Safety considerations concerning crew survivability in Land Platforms

(White Paper)

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1. General

Military Land Platforms continue to face the risks associated with crew survivability and emergency egress in both training, and operational environments. The action of emergency egress can be considered secondary to survivability as crew must first survive an event before attempting to escape from their vehicle. This Paper considers post-event accident and risk sequences with a view to identify critical risk mitigating measures, and to uncover potential areas of concern that may otherwise remain unchallenged and unmitigated. The Paper assumes the reader has an established knowledge regarding the area of Land Platform Post-event Survivability. To set the premise, a generic / typical post event accident sequence is considered below.

Accident / Risk Sequence and Mitigations:

A. Failure to survive event due to overwhelming physical forces - Mitigation: Reinforced Hull; Spall Liners; Blast Attenuation Seating.

B. Failure to survive secondary event hazards such as Smoke and Fire - Mitigation: Crew and Engine Fire / Explosion Suppression System.

C. Failure of crew to locate exit/s - Mitigation: hatch/exit marking system.

D. Failure of crew to open exit/s - Mitigation: Emergency Door Opening Mechanisms.

E. Failure of crew to find an effective secondary exit - Mitigation: egress hatches/points in 3 planes. Exits made or modified to an effective size with snagging hazards minimised.

The text below goes on to discuss each of the above sequences in turn.

2. Discussion

A. Failure to survive event due to overwhelming physical forces: The advances and successes in the employment of V-Shape Hulls in Land Platforms is commonly accepted. Certainly all new Platform directives include requirements to apply this kind of mitigation. The associated technologies have been proven through trial and operational experience. There is no question that this technology has saved lives. However, over the last few years, AGI's attention has been drawn to the physical characteristics encountered during vehicle IED representative blast trials and to some extent real events. Particular observations have been noted with respect to vehicle orientation prior to and during vehicle slam-down. The following observational concerns are noted.

STANAG Blast tests are historically performed in a static condition. However, in reality vehicles are most often moving when hit by an IED. This delta suggests that the accident is currently not considered / tested on a dynamic basis. Vehicles also experience high levels of vibration, suffer off-road incidents and RTAs.

AGI's observations are centred on concerns that these incidents put the crew at risk in all planes, not just the vertical (Z) plane. Current blast attenuating troop seating technology is heavily focussed on shock attenuation in said z axis (vertical) plane only. This lack of attenuation in other planes appears to present a significant risk to crew; especially in a dynamic event such as a moving vehicle or post-event slam-down when the vehicle can be impacted at any given attitude / orientation.

Area of Mitigation for Optimisation - AGI proposes that Multi-dimensional seat attenuation should be considered to improve post event and RTA survivability. Notwithstanding that a change in perspective to advance Military seating would likely also emphasise the benefits of employing an anti-vibration element built into the technology.

B. Failure to survive secondary event hazards such as Smoke and Fire: Should mitigating measures be employed to mitigate the physical forces experienced during an event, crew will likely face further hazards such as explosive flashes, fire and smoke. It is essential to note at this stage of the accident sequence - that if measures are not employed to mitigate these hazards, crew will have a very limited time to escape from the vehicle before suffering heat injury or asphyxiation by smoke. AGI approximates this period as being less than 1 minute (further exacerbated in a panic situation). This concern clearly highlights the potential benefits of explosive flash and fire suppression. Like the employment of V-shape hulls, crew fire suppression has been used as common mitigation, of note within US MRAP vehicle fleets. However, although the potential benefits of this technology remains accepted, concerns have arisen over the years regarding the effective performance of many in-service systems. Users have began to question the reaction times and general effectiveness / reliability of such systems to actually mitigate the associated hazards, particularly with use of gases at cold temperatures.

Area of Mitigation for Optimisation - AGI proposes that Utilisation of gases such as Novec 1230 Gas - offering faster response times and improved operating temperature ranges (-40^{o}C to +70^{o}C) are considered. Obviously such systems would need to be designed to withstand IED/crash events, and have a robust lifing /MTBF.

C. Failure of crew to locate exit/s: NATO Military helicopter operators have been aware of the key risk of spatial disorientation in water and smoke for decades. In the last 20 years many vital lessons have been learned and Military Standards now dictate that helicopters with an over water capability must employ flotation bags, escape lighting, and in many cases personal air supplies. With respect to the prevention of spatial disorientation it is escape lighting that is employed to mitigate the associated risks, along with live dunker training. The Naval Medical Research Laboratory quoted almost twenty years ago:

“Most people survive a water ditching but die because they fail to escape”.

The Author of this report was stationed for over a decade at UK MOD’s Boscombe Down facility serving as an emergency egress advisor to both UK and US governments - specialising in Air and Land Platform trials and evaluation (T&E). One of the key lessons learned in over a decade of UKMOD funded T&E, including live underwater and smoke trials, was that the use of glow and glint (reflective) tapes are inadequate for use as emergency egress lighting. As such, these products are now prohibited for use as emergency egress marking on military helicopters within the UK. This is also the case for the majority of US military helicopters operating near water. Instead, as a result of T&E these platforms now employ use of powered emergency egress lighting systems.

With respect to Land Platforms. despite the recognition of risk in the air domain, for years crew have happily been using glow and glint tape in their vehicles as a means to mark egress points, and have in many cases made the assumption that it will help them escape in water and smoke. Since 2008 both US and UK military land vehicle users have started to recognise the risks of operating near wadis, canals, and irrigation ditches, and are taking appropriate action. This has been influenced following various fatalities from both nations.

The water found in inland sites is likely to be extremely turbid unlike average sea conditions. This risk of increased turbidity levels has influenced land safety requirements pertaining to the need for escape lighting. In some cases, duty of care holders see the risk facing land personnel to be greater than that of helicopter crews (which are primarily concerned with the risks associated with sea water).

The cabin spaces within the majority of armoured vehicles are such that there is potential for crew to become easily disorientated in an event. As well as water risks, the risks associated with IED attacks (due to smoke and disorientation) are at the forefront of safety concerns by Land vehicle operators. Land vehicles are notoriously prone to roll-over, both operationally and in training, and also suffer the continued threat of IED attacks in Theatre. In these situations spatial disorientation is recognised as a key risk; this risk being compounded by the presence of thick smoke, and water. These are the two scenarios where egress lighting would assist crew egress most.

Area of Mitigation for Optimisation - Military Standards in the UK now reflect the need for egress lighting and a Mandatory requirement for Land based Armoured Fighting Vehicles to employ emergency egress lighting has been published [DefStan 00-25 Part 14 -10.5.5.4]. However, with the exceptions of UKMOD, US SOCOM and certain Platforms within the US Marine Corps, the rest of the worlds armoured fleets including the US Army remains in AGI's opinion unmitigated with respect to this accident / risk sequence. Appendix A provides a list of vehicles known to employ LED based egress lighting. AGI proposes that the key messages for Users to acknowledge are:

- Use of Glow Tape, Glint Tape and Electro-luminescent strips (used in some helicopters such as Black Hawk) will not provide an effective penetrative source of light suitable for marking exit profiles in turbid mediums.

- Stated required light levels should only be referenced in candelas per meter squared (cd/m2) which is a measure of Luminance Intensity. AGI recommends light levels in the region of 7000cd/m2. This is relative to lights such as appropriately selected LEDs that are cable of penetrating through turbid mediums.

- Ambient lighting (illuminance - Lux) will not assist with exit location in turbid water or smoke. Lights should precisely mark exit profiles/outlines, handles, and emergency equipment and be capable of penetrating through turbid mediums.

- Route lighting should be avoided in platforms where these could interfere with accurate/intuitive marking of actual exit points. The majority of land platforms have at least one exit within 2m of their seat location which will promote natural orientation from an observed exit outline.

From an emergency egress point of view the most vital message to land vehicle users is that: if, post-event, water or smoke is present in a vehicle cabin then crew must orientate themselves within the first few vital seconds before panic has the opportunity to take over. Instant recognition of the way out and positive spatial orientation suppresses panic and promotes composure post event.

D. Failure of crew to open exit/s - Mitigation: Emergency Door Opening Mechanisms: If sequence C - Failure of crew to locate exits, has been successfully mitigated then crew will have the opportunity to attempt to open doors and hatches post event. Of course, during an event there is a significant likelihood that hatch and / or door frames will become damaged or deformed. This risk is common knowledge in the Land vehicle arena and automatic opening mechanisms are often employed as mitigation. Technologies include hydraulic, pneumatic and electro actuators to force doors and hatches open - most often initiated by the manual operation of a clearly marked Emergency Handle or Button.

Area of Mitigation for Optimisation - Given that the majority of blast protected Land vehicles operating in Theatre now have escape hatches available in 3 planes, the need for door opening mechanisms is considered secondary to the aforementioned mitigations. Plus, the effectiveness of these products to operate is very difficult to measure and test, given the diversity of events that may be experienced. Nonetheless, AGI recommends that this accident / risk sequence remains mitigated wherever possible. Of course, there may be specific vehicles that do not have escape routes available in 3 planes; these vehicles should be considered in isolation.

E. Failure of crew to find an effective secondary exit - Mitigation: As discussed in the above Paragraph the majority of blast protected vehicles now have provisions for escape in 3 planes. Many Platforms have undergone major upgrades to provide both additional exits and to modify existing exits to acceptable sizes (to allow fully kitted 95th Percentile Soldiers to egress).

Area of Mitigation for Optimisation - AGI considers egress provisions in 3 planes to be a critical / fundamental feature to protected vehicle design. Although the majority of vehicles in service now employ effective mitigations, it is known that several Platforms remain that do not yet address this issue. AGI remains hopeful that future upgrade Programs will address these vital concerns.

Conclusion

The final and key area for consideration is the cross related impact of the above (A to E) accident / risk sequences. For a crew member to successfully egress a vehicle post-event it is obvious that all of the above sequences must be overcome in the order presented - whether these are aided by natural circumstances or by the physical mitigations mentioned.

Both US and UK Governments have made sizeable investments in some, but not all of the above recommended mitigations.

Clearly, if vital parts of the accident sequence remain valid but unmitigated, then it poses the question as to whether existing investments will remain justified (ALARP), or indeed be effective at saving lives. Of particular note is the mitigation afforded to accident sequence E (availability of escape hatches in 3 planes). These kind of design measures, particularly to retrofit Programmes have seen large investments. For these investments to fulfil their intention it is clear that Users must be wholly satisfied that prior accident sequences are effectively mitigated. The following scenarios are provided for scrutiny. From this the User can assess if any of these scenarios are relevant and/or credible to the Platform/s they operate.

A. Failure to survive event due to overwhelming physical forces in planes beyond z (vertical). Mitigation such as multi-dimensional seat attenuation is not employed for a dynamic event or RTA.

Accident Potentially Ends. Investment in follow-on mitigations potentially becomes Negated.

B. Failure to survive secondary event hazards such as fire, explosive flash and smoke due to a lack of, or use of an ineffective suppression system. Mitigation such as fast response Crew and Engine Fire / Explosion Suppression System is not employed.

Accident Potentially Ends. Investment in follow-on mitigations potentially becomes Negated.

C. Failure of crew to locate exit/s as hatch marking system not used or is ineffective. Mitigation such as a blast, rollover, water and flame activated LED based hatch/exit marking system is not employed.

Accident Potentially Ends. Investment in follow-on mitigations potentially becomes Negated.

D. Failure of crew to open exit/s. Mitigation such Emergency Door Opening Mechanisms is not employed.

Accident Potentially Ends, unless alternative exits are available and can be located, or an effective and proven door assist mechanism is employed.

E. Failure of crew to find an effective secondary exit - Mitigation such as egress hatches/points in 3 planes is not employed.

Accident Ends - Survivability Not achieved, unless crew can find/ operate an exit and egress.

end of report

Appendix A is presented overleaf

Appendix A Land Vehicles employing HaLO egress lighting

Vehicle	Operator	Approx. Systems Purchased	System
RG31	US SOCOM	200	HalO 1
RG33	US SOCOM	500	HalO 1
MATV	US SOCOM	700	HalO 1
AUV	US SOCOM	100	HalO 1
Foxhound	British Army	500	HalO 1
Mastiff	British Army	700	HalO 1
Wolfhound	British Army	150	HalO 1
Ridgback	British Army	200	HalO 1
CW4x4	British Army	30	HalO 1
Buffalo	British Army	30	HalO 1
Warthog	British Army	100	HalO 1
Warrior	British Army	100	HalO 1
Viking	British Army	200	HalO 1
Husky	British Army	400	HalO 1
AJAX	British Army	600	HaLO 2
Current Contracts			
LVSR	USMC	2	HaLO 2 (inc new modular capacitor powered system)
ACV1.1 (All contenders)	USMC	4	HaLO 2 (inc new modular capacitor powered system)
Cougar (Buffalo)	USMC	2	HaLO 2 (inc new modular capacitor powered system)

About the Author

Neil Ham has spent much of his professional career as an emergency egress subject matter expert and adviser to UK MoD and US DoD. His experience varies from managing live underwater egress trials to assessment of open water helicopter sink rate and canopy jettison trials. Since leaving MoD Boscombe Down Neil has brought his experience to AeroGlow International and has made a successful transition into the Defence Supply Sector. Neil's vocation is take the lessons learned in air domain T&E into both the land and maritime domains. Neil holds an MSc from Kingston University and is an active researcher, developer, and frequently published author in the domains of land and air safety.

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