



Ministry
of Defence



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31-May-25

Our Reference: SECW_01

DESIGN AND PROPOSE A SOLUTION TO A PROVIDED TARGET SET

Abstract

The intent of this report is to demonstrate the techniques used to explore and design a solution to the set brief. The report details a systems engineering approach that explores the target set, designs solutions and refines the design into a set of key subsystem and components. Due to the scope of the project key components here identified and focused on to allow better and more full exploration of these specific areas to demonstrate the use of the toolset. The scope of this report is solely to that of the systems approach taken and does not include aspects of the group structure, performance and analysis. It should be noted that large sections of this work were done in collaboration with the group and the group spreadsheet can be made available on request. [1]

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2. Design Brief Introduction

Before the outset of this task the team was defined and brought together as the task was presented. Upon initial meeting the team outlined broad roles that the individuals would take on and represent. The role of the author was the Test and Evaluation Engineer who is responsible for all aspects of Testing, Performance evaluation and regulatory compliance. The full group breakdown can be seen in Table 1.

Student Number	Initials	Member Order	Role
2217522	GJ	A	Research and Development
2222538	LJ	B	System Safety
2207149	CH	C	Test and Evaluation
2219350	DG	D	Manufacturing
2223157	RM	E	Process Safety
2224230	LG	F	Disposal

Table 1 - Group Breakdown

The initial brief set by the customer was to design a solution that could “Neutralise the communications centre whilst causing minimal collateral damage to the rest of the building structure or potential occupants” with a stretch target to “immobilise / disorientate occupants rather than eliminating them”. Further detail was provided for the structure, layout and construction of the target building. [2]

The information provided detailed a target that was situated in a dense urban environment and consisted of a single 10m x 8m x 4m room within a high-rise building of standard cavity wall construction as detailed in Figure 1

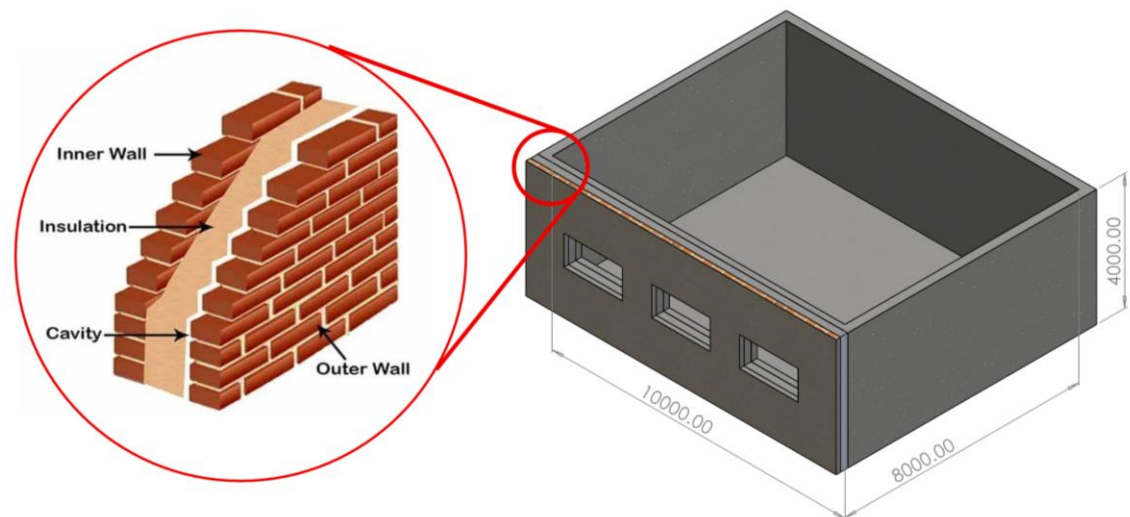


Figure 1 - Target and Construction [3]

Additional information from the customer dictated an energetic solution with a

3. System Design Process

All systems engineering is often based around a cyclical process that flows down through the various stages of the project in an iterative style. This method is often referred to in the project management as a mix between agile and waterfall.

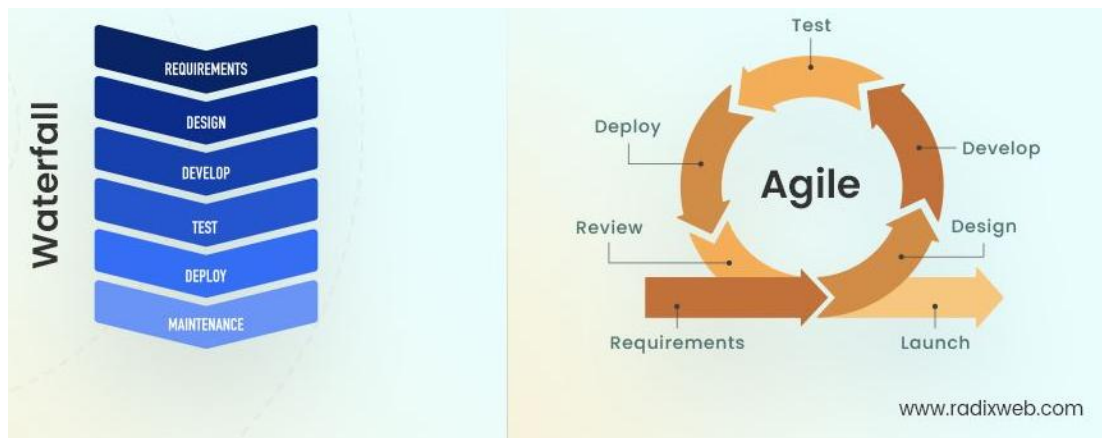


Figure 2 - Agile Vs waterfall [4]

Breaking down the stages for this project we will start with a given system level, define and evaluate requirements, develop functions and concepts before identifying the critical component. From here the same process will repeat for the identified critical component. This process would repeat for every component until sufficient detail is captured but due to time constraints for this project this was deemed excessive.

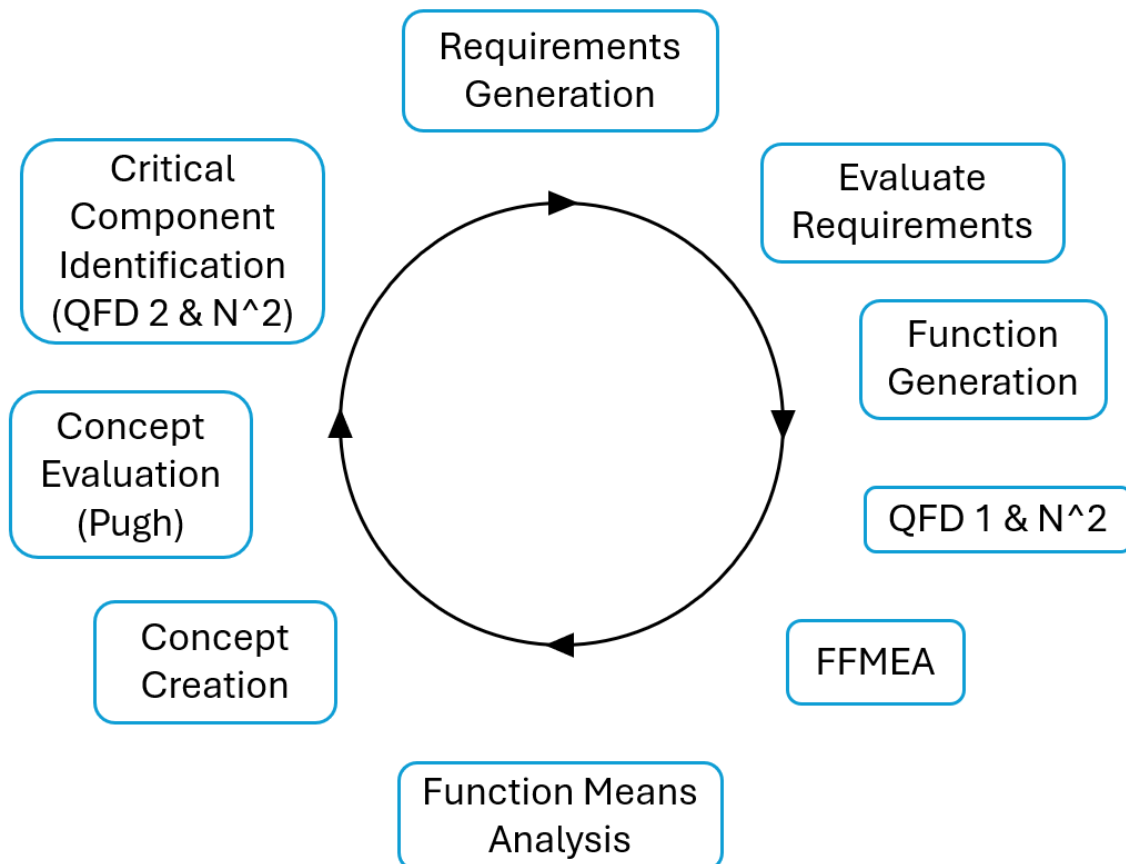


Figure 3 - Systems Process

4. Design Requirements

In the initial stages of any design exercise defining and detailing a good set of requirements is a critical step to ensure that all stakeholder needs are appropriately met, where possible. Without sufficient time and effort spent during the requirements phase greater time and cost will be required to rectify future issues that could have been designed out to begin with. The design team defined an initial set of stake holders using influence maps, affinity Diagrams and Boundary Maps. Which then supported all future requirement generation. The requirements generated for each of the relevant system levels can be seen in Annex A along with the associated Pairwise comparisons.

To best prioritize the requirements at each level, they were self-compared in a pairwise matrices. These matrices then provided the ranking for future use in QFD1's

5. Functionality

Defining functionality for any new system is often a challenging task as without experience or guidance the functions created can often be over specific.

Table 2 below shows the functions derived for the relevant stages in this project. These functions are not perfect and could greatly be improved but where sufficient for this exercise. These functions where developed using a wide range of user experience as well as previous design and system understanding.

System	Missile SAU	SAU EBW
Arm Weapon	Provide PC Initiation	External Casing
Launch/ Release Munition	Provide FTB Initiation	Focus Shockwave
Arm Warhead	Safety Conformation	Provide Detonation
Identify Target	Electronic Circuit	Initiating Composition
Travel to Target	Protect Components	Bridge Wire
Pack down	Contain Components	Environmental Seal
Aim	FTB Interface	
Reload	Sequential Safety Device 1 - Controller Safety Conformation	
Neutralise Target	Sequential Safety Device 2 - Set back	
Enter Target	Sequential Safety Device 3 - Time delay	
Ready System	Receive Electronic Inputs	
	Delay Second detonation	
	Missile Structure Interface	
	Power Buffer	

Table 2 – Functions [1]

6. Concept Derivation and Design Selection

At each system level after defining the functions, the team used an ideation session to generate the set of functional means. This was a brain storming session simply used to generate possibilities for the functions. These could then be assembled to form solutions. These solutions were then listed as a series of options that were then evaluated initially through discussion and then through a Pugh diagram.

When initially eliminating options the same standard set of criteria were used, see Figure 4.

Elimination Criteria	
Elimination Reason	Description
Reliability	Unreliable will not be purchased
Cost	To expensive will become unaffordable.
War Crime	Against the Geneva Convention
Collateral Damage	To much damage is unacceptable
Time	If employment time is excessive it won't be used
Excessive Risk	
Theoretical	
Logistical Burden	

Figure 4 - Elimination Criteria [1]

At the system level the below concepts were proposed. Options 2, 3 and 4 were taken forward and presented to the customer with option 3 being chosen as the favoured design.

Option	1	2	3	4	5	6
Function	EMP Device	Robot Dog	Shoulder Launched Missile	Drone	40mm Grenade	Glider
Ready System	Tripod Launcher	Un-pack	Hand Assemble Weapon	Un-pack	Shoulder launcher	Unpack
Identify Target	Laser Designator	Manual Aiming	GPS Location	Visual ID	Look Through Optic	GPS
Aim	Visual ID	Thermal	Visual ID In Optical Sight	FPV	Manual Aiming	Manual control
Arm Weapon	Electrical	Program	Electrical Controller	Pin	Safety Switch	Electronic
Launch/ Release Munition	Compressed gas launch	Robot dog	Boost Rocket motor	Spring Release	Trigger	Slingshot
Arm Warhead	Setback	Timed Fuse	Electrical SAU	Mechanical	Delayed Contact	Electrical
Travel to Target	Rocket motor	Robot Dog	Sustain Rocket motor	Drone	Ballistic Trajectory	Glide/ propeller
Enter Target	Shape Charge	Kinetic Impact	EFP	Sonic Shattering of Window	Go Through Window	Kinetic impact
Neutralise Target	EMP	Chemical	Blast Warhead	Blast/Frag/Gas (LSD)	Gas	Payload - blast
Reload	Transfer control unit	single use / New unit	single use / New unit	Magazine Fed	Breach Load	New unit
Pack down	Back-Pack/Rucksack	Single Use	Collapsible Control Unit	Back-pack/Ruck-sack	Sling	Single use
Elimination Reason	Theoretical				Reliability	Reliability

Figure 5 - System Level Design Options [1]

The next round of development focused on the key component of the missile, the SAU. 3 designs were proposed internally and option 3 was selected as the favoured choice through a Pugh Diagram

Option	1	2	3
Functions	Point Det Fuze	Mechanical SAU	Eletrical SAU
Contain Components	Metal Case	Metal Case	Metal Case
Protect Componets	Custom Case	Custom Case	Rubber Filling
Electronic Circuirty	Mechanical	Mechanical	Single Sided PCB
Safety Conformation	Series	Interlocking	Resistance Check
Sequential Safety Device 1 - Controler Safety Conformation	Switch	Switch	Software Resistance Check
Sequential Safety Device 2 - Set back	Inertial	Mechanical Tilt Sensor	Compliant Eletrical Mechanism
Sequential Safety Device 3 - Time delay	Delay Composition	Spring Release	Capacitor Disscharge linked to Relay
Power Buffer	NA	NA	Capacitor
Delay Second detonation	Pyrotechnic composition	Mechanical Timer	pyrotechnic composition
Provide PC Initiation	Stab	Stab	EBW
Provide FTB Initiation	HE Booster	HE Booster	HE Booster
Receive Electronic Inputs	NA	NA	Mil Stan Contacts
Elimination Reason	Reliability	Inefective	

Figure 6 - SAU Design Options [1]

In the last stage of development, the same design options process was used to define the manufacturing process for the Exploding bridge wire in the EBW. This step formed the initial stage of defining the manufacturing process.

Function: Fuze EBW	Means								EBW Final Selection
Casing	Mill	Press Form	Print	Extrude	Fold	Turn	Cast		Press Form
Brass waveguide	Mill	Press	Print	Extrude and Cut	Fold	Turn	Cast		Extrude and Cut
Booster	Mechanical	Hydraulic Press Booster	Hand	Pneumatic	Robot	Hammer	Ram in case	Cast	Hydraulic Press Booster
Primary	Mechanical	Hydraulic Press Primary	Hand	Pneumatic	Robot	Hammer	Ram in case	Cast	Hydraulic Press Primary
Assemble Wire	Robot Position and Solder	Hand	Print	soldering	welding	extruding			Robot Position and Solder
Insert EBW	Hand	Robot Positoning	Mass assembly line						Robot Positoning
Header	Melt Cast and Pour	printed	wrapped	pressed					Melt Cast and Pour

Figure 7 - EBW Manufacturing Process Selection. [1]

At the end of these design cycles the basic system architecture was defined and broad designs where in place to allow for the full design process to take place.

Once the final option was selected for each system level a Functional Failure Modes Effects Analysis (FFMEA) was used to identify possible failure modes and appropriate detection or prevention methods that could then either be integrated into the design or mitigating process. These can be found at Annex E.

7. System Architecture and Critical Components

The chosen system can be broken down into a series of component parts and subsystems. At the weapon level the system is made of 3 core components; Command and Launch Unit (CLU), Telescopic Missile Tube (TMT) and Missile shown in Figure 8 respectively. the assembled system is shown in Figure 9. Of the three core components the Missile is deemed to be the most critical component and where the future development and focus is placed.



Figure 8 - CLU, TMT, Missile

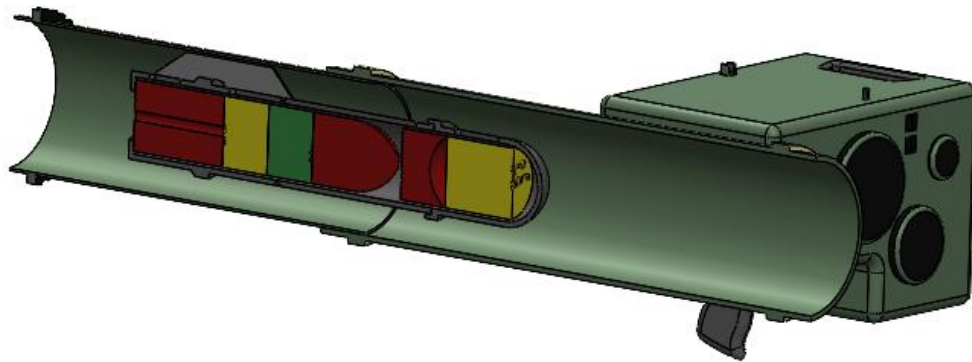


Figure 9 - Weapon System Assembled

Breaking down the Missile into its core components it is made up from a Case, Rocket Motor, Weapon Controller, Safety and Arming Unit, Lethal Package and Guidance Control Unit. Using a QFD 2 the Safety and Arming Unit (SAU) was determined to be the most critical component within the missile.

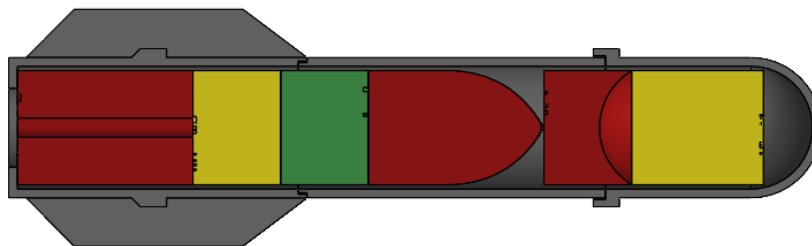


Figure 10 - Missile Cross Section

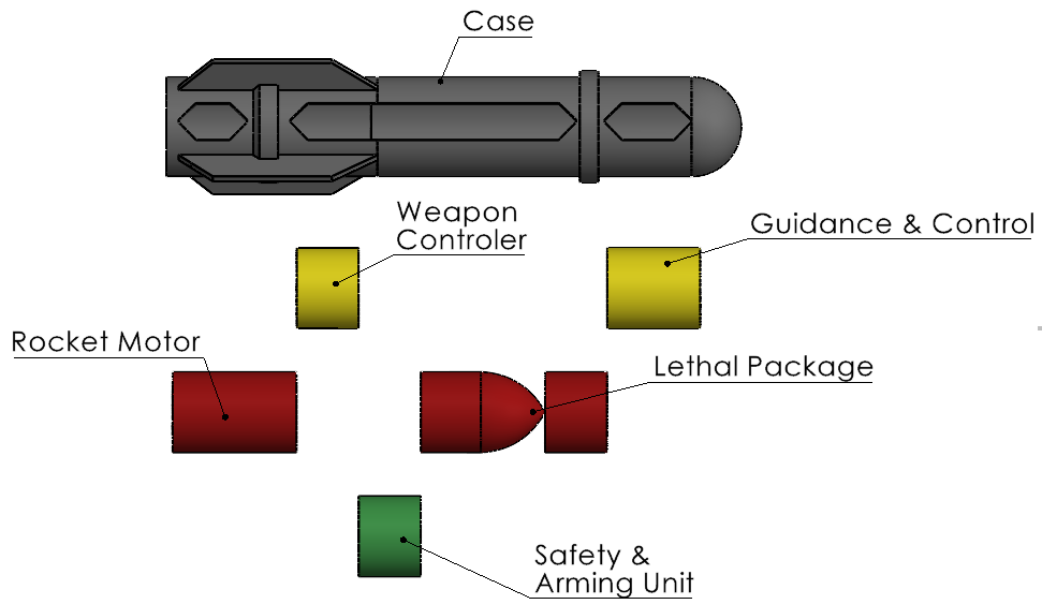


Figure 11 - Missile Component Breakdown

Whilst the full design for the SAU is yet to be determined and finalised broad functionality and sub systems/ components could be determined from current in-service examples below.



Figure 12 - Thales FBM21 [5]



Figure 13 - Ferranti AAM [6]

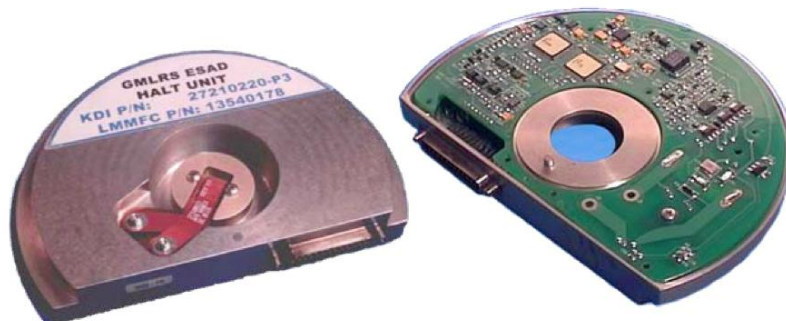


Figure 14 - GLMRS HALT Unit [7] [8]

This research allowed for the determination of a standard set of functions¹ that the SAU required. Of which the initiator that translates electrical signal in to a detonative shock wave was identified as the key component. The chosen solution for this component was an Exploding Bridge Wire (EBW) detonator as shown in Figure 15.

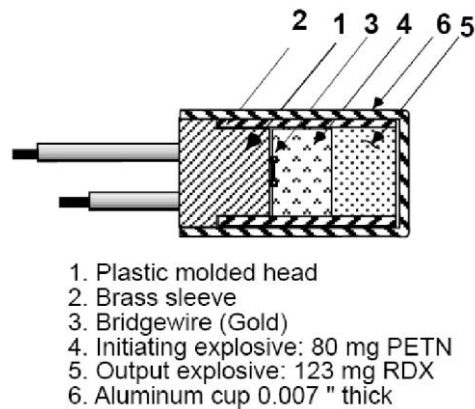


Figure 15 - EBW Detonator [9]

At this stage of the project, it was determined though that it was possible to keep going down the subsystem route and further defining design choices, this stage of development provided sufficient detail.

The final critical component architecture can be seen in Figure 16.

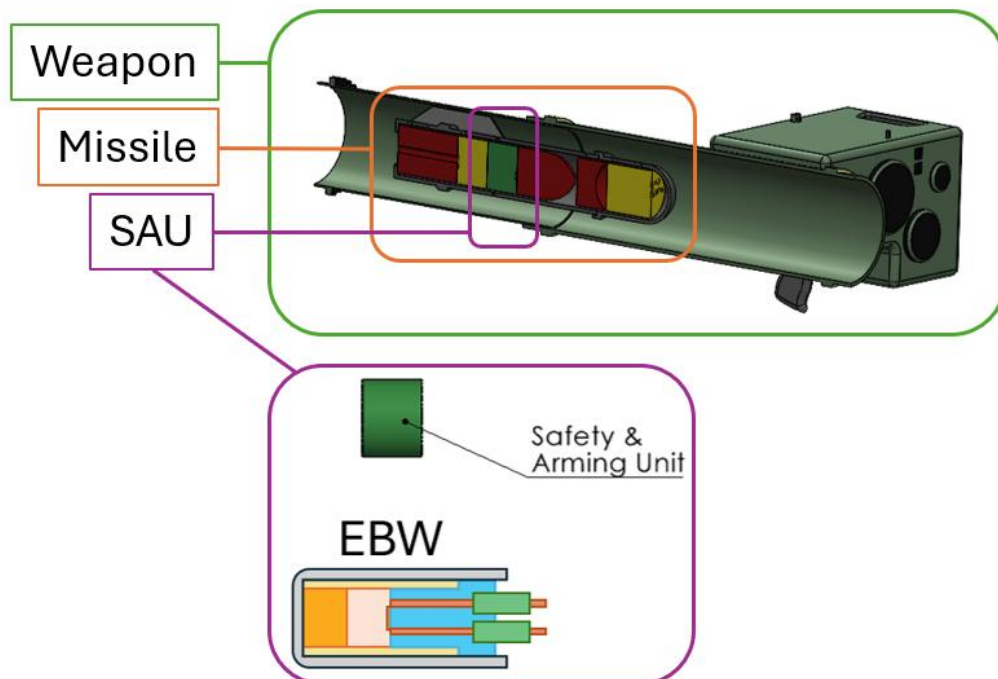


Figure 16 - Critical Component System Architecture

¹ See Table 2

8. Manufacturing Route

The manufacturing route was defined by team member D as they volunteered to represent the manufacturing role within the team. As with the other system levels for the manufacturing aspect of this task the engineer decided to focus on the most important energetic component within the SAU. This was determined to be the EBW and within the EBW the Primary Initiation Pellet (PIP) was the most critical component.

To manufacture the PIP the broad process flow shown below is used. It outlined the broad steps and stages that occur to take the raw energetic material to the finalised pellet ready for further inclusion into the EBW.

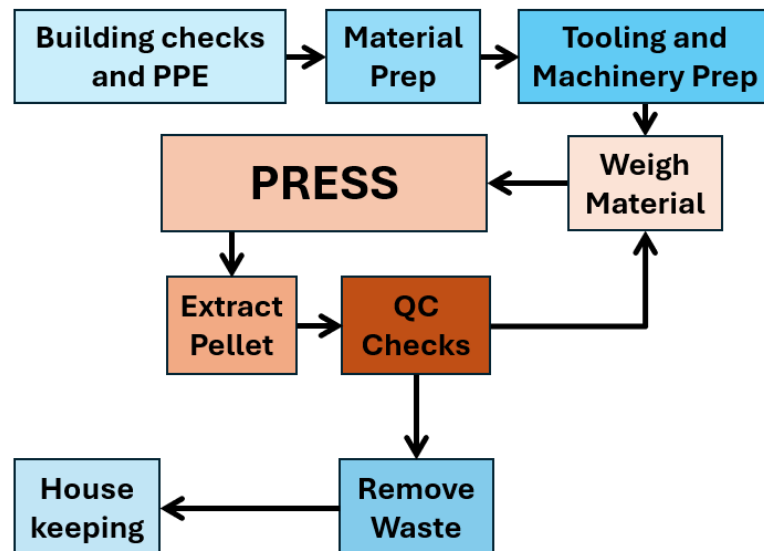


Figure 17 - PIP Manufacturing Process Flow

9. Test and Evaluation.

The Test and Evaluation (T&E) programme was drafted by the author, team member C. As with the manufacturing plan, it was determined that limiting the scope of the testing plan to that of the SAU rather than the whole set of Safe and Suitable for Service requirements would be beneficial and would best allow for detail to be captured without an excessively wide scope. The T&E programme for Safe, Arming and Functioning Devices is defined in the requirements of STANAG 4157 and AOP 20. These standards detail the sequence of tests that must be performed and the results that must be achieved for qualification to be granted. The full T&E plan can be found at Annex B

Though the (T&E) plan forms the qualification requirements for the SAU, it can also be used by manufacturers to support development and evaluate design decisions. For example, the D9 test will effectively test the performance of the EBW and energetic train to provide validation of the manufacturing process. The SAU testing will form a critical part of the Safe and Suitable for Service (S3) requirement that the MOD has for any new item coming into service.

10. Noises and controls

Noises and their associated controls are critical to any product. Noises can have an impact at any stage from design to manufacturing, use or disposal. With complex munitions such as missiles, unmitigated noises are often not fully experienced until many years later when their results are finally present or made obvious. This is why it is vital that at an early stage of design as many effective controls are made to mitigate known noises. In the example of this munition ensuring that the energetics used within the EBW are stable and have a known stabiliser consumption rate will allow for the effective predicting of SAU life and therefore allow for a stockpile to be effectively maintained without excessive Surveillance and Life Extension (SALE) on the inherently sensitive initiating systems.

11. Design Presentation Feedback.

After the final design presentation the "Customer" presented the feedback below.

Charles Hadley	Team 1
Team feedback / Questions	
Q to team.....Alternatives to EBW? Were these considered? simple slides with clear layout. Images are a good size, easy to view. Good contrast between text and background. Theme consistent throughout different sections to give a nice cohesive team feeling. Referring to other people's sections showed good collaboration. Some overlap in safety content, could give the impression of lacking communication between the two. Clear introduction to set out order of events. Would have benefitted from having a distinct conclusion, even one slide summarising the key points. References stated as available on request; it would have been better to include the references slide in the presentation for the sake of transparency. Some misinterpretation of stretch goal between group members?	
Feedback / Comments Dave	
Specifications and sources of legislation understood How do you ensure that subsystems are tested to the right level Systems logic may have slipped to the SAU very quickly How would the go / no go values, for the tests be cascaded down Actions taken to qualify subcomponents?? Smart certification?? What do you need for this??	
Feedback / Comments Jenni	
good volume, quite a fast-paced delivery which could make it difficult for someone to follow if they are not familiar with the area. Good interaction with the audience, open body language. Minimal reading from slides/screen. Confident delivery throughout.	

Figure 18 - Presentation Feedback [10]

The answers to the technical/ systems questions posed are below the remaining statements will be evaluated in the WBGP report.

Q: Where Alternatives to EBW's Considered?

A: Yes see Figure 6.

Q: How do you ensure sub systems are tested to the right level?

A: There is no ideal answer with this as some level of trial and error is required, generally munitions manufacturers are experienced and have been operating for a number of years so have a level of expertise that can be utilised to provide a satisfactory level of confidence at a given level. In short, its down to the experience of the engineers on the project.

Q: How would the go no-go values for the tests be cascaded down?

A: Once the testing criteria are understood these values can then be passed back to the beginning of the process into the requirements. These would be used within the tool set in a QFD.

Q: What actions could be taken to qualify subcomponents? Could smart certification be used?

A: Single manufactures that take raw materials and make every aspect of a munition from scratch don't exist, instead they will use Common Of The Shelf (COTS) products where possible to minimise cost and development time. Consequently, there are often examples of similar scenarios that can be used as read across when qualifying munitions. In addition, documents like waivers can be used where munitions or components are sufficiently understood to pose little unknown risk to the system. This type of approach is gaining popularity within the UK defence as it forms a faster and more cost-effective way to maintain S3 with a minimal change in risk. This is often referred to as a risk-based approach.

12. Conclusion

In conclusion the design solution presented at Annex D has been designed and evaluated to be the most logical option for the customer, it effectively balances the requirements and delivers the designed effect. Although only the preliminary designs have taken place for the critical components, the initial stages of the design have demonstrated that the continued development should yield an effective product. The works conducted demonstrates how the effective use of the systems engineering tool set will guide, inform and document the clear process steps taken to achieve the end result. This not only allows for effective though life communication but also provides clarity and evidence to the customer on the reliability of the design solution and how changes in requirements could affect the chosen design.

13. References

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14. Annex A – Requirements [1]**14.1. System Requirements**

Stakeholder	Operational Requirement	Priority	Requirement Type	Level 2 Name	L2 Description	Level 3
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price		NFS	Regulation Compliance	The system must comply with all relevant legislation,	
Logistics	Deliver a Safe and Reliable Product to the customer at a competitive Price		OR	Packaging	The system should be packaged in standard packaging where possible	
Logistics	Deliver a Safe and Reliable Product to the customer at a competitive Price	Old	NFS	Supply Chain	The munition shall be compatible with the existing Supply chain	
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price		NFP	Field Maintainable	The system will be field maintainable where required.	
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price		NFP	Reliability	The performance shall be reliable with failures of 1e-6 per year	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price		NFP	Operational Climate	The system shall perform in cold and hot climates A1 - C2	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price	Old		Fail Safe	The fail safes to ensure the system shall function in the event of a misfire	
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price		1 NFS	Man Portable	The system shall be Man Portable	
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price	Old		Single Person Usable	The system should be single person useable.	
Customer	Neutralise the Target			Lasting Effects	The system should deliver a disruptive effect that will last no longer than 12h	
Customer	Neutralise the Target		1 NFP	External Access	The entry to the room should be gained through an external wall	
Customer	Neutralise the Target		1 NFP	Incapacitation	The Customer requires that the system should incapacitation or elimination of the Comms Users	
1st Party (User)	Neutralise the Target		NFP	Simple Reloading	The system should have a simple unload / reload procedure	
Customer	Neutralise the Target		NFP	100m Distance	The delivery system shall be able to perform from a minimum distance of 100m.	
Customer	Neutralise the Target		NFP	Damage Containment	The damage be contained to the target room.	
Customer	Neutralise the Target	Old		Geneva Convention	The system must comply with the Geneva Suggestions.	
1st Party (User)	Neutralise the Target		F	Accuracy	The system must be accurate to a 0.25m radius at 100m.	
1st Party (User)	Neutralise the Target			Setup and Deployment	The system shall have a Rapid setup and Deployment time.	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price			Operation Environment	The system shall be able to operate in a dense urban environment	
Customer	Neutralise the Target			Destroy Equipment	The system shall be able to destroy the target equipment.	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price			Operational Safety	The system must be safe under operational Conditions (Backblast, Signature etc)	
1st Party (User)	Neutralise the Target			Ease of Use	The system shall be easy to use.	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price			Disposal	The system must have a safe disposal method.	
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price			Safety	The system must be safe throughout the CADMID Cycle	

14.2. System Pairwise

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Calc		Calc
	Pairwise comparison of requirements 1 = No Preference, Reciprocal = 1 2 = Slight Preference, Reciprocal = 0.5 5 = Preference, Reciprocal = 0.2 9 = Strong preference = 0.1	Regulation Compliance	External Access	Incapacitation	Man Portable	Packaging	Lasting Effects	Field Maintainable	Simple Reloading	Reliability	Operational Climate	100m Distance	Damage Containment	Accuracy	Setup and Deployment	Operation Environment	Destroy Equipment	Operational Safety	Ease of Use	Disposal	Safety	Row Product	nth root of row product	Total Normalised
1	Regulation Compliance	1	5	0.2	0.5	1	1	2	0.2	0.2	1	0.1	0.1	0.1	0.2	0.2	0.2	1	0.5	1	1	16.5	1.150467083	4.745480873
2	External Access	0.2	1	9	9	9	5	2	5	9	5	0.2	5	0.1	5	5	9	0.1	5	5	2	90.6	1.252726919	5.16728529
3	Incapacitation	5	0.1	1	9	9	1	2	5	9	5	1	1	1	2	5	0.1	0.1	2	5	1	64.3	1.231432322	5.079448702
4	Man Portable	2	0.1	0.1	1	5	5	5	9	1	0.2	0.2	0.5	0.1	1	0.1	0.1	0.1	0.2	1	0.1	31.8	1.18883438	4.903739442
5	Packaging	1	0.1	0.1	0.2	1	0.2	1	0.2	0.1	1	0.1	0.1	0.1	0.1	0.5	0.1	0.1	2	0.2	1	9.2	1.117350407	4.60888022
6	Lasting Effects	1	0.2	1	0.2	5	1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	1	1	1	13.2	1.137702458	4.69282897
7	Field Maintainable	0.5	0.5	0.5	0.2	1	5	1	5	0.2	1	0.1	0.1	0.1	0.5	1	0.1	0.2	0.2	0.1	9	26.3	1.177599974	4.85739943
8	Simple Reloading	5	0.2	0.2	0.1	5	5	0.2	1	0.2	0.2	0.2	9	0.1	0.2	0.2	0.1	0.1	1	0.2	9	37.2	1.198194018	4.942346355
9	Reliability	5	0.1	0.1	1	9	5	5	5	1	2	0.5	5	0.2	5	1	1	0.5	5	5	1	57.4	1.224462798	5.050700599
10	Operational Climate	1	0.2	0.2	5	1	5	1	5	0.5	1	0.1	0.1	0.1	0.1	1	0.1	1	0.5	0.5	9	32.4	1.189945992	4.908324652
11	100m Distance	9	5	9	5	9	9	9	5	2	9	1	1	0.5	0.1	9	0.5	0.1	0.1	0.1	5	88.4	1.251188123	5.160938018
12	Damage Containment	9	0.2	9	2	9	9	9	0.1	0.2	9	1	1	0.2	2	5	0.1	0.2	0.2	0.1	1	67.3	1.234243229	5.091043212
13	Accuracy	9	9	9	9	9	9	9	9	5	9	2	5	1	9	2	1	1	5	5	1	118	1.269387158	5.236005938
14	Setup and Deployment	5	0.2	0.5	1	9	5	2	5	0.2	9	9	0.5	0.1	1	1	9	9	1	0.1	9	76.6	1.24225696	5.124098488
15	Operation Environment	5	0.2	0.2	9	2	5	1	5	1	1	0.1	0.2	0.5	1	1	0.1	0.1	0.5	5	5	42.9	1.206765441	4.977702017
16	Destroy Equipment	5	0.1	9	9	9	9	9	9	1	9	2	9	1	0.1	9	1	9	0.1	5	0.1	105.4	1.262240267	5.206526229
17	Operational Safety	1	9	9	9	9	5	5	9	2	1	9	5	1	0.1	9	0.1	1	0.1	0.1	1	85.4	1.249030069	5.15203641
18	Ease of Use	2	0.2	0.5	5	0.5	1	5	1	0.2	2	9	5	0.2	1	2	9	9	1	0.5	5	59.1	1.226250999	5.058076624
19	Disposal	1	0.2	0.2	1	5	1	9	5	0.2	2	9	9	0.2	9	0.2	0.2	9	2	1	5	69.2	1.23596253	5.098135038
20	Safety	1	0.5	9	9	1	1	0.1	0.1	1	0.1	0.2	1	1	0.1	0.2	9	1	0.2	0.2	1	36.7	1.197383594	4.939003493

14.3. SAU Requirements

Stakeholder	Operational Requirement	Priority	Requirement Type	Level 2 Name	L2 Description	Level 3 Name	Level 3 - Sub System Description
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.		NFS	Regulation Compliance	The system must comply with all relevant legislation	Regulation Compliance	The SAU must comply with all relevant legislation, including DSA 03
Logistics	Deliver a Safe and Reliable Product to the customer at a competitive Price.		OR	Packaging	The system should be packaged in standard packaging where possible	H83 Container	The SAU shall fit inside a H83 Container
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price.		NFP	Field Maintainable	The system will be field maintainable where required.	External Safety Check	The SAU shall have an external safety check procedure.
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price.		NFP	Reliability	The performance shall be reliable with failures of 1e-6 per year	Reliability	The SAU shall be reliable with performance failures of 1e-8 Per Use
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.		NFP	Operational Climate	The system shall perform in cold and hot climates A1 - C2	Operating Temperature	The SAU shall have an operating temperature of -30 to + 40
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.	Old		Fail Safe	The fail safes to ensure the system shall function in the event of a misfire	Fail Safe	The SAU shall fail safe in the event of miss sequence of safety events
1st Party (User)	Deliver a Safe and Reliable Product to the customer at a competitive Price.		1 NFS	Man Portable	The system shall be Man Portable	Weight (500g)	The SAU shall weigh no more than 500g
Customer	Neutralise the Target			Lasting Effects	The system should deliver a disruptive effect that will last no longer than 12h	System Initiation	The SAU shall support the initiation of the Device
Customer	Neutralise the Target		1 NFP	External Access	The entry to the room should be gained through an external wall	Charge Initiation	The SAU shall be able initiate the primary and secondary charge
Customer	Neutralise the Target		NFP	100m Distance	The delivery system shall be able to perform from a minimum distance of 100m.	Safety Devices	The SAU shall have a minimum of 2 Safety Devices to detect setback and Time duration since set back.
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.			Operational Safety	The system must be safe under operational Conditions (Backblast, Signature etc)	Safety in operational conditions	The SAU must be safe under all operational conditions
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.			Disposal	The system must have a safe disposal method.	Disposal	The SAU must have a safe disposal method that supports refurbishment
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.			Safety	The system must be safe throughout the CADMID Cycle	Safety	The SAU must be safe throughout the CADMID cycle
Customer	Deliver a Safe and Reliable Product to the customer at a competitive Price.	From FFMEA		Safety	Quality Assurance Checks must be carried out during all stages of manufacture	QA Checks	Quality Assurance Checks must be carried out during all stages of manufacture
		From FFMEA	FP	FTB Intergration		FTB Intergration	The SAU shall mechanically intergrate with the FTB
		From FFMEA	FP	Missile Intergration		Missile Attachment	The SAU shall mechanically intergrate with the Missile
		From FFMEA	NFP	Manufacturing QC Checks			The Manufacturing of the SAU shall contain sufficient QC Checks
		From FFMEA		SAU Connector		SAU Connector	The SAU Shall have a connector that is compliant with the Mil Standards and ESD Safe

14.4. SAU Pairwise

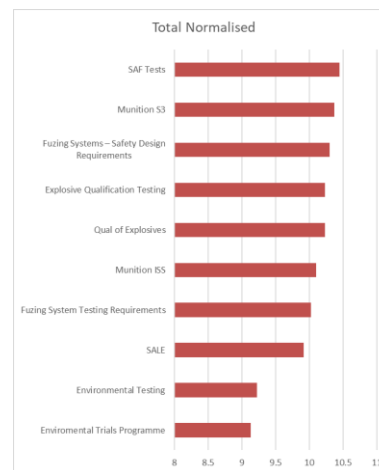
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Calc		Calc
	Pairwise comparison of requirements 1 = No Preference, Reciprocal = 1 2 = Slight Preference, Reciprocal = 0.5 5 = Preference, Reciprocal = 0.2 9 = Strong preference = 0.1	Regulation Compliance	Charge Initiation	Disposal	External Safety Check	Fail Safe	FTB Intergration	H83 Container	Removed (NA)	Missile Attachment	Operating Temperature	QA Checks	Reliability	Safety	Safety Shear Devices	Safety in operational conditions	SAU Electrical Connector	System Initiation	Weight (500g)	Row Product	nth root of row product	Total Normalised
1	Regulation Compliance	1	9	1	0.1	1	9	9	1	0.5	0.5	0.1	0.1	1	0.2	0.5	1	0.1	9	44.1	1.2084312	5.617108299
2	Charge Initiation	0.1	1	9	9	9	9	9	1	9	9	9	9	0.5	0.2	9	9	1	9	111.8	1.26596614	5.884545943
3	Disposal	1	0.1	1	0.1	0.1	0.2	0.2	1	2	0.2	0.1	0.1	0.1	0.1	0.1	9	0.1	2	17.5	1.15385677	5.363431893
4	External Safety Check	9	0.1	9	1	1	5	9	1	5	5	1	0.1	1	1	5	5	0.2	1	59.4	1.226561482	5.701382653
5	Fail Safe	1	0.1	9	1	1	9	9	1	1	2	2	1	1	1	1	9	1	1	51.1	1.217365655	5.658638013
6	FTB Intergration	0.1	0.1	5	0.2	0.1	1	5	1	5	9	2	1	0.2	5	5	9	1	2	51.7	1.218076395	5.661941722
7	H83 Container	0.1	0.1	5	0.1	0.1	0.2	1	1	2	0.5	1	0.5	0.5	0.2	0.2	0.2	0.5	0.2	13.4	1.138558212	5.292320143
8	Removed (NA)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	1.155483173	5.370991845
9	Missile Attachment	2	0.1	0.5	0.2	1	0.2	0.5	1	1	2	2	0.5	0.5	2	5	1	0.5	5	25	1.174618943	5.459939974
10	Operating Temperature	2	0.1	5	0.2	0.5	0.1	2	1	0.5	1	2	1	0.2	0.1	0.5	0.5	0.5	5	22.2	1.167663349	5.427608532
11	QA Checks	9	0.1	9	1	0.5	0.5	1	1	0.5	0.5	1	1	0.2	0.1	0.2	0.2	0.2	0.5	26.5	1.178046121	5.475870406
12	Reliability	9	0.1	9	9	1	1	2	1	2	1	1	1	0.2	0.5	1	0.5	0.5	2	41.8	1.205199143	5.602084842
13	Safety	1	2	9	1	1	5	2	1	2	5	5	5	1	1	5	5	0.5	2	53.5	1.220162544	5.671638695
14	Safety Shear Devices	5	5	9	1	1	0.2	5	1	0.5	9	9	2	1	1	1	5	0.5	5	61.2	1.228393674	5.709899165
15	Safety in operational conditions	2	0.1	9	0.2	1	0.2	5	1	0.2	2	5	1	0.2	1	1	0.1	1	2	32	1.189207115	5.527749661
16	SAU Electrical Connector	1	0.1	0.1	0.2	0.1	0.1	5	1	1	2	5	2	0.2	0.2	9	1	0.1	5	33.1	1.191218418	5.537098731
17	System Initiation	9	1	9	5	1	1	2	1	2	2	5	2	2	2	1	9	1	9	64	1.231144413	5.722685332
18	Weight (500g)	0.1	0.1	0.5	1	1	0.5	5	1	0.2	0.2	2	0.5	0.5	0.2	0.5	0.2	0.1	1	14.6	1.143451222	5.315064149

14.5. Test and Evaluation Requirements

Level 3 Requirement	Level 4 Requirement	Description	Level 5 Name	Level 5 Title	L2 Description
Regulation Compliance	DSA02 OME 107	EM Qualification	STANAG 4170	Qual of Explosives	Principles And Methodology For The Qualification Of Explosive Materials For Military Use
Regulation Compliance	DSA02 OME 107	EM Qualification	AOP 7	Explosive Qualification Testing	Manual Of Data Requirements And Tests For The Qualification Of Explosive Materials For Military Use
Regulation Compliance	DSA02 OME 110	Emrviromental assessment (E3)	AOP-15	Munition S3	Guidance On The Assessment Of The Safety And Suitability For Service Of Non-Nuclear Munitions For Nato Armed Forces
Operating Temprature	DSA02 OME 110	Enviromental assessment (climactic and mechanical)	STANAG 4370	Environmental Testing	Environmental Testing
Operating Temprature	DSA02 OME 101	OME Design Requirements	DEFSTAN 00-035	Environmental Trials Programme	Environmental Trials Programme Derivation And Assessment Methodologies
Regulation Compliance	DSA02 OME 108	Initiating Systems Qualification	STANAG 4187	Fuzing Systems – Safety Design Requirements	Fuzing Systems – Safety Design Requirements
Operatonal Safety	DSA02 OME 108	Initiating Systems Qualification	STANAG 4157	Fuzing System Testing Requirements	Fuzing System Testing Requirements
Operatonal Safety	DSA02 OME 108	Initiating Systems Qualification	AOP-20	SAF Tests	Safety, Arming And Functioning Systems Manual Of Tests
Operatonal Safety	DSA02 OME 104	Manufacture to Target or Disposal Sequence (MTDS)	AOP-15	Munition S3	Guidance On The Assessment Of The Safety And Suitability For Service Of Non-Nuclear Munitions For Nato Armed Forces
Operatonal Safety	DSA02 OME 113	OME Through-Life Capability Management (TLCM)	AOP-63	Munition ISS	In-Service Surveillance Of Munitions Sampling And Test Procedures
Operatonal Safety	DSA02 OME 113	OME Through-Life Capability Management (TLCM)	AOP-46	SALE	The Scientific Basis For The Whole Life Assessment Of Munitions
Operatonal Safety	DSA02 OME 109	software and programable Hardware			

14.6. Test and Evaluation Pairwise

		1	2	3	4	5	6	7	8	9	10	Calc		Calc
	Pairwise comparison of requirements 1 = No Preference, Reciprocal = 1 2 = Slight Preference, Reciprocal = 0.5 5 = Preference, Reciprocal = 0.2 9 = Strong preference = 0.1	Qual of Explosives	Explosive Qualification Testing	Munition S3	Environmental Testing	Environmental Trials Programme	Fuzing Systems – Safety Design Requirements	Fuzing System Testing Requirements	SAF Tests	Munition ISS	SALE	Row Product	nth root of row product	Total Normalised
1	Qual of Explosives	1	1	0.11	9	9	0.11	0.11	0.11	9	9	38.44	1.200160058	10.23593065
2	Explosive Qualification Testing	1	1	0.11	9	9	0.11	0.11	0.11	9	9	38.44	1.200160058	10.23593065
3	Munition S3	9	9	1	5	5	1	1	1	9	9	50	1.216041791	10.37138285
4	Environmental Testing	0.1	0.1	0.2	1	1	0.5	0.5	1	0.2	0.2	4.8	1.081588502	9.22465702
5	Environmental Trials Programme	0.1	0.1	0.2	1	1	0.5	0.5	0.11	0.2	0.2	3.91	1.070554639	9.130551359
6	Fuzing Systems – Safety Design Requirements	9	9	1	2	2	1	1	1	9	9	44	1.208294041	10.30530381
7	Fuzing System Testing Requirements	9	9	1	2	2	1	1	0.11	0.11	0.11	25.33	1.175389372	10.02466631
8	SAF Tests	9	9	1	1	9	1	9	1	9	9	58	1.225099605	10.44863517
9	Munition ISS	0.1	0.1	0.1	5	5	0.1	9	0.1	1	9	29.5	1.184380097	10.10134645
10	SALE	0.1	0.1	0.1	5	5	0.1	9	0.1	0.1	1	20.6	1.163304374	9.921595725



14.7. Annex B – SAU Test and Evaluation Plan

Group	Test	Criteria for Passing Test	Munition	Packaged	Minimum Assets Required	Tailoring	Tailoring Reason
Mechanical Shock	A1 Jolt	Safe for use 1	None	No	1	In	
Mechanical Shock	A2.1 Jumble	Safe for use 1	None	No	1	In	
Mechanical Shock	A3 12-m Drop	Safe for disposal	None, I, L	Both	4	In	
Mechanical Shock	A4.1 1.5-m Drop	Safe for use 4	None, I, L	No	2	In	
Mechanical Shock	A5 Transportation Handling	Operable	None, I, L	Yes	2	In	
Vibration	B1.1 Transportation Vibration	Operable	None	Both	2	In	
Vibration	B3 Tactical Vibration	Operable	None	No	1	In	
Climatic	C1 Temperature & Humidity	Operable	None	No	1	In	
Climatic	C2 Vacuum-Steam- Pressure	Operable	None	No	1	In	
Climatic	C3 Salt Fog	Operable 5	None	No	1	In	
Climatic	C4 Waterproofness	Operable 6	None	No	1	In	
Climatic	C5 Fungus	Operable	None	No	1	In	
Climatic	C6 Extreme Temperature	Operable	None	No	1	In	
Climatic	C7 Thermal Shock	Operable	None	No	1	In	
Climatic	C8 Leak Detection	7	None	No	1	In	
Climatic	C9 Dust	Operable 8	None	No	1	In	
Climatic	C10 Solar Radiation	Operable	None, I	Both	2	In	
Safety, Arming & Functioning	D1 Primary Explosive Component Safety	9	None	No	1	In	
Safety, Arming & Functioning	D2 Projectile Fuze Arming Distance	7,	I, L	No	1	Out	Out for component testing - in for System.
Safety, Arming & Functioning	D3 Time to Air Burst	7	I, L	No	1	Out	Out for component testing - in for System.
Safety, Arming & Functioning	D4 Explosive Component Output	7	None	No	1	In	
Safety, Arming & Functioning	D5 Rain Impact	10	I	No	1	In	
Safety, Arming & Functioning	D6 Brush Impact No-Fire Test	Safe, Operable	I	No	1	In	
Safety, Arming & Functioning	D7 Mortar Ammunition Fuze Double Loading Test	Safe	I	No	1	Out	Not a Mortar
Safety, Arming & Functioning	D8 Progressive Arming Test	1	None	No	1	In	
Safety, Arming & Functioning	D9 Explosive Train Transfer Reliability Testing	7	None	No	1	In	
Aircraft Munition	E1 Jettison	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E2 Low Altitude Accidental Release	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E3 Arrested Landing Munition Pull-off	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E4 Catapult And Arrested Landing Forces	Operable	I	No	1	Out	Non Aircraft Munition
Aircraft Munition	E5 Simulated Parachute AirDelivery	Operable12	None, I	Yes	1	Out	Out for component testing, in for system
Electric & Magnetic Influence	F1.1 Electrostatic Discharge	Safe for use13	None	Both	2	In	
Electric & Magnetic Influence	F2.1 High-Altitude Electromagnetic Pulse	Operable7	I	No	1	In	
Electric & Magnetic Influence	F3.1 EMR Hazards (EMRH)	Operable	None	Both	2	In	
Electric & Magnetic Influence	F4.1 EMR, Operational (EMRO)	Operable	None	No	1	In	
Electric & Magnetic Influence	F5 Lightning	Operable	I	No	1	In	
Electric & Magnetic Influence	F6 Electrical Stress Test (EST)	Operable	None	No	1	In	

15. Annex C – Team Structure and Work Breakdown

Student Number	Initials	Member Order	Role
2217522	GJ	A	Research and Development
2222538	LJ	B	System Safety
2207149	CH	C	Test and Evaluation
2219350	DG	D	Manufacturing
2223157	RM	E	Process Safety
2224230	LG	F	Disposal

16. Annex D – Final Presentation



Team 1 Final Presentation

Presented By:
Gareth James (2217522)
Rachel McColm (2223157)
Libby Jones (2222538)
Charles Hadley (2207149)
Dan Garton (2219350)
Lewis Gray (2224230)

For Group Based Project
ACDA5022



Charles Hadley

Meet The Team

**Gareth
James**

Research &
Development Engineer

**Charles
Hadley**

Test & Trials Engineer

**Daniel
Garton**

Manufacturing Engineer

**Libby
Jones**

Design Safety Engineer
& Project Manager

**Rachel
McColm**

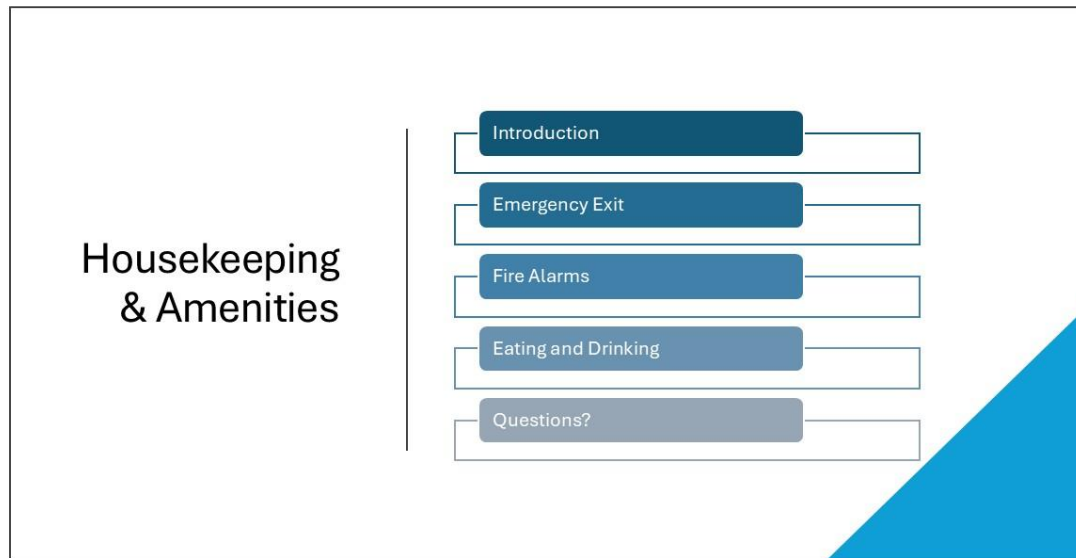
Process Safety Engineer

**Lewis
Gray**

Disposal Engineer



Charles Hadley



Charles Hadley

Agenda

Research & Development

Design Safety

Test & Evaluation

Manufacture

Process Safety

Disposal



Mission Objective:

1. Neutralise the communications centre.
2. Minimise collateral damage to the rest of the building structure or potential occupants
3. Immobilise / disorientate occupants rather than eliminating them.

Requirements:

Contributing Factors:

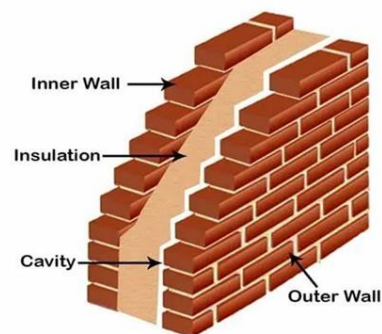
Target specifications:

- External rendered filled cavity block construction – Approx 300-350mm thick.
- Room Dimensions 10m x 8m x 4m Room.

Limiting Factors:

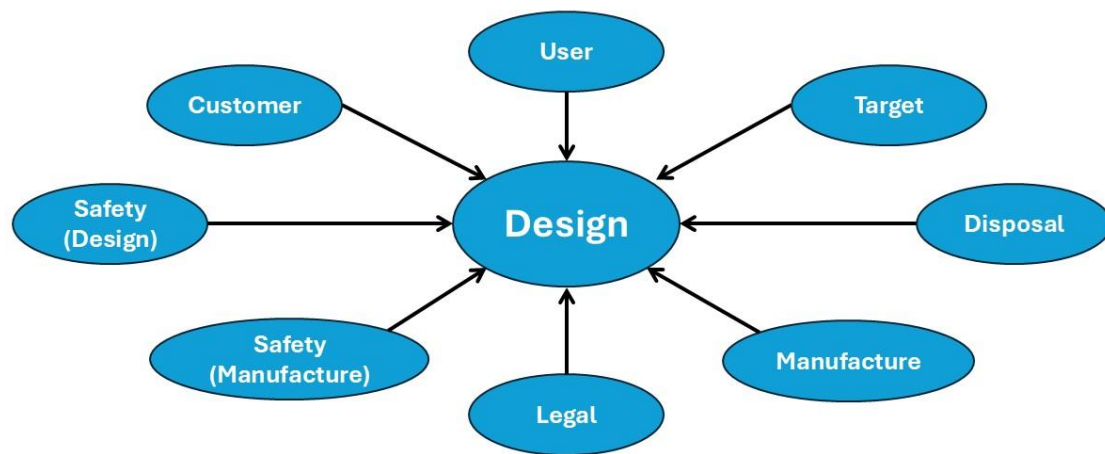
Factors which directly impact design:

- Reduction of collateral damage
- Blast must also not impact the structure



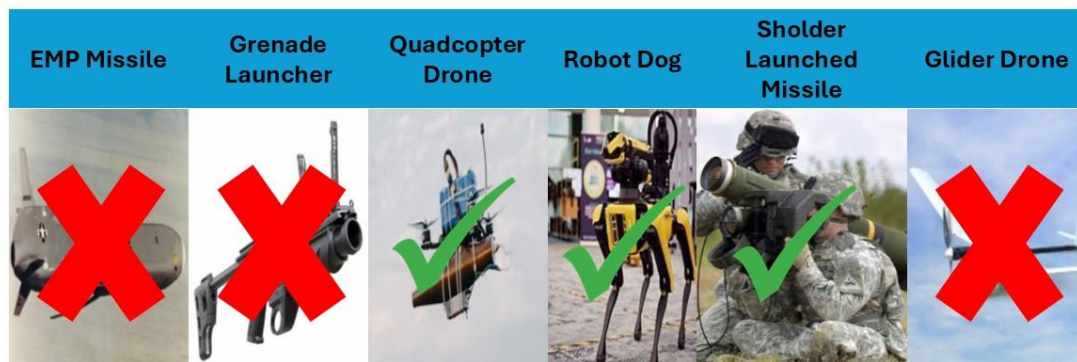
Gareth James

Requirements



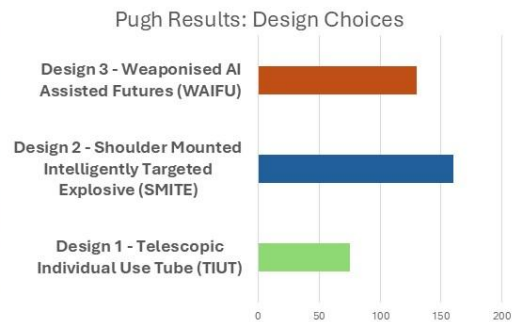
Gareth James

Design Phase Summary



Gareth James

Solution:



Gareth James

System Design Overview

Telescopic Tube

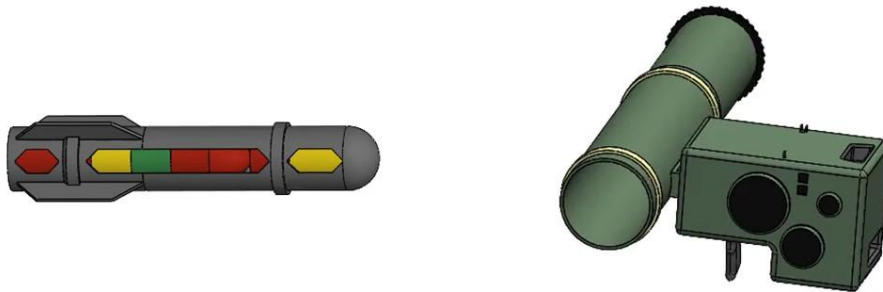


Command and Launch Unit
(C.L.U.)



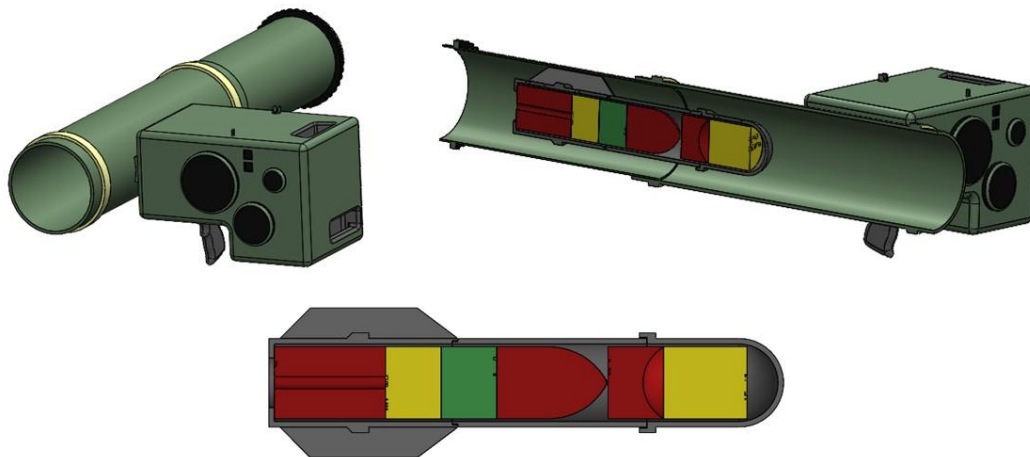
Gareth James

System Design Overview



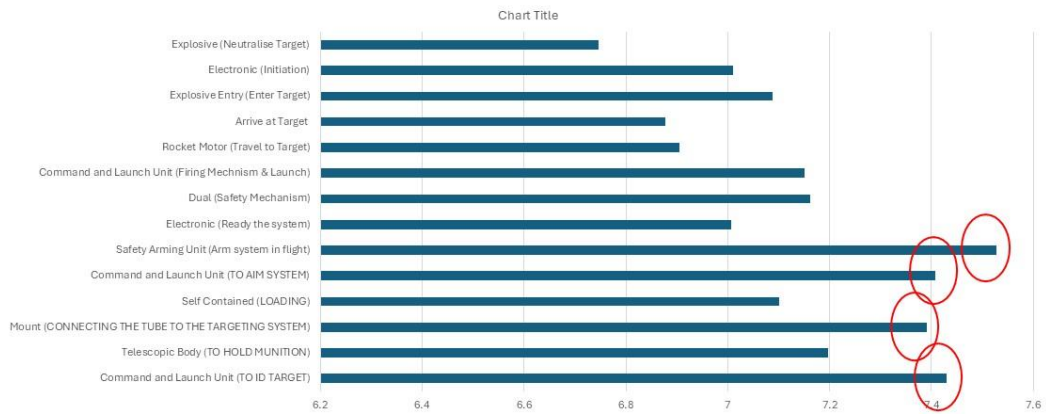
Gareth James

Shoulder Launched Missile



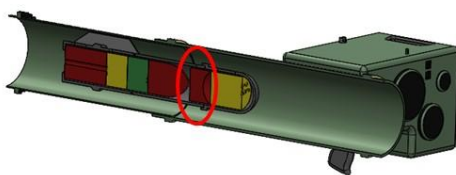
Gareth James

System Design Overview



Gareth James

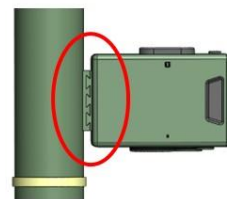
Key Design Features:



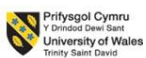
The Safety and Arming Unit



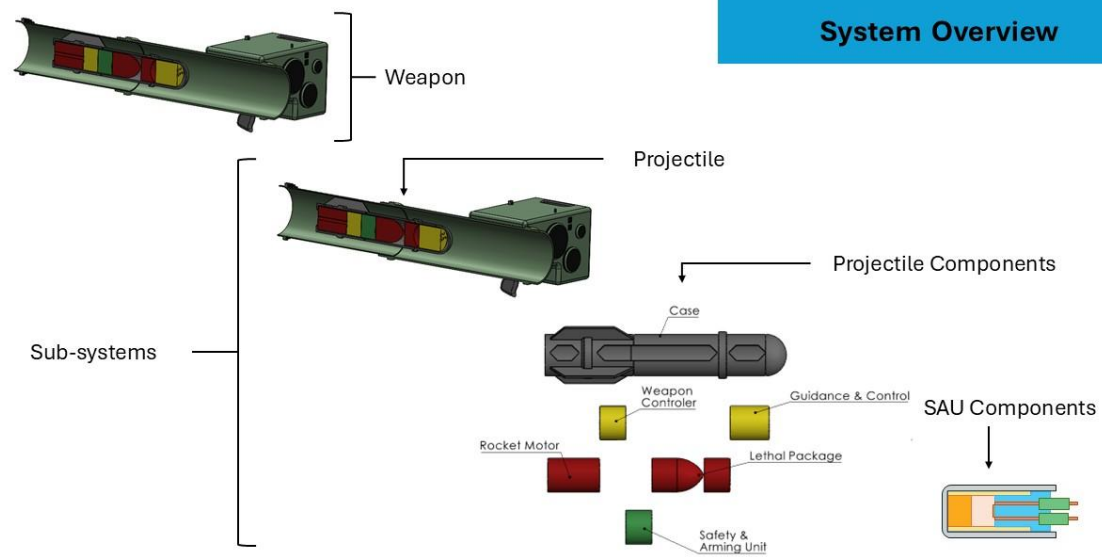
The Command and Launch Unit



The Mount

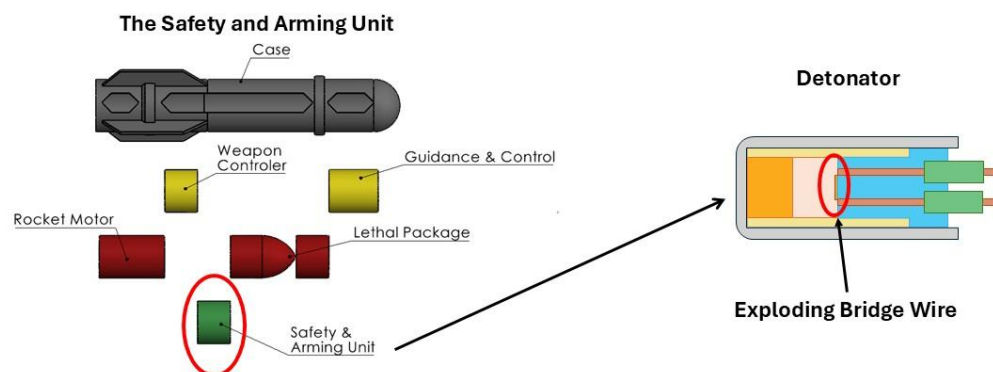


Gareth James

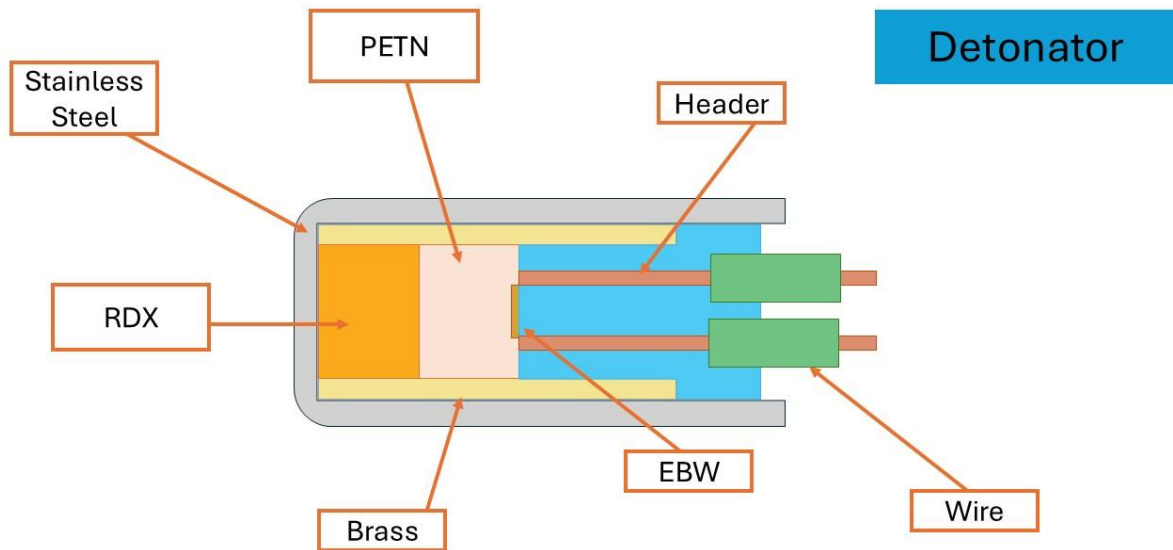


Gareth James

Critical Sub-Systems



Gareth James



R&D Questions?

Libby Jones



Safety Compliance



The Health &
Safety Work Act
1974



The Explosives
Regulations 2014



DSA 02.OME: Defence
Ordnance, Munitions
Explosives Regulations

Libby Jones



Safety Compliance



The Explosives
Regulations 2014

- Prevent an unplanned fire or explosion
- Limit the extent of an unplanned fire or explosion
- Protect people from the effects of a fire or explosion

Libby Jones



Stakeholder Requirements

- The system must be designed as such it is safe to operate
- The system must be designed as such it is safe to handle
- The system must be designed as such it is safe to function



Libby Jones

Push to Fit Mount



- Design Failure Mode Effects Analysis was utilised to identify the ways the system could fail.
 - Over
 - Under
 - No
 - Intermittent
 - Un-intended
- What was the risk ?
- Can we mitigate that?

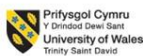
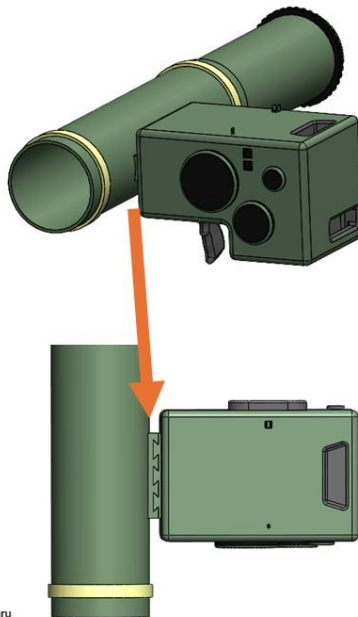
Libby Jones

Eliminate

Hierarchy of Controls

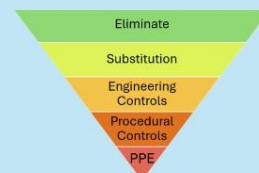


Libby Jones



Dove Tail Mount

- Lower RPN Value when compare with a Press fit on a DFMEA
- Mechanical Interlock, provides consistent, secure attachment, reducing the “Human Element”.
- Ergonomically shaped to withstand vibration during launch.

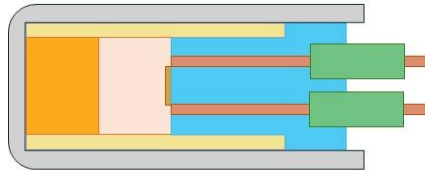


Libby Jones

HAZARD: Unintended Functioning of the EBW System

How this can occur:

- Functioning of the explosive elements in the EBW.
- A presence of a current in the system due to the fusing / arming functioning when unintended.



Libby Jones

HAZARD: Unintended Functioning of the EBW System

Sensitive materials in the EBW i.e. Explosives

Eliminate

- No, the Booster Composition is required to detonate Main charge



Substitute

- Could look into Substitution of PETN & RDX



Engineering Controls

- Not really, we can control the critical diameter and density of the composition



Procedural

- Depending on sensitivity of composition, safe handling procedures



PPE

- Not at this stage



Libby Jones

HAZARD: Unintended Functioning of the EBW System

EBW as a whole

Eliminate

- Yes, but you can't function your main charge

Substitute

- Yes, could initiate with percussion as an example

Engineering Controls

- Yes, could incorporate SAU, to ensure current to EBW is intended

Procedural

- Safe handling procedures

PPE

- Not at this stage

Safety



Deliver Effect



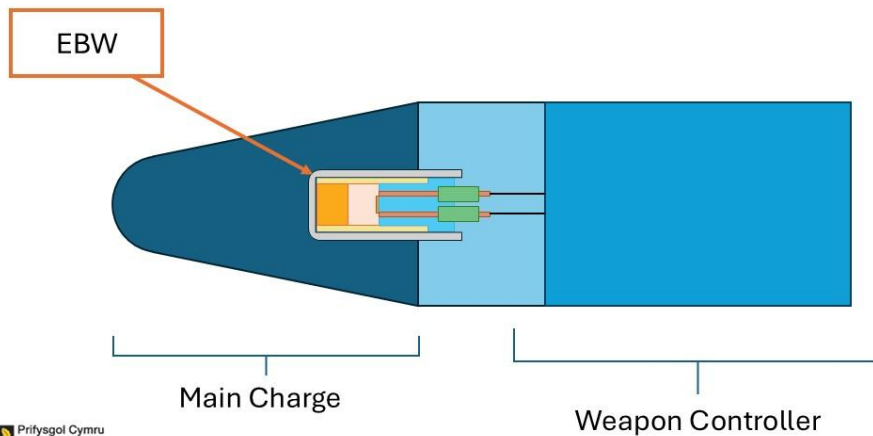
Deliver Effect



Safety

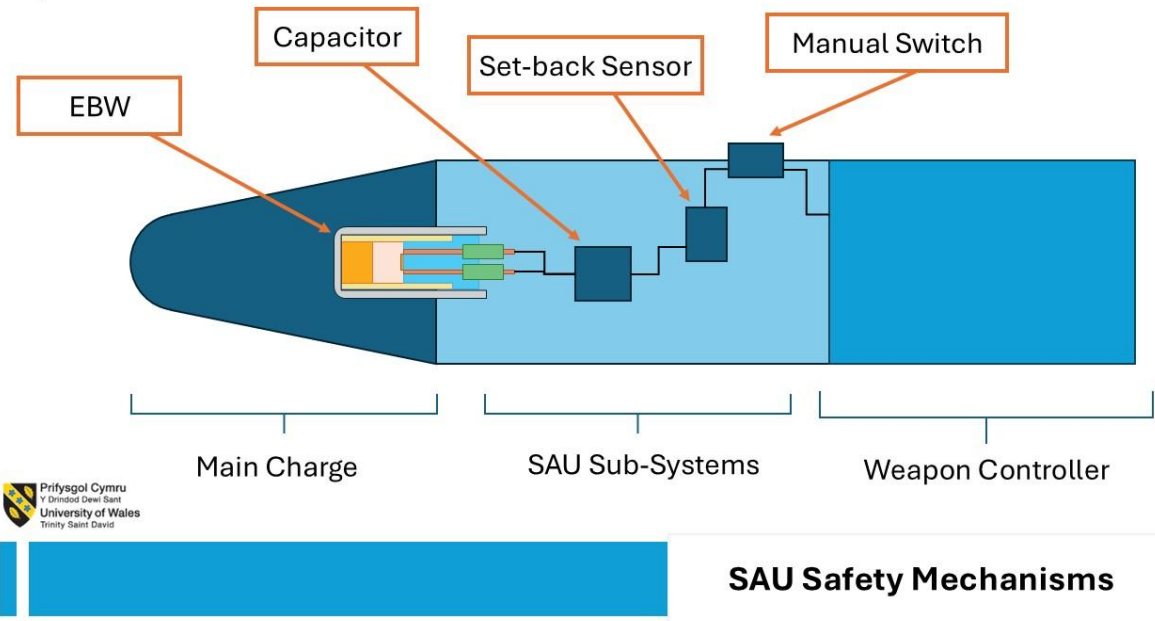


Libby Jones



SAU Safety Mechanisms

Libby Jones



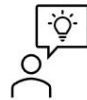
Design Safety Questions?

Test and Evaluation (T&E)

Charles Hadley



Requirements



Approach



Design Feedback



Analysis and Performance

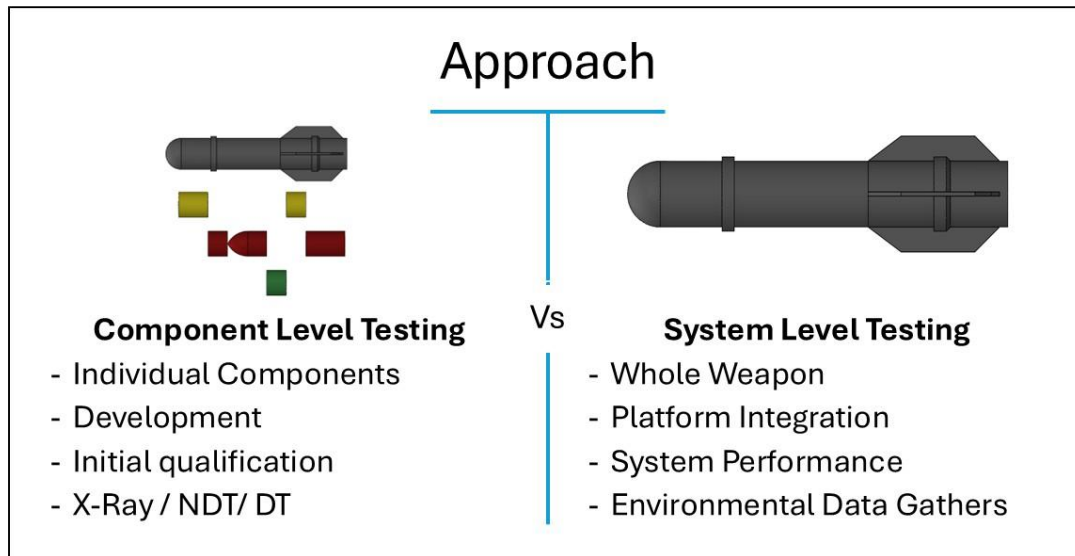


Results

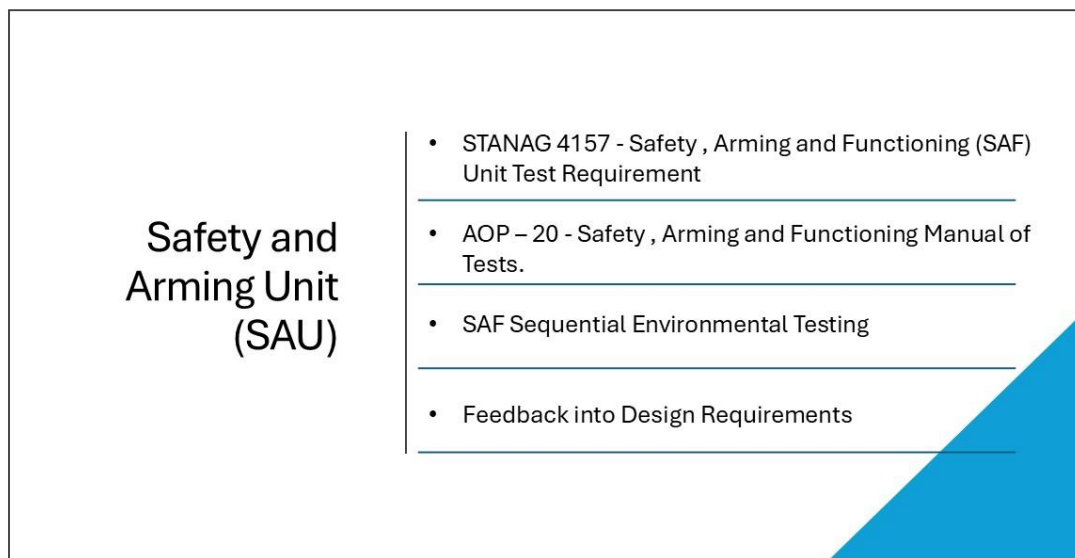
T&E – System Requirements

- Safe and Suitable for Service (S3)
- DSA02 OME 101,107,108,109,110,113
- Defstan 00-035 – Sequential Environmental Testing
- AOP-15 – The process for determining S3 for munitions

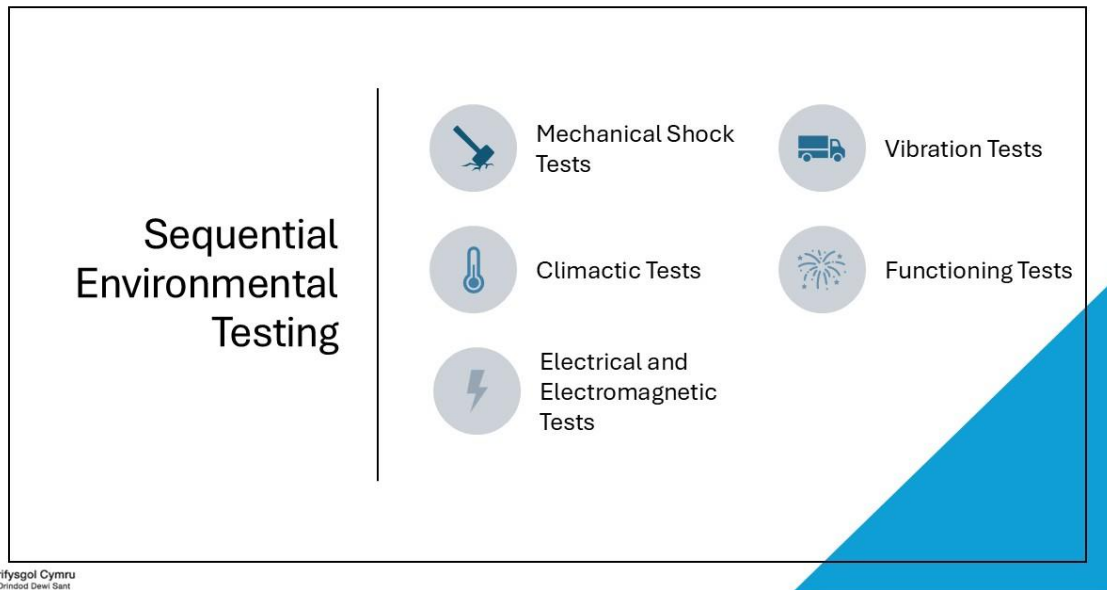
Charles Hadley



Charles Hadley



Charles Hadley



Charles Hadley

Testing Plan

Group	Test	Criteria for Passing Test	Munition	Packaged	Minimum Assets Required	Tailoring	Tailoring Reason
Mechanical Shock	A1 Jolt	Safe for use 1	None	No	1	In	
Mechanical Shock	A2 1 Jumble	Safe for use 1	None	No	1	In	
Mechanical Shock	A3 12m Drop	Safe for disposal	None, I, L	Both	4	In	
Mechanical Shock	A4 11.5m Drop	Safe for use 4	None, I, L	No	2	In	
Mechanical Shock	A5 Transportation Handling	Operable	None, I, L	Yes	2	In	
Vibration	B1 1 Transportation Vibration	Operable	None	Both	2	In	
Vibration	B3 Tactical Vibration	Operable	None	No	1	In	
Climatic	C1 Temperature & Humidity	Operable	None	No	1	In	
Climatic	C2 Vacuum/Steam/Pressure	Operable	None	No	1	In	
Climatic	C3 Salt Fog	Operable 5	None	No	1	In	
Climatic	C4 Waterproofness	Operable 6	None	No	1	In	
Climatic	C5 Fungus	Operable	None	No	1	In	
Climatic	C6 Extreme Temperature	Operable	None	No	1	In	
Climatic	C7 Thermal Shock	Operable	None	No	1	In	
Climatic	C8 Leak Detection	7	None	No	1	In	
Climatic	C9 Dust	Operable 8	None	No	1	In	
Climatic	C10 Solar Radiation	Operable	None, I	Both	2	In	
Safety, Arming & Functioning	D1 Primary Explosive Component Safety	9	None	No	1	In	
Safety, Arming & Functioning	D2 Projectile Fuse Arming Distance	7	I, L	No	1	Out	Out for component testing - in for System
Safety, Arming & Functioning	D3 Time to Air Burst	7	I, L	No	1	Out	Out for component testing - in for System
Safety, Arming & Functioning	D4 Explosive Component Output	7	None	No	1	In	
Safety, Arming & Functioning	D5 Rain Impact	10	I	No	1	In	
Safety, Arming & Functioning	D6 Brush Impact Non-Fire Test	Safe, Operable	I	No	1	In	
Safety, Arming & Functioning	D7 Mortar Ammunition Fuse Double Loading Test	1	None	No	1	Out	Not a Mortar
Safety, Arming & Functioning	D8 Progressive Arming Test	1	None	No	1	In	
Safety, Arming & Functioning	D9 Explosive Train Transfer Reliability Testing	7	None	No	1	In	
Aircraft Munition	E1 Jetison	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E2 Low Altitude Accidental Release	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E3 Arrested Landing Munition Pull-off	Safe for disposal 11	L	No	1	Out	Non Aircraft Munition
Aircraft Munition	E4 Catapult And Arrested Landing Forces	Operable	I	No	1	Out	Non Aircraft Munition
Aircraft Munition	E5 Simulated Parachute Air Delivery	Operable 12	None, I	Yes	1	Out	Out for component testing - in for system
Electric & Magnetic Influence	F1 1 Electrostatic Discharge	Safe for use 13	None	Both	2	In	
Electric & Magnetic Influence	F2 1 High-Altitude Electromagnetic Pulse	Operable 7	I	No	1	In	
Electric & Magnetic Influence	F3 1 EMR Hazards (ELM)	Operable	None	Both	2	In	
Electric & Magnetic Influence	F4 1 EMR Operational (EMRO)	Operable	None	No	1	In	
Electric & Magnetic Influence	F5 Lightning	Operable	I	No	1	In	
Electric & Magnetic Influence	F6 Electrical Stress Test (EST)	Operable	None	No	1	In	

6

Categories

37

Tests

8

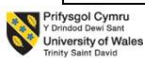
Tailored Out

29

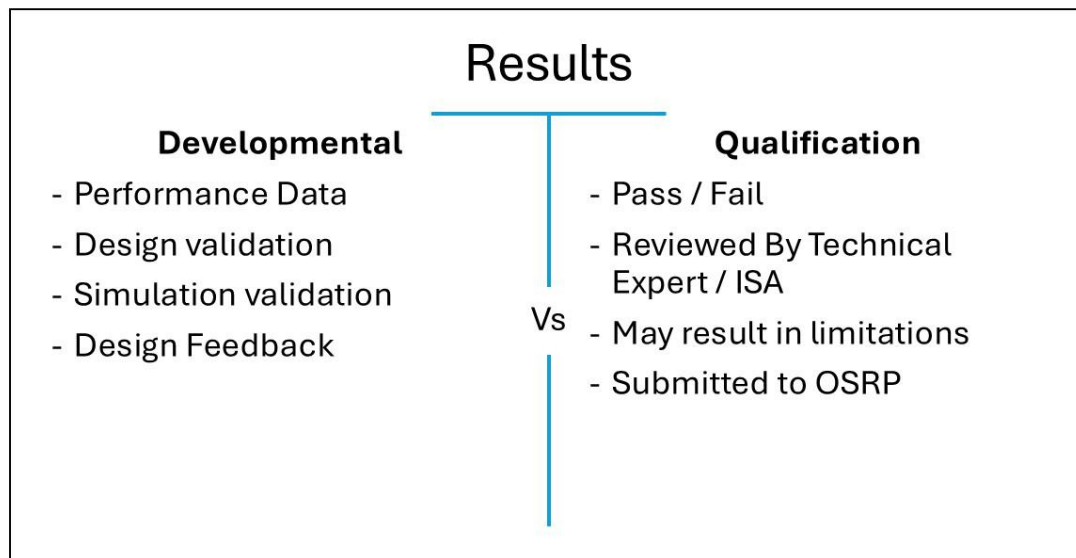
Tailored In

38

Assets Required



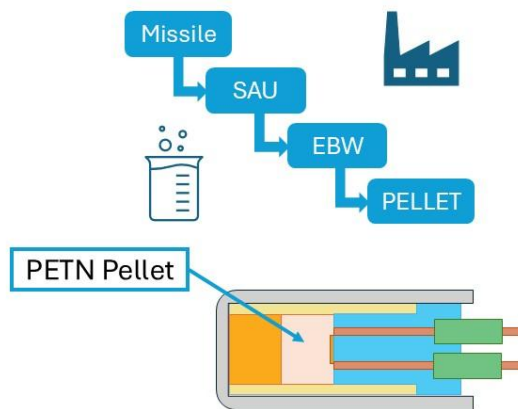
Charles Hadley



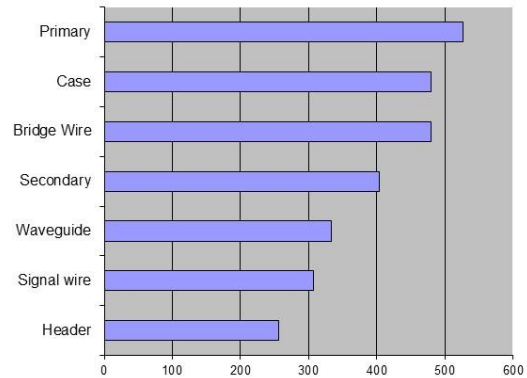
T&E Questions?

Dan Garton

Manufacturing



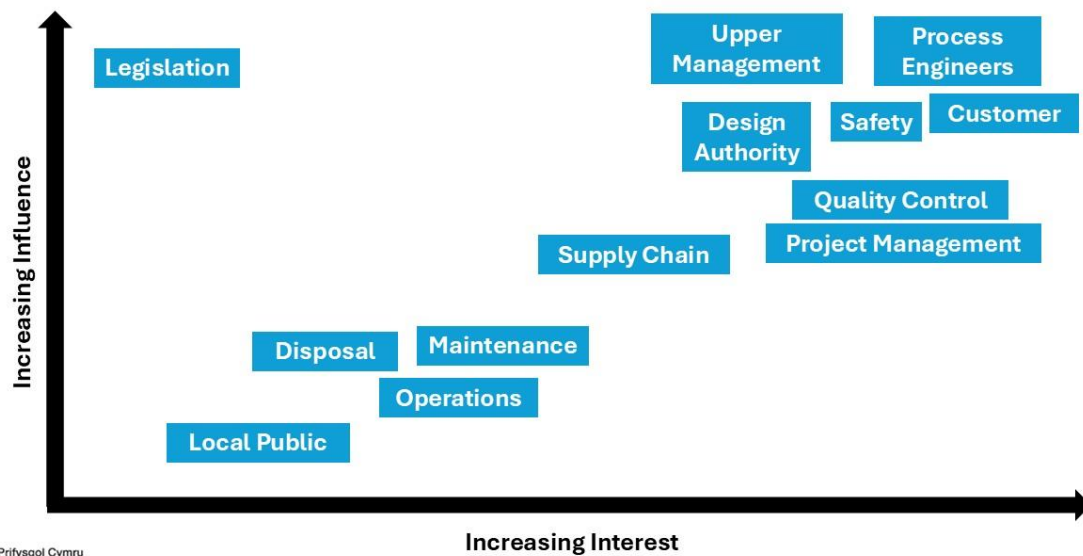
Process Importances Chart



Prifysgol Cymru
Y Ddrindod Dewi Sant
University of Wales
Trinity Saint David

Dan Garton

Manufacturing Stakeholder Map



Prifysgol Cymru
Y Ddrindod Dewi Sant
University of Wales
Trinity Saint David

Dan Garton



Manufacture stakeholder requirements

- ✦ **Operations** → Simple to Follow
- ✦ **Engineers** → Minimal Human Factors and Noise Factors
- ✦ **Safety** → Safe at all point
- ✦ **Supply Chain** → Alignment with Supply Chain
- ✦ **Project Management** → Contract Timelines
- ✦ **Design Authority** → Product Made to Specification
- ✦ **Maintenance** → Easy PM, Training available
- ✦ **Legislation** → Regulatory Compliance
- ✦ **Disposal** → Easy Disposal, Available Disposal Routes
- ✦ **Customer** → Functional & Reliable Product
- ✦ **Upper Management** → Cost-Effective, Time-Effective, High-Yield, Space-Efficient
- ✦ **Local Public** → Minimal Interference (Noise pollution, Light pollution, Road congestion)
- ✦ **Quality Control** → Product Meets Specifications



Dan Garton

Available Processes

Mix and Cast



- Increased Process steps
- Needs casing/moulds
- Voids risk
- Shrinkage casting
- + Proven

RAM



- Expensive
- Not proven
- Needs casing/moulds
- + Increased solid loading

Press

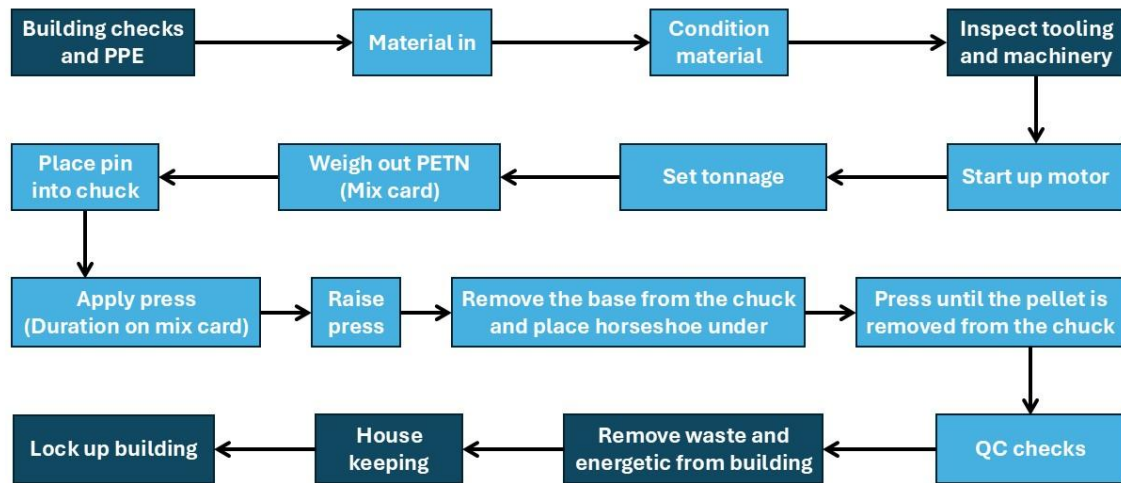


- Specific materials
- + Inexpensive
- + Proven
- + No casing
- + Less heat created
- + Precise shape



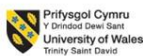
Dan Garton

Top level flow



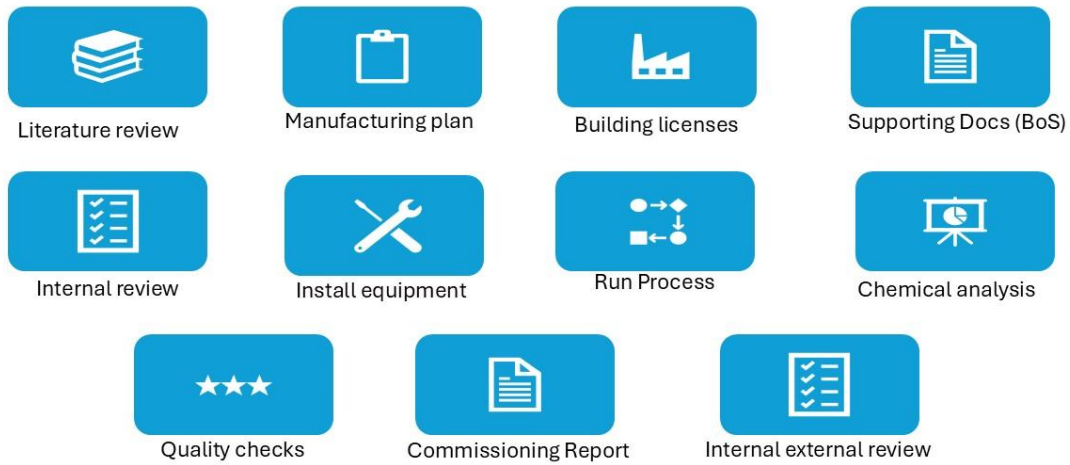
Dan Garton

Work Package Deliverables



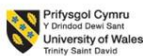
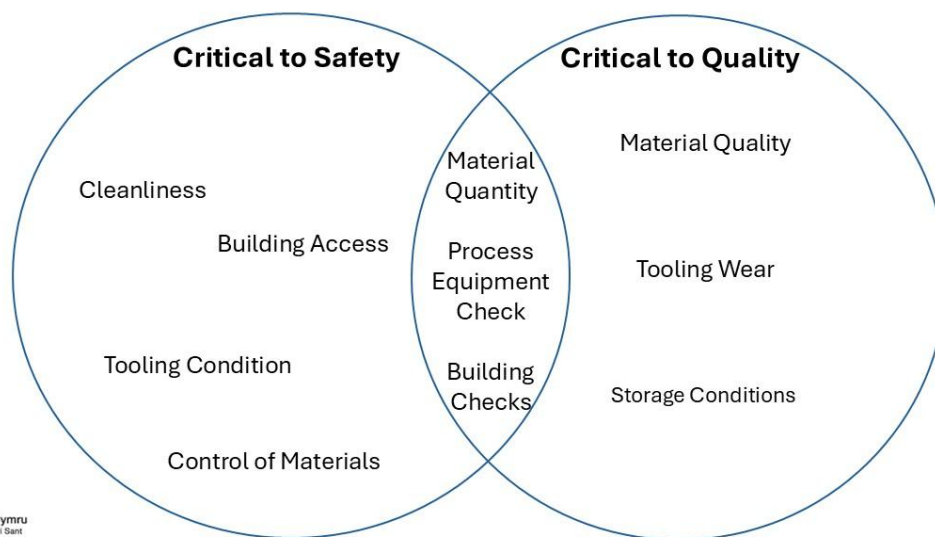
Dan Garton

Work Package Deliverables



Dan Garton

Critical Process steps



Dan Garton

Process Control Plan (PCP)/QFD4



Dan Garton

Validation plan

Blast modelling

Human factors analysis

Shift condition running

Various QC checks through the process

Commissioning report

Manufacturing Questions?

Rachel McColm



Legislation and Regulation



The Explosives
Regulations 2014

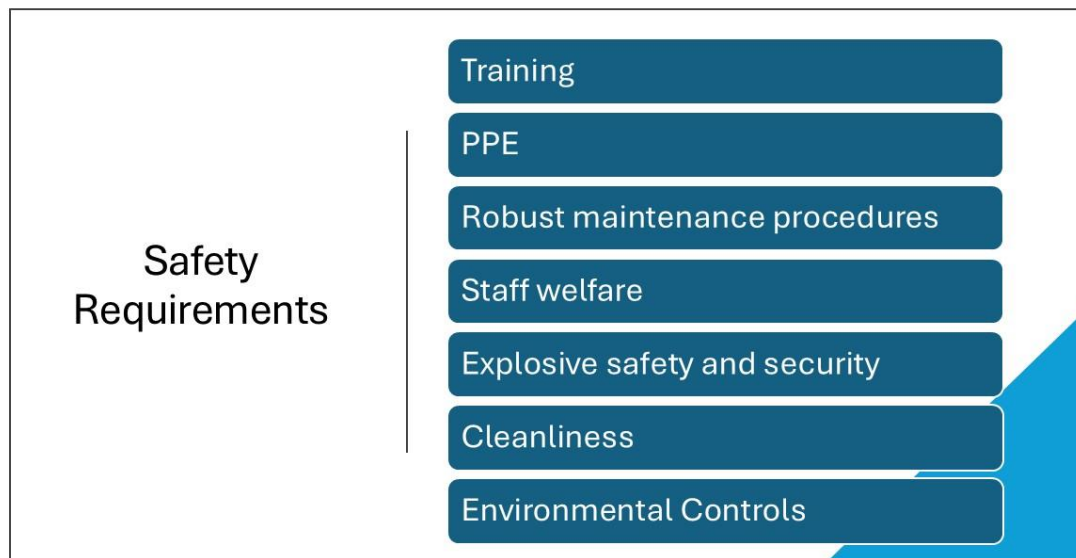


The Health &
Safety Work Act
1974

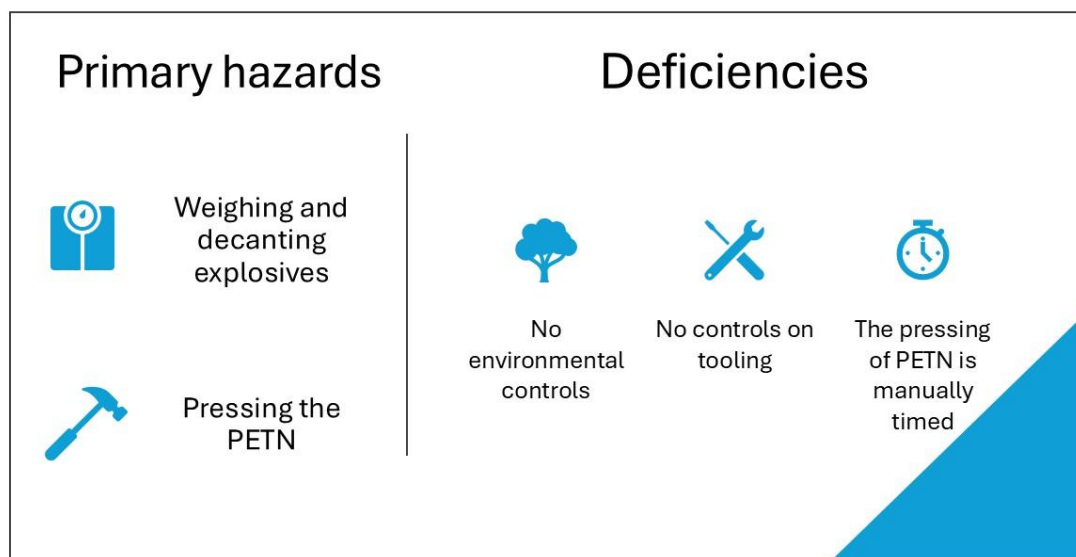


DSA 02.OME: Defence
Ordnance, Munitions
and Explosives (OME)
regulations

Rachel McColm



Rachel McColm



Rachel McColm

Risk Classification

	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med High	High	High
Likely	Low Med	Low Med	Medium	Med High	High
Probable	Low	Low Med	Medium	Med High	Med High
Unlikely	Low	Low Med	Low Med	Medium	Med High
Very Unlikely	Low	Low	Low Med	Medium	Medium

Risk Class	A	B	C	D	E
------------	---	---	---	---	---

Rachel McColm

Mitigations



Tooling Controls



Environmental
Controls



Automation

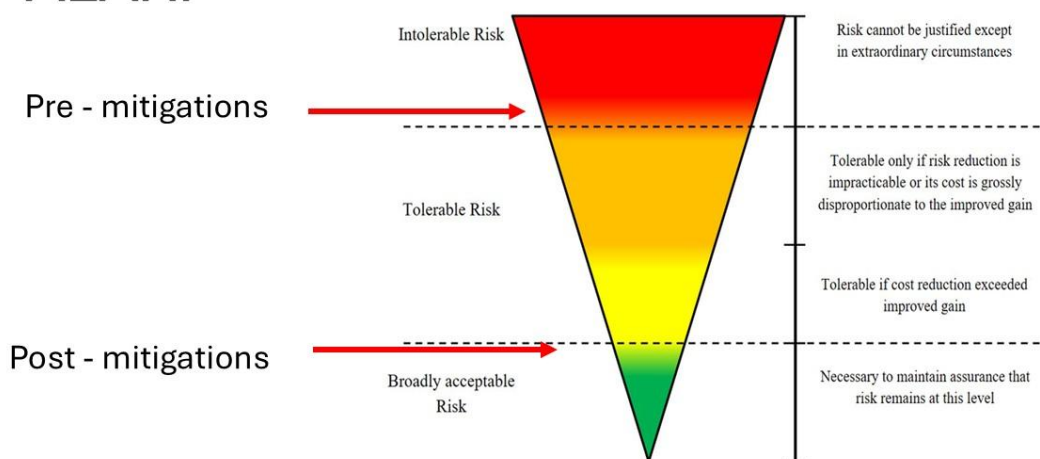


Post Controls Risk Classification

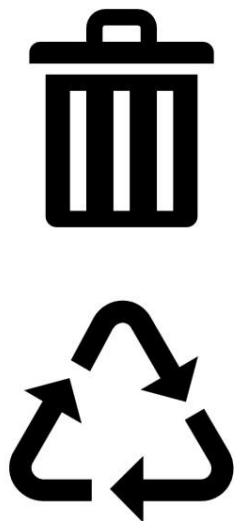
	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med High	High	High
Likely	Low Med	Low Med	Medium	Med High	High
Probable	Low	Low Med	Medium	Med High	Med High
Unlikely	Low	Low Med	Low Med	Medium	Med High
Very Unlikely	Low	Low	Low Med	Medium	Medium

Risk Class	A	B	C	D	E
------------	---	---	---	---	---

ALARP



Process Safety Questions?



Disposal

Lewis Gray

Lewis Gray

Requirements



Safe



Effective



Reliable



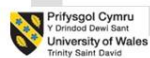
Minimal Environmental Impact



Lewis Gray

Input from Design

- Munition must be recoverable from Launch Tube Assembly
- Subcomponents must be recoverable from missile
- Toxic materials kept to a minimum.



Lewis Gray

Inert Components	Energetic Components
Telescopic Launch Tube	Safety and Arming Unit
Command Launch Unit (CLU)	Rocket Motor
Guidance & Control Unit	Follow Through Bomb
Weapon Controller	Precursor Charge
Storage Case	Blip Motor
Missile Frame	

Components
to be
Disposed of

Lewis Gray

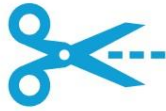
Methods Evaluated



Lewis Gray

Methods Selected

Shredding



- **Non-Energetics**
- Inert Components
- + Cheap
- + Effective
- + Established
- Shredding waste to be recycled by third party



Incineration

- **Energetics**
- Contaminated Components
- + Safe
- + Effective
- + Reliable
- + Established
- Incineration waste to be disposed of by contractors.

Lewis Gray

Waste Management Plan

- Waste generation identified at all levels of manufacture.
- Energetic waste to be disposed of with end-of-life energetic components.
- Inert waste to be shredded.

Disposal / Final Questions?

References available on request

17. Annex E –FFMEA

17.1. System FFMEA

System Purpose		Neutralise Contents	O- Probability of Occurrence			1: Very Rare > 10: Frequent					
			S- Severity of Occurrence			1: No Effect > 10: Most Severe					
			D- Probability of Detection			1: No Detection > 10: Certain Detection					
Owner	Function	Function Failure Mode	Effects								
			On System	On Customer	S	Cause	O	Detection/ Prevention Method	D	RPN	Design Sugestions/ Comments
LJ	Ready System	Too Much	Damage the System	Replacement repair cost	8	Unit error	8	Training	8	512	
			Premature initiation	Reputational Damage / Death	9	System Failure	3	Design	9	243	
		Too Little	Failure to nutralise	Threat escalates to customer	9	System Familiarity	2	Training and design	9	162	
			Wrong target neutralised	Reputational Damage	8	User Error	5	Training and Intel	7	280	
		No Supply	No System to Neutralise	Threat escalates to customer	9	System Failure	3	Design	9	243	
			Mission Failed/ Loss of Life	Reputational Damage	9	System Failure	3	Design	9	243	
		Wrong Supply	System will not initiate	Reputational Damage	8	Unit error	8	Training	8	512	
			System Damage or Destruction	Financial Loss	7	System Failure	2	Human Factors	9	126	
		Intermittent	Unreliable System	Replacement repair cost	8	Unit error	8	Training	8	512	
			Mission may not be completed	Reputaional Damage	9	System Failure	3	Design	9	243	
DG	Enter Target	Too Much	Penetrate too far	More colateral damage	8	Over penetrative ability	3	Testing and Design	3	72	
			Overshoot	Unintended damage to civilian area	8	Over propulsion	3	Propulsion QC check	3	72	
		Too Little	Not able to penetrate the target	Mission failed, civilian damage	8	Little penetrative ability	3	Testing and Design	3	72	
			Fail short	Infrastructure damage	8	Under propulsion	3	Propulsion QC check	3	72	
		No Supply	Desired effect not achieved	Mission failed, incorrect colateral damage	5	Run out	2	Organisation	8	80	
			Delay in effect	Target may be moved	5	Damage to system	2	QC control	7	70	
		Wrong Supply	Wrong effect	Too great effect	8	Incorrect reload	2	Training	8	128	
			Wrong effect	Too little effect	8	Human error	2	Training	8	128	
		Intermittent	Unreliable effect	Increased cost in multiple systems required	5	Manufacturing defects	4	QC chacking	8	160	
			Collateral Damage	Loss of life	8	Manufacturing defects	2	Testing and Design	3	48	
LG	Neutralise Target	Too Much	Collateral Damage To System	User Death	10	Premature Ignition	8	Design	8	640	
			Death of 3rd Party	Bad Publicity	10	Excessive Payload	8	Design	7	560	
		Too Little	Subject to counter-battery fire	Mission Failed	9	Insufficient Payload	7	Design	8	504	
			Threat still present	Mission Fail	9	Insufficient Payload	7	Design	3	189	
		No Supply	Fail to initiate	Bad Reputation	8	Faulty Booster	6	Quality Control	3	144	
			Can't complete mission	Costs for Replacements	8	No Payload	7	Quality Control	7	392	
		Wrong Supply	Wrong munition for mission	Mission cant be conducted	8	Poor Logistics	4	Quality Control	7	224	
			Incompatible Ammunition	Costs for Replacements	6	Poor Logistics	4	Quality Control	7	168	
		Intermittent	Unknown success rate	Mission result in a superposit	7	Poor Guidance	6	Design / RnD / Quality Control	1	42	
			Loss in confidence in system	Costs for system improvements	10	Unreliability	5	Quality Control	10	500	
RM	Aim	Too Much	Wrong target neutralised	Prosecution/Reputational damage	10	Bad Aim	6	Training	8	480	
			Collateral damage surrounding target area	Prosecution/Reputational damage	10	Climactic Effects	7	Design	7	490	
		Too Little	Failure to neutralise target	Mission Failure	6	Bad Aim	6	Training	8	288	
			Wrong target neutralised	Prosecution/Reputational damage	10	Climactic Effects	7	Design	7	490	
		No Supply	Wrong target neutralised	Prosecution/Reputational damage	10	System failure	2	Quality Control	7	140	
			Collateral damage surrounding target area	Prosecution/Reputational damage	10	System malfunction	4	Preventative maintenance	6	240	
		Wrong Supply	Bad Targeting Data	Mission Failure	9	Failed recon	6	Training	8	432	
			User Error	Loss of life	9	Lack of SOEP	6	Training	8	432	
		Intermittent	Minimal damage to target	Reputational damage	6	System malfunction	4	Preventative maintenance	6	144	
			Failure to neutralise target	Mission Failure	6	System failure	2	Quality Control	7	84	
GJ	Reload	Too Much	Double feed	Cost to Repair	5	Misfeed	1	Manual load per item	10	50	
			Explosion	Loss of Life	10	Safety mechanism damaged	1	Delayed arming once leaves location	5	50	
		Too Little	System will not initiate	Mission Failure	5	No Supply	1	Continuity check/arming check	10	50	
			System Inoperable	Mission Failure	5	No Supply	1	covered	8	40	
		No Supply	System will not initiate	Mission Failure	5	No Supply	1	Check Load	10	50	
			System Inoperable	Mission Failure	5	No Supply	2	Ensure secondary load is available	8	80	
		Wrong Supply	Cause damage to system	Mission Failure	5	Wrong Part fitted	2	Visual/Physical	10	100	
			System will not function	Mission Failure	5	Incompatibility	1	Secondary Weapon System	10	50	
		Intermittent	System will not Feed	Loss of Life	10	External	4	Easy to Reload	10	400	
			System will not deploy	Loss of Life	10	External	4	Easy to deploy	10	400	
CH	Packdown	Too Much	Breakage	Cost to repair	6	Structural Failure	3	Training	6	108	
			Loss of system	Cost to Replace - Lack of Capability	7	Enemy Threat	3	Op Sec	2	42	
		Too Little	Loss of system	Cost to Replace - Lack of Capability	7	Malfunction	6	Design	8	336	
			Component Failure	Mission Failure	5	Component Malfunctions	7	Design	3	105	
		No Supply	Damage to system	Injury to User	9	User Error	8	Training	6	432	
			Loss of system	Cost to Replace - Lack of Capability	7	Negligent Discharge	2	Training	4	56	
		Wrong Supply	Incorrect Packaging	Damage to System	8	Supply Failure	7	QC Check	3	168	
			FOD	Collateral Damage	5	Backblast	8	Training	2	80	
		Intermittent	Changes in Operational Procedure	Confusion and mistakes	6	User Error	1	Training	8	48	
			Damage	Injury to user	7	Weapon Failure	7	Design Reliability	1	49	

17.2. SAU FFMEA

System Purpose		Neutralise Contents	O- Probability of Occurrence			1: Very Rare > 10: Frequent						
			S- Severity of Occurrence			1: No Effect > 10: Most Severe						
			D- Probability of Detection			1: No Detection > 10: Certain Detection						
Owner	Function		Function Failure Mode	On System	On Customer	S	Cause	O	Detection/ Prevention Method	D	RPN	Design Suggestions/ Comments
LJ	Contain Components	Too Much	may not get sufficient input	System is not armed	9	Material Expansion	1	Material Conformation Tests	9	81	No current Detection/ Preventative measures in place. Requirement: System needs to be designed to allow the appropriate signal input.	
		Too Little	Doesn't make complete sub-system	System not as intended	10	Design defects	1	QA Checks	9	90		
		No Supply	No SAU	System would not deliver effect.	10	Design defects	1	NA	10	100		
		Wrong Supply	System not as intended	Not able to deliver effect	10	Human Factors, Resourcing limitations	1	Incorrect Filment	10	100		
		Intermittent	System not as intended	Not able to deliver effect	9	Human Factors, Resourcing limitations	1	Incorrect Filament	7	63		
DG	Protect Component	Too Much	Too much weight in the SAU	Decreased portability	1	Too much material in case	1	Testing	7	7	Material testing	
		Too Little	Components break fail in ignition	Mission failure	7	Case is too weak	1	Testing	7	49	Material testing	
		No Supply	Components break fail in ignition	Mission failure	7	No case. No protection	1	QC	10	70		
		Intermittent	Intermittent ignition	Reputational damage	7	Intermittent damage	1	Testing	9	63		
LG	Circuitry	Too Little	No Power to Components	No Function	10	Not enough circuitry to carry power	1	Design / Quality Control	10	100	Robust Q&A assessment	
			No Interaction between Components	Incomplete Weapon Functionality	8	Not enough circuitry to carry power	1	Design / Quality Control	10	80	Robust Q&A assessment	
		No Supply	No Power to Components	No Function	10	No Circuitry	1	Design / Quality Control	10	100	Robust Q&A assessment	
		Wrong Supply	No Power to Components	No Function	10	Incompatible Power Supply	1	Design / Quality Control	10	100	Robust Q&A assessment	
RM	Safety Conformation		Component Damage	No Function	10	Power Surge	1	Design / Quality Control	10	100	Robust Q&A assessment	
		Too Much	Result too high	Unsafe	10	Damage to component	3	Robust Design	10	300		
		Too Little	Result too low	Unsafe	10	Damage to component	5	Robust Design	10	500		
		No Supply	No result	Damaged component	10	Damage to component	4	Robust Design	10	400		
		Wrong Supply	Result too high	Unsafe	10	Damage to component	3	Robust Design	10	300		
		Wrong Supply	Result too low	Unsafe	10	Damage to component	3	Robust Design	10	300		
		Intermittent	Varying Results	Unreliable and unsafe	10	Damage to component	6	Robust Design	10	600		
		Too Much	No Function	None	5	Resistance too high	3	Resistance Check	10	180	Electrical Testing, Resistance Check	
		Too Sensitive	Death	Too much signal	10	Circuit regulates power	3	Circuit regulates power	10	300	Electrical Gate/solenoid testing	
		Too Sensitive	SAU Failure	SAU Failure	9	SAU Damaged	3	Robust Design	10	270	Design review and Consultation	
GJ	Sequential Safety Device	No Supply	No function	None	6	No Signal	3	Secure Connections/fittings	6	108	Robust Q&A assessment	
			No function	Target not Neutralised	6	SAU Damaged	3	Robust Design	6	108	Robust Q&A assessment	
			No function	None	6	No Signal	3	Ensure Correct Supply	10	180	Robust Q&A assessment	
		Wrong Supply	No function when required	Target not Neutralised	6	SAU Damaged	3	Robust Design	9	162	Robust Q&A assessment	
		Intermittent	None	Target not Neutralised	6	Circuitry Damaged	3	Continuity/pre-fire check	2	36	Robust Q&A assessment	
DG	Power Buffer	Too Much	Blow components	Target not Neutralised	6	SAU Damaged	3	Robust design	5	90	Robust Q&A assessment	
		Too Little	wont behave correctly	Mission failure	7	Manufacturing defect	3	QC	10	210		
		No Supply	Failed ignition	Mission failure	7	Manufacturing defect	2	QC	8	112		
		Intermittent	Unreliable	Intermittent success	9	Manufacturing defect	2	QC	5	90		
		Too Much	Overshoot Target	Suboptimal Mission Outcome	6	Composition Variation	3	Batch Testing	9	162		
LG	Delay Second detonation	Too Little	Undershoot Target	Suboptimal Mission Outcome	6	Composition Variation	2	Test and Eval of Delay Composition	7	84		
			No Secondary Detonation	Mission Failed	10	Moisture Ingress	2	Environmental Proofing	6	120		
		No Supply	Target(s) unaffected by munition	Hostile Actors Still Present	10	Environmental Ingress	2	Test and Eval of Delay Composition	5	100		
			Unknown Success Rate	Mission result in a superposition where mission is both successful and unsuccessful until directly observed.	4	Manufacturing defect	2	Test and Eval of Delay Composition	7	56		
			Unreliable	Mission Failure	5	Manufacturing defect	2	Test and Eval of Delay Composition	8	80		
RM	Provide PC Initiation	Too Much	Excessive Initiation Energy to Cord	Mission Failure	10	Composition Variance	4	Batch Testing	9	360	EM Tap Testing	
		Too Little	Insufficient Initiation energy	Mission Failure	10	Composition Variance	4	Batch Testing	9	360	EM Tap Testing	
		No Supply	No Initiation	Mission Failure	10	Bridge wire failed	6	BIT Check	7	420	EMR Hardening	
		Wrong Supply	No Initiation	Mission Failure	10	Bridge wire failed	6	BIT Check	7	420		
		Intermittent	Unreliable Initiation	Mission Failure/Wrong target neutralised	10	Composition Faulty	4	QC Check	6	240		
GJ	Provide FTB Initiation	Too Much	Premature Detonation	Target not Neutralised	10	Signal from SAU too early	2	Q&A checks	10	200	Design the Composition and Fuzing system to be initiated by both the SAU and the PC (Primary Charge)	
		Too Little	No Initiation	Target not Neutralised	10	No input from PC	2	Q&A Checks	10	200	Introduce Robust Q&A through the process (ie stage review after each step).	
		No Supply	No Initiation	Target not Neutralised	10	Damaged fuse between PC and FTB	2	Q&A Checks	10	200	Rigorous design and testing procedures (including review).	
		Wrong Supply	No Initiation	Target not Neutralised	10	Not enough power to deliver effect	4	Q&A Checks	10	400		
		Intermittent	No Initiation	Target not Neutralised	10	Inconsistent power, failure to deliver effect.	2	Q&A Checks	10	200		
CH	Receive Electronic Inputs	Too Much	High Voltage	Mission failure	9	Component Failure	2	SAU Design	9	162	Connectors designed for over voltage	
			ESD	Death of 1st Party	9	EMR Interference	3	SAU Design	8	216	ESD Safe Connectors	
		Too Little	Low Voltage	Weapon Repair or replacement	8	Insufficient Power	2	SAU Sequential Safetys	10	160		
			Not Correct Signal	Weapon Repair or replacement	7	EMR Interference	3	SAU Sequential Safetys	10	210		
		No Supply	SAU Does Nothing	Mission failure	6	Broken Wiring	1	SAU Protection	8	48	Secure Connections	
GJ	Receive Electronic Inputs	Wrong Supply	Incorrect Signals	Reduction In Reliability	5	Intermittent Performance	3	QC Check	7	105	Secure Connections	
		Intermittent	Intermittent Signals	Reduction In Reliability	5	Intermittent Performance	3	QC Check	7	105	Secure Connections	