FFI-rapport/2007/02345

Cluster weapons – military utility and alternatives

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1 February 2008

FFI-rapport 2007/02345

Oppdrag 351301

ISBN 978-82-464-1318-1

Keywords

Militære operasjoner / Military operations

Artilleri / Artillery

Flybomber / Aircraft bombs

Klasevåpen / Cluster weapons

Ammunisjon / Ammunition

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English summary

This report is made through the sponsorship of the Royal Norwegian Ministry of Foreign Affairs. Its purpose is to get an overview of the military utility of cluster munitions, and to find to which degree their capacity can be substituted by current conventional weapons or weapons that are on the verge of becoming available.

Cluster munition roughly serve three purposes; firstly to defeat soft targets, i e personnel; secondly to defeat armoured of light armoured vehicles; and thirdly to contribute to the suppressive effect, i e to avoid enemy forces to use their weapons without inflicting too much damage upon them. The report seeks to quantify the effect of such munitions and to compare this effect with that of conventional weapons and more modern weapons.

The report discusses in some detail how such weapons work and which effect they have against different targets. The fragment effect is the most important one. Other effects are the armour piercing effect, the blast effect, and the incendiary effect. Quantitative descriptions of such effects are usually only found in classified literature. However, this report is exclusively based on unclassified sources. The availability of such sources has been sufficient to get an adequate picture of the effect of such weapons.

The calculations show that many of the cluster weapons have a more modest effect than usually assumed. Cluster weapons do have a satisfactory or adequate effect against most targets. Under certain conditions the effect is quite good. However, no evidence has been found to claim that such weapons are far better than their alternatives to the extent that they indispensable.

A quite common type of cluster munitions is the so-called DPICM (Dual Purpose Improved Conventional Munition) that was used extensively in Lebanon in 2006. The bomblets of this kind is characterized as being small, they detonate at the ground surface, they a limited amount of explosive, and their basic design is such that they eject their fragments almost parallel to the ground of even downwards. Thus their range is limited. Only a few fragments are effective at distance from the bomblet impact point.

Compared with conventional high explosive munition, like the M107 artillery projectile, the effect of cluster munition is up to 50% better against soft targets. Modern high explosive is however claimed to be 30% better than M107. Thus the gap between cluster munitions and unitary high explosives may become quite narrow.

When cluster munitions were introduced they constituted the only viable way to defeat armoured targets at long distance in an indirect mode. In the meantime armoured vehicle have been fitted with kits that limit the effect of small bomblets, rendering cluster weapons less effective against such targets. Additionally, the so-called sensor fuzed warheads (SFW) have become available. A mixture unitary conventional high explosive munitions and SFW’s will be a far better choice than cluster weapons. Even though SFW’s are very expensive, their effect is so superior that their use is cost effective in comparison to cluster munitions.

An extended executive summary is found in appendix E.

Sammendrag

Rapporten er utarbeidet på oppdrag fra Utenriksdepartementet. Dens formål er å kartlegge hvilken militærnytteverdi dagens klasevåpen har og i hvilken grad den kapasitet som slike våpen har, kan erstattes av andre nåværende våpen, eventuelt våpen som er ferd med å bli tilgjengelige.

Dagens klasevåpen har grovt sett tre oppgaver; å bekjempe myke mål, dvs personell, å bekjempe pansrede eller lettpansrede mål, og endelig å bidra til nedholdende ild, dvs hindre den fiendtlige styrken fra å bruke sine våpen uten å påføre ham store tap. Rapporten prøver å kvantifisere den effekten slike våpen har og sammenligne denne effekten med det som mer konvensjonelle våpen, og mer moderne våpen.

Rapporten diskuterer i noen detalj hvordan slike våpen virker og hvilken effekt de har mot de forskjellige mål. Effekten av splinter er den viktigste effekten, men mange klasevåpen gir også en panserbrytende effekt og i noen tilfeller også en trykkeffekt og en brannstiftende effekt. Kvantitative beskrivelser av slike våpeneffekter er vanligvis i finne i gradert litteratur, men i denne rapporten er utelukkende ugradert materiale lagt til grunn. Tilfanget av slik litteratur har imidlertid vist seg å være tilstrekkelig til å gi et tilfredsstillende bilde av effekten av slike våpen.

Beregningene viser at effekten av mange klasevåpen er mer beskjeden enn det man har fått inntrykk av. Klasevåpen en fleksibel våpentype som gir en tilfredsstillende effekt mot de fleste måltyper. Under viss betingelser er effekten meget god. Imidlertid finner man ikke belegg for å hevde at klasevåpen er så mye bedre enn alternativene at de kan betraktes som uunnværlige.

En svært vanlig type klasevåpen er de såkalte DPICM (Dual Purpose Improved Conventional Munition) som Hæren også har, men som nå er omfattet av moratoriet som ble innført i 2006. Substridsdelene fra disse er karakterisert ved at de er små, de detonerer på bakken, de har en begrenset mengde sprengstoff, og deres grunnleggende utforming gjør at de sender ut sine splinter nærmest parallelt med marken og endog litt nedover. Dette fører til at splintene virker best på kort avstand og mot mål som er nær bakken. Kun meget få splinter fra disse typene virker mot mål på litt avstand fra nedslagspunktet.

Sammenlignet med konvensjonell sprengammunisjon, som artilleri-granaten NM28, er virkningen er klasevåpen inntil 50% bedre mot myke mål. Produsenter av moderne ammunisjon hevder av ny sprengammunisjon er 30% bedre slik av gapet mellom klaseammunisjon og sprengammunisjon i så fall blir svært smalt.

Da klasevåpen ble innført utgjorde de den beste muligheten for å bekjempe pansrede avdelinger på langt hold eller med indirekte ild. I mellomtiden har imidlertid pansrede avdelinger truffet tiltak som begrenser effekten av slik ammunisjon, slik av klasevåpnenes virkning mot slike mål er blitt mindre. I tillegg er de såkalte sensorutløste stridshoder (Sensor Fuzed Warheads) i ferd med å gjøre sitt inntog. En blanding av konvensjonell sprengammunisjon i kombinasjon med sensorutløste stridshoder vil derfor være en klart bedre alternativ enn klasevåpen. Selv om sensorutløste stridshoder er svært dyre våpen vil deres effekt være god nok til at det er forsvarlig å bruke dem fra et kost-effektivitets-synspunkt.

Contents

Preface

The purpose of this report is to contribute to the Oslo Process to prohibit the production, stockpiling, use and transfer of cluster weapons that unacceptable harm to civilians. The report reviews the technical status of cluster weapons and their effects. The military role of such weapons and how their utility can be quantified is then discussed.

The military utility of such weapons can be found by assuming a set of possible targets and, by using available software, quantifying the effect of cluster weapons. For most weapons, the ejection of fragments is the dominating effect, but other effects, like armour penetration and blast effects are also discussed. A set of bomblets, representing typical and prevailing cluster weapons, has been selected for this purpose. For comparison, alternatives to cluster weapons are subjected to the same calculations and assessments.

The reader should be aware that not all effects of cluster weapons are quantifiable. There are also scenarios, and urban warfare is an example, in which the environment is so complex and varied that hardly any analysis can be claimed as being general. The analyses will thus only cover simple and generic scenarios.

All data compiled here and the analyses thereof are exclusively based on open and non-classified sources that are available in the public domain.

The report presents cluster weapons and their performance from an objective and unbiased point of view. For the same reason, available information on the topic from sources that may contradict these principles has been avoided to the extent possible.

The work has been done at FFI (Norwegian Defence Research Establishment) and is supported in full by the Royal Norwegian Ministry of Foreign Affairs under contract QZA 1073219.

The calculations made herein are to a great extent done by FFI research scientist Jo H Kiran, who has assisted with some of the calculations and the student Ole Martin Christensen, who developed the calculation program during his stay at FFI in the summer of 2006. FFI research scientist Stian Skriudalen has contributed with proof reading. The author would also like to acknowledge the FFI scientists Asbjørn Oddan and Halvor Ajer for useful discussions during the work. Acknowledgement should also be extended to colonel Stein E Lauglo representing the Norwegian artillery force, Grethe Østern of Norwegian People’s Aid and Colin King of C King Assoc.

1 Introduction

The main goal of the present report is to quantify relevant characteristics of cluster weapons, related to a possible future international agreement to prohibit the use of certain types of these weapons. The main topics of the report are:

- the immediate battlefield effect
- the operational effects and the use of alternative weapons
- the post-war effects of cluster weapons

The basis of such analyses must be found in the basic properties of existing cluster weapons. Consequently, a substantial part of the report describes the technical details of such weapons. As unacceptable human injury is the main reason for launching a ban on such weapons, the effect on humans is discussed in some extent. In order to quantify some of these effects, simple, but still comprehensive calculations are required.

In order to compare cluster weapons with other alternative weapons, both the in-war and post-war effect on humans (soft targets) must be accounted for. In addition, the in-war effects on hard and semi-hard (light vehicles) targets must be considered.

This report is solely based on open and unclassified sources. Some information about cluster weapons and related ordnance are subject to some myths. Consequently, information from some sources had to be checked for consistency and plausibility. It can not be stated with any certainty, that this goal has been successfully achieved in all cases.

The main text does not aim to present a complete overview of all kinds of cluster weapons. However, the appendix presents a list of types of cluster weapons which aspire to be as complete as possible, taking into account that some information is not available through open sources.

2 A short history of cluster weapons

The concept of dispersing a number of explosive submunitions from a single container is in fact quite new. It was probably used for the first time by the German Luftwaffe when bombing harbours on the east coast of England during WWII. The bomblet used then, called the *Butterfly bomb*, had the size of a fist and was stabilized and braked by a four-winged device which was the origin of the name. The USSR also developed an air delivered cluster system at the same time, called OKT 1.5. This system has been in use until recently, as it has been applied in Afghanistan.

The butterfly bomb was later copied, and renamed M83, by the US in the 1950s to be used first in Korea, later in Indo-China in the 1960s. Later on, US developed different cluster bombs for both air delivery and field artillery. Their purpose was to defeat widespread infantry and guerrilla troops in jungle environments. The first artillery round, or cargo round, seems to have been a warhead with chemical bomblet for the Honest John rocket. Later the so-called Dual Purpose

Improved Conventional Munition (DPICM) was developed. This ammunition was introduced quite late in the Vietnam conflict, but it is not certain that it was ever used there.

In the Cold War, nuclear weapons initially had the main focus, but from the 1970s conventional forces were given an ever increasing role. This led to a boost in the development of cluster weapons and especially artillery cargo weapons. The goal was to get a system for defeating large scale infantry and tank formations. Other high value targets were command posts, logistic key points and, not least, artillery formations of the Warsaw Pact, which maintained an artillery operational mode that was well suited for such weapons. Cluster weapons were also a very important component in the doctrine of second echelon strike capacity heralded by the SACEUR, general Bernard Rogers in the mid 1980s.

From there, the technology proliferated to several NATO countries and ultimately also to the Warsaw Pact. In the last two decades cluster weapons have been used in several conflicts in the Middle East as well as in the Balkans, in Caucasus, and in Afghanistan.

3 What are cluster weapons – and what are not?

Apparently, the definition of a cluster weapons may seem quite trivial at first sight. The following definition should approximately cover the content of the concept today:

> **A cluster weapon consists of a container that opens up in air and releases several subunits each containing any injurious compounds such as gas, explosives or pyrotechnic substances.**

However there are many weapons that may or may not be included in such a definition. These borderline types may be:

- systems containing very few charges, e g two or three
- containers attached to the aircraft at the time of opening
- containers with anti-personnel or anti-tank mines which thus are covered by other regulatory treaties
- systems containing non-explosive, but still injurious components
- sensor fuzed submunition that are able to attack individual targets like a single vehicle[1]
- munitions released from a dispenser remaining inside the aircraft's cargo bay

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[1] Sensor fuzed warheads are not considered as cluster weapons in this report. In a rigorous technical sense, however, they may be classified as such. But like a few other special purpose cluster weapons, they are not intended to be dispersed in great multitude over a target area because of their high cost and high efficiency. As opposed to conventional cluster bomblets, they attack point targets. They do not hit at randon. They are also equipped with very advanced self destruct mechanisms that are likely to minimize the dud rate. Their potential conttibution to post-conflict humanitarian harm is definitely minor compared to that of conventional cluster munitions.

3.1 Cluster terminology

This section describes the terminology used in this field and throughout this report.

3.1.1 Bomblets

Bomblets are normally understood as the submunition units of cluster weapons or cargo weapons. It is also understood that a bomblet contains an explosive charge. Many types of cluster munitions may contain submunitions, but not bomblets. An example of the latter is small units spread out in order to interfere with and disturb radio communication.

3.1.2 Cargo munition

Cargo munition is the common name for cluster munition fired from ground based platforms. The term includes mortar munition, munition for field artillery guns or howitzers, and large calibre artillery rocket munition. It is commonly accepted that cargo munition is a subset of cluster munitions.

The concept of cargo munition is sometimes also used for the projectiles containing illumination charges, smoke charges, electronic countermeasures or other non-explosive contents.

3.1.3 Duds

Duds are explosive ordnance items that have not functioned as intended at a prescribed time or at impact with the target or with the ground. Duds may be produced by any weapon firing ammunition with explosive content, also from ammunition that is not a cluster munition. The term does not address the question of whether the object is armed or not.

3.1.4 Reliability

The reliability of a piece of ordnance is understood as the probability that the item will function as intended. Reliability is also connected to subparts of the ammunition; its ability to be fired in a safe manner, that it follows a predicted trajectory to the target, that it functions correctly at, or in the proximity of, the target, and if it fails in any way, that any backup device functions as intended.

The total reliability of ammunition is normally in the range of 90 – 100%. In many cases it is even more than 99%. However, the reliability can be compromised by wrong usage, bad storage conditions, sloppy production, and even by age alone.

3.1.5 Footprint

The very nature of cluster weapons, and their main reason for existence, is that they distribute their effect over an extended area. The alternative, which may be a single unitary charge, has an extremely high effect within a small area, an effect that decreases quite rapidly from the impact point. The footprint is the area over which the bomblets from a single container are dispersed. It does not imply that all targets in the footprint area are subject to total devastation.

For guided weapons, or for sensor fuzed warheads (SFW), which all are able to aim their effect against a point target, the concept of footprint is a bit more subtle. For these weapons, the footprint is the area in which the weapon is able to defeat a target. However, each warhead can attack one single target only. If a target is not found inside the footprint, the warhead will have almost no effect. Thus the degree of devastation inside the footprint may be very limited.

The size of the footprint varies considerably from system to system. Basically, the footprint should be small for systems with a low number of bomblets, and larger for those with high number of bomblets, but that is not always the case. Only rarely does the footprint have dimensions exceeding a couple of hundred meters. The size of the footprint area is, to some extent, adapted to the expected precision of delivery. Also, from a cost-effectiveness point of view, it is often better to engage larger formation with several cluster munition units, than with large unitary munition that each cover a limited area.

3.1.6 Area of effectiveness

This is the area over which the explosive warhead has a destructive effect. The degree of destruction is defined according to a set of criteria that vary from disturbing effect to annihilation. This area is as seen from the attacking side. When seen from the defensive side, it is called *area of vulnerability*. Terms like *lethal area* and *area of incapacitation* are also frequently used. The defender is able to decrease the area by taking protecting measurements, like using protective items like a vest or add-on armour, or by seeking cover offered by vegetation or small scale topography[2]. The total area of effectiveness for a whole cluster bomb is found by adding the individual areas for each bomblet and subtracting the overlapping areas between adjacent bomblets.

The connection between the footprint or dispersion area and the area of vulnerability can be illustrated as follows. If the footprint area is say 5000 m^2 and the probability of incapacitation for a soldier inside that area is say 12%, then the area of vulnerability becomes 5000 m^2 x 0.12 = 600 m^2.

3.1.7 Dispersion

Dispersion and footprint are almost the same. In order to make a footprint, the bomblets have to be dispersed. This can be done by

- timing, as the bomblets are dropped from the container at preset time intervals
- explosively, as the bomblets are thrown out from the container in different directions
- centrifugal forces, induced by the spin of the container
- aerodynamically, as the bomblets meet the air stream at a random attitude and the aerodynamic forces bring the bomblets out in different directions

When considering point target weapons, dispersion can be looked upon as the deviation between separate submunitions.

[2] Small scale topographic is considered as ground features with sizes and distance of one meter or less.

3.1.8 Accuracy

The concepts of dispersion and inaccuracy are often mixed. Indeed, they are quite independent concepts.

Accuracy, in terms of firing of ordnance objects, is the ability of the system to hit where it is supposed to hit. In the context of cluster weapons, it is the ability to disperse its bomblets over the area it is supposed to defeat – ideally, that area, that whole area, and nothing but that area.

Thus, inaccuracy is a non-ideal property, but still it is an inherent part of all weapon systems. The reasons for inaccuracy are manifold:

- inaccurate geographic locations of the target
- navigational errors
- meteorological influence on the firing platform, the cluster munition, and the bomblets
- inaccuracies and errors in the construction of the weapon

Such errors are basically of two kinds

- systematic errors
- random errors

Systematic errors repeat themselves from weapon to weapon. A typical example is errors in the target location. If the location is 300 m in error, all weapons will be aimed at a point 300 m away from the intended aim point, irrespective of how accurate the other parts of the system are. Systematic errors are also often due to meteorological effects. If an unpredicted change occurs in the part of the atmosphere through which the weapons are delivered, the hit point is affected accordingly for every warhead.

Random errors are, as the name implies, errors that has a random effect on individual warheads. If all projectiles in a salvo are aimed at the same point, the actual hit points will be distributed around that point. If no systematic errors were present, the mean point of impact would be at the aim point. Thus, random errors have a dispersive effect on a salvo of weapons. In case of aiming several cluster bomb units at the same point, it will make the affected area larger than the footprint of a single bomb. This dispersive effect should not be mixed with the intended dispersive effect of the bomblets originating from a single unit.

4 The tactical role of cluster weapons

As already mentioned, cluster munitions are almost exclusively used against area targets on land. They are also likely to be used in a fire support role. That is, such weapons are most often not used in combat by the manoeuvring forces, but are used by artillery forces and fire support air forces.

The purpose of using weapons onto an area is twofold:

- Firstly, the main purpose is usually to inflict *damage and destruction* on the enemy, his soldiers, his vehicles, his communication systems, or simply to reduce his ability and will to continue the war. It is a common belief that if 30%[3] of a unit is brought out of action, the whole unit will no longer function on the battlefield. This rate is often used as a guideline for the firepower needed in a combat situation. If 30% is killed or injured, the medical burden on the remaining force is so extensive, that it will inhibit further fighting.
- Secondly and often considered as more important than destruction, is *suppression* of enemy forces. Suppression implies that the fire is less damaging but sufficiently intense over an area that the war fighters stay in their foxholes, remain in their bunkers, put their vehicles under cover and refrain from using their weapons. This gives the friendly forces an opportunity to change position, use their weapons and improve their tactical state. Here the purpose is not primarily to inflict damage, but more to inflict fear. Suppressive fire requires a certain intensity over time. Suppressive fire over an extended period will have a destructive effect.

It is not straightforward to forecast and quantify the damage or injury effect. The suppressive effect is even harder to quantify. It is not just a function of explosive content, fragment size, etc., but is also dependent on the soldiers' moral, motivation, training standard, discipline, tactical situation and other qualitative factors. The effect of suppression is often a function of the destructive capability of the munition in the sense that high destructive power implies high suppressive power.

For both these above purposes, cluster munitions have a role parallel to the use of unitary high explosive fragmenting weapons. Thus it will be a question whether cluster munitions are more effective in solving these tasks than unitary munitions are.

4.1 Artillery systems

Artillery systems using cargo or cluster weapons are of three subtypes:

- mortar systems
- howitzers, mainly 155 mm calibre
- rocket systems ranging from 122 mm to 300 mm calibre

The main reason for using cargo munition instead of the more conventional unitary high explosive systems are the effect against soft targets (i e personnel targets). The reasons for this enhanced effect will be discussed in successive sections. These munitions often have a penetrative effect from the shaped charge, but this does not give any significant contribution to the soft target defeat.

The total effect against soft targets is usually believed to be around 2 -5 times higher against standing unprotected soldiers. Against well protected targets the advantage of using cargo rounds

[3] 30% is a doctrinal number that seems to be valid in most NATO countries. Other doctrines, like that used by the Soviet Army, required at least 50 - 60% destruction to render the target as out of action.

are less pronounced. Soldiers that are well dug-in and protected are difficult targets for cluster weapons as an almost direct bomblet hit is required. Less protective measures like using a vest or flak jacket will usually have a greater effect against bomblets than against unitary ammunition. This is due to the fragment size.

A special task, containing both the destructive and suppressive elements, is to defeat or suppress enemy artillery. This task, called counter battery fire, is typically done as the enemy engages friendly forces and requires hasty routines and good detection capability to find the exact position of the enemy. DPICM ammunition was well suited for this purpose, as it had anti-personnel capability against the crew manning towed guns, while the anti-tank capability worked well against armoured self-propelled howitzers containing large amounts of ammunition. Modern howitzers have been designed to withstand that threat by reinforcing the turret roof, making this target quite difficult for the current cargo munition.

4.2 Air delivered systems

Air delivered cluster munitions are mainly used in the role of Close Air Support (CAS), which is quite similar to the role of artillery, supporting friendly forces by engaging enemy targets in their proximity. These targets are enemy manoeuvring troops or enemy key points like communication nodes, radars, air defence, observations posts, fire support strongholds, etc. Cluster weapons may be well suited for this purpose as they can produce intense and lethal fire over a limited and dedicated area. The role of CAS is mainly to destroy, but also to suppress enemy units over short periods of time

Another role in air operations is Battlefield Air Interdiction (BAI). A classical example of BAI is the 1990/91 Gulf war Operation Desert Shield that was a precursor to Operation Desert Storm. The purpose of BAI is to destroy infrastructure like airfields, harbours and industrial plants in order to minimize the enemy's capability to conduct war. Permanent military installations like radars, rocket sites, ammunition storages and depots will also be preferred targets. Attack on troops will usually be of secondary importance at this stage. The utility of cluster weapons is thus limited in such a role.

4.3 Direct fire systems

Direct fire implies that the gunner can see the target while aiming and firing the weapon. This is opposite to indirect fire where the person operating the weapon does not see the target but points the weapon in a certain direction upon instructions from others. In such a mode, conventional unitary warheads will be the preferred ammunition.

Ammunitions for direct fire and with cluster characteristics are of relatively recent origin, or at the stage of development. Such munition can be fired from ground platforms, like main battle tanks, or from rotary wing aircraft. Their role is both to neutralize infantry and to defeat armoured vehicles. Munitions of this type are used against targets that are not directly visible for the gunner but hidden behind structures or other obstacles. Firing cluster weapons from direct fire platform is thus not truly direct fire.

Cluster munitions made for field artillery and mortars can also in principle be used in a direct fire mode, but this kind of use is quite exceptional and is meant as a last resort self-defence.

5 Means of delivery and their accuracies

5.1 Accuracy and dispersion

It is often claimed that cluster weapons are inaccurate. In some repects that is true. However, inaccuracy is not an inherent property of such weapons. Generally, they are not inaccurate because they are cluster weapons. For all unguided weapons, the ability to hit the target is a function of the environment and the properties of the launching unit, whether that is a gun or an aircraft. Meteorological factors are also of importance, but that is also the case for other weapons. The main difference between cluster weapons and unitary weapons is the descent phase from the ejection of the submunitions to the impact on ground or target. Usually, the deviation due to wind during that phase is insignificant compared to the other factors that influence the accuracy. This factor is most pronounced when bomblets are ejected from aircraft attached dispensers at high altitude.

It is also important to note that the lack of accuracy due to wind is uncorrelated with most other sources of error for the system. This means that there is no connection between the bomblet wind error and errors concerning launching, aiming, positioning and so on. This further implies that such an error does not add linearly to the other errors. As an example, an artillery system may have an error in the positioning of the bomblet ejection point of say 200 m. The error due to the fall phase wind error could be i e 40 m. The total error will then be around 204 m; not 240 m, as it would be if the errors were correlated. Thus we see that it is the largest components of the error budget that dominates the total error, and that smaller uncorrelated errors may become quite insignificant,

Estimating the wind error
The only error component that is genuinely due to the nature of cluster weapons is the wind error after release of the bomblets from the container. Since bomblets mostly have a vertical fall, while the wind is more or less horizontal, the wind will mainly be normal[4] to the bomblet direction of movement, or it will have a side wind character.

The deviation caused by a side wind can be described by the so called Didion’s equation which says

[4] A direction being 90 degrees (or at a right angle) to the referred direction

$$\Delta x = v_w(t - t_0)$$

where Δx is the deviation due to wind, vw is the wind speed, t is the real time of fall and t0 is the hypothetical fall time in the absence of air. Both t and t_0 requires the actual velocity at release as the initial condition.

5.2 Aircraft launched dispensers

Aircraft dispensers are usually dropped from the aircraft pylons[5]. At a specified time, or at a certain height above ground, the bomblets are ejected from the canister in different directions through openings in the canister wall, or they are released as the canister shell opens up. This is what is usually known as a cluster bomb.

A cluster bomb can be activated by some kind of fuze which again is activated in one of several ways:

- by a time fuze that triggers a given time after release
- by a fuze that reacts to a certain air pressure and thus triggers at a certain altitude above sea level
- by a proximity device or radar that triggers at a certain height above ground
- by fuzes that are individual to each submunition and that ejects the submunition at appropriate time intervals

The dispersion of the bomblets is achieved by small powder charges, or by aerodynamic forces.

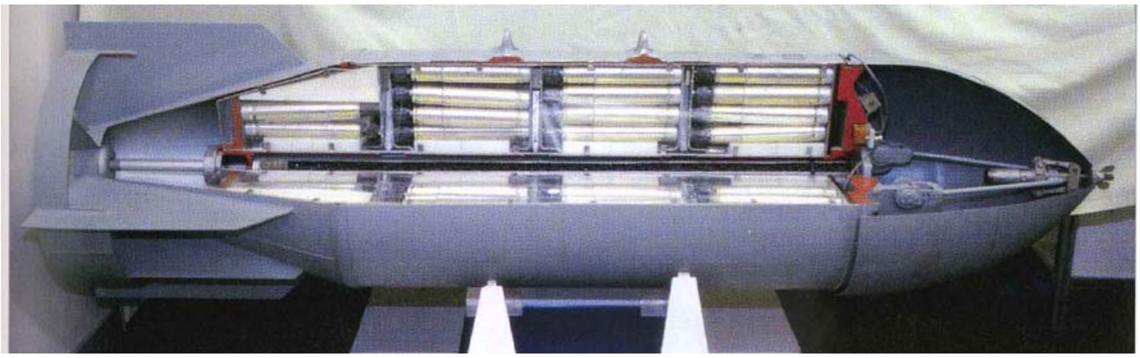

Figure 5.1 A typical cluster bomb; Russian RBK-500 with PTAB bomblets [1]

The Wind Compensated Munitions Dispenser (WCMD) is a relatively inexpensive tail kit that uses inertial guidance to steer cluster bombs from a known release point to precise target coordinates, while compensating for launch transients, winds aloft, surface winds and adverse weather. The WCMD kit may thus turn dumb cluster bombs into accurate and smart weapons. Currently, the dispenser is achieving an accuracy of within 10 meters. Aircraft employ WCMD

[5] An attachment device situated on the botton side of the wings or under the belly of the aircraft.

from a wide range of altitudes, in adverse weather, using various tactics such as level, dive, toss[6] bombing, and bombing on coordinates[2].

So far WCMD is only designed to be used with 1000 lbs bombs. Cluster bombs of this category are the CBU-87 and CBU-97, which with the WCMD kit fitted are called CBU-103 and CBU-105 respectively.

5.3 Attached aircraft dispensers

These systems are different from the previous ones as the dispensers are not dropped from the aircraft, but the submunitions are ejected from a dispenser attached to the aircraft. Due to obvious safety aspects, these bomblets have to be released in a way so that they do not interfere with the aircraft. Thus the bomblets are ejected with some speed in order to bring them away from the aircraft. The submunition may be ejected vertically downwards, sideways, backwards or even forwards.

In this latter mode the submunitions are released against the air stream. Therefore they have to be literally shot out, or propelled forward by a powerful rocket motor. An additional feature of these submunitions is that they can be aimed and fired one-by-one at a point target, just like a direct-fire gun. Thus these systems may not generally be termed as cluster weapons, but their dispensers often are termed as *cluster pods*. These pods thus have the same function as a gun magazine, like on an automatic rifle.

Aircraft dispensers are often constructed in a way that ensures a controlled release of bomblets. They do not release their cargo in bulk as dropped dispensers often do. Aircraft dispensers will therefore be able to distribute their load in a more controlled manner than dropped dispensers.

Figure 5.2 A typical dispenser unit; the American SUU-13[3]

Dispensers attached to the aircraft at the time of ejection may be the system that has the highest degree of inaccuracy. Aircraft equipped with such ammunition will however tend to deliver their

[6] A bomb delivery mode that involves release when the aircraft is in a climbing trajectory which implies that the bomb may impact far away from the point of release.

load at a quite high altitude in order to avoid being threatened by air defence systems. In such cases the ejected bomblets may deviate several hundred meters from the intended hit point.

5.4 Howitzer delivered cargo shells

Conventional artillery covers the calibres from 105 mm to 203 mm. In NATO and other western countries 155 mm is the major calibre. In countries of the former Warsaw Pact or in many third world countries 122 mm and 152 mm are the major calibres.

The maximum range of modern howitzers is around 35 km with unguided munitions. Guided ammunition, though not yet very widespread, can hit targets beyond that distance. Howitzers are usually not used at distances shorter than 3 - 4 km. When using cargo ammunition, the shortest distance will have to be even more restrictive.

The cargo projectile is always equipped with a time fuze that is set for the release of the cargo at the recommended height above the target. The time usually has to be set by the crew, based on calculations made by the fire control system. In modern systems, using modern fuzes, the time can be set automatically, by an inductive arrangement, during the loading of the shell into the gun chamber. This ensures a more reliable setting of the fuze compared to manual systems.

The dominating kind of submunition for firing from howitzers is of the DPICM-type. An overview is given in the table below. The major alternative is the Sensor Fuzed Warhead (SFW) ammunition. These projectiles usually contain 2 bomblets. The deployment of such ammunition is so far very limited.

Calibre	No of DPICM	Range	Dispersion area
105 mm	15 – 21	17 km	1 – 2 ha
122 mm	24 – 32	16 km	1.5 – 2.5 ha
152 mm	49 – 84	25 km	1.5 – 3 ha
155 mm	49 – 88	30 km	1.5 – 3 ha
203 mm	120	30 km	2 – 4 ha

Table 5.1 Artillery DPICM systems

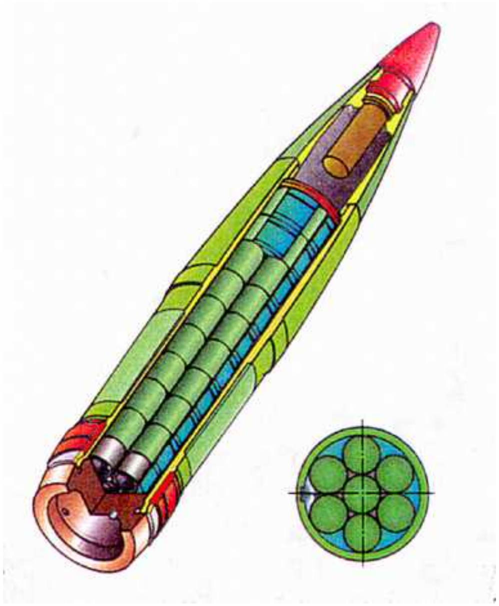

Figure 5.3 Artillery cargo round DM642 with 63 bomblets (shell cross section at the lower right)

At short ranges the most significant contributions to the inaccuracies have normally been variations in the muzzle velocity and uncertainty of the geographical location of the target and the firing gun. However, as the firing ranges have increased, the navigation instruments have improved and a better muzzle velocity management has been introduced, it is now the meteorological factors that remain the main contribution to inaccuracy. Of these factors the wind is dominating, while the contributions from air pressure and density are less significant. At average wind conditions the deviation between the aim point and the impact point is around 1% of the firing range. At more severe wind conditions the deviation increases accordingly. The second most significant contribution to inaccuracy is presently the lack of ability to determine the aerodynamic properties and the possibility to make precise ballistic calculations of the projectile.

5.5 Ground rocket shells

Some of the basic limitations of traditional gun artillery are the strict limitations in calibre, and the increasing complexity and the resources required when targets situated beyond 30 km distance have to be engaged.

The use of rocket propelled field artillery to some extent overcomes these limitations and difficulties. In addition, the load on the payload is much more benign when being fired by a rocket than from a gun. A howitzer may load the shell to more than 20000 G[7], while a rocket launcher may not exceed 1000 G. However, unguided rockets are notoriously inaccurate, as they are very prone to wind gusts during the boost phase. This phase typically takes place in the lower 500 – 800 meters of the atmosphere, a region characterized by having quite variable and unpredictable wind fields. The inaccuracy of an artillery rocket is thus at least twice as high as for a tube artillery round fired at the same range.

[7] One G is an acceleration equal to the gravity; 9.82 m/s^2

Artillery rockets carrying cargo munition comes in a wide variety of sizes and calibres. The smallest is the 122 mm that may carry 39 DPICM bomblets; the largest is the ATACMS system carrying around 950 M74 spherical shaped fragmenting bomblets. Except for the ATACMS, most rockets contain the DPICM bomblets. The Hydra system may also be included in this group, though it is not genuinely artillery, as it is fired from a helicopter at relatively short range and with a 70 mm rocket.

Rockets are well suited for firing very advanced submunitions like SFW units, or the advanced anti-tank munition BAT provided with a multitude of sensor units. (see chapters 9 & 10)

Some rocket artillery systems are also very susceptible to so called tip-off error, also called mal launch error. They are caused by vibration in the launcher, when the rocket is being propelled out of the launcher, and by the crosswind affecting the rocket as it leaves the launcher.

5.6 Mortar shells

Mortars are used by armed forces at various tactical levels, from 51 mm calibre at squad or platoon level, to 240 mm at corps or army level. Cargo munitions are only available for 81 mm, 98 mm, 107 mm and 120 mm. Usually, mortars have smooth bored tubes. However, 107 mm mortars exclusively have rifled bores, and a few 120 mm systems are found with rifled bores.

Mortars are quite light weapons. The weapon itself and a limited amount of ammunition can be carried on foot by a squad. However, most systems are connected to a vehicle, and the weapon is often fired from that vehicle.

Bomblets in mortar cargo ammunition are of the DPICM type with the same dimensions as used for the field artillery systems. The table below shows the range and other characteristics for these munitions.

Calibre	Bore	No of DPICM	Range	Footprint
81 mm	Smooth	9	5.5 km	unk
107 mm	Rifled	20	6.8 km	unk
120 mm	Smooth	12 - 54	7.5 km	1 - 3 ha
120 mm	Rifled	2 (SFW)	8 km 13 km (rocket)	unk

Table 5.1 Mortar DPICM systems

The figure below is an example of a mortar round with DPICM content.

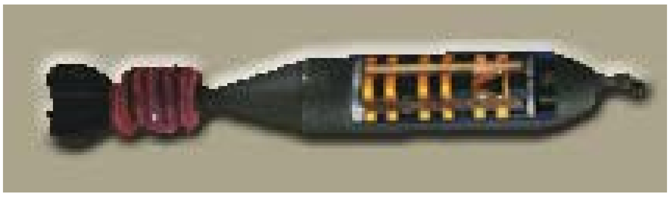

Figure 5.4 The MAT-120 Spanish mortar round [4]

Mortars are usually fired in a high angle mode, meaning that they are fired with an angle of elevation higher than 45°. Compared to ordinary artillery, which usually is fired with low angle, high angle implies long trajectories, long time of exposure to atmospheric interaction and thereby lesser accuracy.

Mortars are operated at battalion or regimental level. Traditionally they do not have any direct access to upper air meteorological information. This implies that the technical basis for fire is more incomplete for mortars than for artillery. Altogether the accuracy will be less for mortars than for howitzer at comparable firing ranges.

5.7 Direct fire

Direct fire cluster weapons is today made with two systems; the US Hydra systems which is a 70 mm helicopter fired rocket containing 9 DPICM bomblets, and the Israeli APAM which is fired from a main battle tank (105 or 120 mm) with 6 ”hockey puck” bomblets in each shell. These are spread out with around 10 m interval along the line of sight.

Basically, direct fire is very accurate. The error is usually within a couple of meters. However, a direct fire cluster munition can not be considered as true direct fire weapons, as they are meant for targets situated below the trajectory of the carrier, like entrenched infantry and targets hidden behind obstacles. Thus, the operator may not always see the target. His accuracy is not solely dependent on his aiming capabilities, but also his ability to judge or measure the distance to the target. He then has to set the time fuze of the shell with an accuracy of a few tens of milliseconds before firing.

So-called direct fire cluster weapons can not be claimed to be direct fire munitions in the true sense. They operate in an indirect mode, but are fired from platforms that are meant for direct fire.

5.8 Accuracy of guided rockets and missiles

Modern guided weapons like ATACMS, G-MLRS, JSOW, JASSM and Tomahawk have a combination of GPS[8] and INS[9]. The accuracy of such systems is usually 10 m or better. This implies that such systems can be considered as point target weapons. Provided that the target

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[8] Global Positioning System
[9] Inertial Navigation System

coordinates are set correctly, that the target is within range of the system, and that it arrives fully intact to the target, the collateral damage inflicted by such weapons should be minimal.

5.9 Monolithic impact of container

For cluster bombs and artillery shells, the correct performance of the munition depends on the functioning of the main fuze of the carrier. This fuze should, at a predefined time, ignite another charge that, consequently, opens the container and releases the payload. If that fuze fails, and no payload is released, the shell or bomb will suffer a monolithic ground impact.

Cluster bombs and most artillery and mortar systems will hit the ground with a speed of 300 – 400 m/s if the fuze fails. If the ground is soft, the projectile will usually penetrate the ground and remain buried. In urban, mountainous and stony terrain, there is a certain chance that the projectile will suffer considerable damage and thereby eject the whole payload or parts of the payload. Bomblets thrown out at such an event may not have time to arm properly and may therefore likely become duds. However, such duds will have less probability of being sensitive to handle, but they should still be handled with utmost care.

6 The effects of cluster submunitions

Warhead containing explosives have four *primary* effects

- blast effects
- fragment effects
- heat effect
- penetrating effect (shaped charge)

Depending on the detailed design of the warhead, these effects are more or less prevailing. However, for most warheads made of a metal casing and filled with a high explosive, the dominating effect comes from the fragments, followed by blast and finally heat as the least significant effect. Many submunitions also have the shaped charge penetrating effect, the purpose of which is to perforate the armour of vehicles. Other possible effects, like electromagnetic radiation and ground shock, are of insignificant importance.

A qualitative picture of the effects is shown below[5].

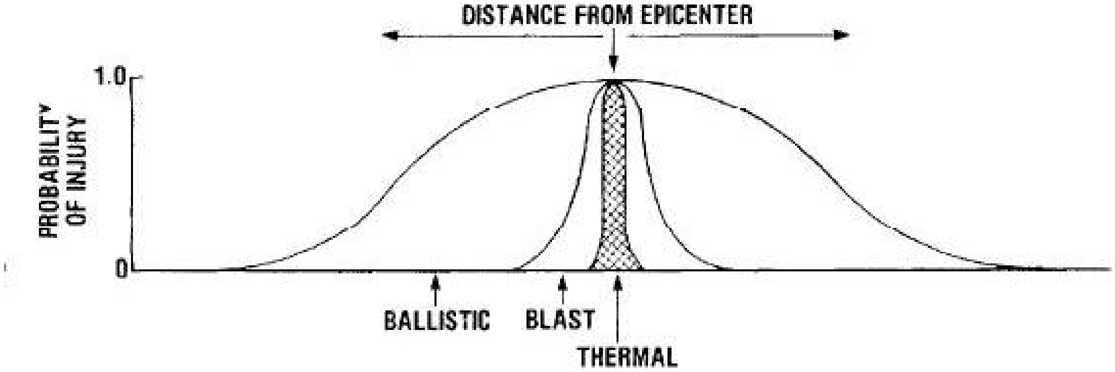


Figure 6.1 Range of effects

Secondary effects, which includes the effect of being hit by debris not originating from the warhead itself, and *tertiary* effects caused when the human body is being thrown around by the blast wave, are not considered here.

In accordance with the laws of war, the purpose of a weapon is not necessarily to kill the enemy, but to incapacitate him, i e making him incapable to continue the fight. Incapacitation is valid both for an individual soldier and for a military unit of any size, being a platoon as well as a division. Incapacitation also implies that the soldier is in need of medical attention and recovery. Incapacitation does not necessarily imply any permanent and incurable injury.

The effect of collateral damage on civilians follows the same lines as on soldiers. The soldier can be considered better trained and in better shape than an average civilian. A soldier will have better knowledge of how to avoid injuries and how to protect himself. The soldier may use protective garments or equipment that a civilian will not have access to. Thus a certain threat may incapacitate or injure a civilian but not a soldier. Civilians involve children, who are less likely to receive hit due to their sheer size, but the body of a child is more vulnerable once hit.

This chapter describes the primary effects in some detail, and discusses ways of quantifying the effects. The effects can be considered both from a military and a humanitarian point of view. The main difference between these two viewpoints is that an injury in the humanitarian sense may only include a permanent injury that may compromise the victim’s life quality. In classical military sense, an injury may also include injuries of a temporary kind that may inhibit the soldier to perform his duty in a time span comparable to the duration of the battle. However, in a low intensity and asymmetric conflict, the military viewpoint may come quite close the humanitarian one.

6.1 Lethal area

Quantifying the effect of ordnance is quite complicated.

- *Blast effects* may be the easiest effect to quantify, as the pressure and impulse from an explosion is a function of the charge size and distance. Other factors are of secondary importance.
- *Fragment effects* are more complicated. Firstly it is a problem to assess the initial state of the fragments, i e their initial velocity, their weight distribution and their shape. Secondly, the aerodynamic performance is not known with certainty. Thirdly, there is some uncertainty about the effect fragments have when entering a human body. Finally, the exposed area and the posture of the human body are to some extent random.
- *Incendiary effects* are also complicated to describe. They will depend on environment, the victim's clothing, and incendiary components. The short term effect may be less severe and vague, while the long term effect could be fatal.

Whatever the effect is, it can be quantified by a two-dimensional function *p(x,y)* which is the probability of being affected by the weapon when the position of the target is given by the ground coordinates *(x,y)*. The position of the bomblet can be set as origo *(0,0)*, although it is not a necessary premise.

When this injury probability function has been established, the effect of the munition can be stated as a single quantity called lethal area. However, the term *lethal* may sound more dramatic than it is. In military context this means *incapacitation* which may not necessarily imply lethality. This term is defined as

$$A_L = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} p(x,y)dx,dy$$

The interpretation of the lethal area in practical terms is the size of the area that is completely affected by the warhead. In military terms, if the number of targets per area is known to be σ, then the number of targets destroyed by the warhead is found as:

$$N = A_L \sigma$$

Example: A 155 mm artillery shell is known to have a lethal area of around 800 m^2 against unprotected soldiers in an upright posture. The density of such soldiers in a target area is assumed to be 20 soldiers per hectare, or 0.002 soldiers per square meter. The number of soldiers incapacitated by this warhead will then be 800 m2 x 0.002 soldiers/m^2 = 1.6 soldiers.

When trying to estimate the probability of being incapacitated when being a distance x from the detonation, the following expression can be used when the lethal area A_L is known.

$$P(x) = \exp\left(-\frac{\pi x^2}{A_L}\right)$$

Example: Returning to the previous example with a lethal area of 800 m^2, the probability of being incapacitated at 3 m distance will be 97%, at 10 m it will be 68%, at 20 m 21%, and at 40 m 0.01%.

When multiple warheads are spread out over a footprint area A_F, there will be more or less overlap between lethal areas originating from different warheads or bomblets. As there is no need to kill a target more than once, the total lethal area will become less than the sum over individual areas. The expression for the cumulative lethal area of a cluster bomb containing N bomblets with individual lethal areas A_L each then becomes:

$$A_{L,total} = A_F \left[1 - \exp\left(-\frac{NA_L}{A_F} \right) \right]$$

This formula presupposes that the bomblets are uniformly distributed over the footprint; if not the total lethal area will be even more diminished.

Of course, these approaches can be applied for any warhead against any target, also for quantifying the humanitarian effect of a cluster munition.

6.2 High explosives and the blast effect

The blast effect of warheads is believed to be the most important effect when suppression of enemy fire is the purpose of the fire mission.

The table below shows the basic characteristics of the most common military explosives.

	Density (kg/m^3)	**Detonation velocity (m/s)**	**Detonation pressure (MPa)**	**Gurney velocity* (m/s)**	**TNT equivalent factor**
Comp B	1742	7920	29.5	2350	1.15
HMX	1903	9110	39.0	2970	1.26
Octol	1843	8480	34.2	2830	1.23
RDX	1806	8700	33.8	2451	1.19
TNT	1654	6930	21.0	2097	1.00

Table 6.1 Properties of some common explosives
** see section 6.3*

The blast effect from an explosive detonation is characterized by a shock wave that propagates outwards from the detonation point. The speed of propagation is initially very high and supersonic (several km/s). Depending on the size of the charge, the speed eventually drops to the sonic level, and the wave becomes an ordinary pressure wave.

The general shape of the shock wave is shown in the figure below. Here the duration is the length of the initial positive part of the pressure.

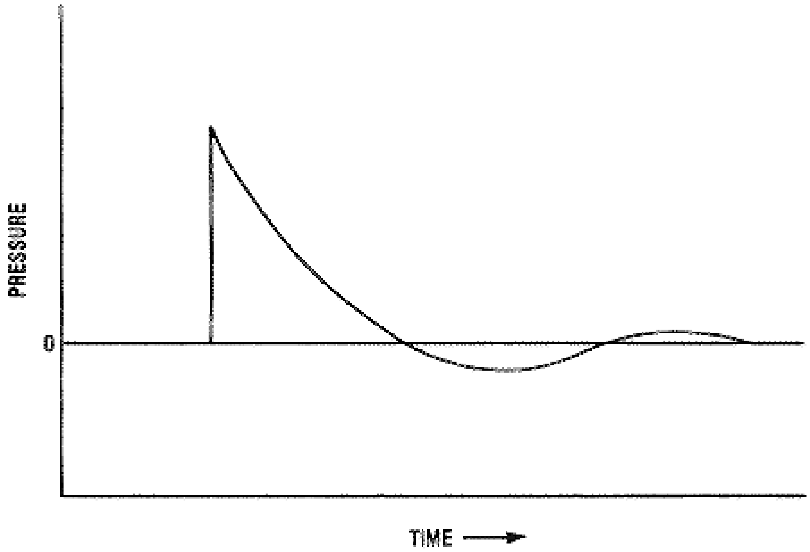


Figure 6.2 The shock wave profile

The quantitative characteristics of a shock wave are its *peak pressure* and its *duration*. The peak pressure is the height of the discontinuous front, while the duration is the time length of the positive phase. These two parameters, which we may call *p* and *t* respectively, can both be scaled according to the size of the charge. The principle behind scaling is shown in the figure below where κ is the geometric one-dimensional scaling factor of the charge.

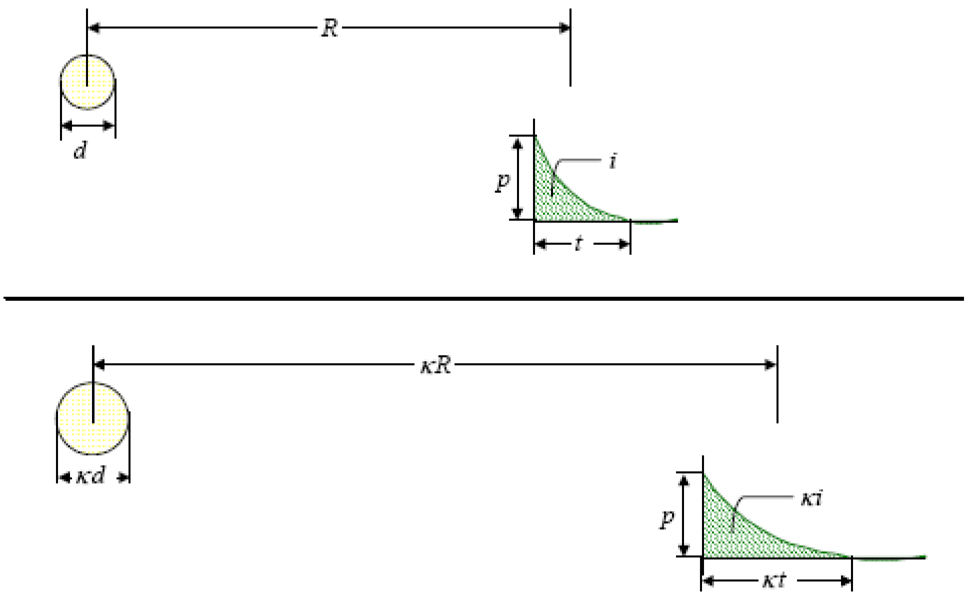


Figure 6.3 Scaling of blast wave effects

The essence of the scaling is that the distance and duration both scale with the charge size, while the peak pressure remains constant at scaled distances. This also implies that the impulse in the shock wave scales with the charge size.

An encased charge will have a somewhat reduced pressure compared to a bare charge. If the casing has a weight twice the weight of the explosive, the pressure will be reduced by more than 50%. The formula to be used here is

$$C' = \left(0.2 + \frac{0.8}{1 + M / C} \right) C$$

where M is the fragmenting mass and C is the explosive mass. C' is the effective explosive mass generating the blast wave.

We will return to these matters in the section on effects on the human body.

6.3 Fragments

Fragments usually originate from the casing surrounding the explosive charge of a bomb or a shell. Fragments may come in all sizes and shapes. When the casing has a smooth and even surface, both at the inside and outside, the casing will splinter up by so-called natural fragmentation. The fragments will then usually get quite irregular shapes, and cover a wide variety of sizes. A typical shape is the elongated one as in the left figure below, but any shape is possible. Prefragmented fragments like those from BLU-97 have a more regular shape as shown in the right picture

Figure 6.4 Examples of fragments[6]

Prefragmentation is made by having grooves or scores on the inside or outside of the bomblets. The casing is split up preferably along these grooves. Alternatively, spherical particles of a hard or heavy metal can be embedded in a matrix of a softer or lighter material. The spheres will then be the main injuring mechanism. Heavy spherical fragments will also have a far longer range than light or irregularly shaped fragments.

The effect of a fragment on humans is determined by its mass and velocity, and to less extent by its size and shape.

The initial velocity of the fragments is given by the so called Gurney's equation

$$v_0 = \frac{\sqrt{2E}}{\sqrt{\frac{M}{C}+k}},$$

where v_0 is the initial velocity. *M* is the mass of the fragmenting material. *C* is the mass of the explosive. *E* is the energy content per mass of the explosive. *k* is a shape factor of the charge. Its value is 0.5 for a cylindrical charge and 0.6 for a spherical charge. The numerator, $\sqrt{2E}$,the Gurney velocity, is found in table 6.1. These values are valid for ideal charges. In reality there will be deviations from these values due to variations in the casing thickness and radius, and other non-ideal shapes. However the Gurney equation may serve as a good estimate of the maximum speed of the fragments. Initial fragment velocities are usually between 800 and 2000 m/s.

All fragments, ejected from a certain part of the warhead, get the same initial velocity, independent of the size. The velocity of small fragments will subsequently decrease far more rapidly than larger fragments. This fact can most easily be illustrated by the so called half-distance defined as the distance over which the velocity of the fragment will be halved. As an example, consider a fragment with initial velocity of 1200 m/s and a half-distance of 30 m. After a travel of 30 m the velocity will be 600 m/s, after 60 m it will be 300 m/s, after 90 m it will be 150 m/s and so on. Actual values of the half-distances are shown in the table below. As most cluster bomblets eject either natural shaped fragments or spherical fragments, and accounting for the difference in air drag for these two shapes, the table below addresses both these shapes.

Fragment mass	Natural shape (steel)	Spherical shape (steel)	Spherical shape (tungsten)
10 mg	4 m	8 m	14 m
100 mg	8 m	17 m	30 m
1g	20 m	40 m	70 m
10 g	40 m	80 m	150 m
100 g	80 m	170 m	320 m

Table 6.3 Performance of fragments in air in terms in distances travelled to reach 50% of their initial velocity.

The ejection direction of the fragments is exclusively determined by the geometry of the charge. In most cases the direction of the fragments will be close to the normal[10] to the surface of the fragmenting body. When the detonation wave sweeps along the inner surface of the body, the direction will be slightly diverted along the direction of propagation. This deviation is, however, usually less than 10°[7].

Many of the members of the DPICM family of bomblets have a predefined fragment mass of 0.1 to 0.2 grams. This is considered the optimum fragment size if the main target is to defeat

[10] At right angle to the surface.

unprotected soft targets [8]. The optimum size is a compromise between having a few massive, long ranging fragments, or high numbered, small and short-ranged ones.

The effective direction of ejection is of course also dependent upon the velocity of descent which is added vectorially to the ordinary ejection velocity. If the bomblet falls with a velocity of less than 100 m/s, this effect can be neglected. A fall velocity of several hundred meters per second will divert the fragments into a lower trajectory that may affect the performance of the ammunition.

Another effect that is very dependent on distance is the hit probability. Let us consider a case where a bomblet detonates ejecting N fragments. Disregarding the velocity loss and the curved trajectory of fragments, the probability that a person will be hit by any of these fragments can be found by the following formula

$$P = 1 - \exp\left(-\frac{NA}{4\pi r^2}\right)$$

where A is the body area exposed to the charge and r is the distance from the bomblet. The formula presupposes that N is a large number. The figure below shows how the hit probability decreases with distance for a typical case of a bomblet ejecting 1000 fragments. The exposed area of the person is set to 0.5 m^2, which is a typical value for an adult person. The figure below shows that at 200 m distance the probability of being hit is quite marginal.

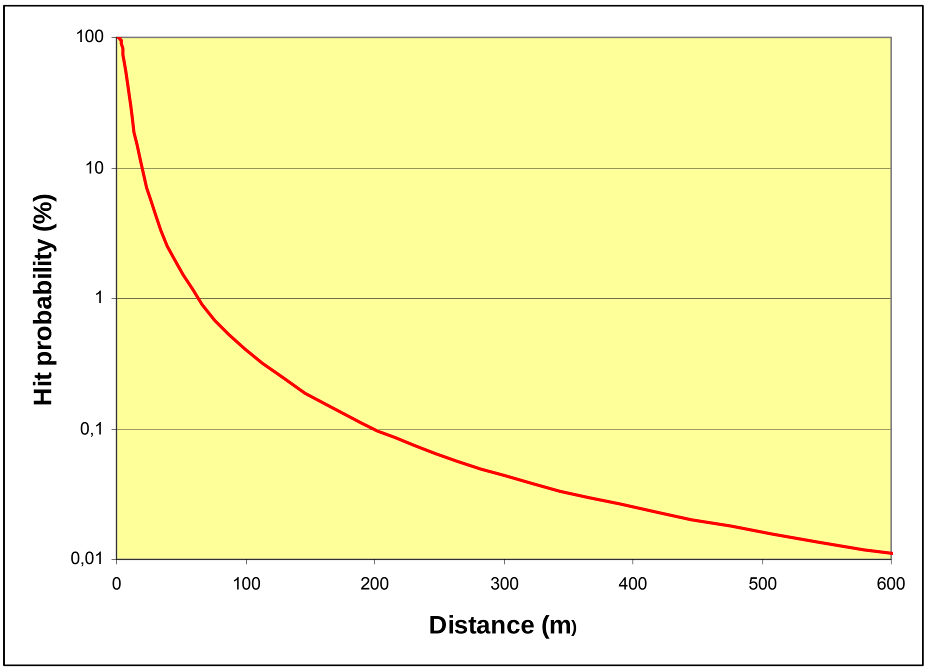


Figure 6.5 Hit probability as a function of range.

The fragment capacity for perforation of armour plates is shown in the following figure, illustrated as the required velocity of a given fragment to perforate a 1 mm or a 3 mm thick armour plate. When these data are combined with the deceleration of fragments in air it can be shown that the ability of bomblet fragments to perforate armour is very limited.

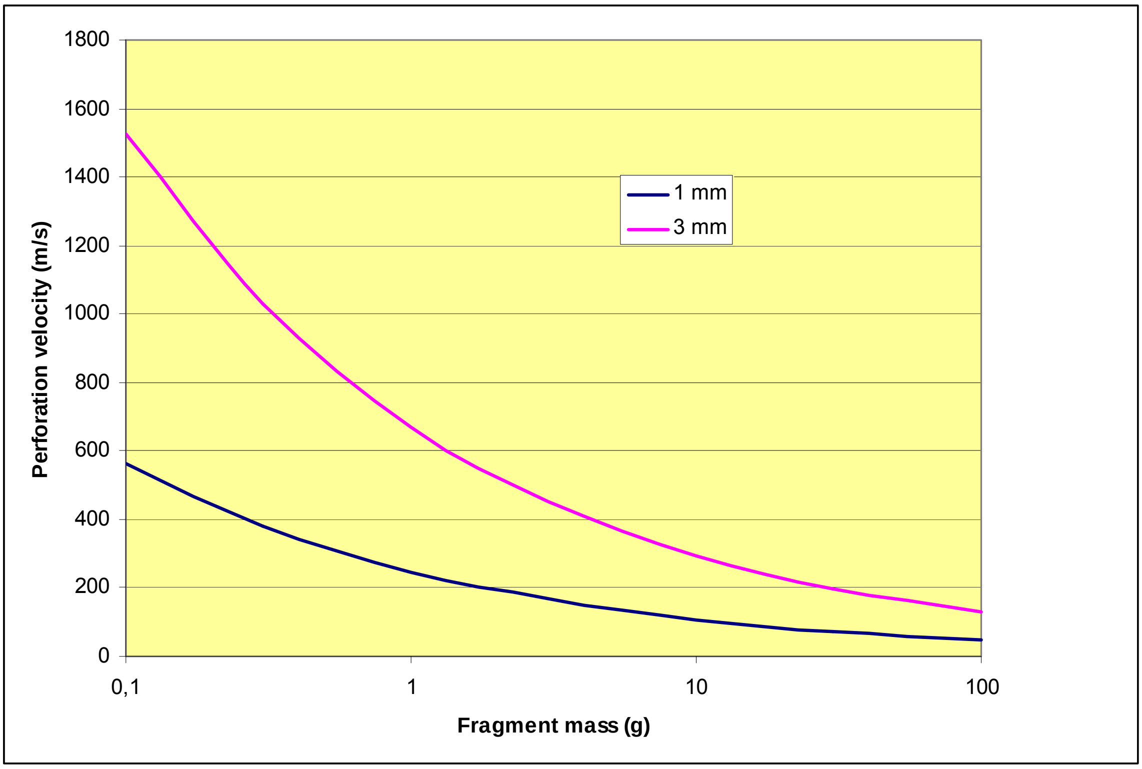


Figure 6.6 Armour perforation capacity of fragments

6.4 Shaped charges

A shaped charge, sometimes called a hollow charge, is the basic design for many cluster bomblets. It is a warhead giving quite an extraordinary effect. It is impressive to see that a charge containing just a few tens of grams of explosive is able to perforate more than 100 mm of even the toughest steel armour. Larger charges used today are for man-portable systems that are able to penetrate more than one meter of steel. However, cluster bomblets will usually not exceed 250 mm penetration.

A shaped charge basically consists of 4 components:
- a cylindrical casing
- an inverted conical liner in the front of the charge
- an explosive filling behind the liner
- an igniter opposite to the liner

The figure below shows the design of a M77 bomblet having a typical shaped charge design.

Upon detonation the liner, usually made of copper, collapses into a thin, high velocity jet. This jet, made of solid metal, has a tip velocity of 8 – 9 km/s. It is this jet that gives this type of charge its high penetrating capacity.

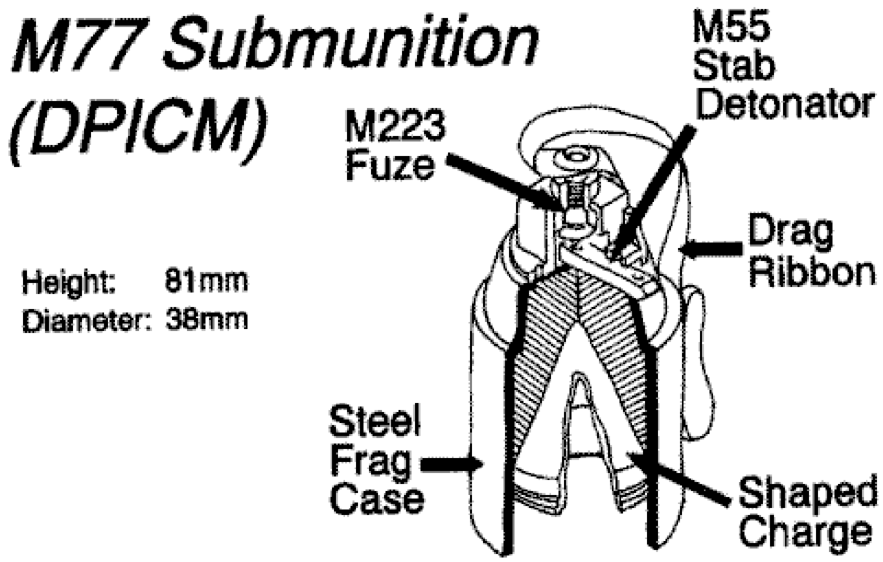


Figure 6.7 The M77 bomblet[9].

The jet is often characterized as molten metal, or sometimes even as a hot gas. None of those claims are true. The jet is in fact solid metal, but the metal is in such an excessively stressed condition that it flows. However, it is a solid state flow; neither fluid nor molten.

Shaped charges have the peculiar effect that they need a certain stand-off to the target in order to work in an optimal way. This effect is due to the formation of the metallic jet. The penetrative capacity of such a jet increases with the length of the jet. The jet needs distance in order to stretch out. However, if the standoff becomes too large, the jet will overstretch and disintegrate. The penetration capacity of a shaped charge may therefore vary according to the figure below for different liner materials.

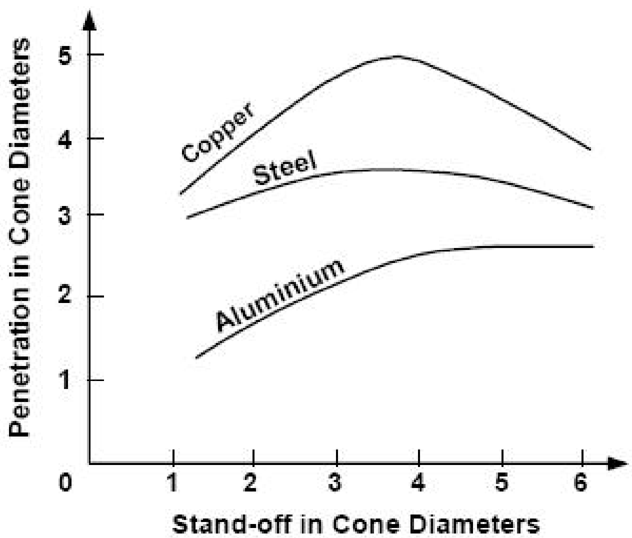


Figure 6.8 The stand-off vs. penetration curve for shaped charges [10]

As the figure shows, a stand-off distance of 3 – 6 times the calibre of the bomblet is optimal. Furthermore a shaped charge should not spin too violently at the time of impact. A high spin will tend to rupture the jet, with detrimental effects for the penetration capacity. These two factors are the reason why some bomblets are equipped with an expandable stand-off device like on Mk118, BLU-97 and BL-755, and why bomblets like M85 have spin braking winglets.

The shaped charge warhead is quite common among cluster bomblets. It is the main component in all DPICM, and in other bomblets dedicated for defeating armoured targets. Those known as SFW (see section 9.6) are also a kind of shaped charges, though working according to different principles than just described, in addition to having advanced sensor equipment.

When a shaped charge strikes an armoured target, the metallic jet perforates the protection, where the remaining high speed jet particles constitute the main injuring mechanism. In addition, particles from the armour itself are brought into the target. For large charges, high pressure detonation products will also contribute to the rising pressure inside the target. This pressure may be able to inflict ear drum rupture, and in rare cases even lung damage. However, for small DPICM of 60 mm calibre or less, this rise in pressure is not significant.

As the name indicates the DPICM should have an effect against both armour and soft targets. It is a common belief that a single hit with a DPICM on an armoured vehicle is equivalent to neutralizing the vehicle. This is a claim that deviates somewhat from the realities.

- Firstly, DPICM bomblets are small – mostly from 31 to 42 mm calibre. The penetration capacity is in the range of 80 to 150 mm. Although this capacity is sufficient to perforate the roof armour of most vehicles, it is not the same as achieving a kill of the vehicle. The size of the explosive charge of these DPICMs is also inadequate to inflict the effects of pressure, heat or smoke required to put the target out of action.
- Secondly, most of today's armoured vehicles are equipped with an interior lining in the crew compartment that reduces the effects of fragments that directly or indirectly enters the compartment. This liner is dimensioned to handle the effect of shaped charge warheads with a calibre of 100 mm or more. Such a liner works quite effectively against small DPICM charges. Therefore, in such targets only components situated in the direction of the impact may be damaged by the attack.
- Thirdly, in order to get a complete destruction of an armoured vehicle, vital or critical components must be hit. By vital components are meant components that are needed for maintaining firepower or mobility like the gun tube, fuel distribution system, parts of the transmission, the crew etc. Critical components may be explosives or propellant charges, where an ignition will completely damage the vehicle.

Based on the placing, size and distribution of such components, it may be stated that an armoured vehicle needs of the order of 10 hits with a DPICM in order to inflict a kill. For vehicles not containing large amounts of ammunition, the number will be even higher. Against modern tanks and modern howitzers, with adequate roof protection, the number may be still higher.

This view can be supported by a report based on the experience of the Russian army in Chechnya in 1994[11]. This report presents the vulnerability of armoured vehicles. However, it can also be seen as an indication on how invulnerable such vehicles are, as three to six shots by shoulder fired RPGs were needed to inflict a lethal damage to the vehicles. The warheads of RPGs are at least three times better in terms of penetration capacity than a typical DPICM bomblet.

In order to achieve 10 hits, an armoured vehicle has to be inside the footprint of an M483A1 155 mm DPICM[11] around 200 times, which clearly shows the futility of defeating large armour formation with this kind of munition unless when there are a high number of targets within the footprint area. Other kinds of DPICM, containing a smaller number of bomblets are even less effective.

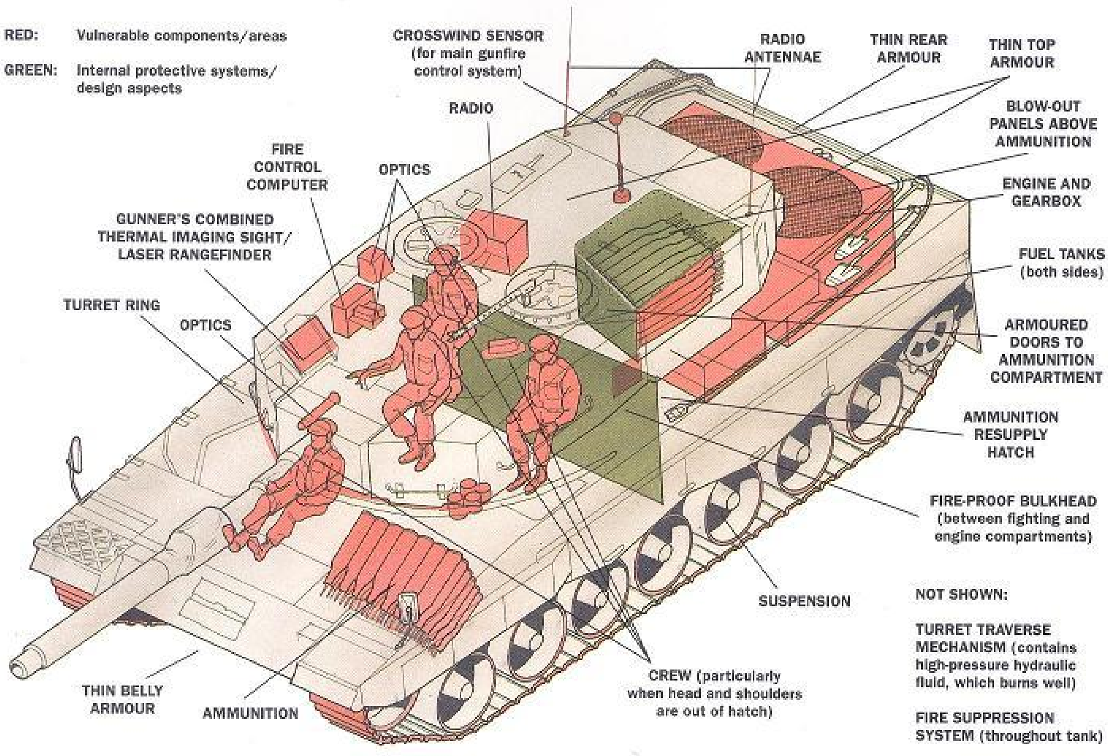


Figure 6.9 The distribution of vulnerable components in a modern tank[12].

6.5 Suppression

As mentioned earlier the purpose of suppressive fire is not primarily to inflict damage, but to avert the enemy from using his weapons. The suppressive effect of fire is more of the psychological kind than of the physical kind. However, it is the physical effect and the presence of weapons that generates fear among the enemy.

[11] Containing 64 M42 bomblets and 24 M46 bomblets

Indirect suppressive fire is usually delivered by field artillery or mortars. Air bombing can in principle be of a suppressive kind, but there are logistical limitations on the use of aircraft in this role.

The suppressive effects are of three kinds [13]

- visual effects (flash, smoke, debris, wounds)
- aural effects (bang, whine, whiz, ricochet, screams)
- tactile effects (heat, pressure, debris, wind)

The effect will, different from other effects, have a duration; e g after being exposed, the soldier will hesitate to transform from a suppressive to an active state. This duration will increase with the strength of the suppressive effect.

The effect will also strongly be a function of discipline, motivation, training and the tactical situation. Not only are such effects dependent on qualitative factors, but may also vary strongly from person to person, and from unit to unit. In addition, one person's reaction to suppressive fire may also affect the reaction of other persons. The different and very complex aspects of suppression is also discussed in detail in[14;15].

US Army Field Artillery School [16] once put up some simple expressions quantifying the suppressive effect. The concept used is parallel to the lethal area concept, but now called suppressive area. Against personnel in the open, attacked by field artillery, this area seems to be around 100 times larger than the lethal areas. Another interesting property of the model is that the suppressive area is assumed as being in linear proportion to the effective explosive content of the ammunition. With respect to the use of cluster weapons, this implies that the suppression is better using a unitary warhead than a cluster weapon with the same dimensions, as the latter will contain far less explosive than the unitary one.

There does not seem to exist a good model giving the suppressive effect of multiple detonations taking place at the impact of a cluster weapons. We will here assume that the suppressive effect is cumulative in the sense that the overlapping effect between the suppressive areas of adjacent bomblets is not taken into account. The total suppressive area is thus the sum of all individual areas. This is a conservative approach as it may slightly favour cluster weapons in comparison to unitary warheads. However, as the duration of the suppressive effect is supposed to be much longer than the audible duration of a cluster impact, this assumption seems plausible.

7 The vulnerability of the human body

7.1 Fragments effects

For most bomblets, the fragment effect is usually what causes most damage to humans, whether that is when the bomblet detonates as intended at impact, or when it detonates in a dud state.

When a fragment enters the human body, its velocity will slow down very rapidly, and transfer energy to the tissue at a very high rate. This will cause the formation of a temporary cavity in the body, which again will induce tissue strain and rupture of muscles, nerves and blood vessels.

Most cluster bomblets detonate on the ground. Exceptions are the BLU-18 and the M43 where the warhead pops up from the ground and functions at a height of 1 to 2 meters. As we all know the ground is usually not totally leveled, but more or less rugged. Thus, any target near the ground and at some distance from the detonation will, to some extent, be shielded by the terrain. The degree of shielding will vary a lot depending on the degree of ruggedness. The figure below shows the degree of shielding for a typical average broken terrain.

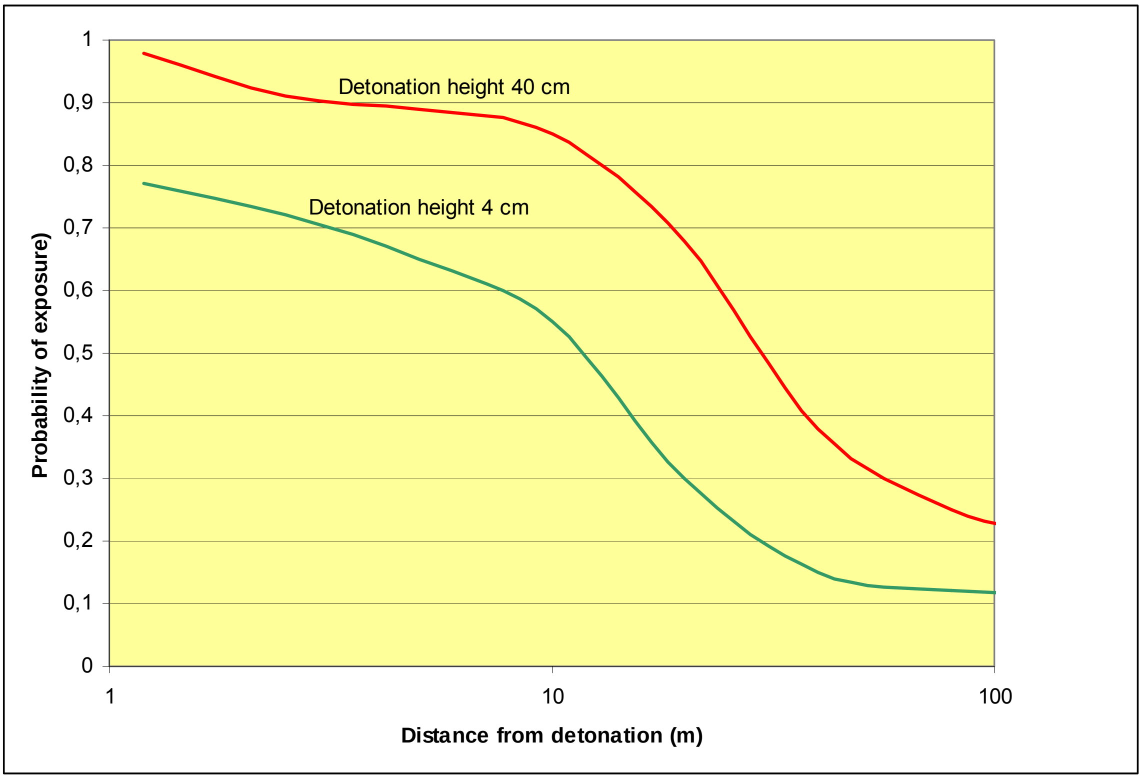


Figure 7.1 The effect of rugged terrain. The figure shows the probability of exposure of a prone soldier from a detonation height of 4 cm and 40 cm. (Example: A soldier located 10 m away from the detonation is only 55% exposed to a DPICM detonating 4 cm above ground)

7.1.1 Quantitative description of fragment damage

There are several ways to quantify the effects of fragments on the human body. Such a model requires the following components

- criteria for a fragment to be able to penetrate the human skin
- the probability of an incapacitating injury if the body is penetrated
- injury criteria have to depend on which part of the body is hit

Starting with the first criterion, according to Lewis[17], the probability of skin penetration for a fragment with kinetic energy *K* and cross section area *A*. The empirical formula for this probability is

$$P(SkinPenetration) = \left[1 + \exp\left(34.19 - \ln\left(\frac{2K}{A}\right)\right)\right]^{-1}$$

when SI-units are strictly applied.

A criterion according to Feinstein is used herein[18]. The probability of injury when being hit by a fragment with kinetic energy *K* is given by the following, quite complex expression containing a log-normal distribution

$$P(injury \mid K) = \int_0^K \frac{1}{x\beta\sqrt{2\pi}} \exp\left[-\frac{(\ln x - \ln\alpha)^2}{2\beta^2}\right] dx$$

When the probability of being injured by a given fragment is known, the total probability of injury when hit by several, say *n*, fragments is

$$P = 1 - \prod_{i=1}^{n} (1 - p_i),$$

where the index *i* designates the individual fragments.

The vulnerability model according to Feinstein divides the human body into three parts: the head, the thorax, and the rest of the body (abdomen, arms, legs). The reason for this rather rough division is believed to be that each of the parts has a quite uniform vulnerability.

There are other criteria for vulnerability of warfighters which use the term incapacitation. This implies that the soldier has received an injury that makes him unable to perform his duties. These criteria, however, are not dramatically different from Feinstein's criteria.

The parameters for each body part are given in the table below

Part	α (J)	β	Area (%)
Head	75	1.32	9
Thorax	60	1.45	23
Abdomen & limbs	130	1.54	68

Table 7.1 The parameters of Feinstein's model

The parameter α indicates the energy level where the probability of kill is 50%, while β is a measure for the width of the region where the probability goes from close to zero to almost 100%.

The actual kill probabilities are plotted below

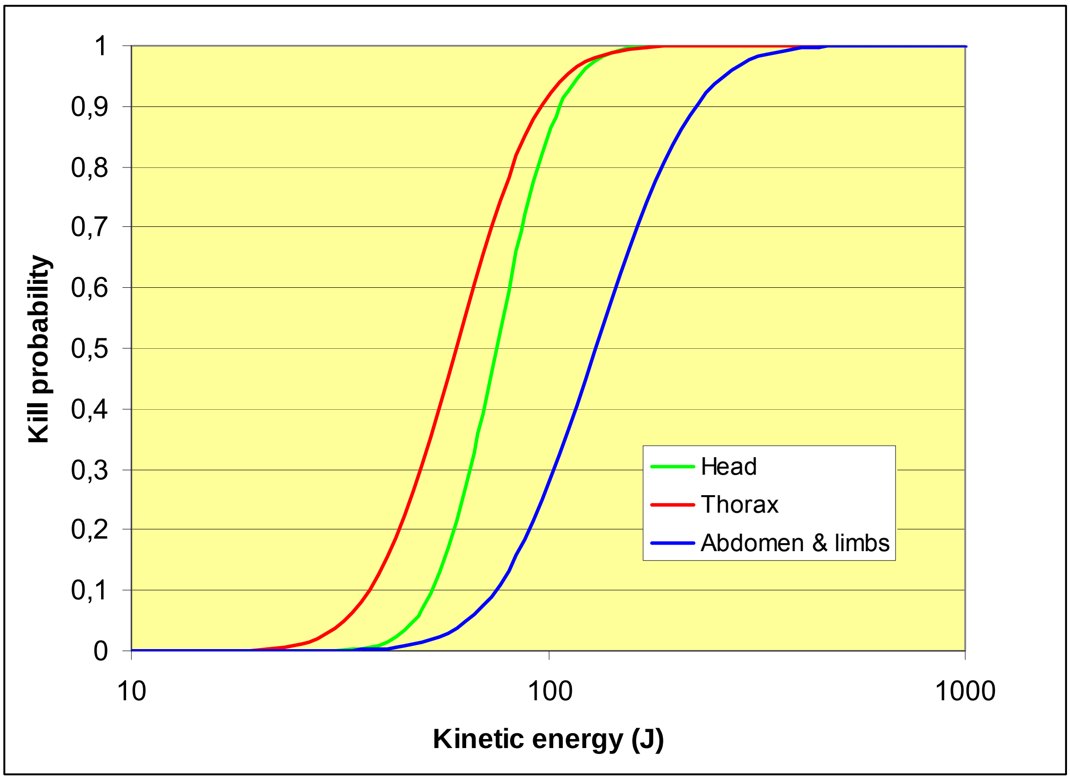


Figure 7.2 Graphical presentation of the Feinstein model

7.1.2 Fragment effects on minors

The destructive effect caused by a fragment is proportional to the kinetic energy that a fragment deploys in the body. Most fragments, except for the very large fragments and fragments that hit a thin body part, will deploy all its energy into the body[12]. It may also be seen as if this energy destroys a certain body volume. As the average mass density is about the same in all humans, it follows that the probability of fatality is proportional to the ratio between deployed energy and body mass. The damage caused by a certain fragment to a person whose weight is 40 kg will be twice as large as for a person whose weight is 80 kg. Thus a child is more vulnerable, once hit.

7.2 Incendiary effects

The injuries due to incendiary effects are functions of temperature and duration of the exposure.

Young people are in general less vulnerable to burn injuries than older people. The skin of a young individual will heal far quicker than that of an older person. As an example, if 30% of the skin is destroyed, is it certainly lethal for a person at the age of 70, while one who is 10 year old will almost certainly survive such an injury[19].

The primary incendiary effect of bomblets is not significant in comparison to the fragment effect and the blast effect. Not even bomblets with intended incendiary effect give an immediate injury

[12] Bullets from small arms will often, as opposed to fragments, pass through the body.

to humans. The effect is rather of secondary or an indirect effect caused by the ignition of surrounding flammable objects.

Burn injuries are products of time and temperature. Serious skin injuries start at a heat exposure rate of 30 kW/m^2. As a comparison, sun exposure is around 1 kW/m^2. Clothing is of course relevant in this respect. While clothing in general will decrease the exposure, burning clothes will make things far worse.

Since incendiary effects are of a secondary nature compared to the other effects, and also because they are so hard to quantify, these effects will not be considered further herein.

Incendiary cluster weapons are not meant to be used directly against soldiers. Flammable structures are the main kind of target. Like bomblets containing high explosives, incendiary bomblets will have the same faults with regard to duds. Incendiary duds will definitely have a fatal effect for those who inadvertently trigger such duds, and they should be treated in the same way as high explosive duds.

7.3 Blast effects on humans

The shock wave originating from the detonation of a high explosive is characterized by pressure as a function of time. A typical pressure profile was shown in figure 6.2 In the close vicinity of the warhead this pressure is a shock. The front of the shock wave is extremely steep – it is an almost instantaneous change in pressure from the ambient pressure to the peak pressure, which may be many times that of the ambient one. This sudden increase means that the body will not have time to adapt to the pressure change and it may thus suffer local deformations and injuries like ruptured blood vessels and torn tissue.

The blast wave from detonations may result in damage to certain organs of the body[20]. The most vulnerable parts are:

- the ear drum
- the lungs including the larynx
- the digestive system (also called the gastrointestinal system)
- the cardiovascular system

The neurological system and the eyes are also vulnerable.

At some distance from the warhead, the shock wave fades out to become a less severe pressure wave. The profile of such waves does not have the steep front. The effect of such waves will usually not have any direct influence on humans. They are more relevant to the vulnerability of structures.

The ear drum is the most pressure sensitive organ. Damage to the ear drum may not always result in a permanent injury; therefore it is more relevant in a military context than in a humanitarian context. The vulnerability of the ear drum is dependent on the peak pressure only and not on the duration. Thus the probability of suffering an ear drum rupture can be displayed as shown in the figure below.

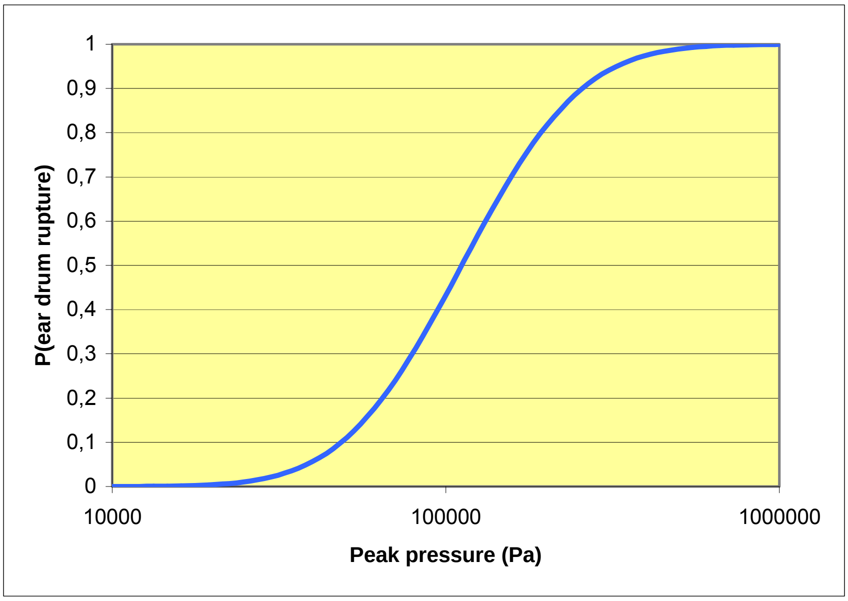


Figure 7.3 Eardrum vulnerabilty

Lung injury is far more serious than ear drum rupture, and it might definitely be fatal. The probability of surviving a lung injury after being exposed to a pressure pulse with a certain peak value and a certain duration is shown in the figure below. Here the effect will depend on whether the person is standing in an open field or standing close to a solid wall on which the shock wave impinges perpendicularly. In the latter case the body will suffer a higher pressure than in the free field. The figure below shows the criteria for fatal lung injuries in the free field case.

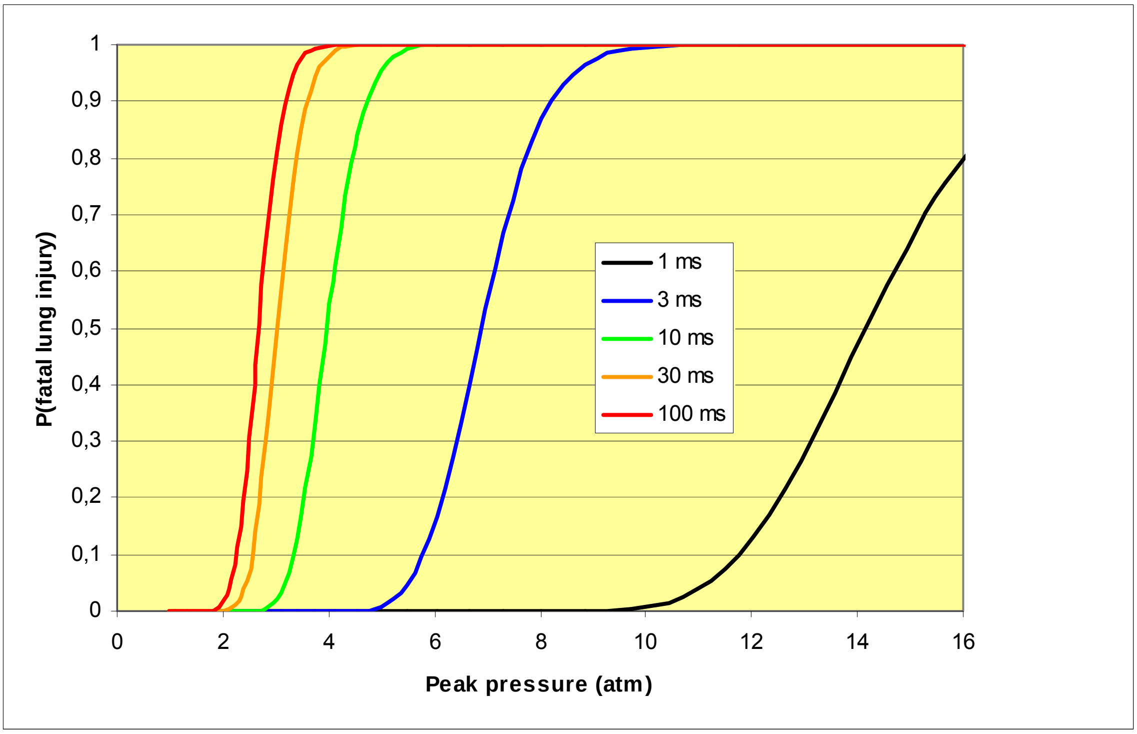


Figure 7.4 Criteria for fatal lung injury for an adult person in a free field

Children are more exposed to lung injuries due to their low body weight. For a given peak pressure, the injuries with 35 kg body mass is comparable to injuries received by an adult if the peak pressure is 26% higher.

7.4 Cratering

Bomblets weighing up to a couple of kilograms, and detonating at the surface, will not create any significant crater. Special types of bomblets, of the anti-runway (AR) type are designed to penetrate and destroy concrete surfaces and may leave craters of several cubic meters size.

7.5 Comparison of effects

7.5.1 Scaling of blast effect

The blast is geometrically scalable; that is, when the linear size of the explosive charge is increased by a certain factor, the range of the blast pressure is increased by the same factor. This implies that the blast pressure at a given distance increases with the cube root of the weight of the explosive. In addition there is an elongation of the duration of pulse. All together the area that is affected by a blast effect increases with the explosive charge as $w^{0.8}$, where w is the weight of the explosive. This law implies that it is slightly better to use a cluster payload than a unitary charge. An example of such a scaling exercise is shown in the factbox below.

Consider two alternative warheads

1) A unitary 155 mm artillery warhead containing 6.5 kg of Comp B surrounded by 30 kg of steel
2) A cargo warhead for 155 mm artillery containing 63 bomblets each with 40 g Comp B surrounded by 160 g of steel

First we can calculate the dampening effect the casings have on the blast effect. The unitary charge will be equivalent to a bare charge with explosive mass of 2.23 kg, while the bomblets will have a charge equivalent to 14.4 g. (see section 6.2)

Then the effect from the unitary charge has a an affected area that can be written as

$$A = kp_{crit} 2.23^{0.8} = 1.90 \cdot kp_{crit}$$

while the affected area from a single bomblet becomes

$$a = kp_{crit} 0.0144^{0.8} = 0.034 \cdot kp_{crit}$$

Here k and pcrit are arbitrary scaling factors. Then the total effect of all bomblets in comparison with the effect of the unitary charge becomes

$$Effect = 63\left(\frac{a}{A}\right) = 63\left(\frac{0.034}{1.90}\right) = 1.13$$

showing that the total blast effect is 13% more effective for the cargo munition compared to the unitary charge. However if there were 49 bomblets in the munition, the cluster solution would be 12 % less effective.

7.5.2 Scaling of fragment effect

The fragment effect is also scalable, but not as simply as the blast effect. Experience seems to show that the fragment effect approximately scales as the square root of the warhead mass, i e when the warhead mass is increased by a factor of 4, the lethality doubles. Mathematically this may be stated as

$$A_L \approx K\sqrt{m}$$

where m is the mass of the bomblet, and K is a factor of proportionality.

> *In this simple equation lies the very rationale for using cluster weapons. It states that it is better to divide the available mass into several smaller mass units, than to use a single unitary mass.*

Provided that the bomblets are spread out such that the areas of effectiveness do not overlap too much, the lethal area for a warhead divided into N subwarheads becomes:

$$A_{L,N} = K\sqrt{Nm}$$

which is better than the unitary alternative by a factor of $\sqrt{N}$. This simplistic view will no longer be valid if the bomblets become so small that their fragments are too tiny to give any effect, or that the mass or volume of the fuze becomes a significant part of the whole warhead.

8 Duds

8.1 Reasons for duds

Any piece of ordnance that is intended to detonate, explode or catch fire has the potential of becoming a dud. There is a multitude of reasons for this. However, the basic reason is often that an ammunition designer has to compromise between the following requirements

1. the product has to be stored, handled and used in a safe manner
2. the ammunition must work as intended when, only when, and always when, it arrives at the target.

These two requirements are in essence contradictory. From the user's and designer's point of view, the requirement that the ammunition always works at the target is the only one that can be compromised.

The ammunition life cycle can briefly be described as follows

- production
- storage
- deployment
- loading
- firing
- arming
- trigging by external or internal influence
- detonation

At any stage up to detonation, there is a possibility that the ammunition can be exposed to effects that inhibits the detonation to take place as intended. More specifically, in order to work, the ammunition must have an intact chain of initiation. This chain is initially broken, but the arming process restores this chain. If the arming process fails to establish the chain, or it is broken prior to impact, a dud will result.

The sustained loads on submunition during ejection from the parent container may damage components that are critical for the arming process. The figure below shows an example of ejection.

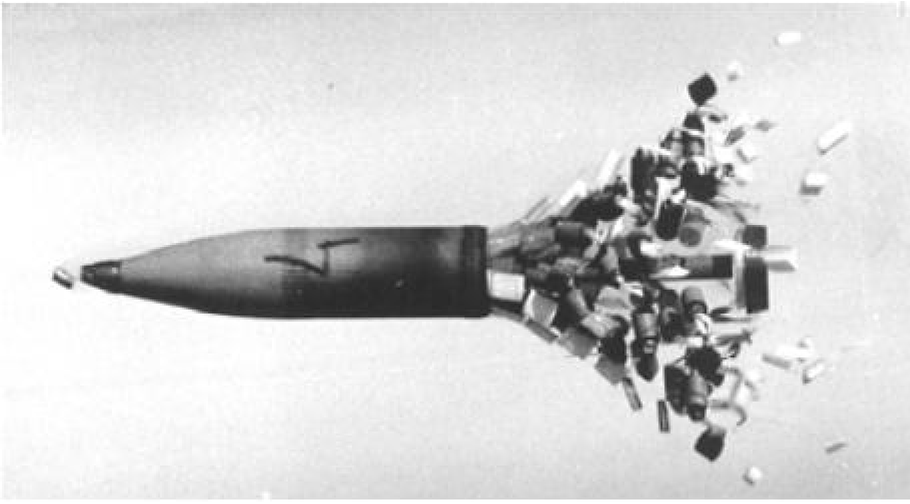


Figure 8.1   DPICM-bomblets being ejected from a 155 mm cargo projectile[21].

Almost all cluster weapons have bomblets with so-called contact fuzes, i e the bomblets should detonate at impact with target or ground. A contact fuze is inherently unreliable mainly due to the compromise between safety and reliability, as mentioned above, and because the force induced will often have another characteristic than intended.

All types of ordnance have the potential of becoming a dud. What the actual dud rates are for different types have not been given much attention, with the exception of cluster bomblets. A Norwegian document [22] based on firing campaign reports over five decades indicates that the dud rate is quite high for most conventional ammunition. Some examples are given below:

- Artillery rounds with HE or smoke 5%
- Artillery rounds with illumination 33%
- Mortar shells with high explosive 5%
- Hand grenades 1%
- 12.7 mm multi purpose 3.5%
- 84 mm HEAT/HE 9%
- 105 mm HEAT/HESH for tanks 5%
- 20 mm multi purpose 20%
- 66 mm M72 HEAT 1.9%

These data are based on observation of several hundred thousands of shots in total, and even several thousands in each category. It should be noted that all the types above, except for the illumination rounds and the hand grenades, have contact fuzes.

All these ammunitions have fuzes that are more sophisticated and costly than most fuzes used in bomblets. In that context, a dud rate for bomblets above 10% is not surprising. A bomblet dud rate of less than 1% may be too much to ask for, when a simple and inexpensive fuze like those on the M77 and M42 bomblets are used.

Fuze producers claim that the reliability of their product are better that 95%, and usually better than 99%.

Many of the categories listed above leaves duds that are relatively safe to handle. They may not create the same humanitarian problem as some bomblets will.

8.2 Environmental effects

8.2.1 Corrosion

Iron and steel are the main materials used in ordnance. The casing of a bomb or a bomblet is usually made of steel, and in some cases forged iron. As we all know such metals are subject to corrosion that will slowly dissolve the metal into the ambient soil or water. Parts of the fuze of a piece of ordnance may be made of aluminium, copper or brass alloys that are less corrosive. Corrosion may degrade critical fuze components in an ordnance component to such a degree that it becomes harmless. However, the corrosion may also make the item more sensitive by weakening springs and brackets. It may even result in a spontaneous detonation of the bomblet if safety mechanisms deteriorate.

The rate of corrosion is very hard to predict. It depends on the climate, the type of soil and on the local conditions. In dry climate the corrosion rate may be very slow. In a hot and humid climate, with high content of certain metallic ions in the soil, the corrosion may be very rapid.

A piece of ordnance may be dangerous and intact for several decades after being deployed. A life time of more than one hundred years is not unlikely under favourable conditions.

8.2.2 Ageing of explosives

Explosives are chemical substances that are quite stable at “normal” temperatures. Explosives should in general be stored in cool conditions, like 15°C or less. Such conditions are often not possible. The sensitivity of explosives to hot storage varies with type. In hot climate the ageing will proceed fast, rendering the ammunition useless within a couple of years.

A dud lying exposed to solar radiation will absorb a lot of heat that may bring its temperature above 70°C. Ammunition that has exceeded its life-time will tend to decompose, a process that in some cases may make it more sensitive or dangerous to use.

8.2.3 Ground cover

An impact fuze works well when impacting a firm, flat and barren ground. We all know that such conditions are not always found in actual conflicts. Grass, bushes, trees, mud, sand and snow will all have varying degree of negative effect on the performance of bomblets with an impact fuze. The force onto the bomblet will be dampened and may not overcome the threshold needed to activate the detonator.

From an effectiveness point of view, vegetation and loose snow will cause the bomblet to detonate inside the medium and the fragments will lose much of its velocity in penetrating that medium.

It has been observed that some DPICM bomblets may reach a dud rate of more than 50% in snow covered ground.

8.3 Self-destruct and self-neutralization mechanisms

Bomblets with self-destruct devices were not present in the early days of cluster munition. The development of mechanisms that destruct the warhead, breaks the ignition train, or put the bomblet in a non-armed mode seems to have been the result of unacceptable numbers of duds found on the battlefield after the use of cluster munitions.

The problem of duds became evident after the Kuwait conflict (the Gulf War) in 1990-91, where 25 US EOD members where killed or injured in the aftermath of the war[23].

Today, most new cluster warheads are designed with some kind of self-destruct mechanism. However, those produced before 1990 are in general made without any such device.

There are basically two ways of implementing a self-destruct mechanism. One way is pyrotechnically, with a slow burning fuze that is activated at push-out, and which sets off the main detonator in case the primary impact function should fail. Alternatively, the self-destruct mechanism may destroy the ignition system, leaving the main charge intact, but less sensitive[13]. Another way is to have a kind of battery that is short-circuited at impact, or some time after impact, and thus neutralizes the warhead.

8.3.1 Pyrotechnic self destruct mechanism

Such devices are equipped with a pyrotechnic delay fuze which is ignited as a side-effect of the arming process. This arming usually takes place just after push-out from the container. The length of the fuze and its burning rate are adapted so that its time of burn is somewhat longer than the expected time of descent. The far end of the delay fuze is adjacent to the main detonator which is set off as the fuze is consumed. The detonator subsequently sets off the main charge.

There are some critical parts in such a fuze that may fail
- the ignition of the delay element fails
- the delay fuze may extinguish due to heat loss or uneven pyrotechnic composition
- the delay fuze may not be able to set off the detonator

8.3.2 Battery-based or electronic self-destruct mechanism

The potential of a battery based self-destruct mechanism is high, as this principle does not depend on mechanical forces to initiate the chain of ignition. Instead the energy needed for ignition is

[13] It is questionable whether this should be called self-destruct or self-neutralization.

stored in the battery. Most submunitions of the SFW-type have a battery-based mechanism for safety and arming. Work has been made to develop a battery on DPICM bomblets. An example of such an application is the US bomblet M80[24], which should ensure that the detonator is ignited, even if the fuze fails to arm. The chain of ignition is thus broken, and even if UXOs remain, they are supposed to be quite safe to handle. A similar solution has been proposed for the improvement of the M85 fuze[25]. The main challenges here are to make the battery inexpensive, reliable and with a sufficiently long storage time.

The Spanish made MAT-120 mortar bomblet applies a somewhat different principle. Here the energy is stored in the main fuze and is transferred to the individual bomblet prior to push-out. This energy is used for both the primary impact function and the secondary self-destruct function. No UXOs are intended to be left with this solution [26].

8.3.3 Sensitivity of bomblets

Most bomblets have a well defined arming device that, in contact fuzes, connects the chain between a firing pin and the detonator. If a bomblet has successfully armed, but not received the force required to ignite the detonator, it will remain as a dud that may detonate whenever the required force is imposed onto it. Bomblets on which the arming process has failed for whatever reason will in general not have the same sensitivity. However, depending on the design, they may successfully go through an arming process by human interference.

9 Alternatives to cluster weapon systems

Most types of cluster weapons have both a low-technology and a high-technology alternative. The low-tech is usually thought of as the system which was replaced when the cluster system was introduced. Such systems were mainly unitary high-explosive charges.

The conventional high-explosive unitary charge is still a part of the basic ammunition load in most armies. However, during Operation Iraqi Freedom, US artillery forces had ammunition loads containing 56% DPICM munition. The commanders, however, requested more HE ammunition, but had to solve their missions by DPICM when HE had been a better and more obvious choice [27].

The high-tech alternative is generally thought of as new developments, based upon innovative use of modern technology. The purpose could be to:

- introduce a guidance system and/or sensor system so that the weapon can be rendered a point-target weapon
- develop a self-destruct or self-neutralization device that is far more reliable than the pyrotechnic and electrical systems used today
- make any dud so insensitive that it is far safer than the large majority found on the battlefields today

9.1 Precision guided and advanced artillery and mortars

As already indicated there are two reasons why DPICM has become popular as artillery ammunition:

1. Unguided artillery is inherently inaccurate, especially at ranges beyond 15 km. The use of cluster munitions which spread their content over an area that is typically 200 m in diameter will, to a large extent, compensate for this inaccuracy. Compared to a unitary charge, a cluster charge will at least give some effect even on a small target, but the disadvantage is that a lot of effect is spilled outside the target area. This disadvantage is severe when the target is small.
2. It was believed that the capacity of DPICM to perforate armour would give a significant effect against the vehicles of a highly mechanized enemy. The development of armour, and especially for main battle tanks and self propelled howitzers, has made these vehicles less vulnerable to such ammunition. Therefore, the advantage of using DPICM is less than before, if at all present.

Guided artillery on the other hand will be able to strike the target with an accuracy of 10 m or less. The advent of guided artillery combined with the use of munitions with sensor fuzed warheads (SFW) implies that the need for using DPICM against armoured targets will not be present anymore. SFW will have a far better effect than the effect from a DPICM against all kinds of armoured vehicles. Against personnel targets conventional HE munition will again become an effective choice when guided munitions comes into use.

Many programs have been launched to develop a fully guided artillery projectile. An example is a joint project in France[28]. These concepts have projectiles that are intended to be fired with current artillery guns, but the projectile has a set of wings for the purpose of despinning, gliding and maneuvering. Both the range and precision will then be dramatically improved compared with traditional projectiles. This solution is very expensive and will require a full renewal of the current stock of artillery ammunition.

An alternative solution for improvement of precision is to develop a special fuze that enables some kind of guidance or rather course correction. This concept has been launched by BAE Systems as “Precision Guided Kit” as a complement to the Excalibur development[29]. The kit is an advanced fuze that, in addition to the safety and arming function, is equipped with GPS navigation and two pairs of winglets that make course corrections along the trajectory. The kit is decoupled from the rest of the projectile by a ball-bearing joint, so that the projectile body spins as before, while the kit does not. It is likely that this kind of kit can compensate for the inaccuracy of the current artillery, and that it is able to increase the precision by at least one order of magnitude. Another advantage of such a concept is that the current stock of unitary artillery munition can be exploited as it is. Only the fuze part has to be exchanged. However, equipping cluster munitions with such a device does not serve any purpose since they are not suited to engage point target.

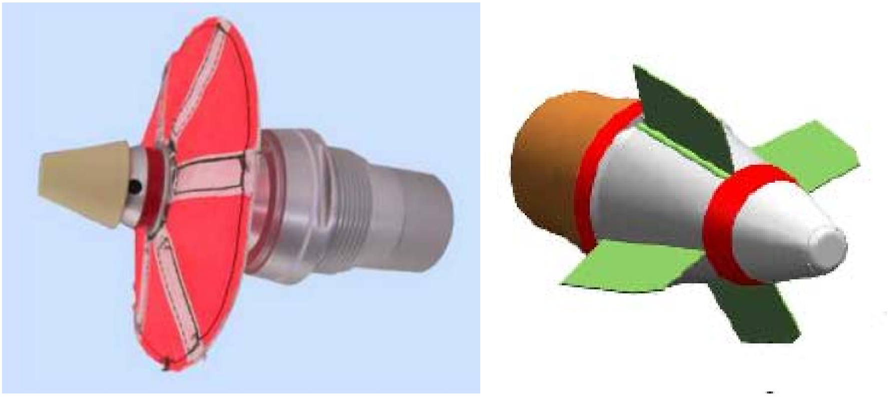


Figure 9.1 Examples of Guidance Kits for 1D-correction (along line of fire only – left) [30]and for 2D-correction (in all directions – right)[31].

9.2 Guided or advanced bombs

Bombs with cluster payload are mostly used in the role of close air support (CAS). In that role bombs suffer from the same limitations as artillery systems. When dropped from a distance or from high altitudes, an unguided bomb is inherently inaccurate due to errors in the aircraft attitude[14] and position at the drop, and of atmospheric effects. Many of the unguided cluster bombs deployed today also have a guided version which is used when the expected accuracy is insufficient.

Cluster bombs usually have a very high number of bomblets. Compared to artillery systems, the bomblets are spread over a smaller area giving a large degree of saturation in the target. Bomblets from air delivered bombs are larger than those from artillery systems. Thus the bomblets that have a DPICM or anti-armour function are more effective than their artillery counterparts.

However, during the last decade the development of SFW bomblets for air delivered bombs like CBU-97 and RBK-500 has progressed. These systems seem to be able to solve the task of armour defeat far more effectively than the current cluster bombs with anti-armour capability. There is also a current development towards using special unitary charges that may give an anti-personnel effect comparable to that of a load of bomblets.

9.3 Alternative direct fire weapons

As mentioned earlier, using cluster munitions in a genuinly direct fire mode does not make sense. In a role for defeating point targets conventional high explosive charges, often with a shaped charge, is definitely a far better alternative. A few muniton systems based on the cluster concept exist that can be used to engage area targets in trenches or hiding behind obstacles[15]. A viable alternative is to use unitary high explosive charges that detonate above the target. Such systems require very accurate time fuzes and a corresponding accuracy in target range estimation. An

[14] The speed, roll and dive angle of the aircraft.
[15] Examples are the US helicopter fired Hydra M261 and the Israeli tank fired 120 mm APAM

inadequate range estimation can, however, be compensated by firing a salvo of charges with different fuze settings on the individual rounds.

9.4 More effective explosives

There is an ever ongoing process of developing more effective explosives. So far this work has progressed in small steps. No revolutionary events have taken place since the development of TNT. HMX and RDX are the most effective explosives in common use, but their performance is not radically different from TNT. One of the latest developments is CL-20 which is about twice as effective as TNT.

A new track of development, involving manufacture of molecules consisting solely of nitrogen atoms, has the potential of being close to 20 times more effective than TNT. This technology is very complex, and it may still take several decades before such explosives are commercially available.

Fuel-air explosives (FAE) and thermobaric explosives (TBX) are often mentioned as new developments. The advantage of these types is the elongated duration of the pressure pulse, which enhances the efficiency, especially when used in confined spaces.

A unitary charge with a very effective explosive could be an alternative to a cluster charge with ordinary explosives. However, the development of better explosives does not by itself counter the development of cluster weapons, as more effective explosives also will enhance the performance of the cluster bomblets.

9.5 Non-lethal or less lethal weapons

These types of weapons have traditionally been used by police forces for riot control and apprehension of criminals. However, there is an increasing military interest for such weapons, especially in peacekeeping and peace restoring operations. Current non-lethal weapons are viable alternatives to the use of small arms and other short distance weapons in such operations.

The nature of non-lethal weapons is that the enemy is temporarily incapacitated for a short time like a few minutes - even seconds. This implies that the enemy is at very short distance. It is possible to imagine the use of non-lethal weapons in a traditional fire support role, with munitions delivered at long range, and containing substances inflicting temporary incapacitation. However, such thoughts do not seem to be seriously debated in the military literature.

9.6 Sensor fuzed warheads

The SFW (Sensor Fuzed Warhead) needs special attention, because they are the most advanced and expensive bomblets that exist today.

In a strict technical sense, sensor fuzed warheads are cluster munitions. However these weapons have a suite of properties which make them so different from what we really conceive as cluster weapons, that they deserve to be placed in a category of their own.

In most cases there are just two, or in some cases five or six submunitions in each carrier. They are often termed as guided, but there is nothing that affects the trajectory of the submunition. An SFW is guided in the sense that the warhead has a detector that scans the target area. If a target is sensed, the warhead fires a kinetic-energy projectile against it. There are no thrust control rockets or mechanical devices that actively steers the warhead. The term "self-aiming warhead" may thus be the most descriptive term. This is indeed a high-tech and very expensive type of cluster munition. The cost per bomblet unit usually exceeds 20000 Euros. The cost creates an incentive for the producer to integrate a safe and reliable self-destruct mechanism in these submunitions.

An SFW usually consists of a cylindrical high explosive warhead of the EFP-type (Explosively Formed Projectile[16]). The lower end of the warhead is shaped like a bottom-up saucer. Upon detonation, this saucer is inverted and formed into a carrot-like projectile with a velocity of around 2 km/s. If the design is right, this projectile will get an aerodynamically stable shape, making it capable of maintaining its penetrative capacity even when fired at a range of 200 m from the target. This projectile is intended to hit and perforate the roof of an armoured target. It may perforate an RHA armour of more than 150 mm thickness, creating a hole of roughly 5 – 10 cm in diameter with devastating results to the target. However, it can not be claimed that any hit with an SFW projectile implies a vehicle kill. Probably 2 to 4 hits are required. The projectile can be made of iron, copper or tantalum. The latter is the most promising material because of its high density at around 16 kg/m^3.

The sensor usually contains at least two of the following four modes:

- infrared sensor to detect hot targets, optionally at different wavelengths
- active millimetre wave radar to detect the range to the target
- passive millimetre radar (radiometer) to detect objects hidden by camouflage or vegetation
- laser scanner that recognizes the height contour of a possible target

[16] By early sources called a Self Forging Fragment (SFF)

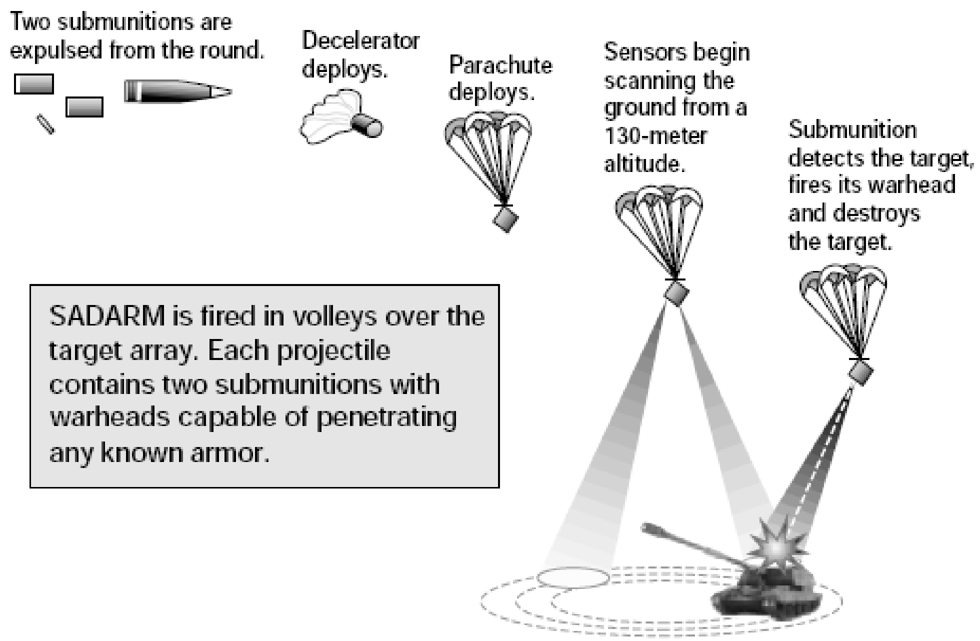


Figure 9.1 Example of a SFW terminal phase (SADARM)[32].

The submunitions are usually delivered by 155 mm field artillery, but some systems are delivered by aircraft or mortars. When the submunitions are released in air, their speed is first decreased by a balute before it enters a stable descent phase by a parachute, an airfoil or a pair of flaps. The sensory device is then folded out and activated. The submunition will inherit the spin of the original projectile. However, the sensory device, or other mechanical features, makes the whole submunition asymmetric, the axis of spin will then be oblique to the natural axis of the warhead. The rotational movement will therefore be nutational[17] and the sensory device will make a scan track on the ground that is like an inward turning spiral. If the sensor discovers anything that is identified as a target, it fires the projectile at it.

The search phase usually starts at an altitude of around 250 - 300 m above ground. The nutational axis may have around 30° obliquity. Thus the scan area may have a radius of around 150 – 180 m. For tube artillery ammunition, where there are two submunitions per round, the scan areas have their centres separated by around 300 m, so that the areas have a slight overlap.

SFW can also be integrated in rocket artillery systems. So far this has only been done for Russian systems. Plans have been laid out for integration on the US MLRS, however, these plans do not seem to have matured into realities.

9.6.1 SADARM

This is the prototype SFW. It was publicly known as early as in the late 70s, but did not appear as a commercial product before around 2000. It is carried by the artillery round M898, to be fired

[17] A nutational movement is characterized by a rotation around an axis that does not coincede with the natural or geometric axis.

like any other artillery shell. The target is sensed by an infra-red sensor in combination with a millimetre wave sensor.

SADARM is known to have been used in Iraq in 2003. It has been claimed that of the 121 projectiles fired, as many as 48 hit and destroyed a target[33]. It is not known how this was counted, whether a double hit on the same target were counted, or whether the hit was an effective hit with a destructive result for the target. The units used in Iraq seem to be a part of a pilot lot. It seems, however, that Alliant, who was the developer, for some reason abandoned the project just before finishing.

In a “lessons-learned” evaluation of different fire support munitions in Iraq, Fort Sill (the US artillery training center) claims the SADARM as the winner and DPICM as the loser in term of being the best munition. It is stated that DPICM is not for use in urban areas and that the dud rate is too high in vegetated areas. It is also indicated that DPICM is a cold war relic, but that the US Forces in Iraq used DPICM because they had no alternatives in sufficient amounts[34;35].

Figure 9.2 Attack on a tank with an SFW

9.6.2 SMArt

This German version of SFW was a joint development by a consortium of the German companies Diehl and Rheinmetall. The sensor suite contains a radiometer (passive mm-waves), a radar (active mm-waves) and an infra-red detector. After push-out, the SMArt® submunition, like the SADARM, is decelerated in the air stream by a balute. When the velocity has been reduced by a satisfactory amount, a primitive parachute is unfurled. The velocity of descent is approximately 13 m/s.

By using its active millimetre sensor, SMArt® will self-destruct a few meters above ground. If this electronic self-destruct mechanism should fail, the battery will drain its energy in a few seconds, prohibiting any unintended discharge of the submunitions.

SMArt® has been produced in two versions, DM702 and DM702A1. The difference is that the first one has a footprint of 1.5 ha for each subunit, while in the improved DM701A1 the footprint is 3.5 ha.

SMArt® probably has the most advanced suite of sensors consisting of three widely different types. The recognition and identification of a target is made by data fusion of the three sources. How this fusion is done is of course classified information, but it gives a good opportunity to correctly identify a valid target and to avoid false targets. A vehicle with the same characteristics as a military vehicle in terms of size, temperature and structure will however be identified as a valid target.

9.6.3 BONUS

The projectile was originally developed by GIAT in France with the name of ACED, but the development was finalized through the international consortium of GIAT and Bofors (the latter is now SAAB Bofors). The last version of Bonus has an infra-red sensor and a laser radar. The fusion of spectral and target profile enables BONUS to separate between combat-worthy targets, damaged or burning targets as well as decoys. Another major difference between Bonus and SMArt® / SADARM, is that the former does not apply a parachute in the phase of descent. Instead BONUS has a pair of wings or vanes that induce the rotational and nutational movement of the submunition. In this way, BONUS attains a higher rotational velocity and a more rapid descent than the others. The scan area has a diameter of 200 m.

Figure 9.2 BONUS[36].

Around 6500 rounds are produced so far. It is only deployed by the French and Swedish armies[37].

9.6.4 BLU-108

The BLU-108 is not a single bomblet, as the name could indicate, nor is it a complete system. BLU-108 contains four subunits, also known as Skeet, and it may be the most advanced SFW available. The BLU-108 is air delivered with CBU-97 or CBU-105 containing 10 units. The latter has a WCMD fitted. The delivery is as with many other 1000 lbs bomb with the SUU-66 container. One SUU-66 thus contains 40 Skeets.

The working mode of one of the subcontainers is rather special. After being released from the SUU-66 a balute and a parachute stabilizes and reduces the speed of the container. At a preset altitude sensed by a radar altimeter, a rocket motor fires to spin the submunition and initiate an ascending motion. The submunition then ejects its four projectiles, which are lofted over the target area. The projectile's sensor detects a vehicle's infrared signature, and an explosively formed penetrator fires at the heat source. The Skeets are ejected in different directions with 90° separation, and each covers an area around 80 meters long and 20 meters wide. A complete CBU-97 will then have the potential of covering 6.4 hectares, but there will be considerable overlap reducing the covered area to around 5 hectares.

A special feature of Skeet is that in addition to the main fragment from the warhead, 16 additional smaller fragments are ejected with about the same velocity and direction as the main one. This is intended to give additional effect in the unit to be attacked.

The SFW unit has a triple self destruct mechanism that consists of

- an altimeter – if no target has been found the unit will detonate a few meters above ground
- a timer – detonates the unit a few second after impact if still alive
- a battery that fades out less than a minute after push-out rendering the munition very difficult to set off

Figure 9.3 BLU-108 and Skeet[38].

BLU-108 is so far only developed for delivery with CBU-97 and CBU-105. The latter is with the WCMD tail kit that makes the ammunition very accurate. There were plans to develop a B version of JSOW (AGM-154B) containing 24 BLU-108. However, these plans seem to have been brought to a halt. Likewise, plans to adapt BLU-108 to Tomahawk, SLAM, JASSM and ATACMS have neither materialized.

There were plans to develop an artillery version of the Skeet warhead to an STS (Selectively Targeted Submunition), on which a samara[18] wing gives the subunit both lift and a nutational movement. This probably makes the search pattern for the submunition more consistent and predictable than for the original system. The latest version of this development is called CSS (Common Smart Submunition). This version is somewhat more compact than the STS with a diameter of 100 mm. It may then even fit into a 120 mm mortar munition. It is also design to withstand the forces during a 155 mm canon firing. The performance is believed to be comparable with SMArt or BONUS, but like Skeet it has the additional feature of having a number of smaller fragments surrounding the main fragment.

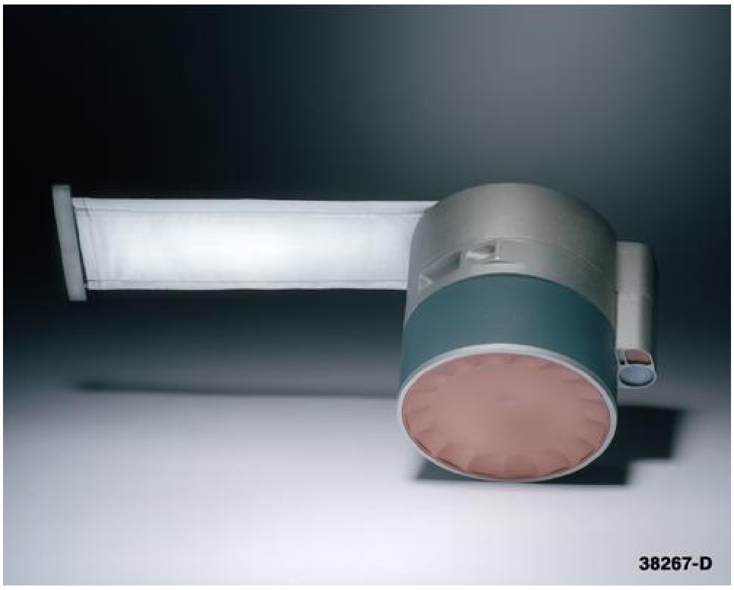


Figure 9.4 STS warhead [39]

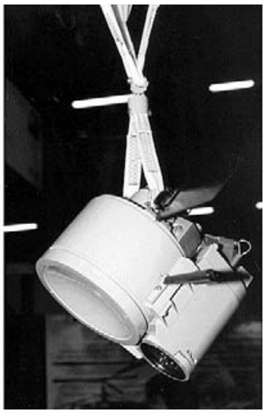
9.6.5 Russian SFWs

This family of sensor fuzed weapons was probably developed in the 1980s. As with any innovative Soviet system, and especially ammunition, it was covered by a cloud of secrecy. Today, there seems to be two SFWs left. They are the large calibre Motiv-3 or SPBE, and the somewhat smaller SFW which seem to have got the generic name Universal Submunition.

Motiv-3 seems to be an earlier development than the Universal Submunition. The main characteristic of Motiv-3, in comparison with other SFWs, is the size of the sensor unit. While other systems have a quite small IR-unit that flips out during arming, Motiv-3 has a rather

[18] A samara wing is a wing attached to the seeds of some trees enabling the seed to “fly” some distance away from the mother tree.

massive sensor unit with 50 – 70 mm diameter and with length that is comparable to the length of the main explosive charge. The Universal Submunition has a small IR-unit but is quite small in calibre as it has to fit into a 122 calibre rocket warhead.



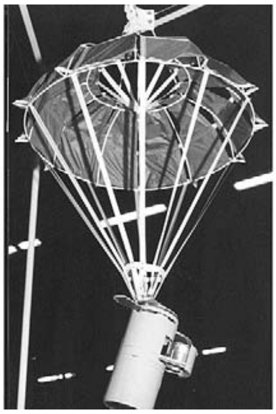


Figure 9.5 Russian SFWs – Motiv-3 (left) - Universal Submunition (right)[40]

Russian SFWs also have got the name SPBE which is a Russian abbreviation for self-aiming warhead. One version, SPBE-D, seems to be the same as the one described as Motiv-3 above. Another version, SPBE-E, seems to have an even bigger sensor unit, which looks like it is placed below and to the side of the charge unit.

9.7 Cost of ammunition

The cost of ammunition varies considerably making it hard to give definite statements. It may also be unrealistic to compare weapons manufactured in the 1960s with those made after 2000. However, considering artillery weapons, the main picture of cost per mass is as follows

- cluster warheads are 2 -3 more costly than unitary warheads
- sensor fuzed warheads are around 20 times more costly than cluster warheads
- the cost of guided unitary warheads is uncertain, due to their still limited access, but the most inexpensive ones are supposed to have the same cost as cluster warheads

Sensor fuzed warheads are quite sophisticated and expensive munition. One unit of SFW has a cost of around 20000 €. A projectile of two units will then have a cost of, say, around 40000 €. This should be compared with the cost of 3000 € for a DPICM and 1500 € for a HE artillery round. Still SFW must be considered very cost-effective in defeating armoured targets compared to the DPICM as showed in the factbox below.

Consider a target area with 10 subtargets distributed over an area of 10 ha. When using an artillery delivered SFW-round with two subunits onto this area the footprint will be 1.5 ha, and the expected number of hits will be 1.5 on the average. Firing an M483 DPICM containing 88 bomblets with a footprint of 2 hectares will give an expected number of hits of 0.17. A hit with an

SFW is of the order of 5 – 10 times more efficient than a hit from an M42. Thus we see that the SFW unit is around two orders of magnitude more efficient, and the cost-effectiveness is around 10 times better than for the DPICM round.

10 Recently fielded or forthcoming cluster systems

Some NATO countries and especially United States are quite open about their future plans for defence acquisitions. Therefore, this section almost exclusively mentions US systems. Future systems from countries like Russia and China seem to be more clandestine. There are also linguistic barriers that make access to information from these countries difficult.

Some cancelled programs for submunitions are included herein, as such systems may be revived when and if the circumstances become favourable.

10.1 Joint Stand-off Weapon

The JSOW (Joint Standoff Weapon) is a medium range missile developed for the US Air Force and the US Navy. It is delivered by aircraft at ranges up to 111 km. It has GPS/INS navigation and is without any propulsive elements using its gliding capabilities to reach the target. Three versions of the weapon were originally planned

- the A version containing 145 BLU-97/B bomblets
- the B version containing 24 BLU-108 SFW units
- the C version with a unitary high explosive warhead

Versions A and C were brought to production in the 1990s and were used in both Serbia and Iraq. The B version was cancelled.

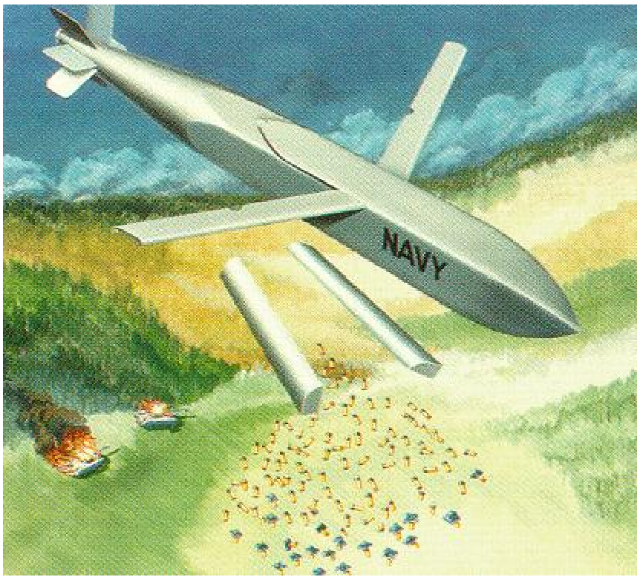


Figure 10.1 JSOW[41].

There seems to exist plans for replacing the A version with an A-1 version that is loaded with BLU-111, which in essence is an Mk82 unitary bomb filled with so-called insensitive explosives according naval requirements. It may seem that the dud problem is the rationale behind these plans. [42]

10.2 BAT

BAT is an acronym for Brilliant Anti-Tank; an example of linguistic poverty, although it is a very sophisticated ammunition. It is an autonomous missile, planned to be made in different versions. The base version had a combination of acoustic and infrared sensors. Later the P3I version came (Pre-planned product improvement) where a millimetre wave sensor replaced the acoustic sensor. The final version is so far the Viper Strike for which the infrared sensor is kept, while the millimetre sensor is replaced by an active laser detection system requiring manual guidance to the target. Thus the latter version is not intended for cluster delivery. The development of the Viper Strike can be seen as a sign of a development towards attacking special high value targets, with less emphasis on wide area targets.

Figure 10.2 BAT [43]

BAT was originally designed to be delivered from air, sea and ground systems. Proposed systems were MLRS (2 BATs inside), ATACMS (13 BATs), Tomahawk (12-16 BATs), SLAM (6 – 8 BATs) and aircraft delivered bombs containing 4 BATs. Only ATACMS still seems to be viable for the autonomous versions. The BAT program was put to a halt in 2002 due to lack of reliability of the unit. However, the work with Viper Strike continues.

10.3 Excalibur

Excalibur is intended to become the next generation of 155 mm field artillery ammunition. The innovative elements in this ammunition, compared to current systems, are the guidance capability and the increased range of the system. It has a combined GPS and INS guidance with should enable it to hit within 20 m of the target. With a 52 calibre[19] gun tube it can be fired out to a range of 47 km. There are plans to develop at least two cluster rounds; one with DPICM containing 64

[19] The length of the barrel is often given as a number of calibers. A 52 calibre barrel with a 155 mm caliber diameter has a length of 52 x 155 mm ≈ 8 m.

M85 bomblets or 85 M80 bomblets, the other will be a SFW round with two subunits. The choice of bomblet content seems undecided at present. The unitary version of the round is already fielded to US forces in Iraq. Neither the cargo round nor the SFW round will be fielded before 2010. Excalibur is developed by a consortium between Bofors and Raytheon.

The priority on unitary warheads for Excalibur can be interpreted as a sign of a decreased need for attacking massed formations of personnel and light vehicle targets. However, a guided system is more adapted to attacking point targets for which a high effect in a small area is needed.

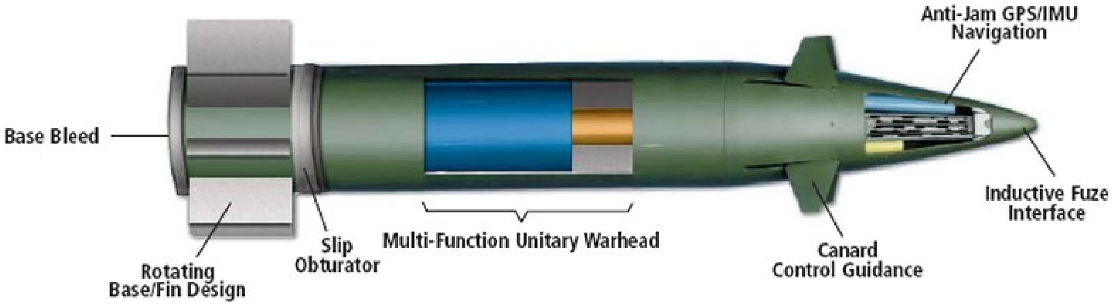


Figure 10.3 Excalibur[44]

10.4 ERM

The Extended Range Munition (ERM), previously called Extended Range Guided Munition (ERGM) is intended to become the US Navy capability to defeat area targets on land and on sea. The development started by Raytheon in the mid 1990s. The guidance is a combination of GPS and INS. ERM is a missile fired from a 127 mm naval gun. It can be fired out to 110 km range; it weighs 50 kg, and contains 72 bomblets of the M80 type with a self-destruct fuze. The bomblets are spread out in an area of diameter between 40 and 100 m[43].

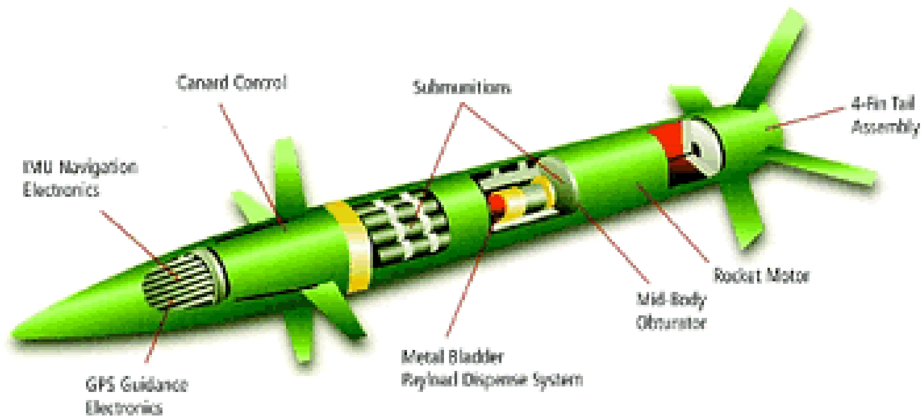


Figure 10.4 Extended Range Munition [45]

ERM is still more or less on the drawing board. Fielding of the system may not take place before 2011.

10.5 ATACMS

ATACMS (Army Tactical Missile System) is not a new system, since it was used in battle in the 1991 Gulf War. In addition 450 missiles were fired during Operation Iraqi Freedom. However, it is still in development, and can still be seen as modern having guidance capability and a range superior to other land based tactical systems.

ATACMS are found in different configurations. The newer or planned versions include warheads containing BAT (see above), or SFW. It will exceed 300 km in range. The basic version, M39, has a range limited to 165 km and contains 950 bomblets of the M74 type belonging to the "guava" family that may be considered as quite primitive. A more recent version, M39A1, with a 300 km range, also has M74 content, but limited to 300 bomblets per warhead.[20] Like any other members of that bomblet family, M74 does not have any self destruct devices.

10.6 APKWS

Advanced Precision Kill Weapon System (APKWS) is made for the US Army to be used from rotary wing aircraft. It is essentially an enlarged version of Hydra-70 and is capable of carrying the same payloads, including the M151 cluster payload. The main difference compared to Hydra-70 is the guidance package. It is not autonomous in the sense that the final target approach is assisted by manual laser illumination[21]. This feature makes it useful against high-valued point targets. However, it may be questioned how this guidance mode adapts to the use of cluster munition payloads.

10.7 Mortar systems

Mortar projectiles with 82 mm calibre or less have too small volumes in order to be effective to carry a bomblet payload, thus 120 mm is the only viable calibre for this purpose. This calibre is also the main subject for innovative development of non-cargo solutions in the domain of mortars.

France, Israel, Spain and USA are countries that have been the frontrunners in the development of 120 mm. One of the more advanced mortar systems is the US XM984, which eventually is to become M984.

In the 1990s France claimed to be developing an SFW for 120 mm rifled mortars. The ammunition was called ACED (Anti Char Effect Dirigee), but the development seems to have been discontinued.

The 120 mm ammunition that has the potential to replace systems containing DPICM is the US concept known as PGMM (Precision Guided Mortar Munition). PGMM became known in the 1990s as future mortar munition, which main feature was an anti-tank warhead carrying a

[20] 371 M39 and 69 M39A1 were expended during OIF. These contain 373150 M74 bomblets. (Pincoski)
[21] This is an example of so-called semi-automatic guidance – guidance with a man-in-the-loop.

conventional shaped charge capable of defeating most tanks. However, this concept was turned down by US authorities because it was seen as "just another tank killer" in a threat scenario hardly containing any heavy armoured targets at all. The development was then changed to contain a simple HE charge. However, PGMM is still expected to become a powerful tool in defeating point targets. The system for guidance and search is quite advanced, covering a footprint area of around 500 x 500 m. The maximum range is believed to in the close to 15 km.

10.8 JASSM

JASSM (Joint Air-to-Surface Standoff Missile) or AGM-158 is a system planned for the US Air Force and US Navy. The production and deployment of the weapon still seems to be pending. It has been declared that the warhead options for this missile will include submunitions, but it is not known whether it will be BLU-108, BLU-97 or any other kind of cluster payload.

JASSM will, like JSOW, be delivered by aircraft, but being equipped with turbojet propulsion, it has a range of at least 330 km. Deployment of the system still seems to be pending.

11 The effectiveness of cluster weapons

The key question at this stage is: How effective are cluster weapons? Are their effects at such a level that they are truly indispensable, or has their significance been overrated?

There are hardly any clear answers to these questions, but in the following we will try to quantify the performance of these weapons.

It would be too comprehensive to make a detailed analysis of any known bomblet. In the following, we have made a selection of some wide-spread and typical bomblets. In addition, they should represent a wide variety of types with very different functions and effects.

In the analyses we have looked at alternatives to current cluster weapons. Both high-end and low-end technologies have been considered. However, there is no one-to-one alternative in the sense that a current system has a unique alternative of low technology and a unique one of high technology.

For most of the bomblets, not all characteristics are known in detail. Thus, whenever necessary these characteristics have to be assumed or deduced in one way or another. This is done based on the knowledge of the warheads in general and from the known properties of the bomblets.

11.1 Dispersion areas

From an effectiveness point of view, the best solution would be to have a dispersion area that could adapt to the size and shape of the target. That would however require a flexibility and complexity of the release mechanism that is not achievable without very advanced sensor solutions.

If the target is small compared to the dispersion area, a lot of firepower will be wasted, and the risk of achieving collateral damage will be present. If the dispersion area is small compared to the target, the aim points for the munitions have to be distributed over the target area.

Ideally, the dispersion area or the impact density of the bomblets, should be adjusted according to the target in such a way that the target is adequately saturated with fragments of blast. If the density is too high the area will be oversaturated, which implies wasted firepower; if the target is under-saturated, the required effect is missing.

The table below shows the dispersion area of some selected cluster weapons. The dispersion area is often circular with an even distribution of bomblets inside. For some systems the area may be rectangular. In a single case the dispersion is along a line (Hydra). The rightmost column shows the logistic mass of the carrier. This term includes the warhead itself in addition to propellant, fuze, and expandible containers, if applicable. The mass of the platform is not included.

System	Bomblet	Dispersion area (m^2)	Density of bomblets (ha^{-1})	No. of bomblets	Logistic mass of warhead (kg)
MLRS	M77	40000	161	644	385
M87 Orkan	KB-1	20000	144	288	389
M483A1	M42/M46	18000	49	88	60
M396	M85	18000	27	49	60
M449	M43	15000	40	60	56
CBU-7/A	BLU-18	12000	1000	1200	360
Hydra	M73	1000	90	9	27
ATACMS	M74	33000	300	950	2050
CBU-58	BLU-63	12000	540	650	370
Mk20	Mk118	10000	250	247	420
CBU-87	BLU-97	5000	330	202	430
Belouga	BLG	5000	300	151	305
RBK-500	OAB-2.5	6400	340	108	500
RBK-250	PTAB-2.5	4800	60	30	275
CBU-97	BLU-108	80000	5	40	416

Table 11.1 Typical values for dispersion areas for different cluster weapons

The distribution of the bomblets inside the dispersion area is not always homogeneous. Especially for bomblets delivered by tube artillery the distribution will be quite uneven. As the dispersion is accomplished by the spin of the carrier, the pattern of impact will have an annular shape with some additional bomblets in the centre of the annulus. This implies that the average distance between neighbouring bomblets becomes far shorter than what it would have been in the case of even distribution. This has negative consequences for the efficency of the weapon. When the distribution is uneven, the degree of overlap between the area of effectiveness between neighbouring bomblets becomes more extensive. If the effect of a single bomblet spans an area that is larger or comparable to the dispersion area, the effect of uneven distribution is neglectable. However, in the case of 155 mm field artillery DPICM, the effect against soft targets will be decreased considerably.

If a target area is saturated with bomblets, the negative effect of uneven distribution will vanish.

11.2 Reliability

If the bomblet does not work as intended, whether it becomes a dud or if it is subject to self-destruction or self-neutralization, the total effect of the projectile becomes smaller than expected. However, this effect is not considered further in the analyses, as the dud also will be present for comparable types of ammunition. The number of dud remaining on the battlefield will always depend of the number of explosive units dropped, making the reliability aspect most critical for cluster munitions.

11.3 Fragment effects

Fragment data on specific warheads are often classified. In order to make an assumptive calculation of the fragment effect the software package SPLIT-X™ [22] has been applied. This software calculates the fragment pattern from a warhead in terms of initial fragment velocity, fragment sizes, and fragment ejection direction. The determination of the fragment pattern is based on a sometimes rough, but realistic, picture of the warhead design, and the types and composition of the explosive components used. Although this method is based on a set of assumptions, e g concerning the metallurgical state of the casing, position of the detonator etc., this is as close as it is possible to come towards a real evaluation of the fragment pattern. SPLIT-X™ does of course use methods that are documented in open literature[46;47].

11.3.1 Arena test

In order to check the correctness of the SPLIT-X™ calculations, an arena test of DM1385 (identical to M85) was made. The purpose of an arena test is to reveal the fragment distribution from a warhead.

The bomblet was placed horizontally about 40 cm above ground. 5 aluminium plates, 2 m by 1 m each were placed vertically with the longer edge resting on the ground. The centre of each plate was 2.4 m away from the charge. Thereby the plates covered more than a semicircle (225°) around the charge. These tests showed that SPLIT-X™ predicted the fragment pattern almost correctly. However, some fragments, originating from the top of the bomblet body, had a more diversified dirstribution than predicted by SPLIT-X™. As these fragments travel in a direction different from all other fragments, they contribute somewhat to the lethality. In the following calculations, the arena test is used for the fragment distribution, while SPLIT-X™ is used for determining the fragment velocities.

[22] SPLIT-X is a product of Century Dynamics Inc. at Berkeley, CA.

SPLIT-X™ has a general weakness in not being able to predict fragments originating from the end sections of the charges. In some cases such fragments may give a significant contribution to the effect.

The test indicated that the prefragmentation of M85 did not work as intended. About 30% fewer fragments than expected were found. The overall outcome of this anomaly is a decreased effect against soft targets.

11.4 Calculation procedure

The following bomblets have been subject to a closer study using SPLIT-X™ to determine the fragment pattern, and software developed at FFI to determine the actual effect of the fragments. The following bomblets, representing a variety of types and sizes are included in the analysis:

- M85 DPICM in DM662 155 mm artillery
- M42/M46 DPICM in M483A1 155 mm artillery and M77[23] as delivered by MLRS
- M73 DPICM for M261 Hydra from rotary wing aircraft
- Mk118 in Rockeye II cluster bomb
- BLU-97 in CBU-97 cluster bomb
- BLU-63/B in CBU-58/B cluster bomb
- M43 in M449 155 mm field artillery projectile

For comparison, we have also included the effect of the following unitary warheads as examples of low-tech alternatives to cluster weapons:

- M107 155 mm artillery shell[24]
- Mk82 500 lbs air delivered GP bomb
- Mk84 2000 lbs air delivered GP bomb

Finally, we have included the Skeet ammunition as used in BLU-108/CBU-105 as a high-tech alternative to cluster weapons.

The calculation of the fragmentation was done with a computer program specially developed for this purpose, based on a method developed by the author in 1979 [48]. The algorithm can roughly be described by the following points:

- input of fragment data (velocities, directions, masses)
- input of bomblet data (velocity, attitude, height above ground)
- input of target data (size, posture, vulnerability criteria)
- calculation of fragment pattern
- calculation, at a large number of target positions, of which fragments hit the target and what probability of injury that implies
- integration of probabilities to produce values for lethal areas

[23] M42, M46 and M77 are assumed as equivalent in performance. M46 may though have somewhat less efficiency due to their lack of prefragmentation in the casing

[24] M107 is considered as an out-dated piece of ammunition, but is still used due to the large stockpiles. Its successor, M795, with its more slender shape, is claimed to be 30% more effective (USMC).

These calculations are repeated for every type of bomblet, for all combinations of targets and target postures, and for several bomblet attitudes.

In addition the fragment penetrating capacity is quantified by calculating the expected number of fragments penetrating a steel plate of one square meter with various thicknesses.

11.4.1 Combat effects

Calculation of combat effects is done with a target representing a standing and a prone soldier. Only the primary effect of fragments is considered. It is, however, known that under some circumstances the effect of fragments ricocheting from the soil surface may contribute significantly to the lethality. This effect is not included in the calculations. According to a study from 1975 it seems that the effect from charges detonating at, or close to, the surface the effect is limited to 10 – 20% of the primary effect[49]. For charges detonating a few feet above ground, the effect may be somewhat larger. There are, however, reasons to believe that this effect will be present for all types of charges, big as well as small ones. Ricocheting effects will thus not have the potential of reversing the conclusions.

Many bomblets, especially those of the DPICM family, have a cylindrical shape which will give a radial distribution of fragments. The initiator is at the top of the charge. The detonation wave will thus propagate downwards. According to theory [7] and numerous experiments, this will give the fragments a downward vertical velocity component. If the bomblets hit in a vertical attitude, all fragments from the cylindrical body part will hit the ground within a few tens of centimetres. However, most bomblets will not have an exactly vertical attitude at impact, but will be tilted up to 25° due to aerodynamically effects.

Detonation of the warhead will take place a few tens of microseconds after impact. If the impact is against a firm and hard surface the whole warhead may have stopped its vertical velocity before the fragments are ejected. It may even have time to rebound from the surface. That will have a positive effect on the fragmenting effect. Otherwise, against soft ground, no significant drop in velocity can take place in such a short time interval, and the fragments will get an additional downward velocity component.

11.4.2 Post-war effect

The post-war effects are somewhat different from the intended effect delivered during war where the target is supposed to be vehicles and personnel in a fighting state. In-battle targets are male persons that are expected to behave as soldiers. They will have equipment providing some kind of protection like rough clothing and even protective vest covering the major part of the torso. A soldier may also be expected to take cover by placing himself in a prone posture that will provide some protection against warheads detonating at ground surface.

The post-war effect may take place against people of all ages and both sexes, and children may become a frequent target due to their high physical and unpredictable activity. If a dud detonates, it will usually do so in the presence of a human foot or hand. This will usually be fatal to the person making contact with the dud. In addition it may inflict injuries to other persons in the area. Civilians are not likely to wear any protective gear, and they will usually also be in an upright posture, thus being more vulnerable to the fragmenting effect of a dud.

The fragment pattern will also often be different in a post-war situation compared to the effect in battle. Many bomblets are designed to give an effect directed radially and horizontally from the detonation point. This is because the bomblet approaches the ground with its axis of symmetry oriented vertically. In a post-war scenario, when being touched by a foot, the dud will likely detonate in a state where the axis of symmetry is oriented horizontally, and when being touched by a hand, with a completely randomly orientation. Thus the vulnerable effect may become higher in the post-war role than in battle.

11.4.3 Targets

The primary data for the four targets to be used in the analysis is given in the table below

Prone soldier Average exposed area [25] 0.20 m^2 Body weight 75 kg Average height above ground 15 cm Standard military uniform w/helmet	**Standing soldier** Average exposed area 0.45 m^2 Body weight 75 kg Average height above ground 90 cm Standard military uniform w/helmet[26]
Adult civilian Average exposed area 0.40 m^2 Body weight 65 kg Average height above ground 85 cm Light clothing	**Child** Average exposed area 0.25 m^2 Body weight 35 kg Average height above ground 70 cm Light clothing

Table 11.2 Targets considered in this study

One should note a subtle difference between military and civilian targets in this context. The vulnerability of military targets are evaluated on the circumstances present in battle; i e the ordnance is used according to the rules, and the target reacts according to what the personnel is trained to do. This implies that the bomblets detonate at the expected height, having the expected velocity of descent and in the most probable orientation.

Civilian targets are addressed in a post-war mode; i e the ordnance detonates as it lies on the ground and with an orientation that is most likely based on the geometry of the bomblet. Calculations are also made for the case where the object is lifted and detonation takes place 1 m above the ground with the axis of the warhead in a vertical position.

[25] The exposed area varies considerable with distance and microtopology. The value given indicates a typical area.
[26] It is anticipated that the helmet gives adequate protection against fragments.

11.4.4 Hard targets

The anti-materiel effect of bomblets is, in addition to the shaped charge mode, made by the fragment effect. In order to compare different warheads in this respect, we have illustrated the effect by giving the number of fragments that will perforate a 3 mm thick steel plate at different distances. The plate is assumed to be 1 m^2 and placed in an upright position on the ground. The criteria for a fragment to perforate these plates were given in figure 6.6.

11.5 Results

11.5.1 Fragment effects

The table below shows the fragment effect, in terms of lethal areas (in m^2), against the different targets for the selected bomblets, unitary charges, and the Skeet SFW.

	Lethal areas (m^2)	
Bomblet	Standing soldier	Prone soldier
M42/M77	12	26
M85	16	66
M73	12	55
M43	11	11
KB-1	10	24
Mk118	34	61
BLU-63	19	29
BLU-97	84	125
AO2.5RT	133	71
M107 PDET	962	525
M107 PROX	1123	856
Mk82	3213	1483
Mk84	5863	3098
BLU-108/Skeet	3	3

Table 11.3 Lethal areas of selected bomblets and unitary warheads

As a kind of check for correctness of these values, a comparison of published values may be done. Values of this kind are found in [5] and [50]. These published values are for 120 mm and 160 mm mortars respectively and give lethal areas of the same magnitude as M107.

It should be noted that the effect of small bomblets detonating upon ground contact is rather limited, especially against standing soldiers. The reason is that the great majority of fragments are thrown out horizontally and therefore mainly hit the lower extremities when standing, while the whole body is exposed when the soldier is in prone position. For large warheads, the effect is opposite as the topography, at some distance, hides the parts of the body being close to the ground.

The next table shows the effect of the whole cluster weapons.

				Lethal areas (m^2)	
System	Bomblet	No. of bomblets	Dispersion area (ha)	Standing soldier	Prone soldier
M483A1	M42/M46	88	1.8	1038	2203
M26 MLRS	M77	644	4.0	7027	13681
DM662	M85	49	1.8	774	3066
M261 Hydra	M73	9	0.1	104	450
M449	M43	60	1.5	646	646
M87 Orkan	KB-1	288	2.0	2746	4460
Mk20	Mk118	247	0.6	5682	7784
CBU-58	BLU-63	650	3.3	7712	9506
CBU-87	BLU-97	202	0.5	4832	4968
RBK-500	AO2.5RT	216[27]	0.6	9435	7842
-	M107 PDET	-	-	869	358
-	M107 PROX	-	-	1154	884
-	Mk82	-	-	4222	1512
-	Mk84	-	-	8128	3118
CBU-97	BLU-108/Skeet	40	8.0	120	120

Table 11.4 Lethal areas of selected cluster weapons and unitary weapons

It should be noted that Mk82 and Mk84 general purpose bombs are supposed to detonate when the nose of the bomb touches the ground. An air burst mode of these bombs at 10 – 15 m height will result in around 50% better performance against prone soldiers. Against standing soldiers the effct does not change significantly.

The next table shows the suppressive effects measured as suppressive areas in hectares (ha)

[27] Number of half warheads. There are 108 bomblets with 2 warheads each.

System	Bomblet	No. of bomblets	Suppressed area per bomblet (ha)	Suppressed area for system (ha)
M483A1	M42/M46	88	0.016	1.4
M26 MLRS	M77	644	0.016	10.3
DM662	M85	49	0.021	1.0
M261 Hydra	M73	9	0.055	0.50
M449	M43	60	0.016	0.96
M87 Orkan	KB-1	288	0.016	4.6
Mk20	Mk118	247	0.124	30.6
CBU-58	BLU-63	650	0.083	54.0
CBU-87	BLU-97	202	0.164	33.1
RBK-500	AO2.5RT	108	0.055	11.9
-	M107	-	-	3.2
-	Mk82	-	-	57.7
-	Mk84	-	-	272
CBU-97	BLU-108/Skeet	40	0.34	13.6

Tabel 11.5 Suppressive effects of selected cluster weapons and some unitary weapons

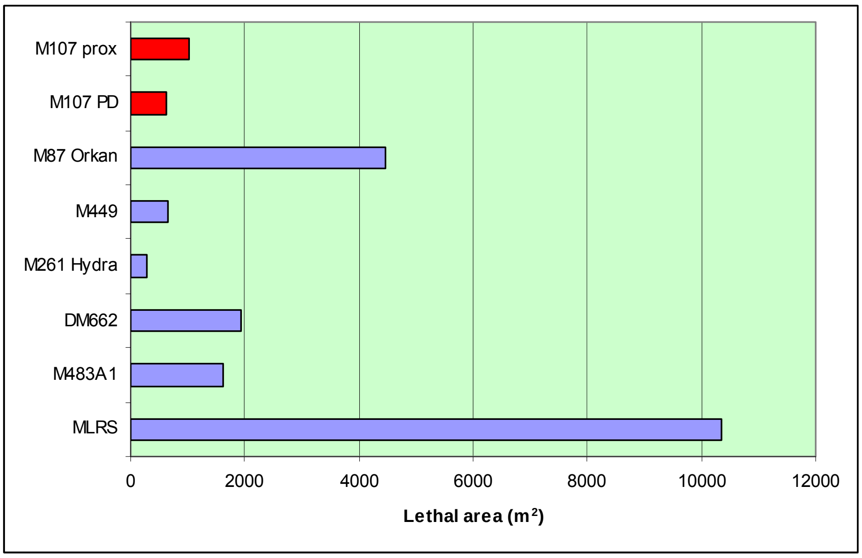
These results are also displayed graphically in the next two pages. The graphs cover ground lauched systems and air-launched systems separately. Here the effectiveness per expended mass unit is also included.

Please note that the unitary weapons have a colour different from the cluster weapons.

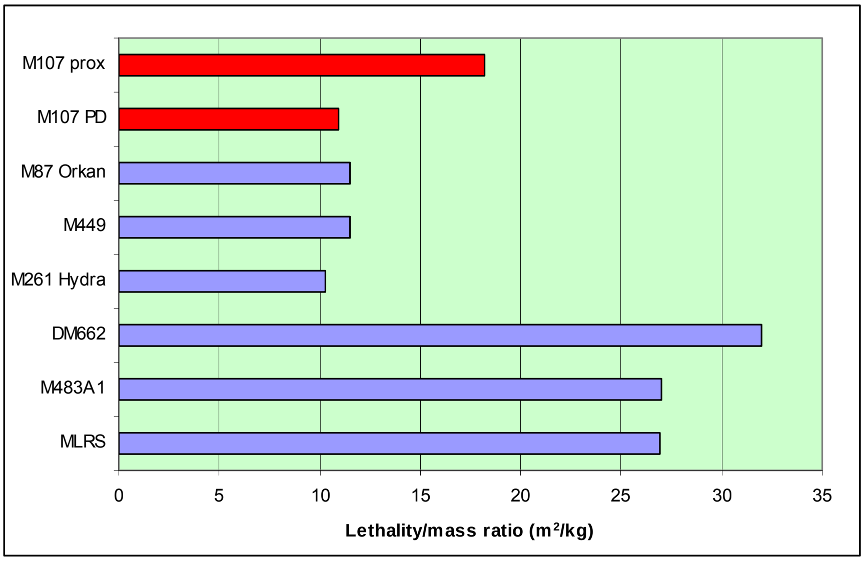
The BLU-108/Skeet is not included because it neither has an anti-personnel nor suppressive role.

Ground delivered systems

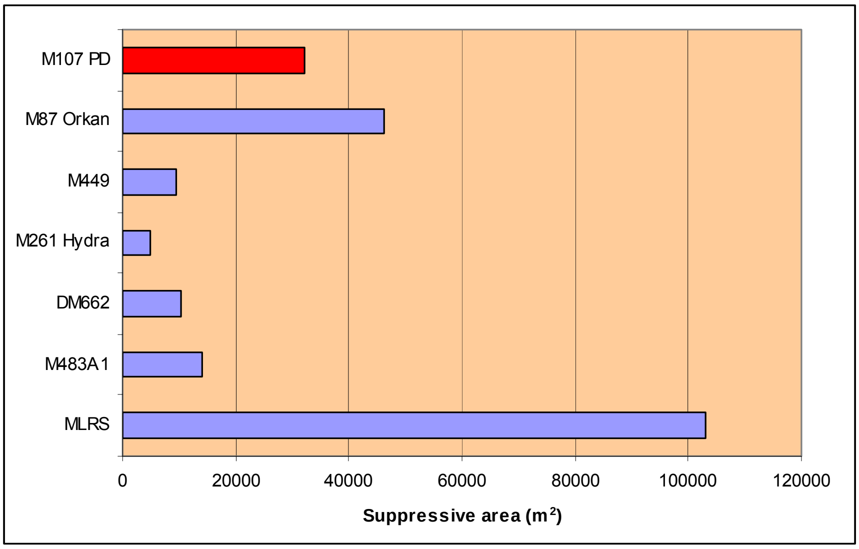
Lethal areas of the cluster munition (m^2)

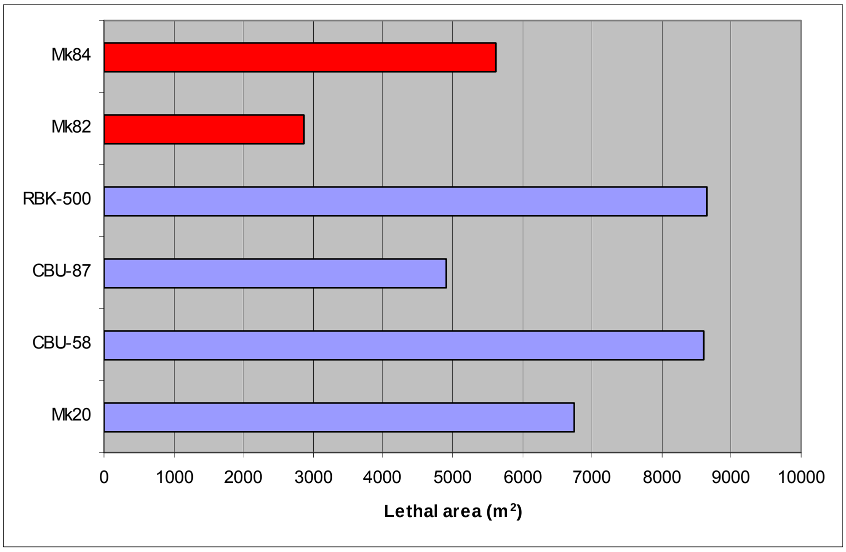


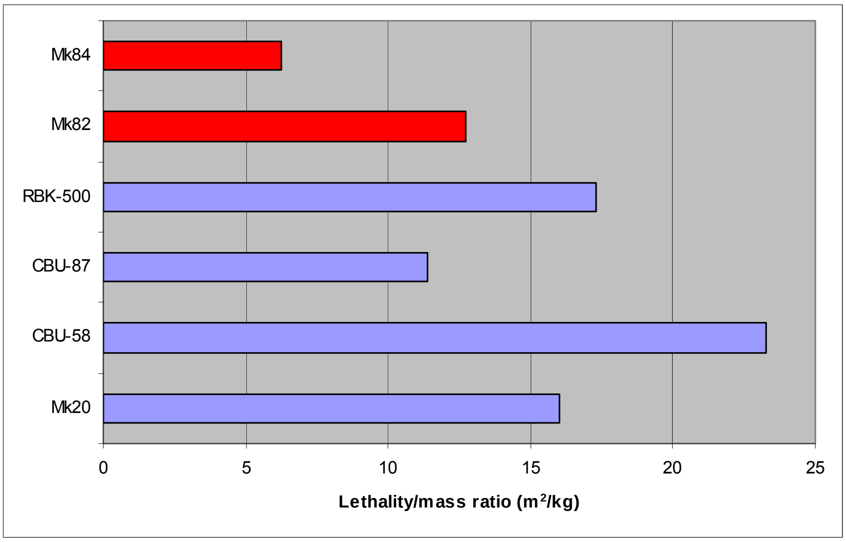
Lethal areas per expended mass (m^2/kg)

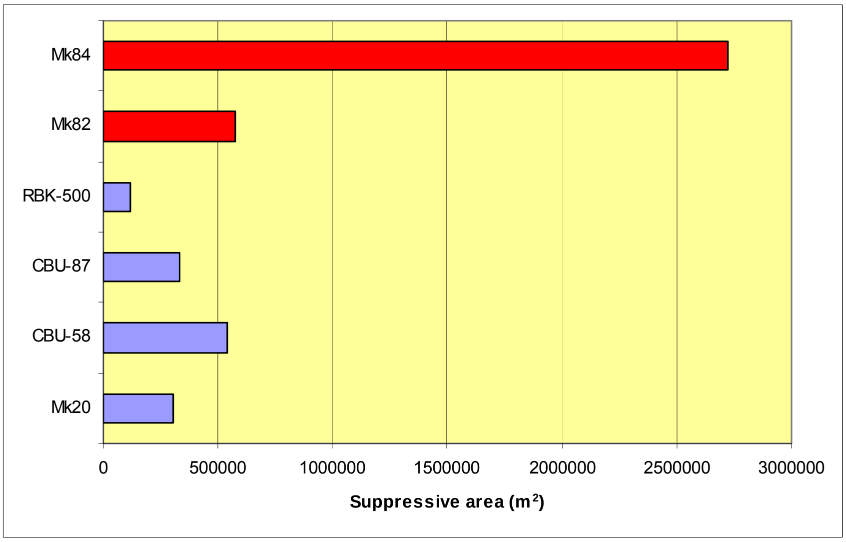


Areas of suppression for the cluster munition (m^2)



<table>
<tr><th colspan="2">Air delivered systems</th></tr>
<tr><td>Lethal areas of the cluster munition (m^2)</td><td>


</td></tr>
<tr><td>Lethal areas per expended mass (m^2/kg)</td><td>


</td></tr>
<tr><td>Areas of suppression for the cluster munition
(m^2)</td><td>


</td></tr>
</table>

11.5.2 Post-conflict effects of duds

The following table shows the lethal areas in the event that the bomblet inadvertently detonates when lying on the ground or when being lifted up to a height of 1 meter above ground. At the ground the warhead is supposed to be lying on the ground with its main axis horizontally. When lifted the axis is supposed to be vertical. Heavy charges are supposed never to be lifted.

Bomblet	Adult	Adult	Child	Child
Position	Ground	Lifted	Ground	Lifted
M42/M77	6	64	9	148
M85	6	85	9	182
M73	10	138	11	159
M43	15	29	38	47
KB-1	4	58	6	96
Mk118	11	150	12	184
BLU-63	20	124	16	98
BLU-97	28	377	25	399
AO2.5RT	29	135	26	107
M107	197	n/a	166	n/a
Mk82	1154	n/a	991	n/a
Mk84	2871	n/a	2450	n/a
BLU-108/Skeet	97	288	85	266

Table 11.6 Effects of duds in a post-conflict setting

As expected, the small bomblets are far more effective when detonating above ground than on the ground. The values for the lifted case must be considered as a worst case position. In reallity all results between the two cases included in the table are possible. A child is in most cases slightly more vulnerable than an adult person, but the difference is often rather insignificant.

11.5.3 DPICM versus unitary charges

It seems to be accepted in literature that DPICM has 2 – 5 times better effect when compared with conventional unitary HE charges [51;52].

When the SPLIT-X™ and the vulnerability model are used, it is hard to see how this advantage for DPICM may come about. The basic problems with DPICM bomblets are that they

- hit the ground with a more or less vertical orientation
- detonate at the ground surface
- have a fuze and a detonator that sits on the top of the bomblet, and this combined with the right cylindrical body, forces the majority of the fragments into a downward trajectory
- eject small sized fragments with limited range
- leave a substantial number of duds

All these factors are to blame for the poor performance of bomblets like M42, M85 and KB-1. Compared to common belief this is surprising. There seems to be a gap between the claims in the literature and the results of the modelling. However, the points mentioned above give plausible explanations of the results. For M85 the experimental tests (see section 11.3.1) support this view.

It should also be noted that when comparing DPICM charges with M107, the latter does not represent state-of-the-art. Modern, more slender unitary artillery shells are claimed to be 30% more lethal than M107[53]. Thus, a modern HE-charge will almost be on par with a DPICM artillery shell.

Against an armoured target, like an IFV[28], around direct 10 hits are required in order to inflict damage with a reasonable probability. When such a vehicle is inside the dispersion area of an M483A1, the probability of one or more hits is around 5%. This means that the target has to be inside the dispersion area around 200 times before it is likely to be destroyed. When firing at such vehicles in combat formations, three or four vehicles may be inside the dispersion area at the same time, but still around 50 – 70 shells must be fired for each kill. A unitary artillery shell has to hit directly or very close to the target to inflict damage. At medium or long ranges, a HE shell may hit randomly within a one hectare area, requiring 150 to 200 shells per damage. In this role, DPICM is thus around three times more efficient than HE. However, when guided artillery shells become available, it will again be possible to defeat such targets by unitary high explosive shells.

DPICM and HE shells are the munition types available for indirect suppressive fire. The M107 HE round was in the analysis above found to have a suppressive area of 3.2 ha. With the same approach the M42 has a suppressive area of around 150 m^2. When all 88 bomblets are spread over the footprint the suppressive area from an M483A1 becomes 1.4 ha provided that no duds are left. Here the aspect of the duration of suppressive fire is not considered, but also the aspect of duration would clearly be in favour of HE instead of DPICM for this purpose.

For the M85 bomblet, the producer claims[54] that the lethal area is 197 m^2 against standing troops and 96 m^2 against prone troops. These numbers deviate quite substantially from the results found in the present work. The arena test done with the DM1385 indicates that the claimed result for standing soldiers must be based on a different set of vulnerability criteria or that the bomblet has to detonate with an attitude that may be hard to obtain in reality.

11.5.4 Entrenched targets

The ability to defeat entrenched infantry has traditionally been an important aspect of war throughout the 20th century. Soldiers hiding in deep, narrow and broken trenches are very difficult to defeat by unitary charges with point detonation fuze. A hit with a 155 mm HE shell within very few meters from the trench is required in order to inflict damage.

Using cluster weapons against entrenched infantry may be more effective than unitary weapons under certain conditions. A bomblet falling into the trench will be very harmful to those staying in the same trench, or the same part of the trench. It is, however, difficult to exactly quantify this

[28] Infantry Fightling Vehicle

effect as it will depend heavily on the size and design of the trench. An example is outlined below.

> Consider a target area where there are 30 m of trenches per 1000 m^2 of target area. The trenches are all 1 m wide. The probability that a bomblet will fall into a trench is then 3%. We may further assume that the design of the trench is such that a bomblet dropping into it will have a lethal area of 3 m^2. For a cargo shell having 88 bomblets the total lethal area will then be 88 x 0.03 x 3 m^2 = 8 m^2. The possibility that a soldier may be injured by two or more bomblets is then neglected. A wider trench will increase the lethal area.

A 155 mm HE, detonating on ground, will probably give a lethal area of 3 - 5 square meters against a well entrenched target. An 88 bomblet cargo shell with the same calibre will have a total lethal area that is a few times larger than that. Still, defeating such targets with cargo ammunition requires a lot of resources.

The comparison between the 155 mm HE and the 155 mm cargo round changes somewhat when the HE shell is equipped with a proximity fuze instead of a point detonating fuze. Fragments from the unitary charge will be ejected downwards into the trenches. For a well designed trench the lethal area now becomes 20 m^2 or more based on rough calculations. The unitary charge may then be more efficient than cargo shells.

12 Conclusions

12.1 The use and need for cluster weapons

The purpose of cluster weapons was originally to defeat large formations of infantry units. That concept applied well in the conflicts in South-East Asia and certainly also in a foreseen clash between NATO forces and Warsaw Pact forces in Central Europe. In asymmetric warfare and counterinsurgency operations such large formations are rare and quite unlikely.

12.1.1 Soft targets

When cluster weapons are compared with unitary weapons of the same size, there are no clear indications that the cluster weapons are substantially more effective in terms of lethality or ability to incapacitate the enemy. The effects of bomblets are good in terrain with smooth surfaces and limited vegetation. In a terrain with rugged microtopography the effects easily become low due to fact that most bomblets detonate upon contact with the surface.

Against entrenched targets it is hard to claim whether unitary weapons are better than cluster weapons, or vice versa. The outcome will depend on the size and quality of the trenches. Defeating targets in well-made trenches will in any case require large resources. Unitary shells with proximity fuze will in any case be a good alternative to cluster warheads in defeating targets in open trenches.

12.1.2 Semisoft targets

These targets are vehicles as trucks, and other field vehicles with a protective level inadequate to protect against small arms fire. With this lack of protection they will neither give adequate protection to fragments from bomblets nor to fragments from larger bombs.

An evaluation of the effectiveness against such targets depends on whether the vehicle itself or the crew is the most valuable component of the target. Since the protection against fragments is insufficient, the crew can be treated just like standing soldiers. As we have shown earlier the advantages of using bomblets against such targets are minimal or completely absent. If the vehicle is considered the valuable component, then the outcome will depend on its robustness. DPICM will generally get an increasing advantage over unitary charges as the vehicle becomes harder due to their ability to perforate such targets when they hit.

Against armoured vehicles and vehicles carrying sensitive loads[29], sensor fuzed warheads will be the best alternative.

12.1.3 Hard targets

Hard targets may be threatened by bomblets with a shaped charge capability. Modern hard targets will often not have the ability to completely stop the effect of the bomblet detonating at the top of it, but the use of soft material as a liner in the ceiling will minimize the effect of small bomblets and also reduce the damage imposed by larger bomblets. A penetration of a shaped charge jet to the interior of a heavy vehicle does not always render the target as killed. It is likely that several hits, sometimes more than a dozen hits, are needed to knock out a heavy tank. The probability of achieving the required number of hits in a cluster attack is quite low.

When guidance devices become available for unitary artillery, this ammunition may also be used for defeating armoured targets.

Sensor fuzed warheads, being in the process of deployment after 30 years in the development stage, is a far better alternative than conventional and passive bomblets. The very size and impulse of the projectile being projected against the target from sensor fuzed warheads makes it difficult to find a viable protection. Even if SFWs are expensive, they seem to give far better cost-effectiveness than both unitary and cluster munitions.

12.1.4 Suppression

It is often claimed that the use of artillery delivered cluster munition is necessary to impose suppressive effects. Against unprotected infantry that claim seems to be unfounded. Personnel in light or heavy vehicles should not be more suppressed by cluster weapons than by unitary

[29] Loads of ammunition, propellents and electronics.

weapons provided that they behave in a rational manner. However, behaviour in battle is usually based on education, motivation and moral that may not coincide with rational norms. Sensor fuzed weapons have a limited suppressive effect, but are normally too expensive for that purpose.

12.1.5 Urban areas

Urban area is a scenario where cluster weapons have been used on several occations. In such areas the effect of cluster weapons is hampered by houses, ditches, canals and other objects. These will provide cover for soldiers and limit the range of fragments. In such a role field artillery, GP-bombs and sensor fuzed weapons could be viable alternatives from a tactical point of view. However, the dilemma is that unitary weapons in urban areas will leave considerable structural damage to houses and infrastrucures, on which small bomblets will give a far more benign effect. Indirectly, unitary weapons could potentially kill more civilians by structural collapse of buildings than the cluster weapons could do by direct effect. The post-war dud problem will, on the other hand, be far less with unitary weapons.

The application of sensor fuzed weapons in urban areas also poses difficulties. An urban scenario will provide a scenario containing a lot of objects that an SFW may interpret as a possible target. It is, and will be, a challenge for developers of such warhead to find algorithms that are able to reliably differentiate between an armored personnel carrier and a civilian bus. A high number of false targets will reduce the effectiveness of such weapons. It may even jeopardize the advantage in cost-effectiveness that SFW have over cluster weapons. The use of SFW in such areas must be accompanied by strickt rules of engagements.

Unitary guided weapons may, in total, be the best alternative in urban warfare if they can be guided with sufficient accuracy and reliability.

12.2 Alternatives to cluster weapons

12.2.1 Unguided unitary warhead

It has been a general belief that DPICM cluster weapons have an advantage over unitary weapons by a factor of 2 – 5 against most targets. The analyses herein make it hard to confirm that an advantage of that magnitude is present. Unitary weapons still are effective weapons against soft targets, especially when such warheads are fitted with proximity fuzes. In some cases such a concept will be as effective as, or even more effective than, DPICM warheads. Against hard targets, neither unitary nor cluster weapons are very effective.

Suppressive effects are hard to quantify, hard to evaluate and depending on a number of psychological factors. The most thorough studies seem to conclude that the effect depends on the amount of explosive that is brought to detonate in an area. Consequently, in the role of suppressive fire, unitary charges seem to have a definitive advantage over cluster charges.

12.2.2 Sensor Fuzed Warheads

Sensor fuzed weapons have come to a stage of maturity that makes them a viable tool on the battlefield. Their potential in defeating hard targets is large. Even though these warheads are very expensive, their effectiveness compared to both unitary charges and other cluster weapons is so high that the cost per kill is far less than the alternatives. Even when only the direct procurement cost is taken into account, the comparison is strongly in favour of the SFWs. When cost of logistics is included, the comparison will become even more favourable.

12.2.3 Guided warheads

Kits for effective guidance of air delivered bombs have been available, and have been in use, for some time. Systems for precision guidance of artillery shells are on the verge of becoming available. Such systems open up the possibility that unitary systems can engage high-valued point targets. These systems, which mostly are based on GPS-technology, may not yet be accurate enough to effectively engage individual vehicles. Such kits may of course also be fitted to existing cluster weapons, both air delivered and ground delivered. If the cluster payload is released at low altitude, the system may be viable for defeating.targets with limited area. However, releasing such payload at low altitude will potentially increase the dud rate.

12.3 Are cluster weapons a necessity on the battlefield?

The main advantage of cluster weapons from a military point of view is that the effect is distributed over an area. This distribution is the essential idea behind cluster weapons. A cluster weapon that does not distribute its payload does not make sense. All bomblets hitting at the same spot will always have an effect that is inferior to an alternative unitary charge. The distribution will also to some extent compensate for the inaccuracy in delivery that is inherent with any unguided weapon, both cluster weapons and unitary weapons. In addition, the total effect of the munition may often be better than for unitary charges, although that advantage may be limited and often absent.

The disadvantages of cluster weapons are numerous. High dud rate and the inability to focus the effect are the most obvious ones. The analyses herein have shown that any target can be effectively engaged with either unitary warheads or with sensor fuzed warhead. The latter is undoubtly a very expensive weapon system but its effectiveness is superior to cluster weapons even if the cost is taken into account. It is hard to see any good reason for aquiring cluster weapons as long as alternative unitary warheads and sensor fuzed warheads are available.

Distribution of the effect across an area does, however, require that the target is large enough to cover that area. Otherwise, the effectiveness will be decreased and a high cost per kill will result. Targets of sufficient size will undoubtedly be present in a grand scale war. In asymmetric warfare and in counterinsurgency operations, targets of that size will be less frequent. Additionally, in such scenarios, the targets may be adjacent to civilian areas that are prone to collateral damage.

12.3.1 Comparison with mines

Some years ago, the Mine Ban Treaty took effect, prohibiting the use of anti-personnel mines for the ratifying nations. From a tactical point of view that treaty was quite dramatic, removing a unique capability from the battlefield. No real substitutes to mines were available, and still no weapons that fully replace the role of anti-personnel mines, have been developed. The answer has been to adapt the tactics so that the use of mines is rendered unnecessary.

For cluster weapons the acceptable alternatives are at hand, and no dramatic changes in tactics are required.

Appendix A Description of various cluster bomblets

It is not possible to give an exact number of how many different cluster munitions there are. This is because many types are exact, or slightly modified, reproductions of earlier or foreign types. There are also numerous examples of types that may look different, but their content may be very different. There are also examples of mine munitions that have evolved into bomblets, or vice versa. This chapter discusses the characteristics of the most common families of cluster bomblets. The performance of some well known bomblets can not be given here, due to the fact that some of the main characteristics of the warheads are classified.

A.1 The Rockeye family

This is a quite numerous family with members in many countries. The prototype seems to be the Mk118 which is contained in the Mk7 container being the main component in the Mk20 Rockeye system. It is a dual purpose anti-tank / anti-personnel warhead with both a shaped charge and fragment as the main effects. Some variants even have an incendiary effect as zirconium pellets are inserted in the explosive charge. The standard bomblet contains an ordinary copper coned shaped charge with 47 mm diameter. The body seems generally to be made of aluminium, but there are also variants with a casing of prefragmented steel. The shaped charge is probably able to penetrate more than 180 mm of RHA steel. The fragmentation effect to its surroundings is limited due to its thin and light casing. The explosive charge is around 180 grams of Octol.

Bomblet	Diameter	Length	Explosive mass
Mk118	50 mm	330 mm	180 g Octol
BLU-77	40 mm	224 mm	57 g RDX
BLU-112	48 mm	316 mm	183 g
WB-AT	53 mm	378 mm	130 g
WB-AP	53 mm	378 mm	150 g
PM-1	48 mm	384 mm	150 g

Table A.1 The Rockeye family

One Rockeye bomb consists of an Mk7 dispenser containing 247 Mk118 bomblets. The bomblet was originally designed to defeat tanks and light armour. However, the development of tanks during the second half of the cold war made these bomblets less adequate against such targets, but it is still a viable mean to defeat lighter armoured vehicles. The Mk118 bomblets are also delivered by cluster bombs CBU-99 and CBU-100 cluster bombs.

After being released in air the bomblets needs around 1.2 seconds to arm. The arming device is a vane placed right ahead of the bomblet fin section, to which the airflow induces a spin. At impact, the front piezoelectric crystal sends an electric pulse to the detonator. Against soft target, the front fuze may fail. A backup fuze is provided by a firing pin that stabs the detonator. However, this backup system should not be considered a self-destruct device.

An improved VECP-version (Value Engineering Change Proposal), in which the piezo-electric fuze was discarded, was the latest stage of development. This version used a set of four shear pins that were to break at impact and that subsequently released a mechanical firing pin.

The bomblet has three polymer fins for stabilizing. There are no braking devices and the bomblet will hit at a speed probably exceeding 100 m/s.

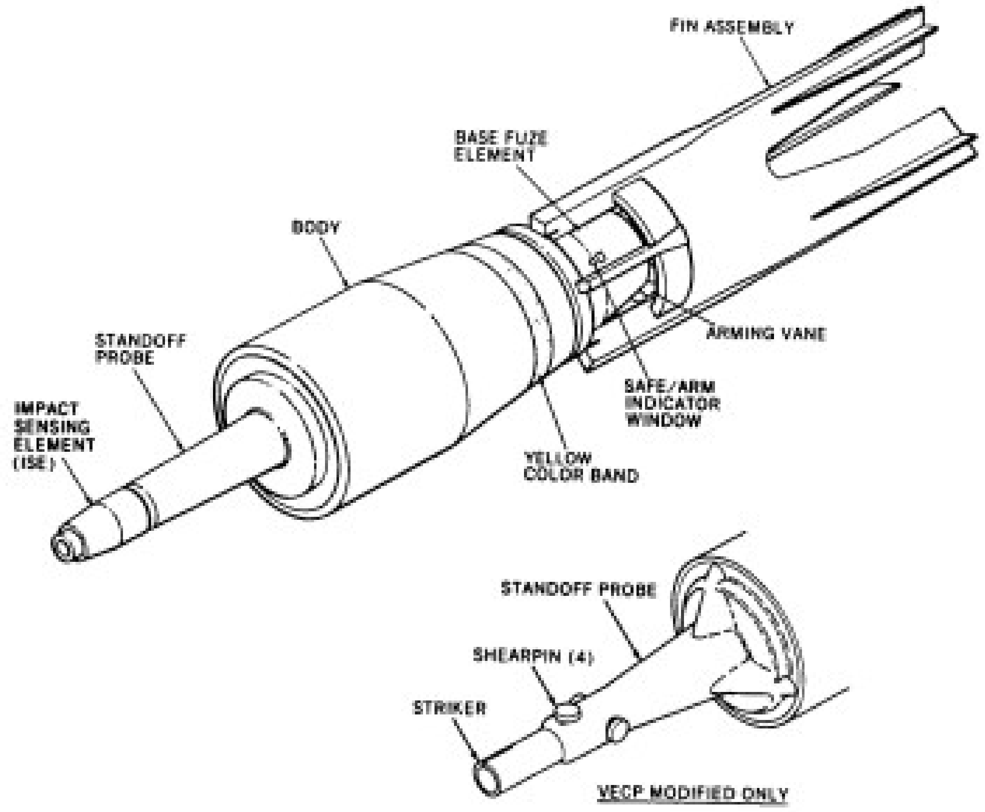


Figure A.1 The Mk118 Rockeye bomblet [55]

A.2 The "pop-up" family

This small family consists of one air delivered bomblet type, and a few types delivered by field artillery. The unique feature for this bomblet is that each bomblet warhead is packed inside a rather massive container which is aerodynamically stabilized during descent. Upon impact with the ground the container ejects the small warhead which due to a delay function detonates at 4 to 6 feet above ground. The warhead has the shape of a slightly oblate spheroid which expels its fragments in all directions.

A.2.1 Air delivered types

The BLU-18 bomblet is contained in SUU-13/A comprising the cluster bomb CBU-7. The canister contains 1200 of these bomblets. The bomblets are spread over an area of the size of 60 x 40 m.

The warhead contains 21.25 grams of Comp A5 explosive. The fragments have an initial velocity of around 1400 m/s. The mass distribution is quite even due to the prefragmented casing of the warhead. There are nearly 100 effective fragments in total with a typical weight of 1.5 grain (0.1 gram).

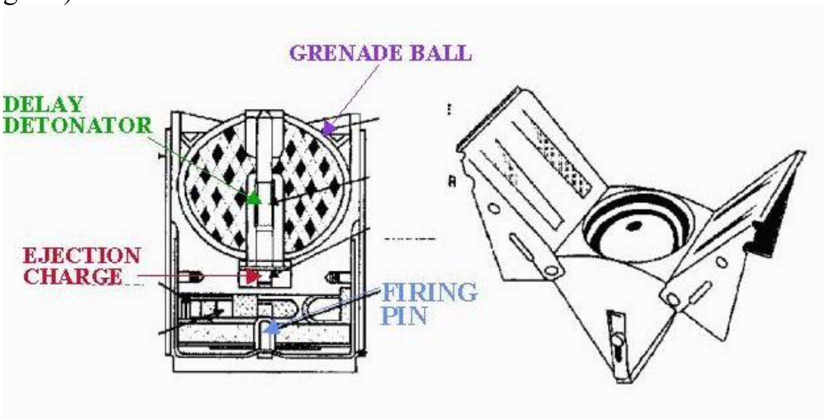


Figure A.2 The M43 bomblet [56]

A.2.2 Artillery delivered types

In the first versions of this type the container had a diamond shaped cross section. Later, pie-shaped bomblets took over, but the spheroid bomblet remained.

M39 is the content of the M444 105 mm artillery rounds. This bomblet had the diamond shaped cross section. 18 bomblets are contained in the round. They are packed with 3 bomblets in each layer.

M36 is used in the 105 mm artillery round M444E1, which is now being phased out by US Army. The pie-shaped container is also used in the artillery delivered AP-mine ADAM M692/M731, and in the US designed so-called Pursuit Deterent Munition (PDM) M86. The pie-shape container has a sectorial angle of 72°, such that 5 bomblets can be packed in each layer of the warhead.

The standard bomblet seems to be the M43 or M43A1, which probably are later versions of M36. They are found in the 155 mm round M449A1 with 60 bomblets. The only difference between the M43/M43A1 and BLU-18 seems to be the shape of the ear-shaped springs on the vanes of the bomblets.

These bomblets are known to have very high dud rates. US Army sources claim a dud rate between 18 and 50%.[57]

The US Army also once had an 8 inch artillery round M404 containing 104 M43 bomblets.

A.3 The DPICM family

Dual Purpose Improved Conventional Munition (DPICM) is the most typical bomblet type used by field artillery. The term *Dual Purpose* refers to the two main damage effects of the bomblets –

the *fragment effect* and the *shape charge* effect. The first is for defeating armoured vehicles; the second for defeating soft targets. Some sources also name this family as MPSM (Multipurpose Submunition). Although the name DPICM implies a dual function, the ability to defeat armour has become second priority. DPICM is usually now marketed for use against soft targets.

DPICM was first developed in the 1960s as the 155 mm artillery projectile M483 with M42 bomblets. This projectile was soon modified to become the M483A1, which has later been exported to several countries. This type was also applied to other calibres and the design has been used in several other projectiles worldwide. The same concept with modified content has also been applied in field artillery rocket systems and even in mortar systems.

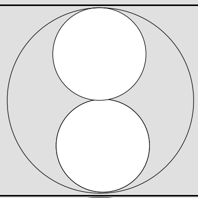
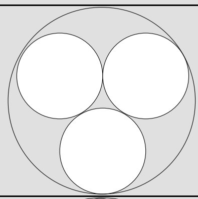
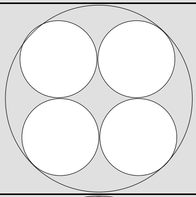
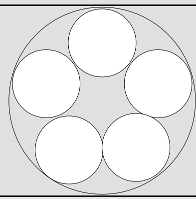
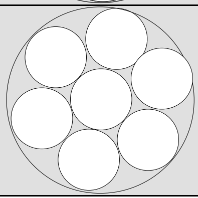
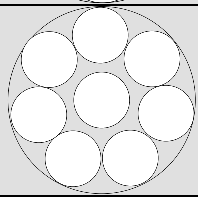
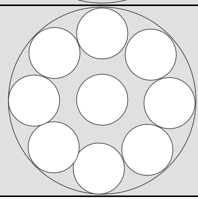
These types of ammunition are usually referred to as of *cargo munition*, opposite to *cluster munition* that traditionally has been reserved for air delivered systems.

The mode of function is the same for all systems. The monolithic shell or rocket is fired with a time fuze that ejects the cargo at a time set by the gun crew. This event takes place at a height of 400 – 800 m above ground. Each bomblet has a cylindrical shape containing a small shaped charge. The safety and arming device and the detonator is at the top of the cylinder. A ribbon, or streamer, is attached to the top of the fuze in order to ensure that the bomblet is stabilized in an upright position. The ribbon also has a role in inducing a relative spin between the bomblet body and the firing pin, enabling the pin to withdraw and activating the arming of the bomblet. Due to the spin of the shell at push-out they are dispersed outwards over a more or less circular area covering up to 3 hectares.

Packaging of DPICM submunitions

Cylindrical bomblets are mostly packed into cylindrical containers. It is also common that the axis of the bomblets is placed parallel to the axis of the container. They are often constructed in such a way that one end fits into the opposite end of the neighbouring bomblets. When the radius of the bomblet and the inner radius of the container are known, it is quite obvious how the packaging of the bomblets is arranged.

Number per layer	Radius ratio	Formula	Example
2	2.000	2	
3	2.155	$1+\frac{2}{3}\sqrt{3}$	122 mm
4	2.414	$1+\sqrt{2}$	MP-98
5	2.701	$1+\sqrt{2+\frac{2}{5}\sqrt{5}}$	
7	3.000	3	DM662
8	3.305	$1+\csc\left(\frac{\pi}{7}\right)$	M483A1

9	3.613	$1+\sqrt{4+2\sqrt{2}}$	M984
Configurations			
			
			

The following sections give a brief presentation of the different variants of DPICM.

A.3.1 M42/M46

The M46 is a kind of archetype of DPICM. It has an extremely simple design consisting of inexpensive, easy-to-make components. The only difference between M46 and M42 is that the latter has some thin and shallow grooves on the inside of the casing to promote a more optimal fragmentation. The diameter of the body is 39 mm which enables putting 8 bomblets in each layer in a 155 mm shell. This bomblet has also been the model for several later bomblets.

A.3.2 M77

M77 was probably developed for the MLRS system as an alternative to M42 and M46 that had been used for US 155 mm ammunition. The dimensions are the same for all these bomblets. The components of M77 are also the same as for M42/46. The most striking difference is the width of the ribbon which is needed to ensure arming of a bomblet that has far less spin than those in the artillery round.

A.3.3 M80

So far, this is known to be the only US DPICM with a self destruct mechanism. The energy source from this device is a tiny battery developed by the company KDI. There are claims that the self destruct device has a reliability of 99.8%. The device is designed to function 6 – 8 minutes after the bomblets have suffered a ground impact[58].

M80 is significantly smaller than any of the other DPICM with a diameter of just 31 mm. This small size makes it possible to pack 9 bomblets in a layer and to fit 54 bomblets all together in 120 mm mortar round and 42 bomblets in a 105 mm artillery round.

The bomblet has a prefragmented casing as that of M42. The explosive content is small – 30 grams of RDX. Thus, the penetration performance is probably limited to 80 mm in RHA steel.

A.3.4 M85

M85 probably was the first DPICM bomblets that had a self-destruct mechanism. It is produced by IMI (Israel Military Industries) from where it was brought into production around 1990. The self destruct mechanism consists of a pyrotechnic fuze string that ignites as the bomblets are thrown out of the container. The fuze burns for about 15 seconds and it then sets off the detonator that brings the bomblet to a full detonation. The bomblets usually hit the ground 7 – 10 seconds after impact. If the bomblet has not responded to the impact force, the self-destruct mechanism should detonate a few seconds after impact.

The whole self-destruct mechanism is placed onto a slider that is released due to the centrifugal forces that acts on the bomblet. The slider will normally not be released unless the spin rate exceeds around 30 rps.

The M85 is found in several artillery delivered ammunitions, such as the German DM662[30], the Israeli M396, the Turkish M396 and the British L20A1. It has also been developed for use with the MLRS, but in a modified version as MLRS does not offer a rotation exceeding 10 rps.

The Swiss company RUAG produces a bomblet that looks almost like M85. One exception is the length of the body. While M85 has a stacking length of 56 mm, the length of the Swiss one is 41.6 mm. The other exception is that the rear end of the slider is somewhat narrower. This is supposed to be due to the fact that mortars lack the spin that artillery systems have. Fuzes for non-spinning bomblets need a spring loaded mechanism that can force the slider into an armed position.

Israel has also used a bomblet, which name is not known for certain, but has the same appearance as M85. However, this one does not have the self destruct mechanism, but the bomblet body is exactly the same as M85. It is supposed to be a forerunner to M85. According to an article in Journal of Mine Action in 2006, it has the name of M79[59], but that can not be confirmed.

A comprehensive analysis of the M85 self destruct mechanism is found in [60].

A.3.5 DM1385

This bomblet is identical to the Israeli M85, except some colouring features not affecting the performance. It is contained in the German cargo shell DM662 known to be in the inventory of Norway, Denmark and Finland.

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[30] Called DM1385 when contained in DM662.

Figure A.3 A dud of DM1385

A.3.6 DM1383

The Germans developed an improved fuzed for bomblets, called DM1384, which works along the same principles as that on M85. In this design, developed by Junghans, the whole fuze and self destruct assembly are put inside a steel housing, which is protecting the critical parts against violent mechanical influence. Tests have shown that this design gives less duds, and a lower number of armed duds. This fuze has, as far as it is known, only been used in the 155 mm shells DM642 and DM652. These shells have never been used in combat.

A.3.7 Ogre F1

The bomblet was developed for the French shell also called OGRE F1 that carries 63 bomblets. Their shape deviates from the other DPICM by the slightly bell-shaped casing. It has a self destruct mechanism, but its quality is not known.

Figure A.4 OGRE F1[61]

A.3.8 KB-1 and KB-2

This is a typical DPICM for field-artillery resembling bomblets like M42, M46, M77, M85 and DM1383. It has a diameter of 40 mm and a stacking height of 50 mm. On KB-1, a part of the casing has an outer layer consisting of a few hundred steel spheres with a diameter of 3.5 mm in a polymer matrix. It is delivered by either 155 mm field artillery containing 63 bomblets M65 projectile) or by the special Yugoslavian 262 mm field artillery rocket containing 288 bomblets[62].

KB-2 seems to have the same size as the KB-1, but is void of the belt of spherical fragments around the body. Apparently it is almost like the M42, but is a bit larger in size.

A.3.9 MAT-120

This is a quite advanced DPICM bomblet made for 120 mm mortar bombs. Each bomb contains 21 bomblets. The bomblet has a quite long stand-off promoting the penetration capacity. The special feature with this bomblet is the self destruct and self neutralization mechanism. After firing, each bomblet is supplied with electric energy from the main time-fuze. The ignition system is exclusively electronic which means that there is a good potential for minimizing the number of duds.

A.3.10 MZD-2

This is a Chinese made bomblet believed to be a development of the older Type-81 bomblet. It was used, probably for the first time in war, by the Hezbollah units during the Lebanon conflict in the summer of 2006. The basic shape is as any DPICM, but it is related to the KB-1 bomblet as it has an outer layer of small steel spheres covering most of the body surrounding the explosive. The steel sphere is around 3.5 mm in diameter and their number is between 300 and 350.

A.3.11 GKO and AGAT

GKO (abbreviation unknown) is a Polish version of DPICM. It has a diameter of 38 mm, the same as M42. Compared to M42, the bomblet seems to have about 30 mm longer skirt, giving the shaped charge function a better stand-off and enhanced penetration capability. The stacking height is about 60 mm. The explosive charge is probably somewhat less, in order to adapt to the increased skirt length. The bomblet is adapted to a wide range of cargo ammunition, like 120 mm mortar, field artillery of 122 mm, 152 mm and 155 mm, and to the Polish mortar with 98 mm calibre.

GKO has a kind of self destruct device that looks more advanced than that on M85. Its way of functioning and its reliability are not known.

Slovakia has a DPICM bomblet, called AGAT (see picture below), that has the same diameter, mass and length as GKO. The outside profile is different, indicating a stacking height of around 85 mm. The explosive charge may also be a bit larger than for the GKO. The kind of relation between the two types is not known.

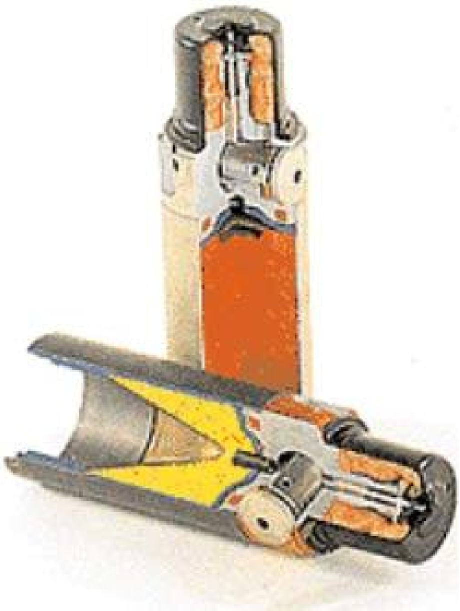


Figure A.5 The AGAT bomblets [63]

A.3.12 M73

M73 is unique among the DPICM due to its size, which is around 60 mm diameter, and due to its mode of usage. M73 is the content of the M261 warhead fired from the Apache Longbow attack helicopter. The M261 is one of several warheads that can be fitted to the Hydra rocket system, which fires rockets with 70 mm calibre from a cluster[31] pod attached to a pylon at both sides of the helicopter body. Each cluster has 19 tubes for rockets.

The M261 warhead for Hydra is reported to have a range of 0.5 to 7.2 km. The range together with the deployment at a helicopter platform means that this is a *direct fire* weapon. It is the only DPICM with this capability. Direct fire in this context means that it is fired to release its content above targets hidden behind obstacles. However, to call this mode of fire direct fire is misleading. The submunition is illustrated in the figure below

[31] Cluster is here used in a different context from the other parts of this report (see sect 5.3).

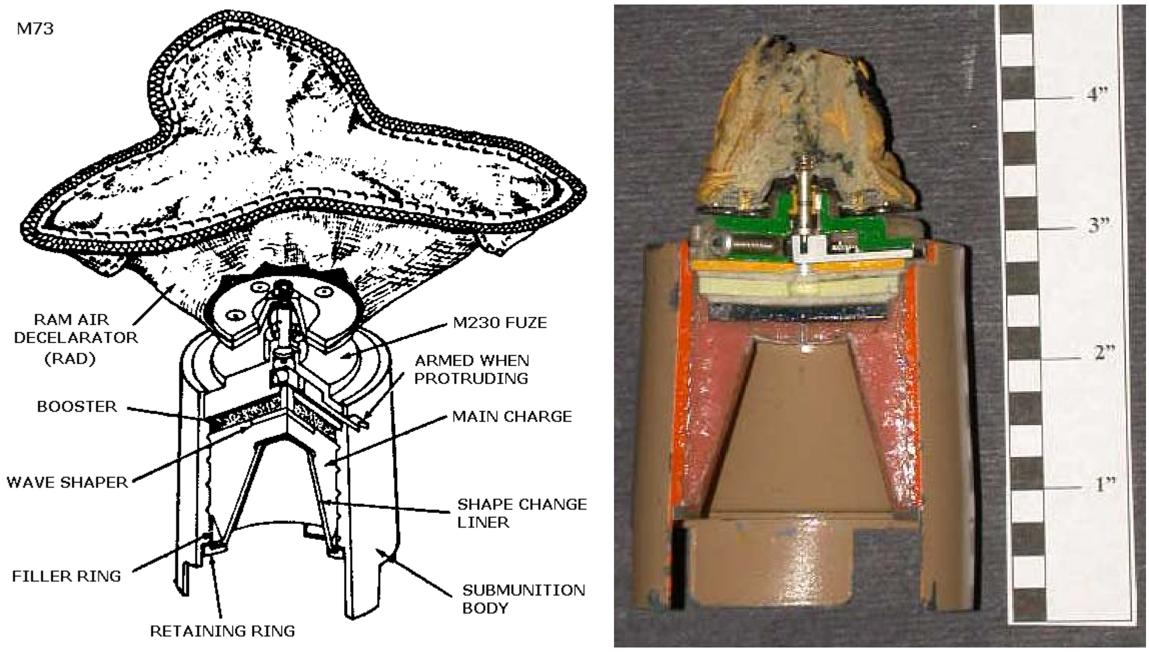


Figure A.5 The M73 bomblet for Hydra [64]

The 9 bomblets are pushed out from the container forwardly. This is also opposite to other DPICM. The bomblets are decelerated and stabilized by a so called Ram Air Decelerator (RAM, as seen on the figure), or by an Air Inlet Decelerator (AID). These devices are often called a balute on other systems. The arming of the bomblets fuze is believed to be activated at push out and the centrifugal forces acting on a slider as on other DPICM. No self destruct mechanism is provided with this bomblet.

The bomblet has a shaped charge of quite modern design. Its penetration capacity is apparently classified, but is assessed as being 150 mm or more. At impact the aluminium body fragmentizes into fragments of around 10 grains each with a velocity of 1500 m/s. At the ground the bomblets impact along a line of 90 m in length along the line of fire.

The dud rate of M73 is not known with any certainty. It seems to have a more advanced fuze than M42 or M77, but details on the reliability are unknown.

A.4 The guava family

This is a family of BLUs and other bomblets that are characterized by the almost spherical shape with fin-like flutes at the surface. They may also give associations to baseballs or tennis-balls. The purpose of the flutes, which may have different designs, is to induce spin that successively arms the bomblet. When pushed into the air stream, the asymmetric shape of the flute will induce a rotational moment around the axis of the safety and arming device inside the bomblet. The table below shows the members of the family. They are all American except for ShOAB-0.5 which is Russian[65].

Bomblet	Diameter	Weight	Expl. weight	Filler	Remark
BLU-26/B	64 mm	435 g	85 g	Comp B	Spherical fragments
BLU-36/B	64 mm	435 g	85 g	Ccom B	Spherical fragments
BLU-41/B	60 mm	500 g	71 g	Comp B	AP mine (unconfirmed)
BLU-42/B	60 mm	500 g	71 g	Comp B	AP mine
BLU-48/B	76 mm(?)				in CBU-68
BLU-54/B	60 mm	500 g	71 g	Comp B	AP mine
BLU-59/B	64 mm	435 g	85 g	Comp B	Spherical fragments
BLU-61/B	89 mm	1200 g	277 g	Octol	
BLU-63/B	76 mm	450 g	113 g	Comp B	
BLU-86/B	76 mm	450 g	113 g	Comp B	
M32	48 mm	204 g	42 g	Comp B	Honest John delivered
M38	43 mm	136 g	27 g	Comp B	
M40	43 mm	136 g	27 g	Comp B	
M74	59 mm	590 g		Comp B	ATACMS delivered
M139	114 mm		500 g	Gas	Obsolete
ShOAB-0.5	60 mm	417 g	71 g	Hexogen	Copy of BLU-54/B 300 ball bearings 5.5 mm

Table A.2 The Guava family

A.4.1 BLU-26, BLU-36 and BLU-59

The special feature with this group is that the casing is made of a light alloy with ball bearings embedded inside. BLU-36 and BLU-59 have a random fuze and are thus area denial munition. BLU-26 has an impact fuze.

A.4.2 BLU-61

BLU-61 is one of the larger members of this family with a diameter of 99 mm (89 mm excluding the winglets) and a weight of 1.23 kg. In addition to 295 g of Comp B, it also contains 52 g of zirconium particles for incendiary purposes. The casing seems to be made of cast steel which upon detonation releases around 150 fragments of 1.5 g each. The usual mean of delivery is the SUU-30B/B with 254 bomblets constituting the system CBU-52/B.

A.4.3 BLU-63 and BLU-86

BLU-63 has a diameter of around 74 mm. BLU-63 is delivered by several cluster bomb systems. When CBU-75/B is applied, 1800 bomblets are contained in SUU-54A/B. In may also be mixed with the similar BLU-86B. The bomblet has an outer thin steel layer and a grooved interior casing creating some 150 fragments of approximately 1 gram each plus a high number of smaller fragments. BLU-86 has a random delay fuze which puts it into the category of area denial munition.

A.4.4 M74

This bomblet was introduced as an improved version of BLU-63 having a pre-engraved tungsten shell instead of the steel shell of BLU-63. The payload of ATACMS Block 1 missile carries no less than 950 bomblets of this type. It has the same size as its predecessor with a diameter of around 74 mm. (59 mm excluding the winglets). Upon detonation it ejects around 250 tungsten fragments with around 0.5 g mass[66].

A.4.5 M139

This is a very old bomblet that once populated the American Honest John chemical cluster warhead. It contained nerve gas, but has been out of service for a long time. This bomblet is probably the same as E130R1 which with a number of 356 constituted one of the payloads of Honest John in the late 1950s. It contained 500 g of Sarin gas.

Figure A.7 The M139 bomblet

A.5 The ring-tail family

This bomblet was developed in the Vietnam era for the purpose of being able to penetrate the jungle canopy and explode on the ground. Thus the bomblet was made quite heavy and with a fuze that needed some force in other to ignite the charge

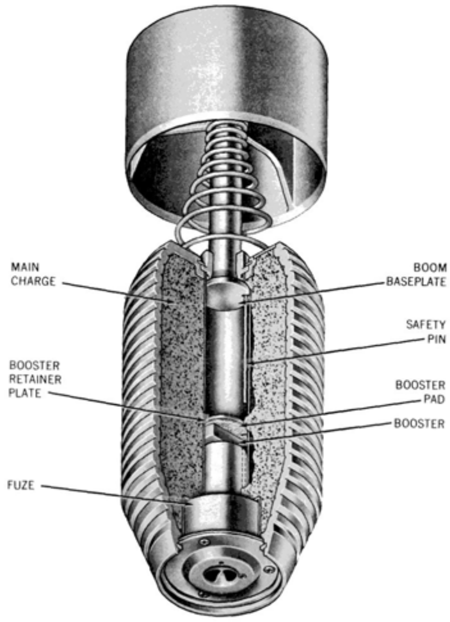


Figure A.8 The BLU-49 bomblet

There are two members of this family, BLU-49 and BLU-84, and some subvariants of these. The design shows some resemblance with the French BLG (Belouga) family, though the latter seems to have been developed at a later stage and are of a far smaller size than the American relative.

A SUU-13 carries 40 or 45 of the BLU-49 bombs. SUU-51 contains 48 of the BLU-84. The release is governed such that the release is evenly distributed over an interval of 1 or 2 seconds. This mode of delivery may give some doubts as to whether this is a cluster weapon or not. It can be claimed that the bomblets are individually fired units, which in principle is the same as for gun fired unitary ammunition.

In stored condition, the bomblet is cylindrical, 257 mm long and 117 mm in diameter. The weight is 6.8 kg and it is filled with 2.02 kg of Comp B. The bomblet is shot vertically out of the SUU-13 canister at a speed of 19 m/s. A mechanical timer arms the bomblet after 2 – 3 seconds. The height of release may vary from 200 to 2000 m above ground.

During the arming of the bomblet, the tail is extended backwards giving the bomblet a total length of 345 mm.

At impact with the ground, the fuze pin is forced into the detonator by its inertia. However, when impacting in water or mud this function may fail. The backup function is based on the entering of fluid into the fuze which presses against the piston that drives the firing pin.

The length of the footprint is determined by the speed of the aircraft. A speed of 500 knot will then give a length of 260 m for a 1 second release time, and twice that value for a 2 seconds release. The width of the footprint may vary from 30 to 140 m depending on aircraft speed and release height.

The corrugated surface of the body ensured a very varied distribution of fragment sizes. The vast majority of the fragments seem to be quite evenly distributed in the mass range from 0.1 to 2 g, roughly covering the angles from 50 to 130 degrees measured from the tip of the bomblet. Their initial velocity is around 1900 m/s.

A.6 The RBK-families

RBK is a Russian acronym for Expendable Cluster Bomb. The concept seems to have been in use since WWII and a large number of different bomblets have been used. There are two main types of these dispensers. One is the RBK-250-275 that can contain a payload of around 100 kg. The other is the RBK-500 with a payload of 250 kg. Some special configurations of these dispensers have also been developed in order to deliver some special types of submunitions.

The Russian Air Force also applies an aircraft dispenser called KMGU, which an acronym for "Universal small size cargo container". This dispenser can deliver approximately the same amounts of submunitions as the RBK-500.

The bomblet types that can be delivered by these containers belong to different families. They are identified by the following acronyms

AO	- Aircraft fragmentation
BetAB	- Concrete aircraft bomb
OAB	- Fragmentation aircraft bomb
OFAB	- Fragmentation and high-explosive aircraft bomb
PTAB	- Anti-tank aircraft bomb
ShOAB	- Spherical fragmentation aircraft bomb
ZAB	- Incendiary fragmentation bomb

The definition AO seems to deviate from the pattern, it seems that OAB are used for more modern developments instead of AO.

These families are actually quite different in performance and design. Some are even not exactly known. The ShOAB bomblet, for which no illustration ever seems to have been published, may be a copy of one of the members of the American guava family, although it can not be stated with certainty.

A.6.1 ПТАБ-2.5М (PTAB-2.5M)

This is a heavy Russian anti-tank bomblet carried by the standard Russian cluster bomb RBK-250-275 and RBK-500. From 30 to 75 bomblets can be carried in a single cluster bomb. The bomblet has a thick casing, thus giving a considerable anti-personnel effect. The warhead is a shaped charge with 0.45 kg of explosives. The performance of the shaped charge is unknown, but its perforation capacity is hampered by the SA-unit placed in the front of the charge. A reasonable guess on performance is around 150 mm of RHA steel. It will also have a substantial fragmentation effect.

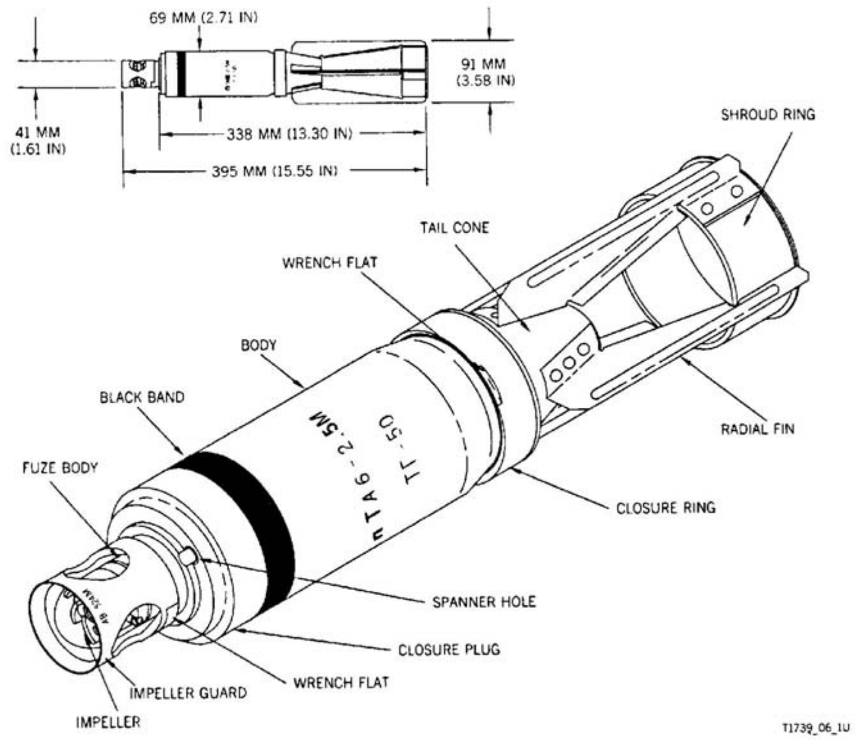


Figure A.9 The PTAB2.5 bomblet [67]

A.6.2 AO-1СЧ (AO-1SCh)

This is a heavy cased cast steel anti-personnel bomblet with 49 mm calibre and a mass of 1.2 kg containing a mixed filling of Amatol and TNT. The number of bomblets carried is 150 for RBK-250-275, and 273 for RBK-500.

Figure A.10 The AO-1SCh bomblet [68]

A.6.3 Bounding bomblets

This type of bomblets deserves special attention due to their special functioning. The bomblets have an odd egg-shaped design, and are composed of two separate hemispherical warheads. The bomblet has 4-5 winglets of variable shape placed on its circumference. This induces spin that is believed to arm the bomblet. Upon impact with the ground the two warheads separate supposedly by a spring system. Each warhead has a delay element which brings it to detonate above ground and with some meters distance between the two halves. Above ground detonation and separation of the two warheads will considerably increase the efficiency of the bomblet.

It seems that this type is found with several designs, but the basic design is the same. In most variants the casing of the warheads seems to be solid but prefragmented steel. The weight of a bomblet seems to be 2.5 kg; its diameter is around 9 cm and the length of the bomblet is around 15 cm.

Figure A.11 The AO2.5RT bomblet; a complete one and a half one. [69]

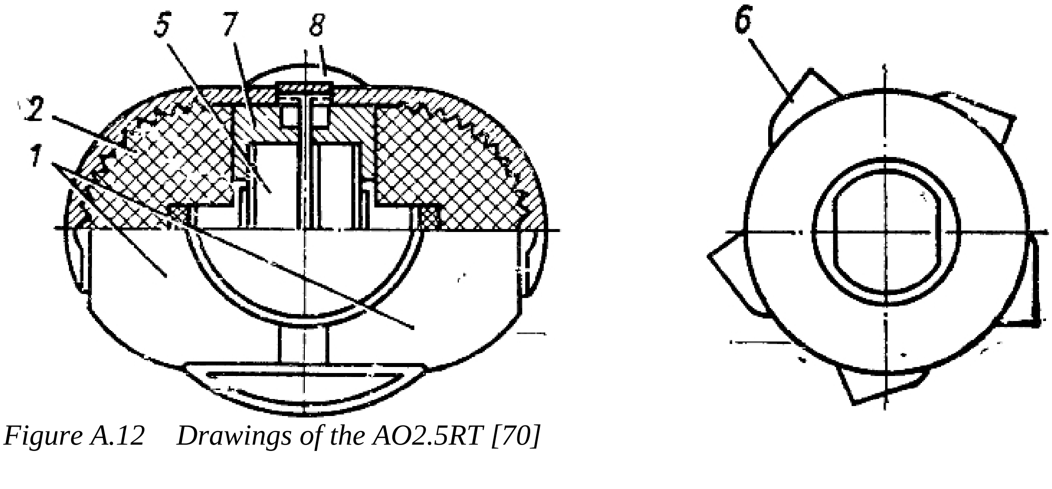


Figure A.12 Drawings of the AO2.5RT [70]

A.7 BL-755

BL-755 was until recently the only operational British air delivered cluster weapon[32]. It is a actually a quite big type of DPICM, with a quite heavy casing, a modern shaped charge with a decent stand-off. It was originally produced with an aerodynamic stabilizer that gave limited

[32] BL-755 is currently not used by Royal Air Force

speed reduction during the fall phase. This model was known as the GP-version. A later version, AAA (Advanced Anti Armour) had a small parachute, with far better braking properties resulting in a hit angle that was closer to the vertical than the previous one. When hitting an armoured target, this property gives a more optimal hit angle against the target resulting in better penetrative capacity.

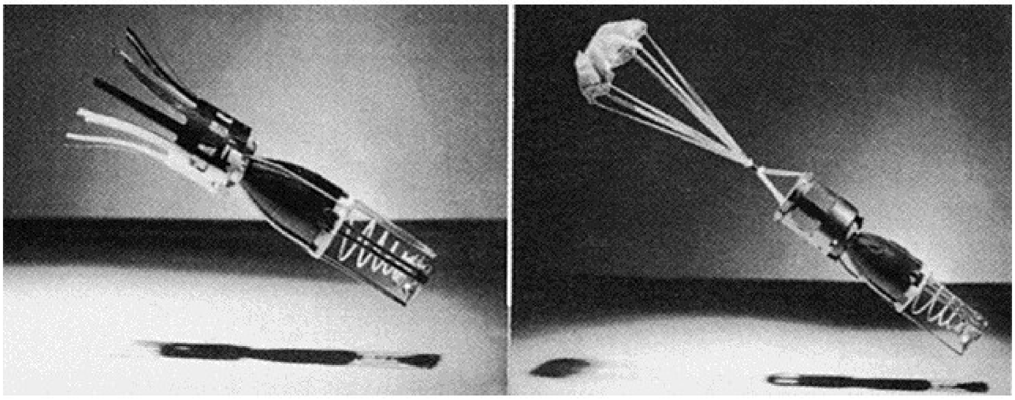


Figure A.13 The two variants of BL-755[71]

A.8 BLU-97

This bomblet iscalled CEM (Combined Effect Munition), alluding to the shaped charge and fragment effects as in a DPICM. It is also the widely known *yellow killer* lately used in Serbia, Iraq and Afghanistan by NATO and US forces. It is acknowledged that this bomblet leaves an especially high number of duds behind. These duds are also known to be quite sensitive due to the quite intricate safety and arming unit. The primary function is an inertia-based impact fuze that requires a certain impact force. A back-up fuze is based on a piezoelectric crystal. This device is a kind of omnidirectional fuze that may function by being loaded from any direction and apparently by an undetermined load.

The figure below show a drawing of BLU-97.

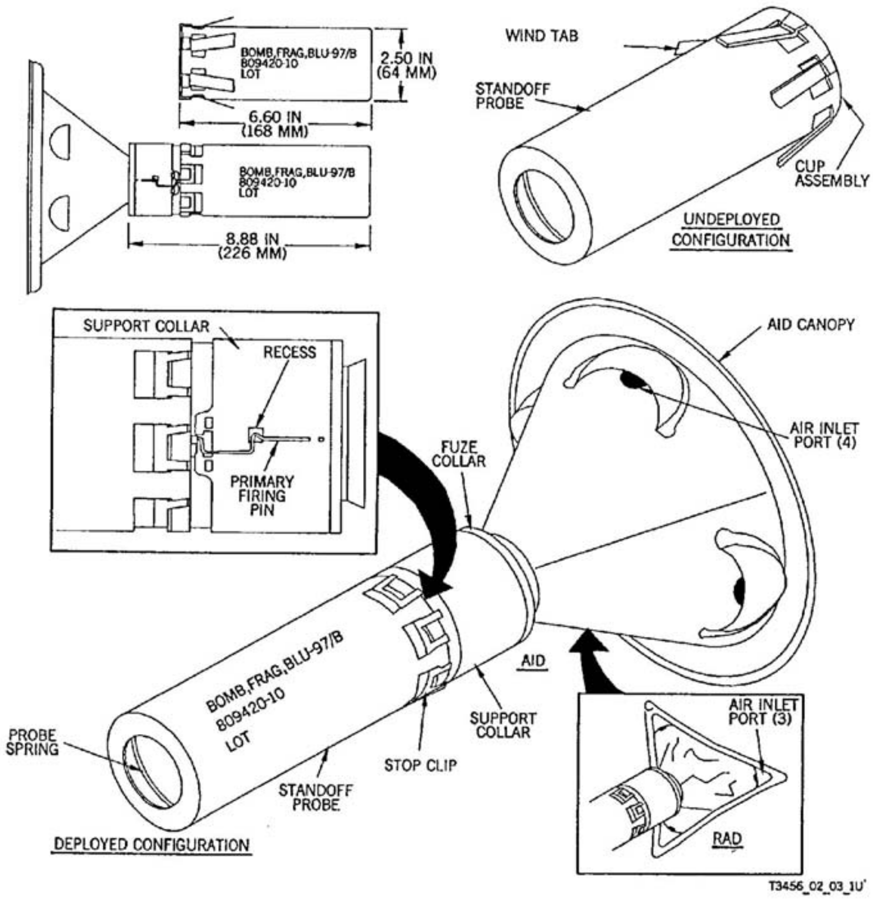


Figure A.14 Drawings of BLU-97 CEM [72]

The picture below shows the AGM-154 when releasing its payload of BLU-97. It carries 145 of these bomblets.

Figure A.15 Release of BLU-97 from AGM-154(JSOW) [73]

A.9 The pineapple family

A.9.1 BLU-3

This is an anti-personnel fragmentation bomblet that was designed in the Vietnam era. It is popularly called the *pineapple*, which is obvious from its shape when then stabilizers are unfolded. It is air-delivered by CBU-2A or CBU-14A, where the container has space for around 400 bomblets. The igniter and SA-unit is placed at the bottom of the bomblet. The explosive is around 200 g of Comp B. The casing is special as it is made of cast aluminium in which 250 hard steel spheres are inserted. The spheres are assumed to get a velocity of around 1300 m/s. They are visible from the outside and the inside of the casing and they have a diameter of 5 mm. This ammunition now seems to be withdrawn from service by the US Armed Forces.

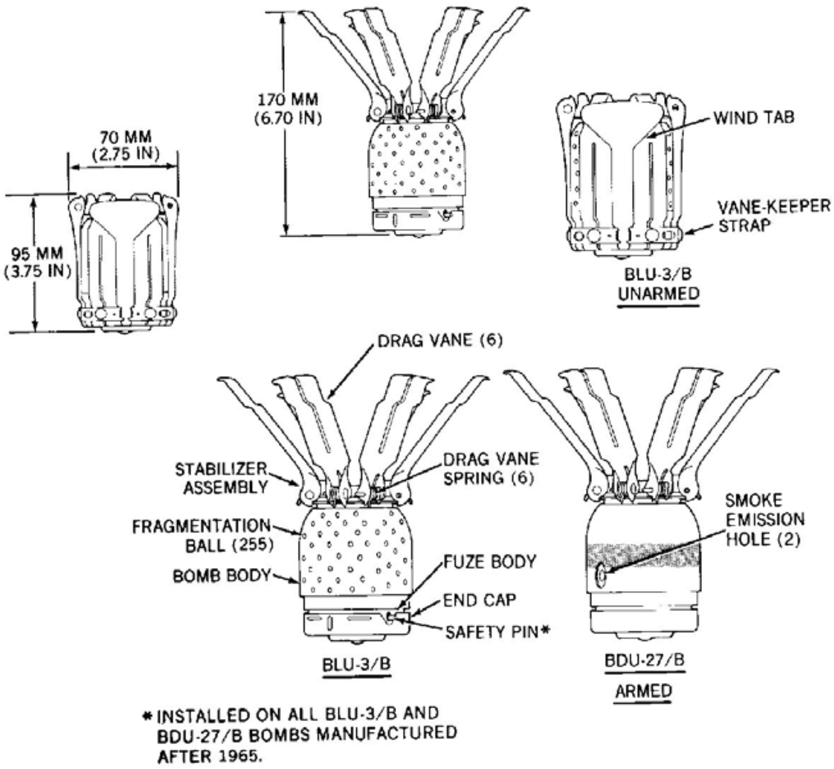


Figure A.16 The BLU-3 bomblet [74]

A.9.2 LBOk-1

Poland has made a replica of the American BLU-3 that seems to be in service with the name LBOk-1. It seems to be produced in two variants – one has the same shape as BLU-3; the other has the same body, but with a somewhat expanded fuze section.

LBOk-1 is found in the air -launched cluster bomb ZK-300 carrying 315 bomblets. Alternatively it can also be dropped from the Soviet made dispenser system KMGU containing 432 bombs in 12 packages with 36 bombs each. Finally it also seems that the cluster bomb called ZR-8 can be used to deliver 8 packages with 13 – 15 bombs inside (see figure below). This system may be the same as LBKas-250 cluster bomb weighing 222 kg and containing 120 bomblets. These bomblets can be distributed over an area of 200 x 1500 m.

Figure A.17 LBOk-1 bomblets with cassette.[75]

A.10 Belouga

Belouga is a French cluster bomb that may contain 3 different variants of the BLG 66 bomblet. The system consists of a streamlined bomb canister, in which there are 151 holes. A bay inside each hole contains a single bomblet. In a single bomb all bomblets seems to be of the same variant. The three variants are:

- BLG 66 AC (Anti Char) – anti-tank
- BLG 66 EG (Emploi Général) – general-purpose
- BLG 66 IZ (Interdiction Zonal) – area denial

All variants have almost the same appearance as shown below. All have a diameter of 66 mm and a weight of around 1.3 kg. They are all stabilized by a parachute. The AC is like an ordinary DPICM with shaped charge and fragment warhead. The IZ and EG variants are quite similar with a prefragmented casing with circular grooves on the outside. The difference is in the fuze section. While EG detonates at impact, the IZ has a random delay element that has a delay of up to several hours, prohibiting forces to occupy the area in that time span.

Figure A.18 The three members of the Belouga suite of bomblets EG (left), AC (middle), IZ (right) [76]

Appendix B Effectiveness calculation of submunitions and alternatives to cluster weapons

This appendix presents the calculations done for the selected types of cluster munitions and for some of the most obvious alternatives to cluster weapons. The physical parameters that are critical for these evaluations are also included.

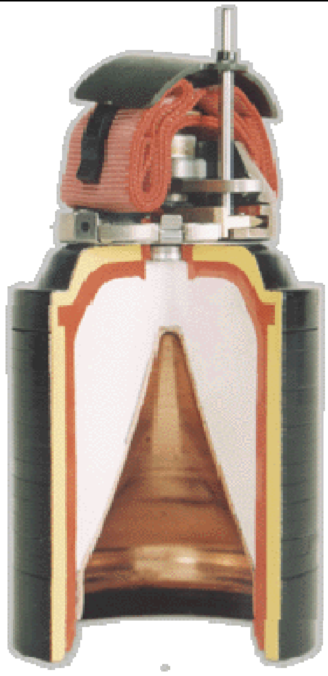
The following items have been subject to the analysis:

Bomblets:
M85
M42
KB-1
M73
Mk118
OAB-2.5
BLU-63
BLU-97
M43

Sensor fuzed warheads:
Skeet (in BLU-108)

Unitary charges:
M107 – 155 mm artillery shell
Mk82 – 500 lbs GP-bomb
Mk84 – 2000 lbs GP-bomb

M85	
Country of origin	Israel
Type	DPICM
Diameter	42 mm
Length	80 mm (56 mm stack)
Weight	292 g
Explosive content	44 g RDX
Delivered by	155 mm FA M396
Number per carrier	49 (in M396)
Dispersion area	Circle 100 m radius / 3 ha
Impact velocity	40 m/s
Angle of impact	85
Casing properties	13 steel rings, prefragmented with about 50 fragments each. 3 mm thickness. Aluminium liner of 2 mm inside.
Number of fragments	700 - 800
Height of detonation	4 cm



Fragment distributions
Most fragments are ejected at an angle of 70 - 95° to the forward axis. Typical fragment mass is 0.2 g with a velocity of 850 m/s. Some fragments of various sizes are ejected from the shoulder and the top of the bomblet.

Armour penetration: Probably 130 mm RHA; officially 105 mm according to IMI.

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	66	16	6/85	9/182
Distance	3m	10 m	30 m	100 m
Fragments per m^2	18	3	1	0
Armour perforations in 3mm steel	1	0	0	0

M42		
Country of origin	US	
Type	DPICM	
Diameter	39 mm	
Length	82 mm	
Weight	213 g	
Explosive content	30 g RDX	
Delivered by	155 mm FA M483A1	
Number per carrier	64 (24 M46 in addition)	
Dispersion area	Circle 100 m radius / 3 ha	
Impact velocity	40 m/s	
Angle of impact	70	
Casing properties	Prefragmented in the inside to give fragment size of ~0.15 grams	
Number of fragments	~	
Height of detonation	3 cm	

Fragment distributions
Most fragments are ejected at an angle of 70 - 95° to the forward axis. Typical fragment velocity is 1000 m/s and the size is 0.15 g. Some fragments of various sizes are ejected from the top of the bomblet.

Armour penetration: 110 mm RHA

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	26	12	6/64	9/148
Distance	3m	10 m	30 m	100 m
Fragments per m^2	18	2	0	0
Armour perforations in 3mm steel	0	0	0	0

KB-1	
Country of origin	Serbia
Type	DPICM
Diameter	38 mm
Length	81 mm (47 mm stack)
Weight	~210 g
Explosive content	~32 g
Delivered by	M63 Orkan
Number per carrier	288
Dispersion area	Circle 100 m radius / 3 ha
Impact velocity	40 m/s
Angle of impact	70
Casing properties	Around 400 ball bearings 3 mm diameter
Number of fragments	400
Height of detonation	4 cm

Fragment distributions: Around 400 spherical fragment of 0.11 grams

Armour penetration 120 mm RHA

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	24	10	4/58	6/96
Distance	3m	10 m	30 m	100 m
Fragments per m^2	30	3	0	0
Armour perforations in 3mm steel	0	0	0	0

M73	
Country of origin	US
Type	DPICM
Diameter	66 mm
Length	~100 mm (stack 61 mm)
Weight	385 g
Explosive content	91 g Comp B
Delivered by	M261 Hydra
Number per carrier	9
Dispersion area	40 m line
Impact velocity	35 m/s
Angle of impact	80
Casing properties	Extruded aluminium
Number of fragments	195 at 0.65 g
Height of detonation	6 cm

Fragment distribution is not known but SPLIT-X™ predicts high velocity fragments of different sizes with initial velocity up to 2000 m/s

Armour penetration: 200 mm RHA

90% casualty at 20 m on prone and exposed soldier

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	55	12	10/138	11/159
Distance	3m	10 m	30 m	100 m
Fragments per m^2	11	2	0	0
Armour perforations in 3mm steel	11	2	0	0

Mk118		
Country of origin	USA	
Type	Anti Tank	
Diameter	53 mm	
Length	331 mm (stack 236 mm)	
Weight	600 g	
Explosive content	176 g Octol	
Delivered by	Mk 20 Rockeye CB	
Number per carrier	247	
Dispersion area	0.48 ha	
Impact velocity	100 m/s	
Angle of impact	75	
Casing properties	Aluminium alloy 2 mm thickness	
Number of fragments		
Height of detonation	12 cm	

Fragment distributions: Around 1000 very small fragment up a few 100 milligrams in mass, mainly thrown out radially at 90 degrees.

Armour penetration: More than 150 mm RHA

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	61	34	11/150	12/184

Distance	3m	10 m	30 m	100 m
Fragments per m^2	94	4	0	0
Armour perforations in 3mm steel	7	0	0	0

BLU-97 CEM	
Country of origin	USA
Type	DPICM
Diameter	64 mm
Length	169 mm 356 mm after ejection
Weight	1.4 kg
Explosive content	287 g 70/30 Comp B
Delivered by	CBU-87 and CBU103 cluster bombs and other planned systems
Number per carrier	202 in CBU-87/B 202 in CBU-103/B 145 in JSOW
Dispersion area	0.3 ha from CBU
Impact velocity	35 m/s
Angle of impact	60
Casing properties	Prefragmented
Number of fragments	
Height of detonation	18 cm

Fragment distributions: Prefragmented casing. Good special distribution of fragments due to the ogive shaped casing.

Armour penetration: Probably 300 mm RHA

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	125	84	28/377	25/399
Distance	3m	10 m	30 m	100 m
Fragments per m^2	18	1	0	0
Armour perforations in 3mm steel	0	0	0	0

OAB-2.5	
Country of origin	Russia (USSR)
Type	APAM
Diameter	90 mm
Length	150 mm
Weight	2.5 kg (1.1 kg per warhead)
Explosive content	~250 g
Delivered by	RBK-500 CB
Number per carrier	108 (216 warheads)
Dispersion area	0.64 ha
Velocity at detonation	0 m/s
Angle at detonation	Random
Casing properties	Prefragmented steel 6 mm thickness
Number of fragments	~100 typically 5 g each
Height of detonation	1 m

Fragment distributions. A few hundred fragment maninly in the range 0.1 to 1 g thrown out I all directions.

Calculated effects of fragments

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	71	133	29/135	26/107
Distance	3m	10 m	30 m	100 m
Fragments per m^2	6	1	0	0
Armour perforations in 3mm steel	6	1	0	0

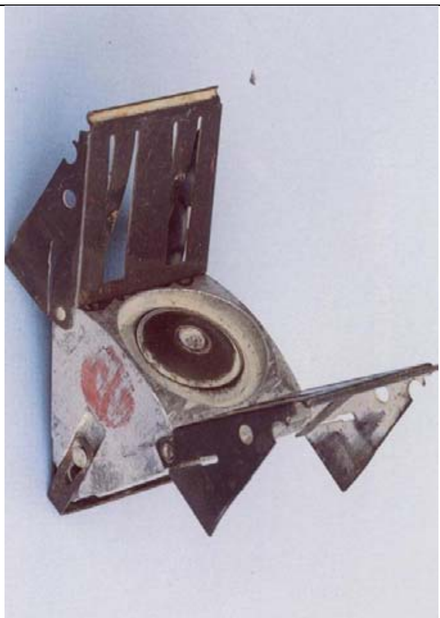
These number are valid for one to the two halves of the warhead.

BLU-63	
Country of origin	USA
Type	AP
Diameter	75 mm
Weight	450 g
Explosive content	113 g Comp B
Delivered by	CBU-58, CBU-75, CBU-77
Number per carrier	650 in CBU-58(B 1420 in CBU-75A/B 1800 in CBU-75/B 790 in CBU-77/B
Dispersion area	1.2 ha
Impact velocity	100 m/s
Angle of impact	n/a
Casing properties	Prefragmented 3 mm steel
Number of fragments	200 typically 1 g each
Height of detonation	3 cm

Fragment distributions: 100 – 150 fragments mainly 0.5 – 1 g thrown out in all direction

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	29	19	20/124	16/98
Distance	3m	10 m	30 m	100 m
Fragments per m^2	5	1	0	0
Armour perforations in 3mm steel	5	1	0	0

M43		
Country of origin	USA	
Type	AP	
Diameter of warhead	36 mm	
Weight	90 g RDX	
Explosive content	25 g	
Delivered by	M449 155 mm FA	
Number per carrier	60	
Dispersion area	2 ha	
Velocity at detonation	0 m/s	
Angle of impact	n/a	
Casing properties	Prefragmented 2.5 mm thickness	
Number of fragments	600 at 0.1 g	
Height of detonation	1.5 m	

Fragment distributions
Narrow distribution of about 600 small steel fragments that are quite uniformly distributed in all directions.

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	11	11	15/29	38/47
Distance	3m	10 m	30 m	100 m
Fragments per m^2	15	1	0	0
Armour perforations in 3mm steel	0	0	0	0

Skeet (on BLU-108)	
Country of origin	USA
Type	SFW
Diameter	127 mm
Length	105 mm
Weight	3.4 kg
Explosive content	945 g Octol
Delivered by	CBU-97
Number per carrier	40
Search area	0.5 ha per Skeet 12 ha for the whole CBU
Descent velocity	30 m/s
Angle of impact	60
Casing properties	5 mm forged steel
Number of fragments	1 big and 16 smaller fragments vertically Natural fragmentation horizontally
Height of detonation	50 m

Calculated effects of fragments (excl. main penetrator)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	3	3	97/288	85/266
Distance	3m	10 m	30 m	100 m
Fragments per m^2	84	6	1	0
Armour perforations in 3mm steel	29	1	0	0

M107	
Country of origin	USA
Type	AP
Diameter	155 mm
Length	700 mm
Weight	43 kg
Explosive content	6.6 kg TNT
Delivered by	155 mm Howitzer
Number per carrier	-
Dispersion area	-
Impact velocity	350 m/s
Angle of impact	60
Casing properties	Forged steel
Number of fragments	5000
Height of detonation	35 cm

Fragment distribution: around 6000 fragment of very varied sizes thrown out in all directions, but mainly between 60 and 110 degrees from the nose.

Calculated effects of fragments

Values when point detonation fuze is fitted

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	525	962	197	166
Distance	3m	10 m	30 m	100 m
Fragments per m^2	244	19	2	0
Armour perforations in 3mm steel	112	8	0	0

Values when proximity fuze is fitted (7 m detonation height)

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	856	1123	197	166
Distance	3m	10 m	30 m	100 m
Fragments per m^2	0	14	1	0
Armour perforations in 3mm steel	0	6	0	0

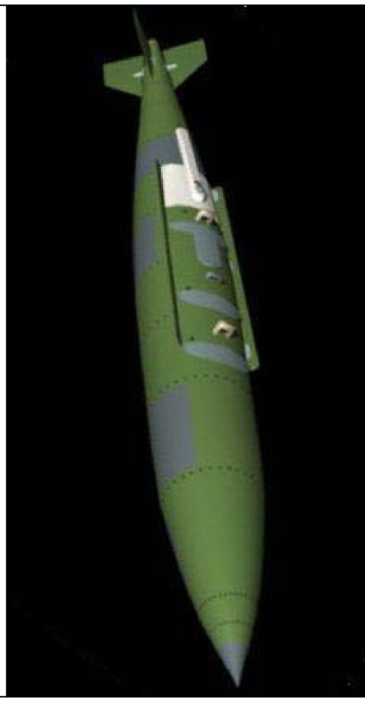
Mk82	
Country of origin	USA
Type	GP
Diameter	273 mm
Length	2.21 m
Weight	241 kg
Explosive content	89 kg H-6
Delivered by	Bomber aircraft
Number per carrier	-
Dispersion area	-
Impact velocity	300 m/s
Angle of impact	60
Casing properties	Forged steel
Number of fragments	20000
Height of detonation	1.1 cm

Fragment distribution: around 20000 fragment of all sizes and ejected in all directions, but mainly between 75 and 115 degrees from the nose.

Calculated effects of fragments

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	1483	3213	1154	991
Distance	3m	10 m	30 m	100 m
Fragments per m^2	618	40	4	0
Armour perforations in 3mm steel	474	26	2	0

Air burst will give 50% better performance against prone soldiers

Mk84		
Country of origin	USA	
Type	AP	
Diameter	460 mm	
Length	3.84 m	
Weight	894 kg	
Explosive content	428 kg H-6	
Delivered by	Bomber aircraft	
Number per carrier	-	
Dispersion area	-	
Impact velocity	300 m/s	
Angle of impact	60	
Casing properties	Forged steel	
Number of fragments	50000	
Height of detonation	1.9 cm	

Fragment distribution: around 50000 fragment of all sizes and ejected in all directions, but mainly between 75 and 115 degrees from the nose.

Calculated effects of fragments

Lethal area (m^2)	Prone soldier	Standing soldier	Standing civilian	Child (40 kg)
	3098	5863	2871	2450
Distance	3m	10 m	30 m	100 m
Fragments per m^2	1424	95	9	1
Armour perforations in 3mm steel	1158	65	5	0

Air burst will give 50% better performance against prone soldiers

Appendix C Table of bomblets

The tables below are compiled from a wide variety of sources. The lists focus on the bomblets, not on the delivery systems.

C.1 Belgium

Bomblet	Type	No. of bomblets	System type	System
28SM 20AMV	AP DPICM	5 36	Rocket	68 mm
FZ100 FZ101	DPICM DPICM	9 9	Rocket	70 mm
FZ122F FZ149amv	DPICM AT	2200 36	Rocket	2.75”
H258 H259 H278 H279		8/12/22	Rocket	Type 68
n/a	DPICM	12	Mortar	M514A1

C.2 Brazil

Bomblet	Type	System type	System
AVIBRAS	DPICM	Rocket	AVIBRAS

C.3 Chile

Bomblet	Type	No of bomblets	System type	System	Weight (kg)	Explosive (kg)	Remarks
PM 1	APAM	50 240 240	CB	CB-130 CB-250 K CB-500	0.8	0.25	Improved version of US Mk118 8 g Zr
PM 2	DPICM	400 431	CB	CB-500 K CB-500 K2	0.79	0.15	100 g Zr pellets
PM 3	AP/Inc	121	CB	CB-770	2.2	0.59 (RDX)	14 g Inc
WASP	AT	130 240	CB	WB-250-F WB-500-F	0.7	0.13	Variant of Mk118

C.4 China

Bomblet	Type	No. of bomblets	System type	System	Remarks
MZD-2	DPICM	39	122 mm rocket	BM-21	
Type 1.2 kg	DPICM				
Type 2.5 kg	AP				
Type 81	DPICM	16 18 30 35 39 63 72	107 mm rocket 120 mm mortar 122 mm FA 130 mm FA 122 mm rocket 152 mm FA 155 mm FA	Type-63 Type-83 Type-59 Type-81/90A Type-62/66	Possibly equal to MZD-2 Diameter 39 mm. Mass 214 g. 29.5 g RDX
Type 84	AP	42		Type-2	
Type 90	DPICM	16 43			
Unk	DPICM	100	203 mm FA		

		320 466	273 mm rocket 320 mm rocket	WM-80 WS-1B	
Unk		189	CB 340 kg		
Unk	AR	12			
Unk	AT	26		Type-2	
Unk	APAM	28		Type-2	

C.5 Czech Republic

Bomblet	Type	No. of bomblets	System type	System	Remarks
AGAT	DPICM	56	Rocket		
LBO	AP	60 120 315	CB		
152-EEK	ECM	44	152 mm FA	ICM EEK	

C.6 Egypt

Bomblet	Type	No. of bomblets	System type	System	Remarks
M-42D	DPICM	72 98 28 15	122 mm AR 122 mm AR 130 mm FA 122 mm FA	Sakr- 18/Sakr-45 Sakr-36	

C.7 France

Bomblet	Type	No. of bomblets	System type	System	Remarks
74 HEAT	AT		disp	Alkan	
BM400	AP	3	disp	BM400	
BONUS	SFW	2	155 mm FA		French/Swedish project
ACED	SFW	2	120 mm mortar	ACED	
GR 66 AC	AT	151	CB	Belouga	

GR 66 EG	AP	151	CB	Belouga	
GR 66 IZ	AP/AD	151	CB	Belouga	
KRISS	AR	10	CB	Apache	52 kg per SM, RDK filling
MAC 50	AP	50 96	Disp		
NR269B1	DPICM	56	Disp		
OGREF1	DPICM	63	155 mm FA	OGRE	
TDA	AT			Alkan	
Type 314	AP			Alkan	

C.8 Germany

Bomblet	Type	No. of bomblets	System type	System	Remarks
BIE	Inc	17	disp		
DM1383	DPICM	63 49	DM642 DM652	155 mm FA	With SD
DM1385	DPICM	63 49	DM632 DM662	155 mm FA	Same design as Israeli M85 w/SD
DM1348	DPICM	63	DM612	155 mm FA	Same design as Israeli Bantam
KB-44	DPICM	4704	disp	MW-1/DWS-24/39	
MIFF	AT	672	disp	MW-1	
MUSA	AP	672	disp	MW-1/DWS-24/39	
MUSPA	AR	672	disp	MW-1/DWS-24/39	
SD1	AP	50 224 392	disp		
SD10A	AP	17	disp		
SD10C	AP	28	disp		
SD15	AP	28	disp		
SD2	AP	23 108	disp		
SD9	AT	28	disp		

SD3	SPICM	40 74	disp		
SD4	AT	40 74	disp		
B2EZ	Inc	17	disp		
STABO	AR	224	disp	MW-1/DWS-24/39	
DM1489	SFW	2	155 mm FA	DM702	
DM1489A3	SFW	2	155 mm FA	DM702A1	

C.9 Greece

Bomblet	Type	No. of bomblets	System type	System	Remarks
M20G	DPICM	20	107 mm mortar		
M24G	DPICM	24	105 mm FA	24G	
M49	DPICM	49	155 mm FA	M49	

C.10 Iraq

Bomblet	Type	No. of bomblets	System type	System
KB-1	DPICM	~750	AR	Al Fat'h

C.11 Israel

Israel has a wide suite artillery cargo-ammunition. The Lebanon war in 2006 showed that they used ammunition both with and witout a self-destruct mechanism. It seems that some ammunitions are available in both options, but that there are no differences in designation between them.

Bomblet	Bomblet type	No. of bomblets	Warhead	Design name	System	Weight (kg)	Diameter	Expl. weight (kg)	Remarks
APAM	APAM	6 6	M337 M329		105 mm tank 120 mm tank	~0,6 ~0.9?	~90 mm ~105 mm	~0,3 ~0.4	
M42/M46	DPICM	88	M483A1		155 FA		39 mm		US origin

M42/M46 SDF	DPICM	88		CL3677	155 mm FA		39 mm		
M77	DPICM	644	M26		MLRS		39 mm		US origin
M79?	DPICM	49 120	 M373	CL3013-C CL3046	155 mm FA 203 mm FA		42 mm		M79 notation cannot be confirmed
M85 CL3022	DPICM	15 24 24 49 56 63 49 49 81 120	M116 M335 M347 M350 M351 M395 M396 M397 M366 M373	CL3131 CL3153 CL3115 CL3150 CL3162 CL3109 CL3013-G-A2 CL3013-U-A2 CL3014 CL3046-A1	105 mm FA 122 mm FA 130 mm FA 152 mm FA 152 mm FA 155 mm FA 155 mm FA 155 mm FA 175 mm FA 203 mm FA		42 mm	44 g	105 mm is for export only
M85 mod	DPICM	404 104 770	M30 LAR-160 MAR-350		MLRS 160 mm rocket 350 mm rocket		42 mm	44 g	Uncorfirmed
M87	DPICM	20 24/32	M970 M971	 CL3144	120 mm mortar 120 mm mortar		42 mm	44 g	
Hornet-5	DPICM	42	M116		105 mm FA	0.155	31 mm	17.5 g	Export only
M89	DPICM - Inert	18	M408	CL3240	155 mm FA		42 mm		Training only
BLU-63	AP	650	SUU-30	CBU-58	Air delivered		76 mm		US origin
TAL1		250?		TAL1		0.5			
TAL2		315?		TAL2		0.4			
RAM	AR	dozens		RAM					

C.12 Italy

Bomblet	Type	No. of bomblets	System type	System	Remarks
M42	DPICM	77	122 mm rocket	APAMB	
Unk		9	81 mm mortar	RS6A2 S6A2	
Unk		12	120 mm mortar	S12B	

C.13 Poland

Bomblet	Type	No. of bomblets	System type	System
GKO	DPICM	12 20 35? 80? 80? 42	Mortar 98 Mortar 120 FA 122 FA 152 FA 155 122 mm rocket	 Hesyt-1
LBOk-1	AP	60 120 315 432	CB	? LBKas-250 ZK-300 KMGU
LBPPO-1	DPICM	60		
LBZ TE 1	AP	60 120		
Meteor	SFW			

C.14 Romania

Bomblet	Type	Carrier	Remarks
GAA-011	DPICM	CG-540 CG-540-ER	Same as Israeli M85
BAAT-10	AT	CL-250	Same as RBK-250
BF-10T	AP	CL-250	Same as RBK-250

C.15 Russia

Russia and former USSR designate their military equipment by the GRAU-index. This index basically consists of a number, some letters, and another number. The first number identifies the type of item, which is 9 for explosive charges, the letter code identifies the subtype, while the final number is a kind of chronological index. For many item this index is not always known, and it seems that bomblets often do not have a proper name or carry the same name as the container they populate.

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
AO-1SCh	AP	150 273	CB CB	RBK-250-275 RBK-500?	1.2	0.20	Amatol/TNT	4800 m2
AO-10	AP	25 66 100						
AO-10-6.5	AP	11						
AO-2.5	APAM	42 96	AACD AACD	KMGU KMGU	2.88	0.50	TNT	
AO-2.5 RTM	APAM	108	CB	RBK-500U	2.5			6400 m2

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
		60		RBK-250-275				
AO-8 M2	AP							
AO-8 M4								
AO-8 M6								
AO-Kh 8	AP/Chem				8.0			
AO-Kh 10	AP/Chem	25 66 100			9.8			
AO-Kh 15	AP/Chem	13 40			15			
AO-Kh 25					23.6			
BetAB	AR/AB	12	CB	RBK-500	25			
BetAB M	AR/AB	10	CB	RBK-500U				
OAB-2.5RT	AP	126	CB	RBK-500U	2.5			Double bomblet warhead
ODS-OD	Inc	8	ACD	KMGU	36	10		FAE
OFAB-2.5	AP	126	CB	RBK-500U				
OFAB-50UD	APAM	10	CB	RBK-500U	50			
PLAB-10K	ASub	6	CB	RBK-100				
Prosab	APAM	90	CB	Prosab-250		0.127		
PTAB-1M	AT	75 248 268 352	CB AACD CB CB	 KMGU RBK-500 RBK-500U	0.94			

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
PTAB-1.5BD	AT	30						
PTAB-1.5M	AT	30						
PTAB-1.5PIBD	AT	30						
PTAB-2.5	AT	30 75 98	CB CB AACD	RBK-250 RBK-500 KMGU	2.5	0.66	RDX/TNT	
PTAB-2.5 KO	APAM	96						
PTAB-2.5M	APAM	30 268	CB CB	RBK-250-275 RBK-500	2.5	0.45	RDX/TNT	
RAP-2.5			CB	RBK-500	2.5			
RAP-3.5			CB	RBK-500	3.5			
RAP-16			CB	RBK-500	16			
ShOAB-0.5	AP	565	CB	RBK-500	0.5			300 x 400 m
ZAB-1E	Inc	116 260 580	CB		1.5			
ZAB-2.5	Inc	30 116 297 580		RBK-250 RBK-500	2.7	1.72		
ZAB-2.5SM	Inc	48 117	CB CB	RBK-250 RBK-500				
ZAB-2.5T	Inc	30 116						

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
		260 580						
n/a	DPICM	45	122 mm MRL	9N218K1/9M27K1 9M218				
9N210	APAM	30	220 m MRL	9M27K	1.85	0.3		SD?
9N230	Chem							
9N235	ICM	72	300 mm MRL	9N139/ 9M55K/9M525	1.75	0.312		SD?
Motiv/SPBE	SFW	15 14	CB CB	RBK-500U RBK-SPBE	15.6	4.5		
Motiv3M/SPBE-D	SFW	5	300 mm MRL	9N152/SPBE-D 9M55K1	14.9	4.5		
SPBE-D	SFW	15	CB	RBK-500 SPBE-D				
Universal SM	SFW	20 5 2	300 mm MRL 220 mm MRL 122 mm MRL	9M55K2 9M27K5 9M22M/9M217				
unk	DPICM	646	300 mm MRL	9N176/9M55K5 /9M531	0.24			SD
Unk	APAM	10		Iskander/SS-21				
Unk	DPICM	8 24 35	152 mm FA 203 mm FA 120 mm mortar	3VO13 3VO14	1.4	0.23		
9N22(?)	DPICM	42	152 mm FA	3VO23/3VO28/ 3VO30	0.35	0.042		

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
	SFW	2	155 mm FA	NIMI				

C.16 Serbia

Bomblet	Type	No. of bomblets	System type	System	Weight	Explosive weight	Filler	Remarks
BL 755 N1	DPICM	147						
KB-1	DPICM	40 288	Rocket 262 mm rock	M77 Oganj M87 Orkan				
KB-2	DPICM	63 288	 262 rock					
KB-44	AT	4536	AACD					
KB-2 FUM	DPICM/Smk	63 288	 262 mm rock					
PETAB-1.5 HC	AT	54	CB	KPT-150				
PETAV-2.5 HC	AT							
RAB-2.5	AP	44	CB	KPT-150				
RAB-3.5	AP	34	CB	KPT-150				
RAB-16	AP	8	CB					
ZAB-45	Inc							
Nk		420	262 mm rok	M87 Orkan RAB 120				

C.17 Singapore

Unk	DPICM	25	120 mm mortar

C.18 Slovakia

Bomblet	Type	No. of bomblets	System type	System	Remarks
unk	DPICM	42	152 mm FA	Trnovik (3O23)	
AGAT	DPICM	50 63	122 mm rocket 152 mm FA(?)		Related to the Polish GKO
AGAT	Inc	6	122 mm rocket		Used together with the DPICM version
unk	AR	1-9	CB	FOBOS	

C.19 South-Africa

Bomblet	Type	No. of bomblets	System type	System	Remarks
Alpha	Ap	40	CN	CB470	
M46	DPICM	56 42	155 mm FA	NR-269 M2001	

C.20 South-Korea

Bomblet	Type	No. of bomblets	System type	System
unk	DPICM	49	155 mm FA	KA-310

C.21 Spain

Bomblet	Type	No of bomblets	System type	System	Remarks
ESPIN	DPICM	21	120 mm mortar		
MAT 120	DPICM	21	120 mm mortar	MAT-120	37 mm dia., 275 g SD/SN-mechanism
ABL-250	APAM	250		ABL-250	
CH	AT	180		BME 330 C	
CP	AP	180		BME 330 C	
MAC-2	AT	516		BME 330 AT	
SAC 1	APAM	512		BME 330 AT	
SAP	AR			BME 330 AR	
SNA	AR	180		BME 330 AR C	
GCC	AT	28		Teruel	
GCP	AP	42		Teruel	
n/a	SMK	14		Teruel	
MAC-2	AT	516			

C.22 Sweden

Bomblet	Type	No. og bomblets	System type	System
MJ-1	AT	72?	CB	BK-90
MJ-2	AP	72?	CB	BK-90
BONUS	SFW	2	155 mm FA	BONUS

C.23 Switzerland

Bomblet	Type	Bomblets per container	System type	System	Remarks
BE-M2	SMK	4	FA 155	SEN-155	
M85	DPICM	63 49	FA 155	KaG-88 KaG-90	Like the Israeli M85
M85 mod	DPICM	84	FA 155	KaG-88/98	
	DPICM	32	Mortar 120	MP-98	Short version of M85 /M85 mod

C.24 Turkey

Bomblet	Type	Bomblets per container	System type	System	Remarks
unk	DPICM	50	122 mm AR	TRK-122	280 g / 75 g RDX
unk	Inc	6	122 mm AR	TRK-122	Combined with above
M85	DPICM	16 49	120 mm mort 155 mm FA	MOD258 M396	Israeli M85

C.25 UK

Bomblet	Type	Bomblets per container	System	System type	Weight (kg)	Remarks
BL755 GP/Mk1	APAM	147	BL-755 RBL-755	CB		
BL755 AAA/Mk2	APAM	147	BL-755 RBL-755	CB		
Mk1 – Mk5	Inc					
Mk10	Inc					
M85	DPICM	49	L20A1	155 mm FA		
SG 357	AR	30	JP-233	AACD	26	
HB876	ADW	215	JP-233	AACD	2.4	Defined as a

Bomblet	Type	Bomblets per container	System	System type	Weight (kg)	Remarks
						mine

C.26 USA

This contains item that are, or has been, in service by US Armed Forces. The list is very extensive, and a few of the items are void of any information except for the name. The reason is believed to be high classification or that the ammunition has been deployed in limited number, or not even reached beyond the stage of development.

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
BAT	AAT	13	M39A3	ATACMS					
BLU-3/B	AP	360 409 5328	CBU-2/A CBU-2B/A CBU-14/A CBU-14A/A n/a	AACD	SUU-7/A SUU-14/A SUU-14A/A SUU-24/A	0.79	0.16	RDX	250 steel pellets
BLU-4A/B BLU-4/B	AP	509	CBU-1/A	AACD	SUU-7/A	0.54	0.08	RDX	Bounding WH
BLU-6/B	SMK								
BLU-7A/B	AP/AM	352 352 371	CBU-3/A CBU-3A/A CBU-3B/A	CB	SUU-10/A SUU-10A/A SUU-10B/A	0.60	0.272	Comp B	
BLU-16/B	SMK	261	CBU-11/A CBU-13/A	AACD	SUU-7B/A				CBU-13/a has a mix of BLU-16/B and BLU-17/B
BLU-17/B	SMK/Inc	213 261 72	CBU-12/A CBU-12A/A CBU-13/A CBU-22/A CBU-22A/A	AACD	SUU-7B/A SUU-7C/A SUU-7B/A SUU-14/A SUU-14A/A	1.05’			Same as above

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
BLU-18/B	AP	1200	CBU-7/A CBU-7A/A CBU-7B/A CBU-7C/A	AACD	SUU-13/A SUU-13A/A SUU-13B/A SUU-13C/A	0.19	0.021	RDX	Bounding WH 40 tubes vertical ejection
BLU-19/B B23	Chem		CBU-15/A	AACD	SUU-13/A			Sarin	
BLU-20/B B23	Chem	40	CBU-16/A CBU-16A/A	AACD	SUU-13/A SUU-13A/A			BZ	
BLU-21/B B45	Chem(s)							Bio	
BLU-22/B B45	Chem(l)							Bio	
BLU-24/B BLU-24B/B BLU-24C/B	AP	132 132 640 264	CBU-25/B CBU-25A/A CBU-46/A CBU-60/A	AACD	SUU-14/A SUU-14A/A	0.726	0.119	Comp B	
BLU-25/B			CBU-18/A	AACD	SUU-13A/A				
BLU-26/B	AP	 665 665 12744	CBU-23/B CBU-24/B CBU-24A/B CBU-24B/B CBU-24C/B n/a	AACD	SUU-31/B SUU-30/B SUU-30A/B SUU-30B/B SUU-30C/B SUU-24/A	0.54	0.085	Comp B	Internal pod 600 steel fragm.
BLU-36/B	AP	665 670	CBU-24/B CBU-24A/B CBU-24B/B CBU-24C/B CBU-29/B CBU-29A/B CBU-29B/B CBU-29C/B	CB	SUU-30/B SUU-30A/B SUU-30B/B SUU-30C/B SUU-30/B SUU-30A/B SUU-30B/B SUU-30C/B	0.435	0.0085	Comp B	 Half with random delay < 30 min
BLU-38/B									
BLU-39/B	Chem	528 1280	CBU-19/A CBU-30/A	CB	 SUU-13/A	0.057		CS	

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
BLU-40/B	AP					0.77			Random delay
BLU-41/B	AP					0.500	0.071	Comp B	unconfirmed
BLU-48/B	AP	 247	CBU-43/A CBU-68/B	CB	SUU-37/A SUU-30/B				
BLU-49/B BLU-49A/B BLU-49B/B	AP/AM	40 45	CBU-38/A CBU-38A/A CBU-38B/A CBU-38C/A CBU-81/A	AACD	SUU-13/A SUU-13B/A SUU-13C/A unkn	6.4	2.1	Comp B	
BLU-50/B								BZ	
BLU-53/B	Inc	18	CBU-41/B		SUU-51/B	9.0		Napalm-B	
BLU-59/B	AP	670	CBU-49/B CBU-49A/B CBU-49B/B CBU-49C/B	CB	SUU-30/B SUU-30A/B SUU-30B/B SUU-30C/B	0.435	0.085	Comp B	
BLU-60/B	AP	40	CBU-50/A	AACD	SUU-13/A	5.9 kg			
BLU-61A/B	AP/Inc	220 290	CBU-52A/B CBU-52B/B CBU-76/B	CB	SUU-30B/B SUU-30B/B SUU-30H/B	1.2	0.277	Octol	Zirkonium pellets
BLU-62/B	AP/AM					0.43		Comp B	Bounding WH
BLU-63A/B BLU-63/B	AP/Inc AP	650 1800 1420 790 825	CBU-58/B CBU-58A/B CBU-75/B CBU-75A/B CBU-77/B Lance	CB Art. rocket	SUU-30A/B SUU-54A/B SUU-51B/B M251	0.45	0.127 0.118	Comp B	Titanium pellets
BLU-66/B BLU-66A/B BLU-66B/B	AP/Inc AP AP	640	CBU-46/A CBU-46A/A CBU-46B/A	AACD	SUU-7C/A	0.726	0.119	Comp B	Backward ejection
BLU-67/B	AR	40	CBU-51/A	AACD	SUU-13/A	5.0			
BLU-68/B	AP/AM	620	CBU-54/B		SUU-30B/B	0.42			Titanium pellets

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
BLU-69/B	AP/AM	132	CBU-57/A	CB	SUU-14A/A	0.73			
BLU-70/B	AP/AM	670	CBU-54/B		SUU-30B/B	0.40			OOS
BLU-73/B	FAE	3	CBU-55/B CBU-55A/B CBU-72/B	CB	SUU-49/B SUU-49A/B SUU-49A/B	59		FAE	
BLU-77/B	APAM	717	CBU-59/B	CB	Mk7 Mod 3	0.46	0.057	RDX	Rockeye II
BLU-85/B	AT	79	CBU-70/B	CB	SUU-30/B	2.6	0.59	RDX	OOS
BLU-86A/B BLU-86/B	AP/Inc AP	650 650 355	CBU-71/B CBU-71A/B CBU-75A/B	CB	SUU-30A/B “ SUU-54A/B	0.45	0.118	Comp B	Mixed with BLU-63 in CBU-75
BLU-87/B	AP/AM	48	CBU-74	CB	SUU-51B/B	6.4	2.1	Comp B	Identical to BLU-49/B
BLU-97A/B BLU-97/B	AP/AM/Inc	202 166 145	CBU-87/B CBU-87A/B CBU-87B/B CBU-103/B CBU-103A/B CBU-103B/B CBU-113/B RGM/UGM-109D AGM-154A	CB	SUU-65/B +WCMD +WCMD +WCMD +WCMD-ER	1.54	0.287	Comp B	
BLU-98/B	SMK	3	CBU-88/B		SUU-49A/B	58		RP	
BLU-99/B	SFW		CBU-92/B		SUU-65/B				
BLU-101/B	AT	9/(12)	CBU-92/B	CB	SUU-65/B				
BLU-106/B	AR	8 24 15	CBU-98/B AGM-109H AGM-130B	CB Cruise missile CB	SUU-64/B SUU-54/B	20.4	2.95		Used together with HB876 Britsh mine
BLU-108/B BLU-108A/B	SFW	40	CBU-97/B CBU-97A/B CBU-97B/B	CB	SUU-66/B	3.4	0.945	Octol	Data are for Skeet-unit 4 Skeets in one

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
			CBU-97C/B CBU-105/B CBU-105A/B CBU-105B/B CBU-105C/B CBU-115/B		 +WCND +WCMD +WCMD +WCMD +WCMD-ER				BLU-108
BLU-114/B	Spec	202	CBU-94/B						Blackout bomb
CSS	SFW					<4.5		(Octol)	
EXJAM	ECM	5	M867	155 mm FA					
ISCB 1	AP	160		CB					
M6	Chem	3	M44	AACD		23		BZ	
M16	Chem	264	M158	AACD		~0.65		CS	
M32	AP	3100	Honest John	Art. rocket	M6E1	0.204	0.042	Comp B	
M35	AP	18	M413	105 mm FA		0.50	0.028	Comp B	
M36	AP	18	M444E1 M453	105 mm FA 107 mm mort.		0.20	0.021	Comp A5	
M38	AP	38520 2025 2025 2020	n/a CBU-62/B CBU-63/B Mk22	AACD CB CB CB	SUU-24/A SUU-30/B	0.136	0.027	Comp B	72 ADU
M39	AP	18	M444	105 mm FA			0.0235	Comp A5	
M40(A1)	AP	38520 2025 2025 2020	n/a CBU-62/B CBU-63/B Mk15	AACD CB CB CB	SUU-24/A SUU-30/B	0.136	0.027	Comp B	72 ADU
M42	DPICM	48 64 180	M864 M483A1 M509A1	155 mm FA 203 mm FA		0.209	0.0305	Comp A5	
M43A1	AP	60 104 400	M449 M404 Mk19	155 mm FA 203 mm FA 406 mm		0.42	0.02355	Comp A5	

Bomblet	Type	Bomblets per container	System	System type	Container	Weight	Expl. mass	Expl. type	Remarks
M43E1 M43E2 M43A2		60 60 60 400	M449E1 M449A1 M449A1	155 mm FA 155 mm FA 155 mm FA		0.43	0.2135	Comp A5	
M46	DPICM	24	M864 M483A1	155 mm FA		0,214	0.030	Comp A5	Used together with M42
M73	AT	9	M261	Hydra		0.54	0.090	Comp B	
M74	AP	950 300	M39 M39A1	ATACMS		0.59			
M77	DPICM	644	M26	MLRS		0,21	0,03	Comp A5	
M80	DPICM	42 42 54 45 85	M915 M916 M964 Mk172 XM982	105 mm FA 105 mm FA 120 mm mort 127 mm NA 155 mm FA			0.016	Comp PAX	With SD 31 mm diam,
M83	AP	24							
M101	DPICM	404	M30	GMLRS		0,21	0,03		with SD
M138	Chem	57	M30	AACD		4.5		BZ	
M139	Chem		Honest John				Sarin		
Mk118 Mod 0 Mk118 Mod 1 Mk118 VEPC	AP/AM	247	Mk20 Mod 2-3 CBU-99/B CBU-99A/B CBU-100/B CBU-100A/B Mk20 Mod 4-6	CB	Mk7 Mod 2-3 SUU-75/B SUU-75A/B SUU-76/B SUU-76A/B Mk7 Mod 4-6	0.60	Comp B Octol	0.18	Rockeye
SADARM	SFW	2	M898	155 mmFA					

Appendix D Abbreviations

AAA	Advanced Anti Armour
AACD	Aircraft Attached Canister Dispenser
AC	Anti-char (French: anti-tank)
ACED	Anti Char à Effet Dirigé (French: Anti Tank with Directed Effect)
ADAM	Area Denial Artillery Munition
ADU	Adapter Unit
AGL	Above Ground Level
AGM	Air-to-Ground Munition
AID	Air Inlet Decelerator
AIR	Air Inflatable Retarder
AO	Авиационная Осколочная (Russian - Aircraft fragmentation)
AP	Anti Personnel
AR	Anti Runway
APAM	Anti Personnel Ammunition
AT	Anti Tank
ATACMS	Army Tactical Missile System
ATAM	Anti Tank Ammunition
BAI	Battlefield Air Interdiction
BASM	Bombe à sous-munitions
BAT	Brilliant Anti-Tank
BDU	Bomblet Dummy Unit
BetAB	Бетонобойная Авиационная Бомба (Russian - Concrete-piercing aircraft bomb)
BK	Bombkapsel (Swedish – bomb capsule)
BKF	Блоках Контейнерных для Фронтовой авиации (Russian: Block of Containers for Frontal aviation)
BL	Bomblet
BLG	Bombe Lance Grenades (French: bomb-launched grenades)
BLU	Bomb Live Unit
BONUS	Bofors Nutating Shell
CAS	Close Air Support
CBU	Cluster Bomb Unit
CDU	Clustering Device Unit
CEB	Combined Effects Bomb
CEM	Combined Effects Munition
CEP	Circular Error Probable
DM	Deutsche Modelle (German: German Model)
DPICM	Dual Purpose Improved Conventional Munition
DWS	Deutsche Waffensysteme (German: German Weapon System)

EG	Emploi Generale (French: General purpose)
ERGM	Extended Range Guided Munition
EOD	Explosive Ordnance Disposal
FA	Field Artillery
FAE	Fuel Air Explosive
GBU	Guided Bomb Unit
GP	General Purpose
GPS	Global Positioning System
GRAU	Главное ракетно-артиллерийское управление (Russian – Main administration for rockets and artillery)
HEAT	High Explosive Anti-Tank
HMX	cyclotetramethylene-tetranitramine – His Majesty's Explosive
ICM	Improved Conventional Munition
INS	Inertial Navigation System
IZ	Interdiction zonale (French: area denial)?
JASSM	Joint Air-to-Surface Standoff Weapon
JSOW	Joint Stand-Off Weapon
KB	Kleinbombe (German: small bomb)
KMGU	Контейнер Малогабаритных Грузов Универсальный (Russian; Universal small size cargo container)
LADAR	Laser Radar
LBOk	Lotnicza bomba oświetlająca
MFA	Ministry of Foreign Affairs
MLRS	Multiple Launch Rocket System
MPSM	Multi-purpose Submunition
MW	Multipurpose Weapon
OAB	Осколочно авиационная бомба (Fragmentation aircraft bomb)
ODS-OD	одноразового действия объемно-детонирующий
OFAB	Осколочно-фугасная авиационная бомба (Fragmentation/high-explosive aircraft bomb)
PBX	Plastic Bonded Explosive
PGMM	Precision Guided Mortar Munition
PTAB	Противотанковая Авиационная Бомба (Russian – Anti-tank Air-delivered Bomb)
RAD	Ram Air Decelerator
RAM	Runway Attack Munition
RBK	Разовая Бомбовая Кассета (Russian - Single-use bomb dispenser)
RBL	Radar Bomblet
RDX	Cyclotrimethylenetrinitramine – Royal Demolition Explosive
RPG	Rocket Propelled Grenade
RHA	Rolled Homogeneous Armour
S/A (S&A)	Safety and arming
SADARM |	Sense And Destroy Armor

SCh	Сталистого Чугуна (СЧ) (Russian- steel casting)
SD	Self Destruct
SD	Sprengbombe Dickwandig (German- Thickwalled explosive bomb)
SFF	Self Forging Fragment
SFM	Sensor Fuzed Munition
SFW	Sensor Fuzed Warhead
ShOAB	Шариковой Осколочной Авиационной Бомбы (Russian – Spherical fragmentation aircraft bomb)
SMArt	Smart Artillery
SPBE	Самоприцеливающиеся боевые элементы (Russian: Self-aiming combat element)
STABO	Startbahnbombe (German) Runway bomb
SUU	Suspended Under-wing Unit
TNT	Trinitrotoluene
UXO	Unexploded Ordnance
WAM	Wide Area Munition
WCMD	Wind Corrected Munitions Dispenser
ZAB	Зажигателная Авиационная Бомба (Russian - Incendiary aircraft bomb

Appendix E Executive summary as presented to the Wellington Conference on Cluster Munition 19 February 2008

Cluster weapons – military utility and alternatives

Introduction

This report addresses cluster weapons in general with special emphasis on their efficiency, their tactical utility and their value in comparison with their closest alternatives, and raises the question of whether cluster weapons are needed on the battlefield.

Use

Cluster weapons can be used against a variety of targets, ranging from soft targets, such as unprotected infantry, to armoured vehicles.

Myths vs. reality

There has been a general belief that cluster munitions have an advantage over unitary weapons by a factor of 2 to 5. The analyses on which this report is based have identified cases where cluster munitions have their advantages compared with conventional unitary weapons. However, in several modes of usage, cluster weapons do not show any advantage at all. This report indicates several situations where the performance of unitary weapons in combination with high technology alternatives is far more efficient than cluster weapons. The analyses are not able to verify, or to render probable, that cluster weapons are generally as efficient as they are claimed to be.

Methodology

The main task has been to quantify the performance of cluster weapons and their alternatives. The methods applied in the analyses are literature studies, computer simulations and some experimental tests. All methods, all models and all input data to the models are fully documented in the public domain. No classified information whatsoever has been used. However, it seems probable that some of the information found publicly accessible literature has been generated from data and methods found in classified sources.

Bomblets

A basic property of almost all cluster weapons is that they contain bomblets that are small, light, and equipped with an impact fuze. Their effect is basically fragments generated by the detonation of the encapsulated explosive. Some types have additional properties such as a shape charge effect to perforate armoured targets, or pyrotechnic materials for incendiary effects.

Fragmentation effects

The fragmentation effect is often severely hampered by the limited size of the munition and by the impact fuze that causes the fragments to originate from a position very close to the ground. This basic property limits the performance quite substantially, as the microtopography, vegetation and other obstacles impede the movement of the fragments. This negative effect is enhanced in units where the detonator sits at the back of the charge. Such a design will give most fragments a downward sloping trajectory that limits the range of the fragments. This kind of design is typical of bomblets that have the additional property of a shaped charge; better known as dual-purpose units.

Anti-armour effects

The shaped charge effect itself enables a cluster subunit to perforate a quite impressive amount of armour. When these subunits were introduced more than 30 years ago, these weapons were the only practical means to defeat armoured units at long range and in an indirect firing mode. Today's heavily armoured vehicles are provided with protection that minimizes the effect a small shaped charge coming from above.

SFWs

The development of *sensor fuzed warheads* (SFW), which has been going on for three decades, has now at last reached at stage where such weapons have an *efficiency*, a *reliability* and a *cost* that make them realistic and viable alternatives to traditional cluster weapons. The widespread introduction of sensor fuzed warheads could eliminate the whole rationale for using small cluster subunits with dual-purpose properties. For defeating armoured targets, sensor fuzed warheads are definitely more cost-effective than cluster munitions.

SFWs are different from traditional cluster weapons

Sensor fuzed warheads are not considered to be cluster submunitions for the purpose of this report. In a rigorous technical sense, however, they can be classified as such. They are not intended to be dispersed in great numbers over a target area because of their high cost and high efficiency. Unlike conventional cluster bomblets, they do not hit at random but identify and engage point targets. At present they are larger than conventional cluster bomblets and equipped with very advanced self-destruct mechanisms. Together, these features significantly reduce the risk for causing post-conflict humanitarian harm.

A DPICM bomblet (left) in comparison with an SFW (right).

Dispersion

Cluster weapons have the inherent property that they disperse the effect over a larger area than traditional unitary weapons do. This dispersion is required in order to give the munition a certain efficiency and to compensate for the limited precision of unguided weapons when used at long ranges. Because of the dispersion, however, some submunitions inevitably detonate outside the target area, decreasing the effectiveness of the fire. Guided unitary weapons will eliminate the need to disperse the effect and eventually eliminate the need for cluster weapons.

Unitary weapons

Unitary weapons are still used extensively from guns, mortar rockets and aircraft. They are effective against soft targets, especially when they are fitted with proximity fuzes. In scenarios involving soft ground or heavy vegetation, cluster weapons suffer both from a decreased direct effect and from an enhanced dud rate. In many situations unitary weapons is still a viable alternative to cluster weapons.

Guided unitary weapons

Guided unitary weapons are becoming increasingly widespread and are a realistic alternative to unguided weapons. For some munitions relatively inexpensive kits are available that give unguided ordnance a guidance capacity that makes them viable against point targets. There is less need for putting such kits on existing cluster munitions.

Suppression

Like most other weapons, cluster weapons are used for destructive effects. However, suppression or suppressive effects are considered by some theorists to be more important than attrition or destructive fire. The suppressive effects are, however, mainly based on psychological responses rather than physical effects. It is therefore difficult to quantify these effects. The few existing models strongly indicate that the suppressive effect is more directly related to the explosive content than to effects like fragmentation and armour penetration. This indicates that there is no advantage in using cluster weapons instead of unitary charges for this purpose.

Alternatives

Basically there are three alternatives to cluster weapons:

- unguided unitary weapons
- guided unitary weapons
- sensor fuzed warheads

Comparisons

The performance of cluster weapons in comparison with their alternatives is roughly summarized in the table below

	Cluster weapons	**Unitary unguided warheads**	**Unitary guided warheads**	**Sensor fuzed warheads**
Soft targets	Adequate	Adequate	Good	Useless
Semisoft targets	Adequate	Inadequate	Adequate	Adequate
Hard targets	Adequate	Inadequate	Adequate	Good
Suppression	Adequate	Good	Good	Useless

These conclusions seem to be valid both in terms of performance per mass spent and in terms of performance per cost.

Not a unique capability

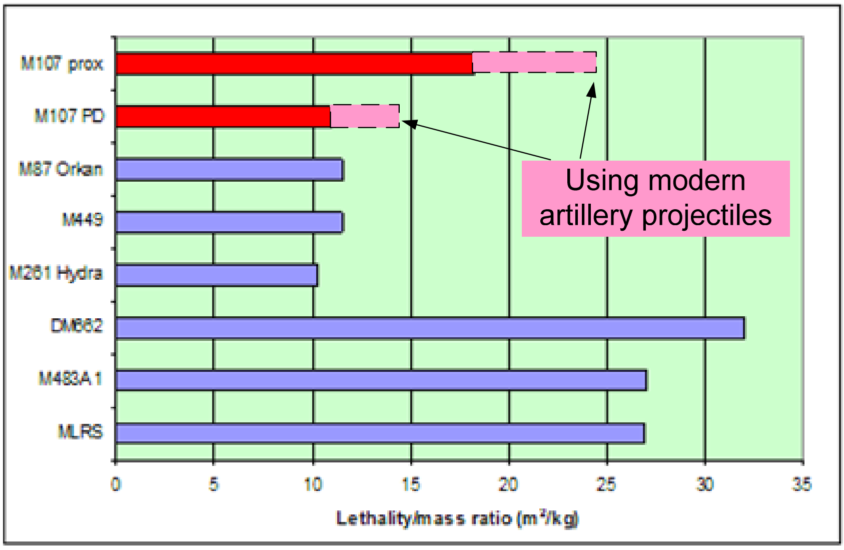
The table shows some cases where cluster weapons perform better than some of the alternatives, and in others where the alternatives are a better choice from the point of view of effectiveness. There are no cases where the use of cluster munitions is a superior choice when all alternatives are considered. It can hardly be claimed that the elimination of such weapons will create any dramatic and permanent flaws in the capability to engage and defeat relevant targets. However, this statement presupposes that sensor fuzed warheads are not included in a regulation of cluster weapons. In the absence of traditional cluster weapons, sensor fuzed warheads will be the only viable way to effectively defeat armoured targets at long ranges. Thus, combinations of sensor fuzed and guided unitary warheads seem to be a better alternative than traditional cluster munitions.

Alternatives exist

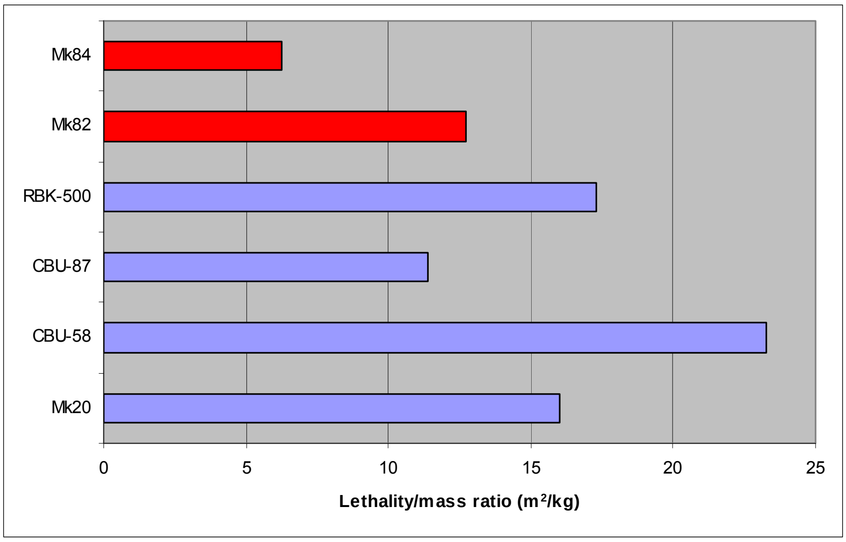
Cluster weapons do not constitute an irreplaceable capability on the battlefield. Alternatives exist, although in some cases they may be less effective than cluster weapons. The consequence may be that more time and resources may be required to accomplish an operation. Thus a prohibition of cluster weapons will not mean that a set of unique capabilities is lost.

The tables below show the relative performance (effect per mass) of some cluster weapons (blue columns) and unitary weapons (red columns) used against personnel.

Ground delivered weapons



Aircraft delivered weapons



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