The Reliability of Cluster Munitions: As Considerations of the Technical Criteria for Negotiating New Regulations

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Abstract

It is often said that there are life-threatening problems with the reliability and accuracy of cluster munitions. Recognizing that the low reliability of these munitions results in the presence of unexploded ordnance following battles, and that this is the principle source of danger to ordinary citizens, the Oslo Process played a decisive role in the agreement for a complete ban on the stockpiling and use of cluster munitions. There has in the past been study of the establishment of standards restricting the use of cluster munitions, based on their reliability, within the framework of the Convention on Certain Conventional Weapons (CCW), to which the United States, Russia, China, Israel and other major users of cluster munitions belong. However, no agreement has been reached to date. This paper will discuss the reasons for cluster munitions' lack of reliability, reasons that the unexploded ordnance problem has not been resolved through improved reliability, and other issues.

Introduction

The international effort to restrict cluster munitions as inhumane weapons began with a study of explosive remnants of war (ERW, to include unexploded ordnance) by the CCW. To minimize the postwar danger presented by ERW, the CCW Second Review Conference, held in December 2001, tasked the Group of Government Experts (GGE) with conducting a study of the adequacy of existing International Humanitarian Law in minimizing post-conflict risks of ERW, both to civilians and to the military, and a study of technical improvements and other measures for relevant types of munitions, including submunitions, which could reduce the risk of such munitions becoming ERW.[1]

As a result of these studies, the 2003 Meeting of the States Parties to the CCW adopted Protocol V, which calls for the eradication of unexploded ordnance that becomes ERW, victim assistance, risk education, and other measures. The CCW-GGE continued to study the issue of cluster munitions, and presented a Draft Protocol on Cluster Munitions[2] at the 2009 Meeting of the States Parties to the CCW. However, that proposal was not adopted.

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1 CCW/CONF.II/2, pp.12-13.

2 "Draft Protocol on Cluster Munitions," presented by the Chairperson of the CCW Group of Government Experts, CCW/MSP/2009/WP.1.

In 2008, the Convention on Cluster Munitions (Oslo Convention)[3] was adopted, prohibiting all use, stockpiling, production and transfer of Cluster Munitions. During the negotiations (generally known as the Oslo Process) that led to the Oslo Convention, a number of countries that use cluster munitions argued at first for the inclusion of a certain number of exceptions that would have allowed them to continue to possess and use highly reliable and accurate cluster munitions. During the ensuing negotiation process it was argued persuasively that the inhumane harm done by cluster munitions would not be abated absent a complete ban, and these countries changed their policies one by one.

It is impossible to guarantee that any munition is 100% reliable and accurate. However, low reliability and low accuracy are all viewed as problems with cluster munitions. Improving the reliability and accuracy of cluster munitions had already been studied within the CCW framework, but there is a consensus among the countries that participated in the Oslo Process that this is not an effective means of reducing the harm done by unexploded cluster munitions. However, have the reasons for the problems with the reliability and accuracy of cluster munitions been pondered? This paper will primarily focus on reliability, which has a large effect on the degree of danger presented following hostilities by unexploded cluster munitions.[4]

1. Restrictions on Cluster Munitions Now in Force

(1) Definition of Cluster Munitions

Cluster munitions are defined as “a conventional munition that is designed to disperse or release explosive submunitions each weighing less than 20 kilograms, and includes those explosive submunitions” (Oslo Convention, article 2, paragraph 2). Parent munitions with their submunitions can be launched from surface weapons such as artillery, mortars, or multiple launch rocket systems (MLRS), or may be dropped from aircraft. Targets of attack can be either personnel or objects such as armored vehicles or runways. The submunitions have a fragmentation effect that makes them lethal to personnel when they impact the ground, and a penetrating effect when they impact armored vehicles and structures. These properties make it possible to control a wide area instantaneously. Just in the last ten years, cluster munitions have

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3 Convention on Cluster Munitions. Adopted at Dublin May 30, 2008 (As of January 2010 only 27 countries had ratified it, so it did not take effect). This treaty was to come into effect six months after 30 countries had ratified, accepted, approved, or acceded to it (Article 17). United Nations Treaty Collection website, <http://treaties.un.org/Pages/ViewDetails.aspx?src=UNTSONLINE&tabid=2&mtdsg_no=XXVI-6&chapter=26&lang=en#Participants> accessed on February 5, 2010.

4 The accuracy problem: when cluster munitions are dropped and explode, which is to say, while a battle is raging, they inflict danger and damage to the civilian population and civilian objects. However, that is not the subject of this article.

Cluster munitions use the same launch platform as unitary warhead munition and remotely-delivered mines, described in the main text. Whether they are air-dropped bombs or ground launched munitions, cluster munitions use centrifugal force to disperse submunitions. Accordingly, their footprint covers a wider area. Depending on the width of the military objective, or if munitions are dropped in an urban area, collateral damage can occur.

been used in Kosovo,[5] Iraq, Lebanon, and Georgia, and the harm to returning civilians has been extremely severe. A large quantity of unexploded ordnance in each location has taken the lives of many people, while others have had limbs amputated. The indiscriminate, inhumane carnage wrought by cluster munitions, comparable to that caused by land mines, served to heighten consciousness of the necessity for international regulation of these armaments.

(2) Generic Safety Standards for the Reliability of Cluster Munitions[6]

CCW Protocol V, mentioned above, is based on a comprehensive approach not limited by type of munition. In Article 9 of that document, each high contracting party is encouraged to take generic preventive measures aimed at minimizing the occurrence of explosive remnants of war, including, but not limited to, those referred to in part 3 of the Technical Annex. The regulations in Protocol V apply, of course, to cluster munitions.

Details of generic preventative measures are given in part 3 of the Technical Annex to Protocol V. In particular, Paragraph (a) of Munitions Manufacturing Management, subparagraph (iii), states that certified quality assurance standards that are internationally recognized should be applied during the production of explosive ordnance, and subparagraph (i) requires that high contracting parties seek to maximize the reliability of munitions.

Unlike the main text of Protocol V, this annex is a proposal to be implemented by high contracting parties on a voluntary basis as a best practice, and is only a non-binding document. However, notwithstanding their status with regard to Protocol V, every country has its own fuse-design safety standards (United States military standard (MIL-STD),[7] NATO's STANAG,[8] Japan's national defense standards,[9] etc.) applying not only to cluster munitions but to all conventional munitions. It can be thought, therefore, that many countries are already executing generic measures to ensure the reliability of munitions.

(3) Technology for Disposing of Unexploded Ordnance

Cluster munitions are designed to explode on impact with the ground, armored vehicles, or other targets. However, they may fail to detonate for any one of a number of reasons. In the past, each of the many countries possessing munitions devised their own measures to render the munition inoperable and avoid leaving unexploded ordnance at the point of impact. These are known as reliability improvement measures, and there are three categories: self-destruction,

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5 International Committee of the Red Cross (ICRC), ed., *Explosive Remnants of War: Cluster Munitions and Landmines in Kosovo* (2000). The ICRC has strongly and consistently asserted that it is the user state's responsibility to clear unexploded ordnance.

6 Factors that can have an effect on reliability include environmental conditions such as severe weather and soft ground, as well as human error. These will not be discussed here.

7 For information on MIL-STD-1316, which establishes safety criteria for fuse design, refer to the Defense Standardization Program database maintained by the U.S. Department of Defense, <http://www.assistdocs.com/search/document_details.cfm?ident_number=36251&StartRow=1&PaginatorPageNumber=1&doc%5Fid=1316&status%5Fall=ON&search%5Fmethod=BASIC> accessed on November 30, 2009.

8 <http://www.nato.int/cps/en/natolive/stanag.htm> accessed on January 25, 2010.

9 <http://www.mod.go.jp/trdi/data/nds.html> accessed on January 25, 2010.

self-neutralization, and self-deactivation.

1) Self-destruction (SD): A method of destroying a weapon's payload using a time-delay device (detonating the munition's main charge).
2) Self-neutralization (SN): A method of rendering a weapon's payload stable by destroying the fuse, detaching it, or rendering it inoperable. The main charge remains within the munition, but since it cannot explode without a fuse, the munition may be regarded as safe.
3) Self-deactivation (SDA): This method renders the fuse inoperable through the irreversible exhaustion of a battery that is essential to the operation of the fuse. As with self-neutralization, the munition's main charge remains.[10]

Unexploded ordnance is generally understood to be munitions that do not detonate at time of impact. However, when the failure rate is debated during international negotiations, munitions that are self-neutralized or self-deactivated as described above are usually excluded.

Within the CCW framework, at least, among munitions that fail to initiate on impact, only those that pose a danger of later detonation are regarded as unexploded ordnance. However, munitions made safe by disabling the fuse are usually excluded from the category of unexploded ordnance.

The failure rate, then, indicates the proportion of munitions that fail to initiate on impact, self-destruct, self-neutralize, or self-deactivate. On the other hand, because munitions reliability is equal to the proportion of munitions that detonate on impact to the number that self-deactivate through self-destruction or self-neutralization, this value can be calculated by representing the total number of munitions dropped as 1, then subtracting the failure rate described above from it.[11]

Of these three types of technology for disposing of unexploded ordnance, self-neutralization and self-deactivation are similar in function. The CCW-GGE second session held in Switzerland in 2002 published the following statement on these two methods.

> "Self-deactivation (SDA) and self-neutralization (SN) are similar technical solutions for disabling fusing mechanisms in duds after the end of the conflict. The difference is that self-deactivation (SDA) applies to electronic fuses whereas self-neutralization (SN)

[10] Achieving self-deactivation by exhausting the internal power source like this is found only in electronic fuses, but time-related deterioration can cause a battery to discharge spontaneously. Accordingly, a design that allows self-deactivation by means of forced discharge is needed. There is no means of deactivating mechanical fuses through exhaustion of the power source. With respect to electronic fuses, the meaning of "irreversible" is that electrical energy transformed into heat does not become electricity again. With a mechanical fuse, no matter what technology is employed to render it inoperable, the possibility that the kinetic energy of a spring will cause the device to operate cannot be completely eliminated.

[11] The word "reliability" can be used to mean that a weapon has displayed its capabilities, but in this article will be used as described above.

applies to mechanical ones. Their effect, however, is the same: they both reduce the direct and present danger of duds on the battlefield to military personnel and civilians.[12]"

There is now a tendency everywhere in the world to think that the substitution of electronic fuses for mechanical fuses improves the reliability of munitions. (For an example, see the French proposal at the 2008 CCW-GGE meeting.)[13] This is because electronic fuses have higher detonation rates than mechanical fuses, and the electronic fuse's self-deactivation, which renders the fuse inoperable through the exhaustion of the battery, is much more reliable than a mechanical fuse's self-neutralization.

2. Land Mine Reliability Standards

Land mines are used as a nuisance to delay and demoralize advancing enemy infantry. They can be used as ambush weapons, or can be designed to detonate when trod upon by soldiers or the treads of armored vehicles. Accordingly, there is a danger that many laid land mines may remain undetonated following the conclusion of hostilities. The self-destruct mechanisms, self-neutralization devices, and self-deactivation functions mentioned above play a significant role in eliminating the danger that these now militarily unnecessary land mines represent to civilian populations. Cluster munitions, which are subject to deficiencies in their primary impact initiation systems, are used in different contexts. However, we seek to avoid accidental detonation of both cluster munitions and mines by eliminating the explosive power of the main charge or rendering it harmless.

Below is an overview of the agreements and points of contention in the discussions of the reliability of both anti-personnel land mines and antitank/vehicle landmines (AVLs) within the present CCW framework.

(1) Anti-personnel Land Mines

The Protocol on Prohibitions or Restrictions on the Use of Mines, Booby-Traps and Other Devices (Protocol II), adopted in 1980 together with the CCW, stated that it is desirable that deployed land mines be rendered harmless following the conclusion of hostilities. However, this regulation left ambiguities with regard to the duty to equip them with self-destruct mechanisms and other specific methods to be employed.[14]

The 1996 revision of Protocol II addressed this, as cited below, imposing a clear duty to incorporate a self-destruction or self-deactivation capability on anti-personnel land mines, both

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[12] CCW/GGE/I/WP.4, p.4.

[13] CCW/GGE/2008-II/WP.3, p.4, para.19.

[14] Before revision, article 5-1(b) of Protocol II had this to say about remotely-delivered mines: "an effective neutralizing mechanism is used on each such mine, that is to say, a self-actuating mechanism which is designed to render a mine harmless or cause it to destroy itself when it is anticipated that the mine will no longer serve the military purpose for which it was placed in position, or a remotely-controlled mechanism which is designed to render harmless or destroy a mine when the mine no longer serves the military purpose for which it was placed in position."

remotely-delivered and manually or mechanically laid, and also specified numerical targets. Manually or mechanically laid anti-personnel mines (or anti-personnel mines scattered to a distance under 500 m) must be laid in a clearly marked and fenced area which is monitored by military personnel to keep civilians out and cleared before the area is abandoned (Article 5-2).

> "All remotely-delivered anti-personnel mines shall be designed and constructed so that no more than 10% of activated mines will fail to self-destruct within 30 days after emplacement, and each mine shall have a back-up self-deactivation feature designed and constructed so that, in combination with the self-destruction mechanism, no more than one in one thousand activated mines will function as a mine 120 days after emplacement. (CCW Revised Protocol II Technical Annex 3 (a))."

Compliance with these technical requirements was deferred for a period not to exceed nine years from the entry into force of this protocol (December 3, 1998). The status of each high contracting party's compliance is to be reported in the annual reports that the high contracting parties themselves submit to the depositary (Article 13-4 (c)), which is to say that each country verifies its own compliance with the reliability requirements established in this protocol, most notably their achievement or failure to achieve targeted failure rates.

As written above, the Ottawa Convention calls for a complete ban on the use of anti-personnel land mines. However, the United States, Russia, China, India, Pakistan, Finland and other major users of land mines persist in their refusal to sign the Ottawa Convention,[15] citing the military effectiveness[16] of anti-personnel land mines. Although coalition forces did not use anti-personnel land mines in the conflicts in Kosovo, Afghanistan, or Iraq (2003), this was only because there was no military necessity for their use in these conflicts. In fact, the United States reserved the right to use landmines during the conflict in Kosovo. Recently, the Obama administration indicated that it will refrain from participating in the Ottawa Convention, maintaining the policy towards land mines established by the last administration.[17]

(2) Antitank/Vehicle Landmines (AVLs)—Obstacles to the Installation of Self-destruct Mechanisms

The revised Protocol II of the Convention on Conventional Weapons is a document that

[15] The Second Review Conference of the Ottawa Convention, known as the Cartagena Summit, convened on November 29, 2009, and closed on the 4th of the following month. The United States and other states not party to the treaty participated as observers. As was remarked on in the Cartagena Declaration, adopted here, universal adherence to the Ottawa Convention has not yet been realized (At the end of 2009, 156 countries were parties to the convention). APLC/CONF/2009/WP.8.

[16] Department of the Navy, U.S. Marine Corps, and Department of Homeland Security and U.S. Coast Guard, eds., NWP 1-14M/MCWP 5-12.1/COMDTPUB P5800.7A, *The Commander's Handbook on The Law of Naval Operations* (July 2007), para.9-3, <http://www.usnwc.edu/getattachment/a9b8e92d-2c8d-4779-9925-0defea93325c/1-14M_(Jul_2007)_(NWP)> accessed on February 5, 2010.

[17] US Department of State, Daily Press Briefing, November 23, 2009, <http://www.state.gov/r/pa/prs/ dpb/2009/nov/132362.htm> accessed on November 30, 2009.

principally regulates anti-personnel land mines, but there is one section that deals with antitank/vehicle landmines (AVLs). These regulations do not impose any strict duties regarding anti-personnel land mines, but do require that high contracting parties, to the extent feasible, equip mines other than anti-personnel mines with an effective self-destruct or self-deactivation mechanism to limit their functioning (Article 6-3). This regulation also prohibits the use of remotely-delivered antitank/vehicle landmines (AVLs). As with the existing CCW framework, though, there are virtually no regulations regarding antitank/vehicle landmines (AVLs).

Following the revision of Protocol II, disputes among CCW high contracting parties regarding the new regulations on antitank/vehicle landmines (AVLs) piled up. This led the United States, Denmark, and other countries to jointly present a draft Protocol on Prohibitions or Restrictions on the Use and Transfer of Mines Other Than Anti-Personnel Mines in 2002. This new proposal would allow the stockpiling and use of remotely delivered antitank/vehicle landmines (AVLs), providing that they met the following efficiency standard:

> No more than 10% of activated mines will fail to self-destruct or self-neutralize within 30 days after emplacement, and no more than one in one thousand will function as a mine 120 days after emplacement.

Previous reliability requirements applied only to anti-personnel land mines, but the standards in this new draft protocol were to apply to antitank/vehicle landmines (AVLs) as well. However, the high contracting parties could not reach an agreement at the Third Review Conference of the States Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons (Third Review Conference) convened in 2006, and the conference ended without adopting the draft protocol. Immediately following the conference’s failure to adopt the draft protocol, the parties to the joint proposal released a joint announcement as a matter of national policy. They promised that, thenceforth, the only antitank/vehicle landmines (AVLs) that each country would continue to possess or use would be those that met the following reliability standard:

> No more than 10% of such activated remotely-delivered mines placed outside of a perimeter-marked area fail to self-destruct within forty-five days after arming, and no more than one in one thousand of such activated mines will function as a mine 120 days after arming.

On these points this practice as a matter of national policy is virtually identical with the draft protocol.[18]

[18] Declaration on Anti-Vehicle Mines, CCW/CONF.III/WP.16. In the end, 25 countries announced their support for the declaration: Albania, Australia, Bosnia and Herzegovina, Belgium, Bulgaria, Canada, Croatia, Denmark, El Salvador, Luxembourg, Estonia, France, Israel, Latvia, Lithuania, Holland, New Zealand, Norway, South Korea, Romania, Serbia, Slovenia, Macedonia, England, and the United States.

It was principally China and Russia that strongly opposed the preparation of the new protocol. The installation of self-destruct mechanisms and other requirements necessarily results in large new expenses. In addition, almost all remotely delivered antitank/vehicle landmines (AVLs) possessed by developing countries use mechanical fuses. To meet the new reliability standards, then, they would have to replace them all with the newest devices that use electronic fuses. These technological problems would impose a heavy burden on them.[19]

Countries' economic conditions and technological capabilities are sometimes impediments to the introduction of self-destruct mechanisms. Furthermore, the installation of self-destruct mechanisms and other devices does not alone guarantee the reliability of munitions. At the 2002 CCW-GGE meeting, the United States explained that the antitank/vehicle landmines (AVLs) it had manufactured since 1978 demonstrated 99.9999% reliability.[20] However, many of the remotely delivered antitank/vehicle landmines (AVLs) placed by the United States military during the Gulf War reportedly failed to self-destruct,[21] which threw doubt upon that reliability figure.

3. Limits on Improving the Reliability of Cluster Munitions

Because cluster munitions use a large number of submunitions, even if high reliability is achieved there will be some number of unexploded submunitions. For instance, each MLRS parent munition contains 644 submunitions. In addition, cluster munitions are seen as dangerous because they are regarded as low-reliability weapons. During the Oslo Process, the participating countries were shown scientific support for the contention that even the installation of self-destruct mechanisms, self-neutralization devices, or self-deactivation capabilities is insufficient to sufficiently improve the reliability of cluster munitions. This played a significant role in forging the agreement for a complete ban.

(1) The Low Reliability of the M85

Many of the countries that possess cluster munitions insisted during the Oslo Process that munitions equipped with self-destruction, self-neutralization, or self-deactivation devices (or capabilities) had extremely low failure rates in the past, and should be considered separately from older types of munitions which caused damage from unexploded ordnance. However, an important report was released at the Vienna Conference on Cluster Munitions (December 2007) that exploded the myth of highly reliable cluster munitions. It was a report of an analysis of the M85 with an SD mechanism, which was regarded as the most reliable of the cluster munitions. Explosive ordnance disposal specialist Colin King, the Norwegian Defense Research Establishment, and Norwegian People's Aid (NPA) jointly studied the failure rate of the M85s

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19 CCW/GGE/II/WP.17; CCW/GGE/VI/WG.2/WP.4.

20 CCW/GGE/II/WP.21.

21 Ian Doucet and Richard Lloyd, eds., *Alternative Anti-Personnel Mines: The Next Generations* (Landmine Action and German Initiative to Ban Landmines, 2001), pp.25-26.

used by Israel in South Lebanon during its 2006 response to Hezbollah, and a test of the M85's reliability conducted in Norway. The results of these studies were presented to the participating countries at the Vienna Conference.[22]

A complete ban on the use of cluster munitions was hammered out in May of that same year. (Restrictions on air-dropped bombs had been established in autumn 2002.) Still, to verify the results of that study, the test was repeated in autumn 2006.[23]

For this second test, M85s in the inventory of the Norwegian military were used. These were manufactured under license from Germany. (The German nomenclature is DM1385, but this will be shortened to M85 in this paper.) A total of 192 DM662 155 mm artillery projectiles were fired, each containing 49 bomblets, for a total of 9,408 bomblets. The M85 bomblets were cluster munitions with a self-destruct mechanism developed by Israeli Military Industries (IMI). Mechanical impact fuses with pyrotechnic delay self-destruct mechanisms and self-neutralization devices were used. If the munition does not detonate on impact, the slide lock pin re-engages with the slide in a mid-way position, neutralizing the mechanism. It is designed to prevent accidental detonation by holding the explosive train out-of-line.[24] The report mentioned above noted that the M85s used by the Israeli military in the summer of 2006 had a failure rate of approximately 10%. The M85 Firing Test (I) conducted in Norway yielded the results shown in Table 1.

Table 1 Results of Test I

Bomblets fired	9,408	
Bomblets detonated	9,304	9,278 by impact initiation 26 by self-destruction
Duds	104	(of which 95 were unarmed)
Failure rate	1.11%	

Source: Colin King, Ove Dullum, and Grethe Østern, eds., *M85: An Analysis of Reliability* (2007), http://www.npaid.org/filestore/M85.pdf, p.59

The 95 unarmed duds were tested in one of the following three ways (Test II): 1) placed in a cement mixer and spun for 30 minutes; 2) dropped from a height of 12 meters onto a steel floor; or 3) thrown into a bonfire. These tests were conducted to verify the functionality of the self-neutralization devices, so the three test methods were chosen to be similar to the ways in

22 Colin King, Ove Dullum, and Grethe Østern, eds, *M85: An Analysis of Reliability* (2007), <http:// www.npaid.org/filestore/M85.pdf> accessed on January 18, 2010.

23 Human Rights Watch and Landmine Action, eds., *Banning Cluster Munitions: Government Policy and Practice* (2009), p.135.

24 "A fuse explosive train is a component with more than one type of explosive. In contrast with other components, it can be retained in an out-of-line position, such that it cannot actuate correctly. This is known as 'out-of-line safe.' " *NDS Y0001D National Defense Standards on Munitions Technical Terms*, (Published July 30, 1971, revised May 13, 2009), p. 35, no. 3095. Regarding the term of 'in-line,' see note 30.

which a civilian population handles unexploded ordnance.

Table 2 Results of Test II

Subject of Test II	M85 reaction	Proportion (%)
1)	Detonated	19.4
2)	Detonated	2.4
3)	Non-violent combustion	25.7
	Deflagration	65.2
	Detonated	9.1

Source: *M85: An Analysis of Reliability*, p.61.

The following conclusions were drawn from these test results:

- Low impact initiation rate: Excluding instances of self-destruction, the M85's failure rate was 1.38%. In the past, the M85 failure rate was certified at 0.06%, well under the 1% reliability standard established by the stockpiling countries.
- Low self-destruction rate: of 104 pieces of unexploded ordnance, nine were armed. This demonstrates that the self-destruct mechanism failed to function. (These bomblets are designed to self-destruct if impact initiation fails when they are armed.) Because they are armed, there is a danger that they could detonate upon the slightest contact.
- Low self-neutralization rate: M85 duds are found in an unarmed state: 1) when they do not initially arm; or 2) if they successfully arm but their self-neutralization device functions because impact initiation fails. In Test II, detonations and deflagration were seen under both these circumstances, showing that the self-neutralization devices did not function correctly, and the munitions re-armed themselves. Although these M85 duds are referred to as "safe" unexploded ordnance, this test demonstrated the danger that they actually represent.

(2) Reasons for Low Reliability

Each parent munition ejects a large number of submunitions, which inevitably results in collisions among falling submunitions. This is one reason that submunitions do not detonate, but are left behind to become unexploded ordnance. This type of malfunction is not limited to the M85, but is common to all cluster munitions. For instance, when submunitions come into contact, their stabilizer ribbons may become entangled, preventing the arming of their fuses. This halts the fuse sequence that takes the munition from initiation to detonation. In addition, when submunitions come into contact with each other or collide, the differences in the times required for each submunition's stabilizer ribbon to unfurl, and the differences in the air resistance exerted upon each submunition, give rise to differences in relative speed. This makes it impossible to prevent contact and collisions. With multiple submunitions colliding like this, a submunition's fuse's operation can be inhibited if a fuse suffers direct damage. Further, if the submunitions burst early while still in flight, fragments of the steel casing fly out at high speed in all directions and damage other submunitions.[25] Submunition fuses arm while in flight, after they are ejected from the parent cluster munition and before impact with the earth. Therefore, if submunitions come into contact with each other or collide before this process is complete, they are often damaged and arming does not take place.

The delay fuse of an M85's self-destruct mechanism is only about as long as the fuse's diameter, so the delay is only 14 to 15 seconds, furthermore, it easily malfunctions as a result of heat loss.[26] This is the principal cause of inoperability of the M85's self-destruct mechanism. A study of the M85s dropped by the Israeli Army in the summer of 2006 showed that approximately half of the M85 duds found were in an armed state. This is because their self-destruct mechanisms did not function correctly.

At the same time, though, there is another, design-related issue that can prevent the M85's self-destruct mechanism from operating. This is that the self-destruct mechanism is designed to operate after the arming stage of the fuse sequence. Even if the self-destruct mechanism's detonation rate were 100%, if the M85 does not arm, it cannot self-destruct. This is why the M85 is said to have limited reliability in comparison with land mines whose self-destruct mechanism functions whether the munition arms or not. This article will for convenience refer to this type of self-destruct mechanism, which is dependent on the operation of the arming mechanism, as the "dependent" type.

(3) The Safety of the "Independent" Type Self-destruct Mechanism

Among the cluster munitions stockpiled by foreign countries (or that they used in the past), are those having self-destruct mechanisms that operate independently whether the munition is armed or not, unlike the M85 (hereafter, the "independent" type).

For instance, U. S. military participants at the 2007 GGE meeting convened by the International Committee of the Red Cross (ICRC) implied that the U. S. military stockpiles cluster munitions with independent self-destruct mechanisms.[27] The addition of an independent self-destruct mechanism made it possible to at least disable the fuse even if there is a malfunction in the arming of the cluster munitions, resulting in higher reliability.

One example of munitions with this sort of independent self-destruct mechanism is the M80 in the United States' arsenal. The M80 is a submunition used with the 105 mm howitzer. The parent

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25 An 'early burst' is explained as, "At fuse arming time or after distance to target has been covered, the projectile (an artillery shell, etc.) actuates before the prescribed ignition time and misfires." *NDS Y0001D National Defense Standards on Munitions Technical Terms*, p.5, no.1046.

26 Because the self-destruct delay time is set long, the delay-charge fuse wires must also be lengthened. Because the M85's delay charge is short, high-density explosives must be used, deflagration happens quickly, and instability can easily occur. This is why deflagration fails to occur. To prevent this, it is necessary to use extremely-high-performance materials for the delay charge.

27 Expert Meeting on Humanitarian, Military, Technical and Legal Challenges of Cluster Munitions, April 18-20, Montreux, Switzerland. See ICRC, *Humanitarian, Military, Technical and Legal Challenges of Cluster Munitions* (2007), pp.38-39, <http://www.icrc.org/Web/Eng/siteeng0.nsf/htmlall/p0915/ $File/ICRC_002_0915.PDF>.

projectile contains 42 M80 submunitions. It uses a hybrid (electro-mechanical) fuse equipped with a mechanical impact mechanism and an electronic time delay self-destruct mechanism. Many electronic fuses use immersion cells, but the M80's self-destruct mechanism has a dedicated lithium reserve battery. This battery's electrolytes are 11.83% aluminum chloride and 88.16% sulfuryl chloride. The battery is activated and becomes a power source when its ampoules break and these two substances contact the lithium.[28] The self-destruct mechanism detonates seven minutes after the M80 impacts the ground,[29] and together impact initiation and self-destruction are said to achieve 99.8% reliability. Because the M80's self-destruct mechanism has its own power source, a self-neutralization function can disable the fuse if the M80 fails to self-destruct. Because the power source of the M80's self-destruct mechanism is already functioning before the submunition is ejected from the parent munition, it is not easily affected after ejection as a result of collisions with other submunitions while falling, or the malfunctions those collisions cause. This is because the self-destruct mechanism operates independently even if the arming mechanism fails. However, if the explosive train is not armed it is not in-line,[30] so even if the self-destruct mechanism operates, only the initiating explosives can be damaged. This is a characteristic of the M80's self-neutralization function.

However, submunitions with independent self-destruct mechanisms also have a safety problem. If the M80's self-destruction mechanism fails after the munition is armed, the mechanical impact mechanism remains in that state. That is to say, it remains in the state wherein it will detonate immediately if the striker impacts the explosive. If it is not equipped with a slider lock function like the M85's, there is a danger that it will detonate upon the slightest contact.

Germany developed the same type of independent self-destruct mechanism in the past. It is known that Junghans Microtec GmbH and GIAT Industries jointly developed a mechanical fuse equipped with self-destruction and self-neutralization devices for the BFT5 bomblet[31] between 2001 and the end of 2004. This fuse is designed so that two methods can initiate the fuse sequence. Centrifugal force can cause the stabilizer ribbon to unfurl, or spinning can pull the striker pin out. Finally, release of the rotor's tether arms the fuse. The self-destruct mechanism ignites when the slider moves forward, and can function whether the fuse is armed or not (The heavy line in the diagram shows self-neutralization when the self-destruct mechanism activates in a fuse that is in an unarmed condition). Impact initiation happens after the rotor has armed the fuse, and if impact initiation fails, the self-destruct mechanism is designed to disable the

[28] "Accelerated Tested Program for the Battery Used in the M234 Self Destruct Fuze," Presentation by Eric R. Bixon, Frank A. Gagliardi, Amsta-ar-qat-p, February 12, 2003, <http://www.dtic.mil/ndia/ 2003fuze/bixon.pdf> accessed on January 18, 2010.

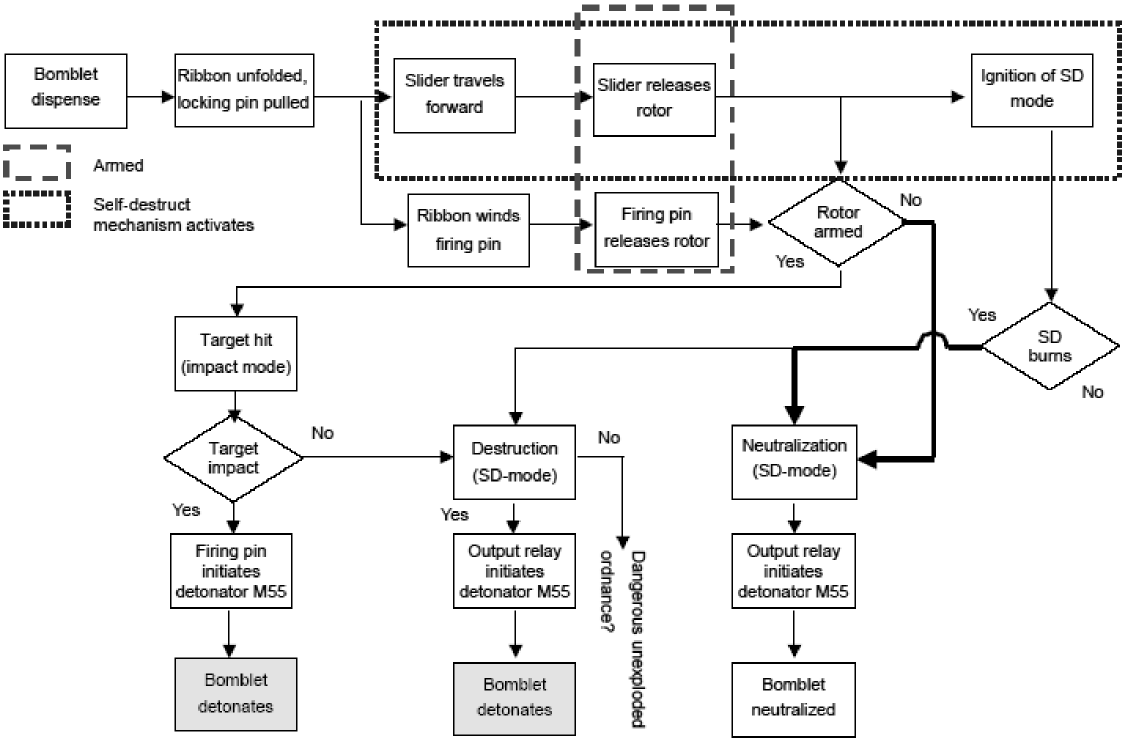
[29] "105mm M915 DPICM Cartridge," *Jane's Ammunition Handbook*, July 18, 2006, <http://jah.janes.com/>.

[30] When a fuse is in line, "The fuse explosive train must be able to propagate the detonation required to actuate the fuse, or it is already in that state," *NYDS Y0001DNational Defense Standards on Munitions Technical Terms*, p.35, no. 3191.

[31] Rudolf Harbrecht, Junghans, "Pyrotechnic Bomblet Self Destruct Fuze (SDF) for GMLRS," Presentation for 48th Annual Fuze Conference, April 26-28, 2004, Charlotte, NC, <http://www.dtic.mil/ ndia/2004fuze/harbrecht.pdf> accessed on January 18, 2010.

weapons payload or detonator. A failure rate of less than 1% was observed in test firings. As with the M80, though, this fuse is equipped with no backup procedure if the self-destruction mechanism fails when the fuse is armed, creating the possibility of leaving behind extremely dangerous unexploded ordnance.

Diagram 1 Impact Initiation, Self-destruction, and Self-neutralization Processes in the BFT5



Source: Rudolf Harbrecht, Junghans, "Pyrotechnic Bomblet Self Destruct Fuze (SDF) for GMLRS," Presentation for 48th Annual Fuze Conference, April 26-28, 2004, Charlotte, NC, <http://www.dtic.mil/ndia/2004fuze/harbrecht.pdf>

(4) Comparison of the Safety of Electronic Fuses and Mechanical Fuses—The Balance Between Operability and Safety

The opinion was expressed above that electronic fuses are more reliable than mechanical fuses. However, the question of whether either type is safer depends on the standpoint from which the matter is viewed.

Because an electronic fuse uses its battery to self-deactivate, the battery is in an irreversibly exhausted state. Therefore, no matter what the cause of a malfunction or failure might be, internal components usually eliminate any danger of accidental detonation.

This is the reason that people get the impression that electronic fuses are "safe." However, it is not the case that there is no danger of the detonation of an electronically deactivated submunition.

Because all the explosives remain within a deactivated submunition, from the electronic primer (detonator) to the main charge, the possibility exists that external influences such as lightning, static electricity, or an extremely strong shock can cause the electronic primer to ignite the charge. On the other hand, although the electronic fuse is only one component, if it doesn't function, nothing does. In comparison, mechanical fuses (pyrotechnic)[32] are simple devices, and are therefore more resistant to impact, and their operability is stable. They also have their drawbacks, though. It was mentioned above that mechanical fuses can be disarmed after a failure to detonate by locking the striker or slider. However, any requirement to employ this technology is limited to national safety standards, with the result that some countries install it on their munitions and some don't. Even when this sort of device is used, there is no uniformity among the safety standards of different countries. If like the M85 the operability of self-neutralization devices is low, and by some chance this lock is released, there is a danger of an explosion. To begin with, there is no way to *irreversibly* exhaust the power source of a mechanical fuse—the only way to irreversibly dissipate the kinetic energy of a spring is to break the spring mechanism—so they may be regarded as more dangerous than electronic fuses. Furthermore, mechanical fuses have the inherent problem that one cannot distinguish among unexploded munitions that failed to detonate or malfunctioned for different reasons. Unless one is an expert, it is not easy to determine whether the striker has partially penetrated the initiating explosives or has not penetrated but is in a position from which it could, or whether the self-neutralization function has disarmed the munition or not. For these reasons, no matter how high the technological reliability may be said to be, one cannot possibly eliminate the danger of unexploded ordnance.

(5) International Efforts to Improve Reliability

(a) Oslo Convention

The Oslo Convention forbids signatories to use, develop, produce or otherwise acquire, stockpile, retain or transfer cluster munitions to anyone. However, stockpiling may continue if, and only if, the following five conditions are met: parent weapons must contain fewer than ten explosive submunitions, and each explosive submunition must weigh more than four kilograms, have been designed to detect and engage a single target object, and be equipped with both an electronic self-destruct feature, and an electronic self-deactivating feature (Article 2(c)). The upper limit on bomblets was set extremely low in comparison with pre-convention cluster munitions, and it is predicted that this will drastically reduce the number of unexploded munitions. These provisions probably assume the use of electronic fuses, and the simultaneous use of self-destruction and self-deactivation capabilities to guarantee a higher level of safety. At the same time, though, when the self-destruct mechanism is of the dependent type, the operation of the self-destruct mechanism imposes conditions on arming, as with the M85, and the effect of bomblets colliding

[32] The kind of self-destruct mechanism ordinarily used in mechanical fuses.

with each other cannot be prevented. If the arming mechanism of the fuse malfunctions, not only does impact initiation become impossible, it cannot be detonated by the self-destruct mechanism.

Whether the self-destruct mechanism is the dependant type or not, the Oslo Convention's exemptions require that when self-destruction fails that the unexploded ordnance eventually disarm by means of self-deactivation. Therefore, the possibility that so-called "safe" unexploded ordnance will leave a footprint cannot be denied, and there is a need to clear this type of unexploded ordnance. Under such circumstances, it is important to provide education designed to reduce the risk presented by unexploded ordnance.

(b) CCW Draft Protocol on Cluster Munitions

The Draft Protocol on Cluster Munitions, a new protocol on cluster munitions within the CCW framework, was drafted at the 2009 CCW-GGE meeting. It established the following standards for the purpose of improving the reliability of munitions.

> Each explosive bomblet possesses one or more of the following safeguards: self-destruction, self-neutralization, and self-deactivation. Further, each munition will incorporate a mechanism or design which, after disposal, results in no more than 1% unexploded ordnance across the range of intended operational environments (Article 4-2).[33]

The first approach is to regard these duties as met with the incorporation of one of the following mechanisms, capabilities, or functions: self-destruction; self-neutralization; or self-deactivation. The second approach is to deem requirements fulfilled if the numerical targets explicitly stated in the protocol are attained, as the type of device or function that should be installed is not specified, and countries employ various approaches to their use.

The self-destruct mechanism and each of the various devices and functions have different roles. No matter which one or two of these are used, the examples of the M85 and M80 demonstrate that reliability is not necessarily guaranteed. Even though these munitions employed both self-destruction and self-neutralization, there were times when the failure rate was high. In addition, although there were times when the failure rate was low, firing statistics on unexploded ordnance that failed to self-deactivate (armed, but with the initiation trigger in standby, which has less than a 0.1% probability of occurring) indicated danger on both quantitative and qualitative levels.

What this means is that, as with the CCW Amended Protocol II on anti-personnel land mines, a combined method that specifies both devices to be installed and numerical targets is thought to be more effective. However, the adoption of numerical targets in the cluster munitions draft protocol as an independent and separate standard is only being considered as one of the

[33] "Draft Protocol on Cluster Munitions," CCW/MSP/2009/WP.1.

alternatives, and no more.

As was pointed out even in the information released at the Vienna Conference of the Oslo Process, mentioned above, the reproducibility of the research on numerical targets conducted by various nations was uncertain. Within the CCW framework as well, no particular verification measures have been established. As in CCW Amended Protocol II, each high contracting party judges the status of its own achievement of numerical goals. For that reason, numerical targets were for a time established independently, but were then introduced in combination with the duty to install self-destruct mechanisms. Therefore, there is a large possibility that the failure rate of cluster munitions used on the battlefield may actually differ substantially from test results.

(6) Considerations from the Aspect of Safety

The technological levels and economic power of countries that stockpile cluster munitions (or that did so in the past) are not uniform. As seen with regard to antitank/vehicle landmines, for instance, there are many areas in which the United States possesses technologies that are out of reach of other countries. Cluster munitions have a more complex structure than land mines, and large sums are required for the development and manufacturing of these weapons. Also, cluster munitions bomblets are extremely small in comparison with unitary bombs, and their fuses are correspondingly complex. It is only to be expected that countries with limited technological capabilities and economic resources would resist the imposition of a duty to install self-destruct mechanisms and take other costly measures.

Even if self-destruct mechanisms and self-neutralization devices that operated according to the same principles were introduced, the design of fuses and their detonation rate would vary from country to country. It is possible that no objective, uniform standard would be established. Even under ideal environmental conditions, a performance test would reveal differences in failure rates among countries.

At the same time, though, considered from the standpoint of reducing the harm done by cluster munitions, it would be a mistake to think that the use of self-destruction, self-neutralization, or self-deactivation devices (or functions) is adequate. If a munition is disarmed using self-neutralization or self-deactivation, the main charge in the warhead will leave a footprint, and it is difficult to distinguish between a munition in that state and hazardous unexploded ordnance by appearance. It is not necessarily connected with reducing the anxiety of the civilian population or lightening the burden of those tasked with clearing unexploded ordnance, but there is no room for disagreement that the first thing to pursue is the self-destruct function. However, the detonation rate of the M85's self-destruct mechanism (stand-alone operability and operating conditions) is actually low, even though the M85 boasts the best performance of any cluster munition—as the Vienna Conference report showed.

Almost all the countries participating in the Oslo Process have reached a consensus that technological measures alone are not an effective response to the unacceptable harm to civilian populations from cluster munitions that remain after hostilities. In light of the scientific demonstration of the limits to the reliability of cluster munitions, as discussed above, one must accept the inevitable and necessary conclusion that a complete ban is needed.

Conclusion—Issues Bearing on the Drafting of a New Protocol

There is no change in the position of some of the countries that stockpile cluster munitions, beginning with the United States, that cluster munitions are effective weapons and remain a military necessity. Among these stockpiling countries are some that lack the technological or economic means to meet uniform reliability standards, which makes it next to impossible to adopt a new cluster munitions protocol within the CCW framework.

The reliability standard in the Draft Protocol on Cluster Munitions that was studied and released by the 2009 CCW-GGE meeting is more lenient than that in Amended Protocol II pertaining to anti-personnel land mines. When considered alongside the fact that the reliability of cluster munitions is comparatively low to begin with, the weakness of these reliability standards is all the more striking.

It is extremely unlikely that any great success in ameliorating unacceptable harm will be achieved within the CCW framework. However, if the stockpiling countries do not devise a plan to implement agreed-upon reliability standards (for instance, reproducible numerical targets, a uniform inspection system, etc.) that is effective, even if only slightly, and that has the power to persuade, there is a danger that regulations advanced by the CCW will end up as regulations *de jure* but not *de facto*.

The harm that cluster munitions inflict on civilian populations is often in the form of physical injuries from which it is difficult to recover (in the worst cases, of course, resulting in death). There are also wide-ranging effects, such as the inhibition of economic development, on a scale that is impossible to measure. Although a comprehensive unexploded-ordnance handling protocol has been adopted within the CCW framework, the harm done by cluster munitions differs qualitatively and quantitatively from that done by ordinary unitary warhead munitions, and for that reason it is desirable to adopt a new protocol in the near future.

Acknowledgment

I would like to express my deepest gratitude to Yuzi Sato, Kazuya Hirose, Minoru Doshida, Eisuke Kigami, and also to the many others who helped and advised me, for their invaluable assistance and cooperation in writing this paper.

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