

# JDM Principles of OME

*by* Joseph McNicholas

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## Principles of OME – YEAR 2

Design of an air dropped munition to destroy hardened military buildings.

# BY JOSEPH MCNICHOLAS

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## Introduction

### 1 User Requirements and possible ways of meeting them

A requirement has been set down by the user for an air to ground munition to attack reinforced buildings. The author will look at potential user requirements below. The main requirements from the user would be method of delivery, guidance system, blast effect and ease of transport and storage.

#### 1.1 Method of Delivery

Any air to ground weapon would have to be compatible with an in-service aircraft. Currently the only suitable aircraft in service with the RAF is the Eurofighter typhoon. The airbus website states that the Eurofighter currently has a total of 13 hardpoints for mounting weapons [1]. The Eurofighter is already equipped to carry air to surface weapons such as laser guided bombs, laser designator pod, "beyond visual range anti air missile" (BVRAAM) and storm shadow missile [2].

#### 1.2 Guidance system

There are two potential methods of delivery via the air. These are freefalling bombs or guided bombs or missiles. While the author has considered using a free falling or even guided bomb, this may place the delivery aircraft in range of potential enemy anti air threat. This could be mitigated by a higher-flying altitude, though this would still be nullified by an enemy with advanced anti air capabilities. While a missile can be used in a standoff role with the aircraft not having to come into range of any defences.

The option for laser guidance via an additional laser pod or via a ground team or unmanned aerial vehicle could be considered. The location could be found by reconnaissance mission pre strike. Without a guidance system the weapon would become "dumb", unable to be controlled and would require extreme precision to hit the target which would put the aircraft and pilot in danger.

#### 1.3 Blast Effect

The customer stated that the intended effect of the weapon is the destruction of lightly reinforced buildings. This would mean that the weapon would penetrate the building and then detonate destroying the building from within. This would require a two-stage warhead, with the first stage penetrating the building and the next detonating within causing the destruction of the building. A standoff missile does currently exist in the Storm shadow missile. UK Defence Journal describes the missile as having a 550km range and a weight of 1300kg [3]. If the missile is unable to penetrate the building then it may not destroy the building and its contents. The penetrating effect is achieved by the first warhead containing a shaped charge to penetrate soil, concrete or armour [4] this is also known as a BROACH warhead or "Bomb Royal Ordnance Augmented Charge" [5]. The main charge itself must be able to cause enough damage to severely damage or completely destroy the structure from the inside, meaning that the munition has to produce a significant overpressure (blast wave). Given the nature of the target the blast wave would need to last a significant time and should not be too brief [6],. This could be achieved by using aluminium in the explosive composition to increase the energy and blast wave of the explosive composition [7].

## 2 Design

### 2.1 Method of functioning

Should a missile be chosen, then a penetrating charge and main charge are required. Before use the missile will have the GPS coordinates of the target building input into the guidance computer onboard, this information will be gathered via special forces on the ground or UAV / satellite. Once airborne the aircraft will manoeuvre into firing range while maintaining distance from potential anti-aircraft defences. It is important to note that the munition will have a GPS connection with the aircraft until firing to make use of a dead reckoning feature. Safety and arming devices are a key part of the munition that ensures the detonator cannot ignite the next charge in the explosive train, only functioning intentionally [8]. Firing will begin by an electric signal being sent to the detonator in the warhead and this will ignite the booster charge propelling the missile. Once fired the missile will begin closing to the target at high altitude before diving into the target. Upon reaching the target the shaped charge will activate before hitting the target to break through, this will require a proximity fuse to enable the shaped charge to detonate and form the penetrating jet which will strike the outer shell of the building. Once penetrated the main charge will enter the breach utilising a delayed fuse and detonate, destroying the target. If a guided bomb is to be used, there the bomb will be guided down using GOLIS (mentioned below) and fins before penetrating the target with sheer kinetic force.

### 2.2 Components

The United States general accounting office gives four major components for a cruise missile these being "a propulsion system, a guidance and control system, an airframe and a payload" [9]. The proposed missile would also need a shaped charge warhead to allow the munition to penetrate the building or bunker it is being fired at, and a safing and arming device to ensure the firing of the munition goes as planned. Two fuses would be required for each charge, a proximity fuse for the shaped charge component and a delayed fuse for the main charge.

#### 2.2.1 Guidance System

With regards to the type of guidance Deshpande et al conducted a literature survey describing two categories "Go-Onto-Target" (GOT) and "Go-Onto-Location-In-Space" (GOLIS), "A GOT missile has ability to target on either a moving or a fixed target, whereas a GOLIS weapon has the ability to target a stationary or a near-stationary target" [10]. Given the user requirement for the target being a building, a GOLIS system was considered practical by the author. Adams et al describes this system as a self-contained guidance system and breaks it down into three categories as seen in **Error!**

**Reference source not found..** [11]. Considering the information in the table below, the author believes that the best way to proceed would be to use a fully autonomous guidance system whereby the target location is already known. According to Critchley, an inertial navigation system is a navigational system which determines current location based on last known location, using "dead reckoning" a process which takes the last known position and adds data to it. This data is taken from gyroscopes and motion sensors and turned into a movement [12].

| GOLIS Category                  | Method of operation                                                                                   |
|---------------------------------|-------------------------------------------------------------------------------------------------------|
| Fully Autonomous                | Pre-set target coordinates and inertial guidance                                                      |
| Dependent on natural sources    | Inertial guidance and sensor information from magnetic, celestial or terrestrial sources              |
| Dependent on artificial sources | Inertial guidance and sensors that can gather positional information from manmade sources such as GPS |

Table 1 - GOLIS categories and their method of operation [11]

### 2.2.2 Propulsion system

The Missile Defence Advocacy Alliance notes that different methods of propulsion determine the speed of the missile, this can be seen in . The advantage of a faster missile would be less time to track and intercept the missile before it can hit the target, some subsonic missiles can also make use of a booster for initial or terminal phase supersonic speed [13]. The MDAA also state that the benefits of a high-flying missile are decreased fuel use due to the higher altitude but that it is easier seen on radar, the reverse is true for a low altitude missile. The Brahmos missile website gives a

| Subsonic | Supersonic / Hypersonic |
|----------|-------------------------|
| Turbofan | Ramjet                  |
| Turbojet | Scramjet                |

Table 2 - Speed of propulsion and their associated jet technology

comparison between two different types of supersonic technology. Both technologies achieve the compression intake using the speed of the aircraft, fuel is injected, ignited and accelerates the air to higher speeds than that at the

inlet, the difference between the two is that a scramjet maintains the speed of the air at supersonic levels throughout the system [14]. The author has concluded that a ramjet is superior as it does not require the moving parts of subsonic propulsion or the mechanisms to cope with flame stability and fuel – air mixing required by scramjet missiles [15]. Segal also mentions that ramjets require extra propulsion for take-off. This is a rocket take off utilising a composite propellant, Akhavan mentions small grains of this propellant would give an impulse of between “2400 – 2600 N s kg<sup>-1</sup>” for short thrust [16]. This would detach the munition from the aircraft and allow the ramjet propulsion to function.

### 2.2.3 Warheads

Given the method of delivery, the author has decided on a two-charge system similar to the BROACH warhead.

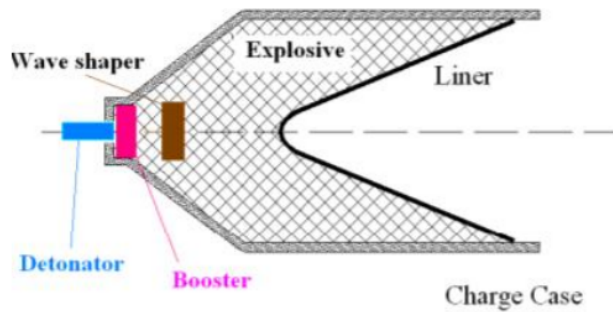


Figure 1- Diagram of a shaped charge [32]

A diagram of a shaped charge is seen in **Error! Reference source not found..** The liner is made from copper or aluminium, upon detonation a detonation wave sweeps moves forward and strikes the liner at its apex and begins to collapse it forming a high velocity molten jet of the material followed by a slug of the material. The depth of penetration depends on five factors; length of jet, density of target material, hardness of target

material, density of the jet, and precision of the jet [17].

The length of the jet is critical as the longer the jet the greater the penetration. The precision and density of the jet formed is dependent on the material used for the liner and the explosive charge composition. Akhavan states that when "dimensional stability, uniformity and high density are essential to the performance of the fabricated explosive composition" the explosive used to propel the metal cone must therefore be capable of being pressed [18]. This can be a RDX or HMX composition, Humphreys gives one formulation as HMX desensitized by TNT or polymer in a 75/25 ratio. Ahmed and Malik give a formula for calculating how the design of a shaped charge should work as " $D=(T+2)/5$ " with D being distance and T being thickness of target. They also go on to state that to achieve maximum penetration at short stand off distance would be a copper liner [19].

The main charge would immediately follow and would destroy the building from the inside. The Geneva International Centre for Humanitarian Demining produced a report on explosive weapons effects, with one aspect looking at the in service Mk82 free falling bomb which contains an explosive fill weight of 89kg. The study goes on to say that within a 31m radius of this bomb all heavily built concrete structures will be severely damaged and at 31m overpressure is 34KPa [20]. Also taken from this study is a table detailing overpressure and effects on structures (Figure 2).

| PEAK OVERPRESSURE | MAXIMUM WIND SPEED | EFFECTS ON STRUCTURES                                                              | EFFECTS ON THE HUMAN BODY <sup>45</sup>           |
|-------------------|--------------------|------------------------------------------------------------------------------------|---------------------------------------------------|
| 7 kPa             | 17 m/s             | Window glass shatters                                                              | Light injuries from fragments occur               |
| 14 kPa            | 31 m/s             | Moderate damage to houses (windows and doors blown out and severe damage to roofs) | People injured by flying glass and debris         |
| 21 kPa            | 46 m/s             | Residential structures collapse                                                    | Serious injuries are common, fatalities may occur |
| 34.5 kPa          | 73 m/s             | Most buildings collapse                                                            | Injuries are universal, fatalities are widespread |
| 69 kPa            | 131 m/s            | Reinforced concrete buildings are severely damaged or demolished                   | Most people are killed                            |
| 138 kPa           | 224 m/s            | Heavily built concrete buildings are severely damaged or demolished                | Fatalities approach 100%                          |

Figure 2 - Table showing Overpressure and windspeed v effects on structures [6]

A more in depth look at the Mk82 bomb from the GICHD mentions that the two types of filling for the Mk82 bomb are "Composition H6 – RDX/ TNT aluminium and calcium chloride or Tritonal a 80 / 20 TNT / Aluminium mix" [21]. Akhavan states that HMX has a greater performance than RDX as an explosive with a higher density, chemical stability and melting temperature than RDX but it can be much more expensive to produce [22]. This is echoed by a table given by Humphreys seen in Figure 3, [23]. The author would like to note that a composition of HMX / RDX and aluminium would make an ideal explosive filling when mixed with a polymeric binder such as "hydroxyterminatedpolybutadiene (HTPB) or Viton" to make it a Polymer Bonded Explosive, which Humphreys accepts as being thermally stable and suitable for casting into a casing [23].

In conclusion, the author believes the main charge should consist of an RDX/HMX Aluminium filler at 70-95% with a polymeric binder at 5-30%, the weight of which can be at least 89kg to simulate the effect of the proven Mk82 bomb which has proven effectiveness.

| Explosive | Ign Temp (°C) | Fol | VoD (ms <sup>-1</sup> ) | Power Index | Det Pressure (kbar) |
|-----------|---------------|-----|-------------------------|-------------|---------------------|
| NG        | 188           | 30  | 7700                    | 170         | 253                 |
| PETN      | 205           | 50  | 8400                    | 167         | 300                 |
| TNT       | 240           | 150 | 6900                    | 116         | 210                 |
| RDX       | 213           | 80  | 8750                    | 169         | 338                 |
| HMX       | 300           | 60  | 9400                    | 169         | 390                 |
| TATB      | 359           | 200 | 7350                    | 101         | 291                 |

Figure 3 - Table showing High explosives and their characteristics

## 2.2.4 Safety and Arming Device

The missile will need a safety and arming device to ensure that it is only activated when intended. First the missile is fired by an electric signal activating a primary explosive which will set off a rocket booster, it is this rocket booster that will enable the ramjet propulsion to work. A patent by Raech

and Cardle sets out an idea for a safety wheel in between the booster and the detonator which has a hole in the wheel. When the missile is to be armed, the wheel is rotated so the detonator can come into contact with the booster [24], with one electric signal both the detonator and the wheel can be activated to initiate the rocket booster. The cable which feeds the missile its current position is also used as the arming switch, a patent from Coleman and Fenska describes this method of S&A. The wire when pulled free from the missile arms it [25]. It is the removal of the wire that will form stage one of the arming procedure. The second part of the arming procedure will be an acceleration sensing device, which must sense horizontal acceleration of a specified G force before arming the main charge of the missile [26]. This can be done by generating enough momentum to push back a "g weight" which holding part of the explosive train away from the rest. As this is pushed back to the correct level, a pin is pushed into an indent in the g weight holding it in position. The shaped charge will be activated by a proximity fuse set at an optimal distance.

#### 2.2.5 Airframe

The airframe of the missile will be designed to fit all of the components mentioned above as well as incorporating a design allowing maximum air intake to allow the ramjet to work. In addition, the missile must be able to withstand the stresses of the high speeds likely encountered during flight.

### 3 Test programme and trials

#### 3.1 Guidance system

Before being implemented into a fully working missile system it would be ideal if the guidance system were simulated first saving money on developing an untested guidance system [27]. Simulations can be run many times to check for errors or problems that may arise infrequently. Once satisfied with the simulations then a physical model can be built and implemented into a missile without a warhead.

#### 3.2 Propulsion System

The missile propulsion at first will have all of its individual components tested under different conditions to ensure robustness in the system. This will include the initial rocket booster component and then the ramjet assembly. Once tested individually they can be tested as a whole and then as a dummy missile without the warhead to make sure the propulsion can convey the missile to the target.

#### 3.3 Warheads

The two different warheads will need their own evaluation to make sure they each perform the intended function. The shaped charge should be tested against differing materials of different thicknesses to see when penetration of reinforced buildings occurs. Also, the width of the hole will need to be considered as the main charge has to go through the hole created by the shaped charge. The tests done on the main charge will be to see if it can enter the hole created by the shaped charge and then cause the damage specified by the customer. As these are the most dangerous parts of the missile, safety tests will be done on the components such as drop tests and environmental tests to ensure that the munition will be safe to store. In addition to this, tests will be done on all components in "reliability, maintainability, supportability, transportability, compatibility and adequacy of proposed training procedures" [28].

#### 3.4 Safety and Arming device

Sauerlaender mentions that to achieve low risk it is necessary to use as few parts as possible and that the "safety criterion as derived from MIL-STD 1316 and STANAG 4187 is as follows: The risk of

premature arming must not exceed one in a million” [29]. Each mechanism will need to be extensively tested to ensure that they meet the above standards. This will require multiple simulations and tests to look for any faults that may occur, such as parts wearing down or a mechanism failing to work or a short circuit.

### 3.5 Overall

Once all components have been tested and have proven satisfactory in their functions in the overall mission of the munition, full tests will be done on the fully assembled missile such as safety tests, environmental tests and operational testing. This will be done to make sure that the munition meets the customer requirement every time it is used. Once the missile has completed initial testing storage tests must be undertaken to determine the conditions the munition can kept in and for how long.

## 4 User guidelines

Given the different materials in the missile it is necessary to store them in an area with constant temperature and humidity. This would ensure that slight variations do not make parts defective and prolong the more intricate or sensitive components of the munition. The department of defence describes buildings the US Navy uses to store missiles as “rectangular, earth-covered concrete magazines”, “special door sizes and interior column spacing to facilitate storage and handling of assembled missiles” [30]. Some general handling and safety requirements for missiles are listed by global security such as using only authorised handling equipment and tools specific to the missile and inspecting any safety devices to ensure they are in the safe position [31].

## 5 Summary

|                            | Type of munition | Guidance System                                             | Charges                                                                                                                                                   | Safety and Arming device                                                                                                   | Propulsion system                                         |
|----------------------------|------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Types</b>               | Missile          | GOLIS                                                       | <ul style="list-style-type: none"> <li>Breaching Warhead (Shaped Charge)</li> <li>Main Charge</li> </ul>                                                  | 2 Stage<br>1. GPS Wire removal<br>2. G Inertia                                                                             | Ramjet with Rocket Boost                                  |
| <b>Further Information</b> | Standoff weapon  | INS dead reckoning system with known GPS location of target | <ul style="list-style-type: none"> <li>Breaching charge – 75/25 HMX/TNT mixture</li> <li>Main Charge – 70/30 HMX/Aluminium to Polymeric binder</li> </ul> | 1. GPS feed wire ignites rocket boost<br>2. As speed increases G force moves the rest of the explosive train into position | Rocket boost component – small grain composite propellant |

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# JDM Principles of OME

## GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

**Instructor**

69/100

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GRADING FORM: SMU GENERIC\_GJ

JOSEPH MCNICHOLAS

68.50

## RESEARCH-INFORMED LITERATURE



Comprehensive range of technical publications and documents cited. Few regulatory examples  
STANAG? JSP 428?

**6.6**

## KNOWLEDGE AND UNDERSTANDING



"Knowledge is extensive. Exhibits understanding of the breadth and depth of established views. Design discussion is logical citing references at appropriate stages. Studies have accurately included elements not yet disseminated in the course. (HTPB binder systems and PBXs)"

**20.7**

## ANALYSIS



"Thoroughly logical work, supported by evaluated evidence. Work has explored regions beyond that which has been taught. A shame the test regime was not explored in further detail. "

**21**

## PRACTICAL APPLICATION AND DEP.



"Comments on the test regime are limited though simulations to explore the design concepts are proposed. Use of systems engineering tools such as FMEA and the examination of noises and controls would have made this good piece of work excellent"

**13**

## SKILLS FOR PROFESSIONAL PRAC.



Can communicate professionally and, confidently in a suitable format.

**7.2**