TWENTYFIFTH EUROPEAN ROTORCRAFT FORUM

Paper No: E1

THE DEVELOPMENT OF AIRWORTHINESS REQUIREMENTS FOR CIVIL NIGHT VISION GOGGLE (NVG) HELICOPTER OPERATIONS

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SEPTEMBER 14-16, 1999
ROME
ITALY

ASSOCIAZIONE INDUSTRIE PER L'AEROSPAZIO, I SISTEMI E LA DIFESA
ASSOCIAZIONE ITALIANA DI AERONAUTICA ED ASTRONAUTICA

THE DEVELOPMENT OF AIRWORTHINESS REQUIREMENTS FOR CIVIL NIGHT VISION GOGGLE (NVG) HELICOPTER OPERATIONS*

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Abstract

Night vision enhancing technology has been used by pilots in military aircraft operations for many years. Steady development and refinement of the technology, together with the availability of associated equipment at reducing cost, has resulted in increasing interest in the use of Night Vision Goggles (NVGs) for specialist civilian aircraft operations. This paper briefly summarises the operating principles of NVGs and outlines the development, by the UK Civil Aviation Authority (CAA), of Airworthiness Requirements for civil NVG operations, following the findings of a proof of concept trial. The need for the requirements and the background to their development is explained, together with the main issues that the requirements need to address. An overview of the requirements is provided in Section 5 and the requirements are reproduced in full in Appendix 1. Finally, an international perspective is provided by describing ongoing activity within the Joint Aviation Authorities (JAA) and the Federal Aviation Administration (FAA) with the objective of producing harmonised requirements for civil NVG operations.

1. Introduction

There is increasing interest in using Night Vision Goggles (NVGs) for specialist civilian tasks; most notably for Police and Emergency Medical Services (EMS) operations. In January 1995, the UK CAA gave approval, on a trial basis, for one Police Constabulary Air Support Unit to undertake an evaluation of NVG operations using a BO105. The Devon & Cornwall Constabulary Air Support Unit believed the trial to be a great success, claiming safety and operational benefits for night operations. Consequently, other police forces are becoming increasingly interested and it was considered appropriate to develop formal requirements to support the use of civil helicopter NVG operations. Clearly, particular safeguards must be in place since there are potential hazards when the pilots view of the outside world is maintained solely by Night Vision Goggles. The military use of NVGs, over many years, has resulted in considerable experience of the benefits and hazards of their use. This experience was given due consideration by reviewing available military documents including, for example, any relevant Military Specifications (Mil Specs). The paper describes the background to the development of the civil requirements and the significant airworthiness issues that need to be addressed. The resulting requirements are presented in full in Appendix 1 to the paper.

The Devon & Cornwall Police Constabulary NVG trial came to an end when the BO105 was retired from service in 1998. The same Constabulary now operate a BK117 and the newly developed NVG requirements are currently being used to approve a full NVG modification to this aircraft.

Police and Emergency Medical Service NVG helicopter operations are being conducted in some other Joint Aviation Authority States and the FAA in the US have recently certificated civil NVG operations. Consequently, the JAA and FAA are discussing NVG requirements with the intention of producing harmonised airworthiness and operational rules. Information on the progress of these discussions is also reported.

2. Principle of NVG Use and Potential Airworthiness Problems

In the electromagnetic spectrum, the human eye responds to wavelengths between 400 and 700 nanometres (nm) which we normally see as colours. However, as light levels reduce, the human eye is less able to distinguish colour and detail. On a dark night, colour perception is lost entirely and objects become shadowy, dim shapes. Night vision can be improved by increasing the amount of light reaching the eye, as with a torch for example, or by imaging technology by creating a visible phosphor-screen image from normally imperceptible radiation, as in a Night Vision Imaging System (NVIS). NVIS goggles consist of two image intensifier tubes and look much like binoculars mounted to a helmet. They operate by the amplification of light in the far red and near infra-red (IR) section of the electromagnetic spectrum (600 to 1000 nm). The two main types of intensifier tube in use are classified as Generation II, which uses a multialkali photocathode, and Generation III which uses the far more sensitive gallium arsenide photocathodes. Even at low light levels, a Gen III tube produces a very sharp image on the phosphor screen with little loss of resolution.

The basic principle of the use of modern Night Vision Goggles is that the outside world is viewed through the goggles and the cockpit is viewed by looking "under" the goggles using the naked eye. The main way of meeting these differing requirements is to provide cockpit lighting that contains no infra-red. The use of the unaided eye to monitor the cockpit instruments requires them to be illuminated by acceptable amounts of visible light. If any illumination in the cockpit emits energy within the response range of the IR-sensitive photocathode, it may degrade the performance of the goggles since they have a built in automatic gain device which reduces their sensitivity and resolution as the level of IR energy is

* Paper presented at the 25th European Rotorcraft Forum, Rome, Italy, September 1999

increased. Therefore, to operate the goggles at maximum efficiency, IR energy must as far as possible be eliminated from cockpit illumination systems. This non IR lighting has a characteristic blue/green colour and is achieved by the use of filters. Standard tungsten filament light bulbs produce approximately 95% of their energy in the infra-red wavelengths and hence will cause major interference with the performance of NVGs unless filtered. This includes warning lights, since a single unfiltered warning light illuminating at a critical phase of flight could cause loss of all external view, with the resulting obvious hazard.

It could be argued that loss of external view through the goggles would not be a problem as a reversion to conventional (non-NVG) flight could be carried out. Although this would be the case in some flight regimes, it is likely that NVGs will be used to manoeuvre the aircraft into situations that would be difficult to get out of without continued use of the goggles. Examples of this might be flight into a cloud topped valley or other operations close to obstacles. It would be potentially dangerous to provide the pilot with a piece of equipment that could be used to fly into difficult situations without also providing a reasonable expectation of adequate integrity and continued availability. For the purposes of drafting airworthiness requirements it is considered that a loss of external view for whatever reason in the critical flight condition should be classified as Hazardous, in accordance with the guidelines of JAR 29.1309 (Ref 1) and associated Advisory Material. This classification implies that the possibility exists for damage to the aircraft and for injury or loss of life, but falls short of the Catastrophic classification of JAR 29.1309, which implies total loss of the aircraft and occupants.

A classification of Hazardous seems appropriate for the critical flight phase, and drives provision of a defined degree of integrity for both goggles and cockpit compatibility through the mechanism of a System Safety Assessment.

3. BO105 Civil NVIS Proof of Concept Trial

A proof of concept trial was carried out by the Devon and Cornwall Constabulary Air Support Unit, with the objective of establishing the benefits, if any, to Police operations from the use of Night Vision Goggles. The aircraft used was the Air Support Unit's BO105, modified for NVG use and operated with GEC Ferranti NiteOp Gen III goggles. The initial phases of the trial involved the CAA, from both Airworthiness and Operational points of view. A CAA Test Pilot and a Flight Operations Inspector were involved in initial approval of the cockpit modifications and early operational use. The early, joint part of the trial was flown using two pilots.

Approval of the cockpit modifications was done without the benefit of formal airworthiness requirements, purely on an 'engineering judgement' basis, which was deemed adequate within the context of a limited trial closely controlled by the operational procedures applicable to police operations. Nevertheless a subjectively good standard of cockpit compatibility was achieved but the process was lengthy and involved considerable discussion, highlighting the need for Airworthiness Requirements to simplify both design and certification of such systems.

Initial operating rules and crew training and qualification standards were established as a result of the initial joint CAA/Police part of the trial. These, combined with the airworthiness approval of the cockpit, allowed Devon and Cornwall Constabulary to continue the trial on an operational basis to assess fully the benefits of NVG use to their type of operation over a prolonged period of time without direct CAA involvement. The basic operational/airworthiness framework that was agreed had the following features:-

- Operations covered by Police Air Operators Manual, i.e. some alleviation and special provisions given against normal Public Transport provisions.
- Permissible crew compliment of one pilot and one specially trained police observer with crew duties defined.
- Agreed standard of pilot/observer training.
- Minimum Transit Height for NVG use of 500 feet above ground level.
- No reduction in weather minima already established for normal night operations.
- No take off and landing permitted using NVGs.
- Mandatory Radio Altimeter, with low height warning system.
- Flight Manual Supplement to detail limitations and procedures, e.g. NVG failure.
- Specified type of Night Vision Goggle.

The trial amassed a significant amount of NVG experience throughout the Devon and Cornwall geographic area. This area consisted of a mix of urban and rural areas, including very dark areas with little cultural lighting and also a considerable amount of coastline. Varied mixes of light conditions, both natural and cultural, and of ground texture were experienced within the context of a variety of police operational tasks. The types of task carried out included training, transit, location of 6 figure grid reference points, orbiting for search purposes, high (500 – 800ft) hovering and vehicle following. This experience allowed Devon and Cornwall Police to write a report assessing the benefits to police operations and to identify any issues associated with NVG operations.

The report concluded that the use of NVGs provided a benefit to Devon and Cornwall Police operations. It is beyond the scope of this paper to present the benefits to police operations but the general experience gained relevant to airworthiness issues is described below.

3.1 Cockpit Lighting/Compatibility

The cockpit lighting was found to be generally satisfactory. Particular points identified were the importance of the additional low height warning light coupled with the radio altimeter, some difficulty with

differentiation of colour on gauges and the need to fit removable Fire Warning Light filters for NVG use. The latter was because it had not been possible to achieve adequate daylight readability with NVG filtered Fire Lights, resulting in the filters having to be removed for day use. A longer term solution of possibly combining filtered lights with audio fire warning was suggested, to avoid the configuration change.

3.2 Night Vision Goggle Equipment

The NVGs used had proven to be reliable. Attention was drawn to the need for separate battery power supply for each tube, to reduce the probability of total goggle failure. Battery management was highlighted as an important issue to avoid in-flight failures and a method for recording operating time for individual batteries was suggested.

The importance of correct helmet fitting and use of a counterbalance in order to provide a stable platform for the goggles were points highlighted, together with the importance of correct pre-flight goggle adjustment.

3.3 Crew Compliment

It was considered that the combination of pilot and specially trained police observer was appropriate and that Crew Resource Management had been an important part of training.

3.4 Hazards

Some potential hazards were identified with suggestions to minimise these.

Depth Perception was a problem in areas of poor texture, highlighting the importance of the radio altimeter and low height warning system. Judging horizontal clearance was also difficult, e.g. when operating close to cliffs. A means around this was to use a horizontal reference such as the tide line on the beach but the problem was perceived as being similar to the difficulty with depth perception.

In the event of a partial, i.e. single tube, goggle failure, continued flight was considered acceptable although uncomfortable, but would be an adequate means to fly the aircraft to an area 'where conventional night flight could be better carried out'.

To allow for continued flight in the event of goggle failure, it was emphasised that weather minima should not be reduced for NVG operations, although it was suggested that this might be possible in areas of high cultural lighting. The need for the pilot to continually make an assessment of the weather/visual cues that would be available for non-goggle flight was highlighted.

Some concern was raised about the effect of goggle and counterbalance weight on the helmet in the event of an accident. The need to be able to remove the goggles quickly was identified and it was recommended that this be done prior to an accident where possible. The problem with this action however, would be the consequent loss of vision that could make an accident more likely, i.e. in the event of total power loss and engine off landing. In this case, even though there would be the chance of a heavy landing, or roll over, with a likelihood of additional injury caused by the weight of the goggles/counterbalance, continued use of the goggles to touchdown could significantly increase the probability of a safe landing being achieved. The report concluded that any additional risks associated with the additional weight seemed acceptable in the context of other perceived safety benefits, but it does highlight the aeromedical issues of NVG use.

4. Background To The Development Of The Requirements

Some nations do not exercise control of police operations through their Civil Aviation Authority, using instead a system of "State" control which has more in common with military methods of control and approval. However, for nations who control such activities through their Civil Aviation Authority, including the UK, there is a need for appropriate Night Vision Goggle airworthiness and operational rules to be developed.

In the UK, the Civil Aviation Authority took the view that the NVG proof of concept trial, using the BO105, should be considered complete when the aircraft was retired from service in 1998. Consequently, any clearance of an NVG modification to any other aircraft, including the Devon & Cornwall Constabulary's BK117 to replace the BO105, should only be made against formally developed requirements. The trial had demonstrated a benefit to police operations and it was apparent that there was a continuing need for NVGs. Hence, it was considered appropriate to develop formal requirements to support the use of civil NVG operations.

Nevertheless, NVGs are highly specialised equipment and the CAA had no prior experience of their use by flight crew on civil aircraft. Although the CAA had some pilots with military NVG experience, the task of developing requirements was large and the likely timescale, due to other commitments, was inconsistent with the operational need.

However, the Police Constabulary Air Support Unit were able to enlist the support of the Home Office, the British Government Department responsible for the Police. The Home Office agreed to provide financial support to enable the CAA to contract an outside agency, with NVG experience, to provide advice on the development of the airworthiness requirements and thereby assist the Authority to produce appropriate requirements more quickly than would otherwise be possible.

Hence, the CAA prepared a project specification and invitation to tender and undertook to conduct a technical evaluation of the bids received, recommend who would be the most suitable contractor, manage the project and,

following its completion, review the project's findings and produce formal draft requirements.

The project specification outlined the objectives and scope of the project as follows:

- To determine the airworthiness and operational factors influencing the safe, reliable and effective use of NVGs and to evaluate their significance.
- To recommend airworthiness requirements and supporting guidance material for the approval of civil helicopter NVG operations.

Whilst the project would also identify the operational issues and risks of civil helicopter NVG operations, the primary aim was to develop *airworthiness* requirements, in the light of the operational issues identified.

The project was to include a search and review of all relevant literature, together with a review of the currently acquired experience of the use of NVGs to determine the factors pertinent to the formulation of the requirements and any necessary guidance material. A review of all available military certification requirements and an assessment of their applicability for civil operations was also to be included. One example of such a document is the US Military Specification "Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible" MIL-L-85762A (August 1988) (Ref 2) which addresses the issue of cockpit lighting compatibility.

Following the issue of an invitation to tender, five proposals were received and the contract was awarded to GKN Westland Helicopters Ltd. The study was duly completed and a number of findings and recommendations were made which covered the following main issues:

- Lighting Compatibility
- Low Height Warning System
- Equipment Specification
- Ergonomics
- Aeromedical Considerations
- Flight Manual Supplement
- Operational Considerations

These issues are described in more detail in the following section.

5. Outline Of The Draft Requirements

In order to maintain an adequate level of safety, it is essential that during NVIS operations, continued compliance with the existing Airworthiness Requirements JAR 29 & 27 (Refs 1 & 3) is demonstrated. The findings of the study described above were used to formulate additional airworthiness requirements and advisory guidance material to support the approval of civil helicopter NVG operations and maintain the levels of safety achieved during normal aircraft operation.

The findings and recommendations from GKN Westland Helicopters Ltd were reviewed and refined by the CAA Flight Department to produce "Draft Airworthiness Requirements For Aircraft Equipped For Operations Using A Night Vision Imaging System (NVIS)". This material specifies additional requirements and limitations for aircraft equipped with NVIS. The requirements are intended to be generic and apply to any NVIS. To date, however, their application has been limited to Night Vision Goggles and it is accepted that they may need to be expanded for some alternative NVIS types.

In keeping with the existing airworthiness requirements, the NVIS requirements are broadly objective, to encompass changing technology, whilst supporting advisory material is also provided that is more detailed and identifies an acceptable means of compliance. The advisory material is referred to as ACJ (Advisory Circular Joint) material in line with the typical Joint Aviation Requirement (JAR) format.

The NVIS Airworthiness Requirements(AR) 1-13 are presented in full in Appendix 1, but each rule is discussed briefly below. It should be borne in mind that these are draft requirements subject to further consultation and the content could change in the event of justifiable commentary on them and experience gained from their application.

AR1 General

(a) **This appendix specifies additional requirements and limitations for aircraft equipped with an NVIS.**

This rule is self-explanatory.

(b) **The minimum standard of aircraft to which an NVIS will be applied shall be multi-engined and certificated for single or dual pilot IFR, non-NVIS night operations.**

Because of the possibility of operations with very restricted visual cues, and taking into account as background information the generalities of the ADS33D type handling qualities criteria (Ref 4) developed in recent times, it was considered that an appropriate level of aircraft stability and control would be that required for IMC flight.

Multi-engined aircraft were considered appropriate to reduce the probability of a power off landing having to be carried out, and these aircraft being mostly Category A, have higher performance and systems integrity standards.

(c) **NVIS operations must not affect continued compliance with the basic aircraft certification basis.**

It was considered that there was no logical reason for compromising the basic airworthiness standards that would apply for normal night flying, when considering NVIS approval. The appropriate JAR, FAR and British

Civil Airworthiness Requirements (BCAR), Section G (Ref 5) should continue to be met, e.g. colour differentiation of gauge markings.

(d) **NVIS operations must be possible without exceptional pilot skill or alertness.**

This rule is intended to avoid unusual complexity or difficulty in carrying out normal and emergency tasks whilst using NVIS.

AR2 **Lighting Compatibility**

(a) **Continued compliance with Paragraph .1381 of the appropriate JAR must be demonstrated, during NVIS operations.**

(b) **Any light emitted from equipment, in either the cockpit or the cabin, during NVIS operations, must be compatible with the NVIS.**

(c) **Any subsequent cockpit, cabin or external modification, including role equipment, involving a light emitting or reflecting device will require re-assessment.**

These rules are intended to ensure that there can be no light sources within the cockpit that could cause a degradation of NVIS performance. This is primarily to avoid a hazardous situation due to the illumination of unfiltered lights that could cause sudden loss of external view.

The Advisory Material suggests, in some detail, a possible test methodology that can be used to demonstrate compliance with these rules.

AR3 **Warning, Caution and Advisory Lights**

(a) **Continued compliance with Paragraph .1322 of the appropriate JAR must be demonstrated, during both NVIS and non-NVIS operations.**

This rule is intended to ensure that the pilot can still differentiate quickly and accurately between the Warning, Caution and Advisory lights displayed by the aircraft's warning system.

It is accepted that it may not be possible to use the original colours but nevertheless, reds and ambers must be identifiable as such, and clearly differentiated from each other and whatever advisory colour is used.

The overall attention getting capabilities of the warning system should not be degraded by the NVIS installation. Any degradation of the visual attention getting capabilities would need to be compensated by, for example, an audio warning system.

The guidelines of Military Specification MIL-L-85762A, Section 3.10.9.8 are suggested in the advisory material as a means of compliance.

AR4 **Instrument Lights**

(a) **Continued compliance of the NVIS compatible instrument lighting with Paragraph .1381 of the appropriate JAR must be demonstrated during non-NVIS operations.**

It would be possible that measures taken to ensure NVIS compatibility could affect adversely normal usage of the cockpit. This rule is intended to ensure that normal daylight and non-NVIS night use of the cockpit is not compromised. This would include the transition from day into night flight when it can be difficult to achieve an acceptable solution, e.g. for Central Warning Panel brightness.

AR5 **Dimming Levels**

(a) **The cockpit lighting must have a dimming range consistent with NVIS operations.**

The rule is self evident, but advice is given in the advisory material to help achieve an acceptable brightness level for day, non-NVIS night and NVIS operation. The advisory material assumes that conventional lighting will be available for non-NVIS night flying, however it is conceivable that only one lighting system would be fitted, i.e. an NVIS compatible system which, by definition, is viewed by the naked eye and also has to comply with normal night lighting standards. The advisory material is not intended to prevent the provision of an NVIS compatible lighting system only.

(b) **Inadvertent selection between Day, Night and NVIS modes must be prevented.**

The consequences of inadvertent selection of non filtered light could be severe. Again an assumption that there will be both conventional and NVIS compatible lighting in the cockpit is made, and equally, such provision is not mandatory. The advisory material suggests some means of switching which first requires a positive action, to minimise inadvertent selection.

AR6 **Chromaticity and Radiance**

(a) **The chromaticity of the light sources in the cockpit and cabin must be sufficiently separated to ensure colour coding discrimination is maintained.**

(b) **The radiance of the light sources in the cockpit and cabin must be compatible with the selected NVIS.**

These rules use the guidance of Sections 3.10.8 and Sections 3.10.9 and Appendix A of MIL-L-85762A to provide advisory chromaticity and radiance limits for cockpit and cabin light sources for a range of NVIS types. Using light sources which meet this standard is an acceptable means of compliance with the above requirement.

AR7 External Lighting

(a) External lighting systems must not unacceptably impair the performance of the NVIS.

This rule is self evident, but more relevant to civil operations than military. Civil aircraft are required to display the appropriate lights at all times whereas military aircraft will often operate lights-out for tactical reasons. The advisory material proposes a qualitative evaluation during flight trials.

(b) **Continued compliance with Paragraphs .1383 to .1401 of the appropriate JAR must be demonstrated.**

This rule requires that any external lights fitted, even though modified to minimise NVIS interference, must still meet the relevant existing requirements.

AR8 Low Height Warning System

(a) A radio altimeter display must be installed at every pilot's crew station from which NVIS operations are to be flown.

The fitted radio altimeter should have the following characteristics:

1) A display that is instantly visible and discernible during NVIS operations.

2) An expanded scale below 1000ft.

3) An integral fail/no track indicator.

4) An integral low height indicator light.

(b) If the cockpit has an EFIS or similar electronic displays, with an electronic radio altimeter presentation, then an additional visual low height indicator must be fitted to the instrument panel.

(c) An unambiguous supplementary visual low height warning, that is discernible during head-up NVIS operations, must be fitted at every pilot's crew station from which NVIS operations are to be flown.

(d) An unambiguous indication of radio altimeter fail, or no track within normal operating range, in addition to that provided by existing instrumentation, must be fitted at every pilot's crew station from which NVIS operations are to be flown.

(e) The luminous area of the supplementary low height repeater light, additional low height indicator light (EFIS if applicable) and radio altimeter fail/no track light (if applicable) must be such that each is clearly visible under all the conditions of flight in which the aircraft is cleared to fly.

(f) The operation of any repeater lights must follow the logic of the installed radio altimeter, and must not flash.

(g) An unambiguous low height audio cue must be fitted, which is readily cancellable.

Night vision systems do not currently give adequate height perception in all conditions of light and ground texture. There is a high probability of encountering conditions that will result in a lack of height awareness by the pilot and a real probability of the aircraft flying into the ground, even when operations are not intended to be carried out at very low heights. It can be very easy to lose 500ft from a nominal operating height (of say 500ft), either due to a descent, or more likely, featureless rising ground. For this reason, it is considered essential that an adequate height reference system, with associated unambiguous warnings of low height and system failure, is provided to ensure safety of flight using NVIS.

The importance attached to this is reflected by the detailed rules and associated advisory material. The effect of these rules is to require at each pilot's crew station an analogue radio altimeter with easily readable scale, repeater low height warning lights, radio altimeter no-track and fail warning lights and an unambiguous audio warning of low height.

AR9 Wire Strike Protection

(a) A wire strike protection system (WSPS) must be fitted to all helicopters cleared for NVIS assisted take-off and landing operations.

This rule could be considered to be operational rather than airworthiness, and may be removed from these airworthiness rules. Currently, no request has been received for NVIS certification for take-off and landing.

AR10 Equipment Specification

(a) The NVIS must be of a kind and design appropriate to its intended function.

This rule allows investigation of the suitability of any proposed NVIS. The advisory material makes recommendations as to NVIS characteristics, but rests heavily on MIL-L-85762A as being an established and accepted standard. Generation III, Type I or II Class B NVIS as defined in MIL-L-85762A, are proposed as the target standard equipment for civil applications.

It is arguable that a dedicated civil standard, such as a Technical Standard Order (TSO), should be created to define minimum NVIS standards, particularly in relation to reliability, as integrating military and civil requirements can be difficult and there is little control over any changes that might be made to military specifications.

(b) **The NVIS equipment and installation must comply with JAR 29.1309 Category A Requirements.**

This rule is intended to ensure that the view outside the cockpit through the NVIS is provided with an adequate certainty of being maintained. The advisory material states that "the NVIS equipment and installation should be subjected to a system safety analysis in accordance with AMJ 25.1309. The loss of external view due to either goggle failure or interference by cockpit lighting is potentially Hazardous and appropriate consideration must be given to this functional failure in the system safety analysis carried out".

(c) **Instructions for the Continued Airworthiness of the NVIS must be established.**

It is important that the originally certificated NVIS standard is maintained in service. Of particular importance is the management of battery life, if this is the chosen power source. Battery failure probably represents the highest risk of goggle failure in flight and adequate means must be proposed to ensure that the probability of failure is low enough to comply with AR10(b).

AR11 Ergonomics

(a) **The NVIS configuration must not compromise the wearer's ability to perform normal duties.**

(b) **Where the NVIS assembly constitutes an additional fit to the protective helmet (i.e. it is not integrated with the protective helmet) a fast removal mechanism must be provided.**

(c) **A fixed stowage receptacle, able to contain the NVIS and batteries (where applicable), must be provided within reach of the crew while strapped in.**

The ergonomics issues are fairly self evident but a requirement to cover these aspects helps to avoid unsuitable situations being presented for certification. A key issue here is the amount of available headroom to allow adequate head movement and the ability to hinge the goggles into the up position. The advisory material makes several recommendations on ergonomic issues to ensure easy operation when using NVIS.

The fast removal and goggle stowage requirements are intended to allow for the emergency landing case when the crew may wish to remove their goggles before landing. The stowage also prevents loose goggles becoming a hazard during normal (non-NVIS) operations.

AR12 Aeromedical Aspects

(a) **The NVIS configuration must minimise the risk of impact injury to the wearer.**

(b) **The total mass of the head-borne NVIS assembly must not exceed 3.0 kg. If the total mass of the head-borne NVIS assembly exceeds 2.5 kg, human factors monitoring will be required.**

(c) **The centre of gravity (C of G) of the total head-borne assembly must be as close as possible to the natural centre of gravity of the wearer's head.**

The aeromedical rules above are intended to minimise the probability of injury during accidents and also during normal NVIS use. The advisory material discusses the relative merits of frangible and non-frangible mounts for goggles but recognises that there is no clear answer on this subject. The head-borne weight limit is based on current military advice, as is the rule and advisory material relating to centre of gravity.

AR13 Flight Manual Supplement

(a) **A specific NVIS supplement must be incorporated into the appropriate Aircraft Flight Manual.**

It is considered that a Flight Manual Supplement must be provided to cover an NVIS modification and subsequent use. The Flight Manual Supplement should, as a minimum, address Limitations as specifically agreed between the Authority and the Operator such as minimum heights, types of operation, internal and external lighting configuration for NVIS operation, minimum equipment and minimum crew. Also included should be the procedures for emergencies and malfunctions, including NVIS failure, normal procedures and some descriptive material covering the NVIS and it's intended operation.

6. European/International Perspective

The NVIS requirements described above were prepared by the CAA in response to a specific and pressing need to generate requirements for the approval of aircraft and equipment for NVG operations in the UK. As a result, the UK CAA acted unilaterally in the first instance to produce NVG requirements. However, Police and Emergency Medical Service NVG helicopter operations are being conducted in some other JAA States and the FAA have also had a similar pressing need to approve NVG operations for EMS operators and have only recently certificated civil NVG operations.

Consequently, the JAA and FAA have now begun discussing the issue of NVG requirements in the Helicopter Joint Harmonisation Working Group with the intention of producing harmonised airworthiness rules.

The FAA have produced airworthiness material largely based on advisory circular (AC) material. An initial comparison of this material with the UK CAA requirements has shown a large degree of commonality in

objective, but with a different emphasis in the role of advisory material versus requirements. It is our intention that the requirements will ultimately form a Notice of Proposed Amendment (NPA) to JAR 27 & 29 but the precise method of promulgation has yet to be decided. A specific meeting to debate the issues and progress the task of producing harmonised NVG airworthiness material has been arranged with the FAA and is timed to coincide with a US Night Vision Conference to be held in October 1999. Significantly, this conference includes a civil night vision workshop which reflects the increasing interest now being shown in the application of night vision equipment for civil flying operations. Completion of the harmonisation process, in due course, will result in agreed airworthiness material available for use by both the JAA and FAA.

A parallel exercise is also ongoing to develop harmonised operational rules and it is intended that an appendix covering NVG operations will form part of JAR-OPS 3 (Ref 6).

7. Conclusion

In response to increasing interest in using Night Vision Goggles for specialist civilian tasks, the UK CAA has developed "Draft Airworthiness Requirements For Aircraft Equipped For Operations Using A Night Vision Imaging System (NVIS)". The requirements were produced following a proof of concept trial and a contracted study to determine all the factors influencing the safe, reliable and effective use of NVGs and their significance for the approval of civil helicopter NVG operations. Consequently, the requirements address the significant airworthiness issues and provide a firm framework for the assessment of aircraft equipped for NVG operations. The requirements are currently being used to approve an NVG modification to a BK117 for police operations. Police and Emergency Medical Service NVG helicopter operations are being conducted in some other JAA States and recently also in the US. Consequently, the JAA and FAA have now begun discussing the issue of NVG requirements with the intention of producing harmonised rules. The UK CAA draft airworthiness requirements will provide a significant input to this process.

8. Acknowledgements

The authors wish to acknowledge the valuable assistance provided by the following individuals and companies: Capt P. Hannant, formerly Air Support Manager of the Devon & Cornwall Constabulary Air Support Unit; Capt P. Ashby, Chief Pilot, Devon & Cornwall Constabulary Air Support Unit; Capt M. Kenworthy, Police Aviation Adviser, Home Office; Mr C. Kitchen, General Manager, Applied Military Optics (a Division of Mann Avionics Ltd); Mr A. Scott, Avionic Systems, Marconi Electronic Systems; Mr B. Thomson, Oxley Avionics (a Division of Oxley Developments Company Ltd); and GKN Westland Helicopters Ltd.

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AIRWORTHINESS REQUIREMENTS FOR AIRCRAFT EQUIPPED FOR OPERATIONS USING A NIGHT VISION IMAGING SYSTEM (NVIS)

1. Assumptions

1.1 Whilst it is acknowledged that both safety and operational benefits can be derived during NVIS operations, nevertheless in some circumstances NVIS operations could carry an increased risk. These requirements have been written to minimise any potential risks. Employment of NVIS will enhance but not replace normal night VMC operations. In the event of a failure of the NVIS, a pilot must be able to revert to normal night VMC techniques.

1.2 "Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible" MIL-L-85762A (August 1988) guidelines will apply as a strategy to overall NVIS compatibility. This is a minimum requirement and if the applicant can demonstrate an improved capability this will be acceptable to the Authority.

1.3 These generic requirements are intended to apply to any NVIS. To date, however, their application has been limited to Night Vision Goggles (NVG) and the requirements may need to be expanded for some alternative NVIS types.

1.4 Pilots involved with NVIS operations will be qualified on type, and be current at non-NVIS night flying in accordance with current regulations.

1.5 NVIS operations may be approved for all flight regimes.

1.6 Exacting standards for all aspects of NVIS application, based on current military experience, will be applied to the civil regulations since safety is regarded as paramount.

2. Glossary of Terms

ACJ	Advisory Circular Joint
AMJ	Advisory Material Joint
AO	Atlanto Occipital
C of G	Centre of gravity
CWP	Central Warning Panel
EFIS	Electronic Flight Instrument System
EO	Electro-optic
GEN (I, II or III)	Generation (1, 2 or 3) of Night Vision Imaging System
JAR	Joint Aviation Requirements
NVG	Night Vision Goggles
NVIS	Night Vision Imaging System
Rad alt	Radio Altimeter
WSPS	Wire Strike Protection System

3. *Airworthiness Requirements*

AR1 General

(a) This appendix specifies additional requirements and limitations for aircraft equipped with an NVIS.

(b) The minimum standard of aircraft to which an NVIS will be applied shall be multi-engined and certificated for single or dual pilot IFR, non-NVIS night operations.

ACJ Material

The stability and control requirements for flight in IMC are required to be met. Under single pilot operations, the pilot must be able to remove his hands from the controls in order to be able to adjust or remove the NVIS, or change power sources in the event of a power failure. In the event of a failure of the NVIS, the pilot may require current instrument flying skills to maintain safe flight of the aircraft.

(c) *NVIS operations must not affect continued* compliance with the basic aircraft certification basis.

ACJ Material

Many of the existing basic airworthiness requirements are equally applicable to NVIS operations and compliance with these requirements must be maintained. Applicable paragraphs of the appropriate JAR include .771, .773, .1301, .1309, .1321, .1322 and .1381. FAA Advisory Circular AC 20-88 "Guidelines On The Marking Of Aircraft PowerPlant Instruments (Displays)" is also applicable.

(d) NVIS operations must be possible without exceptional pilot skill or alertness.

ACJ Material

Consideration should be given to the workload required to control the aircraft and it's systems during NVIS operations. Where possible, control functions associated with all other aircraft systems should be simplified to take account of NVIS operations.

AR2 Lighting Compatibility

(a) Continued compliance with Paragraph .1381 of the appropriate JAR must be demonstrated, during NVIS operations.

(b) Any light emitted from equipment, in either the cockpit or the cabin, during NVIS operations, must be compatible with the NVIS.

(c) Any subsequent cockpit, cabin or external

modification, including role equipment, involving a light emitting or reflecting device will require re-assessment.

ACJ Material

The applicant should ensure compliance by applying the NVIS test methodology described below.

NVIS Installation Test Methodology

Stage 1 Prior to fitting to an aircraft, any NVIS compatible equipment should be viewed in a dark room facility with the selected NVIS. During this assessment any unfiltered light will be detected and the effect of the lighting on the performance of the NVIS will be established. The testing should be carried out by suitably qualified engineers who have experience of NVIS compatible lighting and who are able to recognise the full range of effects due to unfiltered light sources.

Testing of permanently installed NVIS filtered equipment should include assessment of readability under simulated bright sunlight.

Stage 2 Following build of the aircraft, or modification, the aircraft transparencies are blacked out to simulate a dark night ambient lighting condition. The whole cockpit lighting installation, and where applicable, cabin/equipment lighting can then be assessed for:

a) readability of instruments, controls and displays.
b) lighting balance of self illuminated equipment panels and displays.
c) attention getting/brightness/balance of warning and caution indicators and the CWP.
d) the effect of reflections in the transparencies on the view out of the cockpit.
e) compatibility with the selected NVIS.
f) the effect of reflections on the selected NVIS.
g) cockpit ergonomics.

Stage 3 With the transparency blackouts removed, the readability of the permanently NVIS filtered equipment should be assessed under simulated bright sunlight or natural bright sunlight when available. (Bright sunlight equates to a level of 100,000 lux measured on the surface of the equipment under test).

Stage 4 To reduce the risk of failure during flight trials the installation should be assessed in accordance with the 'Lighting System NVIS Compatible Examination' methods specified in Sections 4.8.2 of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority).

Stage 5 The tests detailed in stages 2 and 3 should be repeated during day and night flight in the aircraft's typical operating environment over the extremes of range of natural light levels caused by cloud cover, sun elevation, moon phase and elevation.

For any 'additional' cockpit, cabin or external modification involving a light emitting device, reassessment should begin at the appropriate stage above. For all changes to the cockpit configuration which include the addition of, or relocation of any device including non light emitting devices, such as straps, fire extinguishers, upholstery, clothing, carry-on equipment, etc., the operator should be aware that there is a potential impact on overall night vision compatibility, and therefore should carry out a cockpit assessment, as in stage 2 above.

Within the process described at stage 4 above, the applicant should demonstrate that cockpit transparency transmissivity does not significantly impair the performance of the selected NVIS.

For aircraft types which make provision for light tight barriers between cockpit and cabin (eg. double curtains), NVIS incompatible lighting in cabin equipment may be permissible. In such cases it will be necessary for the applicant to demonstrate the effective nature of the barrier and that the operating procedures which cover movement between the cockpit and the cabin are adequate to ensure unfiltered light does not enter the cockpit. Equally it will be necessary to demonstrate that light escaping from cabin windows has no effect on the cockpit NVIS. Such provision should be demonstrated under stages 4 and 5 of the testing methodology above.

AR3 Warning, Caution and Advisory Lights

(a) *Continued compliance with Paragraph .1322 of the appropriate JAR must be demonstrated, during both NVIS and non-NVIS operations.*

ACJ Material

It may not be possible to obtain fully compatible warnings (red) and cautions (amber) captions without compromising sunlight readability. The lighting level defined in Section 3.10.9.8 of MIL -L -85762A, August 1988 (or its successor, as agreed by the Authority) is designed to achieve a slight measure of incompatibility or flare in the NVIS, which provides a positive attention getting benefit, whilst not compromising the view out of the cockpit.

The overall attention getting capabilities of the warning system should not be degraded by the NVIS installation. Any degradation of the visual attention getting capabilities would need to be compensated by, for example, an audio warning system.

AR4 Instrument Lights

(a) Continued compliance of the NVIS compatible instrument lighting with Paragraph .1381 of the appropriate JAR must be demonstrated during non-NVIS operations.

ACJ Material

The most common method of ensuring NVIS compatibility is to place filters over light sources to prevent emission of light from the portion of the spectrum which is visible to

NVIS. Where NVIS filters are used, it is preferable that they remain installed for day, night and NVIS flight, in order to simplify testing and subsequent operational management of the aircraft. This prevents problems associated with stowages, loose articles, aircraft departing without filters fitted and filters falling off during flight.

Other methods of achieving NVIS compatibility include the use of:

Light emitting diodes
Electro-luminescent panel floodlighting
Incandescent floodlighting.

The lighting installation for non-NVIS operation should not be degraded by virtue of NVIS compatibility.

AR5 Dimming Levels

(a) The cockpit lighting must have a dimming range consistent with NVIS operations.

ACJ Material

NVIS equipment presents an image to an observer by intensifying light that is beyond the part of the spectrum visible to the naked eye. The term used for emitted energy is radiance and is equivalent to luminance when referring to visible light emitted directly from a light source. The term for visible light reflected from a surface is illuminance and the equivalent for reflected energy beyond the visible spectrum is irradiance. The term brightness is generally used to describe luminance and illuminance. Radiance and irradiance cannot be termed brightness as they are invisible to the naked eye. It is true, however, that a non-NVIS compatible light, emitting excessive radiance, will cause the NVIS to overload and present a bright image to the NVIS user.

To ensure that an illuminated aircraft installation is compatible with NVIS equipment it is necessary to filter out that part of the spectrum that the NVIS is intensifying, i.e. Infra-Red. If this is not adequately achieved the NVIS will effectively overload and the definition of the view out of the cockpit will be significantly degraded. However, the visible luminance and illuminance of the aircraft installation should be such that the pilot can view the instruments and controls, etc. when looking into the cockpit, under the goggles, with the naked eye.

Day, Night and NVIS Modes are defined as follows:

Day: Warnings and cautions are presented at full brightness. Instrument and panel lighting are extinguished.

Night: Warnings and cautions are presented at a brightness clearly discernible for night operation. If a dimming capability is provided, all annunciators, including master warning and caution, may be dimmable as long as the annunciation is clearly discernible for night operation at the lower lighting level. Undimmed annunciations have been found unacceptable for night operation due to disruption of cockpit vision at the high intensity. Instrument and panel lighting is variable from extinction to full brightness.

NVIS: Warnings and cautions are presented at a fixed luminance of 15 footlamberts (fL) which maintains attention getting capabilities whilst not degrading the operation of the NVIS, in accordance with Section 3.10.9.8 of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority). Instrument and panel lighting is variable from extinction to full brightness and any non-NVIS filtered equipment lighting is extinguished.

(b) Inadvertent selection between Day, Night and NVIS modes must be prevented.

ACJ Material

Selection between Day, Night and NVIS modes should be by a locked toggle, guarded pushbutton switch or any other mechanism which requires positive action.

AR6 Chromaticity and Radiance

(a) The chromaticity of the light sources in the cockpit and cabin must be sufficiently separated to ensure colour coding discrimination is maintained.

ACJ Material

If NVIS compatibility is being achieved by filtering existing light sources, then filters should be selected to ensure the desired colour separation. If NVIS compatibility is being achieved by installing intrinsically compatible light sources then the chromaticity co-ordinates need to have similar colour separation.

Sections 3.10.8 and Appendix A of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) provides guidelines for the chromaticity of all cockpit and cabin light sources for a range of NVIS types. Using light sources which meet this standard is an acceptable means of compliance with the above requirement.

NVIS Class B standard cockpit lighting (as defined in MIL-L-85762A, August 1988 or its successor, as agreed by the Authority) is aimed at NVIS equipment with 665nm filters and will cause flaring of NVIS equipment filtered to a 645 nm cut off. However, experience has shown that this degree of NVIS flare has little effect on flight safety and therefore may not, as an isolated feature, render non compliant an applicant's solution to NVIS compatibility based on 645nm cut off filters.

(b) The radiance of the light sources in the cockpit and cabin must be compatible with the selected NVIS.

ACJ Material

Sections 3.10.9 of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) provide the radiance limits for cockpit and cabin light sources for a range of

NVIS types. Using light sources which meet this standard is an acceptable means of compliance with the above requirement.

AR7 External Lighting

(a) External lighting systems must not unacceptably impair the performance of the NVIS.

(b) Continued compliance with Paragraphs .1383 to .1401 of the appropriate JAR must be demonstrated.

ACJ Material

If, during night flight assessment, as part of the NVIS installation test process, it is found that the performance of the NVIS is impaired by the external lights, it may be necessary to modify the external lighting installation to obtain compatibility.

External lights which are non-NVIS compatible are increasingly likely to cause unacceptable flaring as height is reduced. The lighting of ground support vehicles should be assessed if appropriate.

The addition of external reflective surfaces, such as a white aerial on a skid, may also affect NVIS performance and may be subject to flight test.

AR8 Low Height Warning System

(a) A radio altimeter display must be installed at every pilot's crew station from which NVIS operations are to be flown.

The fitted radio altimeter should have the following characteristics:

1) A display that is instantly visible and discernible during NVIS operations.

2) An expanded scale below 1000ft.

3) An integral fail/no track indicator.

4) An integral low height indicator light.

ACJ Material

Compliance with AR8(a)(1) would normally be expected by virtue of an analogue display giving both position and rate information.

(b) If the cockpit has an EFIS or similar electronic displays, with an electronic radio altimeter presentation, then an additional visual low height indicator must be fitted to the instrument panel.

ACJ Material

The visual low height annunciation provided by an EFIS display is unlikely to be as obvious as a discrete incandescent lamp. The additional visual low height indicator is intended to provide an equivalent standard to that provided by an analogue altimeter with integral low height indicator light.

The additional visual low height indicator should be fitted as close to the electronic radio altimeter presentation as possible, and in clear association.

The additional low height indicator is considered cautionary and should therefore be coloured amber accordingly. The NVIS YELLOW colour as defined in Appendix A of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) is the closest approximation to this which retains a measure of NVIS compatibility.

(c) An unambiguous supplementary visual low height warning, that is discernible during head-up NVIS operations, must be fitted at every pilot's crew station from which NVIS operations are to be flown.

ACJ Material

A low height repeater light should be fitted on the instrument panel coaming, on the edge of the coaming closest to the pilot. It's position should be such that the pilot can always see the visual low height cue from the full range of seating positions and during all phases of flight.

The low height warning light is considered cautionary and should therefore be coloured amber accordingly. The NVIS YELLOW colour as defined in Appendix A of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) is the closest approximation to this which retains a measure of NVIS compatibility.

(d) An unambiguous indication of radio altimeter fail, or no track within normal operating range, in addition to that provided by existing instrumentation, must be fitted at every pilot's crew station from which NVIS operations are to be flown.

ACJ Material

The warning(s) may be provided, depending on the aircraft configuration, by visual and/or audio means.

The rad alt fail/no track indicator is considered cautionary and therefore any visual indications should be coloured amber accordingly. The NVIS YELLOW colour as defined in Appendix A of MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) is the closest approximation to this which retains a measure of NVIS compatibility.

If the rad alt fail/no track indicator incorporates a light, then it should be co-located with the low height indicator on the instrument panel coaming in front of the pilot.

Confusion with the low height repeater should be avoided. This could be achieved by providing dedicated audio cues.

(e) The luminous area of the supplementary low height repeater light, additional low height indicator light (EFIS if applicable) and radio altimeter fail/no track light (if applicable) must be such that each is clearly visible under all the conditions of flight in which the aircraft is cleared to fly.

ACJ Material

Since viewing distances in cockpits vary, the size of an object is defined in terms of angle subtended at the eye. The accepted acuity angle subtended at the eye for warning indicators, based on human factors research and used to define MIL STD 1472D character sizes, is 6 milliradians. Allowing for the degraded vision offered by NVIS equipment, 10 milliradians is probably acceptable, but no data is available to prove it. Low height repeater lights fitted to current helicopters cleared for NVIS operations subtend up to 22 milliradians at the eye datum position.

(f) The operation of any repeater lights must follow the logic of the installed radio altimeter, and must not flash.

(g) An unambiguous low height audio cue must be fitted, which is readily cancellable.

ACJ Material

The pilot should be able to cancel the audio cue to allow crew inter communication. Cancelling the audio cue should not extinguish any low height visual indications.

Audio cues should be designed to be consistent with the overall aircraft audio cueing philosophy.

AR9 Wire Strike Protection

(a) A wire strike protection system (WSPS) must be fitted to all helicopters cleared for NVIS assisted take-off and landing operations.

ACJ Material

The most common form of wire protection system fitted to existing helicopters consists of an arrangement of wire deflectors and cutting devices such that wires are deflected to a cutting blade and severed before they can damage critical aircraft components. A general specification for a WSPS does not currently exist. The system selected should be based on a consideration of the wire threats within the intended sphere of operations.

AR10 Equipment Specification

(a) The NVIS must be of a kind and design appropriate to its intended function.

ACJ Material

Generation III, Type I or II Class B NVIS as defined in MIL-L-85762A, August 1988 (or its successor, as agreed by the Authority) should be the target standard equipment for civil applications. Class B NVIS equipment allows red to be used in the cockpit.

It is recognised that some commonly used NVIS do not comply with Class B requirements; however, experience of aircraft modifications has shown that a satisfactory level of compatibility can be achieved with such equipment. Where a class B NVIS is not available, compatibility with the cockpit installation should be demonstrated as acceptable by following the NVIS Installation Test Methodology as described under section AR2.

If an NVIS with combining optics is chosen, then no cockpit lighting to which the NVIS is sensitive should be visible when the pilot looks inside the cockpit. This may be achieved through the use of a head position sensor to occult the light sources when the pilot looks into the cockpit. The inter-ocular spacing and location of the Electro-optic (EO) sensors will be different from those of the pilot's eyes and will cause the EO image to appear displaced from the natural image. Alternatively, a means to automatically 'stop down' the NVIS when the pilot looks into the cockpit could be provided.

(b) The NVIS equipment and installation must comply with JAR 29.1309 Category A Requirements for helicopters (or JAR 25.1309 for aeroplanes).

ACJ Material

The NVIS equipment and installation should be subjected to a system safety analysis in accordance with AMJ 25.1309. The loss of external view due to either goggle failure or interference by cockpit lighting is potentially Hazardous and appropriate consideration must be given to this functional failure in the system safety analysis carried out.

(c) Instructions for the Continued Airworthiness of the NVIS must be established.

ACJ Material

Maintenance procedures should be specified and observed e.g. battery checks etc. The maintenance tasks should be included in the maintenance schedule of the aircraft as appropriate. General procedural instructions for equipment testing should be provided to prevent performance degradation which may become a source of hazard.

Appendix material to the appropriate JAR gives guidelines on the Continued Airworthiness information that should be determined.

AR11 Ergonomics

(a) The NVIS configuration must not compromise the wearer's ability to perform normal duties.

ACJ Material

The applicant should provide details of pilots' normal duties

and demonstrate that they can be carried out safely, with emphasis on the considerations listed below:

a) The NVIS configuration should allow full head movement commensurate with all aspects of anticipated operation. If a goggle type NVIS incorporating a hinging mechanism is used, this should include the case of the NVIS hinged into the up position. In order to ensure free head movement, adequate clearance with all structure, with the pilot sat at the eye datum position should be demonstrated. The applicant should ensure that pilots are able to locate and operate from the eye datum position defined by the aircraft manufacturer such that they are able to consistently repeat the same seat adjustment position. If this is not possible, or if specific pilots choose to fly from an alternative seating position, then the applicant should ensure that minimum clearances are not compromised for each pilot and that these pilots are able to consistently repeat the same chosen seat adjustment position.

b) The NVIS, should not impede the pilot's ability to scan the cockpit instruments.

c) The NVIS configuration should not prevent the pilot viewing the outside world with the un-aided eye.

d) The NVIS should not require continual adjustment in flight.

e) The NVIS should be easily removed and refitted during flight.

(b) Where the NVIS assembly constitutes an additional fit to the protective helmet (i.e. it is not integrated with the protective helmet) a fast removal mechanism must be provided.

ACJ Material

In the event of an emergency, the pilot may wish to remove the NVIS assembly to minimise the risk of injury in the event of a hard landing. The emergency removal method should facilitate this with a single action requiring one hand only.

(c) A fixed stowage receptacle, able to contain the NVIS and batteries (where applicable), must be provided within reach of the crew while strapped in.

ACJ Material

When the NVIS is carried in the aircraft but is not being used for NVIS operations, then it should be restrained in the event of an accident. The restraining system should meet the general specification for crash protection specified for that aircraft. A dedicated stowage is recommended, since it is more likely to remain uncluttered by other items. The design of the stowage receptacle should be commensurate with the need to protect delicate optical equipment but should also enable the NVIS to be quickly stowed. It should be possible to open and close the stowage compartment with one hand, using a single action.

If the pilot elects to remove the NVIS in an emergency situation, then locating the NVIS in a stowage receptacle is a reliable means of ensuring that the NVIS does not become loose in the cockpit. Since under emergency conditions, time and convenience are of the essence, the stowage receptacle should be positioned for easy access. Good accessibility will also benefit general usage under normal conditions.

AR12 Aeromedical Aspects

(a) The NVIS configuration must minimise the risk of impact injury to the wearer.

ACJ Material

The main form of impact injury will be to the face if the head-borne assembly rotates forward on the head as a result of an accident or hard landing. Other forms of injury could be incurred by a loose object in the cockpit in the event that the NVIS becomes detached from the helmet.

In selecting the NVIS type the applicant should consider the following factors:

Protective polycarbonate visors worn between the eyes and the NVIS lens are commercially available and will provide added protection to the pilot's eyes in the event of an accident. A protective visor should be considered for the selected NVIS where damage to the eyes or face is possible due to the NVIS design, and if used, should be worn at all times during NVIS operation.

If users are unable to wear a protective visor because of spectacles, the spectacles should be fitted with safety lenses.

The applicant should ensure that helmet fittings are performed with the NVIS attached, in order to minimise NVIS movement relative to the pilot's eyes.

The relative safety merits of frangible and non-frangible NVIS mounts used on NVG types are difficult to determine. There are differing perspectives on the subject. Military users in the UK wear non-frangible types which have the benefit of being less likely to be accidentally knocked off, as well as reducing the likelihood of a loose object hazard in the cockpit following a hard landing. Frangible types are used in the US, and US studies reviewing historical accident data claim evidence for reduced risk of neck injury with frangible mounts. The applicant is advised to consider these issues, particularly with respect to NVIS stowage if the pilot elects to remove the NVIS.

(b) The total mass of the head-borne NVIS assembly must not exceed 3.0 kg. If the total mass of the head-borne NVIS assembly exceeds 2.5 kg, human factors monitoring will be required.

ACJ Material

Any additional weight over and above that of the helmet is undesirable because of the muscular and skeletal loads

imposed on the neck in maintaining control over the head. These loads can result in both short and long term medical problems. Total head-borne mass is linked with weight distribution on the head as covered under requirement AR12(c). The aeromedical impact of increased weight on the head in fixed wing applications particularly under "g" loads is well known and is the basis for the target figure stated.

The total head-borne mass is made up of the protective helmet, any additional electro optical equipment, the safety visor and counterweight.

In exceptional circumstances, where total head-borne mass is permitted to exceed 2.5 kg, an annual human factors review will be required, particularly with respect to continued acceptance by the pilots and reported instances of medical related problems.

(c) The centre of gravity (C of G) of the total head-borne assembly must be as close as possible to the natural centre of gravity of the wearer's head.

ACJ Material

Centre of gravity of the total head-borne assembly is the primary factor associated with both long and short term neck strain injuries and is linked with total head-borne weight as covered under requirement AR12(b). In order to minimise strain on the neck, it is necessary to balance the head-borne mass about the natural C of G of the head. The moment induced by the head-borne assembly under static cases should not exceed 90 Newton.centimetres measured relative to the AO (Atlanto Occipital) complex. (Ref. US Army Aviation Life Support Equipment Retrieval Program: Head and Neck Injury Amongst Night Vision Goggle Users in Rotary Wing Mishaps. US Army Aeromedical Research Laboratory (USAARL), Fort Rucker (Report No USAARL 98-02, October 1997.)

In exceptional circumstances, where the above maximum is permitted to be exceeded, the situation should be periodically reviewed, particularly with respect to continued acceptance by the pilots and reported instances of medically related problems.

AR13 Flight Manual Supplement

(a) A specific NVIS supplement must be incorporated into the appropriate Aircraft Flight Manual.

ACJ Material

The Flight Manual Supplement should, as a minimum, address the following issues:

a) General.

b) Limitations: as specifically agreed between the Authority and the Operator.

1) Minimum heights.
2) Weather minima.
3) Internal lighting.
4) External lighting.
5) Minimum equipment.
6) Minimum crew

c) Emergency and malfunction procedures.

d) Normal procedures.

e) Manufacturer's supplementary information.

1) Technical description of the NVIS.
2) Operating procedures for the NVIS.