

Development and Evaluation of Trial Project using Systems Engineering Approaches

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1.0 Introduction

There are situations where our Armed Forces may need access through a locked door. There are numerous methods to gain access through a locked door, for example picking a lock or using a crow bar. In certain circumstances there may be a need to use the power of explosives to gain access, whereby mechanical means are unsuitable, for example on steel skinned security doors. Methods of how to breach steel door targets can be through either placing explosive charges on the door, which require operatives to be in close vicinity to the door, or by firing multiple 40mm high explosive grenades at the door, which takes up valuable time and causes a lot of damage to the door and surroundings. In an ideal world, an operator could breach a locked steel door, from a safe distance and in as little time as possible, therefore giving the enemy less time to react.

1.1 Customer need/requirement

- The main requirement is for a capability to breach steel door targets from a minimum stand-off distance of 20m, which must then be trialled against existing in service capabilities.
- In addition to the main requirement, the capability must be proportionate, i.e. using the minimum force required to breach the target, and also man-portable.
- A desired requirement is that the behind target effects and fragmentation are negligible. This would reduce the chance of injury to hostages, for example, and would also allow an operator's colleagues to stand closer to the breach and be ready to enter.

In order to find a solution and develop a capability I need to establish what the problem is, what is causing the problem, why I am overcoming this problem and how I plan to overcome the problem.

1.2 Root Cause Analysis

[1]

Why does the door need to be breached in the first place?

There may be an operational requirement to access or exit a location. It is likely the door will be locked.

Why do we need a capability to do this?

There are scenarios where our Armed Forces need to enter a building/compound. This could be to save innocent people's lives, or capture enemy forces, for example. A capability is required to cover as many situations as practicably possible.

Why use explosive power?

Steel doors are designed to be difficult to breach by mechanical means. Explosives can exert a huge amount of force on an object.

Why does the door need to be breached from distance?

This is to ensure the safety of the operatives. In some situations, there may be danger to the operatives in approaching the door prior to breaching.

Why are existing methods not suitable?

The current in service 40mm High Explosive grenade detonates on impact and does not create the desired breaching effects. Multiple firings are required for steel doors and this creates a lot of damage to the surrounding area. The placing of charges manually may not be suitable in certain scenarios where there is danger to approaching operatives

Problem – The problem is getting a sufficient explosive charge to the target remotely.

Sufficient being the key word. It is not currently a problem in getting an explosive charge to a target, as this can be achieved by existing weapons, for example, the 40mm grenade launcher, Rocket Propelled Grenade, Mortar Bomb and 120mm Tank fired ammunition. However, these do not create the desired effect. In the case of the 40mm grenade it is not effective enough, and the other examples, although achieving a breach, would cause too much damage and they also have other limitations in their use.

Possible causes –

The limits of the explosive charge size are determined by the weapon system firing the charge.
Distance from operative to the target. This is the likely root cause of the problem.

Possible solutions

- A robot/drone designed to deliver a range of explosive charges depending on the target – A vehicle that can traverse or fly across the distance between the operator and the target and attach the correct sized charge to the target door and then return to the operator. The charge can then be initiated remotely.
- A modification of the existing 40mm high explosive grenade – A 40mm grenade firing system already exists in-service and is a good method of projecting an explosive charge across small distances with high accuracy. The current high explosive grenade charge is cylindrical and impact detonating which is not particularly effective against

steel doors. A modification to the explosive charge and the method of functioning may improve its on-target effects.

- Design a new weapon system that has the ability to project an explosive charge of a particular size, where it is larger than that of a 40mm grenade but less than a mortar bomb. This will also require the design of a new high explosive projectile.

1.3 Pugh Matrix

I have used a Pugh Matrix [2] to compare the possible solutions.

		Design Concepts			
		Weight	Modified 40mm Grenade	Drone/Robot	Design new weapon
Selection Criteria	Cost	5	S	-	-
	Low Weight	3	S	-	-
	Man portable Size	4	S	-	S
	Time to deploy	2	S	-	S
	Training required	3	S	-	-
	Effect/Performance	5	S	+	+
Total +			0	1	1
Total -			0	5	3
Total Score			0	-4	-2
Weighted Total +			0	5	5
Weighted Total -			0	17	11
Weighted total Score			0	-12	-6

Prior to weighting the selection criteria, the design solution with the highest score of 0 was the modified 40mm grenade, followed by the new weapon solution which scored -2. The drone/robot solution being further back on a score of -4.

An absolute scale was introduced into the matrix [2].

The absolute scale uses the following definitions to weight the criteria:

- 1 minor importance to the stakeholder
- 2 moderate importance to the stakeholder
- 3 important to the stakeholder
- 4 very important to the stakeholder
- 5 extremely importance to the customer

[2]

After weighting has been applied, the design solution with the highest score remains the modified 40mm grenade, followed by the new weapon design. The drone/robot solution score is now much lower than the other two solutions, so this idea is taken no further.

Of the three design solutions input into the Pugh Matrix, the modified 40mm grenade does have a higher score than the other two. In addition to this, the modified 40mm grenade requires less design and development, as it uses an existing weapon platform, therefore saving money and time. For these reasons the decision is to select the modified 40mm grenade as the most suitable solution.

2.0 Constraints

In addition to the main requirements the selected design solution must comply with a number of constraints. These are conditions that have to be met because of limitations set by external interfaces, or project support or technology, for example [3].

A few examples to be considered for this trial;

- Solutions and technical expertise is limited to the design team.
- Range testing limits have to be adhered to.
- The trial has to abide by approved standards and public and international laws and regulations [3].

It is important to include these constraints with the customer requirements throughout the development phase to ensure the end product satisfies all stake holders and is compliant.

3.0 Requirement to design a modification to 40mm grenade

At this stage it has been decided that the next course of action is to look at whether a modification or upgrade to the existing 40mm high explosive grenade can achieve the desired on target effects and give the customer the capability they have asked for. The next step is to evaluate the effect of the solution and in order to do this the modified high explosive grenade must first be designed.

In order for the design to be successful the following design requirements must be met;

- Must fit existing grenade firing weapons systems
How? – Grenade will be 40mm calibre. Grenade will be within acceptable dimensions to fit in the chamber of the weapon.
- Must achieve desired on target effect (must breach the door)
How? – Energetic effect must bend the door and frame to disengage lock mechanism. Shape of charge will not cause penetration (wasted energy). Charge initiation from correct stand-off.
- Must be accurately fired from 20m +

How? – Propellant charge projects the grenade. Weapon barrel imparts spin to projectile which gives it stability.

- Must detonate at predetermined stand off from the target
How? – A stand-off spike will begin the detonation at impact. This means the charge will be at the correct stand-off. Proximity fuse designed to initiate charge at the right time.
- No-to-little behind door effects
How? - Grenade will be constructed with materials that will not turn into high velocity fragments. Shape of charge will not cause penetration (wasted energy).
- Safe to handle/store/transport
How? – Grenade detonator has safety features requiring it to be fired before it is armed. Packed in approved packaging. Robust materials to protect grenade when handled.
- Low cost to manufacture
How? – Utilise existing grenade components. Order in bulk.

Design factors that will determine the effectiveness of the design are as follows;

- Size of explosive charge
- Shape of explosive charge (charge geometry)
- Type of explosive used
- Material of grenade body
- Method of initiation

Due to the cost involved in conducting live explosive trials, computer modelling will be done to determine charge geometry and size, and can show the likely effects of a particular explosive type, shape and/or size against a particular target.

Research will also be conducted into previous similar trials/experiments to determine the fragmentation effects of various materials using different explosives.

Due to cost and complexity involved in creating and incorporating a proximity fuse it is not being trialled. A simple spike that protrudes the front of the grenade will cause the grenade to initiate when the spike makes contact with the door. This creates the desired stand-off using a very simple and cost effective method.

In order for the charge to be detonated from the rear the spike will pass through the explosive charge. The detonator will be held out of line, during storage and transport, so that it is safe. Upon firing the set back forces will cause the detonator to fall in line and hence arm the grenade during flight.

4.0 Trial Plan

Phase 1 –

As per the computer modelling a number of different shapes, sizes and types of explosives have been identified as being able to achieve the required effects. Phase 1 tests the variations of these and also at different stand-off distances to the target.

The trial will consist of testing these charges against steel target doors on an explosive range. The charges will be unconfined, placed manually at the selected stand-off, and then fired remotely using a standard detonator and firing cable. The effects will be recorded.

Phase 2 –

The combination from phase 1 achieving the best result (i.e. best combination of shape, size, type and stand-off) will then go onto phase 2 where the charge will be contained in bodies of different materials with various case thicknesses. Each charge will once again be placed manually next to the target at the optimum stand-off distance and initiated. Fragmentation packs will be placed around the target to capture any particles flying at velocity. The materials being used include plastic, rubber, aluminium and copper.

Phase 3 –

Manufacture and test of final prototype. The results of phase 1 and 2 will now be used to manufacture a grenade. A standard cartridge case and primer will be used.

This trial will test the prototype against the standard 40mm grenade. Each grenade will be fired at 10 separate steel doors, with the effects being recorded for each firing. These results will then be compared and presented to the customer for approval.

After a successful trial witnessed by the customer, the next stage is to have the article and the proposed packaging (modification of existing packaging for 40mm grenade) tested against safety standards for handling, storage and transportation and be classified by the relevant authorities.

5.0 Conclusion

The 5 Whys was helpful in understanding why there is a requirement in the first place. Although the answers are brief, it explains why the customer needs to achieve the capability and why other options aren't suitable.

The Root cause analysis breaks down the problem to which a solution is required. In this example, the cause of the problem is achieving the desired result from over 20 metres from the target (i.e. distance), so it focuses the mind to look for methods to overcome the issue of distance. This leads nicely into brainstorming solutions to solve the problem.

The three design solutions were then analysed using a Pugh Matrix to determine the best solution to take forward. This simple method of directly comparing solutions against a set of design criteria and scoring them, is a good way to see which solutions are not feasible. Although, it does have its limitations. A small number of selection criteria are used, and focused on user-based criteria, not including manufacturing criteria, for example. The criteria are also generic and could be broken down further (i.e. cost could be broken down into

development cost, maintenance/life testing costs and disposal costs etc.). Adding this detail would allow the Pugh Matrix to compare how each solution fares for specific tasks.

The outcome of this trial successfully achieves the customer requirements. Phase 1 of the trial ensures the desired effect at breaching the door meets the requirement, and that it is proportional. Phase two of the trial meets the requirement of having little behind target effects and fragmentation. Phase three of the trial meets the requirement of testing the prototype against existing in service grenades and therefore the results can be compared to the current standard. This is the method of measuring success that the customer wishes to see.

Using systems engineering tools has helped me to understand the true requirements of the customer and was useful in putting together a plan that achieves the capability, but is also realistic. It has been helpful in guiding decisions during the development process and selecting solutions, which then can be taken forward for trials. The results throughout the trial will ultimately determine the final components of the finished product.

Mentioned briefly in this report, and in addition to the main requirements of the customer, there are many other requirements/constraints that would have to be met. These include abiding by all laws, meeting specific safety testing.

This report focuses on the customer requirements, but the requirement and constraints relating to safety are also very important as this is something that will always have to be met. For example, in this trial the body material that creates the least fragmentation will be selected regardless of cost or difficulty to manufacture.

6.0 Reference List

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