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# Night Vision Goggles in Emergency Medical Service (EMS) Helicopters

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Final Report

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Dear Colleague:

Enclosed for your information is a copy of the recently published report **FAA/RD-94/21, Night Vision Goggles in Emergency Medical Service (EMS) Helicopters.**

This document addresses the use of night vision goggles (NVG's) by EMS helicopter pilots. Key issues addressed are the night environment, physiology of the eye, characteristics of night vision devices, maintenance of the NVG, and night operations. Government and EMS industry pilots participated in a flight test program to assess the use of NVG's in EMS operations. Information produced by other government agencies with extensive NVG operational experience was also reviewed for its application in EMS scenarios. Results of both the flight testing and the document review are incorporated in the recommendations of this report

This investigation concluded that NVG's can be a valuable tool during en route and terminal operations during certain EMS scenarios. When properly used, NVG's can increase safety, enhance situational awareness, and reduce the pilot workload and stress that are typically associated with night operations.

As commercial helicopter operations, augmented by emerging technology, increasingly move into night and reduced visibility scenarios, interest in night vision enhancement technology will grow. This report provides data and information to enhance your understanding and awareness of the benefits and potential pitfalls in using such equipment.

It has been said that there are no "new types" of aviation accidents. Indeed, pilots have been involved in the same old types of aviation accidents for many decades. However, the improper introduction of new technology can provide the opportunity to discover new ways to become involved in the same old types of aviation accidents. Fortunately, with

safety improvements over the decades, aviation accidents have become rare events. Thus, in implementing new technology, it is critical that we do so in ways that result in a safety increase rather than a decrease. This report is published with that thought in mind.

*Robert D Smith*  
 for Richard A. Weiss  
 Manager, General Aviation and Vertical  
 Flight Technology Program Office

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16. Abstract <p>This document addresses the potential use of night vision goggles (NVGs) by the emergency medical service (EMS) industry. Key issues analyzed are the night environment, physiology of the eye, characteristics of night vision devices, maintenance of the NVG, and night operations.</p> <p>Pilots from the government and EMS industry participated in a flight program at the FAA Technical Center to assess the capabilities and utility of NVGs in EMS scenarios. The results of the tests are incorporated in the recommendations of this document. Information produced by other government agencies, with extensive experience with NVGs, was reviewed for use in this application and incorporated into the text.</p> <p>This investigation concludes that NVGs are a viable tool during en route and terminal operations during certain EMS scenarios. The NVG, when properly used, can increase safety, enhance situational awareness, and reduce pilot workload and stress normally associated with night operations.</p>			
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## FORWARD

This manual has been developed from text and graphics contained in U.S. Army and Marine Corps night flying training manuals. Additional information was gathered from Federal Aviation Administration (FAA) studies relating to the use of image intensification systems commonly referred to as night vision goggles (NVGs).

The information incorporated into this manual has been edited to delete the military aspects while capitalizing on the lessons learned which are applicable to civil operations. Findings of FAA studies have been used to establish guidance for pilots participating in the FAA's program to enhance emergency medical service (EMS) night operations. The text presents information on night vision imaging systems and procedures for their use.

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## 1.0 NIGHT VISION

### 1.1 INTRODUCTION

The successful completion of a safe, demanding, nighttime EMS mission requires a professional, well-trained crew employing specialized equipment. The ability to conduct night flight safely is based on how well crew members can see and how well trained they are in using their night vision. Flight at night is just like the day, except it is more difficult to see routes, objectives, obstructions, or weather. Although the limits of night vision vary from person to person, most pilots never learn to use their night vision to its fullest capacity. A crew member with average night vision capability who uses proper night vision techniques is more effective than a crew member with superior night vision who does not.

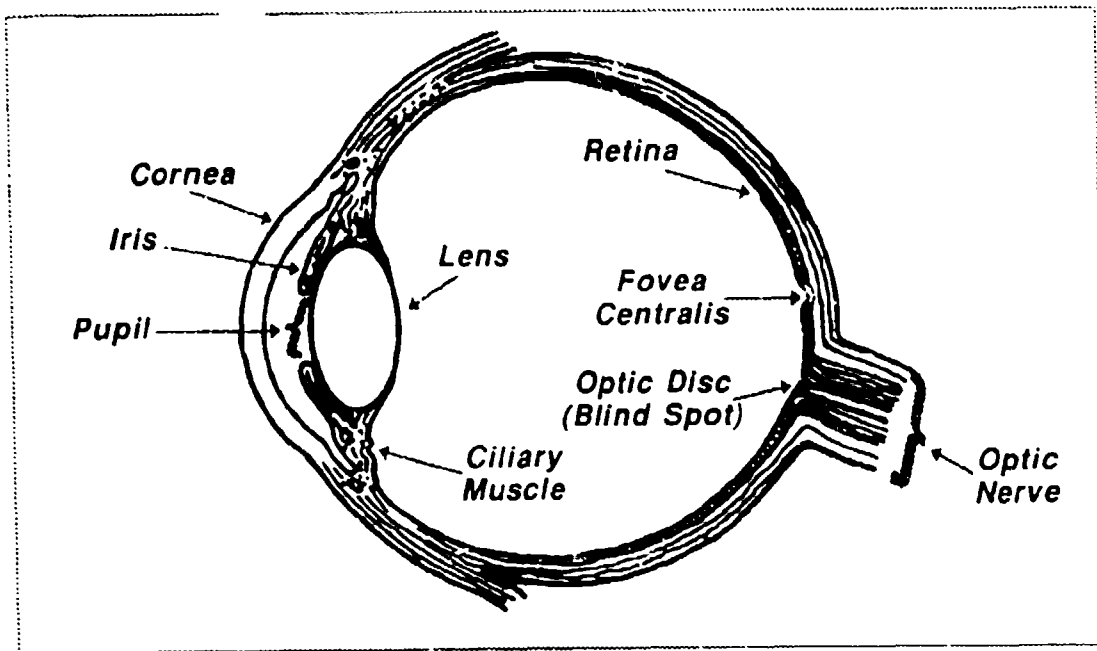
The hours of darkness elevate the need to be fully alert and cognizant of one's surroundings. However, because of the darkness, a person's ability to see is limited by nature and by what assistance training and technology can provide. Night operations decrease the ability to detect and avoid obstructions. The pilot must first understand the limits imposed by the night (the problems of the human eye). Next, the pilot must learn the techniques of how to cope with night flight. These techniques include unaided scanning, use of lights, and use of visual aiding with and without lights.

Night imaging devices, which until recently have been predominately the domain of the military, are now available for civil use. Night vision devices improve the capability of the human eye to see at night, but these devices require specialized training. The safe and effective use of these devices requires a thorough understanding of the night environment. This includes the relationships between ambient illumination, the terrain, the night imaging device, and the human eye. Each of these are critical links in the night vision chain. An understanding of their interrelationships requires that each link be thoroughly understood.

#### 1.1.1 Eye Anatomy and Physiology

The eye is similar to a camera. The cornea, lens, and iris gather and control the amount of light allowed to enter the eye. The image is then focused on the retina. The visual receptive apparatus (retina) has two types of cells, the cones and the rods. Vision is possible because of chemical reactions within these cells. Figure 1 shows the anatomy of the human eye.

Cones. Cone cells are used primarily for day or high-intensity light vision. The concentration of cones in the central retina permits visual acuity in high illumination. The chemical, iodopsin, is always present in the cone cells. Regardless of the ambient light condition, this chemical is readily available so that the cones can immediately respond to visual stimulation.



**FIGURE 1 ANATOMY OF THE EYE**

Rods. The rods are used for night or low-intensity light vision. The peripheral retina is almost exclusively associated with rods. Peripheral vision is less precise than central vision, because the rods perceive only shades of gray and vague forms or shapes. Rhodopsin, commonly referred to as visual purple, is the photochemical found in rods. As the light level decreases, the amount of rhodopsin in the rods builds and the rods become more sensitive. Rods are about 1,000 times more sensitive to light than cones. When illumination decreases to about the level of full moonlight (0.1 footcandle), the rods take over from the cones. The period of highest light sensitivity (adaptation) usually commences after 30 to 45 minutes in a dark environment. The rod cells may become up to 10,000 times more sensitive than at the start.

#### 1.1.2 Light Levels

Measuring light levels can be complex and confusing. Many different units of light measurement and terms are used for various scientific, engineering, and industrial applications. Terms of measurement are usually familiar only to those who work directly with light measurement problems. Some of the terms important to aircrews are defined in the following paragraphs.

Illumination. Illumination is the amount of light that strikes a surface at some distance from a source. The common unit of measurement is the footcandle. A footcandle is the density of light falling on the inner surface of a sphere of 1-foot radius when a point

source of light with an intensity of 1 international candle is placed at the center of the sphere.

Luminance. Luminance is the amount of light per unit area reflected from or emitted by a surface. It is an important measurement for visual displays and is usually expressed in millilamberts or footlamberts. Luminance is frequently called brightness. However, brightness is influenced by contrast, adaptation, and such factors as the physical energy in the stimulus. Table 1 show examples of luminance levels found during commonly experienced conditions.

**TABLE 1 COMMONLY EXPERIENCED LIGHT LEVELS**

CONDITION		LUMINANCE* (millilambert)
Photopic Vision	Surface of Sun at Noon	1,000,000,000
	Tungsten Filament	1,000,000
	Upper Limit of Visual Tolerance	100,000
	Fresh Snow on Clear Day	10,000
	Earth on Clear Day	1,000
	Earth on Cloudy Day	100
	White Paper in Good Reading Light	10
Mesopic Vision	White Paper 1 Foot From Standard Candle	1.0
	Candle	0.1
	Snow in Full Moon	0.01
Scotopic Vision	Earth in Full Moon	0.001
	Snow in Starlight	0.0001
	Grass in Starlight	0.00001
	Absolute Threshold of Vision	0.000001
* One millilambert = 0.929 footlambert.		

Reflectance. Reflectance is the relationship between illumination reaching a surface and the resulting luminance. A perfectly diffusing and reflecting surface is one that absorbs no light and scatters the illumination in the manner of a perfectly flat surface. Such a surface has a reflectance of 100 percent. If illuminated by 1 footlambert, it would have a luminance of 1 footlambert from all viewing angles. In actual practice, the maximum reflectance of a nearly perfectly diffusing surface is about 75 percent.

Contrast. Contrast is a measure of the difference in luminance between an object and its background. Contrast can vary from 100 percent (negative) to infinity (positive) for objects brighter than their backgrounds. Contrast increases when the difference in luminance between an object and its background increases. Contrast is zero when the luminance of an object and its background is the same.

### 1.1.3 Vision Types

The three types of vision are photopic, mesopic, and scotopic. Each type functions under different sensory stimuli or ambient light conditions. Night vision involves mesopic and scotopic vision. Photopic vision at night is possible only when sufficient levels of artificial illumination exist.

Photopic Vision. Photopic vision is experienced during daylight or when a high level of artificial illumination exists. The cones concentrated in the fovea centralis of the eye are primarily responsible for vision in bright light. Because of the high light level, rhodopsin is bleached out and rod cells become less effective. Sharp image interpretation and color vision are characteristic of photopic vision.

Mesopic Vision. Mesopic vision is experienced at dawn, at dusk, and during full moonlight. Vision is achieved by a combination of cones and rods. Visual acuity steadily decreases as available light decreases. Color perception changes because the cones become less effective. As cone sensitivity decreases, crew members should use off-center vision and proper scanning techniques to detect objects during low light levels.

Scotopic Vision. Scotopic vision is experienced under low light levels. Cones become ineffective, resulting in poor resolution of detail. Visual acuity decreases to 20/200 or less. This enables a person to see only objects the size of or larger than the big "E" on visual acuity testing charts from 20 feet away. (A person must stand at 20 feet to see what can normally be seen at 200 feet under daylight conditions). Also, color perception is lost. A night blind spot in the central field of view appears at low light levels. The night blind spot occurs when cone-cell sensitivity is lost.

### 1.1.4 Day Versus Night Vision

Differences between day and night vision involve color, detail, and retinal sensitivity. Day vision is superior to night vision in every respect.

Color. One major difference between night vision and day vision is that color vision decreases or is lost at night. With decreasing light levels, the eyes shift from photopic vision (cones) to scotopic vision (rods). With this shift, the eyes become less sensitive to the red and more sensitive to the blue part of the spectrum. Perception of colors is not possible with the rods. Colors of nonilluminated objects cannot be determined at night under very low illumination. Light and dark colors at night can be distinguished only by the intensity of reflected light. If, however, the brightness or intensity of a color is above the threshold for cone vision, the color can be perceived. This is why, for example, signal flares and runway markers can be properly identified at night.

Detail. Perception of fine detail is impossible at night. Under low illumination, visual acuity is greatly impaired. At 0.1 footcandle (the level of full moonlight), acuity is one-seventh as keen as it is in average daylight. Therefore, objects must be large or nearby to be seen at night. Identification of objects at night is based on perceiving generalized contours and outlines, not on small distinguishing features.

Retinal Sensitivity. Another important distinction between night vision and day vision is the difference in the sensitivity of various parts of the retina. The central part of the retina is not sensitive to starlight illumination levels. During darkness or with low-level illumination, central vision becomes less effective and a night blind spot (5 to 10 degrees wide) develops. This results from the concentration of cones in the fovea centralis and para fovea, the area immediately surrounding the fovea of the retina. The central field of vision for each eye is superimposed for binocular vision. Because the night blind spot for each eye occurs in the central field of view, binocular vision cannot compensate for the night blind spot. Therefore, an object viewed directly may not be detected, as shown in figure 2.

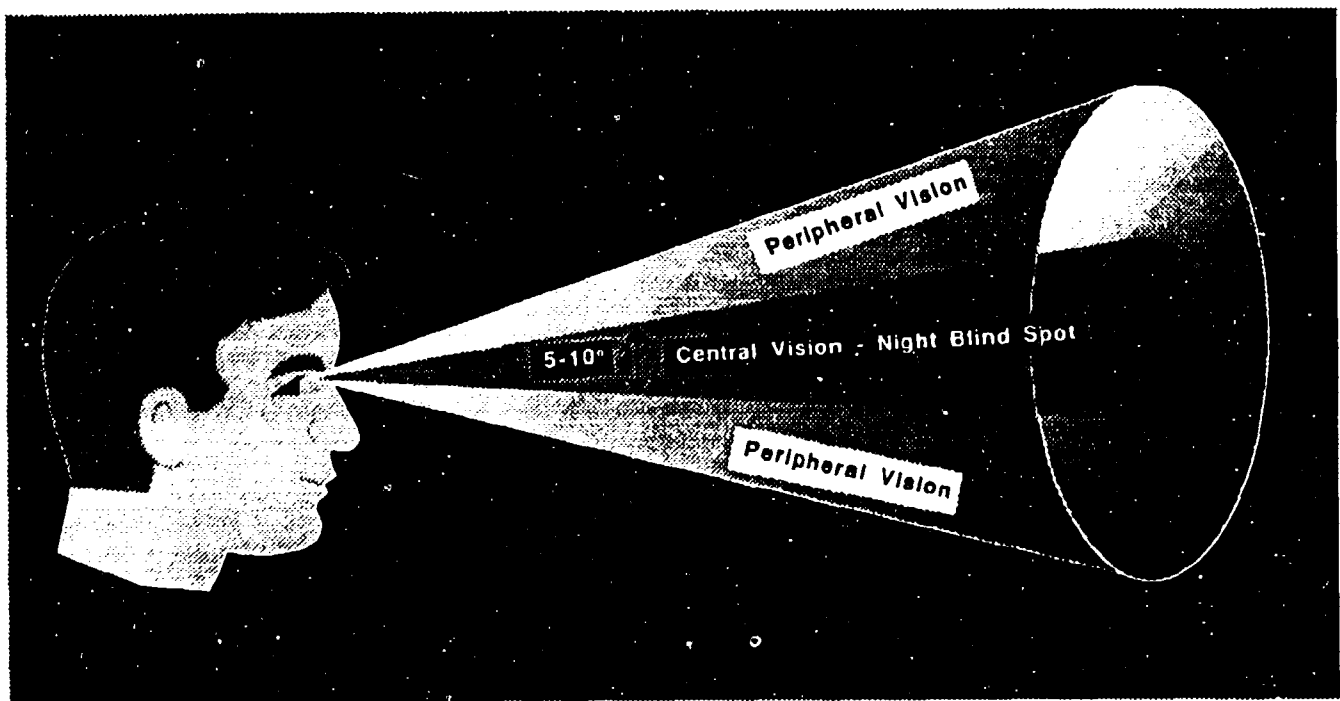
The night blind spot should not be confused with the physiological blind spot (the so-called day blind spot) caused by the optic disk. The physiological blind spot is present all the time, not only during the night. This blind spot results from the position of the optic disk on the retina. The optic disk has no light-sensitive receptors. The physiological blind spot covers an area of approximately 5.5 by 7.5 degrees and is located about 15 degrees from the fovea. Because of the overlap of binocular vision, this blind spot is normally not noticed unless one eye is not used. The physiological blind spot becomes an important consideration when monocular night vision devices, such as pilot night vision sensors, are used.

Because of the night blind spot, larger and larger objects will be missed as distance increases. To see things clearly at night, an individual must use off-center vision and proper scanning techniques. Figure 3 shows the effect of distance on the night blind spot.

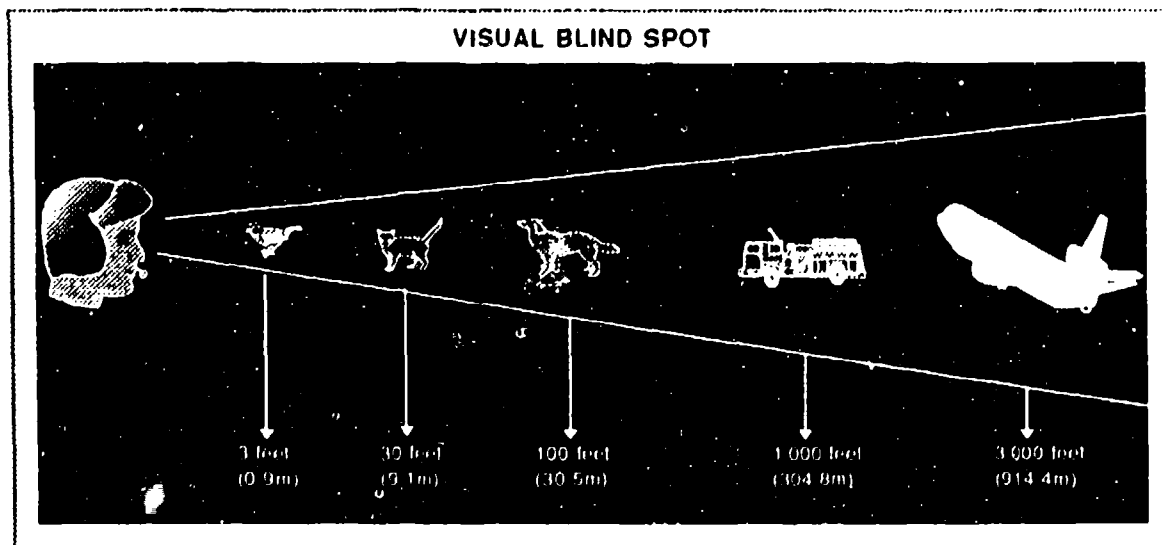
#### 1.1.5 Visual Problems

Several visual problems or conditions affect night vision. These include presbyopia, night myopia, and astigmatism.

Presbyopia. This condition is part of the normal aging process, which causes the lens of the eye to harden. Beginning in the early teen years, individuals gradually lose accommodation; that is, the ability



**FIGURE 2 NIGHT BLIND SPOT**



**FIGURE 3 EFFECT OF DISTANCE ON THE NIGHT BLIND SPOT**

to focus on nearby objects. When individuals are about 40 years old, their eyes are unable to reliably focus at the normal reading distance without reading glasses. As presbyopia worsens, instruments, maps, and checklists become more difficult to read, especially with red illumination. This difficulty can be corrected with certain types of bifocal spectacles that compensate for the inadequate accommodative power of the eye lenses.

Night Myopia. Myopic individuals do not see distant objects clearly; only nearby objects are in focus for them. At night, blue wavelengths of light prevail in the visible portion of the spectrum. Because of this, slightly nearsighted (myopic) individuals will experience blurred vision at night when viewing blue-green light. Also, image sharpness decreases as pupil diameter increases. For individuals with mild refractive errors, vision may become unacceptably blurred unless corrective glasses are worn. Another factor to consider is "dark focus." When luminance levels decrease, the focusing mechanism of the eye may move toward a resting position and make the eye more myopic. These factors are more important when the pilot looks outside the cockpit during unaided night flight. Special corrective lenses can be prescribed to correct for myopia.

Astigmatism. Astigmatism is an irregularity of the shape of the cornea that may cause an out-of-focus condition. If, for example, an astigmatic person focuses on power poles (vertical), the wires (horizontal) will be out of focus in most cases. If the astigmatism is 1.00-diopter or greater, the aviator must be individually evaluated before flying with night-imaging devices that preclude the wearing of eyeglasses.

#### 1.1.6 Dark Adaptation

Going suddenly from bright light into darkness is a common occurrence. For example, people experience this when they enter a movie theater during the day or leave a brightly lit room at night. At first they see very little, if anything. After several seconds, they can start to see dim forms and large outlines depending upon the available light. As time goes by, more details of the environment become apparent as further dark adaptation occurs.

Dark adaptation is the process by which the eyes increase their sensitivity to low levels of illumination. Individuals dark-adapt to varying degrees and at different rates. During the first 30 minutes, the sensitivity of the eye increases roughly ten-thousandfold. Very little increase in sensitivity occurs after that time.

The lower the starting level of illumination, the more rapid complete dark adaptation is achieved. For example, less time is required to dark-adapt completely after leaving a darkened theater than after leaving a brightly lit hangar.

Dark adaptation for optimum night visual acuity approaches its maximum level in about 30 to 45 minutes under minimal light conditions. If



the dark-adapted eye is exposed to a bright light, the sensitivity of that eye is temporarily impaired. The amount of impairment depends on the intensity and duration of the exposure. Brief flashes from a white (xenon) strobe light, commonly found on aircraft, have little effect on night vision because the pulses of energy are so short. On the other hand, exposure to a flare, a searchlight beam, or lightning may seriously impair night vision. In such cases, the recovery of a previously maximum level of dark adaptation can take from 5 to 45 minutes in continued darkness.

Night vision devices affect dark adaptation. Vision with night vision goggles is primarily photopic, but the low light levels produced by the goggles do not fully bleach out rhodopsin. Use of the device does not seriously degrade dark adaptation. NVG use is commensurate with the light coming from an instrument panel.

If a previously dark-adapted crew member wearing night vision goggles removes them in a darkened environment, a 30-minute dark adaptation level can be regained in about 2 to 3 minutes. No dark adaptation period is necessary before using the device.

#### 1.1.7 Night Vision Protection

Night vision should be protected when possible. Some of the steps crew members can take to protect their night vision are described in the following paragraphs.

##### 1.1.7.1 Equipment

Sunglasses. Repeated exposure to bright sunlight has an increasingly adverse affect on dark adaptation. This effect is intensified by reflective surfaces such as sand and snow. Exposure to intense sunlight for 2 to 5 hours decreases scotopic visual sensitivity for as long as 5 hours. Also, a decrease occurs in the rate of dark adaptation and degree of night visual capacity. These effects are cumulative and may persist for several days. If a night flight is scheduled, crew members should wear neutral density (N-15) sunglasses or equivalent filter lenses when exposed to bright sunlight. This precaution will increase the rate of dark adaptation at night and improve night visual sensitivity.

Oxygen Supply. Unaided night vision depends on optimum function and sensitivity of the rods of the retina. Lack of oxygen to the rods (hypoxia) significantly reduces their sensitivity. This increases the time required for dark adaptation and decreases the ability to see at night. Without supplemental oxygen, an individual's night vision declines measurably at pressure altitudes above 4,000 feet. Because night vision device output is photopic and central vision is the last to be degraded by a lack of oxygen, aided night vision is not significantly affected. At night, aviators should use oxygen, if available, when operating unaided above a pressure altitude of 4,000 feet.

### 1.1.7.2 Precautions

Heliport/Airport Lighting. Whenever possible, light sources that may impair the flight crew's dark adaptation should be eliminated. Aircraft scheduled for night flight should be positioned, if possible, where the least amount of light exists. The aviator should select departure routes that avoid highways and residential areas where artificial illumination can impair night vision. Runway and final approach and takeoff (FATO) lights, when practical, should be reduced for departing traffic.

High-intensity Lighting. During night missions, flight crews may be exposed to high-intensity lighting such as city lights, searchlights, landing lights, and other external lightning. These may cause a total or a partial loss of night vision. If a flash or high-intensity light is expected from a specific direction, the pilot should turn the aircraft away from the light source.

When such a condition occurs unexpectedly and direct view cannot be avoided, the pilot can preserve his dark adaptation by shutting one eye and using the other to observe. Once the light source is no longer visible, the eye that was closed can provide the required night vision. This is possible because dark adaptation occurs independently in each eye. However, it should be remembered that problems with depth perception can occur when the pilot views with one dark-adapted eye. This is particularly true when a pilot hovers near terrain obstacles or makes an approach. Techniques to counter expected light conditions are discussed in the following paragraphs.

Lights in Developed Areas. The aviator should select flight routes that avoid developed or metro areas which may have heavy concentrations of light. If this condition is inadvertently encountered, the pilot should alter the flight route to avoid overflying the brightly lit area. While it is understood that the majority of EMS missions originate in large, well lit metropolitan areas, every effort should be made to maintain dark adaptation when flying to rural areas. A decrease in dark adaptation from a single light source, such as a farmhouse or an automobile, can be minimized by looking away from the light.

Flares. When a flare is used to illuminate the viewing area or is inadvertently detonated nearby, the pilot should maneuver to a position along the edge of the illuminated area. This procedure reduces exposure to the light source. Flight crews also should request that fire and police personnel extinguish all flares and sources of white light in the vicinity of the landing zone as soon as practical.

### 1.1.8 Self-Imposed Stress

Night flight is more fatiguing and stressful than day flight. Many self-imposed stressors limit night vision. Flight crews can control this type of stress. The factors that cause self-imposed stress are discussed in the following paragraphs.

Drugs. Drugs can seriously degrade visual acuity during the day and especially at night.

Exhaustion. If crew members become fatigued during a night flight, they will not be mentally alert. Exhaustion causes crew members to respond more slowly, even in situations requiring immediate reaction. Exhausted crew members tend to concentrate on one aspect of a situation without considering the total requirements. Their performance may become a safety hazard, depending on the degree of fatigue. Rather than use proper scanning techniques, they are prone to stare.

Illness. Increased temperature and a feeling of unpleasantness usually are associated with illness. High body temperatures consume a higher than normal rate of oxygen. As a result, hypoxia may be induced and night vision may be degraded. In addition, the unpleasant feeling associated with sickness distracts a crew member's attention and degrades his or her ability to concentrate on night flying requirements.

Poor Physical Conditioning. To overcome this limitation, crew members should participate in regular exercise programs. Crew members who are physically fit become less fatigued during flight and have better night scanning efficiency. However, too much exercise in a given day may leave crew members too fatigued for night flying.

Inadequate Rest. Adequate rest and sleep are important before flying.

Alcohol. Alcohol is a sedative. Its use impairs both coordination and judgment. As a result, crew members impaired by alcohol fail to apply the proper techniques of night vision. They are likely to stare at objects and to neglect scanning techniques. The amount of alcohol consumed determines the degree to which night vision is affected. The effects of alcohol are long-lasting; hangovers also impair visual scanning efficiency.

Tobacco. Of all the self-imposed stressors, cigarette smoking decreases visual sensitivity the most at night. Smoking significantly increases the amount of carbon monoxide carried by the hemoglobin in red blood cells. This reduces the blood's capacity to combine with oxygen so less oxygen is carried in the blood. Hypoxia caused by carbon monoxide poisoning affects peripheral vision and dark adaptation. The results are the same as those for hypoxia caused by

cigarettes within a 24-hour period may saturate from 8 to 10 percent of the capacity of hemoglobin. Smokers lose 20 percent of their night vision capability at sea level. This equals a physiological altitude of 5,000 feet.

#### 1.1.8.1 Hypoglycemia and Nutritional Deficiency

Hypoglycemia. Missing or postponing meals can cause low blood sugar, which impairs night flight performance. Low blood sugar levels may result in stomach contractions, distraction, a breakdown in habit pattern, a shortened attention span, and other physiological changes.

Vitamin A Deficiency. Insufficient consumption of vitamin A may impair night vision. Foods high in vitamin A include eggs, butter, cheese, liver, apricots, peaches, carrots, squash, spinach, peas, and most types of green vegetables. A balanced diet usually provides enough vitamin A. Excessive quantities of vitamin A will not improve night vision and may be harmful.

#### 1.1.9 Scanning Techniques

Dark adaptation is only the first step toward increasing the ability to see at night. Applying night vision techniques will enable pilots to overcome many of the physiological limitations of their eyes. Because the fovea centralis is automatically directed toward an object by a visual fixation reflex, scanning techniques require considerable practice and concerted effort on the part of the viewer.

Scanning. Scanning techniques are important in identifying landmarks, landing sites, obstructions, and other aircraft at night. To scan effectively, crew members look from right to left or left to right. They should begin scanning at the greatest distance an object can be perceived (top) and move inward toward the position of the aircraft (bottom). This scanning pattern is shown in figure 4. Because the light-sensitive elements of the retina cannot perceive images that are in motion, a stop-turn-stop-turn motion should be used.

For each stop, an area approximately 30 degrees wide should be scanned. This viewing angle will include an area approximately 250 meters wide at a distance of 500 meters. The duration of each stop is based on the degree of detail that is required, but no stop should last longer than 2 to 3 seconds. When moving from one viewing point to the next, crew members should overlap the previous field-of-view by 10 percent. Other scanning techniques, such as the ones illustrated in figure 5, may be used if appropriate to the situation.

Pilots will look forward for horizon, familiar terrain shapes, lights on towers, city lights, etc. During contact navigation and reconnaissance, particularly while turning, pilots will look down for visual cues.

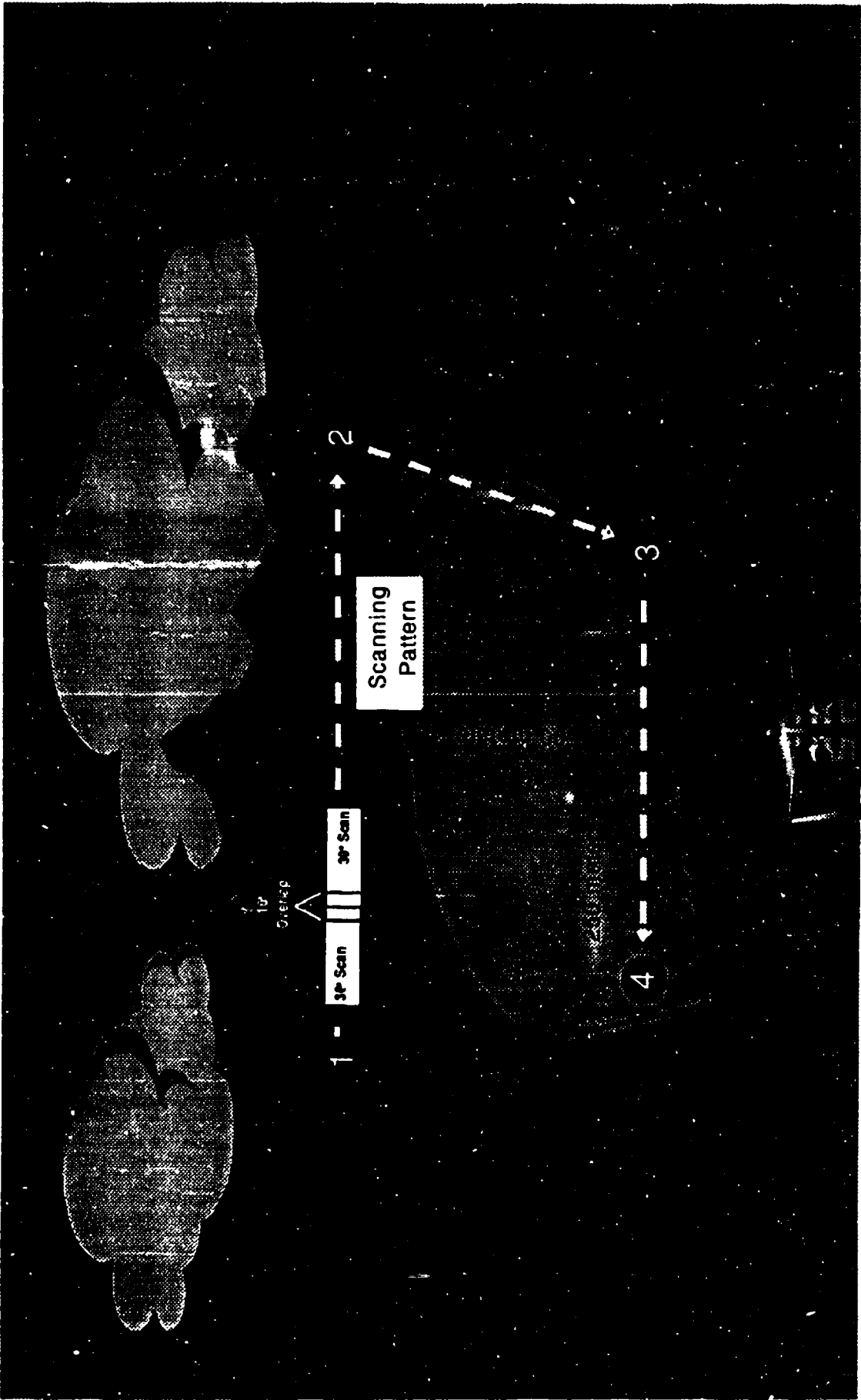


FIGURE 4 PRIMARY SCANNING PATTERN

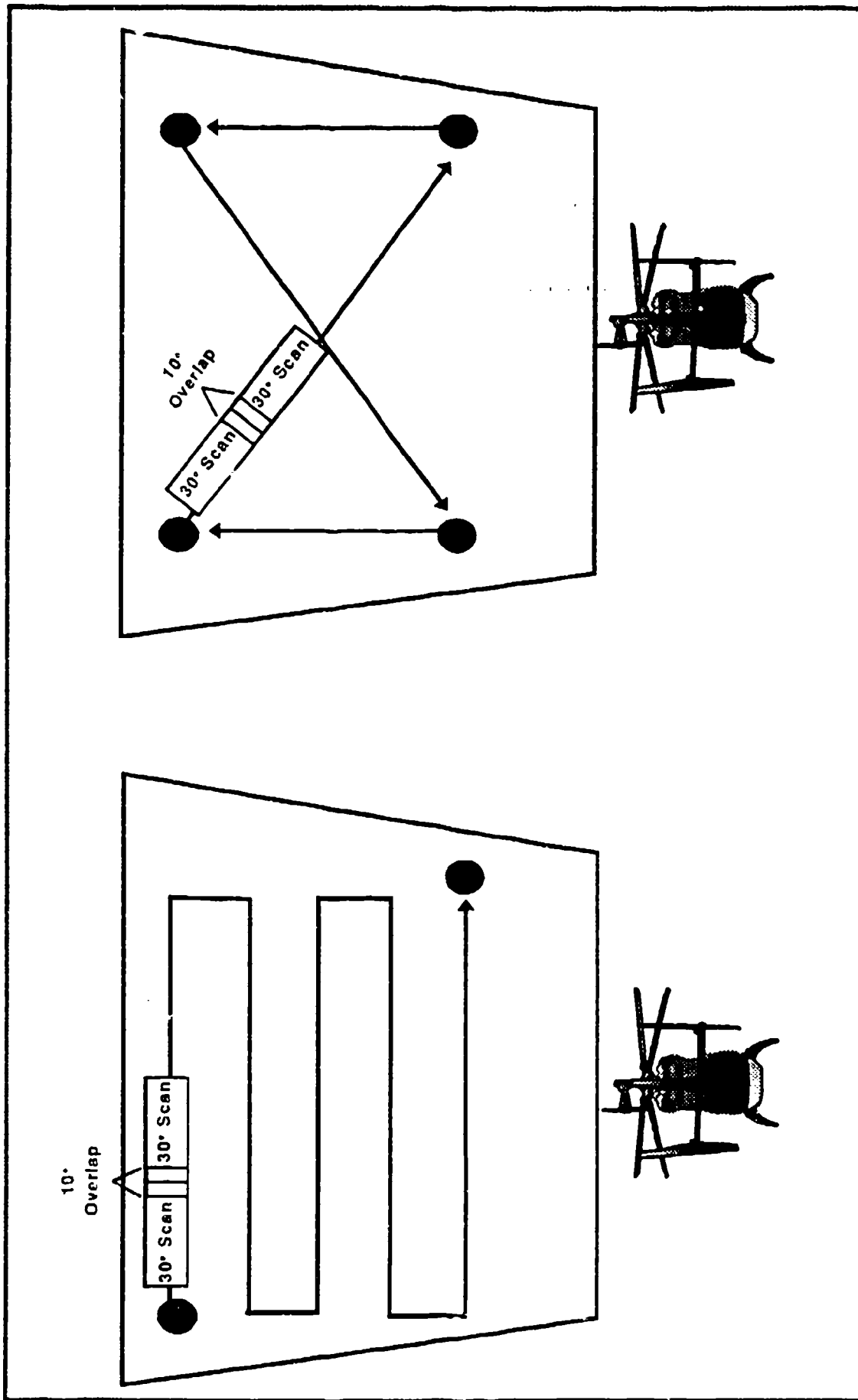


FIGURE 5 ALTERNATE SCANNING PATTERN

Off-Center Viewing. Viewing an object using central vision during daylight poses no limitations. If this same technique is used at night, however, the object may not be seen because of the night blind spot that exists during low illumination. To compensate for this limitation, crew members must use off-center vision as illustrated in figure 6. This technique requires that an object be viewed by looking 10 degrees above, below, or to either side of the object. In this manner, the peripheral vision can maintain contact with an object.

The technique of off-center vision applies only to the surveillance of objects that are dim or minimally illuminated. Under these conditions, cone vision is not stimulated. Central vision is best used when an object is bright enough to stimulate the cones and needs to be seen with considerable detail. When the object begins to fade, it should be redetected using off-center vision and retained until central vision recovers sufficiently to permit further observation.

With off-center vision, the images of an object viewed longer than 2 to 3 seconds will disappear. This occurs because the rods reach a photochemical equilibrium that prevents any further response until the scene changes. This produces a potentially unsafe operating condition. To overcome this night vision limitation, crew members must be aware of the phenomenon and avoid viewing an object for longer than 2 or 3 seconds. The peripheral field of vision will continue to pick up the object when the eyes are shifted from one off-center point to another.

#### 1.1.10 Distance Estimation and Depth Perception

Distance estimation and depth perception cues are easily recognized when crew members use central vision under good illumination. As the light level decreases, the ability to judge distances accurately is degraded and visual illusions become more common. A knowledge of distance estimation and depth perception mechanisms and cues will assist crew members in judging distances at night. These cues may be monocular or binocular. Monocular cues are more important for crew members than binocular.

##### 1.1.10.1 Monocular Cues

The monocular cues that aid in distance estimation and depth perception include motion parallax, geometric perspective, retinal image size, and aerial perspective.

Motion Parallax. This cue to depth perception is a means of judging distances under reduced illumination. Motion parallax refers to the apparent motion of stationary objects as viewed by an observer moving across the landscape. When the crew member looks outside the aircraft, perpendicular to the direction of travel, near objects appear to move backward, past or opposite the path of motion. Far objects seem to move in the direction of motion or remain fixed.

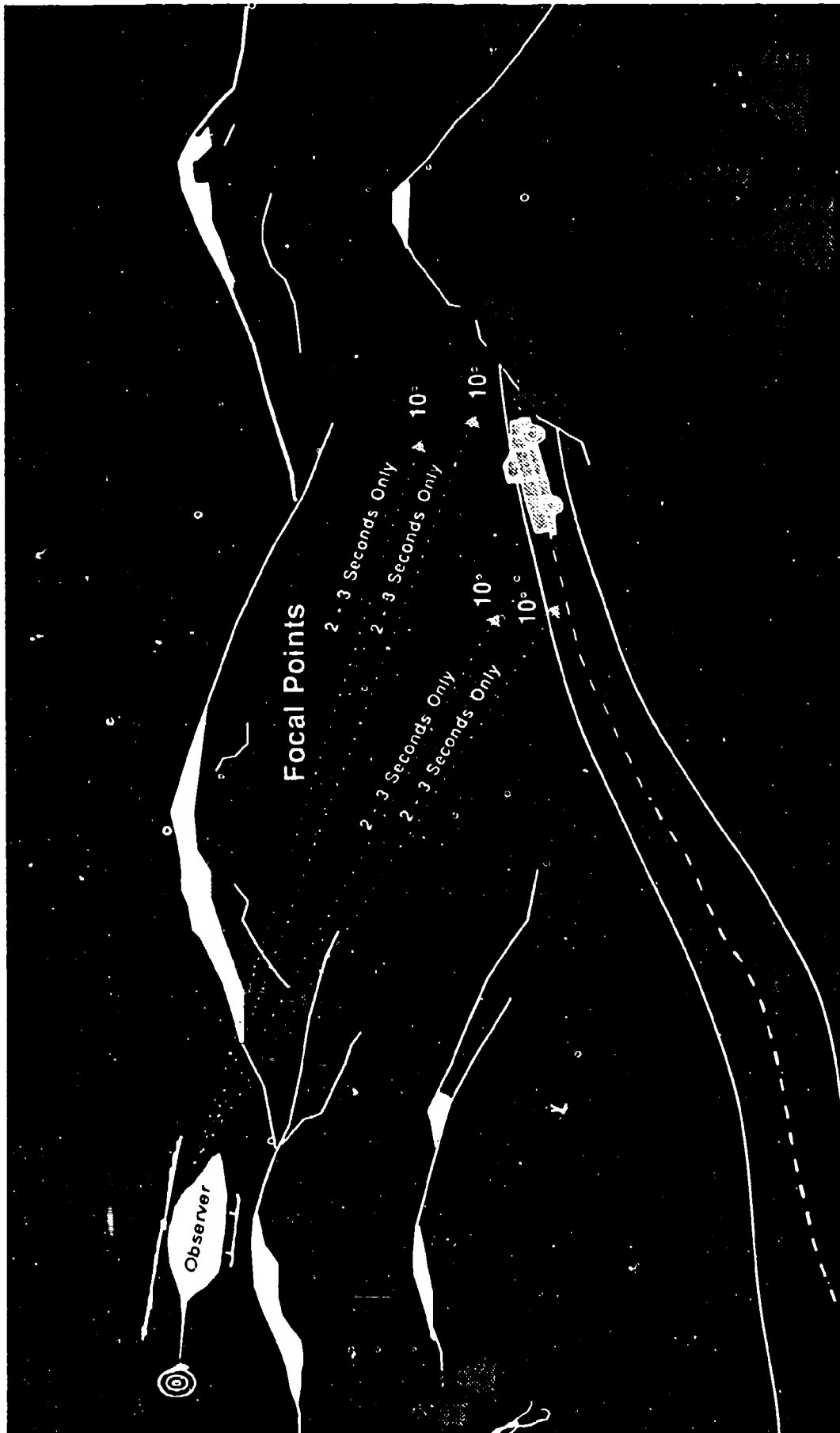


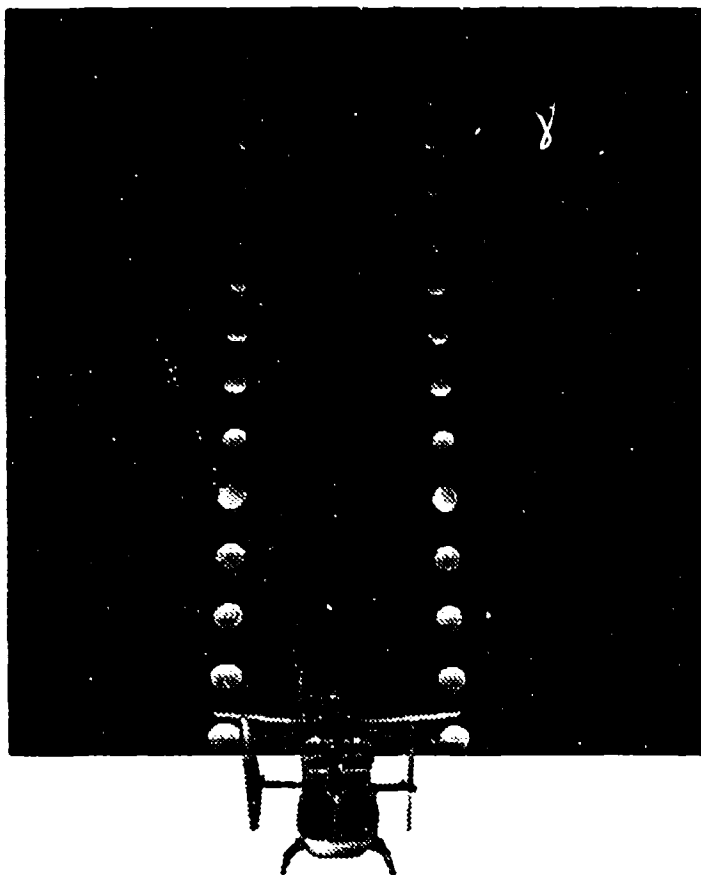
FIGURE 6 OFF-CENTER VIEWING TECHNIQUE



The rate of apparent movement depends on the distance the observer is from the object. For example, as an aviator flies low level, objects near the aircraft will appear to rush past the aircraft while a mountain range near the horizon will appear stationary. As the aviator flies across a power line that extends to the horizon, that part of the power line near the aircraft will appear to move swiftly, opposite the path of motion. Toward the horizon, the same power line will appear fixed. Objects that appear to be fixed or moving slowly are judged to be a greater distance from the pilot than objects that appear to be moving swiftly.

Geometric Perspective. An object may appear to have a different shape when viewed at varying distances and from different angles. Geometric perspective cues include linear perspective, apparent foreshortening, and vertical position in the field.

Linear Perspective. Parallel lines, such as runway lights, tend to converge as distance from the observer increases. This is illustrated in figure 7.



**FIGURE 7 LINEAR PERSPECTIVE**

Apparent Foreshortening. The true shape of an object or a terrain feature appears elliptical when viewed from a distance. As the distance to the object or the terrain feature decreases, the apparent perspective changes to its true shape or form. Figure 8 illustrates how the shape of a body of water changes when viewed at different distances at the same altitude.

Vertical Position in the Field. Objects or terrain features farther away from the observer appear higher on the horizon than those closer to the observer. The higher vehicle in figure 9 appears to be closer to the top and, thus, at the greater distance from the observer. At night, crew members can mistake lights on elevated structures or lights on low-flying aircraft for distant ground structures because of the light's higher vertical position in the field.

Retinal Image Size. The brain perceives the actual size of an object from the size of an image focused on the retina. Four factors are considered in determining distance using the retinal image. They are known size of objects, increasing or decreasing size of objects, terrestrial associates, and overlapping contours or interposition of objects.

Known Size of Objects. The nearer an object is to the observer, the larger its retinal image. By experience, the brain learns to estimate the distance of familiar objects by the size of their retinal images. Figure 10 shows how this process works. A structure projects a specific angle on the retina based on its distance from the observer. If the angle is small, the observer judges the structure to be at a great distance. A larger angle indicates to the observer that the structure is close. To use this cue, the observer must know the actual size of the object. If the observer is not familiar with the object, its distance would be determined primarily by motion parallax.

Increasing or Decreasing Size of Objects. If the retinal image size of an object increases, the relative distance is decreasing. If the image size decreases, the relative distance is increasing. If the image size is constant, the object is at a fixed relative distance.

Terrestrial Associations. Comparing an object, such as an airport, with an object of known size, such as a helicopter, helps to determine the object's size and apparent distance from the observer. Objects ordinarily associated together are judged to be at about the same distance.

For example, a helicopter observed near an airport is judged to be in the traffic pattern and, therefore, at about the same distance as the airport. Figure 11 illustrates terrestrial association.



**FIGURE 8 APPARENT FORTHSHORTENING PERSPECTIVE**

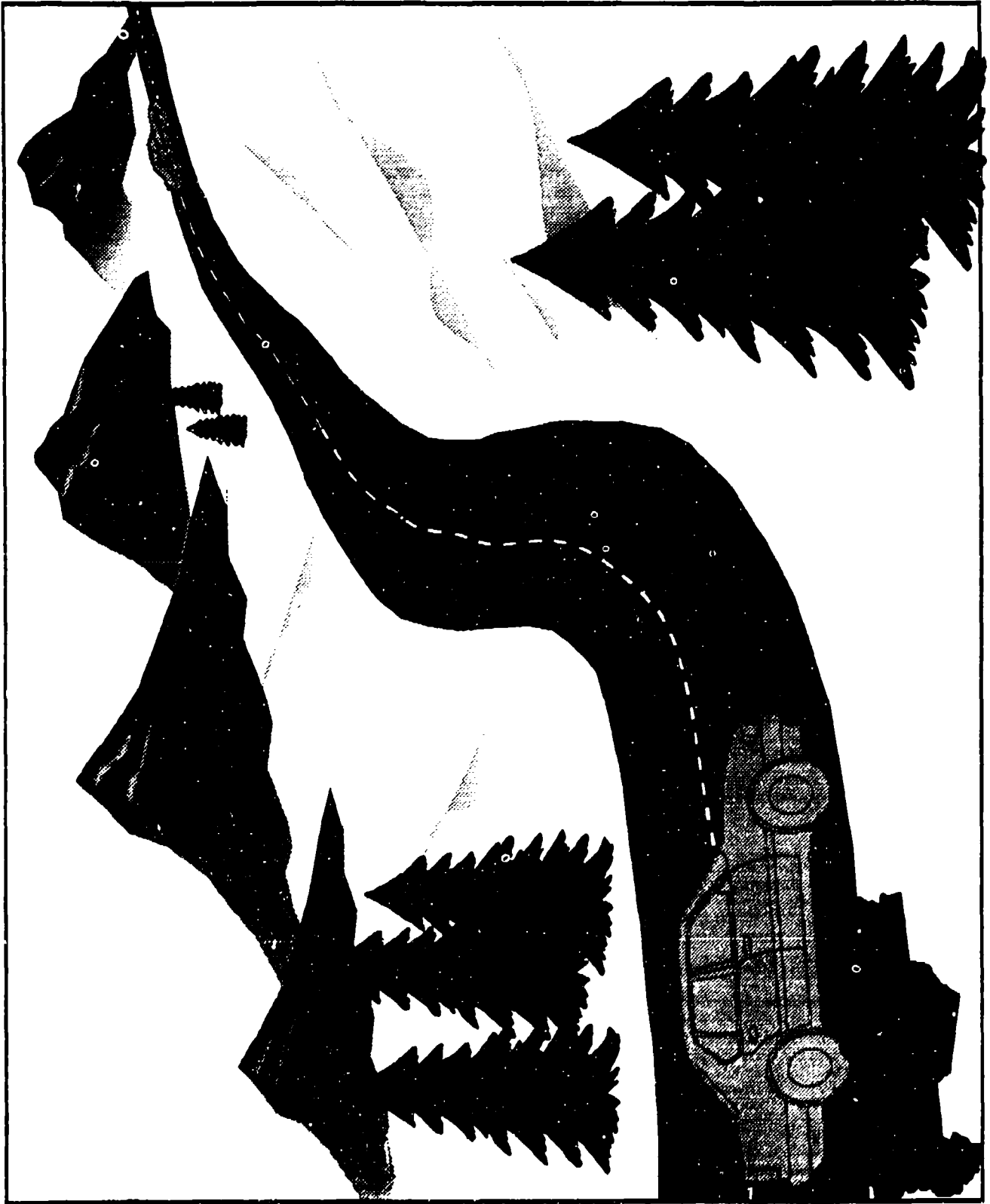


FIGURE 9 VERTICAL POSITION IN THE FIELD

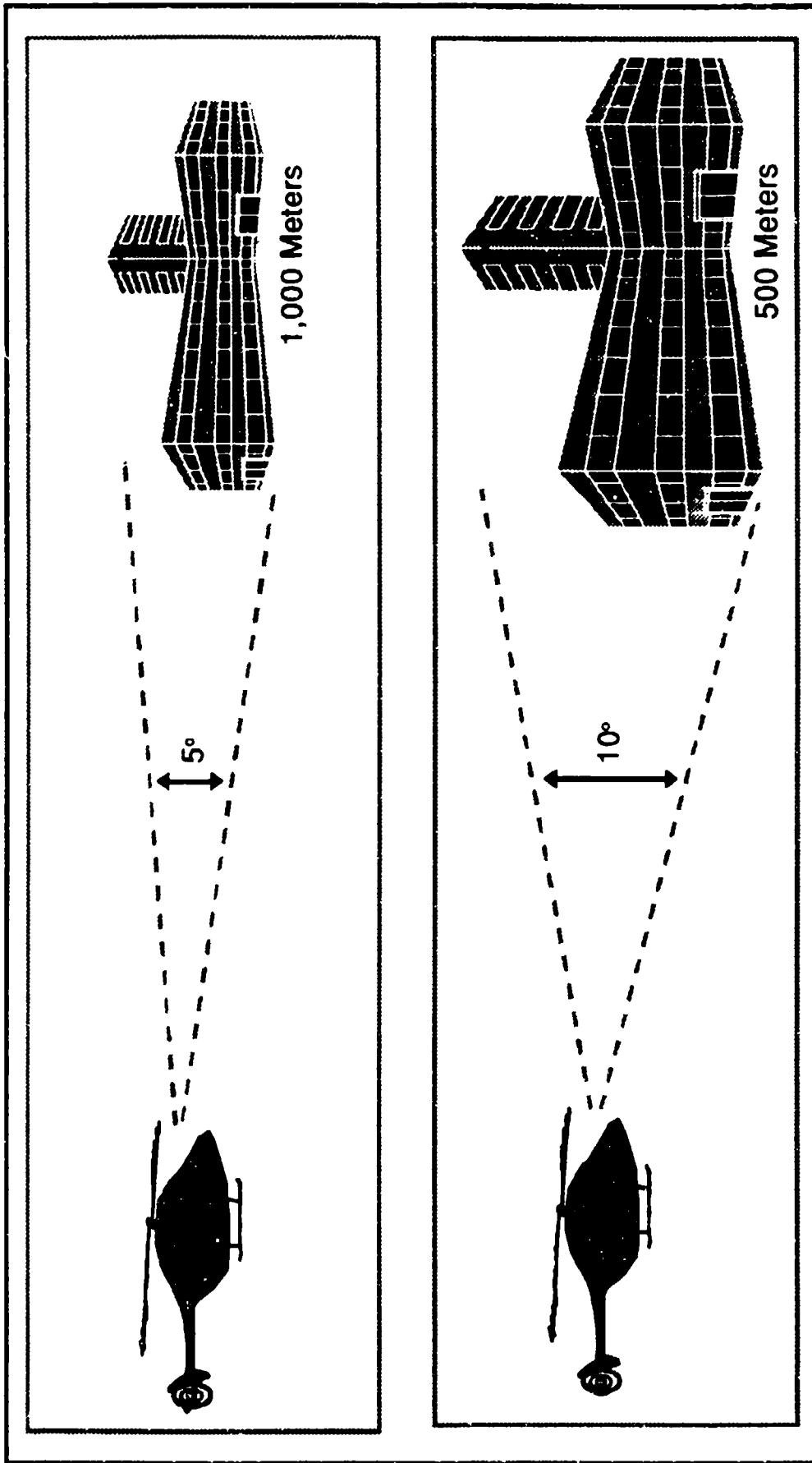


FIGURE 10 KNOWN SIZE OF OBJECTS

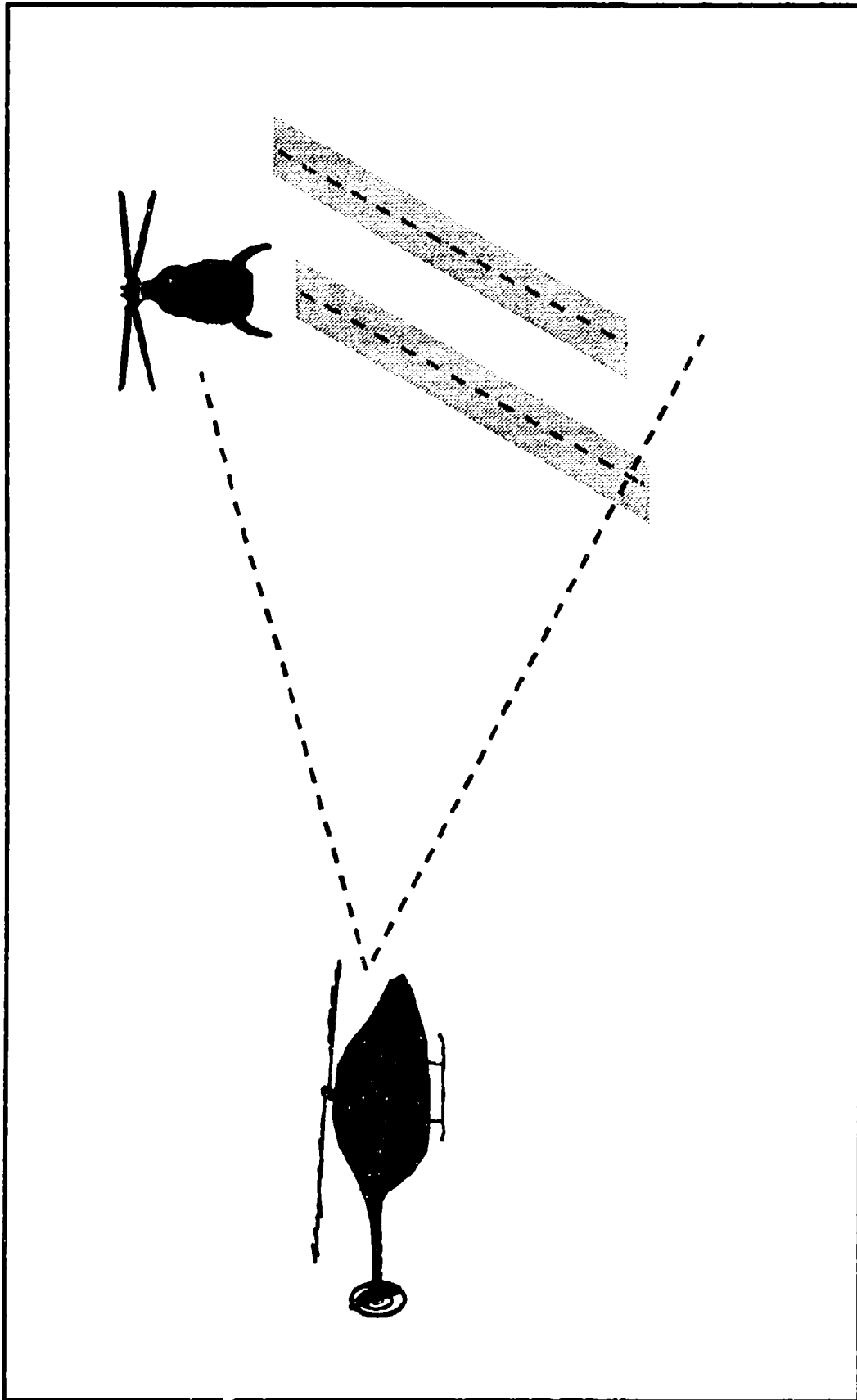


FIGURE 11 TERRESTRIAL ASSOCIATION

Overlapping Contours or Interposition of Objects. When objects overlap, the overlapped object is farther away, as illustrated in figure 12. This overlapping is especially important to consider at night during a landing approach. Lights disappearing or flickering in the landing area indicate barriers between the landing area and the aircraft. The flight path should be adjusted accordingly.

Aerial Perspective. The clarity of an object and the shadow cast by it are perceived by the brain and are cues for estimating distance. Several aerial perspective factors are used to determine distance.

Variations in Color or Shade. Subtle variations in color or shade are clearer the closer the observer is to an object. However, as distance increases, these distinctions blur. For example, the side of a hill from a distance will appear to be a uniform shade with no distinguishable shape. As the aircrew flies closer to the hill, the shade produced by individual trees and the space in between those trees become noticeable. Thus under high light levels at night, color or shade can provide cues for distance estimation.

Loss of Detail or Texture. As a person gets farther from an object, discrete details become less apparent. For example, when a cornfield becomes a solid color and the leaves and branches of a tree become a solid mass, the objects are judged to be far away. Because reduced illumination also decreases resolution, these cues will disappear shortly after sunset or be limited to close viewing distances.

Position of Light Source and Direction of Shadow. Every object will cast a shadow from a light source. The direction in which the shadow is cast depends on the position of the light source. If the shadow of an object is toward the observer, the object is closer than the light source is to the observer.

#### 1.1.10.2 Binocular Cues

Binocular cues depend on the slightly different view each eye has of an object. Consequently, binocular perception is useful only when the object is close enough to make an obvious difference in the viewing angle of both eyes. In the flight environment, most distances outside the cockpit are so great that binocular cues are of little, if any, value. In addition, binocular cues operate on a more subconscious level than monocular cues and are performed automatically.

Visual Illusions. Decreasing visual information increases the probability of spatial disorientation. Reduced visual references also create several illusions that can induce spatial disorientation. Many types of visual illusions can occur in the aviation environment. Included among them are autokinesis, ground light misinterpretation, relative motion, reversible perspective illusion, false horizons,

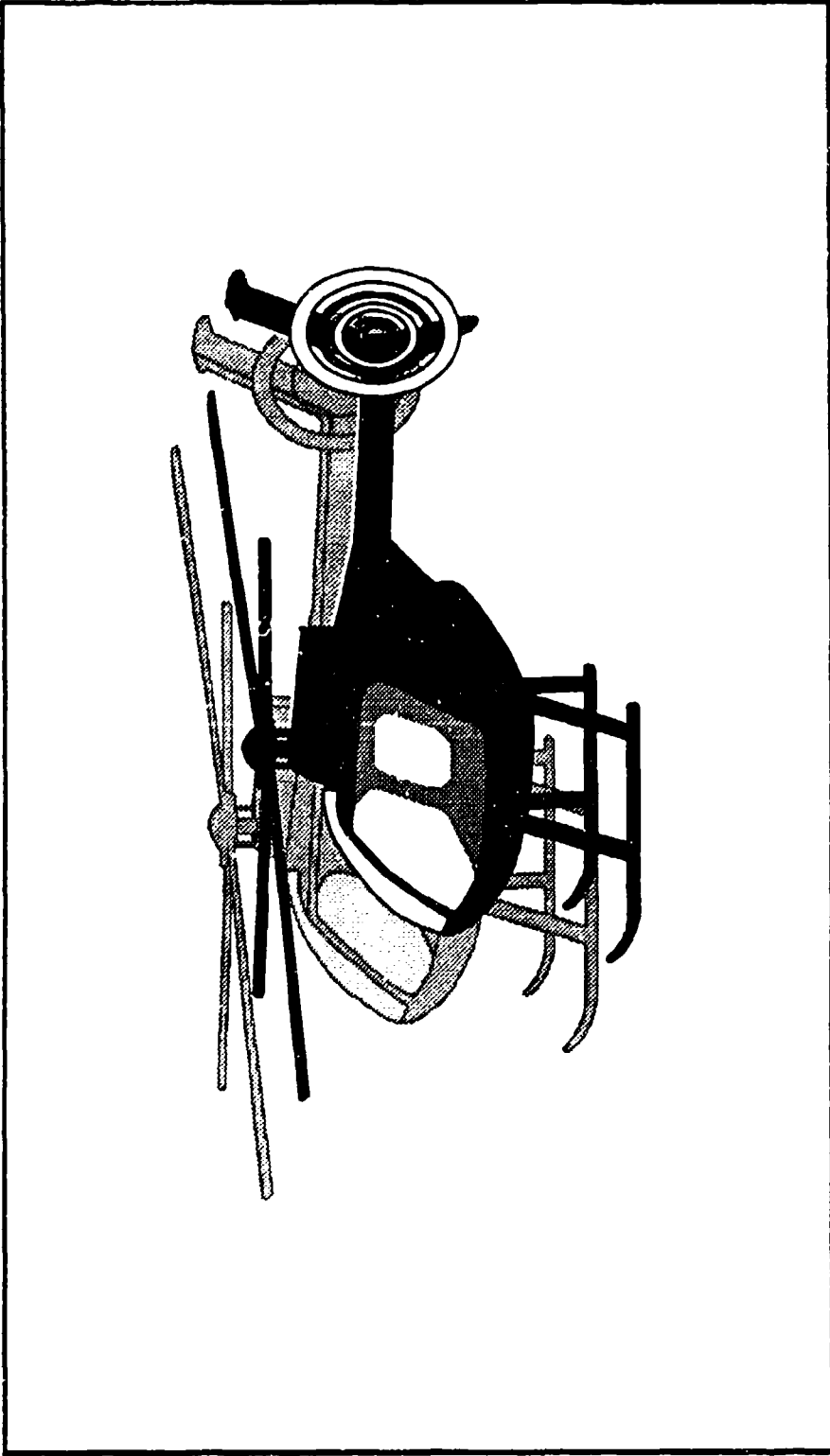


FIGURE 12 OVERLAPPING CONTOUR



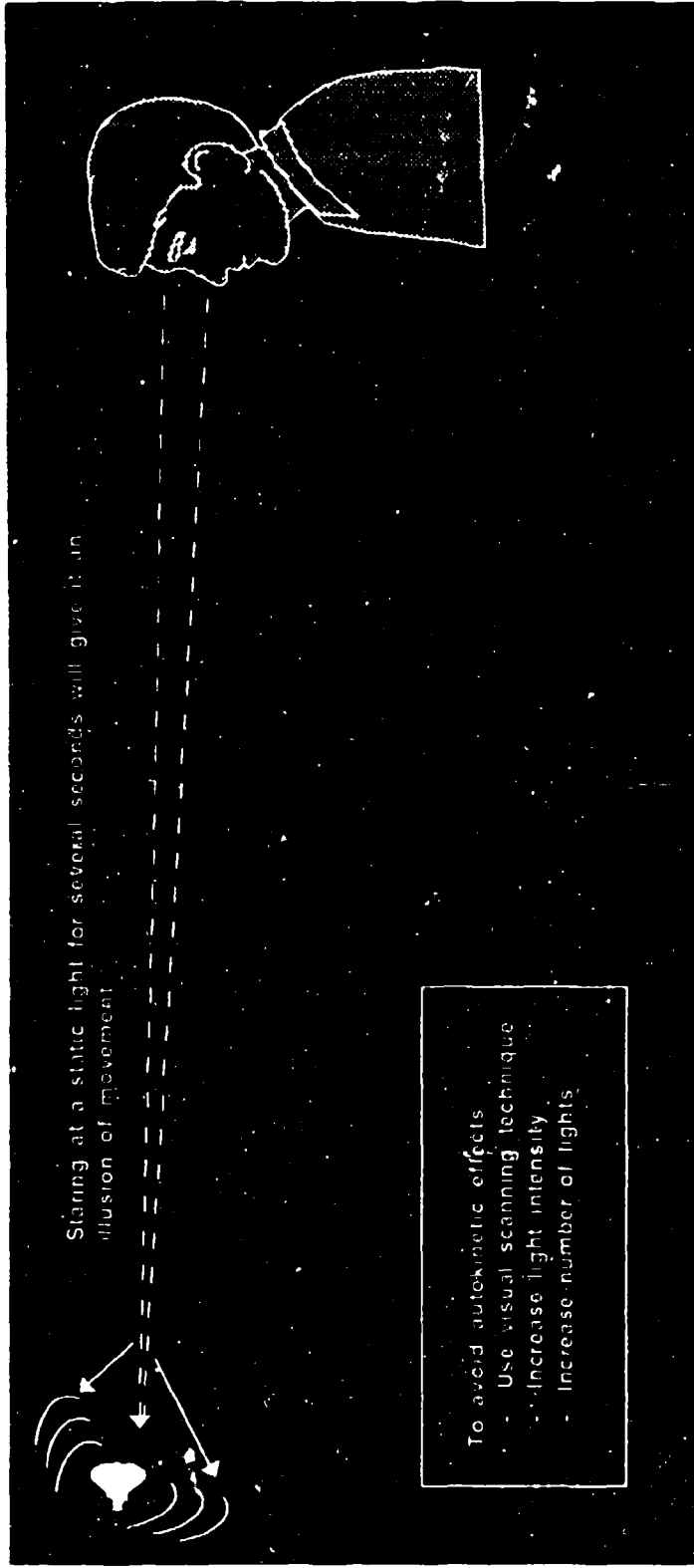
altered reference planes, and height perception illusion. Others include flicker vertigo, fascination (fixation), structural illusions, and size-distance illusion.

Autokinesis. When a static light is stared at in the dark, the light appears to move, as shown in figure 13. This phenomenon can be readily demonstrated by staring at a lighted cigarette in a dark room. Apparent movement will begin in about 8 to 10 seconds. Although the cause of autokinesis is not known, it appears to be related to the loss of surrounding references that normally serve to stabilize visual perceptions. This illusion can be eliminated or reduced by visual scanning, by increasing the number of lights, or by varying the light intensity. The most important of the three solutions is visual scanning. A light or lights should not be stared at for more than 10 seconds. This illusion is not limited to light in darkness. It can occur whenever a small, bright, still object is stared at against a dull dark or nondescript background. Similarly, it can occur when a small, dark, still object is viewed against a light, structureless environment. Anytime visual references are not available, aircrews are subject to this illusion.

Ground Light Misinterpretation. A common occurrence is to confuse ground lights with stars. When this happens, pilots unknowingly position aircraft in unusual attitudes to keep the ground lights, believed to be stars, above them. For example, some aviators have mistaken the lights along a seashore for the horizon and have maneuvered their aircraft dangerously close to the sea; they believed they were flying straight and level. Pilots have also confused certain geometric patterns of ground lights. For example, pilots have identified moving trains as landing zone lights and have been badly shaken by their near misses. To avoid these problems, pilots should cross-check aircraft instruments. Also, position lights of other aircraft in formation can be mistaken for ground lights and might be lost against the horizon when another aircraft is at or below the altitude of the observer.

Relative Motion. The illusion of relative motion can be illustrated by the following example. A pilot hovers an aircraft and waits for hover taxi instructions. Another aircraft hovers alongside. As the other aircraft is picked up in the first pilot's peripheral vision, the pilot senses movement in the opposite direction. The only way to correct for this illusion is to have sufficient experience to understand that such illusions do occur and to not react to them on the controls. The use of proper scanning techniques can help prevent this illusion.

Reversible Perspective Illusion. At night, an aircraft may appear to be going away when it is, in fact, approaching a second aircraft. This illusion often occurs when an aircraft is flying parallel to another's course. To determine the direction of



**FIGURE 13 AUTOKINETIC ILLUSION**

flight, pilots should observe aircraft lights and their relative position to the horizon. If the intensity of the lights increases, the aircraft is approaching. If the lights dim, the aircraft is moving away. Also, remembering the "3 Rs" will help identify the direction of travel when other aircraft are encountered. If the red aircraft position lights are on the right, the aircraft is returning (coming toward the observer).

False Horizons. Cloud formations may be confused with the horizon. Momentary confusion may result when the pilot looks up after having given prolonged attention to a task in the cockpit. Because outside references for attitude are less obvious and reliable at night, pilots should rely less on them during night flight. Using instrument cross-checks can help prevent this situation. While hovering over terrain that is not perfectly level, pilots might mistake the sloped ground in front of the aircraft for the horizon and cause the aircraft to drift while trying to maintain a stationary position. Figure 14 illustrates false horizon.

Altered Reference Planes. When approaching a line of mountains or clouds, pilots may feel that they need to climb even though their altitude is adequate. Also, when flying parallel to a line of clouds, pilots may tend to tilt the aircraft away from the clouds.

Height Perception Illusion. When flying over desert, snow, water, or other areas of poor contrast, crew members may experience the illusion of being higher above the terrain than they actually are. This is due to the lack of visual references. This illusion may be overcome by dropping an object, such as a chemical light stick on the ground before landing. Another technique to overcome this illusion is to monitor the shadows cast by near objects, such as the landing gear, or skid shadows at a hover. Flight in an area where visibility is restricted by haze, smoke, or fog produces the same illusion.

Flicker Vertigo. Much time and research have been devoted to the study of flicker vertigo. A light flickering at a rate between 4 and 20 cycles per second can produce unpleasant and dangerous reactions. Such conditions as nausea, vomiting, and vertigo may occur. On rare occasions, convulsions and unconsciousness may also occur. Fatigue, frustration, and boredom tend to intensify these reactions. During the day, the problem can be caused by sunlight flickering through the rotor blades or propeller. At night, it can also be caused by an anticollision light reflecting against an overcast sky, haze, or the rotor system. This can be corrected by turning the anticollision light off.

Fascination (Fixation). This illusion occurs when pilots ignore orientation cues and fix their attention on a goal or an object. This is dangerous because aircraft ground-closure rates are difficult to determine at night; normal, daylight peripheral

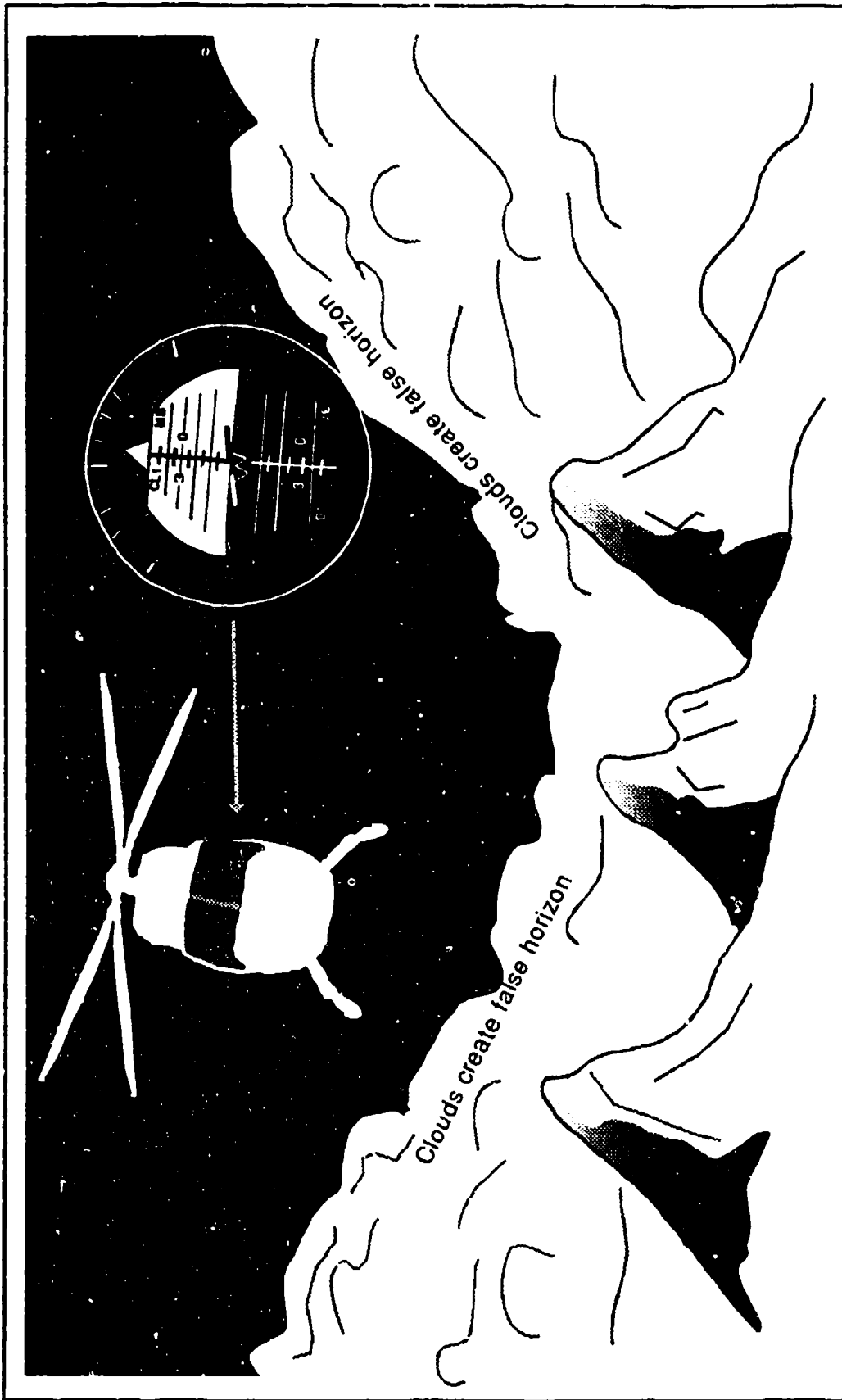


FIGURE 14 FALSE HORIZON ILLUSION

movement is reduced or absent. Preventing this illusion requires increased scanning by the pilot.

Structural Illusions. Structural illusions are caused by heat waves, rain, snow, sleet, or other factors that obscure vision. For example, a straight line may appear to be curved when seen through a desert heat wave or a wing-tip light may appear to double or move when viewed during a rain shower.

Size-Distance Illusion. This illusion results from viewing a source of light that is increasing or decreasing in luminance (brightness). The pilot may interpret the light as approaching or retreating.

#### 1.1.11 Aircraft Design Limitations

The design of aircraft may degrade a crew member's ability to see outside the aircraft. To minimize the loss of night vision because of aircraft design shortcomings, the aircrew must properly prepare the aircraft for night flight. Consideration should be given to the aircraft limitations discussed in the following paragraphs.

Windshields reduce the ability to see outside the aircraft. Dirt, grease, and bugs must be removed from the windshield before each night flight.

Aircraft instruments are easier to read under high levels of instrument illumination. However, the level of illumination needed for optimum reading interferes with maximum dark adaptation for viewing dim objects outside the aircraft.

Interior lights also interfere with dark adaptation. They reflect off the windshield and reduce outside visibility. To reduce the adverse effects of cockpit lights, the pilot should turn off nonessential lights and keep the intensity of essential lights at the lowest useable level.

## 2.0 ILLUMINATION, METEOROLOGICAL, AND TERRAIN FACTORS

### 2.1 INTRODUCTION

Night aviation operations are more easily conducted when ambient light sources provide the greatest amount of illumination. Sources of ambient light include the moon, background illumination, artificial light, and solar light. Regardless of the ambient light source, meteorological conditions will affect the level of light.

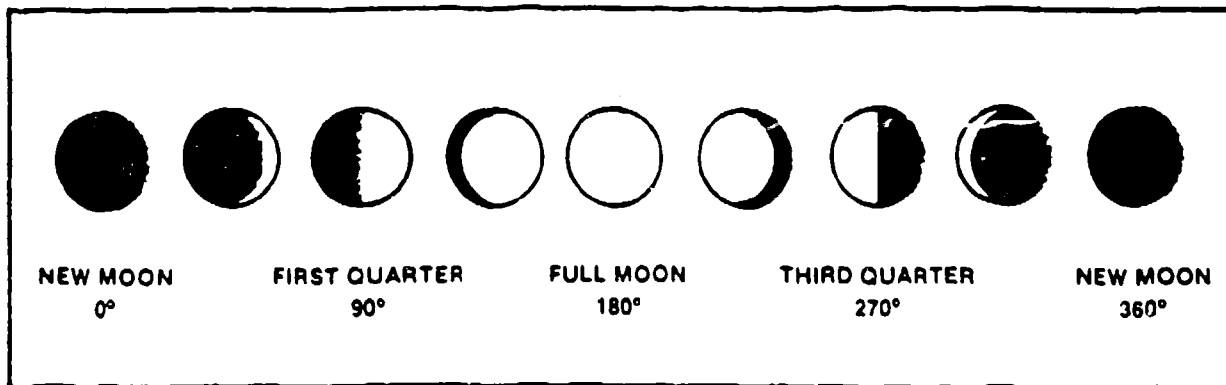
### 2.2 LIGHT SOURCES

The two principal light sources for night aviation operations are natural and artificial. Each type is discussed in the paragraphs which follow.

#### 2.2.1 Natural

The moon is the most important source of natural light at night. The stars provide some background illumination.

- 1) Lunar light. At night the moon provides the greatest source of ambient light. The moon angle changes about 15 degrees per hour (1 degree every 4 minutes). The ambient light level changes as the moon angle changes. Light from the moon is brightest when the moon is at its highest point (zenith). The time at which the moon rises and sets changes continually. Figure 15 illustrates the phases of the moon.



**FIGURE 15 PHASES OF THE MOON**

- a) New moon. The new moon phase is completed in about 8 days. Moonlight increases toward the end of the phase when about 50 percent of the moon is illuminated. A low light level exists.
- b) First quarter. About 7 days are required to complete the first quarter phase. The percentage of moon illumination at the beginning of the phase is about 50 percent. This increases until slightly less than 100 percent of the apparent disk is illuminated.

- c) Full moon. The full moon phase begins when 100 percent of the disk is illuminated. It ends 7 days later when about 50 percent of the moon is visible.
  - d) Third quarter. The duration of the last phase is about 7 days. It begins when about 50 percent of the moon is visible and ends when 2 percent or less is visible.
- 2) Solar light. Ambient solar light is usable for a period following sunset and before sunrise. After sunset, the amount of available solar light steadily decreases. Solar ambient light becomes unusable when the sun is 12 degrees below the horizon. This is called the end of evening nautical twilight or EENT. Before sunrise, solar light becomes usable when the rising sun is 12 degrees below the horizon. This is called the beginning of morning nautical twilight or BMNT.

### 2.2.2 Artificial

Lights from cities, automobiles, and fires are normally sources of small amounts of illumination. The lights of a large metropolitan area will, however, increase the light level around the city. The light from these sources is most pronounced during overcast conditions.

## 2.3 METEOROLOGICAL EFFECTS

Because meteorological conditions vary, the light level can not always be accurately predicted. A flight may begin with clear skies and unrestricted visibility, but meteorological conditions may deteriorate during the flight. Visibility restrictions can occur gradually or suddenly. Adverse weather at night is difficult to detect, and a gradual loss of horizon or decrease in visual acuity may occur as weather conditions worsen. As visual meteorological conditions (VMC) deteriorate, aviators must take precautions to prevent inadvertent entry into instrument meteorological conditions (IMC). Aircrews should be constantly aware of changing conditions. An awareness of these limiting factors will assist in evaluating the available ambient light. Attention to the available ambient light can also provide cues to deteriorating, meteorological conditions.

### 2.3.1 Clouds

- 1) Clouds reduce hemispherical illumination to some extent. The exact amount of reflection or absorption of light energy by different cloud types is not known. Therefore, a common factor cannot be applied to each condition of cloud coverage. A subjective evaluation of light reduction caused by clouds can be made by considering the amount of cloud coverage and the density, or thickness, of the clouds. For example, a thick, overcast layer of clouds will reduce the ambient light to a much greater degree

than a thin, broken layer of clouds. The combined effects of two or more layers of clouds must also be considered.

- 2) Because of reduced night vision (unaided or aided), aviators may fail to detect a gradual increase in cloud coverage and may, without warning, inadvertently enter the clouds. At night, aircrews must be alert for indications that clouds are present. Some of these indications are discussed below.
  - a) The light level is gradually reduced. Visual acuity and terrain contrast are also reduced or lost.
  - b) The moon and stars are obscured. The less visible the moon and stars, the heavier the cloud coverage.
  - c) Shadows obscure the moon's illumination. Crew members can detect these shadows by observing the varying levels of ambient light along the flight route.
  - d) Strong light sources such as obstruction lights on radio towers will produce halo effects and then fade from view when a thin cloud layer is over flown.

#### 2.3.2 Fog, Dust, Haze, and Smoke

- 1) Visibility restrictions reduce hemispherical illumination. Conditions such as ground fog, dust, haze, or smoke are more pronounced at lower altitudes. Haze is common around large cities.
- 2) The probability of fog increases as the temperature decreases and the dew-point spread approaches zero. A decrease in the intensity of ground lights indicates an increase in the moisture content of the air. A halo effect around ground lights indicates that moisture is in the air and that ground fog may be forming.

#### 2.3.3 Lightning

The lightning flash is one meteorological phenomenon that increases illumination. The intensity of the illumination depends on how near the lightning is. Night vision may be impaired if the aircrew is too close to lightning activity.

#### 2.4 TERRAIN INTERPRETATION

The ambient light level, the degree of night adaptation, and night vision techniques influence how well aircrews can interpret the terrain at night. Different conditions affect the visual presentation of natural and man-made features during both unaided and aided flight. This chapter discusses the factors that affect night terrain interpretation and how to compensate for their limitations.



## 2.5 VISUAL RECOGNITION CUES

The ability to detect a natural or man-made feature at night depends primarily on object size, shape, and contrast. Equally important is the effective use of night vision scanning and viewing techniques.

### 2.5.1 Object Size

Large structures and terrain features, such as churches and rivers, are easier to recognize at night than small objects. To see and recognize small features, crew members must view the area several times. A shorter viewing distance also aids in visual recognition.

### 2.5.2 Object Shape

Aircrews can identify objects at night by their shapes or silhouettes. Figure 16 illustrates identification by object shape. Buildings can sometimes be recognized at night by their architectural design. For example, the silhouette of a building with a high roof and a steeple is easily recognizable as a church. Man-made features depicted on the map can help aircrews recognize silhouettes. When shape is used to identify an object, the aviator may have to change the aircraft's position to obtain a different viewing perspective. The shape of terrain features is also a means of identification at night. Landmarks, such as a bend in the river or a prominent hilltop, provide distinct shapes that aid in night terrain interpretation.

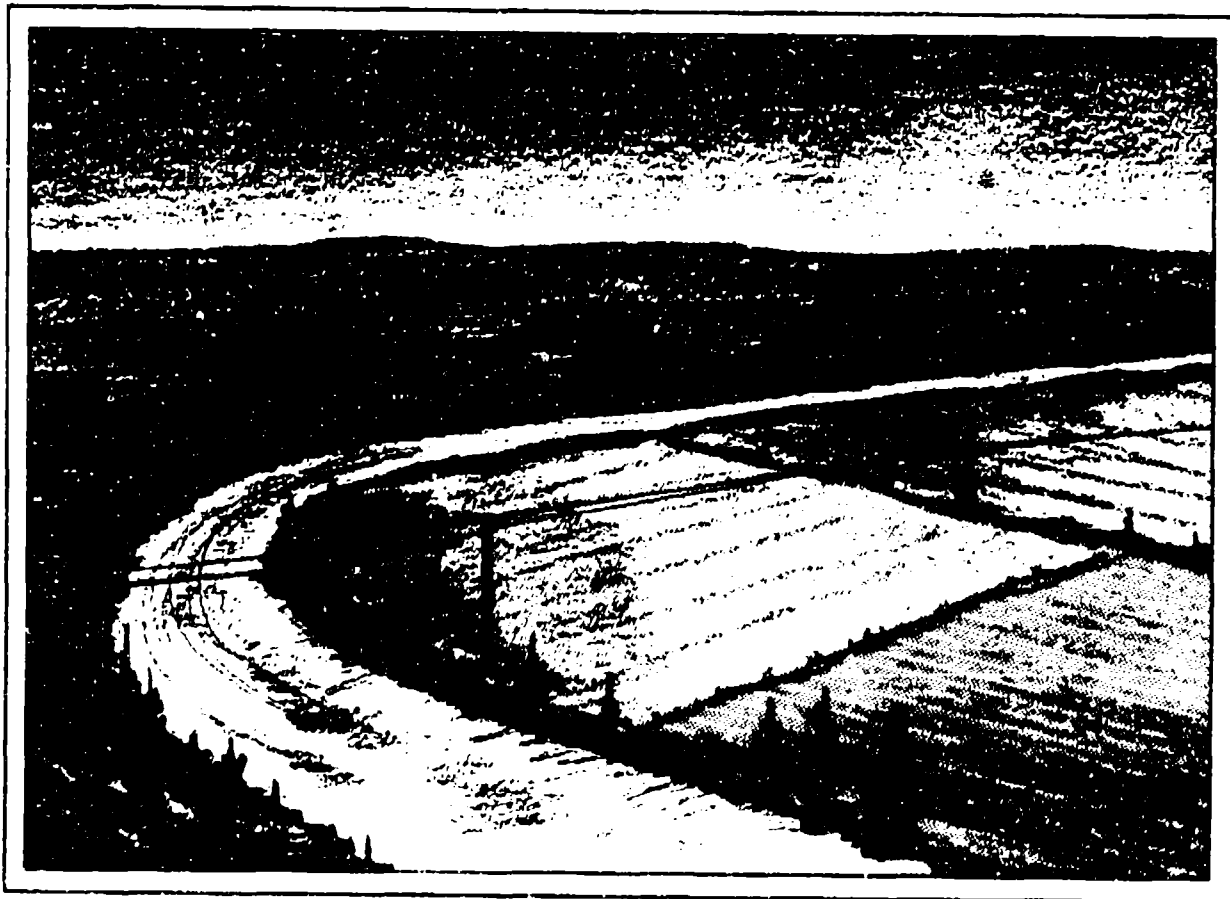
### 2.5.3 Contrast

The contrast between an object and its background can aid in object identification. The degree of contrast, however, depends on the available ambient light, texture of the object, and luminance of the object and its background. Figure 17 illustrates identification by contrast. The problem here is the pilot must operate at very low altitudes to see terrain features such as shown in figure 17. This is not a wise technique for civil operations but this figure does serve to illustrate how previously undetected features can be detected as the aircraft slows and descends to a landing.

- 1) Ambient light. The ambient light level affects the degree of contrast between objects. The higher the light level, the greater the contrast. As the ambient light increases, more light is reflected and shades are more pronounced. Objects with a poor reflective surface appear black during low light levels and dark gray during high light levels. Objects or terrain features with good reflective quality appear gray during low light levels and become progressively lighter as the ambient light increases.
- 2) Color, texture, and background. The color, texture, and background of a man-made or natural feature determine its reflective quality. The various reflective qualities of objects in a field-of-view help determine the degree of contrast. An



**FIGURE 16 IDENTIFICATION BY OBJECT SHAPE WHEN APPROACHING A LANDING AREA**



**FIGURE 17 IDENTIFICATION BY OBJECT CONTRAST**

unplowed field with no vegetation provides a good reflective surface. An area covered with dense vegetation provides a poor reflective surface. A crew member familiar with the reflective quality of a feature may be able to identify it by contrast. Man-made and natural features most identifiable by contrast include roads, water, open fields, forested areas, and desert.

- a) Roads. The surface of some dirt roads provides excellent contrast with the surrounding terrain. Roads cut through heavily forested areas are easily identifiable if visible through foliage. The light color of concrete highways, normally an excellent reflective surface, is easily identifiable during most light-level conditions. Asphalt roads are usually difficult to identify because the dark surface absorbs available light. In desert areas, however, the surrounding contrast can make asphalt roads readily detectable.
- b) Water. Very little color contrast exists between a landmass and a body of water during low light conditions. When viewed from the air, lakes or rivers appear dark gray. As the light level increases, water begins to change color and the contrast between the land and water increases. Moonlight reflected off water is easily detected. When surface wind is present, the ripples on the surface intensify the reflection off the water. This provides additional contrast and aids in terrain identification.
- c) Open fields. Contrast may be very poor in fields covered with vegetation. Most crops are dark-colored and absorb light. During the harvest or the dormant season, the color of the vegetation changes to a lighter color. The contrast with the surrounding terrain then improves. The coarse texture of a freshly plowed field will absorb light.
- d) Forested areas. Heavily forested areas do not reflect light and generally appear as dark areas at night. Because heavy vegetation provides no contrast, forests conceal objects and terrain features. However, excellent contrast is evident between deciduous and coniferous trees as well as between open fields and surrounding forested areas.
- e) Desert. During high illumination, mountain ranges are easily identifiable. The dark color of barren mountains provides an excellent contrast with the light color of the desert floor. Lower rises in terrain between the viewer and the higher ranges are, however, difficult to identify in low ambient light.

## 2.6 INTERPRETATION FACTORS

The ability to use cues for terrain interpretation is affected by a number of factors. These include ambient light, viewing distance, flight altitude, moon altitude, visibility restriction, terrain, and seasons.

### 2.6.1 Ambient Light

Reduced light levels at night decrease visual acuity. This restricts the distance at which an object can be identified. Terrain interpretation by size, shape, and contrast becomes more difficult as the light level decreases. Reduced airspeeds will improve visual interpretation and increase viewing and reaction time.

### 2.6.2 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 become 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 1,500 meters during a high light condition may be unrecognizable at 500 meters during a low light condition.

### 2.6.3 Flight Altitude and Viewing Inclination Angle

The altitude at which an aircraft is flown affects the aircrew's ability to interpret the terrain. The effects of high and low altitude flights are discussed in the following paragraphs.

- 1) High altitude. The ability to identify man-made or natural features progressively increases as the flight altitude decreases. 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.
- 2) Low altitude. Terrain becomes more clearly defined and contrast is greater when the aviator flies closer to the ground. Natural features are, therefore, more easily recognized and navigational capability is improved. The area that a crew member can view at low altitudes, however, is smaller than that at higher altitudes. At low altitudes, the aviator may have to reduce airspeed to permit more accurate terrain interpretation. The aviator can also identify objects by silhouetting them against the skyline at low altitudes.

#### 2.6.4 Moon Altitude

- 1) High altitude. The higher the altitude of the moon, the greater the illumination. An increased ambient light level improves visual acuity and contrast. Shadows that cause distortion and the loss of ambient light decrease at this time. The best conditions for visual interpretation for any phase of the moon exist when the moon is at its highest altitude.
- 2) 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 NVG. When the moon is low on the horizon, terrain features or objects visible along the skyline are more recognizable.

#### 2.6.5 Visibility Restriction

- 1) Conditions such as dust, rain, fog, and snow restrict visibility. These, in turn, 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.
- 2) Dust, rain, fog, and snow affect operations similarly. Light reflecting off blowing dust and snow particles may cause tiny pinpoints of light. Dust and snow swirling from rotor downwash 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.

#### 2.6.6 Terrain

The nature of the terrain will determine the amount of light reflected from the earth's surface. Deserts, rolling terrain, and mountains are examples of the different types of terrain that affect light reflectivity.

- 1) Deserts. The texture and color of the soil of the desert floor provide optimum reflectivity of available ambient light and identification of objects by contrast. Man-made or natural features that appear on the desert floor are easily recognizable. Visibility restrictions are not common. However, depth perception will be poor. Desert terrain provides a minimum of contrast because vegetation is limited. During high winds, blowing sand significantly restricts terrain interpretation.

- 2) Rolling terrain (heavy vegetation). Terrain interpretation is difficult over rolling terrain because of the lack of recognizable terrain features. Contrast is good between forested areas and open fields. Rivers and terrain features that are distinctly different in elevation from the surrounding terrain provide the most recognizable natural landmarks for navigation. Dirt roads and farm structures provide the most distinguishable man-made features. To improve terrain interpretation, the aviator must reduce airspeed. However, he/she will normally fly higher to increase the aircrew's ability to detect and avoid obstructions.
- 3) Mountains. Terrain identification can best be accomplished where rapid changes in elevation occur such as in mountainous areas. Silhouetting objects against the skyline enhances recognition of objects and terrain features. Decreased ambient light can be anticipated in valleys and on the backside of mountains when the moon is low on the horizon. Contrast is poor in areas of heavy, homogeneous vegetation. Barren mountains reflect ambient light so contrast is improved. During high light conditions, navigation is easier. However, airspeed normally will be slower in mountainous regions because rapidly changing terrain requires corresponding altitude changes.

#### 2.6.7 Seasons

The seasons of the year affect the amount of ambient light reflected from the earth's surface. Conditions during winter and summer are discussed in the following paragraphs.

- 1) Winter.
  - a) Contrast improves during the winter because farm areas lack vegetation. Contrast is also improved when snow covers the ground. Snow increases total illumination because it may reflect ambient or artificial light. The light color of the snow, compared with the dark color of structures and heavy forested areas, enhances visual interpretation.
  - b) The loss of foliage on deciduous trees makes ground features, such as small streams, easier to identify. Plants and grass that cover open fields change in color and improve the contrast between open fields and coniferous trees. However, barren trees reflect less light and area, therefore, are harder to see. Because of this safety hazard, the aviator may have to fly higher.
  - c) During the winter, the orbital path of the moon is closer to the earth. The ambient light level is higher than at any other time of the year. This improves visual acuity, which enhances terrain interpretation.
  - d) Cloud coverage and restricted visibility are more likely to occur during the winter than during the summer. Both

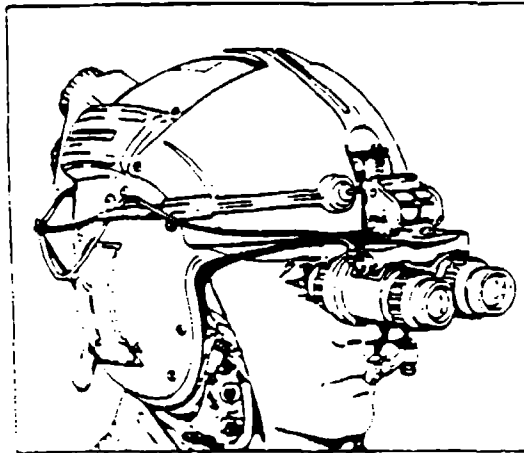
conditions significantly reduce the ambient light level. This, in turn, decreases visual acuity and makes terrain interpretation more difficult unless sources of artificial light, such as cities and towns, are nearby.

- e) During extreme cold, a heavy buildup of snow may conceal man-made and natural terrain features. A snow drift may obscure a road intersection that otherwise provides a good navigation checkpoint. The aircrews can identify an object by associating it with other objects or terrain features. A power line, a fence line, or a cut through a forested area will aid the aircrew in locating the road intersection. Small rivers and lakes indicated on the map may become frozen and covered with snow and therefore unrecognizable. The aircrew can make positive identification only by associating the relative position with terrain features such as a depression or a tree line.
- 2) Summer. Generally, identifying objects and terrain features by contrast in the summer is less effective than in the winter. This is caused by the increased amount of vegetation in open fields and a new growth of foliage on deciduous trees. Small rivers and streams are difficult to recognize.

### 3.0 INTRODUCTION TO THE AN/AVS-6 (ARMY-NAVY/AVIATOR VISION SYSTEM)

#### 3.1 AN/AVS-6, AVIATOR NIGHT VISION IMAGING SYSTEM (ANVIS)

As indicated by its name, ANVIS was a system designed from the outset for aviators. ANVIS is a lightweight, self contained, helmet or harness mounted third generation image intensification system (figure 18). The binocular consists of two identical monocular assemblies mounted on a pivot adjustment shelf (PAS). A helmet mount assembly is provided to attach the binocular to the crew member's helmet.



**FIGURE 18 AN/AVS-6, ANVIS**

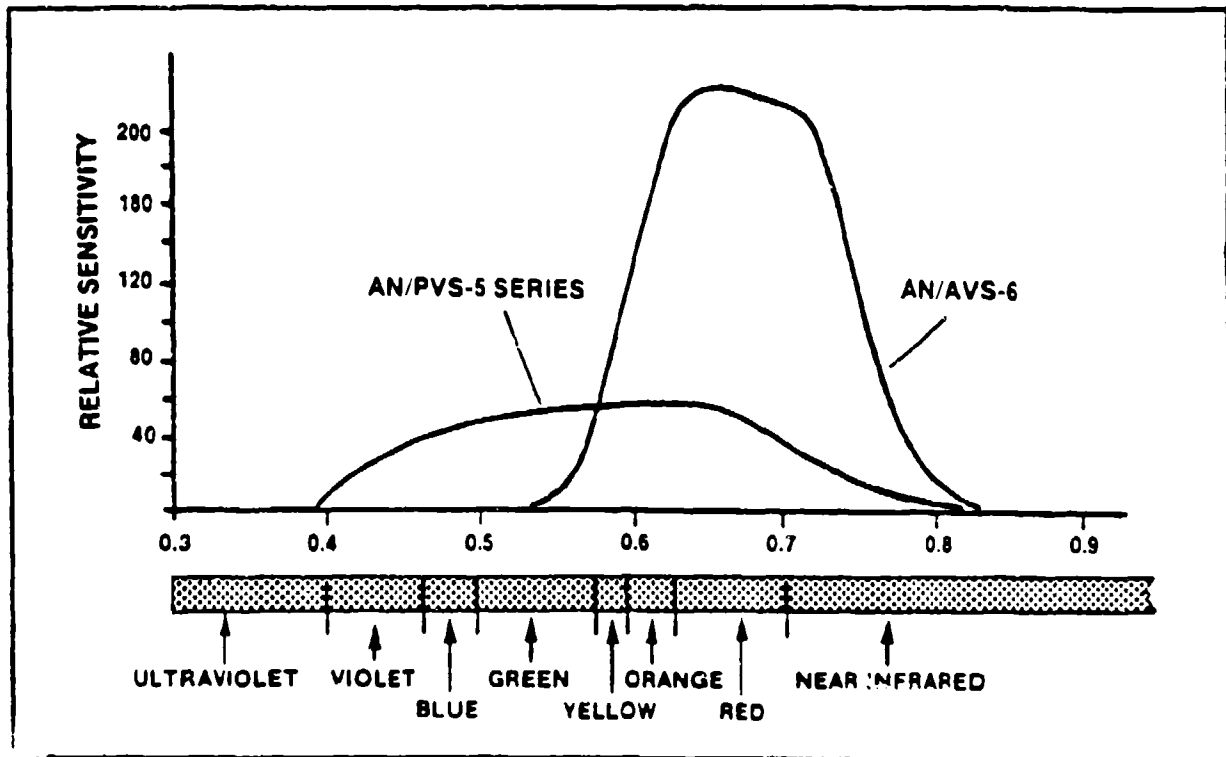
Figure 18 shows the latest generation AN/AVS-6. It has a 40 degree field-of-view (FOV). Under ideal conditions, visual acuity of 20/200 or less can be improved to 20/40 with the AN/AVS-6. The AN/AVS-6 provides greater light amplification over that of the previous generation system, but it also amplifies light in that portion of the spectrum that is most predominant at night. Figure 19 illustrates the increased sensitivity of the AN/AVS-6.

The AN/AVS-6 operates by intensifying ambient light 2,000 to 3,000 times. It can provide sufficient imagery from overcast starlight to moonlight conditions as shown in figure 20. However, below quarter moonlight conditions, artificial illumination may be required to light the helicopter's flight path.

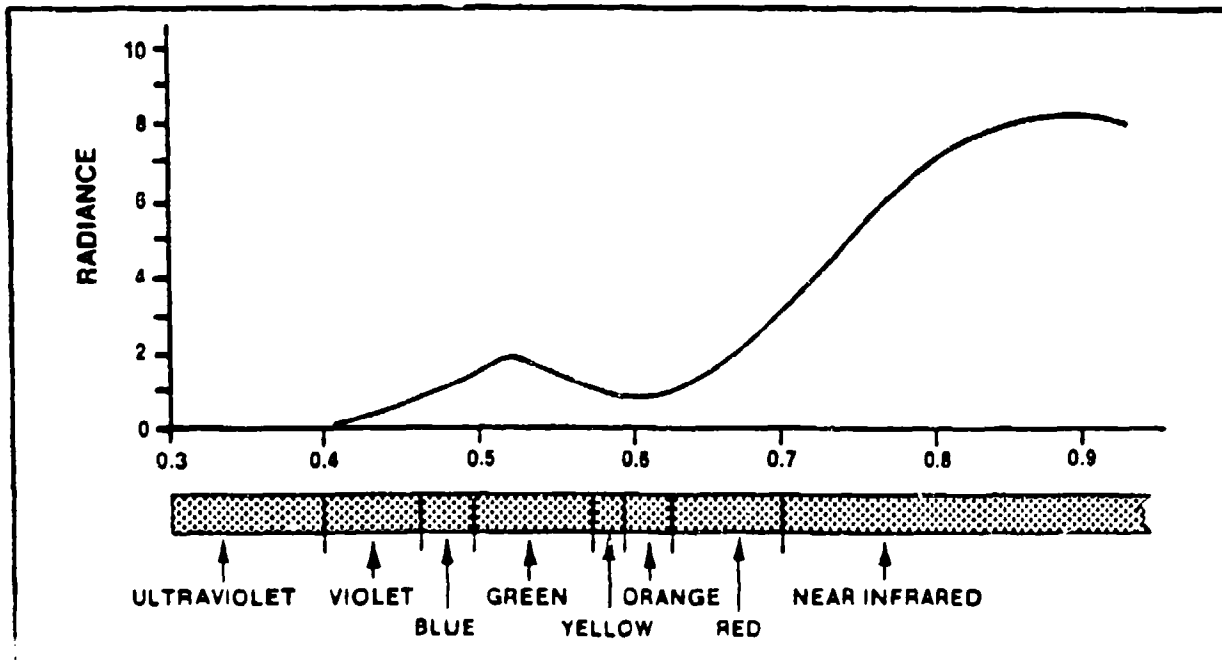
##### 3.1.1 NVG Power Sources

There are presently only two types of batteries that may be used in the ANVIS; the 2.7 volt mercury battery (designated BA-1567/U) and the 3.0 volt lithium battery (designated BA-5567/U).





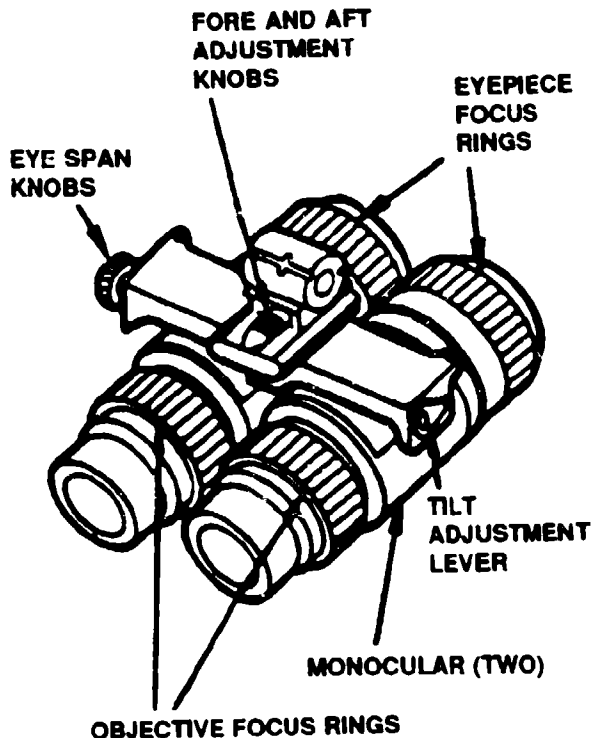
**FIGURE 19 RELATIVE SENSITIVITY OF AN/PVS-5 AND AN/AVS-6 SYSTEMS**



Note: The small peak in the blue-green portion of the spectrum is caused by moon illumination. The size of this peak will vary based on the amount of moon illumination.

**FIGURE 20 SPECTRAL DISTRIBUTION OF STARLIGHT**

The ANVIS system is powered by a power pack consisting of a housing and a three position switch (figure 21). It contains two batteries; one is required, one is redundant.



**FIGURE 21 ANVIS**

The AN/AVS-6 is powered by either AA penlight batteries or lithium batteries. With the lithium batteries, there is a 30-minute, low-voltage warning indicator. The warning indicator is a dim red light emitted between the binoculars above the FOV when 30 minutes or less of battery life remains.

Another feature of the lithium battery is the built in safety vent around the battery's casing. This vent allows the battery to release gas pressure in the event that a malfunction forces the pressure too high. Venting may be sensed through smell, the sound of gas escaping, or through irritation of the eyes. Should a malfunction occur, in which the venting system is activated, the batteries must still be handled with care when removing them from the power pack. Under no circumstances should a person heat, puncture, short circuit, attempt to recharge, or otherwise tamper with the lithium battery. If the battery compartment becomes hot the NVGs should be turned off. When the batteries have cooled they can be removed.

The ANVIS has a magnification of 1:1, and a focal range of 10 inches to infinity. The ambient temperature limits of operation are -56 degrees C to 52 degrees C. Under artificial clinical conditions, ANVIS produced 20/40 vision. However, under ambient illumination

conditions encountered at starlight levels, vision was reduced to 20/80.

The AN/AVS-6 is stowable on the helmet in a flipped-up position, which automatically cuts off power to the tubes. A breakaway feature is designed to separate the binocular from the helmet mount under crash loads. Unaided peripheral view is improved with the AN/AVS-6 by incorporating a minus-blue filter. This filter makes the system insensitive to blue-green cockpit lights and their reflections in the cockpit.

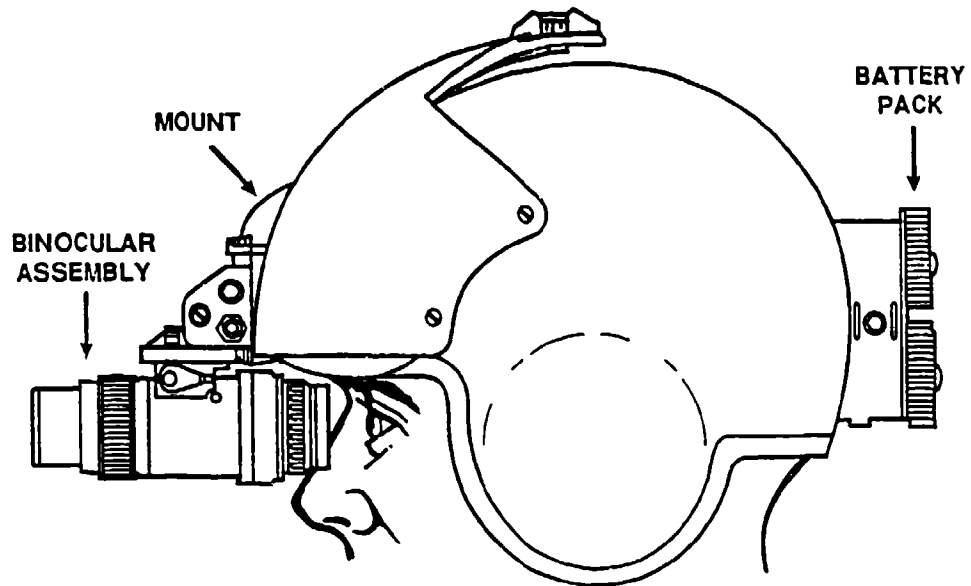
### 3.2 ADJUSTMENT TECHNIQUES

The adjustment process is critical to obtaining optimal visual capability. Improper adjustment can severely degrade visual acuity. NVGs are not hard to use, but their design characteristics require that the operator completely understand how to optimize their capability. This section presents the basics of NVG preflight adjustment procedures for the ANVIS system.

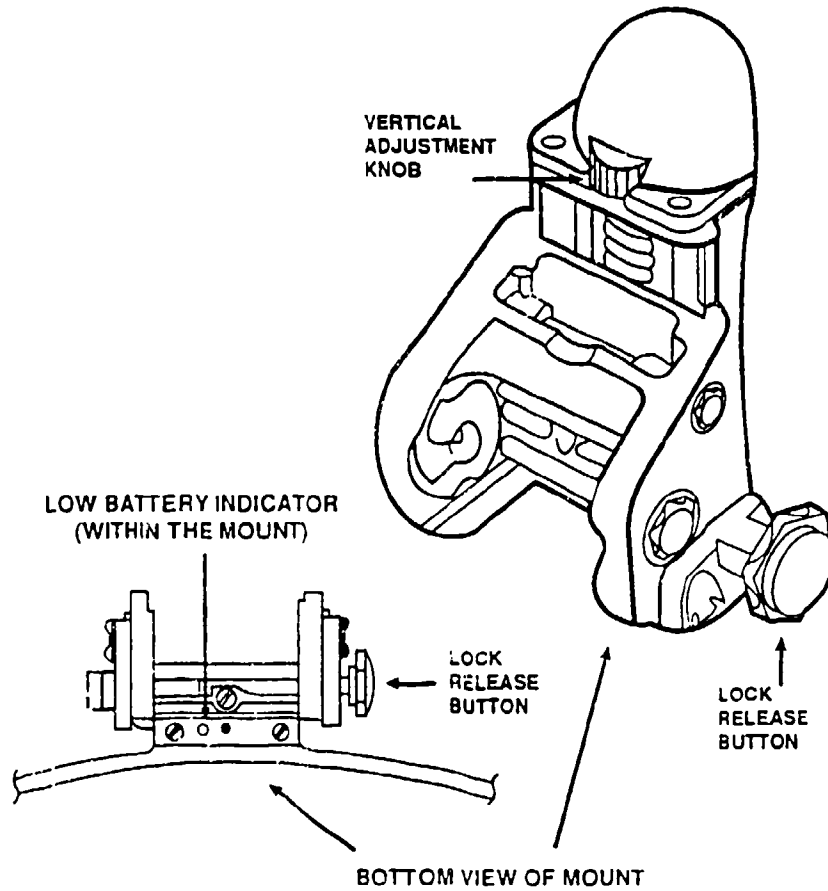
#### 3.2.1 Components

ANVIS NVGs consist of three components.

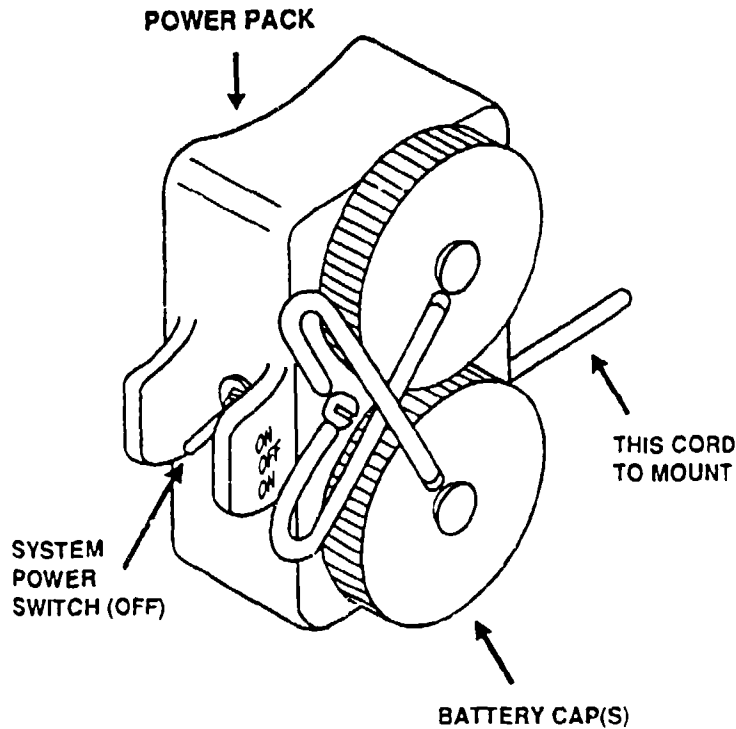
1. Mount. The mount is secured to the helmet and holds the binocular assembly in front of the eyes (see figures 22 and 23). It has three important features.
  - a. Vertical adjustment knob - moves the binocular assembly up and down.
  - b. Lock release button - facilitates rotation of the goggles from the stowed position to the operating position. Helps in removing the binocular assembly from the mount.
  - c. Low battery indicator - provides warning of impending battery failure.
2. Battery Pack. The battery pack powers the device and can be used with either AA penlight batteries or lithium batteries (see figure 24).
  - a. Loading batteries - lithium batteries are inserted with the positive side up, while AA batteries go in positive side down.
  - b. Switching battery power - three position switch with the off position in the middle and separate positions for each of the two battery compartments. ANVIS goggles operate on the battery or batteries which correspond to the switch position, thus providing an internal spare in the system.



**FIGURE 22 NVG COMPONENTS**

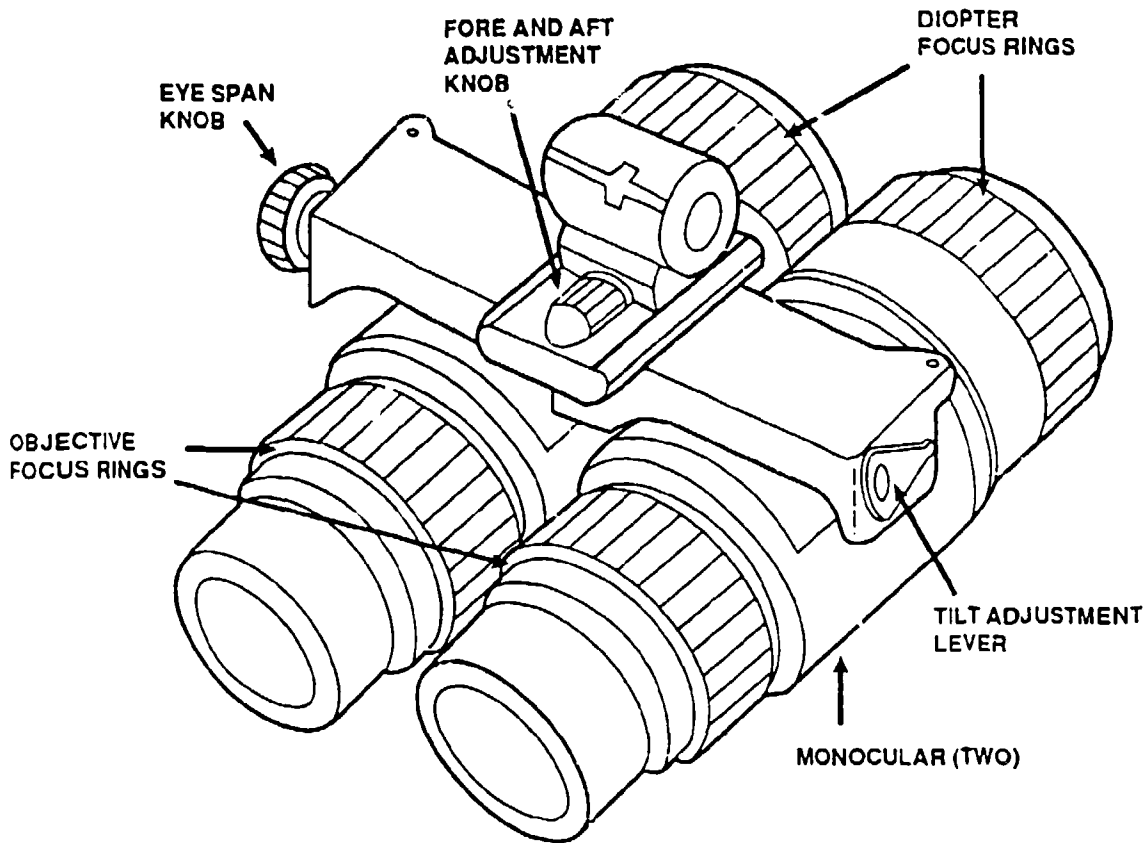


**FIGURE 23 NVG MOUNT FEATURES**



**FIGURE 24 NVG BATTERY PACK**

- c. Handling batteries - lithium batteries contain toxic substances and can vent or explode if handled improperly. Never carry spare batteries in pockets with other potential conductors, particularly keys or spare change.
3. Binocular Assembly. The binocular assembly contains all the optical elements of the system (see figure 25). This component has several adjustment features, and learning to operate them is essential for proper alignment of the device. The following is a list of adjustment features on the binocular assembly:
    - a. Fore and aft adjustment knob - moves the entire binocular assembly toward or away from the eyes.
    - b. Tilt and adjustment knob - allows wearer to rotate the binocular assembly.
    - c. Interpupillary distance (eyespan) adjustment knob - allows wearer to adjust for the distance between the eyes.
    - d. Objective focus ring - focuses the goggles for distance (adjustment range is from 10 inches to infinity).
    - e. Diopter focus ring - permits focus of the NVG to compensate for individual refractive error.

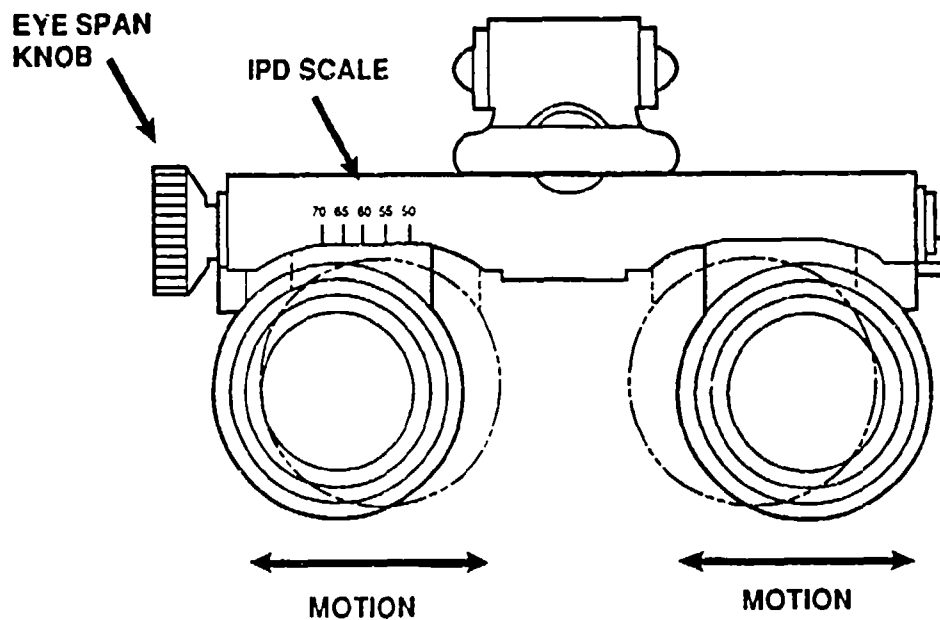


**FIGURE 25 NVG BINOCULAR ASSEMBLY**

3.2.2 Alignment and Focusing Procedures

Before flying with NVGs, a series of alignment and focusing procedures must be performed to verify proper fit and function of the device. Proper alignment of the optics is critical to achieving the best possible visual acuity from the equipment. The following procedures should be performed prior to donning the NVGs.

1. Check the overall condition and security of the goggles. Ensure that all the knobs work properly. Inspect the device for loose parts and frayed wiring.
2. Inspect and clean the lenses if needed. Use lens paper only to prevent scratching the lens surface. Dirty optics can degrade performance by up to 30 percent.
3. Set your interpupillary distance (IPD) using the scale on the front of the goggles as illustrated in figure 26.

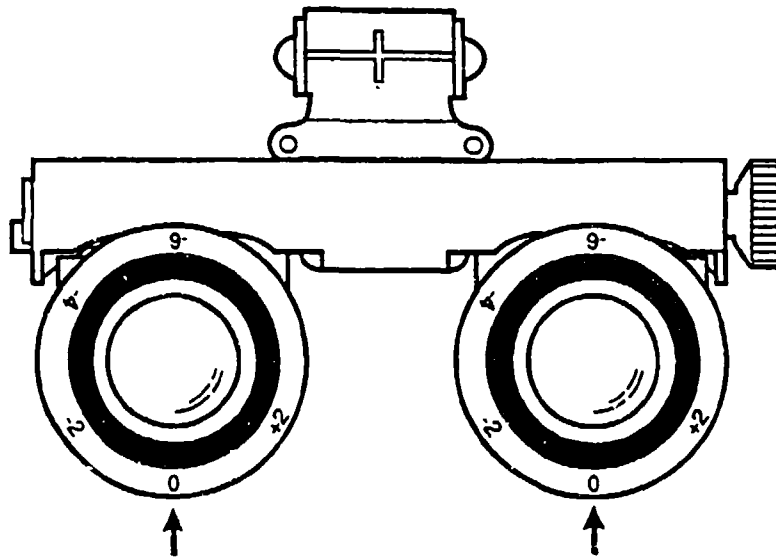


**FIGURE 26 SETTING INTERPUPILLARY DISTANCE**

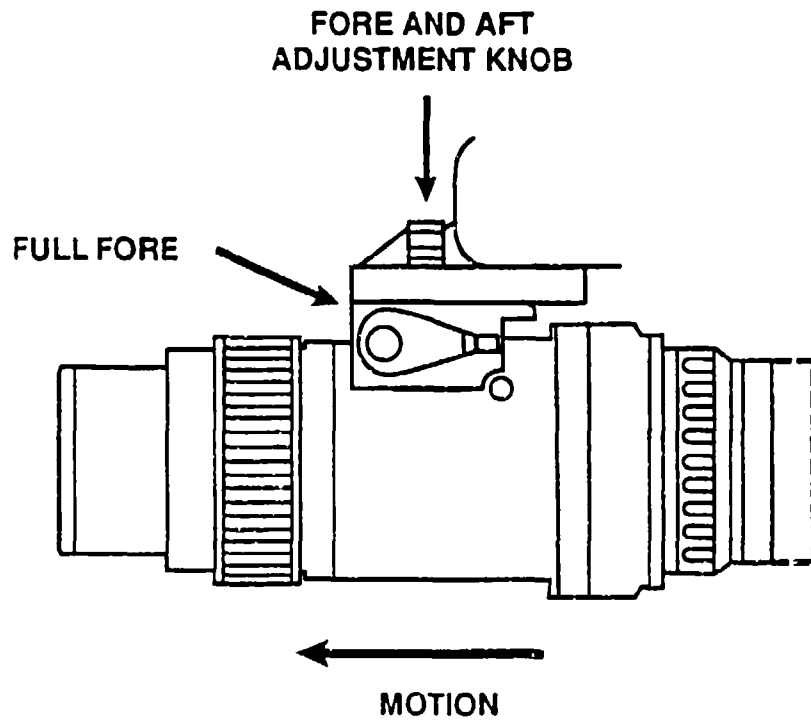
4. Set the diopter adjustment to your individual setting if known. If you do not know your diopter settings, set them at zero as shown in figure 27.
5. Move the binocular assembly as far forward (away from the eyes) as possible (see figure 28).
6. Center the tilt adjustment (see figure 29).
7. Set the mount to a position approximately one-third of the distance from its lowest limit (see figure 30).
8. Attach the mount at the appropriate location.
9. Load the battery pack (with batteries) and connect it to the mount. The pack should be attached to the velcro on the back of the helmet. Confirm that the switch is in the off position.

### 3.2.3 NVG Calibration and Test Lane Set-up

Military experience has shown that even minor alignment discrepancies involving interpupillary distance and goggle tilt can result in significant losses in visual acuity. Inexperienced pilots with IPD errors of as little as 4 millimeters have suffered acuity losses from an attainable 20/40, down to 20/100. A 5 millimeter error can result in visual acuity of 20/200.

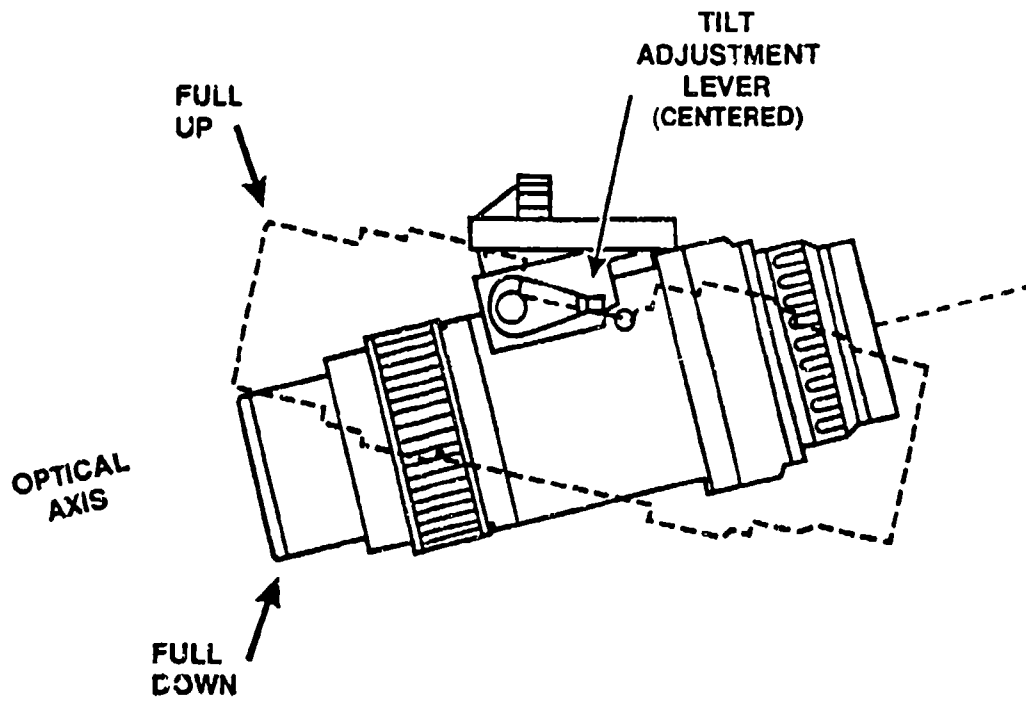


**FIGURE 27 SETTING DIOPTR FOCUS**

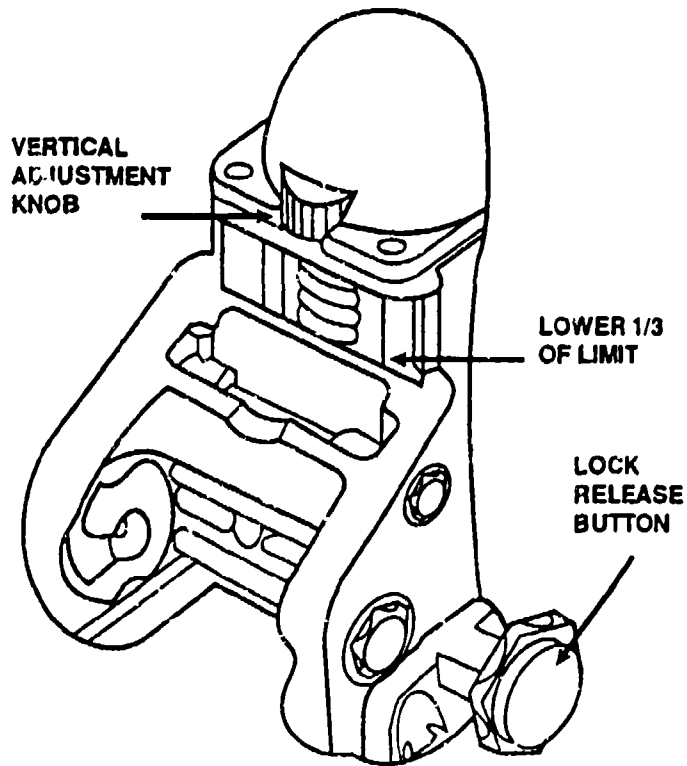


**FIGURE 28 ADJUSTING BINOCULAR ASSEMBLY**



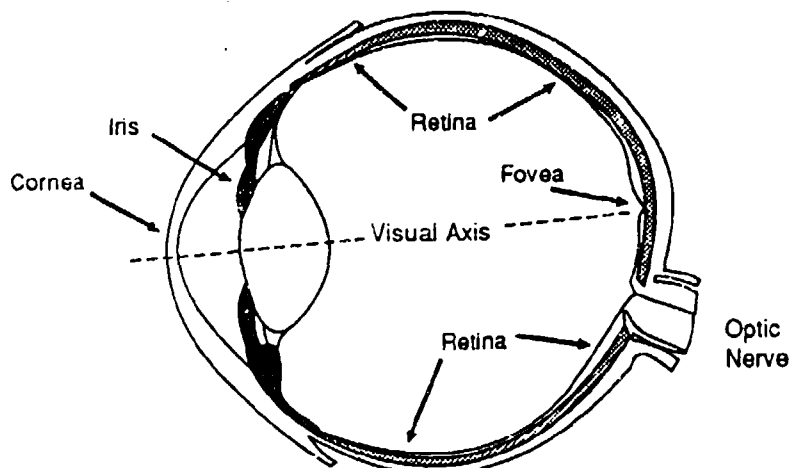


**FIGURE 29 TILT ADJUSTMENT**



**FIGURE 30 SETTING MOUNT POSITION**

The purpose of using the NVG test lane is two-fold. First, it provides a place to align and focus your NVGs and second, it checks the resolution capability of the device. Test lane procedures are divided into two areas: (1) alignment and (2) focusing. The alignment procedure is necessary because NVG design provides the best performance when the device is aligned with the visual axis of the eye (see figure 31). This procedure should be performed before focusing to prevent degradation in acuity caused by alignment errors.



**FIGURE 31 VISUAL AXIS**

1. Equipment

The following equipment is the minimal needed to establish a calibration and test lane.

- a. 7 1/2 watt light bulb (clear) with a standard base.
- b. 1/2 sphere reflector light with a standard base socket and a 110 VAC power cord. The item usually comes with a squeeze clamp to easily attach to any available frame.
- c. In-line 110 VAC rheostat. This unit plugs into a standard socket. The 7 1/2 watt bulb plugs into the back of this rheostat.
- d. Voltmeter with 0-110 VAC range.
- e. NVG resolution chart (100%). VISTECH Consultants, 4162 Little York Road, Dayton, Ohio, 45414.

2. Set-up Procedures

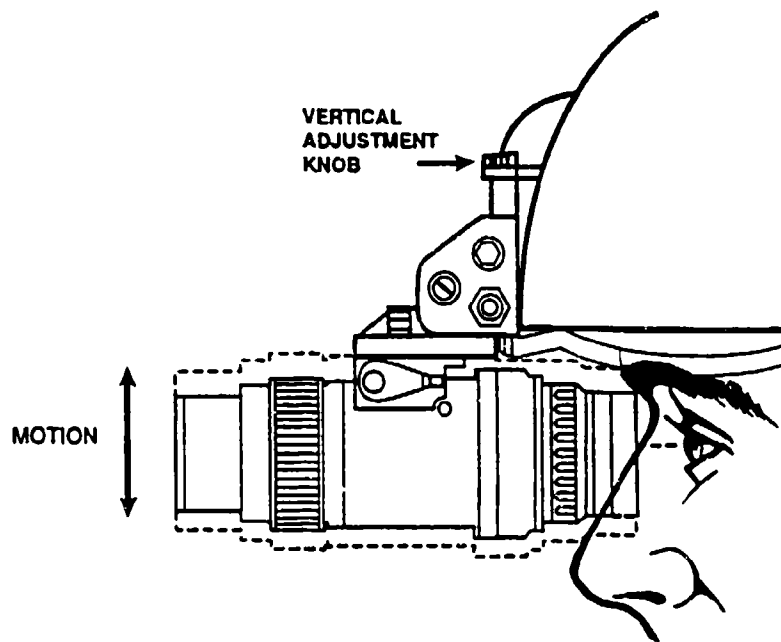
- a. Choose a 30 to 50 foot long area that can be darkened completely. Identify the 20 foot mark with tape on the floor.

- b. Hang the resolution chart on the wall slightly lower than eye height.
- c. With flat black spray paint, paint the back and outside of the 1/2 sphere reflector to minimize back-glare. If there are cooling holes in the reflector, cover these with black tape. This prevents any stray light from going back toward the NVG viewing area. Once the paint on the reflector is dry, screw in the 7 1/2 watt bulb.
- d. Attach the light to the ceiling approximately 10 feet away from the resolution chart so that it points down toward the chart and will not create glare for the viewer.
- e. Plug the rheostat cord into the wall, and plug the light cord into the back of the rheostat plug. Turn the reflector light switch on, and leave it on permanently (use the rheostat switch to turn the unit on and off). Turn the rheostat on and check its operation.
- f. Place the voltmeter leads on the plug prongs between the rheostat and the light plug. Dim the light with the rheostat until the voltmeter reads approximately 20 to 25 VAC. Tape the rheostat control so that it is locked at this setting. [Note: The 25 VAC is an approximate setting, however above 30 to 35 VAC, NVG performance does not get better and can actually get worse by actuating the automatic gain control. Settings below 20 VAC decrease the signal-to-noise ratio (increasing the graininess), and cause NVG performance to decrease.] Once the rheostat control is set and locked with tape, simply use the rheostat on-off switch to light the resolution chart.
- g. Identify two viewing distances and mark them with a taped line on the floor. The first distance should be 20 feet. Second, choose a distance of at least 30 feet (NVG optical infinity), but less than 100 feet, to optimize resolution of the chart.

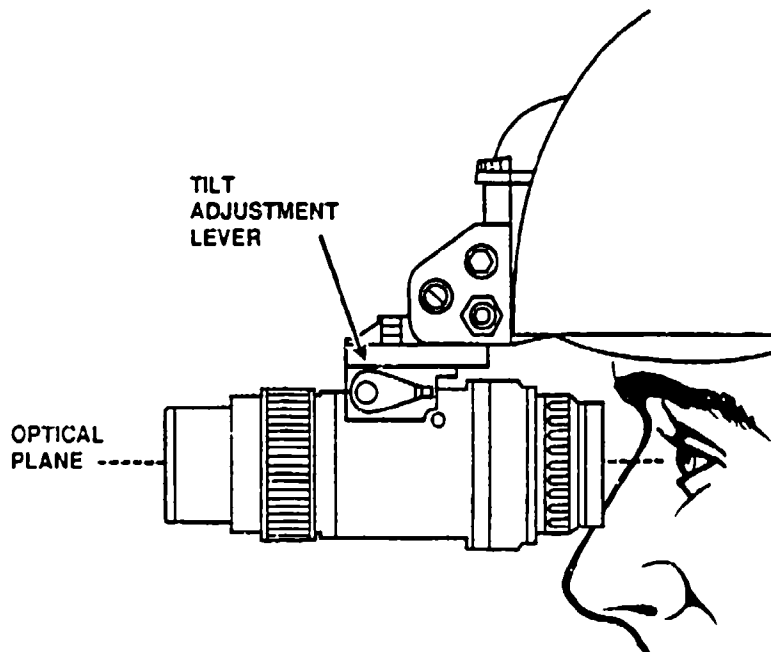
#### 3.2.4 NVG Test Lane Adjustment Procedure

In the test lane with helmet and NVGs donned, turn the lights off and turn on the NVG. Each tube of the NVG must be checked individually, and then the two tubes checked together. (CAUTION: Do not turn on NVGs in lighted areas. Damage to image intensification tubes will result.)

1. Adjust the vertical position of the binocular assembly using the appropriate knob (see figure 32). The binocular assembly should be directly in front of the eyes.
2. Adjust the tilt so the binocular assembly is perfectly aligned with the visual axis (see figure 33). When the tilt is adjusted,



**FIGURE 32 VERTICAL POSITIONING OF BINOCULAR ASSEMBLY**



**FIGURE 33 ALIGNMENT OF VISUAL AXIS WITH BINOCULAR ASSEMBLY**

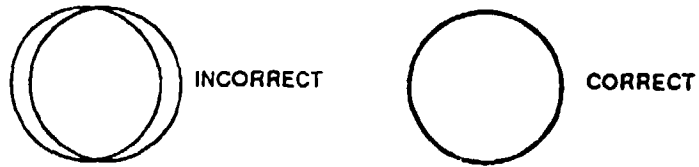
the binocular assembly is rotated and a corresponding vertical adjustment should also be made.

3. Confirm the setting of the interpupillary distance. When properly adjusted, the two images of the tubes overlap to form a single image and each individual image is directly in front of the corresponding eye (see figure 34). It is important to note that improper adjustment of the IPD can cause loss of visual acuity, loss of depth perception, and/or severe headaches.
4. Adjust the eye relief. The device should be brought as close to the eyes as possible without touching eyelashes or spectacles (see figure 35).
5. Evaluate the picture. The NVG should be correctly aligned. There should be no shading in any part of the field-of-view. If there is, then recheck mount positioning and angle. Perfect alignment for each tube occurs when the objective lens circle is directly in the center of the eyepiece lens circle (see figure 35).

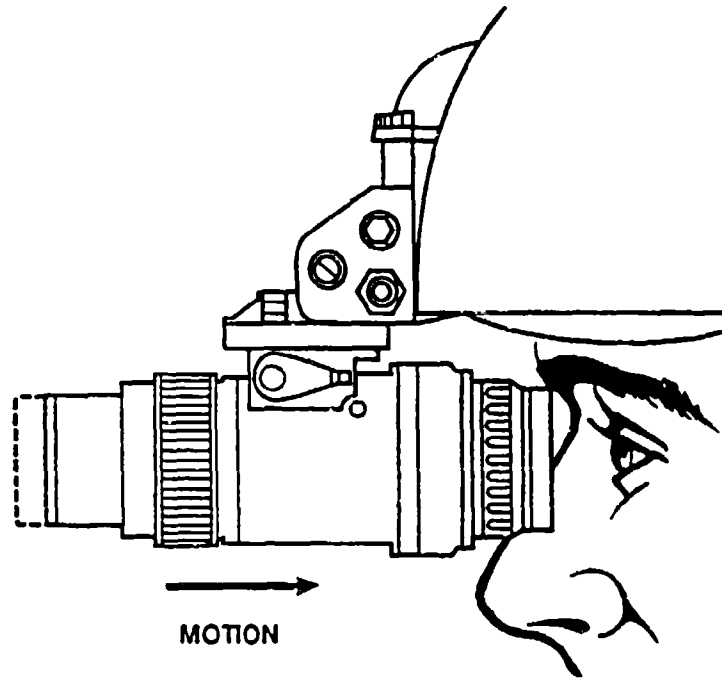
Since the tubes decay at a different rate, it is imperative that each tube is checked for optimal resolution (visual acuity) capability before each flight. Utilizing a calibration lane will provide a properly illuminated resolution target to optimize these adjustments.

#### 3.2.5 NVG Test Lane Focusing Procedure

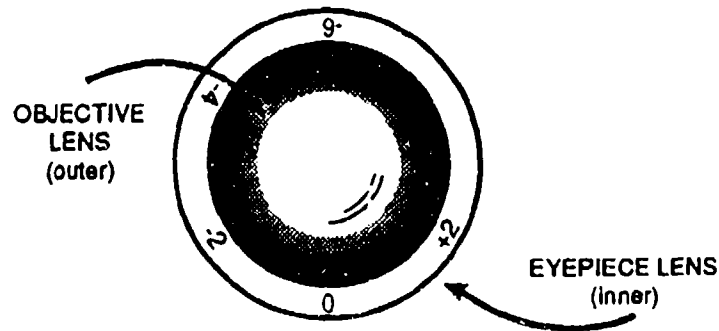
1. Move to the 20-foot line in the test lane and observe the acuity chart. Close one eye, or cover one of the tubes with a free hand (be careful not to touch the lens).
2. With your open eye, focus the vertical and horizontal lines on the chart using the objective (outer) focus ring (see figure 37).
3. Fine tune the picture using the diopter (inner) focus ring (see figure 37). Do this by rotating the ring counter-clockwise towards the positive (see figure 38) until the picture is slightly blurred. Stop here, pause a second, and then slowly rotate the ring back clockwise until the picture becomes sharp. Do not rotate the knob beyond the setting which just sharpens the picture. If the diopter is turned too far, the eye muscles will initially accommodate for the overcorrection, but over time they will become fatigued and loss of visual acuity and depth perception and/or headaches may occur.
4. Do not be alarmed if one tube performs slightly better than the other. Evaluate acuity with both eyes open. Acuity should be, at a minimum, as good with both eyes as it is with the best tube.
5. Before leaving the test lane, note IPD and the diopter settings so they can be rechecked at the aircraft before donning.



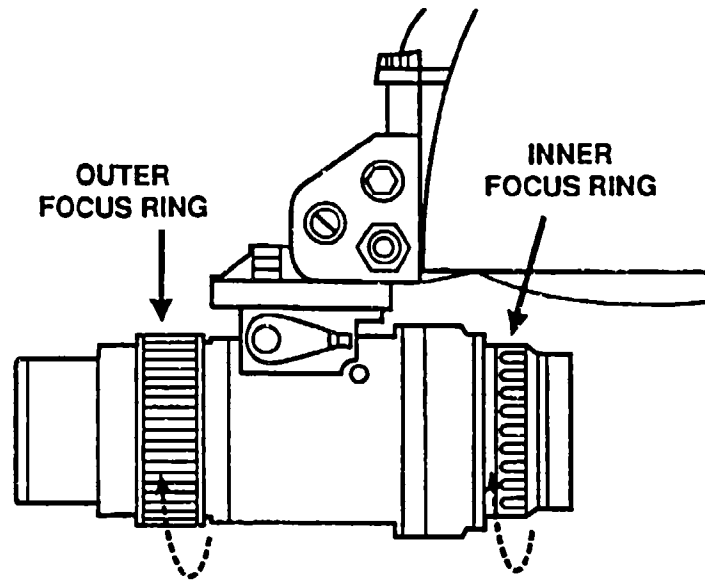
**FIGURE 34 INCORRECT AND CORRECT SETTING OF IPD**



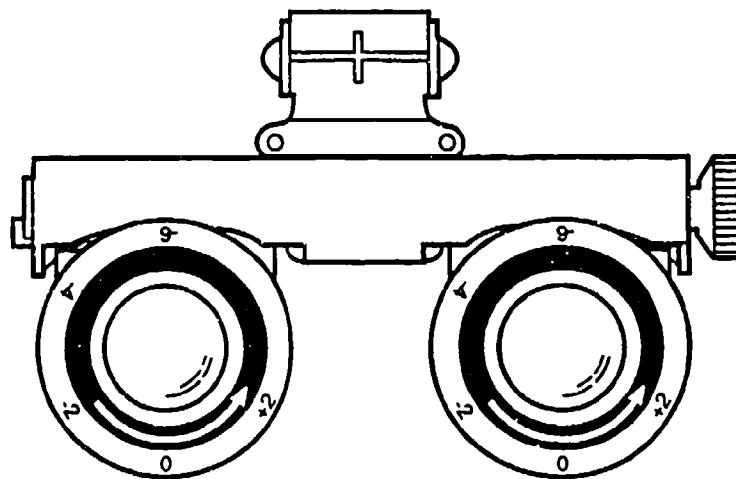
**FIGURE 35 ADJUSTMENT OF EYE RELIEF**



**FIGURE 36 PROPER ALIGNMENT OF NVG**



**FIGURE 37 FOCUSING THE BINOCULAR ASSEMBLY**



**FIGURE 38 INDIVIDUAL FOCUSING OF BINOCULAR ASSEMBLY**

### 3.3 OPERATIONAL CONSIDERATIONS

Magnification. NVG systems do not amplify an image. An object will appear the same size as if it were seen with the unaided eye.

#### Lights.

With NVGs, individuals can detect light sources that may not be visible to the unaided eye. Examples include lights from other aircraft, flashlights, burning cigarettes, and chemical light sticks. As the ambient light level decreases, aircrews can more easily detect these light sources but are less able to estimate distance correctly.

NVG devices are adversely affected by bright lights and periods of high ambient light. When exposed to a bright light source, the AN/AVS-6 is susceptible to whiteout. Saturation of the NVG system appears on the tube as a bright halo effect around the image of the light source. The halo effect also degrades the contrast of adjacent portions of the intensified image. This degradation of performance becomes worse when several bright lights appear in the near field-of-view. Additionally, internal circuitry automatically adjusts output brightness to a preset level to restrict peak display luminance. When an area with bright lights is viewed, the display luminance will decrease. In addition to the halo effect around a bright light source, the overall display luminance of the rest of the viewed scene will dim. The brighter the light source, the dimmer the rest of the viewed scene. The crew member may also experience the dimming effect when viewing in the direction of a full moon at low angles above the horizon.

Tunnel vision limits an individual's ability to see outside an area lit by bright artificial lights such as flares, landing lights, and lights with infrared filters. The ability to see objects within the lighted area depends on the intensity of light and the distance of the object from the viewer. A crew member should not lock directly at a bright light source because it may temporarily degrade the efficiency of the system. When flying with the landing light or searchlight with an infrared band-pass filter on, the aircrew should avoid concentrating on the area illuminated by the light. The aircrew should also scan the area not illuminated by the light for hazards and obstacles.

Depth Perception and Distance Estimation. Depth perception and distance estimation are difficult with NVG systems. The quality of an individual's depth perception in a given situation depends on several factors. They include the available light, type and quality of the NVG system used, degree of contrast in the field-of-view, and viewer's experience. The aircrew must rely on the monocular cues for accurate depth perception and distance estimation.



Color Discrimination. Color discrimination is absent when scenes are viewed through NVGs. The picture seen with NVGs is monochromatic (single color). It has a green hue because of the type of phosphor used on the screen of the tube. The green hue may cause crew members to experience a pink, brown, or purple afterimage when they remove the device. This is called chromatic adaptation and is a normal physiological phenomenon. The length of time the afterimage remains varies with the individual.

Scanning Techniques. Although the basic principles of scanning are the same for unaided and aided flight, crew members must consider a few specific items when conducting operations with NVGs. Flight techniques and visual cues for unaided night flight also apply to aided night flight. NVGs improve ground reference but significantly reduce the field-of-view.

The NVG aided FOV involves significantly reduced peripheral vision as compared with unaided night flight. Thus the crew member must use a continual scanning pattern to increase the observed FOV at the NVG aided visual acuity level. Moving the eyes will not change the viewing perspective; the head must be turned. However, rapid head movement can induce spatial disorientation. To view an area while using NVGs, the crew member must rotate his head and eyes slowly and continuously. When scanning to the right, he/she should move their eyes slowly from the left limit of vision inside the device to the right limit while moving his head to the right. In this manner, the crew member will cover a 70 to 80 degree viewing field with only 30 to 40 degree of head movement. This technique minimizes head rotation. However, maximum visual acuity can only be attained when the crew members view through the center of the tube. Acuity drops to 20/70 or worse in the periphery of the FOV. The crew member should scan back to the left in reverse order and avoid rapid head movements. The crew member must develop scanning techniques that involve a mix of unaided and aided vision.

When viewed through the devices, illumination sources, such as aircraft position lights and ground lights, may not be accurately interpreted according to intensity, distance, or color. Unaided vision can provide this additional information. A slight downward deflection of the eyes will provide all required visual information inside the cockpit.

Practice and experience are necessary to obtain maximum visual information from both unaided and aided vision. Initially, unaided peripheral vision may be somewhat distracting until the crew member develops adequate experience combining through-the-tube viewing with around-the-device scanning.

Obstruction Detection. Obstructions that have poor reflective surfaces, such as wires and small tree limbs, are difficult to detect. The best way to locate wires is to look for the support structures.

Hazardous wires in high-use areas should be marked with reflective devices.

Spatial Disorientation. Maneuvers requiring large bank angles or rapid attitude changes tend to induce spatial disorientation. Therefore, the aviator should avoid making drastic changes in attitude and bank angle and use proper scanning and viewing techniques.

Airspeed and Ground Speed Limitations. Aviators using NVGs tend to overfly their capability to see. To avoid obstacles, they must understand the relationship between the device's range and airspeed. The visual range of NVGs may not allow aviators enough time to avoid obstacles. Ground speed should be reduced so that obstacles can be detected and avoided.

Different light levels affect the distance at which crew members can identify an object. This, in turn, limits the ground speed at which aviators can safely fly in an obstruction environment. Ground speed limitations are not quantified because of continuously changing variables affecting the limitations. Variables include the type of aircraft, type of external aircraft lighting, vision obstruction, and ambient light conditions.

Object acquisition and identification are related to ambient light levels, visibility, and contrast between the object and its background. For safety reasons, light levels required for training may differ considerably from operational requirements. Variables that affect the ability to see with and without NVGs include:

- c condition of aircraft windscreen,
- o moisture content in the air (humidity),
- o individual's proficiency and capabilities,
- o proper care and maintenance of the device, and
- o visibility (haze, fog, rain, low clouds, dust, smoke).

Aircraft Lighting. Various sources of lighting (especially red) that are not compatible with NVG systems may degrade the aviator's ability to see with the system. The adverse effects of aircraft lighting on the device are greatest during low ambient light conditions.

### 3.3.1 NVG Failures

NVGs are susceptible to malfunction at any time. Failures include the following: battery failure, broken intensifier, broken frames, and broken wires. The steps below should be taken in such an instance.

- a. Conduct a positive transfer of controls to the co-pilot. If there is no co-pilot, discontinue NVG operations.
- b. In as much as battery failures are the most common malfunction associated with NVGs, attempt to regain use of the NVG as follows:

- 1) switch to reserve battery with the three-position switch on battery pack; if this does not work,
  - a) turn off the goggles,
  - b) remove the old battery and discard it,
  - c) install a new battery, and
  - d) turn NVG on to check operation.

The following are other common malfunctions that may occur. Should any of these malfunctions be noted, the goggles should be returned for maintenance.

1. Shading - appears as a dark area along the edge of an image. If shading is present, a fully circular image will not be seen with that tube when viewed individually.
2. Edge glow - appears as a bright area along the outer edge of the image. To rule out the possibility that the effect is the result of some incompatible light source, hold one hand in front of the objective lens and see if it is still present.
3. Bright spots - appear as constant or flickering spots anywhere in the image. Hold one hand in front of the objective lens and see if it is still present.
4. Flashes/flickering - more than one flash or flicker requires maintenance.

There are some apparent problems that render NVGs unserviceable. Honeycombing, distortion, veiling glare, and dark spots are the most common items. If NVGs with these types of problems are encountered, evaluate them in the following ways.

1. Honeycombing is most often seen in high light levels. If it occurs in a very dark environment, a problem exists.
2. Distortion is optical bending of a viewed object. Do not use if it is present and excessive.
3. Veiling glare is caused by dirty, chipped, or scratched lenses which scatter light that strikes them at an angle. Do not use if visual acuity is reduced.

Crew Coordination. The value of crew coordination during emergency procedures cannot be over emphasized. Delineation of duties must be clearly stated and clearly understood. The responsibility of all aircrewmembers in ensuring the safe conduct of the flight must be emphasized. A recent U.S. Army safety study offered this poignant observation regarding crew coordination:

"In most NVG-related mishaps, the crew sensed/knew that everything was not right just before the mishap occurred. The crew, or at least one member of the crew, was uncomfortable but, for some reason, did not make

this known, or thought the other crew members had everything under control. Communicate as a crew. If any member of the crew is uncomfortable, he should make his feelings known, get out of the area, regroup, and try again if appropriate. If crews are unsure of how close obstacles are or of how close other aircraft are, they should assume they are too close and clearance is inadequate. Take corrective action."

## 4.0 MAINTENANCE REQUIREMENTS FOR AN/AVS-6 NIGHT VISION GOGGLES

### 4.1 INTRODUCTION

The AN/AVS-6, Aviator Night Vision Imaging System is relatively maintenance free when used under proper conditions. The tubes have a mean-time-before failure (MTBF) of 7,500 hours with a 92 percent reliability. However, operators should be aware that if excessively bright lights are viewed through the goggles, the phosphorous S-20 screens will burn, shortening the life expectancy of the tubes.

As with any system, the key to maintaining the operational efficiency of the ANVIS NVG is proper preflight and postflight care. Likewise, ensuring that the NVG is properly mounted and adjusted prior to each flight is essential to successful NVG operations.

Operators may purchase the Military Specification NVG, otherwise known as MilSpec, (85762A) ANVIS, Type 1, Class A goggle. Military specification goggles meet very high standards for reliability and factory testing to ensure quality and dependability.

Commercial Specification ANVIS goggles are also available however, these goggles do not meet the stringent requirements of the MilSpec goggles version.

### 4.2 INSPECTIONS

1 An/AVS-6 NVGs should receive semi-annual maintenance inspections.

An authorized service center/manufacturee will charge approximately \$200 to \$250 for a semi-annual inspection of an ANVIS-6 NVG. If, during the inspection, it is discovered that repairs will be required, the service facility will not proceed until the owner has been notified and has authorized the repairs.

The following items must be examined during each semi-annual inspection: resolution, gain, near and far focus, collimation (alignment), and low-battery. Further, the goggles are to be purged with nitrogen to ensure that any moisture that may be present within the goggles is removed.

Through usage, particularly in focusing, moisture may be able to bypass "O" rings and get into the eye pieces, tubes, and power supply. At altitude, any moisture that is present, will form condensation rendering the goggles useless.

NVG inspections are to be completed by personnel authorized and certified by the manufacturer. Inspections may be conducted at either the service facility or on-site. The equipment necessary to inspect NVGs on-site costs approximately \$25,000. This expenditure includes both the inspector and purge kits. Prior to placing the goggles back into service, the NVGs must be certified that they meet the manufacturer's specifications.

For the cost of the inspection kits, an operator could have two sets of goggles inspected by an authorized service center for 31 years. However, should the operator have 12 sets of NVGs, the test kit would pay for itself in just 5 years. These figures do not consider any repairs that may be required.

## 5.0 INTERNAL AND EXTERNAL NVG COMPATIBLE AIRCRAFT LIGHTING

### 5.1 INTRODUCTION

NVGs enhance nighttime VMC flight by amplifying reflected low intensity visible and near infrared light. Enhancement occurs between 600 and 900 nanometers (1 nanometer is one billionth of a meter). Any direct or reflective light source should be kept below 600 nanometers so as not to degrade the operation of the goggles.

### 5.2 DIRECT AND REFLECTIVE LIGHTING

Cockpits of many civil aircraft are painted white or light colors that reflect light. These reflections are detected by the NVGs either directly into the tubes or reflected from the windshield or side windows.

White shirts and orange flight suits worn by crewmembers may also be reflected onto the side windows or windshield.

Any light source, either direct or reflective, detectable by the unaided eye may cause interference on the NVG. The brighter the light source, the less effective the viewing device.

To preclude any degradation in the capabilities of the goggles, aircraft internal lighting should be compatible with NVGs. NVG cockpit compatible lighting provides the capability to acquire interior information with the unaided eye. This is accomplished without degrading the image intensification capability of the goggles to see outside of the aircraft at night. Adverse effects are greatest during conditions of low ambient light; as ambient light increases, the effects are reduced.

The problem of achieving NVG compatible cockpit lighting is compounded when attempting to address pre- and post-manufactured aircraft. The AN/AVS-6 goggle is designed to be operated with blue-green cockpit lights. The combination of improved performance in the red and near infrared portion of the spectrum and the minus-blue filter makes red cockpit lights incompatible.

While red cockpit lights are unsuitable, blue-green cockpit lighting is ideal. Although the blue-green cockpit lights will not degrade goggle performance, they should be dimmed to the lowest possible level which will allow the instrumentation to be viewed easily.

In certain types of aircraft, light in the cabin area can not be isolated from the cockpit and will therefore interfere with NVG performance. In these situations, cabin lighting also will need to be made compatible.

NVG compatible cockpit flood lights that illuminate all flight critical instruments can be used. The pilot can turn off all other

cockpit lights and rely on the flood lights to illuminate necessary instruments. This can be accomplished at much less cost than modifying individual instrument lights.

### 5.3 RECOMMENDATIONS

Aircraft cockpit lighting should be made NVG compatible prior to the use of such devices. Compatible cockpit lighting allows the pilot to retain the capability to acquire, interior information with the unaided eye without degrading the goggles capability.

For optimum performance, this modification should begin inside the cockpit with all surfaces being painted black. Placards and other reflective cards should be of a nonreflective color. Clothing worn by crew members should also be of a dark color. In addition, if the following lighting is not compatible, then:

- a. aircraft instruments must be modified with external NVG compatible lighting;
- b. all edge-lighted panels must be modified or replaced;
- c. internally illuminated displays, switches, and readouts must be modified or filtered;
- d. warning, caution, and advisory lights must be replaced or modified;
- e. floodlights, utility, and map lights must be modified or replaced;
- f. in aircraft where the cabin area cannot be isolated from the crew compartment, the cabin lights must also be modified or replaced; and
- g. interior flood and dome lights must be replaced or modified.

Basically, all interior lights in the cockpit and cabin should be modified for or replaced with NVG compatible blue-green lighting.

Response of the human eye is greatest at night in the blue-green region. This allows cockpit instruments to be easily read event at very low intensities.

Compatibility can be achieved by:

- a. spectral separation - electroluminescent lighting and filters;
- b. geometry - baffles, flight location, and taping lights, and
- c. absorption - flat black instrument panel and antireflection coating or treatment.



Windscreens should be thoroughly cleaned. Slightly scratched windscreens that may be acceptable for day flights may not be acceptable for flight with NVGs.

Helmets must be painted in non-reflective, dark flat paint or covered at night.

Searchlights should be modified with an infrared filter lens. Combining the benefits of an IR searchlight and the NVG, a pilot achieves a lighting equivalency 20,000 times greater than without IR capability (USMC NVG Manual 1988).

IR searchlights however, are not to be interpreted as a solution for all low light problems. The U.S. Army had a number of accidents that have been traced to over-dependence on the IR light. In these cases, IR lights were improperly used as a substitute, rather than an augmentation, for ambient light.

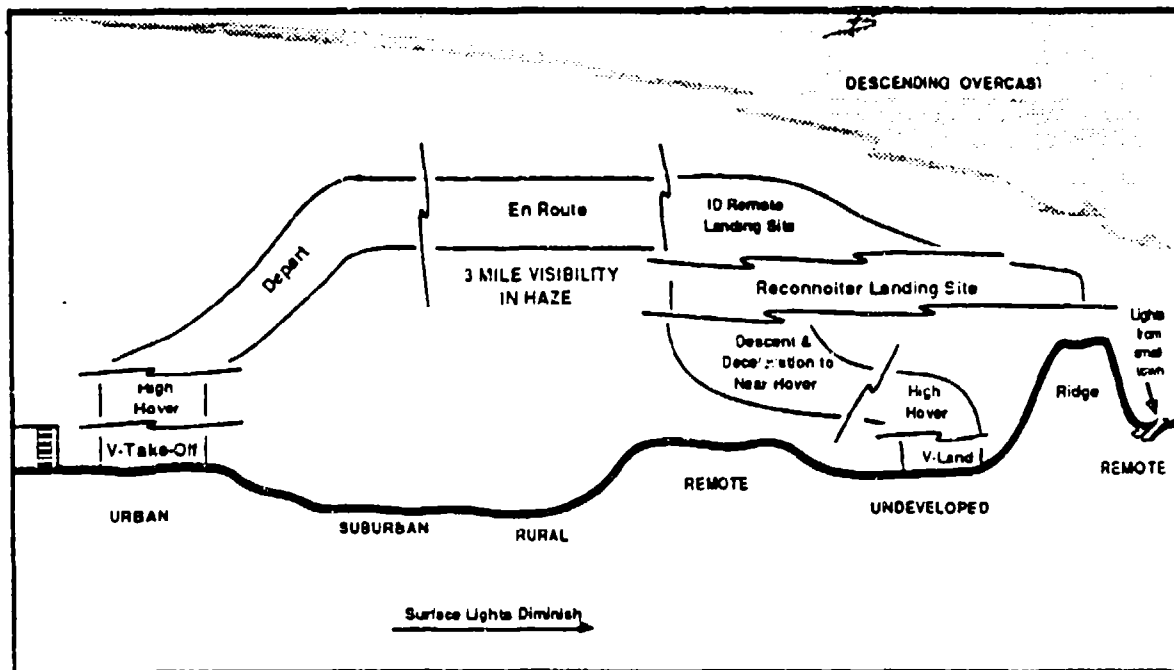
It was discovered during the investigation of these accidents that the pilots were "over flying" the IR searchlight. That is, the pilots were flying at speeds that did not allow them sufficient time to mentally process the visual cues provided by the light. This tendency is accentuated when consciously using the light for obstacle avoidance. The most effective use of an IR searchlight is in the landing phase.

Cockpits should be modified either during production or as a retrofit before NVG flight is approved. Several companies offer various levels of night vision compatible lighting system.

## 6.0 INTRODUCTION TO ENHANCED NIGHT VISUAL OPERATIONS

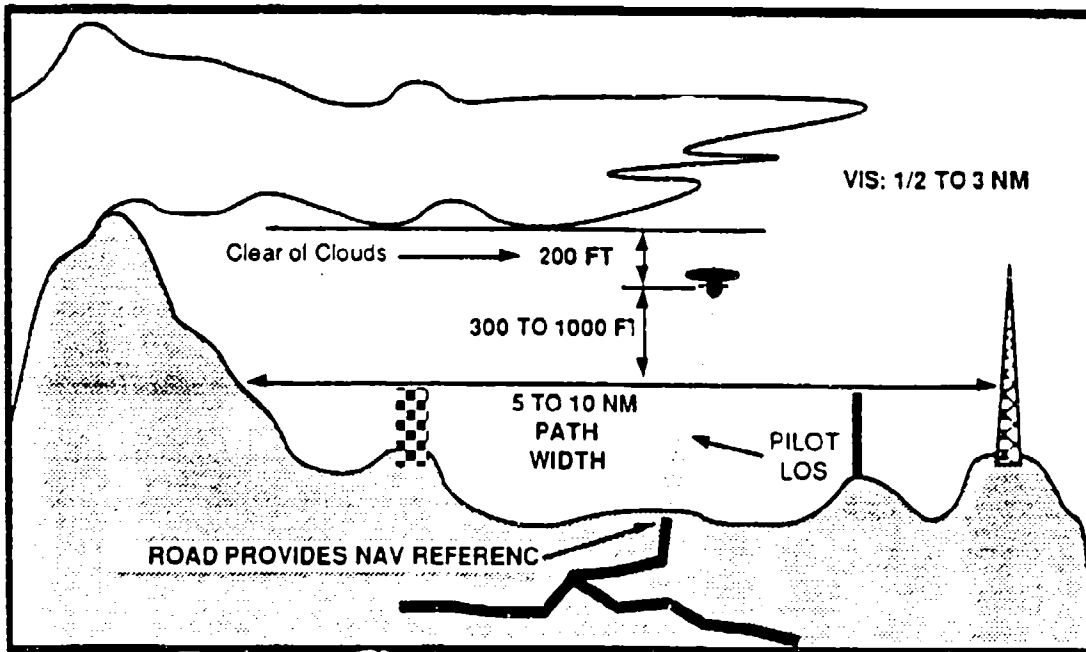
### 6.1 OVERVIEW OF THE EMS PROFILE

Figure 39 illustrates one of the most demanding EMS profiles. This involves a takeoff from a lighted hospital or airport heliport. The crew transitions to some form of NVG-aided operations to assist in locating potential obstructions and other aircraft. NVGs are to be used during VFR conditions only and must not be used as the basis for conducting a flight operation.



**FIGURE 39 DEPARTURE**

EMS en route operations at night during VFR conditions can be flown without NVGs, but NVGs can sometimes enhance the pilot's ability to see and avoid obstacles and other aircraft, while at the same time providing micro navigation information which can help the crew "fly normally" at night. The pilot uses standard planning procedures to establish a route which is 5 to 10 miles wide (figure 40). This path may be bounded by hills or other obstructions but, as shown, it has a floor which is not penetrated by any obstruction. The NVGs are used to see the navigation landmarks; roads, lighted towers, cities, rivers, lakes, bridges, etc. Standard operating procedures and FAA regulations also dictate clearance from clouds and adequate visibility.

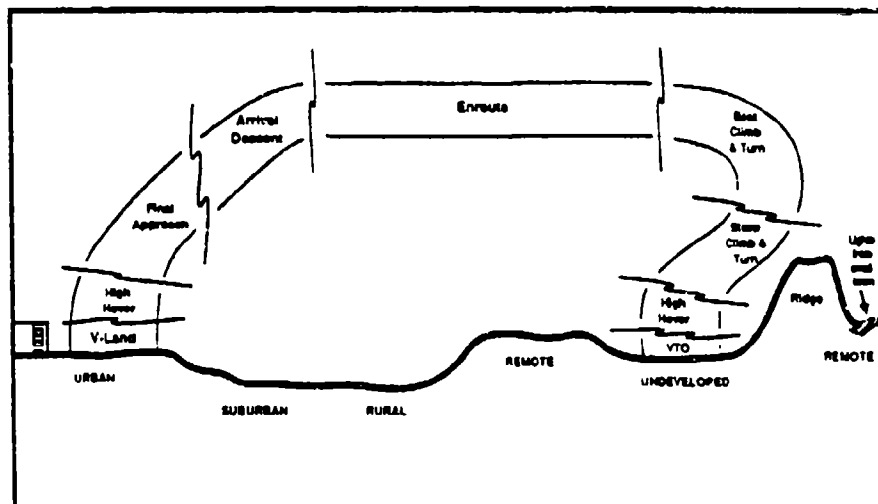


**FIGURE 40 NIGHT EN ROUTE OPERATIONS**

The crew will most often use the NVGs to help locate the incident site. In some cases the emergency lights of public service vehicles can be seen for miles before any other indicator. Arriving at the site, the pilot sets up a pattern to look for obstruction tell-tales such as power line rights-of-way cut through the woods. Spotlights or searchlights are normally used in concert with NVGs during this reconnoiter phase. As the aircraft descends, the pilot turns on hover flood lights. Controllable spot lights and/or powerful searchlights are used to scan hilltops, ridges, and road sides for additional telephone poles, ditches, and any other potential obstructions.

Having observed the wind, the pilot selects a landing approach and departure path. The departure is pre-selected in case a missed approach is required. It also represents the primary departure path after the pick-up is completed. The pilot will attempt to conduct an approach to an initial hover to check the power available and to get the ground speed of the aircraft under control before proceeding to the intended landing point. The initial approach is oriented so as to remain within 90 degrees of the wind during approach and departure. NVGs may be used during this initial descent depending upon the terrain, weather, and use of lights. If the pilot elects to descend and decelerate with NVGs in position, the pilot can scan under the NVGs for the majority of the operation.

The pilot can then continue the approach and complete a normal steep approach to a high hover followed by a vertical descent to a landing without any reference to NVGs. Completing the pick-up, the flight returns to a metro area as depicted in figure 41. Similar pilot procedures can be used during the return.



CAUTION  
 NVGs do not enable night VFR civil helicopter operations.

**FIGURE 41 RETURN FLIGHT**

## 6.2 WHITE LIGHTS CAN ASSIST CREW MEMBERS

The suggested application of NVGs and lights are summarized in figure 42 and table 2. In addition, the following observations provide insight into how and when lights and NVGs compliment each other and apply.

### Aircraft Mounted Lights Can Provide Additional Illumination

- 1) Additional illumination will not improve the ability to see along the flight path or to the sides of the flight path, when operating at altitudes of 300 feet AGL or higher.
- 2) Lights require considerable pilot effort to point and evaluate.

### Light Intensification and IR Vision Systems

- 1) NVGs will often provide very useful visual information at altitudes and ranges that cause lighting systems to become ineffective.
- 2) NVGs will also provide information that cannot be obtained with lights. The horizon line is one such example.

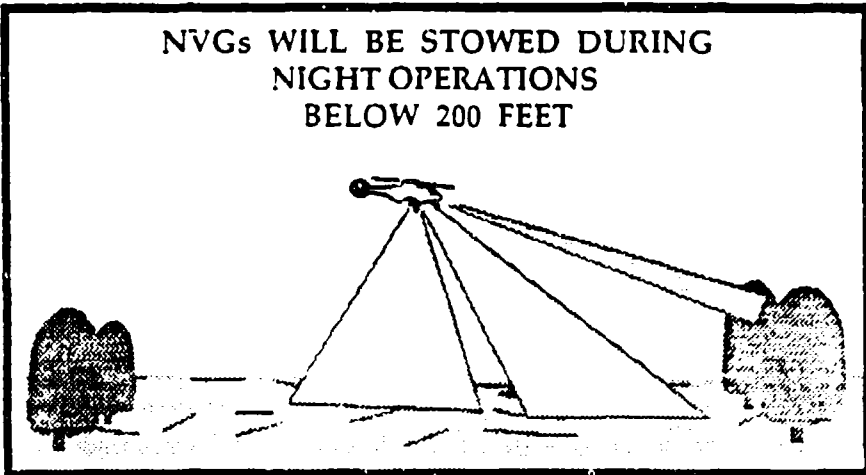
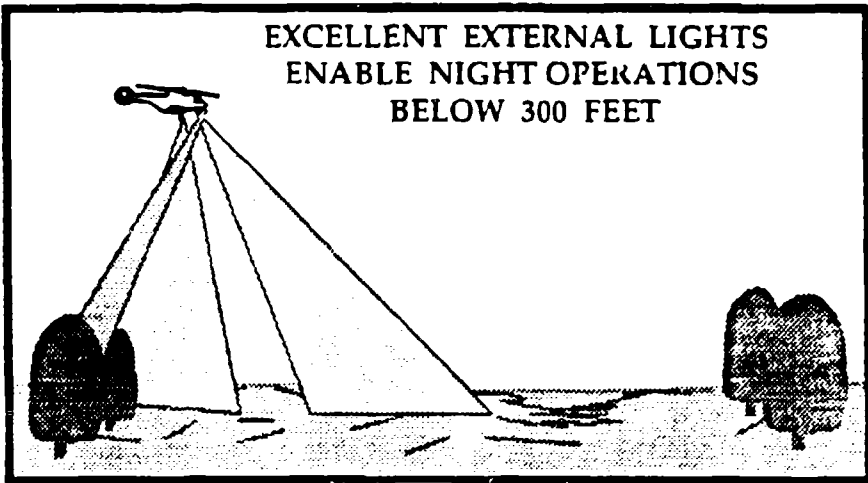
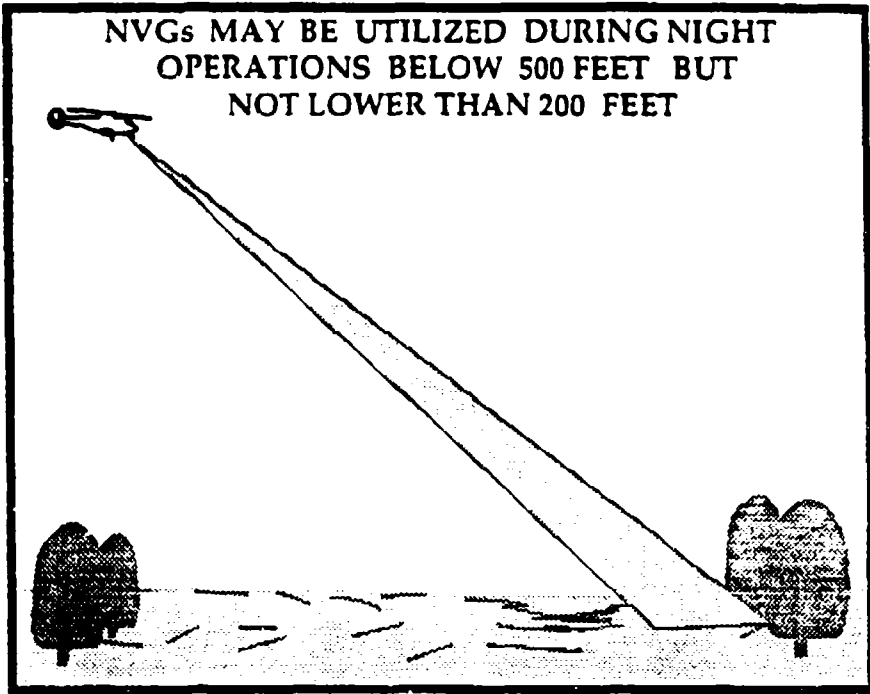


FIGURE 42 APPLICATION OF NVGS AND EXTERNAL WHITE LIGHTS

**TABLE 2 NEED FOR NVG AIDING**

CONDITION	NEED
Initial T.O. from lighted area with helicopter lights	<ul style="list-style-type: none"> <li>o Not required.</li> <li>o Desirable to have available                             <ul style="list-style-type: none"> <li>- Ready to flip down, or</li> <li>- In operate position, look under.</li> </ul> </li> </ul>
Climb out from initial T.O.	<ul style="list-style-type: none"> <li>o Not required but desirable depending upon ambient light. If there is little ambient light NVGs are highly desirable.                             <ul style="list-style-type: none"> <li>- Ready to flip down, or</li> <li>- In operate position, look under.</li> </ul> </li> </ul>
Cruise En Route	<ul style="list-style-type: none"> <li>o Highly Desirable                             <ul style="list-style-type: none"> <li>- Look through - out/under - in and out, or</li> <li>- Selectively flip down then up.</li> </ul> </li> </ul>
Arrival at destination - Use searchlights	<ul style="list-style-type: none"> <li>o Assist in locating destination.                             <ul style="list-style-type: none"> <li>- Look through - out/under - in and out.</li> </ul> </li> <li>o Improves reconnaissance.</li> </ul>
Descent to hover approach initial point. o Use spotlights o Use floodlights o Use landing light	<ul style="list-style-type: none"> <li>o Improves reconnaissance for obstructions during descending deceleration.                             <ul style="list-style-type: none"> <li>- Look through - out/under - in and out.</li> </ul> </li> </ul>
Deceleration to hover, vertical descent and landing. o Use spotlights o Use floodlights o Use landing light	<ul style="list-style-type: none"> <li>o Not required.</li> <li>o Desirable to have available.</li> </ul>
Departure T.O., hover o Use spotlights o Use floodlights o Use landing light	<ul style="list-style-type: none"> <li>o Not required.</li> <li>o Desirable to have available.                             <ul style="list-style-type: none"> <li>- Stowed, ready to flip down.</li> </ul> </li> </ul>
Departure acceleration, climb o Use landing light	<ul style="list-style-type: none"> <li>o Improves horizon cue and obstruction/route reconnaissance.                             <ul style="list-style-type: none"> <li>- Look through - out/under - in and out.</li> </ul> </li> </ul>

### 6.3 EXAMPLES OF ILLUMINATION FACTORS IN THE LOW ALTITUDE ENVIRONMENT

External light is that light which emanates or is reflected into the cockpit from outside the cockpit. Such light can have its origin from any number of natural and man-made sources. The frequency and intensity of this light is of primary importance in evaluating its effect on a pilot for the purpose of conducting aided or unaided flight operations.

Some of the light which is useful as a source for NVG operations can also be used by the pilot for unaided operations. Other light sources cannot be detected by the pilot and are of no value unless NVGs are used. Still, other light is in the useful frequency spectrum but the light is simply not bright enough for the pilot to see. Similarly, a light source may be otherwise useful to a pilot, but the reflectance from objects of interest is too low to be useful when viewed by a pilot in a lighted cockpit. There is also the question of ability to see in the night. Some pilots can see better than others at night, so some will detect objects at a given luminance and others will not. There is also the issue of contrast; the greater the contrast, the more detectable and identifiable an object or surface will be.

With NVGs the pilot will be able to see obstructions sooner than without, but if the airspeed is too high, the result will be the same. This problem can be minimized by avoiding flight into deep shadows. Alternately, the pilot should slow down to some prudently slow speed and direct a searchlight along the flight path.

When the moon rises above the horizon, it becomes a very strong source of illumination which, when viewed directly, can cause the NVG automatic gain control circuit to decrease system gain. Depending upon the relative luminance received from terrain features and obstructions, their associated images can be overpowered or "washed out" by this bright light.

Direct flight towards the moon can be avoided by selecting headings which allow the pilot to see along the flight path without looking directly into the moon. If necessary, headings can alternate back and forth across the moon line. This condition tends to exist for a relatively short period on any given night.

The best lighting for normal flight operations is a quarter moon (or greater), 23 degrees or more above the horizon. Generally the best view of the terrain is developed when the moon is above or over the shoulder of the pilot.

The clear starlight night provides sufficient light for NVG operations.

The frequency spectrum of the light sensed by the NVG allows some light to pass through thin clouds. This depends upon the illumination source, and the density and thickness of the overcast. This ability

to operate under an overcast has been discovered through experience. The characteristic, while known, is not well understood when it comes to approving operations under an overcast. In a few situations, the ability to observe a clearly defined horizon has been used as criteria to define an acceptable NVG operational situation.

The lights from a city many miles away will often reflect from clouds and provide sufficient local illumination. This light will illuminate the surface, providing back lighting for terrain and other obstructions.

Little has been written about this type of cloud lighting but it is a common phenomenon which all aviators have experienced. While there does not seem to be any documentation which quantifies this type of lighting in terms of adequacy for NVG operations, some operators have developed a useful guideline. During preflight they evaluate the available light by proceeding to a suitable observation point and view the horizon through the NVGs. If there is a solid horizon line in the intended direction(s) of flight, the light from all sources is considered adequate. Some of the observed light could come from the moon and stars above the overcast.

It is possible for NVGs to perform adequately in a fog condition which does not allow sufficient light for unaided vision. Upon entering an obscuration and as the obscuration becomes thicker, the pilot will observe increased electronic interference; indicating that the signal to noise ratio is decreasing and action should be taken to improve the lighting situation.

It would appear that when operating under conditions which may result in an IMC situation, pilots should make every effort to establish unaided visual contact reference point on the surface (preferably out ahead on the intended route). NVGs offer no advantage over the unaided eye during operations in heavy falling snow.

The dimensions and character of the reflecting surface, the reflectance of the terrain, the intensity of the source, and the included angle all affect the pilot's ability to see objects such as a wire or pole.

Certain types of objects such as aircraft navigation lights, obstruction lights, and certain emergency ground vehicle lights can be very difficult to see unaided. However, NVGs allow these objects to be identified at dramatically greater ranges than is possible with the unaided eye.



## 7.0 OBJECTIVE CRITERIA FOR ENHANCED NIGHT VFR EMS OPERATIONS

### 7.1 GENERAL

The following apply to the use of helmet- or harness-mounted night vision devices by rotorcraft crews during operations conducted under night visual flight rules (VFR) in compliance with requirements of Part 27, 29, 91, or 135 of the Federal Aviation Regulations (FARs).

- 1) In all cases, flight is authorized based upon the ability of a crew to conduct standard visual operations, observing VFR without any reference to a night vision device.
- 2) The aircraft shall be equipped with internal lighting which is compatible with the night vision device employed and the mode of operation selected.
- 3) The device shall be mounted upon a helmet (or equivalent) so as to:
  - a) allow the viewing portion of the device to be quickly and easily removed;
  - b) provide a stowed position that allows the viewing portion of the device to remain in a stowed condition, out of the pilots normal line-of-sight;
  - c) allow the pilot to align the device in the normal operating position; and
  - d) allow the viewing device to be rotated quickly between the stowed and the normal operating position.
- 4) The pilot may elect to conduct the majority of a flight with the device in the "stowed" position or the "normal-operating" position.

### 7.2 SINGLE PILOT, SINGLE CREW OPERATIONS

The aircraft shall be equipped with hover/landing lights. If the lights are fixed, they shall be adjusted to provide illumination which will produce a minimum negative impact on the pilot's ability to utilize a night vision device at high hover altitudes while providing excellent unaided vision during low hovers, landings, and takeoffs.

- 1) If the device power source fails, it shall be possible to continue safe operations and rotate the assembly to the stowed position.
  - a) It shall be possible to quickly transition from aided to direct view operations. The time allowed will vary with the inherent stability of the aircraft and the proximity of the aircraft to terrain or the severity of the maneuver being accomplished at the time of the failure.

- b) The effort to quickly rotate the device clear of the pilot's eyes and transition from referencing the aided to unaided direct view operations, shall not require special skill, techniques, or training.
- 2) With the device in the ready position, the activation of a bright caution or warning light, or the inadvertent activation of a white flood light, or inadvertent adjustment of any other internal or external light to full bright, shall not require the pilot to use special skill or techniques, or require special training to:
    - a) continue the current maneuver or,
    - b) to execute any other appropriate transition maneuver.
  - 3) If, while the pilot is observing the electronic images of the device, an external light is turned on with sufficient intensity to render the images generated by the device as meaningless, the pilot shall be able to quickly and easily reorient the field-of-view of the device and regain sufficient situational awareness to continue the planned fight maneuver(s). This capability shall include but not be limited to the completion of a:
    - a) vertical landing from a high hover or,
    - b) transition from a high hover to a climbing acceleration, followed by a climb of 1,000 feet to a level cruise before rotating the device to the stowed position.
  - 4) If the aircraft incorporates "attitude hold" or other workload relief stability augmentation equipment, continuation of the current maneuver or execution of appropriate transition maneuver shall be demonstrated after the most critical failure has been introduced into the system.

### 7.3 OPERATING GUIDANCE FOR NVG OPERATIONS

If the aircraft experiences a partial or total power loss, the pilot must demonstrate ability to conduct "rejected takeoff/landing" (during takeoff) and "continue to land" (during approach) after an engine failure while looking under the device. This demonstration need not be conducted with the aircraft loaded at maximum gross weight.

### 7.4 CREW QUALIFICATION

Pilots who desire to operate night vision devices must demonstrate their knowledge of the rules for their use by passing a written exam. They shall also meet the same physical and flight qualification requirements established for pilots qualified to operate under instrument conditions. The pilots shall also demonstrate their ability to fly safely at night with night vision devices.

- 1) A pilot must demonstrate knowledge of rules and characteristics of aided and unaided flight at night by satisfactorily completing a written test.
- 2) Aircraft will be approved for operations with night vision devices by a designated FAA inspector.
- 3) A pilot must demonstrate knowledge and ability to use night vision devices while an using an aircraft the pilot intends to operate or its equivalent.

## 8.0 DEPARTURE FROM BRIGHTLY LIGHTED AIRPORTS, HELIPORTS, AND DARK REMOTE SITES

### 8.1 PREPARING FOR NIGHT OPERATIONS

Prior to donning NVGs in the aircraft, confirm that the IPD and diopter settings are the same as those used in the test lane. Since the device was focused at 20 feet in the test lane, the pilot will have to refocus at infinity (using only the objective focus knob). While re-focusing, try to pick a clearly defined object at least 75 to 100 feet distant, preferably one with vertical edges or features.

Avoid focusing on noncompatible lights because the halos they create are hard to focus on. During flight you may need to make minor adjustments to vertical, tilt, and horizontal alignments due to helmet settling and rotation. Do not change IPD or diopter settings during flight.

#### 8.1.1 After Entering the Cockpit

The pilot is advised to check the proper adjustment of the goggles prior to the first night takeoff. This is to ensure that the proper adjustments have not been altered when the goggles were transported to the aircraft.

The pilot has a variety of options available to him/her depending on the amount of light in the area of the departure. In the case of a brightly lighted airport or heliport, there may be ample visual cues to perform the takeoff unaided. In this situation, the pilot should not transition from unaided to aided flight until the aircraft is stabilized in a positive rate of climb. In areas that are not as well developed, NVGs can provide additional visual cues which enhance the safety of a VFR departure. When there is adequate lighting in the immediate vicinity of the takeoff but very little visual cueing soon after takeoff, the best technique is to place the NVGs in the operating position and use peripheral vision and the landing light for the takeoff to a hover and initial climb and then transition to the aided scan after a positive climb has been established.

### 8.2 EN ROUTE OPERATIONS

#### 8.2.1 Contact Versus Instrument Reference for Flight

Contact flight requires the pilot to fly with reference to the terrain features, natural and man-made. This requires the pilot to look outside the cockpit to ensure that the flight follows the desired course. The pilot must also watch for other aircraft to avoid conflict. This visual activity takes away from the time available to look inside at the flight instruments, tune radios, look at charts, etc. This shared scan provides the pilot with two opportunities to obtain flight management cues. The "outside world" provides one opportunity and the cockpit instruments the other.

On a black night, over an unlit surface on a clear (VFR) night, it may be impossible to fly without spending considerable time on instruments.

The sense of security, or the lack of this feeling, is in some measure a reflection of task complexity. The ability to see the real world seems to contribute substantially to a positive feeling of security. This positive feeling is in turn reflected as low levels of stress and a decreased probability that the pilot will become fatigued. Fatigue can occur even if the pilot's task is limited to monitoring the activities of a fully automatic flight control system. For example, if the autopilot is flying the aircraft at high speed at a low altitude, the pilot must monitor autopilot performance very closely thus creating stress which eventually causes fatigue.

### 8.2.2 Night Operations

Navigation and flight control cues are different at night. Red barns are no longer red and green fields are no longer green. They now are shades of grey. The same type of change occurs when the night is viewed through NVGs.

## 9.0 ARRIVAL AND DESCENT IN PREPARATION FOR A NIGHT REMOTE SITE LANDING

### 9.1 GENERAL

Under normal, night flying operations, a helicopter pilot is expected to arrive at a remote landing site and descend to a safe landing using natural light, lights on the ground, and lights on the aircraft. NVGs may be of significant benefit during the arrival and approach phase.

Landing site. Once the landing site has been located, the pilot must descend to some safe (obstruction clear) altitude and verify the identity and appropriateness of the site as a landing zone. This process should include a reconnaissance to detect obstructions and to plan the approach and departure paths.

The reconnaissance phase should involve the coordinated use of NVGs and white lights. The aircraft's external white lights such as landing lights, searchlights, and floodlights, should be used during this phase of flight.

On a very hazy night, caution should be used when turning on a white light as it may produce significant backscatter, reducing horizon cues.

Spotlights should be used to look at objects on the ground while the pilot circles above. The pilot can look at the spot on the ground through the goggles and often see more than without the NVGs. The pilot also has the alternative of looking under the goggles and viewing the lighted area unaided.

Some features or objects may be easy to detect and interpret with the unaided eye. Other objects will be invisible to the unaided eye, yet easily detected and evaluated with NVGs.

In some cases there may be sufficient light that goggles are not needed. An example is flying low over a well lit city with bright moonlight. In such cases, it may be desirable to flip the goggles up to the stowed position.

An oval pattern is flown to provide the pilot with the opportunity to conduct a thorough reconnaissance of the landing zone. The pilot should look for obstacles and clues that indicate the presence of obstacles. For example, a cut through the woods may indicate the presence of a pipeline or powerline right-of-way. Assuming the landing site is satisfactory, the terrain is checked for alternative approach and departure paths.

During the reconnaissance, the pilot selects a landing site and studies the terrain to evaluate alternative approach paths and departure paths. The pilot must be alert to the possibility that the wind may change direction and speed as the aircraft descends. For

example, the pilot may see a wire on short final and may need to turn to use a different final approach path. Pre-planned alternatives are important.

Having completed the reconnaissance, the pilot must formulate a plan for conducting the approach. This includes a plan for an emergency (for example, an engine failure on approach), and the best takeoff departure route. The wind, terrain, landing site, obstructions, and visibility have all been taken into account during this pre-approach effort.

To summarize, before starting the approach, the pilot may use the NVGs to help find and evaluate the obstructions in the area. This will involve shared viewing where the pilot alternately looks under the goggles at what can be seen with the spotlight and then through the goggles. Next, the floodlights are turned on as the approach is commenced.

## 9.2 FINAL APPROACH TO A REMOTE LANDING

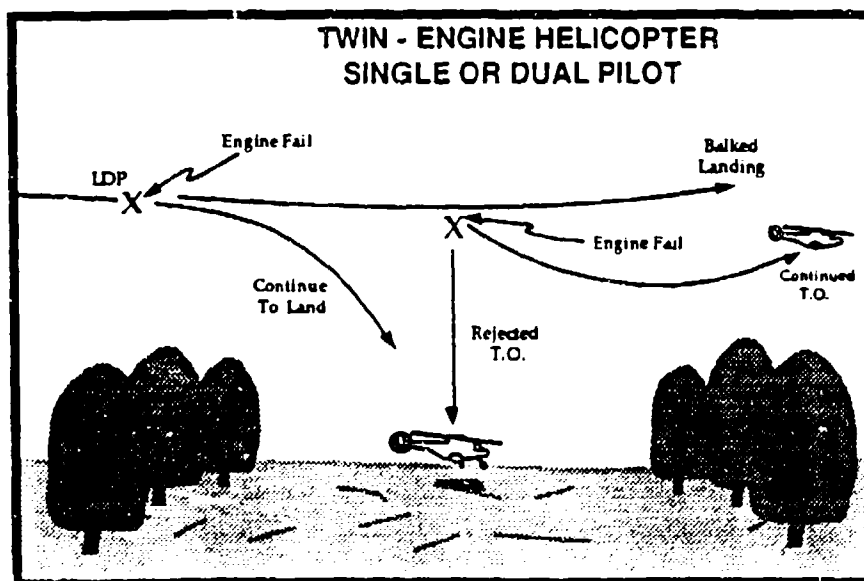
Once the reconnaissance and pre-approach are complete, the pilot is ready to commence the final approach. Prior to beginning the approach the pilot must decide on the visual scan that will be used. This decision will be made based on available light, number of obstacles, and familiarity with NVGs. Once a scanning method has been chosen, it is best to remain with this method throughout the approach. Any of the three scanning methods (aided, unaided, or combination) can be used for the entire approach. The final phase of the vertical descent and landing may involve a need to reduce the intensity and orientation of the white light. Very bright, white spotlights can cause a great deal of light to be reflected back into the cockpit. This light can reduce the pilot's ability to see background cues that are important to a landing. In some cases, it may be advisable to control light intensity by deselecting lights during the descent.

## 10.0 EMERGENCY OPERATIONS

### 10.1 FOLLOWING A PARTIAL POWER LOSS

Should a partial power loss occur while on approach to landing, and the aircraft has passed the landing decision point (LDP), the aircraft must be flown to a landing. The use of NVGs should not negatively affect the crew's ability to complete this maneuver. This applies to vertical landings following rejected takeoff (engine failure) or a continued takeoff following a single engine failure.

Pilots must demonstrate an ability to accomplish a rejected takeoff while looking under the NVGs. If NVGs degrade performance, pilots must either: 1) reduce the operating maximum gross weight of the aircraft until they can accomplish the takeoff/landing task, or 2) they must leave the NVGs up until reaching the point where a continued takeoff can be accomplished (see figure 43).



**FIGURE 43 TWIN ENGINE - SINGLE OR DUAL PILOT**

### 10.3 INADVERTENT IMC

The chances of unknowingly entering IMC are increased when using NVGs. The ability of NVGs to "see through" fog and precipitation can result in a pilot being unaware that he/she is entering weather until they are "in the thick of it." Certain cues on the NVG will alert the pilot of impending IMC.

- 1) A halo may be perceived around the source of illumination. The halo effect tends to increase when atmospheric obscurations are present. The size of this halo should be noted; if it becomes significantly larger, a weather restriction may be developing.



- 2) A gradual reduction in light levels, visual acuity, or terrain contrast might also provide indication of impending IMC.
- 3) Partial obscuration of the moon and stars will accompany cloud build-up. The less visible the moon and stars, the heavier the cloud coverage. Similarly, shadows obscuring the moon's illumination is an indication that clouds are present. These shadows can be detected by observing the varying levels of ambient light along the flight route.
- 4) An increase in NVG "video noise" when atmospheric obscurations are present and the ambient light is low is another indicator. Video noise is similar in appearance to the "snow" seen on a television with poor reception.

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## LIST OF ACRONYMS

AGL Above Ground Level  
AN Army-Navy  
ANVIS Aviator Night Vision Imaging System  
AVS Aviator Vision System  
BMNT Beginning of Morning Nautical Twilight  
EENT End of Evening Nautical Twilight  
EMS Emergency Medical Service  
FAA Federal Aviation Administration  
FAR Federal Aviation Regulation  
FATO Final Approach and Takeoff  
FLIR Forward Looking Infrared  
FOV Field-of-View  
HV Height-Velocity  
IR Infrared  
IMC Instrument Meteorological Conditions  
LDP Landing Decision Point  
MTBF Mean-Time-Between-Failure  
NVG Night Vision Goggle  
OEI One Engine Inoperative  
OGE Out of Ground Effect  
PAS Pilot Adjustment Shelf  
VFR Visual Flight Rules  
VMC Visual Meteorological Conditions