GROUP OF GOVERNMENTAL EXPERTS OF THE STATES PARTIES TO THE CONVENTION ON PROHIBITIONS OR RESTRICTIONS ON THE USE OF CERTAIN CONVENTIONAL WEAPONS WHICH MAY BE DEEMED TO BE EXCESSIVELY INJURIOUS OR TO HAVE INDISCRIMINATE EFFECTS

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Working Group on Explosive Remnants of War

DISCUSSIONS ON IMPROVING MUNITION RELIABILITY

Prepared by Australia

Introduction

1. During the March meeting of military experts on the issue of ERW the Australian delegation undertook to review the matrices produced by the Swiss, British and French delegations. At the time it was the intent to provide detail within the matrices however, upon review, it was determined that a more general approach was warranted.

Identifying high risk munitions

2. The British Matrix, Annex II to CCW/GGE/IX/WG.1/1 dated 31 January 2005, is a useful model in that it uses a risk management approach to make an assessment of the likely potential for a type of munition to become a humanitarian hazard. In terms of trying to attack the humanitarian problem as effectively as possible it is important to take this approach so that those munitions that are causing the most problem are targeted first. Therefore, the key to reducing the humanitarian impacts of ERW is putting the effort where it is most needed rather than demanding an arbitrary across the board increase in reliability. The two factors deciding where it is needed are:

(i) an understanding of which types have the greatest humanitarian impact, and

(ii) an understanding by all States of their own munitions inventory to determine which items pose the greatest threat .i.e. the elements known to have lower levels of reliability.

3. The type of EO, its principles of operation, net explosive quantity and designed terminal effects will all contribute to the consequence of the inadvertent initiation of the EO. To this end it is desirable to gather empirical data to quantify the known reliability of EO in service, in particular its likelihood of generating a significant humanitarian impact if it fails to function as designed. This would provide a more detailed basis for the assessment of potential humanitarian impact.

4. As such, information from the Explosive Ordnance Disposal (EOD) community, both defence and NGO, could be used to further refine the British risk matrix. Once these risks are identified and prioritised, a more detailed and focused assessment on how to improve the reliability of specific munition natures could be undertaken and an approximate cost estimate to implement this increase in reliability could be determined. It would be at this stage where the French matrix would come to the fore as a very structured process to increase the quality assurance process and therefore the reliability of the munitions identified.

An indication of improvement possibilities

5. Most developed nations will attempt to ensure that munitions are going to be safe and reliable, firstly through good design, and then through the application of the engineering process known as Safety and Suitability for Service (S3), (which is just a part of the overall design certification of an item). S3 is known by a number of different names depending on which country you are in. In the NATO arena you will see the term S3 as defined in the Allied Ordnance Publication 15 - Guidance on the assessment of the safety and Suitability for Service of Non-Nuclear Munitions for NATO Armed Forces.

Safety and Suitability for Service (S3)

6. The **assessment of safety** involves an appraisal of the inherent freedom from explosive hazard of the item's design, an evaluation of the risk attendant on deploying the item in prescribed environments throughout its anticipated service life and the consideration of the acceptability of this risk in meeting the operational requirement.

7. **Suitability for Service**. The assessment of suitability for service requires objective evidence that the item or associated elements of a weapon or equipment are capable of **functioning as designed and that functioning will not be unacceptably degraded by the service environments encountered** throughout the anticipated service life. This definition generally excludes operational effectiveness and lethality but may include certain performance characteristics if these aspects are deemed to be part of the item design function. The anticipated service life is defined as the whole of life environment for the particular store, and is known as the manufacture to Target or Disposal Sequence (MTDS) or life cycle.

8. Things can come unstuck when one is forced to operate weapons in regions/environments that are more severe than the weapons have been designed and tested for.

9. **Design/Operational Environment**. Weapon designers in advanced nations are attempting to ensure that their weapon designs result in weapons that have the highest possible level of reliability.

They will be driven by the demands of the armed forces who will operate with the weapons, and they will also be driven by the requirement to present high reliability levels as a sales feature for the munition. That is the theory.

10. Some weapons will be designed and tested to endure the rigours of world-wide use. This will typically involve the requirement to operate in temperature ranges from **Hot Dry** (Storage Temperature 71 °C and Operational temperature without solar loading of 49 °C), down to **Cold** (Storage Temperature -46 °C and Operating temperature -46 °C.) In addition, world-wide operation will also involve exposure in areas of high humidity. Many weapons will **not** have been designed and tested to ensure that they can safely and reliably operate world-wide. The problem is that one is now seeing armed forces operating in climatic areas which may be more severe than their weapons have been tested to. This can lead to reliability problems, safety problems, and dudding.

11. There will be a large number of environmental affects impacting on a weapon as it experiences the various environments in its life cycle. The environmental affects may include: diurnal temperature cycling, vibration, shock, humidity, solar radiation, precipitation, sand & dust, salt spray and electromagnetic radiation. These things acting singly or in combination can cause damage to munitions that may reduce the reliability of the item and may result in increased levels of duds.

12. **The bottom line is that one will be far less likely to have weapons that are producing an unacceptable dud rate, if one is operating weapons that have been designed and tested to ensure they cope with the environment in question. Countries that are not using some form of S3 process should be encouraged to do so.**

The cost of improving reliability

13. The Swiss Matrix, Annex I to CCW/GGE/IX/WG.1/1 dated 31 January 2005 identified that improvements in reliability will predominantly be achieved through enhancements in design, production and storage. In attempting to improve munition reliability it is important to appreciate that the cost/improvement ratio is not linear and as such costs will tend to increase significantly as higher levels of reliability are sought.

14. Importantly it should also be recognised that marked improvements in reliability cannot be delivered from improved production processes alone, but would necessarily have to come from significant changes in the base technologies used in EO. Thus, as also noted in the French matrix, Annex III, **a meaningful step improvement is only likely to be achieved through new designs, particularly in fusing, developed using a systems engineering approach and based on new technologies combined with improvements in testing and material management**. Attached to this paper are NATO Fuze System Design Guidelines which provide a good indication of the approach that can be taken to institute better design practice.

15. In order to achieve a 98-99% level of confidence it would be necessary to significantly increase the quantities of EO that would have to be tested to accept each lot from a new production run, and, it would increase the potential for rejection of production lots, production scrap rates, etc.

In terms of a low/medium/high cost rating it depends on what each break point might be in dollar terms, but annual cost increases to achieve the increased reliability levels could be anywhere in the order of magnitude from 10-50%. The cost increases therefore may be unsupportable for a number of States parties. This would indicate that the priority of effort therefore should be invested in the front end design and pre-production testing prior to the introduction into service combined with comprehensive through life management of the munition.

Annex I, II and III matrices

16. Further enhancement of the work initiated in the matrices developed to date requires States parties to further identify, in detail, their experience of the most problematic munition types that have been listed. In the longer term this will assist in prio ritising the expenditure of limited resources towards maximising the potential humanitarian returns in the most timely manner possible. The following comments, while not expansive provide an indication of how analysis can assist in reducing the size of the remediation problem.

(i) Small Arms Ammunition <14.5mm

17. **Complete Round**. If a round of small arms ammunition does not function when the soldier attempts to fire it on the battlefield, it is likely to be discarded on the battlefield by the soldier. This will leave a complete round on the ground where it has potential to be picked up at some time in the future by a civilian. This comes with some likelihood of a subsequent accident, especially if children find the round. Assuming the rifle/gun was in correct operating condition, the reasons for the failure of the round function could include:

(i) corrosion around the primer,

(ii) degradation of the chemicals in the primer/propellant, (discussed separately below under In Service Surveillance), and

(iii) the ingress of water vapour into the propellant.

18. The design of the round can include features to prevent these failure modes such as the application of some form or waterproofing coat such as varnish/shellac around the primer, and the application of a suitable crimping pressure to ensure a tight fit of the projectile in the cartridge case.

19. Different packaging designs can also have a big impact on how well the ammunition survives in service. Some packaging will include rubber seals on lids and some will not. The ability of a storage box to provide protection from shock, and insulation from heat/cold can also have a significant impact on the long term serviceability of the ammunition.

20. **Projectile**. Generally, the hazard posed to people by a small arms ball round that has been fired and is now lying on the ground is negligible (lead toxicity not included). However, the story may be different when one considers rounds such as the 12.7 mm Multi Purpose round which contains HE and Incendiary materials. This type of round uses a pyrotechnically initiated (PIE) fuze.

It works by the impact of the round rapidly crushing explosive materials causing the materials to explode. If projectiles such as these do not function on impact they will represent a real hazard. The hazard would only be realised if the projectile was subsequently heated or subjected to shock. To have failed to function they will have needed to have ricocheted at a very shallow angle. The cause of this kind of initiation failure could also include landing in snow or mud especially at long range. **As a result there is not a lot that can be done to improve the situation with these pyrotechnically initiated rounds.**

(ii) Cannon Shells >14.5mm

21. The comments made on the Small Arms Ammunition <14.5mm are also applicable to the Cannon ammunition >14.5mm. There may be additional failure modes if the ammunition is electrically initiated. Also, if the ammunition is fuzed, the fuze may be pyrotechnically initiated or it may have some form of mechanical fuze which could fail to function for a large number of reasons. S3 programs would include a detailed assessment of the design of the fuze and would also seek to test the fuze after it has been environmentally stressed. **The S3 process combined with regular proof firings through life of all lots of cannon ammunition will work to identify unsatisfactory designs or lots of ammunition that have reached the end of their service life.**

22. **The incorporation of some form of self-destruct feature is probably the best form of guarantee that significant numbers of these sorts of rounds will not be left as duds around the battlefield.**

(iii) Sub Munitions

23. Different manufacturers of sub munitions around the world have achieved different levels of dud rates with their sub munitions. Some fall within acceptable limits and there is evidence to suggest that many of the older weapon systems fail to meet current reliability standards. Irrespective of the means of delivery of the sub-munitions, States parties should be striving for the highest possible function rate for the sub-munitions. As part of the reliability assurance process regular proof firings of different sub-munition lots should be conducted, and **lots that fail to achieve the required function rate should not be used on operations**.

24. **The inclusion of some form of self destruct system built into a sub munition so that they will function after a defined short time period after impact would substantially reducing the dudding rate.**

(iv) Tank Projectiles

25. **Kinetic Energy (KE) Rounds**. Most KE rounds are unlikely to pose a hazard to people once fired and lying on the ground.

(v) Guided Missiles

26. Guided missiles are in many cases fitted with a means for the operator to command destruct the missile in flight. This is not the case for all systems. **As a general principle it would be good if all guided missiles had some form of command/self destruct. This is clearly difficult with missiles that are fire and forget. In the case of fire and forget missiles, it may be possible for the missile to be programmed to take certain actions including self destruct if serious missile faults are detected in flight through built-in-test.**

27. If a guided missile crashes prior to arming, then the warhead may or may not experience an energetic reaction on impact. If the warhead remains largely intact on impact then it will represent a real hazard to civilians. If some form of self destruct system is fitted to all guided missiles, the self destruct system could possibly endanger the firer if it is able to function prior to the missile achieving the usual safe arming distance. The self-destruct system would have to be designed so it could not function prior to the missile achieving safe separation from the firer.

28. Guided missiles typically feature electrically initiated:

- warheads,
- batteries,
- gas pressure bottles, and
- rocket motors.

29. The designer will attempt to ensure that the electrically initiated devices (EID) are adequately screened to prevent the inadvertent exposure of the EID that electromagnetic radiation EMR. A damaged missile that has landed and not functioned may have suffered a rupture of the outer casing. This could potentially expose wires leading to EID. If the damaged missile is subsequently exposed to EMR an accident could result. **Designers could consider designing the internal EM shielding of certain missiles to minimise the threat posed by EMR if the outer shell of the missile is damaged. The best approach would probably be the inclusion of a self-destruct mechanism.**

(vi) Free Flight Rockets

30. Free flight rockets such as disposable anti tank rockets can pose a serious hazard when they become duds. The situation is worse when the fuzes are piezoelectrically activated. In the case of such a rocket that has landed but not functioned, the fuze can potentially function if it experiences a temperature change, such as that caused by a person casting a shadow over the fuze. Passing clouds can have the same effect.

31. Some rocket fuzes can be fitted with a ‘Graze’ function which is a device to cause the fuze to function if it strikes a target at a shallow angle and starts to ricochet. Some fuzes are not fitted with such a device. This can lead to instances where rockets have landed on soft ground such as snow and eventually slid to a halt in an armed condition.

32. **The inclusion of a Graze function and/or some form of self destruct device is an advisable improvement**. Both features would tend to reduce the hazard posed by armed missiles sitting on the ground especially when fitted with piezoelectrically initiated fuzes.

(vii) Lifeing and In-Service Surveillance

33. Design measures to reduce the likelihood of various munitions not functioning correctly are only the start point. The application of robust procedures such as those of the S3 process will identify design problems or areas of susceptibility that the munition might have. Assuming this is done, reliability assurance will be further improved the conduct of production Quality Assurance and Acceptance Testing (proof) during the production process. This should help to identify production lots that are below the acceptable standards. After this point the munition is then passed into the hands of the military and could conceivably be in storage for 20 years or more before it is used.

Conclusion

34. The matrices shown have some utility because they help articulate the munition types likely to be of most concern and serve as a guide to focus munition manufacturers on those areas where improvements might be made. The next step however is to add detail by getting the respective national experts of the States parties together to articulate clearly the type of processes that can be instituted to improve munition reliability.

35. It is crucial that munitions are regularly checked throughout their storage life to monitor the state of the items. This will include the energetic materials in the munition. Ideally, the **baseline level** of the various chemicals in the energetic materials of a munition will be recorded at the time they leave the factory. Regular breakdown of samples of munitions from different lots should occur to monitor the degradation of the chemicals. The examination of the munitions will include all components and packaging. The **In-Service Surveillance (ISS)** program coupled with a regular proof firing program will provide the best means of dud minimisation during operations. **If a perfectly designed munition is left in store unchecked via an ISS program, it may well eventually degrade chemically and/or physically to the point where it does become unsafe and unreliable on the battlefield.**

Annex

NATO POLICY ON UNEXPLODED ORDNANCE MITIGATION: FUZE SYSTEM DESIGN GUIDELINES

Background: For the purpose of this policy, Unexploded Ordnance (UXO) is defined as a launched or emplaced munition that has been operationally employed but failed to function its explosive contents as intended. Historically, UXOs have posed significant hazards to NATO and Alliance forces during tactical and peace-keeping operations as well as yielded long-term hazardous environmental conditions to civilian populations.

General: Incidents of UXOs may be attributed to a variety of causes such as improper design of the munition and/or weapon system, inadequate quality control during manufacturing of the munition, improper storage, effects of the operational environment including terrain, human operational error, et cetera. Because of the wide variety of causes, a Systems Engineering approach needs to be incorporated towards ensuring mitigation of UXOs. With respect to the munition's fuze system, the following design guidelines should be integrated into the Systems Engineering approach.

Fuze system design guidelines:

1. The fuze system shall be designed, produced and tested in a manner which assures the greatest possible performance reliability in all operational environments.

2. The design of the fuze system shall include features that facilitate, as applicable, effective automated and/or manual quality assurance tests and inspections.

3. The fuze system shall be designed to maintain the required degree of safety in credible accident situations and under all specified natural and induced environmental conditions in its life cycle.

4. The fuze system shall be designed to not being capable of being armed manually.

5. Features shall be incorporated in the fuze system to facilitate the use of EOD tools, equipment and procedures for the application of render safe procedures.

6. Incorporation of fail-safe, sterilization, self destruct features, et cetera, should be considered (reference STANAG 4187).

7. The fuze system for hand emplaced munitions shall either self-destruct or auto-sterilise at the end of planned usage, at the end of the emplacement life, or upon system malfunction.

8. For electrically initiated fuze systems, the design shall include a provision to deplete the firing energy after the operating lifetime of the fuze system has expired. The time required to

dissipate the firing energy shall be reduced to the minimum allowed by the operating requirements for the fuzing system. The means of dissipation shall be designed so that it does not degrade the overall safety of the Safety and Arming device before the system is armed.

9. Electrical initiators used in fuze systems with non-interrupted explosive trains shall not be capable of being detonated by any electrical potential of less than 500 V applied directly to the initiator nor be capable of being initiated by an electrical potential of less than 500 V when applied to any accessible part of the fuze system during and after installation into the munition or any munition subsystem.

10. Only those explosives qualified in accordance with the requirements of STANAG 4170 as acceptable expulsion charges and lead or booster explosives shall be permitted to be in a position leading to the initiation of a high explosive main charge without physical interruption.