The Operational Strengths and Weaknesses of Military Night Vision Equipment

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The UK Ministry of Defence (2003) recently argued that the use of night vision equipment improves 'shared situation awareness' and 'greatly enhanced operational effectiveness… in surveillance and target acquisition in close combat'. They are 'particularly effective in the urban environment' and in support of 'marshalling and logistic maneuvers at night'. However, there is good evidence to suggest that this equipment poses significant risks to military personnel. For instance, the US Army's Black Hawk helicopter fleet has suffered more than 20 fatal accidents in its 29 year service history. Approximately half of these occurred while pilots were wearing night vision devices. This observation is supported by the results of the US Army Safety Center's review of rotary winged aircraft incidents. As can be seen in Table 1, there is a significantly higher accident rate for operations involving the use of night vision equipment. These observations have been replicated by recent studies into incidents looking at military driving and tank operations (Ruffner et al, 1997).

	FY95	FY96
Day	7.59	7.69
Night	9.72	13.87
Night unaided	6.37	9.31
Night aided	11.28	15.80
Total	8.09	9.14

Table 1. Class A-C Rotary-wing Accidents per 100,000 flying hours

These statistics can be misleading. Night vision equipment is, typically, used for operations and environments that carry an increased level of risk. The fact that this equipment was being used at the time of an incident or accident does not imply that it contributed to the failure. The following paragraphs briefly summarize the strengths and weaknesses of night vision systems. It is argued that there is an urgent need to review the operational performance of these devices so that the risks associated with their use do not begin to outweigh their operational benefits.

Good vision is essential for many military operations, such as driving over broken terrain or landing in confined spaces. However, color vision, depth perception, and visual acuity vary depending on the level of light. These differences arise from the distribution of cones and rods in the eye. Each component supports different types of vision under different lighting conditions. Cones support high visual acuity under good lighting conditions but they cannot be relied on when less light is available. In contrast, rods are 'bleached out' under bright lights but can provide more limited forms of vision when less light is available. The cones and rods are not distributed evenly within the eye. Cones are clustered in the middle of the eye and so a 'night blind spot' occurs under low lighting conditions when these components are not so effective. Biochemical reactions increase the level of rhdopsin in the rods under low levels of lighting. Individual differences affect the rate and degree of adaptation. It can take between 30-45 minutes for most people to achieve their maximum acuity under low levels of light. The cones and rods are also sensitive to different forms of light. Blue light has a strong effect on the rods; red has little impact. It is for this reason that red instrument panels are preferred for many military applications. If white light were used then the rods would 'activate' and bleach out the cones requiring a further period to regain full night vision.

A number of training techniques can help maximize any remaining visual resources in low levels of light. As mentioned, the acuity and range of our vision falls after dark. The light-sensitive areas of the retina are unable to perceive images that are in motion. Hence, US Army guidelines recommend a stop-turn-stop-turn procedure (US Department of the Army, 2000). Each visual scan of the image area should be followed by a pause. The duration of each stop is based on the degree of detail that is required, but no stop should last more than 2-3 seconds. When moving from one viewing point to the next, individuals should overlap the previous field of view by approximately 10 degrees. However, these techniques are clearly limited in the degree of support that they provide for low light operations.

There are two main classes of night vision devices. Image intensification (I^2) systems enhance the lighting that is available within the existing environment. Infrared (IR) devices, in contrast, will typically use heat emissions to identify objects that cannot otherwise be detected using available light sources. Neither of these technologies can 'turn night into day'. Most image intensification systems perform poorly in total darkness. Higher amplification is associated with more expensive devices and can imply increased levels of distortion. The intensified image is, typically, viewed on a phosphor screen that creates a monochrome, video-like image, on the user's eyepieces. Unfortunately, a number of disadvantages affect the application of this technology. Many image intensification systems are attached to the users' helmet. Early models included relatively heavy battery packs that restricted the users' head movements. This problem was exacerbated by the need to move the head because many of these devices offer a highly restricted field of vision A post action review of the Canadian Army's deployment in Kosovo found that the current issue helmet and night vision goggles were incompatible and "painful to wear". (Canadian Army Center for Lessons Learned, 2001). This had significant operational consequences, for example, other members of the tank crews had to be trained in turret operations so that they could replace colleagues after sustained periods using the night vision equipment.

Image intensification equipment can also create problems in depth perception. Colour cues and binocular information are lost with many commercial systems. All of these limitations are being addressed by technological innovation. In particular, it is now possible to buy light weight and extended field of vision systems. However, these tend to be expensive and difficult to maintain under field conditions (Salazar and Nakagawara, 1999). Visual acuity from night vision devices is still far from perfect. As with direct sight, higher levels of accuity are associated with closer, slower targets. The visual accuity offered by image intensification rapidly diminshes for objects over 400 feet away. This distance is further reduced, the faster the target is moving. Rain, clouds, mist, dust, smoke, fog all affect performance. In particular, landing in a dusty area will cause 'brown out' and is a frequent cause of accident involving night vision equipment (US Department of the Army, 2000).

The operating characteristics of these devices must be considered during mission planning. As mentioned, image intensification systems amplify the available light. From this it follows that personnel must be aware of the light that will be available during an operation. The moon waxes and wanes at a rate of approximately 15 degree per hour. Hence the background light available for night operations will change over time. Looking at the moon has the same effects as looking directly at the sun under daylight lighting conditions. This creates problems when soldiers move toward a bright moon that is low on the horizon. The brightness of the 'ambient' light source degrades the intensified image. It will also cast deep shadows that can hide hazards, especially excavated fighting positions. This creates considerable problems for drivers trying to locate these emplacements using night vision equipment (US Army Centre for Lessons Learned, 2001).

Image intensification systems can be affected by external light sources. For example, there is also a risk that personnel will fixate on external light sources such as city lights. Attention can be devoted to areas close to these light sources and it is easy to forget to monitor those areas that are less well lit by an external source. Further hazards arise when soldiers using image intensification equipment must operate in areas where other personnel must rely on conventional forms of illumination. A large number of accidents have arisen because vehicle headlights have dazzled soldiers wearing image intensification devices. Further problems arise if personnel must use vehicles and other forms of equipment that have not been adapted for use with these devices. Vehicle instruments and cockpit displays can create "washout" or halo effects. In many road-based vehicles it is possible to turn-off instrument illumination. However, it is a complex and expensive task to alter cockpit lighting systems without compromising the daytime use of the aircraft. These problems are compounded because red lights are frequently used in speedometers and engine instruments. Night vision systems are often particularly sensitive to these sources. Personnel must also be trained not to use red-lens flashlights in situations where image intensification equipment is being used.

In contrast, to image intensification thermal systems detect infrared radiation. Although the human eye cannot directly observe these signals, they can be focused in the same way as conventional light. Thermal imaging systems represent the difference in temperature between objects in a scene. Thermal contrast is then translated into a visual contrast that is, typically, represented in shades of gray on a monochrome display. Unlike image intensification devices, infrared systems can be used in total darkness. They do not rely on the light reflected by an object. Infrared devices also avoid some climatic problems. For instance, they can see through some types of fog. However, problems can arise under different environmental conditions. A wet runway may be cooled to such an extent that it appears to be further away than it actually is. High-humidity reduces thermal contrast and so will adversely affect image quality. There are further limitations. For instance, infrared systems cannot be used to identify precise details on remote objects that are not distinguishable by different heat profiles. Unlike image intensification systems, infrared devices cannot register facial features.

Thermal imaging systems can be used in conjunction with infrared landing and searchlights. These tend to be most effective at low levels of illumination. If there are external lights then pilots tend to limit their scan to within the area directly covered by the searchlight in the same way that personnel can be distracted by external light sources. They have to be trained to expand their search on either side of the beam. Brownout can also occur when there are reflections from an infrared searchlight caused by the dust that is raised in a rotor wash. The heat emitted by infrared searchlights can also help enemy personnel who may themselves be using night vision equipment. As with image intensification systems, individuals can quickly become fatigued through prolonged use of these devices.

An important objective of this short article is to balance the operational benefits with the potential hazards from using night vision equipment. Personnel might be trained to exploit those advantages, for instance by time operations to maximize the light provided by the waxing and waning of the moon under image intensification. More senior officers must establish operational reviews to gain a clear understanding of the hazards associated with these devices. For example, a US Army study identified a sample of 160 accidents that were related to the use of night vision devices in ground vehicles between 1986-1996 (Ruffner et al, 1997). Over two-thirds were attributable to three categories of terrain and roadway hazards: drop-offs greater than three feet (34%), ditches of three feet or less (23%) and rear collisions with another vehicle (11%). 34% involved the High Mobility Multipurpose Wheeled Vehicle (HMMWV), 18% involved the M1 Abrams Tank and 14% involved the M2/M3 Bradley Fighting Vehicle. The most commonly occurring environmental conditions that included dust (24%), blooming from light source (9%), and smoke (8%).

Similar studies have focused on the spatial disorientation caused by the use of night vision devices in helicopter operations (Braithwaite et al, 1998). This study analyzed all US Army class A-C mishap reports involving night-aided flight from 1987-1995. They found that approximately 43% of all spatial disorientation mishaps occurred during flights that used night vision equipment. Only 13% of accidents that did not involve spatial disorientation involved these devices. An examination of the spatial disorientation accident rates per 100,000 flying hours revealed a significant difference between the rate for day flying and the rate for flight using night vision devices. The mean rate for daytime flight was 1.66, while the mean rate for flight with night vision devices was 9.00. The most important factors associated with helicopter accidents were related to equipment limitations, distraction from the task, and training or procedural inadequacies.

The findings from these previous studies must be continually reviewed in the light of changing operational conditions. Recent experiences in Iraq have shown specific risks associated with the use of night vision equipment when interacting with local civilian populations. Night patrols often use night vision equipment with infrared markers. This provides dual benefits. Not only can soldiers covertly observe civilians. They can also mark their locations and hence minimize the danger of friendly fire from other patrols. However, civilians will often run when challenged by an unseen patrol. This led to a fatal shooting in Somalia that changed the Canadian force's rules of engagement. The subsequent enquiry found that it would have been better to deter the local population from approaching the military compounds by using conventional lighting rather than increasing the risk of confrontation by using night vision equipment (Canadian Dept of National Defence, 1997).

The need to constantly review the use of these devices can be further illustrated by recent events in the Gulf. Several coalition partners moved to rapidly acquire large quantities of night vision devices in the months leading to the start of the conflict. For example, the UK Ministry of Defense (2003) issued an Urgent Operations Requirement action. These initiatives were extremely successful in terms of delivering equipment to troops in the field. However, it also exposed a number of problems. Some coalition partners delivered devices for which their recipients had little or no previous training. This resulted in accidents where troops over-estimated the benefits of the devices. It also led to a host of problems in maintaining and repairing equipment that rapidly degraded in the field. Further work is required to determine whether the successful acquisition of these devices shortly before the conflict led to significant increases in the accidents and incidents predicted by Ruffner and his colleagues.

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