UNITED STATES MARINE CORPS
MARINE AVIATION WEAPONS AND TACTICS SQUADRON ONE

MAWTS-1 Helicopter Night Vision Device (NVD) Manual: 5th Edition

27 OCTOBER 1998

A REFERENCE GUIDE FOR THE FLEET MARINE FORCE (FMF) ASSAULT SUPPORT NIGHT WARFIGHTER

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Preface

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To: Distribution List

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1. This manual is published as a reference guide to assist commanding officers and aircrew operators with the challenges associated with planning, briefing and executing Assault Support Night Vision Device (NVD) aided missions. The intent of this manual is to provide a single source reference for squadron night warfighters. The scope of the manual encompasses the many interrelated topics that are considered fundamental to NVD training effectiveness and ultimately, NVD aided operational mission success. Background information on the night environment is provided to identify the fundamental factors that need to be considered during the planning process in order to effectively optimize both Night Vision Goggle (NVG) image intensification based systems and Forward Looking Infrared (FLIR) thermal imaging based systems. In addition, an in-depth technical description of the AN/AVS-6 is provided to highlight the performance differences between the varying Omnibus contract image intensifier tubes. Information is also provided to assist aircrew with the preflight optimization of the AN/AVS-6 and to highlight the factors critical for NVG aircraft compatibility. The final chapters of this manual outline NVG operations, tactics and safety considerations. This manual attempts to present information at both the introductory and advanced levels in order to serve the broad range of experience that exists in the Fleet Marine Force (FMF).

2. Fleet change recommendations for the information or procedures presented in this manual are highly encouraged. Questions, comments and change recommendations can be forwarded to either the MAWTS-1 Aeromedical Safety Officer (AMSO) at DSN: 951-3652 or to the appropriate MAWTS-1 Assault Support Department Head or specific Aircraft Division Head (DSN: 951-2195/3469/2133/ 3361/2132).

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FOREWORD

This fifth edition of the Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) Helicopter Night Vision Device (NVD) Manual represents a major revision in manual format. A dedicated effort was made to update and upgrade all figures and tables used in the manual, as well as to provide an enhanced appearance to the manual. In addition, the content of this manual has changed significantly since the last edition. All content changes that have been added to the previous MAWTS-1 Helicopter NVD Manual: 4th Edition (October 1995) have been marked with column bars for ease of identification. A synopsis of major changes is provided below.

Chapter 1. This chapter remains unchanged with the exception of information concerning the new light level planning calendar, referred to as the Solar/Lunar Almanac Program (SLAP) that is currently under development by the Naval Oceanographic Office.

Chapter 2. This chapter has undergone major reorganization that has included enhancing the illustrations and adding a detailed description of the performance differences found between the difference AN/AVS-6 Omnibus contract image intensifier tubes. In addition, the AN/AVS-7 HUD section was rewritten to include more detailed illustrations of the equipment and information on the CH-53 AN/AVS-7 flight symbology set. Information was also provided to on the parachutist's goggles that are used under the AN/AVS-6 in dusty environments to provide adjunctive eye protection.

Chapter 3. This chapter remains relatively unchanged with the following exceptions. An Assault Support Night Vision Device (NVD) field of view (FOV) summary table was added to compare and contrast current USMC NVDs. Information on the developmental Panoramic Night Vision Goggle (PNVG) was provided to highlight current developmental efforts aimed at improving NVG FOV. A new illustration was provided that compares the sensitivity of the human eye with the different AN/AVS-6 phosphor screen spectral outputs (P22 and P43). Finally, information was added on the HGU-84/P and the HGU-67/P.

Chapter 4. This chapter remains unchanged.

Chapter 5. This chapter has been completely rewritten. This chapter now serves as the single reference source for AN/AVS-6 NVG adjustment and assessment procedures. New information is presented on the HGU-84/P and HGU-67/P V-1B Quick Don Block Mount. Adjustment procedures are provided for both the single interpupillary distance (IPD) Position Adjustment Shelf (PAS) and the Omnibus-III and IV dual IPD PAS. AN/AVS-6 adjustment procedures that were presented in Appendix A in the previous edition were integrated into this chapter.

Chapter 6. This chapter was rewritten to include a more in-depth discussion on NVG lighting specifications and NVG external lighting. In addition, the current USMC Training and Readiness Manual External Lighting Rules policy was overviewed.

Chapter 7. This chapter remains relatively unchanged with the exception of modifications to some of the NVG aided tactical formation positions and a modification to the NVG External Operations landing zone lighting template.

Chapter 8. This chapter remains relatively unchanged.

Chapter 9. This chapter remains unchanged.

Appendix A. This appendix has been completely rewritten and is to be used to support the AN/AVS-6 Adjustment and Assessment Procedures presented in Chapter 5. This appendix specifically provides set-up and operating procedures for the squadron NVG eye lane, the ANV-20/20 NVD Infinity Focus Device and the TS-4348 Test Set.

Appendix B. This appendix remains relatively unchanged.

Appendix C. This appendix remains relatively unchanged.

Appendix D. This appendix was reorganized from the Glossary of the previous edition. The contents remain relatively unchanged.

One of the purposes of the manual is to provide updated information between Tactical Manual (TACMAN) revisions for specific helicopter communities. As the TACMANs proceed through their periodic updates, the information presented in this manual will be incorporated into them.

Due to the rapid growth of both technology and operational experience with NVDs, this manual must be continually scrutinized and revised to remain relevant. The information in this manual is consistent with current Marine Corps policies and directives in effect at the date of publication. This manual is to be used for reference only and does not constitute authority to deviate from any USMC, FMF or local policies or directives. Although written at MAWTS-1, the foundation of information has been developed through operational experience obtained in the FMF. This manual should be used as a reference guide for individual aircrew in order to build their professional knowledge base in the area of NVD aided flight. Any recommendations or changes should be forwarded to the MAWTS-1 Helicopter Night Vision Device Manual Editor:

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Only your input will ensure that this manual continues to serve the needs of the FMF.

LCDR Bill Schutt
MAWTS-1 Aeromedical Safety Officer (AMSO)
MAWTS-1 Helicopter Night Vision Device Manual: 5th ED Editor

Chapter 1

The Night Environment

I. Introduction

Night vision goggle (NVG) and forward looking infrared (FLIR) systems operate in the optical radiation portion of the electromagnetic spectrum (Figure 1-1, Table 1-1). The majority of the spectrum used by NVDs is outside the spectral range of the human eye and has its own unique physical properties. It is critical that these physical properties and the environmental factors that influence NVD performance be properly recognized and ultimately integrated into the night operations planning process. The lack of understanding of the night environment and its impact on NVD performance can potentially result in an unsuccessful mission or even be responsible for an NVG related mishap. In the past, several NVG related mishaps have occurred that have demonstrated a lack of aircrew knowledge regarding the fundamental capabilities and limitations of NVDs. Although there is no device or combination of devices that will turn night into day, a thorough understanding of the influence of the night environment and its impact on NVD performance will enable us to expand our night operations envelope. This chapter will address how the night environment influences NVG (AN/AVS-6) and FLIR performance. It is intended to serve as a bridge between describing the hardware and how it works with the environment in which it operates. This will provide a lead in to sensor image interpretation and mission planning considerations that will be discussed in later chapters.

II. Electromagnetic (EM) Spectrum

In order to understand the impact of the night environment on NVD performance, aircrew must understand the energy available in the night sky and its relationship to the eye and electro-optical systems such as NVGs (AN/AVS-6) and FLIR. NVDs allow us to exploit a greater portion of the EM spectrum as compared to the human eye (Figure 1-1). Many different types of radiation such as light, heat and radio waves are present in everyday life. Just as a radio must be tuned to receive specific frequencies, NVDs and the human eye possess selective sensitivity to different wavelength or frequency ranges on the EM spectrum. These wavelength or frequency bands are inherently similar in nature, therefore can best be related or described by their position on the EM spectrum, shown in Table 1-1 and Figure 1-2. The optical band covered by visible light is a relatively small portion of the entire EM spectrum. All these EM energy sources obey the same laws of physics (i.e., reflection, refraction, diffraction, polarization, etc.) and travel at the same velocity of propagation. They differ from one another only in their frequency or wavelength. Visible light and near Infrared (IR) energy are considered to possess reflected energy characteristics, whereas the EM bands of the mid and far IR possess primarily radiated energy characteristic.

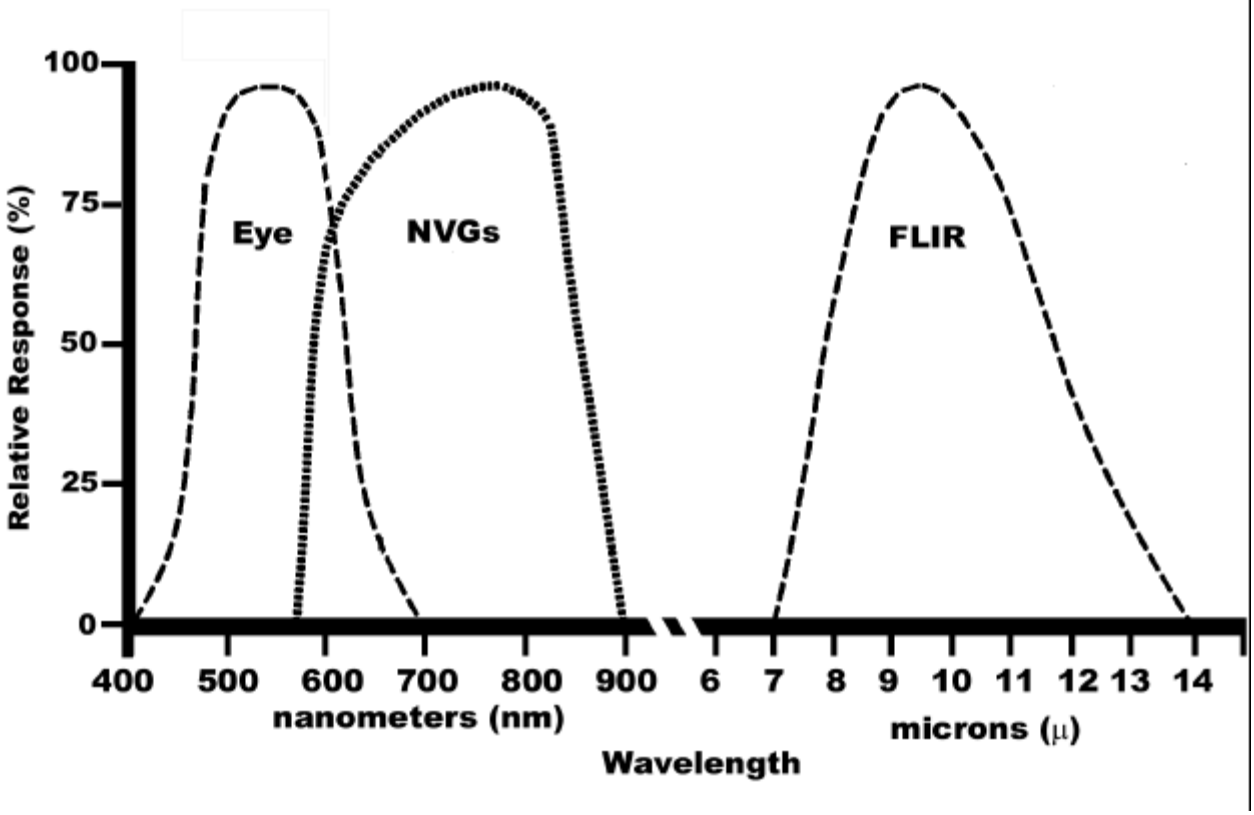

Figure 1 - 1. Relative Spectral Response Comparison of the Human Eye, NVGs and FLIR

TABLE 1 - 1. EM SPECTRUM

Frequency Band	Wavelength	Remarks
Ultraviolet	Below 0.40 Microns	Out-of-Band to Human Eye
Visible	0.40-0.78 Micron	
Violet	0.40-0.46 Micron	
Blue	0.46-0.51 Micron	
Green	0.51-0.58 Micron	Sensitivity Range of Human Eye (In Band)
Yellow	0.58-0.60 Micron	
Orange	0.60-0.63 Micron	
Red	0.63-0.78 Micron	Partial Sensitivity Range of NVGs
Infrared	0.79-1.000 Micron	Partial Sensitivity Range of NVGs / Out-of-Band to Human Eye
Near IR	0.79-1.5 Micron	
Mid IR	1.50-5.6 Micron	
Far IR	5.60-1,000 Micron	Sensitivity Range of Infrared Thermal Detectors

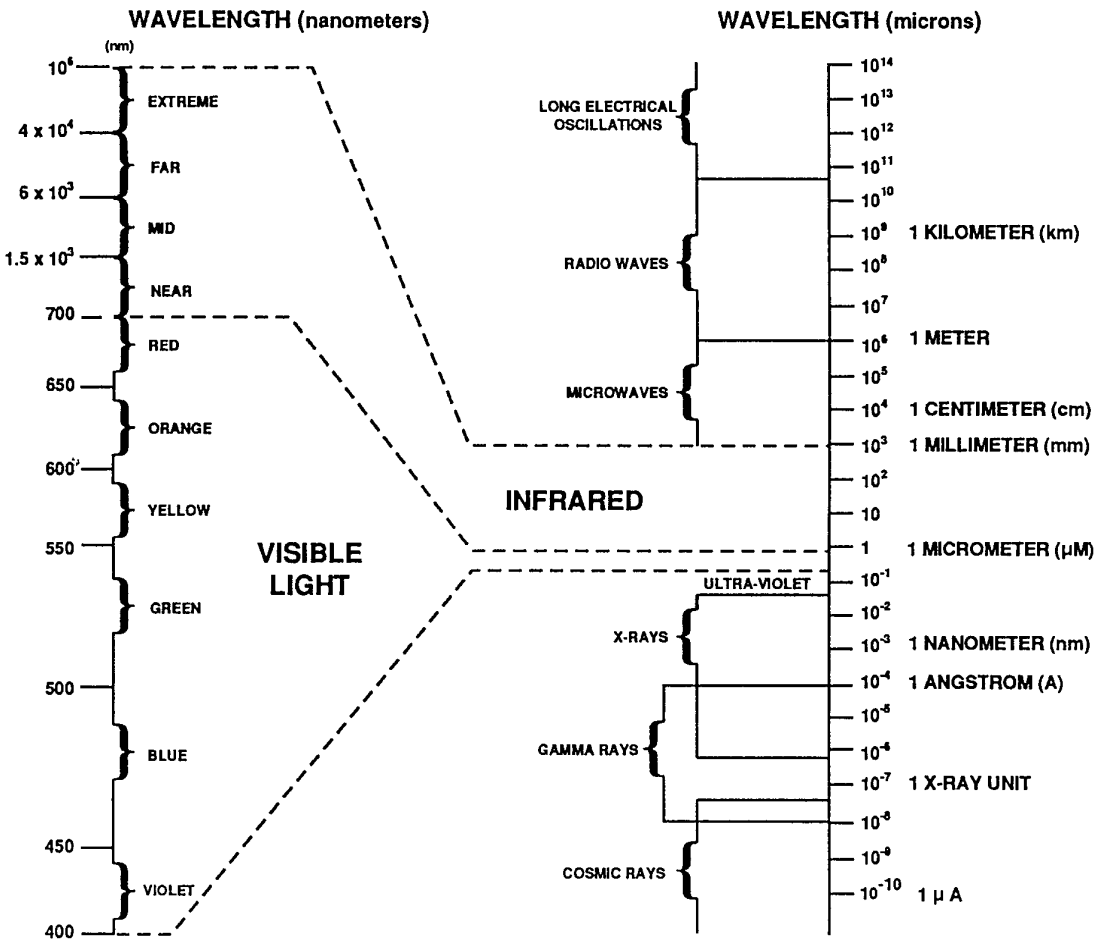

Figure 1 - 2. EM Spectrum

A. Reflected vs. Radiant Energy

The AN/AVS-6 NVGs operate in both the visible and near IR spectrum. In addition, the AN/AVS-6 NVGs are dependent entirely on reflected energy emanating from the terrain. This means that, as with the eye, scene illumination will be required for visual observation. For example, when a scene is illuminated by an external source such as the moon, the scene is observed primarily by reflected energy. Reflected light (luminance) is normally expressed in terms of foot-lamberts (ft-L), while the amount of light generated from a source (illuminance) is expressed in terms of the unit Lux or lumens per square meter (lm/m^2), Figure 1-3. Common photometric measurements are listed in Table 1-2. Below three microns the background is dominated by reflected and scattered solar (lunar) radiation. However, as we proceed into the IR spectrum beyond approximately 4.5 microns, the background becomes dominated by terrain self-emission. Terrain thermal self emission relies on the temperature of the terrain objects and on the objects associated emissivity Figure 1-4. This is the area of the EM spectrum in which FLIR systems operates. Based on the selective sensitivity and the environmental presence of different energy forms, the two sensors, AN/AVS-6 and FLIR, operate at different but complementing regions of the EM spectrum.

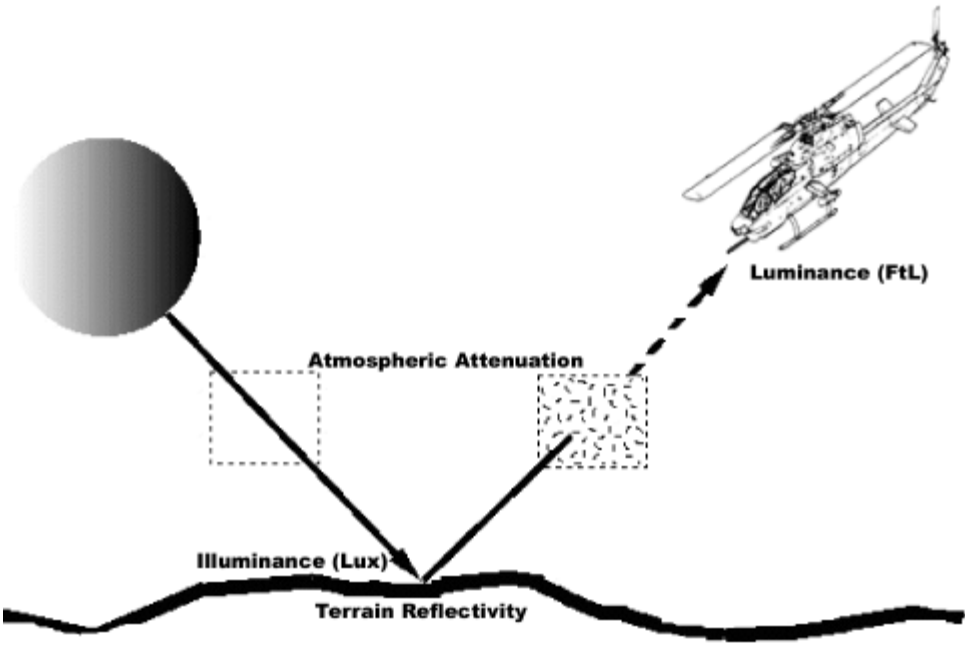

Figure 1 - 3. Photometric Energy Critical for NVG Aided Operations

TABLE 1 - 2. COMMON PHOTOMETRIC CONVERSIONS

Photometric Term	Symbol	Units
Illuminance	**P**	1 lumen/m^2 = 1 lux = 1 meter-candle (m-c) = 0.0929 ft-candle (ft-c)
Luminance	**L**	1 lu/steradian/m^2/c/m^2 =1 lu/w/m^2 = 1 c/m^2 1 c/m^2 = 0.3142 millilambert = 0.2919 foot-lambert (ft-L)

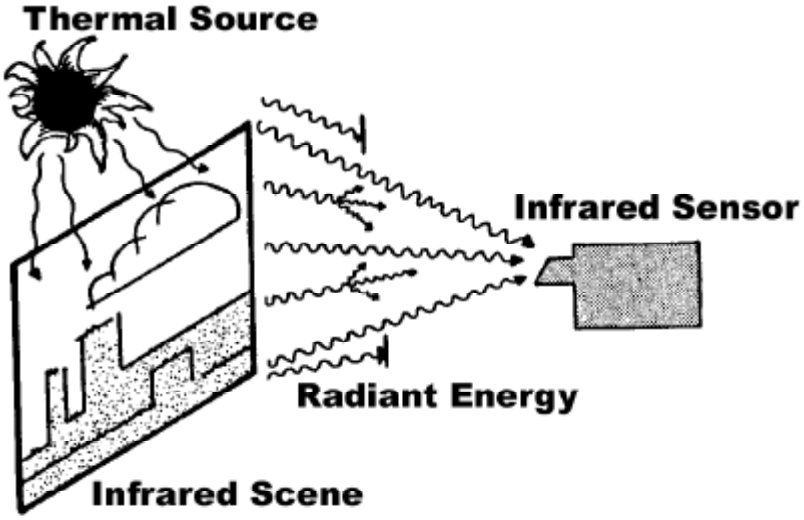

Figure 1 - 4. Radiant Energy

B. Optical Radiation (Light) Theories

The energy that the NVGs and the FLIR receive and the resulting visible image that the pilot ultimately views represents many different forms of EM energy. Light, or optical radiation, can be described in two ways; as particles of energy called photons or as waves propagated through a medium (i.e., air). The particle theory of light provides a description of the emission of light from a source, such as the moon. The intensity of this energy can be measured as the amount of visible light or energy that strikes a surface, illuminance or irradiance, respectively. The wave theory of light is useful in describing the phenomena of EM energy propagation through mediums such as air or an optical system (i.e., NVG, human eye). Regarded as a form of wave motion, EM energy has the characteristics of wavelength, frequency, and velocity. In the visual and IR portion of the EM spectrum, frequency units such as gigahertz and megahertz are so large that they are cumbersome to use. For this reason, by convention the smaller wavelength values are typically used to describe these EM energy regions. A micron, which is one millionth of a meter, is normally used as the unit of measure of wavelength for thermal energy. The nanometer (one thousandth of a micron) is usually the unit used when describing shorter wavelengths associated with the visible and near IR regions of the EM spectrum.

C. Thermal Theory and Principles

All objects with a temperature above absolute zero (-273^{0} C) emit energy, most of which is in the mid and Far IR portion of the EM spectrum. An increase in temperature will increase an objects molecular vibrational motion, thereby increasing its energy state. When the elevated energy state collapses, thermal energy in the form of radiation is emitted. In general, radiation that strikes an object can be absorbed, transmitted or reflected. Naturally occurring thermal energy is produced when objects absorb thermal energy from IR sources such as the sun or warm air currents. Once absorbed, this energy can then be radiated. Another source of thermal energy is from man-made objects such as the heat from a running engine or the heat generated by friction from moving parts. Natural and man-made thermal sources produce the thermal radiance that ultimately creates the thermal scene. FLIR systems typically operate in either the mid infrared (3-5 micron) or far infrared (8-12 micron) band of the EM spectrum. These regions of the EM spectrum are dominated by the thermal self emission bands of energy. This is very different from the human eye and NVGs that are sensitive to the region of EM spectrum that is dominated by reflected energy (0.4-1.2 microns). Whereas NVGs require adequate sources of illumination to operate, FLIR systems require a thermally variable environment in order to create an image for aircrew to use. Radiated energy is independent of illumination sources and is comprised of objects that emit radiation as a direct result of their molecular vibration, or reflect thermal energy from another source. Radiated energy laws can be very complicated so a cursory introduction to operationally relevant considerations will be presented. The purpose of this discussion is not to make thermal physicists out of squadron aircrew, but instead to highlight the unavoidable fact that the thermal environment is very dynamic and complicated. For this reason questions such as “How will a tank look today?” or “Will the FLIR function well tonight?” are not very easy to answer prior to arriving in the objective area. The thermal laws are included in the discussion of the factors that will determine an objects temperature-thermal history, emissivity, thermal mass, and thermal inertia.

1. Thermal History. The thermal history of an object will be determined by its exposure to the principle sources of thermal energy: (1) solar energy, (2) fuel combustion,(3) frictional heat and (4) thermal reflection. If an object has a higher temperature than its surroundings, it

has a negative energy transfer and will become cooler. Conversely, if the object has a positive energy transfer (cooler than its surroundings) it will exhibit a temperature increase. Whether the object is increasing or decreasing in temperature, it will always be emitting radiant energy. The situation becomes more complicated because of the objects thermal reflectance and absorption characteristics.

2. Emissivity. If no incident radiation is reflected or transmitted from an object, the object is said to be a blackbody. A blackbody is defined as a perfect absorber of radiant energy. A blackbody is a theoretical tool that is used as a comparison standard for all objects that radiate thermal energy and is defined as a body with an absorbing, and hence emitting, efficiency of unity (1.00). The ability of any object to emit thermal energy compared to a blackbody at the same temperature is termed the objects emissivity (E). A sample of common material emissivities is given in Table 1-3.

TABLE 1 - 3. COMMON MATERIAL EMISSIVITY

Material	Emissivity
Highly Polished Silver	0.02
Highly Polished Aluminum	0.06
Polished Copper	0.15
Aluminum Paint	0.55
Polished Brass	0.6
Oxidized Steel	0.7
Bronze Paint	0.8
Gypsum	0.9
Rough Red Rock	0.93
White Lacquer	0.95
Green or Grey Paint	0.95
Lamp Black	0.95
Water	0.96

Emissivity determines how much of the energy detected by a FLIR is from self-emission (radiation) and how much is reflected radiant energy by the objects background. Emissivity is generally a function of material type and surface finish and can vary with object temperature, ambient temperature, wavelength, and geometric shape. Most natural objects have a very high emissivity value, therefore have the majority of their thermal signature results from self-emission instead of thermal reflectance. For example, the emissivity of metal is typically low, but increases significantly when coated with a layer of rust due to a decrease in reflectivity and an increase in absorption capability (structural property change). Thermal energy can be radiated in two general ways as a thermal source or as a selective source. A thermal source radiates a spectrum of wavelengths with a maximum radiated energy occurring at a particular wavelength. The sun is a good example of a thermal radiator. Others include the hot metal of a jet engine tailpipe, aerodynamically heated surfaces, motor vehicles, personnel, and terrain. Selective sources on the other hand, have an output concentrated in narrow wavelength intervals called line spectra. A particularly unique selective radiator can be exemplified by the output from a LASER that radiates at nearly a single wavelength. Most natural and man-made objects of interest are thermal radiators that emit in either the 3 to 5 or 8 to 12 micron band of the EM spectrum.

3. Thermal Mass. Usually, most objects heat up (positive energy transfer) during the day and then radiate the IR radiation (negative energy transfer) at night. The ability of an object to store heat is called thermal mass. Thermal mass is determined by the material's temperature, mass and type. The hotter an object, the greater the amount of heat stored. A larger object or mass (density X volume) can also store more heat. Some materials store heat very well (water), whereas others store heat very poorly (air). This is reflected in a measurement called the specific heat of the material. High thermal mass means high heat storage, but it also means it takes more heat to change the temperature of an object. While the amount of heat an object holds is significant, it is temperature differences that cause differences in the FLIR image, not heat differences. For instance, a large rock will have a higher heat value than a smaller rock of the same temperature and composition. Except for size, the FLIR image of the two rocks would appear identical even though the larger rock has a higher thermal mass.

4. Thermal Inertia. Thermal inertia is a combination of thermal mass and thermal resistance and provides a measure of the rate at which objects change temperature. Thermal mass determines the amount of heat stored, while thermal resistance determines the rate at which the heat will flow. An object of high thermal mass and high thermal resistance would change temperature slowly and be considered to have high thermal inertia. Examples of this include large, dense objects such as big rocks, armored targets, and bodies of water. Lightweight objects such as grass, leaves, bushes, and the surface layer of the ground heat and cool quickly and are described as having low thermal inertia.

III. NVD Scene Variables

The three major factors that influence NVD performance include: (1) illumination / thermal scene, (2) terrain contrast and (3) atmospheric conditions. Understanding how these factors impact NVD performance will improve mission planning and execution.

A. Natural Illumination

Illumination is a critical factor for NVG operations, however, does not impact FLIR performance. Illumination for night operations can come both natural and artificial sources and is typically expressed using lux or lumen/meter^2 units, a measurement unit that NVD aircrews will become very familiar with as they are introduced to NVG aided operations.

1. Lunar Illumination. The moon is usually the primary source of natural illumination for NVG operations. The moon reflects about 7% of the sunlight that strikes it. The amount of light provided by the moon is highly variable and is influenced by four factors: (1) lunar cycle, (2) moon angle, (3) lunar albedo (reflectivity) and (4) variation in earth-moon distance.

   (a) Lunar Cycle. The primary lunar illumination factor is lunar cycle or phase (i.e., new, full, quarter, etc.). Each moon phase provides different levels of illumination (Table 1-4). A lunar month is approximately 29.5 days. There may be times as a new NVD player that you will find yourself “chasing the moon.” This term is used to describe the attempt by a prudent training program to introduce AN/AVS-6 flying under optimal conditions. Therefore, introductory flights may be driven by high lunar illumination. Moon phases are influenced by the time of year and global position (latitude and longitude).

TABLE 1 - 4. SOLAR AND LUNAR CYCLE ILLUMINATION

Sky Condition	Approximate Levels of Illuminance Lux (lm/m^{-2})
Direct Sunlight	$1\text{-}1.3 \times 10^5$
Full Daylight (Not Direct Sunlight)	$1\text{-}2 \times 10^4$
Overcast Day	10^3
Very Dark Day	10^2
Twilight	10
Deep Twilight	1
Full Moon	10^{-1}
Quarter Moon	10^{-2}
Moonless, Clear Night Sky	10^{-3}
Moonless, Overcast Night Sky	10^{-4}

(b) Moon Angle. Moon angle, elevation or altitude in relation to the horizon, is the second most significant factor that affects lunar illumination. The moon is at its brightest when it is directly overhead and provides less illumination as it rises or sets (Figure 1-5). Many people will look at a low angle full moon and assume high illumination. However, as shown by Figure 1-5, a quarter moon high overhead can actually be brighter. Moon altitude is also important because of the phenomenon known as terrain shadowing which will be discussed later.

(c) Lunar Albedo. Differences in the albedo (reflectance) of the illuminated portions of the moon surface during the lunar cycle is the third factor. For example, the moon is about 20% brighter during the first quarter (waxing) than it is during the third quarter (waning) due to differences in the lunar surface.

(d) Earth-Moon Distance. The final and least significant factor is the variation in the earth-moon distance due to the elliptical nature of the lunar orbit around the earth. The changes in illumination resulting from this 26% change in distance are deemed insignificant for NVG purposes.

(e) Lite Level Planning Calendar. Due to the wide and rapid changes in lunar illumination, a computer program was developed to help night systems squadrons properly plan their missions. This information is provided in the Lite Level Planning Calendar that is available for MS-DOS computers. In addition, the program has also been incorporated into TAMPS. The computer program provides a global prediction of sun and moon position for most areas of the world. The information is available in various formats through a number of menu options. The two most useful options are the Light Level Planning Calendar and the Sun and Moon Position Chart. All Light Level Planning Calendar options are thoroughly explained in Appendix C. The Naval Oceanographic Office is currently developing a new Windows based Light Level computer program. This Solar / Lunar Almanac Program (SLAP) is currently a module component of the larger Geophysics Fleet Mission Program Library (GFMPL). The SLAP possesses all the core functionality of the current LLPC with the added benefits of possessing an enhanced interface and greater flexibility for storage of operating site locations and output options. In addition, The SLAP uses the DOD standard almanac algorithm that ensures standardization of output data used for mission planning across all services. The SLAP should be ready for fleet release by the end of FY 99.

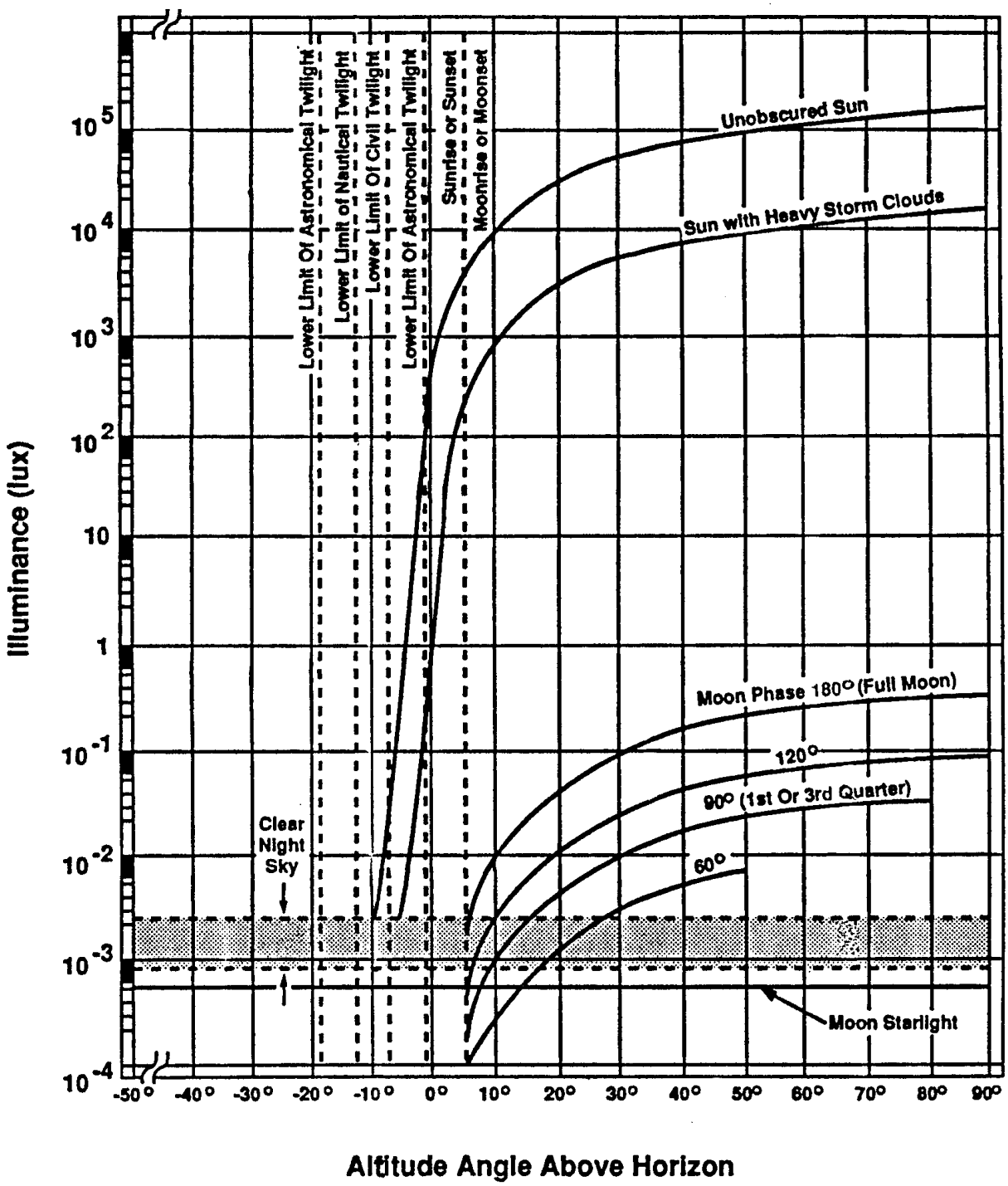

Figure 1 - 5. Moon Phase and Moon Angle Vs. Illumination

2. Night Sky Illumination. Moonless nights also have significant usable light for NVG operations. This is due to the large near IR composition of night sky illumination. This night sky near IR energy matches the peak sensitivity of the AN/AVS-6 (Figure 1-6). It is possible to fly effectively with AN/AVS-6 under these conditions with a good training program and proper pre-flight mission planning. On a moonless night, about forty percent of the light is provided by emissions from atoms and molecules in the upper atmosphere known as airglow. Starlight is the other significant light source and provides about 0.00022 lux (about 1/10 the level of a quarter moon). In addition, other possible night sky illumination sources include: auroras (luminous rays, ribbons, and arc patterns caused by charged particles), gegenscheins (diffuse, faint light caused by sunlight reflecting off of air particles), zodiac lights (faint elliptical disks around the sun caused by reflection off particulate matter) and noctilucent clouds (usually colored, thin clouds with unknown origin).

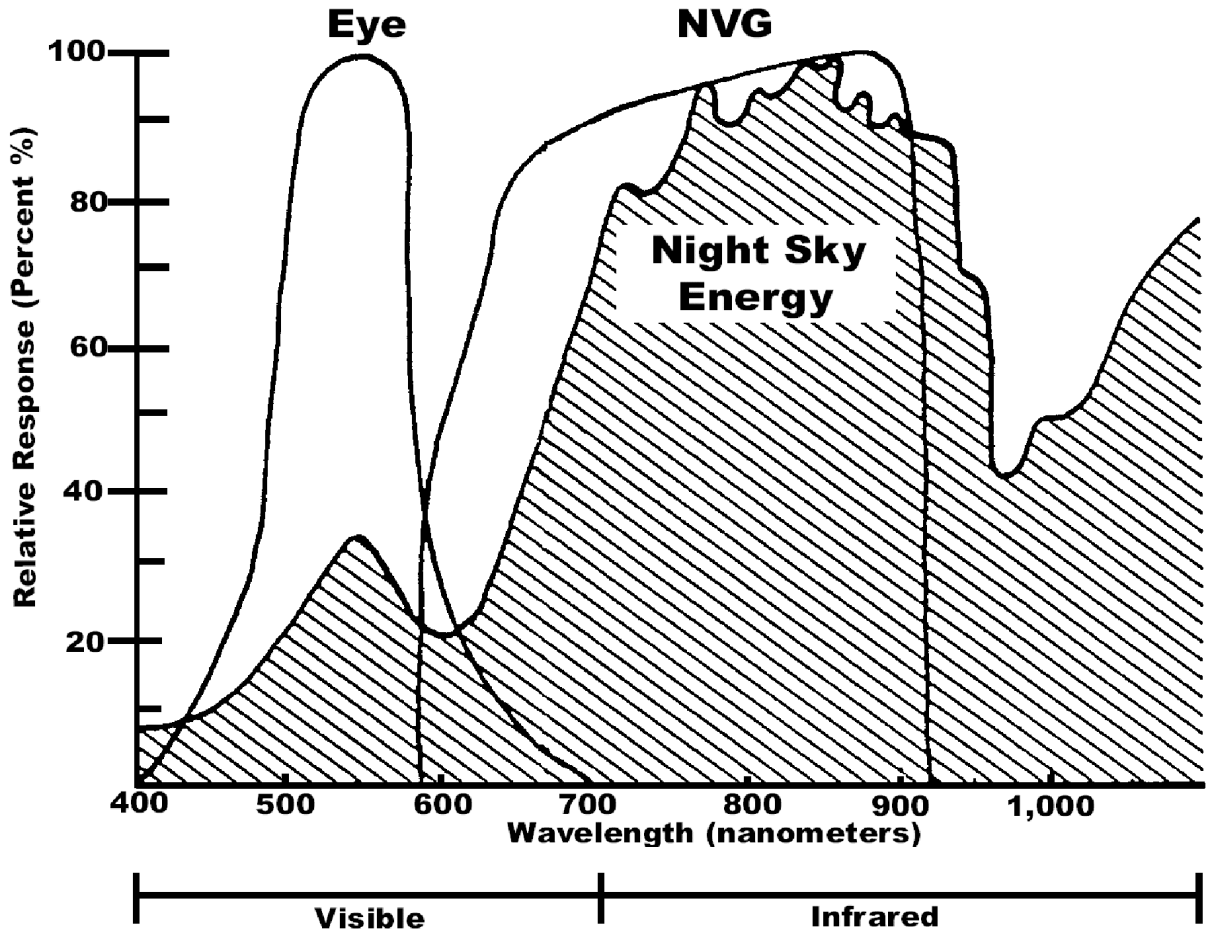

Figure 1 - 6. NVG / Human Eye Spectral Sensitivity Vs. Night Sky Energy Composition

3. Solar Influence (Figure 1-7). Dependent upon the azimuth and relationship to flight path, the sun can provide adequate light for NVG operations at nautical twilight (7-12 degrees below the horizon). Civil twilight (0-6 degrees below) is too bright and astronomical twilight (13-18 degrees below) is too dark for NVG operations (considering only the contribution of the sun). A sun that is well below the horizon can continue to be a significant nuisance if flying toward it, especially in mountainous terrain. This is because of potential activation of the NVG's automatic gain circuitry (Bright Source Protection). For NVG aided operations, aircrew should plan for NVGs to be most effective following the end of evening nautical twilight (EENT) or when the sun has set at least 12^0 or greater below the horizon.

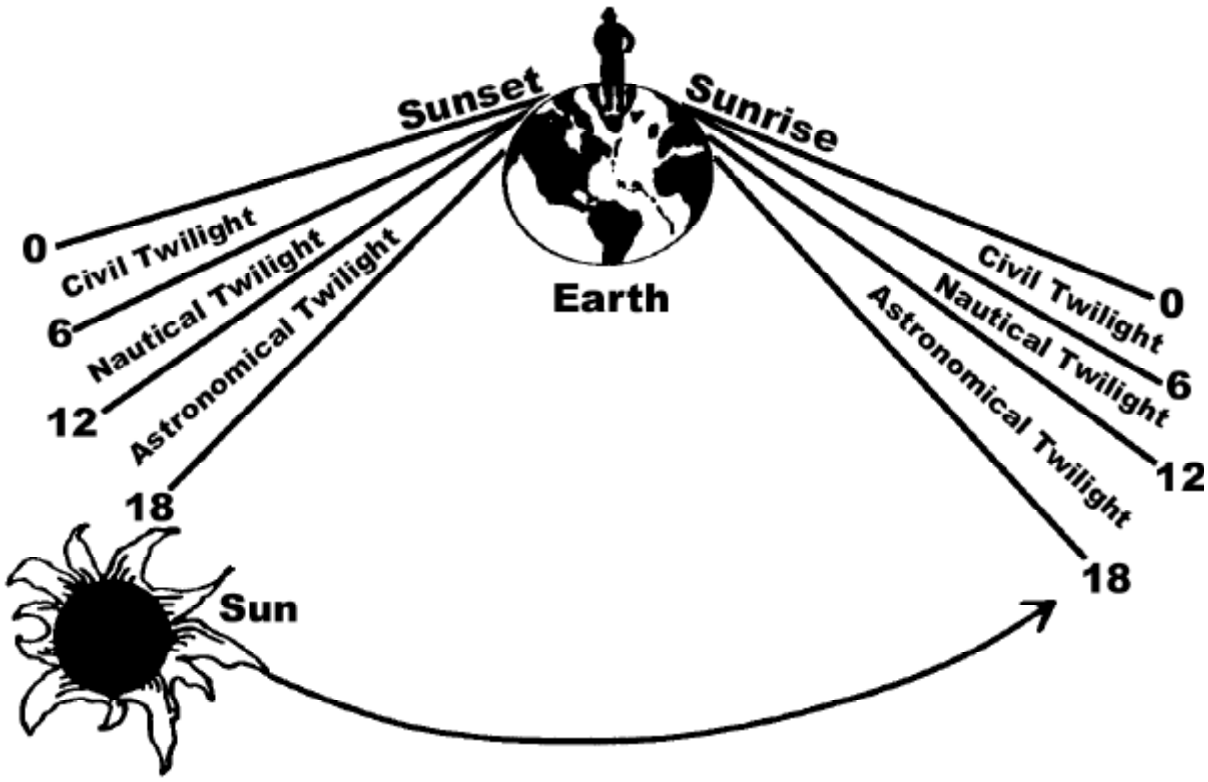

Figure 1 - 7. Solar Illumination

B. Artificial Illumination

Artificial Illumination sources (i.e., lights from cities, vehicles, weapons, flares, etc.,) can provide illumination for NVG operations. As with the sun, these artificial illumination sources can be helpful or hazardous dependent upon the relative placement in or out of the NVG field of view (FOV). As with a low moon angle or the setting / rising sun, a potential exists for the NVG automatic gain control system (Bright Source Protection) to be activated causing the NVGs to "bloom" or "shutdown."

C. NVG Terrain Considerations

Terrain considerations must be understood when discussing NVG performance. The three primary terrain factors that need to be examined for proper NVG mission planninginclude: (1) terrain reflectivity (albedo), (2) terrain contrast and (3) terrain shadowing.

1. Terrain Reflectivity. Terrain reflectivity (albedo) will greatly influence the overall scene luminance available for NVG operations. Surfaces such as snow will reflect more light than surfaces like asphalt or dark rock and therefore will appear lighter in the NVG image. Our ability to see terrain features with NVGs is solely a function of the amount of light reflected by the terrain. Specific examples of reflectivity values are given in Tables 1-5.

TABLE 1 - 5. TERRAIN / OBJECT REFLECTIVITY (ALBEDOS)

Soils	Dry	Wet	
Dark	0.13	0.08	
Light	0.18	0.10	
Dark – Plowed	0.08	0.05	
Light – Plowed	0.16	0.08	
Clay	0.23	0.15	
Sandy	0.25	0.18	
Sand	0.40	0.20	
White Sand	0.55		
Surfaces	**Dry**	**Wet**	**Unspecified / Indifferent**
Rock	0.35	0.20	
Dirt Road	0.25	0.18	
Clay Road	0.30	0.20	
Asphalt			0.10
Lava			0.10
Tundra			0.20
Steppe			0.20
Concrete			0.30
Stone			0.30
Desert			0.30
Fields	**Growing**	**Dormant**	**Unspecified / Indifferent**
Tall Grass	0.18	0.13	0.16
Mowed Grass	0.26	0.19	0.22
Deciduous Trees	0.18	0.12	0.15
Coniferous Trees	0.14	0.12	0.13
Rice	0.12		
Wheat	0.18		
Rye	0.20		
Snow / Ice			**Unspecified / Indifferent**
Fresh Snow			0.85
Old Snow			0.55
Melting Snow			0.35
White Ice			0.75
Gray			0.60
Snow & Ice			0.65

2. Terrain Contrast. Terrain contrast is a measure of the difference between the reflectivity of two or more surfaces. Examples are given in Table 1-6. The greater the difference in contrast, the easier it is to see terrain or objects. The interaction between terrain contrast and illumination level is critically important for aircrew to understand. NVG image brightness remains constant from approximately full moon down to approximately quarter moon illumination through activation of the NVG's automatic gain control circuitry (Automatic Brightness Control). Under these high light level (HLL) conditions, flight over low contrast terrain will significantly washout the NVG image (image will likely be too bright to detect scene detail). As light level decreases below quarter moon, NVG image brightness will start to decrease. Therefore, terrain such as water and desert, that usually has very little contrast, can be troublesome to fly over under these low light level (LLL) conditions. This problem is compounded by a lack of terrain features or texture. The comfort level flying over different terrain is also a function of terrain texture. Texture is important as it provides recognition and depth perception cues. Forests provide a lot of texture, whereas 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 is usually lost as the contrast between the trees is similar and they therefore blend together.

TABLE 1 - 6. SAMPLE TERRAIN CONTRAST ANALYSIS

Sample Terrain Contrast Comparisons	% Contrast
Asphalt / Snow	73
Dirt / Grass	41
Sand / Leaf	39
Asphalt / Grass	18
Grass / Leaf	11

3. Terrain Shadowing. Shadows form at night just as they do during the day. Anything blocking moonlight will create 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 possesses the capability to see into shadows due to both the amount of energy present and capability of the human eye. At night with NVGs there is considerably less energy available and even much less energy inside a shadow cast by the moon. Since NVGs require some illumination to function, it follows that they will not be as useful inside shadows or for viewing from outside to inside shadowed areas. Consequently, detail and even large objects can be lost in shadowed areas (this will be more fully discussed later). It is important to note that shadows can be helpful as well as a hindrance. Some objects, such as tall, narrow pylons, may cast a shadow that will be seen well before the pylon itself. When flying into shadowed areas, the aircrew may depend on help from sensors that do not need illumination to function, such as the FLIR or RADALT.

D. Sources of Thermal Energy

The three principle sources of thermal energy for objects are solar radiation, fuel combustion or frictional heat and thermal reflection.

1. Solar Radiation. Those objects that do not have their own power source obtain most of their thermal signature from the sun. Factors that affect available sunlight will therefore impact the thermal scene. The two most prominent factors that dictate the amount of solar radiation available on a clear day are: (1) time of day and (2) time of year. Quite simply, the higher the sun is in the sky, the more intense the available solar radiation. This is true for two reasons. First, the sun is closer to the earth's surface, and second, there is less atmosphere for the solar energy to pass. Solar elevation coupled with an object's inclination / orientation relative to the sun will influence the amount of solar radiation absorbed. Horizontal surfaces receive different amounts of solar radiation than do vertical surfaces. Horizontal surfaces receive the most intense solar radiation during periods of high solar elevation, while vertical surfaces receive the most during periods of low solar elevation. This is an important generality to remember when flight planning and attempting to approximate thermal signatures of objects.

2. Fuel Combustion or Frictional Heat. The vast majority of thermal energy is derived from the sun and even man-made objects appear very much like themselves when heated by the sun. However, the thermal signature of a machine can appear to be distorted after it has been operating. The heat from areas of artificial heating, such as engine compartments or exhaust, appears as hot spots. Frictional heat from moving parts such as tank tracks usually produce a less intense hot spot and can be easily obscured by coverings such as mud or snow. In general, these localized hot spots tend to form a high contrast spot that aids in detection but could hamper identification efforts.

3. Thermal Reflectivity. As noted previously, the amount of thermal energy emitted by any object is a function of its temperature and emissivity. Most natural objects have a very high emissivity. This means that the majority of their thermal signature is from self-emission. By definition, those objects with low emissivity have high thermal reflectivity and will reflect more of their background temperature. The physics of far IR energy makes most objects appear to be very rough and only smooth or glossy objects will reflect thermal energy. Materials with low emissivity values will reflect the temperature of the surrounding area. If oriented horizontally, the object will normally reflect the night sky and under clear conditions will appear very cold. An example is a vehicle windshield. Under broken or overcast conditions, the cloud base temperature will be reflected by the windshield. On the other hand, vertically oriented surfaces will usually reflect the temperature of the surrounding background (i.e., a canyon wall). Even though it has a high emissivity value, the most significant source of thermal reflection from an operational perspective is water. Water can produce a variety of images depending on the angle viewed and the surface condition and temperature of the water. The angle at which a calm body is viewed determines whether the thermal energy is primarily from the sky or other sources. The lower the viewing angle, the more reflective a calm water surface becomes. As the viewing angle increases, the waters self-emitted energy becomes more dominant and the image produced is primarily a function of its temperature. This phenomenon can cause a body of water to reverse contrast as the aircraft climbs or descends. Swells or wakes are detected because of the change in incident angle of the thermal energy on the surface. Water can also reflect the thermal energy from dams, bridges, boats or trees.

E. Thermal Scene

Visual discrimination of objects in the thermal scene is made possible when objects have a different radiated temperature (energy) than their immediate backgrounds. Even if the radiated temperature differences are less than a degree, they will appear on the display of a modern thermal imager. The temperature differences appear as variations of the brightness levels of the objects when viewed on the FLIR display. The concept of temperature difference, referred to as "delta (D) T," is fundamental to thermal imaging systems. If there is no difference (DT=0) between the radiated temperature of an object and its background, the object will have no contrast and will not be distinguishable from its background. It will, in effect, be invisible. A FLIR system's ability to detect temperature differences is referred to as the mean resolvable temperature difference (MRTD). If the FLIR is not sensitive enough, its MRTD is too high and objects will not be easily detected. Usually, targets have a positive contrast at night (the object is warmer than the background) and a negative contrast (the object is cooler than the background) on sunny days. The thermodynamics of the battlefield can be confusing and cause problems with target recognition. Many of the natural and man-made objects on a typical battlefield undergo continual temperature changes that follow important, predictable trends. For example, natural background objects such as trees, grass and rocks are heated passively through the absorption of solar energy during the day. Even during overcast days, some solar radiation is absorbed. Daily solar heating begins at sunrise. After midday, the sun declines and the background objects begin to cool. After sunset, the objects cool down to approach the temperature of the surrounding air. The daily two part heating and cooling cycle is called the diurnal cycle.

1. The Diurnal Cycle. The diurnal cycle is illustrated in Figure 1-8. During the diurnal cycle, individual background and target objects heat and cool at different rates. Large dense objects such as medium sized rocks, tree timber and non-operating armored targets (high thermal masses) heat and cool slowly. Less dense objects such as blades of grass, tree leaves, bushes and the surface layer of the ground itself are examples of low thermal mass objects that heat and cool quickly. Sometimes the radiated temperature of the target reaches the temperature of the surrounding grass and leaves, resulting in DT=0. However, on hot days the target usually does not reach nighttime background temperature before the sun rises once again to restore the heat cycle. As the sun rises, the cool background warms up rapidly to exceed the target temperature. The point where the background temperature passes the target temperature is called the diurnal crossover. This is illustrated in Figure 1-8 at 0730 and again at 1530 with the interaction between the armored target and grass/tree leaves. At these times, targets may be difficult to detect. Following the crossovers (0730 and 1530), the target will appear brighter than the background and positive target contrast results. The timing of the diurnal crossovers is greatly influenced by environmental factors. Therefore, this simplistic discussion only provides a broad introduction to the topic of the diurnal crossover cycle concepts.

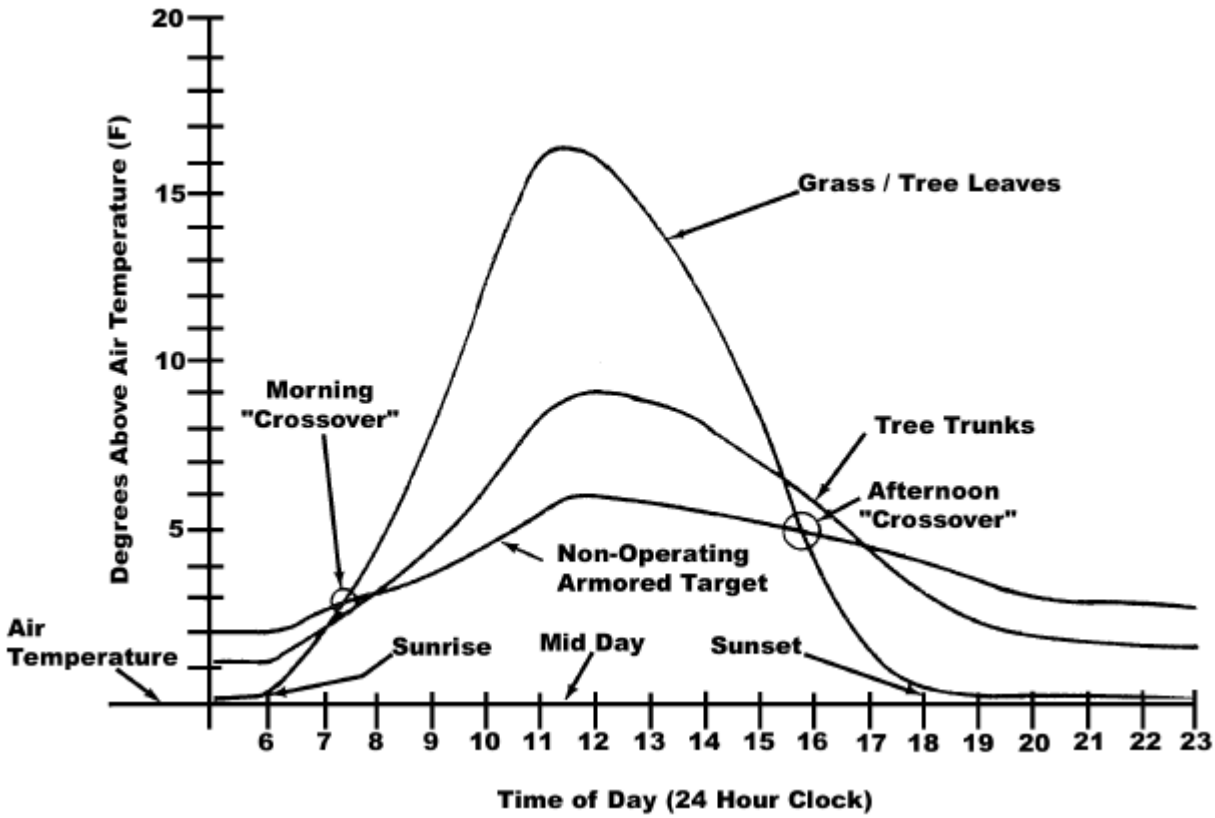

Figure 1 - 8. Thermal Scene Diurnal Cycle

2. Surface Types. Certain smooth, glossy surfaces, such as bodies of water, windshields and glossy painted fenders can reflect IR radiation images incident on them from other sources. Vehicle windshields and fenders often appear very dark because they reflect the low radiant temperatures of the cold night sky.

3. Thermal Shadows. Since the majority of thermal energy the FLIR detects is emitted, it generally does not encounter illumination based dynamic shadowing like NVGs. Thermal shadows usually include the same area as visible shadows during the day, as the surface is shaded from the suns visible as well as solar energy. Thermal shadows tend to dissipate after sunset or when obscured by clouds. Another type of thermal shadow indicates recent activity, such as when aircraft or vehicles are moved. Often these silhouettes can be detected hours after a vehicle or aircraft has moved. This could pose a problem, as it could appear that the object is actually there, thus acting as a thermal decoy. Thermal shadows caused by wind can sometimes be noted in the lee of objects projecting above the surface and can appear similar to wake from a boat. This phenomenon has limited significance, but can draw attention to objects and aid in detection.

F. Atmospheric Effects

The atmosphere is the most important environmental factor controlling the performance of the FLIR and NVGs. The atmosphere can attenuate light and thermal energy, reducing the level of energy reaching the NVGs or FLIR. This attenuation can occur by refraction, absorption or scattering. The impact of refraction is almost negligible, therefore absorption

and scattering are the only attenuating mechanisms addressed here. The impact of these mechanisms on the FLIR or NVG image varies based upon their spectral sensitivities. The FLIR operates by processing differences in thermal energy in the 3-5 or 8-12 micron band and anything that attenuates these wavelengths will affect FLIR system image quality. AN/AVS-6 NVGs, on the other hand, operate by intensifying reflected light energy between 625-960 nanometers. Attenuation of energy that either strikes or reflects off the terrain will effectively reduce the usable energy incident that upon the NVG. This atmospheric attenuation will negatively impact the resulting intensified image quality.

1. Absorption. Atmospheric absorption, particularly molecular absorption, is the primary source of atmospheric attenuation. FLIR performance is most affected by three atmospheric molecules: water, carbon dioxide and ozone, Figure 1-9. In addition to these three molecules, other minor constituents (i.e., nitrous oxide, carbon monoxide and methane) may also contribute to atmospheric absorption. However, due to the relatively low density of these minor constituents, their concentration and variation is considered a constant and does not appreciably affect NVD performance. Molecular absorption occurs across several specific absorption bands. These absorption bands are molecule dependent and occur at specific wavelengths that correspond to the resonant frequency of the specific molecule.

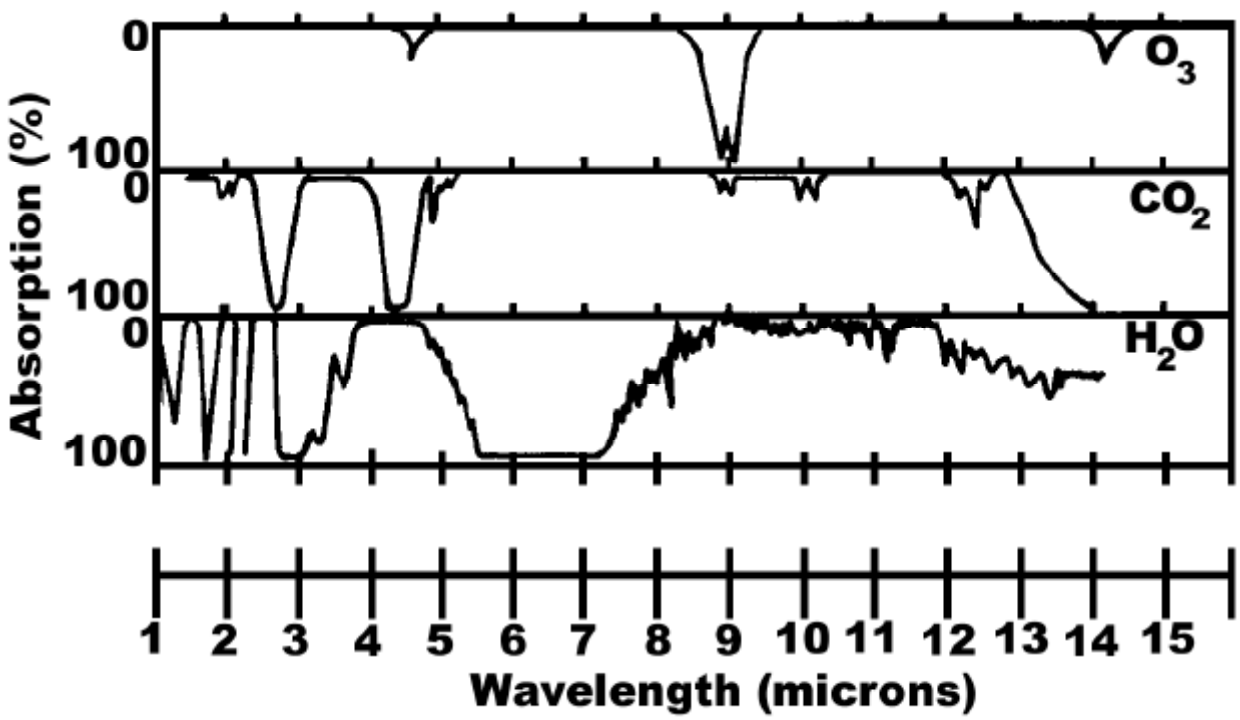

Figure 1 - 9. Atmospheric Absorption Molecules (Ozone, Carbon Dioxide and Water)

(a) Water Vapor. Atmospheric water vapor (humidity) is the most influential absorbing gas, and certainly the most variable. Local humidity conditions can easily double the water vapor content in a matter of hours, such as seen with a changing weather front. When considering FLIR performance, absolute humidity is more relevant than relative humidity. Absolute humidity, also known as vapor concentration or vapor density, is the amount of the mass of water vapor present in a given volume of air and is expressed as grams of water per cubic meter of air (g/m^3). Relative humidity is a ratio that expresses the amount of moisture in the air compared to the maximum amount that could be held at that same temperature. This is the common measurement used by meteorologists when discussing humidity and is expressed as a percentage. This relationship is shown in Figure 1-10. Table 1-6 shows that the warmer the air, the more water vapor it can hold.

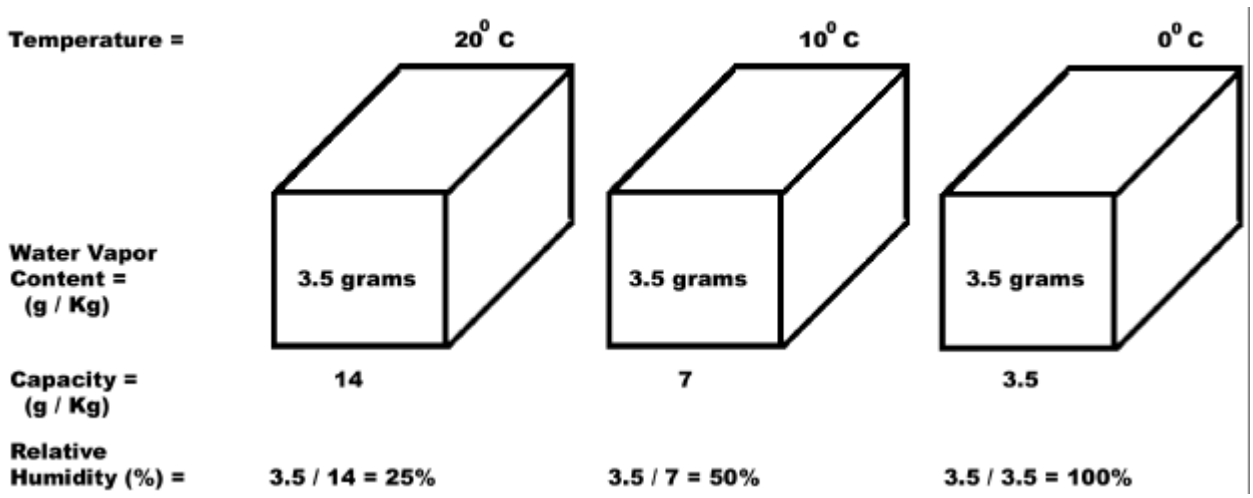

Figure 1 - 10. Relationship Between Relative and Absolute Humidity

TABLE 1 - 7. WATER VAPOR CAPACITY OF AIR

Water Vapor Capacity Temperature (°C)	Grams/KG (At Sea Level Pressure)
-40	0.1
-30	0.3
-20	0.75
-10	2
0	3.5
5	5
10	7
15	10
20	14
25	20
30	26.5
35	35
40	47

1: AN/AVS-6 (ANVIS) Effects. Humidity effects on NVG performance varies with particle size and density. Visible and near IR wavelengths tend to pass more readily through an area of high absolute humidity as long as the particle sizes are small (i.e., light rain, fog, etc.).

2: FLIR Effects. In general, the greater the humidity (absolute or relative), the greater the amount of water vapor present and, therefore, the greater the IR absorption (especially in the far IR band). The quality of the FLIR image therefore depends primarily on humidity. A dry mid-latitude winter day with an absolute humidity of 3.5 g/m^3 is almost completely transparent to far IR energy, whereas a wet tropical atmosphere of 20 g/m^3 becomes an effective wall that severely hinders the operational capability of the FLIR. It is difficult to determine exactly at what point the FLIR becomes unusable as a navigation device. Figure 1-11 shows the relative effect of water vapor on the transmission of energy for two different temperatures across a range of relative humidity values. Because the 70 degree air holds less water than the 90 degree air, its percent transmission of the 8-12 micron band is higher at a given relative humidity value. This demonstrates the need to use absolute humidity vice relative humidity when estimating FLIR performance. Aircrew must understand the effects of water vapor on the FLIR and expect degradation as humidity rises. In addition, since atmospheric pressure decreases with altitude, performance may be improved at higher altitude due to less water vapor concentration. This may be a factor if the route is considerably higher than where the absolute humidity is measured. There are computer programs that can be used to predict FLIR performance as a function of absolute humidity and other variables, analogous to how the Lite Level Planning Program is used to predict illumination levels for missions using NVGs. However, computer programs must be developed for each type of FLIR due to their different operational characteristics.

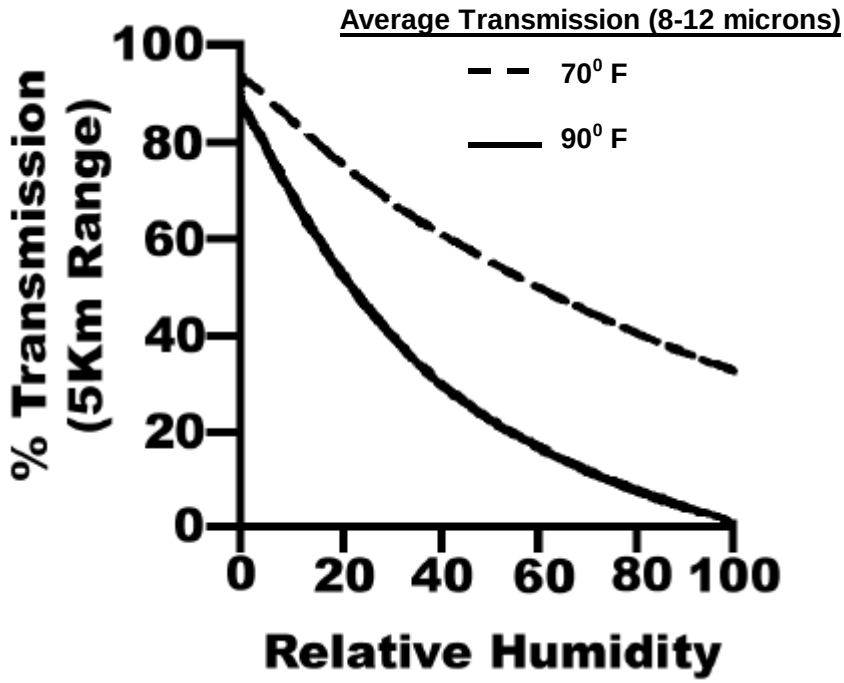

Figure 1 - 11. Atmospheric Transmission Vs. Relative Humidity

(b) Carbon Dioxide. Carbon dioxide is second in importance to water vapor in terms of absorption. The vertical distribution of carbon dioxide in the atmosphere is essentially constant with volume. In addition, the time variations in the amount of carbon dioxide at any altitude are extremely small, so a prediction of the amount of absorption at any time is relatively constant, except for urban areas where the concentration of carbon dioxide is normally higher.

(c) Ozone. Ozone has an erratic effect that is not, at present, usefully predictable. It is rarely encountered since the vast majority is confined to a layer that is centered from 25 to 35 kilometers above the earth. Ozone is produced through the photo-dissociation of oxygen by ultraviolet radiation. This upper atmospheric phenomena provides a protective barrier from ultraviolet light by limiting the amount that reaches the surface of the earth. Some ozone still diffuses through and is directed downward by atmospheric turbulence and winds. Upon reaching the ground, it reacts with organic materials. The total content of natural ozone depends on latitude and season. Higher concentrations of ozone occur at the more northern latitudes and have their peak in the spring and their minimum in the summer/autumn timeframe. The long term effects caused by the diminishing upper ozone layer are still being investigated. On a more practical level, certain environmental conditions can have an affect on performance at tactical altitudes. Significant concentrations of reactive ozone are created by vehicle engines and by emissions from industrial plants. Large releases of industrial pollution and heavy concentrations of vehicle exhaust can create concentrations of ozone near the ground that can attenuate the IR energy and thus limit NVD performance.

2. Scattering. Scattering is second to absorption in the impact of atmospheric effects on NVD performance. As light and thermal energy travels through the atmosphere, it can strike a particle thereby changing the path of the energy. This scattering of energy causes attenuation of the signal. Scattering is generally less significant than absorption when considering NVD performance. It is sometimes difficult to differentiate between the effects of aerosol scattering and absorption for wavelengths less than five microns. There are two types of scattering, molecular and aerosol.

(a) Molecular Scattering. Molecular scattering occurs when light is scattered by particles that are much smaller than the wavelength of the incident radiation. The primary molecules in the air are nitrogen, oxygen, water vapor and carbon dioxide. Each particle in the light path behaves as if it were a secondary light source. The intensity of the scattered light varies inversely to the fourth power of the wavelength. Since blue is one of the shortest wavelengths in the visible spectrum, molecular scattering accounts for the sky's blue color as the shorter visible wavelengths (blue and violet) are scattered the most. Molecular scattering, however, becomes negligible compared to aerosol scattering for wavelengths greater than approximately one micron. Therefore molecular scattering is not considered a major factor for predicting FLIR performance.

(b) Aerosol Scattering. Aerosol scattering involves large particles such as dust or smog and scatters light or thermal energy by reflection. This process is called Mie scattering and results when the energy wavelength is less than or equal to the diameter of the particle. This causes attenuation of the radiation because its energy is redistributed in all directions of propagation and lost to the observer. Therefore, it is the size of atmospheric particles that determines their effect. Because wavelengths detected by a FLIR are about 10 times longer than those detected by NVGs, the impact of smaller particles such as smoke or haze on FLIR performance is relatively insignificant.

Therefore, FLIR systems can be very effective in conditions that greatly hinder the human eye and NVGs. Examples of relative atmospheric obscurant particle sizes are given in Table 1-8.

TABLE 1 - 8. ATMOSPHERIC OBSCURANT PARTICLE SIZE

Particle	Approximate Radii Size (microns)
Smoke	0.2 to 2.0
Haze	0.05 to 0.5
Dust	1 to 10
Fog and Cloud	0.5 to 80 (formed about haze particle)
Fumes	up to 100
Mist	50 to 100
Drizzle	100 to 500
Rain	500 to 5,000

IV. Atmospheric Impact on NVD Performance

Atmospheric conditions will impact each NVD sensor based upon their spectral sensitivity. Direct comparison of the differences in degradation between the NVGs and FLIR will help users achieve the best utilization of each sensor. The following section is designed to compare and contrast the impact of common atmospheric conditions on each NVD sensor.

A. Clouds

There is a great variety of particle size within individual as well as multiple cloud formations. Therefore, it is difficult to predict how much they will attenuate NVG and FLIR performance. The problem is exacerbated by the fact that water in low level clouds is found in the gaseous, liquid, and sometimes even solid forms. This means a varied and unpredictable effect on NVDs, so one must be attuned to noting degradation in each.

1. AN/AVS-6 Effects. Water vapor exists at all temperatures. Because the amount of water vapor a cloud formation can hold increases with temperature, summer clouds generally have higher liquid water content than winter clouds. These liquid water particles are normally between 0.5-80 microns in diameter. In addition, the particles are generally opaque to visible and near IR reflect, therefore reflect these wavelengths. For this reason, thick, dense clouds can be easily seen with NVGs, especially when silhouetted against the night sky. This also means that thick clouds can reduce the amount of illumination that strikes the ground, thereby reducing the available luminance to the NVGs. Thin and wispy clouds have greater space between particles, therefore a greater amount of the near IR radiation will be passed without scattering. Near IR wavelengths have a greater chance of passing through these clouds without being scattered than do the shorter visible wavelengths. For this reason, it is possible for thin, wispy clouds to be seen by the naked eye (visible light or shorter wavelengths) but remain invisible when viewed through NVGs. This potential “invisibility” of thin clouds, fog or marine layers is possible given three conditions:

(a) The clouds are thin and wispy, at least on the edges.

(b) The clouds are low level and set in against the terrain.

(c) The ambient illumination is either very high or very low, degrading NVG performance.

The presence of thin clouds that progress into thicker ones can result in hiding terrain features. This can obviously create a severe hazard for NVG operations. Low clouds lying upon and between hills presents a particularly dangerous situation due to the inability of the aircrew to distinguish between the clouds and the terrain. In that regard, a common question occurs; "If the cloud is invisible, why can't the aircrew see the terrain behind it?" The answer is predictably complex. First, the cloud reduces visual and near IR contrasts and detail. This produces a false perception of distance, resulting in aircrew either not seeing the terrain, or thinking it is much farther away than it actually is. Second, the cloud may get progressively thicker, allowing the pilot to progress through the cloud without initially perceiving a "cloud wall." If a cloud is detected, the perception may be that it is off at a distance. Clouds reduce illumination to an extent dependent on the amount of cloud coverage and cloud density or thickness. For example, a thick, overcast layer of clouds will reduce the ambient light to a much greater degree than will a thin, broken layer of clouds. The aircrew must be alert for a gradual reduction in light level and notice the obstruction of the moon and the stars. The less visible the moon and stars, the heavier the cloud coverage. If the NVG image becomes grainy and begins to scintillate (sparkle), this is an indication that weather may be causing a low ambient light condition. Also, shadows caused by broken or scattered cloud layers blocking the moons illumination can be seen on the terrain. Although clouds can decrease illumination and resulting luminance from the moon and stars, they can, especially if low and broken to overcast, reflect enough cultural lighting to help offset the loss of lunar illumination. Obviously, this will only occur in and around areas with significant cultural lighting and is only helpful if it is clear beneath the overcast.

2. FLIR Effects. The size of atmospheric particles also determines their effect on the FLIR. IR radiation is reflected (scattered) when its wavelength is less than or equal to the diameter of the particle. As previously discussed, far IR energy is easily absorbed by water molecules. It is possible for the FLIR to be either more or less susceptible to attenuation than NVGs depending on cloud conditions. The thermal signature of clouds can mask the terrain thermal signature due to scattered or emitted radiation. Beyond four microns, cloud radiation is due to the thermal emission of the cloud itself as well as reflected earth radiation. Even thin clouds can cause a distinguishable thermal self emission. Measurements made on clouds that were not thick enough to be seen visually, showed radiation in the 8 to 13.5 micron region. This means that the FLIR can detect ("see") clouds that may be invisible with NVGs or to the unaided eye. Cloud cover reduces contrast between sun heated surface elements. It acts like a blanket over the earth and tends to equalize the temperature of objects on the ground. Total cloud cover lasting several days can degrade the FLIR image by producing a washout effect. In some cases, this washout condition has been found to be desirable for the collection of tactical data, since most natural terrain features blend into a uniform background against which non-natural sources, such as military targets, can stand out strongly. On the other hand, this washout effect can be hazardous when depending on the FLIR for navigational information.

B. Fog

The effects of fog are similar to those of clouds. Generally, fog is distinguishable from clouds only in regard to distance from the ground. Particle size varies from 2 to 20 microns, which is very similar to a cloud. Typically, fog has fewer particles and a smaller range of particle sizes than clouds. Fall is the most likely season and early morning the most likely time to encounter fog. Urban areas tend to have less fog (probably due to urban heat islands) than rural and mountainous areas tend to have more fog than sites nearer sea level. Chances of fog increase as temperatures decrease and the dew point spread approaches zero.

1. AN/AVS-6 Effects. Since fog tends to stay close to the ground it is more a navigation hazard to rotary wing aircraft than to fixed wing aircraft. However, fog can mask or partially mask ridgelines and other navigational features making it more difficult to navigate or use funneling techniques in the target area. One way to note an increase in the moisture content of the air while utilizing NVGs is to observe a decrease in the intensity of ground lights. This is especially obvious if you are flying at an altitude high enough to use as a comparison ground lights that might be out of the area of increased moisture content. Also, the halo effect noted around lights when viewed directly with NVGs will tend to get larger and more diffuse in an area of increased moisture. The enhanced contrast in an area illuminated by ground lights will also be lessened or absent.

2. FLIR Effects. The discussion on NVG impact in the previous paragraph is also applicable to FLIR along with the following comments. Fog droplets have their greatest distribution of radii in the 5-15 micron band and will produce almost 100 percent scattering for the FLIR. Larger particles such as raindrops or snow will absorb as well as scatter far IR energy. Regardless, the end result is an attenuation of the FLIR image. Even with these adverse effects, the FLIR can “see” through this atmospheric obscurant better than the unaided eye, and under the right conditions, can still identify “hot spots” such as fires, operating factories, etc. This information may help in detecting targets, but due to the lack of detail surrounding these hot spots, the information will likely be of little help for navigating.

C. Rain

Like clouds, the performance of AN/AVS-6 and FLIR in rain is difficult to predict as droplet size and density are variable. All previous discussions on water vapor, clouds, fog, absorption and scattering are applicable here.

1. AN/AVS-6 Effects. Due to small droplet size and low density, light rains or mists cannot be readily seen with NVGs. However, contrast, distance estimation and depth perception will be effected due to light scattering and the resulting reduction in light level. Heavier rains will be more discernible due to luminance blocking and more obvious signs such as rain on the windscreen.

2. FLIR Effects. The effect of rain on the FLIR is similar to that of fog. Since the droplet size is larger than fog there will be relatively more absorption. But, like fog, there can be some information gained through a light rain or mist. However, with a heavier rain there will be significant attenuation. Also, constant rain over a period of time will cool surfaces to a uniform temperature and thus decrease the thermal contrast and ultimate scene discrimination.

D. Snow

Snow occurs in a wide range of particle sizes and geometric shape. Snow crystals, while small in size, are generally large in comparison to the wavelength of visible, near and far IR radiation and will easily block or scatter those wavelengths. However, snow will not normally degrade thermal signatures as much as fog and rain due to its lower particle density.

1. AN/AVS-6 Effects. As with other forms of moisture, the density of the flakes will determine how much illumination and luminance is blocked and therefore how much degradation occurs to the NVG image. Snow can occasionally be of help, however, in that it can reflect available light and thus enhance luminance when on the ground. Snow covering trees and rocks with some large rocks protruding through can add a degree of depth perception to an otherwise benign scene. Also, snow can add a slightly different texture that may aid in contrast discrimination. Due to the excellent reflectivity of snow, less illumination is required to give the same luminance for the subject without snow. That means the NVGs can see the terrain under lower light level conditions. This must be balanced against a lot of snow covering a large area. In this instance, the snow will tend to act like a large, flat and featureless bright picture for the NVGs. In addition, consideration should be given for the potential of "white out" when conducting landings in snow. The rotor induced "white out" will effectively block luminance and therefore, significantly impact the NVG image.

2. FLIR Effects. As with the other forms of moisture, the effect on the FLIR depends on the flake size and density. Due to the general size of snow flakes, most of the attenuation is caused by scattering of the thermal energy. Therefore, density of the flakes is of primary concern. For snow on the ground, the degree of attenuation will depend on how long it has been there. If it has been there long enough, it can cool surfaces to a reasonably uniform temperature and thus will attenuate 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 NVGs to work.

E. Sand / Dust / Other Obscurants

Sand or dust particle size and density will determine the overall affect on NVD performance. Obscurants can be intentional or unintentional. An unintentional example is factory smoke, whereas intentional examples include such things as battlefield smoke from oil fires or other chemical sources.

1. AN/AVS-6 Effects. The effect of blowing sand or dust is similar to that created by snow except that the particles are far less reflective and much larger. This condition is significant since dust / sand particles completely block the near infrared light from striking and reflecting from the terrain. Since there is less luminance, the scene is darker. As with snow, during vertical operations or with strong winds, there can be an almost total block of IR radiation resulting in a “brown out”. Artillery and/or bomb impacts in the right terrain would put large amounts of sand or dust into the air. The impact of battlefield obscurants on NVG performance is similar to those mentioned above and depends on particle size and density. NVG visibility “inside” these obscurants would be poor but should be balanced against the overall size of the cloud and its position relative to where you are and where you need to see.

2. FLIR Effects. The effects of sand, dust, or battlefield obscurant particles on FLIR visibility are similar to those of rain, fog or clouds in that the particle size will result in scattering of the IR radiation. Unlike precipitation that creates a uniform temperature over a period of time, the effects of sand or dust will diminish as their atmospheric concentration diminishes. The FLIR will continue to see "hotter" objects through sand or dust clouds depending of course on the relative temperature difference and atmospheric concentration of particles. While there may be limited information provided for navigation, targeting capability may still be retained. If the particle size is small, FLIR performance may not even be impacted. For example, FLIR visibility through diesel fog or oil smoke is very good. However, phosphorous smoke from a white phosphorous (WP) marking round or flares significantly hinders thermal transmission. Therefore, WP marks are easily seen by a FLIR. There are also special obscurants that are designed to block thermal signatures and serve as thermal camouflage.

F. Winds

Winds may affect the area of interest for NVGs and FLIR by increasing the density of particles in the air as well as the area of coverage. Wind has a unique impact on the FLIR as it can decrease the thermal contrast which reduces the FLIR systems image quality. For example, the scene of interest when covered with snow may lose its thermal contrast with one or two knots of wind. On the other hand, the scene of interest in a warmer environment may maintain adequate thermal contrast, and thus image contrast, with much higher winds.

G. Lightning

Lightning will temporarily increase illumination. Looking directly at it will cause NVGs to shut down briefly. However, when not looking directly at it, lightning will briefly illuminate the area giving you an enhanced NVG image albeit for a short duration. The brief duration and enhanced image clarity can create the impression that objects are much closer than they really are. Whether it is a help or hindrance depends on the frequency of lightning and its source relative to your flight path. Since lightning has no particulate matter and does not affect thermal contrast, it will not affect the FLIR image.

V. Summary

NVGs and FLIR function using different principles and use different wavelengths. This can result in one of the NVD systems performing better than the other under certain environmental conditions. In some instances, both NVDs could be adversely affected. This complimentary nature is one reason night systems communities decided on this combination of sensors. The overall ability of NVGs and FLIR to use EM energy is a function of both atmospheric absorption and scattering. This includes differences in particulate size and concentration. FLIR performance can be predicted to some degree by knowing the absolute humidity in the area of interest. NVG performance can best be predicted by knowing the illumination level, moon angle and weather. Atmospheric conditions can attenuate both NVG and FLIR performance. The degree of attenuation will depend on factors that are difficult to predict and will, most probably, vary considerably during the sortie. If the weather is bad, don't go. If the weather is good enough to launch an attempt, experience with the systems and their response to the atmospheric conditions will dictate the decision to continue or abort. Therefore, it is important during training to gain an understanding of what conditions affect the sensors and to what degree each is affected.

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Chapter 2

Night Vision Goggle (NVG) Technology

I. Introduction

An examination of the history and evolution of the night vision goggle (NVG) is important before discussing any specific night vision device. In the mid-1960's, U.S. forces began looking for ways to overcome darkness on the battlefield. This effort was aimed not so much to optimize it toward their advantage, but to deny its use to the North Vietnamese. U.S. forces began with searchlights, simple and effective, but hardly designed for rapid maneuver and (worst of all) quite conspicuous. The need for enhanced night vision capability became evident as U.S. forces pinpointed their position to the enemy when trying to illuminate for themselves. An intermediate answer came in the form of near-infrared searchlights and viewers. These were relatively simple and provided U.S. forces with a means of viewing the battlefield without visible light. Unfortunately, the simplicity of the viewers' image converter tubes soon made them common place, for both sides, and U.S. forces once again found themselves illuminating their own positions. What they really needed was a night sighting device that did not emit a traceable signature. That design objective lead to the present day emergence of the image intensifier (I^2) tube.

II. Image Intensifier (I^2) Tube and NVG Technology

An image intensifier is an electro-optical device used to detect and intensify energy in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. Reflected energy from the terrain (luminance) enters the NVG and is focused by the objective lens onto a photocathode. The photocathode is sensitive to portions of both the visible and near IR portion of the EM spectrum. The incident photons (particles of light) that strike the photocathode cause a release of electrons from the photocathode. The number of electrons released from the photocathode is proportionate to the number of photons incident upon photocathode. The NVG power supply accelerates the resultant electrons away from the photocathode surface it's the electrical field. The accelerated electrons are ultimately directed toward and strike a phosphor screen. This phosphor screen emits an amount of light proportional to both the number and the velocity of electrons that strike it. Therefore, the electrical field applied between the photocathode and the phosphor screen serves to further accelerate the electrons and results in an increase in brightness of the NVG intensified image presented to aircrew. The intensified image is ultimately focused back onto to the operator's eye by use of the NVG eyepiece lens, Figure 2-1. The next several sections will be dedicated to a detailed description of I^2 tube technology and the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS).

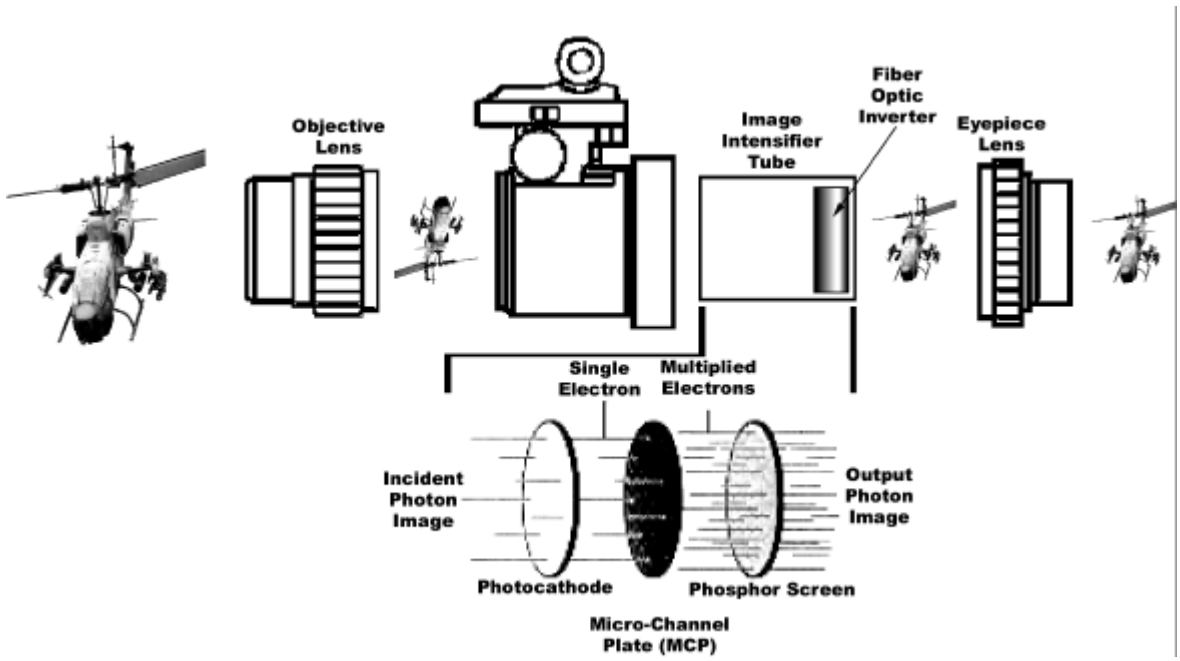

Figure 2 - 1. Image Intensifier Technology

A. Image Intensifier Tube Technology

The internal components of an I^2 tube includes the photocathode, the microchannel plate (MCP: found on Gen-II and higher I^2 tubes) and the phosphor screen, Figure 2-1. Image intensifier (I^2) generation terminology is typically used to identify and categorize the technological progression of these components and the materials used to manufacture I^2 tubes (i.e., microchannel plate, Gallium-Arsenide photocathode, etc.). A general overview is provided to summarize the development of these generation specific I^2 tubes. A more in-depth description of the I^2 components will be provided in the section covering the AN/AVS-6 ANVIS NVG.

1. First Generation (GEN-I) Image Intensifiers. First generation technology was introduced with the development of the starlight scope used by snipers in Vietnam. These systems attained high light level gains by means of a three-stage configuration of the simple image intensification tube (Figure 2-2). These I^2 tubes did not possess the microchannel plate (not yet developed), therefore relied solely upon a photocathode / phosphor screen stack array to achieve amplification or gain. The three-stage coupling provided gains in the range of 40,000 to 60,000 (compared to gains of 40-60 attained in a single stage tube). First generation tubes are very durable and have a very long life, well into the ten thousand hour range. However, they did possess significant deficiencies. First, they were extremely susceptible to "blooming." Blooming is a tendency for the tube to degain if a bright light source appears anywhere in the devices' field of view. As a result, the overall contrast of the intensified image is greatly reduced. In addition, first generation tubes required relatively high voltages to attain the necessary energy levels for light amplification. The weakest parts of the first generation system were the 6.75-volt battery and the oscillator module that converted the battery energy to an alternating current source for the intensifiers power supply. Probably the most significant drawback encountered with the

first generation devices was their size. The starlight scope, for instance, is about a foot long. This is fine for snipers but useless for pilots.

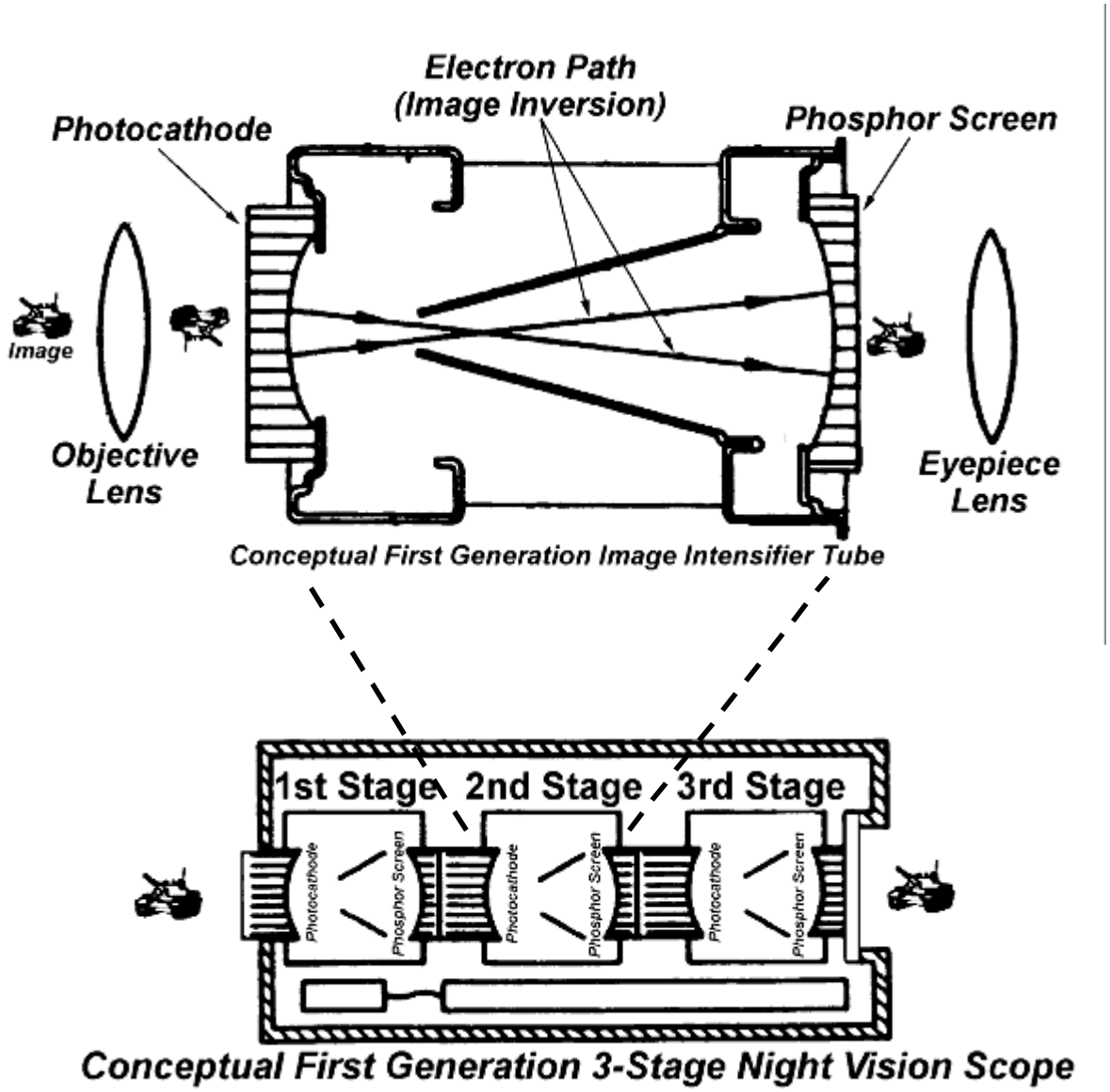

Figure 2 - 2. First Generation (GEN-I) I^2 Tube Technology

2. Second Generation (GEN-II) Image Intensifiers. Second generation I^2 tubes were the first tubes small enough to be placed into systems that could be head mounted. Much of the size invested in the first generation tube was necessary due to the voltage required for sufficient electron velocity to produce the desired gain. But remember, the amount of light produced by the I^2 tube is proportional to both the number and velocity of electrons that strike the phosphor screen. Therefore, by increasing the number of electrons, the required velocity of those electrons may be decreased to achieve the same gains. Essentially, this is the concept led to the development of the microchannel (MCP) and proximity focus in the construction of the second generation I^2 tube, Figure 2-3. In addition, by reducing the distances between these I^2 tube components, little or no image distortion exists. Image distortion occasionally occurred in first Generation I^2 tubes by the influence of stray

magnetic fields acting on the electrons. Second generation tubes are still somewhat susceptible to "blooming" when exposed to a bright light source. However, this tendency was better with the introduction of the MCP. Whereas first generation devices suffered saturation of the entire field of view when exposed, the MCP allows the saturation to be confined to individual channels; thus, contrast degradation is localized. This localized saturation appears as an NVG image "halo" around a bright light source. This NVG image halo effect will degrade the contrast of adjacent portions of the intensified image. Generally, at medium light levels the second generation tubes can be operated for 2,000 to 4,000 hours. This is a marked reduction in durability as compared to the 10,000 hour service life with first generation tubes. Furthermore, the I^2 tube gain associated with second generation tubes is somewhat lower than that of the first generation systems; 10,000 vice 40,000 to 60,000. It is important to point out that there are no inherent qualities in second generation I^2 technology that would lead to improved resolution. Nevertheless, the improvements in second generation technology associated with miniaturization and its accompanying adaptability for head mounted applications use clearly offset its comparable shortcomings.

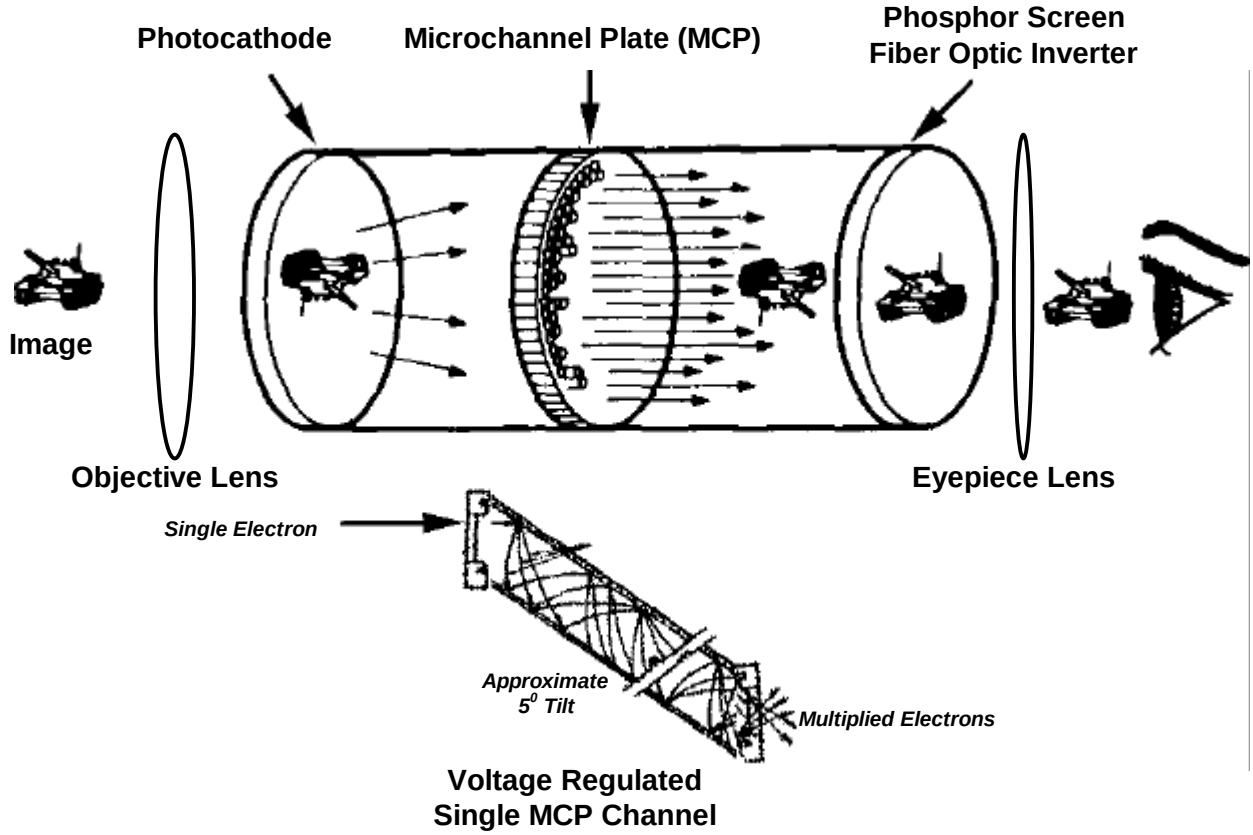

Figure 2 - 3. Second Generation (GEN-II) I^2 Tube Technology

3. Third Generation (GEN-III) Image Intensifiers. There are only two major changes that mark the difference between second and third generation I^2 tubes. The GEN-II multi-alkali photocathode (S-20) was replaced by a gallium arsenide (GaAs) photocathode and an aluminum oxide film was applied to the MCP. These results led to significant performance enhancements over previously developed I^2 tubes. Low light level performance is significantly improved as a result of the increased photocathode sensitivity. The spectral response of the GaAs based photocathode matches the available illumination in the night sky, thereby truly providing the first starlight capable systems for aviation use, Figure 2-4. The aluminum oxide film increases service life to equal the first generation I^2 tubes (reliability of greater than 10,000 hours). The addition of the aluminum oxide film to the MCP of the third generation tube directly offsets shortened service life of the photocathode due to ion bombardment. The film is transparent to electrons. Therefore, the electrons pass from the photocathode to the MCP just as before. However, the film is not transparent to ions. They are trapped in the aluminum oxide film and prevented from contaminating the photocathode. The only repercussion encountered with the introduction of the aluminum oxide film is a voltage increase between the photocathode and the MCP. This, in turn, requires increased spacing between the two components to prevent arcing. This spacing causes an increased halo size when viewing bright light sources. Although dramatic increases in I^2 tube performance have been realized throughout the 1990s, all current fleet AN/AVS-6 NVGs are still considered to be third Generation or GEN-III.

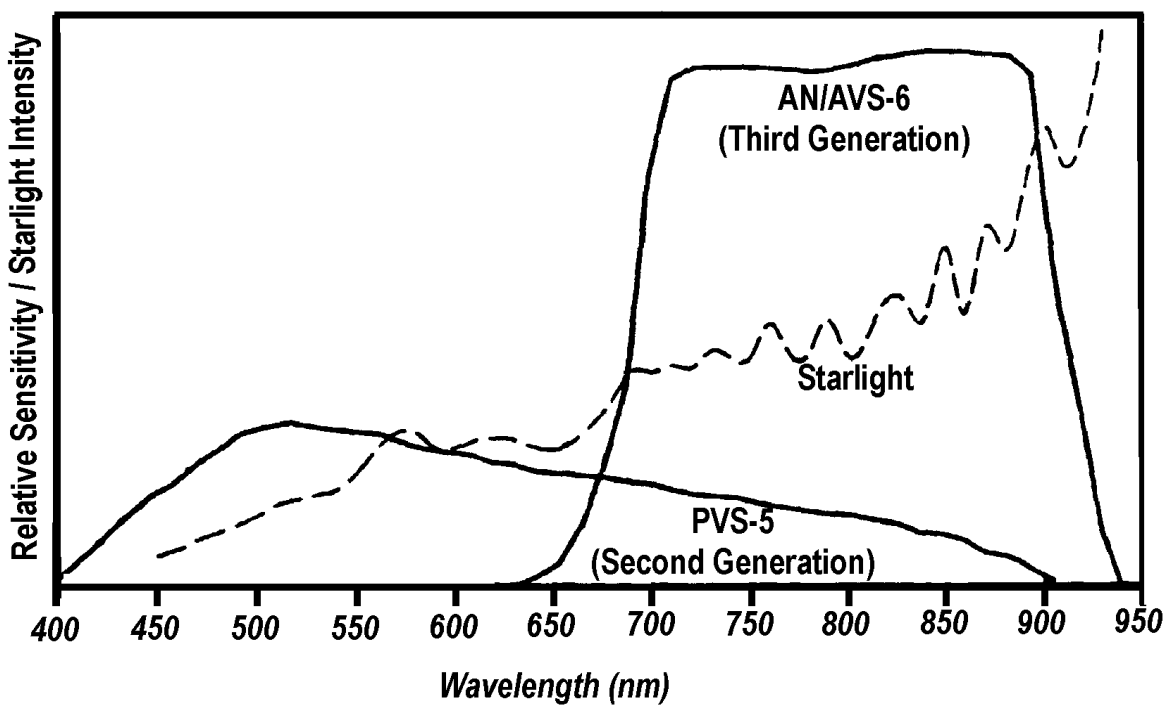

Figure 2 - 4. Third Generation (GEN-III) I^2 Tube Technology

B. AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS)

As indicated by its name, the AN/AVS-6 ANVIS was the first NVG designed from the start for aviation use. The AN/AVS-6 NVG is a third Generation NVG that was phased into USMC and USN service in large numbers between 1988 and 1990 under the DAAB07-88-C-F100 and follow-on Omnibus-II procurement contract to replace the aviation adapted second Generation AN/PVS-5 NVG. The AN/AVS-6 ANVIS is comprised of three primary components: (1) binocular assembly, (2) V-1B (formerly V-3) quick don block mount and (3) power pack, Figure 2-5. The operational, mechanical and optical specifications for the AN/AVS-6 are provided in Table 2-1.

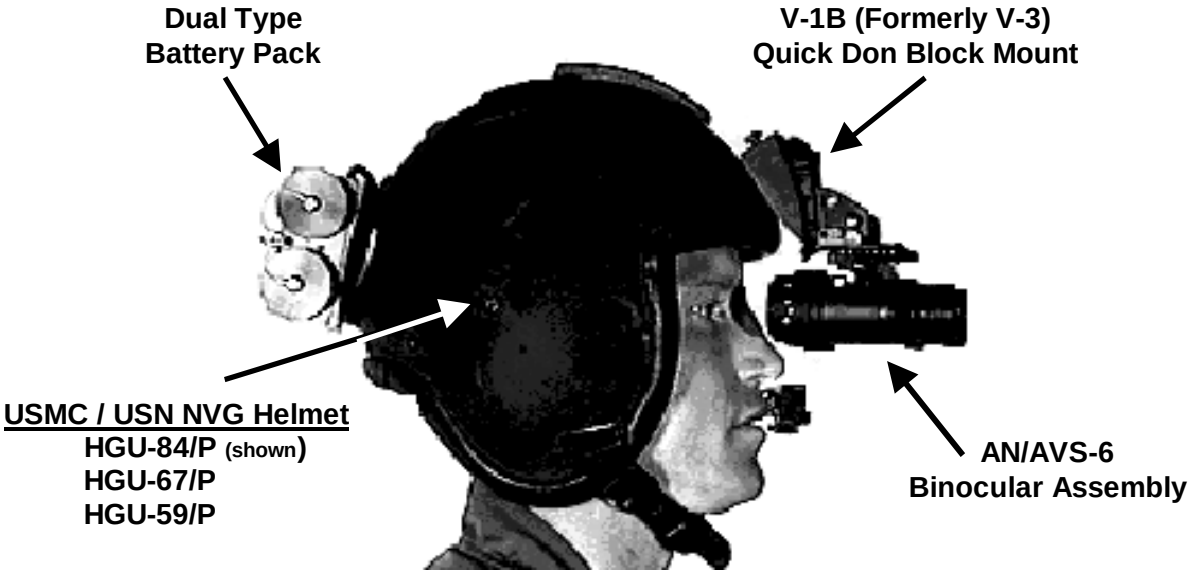

Figure 2 - 5. AN/AVS-6 System Components

TABLE 2 - 1. AN/AVS-6 OPERATIONAL, MECHANICAL AND OPTICAL SPECIFICATIONS

Operational Adjustment AN/AVS-6 Characteristic	Specification
Vertical	16mm Total Travel
Fore and Aft Adjustment	**Single PAS**: 16mm Total Travel **Dual PAS**: 27mm Total Travel
Eye Span	52 to 72mm
Tilt	8 to 10° Total Travel
Eye Relief	**15mm Eyepieces**: 15mm / **25mm Eyepieces**: 25mm
Mechanical AN/AVS-6 Characteristic	
Binocular Assembly Weight	**15mm Eyepieces**: 550 gm (19.4 oz) **25mm Eyepieces**: 590 gm (20.8 oz)
Binocular Assembly Breakaway Force	10 to 15G
Optical AN/AVS-6 Characteristic	
Eyepiece Focus Range	+2 to -6 Diopters
Objective Focus Range	28cm (± 3cm) to Optical Infinity
Magnification	Unity (1X)
Field of View	40^{0}

This systems oriented section will provide a brief overview of the three components that comprise the AN/AVS-6 ANVIS. A more detailed description of the AN/AVS-6 binocular assembly components and associated performance is provided in follow-on sections.

1. AN/AVS-6 Binocular Assembly. The binocular assembly consists of two identical monocular assemblies that house the I^2 tube and optics of the NVG. In addition, the binocular assembly possesses five adjustment controls, Figure 2-6. Table 2-2 is provided to review the functionality of each adjustment.

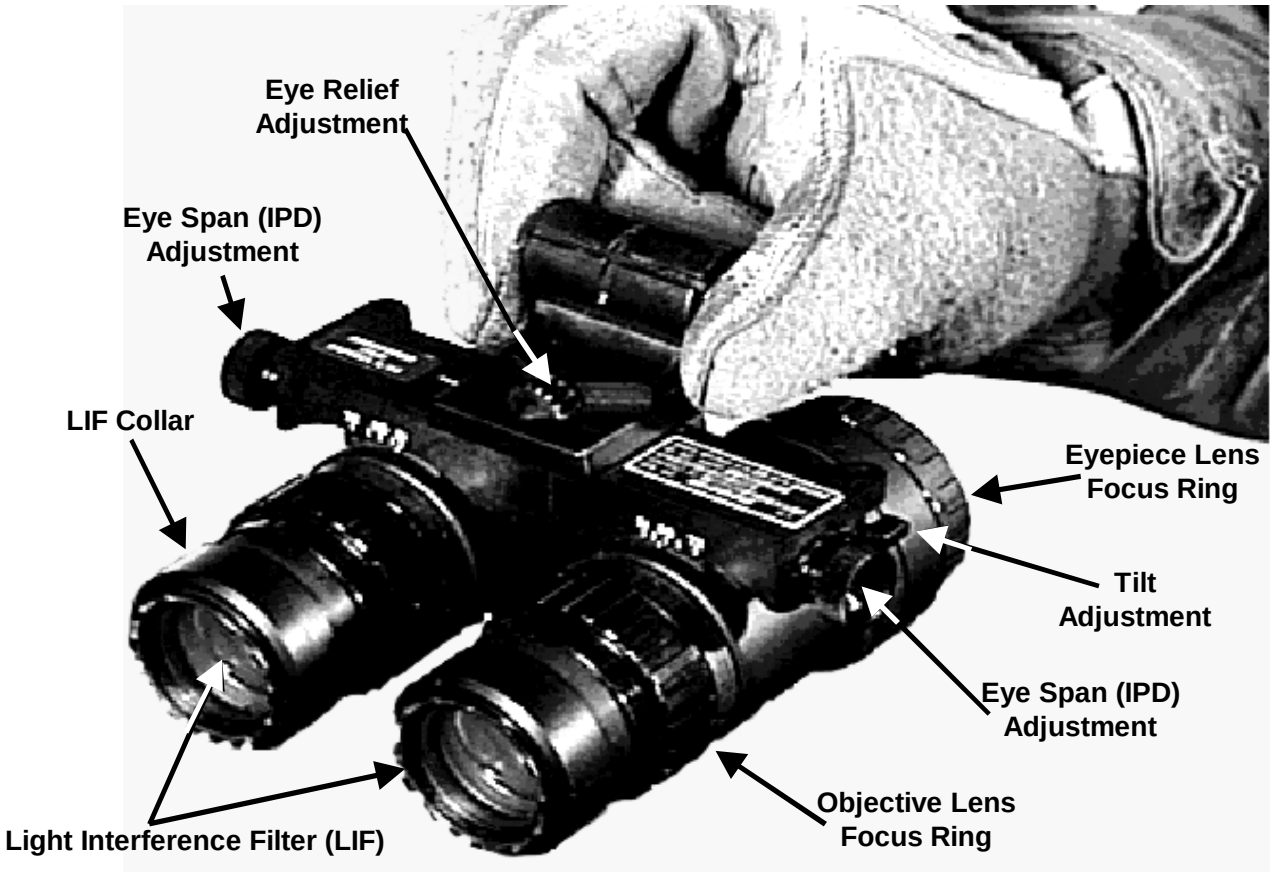

Figure 2 - 6. AN/AVS-6 System Components

2. V-1B (formerly V-3) Quick Don Block Mount. The V-1B quick don block mount allows mounting of the of the AN/AVS-6 ANVIS binocular assembly to either the HGU-84/P or HGU-67/P aircrew helmet. The mount possesses the vertical adjustment control, the lock release button and the low battery indicator, Figure 2-7 and Table 2-2. The low battery LED indicator located on the bottom of the mount will illuminate when battery voltage drops below 2.4 volts, signaling the user that remaining battery life is approximately 30 minutes. Dependent upon the power pack used, this indication will either be a blinking or steady red light. In addition, the AN/AVS-6 V-1B mount also allows the binocular assembly to "break away" from the helmet during a crash load of 10 to 15Gs.

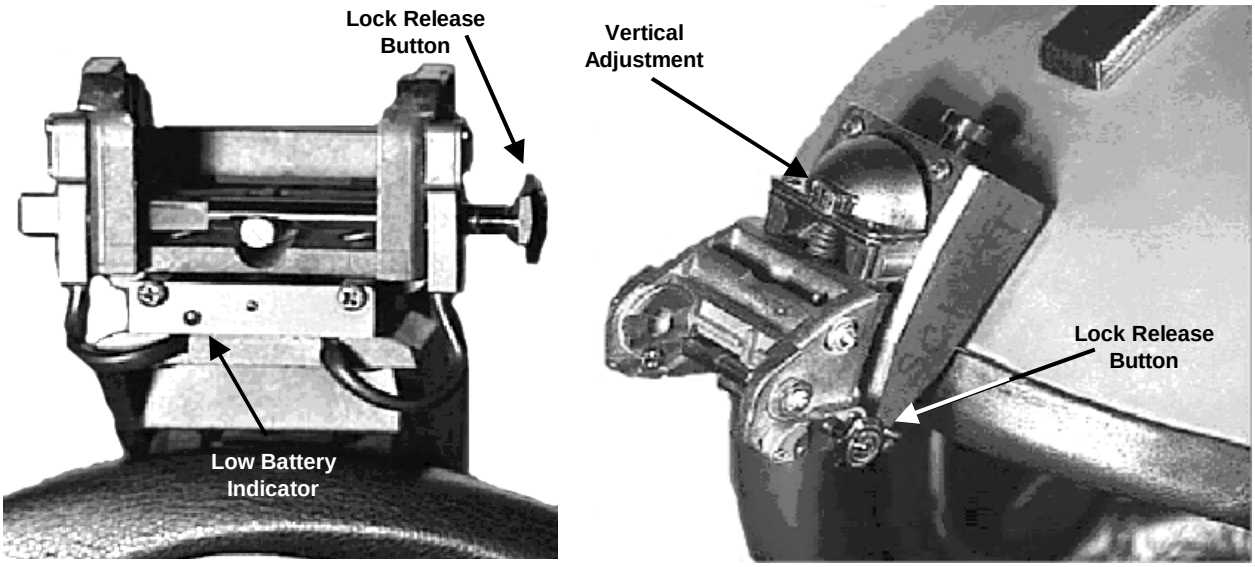

Figure 2 - 7. V-1B Quick Don Block Mount

TABLE 2 - 2. AN/AVS-6 AIRCREW ADJUSTMENTS AND INDICATORS

Controls and Indicators	Function
Power Switch (ON / OFF / ON)	**ON**: binocular on - power drawn from battery compartment to which switch points **OFF**: binocular off **ON**: binocular on - power drawn from battery compartment to which switch points
Objective Focus Rings (28cm to Optical Infinity)	Focuses the objective lenses. Adjust sharpest view of scene. Travel for the objective lens focus ring is 1/3 turn.
Eyepiece Focus Rings (+2 to –6 Diopters)	Focuses the eyepiece lenses. The eyepiece lens focuses the intensified image from the I^2 tube back to the retina. Focus can compensate for refractive errors, however not for astigmatism. Adjust for sharpest image. Travel of eyepiece focus ring ranges from +2 to –6 Diopters. Movement of the fore-and-aft adjustment requires readjustment of the eyepiece lens focus ring.
Eye-span (IPD) Adjustment Knob (51 to 72mm)	Adjusts for operator eye span or interpupillary distance (IPD). **Single IPD PAS**: single knob controls both monoculars **Dual IPD PAS**: independent control of each monocular
Fore-and-Aft Adjustment Knob (Eye Relief) (15 or 25mm)	Adjustment for optimum viewing of the field of view. Turn the knob to obtain a full view of the intensified image. Adjust fore-and-aft to 15mm or 25mm (dependent upon eyepiece lens) to maximize the field of view, yet maintain your peripheral view and "look under" capability.
Vertical Adjustment Knob (16mm Total Travel)	Moves the binocular up or down in a vertical direction. Turn the knob to center the eyepieces in front of the eyes.
Tilt Lever (8 to 10^0 Total Travel)	Allows the binocular to be tilted up or down. Moves the lever to obtain the optimum line-of sight viewing.
Lock-Release Button	Press the lock-release button to rotate the binocular from the stowed position to down and ready for flight position.
Low-Battery Indicator (Steady or Flashes)	When illuminated, it indicates a low battery condition with at least 30 minutes of battery life remaining (lithium battery).

3. NVG Power Sources. There are two types of power packs that are compatible with the AN/AVS-6. Both types of battery packs consist of a housing that contains a primary and redundant battery power source and a three position switch (Figure 2-8). The difference between the battery packs is determined by the type of batteries they can accept. The initial style of battery pack was delivered with the first shipment of AN/AVS-6 and will accept only 3.0 lithium-sulfur dioxide batteries (Original Type). AN/AVS-6 deliveries since 1989 have included a battery pack that is capable of using either the 3.0 volt lithium or two AA alkaline batteries (Dual Battery Type). In addition, some of the new Dual Battery Type power packs possess a new circuit card that makes the low battery indicator blink vice giving a steady red light when the battery voltage drops to 2.4 vdc. This signals to the user to switch the ON/OFF/ON switch on the power pack to the reserve battery compartment. The following battery considerations are provided to ensure aircrew possess a safe, effective and reliable power supply for their AN/AVS-6 NVG.

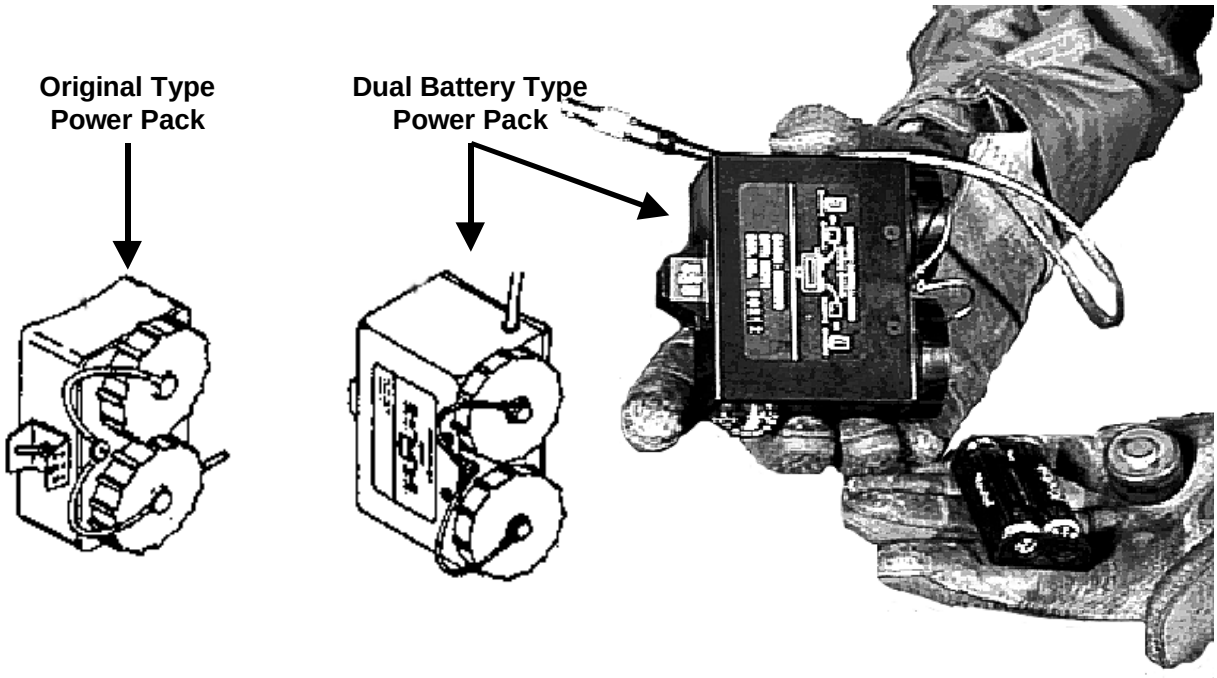

Figure 2 - 8. AN/AVS-6 Power Packs and Batteries

(a) The AN/AVS-6 can be powered by either a 3.0 volt lithium-sulfur dioxide battery (BA-5567/U) or by two 1.5 volt AA alkaline battery (BA-3058/U). The service life of each battery will be affected by environmental temperature. Table 2-3 summarizes the performance capabilities of each battery type.

<<NOTE>>

Alkaline batteries possess a much flatter discharge rate than lithium batteries. A 1997 U.S. Army Aeromedical Research Laboratory report (USAARL No. 97-07) that evaluated alkaline AA battery performance demonstrated no drop-off in AN/AVS-6 image brightness and quality for several hours (5 to 10 hours) following activation of the AN/AVS-6 low battery indicator (2.4 volts). At a minimum, it is recommended that aircrew fly the AN/AVS-6 with one set of new alkaline batteries installed on the back-up side of the battery pack (alternate). The older set of batteries (non-expired, greater than 2.4 volts batteries) placed on the power-on side of the battery pack (primary).

TABLE 2 - 3. AN/AVS-6 ELECTRICAL DATA

Characteristic	Data
Voltage Requirements	3.0 vdc Nominal
Current Drawn by Binocular	400 mA Peak. 100 mA Steady State
Battery, Lithium (BA-5567)	
Voltage	3.0 vdc
Cell Life (one battery)	Until low-battery indicator turns on
100^0 F	13 to 16 Hrs
70^0 F	13 to 16 Hrs
0^0 F	9 to 12 Hrs
-20^0 F	5 to 8 Hrs
Battery, AA, Alkaline (BA-3058)	
Voltage	1.5 vdc (two batteries required for 3.0 vdc)
Cell Life (two batteries)	Until low-battery indicator turns on
100^0 F	10 to 22 Hrs
70^0 F	10 to 22 Hrs
0^0 F	5 to 10 Hrs
-20^0 F	1 to 3 Hrs

(b) One safety 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 pressure too high. Venting may be sensed through smell, the sound of gas escaping, or through irritation of the eyes. When safety vents have operated, batteries must still be handled with care when removing them from the power pack. There is about 0.35 grams of lithium in the BA-5567/U battery. Therefore, the lithium battery does not require special handling for transportation IAW DOT Title 49 CFR 173.206(f) and paragraph 7-21a(17) of AFR 71-4/TM 38-250/NAVSUP PUB 505/MCO P4030.19D/DLAM 4145.3(C6) 12 DEC 86. However, disposal requirements for lithium batteries vary from state to state. Prior to disposal of any lithium batteries, check with the squadron Hazardous Material Control Representative or base environmental office for local disposal procedures. Several documented cases of thermal runaway with lithium batteries have occurred. Lithium batteries should be stored in a place where metal, such as coins, or moisture cannot make contact with the battery. Metal objects can cause the batteries to short circuit and become very hot. In the case of BA-5567 lithium batteries, a short circuit could cause them to explode.

<< WARNING >>

Do not heat, puncture, disassemble, short circuit, attempt to recharge, or otherwise tamper with the lithium-sulfur dioxide battery. Turn off the NVG if the battery compartment becomes hot. Wait until batteries have cooled before removing them. Do not use mercury or rechargeable NiCad batteries. Using these batteries could result in a system failure.

C. AN/AVS-6 ANVIS Binocular Assembly Components

In contrast to the generation terminology discussed in section II.A to define I^2 tube technology, Omnibus nomenclature (acquisition term) is used to categorize or describe NVGs, I^2 tubes, and associated components with reference to the precise specifications of the procurement contract under which they have been purchased. Currently, the AN/AVS-6 inventory is undergoing an upgrade conversion to the Omnibus-III (1992 to 1998) NVG system configuration through supply component replacement by attrition (exception: USMC KC-130 community). This Omnibus component upgrade transition through attrition process limits the ability of the fleet operator to rely solely upon the NVG overt physical appearance to accurately predict, plan and brief NVG mission performance capabilities. By relying on the retrofit by attrition procurement approach, AN/AVS-6 NVG configuration control has become nonexistent, whereby, a single component Omnibus-III upgrade to a NVG does not signify or translate to a complete NVG system retrofit upgrade. For example, if the NVG eyepiece lenses have been upgraded to the Omnibus-III contract specification (25mm eyepiece lenses), this does not automatically dictate that the NVG possesses the other additional Omnibus-III upgrades (i.e., Omnibus-III I^2 tubes, etc.). The NVG aircrew performance significant components that are affected by the Omnibus-II to III and likely follow-on Omnibus-IV retrofit by attrition acquisition process include; (1) the objective lenses, (2) eyepiece lenses (Omnibus-II: 15mm or Omnibus-III: 25mm diameter), (3) position adjustment shelf or PAS (Omnibus-II: Single or Omnibus-III and IV: Dual), and (4) I^2 tube (Omnibus-II, III, IV), Figure 2-9. The following component discussion is provided to highlight these differences and to overview AN/AVS-6 system design characteristics.

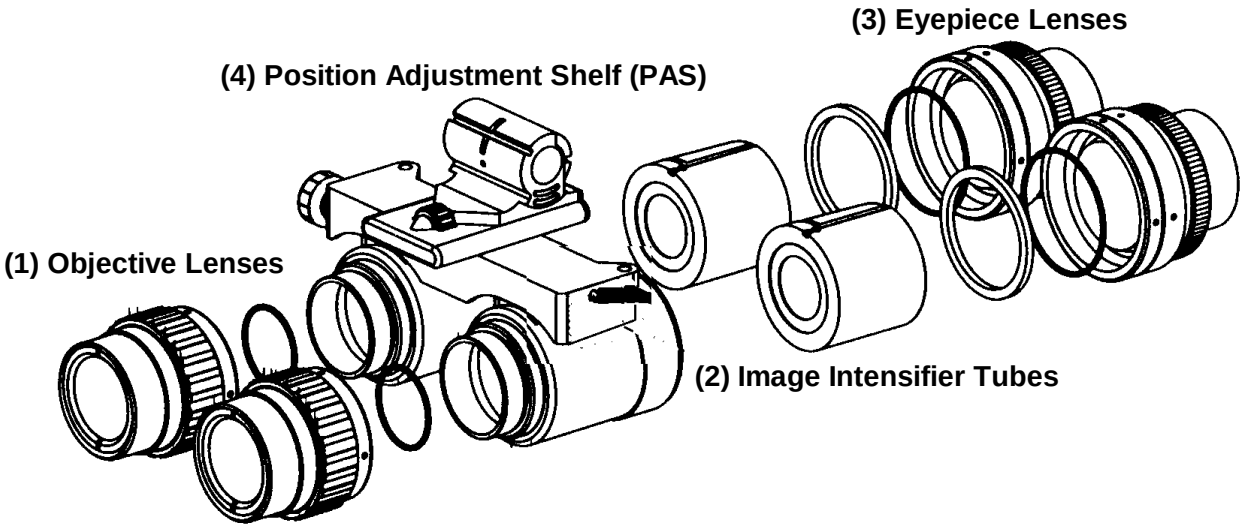

Figure 2 - 9. AN/AVS-6 Binocular Assembly Components

1. Objective Lens. The AN/AVS-6 objective lens is actually a combination of optical elements that function to focus the incoming photons of energy onto the I^2 tube's photocathode. The AN/AVS-6 objective lens can be focused from approximately ten inches (specification: 28cm ± 3cm) out to optical infinity (approximate hyperfocal distance beyond 100 feet). Although the objective lens possesses a large range of focus, the depth of field dramatically decreases at short distances. Therefore, as aircrew optimize the NVGs for flight (optical infinity) and glance inside the aircraft looking through the NVG or view objects a short distance away, the objects will appear out of focus. A more significant

design attribute of the objective lens that dramatically impacts NVG performance is the minus blue objective lens filtering. Some second generation and all third generation NVGs have incorporated this special coating on their objective lenses to reduce interference from aircraft cockpit lighting schemes. This NVG "minus blue" objective lens filtering facilitates aircraft cockpit and display compatibility by restricting the spectral content of energy entering the intensification process, thereby allowing the use of cockpit lighting that will not adversely affect NVG gain and ultimately, NVG image quality. This objective lens characteristic can be readily observed by looking at the AN/AVS-6 objective lenses. The objective lenses appear blue. This results from the lens filtering that "rejects" energy with a wavelength less than 625nm. This "rejected" energy appears blue to the unaided eye. Military Specification MIL-L-85762A categorizes objective lens filters as CLASS-A (blue and green primarily) or CLASS-B (blue/green/reduced red), based on the specific objective lens filter spectral transmission characteristics. Presently, CLASS-A NVG compatible cockpit lighting schemes are used for USMC and USN Assault Support/Rotary Wing aircraft, while Class-B lighting schemes are used for USMC/USN TACAIR night attack aircraft. Per the MIL-85762A, Class-A and B compatibility is defined as NVGs that utilize either "625" or "665nm" minus blue objective lens filters that possess the specific transmission characteristics presented in Table 2-4. USMC/USN TACAIR aircraft communities chose Class-B aircraft cockpit lighting schemes to allow NVG compatibility with their Multi-Purpose Color Displays (MPCDs). A MPCD uses display colors that would shutdown (degain) a Class-A NVG (AN/AVS-6) due to the inband sensitivity that would occur above 625nm. However, with the Class-B filtered TACAIR MXU-810/U or AN/AVS-9 NVG, the objective lenses are filtered to be compatible. Although the Class-B filtering allows less energy to reach the NVG I^2 tube, performance differences between the Class-A and Class-B configured NVGs are negligible. For Assault Support aircraft communities, the future introduction of MPCD and Digital Moving Maps that use additional color schemes may drive the AN/AVS-6 to a Class-B filtering scheme to ensure NVG compatibility with these color displays.

TABLE 2 - 4. MILITARY SPECIFICATION NVG MINUS BLUE OBJECTIVE LENS FILTERING

Assault Support Class-A Wavelength (nm)	TACAIR Class-B Wavelength (nm)	Transmission (Percent)
450 to 550	450 to 585	0.05% Absolute Maximum
600	635	5% Absolute Maximum
625 to 655	653 to 671	50% Transmission Point
655 to 705	671 to 725	50% Absolute Minimum / 80% Average
705 to 1,000	725 to 950	85% Absolute Minimum / 90% Average

2. Image Intensifier (I^2) Tube. The three primary components of the I^2 tube are the photocathode, microchannel plate (MCP) and the phosphor screen. Dramatic performance variation exists between the AN/AVS-6 NVGs dependent upon the Omnibus procurement lot of the I^2 tube. The following overview is provided to highlight these differences.

(a) Photocathode. The photocathode is responsible for converting the incoming visible and NIR energy into electrical energy in the form of electrons. The photocathodes utilized in I^2 tubes are processed or "grown," by vaporizing several elements in a vacuum chamber and depositing them on the vacuum side of the transparent input window before the vacuum seal is made. Photocathode growing is a very delicate process in which the quality and type of the crystals grown directly affects the gain and sensitivity of the I^2 tube. First and second generation I^2 tubes use the S-20 multi-alkali photocathode that provides broad sensitivity between 400-850nm with a peak from 500

to 600nm (Figure 2-4). Since the sensitivity of the photocathode extends into the near infrared, they are able to detect energy in that region which is invisible to the human eye. The gallium arsenide photocathode in the third generation tubes surpasses the photosensitivity of the S-20 multi-alkali photocathode beyond 550nm and has a photo-response from approximately 600-900nm. This is significant since the night sky spectral irradiance is 5 to 7 times greater in the region of 800-900nm than in the visible region near 500nm. In engineering terms, the sensitivity of the third generation photocathode ranges from 1,000 to 1,800 micro-Amps (μA) /lumen (lm), as compared to the 250-550μA/lm range of the second generation photocathode. It is easy to become entangled in these numbers, but the end result is that the third generation tube is far more sensitive in the region where near infrared light from the night sky is plentiful.

(b) Microchannel Plate. The ultimate output from the phosphor screen is determined by both the velocity and the number of incident electrons striking the screen. Second and third generation image intensifiers use an I^2 tube component known as a microchannel plate (MCP). The MCP (Figure 2-3) is a very thin (1mm) wafer comprised of millions of tiny glass tubes or channels. The MCP is located between the photocathode and the phosphor screen. Electrons exiting the photocathode are channeled first through the MCP. The inside passages of the MCP tubes are coated with a material that causes secondary electron emissions. The tiny glass tubes are tilted, typically at an approximate 5^0 bias angle, to ensure a first electron impact near the channel entrance. As each electron strikes a wall, more electrons are emitted from the wall, each of which will in turn strike the wall again, creating a cascading electron multiplier effect. As a result of this process, for each electron that enters the a MCP, 1,000 or more will exit. These electrons are in turn accelerated forward, maintaining their relative spatial position, until they strike and excite the phosphor screen. The development of the Omnibus-IV I^2 tube introduced a MCP that possessed an increased the number of channels (greater than 6 million). This had a dramatic effect on both the I^2 tube resolution and the impact of point light sources on the NVG image. By increasing the number of channels and subsequently decreasing the size of the channels, the image is broken down into finer elements (i.e., pixels), thereby enhancing resolution. Additional increases in resolution were realized as the I^2 tube components were able to be moved closer together, thereby decreasing the distortion of the image field as it transverses through the I^2 tube. Increased gain is also achieved in part due to the increased number of multiplier channels. For aircrew operating in the MOUT environment, the increased number of MCP channels will breakdown an incompatible point light source into smaller elements, thereby limiting the saturating effect on the NVG image. The ability to "see into NVG image halos" exists for the AN/AVS-6 NVGs possessing Omnibus-IV I^2 tubes.

(c) Phosphor Screen. The phosphor screen is a very thin layer of phosphor applied to the input window of the fiber optic output bundle. The underlying function of the phosphor screen is to convert electrical energy back into a visible image for aircrew to view. Phosphors emit light when they are struck by electrons. The output wavelength and ultimate aircrew perceived color of the NVG image is a direct result of the type of phosphor used. Most early AN/AVS-6 I^2 tubes used P-20 phosphor that emits a yellow-green light at a peak output of 560nm and matches the peak sensitivity of the photopic human eye. I^2 tube manufacturers transitioned from P20 to P22 phosphor in order to eliminate the use of Cadmium (environmentally hazardous). Subsequent transition to P43 phosphor (Omnibus-IV I^2 tubes) was stimulated by both environmental purposes and by the desire to reduce optical chromatic aberrations and possibly, to reduce NVG

optical component size and weight by using a narrow band output phosphor (P43). In addition, the P43 phosphor's shorter persistence reduces NVG image streaking or "comet tails" typically created while viewing bright light sources through the NVG. The P43 phosphor is not new for military applications, but is currently used for the F/A-18's HUD and the AH-64's helmet display unit. The P43 phosphor spectral output exhibits a primary peak output in the green ($l = 550nm$) with three secondary output spikes in the blue-green ($l = 490nm$), yellow ($l = 590nm$), and red ($l = 630nm$) region of the color spectrum. The end result is an output image that presents a distinctly yellow tint (lighter green) when compared to the standard green image present with I^2 tubes that use either a P20 (Omnibus-II/III) or P22 (Omnibus-III) phosphor, Figure 2-10.

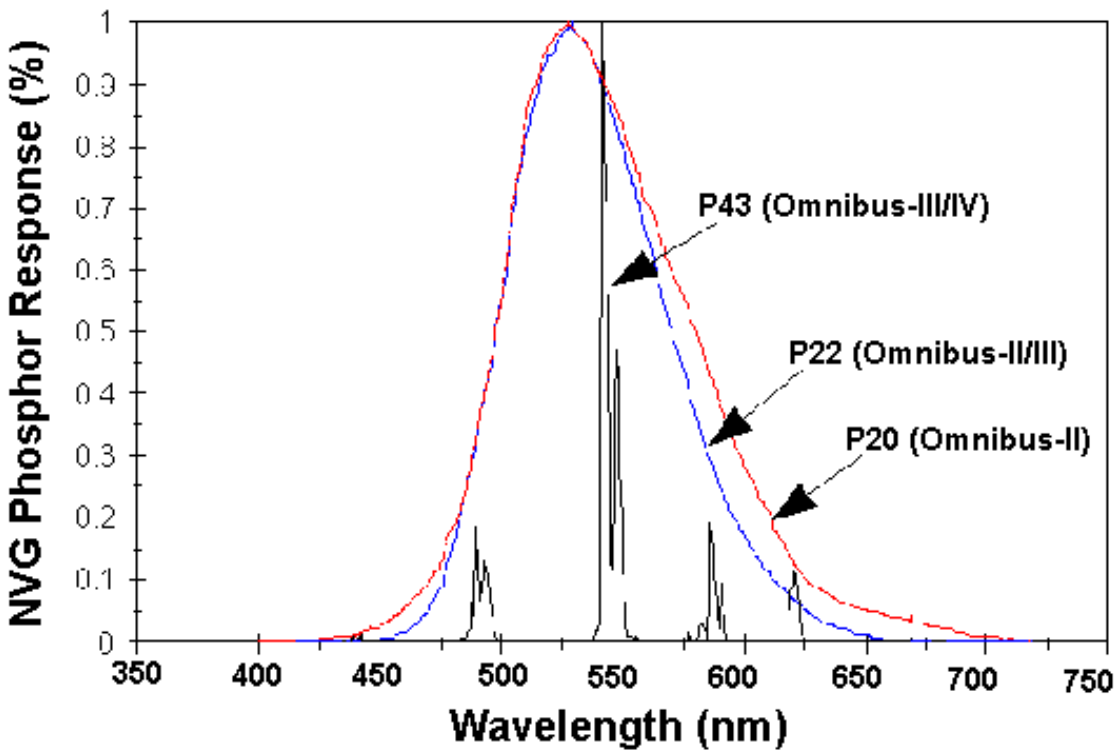

Figure 2 - 10. I^2 Tube Phosphor Spectral Output

(d) Fiber Optic Inverter. In first generation devices, sufficient spacing exists between the photocathode and phosphor screen to allow for image inversion to occur as electrons actually crossover in the middle of the tube (Figure 2-2). This spacing, however, is not available in second and third generation devices where the photocathode, MCP, and phosphor screen are in "proximity focus." That is, they are located very close to each other, providing the miniaturization necessary for a helmet mounted system. With these systems, image inversion is accomplished by attaching the phosphor screen to what is referred to as a fiber optic inverter. This inverter is actually a bundle of millions of microscopic light transmitting fibers. In second and third generation systems, the fiber optic bundle is heated and given a 180 degree twist providing the needed inversion to produce an upright image without requiring a second lens assembly. The fiber optic inverter also collimates the image, making the image at the eyepiece lens appear to be at the appropriate distance from the viewer. Without collimation, the eye's focus would

be set for the distance to the eyepiece lens; a distance that would place severe strain on the eye and lead to significant human factor problems.

(e) Image Intensifier Tube Identification. As the refinement of manufacturing I^2 tube technology has progressed and the identification of more efficient materials has occurred, each successive Omnibus procurement contract has reflected these technological breakthroughs as increased NVG performance specifications. This has lead to better NVGs and I^2 tubes being delivered to the fleet. The identification of the I^2 tubes within a specific NVG can only be accomplished by either reviewing the I^2 tube part number indicated on the intermediate level maintenance OPNAVINST 4790/138 Aircrew Systems Record (IMA "180" day inspection card) for that NVG or by disassembling the monocular housing to literally view the manufacturing label located on the aft end of the I^2 tube (I-level maintenance procedure), Figure 2-11. Omnibus contract specification tubes can be identified by either their National Stock Numbers (NSN) or by their Part Identification Number (ID NO.). Omnibus-II specification tubes can be identified by the NSN: 5855-01-151-4191 or by the ID NO. 5002760-3, Omnibus-III specification tubes can be identified by the NSN: 5855-01-380-5096 or by the ID NO. 5009100 and the Omnibus-IV specification tubes can be identified by the NSN: 5855-01-423-1497 or by the ID NO. A3256389.

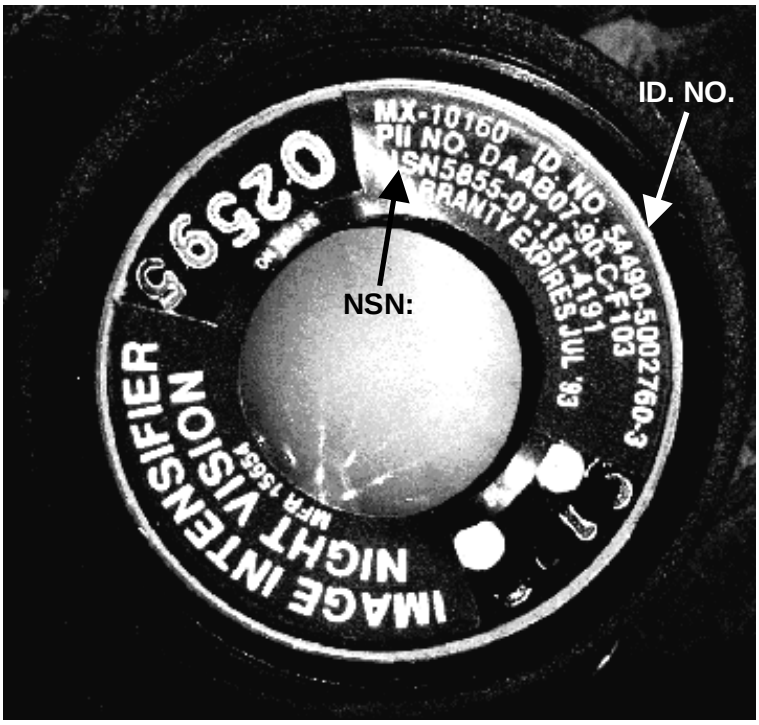

Figure 2 - 11. Image Intensifier (I^2) Tube Identification (Omnibus-II I^2 Tube shown)

(f) Image Intensifier Tube Automatic Gain Control System. Constant exposure of the image intensifier tube to bright light sources may result in damage to the photocathode or the MCP. To prevent damage to the I^2 tubes, the power supply to Generation II and III I^2 tubes have been designed with two automatic protection features designed to control the gain of the I^2 tube.

1: Automatic Brightness Control (ABC) Circuit. The ABC circuitry automatically adjusts MCP voltage to maintain NVG image brightness at a preset output for a full range of ambient illumination levels by controlling the number of electrons that exit the MCP. Sufficient I^2 tube gain is available from full moon down to quarter moon illumination. As light levels pass below quarter moon, each subsequent drop in illumination does not result in an increase in I^2 tube gain, therefore the NVG image starts to decrease in brightness, contrast and NVG image scintillation increases. The ABC circuit provides a protective function to aircrew by limiting the effect of sudden bright flashes (i.e., forward firing munitions, etc.) and by providing an adequate NVG image brightness for low ambient light level operations missions, albeit a more challenging environment exists under these conditions.

2: Bright Source Protection (BSP). The BSP circuitry limits the number of electrons leaving the photocathode by reducing the voltage between the photocathode and the input side of the MCP. This feature automatically activates when high input light levels cause excessive photocathode current to flow. Activation of the BSP is elicited when an incompatible light source enters the NVG field of view and the I^2 tube shuts down or degains leading to reduced NVG image contrast and detail. The BSP circuit is extremely important because the service life of a second or third generation tube is largely a function of the photocathode service life. Photocathode end of life is primarily caused by ion contamination from the MCP. The higher the light input, the more ions are generated and the shorter the life expectancy of the tube.

3. Eyepiece Lens. The eyepiece lens is the final optical component of the AN/AVS-6 ANVIS NVG. As with the objective lens, the eyepiece lens is a series of optical components. The function of the eyepiece lens is to focus the light from the phosphor screen and fiber optic inverter onto the eye. The diopter adjustment for this lens allows for some corrective lens wearers to use NVGs without the aid of their spectacles. However, the majority of personnel that use corrective lenses to correct for astigmatisms, will still need to use spectacles or contact lenses when using NVGs. Dependent upon the Omnibus contract, fleet aircrew may see two different sized AN/AVS-6 NVG eyepiece lenses. The smaller lens (Omnibus-II and prior) possesses a 15mm designed eye relief and the larger lens (Omnibus-III / IV) possesses a 25mm designed eye relief, Figure 2-12. A reference dot on the indicator plate and the diopter markings on the focus ring can be used to identify the 15mm diameter eyepiece. In contrast, the 25mm eyepiece has the reference dot on the indicator plate and the diopter markings on the focus ring. There is no increase in field of view between the eyepiece lenses, however, the enhanced Omnibus-III design allows the NVGs to be kept farther away from one's eyes while still maintaining a 40^0 FOV. This increased eye relief translates into greater look-under ability and clearance for use of special mission equipment (i.e., LEP, CBR gear, etc.). For fleet aircrew, it becomes critically important to properly set the fore and aft adjustment in order to realize the full benefits of the increased eye relief, vice the natural tendency of bringing the NVGs in close to one's eyes. This natural tendency essentially negates the added eye relief gained through the larger Omnibus-III 25mm eyepiece lens design. Aircrew should never fly an

AN/AVS-6 that possesses mixed 15mm and 25mm eyepiece lenses. In addition, some older 15mm eyepieces were made using plastic lenses. Newer 15mm lenses were made from glass. There is no difference in the mechanical function between these two lenses, however there is a weight difference (glass eyepieces are heavier). If the older 15mm eyepiece requires replacement, maintenance instructions require replacement of both eyepieces (no mixing). For aircrew that are flying 15mm eyepieces, if you encounter visual disparity or image distortion between monoculars, return the NVGs for a maintenance check of the eyepiece lenses.

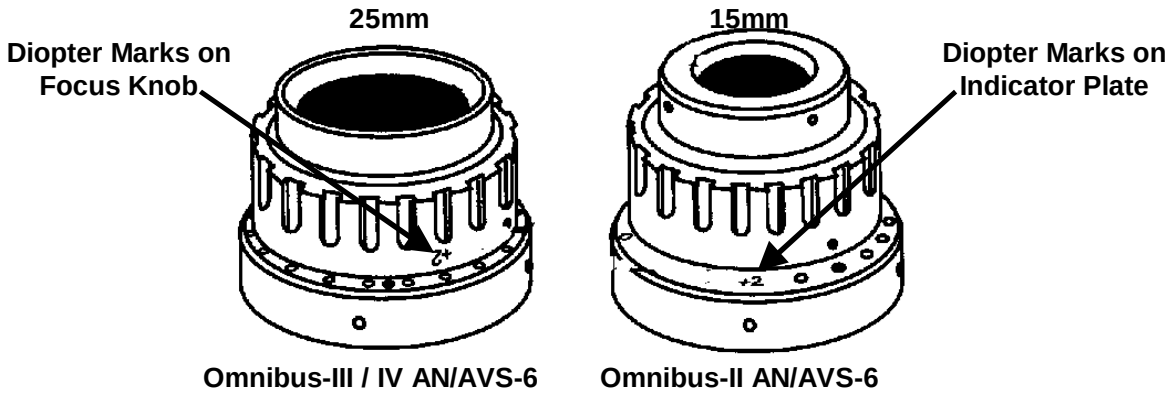

Figure 2 - 12. AN/AVS-6 Eyepiece Lenses

4. Position Adjustment Shelf (PAS). Currently, two different position adjustment shelves are in the AN/AVS-6 fleet inventory, Figure 2-13. The Omnibus-II and older AN/AVS-6 NVGs possess a single eye-span or interpupillary distance (IPD) adjustment PAS. The follow-on Omnibus-III AN/AVS-6 specification contract upgraded to an independent eye-span or IPD adjustment PAS that allows independent movement of each monocular to facilitate greater adjustment capability. With the Omnibus-II and older AN/AVS-6 ANVIS single IPD adjustment PAS, the ability of the aircrew to obtain the proper alignment and subsequent NVG intensified image sight picture (100% overlapped circular image) was limited due to NVG mounting boresight problems, helmet build-up / liner problems and finally, aircrew anthropometric asymmetry. This single improvement allows a dramatic capability for aircrew to effectively attain proper alignment of the NVG image with the eye.

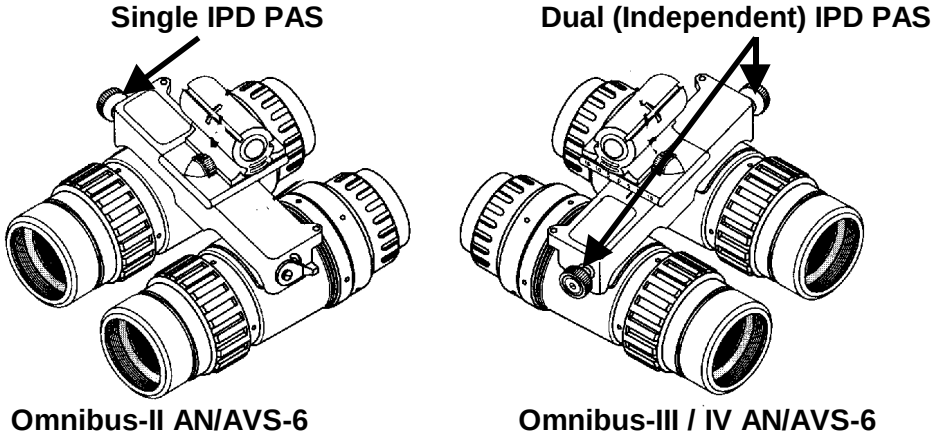

Figure 2 - 13. Position Adjustment Shelf (PAS) Comparison

D. AN/AVS-6 ANVIS Performance

AN/AVS-6 performance is dependent upon the specific Omnibus procurement lot contract under which the NVG or AN/AVS-6 component was purchased. The majority of the USMC and USN AN/AVS-6 NVGs (2,725 of 3,839) were purchased under the DAAB07-88-C-F100 procurement contract. This contract provided goggles and associated supply parts from 1988 through 1990 and was supplied solely through ITT Defense Electronics. The follow-on Omnibus-II procurement contract supplied replacement parts (i.e., I^2 tubes, etc.) and a limited number of USN / USMC full systems (41 NVGs). The Omnibus-II procurement contract was supplied through ITT Defense Electronics (70%) and Varian (30%) from 1990 through 1995. Currently, the Omnibus-III procurement contract is supplying spare parts to the USMC / USN AN/AVS-6 ANVIS inventory. The Omnibus-III contract is being supplied through ITT Defense Electronics (60%) and Litton (40%), the only two remaining U. S. manufacturers of military specification I^2 technology systems. There were 347 sets of NVGs (complete systems) purchased under this contract for the USMC KC-130 community and for the fleet Navy. As previously highlighted, the Omnibus-III significant changes to the Omnibus-II specification NVG included: (1) 25mm eyepiece lenses, (2) improved performance I^2 tube, (3) independent adjustment IPD PAS, (4) one-piece monocular housings and (5) 3-line Light Interference Filter (LIF) LASER protective filters. Currently, the fleet AN/AVS-6 inventory is hybridized between pre-Omnibus, Omnibus-II and Omnibus-III procurement contract configurations. Recent fleet inventory assessments estimate the current AN/AVS-6 fleet composition being comprised of approximately 80% pre-Omnibus/Omnibus-II and 20% Omnibus-III AN/AVS-6 NVG components. In addition to a lack of configuration control *between* AN/AVS-6 procurement contracts, fleet experience has demonstrated that I^2 tube performance range *within* an Omnibus contract can also vary. This variation is dependent upon the manufacturer and production lot of the I^2 tubes. No mechanism exists to identify the performance variability within an Omnibus contract, short of quantitative test bench I^2 tube or system evaluation. The Omnibus-IV procurement contract was signed in February 1996. This contract provides the U. S. Army (USA) with I^2 tube replacements for their ground AN/PVS-7 series NVGs and possessed additional purchase options for the AN/AVS-9 TACAIR NVG. The significance of this contract for Assault Support aircrew was the introduction of the Omnibus-IV specification I^2 tube. ITT Defense Electronics is the sole supplier of the Omnibus-IV contract and 60% supplier of the Omnibus-III contract. Currently, funding is being sought to support a fleet-wide forced retrofit of the USMC / USN Assault Support AN/AVS-6 NVGs to the Omnibus-IV standard. If funding cannot be obtained for this forced retrofit, future retrofit by attrition replacement of I^2 tubes into the AN/AVS-6 ANVIS fleet would not be likely happen until depletion of the Omnibus-III tubes in stock occurs. Recent USA Communications and Electronics Command (CECOM) estimates based on worldwide AN/AVS-6 I^2 tube demand indicate that there is an approximate 2.5 year supply of Omnibus-III I^2 tubes currently in the supply system. Assuming that the current retrofit by attrition philosophy continues, the USMC and USN would not start to see Omnibus-IV I^2 tube delivery to the fleet until nearly the year 2000. Ultimately, the Assault Support AN/AVS-6 upgrade to the Omnibus-IV specification I^2 tubes would mean that both the AN/AVS-6 and the TACAIR AN/AVS-9 would possess the same I^2 tubes, therefore, an *equivalent performance level* would be attained for both the Assault Support and TACAIR communities. Table 2-5 summarizes the performance specifications for current and future fleet AN/AVS-6 NVGs. As a result of the potential disparity in performance between the Omnibus-II, III and IV I^2 tubes and the current lack of fleet AN/AVS-6 configuration control, MAWTS-1 conducted an Assault Support Qualitative Assessment (QA) to ascertain the operational and tactical significance of mixing Omnibus-II, III and IV AN/AVS-6 NVGs within a cockpit, section and division during WTI 1-97 (MAWTS-1 RMG 282300Z AUG 97 and MAWTS-1 QA Report 3960

of 08 Apr 1997). A summary of the AN/AVS-6 specific performance based findings is provided in the following sections.

TABLE 2 - 5. AN/AVS-6 OMNIBUS PROCUREMENT CONTRACT SPECIFICATION

Goggle Characteristic	DAAB07-88C-F100	Omnibus II	Omnibus III	Omnibus IV
Eyepiece Lens Diameter	15mm	15mm	25mm	25mm
Position Adjustment Shelf	Single	Single	Dual	Dual
NVG System Gain (minimum)	2,000	3,000	3,000	6,000
Tube Characteristic			**ITT / Litton**	
Photocathode Sensitivity [µA/lm]	1,000	1,000	1,350 / 1200	1,800
Luminous Gain (min.) [fL/fc]	15,000	20,000 to 35,000	20,000 to 35,000	45,000 to 65,000
Signal-to-Noise Ratio	15	16	19 / 17.1	21
Resolution [Lp/mm]	36	36	45	64
Approximate Snellen Acuity	20/45	20/45	20/35	20/25
Phosphor	P20	P20/P22	P22/P43	P-43
Reliability [hours]	7,500	7,500	10,000 / 15,000	10,000
National Stock Number	5855-01-151-4191	5855-01-151-4191	5855-01-380-5096	5855-01-423-1497
Part Identification Number	5002760-2	5002760-3	5009100	A3256389

1. MAWTS-1 Qualitative Assessment (QA) WTI 1-97 AN/AVS-6 Performance Results. The NAWCAD Patuxent River, MD Crew Systems Integration Lab supported the MAWTS-1 QA by assessing NVG system spectral sensitivity or response, luminous gain and resolution. This system level testing provides assessment of NVG performance inclusive of all the NVG components (i.e., objective lens filtering, objective lens optics, eyepiece lens optics, etc.) and probably provides the best indication of ultimate operational NVG performance. Due to the intervening components and optics, NVG system testing parameter values (i.e., gain, etc.) are typically less in magnitude compared to the same I^2 tube level testing parameter. For example, an Omnibus-IV I^2 tube used to support the QA possessed an I^2 tube gain of 56,000 units while the same tube placed in an AN/AVS-6 NVG possessed a system gain of 8,000 units. The following performance summary is based on four Omnibus-IV I^2 tubes (two NVGs), eight Omnibus-III I^2 tubes (four NVGs) and eight Omnibus-II I^2 tubes (four NVGs). Although this represents a small sample size, it was believed to be representative of current fleet Omnibus-II/III AN/AVS-6 ANVIS NVGs and the follow-on Omnibus-IV production I^2 tubes.

   (a) AN/AVS-6 System Spectral Sensitivity or Response. NVG spectral sensitivity is a direct measure of the response of the I^2 tube's photocathode. As manufacturers find new ways to make the photocathodes more sensitive to the available night sky illumination, the overall effect is that the NVGs will be able to build a better NVG image at lower light levels. Spectral sensitivity or response was measured at 5nm intervals from 350nm to 1100nm. The system spectral response data for each Omnibus contract QA I^2 tube NVG (left and right monocular data) was averaged for comparison. The spectral response units, foot-lambert (fL) per microwatt (µW), are depicted using a log scale on the y-axis, Figure 2-14. The Omnibus-III and II contract NVGs exhibited a similar spectral response from 350nm through 1100nm. Compared to the Omnibus-II and III NVGs, the Omnibus-IV NVGs demonstrated a two to three fold increase in spectral response between 600nm and 900nm. In addition, the Omnibus-IV NVGs demonstrated spectral response activity between 310nm and 480nm. This additional activity in the ultraviolet and visible (violet and blue) portion of the electromagnetic spectrum was initially a source of concern, however, following the pre-QA aircraft

cockpit ground form, fit and function evaluations, no contraindications were noted for Omnibus-IV NVG cockpit compatibility. In addition, Following the MAWTS-1 QA flight evaluation phase, no pilots noted any cockpit compatibility anomalies with the Omnibus-IV NVGs.

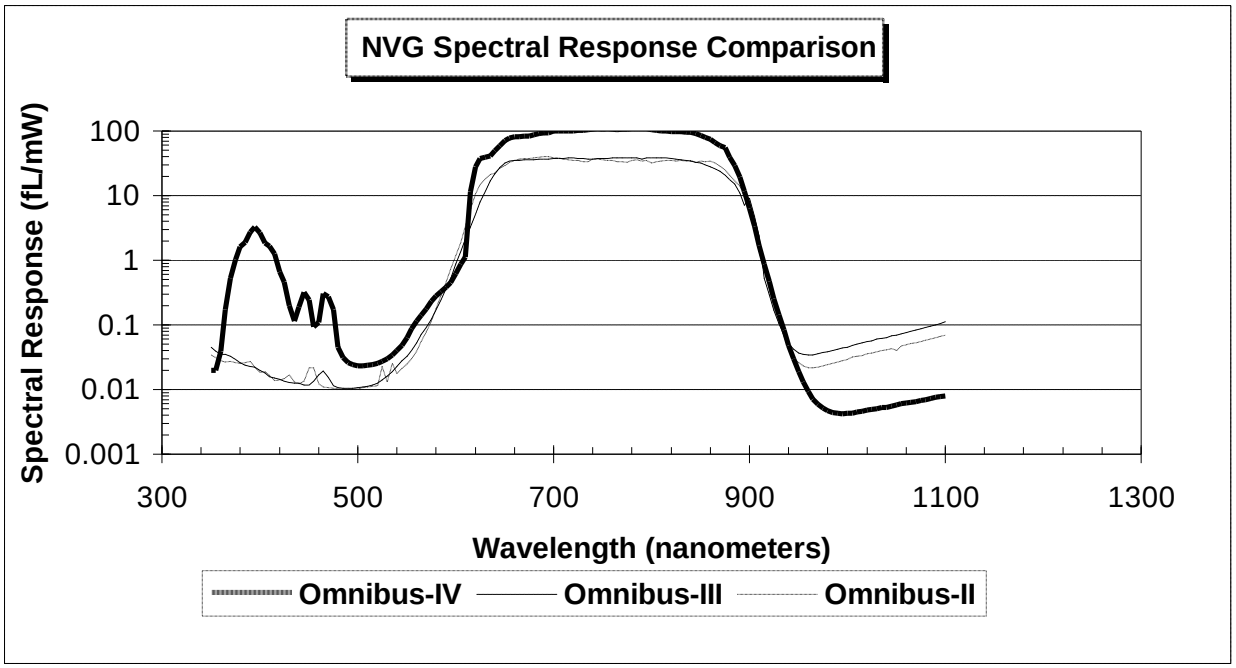

Figure 2 - 14. NVG Spectral Response

(b) AN/AVS-6 System Gain. NVG system (luminous) gain is defined as the ratio of luminance output (foot-lambert, fL) divided by the illuminance input (foot-candle, fc) and may best be described as the changes in NVG image brightness over varying illumination conditions. NAWCAD Patuxent River, MD Crew Systems Integration Lab assessed NVG system (luminous) gain by measuring output luminance (fL) and dividing by the measured input (luminance) to ascertain the gain values. Omnibus-II, III and IV NVG system gain was assessed under varying luminance conditions from 1.0×10^{6} to 3.0×10^{-3} foot-lambert (fL). By varying the input conditions and measuring the changes in system monocular output brightness, the dynamic gain range of the NVG I^2 tube was determined, Figure 2-15. For the ten NVGs assessed, the maximum NVG system gain varied between 2,593 and 8,400, dependent upon the Omnibus procurement contract, the specific NVG (NVG Serial #) and monocular tested (left vs. right). For the two Omnibus-IV QA NVGs, maximum NVG system gain ranged from 7,000 to 8,400 (average maximum gain: 7,750). For the four Omnibus-III QA NVGs, maximum NVG system gain ranged from 2,593 to 3,773 (average maximum gain: 3,121.9). The four Omnibus-II QA NVGs demonstrated a maximum NVG system gain range between 3,560 and 4,750 (average maximum NVG system gain: 4,060). The Omnibus-II average maximum NVG system gain exceeded the Omnibus-III NVGs, however, this did not translate into greater overall system resolution performance. Although NVG system gain has a dramatic effect on NVG image brightness, additional factors, such as increased photocathode sensitivity, improved signal-to-noise ratio, and enhanced I^2 tube Modular Transfer Function (MTF) provide more significant influences on the improved resolution exhibited by the Omnibus-IV NVGs. In fact, NVG system gain on NVGs is set by the manufacturer (contract) and ranges from 2,000 (Omnibus-II) to

6,000 (Omnibus-IV), minimum. Previous laboratory evaluations conducted at the USAF Armstrong Lab Aircrew Training Research Division demonstrated no significant differences in resolution between high system gain (>10,000) and mid-gain (5,000) NVGs. Therefore, aircrew should be cognizant that a ceiling appears to exist between enhanced resolution and maximum system gain levels. A more important issue appears to be the potential gain difference (split) between I^2 tubes both between NVGs and within the same NVG. The QA results documented the variability in NVG system gain both between and within Omnibus procurement contracts. This disparity in NVG system gains may lead to aircrew flying with NVGs that possess a perceivable difference in NVG image brightness. Currently, no guidelines exist to specify the acceptable level of NVG system gain split between I^2 tubes (left vs. right monoculars) within a NVG. In fact, no guideline exists that prohibits the placing of an Omnibus-III I^2 tube into a NVG that possesses a pre-Omnibus specification I^2 tube (i.e., DAAB07-88C-F100, etc.) in the opposing monocular. Large differences in monocular NVG image brightness may lead to significant NVG image perceptual challenges for aircrew and possibly, the introduction of perceptual illusions. The lack of configuration control coupled with the demonstrated differences in NVG tube and system performance within each Omnibus contract may warrant a concerted effort to establish such recommendations or guidelines in the future.

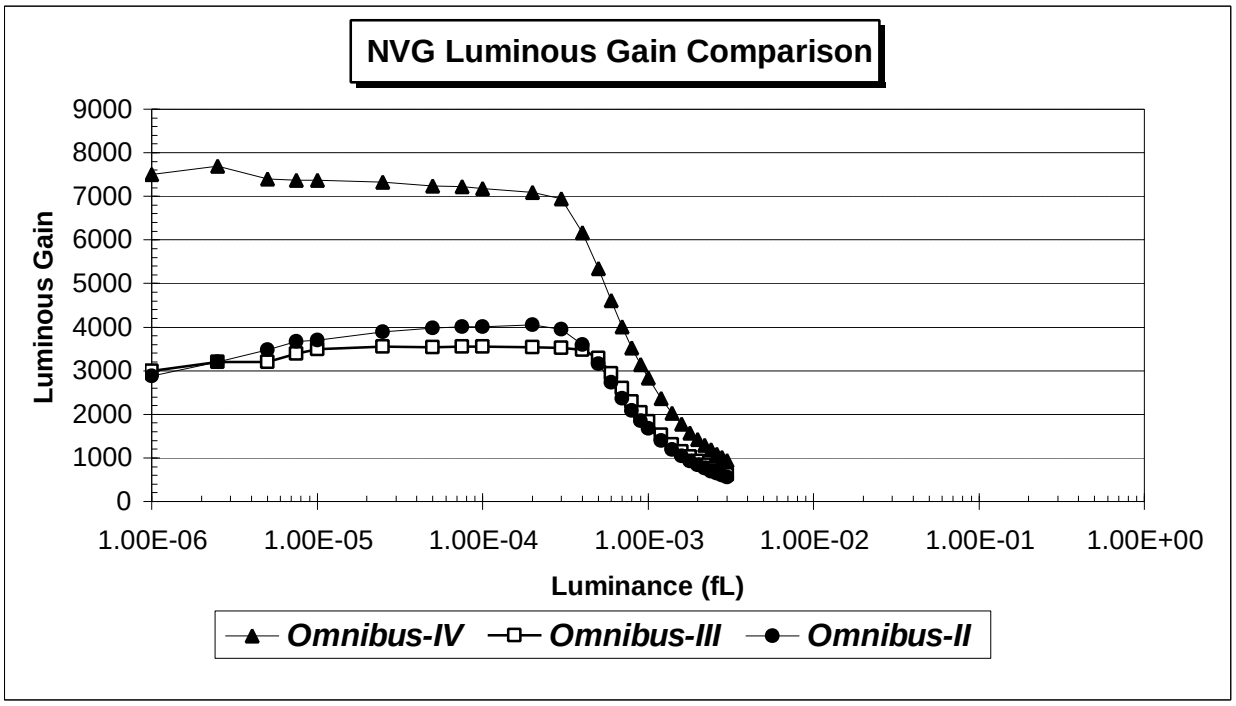

Figure 2 - 15. NVG Luminous Gain

(c) <u>AN/AVS-6 System Resolution.</u> NVG *system* resolution assessment was conducted under varying luminance conditions from 1.0 X 10^{6} to 3.0 X 10^{-3} footlamberts (fL). NVG resolution measurements were taken by viewing a 100% contrast test target (USAF 1951). Omnibus-IV test bench NVG system binocular (both NVG monoculars) resolution results demonstrated superior performance across all luminance conditions compared to the Omnibus-III and Omnibus-II NVGs, Figure 2-16. In fact, compared to the Omnibus-III NVGs, the average Omnibus-IV NVG HLL resolution data demonstrated a greater than 15% increase in performance over the Omnibus-III NVGs

under FM (2.4 X 10^{-3} fL) and 1/4M (5.0 X 10^{-4} fL) luminance conditions. Under LLL conditions, the average Omnibus-IV NVGs demonstrated a greater than 22% and 37% increase in performance under SL (2.5 X 10^{5} fL) and SLO (2.5 X 10^{6} fL) luminance conditions, respectively. Even greater increases in performance were demonstrated when comparing the average Omnibus-IV resolution data with the average Omnibus-II resolution data. Under FM and 1/4M HLL conditions, the Omnibus-IV NVGs exhibited a greater than 22% increase in performance. Under SL and SLO LLL conditions, the Omnibus-IV NVGs demonstrated a greater than 28% and 45% increase in performance over the Omnibus-II NVGs, respectively. The increase in performance of the Omnibus-III NVGs over the Omnibus-II NVGs was less dramatic. From FM down to SLO conditions, the average Omnibus-III NVG increase in performance was approximately 5%. In addition to the demonstrated differences in NVG system binocular resolution performance *between* Omnibus contracts, performance also varied *within* each Omnibus contract. For all luminance conditions and virtually all NVGs, an approximate 10% *within* Omnibus contract variation was demonstrated for the two Omnibus-IV NVGs, four Omnibus-III and four Omnibus-II NVGs assessed.

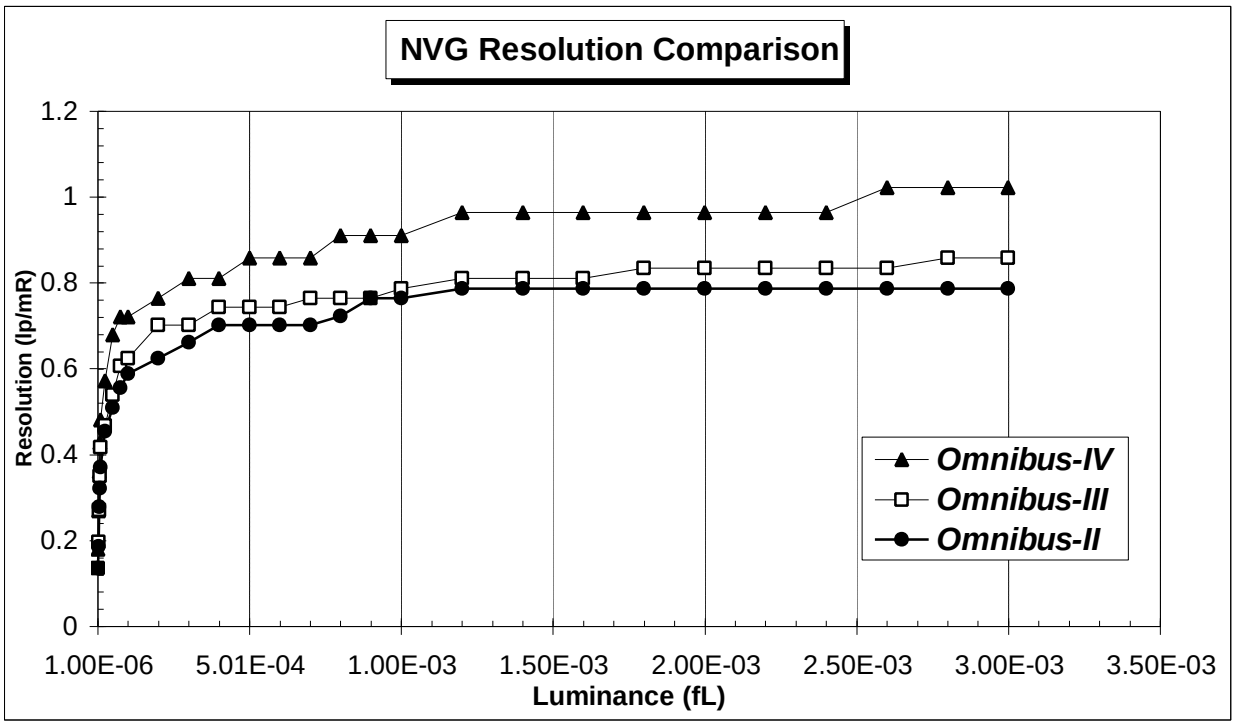

Figure 2 - 16. NVG Resolution

To better describe the NVG system binocular resolution performance demonstrated by the NVGs, the following NVG target detection estimation model was used to describe the operational impact of the different Omnibus I^2 tube configured NVGs. By using the NAWCAD Patuxent River, MD Crew Systems Integration Lab NVG system resolution data summarized above, an estimated detection distance was calculated for viewing a single tank sized target (frontal aspect, non-camouflaged and high contrast target) presented on a uniform background (i.e., tank on a dunes desert). The target was assumed to be "lights-out," with no discernible illumination signature. Resolution data was averaged for each Omnibus contract NVG and converted into the Table 2-6 and Figure 2-17 distances. Under HLL conditions, the Omnibus-IV NVGs would provide an estimated increase in

NVG detection range of 500 and 1,000 meters compared to the Omnibus-III and Omnibus-II NVGs, respectively. As light level decreases to starlight-overcast (SLO), the magnitude of increase in Omnibus-IV NVG performance drops off to less than 200 meters compared to both the Omnibus-III and Omnibus-II I^2 tube NVGs. This model serves as a theoretical distance estimation tool based on laboratory data, actual detection distances may vary dependent on contrast of the target / background, atmospheric obscurants and variations in illumination conditions (i.e., moon azimuth, moon altitude, sun azimuth, etc.).

TABLE 2 - 6. ESTIMATED OMNIBUS-IV, III & II TARGET DETECTION DISTANCES

Luminance (fL)	Omnibus-IV (meters)	Omnibus-III (meters)	Omnibus-II (meters)
1.0×10^{-6} (SLO)	722	540	540
1.0×10^{-5} (SL)	1,924	1,689	1,486
1.0×10^{-4} (1/4M)	2,888	2,499	2,358
1.0×10^{-3} ((1/4M)	3,646	3,150	3,056
3.0×10^{-3} (FM)	4,090	3,432	3,150

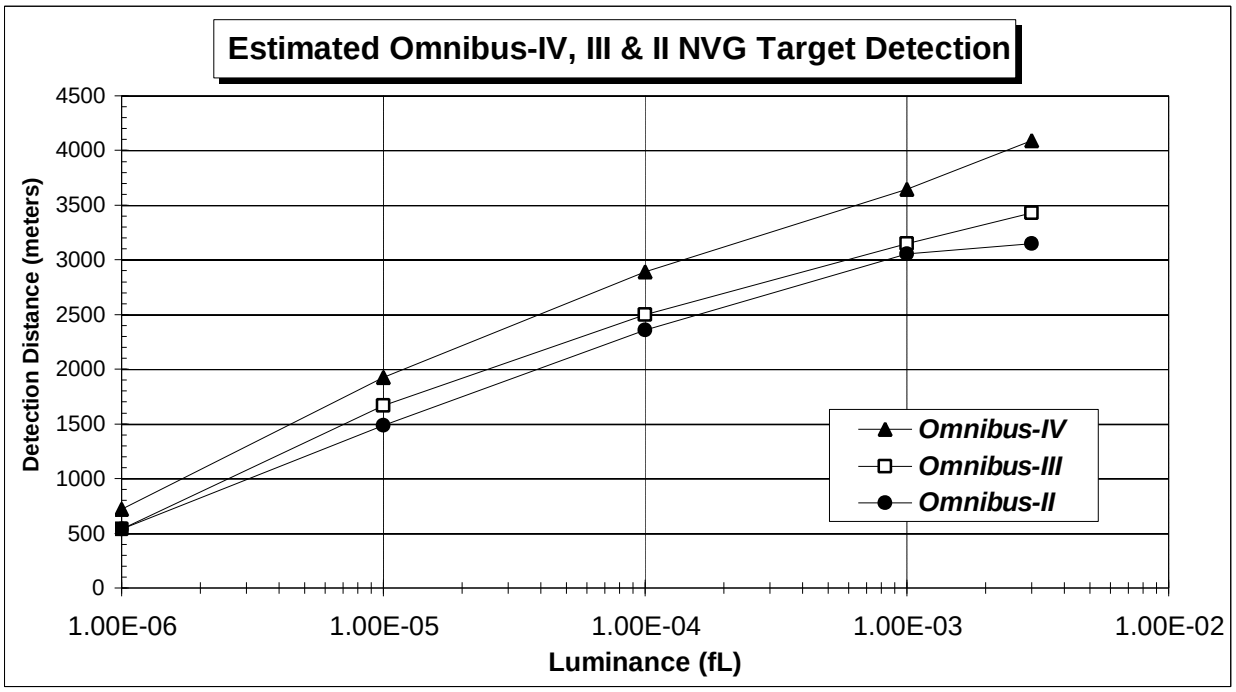

Figure 2 - 17. Estimated Omnibus-II, III and IV Detection Distances

(d) Flight Assessment Results. MAWTS-1 pilots representing the AH-1W, UH-1N, CH-46E and CH-53D/E communities flew 33 sorties for 76.05 NVG flight hours to support the flight assessment. Pilots averaged 2,008.6 total hours in aircraft type and 357.1 total NVG flight hours. Pilots flew two different Omnibus specification NVGs (II vs. III, II vs. IV or III vs. IV) during the same mission. The initial NVG was flown for approximately the first half of the mission (first QA session) and the second NVG was flown during the second half of the same mission (second QA session). Pilots were unaware of the Omnibus contract specific NVG flown during each QA session of the mission. During all flights, pilots flew the lower Omnibus NVG during the first QA session and the higher Omnibus NVG during the second QA session of the mission. Using a post-flight questionnaire, pilots rated *NVG mission performance*, *NVG image quality* and *NVG*

tactical capability. Ratings on a seven point scale ranged from *Greatly Degraded (scale value = 1)* to *Greatly Enhanced (scale value = 7)*. Pilots reported their ratings by comparing the performance of the session two NVG (higher Omnibus Specification NVG) against the session one NVG (lower Omnibus Specification NVG). For the Omnibus-II vs. III assessment comparison QA pilots flew 17 sorties for 39.4 NVG flight hours. For this comparison, pilot post-flight questionnaire rating responses did not demonstrate dramatic differences in performance ratings between the Omnibus-II and III NVGs. Assessment pilots flew 7 sorties for 17.9 NVG flight hours comparing Omnibus-III vs. Omnibus-IV NVGs. For this comparison, pilot post-flight questionnaire responses demonstrated notable differences in performance between the Omnibus-III and IV NVGs. Assessment pilots flew 9 sorties for 19.25 NVG flight hours comparing Omnibus-II vs. Omnibus-IV NVGs. For this comparison, QA pilot's reported dramatic increases in performance for the Omnibus-IV NVGs over the Omnibus-II NVGs. Figures 2-18, 2-19 and 2-20 summarize the flight phase aircrew response results for the assessed NVG mission performance, NVG image quality and NVG tactical capability parameters.

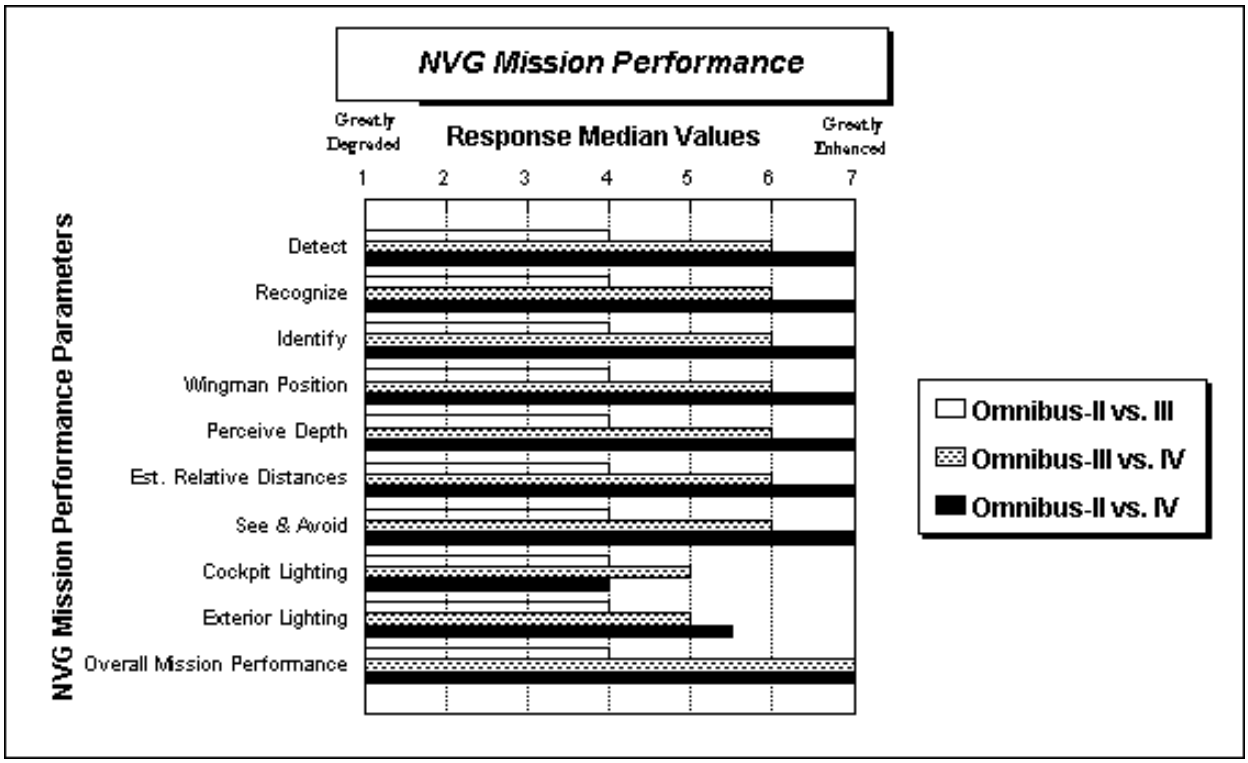

Figure 2 - 18. NVG Mission Performance

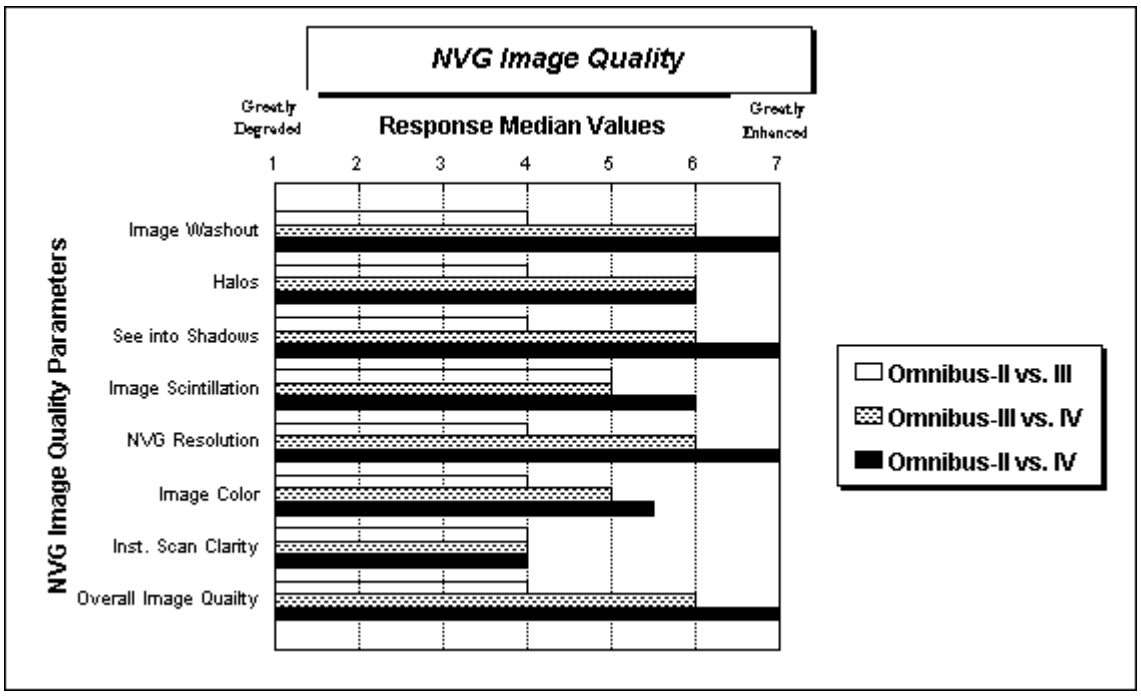

Figure 2 - 19. NVG Image Quality

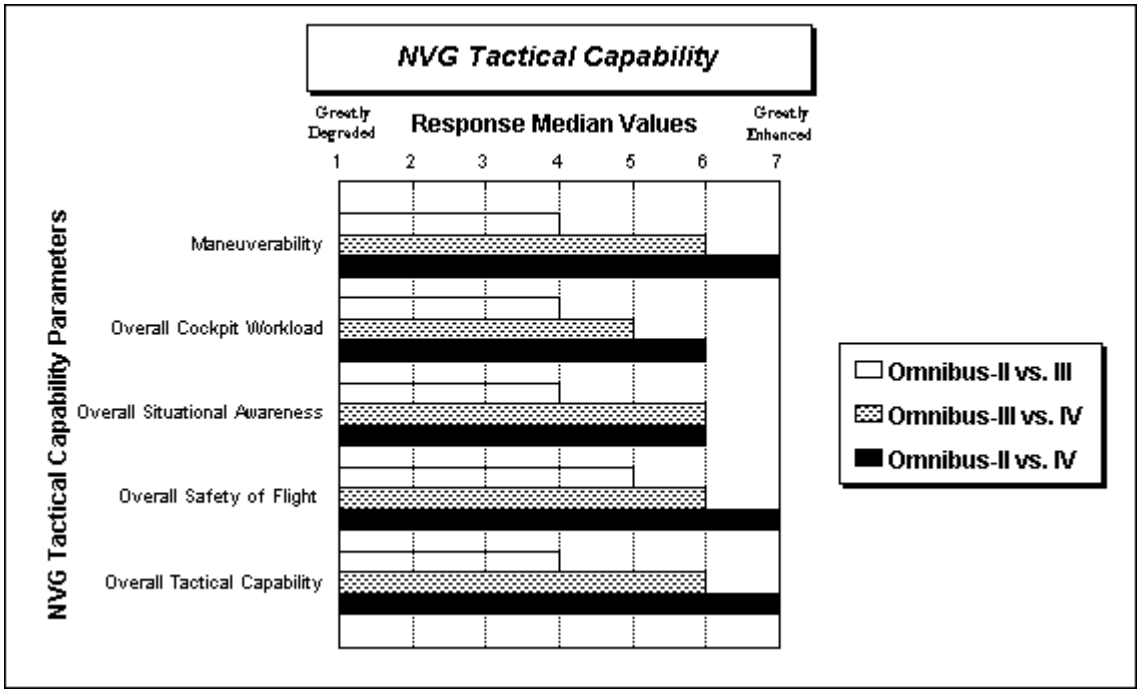

Figure 2 - 20. NVG Tactical Capability

The overall summary trend for QA pilot ratings demonstrated a stepwise increase in reported enhancements for each subsequent Omnibus NVG comparison. Specifically, the following flight assessment conclusions can be made:

1:Aircrew were not able to identify a perceivable difference in NVG performance between the Omnibus-II vs. Omnibus-III AN/AVS-6 NVGs.

2:Aircrew were able to discern notable differences in performance between the Omnibus-III and IV AN/AVS-6 NVGs, however, this difference did not warrant flight safety concerns.

3:Aircrew were able to discern dramatic qualitative differences in performance between the Omnibus-II and IV NVGs. These differences would warrant flight safety considerations. Aircrew indicated that Omnibus-II and Omnibus-IV NVGs should not be mixed within the same aircraft, section or division.

2. AN/AVS-6 Omnibus Performance Summary. Ultimately, I^2 tube and subsequent NVG performance is driven by a multiplicity of factors (i.e., photocathode sensitivity, gain, S/N ratio, MTF, tube resolution, etc.) that are inter-related in providing the best NVG image provided the environmental considerations of terrain, illumination, atmospheric attenuation and battlefield obscurants. Future I^2 tube and subsequent NVG system performance requirements should be aimed at global performance, such as attaining better resolution under LLL conditions while expanding the FOV, rather than focusing on any single independent performance parameter (i.e., higher gain, etc.). As funding is secured to support forced Omnibus-IV retrofit of the AN/AVS-6, aircrew will be required to remain vigilant to ascertain current squadron AN/AVS-6 ANVIS configurations. This knowledge will be critical to safely and effectively integrate the mixed AN/AVS-6 configurations into their mission planning and operational considerations.

3. CNO Policy on Mixing AN/AVS-6 NVGs. CNO(N88) released an interim change (number 22) to the OPNAVINST 3710.7 NATOPS General Flight and Operating Instructions in April 1998 (RMG 062315Z Apr 98). The following specificAN/AVS-6 policy was delineated:

"Mixing of NVDs between aircrew within the same aircraft (all crew positions) and between aircraft in the same section or division should be limited to the maximum extent possible while not impacting operational capability or flight safety. Specifically, the following NVD/aircraft configuration guidelines shall be implemented:

(1) For Rotary Wing / Assault Support aircraft and AN/AVS-6 NVDs:

(A) Mixing Omnibus-IV image intensifier tubes with either Omnibus-III, II or earlier production image intensifier tubes within the same NVD is not authorized.

(B) Mixing of Omnibus-IV AN/AVS-6 and Omnibus-II AN/AVS-6 NVDs within the same Rotary Wing/Assault Support aircraft (all crew positions) and between Rotary Wing/Assault Support aircraft in the same section or division is not authorized.

(C) Mixing of either Omnibus-II and Omnibus-III AN/AVS-6 NVDs or mixing of Omnibus-III and Omnibus-IV AN/AVS-6 NVDs within the same Rotary Wing/Assault Support aircraft and between Rotary Wing/Assault Support aircraft in the same section or division is authorized. However, this will require that aircrew possess the capability to identify the specific AN/AVS-6 Omnibus NVD configuration being flown to facilitate appropriate mission planning."

III. AN/AVS-7 ANVIS Head Up Display (HUD)

The AN/AVS-7 ANVIS HUD is an electro-optical system combining the NVG image with digital symbology and computer-generated graphics. It is intended to display all information required by the aircrew for flight and to eliminate the need to constantly monitor the instrument panel. The AN/AVS-7 ANVIS HUD is mounted on the AN/AVS-6 NVG, thereby providing head up display within the AN/AVS-6. The HUD is lightweight and can be mounted to either tube. It maintains display quality compatible with second and third generation goggles, and causes no apparent degradation in NVG performance. The AN/AVS-7 consists of an "A" kit and a "B" kit. The "A" kit includes: Mounting Hardware and Transducers, Wiring Provisions, Connectors, and a Pilot Control Unit (PCU) for each pilot's Collective Control Lever. The "B" kit includes a Signal Data Converter (SDC), or system processor, a Helmet Display Unit (HDU) for each pilot and a Converter Control Unit (CCU) for in-flight programming and adjustments. A diagram of the AN/AVS-7 HUD system is presented in Figure 2-21.

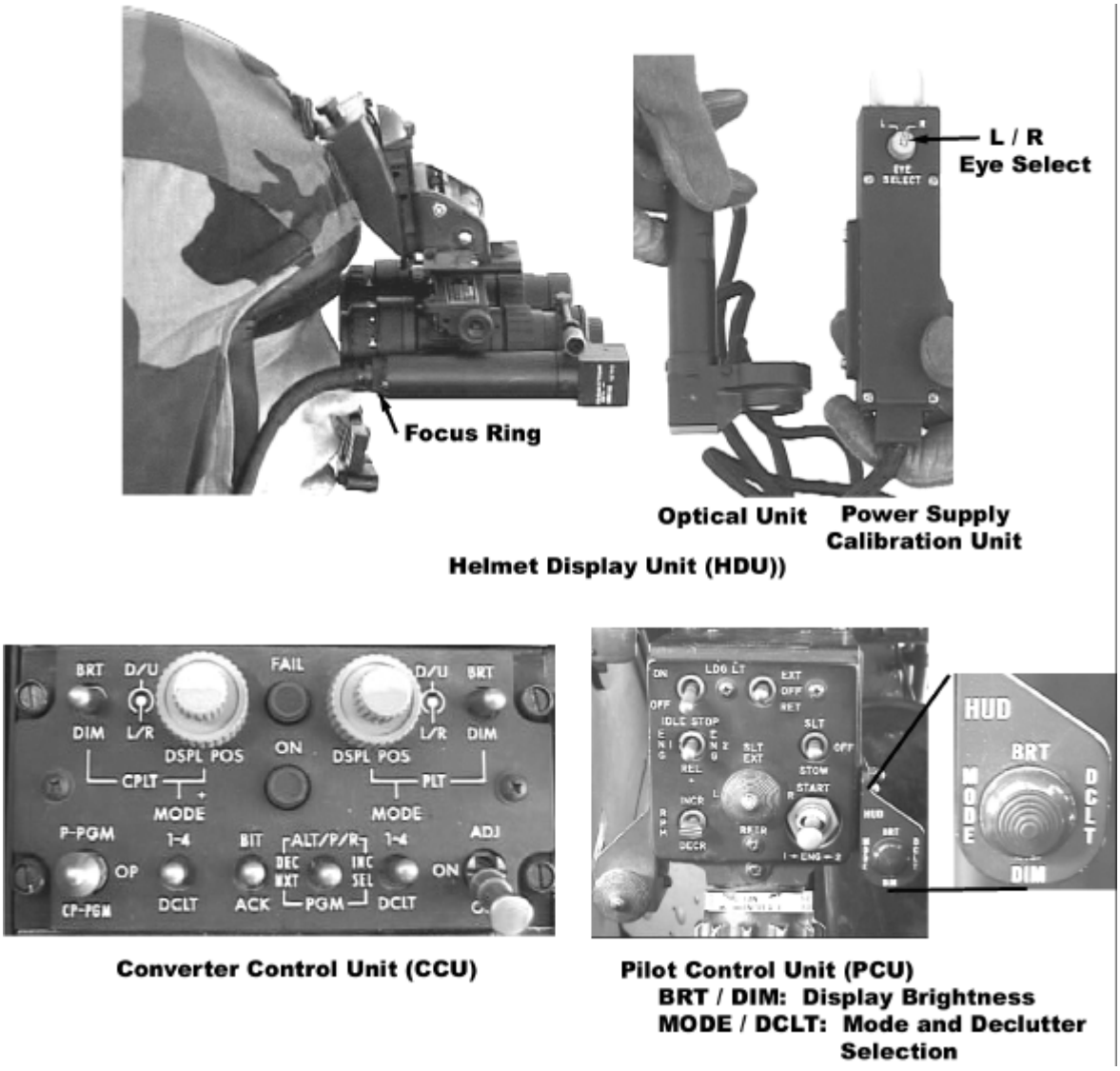

Figure 2 - 21. AN/AVS-7 ANVIS HUD Components

A. Helmet Display Unit (HDU)

The AN/AVS-7 HDU consists of the high voltage power unit (HVPU) module that connects to a display unit (DU) or optical module via a 150 mm cord. The HVPU was designed to provide for quick release while simultaneously eliminating the potential for an electrical arc in the event of a rapid egress from the aircraft. The assembly was designed to require a release force of 7.5 pounds in the event of emergency egress. The HVPU has an eye selection feature for left or right eye HUD viewing. The HDU optical unit imaging device is clamped to a AN/AVS-6 objective lens. Currently, two different style HDU optical units are found in the fleet (AH-1W Gideon and the AN/AVS-7). The first NVG HDU (Gideon) was delivered with the AH-1W Night Targeting System (NTS) upgrade. The Gideon HDU optical units possess a smaller diameter clamping ring. Therefore, the Gideon HUD optical unit can only be mounted onto AN/AVS-6 NVGs that either **do not** possess the Light Interference (LIF) collars (Section-V) or use the screw in AH-1W specific Gideon System ANVIS HUD Adapter (Part No: 20c0138-1) manufactured to make the AN/AVS-6 NVG (LIF collar installed) diameter compatible with the Gideon HUD, Figure 2-22. For all other Assault Support aircraft communities, the AN/AVS-6 LIF collar **must** be installed to accommodate (larger diameter clamping ring) HDU optical unit mounting (Figure 2-22). The wearer is provided with a 512 x 512 pixel array display with an area of 8.3 mm x 8.3 mm and Field of View (FOV) of up to 34 degrees diagonally. The projected HUD display can be adjusted ± 1 mm, horizontally and vertically, for operator flexibility.

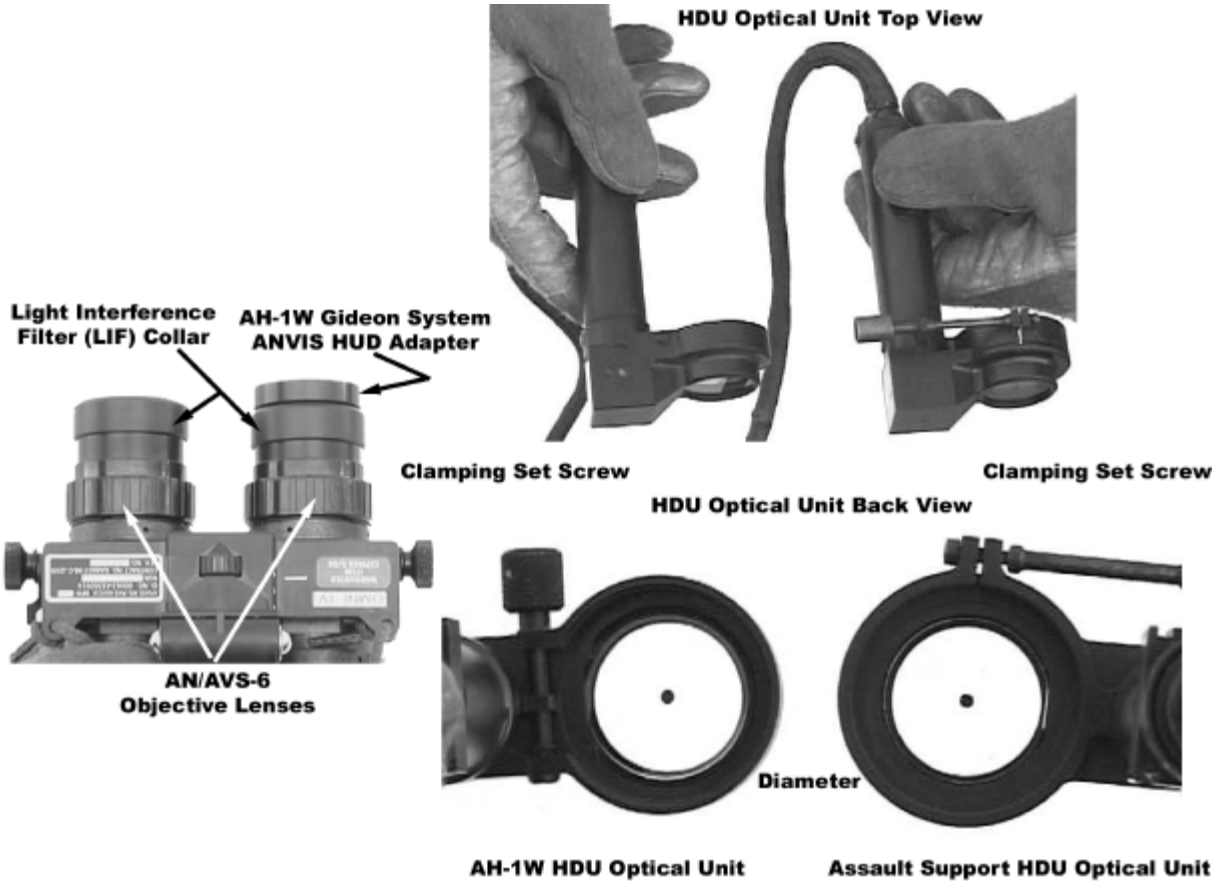

Figure 2 - 22. HDU Optical Unit Differences

B. Signal Data Converter (SDC)

The SDC is a symbol generator designed to use bit plane memory to compile information from various aircraft instruments and systems. This information is processed and sent to the HDU for display. The symbol set generated in the SDC can be upgraded in software through the Electronically Erasable, Programmable, Read-Only-Memory (EEPROM). This allows for individual tailoring to different missions or aircraft while maintaining commonality. The common SDC will be transformed to a mission specific processor at the unit level.

C. Pilot Control Unit (PCU)

The Pilot Control Unit (PCU) consists of a five position, four axis, non-latching switch. The switch is located on the Pilot and Co-Pilot Collective Lever control grips. This which allows the Pilot to either increase or decrease symbology brightness and to change operating modes.

D. Converter Control Unit (CCU)

The Converter Control Unit (CCU) is installed on the lower instrument console. The CCU provides for in-flight control of functionality including:

1. Adjustment of Display Centering: Left, Right, Up and Down.

2. Adjustment of Symbology Modes: Modes 1 through 4 (Normal).

3. Toggling between Normal and Declutter Modes

4. Symbol Set Programming.

5. Brightness Control: Intensity levels from zero.

6. Built-In-Test (BIT) Actuation.

E. Basic Principles of Operation

Pilot and copilot can independently select from four normal symbology modes and four declutter modes that were pre-programmed. Declutter can be used when less symbology is needed. The declutter mode has four vital symbols that will always be displayed : Airspeed, Altitude (MSL), Attitude (pitch and roll), and Torque(s). During operations, an adjust mode can be used to calibrate the barometric altitude, pitch, and roll. The system self test is divided into power-up or operator initialized built-in-test (BIT) and in-flight BIT. The system built-in-test (BIT) is initialized during power-up or selected by the operator. Part of the BIT is a periodic test that is performed automatically along with normal system operation. A failure of the SDC, pilot's HDU, or copilot's HDU will illuminate the CCU FAIL light and display a FAIL message in the HDU.

F. Controls and Functions

The CCU is used for programming and making adjustments to pitch, roll and baralt settings. The CCU is used for centering the symbol set to match the wearer's individual fit. Several functions contained on the PCU are duplicated on the CCU. A depiction of the CCU is

provided in Figure 2-21. The following description is provided to overview the functionality of the CCU:

Control / Indication	CCU Function
FAIL	Indicates a system failure.
ON	Indicates system ON.
BRT / DIM	Pilot/Copilot's control for display brightness.
DSPL POS D/U/L/R	Pilot/Copilot's control for display position down/up (outer knob) and lift/right (inner knob).
MODE 1-4/DCLT	Pilot/Copilot's mode select 1-4 and declutter switch.
ADJ/ON/OFF	Selects adjust mode, enabling the INC/DEC switch to calibrate altitude, pitch, or roll. Turns power on or off to the HUD system.
P-PGM/OP/CP-PGM	Selects pilot or copilot program mode. Used with the PGM NXT/ SEL switch.
BIT/ACK	Selects Built-In-Test to acknowledge a displayed fault, completion of an adjustment, or completion of a programming sequence.
ALT/P/R DEC/INC	Active when adjust mode is selected for calibration and used to decrease/increase altitude/pitch/roll.
PGM NXT/SEL	Active when program mode (P-PGM or CP-PGM) is selected. Allows operator to preprogram the four primary modes and four secondary declutter modes. Operator can select a flashing symbol for display and/or go to the next symbol. Once complete, operator toggles the ACK switch to save programmed display.

G. Modes of Operation

There are two programming modes and one operational mode for the HUD system selected by the programming switch on the CCU. The adjust mode is under the operational mode.

1. Pilot programming: switch set to P-PGM

2. Copilot programming: switch set to CP-PGM

3. Operation (flight mode): switch set to OP (Adjust - ADJ/ON/OFF switch to ADJ)

H. Display Modes

Symbology display modes are programmable by the pilot and copilot via the CCU. Modes are defined by selecting from a master symbology menu. Up to eight (8) display modes can be programmed for each user and can be selected for display using the display modes selection switch on the pilot or copilot collective control or on the CCU.

IV. Aircraft Specific AN/AVS-7 ANVIS HUD Symbology

The following three sections are dedicated to a description of platform specific AN/AVS-7 ANVIS HUD flight symbology. The CH-46E, UH-1N and CH-53 flight symbology and descriptions are provided in Figures 2-23, 2-24, 2-25, 2-26, 2-27 and 2-28. AH-1W pilots should refer to their NATOPS manual for a full description of the AH-1W flight symbology and software selections.

A. CH-46E Master Mode Symbology Set

1. Missile Warning - Pointers. Replication of the AAR-47 display. A triangular pointer oriented along the same "clock code" (representing true bearings to the threat) as the AAR-47. The letter "M" is displayed for orientation to the center of the "clock". The symbol is displayed by exception only.

2. Magnetic Heading - Scale. Displayed in analog form in the range of 0-360 degrees. A range of 90 degrees is always displayed. Heading scale has tick marks delineated every 10 degrees, with numerical markings corresponding to 30 degree cuts. Numerical markings have two digits representing a three digit value (i.e. "33" for 330 degrees).

3. Bearing to Waypoint - Pointer. An analog display of the appropriate bearing to select waypoint as determined by the cockpit display navigation unit (CDNU). The triangle takes on three different positions depending on where the bearing to selected waypoint is in relation to the aircraft's present heading. Whenever the bearing to the selected waypoint is ± 65 degrees of aircraft's heading the pointer will be straight up. The pointer will be horizontal whenever the bearing to the selected waypoint is ± 65-115 degrees of aircraft's heading. The pointer will invert whenever the bearing up the selected waypoint is ± 115-180 degrees of aircraft's heading. In the horizontal and inverted positions the pointer will park itself on the left or right side, indicating the shortest direction toward the bearing. Data will be available as MIL-STD-1553B air frame modifications, to include the APN-217 Doppler Navigation System (DNS) and mini-airborne GPS receiver (MAGR).

4. Magnetic Heading - Numeric. A numerical value corresponding to aircraft's magnetic heading.

5. Aircraft Heading Fix Index/Lubber Line. A vertical line about which the magnetic heading scale rolls past.

6. Indicated Airspeed. A numerical value of indicated airspeed in the range of 0-220 knots.

7. Ground Speed. A numerical value of ground speed from the CDNU. The range should be 0-999 knots. Data will be available when MIL-STD-1553B airframe modifications are complete and will include the APN-217 DNS and MAGR.

8. Radar Altimeter (AGL) - Numeric. A numerical value corresponding to altitude above ground (AGL). The range is 0-5000ft. The height will be indicated every foot from 0-200ft. Above 200ft, the height will be indicated every 10ft. The letter "R" follows the last digit.

9. Low Altitude Warning Box. A flashing box appears around the radar altimeter (RADALT) numerical value in concert with the radar altimeter bug setting in the cockpit. The box only flashes when below the pilot's RADALT setting. Once above the RADALT setting the flashing box disappears.

10. Radar Altimeter Scale. An analog scale from 0-150ft AGL. Horizontal tick marks are displayed every five feet from 0-30ft. Above 50ft the tick marks are every 25ft.

11. Radar Altimeter - Pointer. A triangular pointer positioned horizontally. The pointer replicates the needle in the aircraft's RADALT gauge.

12. Horizon Line. External horizon line displays the pitch and roll angle of the helicopter.

13. Angle of Pitch Scale. The indication of angle is every 10 degrees, in the range of ± 30 degrees.

14. ANVIS/HUD Fail Message. The letters "HUD" appears when there is a HUD failure. Appears by exception only.

15. Inclinometer / Ball. Analog display of electronic inclinometer. Replicates aircraft's turn and slip ball.

16. Navigation Messages. The letters "NAV" appears when the navigation system (CDNU) experiences failures. The message appears by exception only. Data will be available when MIL-STD-1553B airframe modifications are complete and will include the APN-217 DNS and MAGR.

17. Master Caution Messages. The letters "MST" appear simultaneously with the illumination of the master caution light. Appears by exception only. The message disappears once the master caution light is reset.

18. Angle of Roll - Scale. The roll attitude indices are in three 10 degree increments and one 15 degree increment. Tick marks are displayed to indicate wings level and rolls of ± 10, 20, 30, and 45 degrees.

19. Angle of Roll - Pointer. Roll pointer is a triangle which points toward the indices. This display replicates the angle of roll indicated on the attitude indicator.

20. Center of FOV. The external horizon line displays the pitch and roll angle of the helicopter.

21. Vertical Speed Indicator (VSI). The analog VSI has a range of ± 2000ft per minute. Tick marks are displayed in 200ft increments from 0 to 1000ft and in 500ft increments above 1000ft. Numerical values of 0, 1, and 2 to indicate climbs or descents of 0, 1000, and 2000 feet per minute.

22. VSI - Pointer. A triangle that points toward the indices.

23. Torque - Numeric. The highest torque between the two engines is displayed in the range of 0-150% with a resolution of one percent. The numerical value will flash whenever there is a disparity of 10% or more.

24. Estimated Time Enroute (ETE). Displays the ETE to the selected waypoint provided by the CDNU. If greater than one hour transit time, the time is displayed in hours and minutes, (i.e. max 9:59). If less than one hour ETE, the time is displayed in minutes and seconds, (i.e. max 59:59). Data will be available when NMIL-STD-1553B airframe modifications are complete and will include the APN-217 DNS and MAGR.

25. Command Ground Speed. Is displayed in the range from 0-999 knots. Replication of the command ground speed provided by the CDNU. Data will be available when MIL-STD-1553B when airframe modifications are complete and will include the APN-217 DNS and MAGR.

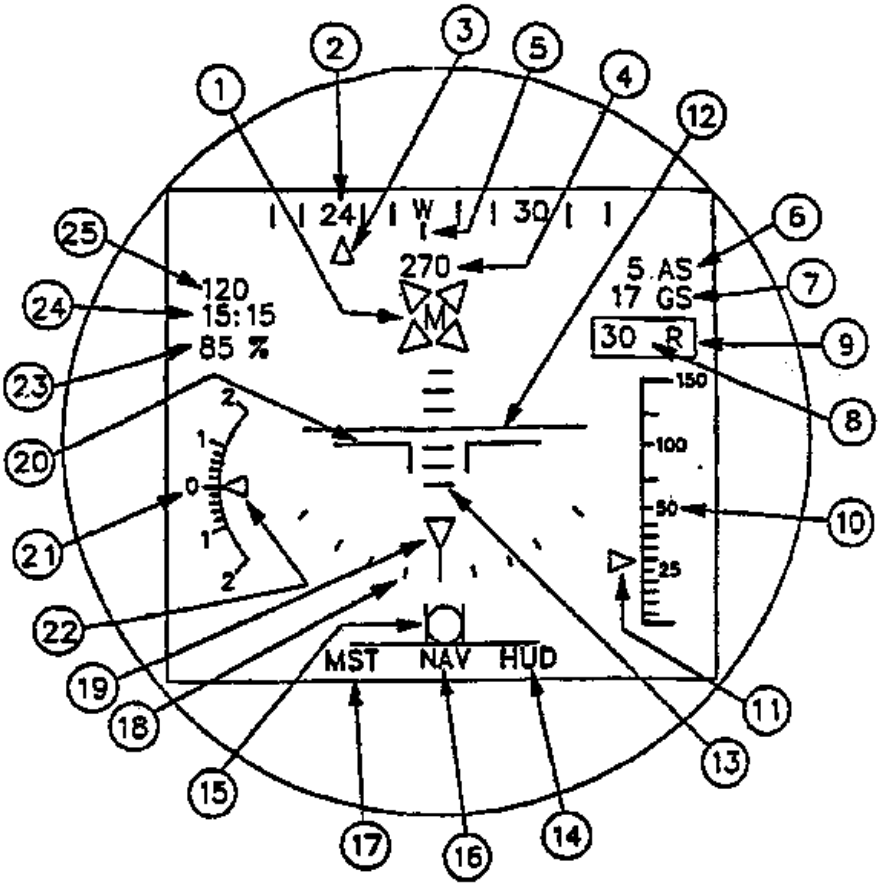

Figure 2 - 23. CH-46E Master Symbol Set

Notes:

(a) Symbols 1, 14, 16 and 17 are only displayed by exception for all modes, normal and decluttered.

(b) Frame around symbology is not present in actual AN/AVS-7 FOV

B. UH-1N Master Mode Symbology Set

1. Compass Reference Scale. This symbol will be displayed as an analog scale in the range from 0 to 359 degrees. A direction range of 90 degrees (± 45 degrees) will appear on the display itself at the same time. Each ten degrees will be marked by a division. Every third division will be marked by two numerals. Every third numerical marking will indicate one of the four cardinal points of the compass (N, S, E, W).

2. Bearing to Waypoint Analog. This symbol is an open caret mark that provides a sense of command direction from the mark.

3. Quadrant Threat Warning. Whenever one or more of the Quad Threat discretes is active, the NW symbol is displayed, together with one or more triangles in the appropriate quadrant as demanded by the discretes. The letters "FS" are on the upper right, "AS" lowered right, "AP" lower left and "FP" upper left.

4. Aircraft Heading Fixed Index

5. Pitch Ladder. Pitch will be displayed for values up to ±90 degrees. Negative pitch bars are dashed and positive bars are solid. All have tic marks on the end point toward the Horizon Line (up for negative pitches and down for positive pitches).

   Pitch Bars Scaling and Number: The pitch bars will be representative of 10 degrees pitch movement. No more than two pitch bars will appear at one time. When two positive or two negative pitch bars are displayed simultaneously, the lower one includes a small numeric near its starboard end. This numeric gives the value of pitch represented by that bar when its center coincides with the center of the aircraft symbol.

   Blanking of Pitch Symbol: In the Normal Modes, the symbol will be blanked when pitch is within the range of ± 6 degrees or greater. In the declutter mode the symbol shall always appear.

6. OK/FAIL Programming Indicator. OK flashes for two seconds when selected mode programming has been accepted by toggling BIT/ACK to the ACK position. FAIL will come on when MODE programming has not been accepted.

7. Time to waypoint. The time to waypoint range shall be [:0:00] to [9:59:59] as described below. The time to waypoint will be indicated in the following format: [H:MM] for time to waypoint greater than 10 minutes. For less than ten minutes, the following format will be indicated: [:M:SS]. The letters "H" indicates hours, "M" indicates minutes and "S" indicates seconds.

8. Distance to waypoint. The range is 0-999.9 nautical miles. The display increments are 0.1 nautical miles.

9. Horizon Line. The Horizon line represents 0 degrees pitch. It moves with the pitch ladder as one symbol. It disappears when the aircraft pitch angle exceeds (+20) degrees or (-10) degrees.

10. AGL - Pointer. Triangular symbol with two sides the same length. The vertex of the triangle shall remain perpendicular to the AGL scale bar. The symbol will disappear when exceeding 220 feet and will reappear of 200 feet. In between 200 to 220 feet, the pointer stops at the upper edge of the AGL scale.

11. AGL Analog Bar. Represents Altitude AGL (Above Ground Level). The value is shown by the pointer position (symbol 19) on the scale. The scale tick marks indicate 10, 20, 30, 40, 50, 100, 150, and 200 feet. The bar and pointer disappear when the altitude AGL exceeds 220 feet and reappears at 200 feet.

12. AGL Numeric. In the AGL range of 0 to 199 feet, height will be indicated every foot. In the AGL range of 200 feet to 400 feet, the height will be indicated every 10 feet. When exceeding 400 feet the symbol disappears and reappears at 380 feet.

13. Angle of Roll Scale. Roll will be displayed for values up to ±60 degrees on a circular arc centered on the center of the aircraft symbol position. The roll scale has marks representing each ten degrees and the ±30 and ± 60 degree markers accentuated. When the roll angle exceeds + 60 or - 60 degrees, the pointer remains at either + or - 60 degrees respectively and the pointer will flash. The horizon line, symbol 26 and the pitch ladder, symbol 25 can move in the roll axis in the range of 0-359 degrees.

14. Angle of Roll Pointer. The angle of roll pointer moves against angle of roll scale (20), pointing towards the center of the arc.

    Blanking of Roll Scale and Pointer: In the Normal Modes, these symbols are blanked when roll is <± 6 degrees. The symbols reappear if the roll value is equal to or greater than ±6 degrees. In the declutter mode, the symbol will always appear.

15. Low Altitude Warning. A flashing triangle, vertex pointed up shall appear for as long as the low altitude warning discrete is active.

16. Fire Warning. FIRE message will appear for as long as the fire warning message discrete is active.

17. ANVIS/HUD FAIL. Placement will be right of the inclinometer display, above the horizontal line and will be displayed by exception only.

18. Trim (slide ball). Range 2 Balls left to 2 balls right.

19. Sensors Fail Messages. When the system detects GYRO INVALID (Attitude) or indicated airspeed out of range a sensor fail warning message shall be displayed respectively, (IAS). In the event of two failures, the display priority shall be 1) ATT and 2) IAS. Using the ACK switch on the converter control will delete the highest priority symbol and display the next failure if it is present.

20. Master Caution Warning. Flashing rectangle (containing four diagonal lines) shall appear for as long as the master caution discrete is active.

21. Stores Master Arm. ARM message shall appear for as long as the master arm discrete is active.

22. Low RPM Warning. A triangle containing the "Nr" with its vertex pointed down shall appear as long, as the low RPM warning discrete is active.

23. Mode Number/Declutter Marker. A number from 1 through 4 will be displayed for normal modes 1 through 4; the letter "D" will be added to these numbers when in the Declutter mode. The mode number is only temporarily displayed in the mode even if the operator has selected the symbol. It will appear for the first five seconds after entering the mode (unless another mode is quickly selected).

24. Torque Numeric. Range 0 to 190 representing 190%. Display increments 1 unit. The symbol value is determined by an arithmetic summation of the two engine torque values. The digital torque numerics flash if the engine torque separation exceeds 10%.

25. Torque Limits. These limits are shown by the appearance of a box around the torque numeric. Yellow range 88-100% (total) is be indicated by a box appearing around the digital readout. The red range (exceeding 100% total) is indicated by the box flashing.

26. Torque Pointer. Triangular symbol with two sides the same length. The vertex of the triangle will remain perpendicular to the tangent of the circle at the point of contact. The torque pointer will be limited at each end of the scale.

27. Torque Analog. This symbol has a circular scale with markers at each end. A single pointer will run against this scale, showing the total torque produced by the two engines. The torque analog scale end marks as shown on the Master Mode Display symbology set represent 20% (tic mark on lower left end of arc) and 120% (tic mark on upper right end of the display). The top center of the arc represents 95% torque.

28. Aircraft Reference. This symbol represents the aircraft, with the side tabs being equivalent to wings. It is fixed relationship to the scales and numerics around the periphery of the display. It forms the reference against which the pitch ladder is read.

    Blanking of Aircraft Reference: In the Normal Modes, the symbol is blanked when the pitch is less than ±6 degrees (and therefore the pitch ladder bar is blanked). The symbol will reappear if pitch exceeds ±6 degrees. In the declutter mode, the symbol always appears.

29. Indicated Airspeed. Range 0 to 220 knots. Display increments 1 knot.

30. Programming Cue (HUD set W)

31. Bearing to Waypoint Numeric. Range 0-359 degrees. Display increments 1 degree.

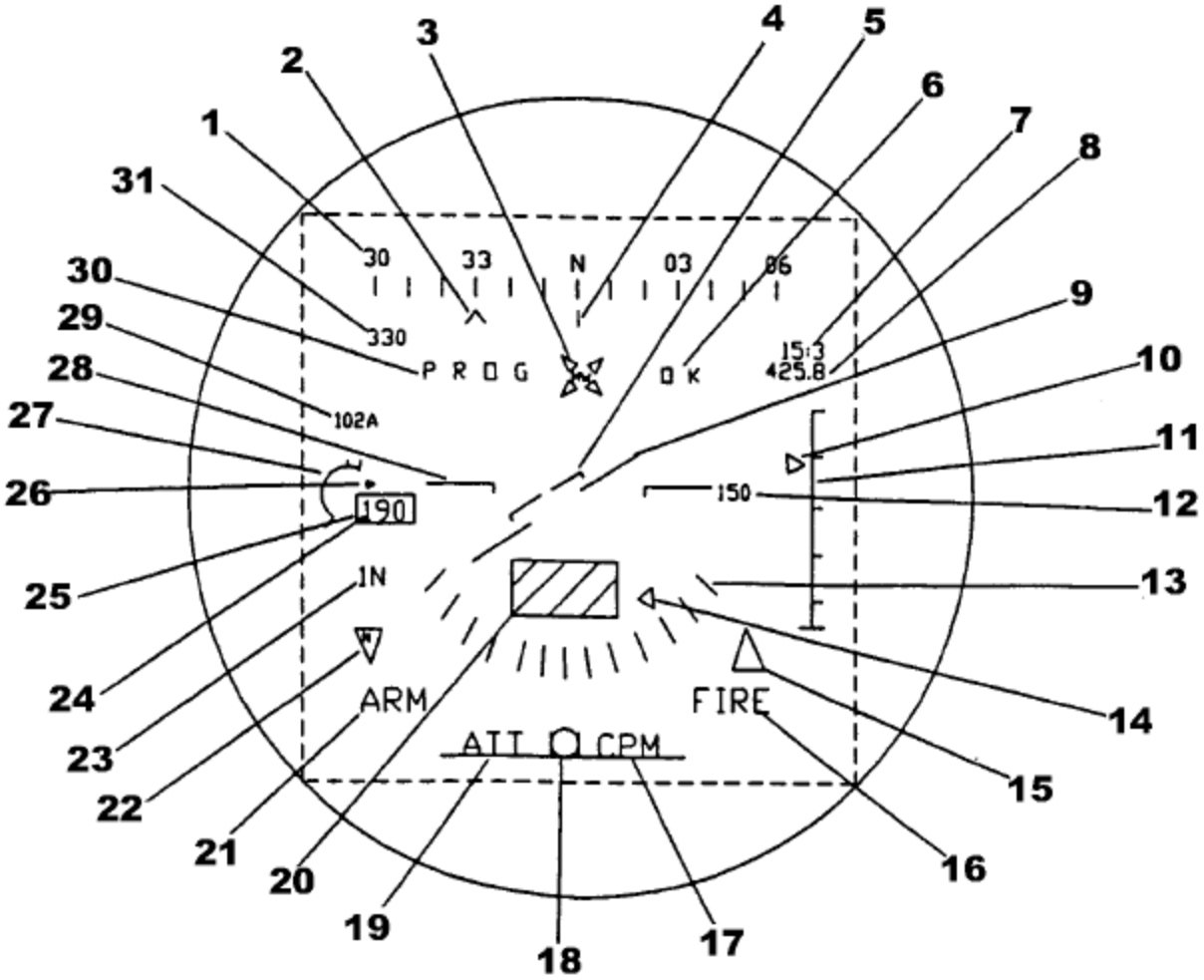

Figure 2 - 24. UH-1N Master Symbol Set

Notes:

(a) Declutter Safety Mode. The following symbols cannot be erased during the declutter mode: 1, 4, 5, 9, 13, 14, 24, 25, 28, and 29.

(b) Adjust Mode. Three parameters can be adjusted during the adjust mode: Pitch and roll are adjusted from zero. For the setting, start at 100 then go up and down one knot at a time. Programming procedure is consistent with the Army program.

(c) Various symbology is displayed by exception.

(d) Frame around symbology is not present in actual AN/AVS-7 ANVIS FOV

C. CH-53E Master / Navigation Mode Symbology Set

1. Aircraft Reference. This symbol represents the aircraft, with the side tabs being equivalent to wings. It is fixed in relationship to the scales and numerics around the periphery of the display. It forms the reference against which the pitch ladder is read. In the Normal Modes, the symbol is blanked when the listed pitch and roll conditions exist:

TABLE 2 - 7. NORMAL MODE AIRCRAFT REFERENCE PITCH AND ROLL CONDITIONS

	Airspeed (< 40 Knots)	Airspeed (≥ 40 Knots)
Pitch	0^0 to $+7^0$	-5^0 to $+5^0$
Roll	-5^0 to $+5^0$	-5^0 to $+5^0$

In the Declutter Mode, the symbol should always appear.

2. Aircraft Heading Fixed Reference. Provides an aircraft heading reference point. Displayed only when compass reference scale is displayed.

3. Compass Reference Scale. This symbol will be a display of the aircraft's MAGNETIC heading as an analog scale in the range from 0 to 359 degrees. A range of 120 degrees will always be displayed (i.e., ± 60 degrees of aircraft's magnetic heading). Each ten degrees will be delineated by a tick mark, with numerical markings corresponding to 30 degree cuts. Numerical markings will be two digits representing a three digit value (i.e. "33" for 330 degrees). Every third numerical marking will indicate one of the four cardinal points of the compass with the appropriate alphabetic character (N, S, E, W).

4. Magnetic Heading – Numeric. A numerical value corresponding to aircraft's MAGNETIC heading displayed with leading zeros: 000 to 359.

5. Digital Airspeed Indicator (KIAS). Provides a range of 40 to 220 knots indicated airspeed in increments of 1 knot. The numerics are followed by the letter "A" to represent airspeed. Below 40 knots the numerics are blanked and automatically reappear at 42 knots. Preceding zeros will be blanked.

6. Digital Ground Speed Indicator. Provides a display of the Ground Speed of the aircraft measured along the ground track. The ground speed is displayed in the range from 0 to 999 knots in increments of 1 knot with preceding 0's blanked. The numerics are followed by the letter "G" to represent Ground Speed.

7. Barometric Altitude, Digital. A digital display which provides a range from –1000 to + 20,000 feet above Mean Sea Level (MSL) in increments of 10 feet. The numerics are followed by the letter "B" to represent barometric Altitude. Numeric values may be adjusted in increments of 5 or 10 feet to closely match the cockpit instrument by using the Adjust mode of the system. Preceding zeros will be blanked and the symbol "-" will designate negative values.

8. RADALT Analog Scale. The scale ladder does not appear until the aircraft is at or below 500 feet AGL. When selected, the RADALT ladder will automatically appear when aircraft descends below 500 feet AGL. When the altitude is $\geq$ 510 feet AGL, the RADALT ladder is blanked. The scale from 0 to 500 feet has 0 to 100 feet occupying the first half of the scale with 10 foot tick marks. The second (upper) half of the scale is from 101 to 500 feet with nonlinear scale tick marks at 300 and 500 feet. Longer tick marks will mark the 0, 50, 100, 300 and 500 foot increments.

9. RADALT Pointer. A triangular pointer that moves against the RADALT Scale (Symbol 8).

10. Digital RADALT Reading. The display provides a numerical readout of RADALT (altitude above ground level) in increments of one (1) foot for altitudes from 0 to 100 feet. For altitudes from 100 to 990 feet, the display provides a numerical readout in increments of ten (10) feet. Above 990 feet, the symbol shall be blanked and shall reappear when AGL drops below 950 feet.

    For all normal master modes, the RADALT Reading Symbol will be initially displayed just left of the RADALT scale vertically positioned between 300 and 500 foot tick marks. As the Indicated Airspeed increases and becomes greater than or equal to 65 knots, the RADALT symbol will be displayed below the RADALT scale (Symbol #8). As the Indicated Airspeed (Symbol #5) decreases, and becomes less than or equal to 60 knots, the digital RADALT symbol will be displayed just left of the RADALT scale vertically positioned between the 300 and 500 foot tick marks. For all declutter master modes, the digital RADALT symbol will only be displayed in the position just left of the RADALT scale vertically positioned between the 300 and 500 foot tick marks of the RADALT scale. The RADALT symbol may overlap with the Pitch, Roll, Horizon line, and the Velocity Vector symbols under some conditions. The numerics will be immediately followed by the letter “R” (no space) and no preceding zeros will be blanked.

11. RADALT Low Altitude Warning. A box appears around the digital radar altitude reading when the pilot’s low altitude warning discrete is active. This directly correlates to the pilot’s low altitude warning indicator. Upon appearance, the box shall flash five (5) times and then shall remain on as long as the warning is active.

12. Not Used.

13. ANVIS/HUD System Fail/NAV Warning/Programming Messages. ANVIS/HUD system failure(s) are indicated by the following messages: CPM, SDR, SDA, PS, PDU, and CPDU. In the same location, a PGM message is displayed. The PGM message indicates that the operator of the other display is programming his symbol set. Finally, in this same position, a NAV message is displayed. The NAV message indicates that the ANVIS/HUD is not receiving data via the ARINC 429 data bus.

    The order of display precedence is: PGM, CPM, SDR, SDA, PS, PDU, CPDU, and NAV. All of the messages displayed shall flash five (5) times, then remain on for the duration of its appearance. The Acknowledge (ACK) switch on the Converter Control will reset the symbol with the exception of PGM. The reset symbol(s) will not appear again until either system BIT is run or system power is cycled. This symbol does not appear again in the programming mode.

14. FIRE. The FIRE symbol will illuminate and blank in accord with the illumination and blanking of the Fire Light.

15. Master Caution Message. The letters “CAUT” appear simultaneously with the illumination of the aircraft’s master caution light (When the Master Caution discrete is active). The message disappears once the aircraft’s master caution light is reset.

16. HOOK Annunciator. The letters “HOOK” will appear simultaneously with the illumination of the aircraft’s Flight Mode Unsafe indication.

17. Navigation System Warning. In the event that aircraft system navigation data is not valid, warning messages with the priorities listed shall appear:

    GPS: GPS Nav Valid Discrete is not active (logic 0)

    DOP: Doppler Invalid Discrete is active.

    These symbols will flash five (5) times then remain on for the duration of their appearance. The Acknowledge (ACK) switch will clear the symbol; it will not appear again until either system reset or power down.

18. Inclinometer/Ball (Trim). Analog display of electronic inclinometer in the range of **±** 2 Ball for indication of side slip.

19. Mode Number/Declutter Marker. The numbers 1 through 3 will be displayed representing the normal modes 1 through 3 and the number 4 will be displayed for the navigation mode. The letter “D” will be added to these numbers when in the Declutter mode. The mode number is only temporarily displayed even if the operator has selected the symbol. It will only appear for the first five seconds after entering the mode (unless another mode is quickly selected).

20. Program/Adjust/OK/Fail. PROG appears in the display being programmed (with the full Master Mode Symbology set) while the user is in the program mode. While in the Programming Mode, the other user will have a PGM message displayed in the System Fail/Programming Messages position (Symbol 13). An OK or FAIL will be temporarily displayed after activating the ACK switch on the Converter Control to indicate a successful or unsuccessful programming secession. The ADJ message will be displayed in the same position as the PROG symbol when the adjust mode is selected on the Converter Control. Pitch, roll, and Barometric Altitude (MSL) are the only parameters that can be adjusted during the adjust mode. Each adjust mode will be indicated on the display unit with the letters "P", "R", or "B" following the ADJ message. These three parameters can be adjusted from the lower (minimum) to the upper (maximum) boundaries of the parameter as follows:

    MSL: from –1000 to +20000 ft, in 5 ft increments for the first 2 seconds of increment switch activation then in 10 ft increments.

    Pitch: from +180 to –180 degrees, in one degree increments

    Roll: from 0 to 359 degrees in one degree increments

Adjustment allows the pilot/copilot to provide a close match between the displayed values and the cockpit instruments. An “ADJ” symbol appears in both displays only while the system is in adjust mode.

21. Vertical Speed Scale (VSI). The VSI scale indicates a range between ± 2000 feet per minute (fpm) for upward or downward acceleration, graduated in 500 fpm increments between ± 1000 fpm indications. A single digit numeric 1 and 2 will indicate ± 1000 and ± 2000 fpm respectively.

22. Vertical Speed Pointer. The VSI pointer is an open caret whose apex remains perpendicular to the tangent of the scale at the point of contact. When the Vertical speed exceeds + 2000 ft/min or – 2000 ft/min, the pointer shall park at the ± 2000 ft limit, and shall flash for as long as the condition exists. The VSI pointer works concurrently with the VSI scale.

23. Horizon Line. The Horizon Line represents 0-degree pitch and moves with the pitch ladder as one symbol. This symbol indicates the pitch and roll angles of the helicopter. The Horizon Line and the Angle of Pitch Scale (Symbol 24) appear/disappear and move together in the roll (0 to 359 degrees) and pitch axes (± 45 degrees).

24. Angle of Pitch Scale. The Angle of Pitch Scale is a ladder symbol that indicates ± 30 degree pitch in 10 degree increments. The ladder movement is limited to ± 45 degrees in pitch. When the pitch of the aircraft is greater than or equal to + 46 degrees (nose up), the – 30 degrees pitch ladder scale mark flashes. When the pitch of the aircraft is greater than or equal to – 46 degrees (nose down), the + 30 degree pitch ladder scale mark flashes. The pitch ladder is concurrent with the horizon line. In the Normal Modes, the symbol is blanked when the listed pitch and roll conditions exist:

TABLE 2 - 8. NORMAL MODE ANGLE OF PITCH INDICATOR PITCH AND ROLL CONDITIONS

	Airspeed (< 40 Knots)	Airspeed (≥ 40 Knots)
Pitch	0^0 to $+7^0$	-5^0 to $+5^0$
Roll	-5^0 to $+5^0$	-5^0 to $+5^0$

In the Declutter Mode, the symbol always appears.

25. Velocity Vector. The vector consists of a small square connected to the center of the aircraft reference symbol by a line. The distance and direction the velocity vector moves from the reference point will represent known DRIFT from the reference point. Full display displacement will indicate 15 knots and direction from reference point indicates relative bearing from aircraft. When the displacement exceeds 15 knots, the Velocity vector will park at the 15 knot position, however the direction may change.

The Velocity Vector will be displayed when the ground speed is ≤ 40 knots. When the ground speed exceeds 40 knots, the velocity vector will be blanked and will reappear when the ground speed is ≤ 35 knots.

The Velocity Vector symbol will blank when the Doppler Invalid Discrete is active (Doppler is transmitting from memory).

26. Torque – Numeric. The numeric torque display is the arithmetical average of the three engine torque values. The average torque will be displayed in % with two (2) percent increments for values from 0 to 120 % and with one (1) percent increments for values from 121 % to 160 %. The torque readings will range from 0 to 160 percent and will be followed by the percent symbol "%" to represent torque value. Preceding zeros will be blanked.

27. Commanded Ground Speed. This symbol will display the Ground Speed (range 0-999 knots) required for the aircraft to arrive at Waypoint 1 within a time period designated by the pilot/co-pilot on the CDNU. The numerics are followed by the letter "C" to represent Commanded Ground Speed.

28. Range to Waypoint, Digital. The Great Circle distance from the present position to the selected waypoint on the CDNU (displayed range will be from 0-999.9 nautical miles).

29. Bearing to Waypoint, Digital. A numeric display of the direction of the selected waypoint on the CDNU, relative to Magnetic North, from the present position of the aircraft. The numeric bearing will be corrected from a true value to a magnetic value using magnetic variation data. The Magnetic Variation is the angular difference between True North and Magnetic North. The Magnetic Variation data will be positive when Magnetic North lies EAST of True North and negative when Magnetic North lies WEST of True North. The bearing to Waypoint Magnetic is calculated using:

$$\textbf{Bearing}_{\textbf{Magnetic}} = \textbf{Bearing}_{\textbf{True}} + \textbf{Magnetic Variation}$$

The display will indicate the heading in the range from 0 to 359 degrees in 1-degree increments. Preceding zeros will be blanked.

30. Bearing to Waypoint – Pointer. Magnetic Heading to Waypoint information will be displayed using an open caret that moves along the Compass Reference Scale (Symbol #3). The closed end of the caret points up for heading directions within ±65 degrees heading relative to the nose of the aircraft *(To)* and downward for directions within ±65 degrees heading relative to the tail of the aircraft *(From)*. In addition, the caret will point right or left as appropriate and flash for headings to either side of the aircraft. (Note that the pointer moves 5 degrees beyond the end of the compass heading scale before limiting. This provides the total range of ± 65 degrees.) The data to drive this symbol will be corrected from a true value to a magnetic value using magnetic variation data. Refer to the description for Symbol 29.

The readout data for Bearing to Waypoint is both digital (Symbol 29) and Analog Pointer (symbol 30). The analog pointer will indicate the direction to the next navigation waypoint as selected by the pilot (by the NAV system) and is combined with the display of the flight direction, Symbol 3. Three different positions are possible depending on the bearing to selected waypoint and aircraft heading (Figure 2-24):

0 to ± 65 degrees: Moving straight up horizontally ("^")

± 66 to ± 115 degrees: Parking and flashing on the left or right side pointing outward indicating the shortest direction to the bearing ("< or >")

+ **116 to ± 180 degrees:** Moving inverted horizontally ("V")

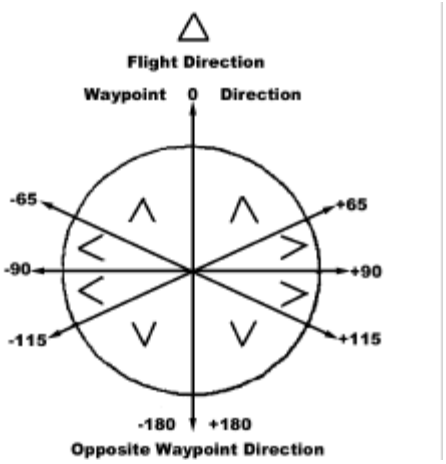

Figure 2 - 25. Bearing Waypoint Symbology

31. Angle of Roll Scale. Aircraft roll is displayed for values up to ± 30 degrees on a circular arc centered between the fixed aircraft reference (Symbol 1). The roll scale extends to ± 30 degrees in ten degree increments. The RADALT symbol may overlap with the Pitch, Roll, Horizon Line, and the Velocity Vector symbols under some conditions. The numerics will be immediately followed by the letter "R" and preceding zeros will be blanked.

32. Angle of Roll Pointer. The triangular scale pointer moves against the Angle of Roll Scale (Symbol 31) to ± 45 degrees and shall maintain a perpendicular orientation to the tangent of the roll scale. When the roll exceeds ± 45 degrees, the pointer shall remain at the ± 45 degree position and flash.

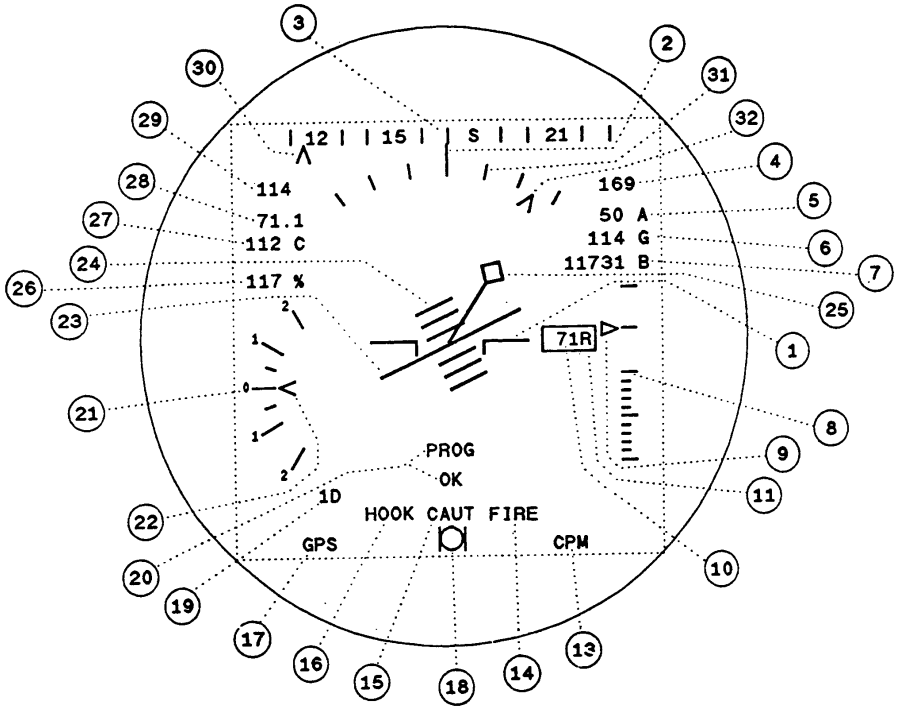

Figure 2 - 26. CH-53E MASER Mode Symbology (Airspeed ≤ 60 Knots)

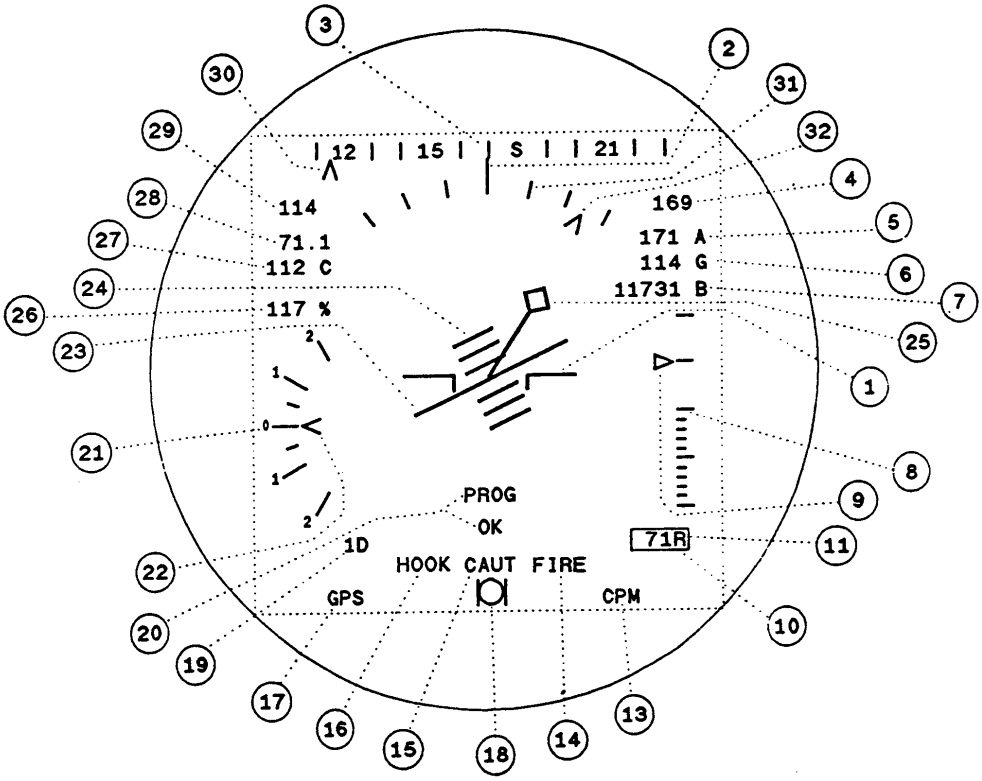

Figure 2 - 27. CH-53E Master Mode Symbology (Airspeed ≥ 65 Knots)

33. Horizontal Percent Deviation Scale (NAVIGATION MODE). This symbol will be displayed as an analog scale in the range of ± 150% (± 3 dots) deviation. Every 50% will be marked by a division, with the center division in the form of an airplane indicating zero percent deviation from course. The analog scale will remain fixed in the display.

34. Horizontal Percent Deviation Pointer (NAVIGATION MODE). The Horizontal Percent Deviation Pointer is a triangle with a line extension from the vertex that points toward the indices. The pointer moves horizontally across the scale to indicate the horizontal percent deviation from the desired course from – 128% to + 127%.

35. Waypoint Identifier (NAVIGATION MODE). A five alphanumeric character symbol that replicates Waypoint ID #1 from CDNU.

36. Estimated Time of Arrival at Destination (NAVIGATION MODE). A display of the Estimated Time of Arrival at the final waypoint in the current flight plan will be displayed in hours, minutes, and tenths of minutes with a maximum time of 06:39:9 (399.9 minutes). The letter "D" will follow the last digit and leading zeros shall be displayed.

37. Estimated Time of Arrival (NAVIGATION MODE). A display of Estimated Time of Arrival (ETA) to waypoint 1 provided by the CDNU. ETA will be displayed in hours, minutes, and tenths of minutes with a maximum time of 06:39:9 (399.9 minutes). The letter "A" will follow the last digit and leading zeros shall be displayed.

38. Estimated Time Enroute (NAVIGATION MODE). A display of the estimated transit time to the designated waypoint selected on the CDNU. The Estimated Time Enroute (ETE) is calculated within the CDNU by dividing the Distance to Go data by the Ground Speed. ETE will be displayed in hours, minutes, and tenths of minutes with a maximum time of 36:24:5 (131,071 seconds). The letter "E" follows the last digit and leading zeros are displayed.

39. Time-GMT (NAVIGATION MODE). A display of Time as transmitted by the CDNU will be displayed in hours, minutes and tenths of minutes. The letter “Z” will follow the last digit and leading zeros shall be displayed.

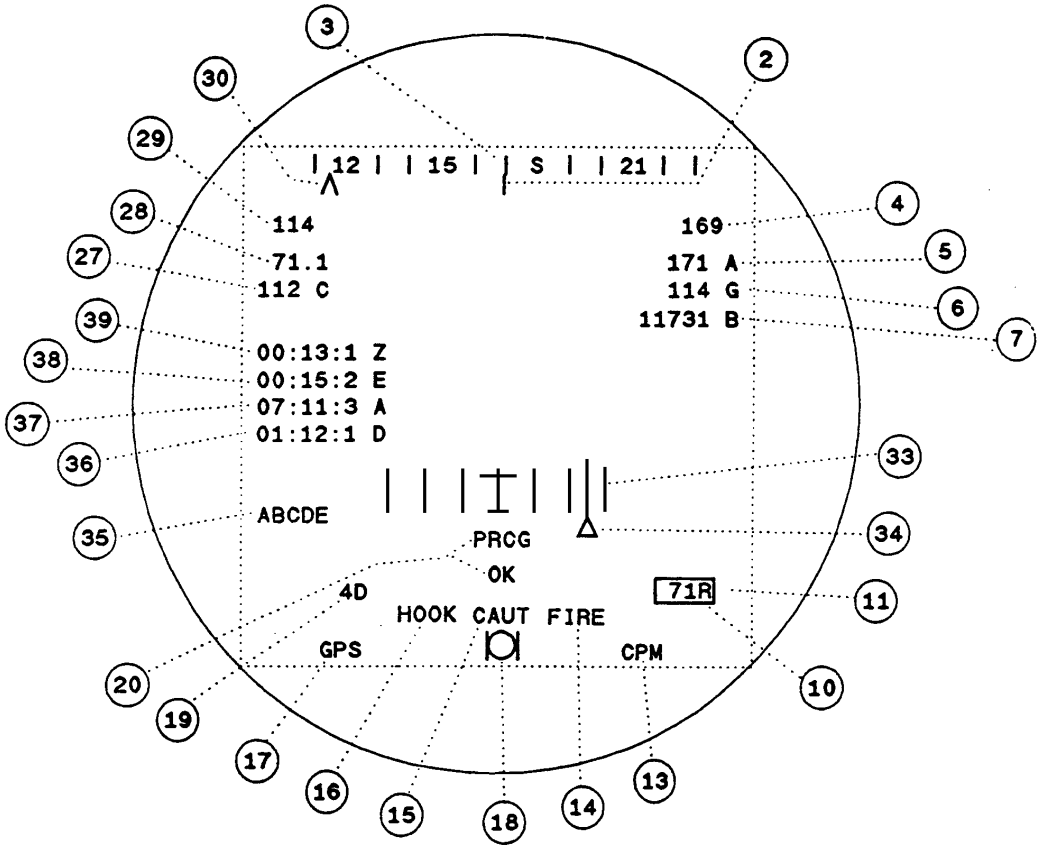

Figure 2 - 28. CH-53E Navigation Mode Symbology

Notes:

(a) The flash rate of the symbology will be 2 Hz.

(b) The AN/AVS-7 ANVIS HUD is capable of 8 displays for the pilot and 8 displays for the co-pilot. The 8 displays are made up of 3 normal and 1 navigation mode display and associated Declutter displays. Each display is created by entering the programming mode and deselecting symbols from the master mode symbology. Therefore, it is possible for the Declutter mode to have more symbology than the associated display mode. All displays are retained in system memory after power is removed, therefore,

reprogramming is not necessary after each flight. The pilot and co-pilot each have independent control over their respective displays.

(c) Non-Deselectable Symbology: In the Normal Modes, all symbols may be deselected. The following is a list of all non-deselectable symbols in the Declutter Mode:

1:HUD System Fail Warning	Symbol 13
2:Fire Warning	Symbol 14
3:Master Caution	Symbol 15
4:Hook Message	Symbol 16
5:NAV System Fail Warning	Symbol 17
6:Mode Number/Declutter Marker	Symbol 19
7:Program/Adjust/OK/Fail	Symbol 20

D. HUD vs. HMD Discussion

When describing a monocular overlay of symbology on a head worn NVD, the term Head Up Display or HUD is truly a misnomer. The AN/AVS-7 ANVIS HUD is not a HUD in the conventional sense. Typical aircraft HUDs consist of a combiner lens that is rigidly attached and referenced to the airframe. These aircraft mounted HUDs provide critical aircraft performance or targeting information, Figure 2-29.

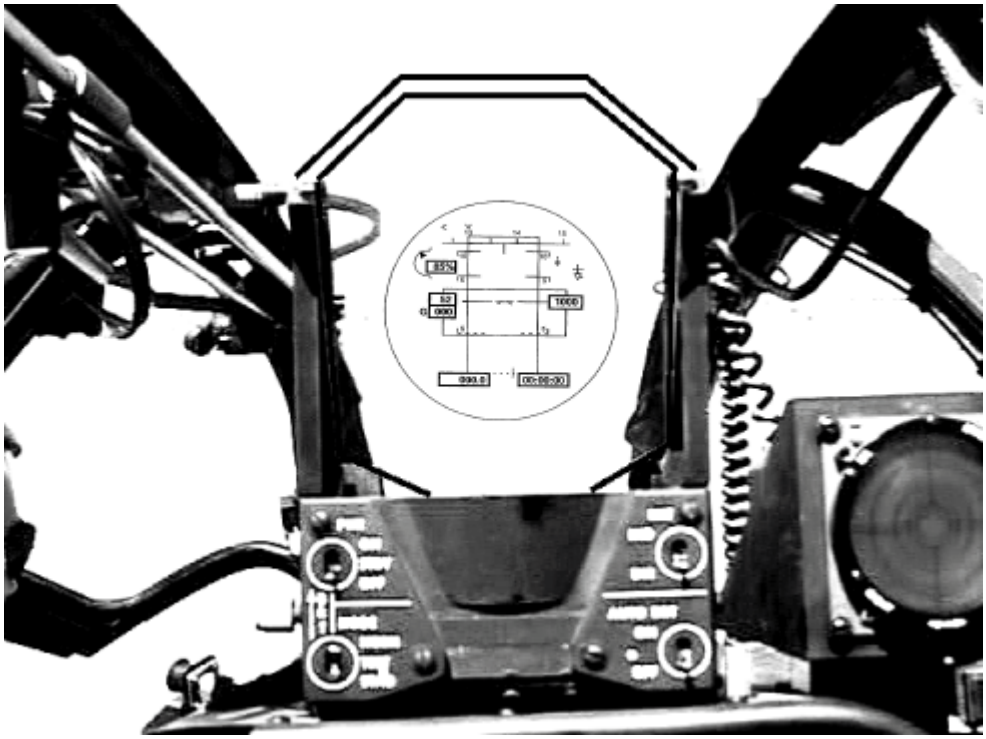

Figure 2 - 29. AH-1W Rear Pilot Station Aircraft HUD

One might argue that because the AN/AVS-7 ANVIS HUD is mounted on the pilot's helmet, that it is better described as a Helmet Mounted Display (HMD). While this description appears more accurate than HUD, HMDs are generally renowned for incorporating head tracking and pilot or world stabilized frames of reference. To date there are only a handful of HMD development efforts fielded. Although HMDs are generally thought of as being binocular, fielded monocular systems like the Integrated Helmet and Display Sight System (IHADSS) used in the AH-64 Apache helicopter, for example, could be considered a HMD. The AN/AVS-7 ANVIS HUD could probably best be described as a flight symbology overlay for the following reasons:

1. Unlike the glass HUD, the AN/AVS-7 ANVIS HUD it is not mounted to the airframe. Although the imagery (symbology) is sensor driven, the sensor (NVD) is directly attached to the pilot's head. For this reason, the device is not limited to a particular head orientation for viewing. The Pilot will have both a sensor image and symbology presentation while looking left, right, up or down... even while looking inside the cockpit. Such flexibility may have a high price.

2. Unlike the HMD, the helmet Display Unit (HDU) associated with the AN/AVS-7 HUD is not head-tracked. It is really a monocular symbology overlay for the helmet-mounted AN/AVS-6 NVG. Conformity or the marriage of the virtual horizon to the actual horizon, becomes a key issue. For Assault Support applications, frame of reference has monumental implications. A world-stabilized reference system either blanks or transforms the symbology to account for look angle that differs significantly from aircraft motion. In the AN/AVS-7 ANVIS HUD application, the symbology is aircraft referenced, the display is head worn but not head tracked, leading to potentially contradictory cueing. The AN/AVS-7 ANVIS HUD is conformal, if and only if, the pilot cooperates by orienting his head so that the two horizon sight pictures coincide. Whenever the pilot tilts his head (i.e., towards the inside of a turn, etc.) the fidelity of the attitude symbology will be degraded. For this reason, use of such a device as a primary flight reference in degraded visual conditions, may not be successful. Conformity issues are not limited to turning flight. In the case of the lateral slide from a hover, for example, with the Pilot looking 90 degrees away from aircraft heading (along the axis of translation), roll cues appear as if along the Pitch axis and vice versa.

With these considerations in mind, it may be best to think of the AN/AVS-7 ANVIS HUD as providing flight worthy symbology for the AN/AVS-6 rather than as a stand alone HUD or HMD.

V. LASER Effects on NVDs

The proliferation of LASERs on the battlefield, whether used as rangefinders, designators, flashblinders or designated weaponry, poses a significant optical / electro-optical threat to our night operations. Our reliance on high technology NVDs that are sensitive to very low levels of reflected visible and near infrared energy may be jeopardized by weapons that can direct visible and / or infrared energy against us. FLIR systems are also threatened by the introduction of directed energy weapons. Meeting the demands of hardening our night systems and protecting our aircrew with appropriate tactical countermeasures begins with a basic understanding of LASER technology, the capabilities, limitations and the depth of the potential threat.

A. LASER Definition

The LASER is an electro-optical device that produces ultraviolet, visible, or infrared radiation by the process of controlled stimulated emission. The acronym LASER stands for Light Amplification by the Stimulated Emission of Radiation. LASERs generate a collimated beam (i.e., parallel rays) of intense, coherent (i.e., the photons are in-phase) and monochromatic energy. The emitted beam can be either continuous wave (CW) or pulsed. A pulsed LASER is usually more powerful and damaging than a CW because the energy is condensed into rapid, bullet-like pulses. These LASER pulses can range in duration from tenths of seconds (10^{-1}) down to nanoseconds (10^{9} seconds). A LASER system's output wavelength is determined by the specific LASER medium (i.e., Ruby, Neodymium, etc.) used in the system. The specific LASER medium ultimately determines the system's application, effectiveness as a threat and the protection required to counter its effect. Figure 2-30 shows the spectral location of the sensors we use at night and the potential LASER threat wavelength lines that pose an in-band threat to those sensors. Those LASERs that emit energy in the same spectral region as the sensitivity of the sensor are considered in-band to the sensor and therefore require very little power or exposure duration to produce damaging effects. LASERs that possess output wavelengths outside the sensitivity of the sensor are considered out-of-band and typically require significantly more power and / or longer periods of exposure to adversely affect the sensor.

B. LASERs and Night Vision

The human eye is sensitive to visible wavelengths between 0.40 and 0.70 microns. Common LASER mediums with outputs in this band include the CW green Argon Ion (0.514 microns), the pulsed green Doubled Neodymium (0.532 microns) and the pulsed red Ruby (0.694 microns). All LASER energy between 0.40 and 1.4 microns is absorbed by the retina and could produce retinal damage, including the out-of-band Neodymium:Yttrium Aluminum Garnet (Nd:YAG) operating at 1.064 microns. UV and IR LASERs (wavelengths $\leq$ 0.40 microns and $\geq$ 1.4 microns) are absorbed by the front structures of the eye. Out-of-band LASERs with sufficient power can produce thermal eye injuries. LASER eye protection must be specifically designed for the threat wavelength, and must have a high scotopic transmissivity; that is, sufficient light must be able to pass through the protection to allow safe night operations.

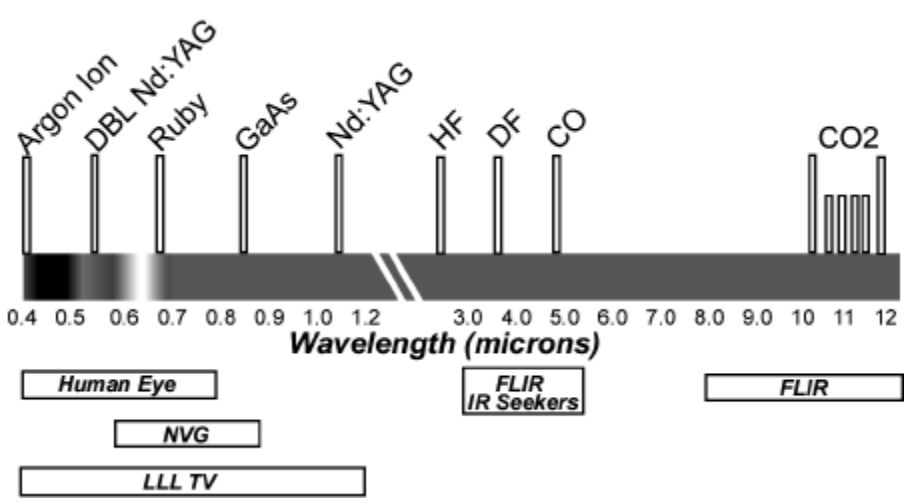

Figure 2 - 30. LASER Output Wavelengths and Sensor In-Band Spectral Sensitivity

C. LASERs and Night Vision Goggles

Generation III I^2 tubes (AN/AVS-6) tubes are sensitive from 0.60 to 0.90 microns, but are effectively filtered for cockpit compatibility below 0.625 (Assault Support Aircraft) and 0.665 (TACAIR Aircraft) microns. Common LASERs that are in-band with the AN/AVS-6 include: Ruby and Gallium Arsenide (GaAs). CW LASER in-band effects on AN/AVS-6 approximate that of conventional light. I^2 tubes will degain (shutdown), bloom, and in extreme cases incur immediate damage. The AN/AVS-6 does afford protection to the aircrew from the LASER in that they will protect the sensitive central field of view of the eye. Since the AN/AVS-6 is not a direct view optic, LASER energy is absorbed mechanically within the intensifier tube and therefore is not transmitted to the eye. Pulsed LASER in-band effects on AN/AVS-6 may include rapid damage to the device without the pilot perceiving any warning (bloom, etc.). Out-of-band CW effects could be expected to produce effects similar to in-band effects, but will require much higher power levels and extended exposure times to do so. Pulsed LASERs, with their associated power levels, can be expected to produce greater out-of-band effects than continuous wave. There are, in fact, two forms of aircrew LASER protection that we must be considered:

1. Aircrew Eye Protection. As previously mentioned, the AN/AVS-6 NVGs provide an inherent degree of protection to the aircrew's central field of vision is protected. This protection is provided by the internal structure of the I^2 tube acting as a mechanical stop against the LASER energy. However, there is no automatic provision to protect aircrew peripheral vision. LASER spectacles that may fit behind the NVG and provide this type of peripheral protection are currently being developed, but certain compatibility difficulties must be worked out before these find widespread use among aviators.

2. NVG LASER Hardening. LASER protection for the NVGs themselves is now available with the introduction of the Light Interference Filter (LIF). The LIF is an out-of-band optical filter designed to protect AN/AVS-6 I^2 tubes from LASER damage. The LIF does not provide any additional protection for the human eye. By design, LIFs reduce the amount of light entering the NVG tubes. The HMX-1 assessment of the LIF concluded that AN/AVS-6 performance may be reduced during low light level and low target/terrain contrast conditions (featureless desert, snow, etc.). During conditions of high target/terrain contrast, regardless of light level, AN/AVS-6 performance was not degraded by the LIF use. The LIF will only mount to those AN/AVS-6 modified with a LIF collar (adapter) over the objective lens assembly. The LIF collar and mounting instructions was distributed to the fleet as part of a LIF package for AN/AVS-6 retrofit. All AN/AVS-6 ANVIS delivered under the Omnibus-III contract include the new LIF attached to the objective lens. Existing AN/AVS-6 can be modified with either the original or new LIF. Figure 2-31 shows the original and new LIFs and LIF container. Original LIFs, by far the most common, have evenly spaced lugs or notches around the outside. New LIFs have a lug missing on each side, 180 degrees from each other, and provide protection against more LASER threat wavelengths. LIF countermeasure information (LASER, wavelength, and optical densities) is outlined in CMC Washington DC//APW//220004Z AUG 94 (SECRET) and is to be incorporated into future helicopter TACMANS (Vol. II).

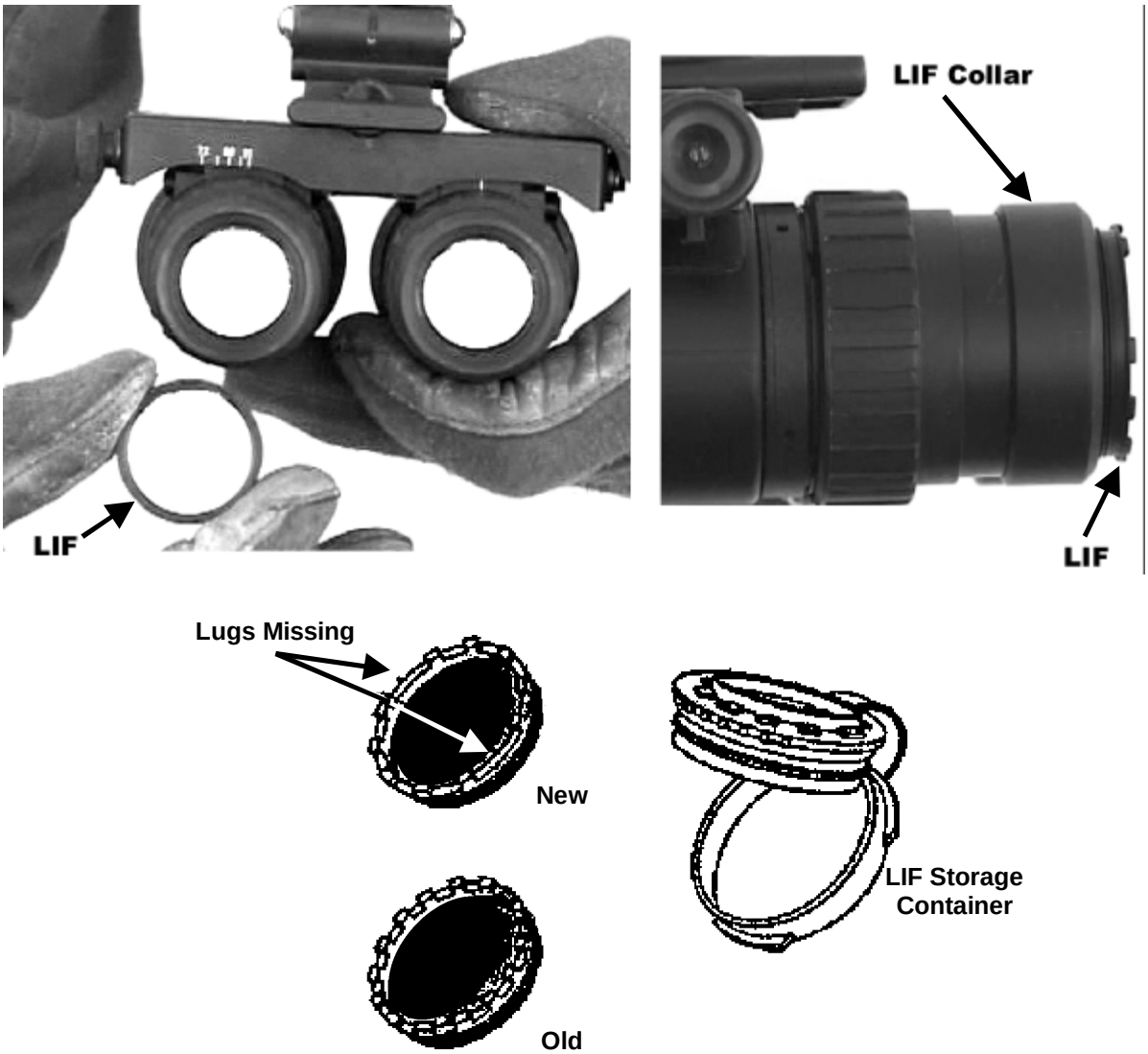

Figure 2 - 31. Light Interference Filter (LIF) and Container

(a) LIF Operational Use. The Assault Support aircraft AN/AVS-7 NVG HUD and the AH-1W Gideon NVG HUD with Gideon Adapter is designed to be mounted only on AN/AVS-6 that have the LIF collar installed. The LIF filter threads into the sleeve and can be installed or removed as required. Use of the LIFs is at the discretion of squadron commanders. In deciding whether to install or remove the LIFs, operational commanders should weigh the potential performance reduction utilizing LIFs in low light level / low contrast conditions against the risk of exposure to damaging LASER energy.

(b) LIF Installation. The following procedures should be used to ensure that the LIFs are installed correctly onto the AN/AVS-6:

1:Remove the light interference filter (LIF) assemblies from the carrying case.

2:If the lens caps are on the objective lenses of the AN/AVS-6, remove them.

<<CAUTION>>

Be careful not to touch the glass surface. If you get fingerprints or contamination on the glass surface, use lens paper to clean the filter. If moisture is needed, dampen the lens paper with clean water.

3:Carefully open one of the containers and remove the filter, Figure 2-31.

4:Hold the filter by the notched end and thread it, clockwise, into the end of the LIF collar on the objective lens of one of the monoculars, Figure 2-32.

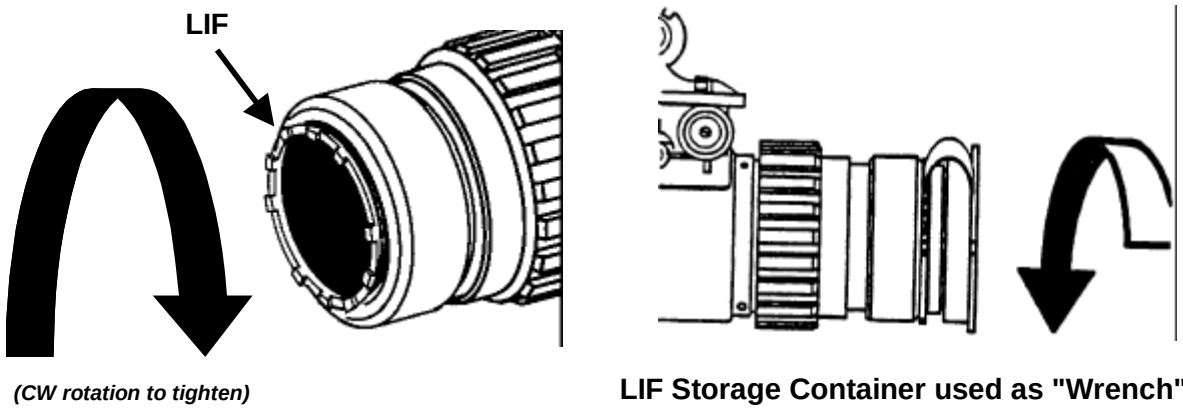

Figure 2 - 32. Light Interference Filter (LIF) Installation

5:Using the ridged side of the storage container as a wrench, engage the ridges on the container with the ridges on the filter and tighten the filter hand tight (Figure 2-32).

6:Place the empty filter container back into the AN/AVS-6 carrying case.

7:Repeats steps (3) through (6) for the other monocular.

8:To remove the LIFs, use the ridged side of a filter container to unscrew the filters. Return the filters to their containers and place the containers back into the carrying case.

<<CAUTION>>

Do not over tighten the filter into the objective lens.

D. LASERs and FLIR

FLIR detectors function by sensing thermal differences (8 to 12 micron range) being radiated by objects and terrain. The most common in-band LASER in this far infrared region is the CO_2 LASER that typically operates at 10.6 microns. The CO_2 LASER will produce saturation of the thermal detector. As the energy is increased, the detectors may be damaged and rendered useless. Attempts at FLIR hardening are ongoing.

E. LASER Eye Protection

Aircrew should utilize LASER eye protection when operating with LASER designators and rangefinders. Aircrew should ensure that proper protection is used based on the assessed threat. Proper protection includes adequate optical density (the attenuation factor) for each threat wavelength while allowing a sufficient amount of "safe" light to be transmitted.

<< CAUTION >>

Most multiple wavelength LASER protection devices currently available have very low night transmittance levels and are deemed unsafe for night flight. Additionally, NAWC studies have shown that these devices, when worn behind the NVG, significantly reduce visual acuity and contrast of the NVG image. New advanced LEP is currently under development to meet this technological challenge.

VI. Adjunctive Eye Protection: Parachutist's Goggles

When operating in areas with high concentrations of ash, dust, fine sand or other atmospheric particulate matter, assault support aircrews are routinely exposed to potential eye hazards, especially during takeoff and landing phases of flight. Enlisted aircrew are particularly affected when their duties require them to extend their head outside the aircraft to report proper obstacle clearance and aircraft drift. This hazard is magnified during NVG aided operations due to the inability of aircrew to lower the helmet visor. The result is virtually no eye protection during low-level NVG aided operations in dusty environments. In order to alleviate this hazard, HMLA-369 identified the potential to use parachutist's goggles under one's helmet visor and under the NVGs for added eye protection. A follow-on HMX-1 Flight Assessment evaluated three different Parachutist's Goggles (18 Jul 94) for day and NVG aided operations. COMNAVAIRSYSCOM subsequently authorized the Gentex Parachutist's Goggle (USAF P/N G022-4607-02) for use with the HGU-84/P for flight (302018Z AUG 94), Figure 2-33. For NVG aided operations, the parachutist's goggles can be attached to the helmet snap fasteners that are used to attach the day bungee visor to the HGU-84/P.

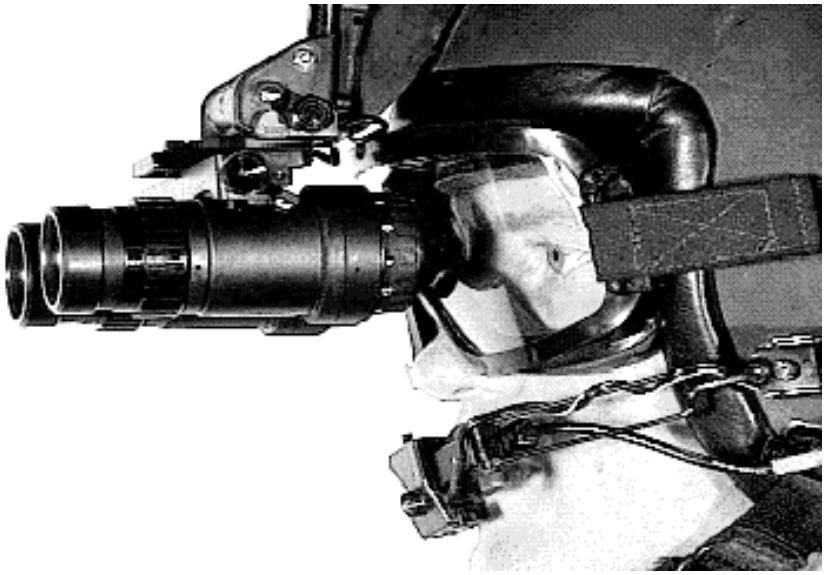

Figure 2 - 33. Parachutist's Goggle Eye Protection integrated with AN/AVS-6

VII. Summary

Over the past 20 years there have been tremendous advances in NVG technology. The original Generation-II aviation adapted AN/PVS-5 NVG possessed a Mil-Spec visual acuity and system gain of 20/50 and 1,000, respectively. The USMC fleet introduction of the first true aviation designed Generation-III NVG (AN/AVS-6) occurred over a decade ago. The performance improvements associated with these first (pre-Omnibus) AN/AVS-6 NVGs were seen as revolutionary over the previously integrated AN/PVS-5 NVGs. The improved sensitivity, resolution and gain of the AN/AVS-6 ANVIS NVGs defined a new generation of I^2 devices. Since the fleet introduction of the first AN/AVS-6 NVGs, I^2 technology manufacturers have improved design and manufacturing techniques that has allowed for a stepwise increase in NVG performance. Although the AN/AVS-6 still remains a Generation-III NVG, the introduction of the Omnibus-IV specification I^2 tube has raised the standard of expected I^2 performance to nearly that of the unaided eye (20/25: Omnibus-IV NVG visual acuity performance under HLL and high contrast viewing conditions). The Omnibus-IV AN/AVS-6 possesses a Mil-Spec visual acuity and system gain of 20/25 and 6,000, respectively. This represents a two fold increase in acuity and a six fold increase in gain over the AN/PVS-5 NVGs and a 1.5 fold increase in acuity and a three fold increase in gain over the first AN/AVS-6 NVGs. As NVG technology improves and the tactics of NVD aided operations evolve, the impetus still remains on the aircrew to understand the underlying capabilities and limitations of the technology in order to safely and effectively exploit these enhancements.

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Chapter 3

Night Vision Device (NVD) Human Factors

I. Introduction

NVD aided operations possess significant aeromedical concerns that must be taken into consideration during mission planning and ultimate mission execution. The first consideration that must be emphasized with NVDs is that they do not allow you to assume a day VFR posture for mission planning or execution. During NVD aided operations we add the challenge of interpreting an electro-optical viewing device for acquiring the critical visually based orientation cues and integrating mission specific and flight instrument crosscheck scan patterns. Unlike looking through a pair of binoculars, NVGs and FLIR systems do not provide direct viewing of the object. Even though vastly superior to night unaided vision, the NVD image is just an artificial TV screen representation of the real world and it does not provide a daylight quality image. NVDs should be treated as a very reliable, very accurate instrument, but as with all other instruments, it must be continually cross-checked with other aircraft systems and / or crewmembers to get an accurate assessment of the real world. There are many visual perceptional limitations associated with NVDs as well as the potential for fatigue, spatial disorientation, breakdown in crew coordination and complacency. Fortunately, many of these limitations can be countered through proper training and detailed preflight planning.

II. Visual Performance

A. NVG Spatial Orientation

The greatest aeromedical challenge for NVD operations is the impact of the NVD / human (visual system) interface and ones ability to correctly interpret the image presented. One's visual sense possesses the strongest input to one's overall spatial orientation and subsequent situational awareness. The visual system is functionally divided into two distinct systems, the central (focal) and peripheral (ambient) systems (Table 3-1). Each of these visual systems is impacted by NVD use and therefore can result in degraded visual capability as compared to the daytime adapted eye's (photopic) performance. Daytime visual performance is the gold standard by which we compare NVD performance. As discussed in Chapter 2, the progression of I^2 technology has lead to significant NVG performance improvements, however, one should never become complacent with the quality of the image that is presented by a NVD. By virtue of NVD design limitations (i.e., FOV, lack of color discrimination, visual acuity, etc.), operationally significant misperceptions and visual illusions can occur during NVD aided operations. The NVD challenge for aircrew remains to develop the knowledge base and training exposure necessary to completely understand and respect the interaction between the I^2 technology, the night environment and the NVD / human interface.

TABLE 3 - 1. HUMAN VISUAL SYSTEM

Central Vision	Peripheral Vision
Information: "What is there?"	Information: "Where am I?"
Conscious Control	Subconscious Control
Small FOV (2^0)	Large FOV (170^0 H X 140^0 W)
Excellent Visual Acuity (20/20)	Poor Visual Acuity (<< 20/20)
Detects Low Contrast	Detects High Contrast

B. Field of View (FOV) / Field of Regard (FOR)

One of the most obvious limitations of all NVDs is the limited FOV. Table 3-2 provides a summary of the USMC Assault Support NVD system FOVs. Compared to the human eye's normal FOV of approximately 180 degrees (H) x 140 degrees (V), the FOV reduction with NVDs is dramatic and necessitates some compensation on the part of the aircrew. The ability to scan gives AN/AVS-6 NVGs and TFLIRs a significant advantage in FOR over fixed-forward NAVFLIRs. An active, aggressive scan is essential to overcome the reduced AN/AVS-6 FOV. The FOR for the AN/AVS-6 is limited by aircrew movement restraints, aircraft crew position and aircraft design features. Exclusive fixed forward viewing will increase the potential for loss of situational awareness and reduces the ability to judge height and distance. The increased scan with NVGs must be balanced against excessive head movement as the potential for disorientation and fatigue increases with increased head movement. Limitations on excessive flight maneuvering should also be considered during night operations using NVDs.

TABLE 3 - 2. USMC ASSAULT SUPPORT NVD FIELD OF VIEW (FOV) SPECIFICATIONS

Aircraft	NVD	Optics Mode	FOV (degrees)	Power	FOR (degrees)
All	AN/AVS-6	Standard Lens	40 Circular	1X	Crew Position Limited
AH-1W	NTS	Wide FOV Medium FOV Narrow FOV Narrow FOV	24.3 H X 18.4 V 7.2 H X 5.4 V 2.0 H X 1.5 V 1.0 H X 0.75 V	2X 7X 25X 50X	Azimuth: 180 (90 Right / 90 Left) Pitch: +30 / -50
UH-1N	NTIS	Wide FOV Narrow FOV Narrow FOV	28.0 H X 16.8 V 5.0 H X 3.0 V 2.5 H X 1.5 V	2X 5.6X 11.2X	Azimuth: 360 Pitch: +30 / -120
CH-53E	HNVS	Wide FOV Narrow FOV	30.0 H X 40.0 V 5.0 H X 6.7 V	1X 6X	Azimuth: 180 (90 Right / 90 Left) Pitch: +20 / -45

AN/AVS-6 NVG FOV can be less than the designed optimum if the NVG eyepiece lenses are too far away from the eyes (Figure 3-1). Conversely, the eyes will be unnecessarily fatigued and look-under ability will be greatly reduced if the NVGs are brought in too close to the eyes. This will translate into less ability to comfortably read maps and cockpit instruments. The recommended distance between the eye and NVG eyepiece lens, commonly referred to as eye relief, is 15mm and 25mm for the Omnibus-II and Omnibus-III/IV AN/AVS-6 NVGs, respectively. In some instances, aircrew may not be able to get the eyepiece lens close enough to provide full FOV due to either helmet fit or anthropometric physical challenges. In addition, when the AN/AVS-6 NVGs are worn in conjunction with the A/P22 P9(V) chemical, biological respirator assembly, the wearer can expect a reduced image intensified FOV due to extended eye relief distance as well as a lower visual field area loss resulting from obscuration by the black portion of the faceplate and its imbedded oral-nasal mask.

HMX-1 conducted an operational assessment that found the average eye relief for 10 subjects wearing the AR-5 and / Omnibus-II AN/AVS-6 combination to be 32mm. The 32mm eye relief gave an intensified AN/AVS-6 FOV of 32 degrees, a 20% FOV loss. The Omnibus-II AN/AVS-6 that incorporate 15mm eyepiece lenses, hence, the recommended eye relief distance for a 40 degree FOV is 15mm. The same assessment also evaluated the AR-5 / Omnibus-III AN/AVS-6 (25mm eyepiece lenses) combination. The Omnibus-III AN/AVS-6 incorporate 25mm eyepiece lenses. The average 32mm eye relief distance found with the AR-5 / AN/AVS-6 combination would give an intensified FOV of 39 degrees with the Omnibus-III AN/AVS-6, a loss of only 2.5%. As discussed in chapter 2, the Omnibus-II AN/AVS-6 15mm eyepiece lenses are being replaced by 25mm eyepiece lenses on an attrition basis.

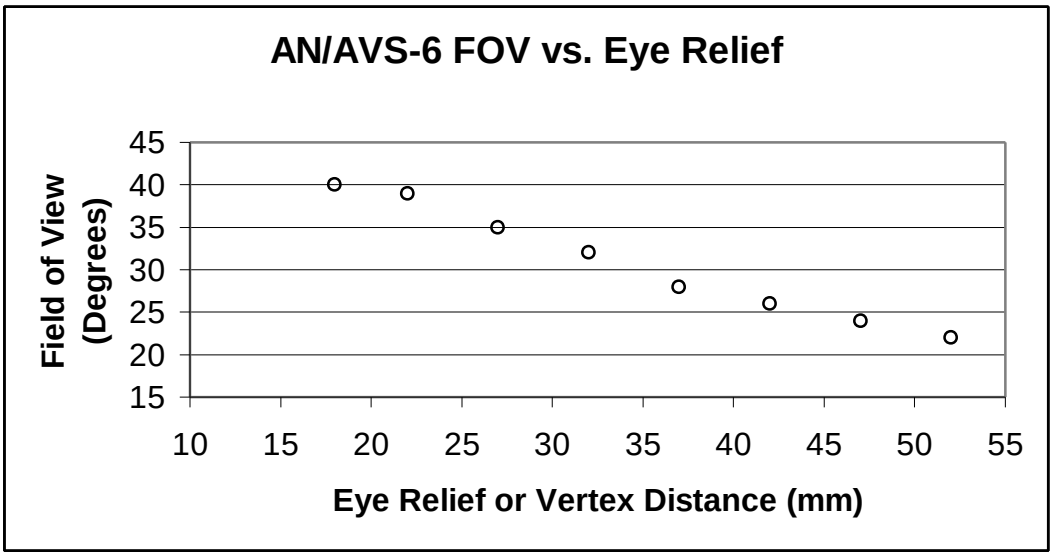

Figure 3 - 1. AN/AVS-6 Field of View vs. Eye Relief or Vertex Distance

A common question concerning NVD FOV is "Why can't FOV be increased?" Unfortunately, this is one of the many NVD design trade-offs. NVD FOV can be increased with current technology, but only at the expense of resolution, weight/size, and cost. The NVD designs of today represent the best compromise between these competing needs and improvements will only result from engineering and scientific breakthroughs. Several developmental programs are underway within DOD to explore enhancements to NVG FOV. The most promising appears to be an USAF Research Lab effort that is pursuing development of a Panoramic NVG or PNVG. The PNVG (Figure 3-2) uses four independent I^2 tubes and optical paths. This design provides a central 100% overlapping 30^0 FOV with the central two I^2 tubes / optical elements. Two additional I^2 tubes / optical elements are placed outboard of the two central elements and provides an additional 35^0 FOV per side. The resultant PNVG intensified FOV is 100^0H X 40^0V. Early prototypes demonstrated promising FOV increases, however, NVG visual acuity was limited due to the use of older AN/PVS-7 (ground system) I^2 tubes in the first prototype system. Follow-on PNVG designs call for using smaller diameter (16mm) I^2 tubes with goals set at the Omnibus-IV performance level. For future increased FOV NVGs to be accepted in the fleet, a minimum Omnibus-IV I^2 tube performance will be required to compete with existing technology.

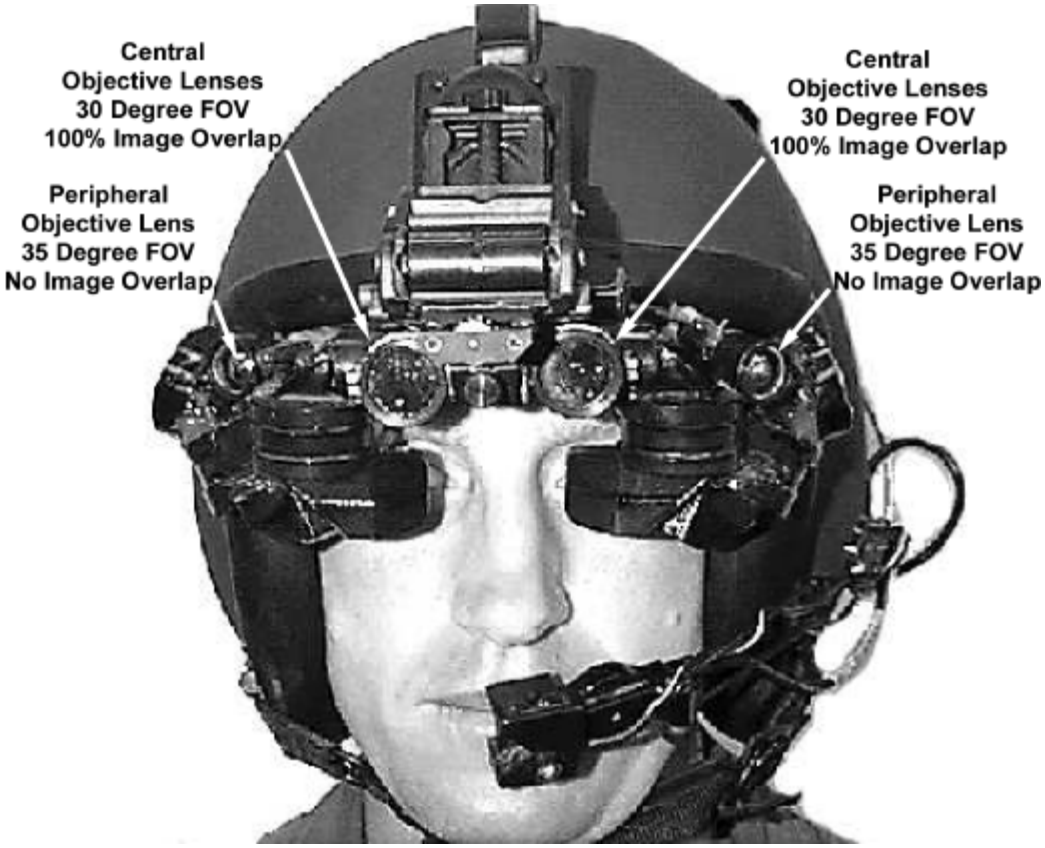

Figure 3 - 2. USAF Panoramic Night Vision Goggle (PNVG)

In contrast to NVG FOV and FOR, FLIR systems vary dramatically dependent upon the mission of the aircraft, Table 3-2. For example, the AH-1W Night Targeting System (NTS) FLIR FOR is 180 degrees azimuth (90 degrees each side of the nose) and +30 degrees to -50 degrees elevation. The FOR for the UH-1N NTIS FLIR is 360 degrees azimuth and +30 degrees to -120 degrees elevation, while the slew rate is zero to less that or equal to 60 degrees per second, variable in both axes at airspeeds less than or equal to 200 KIAS. The CH-53E HNVS possesses a 180 degree azimuth and +20 and –45 degree pitch FOR.

C. NVD Visual Acuity and Resolution.

There are many factors that determine whether an object is detected by aircrew (Table 3-3). The angular size of an object is the relative size of object when focused onto the retina. This is typically evaluated by reading an eye chart. A person who is 20/20 can distinguish an object that subtends 1 minute of arc on their retina at 20 feet. A person who is 20/40 has to either get twice as close (10 feet) or the object has to be doubled in size (2 minutes of are) to see the same level of detail as the 20/20 individual. Awell illuminated object is easier to see than a poorly illuminated one. Vision exams are conducted under high illumination conditions. Typically, the eye is adapted to the ambient light level for the evaluation. In addition to illumination, contrast is also critical for vision acuity. Higher contrast objects are easier to see than lower contrast objects. Again, vision is tested with 100% contrast targets, black letters on a white background. Unlike unaided binocular viewing, NVDs do not provide direct viewing of the scene. Instead, the electro-optical process within the NVD provides what amounts to a TV image. This monochromatic green, or gray, electro-optical image is

not without its visual limitations. As with the eye, NVDs are impacted by the same factors summarized in Table 3-3. In flight, the physical limitations of the NVD and the reduction in ability to recognize and detect objects, terrain, and targets must always be a considered. Although not as noticeable as NVD decreased FOV, a reduction in visual acuity (esolution) and image contrast also occurs with NVDs. This loss of resolution and contrast is usually very insidious, therefore, very important to consider for NVD mission planning due to the impact on virtually all visual cues used for orientation, target and hazard detection.

TABLE 3 - 3. HUMAN VISUAL SYSTEM CUEING

Factor	Description
Angular Size of Object	The larger the angular size, the larger the retinal Image and improved detection and cueing.
Illumination of Object	Illumination must be in the optimum range to be seen. Too much or too little illumination can decrease visibility. Generally, detection and cueing improves with increased illumination.
Contrast	The higher the contrast, either color or reflective, the greater one's detection and cueing.
Retinal Adaptation	The eye must be adapted for the illumination conditions. If the retinal adaptation is poor, detection distances will be reduced.
Atmospheric Conditions	Atmospheric obscurants will hinder the travel of light through the atmosphere. As atmospheric obscurants increase, visibility will decrease.
Relative Motion of Object	Detection increases with an object's movement in the visual field. The faster the motion, the greater the chance for detection.
Search Pattern and Time	The visual system needs time to see an object. The length of time needed will depend on many of the above factors. At a minimum, it takes about 0.8 seconds for the visual system to detect an object.

AN/AVS-6 NVG system and I^2 tube military specifications were summarized in Table 2-5. MIL-SPEC resolution for Omnibus-IV AN/AVS-6 I^2 tube is 64 line-pairs (Lp)/mm along the tube's optical axis. This I^2 tube parameter will correspond to an approximate system NVG Snellen visual acuity (SVA) of 20/25. MIL-SPEC resolutions for Omnibus-III and II AN/AVS-6 I^2 tubes are 45 Lp/mm and 36 Lp/mm, respectively. These resolutions correspond to approximate system NVG SVAs of 20/35 and 20/45, respectively. Depending upon the Omnibus lot of the I^2 tube in the NVG that you are flying, dramatic variation can exist that may significantly impact target detection distance (Figure 2-17). FLIR MIL-SPEC baseline resolution is typically less than that of the AN/AVS-6. These values would appear to make NVDs unacceptable for flight since 20/20 vision is prerequisite for flight status. However, the dark adapted, unaided eye provides at best 20/200 to 20/400 visual acuity under low illumination conditions. Therefore, while not meeting photopic eye capability, NVDs far exceed the eyes performance at night. NVD resolution is typically determined in a laboratory under ideal conditions and this level of resolution cannot be expected when flying due to variables such as incompatible cockpit lighting, windscreen and HUD transmission properties, environmental conditions, and poor focusing technique.

As with FOV, NVD system resolution is limited by design constraints. AN/AVS-6 resolution is driven a multitude of factors that includes; the number of channels in the microchannel plate (MCP), the quality of the optics, the distance between internal I^2 tube components and the inherent video noise within the tube. Recent improvements in MCP technology have revolved around increasing the number of channels in the MCP, which is comparable to increasing the number of pixels in a computer monitor. The video noise that is seen under low light level conditions is the primary reason for reduction in visual acuity as the contrast of the image is reduced. FLIR resolution is determined by detector size and number, scan rate,

optics, display resolution, and inherent noise. Detector number / size and display resolution appear to be the promising areas for near term improvements in FLIR resolution.

1. Contrast. In Chapter 1, the environmental factors that influence image contrast were discussed. Figure 3-3 demonstrates how contrast and illumination will influence AN/AVS-6 (Ultra Tube) SVA. With NVDs, a reduction in contrast occurs as the eye is presented a monochromatic green or gray image and color contrast cues are lost. AN/AVS-6 contrast is further reduced as ambient light levels decrease beyond the capability of the I^2 tube's automatic brightness control. Contrast will also be reduced when a bright light source, such as the moon or city lights enters the NVG FOV and the NVG begins to degain (bright source protection activation). Reduced contrast manifests itself primarily as reduced visual acuity since low contrast objects are more difficult to see than those that have high contrast. Currently, NVG resolution or aircrew NVG SVA performance is assessed by using high contrast test charts illuminated under high light level conditions. This procedure allows for greater accuracy when comparing I^2 tube performance or NVG system performance to a MILSPEC, however, these assessments typically do not provide an operationally accurate assessment of NVD performance under low contrast conditions. In addition, individual differences in contrast sensitivity may exist between aircrew. This may translate into differences amongst crewmembers of the same flight in regard to what they can see and when they can see it. Contrast sensitivity has generated a lot of attention in the past few years, and it impacts NVD operations since individuals with good contrast sensitivity would appear to be more suited for NVD flying.

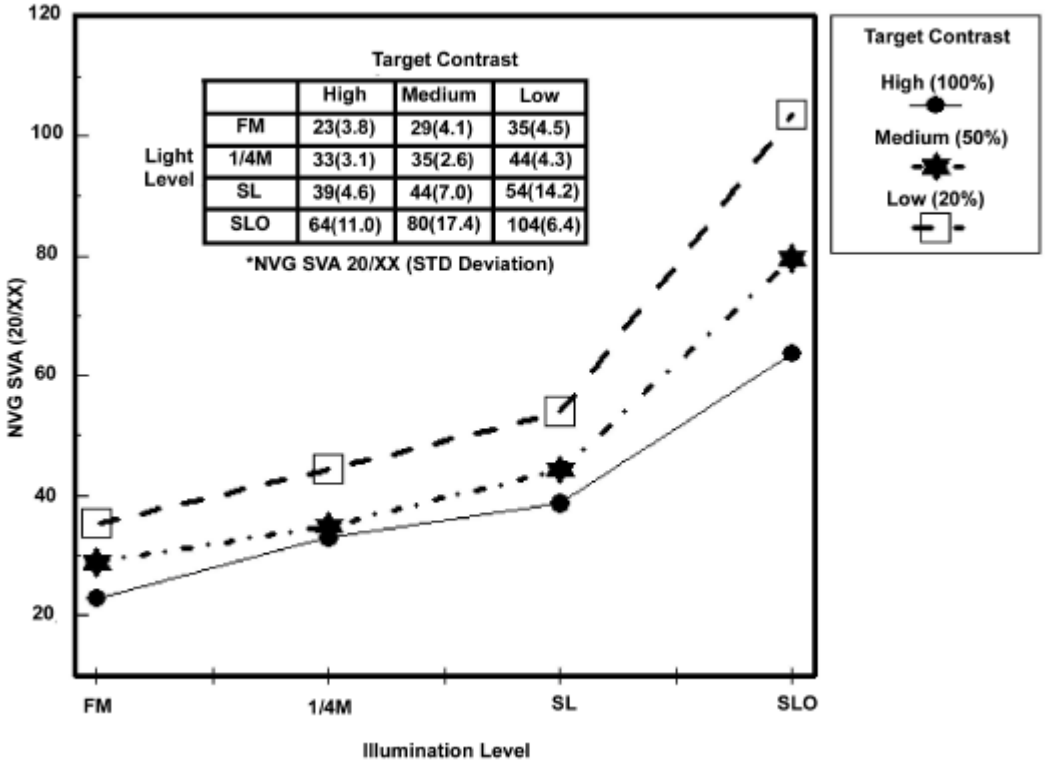

Figure 3 - 3. AN/AVS-6 (Ultra I^2 Tube) NVG Snellen Visual Acuity vs. Target Contrast

FLIR image contrast will decrease as thermal contrast decreases or as atmospheric attenuation increases (i.e., increased absolute humidity). Visual discrimination of objects in the thermal scene is made possible when objects have a different radiated temperature than their immediate background and a different radiated temperature from each other. Even if the radiated temperature differences are less than one degree they will appear on the display of a modern thermal imager. The temperature differences appear as variations in the brightness levels of the objects on the FLIR display. Usually, objects have a positive contrast at night (the object is warmer than the background) and a negative contrast during sunny days (the object is cooler than the background). Many natural and man made objects typically undergo continual temperature changes that follow important, predictable trends. For example, natural background objects such as trees, grass and rocks are heated passively through the absorption of solar energy. Even during overcast days, some solar radiation is absorbed.

To enhance the FLIR image for optimum contrast and brightness, the shades of gray scale can be selected by the aircrew for setting up the displays. The scale provides a standard by which the displays can be adjusted without relying exclusively on the outside scene. To ensure that the displays are set up so that the maximum dynamic range of the FLIR is visible, the displays should be adjusted so that all visible steps of the gray scale can be equally resolved, and the black step is indeed black. Adjusting the intensities initially to the outside scene can result in degraded image contrast if different thermal conditions are encountered later in the flight. Target recognition requires more target detail than detection, so more discrimination between adjacent areas of the target is needed. White hot has typically shown less contrast discrimination than black hot. In addition, black hot presents a more natural looking image to the pilot, which enhances target recognition after initial detection. Experience has shown, however, that individuals use the mode that provides what they perceive to be the best image.

2. AN/AVS-6 Misadjustments. Cockpit workload dictates that the NVGs should be properly adjusted on the ground. Even for experienced aircrew, the most common adjustment errors involve IPD, eyepiece or diopter lens focus and objective lens focus adjustments. In depth AN/AVS-6 adjustment procedures are provided in Chapter 5 and NVG eye lane procedures are summarized in Appendix A.

   (a) Interpupillary Distance (IPD) Adjustment. One of the most common misadjustments made with AN/AVS-6 is interpupillary distance (IPD). In some instances, novice AN/AVS-6 aircrew believe that increasing IPD will increase FOV. This is not true and in fact will impair visual performance. There should be 100% overlap of the monocular NVG intensified images. Novice AN/AVS-6 aircrew typically bring the tubes too close together. This is normal as the eyes naturally track in (converge) between 3-5mm when looking at something up close. This convergence places the eyes in a dilemma. Since the best resolution is found in the center the image (NVG optical axis), the eyes can remain fixed forward causing degraded visual acuity or they can converge to look at the best resolution, thereby increasing eye fatigue and inducing the potential for near-sightedness. Error in IPD adjustment by only a few millimeters can reduce aircrew NVG visual acuity. It is recommended that all Omnibus-II AN/AVS-6 users have their IPD measured by a flight surgeon or Aeromedical Safety Officer (AMSO) and use that measurement to set the NVG IPD prior to flight. With the introduction of the Omnibus-III dual adjustment PAS, each monocular can be moved independently. This will greatly increase the ability of aircrew to obtain the optimal 100% overlapped circular NVG

intensified image sight picture. For Omnibus-III aircrew, measurement of IPD is not required, however, training time should be spent exposing aircrew to the proper NVG sight picture.

In addition to loss of resolution, misalignment can cause accommodative eye fatigue. This is caused by the eyes continuously and automatically focusing and refocusing to offset binocular misadjustment or differences in monocular resolution. A 1986 NAWC Warminster study showed that if the NVG IPD is improperly adjusted, the user will have to add either convergence or divergence for the duration of the mission in order to have a single fused image. Prolonged viewing with the wrong IPD may lead toreduced near depth perception post flight as well as in-flight headaches. Far depth perception, based primarily on monocular depth cues (discussed later), was unchanged. The study implies that careful adjustment of the IPD is essential for the proper use of NVGs.

(b) Eyepiece Lens or Diopter Focus Adjustment. Although recommended, the use of corrective lenses is not always necessary with NVGs because of the diopter focus adjustment capability of the eyepiece lens. This will adjust for eyes that are between 20/10 and 20/200 to the optimal level of 20/25 to 20/45 depending on the omnibus lot[2] tubes incorporated into the AN/AVS-6. The eyepiece or diopter focus adjustment cannot compensate for astigmatisms, which are imperfections in the eye's lens or cornea. Corrective lenses (glasses or contacts) must be worn to correct this visual defect. Previous studies have found that inexperienced NVG users adjust the diopter adjustment ring by putting in too much negative diopter (induced myopia or near-sightedness). There is usually enough accommodative capability for the eyes to change the shape of the lens to compensate for this adjustment error. However, as the eye fatigues it cannot accommodate this error as well and visual acuity drops. This drop is not usually recognized unless the individual is placed in front of a visual acuity chart. For additional guidance on the proper focusing of the eyepiece lens see Chapter 5 and Appendix A.

(c) Objective Lens Focus Adjustment. The objective lens of the AN/AVS-6 has a focal range from 28cm +/- 3cm (10 inches) to optical infinity (approximately beyond 100 feet). The electro-optics of the NVG enables the system to be collimated to infinity. This is why things appear in focus at optical infinity even though you are looking at a TV screen image approximately one inch from your eye. The NVG objective lens possesses a shallow depth of field, therefore, under some viewing conditions part of the NVG image can be out of focus. For example, when the NVG is focused on a near object (less than 10 feet), the background objects are out of focus. Conversely, when the background objects are in focus, the closer foreground objects now become out of focus. Fortunately, AN/AVS-6 depth of field is adequate enough not to require refocusing for typical flight profiles which may require seeing objects within 30 feet, such as going into a landing zone or launching from a ship, etc.

3. Tube Alignment, Image Differences and Binocular Fusion. The visual system is designed to subconsciously fuse the images from each eye into a single image without the perception of two separate images. This concept is called binocular fusion and occurs within the nervous system. Binocular fusion requires coordination of the muscles of each eye. There is unequal contribution from each eye in determining the image because one eye is usually dominant and will provide the greater share of information. Eyestrain, fatigue, disorientation or nausea could occur if NVG tube alignment errors (Chapter 5) or image differences in brightness or contrast are of significant magnitude. If fusion becomes

difficult, double images can form (diplopia). Subconscious effort to maintain fusion may have negative cumulative consequences. NVGs that appear to have no adverse effects when used for a short period of time may prove intolerable when used for longer periods. Headaches can develop, usually felt behind the ears and continuing down the neck, without apparent eyestrain or fatigue. Usually, these headaches are attributed to poor helmet fit, dehydration, or poor diet. There is a wide range of tolerance to misalignment and image differences and disparities that go unnoticed by one individual may be intolerable to another.

D. Additional Visual Cues.

In addition to FOV, contrast and resolution, other visual cues are also impacted by NVDs. These additional visual cues are (1) depth perception, (2) distance estimation, and (3) static and dynamic cues. These are visual processes that are usually automatically or subconsciously processed by the visual system. Unfortunately, the loss or degradation of these cues will not be recognized unless demonstrated or a conscious effort is made to remain aware of these limitations. Ultimately, this means that normal day visual cues may not be available or could be misinterpreted when using NVDs.

1. Depth Perception. One common erroneous statement made by aircrew is how poor depth perception is with NVGs and FLIR. In fact, depth perception is easily acquired using NVGs. However, the depth perception task is commonly confused with the more challenging distance estimation task. Whereas depth perception is primarily determining the relationship of objects in relation to each other, distance estimation is determining "how far away an object is away." We utilize two types of depth perception cues, binocular and monocular. The binocular factors of convergence and stereopsis are involved with depth perception. Stereopsis, caused by the disparity of images on the retina of the two eyes, is the most important factor in judging the distance of near objects. In flying aircraft, it is felt that the maximum practical limit of stereopsis is only 200 meters. With NVDs, this type of depth perception appears to be limited, with monocular cues being primarily utilized for depth perception. The monocular cues to depth perception (conscious and subconscious cues learned from experience) include relative size and height, overlapping contours, distribution of light and shadow, atmospheric/aerial perspective, texture gradients, convergence of parallel lines, and, perhaps most importantly, motion parallax. Although these monocular cues provide depth perception for all distances, they become more dominant as the distance between the observer and the object in question increases. Keep in mind that anything that will adversely impact NVG resolution will also impact the perception of these cues. Therefore, as aircrew NVG visual acuity decreases due to lower illumination or lower contrast scenes, the cues will be less discernible resulting in poorer depth perception.

2. Distance Estimation. Distance estimation is significantly altered with NVGs for a variety of reasons. The end result is that objects will appear further away than they actually are. The reduction in visual acuity influences distance estimation. This is primarily a learned subconscious phenomenon as we expect objects that are less distinct in detail to be farther than ones that possess sharp detail. Another factor that degrades distance estimation is the phenomenon of minification. Minification is a decrease in the perceived size of an object, or of its image, in relation to the object. Dialing in too much negative diopter in the AN/AVS-6 eyepiece lens will cause minification. Minification can be a particularly noticeable phenomenon during formation flying or confined area landings. Care must be taken to maintain adequate separation from other aircraft or obstacles. Both depth

perception and distance estimation are visual processes that are usually automatically, subconsciously processed by the visual system. The loss or degradation of these cues will not be recognized unless they are demonstrated or a conscious effort is made to remain aware of these limitations.

3. Static and Dynamic Visual Cues. Static and dynamic visual cues are used to provide aircrew cues for direction, altitude and speed. There are three primary dynamic cues: (1) static cue motion, (2) optical flow and (3) peripheral vision motion.

   (a) Static Cue Motion. Static cue motion is the summed effect of the change in one or more of the static cues caused by aircraft movement. Static cues include elevation, known size, density, masking, and perspective. Central vision tracking is a method for seeing static cue motion and will be degraded by NVDs.

   (b) Optical Flow. Optical flow is the angular rate and direction of movement of objects as a result of aircraft velocity measured relative to the aviator's eye. This provides the visual perception system the information necessary to interpret speed and direction of motion. If there is no relative motion, there is no optical flow. We use central vision to obtain optical flow information. Since visual acuity is degraded with NVDs, the optical flow cues will be degraded when compared to daytime cues.

   (c) Peripheral Vision Motion. Peripheral vision motion, also known as motion parallax, is a subconscious method of detecting optical flow. It is dependent on a wide FOV and is the primary airspeed and altitude sensory input. With the significant reduction in FOV of NVGs and FLIR, this cue is severely degraded and central vision tracking becomes the primary detection means. This leads to one of the most insidious dangers when flying low altitude profiles. Just as in the day, visual acuity will improve as the aircraft gets closer to the ground. However, because of the reduction in peripheral vision motion, the ensuing "speed rush" that would indicate close proximity to the ground is not available and controlled flight into terrain (CFIT) becomes a real possibility. The use of an aggressive scan will help "fill in the blanks." 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 all-important cue. The radar altimeter becomes a crucial instrument to cross check when flying TERF profiles.

4. Summary. The end result of the various visual limitations is that while wearing NVGs, there is reduced detection and recognition of objects, terrain and targets. It is important to remember that this statement is in comparison to the human eye under daylight conditions. NVGs do not turn night into day, but they are vastly superior to the human eyes' performance under night conditions.

E. Dark Adaptation

The use of NVDs does not require complete dark adaptation. The ? tube output brightness (luminance) at the eyepiece lens of the ANAVS-6 and FLIR video display unit is sufficient to activate the photopic visual system (cones). The use of AN/AVS-6 does influence dark adaptation, however, the impact is limited due to the peak outputs from the AN/AVS-6 phosphors (P20, P22 and P43). The phosphor outputs match the peak sensitivity of the photopic eye, but are offset from the peak sensitivity of scotopic (night adapted) vision (510 nm), Figure 3-4. Army studies have shown that a dark-adapted individual reacquires dark

adaptation within three minutes of degoggling. From operational experience, it is believed that for a non-dark adapted individual, an approximate 10 minute time period is required to "dark adapt" or maximize unaided vision after removal of the AN/AVS-6. Full dark adaptation never really occurs in the cockpit because of the light intensity provided by instrument lights. One of the common misconceptions about NVGs is their response to bright lights such as weapons flash. The NVGs "shut-down" as they degain from the input of bright light. It takes less than one second for NVGs to recover compared to the dark-adapted eyes recovery time of up to 30 minutes.

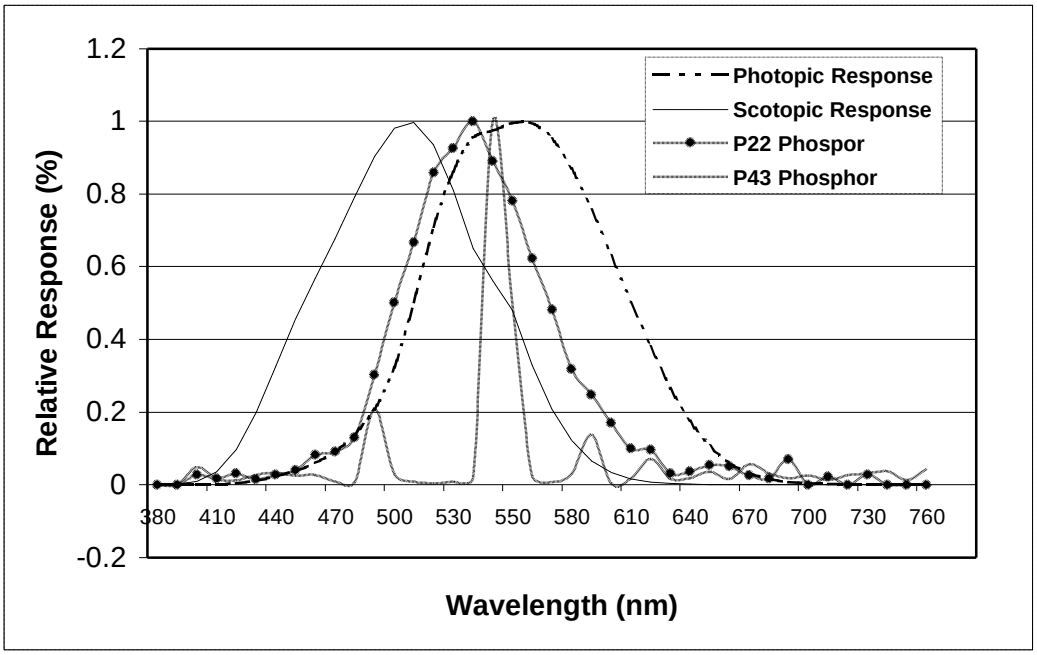

Figure 3 - 4. Spectral Sensitivity of Human Eye (Photopic & Scotopic)

F. Unaided Peripheral Cueing

How much unaided (normal night vision) peripheral cueing is available and whether or not it is helpful in the NVD environment is a somewhat controversial subject. It is well known that ones source of balance and perspective is largely due to peripheral cueing, while central cueing is responsible for fine detail and interpretation. So, how much can really be seen in the unaided peripheral vision when utilizing NVGs? Due to the design of the AN/AVS-6 and the helmet, there is considerable unaided peripheral viewing capability. What can be seen in the periphery depends on many variables; illumination level, terrain type, artificial light sources, etc. Although aircrew are not completely dark adapted, one is partially dark-adapted and able to discern some features outside or around the NVG intensified image. For example, flying over terrain where cultural lighting is generously scattered, many lights and 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, information that is familiar from unaided night operations. 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 can result in significantly enhanced spatial orientation.

G. Post-Flight Visual Problems

There are some temporary changes in vision that can occur after NVG use. To date, there is no evidence of any permanent changes to vision and experience indicates that there are none. The reductions in contrast, resolution and FOV all contribute to visual fatigue. Improper adjustment of IPD will also contribute to eye fatigue and headaches.

1. Color Sensitivity. Because of the green monochromatic NVG display, the green sensitive cones may become overwhelmed leading to temporary orange to brown afterimages upon goggle removal. This condition does not pose a hazard although color discrimination may be temporarily skewed.

2. Near Depth Perception. As discussed earlier, post-flight loss of near depth perception may result due to improper AN/AVS-6 IPD adjustment. This forces the eyes to converge or diverge, which in turn can cause errors in binocular viewing and therefore, near depth perception. Far depth perception, a function of monocular cues, is not affected by extended NVG use. NAWC Warminster found that the return of near depth perception can be in as little as one hour. The proper adjustment of IPD will reduce or eliminate this problem.

III. Fatigue

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 will be discussed in detail. Fatigue has always been a problem in aviation, however, night operations introduce additional stress and physical limitations that makes fatigue an even more insidious threat. Fatigue can be caused by many things such as excessive flying and duty time, self-regulated crash diets, missed meals, task saturation, hypoglycemia, recent illness or sleep loss. There are three types of fatigue; (1) acute fatigue, (2) cumulative fatigue, and (3) circadian fatigue.

A. Acute Fatigue

Acute fatigue is intense tiredness or exhaustion felt as a result 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 and is characterized by a feeling of being "worn out" and will usually be relieved by a single night's rest.

B. Cumulative Fatigue

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 work weeks 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 nights rest to recover normal energy levels. Studies indicate that cumulative fatigue results in an exponential increase in performance errors. For the night systems

player, 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.

C. Circadian Fatigue

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, Figure 3-5. The word circadian comes from the Latin "circa" and "dies" which means "about" and "days," respectively. Circadian rhythm should not be confused with the discredited biorhythm theory. That theory touted the ability to pinpoint productive and nonproductive days based on the interaction of physical, emotional, and intellectual cycles set into motion on an individuals date of birth. 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 somewhat 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.

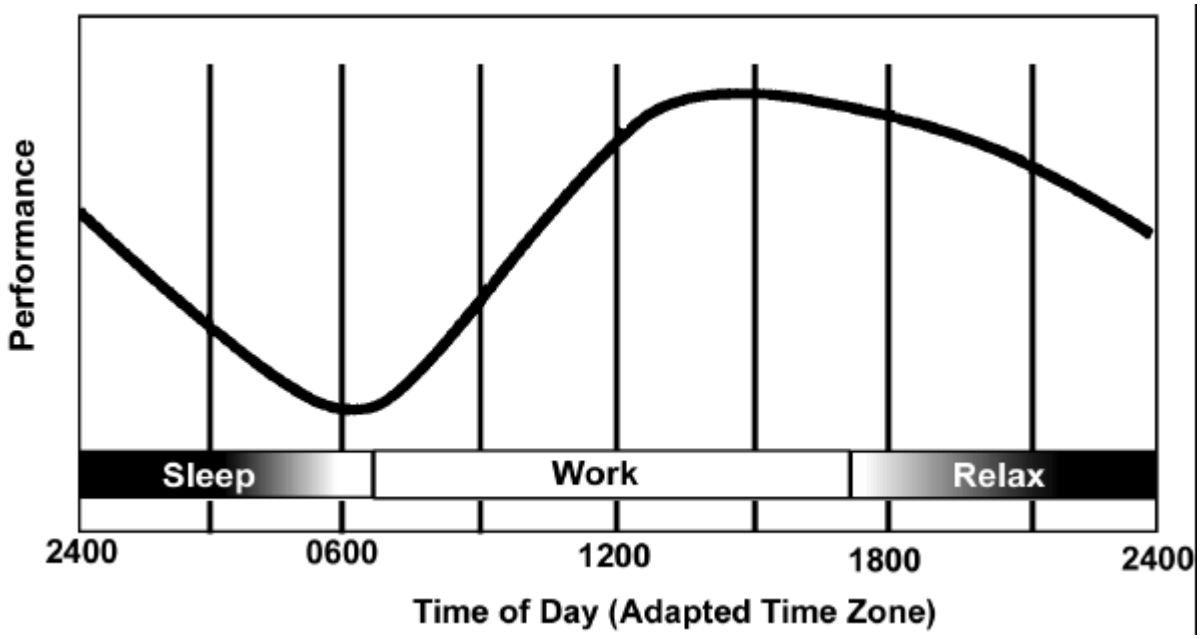

Figure 3 - 5. Circadian Rhythm Cycle for Performance

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. These daily events which 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.

Night NVD aided missions can combine all three types of fatigue and can potentially present a significant problem. One's normal squadron routine combined with the workload of the night NVD aided mission creates acute fatigue on a daily basis. 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 will be discussed in detail. Two components of circadian disruption are the physiological nadir and desynchronosis.

1. Physiological Nadir. The physiological nadir results from the reality that man has evolved as a daytime creature. This places the body's natural performance cycle out-of-synch with night missions. The performance cycle in Figure 3-5 shows alertness and performance levels plotted against a number of factors such as body temperature, pulse rate, respiration, and hormonal activity. Studies indicate that for most individuals, the physiological nadir occurs during the 0300-0600 time frame when metabolism and performance are at their lowest ebb. There is significant performance degradation during this time period.

2. Desynchronosis. Desynchronosis usually occurs as a result of the body's internal rhythm being out-of-synch with the normal routine when shifting to a new work schedule (Figure 3-6). This is a problem that is encountered in rapid transmeridian travel where it is referred to as "jet lag." This also shifts the time of day for the physiological nadir. The body can physically readjust to crossing time zones at the rate of about 1-1.5 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 desynchronosis will be more difficult because the activity pattern is out-of-synch with both circadian rhythms and the daily zeitgebers 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. It is possible that some aircrew may never fully adjust during a normal night training cycle.

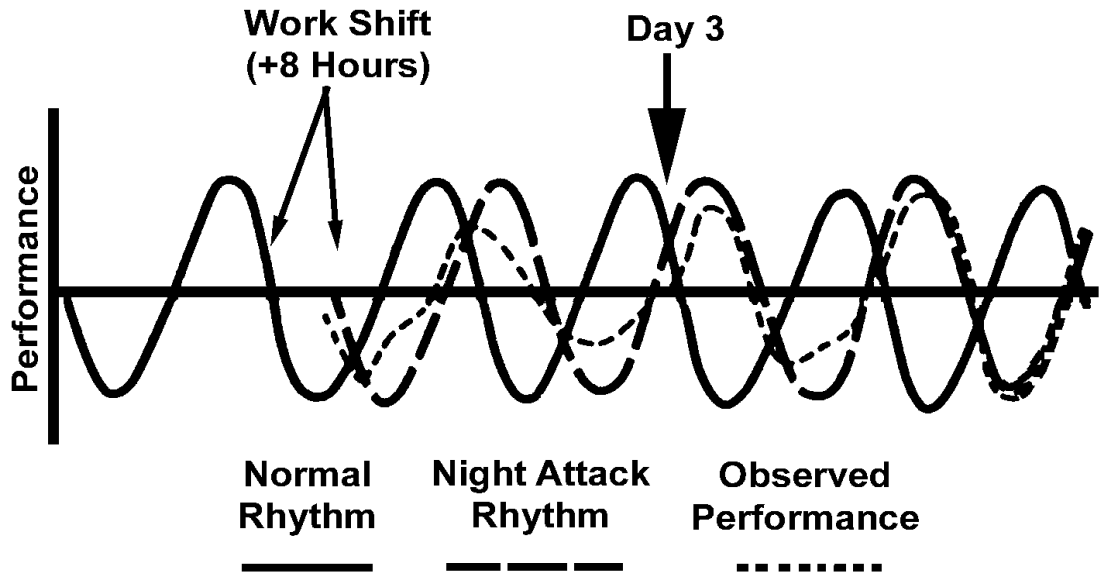

Figure 3 - 6. Desynchronosis

D. <u>Effects of Fatigue</u>

Fatigue, especially cumulative fatigue associated with circadian disruption and sleep deprivation, poses a serious threat to night NVD aided mission accomplishment. Many experts believe that performance will degrade anytime the circadian rhythm is disrupted. This is recognized by many manufacturers that 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. In general, it can be stated that fatigue creates a C^{3}I^2 problem.

1. <u>Complacency</u>. Complacency allows for acceptance of situations that would normally not be permitted, especially in the context of a NVD aided missions. 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.

2. <u>Computational</u>. 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.

3. <u>Communications</u>. Communications are affected by either neglecting to make appropriate calls or not responding to calls. 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 he expects to hear as opposed to what is actually transmitted. The desire to initiate action decreases with fatigue, including interactions with other people.

4. 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.

5. 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.

E. Sleep

The biological function of sleep is not completely understood but it acts in some sort of restorative manner. 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. For circadian purposes, there are basically two types of people. Introverts or "larks" get up early in the morning, peak early in the evening, and usually have difficulty adjusting to phase-shift changes. Extroverts or "owls" generally stay up later and adapt more easily to the night regime. Neurological research has shown that sleep is not just a passive unconsciousness, but rather a very intense physical activity of great complexity. There are various stages of sleep and although everyone has their own distinctive sleep behavior, sleep does have a classic pattern. An average person spends about 40% 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. Other research indicates that this is not always true. Shifting to a night routine can cause problems over a period of 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 with at least one very long sleep to prevent cumulative fatigue.

F. Recommendations for Coping With Fatigue

NVD aided missions may combine acute, cumulative, and circadian fatigue. At the same time, NVD aided missions demand maximum aircrew performance. As stated earlier, some aircrew will not be able to fully adjust to the night routine, especially if the transition is poorly handled by the squadron or by the individual. There are means to reduce the impact of fatigue and thereby improve performance and increase safety. The following recommendations are based on studies conducted by the Naval Health Research Center, the USAF School of Aerospace Medicine Crew Performance Laboratory, the Henry Ford Hospital Sleep Disorders Laboratory, and experience from USMC and USN NVD squadrons and USAF F-117A squadrons. These recommendations have been shown to reduce the effects of fatigue. It must be understood that any feasible night operations schedule will probably be a blend of these recommendations and operational requirements.

1. Squadron Recommendations. Studies and experience indicate that task familiarity and motivation can overcome or delay the effects of fatigue. However, fatigue will eventually take its toll as performance will drop under these conditions of additional effort. Understanding that there is a natural low in daily performance, and making an extra effort, appear to be the best means to compensate for fatigue. Extra effort in this case means being alert to the causes and effects of fatigue, and not pushing aircrew after an already long day.

   (a) Crew Day /Crew Rest. Enforce a maximum workday for aircrew on a night operations schedule, including flying and non-flying duties. This is due to the fact that cumulative fatigue magnifies the effects of acute fatigue. Long workdays may not be a problem for a few days, but will eventually catch up with aircrew. Providing 12-hours off-duty time after the aircrew leaves the squadron (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 NVD aided mission. To aid aircrew in meeting crewday requirements (prevent early arrivals to the squadron), if feasible, the entire squadron should be placed on a night cycle for two weeks during the first quarter and full moon phases. A squadron show time of 1200 would allow for first flights at 1400 with flights continuing to 2400.

   (b) Ramping. Try to use an adaptation schedule to ease aircrew into late recoveries. As a rule of thumb, shift 1.5 hours per night (e.g., Monday night, 2100; Tuesday night, 2230; Wednesday night, 0000). This reduces the effect of circadian disruption. Stabilize the flight schedule so that aircrew can anticipate their schedule. The experienced aircrew should be assigned to the later hops, only experienced crews should be assigned two night systems hops in one night, and the same crew should never be assigned two night systems hops more than two days in a row unless there is an absolute necessity. When feasible, have all aircraft on the deck by 0230 hours. This is to avoid the fatigue and performance degradation associated with the 0300-0600 physiological nadir. This will be more difficult during the summer schedule due to limited night time, however, every effort should be made to allow aircrew to get home 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.

   (c) Diet. Light meals, nutritious snacks and fruit juices should be made available to the crews between early and late launches. This provides energy for the second go and gives everyone a chance to relax between flights. Digestive tract problems are more prevalent in people who work night shifts. Aircrews are not known for excellent dietary habits and this added touch will help maintain a better energy level and help prevent problems.

   (d) Family Briefs. Have the squadron flight surgeon meet with squadron families as a group to explain the importance of rest for night missions. Let the families know that they are an integral part of the team. Good family morale and a sense of well being helps maintain a positive attitude for both the families and aircrew. Night missions require sacrifices from all those involved. This includes aircrew, maintenance, and anyone that is required to endure the disruptive nature of night mission schedules over a period of time, including the families.

2. Aircrew Recommendations. Whatever scheduling requirements the squadron utilizes, aircrew still have the ultimate responsibility of managing their off-duty time to prepare for each night training period. When night training periods extend over a weekend or day off, the aircrew should not abandon their night schedule entirely. In this way the aircrew will maintain some type of circadian adaptation on days off.

   (a) Sleep Environment. Most families are oriented to a daytime schedule, therefore switching back and forth to the night schedule can pose a strain. The family must understand the hazards associated with fatigue and help provide an atmosphere which lends itself to quality sleep. Every attempt should be made to provide a dark, quiet, and cool environment to help induce sleep. Black out curtains and turning down the thermostat will enhance sleeping during daylight hours. When possible, aircrew should attempt to sleep between 2300 and 0700. This "sleep opportunity period" has been shown to help provide quality sleep time. In any event, aircrew should attempt to get to bed before sunrise to avoid the suns affect on the biological clock.

   (b) Physical Conditioning. 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.

   (c) Caffeine/Alcohol. Aircrew should limit their caffeine intake during the late shift at the squadron to reduce its effects on the central nervous system in flight and help improve the quality of sleep at home. Caffeine also has a dehydrating effect which can affect aircrew performance. Alcohol can influence the quality of sleep. While it can help a person wind down and lull one into deep sleep, it has a detrimental effect on sleep quality and can prevent the restful sleep that is really needed.

   (d) Time Management. Aircrew must manage their time efficiently and prioritize their efforts. Department head or higher positions cannot be afraid to delegate to subordinates. Fulfill ground job requirements prior to the night training period so that the majority of effort during this period can be placed on flying.

   (e) Cancellation. If feeling tired or "burned out" prior to a flight, it is highly probable that the individual is fatigued and will experience degraded performance during the mission. This brings up one of the more important yet most difficult recommendations to implement; CANCELLATION. For whatever reason, if an aviator honestly feels too fatigued to successfully accomplish the mission, he should cancel the flight. This is obviously easier to say than to do. To make canceling a viable option, it must be implemented through a combination of aircrew education and highly visible support by wing / group / unit commanders, operations officers, and senior aircrew. In order to train the way we fight, it is necessary for the night aviator to confront the night environment with its accompanying fatigue and sleep disruption. All aircrew must take the appropriate steps to minimize fatigue and be able to recognize the effects of fatigue on performance. The judgment needed to effectively deal with intermittent night operations demands a mature attitude. The ability to weigh operational commitments against realistic conditions is crucial to the successful completion of the night systems mission in a safe, effective manner.

IV. Crew Coordination

The high demands of the night systems mission requires good crew coordination between aircrew, with other aircraft in the flight and controlling agencies. Degraded crew coordination during a critical phase of the mission can lead to poor performance and the increased chance of a mishap. For this reason, night systems briefs must be very thorough and cover many topics that may not be discussed during most briefs (i.e., moon angle, lux level, absolute humidity, etc.). It's not the intent of this manual to dictate crew coordination procedures and is beyond the scope of this document. It is mentioned here for completeness and to highlight the need to fully investigate the crew coordination issues peculiar to the night systems environment.

V. Spatial Disorientation

Maintaining spatial orientation requires inputs from both components of the visual system (Table 3-1). These two components are central (focal) vision and peripheral (ambient) vision. Central vision is primarily a conscious function and consists largely of object recognition. Peripheral vision is primarily a subconscious function and uses multiple inputs that help define spatial orientation. Maintaining spatial orientation at night requires complex conscious processing of data from various instruments and displays. The task of maintaining spatial orientation competes with the usual tasking of navigation, terrain masking, target acquisition, weapons delivery and threat avoidance. Add to this the fact that fatigue occurs more frequently at night and it is easy to understand why the incidence of spatial disorientation in this environment appears to be exponentially magnified as variables are added. In fact, the most common contributing factors in spatial disorientation mishaps include: degraded visual environment, high task loading / saturation, reduced performance capability secondary to night time or fatigue and a fundamental breakdown in scan. This general description makes the night systems mission appear to be very vulnerable to spatial disorientation incidents. Constant vigilance and a good scan pattern, both inside and outside the cockpit, must be maintained to help prevent spatial disorientation and loss of situational awareness.

VI. Complacency/Overconfidence

Throughout this document appears the statement "NVDs DO NOT TURN NIGHT INTO DAY." However, after initial NVD flying experience and some flights in low illumination conditions, there is a natural tendency to be overly comfortable when flying in high illumination conditions. Another potential area of complacency / overconfidence is returning to day TERF flights after a night training period. Because of the significant increase in visual cues and the efficient scan developed, there is a tendency to be overly comfortable in the low altitude arena. While there is an increase in skill level, the complacent mindset could be a setup for a mishap.

VII. AN/AVS-6 Helmet Integration

The primary integration considerations for NVD aided missions are to ensure that aircrew obtain a properly fit helmet and are able to optimize the AN/AVS-6 adjustments. A properly fit helmet will help increase helmet comfort, stability and retention, as well as help reduce NVG misalignment problems. It maybe well worth your time to let squadron flight equipment personnel properly fit your helmet. Bring to their attention any helmet problems you may be

encountering (hot spots, forward rotation of the helmet, etc.) so these problems may be resolved.

<<WARNING>>

Based on test data gathered by the U.S. Army Aeromedical Research Lab (USAARL), it is strongly recommended that the AN/AVS-6 neck cord not be attached to the helmet in any way, i.e., wrapping the neck cord around the visor housing on top of the helmet. It is recommended that the neck cord be long enough to allow it to hang around the base of the user's neck. Securing the AN/AVS-6 to the helmet by other than the breakaway mount defeats the purpose of the breakaway mount. This may cause the user's neck to be exposed to the deceleration forces of the head, helmet, and AN/AVS-6 in a crash, increasing the risk of neck injury, even in a minor mishap.

A. HGU-67/P

The HGU-67/P was the first Assault Support helmet that integrated the benefits of the TACAIR helmet shell into a rotary wing aircraft (AH-1W). While the unavailability of spare parts for the HGU-67/P is currently a major issue, the helmet does offer some real improvements including better stability, comfort, and retention. The HGU-67/P comes in three helmet shell sizes (medium, large, and x-large). Up to three layers of the five layer preformed liner may be removed to form fit the helmet to the aircrews head. The Thermo-Plastic Liner (TPL) that can be further formed to fit the aircrews head by heating the liner to soften it slightly, replacing the liner into the helmet, and then having the aircrew don the helmet and hold it snugly on the head until the liner cools and sets. Convection ovens are currently available at most sites to accomplish this phase of the form fitting process. Aircrew should consult their squadron flight equipment or Aeromedical Safety Officer (AMSO) for any helmet fitting problems. The HGU-67/P center-of-gravity (CG) has been moved down and aft to more closely match the natural CG of the aircrews head. This will make the helmet "feel lighter." Total helmet weight of the HGU-67/P is less than the previous HGU-54/P due to the new visor system (bungee visor) and lighter helmet shell material. A common helmet mount is used to attach the AN/AVS-6 or HSS to the helmet. The AN/AVS-6 (V)2 offset mount is no longer used with the HGU-67/P, so (V)2's are in the process of being converted to (V)1's. In addition to the TPL, other HGU-67/P features that help to increase stability, comfort or retention are an integrated chin/nape strap, crushable, tapered ear cups and a thick edge roll. During the fleet retrofit of the HGU-67/P, flight equipment personnel were required to remove the helmet’s impact liner (Styrofoam). While the helmets were reassembled, many problems arose due to misalignment of these helmet liners within the helmet shell. Aircrew should not settle for anything less that a complete 100% overlapped circular NVG intensified image.

B. HGU-84/P

For the rest of USMC / USN Assault Support communities, the HGU-84/P has replaced the HGU-59/P helmet. The HGU-84/P incorporates the same basic features as the HGU-67/P described above, but is available in four sizes (medium, large, x-large, and x-large/wide). Protection capabilities of the HGU-67/84 helmets are at least equal to the helmets they replaced. The integrated chin/nape strap will aid in their retention during a crash. Both helmets use an internally wired AN/AVS-6 interface. The AN/AVS-6 interface kit (commonly referred to as the V-1B (formerly V-3 kit) consists of the interface block and the wiring harness that is run through the inside of the helmet. Aircrew should closely evaluate the fit of

their helmet and their ability to attain the proper AN/AVS-6 NVG intensified image sight picture. During the fleet retrofit of the HGU-84/P, flight equipment personnel were required to remove the helmet's impact liner (Styrofoam). During the reassembly of the helmet, many problems arose due to misalignment of these helmet liners within the helmet shell. Aircrew should not settle for anything less that a complete 100% overlapped circular NVG intensified image.

VIII. Summary

In summary, we have discussed many aeromedical factors of concern to the night systems crew. These factors must be considered when planning and flying night NVD aided missions. There are many NVD human limitations that will impact flight performance with visual performance and fatigue being the two biggest concerns. Do not be lulled into a false sense of security that the NVDs will allow you to fly day VFR profiles without significant experience, increased performance demands, and good mission planning. There is an inherent tendency for the newcomer to anticipate too much from NVDs. "WHAT YOU SEE IS NOT ALWAYS WHAT YOU GET." Treat the NVD visual display with healthy disrespect and cross-check with other instruments to enhance situational awareness through validation of the "true" attitude, altitude and airspeed.

Intentionally Blank

Chapter 4

Night Vision Device Scene Interpretation

I. Introduction

Many factors affecting NVD scene interpretation have already been discussed. However, these points are worth mentioning again in an operational concept. This section describes the NVD environment as subjectively seen by the aircrew using NVDs. The NVG scene and the FLIR scene will be described separately using some basic terrain and man-made features as illustrations. The purpose is to make the aircrew aware of the capabilities and limitations of the different NVDs while appreciating their complimentary nature. The following are examples of some of the more obvious features or objects typically seen during NVD use. Keep in mind contrast, shadows, moon angle, illumination level, thermal signatures, absolute humidity, and NVD hardware capability are all factors that need to be considered during NVD mission planning. This chapter provides a brief overview and introduction to the discussion of NVD sensor integration.

A very common question about NVDs is "Which is better, NVGs or the FLIR?" The answer is a very ambivalent "it depends." Instead of looking at the two technologies as competing against one another, the two should be considered to be complimentary. This is the premise of sensor fusion. Where one sensor fails, the other may excel. Each technology has its strengths and weaknesses. Thermal sensors have achieved the standards of thermal and spatial resolution necessary to fulfill a range of military functions to a point where reliable field use is becoming widespread. The challenge is to provide adequate sensitivity for detecting weak thermal patterns, as well as large dynamic range and better automatic gain control to prevent saturation from large thermal variations. FLIR systems are very expensive and are usually of significant weight. Their FOV is usually less than that of NVGs. Additionally, few operationally fielded thermal sensor display systems are helmet mounted, which means their field of regard is considerably less than helmet mounted NVGs. This hinders the ability to rapidly scan a given area. Thermal imagery is also limited by certain environmental factors that tend to wash away temperature differences and make navigation and target detection more difficult. However, there are some significant advantages of thermal systems. Since no illumination is required, the performance of a FLIR is virtually independent of the time of night or day, and theirshort range performance is independent of most weather conditions. Even at longer ranges, where atmospheric absorption of IR energy can become significant, FLIR images invariably are better than the unaided eye. In addition, the information presented typically provides more information about the scene than that of both the unaided eye and AN/AVS-6. For example, FLIR imagery will disclose which engine, furnace or boiler is operating, which buildings are heated, and even the liquid levels in storage tanks. FLIR also has the ability to penetrate some types of camouflage, to detect the thermal shadow of a relocated aircraft or vehicle long after it has been moved, to view targets in a heavily lighted area such as a city, and to provide a detailed image of the scene. It is obvious, that a combination of thermal imagery and NVGs will provide aircrew

with the best of both near and far infrared worlds and offer the best chance for mission accomplishment and survival. However, there will be times when the environmental conditions are so severe that neither NVD will be adequate. This is the domain for all-weather aircraft that have terrain following or terrain avoidance radar systems such as theF-16 LANTIRN or F-15E.

II. Terrain Assessment

The terrain that aircrew fly over is the source of visual cues that were discussed in Chapter 3. For that reason, it is important that the night systems crews thoroughly preflight terrain characteristics to help predict visual performance with NVDs. Flight terrain assessment should take in to account both mission planning and inflight considerations. Preplanning will give the crew an idea of how much time will be needed for terrain clearance tasks. The crew must also use their judgment and skill to recognize changes in the flight profile based upon the visual cues obtained from the terrain. This assessment can be divided into three basic areas: (1) density, (2) terrain profile, and (3) unacquired vertical obstructions.

A. Density

Density is the relative measure of "how many things are on the ground that can be seen." In order to be seen an object must have sufficient size and contrast to be perceived as distinct objects 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 poor density are open areas, completely snow covered terrain, most deserts, and calm water. Because of the reduction in resolution, contrast, and FOV, the terrain density will be perceived to be less with NVDs than with the photopic eye. The reduction in density increases the potential for spatial disorientation. Therefore, altitude and airspeed cues derived from terrain density must be cross checked and verified with cockpit instruments, in particular the radar altimeter (RADALT).

B. Terrain Profile.

Terrain profile is the terrain assessment which measures two characteristics of the terrain; terrain gradient and terrain slope.

C. Terrain Gradient.

Terrain gradient is the contour of the terrain and can be divided into three broad categories. Flat terrain will require the least amount of effort devoted to monitoring the flight path. Rolling terrain will require more effort to be directed toward flight path monitoring due the possible presence of the possibility of hidden hills. Rough terrain will require almost exclusive effort be devoted to flight path monitoring because of the rapid changes in terrain features to include hidden hills. The possibility of not seeing hills or other terrain features increases with NVGs because of their visual limitations in regard to contrast and their poor performance in very low illumination conditions, such as terrain shadowing.

D. Terrain Slope.

Terrain slope is the measure of the tilt of the overall terrain. An up-slope will require more effort be devoted to flight path monitoring compared to even or down-sloping terrain. Low density terrain and reduced NVD visual performance makes detection of gentle up-sloping

terrain very difficult. Turns in these situations become critical because of the reduced acquisition time available for detecting the up-slope. The RADALT is your best means to detect changes in slope. Unfortunately, the RADALT only tells you what was below the aircraft and does not provide any rate information. The RADALT also has roll and pitch limitations that make it an unreliable source of information in certain maneuvers. Good mission planning and situational awareness will help reduce the possibility of a CFIT mishap.

E. Unacquired Vertical Obstructions.

This category includes anything that sticks up into the aircraft's flight path such as trees, power lines, antennas, poles, or hidden hills. The reduced contrast, resolution, and FOV provided by NVDs combine to create the potentially hazardous situation of not detecting these obstructions until it is too late. Presently, the best way to cope with this hazard is to maintain up-to-date hazard maps, situational awareness, and extra vigilance when searching.

III. Common NVD Scene Descriptions

A. Shadows

Both NVG and FLIR performance are influenced by shadows. Shadows for NVGs are formed by illumination sources (usually the moon) being blocked by terrain or cultural objects. Since FLIR performance is independent of illumination, it does not "see" this type of shadow. Shadows depicted on the FLIR image are formed when terrain or objects blocks a thermal source (usually the sun) for a long enough period of time to create temperature differential.

1. AN/AVS-6. Shadows for ANVIS are created when an object impedes light from striking a surface. Objects which may create shadows include terrain, man-made objects, clouds, and aircraft. The amount of obscuration within a shaded area, as perceived with NVGs, is dependent upon the amount of ambient illumination, relative position of the moon, and height of the object.

   Shadows created by clouds can create visual illusions leading to disorientation. For example, while flying underneath a broken layer on a HLL night, the pilot will be constantly in and out of shadows causing the AN/AVS-6 gain to fluctuate, thereby making it more difficult to pick out terrain features and ascertain depth perception. A scattered layer will not be as distracting but can mask or hide important navigation or targeting information. In the brighter areas between the scattered cloud layers, the NVG gain will be driven down making it more difficult to see objects lying within the shadows. Once inside the shadowed area the gain will readjust, perhaps making it easier to see the previously hidden objects. However, by that time it may be too late. Some shadows can be predicted, such as those cast by towers, smoke stacks, and mountains. Using the Shadow Formula in Appendix C, one can plan these for considerations.

   Knowing the moon angle and azimuth, combined with a thorough map study, will 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 include (1) Will the targets shadow aid in locating the target? (2) Will I be within a mountain shadow when attempting to visually identify a turn point? and (3) Am I going to be in shadowed terrain

while terrain masking? Remember that shadows can help or hinder and need to be considered during mission planning.

2. FLIR. A unique feature of FLIR imagery is the capability to show thermal shadow information. Some thermal shadows include the same areas as normal shadows. They are caused by the ground surface temperature being lower in the area shaded from direct radiation. These thermal shadows usually dissipate shortly after the sun sets or if the sun is obscured by clouds. The rate of dissipation depends on the physical characteristics of the shaded area and upon prevailing meteorological conditions. Other shadows indicate previous thermal activity. For example, while an aircraft is turning it is heating the ground beneath it. Once the aircraft has moved, the ground remains hotter than the surrounding ground leaving a "shadow." Often these silhouettes can be detected hours after the object has moved. Wind shadows can sometimes be noted in the lee of objects projecting above the surface, and are similar to a thermal wake. Since the wind does not disturb the surface in the lee of an object, this area may be warmer or cooler than the surrounding area, depending upon whether the breeze is warming or cooling the surface over which it is blowing. This phenomenon usually has limited operational significance but in some cases may aid in locating or identifying terrain or cultural features.

B. Roads

1. AN/AVS-6. The ability to detect roads with NVGs depends primarily on the albedo difference between the road and the surrounding terrain. 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. On the other hand, an asphalt road may be more discernible in desert conditions where the albedo difference will likely be much greater. The bottom line is that roads may or may not be easily seen and preflight planning will help reduce surprises.

   Sometimes it is not the road itself that will be seen initially but something else that alerts the aircrew to its presence. For example, noting a swath or cut through a forested area that was cleared for a road. Also, distant moving vehicular lights indicate the presence of a road and can even aid in finding bridges or tunnels well before they can be seen visually.

2. FLIR. Concrete and asphalt roads have a high thermal capacity enabling them to retain heat longer into the night than surrounding terrain. This produces a good thermal image. As heat is gradually dissipated below that of the surrounding terrain, the road will appear black (with white-hot polarity selected). Runways are normally "seen" with the FLIR at greater ranges than with NVGs. However, if the runway happens to be cooled to the same temperature as the surrounding terrain (crossover), and the runway is more reflective than the surrounding terrain (usually the case), then NVGs may be the first sensor to acquire it. Gravel and dirt roads will cool and heat more quickly due to their increased surface area and will therefore quickly adapt to the temperature of the surrounding area making them less distinguishable with the FLIR. Vehicular lights will be of no use to the FLIR, but thermal signatures from vehicular activity may aid in finding a road that may otherwise be difficult to see.

C. Water

1. AN/AVS-6. There is very little contrast between a land mass and a body of water during low light conditions. When viewed through the NVGs, lakes or rivers appear dark. As the light level increases and moon angle decreases, the water begins to change color, land-water contrast increases, and reflected moonlight is easily detected. When overflying large open areas of calm water, reflections from clouds, stars or the moon can be disorienting. However, when a surface wind or swells exist, the resulting whitecaps can provide contrast to assist in altitude and speed estimation. Regardless, due to the lack of density, flight over open water is best performed by relying heavily on flight instruments.

2. FLIR. The reflectivity and emissivity of a water surface varies greatly with change in the irradiation angle of incidence on the surface. At shallow angles (up to five degrees) a calm water surface will reflect most radiation incident upon it. At steeper angles of 30 to 90 degrees, the water's surface will be almost entirely emissive, radiating its surface temperature. In either case, the entire FOV of the FLIR could consist of a constant thermal scene. In other words, no detail. Due to its use at low altitudes, a FLIR will normally view a surface at very shallow angles (0 to 11 degrees) when in level flight. Thus, on a calm night the FLIR may not be able to produce a horizon. NVGs may be able to display a horizon, but due to the lack of surface texture, height above water may be impossible to perceive. As the sea state increases, the irradiation angle of incidence changes, causing a thermal differential between the water and the surrounding terrain (normally the sky). This creates a "horizon". With an increased sea state, NVGs can detect texture that may aid in altitude estimation and depth perception. Depending on the temperature differential and wind conditions, a thermal inversion layer normally builds over the water as the evening temperature drops. This inversion layer has been shown to mask the presence of hot objects (boats) on the water, until thermal conditions stabilize. Exact timing depends on daytime heating, cloud cover and object characteristics, but in general terms there is a temporary thermal washout in early evening as the more "reflective" objects transfer from hot to cold. NVGs may aid in target / object detection during these thermal inversions.

D. Open Fields

1. AN/AVS-6. Contrast is very poor in large fields covered with similar vegetation. If the vegetation has leaves that contain chlorophyll, they will 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. This is one example of how the difference in wavelength sensitivities between the eye and NVGs alters the "normal" scene interpretation to which we have grown accustomed. During the harvest or the dormant season, the color of the vegetation changes to a lighter color and contrast can improve. A freshly plowed field will likely have little vegetation. Additionally, the roughened terrain will probably absorb more easily than reflect energy. This combination will create an area darker than one containing more highly reflective materials. Overflying a series of smaller fields with differing vegetation can help overall situational awareness. Also, fields with vegetation will usually have high density that aids in orientation.

2. FLIR. Under normal conditions, soil appears quite warm in the FLIR image. This results from high emissivity, sun heating during the day, and the high thermal capacity of the earth. On the other hand, grass appears very cold to the FLIR. Grass is unable to draw heat from the earth because of its poor thermal contact with the ground, and rapidly becomes cold. For this reason, air temperature at ground level is usually lower at night

than air temperature a few feet above ground, a phenomenon known as night inversion of air temperature gradients. This hot and cold combination creates good contrast for the FLIR image and is particularly noticeable in agricultural areas. Any disruption in this otherwise organized picture would be easily noted, such as a building, road or graded area. If the fields are completely covered with similar vegetation, detail is lessened. NVGs react much the same in this environment but, depending on the type of vegetation and its size, they can "see" texture and help by aiding both distance estimation and depth perception.

E. Desert

1. AN/AVS-6. Most of the time, open deserts present a washed out image through the NVGs due to poor contrast and poor density. Mountain ranges can be easily identified because of the dark color of barren mountains contrasted against the light color of the desert floor. However, gradually rising terrain and ridgelines can be particularly difficult to discern and may first be noted by a change in the RADALT. On a particularly bright night with the moon high overhead, the NVGs can begin to degain or washout considerably, making it even more difficult to pick out what little contrast or density is available. Additionally, fixed pattern noise (honeycomb) may be seen under these conditions creating "focus trapping" and making it even more difficult to discern small contrast differences. In general, flying over this type of terrain is similar to flying over water (without the reflection) and is best accomplished at a higher altitude and/or using instrument flight techniques. Scars on the desert floor, usually caused by vehicle tracks, roads, revetments, SAM sites, etc., as well as scrub brush in the operating area, will give some depth perception and altitude estimation cues which are not available in a strictly dunes desert environment. At higher altitudes, these scars may be seen several miles away under the right conditions.

2. FLIR. As with NVGs, the flat featureless desert floor offers little thermal variation for good imagery. Usually there is enough thermal difference between the night sky and desert floor to give a good horizon, and anything between the desert floor and the night sky is usually noticed (mountains, ridgelines, saddles, etc.). Once again, gradually rising terrain is not easily discernible. In moderately undulating desert terrain, ridgelines can hide themselves behind one another quite well and are not easily seen with NVDs. As with flying over water, increased attentiveness and the use of instrument flying techniques may be necessary.

F. Forests

1. AN/AVS-6. Heavily forested areas may not reflect light efficiently and solid canopied forests can appear as dark areas unless the trees have leaves with high levels of chlorophyll (usually the spring). Excellent contrast and texture differences do exist between deciduous (leafy) and coniferous (pines, firs, etc.) trees, as well as between open fields and surrounding forested areas. Also, when trees are grouped in small groves or are scattered they can be of great benefit in helping with distance, altitude and airspeed estimation.

2. FLIR. Trees appear cool to warm on the FLIR. This is associated with the convective warming of the trees by the air in conjunction with the night inversion of air temperature gradients (although heating from the life processes of the tree has some impact). Vegetation is a strong reflector of thermal energy (the "chlorophyll effect") and leaves that appear dark to the unaided eye generally appear light on the FLIR. Trees offer a good

thermal source for scene interpretation because a tree looks a lot like a tree. This is particularly helpful when flying low altitude and high airspeed because the image is very similar to the normal daytime scene, which enhances situational awareness. There will be less definition over a compact, dense forest than over orchards or scattered groves of trees.

G. Snow

1. AN/AVS-6. Fresh, wet snow reflects about 85% of the energy incident upon it thereby providing good natural reflectivity. However, high light levels can provide excessive luminance, which, like the desert, can lower gain and degrade resolution (NVG image washout). Flying over snow covered terrain on a moonlit night, even with an overcast 3000 feet thick, has been shown during flight tests to provide enough light to conduct night TERF. The ability to conduct night TERF under these conditions depends on a sufficient number of objects protruding through the snow for contrast and density. Without these objects, terrain recognition will be more difficult in a snowy region due to the obscuration of prominent landmarks.

2. FLIR. A heavy blanket of snow will cool surfaces uniformly, eventually erasing all thermal variables. A light snow, on the other hand, can enhance thermal contrast by cooling some areas and not others. Naturally, internally heated sources, such as factories or fires, are much less effected and may become more prominent at greater distances. NVGs may be able to pick out protrusions through the snow, such as trees or rocks, that may aid in deciphering the FLIR image and also enhance depth perception. As with winds and cloud covers, the thermal influence snow has is dependent on how long it has been in contact with the various surfaces.

H. Artificial Light Sources

Highly populated areas can generate very significant levels of ambient light. Many of the discrete artificial sources exhibit overlapping halos in the NVG image substantially reduces contrast and detail between sources. The FLIR would be particularly useful in these situations. Although lighted areas can be seen from great distances, specific buildings or objects cannot always be distinguished unless they are recognizable by individual lighting patterns. When associated with an overcast layer, city lights can supply increased illumination to less illuminated areas by reflecting light from the bottom of the cloud layer. Sodium lights used on the back of farmhouses can make a rural area look like an industrial complex. A baseball field lit up at night can look like a small town. Automobile lights can provide excellent cues to the presence of a road, but direct light from an automobile, especially halogen types, can be very disconcerting at low altitude. The red lights on top of radio and microwave towers are visible from 10-30 miles, depending on the atmospheric conditions, but their range and relative distances can be hard to judge. Aircraft anti-collision lights can be seen at even greater distances. Weapon flashes, flares, and explosions, all of which contain significant levels of near IR radiation, are intensified by the NVGs. Since dark adaptation is unnecessary for NVG use, the bright flashes are of minimum impact on the unaided eyes capability to see the intensified image. Simply scanning away from the source or changing aircraft heading can help compensate for unwanted illumination. If unavoidable, it may be necessary to revert to instrument flight for brief periods realizing that maneuverability is adversely impacted. Near IR LASER pointers (i.e., IZLID-II, LPL-30, etc.) are increasingly utilized by FACs and TACP teams to mark targets for NVG equipped Close Air Support aircraft. The effective range of these target marking devices and the range al

which they are observable to CAS aircrew depends upon the output power of the LASER, atmospheric conditions, illumination, aircrew experience with the devices, and other variables. The target spot is most pronounced under overcast or low light level conditions when the NVGs are operating at a higher gain. Another artificial light source that can impact NVG operations is aircraft exterior lighting. Unless exterior lighting is compatible, it will adversely impact multi-ship maneuvers, such as off target rendezvous. The lights will adversely affect NVG gain and cause blooming that may mask closure rate and distance estimation thus making join-ups increasingly dangerous. Additionally, if flying a reasonably close wing, the blooming caused by leads exterior lighting may lessen the wingman's ability to see surrounding ground references. Other missions, such as in-flight refueling, will also be difficult or impossible to perform unless exterior lighting is compatible (NVG compatible lighting is more fully discussed in Chapter 6).

I. Thermal Size and Shape

Although the FLIR scene is a reasonable reproduction of the real scene, it is not always accurate in its depiction of size and shape. Thermal radiation can occasionally produce some odd signature effects. For example, the higher the objects heat content, the greater its blooming effect and the larger it may therefore appear. In addition, the blooming may round edges, change the overall shape or distort the image. The opposite can be said for objects much cooler than other objects in the immediate area, as they may be partially hidden by the size and shape of hotter objects. Although the true size or shape of an object may not be immediately apparent, being familiar with the route and/or target area can help compensate for this. Fortunately, most features or objects used for navigation purposes are large and consistent, thus an accurate image is relatively simple to reproduce.

J. Internally Heated Sources

Most of the preceding generalizations assume that objects are not artificially heated (i.e., all thermal energy involved arises from solar heating). In this case, the best FLIR image is acquired under clear skies with no wind. Many objects, such as buildings and vehicles, have an internal heat source so may be much warmer than their surroundings. Within the object itself, significant temperature differences may occur. Objects such as tanks, trucks, and APCs have internal temperature variations that form visible patterns that are the fundamental elements of their signature cues. The hottest vehicle parts, such as the engine and exhaust, stand out as bright shapes with white hot polarity selected. Medium temperature objects, such as warm tracks and other moving parts, appear medium bright, while the relatively cool hull appears dark. Also, parts of a truck or tank will remain hotter than its surroundings for several hours after use. A factory chimney stack or cooling tower may be a very strong IR source. In all cases however, the emissivity must be considered. Special low emissivity paints can greatly reduce the radiation from hot surfaces of a vehicle or building, though simultaneous camouflage against both visual and IR detection is extremely difficult. Objects with their own heat source, such as a battle tank, are relatively unaffected in tone by meteorological variables assuming a clear line of sight. For example, during and after a rainstorm the natural scene tends to become isothermal and exhibit a certain amount of "thermal washout." Given this washed out natural scene, a thermally active object, such as a tank, can actually be detected at a greater distance because of its relative heat differential with the background. Though this type of information is more applicable to TFLIR employment, it is important to understand all parts of the FLIR image. Smaller objects such as tanks or trucks may not be of much help in navigation, but larger objects such as factories or chimneys can be.

K. Day Thermal Scene

Day thermal signatures can differ greatly from night signatures, especially when comparing sunny days with clear nights. This difference is less noticeable during overcast or rainy days and nights. The source of the differences is primarily the solar heating effect. Solar heating generates object shape cues that can make daytime FLIR target recognition more difficult than nighttime. Objects are heated by the sun on clear days to relatively high temperatures, but the outer surface does not always heat evenly due to shadowing. IR reflections during the daytime can also provide spurious hot spots on the object. Another factor in daytime scene/target recognition is the daytime contrast reversal whereby background features and other objects increase screen clutter. This is especially troublesome from mid-morning through mid-afternoon. The combination of shadows, reflections and uneven heating can make the daytime FLIR image very difficult to decipher. The many hot background objects make long range detection difficult. Rainy day IR signatures are most consistent with expected cues. As the rain cools the background, thermally significant objects will tend to stand out conspicuously.

IV. Summary

The interpretation of the NVD scene remains a constant challenge to NVD aided aircrew. Aircrew must completely understand the capabilities and limitations inherent to the NVDs used and apply that knowledge to an ever-changing environment. The synergistic effects of the NVD sensors must be integrated into the mission planning process. For AN/AVS-6 aided aircrew, the fundamental factors that will dictate the quality of the intensified image and impact image interpretation includes; (1) illumination, (2) terrain contrast and (3) atmospheric obscuration. For aircrew flying aircraft that possess FLIR, the fundamental factors that drive the quality of the presentation of the thermal image includes; (1) terrain and target emissivity, (2) thermal contrast and (3) atmospheric attenuation. An aggressive scan across the onboard NVDs coupled with attention to environment changes and cross-checking the information presented with flight instruments, aircrew will best optimize NVD employment.

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Chapter 5

AN/AVS-6 Preflight / Post-flight Considerations

I. Introduction

As with any system, the key to achieving full the operational capability of the AN/AVS-6 NVG is through proper preflight and follow-on post-flight care. Ensuring that the NVG is properly mounted and adjusted prior to each flight is essential to successful NVG aided operations. Improper adjustment of goggles can result not only in degraded system performance, but also converging or diverging vision and neuromuscular (accommodative) eye fatigue. This section is dedicated to those procedures critical for AN/AVS-6 optimization.

II. AN/AVS-6 Adjustment and Assessment Procedures

Adjustment and assessment procedures should be performed using either the NVG eye lane, the ANV-20/20 NVD Infinity Focus Device or the TS-4348 test set. The specific set-up and operating instructions and procedures for the NVG eye lane, TS-4348 and ANV-20/20 are provided in Appendix A. The significance of the adjustment and assessment procedures can not be understated. These regimented procedures for inspection, adjustment, alignment, focus, NVG image assessment and the final infinity focus of the AN/AVS-6 are critical to optimizing the sensor. Although aircrew are exposed to these procedures during their initial Fleet Replacement Squadron (FRS) Night Imaging and Threat Evaluation (NITE) Lab training and familiarization flights, the squadron Night Systems Instructors (NSIs) and/or Aeromedical Safety Officers (AMSOs) should be used for refresher training or questions regarding AN/AVS-6 preflight procedures. Through practice and NVG experience, aircrew will easily master the ability to get the most out of their NVGs. These procedures can be broken down into the following five steps: (1) inspection and initial adjustment procedures, (2) alignment procedures, (3) focus procedures, (4) NVG image assessment procedures and (5) aircraft adjustment procedures.

A. Inspection and Initial Adjustment Procedures

Inspection procedures for the AN/AVS-6 are similar to the preflight procedures for any other aircraft system. The guiding premise is to determine if all parts are in working order and if the system is functional prior to getting airborne. The initial adjustment procedures performed during this phase will place the binocular assembly in a favorable location in front of the eyes once inserted in the mount and rotated into the down/locked (ready for flight) operating position. These procedures will facilitate the next step in the pre-flight process, the alignment procedures. As with most flight oriented procedures (i.e., emergency procedures),

aircrew are less likely to miss an item if the inspection and initial adjustment procedures are consistently performed in the same order, Figures 5-1 through 5-6

1. Inspect Helmet. Inspection of the helmet should be the same as for unaided flight. However, particular attention should be paid to helmet fit due to the extra weight and forward center of gravity caused by the helmet V-1B NVG mount and AN/AVS-6. In addition, one should inspect the helmet NVG mounting bracket and ensure that it is free and clear of debris, Figure 5-1.

2. Inspect V-1B (Formerly V-3) Quick Don Block Mount. Ensure the mount is not cracked and that all contacts are clear and clean, and check wiring for integrity. Test all controls for smooth operation, Figure 5-1.

3. Load Battery Pack and Mount to Helmet. Prior to inserting the batteries, make certain that the power pack is turned off. Ensure the batteries are correctly inserted. Attach battery pack to helmet. Connect battery pack cable to helmet wiring harness tail by matching red dots located on each connector and applying finger tip pressure, Figure 5-1

4. Inspect Binocular Assembly. Ensure there is no obvious damage to either monocular housing. The monocular housings are attached to the position adjustment shelf (PAS), which is constructed of a lightweight plastic material. Consequently, each monocular may move independently of the other, but the movement should not be excessive. Rotate the objective and eyepiece or diopter focus controls to ensure freedom of movement. The diopter controls are naturally "sticky" in their travel due to a plastic-on-plastic design. However, if the controls are very difficult to turn, notify maintenance. In some instances, maintenance can simply release some of the nitrogen pressure and the controls will loosen. Test all other adjustment controls for free movement and smooth operation. In addition, ensure that all adjustment knobs and levers are free from dust, dirt and grime, Figure 5-1.

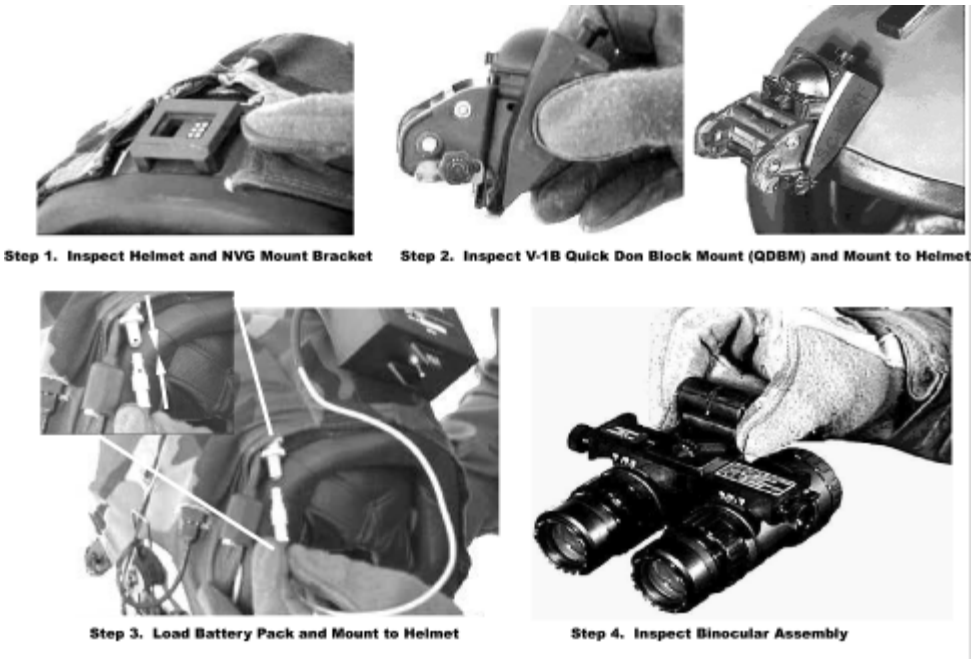


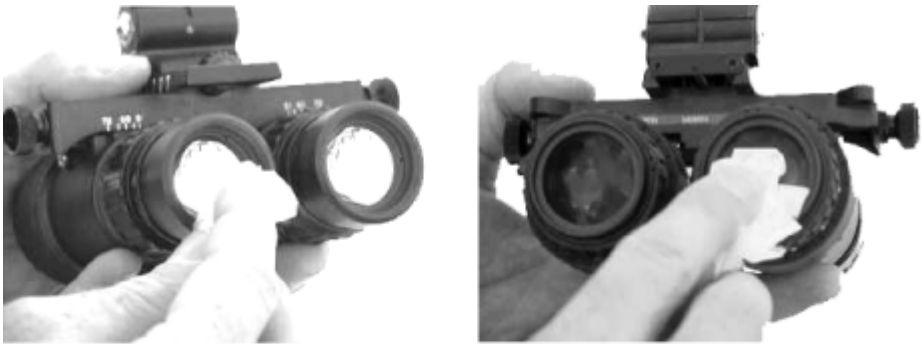
Figure 5 - 1. AN/AVS-6 Inspection and Initial Adjustment Procedures (Steps 1 through 4)

5. Inspect and Clean Lenses. Inspect the objective and eyepiece lenses for scratches, smudges or other damage. Clean the lenses with lens paper or equivalent material and not with a piece flight suit or tee shirt. If available, wet lens paper with either water or denatured alcohol prior to cleaning, Figure 5-2. USAF data has demonstrated that a single thumbprint on one of the lenses may degrade visual acuity by as much as thirty percent.

<<NOTE>>

Some Omnibus-II 15mm eyepiece lenses were made using plastic (concave lens shape). Newer Omnibus-II 15mm eyepiece lenses were made of glass (convex lens shape). Aircrew have noted distortion when using AN/AVS-6 NVGs with mixed eyepiece lenses. The current AN/AVS-6 maintenance instruction (NAVAIR 16-35AVS-5) restricts mixing glass and plastic 15mm eyepiece lenses on the same AN/AVS-6 NVG.

6. Preset Eyepiece or Diopter Adjustment Ring Focus. The eyepiece lens focuses the output image from the image intensifier tube back onto the retina of the NVG user. The eyepiece focus adjustment allows one to change the focal length of the eyepiece lens. The eyepiece focus setting is a function of the both refractive capability of the operator's eye and the NVG eye relief selected. The eyepiece lens focus adjustment will allow one to compensate for visual refractive focus errors, however, it will not correct for astigmatisms. It is recommended that aircrew that require corrective lenses use either contact lenses (preferred) or spectacles when using NVGs. The eyepiece focus adjustment ring has a range of +2 through -6 diopters. A diopter is a unit of measure for lens refractive power. Initially, aircrew should set the diopter on each monocular to zero, Figure 5-2. This will help ensure that the resolution chart will be initially viewable when beginning the focusing procedures.



5. Inspect and Clean Lenses (Objective Lenses and Eyepiece Lenses)

6. Preset Eyepiece or Diopter Adjustment Ring to "Zero"

Figure 5 - 2. AN/AVS-6 Inspection and Initial Adjustment Procedures (Steps 5 and 6)

<<NOTE>>

In some instances, NVG Manufacturers recommend rotating the eyepiece or diopter lens to the full counterclockwise position (+2) for initial adjustment. While this technique will work, operational experience has shown that one's initial inability to see the NVG eye lane or ANV-20/20 target with this propositioned diopter setting distracts away from the subsequent critical focus adjustment procedures.

7. Preset Fore-and-Aft or Eye Relief Adjustment. Eye relief is the distance between the NVG eyepiece lens and the eye. Eye relief adjustment is made with the fore and aft adjustment knob on the AN/AVS-6. Initially, position the binocular assembly as far forward (away from the helmet mount) as possible. This will avoid damage to spectacles (as applicable) and placement of oil on the lens from eye brows or eye lashes when the NVGs are initially attached to the mount and rotated into the down/locked (ready for flight) operating position, Figure 5-3.

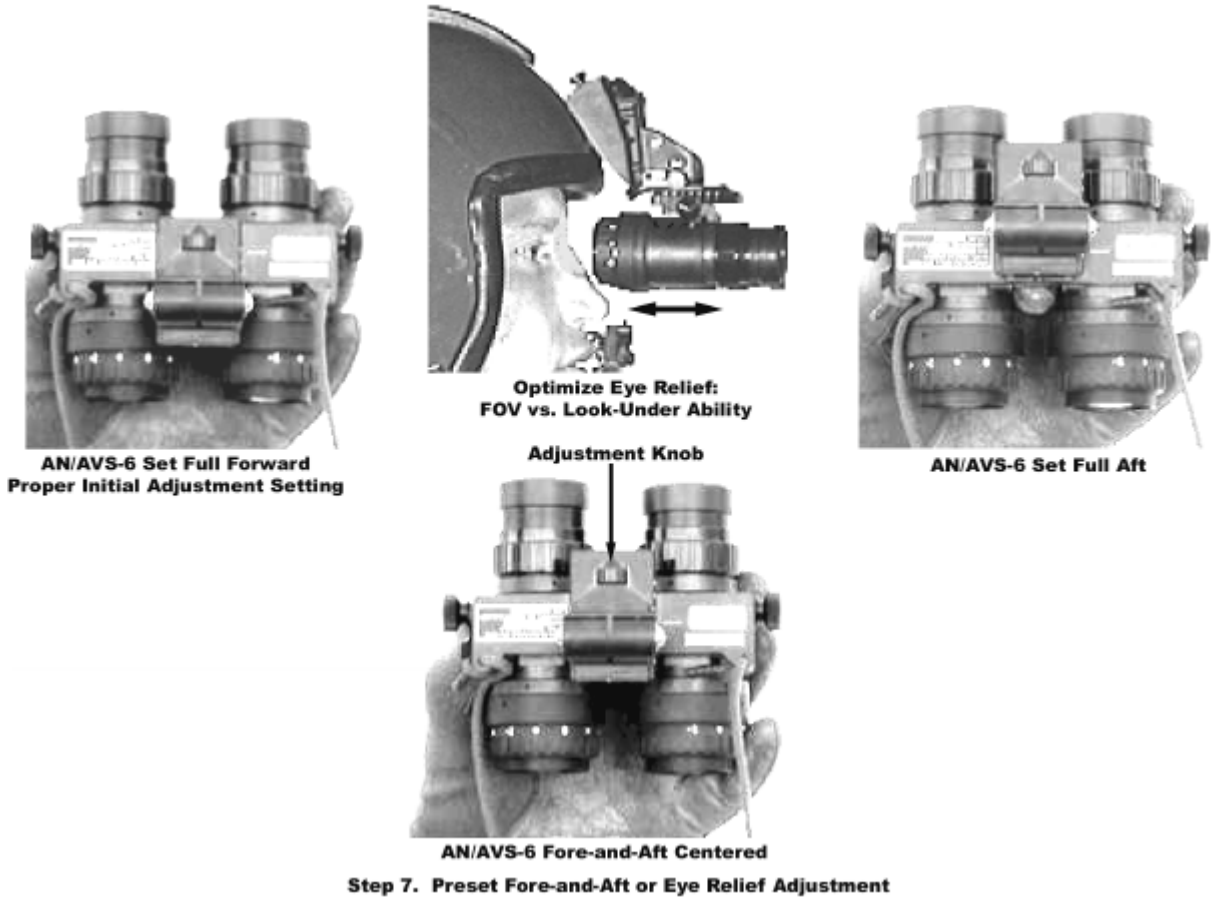


Figure 5 - 3. AN/AVS-6 Inspection and Initial Adjustment Procedures (Step 7)

8. Center Tilt. Initially set the tilt adjustment to the centered position (determined by aligning the tilt lever with bottom portion of the bridge). Ensure the IPD adjustments do not move when manipulating the tilt lever, Figure 5-4.

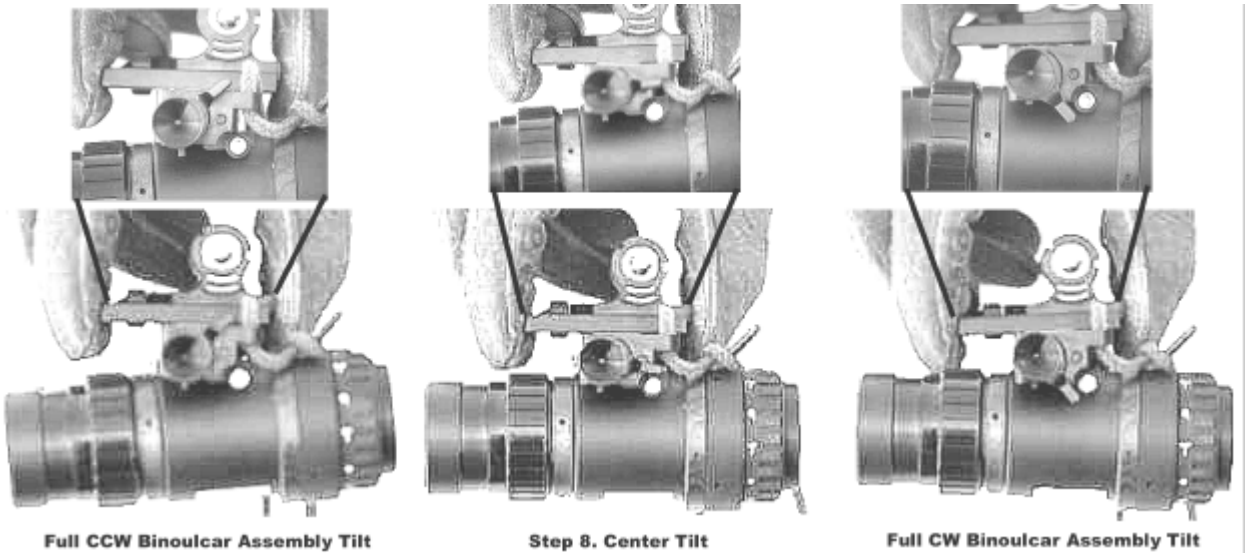


Figure 5 - 4. AN/AVS-6 Inspection and Initial Adjustment Procedures (Step 8)

9. Set IPD. Rotate the IPD thumb wheels to ensure the mechanisms move freely and that the tilt lever does not move as the monoculars track along the bridge. For aircrew using Omnibus-III/IV AN/AVS-6 NVGs with the independent or dual IPD adjustment Position Adjustment Shelf (PAS), initially center the IPD for each monocular. For aircrew using Omnibus-II AN/AVS-6 NVGs with the single adjustment PAS, use a millimeter ruler to set the appropriate IPD distance between the two monoculars, Figure 5-5.

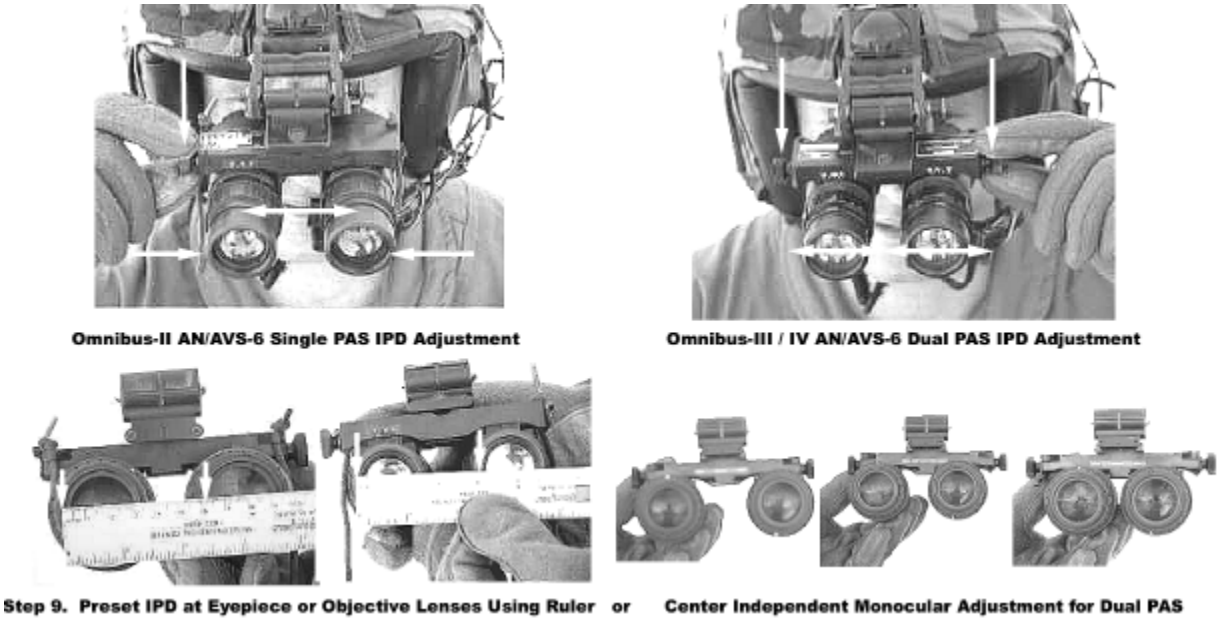


Figure 5 - 5. AN/AVS-6 Inspection and Initial Adjustment Procedures (Step 9)

10. Adjust Vertical. Ensure the adjustment mechanism located on the V-1B NVG mount tracks smoothly to the upper and lower limits of movement, and ensure the thumb wheel moves freely. Set the adjustment to the centered position, Figure 5-6

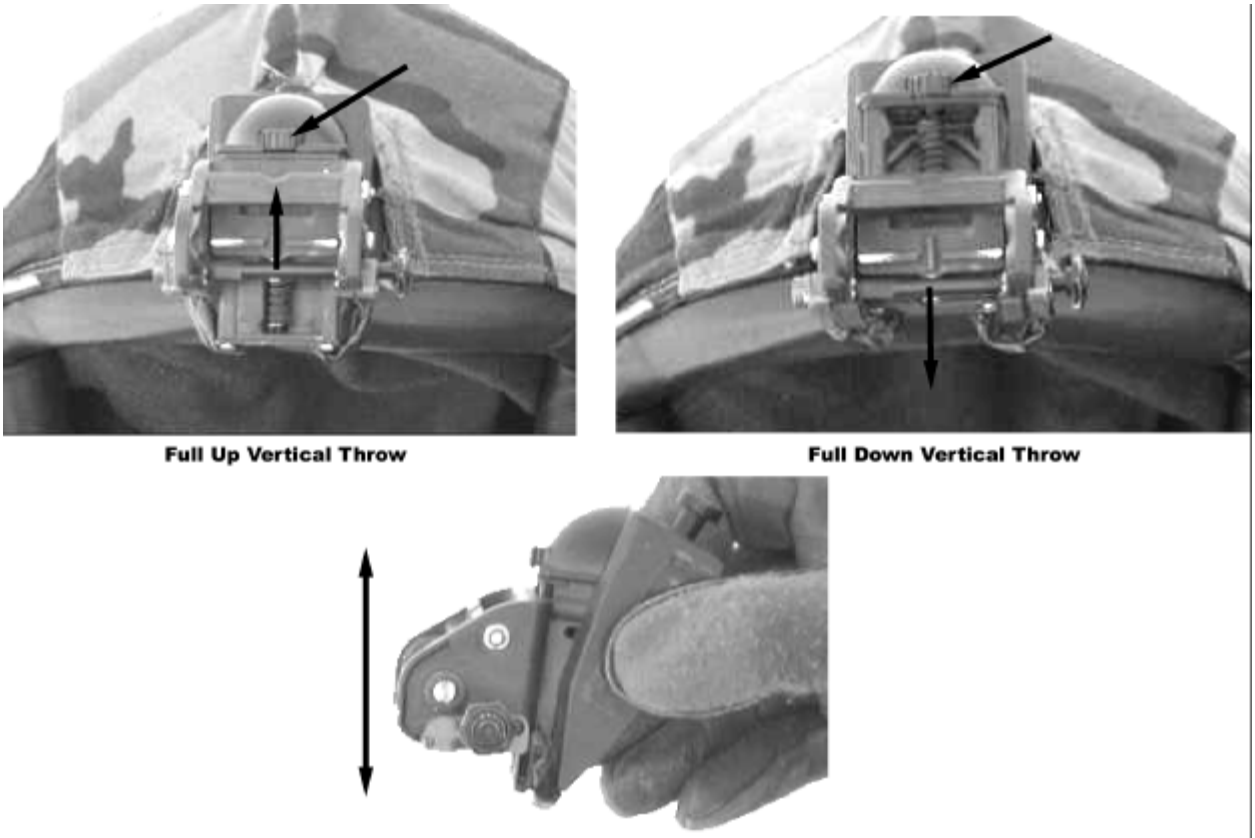


Figure 5 - 6. AN/AVS-6 Inspection and Initial Adjustment Procedures (Step 10)

11. Don Helmet. The helmet should be donned in order to check for comfort and to prepare for attaching the NVGs. Fasten and adjust the integrated chin/nape strap. For KC-130 aircrew, if an oxygen mask is to be used, it should be attached andadjusted as it would be for flight. This is to ensure no additional adjustments will be required in the cockpit due to a shift in helmet position when the mask is attached.

12. Attach and Remove Binocular Assembly. Attach the binocular assembly to the helmet mount assembly by holding the AN/AVS-6 in a vertical position (90^0 or perpendicular to mount), Figure 5-7. Align the spring loaded bearings of the binocular assembly with the channels on the V-1B Quick Don Block mount assembly shelf and push gently until the binocular assembly snaps into place. Do not exert excessive force. If too much force is required, it is an indication that the bearings are not properly aligned and the binocular assembly may fail to seat properly or become jammed in the mount.

Figure 5 - 7. AN/AVS-6 Binocular Assembly Mounting

(a) Do not release the binocular assembly until confirming that it will lock securely in the up/stowed position. This action confirms two important points:

1: The binocular assembly is properly seated in the mount.

2:The binocular assembly has not been mounted backwards.

(b) Once the binocular assembly has been properly seated, press the lock release button and rotate the assembly into the down/locked (ready for flight) operating position. The eyepiece lens (diopter adjustment) should now be closest to the eyes

(c) Begin removing the binocular assembly by pressing the lock release button and turning the binocular assembly to the intermediate vertical position. Once out of the locked position, the lock release button can be released. Pull the binocular assembly straightforward out of the mount, preferably using both hands. Easy removal may be facilitated by first pulling one side slightly out of the detent (slight rocking) and then pulling forward on the assembly.

(d) Practice donning and doffing the AN/AVS-6 binocular assembly until comfortable with the technique.

B. Alignment Procedures

In a binocular helmet mounted system, such as the AN/AVS-6, there are two images, one for each eye. The two images may differ due to horizontal and vertical alignment error or due to differences in the intensified images. Proper alignment is important because best visual performance is possible only when the optical axis of the AN/AVS-6 is perfectly aligned with the visual axis of the eye, Figure 5-8. Therefore, optimum focus can not be attained until proper alignment has been accomplished. Ideally, the NVG eye lane or ANV-20/20 should be used for these procedures. Alignment errors may result because the two optical axes are

not parallel. Some imperfection can be present without appreciable adverse effects, however, aircrew should strive for attaining a 100% overlapped circular image sight picture through proper alignment of the AN/AVS-6 NVG axis with the visual axis of the eye. Table 5-1 lists the different types of alignment errors and optical image differences that the NVG aircrew may encounter.

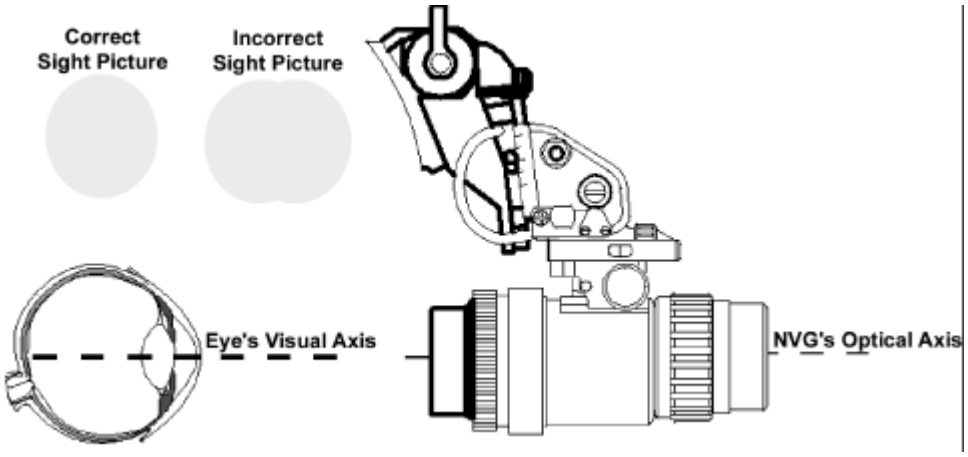


Figure 5 - 8. AN/AVS-6 NVG Alignment and Sight Picture

TABLE 5 - 1. ALIGNMENT ERROR/OPTICAL DIFFERENCES BETWEEN NVG IMAGES

Fault or Error	Definition
Vertical Misalignment	One optical axis is tilted up or down with respect to the other axis. Difference in vertical position of images.
Horizontal Misalignment	One optical axis points inward or outward.
Rotation Difference	One image is rotated (tilted sideways or twisted).
Luminous Difference	One image is brighter than the other.
Contrast Difference	The two images differ in contrast.

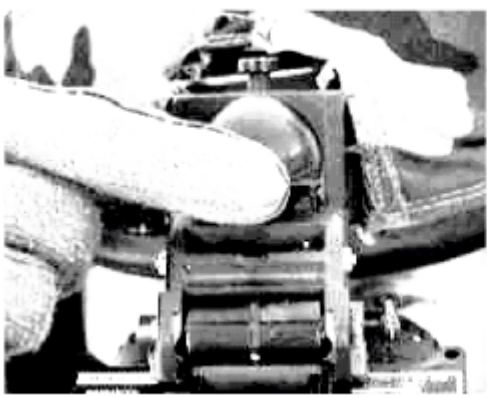
The effect of these faults or errors was discussed in Chapter 3. Aircrew should perform the AN/AVS-6 NVG alignment procedures in the following order:

1. Vertical Adjustment. Vertical adjustment and tilt are important factors for proper NVG monocular alignment with the eye. If not properly aligned with the eye, the upper or lower portion of the field of view will be reduced and the viewer will see the inside walls of the tube. Poor alignment can also result from a defective NVG PAS or poor helmet/helmet liner fit. Adjust the vertical position of the binocular assembly using the vertical adjustment control located on the V-1B quick don block mount. The binocular assembly should be set located directly in front of the eyes.

2. Tilt Adjustment. Adjust the tilt so the optical axis of the binocular assembly is perfectly aligned with the visual axis of the eyes. If the upper or lower edges of the image areas are blurred, adjust both the vertical adjustment knob and the tilt lever until the blurred edge is removed and an optimal view out to all edges is achieved. Changes in tilt usually require a correction in the vertical adjustment, and vice versa.

3. Fore-and-Aft or Eye Relief Adjustment. The recommended eye relief for Omnibus-II AN/AVS-6 is 15mm. The recommended eye relief for the Omnibus-III / IV AN/AVS-6 is 25mm. This value may not be achievable due to helmet or helmet liner configurations and

some anthropometric facial features, such as deep set eyes or protruding foreheads. If the NVGs are brought in too close to the eyes, one's look-under ability or the ability to look under the NVGs to read instruments or maps is impaired and an unnecessary strain may be placed upon the eyes that may accelerate fatigue. However, if the NVGs are too far away, a significant loss of field of view can occur. To adjust, move the binocular assembly closer to the eyes, Figure 5-9. As the binocular assembly is brought aft, aircrew should see an increase in field of view (FOV). Particular attention should be focused on the periphery of the intensified image. The stopping point for adjustment is when one no longer sees an increase in FOV with movement of the binocular assembly aft. As discussed earlier, eye relief should be positioned to maximize the field of view without unnecessarily reducing the ability to see around the NVG to view cockpit displays or perform other tasks. It is especially important that the goggle never be positioned so close to the face that the eyepiece lenses contact spectacles or eyelashes.



Step 1. Vertical Adjustment

Step 2. Tilt Adjustment

Step 3. Fore-and-Aft Adjustment

Figure 5 - 9. AN/AVS-6 Alignment Procedures (Steps 1 through 3)

4. Interpupillary Distance (IPD) Adjustment. IPD is the distance between the pupils of the eyes. It is also referred to as eye span. The center of the intensifier tubes should be aligned with the pupil of the eyes. The distance between the center of the tubes should be equal with the user's IPD. If the tubes are not aligned, the eyes tend to drift towards the center of the tubes where the optics are at their best. This leads to focusing problems, visual fatigue and headaches. It has also been attributed as the cause of short-term post-flight reduction of near depth perception. The standard method of aligning the tubes was

the subjective overlapping of the images, which causes most people to bring the tubes too close together. However, with the Omnibus-III introduction of the dual IPD adjustment PAS, this procedure has become the preferred method. For the Omnibus-II AN/AVS-6 (single IPD adjustment PAS), the preferred method of setting IPD is to physically measure aircrew IPD and use a ruler to set the NVG IPD to the specified distance. IPD is adjusted with the IPD adjustment knob on the AN/AVS-6, Figure 5-10. The adjustment range is from 51-72 mm. During the alignment procedures, one should adjust each IPD to independently center the monoculars in front of each eye. Close or cover one eye and center the image in front of the other eye. Carefully evaluate each monocular image for clarity of the edges bordering the circular intensified image. Repeat for the opposite eye. With both eyes open, evaluate the two monocular images. Observe closely the clarity of the combined edges of the overlapped NVG intensified image. If the outside edges are blurred, the monoculars are too close together. If the inside edges are blurred, the monoculars are too far apart. When properly adjusted, the edges of the images in both monoculars will be clear and the resultant NVG intensified image will appear as a single 100% overlapped circle.

Omnibus-II IPD Alignment

Omnibus-III & IV IPD Alignment

Step 4. Interpupillary Distance (IPD) Adjustment

Figure 5 - 10. AN/AVS-6 Alignment Procedures (Step 4)

5. Evaluate the NVG image. When the goggles are correctly aligned, there should be no shading of any part of the image. If shading is present, attempt to eliminate it by making adjustments in the direction of the shading. If there is insufficient travel in the goggle adjustments, move the entire helmet in the direction of shading. If proper alignment can only be made by moving the helmet, it is an indication that the mount assembly is not properly positioned on the helmet. Notify flight equipment so the problem can be corrected.

C. Focus Procedures

Common methods currently used to focus and adjust NVGs, such as focusing on a small light source or lettering on a nearby aircraft on the flight line, are not sufficient to ensure that the NVGs are properly adjusted for flight. The NVG eye lane (Appendix A) provides a simple method to accurately adjust and focus NVGs. The system is inexpensive and provides a standard to assess NVG tube performance and the ability to properly adjust and focus the NVGs. This preflight function is of particular value to inexperienced NVG users and should be assisted by the squadron Night Systems Instructors (NSIs). In addition to the NVG eye lane, focus procedures can also be conducted using either the ANV-20/20 or the TS-4348 test sets. As the ANV-20/20 NVD infinity focus devices become available in the fleet, they will most likely become the standard for NVG preflight optimization of the NVG. This is due to the ability of aircrew to quantify the optical infinity focus of the NVG. On the other hand, although the TS-4348 is currently available in the fleet, operational experience has shown that this monocular device may be difficult to effectively use for aircrew preflight focus and adjustment. Regardless of the modality used for NVG preflight focus adjustments, the procedures remain virtually the same. To perform a preflight quality assurance check of the NVGs each tube must be checked individually and then the two tubes checked together. When viewing the NVG visual acuity targets (i.e., NVG eye lane, ANV-20/20 target, etc.), the objective is to be able to discern the orientation of the grid lines as being either vertical or horizontal. Every line in the grid may not be perfectly clear, but the direction of the lines should be readily apparent. Start by using the coarser grids (larger lines) try not to initially focus on the finer grids until the eyepiece or diopter lens adjustment has been made. Aircrew should use the following sequential procedures while adjusting the AN/AVS-6 for focus:

1. Objective Focus. With one eye closed or one tube covered, turn the objective lens (outer ring) of the opposing monocular housing while viewing one of the coarser grids of the NVG visual acuity chart. Attempt to bring the coarse lines into focus. Do not spend a great amount of time with this initial objective lens focus, as the purpose is to obtain an image that is adequate to facilitate a suitable diopter adjustment

2. Eyepiece or Diopter Focus. Next, turn the diopter focus adjustment (inner ring) counterclockwise (toward "+" diopter) until the image is blurred. Pause for one to two seconds to allow the accommodative eye muscles to relax, then turn the diopter adjustment clockwise until the image just comes into sharp focus **~ STOP**. If one continues clockwise rotation of the diopter focus ring past the initial point of sharp focus, a range will be seen where the image still maintains clarity or sharpness, Figure 5-11. Do not leave the diopter adjustment beyond the point at which the image initially becomes sharply focused, even though the image remains quite clear. Rotating the diopter adjustment beyond this point forces the accommodative eye muscles to actively work to keep the image focused. Throughout an NVG aided mission, these eye muscles will become fatigued and unable to maintain this accommodative focus. This will result in an insidious and gradual loss of NVG resolution and depth perception that may not be perceivable to the aircrew. In addition, this maladjustment may also induce severe eyestrain and/or headache. If the diopter adjustment is rotated too far, the procedure should be repeated beginning with the initial counterclockwise rotation to an out of focus position. Performed correctly, this procedure focuses the image on the retina of the eye without accommodative muscular effort.

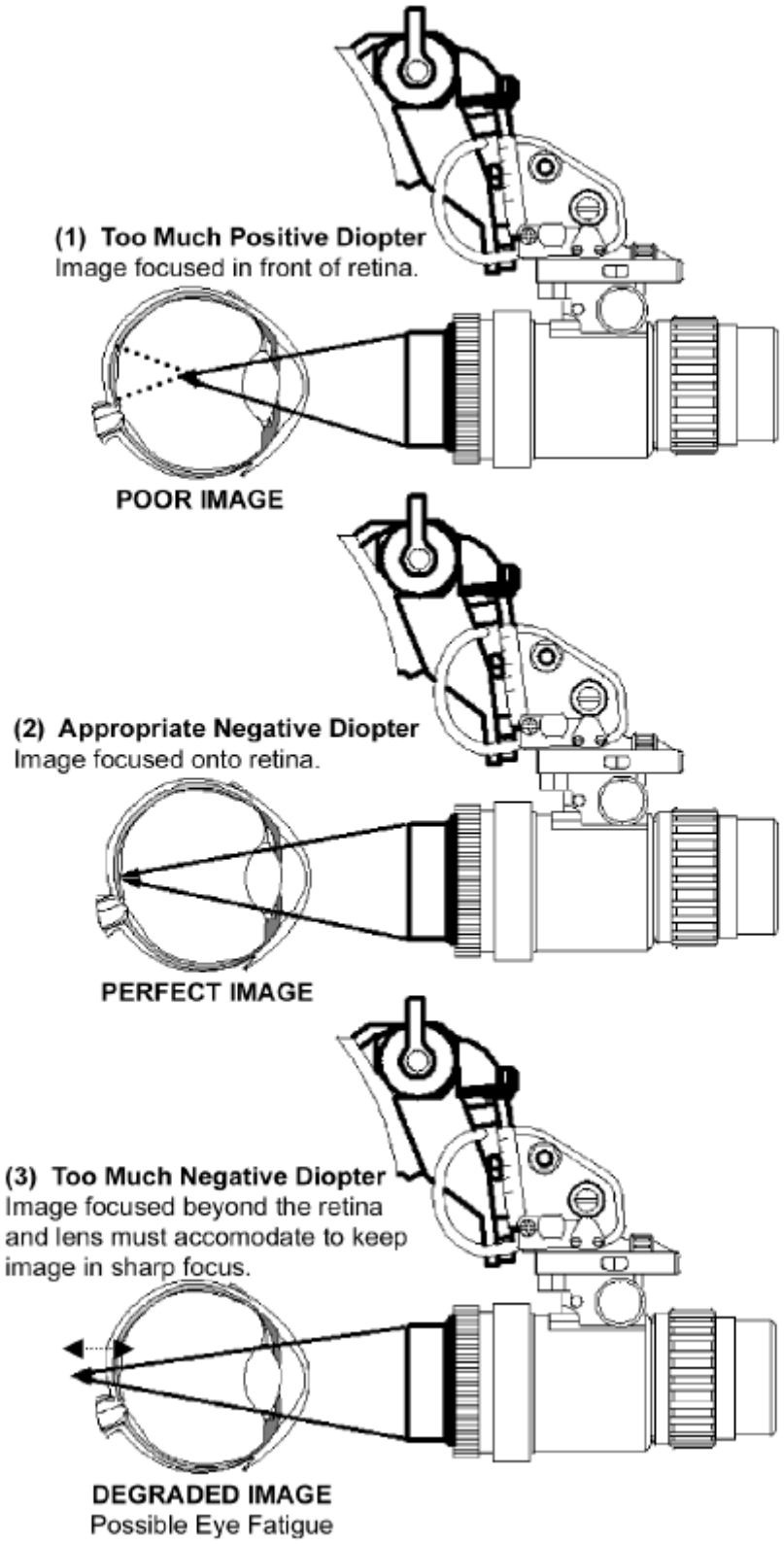


Figure 5 - 11. Optimal Eyepiece or Diopter Adjustment

3. Readjustment of Objective Focus. Once the diopter has been adjusted, fine tune the focus by readjusting with the objective adjustment to bring into focus as many of the grids as possible. This accomplishes two things. First, it assures aircrew that the diopter adjustment has been satisfactorily performed. Second, it allows for an accurate assessment of AN/AVS-6 performance. At first it may take several attempts going back and forth between the diopter and objective adjustments to obtain the best focus. However, once comfortable with the procedure, focusing can be accomplished accurately and consistently with ease.

4. Focus of Opposite Monocular. After focus of the first monocular is accomplished, the same procedures should be used to focus and evaluate the remaining monocular. Do not be concerned if one monocular image is slightly sharper. A slight difference in the performance of individual I^2 tubes is common, Figure 5-12.

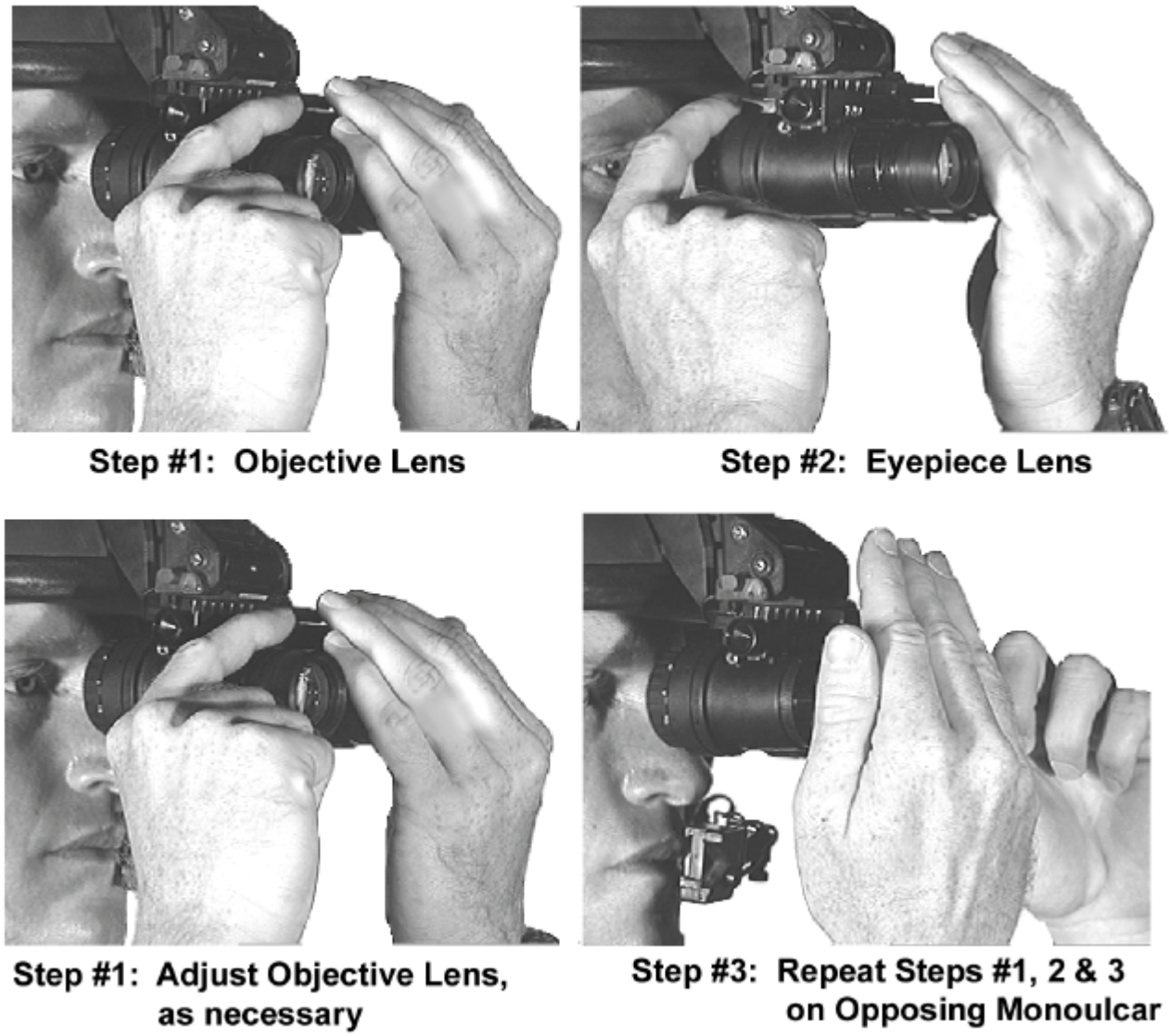


Figure 5 - 12. AN/AVS-6 NVG Focus Procedures

D. NVG Image Assessment Procedures

Assessment of the NVG image serves as the quality assurance step for preflight of the AN/AVS-6. With experience, these procedures can easily be integrated into alignment and focusing phases of the AN/AVS-6 pre-flight.

1. Evaluate NVG Visual Acuity. NVG Visual acuity obtained with both eyes should be at least as good as that obtained through either monocular. If this is not the case, the AV/AVS-6 should be returned and another pair obtained. The minimum NAVAIRSYSCOM acceptable NVG visual acuity for the AN/AVS-6 is dependent upon the Omnibus procurement lot of the NVG I^2 tubes. The Omnibus-IV, III and II procurement contract specification for I^2 *tube* resolutions are1 64Lp/mm, 45Lp/mm and 36Lp/mm, respectively. NAWCAD Patuxent River test bench NVG *system* resolution data demonstrated reduced performance from the I^2 tube resolution specifications most likely due to the inherent transmission losses of the objective and eyepiece lens optics. Therefore, dependent upon the specific Omnibus lot of the I^2 tube, aircrew may see NVG visual acuity variation that ranges from **20/25 (Omnibus-IV) to 20/40 Omnibus-II)** while viewing a high contrast target under high illumination conditions (NVG eye lane conditions). However, one should always try to maximize the NVG visual acuity performance.

2. Evaluate Image Quality. NVGs have historically been very reliable. However, the manufacturing process, especially with regard to intensifier tube development, is tedious and susceptible to errors. The following describes potential AN/AVS-6 NVG image anomalies or peculiarities. In some instances, these intensified image peculiarities are normal NVG image nuances, while others are defective in nature. It is important to know the difference to correctly diagnose the image peculiarity and to better write the AN/AVS-6 Maintenance Action Form (MAF), if warranted. The most common image peculiarities include:

   (a) **Shading**. Each monocular should present a perfect intensified image circle. If shading is present, you will not see a full circular image, Figure 5-13. It appears as a dark area along the edge of the image. Initially, try readjusting the controls (i.e., Tilt, IPD and Vertical Adjustment). If the shading persists, try moving the NVG and/or helmet toward the shaded edge. Uncorrectable shading is indicative of a dying photocathode caused by a defective vacuum seal on the image intensifier tube. Shading is very dark and one cannot see an image through the shaded region. Shading will always begin on the edge and will eventually move inward across the entire image area. The shaded region will also present a high contrast and distinct line of demarcation. Do not confuse shading with variations in output brightness. If uncorrectable shading is present, write a MAF and turn the AN/AVS-6 into maintenance.

   (b) **Edge Glow**. Edge glow appears as a bright area along the outer edge of the image, Figure 5-13. It is usually the result of an incompatible light source within or just outside the NVG FOV, although it can also be the result of an I^2 tube's microchannel plate shift induced by mishandling. If detected, simply cup your hand over the objective lens to block out all light. If the image still displays edge glow, the bright area will still show up. If the edge glow does not disappear, write a MAF and turn the AN/AVS-6 in for maintenance.

(c) **Bright Spots**. Bright spots can be defects in the image area caused by a flaw in the film on the I^2 tube's microchannel plate. A bright spot is a small, non-uniform, bright area that may appear either as a flicker or as a constant output, Figure 5-13. Notall bright spots are downing gripes for the AN/AVS-6. Bright spots usually go away when light is blocked from the objective lens and are considered cosmetic defects that are signal induced. To determine the significance of the bright spots, cup your hand over the objective lens to block out all light. If the bright spot(s) remain, write a MAF and turn the AN/AVS-6 in for maintenance. Bright spots can be acceptable if they do not interfere with the aircrew's ability to view the NVG Image. In the AN/AVS-6 specification, there are guidelines that limit the size, location and number of bright spots within the NVG I^2 tube. If the spots are distracting or interfere with the operator's ability to perform the mission, write a MAF and return the AN/AVS-6 for maintenance

(d) **Black Spots**. Black spots can be either cosmetic blemishes in the I^2 tube or dirt/debris between the lenses, Figure 5-13. Black spots are acceptable as long as they do not interfere with viewing the NVG image. As with bright spots, the AN/AVS-6 specification has guidelines that limit the size, location and number of black spots within the NVG intensified image field. If the spots are distracting or interfere with the operator's ability to perform the mission, write a MAF and return the AN/AVS-6 for maintenance

(e) **Emission Points**. Emission points are steady or flickering pinpoints of bright light in the NVG image area that do not go away when all light is blocked from the NVG's objective lens, Figure 5-13. The position of the emission points within the image will not move. Emission points are not necessarily a downing gripe for the AN/AVS-6. Emission points become unacceptable if they are brighter than the background scintillation of the I^2 tube under low light level illumination conditions.

(f) **Honeycomb Pattern (Fixed-Pattern Noise)**. The honeycomb pattern is usually a cosmetic blemish characterized by a hexagonal (honeycomb) pattern visible across the entire intensified FOV, Figure 5-13. The honeycomb pattern most often occurs under high light level viewing or when a bright light source is introduced into the NVG's FOV. This pattern is an artifact of the manufacturing process in which the fiber optics are assembled within the tube. Normally it is faint in appearance and does not affect NVG performance. Should it appear as a bold outline or during low light level NVG conditions, write a MAF and turn the AN/AVS-6 in for maintenance

(g) **Chicken Wire**. An irregular pattern of dark thin lines in the FOV either throughout the entire intensified image field or simply in select parts of the NVG image area, Figure 5-13. Under the worst case condition, the lines will form hexagonal or square-wave shaped lines. These lines are caused by defective fibers that do not transmit light at the boundaries of the fiber bundles in the output optic of the I^2 tube. If the chicken wire interferes or distracts the aircrew, write a MAF and return the AN/AVS-6 for maintenance.

(h) **Distortion**. Distortion is introduced into an I^2 tube during the manufacturing process (fiber optic twist). The resultant distortion will not change over the life of that tube. The specific amount of distortion varies from tube to tube. AN/AVS-6 I^2 tubes manufactured in December 1989 and later were built to a maximum allowable 30 micron distortion specification. This small amount of distortion is not perceivable to the human eye. I^2 tubes manufactured prior to December 1989 (pre-Omnibus tubes) were built to a maximum allowable 75-micron distortion specification. These tubes may or may not

exhibit distortion that is visible to the human eye. The amount of individual tube distortion, the exact location of the distortion within that tube, and the combined effect of two different tubes together all contribute to the image quality that the aviator sees. Currently, a distortion check is required whenever an image intensifier has been replaced or an aviator returns the AN/AVS-6 for excessive distortion (NAVAIR 16-35 AVS-5 Technical Manual). Only experienced NVG aircrew are authorized to perform the distortion check. This check is designed to identify I^2 tubes that may have unacceptable localized distortion in the central portion of the image. As with any optical device, the AN/AVS-6 can have some acceptable distortion on the outer edges of the image and some minor distortion near the center. Distortion check procedures are outlined in the NAVAIR 16-35AVS-5 Technical Manual. In addition, an AN/AVS-6 NVG Distortion Training Aid Video(NAVSURFWARCENDIV CRANE IN 8052, October 1993) is available at the fleet NITE Labs. The two most common types of distortion perceivable in the NVG image are “bending” or “wave” distortion and “shear” distortion, Figure 5-13. Wave distortion is demonstrated when vertical linear objects, such as trees or poles appear to wave or bend when one moves their head either horizontally or vertically. Shear distortion is present when static linear objects appear "chopped and pasted " to form an image that appears misaligned. It would be highly unlikely to see distortion in an AN/AVS-6 Omnibus-III or IV I^2 tube. However, if aircrew perceive distortion, the AN/AVS-6 should be downed. A MAF should be written and the NVGs should be returned for maintenance.

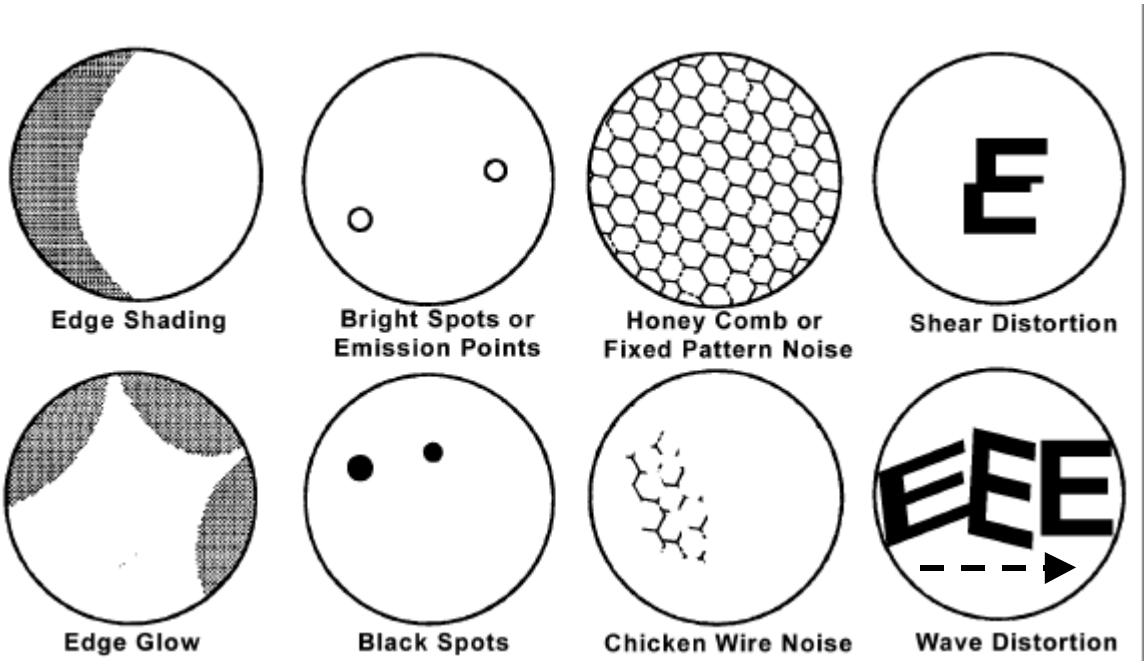


Figure 5 - 13. NVG Image Defects

(i) **Image Flickering**. Flashing, flickering or intermittent operation of the NVG may reflect an impending failure of the tube, dirty electrical contacts, faulty wiring, or battery. This can occur in either one or both monoculars. If there is more than one flicker, check for dirty contacts, loose wires, loose battery cap or weak batteries. If corrective action does not alleviate the condition, write a MAF and turn the AN/AVS-6 in for maintenance. If airborne, switch to the alternate battery and assess AN/AVS-6 operation.

(j) **Veiling glare**. Veiling glare occurs when light outside the FOV strikes the objective lens of the AN/AVS-6 and scatters instead of passing through the lens. Veiling glare produces a decrease in NVG image contrast and appears as a light haze across the entire image. It can be caused by excessively scratched, pitted or chipped objective lenses. In addition, dust, smudges or fingerprints may also contribute to this condition. Ensure the lenses are clean. If the anomaly remains, write a MAF and turn the AN/AVS-6 in for maintenance.

(k) **Scintillation**. Scintillation or image graininess is a normal nuance of the NVG image that occurs as light level decreases. Scintillation appears as a "sparkling" effect over the NVG image and results from electronic noise created at the high gain levels achieved under low illumination conditions. In flight, it can be an indication of decreasing illumination caused by such things as worsening weather conditions or flight into shadowed areas. The use of the P43 phosphor and the enhanced performance AN/AVS-6 Omnibus-IV I^2 tubes has resulted in a different perceptual appearance of the NVG image scintillation. Aircrew that have flown Omnibus-IV AN/AVS-6 NVGs report that the resultant scintillation "grains" or "sparkles" appear smaller in size and that the light level threshold for scintillation onset appears to be delayed (onset occurs at lower light levels). Aircrew that are used to scintillation onset under very specific illumination conditions while using Omnibus-II or III AN/AVS-6 NVGs, should note the delayed onset with the Omnibus-IV AN/AVS-6. Aircrew new to the Omnibus-IV I^2 tubes should anticipate this nuance and look for these subtle image differences in performance compared to the older Omnibus-II or III AN/AVS-6 NVGs during their initial introductory flights.

(l) **Brightness (Luminous) Difference**. During or after making the adjustments for IPD and binocular focusing, one image may appear less bright (dimmer) than the other If the brightness difference is judged to be great enough to interfere with mission performance, the NVG should not be utilized. Down the NVG, write a MAF and turn the AN/AVS-6 in for maintenance.

(m) **Contrast Difference**. During or after making the adjustments for IPD and binocular focusing, the two images may differ in contrast. In a contrast comparison, the user is looking for noticeable differences in the range between the darkest and lightest portions of an image. For example, if a highly reflective tree is extremely bright in one tube, and relatively dim in the other, contrast differences may be deemed unacceptable for that set of NVG. This may be indicative of a defective tube. However, the degree of the deficiency will not automatically dictate that the goggles not be used. As dictated by ambient light levels, terrain, user experience, and degree of tube differences, the user may elect whether or not to utilize the NVG for a given mission

(n) **Acuity or Image Disparity**. This condition exists when there is a difference in performance between the two image intensifier tubes within the same binocular. This is usually noted by one monocular attaining a better acuity than the opposing monocular. If the acuity or image disparity is judged to be great enough to interfere with mission performance, the NVG should not be utilized. Down the NVG, write a MAF and turn the AN/AVS-6 in for maintenance.

III. Aircraft Ground Adjustment Procedures

Perform the following procedures prior to takeoff:

A. Confirm IPD and Diopter Settings

Before donning the NVGs in the aircraft, confirm that the diopter settings are the same as determined in the NVG eye lane. If the diopter adjustment has been inadvertently moved, it is unlikely, due to play in the adjustment mechanisms, that the setting obtained in the NVG eye lane can be correctly achieved by placing the diopter adjustments in the previously noted position. Therefore, if this occurs, it is best for aircrew to repeat the pre-flight objective and eyepiece diopter lens adjustment procedures using a distant target (i.e., stars, non-illuminated objects with vertical or horizontal linear features, etc.).

B. NVG Optical Infinity Focus following NVG Eye Lane

If the NVG eye lane was used, the AN/AVS-6 was focused at 20 feet; therefore it will be necessary to refocus the AN/AVS-6 at infinity before flight using only the objective lens (unless the diopter setting has been inadvertently moved). This final objective lens infinity focus adjustment can be accomplished by focusing on an object at least **100** feet away, preferably using an object with well developed vertical or horizontal features. The object should be illuminated well enough to be easily seen with NVGs, however, excessive illumination will wash out or shut down the AN/AVS-6. Avoid focusing on incompatible lights because the halo effect will make it difficult to discern when the image is in precise focus. Stars are excellent point light sources that do not cause halos and provide for a good endpoint for focusing. For Assault Support aircraft that possess an aircraft head-up-display (HUD), previous USAF documents have referenced using HUD symbology to make this final infinity focus adjustment. Recent MAWTS-1 Qualitative Assessment of the Hoffman Engineering Corporation's ANV-20/20 highlighted the fact that the aircraft HUDs are collimated to optical infinity for the unaided eye (approximately 30ft). Previous NAWCAD Patuxent River evaluations discovered that the measured collimated HUD optical infinity distances varied between both the aircraft type and the specific HUD between same model aircraft. In fact, it was not uncommon to find the HUD symbology collimated to less than 15ft. The collimated optical infinity distance of the AN/AVS-6 is beyond 100ft. The disparity between the HUD symbology collimation, designed for the unaided eye (variable between aircraft) and the AN/AVS-6 collimation may further reduce HUD symbology viewing clarity. If one were to conduct the optical infinity focus on the aircraft HUD, the AN/AVS-6 would be focused at 15 to 30ft dependent uponthe aircraft and HUD. This would decrease the overall NVG distant visual acuity performance expected of the AN/AVS-6. In contrast, when the AN/AVS-6 is properly focused for distant viewing, the HUD symbology will be slightly blurred. Aircrew should anticipate and evaluate this AN/AVS-6 and HUD interaction during their introductory flights with the AN/AVS-6. However, aircrew ***SHOULD NOT PERFORM*** the final AN/AVS-6 optical infinity focus using their aircraft HUD.

C. AN/AVS-6 Optical Infinity Focus following ANV-20/20 or TS-4348 Use

Following pre-flight ANV-20/20 use, verification of the infinity focus should be conducted by viewing either distant stars or objects with distinct vertical or horizontal linear characteristics at least 100ft away. This is merely a verification step and changes in objective lens focus should not be required following ANV-20/20 use

D. Set Aircraft Lighting and Display Intensity

Set lighting and display intensity so information can be easily interpreted when looking around or below the NVG. When the NVG is initially turned on, unaided night vision will be adversely affected, and lighting and display intensity may need to be increased. As the eye adapts to the brightness of the image, the intensity may be able to be decreased. The important point for aircrew is to understand the need to be able to read and interpret all instruments and displays at all times (instrument crosscheck).

Practice NVG Donning and Removal

Practice donning and emergency removal of the NVG in the aircraft prior to flight. This will become less necessary as aircrew become experienced with donning and removal of goggles.

IV. Aircraft Airborne Adjustment Procedures

Make the following minor adjustments during flight as required

A. Vertical Adjustment

As the helmet settles and/or rotates during flight, it may be necessary to make minor vertical adjustments as needed to keep the image in the proper position in front of the eyes

B. Tilt Adjustment

Any vertical adjustment will likely require readjustment of the tilt adjustment.

C. IPD

Make small adjustments to IPD as required.

D. Fore-and-Aft or Eye relief Adjustment

Eye relief may need readjusting to allow better viewing of cockpit instruments or displays, or in some cases, to maintain the full FOV. If significant inflight eye relief adjustments are made inflight, the diopter lens focus will have to be readjusted.

V. NVG Care in Adverse Environments

Sand/dust, rain or humidity, salt water and cold weather all require special considerations to protect the NVG lenses, circuitry and housing mechanisms. The following procedures are recommended:

A. Dust or Sand

1. Exposure of the objective lenses to blowing dust or sand may scratch them and seriously degrade performance.

2. Keep the carrying case closed when not removing or replacing items

3. Ensure that all dust and sand is removed from the binoculars, mount, power pack and carrying case after operation.

4. When using lens paper, ensure all sand has been brushed or blown from the lens to avoid damage.

B. Rain, Humidity, or Cold Weather

1. Keep the carrying case closed when not replacing or removing items.

2. Dry off parts and surfaces after exposure to rain or high humidity.

3. Do not store any part of the NVG systems in a wet carrying case.

C. Salt Water

After operations in a salt water environment, the following steps should be taken:

1. Clean all hardware thoroughly with a clean, soft cloth dampened with fresh water.

2. Separate and individually clean the binoculars and all mounting hardware attached to the helmet. Do not submerge in water.

3. Carefully inspect for corrosion on the electrical contacts.

4. Clean as described in the general care and cleaning section (outlined below).

D. General Care and Cleaning

To ensure the continued, reliable performance of the NVG, careful adherence to the following post-flight care and cleaning procedures should be observed

1. Cleaning

(a) Gently brush off all dirt with a soft lint free cloth or use photographer's canned air to blow it off.

(b) Moisten the cloth with clean fresh water and gently wipe external surfaces free of foreign material.

(c) Dry with another clean, dry soft cloth.

(d) Carefully remove all loose dirt from lenses with lens paper or canned air.

(e) Lightly and slowly wipe the lenses with a dampened piece of lens paper.

(f) Repeat these procedures until the glass surfaces are clean.

(g) Store NVGs in a clean and dry carrying case.

2. Additional Care Considerations

(a) Lens caps should be installed on the NVGs when not in use.

(b) When installing or removing a battery, ensure that the selector switch is in the "off" position. If the switch is "on", intermittent electrical contact is made when removing or replacing the battery cap. This may cause a power surge in the system that can result in burn spots on the tubes.

(c) Always remove the battery from the goggles or power pack. If the devices are stored with the battery installed, corrosion may develop.

VI. Summary

To effectively optimize the AN/AVS-6 NVGs, aircrew must completely understand the procedures necessary to conduct a proper AN/AVS-6 preflight. The techniques and procedures used to optimize AN/AVS-6 operation are ideally developed through dedicated and consistent use of the NVG eye lane or ANV-20/20. The NVG eye lane and ANV-20/20 allow aircrew the opportunity to quantify the performance of the NVGs prior to flight by using a graded target at a known distance. When operating under austere conditions, without the aid of an adjustment modality (i.e., NVG eye Lane, ANV-20/20, etc.), aircrew that had previously developed the cognizant techniques and procedures to optimize AN/AVS-6 performance will be better able to improvise and achieve an acceptable AN/AVS-6 performance level. One cannot overstate the importance of conducting the proper AN/AVS-6 NVG preflight procedures to realize the full potential of this sensor. Aircrew should not settle for an intensified image that does not possess a 100% overlapped 40^0 FOV with no image anomalies and the best visual acuity for that specific Omnibus lot I^2 tube.

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Chapter 6

Aircraft NVG Compatibility

I. Introduction

To effectively integrate NVGs into our fleet aircraft, both internal and external aircraft lighting must be compatible. NVG objective lens filtering was discussed in Chapter 2 as it related to NVG technology and performance. This chapter will complete the discussion on NVG objective lens filtering by highlighting the aircraft considerations that must be taken into account to ensure effective integrated NVG aided operations. NVG objective lens filtering allows the use of cockpit lighting that will not adversely effect NVG gain and the resultant NVG image quality. However, if the aircraft cockpit or external lighting is not properly designed or manufactured, there may be light source output energy emissions that may not be filtered by the NVG and therefore could negatively affect NVG performance. Aircrew should be constantly alert and vigilant in their efforts to determine the adequacy of their aircraft lighting packages in order to identify degradations that may lead to decreased NVG performance. In simple terms, aircraft interior or cockpit NVG compatible lighting should be considered a prerequisite to ensure that the NVGs may be safely and effectively used. In contrast, aircraft external lighting facilitates the most effective tactical utilization and integration of the NVGs into our night NVG aided mission areas.

II. Aircraft Lighting Considerations

The response of the AN/AVS-6 is spectrally filtered for sensitivity in the red region of the visible spectrum and into the Near IR (NIR) spectrum (625nm to 900nm). To make aircraft interior lighting compatible with the AN/AVS-6, the output from the NVG "compatible" interior lighting is designed so that (exception of emergency warning lights) it does not fall within the spectral sensitivity range of the NVGs. Therefore, the NVG does not "see" the output from these interior lights, however the light output is sufficient for unaided viewing of instruments around the NVG monoculars. This design strategy ensures that NVG gain will not be affected by light sources that are used to light the interior of the aircraft. For aircraft exterior lighting, the objective is to match exterior light output to the NVG sensitivity so that the NVG can "see" the light output without negatively impacting NVG performance (halo, bloom or shutdown) Compatibility in lighting can be achieved in one of three ways: spectral separation (electroluminescent lighting, filters, etc.), geometry (baffles, light location, etc.) and absorption (flat black instrument panels, anti-reflection coating/treatment, etc.). These methods can be applied to provide NVG compatibility for cockpit lighting, cabin lighting and external aircraft lighting. Aircraft lighting can profoundly impact NVG performance. It will be quite easy, even for the lesser-experienced aircrew, to identify gross instances of light source incompatibility. However, it will be up to the squadron NSI to train new squadron NVG aircrew to identify the nuances of poor NVG lighting compatibility that may not necessarily be readily apparent.

A. Interior Lighting

NVG compatible interior lighting is described as lighting that provides the capability to view interior aircraft instruments (aircraft flight and engine instruments, maps, circuit breakers, etc.) and to complete other aircraft tasks with the unaided eye while not negatively impacting or degrading the out-of-cockpit intensified NVG image. For the majority of Marine Corps Assault Support aircraft, this compatibility is obtained through the use of hard-wired NVG compatible interior lighting modifications. In some older fleet aircraft and in some communities that are transitioning to NVGs, NVG compatibility is achieved through the use of squadron installed NAWC/AD developed blue light kits. The NAWC/AD blue light kits consist of a package of glass filters that attach over the top of instrument faces to filter light leaving the instrument face for NVG compatibility. Special considerations should be followed when using these NAWC/AD blue light kits. If the filters do not have a good seal around the instrument face, adverse NVG effects (windscreen glare, BSP and ABC activation) may result that will ultimately lead to degraded NVG performance. These adverse conditions are most hazardous during low light level conditions. During preflight, pilots should ensure that all required lights are covered with the NAWC/AD approved blue filters and that they are properly adjusted so as not to interfere with NVG performance.

<<NOTE>>

Ensure that cockpit floodlight lens covers are adjusted full down to provide maximum instrument reading effectiveness.

1. AN/AVS-6 NVG and Cockpit Lighting Interaction. Generation-III I^2 tubes demonstrate spectral sensitivity between approximately 570 and 900nm. This sensitivity region is filtered back (625 to 900nm) by the addition of a minus blue objective lens filter coating that is placed on the objective lens of the AN/AVS-6 NVG. This filtering effectively creates a window of opportunity in the blue-green region of the color spectrum that can be used for NVG compatible interior cockpit lighting. Military Specification MIL-L-85762A categorizes objective lens filters as either CLASS-A (blue and green primarily) or CLASS-B (blue/green/reduced red. Currently, CLASS-A NVG compatible cockpit lighting schemes are used for USMC and USN Assault Support/Rotary Wing aircraft, while Class-B lighting schemes are used for USMC/USN TACAIR night attack aircraft. Per the MIL-85762A, Class-A lighting is defined as lighting schemes that are compatible with NVGs that utilize a "625nm" cut-off minus blue objective lens filter coating. In contrast, Class-B lighting provides compatibility for NVGs that possess a "665nm" cut-off minus blue objective lens filter coating. The specific spectral transmission characteristics for each lighting specification is presented in Table 6-1 (copy of Table 2-4).

TABLE 6 - 1. MILITARY SPECIFICATION NVG MINUS BLUE OBJECTIVE LENS FILTERING

Assault Support Class-A Wavelength (nm)	TACAIR Class-B Wavelength (nm)	Transmission (Percent)
450 to 550	450 to 585	0.05% Absolute Maximum
600	635	5% Absolute Maximum
625 to 655	653 to 671	50% Transmission Point
655 to 705	671 to 725	50% Absolute Minimum / 80% Average
705 to 1,000	725 to 950	85% Absolute Minimum / 90% Average

USMC/USN TACAIR aircraft communities use Class-B aircraft cockpit lighting schemes to allow NVG compatibility with their Multi-Purpose Color Displays (MPCDs). A MPCD uses

display colors that would shutdown (degain) a Class-A NVG (AN/AVS-6) due to the inband sensitivity that would occur above 625nm. By shifting the minus blue objective lens rejection filter coating toward the NIR (665nm cut-off), the Class-B filtered TACAIR MXU-810/U and AN/AVS-9 NVGs are designed to be compatible with these displays. Although the Class-B filtering allows less energy to reach the NVG I^2 tube (less area under sensitivity curve), performance differences between the Class-A and Class-B configured NVGs are negligible. For Assault Support aircraft communities, the future introduction of MPCD and Digital Moving Maps that use additional color schemes will drive the AN/AVS-6 to an AN/AVS-9 like Class-B filtering scheme (without leaky green notch filter) to ensure NVG compatibility with these color displays in the future, Figure 6-1.

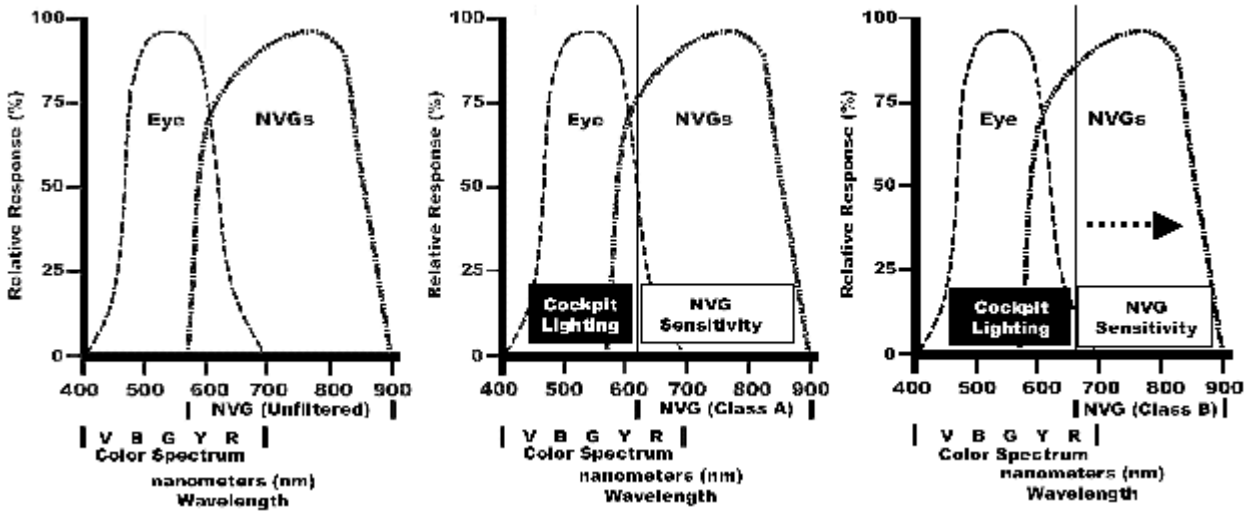

Figure 6 - 1. NVG Sensitivity and NVG Compatible Cockpit Lighting Comparison

The incorporation of the AN/AVS-6 Class-A minus blue objective lens (625 nm) filter makes blue-green light almost undetectable to the AN/AVS-6. In addition to this color being in a region that the NVG does not "see", it also matches the peak response of the human eye. Therefore, cockpit instrument lights that fall in this blue-green region are easy to read even at very low intensities. AN/AVS-6 Class-A filtering still passes some wavelengths in the color spectrum. Red, yellow or white light still falls in the region of NVG sensitivity and will still activate the NVG's BSP and impact the ABC gain circuitry. Therefore, these color spectral outputs can not be used for interior lighting while still maintaining AN/AVS-6 NVG compatibility. Depending on the ambient light level, the performance of the AN/AVS-6 may be profoundly degraded if these output regions are introduced into an aircraft that is designed for AN/AVS-6 NVG compatibility (Class-A cockpit).

Aircrew should remember that any incompatible light introduced into the cockpit will affect NVG gain to some degree. A large change in gain that leads to an obvious degradation in visual acuity will be apparent to all aircrew regardless of previous NVG experience. The real problem occurs when there are subtle degradations in NVG visual acuity that may not be readily apparent to the aircrew. In these cases, important details such as the presence of pylons or ridgelines may be missed. In addition, an incompatible light does not have to be directly within the NVG FOV for it to have an effect on BSP or ABC gain. Reflected light off the windscreen or canopy may dramatically impact the quality of the NVG intensified image. Aircrew should also bear in mind that incompatible cockpit lights cannot be turned

down enough to make their outputs compatible. If the lights can be seen with the unaided eye, they will affect the NVGs. In fact, even if an incompatible light is turned down too dim for the unaided eye to see, the NVGs will still likely be adversely affected due the IR signature of the lamp filament. Thus, the danger of attempting to turn down incompatible cockpit lights to make them compatible is double edged: first, they will continue to degrade NVG performance; second, when turned down to a very low intensity, vital cockpit instruments may not be as readable.

2. Adjunctive Interior Cockpit Lighting. In addition to integrated aircraft hard-wired cockpit lighting, aircrew are required to fly with a flashlight that possesses a NAVAIR approved NVG compatible filter covers or the older NAWC/AD approved blue glass lens installed. This adjunctive light will aid aircrew in viewing maps, instruments and circuit breakers, etc. In addition, cockpit dome lights, properly filtered with NVG compatible lenses, can aid in most of these functions as well. Squadrons should also give consideration to procure microphone (lip) lights and/or finger lights. The advantage to using these two types of lights is that it frees one's hands to perform their duties while simultaneously being able to illuminate the specific area of concern. An important interaction that should be demonstrated to aircrew during training is the impact of filtered (color) light on NVG cockpit compatibility (i.e., flashlight lenses, etc.). When a lamp filament glows, it releases a significant amount of near-IR energy to which the NVG is sensitive. Therefore, this lamp's output will affect NVG gain and performance. Light bulbs and other light sources must be coated, filtered or treated in some way to block the emission of near-IR energy in order to make them NVG compatible. Just because a light is green or blue does not necessarily mean that it is NVG compatible. The blue filter that comes with the aircrew gooseneck flashlight, the green filter that comes with the mini-Mag-Lite and the E-LUME Pilot's Kneeboard are all examples of green or blue lights that are **NOT** NVG compatible. Only flashlight filters, microphone and finger lights that have been specifically designed and NAVAIR evaluated for NVG operations should be used during NVG aided flight, Table 6-2.

TABLE 6 - 2. NVG FLASHLIGHT FILTERS, FINGER AND MICROPHONE LIGHTS

Company	Item: Model Number
Hoffman Engineering Corporation 20 Acosta Street Stamford, CT 06902 Phone: (203)325-8933	**NVG Compatible (Green) Flashlight Filter**
Seitz Scientific Industries 201 E. Hickory Bend Rd Enterprize, AL 36330-1007 Phone: (205)347-9713	**Finger Light**: FL-5 **Microphone Light**: ML-2 **Microphone Light**: ML-8

B. Exterior Lighting

USMC Assault Support aircraft currently possess either incandescent (heat generated) and/or electroluminescent aircraft exterior lighting. Incandescent navigation/position lights (normal setting) typically triggers the NVG's I^2 tube BSP and ABC circuitry thereby eliciting NVG halo, blooming and shutdown effects. The end result is that the aircrew will be able to see the aircraft lights, but not see the aircraft or anything else surrounding the aircraft. This can result in closure rates and relative positions being based solely on the navigation light triangulation or alignment. This problem can be particularly dramatic for an AH-1W crew that face interference not only from their wingman's navigation lights, but from their own. The

following discussion overviews the four commonly accepted categories of aircraft external lighting.

1. Standard Lighting (Navigation/Anti-collision Lights). This describes the typical navigation/anti-collision external lighting package found on all aircraft. This lighting package is designed to be visible to the unaided eye and incorporates colors to assist with the determination of aspect and beacons or strobes to assist with long range detection. This lighting, in normal modes, will adversely affect NVG performance when operating in close proximity to other aircraft (i.e., formations, rendezvous, etc.). In contrast, the same lighting package does allow aircraft detection at significant ranges with the NVGs (in excess of 50Nm). The two primary factors that negatively confound one's ability to ascertain aircraft positioning and closure with the standard external lighting package includes:

   (a) Aspect. During NVG aided operations, a complete understanding of aircraft aspect visual cues is critical because certain lights may be masked by aircraft structure when viewed from different directions, altitudes and during specific phases of flight (i.e., maneuvering, etc.). In addition, 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 the aspect-induced appearance or disappearance of the variousposition 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 (i.e., formation, during a rendezvous, etc.). Aircrew should be exposed to these potential visual cue misperceptions during their initial NVG flight training.

   (b) Light Source Characteristics. The type (i.e., incandescent, LED, etc.), brightness and spectral output content or color of light source will all have varying effect on NVG performance and subsequent detection ranges. The type of light will determine how much IR energy is being emitted, which in turn will impact detection based on the high sensitivity of the NVG I^2 tubes to NIR energy. By increasing the brightness of an individual light source, the detection range also will likely be increased. Color or light source spectral output differences will also have a dramatic effect on detection ranges. For example, for any given equivalent brightness, a red light will be seen at a greater distance than a green light (assumes same amount of IR energy being generated by the source). This effect is a byproduct of the NVG's objective lens filtering that rejects light in the green region and allows red wavelengths to pass and reach the I^2 tube.

2. NVG Compatible External Lighting. The term "NVG compatible" lighting is used to describe a light source that minimizes the adverse effects of the NVG performance (no halo, blooming or shutdown). This is accomplished by reducing both the output light source's IR and color emissions in the region that the NVG is sensitive. This type of external lighting can be designed to be detectable with the NVGs at ranges suitable for specific tactical applications, but in some instances, may not meet FAA requirements for flight within non-restricted airspace. Electroluminescent (EL) formation strip lighting is an example of this type of NVG compatible external lighting. EL formation strip lighting is now available for many Assault Support aircraft, Figure 6-2. EL formation strip lighting provides an NVG compatible reference that can be used for aircraft attitude and closure rate cueing. For some aircraft, the formation strip lights can be switched between NVG compatible and IR covert (described below) modes and can vary in output intensity. Depending upon the

ambient light available, these lights can typically be set to luminance levels virtually invisible to the naked eye but clearly discernible on the goggles. Placement of the EL formation strip lights on the aircraft varies dependent upon the airframe. The specific pattern chosen should allow aircrew to instantaneously ascertain aircraft position to allow greater ease of formation flight and rendezvous.

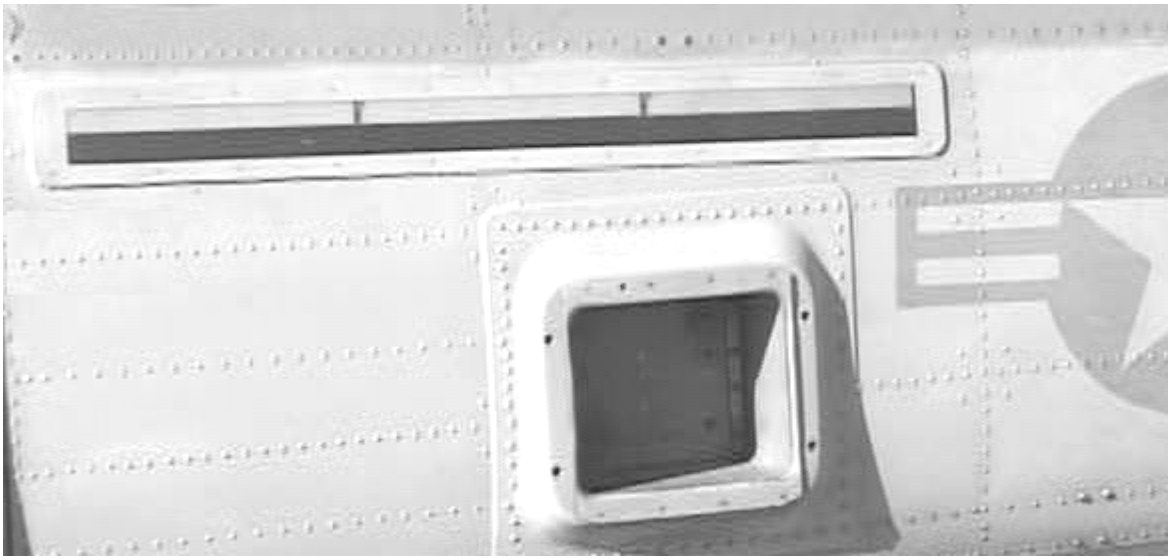

Figure 6 - 2. UH-1N Electroluminescent Formation Strip Lighting

3. Covert Lighting. Covert lighting generally refers to the use of infrared (IR) light sources that are not visible to the unaided eye. The proliferation of NVG technology throughout the world has increased the likelihood that aircraft exterior IR lights may no longer be "covert". It is important to consider the intent of the tactical employment/integration of the IR covert lighting in order to correctly match the threat. For example, if the intent is to remain completely covert, it may be best to simply secure all external lights. However, if the intent may be to remain "relatively covert" such that tactical situations are not compromised (i.e., post objective areas rendezvous, formation flight, etc.) and the threat concerns are minimized then existing IR external lights should be sufficient. In this case, the intensity (brightness) of the lighting may need adjusting to ensure detection at predetermined ranges. The NVG capability of the enemy needs to be taken into consideration to determine the desired lighting configuration used during NVG aided operations

4. NVG Friendly Lighting. The term "NVG Friendly" lighting refers to light sources that have been modified to meet FAA and service requirements while at the same time, minimize the adverse effect on the NVG performance (halo, bloom and degain). This is accomplished by reducing the emission of IR energy from the light source while allowing visible light (red and green) to be transmitted. There have been some problems with producing sources that will actually accomplish both goals effectively and more test and evaluation needs to be accomplished in order to determine design efficacy. If this design strategy does work, it may ultimately alleviate the need for having separate light sources for various tactical or training applications.

The current USMC rules governing aircraft external lighting configuration are outlined below in paragraph (II.C). To operationally supplement these rules, the following NOTE on techniques is provided to guide anti-collision light usage.

<<NOTE>>

Due to the level of crew coordination required in the critical phase of final approach to landing, a comprehensive aircrew brief must have been accomplished covering individual responsibilities, switchology, and timing. During flight, aircrew should be notified of changes in desired aircraft lighting configuration. The use of the bottom anti-collision light could increase the chance of flicker vertigo in the low level and TERF environment and during the landing phase of flight. Through operational experience, a suggested technique is to secure both anti-collision lights prior to landing to minimize the chance of disorientation on final. Lights must be turned on again after take-off.

C. USMC MCO P3500.14 T & R Volume 1: External Lighting Rules

Aircraft external lighting shall comply with FAA rules except as modified in FAA Exemption No. 5978A (Appendix H of MCO P3500.14 T & R Volume 1) and shall include the following

1. Single Aircraft Operations

(a) Navigation lights on at the highest intensity consistent with NVG compatibility and anti-collision lights on.

(b) When conducting ground hover or during terminal phase of landing at designated training areas, anti-collision lights and/or navigation lights may be turned off if they interfere with operations or safety.

(c) When operating in Class D airspace, controller permission is required prior to securing lights during hover or terminal phase of landing

2. Multi-Aircraft Operations

(a) Non-Restricted Areas. Flights of up to four aircraft shall have, as compatible with NVD operations:

1: Leads through dash three's navigation lights on the highest intensity

2:Lead through dash three's anti-collision lights on except when pilot in command or flight leader determine that it would be in the interest of flight safety to turn off the anti-collision lights on lead through dash three.

3: The last aircraft's anti-collision and navigation lights on.

4: Formation and blade tip lighting on the highest intensity.

(b) Non-Restricted Areas Covered by FAA Exemption. Flights of up to four aircraft, as compatible with NVD operations:

1: May have lead through dash three's navigation and anti-collision lights off.

2: Shall have formation and blade tip lights on the highest intensity.

3: Shall have the last aircraft in each flight with anti-collision light on and navigation lights on the highest intensity.

4: Shall be familiar with the requirements of the exemption as stated in MCO P3500.14 Appendix H.

(c) Restricted Areas. When operating in restricted areas exclusively with NVDs, flights shall operate as follows:

1: Lead to but not including the last aircraft may have navigation and anti-collision lights off.

2: Shall have formation and blade tip lights on the highest intensity compatible with NVD operations.

3:Shall have the last aircraft in each flight with anti-collision lights on and navigation lights on at the highest intensity compatible with NVD operations. Separation between the lead aircraft and the last aircraft in the flight shall not exceed 1 nm.

4: These requirements should not prevent securing of external lights due to lighting effects on NVDs during TERF or hovering flight.

(d) Flights outside CONUS shall obtain approval from the airspace controlling authority prior to conducting training with position lights off.

(e) IR position / formation lighting (if installed) is preferred in Restricted Airspace. The use of IR lighting during flight is at the discretion of the aircraft commander / flight leader. This does not preclude the requirement for the last aircraft in the flight to have position lights set at the highest intensity consistent with NVD compatibility and the anti-collision light on. Aircraft IR external lights do not replace the standard navigation light's requirement outside of Restricted Airspace.

(f) The FAA regulation to see and avoid shall take priority over NVD tactical training. Modification, taping or cat-eyeing of external lighting is not authorized.

D. Spotlights/Landing Lights

The use of the IR spotlight/landing light during NVG aided missions is at the discretion of the aircraft commander/flight leader. For all LLL NVG operations, aircraft shall have an operational spotlight. It is recommended that an IR filter be installed. Benefits or limitations of the IR spotlight will be 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 NVGs becomes more evident. The area illuminated by the beam

of the spotlight will be brighter and the area outside of the beam will appear darker on the NVGs.

Terrain albedo or reflectivity will affect the benefits of the IR spotlight. Different types of terrain will absorb or reflect IR light to varying degrees as mentioned in Chapter 1. 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 will appear either dimly lit or dark with no contrast on the NVGs.

The position of the spotlight beam is going to affect what is perceived through the NVGs. Actual positioning of the light is dependent on individual preference. However, positioning the spotlight so that its beam is pointed straight down has proven effective for identifying objects in the landing zone. Another consideration when flying with multiple aircraft is to have the last aircraft use his IR spotlight in the landing phase to "back-light" the LZ for the flight. This procedure does have its drawbacks. The preceding aircrew, who are responsible for clearing their respective aircraft into the landing zone, may have their NVGs shutdown by the introduction of the IR spotlight (incompatible light source).

When flying in built-up areas (i.e., MOUT, runway/airfield environment, etc.) with increased cultural lighting, consideration should be given for use of the IR spotlight to offset the NVG "washout". This can be accomplished by utilizing the spotlight or landing light to "burn through" the excessive illumination created by the cultural lighting, thereby allowing aircrew a better representation of the surrounding terrain. Utilization of this technique should be based on METT-T considerations.

E. Preflight Preparation

The nature of NVG flight demands special consideration in terms of aircraft assignment and preparation. Special attention should be focused on the following preflight preparations to ensure effective NVG integration and compatibility.

1. For any night evolution, consideration should be given to schedule the preflight during daylight whenever possible.

2. Aircraft must have all systems operable for night flight in accordance with appropriate Mission Essential Subsystem Matrices (MESM).

3. Windscreens/canopies should be thoroughly cleaned to preclude visual obstruction and the effects of glare from internal and external lights.

4. The mission aircraft must possess either hardwired NVG compatible cockpit lighting or use the USMC approved NAWC/AD blue light kits for NVG flights

<<WARNING>>

For aircraft equipped with NAWC/AD blue light kits, aircraft warning, caution, and advisory lights may not be daylight readable. Kits should be removed or installed as soon as possible when transitioning from night to day or day to night operations.

III. Summary

NVG aided operations places an impetus on aircrew to understand the full capabilities and limitations of the NVDs that are employed. The concepts of NVG aircraft lighting compatibility are fundamental to the understanding of NVG performance. Any incompatible light source, either within the aircraft or placed on the exterior of the aircraft, will have some affect on NVG BSP/ABC gain and the resultant quality of the NVG image. The real danger is that the effect may not be obvious even though there has been a significant reduction in NVG performance and visual acuity. As tactics further evolve to support NVG aided operations, new emphasis may have to be placed on the use of aircraft external lighting in order to exploit the I^2 technology while not exposing one's flight to the threat.

Chapter 7

Night Vision Goggle (NVG) Aided Operations

SECTION I: INTRODUCTORY NVG TRAINING

I. Introduction

Competency on NVGs in a tactical environment must begin with a firm foundation in the execution of basic helicopter pilotage skills. The following section presents a building block approach to the execution of these basic maneuvers. The importance of crew coordination must be emphasized in early NVG flights as being essential to safety of flight. Maneuver descriptions presented here are deliberately generic in nature and have been proven to be effective for all helicopters. Discussions of each maneuver have been divided into a description of the desired maneuver, procedures required to execute maneuver, techniques that facilitate ease of execution and the common errors that have been frequently observed in pilots under instruction.

II. Light Demonstration

A demonstration of the effects of various aircraft lighting on NVGs should be conducted on a pilot's first NVG flight. This demonstration should show all possible light positions and intensities, to include both internal and external lighting considerations. The pilot under instruction is made aware of which light configurations may benefit NVG operations and which light configurations will hinder operations with NVGs.

III. Ground Taxiing

Ground taxiing is the movement of a wheeled helicopter under its own power on the ground. It is normally the safest means of moving a helicopter from the flight line to the intended point of takeoff when operating in close proximity of other aircraft and obstacles.

A. Procedures

Procedures for taxiing on NVGs are the same as those for taxiing during the day or at night unaided.

B. Technique

Techniques for taxiing on NVGs are similar to those during the day and at night unaided with the following special considerations:

1. All crewmembers should provide the pilot at the controls with aircraft obstacle avoidance cues during taxi evolutions.

<<NOTE>>

Do not assume that personnel operating without NVGs in and around taxiing helicopters are capable of detecting hazards with the same level of situational awareness as can be attained with NVGs.

2. NVG ground taxi differs from unaided night taxi in that the pilot at the controls is provided limited references to judge closure rates (due to poor distance estimation). An aggressive scan pattern, emphasizing lateral scan, will help offset this inadequacy.

3. High light levels associated with most airfields can activate the NVG I² tubes Automatic Gain Control circuits (BSP and ABC), resulting in degraded scene image. Consideration should be given to using onboard lighting with unaided vision to alleviate this problem.

C. Common Errors

1. CH-46

(a) Inadvertent application of brakes to both wheels simultaneously.

(b) Cyclic too far aft, causing the nosewheel to center itself fore and aft.

(c) Cyclic too far forward, collapsing the nose strut and preventing it fromcastering.

(d) Insufficient lateral displacement of the cyclic to effect a turn.

(e) Insufficient collective to provide necessary power for movement through a turn.

(f) Taxiing too fast (i.e., "faster than the average man can walk").

(g) Improper NVG scanning techniques (slow scan, forward fixation).

2. CH-53

(a) Improper NVG scanning techniques (slow scan, fixation).

(b) Excessive or erratic flight control inputs.

(c) Taxiing too fast (i.e., "faster than the average man can walk").

(d) Lack of tip path awareness.

IV. Air Taxi

An air taxi is a slow, controlled movement of the helicopter at hovering altitude. Technique and procedures are similar to those used during the day or at night unaided, except a more aggressive scan must be used.

A. Procedure

1. From a hover, displace the cyclic in the desired direction of flight.

2. Utilize rudder pedals to maintain heading, collective to maintain altitude and cyclic to maintain the desired track over the ground at a rate of movement commensurate with the pilot's ability and the environment.

3. Before taxiing aft, consideration should be given to increasing altitude slightly to prevent skid strikes or inadvertent ground strikes.

B. Technique

1. Caution should be exercised when stopping the aircraft to prevent skid strikes or inadvertent ground strikes. Large aft cyclic inputs could result in tail rotor strikes.

2. While in an air taxi, an aggressive scanning technique should be utilized to maintain orientation.

C. Common Errors

1. Improper NVG scanning technique (e.g., fixating on direction of travel).

2. Excessive taxi speeds caused by failure to scan to the abeam position.

3. Failure to recognize a rate of descent while in a rearward taxi.

4. Failure to recognize a rate of descent inside-ward flight.

V. Vertical Takeoff

A vertical takeoff is a transition maneuver in which the helicopter is raised vertically from the ground to a hover with minimum fore-and-aft and lateral movement.

A. Procedure

1. Neutralize the controls. Establish the hover scan and initiate a slight aft cyclicinput with a smooth collective input. Anticipate the requirement for rudder pedal input to maintain alignment on lift off. Continue increasing the collective while neutralizing cyclic until the desired hover altitude is reached.

2. Hover altitudes should be in accordance with each individual aircraft NATOPS manual. However, on initial NVG flights, pilots should consider hovering at slightly higher altitudes until they are proficient at recognizing drift and inadvertent altitude deviations.

3. Maintain heading with rudder pedals and eliminate drift with cyclic.

B. Technique

1. During the takeoff, emphasize the NVG scan.

2. Ensure that drift is eliminated as the aircraft becomes "light on the skids/gear."

3. Utilize cues from aircrewmen, as necessary, for altitude and drift information.

C. Common Errors

1. Improper NVG scanning technique.

2. Failure to neutralize the cyclic prior to ascending causing forward, aft or lateral drift resulting in an erratic ascent.

3. Rushing the initial liftoff.

4. Failure to maintain a constant heading.

VI. Hovering

Hovering is a maneuver in which the helicopter is maintained in nearly motionless flight over a ground reference point, at a constant altitude and heading.

A. Procedure

1. Use same control inputs for hovering on NVGs as those used during day or night unaided hovering.

2. Utilize smooth corrections/control inputs and a more vigilant scan.

B. Technique

1. Several scanning techniques have proven effective. The basic principles of an effective NVG scan are:

   (a) The pilot must keep his head moving between several reference points to notice drift.

   (b) Reference points should be stationary objects such as bushes, trees, rocks, etc.

<<WARNING>>

Hovering/landing in open areas of grass, sand or snow may be disorienting due to blowing grass, sand or snow and the lack of a stationary reference point.

   (c) To detect fore/aft drift, scan to a reference point abeam.

   (d) To detect lateral drift, scan to a reference point forward.

(e) Scan inside to the RAD ALT to determine altitude. The pilot not at the controls may assist in this respect by reporting altitudes over the ICS.

2. Control hovering altitude and attitude with small, smooth and slow corrections.

3. The pilot not flying should provide the pilot at the controls with aircraft performance information prior to and during the initial hover.

4. Select easily identifiable reference points for the lighting available at the training site.

5. Utilize cues from crew chiefs and aerial observers, as necessary, for altitude and drift information.

<<NOTE>>

In unfamiliar locations without a ground spotter, pedal turns with tail rotor equipped aircraft should be turns about the tail to ensure tail rotor clearance.

C. <u>Common Errors</u>

1. Improper NVG scanning techniques (e.g., slow scan, fixation and scanning too far from the hover environment).

2. Failure to recognize spatial disorientation that may be caused by the 40^0 FOV.

3. Failure to maintain a constant hover altitude.

4. Erratic heading changes caused by over-controlling the rudder pedals.

5. Failure to recognize drift and to take corrective action.

VII. Vertical Landing

A vertical landing is a maneuver in which the helicopter is lowered vertically from a hover to the ground with a minimum of fore-and-aft and lateral movement.

A. <u>Procedure</u>

1. Smoothly lower the collective to begin a slow descent.

2. Maintain heading with rudder pedals. Eliminate drift with cyclic.

3. The rate of descent may slow or stop as the helicopter nears the ground. Continue the descent through this "ground effect" by gently lowering the collective.

4. When on the ground, smoothly lower the collective to the full down position.

<<WARNING>>

Without the full weight of the helicopter on the landing skids/gear, aircraft drift is possible. After landing, other than minimum rotor pitch settings can lead to aircraft damage and possible dynamic rollover.

B. Technique

1. Emphasize the NVG scan.

2. A slight forward drift on touchdown will tend to eliminate lateral drift.

3. Due to degraded distance estimation and limited FOV, ground contact may be sooner than anticipated. Therefore, a slow descent is in order.

C. Common Errors

1. Improper NVG scanning techniques.

2. Over-controlling the cyclic and collective.

3. Rushing the landing.

4. "Reaching" (feeling) for the ground.

5. Failure to maintain heading with rudder pedals after ground contact.

6. Rearward drift prior to touchdown.

VIII. Turn on the spot

A turn on the spot is a maneuver performed at hovering altitude during which the helicopter is rotated about its vertical axis while maintaining position over a reference point. Initially, turns should be made in the direction most easily monitored by the pilot at the controls. Once comfortably accomplished, turns in the opposite direction may be performed. Turns should be made at a rate no faster than 360 degrees in 30 seconds.

A. Procedure

1. From a hover, commence a slow, constant rate of turn with the rudder pedals, not to exceed the pilots scanning ability and NATOPS limitations.

2. As the helicopter starts to turn, adjust the cyclic to remain over a reference point.

3. On tail rotor equipped helicopters, rate of turn increases and the nose tucks as the tail passes through the wind line. Use rudder pedals as necessary to control the rate of turn and cyclic to maintain position over the reference point.

B. Technique

1. With tail rotor equipped aircraft, a left turn should always be attempted prior to a right turn in order to ensure that there is sufficient tail rotor authority.

2. Tail rotor equipped helicopters tend to climb in a left turn on the spot, and descend in a right turn. Anticipate these tendencies with collective to maintain a constant altitude.

3. Utilize cues from aircrewmen, as necessary, for altitude and drift information.

C. Common Errors

1. Improper NVG scanning techniques.

2. Excessive or erratic rate of turn, caused by over-controlling the rudder pedals.

3. Failure to maintain a constant altitude.

4. Failure to maintain position over the reference point.

IX. NVG Takeoff

The NVG takeoff is a transition maneuver in which an increase in altitude and airspeed is safely and expeditiously accomplished from a hover.

A. Procedure

1. From a stable hover, begin forward motion by displacing the cyclic.

2. Simultaneously, increase collective pitch with a smooth, positive pressure, maintain heading with rudder pedals, and apply sufficient forward cyclic to enter translational lift.

3. As translational lift is reached, the flight controls will have to be adjusted to maintain the proper climb attitude.

B. Technique

1. Note MSL altitude of landing zone (LZ)/intended point of landing (IPL) and up-wind (run-in) heading to provide a reference for appropriate pattern checkpoints.

2. Maintain runway alignment until reaching best single engine airspeed.

3. An altitude over airspeed takeoff (similar to an ITO) is recommended to ensure that a positive rate of climb is established as the helicopter begins to accelerate.

4. The primary scan for the pilot at the controls should be outside, with an occasional instrument scan.

5. The pilot not at the controls should scan outside and inside to provide the pilot at the controls with performance instrument readings, including VSI and nose attitude.

6. Utilize cues from aircrewmen, as necessary to provide obstacle clearance information.

7. Smoothly reduce collective and lower the nose so as to level off at pattern altitude. A pattern altitude of 300' above LZ/IPL and 80 KIAS has proven effective for the NVG landing pattern. The altitude can be lowered in accordance with T&R Vol. I once pilots become proficient with NVGs and as light levels decrease.

C. <u>Common Errors</u>

1. Excessive forward cyclic resulting in a nose low attitude and excessive power requirements.

2. Failure to anticipate effective translational lift, causing the nose to pitch up.

3. Reducing power as the aircraft accelerates through translational lift, thus slowing the rate of climb.

4. Failure to select a ground reference point to maintain ground track.

5. Failure to note zone altitude and reciprocal headings for pattern establishment in remote site operations.

6. Failure to reduce power in sufficient time to allow a level off at pattern altitude.

X. NVG Approach

The NVG approach is a transitional maneuver taking the helicopter from forward flight to a hover or landing, as desired.

A. <u>Procedures</u>

1. Establish a 300' above LZ/IPL, 80 knot downwind for initial pattern work. Pilots may want to fly patterns at lower altitudes once proficient with the NVGs and as light levels decrease.

2. Abeam the intended point of landing, reduce collective slightly. Apply aft cyclic, and turn to intercept the course line.

3. Intercept the course line at approximately 125' above LZ/IPL, 45 knots. Establish a shallow (3-6 degree) glide slope and adjust the collective to maintain a constant descent along the glide slope.

4. Assume a landing attitude. Utilize the wing down, top rudder-crosswind correction method below 50 feet.

5. As forward airspeed is dissipated, increase the collective pitch to arrive over the intended point of landing at hover altitude and zero airspeed, simultaneously. If a no hover landing is desired, continue the descent until the ground cushion is reached, then lower the collective while adjusting the cyclic to touchdown with zero airspeed and zero drift.

6. Be prepared to wave-off at anytime during the approach.

B. Technique

1. A proper 180-degree position is essential in correct execution of the approach.

2. A shallow descent on final is recommended to offset limited FOV and degraded distance estimation. Pilots should be aware of constraints indicated in the height/velocity diagrams of their respective NATOPS.

3. A shallow glide slope is best maintained using a fairly constant cyclic position, and collective adjustments as necessary to control both airspeed and rate of descent. This technique affords the best wave off capability from any point along the glide slope.

4. The same pilot/copilot coordination used in the NVG takeoff should be utilized throughout the approach.

5. Utilize cues from aircrewmen, as necessary, for altitude and drift information, especially below 25 feet AGL.

6. To execute a wave off, level the wings, set a proper nose attitude and smoothly apply power to establish a positive rate of climb. Confirm the positive rate of climb on the VSI.

C. Common Errors

1. Failure to establish a downwind parallel to runway heading.

2. Improper entry altitude and airspeed, especially at the 180 degree position.

3. Failure to establish proper runway/LZ alignment.

4. Failure to maintain a constant approach angle. Excessive nose-up attitude below 50' AGL.

5. Failure to determine ground speed resulting in excessive closure rate after intercepting the course line.

6. Insufficient lateral scan below 50' AGL resulting in an overshoot of the intended landing point.

7. Descent through the selected hover altitude.

8. Poor NVG scanning technique, to include not referencing instruments throughout the pattern to reinforce basic airwork/hitting checkpoints.

9. Failure to use wing down top-rudder crosswind correction resulting in lateral drift.

10. Failure to use lesser angles of bank at slower airspeeds when turning base, thus avoiding an undershooting scenario.

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Night Vision Goggle (NVG) Aided Operations

SECTION II: TERRAIN FLIGHT

I. Introduction

Denial of the enemy's acquisition is the key to increasing survival for rotary wing aircraft on the modern battlefield. A helicopter that cannot be seen, or otherwise detected, cannot be engaged. The single aircraft low work and pattern work described in the preceding section established the basis for training in the next stage of maneuvers. This section will present considerations for developing more advanced NVG skills. It is not a discussion of tactics. It is a description of maneuvers and techniques which, when applied in a given scenario, will enhance the ability to operate in a tactical environment.

II. Training Areas

A preliminary consideration in NVG training is the training area. The training area must be specifically designated for low level military training. The squadron conducting training should ensure that the area is reserved and clear of all other aircraft. If for some reason a squadron cannot attain sole possession of an area for a specific training evolution, coordination with other units working in the area must be accomplished in order to ensure deconfliction. Finally, a hazard map of all known obstacles in the training area must be maintained for the pilots' reference. If a current hazard map of the area is not available, the area/route should be flown during the daytime in order to locate/identify hazards for marking on a hazard map.

General Techniques for NVG Aided Terrain Flight

The move from a runway environment to operations in the TERF environment brings with it special considerations for execution and safety. The following procedures are generic and should apply to every NVG flight:

A. <u>Takeoff</u>

Before takeoff, a visual reconnaissance of the projected departure path should be conducted by all crewmembers. The purpose of this reconnaissance is to identify any potential obstacles on the flight path or immediately adjacent to the path in order to offset the limiting effects of the NVG's FOV. Takeoff can be executed from the ground or a hover and emphasis during the transition should be altitude over airspeed until reaching an altitude that will ensure obstacle clearance. While climbing to an altitude clear of obstacles, gradually accelerate to the desired airspeed.

<<NOTE>>

Extreme nose low attitudes should be avoided during takeoff on NVGs to preclude inadvertent descent. The pilot not at the controls should monitor the cockpit instruments to ensure a positive rate of climb immediately after takeoff. Aircrewmen should immediately notify the pilots of any perceived settling or drift during takeoff.

Obstacles and wind permitting, takeoffs should be made in the direction of the first leg of the route to be flown. If this is not possible, consideration may be given to overflying the takeoff point in the direction of the first leg to aid in navigation.

B. Enroute Procedures

Cockpit responsibilities and division of aircrew duties must be clearly delineated and consistently executed during NVG aided operations. The attention of the pilot at the controls should be primarily directed outside of the helicopter. The AN/AVS-6 affords aircrew adequate look-under capability to view cockpit flight instruments, therefore, any tendency to remain "in the cockpit" for extended periods should be avoided. Frequent monitoring of the flight instruments will be the responsibility of the pilot not at the controls, as will most navigation duties, radio adjustments and other functions that could divert the pilot's attention away from outside obstacle clearance. Aircrewmen provide assistance enroute by providing obstacle clearance, assisting with checkpoint identification and by occasionally monitoring certain cockpit functions, i.e. fuel transfer. This function of aircrew coordination will be expanded upon later in Chapter 9.

C. Altitude Changes

It is difficult to estimate altitude above terrain features during a descent while on NVG's. Descents should be made using gradual reductions in altitude. Stair stepping is advisable. The stair step approach is executed through a series of descents and levelоffs until arriving at the desired altitude. This tends to offset the effects of the limited FOV associated with the NVGs that can result in disorientation while descending. Rapid changes in nose attitude to initiate descents, climbs or turns should be strictly avoided. Erratic maneuvers of this sort combined with the NVG's limited FOV could easily induce disorientation or vertigo. During low light level (LLL) NVG operations, pilots have a tendency to increase altitude.

D. Airspeed

A common tendency among aviators is to over fly the capabilities of the NVGs. Their airspeed does not allow adequate time to mentally process the visual cues provided by the NVGs. This is similar to driving your car too fast at night and not detecting hazards in the road in time to stop. It is important to understand the relationship between NVG hazard detection capabilities, airspeed and pilot reaction time in order to avoid obstacles when flying on NVGs.

1. Hazard Detection. Available ambient light levels largely determine the distance at which an object can be identified on NVGs. The Hazard Detection chart provides a means of estimating the maximum range at which an obstacle can be detected, Figure 7-II-1. In this case, it is an obstacle three meters high and 15 centimeters in diameter. The chart covers the detection range for the AN/AVS-6 (Omnibus-II) at various light levels from overcast starlight (< 0.00022 Lux) to full moon-clear sky (> 0.22 Lux). As depicted by this chart, a

pilot utilizing the Omnibus-II AN/AVS-6 can detect obstacles at ranges 15% greater under quarter moon conditions (0.0022 Lux) than under starlight conditions (0.00022 Lux).

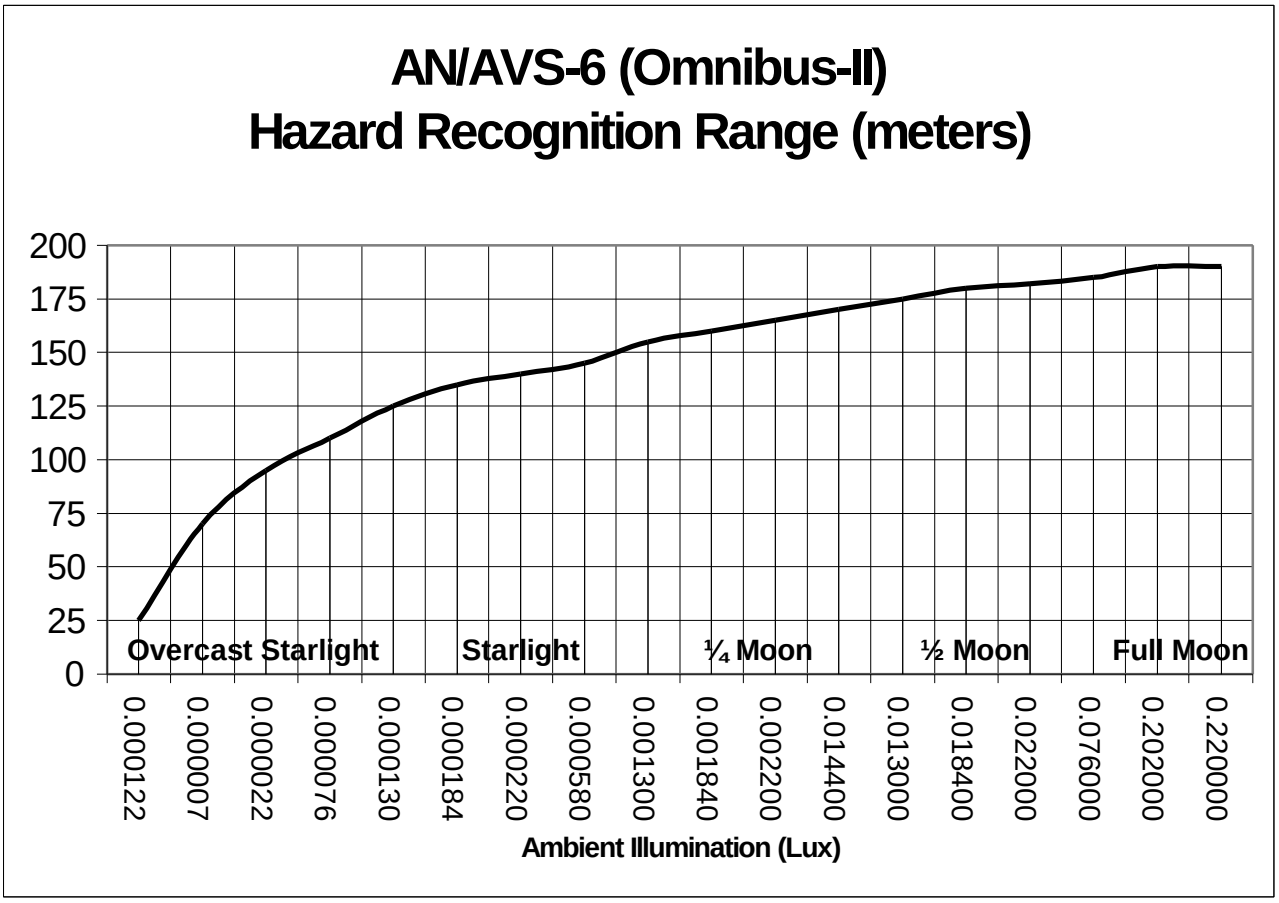

Figure 7 - II - 1. Estimated Detection Distances for Omnibus-II AN/AVS-6 NVGs

2. Detection Range Factors. A number of factors can contribute to detection ranges including condition of the NVG tubes, size of the obstacle and atmospheric conditions (smoke, humidity, ambient light, dust, haze, etc.). A study completed by the Operational Test and Evaluation section of HMX-1 in May of 1987 concluded that airspeed itself affected detection ranges; slower airspeeds can increase acquisition/identification ranges in low level operations. Although some training areas can accommodate faster airspeeds than others, airspeeds flown on any given night should ensure adequate reaction times for obstacle avoidance. Therefore, as the light level decreases so should airspeed. One consideration for AH-1 crews is to have the pilot in the front seat flying the en route phase while the pilot in the back seat navigates. Additionally, pilot experience will affect reaction time. Ultimately, common sense and experience will be the greatest determinants in this and all aspects of NVG flight.

E. Approaches and Landings

The initial challenge of landing at a remote site is largely one of navigation. Navigation must be precise and arrivals planned to reduce airspeed prior to intercepting a desirable glide path since line of sight contact with the zone cannot be established until relatively close to the zone. The final approach should be planned to allow the helicopter to pass over the highest obstacle in the descent path. Throughout the approach, the pilot at the controls should be focused outside the aircraft, avoiding obstacles and adjusting his approach angle and closure rate. The pilot not at the controls should be monitoring performance instruments and calling out airspeeds/altitudes to the flying pilot. The aircrewmen should be actively involved in clearing each side of the aircraft, the tail of the aircraft and below the aircraft. Approaches can be made to a hover however, no hover approaches are preferable as they minimize blowing dust and debris in the zone. Ensure that there is no lateral drift when executing no hover landings. To ensure that there is no lateral drift when executing no hover landing, a slower descent to landing is required along with a vigilant NVG scan. During low light level NVG operations pilots may consider using the IR search light in the terminal phase of the approach and landing to increase visual acuity and obstacle detection within the LZ. Once on deck, the IR light can be secured in order to see beyond the LZ confines.

<<NOTE>>

For AH-1W crews: Due to the increased obscuration from the back seat, pilot proficiency being equal, it is advisable to have the pilot in the front seat perform all landings to confined areas.

F. Landing Zones

In general, LZs should be larger than those required for daylight operations to accommodate restrictions imposed by the NVGs, such as reduced visual acuity and FOV along with the associated difficulties of depth perception/distance estimation. LZ size should be increased as light level decreases. Whenever and wherever possible, zones should be reconnoitered to ensure that they are relatively free of obstacles, particularly along projected takeoff and departure paths.

1. Dusty Zones. Special considerations are required to execute an NVG landing in a dusty LZ. Obstacles permitting the approach should be somewhat shallow (30 - 40^0 approach angle) and into the wind. The approach should terminate with a no hover landing to help minimize the effects of blowing sand and debris during the landing transition. On final, a prominent ground reference point near the intended point of landing should be selected. Contact with the ground reference point inside the rotor disk should be maintained throughout the landing transition. If a "brown-out" condition is experienced which obscures the intended point of landing and/or the ground references, a wave-off should be executed immediately. In the CH-53, if a proper NVG approach has been flown, the helicopter will arrive in a stable hover as the dust cloud moves clear of the pilot's scan. In this area of relative calm, ground contact can be maintained allowing a vertical landing. The entire crew should be aware of zone obstacles. NVG visual acuity will be degraded in dusty zones, especially during LLL illumination conditions.

2. Snow. An additional problem in executing approaches on NVGs in a snow environment is lack of contrast. Reflectivity off of snow tends to result in a lack of contour definition making altitude and drift determination extremely difficult, particularly under high ambient

light conditions. The effects encountered while landing a helicopter in dry snow are very similar to those found in a dusty environment.

<<NOTE>>

A close-in scan and attention to the calls of the aircrewmen are imperative. A large power deviation in transitioning to a landing in a snow or dusty environment only serves to increase "white-out," "brown-out" and other disorientation problems. Likewise, extended hovering in these conditions will tend to re-circulate the already disturbed obscurants, greatly reducing the pilot's visibility. When executing an approach, if the pilots and aircrewmen lose visual contact with the ground or horizon, a wave-off should be initiated immediately.

3. Wave-off. A wave-off should be initiated any time any member of the crew perceives that an approach is too steep/shallow, rate of closure is not under control, aircraft clearance into a zone is not assured, or visual contact with the intended point of landing is lost. Due to reduced visual cues, reaction times may be delayed. Therefore, the wave-off should be called for and initiated as early as possible in the approach to allow a smooth transition. In executing a wave-off on NVGs, attention must be focused first at performing an ITO, leveling the wings, leveling the nose, arresting the rate of descent, and establishing a positive altitude-over-airspeed transition out of the zone. Do not attempt to expedite the transition out of the zone by lowering the nose and adding power, particularly during brown-out conditions. Additional considerations during planning and briefing is required with regard to wave-offs in multiple aircraft flights to include the safest way to rejoin the flight after a wave-off has been executed.

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Night Vision Goggle (NVG) Aided Operations

SECTION III: NVG GOGGLING PROCEDURES

Introduction

NVGs are essentially the helicopter crew's "eyes" for visual cues outside the aircraft during night aided operations. As noted in previous chapters, the effectiveness of NVGs is highly dependent on ambient illumination, artificial illuminations, environmental conditions and mission requirements. Considering these factors, the flight leader/mission commander must determine when NVGs will be utilized. He is responsible for the goggle and/or de-goggle procedures and will brief the sequence to be used, as well as the required lighting configuration.

Goggle/De-goggle Considerations

A. <u>Ambient Illumination</u>

Ambient illumination at the time of initial takeoff may not be compatible with NVGs. Therefore, goggling may be required at some point during the mission once favorable conditions exist. One example of this would be a mission that begins during daylight hours and continues into the hours of darkness. A similar situation for degoggling may arise when a mission requires a flight during early morning hours of darkness into daylight conditions.

B. <u>Artificial Illumination on the Battlefield</u>

Chapter 2 discussed the blooming or washout effect of NVGs created by bright light sources entering the in the NVG's FOV. These effects may result from flares, fires created by ordnance, etc. In cases where ambient illumination is high and artificial illumination is sparse and easily eliminated from the NVG's FOV, these light sources will not be detrimental to continued use of the NVGs and may in fact be beneficial. However, in conditions of low ambient illumination with unavoidable artificial illumination in the NVG FOV, significant blooming or washout effect may occur. Aircrew must consider these possibilities during mission planning and develop a plan to account for potential artificial illumination NVG performance degradation.

II. NVG Goggling/De-goggling Procedures

There are basically three times during a flight when goggling or de-goggling can take place. These times are chock to chock, airborne or at an outlying field or landing zone. The mission/aircraft commander is responsible for determining when and where goggling or de-goggling will take place based on the considerations mentioned earlier in this chapter. A

discussion of the procedures for goggling or de-goggling in each of these three situations follows.

A. Chock to Chock

1. Goggle. Prior to take off, all aircrew will have their goggles donned and activated for use. All exterior and interior lighting will be set as briefed in accordance with Marine Corps policy for NVG compatibility.

2. De-goggle. The final landing will be accomplished with the goggles on. De-goggling will take place after the final landing.

3. Taxi. Taxiing to or from the take off or landing point with or without NVGs will be determined by the flight leader/aircraft commander based on airfield lighting considerations, local directives and SOPs.

B. Airborne

In-flight goggling is an acceptable method to use when goggling the flight on the deck is impractical or not environmentally suited (in-flight transition from day to night). Goggling or de-goggling in flight requires good crew coordination within each cockpit and between each aircraft. The flight leader must ensure that the sequence has been thoroughly planned, properly briefed and understood by all crews

1. Goggle. Goggling will commence at a pre-briefed geographical point, time or on cue with a visual signal or radio call. Whatever the case, all crews must be aware that goggling is taking place. Goggling within each aircraft should be done with one pilot at the controls and one aircrewmen clearing the aircraft while the other pilot and aircrewmen adjust the interior/exterior lighting and goggle. Once these crewmembers are goggled, controls will be changed to the goggled pilot and the remainder of the crew will goggle.

2. De-goggle. The procedures for de-goggling should be the same as those for goggling, with the exception that internal lighting must be changed from the blue NVG compatible lighting to the appropriate night unaided cockpit lighting. This lighting transition should not occur until both pilots are de-goggled.

Night Vision Goggle (NVG) Aided Operations

SECTION IV: FORMATION FLIGHT

I. Introduction

This section will focus on the specific considerations for conducting formation flights on NVGs, and considerations designed to ensure safe mission accomplishment, during training and combat.

II. Initial NVG Formation Training

Introducing a pilot to flying in formation while wearing NVGs requires some special considerations due to limited FOV and poor distance estimation with the NVGs. This discussion is intended to aid the instructor and student by giving some basic points associated with flying formation on NVGs. As with all other aspects of training, the building block approach should be taken.

A. Procedures

A 20 to 30^0 bearing will allow the pilot to see both the lead aircraft and the terrain in his flight path in the NVG FOV, reducing his scanning requirements, while increasing scanning efficiency. By flying more acute than a 30^0 bearing, the pilot must exercise a vigilant scan forward to perceive obstacles in the route of flight and then back to the lead aircraft.

B. Technique

Techniques for formation on NVGs are similar to those during the day. However, lateral separation may be difficult to perceive. Consideration should be given to flying a position where the pilot can see a clear picture of the lead aircraft so that he can best pick up cues for aircraft attitude, altitude, airspeed and relative motion. This will be greatly affected by ambient illumination and atmospheric restrictions to visibility.

C. Common Errors

1. Not holding a constant lateral separation. This creates an accordion effect within the formation.

2. Flying with too much step-up.

III. Maneuver Element

The best maneuver element (as in day operations) is the smallest element capable of accomplishing the mission. This is the helicopter section, whose inherent advantages of ease of maneuver and mutual support are retained on NVGs. The helicopter section is the basic building block for all larger formations. METT-T factors may warrant the use of division size elements (or larger) when conducting NVG operations. Whether operating as a section or a division on NVGs, the joining of those flight elements is demanding, especially during the critical objective phase of a mission. Procedures for joining must be thoroughly planned. In addition to those already presented, the following considerations should be taken into account when selecting the size of an element to be flown.

A. Ease of Detection

Properly planned and executed, the conduct of flight in a low-level environment under the cover of darkness significantly reduces the enemy's visual acquisition capabilities. Probabilities of electronic acquisition are increased as the size of a flight increases. Flights in a potentially contested area must be protected in the planning stages by application of intelligence, as well as minimizing the radar and acoustic signature of our assets by reduced numbers, careful routings and/or both.

B. Dispersion Capability

Most assault support or heliborne missions should be planned to go where the enemyis not. However, in preparing for the worst, the flight must possess the flexibility and maneuverability to evade an unforeseen threat and continue the mission. In terms of section vs. division tactics, a "scatter plan" is more easily executed with the smaller element. When forced to operate in a larger formation, the "scatter plans" must be situation developedin terms of direction of the attack, range of the threat and nature of the threat (i.e., small arms, rockets, AAA, SAM, aerial threat, etc.). Planning must include those actions to be taken by assault aircraft and those actions to be taken by escorts. Maneuvers must be plannedin terms of different aircraft positions in the flight and the position of the flight in terms of terrain. Likewise, execution of the maneuvers must be planned with respect to the limitations of the NVGs. Emphasize the requirement for simplicity in coordination of the flight and smooth individual execution to avoid vertigo and disorientation. Finally, the plan must be completely understood by all members of the flight.

C. Mutual Support

Mutual support is especially important in multi-helicopter NVG operations. Lookout doctrine, placed alongside the demands imposed by the NVG's FOV, can overwhelm a poorly prepared or coordinated crew, even one with four sets of eyes. The additional cues provided by additional aircrew could be most beneficial in identifying a checkpoint, an obstacle or the enemy. NVG operations over water are enhanced by the mutual support afforded by helicopter formations. Experience has shown that due to the limited contrast provided when using NVGs over a smooth water surface, pilots have difficulty perceiving a gradual loss of altitude. Aircrew coordination can be used to complement inter-plane communication in formation flights.

IV. Tactical Formations on NVGs

The same cruise principles of using radius of turn to maintain or regain position apply to NVG operations. However, pilots must understand that NVG limitations dictate a more conservative approach regarding closure rates. In low ambient light conditions a wingman should always stay close enough to the lead aircraft to recognize any attitude, altitude or airspeed changes. Greater distances reduce visual cues needed to effectively maintain position in the flight.

A. <u>High Light Level (HLL)</u>

Tactical formation flights conducted under HLL with favorable atmospheric conditions differ little from daylight formations. This environment offers excellent visual acuity and depth perception. Tactical (TAC) turns can be performed, but should be preceded by a thorough execution brief. Aircrew must continue to exercise diligent scanning techniques to ensure the safe conduct of NVG aided operations.

B. <u>Low Light Level (LLL).</u>

The LLL flight regime is the most difficult and demanding environment to operate in. It requires detailed briefing, excellent crew coordination and a vigilant scan. Lack of visual cues, decreased depth perception and poor external lighting require reduced separation between aircraft (tighter formation) in order to adequately maintain sight of lead. Under low ambient light conditions and when atmospheric conditions deteriorate, wingmen should decrease lateral separation to stay close enough to the lead aircraft to recognize any attitude, altitude or airspeed changes. TAC turns are not recommended under LLL conditions

C. <u>Combat Cruise (NVG)</u>

This formation is designed for both NVG HLL and LLL conditions. The same cruise principles of utilizing radius of turn to maintain or regain position applies to NVG aided flight. However, pilots must understand that NVG limitations dictate a more conservative approach regarding closure rates. Greater lateral distances reduce visual cues needed to effectively maintain position in flight.

1. <u>Bearing</u>. The optimum position for wingman is between the 20^0 to 30^0 bearing (5 to 7 o'clock). The 20^0 bearing being the preferred for extended navigation legs, which will keep the lead aircraft within the NVG's FOV and allow for greater forward situational awareness. Though Combat Cruise (NVG) allows wingmen the flexibility to fly 10^0 forward of abeam on either side of the aircraft in front, wingmen positioned forward of the 30^0 bearing will reduce flight maneuverability. Wingmen should avoid prolonged periods of flight in the 6 o'clock position due to the degradation of most cues required for attitude and closure rates.

2. <u>Lateral Separation</u>. Since visual cues are reduced, night lateral separation between aircraft may need to be reduced. The optimum lateral separation is 100 to 300 feet. Increased light levels and the introduction of the Omnibus-IV NVGs may allow for greater distances between aircraft, however, lower light levels and lesser performing NVGs may require tighter rotor distances. Consideration should be given to employing the "welded wing" concept (remain in fixed position) during extended portions of flight, like straight leg portions of a navigation route.

3. Step-up. Wingmen flying in close proximity to the lead (200 feet or less) or when experiencing poor visual acuity from reduced light levels should fly with 10 feet of step-up. When the situation dictates, wingmen have the option to fly a level altitude or step-down.

D. Spread

NVG flight conducted in a spread formation will result in the pilot at the controls constantly shifting his scan between the lead aircraft and his direction of travel. The inflexibility that automatically accompanies operations in spread will most often make it less desirable than combat cruise. This is particularly so when realizing most, if not all, of the advantages from flying spread can also be achieved in cruise formation. LLL spread formation is not recommended. Inflexibility, coupled with a demanding scan pattern and poor frontal situational awareness, makes this formation undesirable.

E. Aircraft Lighting

As pointed out in Chapter 6, NVG operations require modification of the standard lighting configuration used in night flight. For instance, besides being disorienting for pilots during the landing transition, use of anti-collision lights within a formation can be distracting to the point of being unsafe to others in the formation. Standard position lights, when placed to bright, are also distracting. Aircraft capable of dimming these lights should do so in accordance with unit SOPs or as dictated by the comfort level of your wingman.

<<NOTE>>

If a wingman is uncomfortable with a particular light scheme, he should request a change.

Formation and blade tip lights are also adjustable on many aircraft and should be adjusted as required. While the tail position light is an effective signaling device, using it as a matter of course is not recommended as this configuration may set-up the wingman for perceptual illusions and its associated hazards. In a tactical scenario, any consideration of lighting must be balanced against the enemy's capability to detect. Consideration for that balance has led us toward the development of external lighting that is invisible to the unaided eye. Until that lighting is fully integrated, we must not lose sight of the fact that safety-of-flight considerations in training should not be ignored in combat. If we run into each other due to a lack of NVG capable lighting that we have abandoned to avoid the enemy's detection, we have accomplished the enemy's objective.

V. Section Maneuvering on NVGs

Section maneuvers are designed for effective and efficient movement of the flight. However, before executing these maneuvers on NVGs, you should carefully consider the ambient light level, the severity of the maneuvers to be executed and the crew coordination required.

A. Ambient Light Levels

Ambient light levels must be high enough to meet the requirements for adequate lateral separation. The key is to attain safe enough separation to comfortably execute the maneuvers without losing sight of sufficient formation flight cues. Before leaving a discussion of ambient light levels versus lateral separation, a warning regarding operations in

proximity to culturally lit areas should be discussed. Lights several miles away from a flight or a low angle moon may impair a wingman attempting to track his lead's lights against the background lights. The greater the lateral separation, the more easily lead's lights are lost. Such a condition will require a flight to close up until respective aircraft silhouettes are clearly defined. A means of facilitating this definition may be to set up a "step down" position on lead to place him more "on the sky line". This would be possible only with sufficient altitude to ensure the wingman's safe clearance in his new "step down" position. Another option might be to execute a cross over, to place the wingman between the lead and the lighted area or the moon.

B. Angle of Bank/Severity of Maneuver

Due to a potential for disorientation on NVGs, rapid execution of large angles of bank is not recommended. NVG maneuvers should be smooth, measured and coordinated to reduce the chance of inducing spatial disorientation or vertigo.

C. Aircrew Coordination

Clear communication of terms must be addressed. Aircrew should give continuous updates on the wingman's position. NVG aircrew coordination is discussed in detail in Chapter 8, Section III.

VI. Separation of Aircraft

Ultimately, it is the mission commander/flight leader's judgment that will determine flight separation. It should be based on the following considerations:

A. Ambient Lighting

Ambient lighting as well as the atmospheric conditions that affect visibility will determine separation and numbers of aircraft in a flight. The ability for the wingman to perceive closure rates and relative motion of the lead must be considered as well.

B. Aircraft Lighting

The two primary considerations for planning NVG exterior lighting configurations should be: (1) how well aircraft within the flight can detect one another and (2) how easily the flight may be detected by aircraft or threats external to the flight. In combat we may not want our flights to be identified, but in training we must provide a way for pilots external to the flight, to see and avoid the flight. In training, a large flight of aircraft may be stretched out, dash last being the only aircraft with anti-collision lights on. Aircraft external to the flight may not see the lead aircraft and think that they have safe separation from the flight when in fact they do not. CMC policy for USMC aircraft lighting is delineated in MCO P3500.14 (T&R Vol. I) and was summarized in Chapter 6. Anytime separation between aircraft within a flight gets extended or if a wingman perceives an unsafe situation developing, a traffic call or a call for anti-collision lights must be made on the radio. During LLL conditions, use of the IR searchlight or landing light to identify aircraft position is also recommended.

VII. Additional Tactical Considerations

A. Takeoffs

The flight leader should plan a specific way to know that all members of the flight are ready for takeoff. A smooth transition out of the zone should be executed to allow wingmen to take their pre-briefed position in the flight as expeditiously as possible. Turnouts after takeoff should be accomplished utilizing radius of turn, vice power changes.

B. Landing

In executing landings, every effort should be made to minimize hover time prior to landing, especially in dusty environments. In those environments, consideration should be paid to allowing follow-on wingmen to land prior to lead. This prevents those wingmen from being victimized by the dust cloud of the lead aircraft.

C. Wave-offs

Multiple aircraft wave-offs may be conducted at the flight leader's discretion, but consideration should be given to allowing individual wingmen to land if the approach to their landing point is clear.

Night Vision Goggle (NVG) Aided Operations

SECTION V: NVG EXTERNAL OPERATIONS

I. Introduction

NVGs enhance one's ability to conduct external operations. Visual contact with loads, ground personnel and obstacles can be easily established and maintained with the use of NVGs. However, external operations with NVGs may present problems not encountered during daylight external operations. The lack of depth perception and decreased visual acuity may cause a decrease in the pilot's ability to maintain a stable hover and could result in longer hook-up times. Detailed planning and frequent external training will build the experience necessary to overcome these challenges.

A. Landing Zone Selection

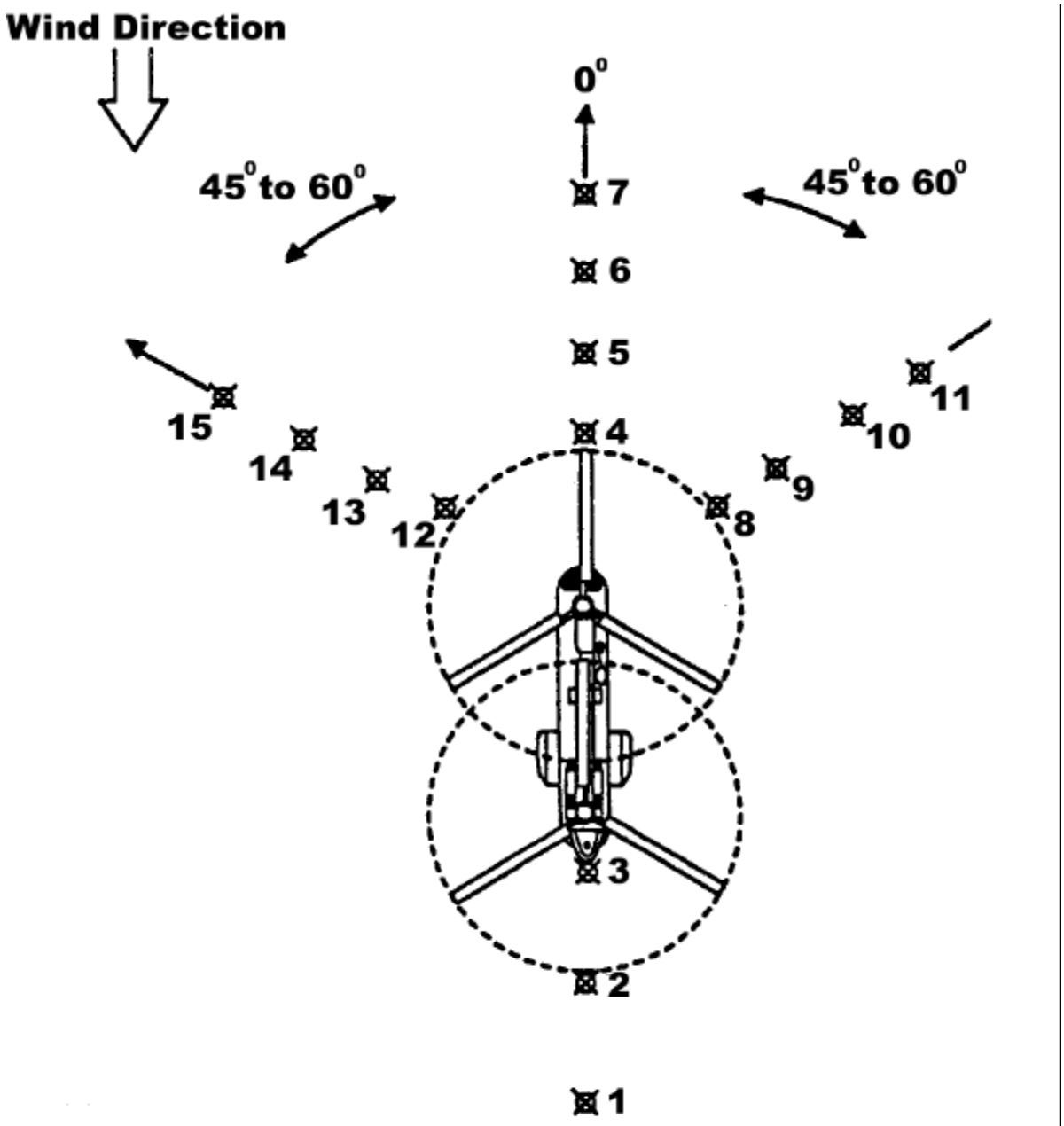
Landing zones for NVG externals should be larger than those required for day externals. The LZ approach and departure routes should be free of obstacles. Careful consideration should be given to the stability/composition of the prospective LZ. Surface blowing dust, sand or snow can seriously hamper one's ability to detect drift. Extremely unstable surfaces can preclude the use of some LZs since the blowing sand/dust/snow will not provide any reference required for maintaining a stable hover. In addition, the slope of the terrain in the LZ must also be closely evaluated. During daylight operations, excessive slopes may be easily perceived and avoided. During NVG aided externals, NVG design and perceptual limitations may cause these same slopes to be undetectable at night. Ground personnel should be aware of these terrain slope considerations and direct the aircrew to a suitable load placement point.

B. Landing Zone Preparation

NVG compatible lighting is the only consideration for NVG externals that differs from normal day/unaided night operations. If lights are used for LZ marking or for support personnel, then their compatibility with NVGs must be ensured. Chemsitcks are compatible and the most commonly used. LZ lighting may be utilized for downwind zone identification and final approach course alignment. If LZ lighting is desired, one simple and easily set up configuration is to mark the load placement site with a chemstick indicating each corner of a square pattern. This method enables easy identification of the pickup and delivery site and is free from excessive lights in the landing area. If desired, Figure 7-V-1 depicts a more defined configuration.

<<NOTE>>

LZ lights should not be utilized as the primary reference points for a hover scan.



Notes:

1. Distance between lights: 15-meters (15-paces)
   (1-pace equals approximately one full length stride or 3-feet)
2. Lights 8 to 11 and 12 to 15 should be placed in line along the 45 to 60 degree bearing line from the nose of the aircraft.
3. Lights 4, 8, and 12 shuold be placed below the outer edge of rotor area with lights aligned by sector (4 to 7, 8 to 11 and 12 to 15) on bearing.
4. Distance between lights 3 and 4: 22-meters (22-paces)
5. Color of lights determined by light level condition and enemy situation.

Figure 7 - V - 1. NVG LZ Lighting Template

C. HST Requirements

A thorough preflight brief with the HST should be conducted. At a minimum, the following topics should be covered:

1. LZ Lighting. Along with stressing the importance of NVG compatibility, the flight leader must clearly delineate expectations regarding LZ layout. This should include light placement and light discipline.

2. Taxi Directors. Procedures to be utilized between the pilots and directors must be addressed in the brief. The HST NCOIC must be instructed as to where directors should be positioned to be easily seen. Emergency procedures regarding the helicopter, the load, the LZ and ground personnel must be clearly understood by all participants. It is recommended that HST personnel be NVG equipped.

3. Hook-Up Team. In the preflight brief, the hook-up team should be directed regarding any necessary lighting on the load and advised as to pendant lighting. The hook-up team must understand what is expected of them in case of a fouled load and which direction to clear in the event of an emergency.

4. Communication. Primary and secondary working frequencies and call signs should be briefed. Prior to conducting NVG external operations, two-way radio communications between the HST personnel and the aircraft should be established. Backup signals for emergencies should be covered as well.

D. Lighting Considerations

1. Cargo Illumination. Chemsticks provide an excellent aid in illuminating the top of a load. This assists the aircrew in load identification and directing the pilots over the load. When available, IR chemsticks can perform this function while eliminating detectable unaided light signatures in a tactical environment.

2. Pendant Hook. Marking pendant hooks with chemsticks enables ground crews to expedite hook-ups and allows them to avoid inadvertent pendant swings.

3. Hook-up Site Illumination. CH-53E pilots conducting dual point external lifts may consider the use of the non-IR filtered spotlight to illuminate the hook-up site when conducting initial training for the HST. Prior to initiating a hover, the pilots should position the spotlight aft and down so as to illuminate the cargo and the pendant hooks. This is easily accomplished on the deck with the assistance of the crew chief who is standing outside of the cabin. After the spotlight is in the proper position, the pilots will select the appropriate position, COPLT or PLT, on the REFUEL LT panel and adjust the dimmer control to an appropriate intensity. The intensity should be sufficient enough to illuminate the hook up site without degrading the NVGs. After the position and intensity of the spotlight are adjusted, secure the spotlight without stowing it until just prior to conducting the external hook-up. Pilots have found that this procedure is an effective way to decrease the time required for cargo hook-ups, especially on FMF equipment.

II. Aircrew Coordination

The importance of proper crew coordination between pilots and aircrew conducting NVG externals cannot be over emphasized. The pilot at the controls (PAC) focuses his scan on close in reference points in order to maintain a stable hover. Due to this increased attention on close in references, he may not readily observe mandatory signals from the directors. In addition to backing up the PAC on drift altitude and corrections, it is recommended that the pilot-not-at-the-controls (PNACs) monitor the directors for signals. Calls from the crewman directing the pilot over the load should not differ from normal day external calls.

Night Vision Goggle (NVG) Aided Operations

SECTION VI: NVG ESCORT OPERATIONS

I. Introduction

The necessity for the protection afforded by armed escorts for assault helicopters does not go away with NVG aided operations. Many of the procedures already discussed in this manual are directly applicable to the night escort mission. Nevertheless, certain special considerations rate mention here to aid in planning and coordinating for this segment of NVG aided mission area.

II. Goggle/De-goggle/Transition Procedures

It is the responsibility of the mission commander, with input from the escort flight leader, to brief NVG goggle/de-goggle transition procedures to all members of the flight. The following are specific aspects of the NVG transition as they pertain to escorted flights. While it is understood that an NVG transition in flight is the least preferable method, certain tactical situations may require the members of the flight to do so. The preferred method of "transitioning" flights while airborne requires that the escort aircraft transition first. The emphasis here is to allow the escort aircraft to safely see and avoid the assault aircraft. If the assault aircraft are transitioning first and successively secure their external lighting, the escorts could lose sight of them, thereby increasing the chance of a mid-air collision. Once all of the escorts have transitioned, the assault aircraft should begin their transition procedures. The escort aircraft are responsible for separation from the assault aircraft. Special care must be taken when performing the transition, while heading into a setting sun.

III. Formations

All of the considerations outlined in the formation section, published earlier in this manual, will apply to escorted flights. In addition to those considerations the following particular concerns should be addressed during planning.

A. <u>Airspeed</u>

Airspeed for flights must be appropriate to not only allow the escorts to stay with the flight, but also move ahead of the flight as the tactical situation dictates.

B. <u>Formation Maneuver and Flexibility</u>

Formation maneuver and flexibility considerations include possible changes in the mission or the situation and evasive tactics to be used. The escort flight leader and assault flight leader must coordinate the formations that the flight will use in order to de-conflict any possible

problems. This will aid the escort aircraft in identifying the best location for protection of the flight. During NVG escort operations, all turns made by the flight should be at a constant rate and not exceed 30^0 AOB. This will give the escort aircraft ample time and maneuver space to react to turns. The flight should avoid planning route segments that require heading changes of more than 60^0.

C. Ambient Light Considerations

As ambient light levels decrease, it may be necessary to "tighten up" formations, reduce airspeed or descend in order to increase reaction time. As a result of the reduced NVG visual acuity and limited FOV, escorts should use power to make turns rather than using the radius of turn principles. This means that escort aircraft should remain on their respective sides of the assault aircraft during turns. If a crossover is necessary (i.e. assault aircraft turn rate is so high that it precludes the escorts from maintaining their positions), consideration should be given to indicate the intention to crossover with a signal (i.e., radio, light, etc.). Under certain ambient light conditions, escort aircrew may find it advantageous to fly step down vice step up to maintain better visual contact with the assault aircraft. This option is available only when altitude and/or terrain permit, and should be communicated to the assault aircraft.

D. Lighting

Use of covert external lighting such as IR position light filters, IR landing/search lights, EL strips and IR chemsticks may facilitate observation and provide a better contrast between assault aircraft and escorts. Varying light configurations may aid in aircraft identification. The use of any light must be weighed against the enemy's detection capabilities.

E. Formation Join Up Procedures

The most preferable method of joining the escort and assault aircraft under NVGs is on the deck. If the tactical situation will not allow a join up on the deck, then it obviously must be done in the air. A specific time and easily identifiable location are a necessity and must be pre-briefed. The join up should not be accomplished in a holding pattern, rather enroute from one checkpoint to the next. The rendezvous point is intended to allow for visual contact between the escorts and assault aircraft, and to allow for holding due to timing problems. Once visual contact is made, the assault aircraft should slow to between 60 and 80 knots to allow the join up to occur. Altitude considerations should also be given to a separate rendezvous altitude, particularly during low light level conditions. It is the responsibility of the escorts to maintain separation from the assault aircraft. Once the join up has been accomplished, the flight can then resume the pre-briefed airspeed.

F. Evasive Actions

Any type of evasive action conducted while wearing NVGs, either single ship or in formation, will require thorough preflight briefings among the individual aircrew and with members of the flight. Should a flight encounter enemy fire, the escorts must determine whether the flight is receiving effective fires prior to returning the enemy's fire, as this will expose the aircraft's position and the position of the flight. Assault aircraft, if necessary break away from the fire and inform the escort of their actions. Assault aircraft should avoid breaking off into numerous directions, as this will increase the possibility of a mid-air collision and also increase the difficulty of reorganizing the flight. One of the advantages at night is the ability

to evade and disengage, as opposed to engaging a threat when brought under fire. At no time can the right for self-defense be denied; however, assault aircraft gunners should not fire if it will interfere with the escort aircraft's ability to suppress or destroy a target. Door Gunner fire can be effective for marking enemy positions by tracer fire. It is essential for assault aircraft to use magnetic heading when calling out the threat.

There are also considerations that must be given to the surface threat. Small arms should not be treated the same as SAMs or AAA. The evasive actions should be the same as in day, but it becomes more important to pre-brief those actions. RWR indications should be called out for the flight, but extreme care must be given to the deployment of expendables at night. Even though chaff is not visible, the firing squib is quite visible. Flares will definitely silhouette the flight and may actually induce greater harm than good. These considerations should be discussed and are dependent upon METT-T.

The likelihood of coming under attack from enemy aircraft is reduced at night. It must be remembered though, that the presence of night targeting systems in the enemy's inventory (i.e., airborne intercept (AI) radar, FLIR, infrared search and track (IRST) systems and low light level televisions (LLTV)), will not allow the air threat to be automatically discounted.

IV. Landing Zones/Holding Areas

LZ avenues of approach must be considered during planning with the emphasis placed on the ability of supporting arms and escort to both cover and prepare the LZ. Escort aircraft attack positions, cover patterns, routing and fields of fire must be known by the entire flight prior to commencing an assault. All supporting arms and fire support coordination measures need to be pre-briefed and understood by the flight.

All ordnance utilization in the LZ is under the control of the escort flight leader until such time as the GCE can control the situation. This includes the door guns of the assault aircraft. During the brief, any limitations placed on the assault aircraft gunners must be understood, to include lateral limits and effective fire range of the guns. Using prominent terrain or man-made features for restricted fire line orientation is preferred for deconflicting door gunner and escort fires. In addition, Target Reference Points (TRP) can be established to orient all fire support assets to a suspected threat. Once again, the right for self-defense should not be denied.

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Night Vision Goggle (NVG) Aided Operations

SECTION VII: NVG WEAPONS EMPLOYMENT

I. Introduction

The same conditions that degrade the enemy's ability to acquire our forces will also likely impede our ability to acquire and engage him. All helicopter armament systems can be employed while conducting NVG aided operations, however, some will be employed more effectively than others. This section will examine proven techniques for individual weapon systems employment.

II. Acquisition Range

The first step in delivering ordnance is target acquisition and identification. NVG visual acuity, even under the most ideal conditions, allows for acquisition ranges well below those enjoyed during daylight operations. Acquisition ranges will also decrease as light levels decrease. These acquisition ranges are usually well within the enemy's weapons engagement parameters but his visual and optical detection capabilities will also be limited at night. As a general guideline, acquisition ranges under a clear sky and quarter moon illumination conditions are as follows:

A. <u>Personnel</u>

Personnel can generally be detected at ranges up to 400 meters (1,310 feet).

B. <u>Vehicular targets</u>

Vehicular targets and other large stationary objects may be acquired at ranges up to 2,000 meters (6,560 feet). Acquisition in excess of 3,000 meters (9,840 feet) is possible when the vehicles are moving.

C. <u>Terrain Features</u>

Prominent terrain features and buildings are recognizable at ranges up to 3,000 meters.

The Marine Wing Support Squadrons' (MWSS) meteorological sections have the capability to produce Electro-Optical Tactical Decision Aids (EOTDA) Data. NVG acquisition ranges and LASER propagation data can be computed for a given target based on target area weather and environmental conditions.

<<NOTE>>

These ranges address targets "in the open." Masking of targets by camouflage and lower light levels will reduce acquisition and identification ranges. Poor light discipline, moving targets and dust signatures will increase acquisition ranges. A vehicle on the move using blackout drive lights can be acquired miles away. As light levels decrease, poor light discipline becomes more evident.

III. Assault Support Aircraft Armament

A. Crew Served Weapons

All crew served weapons (M-60, GAU-17, GAU-16, XM-218 .50 cal and M-240) can be effectively fired by an aircrewmen wearing NVGs with only minor variations from day operations. Aircrewmen must be aware that muzzle flash associated with these systems will cause the NVGs to shut down for the duration of the firing burst. During NVG shutdown, aircrewmen may completely lose sight of the target. This effect is temporary until the end of each burst. The aircrewmen must then reacquire the target. Once on the target, fires should be directed in short (1-2 second) vice sustained bursts, to reduce the time the target is visually lost due to NVG shutdown. By sequencing in short bursts and immediately reacquiring the target, aircrewmen can exercise maximum advantage in keeping rounds on the target. Short bursts ensure the additional tactical advantage of minimizing the time a helicopter highlights its own position, by way of its weapon's muzzle flash. Another alternative is to remove every other tracer and re-link the rounds creating a 9:1 ratio. Crew coordination in directing fire and fire discipline are even more important while on NVGs. The integration of IR searchlights with crew served weapons should be considered as an aid in providing an additional light source for target acquisition. In addition, when crew served weapon IR LASER Pointers (i.e., GCP-2, AIM-1, etc.) are integrated into NVG aided operations, the accuracy of fires can be significantly improved.

B. Defensive Armament Subsystem (DAS)

With the DAS on the UH-1N, both the aircraft commander and copilot can fire the GAU-17 in the fixed forward position. Utilizing the same techniques described in the crew served weapons procedures, targets can be engaged on the NVGs. Pilots must be keenly aware of the necessity for firing short bursts. There is a tendency to allow the helicopter to descend when firing sustained bursts. Crew coordination, courses of action concerning target fixation, loss of altitude, aircraft attitude and excessive aircraft drift should be thoroughly briefed and understood by all crewmembers.

IV. Attack Helicopter Armament

A. AH-1W Night Targeting System Employment

The FLIR on the AH-1W Night Targeting system uses thermal detectors designed to detect energy in the 8 to 12 micron region. This region is typically used for military FLIRs, as it offers the greatest window of atmospheric transmissivity. In addition, the AH-1W NTS system uses a Neodymium:YAG pulsed LASER. The LASER is designed for target designation and rangefinding applications. The AH-1W NTS system enhances the night

ordnance delivery capabilities by detecting and tracking targets, LASER ranging targets and LASER designating targets. All the weapons systems discussed above will have increased night lethality when delivered from an AH-1W NTS aircraft.

B. AH-1W 20mm Cannon

Fire can be delivered from the AH-1W when using the 20mm from the rear seat in the fixed mode. Minimal NVG shutdown degradation will be experienced due to the relative separation and location from the fixed gun. However, as ambient light levels decrease, the muzzle flash becomes more pronounced. Tracer rounds can be acquired and adjusted onto the target. MK 56 tracer burnout is between 1,200 and 1,500 meters. When operating the system in this manner, rounds must be adjusted by changing the nose attitude of the aircraft. The pilot will have to maintain an aggressive scan to keep the aircraft clear of obstacles while having good target effect. The copilot has to keep the pilot aware of aircraft drift, settling, and obstacles. The copilot should provide round adjustment communication to the back seat pilot. AH-1W crews can utilize either the day mode or the night filter of the Heads up Display (HUD). Both modes have proven compatible with the NVGs; however, the illumination of the HUD must be reduced to its minimum level in order to reduce glare and enhance NVG performance.

C. AH-1W TSU Gun Delivery

The most effective method of employing the Telescopic Sighting Unit (TSU) at night is with coordinated artificial illumination, without NVGs. Only under the most ideal conditions can targets be located and identified with NVGs through the TSU at stand-off ranges. The reflected light of a target is reduced approximately 70 percent when viewed through the TSU. Upon trigger pull, the tracers have a potential of washing out the target area. Specific techniques and methods of employment for night weapons delivery through the TSU will be covered under the TOW missile employment portion of this section.

D. AH-1W HSS (Helmet Sight Subsystem) Delivery

The techniques for employing the 20mm cannon on NVGs with the HSS will be identical for either the front or rear seat of the AH-1W. It is important to note, however, that the copilot cannot employ the 20mm in the fixed forward mode. Therefore, when in pilot override, the copilot is forced to use the M-197 with the HSS or lose use of the system. NVG shutdown degradation is more pronounced due to the muzzle flash being in the NVG FOV when shooting off axis. When the HSS helmet is configured with the NVG Helmet Sight Assembly (HSA), the helmet sight reticle cannot be physically employed. This limitation requires a modification in the method the HSS helmet is boresighted in order for the operator to use the NVG's 40^0 FOV as the system's sight reticle.

1. When boresighting NVGs to the HGU-67/P (cobra helmet), only the NVG mount is required.

2. Sufficient ambient light must be available to allow flight equipment personnel to view a distant (approximately 3,000m) aiming point when sighted through the bore-sight scope. A point of light at this distance can be used to boresight at night.

3. With NVGs attached to the helmet and focused on a distant aiming point, have flight equipment personnel adjust the HSS sight to the same point. By doing so, the 40^0 FOV

afforded by the NVGs becomes the sight reticle, as the center of that FOV is aligned with the HSS boresight scope. Ideally, this procedure should be accomplished just prior to manning the aircraft for a mission. This prevents the chance of losing the boresight by removing NVGs from the helmet. Should necessity dictate, boresighting may be accomplished well ahead of launch times, provided NVG and mount adjustments remain unchanged. Degradation will almost surely occur, however, if the NVGs are removed from the HGU-67 helmet.

<<NOTE>>

Prior to using the HSS reticle for day operations, the helmet must be re-boresighted.

Once the NVGs and HSS have been boresighted, the AH-1W crews can effectively deliver 20mm rounds, maximizing the off-axis capabilities of the system. Tracer rounds can be easily acquired and adjusted onto targets. Helmet fit, adjustment of NVG position, alteration of head position and numerous other factors can adversely affect 20mm cannon accuracy.

E. 2.75"/5" Rocket Delivery

Crews of both the DAS configured UH-1N and AH-1W can employ 2.75" rockets using NVGs. In addition, the Cobra has a 5" Zuni capability that can be employed with NVGs. Aircrew may momentarily lose sight of the target due to the NVG shutdown effect produced from the rocket motor and must be prepared to reacquire the target (more pronounced with Zuni's). Care should be taken when firing these rockets on NVGs in a hover or while traveling at low altitudes to prevent inadvertent descent. Aircrew must ensure that safe separation is maintained between the helicopter and the ordnance fragmentation pattern due to compressed target acquisition and firing ranges. Rocket impacts can be easily seen through NVGs. Sight reticle lighting considerations, identical to those discussed earlier in regard to delivering 20mm fires, must also be taken into account to minimize NVG degradation. Similar to use during the day, the use of predetermined mil values/range estimation will increase accuracy.

F. Artificial Illumination on the Battlefield

For all of the recent advances in NVGs, artificial illumination designed to augment weapons delivery will remain a viable consideration on the battlefield. Compatibility can be accomplished with artificial illumination in conjunction with NVG operations. This will call for a distinct division of duties between gunner and pilot, with the gunner concentrating on using the illumination (with unaided vision) and the pilot avoiding direct viewing of the artificial illumination. The tremendous amount of light emitted by most battlefield illumination devices can severely degrade NVG performance if the light source appears in the NVG's FOV. The primary means of artificial illumination on the battlefield has been byflares which are fired by field artillery and mortars. Targets requiring illumination may be beyond the range of supporting field artillery. The use of aircraft-dropped flares could subject the flare-dispensing aircraft to the risk of being engaged by the enemy. To overcome these limitations, the M257 illumination warhead was developed for the 275 inch rocket system. This warhead gives the attack helicopter aircrew the capability to illuminate the target from a safe distance and a low altitude thus reducing exposure to enemy detection.

TABLE 7 - 1. M257 ILLUMINATION WARHEAD PERFORMANCE

Characteristic	MK40 Rocket Motor	MK66 Rocket Motor
Optimum Flare Ignition Altitude	1,800 feet	1,800 feet
Stand-off Range	3,000 meters	3,500 meters
Light Output	1,000,000 Candlepower	1,000,000 Candlepower
Light Duration	120 seconds	120 seconds
Average Rate of Descent	13.0 feet per second	13.0 feet per second
Time for Flare to Deploy	13 seconds	12 seconds

<<CAUTION>>

The intensity of the flare rocket after ignition may cause the aircrew firing these rockets to lose their adapted night vision when performing the mission with the unaided eye. To avoid the loss of night vision, one crewmember should turn his head away from the illuminated area or close one eye when viewing the flare. Crewmembers wearing NVGs should avoid visual line of sight with the rocket. Targets observed beneath the flare and off to the sides are not degraded by the light source when viewed through the goggles.

G. <u>Night Tube Launched, Optically Tracked, Wire Guided (TOW) Missile Firing</u>

Combat necessity may require firing TOW missiles during periods of darkness. Once established in the firing position the gunner removes his NVGs and awaits the flare deployment. The pilot remains on NVGs for obstacle avoidance. Once the gunner is able to acquire a target the pilot must get the helicopter into pre-launch constraints and the gunner fires the missile. It will be necessary for the pilot to increase the HUD lighting intensity once the M257 rockets deploy. The missile motor and IR emitter may momentarily cause the gunner to lose sight of the target. Once the missile impacts the target, the gunner either acquires/engages another target or goggles for egress. NWP 55-3-AH-1, Vol. 1 (Rev. D) AH-1 Tactical Manual describes the procedures for designated illumination and self-illumination.

H. <u>Hellfire</u>

The Hellfire missile does not require the pilot to visually acquire a target prior to launch. Since the AH-1W community has limited self-designating capability, that vital function is normally accomplished from an external source. The limiting factor affecting the employment of Hellfire at night is the ability/inability of the designator platform to acquire targets. Once that has been accomplished and the aircraft is within proper missile capture constraints, the system can be employed at night. Once the missile has been launched, the aircrew can anticipate moderate, momentary NVG shutdown degradation, similar to that encountered with a 5" Zuni rocket launch.

I. <u>AIM-9 (Sidewinder)</u>

The hours of darkness do not degrade the capabilities of the AIM-9L/M. Due to cooler background surfaces and greater target contrast, the seeker sensitivity of the missile is better at night than day. Like the Hellfire, the limiting factor in employing the Sidewinder at night is the ability to acquire and identify a target. When using an AIM-9 at night, the helicopter crew still must visually acquire the target. Night target cueing by an external source (i.e., GCI, E-2C, E-3A, etc.) may be provided until a visual acquisition is accomplished. A night "chance encounter" will require the aircrew to detect and identify an aircraft as hostile. Once this is

accomplished the aircrew must maintain sight of the "Bandit", maneuver into an acceptable firing parameter, and launch the missile. As with Hellfire, the aircrew should anticipate momentary NVG shutdown.

J. Sidearm

The sidearm is employed as in daylight. Its capabilities are not degraded by darkness. Avoid the common tendency to fixate on the HUD and APR-39. Maintain a vigilant scan while maneuvering into parameters.

V. ALE-39

Aircrew must continually evaluate the equipment, capabilities and tactics of our adversaries. The ALE-39 should be programmed to optimize aircrew and aircraft survivability.

A. Flares

Flares are effective against most IR guided missiles. The rule of thumb for IR missiles with IRCCM capabilities is to use two flares per second and for IR missiles with no IRCCM capability, use one flare per second. Man portable IR Missiles are degraded at night by the gunner's ability to acquire targets. Consideration must be given to the signature that flares give off, silhouetting your aircraft or flight and inducing NVG shutdown. For these reasons, pre-emptive use of flares is not recommended at night.

B. IR Flares

The MJU-27B flare possesses a reduced visual signature. These flares have been successfully tested; however, the firing squibs still give off a bright flash and are detectable to the unaided eye at close range. The MJU-27B is the optimal decoy flare for night NVG aided operations.

C. Chaff

Chaff is just as effective at night. Like the flares, the firing squib gives off a bright flash that could cue the enemy to your location.

D. Low Light Level Considerations

1. Muzzle flashes, tracer rounds and rocket motors will create more NVG shutdown affects on the goggles.

2. Target acquisition and engagement ranges will decrease.

Night Vision Goggle (NVG) Aided Operations

SECTION VIII: NVG SHIPBOARD OPERATIONS

I. Introduction

World events clearly demonstrate that the possibility of elements of the Navy/Marine Corps combined arms team being placed in harms way is a very real one. Should that possibility become a reality, it is equally clear that the CATF will exercise every means available to him to preserve his assets. This will include the standard practice of "darkened ship" operations and the use of NVGs in helicopter shipboard operations. The precedent for NVG operations aboard LHDs/LHAs/LPHs and LPDs/LSDs and other aviation capable ships has long been established by the Marine Corps and other USAF and Army special operations units.

II. Procedures

The procedures for NVG carrier qualifications are the same as those for day carrier qualifications (Charlie Pattern). The pattern is flown at 300 feet above the water, 80 knots, and approximately 1,600 feet abeam (2 LPH or 1.5 LHD/LHA ship lengths). A correct abeam position should be stressed because if the pattern is flown too close, a new pilot will have difficulty adjusting as he turns to final. If the abeam position is flown too wide, the pilot tends to lose visual detail of the ship and ends up flying a long straight-in to the spot, which also interrupts other aircraft flying the correct pattern. Consideration should be given to making any extensions of the standard Charlie pattern upwind, in order to arrive at a proper abeam position. The pattern should not be extended downwind. Ambient illumination needs to be considered, as well as sun/moon position when conducting NVG aided ship operations. The ships superstructure can create shadows that will affect the amount of ambient illumination during the terminal approach/hover over the spot and the visual cues required for closure rate control.

A. NVGs for Shipboard Personnel

Evaluations and experience indicate that NVG operations are greatly facilitated by outfitting the Air Boss, flight deck supervisor(s) and LSEs with NVGs. Modified full face NVGs, with skullcaps, are best for flight deck personnel, since this allows them to wear their standard cranials while retaining a clear view of the aircraft in the pattern. This is particularly true for those nights with a Lux value of 0.04 or less. On nights with a Lux value greater than 0.04, the deck crews are able to maintain visual reference with the aircraft in the pattern, as well as move about on the flight deck safely without the use of NVGs. This is due to the ambient light reflected off of the moon. The Air Boss is afforded a better capability of maintaining control of the pattern aircraft with the NVGs, although his goggles may be degraded by the glare cast off of the glass in Pri-Fly. A requirement for compatible lighting in Pri-Fly is essential for further aggressive NVG aided shipboard operations. Additional recommendations for NVG operations

aboard aviation capable ships are found in the current edition of the LHA/LPH/LHD NATOPS manual, NAVAIR 00-80T-106.

B. Ship's Lighting

The lighting discipline maintained by the ship is a major concern for the Captain when the ship is underway. It is even more important when NVG operations are being conducted. Consult the applicable COMNAVSURFPAC and COMNAVSURFLANT SOP's to determine the lighting requirements of the deck, navigation and mast lights. These SOP's are in message format.

C. Aircraft Lighting

Aircraft in the ship's landing pattern should utilize normal night lighting to allow Pri-Fly to track their progress. A blue lens flashlight may be substituted for those signals calling for red dome lights or red lens flashlights. In addition, the following lighting procedures have historically demonstrated their utility:

1. Anti-collision Lights. Bottom rotator secured to preclude the blinding effect of the light on the aircrew, deck crew and Air Boss.

2. Navigation Lights. Set at dim. Normal night DLQ lighting procedures apply.

3. Tail light. Secured.

4. Formation and Blade Tip Lights. Set at three clicks or mid range for low light levels and gradually increase the intensity as the light level increases. The formation and blade tip lights will aid the deck crew in keeping track of the aircraft while in the pattern and gives the other aircraft on short final a visual reference to the tip path plane of the aircraft turning on deck.

5. Hover/Searchlight. Secured.

D. Crew Coordination in the Landing Pattern

1. On NVGs, the pilots have the opportunity to maintain a visual reference with the horizon at all times. They can use the NVGs as another part of their instrument scan while executing an ITO. During this time, the pilot not at the controls should be assisting the pilot at the controls, by verifying a positive climb and an increase in airspeed.

2. Aircrewmen should keep the pilots informed of their aircraft's position in the landing pattern as well as the location of the other aircraft in the pattern.

3. Due to greater visibility, initial NVG carrier qualifications should be accomplished from the right seat. This however, will not preclude the instructor pilot from executing a landing from the left seat at his discretion.

4. Further crew coordination guidance can be obtained from the parent MAG and/or MAW SOP's covering night flight operations in a shipboard environment.

E. Approach and Landing

1. Incorporation of an instrument scan along with outside cues is advisable for the pilot at the controls until turning final. At that time, his attention should shift outside of the aircraft to maintain glide slope and closure rates.

<<NOTE>>

The limited FOV and associated lack of visual cues on the NVGs can affect the pilot's perception of closure rates. An important fact to remember is that the closer you get to the ship, the bigger it becomes in the FOV. The key is closure rate control.

2. The pilot not at the controls will assist by providing air speed, radar altitude, angle of bank, pitch attitude and VSI readings as appropriate.

3. The aircraft should arrive on final with 40 to 60 KIAS. The pilot at the controls should scan the entire ship and flight deck to maintain situational awareness and closure rate. A constant angle approach should be maintained. "Stair stepping" and excessively shallow or steep approaches should be avoided.

4. Approaches to landings on LPH/LHA/LHD/LPD/LSDs should be planned to arrive in a hover over the intended landing spot. From that position, the pilot can be directed down by verbal cues from the aircrewman and visual signals by the LSEs. The key to landing on the spot has to do with the scan of the pilot at the controls. The better his scan, the better he will be at detecting any relative drift. Constant scanning out to the front and to the side (as in the scan used in CAL's), will produce the best results in maintaining a stable hover over the spot.

5. LSEs on all decks should utilize the same hand and arm signals during NVG CQs, as they would during unaided night CQs. Their positioning on the flight deck will not change in any respect from normal.

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Night Vision Goggle (NVG) Aided Operations

SECTION IX: NVG AERIAL REFUELING PROCEDURES

I. Introduction

NVG aerial refueling (AR) is desirable in order to avoid de-goggling and to avoid detection near the battle area while extending the range of the assault force. NVGs also provide more visual cues than unaided night refueling under most conditions. Accordingly, this section is provided to alert aircrew to factors that should be considered for NVG aided refueling.

Helicopter NVG aerial refueling operations utilize all normal procedures and emission controlled (EMCON) aerial refueling procedures as described in the KC-130 Tactical Manual, NWP 55-10-KC130, and as further amplified by the NATOPS Air Refueling Manual, NAVAIR 00-80T-110. Procedures and checklists that are covered by the respective NATOPS Manual should also be reviewed and used for planning, coordination and execution.

II. Concept of Operations

The NVG aerial refueling control point (ARCP) is a pre-briefed point over the ground or along the preplanned route that is easily identified by terrain features. The NVG aerial refueling control time (ARCT) is the planned time when both the receivers and the tankers will arrive at the ARCP. NVG refueling is accomplished in a low altitude environment (as directed by current directives) either along the route or in an orbit over a known point (i.e., CP, RP). Selection of the route and the NVG ARCP should preclude detection by enemy forces.

III. Mission Planning

The nature of the mission will dictate many of the parameters involved in a helicopter aerial refueling mission. A thorough threat assessment and terrain analysis must be made to properly select the aerial refueling area, altitudes and routes to and from the operation area. Additionally, the number and sequencing of helicopters will dictate the size or length of the ARCP.

A. <u>Brief</u>

The following essential items (as a minimum) should be coordinated prior to any NVG aerial refueling operations:

1. <u>Altimeter Settings</u>. The altimeter setting to be used will be briefed to all flight crews. This will usually be the setting of the nearest airfield to the ARCP. However, as necessary, the standard pressure altitude (29.92 Hg) may be used.

2. Visibility. Minimum visibility for an NVG rendezvous for aerial refueling is 5 nautical miles. The minimum suggested effective illumination for NVG contacts is equal to the minimum illumination dictated by SOP. Flight through clouds after contact is not recommended. Unfortunately, due to the ability of NVG to see through light layers of clouds and precipitation, aircrew may not be able to readily detect clouds. Therefore, crew coordination briefs must emphasize remaining alert to gradual reductions in visual acuity that could indicate impending IMC. In addition, an in-depth analysis should be conducted for illumination along the route and at the ARCP for the duration of the refueling evolution.

3. ARCP. As previously mentioned, the planned ARCP should be a dominant terrain feature, easily recognized from numerous approach angles.

4. Aerial Refueling Control Time (ARCT). Takeoff times should be planned to reflect arrival time over the ARCP at the planned ARCT.

5. Refueling Altitude. The refueling altitude should be the lowest usable altitude to avoid enemy detection while maintaining a margin of safety. Awareness of low altitude turbulence, low moon angle and terrain shadowing may render some altitudes unusable.

6. Refueling Course. The refueling course should also be planned considering METT-T, emphasizing illumination requirements. The moon angle and azimuth become important here when considering formation requirements and pilot to drogue perspectives.

7. Fuel Requirements. Brief not only the scheduled on-load, but also the bingo plan for all aircraft, to include time, fuel required and divert fields.

8. Pod Lighting. Coordinate with the tanker to ensure that the pod and hose illumination lights are off prior to reaching the observation position. KC-130 pod lights should be dim and/or taped. The tape should have a hole that is large enough to see the light color. KC-130 pod lights should not be set to bright, as receiver vision will be severely restricted.

9. Non-NVG Compatible External Lighting Equipped KC-130 When the receivers are established in port observation, tanker external lighting should be configured as:

   (a) ANTI-COLLISION LIGHTS – **OFF**

   (b) NAVIGATION LIGHTS - **STEADY DIM (Tail OFF)**

   (c) FORMATION LIGHTS - **OFF**

   (d) LANDING LIGHTS – **OFF**

   (e) TAXI LIGHTS – **OFF**

   (f) LEADING EDGE LIGHTS – **OFF**

   (g) POD & HOSE ILLUMINATION LIGHTS – **OFF**

10. Receiver External Lighting. Receiver probe light should be off or set no higher than 50%. If receiver probe light is opened 100% it restricts the KC-130 loadmaster's ability to see the receiver and limits the visibility of hose range markings. Receiver external lighting should be configured as:

    (a) Anti-Collision - **OFF** (DASH-1) / **ON** (Upper DASH-2)

    (b) NAVIGATION - **OFF** (DASH-1) / **ON BRIGHT** (DASH-2)

    (c) PROBE TIP LIGHT – **OFF**

11. Tanker/Receiver Signals. EMCON signals shall be in accordance with NAVAIR 00-80T-110 or as modified by prior coordination between the tanker and the receiver. The crew chiefs should be briefed on the EMCON signals as they can assist the pilots.

B. Rendezvous Procedures

The recommended rendezvous procedure for training is to have the tanker conduct the rendezvous at the ARCP at the ARCT, hoses in and normal external lighting. The receivers should climb or descend to join the tanker after the tanker has passed the receivers on the starboard side and has taken the lead. The receivers request port observation and a switch to NVG AR external lighting configuration. The hoses should be extended with the receivers in the observation position.

<<NOTE>>

The move from the observation to the stabilized position should be slow and deliberate in order to achieve the three to five feet stabilized position. Clearance to move to the stabilized position will be given by the tanker, via light signal.

<<NOTE>>

The KC-130 Loadmaster should be equipped with NVGs and a flashlight with a blue filter lens for all NVG/EMCON signaling. An alternate method of signaling the receiver would be to use the ALDIS lamp with an NVG compatible filter kit installed or IR chemsticks.

C. Contact/Fuel Transfer

When clearance is received from the tanker via the light signal, the receiver maneuvers into a three to five foot (probe to drogue) stabilized position. Movement to contact remains the same as for day plugs. The pilot should stabilize in the contact position prior to moving to the refuel position.

<<NOTE>>

Caution is required by the receiver helicopter during join-up to the stabilized position in order to avoid the tanker's wake turbulence.

<<NOTE>>

Adjusting the probe light brightness with the rheostat can be accomplished to emit enough light to illuminate the drogue yet not be visible to the eye. Fifty percent is the maximum recommended setting for the probe light, as brighter positions shutdown the KC-130 loadmaster's NVGs. The brightness of the copilot's spot light (with or without an IR lens) may also be reduced to provide the additional cues required by the pilot. The shutdown effect on the KC-130 loadmaster's NVGs must still be considered. When the probe light is used, a shadow cast at 4:30 on the drogue will provide additional line-up cues.

Hose range markings should be visible to the copilot and should be given to the pilot in terms of trends (e.g., "You're at MIN distance and closing"). The copilot can assist with wing and flap cues for line up on the tanker. Pre-briefed aircrew coordination is an absolute requirement if effecting contact. The aircrewmen should be used to monitor fuel upload and tank selection, while the pilot not on the controls acts as a safety monitor/back-up. If the pod refueling signal lights have not been taped, the hose range markings will be harder to see until in the refueling range.

D. <u>Disconnect</u>

The procedures defined by NATOPS for disconnect and post refueling will apply here. If other than NATOPS procedures are to be used, they must be pre-briefed. A rule of thumb to consider for the disconnect is to place the hose at the 6 o'clock position on the pod, and line up the wing flap with the pod support. This will provide both proper line up and altitude forthe disconnect.

E. <u>Training</u>

Initial training should utilize a building block approach. Start the training in high light level at a higher altitude, with communications normal before attempting these procedures in lower illumination or under EMCON conditions.

Night Vision Goggle (NVG) Aided Operations

SECTION X: NVG LOW LIGHT LEVEL (LLL) CONSIDERATIONS

I. Introduction

To take full advantage of the night environment, the AN/AVS-6 NVGs have been designed to perform under LLL conditions, defined as illumination less than 0.0022 lux. Through proper training and an understanding of the capabilities and limitations of the NVGs in reduced ambient light conditions, pilots can safely conduct low light level operations. This section is intended to provide pilots information on the peculiarities of NVG low light level operations.

II. NVG Performance

NVG performance in conditions of low ambient illumination is characterized by decreased resolution, visual acuity, contrast and hazard detection range. Low ambient illumination also creates an increase in the blooming effect from artificial illumination sources (i.e., aircraft lighting, muzzle flashes, rocket motors, flares and cultural lighting, etc.). The decreased resolution, visual acuity, contrast and hazard detection ranges is a result of the small amount of light (photons) available to strike the photocathode. Since the photocathode is not completely saturated by light, the intensified image presented to aircrew at the eyepiece lens possesses "scintillation" or "video noise", commonly referred to as "graininess", "sparkling" or "snow". This situation is similar to television reception with a weak signal. The picture quality is poor and will remain so until the signal becomes stronger. Signal strength is a function of illumination with a stronger signal occurring with higher light levels.

Under LLL conditions, the affect of incompatible lights on the NVG I^2 tube's automatic gain control circuits results in an increase in NVG image blooming. As described in Chapter 2, the ABC circuit functions to maintain constant output brightness at the eyepiece lens. Under LLL conditions, the ABC is at maximum gain. When a light source enters the NVG FOV, the light appears extremely bright with a significant halo effect. If the light source is bright enough, as with a flare, both the NVG's Bright Source Protection (BSP) and ABC will be activated to reduce system gain. The resultant decreased gain decreases the intensified image contrast and increases the difficulty of seeing the surrounding terrain features

Visibility is further degraded by the halo effect or blooming around the light source. This phenomenon occurs when electrons from the area of the photocathode, which receives the bright light source photons, "bleed over" into neighboring channels of the microchannel plate (MCP).

The above-mentioned NVG image nuances are not necessarily unique to NVG performance below 0.0022 lux. However, these effects become much more significant in determining NVG performance in the low light regimes than they do in high light conditions. Mission planning should reflect these LLL challenges

III. Aircraft Lighting

Low ambient light levels cause the automatic gain control feature on the NVGs to operate in such a manner that the goggles receive as much light as possible. Aircraft lighting configurations become very important in these lower light conditions due to the increased blooming effect created by the increased gain.

A. Interior Aircraft Lighting

The 625nm minus blue objective lens filtering cut-off incorporated in the AN/AVS-6 NVG in conjunction with the NVG compatible cockpit lighting configuration has alleviated much of the windscreen glare that was associated with the 2nd Generation NVGs (AN/PVS-5). However, due to the increased gain of the AN/AVS-6 in low light level conditions, even the smallest escape of unfiltered light in the cockpit will have a negative (blooming) affect on the goggles either directly or through windscreen glare. It is important that all cockpit lighting filters and covers fit properly and that all instrument and console lights are adjusted properly to achieve maximum performance from the NVGs.

B. Exterior Aircraft Lighting

Exterior lighting may not only affect aircraft in formation but the pilot's ability to aviate his own aircraft as well. The port navigation light and white taillights on all aircraft create a large halo/blooming effect that washes out aircraft identifying features for formation even at their lowest intensity. The port navigation light also makes it very difficult, if not impossible, for pilots as well as crewchiefs and observers to detect hazards or visual cues on the port side of their own aircraft during terminal/landing phases of flight.

C. Anti-Collision Lights

Anti-Collision lights have a similar effect as the port navigation light due to the red color. However, the intensity of the anti-collision light is not adjustable. The strobe or rotating effect of the anti-collision light can also induce vertigo due to the flashblinding effect on the NVGs. Flying with the rotators off is not a solution to the problem, if we are to remain visible to the unaided pilot.

D. Searchlights

The use of the IR searchlights will be at the discretion of each pilot and crew. Keep in mind that the IR light will illuminate, and if positioned correctly, enhance visual acuity within its beam. However, it darkens and reduces visual acuity of everything outside of it's beam. Another consideration is the effect that the searchlight has in a dusty LZ where the light is being reflected off of the dust particles. The increased gain of the goggles increases the effects of brownout.

E. IR Covert Lighting

IR lighting currently being integrated into USMC helicopters, although advantageous, does not replace the unaided visual requirements outlined in MCO P3500.14 (T&R Vol. 1). Use of IR lighting (IR spotlights, navigation lights and anti-collision lights) increases situational awareness/flight deconfliction and should be thoroughly planned for and briefed by the flight lead based upon the METT-T considerations

IV. Terrain Flight

Because of reduced visual acuity during LLL NVG aided operations, terrain flight may be a necessity. There are two primary considerations when flying at TERF altitudes (< 200ft) under LLL conditions. These are hazard detection/avoidance and terrain feature recognition for navigation. Both of these will be reduced due to those factors discussed in paragraph two of this section. The following additional factors should also be considered:

A. Enroute

1. Navigation. Navigation at TERF altitudes under LLL conditions calls for greater reliance on time, distance and heading due to limited the visibility of the horizon and key terrain features.

2. Altitude. Factors that need to be considered are:

   (a) Higher altitudes will reduce visual acuity but may also reduce the number of obstacles in the path of flight.

   (b) Lower altitudes will allow for better visual acuity and in most cases better hazard detection. However, hazard avoidance reaction time is reduced.

3. Airspeed. Slower airspeeds and a more vigilant scan are required to increase reaction time. This allows pilots more time to detect and react to obstacles, targets and terrain features.

B. Approaches/Landings

Obstacles and reference points may not be as apparent approaching or in the LZ due to reduced visibility under LLL conditions. The pilot's ability to determine closure rate is also affected. Therefore, a more vigilant scan by all crewmembers and sound crew coordination is a necessity. Consideration may be given to utilizing the IR searchlights on final approach to the LZ. This may help in illuminating obstacles and selecting hover reference points provided the zone is not too dusty. Another significant consideration is the crewmembers' ability to accurately judge altitude during the landing transition In some instances, it maybe necessary to call altitudes from the radar altimeter until well below 50 feet. Below 50 feet, the crewchief/observer will be able to judge altitude with greater accuracy.

Pilots should consider selecting larger landing zones as ambient light conditions decrease. Two other factors to consider are shadowing in zones surrounded by trees and the affects of dust in zones created by loose packed soil or sand.

1. Shadowing. A clearing in trees will appear darker since there is a limited amount of ambient light from directly overhead. The shadowing affect is created by the trees blocking ambient light other than that from overhead. Use of the IR search light in this condition may be helpful.

2. Dust. Dust circulating through the rotor system tends to cause brownout or at least restricted visibility. This is exacerbated under LLL conditions with visibility already restricted. Utilizing an IR search light in these conditions only tends to amplify the brownout condition. Another illusion associated with a dusty LZ is referred to as the "sparkle" effect. This is created by static discharge from the rotor system reacting with the dust and/or sand particles. It is amplified when gain on the NVGs is increased and can have the same degrading effect as artificial illumination in the NVGs FOV.

C. Formation

Pilots must reduce aircraft separation in their formation to acquire the visual cues necessary to maintain position in formation. This is especially important when flights are being escorted. Selection of exterior aircraft lighting configuration and intensities is very important for maintaining visual cues by minimizing the halo effect on the NVGs. Lead must fly the most stable platform possible and avoid abrupt maneuvering.

D. External Operations

1. Lighting. Care must be taken when setting-up zone lighting for LLL NVG external operations. As previously discussed red and IR chemsticks can be used as reference lights. In addition, it is recommended that directors utilize red or IR chemsticks as wands during low light level operations. Blue or green chemsticks should be avoided due to their spectral output and reduced detection through the NVGs at long distances

2. Crew Coordination. Precise hover skills and sound crew coordination are the keys to success in hooking-up and delivering external loads in low ambient light conditions. The pilot's visibility is somewhat restricted during external operations. Therefore, direction from the crewchief as well as back-up from the pilot not at the controls is imperative.

E. Weapons Employment

As mentioned earlier in this section, light created from firing weapons will create significant blooming on the NVGs. Utilizing firing techniques discussed in Chapter 7, section VII will limit these degrading effects. Additionally, pilots may consider increasing altitude and increasing separation from wingman before firing. Pilots must also consider the adverse effects of expendable chaff and flares on wingmen.

Target detection ranges will be significantly reduced during low light level operations. Planning factors should take into account these reduced acquisition ranges and attack patterns/formations should be kept simple for ease of control under the darker conditions.

F. Shipboard Operations

The ability to see the horizon and ship structure with NVGs makes night shipboard landing less difficult. However, the reduced visibility associated with NVG under LLL conditions makes it difficult to determine closure rate. Therefore, pilots landing aboard ship must

ensure that they fly precise patterns and well-controlled approaches. Another consideration for shipboard operations is the lighting configurations of both the ship and aircraft. All of those considerations discussed in Chapter 7, section VIII apply. It is imperative, however, under LLL conditions that all lighting is NVG compatible. Even the slightest amount of non-NVG compatible light is intensified and will degrade NVG performance.

G. Planning Considerations

At this time there is no black and white determining factor for go/no-go illumination for LLL NVG aided operations. There are ongoing efforts to enhance planning by having the Light Level Planning Calendar incorporate weather and terrain data and by employing resolution/contrast systems that can be used in the field. However, it still requires good headwork and sound judgment on the part of everyone involved from unit commanders down to pilots, crewchiefs and aerial observers. Several factors must be considered when planning for low light level operations under LLL conditions. Below is a list of those planning considerations based on discussions earlier in this chapter.

1. Planning for low light level NVG aided operations under LLL conditions should allow greater time to complete a given mission due to slower airspeeds, higher aircrew workloads and greater difficulty in navigation.

2. Formations should be flown tighter.

3. Aircraft and landing zone lighting will be critical.

4. Target detection ranges will be significantly reduced and weapon effects will be more pronounced.

Checkpoints for navigation routes should be very prominent and if possible closer together. Further, IP selection distance from LZ/Objective area is critical to prevent disorientation during NVG aided operations conducted under LLL conditions.

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Chapter

8

Night Vision Goggle (NVG) Tacitcs

SECTION I: NVG MISSION PLANNING

I. NVG Mission Planning Overview

This section on NVG mission planning is intended to assist pilots in preparation for planning NVG aided missions. The considerations are broad in scope to enable all communities to use this section as a guideline for any NVG aided mission, for training or for combat operations.

A. Mission

Whether it's a training flight or a real world contingency, pilots must know their ultimate objective or goal. They must identify where they are going, when they need to be there (i.e., L-hour/TOT), how they will get there, how many troops or how much gear needs to be transported, what needs to be killed or suppressed and what the actions will be in the objective area.

B. Threat

When considering the threat during NVG missions we must look at how effective the enemy is under the cover of darkness. Areas of particular attention are:

1. Detection capability at night. Visual or optical with night vision devices to include image intensification systems and thermal systems as well as radar or electronic capabilities.

2. Weapons system capabilities at night.

3. Possible use of artificial illumination.

C. Environmental Considerations

Environmental conditions require close scrutiny when planning for any NVG aided mission. The following environmental conditions and how they will affect the entire flight must be considered:

1. Illumination. Ambient as well as artificial illumination must be considered. As discussed earlier the only approved means of determining available ambient illumination is the Global Light Level Planning Calendar. There are several uses for the Global Light Level Planning

Calendar as discussed in Appendix C of this manual. The information that is important for any NVG flight is:

(a) Solar and Lunar Lux. Determines the amount of ambient light.

(b) Lunar Elevation and Azimuth. By knowing the relative position of the moon and using the shadow formula one can determine shadowing along the route and in the objective area.

(c) Solar Elevation and Azimuth. Determines the effects of a rising or setting sun. Solar Lux will degrade NVG performance anytime during civil and nautical twilight (sun is within 12^0 below horizon) that the sun enters the NVG FOV. If operations require aircraft positioning into a rising or setting sun, consideration should be taken to plan missions timing so that the sun is at least 15 degrees below the horizon

2. Weather. Weather will influence NVG operations as discussed in Chapter 1. The Global Light Level Planning Calendar does not take weather into consideration and therefore it is the mission commander's responsibility to set go/no-go criteria based on weather. Particular areas of interest are:

(a) Cloud Cover. This affects ambient light levels and creates shadows cast by clouds that can create visual illusions.

(b) Atmospheric Obscurants. These phenomena include haze, fog, snow, rain, smoke, dust, etc. that reduce NVG detection ranges.

3. Terrain. When considering terrain, the planner should not only look at contour of the terrain for possible shadowing but also the relative reflectivity of the terrain. Ultimately, terrain contrast will drive NVG performance and the visual cues that are available for NVG aided operations.

D. Assets Required

From the mission requirements one can determine the number of aircraft required to accomplish the mission. With the number of aircraft known, a decision must be made on the size of formation(s). Several factors must be considered in making this determination:

1. Illumination. The amount of ambient illumination will affect formation size due to the ability of dash last to clearly see the lead aircraft. The size of a formation and the separation between aircraft and escorts must be considered.

2. Enemy Detection capability. The ability for the enemy to detect larger flights.

3. Organic Capability. The number of assets and trained crews available to include escorts.

E. Goggle/De-goggle Procedures

A determination must be made on when and where crews will goggle and de-goggle (Chapter 7, section III).

II. NVG Map Preparation Considerations

Initial steps in planning preparation should include assembling maps and photo imagery. Below is a list of maps and other essentials the planner will need:

A. Joint Operation Graphic (JOG)

The JOG (either 1501 JOG-ground or the 1501A JOG-air) is a 1:250,000-scale map that is normally the primary map for planning and flying the enroute portion of a mission. The JOG is configured with both latitude/longitude markings and UTM grid.

B. VFR Sectional (CONUS)

The 1:500,000 VFR sectional is updated semi-annually and provides accurate information on major towers, airports, beacons, power lines and cities. The sectional should not be used for low level flight due to its scale, but rather as a vehicle to transfer pertinent information to the primary map.

C. Tactical Map

The 1:50,000-scale tactical map should be used to accurately locate and confirm unique terrain features along a proposed route of flight for transfer to the JOG. This map is of primary importance as a planning document for the objective phase of a mission due to the detail it can provide regarding IPs, LZs and other factors that require utmost accuracy. The tactical map is recommended exclusively for operations within 5 nautical miles of the objective area. Use caution when transitioning to this map from the JOG in flight by selecting a key terrain feature as a transition point since relative motion will change significantly between the 1:250,000 and the 1:50,000.

<<NOTE>>

Determine magnetic variation from the tactical map. Magnetic variations on aeronautical charts are computed for normal flight altitudes, which could be 10,000 feet or higher.

D. Chart Updating Manual (CHUM)

The CHUM is a supplementary publication, with bulletins published quarterly, that can be consulted for the most current information on potential low level hazards (i.e., towers, power lines, etc.).

E. Other Supplementary Sources

For training and real world contingencies, a number of other sources are available to provide information for routing, checkpoint and landing zone selection. Aerial photos, especially those taken from low altitude oblique angles, can be extremely helpful during the planning sequence. These should be requested for the objective area, holding areas, checkpoints, LZs and portions of the route when conflict exists between maps. Where available, video tape footage gathered by UAV or any other appropriately configured platform can provide real time information on the objective area, holding points or specific routes. The benefits of

automated mission planning systems currently in the fleet (CHAMPS, TAMPS, PFPS, TOPSCENE, etc.) should not be overlooked in planning your mission.

<<NOTE>>

Though it may not be possible for real world contingencies, it is strongly recommended that a visual reconnaissance be conducted during daylight over the planned route of flight and in the objective area for identification of any potential hazards.

III. Specific NVG Mission Planning Areas

A. Actions in the Objective Area

What takes place or does not take place in the objective area will more than likely determine the success of the mission. Therefore we must focus our attention to the finite details of what should happen from the IP inbound to the objective area. The following areas should be covered in detail and must be understood by all participants:

1. Landing Zone Considerations. Landing point selection in both the primary and alternate landing zone.

2. Escort Considerations. Escort procedures, attack positions and firing point selection (engagement areas, fields of fire, target prioritization, engagement sequence, target analysis, etc.).

3. Objective Area Routing Considerations. Routes from IP to both primary and alternate LZs. Threat and terrain permitting, these routes should be into the wind to lessen early detection by the enemy and to facilitate a straight-in landing.

4. Objective Area Flow Considerations. Sequencing and separation of aircraft in the objective area must be planned precisely with alternate plans equally detailed and clearly understood.

5. LZ Identification. LZ identification and marking must be considered.

6. Enroute Considerations. Once actions in the objective have been thoroughly planned, planners must consider how to get to and from the objective area.

B. Route Selection

The route to and from an objective area should be tactically sound, but not so difficult as to deter successful navigation. Alternate ingress and egress routes should always be planned in the event the primary route is blocked, due to weather or threat. To help offset difficulties encountered in navigating on NVGs, routes should be planned to be as simple as tactically allowable, preferably in straight lines between checkpoints. Checkpoints should be planned to circumnavigate any terrain or obstacles that would compromise the tactical integrity of the route. In addition to these generic considerations the following proven specifics are provided as guidelines for NVG route selection.

1. Cultural Area Considerations

(a) Avoid brightly-lit areas, roads and population centers. These areas and their associated ambient light levels may degrade NVG effectiveness.

(b) Avoid navigational aids and airports because of hazards associated with other aviation operations and to prevent detection by radar associated with these facilities.

(c) Anticipate wires, including parallel sets, near roads, towers and buildings isolated in open fields. Look for associated posts, poles and stanchions. Flight directly over the poles will aid in obstacle clearance. Unexplained linear cuts in vegetation are also useful in locating wires.

(d) Avoid towers and do not use them as checkpoints. Towers are generally lit with bright lights that degrade the NVGs capability. They normally have guide wires associated with them that cannot be detected with NVGs and present an added hazard.

2. Solar and Lunar Considerations

(a) Plan to negotiate large valleys on the illuminated side with respect to the moon's position. This will avoid shadows cast off terrain by the moon that silhouettes terrain features for navigation. When traveling east to west (or west to east) in mountainous terrain, use narrow valleys or passes to cross north-south ridgelines to avoid flight in shadows. Shadows may aid in concealing the aircraft to some degree, but also make identification of hazards and checkpoints difficult. The decision to fly in shadows should be weighed against aircrew proficiency and METT-T.

(b) Avoid a route that heads directly into a low rising or setting moon/sun. If the timing of the launch forces this condition, plan to proceed in a zigzag advance across the route of flight using an approximate 30^0 offset to either side. This technique should help to counter the degrading influence of either the moon or sun on the NVGs.

(c) Avoid being silhouetted by the moon during all phases of the flight and pay particular attention while on approach into the objective area.

3. Additional Route Considerations

(a) Do not fly parallel to roads, rivers, railroads or other obvious avenues of approach. When possible, cross these at right angles to minimize exposure time.

(b) If the threat and terrain permit, plan to fly the final leg, IP to the objective area, into the wind to reduce the noise signature and early warning in the objective area.

C. Check Point (CP) Selection

After a general route has been determined, checkpoints to control movement along the route must be selected. Appropriately spaced checkpoints serve not only as a reassuring update of the progress of the flight, but can also be positive control features to signal events that are to take place during the flight (radio check-ins, penetration checklists, etc.). In selecting checkpoints, the following areas should be considered.

1. CPs should be unique natural or man-made features, easily detectable at a distance. Furthermore, they should be identifiable from a number of angles (not just when passing overhead) to facilitate reorientation if the flight is approaching the CP from a direction not originally planned.

2. CPs should contrast with surrounding terrain by shape, size, color or elevation.

3. If possible, CPs should not be selected in the vicinity of towns, since towns invariably grow and may alter the CP or make its detection difficult. Similarly, brightly lit areas should be avoided during CP selection, as the CP may be made indiscernible.

4. A CP when possible, should be easy to confirm by association with adjacent prominent features to alert the pilots to its location.

5. Moon phase (percent illumination), elevation and azimuth throughout the course of the flight must be considered. CPs should not fall within the shadow cast by a terrain feature.

6. Select prominent barrier features near CPs, particularly where a turn is planned. The barrier is used to alert the pilot that he has over flown a CP. It is often better to discard a good (i.e., easily identifiable) CP with no barrier feature in favor of a not so good CP with a solid barrier feature.

7. Make note of the MSL altitude of each checkpoint during planning to aid in CP confirmation when flying in mountainous or hilly terrain.

8. If possible, CPs should be no further than 20NM apart in terrain of varying elevation. In this environment, errors in timing may occur due to inadvertent airspeed variations while climbing and descending to maintain TERF altitudes. Keeping CPs relatively close can reduce these types of errors. When terrain is level, distances between CPs can be comfortably extended to up to 40NM. In all cases, however, the final 100NM of a navigation route should have no less than fiveCPs.

9. Select intermediate reference points between CPs to ensure course confirmation and route timing. The lower the ambient light level, the more intermediate reference points should be used.

10. The first and last CPs of a route are the most important. An easily identifiable feature must be utilized for both of these, even if a route must be altered slightly. These checkpoints should be approximately five nautical miles from the departure point or the objective area to ensure accurate timing and navigation. The final CP should not involve a turn if at all possible. Never have a final leg longer than five to eight nautical miles from the initial point (IP) to the objective. This precludes compromise of the objective and facilitates accurate timing.

D. Tactical Airspace Management

When planning any mission, consideration must be given to how aircraft will integrate and deconflict in the training area or on the battlefield. The simplest way to ensure this integration and deconfliction is to "see and avoid". However, due to several limiting factors (i.e., aircrew tasks, ambient lighting, etc.) "see and avoid" does not ensure successful airspace management. A systematic approach to sequencing aircraft to/from and in the

objective area is necessary. There are several ways in which this can be accomplished. Time separation, phase lines, separate routing, altitude separation, rendezvous points (RPs) and holding areas can be used individually or in combination. RPs must be identified by their location, altitude, airspeed, direction of turn and inbound/outbound heading as well as what time each flight is to arrive or depart. Sequencing into and out of the objective area should be specified as flowing clockwise or counterclockwise. This flow can be controlled by timing or by a visual or radio signal. The planning for intermediate landing points or holding areas, and the return to the originating airfield should be as detailed as the objective area plan, especially when large numbers of aircraft are involved. Above all, ensure that there is a properly planned flow sequence that all pilots understand.

IV. NVG Mission Planning and Execution Mechanics

A. NVG Map Preparation

With the ability to look under the AN/AVS-6, maps can be read much the same as during daytime flights. However, due to limited lighting and other considerations, it will be necessary to prepare maps for ease of use in NVG operations. The following guidelines are presented for NVG map preparation. Figure 8-I-1 is one example of how to prepare a map for navigation with NVGs.

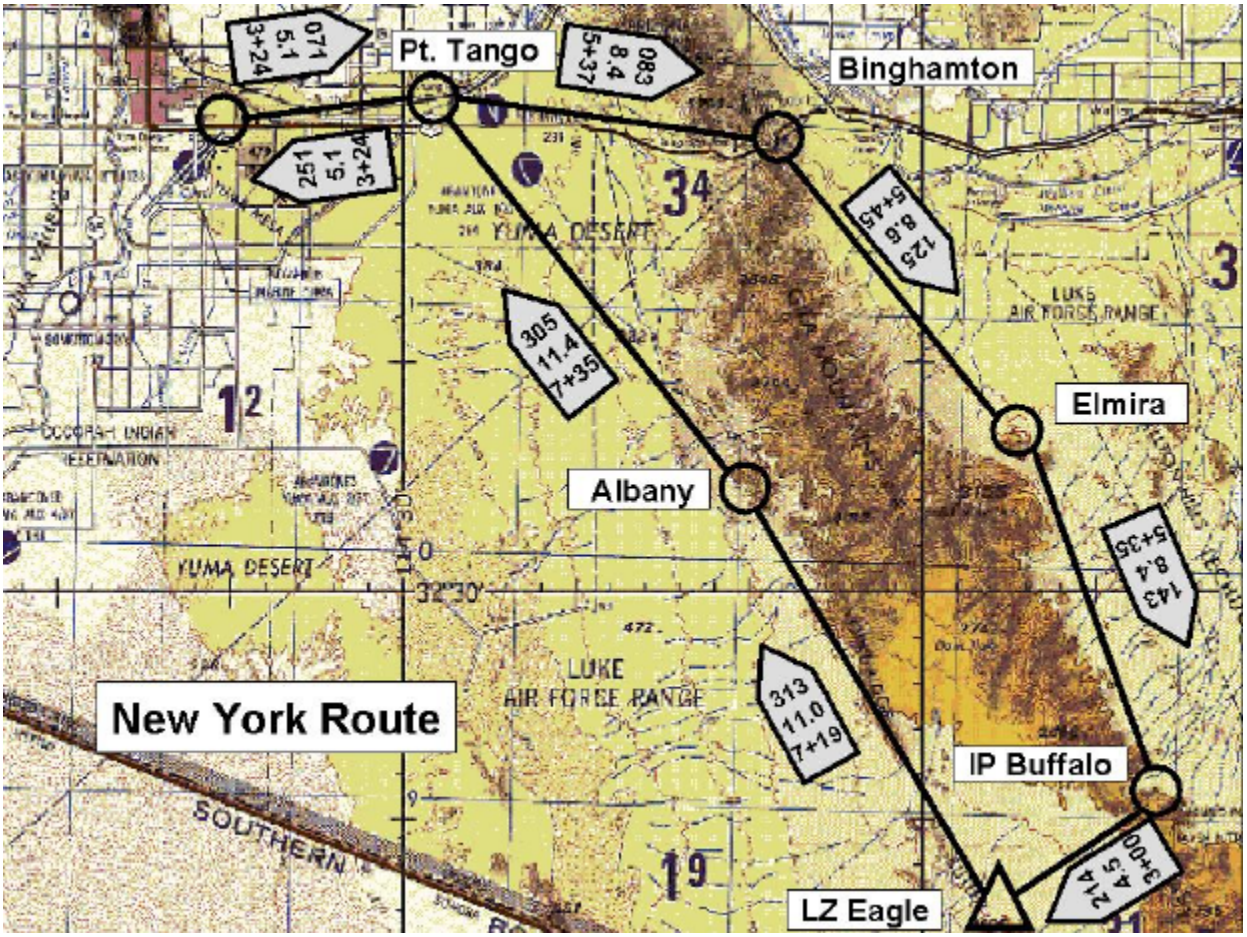

Figure 8 - I - 1. Sample NVG Map

1. The JOG is the primary reference for NVG navigation. Map preparation must be meticulous since its accuracy is paramount to successful navigation.

2. Place the CPs and route on the map first.

3. Transfer hazards and other key features from adjunctive sources (i.e., VFR sectionals, CHUM, photos, etc.). Care must be taken to avoid plotting too much information on the map so that map clarity is not lost.

4. Mark hazards within 10NM of the planned route in the event of route deviation (planned or unplanned). Mark lighted towers, beacons, cities and other features that emit large amounts of light within 30NM of the route. These "hazards" may also function as an aid to navigation.

5. Place a checkpoint identifier (name, number or letter) beside each CP. If there is an L-hour or TOT, place the real time at which you should be at that CP beside it.

6. To permit continuous position confirmation, insert timing or distance ("tick") marks along the course to be flown. These marks may be placed at one to five minute or one to five nautical mile minute intervals as dictated by the terrain or pilot preference. These marks can be used in conjunction with intermediate CPs to confirm positive orientation and timing.

7. To avoid having to continuously check NAV cards, it is suggested that the time, heading, and distance for each leg be placed beside the course line for each leg on the map.

8. Do not over-prepare the map. Put only that information needed to navigate the route. Over-marking the map may result in disorientation.

9. Establish a clearly defined transfer (map changeover) point for transitioning fromthe JOG to the tactical map for the objective phase of the mission. For this transition a point must be chosen that is readily identifiable on both maps. Care should be taken when transitioning from the JOG to the 1:50,000 to accommodate navigation scale adjustments.

10. NVG maps should not be laminated. The plastic coating tends to reflect light around the cockpit.

11. Maps should be folded so they are manageable in the cockpit and unfold like a book along the route of flight. To permit rapid orientation, place a magnetic north symbol on each fold of the map.

B. NVG Time-Distance-Heading (TDH) Card

The NVG time-distance-heading (TDH) navigation card (Figure 8-2) is constructed from a 5x8 inch white card and is designed to contain all information that is essential for the navigation portion of a mission. Its format is kept simple to ease readability under low light conditions. The following is a list of general rules for preparing the TDH navigation card.

1. All lines and writing on the card are made with black ink for contrast. (Computer generated TDH cards are usually more legible).

CP	HDG	DIST	TIME	FREQ	REMARKS
			Leg Real		
NORFOLK	264	12	7+12 2013:56	274.8 382.8	100 KIAS
HAMPTON	268	16	9+36 2023:32	274.8 277.0	
RICHMOND	283	18	10+48 2034:20	274.8 277.0	PEN CHECK LIST
ROANOKE	331	14	8+24 2042:44	274.8 362.1	PL CHEVY
RADFORD	18	8	4+48 2047:32	274.8 362.1	MSN FUEL 0+40
QUANTICO	25	10	6+00 2053:32	274.8 362.1	
P FAIRFAX	337	6	3+36 2057:08	274.8 44.15	PL FORD
LZ OSPREY	316	4.3	2+52 2100:00	274.8 44.15	90 KIAS

Figure 8 - I - 2. Sample NVG Time-Distance-Heading (TDH) Navigation Card

2. All letters and numbers should be at least 1/8inch size for clarity.

3. All headings should be corrected for magnetic variation.

4. The time block on the NVG TDH navigation card is divided in two. Timing between checkpoints (leg time) should be written in the top half of the block. "Real time" for expected arrival at each CP should be written in the bottom half. "Real times" are particularly beneficial in flying missions with an L-Hour or TOT. This allows the pilot to track his progress along the route and vary his airspeed as necessary to arrive at the objective on time. Individual CP "real times" are determined by working back from the designated L-Hour/TOT and subtracting the individual leg times between each CP.

5. The Latitude/Longitude block provides a space for latitude and longitude of appropriate checkpoints.

6. All times, distances, headings and latitude/longitude listed on NVG TDH cards must be double-checked prior to launch to ensure accuracy with all members of the mission.

C. Timing

Although onboard aircraft precision navigation equipment is being integrated into FMF aircraft, dead reckoning navigation still remains the primary means for maintaining orientation during NVG aided operations. To facilitate timing during dead reckoning navigation, two clocks (or stopwatches) should be utilized. One clock is set from the "time hack" and will be used to track "real times". The other clock will be utilized for timing between individual CPs and will be reset upon arrival at each CP. By comparing actual (real) time with projected times, the effect of winds on timing can be determined. Likewise, if a pilot should become disoriented or behind in timing, leg times can be used to plot aircraft position en route or used to delay L-Hour or time-on-target (TOT), as required.

<<NOTE>>

Standard eight-day clocks presently installed in U.S. Marine Corps helicopters are not recommended for use as a primary instrument for timing. Size and location of these clocks are not conducive to easy reference for the unaided crosscheck instrument scan that is performed under/around the NVGs.

D. Map Interpretation

In spite of the meticulous measures taken to prepare for NVG navigation, the ability to correlate terrain features on a map with what is actually seen through the goggles is difficult. Successful navigation begins by identifying major features along the route. From these major features the pilot can "fix" his relative position along the route.

E. Escort Requirements

By considering METT-T planners can make a determination as to the number of escort aircraft required and the type of escort pattern (attached, detached, etc.) that will be used.

F. Ordnance Requirements

Ordnance requirements for NVG aided missions will be threat dependent just as they are for day missions. However, there are some special considerations when delivering ordnance on NVGs. Several weapons employment considerations were discussed in Chapter 7, Section VII. Along with those considerations (i.e., effects of muzzle flash, rocket motors, etc.) one must keep in mind that we are at a minimum, attempting to deny the enemy visual detection. Weapon's condition and ROE must be set in advance. An enemy that is taking random shots in the air may not actually see you but your return fire, muzzle flash and tracers may lead him right back to your aircraft. Even the flash from a chaff squib may highlight your position at night.

G. Contingencies

There are many variables that may cause the mission to not go as planned. These variables or contingencies must be considered during the planning phase. Below is a list of typical contingencies that must be planned for in detail so that if an unforeseen situation arises

during the mission, a methodical change to the initial plan or an intelligent decision for go/no-go can be made. The following contingencies should be accounted for:

1. Inadvertent IMC both enroute and in the LZ or objective area.

2. Lost communications (signals and procedures).

3. Downed aircraft.

4. Threat encountered unexpectedlyenroute (evasive actions).

5. Alternate routes and LZs.

6. Emergency extraction and follow-on missions.

H. Forward Arming and Refueling Points (FARP)

During long range missions it may be necessary to utilize a FARP. Utilizing a FARP while flying with NVGs will be similar to day FARP procedures with a few additions.

1. All pre-stage, arm/de-arm areas, refueling points and post stage areas should be marked with NVG compatible lighting. Aircraft directors should use some type of NVG compatible wands for directing aircraft.

2. All procedures covered in the applicable T/M/S TACMANs apply to FARPs with NVGs just as they apply to day FARPs.

I. NVG Mission Checklist

To ensure all requirements of an NVG mission are met, the mission commander may want to use a mission checklist. The mission checklist should be written in chronological sequence from brief to debrief. Each event may have a specific time, phase-line or checkpoint associated with it. As each event takes place the mission commander can check that event off and move on to the next event taking the actions necessary to ensure that each event is covered. These events may include items such as radio checks, lighting configurations, goggling, reporting certain events to controlling agencies and penetration checklists, etc.

J. Low Light Level Planning Considerations

1. Select routes carefully and use prominent checkpoints and barrier features due to reduced NVG performance.

2. Navigation requires greater reliance on time, distance and heading.

3. Wires and unlit obstacles will be more difficult to detect.

4. Crew selection and crew coordination becomes more critical.

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Night Vision Goggle (NVG) Tactics

SECTION II: NVG MISSION BRIEFING

I. Introduction

The NVG Briefing Guide provided in this section should be used during NVG mission planning and briefing. Specifically, the NVG Briefing Guide is a tool that will compliment the information contained in the NATOPS Manuals. It should be noted that even the most basic NVG mission requires a thorough brief. Your individual NATOPS Briefing Guide and the enclosed NVG Briefing Guide can be combined to ensure compliance with NATOPS, minimize redundancy and maintain a logical flow of information.

A. General

Generic information, applicable to all aircrew in the flight should be addressed first. A detailed weather brief, to include training area weather and astronomical data is a key consideration in your brief. The Light Level Planning Calendar can supply much of the information you will need for planning and briefing purposes. In particular, the Sun and Moon Position Chart provides moon angle, azimuth, moon phase and illumination level (Lux) at 10 minute intervals. This information is essential for a thorough analysis of shadows along your intended route of flight and within the objective area. The use of the Shadow Formula and its application will be described in greater detail in Appendix C. Crew responsibilities must be clearly delineated. Assault Support Crew served aircraft must not forget to thoroughly brief their crewchief/gunners/aerial observers.

B. Mission

This section is provided to ensure the execution phase is discussed in detail. Considerations may range from route analysis and actions in the objective area to pattern work. The bulk of the mission brief should focus on the objective area. The coordination and control of all aircraft in any situation is absolutely essential.

C. Safety Considerations

NVG aided operations require planning and briefing for several additional safety of flight considerations. The emergency procedures section of your NATOPS brief will require added detail to cover the necessary NVG aided crew coordination considerations.

II. NVG Briefing Guide

A. Light Level Planning Calendar Considerations

1. Sunrise/sunset - Lux levels
2. Moon rise/moon set - Lux levels/percent illumination
3. Moon angle/azimuth
4. Ambient conditions
5. Visual illusions
6. Shadowing

B. Goggle/De-goggle Procedures (if applicable)

C. Internal/External Aircraft Lighting

1. Cockpit blue light kit installed/IR searchlight lens cover(s) installed (if applicable)
2. Anti-collision lights
3. Navigation lights
4. Map light on/off as required
5. Formation/blade tip lights adjusted
6. Internal aircraft lighting
7. Use of IR searchlight

D. Radar Altimeter (setting)

E. Hazards

F. Formation Considerations

G. Minimum Essential Equipment/Cargo/Passengers

H. Crew Preparation

I. ROC/Currency Requirements

J. NVG Emergencies, i.e., In flight, Terminal Phase, IMC (if applicable)

K. <u>LZ Operations (if applicable)</u>

1. Hook(s) setup/chemical light sticks
2. LZ preparations, i.e., lighting sequence
3. Safety frequencies
4. ICS procedures
5. Altitude and airspeed
6. Pick up/drop procedures/scan/cues altitude, approach considerations
7. With/without load, emergency procedures

L. <u>NVG Preflight (if applicable)</u>

1. Ready room/NVG eye lane/ANV-20/20
2. Cockpit area
3. Cabin area
4. Hook(s)/pendant

M. <u>Ordnance Employment/Coordination</u>

1. Effects of ordnance induced NVG shutdown/regain
2. Artificial illumination

N. <u>Air Refueling Considerations (if applicable)</u>

O. <u>Crew Coordination</u>

1. **PILOT AT THE CONTROLS** - terrain/obstacle clearance, radio calls, emergencies
2. **PILOT NOT AT THE CONTROLS** - navigation, barriers, monitor performance instruments, gauges, normal duties, emergencies
3. **CONTROL CHANGES** – positive
4. **AIRCREW** - lookout, navigation, obstacle clearance, emergencies

III. Summary

NVG mission planning requires a detailed game plan. In most cases, mission success can be measured by the quality of the brief. The briefing guide is designed primarily for NVG T&R syllabus flights and can be used in conjunction with the NATOPS briefing guide. A more thorough brief will be required for advanced tactics T&R syllabus flights and real world

contingency operations. Therefore, the NVG briefing guide should be used in conjunction with the applicable NATOPS/TACMAN manuals.

Night Vision Goggle (NVG) Tactics

SECTION III: CREW COORDINATION

Introduction

Survival in a threat environment as well as a training environment depends largely on how well a particular aircrew understands its portion of the mission and how they perform their specific crew functions. The "Tactical Aircrew Coordination Considerations" academic support package published by MAWTS-1 provides a detailed discussion of helicopter crew coordination and a "must read" item for all aircrew. Crew coordination is more critical while operating on NVGs than in any other flight environment. Due to the limited peripheral vision, degraded depth perception and the 40^0 field of view associated with NVGs, aircrew lookout doctrine must be strictly briefed and adhered to for all phases of the flight. Each member of the crew must understand and comply with the briefed goggle/de-goggle procedures and the NVG related emergency procedures. It is imperative that the aircraft commander be advised any time a crewmember's NVG capability has been degraded. NVG specific crew responsibilities are as follows:

A. <u>Pilot at the Controls</u>

The pilot at the controls, as in TERF, DM and ACM, is primarily responsible for avoiding obstacles and maintaining control of the aircraft. He should assist the non-flying pilot in navigation by calling recognizable terrain and man made features. During the landing phase, he should keep all crewmembers apprised of references in the landing zone and comply with briefed inadvertent IMC procedures during landing should those references be lost. His status and intentions should be communicated to other aircraft in the flight as applicable. The pilot at the controls primary emphasis and attention must be devoted outside the aircraft during NVG operations. When possible he should avoid distractions inside the aircraft and allow the pilot not at the controls to manipulate cockpit switchology and frequency changes.

B. <u>Pilot Not at the Controls</u>

The pilot not at the controls is responsible for navigation, avoiding obstacles and directing the pilot flying as required to keep the aircraft on course. He will also back up the pilot flying on altitude and airspeed along the route of flight. During the landing phase he will assist by monitoring rate of closure and descent, altitude and aircraft drift over the intended point of landing. He will make altitude calls from the radar altimeter to a pre-briefed altitude, at which time the crewchief/observer will take over in multi-crew aircraft. Should the aircraft encounter IMC conditions or wave off criteria during the landing transition, the pilot not at the controls will provide information regarding rate of climb, aircraft attitude, airspeed, altitude, and engine performance during the wave-off or until VMC. He should be prepared to assume control of the aircraft at any time. The pilot not at the controls should handle allswitchology (when possible), thus allowing the flying pilot to concentrate solely on aircraft control.

C. Crew Chief

The crew chief will keep the pilots informed as to the location of other aircraft in the flight and comply with established lookout doctrine. He will assist the pilot not at the controls by monitoring the mechanical functions of the aircraft as required and reporting prominent terrain and man made features along the route of flight for navigation purposes. During the landing phase, the crew chief will keep the pilots apprised of obstacles in the landing zone and monitor aircraft drift over the intended point of landing. He will take over altitude calls from the pilot not at the controls at a pre-briefed altitude and continue them until the aircraft has touched down. Generally speaking, due to his position in the aircraft and ability to look straight down at the ground, the crew chief may be able to keep sight of references even thought pilots have lost theirs. If this situation occurs, he should continue to advise the pilots of drift, altitude and aircraft attitude throughout the wave-off. Should he lose sight of ground references, he must pass that information to the pilots immediately.

D. Aerial Observers/Gunners

The observer/gunner will assist the pilot not at the controls by reporting all geographical and manmade features along the route of flight and maintain lookout doctrine. During the landing phase he will assist the crew chief in obstacle identification, monitoring aircraft drift and maintaining a reference point on the ground.

II. Summary

Positive crew coordination within aircraft and flights of aircraftare crucial to mission success. Pilots of all aircraft in the flight should back-up the lead aircraft's navigation. If the lead aircraft appears disoriented there should be no hesitation by any pilot in the flight, to reorient the flight either through pre-briefed visual signals or via radio communications.

Chapter 9

Night Vision Goggle (NVG) Safety Considerations

I. Introduction

During NVG flight, one's ability to effectively respond to an emergency may be delayed due to reduced visual cues and accompanying physiological and psychological stressors. To overcome these limitations, the aircrew must be proficient in handling aircraft emergencies and systems failures in a darkened cockpit environment. When briefing, safety considerations may be divided into aircraft emergencies, NVG malfunctions, inadvertent IMC, loss of situational awareness and aircrew coordination. In all cases, appropriate procedures should be tailored for the mission, ambient conditions, weather factors, terrain and aircrew experience.

II. Emergency and Safety Considerations

A. Aircraft Emergencies

Under low light level (LLL) conditions, it is recommended that the pilot at the controls remain goggled and initiate required immediate action procedures. Terrain permitting, primary consideration should be given to landing the aircraft, followed by the execution of remaining procedures on the deck. Where terrain prohibits this course of action and emergency procedures permit, it is advisable to "climb to cope" to gain reaction time, improve landing site selection and increase overall situational awareness. The pilot not at the controls should remain goggled to retain outside visual cues while simultaneously assisting the pilot at the controls as briefed or required. In crew-served helicopters, the crewchief and observer should also remain goggled, clear the aircraft of obstacles and assist the pilots, as required. They can also be used to locate various switches and circuit breakers, not easily accessible to the pilot and copilot while they're wearing NVGs.

B. NVG Malfunction

Although NVGs are quite reliable, as with any EO device, malfunctions may occur. Battery failure, broken intensifier tubes, broken frames or broken wires may occur at any time. The following steps should be taken:

1. Communicate the NVG Malfunction to the crew. If the malfunction affects the pilot at the controls conduct a positive transfer of the controls to the pilot with the operable NVGs with the pre-briefed words "Goggle Failure, you have the controls."

2. If a battery failure has occurred, attempt to regain the use of the NVG as follows:

   (a) AN/AVS-6 - switch to the back-up alternate battery compartment.

   (b) If NVGs are still not operational, replace them with spare NVGs.

<<NOTE>>

A minimum of one extra set of NVGs should be carried on the aircraft as a replacement set for any that become inoperable. In addition, extra batteries should also be carried by each individual crewmember for back up.

C. Inadvertent IMC

Inadvertent IMC may be encountered in flight or during the takeoff or landing transitions. As mentioned in Chapter 1, the chances of entering inadvertent IMC are increased due to the NVGs ability to see through some atmospheric obscurants as well as its inability to detect others until it's too late. In either case, the aircrew ability to "see and avoid" obstructions (below, above, behind) is diminished. The best course of action to preclude inadvertent IMC is to avoid it through preflight planning. However, this is not always possible due to un-forecast weather conditions and changes in landing areas. Therefore, the aircrew must be alert and recognize the following cues to reductions in ambient illumination that will affect visibility:

1. Increased "Halo Effect" Around Point Light Sources. The halo size will increase as weather restrictions develop.

2. Degraded NVG Image. Gradual reduction in light levels, visual acuity, depth perception or intensified image contrast.

3. Obscuration of the Moon and Stars. The less visible they are, the heavier the cloud cover. In addition, shadows obscuring the moon's illumination are an indication that clouds are present. Shadows may be detected by observing the varying levels of ambient light along the route.

4. NVG Image Scintillation. NVG image scintillation (graininess or video noise) is similar to "snow" seen on televisions with poor reception. Should this occur, verify the condition with other crewmembers to distinguish weather restrictions from NVG malfunctions.

5. Loss of Ground Lights.

As visibility decreases and prior to entry into IMC, the pilot at the controls/flight leader should alter the course and/or altitude to maintain VMC. Landing the aircraft/flight may be necessary until visibility improves.

If inadvertent IMC cannot be avoided, execute the pre-briefed inadvertent IMC procedures. If METT-T factors require deviations from pre-briefed procedures, intentions must be broadcast to the entire flight.

Inadvertent IMC procedures should be planned and briefed with consideration for size of flight, formations, threat, terrain, obstacles to flight and dissimilar aircraft performance

parameters where applicable. In addition, exterior lighting schemes should be considered to aid in the reconstitution of the flight and midair avoidance.

As previously mentioned, inadvertent IMC may be encountered on takeoff or landing transition, as well as in flight. A plan to safely exit "brown" and "white" out situations should also be briefed. Consideration should be given for single and multi-aircraft evolutions. The incorporation and execution of crew coordination concepts become extremely important to avoid obstacles during the transition from IMC to VMC or vice versa. If IMC is encountered, the pilot at the controls must immediately advise the crew that he has lost visual references to the ground and/or horizon and immediately transition to an instrument scan. He should maintain his instrument scan until advised by the crew that VMC has been regained. The pilot not at the controls will back up the pilot at the controls by monitoring the instruments, ensuring that pre-briefed procedures are followed and scanning outside to regain VMC.

D. Loss of Situational Awareness (SA)

Situational awareness is defined as the degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time. Due to the dynamic and complex nature of NVG aided operations, aircrew must continually maintain an effective scan and task share between terrain clearance tasks, mission cross-check tasks and the environmental factors that are inherent to NVG aided operations. This process begins with preflight planning, continues with the briefing evolution, and is constantly updated in flight by all available means. Maintaining the proper level of SA to safely achieve mission success is largely dependent upon the crew's ability to coordinate and communicate as a team. The biggest threat to loss of SA by a crew is when the entire crew has their attention focused on one aspect of the flight. A faulty switch or an unidentified set of aircraft position lights can quickly preoccupy all crewmembers and distract them from their pre-briefed responsibilities. Crews should be alert to this possibility and ensure a division of duties is maintained during all responses to unforeseen circumstances that may develop during the mission.

E. Aircrew Coordination

The various visual, perceptual and spatial orientation problems associated with NVG aided flight can be compensated for in most instances by using the technique of validating visual and sensory cues of aircraft performance with the information provided by the flight instruments. Safe and effective NVG aided flight requires that a system of continuous cross checks and cross references between these two sources of information be employed to provide the pilot with timely and accurate information on aircraft employment and spatial orientation. However, the demands of NVG aided flight require the pilot to devote his full attention to the mission and to visual references, external to the cockpit, and he must rely on the other pilot for the necessary flight instrument information. Aircrew coordination must organize cockpit duties in a safe, effective manner for NVG aided flight. Specific aircrew duty assignments and responsibilities may vary depending on the mission, pilot experience and the tactical situation. Aircrew duties and responsibilities shall be assigned and thoroughly explained by the AHC/HAC/PQM during the preflight briefing.

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Appendix A

Night Vision Goggle (NVG) Preflight Adjustment Modalities

I. Introduction

Night Vision Goggle (NVG) performance is optimized through proper preflight focus and adjustment. Currently, aircrew use a variety of modalities to ready their goggles for flight. These modalities may include; (1) the squadron NVG eye lane, (2) the ANV-20/20 NVD Infinity Focus Device and (3) the TS-4348. Regardless of which NVG pre-flight modality is available for use (if any), the procedures described in Chapter 5 must be followed in order to optimize NVG performance. The USMC Training and Readiness Manual (T & R Volume 1) currently requires aircrew to preflight their NVGs using one of the above mentioned modalities

Early operational NVG experience and fleet USMC, USAF and USA research has revealed that NVG preflight adjustment and focusing procedures were historically inadequate. An Army field study showed that interpupillary distance (IPD) and diopter adjustment ring errors were especially common among inexperienced NVG aircrews. These errors were large enough to cause a significant reduction in visual acuity and adversely contribute to aircrew eye fatigue. NVG performance was being degraded through improper adjusting and focusing which hindered obstacle detection and avoidance as well as target recognition. Common methods currently used to focus and adjust NVGs such as focusing on a small light source or lettering on a nearby aircraft are not sufficient to ensure that the NVG is properly adjusted for flight.

The purpose of using an NVG preflight adjustment modality vice using a field expedient method is for one to be able to quantify the performance of the NVG to a know standard. Although experienced aircrew may feel confident with NVG preflight focus adjustments by solely using an aircraft on the flight line, unlit hanger or star, one can never quantify the actual performance of the NVG using these methods. In addition, during low light level nights, aircrew will not be able to achieve an NVG image that would be suitable to conduct the focus adjustments. By using the NVG eye lane, ANV-20/20 or TS-4348, an NVG resolution chart is placed at a known or calibrated distance and illuminated by a high light level source to present an optimal target for initial NVG preflight alignment and focusing. Upon completion of the NVG preflight adjustments, aircrew are then able to ascertain the performance of the NVG (i.e., 20/30, etc.) as compared to the system's specification. In the past, aircrew operating in austere environments or aboard the boat were limited by space and not able to set-up an NVG eye lane. The introduction and ongoing fielding of the ANV-20/20 addresses this NVG eye lane limitation by providing a readily deployable device that allows one to conduct a complete binocular NVG preflight adjustment and assessment while focused at optical infinity.

II. NVG Preflight Adjustment Modalities

A. Squadron NVG Eye Lane

The NVG eye lane provides a simple method to accurately adjust and focus NVGs. The system is inexpensive and provides a standard to assess NVG performance prior to flight. To perform a preflight quality assurance check of the NVG, each tube must be checked individually, and then the two tubes checked together

1. Equipment

(a) Item: 7½ Watt Light Bulb-Coated White (Open Purchase)

Source: Hardware, Department or Lighting Store (Open Purchase)

(b) Item: Half Sphere Reflector or Indoor "Clip Lamp"

Source: Hardware, Department or Lighting Store (Open Purchase)

(c) Item: NVG Visual Acuity Targets to make Chart

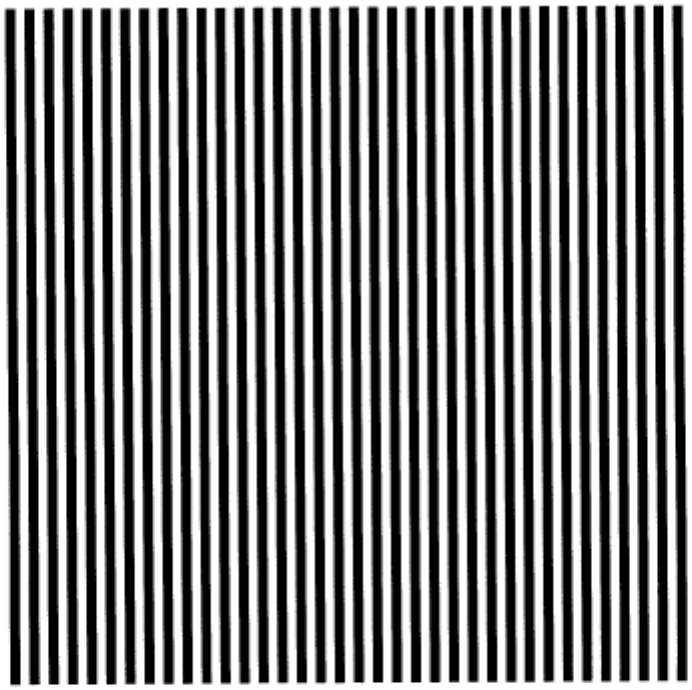
Source: MAG AMSO / Wing AMSO / NITE Lab

2. Set-Up Procedures

(a) Space Considerations

1: Select a squadron space (ideally, 20 to 25 feet long) that can be sealed from external light.

2: Obtain computer generated NVG resolution targets (select 9 targets from 20/20 through 20/70) from your MAG AMSO, Wing AMSO or NITE Lab facility that are calibrated for the distance of your squadron eye lane (i.e., 15, 16, 17, 18. 19 or 20 feet, etc.), Figure A-1. The computer program can generate NVG resolution charts for different distances (5 to 50ft) and different contrast settings (0 to 100%). It is recommended that the squadron NVG eye lane chart be set at 100% contrast (black lines on white paper) and set for a distance beyond ten feet. Using lesser contrasts will defeat the purpose of the assessment and not allow aircrew to assess NVG performance against the go/no-go NVG performance specification. Using shorter distances (< 10ft) will make even minor changes (several inches) in distance closer or further from the chart invalidate the scale. Combine the targets into a chart that ranges from 20/20 to 20/70 (i.e., 20/20, 20/25, 20/30, 20/35, 20/40, 20/45, 20/50, 20/60, 20/70). When mounting the individual targets onto the combined chart use both the vertically and horizontally test grids. In some instances, past assessments have demonstrated that aircrew may be more or less sensitive to the targets based on the orientation of the test grid (vertical or horizontal lines). In addition, avoid using any type of glossy finish on the chart (i.e., lamination, etc.). This will ensure that no reflective glare will result from the simulated moon shining onto a glossy surface. Place the NVG resolution chart, slightly lower than eye height, at one end of the eye lane.



20/25 @ 15 ft

1.38 cyc/mrad

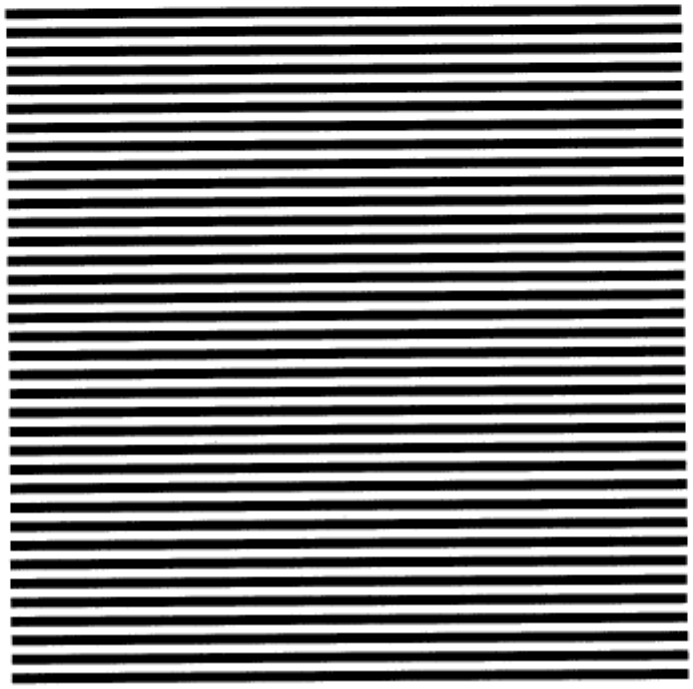


Figure A - 1. Computer Generated NVG Resolution Target (20/25 @ 15 ft)

(b) Simulated High Light Level Target Illumination. To modify a standard half sphere reflector or indoor "clip lamp" for use in the eye lane follow these instructions

1: The clip lamp should accept a standard 7½-watt light bulb. With a bulb to edge distance of approximately 40mm, a 5mm whole in the cover will approximately simulate full moon illumination. With a bulb to edge distance of approximately 55mm to 58mm, a 6mm whole in the cover will approximately simulate full moon illumination, Figure A-2.

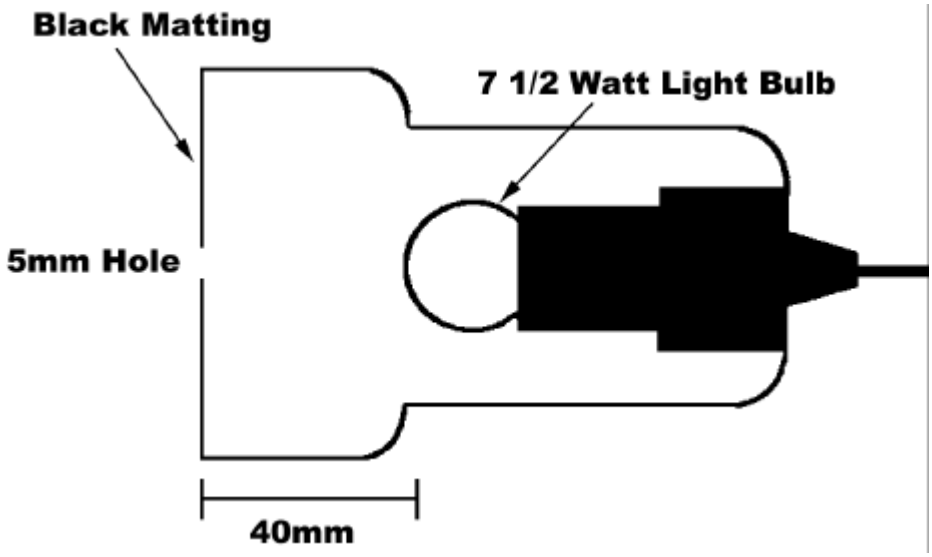


Figure A - 2. Squadron NVG Eye Lane Light Source

<<NOTE>>

Although the above recommendations have been calculated to approximate full moon illumination, the objective of the squadron NVG eye lane is not to quantify light level. Rather, to present an NVG visual acuity chart to aircrew under ideal (high light level) conditions void of NVG scintillation and NVG degain effects. Therefore, squadron NSIs should not be overly concerned with the exact light level of the illumination source, but should be critical of the presentation of the NVG target.

2: Paint the inside half of the reflector with flat back paint to minimize back glare. Cover any vent holes in the reflector with electrical tape to prevent light leakage out the back.

3: Trace a disk of black matting paper the size of the light fixture opening and carefully cut out the disc, Figure A-3.

4: Make a hole in the center of the disc. From ten feet away this aperture will reduce the level of light to approximately full moon equivalent

5: Install the light bulb in the fixture.

6: Tape the matting disk over the front of the light fixture using electrical tape. Secure all edges to prevent light leaks.

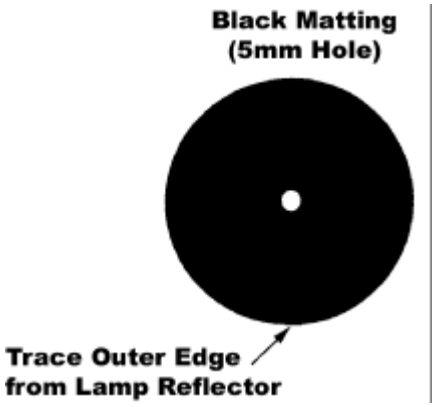


Figure A - 3. Squadron NVG Eye Lane Light Source Cover

(c) Mount the reflector or light housing to the ceiling 10ft from the visual acuity chart and position the light so that it will not create glare for the viewer.

(d) Mark a spot on the floor at the distance calibrated for the NVG visual acuity chart. Small errors in viewing distance can cause large differences in apparent acuity.

(e) To test the eye lane, turn on the light source and turn off the room light. Turn on the NVGs and center the light on the resolution chart. Utilize the NVGs to identify places in the eye lane where excessive light is leaking into the room. Try to seal the eye lane from any light leaks.

3. NVG PreFlight Adjustment Procedures. Refer to Chapter 5 for the appropriate AN/AVS-6 NVG pre-flight adjustment procedures.

B. ANV-20/20 Night Vision Device (NVD) Infinity Focus Device

The ANV-20/20 NVD Infinity Focus Device is a compact portable system designed to provide aircrew an accurate means of performing a quantitative preflight NVG alignment and infinity focus adjustment capability, Figure A-4.

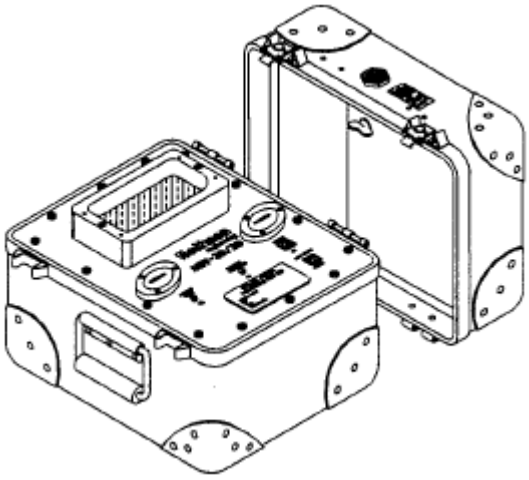


Figure A - 4. ANV-20/20 Night Vision Device (NVD) Infinity Focus Device

The system accommodates both AN/AVS-6, AN/AVS-9 and MXU-810/U style NVGs and is powered by 4 D-cell alkaline batteries, Figure A-5. The physical characteristics of the ANV-20/20 are provided in Table A-1.

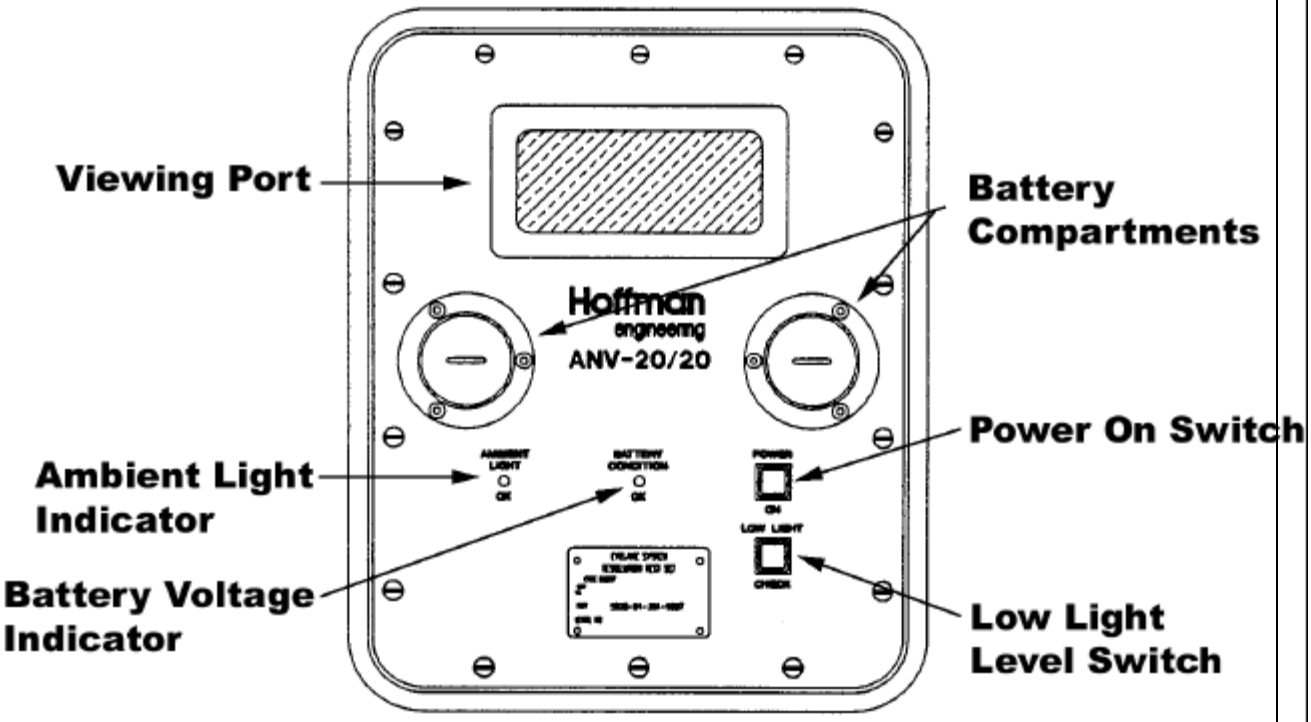


Figure A - 5. ANV-20/20 NVD Infinity Focus Device Front Control Panel

TABLE A - 1. ANV-20/20 SPECIFICATIONS

Mechanical	ANV-20/20 Specification
Case Size (with cover)	13" x 10.5" x 9.6"
Case Size (without cover)	13" x 10.5" x 6.2"
AVN-20/20 Weight	26lbs (with 4-D Cell Batteries)
Electrical	
Power Source	4-D size Alkaline Batteries
Battery Life	1,500 cycles (3-min per cycle)
Battery Replacement	< 1.05 V
Ambient Light Sensor	Silicon Photodiode
Ambient Light Level Limit	< 0.1 foot-candle
Optical	
Light Source	LED
Focal Settings	100m (min.) & optical infinity (max.)
Reticle Resolution (Snellen)	0.49LP/mR (20/70 SVA) to 1.72LP/mR (20/20 SVA)
Reticle Luminance	Normal Mode (1/4 moon) & Low Light Mode (Starlight)
Source Accuracy	+/- 5% (Normal Mode)

1. ANV-20/20 NVD Infinity Focus Device Operation. Two push buttons and two LED indicators located on the front panel control operation of the ANV-20/20, Figure A-5. Depressing the power-on push button turns-on the unit for a three-minute operation cycle. By holding the power-on push-button, the status indicators activate to evaluate both battery condition and ambient room lighting. The green Battery Condition OK indicator will light when battery voltage exceeds 4.2 volts (1,500 / three-minute operational cycles). If the indicator fails to light, the batteries should be replaced (approximately 100 / three-minute operational cycles remaining). To optimize ANV-20/20 operation, ambient room lighting should be minimized. The green Ambient Light OK indicator will not light when ambient light entering the viewing port exceeds 0.1 foot-candle, thereby alerting the operator to reduce ambient lighting prior to operation.

2. ANV-20/20 NVD Infinity Focus Device Operational Modes. The ANV-20/20 can operate in two modes: Normal and Low Light. The Normal Mode or high light test level is equivalent to viewing a medium contrast target under ¼ moon illumination and should be used for the critical NVG pre-flight focus and adjustment. By looking through the viewing port, aircrew can observe the ANV-20/20 Snellen Visual Acuity (SVA) test pattern that has been set at optical infinity. The centrally placed projected SVA test pattern contains nine test targets (grids) that range from 20/20 SVA to 20/70 SVA, Figure A-6. Each test target has two sets of vertical and horizontal test pattern grids. If one can resolve both the horizontal and vertical test patterns associated with that test target grid, the individual has achieved that level of SVA. For example, test grid "35" is equivalent to a SVA of 20/35, etc. The test grid fills approximately 6^0 (MXU-810/U) to 10^0 (AN/AVS-6 / AN/AVS-9) of the NVG FOV. After the operator has achieved the best focus possible using the Normal Mode, the Low Light Mode can be used to gain perspective on anticipated LLL (starlight) NVG performance. Depressing and holding the Low Light push-button activates the Low Light Mode. No focus adjustments should be attempted while viewing the SVA test pattern in the Low Light mode.

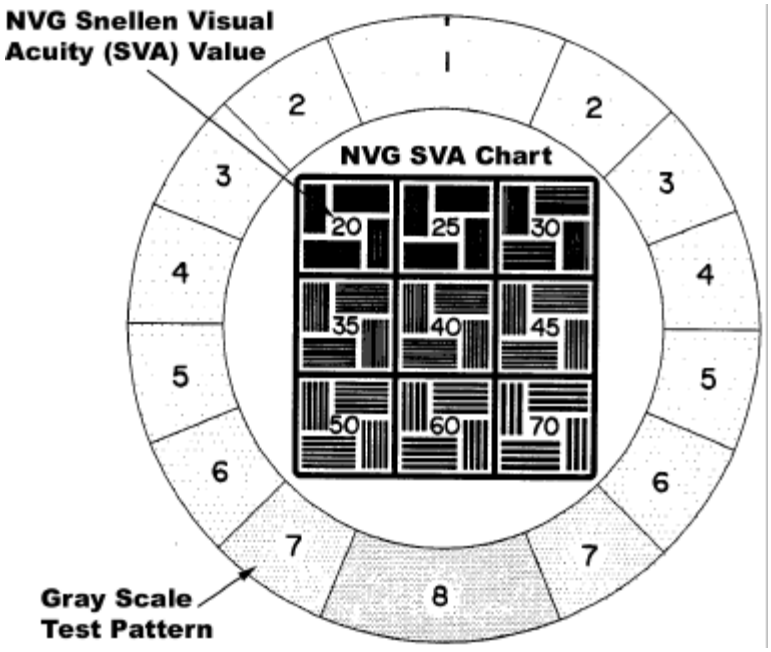


Figure A - 6. ANV-20/20 NVD Infinity Focus NVG SVA Chart

In addition to the SVA test pattern, the ANV-20/20 incorporates a circular eight step (Figure A-6) gray scale purportedly used for evaluating the dynamic gain range of the NVG. The eight successive steps between the brightest pattern-#1 (clear) located at the 12 o'clock position and the darkest pattern-#8 (black) located at the 6 o'clock position represents the dynamic range of the scale. Each progressive step from #1 to #8 (clockwise or counter clockwise) represents a ½ decrease in brightness (i.e., 1/4moon to 1/8moon, etc.). The capability exists to detect NVG performance anomalies by comparing the I^2 tube contrast sensitivity between adjacent segments of the gray scale pattern. Following extended operational use, this scale may add insight to the effective detection, recognition and identification ranges to be anticipated during that night's flight. The test pattern can be used in both the Normal Mode and the Low Light Level Mode to represent environmental conditions ranging from 1/4 moon (Normal Mode & Gray Scale #1) to heavy overcast starlight illumination (Low Light Mode & Gray Scale #6), Table A-2. Although this gray scale test pattern luminance levels have yet to be quantified, the scale may ultimately possess some potential operational applications.

TABLE A - 2. ANV-20/20 GRAY SCALE LUMINANCE

Gray Scale Step	High Light Level (Normal Mode) Luminance*	Low Light Level (Check Mode) Luminance*
1	1/4 Moon	Starlight
2	1/8 Moon	Hazy Starlight
3	1/16 Moon	Cloudy Starlight
4	Horizon Moon	LT. Overcast Starlight
5	Starlight	MED. Overcast Starlight
6	Hazy Starlight	Heavy Overcast Starlight
7	Cloudy Starlight	
8	Light Overcast Starlight	

***System Luminance levels listed for average terrain with a reflectivity of 30 to 50%**

3. NVG Preflight Adjustment Procedures. Refer to Chapter 5 for the appropriate AN/AVS-6 NVG preflight adjustment procedures.

C. TS-4348 System Specifications

The TS-4348 is a compact device that was designed for use by both aircrew and organizational level maintenance personnel. Unlike the ANV-20/20 NVD Infinity Focus Device, the TS-4348 possesses a monocular design that only allows one to place only a single monocular into the device at any one time. Although maintenance personnel have used the device without difficulties, USMC operational experience has demonstrated that this monocular design limits the operational use of this system for the aircrew preflight focus adjustment procedures.

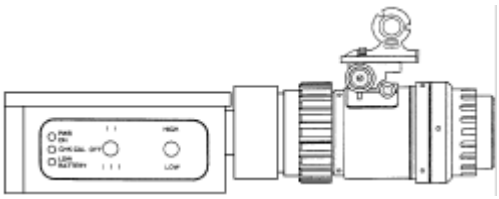


Figure A - 7. TS-4348 Attached to AN/AVS-6

1. TS-4348 System Operation

(a) TS-4348 System Setup. Before using the TS-4348 Test Set, refer to TM 11-5855-299-12&P to set up and familiarize yourself with its operation and the warnings and cautions associated with the test equipment. The following procedures are designed to check the performance of the image-intensifier assembly in each monocular.

(b) Resolution Tests. Test the binocular for low-light and high-light resolution performance according to the following steps:

<<NOTE>>

This test must be performed in a darkened area. Your eyes must be dark-adapted to perform this test. Review the following test procedure before entering the darkened area. You will need a flashlight with an AN/AVS-6 compatible filter to read this procedure while in the darkened area. While conducting the high light level test, one can normally expect cosmetic blemishes, such as chicken wire, black spots and fixed-pattern noise to stand out. This is acceptable.

1:Place the HIGH/LOW switch on the test set to the LOW position.

2:Turn-off room lights and let your eyes adjust to the dark (minimum time: 10 minutes).

3:Turn-on the test set by setting the "II/III" (I^2 Generation Technology) switch to the "III" position (GEN-III AN/AVS-6 goggles).

4:Turn-on the NVG via the power pack's ON/OFF/ON switch.

5:Look through the appropriate monocular and view the projected pattern, Figure A-8. Use the focusing procedures described in Chapter 5.

6:Determine the group number and element of the smallest pattern resolvable.

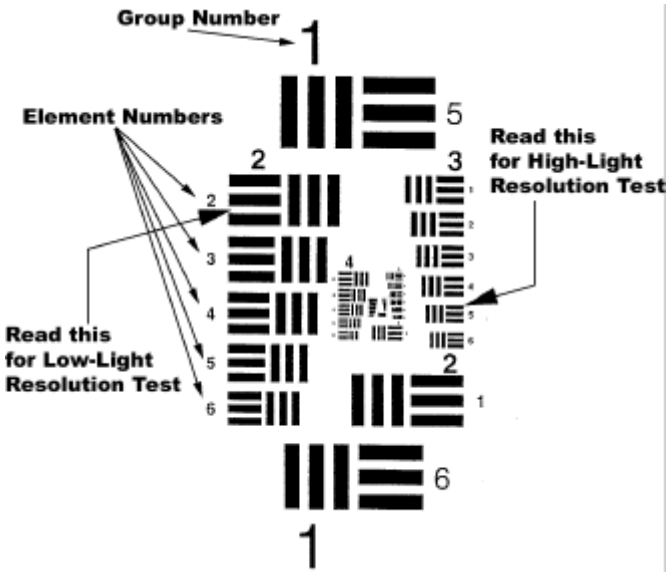


Figure A - 8. TS-4348 Test Set Resolution Pattern

<<NOTE>>

For a pattern to be resolvable, three vertical bars and three horizontal bars must be visible.

7: The AN/AVS-6 must be able to resolve **Group 2 : Element 2** under low-light condition to pass the test. If the monocular does not pass the test, return the ANVIS to maintenance.

8: Repeat steps (5) through (7) for the other monocular.

9: Flip the HIGH/LOW switch to the HIGH position.

10: Again, look through the monocular and view the projected pattern (Figure A-8). If necessary, focus the objective lens and then the eyepiece of the monocular to obtain the sharpest image.

11: Determine the group number and element of the smallest pattern resolvable

<<NOTE>>

For a pattern to be resolvable, three vertical bars and three horizontal bars must be visible.

12:The ANVIS must be able to resolve **Group 3 : Element 5** under high-light condition to pass the test. If the monocular does not pass the test, return the ANVIS to maintenance.

13:Look for flashing, flickering, or other non-stable behavior of the image-intensifier assembly. Also check the image intensifier for other unacceptable characteristics described in paragraph 9. If any unacceptable conditions are noted, return the ANVIS to maintenance.

14:Repeat steps (10) through (13) for the other monocular.

2. NVG Preflight Adjustment Procedures. Refer to Chapter 5 for the appropriate AN/AVS-6 NVG preflight adjustment procedures.

III. Summary

For further assistance or information, contact the MAWTS-1 Aeromedical Safety Officer (AMSO) at DSN: 951-3652 / 2500 or Com: (520)341-3652 / 2500.

Appendix

B

Aircraft Blindfolded Cockpit Checks

I. Introduction

The necessity of being able to locate essential switches and controls without visual reference was recognized in the aviation community long before the introduction of image intensification devices. The ability to locate and use cockpit equipment associated with immediate action emergency procedures without lights may be fundamental to survival. Beyond emergency procedure considerations, proficiency in blindfold cockpit drills will aid the pilot in performing routine functions like navigation, hazard avoidance, and reconnaissance while giving up less time for scanning inside the cockpit.

Being able to identify switch location by memory will shorten reaction times of the pilot under both normal and emergency situations. However, experience has proven that even pilots that are proficient with these blindfold cockpit checks have mistaken switches, levers, etc. Therefore, it is suggested that pilots still positively identify a switch, lever, etc. visually with a flashlight prior to activating or deactivating.

In an effort to standardize and therefore ensure the completeness of blindfold cockpit checks in Marine Corps helicopters, the following checklists are provided:

A. UH-1N Blindfold Cockpit Check:

1. Pilot

(a) Console Light Dial

(b) Navigation Light Switches

(c) Anti-collision Light Switches

(d) Battery Switch

(e) Fire Pull Handles

(f) Fire Extinguisher Switch

(g) Transponder Control Switches

(h) Fuel Switches

(i) UHF Channel Select Switch

(j) SCAS Engage Button

(k) ICS/Radio Rotary Switch

(l) Landing/Searchlight Switches

(m) RPM "Beep" Switch

(n) Vent Blower Handle

(o) Door Jettison Handle

(p) Rotor Brake

(q) ALE-39 Dispenser Switch

(r) Fuselage Light Circuit Breaker

(s) Pedestal Light Dial

(t) Secondary Light Dial

2. Co-Pilot

(a) Weapons Circuit Breakers

(b) Formation Light Switches

(c) Vent Blower Switches

(d) Voltmeter Switch

(e) Armament Panel Control Switches

(f) FM radio "On/Off" Switch

(g) SCAS Engage Button

(h) ICS/Radio Switch

(i) RPM "Beep" Switch

(j) Vent Blower Handle

(k) Door Jettison Handle

(l) ALE-39 Dispenser Switch

B. AH-1 Blindfold Cockpit Check:

1. Pilot

(a) Right Radio Console

1:External Light Control Panel

2:Interior Lighting Rheostat

3:AN/APX-72 Identification Transponder

4:UHF/FM ARC-182 Radio/CDU Panel

5:Master Caution Panel (Reset/Bright/Dim/Switch)

(b) Main Instrument Panel

1:APR-39 Discriminator Switch

2:Gearbox chip indicators

3:Fire Pull Handles

4:Canopy Jettison Handle

5:Wire Cut

6:AIM-9 CCU (Off/Stby/Arm)

(c) NARCADS Stores Control Panel

1:Master Arm Switch (Off/Stby/Arm)

2:Weapons Control Switch (Fixed/Pilot/Gunner)

3:Station Select

(d) Left Console

1:ICS Transmitter Select Switch

2:SCAS Control Panel

3:Fuel Switch

4:Oil cooler switch

5:Hydraulic Control Switch

6:Armament CB Panel

(e) Collective

1:Jettison

2:AIM-9 Fire Switch

3:Idle Stop Release

4:Landing Light Switch

5:AN/ALE-39 Actuator Switch

(f) Head up Display/Pilot Sight

1:Power Switch

2:Mode Switch

3:HUD Brightness Control

4:Night Filter Control

5:Automatic Brightness Switch

(g) Miscellaneous

1:Rotor Brake Handle

2:Hellfire Missile Launcher Arm Switch

2. Co-Pilot

(a) Gunner Armament Control Panel

1:Pilot Override Switch

2:Turret Depression Limit

3:Wing Stores Jettison

4:Wing Stores Select

(b) Instrument Panel

1:Caution Panel Bright/Dim

2:THCDP

3:Wire Cut

4:Gunner Sight Hand Control Panel

(c) Left Console

1:External Lights

2:Interior Lighting Rheostat

3:Electrical Power Emergency Off

4:Wing Store Jettison

5:AN/ALE-39 Copilot Actuator Switch

(d) Miscellaneous

1:UHF Emergency Switch

2:Canopy Jettison Handle

3:ICS Transmitter Select Switch

C. <u>CH-46 Blindfold Cockpit Check</u>

1. Emergency Window Release Handle
2. Armored Wing Release Handle
3. Formation Light Rheostat
4. Blade Tip Light Rheostat
5. Lower Anti-collision Light Circuit Breaker
6. Forward Utility Hydraulic Isolation Switch
7. Console Light Rheostat
8. Anti-collision Light Switch
9. Navigation Light DIM/BRIGHT Switch
10. Navigation Light STEADY/OFF/FLASH Switch
11. Tail Light Switch
12. Console Light Switch
13. APU Switch
14. APU Power/Ground Power Switch
15. APU Power Off Switch

16. Power Control Master Switch
17. Fuel Jettison Switches
18. Cross-feed Select Switch
19. Low Altitude Warning Switches
    (a) Instrument Panel
    (b) Cyclic
20. Hydraulic Control Boost Interlock Switch
21. AFCS Switch
22. Rotor Brake Arming Lever
23. Engine Condition Levers
24. Cargo Emergency T-Handle
25. PMS Switch
26. Emergency Throttle Reset Switches
27. Fire T-Handles
28. Cable Cutter
29. Emergency Throttle Arming Switch
30. Engine Beep Trim Switches
31. Searchlight ON/OFF Switch
32. Searchlight Direction Coolie Hat
33. ALE-39 Dispenser Switch
34. Landing Hover Light Switch

D. CH-53D Blindfold Cockpit Check

1. Overhead Control Panel

   (a) Instrument Light Rheostats

   (b) Secondary Flood Lights (Dim/Bright/Rheostat)

   (c) Engine Speed Control Levers

   (d) Fuel Control Levers

   (e) APP

      1:Circuit Breaker

      2:Start Lever

   (f) Emergency Panel

      1:Emergency Start Switch

      2:APP By-pass

      3:Engine Fire Extinguisher Switch

   (g) Interior Lights

   (h) Exterior Lights

      1:Landing Lights

      2:Hover Light

      3:Position Lights

      4:Formation Lights

      5:Blade Tip Lights

   (i) Generator Switches

   (j) Rotor Brake Switch

   (k) KY-58 Control Panel

2. Center Cockpit Console

   (a) Landing Gear Control Handle

   (b) Emergency Landing Gear Extension Handle

(c) ALE-39 "ON/OFF/SALVO" Switch

(d) ALE-39 Dispenser Switch

3. Miscellaneous

(a) Armored Wing Release

(b) Emergency Window Release Lever

E. CH-53E Blindfold Cockpit Check

1. Overhead Control Panel (Pilot's Side)

(a) Interior Lights

1:Console

2:Pilot Instruments

2. Overhead Control Panel (Center)

(a) Rotor Brake Switch

(b) FAS pressure

(c) APP

1:Circuit Breaker Control

2:APP Lever

(d) Fuel Control Levers

(e) Emergency T-Handles

(f) Emergency Panel

1:Emergency Start

2:Emergency APP

3:Emergency Fire Extinguisher Switch

3. Overhead Control Panel (Copilot's Side)

(a) Cargo Hook Mode Switch

(b) Refuel Lights

(c) Exterior Lights

1:Anti-collision Light

2:Position Lights

3:Formation Lights (Fuselage/Blade Tip)

(d) FM Antenna Switch

4. Center Cockpit Console

(a) ALE -39 "ON/OFF/SALVO" Switch

(b) Landing Gear Control Handle

(c) Emergency Landing Gear Extension

(d) Emergency Control Panel

1:Auxiliary Tank Jettison

2:Hook Shear

5. Collective

(a) Servo Off Switch

(b) ALE -39 Dispenser Switch

6. Miscellaneous

(a) Armored Wing Release Lever

Emergency Window Release Lever

Intentionally Blank

Appendix

C

Light Level Planning Calendar (LLPC) and Shadow Formula

I. Introduction

The computer generated Light Level Planning Calendar (LLPC) is the only approved method for deriving illumination. As indicated in Chapter 1, the Naval Oceanographic Office is currently developing a new Windows based computer program that will ultimately replace the DOS based LLPC. This new program is called the Solar / Lunar Almanac Program or SLAP. SLAP is currently a module component of the larger Geophysics Fleet Mission Program Library (GFMPL). SLAP possesses all the core functionality of the current LLPC with the added benefits of possessing an enhanced interface and greater flexibility for storage of operating site locations and output options. In addition, SLAP uses the DOD standard almanac algorithm that ensures standardization of output data used for mission planning across all services. SLAP should be ready for fleet release by the end of FY 99.

The LLPC provides estimations of illumination conditions that can be extremely beneficial during NVG aided operations planning. The LLPC values generated assume clear conditions and do not take into account the effects of cloud cover, humidity, haze, dust or low moon angle, etc. In addition, the LLPC only provides illumination predictions based upon lunar illumination in the visible part of the spectrum. Therefore, sound judgement by all involved with NVG aided operations must be the final determining factor. The LLPC can be a very valuable planning tool when used correctly. The program provides accurate light level prediction for any date to 2116 with input of only date, latitude, longitude and time zone. The LLPC was derived from similar programs developed by the U.S. Naval Observatory and the U.S. Army Atmospheric Sciences Laboratory. The program's main menu has seven selections and each one will be covered in detail so that they can be used effectively. In addition to the LLPC overview, a brief discussion is provided to explain the shadow formula and it's direct application from the data provided by the LLPC can be used for mission planning.

II. LLPC and Shadow Formula Overview

A. LLPC

1. Choose Light Level Boundary Value The Calendar uses symbols to indicate whether illumination from the moon is above or below a specified boundary level. The program is written with the boundary level equal for 0.0022Lux or 2.2mLux of lunar illumination. The "Choose Light Level Boundary" allows the user to select any desired illumination (Lux)

level as the boundary value. This allows the user to customize the Calendar for any specific type of activity.

2. Light Level Planning Calendar. This option prints the Calendar for use in operations planning or scheduling. The Calendar printout (Figure C-1) provides an easy means of identifying the times when NVG operations are authorized. The body of the calendar is divided into three sections. On the left are event times for the afternoon and evening and the percent of illuminated moon surface at 2400. On the right are event times for the following morning. Because the moon sometimes rises and sets during the day, a single letter prefix is attached to the moonrise and set times. The center contains the symbols that identify five different astronomical conditions in 10-minute intervals. The five conditions are represented by symbols that are identified in the legend at the bottom of the calendar. Illumination from the sun changes dramatically during twilight and is ignored in the construction of the calendar.

```
************************ LIGHT LEVEL PLANNING CALENDAR for Lat N 32  39.4  Long W 114  36.3  with clear sk
                                  1 November 1990  to  30 November 1990  Times are ZULU -7 Hours
 For   Moon  Sun  %Mn@ 1700  1800  1900  2000  2100  2200  2300  2400   100   200   300   400   500   600
PM on   R/S  set  2400   |     |     |     |     |     |     |     |     |     |     |     |     |     |
 1 Nov R1646 1748  99%  .....+++++++++-------------------------------------------------------+++++++++++++
 2 Nov R1728 1747 100%  .....++++++++++++++-----------------------------------------------------+++++++
 3 Nov R1816 1746  97%  .....***X+++++++++++++++-----------------------------------------------------
 4 Nov R1914 1745  92%  .....*********XX++++++++++++++-----------------------------------------------
 5 Nov R2019 1744  84%  .....***************XXX+++++++++++++++-------------------------------------
 6 Nov R2128 1744  74%  .....**********************XXXX++++++++++++-------------------------------
 7 Nov R2238 1743  64%  .....*****************************XXXX+++++++++++++-----------------------
 8 Nov R2346 1742  53%  .....***************************************XXXXX++++++++++-----------------
 9 Nov S1328 1741  42%  .....*****************************************************XXXXXX+++++++++----------
10 Nov S1359 1741  32%  .....*******************************************************XXXXXXX+++++++-----------
11 Nov S1427 1740  23%  ....*************************************************************XXXXXXXXXXXXXX+------
12 Nov S1455 1739  15%  ....*****************************************************************XXXXXXXXXXXXXXX
13 Nov S1522 1739   9%  ....*******************************************************************XXXXXXXXXX
14 Nov S1551 1738   4%  ....*********************************************************************XXXX
15 Nov S1623 1738   1%  ....*************************************************************************
16 Nov S1659 1737   0%  ....*************************************************************************
17 Nov S1740 1737   1%  ....*************************************************************************
18 Nov S1825 1736   3%  ....XXXXX********************************************************************
19 Nov S1916 1736   7%  ....XXXXXXXXXX***************************************************************
20 Nov S2010 1735  13%  ....XXXXXXXXXXXXXXXX********************************************************
21 Nov S2107 1735  20%  ....XXXXXXXXXXXXXXXXXXXX****************************************************
22 Nov S2205 1735  28%  ....---------++++++++XXXXXXXXXXXX*******************************************
23 Nov S2303 1734  37%  ....-----------------+++++++++XXXXXXXX*****************************************
24 Nov R1236 1734  47%  ....----------------------+++++++++++XXXXXX*************************************
25 Nov R1306 1734  58%  ....-----------------------------+++++++++++XXXXX*******************************
26 Nov R1335 1733  68%  ....-------------------------------------+++++++++++XXXX***********************
27 Nov R1405 1733  78%  ....-----------------------------------------------+++++++++++++XX*************
28 Nov R1439 1733  87%  ....-------------------------------------------------------++++++++++++XX*******
29 Nov R1517 1733  94%  ....+-------------------------------------------------------------++++++++++++X******
 Date   R/S  Sun  %Mn@   |     |     |     |     |     |     |     |     |     |     |     |     |     |
        Moon  set  2400 1700  1800  1900  2000  2100  2200  2300  2400   100   200   300   400   500   600

.... Indicates Sun above horizon          **** indicates Moon below horizon
---- indicates the Moon is at least 20 percent illuminated and at least 30 degrees above the horizon
++++ indicates Moonlight Level greater than or equal to .0022 lux but moon not 20% illum or not 30 deg abc
XXXX indicates Moonlight Level less than .0022 lux and moon not 20% illum or not 30 deg above horizon or r
```

Figure C - 1. Light Level Planning Calendar Printout

3. Sun and Moon Position Chart. This option provides more detailed information about the astronomical data contained in the center portion of the calendar. Figure C-2 is an example printout of this option. Information on sun and moon azimuth, sun and moon altitude above the horizon, percent moon illumination, and sun and moon illuminance in lux is provided in 10-minute intervals for a 10-hour period. The information from this printout is extremely useful for planning purposes and helps assess NVG performance.

****** SUN & MOON POSITION CHART ******
for Lat N 32 34.1 Long W 114 32.3
Times are ZULU -7 Hours starting on 1 Sep 1995

	Sun Position		Lux	Moon Position		% Moon	Lux
Time	Azimuth	Altitude	Illum	Azimuth	Altitude	(phase)	Illum
900	280	0	900	195	37	47	.012
910	281	-2	130	198	37	47	.012
920	283	-4	17	200	36	47	.012
930	284	-6	1.9	203	35	47	.012
940	285	-8	.21	206	35	47	.011
950	287	-10	.023	208	34	47	.011
000	288	-12	.0026	211	33	47	.011
010	290	-14	.00029	213	31	47	.01
020	291	-16	.00003	215	30	47	.0098
030	293	-18	0	218	29	47	.0094
040	295	-20	0	220	28	48	.0089
050	296	-22	0	222	26	48	.0084
100	298	-24	0	224	25	48	.0079
110	300	-26	0	226	24	48	.0073
120	302	-28	0	228	22	48	.0067
130	304	-30	0	230	21	48	.0061
140	306	-31	0	231	19	48	.0055
150	308	-33	0	233	17	48	.0049
200	310	-35	0	235	16	48	.0042
210	312	-36	0	236	14	48	.0036
220	315	-38	0	238	12	48	.003
230	317	-39	0	239	11	48	.0024
240	320	-41	0	241	9	48	.0018
250	323	-42	0	242	7	49	.0013
300	326	-43	0	244	5	49	.00088
310	329	-44	0	245	4	49	.00056
320	332	-45	0	246	2	49	.00033
330	335	-46	0	248	0	49	.00017
340	339	-47	0	249	-2	49	.00003
350	342	-48	0	250	-4	49	0
000	346	-48	0	252	-6	49	0
010	349	-49	0	253	-8	49	0
020	353	-49	0	254	-10	49	0
030	357	-49	0	255	-12	49	0
040	1	-49	0	256	-14	49	0
050	5	-49	0	258	-16	50	0
100	8	-49	0	259	-18	50	0
110	12	-49	0	260	-20	50	0
120	16	-48	0	261	-22	50	0
130	19	-48	0	262	-24	50	0
140	23	-47	0	263	-26	50	0
150	26	-46	0	265	-28	50	0
200	29	-45	0	266	-30	50	0
210	32	-44	0	267	-32	50	0
220	35	-43	0	268	-34	50	0
230	38	-41	0	269	-36	50	0
240	41	-40	0	271	-38	50	0
250	44	-39	0	272	-40	50	0
300	46	-37	0	273	-42	51	0
310	49	-36	0	275	-44	51	0
320	51	-34	0	276	-46	51	0
330	53	-32	0	278	-48	51	0

Figure C - 2. Sun and Moon Position Chart Printout

4. Spot Data for the Sun and Moon. This option provides the same basic information from the Sun and Moon Position Chart for a specified time and location. The printout (Figure C-3) provides sun and moon azimuth, elevation, illuminance and percent moon illumination. This option is helpful in mission planning for predicting conditions in areas that are located away from the location that your calendar is written for. Examples are landing zones, checkpoints, or other selected points along a route.

2200 Zulu -7 hours on 4 November 1990 at n 32 39.4 w 114 36.3
Moon Azimuth (deg.) 77 Moon Altitude (deg.) 30
With 92 % Moon (phase) the Moon Illuminance (LUX) is .047
Sun Azimuth (deg.) 289 Sun Altitude (deg.) -54
With Sun Illuminance (LUX) of 0

Figure C - 3. Spot Data for the Sun and Moon Printout

5. Trip Data for the Sun and Moon. This option would be selected if spot data for the sun and moon were needed for a series of locations and times on the same night. The printout provides the same information as the spot data. This option is helpful in mission planning as a sequence of locations along the mission route can be analyzed.

6. Daily Event Times. This option gives sunrise, sunset, moonrise, moonset, civil twilight, nautical twilight, total daylight and the times the moon and sun pass the meridian (at its highest point in the sky). This printout (Figure C-4) is very useful for schedule writing.

4 November 1990 at n 32 34.1 w 114 32.3
Times are Zulu –7
Time Sun Passes meridian is 1222 at Altitude of 42 degrees
Sunrise at 0658
Sunset at 1745 for 11 hours 47 minutes of daylight

Morning Civil Twilight begins at 0633
Evening Civil Twilight ends at 1811

Morning Naut. Twilight begins at 0603
Evening Naut. Twilight ends at 1840

Time Moon passes meridian is 0140 at Altitude of 81 degrees
Moonrise at 1914 Moonset at 0910

Figure C - 4. Daily Event Times Printout

B. Shadow Formula

The problems associated with terrain shadowing and NVGs require that mission planners take into account this phenomenon. Experience has proven that unless the moon is directly overhead, shadows can be a factor with even moderate terrain relief, tall trees or buildings. The Shadow Formula and its associated table of tangent values can help predict the location and size of shadows which may be encountered during the NVG mission.

1. Shadow Formula Explanation. The Shadow Formula that is used to predict shadow length is based on geometry, specifically the tangent formula used in trigonometry, Figure C-5.

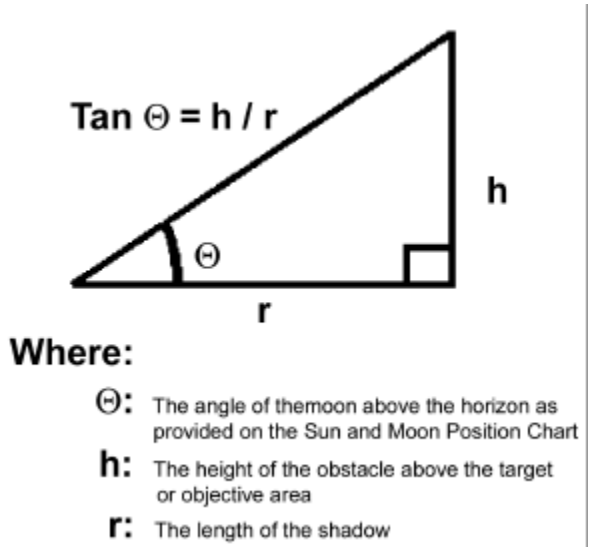


Figure C - 5. Tangent Formula

It is important to remember that the value of h is the height above the target area, which may not be equal to its actual height (MSL elevation). Let's take an example of a ridgeline that has an elevation of 3,000 ft. MSL and a valley below at 1,200 ft. MSL (Figure C-6). To determine the shadow length (r) on the valley floor, h would be equal to 1,800 or the elevation difference between the ridgeline and valley. Using h=3000 would give a large, inaccurate estimation of shadow length. Moon angle, azimuth, and relative elevation differences are the variables which will determine shadow length. Moon azimuth does not directly apply to the formula, but does determine where the shadow will fall on the earth's surface.

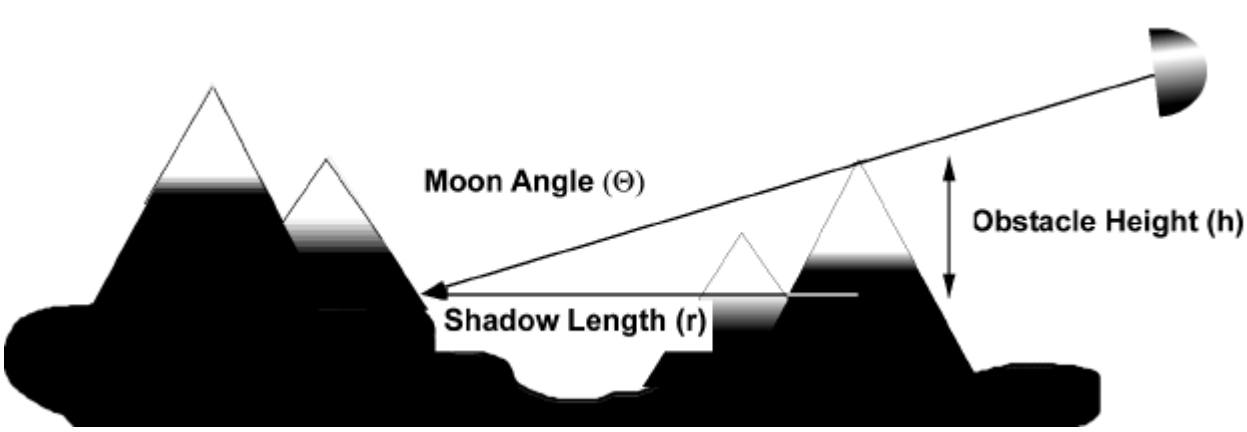


Figure C - 6. Shadow Formula Operational Application

2. Shadow Table. By using Shadow Tables (Tables C-1 through C-9) and the obstacle's height, the shadow length can be determined. The Shadow Tables are not unit dependent and therefore can be used for any unit of distance measure (i.e., meters, feet, yards, etc).

For example, if an obstacle height is 1,800 meters (5,904 feet) and the moon angle is 10 degrees above the horizon, the shadow length would be approximately 10,213 meters (33,477 feet). This was determined by using the 100 meter obstacle height shadow value of 567.42 and multiplying it by 18 or by using the 1,000 feet obstacle height shadow value of 5,674.22 and multiplying by 5.9).

III. Summary

By using the Shadow Formula, mission planners are able to construct a visual model of the shadows on ingress routes, objective/target areas andegress routes. This will aid the aircrew in pre-flight route planning, LZ selection, attack positions/firing point selection, artificial illumination placement and ultimately flight safety/mission effectiveness. On a transparency, Xerox a copy of the route or objective/target area 1:50,000 scale map with the predicted shadows, routes, LZ's, attack positions, target areas and threats. This briefing tool will significantly enhance mission planning, briefing and aircrew preparedness.

TABLE C - 1. 10 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	113.48	40	226.97	60	340.45	80	453.94
100	567.42	120	680.91	140	794.39	160	907.87
180	1021.36	200	1134.84	220	1248.33	240	1361.81
260	1475.30	280	1588.78	300	1702.27	320	1815.75
340	1929.23	360	2042.72	380	2156.20	400	2269.69
500	2837.11	520	2950.59	540	3064.08	560	3177.56
580	3291.05	600	3404.53	620	3518.02	640	3631.50
660	3744.98	680	3858.47	700	3971.95	720	4085.44
740	4198.92	760	4312.41	780	4425.89	800	4539.37
820	4652.86	840	4766.34	860	4879.83	880	4993.31
900	5106.80	920	5220.28	940	5333.76	960	5447.25
980	5560.73	1000	5674.22	1020	5787.70	1040	5901.19

TABLE C - 2. 20 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	54.98	40	109.96	60	164.94	80	219.92
100	274.90	120	328.88	140	384.86	160	439.84
180	494.82	200	549.80	220	604.78	240	659.76
260	714.74	280	769.72	300	824.70	320	879.68
340	934.66	360	989.64	380	1044.62	400	1099.60
420	1154.58	440	1209.56	460	1264.54	480	1319.52
500	1374.50	520	1429.48	540	1484.46	560	1539.43
580	1594.41	600	1649.39	620	1704.37	640	1759.35
660	1814.33	680	1869.31	700	1924.29	720	1979.27
740	2034.25	760	2089.23	780	2144.21	800	2199.19
820	2254.17	840	2309.15	860	2364.13	880	2419.11
900	2474.09	920	2529.07	940	2484.05	960	2639.03
980	2694.01	1000	2748.99	1020	2803.97	1040	2858.95

TABLE C - 3. 30 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	34.66	40	69.32	60	103.99	80	138.65
100	173.31	120	207.97	140	242.64	160	277.30
180	311.96	200	346.62	220	381.28	240	415.95
260	450.61	280	485.27	300	519.93	320	554.60
340	589.26	360	623.92	380	658.58	400	693.25
420	727.91	440	762057	460	797.23	480	831.89
500	866.56	520	901.22	540	935.88	560	970.54
580	1005.21	600	1039.87	620	1074.53	640	1109.19
660	1143.85	680	1178.52	700	1213.18	720	1247.84
740	1282.50	760	1317.17	780	1351.83	800	1386.49
820	1421.15	840	1455.82	860	1490.48	880	1525.14
900	1559.80	920	1594.46	940	1629.13	960	1663.79
980	1698.45	1000	1733.11	1020	1767.78	1040	1802.44

TABLE C - 4. 40 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	23.85	40	47.70	60	71.56	80	95.41
100	119.26	120	143.11	140	166.97	160	190.82
180	214.67	200	238.52	220	262.37	240	286.23
260	310.08	280	333.93	300	357.78	320	381.64
340	405.49	360	429.34	380	453.19	400	477.04
420	500.90	440	524.75	460	548.60	480	572.45
500	596.31	520	620.16	540	644.01	560	667.86
580	691.71	600	715.57	620	739.42	640	763.27
660	787.12	680	810.98	700	834.83	720	858.68
740	882.53	760	906.38	780	930.24	800	954.09
820	977.94	840	1001.79	860	1025.64	880	1049.50
900	1073.35	920	1097.20	940	1121.05	960	1144.91
980	1168.76	1000	1195.61	1020	1216.46	1040	1240.31

TABLE C - 5. 50 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	16.80	40	33.59	60	50.39	80	67.19
100	83.99	120	100.78	140	117.58	160	134.38
180	151.17	200	167.97	220	184.77	240	201.56
260	218.36	280	235.16	300	251.96	320	268.75
340	285.55	360	302.35	380	319.14	400	335.94
420	352.74	440	369.54	460	386.33	480	403.13
500	419.93	520	436.72	540	453.52	560	470.32
580	487.12	600	503.91	620	520.71	640	537.51
660	554.30	680	571.10	700	587.90	720	604.69
740	621.49	760	638.29	780	655.09	800	671.88
820	688.68	840	705.48	860	722.27	880	739.07
900	755.87	920	772.67	940	789.46	960	806.26
980	823.06	1000	839.85	1020	856.65	1040	873.45

TABLE C - 6. 60 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	11.56	40	23.12	60	34.68	80	46.24
100	57.81	120	69.37	140	80.93	160	92.49
180	104.05	200	115.61	220	127.17	240	138.73
260	150.30	280	161.86	300	173.42	320	184.98
340	196.54	360	208.10	380	219.66	400	231.22
420	242.78	440	254.35	460	265.91	480	277.47
500	289.03	520	300.59	540	312.15	560	323.71
580	335.27	600	346.83	620	358.40	640	369.96
660	381.52	680	393.08	700	404.64	720	416.20
740	427.76	760	439.32	780	450.89	800	462.45
820	474.01	840	485.57	860	497.13	880	508.69
900	520.25	920	531.81	940	543.37	960	554.94
980	566.50	1000	578.06	1020	589.62	1040	601.18

TABLE C - 7. 70 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	7.29	40	14.59	60	21.88	80	29.17
100	36.47	120	43.76	140	51.05	160	58.35
180	65.64	200	72.93	220	80.23	240	87.52
260	94.81	280	102.11	300	109.40	320	116.69
340	123.99	360	131.28	380	138.58	400	145.87
420	153.16	440	160.46	460	167.75	480	175.04
500	182.34	520	189.63	540	196.92	560	204.22
580	211.51	600	218.80	620	226.10	640	233.39
660	240.68	680	247.98	700	255.27	720	262.56
740	269.86	760	277.15	780	284.44	800	291.74
820	299.13	840	306.32	860	313.62	880	320.91
900	328.20	920	335.50	940	342.79	960	350.08
980	357.38	1000	364.67	1020	371.97	1040	379.26

TABLE C - 8. 80 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	3.54	40	7.08	60	10.64	80	14.16
100	17.71	120	21.25	140	24.79	160	28.33
180	31.87	200	35.41	220	38.95	240	42.49
260	46.03	280	49.58	300	53.12	320	56.66
340	60.20	360	63.74	380	67.28	400	70.82
420	74.36	440	77.91	460	81.45	480	84.99
500	88.53	520	92.07	540	95.61	560	99.05
580	102.69	600	106.23	620	109.78	640	113.32
660	110.86	680	120.40	700	123.94	720	127.48
740	131.02	760	134.56	780	138.10	800	141.65
820	145.19	840	148.73	860	152.27	880	155.81
900	159.35	920	162.89	940	166.43	960	169.97
980	173.52	1000	177.06	1020	180.60	1040	184.14

TABLE C - 9. 90 DEGREE MOON ANGLE

Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length	Obstacle Height	Shadow Length
20	0.02	40	0.03	60	0.05	80	0.06
100	0.08	120	0.10	140	0.11	160	0.13
180	0.14	200	0.16	220	0.18	240	0.19
260	0.21	280	0.22	300	0.24	320	0.25
340	0.27	360	0.29	380	0.30	400	0.32
420	0.33	440	0.35	460	0.37	480	0.38
500	0.40	520	0.41	540	0.43	560	0.45
580	0.46	600	0.48	620	0.49	640	0.51
660	0.53	680	0.54	700	0.56	720	0.57
740	0.59	760	0.61	780	0.62	800	0.64
820	0.65	840	0.67	860	0.68	880	0.70
900	0.72	920	0.73	940	0.75	960	0.76
980	0.78	1000	0.80	1020	0.81	1040	0.83

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Appendix D

Glossary

I. Abbreviations and Acronyms

ABC	Automatic Brightness Control
ANVIS	Aviators Night Vision Imaging System
ATA	Airport Traffic Area
AHC	Attack Helicopter Commander
BMNT	Beginning Morning Nautical Twilight
BSP	Bright Source Protection
BVA	Binocular Visual Acuity
CATF	Commander Amphibious Task Force
CP	Check Point
CRT	Cathode Ray Tube
DAR	Diopter Adjustment Ring
DAS	Defensive Armament System
E	Emissivity
EENT	End Evening Nautical Twilight or "Double E NT"
EL	Electroluminescent
EO	Electro-Optics
EU	Electronics Unit
FFAR	Folding Fin Aerial Rockets
FLIR	Forward Looking Infrared
FOR	Field of Regard
FOV	Field of View
Ftc	Foot-Candle
FtL	Foot-Lambert
GEN II	Second Generation Intensifier Tube
GEN III	Third Generation Intensifier Tube
HLL	High Light Level
HAC	Helicopter Aircraft Commander
HgCdTe	Mercury-Cadmium-Telluride
HAS	Helmet Sight Assembly
HSS	Helmet Sight Subsystem
HST	Helicopter Support Team
HUD	Heads Up Display
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IPD	Interpupillary Distance
IR	Infrared

GLOSSARY: ABBREVIATIONS AND ACRONYMS

LED	Light Emitting Diode
LLL	Low Light Level
LLTV	Low Light Television
LZ	Landing Zone
MAF	Maintenance Action Form
MCP	Microchannel Plate
MILSPEC	Military Specification
MITAC	Map Interpretation and Terrain Analysis Course
NAVFLIR	Navigation FLIR
nm	Nanometer
NM	Nautical Miles
NVD	Night Vision Device
NVG	Night Vision Goggle
OLF	Outlying Field
PAS	Pivot Adjustment Shelf
REM	Rapid Eye Movement
SA	Situational Awareness
TFLIR	Targeting FLIR
TOW	Tube launched Optically tracked Wire guided missile
TSU	Telescopic Sight Unit
UV	Ultraviolet
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

II. Terms and Definitions

ABSORPTANCE. The ratio of the radiant energy absorbed by a body to that incident upon it.

ACCOMMODATIVE EYE FATIGUE. Fatigue associated with NVG flight; the eyes continuously and automatically focusing and refocusing to offset binocular misadjustment or differences in intensifier tube resolution.

AIDED. A term used to describe those times when NVDs are being used as the visual system is being aided by these devices.

ALBEDO. The ratio of the amount of light reflected from a surface to the amount of incident light.

APPARENT DISK. The sunlit surface area of the moon that can be seen from the earth.

ASTIGMATISM**. A defect of the refractive system of the eye (usually due to corneal irregularity). With this condition, rays from a point fail to meet in a focal point resulting in a blurred and imperfect image. This condition is not correctable with ANVIS.**

ASTRONOMICAL TWILIGHT. The time when the true altitude of the center of the sun (setting) is 18 degrees below the horizon. Solar illuminance levels at this time are compatible with NVG operations.

AUTOMATIC BRIGHTNESS CONTROL (ABC). One of the automatic gain control circuits found in second and third generation NVG devices. It attempts to provide consistent image output brightness by automatic control of the microchannel plate voltage.

AUTOMATIC GAIN CONTROL (AGC). Comprised of the automatic brightness control and bright source protection circuits. Is designed to maintain image brightness and protect the user and the image tube from excessive light levels. This is accomplished by controlling the gain of the intensifier tube.

BEGINNING MORNING NAUTICAL TWILIGHT (BMNT). That time when the true altitude of the center of the sun (rising) is 12 degrees below the horizon. Solar illuminance levels at this time are compatible with NVG operations. Illuminance levels when the sun is higher than 12 degrees below the horizon will most likely not be compatible with NVG operations.

BLACKBODY. An ideal body of surface that completely absorbs all radiant energy falling upon with no reflection.

BLOOMING. Common term used to denote the “washing out” of all or part of the NVG image due to degaining of the I^2 tube when a bright light source is in the NVG FOV.

BRIGHT SOURCE PROTECTION (BSP). Protective feature associated with second and third generation NVGs which protects the intensifier tube and the user by controlling the voltage at the photocathode.

GLOSSARY: TERMS AND DEFINITIONS

BROWN-OUT. Condition created by blowing sand, dust, etc., which can cause the pilots to lose sight of the ground. This is most commonly associated with landings in the desert or in dusty LZs.

CIVIL NAUTICAL TWILIGHT. The time when the true altitude of the center of the sun is six degrees below the horizon. Illuminance level is approximately 3.40 lux and is above the usable level for NVG operations.

CLIMB TO COPE. Increasing altitude from the terrain flight profile in order to increase reaction time and comfort level.

DEGOGGLE. The action of flipping up the AN/AVS-6 for unaided flight operations.

DELTA T. The difference between an objects temperature and that of its background or surroundings. By convention, this difference is expressed as temperature; however, the difference in thermal radiation can also be due to differences in emissivity.

DIOPTER. A measure of the refractive (light bending) power of a lens.

DONNING. Those actions involved in physically attaching the NVGs to the helmet.

ELECTRO-OPTICS (EO). The term used to describe the interaction between optics and electronics, leading to transformation of electrical energy into light or vice versa.

ELECTROLUMINESCENT (EL). Referring to light emission that occurs from application of an alternating current to a layer of phosphor.

EMISSIVITY (E). The relative power of a surface to emit heat by radiation; the ratio of the radiant energy emitted by a surface to that emitted by a blackbody at the same temperature.

EVENING NAUTICAL TWILIGHT. That time when the true altitude of the center of the sun (setting) is 12 degrees below the horizon. Solar illuminance levels approximate 10^3 Lux at this time and are compatible with NVG operations.

FLUX. The rate of transfer of energy across a given surface.

FOOT-CANDLE. A measure of illuminance; specifically the illuminance of a surface upon which one lumen is falling per square foot.

FOOT-LAMBERT. A measure of luminance; specifically the luminance of a surface which is receiving an illuminance of one foot-candle.

GAIN. When referring to an image intensification tube, the ratio of the brightness of the output in units of foot-lambert, compared to the illumination of the input in foot-candles. A typical value for a GEN III tube is 25,000 to 30,000 Fl/fc. A “tube gain” of 30,000 Fl/fc provides an approximate “system gain” of 3,000. This means that the intensified NVG image is 3,000 times brighter to the aided eye than that of the unaided eye. In regard to FLIR, it pertains to the temperature range corresponding to the displayed dynamic range.

GREYBODY. A radiator or absorber with a constant emissivity value of less than one.

GOGGLE. The action of flipping down and activating the AN/AVS-6 and/or configuringaircraft lighting for NVG compatibility.

HYPEROPIA. Commonly called farsightedness; the optical error in which an image has not yet come to a point of focus when it reaches the retina. This condition is correctable on NVGs by adjusting the Diopter Adjustment Ring. It is also correctable with glasses or contact lenses.

ILLUMINANCE. Also referred to as illumination. The amount, ratio or density of light that strikes a surface at any given point.

IMAGE INTENSIFIER. An electro-optic device used to detect and intensify optical images in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. This component actually performs the intensification of the image; i.e., the MX-10160 in the ANVIS. This component is composed of the photocathode, MCP, screen optic, and power supply. It does not include the objective and eyepiece lenses.

INCANDECENT. Refers to a source that emits light based on thermal excitation, i.e., heating by an electrical current, resulting in a very broad spectrum of energy that is dependent primarily on the temperature of the filament.

INFRARED. That portion of the electromagnetic spectrum in which wavelengths range from 0.7 microns to 1 millimeter. This segment is further divided into near infrared (0.7-3.0 microns), mid infrared (3.0-6.0 microns), far infrared (6.0-15 microns), and extreme infrared (15 microns-1 millimeter).

IRRADIANCE. The radiant flux density incident on a surface. For the purpose of this text the terms irradiance and illuminance shall be interchangeable.

LOW LIGHT LEVEL. Ambient illumination less than 0.0022 lux.

LUMEN. A measurement of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle intensity.

LUMINANCE. The luminous intensity (reflected light) of a surface in a given direction per unit of projected area. This is the energy used by NVGs.

LUX. A unit measurement of illumination. The illuminance produced on a suface that is one meter square from a uniform point source of one candle intensity or one lumen per square meter.

MICROCHANNEL PLATE. A wafer of between 3 and 6 million specially treated microscopic glass tubes designed to multiply electrons passing from the photocathode to the phosphor screen in second and third generation intensifier tubes.

MICRON. A unit of measure commonly used to express wavelength in the IR region, equal to one millionth of a meter.

MINIFICATION. A decrease in the apparent or perceived size of an object, or of its image in relation to the object. A negative power lens will create this effect, i.e., dialing in too much negative diopter in the ANVIS eyepiece lens. The resultant decrease in the apparent size of an object in relation to the object leads to increased difficulty with in-flight distance estimation.

MORNING NAUTICAL TWILIGHT. The time when the true altitude of the center of the rising sun is 12 degrees below the horizon.

MYOPIA. Commonly called nearsightedness; the optical error in which an object comes to a point of focus before it reaches the retina, and is thus out of focus on the retina. This condition is correctable on the NVGs by adjusting the Diopter Adjustment Ring. It is also correctable with glasses or contact lenses.

NANOMETER (nm). A unit of measure commonly used to express wavelength in the visible and near IR region; equal to one billionth of a meter.

NIGHT VISION DEVICE (NVD). An electro-optical device used to provide a visible image using the electromagnetic energy available at night, i.e., ANVIS and FLIR.

NVG TRANSITION. Progression of exterior lighting sequence for an entire flight from unaided to aided, and aided to unaided vision during multi-aircraft operations.

PHOTON. A quantum (basic unit) of radiant energy (light).

PHOTOPIC VISION. Vision produced as a result of the response of the cones in the retina as the eye achieves a light adapted state (commonly referred to as day vision).

RADIANCE. The flux density of radiant energy reflected from a surface. For the purposesof this manual the terms radiance and luminance shall be interchangeable.

REFLECTIVITY. The fraction of energy reflected from a surface.

SCOTOPIC VISION. That vision produced as a result of the response of the rods in the retina as the eye achieves a dark adapted state (commonly referred to as night vision).

SITUATIONAL AWARENESS (SA). Degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time.

STARLIGHT. The illuminance provided by the available (observable) stars in a subject hemisphere. The stars provide approximately 0.00022 lux ground illuminance on a clear night. This illuminance is equivalent to about one-quarter of the actual light from the night sky with no moon.

STEREOPSIS. Visual system binocular cues that are used for distance estimation and depth perception. Three dimensional visual perception of objects.

TRANSMITTANCE. The fraction of radiant energy that is transmitted through a layer of absorbing material placed in its path.

ULTRAVIOLET. That portion of the electromagnetic spectrum in which wavelengths range between 0.1 and 0.4 microns.

UNAIDED. Term used to describe those times when NVDs are not being used/worn as the visual system is not being aided by these devices.

WASHOUT. See definition “Blooming”.

WAVELENGTH. The distance in the line of advance of a wave from any one point to the next point of corresponding phase; is used to express electromagnetic energy including IR and visible light.

WHITEOUT. A condition similar to brown-out but caused by blowing snow.

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