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Operational test and evaluation of fixed wing aircraft equipped with spectral radiation remote sensing devices

Mark R. Mitchell

To the Graduate Council:

I am submitting herewith a thesis written by Mark R. Mitchell entitled "Operational test and evaluation of fixed wing aircraft equipped with spectral radiation remote sensing devices." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph D. Kimberlin, Major Professor

We have read this thesis and recommend its acceptance:

Pere Solies, Arthur Mason

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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OPERATIONAL TEST AND EVALUATION
OF FIXED WING AIRCRAFT EQUIPPED WITH
SPECTRAL RADIATION REMOTE SENSING DEVICES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

LtCol Mark R. Mitchell, USMC

May 1991

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ABSTRACT

Until recently, the use of spectral radiation remote sensing devices to support nighttime flight operations was limited to the helicopter community. Significant progress is now being made in the development of spectral radiation remote sensing devices, commonly referred to as night vision devices, for use in fixed wing, fast moving aircraft to provide the aircrew with an effective nighttime attack combat capability. A well designed "night vision system" should provide the aircrew with better situation awareness, increased low altitude flying capability and enhanced survivability during the hours of darkness.

Night vision systems for fixed wing aircraft are now being fielded and a method to evaluate accurately their performance under actual operational and environmental conditions is needed. This study proposes a thorough flight test plan that evaluates the operational effectiveness and logistical suitability of an aircraft equipped with a night vision system.

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NOMENCLATURE

AAW	Antiair Warfare
AMRAAM	Advanced Medium Range Air-to-Air Missile
ANVIS	Aviator's Night Vision Intensification System
CAP	Combat Air Patrol
CAS	Close Air Support
DAS	Deep Air Support
DMS	Digital Map Set
ECP	Engineering Change Proposal
FLIR	Forward Looking Infrared
HUD	Head-up Display
ICS	Intercommunications System
INS	Inertial Navigation System
KIAS	Knots Indicated Airspeed
MAS	Maritime Air Superiority
MDI	Multipurpose Display Indicator
MDRI	Multipurpose Display Repeater Indicator
MPCD	Multipurpose Color Display
MPI	Mean Point of Impact
NAVFLIR	Navigation Forward Looking Infrared
NVG	Night Vision Goggles
OFP	Operational Flight Program
WAS	War-at-Sea

CHAPTER I

INTRODUCTION

Background

In 1984 the U S Navy and Marine Corps began a serious investigation of the tactical employment of jet aircraft using night vision devices to enhance combat effectiveness and survivability at night. During flight test, the concept was proven potentially operationally effective and the decision was made to field a workable night vision system into combat attack aircraft such as the AV-8B Harrier and F/A-18 Hornet. The "night vision system" consists of several key components:

1. Night Vision Goggles (NVG) worn by the pilot
2. Forward Looking Infrared Receiver (FLIR) system
3. Raster capable Head-up Display (HUD)
4. Digital moving map display
5. NVG compatible cockpit lighting

NVG and FLIR systems are used for the remote sensing of visible, near infrared and far infrared radiation of the electromagnetic spectrum. Their application as night vision devices in tactical aircraft is integral to the night vision system. The raster capable HUD is a transparent glass plate mounted above the instrument glare shield through which the pilot views the outside world directly to his front. The field of view is limited (about 20° square) but the HUD gives the pilot a "heads up" display of critical flight and weapon information. The raster capability of the HUD allows the projection of the FLIR image much like the raster projection of a image onto a television screen. The infrared image is superimposed over the actual nighttime scene to give the pilot as real a depiction of the outside world as possible. The digital moving map is a separate computer generated map display that provides the pilot with an accurate depiction of the terrain surrounding him, which is important in the absence of good visual peripheral cues at night.

Purpose

The incorporation of night vision devices into fast moving fixed wing tactical aircraft presents a challenging problem in the operational test and evaluation of this new capability. The effectiveness of the individual components of the night vision system as well as the interoperability of the components must be evaluated to ensure the pilot is provided with a functional night vision system. To date there is no standardized or proven program that accurately evaluates the operational effectiveness and logistical suitability of the night vision system in fixed wing aircraft. This paper is a single source reference on the remote sensing of spectral radiation as it applies to night vision devices in tactical aircraft and provides a formal method of flight testing to evaluate the operational effectiveness and suitability of an aircraft equipped with a night vision system. Observations from actual flight test of developmental night vision systems for fixed wing aircraft from 1988 to 1990 will be included when applicable. The testing and evaluation of an aircraft outfitted with a night vision system requires the test director to be familiar with the basics of spectral radiation sensing. A background discussion on spectral radiation and methods of remote sensing as they apply to tactical aviation will include the following:

1. A discussion of the visible light spectrum and its intensification by NVGs.
2. A discussion of radiation in the infrared portion of the electromagnetic spectrum and its remote sensing by FLIR systems.

Together, the NVG and FLIR components are the heart of the night vision system for tactical jet aircraft. The concept of night vision devices in combat aircraft opens an entirely new chapter in modern aerial warfare. No longer can an enemy take refuge under the cover of darkness.

CHAPTER II

A DISCUSSION OF SPECTRAL RADIATION

Measurement of Spectral Radiation

The energy received and then made visible to a pilot when using night vision devices is called electromagnetic energy. Light or optical radiation is just a portion of the entire electromagnetic spectrum as depicted in Figure II-1 (COMOPTEVFOR 3-2) which includes all forms of electromagnetic energy from radio waves to cosmic radiation. There are several theories that attempt to explain the behavior of light:

1. The photon or particle theory, and
2. The wave propagation theory.

Particle Theory. The particle theory of light is convenient for describing the emission of light from a source, such as the stars. Light energy is measured radiometrically against a known standard, or photometrically through perceptions of brightness and color. In the discussion of night vision devices, photometric units are commonly used. Table II-1 lists some spectral radiation terms and equivalents (Wolfe, Zissis 1-4,5).

Wave Theory. The wave theory in turn is useful in explaining the propagation of light through air or other mediums as well as optical systems like night vision goggles

(NVG) or the eye. The wave theory of light assigns the properties of wave propagation to electromagnetic radiation

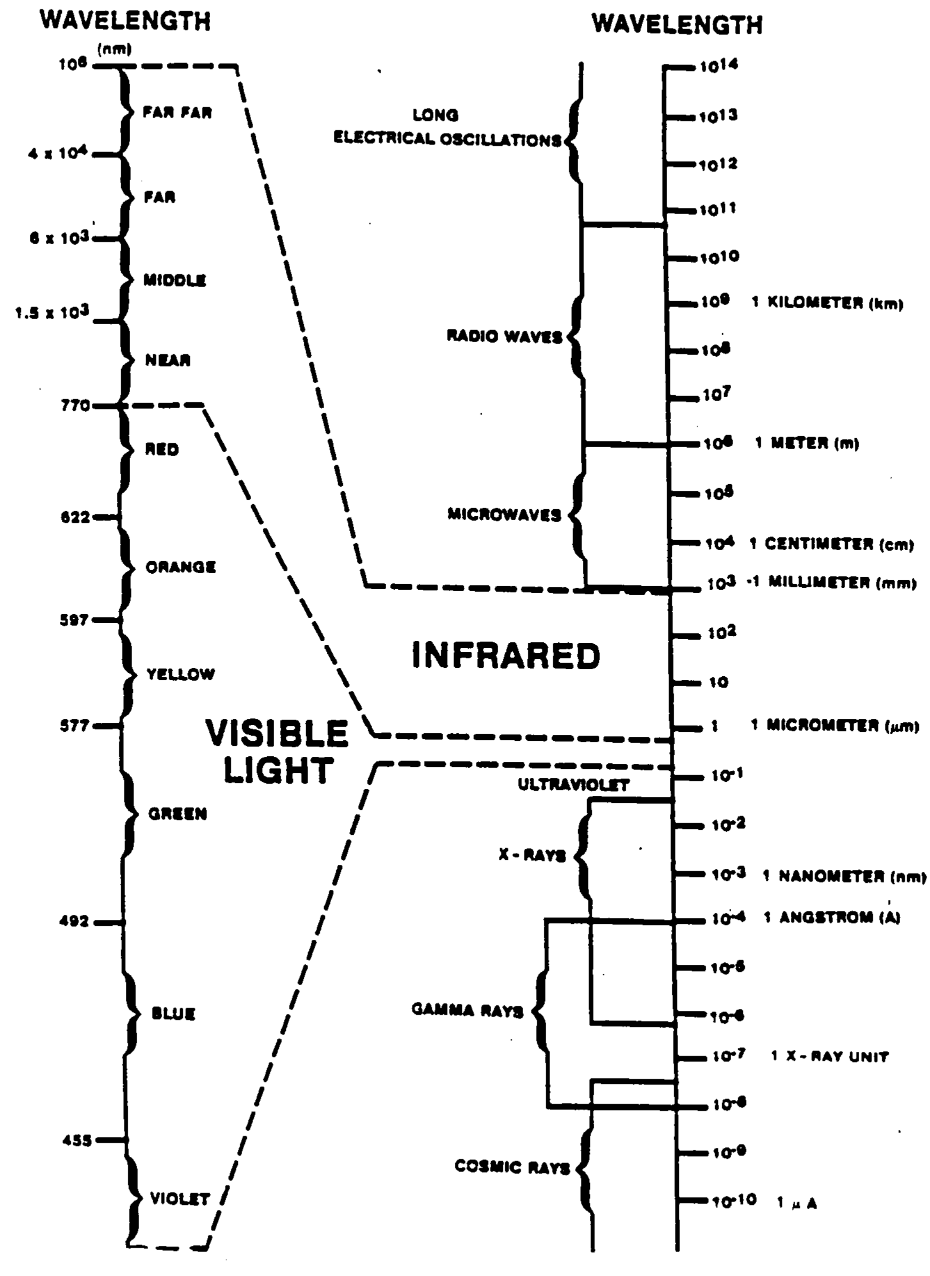

Figure II-1. The Electromagnetic Spectrum.

such as wavelength, frequency and velocity (Kerker 11). In the discussion of visible and infrared (IR) light, frequency units are so large and cumbersome when measured in gigahertz and megahertz, that units of wavelength are typically used in

Table II-1

Radiometric and Photometric Terms

Radiometric term	Symbol	Units	Photometric term	Symbol	Comparable Units
Radiant flux	Φ_e	watt	Luminous flux	Φ_v	lumen (lu)
Radiant Exitance	M_e	watt/m^2	Luminous Exitance	M_v	watt/m^2
			Candlepower		1 candle (c)
Irradiance	E_e	watt/m^2	Illuminance	E_v	1 lu/m^2 = 1 lux = 1 m-candle (mc) = 0.0929 ft-candle (ft-c)
Radiance	L_e	watt/ω/m^2	Luminance	L_v	1 lu/ω/m^2 = 1 c/m^2 = 0.3142 milli-lambert (mL) = 0.2919 foot-lambert (ft-L)

differentiating spectral radiation characteristics. For IR energy the micrometer (μm), more commonly referred to as the micron when discussing FLIR systems, is the common unit of wavelength measurement. A micron is one millionth of a meter. For near IR and visible light, the wavelengths are shorter and are often discussed in terms of nanometers which is one thousandth of a micron.

Optical Response. Much like a radio receiver must be tuned to the proper frequency in order to enjoy a favorite music station or talk show, so too are the human eyes sensitive to only certain frequencies of the electromagnetic spectrum. Likewise, night vision devices such as FLIRs and NVGs are also specifically designed to enhance certain portions of the spectrum. The unaided human eye is capable of perceiving light with wavelengths from 0.4 to 0.7 microns or basically the colors of the rainbow (Boyd 98). NVG sensitivity range extends from the deep red area of the visible range into the near IR region from 0.6 to 0.9 microns. The FLIR systems currently in place operate in the far IR region of 8.0 to 12.0 microns. Figure II-2 (Allen 61)

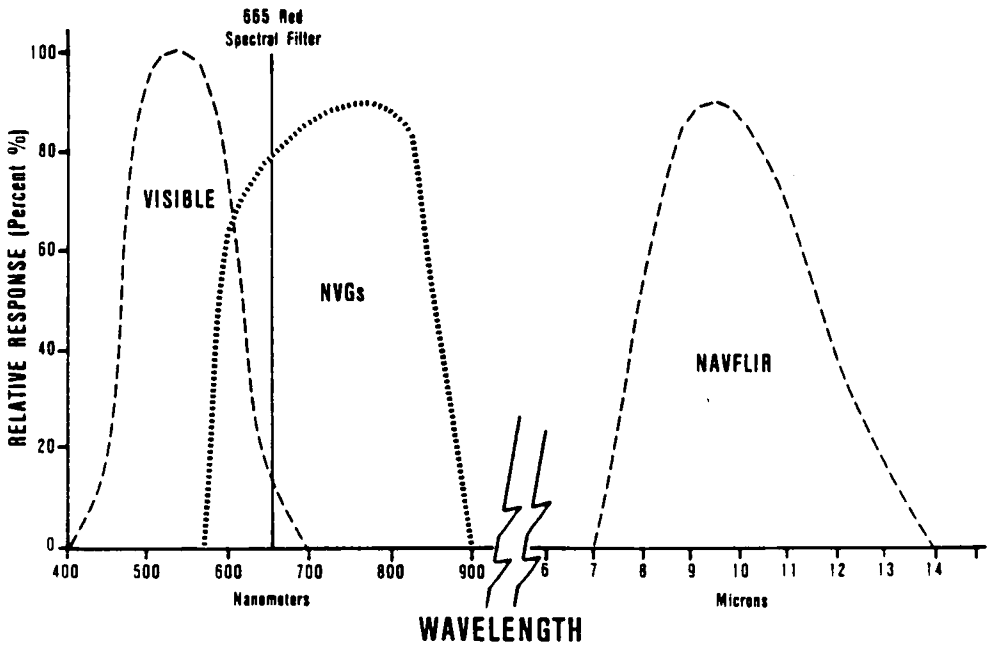

Figure II-2. Relative Spectral Response and Wavelength Sensitivities of Eye, NVG and FLIR Optical Sensors.

illustrates the response of the eye, NVGs and FLIR optical systems to those regions of the electromagnetic spectrum to which they are sensitive. The purpose of NVGs and FLIR systems is to detect spectral radiation in areas where our eyes are insensitive and then convert that energy into that part of the spectrum visible to the human eye.

Visible Light: Illuminance and Luminance

As mentioned earlier, night vision goggles (NVG) intensify the ambient light, unlike forward looking infrared receivers (FLIR) that sense far IR radiation, NVGs intensify light in the visible and near IR region from 0.6 to 0.9 microns. Most stars have a spectral irradiance between 0.8 and 1.0 microns which means a majority of the optical energy provided by stars is invisible to the human eye but is within the sensitivity range of NVGs. For this reason, NVGs are somewhat effective even on moonless nights but flight test has shown the necessity for the additional enhancement of the far IR provided by FLIR systems. Illuminance and luminance are several properties of particle (or photon) theory important in the use of NVGs. As shown in Table II-1, illuminance is expressed in lumens, lux, or foot-candles and luminance in foot-lamberts. Table II-2 (Allen 51) lists the approximate levels of illuminance under varying sky conditions.

Illuminance. Illuminance refers to the amount of light striking the surface of an object at a distance from a given source or sources. An example of illuminance would be the amount of ambient light from the moon and stars that strikes

Table II-2

Illuminance Levels of Various Sky Conditions

Sky Condition	Approximate Levels of Illuminance - lux ($lm\text{-}m^{-2}$)
Direct Sunlight	10^5
Indirect Sunlight	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	10^{-3}
Moonless, Overcast Night	10^{-4}

the terrain as a pilot flies over it. Sources of illumination include the sun, moon, stars, fires, cultural lighting and others. A lumen (lu) is defined as the flow of light from a uniform point source of one international candle (c) (Boyd 95). A lux is a measure of illuminance and is equal to the illumination produced from the flux, or energy transfer, of one lumen against a one m^2 surface. A lux can also be defined as the illumination provided to a surface that is one meter distant at all points from a point light source of one international candle. One meter-candle (m-c) is the illuminance of a one m^2 surface with one lumen falling upon it, which, in turn, is equal to 0.0929 foot-candle (ft-c). Flight test has shown that flying below 10^{-2} lux, which equates to about one quarter moon, becomes extremely difficult with NVGs alone. Below 10^{-2} lux, the NVGs become less effective, requiring the pilot to depend more heavily on the FLIR system.

Luminance. Luminance refers to the amount of light reflected from a surface. At night, luminance from the surface of objects being illuminated by the moon and stars allows the pilot to see those objects with the aid of NVGs. Luminance is measured in foot-lamberts (ft-L) which is the measure of reflected light from a surface receiving an illuminance of one ft-c. NVGs simply amplify the energy available through luminance to aid the pilot visually.

Albedo. The relationship between illuminance and luminance yields a ratio of reflected light to incident light which is called "albedo" (Allen 26). Surfaces have different albedos which vary with the texture, color, moisture content and reflectiveness of the object under given ambient light conditions, as shown in Table II-3 (COMOPTEVFOR 4-62). Experienced highway drivers have seen the difference in albedo between a black asphalt road and a light concrete road when driving at night under the same ambient light conditions.

Table II-3

Albedos for Various Surfaces

Object	Albedo (Illumination/lumination)
Dark wet soil	.08
Dark ploughed soil	.08
Dark dry soil	.13
Deciduous trees	.18
Desert	.30
Rock	.35
White sand	.55
Snow and ice	.65
Fresh snow	.85

Albedo of the terrain is important during night flying in that the contrast or distinction between various terrain features or objects depends on the differences in albedo between them. Contrast is what a pilot uses to distinguish an approaching ridgeline from the terrain in the foreground or background. Additionally, on dark moonless nights, the albedo of the terrain has a direct impact on the effectiveness of the NVGs worn by the pilot. Snow covered terrain has a high luminance therefore a high albedo, where as dark soil has a low albedo. A pilot using NVGs on a dark night may have enough luminance over fresh snow, which reflects 85% of the ambient illumination, to allow him to fly safely at low altitude but unable to continue when flying over dark ploughed fields.

In summary. Light sources provide illumination or illuminance, but what the eye perceives, and what NVGs intensify, is the reflected light or luminance from the object or terrain being illuminated.

Infrared Radiation; Absorption and Emissivity

Table II-4 lists the four sub-bands of the infrared portion of the electromagnetic spectrum. The Latin prefix

Table II-4

Infrared Sub-bands

IR Band	Wavelength (microns)
Near	0.77 to 1.5
Mid	1.5 to 6.0
Far	6.0 to 40.0
Extreme	40.0 to 10,000

"infra" means below and in the discussion of spectral radiation infrared implies that part of the spectrum which is below the visible red in terms of frequency. As depicted in Figure II-1, the infrared spectrum is further divided into the near, middle, far and far far or extreme sub-bands.

Infrared Wavelength. Unlike NVGs, FLIR systems do not intensify visible light but rather detect IR radiation from the terrain and process that energy into a visible scene for the pilot's use. Since FLIR systems use IR radiation and are not dependent on illumination, they are useful both during the day and on the darkest nights. Most all FLIRs currently in development are sensitive to the far IR region from 7.0 to 14.0 microns, as shown in Figure II-2, which is the region most commonly encountered in nature. Weapon systems, such as the IR heat seeking Sidewinder missile, operate in the mid IR 3.0 to 5.0 micron region which is a typical wavelength band for IR radiation of jet aircraft tailpipes.

Absorption. The theory of IR radiation is based on the laws of molecular motion within a mass. All objects with temperatures above absolute zero (-273°C) emit energy in the IR region of the electromagnetic spectrum. Heat raises the energy states of objects by increasing the molecular vibrational motion of the atoms and when the elevated state of energy collapses, equal amounts of radiation in the form of IR energy are emitted. Energy striking an object can be absorbed, transmitted or reflected. A "blackbody" radiates energy, mostly in the IR region, equal to the amount of energy it absorbs (Smith, Jones, Chasmar 22). The concept of blackbody radiation has its basis in quantum theory as developed by Planck who theorized that radiant energy at a given frequency is not emitted continuously from a body but in bundles or 'quanta' in an amount as adjusted by a constant, called Planck's constant (Smith, Jones, Chasmar 26). A blackbody is the standard by which all other objects that emit IR energy are compared. As per Kirchhoff's law, a blackbody is said to have an efficiency of 1.0, which means it is a totally efficient energy absorber and therefore a perfect energy emitter (Boyd 33). An object that totally absorbs incident radiation appears black to an observer since no light energy is reflected.

Emissivity. Emissivity is a term used to compare the efficiency of the absorption/radiation characteristics of an object to a blackbody (Wolfe, Zissis 1-28). The emissivity of a blackbody at a given temperature is 1.0; the emissivity of a rough red brick at the same temperature is 0.95, that is, a brick is a fairly good energy absorber and emitter when compared to a blackbody. A highly polished silver spoon, on the other hand, reflects most of its incident energy and therefore has a low emissivity of 0.02 when compared to a blackbody. Since the silver spoon absorbs less radiation, it emits less. Table II-5 (COMOPTEVFOR 4-2) lists the emissivities of some common items.

IR Radiation Sensing. In very simple terms, a dark rock found on a hot desert floor, would probably be too hot to hold for any length of time. Radiated energy emitted by the rock would be perceived not by sight but by touch (Smith, Jones, Chasmar 7). It is the remote sensing of that IR radiation (or lack thereof) that FLIR devices use both day

Table II-5

Emissivity of Common Materials

Material	Emissivity
Highly polished silver	0.02
Highly polished aluminum	0.08
Polished copper	0.15
Aluminum paint	0.55
Polished brass	0.60
Oxidized steel	0.70
Bronze paint	0.80
Gypsum	0.90
Rough red brick	0.93
White lacquer	0.95
Green or gray paint	0.95
Lamp black	0.95
Water	0.95
(Blackbody	1.00)

and night to provide the pilot a view of the outside world. The amount of IR radiation, or radiant power, of an object is a function of its: (1) absolute temperature, (2) emissivity, and (3) radiation wavelength (Greening 5). Differences in radiant power between objects provide the thermal or temperature differential (ΔT) necessary for FLIR systems to distinguish a tank from the background surrounding it (Morten 16).

Attenuation. Of special interest in the discussion of remote sensing of IR radiation is the attenuation and scattering of IR radiation by the atmosphere. Atmospheric attenuation of IR radiation can seriously degrade the effectiveness of FLIR systems by absorbing IR radiation emitted by the terrain (Wright 14). Water, carbon dioxide and ozone are the major attenuators of IR radiation in the 0.1 to 15.0 micron region where most IR sensing missiles and FLIR systems operate. Figure II-3 (COMOPTEVFOR 4-24) depicts

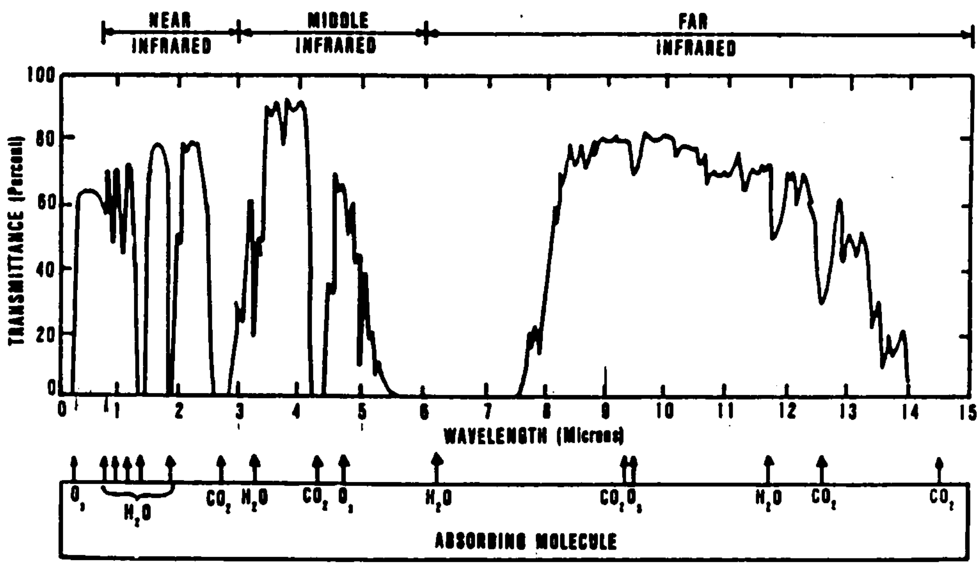

Figure II-3. Atmospheric Transmittance and Attenuation Due to H_2O, CO_2 and O_3 at 17 g/m^3 Absolute Humidity.

the areas in the IR spectrum that are heavily attenuated by H_2O, CO_2 and O_3 at 17 g/m^3 absolute humidity. Note the atmospheric transmittance or IR windows (Morten 4) at the 3.0 to 5.0 and 8.0 to 14.0 micron regions. The 3.0 to 5.0 micron window is the region in which IR missile seeker heads operate and FLIR systems are designed to detect radiation in the 8.0 to 12.0 micron window. Water vapor in the form of absolute humidity is the biggest culprit in degrading the remote sensing of the IR spectrum. Dry winter air with an absolute humidity of 3.5 g/m^3 is essentially non-intrusive to FLIR detection. However, on a hot, humid day with absolute humidity above 20 g/m^3, the IR attenuation due to water vapor in the 8.0 to 12.0 micron region is nearly complete and the effectiveness of the FLIR is nil.

Attenuation Range. Attenuation of IR radiation between the IR sensor and the source increases with distance. At a given altitude and under homogeneous atmospheric conditions, the transmittance of radiant power at a particular range is approximated by:

$$\tau(R) = e^{-\sigma R}$$

where

τ = Transmittance
R = range (in km or equivalent)
σ = extinction coefficient (in km^{-1} or equivalent)

When attenuation is the result of several sources, then the extinction coefficients of the various mediums should be considered and can be represented by:

$$\tau_{(i,j)}(R) = e^{-(\sigma_i + \sigma_j)R}$$

where σ_i, σ_j are the individual extinction coefficients.

Extinction coefficients vary in magnitude between 0.986 for a clear day at an altitude of 23 km, to 0.937 for a hazy day (Greening 10).

Scattering. Scattering of IR radiation is less of a problem than molecular absorption but it is still a factor to consider in a tactical scenario where battlefield smoke, haze and dust can hinder the use of FLIR systems. Aerosol scattering involves large particles such as dust or smog and scatters incident radiation by reflection (Greening 8). The closer the particles are in size to the spectral band of detection of the FLIR the worse the affect on the system. Fog droplets with radii in the 5.0 to 15.0 micron range have a 100% scattering effect on the IR radiation where smoke and haze at 0.5 microns have less affect. Although FLIR visibility through smoke, haze and dust is reduced, it is usually superior to the naked eye (Allen 4).

Summary of Chapter II

Chapter II discussed the common units of measure for spectral radiation. In the study of night vision devices such as NVGs and FLIRs, photometric terms like lux and foot-lamberts are typically used to describe the illuminance and luminance properties of visible light. Albedo is the ratio of reflected light to incident light. NVGs intensify the ambient luminance in the visible and near IR region of the electromagnetic spectrum. FLIR systems, on the other hand, remotely sense IR radiation in the far IR region of the spectrum. IR radiation is described through the theories of absorption and emissivity which use the perfect blackbody as a standard. Atmospheric attenuation and scattering of IR radiation adversely impact the effectiveness of IR remote sensing.

CHAPTER III

THE REMOTE SENSING OF SPECTRAL RADIATION IN TACTICAL AIRCRAFT THROUGH THE USE OF NIGHT VISION DEVICES

Night Vision Goggles (NVGs)

Introduction. The need for an optical device to allow an observer to see during the hours of darkness surfaced during the Vietnam War. Searchlights, flares and even near-infrared flood lights all had the disadvantage of highlighting friendly defensive positions to the enemy. What was needed was a totally passive form of viewing the night environment that did not compromise the observer's position or alert the enemy being observed. In the mid-1960s, the first generation of NVGs appeared which provided the user with an effective device to see in the dark. These original devices were long and heavy, suitable for ground use only (MAWTS 1-4). Since that time, three generations of NVGs have been developed with tactical application first for mobile infantry personnel, then in helicopters and most recently in fixed wing jet aircraft.

Image Intensifier Tube. As mentioned in Chapter II, NVGs are sensitive to the visible red and near IR regions of the radiation spectrum from 0.6 to 1.0 microns depending on the type of NVG. The basic component of all NVGs regardless of type is an electro-optical device called the image intensifier tube. The image intensifier tube senses the ambient light and luminance (reflected light) of the night scene in the red and near IR region, amplifies the input and then projects an enhanced image to the observer. The following items are integral to the function of current image intensifier tubes (COMOPTEVFOR 4-42):

1. Objective lens. Focuses the outside world onto the photocathode plate.

2. Photocathode plate. Light sensitive (red and near IR) material on the plate releases electrons proportional in number to the amount of light projected through the objective lens (Boyd 143).

3. Power Source. Usually a lithium battery that provides electron acceleration through a voltage differential.

4. Microchannel Plate. Secondary-emission current (electron) amplifier used to increase number of electrons emitted by the photocathode plate.

5. Phosphor Screen. Transforms electrons back to a visible intensified image used by viewer.

Figure III-1 illustrates the major components of the image intensifier tube. In theory, the mechanization of the image intensifier tube is actually quite simple. The outside scene is focused on the photocathode plate by the objective lens. The photocathode plate is coated with several vaporized elements deposited on one side of the plate through a delicate culturing process done in a vacuum. The type of

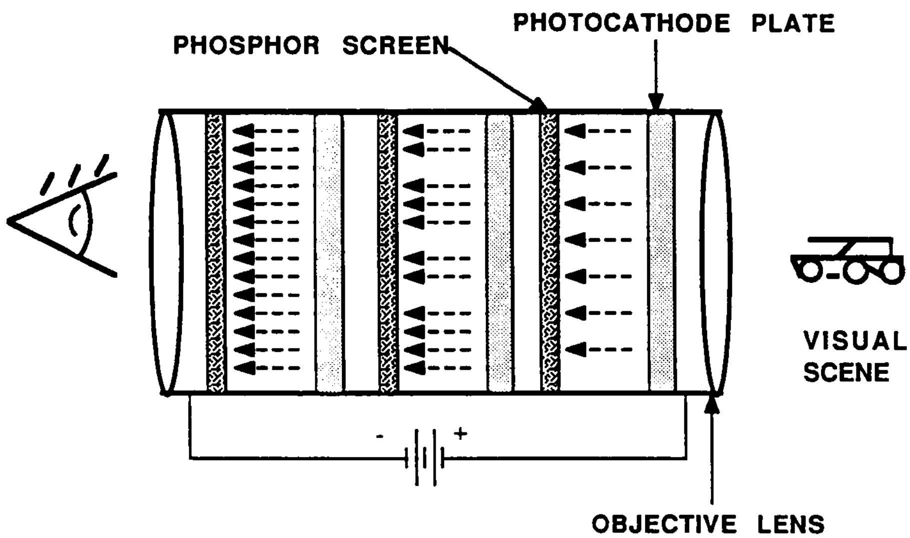

Figure III-1. Image Intensifier Tube Components.

elements used in making the photocathode plate determines the sensitivity and spectral region of intensification. Photons emitted or reflected by the scene and focused on the photocathode plate cause the plate to release electrons proportionate to the amount of light illuminating the plate (Boyd 150). These electrons are accelerated by the power source onto a phosphor screen which causes the phosphor screen to brighten. In first generation NVGs, this process is repeated several times within the intensifier tube until the original scene brightness is multiplied 40,000 to 60,000 times. The brightness of the screen depends directly on the velocity of the accelerated electrons as well as the number of electrons striking the phosphor. The intensification process in first generation NVGs is based mainly on electron acceleration which requires large and heavy power sources. Later versions of NVGs used a device called a microchannel plate to multiply the number of electrons generated by the photocathode plate to produce an enhanced image of the outside scene. This method requires less power and therefore opened the door to miniaturization of the image intensifier tube.

Microchannel Plate (MCP). The MCP is the device that distinguishes second generation NVGs from the bulky "starlight" scopes of the Viet Nam era. The MCP shown in Figure III-2 (COMOPTEVFOR 4-44) is a 1 mm thin plate of about 1.5 million densely packed tiny glass tubes canted 8°

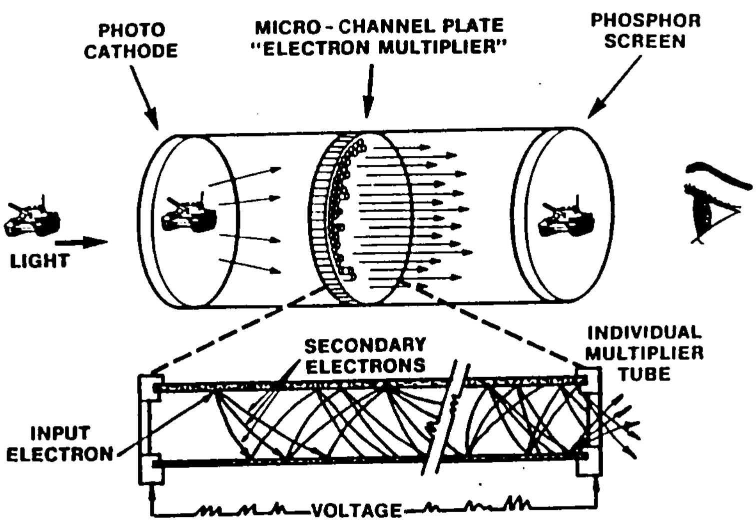

Figure III-2. Microchannel Plate.

to the path of incoming electrons emitted by the photocathode plate. Through a special hydrogen reduction process, these lead silicate glass tubes are left with a silica rich coating on the inside circumference of the tubes that emitted additional electrons for each electron that struck the wall (COMOPTEVFOR 4-43). The 8° cant of the tubes ensures electrons from the photocathode plate strike a wall and are multiplied in number as the electrons ricochet down the glass tubes. The gain realized by second generation NVGs using MCP technology is about 20,000 to 30,000, less than first generation NVGs, but with a great savings in power requirements, weight and size. The glass tubes of the MCP effectively maintain the position and orientation of the multiplied electrons as they accelerate along impact the phosphor screen. Major improvements in the coatings of the photocathode plate and MCP mark the introduction of third generation NVGs.

Improved Photocathode Plate and Phosphor Screen. As shown in Figure III-3 (MAWTS 2-11), third generation NVGs are different from second generation NVGs in only two ways: the multi-alkali coated second generation photocathode plates are replaced with gallium arsenide photocathode plates and the MCP is coated with a metal oxide film. The gallium arsenide photocathode plate is three times more sensitive above 550 nm than the multi-alkali photocathode plate and, with peak sensitivity at 800-900 nm, it enjoys superior performance in the near-infrared where the night spectral radiation environment is most plentiful (MAWTS 2-14).

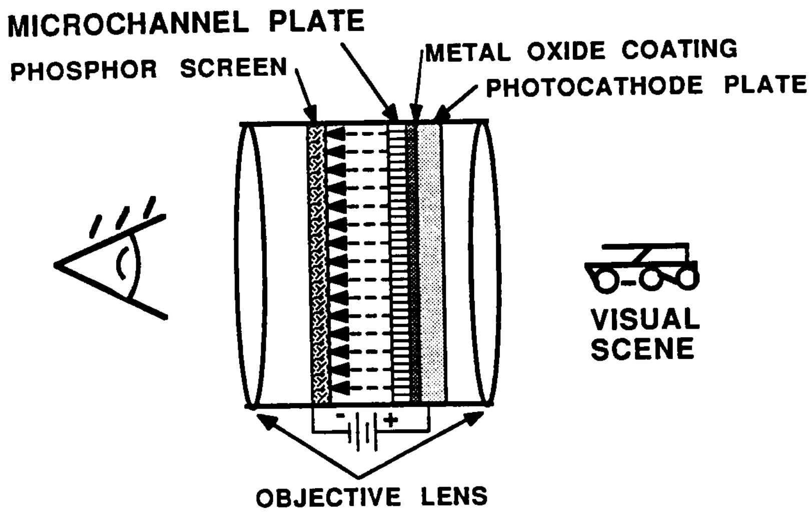

Figure III-3. Third Generation Image Intensifier.

In order to lengthen the useful life of the photocathode plate, third generation NVGs incorporates a protective metal oxide coating on the MCP between it and the photocathode plate. This protective coating prevents the back scatter of ions released in the process of electron multiplication in the MCP from contaminating the delicate photocathode plate. The metal oxide coating acts as a one way mirror by allowing electrons to pass freely from the photocathode plate to the MCP at the same time preventing ions from bombarding the photocathode by reflecting them back into the MCP. The result of these two modifications in third generation NVGs is an increase in nighttime performance and an extended service life from two to four thousand hours to 10,000 hours (Allen 20). There are two types of third generation NVGs in use; the Aviator's Night Vision Intensification System (ANVIS) goggles and the Cats Eyes NVGs which are discussed in the following sections.

Aviator's Night Vision Intensification System (ANVIS). ANVIS goggles have been used by the helicopter community for many years. The ANVIS goggles shown in Figure III-4 (MAWTS 2-16) resemble a pair of small binoculars mounted

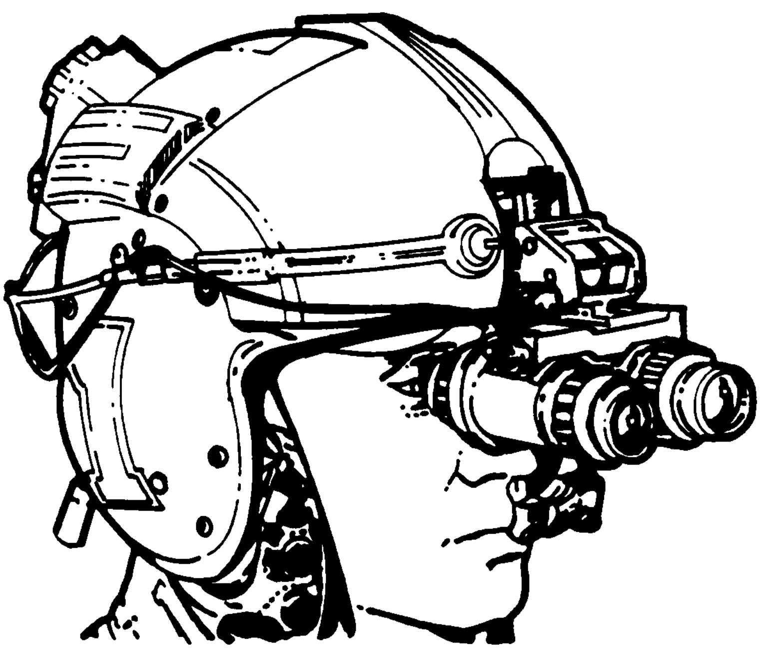

Figure III-4. Aviator's Night Vision Intensification System (ANVIS).

on the pilots helmet through which the pilot views the intensified scene directly through the intensifier tubes. Viewing the outside scene in this straight-through format provides a 40° field of view and with good resolution. The arrangement is also fairly lightweight. Unfortunately, the head-up display (HUD) stroke and raster presentation format of modern fixed wing aircraft is in a spectral band outside the sensitivity range of third generation intensifier tubes and suffer loss of resolution when viewed through the ANVIS goggles. HUDs of late model AH-1 Cobra attack helicopters were modified to be ANVIS compatible through the use of special NVG filters that improves the interoperability of the ANVIS goggles and HUD. For the Navy/Marine F/A-18 Hornet, AV-8B Harrier and A-6E Intruder jet aircraft a different approach was taken in the form of Cats Eyes NVGs.

Cats Eyes NVGs. Although heavier and a having a smaller field of view (30° vice 40°) when compared to ANVIS goggles, Cats Eyes as depicted in Figure III-5 (Allen 15) are the NVGs of choice for Navy/Marine fixed wing aircraft primarily for their better HUD symbology compatibility. As shown in Figure III-6 (COMOPTEVFOR 4-58), the major difference between ANVIS and Cats Eyes NVGs is in the optical train from the intensifier tubes to the eye. Where ANVIS uses an axial or straight-through format, Cats Eyes employs an Amici prism to bend the intensified image 90° in order to project the scene on a "combining glass" for the pilots viewing. The function

Figure III-5. Cats Eyes Night Vision Goggles.

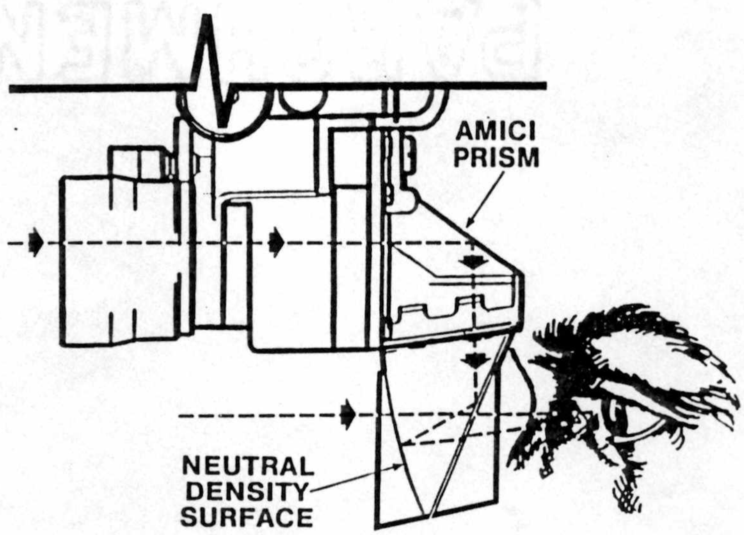

Figure III-6. Optical Train for Cats Eyes NVGs.

of the combining glass is to mix the intensified image onto the real image which includes the HUD symbology. With the Cats Eyes NVGs, the pilot views the outside scene enhanced by the intensifier tubes superimposed over the flight and weapon symbology projected on the HUD. Additionally, the Cats Eyes NVGs offer good peripheral vision to the side and beneath the combiner glasses which allows the pilot adequate line of sight to the head-down cockpit instrumentation. A red spectral filter inhibits light wavelengths below 665 nanometers from entering the intensifier tubes to preclude intensification of special NVG compatible cockpit lighting which is in the blue-green region of the spectrum (Allen 14). Cats Eyes NVGs, as do all NVGs, cause a degradation in pilot visual acuity from 20/20 to about 20/50 under clinical conditions (COMOPTEVFOR 4-61). Additionally, since the HUD symbology is viewed through the combiner glasses, which have a light transmissivity loss of 14%, the brightness or intensity of the HUD must be adjusted to higher than normal settings for night flying. This is not a problem usually since the pilot is not actually "night adapted" when using NVGs. Cats Eyes NVGs are not ejection safe and must be removed prior to ejecting from an aircraft. For this reason, development of an ejection safe, integrated NVG and helmet mounted sight display helmet system is on-going.

Navigation Forward Looking Infrared Receiver (NAVFLIR)

Introduction. FLIR technology has been used for many years for guidance and control of different weapons as well as in target detecting sensors for aircraft. Only recently has this FLIR technology been applied to the night terrain avoidance and navigation requirements of night attack fixed wing aircraft. In 1984 a test was conducted to determine if a targeting FLIR, that projects an IR image on a heads down display (not a on HUD), could be used as a navigation and terrain avoidance device (COMOPTEVFOR 1-5). It could not. But it was realized that the potential for passive, non-radar low level flight existed if the FLIR was optimized for that purpose.

NAVFLIR Concept of Employment. The concept of using NAVFLIR sensors for navigation and terrain avoidance centers on the ability of the system to provide the pilot with a one-to-one, fixed forward, real time depiction of the outside scene projected on a HUD that allows the pilot the same flight ques as are available during the day. Developmental NAVFLIRs are sensitive to the far IR region of the radiation spectrum from 7.0 to 14.0 microns. The NAVFLIR, combined with the use of NVGs, provides the pilot with a remote sensing system that covers a wide range of the electromagnetic spectrum. Figure III-7 depicts the basic concept of the NAVFLIR (Allen 5).

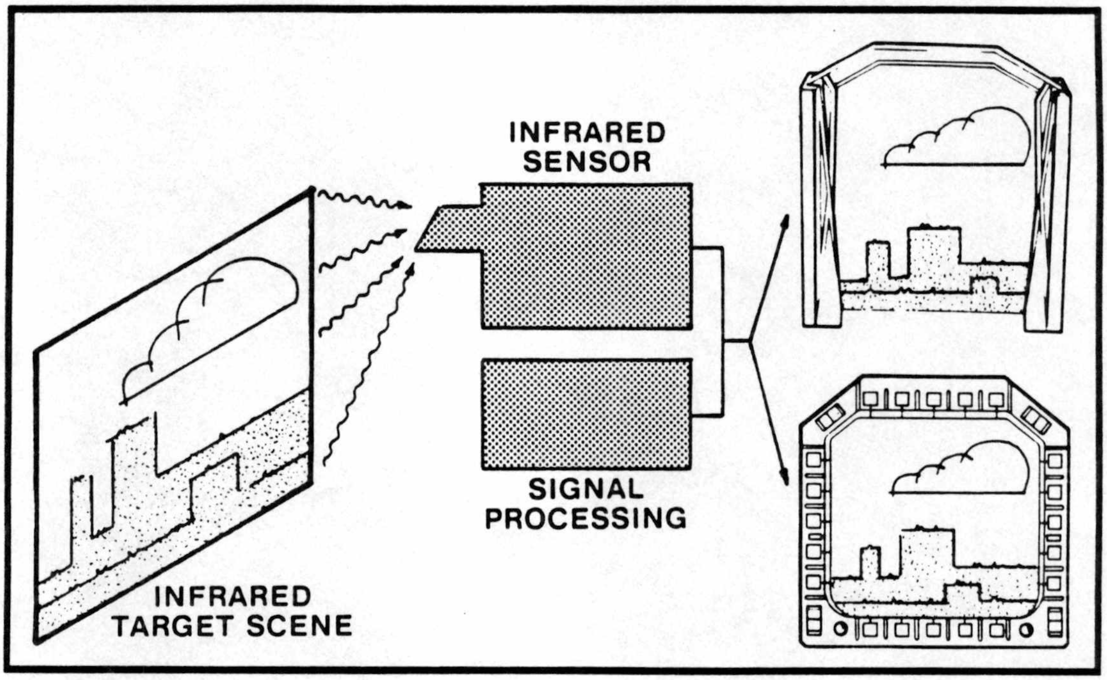

Figure III-7. Basic Concept of the NAVFLIR.

NAVFLIR Components. The NAVFLIR is designed to detect the IR radiation emitted by the scene, process the energy into the visible spectrum and then project the image in a raster television type format to the pilot. This process also compensates for inherent noise in the transmission medium, the atmosphere, which acts to degrade the performance of remote IR sensing. The two primary components of the NAVFLIR system are the sensor head and the electronics unit.

NAVFLIR Sensor Head. The sensor head or IR detector unit as depicted in Figure III-8 (Allen 7) gathers and focuses the

IR scene onto a cooled detector array where the IR energy is converted into an electrical signal. The signal is then

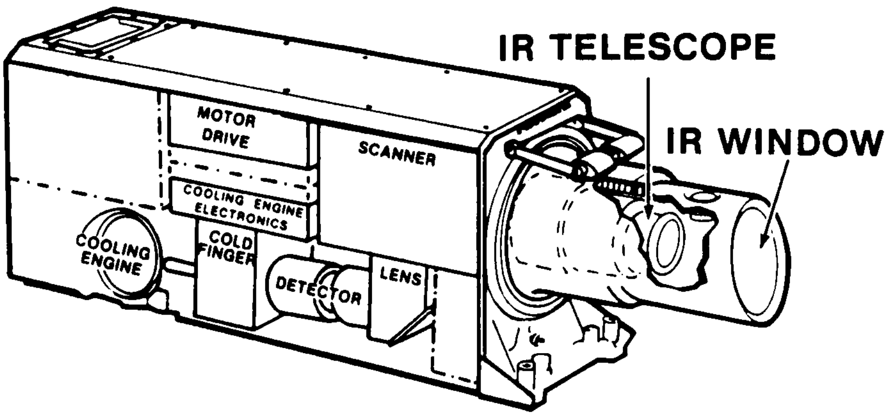

Figure III-8. NAVFLIR Sensor Head.

modified, adjusted and balanced prior to transmission to the electronics unit. The sensor head is covered by a germanium window that is strong enough to protect the head from wind blast but allows transmission of IR radiation to the detector (Kimmitt 27). A series of mirrors scans the IR scene and directs the received radiation through a lens onto a photoconductive detector array (Morten 18). The photoconductive detector array is a quantum detector which measures small increments of radiant energy. The detector is cooled either cryogenically or through the use of a Stirling split-cycle cooling engine that alternately compresses and releases air pressure to achieve required temperatures. Cooling the detector increases the sensitivity of the device by reducing inherent thermal agitation (Kimmitt 63). The detector array is constructed in a vertical arrangement of eight separate elements composed of mercury-cadmium-telluride. As IR energy strikes the detector, the conductivity of the detector is changed which causes a measurable change in the current flow across the detector. The generated signal is then sent to the electronics unit for further processing.

NAVFLIR Electronics Unit. The electronics unit shown in Figure III-9 (Allen 9) takes the generated signal from the sensor head, stabilizes and enhances the quality of the signal, converts the image into television signals, controls

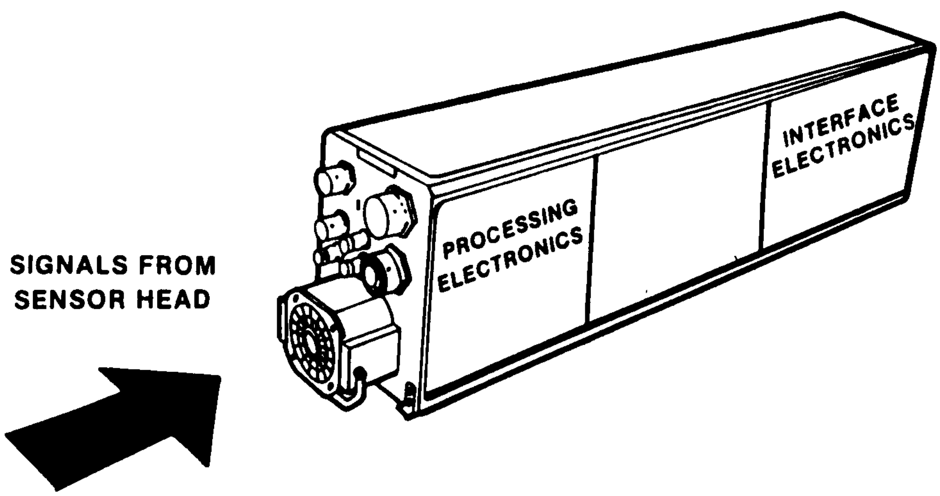

Figure III-9. NAVFLIR Electronics Unit.

the gain and contrast of the image and provides control and monitor of the system operation. The electronics unit is composed of two major units: the interface electronics unit and the processing electronics unit.

The interface unit provides an integration link between the NAVFLIR and other aircraft avionics. NAVFLIR operation, built-in-test, power-up sequencing and NAVFLIR subsystem control are all provided by the interface unit. Automatic gain and contrast control is also provided by the interface unit which optimizes the video picture based on flight conditions and aircraft attitude.

The processing electronics unit takes the IR video signal generated from the eight vertical detector elements and controls the gain and matching of each channel. The signal-to-noise ratio is improved, correct thermal gain and contrast is set and the IR signal is compressed into television scan rates for television signal processing (Morten 106). The processing electronics unit provides the pilot with fine tuning of the video presentation on the HUD or other cockpit displays.

Summary of Chapter III

Chapter III discussed the mechanization and concept of employment of night vision goggles and navigation FLIRs. The integration of the two systems provides the pilot with a passive, night low level flight, navigation and attack capability unprecedented in fixed wing aviation. Chapter IV will discuss a recommended plan for the operational test and evaluation of the fixed wing night vision system.

CHAPTER IV

RECOMMENDED PLAN FOR THE OPERATIONAL TEST AND EVALUATION OF AIRCRAFT EQUIPPED WITH NIGHT VISION SYSTEMS

Operational Test and Evaluation Overview

Introduction. Thousands of manhours and millions of dollars are spent during the research and development of new avionic or weapon systems But no matter how much time and money are expended on a system, if the intended user finds it cumbersome, unmaintainable, or in the worst case, dangerous, then the user is probably better off without it. The purpose of operational test and evaluation is to exercise the new system in the environment and in the manner the user will employ it. For Navy and Marine aircraft and aircraft weapon systems, that environment could be anywhere in the world under the most demanding combat conditions. If operational test and evaluation finds the system tactically ineffective or logistically unsuitable, then the identified deficiencies should either be corrected or the system shelved. The mission of operational testing is to investigate thoroughly the usefulness and hardiness of new systems prior to their introduction to the operator so that only the best possible product is provided to the young men on the front lines. Care must be taken to ensure the evaluation encompasses the system as a whole and does not focus on individual components. For example, an air-to-air radar missile may function perfectly when launched but, if the pilot can not effectively employ his radar set to get a radar lock on the target, then the "system" as a whole is not effective.

Operational Test Objectives. The objectives of any test and evaluation plan must be clearly delineated to give the project direction. The objectives of a night vision system operational test plan must be established based on the operational characteristics desired of the system. That is, if a desired operational characteristic for an aircraft equipped with a night vision system is to be able to navigate, maneuver, identify and attack targets during the hours of darkness against the anticipated threat, then one of the objectives of testing should be to determine if the system in fact possesses this capability. There may be several operational effectiveness and suitability characteristics desired of the system and all should be formalized in the test plan as stated objectives. Once the objectives of testing are outlined, they can be described as issues to be resolved that are critical to answering the question of operational effectives or suitability of the system. The "critical operational issue" for resolution based on the aforementioned test objective might be to demonstrate the ability of the system to allow the pilot to attack successfully a target at night; or in shorter terms, "Target Prosecution" may be one of the critical operational issues requiring resolution.

Evaluation Criteria. Certain characteristics of a system are quantifiable and can be measured against a given standard or threshold. These thresholds are usually established by the operational requirement the system is to satisfy. For example, if the current or projected enemy threat dictates that a pilot should avoid a certain surface combatant by five miles to deny weapons employment, then an operational requirement for a night vision system might be to provide the pilot with a detection capability of not less than eight miles on that size ship. Other quantifiable characteristics include system reliability, availability and maintainability for which threshold figures should be set. Evaluation criteria are usually established by the acquisition agency and provided to the developing agency as technical specifications. They are then used by the operational test director to ensure the developers did their job.

In operational test many desired system characteristics are not quantifiable. Such critical operational issues as the system's compatibility with the operating environment, interoperability with other on-board systems, human factors design and safety features must be "qualitatively" evaluated during testing. Operator opinions and observations are required from a number of users to formulate broad based conclusions in resolving the issue in question. In the case of the night vision system, a cadre of several project pilots must be established to evaluate the system adequately. The pilots should be experienced in the aircraft being evaluated but having experience in other types of aircraft especially aircraft with night vision systems is optimum. Project pilots must avoid the tendency to compensate for system deficiencies and report their observations and feelings objectively.

Operational Test Scenarios. Since testing new weapon systems in actual combat is impractical, "scenarios" must be developed to simulate as closely as possible actual combat environments. Scenarios are based on the missions the aircraft is expected to perform. As an example, the F/A-18 Hornet is designed to perform both air-to-air and air-to-ground missions. To test the F/A-18 thoroughly, scenarios should be based on its specific missions of power projection, close air support, anti-air warfare and war-at-sea. Operational test of night vision systems must be oriented to the conduct of assigned missions during the hours of darkness. Simulating the environment and conditions in which the system is to be deployed is the challenge the operational test director must face.

Operational Testing. In order to accomplish the objectives of the test, the assigned critical operational issues must be resolved as either satisfactory or unsatisfactory. Only then can logical conclusions be made as to whether or not the operational requirements of the system have been realized. Specific tests must be designed by the test director to resolve each issue under the applicable scenario. Tests to evaluate the effectiveness of the system under combat conditions and in various environmental settings need to be formulated. Additionally, system suitability issues must be resolved by designing tests that will challenge the system's hardiness under actual operating conditions.

Test Procedure. Once the objectives of the operational test are established and critical operational issues are assigned, then the test director can design a test procedure that will resolve the issues based on the the systems performance in a given scenario. The test procedures may be simple or complex but should always attempt to simulate the combat conditions and actual natural environments in which the system is designed to operate.

Data Analysis. Data analysis is either quantitative or qualitative. Data are gathered from different sources such as range score sheets for ordnance delivery accuracy, pilot debriefs for target detection, recognition and identification ranges and from maintenance records for suitability issues. The data are collected and analyzed in order for the test director to be able to make informed conclusions about the resolution of the issues; either they are resolved as being satisfactory or unsatisfactory. Once all the issues are resolved and the objectives of the test accomplished, then a conclusion can be reached as to the adequacy of the system and its readiness for introduction to the users.

Night Vision System Operational Test and Evaluation

Appendices A through C provide a complete operational test plan devised by the author that is generic to any operational test of an aircraft equipped with a night vision system. The test plan outlines objectives, critical operational issues for resolution, evaluation criteria, scenarios and specific effectiveness and suitability test procedures that may be applied to any operational test of a night vision system. The test plan can be modified for either an air-to-air or air-to-ground type aircraft and the mission scenarios are broad and all inclusive. The test plan addresses issues from tactical employment to human factors design. Training, safety and documentation issues are also covered. It is designed to give prospective operational test directors a cook book guide to evaluating thoroughly the increasing number of aircraft currently being equipped with night vision devises that provide aircrew with a unique night attack capability.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This paper, as a single source document, provides a prospective operational test director with the necessary background in the theory of remote sensing of electromagnetic radiation and its practical application to fixed wing aviation. It also provides a discussion of the technology currently available to enhance the night vision system operator's night vision capability. Finally, a detailed operational test plan is provided to guide the test director through a most challenging operational evaluation of a unique and complex night vision device system.

Recommendations

This paper was based on a study of the theories of spectral radiation and remote sensing devices. The operational test plan provided was developed over months of research, study, consultations and extensive critique by experienced aircrew and operational test directors. Its utility has been proven during the operational test and evaluation of the Night Attack F/A-18C/D Hornet aircraft. The test plan, as modified by the user for his particular aircraft system, is highly recommended as a proven guide for future operational testing of aircraft equipped with night vision systems.

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APPENDICES

Appendix A

OPERATIONAL TEST PLAN FOR AIRCRAFT EQUIPPED WITH A NIGHT VISION SYSTEM

Section 1

Scope of the Evaluation

101. Objectives. The objectives of this operational test are:

Operational Test Objectives	Critical Operational Issues for Resolution	Test
Determine that the basic warfighting capability (air-to-air and air-to-ground) of aircraft equipped with night attack systems has not been degraded as compared to previous aircraft configurations.	Basic Aircraft Performance	E-1
Determine the effects of various natural environmental conditions on night vision mission capability.	Tactics	E-2
Determine the capability of aircraft equipped with night vision systems to conduct nighttime operations to include; section tactics, lights-out in-flight refueling, and unlit field operations.	Tactics	E-2
Determine the capability of aircraft equipped with night vision systems to navigate, maneuver, identify, and attack targets during the hours of darkness against the anticipated threat.	Target Prosecution	E-3
Assess aircraft survivability.	Survivability	E-4

Determine the Night Vision Systems' reliability, maintainability and availability.	Reliability	S-1
	Maintainability	S-2
	Availability	S-3
Assess compatibility and interoperability.	Compatibility	S-5
	Interoperability	S-6
Assess logistic supportability and technical documentation.	Logistic Supportability	S-4
	Documentation	S-10
Assess training, human factors and safety.	Training	S-7
	Human Factors	S-8
	Safety	S-9

102. Evaluation Criteria. The criteria listed in Table A-1 are usually provided by the project sponsor.

Table A-1

Evaluation Criteria

1. Effectiveness Parameters	Thresholds
a. NAVFLIR Target Detection, Recognition and Identification Ranges (Note 1)	Det/Rec/ID
(1) Kresta Size Ship	* / * / * nm
(2) Komar Size Ship	* / * / * nm
(3) Battlefield Tank	* / * / * nm
b. NAVFLIR Bombing Accuracy (Note 2)	
(1) 50th Percentile Bomb (CEP)	* mils
(2) 90th Percentile Bomb	* mils
2. Suitability Parameters	
a. Night Vision System Reliability (Note 3)	* hrs
b. Night Vision System Maintainability (Note 3)	* hrs

Table A-1 (Cont)

Evaluation Criteria

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c. Night Vision Mission Availability (A_{o}-na) (Note 4)	* hrs

* To be determined by the Project Sponsor

NOTES:

(1) Aircraft operating at 4000 ft MSL, outside air temperature of 65°-70° Fahrenheit and relative humidity not greater than 85%.

(2) Bombing accuracy for low drag, cluster and rocket weapons delivery using the NAVFLIR for target designation and steering to weapons release.

(3) Thresholds for reliability expressed in mean flight hours between failures (MFHBF) and maintainability in mean time to repair (MTTR) for night vision system components consisting of the following aircraft components: NAVFLIR, DMS, NVG compatible cockpit lighting, raster HUD, MPCD, MDIs and MDRIs.

(4) Availability of the aircraft to perform the night attack mission. To be calculated with the following formula:

$$A_{o}\text{-na} = \frac{\text{Night Attack Mission Capable Time}}{\text{Total Time (FMC + PMC + NMC)}}$$

where; FMC = Full Mission Capable time
PMC = Partially Mission Capable time
NMC = Not Mission Capable time

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103. <u>Testing</u>

a. Test operations will exercise the aircraft equipped with night vision systems in realistic scenarios derived from current threat assessments in representative operational scenarios and natural environments. These operations will provide the data for evaluation in individual tests of operational effectiveness (E-tests) and operational suitability (S-tests) discussed in Sections 2 and 3.

Section 2

Operational Effectiveness

201. Scenarios. The scenarios for effectiveness testing of aircraft equipped with night vision systems are described below and have been developed from current threat assessments which describe the current, projected and technologically feasible threat. Effectiveness testing will be conducted under various weather and environmental conditions. Specific scenarios are described in the procedures for individual tests.

a. Antiair Warfare (AAW). AAW scenario with aircraft equipped with night vision systems opposing bomber, fighter and helicopter threats attacking at various altitudes, airspeeds and formations under the cover of darkness.

b. War-at-Sea (WAS). Nighttime WAS scenario with aircraft equipped with night vision systems conducting long range tactical strikes against heavily defended surface combatants.

c. Power Projection. Nighttime deep air strike (DAS) and strike escort scenarios with aircraft equipped with night vision systems conducting long range tactical strikes against heavily defended shore-based targets with both land and airborne threats.

d. Close Air Support (CAS). Nighttime CAS scenario with aircraft equipped with night vision systems conducting airborne fire support of ground forces in both permissive and sophisticated threat environments.

202. Test E-1, Basic Aircraft Performance

a. Object. To determine that the installation of the night vision system into the aircraft has not degraded the basic warfighting capability (air-to-air or air-to-ground) as compared to previous aircraft configurations.

b. Procedure. Throughout the course of testing, the test director will observe the aircraft equipped with night vision systems basic aircraft performance in day and night mission scenarios and evaluate whether any degradation in warfighting capability has occurred. The test director will perform the following tasks:

(1) Ensure aircrew complete Data Sheets 1 and 3-9 (Appendix B) after each mission.

(2) Note any reduction in on-station loiter time, range performance, air-to-air and air-to-ground ordnance delivery accuracy, sensor performance, air combat maneuvering capability, flying qualities and human factors engineering qualities in aircraft equipped with night vision systems. Suspected performance degradations will be thoroughly investigated to ascertain positively whether a degradation has occurred.

(3) If a degradation in warfighting capability exists, the test director will determine the cause of the degradation (Night Vision System related, OFP related, etc.), and the severity of the degradation and its impact on operational effectiveness.

c. Data Analysis

(1) Where no established criteria exist for Basic Aircraft Performance, a qualitative evaluation will be made by the test director based upon operator experience and past aircraft performance.

(2) Where Basic Aircraft Performance relates directly to aircraft or system performance criteria as listed in reference (a) and Table A-1, direct comparisons to effectiveness thresholds will be quantitatively analyzed to assess any degradation in warfighting capabilities.

203. Test E-2, Tactics

a. Object. To determine the effects of various natural environmental conditions on night attack mission capability and to determine the capability of the aircraft equipped with night vision systems to conduct nighttime operations to include section tactics, in-flight refueling and unlit airfield operations.

b. Procedure

(1) The operational effectiveness of the aircraft equipped with night vision systems in the scenarios listed in paragraph 201 will be evaluated under various natural and cultural environmental conditions. Night vision system evaluations will be conducted at sites that offer various environmental conditions such as Cold Lake, Canada for cold weather operations and Eglin AFB, FL, for warm humid weather operations. AAW, WAS, DAS and CAS operations will be conducted from these deployment sites to evaluate the environmental effects on mission success in each scenario. The test director will ensure aircrew complete Data Sheets 1 and 10-17 (Annex B) after each mission. The effects of environmental conditions on mission effectiveness during the

hours of darkness will be investigated in the various conditions and locations described below:

(a) Ambient light levels

1. High light levels to include the effects of low to high moon-above-horizon angles.

2. Low light levels to include starlight only, occluded and overcast sky or "under the weather" conditions and cultural lighting.

(b) Terrain

1. Mountainous to flat desert (NWC China Lake and NAS Fallon ranges).

2. Rolling to flat vegetated (Eglin AFB ranges).

3. Mountainous to flat snow covered (NWC China Lake and Cold Lake, Canada ranges).

4. Over water to include water-to-land and land-to-water transitions.

(c) Weather

1. Warm and humid (Eglin AFB ranges).

2. Hot and dry (NWC China Lake and NAS Fallon ranges).

3. Extreme cold (Cold Lake, Canada ranges).

4. Long term inclement weather that thermally neutralizes or "cold soaks" the terrain (NAS Whidbey working areas).

(2) The test director will investigate the capability of aircraft equipped with night vision systems to conduct nighttime operations safely in the following areas:

(a) Section tactics: The test director will evaluate the feasibility of employing section tactics using aircraft equipped with night vision systems in the scenarios described in paragraph 201. The evaluation will focus on the capability of aircraft equipped with night vision systems to allow the aircrew of a two-ship formation to maintain situational awareness and aircraft deconfliction within the section during low altitude nighttime operations. Tactical application and limitations of night formation flying with minimum or no on-board external lighting will be investigated to determine the feasibility of the following:

1. Using section attacks to reduce target window requirements and ease strike package deconfliction.

2. Visual escort of ingressing strike aircraft in the WAS and DAS scenarios to evaluate the feasibility of close, low altitude strike escort at night.

3. Administrative formation flying will be conducted without external lighting to evaluate feasibility of using daytime formation return-to-base procedures at night.

(b) In-flight refueling: The feasibility of nighttime lights out aerial refueling will be evaluated at altitudes from 1000 ft above the highest local terrain to 20,000 ft MSL and at airspeeds from 250 KIAS to 325 KIAS. In-flight refueling will be conducted from KA-6, KA-3, KC-135, KC-10 and KC-130 refueling aircraft.

(c) Unlit airfield operations: The feasibility of operating from unlit airfields will be evaluated. Lights out takeoffs and landings in aircraft equipped with night vision systems will be conducted under the various ambient light and environmental conditions described in paragraph 202 to determine the limitations of the aircraft equipped with night vision systems while operating from an unlit airfield.

c. Data Analysis. Where no established criteria exist for Tactics, a qualitative evaluation will be made by the test director based upon aircraft performance.

204. Test E-3, Target Prosecution

a. Object. To determine the capability of the aircraft equipped with night vision systems to navigate, maneuver, identify and attack targets at night against the anticipated threat.

b. Procedure

(1) The test director will construct realistic scenarios at various deployment locations to evaluate aircraft equipped with night vision systems in different roles and environments. Aircrews will complete Data Sheets 1 and 11-17 (Appendix B) after completion of each mission. This test will evaluate the capability of aircraft equipped with night vision systems to allow the aircrew to perform the following tasks:

(a) To easily and accurately navigate over extended ranges at low altitude while using the MPCD, DMS and HUD navigation displays to maintain situation awareness. The evaluation will be conducted in overland scenarios and in water-to-land transitions.

(b) To aggressively maneuver at high airspeeds and low altitude in order to terrain mask, defeat surface-to-air threats and deliver ordnance. The capability of the aircrew to use daytime defensive tactics at night in order to deny radar acquisition and target tracking, or to defeat simulated missile or gun firings will be investigated at threat emitter ranges.

(c) To identify, with reasonable assurance, DAS, WAS and CAS targets using on-board systems (radar, targeting FLIR, Data Link) and night vision devices (NVGs, NAVFLIR) in sufficient time to employ the desired weapons. Effectiveness parameters for the NAVFLIR listed in Table A-1 for target detection, recognition and identification ranges of Kresta and Komar size ships and for battlefield tanks will be tested for threshold compliance. Aircrew will complete Data Sheet 10 (Appendix B) during flight to record NAVFLIR performance results. Threshold compliance will be based on the NAVFLIR display presented on an MDI/MDRI; the NAVFLIR HUD display will be evaluated qualitatively.

(d) To attack targets and accurately deliver ordnance using single aircraft and formation attack tactics. Effectiveness parameters for the NAVFLIR listed in Table A-1 for bombing accuracy will be tested for threshold compliance. Ordnance delivery accuracy testing will be conducted on scored ranges using MK-76 and BDU-48 practice bombs and inert 20mm gun ammunition. Both 50th and 90th percentile bomb accuracies will be computed. "Operational" ordnance ranges will be used to conduct attacks against realistic ground targets to evaluate the effects of aircraft maneuvering, target concealment and target size on ordnance delivery accuracy.

(2) Current strike tactics will be employed against threat representative targets under the various environmental conditions as described in paragraph 202. The capability of the aircraft equipped with night vision systems to navigate, maneuver, identify and attack targets at night against the anticipated threat will be evaluated in the following AAW, WAS, Power Projection and CAS scenarios:

(a) AAW

1. Aircraft equipped with night vision systems will be evaluated in a vital area defense role tasked to defend against ingressing low altitude strike aircraft at

night. The aircraft equipped with night vision systems will maintain both high and low altitude combat air patrols (CAPs) and will use current tactics to intercept the attackers. Simulated lookdown AIM-7 Sparrow shots followed by high-to-low conversions for an AIM-9 Sidewinder or gun shot will be conducted to evaluate the capability of the night vision system to allow the aircrew to maneuver the aircraft aggressively in the low altitude arena to bring air-to-air weapons to bear. Low altitude CAPs will engage the attackers in head-on and stern conversion low altitudes intercepts. A live AIM-9 Sidewinder missile shot will be conducted at night against a low altitude subscale target to verify the night low altitude intercept capability of aircraft equipped with night vision systems.

2. Aircraft equipped with night vision systems will be evaluated in an area denial role against nighttime helicopter troop insertions escorted by attack helicopters where the aircraft equipped with night vision systems versus helicopter capability will be evaluated.

(b) WAS

1. Aircraft equipped with night vision systems will be evaluated in the nighttime Surface Search, Surveillance and Control (SSSC) role where surface vessels will be detected, identified and marked as to heading and speed.

2. Aircraft equipped with night vision systems will be evaluated in the nighttime WAS mission using current tactics against simulated seaborne target vessels.

(c) Power Projection

1. Aircraft equipped with night vision systems will be evaluated in the nighttime overland and water-to-land DAS missions. Scenarios will vary from single ship tactics to multiship strike packages. Missions will include strikes against a variety of targets; airfields, petroleum storage areas, truck parks, surface-to-air missile and artillery sites and urban areas. Degree of target defenses in the power projection scenarios will vary from permissive to sophisticated including simulated surface-to-air and air-to-air threats. Aircraft equipped with night vision systems will be evaluated as a strike aircraft and as a strike escort aircraft.

2. Strike escort will be conducted with aircraft equipped with night vision systems in visual contact with the strike package at low altitude. Detached low

altitude CAPs and fighter sweeps in support of a strike package will also be evaluated.

(d) CAS

1. Aircraft equipped with night vision systems will be evaluated in the nighttime CAS mission. Sophisticated and permissive threat CAS tactics will be employed during this test. For the high threat CAS scenario, aircrew will receive standard nine line briefs from ground or airborne Forward Air Controllers and use typical daytime CAS tactics to attack the target. Target acquisition and ordnance delivery accuracy in the CAS scenario will be evaluated. Forward Air Controllers with mortar and laser target marking teams will be used during the evaluation.

2. Aircraft equipped with night vision systems two-seat aircraft will be evaluated in the role of Tactical Air Control (Airborne) and Forward Air Control (Airborne) in the CAS scenario. Control of airborne assets and marking of targets both day and night will be evaluated.

c. Data Analysis

(1) Where no established criteria exist for Target Prosecution effectiveness, a qualitative evaluation will be made by the test director based upon operator experience and past aircraft performance.

(2) Where Target Prosecution effectiveness relates directly to aircraft or system performance criteria as listed in reference (a) or Table A-1, direct comparisons to effectiveness thresholds will be quantitatively analyzed to determine threshold compliance and to assess any degradation in warfighting capabilities.

205. Test E-4, Survivability

a. Object. To assess susceptibility and vulnerability of aircraft equipped with night vision systems.

b. Procedure

(1) The susceptibility of aircraft equipped with night vision systems will be assessed by observing its performance in its intended operating environment for the mission scenarios listed in paragraph 101. Electro-optical countermeasures susceptibility evaluations will be conducted at White Sands Missile Range from Holloman AFB, NM. The results and observations obtained during effectiveness testing will be reviewed by the test director and recorded in the test director's Journal.

(2) The vulnerability of aircraft equipped with night vision systems will be assessed by reviewing all reports relating to vulnerability testing conducted by the DA or contractor and by comparing the system's survivability design features to the anticipated operational threat.

c. Data Analysis. The susceptibility and vulnerability assessment will be a qualitative analysis based on observations during all phases of testing and on the examination of system design features. The test director will make a qualitative assessment to determine if any degradation in susceptibility or vulnerability has occurred as compared to previous aircraft.

Section 3

Operational Suitability

301. General. The suitability testing will, in most instances, use data generated by operation of the equipment throughout test operations, including the E-test runs described in Section 4. Reliability and maintainability tests and evaluations will be conducted only on the Night Vision System specific hardware as described in paragraph 102 and not on other aircraft systems. Availability tests and evaluations will be focus on the availability of the aircraft in performing the night attack mission. If sufficient maintainability data are not available at the completion of testing on the Night vision System components, a maintainability demonstration will be conducted. Tests specifically designed to generate suitability data are described in the individual S-tests.

302. Test S-1, Reliability

a. Object. To assess the reliability of the night vision system components when used in the intended operating environment.

b. Procedure. Maintenance Action Forms (MAFs) will be completed for:

(1) Each failure or discrepancy of components noted during operations.

(2) Each preventive maintenance action that finds a failed component part.

c. Data Analysis

(1) MFHBF will be calculated for night vision system components using the formula:

$$MFHBF = \frac{\text{Total System Operating Flight Time}}{\text{Number of Critical plus Minor Failures}}$$

(2) Failures of night vision system components are defined as follows:

(a) Critical. Prevents the system from performing its mission or results in the loss of some significant mission capability.

(b) Minor. Affects system performance but does not impact the ability to perform the mission.

303. Test S-2, Maintainability

a. Object. To assess the maintainability of the night vision system components when used in the intended operating environment.

b. Procedure

(1) MAFs will be completed for:

(a) Each component failure or discrepancy noted during operational testing.

(b) Each preventive maintenance action that finds a failed component part.

(c) Any component malfunction or damage found during testing.

(2) In the event of insufficient failures to determine the maintainability of the night vision system components, a maintenance demonstration will be conducted.

c. Data Analysis. Collected data will be used to determine the mean time to repair (MTTR) night vision System components. MTTR is the average time required to perform active corrective maintenance. Corrective maintenance is the time during which one or more personnel are repairing a critical failure and includes: preparation, fault location, part procurement from local sources, fault correction, adjustment and calibration and follow-up checkout times. For most components in the night vision system, MTTR is the average time required to remove and replace the the faulty systems divided by the total number of removal and replacement actions. It excludes off-board logistic delay time.

304. Test S-3, Availability

a. Object. To determine the operational availability of the aircraft equipped with night vision systems to perform the night attack mission in the intended operational environment.

b. Procedure. All operator logs, MAFs and time meter recordings from Tests S-1 and S-2 will be reviewed.

c. Data Analysis. The night attack system operational availability (A_{o-na}) is the aircraft's night attack mission capable rate computed using the formula:

$$A_{o\text{-}na} = \frac{\text{Night Attack Mission Capable Time}}{\text{Total Time (FMC + PMC + NMC)}}$$

where;

FMC = Full Mission Capable time
PMC = Partially Mission Capable time
NMC = Not Mission Capable time

Down time begins when the failure is reported and is defined as any discrepancy that causes the aircraft equipped with night vision systems to be not night attack mission capable.

305. Test S-4, Logistic Supportability

a. Object. To assess the logistic supportability of aircraft equipped with night vision systems. This test examines the configuration, integration and efficiency of the following elements of logistic support:

(1) Maintenance planning.

(2) Manpower and personnel.

(3) Supply support.

(4) Support equipment, including the adequacy of special tools, test sets and equipment.

(5) Packaging, handling, storage and transportation.

(6) Technical logistic data.

(7) Software configuration management and plans to provide updated system software to the fleet.

(8) Facilities.

b. Procedure. This test will be conducted throughout the evaluation. The following procedures will be applied as applicable to all components of the aircraft equipped with night vision systems.

(1) The configuration, integration and efficiency of the logistic support resources provided to support aircraft equipped with night vision systems aircraft will be observed throughout the evaluation.

(2) Maintenance personnel will be observed performing their duties and interviewed as appropriate.

(3) The adequacy of the Integrated Logistic Support Plan will be assessed.

(4) Planned Maintenance System (PMS), addressed in Test S-10 (Documentation), will be reviewed in connection with adequacy of maintenance planning, support equipment and test equipment.

(5) Provisions for software configuration management, software block upgrades and the maintenance and replacement of system software in the fleet will be reviewed.

(6) The effect of maintenance requirements on manning will be assessed.

(7) Trouble and Maintenance Action Reports will be completed as appropriate.

(8) Suitability questionnaires will be completed by maintenance and supply personnel.

(9) Test director observations, interview responses and documentation reviews will be recorded in the test director's Journal.

(10) The adequacy of all technical manuals and PMS documentation (in preliminary or final form), including Maintenance Requirement Cards, will be assessed.

(11) Availability and adequacy of Allowance Parts and Allowance Equipage Lists.

(12) The availability and adequacy of all related test equipment and special tools will be assessed.

(13) DD Form 1348 with part number and Allowance Parts List number (or nomenclature of parent equipment) for each spare part used during testing will be reviewed to assess the requirements for and availability of spare parts.

(14) The adequacy of shipboard logistic support for the aircraft equipped with night vision systems will be assessed.

c. Data Analysis. Test director's Journal entries and suitability questionnaires will be reviewed. The adequacy of each element of logistic support in supporting aircraft equipped with night vision systems in an operational environment will be assessed. The integration of all logistic elements into an overall concept of logistic support will permit qualitative assessment of the suitability of logistic support planning in meeting operational and readiness objectives.

306. Test S-5, Compatibility

a. Object. To assess the compatibility of aircraft equipped with night vision systems with its operating environment.

b. Procedure. The test director will assess the capability of aircraft equipped with night vision systems to operate in its intended environment without adverse effects between on-board systems. A shipboard evaluation will be conducted to assess shipboard compatibility. Forty arrested landings and catapult launches will be performed to evaluate aircraft component performance when subjected to the shipboard environment. The test director will assess compatibility based on review of completed Data Sheets 1-17 (Appendix B), and project aircrew verbal debriefs. His assessment will include the following:

(1) Functional compatibility of the aircraft equipped with night vision systems with the associated night vision system hardware changes, to include the effects of maneuvering, airspeed, altitude, terrain and weather on the system components.

(2) Physical compatibility of the aircraft equipped with night vision systems with handling, installation and storage areas.

c. Data Analysis. Data analysis will be qualitative.

307. Test S-6, Interoperability

a. Object. To assess the adequacy of the following:

(1) Man and machine interface between the aircrew and aircraft equipped with night vision systems for information transfer or "operability".

(2) The interfaces between the night vision system and the aircraft.

(3) The interfaces between the aircraft equipped with night vision systems and external systems.

b. Procedure. The test director will evaluate interoperability of the aircraft equipped with night vision systems during the E-tests as described in Section 4 and record his observations in the test director's Journal. The test director will assess interoperability based on review of completed Data Sheets 1-17 (Appendix B), and project aircrew verbal debriefs. The following interoperability issues will be addressed:

(1) The test director will evaluate the man and machine interface for aircrew "operability" and will note in the test director's Journal any problems in information transfer between the aircrew and between the aircrew and the aircraft. Problems with aircrew and night vision system interface, such as inability of the aircrew to use the NAVFLIR/HUD display for terrain clearance, inability of the pilot to interpret HUD symbology with NAVFLIR video on HUD, or inadequate DMS displays for navigation will be investigated by the test director to determine if the cause is system related, i.e., poor sensor performance, poor human factors engineering design, OFP problems, or an environmental factor.

(2) The test director will evaluate the internal interoperability of aircraft systems with emphasis on the integration of the night vision system components into the aircraft.

(3) The test director will insure that no degradation in interoperability has occurred between on-board aircraft systems and external systems such as data link capability with AWACS or the E-2C. Avionics interoperability with shipboard systems such as ship's inertial navigation alignment system and automatic carrier landing system will be evaluated.

c. Data Analysis. Data analysis will be qualitative.

308. Test S-7, Training

a. Object. To assess the adequacy of operator and maintenance training.

b. Procedure. Prior to the commencement of project operations, aircrews and maintenance personnel will receive training developed for fleet personnel and will make comments on Data Sheets 18 and 19 as to the adequacy of training received. The test director will observe their performance during project operations.

c. Data Analysis. Data analysis will be qualitative.

309. Test S-8, Human Factors

a. Object. To assess the adequacy of human factors features of aircraft equipped with night vision systems.

b. Procedure. The test director will interview aircrew and maintenance personnel and record the results in the test director Journal to evaluate human factors in the following areas:

(1) Design factors related to the accessibility and maintainability of the night vision system components to Navy and Marine maintenance personnel.

(2) Human factors engineering design of the man and machine interface of the night vision system components to enhance mission success. The test director will evaluate the human factors engineering design of the individual night vision system components that are essential to optimum aircrew/system interface. This evaluation will focus on cockpit layout, display formats, display control and adjustment and other human factors engineering design features that enable the aircrew to perform the night attack mission safely and effectively. Particular attention will be given to night vision system system switchology, ease of operation and aircrew workload reduction features such as "hands on throttle and stick" or automatic control functions. Table D-1 (Annex D) outlines important human factors engineering design features to be evaluated in interoperability . The test director will assess the adequacy of the human factors engineering design based on review of completed Data Sheets 1 and 3-9 (Appendix B), and project aircrew verbal debriefs.

c. Data Analysis. Data analysis will be qualitative.

310. Test S-9, Safety

a. Object. To assess the adequacy of safety features of aircraft equipped with night attack systems.

b. Procedure. Safety features will be assessed in the normal operating environments to verify no unusual hazards to personnel, mission accomplishment, or equipment exist. The test director will record safety observations in the test director Journal. In addition to on-board safety features of aircraft equipped with night attack systems the test director will evaluate the safety hazards associated with the night attack mission. Some items of interest will be:

(1) Impact of interim and continuous night operations on aircrew and maintenance personnel work efficiency, health and welfare.

(2) Physiological impact of extensive use of NVGs and NAVFLIR imagery for night flight.

(3) Sensory perception problems when using night vision devices in dynamic three-dimensional maneuvering.

(4) Fatigue problems induced by the night attack environment, i.e., the wearing of helmet mounted NVGs, limited peripheral vision, high workload in constantly monitoring altitude and terrain clearance, etc.

c. Data Analysis. Data analysis will be qualitative.

311. Test S-10, Documentation

a. Object. To assess the adequacy and accuracy of the documentation provided for aircraft equipped with night attack systems.

b. Procedure. An extensive review will be made of existing publications for completeness to provide life cycle support. All applicable maintenance publications, preliminary flight crew operating procedures and available checklists will be reviewed by the test director. The test director will record observations in the test director's Journal.

c. Data Analysis. Data analysis will be qualitative.

Appendix B

FORMS AND DATA SHEETS

Table B-1

Data Collection Requirements

Data Sheets	Completed by	When Completed	Tests
1	Aircrew	After Flight	E-1 to E-4 S-5 to S-9
2	Aircrew	After Flight	E-1 to E-4 S-5 to S-10
3-9	Aircrew	During/After Flight	E-1,2 S-5,8
10	Aircrew	During/After Flight	E-3 S-5,6
11-17	Aircrew	Before/After Flight	E-1,3 S-5,6
18	Aircrew	Before/After Training	S-7
19	Maintenance Personnel	Before/After Training	S-7

Data Sheet 1

Aircrew Mission/System Debrief Sheet

AIRCREW ______/_________ ACFT# ______ FLT TIME _____ DATE ______
WING ______________ ACFT# ______ FLT TIME _____ NVG TIME ______
MISSION _________________________ ORDNANCE ______________
TEST ITEMS?: TFLIR LTD OTHER ________ TEST RANGE ______________
VISIBILITY _____ WINDS ______ OAT ___° REL HUM ____% ABS HUM ____gm/m3
SKY CONDITION : CLEAR, HI / LO SCT BKN OVC, HAZE, DUST, RAIN, SNOW, OTHER ___
LIGHT CONDITIONS: STARLIGHT/MOONLIGHT, MOON PHASE/ANGLE _____/_____

MISSION DEBRIEF:

COMMENT ON MISSION CONDUCT AND RESULTS. DISCUSS ANY ANOMALIES THAT MAY IMPACT DATA OR RESULTS. DISCUSS FAVORABLE/UNFAVORABLE IMPRESSIONS OF F/A-18 IN ACCOMPLISHING GIVEN MISSION OR TASKING.

SEE BACK FOR AG ORDNANCE DELIVERY RESULTS AND STR DEBRIEF

SYSTEM DEBRIEF:

NOTE PROBLEMS WITH OPERATION, SYMBOLOGY, HUMAN FACTORS, TACTICAL EMPLOYMENT, ETC, OF THE RADAR, FLIR, LDT, AND WEAPON SYSTEMS. NOTE ANY COMPATIBILITY OR PERFORMANCE PROBLEMS WITH ANY ONBOARD SYSTEM WITH FOCUS ON THE MC's, FCC's, SDP, AND DSU.

SYSTEM TROUBLE REPORT (STR) RECOMMENDATIONS:

WRITE UP ANY PROBLEMS THAT NEED FIXING OR RECOMMEND CHANGES THAT WOULD IMPROVE THE F/A-18. THESE MAY BE SUBMITTED AS STR's.

ORDNANCE DELIVERY RESULTS:

RUN	1	2	3	4	5	6	7	8	9	10	11	12
SENSOR (RDR/FLIR LDT/VISUAL)												
MODE (AUTO/CCIP FD/MAN)												
RANGING (AGR/BARO)												
REL RNG (FT)												
G's												
ALT												
TAS												
FPA												
HIT (BRG/RNG)												
AIM PT (BULL)												
COMMENTS												

DISCUSS PERFORMANCE/PROBLEMS/COMPATIBILITY OF ANY OF THE F/A-18C ONBORAD SYSTEMS WITH FOCUS ON THE NAVFLIR, RASTER HUD, DMS, MDI/MDRI, & MPCD. NOTE ANY PROBLEMS WITH OPERATION, SYMBOLOGY, HUMAN FACTORS, TACTICAL EMPLOYMENT, ETC. FOR SENSOR PERFORMANCE, LIST DETECTION, RECOGNITION, AND IDENTIFICATION RANGES.

Data Sheet 2

Aircrew Maintenance System Debrief Sheet

NAME ______________ A/C# ______ DATE ________ FLT TIME ____

SYSTEM	COMMENTS	BLIN	B	O	A
NAVFLIR ↑ ↓ →					
MPCD/DIGITAL MAP SET ↑ ↓ →					
RASTER HUD ↑ ↓ →					
MDI/MDRI ↑ ↓ →					
COMPATIBLE COCKPIT LIGHTING ↑ ↓ →					
TARGETING FLIR ↑ ↓ →					
OTHER __________ ↑ ↓ →					

INS ↑ ↓ →	POST 1	POST 2
WYPT 0 UPDT ____°/ ____ nm	POS N______W______ ALN TIME ________ NAV TIME _____ PER __	ERROR CUM VEL N/W ___ ___ ___ E/W ___ ___ ___

USE BACK FOR ADDITIONAL COMMENTS →

ADDITIONAL COMMENTS:

INSTRUCTIONS: THIS IS A MAINTENANCE DEBRIEF SHEET FOR REPORTING ANOMALIES OR PROBLEMS WITH THE LISTED SYSTEMS. PLEASE CIRCLE UP, DOWN, OR MARGINAL ARROWS, MAKE COMMENTS ON ANY DOWN OR DEGRADED SYSTEMS, LIST "BOA" AND BLIN CODES, AND CIRCLE ANY POST FLIGHT MMP CODES. ENTER POST 1 & 2 INS DATA AND THE WYPT 0 UPDT INFORMATION.

Data Sheet 3

Night Attack Systems Kneeboard Cards

MDI / MDRI:

EVALUATE HUMAN FACTORS DESIGN OF CONTROL SWITCHES/KNOBS FUNCTION AND LOCATION:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

EVALUATE BRIGHTNESS & CONTRAST RANGE OF CONTROL (DAY / NIGHT ?):

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

EVALUATE EFFECTS OF SUNLIGHT, GLARE, OR COCKPIT SHADOWS:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

ARE THE PUSH TILE LABELS READABLE, UNDERSTABABLE, UNOBSTRUCTED?:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 2A

MDI / MDRI (CONT)

EVALUATE THE HUMAN FACTORS OF THE MENU FUNCTIONS, OPTIONS, & LOOPS. ARE THEY USER FRIENDLY?:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

EVALUATE THE TRI-COLOR FORMAT:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

WHAT WOULD YOU ADD OR CHANGE TO THE MDI/MDRI FUNCTIONS, MODING, ETC.?

COMMENTS:

UP FRONT CONTROL

EVALUATE THE HUMAN FACTORS DESIGN OF THE UFC (EASE OF OPS, LIGHTING, ETC.):

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 2B

Data Sheet 4

Night Attack Systems Kneeboard Cards

MPCD / MOVING MAP

EVALUATE THE HUMAN FACTORS DESIGN OF THE ADJUSTMENT AND CONTROL KNOBS/ROCKERS OF THE MPCD:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE QUALITY OF THE MOVING MAP DISPLAY AND STROKE SYMBOLOGY (COLOR, CLARITY, RESOLUTION) - ALL SCALES:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE ADEQUACY OF THE "RANGE OF CONTROL" OF THE CONTRAST & BRIGHTNESS CONTROLS. (DAY / NIGHT ?)

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE EFFECTS OF SUNLIGHT, GLARE, SHADOW, ETC. ON THE MPCD:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 3A

MPCD / MOVING MAP (CONT)

EVALUATE THE HUMAN FACTORS OF THE MENU FUNCTIONS, OPTIONS, & LOOPS. ARE THEY USER FRIENDLY?:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE PUSH TILE LABELS (READABLE, UNDERSTABABLE, UNOBSTRUCTED):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

WHAT WOULD YOU ADD OR CHANGE TO THE MPCD FUNCTIONS, MODING, ETC.?

COMMENTS:

DO YOU LIKE THE PRESENT COCKPIT HARDWARE ARRANGEMENT OF THE MDI/MPCD/ UFC? IS THERE A BETTER ARRANGEMENT?

COMMENTS:

CARD 3B

Data Sheet 5

Night Attack Systems Kneeboard Cards

RADAR

EVALUATE EASE OF RADAR OPERATION:

- OVERALL HUMAN FACTORS DESIGN OF ALL MODES & MENU OPTIONS

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- HOTAS FUNCTIONS

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

DESCRIBE WHICH DISPLAY YOU LIKE ON EACH MDI/MDRI/MPCD DURING:

		LT MDI	MPCD	RT MD
NAV	PILOT			
	WSO			
A/A	PILOT			
	WSO			
A/G	PILOT			
	WSO			

CARD 6C

HEAD DOWN NAVFLIR (MDI/MDRI/MPCD)

WATER / LAND?

EVALUATE RANGE OF BRIGHTNESS & CONTRAST CONTROL OF HEAD DOWN NAVFLIR ON MDI / MDRI / MPCD. (DAY / NIGHT ?)

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE HEAD DOWN NAVFLIR VIDEO QUALITY, ALL MODES (CLARITY, RESOLUTION, REGISTRATION). STRAIGHT & LEVEL / MANUEVERING:

PUT SCORE FOR EACH COMBINATION IN BOXES BELOW

	AC CPL	CPL	DC CPL	
ALG				
ALG 2				
MAN				
	WH	BH	WH	BH

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS (WHAT COMBINATION WAS YOUR FAVORITE/LEAST FAVORITE):

CARD 7

Data Sheet 6

Night Attack Systems Kneeboard Cards

HUD NAVFLIR

WATER / LAND?

EVALUATE HUD NAVFLIR RANGE OF BRIGHTNESS, BLACK LEVEL, & BALANCE CONTROL:

- LOOKING THRU NVG W/TUBES ON:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

INDICATE BEST SETTING:

○ BRT ○ BL LEV ○ BAL

- LOOKING UNDERNEATH NVG:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

INDICATE BEST SETTING:

○ BRT ○ BL LEV ○ BAL

EVALUATE THE HUMAN FACTORS DESIGN OF THE HUD NAVFLIR CONTROL PANEL:

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 8A

HUD NAVFLIR (CONT)

WATER / LAND?

EVALUATE HUD NAVFLIR VIDEO QUALITY (RESOLUTION, REGISTRATION, CLARITY):

- LOOKING THRU NVG W/TUBES ON

PUT SCORE FOR EACH COMBINATION IN BOXES BELOW

	AC CPL CPL		DC CPL	
ALG				
ALG 2				
MAN				
	WH	BH	WH	BH

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 8B

Data Sheet 7

Night Attack Systems Kneeboard Cards

WATER / LAND?

HUD NAVFLIR (CONT)

EVALUATE HUD NAVFLIR VIDEO QUALITY (RESOLUTION, REGISTRATION, CLARITY):

- LOOKING UNDERNEATH NVG

PUT SCORE FOR EACH COMBINATION IN BOXES BELOW

	AC CPL	CPL	DC CPL	
	WH	BH	WH	BH
ALG				
ALG 2				
MAN				

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 8C

WATER / LAND?

HUD NAVFLIR (CONT)

EVALUATE HUD NAVFLIR VIDEO QUALITY (RESOLUTION, REGISTRATION, CLARITY):

- LOOKING THRU NVG COMBINER GLASS W/TUBES OFF:

PUT SCORE FOR EACH COMBINATION IN BOXES BELOW

	AC CPL	CPL	DC CPL	
	WH	BH	WH	BH
ALG				
ALG 2				
MAN				

UNSAFE	BARELY WORKABLE	COULD BE BETTER	OK	GREAT!
0 •	1 • 2 • 3 •	4 • 5 • 6 •	7 • 8 • 9 •	10

COMMENTS:

CARD 8D

Data Sheet 8

Night Attack Systems Kneeboard Cards

WATER / LAND?

HUD NAVFLIR & NVG INTEROPERABILITY

EVALUATE THE FOLLOWING HUD NAVFLIR & NVG COMBINATIONS UNDER PRESENT ILLUM CONDITIONS:

- NAVFLIR OFF / NVG ONLY:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NAVFLIR ON / NVG ON

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NAVFLIR ON / NVG ON, BUT LOOKING UNDERNEATH GOGGLES:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 9A

WATER / LAND?

HUD NAVFLIR & NVG INTEROPERABILITY (CONT)

EVALUATE THE FOLLOWING HUD NAVFLIR & NVG COMBINATIONS UNDER PRESENT ILLUM CONDITIONS:

- NAVFLIR ON / NVG OFF:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

WOULD YOU LIKE AN "AUTO SCENE REJECT" CAPABILITY? (CIRCLE ONE)

ABSOLUTELY NOT — DON'T CARE — MUST HAVE

COMMENTS:

WOULD YOU LIKE HOTASABLE ...

1. NAVFLIR OFF/ON?

ABSOLUTELY NOT — DON'T CARE — MUST HAVE

2. NAVFLIR WHT HOT / BLK HOT?

ABSOLUTELY NOT — DON'T CARE — MUST HAVE

3. AC CPL / DC CPL?

ABSOLUTELY NOT — DON'T CARE — MUST HAVE

CARD 9B

Data Sheet 9

Night Attack Systems Kneeboard Cards

HUD NAVFLIR & NVG INTEROPERABILITY (CONT) WATER / LAND?

WOULD YOU LIKE HOTASABLE ...

4. NAVFLIR BRIGHTNESS BUMP?

ABSOLUTELY NOT	DONT CARE	MUST HAVE

5. AUTO CUER OFF/ON?

ABSOLUTELY NOT	DONT CARE	MUST HAVE

6. OTHER? EXPLAIN:

OVERALL HOTAS COMMENTS:

OVERALL HUD NAVFLIR & NVG INTEROPERABILITY OBSERVATIONS OR COMMENTS:

CARD 9C

AIRCRAFT LIGHTING

INTERNAL - EVALUATE INTERNAL COCKPIT/ WARNING LIGHTS (RANGE OF BRIGHTNESS CONTROL, NVG COMPATIBILITY, EASE OF FINDING KNOBS, ETC):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- EVALUATE HUMAN FACTORS DESIGN OF CHART LIGHT AND GRIMES LIGHT (NVG COMPATIBLE, LOCATION, ABILITY TO SEE KNEEBOARD CARDS):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EXTERNAL - EVALUATE EXTERNAL AIRCRAFT LIGHTING (NVG COMPATIBILITY, COCKPIT DISTRACTION, ETC):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 15

Data Sheet 10

NAVFLIR Performance Kneeboard Cards

HUD & HEAD DOWN NAVFLIR DETECTION, RECOGNITION, & IDENTIFICATION RANGES

DETERMINE DET, REC, & ID RANGES OF LAND BASED TARGETS:

TARGET DESCRIPTION ____________

RUN		DET (NM)	REC (NM)	ID (NM)
1 (CIRCLE) ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
2 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
3 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
4 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
5 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
6 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			

COMMENTS:

CARD 8E

HUD & HEAD DOWN NAVFLIR DETECTION, RECOGNITION, & IDENTIFICATION RANGES

DETERMINE DET, REC, & ID RANGES OF SEA SURFACE TARGETS:

SURFACE VESSEL (TYPE: ____________)

RUN		DET (NM)	REC (NM)	ID (NM)
1 (CIRCLE) ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
2 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
3 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
4 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
5 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			
6 ALG AC CPL ALG2 DC MAN WH/BH	MDI			
	HUD			

COMMENTS:

CARD 8F

Data Sheet 11

Night Attack Mission Effectiveness Kneeboard Cards

NIGHT ATTACK EVALUATION

DATE ______________

AIRCRAFT ______________

AIRCREW ________/________

TAKEOFF/LAND ______/______

FLIGHT TIME ______________

NVG__TIME ______________

WORKING AREA: ______________

TARGET ______________

ORDNANCE ______________

EQUIPMENT NVG, NAVFLIR, TGTFLIR, LDT, LDTR ______________

SKY CONDITION:

CLEAR, HI/LO - SCT BKN OVC, HASE, DUST

OTHER: ______________

REL HUM: ______% OAT ________°C

ABS HUM (EXT: 6335/5470) ______ gm/m ^{3}

MOON CONDITION:

PHASE: ____________

ANGLE: ____________

CARD 1A

TAKEOFF/LANDING/FQ/PERFORMANCE

EVALUATE TAKEOFF SITUATION AWARENESS (SA), COMFORT LEVEL, SAFETY USING THE HUD NAVFLIR:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE LANDING SITUATION AWARENESS (SA), COMFORT LEVEL, SAFETY USING THE HUD NAVFLIR AND NVG COMBINATION:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

DESCRIBE ANY FLYING QUALITIES OR AIRCRAFT PERFORMANCE OBSERVATIONS YOU HAVE:

CARD 1B

Data Sheet 12

Night Attack Mission Effectiveness Kneeboard Cards

A/G EFFECTIVENESS

EVALUATE THE A/G STROKE SYMBOLOGY & HUD RASTER COMPATIBILITY (BALANCE, CLARITY, ETC.):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE TARGET ACQUISITION USING THE HEAD DOWN NAVFLIR DURING ATTACK:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE TARGET ACQUSITION USING THE HUD NAVFLIR DURING ATTACK:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

DESCRIBE BEST NIGHT BOMBING TECHNIQUE (PILOT DOES ALL, WSO CONTINUOUSLY UPDATE SOLUTION ON MDRI NFLIR, TGT FLIR, ETC?):

CARD 10A

A/G EFFECTIVENESS (CONT)

WATER / LAND?

EVALUATE THE EFFECTIVENESS OF THE NA SYSTEM IN ALLOWING THE AIRCREW TO MANUEVER, ACQUIRE TGTS, AND DELIVER ORDNANCE IN THE FOLLOWING ATTACK TACTICS:

- LEVEL LAYDOWN

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS: (SINGLE / SECTION?)

- ROLL AHEAD LOW POP UP

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS: (SINGLE / SECTION?)

CARD 10D

Data Sheet 13

Night Attack Mission Effectiveness Kneeboard Cards

A/G EFFECTIVENESS (CONT)

WATER / LAND?

EVALUATE THE EFFECTIVENESS OF THE NA SYSTEM IN ALLOWING THE AIRCREW TO MANUEVER, ACQUIRE TGTS, AND DELIVER ORDNANCE IN THE FOLLOWING ATTACK TACTICS:

- OFFSET LOW POP UP

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS: (SINGLE / SECTION?)

- HORNET HIGH POP UP

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS: (SINGLE / SECTION?)

CARD 10E

A/A EFFECTIVENESS

WATER / LAND?

EVALUATE THE A/A STROKE SYMBOLOGY & HUD RASTER COMPATIBILITY (BALANCE, CLARITY, ETC.):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE ABLILITY OF THE NA SYSTEM TO CONDUCT LO ALT INTERCEPTS AGAINST LO ALT TARGETS (BOTH A/C LO ALT):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

EVALUATE THE ABLILITY OF THE NA SYSTEM TO CONDUCT HI-TO-LO CONVERSION INTERCEPTS AGAINST LO ALT TARGETS (12° LOOK DOWN FOX-1 TO 1 NM REAR QTR FOX-2):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 11

Data Sheet 14

Night Attack Mission Effectiveness Kneeboard Cards

EVALUATE ORDNANCE DELIVERY ACCURACY

TYPE ORDNANCE: ______

RUN:	1	2	3	4	5	6
TYPE DELIVERY:						
NAVFLIR MODE: (CIRCLE)	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH
ATK MODE (AUTO/CCIP FD/MAN)						
RNG						
ERROR L/R						
G's						
BANK L/R						
ALT						
RANGING (B/AGR/R)						
TAS						
FPA						
ROLL L/R						
TOF/ERROR						
HIT (BRG/RNG)						
AIM PT						

CARD 10B

EVALUATE ORDNANCE DELIVERY ACCURACY

TYPE ORDNANCE: ______

RUN:	7	8	9	10	11	12
TYPE DELIVERY:						
NAVFLIR MODE: (CIRCLE)	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH	ALG ALG2 MAN CPL WH/BH
ATK MODE (AUTO/CCIP FD/MAN)						
RNG						
ERROR L/R						
G's						
BANK L/R						
ALT						
RANGING (B/AGR/R)						
TAS						
FPA						
ROLL L/R						
TOF/ERROR						
HIT (BRG/RNG)						
AIM PT						

CARD 10C

Data Sheet 15

Night Attack Mission Effectiveness Kneeboard Cards

NA SYSTEM OVER LAND OPERATIONS

COMFORT LEVELS:

FLAT TERRAIN: ______AGL

ROUGH TERRAIN: _____AGL

FORMATION: ________AGL

OTHER ___________: _________AGL

UNDER GIVEN CONDITIONS, ASSESS CONTRIBUTION TO SA, COMFORT LEVEL, & OPERATIONAL EFFECTIVENESS OF FOLLOWING NA SYSTEM COMPONENT COMBINATIONS:

- NVG ONLY

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NAVFLIR ONLY

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NVG & NAVFLIR COMBINATION

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 13A

NA SYSTEM OVER LAND OPERATIONS (CONT)

DESCRIBE ANY PROBLEMS WITH ENVIRONMENT (SHADOWS, GLARE, CLOUDS, MOISTURE, DUST, LIGHTS, TERRAIN, OBSTACLES, ETC.):

DESCRIBE ANY PROBLEMS WITH THE NA SYSTEM COMPONENTS (NVG, NAVFLIR, MDI, MDRI, MPCD - HUMAN FACTORS, COMPATIBILITY, INTEROPERABILITY, ETC.):

DESCRIBE ANY PROBLEMS WITH FLIGHT GEAR (HELMET, FLASHLIGHTS, FINGER LIGHTS, KNEEBOARDS, ETC.) ANY SUGGESTIONS?

CARD 13B

Data Sheet 16

Night Attack Mission Effectiveness Kneeboard Cards

NA SYSTEM OVER WATER OPERATIONS

COMFORT LEVEL (OVER WATER): ______

UNDER GIVEN CONDITIONS, ASSESS CONTRIBUTION TO SA, COMFORT LEVEL, & OPERATIONAL EFFECTIVENESS OF FOLLOWING NA SYSTEM COMPONENT COMBINATIONS:

- NVG ONLY

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NAVFLIR ONLY

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

- NVG & NAVFLIR COMBINATION

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 14A

NA SYSTEM OVER WATER OPERATIONS (CONT)

ASSESS EASE OF LAND-TO-WATER INGRESS TRANSITION:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

ASSESS EASE OF WATER-TO-LAND EGRESS TRANSTION:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

ASSESS EASE OF SHIP ATTACK W/NA SYSTEM (SA, COMFORT LEVEL, ASW EFFECTIVENESS):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

CARD 14B

Data Sheet 17

Night Attack Mission Effectiveness Kneeboard Cards

NA FORMATION FLYING

EVALUATE FORMATION LEADER'S EXTERNAL LIGHTS (NVG COMPATIBILITY, CONTRIBUTION TO SA, ETC.):

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

AS WINGMAN, DESCRIBE MOST COMFORTABLE LIGHTING ARRANGEMENT ON LEADER:

STROBES: OFF/ON BRT/DIM

POSITION: OFF/ON BRT SETTING: ○

FORM: OFF/ON BRT SETTING: ○

EVALUATE THE ABILITY OF THE NA SYSTEM TO ALLOW LIGHTS-OUT FORM FLYING:

UNSAFE		BARELY WORKABLE		COULD BE BETTER		OK		GREAT!
0	•	1 • 2 • 3	•	4 • 5 • 6	•	7 • 8 • 9	•	10

COMMENTS:

DESCRIBE YOUR MOST COMFORTABLE FORMATION POSITION (LTS ON/OUT IF DIFFERENT):

COMMENTS:

BRG: ____

DIST: ____

STEP UP/DOWN

CARD 12

Data Sheet 18

Aircrew Training Debrief Sheet

Subject:______________________________

Training Provided By:__________________

Date:__________Instructor:______________

1. Course Content:

2. Training Adequacy:

3. Comments:

Data Sheet 19

Maintenance Personnel Training Debrief Sheet

Subject:________________________________

Training Provided By:____________________

Date:__________Instructor:______________

1. Course Content:

2. Training Adequacy:

3. Comments:

Appendix C

AIRCRAFT EQUIPPED WITH A NIGHT VISION SYSTEM HUMAN FACTORS ENGINEERING DESIGN EVALUATION PLAN

Table C-1

Night Vision System Components
Human Factors Engineering Evaluation Plan

---

1. NAVFLIR

a. Evaluate the following human factors engineering design features of NAVFLIR control and adjustments:

(1) Range of brightness, balance and contrast adjustments for both day and night operations.

(2) Control panel layout and switch/knob positions.

(3) Control of the following NAVFLIR functions (no "hands on throttle and stick" capability):

(a) NAVFLIR HUD display OFF/ON.

(b) Black Hot/White Hot.

(c) AC Coupled/DC Coupled.

b. Evaluate the human factors engineering design of the NAVFLIR HUD display and HUD symbology integration for ease of interpretation and readability:

(1) Air-to-air, air-to-ground and navigation master mode symbology.

(2) Threat emitter symbology.

c. Assess the requirement for the following capabilities not incorporated at this time:

(1) NAVFLIR Auto-Cuer function.

(2) NVG Auto-Scene reject when NAVFLIR HUD display used.

Table C-1 (Cont)

Night Vision System Components
Human Factors Engineering Evaluation Plan

---

2. MDI, MDRI, MPCD/DMS

a. Evaluate the following human factors engineering design features of MDI, MDRI and MPCD/DMS control and adjustments:

(1) Range of brightness and contrast adjustments for both day and night operations.

(2) Control panel layout and switch/knob positions.

b. Assess the affects of direct sunlight and glare on the MDI, MDRI and MPCD/DMS.

c. Assess the quality and utility of the tri-color MDI and MDRI displays.

d. Evaluate the quality and utility of the DMS graphics.

3. Intercommunications System (ICS)

a. Evaluate the human factors engineering design of the ICS installed in the aircraft equipped with night attack systems for user friendliness.

b. Evaluate the human factors engineering design of the ICS control and adjustment panel.

4. Night Attack Aircraft Lighting

a. Evaluate the adequacy of internal cockpit lighting to include:

(1) NVG compatibility.

(2) Range of brightness control for the instrument and console panels.

(3) Lighting balance between instrument displays.

(4) Adequacy of flood/chart lighting such as NVG chart light position in the aft cockpit and NVG compatibility.

Table C-1 (Cont)

Night Vision System Components
Human Factors Engineering Evaluation Plan

---

b. Assess the adequacy of external aircraft lighting to include:

(1) Impact of non-compatible external lighting on own-ship aircrew wearing NVGs.

(2) Impact of non-compatible external lighting on wingman aircrew wearing NVGs.

VITA

LtCol Mark R. Mitchell received his Bachelor of Science degree in Civil Engineering from Texas A&M University prior to entering the U.S. Marine Corps in 1973. He has since accumulated over 3600 tactical flying hours in F-4 and F/A-18 aircraft over 17 years of service. He is a graduate of the TOPGUN Navy Fighter Weapons School and the USAF Test Pilot School. He was an F-4 tactics instructor at the Marine Air Weapons and Tactics Squadron One, Yuma, AZ, until joining one of the first USMC F/A-18 Hornet squadrons at MCAS El Toro, CA. LtCol Mitchell has flown over 30 different aircraft, was on MIG CAP during the 1986 Libyan air raid into Benghazi, and was selected as a USMC Astronaut Candidate. He is currently the Director, Operational Test and Operations at Air Test and Evaluation Squadron Five, NWC China Lake, CA, where he resides with is wife Dee and three children.