

Principles of OME assignment

by Steven James

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Principles of OME



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AWE Plc

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1 Introduction

This report details the processes undertaken in developing a munition for a required purpose. In this example a blast/fragmentation bomb is to be delivered from an aircraft. The target and the aircraft are specified by the user. This report includes; a procurement specification of which consequences of failure to deliver will be acknowledged; how the designer can meet the requirement; design or designs of the munition; a valid test programme example, and the role of the user upon delivery from manufacturer. Some of the thoughts developed through the report have been taken from the Ministry of Defences CADMID cycle as seen in Figure 1

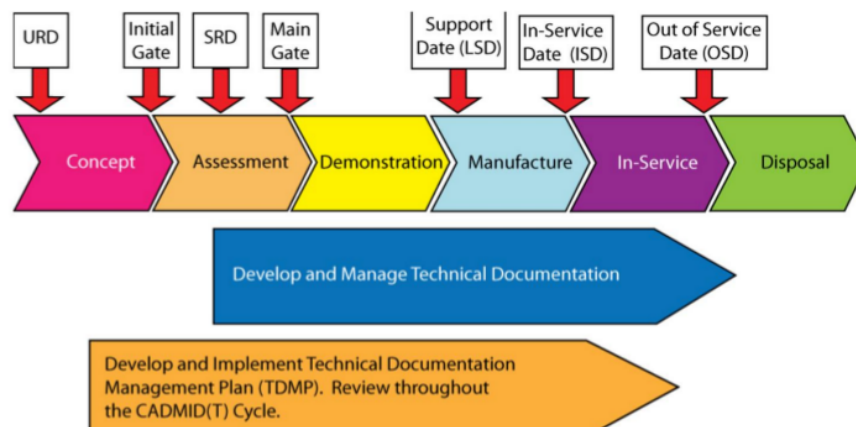


Figure 1 - CADMID cycle [1]

2 Requirements from user

2.1 Initial requirement

A requirement has been received for a munition that can penetrate and destroy a deep buried, hardened bunker. The United States has broken down buried bunkers into three classes [2];

Class 1, near earth surface. Walls of up to 5m thick hardened concrete, built by 'cut and cover' typically less than 30m deep.

Class 2, natural caves or shallow tunnels dug into rock, up to 18m deep. These are often dug into the side of a mountain and can be harder to find.

Class 3, natural caves or deeply tunnelled facilities ranging from 20m deep, to 1000m deep. Mostly likely dug down from the surface, these facilities may be too deep for most earth penetrating munitions.

2.2 Key requirements

2.2.1 Target, building

The user defines the target as “those targets in classes 2 and 3”. It is understood that conventional technology may not exist to penetrate to 1000m deep. It will be beneficial for the munition to accommodate ‘class 1’ in the design.

Should the munition not meet the requirement, then it will not be purchased or allowed to go forward.

2.2.2 Delivery system

The deliver aircraft are Eurofighter Typhoon and F35 Lightning II.

Consultation must take place with the manufacturer/designer of the weapon’s bay/rails to allow this new system to fix to existing mountings. F-35 has a payload capability of 6,800kg [3]. This is over 4 stations. The maximum weight of the weapon shall be 1700Kg.

LOCKHEED MARTIN LIGHTNING (LIGHTNING F-35B):

- **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)

Figure 2 - excerpt from RAF website about F35 [3]

Not meeting the specification of the existing mountings design, extra cost will be incurred to build new mountings. There is no alternative delivery system.

2.2.3 Guidance

The munition must interact with current guidance systems.

Consultation must take place with the manufacturer/designer of the guidance systems to allow this new munition to synchronise to existing guidance.

Not meeting the specification of the existing guidance systems extra cost will be incurred to build a new system. There several guidance systems available which may only require an update.

2.2.4 Lifespan

The munition must have a lifespan of 20 years. Including storage and in theatre. In theatre could include cyclic temperatures up to 45°C and/or down to -50°C and open to the environment whilst on the aircraft. The munition must not become damaged due to bird strike or other environmental features (hail etc).

Materials, from casings to subsystems and explosives, shall be manufactured out of material that, through life, shall not lose strength, shape or other useful physical properties. Time, temperature variations, aerodynamic heating must be considered when choosing the material. Materials in the airstream shall be selected that can take accidental impact without distortion at lower speeds.

Failing to meet lifespan requirement, the munition may not function as desired, with risks to operators or other service personnel. It will require extra service downtime and possibly make the costs unbearable.

2.2.5 Easy to assemble/service

The munition shall be easy to assemble by munition depot workers. In service support will be of such that it is out of service for the least amount of time.

Munition shall be assembled of 'blocks' or 'subsystems' each removable and changeable during maintenance, without full deconstruction of each subsystem. Each section shall be of a nature allowing ease of assembly/disassembly.

If it is not possible, the munition will be re designed or scrapped.

2.2.6 Safe

The munition shall pass all criteria for IM (Insensitive Munitions).

Munition must pass all mandatory tests in Table 1:

STANAG 4170	Principles and Methodology for the Qualification of Explosive Materials for Military Use [4].
AOP – 7	Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use [5].
STANAG 4439	Policy for Introduction, Assessment, and Testing for Insensitive Munitions (MURAT) [6].
UN Orange Book	Recommendations on the Transport of Dangerous Goods, manual of tests and Criteria [7].

Table 1 - Required test methodologies

If munition cannot adhere to these policies, it won't be accepted. It must be redesigned to pass all test criteria.

2.2.7 Cost

Each unit must cost no more than 1.5% the delivery system. Development costs to be capped at 15% of delivery system

The F35 lightning II is the higher cost delivery system, with an undisclosed cost per unit believe to be ~\$115M (US). This allows a per unit cost of munition of ~\$1.175M (US).

Should the design show a higher cost, further consultation and renegotiation will take place to prevent costs spiralling.

2.2.8 Munition

This is to be a conventional munition. The system shall remain undistorted through the harsh forces of impact and penetration. The explosive must not crack or sag, shock absorbent materials may be used at the forward end of the warhead and harsh shapes, angles avoided.

Failing to meet the requirement could cause premature or incomplete detonation of the warhead rendering the munition inadequate.

2.2.9 Disposal

The munition must be made of materials that (at time of design) are not expected to be a further hazard (physical or environmental) when the end of service life is reached

The munition must have an end of life plan [1]. Once out of service the munition must be disposed of in an environmentally clean manner. No harmful materials (with the exception of those specifically used for the design intention) are to be used. Should any of these materials be used, the waste stream should be planned in the concept stage of the munition design.

Should it not be possible to acquire a disposal route from the outset, the design cannot progress forward.

3 Designer input

3.1.1 Target, building

The munition must penetrate as deep as possible. A tandem warhead system will expedite penetration. A large shaped charge at the forward end shall create a weak point for the follow through penetrator.

The charge cone shall be made of aluminium and shall have an angle of 120° as this is the known to be beneficial against concrete [8].

The penetrator shall be 'long', 'thin' and straight with a thick hard tip; made from a substance such as titanium, depleted uranium, tungsten, carbon or tantalum. A mixture of the materials or alloys may suffice.

Alloys of depleted uranium have proven to 'self sharpen' while penetrating armour and may reduce some of the political tension caused from using pure depleted uranium.

For increased velocity on impact, a rocket motor which will accelerate the munition at very low altitude shall be employed

3.1.2 Delivery system

To fit both the F35 and the EF Typhoon, an adapter shall be manufactured to the both internal and external pylons of both platforms.

F35 can carry stores up to 6,800 kg [3] across 4 stations. The maximum weight for the munition must not exceed 1700kg.

3.1.3 Guidance

“Paveway” weapon system already carried by the delivery system uses GPS/INS and a laser guidance system [9]. Consultation with ‘Raytheon’ regarding integration of the guidance system will be required.

3.1.4 Lifespan

The munition will be designed to last 20 years. For the explosives, due to its aging characteristics, avoid nitrocellulose.

In service the munition will be open to the elements. External surface will be manufactured from material less susceptible to oxidation. They shall also be tested against long term temperature effects and cyclic changes.

Suitable compatibility testing will have to be done, ensuring materials used in the munition do not react with each other or the explosive. As this can significantly reduce the life of the weapon. For incompatibilities, alternate materials will be sought.

3.1.5 Easy to assemble/service

The munition will be made up of sub-assemblies to be maintained and changed out with ease, where appropriate. For in service support, the full disassembly assembly time shall be one week.

Full AP (Aircraft Protocol) and TIAD (Technical Information for Armament Depots) book shall be provided to the companies maintaining the munitions.

3.1.6 Safe

Knowledge of existing explosives will be used to meet the safety requirements. The Ministry of Defence will be able to provide guidance on pre-existing systems of which some elements may be available for use.

Alternately NATO's MSIAC (Munitions Safety Information Analysis Center), provide similar international advice. The UK is an MSIAC nation and can therefore ‘pull’ information should it be required [10]. MSIAC also currently have a workshop ‘Effect of Ageing on Materials and Munitions Safety’.

An ‘IHE’ (Insensitive High Explosive) formulation should be considered.

A Directory of Insensitive Munitions Testing facilities has been compiled by MSIAC [11].

3.1.7 Cost

Where possible munition will be integrated with existing systems including existing guidance and control systems, existing explosive formulations, existing power supply unit. This will reduce development costs and use manufacturing systems that are already in place.

3.1.8 Munition

The high explosives in the system will be pressed and machined, pressed into the warhead area or melt cast dependant on design.

The precursor shaped charge will not need the survivability of the main charge as it will have been deployed prior to the impact. An HMX based charge >90% with a Viton binder would be a good example. KS33 – HMX/HTPB (90/10) pressed to 1.71g/cc [12].

Bitumen is used to absorb shock in warheads. This (or another suitable liner) will be employed at the front of the cased main charge. Alternatively, a material of honeycomb design may be suitable.

The high explosive in the warhead should be a TATB formulation. Less powerful than HMX, it is an IHE and suitable for IM testing. Should the power be definite, RDX is less shock sensitive than HMX and can be mixed with TNT and aluminium to assist in enhancing the blast.

Enhanced Blast explosives such as RDX/TNT/Al or RDX/TNT/B have a slower blast wave but are much more suitable for use in an underground bunker or cave [13].

A formidable solution to use safety with enhanced blast will be PBXN-7 (60% TATB, 35% RDX 5% Viton [14]), with 7% aluminium.

The rocket motor should be made of an ammonium perchlorate or NTO formulation, as nitrocellulose-based rocket systems will need to be replaced due to aging in the material, ammonium perchlorate/HTPB/Aluminium for example. ROXEL (UK Rocket motors) should be contacted for manufacture.

Choice of an existing explosive/propellant, will result in lower costs as it will have already been through the vast material scale up and qualification trials as found in section 6. Munition qualification trials shall still be required.

3.1.9 Disposal

Munition disposal should be designed to fit in with the guidance in JSP 520 [15]

No materials on the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) list should be used in the munition. Data suggesting a material will be added to the list should be avoided. Metals such as cadmium which are carcinogenic shall not be used.

Guidance on the disposal of uranium is available in a comprehensive document written by Neall [16]. The disposal of the DU should be planned to follow this guidance.

Most of the casings will be made from standard materials that can be recycled. Those in contact with explosives will be certified free from explosives before being sent to any no explosive facility.

Explosive items themselves will be disposed of by burning/detonation.

4 Designs

Forward of the weapon is the guidance system; the laser illumination detector, GPS antenna, RADAR height system and impact fuze. The guidance system will be distributed to the outside of the forward section, leaving room for the shaped charge jet to flow form unobstructed.

Behind the guidance section is the precursor shaped charge. There will be a firing unit at the back of the shaped charge which will fire when it receives the correct signal from the SAU. The penetrator/follow through bomb will be to the rear of the precursor. The penetrator will have a firing unit at the rear firing when it receives the signal from the SAU

Behind the Penetrator is the SAU (safety and arming unit) uppermost and the power unit below. The SAU will contain smart technology to allow the munition to be detonated at the correct depth [17]. The SAU will have several arming codes including:

- Direct signal from aircraft, 2 physical switches, one a simple pull out pin, the other attached to the umbilical.
- Pressure sensor detects change in height and at set pressure electronic arming signal given.
- GPS signal used for further arming of the system.
- RADAR system detects exact height

The power unit will contain batteries for power and capacitors for the firing circuit. The umbilical connection from the aircraft will provide power until release.

At the rear of the weapon is the tail and control section. The 4 tail fins will move to allow the munition to be guided onto the target. In the middle of the rear section will be the rocket motor. The rocket motor will initiate when it receives the signal from the SAU.

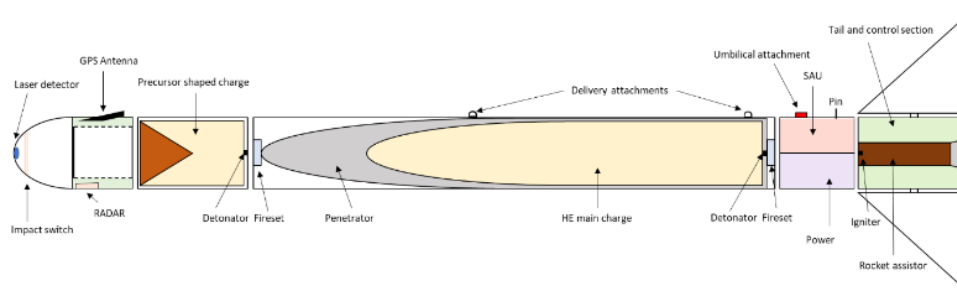


Figure 3 - diagrammatic view of concept design

The sequence of use for the weapon is found in Appendix C.

5 Test Programme

The explosives will be tested in accordance with relevant protocols. Powder hazard a scale up testing shall take place following tests as laid out in the EMTAP (Energetic Materials Test and Assessment Policy Committee) manual of tests, including but are not limited to:

- Rotter Impact
- Mallet friction
- Ease of ignition (Bickford fuze)
- Temperature of ignition
- Train test
- Rotary friction
- Mechanical properties testing

These tests will assist qualification as required to qualify any materials/systems (STANAG 4170/AOP-7) tests. The full list of required tests can be found in Appendix A [5].

Integration with the aircraft and guidance systems will use inter versions. flight characteristics will also be proven with inert 'guidable' examples.

The shaped charge warhead can be tested against concrete to measure maximum charge depth.

The penetrator will be rocket propelled via sled track into a hard target measuring penetration at the predicted speed of the munition.

Each section shall go through an environmental test programme, consisting of; 'shake, rattle and roll' vibration testing, centrifuge testing, variant and cyclical heat testing. Ensuring each part of the munition will survive the environment it. Testing at subsystem level will allow redesign an early stage. A full weapon shall also go through the test regime.

Final qualification testing will follow STANAG 4439 [6], Appendix B. To complete this test series, 10 munitions shall be manufactured using a tantalum/tungsten alloy to prevent, contamination following the tests.

Those munitions not used for the STANAG 4439 qualification shall then be used for transport classification testing (12m drop, test 4 (b) (ii) [7]) and final proof of performance and system demonstration. Final performance demonstration shall be on a deep target on a firing range.

6 Storage and handling

Storage and processing will be at DM Beith, this facility already has suitable facilities to store handle and process complex weapons and meet ESTC standard No 6 [18], JSP 482 [19], JSP 520 [15]. Storage only will be at MoD Longtown and Kineton.

The munition will be stored in a climate-controlled environment, 19°C +/- 2°C. the air should be kept at a humidity of around 40%RH. A record of the climate shall be kept to manage periods where control falls outside requirements.

The munition shall only be handled in its transport container, exceptions are when being loaded/unloaded as weapon stores, whilst as stores on aircraft or whilst being processed.

Munition shall not (without reason) be lifted above one metre

Munition shall not (without good reason) be lifted over another munition

Maintenance, instructions shall be followed as provided. Each weapon or component shall always be earthed .

7 Conclusion

A target has been designated as a deep buried, hardened bunker. The target must be neutralised by a bomb dropped from an F35 and a EF Typhoon.

The weapon will be a guided bomb, using Raytheon 'Paveway' guidance system. GPS, laser and radar will all be employed to ensure correct targeting. The steering system shall be controlled from the tail section of the weapon

The destructive components shall be a precursor charge of KS33 with an aluminium conical liner. The main charge shall be constructed in a DU Alloy case and the explosive fill shall be of 93% PBXN-7 with a 7% aluminium dust(to enhance the blast from the TATB). The rocket boost motor shall be made of AP/AL/HTPB formulation. Booster charges of HNS will be required to initiate the main charges from the detonators.

The safety and arming unit will use several sensors (strong links) to ensure that the correct arming sequence is followed. There will also be weak links, designed to ensure the weapon fails safe during accident scenario.

The explosives used shall meet all criteria of relevant test standards, STANAG 4170, AOP-07, UN transport classifications and STANAG 4439.

The munitions shall be stored of relative ease to process and DM Beith and stored in appropriate conditions at Beith, Kineton and Longtown. Instruction manuals shall be provided for process staff.

The system has been designed for a 20year shelf life, disposal has been considered form the start. No component has been included that does not have a disposal route.

8 Bibliography

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Appendix A – Tests required for qualification of explosives [5]

HIGH EXPLOSIVES

A. Mandatory Data for Primary Explosives:

- (1) Ball and Disc
- (2) Small Scale Explosiveness 201.01.003
- (3) Grit Sensitisation 201.01.004
- (4) Emery Paper Friction 201.02.002
- (5) Temperature of Ignition STANAG 4491 or 4515
- (6) Ease of Ignition STANAG 4491
- (7) Train Test 202.01.003
- (8) Electric Spark STANAG 4490

B. Mandatory Data for Booster Explosives

- (1) Rotter Impact Test STANAG 4489
- (2) Small Scale Explosiveness 201.01.003
- (3) Grit Sensitisation 201.01.004
- (4) Rotary Friction STANAG 4487
- (5) Temperature of Ignition STANAG 4491 or 4515
- (6) Ease of Ignition STANAG 4491
- (7) Train Test 202.01.003
- (8) Electric Spark Test STANAG 4490
- (9) Small Scale Gap Test STANAG 4488
- (10) Fragment Impact Test 201.06.003
- (11) Tube Test – Internal Ignition 202.01.005
- (12) Tube Test – Fast Heating (Fuel Fire) 202.01.006
- (13) Tube Test – Electrically Heated STANAG 4491
- (14) Critical Diameter 302.02.002
- (15) Detonation Velocity 302.02.001
- (16) Vacuum Stability STANAG 4556
- (17) DMA (for PBX) STANAG 4540
- (18) TMA (for PBX) STANAG 4525
- (19) Uniaxial Tensile (for PBX) STANAG 4506
- (20) Stress Relaxation (for PBX) STANAG 4507
- (21) Uniaxial Compression (for PBX) STANAG 4443
- (22) Thermal Characterization by DSC/DTA STANAG 4515

C. Mandatory Tests for Main Charge High Explosives

- (1) Rotter Impact Test STANAG 4489
- (2) Small Scale Explosiveness 201.01.003
- (3) Grit Sensitisation 201.01.004
- (4) Rotary Friction STANAG 4487
- (5) Temperature of Ignition STANAG 4491 or 4515
- (6) Ease of Ignition STANAG 4491
- (7) Train Test 202.01.003
- (8) Electric Spark Test STANAG 4490
- (9) Gap Test STANAG 4488

- (10) Fragment Impact Test 201.06.003
- (11) Small-Scale Spigot Drop Test 201.01.005
- (12) Tube Test – Internal Ignition 202.01.005
- (13) Tube Test - Fast Heating (Fuel Fire) 202.01.006
- (14) Tube Test – Electrically Heated STANAG 4491
- (15) Critical Diameter 302.02.002
- (16) Detonation Velocity 302.02.001
- (17) Vacuum Stability STANAG 4556
- (18) DMA (for PBX) STANAG 4540
- (19) TMA (for PBX) STANAG 4525
- (20) Uniaxial Tensile (for PBX) STANAG 4506
- (21) Stress Relaxation (for PBX) STANAG 4507
- (22) Uniaxial Compression (for PBX) STANAG 4443
- (23) Thermal Characterization by DSC/DTA STANAG 4515

PROPELLANTS

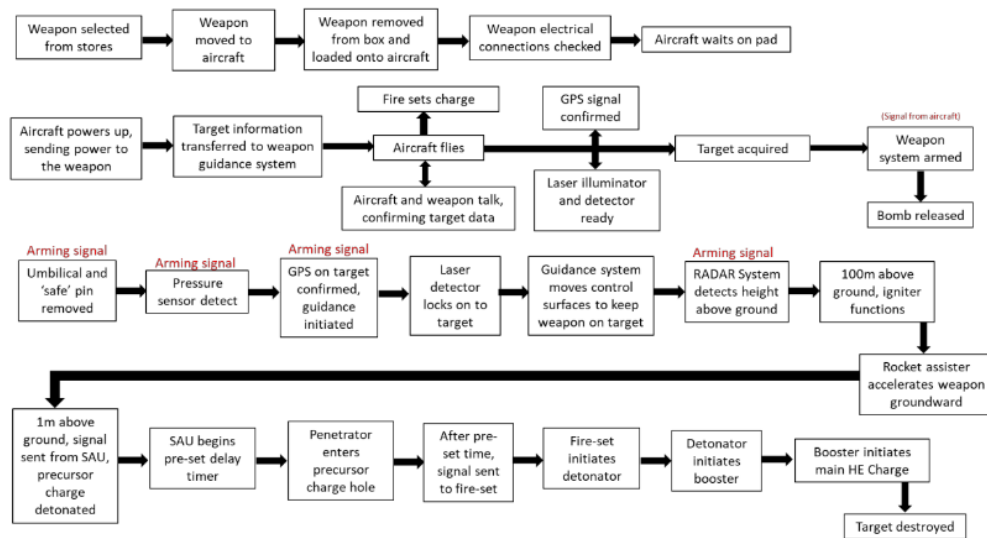
A. Mandatory Data for Solid Propellants

- (1) Rotter Impact Test STANAG 4489
- (2) Small Scale Explosiveness 201.01.003
- (3) Grit Sensitisation 201.01.004
- (4) Rotary Friction STANAG 4487
- (5) Temperature of Ignition STANAG 4491 or 4515
- (6) Ease of Ignition STANAG 4491
- (7) Train Test 202.01.003
- (8) Electric Spark Test STANAG 4490
- (9) Gap Test STANAG 4488
- (10) Model Scale Motor Test 201.06.001
- (11) Fragment Impact Test 201.06.002
- (12) Shaped Charge Attack Test 201.07.001
- (13) Small-Scale Spigot Drop Test 201.01.005
- (14) Tube Test – Internal Ignition 202.01.005
- (15) Tube test - Fast Heating (Fuel Fire) 202.01.006
- (16) Tube test – Electrical heating STANAG 4491
- (17) Critical Diameter 302.02.002
- (18) Chemical Stability STANAG 4527, 4117, 4541
- (19) Vacuum Stability STANAG 4556
- (20) DMA STANAG 4540
- (21) TMA STANAG 4525
- (22) Uniaxial Tensile (for rocket propellant) STANAG 4506
- (23) Stress Relaxation STANAG 4507
- (24) Uniaxial Compression STANAG 4443
- (25) Thermal Characterization by DSC/DTA STANAG 4515

Appendix B – Tests required by STANAG 4439, POLICY FOR INTRODUCTION, ASSESSMENT AND TESTING FOR INSENSITIVE MUNITIONS (MURAT)

- (1) Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces AOP-15
- (2) Guidance on the Development, Assessment and Testing of Insensitive Munitions (MURAT) AOP-39
- (3) Determination of the Classification of Military Ammunition and Explosives STANAG 4123
- (4) Liquid Fuel Fire Tests for Munitions STANAG 4240
- (5) Bullet Attack Tests for Munitions STANAG 4241
- (6) Slow Heating, Tests for Munitions STANAG 4382
- (7) Sympathetic Reaction, Munition Test Procedure STANAG 4396

Appendix C – Sequence of weapon use



Principles of OME assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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STEVEN
JAMES

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RESEARCH-INFORMED LITERATURE



Excellent range of publications accessed including technical, Explosive and regulatory (JSP and STANAG) publications

7.5

KNOWLEDGE AND UNDERSTANDING



"Knowledge is accurate with a good understanding of the field of study. Safety criteria require a little re-investigation. Something to bear in mind later in the course. "

17.1

ANALYSIS



"A good and appropriate application of standard methods, materials, tools and/or techniques. Use of System engineering tools and techniques would help explain some of the design decisions."

18.6

PRACTICAL APPLICATION AND DEP.



"A appreciation of the tools required to examine the service life of the store prior to certification and

12

release into service. A little more detail including the manufacture to disposal sequence would assist."

SKILLS FOR PROFESSIONAL PRAC.



Can communicate well, confidently and consistently in a suitable format.

6