD 1.6. It is surprising that HD 1.6 is stricter than SSD 1.2.3.

Finally, benefits that may be achieved by the development of specific regulations for IM may be illustrated by the use of Cost Benefits Analysis (CBA) applied throughout the life cycle *from cradle to grave*. Tools dedicated to this aspect may be used to assist in quantifying the cost savings provided by IM at various stages of the MTDS. IM provides enhanced safety during peacetime phases of the MTDS (production, storage, transport etc.) as well as during military logistics operations. A better understanding of these improvements when preparing future regulations will be profitable to all. To provide this greater understanding is the main objective of this paper.

10 BIBLIOGRAPHY

[1] "European Industry involved in logistic gains assessment", 2006 IM & EMTS, Bristol, United Kingdom,
[2] Règlement CE n°1272/2008 du 16 décembre 2008 relatif à la classification, à l'étiquetage et à l'emballage des substances et des mélanges dit "Règlement CLP"
[3] Manual of Standards for the Storage and Transport of Military Explosives – ESTC No. 15 Storage Requirements for Insensitive Munitions – 20th April 2006,
[4] Note N° 1358 DGA/IPE du 23 septembre 1997 sur l'application aux munitions MURAT de la réglementation française.
[5] Circulaire Interministérielle du 20 avril 2007 concernant l'application de l'arrêté fixant les règles relatives à l'évaluation des risques et à la prévention des accidents dans les établissements pyrotechniques,
[6] "Assessing the risk and the Cost Benefits associated with the introduction of IM – Part 2: Cost Benefit Analysis – Final Report" – P. Marchandin & al. NIMIC L-77 (December 2001).
[7] "Intrinsic Benefits of Insensitive Munitions" – P. Marchandin, NIMIC O-75 (December 2002) and related references.
[8] "ACB 2.7: Cost Benefits Analysis software" – C. Mas (Club MURAT), RIMFORSA (2001).
[9] "Interest and Cost of the Muratisation of Munitions of the French Army" – F. Barioz, B. Longuet & al., IMEMTS 2006 (April 2006).
[10] "German Rules and Regulations" – F. Jüptner, BWB K1.3, IM Day 2009 (May 2009).
[11] "How to achieve actual logistic benefits with IM" – Dr H. Muthig, IMEMG, IM Day 2009 (May 2009).
[12] "Cost Benefit Analysis Studies of the Introduction of Insensitive Munitions – Is IM Cost of Ownership Cheaper?" – NIMIC O-80 (2003).
[13] ST/SG/AC.10/11/Rev.5 (2009) Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria (fifth revised edition).
[14] ST/SG/AC.10/38/Add. (8 mars2011) Amendments to the fifth revised edition of the Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria (ST/SG/AC.10/11/Rev.5).

11 ABBREVIATIONS

ACB	Analyse Coût Bénéfice (Club Murat/IMEMG)
CBA	Cost Benefit Analysis
CBAM	Cost Benefit Analysis Model (NIMIC/MSIAC)
COBEAN	COst BEnefit ANalysis (CINO/DOSG)
CLP	Classification Labelling Packaging
EDA	European Defence Agency
EFP	Explosive Formed Projectile
EIDS	Extremely Insensitive Detonable Substance
ETO	Etude Technico-Opérationnelle
EWG	Expert Working Group
GHS	Global Harmonised System
HD	Hazard Division
IM	Insensitive Munition
IMIP	UK IM Implementation Plan
IMIS	UK IM Implementation Strategy
IMEMG	IM European Manufacturers Group
MSIAC	Munition Safety Information Analysis Center (formerly NIMIC)
MTDS	Manufacture to Target / Disposal Sequence
MURAT	Munition à Risques Atténués
NEQ	Net Explosive Quantity
NIMIC	NATO Insensitive Munitions Information Center
PBX	Plastic Bounded explosives
QRA	Quantitative Risk Assessment
SSD	Sub Storage Division