

Skyline Aviation Ltd



NVIS Ground Training

Course



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Introduction

NVIS Ground Course Syllabus: from Radio Technical Commission for Aeronautics (RTCA) recommendations which were from a working group made up of European and North American operators, maintenance organisations, manufacturers and regulators.

The syllabus of the New Zealand NVIS Ground training course (from AC 91-13, Night Vision Imaging Systems, Appendix II) is based on the RTCA recommendations, with some adjustments for our rules, etc.

Eligibility As per AC91-13, Revision 1, page 13. I.e.:

Pilots Prior to undergoing NVIS Flight training, a pilot should meet the following prerequisites:

- hold at least a current Private Pilot Licence; and
- hold a current type rating for the aircraft to be used for NVIS flight operations; and
- hold a current night cross-country certification for night operations beyond 25nm of a lit heliport or aerodrome; and
- have a minimum of 20 hours unaided night VFR flight including 10 hours PIC of which 5 hours are on unaided cross-country; and
- demonstrate to an appropriately qualified instructor acceptable instrument flight proficiency by:
 - Maintaining a nominated altitude within ± 100 feet, a nominated heading within $\pm 5^\circ$, balance within $\frac{1}{2}$ ball deflection during straight and level flight and level turns;
 - Maintaining a rate one turn or a nominated angle of bank $\pm 10^\circ$ during all turning manoeuvres to within $\pm 10^\circ$ of pre-selected roll-out heading; and
 - Maintaining a nominated climbing or descending speed within ± 5 knots. Level flight to be re-established at the pre-selected altitude \pm no more than 100 feet; and
 - Performing an instrument recovery appropriate for the area of operations whilst maintaining the above manoeuvring limits; and
 - Correctly identifying an aircraft unusual attitude and returns to straight and level references after a small delay, without entering a second unusual attitude while attempting to regain the references; and

Note: the emphasis is for a pilot flying night VFR utilising NVIS to obtain, and maintain, proficiency in instrument flying skills. It is recommended, but not essential for the pilot to hold an instrument rating.

The holder of an instrument rating will be better placed to cope with the NVFR/NVIS environment.

- have at least 250 total hours of flight time as PIC in the appropriate category of aircraft, of which no more than 50 hours can be in an approved flight simulator representative of the aircraft category that will be used for NVIS training; and
- have completed an approved NVIS ground theory course that follows a syllabus acceptable to the Director. Appendix II of AC91-13 represents the acceptable ground theory training (for both pilots and crew members), which should be conducted by a Part 141 aviation training organisation certificate holder or as part of the air operator training programme

conducted under Part 119 air operator certificate if the certificates authorise NVIS ground training.

The above prerequisite flight performance parameters are based on those required in AC 61-5 for the issue of a CPL with night certification. The above prerequisites are therefore mandatory for CPL holders and the Director considers it necessary in the interests of aviation safety for PPL holders to meet the same minimum prerequisites as commercial pilots.

NVIS Initial flight Check An NVIS initial flight check should, as a minimum, require the candidate to demonstrate competency in the following:

1. mission planning/flight planning for the flight;
2. determining the serviceability of NVIS equipment, including the aircraft components;
3. performing cockpit drills and 'Goggle/de-goggle' procedure";
4. performing NVIS hover (if appropriate), taxi departure, transit, navigation and arrival procedures;
5. performing NVIS practice malfunctions and emergency procedures;
6. performing circuit operations to an unlit area;
7. performing loss of visual reference procedures on landing and take-off;
8. performing inadvertent IMC penetration procedures and safe recovery to VMC flight, including a single pilot unusual attitude recovery, maintaining controlled flight within the limits stated in 'pilot training prerequisites'; and
9. perform a selection of practice aircraft emergency procedures, under NVIS conditions, applicable to the aircraft type.

The initial flight check can be completed as part of an approved NVIS flight training course. The initial flight check is to be conducted by an appropriately qualified instructor or examiner.

NVIS Crew Member All additional personnel required for the safe operation of the aircraft during an operation using NVIS must be required to wear approved NVGs and must receive ground and flight training as detailed in the training guidelines herein. Crew Members must also meet the following minimum qualifications/experience to qualify as NVIS crew members:

- Meet experience, standards, recency and qualification requirements as stipulated in the relevant exposition for day and night (unaided) operations for the relevant crew position and aircraft type; and
- meets any existing physical and medical standards prescribed by the operator's exposition; and
- have completed an approved NVIS ground theory course that follows a syllabus recognized by the Director. Appendix II of AC91-13 represents the minimum ground theory training (for both pilots and crew members), which is to be provided by a Part 141 or Part 119 organisation with NVIS ground training approvals; and
- subsequent to completing an approved NVIS ground theory course, complete an approved NVIS flight training course, minimum of 2 hours flight time, conducted by a Part 141 or Part 119 organisation with NVIS flight training and checking approvals. Appendix V of AC91-13 represents the minimum NVIS flight training to be completed by a crew member on an approved NVIS flight training course.

On meeting these requirements, such persons may be endorsed in the form of a certificate signed by a NVIS crew member Instructor certifying the NVIS qualification. This certificate is to be retained in the company's crew member files.

NVIS Recency flight experience

In order to meet the recent flight experience requirements under rule 61.37, a pilot with a night certification endorsement using NVIS must not act as PIC of an aircraft conducting a NVGO carrying passengers unless, within the preceding 90 days, the pilot—

1. Has performed 3 night vision goggle operations involving:
 - a. Three takeoffs and 3 landings as required by rules 61.37(c) & 61.37(d) using night vision goggles; and
 - b. each takeoff and landing must include a transition circuit between the take-offs & landings and an enroute segment or an area reconnaissance; and
 - c. for helicopters, 3 hovering tasks utilising night vision goggles. These tasks may be combined with the take off and landings required in paragraphs (a) and (b); and
 - d. the same type of aircraft in which NVGOs are normally performed; and
2. Demonstrates instrument flight proficiency to an appropriately authorised flight instructor or examiner, company pilot, or person approved by the Director, within the limits stated in 'pilot training prerequisites' (AC91-13, section 4.2.1). This instrument flight time is to include a simulated inadvertent IMC penetration and recovery to VMC flight. The method of instrument flight proficiency may be prescribed in an operator's exposition and must be recorded in accordance with those exposition procedures.

A pilot must not act as PIC of an aircraft conducting a NVG flight operation unless—

1. Within the preceding 120 days, the pilot meets the requirements of 1 above; and
2. Within the preceding 12 months, the pilot has logged one hour of NVIS flight time on the specific aircraft type/class.

A **NVIS Proficiency Check** (AC91-13, page 15) is to be completed by a PIC who does not meet the NVIS Recency requirements.

Additionally, **NVIS Recurrent Training** is to be completed by pilots/crew members on an annual basis. See AC91-13, Appendix VI for the minimum flight and ground training to be completed by a pilot or Crew Member on a NVIS recurrent training course. The proficiency flight check can be anticipated by up to 60 days.

Operating Limitations (As laid down in AC91-13)

- **Weather**

The meteorological limitations of CAR 91.301, 125.155, and 135.155 apply to all NVG Flight operations. NVIS is a tool for assisting flights under current VFR rules to increase safety, enhance situational awareness and reduce pilot workload and stress. NVIS is not a tool to enable additional capabilities in marginal VMC.

- **Minimum Heights**

Operating with a NVIS and using night vision goggles does NOT provide any exception to the minimum heights requirements for VFR flights prescribed in CAR 91.311, 135.85 and 135.93.

- **Overwater Operations**

Overwater operations and operations to small offshore islands, ships decks and offshore platforms, using NVIS below 500 feet above the surface, are not to be carried out unless procedures covering these operations have been established in the operator's exposition and accepted by the Director.

The procedures should address, at least, the following issues:

1. Sea state and wind velocity:
2. The ability of the crew to maintain continuous visual contact with the shoreline using NVG, including any illumination levels and potential hover references:
3. Any specific training and checking requirements above that required for overland NVG flight operations:
4. Availability of sufficient water/surface disturbance and/or surface objects which may provide adequate surface contrast to maintain depth perception which may assist the crew in maintaining a safe height:
5. Whether the crew are trained to use any height hold function or automatic hover function coupled to the automatic pilot/stabilisation equipment.

- **Carriage of passengers during NVIS flights or operations**

Persons who are not essential to the flight or operation must not be carried during NVIS crew training, qualification or proficiency flights. Trainees may be carried on any suitable NVIS flight operation.

- **Use of dissimilar NVG**

Where dissimilar type/models of NVGs are used, the PIC needs to wear the highest performance and capability level (in terms of resolution, gain and acuity) of NVG. The operator must establish procedures for the use of dissimilar NVG.

- **Operational Risk Management Procedures**

As part of any safety management system for the operation of an aircraft, a risk assessment needs to be done before any night vision goggle operation. The risk assessment needs to take into account at least the following:

- Illumination level of the flight environment
- Weather
- Recency of experience for pilot and crew
- Crew composition
- Operator/crew experience with NVG flight operations
- PIC field of regard
- PIC/crew rest condition and health
- Aircraft serviceability (MEL)
- Windshield/window condition
- NVG tube performance, battery condition
- Types of operation allowed and applicable SOPs
- External lighting environment.

US State Department Export Licence

For those NVGs that have been imported under a US State Department Export Licence, make yourself aware of the 'Limitations and Provisos' attached to each licence.

In particular take note of what types of tasking are permitted to be conducted (not for any "commercial operations"), and the security requirements for the NVGs.

Light, the Human Visual System and Spatial Disorientation

In order to appreciate how NVGs operate, it is important that you understand how the human visual system functions, and how various attributes of the human visual system may impact NVG operations.

Terminology

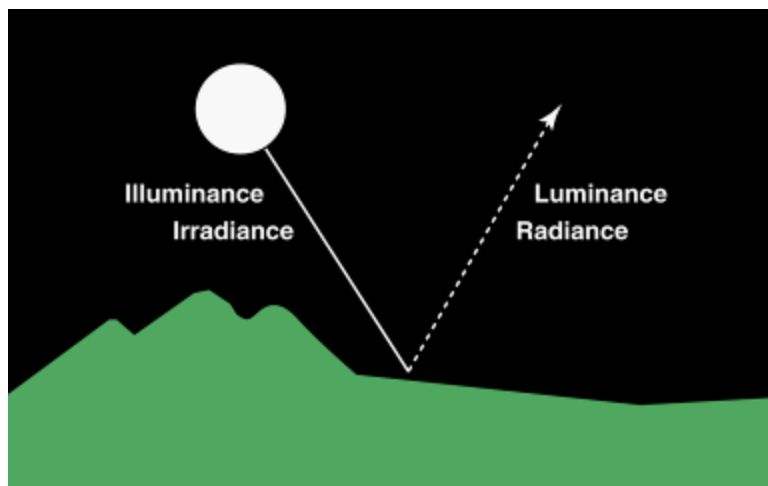
There are a few terms regarding the use of NVGs with which you should be familiar. The terms tend to be used interchangeably and, at times, incorrectly. It is not important to memorize the terms, but it is important to understand the concept the terms represent.

Before defining the terms, you should have a basic understanding of how NVGs operate. Goggles produce an image by gathering and intensifying available reflected energy. That is why NVGs will not function in total darkness, and why they do not perform as well on very dark nights, such as during overcast starlight conditions.

Since the eye uses reflected light to form an image, it may, at times, be helpful to compare the eye with NVGs. The main differences between the two lie in the fact that the eye uses only visible energy (light), whereas NVGs use both visible and near IR energy. In addition, goggles artificially intensify the energy they receive. This will be covered in greater detail later.

Illuminance/Irradiance and Luminance/Radiance

- Illuminance. The total amount of visible energy incident to a surface.
- Irradiance. The total amount of radiant energy incident to a surface.
- Luminance. The total amount of visible energy reflected from a surface.
- Radiance. The total amount of radiant energy reflected from a surface.



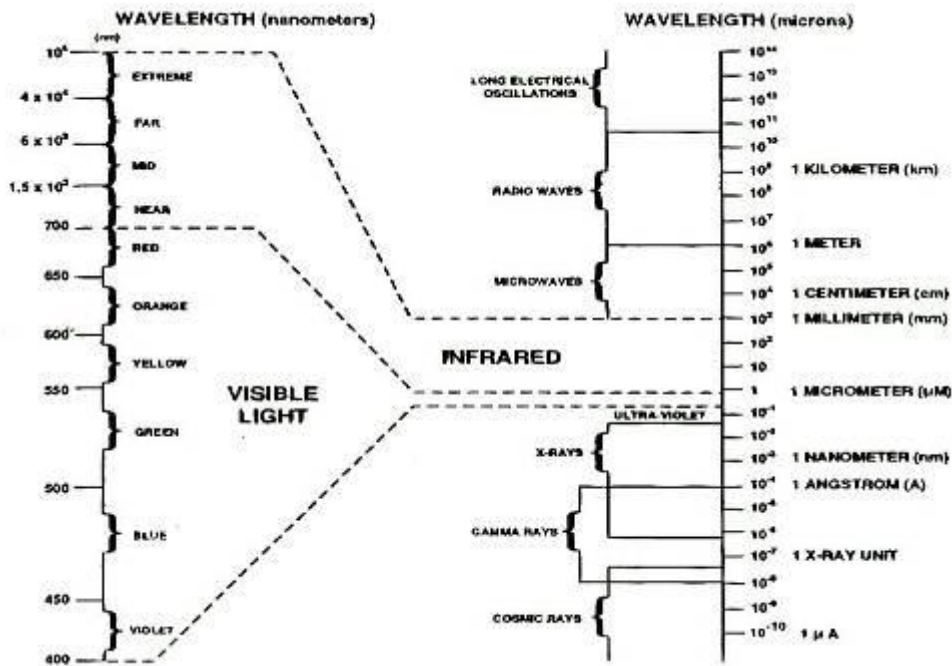
The terms illuminance and irradiance refer to energy produced from a source such as the sun or moon. The difference between the two terms is that illuminance refers to only visible energy (light), whereas irradiance refers to all radiant energy, e.g. near-IR energy as well as visible. The same is true for the terms luminance and radiance in that luminance refers to reflected visible energy, whereas radiance refers to all reflected radiant energy.

The correct terms help to reinforce that NVGs use reflected energy to produce an image, a fact that is important to understand when discussing their limitations.

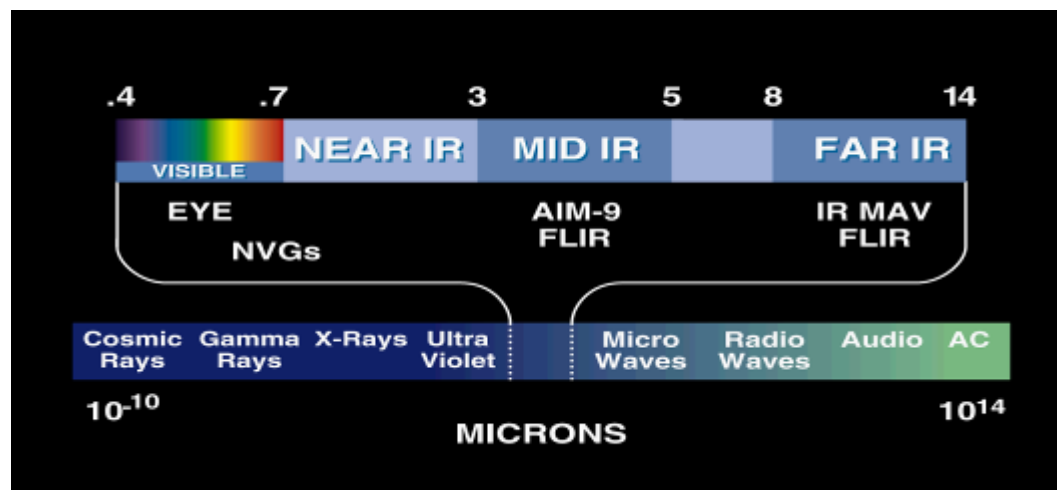
Electromagnetic Spectrum

To clarify differences between the eye, NVGs, and other sensors that are sensitive to radiant energy, and to understand how each is affected by environmental conditions, you should be familiar with the electromagnetic (EM) spectrum.

The EM spectrum contains the entire spectrum of all types of radiant energy. Since radiant energy refers to energy transmitted in wave form, the various components are placed in sequence based on the lengths of their wave forms. Since visible and IR energy are both forms of radiant energy, they are placed in the spectrum at locations appropriate to their respective wavelengths.



The diagram below is used to demonstrate where the eye, NVGs, and other sensors fit into the EM spectrum. The lower portion of the diagram is broken into various categories of radiant energy, with those having the shortest wavelengths on the left. The length of individual wavelengths can vary from as short as one micron (one millionth of a meter) or one nanometer (one-billionth of a meter), to as long as several kilometers.



The portion of the diagram that includes both visible and IR energy has been expanded to see where in the EM spectrum those wavelengths are located. The top of the diagram lists the wavelengths of the various sections in microns. For example, visible energy is in the 0.4 to 0.7 micron range, and near-IR energy is in the 0.7 to 3.0 micron range. Thermal imaging systems, such as forward looking infrared (FLIR) systems, are sensitive to energy in the mid-IR and far-IR regions.

Environmental constituents such as humidity and smoke affect radiant energy as it passes through the atmosphere, and the effect is largely dependent on the wavelength of the energy. By having an idea of the wavelengths to which various sensors are sensitive, and knowing the relative position of those wavelengths in the EM spectrum, you will be able to understand why one sensor may function better than another under certain conditions.

Atmospheric Effects

The most important environmental influence on electromagnetic energy is the atmosphere. As radiant energy wavelengths pass through the atmosphere, the constituents that make up the atmosphere can affect the wavelengths in various ways, and each constituent can have a different effect. The most important effect can be a reduction, or attenuation, of the wavelength's energy level. This can result in less energy reaching a sensor, which, in turn, can affect how much information is presented by the sensor's image. The degree of attenuation is dependent on several factors:

- **Wavelength** Various atmospheric constituents, such as water vapor or carbon dioxide, affect some wavelengths more than others. For example, NVGs are responsive to wavelengths that are shorter than the wavelengths to which FLIR sensors are sensitive (NVGs operate better than FLIR systems in areas of high humidity).
- **Constituent Size** The difference in size between various types of atmospheric constituents (e.g., raindrops versus fog droplets) is another factor. The shorter wavelengths, relative to NVGs, to which the eye is sensitive, are partially blocked by light moisture, thus making a thin fog layer easily visible. However, the longer wavelengths to which NVGs are sensitive pass readily through the light moisture, thus making the thin fog bank virtually invisible.
- **Constituent Volume** The relative volumes of the various constituents are yet another factor. For example, it is possible to see through a light rain shower when driving a car but a heavy rain shower (i.e. more volume) may block all visible information. The same concept holds for NVGs, no matter what the atmospheric constituent (e.g., rain, smoke, dust, haze or fog). Given these effects, it is important to understand that not all wavelengths are affected the same way or to the same degree.

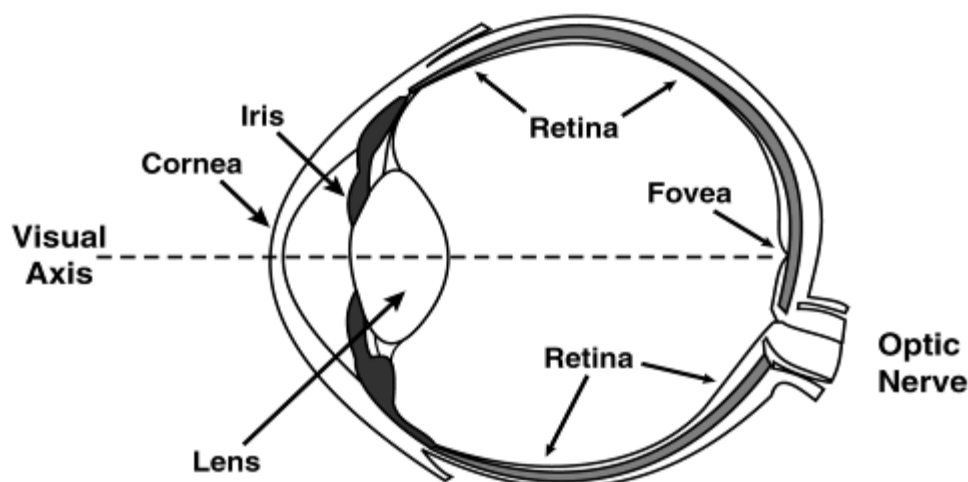
Anatomy of the Eye

The purpose of this section is to identify what is relevant to the use of NVGs. The key discussion item concerns the "visual axis" and its importance to proper NVG alignment and adjustment. In order to obtain the best visual acuity possible when adjusting NVGs, it is vital to align the "optical axis" of the goggle with the eye's visual axis.

"Alignment techniques" will be thoroughly covered during the hands-on adjustment training phase of the course. In addition to the visual axis, it is worthwhile to reconfirm the purpose of the fovea since it is with foveal vision that the NVG image is interpreted. The relevance to NVGs is associated with the increased risk of spatial disorientation when attempting to simultaneously perform several functions that require conscious thought (e.g., interpreting the NVG image, deciphering a radar/EFIS display, scanning the flight instruments, etc). The end result of this potential "task saturation" could be misinterpreting or not seeing critical information.

Note that the F4949 NVG has a diopter adjustment, although this adjustment will not make up for any problem associated with the curvature of the cornea (astigmatism). Since most spectacle wearers have an astigmatic correction as well as a near/far distance correction, you would therefore need to wear spectacles (or contacts) when using NVGs.

Eye Components:



- **Cornea.** The cornea is the clear, curved, outer surface of the eye that is responsible for most of the focusing of the image perceived by the individual. An abnormal curvature of this surface is called “astigmatism” and may necessitate the use of spectacles.
- **Iris.** The iris consists of muscles that control the size of the pupil. When there is a lot of light, the muscles will constrict the pupil to keep too much energy from reaching and possibly damaging the retina. When there is less light, the muscles allow the pupil to become enlarged, or dilated, so that more energy may reach the retina – decreasing the sharpness of an image.
 - **Note:** Pilots may not need to wear glasses during daylight viewing conditions when the pupil is small; however, at night, the pupil becomes larger causing vision to blur.
- **Lens.** The lens consists of soft, clear tissue that, through changes in its shape, accomplishes “fine tuning” of the image onto the retina. The shape of the eyeball, aging, and other influences such as the sun, have varying effects on the lens’s capability to focus an image onto the retina. These effects can result in the need for spectacles to improve near and/or distant vision.
- **Retina.** The retina is the inside surface of the eye onto which the image is focused. It contains all the components necessary for changing electromagnetic energy into signals the brain can use to interpret the visual scene.
 - **Rods & Cones** The retina consists of ten layers, one of which is the Jacob’s Membrane which contains the photoreceptor cells, rods and cones (named because of their shape). These photoreceptor cells translate light images into electrical impulses for transmission via neurons to the brain.
 - Cone cells (7 million, each connected to a single neuron cell) are responsible for day, high-light, high resolution vision and allow you to identify colours i.e. used primarily during daylight hours or when a bright light source is present.
 - Rod cells (120 million) populate the peripheral retina area (17° to 20° offset from the fovea) and are responsible for low level light (night) vision. They cannot sense colour, but are 10 000 times more

sensitive to light than the cone cells. The decreased visual acuity and colour sense is due to the increase ratio of rod cells to neuron cells (compared to the cone cell ratio).

○ **Retinal Blind Spots**

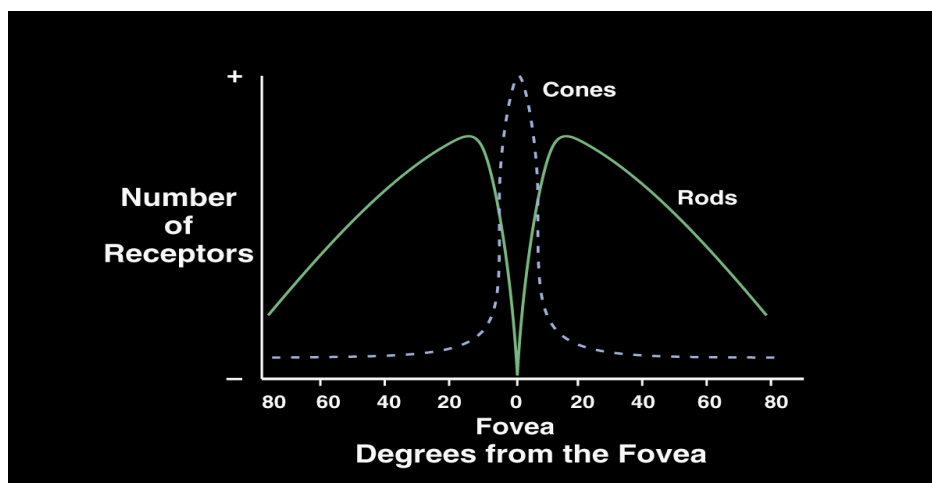
- Day blind spots are in the area of the optic disk caused by an absence of photoreceptor cells (rods and cones). It covers an area of 5°-7.5° degree field.
- Night blind spots occur in and around the central viewing axis (parafovea) where there is an absence of rod cells, and is due to the inability of cone cells to function under low ambient light conditions. Covers an area from 5°-10° wide in the centre of the visual field.
 - Therefore: use off-centre viewing techniques to maintain visual sighting of objects and hazards.
- **Fovea.** The fovea is a small portion of the retina (which contains only Cone cells) that is approximately two degrees in size and is responsible for best visual acuity.
- **Visual axis.** The visual axis is the “line of sight” along which reflected energy from objects in the visual field reaches the fovea, thus allowing them to be seen with the best visual acuity. It is vital to align the visual axis correctly with the goggle’s optical axis in order to maximize NVG performance. This will be described in detail during adjustment procedure training.

Visual Deficiencies

- **Astigmatism** An unequal curvature of the cornea resulting in the inability to focus on different meridians simultaneously such as vertical and horizontal objects e.g. being able to focus on power poles but not the power lines (or vice-a-versa).
- **Hyperopia** (far-sightedness) is the condition caused by a refractive error in the lens, which focuses near objects behind the retinal plane.
- **Myopia** (near-sightedness) is the condition caused by a refractive error in the lens, which focuses near objects in front of the retinal plane.
- **Presbyopia** occurs when the natural aging process affects the human eye causing the lens to lose its elasticity resulting in an inability of the eye to focus on near objects.

Types of Vision

It is important to review the three types of vision in order to understand some of the operational issues regarding NVG use (e.g., dark adaptation after NVG removal, peripheral vision while wearing NVGs, etc.).



The graphic shows the distribution of rod and cones throughout the retina and is drawn with the middle of the lower axis representing the fovea. The dashed line represents the distribution of cones and the solid line that of rods.

- **Photopic Vision (Day)**

Cone cells are responsible for providing colour vision and maximising visual acuity. There are approximately seven million cone cells distributed throughout the retina but most are located near or within the fovea. Each cone cell is connected to a single nerve cell, thus localising the impulse to a very small area that results in maximising acuity. Visual acuity is maximised in the fovea because that is the location of most of the cones. Peripheral to the fovea (peripheral vision) there are less cones and acuity is degraded. However, because there are cones scattered throughout the retina, colour can be perceived in the periphery. For cone cells to function appropriately there must be enough energy to stimulate them (e.g. daylight). However, any artificial light, such as a reading lamp or the NVG image, which is powerful enough, will stimulate the cones. When there is not enough energy, the cones will not function, colour vision will be lost, and visual acuity will be degraded.

In photopic vision, distance estimation takes place through the focus of both eyes, referred to as 'stereopsis'.

- **Scotopic Vision (Night)**

There are approximately 120 million rod cells, which allow greater coverage throughout the retina (except for the fovea where there are essentially no rod cells). Each rod cell is roughly 10,000 times more sensitive to light than a cone cell, and this increased sensitivity allows for some reaction to the weak energy levels present in the night environment. In an effort to amplify the nerve impulse, several rod cells share the same nerve cell to create a "recruiting" or "summation" effect. This results in spreading the nerve impulses over a larger area thus **reducing acuity**. Though these characteristics help maximise night vision, "typical" unaided night vision (20/200-400) is considerably poorer than "normal" day vision (20/20).

Additionally, unaided night vision is subject to being degraded under high light conditions, there is an absence of colour discrimination, and there is a night blind spot caused by the lack of rods in the fovea.

- **Mesopic Vision (Intermediate)**

Mesopic vision is an intermediate state in which both rod and cone cells are stimulated. The energy present is not enough to completely degrade rod cell function, but also is not enough to maximise the effectiveness of cone cells. There is a wide range of light levels where the stimulation of both types of cells takes place (e.g. dawn and dusk).

During periods of lower illumination, visual acuity and colour discrimination are degraded over that experienced during periods of higher illumination levels. Studies of automobile accidents have shown that many accidents occur during dusk because drivers think they can see better than they actually are able (a problem similar to that noted by inexperienced NVG aircrew).

Aircrew view the NVG image with foveal vision (i.e. cone cells), as evidenced by seeing a green image. The brightness of the image is set at a point to maximise interpretability, but as the image brightness decreases during low illumination conditions so does acuity. Also, since the rod cells are only slightly degraded by the brightness of the image, they maintain some function and recover after removing the NVG image.

Correct Night Vision Viewing Techniques

- **Scanning**
 - Stop-turn-stop-turn technique – starts approximately 500 metres out and continues the scan (side to side) working closer until just in front of the aircraft.
 - 10° circular overlap with only 2-3 second stops (to prevent the image being bleached out by rhodopsin).
- **Off-centre viewing**
 - Used to compensate for the night blind spot.
 - View an object by looking 10° above, below or to either side of the object in order to use peripheral vision.

Dark Adaptation

- **Unaided Adaptation Time**

Dark adaptation refers to the eye's capability to adjust to a darkened environment. It is a matter of the rod cell's ability to regenerate rhodopsin, a chemical that is very sensitive to light. The chemical is easily broken down by increased light levels, thus degrading rod cell function. Though there is a wide physiological variation among individuals in the time required for the chemical to regenerate, the average time to reach maximum sensitivity is approximately 30-45 minutes. Use red light sources as rod cells are least affected by the wavelength of dim red light.

The time for regeneration can also be impacted by other variables. Bright sunlight reflected from a sandy beach or from snow can dramatically increase the time necessary for rod cells to recover. After prolonged exposure to bright light, it can take several hours of dark adaptation to regain the same level of unaided night vision performance normally expected after less than an hour. Wearing sunglasses helps avoid this potential problem.

- **Aided Adaptation Time**

The eyes are in a mesopic state during NVG use, which means rod function is not completely degraded. Therefore, the times required to dark adapt after removing or turning off the NVGs is lessened. Nonetheless, reverting from aided to unaided operations will require some adaptation time in order to maximize unaided visual acuity.

A good rule of thumb, based largely on operational experience, is to allow approximately 30 seconds to 5-10 minutes prior to relying on unaided vision for any reliable information. As with unaided adaptation time, aided adaptation time varies due to physiological and external factors (exposure to very bright light sources during the day, etc).

Limitations of Night Vision – Summary

- **Depth Perception**
 - Perception may be that you are higher in altitude than you actually are – especially during low level operations and approach & landing.
 - Use other visual cues (instruments, unaided peripheral vision) and proper crew coordination (if manned with crew members).
 - See page 17.
- **Visual Acuity**
 - Visual acuity (with or without corrective lens) should be close to 20/20 during daylight but degrades to 20/200 at night.
 - Pre-flight planning is fundamental when completing night flight operations – identify and highlight any obstacles and hazards (via map preparation and/or day reconnaissance).

- **Blind spot**
 - Day (5.5° by 7.5°) versus night (5°-10° wide in the centre of the visual field).
 - Use of correct scanning techniques.
- **Dark Adaptation**
 - As above.
- **Colour Vision**
 - Cone cells inactive during low light levels so you may only see shades of grey, black and white.

Methods Used To Protect Night Vision

- Wear sunglasses when exposed to high ambient light or in combination with light reflecting off water, snow or sand.
- Adjust cockpit lighting to lowest readable level.
- Adjust internal cabin and external lighting to lower levels.
- Cover (or close) one eye if exposed to any bright light sources.
- Avoid brightly lit areas.
- Healthy nutrition.
- Good levels of hydration.

Self Imposed Stress Factors and Night Vision

- **Drugs**
 - Consult DME for use of any medications. Self medication not authorised.
 - Decreased awareness levels, reaction times and degradation of motor skills.
 - Possible illness.
- **Alcohol**
 - Impairs the brain, even in small amounts. The eye is an extension of the brain, and is affected more than any other part of the body or brain.
 - Inhibited dark adaptation and peripheral retina due to loss of oxygen (histotoxic hypoxia).
 - Alters and slows coordination of complex tasks.
 - Detrimental effect on judgement, perception, reaction time, coordination and correct scanning techniques (tendency to stare at objects).
 - One ounce of alcohol will place you at 2 000 feet physiologically. Can be long lasting physiological effects.

Note: CAR 19.7:

No crew member while acting in their official capacity shall be in a state of intoxication or in a state of health in which their capacity to act would be impaired by reason of them having consumed or used any intoxicant, sedative, narcotic or stimulant drug or preparation.

- **Tobacco**
 - Carbon monoxide replaces oxygen in the blood, decreasing the blood/oxygen to the eyes (Hypemic Hypoxia), causing a greater degradation in the peripheral retina (rod cells).
 - Movement detection and orientation is also reduced (in the lower mesopic vision).

- Smokers who have not smoked recently need 1.5 times the light of a non-smoker to see objects. Smokers who smoke prior to flight need twice the light of a non-smoker to see objects.
- If a smoker smokes three cigarettes in rapid succession (or 20 – 30 in a 24 hour period) raises the CO content of the blood to 8-10%. The physiological effect at ground level is the same as flying at 5000ft i.e. the smoker has lost 20% of the night vision capability at sea level.
- The greatest threat to night vision is Hypemic Hypoxia.
- **Exhaustion**
 - Lack of rest, sleep, exercise or broken sleep cycles can lead to lack of concentration and attention.
 - Ineffective night vision viewing techniques related to staring and lack of awareness.
- **Nutrition**
 - Meals are the natural sources for glucose → don't skip meals as this can lead to low blood sugar levels, resulting in hunger pains, distraction, breakdown in habit patterns and shortened attention span.
 - Vitamin A is essential to the eye's ability to process low light levels (vitamin A deficiency hinders rhodopsin production). Green leafy vegetables provide the best source of Vitamin A & orange coloured veges are also good.
 - Don't overdo supplement taking as you are only trying to PROTECT your night vision and not ENHANCE it.

Cues to Depth Perception

- **Binocular Cues** Each eye has a slightly different view of an object when the object is close enough to make a perceptible difference in the viewing angle of both eyes. Usually these cues are of little value when flying due to the distances involved. Binocular cues operate on more of a subconscious level compared to monocular cues.
- **Monocular cues** When objects are seen as one image. They are derived from experience and are subject to interpretation.
 - **Geometric perspective** occurs when objects appear to have different shapes when viewed at varying distances:
 - **Linear Perspective** Parallel lines tend to converge as distance from observer increases (e.g. railway lines).
 - **Apparent foreshortening** The shape of an object appears elliptical from a distance, but as distance is decreased the true shape is revealed.
 - **Vertical position in the field** When objects or terrain features that are further away appear higher on the horizon than those that are closer to the observer.
 - **Retinal Image Size** Occurs when an image is focussed upon the retina and is perceived by the brain to be of a given size:
 - **Known size of image** The closer an object is to an observer, the larger its retinal image. The brain learns, through experience, to estimate the distance of familiar objects by the size of the retinal image.
 - **Increasing or decreasing size of objects** is used to judge whether an object is moving towards or away from an observer by its increasing or decreasing retinal image size.
 - **Terrestrial association** is the comparison of one object with another object of known size to help determine the relative size and apparent distance of the object from the observer.
 - **Overlapping contours** when objects overlap and the hidden obstructed/hidden object is further away.
 - **Aerial Perspective** Distant information can be gained by the clarity of an object or by the shadow that is cast by an object:
 - **Fading colours or shades** Objects seen through haze, smoke or fog are seen less distinctly and appear to be at greater distances than they actually are. If there is a very clear day/night, allowing unrestricted transmission of light, then objects can be seen more distinctly and appear to be closer than they actually are.
 - **Detail and texture** is lost or is less apparent with increasing distance.
 - **Lights and Shadows** If a shadow is cast towards an observer then the object is closer than the light source (required to produce the shadow).
 - **Motion Parallax**
 - **One of the most important cues to depth perception.**
 - The apparent, relative motion of stationary objects as viewed by a moving observer.
 - Near objects appear to move past or opposite the landscape. Far objects seem to move in the direction of motion or remain fixed.
 - The rate of apparent movement depends on the distance the observer is from the object.
 - Rapidly moving objects are judged to be near while slow moving objects are judged to be distant.

Visual Illusions

The visual system is the most reliable of the senses. With all the above information so far on the mechanics of the eye, it is important to remember that the brain has to interpret the scenes based upon certain rules and criteria that have been learned over the experience of the individual.

When the brain misinterprets its reference, or visual information decreases, the probability of spatial disorientation increases.

The most likely visual illusions are:

- **Relative Motion illusion** Relative motion between the observer and a nearby moving object may cause confusion as to which is actually moving. Be aware they can occur and don't overreact on the controls.
- **Confusion with ground/star lights** can occur in rural/coastal areas, resulting in the a/c being put into an unusual attitude. Mitigated by referring to the a/c instrumentation (AI, A/H, etc).
- **False Horizons** when vertical or horizontal cues other than the actual horizon are interpreted as being horizontal/vertical e.g. ridge lines, cloud formations or coastlines.
- **Height/Depth perception illusion** Flight over featureless terrain (water, snow) can lead to incorrectly assessing the actual height above terrain due to the lack of visual references.
- **Structural illusion** caused by curved glass, heat waves, rain, snow or any other disturbance of the environment through which we see. The distortion/disturbance may produce curving of the horizon or duplication of lights. E.g. rain on the windshield may make a runway 0.5nm away appear to be 200ft lower than it actually is.
- **Autokinetic illusion** can occur, due to lack of visual references, when you stare at a light in the void of darkness and the light may appear to move. Prevented by not fixating on the light → use off-centre vision and scanning.
- **Size-distance illusion** occurs when there is a false perception of distance from an object or the ground i.e. when a pilot sees an unfamiliar object's size to be the same as an object they are normally accustomed to seeing. E.g. If used to approaching a 200' wide by 5000' long runway, he may fly too low if making the same approach to a smaller airstrip of 100' wide by 2 000' long.
- **Flicker Vertigo** occurs when a light flickers at a rate of 4 to 20 cycles per second e.g. sunlight flickers through the rotor disc. It is more of a condition than an illusion. Can cause nausea, vomiting, convulsions and unconsciousness. Fatigue and boredom can contribute to flicker vertigo.
- **Fixation** occurs when crew ignore orientation cues and focus their attention on their object or flying goal. They become so engrossed on an object they are looking at, that they delay gaining height until too late and impact the ground (target hypnosis). Also occurs if you become mentally fascinated with something in flight, such as assisting a crewmember with some task, or when concentrating had on doing the next manoeuvre correctly, that we forget to fly. Maintain correct scanning techniques and 'fly the a/c'.
- **Reversible perspective illusion** can occur a night. An a/c may appear to going away when it is actually approaching, experienced when aircrew see another a/c flying a parallel course → observe the a/c position lights.
- **Altered planes of reference** can occur when aircrew approach a line of clouds or mountains; the planes of reference are altered → may feel the need to climb even though their altitude is adequate. Pilots may tend to tilt away from clouds when flying parallel to a line of clouds. Negated by reference to a/c instrumentation.

Spatial Orientation

It is vital to appreciate how too much dependence on the NVG image may lead to spatial disorientation, a problem that has been implicated in a number of NVG-related mishaps. Primary control of one's ability to move and orient themselves in three-dimensional space, i.e. spatial orientation, is mediated by the visual system. Functionally, vision must be considered as two separate systems, focal vision and ambient vision.

Focal vision is primarily responsible for object recognition, and ambient vision is primarily responsible for spatial orientation.

- **Focal Vision**

Focal vision is limited to the central two degrees of vision, i.e. the fovea, and is primarily a conscious function. Focal vision allows one to see clearly in order to recognise objects and read displays. However, since it requires conscious thought it is a relatively slow process.

Focal vision is thus not primarily involved with orienting oneself in the environment, but can be used to acquire visual information about orientation. For example, in degraded visual environments such as night or in weather, aircrew will depend on reading cockpit instruments in order to orient themselves. The point should be made that this is not a subconscious function but requires conscious effort.

- **Ambient Vision**

Ambient vision refers to a component of vision outside, or peripheral to, the fovea, hence the term "peripheral vision". Ambient vision is essentially a subconscious function, the primary role of which is to orient an individual in the environment, and it is independent of the function of focal vision.

For example, one can fully occupy focal vision by reading, a conscious action, while simultaneously obtaining sufficient orientation cues from peripheral vision, a subconscious function, to walk or ride a bike.

In order to use the tremendous amount of information being generated by ambient vision, the information is processed extremely rapidly, especially when compared to the processing time required for focal information.

You need to understand the basics of focal and ambient vision, and how NVGs fit into the picture, to fully comprehend the trade-offs of depending upon focal vision for spatial orientation.

Spatial Disorientation

Anything placing a higher demand on or degrading **focal** vision will **increase** the risk of spatial disorientation.

Some of the more common contributing factors that affect focal vision, and therefore could contribute to the onset of spatial disorientation during the use of NVGs, include the following:

- **Degraded Visual Environment**

Both aided and unaided acuity is degraded relative to normal day vision. Therefore, just the nature of doing business at night and/or using NVGs increases the risk of spatial disorientation. Additionally, anything that causes the NVG image to worsen, such as decreased illumination levels or atmospheric obscurants, will, in effect, further increase the risk of spatial disorientation.

- **High Task Loading/Saturation**

Interpretation of the NVG image requires focal vision, which means aircrew must "time share" the available focal vision processing time with many other tasks requiring conscious effort. Some of the more important of these include: aircraft control, crew coordination, navigation, terrain avoidance and communication.

Unfortunately, there is only so much that can be mentally processed effectively. This increase in task loading may result in saturation, at which point aircrew, for example, may

not perceive an important object in the NVG image or may not process a change in altitude/attitude.

- **Reduced Performance Capability**

Conducting business at night, whether or not NVGs are used, increases the risk of spatial disorientation due to such factors as fatigue and working outside the body's normal operating envelope.

Avoiding Spatial Disorientation

Perhaps the most important way to avoid spatial disorientation when using NVGs is through sound training and extensive experience. However, it may take a long time to accumulate NVG experience (especially in some aircraft), and, unless you fly in many different environments on nights with varying conditions, an "extensive" experience level may never be reached. Therefore, it is paramount to gain as much experience during training as possible. The following are recommended items to learn the value of during initial training and to apply during operations:

- **Instrument scan**

You need to be aware that NVG flight is only a heartbeat away from instrument flight. The NVG image can be degraded or eliminated by any number of sources (e.g. flying into weather, looking into a bright light source, possible goggle or battery failure etc.). When this occurs, it is necessary to immediately transition to instrument flight in order to maintain spatial orientation and situational awareness.

If you are not instrument qualified, consider it. Otherwise, get some instrument training and learn how to rely on those instruments.

Note: 10 hours dual Instrument training is required as part of a night, unaided, cross-country rating.

An aggressive instrument scan should be part of all NVG operations regardless of illumination levels, flight altitudes or mission profiles. In order to effectively scan and transition to instruments, instrument lighting must be set at a level facilitating readability. Incidents have occurred where aircrew have failed to note degraded flight instrument readability until an emergent situation arose. In some cases, the inadvertent loss of good instrument readability occurred because aircrew were relying too much on the visual information provided by the NVGs.

When conditions deteriorate at night, be ready to commit to the instruments and commit to instrument flight.

Inadvertent IMC AT NIGHT IS AN EMERGENCY.

If you even suspect that you are having spatial disorientation, use the instruments until you feel you can transition back to visual flight.

- **NVG Scan**

The greatest advantage NVGs offer is to allow aircrew to view the outside scene and the most important item in the outside scene that contributes to spatial orientation is the horizon. By constantly scanning the horizon and always seeking the horizon during aggressive manoeuvring, aircrew can avoid disorientation. This requires concentration and good habit patterns, which should be emphasized and developed during training. Without a good horizon, more dependence will be placed on the instrument scan, just like daytime flights.

Note: There are various **NVG scans**:

- Scanning within the NVG picture;
- The scan involving moving the whole NVG picture;
- The scan 'outside' the NVG picture utilising peripheral vision and/or direct viewing of a/c instrumentation; and
- The scan in/out of the NVG picture.

- **Scanning in forward flight.** To scan effectively look from left to right, or right to left. Begin scanning at the greatest distance an object can be perceived (top) and move inward toward the position of the aircraft (bottom).

The eyes should lead every turn of the head.

If an object of interest enters the FOV, by the time the head stops moving, the object should be close to the centre of the picture. The duration of the stop is based on the degree of detail that is required, but no stop should last longer than 2 -3 seconds.

- **Scanning in the Hover.** Large, rapid changes of head position should be avoided as balance and spatial orientation are so much more important in the hover. As for forward flight, ***the eyes should lead every turn of the head***, but in the hover if large changes in head position are required then this should be accomplished by 'leap-frogging' the FOV i.e. first move the eyes to the edge of the FOV and focus on an object, then shift the picture in the desired direction and repeat as required. Without this positive anchoring of the eyes you remain at the mercy of the inner ear, which is dangerous.

- **Mission Planning**

Proper mission planning may help avoid surprises and thus eliminate or reduce the potential for spatial disorientation. For example, knowing the moon angle and being familiar with the terrain will allow aircrew to avoid inadvertently entering a shadowed area, the result of which may be suddenly losing the horizon and/or ground detail. If flying in an unfamiliar area, thorough map study during pre-flight preparation will also help.

Note: Moon phases, moonrise and moonset times can be found in daily papers or on internet sites such as www.hydro.linz.govt.nz/astro/index.asp.

- **Attention to Environmental Changes**

Another pre-flight item of particular importance to NVG use is the weather briefing. Being aware of current weather conditions and being familiar with local weather patterns may help aircrew avoid inadvertent weather entry, an event that has been implicated in several NVG-related mishaps. Additionally, subtle changes in the quality of the NVG image may indicate possible changes in the outside environment e.g. slight reduction in contrast due to reduced illumination caused by flight into light fog, or increase in scintillations (discussed in more detail later).

- **Proper Rest**

When fatigued, aircrew can inadvertently omit critical scan items or, if significantly fatigued, can fail to process vital information even if scanned. Due to the effects of working during night-time, and the increased focal vision task loading, aircrew are more susceptible to the effects of fatigue when conducting NVG operations. Proper rest is paramount to help avoid this potentially hazardous situation.

THE BEST ADVICE:

Stay well trained, rested, proficient and informed. It is the best way to avoid all visual illusions and spatial disorientation.

Additional Considerations

There are other considerations to think about when discussing the human visual system in conjunction with NVGs. Two of the more important ones include:

- **Individual Visual Acuity with NVGs**

Approximately 15% of aircrew members have substandard visual acuity with NVGs. In other words, they cannot see with NVGs as well as expected, and this can happen even though their day vision may be 20/20 or better, corrected or uncorrected. This is generally discovered during adjustment training when the individual cannot obtain the same visual acuity as other students when using the same NVG under the same conditions.

One cause may be an incorrect vision prescription (prescription for their spectacles or contacts is old?). In this case it may be good to recheck the aircrew after a new prescription is acquired. In other cases, it may be impossible for the student to obtain the same visual acuity as others regardless of how much time is spent training, and the cause may not be obvious. One possible explanation is the emergence of a defect in the cornea that is normally hidden during daytime when the pupil size is considerably smaller. However, this is speculation at best and the root cause will be the subject of future studies. In the meantime, should the problem surface during training, it is recommended that the student be corrected to their best possible visual acuity.

- **Contact Lens**

Due to the eye relief limitations of NVGs and the great variety in facial dimensions among individuals, contact lenses have worked well for NVG aircrew. For example, the use of spectacles may not allow the user to maximize the NVG field of view.

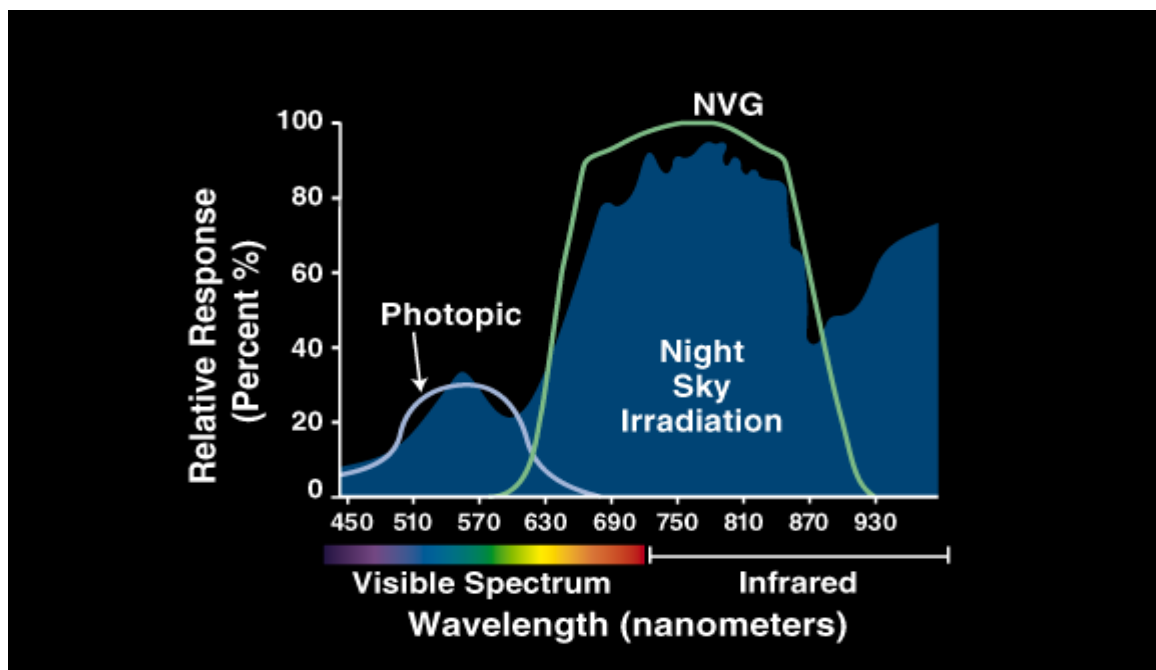
Introduction to Night Vision Goggles and Environmental Factors

Fundamentals of Night Vision Goggle Operation

Both the eye and NVG use reflected energy. That is, each sees objects and discriminates between objects based on differences in the objects' reflective characteristics. However, the ability of NVGs to create an image during night-time is much better than the eye's due to two factors:

1. NVGs are sensitive to a greater range of available energy in the night sky.
2. NVGs intensify the available energy to which they are sensitive.

Sensitivity Range of Eye and Night Vision Goggles



The diagram demonstrates where in the electromagnetic spectrum lies the sensitivity ranges of both the eye and the NVG. The horizontal axis shows where visible light wavelengths start and end, and where infrared wavelengths begin. NVGs are sensitive to both visible and near-IR wavelengths. Even though the near-IR spectrum extends from approximately .7 to 3 microns, Gen III NVGs are sensitive only to wavelengths just beyond .9 microns. Design considerations and decreasing levels of reflective energy limit NVG sensitivity to this area of the spectrum.

Night Sky Irradiation

The area depicted under the curve (above) represents electromagnetic energy present in the night sky. The predominate form of energy is in the near-IR region, so NVGs were designed to take advantage of this fact.

Illumination Sources

There are many sources of both natural and artificial illumination in the night sky to which the NVG is sensitive. You should be aware of the more familiar sources and understand how they contribute to NVG function.

- **Natural Sources of Illumination**

- **Moonlight.** Moonlight provides the greatest percentage of illumination present in the night sky. Moon angle changes 15° per hour (1° every 4 minutes).
- **Chemical Reactions.** Chemical reactions in the upper atmosphere account for the majority of near-IR energy present on a moonless night.
- **Starlight.** There are about 8000 stars that are visible to the unaided eye and approximately 2000 of them are visible on any given night from either hemisphere. Though stars contribute some visible light, most of their contribution is in the form of near-IR energy. This can be appreciated by looking at the night sky with NVGs and noting how many more stars can be seen compared to viewing with the unaided eye.
- **Solar Light.** Ambient light from the sun can be used by NVGs at certain times following sunset and before sunrise. This light can also degrade the NVG image, when the sun is higher than 12° below the horizon i.e. before End of Evening Nautical Twilight (EENT).

EENT occurs (in NZ) approximately 30 minutes after end of evening civil twilight (EECT). EECT occurs about 30 minutes after the sun rotates below the horizon. Some solar light is available until the end of evening astronomical twilight (EEAT).

- **Artificial Sources of Illumination**

Depending on where NVG operations take place, there can be many sources of artificial illumination. Some of the more important sources include: city lights, industrial sites, fires, flares, or searchlights. Most of the artificial sources contain energy in the form of visible wavelengths.

F4949 Components and Operational Sequence

Objective Lens

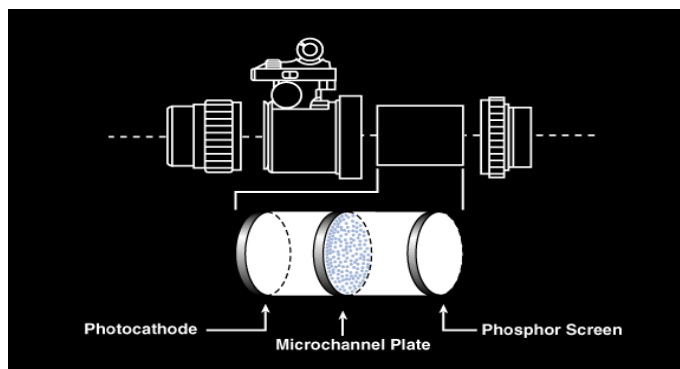
An optical element that gathers light and can be focused for the distance of an object. The objective lens contains a 'minus-blue' coating which filters out light from the aircraft instrument panel.

Eyepiece lens

The function of the eyepiece lens is to focus the image from the fibre optic inverter onto the eye by adjusting for individual eye acuity, using the eyepiece focus rings.

Image Intensifier Assembly

The discussion so far has centred on the wavelengths and illumination sources to which NVGs are sensitive. The image intensifier is the component in the goggle where the intensification process takes place. It is very small and lightweight when compared to the rest of the NVG hardware. Most of the weight in the NVG is comprised of optical components and supporting structure.



The graphic shows where in the goggles (monocular depiction) the image intensifier is located.

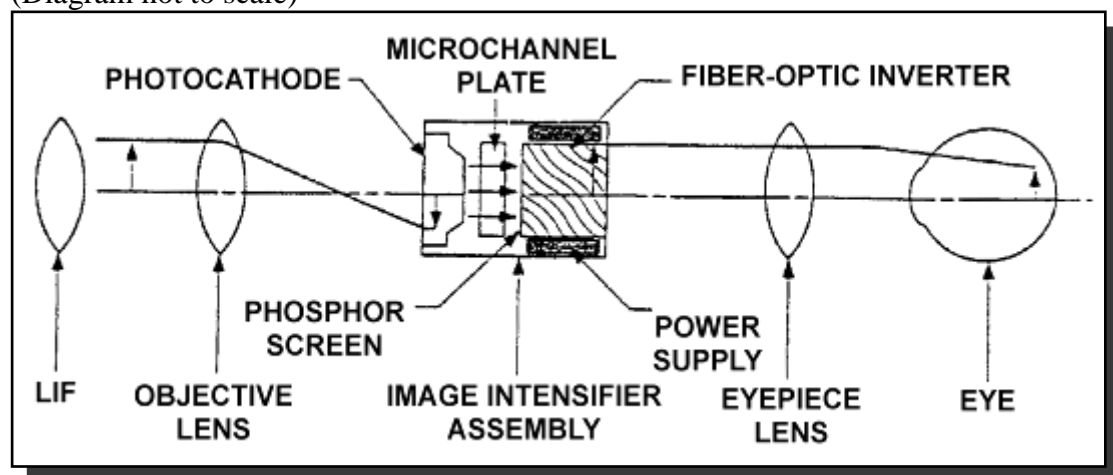
Image intensifier tubes are manufactured with electrical regulatory circuits that counter the constant exposure of the image intensifier tube to bright light sources that ultimately could result in damage to the photocathode and microchannel plate (MCP).

The power supply to the image intensifier tubes has been designed with two automatic protection features designed to control the gain of the intensifier tube.

- **Automatic brightness control (ABC):** automatically adjusts MCP voltage to hold eyepiece brightness to a preset level for a full range of ambient illumination levels by controlling the number of electrons which exit the MCP. This protects the viewer from bright flashes and provides sufficient light to the viewer under low ambient light conditions.
- **Bright source protection (BSP) circuit:** limits the number of electrons leaving the photocathode by reducing the voltage between the photocathode and the input side of the MCP. This feature automatically activates when high input light levels cause excessive photocathode current to flow. The BSP circuit is extremely important because the service life of a tube is largely a function of the photocathode service life. Photocathode life span is severely limited by ion contamination from the MCP. The higher the light input, the more ions are generated and the shorter the life expectancy of the tube.

Image Intensification Process

(Diagram not to scale)



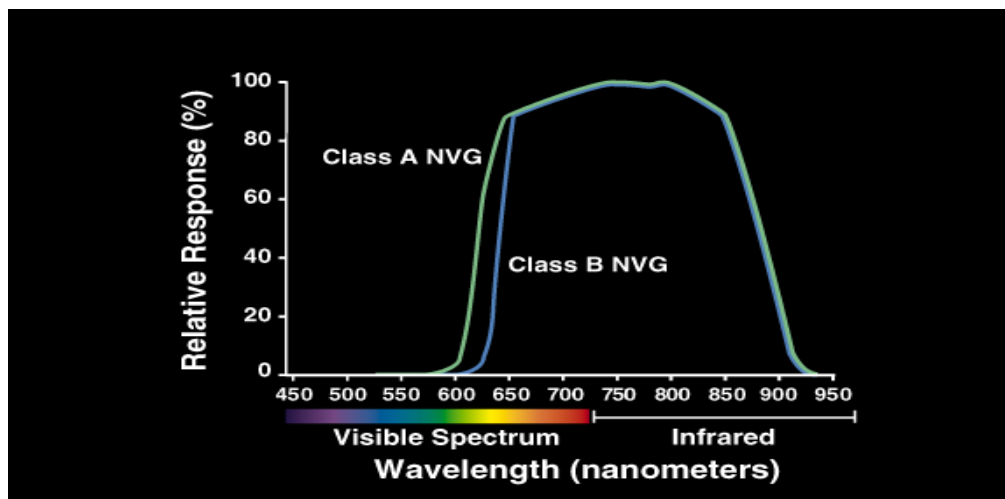
- Visible and near-IR energy (light) enters the objective lens, which focuses energy on the photocathode. During this process, the image is inverted and reversed due to the shape of the objective lens.
- The photocathode is made of a material (gallium arsenide) that releases electrons when struck by light (photons). An energy field created by the power supply accelerates the electrons towards the microchannel plate (MCP). The power supply is regulated to control the acceleration based upon the amount of light present.
- Electrons enter the microchannel plate where they strike the inner walls of tiny microtubules that are all tilted at a small angle to ensure collision. The microchannel plate contains approximately 10.6 million tubules and is about the size of a 10 cent piece.
- Each of these glass tubes is coated with a lead compound that, when struck with an electron, will release several other electrons which in turn strike the wall farther down the microtubule, causing the release of more electrons, repeating down the length of the microtubule. This "cascade" effect is an essential part of the intensification process.

- As the electrons (negative charges) leave the microchannel plate, they are accelerated towards the phosphor screen by a positive electrical potential. Because the electrons are accelerated, their energy is increased.
- The electrons, now increased in number and intensified in energy, strike the phosphor and cause it to glow. As the phosphor glows, photons are released in the same pattern (image) as the one that entered the intensifier. Electrical energy has been reconverted into electromagnetic energy (light).
- The image is then inverted back by a fiberoptic bundle. The subsequent image is focused onto the retina by the diopter (eyepiece) lens.

Night Vision Goggle Objective Lens Filtering

In order to select the spectrum of energy entering the intensification process, a filter coating is placed on the inside of the objective lens.

The point to learn regarding objective lens minus blue filtering is that certain wavelengths are blocked from entering the intensification process, thus allowing the use of cockpit lighting that will not affect NVG performance.



The diagram illustrates the end result of these minus blue objective lens filters. At present, primarily two filters are present in NVGs that are used by aircrew. One filter blocks energy below 625 nanometres and the other blocks energy below 665 nanometres.

- **Class A Filter** (625 nanometres) The Class A filter blocks wavelengths shorter than the orange region of the spectrum. It has been used for many years, and is in the goggles used in rotary wing aircraft. Examples of NVGs containing this filter include the AN/AVS-6 and the F4949. This filter was chosen so the blue/green region of the spectrum could be used for cockpit lighting.
- **Class B Filter** (665 nanometres) The Class B filter blocks wavelengths shorter than the middle red region of the spectrum. It is used in goggles that will be utilised in cockpits having multipurpose colour displays, moving maps and warning/caution lights. This filter was chosen because it blocks more wavelengths, thus allowing the use of some yellows and reds. These colours (wavelengths) would enter the intensification process in NVGs with a Class A filter, adversely impacting goggle performance.
- **Notch Filtering** The purpose of a “notch” filter is to allow a specific wavelength to enter the intensification process. This filter is installed in NVGs that will be used in aircraft equipped with heads-up-displays (HUDs).

Night Vision Goggle Image Colour

The NVG image appears in shades of green. Since there is only one colour, the image is said to be “monochromatic”. This colour was chosen mostly because the human eye can see more detail at lower brightness levels when viewing shades of green.

Colour differences between components in a scene helps one discriminate between objects and aids with depth perception and distance estimation. The lack of colour variation in the NVG image will degrade these capabilities to some extent. Image intensifier tube phosphor drives the specific output colour characteristics of the image that aircrew view.

Night Vision Goggle Image Gain

Gain refers to the ratio of output to input, i.e. the amount of energy the intensification process produces relative to the amount of energy that entered the intensification process. A goggle has circuitry that determines the amount of energy entering the intensification process, which then automatically controls the level of intensification needed to produce images of consistent brightness over a wide range of illumination levels. This automatic control of the level of intensification is referred to as “automatic gain”.

As mentioned on page 25, the automatic gain is controlled by the Automatic Brightness Control (ABC) circuit that regulates output from the MCP and by the Bright Source Protection (BSP) circuit that regulates output from the photocathode.

As illumination decreases, NVG gain increases as a direct result of increased output from the MCP. Maximum MCP output is reached at approximately 1/4 moon illumination. Subsequent decreases in illumination below 1/4 moon no longer result in increased gain, therefore the image contrast decreases.

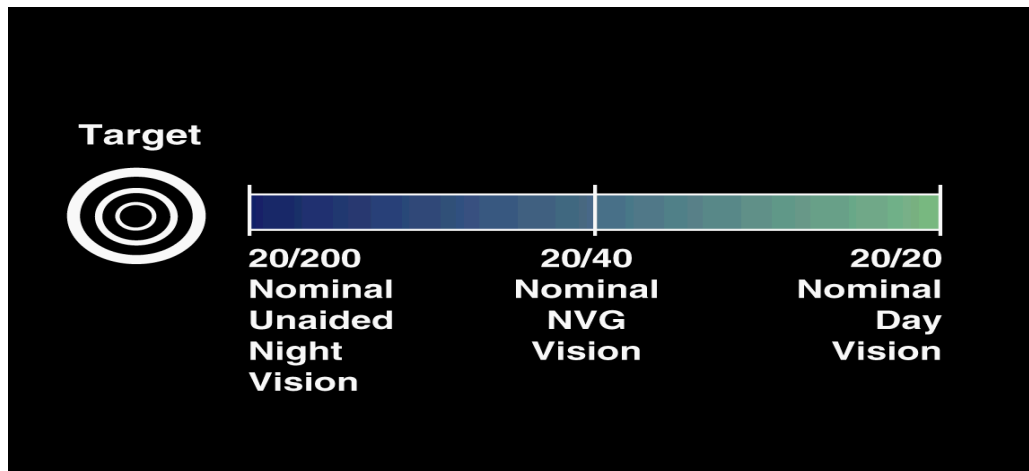
At some point, the gain can be raised no further and image quality begins to degrade. For current NVGs, this is what happens as illumination levels lower to less than approximately a quarter moon equivalents. Image degradation caused by this process can be very subtle and lead to problems for aircrew.

Night Vision Goggle Image Resolution

Resolution refers to the capability of the goggle to present an image that makes clear and distinguishable the separate components of a scene or object. Resolution will be expressed in Snellen acuity measurements. This technique bases “normal” vision at 20/20. In other words, a person sees at 20 feet what they should see at 20 feet. However, if, someone has 20/40 vision, it means that the person has to be at 20 feet to see what they should see at 40 feet. Another way to compare the two examples is to say that the person with 20/20 vision has vision twice as good as the person with 20/40 vision.

Current NVGs typically have a resolution of between 20/25 and 20/40 when optimally adjusted. In order to place this capability into an operationally meaningful perspective, it is necessary to compare visual acuity while wearing NVGs with both normal daytime vision (20/20) and the unaided eye’s night-time capability (20/200 at best):

Type Vision	Visual Acuity	Comparison
Daytime	20/20	Ten times better than unaided night vision and twice as good as NVG Visual Acuity.
NVG vision	20/25 to 20/40	Five times better than unaided night Vision.
Unaided night	20/200	



The diagram illustrates how the target can be seen further away with daytime vision than with either NVGs or unaided night vision, and can be seen further away with NVGs than with unaided vision.

For example, if aircrew using NVGs could pick out a pylon at one mile, it is likely the obstacle would not be seen with unaided night vision until within a fifth of a mile, which would possibly be too close to manoeuvre around the pylon.

NVGs do not provide visual acuity equal to that of daytime vision. Consequently, detection ranges of unlit targets/obstacles will be shorter, which will require more thorough flight preparation (e.g. map study) and aggressive NVG scanning of the outside scene.

Night Vision Goggle Field of View

Field of view refers to the total instantaneous area covered by the NVG image. The field of view of an NVG is determined by design constraints, and is 40° for the F4949. Regardless of the field of view of any particular goggle, it is considerably less than that of the eye, which normally covers an ellipsoid shaped area approximately 120° vertically and 200° horizontally. With this limited field of view, students should appreciate the need to “scan” the scene outside the aircraft in order to see as much as possible.

Field of Regard

The total area that the field of view can be scanned is called the Field of Regard. The field of regard will vary depending on several factors: physiological limit of head movement, NVG design and cockpit design/layout e.g. seat location, proximity of windscreen, door frames, etc.

Night Vision Goggle Design Considerations

There are three basic design approaches used for head mounted NVG systems: binocular, biocular, and monocular. Biocular is viewing a single image source with both eyes (e.g. watching a TV set).

A binocular system consists of two monocular assemblies. Each monocular contains its own optical system and intensification tube, and, with the exception of a common power source, operates independently from the other monocular. Consequently, the image formed by each monocular is presented to the respective eye. The decision was made to use binocular assemblies in aviation after considering many advantages and disadvantages, and the trade-offs between them. Among the advantages were avoiding the possible negative physiological effects inherent in a monocular system when presenting an image to only one eye, and the desire to have redundancy in the system. Some disadvantages included increased weight and increased cost.

NVG Performance Specifications

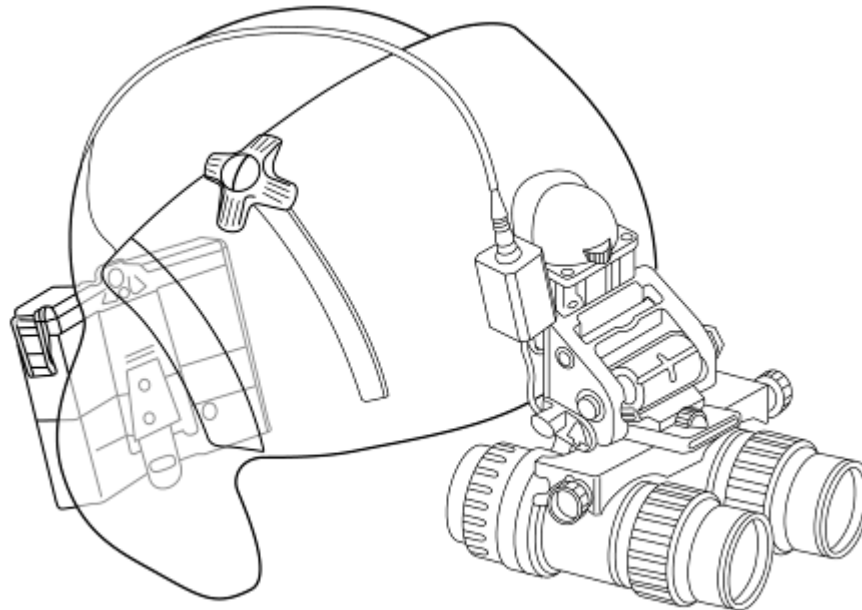
All NVGs currently in approved civil aviation operations use Generation-III level technology image intensifier tubes. Although all NVGs possess GEN-III image intensifier tubes, NVG performance vary dramatically dependent upon the NVG system design type, specification lot contract (Omnibus) and date manufactured. Specifications can be either described in terms of the image intensifier tubes or NVG systems. Image intensifier tube specifications are independent of the optical system of the NVG; therefore reflect only the tube's performance. Whereby, the NVG system specifications include the tube's performance placed into the NVG system. Therefore, the NVG system specifications will account for design differences and the optical paths for that goggle.

ITT Model F4949, AN/AVS-9 ANVIS Specifications and Characteristics



- A passive light amplification/intensification system that intensifies light 6000 times.
- Frequency sensitivity in the near Infra-red range (450nm to 950nm). The minus-blue coating makes the F4949 less sensitive to blue lighting.
- Magnification 1:1.
- 40° field of view. 25mm eye relief (eyepiece lens).
- Visual acuity attainable: 20/25.
- Focal Range 24" to infinity (greater than 33m).
- Binocular weight 590gm.
- Monochromatic viewing (green). No colour discrimination provided.
- Demonstrated temperature range 52°C to -32°C.
- Tube resolution: 64 lp/mm. System resolution 1.3.
- Diopter adjustment +2 to -6. No correction for Astigmatism.

Components of the ITT Model F4949

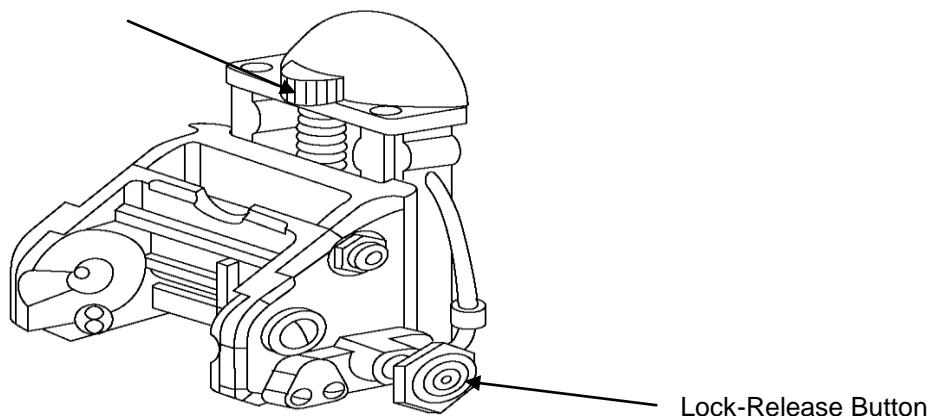


NVG Associated Equipment

- Operators Manual.
- Carrying Case – for safeguarding the NVGs when not in use (take with you during operations?).
- Lens Paper/Lens cleaning pens.
- Lens caps - to protect the eyepiece and objective lenses.
- Neck cord:
 - Attached to the NVGs at the Pivot Adjustment Shelf (PAS), required to be installed on the F4949 NVGs.
 - Can tie the cord to the helmet visor to ensure NVGs don't get dropped off the helmet.
 - If hanging the NVGs by the neck cord, install the lens caps to protect the lenses from being scratched, or twist the cord so that the NVGs hang high on the chest.

Mounting Bracket

Vertical adjustment Knob



The mounting bracket attaches to the helmet, provides a place to mount the binocular assembly and provides attachment to the power supply.

The **Vertical adjustment knob** adjusts the binocular up or down in a vertical direction to align for the individuals eye line.

The **Lock-Release Button** unlocks the monocular assemblies so they can be rotated up into the stowed position or down into the NVG 'aided' position.

NOTE: The mechanism can be easily overridden by forcing the binocular assembly out of the locked position, eventually wearing out the plastic parts. If this occurs, the binocular assembly will not stay in the stowed position, and will bounce up and down when in the operational position during sudden head movements or in turbulence.

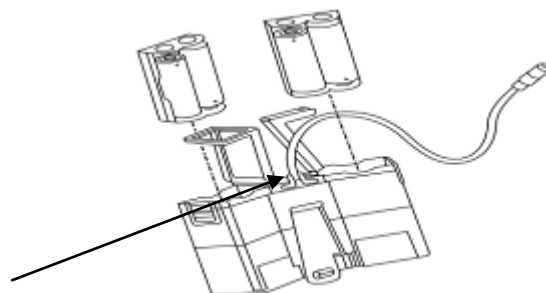
There is a groove on each side of the interior portion of the housing that accepts the binocular assembly. They serve as tracks to guide the spring loaded ball bearings in the binocular assembly into the correct position.

There are two copper contacts on each side of the housing near the grooves (one for each battery compartment). When these are touching the copper strips next to the ball bearings in the binocular assembly, power is supplied to the NVG. As the goggle is rotated from the operating to the stowed position, the contacts separate from the strips and power is removed from the NVG. Hence, as long as the power switch remains turned on, the goggles will automatically be powered whenever the binocular assembly is rotated from the stowed to the operating position.

NOTE: The NVG can inadvertently be turned on if the power switch is left on and the goggle is rotated to the operating position. Ensure the on/off switch is turned off whenever NVG operations are complete.

Power Supply

- Batteries authorised for use are AA Alkaline. Do not use any other type of batteries – NiCad, mercury, carbon AA Lithium, etc.
- Battery life (for the two 1.5 Volt DC batteries) will be approximately 20 -30 hours at room temperature.
- Dual-battery low profile power pack accepts four AA alkaline batteries. Is attached to the rear of the helmet via Velcro or clip – should be low on the back of the helmet.



ON-OFF-ON switch

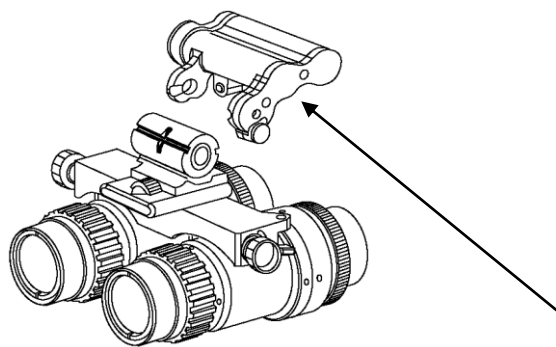
- Counter-weights
 - Low profile Battery pack Counter Weight (made of a non-toxic lead alloy material) is form fitting to the battery pack and is easily attachable (with the provided kit).
 - The two counterweights (2.0 & 3.5 ounces) can be used separately or together. Additional 2.0 ounce weights are also available.
 - The recommended initial weight is 5.5 ounces. Add or remove weight to achieve the best balance and comfort (≤ 22 ounces).

- The adjustment of weight should be made with the binoculars attached and flipped down.
- The ON-OFF-ON power switch has three positions: (1) selecting the right (primary) position provides power from the right battery compartment, (2) the center position turns the goggle off, and (3) the left position provides power from the left (alternate) battery compartment.

NOTE: The power switch is not guarded and it is easy to inadvertently turn power on when handling the mount. **Always** ensure the switch is in the off position when inserting batteries to avoid power surges and to avoid inadvertently turning on the goggle in a lit area.

CAUTION: DO NOT turn on the NVGs in brightly lighted areas. Repeated exposure to bright light will result in a reduction in the life of an intensification tube.

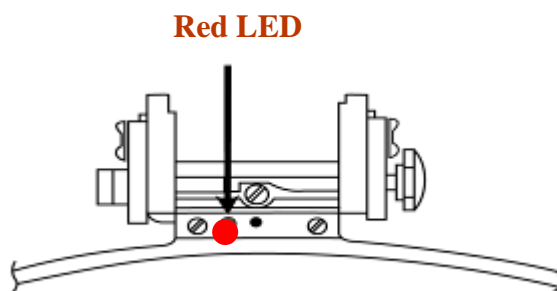
- Clip-On Power Source (COPS) utilises two AA batteries.



Clip-On Power Source

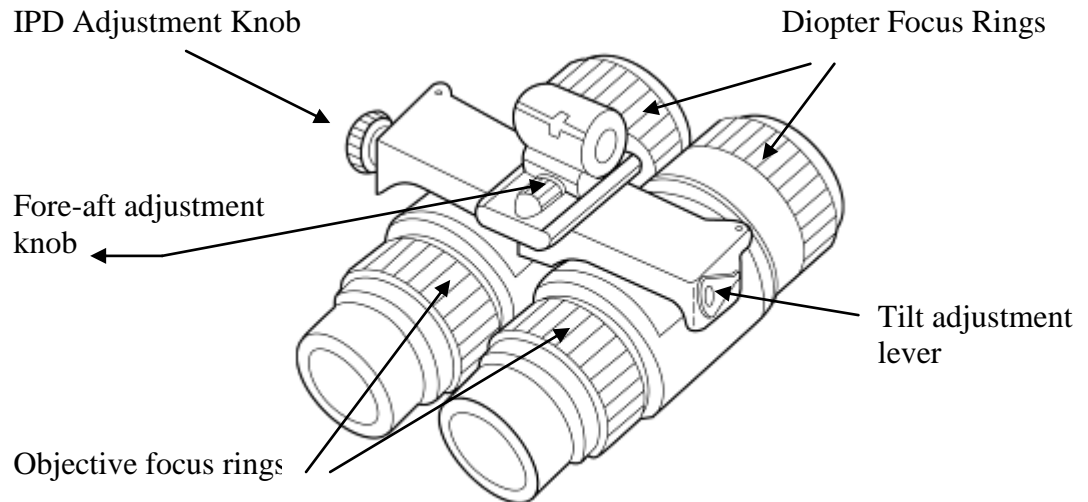
The COPS is designed to power the NVGs during training, operator checks, maintenance procedures and survival/operational situations when you don't want to wear a helmet.

Mounting Bracket - Low Battery Indicator is on bottom of mount



- Low Battery Indicator. On the bottom of the mount assembly is a small red light emitting diode (LED) that provides warning of impending battery failure (illuminates when battery power is less than 2.4 volts).
- Should the light come on, switch to the alternate (left) battery compartment and continue operations. Depending on helmet fit, the light may be difficult to see when illuminated.
- The low battery/electrical indicator test can be checked by undoing one battery compartment and then attempting to turn the goggle on by selecting that compartment (i.e. move the "On" switch towards the unsecured compartment). The goggle circuitry will sense the absence of power in the empty compartment and cause the low battery indicator to illuminate.

Binocular Assembly



Control Features

The binocular assembly contains the optical elements of the system and several adjustment controls. Learning the purpose of each control and how it should be adjusted is essential for proper alignment and focusing of the goggle. The adjustment controls on the binocular assembly include the following:

- Fore and Aft adjustment knob. Moves the entire binocular assembly toward or away from the eyes. The design of the eyepiece lens allows for aircrew to obtain the full 40-degree field of view when the objective lenses are positioned at a maximum distance of 25 mm from the eyes.
- Tilt adjustment lever. Tilts the binocular assembly to align the optical axis of the monocular assemblies with the visual axis of the eyes i.e. obtain optimal line-of-sight view.
- Interpupillary Distance (IPD). Moves the monocular assemblies laterally to match the distance between the eyes. Each monocular adjusts independently.
- Objective Focus. Focuses the goggles for distance. The adjustment range is from 28 cm to optical infinity (> 33m).
- Eyepiece (Diopter) Focus. Focuses the image on the retina of the eye i.e. adjusts for individual eye acuity within +2 to -6 diopters. Compensates for individual refractive error but not for astigmatism.

Adjustment and Assessment Procedures

Pre-flight Inspection

- Inspect Helmet. Inspection of the helmet should be the same as for unaided flight. However, particular attention should be paid to helmet fit due to the extra weight and forward center of gravity caused by the mount, goggle and battery pack.
- Inspect Mounting Bracket. Ensure the mount is not cracked and that all contacts are clear and clean, and check wiring for integrity. Test all controls for smooth operation.
- Load Battery Compartment.
 - Prior to inserting the batteries, make certain that the NVG is turned off. Ensure the batteries are correctly inserted (positive poles to the outside of the compartments).
 - Check wiring for integrity.
 - Perform the low battery/electrical indicator test.
- Inspect Binocular Assembly.
 - Ensure there is no obvious damage to either monocular housing.
 - Each housing is attached to the binocular assembly bridge which is constructed of lightweight plastic material. Consequently, each monocular may move independently of the other, but the movement should not be excessive.
 - Rotate the objective and diopter controls to ensure freedom of movement. The diopter controls are naturally “sticky” in their travel due to a plastic-on-plastic design. However, if the controls are very difficult to turn, notify maintenance. Sometimes simply releasing a little of the nitrogen pressure will loosen the controls.
 - Test all other controls for smooth operation.
- Inspect and Clean Lenses. Inspect the objective and eyepiece lenses for scratches or other damage. Clean the lenses with lens paper, pen or equivalent material and not with the flight suit or a tee shirt. A single thumbprint on one of the lenses may degrade visual acuity by as much as thirty percent.
- Set Diopter. Set the diopter on each monocular to zero.
- Adjust Eye Relief. Eye relief is the distance between the eyes and the surface of the eye piece lens. Position the binocular assembly as far forward (away from the eyes) as possible to avoid damage to spectacles and placement of oil on the lens from eyebrows/lashes when the NVGs rotated to the operating position.

NOTE: The operational eye relief position varies person to person and is dependent on a number of factors. Essentially, the selected position should allow the user to easily view the cockpit area when looking around or below the goggle without sacrificing the full field of view.

Mounting/Dismounting Binocular Assembly to Helmet Mount Assembly

If the F4949 is forced on to the mount assembly upside down or backwards, damage to the visor mounts could result. When correctly mounted, the NVGs will have the minus blue coated objective lenses facing outwards and the eyepiece lenses facing the user when in the flipped down position.

Mounting as follows:

- Make sure the power switch is turned OFF.
- Hold the binocular assembly with both hands at approximately a 30° angle so the eyepieces face you.

- Slide the spring loaded ball bearings of the fore-aft assembly into the mount channels until they lock into place.
- When securely attached, place in the stowed (UP) position.
- Secure to the helmet with the lanyard.

Dismounting procedure: **NOTE**, when removing the binocular from the mount do not grasp one of the monocular and pull it out of the mount with a twisting motion. This will damage the mechanism in the PAS (causing looseness in the binocular housing), or possibly crack the visor mount.

- Ensure the battery pack power switch is in the OFF position.
- Press in the lock-release button with the left index finger.
- Rotate binocular assembly up to a middle position.
- Gasp the binocular assembly with both hands at the PAS and remove from the visor mount.
- If Returning to the carry case:
 - Rotate Objective lens to full (anti-clockwise) position.
 - Rotate Eyepiece (Diopter) ring so '0' is aligned with the reference dot.
 - Return the tilt adjustment lever to the neutral position.
 - Adjust each IPD so that each monocular is aligned with the '60' marking
 - Replace lens caps.
 - Place into the carry case (should go in easily) while holding the PAS (AFT down).

Flip Down/Up Procedures and Powering the F4949

NOTE:

- **Never** flip the binocular assembly up or down without using the lock-release button, as the NVGs could be damaged or even come out of the mount.
- When the NVGs are in the flip-down position, it is possible to adjust the vertical adjustment knob too high which will not allow the binoculars to rotate into the fully down locked position.
- **Flip down procedure:**
 - Grasp the binocular with the left hand.
 - Press in the lock-release button with the thumb of the left hand.
 - Smoothly rotate the NVGs downward until it stops.
 - Release the lock-release button. Ensure the NVGs are locked into the operating position.
- **Flip-up procedure**
 - Reverse of the flip-down procedure. Ensure the NVGs are locked in the up (stowed) position before releasing the binocular.
- **Powering the NVGs**
 - NOTE:** Do not expose the F4949 to bright lights when they have power. Operate the F4949 only in a darkened environment.
 - Press the lock-release button and rotate the binocular to the down and locked position.

- Switch the power switch to the primary (Right) position. A green glow will appear in each eyepiece. If a red light appears at the base of the NVG mount, repeat the low battery indicator check procedure.

Initial Adjustment Procedures

The initial adjustments performed during this time will place the binocular assembly in a favorable location in front of the eyes once inserted in the mount and rotated to the operating position, thus facilitating the alignment procedures.

- Center Tilt. Set the tilt adjustment to the centered position (determined by aligning the tilt lever with bottom portion of the bridge). Ensure the IPD adjustments do not move when manipulating the tilt lever.
- Set IPD. Actuate the IPD controls to ensure the mechanisms move freely and that the tilt lever does not move as the monoculars track along the bridge.
- Adjust Vertical. Ensure the mechanism tracks smoothly to the upper and lower limits of movement, and ensure the thumb wheel moves freely. Leave the adjustment in the centered position.
- The helmet should be donned in order to check for comfort and to prepare for attaching the NVGs. Note, once familiar, and if desired, you could fit and fasten the NVGs to the helmet (with the neck cord) prior to putting the helmet on.
- Attach and Remove Binocular Assembly. Attach the binocular assembly to the mount by holding the binocular assembly in a vertical position (i.e., parallel to the body), aligning the spring loaded bearings in the binocular assembly with the grooves in the mount, and pushing gently until the assembly snaps into place. Do not exert excessive force. If too much force is required, it is an indication that the bearings are not properly aligned and the binocular assembly may fail to seat properly or become jammed in the mount.

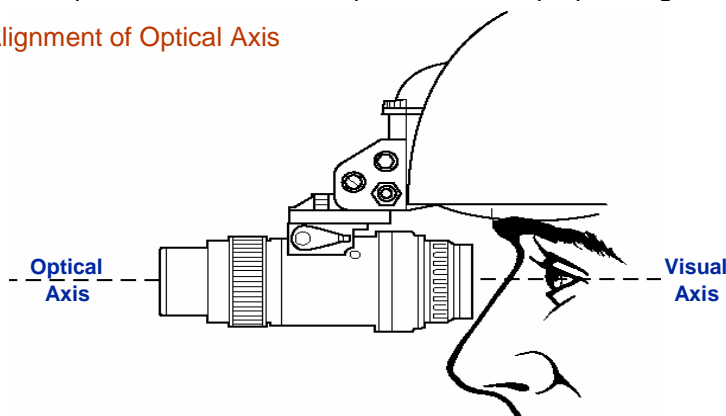
Do not release the binocular assembly until confirming that it will lock securely in the stowed position. This action confirms two important points: it indicates that the binocular assembly is properly seated in the mount, and that the assembly has not been mounted backwards.

Once the binocular assembly has been properly seated, press the lock release button and rotate the assembly to the operating position. The eye piece lens (diopter adjustment) should now be closest to the eyes. Begin removing the binocular assembly by pressing the lock release button and turning the assembly to a vertical position. Once out of the locked position, the lock release button can be released. Pull the binocular assembly straightforward out of the mount, preferably using both hands. Easy removal may be facilitated by first pulling one side slightly out of the detent, and then pulling forward on the assembly.

Alignment Procedures

Proper alignment is important because best visual performance is possible only when the **optical axis of the device** is perfectly aligned with the **visual axis of the eye**. For this reason, precise focus is not possible until proper alignment has been accomplished.

Alignment of Optical Axis



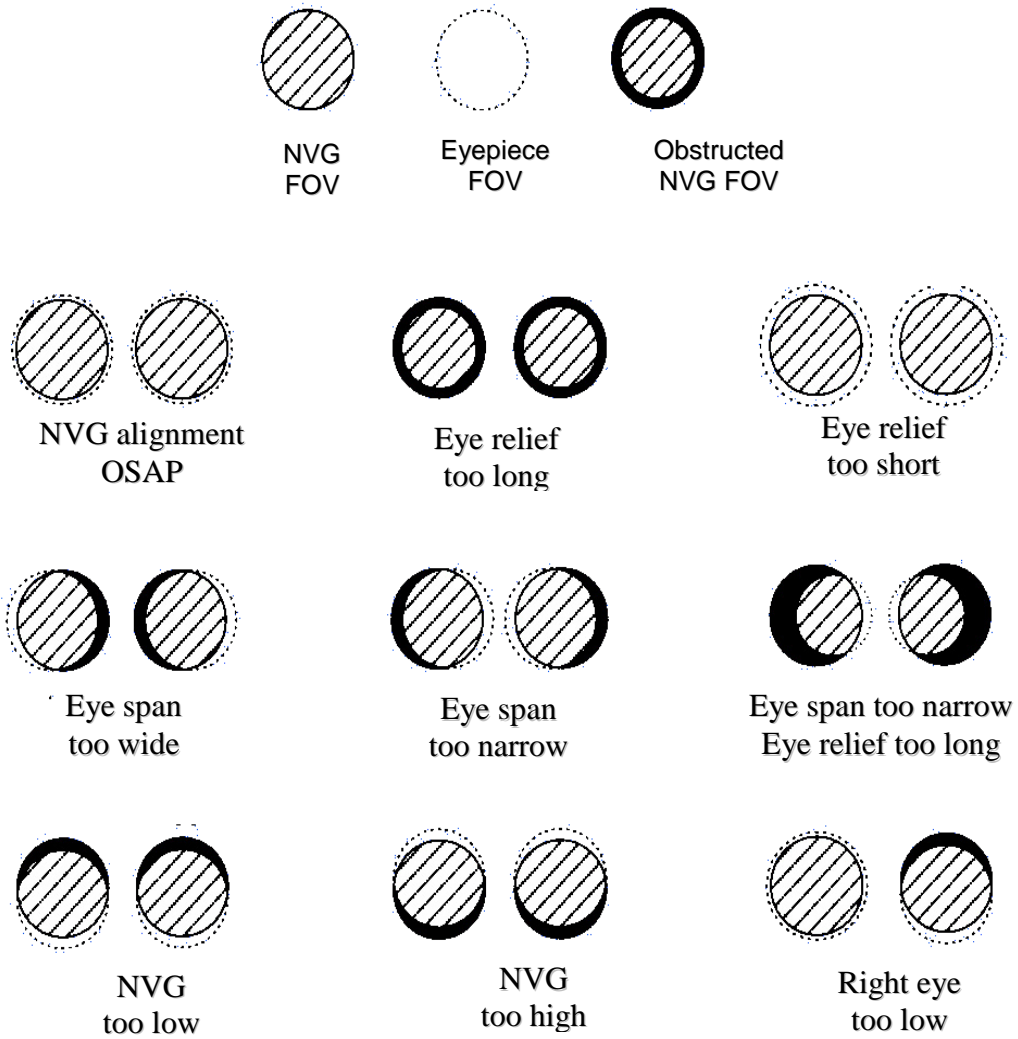
Perform alignment procedures in the following order:

- **Vertical Adjustment.** Adjust the vertical position of the binocular assembly using the vertical adjustment control. The binocular assembly should be located directly in front of the eyes.
- **Tilt Alignment.** Adjust the tilt so the optical axis of the binocular assembly is perfectly aligned with the visual axis of the eyes. Changes in tilt usually require a correction in the vertical adjustment, and vice versa.
- **Eye Relief Adjustment.** If necessary, move the binocular assembly closer to the eyes – to approximately 1 inch. As discussed earlier, eye relief should be positioned to maximise the field of view without unnecessarily reducing the ability to see around the NVG to view cockpit displays or perform other tasks. It is especially important that the goggle never be positioned so close to the face that the eye piece lens contact spectacles or eyelashes.
- **IPD Adjustment.** Center the image in front of the each eye using the individual IPD control. Repeat for the opposite eye. With both eyes open, the two images should overlap to form a single image. Small adjustments may be necessary to form a single image or for comfort.
- **Evaluate Image.**

When the goggles are correctly aligned, there should be no shading of any part of the image, resulting in the **Optimal Sight Adjustment Point** (OSAP). If shading is present, attempt to eliminate it by making adjustments ***in the direction of the shading.***

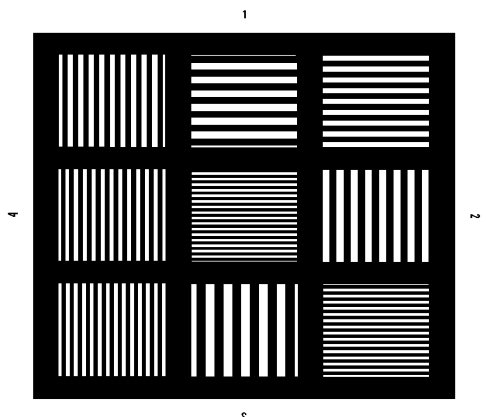
[PTO for OSAP diagram examples]

If there is insufficient travel in the goggle adjustments, move the entire helmet in the direction of shading. If proper alignment can only be made by moving the helmet, it is an indication that the mount assembly is not properly positioned on the helmet.



Focus Procedures

We tend to focus the NVGs outside; however, if using an indoor chart, move to approximately 20 feet away from the target e.g. a resolution chart.



The objective is to be able to see the grids well enough to determine whether the lines are horizontal or vertical. Every line in the grid may not be perfectly clear, but the direction of the lines should be readily apparent. Start by using the coarser grids, not trying to focus on the finer grids until the diopter adjustment has been made.

Use the following sequence whenever focusing NVGs:

- Turn both objective focus rings fully anticlockwise and both eyepiece focus rings so the reference dot and 0 diopter marks are aligned.
- **Objective Focus.** With the left tube covered (with a cupped hand – do not touch the lens & do not close the left eye), turn the right objective lens (outer ring) slowly clockwise. Stop when the lines are brought into a sharp focus.

Do not spend a great amount of time with this initial focus, as the purpose is to obtain an image that is adequate for permitting a suitable diopter adjustment.

- **Eyepiece (Diopter) Focus.** Next, turn the right diopter focus adjustment (inner ring) anticlockwise (to the left) until the image is blurred. Pause for one to two seconds to allow the eye muscles to relax, then turn the diopter adjustment clockwise until the image just becomes quite sharp - then stop.

If, in an attempt to find the point of sharp focus the diopter adjustment is rotated too far, the procedure should be repeated beginning with the initial counter clockwise rotation.

***Do not** leave the diopter adjustment beyond the point at which the image becomes sharply focused, even though the image remains quite clear. Performed correctly, this procedure focuses the image on the retina of the eye without accommodative effort by the eye muscles.*

Rotating the diopter adjustment beyond this point forces the eye muscles to actively work to keep the image focused. Over time, the eye muscles will become fatigued and unable to maintain focus. This results in a gradual loss of visual acuity and depth perception and often caused severe eyestrain and/or headache.

NOTE: The diopter adjustment is the one most misunderstood by aircrew, and if maladjusted can result in degraded visual acuity.

- **Readjustment of Objective Focus.** Once the diopter has been adjusted, fine-tune the focus by readjusting with the objective adjustment to bring into focus as many of the grids as possible. This accomplishes two things. First, it assures aircrew that the diopter adjustment has been satisfactorily performed. Second, it allows for an accurate assessment of NVG performance.
- **Focus of Opposite Monocular.** After focus of the first monocular is accomplished, the same procedures are employed to focus and evaluate the remaining monocular. Do not be concerned if one side is slightly better than the other. Slight differences in the performance of individual intensification tubes are common.

Aircraft Ground Adjustment Procedures

If you have focused the NVGs indoors, perform the following procedures prior to takeoff:

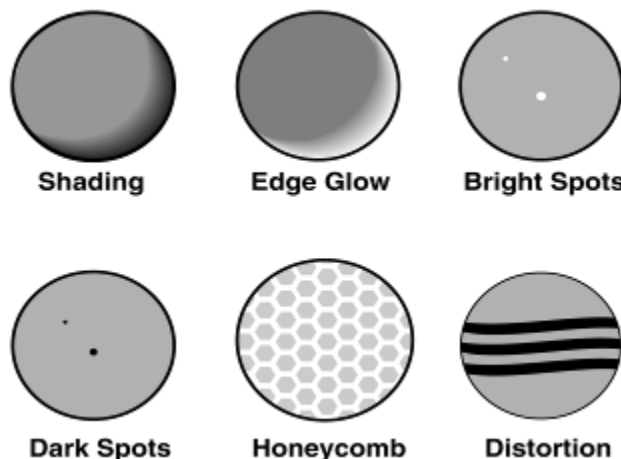
- **Confirm Diopter Settings.** It is best for aircrew to repeat the adjustment procedures (both objective and diopter adjustments) using a distant target (e.g. stars or unlit buildings) and the same focusing procedures as above.
- **Focus the NVG at Optical Infinity.** Because the device was focused at 20 feet indoors, it will be necessary to refocus at infinity before flight using only the objective lens (unless the diopter setting has been inadvertently moved). This can be accomplished by **focusing on an object at least 150 feet distant**, preferably one with well developed vertical or horizontal features. It must be illuminated well enough to be easily seen with NVG's but not so brightly lit that the image blooms or washes out. Avoid focusing on incompatible lights because the halo effect they create makes it difficult to discern when the image is in precise focus. Stars are excellent point light sources that do not cause halos and provide for a good endpoint for focusing.

- Assess the NVG image and check for operational defects and cosmetic blemishes (as below).
- Set Aircraft Lighting and Display Intensity. Set lighting and display intensity so information can be easily interpreted when looking around or below the NVG. Slightly adjust the vertical/tilt position of the NVGs if required to accommodate for changes to body posture due to the seating position.

Assessment of NVG Image

When focusing is complete, assess the NVG image. With experience, some of these things will be noted when performing alignment and focusing procedures.

- Evaluate Visual Acuity. Visual acuity obtained with both eyes should always be at least as good as that obtained by either side.
- Evaluate Image Quality. A number of image peculiarities and defects exist, some acceptable and others not acceptable.
- **Unacceptable Faults/Operational Defects:** There are **three** unacceptable defects:
 - **Shading.** Appears as a shaded or indistinct area along the edge of the image. If it cannot be eliminated by adjusting the IPD or by moving the goggle toward the shading, the defect is likely within the optics and the NVG should not be used.
 - **Edge glow.** Appearing as a bright area along the outer edge of the image, edge glow is most often the result of a bright light source somewhere just outside the image field of view. If noted, turn away from any bright lights or hold one hand over the objective lens. If the edge glow persists, it is an indication of damage to the intensification tube and the goggle should not be used.
 - **Flashing, flickering or intermittent operation.** The image may appear to flicker or flash in either one or both monoculars. The NVG image from one or both tubes may flicker. If noted, do not use the NVG. Check for loose wires, battery caps, and weak batteries if there is more than one flicker. Take a note of the rate of flicker/flash for maintenance action.

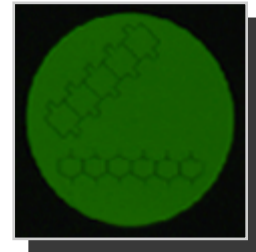


- **Acceptable faults/cosmetic blemishes:** The following are deemed acceptable faults and do not necessarily make the NVGs unserviceable:
 - **Bright spots.** Defects in the image area caused by a flaw in the phosphor screen or the aluminium oxide film covering the MCP. Bright spots are small, non-uniform bright areas or bright points that may flicker or appear constant. Not all bright spots make the F4949 unserviceable. Hold one hand in front of the objective lens and any bright spots will

disappear. Bright spots are only acceptable if they do not interfere with the ability to perform the mission.

- **Emission Points** are steady or fluctuating pinpoints of light in the image area and are normally caused by objects between the photocathode and the MCP. The pinpoint does not go away when all light is blocked from the lens. The position of an emission point within the image area does not move. Emission points are unacceptable if they are brighter than the background scintillations.
- **Dark/Black spots.** Dark or black spots in the image. These are cosmetic blemishes in the image intensifier or dirt between the lenses. If large, numerous, or located near the centre of the image, the goggle should not be used.
- **Honeycomb** (Fixed-Pattern Noise). A honeycomb-like pattern (literally an image of the MCP) in the image which is most often seen in high light-level conditions. The pattern can be seen in every image intensifier if the light level is high enough. Removing the goggles from the high light level will eliminate the condition. However, if the pattern persists, even in a dark environment, or if the pattern interferes with the image, the honeycomb is unacceptable.
- **Image Distortion.** The most common types of distortion noted in the NVG image are “bending” distortion and “shear” distortion. This problem is more easily detected in high-light conditions. Bending distortion results in the image having a wavy appearance, usually in the horizontal or vertical directions. Shear distortion results in a choppy appearance somewhere in the image. Each image intensifier has been screened for distortion before the first use so no action is required if this condition is present unless it interferes with viewing the image. If distortion is present and it is deemed likely to interfere with normal operations, do not use the NVG.

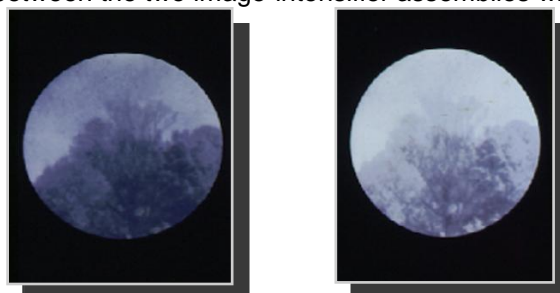
- **Chicken Wire.** An irregular pattern of dark lines in the FOV throughout the image area or in parts of the image area. These lines are caused by defective fibres that do not transmit light. These fibres occur at the boundaries of the fibre bundles in the fibre optic inverter. Can form hexagonal or square-wave shaped lines in the worst case conditions.



- **Output Brightness variation.** Is evidenced by areas of varying brightness in or across the image area. The lower contrasts do not exhibit distinct lines of demarcation nor do they degrade image quality. Do not confuse output brightness with shading.



- **Image Disparity.** May exist when there is a difference in brightness between the two image-intensifier assemblies within the same binocular.



- **Veiling Glare.** Veiling glare is caused by light hitting excessively scratched, pitted, or chipped lenses at an angle. The light is scattered instead of being focused properly onto the photocathode. Dust, smudges or fingerprints may also be a contributing cause. Therefore, first ensure that the lenses are clean.
- **NOTE: Scintillation** – Is not really a ‘cosmetic blemish’, but is a normal finding at low light levels. It is seen as a sparkling effect over the image and represents electronic noise created at the high gain levels which occur during low illumination conditions. In flight, it can be an indication of decreasing illumination caused by such things as worsening weather conditions or flight into shadowed areas.

NOTE: Newer intensification tubes have improved signal to noise capability. Consequently, scintillation may be more subtle and may not occur until darker conditions. If aircrew are used to a certain level of scintillation under specific conditions, the use of an NVG with newer tubes may lead them to believe conditions are better than actual.

Aircraft Airborne Adjustment Procedures

Make the following minor adjustments during flight as required:

- **Vertical.** As the helmet settles and/or rotates during flight, it may be necessary to make minor vertical adjustments as needed to keep the image in the proper position in front of the eyes.
- **Tilt.** Any vertical adjustment will likely require a readjustment in tilt.
- **Eye Relief.** Eye relief may need readjusting to allow better viewing of cockpit instruments or displays, or in some cases, to maintain the full field of view.
- **IPD.** Make small adjustments to IPD as required.

NOTE: Limit changes to diopter settings. Once adjusted correctly, the diopter should **never need** to be reset in flight. Only adjust when on the ground. If the diopter was not adjusted prior to flight or if the setting was inadvertently moved, both objective focus and diopter should be readjusted using the standard procedures and an appropriate target (e.g. stars, etc).

Care and Cleaning Steps of the F4949

Operator maintenance is limited to cleaning the system as follows (Ref: Operator’s manual):

Caution

- The system is a precision electro-optical instrument and must be handled carefully.
- Do not scratch or touch the external lens surfaces.
- Do not use abrasive materials to clean the gold-plated electrical contacts.
- Gently brush off any dirt using only a soft, lint-free cloth.
- Moisten the cloth with fresh water and gently wipe the external surfaces (except lenses) so they are free of foreign material.
- With another dry, clean, soft, lint-free cloth, dry any wet surfaces (except lenses).
- Using lens paper, carefully remove all loose dirt from the lenses.
- Dampen a folded lens paper with clean water and lightly and slowly wipe the lenses. After one straight stroke, discard the lens paper. Repeat this step until the glass surfaces are clean.

Operational Issues

Night Terrain Interpretation

- **Indications of Restrictions to Visibility at Night**

Note: You may fail to detect a gradual increase in cloud coverage (fog, haze, or precipitation) and may inadvertently enter the clouds.

Occasionally look under the goggles (unaided) and check for indications of deteriorating weather conditions.

1. **Loss of celestial lights** – The moon and stars may fade or disappear due to overcast cloud cover.
2. **Loss of ground lights** – The city or rural lights will fade due to obscuration.
3. **Reduced ambient light levels** – Forecast light levels (as indicated by a Lunar illumination Chart) will be reduced further due to obscurations. The exact amount of reduction will vary with conditions and the available ambient light.
4. **Reduced visual acuity** – Visual acuity may be reduced depending on the type and amount of ambient light and the presence of obscurations.
5. **Scintillation** – Increases in video noise as a result of low ambient light levels.
6. **Increase in the halo effect** – Halos will always be present when viewing light sources through NVGs. However, with an increased saturation density of water molecules (rain, fog, etc) occurring in the atmosphere, larger halos form around any viewed sources of light.

- **Cues for visual recognition at night**

- **Object size** – Increasing the angular size of an object.
 - Large structures and terrain features are easier to recognise at night than small objects.
 - Crewmembers must view the object several times (scan) to interpret the objects relationship to its surroundings.
- **Object shape:**
 - The shape or silhouette of terrain features and structures provides a means of identification at night.
 - Familiarity with a form of architecture peculiar to a certain flying area may assist you in identifying a structure.
 - When relying on a shape to identify an object you may need to change your position to gain a different perspective.
- **Contrast** – The difference between an object and its background can be used as an aid in object identification. Contrast is the most important section of visual cues and is dependent on the following:
 - Ambient light – Contrast depends on the difference between the light (visible or near infrared) given off by an object and its background. The greater the difference, the higher the contrast. If the light given off by an object is nearly the same as that given off by its background, the contrast will be low.
 - Colour – A green object against a green background provides poor contrast. However, good daytime colour contrast does not necessarily mean good NVG contrast and likewise.
 - Texture – The surface appearance or quality of an object e.g. unploughed fields as compared to ploughed fields.

- Background – The surface against which an object is viewed. A dark background makes a lighter colored object stand out.
- Reflectivity – Features which reflect light well are more readily seen, for example, a metal pole versus a wooden pole. White is the normal mixture of all visible light. White reflects all colors and absorbs none. Black absorbs all colors and reflects none.

Warning

Exercise extreme caution when flying over low-contrast terrain (snow, water, sand, grassy hills) under LOW ambient light conditions. Low-contrast environments degrade visibility, thereby disguising or masking changes in terrain. This is especially true under low-light conditions (starlight and overcast starlight) and higher speeds.

• **Factors Affecting NVG/Night Terrain Interpretation**

- **Ambient Light** – Reduced light levels at night decreases visual acuity. This restricts the distance at which an object can be identified. Terrain interpretation becomes more difficult as the light level decreases. Reduced airspeeds will improve visual interpretation and increase viewing and reaction time.

Warning:

Exercise extreme caution when flying from high ambient light conditions to low ambient light conditions (similar to flying from the sunny side of a valley into a shaded area). Under low light conditions, the goggles lose some resolution that they have under high light conditions. Flying from high light to low light conditions quickly reduces the sharpness and definition of terrain images.

- **Viewing Distance** – The viewing angle becomes smaller as the distance from the object increases. Therefore, large and distinctly shaped objects may become unrecognizable when viewed from a great distance at night. Range is also difficult to estimate at night and can result in a miscalculation of the object's size. The distance at which interpretation of an object becomes unreliable also depends on the ambient light level. An object that can be identified by its shape and size at a distance of up to 1500 metres during a high light condition may be unrecognizable at 500 metres during a low light condition.
- **Flight altitudes** – The altitude at which an aircraft is flown affects the aircrew's ability to interpret the terrain.
 - **High altitude** – The ability to identify man-made or natural features progressively decreases as the flight altitude increases. This condition is affected by all levels of ambient light. When the flight altitude increases, contrast between features becomes less distinguishable and features tend to blend together. As terrain definition becomes less distinct, detection from altitude becomes difficult. Changes in the viewing angle and the distance at which the object is being viewed will change the apparent shape of an object.
 - **Low altitude** – Terrain becomes more clearly defined and contrast is greater when flying closer to the ground. Man-made and natural features are more easily recognized and navigational capability is improved. The area that a crewmember can view at low altitudes is smaller than that at higher altitudes. At low altitudes, you may have to reduce airspeed to permit more accurate terrain interpretation. You can also identify objects by silhouetting them against the skyline at low altitudes.
- **Moon Altitude.**
 - **High altitude.** The higher the altitude of the moon, the greater the illumination. An increased ambient light level improves visual acuity and contrast. The best conditions for visual interpretation for any phase of the moon exist when the moon is at its highest altitude.

- **Low altitude** – Terrain interpretation is more difficult when the moon is low on the horizon. This is due to the lower light level that prevails and the shadows that form. If low level flight is conducted toward the moon when it is low on the horizon, the aircrew may be bothered by glare. Glare distorts vision and can cause a loss of dark adaptation. During aided flight, glare will also degrade the capability of the intensifier tubes device used. When the moon is low on the horizon, terrain features or objects visible along the skyline are more recognizable.
- **Visibility Restrictions.**

Such conditions as dust, rain, fog and snow can restrict visibility. These reduce the ambient light level and result in a loss of visual acuity. Visibility restrictions normally occur gradually. Initially, the visual range is reduced followed by a loss of terrain definition. As visibility decreases, night vision may become so impaired that terrain flight should be discontinued.

Light reflecting off blowing dust and snow particles may cause the illusion of relative motion even if the aircraft is in a stable hover. The scan pattern should include any visible fixed reference points that have vertical, relief; for example, bushes, trees and rocks.
- **Terrain** – The nature of the terrain will determine the amount of the light that is reflected from the surface of the earth. Various types of terrain include:
 - Desert – The texture and color of the soil on the desert floor normally provides optimum reflectivity of available ambient light and identification of objects by contrast. Manmade objects, in particular, will stand out well against their background. Normally very little vegetation exists but it does provide good contrast when available. Blowing dust or “Brown (Green) out” can be encountered in this environment and will require a practiced technique to overcome.
 - Rolling terrain – Rivers and terrain features which give distinct changes in elevation from surrounding terrain provide the most recognizable natural landmarks for navigation. Dirt roads and farm structures provide the most distinguishable man-made features and contrast is good between forested areas and open fields.
 - Mountainous terrain – Large distinct terrain features aided by terrain silhouetting makes for easy interpretation of mountainous terrain. Barren mountains reflect ambient light well. However, low moon angles produce large shadowed areas which can severely restrict vision.
 - Forest – forest canopies tend to obscure vertical terrain development which makes interpretation difficult. Also, green on green gives little contrast.
 - Alpine/Snow/Ice covered areas – A flat snow/ice surface provides very little contrast but its reflectivity may provide abundant light. Blown snow can fill in valleys and create hills making terrain interpretation difficult. Rocks contrast well with snow/ice.
- **Seasonal changes**
 - **Winter**
 - Contrast with natural and man-made features is improved.
 - Vegetation will appear different due to seasonal changes.
 - Best effect of moon illumination (lower orbital path).
 - Poorest weather season.
 - Heavy snowfall can cover or completely obscure features.

- **Summer**
 - Contrast may be less distinct than in winter.
 - Vegetation covers more of the terrain and contrast between types is less distinctive.
- **Night Navigation Cues**
 - **Terrain relief**
 - Terrain features – Analysis of the terrain is the most reliable means of orientation. Features, which are unique in shape or provide a distinct change in elevation, are excellent checkpoints.
 - Silhouetting – Most helpful for low altitude flights. High terrain can create shadows, which hide hazards or other important features from view. Can be used to locate terrain definition as well as manmade objects.
 - **Vegetation:**
 - Vegetated areas – Heavily forested areas do not reflect light well and appear as dark areas at night. Open fields will stand out in forested areas because of the good contrast. Use contrast, shape, and texture as cues as to which type of vegetation is being viewed.
 - Fields – The amount of light reflected by a field will depend on the season of the year and the amount and type of vegetation. Harvested or plowed fields generally provide excellent contrast. Fields may be masked due to surrounding trees.
 - Hydrographic features – The contrast between water and land is usually good, but note water can provide little contrast unless the surface is disturbed by wind. Identification will depend on the amount of reflectivity and ambient light.
 - **Cultural features:** Man-made features can be excellent NVG navigational cues.
 - **Roads:**
 - Dirt roads provide excellent contrast between the surrounding terrain and vegetation and its surface. Different soil compositions will give varying degrees.
 - An asphalt road is difficult to identify because its dark surface reduces the contrast between it and surrounding terrain and vegetation, unless the surrounding terrain is highly reflective.
 - Although roads are not good navigation checkpoints, they may have certain features, which can serve as orientation cues, or checkpoints. Roads can make excellent barriers when associated with other checkpoints.
 - **Intersections** – When correctly identified, intersections make very good checkpoints. Check the type of intersecting roads, their headings, and surrounding cues to ensure the correct intersection has been located. Large trees can completely obscure intersections at low levels.
 - **Bridges** – Bridges can be good checkpoints especially if they have vertical development. Bridge surfaces which contrast with road surfaces or the surrounding vegetation will stand out well.
 - **Railroads** – Railroads are easily identified but are often hidden by surrounding vegetation or terrain.
 - **Wires** – A very important and deadly hazard for night operations. Wires may be virtually impossible to see, depending on the angle you are sighting them from. You must anticipate their location, especially near buildings and roads. Often, seeing the cut through the trees or seeing the poles is the only way

you may locate wires. Know the location of all wires and plot them on your map using common symbols.

- **Buildings** – Buildings that are isolated, uniquely shaped, large, or lightly colored have good contrast and are useful navigation cues. The converse is also true.
- **Antennas/towers** – Tall towers are generally lighted and easy to locate. However, with NVGs their range can be very difficult to judge.

WARNING:

Beware of supporting wires. Some antennas may be unlighted and are very difficult to detect. Information about obstructions must be plotted on a hazard map and made available to aircrews for use in flight planning.

Company NVG Operations Procedures

As per Appendix I of AC91-13, the following items, at a minimum, must be included in the NVG operations procedures:

Airworthiness and Maintenance of Night Vision Equipment

1. Aircraft pre-flight
2. NVG pre-flight
3. MEL
4. Reporting of NVG Equipment discrepancies

Crewmember Responsibilities

1. Pilot:
 - a. Duties, responsibilities and authority
 - b. Logging HNVGOs
 - c. Training and qualification
 - d. Recency of experience.
2. NVIS Crew Member:
 - a. Duties, responsibilities and authority
 - b. Training and qualification
 - c. Recency of experience.
3. NVIS Flight Instructors:
 - a. Experience and qualifications
 - b. Duties, responsibilities and authority
 - c. Recency of experience.

Flight Operations

1. Pre-flight and departure:
 - a. Before takeoff NVIS check
 - b. NVG Goggle and de-goggle limitations. transition:
 - unaided to aided
 - aided to unaided
 - c. Area of operations
 - d. Route planning
 - e. Risk assessment procedures to be completed (see below)
 - f. NVIS flight operations ceiling and visibility requirements
 - g. Fuel requirements
 - h. Briefing of passengers
 - i. Equipment requirements.
2. Enroute:
 - a. Minimum safe altitudes
 - b. Hostile terrain
 - c. Helicopter surface reference
 - d. Operating near other aircraft.

3. Standard Flight Manoeuvres.
4. Arrival:
 - a. Landing area requirements
 - b. Reconnaissance
 - c. Unimproved landing sites.
5. Post Flight Procedures.

Crew Procedures

1. Minimum Crew.
2. Pre-flight Brief:
 - a. Required actions of each person, duties and responsibilities during each phase of flight
 - b. Light discipline
 - c. Sterile cockpit procedures
 - d. Crew resource management
 - e. Standardise terminology.

Emergency Procedures

1. Inadvertent IMC
2. NVIS equipment failure
3. Aircraft emergencies.

Reports and Forms

1. Training Forms
2. Recency of Experience Forms
3. NVG Maintenance and inspection Log.

Definitions

NOTE: Operational Risk Management Procedures

As part of any safety management system for the operation of an aircraft, a risk assessment needs to be done before any night vision goggle operation. The risk assessment needs to take into account at least the following:

- Illumination level of the flight environment
- Weather
- Recency of experience for pilot and crew
- Crew composition
- Operator/crew experience with NVG flight operations
- PIC field of regard
- PIC/crew rest condition and health
- Aircraft serviceability (MEL)
- Windshield/window condition
- NVG tube performance, battery condition
- Types of operation allowed and applicable SOPs
- External lighting environment.

NVG Flight techniques

(Note: Some NVG flight techniques are as for unaided night flying)

- Use of landing light – generally speaking the landing light is best placed directly underneath the aircraft when close to the ground, as this will limit glare in the cockpit and loss of ground detail close to the aircraft. You will be able to scan outside the NVG picture to pick up detail with the naked eye. Prior to take-off clear the area ahead/above for obstacles with the light.
- Lifting to the hover – position your head/eyes so that you have the ground and some part of the aircraft structure in your picture to help assess movement and aircraft attitude.
- Hover taxi/manoeuvring – manoeuvre slowly as you may not have sufficient cues to judge height and movement if you move the body of the aircraft too quickly. While hover taxiing, keep the horizon at the top of your NVG picture and have some aircraft structure and ground in view – to assist in judging rates of movement and height above the ground (use of RADALT in a high hover?).
- The take-off is always flown using a shallow towering technique.
- Cruise flight – utilise the normal NVG scan technique (external horizon cues) in combination with an instrument scan to confirm performance (altitude, attitude, etc).
- Approach – the approach is flown on the same glide-path as a day approach but a little slower. Look in the same places as if flying the approach by day but remember to keep part of the aircraft structure in your picture. You may have to look slightly off-centre to be able to correctly judge your closure rate – do so in combination with an instrument scan (ASI, VSI).
- Confined area operations
 - The limited field of view/acuity of NVGs means you may not be able to see all the obstacles in a certain area. This requires a slow and cautious approach to a confined area.
 - In a crewed environment, to overcome the limited field of view, you can/should place a great deal of reliance on the crew to avoid obstacles. You must listen to the rest of the crew and act on their commands promptly.
 - Wind assessment can be awkward with NVGs. Use of forecast or prevailing wind backed up by the GPS and IAS/Groundspeed relationship is normally necessary.
 - Hover references – will depend on hover height and the nature of the pad, but a mixture of in/out of NVG hover references can be used. Be aware of:
 - Long grass can set up a wave effect that could be very distracting.
 - Dusty pads (or freshly mown grass, fresh snow) can reflect light particularly well and obscure forward vision. The best place to look in a 'greenout' is downwards (under NVG picture?) just outside the skids.
 - During your slow, cautious approach, you may be able to get better visual cues for accurate height and groundspeed if you position the aircraft comfortably low over the trees at a fast hover taxi speed (just above translational).

Crew Resource Management

You should be aware that many NVG accidents in the USA (mostly military) have been attributed to a breakdown or lack of crew coordination and/or crew resource management.

One version of the basic elements to crew resource management and coordination is **The Three C's**:

Conditioning

- **Personal Conditioning** (highlights from protecting your Mesopic Vision)
 - Avoid self-imposed stresses
 - Maintain a healthy diet
 - Avoid sudden changes in your sleep cycle
 - Stay proficient with NVGs
 - Use a 'crawl-walk-run' measured approach as you gain NVG experience
 - Fly regularly and stay proficient
 - Train and seek additional training to expand your experience
 - Know your personal and NVG limitations.
- **Crew conditioning** (team building)
 - Train as a crew
 - Maintain crew integrity when feasible
 - Maintain a professional cockpit working environment.

Communication

- Use positive communication – be specific!
- Be explicit when directing action
- Direct and request assistance
- Announce your actions
- Acknowledge the action of others – don't assume
- Be assertive – not argumentative
- Announce when your attention is focused inside.

Coordination

- Establish leadership
- Establish responsibilities and priorities
- Brief the flight (use of an established briefing card?)
- Encourage feedback from all crew members
- Watch for and detect errors
- Cross monitor each other
- Don't allow cockpit information systems to overwhelm or distract you → **KEEP FLYING THE AIRCRAFT**
- Diversify your attention – avoid fixation
- Establish a professional working environment inside your helicopter.

Night Vision Goggle Emergencies

- **Tube flicker/Failure or Total Goggle Failure During Flight**
 - Announce “**GOGGLE FAILURE**” to all the crew.
 - Low altitude operations → initiate a climb
 - Switch to the backup battery position on the battery pack
 - If night vision is restored → continue flight
 - If night vision is not restored → stow NVGs and transition to unaided flight.
NOTE: It takes time to regain normal night unaided vision.
- **Power Warning LED illuminates**
 - Low altitude operations → initiate a climb
 - Switch to the backup battery position on the battery pack
 - If warning LED extinguishes → continue flight
 - If warning LED does not extinguish or goggles fail when the battery pack is switched → stow NVGs and transition to unaided flight.
- **Aircraft Emergencies**
 - An emergency procedure that requires a “**Land as Soon as Practicable**”:
 - Determine if landing with NVGs is acceptable (returning to a well lit airport)
 - Determine if your emergency would make a goggle approach preferable (complete electrical failure)
 - Complete the applicable approach.
 - An emergency procedure that requires a “**Land as Soon as Possible**”:
 - Determine if there is time to transition back to a reasonable night unaided level, if required
 - Determine where you plan to terminate the emergency.
 - An emergency procedure that requires a “**Land Immediately**”:
 - Remain under goggles.
 - Autorotations
 - The limited field of view does not allow safe constant attitude engine-off landings – when your head is down looking for the aim point you can't see the horizon and vice versa and if you try to move rapidly between the two, you risk disorientation at in a critical phase of flight. Use the variable flare engine-off technique.
 - Enter autorotation in the normal manner, followed by turning the landing light.
 - You may feel more comfortable initiating the flare higher than the day flare. This will allow a longer period to assess the profile and allows you to slow down with a lower nose attitude so we don't lose sight of the aim point, or horizon.
 - The level is generally slightly higher than normal due to the poorer height reference.
 - Run-on landings
 - Emergencies which require run-on landings should ideally be flown to a runway or other feature which will help the pilot keep the aircraft straight. The landing light should be used during the approach and

landing → move it up to light as far ahead of the aircraft as possible to assist in keeping straight while preventing glare in the cockpit.

Inadvertent IMC

Avoiding IIMC Conditions

The best ways to avoid inadvertent flight into IMC conditions are by obtaining a thorough weather brief (including pilot reports), and being familiar with weather patterns in the local flying area. However, there are subtle changes to the NVG image that occur during entry into IMC conditions aircrew should learn to recognise. By doing so, they may be able to ascertain their predicament before things get worse. The following are the more obvious changes to the image:

- **Onset of Scintillation.** The attenuation of energy reaching the NVG secondary to obscurants such as light rain or fog may cause the onset of scintillation in the image, or an increase in the degree of scintillation if already present. However, due to an improvement of the signal to noise ratio in goggles currently manufactured, scintillation may or may not be a reliable indicator. Becoming familiar with the characteristics of your goggles will help solve this problem.
- **Loss of Scene Detail.** As flight into IMC conditions occurs, scene detail (terrain, etc.) will degrade, become progressively worse as the moisture content increases. The initial loss of detail may be very subtle so it is important to continuously pay attention to the quality of the image, particularly if flying around known weather systems.
- **Change in the Appearance of Halos.** As the energy from light sources is scattered and refracted by moisture in the atmosphere, halos appear to become larger and less intense. By noting the appearance of halos during the flight, it may be possible to determine when a change has occurred and thus indirectly establish the presence of moisture.

NOTE: Be aware of the difference between the effects on the image caused by a reduction in illumination versus those effects caused by entry into IMC conditions. Both results in a reduction in gain which leads to increased scintillation and a loss of scene detail. However, the effect on the appearance of halos differs. Moisture content in the air results in a more diffuse appearing halo, whereas a lowering of the illumination in clear air results in a more intense appearing halo (secondary to the increase in gain).
- **Reflection from the anti-collision light** may be more obvious with any increase in moisture/cloud type obscurants.

Use Company Exposition IIMC procedures, as well as de-goggling once a settled instrument scan has been established. Consider turning off the anti-collision light as the reflections may become distracting in clouds.

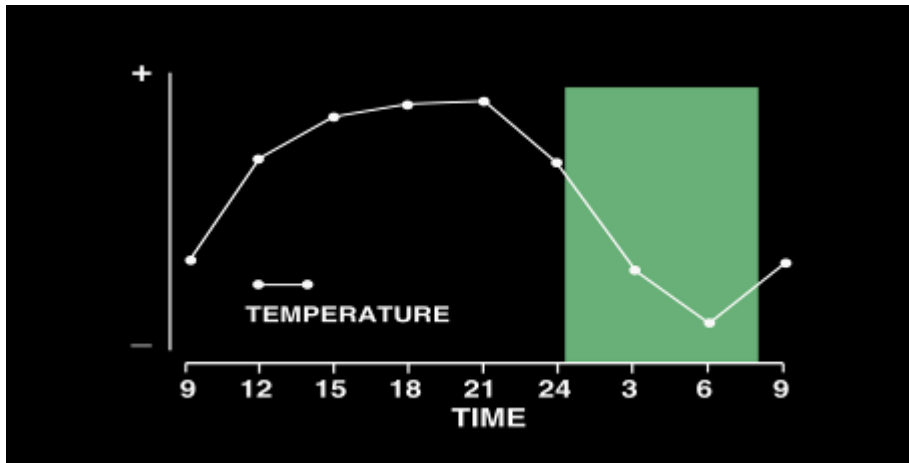
Flight & Duty and Fatigue Factors

Circadian Rhythm

Circadian rhythm can be defined as the body's "internal clock". It is an autonomous cycle varying from person to person that ranges from 21 to 30 hours in duration, but averaging approximately 25 hours for most people. For each person there are over 50 physiological functions affected by at least 40 environmental variables, all defining this rhythmic cycle.

- **Effects of Circadian Rhythm on Performance**

Each aircrew member's performance follows the circadian cycle, and performance degradation occurs during a time when NVGs could be used.



Performance degradation occurs during the early morning hours, the same time period when most physiological functions e.g. temperature are at their ebb.

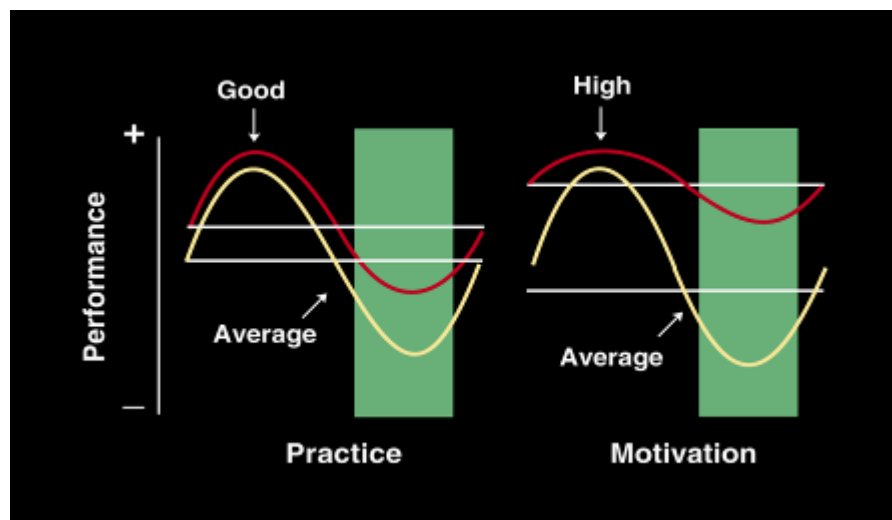
An important point to remember when operating at night is that no matter how much aircrew adapt, they will never fully adapt to these hours i.e. aircrew will never be as good at their job at night as they are during daytime.

- **Effects of Sleep**

Manipulating sleep conditions may alter the degree of performance degradation, but will not change the overall effect of circadian rhythm. Therefore, performance lows continue to occur during the early morning hours.

- **Effects of Motivation and Proficiency**

Two final graphs illustrate the profound effects motivation and proficiency may have upon aircrew performance during the circadian cycle.



Performance can vary by as much as 75 percent between the high and low portions of the circadian cycle for complex tasks involving people with both poor motivation and poor proficiency levels. On the other hand, the difference in performance can be reduced to less than 10 percent for similar tasks involving persons with high levels of motivation and proficiency.

The graph on the left illustrates the effect practice has on performance. The trough is less deep (i.e. performance is improved) as practice, or training, increases. The graph on the right illustrates the effect motivation has on performance during the circadian cycle. The effect of motivation is significant. The circadian trough is not nearly as deep when individuals are motivated to do their jobs.

However, performance continues to be low during the circadian trough when compared to daytime levels of performance.

- **Countering the Effects**

In summary, reduced performance continues to exist during the early morning hours (the circadian trough), regardless of personality type, proficiency, motivation, or proper rest. However, there are guidelines to help lessen the effects secondary to the circadian trough, which, if implemented, may result in maximising performance during periods when NVGs will likely be used. Some of the more important guidelines include the following:

- Assign suitable personnel;
- Conduct thorough training;
- Increase motivation; and
- Ensure proper rest.

Fatigue

Fatigue, a common problem during night-time operations, can significantly degrade performance. However, the degree of degradation can be controlled to some extent if methods are developed that aid with the recognition and management of fatigue. There are three basic types of fatigue and in order to devise guidelines for their management it is necessary to understand how they differ. The three types of fatigue are acute fatigue, cumulative fatigue, and circadian fatigue (circadian desynchronosis):

- **Acute Fatigue.** Acute fatigue is the tiredness experienced after any demanding mental or physical activity. Examples of this type of fatigue include the mental tiredness experienced after flying a demanding sortie and the physical tiredness experienced after performing a triathlon.
- **Cumulative Fatigue.** Cumulative fatigue is the fatigue which occurs over time as a result of inadequate rest and/or after a continuous heavy workload. An example of this would be the fatigue experienced after continuous operations during a two week detachment.
- **Circadian Fatigue.** Circadian fatigue is the tiredness produced either by shifting the sleep/wake cycle, or experiencing transmeridian travel (jet lag).

Circadian Fatigue Causal Factors

This type of fatigue can result from several different causes. Examples you should be familiar with include the following:

- **Disrupted sleep/wake cycle.** If the sleep/wake cycle is disrupted a significant degradation of human performance may occur. The body requires a certain amount of rapid eye movement (REM) or deep stage sleep in order to receive true rest. If this deep stage sleep is minimised, then rest is minimised. It is physiologically possible to get a full night's sleep, but get little to no rest. As an example, alcohol keeps the body from entering deep stage sleep, thus affecting the amount of rest received (one of the reasons you feel so tired after a night on the town).

- Constantly changing schedule. Poor performance will persist at levels near the circadian low until a new circadian rhythm can be established. However, if one's schedule constantly changes and never stabilises for any length of time, a new rhythm may never become established. In this case, performance continues to remain at very low levels.
- Inadequate adaptation period. There is significant individual variation both in the degree of impairment and in the rate of adjustment to a new cycle, and there are factors contributing to that variability. For example, the degree and rate of adjustment to a new cycle can be affected by the age or physical condition of an individual.

Prevention of Circadian Fatigue

The prevention of circadian fatigue requires the establishment of rules and guidelines that minimise the effects without adversely affecting the mission.

NOTE: The following guidelines were derived from many sources of research and experience. Some of them may not be applicable to all missions, but the concepts should be clear.

- Allow a minimum of 3 to 4 days for initial adaptation to a new schedule or time zone.
- Anticipate at least two weeks for full adaptation to a true night schedule.
- During off-duty hours, continue to maintain the same hours required by the work schedule, or as closely as possible. For example, if conducting extended night operations, do not retire until at least 0200 and minimise family and other activities before 1000 during off-duty hours.
- Avoid the observance of sunrise. Watching the sun rise stimulates powerful physiological functions that will attempt to reset the body's clock to a daytime cycle. This can easily negate all previous efforts to minimise low performance during the circadian trough.

Predictors of In-flight Fatigue

One of the best ways to avoid fatigue is to anticipate (predict) when it may occur, then take action through scheduling and planning. The risk of in-flight fatigue is increased when:

- Landing times are later than 0230;
- Landing time is more than 14 hours after waking;
- Landing time is 10 hours after arriving at work;
- Flying on a fourth consecutive night;
- Flying a second sortie on the same night; and
- Pre-flight fatigue.

Of all those listed, pre-flight fatigue is the best predictor of in-flight fatigue. Cancellation due to pre-flight fatigue should be considered a conscientious, responsible, and mature action that is free from retribution.

Impact of Fatigue on Spatial Disorientation

An important aspect of fatigue is to appreciate the impact it has upon aircrews' sensitivity to spatial disorientation. Earlier, it was stated that spatial orientation during degraded visual conditions requires conscious, complex processing of data from instruments and displays.

Furthermore, it was stated that anything degrading pilot performance, such as fatigue or illness, could contribute to the onset of spatial disorientation by adversely impacting aircrews' conscious, complex processing capability.

Fatigue also has an influence on other factors important to safety of flight; with the following being most often implicated human factors causes of fatal aircraft accidents:

- Loss of situational awareness. Fatigue contributes to the loss of situational awareness by reducing math and abstraction abilities. The impact of this problem manifests itself by increasing the time it takes to interpret instruments and displays.
- Channelised attention. Fatigue can aggravate channelised attention which in turn can result in errors of omission.
- Complacency. Fatigue can cause or contribute to the insidious onset of complacency, which has been implicated in many aircraft mishaps.
- Increased incidence of spatial disorientation. The greater the level of fatigue, the worse the effect. The three types of spatial disorientation include:
 - Type I (Unrecognised). Aircrew do not recognise their disorientation so no corrective action is taken. This results in mishaps in which no attempt is made to recover prior to ground impact.
 - Type II (Recognised). The pilot is aware that something is wrong, but may not realize that the source of the problem is spatial disorientation.
 - Type III (Recognised but impaired). Type III is incapacitating spatial disorientation; the pilot knows something is wrong, but the physiological or emotional responses to the disorientation are so great that the pilot is unable to recover the aircraft.

Recommendations for Night Operations

The following recommendations are based on many studies conducted over several years, a few of which were initiated after NVG-related mishaps in various aircraft. Consequently, they all cannot be applied to each mission or aircraft type. It is important that you determine which may apply to their particular situation.

- Educate personnel and their families. All personnel and their families (aircrew, maintenance, and other support personnel) should be educated about circadian rhythm and fatigue hazards.
- Recognise signs of fatigue. All personnel and supervisors must be prepared to recognise the signs of fatigue and respond accordingly. At times this may require confronting someone who may not realise the state of their dysfunction, a problem not unusual in the flying community where many personnel are highly motivated.
- Establish adequate training standards. Obtaining NVG experience requires a dedicated plan as there are many variables to overcome when conducting night missions (e.g. compatible aircraft availability, range availability, night-time manning, etc). Additionally, aircrew must experience a broad range of conditions (e.g. different illumination levels, various types of terrain, etc) in order to be truly NVG qualified. Adequate training standards will help ensure aircrews have the correct start towards gaining the required level of experience.
- Adopt appropriate currency requirements. Once a creditable level of NVG experience is obtained, the requirements can be adjusted (reasonably) to meet specific needs.
- Block scheduling. It is a known fact that people do better when they have definitive start and stop points in their work schedule. By block scheduling, aircrew will have that information. This approach will also allow better family interaction and planning.
- No landings after 2230 on the first night. This recommendation is based on adapting to a new schedule (as discussed earlier) and will help ensure aircrews are not flying during the low points of their circadian rhythm.

- Landings no more than 1.5 hours later each night. This recommendation will help lessen the effects of circadian fatigue by adapting the personnel slowly and by reducing the degree of performance decline during the circadian trough.
- Restrict flying to a maximum of three consecutive nights. One of the findings during a research study was that twice as many aircrews were fatigued on the fourth night of flying as opposed to the second night. The result was a recommendation to restrict individuals to a maximum of three consecutive nights of flying.
- Utilise more experienced aircrew for long or difficult sorties.
- Allow cancellation due to fatigue. Cancelling due to fatigue is recognised as a sign of maturity in many communities and should be encouraged when applicable.

Additional Considerations

These additional considerations were included in many of the same studies referred to earlier, and are added here to further enhance understanding of the problems associated with performing the night mission both safely and effectively.

- Sleep Rooms. When on a night schedule, sleep rooms should be arranged that are conducive to getting proper rest. Since sleeping may occur during daylight hours, it will require prior planning and coordination. If possible, sleep rooms should contain the following:
 - Blackout curtains. Blackout curtains will keep the environment darkened. Light is a tremendous stimulus to the human body's physiological system and can keep an individual from getting proper rest even if asleep.
 - Adequate air conditioning. Another strong physiological inducement to sleep is air temperature. Since humans evolved as day animals, they became physiologically sensitive to the lowering of temperature at night – a time when they would naturally rest. It is therefore necessary to control air temperature in order to ensure proper rest.
- Quiet environment. Some people are more susceptible to noise than others, and it is possible for a noise to be loud enough to bring someone out of deep stage sleep, but not loud enough to awaken them. This will decrease the amount of rest the person obtains, regardless of the amount of sleep acquired. This problem can be particularly hard to control if one goes home during off duty days.
- Good nutrition habits. The type of food eaten is another possible source of problems during night operations. Food high in carbohydrates will cause the absorption of certain substances in the body that may result in drowsiness. Also, it is best to have light meals between and/or during flights. One of the most common problems during night operations is the availability of proper meals, or in many cases, any meals.
- Limit caffeine intake. Coffee, tea, colas, and chocolate contain substances that can delay the onset of sleep. It is not necessary to completely avoid these, but it is important to avoid their use close to the time one wants to sleep. In general, it is best not to have any of these within two or three hours of bedtime.
- Moderation in alcohol consumption. Alcohol consumption can lead to two adverse effects. First, as discussed earlier, it suppresses deep stage sleep which has an adverse effect upon rest. Alcohol also has a prolonged effect on the inner ear by changing the specific gravity of the fluid in the semicircular canals, which, in turn, has an adverse effect upon equilibrium that can last more than 72 hours.

- Abstinence from tobacco use. It is best to abstain from the use of all forms of tobacco to prevent any possible adverse effects on night vision. Tobacco's effects on unaided night vision are well documented, particularly at altitude. How these effects influence NVG utilisation is the subject of current research.

Proficiency and Experience

High levels of proficiency will help to offset the performance degradation associated with night-time operations. However, in addition to proficiency, it is necessary to have a well balanced experience base.

This requires aircrew to see the whole range of NVG effects, limitations, and illusions before they are truly qualified.

In order to accomplish this, training plans should take into consideration such factors as moon angle, illumination levels, terrain types, and cultural features, and an attempt should be made to expose aircrew to as many different variations of these as possible.