Assessing Night Vision Goggle Performance in Security Applications

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ABSTRACT

Police and border security operations are an important and growing application of night vision devices (NVDs). NVDs improve visibility at night but suffer from a variety of perceptual artifacts and human factors issues. In a series of helicopter-based flight trials we analyzed subject performance on model tasks based on typical security applications. Subjects performed the tasks under conditions of unaided daytime vision, unaided nighttime vision or image intensified nighttime vision. The tasks included directed search over open and forested terrain, detection and identification of a temporary landing zone and search/tracking of a moving vehicle marked with a covert IR marker. The results of this study confirm that NVDs can provide significant operational value but also illustrate the limitations of the technology.

INTRODUCTION

Modern public security and anti-terrorism activities require constant vigilance and the ability to deploy countermeasures day or night. Night Vision Goggles (NVGs) have found standard application in military covert operations that usually rely on low-level flight and high speed for stealth making NVGs essential for safe night flight. However, civilian (police and paramilitary) counterterrorism efforts are usually deployed under different constraints. Inspired by the success of night vision aids in the military there is strong desire from security personnel to use night vision aids and other sensors in surveillance, detection and tracking of threats from airborne platforms. Similar nighttime covert operations are required for border and law enforcement activities including border patrol, anti-terrorism, security enforcement, and related activities. Canadian law and border enforcement officials face difficult challenges in monitoring our large borders and waterways. While Canada is currently conducting operations at night aided by technologies such as FLIR cameras, it would be advantageous to enhance safety and effectiveness by integrating NVGs into normal operations.

In this paper we describe a set of research flight trials to evaluate the utility of night-vision aids for a variety of typical airborne security tasks. In keeping with the scope and aims of this Flight Test Methodology conference we will concentrate on the methodology and conduct of the experiment before briefly describing some general findings and their implications.

Figure 1- Bell 206 research platform used for the flight trials

FLIGHT TEST METHODS

Area of Operations and Conditions

The flight trials were conducted at and near Pendleton airfield, which is located east of the city of Ottawa. The airfield, surrounding woods and an adjacent golf course were used for staging the experiments. The areas were surveyed by air/foot prior to the experiments. As the experiments were performed in winter access to the area of operations was by cross-country ski and snowshoe.

The experiment was conducted over a series of day and night sorties during February 20-23, 2006. Some of the daytime flights involved a brief touch down at Pendleton to switch experimental subjects (but note that no one was exposed to the experimental protocol before serving as a subject). The weather was mainly overcast but with good visibility. However, snow showers and stormy weather terminated trials at the end of the week. Typically two sorties were flown each night scheduled so that experiments would start after astronomical twilight.

Equipment and Personnel

The study was performed using an NVG-compatible, specially-instrumented Bell 206 helicopter. The Flight Research Laboratory of the National Research Council of Canada's (NRC) Institute for Aerospace Research has modified this aircraft to serve as a 'flying laboratory'. Most relevant for the current study is the ability for continuous recording of precise aircraft GPS, inertial and altitude data and for the synchronous recording of experimental data such as special purpose switches mounted in the cockpit and designated for experimental input (including 'event marker' buttons). Continuous voice recordings were synchronized with the aircraft data collection system. During the experiments an NRC test pilot flew the aircraft (aided by NVGs on the night flights). No data was collected from these pilots who were in control of the aircraft but did not participate directly in the experimental tasks. A flight test scientist/engineer was onboard the aircraft (in the back seat) to monitor the data collection and coordinate the experiment from the air.

Ground personnel consisted of field crew (5 people) as well as support at the hanger. The ground crew arranged and activated the landing lights for the approach task, drove the marked car for the car search tasks and acted as and placed targets for the search task. A ground coordinator maintained communication with the aircraft pilot and flight test engineer on board the aircraft. The ground team surveyed the site and made portable GPS measurements of target locations.

Observers

The experimental subjects were seated in the evaluation pilot seat and did not fly the aircraft during the test phases of the sorties. The five male subjects were NVG-qualified helicopter pilots who had experience working in airborne law enforcement (2 pilots from the Royal Canadian Mounted Police and two from the Ontario Ministry of Natural Resources) or in related regulatory aspects (one pilot from Transport Canada). Due to weather constraints only three pilots completed the full flight test protocol.

Tasks

The subjects performed three tasks: a car search, an approach to a remote landing zone and a simulated ground search. The tasks were performed under daylight conditions (except the car search task), unaided nighttime conditions or NVG aided nighttime conditions. The order of nighttime aided and unaided viewing conditions was counterbalanced between subjects. The sequence of events for the daytime and a typical nighttime protocol were spelled out and incorporated into flight data cards followed by the FTE. A typical nighttime sequence of the experiment would take 1.75 hours with 0.75 hours in transit and the car chase and 1.0 hours over Pendleton. A typical sortie would involve a series of events such as:

Figure 2- Automated lights used for car tracking (middle bottom) and landing zone tasks

1. Take-off
2. Detour over target area and perform car search enroute
3. Goggles up/down (depending on experimental order)
4. Perform landing approach task (2 or 3 approaches, 5 minutes each)
5. Goggles up
6. Perform search task search area A (10 minutes)
7. Goggles down
8. Perform search task area B (10 minutes)
9. Goggles up/down
10. Perform landing approach task (2 or 3 approaches, 5 minutes each)
11. Direct return

The *car search* task was performed on night sorties only and simulated the search and tracking of a vehicle marked covertly with a flashing infrared beacon. The beacon was supplied by Adventure Lights and designed to strobe an IR LED for easy identification. At takeoff for the sortie, a call was made from the hanger to the driver to turn on the beacon and GPS logging and to drive up and down a predetermined road turning around at predetermined intersections. During the outbound flight to the main area of operations the pilot approaches highway to the first endpoint and made single pass of the route. If the observer (who was not in control of the aircraft) finds the target vehicle they were to press the event marker button, audibly mark the event and localize the target vehicle with respect to the aircraft (e.g. 11:00, westbound, etc.). The FTE noted the time and details of the response. If the vehicle was not spotted a second pass was not made and the task was judged to have failed.

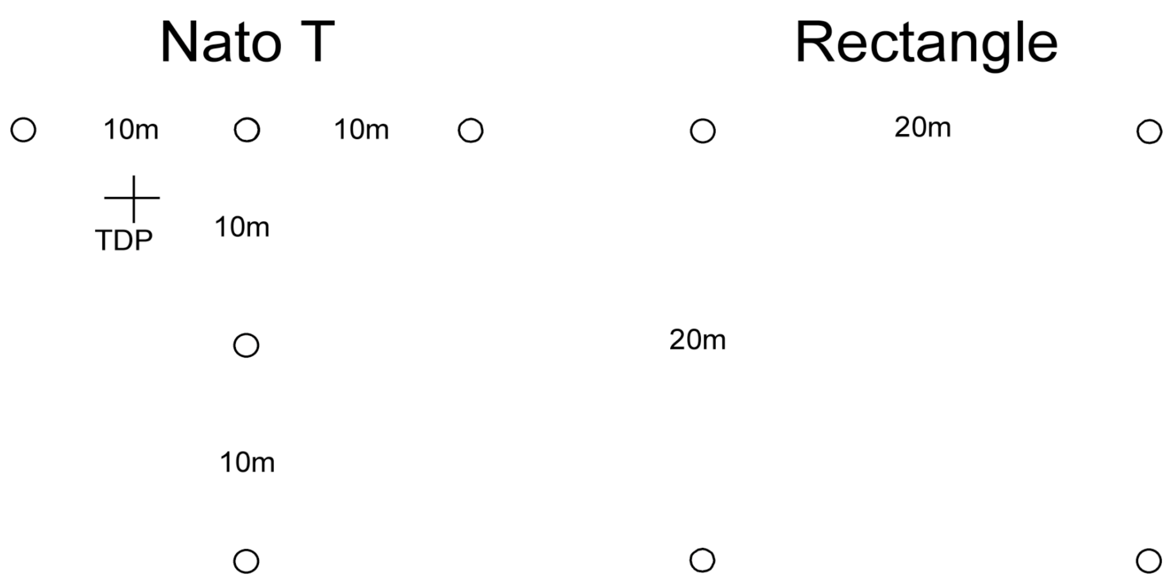

Figure 3- NATO-T and Rectangular Landing Zones defined by cones or IR beacons (under NVG viewing)

In the *approach or landing zone* task the subject was required to look along the direction of heading and attempt to detect a remote landing zone. When the landing zone was detected the subject was asked to discriminate it as one of two configurations, a NATO-T or a square arrangement of the landing lights. For each approach the ground controller determined the landing zone configuration for the current trial and whether it was to be marked by visible lights, infrared lights or with traffic cones. The visible and infrared lights were prototype remote control tactical lights provided by Adventure lights and operated remotely by the ground controller. When the configuration was setup the ground controller notified the pilot who began the approach from a

Figure 4- Layout for the rectangular and NATO-T landing zones

distance of approximately 10km. The subject (in the evaluation pilot seat) monitored the scene for the landing zone. When he detected the zone he marked the time with an event click and audible marking of the event. When he could confidently discriminate the landing zone (T or square) he marked the time with an event click and audibly identified the configuration. The FTE noted times and responses in the log.

In the *simulated ground search* task the scenario was that the airborne officers were to search for a set of people or objects associated with suspicious activity based on intelligence supplied by ground officers. Two search areas were defined: one over the woods behind the airfield and the other over an adjacent golf course. For each subject the daylight search was performed over one area and the nighttime search over the other area in an experimenter defined order. Preliminary studies showed that nighttime unaided search had extremely low detection rates so the nighttime search was performed unaided and then with NVGs allowing the same search area to be used. Subjects had a known list of targets for the search that included people. The search time was limited to 10 minutes. The pilot started by flying circular paths around the search area but encouraged the subject to direct him to fly particular paths or over areas of interest. When the subject spotted a target they marked the event audibly and with the event marker, made a verbal identification and indicated its location with a grease pencil on an aerial photograph. The FTE verified and logged the identifications.

To evaluate the task demands and the effects of using the night vision devices, the tasks were evaluated using objective performance measures and subjective impressions and responses obtained from the observers. Subjects were encouraged to 'think aloud' and to verbalize their thoughts and strategies for performing the tasks. This stream of consciousness was recorded on the cockpit voice recorder and subjects were briefed to pay special attention to task demands, visual performance, orientation, workload, spatial awareness, information required and obtained, strategies followed, progress and history of the task, problems encountered and also to the advantages and disadvantages with the various viewing conditions.

Following the final sortie for each subjects a structured debriefing occurred with the observers being asked an open-ended series of 36 questions designed to address task and NVD issues. The questions were grouped into categories: General questions related to conditions and NVD impact (7 Questions), Car tracking task (9 Questions), Approach task (8 Questions) and the Ground Search task (12 Questions).

RESULTS AND DISCUSSION

Car Search Task

Subjects found the marked vehicle easy to track once located and motion of the vehicle was not reported to be an issue. The flashing of the strobe was distinct but could be confused with tail and signal lights during the search; the subjects felt more experience would be beneficial. They also felt that the task would be easy in rural settings but more difficult in urban settings.

It is important to note that use of an infrared (IR) target allows for covert tracking with NVG or FLIR. This permits the covert marking of field officer vehicles for guidance and situational awareness as well as the unobtrusive marking of suspect vehicles to trail.

In general the car search task was easy despite the constraints (single pass along a suburban road with unknown initial location of the vehicle). Once detected, the vehicle was easy to track and unambiguous identification was more of an issue than detection of the beacon. Also NVG halos from vehicle light can mask the target and limit detection/identification range.[1]

Use of NVGs causes restriction on field of view and load on the head that effects efficient head movements. Pilots learn strategies for scanning instruments and scenes to facilitate accurate VFR flight. One issue that was not fully addressed here was the impact of these restrictions and scanning strategies on the effectiveness of visual search.

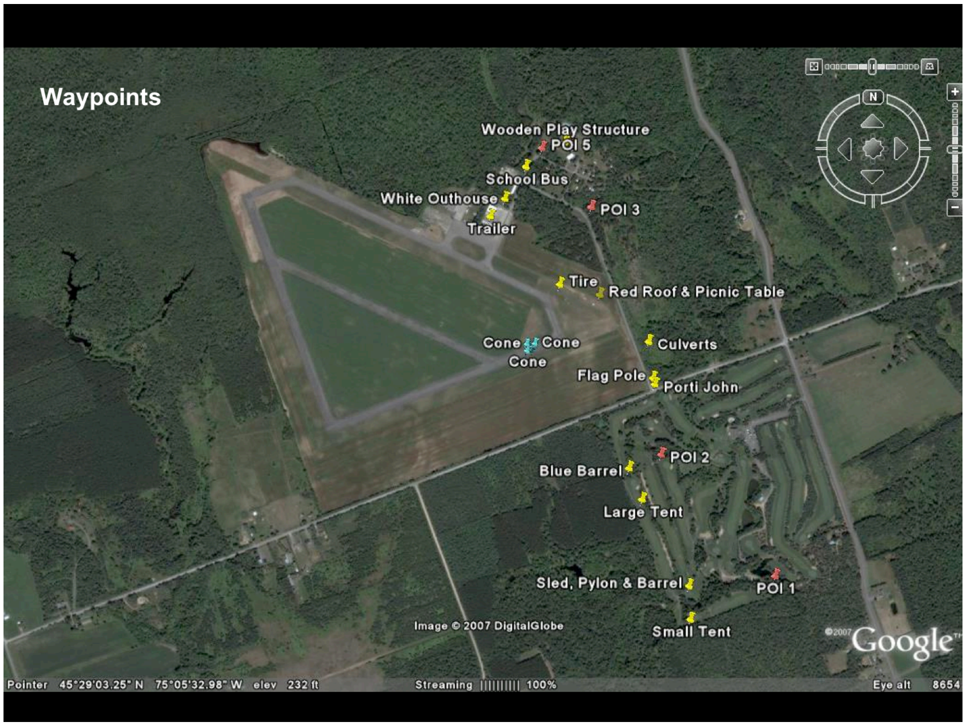

Figure 5 - Aerial view of the search areas with target objects or persons of interest (POI) shown

Approach Task

In this task subjects needed to detect the landing zone (LZ) and then positively identify it as the T or Square configurations. How far away can the LZ be detected and segregated from other environmental lights? During the day the landing lights were not visible and detection and discrimination was based on the traffic cones. These were detected from a range of approximately 0.8-4.5km in daylight mostly from surrounding tramped down snow rather than the cones themselves. At night the un-illuminated cones were virtually impossible to see (unaided or NVG). On the other hand, the nighttime IR and visible lights were highly visible from at least several km (3.8-9.8km NVG). The visible lights were conspicuous to the naked eye and could be detected from approximately the same range as with NVGs. The IR lights can of course be used for covert landing zones with NVG viewing. It is important to note that the lights themselves were very directional making a proper approach essential.

How well can subjects discriminate different LZ patterns? Subjects often needed to approach significantly closer to the target to identify it than to spot it. This is to be expected since detection of a light or a configuration of lights is a function of intensity and not resolution, whereas to identify the configuration requires spatial resolution of the pattern of lights. Thus, identification occurred at nearer distances (1.7-5.6km with NVG) where the lights could be resolved. Subjects reported that occlusion and merging of the lights as well as uncertainty in the number and layout hinder the ability to identify the configuration. Halo was judged to be minimal with these lights and at these distances and subjects did not feel halo was a limiting factor on LZ identification.

NVG judgment of landing zone orientation and ground slope was reported as more difficult than detection or identification. This is important since these judgments are used in the control of direction of approach and glideslope and this may indicate caution. Note that NVGs do improve visibility of the ground compared to unaided eye night vision. One pilot commented that he would prefer to overfly these nighttime LZ before attempting a landing. While prudent, this may be limiting in covert or time sensitive operations.

Search Task

Daytime search performance was high although people on the ground are difficult to spot. Unaided nighttime search for small to medium sized targets (as oppose to say building-scale) was virtual impossible under the conditions of the flights. NVG aided vision enabled successful nighttime search. However search success rates and search times for finding at least 2/3 of the targets increased at night. Furthermore confidence decreased under night NVG-aided conditions compared to daylight conditions.

Observers noted that it is difficult to find people in the presence of cover/clutter even in daylight. At night (NVG-aided) this is compounded by loss of detail and confusion with trees especially if still. Complementary tools such as FLIR/thermal imaging and intelligence can be invaluable here. Anecdotally, we found that people lit up with visible (flashlight) or infrared markers were easily detected from the air using NVGs.

Subjects report that NVDs improve spatial awareness and ability to orient and this may lead to more effective search. Use of a head coupled imaging device such as NVDs allows for the use of an egocentric frame of reference when orienting and scanning the environment. Conversely, the limited field of view necessitates deliberate scan patterns that may interfere with normal search strategies.

CONCLUSIONS

Image intensified night vision devices offer significant benefits for nighttime search tasks over unaided vision. The improved detail and definition enables visual tasks that would otherwise be impossible without active illumination (and all for the use of covert IR illumination). This potentially allows for increased safety, avoidance of inadvertent IMC, situational awareness and operational effectiveness. However the devices do not simply turn night into day and operators require vigilance and training for potential perceptual artifacts and human factors limitations[2-6]. We described techniques and results from a set of flights designed to evaluate these issues. The results of this study confirm that NVDs can provide significant operational value by improving nighttime visibility and allowing covert identification and tracking using infrared markers. Often the possibility for active lighting exists (e.g. visible or infrared nitesuns). However, the range of vision, and hence speed and operational range, is limited under active lighting and stealth is compromised. Infrared and thermal cameras are complementary technology sensitive to different wavelengths and environmental features. NVGs, FLIR and active lighting provide complementary functions and serve as useful tools in airborne law enforcement operations. These studies provide the basis for further research intended to support rational decision processes for the adoption and integration of NVD technology into law enforcement and related operations.

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REFERENCES

[1] G. Craig, T. Macuda, P. Thomas, R. Allison, and S. Jennings, "Light source halos in Night Vision Goggles: Psychophysical assessments," Proceedings of SPIE - The International Society for Optical Engineering, 5800, 40-44, Orlando, FL, United States, 2005.

[2] M. G. Braithwaite, P. K. Douglass, S. J. Durnford, and G. Lucas, "The hazard of spatial disorientation during helicopter flight using night vision devices," *Aviation Space and Environmental Medicine*, **69**, 1038-1044, 1998.

[3] H. L. Task, "Night vision goggle visual acuity assessment: Results of an interagency test," Proceedings of SPIE - The International Society for Optical Engineering, 4361, 130-137, Orlando, FL, 2001.

[4] J. P. Estrera, T. Ostromek, W. Isbell, and A. Bacarella, "Modern Night Vision Goggles for Advanced Infantry Applications," Proceedings of SPIE - The International Society for Optical Engineering, 5079, 196-207, Orlando, FL, United States, 2003.

[5] J. Rabin, "Spatial Contrast Sensitivity through Aviators Night-Vision Imaging-System," *Aviation Space and Environmental Medicine*, **64**, 706-710, 1993.

[6] W. R. Uttal and R. W. Gibb, "On the psychophysics of night vision goggles," *Interpreting remote sensing imagery: human factors*, R. R. Hoffman and A. B. Markam, Eds., 117-136, Lewis Publishers, Boca Raton, FL, 2001.