

Principles of OME G.Goddard

by George Goddard

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PRINCIPLES OF OME

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AWE PLC

Abstract

A requirement was raised for the design of a fragmentation blast bomb. This report details the customer requirements the various aspects of the weapon that needed to be considered. These include case materials, type of explosive, guidance and safety. The report also details the tests that are required to be carried out on the explosive fill and the complete munition.

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Introduction

This report will cover the design requirements for a blast/fragmentation bomb. It will look at the customer requirements and design specifications. It will explore all details of a bomb including case material, type of explosive fill, guidance, manoeuvrability and safety and arming. The report will also detail the safety tests that need to be carried out on the munition as well as post procurement and storage requirements.

Key requirements

Target

The intended target for the munition will be a reinforced concrete building. The munition will need to penetrate to the inner area of the building before detonating, this will ensure maximum damage is incurred.

Delivery

The delivery of the munition will be via the F-35B lightening fighter jet. Air-to-surface, electronic warfare intelligence gathering, and air-air combat are all capable by the F-35 [1].

The F-35B has the following specifications:

LOCKHEED MARTIN LIGHTNING:

- **Powerplant:** one Pratt & Whitney F135 turbofan rated at 40,000lb st (177.88kN) with afterburning and 40,500lb st (180.10kN) for vertical take-off
- **Length:** 51ft 2¼in (15.60m)
- **Height:** 14ft 3½in (4.36m)
- **Wingspan:** 35ft (10.70m)
- **Wing area:** 460sqft (42.70m²)
- **Maximum take-off weight:** around 60,000lb (27,216kg)
- **Maximum speed:** Mach 1.6
- **Combat radius:** on internal fuel more than 450nm (833km)
- **Maximum altitude:** 50,000ft
- **Armament:** typically two AAMs and two bombs carried internally, with optional 25mm gun pod and underwing pylons enabling stores carriage up to 15,000lb (6,800kg)

[1]

From the target and aircraft specifications a list of specifications can be drawn up to enable the design of the munition.

Likely requirements:

- Safe to manufacture
- Environmentally friendly manufacture, life and disposal
- Safe to handle
- Safe to transport
- Mount to aircraft
- Reach target
- Detonate when intended
- Give required effect
- Manoeuvre
- Track target
- Safely arm
- Be reliable

Requirement	How to meet requirement	Consequences of not meeting requirement
Safe to manufacture	Use of insensitive HE	Dangerous to manufacturing personal
Environmentally friendly manufacture, life and disposal	Non toxic ingredients	Environmental impact, fines or imprisonment
Safe to handle	Use of insensitive HE	Dangerous to user
Safe to transport	Must be adaptable to current aircraft	Dangerous to transport personal and public
Mount to aircraft	Must be adaptable to current aircraft	Unusable component
Reach target	Guidance system, ability to change course	Miss target, injure or kill civilians
Detonate when intended	Different fuse for different targets	Not give intended effect
Give required effect	Release shrapnel, scored case	Incorrect shrapnel, not effective
Manoeuvre	Guidance system, ability to change course	Miss target, injure or kill civilians
Track target	Adaptive guidance system	Miss target, injure or kill civilians

Safely arm	Only arm when close to target	Safety of everyone involved
Be reliable	Give desired effect every time	Not detonate at correct time, poor or no effect

Meeting requirements

From the requirements given by the customer the most important is that the bomb gives the desired effect when required. These requirements can be split into five main parts which if all met will enable the bomb to function as intended. These are:

- Manufacture, handling and disposal
- Casing and mounting
- Explosive
- Guidance
- AFAF (Arming fusing and firing)

Meeting these requirements is key to the bomb functioning as required, to assess if the requirements have been met several goals will need to be set that can be checked against.

Manufacture, handling and disposal

The bomb is manufactured to a set process that ensures a good quality product

The bomb is safe to manufacture and handle

A full lifecycle plan is in place including decommissioning and disposal in an environmentally friendly way

Casing and mounting

The case shatters and produces fragments upon detonation

The case protects the high explosives, guidance system and AFAF system

The bomb is mountable to an F35-B aircraft

The case will penetrate concrete walls

Explosive

The explosive has the correct properties to shatter the case and produce high velocity fragments

The explosive is safe to manufacture

The explosive meets current environmental guidance

Guidance

The bomb reaches the target within a given tolerance
If needed the bomb can alter its trajectory to reach the target

AFAF

The bomb is only fused when certain conditions are met
The bomb detonates after penetrating the building wall
The bomb only functions when it has reached its target

Designs

Manufacture

Depending on the case material the case can be turned from a solid billet of metal or rolled, and seam welded. The process of machining involves a lot of waste as the internal cavity needs to be removed. However, machining from a solid billet gives a strong case with no weak point. With rolling the case is produced from a sheet of metal and rolled into the required shape and seam welded. This seam can produce a weak spot if the weld isn't perfect.

Case materials

The case of the bomb is critical to how the bomb functions and its performance in the air. If the material is too ductile the bomb won't produce the required fragments. Metals are heavy versus non metals and a heavier material will affect the aircraft's operational distance. As the bomb is designed to reach the inner part of a building the tip of the case or whole case will need to be made of a very hard material.

The following materials could be considered for use in the bomb:

- Composite materials eg carbon fibre
- Steel
- Aluminium
- Tungsten
- Iridium

Iridium is a silvery white metal that is very hard and brittle, and the second densest material known. Due to its physical properties Iridium is very difficult to work with and is typically 3D printed to give the component. As laser sintering gives a near net component it leaves very little postproduction machining and it would enable scores to be printed on the inner surface of the case. Laser sintering works by layering fine layers of metallic powder onto a base. Once the powder has been placed down a high-power laser fuses the powder to the previous layer, this process of powder followed by laser continues until the component is finished.

Material	Youngs modulus (Gpa)	Density
Carbon fibre	110-120	1.6 g/cm ³
Steel	190-203	7.85-8.06 mg/m ³
Aluminium	66-88.5	2.27-2.95 mg/m ³
Tungsten	660-686	15.25-15.88 mg/m ³
Iridium	525-545	22.4-22.6 mg/m ³

Table 1 [2]

Table 1 shows the young's modulus and density for materials that could be considered for the case of the bomb. Getting the fragmentation material correct is important as the young's modulus and density will affect the size and velocity of fragments.

Explosive

Getting the right explosive fill is key to the bomb functioning as intended and producing the required fragments.

Explosive	Composition	Velocity of detonation	appearance
Comp B	$C_{24}H_{37}N_3O_2$	7638	Brown solid
HMX	$C_4H_8N_8O_8$	9100	White powder
TNT	$C_7H_5N_3O_6$	6940	Yellow solid
RDX	$C_3H_6N_6O_6$	8750	White powder

Table 2 shows different explosives, their composition, velocity of detonation and appearance.

Composition B is a mixture of RDX and TNT typically at a 60/40 ration. It is commonly used in military shell fillings. Comp B has a wax binder to stabilize the material.

HMX is 'also known as octogen and cyclotetramethylenetetranitramine $C_4H_8N_8O_8$ is a white, crystalline substance which appears in four different crystalline forms differing from one to another on their density and sensitivity to impact.' [3]

TNT is often used as an industry standard explosive that other explosive compositions are measured against. One of the main reasons TNT is Widley used are its handling properties. TNT is insensitive to shock and friction making it safer than more sensitive explosives.

As Table 2 shows, RDX has ta high velocity of detonation, this will shatter the case into the preformed fragments. Although RDX is good for a fragmentation bomb it cannot be cast and therefore isn't practical as a filling unless mixed with another explosive and/or binder.

Guidance and manoeuvrability

Guidance

There are several different guidance systems and sub systems available for use in bombs and missiles. The use of each system will depend on the target, range, and if the target is visible.

Guidance method	Ground to missile contact	Guidance
Fly by wire	Thin wire	Sight
Beam Rider	Follows a beam of radio waves or laser	Sight
Track via missile	TV camera mounted in nose	Sight
Active guidance	None	Radar
Pre-set Guidance	None	Radar

Table 3

Table 3 shows different guidance methods and the systems they use, each of the above needs an input from an operator, depending on what form of guidance will depend on the operator.

Manual command to line of sight is fully operator based with the operator tracking the missile by eye and guiding it to its intended target. This method relies on the target being visible to the operator with no blocks such as roads or mountains. Track via missile is also fully operator based with the operator watching a monitor to guide the missile rather than the missile itself.

Semi-automatic guidance systems require some operator input. Depending on the system it will vary as to what input is required. Some systems require the target to be tracked, others require the missile to be tracked.

Fully automatic guidance systems mean the missile will track the target and manoeuvre itself to follow the target. This can include following a pre-programmed flight path or receiving instructions via radio waves.

Radar homing systems can be automatic, semi-automatic or passive. With semi-automatic radar guidance, a powerful radar is used to find the target and this radar is then used to track the target. With automatic guidance the radar in the missile will be smaller and could therefore be less accurate. Passive homing is typically used as an anti-aircraft device as it uses an infrared seeker to track the heat given off by the jet engine.

Satellites can be used to guide bombs to the intended target. Just as a car GPS will guide the vehicle to its destination a GPS in a munition will do so in the same way. The bomb will be told its target through the umbilical cord attached to the aircraft. During the launch sequence the bomb will acquire satellites and know its exact location before being dropped over the target.

Manoeuvrability

The ability for the bomb to hit the target depends on its ability to manoeuvre to hit the intended target. If the munition has no way of manoeuvring itself, it is known as a freefall bomb.

One way of manoeuvring is via the use of fins, the fins move in the same way aeroplane wings move to alter the course of a plane. The fins can be moved via motors and actuators electronically, or via pressure actuators with the pressure coming from an internal gas bottle or gas generator.

Small thrust motors can be incorporated into the case of the munition. If required these motors can be burnt to change the course of the bomb. As these are small rocket motors they can only be used once so if another course adjustment is required the bomb will miss its target.

Safety and arming unit

Ensuring the weapon is safe until it reaches its target is the job of the safety and arming unit, a they key requirements of the SAU are:

- 'Be extremely robust against hazards and environments in storage or flight before use
- Maintain and control safety until it is safe to arm the weapon
- Discriminate the target accurately in the presence of countermeasures and clutter
- Use sophisticated algorithms to optimise the effectiveness of small modern warheads, to accurately defeat targets with minimal collateral damage.' [4]

There are many different parts to the SAU and within each part there are different ways it can operate.

There are many safety features built into SAU's to ensure that until the bomb is ready to detonate it is in a safe state. Many SAU's will require several conditions to be met before the weapon is armed. These conditions could be:

- Pressure
- Distance
- Time
- Vibration
- Remote authorisation
- Disconnection of umbilical
- Centrifugal force

These conditions are met using various sensors, transducers and other components such as springs, and clockwork escapements. The following images show different safety and arming units.

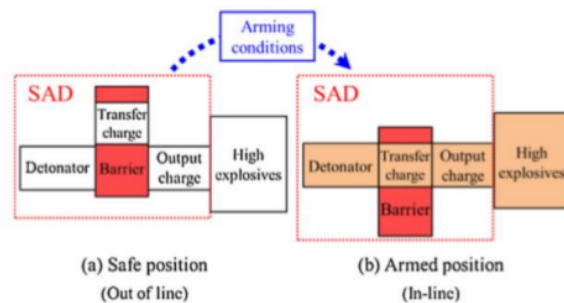


Figure 1 Shows how a SAU keeps the munition safe until ready to fire [8]

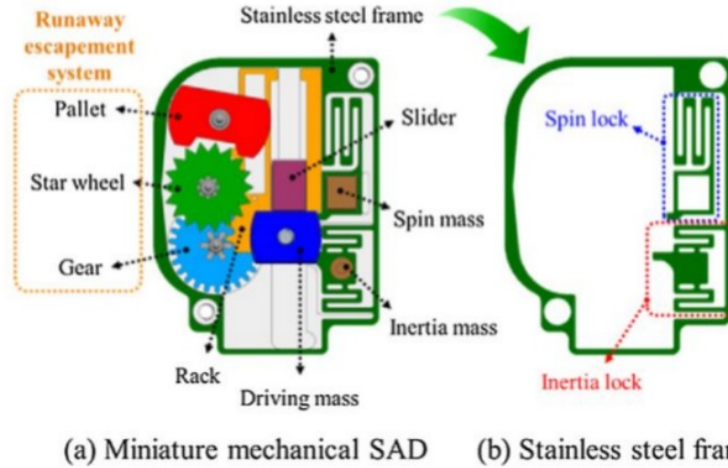


Figure 2 show a escapement based SAU [8]

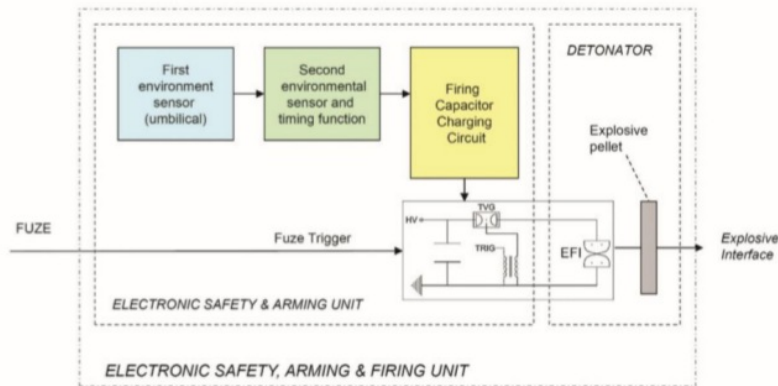


Figure 3 shows the conditions that need to be met in an SAU [11]

Once the SAU has met its requirements the fuse will detonate the explosive fill. There are different types of fuse and the fuse used will depend on the intended target. Impact fuses do as the name suggests and detonate on impact with a solid object. Proximity fuses detonate when a specified distance from the target and can use reflected radio waves to gauge distance. Airburst fuses detonate at a specific height set before firing and give detonation in air rather than in the target. Some fuses have delays fitted, when the Weapon reaches its intended target and fires a mechanical or chemical delay can be used to start the fire train to the main fill.

Test program

To ensure the weapon is safe several tests will need to be carried out. STANAG 4170 [5] is the NATO methodology for the qualification of explosive materials for military use and details all of the tests that must be passed.

Small scale testing

Small scale tests are used to test the explosive and certify it for use. Appendix 1 shows the tests required under Stanag 4170, the tests include, impact, friction, ignition temperature among other tests. Figure 4 shows how a spark test is conducted.

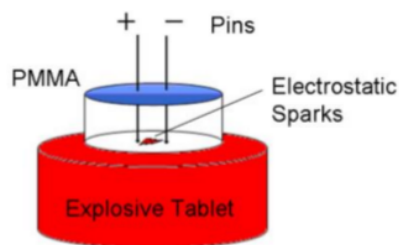


Figure 4 shows how an ESD spark test is carried out [10]

Transport testing

Tests to ensure the bomb is safe in service include a fire test. This test is designed to emulate a fire around the weapon. Often set up as a fuel fire as this is the most likely fire the weapon will encounter, the weapon is suspended under a mock aircraft and aviation fuel poured over and around and ignited. Another test to ensure the munition is safe is a drop test. The bomb is armed and dropped from a set height to ensure that the device does not function. This height will be determined by the highest the weapon will be lifted during its lifecycle; this height will also include a safety factor.

Transport safety tests ensure that if there were an accident during transport the munition wouldn't function. The tests depend on transportation methods. Some emulate a lorry crash at motorway speeds, this ensures that the public would be safe should the lorry crash. If the bomb is to be transported by rail the bomb must be able to withstand a rail crash.

Full scale testing

Full scale testing involves the testing of all weapon components. These tests verify and validate that the bomb functions as intended. These tests can include static detonations to check the explosive and shrapnel case function as intended. The bomb will be placed in a test pit with witness screens placed 360° around the bomb at various intervals. These screens are inspected to see the damage caused, the inspection will check for size of the fragments and how far they travel. High speed cameras will also be used to view how the fragments travel.

Air tests will test the bombs guidance system and see how the bomb falls in real life. These tests are expensive as they use a real aircraft to drop the bomb. Because of this only a small number of air tests are carried out. The bomb may be filled with an inert simulant, so it doesn't explode on reaching the target. This enables the CEP (circular error or probability) to be calculated. The CEP is how accurate the bomb is at hitting its intended target.

Post Procurement

Once the bomb has been handed over to the user it becomes their responsibility to handle and store the munition correctly. The munition must be stored in accordance with Defence code of practice In-Service and Operational Safety Management of OME [6], this details regulations and licencing of OME.

As the bomb contains high explosives it must be transported and stored in line with government regulations. For transportation this mean following ADR guidelines and ensuring drivers are trained as such. The bomb must be stored in an appropriately licenced building.

Conclusion

From the customer requirements and design ideas the following design items will be incorporated into the bomb.

The case will be manufactured from Iridium. The case will be produced by 3D printing using a laser sintering printer. This use of 3D printing enables a material that cannot be machined as a normal metal to be used in a weapon. The 3D printer will print different sized score marks into case producing different sized fragments. It will provide a near net component with just a small amount of material removed to finish the outside of the case. The material has also been chosen because it is very dense and brittle, these properties will enable the case to shatter on detonation and create the different sized fragments. These different sizes will fly at different velocity's and therefore cause more damage.

RDX has been chosen as the explosive fill for the bomb. Although RDX isn't a castable explosive it can be mixed with a binder and pressed into the shell to give a good fill. The VOD of RDX is 8750 m/s this will shatter the case immediately and produce a large blast wave adding to the damage caused by the primary fragmentation. It will also produce secondary fragmentation from building materials such as concrete and glass.

A fully automatic guidance system will be used on this bomb. As the intended target is a building tracking of the target is not necessary as it would be with a ship or other moving target such as enemy camp. The bomb will be given its intended target through the umbilical cord connected to the aircraft.

Once released from the aircraft the umbilical will disconnect starting the arming process. This will be the first condition met to arm the weapon. The next condition will be an escapement-based safety feature that after a set period will arm the bomb. When the bomb hits its target and penetrates the first wall this will active a delay fuse that will detonate after a set period.

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Stanag 4170 [5]

STANAG 4170
(Edition 3)

[illegible]

Principles of OME G.Goddard

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

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GRADING FORM: SMU GENERIC_GJ

RESEARCH-INFORMED LITERATURE



Good balance of munition, explosive and regulatory references

7

KNOWLEDGE AND UNDERSTANDING



Knowledge is accurate with a good understanding of the field of study. In order to get higher marks the knowledge he has needs converting into the so what factor. He understands the importance of the VOD but needs to spell it out for the reader

17.1

ANALYSIS



good attempt at using systems engineering techniques i.e. function requirements and potential solutions and consequences of failure.

19.5

PRACTICAL APPLICATION AND DEP.



Use of systems tools is good but needs to follow through on the argument the case for higher density fragments was well made but the "so what" needed a little more emphasis

13

SKILLS FOR PROFESSIONAL PRAC.



Can communicate well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

6.5