

OME Principles assignment - M Dand - 1810440 FINAL

by Alexander Dand

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Figure 1 - Mk 82 type aircraft bombs fuze and fitted to an A-6 Intruder (photo credit: © BrokenSphere / Wikimedia Commons) [1]

Principles of OME

PROCUREMENT CRITERIA – MILITARY HE DEVICE

Alexander Dand | Principles of OME L5 | May 2020

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Introduction

The following brief has been delivered as the basis of this report: A military requirement has been identified for the procurement of a guided blast/fragmentation bomb to be delivered by specified aircraft for the attack of buildings of specific design.

The report will fulfil this brief by considering the likely specifications designated by the customer. Due to the non-specific nature of the brief, certain details will be assumed by the author in order to address essential requirements that should be listed. The assumptions are that the target will be an earth mounded explosives storage magazine built to specifications outlined in MoD Explosives regulations JSP 482 [2]; the guidance system will be on-board image guidance, with radio guidance as a redundancy; the aircraft design will have no effect as discussed below. Discussion of how these assumptions have been made will be available in the Appendix.

Requirements

Performance

- The device will require sufficient power to destroy or severely damage the target. This is the primary requirement of the device. Should this not be satisfied, the entire brief has failed.
- The device must release its energy when required, and only then. Precision Guided Munitions (PGMs) were developed with accuracy in mind, and if the main effects of the device were to happen before it arrives at the target, it would be wasted and potentially put unintended people at risk. Similarly, if the device detonates too late or not at all, it will potentially not perform the task it was designed for.

The first requirement will be achieved by selecting the correct type and amount of high explosive to satisfy the blast requirement. To satisfy the fragmentation requirement, the case must be considered. A thinner steel or lighter brittle metal form better natural fragments as the case shatters sooner, allowing for less of an overpressure build-up within the device. The other side of this is that a stronger steel case holds for longer, allowing for more overpressure build-up, and a greater resultant blast. The case can also be scored along pre-set lines (mechanically, or by the use of heat or chemicals [3]), forming pre-designed geometries for higher damage output and allowing greater control over the allocation of blast versus fragmentation priority.

The second requirement has several considerations. Firstly, as the munition will be delivered by aircraft, will it be a direct or indirect fire system [3]? If the assumption is made that the fire system is indirect

(increases safety for the operator of the system as they cannot likewise be seen by the target), the further assumption must be made that the device must have some sort of powered flight capabilities. Without thrust capability, the device will be limited in its effectiveness of hitting a target within its circular error probable (CEP) however the requirement for propellant must be balanced with the weight of the device (weight capacity of the aircraft) versus the working range of the device (including any potential additional manoeuvres performed outside the initial trajectory). If the assumption is made that the munition is direct fire, it simplifies the design (and therefore cost and complexity) considerably. The munition can be deployed above the target out of range of most defences to mitigate the hazard to the aircraft.

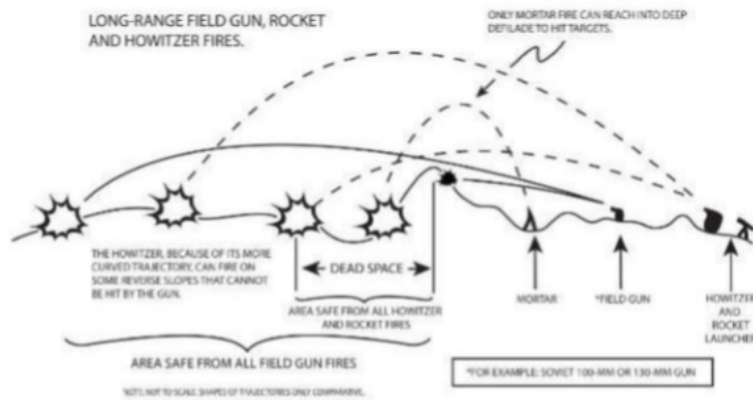


Figure 2 - Comparative trajectories for indirect-fire artillery systems [4]

The guidance system must be considered to ensure the device arrives at the target with any form of accuracy. The device will be fired at the target, and either receive instructions from the guidance system on the firing aircraft, or from its own on-board systems [5]. If the guidance is to come from the aircraft, information is transmitted via radio waves between the device and the aircraft, offering more human input to the trajectory. The downsides of this are that radio waves can be affected by weather, resulting in poor communication and therefore less guidance. Another factor for consideration in radio guidance is that conditions affecting visibility will affect the accuracy of this method of guidance. Some designs contain a pre-programmed image of the target (see Figure 3) and the onboard computer matches images to guide the device.

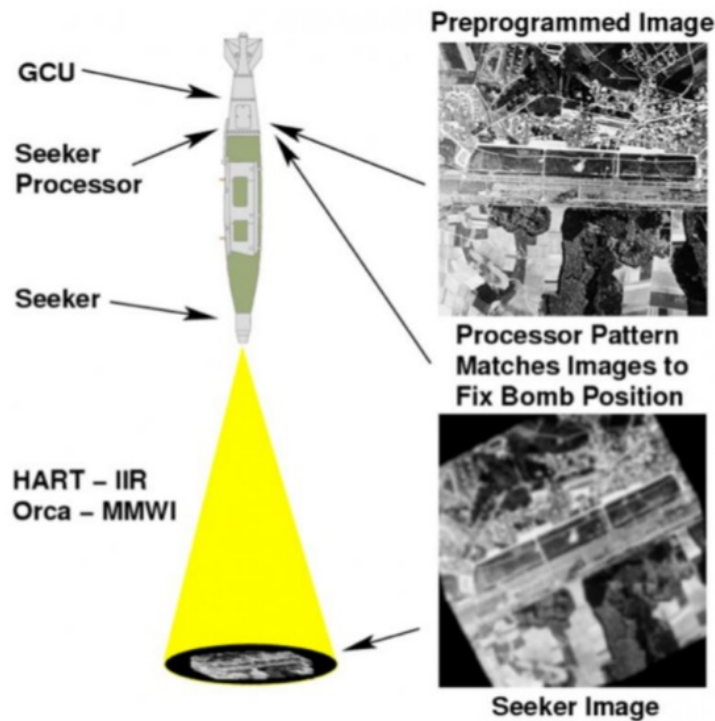


Figure 3 - Diagram of the GBU-38 JDAM, fitted with a millimetric wave imaging, or an infra-red imaging homing seeker head [6]

Laser guided methods of guidance rely on a sensor in the device searching for a specific frequency of radiation reflected off the target. This method requires an external source illuminating the target such as a person or vehicle on foot, or a second aircraft or drone [7] [8]. This reliance on an external targeting source is one of the weaknesses of this method of guidance as the accuracy of the guidance is keyed to this. This method is also vulnerable to weather conditions. A third method of guidance is that of satellite guidance, and the use of GPS coordinates for a 'Fire and Forget' methodology. Satellite guidance is not reliant on weather conditions for accuracy, however it is susceptible to signal jamming. If the system is interrupted or subverted, the device either reverts to inertial guidance [9], severely decreasing its accuracy or potentially has its course diverted away from its intended target. More recent designs of PGMs have a combination of laser and satellite guidance systems within each device for the advantages of each within the weapon. GPS guidance is used to get the device into the vicinity of the target, with laser sensors installed for increased flexibility and mitigation against jamming [10].

Safety

- The device will be safe to store under defined conditions for a defined lifetime. Should this requirement not be met, the device could deteriorate during storage, and not be suitable for use at the desired time. Environmental conditions could also affect the sensitiveness of the contained explosives.
- The device will be safe to transport and deploy, being sensitive enough to detonate under the correct stimulus, but not so sensitive as to initiate if exposed to a credible insult (heat, impact, electrical insult, chemical incompatibility) [11].
- There must not be adverse environmental implications during manufacture, storage or deployment. With a greater modern focus on environmental considerations, and due to the toxicity of many commonly used ingredients in the manufacture of explosives, care must be taken that harm to the environment is reduced or removed entirely.

Safety is a key factor in the manufacture of munitions and needs to be exhaustive. Energetic materials are extremely hazardous to health and safety, not only due to their decomposition processes but also since their component makeup tends to have adverse effects on health. Munitions containing TNT for example, tend to exude isomers of dinitrotoluenes and trinitrotoluenes when stored at even slightly elevated temperatures [12]. This can lead to cavities forming in the explosives with a resultant decrease in density, increased shock sensitivity, and possible interference with the fuse causing the munition to either detonate prematurely or not at all. This phenomenon gives rise to the requirement of segregation of the fuse from the explosive component until the device is deployed. Other considerations are sublimation and vaporization and subsequent condensation of explosives during storage. This could result in hazardous atmospheres or build-up of unwanted explosives within the storage facilities [2].

The second consideration is that of the safe transport and deployment. The prime consideration here would be the HE fill of the unit, and its reaction to heat, impact, friction. Testing regimes can provide the information, and there has been much information obtained throughout the years on the comparative sensitiveness of various different explosive compounds, with more recent requirements in the industry towards the use of Insensitive Munitions (IM), or Insensitive High Explosives (IHE) [12] where the inherent structure of the explosives are more stable and less prone to initiate without a designed stimulus. Mitigation can be through protective containers that pass rigorous testing regimes (stacking, dropping, burning etc.) in order to meet legal specifications [13]. The casing of the device itself can also contain safety designs (such as vents to release pressure in case of fire, eyelets for securing the device to packaging etc.)

Some HE compounds contain ingredients that have a negative impact on the environment. During storage and transport, care must be taken that these ingredients do not escape containment (mitigated by packaging). Research is currently underway into 'green' explosives that are environmentally compatible [14] [15] [16] to mitigate the natural toxicity of many explosives. However, as these are many times more expensive to manufacture than current formulations, these newer substances are not seeing much use across the industry.

Manufacturing Capability

- Ease of manufacture. If the manufacture of the device is so complex it takes too long to build or puts people at risk due to poor processes or overly dangerous material, other designs should be considered.
- Availability of materials to manufacture the device. As with the above point, if the materials required are in limited supply, or too expensive to procure or manufacture, other designs should be considered.
- Availability of a manufacturing facility. Without a suitable manufacturing facility, the device will not be made to the required specification. Poor standard facilities also run the risk of safety concerns to the workers and environment.
- The availability of skilled resource to manufacture and deliver the device to the User.

With this brief, the most complex item of the design will be the guidance system. For a large company containing multiple engineering disciplines, each part of the manufacturing process (guidance system, casing, fuse/detonator, HE manufacture, and the assembly of the component parts to the finished product) would be overseen by separate sections, with (ideally) an overarching systems engineering view coordinating the various disciplines. In a smaller company, there would most likely be a field that they specialize in (most probably HE operations and assembly) with the other aspects of the build contracted out to other companies.

Customer Specific Requirements

- Cost. Any customer will be expecting 'value for money' when awarding a contract/designing a product, and this type of product is no exception. Each of the previously stated requirements feed into the eventual cost of the device, and the concept of ALARP must be considered in almost all design particulars due to the nature of the device.

The definition set out by the Court of Appeal (in its judgment in *Edwards v. National Coal Board*, [1949] 1 All ER 743) is:

“‘Reasonably practicable’ is a narrower term than ‘physically possible’ ... a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them.”

In essence, making sure a risk has been reduced ALARP is about weighing the risk against the sacrifice needed to further reduce it. The decision is weighted in favour of health and safety because the presumption is that the duty-holder should implement the risk reduction measure. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved. Thus, the process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices. Extreme examples might be:

- To spend £1m to prevent five staff suffering bruised knees is obviously grossly disproportionate; but
- To spend £1m to prevent a major explosion capable of killing 150 people is obviously proportionate.

Figure 4 - Excerpt from 'ALARP at a glance' [17]

- Delivery Mechanism – specified aircraft. This sets size boundaries on the device, as space is limited within aircraft. If the device is to be mounted externally, the casing will need eyelets or fastening platforms in order to integrate with the aircraft. Also externally mounted devices will be subject to greater forces (build-up of heat due to air friction, vibration and potential supersonic effects) than the naturally more protected internally stored devices.

Method of Functioning

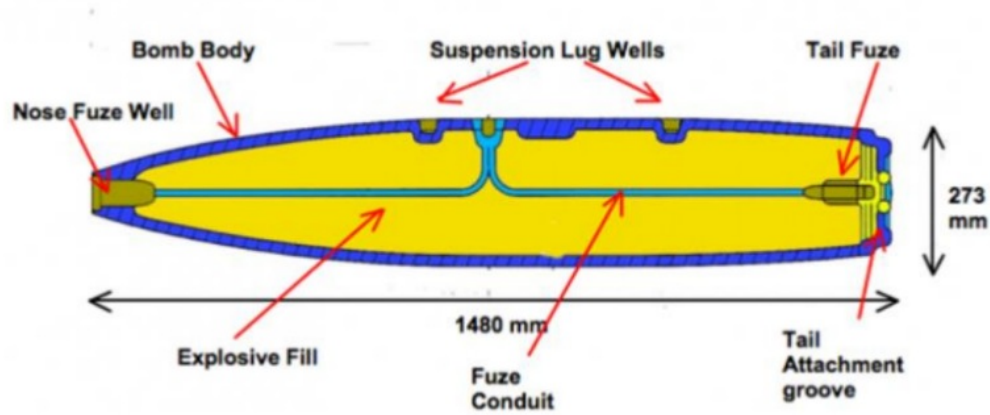


Figure 5 - Diagram of the Mk 82 bomb body without a tail or guidance unit [6]

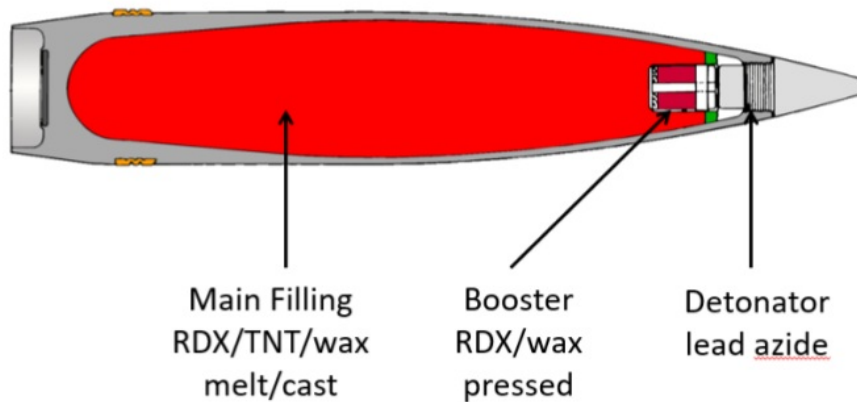


Figure 6 - HE Munition 155mm L15 round [18]

As can be seen in Figures 5 and 6, the design of a HE round is fairly standardized, in that the general design is that of a large HE fill surrounded by a metal casing. The fuzeing mechanism is differentiated depending on the purpose of the device. In Figure 8, there is a fuze at the tip with a sensitive detonator compound, most likely for detonation on impact. In Figure 7, there is a double fuze and a conduit linking the two. This suggests that the detonation will be more sophisticated, causing the propagation wave to set off from each end of the device. This would cause a greater build-up of pressure around the centre of the device which would influence the direction of any fragments generated by the device.

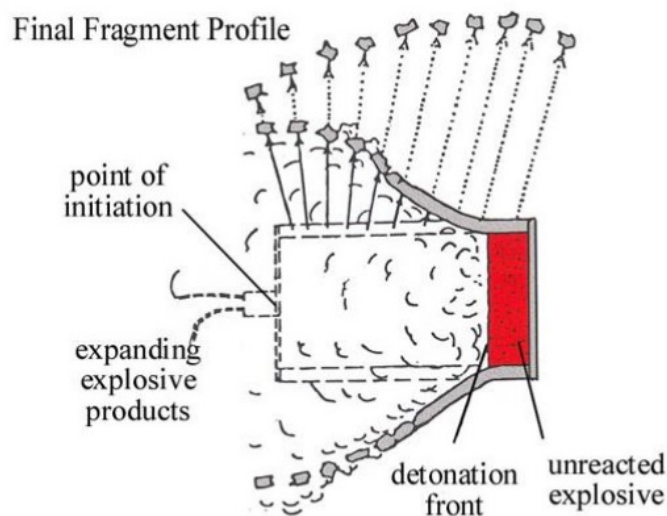


Figure 7 - Fragment trajectory as influenced by direction of detonation [19]

In Figure 7, the fragments are directed based on the direction of the propagation through the HE. If the detonation wave were coming from two directions, the fragments would be directed around the device, rather than in front or behind, causing more surrounding damage.

For this design, the fuze should be on a timer, set to ignite shortly after the initial impact. This would give the device a short delay for it to penetrate the earth mound, and only detonate within the target building. The difficulty brought by a more sophisticated fuze is one of complexity. The more complex anything is, the more vectors for it to malfunction. If the timer caused the device to detonate too early, the device would not function as required. A way of mitigating against this is to have a remote detonating signal transmitted should the device malfunction.

Also seen in Figure 5, there is a fuze well in the nose of the munition. This would indicate that the fuze could be installed at either end of the munition. As a fuze in the nose would potentially be damaged on impact (unless protected by a hardened penetrator such as tungsten), it may be better to have it fitted in the base for this brief.

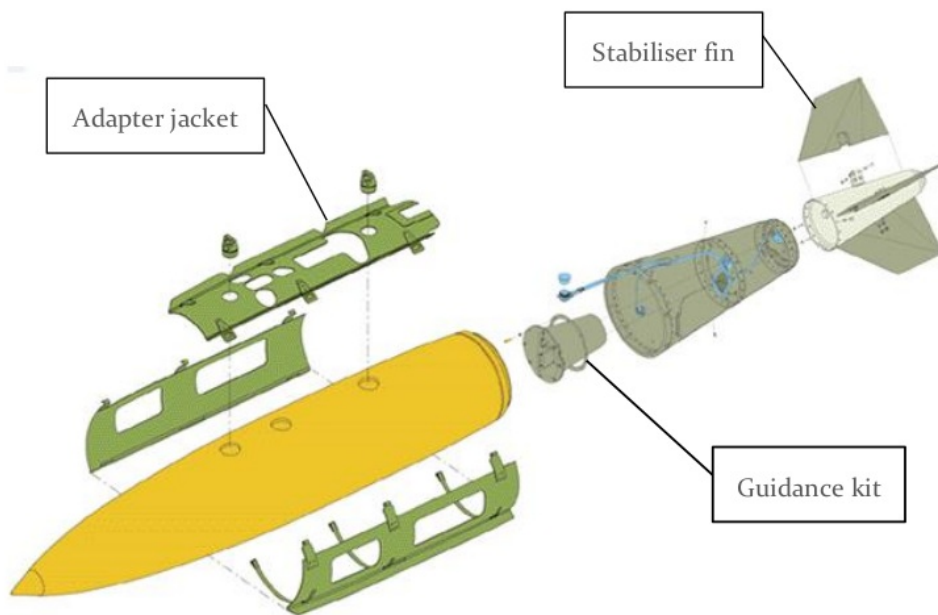


Figure 8 - JDAM cutaway [20]

As shown in Figure 10, the near generic design of General Purpose (GP) bombs allow for kits to tailor the bomb to the requirement. The adapter jacket can be manufactured/purchased much cheaper than the bomb itself, so these can be sourced according to the aircraft. The Tail Kit shown allows for GPS guidance, and feeds data to the stabiliser fins to guide the device to the target. Other variations of the tail kit allow air-braking (or Tail Retarding) for the device in order that the deploying aircraft can deploy at low altitude and be clear of the designated target area before the device had impacted (see Figure 9).

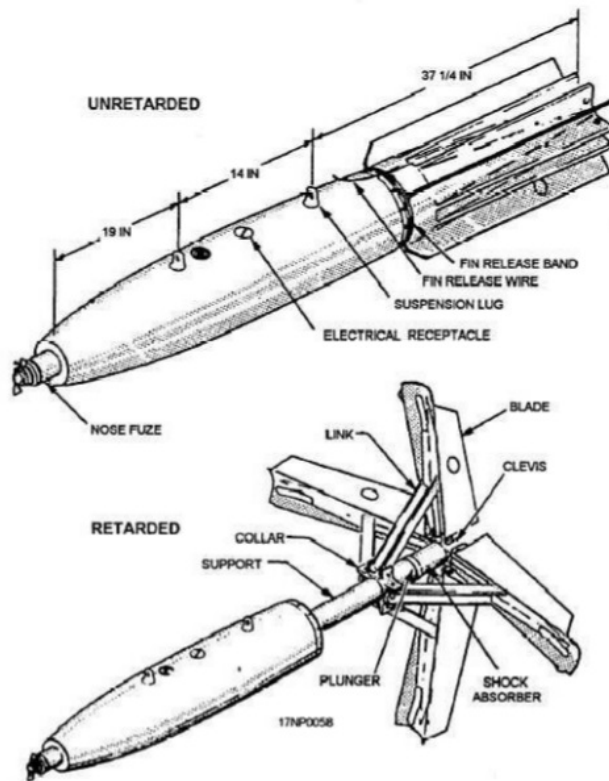


Figure 9 - Snakeye Fin Assembly Mk 15 with Mk 82 Bomb [21]

As well as tail kits, nose modifications are also available. These kits, like the tail kits, customise the GP bomb to meet the requirements of the User.



Figure 10 - GBU-12 Laser Guided Mk 82 [22]

As can be seen in Figure 10, a new addition can be attached on the nose of the device. In this case, it is a laser detector (as discussed in the 'Performance' section of the 'Requirements' discussion above). Other such nose kits include infra-red or optical seeker cameras, which give multiple options depending on the desired effect.

Testing regime

Testing for the munition should fall under several categories and is legislated for as part of the UK's Defence Ordnance Safety Group requirements for safety [23] [24].

Performance

These tests will be performed as part of the design and qualification of the device. Performance tests will ensure that the device meets the capability standards required by the customer. The questions that will need answering will be as follows:

- Can the device be transported and deployed by the specified aircraft? With the correct adapter jacket, the device can be adapted to fit various aircraft configurations.
- Does it do the required amount of damage to the target? Can the device be used effectively against other targets? These questions can be answered with modelling, however for suitable testing, live deployment can occur against targets with varying specifications in order to obtain data
- Can the device function in/during/after adverse conditions? If not, does the device 'fail safe'? The device should undertake a series of tests including submersion, desiccation, exposure to humidity, high temperatures (including chemical and oil fires), low temperatures, vibration, impact, altitude tests (including rapid decompression) and testing after the ingress of sand, grit, dust and rain. [25]

In-Service Testing

These tests will be performed to ensure the continued safe operation of the device. Periodic random sampling of the devices for inspection at regular time periods should include:

- Full strip to check conformity of the chemical components (HE for cracks, sublimation, exudation; interfaces between the HE and the non-HE parts of the device; metals and plastics to ensure no degradation due to incorrect storage or handling
- Regular visual checks of all devices for an 'early warning' outside of the full check periods
- Regular checks of electricals and electronics to ensure operational capability is maintained

These tests can be performed whilst under the custodianship of the customer and indeed, the visual checks can be performed by the customer as part of their safety responsibilities [11].

Lifetime

These tests will define the lifespan of the device. As it will be impractical to wait many years to ascertain the true effects of time, artificial environmental aging of the device can be performed (mainly to check the effects on the HE, as the metals, plastics, electricals and electronics can be predicted as these properties are well established). Once these trials have been carried out, the device is stripped and inspected, and any explosives are re-tested for safety and conformity.

These tests are necessary for qualification of the device, so should be carried out before delivery to the customer.

Post Procurement

After the munitions have been transferred to another custodian, legal responsibility for the munition then lies with them. The Explosives Regulations 2014 [2] outlines the duties that a custodian must adhere to in order to be granted an explosives licence. These regulations define the actions to be taken to maintain the safety and security of the explosives for people or companies who wish to make use of explosives for whatever purposes. The Health and Safety Executive (HSE) are responsible for ensuring that these regulations are followed and have published guidelines or Codes of Practice to follow to ensure that these regulations are met. Whilst the Codes of Practice are not laws per se, if they are followed, then the Licence Holder will be behaving in such a manner as to be assured they are working within the regulations [1].

At the bare minimum, the User must adhere to the requirements that were set out in the brief. If a munition is designed and qualified against a set of requirements, it is the User's responsibility to make sure that the device is stored and used only under the conditions outlined in the brief. To do otherwise would expose the device to conditions that it may not have been tested as safe against, and potentially put the safety of the User or their representatives at risk.

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Appendix

Brief assumptions

The Target

The first thing to consider in the design of a munition is the nature of the target. Different effects can be achieved depending on the design of the weapons system, and these effects will in turn differ depending on what target they are used against. A system designed to cause maximum damage to 'soft' or lightly armoured targets will not affect a reinforced concrete building with anything near the same effectiveness. Likewise, it should be considered how the munition will strike the target. If the walls of the structure are angled, will the munition bounce away if it does not strike head on?

The Guided Bomb

Currently, guided (or 'Smart') bombs are guided by a limited selection of systems. They are controlled by radio, laser, or satellite. Radio guided bombs generally utilise a front-facing camera in the nose of the bomb, feeding data back to a controlling aircraft where a human operator or guidance system guides the device with steering fins. A laser guided device possesses sensors which detect an object 'painted' with a specific light frequency laser and have onboard guidance which directs the device towards the highlighted target [5]. Satellite guided devices are given specific GPS coordinates and the guidance system will cause the device to travel towards the given point. There are pros and cons to each type of guidance system, and these will be discussed in the requirements section of this report.

Blast/Fragmentation

Given the previous statement that the target should dictate the munition to be used, in the case of this theoretical report, the opposite is true. As the focus of damage has already been specified (a combined blast/fragmentation device), a structure was selected to suit this. The design of an explosives storage magazine is such that it keeps an unintended explosion from propagating or minimizing the damage of any secondary effects of said explosion. Whilst these qualities are requirements for safe storage, they do preclude external hardening of the building thus reducing the need for a greater blast in order to penetrate the building. If correctly fused, the bomb will detonate inside the magazine, and the fragments will cause further insult to any explosives/munitions not detonated by the initial blast.

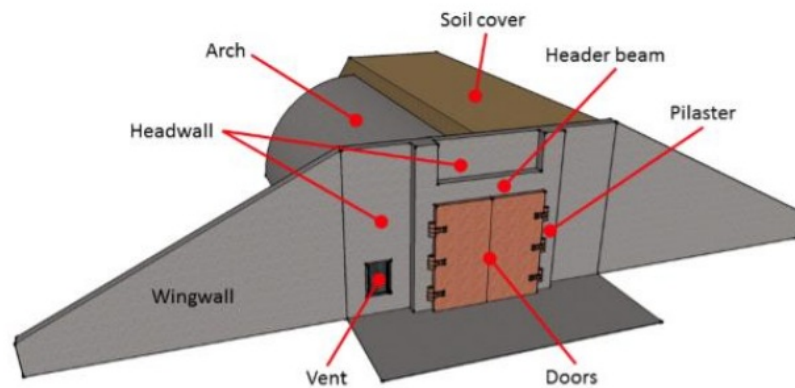


Figure 11 - ECM (Earth Covered Magazine) components [26]

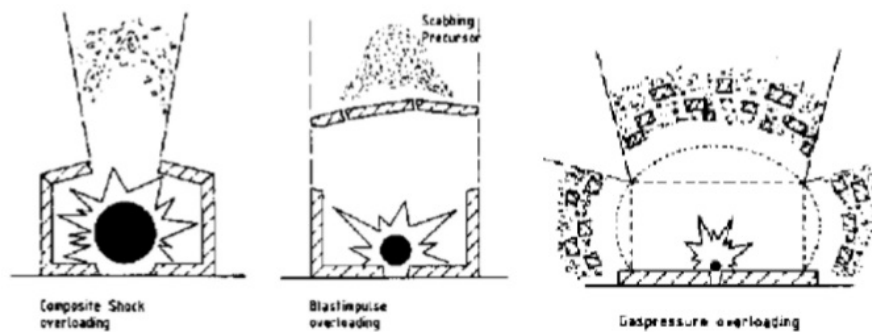


Figure 12 - The Three overloading regimes for RC magazines [27]

With research showing that the general damage output of a combined blast/fragmentation bomb versus concrete is greater than that of an explosive device that is loaded towards either blast or fragmentation [28], this would also give reason to use this specification within the brief.

Specified Aircraft

For this report, the actual delivery vehicle does not need to be specified. Certain aspects of the munition need to match the vehicle (weight, size, mounting fittings, etc.) but these can be generalized in the requirements section of the report.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

57 /100

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GRADING FORM: SMU GENERIC_GJ

**ALEXANDER
DAND****57.20****RESEARCH-INFORMED LITERATURE**

Very good range of technical, explosive and regulatory publications

6.5**KNOWLEDGE AND UNDERSTANDING**

"Knowledge is accurate with a good understanding of the field of study. Be careful not to drift too far from the brief. We are talking about aircraft delivered systems and the occasional voyage into artillery systems could confuse the reader."

18**ANALYSIS**

"Sound, logical, analytical thinking; synthesis and evaluation. For example testing regimes included a performance , environmental and inservice monitoring. However, what was the bomb actually

15

filled with and why was the filing selected? This is left unclear. Hence the amrk was reduced "

PRACTICAL APPLICATION AND DEP.



Good appreciation of the context of the application, with some use of examples, where relevant.

11.2

SKILLS FOR PROFESSIONAL PRAC.



Can communicate well, confidently and consistently in a suitable format.

6.5