



Joseph Nelhams

Risk Assessment & ALARP Justification

School of Applied Computing
ACDB5013 Safety and Hazard Assessment

Academic Year: 2025 - 2026

Lecturer: Austin Clark

June 2026

Table of Contents

List of Tables	iii
1 Introduction.....	1
1.1 Report Outline.....	1
1.2 Hazard Matrix	1
1.2.1 Hazard Matrix Definitions	1
2 Risk Assessment.....	1
3 ALARP Justification - High-pressure Gas.....	5
3.1 Introduction	5
3.2 Selected Controls and Mitigations	5
3.2.1 Obturation/breech seal design with redundant secondary sealing	5
3.2.2 Periodic proof/pressure testing.....	6
3.2.3 Condition based inspection and breach seal replacement	6
3.2.4 Lot-sampling and shelf-life of munitions	6
3.2.5 Defined Operating Temperature Envelope	7
3.2.6 Personnel Stand-off/Exclusion Zone	7
3.3 Discounted Controls and Mitigations.....	7
3.3.1 Disposable Gun System.....	7
3.3.2 Fully Autonomous Gun System	7
3.3.3 Continuous Barrel Telemetry.....	8
3.4 Cost-Benefit Analysis.....	8
3.5 Conclusion	9
4 References	10
Appendix A Group project Risk Assessment	11

List of Tables

Table 1 - The Hazard Matrix, also known as a Risk Classification Matrix, used for
the risk assessment in section 2..... 1

Table 2 - Table displaying the values for the GDF. 9

1 Introduction

1.1 Report Outline

This report will outline the hazards associated with using a 115mm Large Calibre Gun platform, notable uses include the T-62 main battle tank [6]. A full risk assessment for usage of the gun is shown in Section 2, the hazard matrix associated with the creation of the risk assessment is shown in section 1.2. An ALARP (As Low as Reasonably Practicable) justification behind one of the hazards, high-pressure gas, will then be performed in Section 3 of the report. The risk assessment was developed from a Hazard Identification (HazID) process, the outputs of which will be shown in Appendix A.

1.2 Hazard Matrix

The hazard matrix is a visual aid used to determine risks by comparing the likelihood of the event to the severity of the event, this breaks down a hazard into a risk classification, which is defined by the tolerability framework shown in Figure 1.

Table 1 - The Hazard Matrix, also known as a Risk Classification Matrix, used for the risk assessment in section 2.

	Catastrophic	Critical	Marginal	Negligible
Frequent	A	A	A	B
Probable	A	A	B	C
Occasional	A	B	C	C
Remote	B	C	C	D
Improbable	C	C	D	D
Incredible	C	D	D	D

1.2.1 Hazard Matrix Definitions

The definitions for severity are as follows:

- Catastrophic – Multiple fatalities of associated personnel and/or single fatality of non-associated personnel. Long-term environmental impact or complete loss of facility.
- Critical – Single fatality of associated personnel and/or a long-term injury to non-associated personnel.
- Marginal – Medium-term injury to associated personnel and/or short-term injury to non-associated personnel.
- Negligible – Short-term injury to associated personnel.

The definitions for frequency of event are as follows:

- Frequent – 1.0×10^{-2} (1 in 100 chance of occurring)
- Probable – 1.0×10^{-3}
- Occasional – 1.0×10^{-4}
- Remote – 1.0×10^{-5}
- Improbable – 1.0×10^{-6}
- Incredible – 1.0×10^{-9}

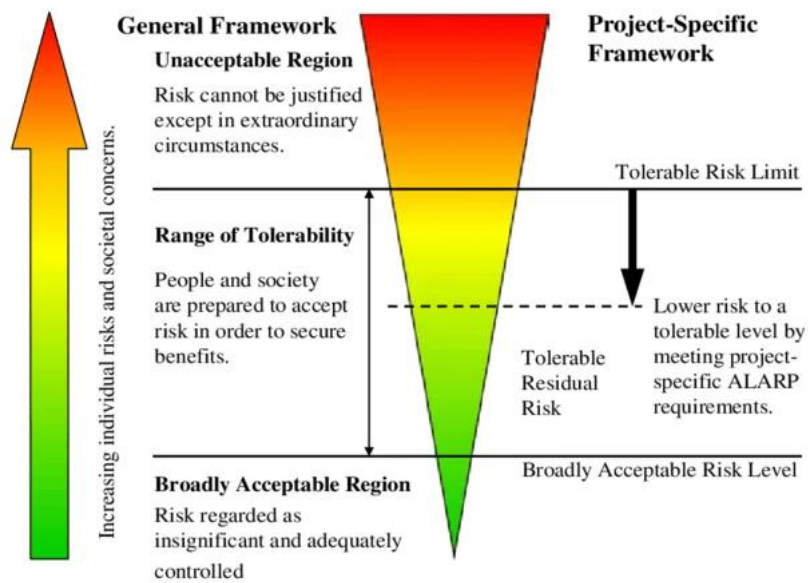


Figure 1 - The tolerability framework describing the acceptability of the risk classes [7].

2 Risk Assessment

Hazard	Description	Causal Pathway	Pre-Control Risk	Controls	Mitigations	Post-Control Risk
H1 – Explosion	Unintended initiation of the munition, causing major damage to the gun system and potentially killing the onboard crew and nearby personnel.	- Electrostatic discharge from systems within the platform causing an unintended firing of the loaded gun. - Low drop (unpacked) of the munition during the process of reloading the gun. - IM threats: fragmentation attack, bullet impact, shaped charge jet, sympathetic reaction, slow/fast cook-off. Caused by an attack on the weapon from outside the system. - Electromagnetic radiation (EMR), either from within the system or from an attack outside the system could cause unintended initiation of the munition. - Hangfire / misfire potentially caused by improper loading or poor build quality of the munition.	Remote / Catastrophic (Class B)	- Insensitive Munitions (IM) compliant fill/design (STANAG 4439) [1] to reduce likelihood of a violent reaction to unintended stimuli. - ESD control: conductive packaging, earthing straps, humidity control in preparation areas and storage areas. - Drop-qualification testing to STANAG 4370 prior to service release. - EMR shielding of firing circuits; control of contraband (RF sources) near explosives areas (JSP 482) [3]. - Explosive Safety Quantity-distance (ESQD) to limit the consequences of a sympathetic reaction (JSP 482) [3]. - Mandated hangfire/misfire drills with defined wait-times before approach. - Automatic loading system, to minimise risk and exposure to personnel.	- Minimum safe manning - Personnel exclusion zones during live firing	Improbable / Catastrophic (Class C)
H2 – Electrical	Electrical discharge from the system during use causing electrical shocks to nearby personnel resulting in burns and potential cardiac issues.	Damage from animals, such as vermin chewing through cabling can cause a potential ESD event, causing harm to nearby personnel or an unintended initiation of the munition.	Improbable / Critical (Class C)	- Protected cable routing / conduit - Lightning protection system with bonded earthing - Electromagnetic compatibility (EMC) compliance to JSP 482 [3].	- RCD (residual current device) protection: circuit breaker. - Insulated PPE for maintainers: ESD boots and wrist strap.	Incredible / Critical (Class D)

Hazard	Description	Causal Pathway	Pre-Control Risk	Controls	Mitigations	Post-Control Risk
		- Lightning strike on the system causing harm to nearby personnel and potential damage to the system. May also cause unintended firing of the munition. - EMR causing damage to circuitry, potentially harming personnel through an unexpected ESD event. - Environmental effects such as heating/cooling and rain causing degradation of components over time, and damage to any exposed components. - Degradation through poor maintenance regime. - Water ingress causing short circuits and exposing personnel to ESD risk.		- IP-rated enclosures against water ingress - Scheduled inspection, insulation-resistance testing and permit-to-work for maintenance	Lock-out/tag-out during maintenance	
H3 – Toxicity / Fumes	Fumes produced by deflagration of propellant within the firing sequence, potentially poisoning affected personnel or even death by asphyxiation.	Toxic fumes released from propellant combustion	Frequent / Critical (Class A)	- Forced ventilation / local exhaust extraction at the firing point - Propellant formulation selection to minimise toxic combustion products - COSHH-based Workplace Exposure Limit (WEL) monitoring - Mandated fume-clearance time before re-entry or reload - Respiratory PPE for enclosed or vehicle-mounted use	Health surveillance / biological monitoring for high-exposure roles	Remote / Critical (Class C)

Hazard	Description	Causal Pathway	Pre-Control Risk	Controls	Mitigations	Post-Control Risk
H4 – High-Pressure Gas	High-pressure gases produced by deflagration of the propellant which can cause harm to nearby personnel if exposed.	- Misfire - Breech failure: obturation failure, firing at elevated temperature, damaged/aged munition, poor assembly, seal wear	Frequent / Critical (Class A)	- Obturation/breech seal design with redundant secondary sealing - Periodic proof/pressure testing and a written scheme of examination by a competent person. - Condition-based seal inspection and replacement (age/round-count triggered) - Munition shelf-life and lot-sampling condition management. - Defined operating-temperature envelope - Personnel stand-off / exclusion zone during firing; immediate-action misfire drill	- Immediate-action drill for suspected breach failure - Pressure-relief pathway in breech design	Remote / Critical (Class C)
H5 – Heat	Hot byproducts of firing, particulates and residual heat on the weapon system causing burns on nearby personnel.	- Repeated firing of gun during operation. - Hot casing being expelled from barrel after firing. - Residual heat in the system after firing. - Hot gases and particulate being expelled from the barrel during firing.	Frequent Marginal (Class A)	- Rate-of-fire limits and mandated cool-down periods to prevent gun over-heating. - Barrel/casing shielding and thermal insulation particularly by the breach end of the gun to prevent personnel being exposed to hot temperatures after firing. - Forced-air or passive cooling systems to expel heat from the barrel after firing. - Post-fire handling procedure with mandated cool-down time before contact.	- Thermal PPE such as gloves and coveralls. - Thermal-indicator labelling to notify personnel that the gun is hot after firing.	Occasional / Marginal (Class C)
H6 – Noise	Noise produced from the weapon system during use potentially	Firing of the system	Frequent / Critical (Class A)	Mandatory hearing protection within the defined noise zone	Audiometric health surveillance to	Probable / Marginal (Class B)

Hazard	Description	Causal Pathway	Pre-Control Risk	Controls	Mitigations	Post-Control Risk
	causing long-term hearing damage to nearby personnel.	• Projectile in flight and on detonation. • Breech mechanism operation		• Installation of a Muzzle on the end of the barrel to reduce the noise generated, minimising impact on those outside the vehicle. • Exposure-duration limits under the Control of Noise at Work Regulations 2005 [5]. • Exclusion distances for non-essential personnel and the public	monitor the health of potentially affected personnel and remove them from service should their hearing be affected.	

3 ALARP Justification - High-pressure Gas

3.1 Introduction

This section of the report justifies the ALARP position reached for the High-Pressure Gas Hazard (H4 in the risk assessment) by outlining how the hazard has been mitigated to an ALARP position. Each of the mitigations and controls used for reducing the risk will be described, and some controls shall be outlined for the reasons why they were not included within the risk assessment. When uncontrolled this hazard is risk class A, intolerable, and therefore not ALARP. The risk assessment outlines the necessary mitigations and controls required to reduce this hazard from risk class A, down to risk class C.

3.2 Selected Controls and Mitigations

The following controls and mitigations will be outlined and selected against the ERIC PD (*Eliminate, Reduce, Isolate, Control, PPE and Discipline*) hierarchy to rank them in order of importance, it is worth noting that due to the functionality of the gun it is not possible to eliminate or reduce the hazard as the gun would not function without it. The main causal pathway is obturation failure which consists of seal wear, firing outside of the temperature envelope, damaged or aged munition, or poor assembly of the gun; a misfire is the other causal pathway. Together the following controls and mitigations would reduce the probability of the hazard from Frequent to Remote, lowering the risk class.

3.2.1 Obturation/breech seal design with redundant secondary sealing

This is an engineering *control* which can isolate or control the hazard by adding some redundancy to the system should the primary seal degrade to the point of failure, by having redundant sealing should the primary seal fail then nearby personnel would not be directly exposed to the high-pressure gas from the gun barrel.

3.2.2 Periodic proof/pressure testing

This is an engineering *control* which specifies periodic testing of the system, pressurised systems are required to have these examinations as specified under the Pressure Systems Safety Regulations 2000; ACOP L122 [4]. However, a 115mm Large-calibre gun is likely to be exempt from these regulations due to the definitions of a pressurised system within the regulations. Whilst this gun would not store pressurised gas, its functionality is reliant on pressurised gas created by a propellant to function. So, it is appropriate to ensure the system should have a written scheme of examination which closely follows those which are laid out in the Pressure Systems Safety Regulations. The importance of maintenance and surveillance regimes in gun systems is key to maintaining safe usage of those systems.

3.2.3 Condition based inspection and breach seal replacement

Frequent inspections of the gun system should be performed to *reduce* the likelihood of the hazard occurring. These should be performed according to the age of the gun, or the quantity of rounds fired, for example if the system was used 100 times then a mandatory inspection of the breach should be performed to ensure the wear isn't so great to present a hazard. This will allow the operators to catch potential issues before they become outright failures.

3.2.4 Lot-sampling and shelf-life of munitions

Lot-sampling and shelf-life will *reduce* the likelihood of an unintended event occurring. Lot-sampling involves randomly testing munitions from specific batches to verify the safety and performance, should the lot not meet the requirements then all munitions from that lot will be removed from service to prevent any hazardous events occurring. Removing the lot also allows an investigation to take place to understand why the lot failed, was it due to manufacturing practices, storage or something else? Additionally incorporating a shelf-life into munitions is key, as explosives age their properties change, these changes can cause the munition to behave unexpectedly leading to misfires.

3.2.5 Defined Operating Temperature Envelope

This is a procedural *control* placed upon the system. At higher temperatures material properties change and, in some circumstances, can lead to the gun system not operating as intended. This increases the likelihood of an event occurring and thus increases risk. By limiting the conditions in which the gun is allowed to operate you reduce the likelihood that the hazard will occur.

3.2.6 Personnel Stand-off/Exclusion Zone

Establishing a stand-off distance/exclusion zone during use of the system would reduce the risk of the hazard by limiting the number of personnel affected by the hazard. This falls under the *discipline* portion of the ERIC PD hierarchy and therefore is the lowest order control. Should the gun be used in the environment is it designed for these exclusion zones become significantly harder to enforce.

3.3 Discounted Controls and Mitigations

An ALARP position is defined by what controls have been put in place, as well as what was not selected due to the controls being considered grossly disproportionate. A few reasons why something may be considered grossly disproportionate are due to costs or implementation.

3.3.1 Disposable Gun System

To eliminate the risks of wear and to eliminate any requirements on maintenance the 115mm Large-Calibre Gun system could be designed to be used only once. As these systems are always mounted on a platform, typically a tank but also a warship, the time and resource taken to replace the gun system every shot is excessive. Whilst it may slightly reduce the risk and save on maintenance, the time taken for reinstallation of the gun system as well as the extortionate costs of replacing the system makes this control grossly disproportionate.

3.3.2 Fully Autonomous Gun System

With the recent developments in drone technology, it is entirely plausible that an autonomous tank with a 115mm gun system could be developed and used in the field, entirely negating the risk to the operators. However, the costs to develop

are very high and the time to develop the system makes it currently an unfeasible option. Though in the near future autonomous platforms will become more likely.

3.3.3 Continuous Barrel Telemetry

Continuous barrel telemetry refers to the process of monitoring the conditions of the barrel and the munitions after each shot. Outputting information such as barrel wear and temperature. The information collected could be input into a logic system which automatically aborts the firing process should the conditions within the barrel fall out of the operational requirements. The development of such a system will be reasonably expensive and require a fair amount of development and integration time, the benefits of such a system are negligible when brought in alongside the current controls and mitigations. At best this system may change the probability of an event occurring from improbable to incredible, but due to the severity of the hazard this would not change the risk class. With the development of artificial intelligence (AI), the integration of this diagnostic may allow the elimination or reduction of other controls such as maintenance regimes. As an AI may be able to interpret exactly when a gun should no longer be used and when it should be maintained/replaced.

3.4 Cost-Benefit Analysis

A cost benefit analysis has been performed on the redundant second seal to compare the cost of the control with the cost of the Health and Safety Executive's (HSE) Value of a Prevented Fatality (VPF).

The CBA equation provides a threshold Grossly Disproportionate Cost (GDC), the cost to implement a control/mitigation can be compared with the calculated figure:

$$GDC = VPF \times [P_1 \times GDF1 - P_2 \times GDF2]$$

The HSE currently has the VPF at approximately £2 million. The GDF (Grossly Disproportionate Factor) is outlined from Table 2. P_1 is the probability of the event occurring pre controls, P_2 is the probability post controls.

Table 2 - Table displaying the values for the GDF.

Injury Type	Gross Disproportionate Factor
Fatality	10
Major Illness/Injury	5
Minor Illness/Injury	3

Assuming that there are 2 personnel manning the gun, the GDC over one year can be calculated as:

$$GDC = (2 \times 2 \times 10^6) \times [(1 \times 10^{-5} \times 10) - (1 \times 10^{-6} \times 10)] = £360$$

If the systems service life is 10 years then the GDC rises to £3,600. With an approximate fleet size of 100 tanks that brings the total to £360,000. The cost to procure and integrate this secondary seal sits fairly below this, showing that this is a proportional implementation to make.

3.5 Conclusion

The high-pressure gas hazard has been reduced from a Class A, unacceptable, to Class C, tolerable, by addressing each causal pathway and setting controls and mitigations against them. Three other controls and mitigations were outlined and discounted as grossly disproportionate and explained with reasoning. Some of these discounted controls have the potential to be proportionate as technology develops, and as an ALARP position is ever evolving it can be concluded that the current risk assessment is justified as ALARP but may not be considered ALARP in the near future.

4 References

1. T. Swierk, Naval Surface Warfare Center, IM Assessment Panel, US Navy, R. Beauregard, and S. Blashill, "IM testing and assessments." [Online]. Available: <https://publications.sto.nato.int/publications/STO%20Educational%20Notes/STO-EN-AVT-214/EN-AVT-214-02.pdf>
2. "STANAG 4370 PDF." <https://www.scribd.com/document/244566044/STANAG-4370-PDF>
3. Ministry of Defence, "MOD explosives regulations (JSP 482)," GOV.UK, Aug. 23, 2013. <https://www.gov.uk/government/collections/jsp-482-mod-explosives-regulations>
4. "Safety of pressure systems - HSE." <https://www.hse.gov.uk/pubns/books/l122.htm>
5. "The Control of Noise at Work Regulations 2005." <https://www.legislation.gov.uk/ukxi/2005/1643/contents>
6. "T-62 - The Tank Museum," *The Tank Museum*, Feb. 06, 2025. <https://tankmuseum.org/tank-nuts/tank-collection/t-62/>
7. D. S Bowles, Ed., *What is ALARP and how can it improve dam safety decisions?* 2013. [Online]. Available: https://www.researchgate.net/publication/316282213_What_is_ALARP_and_how_can_it_improve_dam_safety_decisions

Appendix A Group project Risk Assessment

The following resources were produced during the group activities following on from the Hazard Identification brainstorming session.

A.1 Risk Assessment for the 115mm Gun

HI D	Hazard	Description	Uncontrolled Hazard Probability	Uncontrolled Hazard Severity	Uncontrolled Risk Class	Controls	Mitigations	Controlled Hazard Probability	Controlled Hazard Severity	Accident	Controlled Risk Class
H1	Explosion	Unintended Initiation of the munition.	Remote	Catastrophic	B						
H2	Electrical	Electrical discharge from the system during use.	Improbable	Critical	C						
H3	Toxicity/Fumes	Fumes produced by deflagration of propellant within the firing.	Frequent	Critical	A						

H4	High-Pressure Gas	High-Pressure gases produced by deflagration of the propellant.	Frequent	Critical	A														
H5	Heat	Hot byproducts of firing, particulates and residual heat on weapon system.	Frequent	Marginal	A														
H6	Noise	Noise produced by the use of the weapon system.	Frequent	Critical	A														

A.2 Hazard Matrix

Hazard	Owner	Justification	Causal Pathway (Accidents/causes)
Explosion	Tom	Complete failure of the system, potential for multiple unintended casualties.	1. Electrostatic Discharge 2. Low Drop (Unpackaged) 3. Insensitive Munition Threats (Fragmentation attack, Bullet Impact, Shaped Charge Jet, Sympathetic Reaction, slow and fast heating) 4. Electromagnetic Radiation 5. Hangfire and Misfire
Electrical	George	Required for firing the system, has the potential to cause an unintended injury/fatality.	1. Damage from animals 2. Lightning 3. Electromagnetic Radiation

			4. Environmental effects (Inclement weather/exposed cabling) 5. Degradation (Maintenance) 6. 6. Water Ingress
Asphyxiant/Toxicity	James	A byproduct of using the system that has the potential to cause serious harm to personnel.	1. Toxic fumes from propellant
High Pressure Gas	Joseph	A byproduct of using the system that has the potential to cause serious harm to personnel.	1. Misfire 2. 2. Breach failure (Obturation, firing at increased temperatures, damaged (aged) munition, poor assembly, Seal wear)
Heat	Pippa	A byproduct of using the system that has the potential to cause harm to personnel.	1. Repeated Use 2. Hot casing 3. Residual heat in system 4. Electrical fault

			5. 5. Hot gases and particulate
Noise	Charlotte	A byproduct of using the system that has the potential to cause serious harm to personnel, and general public perception.	1. Firing the system creates noise 2. Projectile Explosion 3. 3. Breach mechanism