

OME Joshua Martin

by Joshua Martin

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Principles of OME

GUIDED WEAPON DESIGN & DEVELOPMENT
JOSHUA MARTIN | 1810346

UWTSD | BAE Systems

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1 Introduction

The first recorded guided weapon was developed and used by the Germans in WWII; these were the V weapons. The V1 flying bomb is most comparable to a cruise missile in the present day, it had a velocity of roughly 400mph and used a magnetic compass and gyroscopic autopilot to follow a pre-determined route. The V2 is most comparable to a ballistic missile as it is a much faster weapon with a terminal velocity of 2,386mph, it was classed as the V2 rocket as it relied on rocket thrust to reach its target. It also used a gyroscopic mechanical system to guide it to the target, later they were developed to allow adjustments to its flight through radio signals however it was not very effective as it is prone to human error. In this report, the author will look at the processes required to successfully design a modern guided blast/fragmentation bomb to meet a specified purpose. The processes involved will go from initial requirements and developing the specification, through design possibilities and looking at the makeup and functions that go into a guided weapon, finished off with how the weapon should be safely stored to the end of its life. [1]

1.1 Blast & fragmentation

The performance of a weapon in this context can be classified in two ways, it can be focused on blast or fragmentation performance. For a blast weapon, the focus needs to be on the filling material, the chemical composition must create a huge amount of energy, releasing a large amount of gas into the atmosphere and sending a powerful shockwave into the target to compromise the structural integrity and bring the building down. A range of chemical mixtures and additives can be introduced to the explosive material to increase its energy such as adding aluminium, this increases the heat of the reaction, resulting in a greater blast effect. Fragmentation is more dependent on the mechanical properties of the bomb, wall thickness and material are vital, a thicker wall of the bomb will produce larger fragments, along with a material like steel. Essentially a thick steel wall would be used in a fragmentation bomb, commonly used for artillery. A thinner aluminium wall would be used for maximum blast effect in a guided weapon, the lighter aluminium body is also helpful for the purpose of flight for the missile. [2]

1.2 Delivery

Delivery of a guided weapon can be done through a range of options, tomahawk is launched from a submarine, stormshadow is launched from a Eurofighter typhoon and the BGM-109G is ground launched [3]. For this report, an air to surface weapon will be designed to be launched from the Eurofighter typhoon and F35-lightning, these aircraft are suitable as they have existing capability of carrying heavy guided weapons into enemy territory, the design of the weapon in this report must be able to fit onto the platform of these aircraft. Considering current affairs in the world, the target for the weapon is going to be a stationary structure, such as a compound that could resemble anything from a normal house to a lightly reinforced magazine/weapons cache.

1.3 Cruise missile

The key definition of a cruise missile is that it 'cruises' in flight, this means that it primarily relies on aerodynamic lift to travel through the air, this results in the engine being a small part of the all-up weapon and more space is left over for the explosive filling. The advantages of this type of weapon is that it is cheaper than a ballistic missile, can give a much greater blast effect and defeat larger targets at long range. However, it is much slower, and it uses reasonably simple technology, due to this fact it is reasonably vulnerable to defences such as jamming or interception. Cruise missiles can be put into three different classes; a strategic missile has a very long range of 2000-3000km, anti-ship missiles have a range between 50-500km, and finally a tactical land attack missile has a range of 180-600km. [3]

1.4 Ballistic missile

The key characteristic of the ballistic missile is that it is powered by thrust, it is a high-speed missile that uses rocket fuel to get to its target as fast as possible. They carry their own oxidiser, and due to the need for so much fuel, the engine takes up a large portion of the weapon [4]. The target for a ballistic missile is likely to be a faster moving target such as a light vehicle, the fact the engine also takes up so much space reduces the amount of explosives that can be used, for this reason ballistic missiles aren't suitable to take down larger structures. They are more expensive than a cruise missile as the guidance system is much more complex to ensure it can keep track of its target while travelling at such high speeds.

2 Requirements

Requirement	How to meet the requirement	Likely consequence of not meeting the requirement
The munition must be capable of avoiding terrain to reach its target	• Sensors • Radar • Manually remote controlled	The munition could encounter an obstacle and due to not being able to avoid it, it will make contact and detonate, this could result in a wasted munition, or worse case scenario, it could cause collateral damage to people or structures
The munition must have an operational range of >200km	• Aerodynamics • Height of launch • Fuel	A shorter range than requested could mean that the munition drops short and could cause collateral damage, or it could mean the user needs to position themselves further into enemy territory, putting themselves at risk.
The munition must be capable of destroying an above ground building/magazine	• Fragmentation • Blast • Delay fuse • Shaped charge • Tandem warhead • Proximity fuse • NEQ	Premature detonation outside the building would cause damage to the building, however it might not destroy it completely, failure to detonate may cause an unsafe situation for people in the future, or the risk of technology falling into enemies' hands. If it is hitting a weapons cache and does not effectively destroy it, the weapons are still able to be used by the enemy, putting innocent people's lives at risk
It must be capable of being launched from a Eurofighter typhoon when required	• Correct mounting platform • Tested release mechanism • Tested control system • Ability to withstand extreme conditions	If it is not safely mounted or released at the correct time, it may cause damage to the aircraft or unintended surroundings. If it cannot withstand the extreme temperatures and pressures that the aircraft is exposed to then it may fail to initiate when required
Components should be safe to manufacture, store and use	• Insensitive explosive filling • Compatible components • Appropriate storage conditions	Unsafe components could lead to an event during manufacture, causing harm or death to the operators, incompatible components may have accelerated degradation and make the munition unsafe to use, giving it a much shorter lifespan.

It must be capable of correcting its flight path	• Communication between operator and munition • Manoeuvrability (wings & tail)	Environmental conditions such as wind could cause the munition to fly off course, if it is not corrected, then it could cause collateral damage, or best-case scenario it is a wasted munition
It must keep civilian casualties to a minimum	• Minimal fragmentation • Precision attack • Internal blast	Civilian casualties are not acceptable, and every effort must be made to ensure this is not a possibility, if there are civilian casualties then there could be national outrage and it is morally unacceptable.

Figure 1 Requirements table

3 Design

3.1 Cruise missile

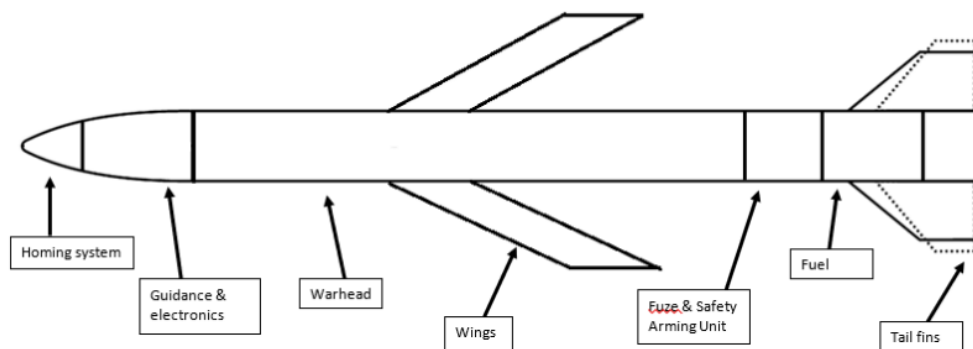


Figure 2 Cruise missile design

4 Functions

4.1 Homing system

The homing system for this missile will use radar, a small radar will be fitted into the nose cone, and when the radar detects it is within a specified distance of the target, it will communicate with the electronics package to adjust the wings and tail to gain altitude, then igniting the fuel to increase speed to come down vertically onto the target. [5]

4.2 Guidance & Electronics

The guidance of the missile will use an ACLOS system, this stands for 'Automatic Command to Line Of Sight'. There are other options for the guidance such as manual and semi-automatic however they are not suited to this purpose, this is because they require human interaction to correct the trajectory [6]. For an air launched missile, the pilot is unable to track and adjust the missile, so it will need to be done automatically. Once the missile is launched, a radar will track it and a computer will communicate back to the missile to adjust its course if necessary. Although the missile is aiming for stationary targets, the radar will help adjust the missile if the environment causes it to go off course to ensure it meets the requirements given by the customer. The disadvantage of this system is that it requires a complex computer network, and this increases the cost of the munition. [6]

4.3 Warhead

The warhead is the section that is filled with explosive, to meet the requirement of being able to destroy a building, this will not be a directed energy warhead like some missiles. This munition will utilise a conventional blast warhead, this also helps to minimise cost. The filling of the warhead could be a range of different explosives, such as TNT, RDX, HMX among others. For this munition to meet the requirement of producing a large blast effect, an explosive such as TNT will not produce an adequate effect for a large structure. This warhead will be filled with RDX, the high chemical stability will help its survivability in the extreme conditions it is subjected to during flight as an externally mounted weapon, it also has a higher explosive power than both TNT and HMX. The RDX will be combined with a wax to decrease its sensitivity and will also be mixed with aluminium particles to increase the temperature of the reaction, increasing the blast effect again [7]. The warhead itself should have a thin casing to ensure most of the explosive energy is converted into blast instead of fragmentation.

4.4 Wings

Due to the munition being a cruise missile and not a ballistic missile, it requires aerodynamic features that allow the missile to use natural lift to travel long distances. These wings are controlled by actuators in the body of the missile and shall extend once released from the aircraft as it is easier for storage and transportation if they are in the retracted position. This effect is much like the effect of a commercial aeroplane, due to this lift, the fuel required is much less than a thrust powered missile which leaves more space for the explosive filling [3]. This in turn gives a much greater blast effect.

4.5 Fuze/Safety arming unit

The fuze used in this munition will be a contact delay fuze, once the nose cone contacts the structure, a delay signal will be sent to the fuze long enough for the warhead to reach the optimal position within the structure before it detonates. This delay time can be adjusted by the user as they will know the size of the structure prior to deployment. The safety & arming unit is there to stop the warhead from initiating prematurely, similar to the pin in a grenade. In this instance, the safety & arming unit will only release once the guidance system has communicated that it is a safe distance away from the launch platform [8]. Once the safety & arming unit has released the safety mechanism, the missile is able to detonate.

4.6 Fuel

This missile will require a rocket propellant, they are similar to gun propellants, however they contain slight formulation differences to cope with the differing operational conditions. A rocket propellant is designed to burn smoothly without the risk of detonation and need to provide a sustained propulsion effect [9]. Gun propellants have an almost instantaneous ignition to provide immediate thrust to the projectile. Rocket propellants can come in liquid or solid form, in liquid form it can be a monopropellant however these generally provide enough thrust for attitude control thrusters on satellites and space probes, they have little use elsewhere. Liquid bipropellants are very powerful systems that are used to power large rockets such as space vehicle launchers, this would be overkill for a single medium sized missile [9]. The preferred method of thrust would be a solid propellant, the rate of reaction can be controlled through grain geometry, a larger surface area will produce a greater amount of thrust, but for a much shorter time. The propellant in this case is going to be initiated within a few hundred metres of the target to give a sudden increase in



Figure 3 Star grooved propellant [11]

acceleration in order to increase the penetration of the missile. This will require a fast burning propellant; the geometry should maintain the surface area while burning to give a constant thrust, a star patterned propellant would be ideal in this situation. The propellant would also need to be case bonded to prevent the flame propagating around the propellant resulting in an uncontrolled burn. [9]

4.7 Tail fins

The tail fins will perform similarly to the wings, they will be powered by actuators within the body of the missile and will adjust the trajectory when required through the guidance and electronics command system. The tail fins are not just there to adjust the flight path, but they also help with stability through flight, this will ensure that the target has the best chance of reaching its destination without having a premature collision and detonation that could cause collateral damage to civilians. [3]

5 Test programme

5.1 Environmental

A range of environmental tests need to be performed before the munitions can go into full scale production. The explosive materials themselves need to be tested for toxicity, and to ensure that any waste material is able to be disposed without damaging the environment. An accelerated aging test should also be carried out to ensure the explosives can survive the full shelf life of the material. This is done by putting the munition through a series of temperature changes and vibrational tests to simulate the lifetime of the product, once it has completed the test it must be dismantled and have each component checked to ensure there have been no failures within the product.

5.2 Performance

The performance tests referred to here will be for the lethal package and the fully assembled missile, tests on electronics and fuzing will have to be done but they are not the focus here. Firstly, a static trial will be conducted, this involves the warhead being detonated in a stationary position, excluding the missile body. This would be conducted at either Ridsdale range or COTEC. The number of products tested would be determined by the project manager to fit in with the projects budget. The next test would be a sled trial at Pendine, the sled trial will use a fully assembled missile secured to a sled on a railway. The sled will be propelled at the equivalent speed that it would experience in a real-world deployment scenario and will come into contact with a building specifically built to match the real-world requirement. This test will be done with a range of different building types, particularly of different structural strengths and angles to ensure the explosive goes off when required. The final test is the operational test, this will first be done with a number of INERT missiles with full navigational capability, this ensures that the missile can be safely released by the aircraft, and successfully reach its target. Once the project manager is happy with how the INERT missiles perform, the programme will move into live tests. As this is a long-range missile, the tests will need to be performed somewhere with large empty space to ensure if there are any problems then it doesn't put any civilians at risk. Australia is a common testing ground for a weapon like this, the missile will be released by the aircraft and should navigate itself to a pre-built target, video evidence will be captured at both the release stage and the impact stage. This will be repeated a number of times determined by the budget, once this is complete, the video evidence can be used to support the handover to the customer, stating the missile is ready for operation.

6 Handling & storage

Primarily, the handling and storage of explosives must comply with the DS03 (formerly JSP 482) regulations. To do this, the missile must first be classified as a type 1.1 explosive due to the RDX filling and stored appropriately. To store it safely and to avoid propagation of the explosive, the regulations state that adequate quantity distances between facilities need to be in place, this will be determined by the NEQ of the storage facility. In case of explosion, the damage should be limited to the one building and not spread to other buildings. Also, the building should be made from reinforced concrete, this will attenuate the blast over-pressures to levels where damage/injury should not occur [10]. This is the responsibility of both the manufacturer while the products are going through production, and the user while they are in storage waiting to be used.

7 Conclusion

This report has shown that a cruise missile is best suited to meet the requirements, and each part labelled in the design diagram has been explained to perform a particular function that supports the requirements. A ballistic missiles main priority is fast and targeted attack on moving vehicles therefore not suited to a long-distance stationary target. The cruise missile type of construction is better suited, the smaller amount of fuel means a much larger amount of space to fill with explosives, meaning it can take out a much larger structure such as a building. The cost of navigation and the aerodynamics will make it more expensive than the ballistic missile however the need to take out a structure will be reserved for a high priority target, meaning the missiles will not need to be used regularly. As stated throughout the functions section, each of the requirements have been met and the missile is considered fit for purpose, further research into guidance and homing systems would be beneficial to enhance the design of the weapon even further.

8 References

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FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: SMU GENERIC_GJ

JOSHUA
MARTIN

58.90

RESEARCH-INFORMED LITERATURE



Functioning and explosives covered well.
Environmental and regulatory factors less so.

5.9

KNOWLEDGE AND UNDERSTANDING



"Good discussion, working principles of device well understood. Needed perhaps to include some discussion on environmental and safety testing as well as performance. Errors in the understanding of the explosive molecules relative power output. Statements need substantiating.

16.5

ANALYSIS



Good demonstration of understanding of the functional requirements on the system. Design alternatives proposes.

17.4

PRACTICAL APPLICATION AND DEP.



The design method and choices were logical and well explained. Evidence of systems thinking in the description of functionally and discussion of potential solutions. A little concerned at the choice of a project manager rather than a design authority to make the design call.

11.6

SKILLS FOR PROFESSIONAL PRAC.



Report was well structured and logically presented

7.5

