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Risk Assessment & ALARP Justification (Individual Written Report)

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- no animals were harmed in the writing of this essay.
- the thesis submitted has not been previously submitted to this university or any other.
- that all content, including primary and/or secondary data, is true to the best of my knowledge.
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1 Introduction and Risk Assessment

AJAX is a family of Armoured Fighting Vehicles (AFV) currently in service with the British Army [1]. There are six variants of the AJAX [2], including:

- AJAX: A turreted reconnaissance platform mounting a 40 mm cannon.
- ARES: An Armoured Personnel Carrier (APC) variant armed with a 12.7 mm machine gun.
- Athena: A Command and Control vehicle armed with a 12.7 mm machine gun.
- Argus: An engineering reconnaissance vehicle.
- Atlas: An equipment support variant optimised for recovery of casualty vehicles, not fitted with a crane.
- Apollo: A second equipment support variant of the AJAX platform with attached crane.

The AJAX variant includes a turret-mounted 40 mm cannon with a coaxial 7.62 mm chain gun. All AJAX variants can be fitted with the Kongsberg 'Protector' remote weapon station capable of mounting a variety of weapons systems [3] including a 7.62 mm General Purpose Machine Gun (GPMG) a 12.7 mm Heavy Machine Gun (HMG) and a Javelin Anti-Tank Guided Missile (ATGM).

The following risk assessment is concerned with hazards posed by the energetic materials utilised within the AJAX system. Risks will be assessed using the following Risk Category Matrix (RCM):

	Apocalyptic	Catastrophic	Serious	Major	Marginal	Minor
Frequent	A	A	A	A	B	C
Probable	A	A	A	B	C	C
Occasional	A	A	B	C	C	D
Remote	A	A	B	C	C	D
Improbable	A	B	C	C	D	D
Incrediabolical	A	B	C	D	D	D

Table 1 - Risk Category Matrix

Severity	Definition
Apocalyptic	Multiple deaths or serious injuries of Direct and Indirect Personnel, complete loss of multiple platforms, destruction of associated infrastructure.
Catastrophic	Multiple deaths or serious injuries of Direct Personnel, death or long-term harm of Indirect Personnel, complete loss of platform. Damage to associated infrastructure.
Serious	Death or long-term harm of Direct Personnel, significant harm to Indirect Personnel, severe damage to platform.
Major	Significant harm to Direct Personnel, moderate harm to Indirect Personnel, significant damage to platform.
Marginal	Moderate harm to Direct Personnel or minor damage to platform.
Minor	No significant harm to personnel or damage to platform.

Table 2 - Severity Definitions

Likelihood	Probability
Frequent	1×10^{-1}
Probable	1×10^{-2}
Occasional	1×10^{-3}
Remote	1×10^{-6}
Improbable	1×10^{-9}
Incrediabolical	1×10^{-12}

Table 3 - Likelihood Definitions

Hazard ID	Hazard	Hazard Description	Accident	Cause	Cause Description	Likelihood (P(O))	Severity	Risk Class	Risk Reductions	Likelihood (P(O))	Severity	Risk Class
Haz01	Inadvertent Detonation of HE Projectile	The potential of the 40 mm HE munition projectile to initiate outside of normal operating conditions	Initiation of the HE projectile may lead to: -Fatality or Major Injury of Direct Personnel due to HE effect (blast, fragmentation, heat)	Exposure to heat	Exposure of HE projectile to heat can lead to a deflagration to detonation transition resulting in initiation of HE fill	Remote (1x10 ⁻⁶)	Serious	B	Control 1: Training of personnel Control 2: Storage of munitions within fireproof compartment Mitigation 1: Storage of munitions within blast-resistant compartment	Improbable (1x10 ⁻⁶)	Major	C
				Detonation of nearby HE munitions	Inadvertent detonation of HE munition may cause sympathetic initiation of other HE munition projectiles	Remote (1x10 ⁻⁶)	Serious	B	Control 3: Insensitive munitions Mitigation 1: Storage of munitions within blast-resistant compartment	Improbable (1x10 ⁻⁹)	Major	C

Haz02	Projection (40mm ammunition)	The firing of 40mm projectiles outside of normal operating conditions	Unintended firing of 40mm ammunition may lead to:	Heat	Residual heat in the breech of the 40mm cannon due to firing may cause initiation of 40mm ammunition propellant	Occasional (1×10^{-3})	Catastrophic	A	Mitigation 2: Muzzle discipline	Improbable (1×10^{-9})	Catastrophic	B
			-Major injury of Direct Personnel due to mechanical movement of 40mm cannon parts	User error	Misoperation of 40mm cannon firing system may lead to unintended discharge of 40mm ammunition	Occasional (1×10^{-3})	Catastrophic	A	Control 1: Training of personnel	Improbable (1×10^{-9})	Catastrophic	B
			-Fatality or Major Injury to Direct or Indirect Personnel due to munition effect (blast, fragmentation, heat, kinetic)	Mechanical failure	Failure of firing system mechanics may lead to unintended discharge of 40mm ammunition	Remote (1×10^{-6})	Catastrophic	A	Mitigation 2: Muzzle Discipline Control 5: Quality control during production Control 6: Inspections & Maintenance	Improbable (1×10^{-9})	Catastrophic	B

Haz03	Fire (40mm Ammunition)	The deflagration of 40mm ammunition propellant outside of normal operating conditions	Unintended deflagration of 40mm ammunition propellant may lead to: -Death or Major Injury of Direct Personnel due to fire	Heat	Fire in the crew compartment may lead to deflagration of 40mm ammunition propellant	Occasional (1x10 ⁻³)	Serious	B	Control 1: Training of personnel Control 2: Storage of munitions within fireproof compartment Mitigation 3: Personal Protective Equipment Mitigation 4: Training of personnel	Remote (1x10 ⁻⁶)	Major	C
Haz04	Inadvertent Detonation of Javelin ATGM Warhead	The potential of the Javelin ATGM warhead to initiate outside of normal operating conditions	Unintended initiation of the Javelin ATGM warhead may lead to: -Death or Major Injury of Direct	Failure of SAU	Failure of the Safe and Arming Unit of the Javelin ATGM may lead to inadvertent initiation of warhead energetics	Remote (1x10 ⁻⁶)	Major	C	Control 7: SAU design	Improbable (1x10 ⁻⁹)	Major	C

			Personnel due to HE effect (Blast, fragmentation, heat)	Heat	Exposure to heat (ie, tracer ammunition/fuel fire) may lead to inadvertent initiation of warhead energetics.	Occasional (1x10 ⁻³)	Serious	B	Control 3: Insensitive munitions	Remote (1x10 ⁻⁶)	Serious	B
Haz05	Projection (Javelin ATGM)	The firing of Javelin ATGM outside of normal operating conditions	Unintended firing of the Javelin ATGM may lead to: -Death or Major injury of Direct Personnel due to rocket motor initiation (heat)	User error	Misoperation of Javelin ATGM firing system may lead to unintended firing of Javelin ATGM	Occasional (1x10 ⁻³)	Catastrophic	A	Control 1: Training of personnel	Improbable (1x10 ⁻⁹)	Catastrophic	B
			-Death or major injury to Indirect Personnel due to kinetic impact of Javelin ATGM	Software error	Error of the Javelin ATGM firing system may lead to unintended firing of Javelin ATGM	Remote (1x10 ⁻⁶)	Catastrophic	A	Control 8: Software design	Improbable (1x10 ⁻⁹)	Catastrophic	B

Haz06	Fire (Javelin ATGM)	The potential of errors in manufacture of the Javelin ATGM to cause a failure of the rocket motor on launch resulting in fire.	Failure of the Javelin ATGM rocket motor may lead to: -Death or Major Injury of Direct Personnel due to fire.	Manufacturing error	Errors during manufacture of the Javelin ATGM rocket motor may lead to failure of the rocket motor during launch.	Remote (1x10 ⁻⁶)	Serious	B	Control 5: Quality control during production Mitigation 4: Training of personnel	Improbable (1x10 ⁻⁹)	Marginal	D
Haz07	Projection (7.62mm)	The firing of 7.62mm ammunition outside of normal operating conditions	Unintended firing of 7.62mm ammunition may lead to: -Minor Injury to Direct Personnel due to mechanical movement of 7.62mm machine gun parts	User error	Misoperation of 7.62mm machine gun may lead to unintended discharge of 7.62mm ammunition	Occasional (1x10 ⁻³)	Catastrophic	A	Control 1: Training of personnel Mitigation 2: Muzzle discipline	Improbable (1x10 ⁻⁹)	Catastrophic	B
			-Burns to Direct Personnel due to ejected shell casings -Death or Major Injury to Indirect	Mechanical failure	Failure of 7.62mm machine gun components may lead to unintended discharge of 7.62mm ammunition	Remote (1x10 ⁻⁶)	Catastrophic	A	Control 6: Inspections and maintenance Control 5: Quality control during production Mitigation 2:	Improbable (1x10 ⁻⁹)	Catastrophic	B

			Personnel due to 7.62mm ammunition effect (kinetic)						Muzzle discipline			
Haz08	Fire (7.62mm)	The deflagration of 7.62mm ammunition propellant outside of normal operating conditions	The deflagration of 7.62mm ammunition propellant may lead to: -Minor Injury of Direct Personnel	Heat	Fire in the crew compartment may lead to deflagration of 7.62mm ammunition propellant	Occasional (1×10^{-3})	Major	C	Control 2: Storage of munitions within fireproof compartment	Remote (1×10^{-6})	Minor	D

2 ALARP Justification

2.1 Requirements

DSA.01 [4] requires that defense projects 'comply with UK health, Safety and Environmental statutory requirements'. This refers to the Health and Safety at Work Act 1974 [5], which states that 'all employers have a duty of care to their employees, the general public and the wider environment' and that plant and systems of work are safe 'so far as is reasonably practicable', interpreted by JSP 815 [6] as 'as low as reasonably practicable (ALARP)'. Within the MoD this includes an obligation to manage the risk to life associated with the operation of military systems.

Reducing a risk to ALARP refers to balancing the risk involved in a certain activity to a tolerable level, while balancing the degree of sacrifice required to continue reducing the risk concerned. Should the degree of sacrifice become 'grossly disproportionate' to the reduction in risk, the risk may be considered ALARP and no further measures are required, provided that the risk can be considered tolerable.

Tolerability is defined in JSP 815 [6] as 'the willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled'. In the context of military systems, this refers to the willingness to live with the risk posed by said systems to both Direct and Indirect Personnel in order to conduct military operations.

Tolerability can be illustrated as below [7]:

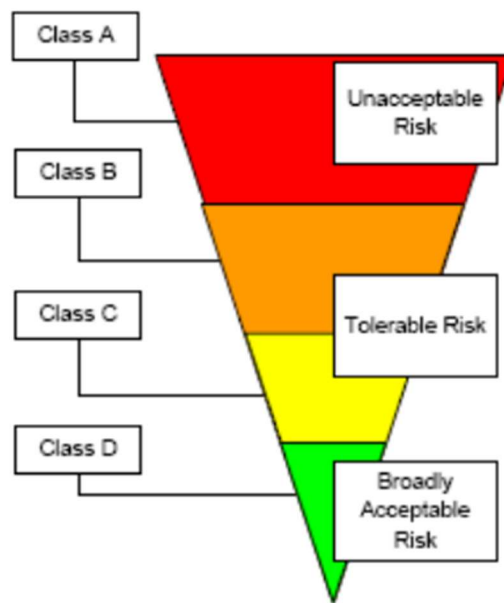


Figure 1 - The Tolerability Triangle

Risks classified as 'Class A', which are considered both likely and posing serious consequences (usually involving serious risk to life) are considered unacceptable even if the risk has been shown to be ALARP.

Class B or C risks, usually considered likely but without serious consequences, or as having serious consequences but being unlikely, can be accepted if it is shown that they have been reduced to ALARP through controls or mitigations. These risks are referred to as 'tolerable'

Class D risks, which have been assessed as having both a low probability and less serious consequences, and are accepted when shown to be tolerable and ALARP.

Risks which are considered ALARP must be monitored to ensure that they remain ALARP throughout the lifecycle of the system, as configuration changes may affect the likelihood or consequence of the risk – for example, a change in the chemical properties of a rocket motor may either reduce or increase the likelihood of fire.

2.2 Assumptions

The following assumptions are made regarding the operation of the AJAX platform:

- That the platform is operated only by trained and qualified personnel
- That the platform is operated in accordance with the recommended operating procedures
- That the platform is maintained and inspected in accordance with an approved maintenance and inspection schedule.

2.3 Hazard 02

Hazard 02 relates to the uncommanded firing of 40 mm ammunition from the 40 mm cannon mounted on the AJAX reconnaissance variant. This hazard is specific to the AJAX and does not apply to other variants of the AJAX platform (i.e. ARGUS).

The AJAX carries a variety of 40 mm ammunition including high explosive and armour piercing projectiles [8]. These projectiles pose a significant risk to human life and the risk of uncommanded firing must therefore be reduced to tolerable and ALARP.

The causes relating to Hazard 02 are outlined in table 4 below:

Projection (40 mm ammunition)	Cause 1	Heat	Residual heat in the breech of the 40mm cannon due to firing may cause initiation of 40mm ammunition propellant
	Cause 2	User error	Misoperation of 40mm cannon firing system may lead to unintended discharge of 40mm ammunition
	Cause 3	Mechanical failure	Failure of firing system mechanics may lead to unintended discharge of 40mm ammunition

Table 4 - Summary of Hazard 02

These causes have been evaluated for likelihood and severity as follows:

Cause	Likelihood	Severity	Risk Class
1	Occasional (1×10^{-3})	Catastrophic	A
2	Occasional (1×10^{-3})	Catastrophic	A
3	Remote (1×10^{-6})	Catastrophic	A

Table 5 - Initial Risk Classifications for Hazard 02

Table 5 shows that each cause is considered Risk Class A due to the potential harm to Indirect Personnel. As a Risk Class of A cannot be accepted, the risk must be mitigated and controlled down to a tolerable level (Risk Class B or below).

2.3 Mitigations and Controls

The mitigations and controls to be applied to Hazard 02 are shown in table 6:

Cause	Mitigations / Controls
1	Mitigation 2: Muzzle discipline
2	Control 1: Training of personnel
3	Mitigation 2: Muzzle Discipline Control 5: Quality control during production Control 6: Inspections & Maintenance

Table 6 - Mitigations and Controls

Mitigation 2: Muzzle discipline

Muzzle discipline ensures that the barrel of the 40mm cannon is only trained in a safe direction when the system is loaded. This ensures that in the event of an unintended discharge, any 40 mm rounds fired will not strike unintended targets, however this will not prevent effects on targets or injury to platform operators from mechanical movement of the 40 mm cannon.

Control 1: Training of personnel

Operators of the AJAX platform will be trained in the following areas:

- Safe operation of the 40 mm cannon. This will reduce the likelihood of operator error resulting in an unintended discharge.
- Human factors. Human factors training is currently mandated within the UK MoD air domain [9]. Expanding the requirement to cover the Land Domain will enable operators to recognise the dangers posed by human factors such as fatigue and stress, which may lead to misoperation of the 40 mm cannon resulting in unintended discharge.
- Basic inspections of 40 mm cannon components: AJAX operators will be trained to identify faults of system components so that these can be addressed in a timely manner, reducing the likelihood of worn or damaged components remaining in service.

Training of personnel significantly reduces the likelihood of an unintended discharge of the 40 mm cannon, but does not reduce the severity of an accident as the effect on target will remain the same.

Control 5: Quality Control during production

Quality control during production is the inspection and proving of weapon system components during and following production and assembly of the system. These inspections will be carried out by the manufacturer and will reduce the chances of defective components entering service.

Control 6: Inspections & maintenance

This refers to the periodic checks performed on in-service equipment by qualified personnel. This will reveal defects within the system which may lead to an unintended discharge, and the defective components can be repaired or replaced. This will reduce the likelihood of mechanical failure leading to an unintended discharge but will not reduce the severity should an unintended discharge occur.

2.4 Residual Risk

Following the introduction of the controls and mitigations laid out in Table 6, the risk is reduced to the level shown in Table 7:

Cause	Likelihood	Severity	Risk Class
1	Improbable (1×10^{-9})	Catastrophic	B
2	Improbable (1×10^{-9})	Catastrophic	B
3	Improbable (1×10^{-9})	Catastrophic	B

Table 7 - Residual Risk

Table 7 shows that following the introduction of the above mitigations and controls, the risk class is reduced to a level considered tolerable.

In order to further reduce the risk level, the following controls were considered:

Change of Material Specifications

This refers to a change in the materials used in 40 mm cannon components in order to reduce residual heat in the breech, and therefore reduce the likelihood of a 40 mm round 'cooking off'.

While potentially effective, this was considered prohibitively expensive as the AJAX system is already in-service and the cost of production of new components and refitting the existing vehicle fleet was considered disproportionate to the potential reduction in risk.

Replacement of Human Operator with a Robotic Component

This refers to the removal of a human operator for the 40 mm cannon and the installation of a robotic fire-control unit, capable of identifying targets and manipulating the weapon system.

While this would entirely remove the possibility of an unintended discharge caused by human error, the costs involved in development of this component were considered prohibitively expensive. It was also suggested that such a component would introduce new risks potentially more serious than those removed through its introduction.

Training Restrictions

The restriction of 40 mm cannon firings to ranges located in Canada or the Arctic regions, where the likelihood of Indirect Personnel being affected by an unintended discharge would be significantly reduced.

This was rejected as it would significantly disrupt AJAX crew training and reduce the operational effectiveness of AJAX units to a level that was deemed disproportional.

3. Conclusion

The risk associated with Hazard 02 has been assessed and reduced to a tolerable level through the application of sustainable mitigations and controls. While the risk could be further reduced through the application of further mitigations and controls, these further controls would introduce a disproportionate degree of sacrifice. The risks associated with Hazard 02 are therefore suggested to be both Tolerable and ALARP.

References

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