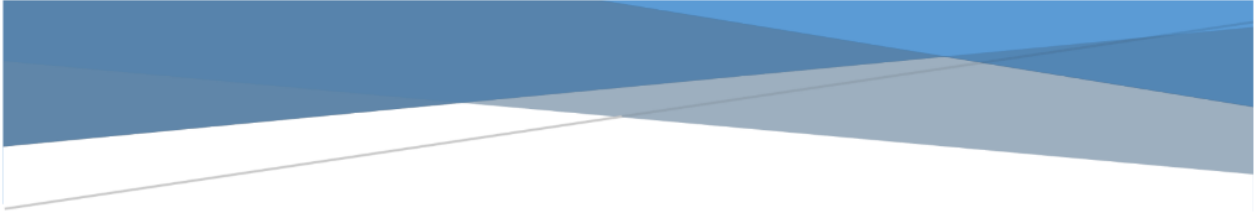


1810348 OME Coursework

by Fergus Russell

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ACDA5010-Principles of OME

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1-Introduction

Weapon systems in use in modern military powers have to take into consideration a significant number of factors to achieve the desired outcome. These factors include the platform that is going to field the weapon system in service, the required target effects of the weapon, the safety considerations of the weapon system from manufacture through to demilitarisation and disposal. This report will outline the considerations and specifications required for the design of a guided bomb with blast and fragmentation weapon effects for use against building structures. The report will outline the likely requirements of such an ordnance, how designers can meet those requirements, propose designs and suggesting the methods of functioning, system components, material properties and failure mechanisms that may be encountered. A test program for the ordnance will be proposed that meets the requirements and the role of the user in the handling and storage of the munition.

2-Ordnance Requirements

2.1-Requirements Engineering

The first stage in any design process is to determine a set of requirements for the ordnance. This is an example of “Requirements Engineering” [1]. In the UK major stakeholders will set out the requirements they require of proposed munition. Such stakeholders may include the Ministry of Defence (MoD), Army, Royal Air Force (RAF), Royal Navy (RN), Defence Ordnance Safety Regulator (DOSR), Defense Ordnance Support Group (DOSG) and industry partners such as BAE Systems and MBDA. These organisations will develop a set of requirements based on their operations and equipment and the industry partners will develop their solution in response to the requirements that have been set out.

2.2-Proposed Requirements

2.2.1-Delivery System

As the proposed munition is to be airdropped it is paramount that it integrates flawlessly with the delivery system. In the UK there are currently two frontline aircraft that carry out the ground attack role both for the Royal Air Force [2] and the Royal Navy [3]. In the case of the Royal Air Force currently the Eurofighter Typhoon and the F35 Lightning II carry out the ground attack role and for the Royal Navy it is the F35 Lightning II. Both aircraft are shown in Figure 1 [4] and Figure 2 [5]



Figure 1-F35 Lightning II



Figure 2-Eurofighter Typhoon

Because of this requirement there are various considerations that need to be taken into account, these include:-

- Attachment to aircraft hardpoints
- Mass of all up round
- Aerodynamics of munition
- Integration into aircraft controls and systems
- Electromagnetic radiation protection
- Temperature of operation
- Vibration

2.2.2-Performance and Target Requirements

Another set of requirements that need to be considered are the performance requirements of the munition. These requirements could be drawn up from the intended type of target that the ordnance will be used against. Typical military structures include facilities such as Explosive Store Houses (Figure 3 [6]), modern fortification structures (**Error! Reference source not found.** [7]) and airfields and supporting infrastructure (Figure 5 [8])



Figure 3-Explosive Store House



Figure 4-HESCO Fortification



Figure 5-Port Stanley Airfield after Black Buck bombing raid

Most of these structures have reinforcing in their design and use vast amounts of concrete and are constructed in such a manner that destroying such structures can, at times, prove difficult. Current weapon systems designed to destroy such targets include the BLU109 (Figure 6 [9]) which are capable of penetrating 2m of reinforced concrete [10].



Figure 6-BLU-109 Bomb

Fuzing of the munition is also another requirement and is dictated by the use of the munition. For example in the case of a nuclear weapon It is detonated above ground to take advantage of the reflected blast waves generated when the original blast wave interacts with the ground creating a more destructive effect. A bunker buster however needs to penetrate a distance below ground before initiating.

2.2.3-List of Requirements

From the considerations outlined a set of requirements can be drawn up. A series of requirements for such a munition may look like the following:-

- Shall fully integrate with Typhoon FGR4 and F35 Lightning II platforms
- Shall have a penetration of 2.5m through reinforced concrete
- Shall contain enough energetics to have a destructive area of 250m diameter in airburst with a blast fragmentation effect
- Shall have selectable fuzing capability for airburst, impact and delay
- Shall have a form of guidance control
- Shall have laser target designation
- Shall have a high level of reliability

In terms of reality a real list of requirements would be considerably more in depth but in the context of this academic exercise these requirements will be sufficient.

These requirements must be met in the development of the ordnance as failure to do so may result in the ordnance not being procured by the stakeholders or the ordnance not being fully compatible with the required aircraft or the ordnance not performing as required in theatre.

3-Ordnance Design

3.1-Initial Design

3.1.1-Standards

Initial research into the design of the ordnance needs to be carried out. The first requirement states that the ordnance must integrate fully with the Typhoon FGR4 and F35 Lightning II. Part of this integration will be how the ordnance will be fitted to the aircraft for use. As such the specification of such hardpoints have been standardised and the requirements for such are set out in MIL-STD-8591

[11]. Researching standards that may be applicable to the design of the ordnance is critical to designing the ordnance so that it can integrate fully with already existing technology and platforms.

3.1.2-Penetrator and Energetics Design

The requirements have set out that the ordnance must penetrate through 2.5m of reinforced concrete and have a destructive area of 250m in diameter with a blast/fragmentation effect. Historically the design of these would have been characterised through the use of empirical tests and developing mathematical equations that model the behaviour of the effect. Classical Newtonian physics can be used to predict the mass of the ordnance required to penetrate through 2.5m of concrete. Branches of physics and chemistry can be applied to predict the amount of explosives required to provide a blast diameter of 250m. More modern techniques such as Finite Element Analysis and computer modelling can streamline the process and make it considerably more accurate and faster than what was available to the ordnance designer 20 years ago.

3.1.3-Fuzing

The requirements set out that the fuzing of the ordnance must be selectable between airburst, impact and delay. Selectable fuzing used to be conducted through a mechanical selector built into the fuze that would have been selected by the armourer whilst loading out the aircraft for the mission. An example of a mechanical selectable fuze is the AZ-111 [12]. The AZ-111 is an impact fuze however there is a delay feature where can be mechanically selected through a selector screw. An example of the AZ-111 is shown in Figure 7 [12]



Figure 7-AZ-111 Fuze

More modern fuzes have electronics in their operation and are programmed prior to use. Such an example of an electronic fuze is the Northrop Grumman Mk 419 Multi Function Fuze [13] shown in Figure 8 [13]

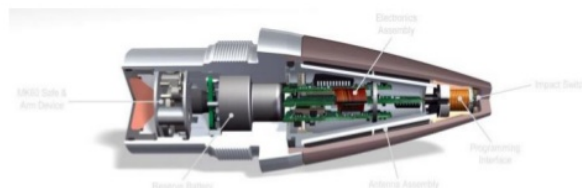


Figure 8-Northrop Grumman Mk419 MFF

The electronics package allows for a variety of modes including proximity for use against air targets, height of burst, autonomous that combines both proximity and height of burst functions, point detonating and an electronic time function [13]. This fuze is used primarily in artillery and large calibre guns however similar electronics providing similar functionality would be desirable for the ordnance. If these electronics could be further integrated into the aircrafts systems the fuzing system could be selectable while on mission to allow for changes in the mission dynamic.

3.1.4-Guidance

The guidance of the weapon is another important design requirement that needs to be met. Current in-service munitions used in similar roles, such as the Paveway III, use laser designation and GPS and satellite guidance control to ensure the weapon can travel to target [14]. The guidance control unit then sends signals to the control surfaces of the ordnance which act on the airflow around the munition and change its course to the required direction. Figure 9 [14] shows an F16 dropping a Paveway III. As can be seen in the figure the laser sensor at the very front will detect a laser designator either from the pilot or from an external source on the ground and the forward canards and tail fins then adjust their angle of attack to direct the ordnance to the target.



Figure 9-American F-16 dropping Paveway III

3.1.5-Explosive Train Chemical Makeup, Casing Materials and Design

The explosive train of the ordnance needs to be considered due to the operational requirements of the ordnance. In recent years there has been an increased drive to use more and more insensitive energetics in ordnance to make them safer to handle and store. The use of electronics in the fuzing mechanism reduces the need for impact sensitive energetics such as Lead Styphnate [15] and can be replaced with electrically sensitive compositions as used in components such as the Reynolds RP80 Explosive Bridge Wire Detonator [16] shown in Figure 10 [16]. The figure shows that the explosive train of the detonator is such that the exploding bridge wire, a wire that when enough current and voltage passes through it that it instantaneously explodes imparting enough energy to detonate the PETN initiating explosive which in turn imparts enough energy to initiate the RDX output explosive which can then initiate much larger charges of explosives such as RDX based PE7 and PE8.

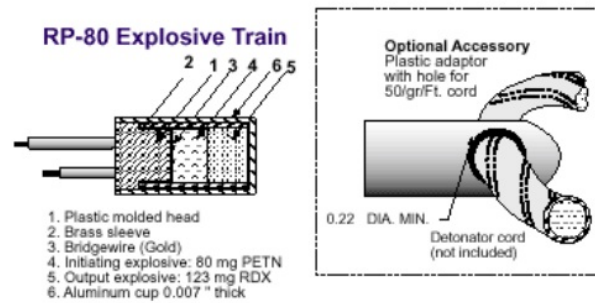


Figure 10-RP80 EBW Detonator

The main type of explosive charge that can be utilised will be dependent on the choice of casing materials, as an element of the ordnance is to breach 2.5m of reinforced concrete then the casing materials will need to have a significant amount of density and hardness so as to not break apart under impact but will break apart when subjected to the energy released by the explosives. The BLU 109 munition uses a hardened steel casing with a variable thickness that consists of 95mm thick steel at the nose and 28.6mm along the rest of the casing [17]. This thick casing at the nose combined with the density of steel being 8000kg/m^3 [18] provide enough kinetic energy when dropped from height and with speed to impact through reinforced concrete and remain together yet the thinner casing away from the nose allows the explosives to break through the casing and neutralise the intended target. Further lethality can be engineered into the munition casing through the implementation of adding notching to the inner walls of the casing or embedding fragmentation pieces into the outer wall of the casing such as is shown in Figure 11 [19]

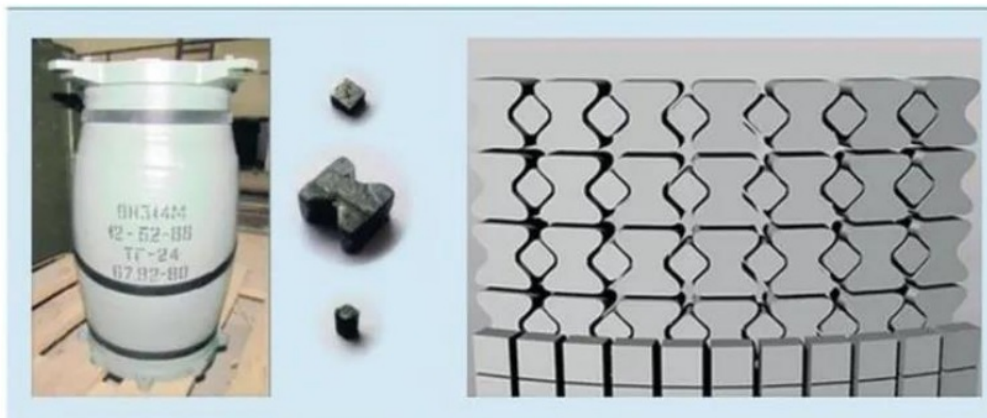


Figure 11-9M314M Warhead Bowtie Fragmentation Pattern

The outside appearance of the round also needs to be considered. In the case of the BLU-109 the round is streamlines so it can travel cleanly through the air and maintain a high degree of speed with minimal drag. The round also needs to be shaped so that it can travel at potentially supersonic speeds with the aircraft it is to be used with, failure to conduct testing in this area may result in damage to and loss of aircraft and aircrew whilst in service.

4-Testing

4.1-DSTAN

DSTAN or Defence Standards are a series of standard written by the Ministry of Defence and relevant stakeholders which sets out a number of requirements when it comes to ordnance and the testing and proofing of ordnance. The Defence Standard that sets out the proofing procedures for ordnance is set out in DSTAN-05-101 [20].

4.2-Trials Testing

DSTAN-05-101 sets out what must be proofed in new ordnance however these proofs and tests would be carried out through energetic trials to provide the scientific evidence the ordnance meets the required proof as set out in any standards or acceptance criteria. For example, the lethality of the warhead may be determined through the use of an arena trial. Figure 12 [21]



Figure 12-COTEC Fragmentation Trial Arena

In this trial the ordnance is placed in the middle and initiated. The blocks surrounding the ordnance capture any fragmentation released from the ordnance and from this a probability of kill can be determined for the fragmentation element of the ordnance. Further large scale trials can be carried out to assess how the ordnance under test passes the requirements that have been set out. For example the BLU-109 warhead shown in Figure 6 was subjected to a penetration test by being propelled by a rocket sled into a 4 foot thick reinforced concrete block [22]. Aerial trials on aerial ranges such as MoD Benbecula or MoD Tain could be performed to assess weapon performance, targeting and accuracy. These trials involve getting an aircraft to drop an inert variant of the ordnance on a designated target and various trials instrumentation such as RADAR and high speed videography observe the target and track the ordnance through its flight. Electro-magnetic testing is another test that will need to be performed on the ordnance to assess the ordnance's susceptibility to electro-magnetic noise in all environments [23] as well as temperature variation testing for all operating environments. A final trial that may need to be conducted could be a render safe procedure trial where the ordnance is destroyed whilst trialling a procedure which will render the

ordnance safe, this is particularly useful for bomb disposal techniques and may be of use if the ordnance fails to initiate on the required target.

5-Storage and Safety

The final aspect of the ordnance design is storage considerations. The requirements for storage by the user, particularly in the UK are set out in DSA03 OME Part 2: In-Service and Operational Safety and Management of OME [24]. The document also sets out the classification of the ordnance for explosives and transport. The classification of the explosive will be determined by the hazard division the ordnance will be assigned to. The hazard divisions are [25]:-

- 1.1: Substances and articles which have a mass explosion hazard
- 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard
- 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
- 1.4: Substances and articles which present no significant hazard
- 1.5: Very insensitive substances which have a mass explosion hazard
- 1.6: Extremely insensitive articles which do not have a mass explosion hazard

Depending on the energetic filling of the ordnance, the ordnance will be determined to be either 1.1 or 1.5 if the fill is of an insensitive nature such as IMX-101.

Complementing these hazard divisions are further classifications which dictate the compatibility group of the ordnance. These groups are in appendix I [25]. From these compatibility groups the ordnance can fall into a compatibility group of either 1.1D or 1.5D if the fuze system is stored separately from the main ordnance or 1.1F or 1.5F if the fuze system is contained within the munition during storage.

Once the hazard division and classification group has been determined for the munition it can then be placed in an explosive store house. Explosive store houses in the UK are temperature controlled environments and the design requirements of them is set out in DSA03 OME Part 2: In-Service and Operational Safety and Management of OME [24].

6-Conclusion

The report has outlined a number of aspects that must be considered in the design of a piece of ordnance that has to be guided to engage military structures and provide a blast and fragmentation effect. The report has outlined and discussed sample requirements that would need to be considered further in depth for the design of such an ordnance both from the user and from the requirements for proposed targets. The report has discussed and outlined some examples of how weapon designers could solve some of the issues facing them including using defence standards to interface with aircraft, potential fuze designs, potential energetics that could be used in the application along with potential fragmentation designs and guidance systems. The report then discussed proofing and testing of the ordnance through the proofing setting out in UK Defence Standards as well as trial testing involving arena trials, aerial trials, electromagnetic field trials and finally render safe procedure trials. Lastly the report discussed safety and storage of such an ordnance and that the ordnance will be required to be classified based on the hazard it presents and that within the UK there are specific regulations and standards that the ordnance must be stored under.

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Appendix I-Classification Groups

- A: Primary Explosive Substance
- B: Article containing a primary explosive substance and not containing two or more effective protective features.
- C: Propellant explosive substance or other deflagrating explosive substance or article containing such an explosive substance
- D: Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without a means of initiation and without a propelling charge, or an article containing a primary explosive with substance and containing two or more safety features
- E: Article containing a secondary detonating explosive substance without its own means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids)
- F: Article containing a secondary detonating explosive with its own means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids) or without a propelling charge
- G: Pyrotechnic substance, or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear- or smoke-producing substance (other than a water activated article or one containing white phosphorus, phosphides a pyrophoric substance, a flammable liquid or gel, or hypergolic liquids)
- H: Article containing both an explosive substance and white phosphorus
- J: Article containing both an explosive substance and a flammable liquid or gel
- K: Article containing both an explosive substance and a toxic chemical agent
- L: Explosive substance or article containing an explosive substance and presenting special risk (e.g. due to water-activation or presence of hypergolic liquid, phosphides or a pyrophoric substance) and needing isolation of each type.
- N: Articles containing only extremely insensitive substances
- S: Substances or articles so packed and designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast projection effects are limited to the extent that they do not significantly hinder or prohibit firefighting or other emergency response efforts in the immediate vicinity of the package.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

66/100

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GRADING FORM: SMU GENERIC_GJ

FERGUS RUSSELL

65.80

RESEARCH-INFORMED LITERATURE

 Excellent range of publications accessed including technical, explosive, regulatory (Both DSA 03 and Transport regs) and past accident reviews

7.8

KNOWLEDGE AND UNDERSTANDING

 Knowledge is extensive and goes beyond the material already disseminated on the course. (e.g. fusing and certain examples of fragmentation)

19.5

ANALYSIS

 The testing regime is incomplete. We have a good understanding of performance testing and categorisation of the warhead but the environmental and life cycle aspects are not discussed in full

18

PRACTICAL APPLICATION AND DEP.

 "A very good application of a range of methods, e.g. Systems tools including an understanding of stakeholder requirements in evidence. Modelling and simulation proposed in the concepting stage"

13

SKILLS FOR PROFESSIONAL PRAC.



Can communicate professionally and, confidently in a suitable format.

7.5