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Norwegian People's Aid

M85
An analysis of reliability

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Caption: MACC SL Community Liaison Assistant Hassan Al Ali marking a newly found M85 dud in Aytaroun, October 2006.
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C King Associates Ltd (CKA) is a small company specialising in the technical and procedural aspects of mine clearance and explosive ordnance disposal (EOD). The company was founded by Colin King, a former British Army Bomb Disposal Officer, who has been engaged in EOD throughout the last 20 years.

Norwegian Defence Research Establishment (FFI) is the primary institution responsible for defence-related research in Norway. It is the main advisory body on defence-related science and technology to the Norwegian Ministry of Defence and the Norwegian Armed Forces.

Norwegian People's Aid (NPA) is the humanitarian solidarity organization of Norway's trade union movement. It is also one of the world's largest humanitarian mine action organizations, with more than 2,000 employees in 14 countries affected by mines, cluster munitions and other explosive remnants of war (ERW).

M85 – an analysis of reliability

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Simon Lovell, an EOD specialist from BACTEC, carefully examines an M85 dud at the site CBU 808 in Blida, South Lebanon. Photo: Ove Dullum/FFI

Executive summary

The primary purpose of this study is to examine the performance of the M85 bomblet in combat conditions, because this specific bomblet has become the symbol of a proposed approach to solve the problems that cluster munitions cause. This approach suggests that bomblets with self-destruct (SD) mechanisms can reduce a cluster munition's failure rate to less than 1% and that this will sufficiently address humanitarian concerns. On this basis some states are proposing that an emerging international treaty, currently discussed within the so-called Oslo process, should only prohibit cluster munitions that do not have SD mechanisms or that do not meet a fixed maximum percentage of failure, such as 1%.

This approach appears, superficially, to provide a neat and simple delineation. Until now, however, there has been a serious lack of field-based knowledge about the reliability of SD bomblets and hence about the utility and practicability of requirements for SD mechanisms and/or a maximum failure rate as a basis for legal control of cluster munitions on a global scale.

M85 is currently considered as the 'benchmark' among bomblets equipped with SD mechanisms - meaning that it is widely acknowledged as the best available technology with the lowest possible failure rate. M85 is also the only SD bomblet ever documented to have been used in combat; in 2003 by the United Kingdom in Iraq, and in 2006 by Israel in Lebanon. In the past year, countries such as Austria and Norway have introduced national moratoria on their stockpiles of M85 and argue against exemptions for SD bomblets in the international treaty, yet other countries continue to argue that by equipping bomblets with SD mechanisms a sufficient level of protection to the civilian population is provided.

This report presents a detailed analysis of M85 performance based on survey and clearance of M85 contaminated sites in southern Lebanon and on detailed analysis of M85 performance under test conditions, leading to the following conclusions:

Conclusions

Despite the incorporation of a high-quality SD-mechanism, M85 bomblet reliability in combat is substantially worse than has been indicated by tests. It produces post-conflict contamination at a level that, according to the policies of many countries, must be considered unacceptable.

The specific example of the M85 demonstrates that while SD mechanisms in general may help to lower failure rates, they are not capable of ensuring against post-conflict contamination at an unacceptable level.

The specific example of M85 also illustrates the substantial difference between results obtained during testing and the reality seen during operations. This suggests that current testing practices may have little or no utility as a predictor of the risk that will be created to the post-conflict civilian population. An analysis in this report of the limitations of testing and test results - the tools available for verification of reliability - raises a number of serious questions about using a maximum failure rate as a basis for new legal control over cluster munitions. Currently, if a failure rate threshold were to be adopted as an acceptance criterion, there would be no way to accurately assess compliance.

In particular, this report strongly rejects the distinction between 'hazardous' and 'non-hazardous' duds as conceptually flawed, misleading and dangerous. An international treaty based on a maximum 'hazardous dud rate' would be even more difficult to implement and monitor than one based on a maximum failure rate – and would have even less relevance to the experience of post-conflict populations.

The detailed conclusions of the report by section are as follows:

M85 reliability in combat

- The use of M85 by the UK in southern Iraq in 2003 gave the first indications that the failure rate in combat was higher than expected.
- The inescapable conclusion from Israel's use of M85 bomblets, amongst other cluster munitions, in

South Lebanon in 2006 is that they failed far more often than would have been predicted based on the claims of stockpiling states and manufacturers.

- A detailed analysis of strike sites in South Lebanon, undertaken for this report, suggested that a consistent dud rate for M85, as used in Lebanon, is likely to have been around 10%.
- Failure rates from three example sites where data was sufficient to draw firm conclusions were 9.6%, 11.5% and 12.2%. From other sites where firm conclusions could not be drawn it could still be stated with confidence that the failure rates were substantially higher than 1%. The methodology used to assess reliability was conservative in that it discounted instances where whole containers had failed to open correctly (but still resulted in the spread of bomblets.)
- While the M85 bomblets did not achieve the reliability claimed by the manufacturers, they did have a significantly lower failure rate than the US produced non-SD types. However, it is not clear to what extent this difference in performance can be directly attributed to the presence of the SD device rather than other factors such as design, age, storage and manufacturing standards.
- The M85 bomblets performed poorly even though the conditions were generally ‘favourable’ for bomblet reliability. The failure rate for M85 must be expected to increase further when old, poorly maintained stockpiles are used by undisciplined soldiers in more stressful and adverse conditions, and fired into soft, heavily vegetated ground.
- SD mechanisms cannot be relied upon to reduce post-conflict contamination from cluster munitions to a level that is acceptable according to the policy positions of a number of states. Performance in combat may produce far higher levels of contamination than would be expected on the basis of tests.
- The current focus on failure rates can also obscure the fact that in the case of cluster munitions, the sheer quantities of submunitions involved means that very large numbers of duds would be produced, even with a figure as low as 1%.

Munition functioning and failure analysis

- In most operational applications, a proportion of bomblets will fail due to factors beyond the control of the designer, such as human error, ageing and environmental conditions. This ‘base’ failure rate is further increased by those failures originating from design and construction.
- By comparison with other bomblets, the M85 was designed with care and built to a high standard, using good quality materials and modern processes, yet it still has a substantial failure rate in actual combat.
- Spin is fundamental to the arming sequence of M85, yet the rate of spin can vary substantially depending on the firing charge. The force experienced by components of an individual bomblet also depends on its location within the parent projectile and its orientation. The combination of these three factors creates a ‘margin for error’ apparently exceeding the design tolerances of the bomblet. The higher the spin rate, the higher the failure rate; this means that projectiles fired on higher charges tend to dispense more dud bomblets.
- Examination of bomblets that had successfully deployed, but failed to detonate, showed that many had sustained obvious mechanical damage originating either from a ‘crimping effect’ to the fuze during ejection, or from component failure (apparently caused by excessive spin). Others bore signs of collision or fragmentation impact from a nearby detonation with consequent interference to the arming process, prior to the movement of the slide, meaning that neither the impact nor the delay SD systems could function. This included several instances where the ribbon had failed to deploy, or had been torn off.
- In some cases, there was no obvious pre-impact damage and arming was complete. Here, a faulty explosive component seems to offer the best explanation as to why both initiation systems in a fully armed bomblet should fail to function.
- Given that the M85 is probably among the highest quality submunitions of its type in terms of production standards, it is unlikely that any similar mechanically fuzed bomblet will achieve significantly better results under operational conditions. Conversely, submunitions of poorer quality are likely to be even worse.
- While SD mechanisms may help to lower failure rates, this potential is limited and they are therefore not a full solution to the problems that cluster munitions cause.

Munition testing as a verification of reliability

- Common testing regimes tend to produce very optimistic indications of performance; test results are therefore misleading as predictors of the actual risk to civilians.
- Operational failure rates result from a combination of ‘systematic’ failures along with malfunctions due to human error or improper use, and a complex array of environmental factors, including the effects of ageing. It is extremely difficult adequately to represent these ‘real world’ considerations within a scientifically controlled and practicable testing program.
- The characteristics of many submunitions - particularly those of the DPICM family - make them particularly vulnerable to environmental changes. Thus, the discrepancy between testing and operational performance is greater for submunitions than for other ammunition.
- Test results for submunitions with SD mechanisms are particularly unrealistic because the hard ground conditions favour the impact fuze, leaving the SD device largely untested.
- The inability of M85 testing to give an accurate indication of combat condition failure rates highlights the difficulties involved in performance validation. A quality-based international prohibition - with requirements for SD mechanisms and/or a maximum failure rate requirement - would be fraught with problems. It is hard to envisage a robust, functional verification and monitoring system for such a prohibition, and implementation would then be left to the discretion of each individual state and manufacturer.
- If a quality-based international prohibition were adopted it is unlikely that it would solve the post-conflict humanitarian problems associated with these weapons.

Claims regarding ‘non-hazardous’ duds

- It is misleading to draw a distinction between ‘hazardous’ and ‘non-hazardous’ duds. All duds are inherently hazardous both to deminers and to the post-conflict civilian populations that are left to deal with them.
- The sequence of events required for bomblet arming can be stopped at any point, by a wide variety of causes. In many instances, it can then be recommenced (by an external stimulus) through to detonation. It is therefore a dangerous over-simplification to suggest a distinction between ‘hazardous’ and ‘non-hazardous’ duds on the basis of whether they are armed or unarmed; an unarmed dud does not equate to it being ‘non-hazardous’.
- Sensitivity testing examined in this report has shown that bomblets, including M85, in an unarmed state are capable of being brought into an armed state and then detonated by exposure to forces equivalent to rough handling or transportation of these items.
- The concept of a ‘hazardous dud rate’ is also misleading, and often used in a confusing way. Manufacturers and states that continue to insist on using this term should make it clear that they are not referring to the total numbers of duds produced in tests.
- A ‘failure rate approach’ will not provide an effective indicator of the risk to civilians that will be produced by specific cluster munitions in combat. A ‘hazardous dud rate’ approach would be even less useful or effective. An international treaty based on a maximum ‘hazardous dud rate’ would be even more difficult to implement and monitor than one based on a maximum failure rate - and would have even less relevance to the post-conflict humanitarian impact.

1. Introduction

In all conflicts where they have been used, cluster munitions have caused extensive contamination with ‘duds’ - bomblets that have not exploded as intended on impact with the target area and that remain on the ground as unexploded ordnance (UXO). This contamination creates a risk to the civilian population and also to ‘friendly’ forces that must operate in target areas after attacks.[1]

This has spurred some weapons manufacturers to make efforts to increase the reliability of their bomblets, or rather reduce their ‘failure rate’ - i.e. the percentage of the bomblets that become duds. One of the most significant efforts in this regard has been the development of bomblets with self-destruct (SD) mechanisms.[2]

A growing number of states are recognising a need to prevent further human suffering from cluster munitions. Currently, more than 90 nations are involved in the so-called Oslo Process. Launched in Oslo in February 2007 this process is working towards the conclusion of a new international treaty by the end of 2008. The aim is a prohibition on the use, production, transfer and stockpiling of all cluster munitions that “cause unacceptable harm to civilians.”[3]

There seems little doubt that most cluster munitions currently in service will be considered to cause “unacceptable harm.” As the process continues, however, the challenge will become where and how to draw the line between the acceptable and the unacceptable - if indeed such a line can be drawn within the category of cluster munitions. This should finally be decided at diplomatic negotiations scheduled to take place in Dublin in May 2008.

Almost all states involved in the Oslo Process presently seem willing to prohibit older generation cluster munitions with large numbers of free-falling bomblets without SD mechanisms. A particularly contentious issue, however, will be whether bomblets with SD mechanisms should be included or excluded from the prohibition.[4] Several weapons manufacturers and states claim that tests show that their SD bomblets have failure rates below 1% or 2%. On this basis they argue that SD bomblets are an adequate solution to the post-conflict problems caused by cluster munitions - that there is a technical “fix” to these problems. Consequently, they are proposing that the emerging international treaty should only prohibit cluster munitions with bomblets that are not equipped with SD.[5] Yet others have proposed to link this SD requirement with a maximum failure rate requirement; that the international treaty should only prohibit cluster munitions that do not meet a fixed maximum percentage of failure, such as 1%.

The approach described above appears, superficially, to provide a neat and simple delineation. Until now, however, there has been a serious lack of field-based knowledge about the reliability of SD bomblets and hence about the utility and practicability of requirements for SD mechanisms and/or a maximum failure rate as a basis for legal control of cluster munitions on a global scale.

The primary purpose of this study is to examine the performance of the M85 bomblet in combat conditions. This submunition is currently considered as the ‘benchmark’ among bomblets equipped with SD mechanisms - meaning that it is widely acknowledged as the best available technology with the lowest

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[1] In some conflicts, duds from cluster munitions have been present in such large quantities that they have been nicknamed ‘dudfields’, because, like minefields, they create fratricide hazards and mobility limitations for friendly forces, along with death and injury among civilians. See United States General Accounting Office (2002) *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War.*

[2] As a result of some states using the term ‘dumb’ cluster munitions to refer to those without SD, there is an unfortunate tendency to refer to bomblets equipped with SD as ‘smart’. This misleading and ambiguous terminology has been condemned at successive international meetings on cluster munitions. See for example ICRC (2007) Humanitarian, Military, Technical and Legal Challenges of Cluster Munitions.

[3] See *Declaration of the Oslo Conference on Cluster Munitions*, 22-23 February 2007.

[4] Note that this study only discusses SD as the primary solution to the problems caused by cluster munitions, i.e. the notion that simply the presence of SD mechanisms in a cluster munition’s bomblets qualifies it for exemption from the future ban. It does not address SD as one of several elements of a solution, e.g. in advanced weapons with a small number of larger, individually target-seeking bomblets.

[5] See for example. UK non-paper *Proposed Draft Text for an Instrument.*

possible failure rate. M85 is also the only SD bomblet ever documented to have been used in combat; in 2003 by the United Kingdom in Iraq, and in 2006 by Israel in Lebanon. As such, M85 will be a critical point of reference during the negotiations of the future cluster munitions treaty. In the past year, countries such as Austria and Norway have introduced national moratoria on their stockpiles of M85 and argue against exemptions for SD bomblets in the international prohibition, yet other countries continue to present them as the solution.

If an international treaty is negotiated which defines acceptability by setting a maximum failure rate requirement of, say 1%, then the problem of how to determine, in an accountable way, whether a given cluster munition meets this requirement or not, must also be addressed. This is an issue that presents substantial further complications. By reviewing M85 tests carried out in Norway, a secondary purpose of this study is to shed light on the limitations of common testing regimes for cluster munitions as a tool for global legal control.

Finally, this study examines the confusion which has been created because some actors persistently refer to a so-called ‘hazardous dud rate’, instead of the more commonly used term ‘failure rate’ (despite a widespread consensus that the former term is misleading). M85 is a prominent example in this regard; while most references claim less than ‘1% failure rate’, other sources talk about a ‘0.06% hazardous dud rate’ for this bomblet. The debate on cluster munitions cannot be carried forward in a responsible way without a clear understanding of the significant differences between these two concepts. This report seeks to detail, once again, serious concerns with any approach based on a distinction between ‘hazardous’ and ‘non-hazardous’ duds.

2. Facts

2.1. DPICM

M85 belongs to a category of ground-launched bomblets which can be dispensed from a variety of cluster munitions, including artillery cargo projectiles, mortars and rockets, and which are known as Dual-Purpose Improved Conventional Munitions (DPICM). The two functions of this category of bomblets are to penetrate armour using a shaped charge and to create fragmentation for an anti-personnel/anti-materiel effect. Most DPICM are based on the design of the US M42, variants of which include the M46 and M77.

DPICM are compact munitions, designed to be as small as possible while still producing adequate lethality and armour penetration. DPICM bomblets typically weigh around 300 grams, have a diameter of around 40 mm, and contain 20-50 grams of high explosives. Their shape is governed by the geometry of the shaped charge and the need for compact packaging within the parent cluster munition. The bomblets are stacked on top of each other with the hollow end and conical shaped charge accommodating the upper section (the fuze) of the bomblet below.

All DPICM have a mechanical impact fuze, meaning that they are designed to detonate on impact with a hard target or ground.

2.2. DPICM with self-destruct mechanisms

While most DPICM have only an impact fuze, a newer generation of DPICM incorporates an additional self-destruct (SD) mechanism, which is designed to detonate the main charge of the bomblet if the primary impact fuze fails to function. Most SD mechanisms consist of a pyrotechnic delay element, but electrical (battery) SD features also exist.

At least 17 states have produced cluster munitions containing DPICM equipped with SD mechanisms; France, Germany, India, Israel, Poland, Romania, Russia, Singapore, Slovakia, South Africa, South Korea, South Africa, Spain, Switzerland, Turkey, UK, and USA.[6]

DPICM with SD are stockpiled by at least 22 countries. Quantities of SD DPICM in stockpiles are, however, very modest compared to known holdings of non-SD DPICM, which according to Human Rights Watch (HRW) are stockpiled by at least 31 states. Examples of ground-launched DPICM with SD mechanisms are shown in Table 1.

Examples of ground-launched DPICM with SD mechanisms			
Bomblet name	**Carrier name or type**	**Producing country**	**Also stockpiled by**
M85 family	See Annex A	Israel, with licence production in India, Germany, Romania, Switzerland, Turkey, UK, USA	Finland, Norway
DM1383	DM642 DM662	Germany, cooperation with Italy	Austria, Denmark, Greece, Norway
GKO	122 mm rocket warhead 98 and 120 mm mortar bomb 122, 152 and 155 mm projectile	Poland	--
<unknown>	K310	South Korea	Pakistan
M2001	M2001	South Africa	--
F1	OGRE	France	--
<unknown>	155 mm artillery shell 120 mm mortar bomb	Singapore	--
M80	M915	USA	--
<unknown>	9M55K5 (9N176 warhead)	Russia	--
AGAT	122 mm rocket warhead 152 mm artillery projectile	Slovakia	--
	MAT-120	Spain	

Table 1

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[6] Argentina revealed recently that it had developed a production capacity for a pyrotechnic SD fuze and 155mm artillery DPICM projectiles, but these never entered production.

2.3. M85

M85 with its SD feature was developed by Israel Military Industries (IMI) specifically to deal with the high failure rates that were experienced with the US DPICM (M42, M46, M77).

Israel produces and exports several types of field artillery cluster munitions (cargo projectiles) containing M85 bomblets, most notably the 155 mm cargo projectiles M395, M396 and M397. It also produces M85 bomblets for all other major field artillery calibres; 105 mm, 122 mm, 130 mm, 152 mm, 175 mm and 203 mm.

Israel also licences production of some or all parts of the system in other countries. For example, the UK produces 155 mm L20A1 cargo projectiles for deployment of M85 bomblets. Germany produces and exports DM662 155 mm cargo projectiles with M85, but the bomblets are then designated DM1385 because they are incorporated into a German projectile. Romania licence-produces the 152 mm cargo projectiles CG-540 and CG-540 ER with M85 bomblets that are designated GAA-001.

The M85 mechanism is designed to use the high rate of spin that is imparted to artillery projectiles on firing. In its original form, therefore, it cannot be deployed from mortar bombs or rockets, which have a far lower spin rate than artillery projectiles. M85 has, however, been adapted by IMI to various mortar bombs and to artillery rocket systems like MLRS, LAR-160 and MAR-350, but with a modified fuze mechanism. One such adapted version is designated M87. IMI has also produced a smaller version, named Hornet-5. There are no indications that these M85 variants have been used in South Lebanon.

For an overview of various known cluster munitions with SD bomblets from the M85 family, refer to Annex A.

Some countries (most notably Switzerland) claim to have made technical modifications to their versions of M85 that set them apart from those used by Israeli Defence Forces (IDF) in Lebanon. As is explained in Section 4 of this report, bomblet failures are caused by a wide range of internal and external factors, and minor design amendments - such as those incorporated into the Swiss variant of M85 - would have no effect in relation to most of these factors. Figure 1 shows the cross section of an M85 bomblet, and Table 2 presents basic data for M85.

Basic data for M85	
Country of origin	Israel
Manufacturer	Israel Military Industries (IMI)
Type	DPICM
Diameter	42 mm
Length	82 mm excl. ribbon (56 mm stacking height)
Weight	292 g
Explosive content	44 g RDX
Delivered by	e.g. 155 mm artillery projectile (M396)
Number per carrier	49 (in M396)
Dispersion area	Circle up to 100 m radius/3 ha
Impact velocity	40 m/s
Angle of impact	80 - 90°
Casing properties	13 steel rings, prefragmented 3 mm thick. Aluminium liner of 2 mm inside.
Number of fragments	~1200

Table 2

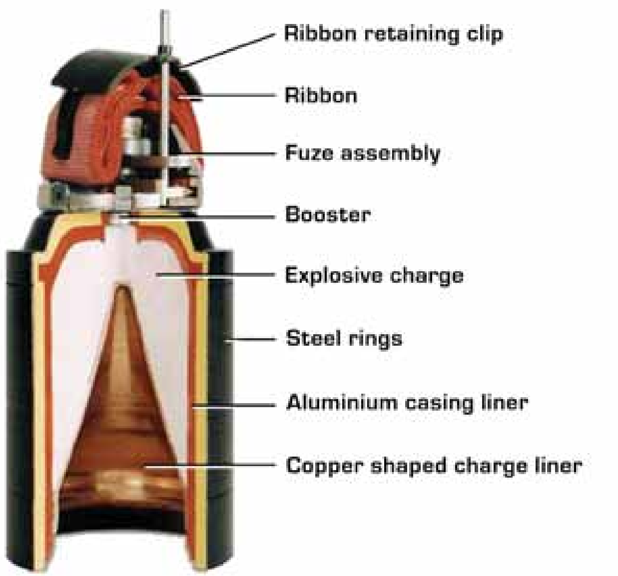

Figure 1: Cross section of an M85 bomblet.

2.4. The cargo projectile

The M85 bomblets found in Lebanon during the research for this report were all delivered by 155 mm IMI cargo projectiles designated CL 3013-E1, corresponding to M396; these are extended range projectiles with base-bleed elements[7] and which contain 49 bomblets. Figure 2 shows a cross section of the German DM662, which is comparable to the M396. For ballistic data on M396, refer to Annex B.

Projectiles carrying M85 bomblets and other DPICM are fitted with a time fuze at the nose, which should be set by the gun crew to function between 400 and 600 m above ground level. When this fuze functions it ignites a powder charge at the front of the casing. This charge pushes out the bomblets from the back of the projectile and the spin of the shell contributes to their dispersion. By the time they reach the ground, the bomblets are typically spread out in an elliptical or ring shaped pattern, as illustrated in Figure 3.

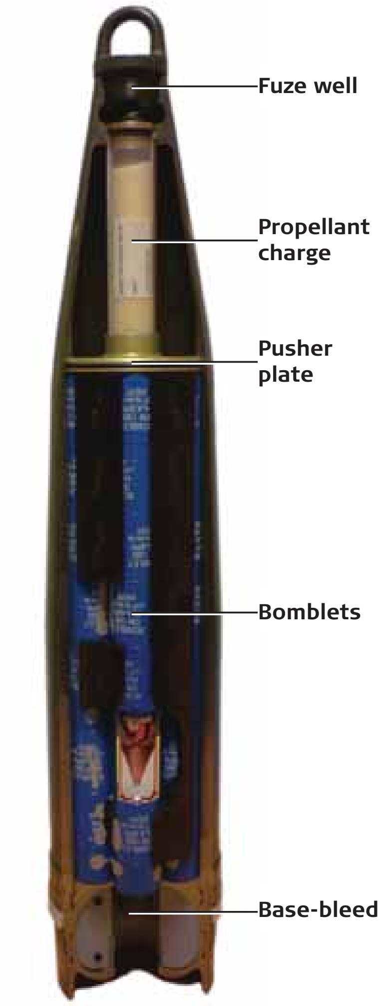

Figure 2: Cross section of 155 mm cargo projectile with 49 M85 bomblets (blue training bomblets). Photo: Are Hauger.

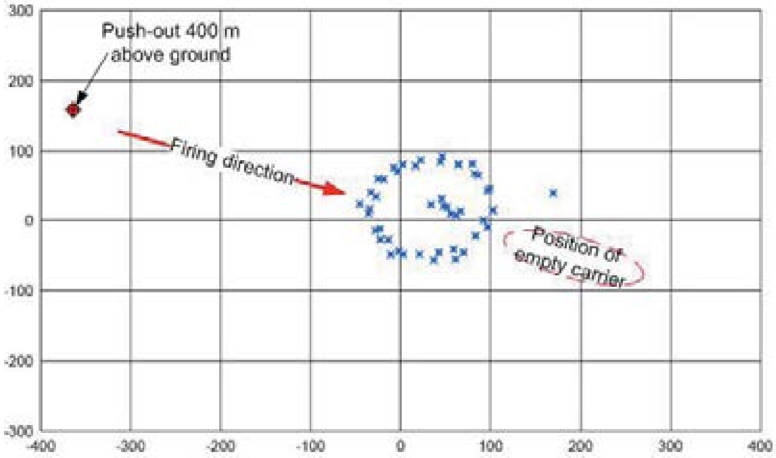

Figure 3: Typical plot of bomblet impact dispersion pattern from a 155 mm cargo projectile, in this case a DM662 containing 49 M85 bomblets, as registered during tests in Norway. The distances are in metres. The main ring pattern originates from the peripherical bomblets, while the cluster in the middle is from the central stack of bomblets. The far right bomblet is probably one that has lost its ribbon. This pattern contains only 47 impacts, meaning that two bomblets remained as duds. The shape of this distribution pattern is typical for fall angles higher than 40°, which take place at ranges beyond 20 km. At shorter ranges the pattern becomes increasingly elliptical. The size of the pattern increases slowly with increasing spin rate at push-out. The position of the empty projectile depends on the angle of fall. With low angles the projectile lands some distance in front of the bomblets and with high angles, closer to the bomblets.

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[7] The term base-bleed refers to a propulsive element in the base of the projectile whose role is to generate gas in the vortex, or wake, behind the projectile during flight. The pressure of this gas reduces the drag and thereby extends the range of the projectile. The addition of a base-bleed unit will typically increase the range of a projectile by 20 – 25%.

3. M85 reliability in combat

3.1 Iraq 2003


Figure 4: M85 dud in Basra. Photo: DanChurchAid archives


Figure 5: M85 dud in Basra. Photo: Bonnie Docherty, HRW

In 2003, when the British Army first employed its L20A1 projectiles with M85 bomblets under combat conditions in southern Iraq,[8] the British MoD stated that commanders were operating on the assumption that the failure rate was 0.74%.[9] Many states stockpiling M85 submunitions still claim that tests show they satisfy a 1% maximum failure rate requirement, despite published results of Norwegian and subsequent UK testing showing failure rates higher than this.

The use of M85 in Iraq gave the first indication that the failure rate for M85 in combat might be significantly higher than expected. Although this raised concerns, the haphazard nature of the clearance tasks and lack of systematic recording meant that there were insufficient data to draw firm conclusions. Only anecdotal evidence is available, from people who were on the ground in southern Iraq. Among them was the military EOD expert Knut Furunes. He explains:

> *"The normal situation would be that there were 2-3 duds per projectile and sometimes 4 duds. For instance, I remember one M85 site northwest of Basra where I walked into the footprint and located the centre of the strike and from there I could easily see either 3 or 4 duds."*[10]

With 2-4 duds per projectile this would equate to a failure rate of 4% to 8%, and between 4,000 and 8,000 duds from this submunition type in southern Iraq, mainly focused around the Basra area.[11]

Furunes' impression is supported by Sam Christensen, Head of Operations and Planning in the Mine Action Unit of DanChurchAid, who has attested that their staff on the ground at the time found significant numbers of M85s.[12]

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[8] A total of 102,802 M85 bomblets were fired by the Royal Artillery in 2,098 L20A1 projectiles (each of which contains 49 bomblets). Most of this was in the Basra area. See Hansard, 16.6.03, Col. 55W.

[9] Email from Wg. Cdr. Barrowcliffe to Richard Moyes, Landmine Action, 23 November 2007, MoD communication ref: *M85 proportionality assessments in Iraq PS 05-10-2007-071341-002 - R.Moyes*

[10] Interview with Knut Furunes 15 October 2007. Furunes was involved in technical survey for the Telemark Engineer Squadron, a Norwegian force contribution under UK operational command.

[11] See footnote 8.

[12] Email from Sam Christensen 8 November 2007.

Human Rights Watch (HRW) has also reported that it "found evidence of duds in multiple areas of Basra"[13] caused by the UK's use of M85 bomblets. The organization described these bomblets as "littering" some neighbourhoods.[14]

3.2 South Lebanon 2006

As of 5 October 2007, a total of 943 strike locations for cluster munitions had been recorded in South Lebanon after the 34-day conflict between Israel and Hezbollah in the summer of 2006.[15] According to the Mine Action Coordination Centre in South Lebanon (MACC SL), information drawn from Israeli media reports suggest the number of bomblets of all types fired into South Lebanon to be around four million. The MACC SL considers 25% to be a realistic overall failure rate – which would mean that perhaps one million duds will have been left on the ground. By far the most widely used bomblets were the older US-produced non-SD M42, M46 and M77.[16] These bomblets are known to be unreliable and, not surprisingly, a high proportion failed to function and were left unexploded across large areas of land.

The Israeli-produced M85 bomblets were used in substantially smaller quantities but, nevertheless, their use constituted a rare opportunity for improved knowledge about their performance in combat conditions as opposed to tests. Soon after the conflict, MACC SL stated categorically that they were finding large numbers of unexploded M85 submunitions.

In addition to M85 bomblets, a very similar Israeli non-SD bomblet is being found in South Lebanon. The bodies of these two bomblets are exactly the same, but there are clear differences in the fuze. Because of their similarity, clearance operators in South Lebanon have referred to both as M85 ('M85 with SD' and 'M85 without SD' respectively). They are, however, two separate bomblet types. This study has attempted to obtain information from IMI and other Israeli sources about the correct designation for the bomblet without SD, but has not received any responses. In this report, 'M85' is exclusively used to refer to the bomblet with SD, while the similar non-SD bomblet is referred to as 'non-SD Bantam.[17] Throughout the field research and clearance carried out for this study, there has been no doubt as to the difference between M85 and the non-SD Bantam or the identification of bomblets, which were all photographed as proof. See Annex C for information on the visual differences between M85 and the non-SD Bantam.

On the basis of information from MACC SL and individual ordnance clearance organizations, 107 locations have been identified where either M85 or non-SD Bantam had been dropped. Of these 107 locations, the research has verified 19 as M85 sites and 11 as non-SD Bantam sites.[18] See map in Annex D1 and a table listing the sites in Annex D2.

3.2.1. Failure rate analysis

Some argue that it is not possible to draw conclusions about the failure rate of M85 in South Lebanon without data about strike locations and the total numbers of projectiles and bomblets used; data which IDF have not released. A clear quantitative picture can, however, be formed by sampling sites of contamination.

This study has collated detailed analysis of six of the 19 identified locations where M85 had been used. Four of the six locations have also been subjected to full surface and subsurface research clearance per-

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13 HRW (2003) *Off Target: The Conduct of the War and Civilian Casualties in Iraq*, page 112.

14 Ibid, page 107.

15 See 'September 2007 report of the Mine Action Coordination Centre, South Lebanon', 5 October 2007. New strike locations for cluster munitions are still being recorded.

16 The M42/ M46 bomblets were delivered using M483A1 projectiles, and the M77 bomblets with M26 rockets.

17 Some documents have used the designation M79 for this non-SD bomblet, but in the absence of information from IMI it cannot be verified whether this is correct. The Rheinmetall AG designation for this non-SD type is DM1348.

18 Verification took place through field visits or interviews coupled with photographic evidence. Further locations among the 107 have been researched without finding evidence allowing for determination of whether it was M85 or non-SD Bantam that had been used.

formed by an NPA Battle Area Clearance (BAC) team specifically trained for this purpose. Information about indicators and data collection can be found in Annex E, while the Technical Survey Form used is shown in Annex F. Only time and access limitations have prevented detailed analysis of more than these six locations, although several other M85 sites have been visited and inspected.

All 107 M85 and non-SD 'Bantam' strike locations were reported by the MACC SL and by individual clearance operators on the basis that they presented some level of unexploded contamination from these bomblet types.[19] The research was incorporated into NPA's normal operations and research in the form of surface and subsurface clearance of specific sites was possible as and when such sites were assigned to NPA by MACC SL on the basis of humanitarian priorities only. The likely humanitarian impact of the contamination is assessed on the location of the site, not on an assessment of the quantity of unexploded bomblets.

After the first field visits it was clear that the failure rate for M85 in South Lebanon was substantially higher than 1%. At each location, several unexploded bomblets were visible on the surface where, if they had performed as claimed, only the occasional one would have survived.

For three of the six sites researched in detail, the failure rates were proven to be:

• **CBU 804 (see Box 1):**	**At least 9.6%**
• **CBU 805 (see Box 2):**	**11.5%**
• **CBU 601 Alpha (see Box 3):**	**12.2%**

These sites show a consistent dud rate for M85 as used in Lebanon of around 10%.

For the three other sites researched in detail (CBU808, CBU 622 and CBU 601 Alpha), the evidence on the ground did not allow for firm conclusions about the failure rate, but it was clear that it was considerably higher than 1%.

At site CBU 622 for instance, at least 20 M85 duds were located in an area of 50 x 50 m. The density of the duds indicates that they were the result of more than one projectile. But if 20 duds were to have been produced with a failure rate of 1% within such a small area, then 40 projectiles would have had to have been fired against, and hit the same point target. Clearly this was not the case; apart from being highly unlikely, such a large strike would have left very obvious indicators.[20] For more information on the findings from these further sites, refer to Annex G.[21]

Although a dud rate for M85 consistently around 10% has emerged, it was not the intention of this study to determine an average failure rate for all M85 use in South Lebanon. The research does, however, prove beyond doubt that in, many cases, the failure rate is much higher than in tests. In the words of Chris Clark, the UNMAS Programme Manager at MACC SL:

> *"Regardless of the actual failure rate figure for this weapon it is most definitely higher than the less than 1% figure doggedly quoted by military users and manufacturers/designers."*[22]

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[19] To this extent the pool of sites sampled is necessarily skewed towards there being some presence of unexploded ordnance. If sites exist where M85 were used but did not leave any UXO, they would not have been reported to MACC SL.

[20] 'Indicators' are signs left by a strike. See Annex E for information on the indicators used in the research.

[21] Information is also available about CBU 679 in Task Dossier 6-020 in Kfar Seer, where the clearance organization Mines Advisory Group (MAG) estimated a failure rate for M85 of 1.5-3% on the basis of an EOD spot task, but recommended that the area be "subjected to further clearance by a BAC team conducting both visual and instrument search where undoubtedly more items would be found." Source: MAG: M85 SD Sub Munition Strike: Kfar Seer UTM – 0722130 – 3688817.

[22] See ICRC (2007) *Humanitarian, Military, Technical and Legal Challenges of Cluster Munitions*, p 42.

Figure 6: An olive farmer at site CBU 808 in Blida standing next to two M85 duds. This site was visited in October 2006 as an EOD team from BACTEC had just arrived. They identified six M85 duds just along a road when they started to move into this area. A total of 26 M85 duds were removed by the BACTEC EOD team that day and the day after. Photo: Hassan Al Ali/MACC SL.

3.2.2. Only duds from normal deployment taken into account

Conclusions about failure rate in this study have only been made with respect to duds from projectiles that have deployed normally. Some sites inspected during the research presented munitions that were excluded from the analysis because they had either opened very close to the ground, or were 'complete failures.' This means that, rather than functioning as intended, they struck the ground without opening and with the impact causing an uncontrolled spread of the bomblets. [23]

This study elected to exclude duds from such abnormal deployments because they do not shed light on the reliability of the M85 bomblet as such. Were they to be included, the figures would often be very high. CBU 601 Alpha (see Box 3) is an example of a location where a total of 43 M85 duds from three projectiles were discounted because they were clearly the result of abnormal deployment.

Abnormal deployments may be common in combat conditions, either because of stress-induced human error or component malfunctioning.[24] From a humanitarian impact and post-conflict clearance perspective, there is no reason why such duds should be discounted, since they still constitute as much of a danger to civilians and deminers as duds from normal deployments. They are also present in even higher numbers, all of which have to be dealt with individually.

Figures 7-9 show an example of the clearance necessary in many cases where the projectile has failed to deploy normally. Such failures were excluded from the analysis in order to maintain a specific focus only on bomblet reliability. This choice of methodology should be recognised as being conservative – understating, rather than overstating, the overall failure rates suggested by the data.

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[23] Examples have been seen of total failure where the unopened projectile's impact with the ground has ejected bomblets several metres away, especially when the projectile hits sloping ground.

[24] Abnormal deployments can happen as a result of a faulty fuze, when the fuze has not been fitted or not set correctly, if the fuze fails to arm, or if the fuze malfunctions after arming. This is covered in far greater detail in Section 4: *Munition functioning and failure analysis.*

Figures 7-9: On 26 June 2007 Swedish Rescue Services Agency (SRSA) were called to a site in Deir Qanoun Al Nahr to investigate a complete failure of a 155 mm cargo projectile. The projectile's entry hole was just by the back wall of a block of flats. Upon arrival, they found three M85 duds in the middle of the road between the block of flats and an orange grove. The entry hole was excavated and M85 bomblets were found at various depths along the entire entry hole, but most of them just before the projectile casing, which was a CL3013-E1. No bomblets remained inside the projectile. Photos: Robert Ericsson/SRSA

3.2.3. Favourable conditions

Despite the high failure rates observed in Lebanon, the conditions they were deployed in were actually 'favourable' to bomblet functioning – suggesting that performance could be even worse in other environments. Both Iraq and Lebanon represented benign conditions for cluster munition reliability. Of the many adverse factors that can contribute to increase the failure rate of a cluster munition in combat, few were present in either theatre of operation:

The submunitions were of fairly recent manufacture;[25] properly stored and maintained; deployed by professional soldiers; onto predominantly hard, lightly vegetated ground; in good climatic conditions. In the case of Lebanon, the Israeli gun crews were in home territory and (not receiving counter-battery fire) with comparatively low levels of stress.

The failure rate for M85 must be expected to increase further when old, poorly maintained stockpiles are used by undisciplined soldiers in more stressful and adverse conditions, and fired into soft, heavily vegetated ground.

3.3. Percentages explained in real terms

Failure rates and percentages do not necessarily contribute to a good understanding of a cluster munition's real potential to create UXO. From the perspective of a community affected by cluster munition strikes it is not the percentage of duds which is significant, but the actual number of potentially lethal unexploded munitions left on the ground. It will be very hard for any DPICM to achieve a maximum failure rate of 1% under combat conditions. But if it were possible, what would that mean in real terms?

- If the failure rate of all cluster munitions used in the Gulf War in 1991[26] had been only 1%, the result would still have been around 200,000 duds.
- If the failure rate of all cluster munitions used over South Lebanon in the war in 2006 had been only 1%, the result would still have been approximately 40,000 duds.
- One full launcher load from MLRS (consisting of 12 rockets each with 644 submunitions) would still result in more than 77 duds.

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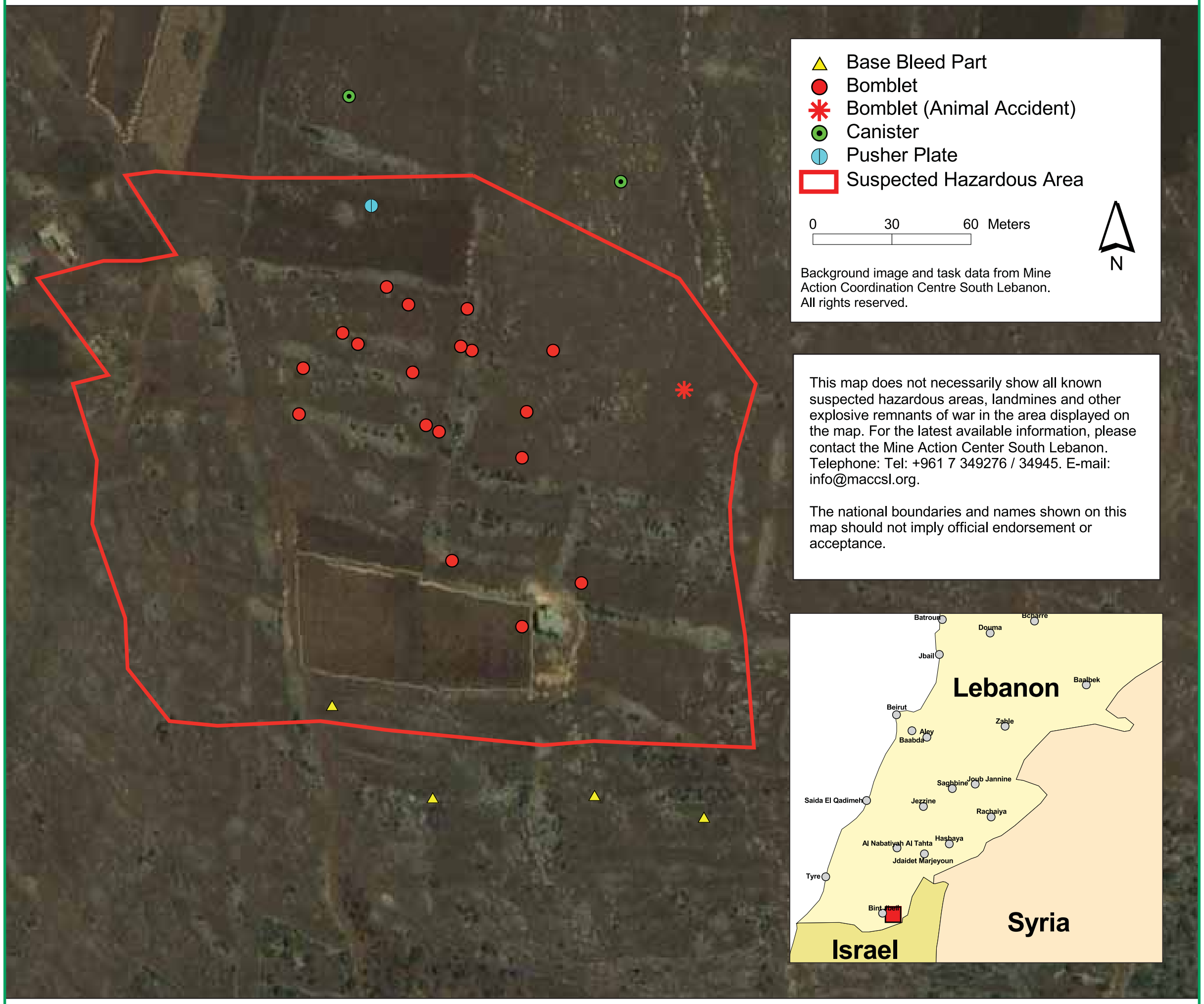
[25] All of the M85 bomblets seen in Lebanon were produced in 1990, making them older than both the Norwegian and UK stockpiles tested in Norway (for more information see Section 5). In this instance, with a small age difference and well maintained ammunition, age is unlikely to have had a significant effect on failure rate. However, the eventual degradation of older ammunition will inevitably affect its reliability. As discussed in Section 4, pyrotechnic components, like in an SD, tend to age faster than other components.

[26] In the Gulf War in 1991, 61,000 cluster munitions with some 20 million submunitions were used, according to HRW data.

Site: CBU 804, Task Dossier: 3-020

Location: 5 km east from Aytarun village, Bint Jbeil district
Status: Surface and subsurface clearance finished and area released
No. of M85 duds found: 19, but indications that there have been 3 more
Failure rate analysis: At least 9.6%



Background image and task data from Mine Action Coordination Centre South Lebanon. All rights reserved.

This map does not necessarily show all known suspected hazardous areas, landmines and other explosive remnants of war in the area displayed on the map. For the latest available information, please contact the Mine Action Center South Lebanon. Telephone: Tel: +961 7 349276 / 34945. E-mail: info@maccsl.org.

The national boundaries and names shown on this map should not imply official endorsement or acceptance.

The site CBU 804 consists of stony/hard soil. The owner had not been able to use the land since the conflict. A total of 7 M85 duds were found during the research clearance, one of which was buried at 5 cm depth. Earlier, a total of 11 M85 duds had been destroyed by Lebanese Armed Forces (LAF) at sites marked by the landowner and/or MACC SL and for which the exact positions were established. According to LAF they cleared an additional three duds, but these have not been included in the findings since their position and existence could not be verified. The landowner also pointed out a spot where a dud had exploded and killed a goat, and this dud was included in the failure rate calculation.

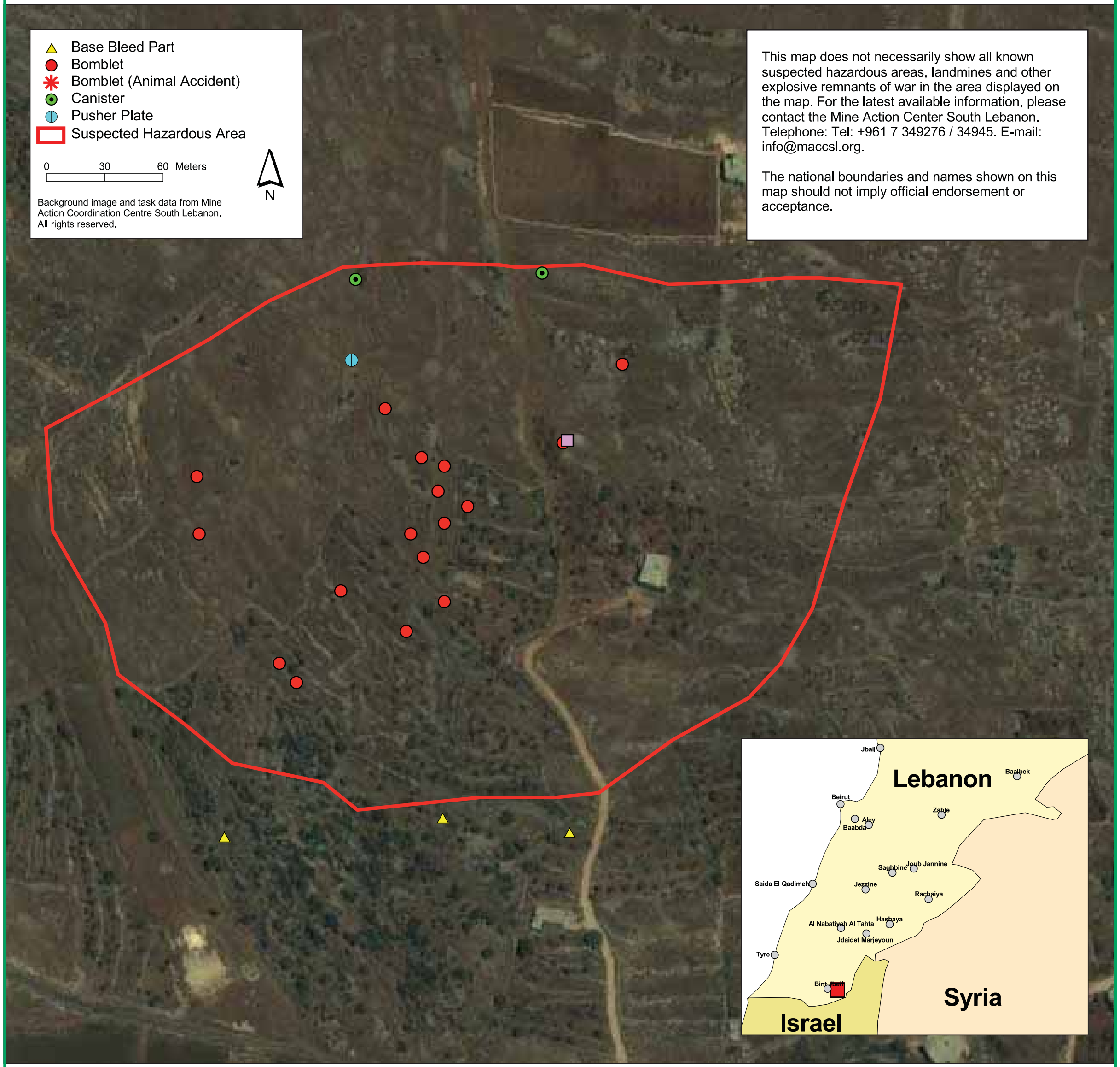
Two empty projectiles were located at the expected range from the footprint/strike area. The research concluded that the duds found in CBU 804 were the result of a maximum of four normally deployed base-bleed projectiles (with 49 bomblets each). This means that a total of at the most 196 bomblets were fired into the area. With at least 19 duds this means a failure rate of at least 9.6%.

It is likely that the actual number of projectiles was three, rather than four. Four base-bleed parts were found, but the firing direction pattern indicates that the easternmost of these could belong to a projectile that would have dispersed its payloads east of the perimeter of CBU 804.

Box 1

Site: CBU 805, Task Dossier: 3-020

Location:	3 km south-east from Aytarun village, Bint Jbeil district
Status:	Surface and subsurface clearance finished
No. of M85 duds found:	17
Failure Rate Analysis:	11.5%

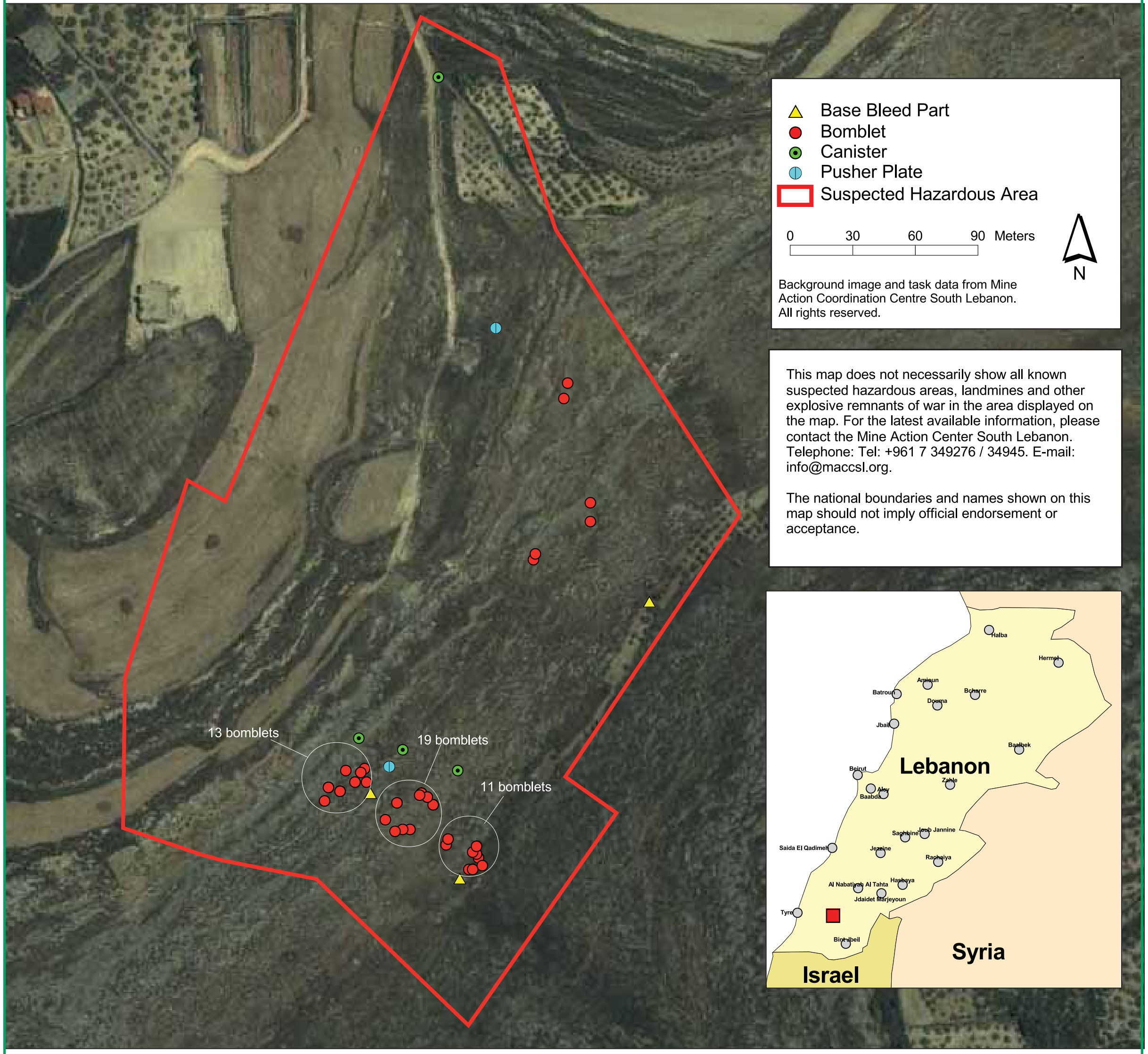


This area consists of olive groves and cactus located around a house. The ground is a mix of stony/hard soil and farmland. The owner had not been able to use the land since the conflict. The research clearance team found 6 M85 duds. In addition 11 marked M85 duds which had previously been visually inspected by the researchers for this report had been removed by LAF from positions that could be accurately established. Two empty projectiles and three base-bleed elements were found. In addition, one projectile was found at 1.5 m depth that had failed to open. The research concluded that three base-bleed projectiles (with 49 bomblets each) had been normally deployed in the area, resulting in 17 duds and a failure rate of 11.5%. The research found that one additional projectile had failed to open but this was not utilised in the calculation of bomblet failure rates. It cannot be ruled out that one of the 17 duds had been ejected from this latter failed projectile after it crashed into the ground. If this one dud is excluded from the analysis, then the failure rate is 10.9%.

Box 2

Site: CBU 601 Alpha, Task Dossier: 8-010

Location: Bafliyah, Sur Middle District
Status: Surface and subsurface clearance finished and area released.
No. of M85 duds found: 49
Failure Rate Analysis: 12.2% (for one normally deployed projectile)



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This map does not necessarily show all known suspected hazardous areas, landmines and other explosive remnants of war in the area displayed on the map. For the latest available information, please contact the Mine Action Center South Lebanon. Telephone: Tel: +961 7 349276 / 34945. E-mail: info@maccsl.org.

The national boundaries and names shown on this map should not imply official endorsement or acceptance.

The site CBU 601 Alpha is located in a steep valley covered with grass and bushes and with olive trees at the bottom. The ground is mostly stony/hard soil. The analysis concluded that a total of four base-bleed projectiles had been fired into this area, containing a total of 196 bomblets. The number of M85 duds found by the research clearance team in the area was a total of 49.

However, three of the projectiles did not deploy normally. They either crashed to the ground unopened and then ejected their payload, or they opened at a very low height. At least one of these three projectiles must have opened at only approximately 10 meters altitude, as there was a clearly identifiable footprint of only 3 m in diameter. The footprints from the abnormal deployments show that most of the bomblets did indeed detonate as intended (the flight time required for arming of M85 bomblets is very short). Nevertheless, the 43 duds that resulted from the three projectiles that did not deploy normally have been disregard in the failure rate analysis.

A conclusion about failure rate has only been made for the strike that clearly was a result of a normal deployment of one base-bleed projectile. The footprint of this single projectile was clearly identifiable on the rocks approximately 150 m away from the other three strikes, and included six duds. In conclusion, the failure rate in this case of normal deployment was 12.2%.
If the duds from the abnormal deployments were to be taken into account, the failure rate for the area where the three abnormally deployed projectiles were concentrated would have been 29.3% (43 duds of 147 bomblets deployed). The failure rate for the entire site would have been 25% (49 duds of 196 bomblets deployed).

Box 3

Figure 10: MACC SL Operations Officer Albert Philip investigating the scene of an accident where a woman was killed on 5 April 2007 when she disturbed a buried M85 dud while working in her garden in the village Aynata. Pieces of M85 were found in and around a large detonation hole. M85 duds were surface cleared from this locality, which is located in strike area CBU 519, during the emergency phase of operations. According to MACC SL Community Liaison Assistant Hassan Al Ali, not less than 17 M85 duds were removed from the surface of this and other gardens and olive groves around houses in the site CBU 519. Photo: Hassan Al Ali/MACC SL

Clearing M85 duds

In the case of duds from SD bomblets like M85, the fact that there are two possible modes of initiation (via the impact fuze and the SD delay) increases the number of possible scenarios by which accidental initiation could occur. In that sense, their disposal is more problematic than that of non-SD bomblets.

In addition, armed M85 duds cannot be neutralized manually, because the mechanism prevents EOD personnel from pushing the slide back in, an action often performed with more primitive bomblets like M42/M46 and M77.

Box 4

3.4. Conclusions

- The use of M85 by the UK in southern Iraq in 2003 gave the first indications that the failure rate in combat was higher than expected.
- The inescapable conclusion from Israel's use of M85 bomblets, amongst other cluster munitions, in South Lebanon in 2006 is that they failed far more often than would have been predicted based on the claims of stockpiling states and manufacturers.
- A detailed analysis of strike sites in South Lebanon, undertaken for this report, suggested that a consistent dud rate for M85, as used in Lebanon, is likely to have been around 10%.
- Failure rates from three example sites where data was sufficient to draw firm conclusions were 9.6%, 11.5% and 12.2%. From other sites where firm conclusions could not be drawn it could still be stated with confidence that the failure rates were substantially higher than 1%. The methodology used to assess reliability was conservative in that it discounted instances where whole containers had failed to open correctly (but still resulted in the spread of bomblets).
- While the M85 bomblets did not achieve the reliability claimed by the manufacturers, they did have a significantly lower failure rate than the US produced non-SD types. However, it is not clear to what extent this difference in performance can be directly attributed to the presence of the SD device rather than other factors such as design, age, storage and manufacturing standards.

M85 reliability in combat

- The M85 bomblets performed poorly even though the conditions were generally ‘favourable’ for bomblet reliability. The failure rate for M85 must be expected to increase further when old, poorly maintained stockpiles are used by undisciplined soldiers in more stressful and adverse conditions, and fired into soft, heavily vegetated ground.
- SD mechanisms cannot be relied upon to reduce post-conflict contamination from cluster munitions to a level that is acceptable according to the policy positions of a number of states. Performance in combat may produce far higher levels of contamination than would be expected on the basis of tests.
- The current focus on failure rates can also obscure the fact that in the case of cluster munitions, the sheer quantities of submunitions involved means that very large numbers of duds would be produced, even with a figure as low as 1%.

4. Munition functioning and failure analysis

The following section analyses M85 functioning and discusses the causes of M85 bomblet failures based on examinations of dud bomblets found on the ground in South Lebanon and produced during the Norwegian test firings.

4.1. M85 design considerations

M85 was designed to maximise reliability and minimise the number of unexploded bomblets remaining from a strike. The systematic approach to safety and reliability applied to the M85 involves a number of elements:

- **Original design:** unlike most DPICM, the fuze of the M85 has little in common with the US M42 types. Other than the requirement to sit within the base of the next bomblet (in order to stack), and the use of a ribbon to unscrew the striker, the design of the fuze is largely original.
- **Self-destruct (SD) mechanism:** while most DPICM have only an impact fuze, M85 incorporates an additional SD feature, which is designed to detonate the bomblet if the primary impact fuze fails to function. The SD uses a pyrotechnic delay, which is ignited as the mechanism arms, and is designed to initiate the primary detonator 15 seconds later.
- **Materials:** the materials used in the fuze are of a high quality, and have been specifically selected for their respective roles. They are machined to close tolerances and, where necessary, have been given an appropriate surface finish.
- **Arming:** while many DPICM incorporate springs to move fuze components during arming, M85 relies mainly on the centrifugal force[27] created by the spin of the parent projectile.

4.2 Operation

The M85 bomblet is designed to function as follows:

The fuze of the cargo projectile is set to an appropriate time delay, calculated according to factors such as the range and relative altitudes of the firing point and target. After the projectile has been fired and the delay has expired, the fuze initiates an internal propellant expelling charge; this bears on a ‘pusher plate’, which drives the stacked submunitions towards the rear of the projectile. The base part of the projectile is ejected, allowing the submunitions to exit from the rear of the casing at approximately 70 m/s.

Since the projectile is spinning fast, most of the submunitions are forced outwards, in a radial pattern, as they exit the casing. The exception is the central stack, which are dispersed in the turbulent air-flow behind the projectile. Each bomblet also retains the high rate of clockwise spin from the parent projectile.

Within the bomblet fuze, a spring-loaded transverse locking pin, made from a dense tungsten alloy, is forced outwards by the spin, releasing the slide. If, for any reason, the slide does not move across fully, the locking pin should re-engage with the slide in a mid-way position, neutralising the mechanism.

As the bomblet enters the air stream, the small clip holding the folded ribbon in place on the top of the fuze falls away, allowing the ribbon to unfurl. The ribbon produces anti-clockwise drag on the striker, also slowing and stabilising the bomblet to bring it into a ‘nose-down’ orientation.

The striker is unscrewed into its collar by the drag on the ribbon, withdrawing it from the slide while also releasing the two wing retaining tabs. With the two elements that retained the slide now released (the locking pin and the point of the striker), the slide moves across to the armed position under centrifugal force.

As the slide moves across, the hammer and firing pin at the end rotate - again under centrifugal force -

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[27] ‘Centrifugal force’ is a convenient term used to explain the force, away from the centre, that appears to act on a body moving in an arc. In reality, it is centripetal force (acting towards the centre) that prevents the body from following a straight path.

driving the pin into the stab receptor at the end of the slide. This ignites the SD pyrotechnic delay composition in a tube within the slide.

As the slide reaches full extension, a non-return pin on the underside locks it into position. With the wings deployed, the rate of rotation slows; this is because a high spin rate would degrade the performance of the shaped charge.

On impact, the striker falls onto the stab-sensitive detonator to initiate the high explosive booster pellet and main charge. Should this fail, the pyrotechnic delay should fire the detonator 15 seconds after it was initiated (and normally 5-7 seconds after impact).

As the main charge detonates, the steel rings around the body are shattered to create a fragmentation effect. This creates approximately 700 steel fragments, each a 3 mm cube weighing around 200 mg. Around 500 additional fragments of different shapes and sizes originate from the inner aluminium liner and from the end sections. At detonation, the fragments will attain a velocity between 700 and 850 m/s and are likely to be lethal within 10-12 m.

Also as the main charge detonates, the conical copper shaped charge liner is formed into a high velocity jet, fired forwards along the axis of the bomblet, to penetrate armour. This jet is capable of penetrating approximately 100-120 mm of steel armour, making a hole around 10 mm wide.

The operating sequence is summarised in Figure 12.

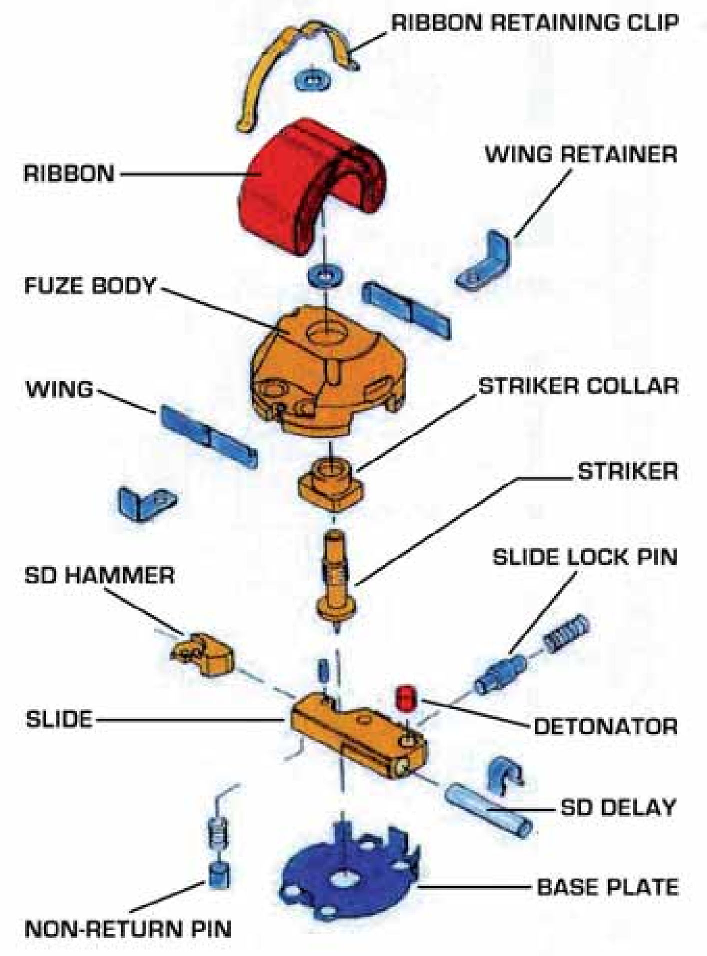

Figure 11: Components of the M85 fuze

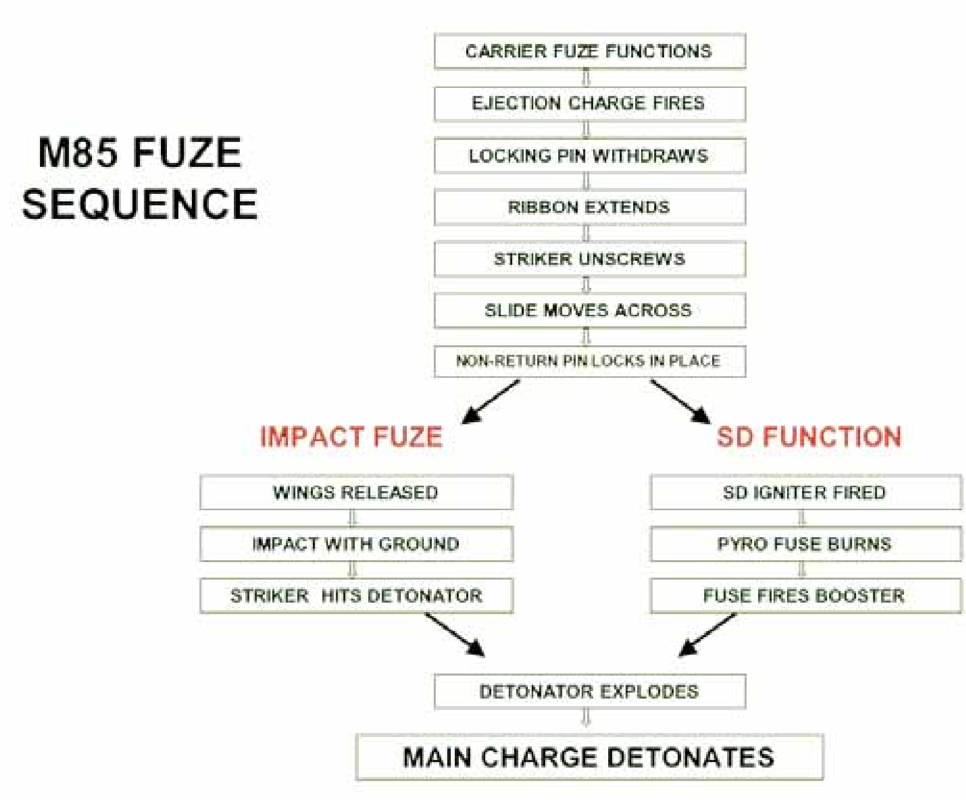

Figure 12: Summary of the M85 fuze sequence. It is important to note that the M85 is only capable of providing an additional level of reliability in certain instances of impact-fuze failure. If the arming sequence is stopped at any point, the bomblet will fail. Only when it is fully armed can either fuze (impact or SD) function.

4.3. Design weaknesses

Despite the originality and ingenuity of the M85 design, it has a number of weaknesses:

- **Complexity:** the fuze incorporates a large number of components and required actions, resulting in many possible causes of failure. For each 'event' in the operating sequence (summarised in Figure 12), there are typically 3-5 things that can go wrong.[28] Consequently, there are at least 20 possible causes of failure during the arming sequence before the two fuzing systems (impact and SD) become operative, and a further number that might prevent each of them from functioning correctly.
- **SD dependent on arming:** the SD function is not fully independent of the impact initiation system, but relies on the successful completion of the arming process. If the sequence of events is stopped before full extension of the slide, neither the impact nor the SD delay initiation will be capable of functioning correctly.
- **Shared detonator:** the SD delay uses the same detonator as the impact initiation system. If this single detonator is non-functional, then both initiation systems will fail.
- **'Fail-safe':** although the fuze is designed to 'fail-safe' if it does not fully arm, tests have proven conclusively that the arming sequence can still be recommenced (by an external stimulus) through to detonation (for more information on this, see Box 5 at Section 6.)[29]

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[28] For example, instead of the ribbon unfurling correctly, it may: remain folded, with the clip in place; become knotted; get ripped off completely; or become tangled with another bomblet. Another example is that the firing pin may not unscrew because it is corroded or stuck, or because of insufficient time/drop height or insufficient spin.

[29] The concept that a dud is either 'safe' or 'hazardous' is mistaken, since the arming sequence may be interrupted at any point, and can then be completed by subsequent actions, resulting in detonation. The term 'non-hazardous dud' is therefore misleading and should not be used. A more detailed analysis of the problems with this terminology is given in Section 6.

4.4. Failure analysis

4.4.1. General

There are many reasons why the sequence shown in Figure 12 may be interrupted, causing the M85 bomblet to fail.

Assuming that the bomblet is successfully deployed from the parent munition, mechanisms that may interrupt the operating sequence to cause failure include:

- Bomblet damage sustained during ejection (see 4.4.4);
- Bomblet damage sustained during flight (see 4.4.5);
- Malfunction of bomblet mechanical components (see 4.4.6);
- Malfunction of bomblet explosive components (see 4.4.7).

In addition to 'systematic failures' (those relating to the design and function of the munition), the bomblet may also fail due to improper use and environmental factors.

4.4.2. Human factors

No matter how well ammunition is designed, it relies on people to use it correctly. During testing, errors can be minimised through good planning, preparation and checking. However, combat conditions often involve time pressure, difficult field conditions, tiredness and high levels of stress, all of which increase the likelihood of human error. Examples of human error that may lead to ammunition failure include:

- Rough handling, leading to damage;
- Procedural errors, such as failing to set the projectile fuze correctly;
- Miscalculation of range and/or elevation.

4.4.3. Environmental factors

Environmental factors, which can affect any type of DPICM, include circumstances such as:

- Poor ammunition storage or maintenance, leading to problems such as corrosion;
- Ageing, leading to the degradation of some components;
- Extremes of temperature, beyond design limitations;
- Cushioning of impact by soft ground or vegetation;
- Ribbons catching on structures or vegetation.

4.4.4. Bomblet damage sustained during ejection

As an outer stack of bomblets exits the base of the spinning carrier projectile, they are thrown outwards by the centrifugal force. However, since the fuze of one bomblet sits within the base of the next, it may not be released cleanly. This leads to a levering effect, as the fuze of the free bomblet rotates outwards, while the edge of the base scrapes across the surface of the fuze body of the bomblet still held in place.

This effect often leads to scratching or deformation of the fuze body. Whenever this damage affects the slot housing the slide, the opening will most likely be crimped and the slide stuck inside the housing,[30] thus preventing the bomblet from arming; this can be seen in Figure 14. The higher the spin rate, the

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[30] The slide itself will not be able to overcome the strength of any crimping obstructing the opening as the net centrifugal force acting on the slide is very weak and as the slide has quite low mass (4.5 g).

Figure 13: The bomblet ribbon can get caught on structures and vegetation. A fully armed bomblet hanging above the ground creates an extremely dangerous situation. This photo shows MACC SL Operations Officer Albert Philip next to an M42 bomblet, but the same problem occurs with M85 bomblets and all other DPICM. Photo: Hassan Al Ali/MACC SL.

greater the forces acting on the bomblets[31] and the more likely they are to sustain this damage during ejection. Two possible ways in which the fuze can be damaged during the ejection and separation of bomblets are illustrated in Annex H.

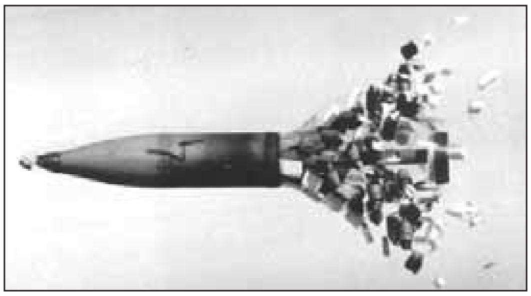

Figure 14: The separation process.
Source: Presentation by Mark Hiebel;
XM242 Pyrotechnic Self Destruct Fuze
for 155 mm XM864E2 Recap;
51st Annual Fuze Conf., Nashville, TN, 2007

Figure 15: An example of a crimped fuze as a result of damage by an adjacent bomblet because of the levering effect during ejection. This dud is of the type DM1385 (another designation for M85) and was a result of test firings in Norway. Photo: Colin King

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[31] The centre stack of bomblets is ejected along the shell axis and will not be exposed to substantial centrifugal forces.

4.4.5. Bomblet damage sustained during flight

Live firing tests showed that there are some mid-air detonations.[32] These produce a large number of high velocity fragments that may damage other bomblets at substantial distances. Testing has also confirmed that some bomblets collide during flight. This can also result in mechanical damage that may interfere with the arming sequence. Other consequences of mid-air collisions include tangling or ripping of the arming ribbons, which will usually result in the malfunction of the bomblet.

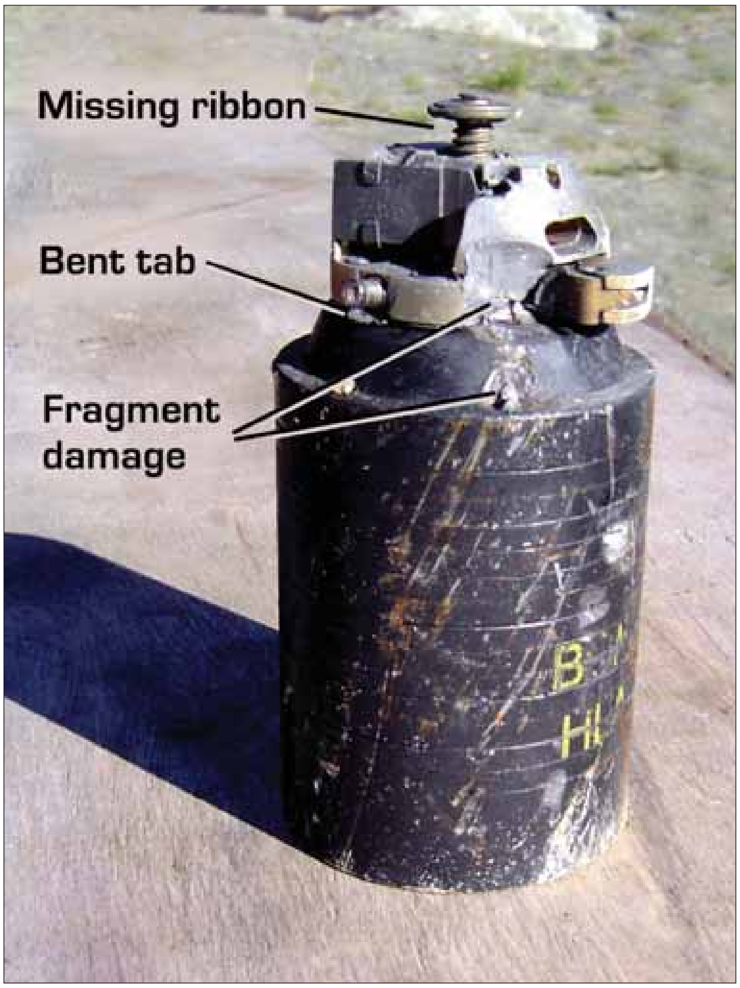

Figure 16: This dud bomblet from the Norwegian tests illustrates three of the major causes of failure. The ribbon has been torn off, excessive spin has caused the slide locking pin to bend over its retaining tab, allowing the spring to escape, and the bomblet has been damaged by fragments from nearby detonations. Photo: Colin King.

4.4.6. Malfunction of bomblet mechanical components

Examination of dud bomblets has shown that where damage to mechanical components prevented them from functioning it was often sustained as described above (i.e. during ejection or as a result of collision).

However, in other cases certain components have failed or been damaged during what appears to be routine deployment. Examples include:

- Bending of the retaining tab resulting in loss of the slide locking pin;
- The ribbon retaining clip remaining in place and preventing ribbon deployment;
- The slide becoming completely detached (lost) from the fuze body.

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[32] In the Norwegian tests up to ten bomblets from one projectile suffered air-detonation after push-out. This was an extreme event, while one or two air detonations were quite typical.

Spin is fundamental to the arming sequence of M85. Fuze components, such as the spring for the slide locking pin, have a fixed specification (in this case, a given ‘spring rate’). However, the force that they experience will vary with the spin rate (which is substantially dependent on the propellant charge and resultant muzzle velocity), and the location and orientation of the bomblet within the projectile. Some component failures appear to be due to excessive centrifugal force generated by a high spin rate, which have exceeded the design tolerance. The Norwegian test firings have shown that the higher the spin rate, the higher the failure rate; this means that projectiles fired on higher charges tend to dispense more dud bomblets.[33]

4.4.7. Malfunction of bomblet explosive components

In some examples, bomblets appear to have armed and impacted correctly on hard, level ground yet failed to detonate. This indicates a probable failure of the detonator. In these unexploded bomblets, the SD back-up has also failed.

Figure 17: In some fuzes, the pyrotechnic SD delay had burned, but had not initiated the bomblet; this means that both the primary impact mechanism and the SD mechanism had failed. Photo: Amir Musanovic/NPA.

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[33] 155 mm base-bleed cargo projectiles, such as the Israeli M396, the British L20A1 and the German DM662 – which all contain M85 bomblets - can be fired with a so-called super charge when using the 52 calibre barreled cannons that some states have (including Israel, the UK, Germany and Switzerland). As a result of the high muzzle velocity and spin rate, higher failure rates may then be expected. For more information, see Annex B and Section 5.1.3

Examination shows that in some cases the SD delay has begun to burn, but failed to cause detonation.

This is most likely to be caused by one of three reasons:

- The pyrotechnic delay has been extinguished at some point before completion;
- The delay has reached the detonator, but failed to initiate it, indicating a faulty detonator;
- The detonator has exploded, but failed to initiate the main charge.

As US army fuze specialist Leon Springer[34] points out, pyrotechnic fuze delays are notoriously sensitive to the effects of ageing and environment, making them potentially unreliable. In addition to factors such as chemical decomposition, the pyrotechnic train must also endure the extreme forces of set-back (during firing), spin and ejection.

During the South Lebanon research, around 50% of the M85 duds found from projectiles that had deployed normally were fully armed. In these cases both the primary and the SD fuzing have failed.[35]

In the Norwegian test firings of M85 in 2006, 74% of the SD mechanisms that were actually tested (meaning that the bomblet had armed and impacted, but not detonated through the primary fuze mechanism) functioned. In other words 1 in 4 of the tested SD mechanisms failed. For more information on this, see Section 5. The number of SD mechanisms actually tested was very low and the result is not statistically significant. However, earlier Norwegian tests had also shown the M85 SD mechanism to have a 70% to 80% reliability.

4.5. Conclusions

The analysis and observations listed above lead to the following conclusions:

- In most operational applications, a proportion of bomblets will fail due to factors beyond the control of the designer, such as human error, ageing and environmental conditions. This 'base' failure rate is further increased by those failures originating from design and construction.
- By comparison with other bomblets, the M85 was designed with care and built to a high standard, using good quality materials and modern processes, yet it still has a substantial failure rate in actual combat.
- Spin is fundamental to the arming sequence of M85, yet the rate of spin can vary substantially depending on the firing charge. The force experienced by components of an individual bomblet also depends on its location within the parent projectile and its orientation. The combination of these three factors creates a 'margin for error' apparently exceeding the design tolerances of the bomblet. The higher the spin rate, the higher the failure rate; this means that projectiles fired on higher charges tend to dispense more dud bomblets.
- Examination of bomblets that had successfully deployed, but failed to detonate, showed that many had sustained obvious mechanical damage originating either from a 'crimping effect' to the fuze during ejection, or from component failure (apparently caused by excessive spin). Others bore signs of collision or fragmentation impact from a nearby detonation with consequent interference to the arming process, prior to the movement of the slide, meaning that neither the impact nor the delay SD systems could function. This included several instances where the ribbon had failed to deploy, or had been torn off.
- In some cases, there was no obvious pre-impact damage and arming was complete. Here, a faulty explosive component seems to offer the best explanation as to why both initiation systems in a fully armed bomblet should fail to function.

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[34] Remarks made at the ICRC convened expert meeting on cluster munitions, Montreux, 19-20 April 2007

[35] See also Section 6.

- Given that the M85 is probably among the highest quality submunitions of its type in terms of production standards, it is unlikely that any similar mechanically fuzed bomblet will achieve significantly better results under operational conditions. Conversely, submunitions of poorer quality are likely to be even worse.
- While SD mechanisms may help to lower failure rates, this potential is limited and they are therefore not a full solution to the problems that cluster munitions cause.

These two pages show individual M85 duds found in Southern Lebanon.

5. Verifying reliability

The findings from South Lebanon undermine confidence in the claims made by respected producers and key stockpiling states about the quality and reliability of M85. In the light of past experience though, these findings should come as little surprise. There is a long history of confident and repeated assertions about the reliability of various types of non-SD bomblets, whilst these very same munitions caused extensive UXO problems in successive conflicts.[36] The inability of M85 in South Lebanon to meet the optimistic claims made about its reliability should serve as an important reminder that failure rates in combat conditions are always considerably higher than in tests.

Figure 18: Military EOD team searching for duds produced during the Norwegian tests at Hjerkinn in 2006. Photo: FFI

Figure 19: An NPA operator looking for duds at a cluster contaminated site in Bafliyah, South Lebanon, July 2007. Photo: Werner Anderson/NPA

The problem is not simply that tests do not accurately predict combat performance, but that decision-makers have sometimes based supposedly humanitarian policies on testing data that they do not understand. In several countries, politicians have placed great confidence in the test results they have been presented with, and have made statements and decisions about national policy accordingly.[37] Currently, some states are also proposing that the emerging international treaty on cluster munitions should define acceptability and non-acceptability by setting a maximum failure rate requirement, such as 1%. Regardless of the fact that such an arbitrary figure, achieved in tests, has little relevance to the likely post-conflict humanitarian impact, the problem would also remain of how to verify, in an accountable way, whether a given cluster munition met this standard or not. This would be an extremely complex approach which does not seem practicable as a basis for global legal control.

5.1. The limitations of testing and test results

In the following section, some of the most significant limitations of testing and test results are highlighted, with particular reference to tests done in 2006 at the Norwegian testing range at Hjerkinn in Norway on a sample of the Norwegian stockpile of M85[38] submunitions. The result of these tests was an average failure rate of just above 1%. The Norwegian trials are typical of common testing regimes for cluster munitions and may be amongst the most rigorous in terms of accuracy of data collection (this is not, however, to say that they are better than other testing regimes as a predictor of combat performance.) For more background on the Norwegian tests, see Annex I.

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[36] Claims about failure rates as low as 2%–6% have been the norm also for non-SD bomblets, whilst clearing organizations working in the field after conflicts have reported rates of 10%–30% and even higher (e.g. Southeast Asia, Kuwait, Kosovo and Serbia proper, Lebanon).

[37] Norway provides a good example: Confident in the information it had been presented with about the ‘less than 1% failure rate’ of its cluster munitions, in July 2004 the Norwegian government stated, during a meeting within the framework of the Convention on Conventional Weapons (CCW), that it had introduced a national “maximum limit of acceptable dud rate for bomblets” of 1%. It was further noted that “this limit will apply, regardless of the type of munition, regardless actual climatic conditions and regardless the terrain in the target area.” See Meeting of Governmental Experts on ERW July 2004. Military Experts Meeting 12 July. Intervention by Norway.

[38] Norway holds a stockpile of DM662 projectiles containing bomblets with the designation DM1385, which are in fact M85 bomblets. They have been given a Deutsche Model name because they have been incorporated into a Rheinmetall projectile. For the purposes of this report, DM1385 is referred to as M85.

5.1.1. Narrow parameters

Test conditions are considerably removed from real combat conditions. In tests, many of the factors of use and environmental conditions that greatly influence the actual UXO risk in an operational environment are removed; these include soft ground, dense vegetation, low or high temperatures, humidity, wind, transportation, storage and maintenance, and human error. In fact, test results may often represent the lowest failure rate that it is possible to achieve under controlled conditions.

It should therefore be accepted that the introduction of additional (untested) factors may increase failure rates. In other words, if bomblets are subsequently used outside the relatively narrow parameters of the test, the data may not be accurate and worse results should be expected. Thus, test results are not reliable indicators of the likely outcomes in conflict.

5.1.2. Ground conditions

Figure 20: The Norwegian testing range for cluster munitions at Hjerkinn. Photo: FFI

The ground conditions are a particularly unrealistic feature of common testing regimes. The tests in Norway are carried out against a flat surface covered with hard gravel. The ground that a bomblet falls on has been proven to be a crucial factor in the failure rate of impact fuzed bomblets. Use of cluster munitions in several conflicts have shown that when the ground is heavily vegetated or soft, i.e. snow, mud etc, the failure rate increases - because the impact with the ground is not sufficient to actuate the fuze. It has been argued that the ground conditions would not have an impact on the failure rate of bomblets with SD-mechanisms, because the SD would “take care of” any duds. In fact, tests of bomblets with SD mechanisms on hard ground are particularly unrealistic, because the ground conditions are likely to mean that the SD mechanisms are not substantially tested (due to a relatively good performance of the main impact fuze).

As a result of the low number of SD mechanisms actually put to the test (as described above) potential SD reliability problems do not become apparent and are not recognised. If the same bomblets were to fall on heavily vegetated or soft ground a much larger proportion of them would fail to function on impact, and thus a greater responsibility would be placed on the performance of the SD mechanisms. Only in these circumstances will the higher number of duds reveal problems with the SD function.

Given that SD is currently being portrayed by many states as an effective solution to the dud problem, the use of surfaces that favour impact fuzes is a particularly weak point in the testing regimes of Norway and others.

With the optical and acoustic testing equipment at Hjerkinn it is possible to register which detonations are caused by the primary fuze mechanism and which are caused by the SD. Of the 9,408 M85 bomblets tested during the comprehensive 2006 trial, there were 104 duds.[39] The remainder detonated. But only 26 of those 9,304 detonations were caused by the SD. In addition, 9 of the 104 duds left on the ground were armed - and this means that in those 9 cases the SD had failed to function as intended.[40] All in all, this means that a total of only 35 SD mechanisms were tested. This does not constitute a solid statistical basis for analyzing the effectiveness of the SD mechanism. In conclusion, if the same bomblets had been

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[39] See Annex I.

[40] Any firing of cluster munitions will result in a varying ratio of armed and unarmed bomblets. The SD mechanism of the M85 can only come into play if the bomblet has armed. Thus all bomblets that do not arm sufficiently become duds.

used in actual conflict against overgrown ground or softer soil, the failure rate would most likely have been considerably higher. It is also important to note that this means that if the same munitions used in the Norwegian tests had not had SD mechanisms, only 26 more duds would have been produced and the average failure rate would have been 1.38% instead of 1.11%.

5.1.3. Propellant charges

Figure 21: Firing of cargo projectiles during the 2006 tests at Hjerkinn. Photo: Fredrik Neumann

The tests in Norway demonstrated that the propellant charge used for firing of the cargo projectiles has a significant bearing on the failure rate.[41] The higher the charge, the higher the failure rate – because a high charge causes a higher muzzle velocity, resulting in a higher spin rate and consequently greater centrifugal forces and stress on the bomblets.

The highest charge in the Norwegian test was 5M,[42] because the maximum number of charge modules in the 39 calibre barrels[43] of the Norwegian cannons is five, with a resultant muzzle velocity of 791 m/s.

When firing the same cluster munitions with the 52 calibre barrels of the UK, Israel, Germany and Switzerland, the propellant charge 6M can be used, increasing the muzzle velocity to 930 m/s. Thus higher failure rates than in the Norwegian tests can be expected with guns having 52 calibre barrels. For more information, refer to Annex B.

5.1.4. Averages

The average failure rate for M85 in the Norwegian 2006 tests was 1.11%, and this was the figure that was publicised. However, the failure rate with propellant charge 5M was 1.47.[44]

States proposing an international treaty based on a maximum failure rate requirement for cluster munitions would have to make it clear whether average failure rates will be sufficient proof of compliance. If so, they must consider whether it should be acceptable to substantially exceed the maximum failure rate requirement in one situation, so long as other situations bring the average down below the threshold.

The true meaning of an average failure rate is not always clear. In the past, problematic national practices have included combining completely different sets of test results in order to calculate a favourable mean failure rate.[45]

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[41] The Norwegian 2006 test firings indicated that the failure rate increased significantly when the spin rate exceeded around 160 rps.

[42] The amount of propellant used to fire each projectile can be altered to help achieve different ranges; 5M refers to the number of modules of propellant used, in this case the DM72 charge system.

[43] Barrel length is often quoted as a multiple of the caliber.

[44] For more details, see Annex I.

[45] See Landmine Action (2006) *Failure to protect: A case for the prohibition of cluster munitions*. Page 23. In a letter of 27 March 2006 from UK MoD to Landmine Action it combined the 2.3% test result from the 2005 trial in Norway with another set of data gathered during "acceptance proof" testing showing a failure rate of 0.74%. On this basis they asserted that "across both in-service and proof tests the failure rate is 1.9 percent".

5.1.5. Statistical significance

In order to statistically prove a reliability of 99%, the size of the required test sample (the number of bomblets tested) will have to be large.

Many claims about low failure rates are based on tests of samples too small to have sufficient statistical significance. A test of 10,000 bomblets is a very comprehensive test by current standards, but may often actually be a too small sample from which to make claims with statistical significance about a failure rate lower than for instance 1%. For more information on the statistical aspects of testing, refer to Annex J.

Small sample sizes are often a consequence of the high costs involved in ammunition trials. Many countries also do not have very large stockpiles of cluster munitions from which to take the test samples. This is particularly relevant to advanced cluster munitions, such as sensor-fuzed weapons. In this case, the cost of live-fire testing with statistical significance would be prohibitively expensive.

5.1.6 Lack of transparency

An additional problem is that most manufacturers and states are not willing to publicise their testing data and details of testing parameters. On the rare occasion that they do so, the data is often very vague.[46]

The number of factors that influence test results are numerous. Testing parameters also differ from manufacturer to manufacturer and from state to state. Test results therefore have limited value unless both the test parameters and the basis on which they were interpreted are known. Unqualified data should be treated with the greatest caution.

5.2. Is it possible to have more realistic testing?

At an ICRC expert meeting on cluster munitions in Montreux in April 2007, a prominent theme was the apparent rarity of testing under simulated battlefield conditions. In its report on the meeting, ICRC wrote that “the absence of battlefield conditions in testing was viewed as a very striking and important point,”[47] and that “some participants felt that the absence of testing in realistic conditions undermined testing as a reliable indicator on how submunitions would function when actually used.”[48]

Leon Springer, Director of the US Army Fuze Management Office, Picatinny Arsenal, USA said in his address to the Montreux meeting that:

> *“Testing is a significant challenge. End product tests are required and are made as comprehensive as feasible but cannot economically consider all use conditions. If there are failures, the products may not be recovered for analysis and if they are, they are heavily damaged, making investigation of the failure extremely difficult. Therefore, investigating failures is also a challenge. Testing for ageing is also a challenge because there is no test that can adequately substitute for actual ageing.”*[49]

The improvement of testing has major implications for resources (cost, personnel, time, equipment, land etc), safety and environmental impact. For example, if a state were to regularly test cluster munitions in densely vegetated environments, the increased failure rates would present a significant challenge in terms of the cost, duration and safety of subsequent clearance operations.

Furthermore, in order for tests to be implemented scientifically they must take place in a controllable and monitored environment. Some manufacturers and governments claim that they have conducted tests

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[46] The Norwegian Government and Army’s openness about the 2006 test results and their willingness to engage in a dialogue about their quality was a display of transparency which may not be expected in many countries.

[47] ICRC (2007) *Expert Meeting on Humanitarian, Military, Technical and Legal Challenges of Cluster Munitions*, page 47

[48] Ibid, page 46.

[49] Leong Springer, address to the Expert Meeting held in Montreux, Switzerland, 18-20 April 2007.

against various kinds of ground and vegetation.[50] Given the large range of environmental factors and the almost limitless number of possible permutations, testing can never be comprehensive. The question is whether it is practical to make trials more representative of field conditions (unless on very small scale with low statistical confidence) while also accurately registering exactly how many duds are produced and what condition they are left in.[51] Identification and analysis of duds might then require excavation from deep snow, mud, thick vegetation etc. Experience from actual clearance work demonstrates that this is time consuming, resource intensive and dangerous work (see Figures 18 and 19).

Prevailing weather conditions, which may be a significant factor in submunition performance, also add a further challenge to the conduct of trials. The 2006 Norwegian tests were suspended for one day due to winds over 20 knots. This suspension was not ordered because of the effect that wind would have on the bomblets, but because the noise from the wind hampered the acoustic monitoring of the explosions.

5.3. Greater discrepancy between testing and operational performance for submunitions than for other munitions

All types of ammunition are likely to perform better during trials than in combat. However, the characteristics of most submunitions - especially DPICM - make them particularly vulnerable to environmental changes. Thus, the discrepancy between testing and combat performance may be greater for submunitions than for other ordnance. Factors that may make DPICM more vulnerable to environmental changes include:

- DPICM, with a low mass and terminal velocity, have far less inertia than ordnance such as artillery shells, mortar bombs or air-dropped bombs. This means that, for example, vegetation or superficial soft ground that would barely affect the impact of larger munitions can cause DPICM to malfunction.
- While DPICM ribbons can get caught up in structures and vegetation, this failure mechanism is not present with other types of ammunition.
- Time fuzing, which is almost exclusively used for cargo ammunition, is an additional parameter for the gun crew to control – providing greater potential for human error.
- Linked to the time fuzing of cargo ammunition, steep slopes in the target area introduce another significant factor. Here, a small mapping or range calculation error can lead to a substantial altitude difference. If the ejection height is too low bomblets may have insufficient time to arm; in a unitary munition, this is not normally a factor.

5.4. The prospects of a quality-based solution

All efforts to improve the reliability of munitions should, of course, be encouraged. However, an international legal control regime based on an arbitrary quality standard (e.g. 1%,),[52] assessed in tests that bear little relation to reality, will be unrealistic and impossible to implement effectively. This should be clear from the points emphasized above about the serious limitations of testing and test results - the tools used to measure the quality of cluster munitions.

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[50] For example, in 1999 Norway once carried out tests where spruce trees were planted on the testing ground at Hjerkinn. No bomblets were registered as having been caught in the trees and it was concluded that the vegetation had no impact on the failure rate. However, the foliage on spruce trees is very different from, for example, the olive trees in Lebanon, where a large number of bomblets have been caught.

[51] Analysis of each and every dud would be particularly important to tests that seek to establish the so-called 'hazardous dud rate'. See Section 6 for more detail on this.

[52] Landmine Action's Richard Moyes has commented that there are strong grounds for suspecting that the 1% standard has been made up in an arbitrary manner without any consideration of either how it related to reality of civilian harm (the problem that it purportedly solves) and without consideration of how it would be interrogated. The most probable explanation is that the standard has been set because producers and users have determined that 1% is the lowest failure rate reasonably achievable under test conditions and therefore it sets a sufficiently challenging target for them. This approach would not seem to be consistent with a strong commitment to addressing civilian harm from cluster munitions. See "Testing of M85 Submunitions. Comments from Richard Moyes", September 2006.

In order to have any credibility, a treaty prohibition based on a maximum failure rate requirement would have to be accompanied by elaborate international testing criteria and transparency requirements, as well as an unusually comprehensive verification and monitoring system. Few states and producers would be amenable to this and compliance would be difficult, if not impossible, to ensure.

Some states have indicated that simply the presence of an SD in the bomblets should be a satisfactory requirement.[53] As this report has shown, even well-designed SD mechanisms have not proven their ability to substantially improve reliability. Permitting any manufacturer to legitimise their bomblets by the simple addition of an SD function, which may or may not be reliable, would do little to solve the humanitarian problems associated with these weapons.

If an international prohibition were based solely on requirements for SD mechanisms and/or a maximum failure rate it is very unlikely that it would solve the post-conflict humanitarian problems associated with these weapons. Such an outcome might even effectively legitimize a problematic class of weapons, resulting in greater overall usage. [54]

Even if such an approach were successfully adopted, it would only address the post-conflict problems caused by cluster munitions and would no nothing to limit the indiscriminate area effect of the cluster munitions at the time of use.

5.5. Conclusions

- Common testing regimes tend to produce very optimistic indications of performance; test results are therefore misleading as predictors of the actual risk to civilians.
- Operational failure rates result from a combination of ‘systematic’ failures along with malfunctions due to human error or improper use, and a complex array of environmental factors, including the effects of ageing. It is extremely difficult adequately to represent these ‘real world’ considerations within a scientifically controlled and practicable testing program.
- The characteristics of many submunitions - particularly those of the DPICM family - make them particularly vulnerable to environmental changes. Thus, the discrepancy between testing and operational performance is greater for submunitions than for other ammunition.
- Test results for submunitions with SD mechanisms are particularly unrealistic because the hard ground conditions favour the impact fuze, leaving the SD device largely untested.
- The inability of M85 testing to give an accurate indication of combat condition failure rates highlights the difficulties involved in verification of reliability. A quality-based international prohibition - with requirements for SD mechanisms and/or a maximum failure rate requirement - would be fraught with problems. It is hard to envisage a robust, functional verification and monitoring system for such a prohibition, and implementation would then be left to the discretion of each individual state and manufacturer.
- If a quality-based international prohibition were adopted it is unlikely that it would solve the post-conflict humanitarian problems associated with these weapons.

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[53] E.g. the UK has prepared a non-paper entitled “Proposed Draft Text for an Instrument” which proposes to prohibit “cluster munitions that contain Basic Sub-Munitions: i.e. sub-munitions that contain explosives but no [...] fail-safe mechanism.”

[54] HRW has pointed out that ironically the fact that the British forces in Southern Iraq were using the new M85 bomblets with the promise of a low failure rate only “lulled” them “into taking less care when using it”. See HRW (2003) *Off Target: The Conduct of the War and Civilian Casualties in Iraq*, page 97.

6. Non-hazardous duds?

A 'dud' is any bomblet that has not exploded as intended on impact with the target area and has remained on or under the ground as UXO. Some manufacturers and states attempt to differentiate between what they call 'hazardous' or 'dangerous' duds on the one side (meaning duds that are armed),[55] and 'non-hazardous' or 'non-dangerous' duds on the other side (meaning unarmed duds). However, there is widespread consensus amongst ordnance disposal specialists that this terminology is misleading and potentially dangerous. Such terminology fails to take into consideration that, in reality, duds are left on the ground in a wide variety of states presenting different levels of risk and volatility and that any munition containing high explosive is inherently dangerous. It is therefore an over-simplification of a complex reality.

The arming of bomblets is not a simple on-off process. As was explained in Section 4, there are many reasons why the arming sequence of a bomblet may be interrupted, causing it to fail. Similarly, the arming process may be completed by subsequent actions (such as when a dud is handled by civilians) resulting in detonation. Testing of unarmed M85 duds exposed to various forces confirms that this is the case.

6.1. The 'hazardous dud rate' approach

The 'hazardous/dangerous dud rate' approach asserts that a cluster munition's acceptability should be determined in tests, solely on the basis of those duds that are considered fully armed (not on the overall number of remaining duds). This is an extension of the 'quality' approach discussed in the Section 5, but this policy is even more disconnected from post-conflict reality. The implications of this approach are illustrated by the following theoretical example:

- If a sample of 5,000 bomblets are tested and 350 duds are left on the ground after the trial firings, then this represents a 'failure rate' of 7%.
- If 35 out of those duds are armed and the remaining 315 unarmed, then the 'hazardous dud rate' in this case is 0.7%.[56]

These are completely different figures but they refer to the same situation. The 315 duds that are not counted when using the 'hazardous dud rate' approach will still constitute an explosive threat present in the post-conflict environment.

This approach has been incorporated in a draft protocol on cluster munitions introduced by the German Government in the context of the UN Convention on Conventional Weapons (CCW).[57] This protocol proposes an immediate cessation in the use of "cluster munitions which contain submunitions of a dangerous dud rate of one percent or more"[58] Needless to say, it is considerably easier to satisfy a reliability requirement of a 'hazardous/dangerous dud rate' of 1%, than an overall 'failure rate' of 1%. Many more cluster munitions would pass the first trial than the second. If an international requirement of a maximum 'hazardous dud rate' of 1% were to be fixed, then it is not inconceivable that tests might even accredit some of the 'worst offender' non-SD bomblets (those known to have caused particularly serious UXO problems in the past.) A maximum 'hazardous dud rate' requirement of 1% would allow for a total failure rate that is many times higher - as much as 10% or more.[59] Such an approach is based on the fundamental fallacy that unarmed duds do not present a post-conflict hazard. As concluded at the ICRC Expert Meeting in Montreux, this approach should be recognised as being misleading and dangerous.

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55 The position of the slide normally indicates whether an M85 bomblet is armed or not. If the slide is fully extended (bringing the detonator into line beneath the striker), then the fuze is armed; if the slide has not moved, and is aligned at both ends with the faces of the fuze body, then the fuze is unarmed. The locking pin can also lock the slide in a midway position if there is insufficient spin or slide movement. In any firing of cluster munitions some of the bomblets will arm and others will fail to arm. All bomblets that fail to arm will become duds, since the SD mechanism can only function on armed bomblets. Among the bomblets that arm, some will detonate as intended on impact with the target area, others will not. The SD ensures that a proportion of the bomblets that fail to detonate on impact, are still brought to detonation. But often the SD mechanism also fails. There will therefore always be a varying ratio of armed and unarmed duds.

56 The 'hazardous dud rate' will invariably be lower than the total 'failure rate' since only armed duds are counted. It is not uncommon that there are less armed duds than unarmed duds after a firing with cluster munitions. In the Norwegian 2006 tests for example, only one in ten duds were armed (see Section 5.1.2).

57 CCW/GGE/2007/WP.1, 1 May 2007

58 CCW/GGE/2007/WP.1, 1 May 2007 (emphasis added).

59 10% is provided as an example here based again on a 1:10 ratio of armed to unarmed duds from Norwegian M85 tests.

Putting 'non-hazardous' duds to the test

When unarmed and so-called 'non hazardous duds' were exposed to sensitivity tests in Norway, a large portion of them exploded. The objective of the sensitivity tests was to analyze how prone unarmed duds from the 2006 trial firings would be to explosion when disturbed. It should be emphasized that FFI, which designed the tests, believed from the outset that the trials would prove that the unarmed duds would **not** explode when disturbed: however, contrary to expectations, the tests demonstrated quite the opposite.

The trials included 95 M85 duds and 41 DM1383 duds, all of which were unarmed. They went through a set of tests designed to reflect different actions that civilians might consciously, or inadvertently, subject duds to.

The most interesting result was produced when duds were put in a cement mixer, which would run for up to 30 minutes, to reflect rough handling and/or transport. Some 24% of the unarmed and so-called 'non-hazardous' duds exploded in the cement mixer test (32 of a total of 133 tested). Breaking this down into bomblet types, 19.4% of the M85 duds exploded (18 of 93), and 35% of the DM1383 duds exploded (14 of 40 tested). See Figure 22 and refer to Annex K for more information on the sensitivity tests of unarmed duds.

According to IMI, M85 has a "safety mechanism" which "prevents inadvertent arming of duds by manual means." This safety mechanism refers to the spring-loaded locking pin which keeps the slide in place and which is claimed to require high centrifugal forces to move. The cement mixer test however showed conclusively that although the M85 fuze is designed to 'fail-safe' if it does not arm for any reason, the arming sequence can be recommenced by an external stimulus, through to detonation.

The low spin rate in the cement mixer is unable to move the locking pin and the slide, but the combination of the low spin rate, impulsive loads and the vibration was apparently sufficient to do so. This combination is comparable to what a dud might be exposed to during transportation.

The slide can also be moved without any spin at all, as a result of the unarmed bomblet being jolted. This was confirmed by holding individual inert bomblets by the ribbon and striking them with a hammer (see figure 23.) Contrary to IMI's claims, and to most expectations, one light blow can be sufficient to arm a bomblet.

With respect to the 'safety mechanism' on M85, it should be noted that it is easy for somebody, such as a curious child handling a bomblet, to manually open the small retaining tab on the side of the fuze. With the spring compression removed and the slide locking pin released, the bomblet is then free to arm. As mentioned in Section 4, analysis of M85 duds in Lebanon, and those from the Norwegian test firings recorded the bending or breaking of this tab, and consequent release or loss of the locking pin, as a common problem. See Figures 24 and 25.

Figure 23: Tests with inert bomblets have shown that one hammer strike to the body of an M85 dud can be sufficient to make it arm. Photo: Ove Dullum/FFI.

Figure 22: A total of 32 cement mixers were blown to pieces by unarmed and so-called 'non-hazardous' duds during sensitivity tests in Norway, which included both M85 duds and DM1383 duds. 1 in 4 of the unarmed duds exploded during the cement mixer tests. Photo: Grethe Østern/NPA

6.2. “0.06%”

Specifically, while some actors talk about a less than ‘1% failure rate’ for M85 bomblets others refer to tests that show a “0.06% hazardous dud rate.”[60] This undoubtedly creates confusion.

The “0.06% hazardous dud rate” is a claim that the SD-mechanism in M85 works so well that it “takes care of” virtually all armed duds. This assertion is contrasted by evidence on the ground in South Lebanon, where approximately half of all the M85 duds produced as a result of normal deployment and analyzed during research for this report, were armed. As previously explained, this study warns against the practice of distinguishing between armed and unarmed duds, and against the concept of ‘hazardous dud rates’. However, purely for the sake of comparison, it is worth pointing out that the ‘hazardous dud rate’ then appears to be around 5% in Lebanon – 83 times higher than the 0.06% claim.

Statistically, 0.06% is such a low figure that it demands more detailed information about the testing protocols. It is for instance not possible to claim a rate below 0.1% if the test sample consists of only 1,000 bomblets. If the sample size is 10,000, it may be claimed that the failure rate is less than 0.06% only if no more than one failure (one armed dud) is observed among all the 10,000 tested bomblets. For more information about the statistical aspects of testing and required test samples, refer to Annex J.

Figures 24 and 25: (Above) An example of an M85 dud found at site CBU 601 Alpha where the retaining tab for the locking pin has broken away at some stage during the bomblet’s deployment. The spring in front of the locking pin is missing, and the locking pin exposed. (Right) At the same site, two separated locking pins were found during the research clearance. Photos: Amir/Musanovic/NPA

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[60] See, for example, letter from IMI dated 14/02/2007 to Australian Senate Standing Committee Inquiry into Cluster Munitions (Prohibition Bill). This submission also exploited the confusion between ‘failure rate’ and ‘hazardous dud rate’. See page 1 of the submission, where the 0.06% ‘hazardous dud rate’ for M85 is compared with what are obviously overall failure rate figures for other submunitions: *“Our testing suggests that the M85 cluster device has hazardous dud rate of 0.06%, compared with rates reported by the UN from American M42, M46 and M77 devices of 20-40 percent.”*

6.3. Conclusions

- It is misleading to draw a distinction between ‘hazardous’ and ‘non-hazardous’ duds. All duds are inherently hazardous both to deminers and to the post-conflict civilian populations that are left to deal with them.
- The sequence of events required for bomblet arming can be stopped at any point, by a wide variety of causes. In many instances, it can then be recommenced (by an external stimulus) through to detonation. It is therefore a dangerous over-simplification to suggest a distinction between ‘hazardous’ and ‘non-hazardous’ duds on the basis of whether they are armed or unarmed; an unarmed dud does not equate to it being ‘non-hazardous’.
- Sensitivity testing examined in this report has shown that bomblets, including M85, in an unarmed state are capable of being brought into an armed state and then detonated by exposure to forces equivalent to rough handling or transportation of these items.
- The concept of a ‘hazardous dud rate’ is also misleading, and often used in a confusing way. Manufacturers and states that continue to insist on using this term should make it clear that they are not referring to the total numbers of duds produced in tests.
- A ‘failure rate approach’ will not provide an effective indicator of the risk to civilians that will be produced by specific cluster munitions in combat. A ‘hazardous dud rate’ approach would be even less useful or effective. An international treaty based on a maximum ‘hazardous dud rate’ would be even more difficult to implement and monitor than one based on a maximum failure rate – and would have even less relevance to the post-conflict humanitarian impact.

Annex A: Known cluster munitions with bomblets from the M85 family

Carrier	Design code	System	Country	No. of bomblets	Remarks
M116		105 mm T	IL	15	Export only
M116		105 mm T	IL/US	42	Hornet-5. Export only
M335	CL3153	122 mm T	IL	24	
		127 mm T	IL	45	Hornet-5
M347	CL3115	130 mm T	IL	24	
M350	CL3150	152 mm T	IL	49	
M351	CL3162	152 mm T	IL	56	
M395	CL3109	155 mm T	IL	63	
M396	CL3013-G-A2	155 mm T	IL	49	Base-bleed
M397	CL3013-U-A2	155 mm T	IL	49	Base-bleed
	CL3013-E1	155 mm T	IL	49	Base-bleed
M366	CL3014	175 mm T	IL	81	
M373	CL3046-A1	203 mm T	IL	120	
L20A1		155 mm T	UK	49	Base-bleed. Similar to M396
DM632		155 mm T	GE	63	Similar to M395
DM662		155 mm T	GE	49	Base-bleed. Bomblet DM1385
KaG-88		155 mm T	SU	63	M85
KaG-90		155 mm T	SU	49	Modified M85
KaG-88/99		155 mm T	SU	84	Short M85
MP-98		120 mm M	SU	32	Short M85
M396		155 mm T	TU	49	
MOD258		120 mm M	TU	16	M87
M26A1		227 mm R	US	518	MLRS
M30		227 mm R	IL/US	404	GMLRS
Unknown		160 mm R	IL	104	LAR-160
Unknown		350 mm R	IL	350	MAR-350
CG-540		152 mm T	RO		
Unknown		214 mm R	IN		Picacha rocket
M970/		120 mm M	IL	20	M87
M971*	CL3144	120 mm M	IL	24	M87
M971*/MP98		120 mm M	SU	32	M87

T = tube artillery, R = rocket artillery, M = mortar
*According to www.globalsecurity.org there is also a third M971 for 120 mm mortar with IMI/Alliant connections. It has 54 bomblets, probably of 31 mm diameter.

Annex B: Ballistic data for the M396 cargo projectile

The M85 bomblets found during the research for this report were all delivered by 155 mm IMI cargo projectiles designated CL 3013-E1. These contain 49 bomblets and correspond to the M396 extended range projectile with base-bleed.[61] According to IMI the maximum range of the M396 projectile is 30 km using a 39 calibre barrel and 36 km using a 52 calibre barrel.[62] According to Jane's Ammunition Handbook the weight of the projectile, including the fuze, is 42.7 kg and the muzzle velocity (presumably in a 39 cal. barrel) is 840 m/s. It is assumed that the aerodynamics of M396 are very close to those of the parallel German cargo projectile, DM662.

It is not known exactly what charge system IDF used for M396 during the conflict in Lebanon, but it is common practice to fire base-bleed projectiles with high charges only. For firing against targets at short range, non base-bleed projectiles are normally used and IDF has such a projectile; the M395 containing 63 M85 bomblets.[63] Assuming that M396 can be fired with a medium charge with a muzzle velocity of 650 m/s, a high charge with a muzzle velocity of 840 m/s, and a super charge when using a long barrel giving a muzzle velocity of 930 m/s, the properties of the projectiles will be as shown in the table below.

Range type	Muzzle Velocity	Range	Elevation	Spin rate at push-out	Time of flight	Angle of fall	Velocity at push-out
Minimum Maximum	650 m/s	14.0 km 21.2 km	18.7° 47.5°	162 rps 147 rps	33 s 77 s	24.8° 59.8°	321 m/s 337 m/s
Minimum Maximum	840 m/s	19.5 km 30.0 km	17.6° 52.8°	195 rps 185 rps	40 s 104 s	28.7° 68.0°	327 m/s 368 m/s
Minimum Maximum	930 m/s	27.0 km 36.1 km	25.5° 52.3°	210 rps 203 rps	61 s 113 s	46.1° 67.4°	332 m/s 391 m/s

Table B1: Some assumed ballistic parameters for M396 using data for DM662

Impact of ballistic parameters on bomblet failure rates:

- **Rate of spin:** During the Norwegian tests, it was observed that the dud rate increased when the spin rate during push-out exceeded 160 rps. It is suspected that this is caused by the high load suffered by the bomblets during push-out (see 4.4.4). As the table above shows, the spin rate is strongly dependent on the muzzle velocity, which in turn is dependent on the propellant charge. The higher the propellant charge, the higher the muzzle velocity and the spin rate. The spin rate is the only parameter that can substantially affect the push-out process. Even though 14 km may be claimed as a minimum recommended range for base-bleed shells, it is still possible to use such projectiles at shorter range without a substantial degradation of performance. Using high charges at short ranges will cause somewhat higher spin rate at push-out as the spin decreases slowly throughout the trajectory.
- V**elocity at push-out:** Although the air drag on the bomblets will be greater at higher velocities, it does not appear that this should significantly affect bomblet reliability. In addition, when firing at ranges beyond 15–20 km, the velocity at push-out does not vary too much.
- **Angle of fall at push-out:** The angle of fall at push-out is measured between the projectile axis and the horizon. It concerns only the orientation of the projectile and does not affect either the centrifugal forces or air drag on the bomblets. Angle of fall at push-out should therefore not affect bomblet reliability.
- **Height at push-out:** Bomblet performance may be affected if the height at push-out is less than around 200 m. Below this level bomblets will impact with a higher velocity and at a more oblique angle. Push-out heights above normal levels should not affect reliability, unless it is so high that the SD functions before impact. Such events will occur if the push-out height exceeds approximately 700 m.

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[61] The term base-bleed refers to a propulsive element in the base of the projectile whose role is to generate gas in the vortex, or wake, behind the projectile during flight. The pressure of this gas reduces the drag and thereby extends the range of the projectile. The addition of a base-bleed unit will typically increase the range of a projectile by 20 – 25%.

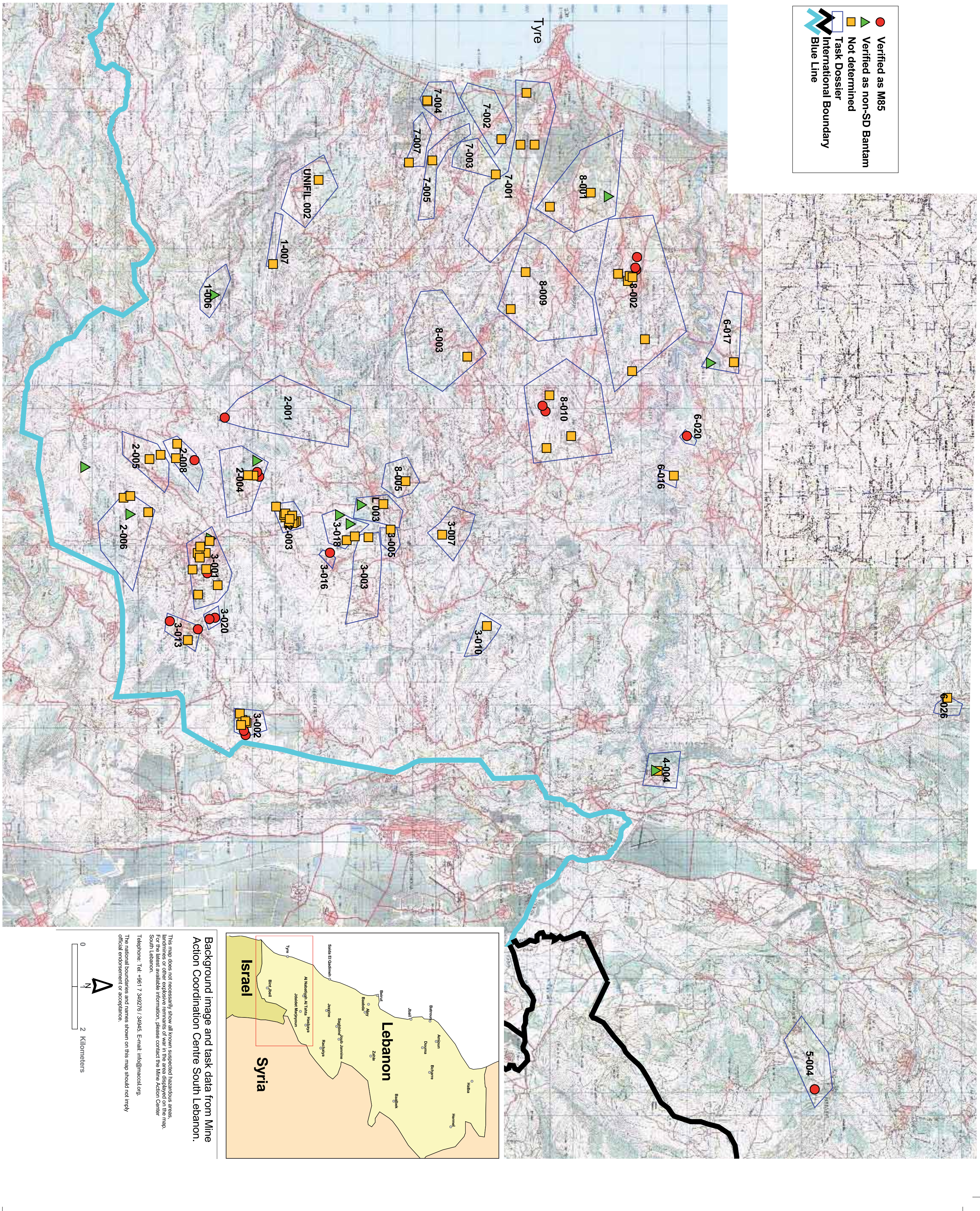
[62] IMI website: http://www.imi-israel.com/Business/ProductsFamily/Product.aspx?FolderID=32&docID=412 last accessed 28 November 2007.

[63] There is no evidence of non-base-bleed carriers of M85 being used in South Lebanon.

Annex C: Comparison between bomblets

M85 (SD) **Bantam (non-SD)** **M77 (non-SD)**

Annex D1: Sites where either M85 or non-SD Bantam have been used: Map



Background image and task data from Mine Action Coordination Centre South Lebanon.

This map does not necessarily show all known suspected hazardous areas, landmines or other explosive remnants of war in the area displayed on the map. For the latest available information, please contact the Mine Action Center South Lebanon.

Telephone: Tel: +961 7 349276 / 34945. E-mail: info@maccsl.org.

The national boundaries and names shown on this map should not imply official endorsement or acceptance.

Annex D2: Sites where either M85 or non-SD Bantam have been used: List*

Task Dossier	Dangerous Area Name	Status	IMSMA ID	XUMTN36	YUTMN36	REFPTLAT	REFPTLONG
1-006	CBU-799	Non-SD Bantam	LB-2993	716024	3668319	33,132100	35,315700
1-007	CBU-603	Not determined	LB-2797	714689	3670863	33,155300	35,302000
2-001	CBU-622	M85	LB-2816	721419	3668750	33,134900	35,373600
2-003	CBU-15	Not determined	LB-2209	726013	3671552	33,159200	35,423500
2-003	CBU-229	Not determined	LB-2423	725711	3671700	33,160600	35,420300
2-003	CBU-230	Not determined	LB-2424	725950	3671861	33,162000	35,422900
2-003	CBU-231	Not determined	LB-2425	726008	3671784	33,161300	35,423500
2-003	CBU-232	Not determined	LB-2426	726056	3671708	33,160600	35,424000
2-003	CBU-233	Not determined	LB-2427	726041	3671552	33,159200	35,423800
2-003	CBU-234	Not determined	LB-2428	725994	3671551	33,159200	35,423300
2-003	CBU-235	Not determined	LB-2429	725793	3671391	33,157800	35,421100
2-003	CBU-236	Not determined	LB-2430	725701	3671333	33,157300	35,420100
2-003	CBU-379	Not determined	LB-2573	725615	3671398	33,157900	35,419200
2-003	CBU-380	Not determined	LB-2574	725711	3671700	33,160600	35,420300
2-003	CBU-382	Not determined	LB-2576	725863	3671592	33,159600	35,421900
2-003	CBU-807	Not determined	LB-3001	725317	3670992	33,154300	35,415900
2-004	CBU-820	M85	LB-3014	723999	3670262	33,148000	35,401600
2-004	CBU-821	M85	LB-3015	723805	3670169	33,147200	35,399500
2-004	CBU-822	Not determined	LB-3016	723958	3669995	33,145600	35,401100
2-004	CBU-823	Not determined	LB-3017	723954	3669762	33,143500	35,401000
2-004	CBU-863	Non-SD Bantam	LB-3078	723291	3670191	33,147500	35,394000
2-005	CBU-795	Not determined	LB-2989	723240	3665463	33,104900	35,392300
2-005	CBU-841	Not determined	LB-3035	723042	3665946	33,109300	35,390300
2-006	CBU-816	Not determined	LB-3010	725567	3665405	33,103900	35,417200
2-006	CBU-818	Non-SD Bantam	LB-3012	725641	3664641	33,097000	35,417800
2-006	CBU-850	Not determined	LB-3045	724938	3664314	33,094200	35,410200
2-006	CBU-851	Not determined	LB-3046	724866	3664612	33,096900	35,409500
2-008	CBU-190	Not determined	LB-2384	722569	3666657	33,115800	35,385400
2-008	CBU-725	M85	LB-2919	723279	3667427	33,122600	35,393200
2-008	CBU-840	Not determined	LB-3034	723205	3666616	33,115300	35,392200
3-001	CBU-59	Not determined	LB-2253	728081	3667328	33,120700	35,444600
3-001	CBU-518	Not determined	LB-2712	729186	3667586	33,122800	35,456500
3-001	CBU-519	M85	LB-2713	728234	3667986	33,126600	35,446400
3-001	CBU-527	Not determined	LB-2721	728067	3667937	33,126200	35,444600
3-001	CBU-559	Not determined	LB-2753	727348	3667910	33,126100	35,436900
3-001	CBU-560	Not determined	LB-2754	728765	3668442	33,130600	35,452200
3-001	CBU-567	Non-SD Bantam	LB-2761	726699	3668150	33,128400	35,430000
3-001	CBU-806	Not determined	LB-3000	726840	3668086	33,127800	35,431500
3-001	CBU-817	Not determined	LB-3011	727083	3667670	33,124000	35,434000
3-001	CBU-774	Not determined	LB-2968	727430	3667623	33,123500	35,437700
3-001	CBU-775	Not determined	LB-2969	727364	3667633	33,123600	35,437000
3-001	CBU-776	Not determined	LB-2970	727347	3667555	33,122900	35,436800
3-001	CBU-777	Not determined	LB-2971	727560	3667659	33,123800	35,439100
3-002	CBU-61	Not determined	LB-2255	734739	3669649	33,140200	35,516500
3-002	CBU-367	Not determined	LB-2561	734761	3669527		35,516700

Task Dossier	Dangerous Area Name	Status	IMSMA ID	XUMTN36	YUTMN36	REFPTLAT	REFPTLONG
3-002	CBU-569	Not determined	LB-2763	734803	3669706	33,140700	35,517200
3-002	CBU-570	Not determined	LB-2764	734668	3669514	33,139000	35,515700
3-002	CBU-571	Not determined	LB-2765	734400	3669397	33,138000	35,512800
3-002	CBU-808	M85	LB-3002	735336	3669663	33,140200	35,522900
3-002	CBU-809	M85	LB-3003	735151	3669592	33,139600	35,520900
3-002	CBU-810	Not determined	LB-3004	734902	3669453	33,138400	35,518200
3-003	CBU-564	Not determined	LB-2758	726660	3675029	33,190400	35,431300
3-005	CBU-616	Not determined	LB-2810	726321	3675997	33,199200	35,427900
3-007	CBU-373	Not determined	LB-2567	726557	3678255	33,219500	35,431000
3-010	CBU-617	Not determined	LB-2811	730559	3680213	33,236300	35,474400
3-013	CBU-529	Not determined	LB-2723	731167	3667123	33,118200	35,477600
3-013	CBU-609	M85	LB-2803	730690	3667577	33,122400	35,472600
3-013	CBU-1026	M85	LB-3244	730336	3666348	33,111400	35,468500
3-016	CBU-1065	M85		727331	3673345		
3-018	CBU-562	Not determined	LB-2756	726794	3674089	33,181900	35,432500
3-018	CBU-563	Not determined	LB-2757	726628	3674429	33,185000	35,430800
3-018	CBU-757	Non-SD Bantam	LB-2951	726072	3674260	33,183600	35,424800
3-018	CBU-758	Non-SD Bantam	LB-2952	725672	3673796	33,179500	35,420400
3-020	CBU-804	M85	LB-2998	730186	3668331	33,129300	35,467400
3-020	CBU-805	M85	LB-2999	730239	3668088	33,127100	35,467900
4-004	CBU-216	Not determined	LB-2410	736914	3687690	33,302300	35,544500
4-004	CBU-228	Non-SD Bantam	LB-2422	736878	3687623	33,301700	35,544100
5-004	CBU-955	M85	LB-3173	750865	3694556	33,361000	35,696100
6-016	CBU-497	Not determined	LB-2691	723955	3688393	33,311400	35,405600
6-017	CBU-126	Not determined	LB-2320	718986	3691009	33,336000	35,352900
6-017	CBU-489	Non-SD Bantam	LB-2683	719008	3690033	33,327200	35,352900
6-020	CBU-679	M85	LB-2873	722209	3688963	33,316900	35,387000
6-026	CBU-811	Not determined	LB-3005	733701	3700352	33,417100	35,513300
7-001	CBU-80	Not determined	LB-2274	707183	3681951	33,256700	35,224100
7-001	CBU-200	Not determined	LB-2394	709451	3682288	33,259300	35,248500
7-001	CBU-341	Not determined	LB-2535	709445	3681689	33,253900	35,248300
7-002	CBU-321	Not determined	LB-2515	709202	3680841	33,246300	35,245500
7-003	CBU-1042	Not determined	LB-3260	710755	3680608	33,243900	35,262100
7-004	CBU-160	Not determined	LB-2354	707546	3677621	33,217600	35,227000
7-004	CBU-161	Not determined	LB-2355	707509	3677598	33,217400	35,226600
7-005	CBU-193	Not determined	LB-2387	710143	3677832	33,219000	35,254900
7-007	CBU-579	Not determined	LB-2773	710231	3676802	33,209700	35,255600
8-001	CBU-246	Non-SD Bantam	LB-2440	711710	3685566	33,288400	35,273500
8-001	CBU-288	Not determined	LB-2482	712176	3682969	33,264900	35,277900
8-001	CBU-435	Not determined	LB-2629	711559	3684764	33,281200	35,271700
8-002	CBU-47	Not determined	LB-2241	715265	3686576	33,296800	35,311900
8-002	CBU-127	Not determined	LB-2321	717974	3687125	33,301200	35,341100
8-002	CBU-249	Not determined	LB-2443	719375	3686568	33,295900	35,356000
8-002	CBU-327	M85	LB-2521	714936	3686746	33,298400	35,308400
8-002	CBU-330	Not determined	LB-2524	715428	3686380	33,295000	35,313600

Task Dossier	Dangerous Area Name	Status	IMSMA ID	XUMTN36	YUTMN36	REFPTLAT	REFPTLONG
8-002	CBU-331	Not determined	LB-2525	715212	3686453	33,295700	35,311300
8-002	CBU-332	M85	LB-2526	714926	3686757	33,298500	35,308300
8-002	CBU-797	Not determined	LB-2991	715112	3685951	33,291200	35,310100
8-002	CBU-824	M85	LB-3018	714366	3686789	33,298900	35,302300
8-003	CBU-205	Not determined	LB-2399	718745	3679353	33,231000	35,347500
8-005	CBU-412	Not determined	LB-2606	724207	3676647	33,205500	35,405400
8-009	CBU-128	Not determined	LB-2322	716651	3681248	33,248500	35,325500
8-009	CBU-788	Not determined	LB-2982	715043	3681900	33,254700	35,308400
8-010	CBU-45	Not determined	LB-2239	720435	3682953	33,263100	35,366500
8-010	CBU-471	Not determined	LB-2665	722231	3683903	33,271300	35,386000
8-010	CBU-601 Alpha	M85	LB-2795	721126	3682780		
8-010	CBU-601 Beta	M85	LB-2795	720884	3682659		
8-010	CBU-828	Not determined	LB-3022	722750	3682817	33,261400	35,391300
UNIFIL 002	CBU-33	Not determined	LB-2227	710988	3672846	33,173900	35,262800
L 003	CBU-17	Not determined	LB-2211	725218	3675683	33,196600	35,416000
L 003	CBU-60	Non-SD Bantam	LB-2254	725239	3674752	33,188200	35,416000
	CBU-957	Non-SD Bantam	LB-3175	723566	3662663	33,079600	35,395100

*The list is compiled on the basis of field visits and information from MACC SL and individual clearance organizations. Of the 107 locations on this list, 19 have been verified during the research as M85 sites, and 11 as non-SD Bantam sites. Other sites among the 107 have also been researched, but without finding information allowing for determination of whether it was M85 or non-SD Bantam that had been used. Time has not allowed for research of all the 107 sites. It should also be mentioned that the list is not exhaustive, because: 1) it does not include information about spot tasks outside of Dangerous Areas registered with a CBU number by MACC SL; 2) not all clearance activities by all actors in the first emergency phase were recorded; and 3) new sites are continuously being discovered and registered.

Annex E: Indicators and data collection

Conclusions about local failure rates in this report have been arrived at on the basis of the number of M85 duds found at the analysed sites assessed in relation to evidence in and around the strike site regarding the number of projectiles used in the specific area. The following indicators were used:

- empty projectiles;[64]
- projectile impact craters;[65]
- base parts of projectiles;[66]
- pusher plates;[67]
- bomblet detonation holes;
- density of duds;
- packing materials;[68]
- remaining ribbons from detonated bomblets;[69]
- information from local people with detailed knowledge of the area;[70]

Where analysis of the available indicators is coupled with technical and tactical knowledge about the ordnance in question the footprint of one projectile may often be clearly defined.

When sufficient evidence about the number of projectiles used was not available, conclusions about failure rates were not made.

In the cases where conclusive evidence about numbers of projectiles is not available, equally useful information can often be arrived at by reverse analysis; e.g. by projecting how many projectiles would have had to have been used in order for the number of duds that had been found in a specific area to be produced if the failure rate was only 1%.

As pointed out in Section 3.2.2, conclusions about failure rates have only been made with respect to duds from projectiles that have deployed normally.

All the sites analysed in detail for this study were clear M85 sites, meaning that the M85 bomblets and their projectiles were not found mixed with bomblets or projectiles from other types of cluster munitions.

Data collection during surface and subsurface clearance

The surface and subsurface clearance part of the research was carried out by an NPA Battle Area Clearance (BAC) team[71] specifically trained for this purpose to ensure that the data gathered had scientific value. The research was an integral part of normal BAC operations, with the Task Dossiers in question being received from MACC SL along with Dangerous Area Reports (DA Rep), Clearance Plans and

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[64] The empty projectiles will be found further ahead of the bomblets in the firing direction. More than a year after the fighting some of the sites still contained the empty projectiles because the population was afraid to enter these contaminated areas.

[65] Impact craters from the empty projectiles are a particularly important indicator. Unless the ground is very hard, these impact craters are very distinct and they were still clearly visible many places.

[66] The base parts fall off immediately before ejection of bomblets and will land either among the bomblets or behind the bomblets. This part will, however, easily bounce and roll, especially on a hard surface, making its final position unpredictable. The base part of the Israeli-produced 155mm projectiles will either be a simple hollow base back part (for the projectiles containing 63 bomblets) or a larger base-bleed element (for the projectiles containing 49 bomblets). In all the M85 sites researched for this report only base-bleed elements have been found.

[67] The pusher plate is an approximately 10 mm thick aluminium plate in front of the payload of bomblets which is ejected together with the bomblets. The plate can have a discus effect in the air and may be found further ahead of the bomblets in the firing direction.

[68] M85 packing materials have a larger dimension than packing materials for M42/M46 and M77 bomblets.

[69] M85 ribbons are wider than M42/M46 ribbons and narrower than M77 ribbons.

[70] In several sites, local goat herders and land owners had detailed knowledge about the area and the contamination on it. They had often marked duds with piles of stones.

[71] NPA's Emergency Mine Action Programme (EMAP) in South Lebanon has been accredited by MACC SL to conduct BAC according to IMAS and National Technical Standards and Guidelines (NTSG). NPA EMAP Standard Operations Procedures (SOP) have been prepared in accordance with IMAS and NTSG.

maps. In addition to the normal recording requirements for MACC SL, a Technical Survey Form specific to the research was completed for each site. This form can be found in Annex F.

In cases of positive identification of a dud, the following information was recorded:
- Time of find
- UTM taken on object
- Status of the dud according to Technical Survey Form
- Photo of the dud (linked with the UTM) from available angles

The BAC process was undertaken as follows:
- A control point is established in safe distance from the UTM indicated in the DA Rep. Initial clearance starts from the UTM in the DA Rep and a box of a minimum of 50 m x 50 m is cleared by using instrument aided visual search.
- Action taken on positive location of duds: The BAC operator reports to team leader who, together with supervisor, makes an identification and records information as detailed above.
- Fade out of clearance is made 50 m from the last object found.
- A sketch map of the area is updated on a daily basis, which includes all perimeters of the searched area, locations of duds or other parts of the cargo projectiles including empty canisters, base parts, pusher plates etc. The sketch map is used for further planning of subsurface search of the actual strike.
- Subsurface clearance is conducted with Schonsted GA-72Cd across the designated area down to a depth of 20 cm.
- Action taken on signal: BAC operator excavates according to Standard Operating Procedures (SOP). On locating the object the team leader and supervisor are called in for identification and recording of information as detailed above.
- After clearance of the area is conducted, the Operations Officer from MACC SL is requested to verify the clearance of the task
- Quality Assurance (QA) visits take place at random intervals to all clearance sites in south Lebanon and are undertaken by MACC SL (from both the Lebanese and UN authorities).
- All data are entered into ArcGis.

Figure 26: Indicator collection point during research clearance at the site CBU 804.
Photo: Amir Musanovic/NPA

Annex F: Technical Survey Form

M85 Technical Survey Report

^{1}General information

$^{1.1}$ Dangerous Area No	
$^{1.2}$ Owner MAC:	
$^{1.3}$ Reported by: (Address & Tel)	$^{1.12}$ Organization (Address & Tel):
$^{1.4}$ Position:	$^{1.13}$ Date of report:
$^{1.5}$ Data entry date:	$^{1.14}$Date report received:
$^{1.6}$ Data entry by:	$^{1.15}$ Date of verification:
$^{1.7}$ Verified by:	$^{1.16}$ Referenced TaskID:
$^{1.8}$ Status:	

^{2}Geographical reference

$^{2.1}$Region:	$^{2.6}$Coord. system:	$^{2.11}$Map name:
$^{2.2}$State/County:	$^{2.7}$X/ Easting/ Long.:	$^{2.11}$Map series:
$^{2.3}$Locality/Payam:	$^{2.8}$Y/ Northing/ Lat.:	$^{2.11}$Map edition:
$^{2.4}$Nearest Village/Boma:	$^{2.9}$MGRS Coord[1].:	$^{2.11}$Map sheet:
$^{2.5}$Municipality:	$^{2.10}$Coord. fixed by: ☐ DGPS ☒ GPS or Map with ☐ <30 m or ☐ >30 m accuracy	$^{2.11}$Map scale:

$^{2.12}$Description of the geographical reference

^{3}Description of the dangerous area perimeter points

From Point	No.	To Point	$^{3.1}$Bearing	$^{3.2}$Distance	$^{3.4}$X/ East./ Long.	$^{3.5}$Y/ North./ Lat.	$^{3.6}$MGRS Coord.

---

[1] MGRS provided when X/Y absent and vice versa.

M85 Technical Survey Report

$^{4.1}$Distance from nearest town: km :

$^{4.2}$Direction from nearest town: North   South   North – East   South – East
East   West   North – West   South West

$^{4.3}$Information source: Civilians   Accidents involving animals   Accident report
Military person   Site record

$^{4.4}$Type of area: Urban   Residential
Barren field   Pasture field   Cultivated

$^{4.5}$Type of vegation: Grass   Bushes   Trees
Height ____meters   Height_____meters   Height ____meters
Type of trees_____________

$^{4.6}$Type of ground / soil: Stony   Sand or gravel
Hard soil   Soft soil   Wet area
Other _________________________________

$^{4.7}$Estimated length of the area: $^{4.8}$Estimated width of the area:

$^{4.8}$Azimut: ° $^{4.8}$Calculated size of area:

$^{4.9}$Marking: Official signs   Local signs   Fenced   Several   None

^{5}Position of bomblets found

No.	$^{5.1}$Type i)	$^{5.2}$UTM	$^{5.3}$Result of Normal Deployment? ii)	$^{5.4}$Condition iii)	$^{5.5}$Arming iv)	$^{5.6}$Burial v)	$^{5.7}$Locking Pin/Tab State vi)	$^{5.8}$Ref. to photo
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								

i) Indicate as “**M85 w SD**” or “**M85 w/o SD**”.
ii) Indicate as “**Yes**” if the bomblet id a result of normal deployment, or “**No**” if not normal deployment.
iii) Indicate as Complete (**C**), or Fuse broken off (**FO**).
NB: If fuse is broken off, then 5.4, 5.5 and 5.6 are not to be filled in.
iv) Indicate as Armed (**A**), Unarmed (**U**), Partially Armed (**P**) or Not Decided (**N**).
v) Indicate as Buried (**B**), and indicate depth in centimeters, Surface (**S**) or Not Decided (**N**).
vi) Indicate as Not Visible (**NV**), Tab Open (**TO**) or Tab Closed (**TC**).
vii) Date and Time of photo of Object, or of first photo in a series.

[6]Position of other objects (canisters, base parts, propulsive elements, end-pieces, pusher plates, fins, etc.)

No.	[6.1]Type	[6.2]UTM	[6.3]Remarks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

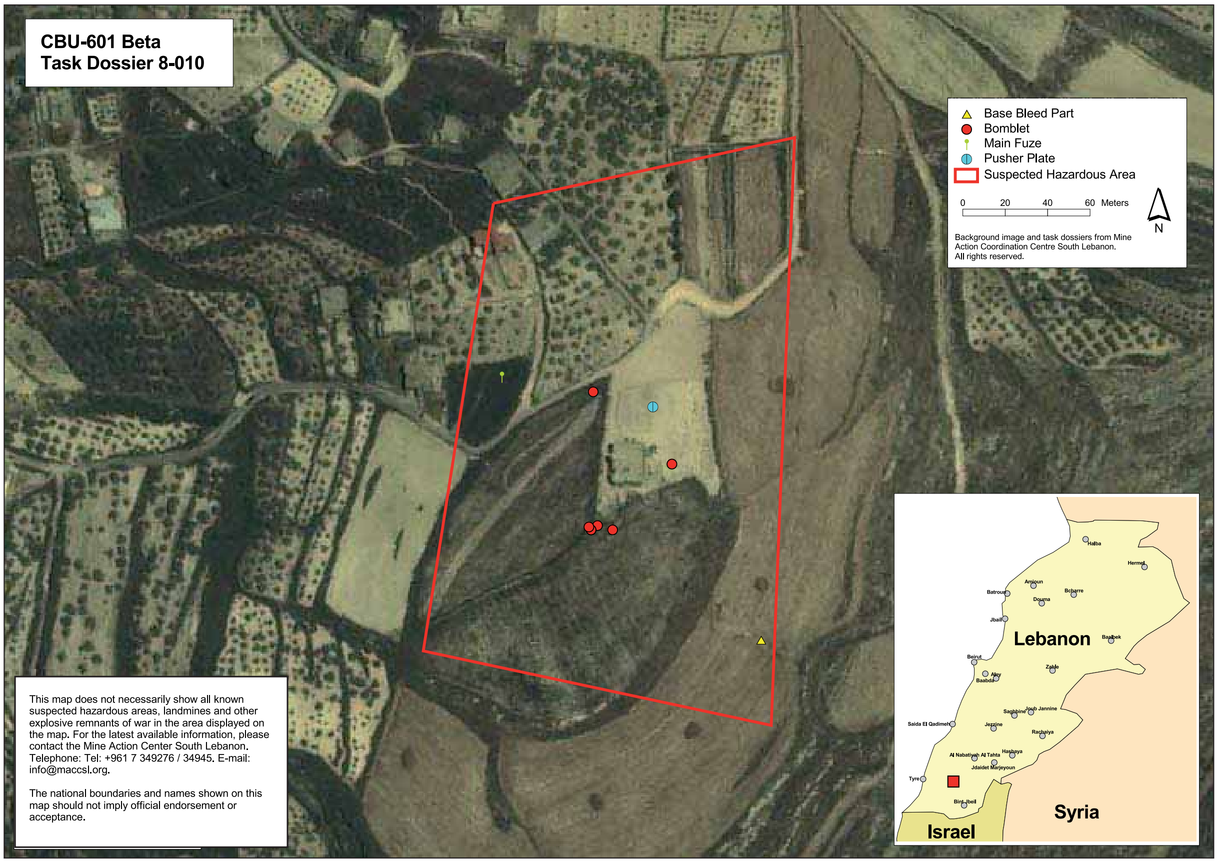
[6.4]If possible, describe presence, position and the number of other indicators found in the area (spacer, ribbons, etc.)

[7]Information about earlier EOD and clearance in area

Annex G: Findings from further researched sites

a)

Task dossier: CBU no. Location: Status:	**8-010** **601 Beta** Bafliyah, Sur Middle District Surface and subsurface clearance finished and area released.
No. of M85 duds found:	**6 duds found (indications of at least 3 more)**
Failure rate analysis:	**Inconclusive, but more than 1%**



This area is covered with grass and olive trees. The research clearance team found six M85 duds, all of which were the result of normal deployment. Three of the duds were found buried, one at 4 cm and two at 2 cm. It seems that at least two duds had earlier been disposed of by Lebanese Armed Forces (LAF). A boy in the village was also said to have removed one dud and thrown it away at the village garbage point some 250 m away. Thus there are indications of three additional duds to those confirmed during research.

Indicators found in this area imply that not more than two projectiles were used. The research on this site was, however, not conclusive because of contradictory information about the degree to which other actors had removed duds, projectiles and other indicators. It was, therefore, not possible to draw firm conclusions about the numbers of projectiles.

If the six duds found during this research were the result of a failure rate as low as 1%, then 12 projectiles would have had to have hit an area of less than one hectare. Based on the evidence on the ground it is concluded that this is highly unlikely.

b)

Task dossier: CBU no. Location: Status:	**3-002** **808** Blida Clearance not completed. Task temporarily suspended.
No. of M85 duds found:	**At least 26**
Failure rate analysis:	**Inconclusive, but considerably higher than 1%**

This is an olive grove area in a sloping valley located right next to the Blue Line. The ground is a mix of loose soil and stones. The researchers visited this area as a BACTEC EOD team had just arrived there on a spot task. The EOD team identified six M85 duds just along the road as they started to move into the area. A farmer pointed out two further M85 duds in the olive yard and said that there were dozens more on the approximately 5 hectares of olive grove hillside. It was clear that the eight inspected duds were the result of normal deployment. A total of 26 M85 duds were removed by the BACTEC team during two days of operations.[72] Local teams and Armour Group also cleared M85 duds from this area. It has not been possible to document exactly how many M85 duds were finally removed during EOD and surface clearance from this site alone. Subsurface clearance has not yet been undertaken, making it very likely that further M85 duds will be found.

Just on the basis of the 26 M85 duds that were removed by the BACTEC EOD team in those two first days it is clear, however, that the failure rate on this site far exceeds 1%. In order for a 1% failure rate to produce 26 duds as many as 54 projectiles would have had to have been fired into this small area. This is highly unlikely and there were no indications of a large number of projectiles.

c)

Task dossier: CBU no. Location: Status:	**2-001** **622** A piece of land located along the road between Debel and Rshaf in the District Bint Jbeil of Nabatiyah province. EOD done by UNIFIL. Subsurface clearance not yet undertaken.
No. of M85 duds found:	**At least 20**
Failure rate analysis:	**Inconclusive, but considerably higher than 1%**

This area is used for herding of goats, and consists of hard soil, stones and bushes. It was filmed in October 2006 by John Rodsted, who was working for NPA specifically to document M85 strikes.[73] The film showed approximately 20 bomblets in an area of 50 m x 50 m. The site was later inspected and analyzed during the research for this report, although after the visible duds had been removed.

According to information from UNIFIL, a total of 42 M85 duds were removed from this site, but their exact locations cannot be established.[74] Shepherd Atil Osaileh from Rshaf indicated the boundaries of the area to the researchers and confirmed that all of the bomblets known to him had been removed.

Sufficient evidence was not available on the ground during the research visit and no conclusions can be made about the number of projectiles used. On the basis just of the 20 duds documented in the Rodsted film, however, it is clear that the failure rate far exceeds 1%. The density of the bomblets indicates that they were the result of several projectiles. But if 20 duds were to have been produced from a failure rate of 1% within an area of 50 m x 50 m, then 40 projectiles would have had to have been fired against the same point target. This is highly unlikely.

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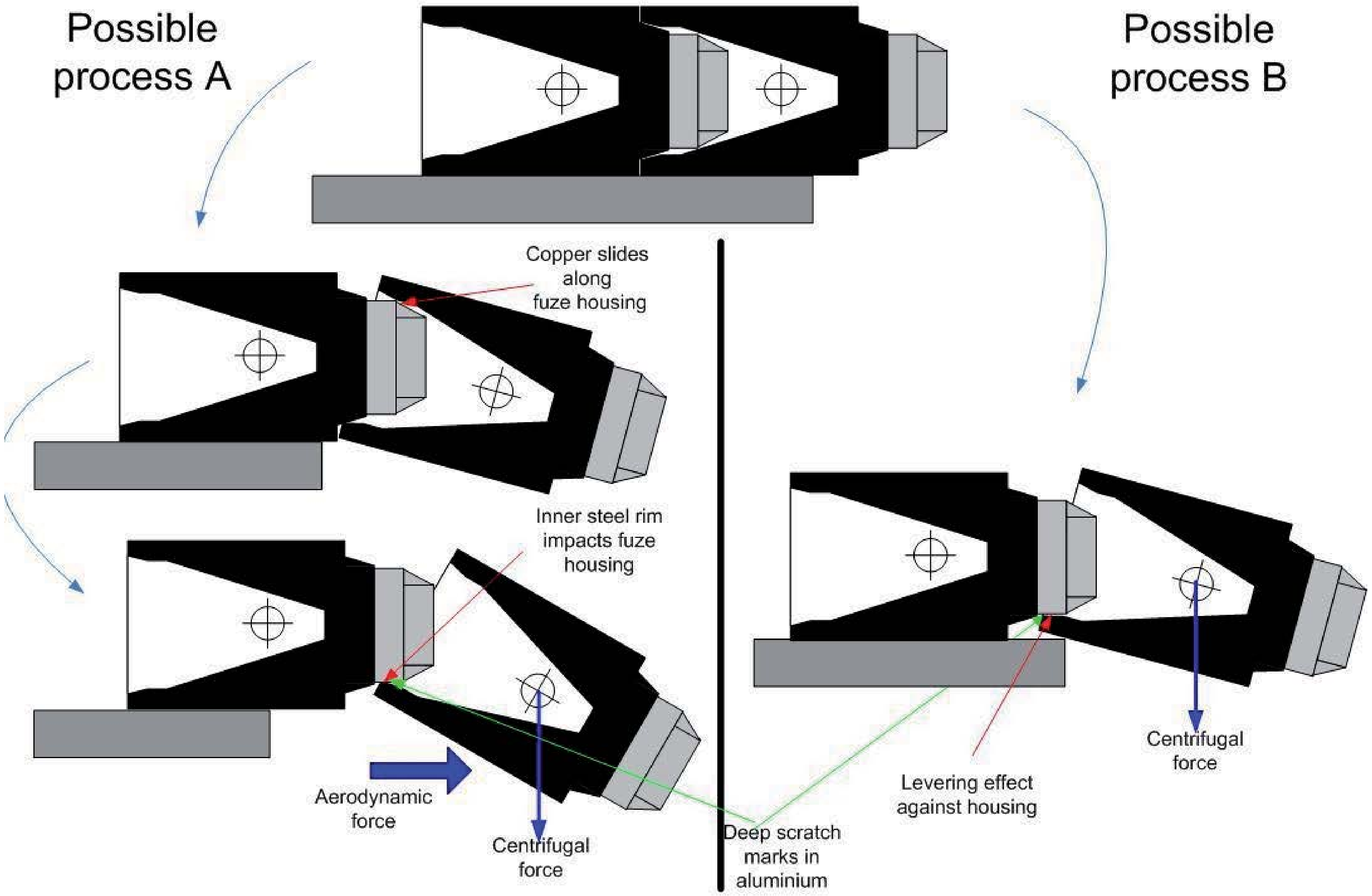
[72] Information from BACTEC obtained during research visit in October 2006.

[73] See the film on http://npaid.websys.no/item5/eng/1170798601

[74] Table from Col. Marnik Jacobs, UNIFIL, July 2007.

Annex H: The ejection and separation process



Annex I: Background on the Norwegian test firings of cluster munitions

Norway holds a stockpile of 53,000 artillery delivered cluster munitions, or cargo projectiles, of the types DM642 (which contain bomblets designated DM1383) and DM662 (which contain bomblets designated DM1385). This stockpile constitutes 40% of Norwegian artillery ammunition.

DM1385 are in fact M85 bomblets, but have been given a Deutsche Model designation because they are incorporated into a Rheinmetall projectile. For the purposes of this report, DM1385 is referred to as M85.

For many years, the Norwegian government was satisfied that its stockpile of cluster munitions had a less than 1% failure rate. This confidence was weakened when information surfaced through the media that the Norwegian Army, in the autumn of 2005, had facilitated tests for the British Army of their parallel M85 stockpile showing a failure rate of 2.3%,[75] and that tests of the Norwegian stockpile of M85 bomblets had produced a failure rate of 2.04%. The Minister of Defence then ordered new tests to establish whether the Norwegian stockpile of cluster munitions was in compliance with the Norwegian policy requiring a failure rate of less than 1%.

The new tests took place in weeks 38-40 of 2006 and comprised both of the two cluster munitions in the Norwegian stockpile. For the purposes of this report, only the results for M85 are cited.[76]

The Norwegian tests are carried out at a fenced testing range specifically designed for testing of cluster munitions in the mountains at Hjerkinn, Dombås. This is a flat and slightly sloping 400 m x 600 m field covered by sand and gravel. An advanced system, using acoustical and optical sensors, records the time and position of every detonation.

The 2006 tests were the most comprehensive ever carried out on cluster munitions in Norway. 192 projectiles of the type DM662 were fired during the tests, containing a total of 9,408 M85 bomblets.[77] The firing distances for M85 were 17 and 21 km. The firings at Hjerkinn are made from a 155 mm howitzer with 39 calibre barrel. The propulsion charges used were DM72 consisting of 4 or 5 modules (M), resulting in a muzzle velocity of 636 m/s and 791 m/s respectively. 4M was used at both 17 km and 21 km range, while 5M was used at 21 km range only. The results are presented in the following table:[78]

Projectile	**Bomblet**	**Charge**	**# bomblets**	**# duds**	**Failure rate%**
DM662	M85	4M	6272	58	0.92
	M85	5M	3136	46	1.47
Total/Average			9408	104	1.11

Table I1.

As can be seen from the table, the 2006 tests of the Norwegian stockpile of M85 bomblets produced a total of 104 duds and showed an average failure rate of 1.11%, which was just above Norway's self-imposed maximum failure rate of 1%.

Looking at the individual results for the two different propellant charges that were used in the test firing, we see that with the lower charge (4M), the failure rate achieved was 0.92%, and with the higher charge (5M), the failure rate was 1.47%.

After the 2006 tests the Norwegian government prolonged an already established unilateral moratorium on its remaining stockpile of cluster munitions, including the M85 bomblets.

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[75] This figure was released under the UK Freedom of Information Act by the UK MoD in a letter dated 27 March 2006 to Richard Moyes, Landmine Action. This was and is the highest test result ever quoted for M85.

[76] The failure rate in the 2006 test for DM1383 was slightly below 1%, whilst for M85 slightly above 1%.

[77] The tested bomblets were 8-9 years old, slightly older than the UK stockpile when this was used in Iraq but 6-7 years younger than the Israeli M85 stockpile that was used in southern Lebanon.

[78] Sources: FFI (2006) *Sluttrapport etter ekstraordinær tilstandskontroll av artilleriammunisjon*, and FFI (2006) *Drøfting av resultatene fra cargo-skyting.*

Annex J: The statistical aspect of testing

The normal requirement for any statistical claims about quality is that they should have a confidence level of 95% - meaning that there should be less than 5% probability that the quality claim is false. With a confidence level of 95%, the claim may be said to have good statistical significance.

When attempting to verify, to a confidence level of 95%, that the probability of failure for a device (in this case bomblets) is below a certain value, it is not possible a priori to determine the required number of devices to be tested, as this will depend on the number of failures observed during the process. In mathematical terms this can be stated as finding the lowest value for *n* that satisfies the following equation:

$$\sum_{x=0}^{s} \frac{n!}{x!(n-x)!} p^{x} (1-p)^{n-x} < 0.05$$

where *n* is the number of test devices required, *s* is the number of failures observed and *p* is the quality requirement (reliability limit).

In testing the failure rate of bomblets, a number of bomblets will be dropped, and the number of failures (*s*) is registered. To claim that the reliability is less than a certain limit (*p*) with 95% confidence, the required number (*n*) is found by the above equation resulting in the following table:

	Number of failures observed			
Reliability limit	0	1	2	3
0.06%	4992	7905	10491	12921
0.1%	2995	4742	6294	7752
0.3%	998	1580	2097	2583
1%	299	473	628	773
2%	149	236	313	386
3%	99	157	208	257

Table J1: Required sample sizes in order to claim a reliability lower than the criterion.

The table shows that if a 0.06% reliability limit is used as the criterion, the minimum number of tests required is 4,992 provided that no failures are observed. If 2 failures are observed 10,491 tests are required. In practice, if no failures are observed during the first 4,992 tests, the reliability limit can be considered to have been met with 95% confidence. However, if 2 failures are observed before testing 4,992 devices, the test has to continue to 10,491 devices, without any additional failures, in order to meet this reliability limit with 95% confidence.

When the sample size is fixed in advance, a maximum number of registered duds will, according to the equation above, be permissible in the test in order to claim with 95% confidence that the true failure rate is less than a certain value. The table below uses three sample sizes – 1,000, 10,000 and 100,000 – as examples and specifies the maximum number of allowed duds to claim that the result is better than 0.1%, 0.3%, 1% and 3%.

	Bomblets dropped (sample size)		
Reliability limit	1000	10000	100000
0.06%	Not possible	1	47
0.1%	Not possible	4	83
0.3%	0	20	271
1.0%	4	83	948
3.0%	20	271	2911

Table J2: Maximum number of permissible failures for different sample sizes in order to claim a reliability lower than the reliability limit with 95% confidence.

It is not possible to claim a rate below 0.1% if the test sample consists of only 1,000 bomblets. If the sample size is 10,000, it may be claimed that the failure rate is less than 0.06% only if no more than one failure is observed.

All the above calculations have used the 95% confidence level, which is the usual value for quality control. For very critical components, a better confidence level may be required, like 99%. In that case the sample sizes will have to be increased accordingly.

Annex K: Sensitivity tests of unarmed duds

The Norwegian live-fire tests in 2006 left 104 duds of the bomblet M85[79] and 45 duds of the bomblet DM1383. Of these, 95 and 41, respectively, were in an unarmed condition. All of these were subject to a progressive set of tests designed to reflect different degrees of handling that they may advertently or inadvertently be subjected to by civilian populations.[80] The tests were:

- Putting the dud in a cement mixer, and letting it run for up to 30 minutes. This test generally reflects rough handling and transport of the bomblet.
- A drop test where each bomblet was dropped from a height of 12 m onto a steel floor. This will give the bomblet a velocity of 15 m/s. This test is intended to reflect situations where a dud bomblet is thrown against a solid wall or ground. This test was made up to three times for each bomblet.
- A bonfire test where the bomblet were dropped into burning wood and remained there until the explosive combusted.

In some cases the drop test was run before the mixer test in order to check if that had any significance.

Of course, if any of the first two tests resulted in a positive reaction in the bomblet, that bomblet would not be subject to the subsequent test(s.)

In the bonfire test a detonation is easily distinguished, however there is no clear-cut way to differentiate between a deflagration and non-violent combustion (burning).

The results of the tests, showing the percentage of positive responses can briefly be summed up as follows:

Test	DM1385	DM1383
Mixer test (detonated)	19.4 %	35.0%
Drop test (detonated)	2.4%	6.3%
Bonfire – non-violent combustion	25.7%	11.1%
Bonfire – deflagration	65.2%	72.2%
Bonfire – detonation	9.1%	16.7%

Table K1.

Further details, including the actual numbers, are shown in the illustrations on the following page:

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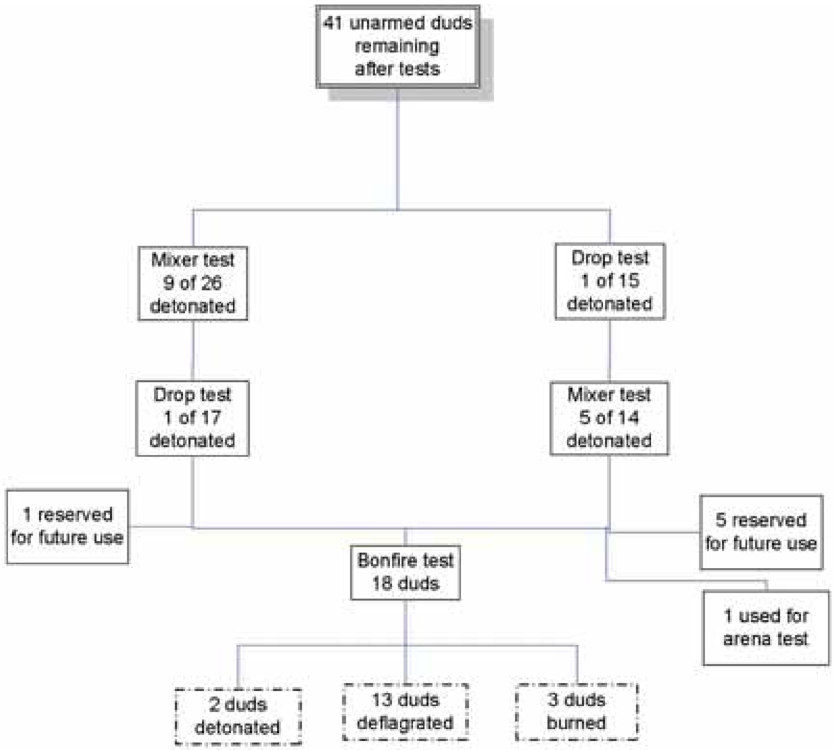
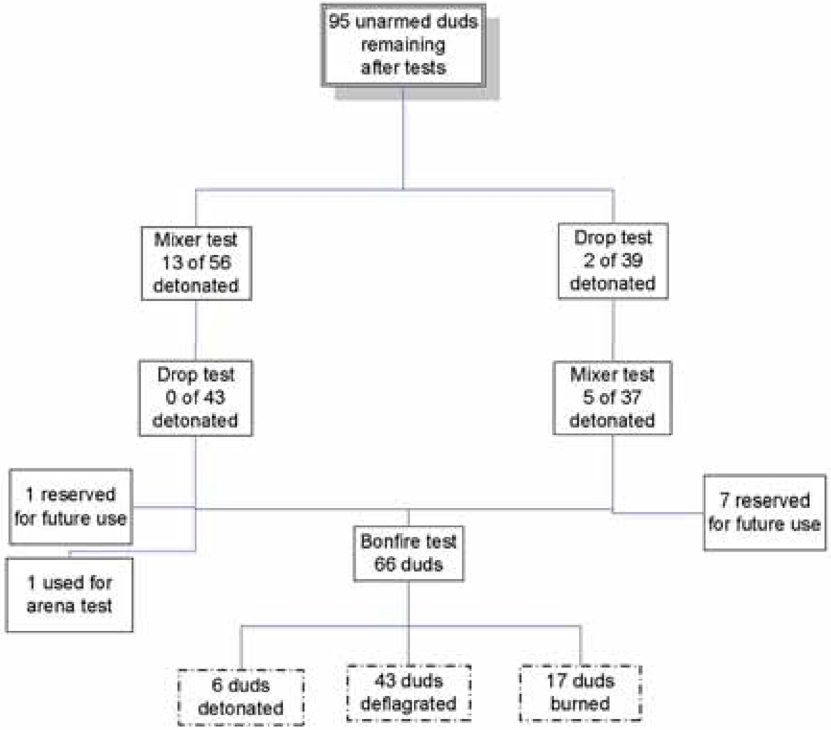
[79] The bomblets in the Norwegian stockpile of DM662 projectiles are named DM1385. They are M85 submunitions but have been given a Deutsche Model designation because they are incorporated into a Rheinmetall projectile.

[80] Oddan Asbjørn, Dullum Ove; *Sensitivity testes of duds from cargo ammunition*, FFI-rapport 2007/02346 (to be published)

DM1383



DM1385



Abbreviations

BAC	Battle area clearance
BACTEC	Battle Area Clearance Training Equipment Consultants. A UK-based explosive ordnance disposal and landmine clearance company
CBU	Cluster Bomb Unit – from the US designations applied to air-dropped cluster munitions. MACC SL records cluster munition strikes with the label CBU followed by a number, e.g. CBU 804
CKA	C King Associates Ltd. A UK-based EOD consultancy company
CCW	United Nations Convention on Conventional Weapons
DPICM	Dual Purpose Improved Conventional Munition – a ‘family’ of cluster munitions
ERW	Explosive remnants of war
FFI	Norwegian Defence Research Establishment (Norwegian: Forsvarets Forskningsinstitutt)
FSD	Fondation Suisse de Deminage, a Swiss-based humanitarian mine clearance organization
HRW	Human Rights Watch
IDF	Israeli Defence Forces
IMI	Israel Military Industries
LAF	Lebanese Armed Forces
MACC SL	Mine Action Coordination Centre, South Lebanon
MAG	Mines Advisory Group – a UK-based humanitarian mine clearance organization
MLRS	Multiple Launch Rocket System
MoD	Ministry of Defence
NGO	Non-governmental organization
NPA	Norwegian People’s Aid
SD	Self-destruct
SRSA	Swedish Rescue Services Agency – a Swedish-based humanitarian mine clearance organization
UK	United Kingdom
US	United States of America
UXO	Unexploded ordnance

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