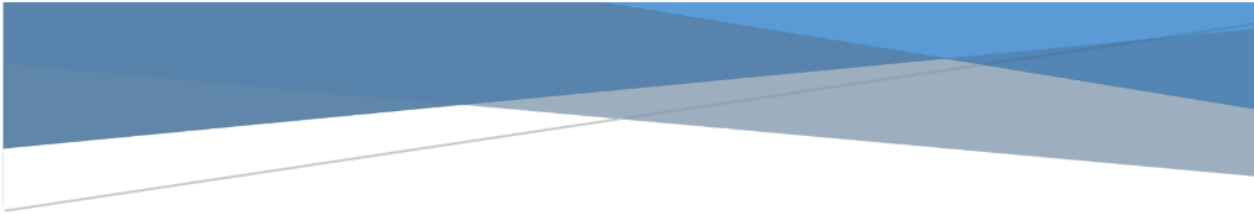


Principles of OME Assignment

Max Smith 1810364

by Max Smith

FILE	11931_MAX_SMITH_PRINCIPLES_OF_OME_ASSIGNMENT_MAX_SMITH_1810364_233318_1693446514.DOCX (2.76M)		
TIME SUBMITTED	30-JUN-2020 11:11AM (UTC+0100)	WORD COUNT	3413
SUBMISSION ID	131226149	CHARACTER COUNT	18979



PRINCIPLES OF OME

Design of a Blast Munition to take out a Specified
Target

True Word Count: 2726

Max Smith (1810364)
1810364@student.uwtsd.ac.uk

Table of Contents

1	Introduction.....	2
2	Target	Error! Bookmark not defined.
2.1	Viable Target	3
2.2	Target Structure	3
2.3	Evaluation.....	4
3	Requirements	5
3.1	Customer Requirements	5
3.2	Manufacturing Requirements	6
3.3	Risk and Safety Requirements.....	6
3.4	Performance Requirements	7
4	Weapon Specification.....	8
4.1	Technical Requirements.....	8
4.2	Appropriate Materials.....	8
4.3	Weapon Design	9
4.3.1	Detonation System.....	11
4.3.2	Booster System	11
4.3.3	Guidance System.....	11
4.3.4	Delivery System.....	11
4.4	Testing.....	11
4.5	Storage Requirements.....	12
5	Conclusion	13
5.1	Summary	13
5.2	Recommendations	13
6	Bibliography.....	14
7	Appendix.....	16
7.1	QFD.....	16
7.2	FMEA.....	17

1 Introduction

The aim of this report is to combine system's engineering and OME principles to design a high explosive device to be applied for military purpose. Utilising the various design models to ensure the best result is achieved. The military requirements are as follows:

A guided targets blast/fragmentation bomb to be delivered by specified aircraft for the attack of buildings of specified design.

In this it will go into the likely requirements desired by the user, customer, safety, engineering and design groups.

A variety of methods are to be explored as a result of multiple system processes, looking at desired materials and properties, exploring the possible or likely failure mechanisms that could be met and finding ways to mitigate these potential problems.

A test process has been devised to ensure the device meets acceptable safety standards and is compliant in a regulatory sense.

A brief product life cycle has been looked at to determine how the device handles over its shelf life.

To discuss the processes that that should be undertaken to achieve a successful design of a high explosive device as an example of general procedures applicable to reliable procurement.

Military requirement has been raised for:

- *A guided targets blast/fragmentation bomb to be delivered by specified aircraft for the attack of buildings of specified design.*
1. *List the likely requirements to be included by the User in the procurement specification, how they can best be met, and the likely consequence of not meeting them in the design.*
 2. *List and discuss ways in which the designer could meet those requirements.*
 3. *Propose designs describing the method of functioning, the components of the system, the desired properties of the materials, and likely failure mechanisms and ways of mitigating them.*
 4. *Describe a test programme to demonstrate the overall suitability of the proposed design and to identify and assess likely hazards.*
 5. *Describe the User's role in post-procurement handling and storage of the munitions.*

2 Target

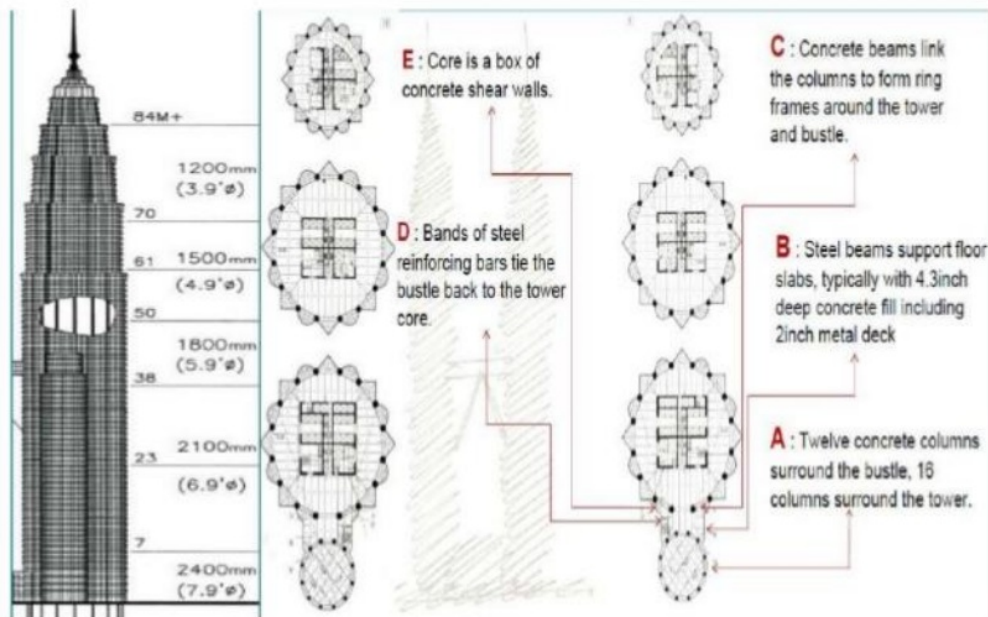
The intended target is for assignment use only, this is not a planned or target to be acted on.

2.1 Viable Target

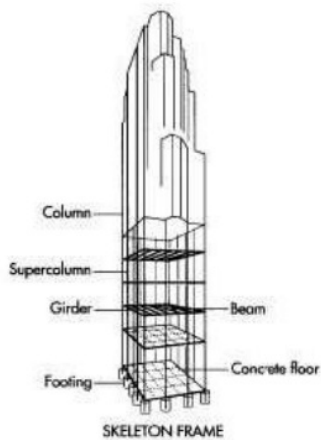
The military target for this assignment is the Petronas Twin Towers based in Kuala Lumpur, Malaysia. Petronas Twin Towers represent the commercial and cultural achievement made by the Malaysians in the late 1990's and held the title of world's tallest building for six years before being trumped by Taipei 101. The target was selected to cripple the oil/petrol industry in the country, dealing a massive financial blow and demoralising the country.

2.2 Target Structure

PETRONAS TOWER, KUALA LUMPUR



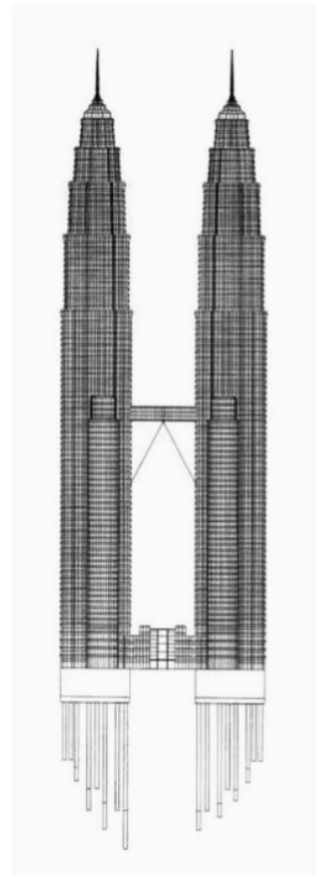
[1]. Each tower is identical, consisting of 88 stories with a pyramid shaped pinnacle surmounted by a slender spire. Each building is supported by 16 large columns, which along with the rest of the frame is made from high strength, steel reinforced concrete. The cladding is made from Type 316 Stainless Steel which is of ferrous nature. The structure has an approximate weight of 600,000 tonnes. The towers due to the sheer size, require strong foundations, the Petronas Twin Towers' foundations go to a depth of 120m in the ground, beneath the building's initial footings.



2.3 Evaluation

The foundational and structural integrity of the building means a high level of energy would need to be released in order to bring down the structure. The building is in a highly populated area which could lead to a mass loss of populous. The Petronas Twin

Towers each have an anchor which runs down the centre of the towers, this is to protect against wind and typical ground movements. Due to this, a typical blast bomb would not achieve the full effect on detonation with a chance of failure as the anchors could counteract the movement. [1] [2]



3 Requirements

Failure to meet the requirements could lead to failure to secure licencing to manufacture from the regulatory bodies, legal action and/or loss of life.

3.1 Customer Requirements

Components are to be proved out to 99.9%, with critical safety related components being proved out to 99.99%. Qualification or prove out of components is normally achieved through tests, however analysis may be acceptable. Typical component design for qualification would undergo the following tests:

Temperature Variation (High/Low), components are put at both maximum (+70°C) and minimum (-40°C) operating temperatures and survivability measured.
Vibration , components to be subject to vibration sweep and random vibration, these would be representative of vibration achieved on transport via aircraft and vibration on delivery, in this case robust levels as is recommended for military applications.
Operational shock , ~6 operational shock loads and ~3 crash safety shock loads are to be applied in each direction for each major orthogonal axis.
Fluid Susceptibility, Humidity and Sand/Salt Tests , used predominantly on seals and areas where electrical devices are, to determine resistance to fluid ingress.
Icing , to determine how extreme environmental conditions or frozen moisture as result of ingress into a non-hermitically sealed compartment will affect performance or pose other potential issues.
Proof/Burst Pressure Test , to prove out seals, material and design integrity.
Endurance , components put into an environmental test chamber to simulate the life cycle of the components, undergoing shake, rattle and roll etc.
Fatigue durability , using a realistic load spectrum, the components undergo the same testing of endurance, but for ~4 life cycles as opposed to 1. This will simulate how the components will age over time.
Pressure Impulse testing , demonstrating the seal and structural integrity of the component.
Radiofrequency (RF) susceptibility , to determine any electrical equipment/component response to RF threats.

Functional tests are to be carried out throughout, ensuring critical performance criteria is met. Additional testing may be required, though typically any problems will be highlighted in the above tests [2]. It is common practice to use a single component for environmental qualification, opposed to multiple components, as in service the same component would have to undergo all the environmental conditions. Should multiple components be used, there is the potential for flaws not to be exposed [3].

Materials used must be relatively insensitive, so that self-arming won't occur. The materials must have minimal hygroscopicity as to not introduce moisture into the system or compound from manufacture to point of use. Sulphur and/or phosphorus chlorates are prohibited unless approved by HSE. Combustible

and/or oxidising materials must be stored separate until required for manufacture/assembly. All materials and/or unit should be containerised until required for use.

The unit once assembled must be compatible with a B-2 Spirit and must not exceed a weight of 15 tonnes. The B-2 Spirit can accommodate a multitude of fixings to support and utilise weapons.

The build of the unit must ensure that it does not prematurely detonate. A time delay of up to 60 minutes must be achievable to enable civilian evacuation (if required).

Post procurement handling and storage must be considered through PLM. On decommissioning, some units are to undergo surveillance disassembly, this will ensure/determine if ageing has occurred as expected. All builds and disassembly's will be accompanied with a BOM listing and configuration sheet so that full traceability and history of components occurs.

3.2 Manufacturing Requirements

Resources are not to be spent on bespoke materials, with most materials being commercially available. The manufacture process must not generate excess waste which is irrecoverable.

Certification of material is to be received on receipt from the supplier, alternatively, the material must undergo the testing as mentioned in 3.1. Problem material must be quarantined pending replacement from the supplier. Sample material that is manufactured will be tested in accordance with Health and Safety guidelines. This may include thermal characterisation through use of differential scanning calorimetry (DSC), impact and friction tests.

Test	Method
DSC	A small sample is heated at a constant rate with the flame being monitored in an inert atmosphere.
Impact	The sample will be subject to insult from impact using a standardised falling weight.
Friction	The use of a standardised ceramic pin and plate on a small sample.

[4]

The process for manufacturing must, where possible be altered to reduce the generation of waste explosives and other hazardous substances. Where not possible, all explosive waste must be dealt with in accordance with the Explosive Regulations 2014 [5]. To remove the introduction of hazards to the public, the waste material is to be disposed of in a controlled manner on site. The method of disposal will be dependent on the explosive material used. The main methods of disposal are, Burning; Detonation; Dissolving/Dilution by solvent; Chemical Destruction or Functioning in the design mode. A combination of these methods can be used. Burial or sea dumping of explosives is not a safe method of disposal and would introduce hazards in the environment and to animal life. [6]

3.3 Risk and Safety Requirements

For most explosives products, a shelf life of one year is recommended, although satisfactory performance can be expected from most products two, three, and even four years later. [7]. For safety purposes shelf life from certification will be set to 1 year. The service life of the entire unit will be set to 25 years as a maximum; however, units are to be swapped out every 20 years.

On use the bomb must have minimal environment impact. Equally on manufacture, materials and chemicals used must not have an adverse effect on the personnel involved. Fluorine cannot be used at

any point in the process, nor be a by-product of use. Materials and chemicals used that are hazardous, must have controls and engineered preventative measures in place to protect people and the environment.

All buildings and transport associated with the storage, manufacture and testing of explosive articles must comply with ESTC No.6, ensuring that all equipment and facilities are in an acceptable state for operation. [8]

On storage, manufacture and completion, items must be kept within humidity and temperature-controlled environments. Higher humidity reduces the likelihood of ESD occurrence, equally temperature reduces the likelihood of materials being adversely affected by moisture ingress. Storage of explosive articles must comply with the Explosive Regulations 2014 and HSE Guidelines. Contingency/emergency plans must be developed and implemented in accordance with COMAH 2015. [9]

On transport, to protect against insult by vibration, the outer transit container is to be equipped with internal shock absorbers to protect the inner transit container from receiving excess stimuli.

When decommissioning explosive articles, the cost and environmental impact is generally very high, with one method being incineration with a sophisticated gas treatment. Methods like this are limited due to capacity and energy requirements. BS8001:2007 looks at valorising energetic material, which reuses military material for civil application. This reduces environmental impact across all areas and displaces production requirement for civil energetic material [10]. On disassembly or decommissioning where possible, reapplication of energetic material is to be taken.

3.4 Performance Requirements

The energy within the explosive material will need to release rapidly upon detonation at the intended target, with the energy released only on demand.

On function the munition must create enough blast energy to send a shockwave through the ground destroying the foundations and produce enough heat energy to create a cavity beneath the surface.

Whilst the velocity of the bomb will be gained predominantly by gravity due to the height of delivery, a rocket propulsion compound will be necessary to aid ground penetration. Due to delivery height, the munition must be able to stabilise in-flight to strike the designated target.

An arming delay is necessary so that the bomb does not prematurely detonate before reaching the target foundations, additionally it would potentially reduce civilian casualties, enabling people to evacuate the area.

The munition must remain safe against accidental functioning due to impact and excessive temperature insult.

On storage the sealed volume must not emit any hazardous gases, and on function must not release products unacceptable to the environment.

Due to advancements in aviation technology, it's possible to refuel in-flight, making flight distance irrelevant.

4 Weapon Specification

4.1 Technical Requirements

The key technical requirements are as follows –

High energy release

Aerodynamic

Ground Penetration

Time Delay/Timed Detonation

Stabilisers

Guided to target

See sections 5.2 and 5.3. See QFD and analysis in 7.1.

4.2 Appropriate Materials

The casing is to comprise of Maraging Steel alloyed with tungsten. Maraging Steel, typically steel and nickel has low carbon content and is extremely strong. Tungsten is a rare metal, so using it singularly for the case would increase the cost. It is very high in tensile strength and melting point; and has the lowest coefficient of thermal expansion. By alloying tungsten with the Maraging Steel, the casing is more likely to protect the inners from external heat flux and provide sufficient hardness/strength when penetrating the ground. [11]

The casing tip is to be made of graphite, graphite whilst soft has high heat resistance and won't deform at very high temperatures. This would protect any electrical or guidance equipment.

To produce the required energy, the explosive compound will be a mixture of PETN, RDX and aluminium, which are commercially available.

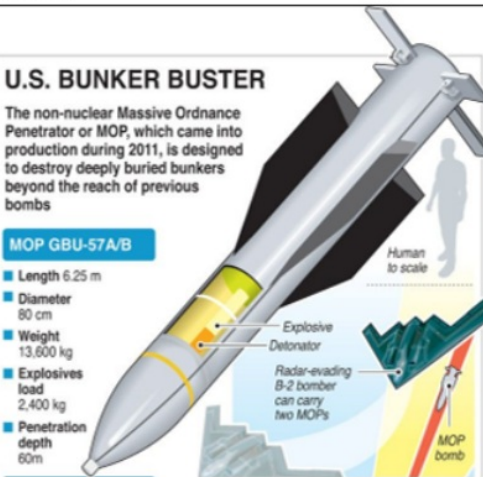
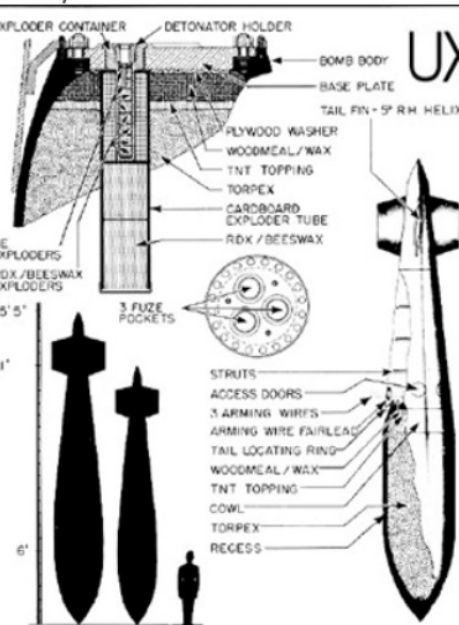
PETN	RDX	Aluminium
PETN is one of the most powerful explosives currently used. Like TNT it contains nitro-groups, only more, therefore on detonation it has more power. However, PETN is difficult to achieve detonation singularly, thus is often used in combination with RDX. PETN also has a low toxicity meaning less risk to environment and personnel. PETN is often mixed with a plasticiser to increase stability and phlegmatize it. The greatest hazard is an instantaneous blast on detonation not from fragments or projectiles. PETN can safely	RDX transfers energy quickly on ignition making it suitable for use in combination with PETN due to PETN requiring a fair amount of energy to initiate. RDX is more powerful than TNT and is a lot more stable. RDX is toxic by inhalation and dermal routes so precautions would have to be taken to protect those working with it. It can withstand storage at 85 °C for 10 months or at 100 °C for 100 hr without significant deterioration. [13] Acrid fumes of nitrogen oxides may be released when heated to decomposition. This should not	Aluminium in a powder form mixed with the explosive material, will increase the detonation velocity, increase the explosion heat and will influence the thermal stability of the compound. The increase in detonation velocity and explosion heat, significantly increases the magnitude of the shockwave created on full detonation. [14]

withstands storage for 18 months at 65°C, even when stored at 100°C it shows no sign of deterioration. [12]	be too big an issue as the detonation will be happening underground so any protect created on decomposition will not reach the surface.	
---	---	--

[15]

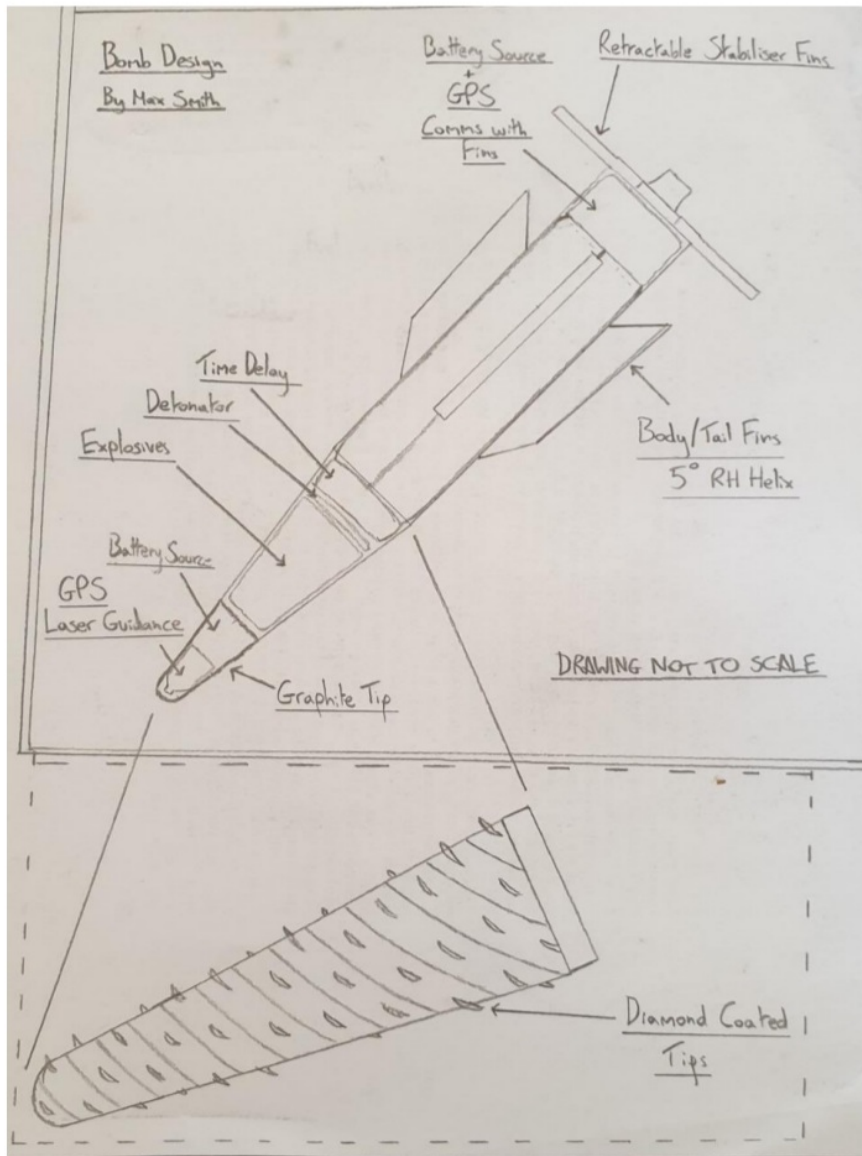
4.3 Weapon Design

The two weapons in the table below are like what the customer requires. The design therefore will be based off existing and new technology.

GBU-57  U.S. BUNKER BUSTER The non-nuclear Massive Ordnance Penetrator or MOP, which came into production during 2011, is designed to destroy deeply buried bunkers beyond the reach of previous bombs MOP GBU-57A/B - Length 6.25 m - Diameter 80 cm - Weight 13,600 kg - Explosives load 2,400 kg - Penetration depth 60m Explosive Detonator Radar-evading B-2 bomber can carry two MOPs MOP bomb	Tall Boy Bomb  EXPLODER CONTAINER DETONATOR HOLDER BOMB BODY BASE PLATE TAIL FIN - 5° RH HELIX PLYWOOD WASHER WOODMEAL/WAX TNT TOPPING TORPEX CARDBOARD EXPLODER TUBE RDX / BEESWAX GE EXPLODERS RDX / BEESWAX EXPLODERS 3 FUZE POCKETS STRUTS ACCESS DOORS 3 ARMING WIRES ARMING WIRE FAIRLEAD TAIL LOCATING RING WOODMEAL / WAX TNT TOPPING COWL TORPEX RECESS Figure 28—D. F. 12,000-lb. and 27,600-lb. bombs
[16] Modern and in use weapon, a lot of the inner materials are unknown due to it being an in service weapon and classification issues. It has a length of 6.25m and a diameter of 80cm. It weighs 13.6T and is able to penetrate up to 60m depth into the ground. The depth capacity would vary depending on the material type. It carries 2.4T of explosive payload. The casing is made of a hardened ferro-cobalt alloy enabling survival of impact. The casing along is ~80% of the overall weight. It has a laser guided GPS system in the nose to enable accurate targeting and delivery. Trajectory adjustments can be made using the stabiliser fins at the rear of the bomb, this	[17] The first ground penetration bomb, or earthquake bomb made. It is ~6.4m in length with a diameter of ~0.95m. It has a weight of ~5.4T, of which 2.4T is explosive payload. 'Detonators: Sensitive type - delays up to 60 mins., as required operationally. Exploders: Primary - 2 ring and 2 solid C.E. pellets; 4 solid R.D.X./Beeswax pellets. Secondary - 2 ring and 2 solid large R.D.X./Beeswax pellets (placed in a special exploder tube into which the standard exploder con-tainer fits.) Filling: Torpex - approx. 5200 lbs., surmounted by a 1 in. topping of T.N.T.' [18]. It had a delay

information is relayed as part of the GPS guidance through the laser at the front. The aerodynamic design of the bomb ensures that it achieves supersonic velocity before impact.

capability of up to 60 minutes. The casing was made of high tensile steel with the tail being made out of aluminium. The stabiliser fins has a slight twist on them for rotation, the gyroscopic effect generated stopped the pitching and yawing, improving the aerodynamics and accuracy.



Above is a final concept design of the bomb to meet the customer requirements. The high energy release has been achieved via the selection of materials to be used in the bomb. The design is both aerodynamic and stable, utilising the helix fin design from the tall boy bomb, these will aid the gyroscopic motion reducing yaw and increasing accuracy. The retractable fins at the aft of the bomb will communicate with

the GPS system at the fore of the bomb, continuously updating and correcting positioning. Whilst the GBU-57 bomb is capable of excellent penetration, it was deemed that to penetrate far enough beneath the target, it would have to be able to go through many meters of high strength reinforced concrete. Therefore, to aid with the penetration the front end of the shaft has diamond coated angular tips wrapping it, the idea is that the rotational velocity at point of impact would cause the bomb to act as a drill. The diamond coating would simply reduce the effort of the penetration. See 7.2 for an FMEA of the concept.

4.3.1 Detonation System

The bomb is equipped with an electronic detonation system, which are commonly used. The function of each one is unique as these can be tailored to the manufacturer's systems, protocols, components etc. Safety is key when it comes to the detonation system, as such, the bomb is to be fitted with an alternate timer safety and arming device, so should the bomb detect that it is not going to hit the target, the timer would send the signal to detonate whilst the weapon was still safely airborne. The fuzing system for detonation would be a combination of ambient and timer, with the remote ability to deselect one or another. The ambient part is able to detect unique environments, i.e. depth underground, once depth is achieved it would then activate the timer part of the fuze system, where after a predetermined amount of time a signal would be fired to the detonator initiating the bomb. However, should the required depth not be achieved, it could be armed by disabling the ambient detection remotely and arming the timer unit. [19] [20]

4.3.2 Booster System

An ideal booster for this bomb would be pentolite. Pentolite is an equal mixture of Pentaerythritol Tetranitrate and TNT. Pentolite on detonation causes a massive blast, which should provide enough stimuli to cause detonation of the explosive compound.

4.3.3 Guidance System

A laser guided GPS system in conjunction with the beam rider method. The GPS and guidance equipment are contained in the nose of the bomb, protected by the graphite tip of the casing. The bomb has been designed so that it is able to formulate its own correction signals based on its position with respect to the radar scan axis. The missile's flight path control unit is sensitive to any deviation from the scan axis of the guidance radar and can compute the proper flight path correction. It is key to maintain accuracy when released from such a height, as it's likely to be affected by weather conditions. Advantages of this method of guidance is only one radar is required for communication as opposed to two or more, secondly the bomb formulates its own directional commands and corrections. [19]

4.3.4 Delivery System

B-2 Spirit Aircraft to deliver from a minimum height of 30,000ft and a maximum height of 50,000ft from sea level. The B-2 Spirit aircraft is largely made from composite material, it is very difficult to be detected due to its vastly reduced signal output such as infrared, radar, acoustic and electromagnetic. Without refuelling it can travel up to 6000 miles, with in air refuelling, it can travel anywhere in the world [21].

4.4 Testing

Must have test plan against customer requirements as stated in section 3.1. The sub-systems of the unit will be tested individually to ensure correct functionality occurs and is safe.

4.5 Storage Requirements

The bomb and materials before assembly are to be packaged and stored in accordance with the Explosive Regulations 2014. For these locations, contingency and emergency plans must be developed and implemented in accordance with COMAH 2015 regulations. Prior to assembly all explosive material must be stored in a temperature and humidity-controlled environment in sealed containers. Separate locations will be required in accordance with Explosive regulations to reduce the impact should the items be exposed to any adverse stimuli.

5 Conclusion

5.1 Summary

The aim of this assignment was to discuss the processes involved in successfully designing a high explosive device, using a combination of systems engineering and the application of OME principles. CADMID/T has been applied throughout this process, from specification, to manufacture and design of the high explosive device. The full life cycle has been considered from procurement to disposal/decommissioning.

Using the requirement given in the task description and applying PLM, a guided blast bomb was successfully designed for military purposes against the target and delivery specifications.

The customer requirements laid the foundations for the design and incorporated the testing requirements to achieve the high standard of components used.

The manufacture and safety requirements were applied across the life cycle of the bomb and/or materials, this was based on a combination of legislation and professional knowledge.

The performance requirements incorporated the customer, manufacturing and safety requirements. It was tailored to meet the unspecified requirements to bring down the target structure. It was based on old and new military technology.

Materials selected were chosen for compatibility and to achieve the necessary attributes to meet the overall requirement.

The bomb design was based on old and current bombs that have been and are in service. Considering the pros and cons of each design and applying them to the concept design.

When designing a high explosive device, the key areas to look at are, what the customer requirements are, does it meet? And the safety requirements from storage through to use. It is key that when doing this, people from multiple disciplines are involved to cover all bases, else you end up with a design that is, for instance, so heavily safety based that it would not function.

5.2 Recommendations

It is acknowledged that the level of detail and model implementation is limited. A greater depth in understanding and evaluation would have occurred with the utilisation of other resources, such as access to modelling and design software, or funding to get a simulation built at work to run through prospected designs.

If this was carried out as a real-work project, people from the various disciplines would have been pulled in from across the company to work on this.

The preformed design for this assignment could have affected the overall requirements for the bomb design. Had this been carried out with more than one person, the requirements would have remained unbiased and would have covered a better overall basis.

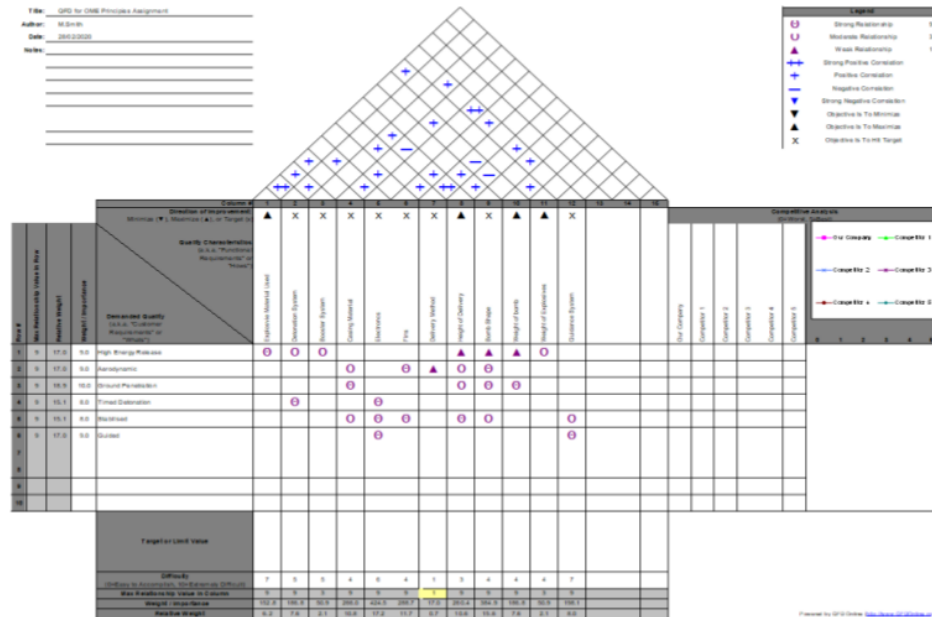
6 Bibliography

- [1] R. K. Ravindran, "DD 203 Skyscraper Petronas Twin Towers," 25th March 2012. [Online]. Available: <https://www.slideshare.net/RanjuRavindran/skyscrapers-petronas-towers>. [Accessed 16th March 2020].
- [2] I. 2. A. a. s. v. T. Committee, *ISO-7137:1995 Environmental Conditions and Test Procedures for Airborne Equipment*, International Organization for Standardization, 2018.
- [3] P. Wayne Stout, *Aerospace Hydraulic Systems*, Design Aerospace LLC, 2013.
- [4] R. Cornwell, E. Wrobel and P. E. Anderson, "Research and Development of High Performance Explosives," *Journal of Visualised Experiments*, 2016.
- [5] HSE, "Discarding and disposal of explosives," HSE, 20th April 2016. [Online]. Available: <https://www.hse.gov.uk/explosives/disposal.htm>. [Accessed 19th March 2020].
- [6] N. Davis, "9 OME Safety and Processing," Nigel Davis, Swansea, 2019.
- [7] N. P. Service, "Chapter 2 Explosives," in *National Park Service Handbook for the Storage, Transport and Use of Explosives*, Washington DC, National Park Service, 1999, p. 26.
- [8] M. o. Defence, "Explosives storage and transport committee Standard No. 6," Ministry of Defence, London, 2015.
- [9] Government, "The Control of Major Accident Hazards Regulations 2015," HSE, London, 2015.
- [10] C. Ferreira, J. Ribeiro, R. Clift and a. F. Freire, "A Circular Economy Approach to Military Munitions: Valorization of Energetic Material from Ammunition Disposal through Incorporation in Civil Explosives," *Sustainability*, vol. 11, no. 255, pp. 1-14, 2019.
- [11] MetalSuperMarkets, "The Strongest Metals," MetalSuperMarkets, 22nd October 2015. [Online]. Available: <https://www.metalsupermarkets.com/the-strongest-metals/>. [Accessed 23rd March 2020].
- [12] P. Database, "Pentaerythritol tetranitrate," PubChem, 2019 Update. [Online]. Available: <https://pubchem.ncbi.nlm.nih.gov/compound/Pentaerythritol-tetranitrate#section=Stability-Shelf-Life>. [Accessed 23rd March 2020].
- [13] S. C. I. L. e. a. A. H, "Toxicological Profile for RDX," Atlanta: Agency for Toxic Substances and Disease Registry (US), Atlanta, 2012.
- [14] K. G. A. K. K. C. T. G. Angelika Zygmunt, "Application and Properties of Aluminium in Primary and Secondary Explosives," *Journal of Elementology*, vol. 22, pp. 747-756, 2017.

- [15] M. Smith, "Chemistry fo OME," 2020.
- [16] J. D. Weekly, "Too Cats - Original Thoughts," 2011. [Online]. Available: <https://toocatsoriginals.tumblr.com/post/101693283769/gbu-57-massive-ordinance-penetrator-mop-via-x>. [Accessed 23rd March 2020].
- [17] O. H. Inc., "Motis Category - Bombs," 2000. [Online]. Available: http://uxoinfo.com/blogcfc/client/includes/uxopages/Mulvaney_Details.cfm?Ord_Id=FB26. [Accessed 23rd March 2020].
- [18] U. S. N. B. D. School, "U.S.N.B.D. - BRITISH BOMBS AND FUZES; PYROTECHNICS; DETONATORS MISCELLANEOUS BOMBS," United States Navy Bomb Disposal School, [Online]. Available: <http://michaelhiske.de/Allierte/USA/USNBD/GBR/BombsAndFuzesUK/Section01/Page185b.HTM>. [Accessed 23rd March 2020].
- [19] W. a. S. E. Department, "Fundamentals of Naval Weapons Systems," [Online]. Available: <https://fas.org/man/dod-101/navy/docs/fun/part15.htm>. [Accessed 23rd March 2020].
- [20] W. R. O. O. o. S. M. U. D. o. t. I. Office of Technology Transfer, "Initiation Systems," Sheridan District Office, Wyoming Department of Environmental Quality, Land Quality Division, Denver, Colorado, 2019.
- [21] A. F. Technology, "B-2 Spirit Stealth Bomber," Air Force Technology, 2020. [Online]. Available: <https://www.airforce-technology.com/projects/b2/>. [Accessed 18th March 2020].
- [22] R. Morgan, "QFD Analysis Template," Richard Morgan, Swansea, 2019.
- [23] R. Morgan, "FMEA Template," Richard Morgan, Swansea, 2020.
- [24] A. Kossiakoff, W. N. Sweet, S. J. Seymour and S. M. Biemer, Systems Engineering Principles and Practice, Hoboken: Wiley, 2011.

7 Appendix

7.1 QFD



[22]

A QFD (Quality Function Deployment) was carried out based on customer requirements and design specification. The requirement for high energy release has relationships with many of the design specifications, making this a vital area that needs to be considered and addressed. Followed by the stabiliser requirement, it is key that this is met so that precision and accuracy are achieved else the bomb would fail and/or miss.

There are many areas of conflict between the requirements, however the bulk have a positive impact on the others. A few areas to watch out for when going into the concept designs will be the casing material used, as if the material is not heat resistant enough or strong enough then the height of delivery would have to be lowered, decreasing the maximum potential energy that could be released. The weight of the bomb would also have an adverse effect on height of delivery and the method of delivery. If the bomb is too heavy it will limit the possible delivery methods with the financial impact being high, equally if the bomb is too light, it would be more likely from delivery to be too off target.

To meet the specification requirements the explosive material used needs to have high energy capabilities for the desired effect to be achieved. The height of delivery will also increase the potential energy achieved and reduces detectability. The weight of the bomb needs to be substantial enough to aid velocity and penetrative capacity.

The importance weights along the bottom indicate which specifications will be key in the design, with the most important aspect being the electronics inside the bomb, as it be required for guidance, detonation and stabilisation.

7.2 FMEA

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Controls	D	R	Recommended Action(s)	Responsibility and Target Completion Date	Action Results			
											Actions Taken	S	D	R
Arm Munition	Electronics built	Munition won't arm. Penetration detection. Loss of life.	10	Munition ingress. Damage to components on installation	3	Operations and storage in a temperature-humidity controlled environment. Trained personnel carrying out all operations. Independent writer overseeing all operations and operators are under direct supervision.	8	240	Carry out preassembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Production Manager	Process for kit checking of components implemented and carried out for each assembly. All IV and supervisor have been placed within each team. Process for electrical testing of electrical components implemented for an annual basis ensuring compliance. Building and plant undergo compliance testing. Compliance testing is carried out in the building. This is carried out. There are multiple temperature-humidity/readers throughout the building. The storage containers are fitted with humidity indicator cards and desiccant. When a munition is being desiccated, the humidity indicator cards are replaced. Verification received that all specified aircraft have been modified for the munition application. Quality assurance is carried out throughout ensuring full compliance with design and process.	10	1	90
	Storage container built. Storage conditions breached. Not able to move the container. Life.	Unable to store or transport the munition. Munition gets wet from moisture ingress. Malfunction. Loss of life.	10	Fully container seal. Building goes out of conditions.	4	Maintenance is carried out on all containers checking applicability before use. Maintenance is carried out on the building and plant which keeps the building within conditions. Building is checked for humidity. Reports are updated and analysed bi-weekly.	7	230	Regular maintenance programme for all containers to be carried out. Regular maintenance schedule for building and plant. Have multiple temperature humidity readers within the building to cover more than one storage area. Humidity readers fitted with a humidity indicator card and desiccant.	01/04/2020 Containers Manager 01/04/2020 Maintenance Manager 23/03/2020 Production Group 02/04/2020 Operations Group				
Load Munition	Holders for munition not in place. No method to load munition. Aircraft built.	Munition cannot be loaded into aircraft.	7	agreed to accommodate the munition. Munition must be stored allowing for hold-down.	2	All adjustments were implemented on agreement of munition design. All specified aircraft have been modified to accommodate this munition. Casing manufacture is computer controlled.	10	140	Get verification that all modifications have been made to all specified aircraft. Carry out electrical tests on electrical components to check communication links are intact.	20/03/2020 Programme Manager 01/04/2020 Quality Manager	Process for electrical testing of electrical components implemented. carried out with IV and direct supervision. Target acquisition requires multiple personnel automation. Overall function intact.	10	1	100
Acquire Target	Wrong target identified. GPS error. Electrical built.	Wrong target. Loss of control of munition.	10	Human error. Damaged electrical components.	3	Trained personnel carrying out all operations. Independent writer overseeing all operations and operators are under direct supervision. Two people are required to authorise target selection and mission.	8	240	Carry out electrical tests on electrical components to check communication links are intact. Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Production Manager 01/04/2020 Military Command	Aircraft gets maintained MORT every 6 months. Process for pre-flight checks implemented to check functionality. Process for kit checking of components implemented and carried out for each assembly. All IV and supervisor have been placed within each team. Process for electrical testing of electrical components implemented.	10	1	90
Arm Weapon	Shutters won't open. Electrical fault. Aircraft built.	Loss of life. Loss of control of munition.	10	Human error. Damaged electrical components.	4	Trained personnel carrying out all operations. Maintenance is carried out on the aircraft.	8	320	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	24/03/2020 Military Personnel	Process for kit checking of components implemented and carried out for each assembly. All IV and supervisor have been placed within each team. Process for electrical testing of electrical components implemented.	10	1	100
Install Weapon	Systems not functioning. Fault with the materials. Electrical built.	Munition won't function as required. Release the munition as expected.	10	Moisture ingress. Damage to components on installation	3	Operations and storage in a temperature-humidity controlled environment. Trained personnel carrying out all operations and operators are under direct supervision.	8	240	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Production Manager	Process for kit checking of components implemented and carried out for each assembly. All IV and supervisor have been placed within each team. Process for electrical testing of electrical components implemented.	10	1	90
Provide Make Force	Propellant missing. Aircraft does not release the munition as expected.	Munition won't hit the target. Munition does not release the munition as expected.	7	Propellant materials damaged. Damaged aircraft holdings in the munition.	2	Trained personnel carrying out all operations. Maintenance is carried out on the aircraft.	8	112	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Production Manager 24/03/2020 Military Personnel	Process for kit checking of components implemented and carried out for each assembly. All IV and supervisor have been placed within each team. Process for electrical testing of electrical components implemented.	10	1	90
Stable Projectile	Fits broken. Casing material managed. Munition fits not functioning.	Munition won't hit the target. Munition does not release the munition as expected.	10	Munition casing has not been manufactured properly. Damaged on transport. Electrical fault in the munition.	4	Casing manufacture is computer controlled. Operations and storage in a temperature-humidity controlled environment. Trained personnel carrying out all operations. Independent writer overseeing all operations and operators are under direct supervision.	8	320	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	20/03/2020 Quality Manager 01/04/2020 Production Manager	Quality assurance is carried out throughout ensuring full compliance with design and process. Containers get maintained on an annual basis ensuring compliance. Building and plant undergo compliance testing. Compliance testing is carried out in the building. This is carried out. There are multiple temperature-humidity/readers throughout the building. The storage containers are fitted with humidity indicator cards and desiccant. When a munition is being desiccated, the humidity indicator cards are replaced. Verification received that all specified aircraft have been modified for the munition application. Quality assurance is carried out throughout ensuring full compliance with design and process.	10	1	90
Manoeuvre Munition	Fits faulty. Propellant missing. Aircraft does not release the munition as expected.	Munition won't hit the target. Munition does not release the munition as expected.	10	Munition casing has not been manufactured properly. Damaged on transport. Electrical fault in the munition.	4	Casing manufacture is computer controlled. Operations and storage in a temperature-humidity controlled environment. Trained personnel carrying out all operations. Independent writer overseeing all operations and operators are under direct supervision.	8	210	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Quality Manager 01/04/2020 Production Manager	Quality assurance is carried out throughout ensuring full compliance with design and process. Containers get maintained on an annual basis ensuring compliance. Building and plant undergo compliance testing. Compliance testing is carried out in the building. This is carried out. There are multiple temperature-humidity/readers throughout the building. The storage containers are fitted with humidity indicator cards and desiccant. When a munition is being desiccated, the humidity indicator cards are replaced. Verification received that all specified aircraft have been modified for the munition application. Quality assurance is carried out throughout ensuring full compliance with design and process.	10	1	90
Track to Target	GPS communication faulty. Electronics not working.	Munition may not hit the target. Loss of communication.	10	Electrical fault in the munition.	4	Trained personnel carrying out all operations. Independent writer overseeing all operations and operators are under direct supervision.	7	230	Carry out pre-assembly component checks to ensure fit. Carry out electrical tests on electrical components to check communication links are intact.	01/04/2020 Production Manager 24/03/2020 Military Personnel	Process for kit checking of components implemented and carried out for each assembly. All IV and direct supervision. Target acquisition requires multiple personnel automation. Overall function intact.	10	1	90

[illegible]

Principles of OME Assignment Max Smith 1810364

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

51 / 100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

GRADING FORM: SMU GENERIC_GJ

MAX SMITH**51.30****RESEARCH-INFORMED LITERATURE**

Excellent engagement with literature including technical, explosive, regulatory, target analysis and systems engineering publications

7.8**KNOWLEDGE AND UNDERSTANDING**

Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.

15**ANALYSIS**

"Evidence of some logical, analytical thinking and synthesis. However I would recommend looking at a more structured approach for presenting the requirements. If you are not careful you can get into a long list of specific almost random facts which, in the interests of clarity, would be better expressed as an overarching requirement. E.g. talk about compatibility rather than the specifics of chlorates and fluorine."

13.5

PRACTICAL APPLICATION AND DEP.



"An adequate awareness and mostly appropriate application of well-established methods, materials, tools and/or techniques. Again there is a need to string the knowledge together as a logical sequence rather than an assembly of somewhat random facts."

10

SKILLS FOR PROFESSIONAL PRAC.



Can communicate in a suitable format but with some room for improvement.

5