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Fundamentals of Flight

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the excellent reflectivity of snow, less illumination is required to give the same luminance for the subject without snow. Thus the NVG can see the terrain under lower light level conditions.

4-103. As with other forms of moisture, the effect on the FLIR depends on the flake size and density (figure 4-31). Due to the general size of snowflakes, scattering of the thermal energy causes most of the attenuation. Therefore, density of the flakes is of primary concern. For snow on the ground, the degree of attenuation depends on the duration of the snow cover. Snow can cool surfaces to a reasonably uniform temperature and thus attenuates the FLIR image. However, a fresh blanket of snow on the ground may be "invisible" to the FLIR, making it the sensor of choice if there is little texture/contrast for the NVG to work.

Figure 4-31. Snow

SAND, DUST AND OTHER OBSCURANTS

4-104. The impact of battlefield obscurants on NVG performance depends on particle size and density. NVG visibility "inside" or through these obscurants is usually poor (figure 4-32). Hovering in a dusty environment can be very dangerous. Visual references are easily lost and disorientation follows rapidly due to the swirling dust. Use of aircraft systems such as the HUD or HDU is strongly recommended. Dust operations are normally trained at the unit. Aviators should use high contrast references closer to the aircraft. Aircraft position and anti-collision lights can interfere with the ability to see outside the aircraft to the point of jeopardizing the safety of the aircraft. The pilot in command should consider turning off aircraft lights according to regulations and local SOP. Even small amounts of dust with light winds can obscure the horizon.

Figure 4-32. Obscurations/dust

SECTION IV – TERRAIN INTERPRETATION

4-105. Terrain interpretation becomes extremely important in environments where electronic warfare is utilized to degrade electronic capabilities. Aircrews should train degraded navigation and terrain interpretation to proficiency to maintain combat power.

VISUAL RECOGNITION CUES

4-106. During night unaided and NVG flight, color vision is degraded or entirely absent. Aviators do not have the relatively high level of visual acuity to identify objects in their environment and must rely on cues such as the size, shape, contrast, color, texture, shadow, reflectivity, and construction of objects. The size and shape of objects should be unique in relation to the operating environment.

SIZE

4-107. Large structures and terrain features, such as towers, are easier to recognize at night than small objects. Small objects tend to get lost in the clutter of other objects. To see and recognize small features often requires crewmembers to view an area several times. A shorter viewing distance also aids in visual recognition.

SHAPE

4-108. Aircrews can identify objects at night by their shapes/silhouettes. Some buildings are recognizable at night by their design. For example, a church may be marked by a steeple or cross on top of the structure. Religious buildings of other faiths may look markedly different. Aviators should consider these details in mission planning. Aviators may have to reposition aircraft to see objects from different perspectives to recognize their shape. A water storage tank/tower may be similar in shape to an oil storage tank requiring the aircrew to seek other viewing angles or supporting information. For example, storage tanks positioned in a group are likely oil tanks not water tanks. 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 and assist in night terrain interpretation.

CONTRAST

4-109. The contrast between an object and its background can aid in object identification. The degree of contrast depends on the type and amount of ambient light, texture of the object, background, and whether the object is illuminated. These items also serve as cues in identifying objects or features. There are several different types of contrast.

COLOR

4-110. While full color information is not available under NVDs, a significant amount of information can nevertheless be obtained which can help distinguishing an object from similar objects or from its environment. Light objects stand out well against dark objects, and vice versa. Shadows can be used to provide additional contrast between objects. This is one reason why flying with a lower angle moon may be easier than flying with a moon that is high in the sky. A dark blue truck, for example, looks markedly different than a light brown truck, even under NVG. It may be necessary to verify the NVD image with the unaided eye to prevent misperceptions and assumptions.

4-111. Color contrast is very poor in large fields covered with similar vegetation. If the vegetation has leaves that contain chlorophyll, they appear lighter in color, and can appear almost white, even when those leaves are dark green to the unaided eye. This is because chlorophyll has a very high near IR reflectivity value (figure 4-33). This is one example of how the difference in wavelength sensitivities between the eye and NVG alters the "normal" scene interpretation to which we have grown accustomed. This problem is compounded by a lack of terrain features or differing textures.

Figure 4-33. Infrared reflectivity value

TEXTURE

4-112. Contrast of texture is the difference between the reflectivity of two or more surfaces (figure 4-34). A shiny object stands out well against a matte surface. Texture contrast also refers to the difference between the patterning or construction of the objects. For example, a man-made structure such as a barn is constructed of sharp angles and distinct lines. This texture stands out well against a more homogenous background of a desert environment. It tends to blend in, however, with the busier background of a forest or mountainous environment. Texture provides recognition and depth perception cues and improves the comfort level of aircrew. Forests provide a lot of texture, whereas flat deserts, even though they have higher light reflectivity values, have poor contrast and little texture. This is why flying over forests can be easier, even though they do not reflect as much light as the desert or snow. However, in conditions of low illumination, this advantage can be lost as the color contrast between similar trees is lost and they blend.

Figure 4-34. Texture contrast

SHADOWS

4-113. Shadows form at night just as they do during the day. Anything blocking moonlight creates a shadow. This can include terrain, cultural objects, and even aircraft. One big difference between day and night shadows is the amount of energy present inside the shadow. During the day, the human eye can see into shadows due to the amount of energy still inside the shadow. At night the amount of energy in a shadow can approach zero. Since NVG require some illumination to function, they are not as useful for viewing inside shadowed areas. Even large objects can be lost in shadowed areas.

4-114. Shadows can be helpful as well as a hindrance. Some objects, such as tall, narrow pylons, may cast a shadow that is seen well before the pylon itself. Shadows may also help to discern terrain features while flying over low contrast terrain, such as sand dunes. When flying into shadowed areas, the aircrew may depend on help from sensors that do not need illumination to function, such as the thermal sensor or radar altimeter.

4-115. Shadows created by clouds can create visual illusions leading to disorientation. For example, while flying underneath a broken layer with high illumination, the pilot is constantly in and out of shadows causing the NVG gain to fluctuate, making it more difficult to pick out terrain features. The changes in illumination can also affect depth perception. A scattered layer is not as distracting but can mask or hide important navigation or targeting information. In the brighter areas between the scattered cloud layers, the NVG gain is driven down making it more difficult to see objects lying within the shadows. Once inside the shadowed area, the gain readjusts, making it easier to see the previously hidden objects. Some shadows can be predicted, such as those cast by towers, smoke stacks, and mountains. Using the SLAP Shadow Formula can plan for these types of shadows.

4-116. Shadows can help or hinder, but need to be considered in mission planning. Knowing the moon angle and azimuth, combined with a thorough map study, can enhance the capability of the aircrew to use or avoid shadows as necessary. Examples of questions to ask regarding moon angle/azimuth and shadows while flight planning are—

- Will the target's shadow aid in locating the target?
- Will the aircraft be within a mountain shadow when attempting to visually identify a turn point?
- Will the aircraft be in shadowed terrain while terrain masking?

REFLECTIVITY

4-117. Terrain reflectivity (albedo) greatly influences the overall scene luminance available for NVG operations. Surfaces such as snow reflect more light than surfaces like asphalt or dark rock and appear lighter in the NVG image. A concrete road (quite reflective) should be easily seen in farming country where the surrounding terrain may be less reflective. However, a concrete road may be less discernible in a desert environment where the road and terrain may have similar reflective values. The ability to see terrain features with NVG is solely a function of the amount of light reflected by the terrain. Additionally, individual reflective objects are easily visible against a non-reflective background. The reverse is much less true.

CONSTRUCTION

4-118. Man-made objects are generally constructed with hard edges, sharp angles, and a combination of strong vertical and horizontal lines. As such they generally stand out well against more random natural environments, particularly those of low contrast. For example, a log cabin in the woods shows up reasonably well due to the sharp angles and regular lines, despite being made of the same material as the surrounding foliage. The same log cabin in a desert environment stand outs plainly. However, the busier the background, and the closer the construction material is to the surroundings, the less obvious the construction. Stone huts in the mountains of Afghanistan can be nearly impossible to see.

FACTORS

4-119. Mission planners must be aware of additional factors besides terrain itself. Ambient light available along with distance and altitude contribute to terrain interpretation. Planners should consider these factors when route planning to aid aircrews for mission success.

AMBIENT LIGHT

4-120. NVG performance and ability to interpret terrain are directly related to ambient light levels in the flying environment. Reduced light levels at night decrease visual acuity. This restricts the distance at which an object can be identified, and terrain interpretation becomes more difficult as light level decreases. Adjustments in airspeed and/or altitude may be required to improve visual interpretation and increase viewing and reaction time. Reduced ambient light levels can be detected by recognizing the following indications:

- Scintillation-Increase in video noise within the NVG image as a result of low ambient light levels.
- Increase in halo intensity-As ambient light levels decrease, halo intensity increases.
- Loss of celestial lights-The moon and stars fade or disappear due to cloud cover or other obscurants.
- Loss of ground lights-Cultural lighting begins to fade or disappear due to obscurants.
- Loss of scene detail-As ambient light levels decrease, loss of scene detail occurs.

VIEWING DISTANCE

4-121. The viewing angle becomes smaller as the distance from the object increases; therefore, large and distinctly shaped objects viewed from a great distance at night may become unrecognizable. Range is also difficult to estimate at night and can result in a miscalculation of object size. The distance at which interpretation of an object becomes unreliable also depends on ambient light level. Aviators may be able to identify an object by its shape and size up to 1,500 meters during a high light condition; however, they may not be able to recognize the object at 500 meters during a low light condition.

FLIGHT ALTITUDE

4-122. The altitude AGL at which an aircraft is flown affects the aircrew's ability to interpret terrain. The effects of high- and low-altitude flights are discussed in the following paragraphs.

High Altitude

4-123. Changes in viewing angle and distance at which an aviator is viewing an object change the apparent shape of that object. The ability to identify man-made or natural features progressively decreases as flight altitude increases. This condition is affected at all levels of ambient light. When flight altitude increases, contrast between features becomes less distinguishable and features tend to blend. As terrain definition becomes less distinct, detection from altitude becomes difficult.

Low Altitude

4-124. Terrain becomes more clearly defined and contrast is greater when an aviator flies closer to the ground. This allows man-made and natural features to be more easily recognized and permits increased navigational capability. However, the viewable area of a crewmember at low altitudes is smaller than at higher altitudes. With NOE/contour altitudes, that area is even smaller, sometimes requiring an aviator to reduce airspeed to permit more accurate terrain interpretation. Objects can also be identified at low altitudes by silhouetting them against the skyline.

MOON ANGLE

4-125. Moon angle has the same effect as the angle of the sun regarding ambient light levels. The position of the moon should be considered during each phase of aviation operations. However, the angle of the moon would have the most impact of LZ selection and landing direction.

HIGH-ANGLE MOON

4-126. Higher moon angles produce greater levels of illumination and reduce shadows that cause distortion and loss of ambient light. By eliminating those shadows, however, they also remove cues to the nature of the terrain. This is particularly important in low rolling terrain such as tree covered hills or sand dunes. The more direct overhead light can also flatten the landscape, making distance estimation and depth perception more difficult.

LOW-ANGLE MOON

4-127. A low-angle moon may be beneficial in areas with little terrain relief. Terrain interpretation is generally more difficult when the moon is low on the horizon. This is due to the lower light level and the shadows caused by the low angle. If unaided low-level flight is conducted toward the moon, glare may bother the aircrew causing distorted vision and a loss of dark adaptation. During aided flight, glare may also degrade NVD capability. However when the moon is low on the horizon, terrain features or objects on the skyline may be more recognizable.

SEASONS

4-128. Seasons of the year affect the amount of ambient light reflected from the surface of the earth; however, aviation focuses on two seasons—winter and summer. While significant differences are present between the two seasons, which season is easier to interpret terrain and detect visual cues is determined by that AO. Aviators must evaluate each location separately to avoid generalizations or assumptions.

WINTER

4-129. Contrast improves during winter as many areas lack vegetation. Ground snow also improves contrast by increasing total illumination as it reflects ambient or artificial light. The light color of snow, compared with the dark color of structures and heavily forested areas, enhances visual interpretation.

4-130. The loss of foliage on deciduous trees makes ground features, such as small streams, easier to identify. Plants and grass in open fields change color and improve contrast between open fields and coniferous trees. Barren trees, however, reflect less light and become more difficult to see often causing an aviator to fly higher.

4-131. In winter, the orbital path of the moon is closer to the earth causing the ambient light level to be higher than at other times of the year. This improves visual acuity and enhances terrain interpretation.

4-132. Cloud cover and restricted visibility occur more often during winter than summer. Both conditions significantly reduce ambient light level, thereby decreasing visual acuity and making terrain interpretation more difficult unless sources of artificial light are nearby.

4-133. Heavy buildup of snow may conceal manmade and natural terrain features. Snowdrifts may obscure a road intersection normally used as a navigational control point (CP). An aviator can still identify this obscured CP by associating it with other objects or terrain features such as a power line, fence line, or cut through a wooded area. In addition, heavy snow buildup combined with severe cold cause small rivers or lakes to freeze over and become unrecognizable. Aviators must identify these landmarks by associating them with a depression or tree line.

SUMMER

4-134. Identifying objects and terrain features by contrast in summer is less effective than during winter months. The increased amount of vegetation and abundance of growth on deciduous trees makes it difficult to recognize small rivers or streams and decreases the ability to recognize military targets when located in or near forested areas. In vegetated areas, concealment and camouflage are much easier during summer months.

TERRAIN DENSITY

4-135. Terrain density can be referred to as "how many things are on the ground that can be seen." An object must have sufficient size and contrast to be distinctly perceived by either central or peripheral vision. This information is used to determine optical flow and helps to determine airspeed and altitude. Examples of areas with low density are open areas: completely snow covered terrain, most deserts, and calm water. Because of the reduction in resolution, contrast, and FOV inherent with NVDs, the terrain density is perceived to be less than with the photopic eye. The reduction in density increases the potential for spatial disorientation and may increase mission crosscheck times as the aircrew must "fill in" the gaps in information using instruments. Therefore, altitude and airspeed cues derived from terrain density must be crosschecked and verified with cockpit instruments, in particular the radar altimeter. Areas of higher density include wooded areas, mountainous terrain, broken terrain and urban areas. High density areas require less instrument crosscheck but may require lower airspeeds in order to adequately process information about the flight environment, depending on the mission.

VEGETATION

4-136. The amount and quality of vegetation can substantially alter a given scene. Drought can change the color and reflectivity of leaves, while lush vegetation can shroud objects normally easily visible. Regular spacing, rows, or fields with a consistent texture across the entire field indicates cultivated vegetation. Aviators should beware of obstacles and the increased likelihood of brownout on landing.

TERRAIN TYPES

4-137. Mission planners should be aware of obstacles that terrain can create to mission success and plan accordingly. However, terrain should also be exploited for any benefits to the mission. Such as recognizable features for navigation and concealment of the flight.

URBAN

4-138. The ability of crewmembers to interpret urban terrain varies greatly in a combat environment. Generally, an urban environment contains high levels of contrast and the cultural lighting provides high levels of ambient light over the city and adjacent terrain. This is particularly true when a low overcast cloud layer is present, which reflects some of the light energy. These benefits, however, are often accompanied by the confusion of flashing lights, high intensity lights/fires, and power outages. Lighted and/or unlighted towers in urban areas can also create an extremely hazardous environment for terrain flight operations.

4-139. Estimating hover height over asphalt or concrete is difficult due to a lack of visual cues. These surfaces lack contrast; however, a distinct contrast exists where a hard surface adjoins a soft surface. An aviator can use markings, such as taxiway lines or centerlines, to provide reference points.

MOUNTAINOUS

4-140. Terrain interpretation can be enhanced due to large distinct terrain features and is aided by terrain silhouetting. When the moon is near the horizon, large shadows can severely restrict what can be seen in the shadowed areas. Varying lighting conditions may make it difficult to see folds in the terrain, such as ridges or valleys. Mission planners should allow additional time for reconnaissance or attack missions in mountainous terrain. The complex textures normally found in mountains can mask flight hazards such as towers, wires, or other man-made structures. It is not safe to fly into areas too dark for obstructions to be seen.

VEGETATED/ROLLING TERRAIN

4-141. Dirt roads and farm structures provide the most distinguishable man-made features; contrast is good between forested areas and open fields. Rivers and terrain features which give distinct changes in elevation from surrounding terrain provide the most recognizable natural landmarks for navigation. Visibility of these terrain features depends on the amount of vegetation present; dense vegetation can mask terrain features and changes in elevation. Dense vegetation makes reconnaissance difficult and may mask thermal signatures. Airspeed may need to be reduced during these missions.

JUNGLE

4-142. Jungles are similar to heavily vegetated rolling terrain areas. The canopy obscures the view of most features lacking significant vertical development. Precise terrain interpretation is more difficult as the dense vegetation may also mask changes in elevation.

DESERT

4-143. The amount of vegetation varies greatly from substantial numbers of shrubs and trees to sparse, sandy wastelands. In sparsely vegetated, sandy deserts, the texture and color of the soil on the desert floor is normally very uniform. This can make it difficult to identify changes in terrain elevation or locate individual features, such as ridges, valleys, wadis, or ravines. The sandy soil provides optimum reflectivity of available ambient light and a useful background for identification of objects by contrast. Man-made objects in particular usually stand out well against their background. Vegetation that does exist aids terrain interpretation by providing good contrast with the soil.

4-144. Desert terrain can vary from relatively flat expanses of sand to mountains. The amount of detail available may change dramatically during a single mission. Gradually rising terrain may be quite difficult to detect, particularly in areas of lower contrast. Aircrews should exercise caution when transitioning to areas of lower contrast. Comparing MSL and AGL altitudes can assist crewmembers in identifying rising or descending terrain.

4-145. Aviators can encounter blowing dust or brownout in this environment requiring a practiced technique to overcome. Low-level winds can raise just enough dust to obscure the horizon without otherwise interfering with visibility. Lack of terrain features and reference points makes terrain flight navigation and concealment more difficult.

ARCTIC/SNOW

4-146. Visible vegetation and dark features provide good contrast. Similar to the desert environment, blowing snow can cause a "white-out" condition and high reflectivity may cause the NVG to gain down, reducing image clarity (figure 4-35). Terrain interpretation may be difficult due to drifting or deep snow that can hide key features, fill in valleys, or create hills. Unlike desert terrain, there are very few differences between various areas of snow, making it very difficult to distinguish terrain features. Landing to snow must be considered with great caution, as obstructions, holes or partially frozen bodies of water may be impossible to detect. The ability to judge height and determine the contour of terrain is difficult when it is covered with snow. The normal tendency is to estimate altitude as being higher than it actually is and misjudge slope angles. Check instruments frequently.

Figure 4-35. Snow conditions

OVERWATER

4-147. Poor contrast, minimal reference points, and a reduced sense of motion parallax make aviators operating overwater susceptible to a variety of visual misperceptions and spatial disorientation. Long flights overwater without a visible horizon should be avoided. A greater reliance on flight instruments and heads-up display systems is required to maintain spatial orientation and situational awareness. Before flying over water, check the barometric and radar altimeters for proper operation. Aviators should set the radar altimeter low altitude indicator to the minimum acceptable altitude. As an aviator crosses from land to overwater, the aircraft may appear to stop in mid-air due to the loss of visual references. As a result, there is a tendency to lower the nose of the aircraft and enter an unintended descent. Aircrew not on the controls should maintain a cross-check of the flight instruments and other indications of altitude to prevent inadvertently flying into the water. Trail aircraft should monitor and advise the flight if any aircraft appears to be descending below the briefed altitude.

4-148. Water is the most difficult surface over which to hover as there are almost no visual references (figure 4-36, page 4-32). Loss of the visible horizon has a significant impact on the ability to maintain aircraft orientation. Aviators display a tendency to drift in the direction of waves. If possible, the aircraft should be maneuvered near some object, such as a tree stump or buoy to provide a reference point. Remember that objects floating in the water may move unexpectedly.

Figure 4-36. Overwater

CULTURAL FEATURES

4-149. Common to all terrain types are several key cultural features. These can be critical to tactical or navigation tasks. Man-made objects can be equal to or better than natural features as navigation aids, particularly because navigation is primarily conducted through aircraft systems and may be more accurately plotted.

ROADS

4-150. A dirt road may provide excellent contrast between the surrounding terrain, vegetation, and its surface. Composition of the soil must be considered as it changes the degree of contrast the road provides in comparison to the surrounding terrain. In addition, roads cutting through heavily forested areas are easily identifiable if visible through foliage. A concrete road is generally more reflective than an asphalt road but may be more or less visible through NVG due to surrounding background reflectance. Freshly paved asphalt roads appear dark through NVG; however, roads reflect more IR energy as they age and wear. An asphalt road is usually difficult to identify as its dark surface reduces the contrast between it and the surrounding terrain. The exceptions are if the asphalt road is located in a desert or snow-covered environment or an area with open fields, which provides good contrast, making it easier to recognize. Although roads are not good CPs, certain features can serve as orientation cues or CPs. Roads normally make excellent barriers when associated with other CPs.

INTERSECTIONS

4-151. Intersections accurately plotted on maps can serve as orientation cues or CPs. The type of intersecting roads, road heading, and surrounding cues should be checked to ensure the correct intersection has been located.

BRIDGES

4-152. Bridges can be good CPs if they have vertical development. A bridge is also a good CP if its surface contrasts with the road surface or surrounding vegetation.

RAILROADS

4-153. Aviators can easily identify railroads; however, surrounding vegetation or terrain often hides them. The viewing angle is important for locating railroads. They make poor CPs and barriers unless they are in open fields.

BUILDINGS

4-154. Isolated, large, or light-colored buildings provide excellent contrast. Aviators should not use small, dark-colored buildings as orientation cues.

CEMETERIES

4-155. Western cemeteries have light-colored, polished headstones contrasting well against a natural background and often reflecting a considerable amount of light. Cemeteries in the Middle East, on the other hand, consist of small buildings that may be impossible to distinguish from the adjacent town.

SECTION V – OPERATIONAL CONSIDERATIONS

4-156. Operational considerations such as visual cues should be a factor at all stages of planning. The following considerations should be briefed during mission rehearsals to expand on situational awareness and mission contingencies.

DISTANCE ESTIMATION AND DEPTH PERCEPTION

4-157. Distance estimation and depth perception are closely related. Distance estimation relates to determining distance to objects, while depth perception primarily refers to the relationship of objects to each other. The quality of both is affected by ambient light, type and quality of NVG, degree of contrast in the field of view, and viewer's experience utilizing monocular cues. Objects tend to appear further away than they actually are.

Reduction in visual acuity negatively influences distance estimation, because we expect objects that are less distinct in detail to be farther than ones that possess sharp detail.

CUES

4-158. Both depth perception and distance estimation are visual processes that are usually automatic. The loss or degradation of these cues is not recognized unless they are demonstrated or a conscious effort is made to remain aware of these limitations. We utilize two types of cues: binocular and monocular.

Binocular

4-159. The binocular factors of convergence and stereopsis are involved with depth perception. Both of these systems are primarily used at distances less than 10 meters (30 feet). At greater distances, it is usually considered that the information provided by these systems is minimal, and the brain primarily relies on monocular cueing for distance and depth information.

4-160. Convergence is used to measure of the difference in the angle of the two eyes. The steeper the angle between the two eyes as they look at an object, the closer that object is to the viewer.

4-161. Stereopsis is caused by the difference in the images on the retina of the two eyes. The amount of overlap in the overall scene provides distance information to the observer. Convergence is the more significant factor of the two in judging the distance of near objects.

4-162. Binocular depth perception is primarily used when hovering or when flying at NOE altitudes. Depth perception using ANVIS is particularly degraded at short distances (10 meters or less). This results from the eye's fixed focus in the NVG (approximately 6 feet). This does not match the information by the other native short-range visual tools, convergence and stereopsis. Further confusion arises due to the fact that the image in the ANVIS is very blurred (the ANVIS being focused for 50 meters). The aviator's visual system cannot resolve the inconsistency in these inputs and is unable to determine the distance to the object in question. This becomes particularly apparent when hovering near the ground, taking off, and landing. Until the aviator develops other tools to assist in distance estimation and depth perception, the aviator's perception is degraded, particularly in determining hover height.

Monocular

4-163. Monocular cues are derived from experience and are subject to interpretation. Monocular cues can assist in identifying possible hazards to include man-made structures, associated terrain, and actual position of the ground in reference to present altitude and position. Although these monocular cues provide depth perception for all distances, they become more dominant as distance between the observer and the object in question increases. Anything that adversely impacts NVG resolution also impacts the perception of these cues. Therefore, as aircrew NVG visual acuity decreases due to lower illumination or lower contrast scenes, the cues are less discernible, resulting in poorer depth perception. The types of monocular cues include geometric perspective, retinal image size, aerial perspective, and motion parallax.

Geometric Perspective

4-164. An object appears to have a different shape when it is viewed at varying distances and from different angles. Geometric perspectives include linear perspective, apparent foreshortening, and vertical position in the field:

- Linear perspective (figure 4-37)-parallel lines such as railroad tracks appear to converge as distance from the observer increases.

Figure 4-37. Linear perspective

- Apparent foreshortening (figure 4-38)-the shape of an object or terrain feature appears distorted when viewed from a distance at both higher and lower altitudes. Round objects appear elliptical (oval and narrow), while square objects take the shape of a trapezoid. As the distance to the object or terrain feature decreases, the apparent perspective changes to its true shape or form. When flying at lower altitudes and at greater distances, crewmembers might not see objects clearly. If the mission permits, pilots should gain altitude and decrease distance from the viewing area to compensate for this perspective. Once altitude increases and distance between the aircraft and viewing area decreases, the viewing field widens and enlarges so objects become apparent.

Figure 4-38. Apparent foreshortening

- Vertical position in the field-objects or terrain features at greater distances from the observer appear higher in the field of view than those closer to the observer. When viewing a scene, a higher vehicle appears closer to the top and at a greater distance from the observer. Before flight, crewmembers should already be familiar with the actual sizes, heights, and altitudes of known objects or terrain features within and around the planned flight route. If situation and time permit, crewmembers can reference published information to verify actual sizes and heights of objects and terrain features within their flight path. In addition, crewmembers should cross-reference the aircraft altitude indicator to confirm actual aircraft altitude is adequate to safely negotiate the object or terrain feature without prematurely changing aircraft heading, altitude, or attitude.

CAUTION

Caution should be employed when using this cue with other aircraft, as the target's elevation must be taken into account.

Retinal Image Size

4-165. An image focused on the retina is perceived by the brain to be of a given size. The factors that aid in determining distance using the retinal image are—

- Known size of objects (figure 4-39)-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 image. An object projects an image on the retina based on its distance from the observer. If the image is small, the observer judges the object to be a great distance away, while a larger image indicates the object is close. To use this cue, the observer must know the object's actual size and have prior visual experience with it. If no experience exists, the observer determines the distance to an object primarily by motion parallax.

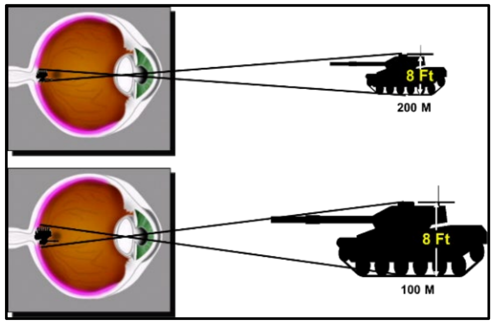

Figure 4-39. Known size of objects

- Increasing or decreasing size of objects-if the retinal image of an object increases in size, the object is moving closer to the observer. If the retinal image decreases, the object is moving further away. If the retinal image is constant, the object is at a fixed distance.
- Terrestrial association (figure 4-40)-comparison of one object such as an airfield with another object of known size such as a helicopter helps in determining the relative size and apparent distance of the object 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 airfield.

Figure 4-40. Terrestrial association

- Overlapping contours (figure 4-41, page 4-36)-an object partially concealed by another object is behind the object concealing it. Crewmembers must be especially conscious of this cue when making an approach for landing at night. Lights disappearing or flickering in the landing area should be treated as barriers and the flight path adjusted accordingly.

Figure 4-41. Overlapping contours

Aerial Perspective

4-166. An object's clarity and its shadow are perceived by the brain and cues for estimating distance. Crewmembers must use the following factors to determine distance with aerial perspective:

- Fading colors or shades (figure 4-42)-the colors of objects appear to fade with distance. However, an object viewed through haze, fog, or smoke can appear less distinct and at a greater distance than it actually is. Conversely, if atmospheric transmission of light is unrestricted, the object can appear more distinct and closer than it actually is.

Figure 4-42. Fading colors/shades

- Loss of detail or texture-sharpness and clarity of details or texture is lost or is less apparent with distance. For example, at a distance a cornfield appears to be a solid color, tree leaves and branches appear to be a solid mass, and objects appear to be at a great distance. When an aircraft is operating near the ground, crewmembers can see the grass or gravel immediately below, in front of, and alongside the aircraft. They can use these details to help them determine airspeed and altitude. If they maintain that view as the aircraft slowly ascends, the crewmembers notice the clarity and detail of the surface fades and eventually blends in with the terrain as a whole, making accurate determination of airspeed and altitude difficult or impossible. Again, environmental factors such as fog or dust may degrade apparent texture and increase the apparent distance to an object.
- Position of light source and direction of shadow (figure 4-43, page 4-37)-every object casts a shadow in the presence of a light source. The direction in which the shadow is cast depends on the position of the light source. If an object's shadow is cast toward an observer, the object is closer to the observer than the light source.

Figure 4-43. Position of light source

Motion Parallax

4-167. This is often considered the most important cue to depth perception. It is the primary visual cue used in hovering. Motion parallax is the apparent, relative motion of stationary objects as viewed by a moving observer (figure 4-44). When judging airspeed, near objects appear to move past or opposite the landscape. Far objects seem to move in the direction of motion or remain fixed. The rate of apparent movement depends on the distance the observer is from the object. Rapidly moving objects are judged to be near while slow moving objects are judged to be distant. When hovering at night, keeping a tree or similar object near the helicopter stationary in relation to another object greatly aids in keeping the helicopter steady. Remember that this does not detect movement toward or away from the two objects. This awareness must be maintained in at least two directions to detect helicopter movement.

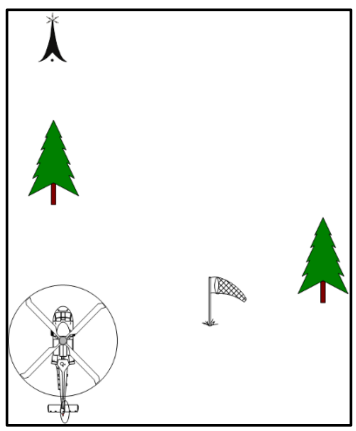

Figure 4-44. Motion parallax

Other Cues

4-168. Secondary cues should be utilized to facilitate primary scans. The effects of external sensory equipment failure could be extremely detrimental if secondary scans are not utilized by aircrews.

Optical Flow

4-169. Optical flow is referred to as the angular rate and direction of movement of objects because of aircraft movement. This provides the information necessary to interpret speed and direction of motion. If there is no relative motion, there is no optical flow. Normally, peripheral vision is used to detect optical flow; central vision is used to assess its speed. Since the NVG field of view is severely restricted, the optical flow cues will be severely degraded when compared to day flight and central vision tracking becomes the primary means of detection. This leads to one of the most insidious dangers when transitioning to terrain flight from higher altitudes. Because of the reduction in peripheral vision motion, the ensuing "speed rush" that would indicate close proximity to the ground is not available, resulting in reduced ability to judge airspeed and rate of climb or descent. This is why it is very important that aviators maintain an aggressive scan during NVG flight. During high cockpit workloads or periods of fatigue, scanning is one of the first tasks to be impacted. A dedicated effort must be made to avoid fixation and to maintain the scan necessary to provide this essential cue.

Unaided Peripheral Cueing

4-170. How much unaided (normal night vision) peripheral cueing is available and whether or not it is helpful in the NVD environment depends on many variables: illumination level, terrain type, and artificial light sources. Although aircrews are not completely dark adapted, they are partially dark-adapted and able to discern some features outside or around the NVG intensified image. For example, while flying over terrain where cultural lighting is generously scattered, the motion of these lights as they speed by can be detected in the periphery while looking into the NVD image. This adds to overall orientation (situational awareness) by feeding familiar information to the aircrew. When flying in canyons during periods of good illumination, features and motion may be detected in the periphery outside the NVG FOV. When peripheral cueing is added to both the NVG and FLIR image, a good marriage of sensor and real world imagery results in significantly enhanced spatial orientation.

Spatial Orientation/Disorientation

4-171. The greatest challenge for NVG operations is the impact of NVG on the aircrew's ability to correctly interpret the image presented. Visual cues provide the strongest input to overall spatial orientation and situational awareness. The visual system is functionally divided into two distinct systems: the central (focal) and peripheral (ambient) systems. Each of these visual systems is impacted by NVG use and is degraded as compared to daytime (photopic) performance. Daytime visual performance is the standard by which we compare NVD performance.

4-172. By virtue of NVD design limitations (for example, FOV, lack of color discrimination or visual acuity), operationally significant misperceptions and visual illusions can occur during NVD aided operations. The challenge for aircrew remains to develop the knowledge base and training necessary to understand and overcome NVD limitations and effectively use NVDs in flight.

4-173. Night unaided/aided flight increases the likelihood of experiencing visual illusions and spatial disorientation in comparison to the day environment. Degraded visual acuity, fatigue, high task loading, limited field of view, and inexperience are all contributing factors that must be anticipated during night unaided/aided flight. Other factors that can aggravate the tendency for spatial disorientation include extreme aircraft maneuvering and three axis head movements. Peripheral vision also helps reduce or eliminate the effect of middle ear disturbances (vestibular illusions). This is one reason spatial disorientation is more common at night.

4-174. Spatial disorientation can be induced or aggravated by the following:

- Aircraft bank greater than 30 degrees.
- Significant or abrupt aircraft maneuvers.
- Three axis head movements.
- Unfamiliar perception related to a lack of NVG experience.
- Degraded visual acuity.
- Fatigue.
- High task loading.

4-175. This is due in part to the fact that the peripheral visual system is heavily used as a backstop or sanity check for the vestibular and proprioceptive systems. As the amount and quality of information deteriorates, disturbances in these systems are more likely to produce disorientation.

4-176. The other major factor lies in the fact that the aviator's primary means of orientation is the horizon. The severely restricted field of view available to NVDs can limit or eliminate the visible horizon, particularly under degraded conditions. Increased reliance on aircraft instrumentation can be necessary to preventing disorientation. Use of HUD helps substantially. It may become necessary to change the flight profile, revise the mission timeline, or revise or abort the mission entirely as conditions deteriorate.

AIRSPEED AND GROUND SPEED LIMITATIONS

4-177. Aviators using NVDs tend to overfly their capability to see. To avoid obstacles, they must understand the relationship between the NVG's visual range, forward lighting capability, and airspeed. This is especially true when flying in a terrain flight mode.

4-178. Different light levels affect the distance at which objects are identified and limit the ground speed flown at terrain flight altitudes. Ground-speed guidance is not specified due to continuously changing variables such as type of aircraft, supplemental lighting, visual obscuration, and ambient light conditions. Aviators should reduce ground speed to allow enough reaction time for detection and obstacle avoidance, especially during low ambient light levels or when visibility is poor.

4-179. Object acquisition and identification are related to ambient light levels, visibility, and contrast between the object and its background. Light levels appropriate for training may need to be different from operational conditions to ensure safe operation and reduce risk. Variables affecting the ability to see with NVG include—

- Type, age, and condition of NVG.
- Cleanliness of aircraft windscreen or sensor window.
- Moisture content in the air (humidity).
- Individual and collective proficiency and capability.
- Weather conditions (fog, rain, low clouds, or dust) and amount of ambient light.

HAZARDS TO NIGHT FLIGHT

4-180. There are many hazards to night flight that must be considered by Army Aviation, such as lasers, nerve agents, aircraft lighting, and more.

LASERS

4-181. A lasers are used to produce an intense, narrow beam of light (figure 4-45). Normally each laser can only produce a single frequency or color of radiation. Military lasers generally produce light in the visible or the near-IR portion of the spectrum.

Figure 4-45. Laser beam

4-182. The eye is more vulnerable to laser damage at night as the iris of the eye opens more to accommodate lower levels of illumination (figure 4-46, page 4-40). Laser damage to the eyes may include flash blindness, retinal burns, and impaired night vision. The effect of flash blinding is similar to the temporary effect of a flashbulb and can last seconds to minutes, possibly leaving colored spots in the field of vision that are distracting and potentially dangerous. Minor retinal burns can cause discomfort and interfere with vision. The injuries may involve internal bleeding in the eye, immediate pain, and possible impaired or permanent loss of vision. Night vision acuity may be lost due to undetected damage. Fovea damage may affect vision sharpness and color interpretation. Normal cockpit tasks, obstacle avoidance, and use of acquisition or targeting devices may become difficult or impossible. Aviation unit training must emphasize aircrew use of the aviator's helmet laser visor when performing missions in an anticipated or known laser environment. To reduce chances of laser injury, aviation support personnel must be trained to wear laser protective spectacles when performing aviation ground support functions.

Figure 4-46. Laser damage

Classes of Laser

4-183. There are five classes of lasers in use today. Lasers are categorized according to the power in the laser beam. All lasers are treated with the same degree of caution as if firing tracers from a rifle. It is possible to cause permanent injury, especially with IR lasers.

Nominal Ocular Hazard Distance

4-184. All lasers have an associated nominal ocular hazard distance (NOHD). This is the minimum distance from a laser exit port at which a laser is considered to be eye-safe. This only means that the person's eye is not permanently damaged; it does not mean that the laser will not impact their ability to see and function at night. Treat lasers as loaded weapons, and never point them at friendly or neutral targets.

Lasers and Night Vision Goggles

4-185. Laser light causes damage by impacting directly on body tissues, such as skin or the retina. Laser light travels directly through optical devices such as binoculars to the retina. NVG generally convert light energy into electrical energy, amplify the electrical energy, and then turn it back into light energy. This means that, while laser energy probably damages the NVG, it does not pass through the NVG to damage the operator's eyes. The laser may still cause damage to other areas, such as the skin around the eyes.

Protective Measures

4-186. Lasers can damage eyes from a considerable distance, although a beam's energy level decreases as its diameter widens with increasing distance. Therefore, distance is the best protection against lasers. Protective ballistic and laser protective eyewear goggles or visors also offer limited protection (figure 4-47). FM 8-50 contains more extensive information.

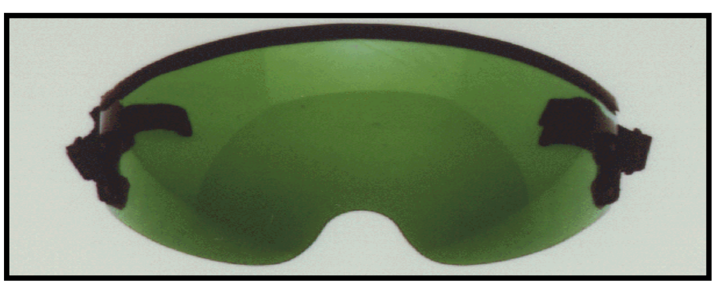

Figure 4-47. Protective measures

NERVE AGENTS

> ***Note.*** Many insecticides are nerve agents.

4-187. Nerve agent hazards are always a possibility and can be present during night operations. The survivability of your crew may depend on how quickly you identify the physiological effects of nerve agents.

4-188. Minute amount of nerve agents may cause miosis, constriction of the pupils (figure 4-48). Pupils do not dilate (enlarge) in low ambient light as they would normally. The aviator would notice a significant increase in the time it takes to dark adapt, or may not be able to dark adapt at all. The intensity of these effects and speed of recovery depends on the agent concentration and the cumulative effects of repeated exposure. Severe miosis may persist for 48 hours or longer after onset of exposure. Complete recovery may take up to 20 days or longer. Chemical alarms may not detect presence of nerve agents. The incident must be reported to the chain of command and medical treatment sought ***IMMEDIATELY***.

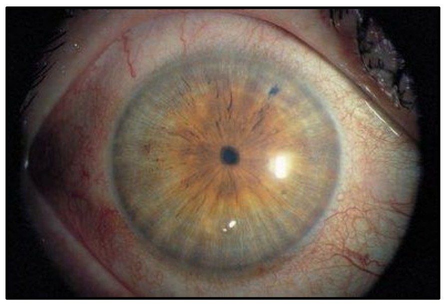

Figure 4-48. Misosis

4-189. Nerve agents need not be military; insecticides and other household chemicals also fall into this category.

AIRCREW COORDINATION

4-190. Aircrew coordination is especially important at night. Aviators frequently do not allow enough time to clear aircraft movements and tend to assume the other crew members see obstacles or other hazards.

4-191. Clear and deliberate coordination between crewmembers is necessary for aircrew members to perform flight tasks efficiently, effectively, and safely.

PREFLIGHT INSPECTION

4-192. Aircraft preflight inspection is a critical aspect of mission safety. It must comply with the appropriate aircraft operator's manual. Preflight should be scheduled as early as possible in the mission planning sequence, preferably during daylight hours, allowing time for maintenance assistance and correction.

4-193. If a night preflight is necessary, a flashlight with an unfiltered lens should be used to supplement lighting. Comprehensive preflight checks are more important than dark adaptation, particularly when using NVG.

4-194. Oil and hydraulic fluid levels and leaks are difficult to detect with blue-green or red lens. Windscreens must be checked ensuring they are clean and relatively free of scratches. Slight scratches that are acceptable for day flight may not be acceptable for night flight. The searchlight or landing light should be positioned for the best possible illumination during an emergency descent. Above all, the preflight should not be rushed. Even large problems may go unnoticed in marginal lighting conditions, even when supplemented with an unfiltered flashlight.

Aircraft Lighting

4-195. Aircraft lighting configuration is standardized in AR 95-1, the relevant aircrew training manual, the aircraft operator's manual, and the unit SOP. AR 95-1 provides that the PC of the aircraft can adjust lighting as necessary when the safety of the aircraft is in question.

Cockpit Lighting

4-196. Cockpit illumination should be kept illuminated at the lowest level consistent with safe operation of the aircraft. This does not mean 'as dim as possible.' As ambient level decreases from twilight to darkness, intensity of the cockpit lights is continually reduced to a low, usable intensity level reducing any glare or reflection off the windscreen. This means that cockpit instruments should be instantly and easily readable. The delay required for aviators to adapt their vision to cockpit illumination levels that are too low can result in unacceptable loss of situational awareness, particularly at NOE altitudes. Crewmembers should be discreet in the use of supplemental lights to avoid detection by enemy forces.

Anti-Collision Lights

4-197. In formation flight, anti-collision lights are normally turned off with the exception of trail aircraft. Operation of anti-collision lights can be a major distraction to succeeding aircraft within the flight and may hamper safe operation. Anti-collision lights are used according to AR 95-1, Federal Aviation Administration (FAA) directives, host country/theater directives, and appropriate SOP guidance.

Landing Light or Searchlight

4-198. The landing light must be used with discretion and due consideration for other aircraft and safety.

4-199. During tactical operations, the landing light is only used to prevent a hazardous situation from developing, with due consideration of enemy threat. The unfiltered landing light can be used with NVG under emergency/administrative conditions, but aircrews must direct their scan and the light to prevent dimming the NVG and reducing their effectiveness.

4-200. Use of landing lights or searchlights is determined by factors such as crewmember experience and ambient light conditions (figure 4-49). Aviators who constantly rely on it might not develop techniques to fly without it; however, a crew striving to never use it may put the aircraft at risk. The use of the landing light may reduce the ability to see under certain atmospheric conditions such as fog or blowing snow. Each situation must be evaluated separately.

Figure 4-49. Landing light/searchlight

4-201. The use of IR searchlight/landing light during NVG aided missions is at the discretion of the aircraft or flight lead pilot in command. For all NVG operations, aircraft are required to have an operational searchlight, preferably with an IR filter installed. Benefits or limitations of the IR searchlight are dependent on ambient illumination, reflectivity of the terrain, and the positioning of the output beam. As ambient illumination decreases, the "flashlight" effect from the IR spotlight on the NVG becomes more evident. The area illuminated by the beam of the light is brighter and the area outside of the beam appears darker on the NVG. Terrain albedo, or reflectivity, affects the benefits of the IR light. Different types of terrain will absorb or reflect IR light to varying degrees. Some terrain such as sand or snow may even reflect too much light and create a "washed out" NVG intensified image. Terrain consisting of plowed fields or asphalt may absorb the IR light and appear either dimly lit or dark with no contrast on the NVG.

4-202. The position of the light beam also affects what is perceived through the NVG. Actual positioning of light is dependent on individual preference. However, positioning light so that its beam is pointed straight down has proven effective for identifying objects in the landing zone (watch out for the crater effect illusion). Another consideration when flying with multiple aircraft is to have the last aircraft use their IR light in the landing phase to "back-light" the LZ for the flight; however, this procedure does have its drawbacks. The preceding aircrews, which are responsible for clearing their respective aircraft into the landing zone, may have their NVG shut down by the introduction of the IR light (incompatible light source). When flying in built-up areas (MOUT, runway/airfield environment) with increased cultural lighting, IR light to offset the NVG "washout" should be considered. Utilizing the light or landing light to "burn through" the excessive illumination created by the cultural lighting, thereby allowing aircrews a better representation of the surrounding terrain, can accomplish this.

4-203. The other major concern with use of the NVG light is the tunneling effect it has on aircrew members' perception. Aircrew members tend to focus on the illuminated area, to the exclusion of the areas around it. Utilization of the searchlight should be based on METT-TC. The light can be seen from a much greater distance than it aids vision, and the increasing availability of basic IR sensors in the world may make this technique tactically unsound, except for short, limited periods.

POSITION LIGHTS

4-204. Inappropriate use of position and navigation lights can degrade night vision and increase the possibility of detection by an existing threat. Aircraft in formation flight can be distracted by position and navigation lights, thereby hampering safe operation. During formation flight, with the exception of trail aircraft, position, or navigation lights should be dimmed or turned off according to AR 95-1, FAA directives, host nation/theater directives, and appropriate SOP guidance. Use of IR lighting should be maximized in a tactical environment.

4-205. Army RW aircraft currently possess incandescent (heat generated), light emitting diode (LED), or electroluminescent (slime) aircraft exterior lighting. While on their normal setting, incandescent navigation/position lights typically trigger the NVG's automatic brightness control circuitry. This causes NVG halo, blooming, and shutdown effects. The result is that the aircrew are able to see the aircraft lights, but may not see the aircraft or anything else surrounding the aircraft. This can result in errors in distance estimation.

4-206. NVG visual cues may be impacted by NVG image differences between port and starboard navigation lights. For example, an unobstructed red position light can be seen at greater range than the green position light. Therefore, the aircraft can be detected further away at different times due to the aspect-induced appearance or disappearance of the various position lights (particularly the port side). The same is true for other external lights. The problem is compounded when operating in close proximity to other aircraft (for example, formation or during a rendezvous). It is also impossible to distinguish the red from the green position lights, which may make it difficult to determine if an aircraft is approaching or departing. Aircrew members should be aware of these potential visual cue misperceptions and continually cross-check NVG viewing with unaided vision.

SUPPLEMENTAL COCKPIT LIGHTING

4-207. Supplemental cockpit lighting is any light device not part of the aircraft lighting system. Examples include finger lights, lip lights, flashlights, and chemical light sticks (figure 4-50, page 4-44). Light sources must be compatible with NVG and checked according to current directives for compatibility with NVG.

Figure 4-50. Supplemental cockpit lighting

4-208. Light discipline is essential. NVG friendly lighting is, by definition, visible to NVG. Overhead lighting that does not gain down the NVG is still visible to an observer outside the aircraft. Finger lights and lip lights decrease the lighting signature of the aircraft while freeing the aircrew's hands to perform their duties. This does not, however, eliminate the need for caution. Lip lights can be seen at tactically significant ranges using NVG. In this case, an aircrew that has taken great pains to remain undetected could be compromising their position themselves merely through improper use of a lip light.

COCKPIT NIGHT VISION GOGGLE COMPATIBILITY

4-209. A bright light that leads to an obvious degradation in visual acuity is apparent to all aircrew members regardless of NVG experience. The real problem occurs when there are subtle degradations in visual acuity that may not be readily apparent to the aircrew. In these cases, important details may be missed. Additionally, an incompatible light does not have to be within the NVG FOV for it to have an effect on NVG gain. Aircrew should also keep in mind that incompatible cockpit lighting cannot be turned down enough to make it compatible. If the lights can be seen with the unaided eye, they will affect the NVG. Thus, the danger of attempting to turn down incompatible cockpit lights to make them compatible is double edged: first, they continue to degrade NVG performance; second, when turned down to a very low intensity, vital materials (maps, pilot packs) may not be readable. Just because a light is green or blue does not mean it is NVG compatible. A light is "NVG compatible" only if it is visible to the unaided eye but does not interfere with the NVG. Light sources which are visible to both the eye and NVG, yet do not bloom or gain the NVG down significantly are described as "NVG friendly." The blue filter that comes with the aircrew gooseneck flashlight, and the green filter that comes with the mini-Maglite are examples of green or blue lights that are not NVG compatible.

COMPATIBILITY CHECK

4-210. The only method to determine whether a light is NVG compatible is the supplemental cockpit lighting compatibility check. The check must be conducted at night, in an aircraft located in an area of low ambient light, such as an LZ, with interior lighting set for NVG operations, and with ANVIS prepared for use. The general procedure to conduct a light degradation check is as follows:

- Position a reflective material (map sheet, note card, vinyl checklist) approximately 12 to 18 inches from the eyes.
- Shine the supplemental light onto the material.
- With the unaided eye, look at the resultant reflection cast on the windscreen. Observe this same reflection through the ANVIS. An acceptable supplemental light source does not interfere with the operator's ability to see outside the aircraft using NVG. The reflection of the light source in the windscreen may even disappear. If the reflection, glare, or stray light interferes with the ANVIS aided vision of any crewmember the light source is unacceptable.

FATIGUE

4-211. Fatigue has always been a factor in night operations. NVG aided missions can be extremely demanding with the potential for inducing acute, cumulative and circadian fatigue. Fatigue can be overcome, but only at the expense of increased physiological and psychological effort from the aircrew. This increased effort may add to the problem and lead to the feeling of being "burned out." Of greater concern is the reduction in performance caused by fatigue. Because of the potential impact on night aided operations mission accomplishment, fatigue is discussed in detail. Fatigue has always been a problem in aviation; however, night operations introduce additional stress and physical limitations that make fatigue an even more insidious threat. Many things can cause fatigue, such as excessive flying, self-regulated crash diets, missed meals, task saturation, hypoglycemia, and recent illness or sleep loss. Flying with improperly focused NVG causes or exacerbates fatigue. There are three types of fatigue: acute fatigue, cumulative fatigue, and circadian fatigue.

ACUTE FATIGUE

4-212. Acute fatigue is intense exhaustion felt because of the natural build-up of muscular metabolic wastes. This can be the result of intense physical exertion, a demanding flight or a long workday. Acute fatigue is short-term, is characterized by a feeling of being "worn out," and is usually relieved by a single night's rest.

CUMULATIVE (CHRONIC) FATIGUE

4-213. Cumulative fatigue is less intense than acute fatigue and is characterized as an accumulation of fatigue over time, usually days or even weeks. This can be the result of extended workweeks with little time off or failing to obtain adequate sleep (short duration or poor quality). Cumulative fatigue is associated with a feeling of being "burned out." It takes the body longer than one night's rest to recover normal energy levels. Studies indicate that cumulative fatigue results in an exponential increase in performance errors. For the night systems aviator, cumulative fatigue means that the second night of a cycle can be more tiring than the first and by the end of the cycle fatigue can be very obvious. A single night's sleep is not adequate to overcome the effects of prolonged inadequate rest. Recovery from five days of inadequate sleep can take two weeks or more.

CIRCADIAN FATIGUE

4-214. The human body and its physiological functions are strongly controlled by a biological clock. This "biological clock" or circadian rhythm describes the approximate 24-hour cycle or rhythm that drives many physiological body functions that are highly correlated with numerous human performance parameters. Circadian rhythm problems associated with night operations were experienced by German Luftwaffe night fighter pilots in WWII and again by night fliers in Vietnam. As so often happens, the importance of information derived from experience is lost when the world returns to a more normal state. The far-reaching effects of the night mission on many aviation communities has brought back the hard reality of dealing with performance over extended periods of night operations.

4-215. A great deal of research has been conducted on circadian rhythms in connection with the space program. At least 50 different bodily functions such as body temperature, hormonal levels, and performance have been directly related to the circadian rhythm. Research indicates that circadian rhythms are tailored to each individual and are entrained, that is dragged along or activated, by as many as 40 different environmental factors. These factors include the dark-light cycle and to a surprisingly strong degree, normal social interaction, especially meal times. The daily events that affect and help to trigger circadian rhythms are referred to as "zeitgebers" (time givers). It is as though the human body is an imprecise watch that needs constant resetting by the zeitgebers. It appears that the body is designed to run longer than the typical 24-hour day because studies and experience show that when isolated from normal environmental cues, individuals usually function on at least a 25-hour cycle. The shifting of daily sleep/work schedules may induce circadian fatigue (circadian disruption or desynchronosis) and is associated with the body's underlying natural performance lows and related phase shift problems.

4-216. Shifting into a night training period causes circadian disruption. Add to this the layering effect of cumulative fatigue over time and it is clear that aircrew must understand how to deal with fatigue. The cumulative effect of fatigue means that the second night of a training period can be more tiring than the first night and as the training period progresses the effects can become significant. The effects of cumulative fatigue and circadian disruption magnify the effects of normal acute fatigue. One factor associated with circadian disruption is disturbance of the sleep cycle. Because of their impact on the night systems mission, sleep and circadian disruption are discussed in detail. Two components of circadian disruption are the physiological nadir and desynchronosis.

4-217. Physiological Nadir. Physiological nadir results from the reality that humans are daytime creatures. Studies indicate that for most individuals, physical and mental performance are at their lowest levels between 0300 through 0600. This places the body's natural performance cycle out of synch with night missions.

4-218. Desynchronosis usually occurs because the body's internal rhythm becomes out of phase with the normal routine when shifting to a new work schedule. This is a problem that is encountered in rapid travel, where it is referred to as "jet lag." The body can physically readjust to crossing time zones at the rate of about 1 to 1.5 hours per 24-hour period. Since the natural body cycle is set for a longer day, it is normally easier to adjust to a new time schedule when traveling from east to west than vice versa. Aircrew starting a night training period will experience similar problems. However, readjustment to this type of shift is more difficult because the activity pattern is out of synch with both circadian rhythms and the daily physiological processes that work to reset these rhythms. Studies and experience have demonstrated that it can take many up to two weeks to readjust to changes in sleep/work cycles. The degree of adjustment to desynchronosis varies greatly among individuals. Some people adjust readily while some never can fully adjust, but everybody is affected to some extent. Some of the factors that affect adjustment to desynchronosis are personality, age, motivation, sleep quantity and quality, amount of physical exertion, and the extent of the desynchronosis. Some aircrew may never fully adjust during a normal night training cycle. This process also shifts the time of day for the physiological nadir.

EFFECTS OF FATIGUE

4-219. Fatigue, especially cumulative fatigue associated with circadian disruption and sleep deprivation, poses a serious threat to night mission accomplishment. Studies indicate that individual performance degrades anytime the circadian rhythm is disrupted. Many manufacturers recognize this and slow the assembly line during the second half of the late shift to compensate for reduced performance. The accidents at Three Mile Island, Chernobyl, and Bopal all occurred during the "graveyard shift." In many ways, fatigue is very similar to hypoxia. It subtly erodes performance, is difficult to recognize, and fosters an unwillingness to do anything about it.

4-220. **Complacency.** Complacency allows for acceptance of situations that would normally not be permitted, especially in the context of a night mission. Attention span and vigilance are reduced, important elements in a task series are overlooked, and scanning patterns that are essential for situational awareness break down (usually due to fixation on a single instrument, object, or task). Critical but routine tasks are often skipped because fatigue reduces overall willingness to respond.

4-221. **Computational.** Computational skills become degraded. The most difficult tasks for a fatigued aviator are those that require complex, swift decisions or planning. Fatigue typically results in errors caused by omission of a task as opposed to performing a task incorrectly. Uninteresting or complex tasks are more seriously affected by fatigue than interesting or simple tasks. The error rate increases exponentially with fatigue.

4-222. **Communications.** Either neglecting to make appropriate calls or not responding to calls affects communications, CRM and mission accomplishment. This is because short-term memory is seriously affected. Communications from a fatigued aviator often trail-off and there are a lot of "uhs." There is a tendency to inaccurately restructure conversations and the individual tends to hear what they expect to hear as opposed to what is actually transmitted.

4-223. **Irrational Decisions.** The ability to assimilate information and form a rational solution is significantly degraded when fatigued. The decisions made may be different than what a well-rested aviator would make in the same situation. The desire to initiate action decreases with fatigue, including interactions with other people. This can lead to overreaction to events as well as flawed reactions.

4-224. **Irritability.** Fatigue makes people more irritable and less tolerant of others. This can significantly degrade crew communication and coordination, both of which are critical for successful night systems mission accomplishment.

SLEEP

4-225. The biological function of sleep is not completely understood. The sleep cycle affects many bodily functions that are timed throughout the day. If sleep schedules are disrupted, the cycles of body temperature and performance are also disrupted. Interestingly, there is no chemical or physiological difference between tired and rested aircrew that are on the same cycle. The brain appears to be the real driving force for the need to sleep and the subsequent source of sleep deprivation effects. Boredom can induce sleep in the same manner that motivation can delay the effects of fatigue or sleep. Sleep is not passive unconsciousness, but also a very intense physical activity of great complexity. The quality of sleep is very important. An average person spends about 40 percent of their sleep in the rapid eye movement (REM) stage. This stage has long been thought to be the essential portion of sleep, and without it, fatigue would quickly result. When this phase is interrupted, the positive effect of sleep is significantly reduced.

4-226. Shifting to a night routine can cause problems over time. The individual may be able to satisfy sleep requirements with less sleep and maintain good efficiency by napping for short periods; however, eventually, the sleep account will be overdrawn and the balance will have to be restored.

RECOMMENDATIONS

4-227. The following are recommendations to help circumvent the adverse effects of possible night flight hazards.

RAMPING

4-228. Try to use an adaptation schedule to ease aircrew into late recoveries. As a rule of thumb, shift 1.5 hours per night (such as Monday night, 2100; Tuesday night, 2230; or Wednesday night, 0000). This reduces the effect of circadian disruption. Stabilize the flight schedule so that aircrew can anticipate their schedule. More experienced aircrews should be assigned to the later flights. When feasible, have all aircraft on the ramp by 0230 hours. This is to avoid the fatigue and performance degradation associated with the 0300 through 0600 physiological nadir. This is more difficult during the summer schedule due to limited night flight time; however, every effort should be made to allow aircrew to get to bed before sunrise. This is because sunlight causes hormonal changes in the body and resets some biological clocks. When feasible, schedule long weekends for aircrew coming off extended night training periods.

MANAGE THE ENVIRONMENT

4-229. The flight environment cannot generally be changed to any great extent, but commanders can manage their assets intelligently to minimize the impact of distracters and administrative problems on aircrews. Flexibility and creative thinking are required to find ways to protect aircrews from unnecessary stress.

PROTECTED SLEEP AREAS

4-230. Daytime sleep is not as sound as nighttime sleep, particularly in field environments, in which normal daytime activity and noise from aircraft maintenance interfere with the quantity or quality of crew rest. Crewmembers should be encouraged to do what they can to deal with these environments, such as the use of earplugs, sleep masks, or other aids.

LIMIT DUTY DAY SHIFTS

4-231. Commanders should minimize duty day adjustments by air crewmembers to limit circadian disturbance, as discussed above. It is also important for aviators to avoid returning to normal day activity during days off within prolonged duty day shift periods.

CREW ENDURANCE POLICY

4-232. Enforce a maximum workday for aircrew on a night operations schedule, including flying and non-flying duties. This is because cumulative fatigue magnifies the effects of acute fatigue. Long workdays may not be a problem for a few days, but eventually catches up with aircrew. Allowing for twelve hours of off-duty time after aircrews leave the unit (not after landing) has been shown to be very effective and is usually workable. There is a definite wind-down time involved with night missions. It normally takes 3 hours before most aircrew can sleep after a rigorous night aided mission. Commanders must design and establish a crew endurance program tailored to their unit's mission, and include it in the unit's SOP. When scheduling night terrain flights, it is recommended commanders limit aircrew work load to night flights only, with minimal additional duties. Because night terrain flight is more fatiguing than day flight, adequate facilities must be available so crewmembers are given ample opportunity to rest. Commanders must avoid pressuring pilots to exceed duty day requirements or routinely extend missions beyond crewmember duty day limits.

SLOW DOWN

4-233. The night flying environment is challenging. Aviators must be willing to adjust airspeed to match flight conditions. Maneuvering must be more conservative at night due to reduced visibility. Ability to identify obstacles and clear turns is degraded, demanding lower airspeeds and shallower turns. Reactions to direct engagements must be adjusted accordingly. Unit training should emphasize this. Mission planning and SOP must take these factors into account.

OPERATING TEMPO OF SUPPORTED UNIT

4-234. Ground units do not have the same requirements and restrictions that aircrews have. They tend to demand missions, timelines and speeds in excess of the ability of aviation units to provide. It is important that aviators not allow themselves to assume the OPTEMPO of the units they are supporting.

PHYSICAL FITNESS

4-235. Good physical conditioning is important to ensure adequate sleep, but due to possible acute fatigue and dehydration, aircrew should not conduct a strenuous workout on the day of a night systems flight.

COMPLACENCY AND OVERCONFIDENCE

Note. NVDs ***DO NOT*** turn night into day.

4-236. There is a significant tendency with NVDs to outfly the ability to see. It is also common to miss subtle indications in the visible image that indicate a gradual reduction in the light level, leading to the aviator's misconception that the aviator can see more clearly than the light level actually permits.

4-237. As indicated previously, lack of color information and the challenges associated with LED lighting require aviators to frequently cross-check NVD information with other systems, such as aircraft instruments, ANVIS, thermal sensors or the unaided eye. Unwillingness or laxity in performing these cross-checks can lead to significant gaps in situational awareness.

4-238. When transitioning from low illumination conditions to high illumination conditions, there is a natural tendency to be overly comfortable. Another potential area of complacency/overconfidence is returning to day flights after a night training period. Because of the significant increase in visual information and the efficient scan developed, there is a tendency to be overly comfortable at terrain flight altitudes. While there is an increase in skill level, the complacent mindset could be a setup for a mishap.

SECTION VI – NIGHT FLIGHT TECHNIQUES

4-239. Most aircraft training manuals include techniques for night flight with flight related tasks. Visual cues diminish significantly under limited ambient light. The following techniques may be used to supplement those tasks.

SCANNING TECHNIQUES

4-240. The following scanning techniques aid aviators regarding specific phases of flight. The intent of the following techniques is aid aircrews in combining multiple cues for spatial orientation.

HOVER

4-241. It is impossible to overstate the importance of scanning during night flight, whether unaided or using NVG. With peripheral vision reduced or eliminated, it can be very difficult to detect aircraft drift.

4-242. During night flight, aviators use motion parallax to detect drift. Pick an object to the front of the aircraft that is relatively close. This can be a bush, a tree branch of an unusual shape, or some other easily identifiable