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AS90 155MM GUN RISK ASSESSMENT WITH ALARP STATEMENT FOR UNINTENDED TURRET MOVEMENT

References. See footnotes and references section 0.

1. Abstract

The intent of this report is to satisfy the requirements of the coursework as set out by the lecturer, it will provide a basic risk assessment and ALARP justification for a 155mm Gun. The example chosen for this case is AS-90 with an ALARP statement for Accident 1 - Blast / Fragmentation from Munition impact Vehicle or Directly/ Indirectly involved personnel or 3rd Parties. This report explores the possible hazards, risks and controls associated with the AS-90 Gun system and justifies why the chosen hazard is ALARP.

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3. Introduction and Background

AS-90 is the current in service self-propelled howitzer for the British army, it is fitted with a 155mm, 39-Calibre Gun that has an auto loading and aiming system to aid in the support of rapid fire. The vehicle itself has storage capacity for 48 155mm rounds and associated bag charges. The gun is fitted to a turret system that sits on the main tracked chassis. [1]



Figure 1 – AS-90 [2]

The AS-90 155mm Gun uses munitions provided by BAE systems. [3] The ammunition fired from the gun consists of a Shell fitted with a fuze, Propelling charge with increments and a primer cartridge to initiate the firing. Each of these component parts are stored separately in the vehicle either in ammunition stowage racks, Charge Bins or the Primer Magazine. There are several types of compatible shell, charges and primers that are used by the British army, these can be found at Annex A.

The vehicle contains 5 crew consisting of: Commander, Driver, Gunner, Gun Layer and Loader. This is also complimented by a 4–5-person detachment for loading from external vehicles to support sustained firing, consequently, there could be 10 people directly involved with the weapon firing. For this exercise the hazards considered will be for a specific scenario to limit the numerous possibilities that must be considered. The scenario chosen for this example is a static firing of 1 round L21 HE with a L116 Fuze at Charge 5 in a UK training scenario with the full complement (10) of firing and loading crew. The scenario will start with the round outside of the vehicle on a pallet and finish with the round leaving the barrel. This will allow for a clear assessment of the hazards whilst firing in a training scenario.

4. Risk Assessment

The below tables list the definitions to be used in this assessment. They include Severity and Probability that are used throughout. Defining these key terms sets a standard baseline for the readers understanding. Some of these terms have been drawn directly from OME regulation standard DSA03.OME [4] and Defstan 00-56 Part 1 [5]. In recent updates of defence standards, less importance has been placed on system damage as a form of severity classification hence in Table 1 this is not included, and emphasis is placed on 1st and 3rd party injury and death respectively.

Severity	1st Party (Directly involved)	3rd party (Indirectly Involved)
Catastrophic	2 or more deaths	1 death or multiple sever injuries or occupational illness
Critical	1 death or multiple Sever injuries or occupational illness	Single severe injury(s) or multiple minor injuries or occupational illness
Major	Single severe injury or multiple minor injuries or occupational illness	Single minor Injury or occupational illness
Marginal	Single minor Injury or occupational illness	Less than a minor injury
Negligible	Less than a minor injury	NA

Table 1 - Severity Definitions

Probability	Severity				
	Catastrophic (Cat)	Critical (Crit)	Major (Maj)	Marginal (Mar)	Negligible (Neg)
Frequent (Fr)	A	A	A	B	C1
Probable (Pr)	A	A	B	C1	C2
Occasional (Oc)	A	B	C1	C2	D
Remote (Re)	B	C1	C2	D	D
Improbable (Im)	C1	C2	D	D	D
Incredible (In)	C2	D	D	D	D

Table 2 - Risk Classification Matrix [6]

During a group exercise an initial Hazard Log Working Group (HLWG) was conducted to discuss and determine the severity definitions for 1st and 3rd party and to generate some initial hazards and top events that could be further expanded upon individually to create the below. During this HLWG it was discussed that defining the mathematical terms of probability beyond ranking them as detailed in Table 2 was not necessary as no substantive calculations could be made at this stage.

Top Event	Hazard	Hazard Description	Cause	Pre-Controls				Control Title	Post Controls				ALARP
				Severity	S	P	R		Severity	S	P	R	
A1 – Blast / Fragmentation from Munition impact Vehicle or Directly/ Indirectly involved personnel or 3rd Parties	HAZ01 - Shell Initiation	Shell initiation in proximity of the vehicle or directly/ indirectly involved personnel or 3rd parties/	Unintended Initiation of Booster Pellet	Multiple 1st Party Fatality	Cat	Oc	A	• Insensitive Munition Compliance	Multiple 1st Party Fatality	Cat	Re	B	Through the implementation and use of proper munition design, qualification, through life management and usage procedures the risk associated with inadvertent Shell initiation can be managed and minimised to reduce the probability of occurrence and risk category to an ALARP level.
			Failure of Shell fuze					• Fuze Safety Locks					
			Munition Exposure to Extreme Environments					• Controlled Storage Conditions • Drop Tested • Munition handling procedures • No hot load procedures					
			Munition defect prior to delivery from manufacturer					• Unpackaging Inspection • Pre-Load Inspection					
			Ageing of energetics					• Surveillance and life extension programmes					
			Fuze Electromagnetic affects					• E3 Qualification					
	HAZ02 - Propelling Charge Initiation	Propelling Charge initiation outside of the closed breach in proximity of the vehicle or directly/ indirectly involved personnel or 3rd parties	Munition Exposure to Extreme Environments	Multiple 1st Party Fatality	Cat	Oc	A	• Controlled Storage Conditions • Drop Tested • Munition handling procedures • No hot load procedures	Multiple 1st Party Fatality	Cat	Re	B	
			Munition defect prior to delivery from manufacturer					• Unpackaging Inspection • Pre-Load Inspection					
			Ageing of energetics					• Surveillance and life extension programmes					
	HAZ03 – Primer	M82 Primer Initiation	Unintended Initiation of M82 primer cap	Multiple 1st	Cat	Oc	A	• Insensitive Munition Compliance		Cat	Re	B	

Top Event	Hazard	Hazard Description	Cause	Pre-Controls				Control Title	Post Controls				ALARP
				Severity	S	P	R		Severity	S	P	R	
	Cartridge Initiation	outside of the closed BVA in proximity of the vehicle or directly/ indirectly involved personnel or 3rd parties	Munition Exposure to Extreme Environments	Party Fatality				- Controlled Storage Conditions - Drop Tested - Munition handling procedures - Hot load procedures	Multiple 1st Party Fatality				
		Munition defect prior to delivery from manufacturer					- Unpackaging Inspection - Pre-Load Inspection						
		Ageing of energetics					Surveillance and life extension programmes						
A2 - Gun Fires Abnormally and injures Directly involved personnel	HAZ04 – Primer Cartridge Initiation Failure	M82 Primer Fails to initiate in the BVA	User Error – Failure to remove Protective Cap	Less than minor injuries	Neg	Fr	C1	Training and procedures	The design of the BVA and breach will contain a misfire.	Neg	OC	D	
			Ageing of energetics					Surveillance and life extension programmes					
			Munition Exposure to Extreme Environments					- Controlled Storage Conditions - Drop Tested - Munition handling procedures - Hot load procedures					
	HAZ05 – Propelling Charge Initiation Failure	Failure of the Propelling charge to initiate	User Error – Failure to remove Protective Cap	Less than minor injuries	Neg	Fr	C1	Training and procedures	The design of the BVA and breach will contain a misfire.	Neg	OC	D	
			Ageing of energetics					Surveillance and life extension programmes					
			Munition Exposure to Extreme Environments					- Controlled Storage Conditions - Drop Tested - Munition handling procedures - Hot load procedures					

Top Event	Hazard	Hazard Description	Cause	Pre-Controls				Control Title	Post Controls				ALARP
				Severity	S	P	R		Severity	S	P	R	
	HAZ06 – Firing Solenoid Failure	The firing solenoid is electrically powered and mechanical initiates the firing pin.	Mechanical Failure	No Injuries if the weapon does not initiate as intended	Neg	Fr	C1	• System Maintenance and Performance qualification	No Injuries if the weapon does not initiate as intended	Neg	OC	D	Through implementation of proper design and management procedures with the associated training and in-service management the likelihood of abnormal firings can be reduced. The procedures following post abnormal firing will enable the users to safely manage the results of abnormal firings and minimise severity.
			Electrical Failure					• System Maintenance and Performance qualification					
			Electromagnetic Interference					• E3 Qualification					
			Exposure to Extreme Environments					• S3 Qualification					
	HAZ07 – Breach Obturation Failure	Breach obturation Failure	Mechanical Failure	1 st Party Single Injury	Maj	Oc	C1	• Regular and preventative maintenance • Training and procedures	1 st Party Single Injury	Maj	Re	C2	
	HAZ08 – Hung Round	After firing if the round does not leave the barrel this presents an initiation hazard	Linked to Haz 01	Multiple 1st Party Fatality	Cat	Oc	A	• Linked to Haz 1	Multiple 1st Party Fatality	Cat	Re	B	
	HAZ09 – Delayed initiation	In some instances, there may be a delay in initiation from the gunner initiating the firing.	Exposure to Extreme Environments	No Injuries if the weapon does not initiate as intended	Neg	Fr	C1	• S3 Qualification	No Injuries if the weapon does not initiate as intended	Neg	OC	D	
			Hot Gun					• Barrel Cooling mechanism					
			User Error, link to HAZ04					• link to HAZ04					
	HAZ10 – User Error	Incorrect Target Settings entered into the Fire control Computer	Human Error	Multiple Sever Injuries	Maj	Re	C2	• Training and procedures	Multiple Sever Injuries	Mar	Im	D	
			Exposure to Extreme Environments					• PPE, Compartment warmer and cooler, HFI controls, Procedures					

Top Event	Hazard	Hazard Description	Cause	Pre-Controls				Control Title	Post Controls				ALARP
				Severity	S	P	R		Severity	S	P	R	
A3 - Uncommanded Movement of turret system injures Directly involved personnel	HAZ11 – SCB Failure	Failure of the Turret Servo Control Box.	Mechanical Failure	Single Death	Maj	Re	C2	• Maintenance preventative and regular • Design to Fail safe • Mechanical override and failsafe’s	Single Minor Injury	Mar	Im	D	Using danger safety areas, process procedures and good design the risk associated with Uncommanded movement of the turret can be minimised.
			Electrical Failure										
	HAZ12 – Electrical Interference	Electrical interference from external sources	Software Failure	Single 3 rd Party Death	Cat	Re	B	• Safety Design and assessment • Mechanical locks	Single 1 st Party Death	Crit	Im	C2	
			Software attack					• Cyber security accreditation and GVA qualification					
	HAZ14 – Automatic Gun Laying System	Failure of the AGLS could lead to inadvertent Uncommanded movement of the gun and turret.	Human Error	Multiple Sever Injuries	Maj	Re	C2	• Training and procedures	Single Minor Injury	Mar	Im	D	
			Software Failure					• Safety Design and assessment • Mechanical locks					
			Design Failure					• Ground Vehicle Architecture standards. • Design to Fail safe					
A4 - Weapon strikes	HAZ15- Weapon Recoil	As the weapon is Fired it will Recoil into the turret. This protrusion into the turret could impact directly involved personnel.	Communication issues	Single first party Fatality	Crit	Oc	B	• Visual and verbal communication methods and procedures	Single severe major injury	Maj	Re	C2	Using danger safety areas, process procedures and good design the risk associated with the
			Users out of place when firing					• Seat Switches • Training					
			Firing procedure Incorrectly Written					• Document verification procedures					
			Firing procedure Incorrectly Followed					• Training					

Top Event	Hazard	Hazard Description	Cause	Pre-Controls				Control Title	Post Controls				ALARP
				Severity	S	P	R		Severity	S	P	R	
directly/ indirectly involved personnel.	HAZ16 – Parts of the Gun detach, and strike directly involved personnel	During firing there are several parts that can be removed for maintenance or become detached through failure.	Incorrectly fitted weapon parts	Single Death	Maj	Re	C2	• Training • Double check procedures • Maintenance	Single Death	Maj	Im	D	weapon striking personnel can be minimised.
			Weapon Damage from loading and handling errors					• Training and procedures.					
			Link to A2					• Link to A2					
	HAZ17 – Recoil Mechanis m Failure	Failure of the recoil mechanism	Mechanical Failure	Single sever Injury	Maj	Oc	C1	• Design Standards	Single sever Injury	Maj	Re	C2	
			Design Failure					• Design Safety factor					
	A5 - Munition Impacts directly/ indirectly involved personnel	HAZ18 – Handling Error	Human error during loading the vehicle or weapon could lead to the munition being dropped	Loading procedures Incorrectly Written	Multiple Severe Injuries	Crit	Oc	B	• Document verification procedures	Multiple Severe Injuries	Crit	Re	
Firing procedure Incorrectly Followed				• Training									
Manhal Handling Error				• Training and Communication									
HAZ19 – Stowage Failure		Stowage failure could lead to the munition falling on to the user	Mechanical Failure of stowage bins	Single sever Injury	Maj	Oc	C1	• Design and Maintenance	Single sever Injury	Maj	Re	C2	
			Stowage procedures Incorrectly Written					• Document verification procedures					
			Stowage procedure Incorrectly Followed					• Training					

5. ALARP Statement

This ALARP statement will cover Top Event (TE) A1, Blast / Fragmentation from Munition impact Vehicle or Directly/ Indirectly involved personnel or 3rd Parties.

There are three main constituent parts of the ammunition, L21 Shell with L166 Fuze, L8A1 Propelling Charge and M82 Primer Cartridge. These collectively come together to form the munition. These parts directly correlate to the three main hazards associated with TE A1, HAZ1 – Shell Initiation, HAZ02 – Propelling Charge Initiation and HAZ03 – Primer Cartridge Initiation. These three hazards form the largest proportion of the risk associated with A1.

The below sections explore each of these hazards individually and how they have been controlled and mitigated¹.

5.1. HAZ1 – Shell Initiation (Including Fuze)

The shell is a steel case shell filled with approximately 6.8kg of TNT [3] the shell also has a booster pellet that sits just below the fuze pocket. The shell is fitted with a L166 fuze that is an inductively set electronic multi-option fuze with an electronic firing train. [7]

Due to the quantity of explosive detonation of the shell warhead initiation is the worst-case scenario contributing to A1 as detonation of a single warhead within or near the crew compartment would lead to multiple fatalities.

Shell

As the shells are designed to be fired and survive firing forces the warhead and booster are highly insensitive and have undergone Insensitive Munitions (IM) testing which provided IM compliance and understanding to be able to best calculate hazard probabilities from real data. As is typical with most artillery shells worst case scenario the shell would experience a Type 5 Burning [8] reaction no detonation. This is due to munition design having a weak point at the tip of the shell where the fuze is located. In the event of fire, the TNT would expand, and gasses formed would push out the fuze before sufficient confinement is achieved for a Deflagration to Detonation Transition.

Through normal storage the shell ages and stabiliser is consumed, there is a risk that the stabiliser in the explosive is depleted to a point that the IM qualification of the shell is reduced. This is managed through In-Service Surveillance (ISS) and Life Extension otherwise known as Surveillance And Life Extension (SALE) which will provide independent scientific and engineering assessment of the explosives.

To ensure the minimal consumption of explosive stabiliser the best storage conditions are used for long term storage of the shells. These are often a cool dry place with temperatures around 15-20 degrees Celsius.

The weight of the shell is a significant factor during handling and prevention of an incident is a key aspect of risk mitigation. Although the shell is IM and therefore Drop tested correct procedures and packaging further protect the shell and user from injury. Lastly inspections of the munition are carried out before at key stages to identify Foreign Objects, Debris or Damage (FODD) that could cause the shell to be unsafe.

¹ Note: As AS90 is in service statements around testing can be made as simply for that item to be in service certain testing and qualification must have been performed. No qualification data is included or available to this report due to the unclassified nature of this document.

Barrel temperature is a possible cause of auto initiation, if the barrel is sufficiently hot and the shell is soaked for sufficient time the TNT in the shell can be liquified and ooze out of the shell in this state a breach detonation could occur. To prevent this controls such as a barrel cooling mechanism is installed along with Hot loading procedures where a round is only loaded when ready to fire. This reduces the soak time and mitigates this issue.

In summary the shell would require a large energy to initiate, this event is considered unlikely and therefore the probability of this hazard can be reduced.

Fuze

The fuze is one of the most critical parts contributing to HAZ01 as it is designed to initiate the shell but only when intended. It has several mechanical and electrical safety interlocks that will prevent inadvertent initiation. These have been designed in accordance with AOP 22 and STANAG 4369 [7].

The fuze is designed with three main safety interlocks, the first to be released is the Setback shutter. This shutter releases when the munition is fired and experiences a setback force, the second is a rotational shutter. This requires the round to spin a number of times before it will release, this spin is induced by the barrel rifling and will provide a minimum distance from the gun to arm. Lastly is an electrical interlock that will only release 3 seconds before the programmed time of flight ensuring safety in flight.

Electromagnetic environments present a significant risk to the Fuze due to its electrical nature and utilising an exploding bridge wire. These have been individually assessed using Electromagnetic Environmental Effects (E3) assessment through Weapon Technical Services (WTS, Ex DOSG)

These fuze systems will also be subject to SALE to ensure they are performing as expected through life.

In summary the fuze would require multiple failures to inadvertently initiate the warhead which allows the reduction of probability to a tolerable level.

5.2. HAZ02 – Propelling Charge Initiation

The L8A1 Charge System consists of Nitrocellulose (NC) Combustible Charge Bag (CCB) containing further CCB Increments that house the NC stick propellant.

As with the shell the NC charge system has undergone IM testing, and it demonstrates that even under confinement and with a large initiation energy the NC will only Burn with a type 5 reaction due to its unconfined nature.

The entire Propelling charge is designed to be consumed on firing and hence the charge presents a significant risk in the event of unintentional initiation. Prior to firing the charges are held in segregated and sealed charge bins that protect the charges from FODD. These bins also limit their exposure to extreme environments such as, flames, gasses, Sparkes and other aspects that could initiate them. In addition to this the outer CCB is soaked with a chemical that limits the combustion to a temperature reached at the end of the burn in the chamber. This allows the bag to protect the more sensitive sticks from accidental ignition.

As the packaging and casing of the charge forms such an integral part of the safety mechanisms charges are inspected for FODD upon unpackaging and prior to firing.

Barrel temperature is a possible cause of auto initiation of the charge, if the barrel is sufficiently hot and the charge is soaked for sufficient time the NC could self-ignite. To prevent this controls such as a barrel cooling mechanism is installed along with Hot loading procedures where a round is only loaded when ready to fire. This reduces the soak time and mitigates this issue.

The Charge will also be subject to SALE programmes to ensure they are performing as expected through life.

In summary cartridge is a simple bag of propellant that can be sufficiently managed and handled to ensure minimal risk to personnel.

5.3. HAZ03 – Primer Cartridge Initiation

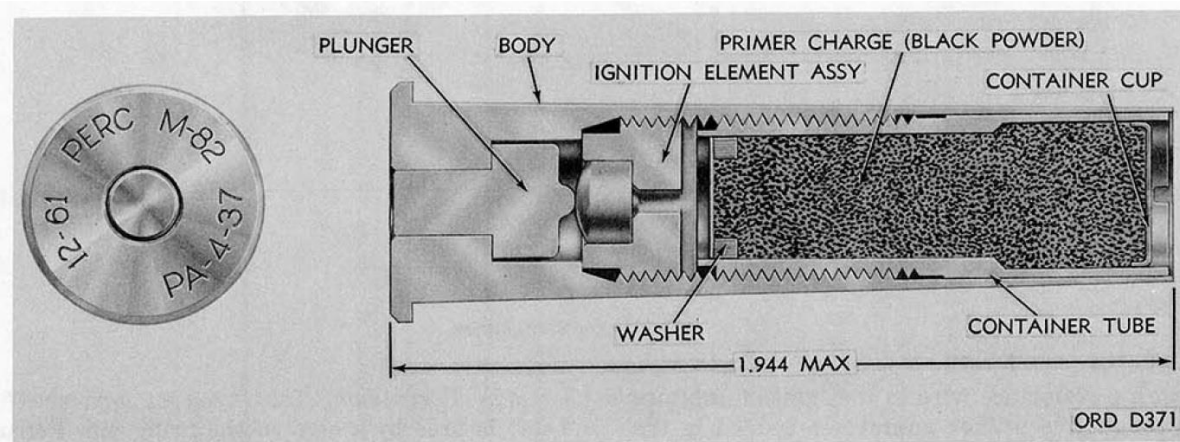


Figure 4-14. Percussion primer.

Figure 2 – M82 Primer Cartridge

The M82 primer Cartridge consists of a brass cartridge case filled with a NC based powder it has an internal striking pin and percussion cap that ignites the powder the top of the primer has a protective cap not seen in Figure 2. The cartridges are stored in the primer magazine next to the breach of the weapon prior to firing and in dedicated stowage bins during transport.

Barrel temperature is a possible cause of auto initiation of the Primer cartridge, but this is less of an issue as although thermally coupled to the breach the BVA that the cartridge is loaded in to sits separate from the breach and is sufficiently cooled by its surroundings to avoid Heat soaking. To prevent the possibility of heat soaking Hot loading procedures are still used with the primer. This reduces the soak time and mitigates this issue fully.

The main design of the primer means that the percussion cap is protected from impact initiation by the plunger as sufficient force must hit the tapered plunger to move it forwards to then initiate the percussion cap and NC based powder. The brass casing also shields the powder from EM radiation

The cartridge will also be subject to SALE programmes to ensure they are performing as expected through life.

In summary the Primer cartridge is a simple device that can be sufficiently managed and handled to ensure minimal risk to personnel.

5.4. Conclusion

In conclusion the safety assessment carried out above demonstrates that all reasonably practicable measures to assess, reduce and control the risks have been applied. These have been applied in accordance with the relevant legal requirements, applicable standards and guidance. The tolerability of the risk has been established above and further risk reduction measures are deemed grossly disproportionate in terms of capability, money, time and effort in comparison to the risk reduction seen. The residual risk is therefore considered to be As Low As Reasonably Practicable (ALARP)

6. References

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7. Anex A: AS90 155mm Ammunition [3]

SHELLS					
HIGH EXPLOSIVE		ILLUMINATION (ILLUM)		SMOKE	INERT
					
L15	L21	L27	M485	L28	L17
Body Colour:	Body Colour:	Body Colour:	Body Colour:	Body Colour:	Body Colour:
Olive Drab	Olive Drab	White	Olive Drab	Eau de nil	Deep Saxe Blue
Marking Colours:	Marking Colours:	Marking Colours:	Marking Colours:	Marking Colours:	Marking Colours:
Golden Yellow	Golden Yellow	Black	White	Brown	White
Authorised Fuze:	Authorised Fuze:	Authorised Fuze:	Authorised Fuze:	Authorised Fuze:	Authorised Fuze:
L166	L166	L163	L163	L163	PRF SX 144

CHARGES				
L15 SYSTEM		PRIMER	M107 SYSTEM	PRIMER
				
				
				
				
L6A1	L10A1	DM191	M3A1/L18A1	M82
Remove all increments numbered higher than the Charges ordered	Stand-alone Top Charge (Charge 8)		Remove all increments numbered higher than the Charges ordered	

FUZES & FUZE SETTER				
POINT DETONATING	PROXIMITY & MRF*		ETF**	FUZE SETTER
		Functions: Proximity High (10m +/-2m Burst Height) Proximity Low (4m +/-2m Burst Height) Min Proximity 5 secs Point Detonating Super Quick (PD/SQ) Point Detonating Delay (PD/D)		
L174 PD	L166 MRF	L163 ETF	L7A1	
Point Detonating Only (PD/OA)	Min 2.0 Sec Max 120 Sec	Min 2.0 Sec Max 120 Sec		
	*MRF - Multi-Role Fuze	**ETF - Electronic Timer Fuze		