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THE USE OF SIMULATION IN THE DEVELOPMENT OF NIGHT VISION GOGGLE SHIPBOARD COMPATIBLE LIGHTING PACKAGES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Allison Dee Webster-Giddings

May 1994

DEDICATION

This thesis is dedicated to

my friend and husband, Gavin,

who survives my continual efforts to complicate life

and who smiles dispite them.

ACKNOWLEDGEMENT

I would like to thank Mr. Kurtis Long for his enthusiasm, motivation and teaching skills during the writing of my thesis.

DISCLAIMER

The information presented in this thesis is the sole opinion of the author and in no way reflects the views of the Naval Air Warfare Center Aircraft Division, Naval Air Systems Command, or the United States Navy.

ABSTRACT

Military helicopters have been operating aboard ships since 1943. Since then, shipborne helicopters have grown from a novelty to a necessity. Just as helicopter technology has grown, so to have the devices used to assist aircrews in the accomplishment of the helicopter mission. Since the Vietnam War, helicopter crews have flown with night vision goggles to provide them with the ability to navigate during night missions. The development of a night vision device compatible flight deck lighting began in 1989 with the first evaluation aboard USS TARAWA. By 1993, it became evident that decreasing ship availability and rising flight and ship costs in the environment of a downsizing navy, resulted in shipboard testing becomming a luxury. The result was to develop simulator capability to model prototype lighting packages with sufficient fidelity to conduct ground evaluations. This capability would not only result in increasing shipboard test efficiency, but also provide an excellent training tool.

This thesis discusses the technology of night vision goggles as it applies to simulation, the basics of simulator modeling and finally, presents the development of the model created for the night vision goggle compatible shipboard lighting package. Specific findings include the need for

modelling of windshield transmissivity, starlight illumination, and an exact coloring matrix.

This thesis and all reference material listed are unclassified. In addition, information from limited distribution government reports was not carried over into the content of this thesis.

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CHAPTER 1

INTRODUCTION

Military helicopters have been operating aboard ships since a U. S. Army Air Force pilot landed an Army XR-4 aboard SS Bunker Hill, 1943.[1] Since then, shipborne helicopters have grown from a novelty to a necessity. During the Vietnam War, helicopter crews first began use of the night vision goggle (NVG).[2] Since then, the use of NVGs has become commonplace, with the U.S. Marines using 90 percent of their night training hours using NVGs. Since 1989, shipboard testing of NVG compatible shipboard lighting packages has been conducted.[3] The objectives of these tests were to create lighting that illuminated the flight deck for the non-NVG users without detrimental effects on the NVG users.[4] The testing of this lighting package has been

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[1]Thomason, Tommy, "The History of Helicopters in the U.S. Navy," Vertiflite (May/June 1984), p. 68-69

[2]Helicopter NVG Manual, Marine Corps Air Station Yuma: Marine Aviation Weapons and Tactics Squadron One, 1990, p.2-1

[3]Talbot, Steve, Davidovich, Paul, Rudzis, J., Meir,M., Mueller, and Long, Kurtis, AH-1W and CH-53E LPD 4 Class Expanded Capability Flight Deck DI Testing Aboard USS PONCE (LPD 15), Patuxent River: Naval Air Test Center, 1990, p.i

[4]Ibid., p.1

slowed by the limited availability of funding and of testing platforms. Thus, engineers have been driven to find alternatives to testing or ways of minimizing the testing process. One alternative was to create a simulation process with sufficient fidelity to mimic the visual shipboard environment which may be viewed by both the naked human eye and the NVG aided human eye. This study covers the operating theory of NVGs and of simulation, and the development of NVG compatible lighting in the simulator. The model created in the Manned Flight Simulator, located at Naval Air Station Patuxent River, Maryland, adequately represents the actual visual landing aids package under both NVG aided and unaided conditions. Future efforts should be directed toward better texturing of lighted surfaces, simulating infrared light source provided by starlight, developing a correlation between light frequency and simulator color setting functions, simulating aircraft windshield transmissivity properties, and using distributive interactive simulation network to link many task trainers for real-time battle field modeling.

CHAPTER 2

NIGHT VISION GOGGLE PRINCIPLES OF OPERATION

GENERAL

The principles of all night vision goggles remain the same, regardless of the manufacturer. The NVG is made up of an image intensifier tube, a power source, and various mechanical fit adjustments. It is necessary to understand the principles of the NVG to appreciate the critical aspects of using NVGs in simulators. This chapter addresses the theory and operations of the night vision goggles used in the fleet today. It specifically addresses those NVG characteristics which were found to cause unique problems in simulation. A more thorough description of night vision goggle theory is provided in "Integration of Night Vision Goggles in the A-6E Intruder Airplane" Master of Science Thesis in Aviation Systems, University of Tennessee, Knoxville by Mike A. Bryan.

THE IMAGE INTENSIFIER TUBE

General

An image intensifier tube is an electronic device that amplifies light to form an image viewable by the human eye.

A simple diagram of the image intensifier tube in use today is presented in figure 1.

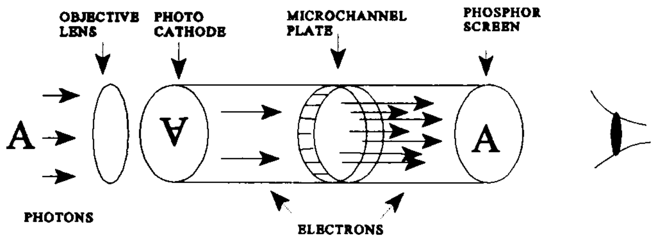

Figure 1. Image Intensifier Tube

Source: Helicopter NVG Manual, Marine Corps Air Station Yuma: Marine Aviation Weapons and Tactics Squadron One, 1990

The first component of the image intensifier tube is an objective lens. This lens focuses the incoming photons of light on the next component, the photocathode. The photocathode converts the incoming photons into electrical energy in the form of electrons. The electrons leaving the photocathode are amplified by an electron multiplier or a microchannel plate prior to striking the phosphor screen. These electrons strike the phosphor screen, producing a visible image. The resulting image is of green and white color, not unlike a black and white television with its green tint increased. Appendix A, figure 2 presents a photograph taken by a camera fitted with one intensifier tube from an AN/AVS-6 NVG.

Development of the Image Intensifier Tube

The development of the image intensifier tube has advanced to now a third generation of tubes. The third generation tube is that which is use by the majority of flight crews in the US military, however the second generation tube is still used by ground and flight deck crews. The second generation (GEN II) tubes are used in the AN/PVS-5 NVG and the third generation (GEN III) tubes are used in the AN/AVS-6 NVG. A third set of NVGs, Catseye, are used by fixed wing military pilots. The Catseye also uses third generation tubes. This type of goggle, however, is not used on the ships for which the lighting package was developed, and therefore is not addressed.

The technological growth of the image intensifier tube has been in the photocathode and in the microchannel plate. The quality and type of the photocathode determines the sensitivity of the intensifier tube. Because of the process of producing a photocathode, the second generation photocathode, the S-20 multi-alkali, is sensitive to light within the 400 to 850 nanometer (nm) range. This has an average output of 350 microamps/lumen. The third generation photocathode, a gallium arsenide photocathode, is sensitive to light from 550 nanometers to 950 nanometers with more than 1,000 microamps/lumen.[1]

A metal oxide film is applied to the microchannel plate of the third generation tube to filter out wavelengths below 625 nm.[2] The microchannel plate in the GEN II tube does not incorporate this filter. The advantage of the metal oxide film is its transparency to electrons, and not to ions, which damage the photocathode plate. The metal oxide film traps the ions and prevents their contamination of the photocathode plate. The trapped ions cause a high voltage between the photocathode and the microchannel plate. This high voltage is decreased by an increased distance between the photocathode and the microchannel plate.

Figure 2 shows the relative wavelength response of the image intensifier tubes in the AN/PVS-5 and AN/AVS-6 NVGs.

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[1]Richard C. Hebb (1991). Night Vision Goggle Simulation, p.9, Orlando: Naval Training Systems Center

[2]MAWTS-1 (1990), Ibid., p. 2-7

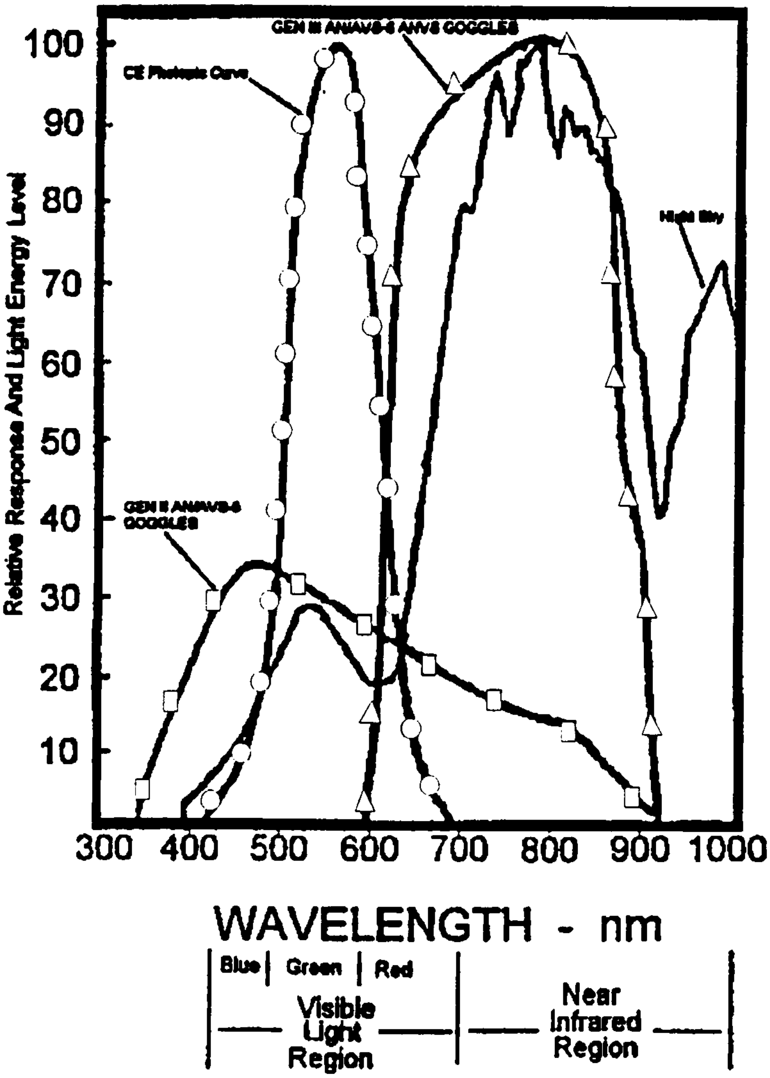

Figure 2. Comparison of AN/PVS-5 and AN/AVS-6 Sensitivities Adapted from: Night Vision Goggle Simulation, Orlando: Naval Training Systems Center Advanced Simulation Concepts Division, 1991

AN/PVS - 5 NIGHT VISION GOGGLE CHARACTERISTICS

Second Generation Intensifier Tube Characteristics

The characteristics of the GEN II intensifier tubes used in the AN/PVS-5 NVG, pictured in figure 3, are presented in appendix B, table 1.

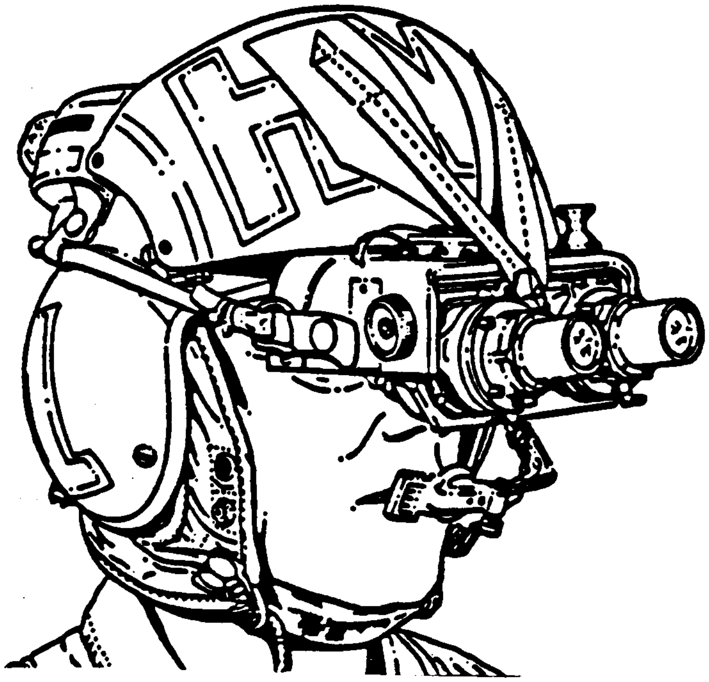

Figure 3. AN/PVS-5 (MFP) Night Vision Goggles
Source: Helicopter NVG Manual, Marine Corps Air Station Yuma: Marine Aviation Weapons and Tactics Squadron One, 1990

It is important to note that the values listed under visual acuity are for ideal laboratory conditions only. Under actual conditions of use, the visual acuity obtained with the goggle imagery will typically degrade by a factor of at least two.[3] The result of these characteristics is that the GEN II NVG is more susceptible to "blooming" or washing out of an image if a bright incompatible light source appears in its field of view. The GEN II NVG is also

[3]Richard C. Hebb (1991), Ibid., p.11

sensitive to, or non-compatible with, a broader range of light wavelengths, and therefore is more susceptible to blooming. Appendix A, figure 1, shows the electromagnetic spectrum of light. By comparing the plot of relative response of the GEN II NVG in figure 2, with appendix A, figure 1, it is evident that the GEN II NVG responds to light from the violet to near infrared (IR) color wavelength range. An evaluation of GEN II (AN/PVS-5) and GEN III (AN/AVS-6) image intensifier tubes determined the visual acuity performance differences under various night sky conditions. Table 1 presents these differences.

Table 1. Comparison In Visual Acuity Between AN/PVS-5 and AN/AVS-6

Source: John C. Kotulak and Clarence E. Rash, Visual Acuity with Second and Third Generation Night Vision Goggles Obtained from a New Method of Night Sky Simulation Across a Wide Range of Target Contrast, Fort Rucker: United States Army Aeromedical Research Laboratory, 1992

NIGHT SKY CONDITION	CONTRAST LEVEL					
	HIGH		MEDIUM		LOW	
	AN/AVS-5	AN/PVS-6	AN/AVS-5	AN/PVS-6	AN/AVS-5	AN/PVS-6
Full Moon	20/47±7	20/33±6	20/98±29	20/58±14	20/172±32	20/186±25
Quarter Moon	20/63±9	20/40±7	20/185±45	20/90±30	>20/250	20/191±32
Starlight	20/92±18	20/54±9	20/269±68	20/146±44	>20/250	>20/250
Overcast	20/183±48	20/87±14	>20/600	20/317±88	>20/250	>20/250

The GEN II image intensifier tube life span under medium light conditions is generally 2,000 to 4,000 hours.[4]

AN/PVS - 5 Physical Characteristics

The AN/PVS-5 NVGs are binocular, using one second generation intensifier tube for each eye. These goggles are used primarily by flight deck crews, and not by military helicopter pilots. The goggles permit an instantaneous field of view of 40 degrees[5]. However, the goggles are adapted with a faceplate designed to protect the wearer from flying debris encountered in the flight deck environment. This protection also precludes any peripheral vision.

AN/AVS-6 NIGHT VISION GOGGLE CHARACTERISTICS

Third Generation Intensifier Tube Characteristics

The characteristics of the GEN III intensifier tubes used in the AN/AVS-6 NVG, pictured in figure 4, are presented in appendix B, table 1.

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[4]MAWTS-1 (1990), Ibid., p.2-7

[5]Ibid., p.2-8

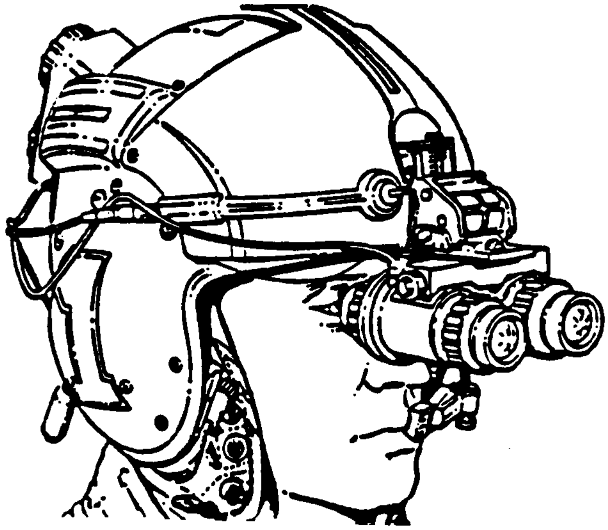

Figure 4. AN/AVS-6 ANVIS Night Vision Goggles
Source: Helicopter NVG Manual, Marine Corps Air Station Yuma: Marine Aviation Weapons and Tactics Squadron One, 1990

Two major differences distinguish the GEN III tube from the GEN II tube. These are the quality of the photocathode and the coating on the microchannel plate. The result of the higher quality photocathode, the filtered multichannel plate, and the greater spectral coverage resulted in a greatly improved performance in terms of a higher spectral response at wavelengths beyond 550 nm and greater sensitivity in the non-visible region of near IR where radiation from the night sky is higher.[10] This is evident in the comparison of appendix A, figure 1, and figure 2. The generation III NVG responds only to light in the red to near IR color frequency range, and not to the blue range. The increased distance between the photochathode and the microchannel plate designed to decrease voltage, results in increased halo size when viewing bright non-NVG compatible light sources.[11]

AN/AVS-6 Physical Characteristics

The AN/AVS-6 NVG is used by military aircrews of helicopters only. The NVGs are attached to the helmet to allow the pilot to view the cockpit gauges by looking underneath the NVGs. Night vision goggle compatible aircraft cockpits have been designed or modified to ensure the cockpit lights and instruments are in regions of low or no NVG response[12]. This is designed to prevent the aircraft instruments from causing NVG blooming. The AN/AVS-6 NVGs do not have a faceplate to inhibit vision, and therefore, the

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[10]Mike A. Bryan, "Integration of Night Vision Goggles in the A-6E Intruder Airplane" Master of Science Thesis in Aviation Systems (1993), p.12, Knoxville: The University of Tennessee

[11]MAWTS-1 (1990), Ibid., p.2-7

[12]Ibid., p.10-32.

pilot is also able to use unaided (non-NVG aided) peripheral vision to view flight deck cues, when available.

HUMAN EYE SENSITIVITIES

The CIE Photopic Curve, depicted in figure 2, is the response of the human eye during daytime illumination levels to wavelengths between approximately 400 to 700 nanometers.[9] Appendix A, figure 1, shows this range of wavelengths encompasses the range of colors from violet to red. The night sky curve, in figure 2, shows the amounts of radiation available from starlight and moonlight. By comparing these two plots with the GEN II and GEN III curves, it is evident that all of the light which is visible to the human eye (400 to 700 nm) is also visible to the generation II NVG (400 to 850 nm). Only light in the yellow green to red wavelength range (550 to 700 nm) is visible to both the human eye and to the generation III NVG (550 to 950 nm). Whereas, light from the violet to yellow green (400 to 550 nm) range is visible to the human eye and not to the GEN III NVG. It was upon this premise that the NVG compatible shipboard lighting package was designed.

[9] Richard C. Hebb (1991) Ibid., p.11

CHAPTER 3

VISUAL LANDING AIDS PACKAGE

USS DULUTH

The shipboard visual landing aids (VLA) package modeled during this test was installed on USS DULUTH (LPD 6). USS DULUTH (LPD 6) was a USS AUSTIN (LPD 4) class amphibious transport dock. Each ship of the LPD 4 class was approximately 570 feet long, 100 feet wide, and displaced 17,240 tons, fully loaded. Each ship of the class was powered by two Foster-Wheeler boilers, which drove two turbine engines, producing a total of 24,000 shaft horsepower (SHP), and a maximum speed in excess of 20 knots[1]. USS DULUTH, commissioned in 1965, was originally designed to embark, deploy, and land elements of a Marine Air Ground Task Force. More recently, LPD 4 class ships have supported heliborne reconnaissance, strike, command and control, special operations, and mine countermeasures operations. LPD 4 class ships were equipped with a docking well for aircushioned landing craft (LCAC) and conventional landing craft, a helicopter flight deck and hangar, and various cargo and vehicle holds. The flight deck was located approximately 35 feet above the design waterline. A

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[1]Jane's All the World's Ships, Coulsdon Surrey, England: Sentinel House, 1992

deck dimensional drawing and aviation facilities summary of LPD 6 are presented in appendix A, figures 3 and 4, respectively.[2]

BASELINE VLA SUITE

The baseline non-NVG compatible LPD 4 class flight deck VLA lighting suite included red deck edge lights, amber and white overhead floodlights, strobing white lineup and extended lineup lights for both port and starboard oblique approaches at spots 1 and 2, and a Glide Slope Indicator (GSI)/waveoff light system. The GSI, mounted atop the Helicopter Control Station (HCS), was slewable, although normally remained fixed, pointing directly aft. In 1992, as a result of known LPD 4 class flight deck lighting deficiencies and evolving operational requirements, Naval Air Systems Command initiated a program to install a supplemental lighting suite, known as Aviation Capable Ship Service Change 17 (ACS 17), aboard all LPD 4 class ships.[3] ACS 17 added four six lamp dropline and 16 to 18 deck surface floodlights to the baseline LPD 4 class lighting

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[2] Shipboard Aviation Facilities Resume, Lakehurst: Naval Air Warfare Center, Aircraft Division, (1993) p.213

[3] Long, Kurt, "CH-46E, UH-1N, CH-53E, SH-60 Dynamic Interface Aboard USS DULUTH (LPD-6) Test Plan," Patuxent River: Naval Air Warfare Center, Aircraft Division, (1993) p.5

configuration. USS DULUTH received ACS 17 in January 1993. A summary of all baseline VLA lighting components aboard USS DULUTH is presented in appendix B, table 2.

NVD-COMPATIBLE VLA SUITE

The baseline VLA marking and lighting configurations in ACS 17 were not night vision device (NVD) compatible. In 1989 to 1992, Naval Air Warfare Center developed and tested several types of specially treated filters and light components, each of which was designed to minimize NVD-incompatible IR emissions while providing sufficient deck illumination for non-NVD equipped deck personnel.[4] Each of the evaluated components demonstrated increased NVD compatibility and maintained non-NVD usability.[5] These lights were included in the VLA package evaluated aboard USS DULUTH. The NVD-compatible exterior lighting components, summarized in appendix B, table 2, included 10 NVD-compatible gold plated blue glass overhead floodlight filters, replacing the amber filters in the overhead floodlights, and 16 NVD-compatible blue glass filters and 32

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[4]Ibid., p.4

[5]Long, K., Talbot, S., LHA 1 Class Night Vision Goggle (NVG) Compatible Lighting Dynamic Interface (DI) Testing ABD USS BELLEAU WOOD (LHA 3), First Interim Report, Patuxent River: Naval Air Test Center, para.7

"cool beam" lamps, replacing the amber filters and high temperature lamps in all deck surface floodlights. The NVD-compatible interior lighting components included eight NVD-compatible blue well deck overhead floodlight filters, replacing some of the amber filters in the well deck overhead floodlights, and several green electroluminescent (EL) lighting panels mounted on the ceiling of HCS.

The spectral properties of the PAR 56 overhead floodlight, the gold plated filter placed over the PAR 56 overhead floodlight, and the glass filter placed over the cool beam deck surface floodlights are presented in appendix A, figure 5. The effect of the filters was to narrow the frequency band of the emitted light. While the filters were optimized for GEN III compatibility, they remained slightly incompatible with the GEN II image intensifier tube. This can be seen by comparing appendix A, figure 5 with figure 2. Enlisted Landing Signalmen (LSE), who provided hand signals to aircraft on approach to the ship, found the glass NVG filtered deck edge surface floodlights caused moderate amounts of blooming in their NVGs whereas the gold plated filtered overhead floodlights caused only small amounts of blooming.[6]

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[6]Arvai, J., McCulley, S., Barber, J., CH-53E Dynamic Interface Tests Aboard USS WASP (LHD-1), Patuxent River: Naval Air Warfare Center, Aircraft Division, (1993), p.8

CHAPTER 4

COMPUTER SIMULATION

INTRODUCTION

The scope of this study was to develop a simulated model which would accurately depict the shipboard night environment under unaided human eyesight while simultaneously resulting in an accurate image presented in the night vision goggle. Making one scene representative of both NVG aided and unaided shipboard lighting environment eliminated the need to create a separate simulation of an NVG scene and allowed the designers to evaluate a light characteristic change effect in one simulation program. Computer simulation technology is a rapidly growing field, in size and technological advances. Modern simulators are a combination of several very basic image generators and visual systems; motion systems make up the third side of the simulation triangle. Though the trial simulator operated with motion, motion was not necessary to be included in the scope of this evaluation.

FUNDAMENTALS OF VISUAL FLIGHT SIMULATION

Image Generator Systems

Visual flight simulation is comprised of an image generation end and a visual display end. The image

CHAPTER 4

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FUNDAMENTALS OF VISUAL FLIGHT SIMULATION

Image Generator Systems

Visual flight simulation is comprised of an image generation end and a visual display end. The image generator (IG) is the mechanism by which the visual scene is generated. The IG consists of data bases to store the modeling information and a system for the retrieval of instantaneous scenes. In these early systems, a film camera and model approach was utilized. A three dimensional model was created from a computer work station and transferred electronically via an optical pickup to a television screen. Later systems incorporated film rather than television in the visual display system (VDS). In these more advanced systems, a typical real life mission profile such as a landing and take off, were filmed from the aircraft. This scene was then projected onto the visual scene in the simulator. As the pilot flew, any deviations from the optimal flight path were provided by manipulation of the image optically. The perspective of the projected image was optically modified by cylindrical lenses. The film was translated to reflect lateral deviations. The flight envelope of this system was severely constrained by the amount of video taken, but provided real world modeling.

A more flexible form of image generation is computer image generation (CIG). Hybrid systems have been developed to incorporate film and CIG. CIG systems generally are able to handle large fields of view, provide high resolution, allow flexibility in changing the data base, and viewpoints and provide infinite depth of field, however are limited to generation of image detail.[1] This limitation is overcome by increasing the system's edge display capacity.

Visual Display Systems

General

The purpose of the visual display end is to present the desired generated image to the eyes of the observer with sufficient brightness, a minimal loss in resolution, a sufficiently wide field of view, minimal distortion, and true apparent distances. Optimizing these individual characteristics increases the fidelity of the system.

Visual display systems are classified as either pupil forming or non-pupil forming. The latter is a system that allows the observer to move a reasonable distance away from the design eyepoint until a gradual illumination degradation is noted. The former provides directionality to all of the rays emanating from the displayed scene. When the observer moves away from the design eyepoint volume of space in a pupil forming system, a dramatic degradation in illumination is evidenced.

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[1]Kraft, Conrad L. and Shaffer, Larry W., "Visual Criteria For Out of the Cockpit Visual Scenes," Massachusetts Institute of Technology: Boston 1987, p.7-64

Visual display systems are further classified the way in which image is projected to the observer: Screen, Refractive, and Reflective.

Screen Display System

The two types of screen display systems, front and rear projection, use diffusing screens of a low gain, and therefore are non-pupil forming as shown in figures 5 and 6.

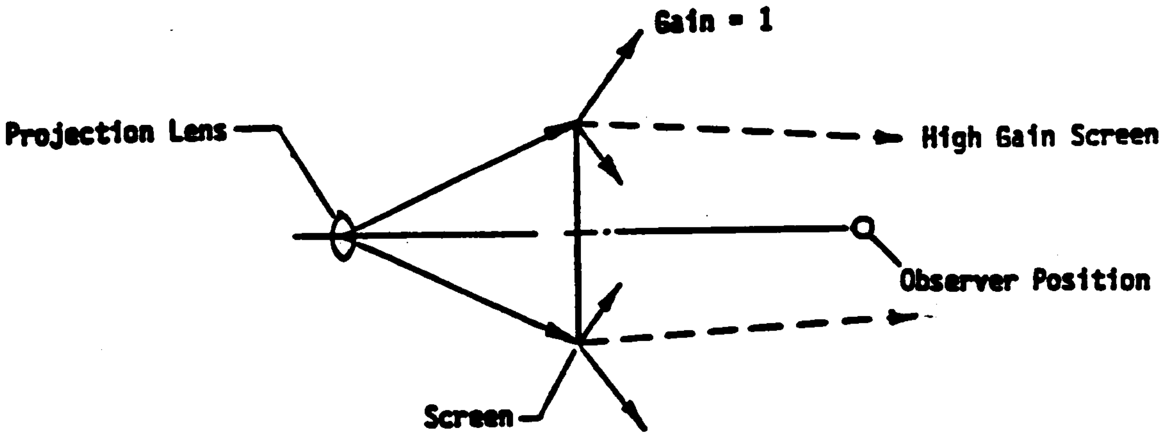

Figure 5. Rear Projection Screen Display System

Source: Young, Kenyon, Elias, Fundamentals of Flight Simulation (1987), Boston

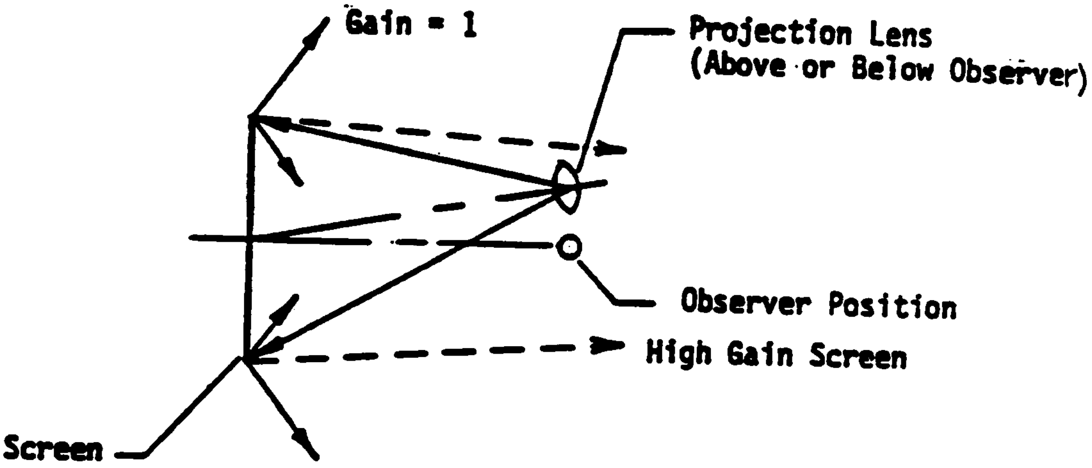

Figure 6. Front Projection Screen Display System

Source: Young, Kenyon, Elias, Fundamentals of Flight Simulation (1987), Boston

When the screen gain is high, these systems may be quasi-pupil forming where the transmitted (rear projection) and reflected (front projection) light is directed towards a relatively large volume within which an observer must locate his eyes to see the scene. High gain infers the projected illumination is reflected or refracted toward a given volume rather than diffused which would result in low gain. In the screen system, the projected image appears at the same distance from the screen as the observer. The field of view is limited by screen distance, screen size, and the required brightness. Eye relief distance is determined by the screen distance. Apparent brightness is a function of projected lumens, screen area and gain. Generally, a screen system has a lower resolution and contrast rendition than the other systems.

Refractive System

The refractive display system may be either pupil or non-pupil forming as shown in figures 7 and 8.

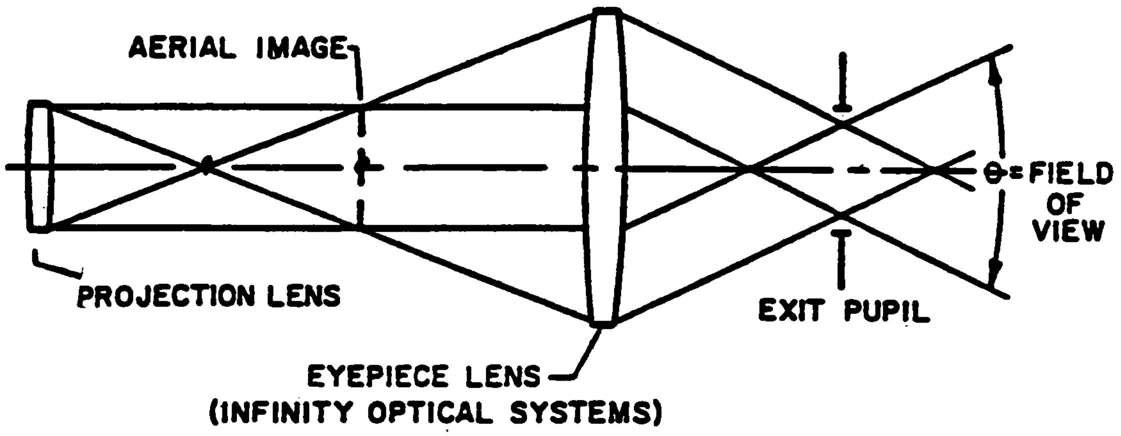

Figure 7. Refractive Visual Display System, Pupil Forming

Source: Young, Kenyon, Elias, Fundamentals of Flight Simulation (1987), Boston

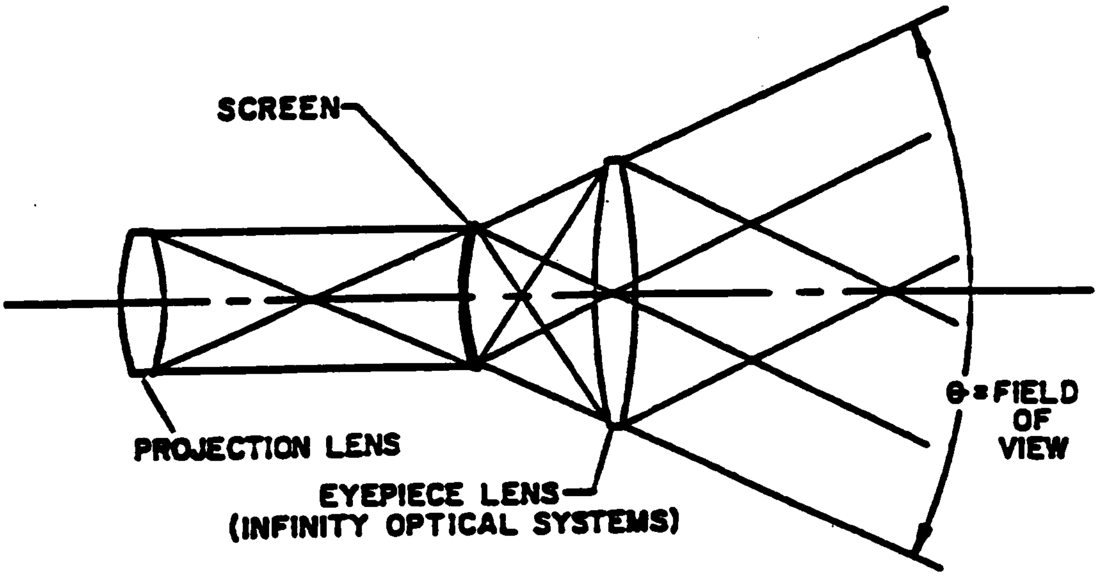

Figure 8. Refractive Visual Display System, Non-Pupil Forming

Source: Young, Kenyon, Elias, Fundamentals of Flight Simulation (1987), Boston

The field of view of a refractive system is limited by the observer's position and the eyepiece lens diameter. Within the limitations of FOV and pupil size, a refractive system can offer good eye relief, measured from the observer's eye position to the eyepiece lens. The pupil size is dependent on the projection lens size. Because G84 lenses are large and costly, normally a lens is designed for a minimum acceptable pupil size of eight to ten inches.[2] The light transmission of a the pupil forming system is

[2]Ibid., p.5-10

limited only by the transmission efficiently of the optical elements, however, the non-pupil forming system light transmission is moderated by the intermediate screen and its gain.

Reflective System

The reflective system employs an eyepiece mirror as the final optical element of the system toward the observer. The eyepiece mirror projects the displayed scene to optical infinity. In figure 9, the eyepiece mirror receives light from the spherical mirror and generates a pupil.

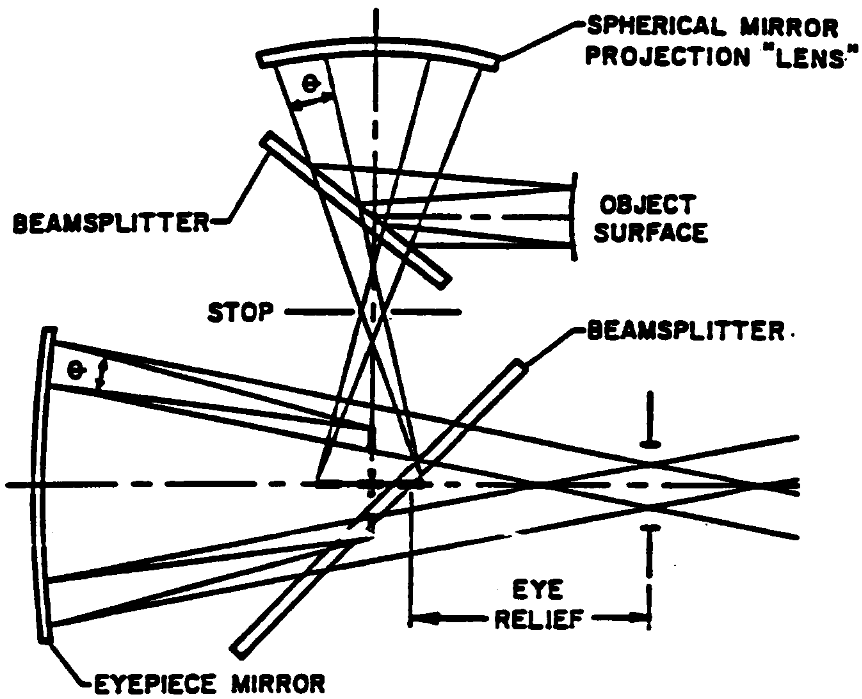

Figure 9. Reflective Visual Display System, Pupil Forming

Source: Young, Kenyon, Elias, Fundamentals of Flight Simulation (1987), Boston

In figure 10, the eyepiece mirror receives light from a diffusing screen and forms no pupil.

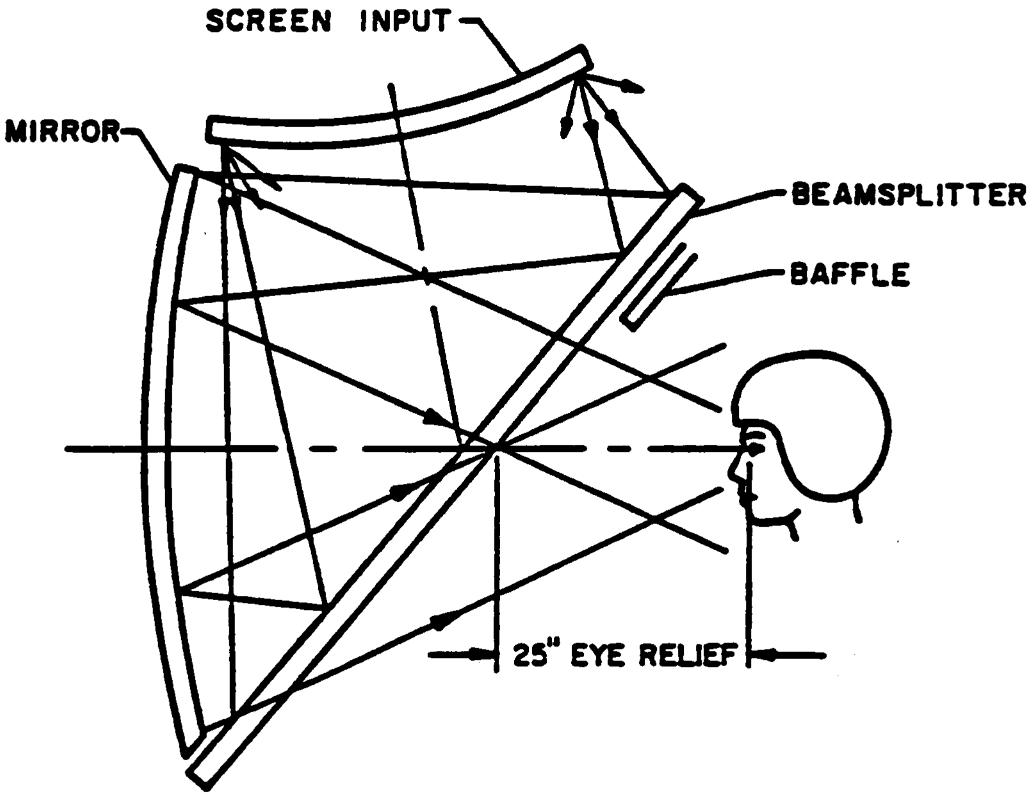

Figure 10. Reflective Visual Display System, Non-Pupil Forming

Source: Young, Kenyon, Elias, <u>Fundamentals of Flight Simulation</u> (1987), Boston

The FOV of the pupil forming system can be as large as 100 degrees horizontally and 70 degrees vertically. This is because the image is projected close to the eyepiece mirror.

The non-pupil forming system FOV is limited by the distance of the screen input to the beamsplitter, which attenuates the light in the reflective system. The eye relief for the reflective system is determined by the axial distance from the tilted beamsplitter to the observer's eye position. The pupil size of the reflective system is limited in the same manner as was the refractive system.

CHAPTER 5

MANNED FLIGHT SIMULATOR

GENERAL

The simulator used to develop the subject lighting package was the Manned Flight Simulator (MFS), located at NAS Patuxent River, Maryland. The MFS used the COMPU-SCENE IVA Image generator built by General Electric to provide the visual simulation through CIG. The images were displayed on a high quality, stable visual display system, the WIDE II. The MFS also provided six axes of motion which were used during the evaluations to facilitate training, but were not a subject to this study. Figure 11 is a functional diagram of the system integration.

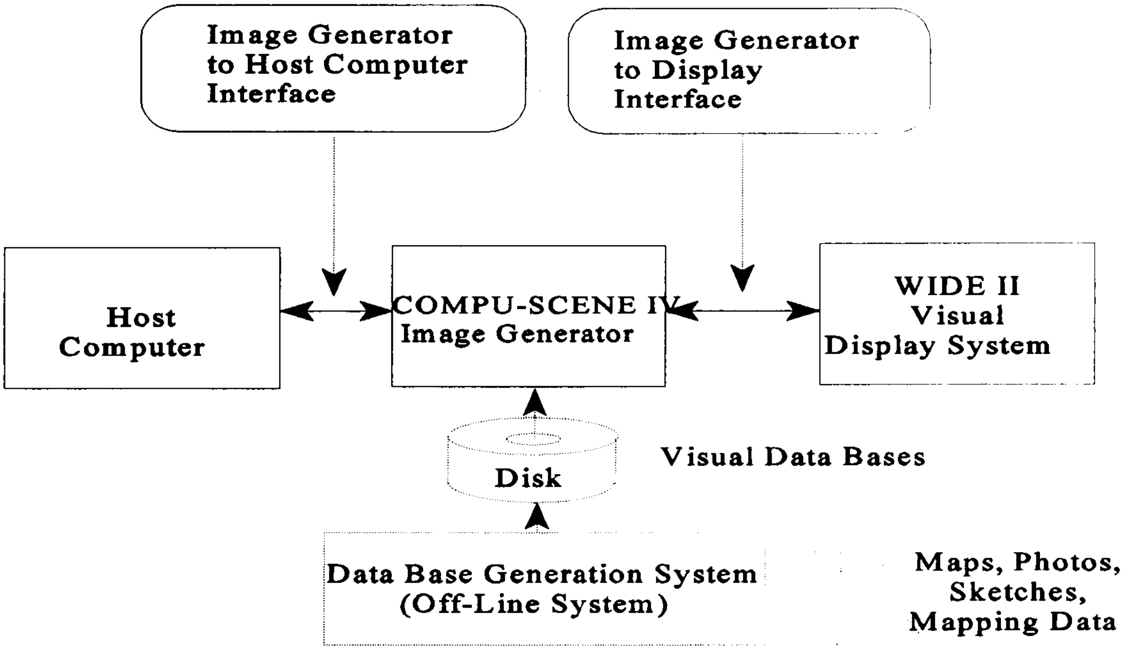

Figure 11. MFS System Integration

Adapted From: "Advanced Visual Technology Systme (AVTS) SCSD Program Profile (1984), Daytona Beach: General Electric, p. 2 and Controls Analysis and Simulation Test Loop Environment (CASTLE) User's Guide, Version 1.3, Patuxent River: Naval Air Test Center, p.13

COMPU-SCENE IVA IMAGE GENERATION SYSTEM

System Description

The COMPU-SCENE IVA Image generation system consisted of visual data bases, an advanced real-time Image Generator, and an Data Base Generation System (DBGS) using computer image generation technology. The DBGS, comprised of a modeling work station and a cell texture work station, provided an off-line process for creating and modifying the visual data bases from maps, photos, sketches or prepared data sources. The visual data base contained two and three dimensional generic models needed to represent the real-world scenes. These generic models included rolling terrain, model complexes, universal features (trees, rocks, bushes, etc.), moving models (aircraft, tanks, trucks, etc.), light models and point features, sky, ground, and cloud models, and special effect models (explosions, smoke, etc.). The IG processed the visual data bases against an instantaneous viewpoint position and attitude, and generated real-time video to be presented on the WIDE II visual display system.[1]

The IG performed three functions basic to the CIG theory.[2] These functions were:

a. IG to simulator host interface

b. IG to visual data base interface

c. IG to visual display system interface

The IG to simulator host interface provided the functional interface with the host computer and processes the

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[1]"Advance Visual Technology System (AVTS) SCDS Program Profile" (1984), Daytona Beach: General Electric, p. 1-2

[2]Rick D. Bess, "Image Generation Implications For Networked Tactical Training Systems," Proceedings of the 1992 Image VI Conference (1992), Tempe: The IMAGE Society, Inc. p. 83

instantaneous viewpoint positions and attitude data, moving model locations and mission data. The IG to visual data base interface provided the data base management for retrieving the active visual data base from disc storage and traversing this data to the support computer. The IG to display interface supported the variable update rates, channel switching, multiple configurations and pixel aspect ratios. The IG also provided an interface with the maintenance station.

The IG interfaces also functioned to transform the three-dimensional coordinate system visual data base developed at the modeling station to a two-dimensional system in the proper perspective to the observer's viewpoint. It also sorted potentially visible data into correct order of occulation with respect to the observer's viewpoint.

The visual display system interface processed the two-dimensional face data and computed the color for each picture element (pixel) to be output to the WIDE II display system. In this interface, various hardware functions are performed to provide cell characteristics. Of particular importance was a cell texture generator which computed cell texture, curvature shading and/or fading for each face. The The database and visual display system interfaces worked to process cell color and computed the final combined color of each pixel as a function of the area, fading and modulation for each face in the element.[3]

Image Generation Modeling Features

The IG had several features which facilitate the process of making high fidelity models. Models were created at a workstation, a subset of the DBGS. The models were then forwarded to the VDB and processed through frames I, II, and III. The IG was able to process up to 4000 high resolution and 8000 low resolution potentially visible faces on the screen at one time.[4] Faces pointing away from the viewpoint were not counted as potentially visible. It uniquely prioritized all potentially visible models and faces of each model as a function of occulting with respect to each viewpoint.

The IG processed light sources modeled from faces and points. Each model had separate brightness, blending and fading characteristics. The face light, was able to be any shape or size, and it's shape attenuated as a function of distance in the same mannner as a non-light shape. The point light, a spherical shape, was able to be as large as 15 pixels, and as small as one pixel. The point light size

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[3]Bess, Ibid., p.83

[4]General Electric (1984), Ibid., p. 2

attenuated as a function of distance as depicted in appendix A, figure 6. The attenuation of a real world point light is also shown. Both point and face lights' brightness attenuation as a function of distance was adjustable. Appendix A, figure 7 is a plot of the brightness attenuation function. The default distance vaules for points A, B, and C were 30,380 feet, 60,760 feet and 99,999 feet.

The IG also provided eight on-line light color tables and eight on-line light parameter tables. Each color table contained 256 entries consisting of red, green and blue components, with each component having 256 intensities. Each light parameter table contained 256 light characteristic entries consisting of brightness, extinguishing range, visibility and strobe rate. Color tables were able to be updated in real time to allow a selection of various diurnal (day, dusk, night) or weather (rain, sleet, snow) conditions. The color assigned to each face was modified by illumination, cell texture modulation, curved surface shading, and atmospheric visibility to calculate one of 4096 possible color intensity levels for each primary color component of every pixel.

WIDE II VISUAL DISPLAY SYSTEM

The WIDE II visual display system, shown in figure 12, presented data received from the COMPU-SCENE IVA image generator. It was a non-pupil forming, reflective system.

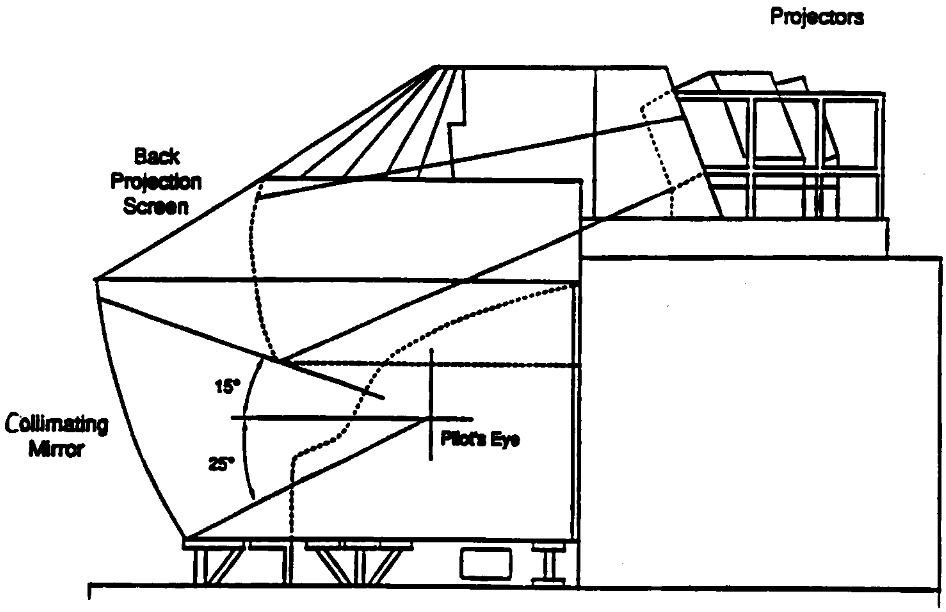

Figure 12. WIDE II Visual Display System

Source: "Wide Display System" Rediffifusion Simulation, GM Hughes Electronics Company (1988)

The fundamental principle of the WIDE II Visual Display System was to form an image on the back projection screen which could be viewed by an observer via the large collimating mirror. The collimating mirror was a mylar sheet held taut by vacuum pressure. The mylar sheet acts as the reflecting surface, and is attached around its edges to the front face of a hollow airtight chamber. The edges of the chamber are shaped to a specific shape and when some of the air is sucked from the chamber, differential airpressure forces the mylar sheet into a concave shape.[5] The structure for the mirror was provided by the simulator structure. Four projectors were used to provide a large (160 degrees horizontal by 40 degrees vertical) continuous field of view. The FOV is limited by the large mirror required for a non-pupil forming system as discussed earlier. This continuous image was achieved by using electronic overlap and fading techniques at the adjacent edges of each projected image. The collimating mirror produced a virtual image at infinity of the real image on the back projection screen. The projector structure maintained the required geometry and provided an enclosed cockpit support. The visual scene was received from the COMPU-SCENE IVA image generator at a rate of 60 hertz. The WIDE II performance capabilities are specified in appendix B, table 3.

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[5]"Increased Vertical Field Of View For Wide-Angle Collimated Displays," Proceedings of the 1992 Image VI Conference (1992), Tempe: The IMAGE Society, Inc. p. 504

CHAPTER 6

DEVELOPMENT OF THE SIMULATION MODEL

GENERAL

The development of the visual landing aids package simulation model was a three step process. The first step was to develop the simulator model using the existing database, photographs, and pilot input, and to familiarize the pilots with the simulator model. The same pilots would be used in later flight tests of the system aboard ship. Next, the actual lighting package was installed on the ship, USS DULUTH (LPD 6), and evaluated for its NVG compatibility. After the flight tests, the model was evaluated for its similarity with the subjective and photographic data gathered aboard ship and changes were made to the model to increase fidelity for future flight tests.

Although the Manned Flight Simulator was chosen for this evaluation because of its proximity to other test resources and its availability, it is important to note that other simulation models are being developed to simulate the night vision goggle scene. An MH-53J simulator, located in Albuquerque, NM has been developed to fully simulate the night vision goggle scene. The simulator does not necessitate the use of NVGs. The visual scene is that which would be viewed through NVGs. The drawback of this model is the requirement for a second NVG specific model to be developed in addition to a non-NVG model. Nor does this model permit the pilot to utilize unaided peripheral vision provided by the ANVIS NVG. These two drawbacks would make the model development and evaluation a more lengthy process.

INITIAL MODEL DEVELOPMENT

General

Because the COMPU-SCENE IVA was limited by various memory parameters, the USS DULUTH simulation consisted of three individual super models. These models were the hull, the superstructure and the lighting package. The hull and superstructure, presented in appendix A, figures 7 and 8 respectively, were three dimensional models. Each face was assigned a color, texture, shading, fading, and blending characteristic. The flight deck markings were a part of the hull model. The light model is presented in appendix A, figures 9, 10, and 11. The light models were characterized by their color, brightness, blending, fading, and clamping levels. Clamping is a function designed to restrict the minimum size of a model. The number of faces, verticies, and edges of each model is presented in table 2.

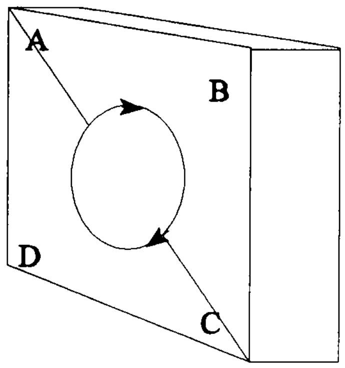
Table 2. Composition of LPD-4 Model

MODEL NAME	NUMBER OF FACES	NUMBER OF VERTICIES	NUMBER OF EDGES
Hull	456	944	1900
Superstructure	247	1252	1308
Lights	876	1253	3663
Total	1579	3449	6841

A picture of the final model at night is presented in appendix A, figure 12. Appendix A, figure 13 is a photograph of the same scene taken through an ANVIS intensifier lens.

Hull and Superstructure Model

The simulator models were of a series of two dimensional polygons joined together to form a set of three dimensional flat sided shapes. The hull and superstructure models were developed by first defining a coordinate system with a point origin in space. Vertices of the two dimensional polygons, or faces, were then defined in space, relative to the origin. Connecting the vertices in a clockwise order defined the front side of a face. In the example below, if the face is defined as A, B, C, D, then the front face is to the left in the drawing, because, to connect the letters, one must move in a clockwise direction.



The image generator presented to the WIDE II visual system only the front faces of each polygon, and only then if there were no other faces between it and the observer's viewpoint. This permitted the observer to see only the outside of the ship and not the skeletal inside of a modeled ship.

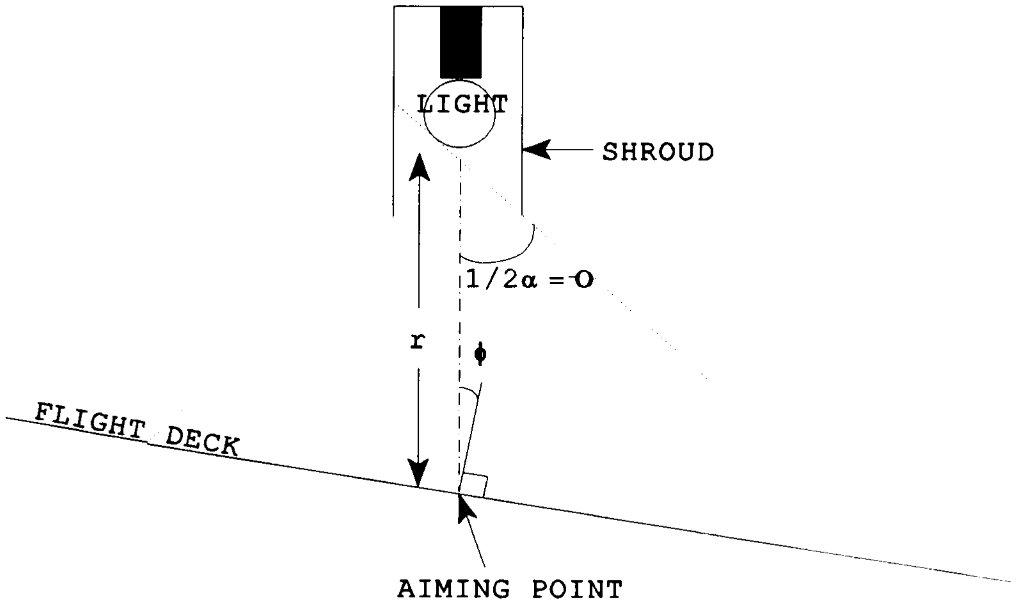
The colors assigned to each face were based on a subjective comparison of the model and photographs of the ship. Each face color was made up of 256 possible intensities each of red, green, and blue. An all green face would have had zero red, zero blue, and some amount (0 to 256) of green. A green of the level 256, was much more brillant than a green of level one. Combinations of red, green, and blue were formed to generate other colors. The flight deck markings were colored with an equal amount of all colors, to generate white. No face texturing was modeled because of the processing time required, however two dimensional texture patterns were available. Curved shading, the other texturing option, computed a gradient of shade across the face to generate the effect of a curved surface. No translucency value was applied to the face, which resulted in each face being solid, rather than opaque or translucent. Finally, flat face shading was applied to all faces. The flat face shading allowed the IG to modify the color of the face as a function of the angle between the normal vector to the face and the sun angle.

Light Model

The light model faces were generated using the same coordinate system as the hull and superstructure models. The VLA package light elements with filters were modeled separately from the illuminated area of the light. The light model was superimposed on the hull and superstructure models. This allowed hull model features such as the flight deck markings to appear through the translucency of the light model.

Shape Development

The shape of the illuminated area was determined by applying the equation for the area of an ellipse, the location of the light, the light shrouding, and the point on the flight deck to which the light was aimed. A computer program was written to facilitate multiple iterations of calculations. The resultant ellipses were modeled as light faces. The space between the light filter and the illuminated flight deck was not modeled. Therefore, an object between the light source and the flight deck did not appear to be illuminated by the light source. However, the flight deck appeared to be illuminated by the translucent ellipse model. The light location and shrouding dimensions, obtained from the ship's drawings determined α, the angle of lumination created by the shrouding of the light. The major and minor axes dimensions of the elliptic illuminated flight deck portion were then calculated using α, the location of the light, and the location of the aiming point. Smaller concentric ellipse dimensions were calculated by decreasing α. The smaller concentric ellipses were used to model the fading, or decreasing levels of lumination away from the aiming point. All curved lines were modeled with a series of straight lines designed to trick the eye into seeing a curve. The overhead floodlights were each drawn with 18 vertices and the deck edge lights with four vertices each. The following sketch depicts the geometry used for both the model shape and illumination development.



Illumination

The level of illumination of each concentric ellipse was calculated using the formula:[1]

$$E=\frac{COS(\phi)}{r^2}\iint B\cos(\theta)\,dS$$

E = illuminance

ϕ = angle formed by the incident light and the normal to the flight deck.

θ = 1/2 α

r = distance between the light and the aiming point on the flight deck.

B = Photmetric Brightness (luminence)

dS = area

This formula gave the total illuminance of the ellipse. In order to model the ellipse with a series of concentric ellipses, the illuminance of each smaller ellipse was subtracted from the value of illuminance of the larger ellipse. This value was then used in setting the light intensity of the modeled ellipse.

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[1]Young, Kenyon, Elias, Fundamentals of Flight Simulation, Boston: Massachusetts Institue of Technology, 1987, p.7-18

Initially, three lumination rings were modeled for all of the lights. However, because pilots found negligible additional cuing from the third ellipse in the overhead floodlight, and because of the time required to model the rings and the limitation in the number of faces permitted, only two lumination rings were drawn. These rings were those defined by α and half α. Because of the proximity of the deck surface floodlight to the flight deck, the third ring did provide additional cuing. A fourth ring cluttered that model. Thus the deck surface floodlight model remained at three rings.

Color

Because no correlation existed between light frequency and the color programming feature, the colors of the original model were estimated and then subjectively evaluated by pilots in the simulator. The gold filtered hangar flood lights were colored with a blue light of 256 parts blue and no red or green. This was designed to reflect this filter's narrow frequency range as depicted in appendix A, figure 5. The glass filtered deck edge lights were colored with a 200 part blue. The lower level of blue was used to simulate the broader frequency range characteristic of this light, as shown in appendix A, figure 7. The remaining standard lights were either all white (equal parts of red, blue, and green), all red, or amber (equal parts of red and green only). Appendix B table 4 presents the initial colors of all lights modeled.

Translucency and Shading

The translucency of each light face was variable, from opaque, with a value of zero, or clear, with a value of 16. The translucency level of the larger of the two overhead floodlight rings was set at 12, with the inner ring at 14. The deck edge floodlight translucency levels were set at 12, 13, and 14 for the outer, middle and inner rings, respectively. These levels most accurately reflected photos of previous flight deck installations by illuminating the white flight deck markings as depicted in appendix A, figure 13. Flat face shading was assigned for all light faces.

Fading

The image generator's fading function was designed to decrease the brightness of the light as a function of viewing range. The fading function is used to compensate for the mismatch between the modeled point light and the real world point light size attenuation for a point light below one pixel, as depicted in appendix A, figure 6. The original model included the image generator's default settings for points A, B, and C, (30,380 feet, 60,760 feet, and 99,999 feet respectively) as shown in appendix A, figure 7. By multiplying the plots in appendix A figures 6 and 7, the IG made a light appear to fade at the same rate as a real world light. The blue overhead and deck surface floodlights were modeled as face lights and therefore decreased in size linaerly at the simulator's default function.

FLIGHT TESTS

Scope

The VLA package with the ACS-17 modification was installed aboard USS DULUTH in February 1993. Appendix A, figure 15 is a photograph of the installation without the aid of NVGs. Appendix A, figure 16 is a photograph of the installation under AN/AVS-6 NVGs. The tests were conducted five to 100 miles off the Californian coast in the vicinity of San Diego. Approximately 20 hours of night flight tests using ANVIS 6 NVG aided and unaided pilots and PVS 5 aided and unaided LSEs were conducted. Sixteen pilots participated in the evaluation flying a total of five aircraft: UH-1N, CH-46E, CH-53E, SH-60B, and SH-60F. All pilots were either U.S. Navy, U.S. Marine Corps, or U.S. Air

Force graduates of a test pilot school and brought with them various levels of experience in shipboard operations and night vision goggle use. Seven of the sixteen pilots flew the MFS simulator prior to participating in the shipboard flight tests. The VLA evaluation was conducted in conjunction with expansion of launch and recovery envelopes. The LSEs were fleet operators without any prior test experience. Their comments were given in response to being asked for the apparent advantages and disadvantages to the ACS-17 modified VLA.

The conditions under which the VLA was evaluated varied from civil sunset to the point at which a horizon was no longer visible with the use of NVGs. The loss of a visual horizon occured first without the NVGs, followed by its loss with the use of NVGs. The ambient light, after sunset, was predicted by USMC Computer Generated Global Light Level Calendar to be less than 0.0022 lux, which is considered to be low light level.[2] However, starlight and cultural lighting brightened the night sky on some test flights and a solid overcast darkened the night sky on other test flights. Still photography and video were used to document the installation for further comparison with the simulator model.

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[2]MAWTS-1 (1990), Ibid., p.16

Findings

Upon conclusion of each of the two to three hour night sorties, pilots were asked to comment on the differences between the shipboard VLA package and the simulator, the deficiencies of the shipboard VLA package, and the adequacy of the simulator to prepare the pilots for shipboard flight tests. In general, pilots having flown the MFS prior to the flight tests found the simulator to be representative of the actual VLA package. Differences between the actual VLA package and the simulator model were noted. The following major findings were identified. Corrections to the simulator deficiencies noted during the flight test are addressed later in this chapter.

VLA Intensity Settings

During the flight test, the ambient light was predicted to be less than 0.0022 lux, however, cultural lighting and low cloud cover prevented accurate measurement of the light levels. In attempting to optimize the intensity setting of the VLA, no one setting was found to be optimal for all pilots and for all LSEs under all conditions. During very dark nights, NVG compatible lights were at higher settings than normal and non-NVG compatible lights were at slightly lower than normal settings. During nights with significant star and cultural lighting, the reverse tended to be true. In general, however, the LSEs preferred the hangar flood lights at full intensity (100%), and the deck edge lights at a mid intensity (40%). This was attributed to the broad frequency range PVS-5 and the broad frequency glass filters fitted to deck edge lights. The angle of incidence also affected the LSEs' preferences. In the conduct of their duties, the LSEs did not find it necessary to look directly into the overhead floodlights. However, the deck surface floodlights were angled such that the light shined into the LSEs' eyes during aircraft approach. This problem was initially solved by angling the lights more toward the flight deck, but slight blooming of the LSEs' NVG still occurred. Pilots generally desired the hangar flood lights at a lower setting than that desired by the LSEs, however found the high level acceptable.[3] The pilots used the blue filtered light in their unaided peripheral vision while in a hover over the flight deck. The intensities of the ANVIS-compatible blue lights did not adversely affect the pilots under aided conditions. Both the pilots and the LSEs desired the white lineup lights and red lights to be barely

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[3]Schultz, E., Gilligan, W., Schreiber, S., Kenney, K., Switick, K., Fitzgerald, T., SH-60B/F Dynamic Interface Testing Aboard USS DULUTH (LPD-6), Patuxent River: Naval Air Warfare Center, Aircraft Division, (1993), p.7

visible to the unaided eye, thus preventing excessive NVG blooming.

Light Intensity Adjustments

The shipboard light intensities were found to be adjustable in groups of lights rather than individual lights as modeled in the simulator. The light groups are those listed in appendix B, table 2. The light intensities were adjusted by rheostat switches, from low (zero percent), to full (100 percent). Frequent light intensity level adjustments were made with the changing ambient light levels, at the request of different subject pilots, and during different phases of the approach. Light group intensity changes were most frequently made on the white approach lights. These non-NVG compatible lights were used on final approach, approximately one thousand yards from the ship, to identify the spot to which the aircraft's approach would be made. The pilots requested the HCO to lower the light intensities as their aircraft approached the flight deck. Having these adjustments made quickly increased the confidence of the pilot to make an accurate approach to the flight deck.

Light Fading

A subjective comparison of the fading characteristics of the lights at nominal settings showed that the shipboard lights faded significantly faster as a function of distance, than the simulator model lights faded. At three miles, the shipboard white lineup lights were dim but visible and indistinguishable, while the red and blue lights were not visible. Under similar conditions, the same simulator lights, at settings agreeable to the pilots, did not fade until approximately five miles (30,380 feet). The result was the simulator lights dominated the ship model at increased distances, making identification of the ship significantly easier than under actual conditions.

Light Texturing

The overhead and the deck surface floodlights generated a much smoother graduated illumination spot on the flight deck than the simulator's model. The shipboard installation had no visible rings of differing intensities as seen in appendix a, figure 14. While the pilots were not adversely effected by the "fried egg" appearance of the simulator modeled illuminated flight deck, they found the simulator model "cartoonish" in comparison to the actual installation.

Ambient Lighting

Pilots commented on the brighter ambient lighting under actual conditions, even under the very dark nights. The general flight deck environment, when viewed through the NVG, was brighter than that in the simulator, given the same level of brightness in the unaided flight deck scenes. Under NVGs, a greater distinction in brightness between the night sky and the water was noted, as well as greater contrast between the ship and the background environment. This increased brightness permitted greater use of cues during the approach to the ship, decreasing the pilot workload during shipboard approaches.

SIMULATOR MODEL CHANGES

Following the flight test, pilots reaffirmed their comments concerning simulator deficiencies when flown in the simulator. Several changes were made to the lighting model to eliminate the identified deficiencies.

VLA Intensity Settings

During the flight test, an attempt was made to determine the intensities for permanent settings to be modeled in the simulator. However, not one set of intensities for the lights was determined. Relative intensities were determined, and the following changes were made. A low intensity level of two was chosen for the white and red lights, and a level of five was chosen for the overhead flood lights and four for the deck edge lights. The disproportionate light fading intensities and the light intensity adjustments are addressed in the following paragraphs.

Light Intensity Adjustments

Light tables were developed to permit the intensity adjustments of the same group of lights as on the ship. This change will prevent the designer from setting different intensity levels for lights in the same group and necessitates only one level intensity change for the entire group of lights. Adjustments to the light intensity levels were made during the aircraft's approach for landing. In the simulator, this would require like adjustments to be made. However, in the present IG layout, light intensity levels may be made only by reprocessing the scene, thus interrupting the approach. The simulator modeler should be able to provide a similar rheostat function to allow the simulator operator to act as the Helicopter Control Officer (HCO) in adjustment of lights during aircraft approach phase. Future image generators should be designed to allow the real time adjustment of light characteristics.

Light Fading

The fading characteristics of all lights were adjusted to more accurately reflect the actual characteristics. The new fading characteristic settings for appendix A, figure 7 were A=304, B=608, and C=1,000 feet. The changes made to the original fading characteristics were made to make the simulator fading function look more like the laboratory conditions curve, for lack of numerical data from the ship. The final simulator curve differs from the actual (under laboratory conditions) to account for the simulator environment being dimmer than the real environment and for the affects of atmospheric conditions.

Light Color Composition

The greater NVG incompatibility of the deck surface floodlights than the overhead floodlights, identified by during the flight tests, may have been due to the inaccurate modeling of the light color, as well as the differing intensity levels. Because no correlation exists between an actual light frequency and the simulator modeling color levels, the determination of color was purely subjective.

Determined by comparison of ship photographs and by pilot input. Changes were not made to the simulator model to reflect the flight test findings because of a future effort to develop the correlation between light frequency and simulator color levels.

Light Texturing

Two solutions were proposed to provide a more realistic depiction of the flight deck illumination. The first was to remove the smaller concentric rings and to model the remaining ring as a curved surface. This may result in the flight deck appearing to have potholes or mounds. The second option was to photograph a similar light dispersion and enter that photo into the IG database. This could then be applied as a texture. Neither of these solutions have been implemented and should be investigated.

Ambient Lighting

Several attempts were made to increase the brightness of the NVG scene without excessive increase in the unaided scene brightness. These attempts included changing the angle of the light source (sun and moon) and increasing the percentage of overall scene illumination (more sun). These options did not provide satisfactory results. Achieving the same level of brightness under the use of NVGs resulted in the visual scene being to bright without the use of NVGs. This may be attributed to the lack of infrared light sources. A point infrared light source modeled to simulate starlight may provide the answer. Additional cuing on the horizon, such as city lights and ships, provided additional horizon cues.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

As flight test budgets and availability of material resources decrease, more efficient modes of testing are essential. This development of a simulator to model one of the fastest growing mission areas begins to fulfill this goal. The simulator model of the VLA package aboard the USS DULUTH was found to adequately represent the actual ship configuration. Several deficiencies were noted. Action was taken to correct those deficiencies. Relative lighting intensities between the various lighting groups were identified. Deficiencies were noted in the simulator fading and texturing characteristics. The disparity between actual ship and simulator scene illumination was also identified. While action was taken to correct the fading lighting intensity deficiencies, the scene illumination and texturing deficiencies were not corrected in the simulator model. Potential solutions, however, have been identified.

With the development of this simulator model, future shipboard lighting configurations and flight deck design will be significantly enhanced.

RECOMMENDATIONS

Correction of Deficiencies

This lighting package model will be significantly enhanced if the texturing and scene illumination deficiencies are corrected. The texturing deficiency may be corrected by either using the curved surface texturing function available in the IG or to texture with an actual photograph entered into the database. The low scene illumination in the simulator may be corrected by developing point light sources of infrared frequencies to model starlight. The simulator operator must have the capability to simulate the functions of the HCO. This would include allowing adjustments of the light intensities during a flight maneuver.

Future Action

Light Frequency Correlation

The modeling of the light color will be significantly enhanced by developing a set of light frequencies that correlate to the simulator's color coding function. This will allow the accurate assignment of colors without the subjective comparisons presently made. Because ship light packages are standard and the light frequencies are known. It is possible to measure the frequency of the light emitted from the simulator visual screen and correlate that to the level and combination of light colors modeled. After completion of this table, light color modeling will be a much quicker and more accurate process.

Aircraft Windshield Transmissivity

This simulator model does not account for aircraft windshield transmissivity. The windshield transmissivity changes the levels of light entering the aircraft cockpit and subsequently the NVGs. Because the transmissivity characteristics vary from aircraft type to type, different models will need to be made. The effect of windshield transmissivity may decrease with future aircraft designs as windshields will be manufactured to optimal characteristics. However, with the aircraft life span of forty years, windshield transmissivity will remain a factor.

Distributive Interactive Simulation Network

Distributive Interactive Simulation (DIS) networks allow two or more simulators to be electronically linked together allowing simulators at different geographical sites to operate using the same visual model. The effects of the maneuvers performed in one aircraft, ship, tank, or other vehicle will be seen and responded to by the operator in a remote simulator. The use of DIS networks would allow the HCO to operate a simulated flight deck envrionment with the night vision goggle equipped pilot. In that scenario, the HCO would be able to provide real time control of flight deck light levels, thus solving the noted discrepancy of the present IG configuration. As DIS networks grow and become more essential in training and test and development environments, it will be essential that all simulators have similar visual capabilities. Thus a standard for NVG simulation must be created from which each simulator modeler may work.

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APPENDIX A. FIGURES

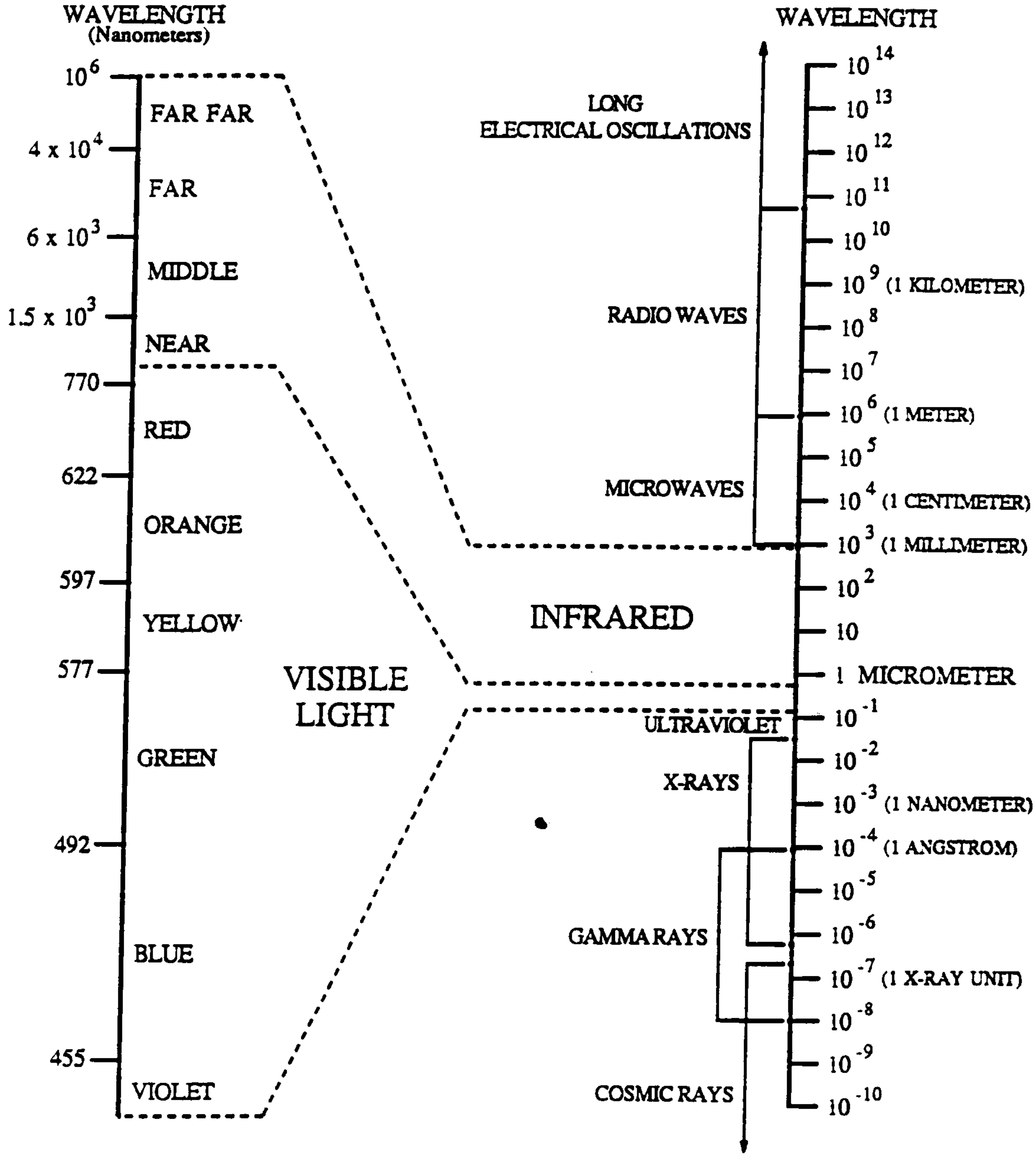

Figure 1. Electromagnetic Spectrum

Source: Tactics Guide TZ 1031-03-93 for A-6E Night Attack (1993), China Lake: Air Test and Evaluation Squadron Five

Figure 2. Night Vision Goggle (AN/AVS-6) Aided Scene

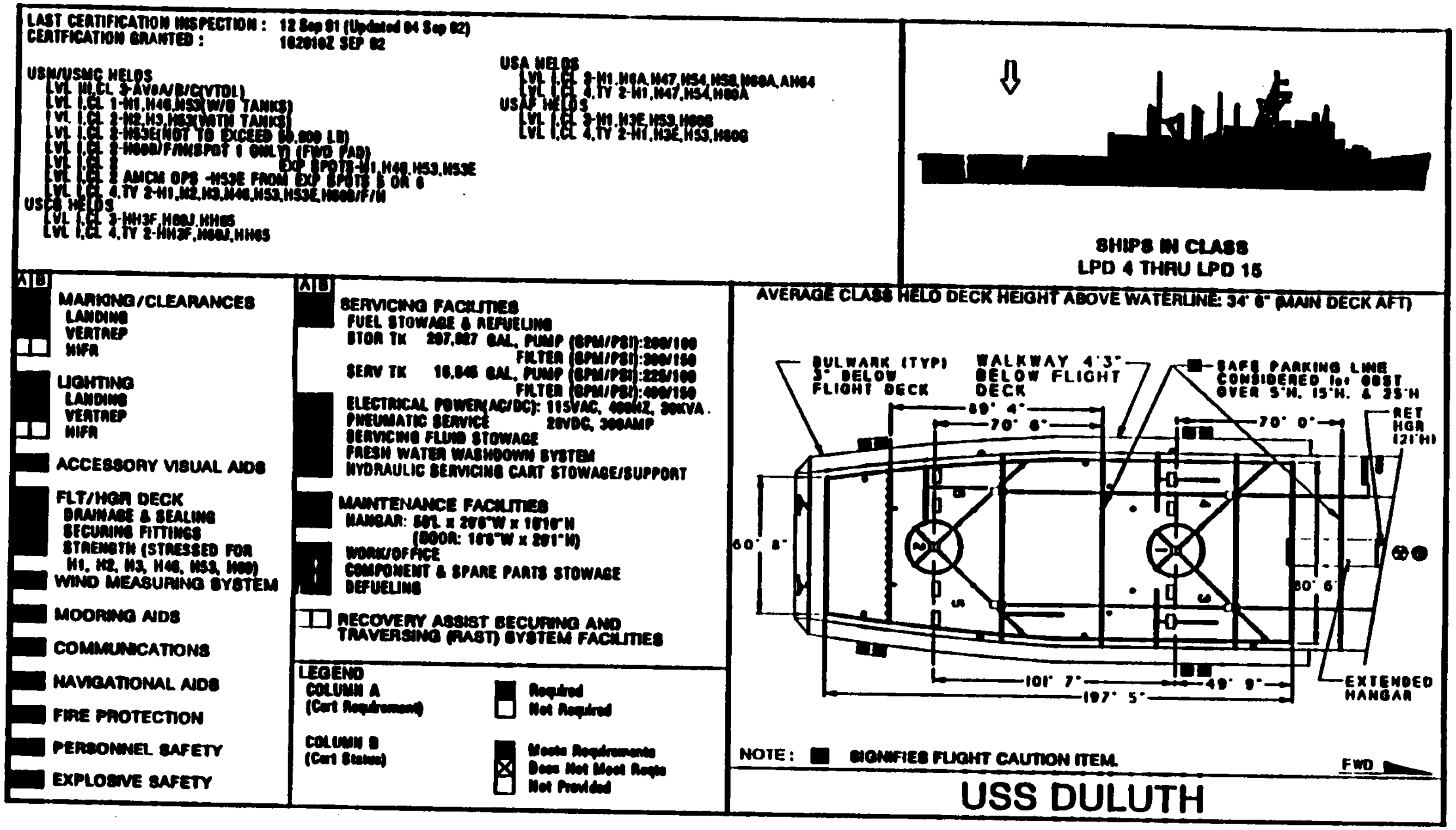

Figure 3. LPD 6 Flight Deck and Aviation Facilities

Source: Shipboard Aviation Facities Resume (1993), Lakehurst: Naval Air Warfare Center Aircraft Division

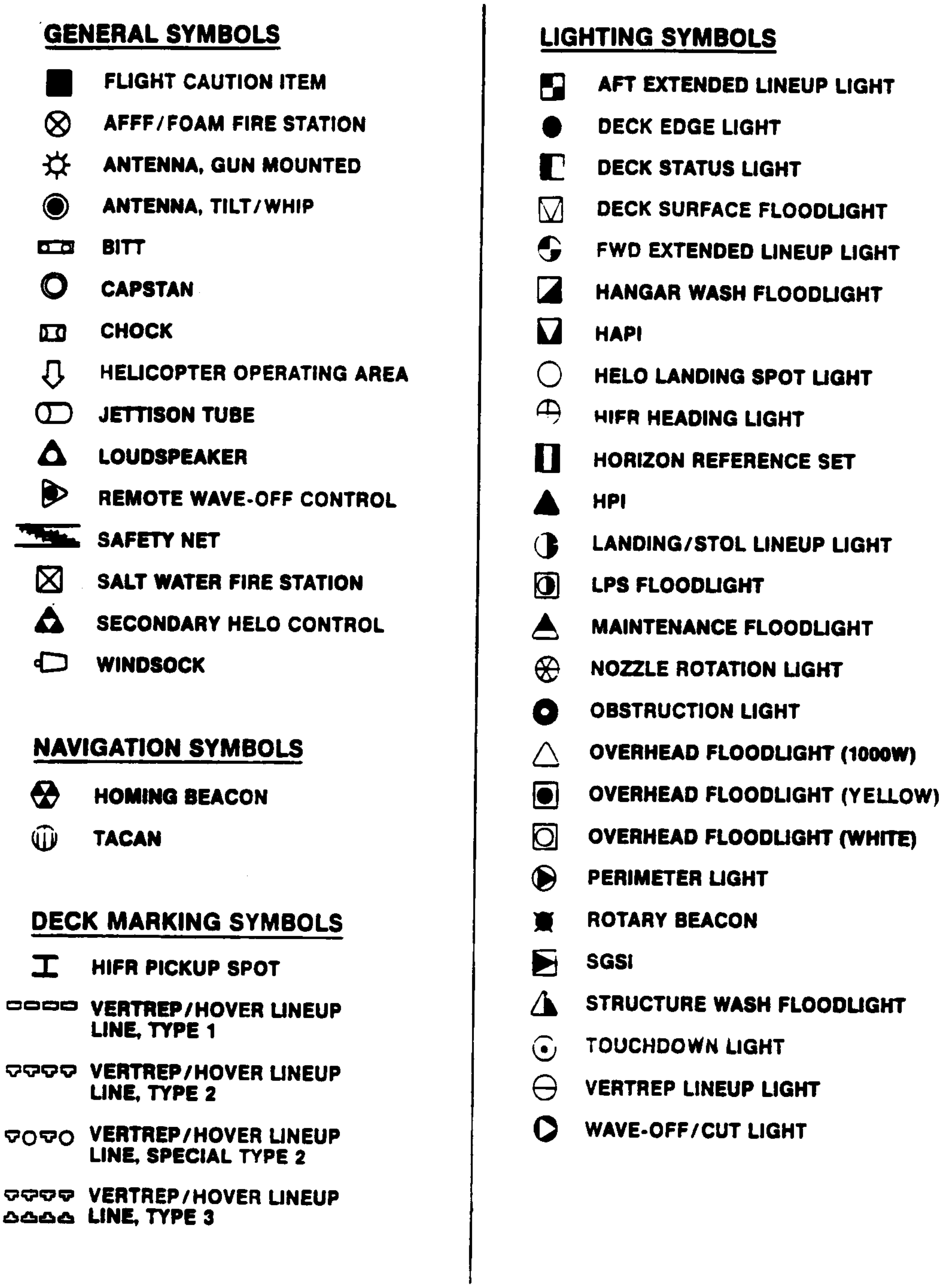

Figure 4. List of Symbols

Source: <u>Shipboard Aviation Facities Resume</u> (1993), Lakehurst: Naval Air Warfare Center Aircraft Division

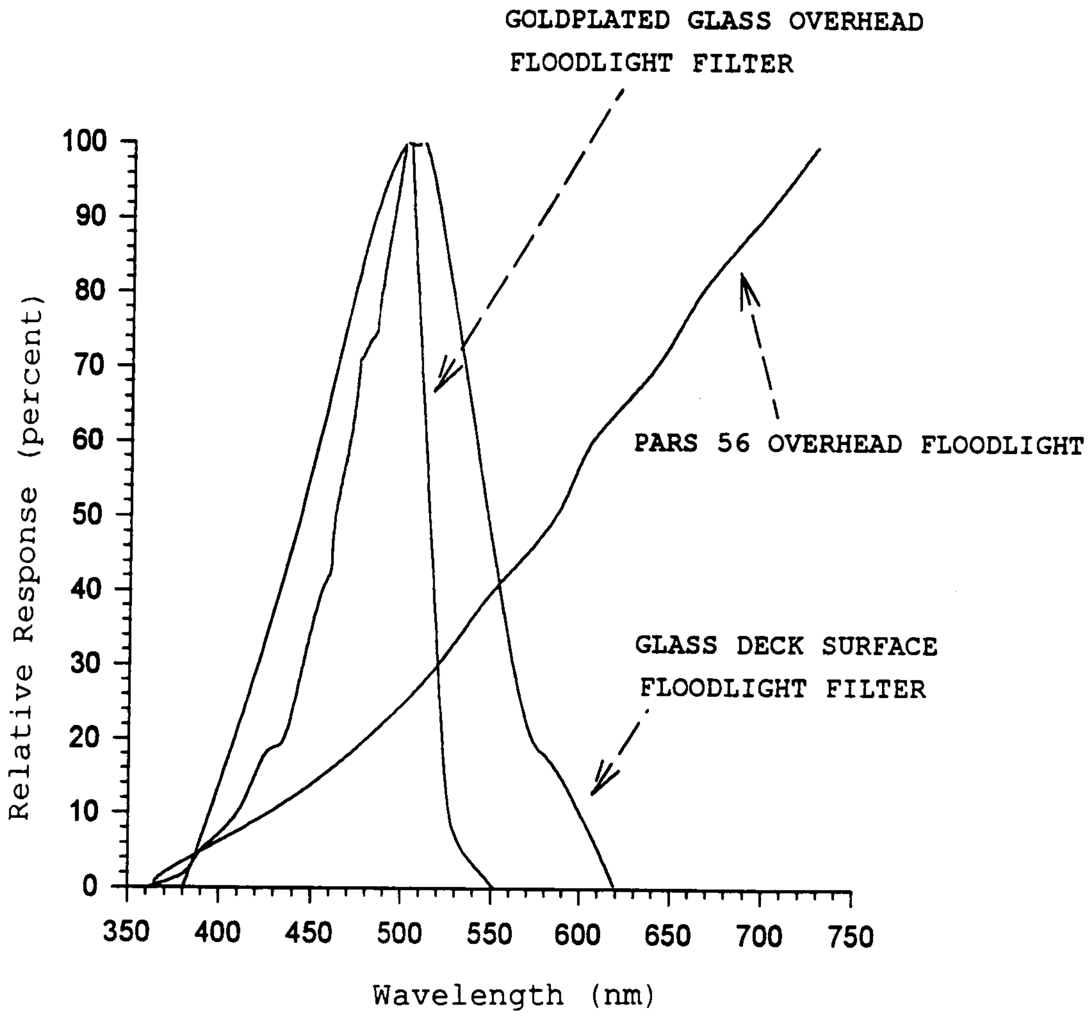

Figure 5. Spectral Properties of PAR 56 Overhead Floodlight, Goldplated Glass Overhead Floodlight Filter and Glass Deck Surface Floodlight Filter

Source: Photo Research, Kollmorgen Corporation, 1987

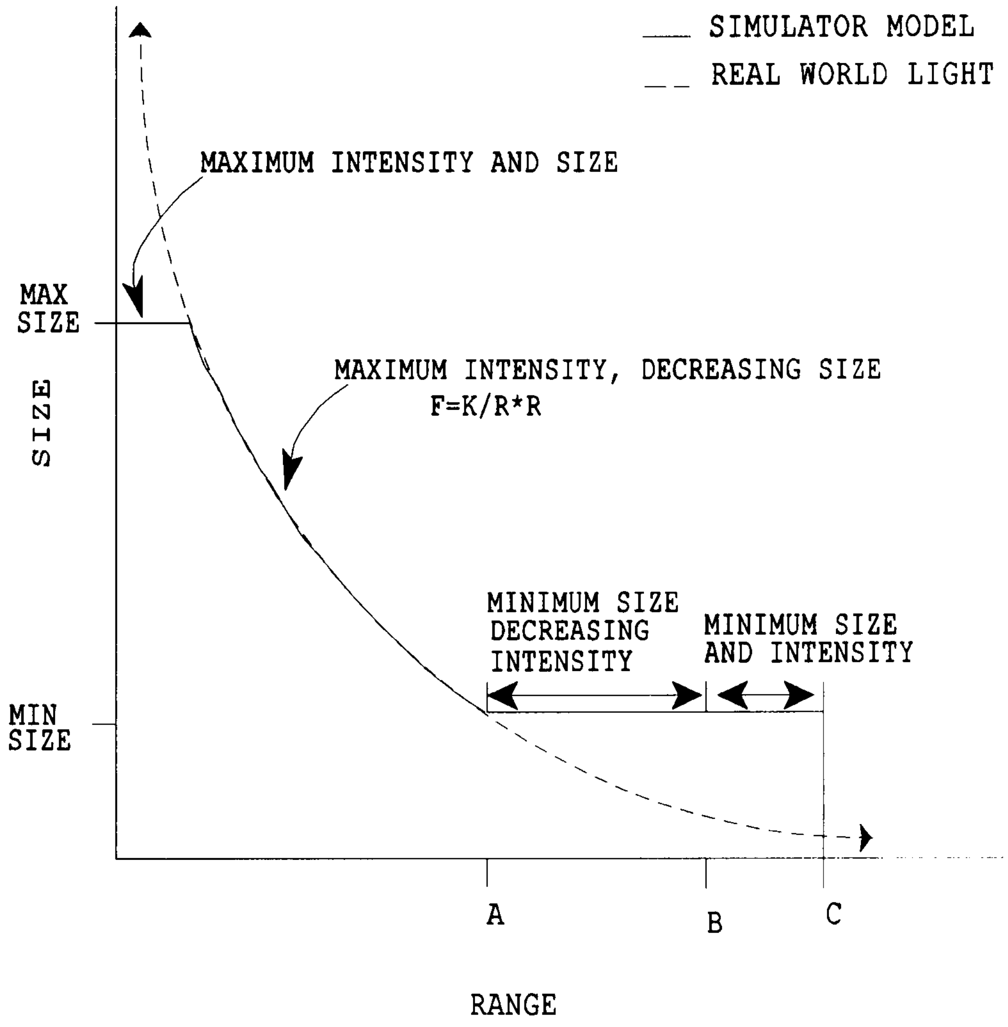

Figure 6. Representation of Point Light Sizes in Night Scene

Adapted From: Young, Kenyon, Elias, <u>Fundamentals of Flight Simulation</u>, Boston: Massachusetts Institute of Technology, 1987.

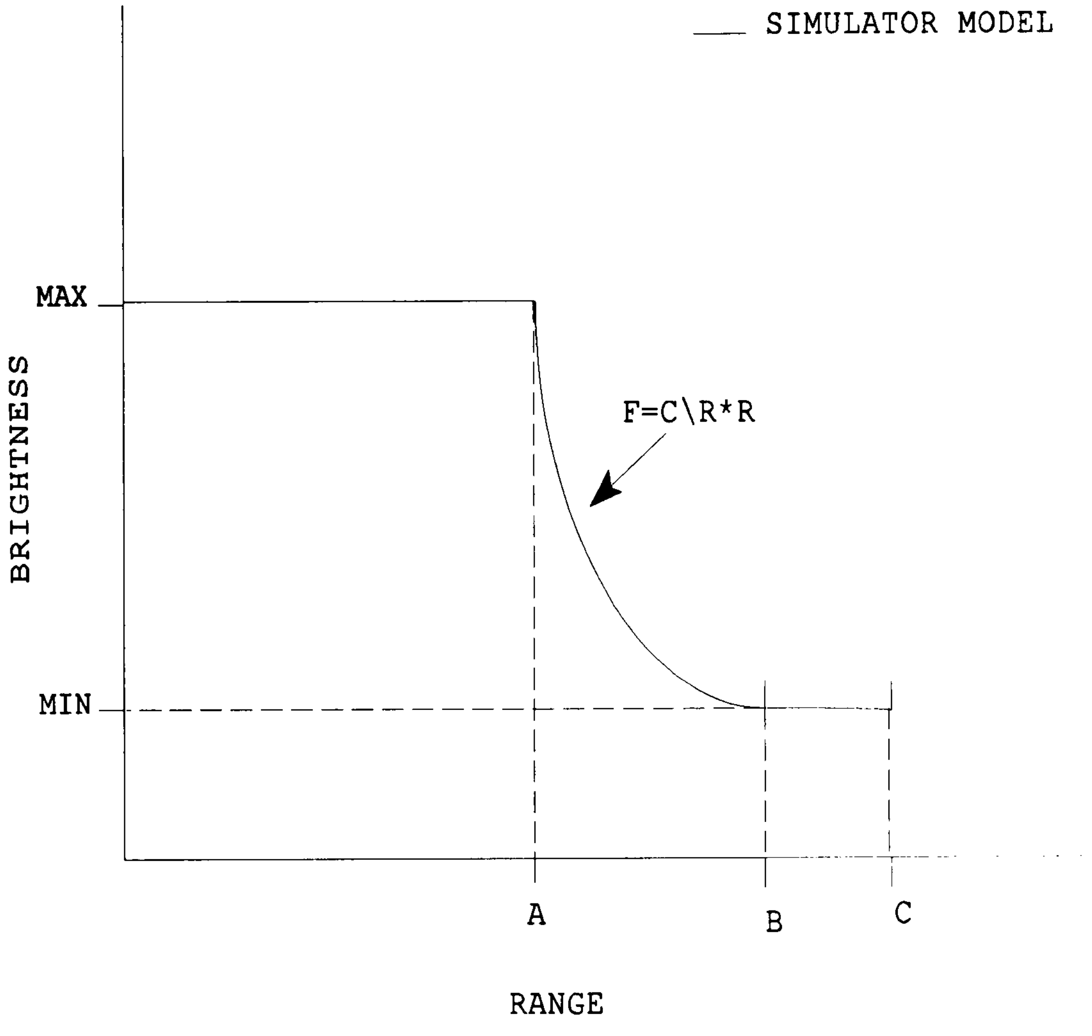

Figure 7. Manned Flight Simulator Light Model Brightness Attenuation

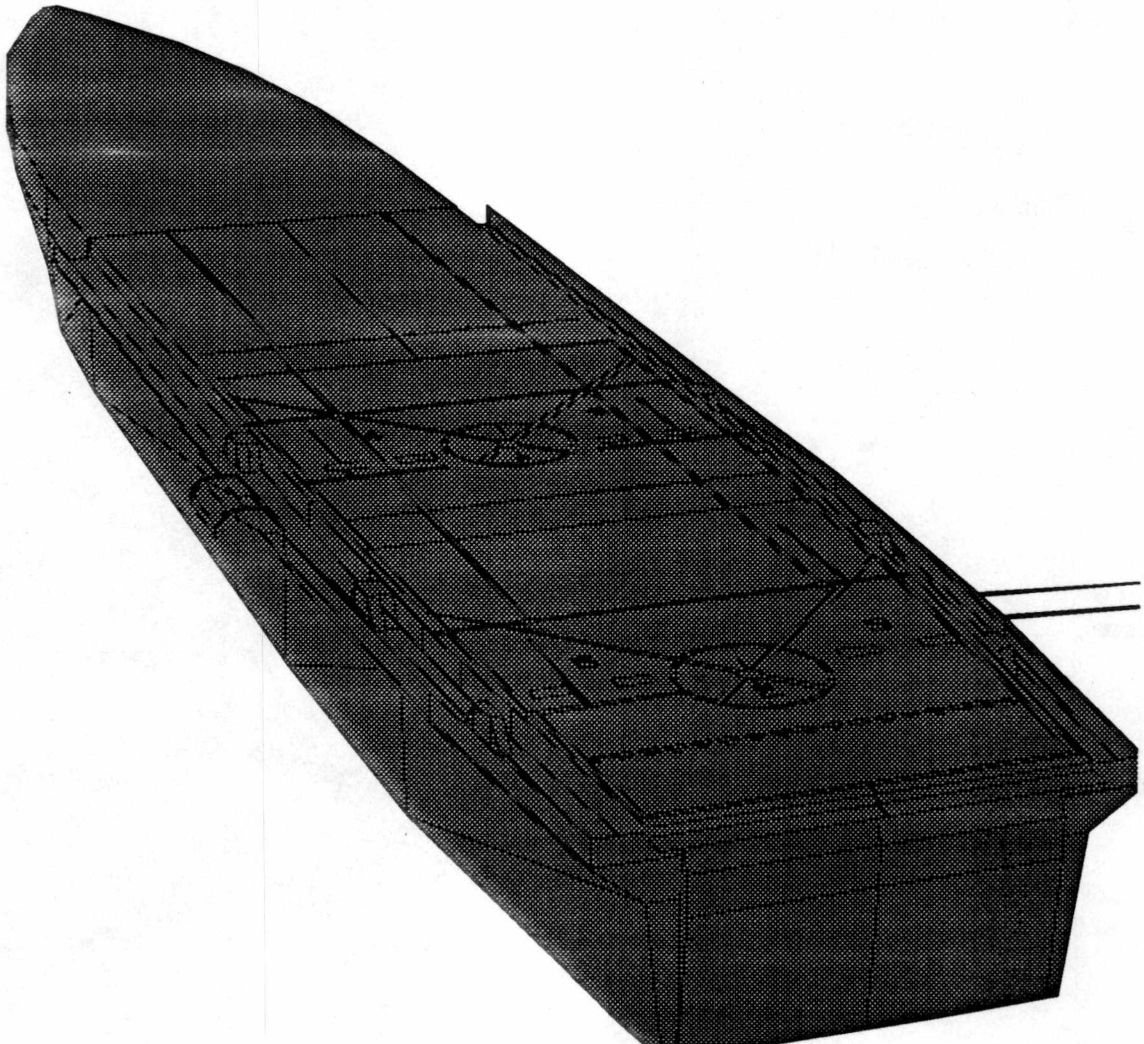

Figure 8. Manned Flight Simulator LPD-6 Hull Model

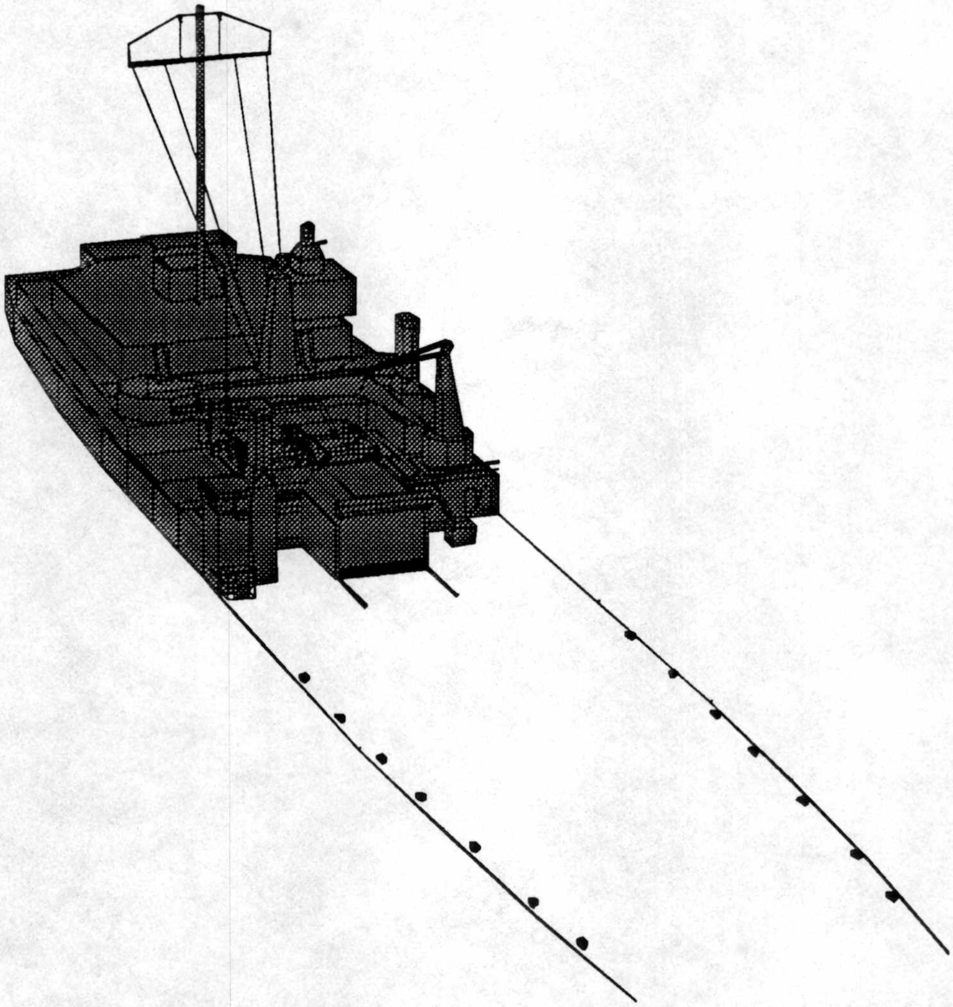

Figure 9. Manned Flight Simulator LPD-6 Superstructure Model

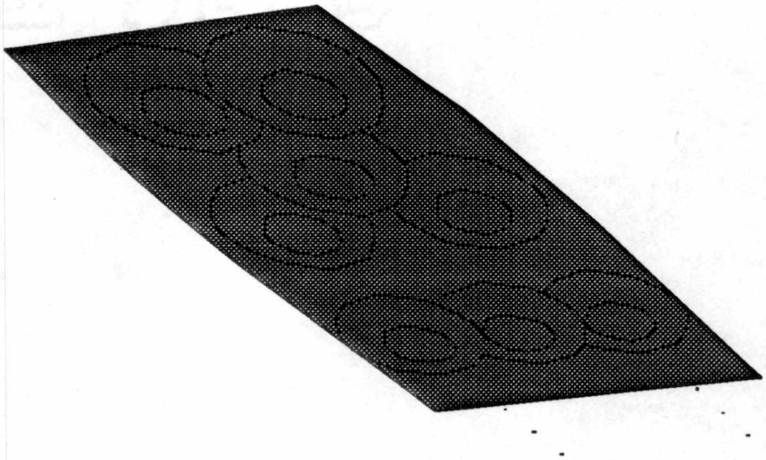

Figure 10. Manned Flight Simulator Light Model, Page 1

Figure 11. Manned Flight Simulator Light Model, Page 2

Figure 12. Manned Flight Simulator Light Model, Page 3

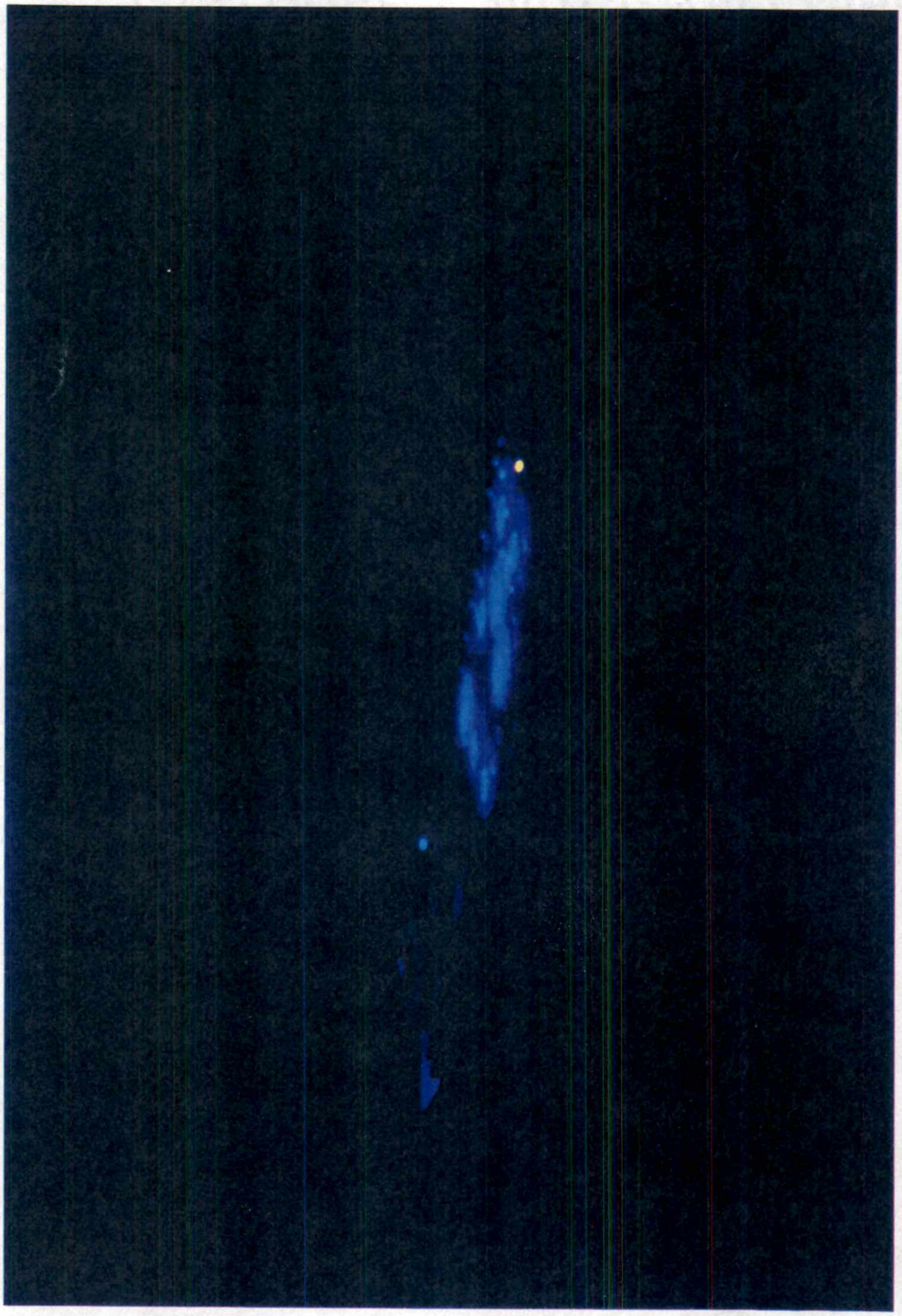

Figure 13. Photograph of Manned Flight Simulator LPD-6 Model, Night, Unaided

Figure 14. Photograph of Manned Flight Simulator LPD-6 Model, Night, AN/AVS-6

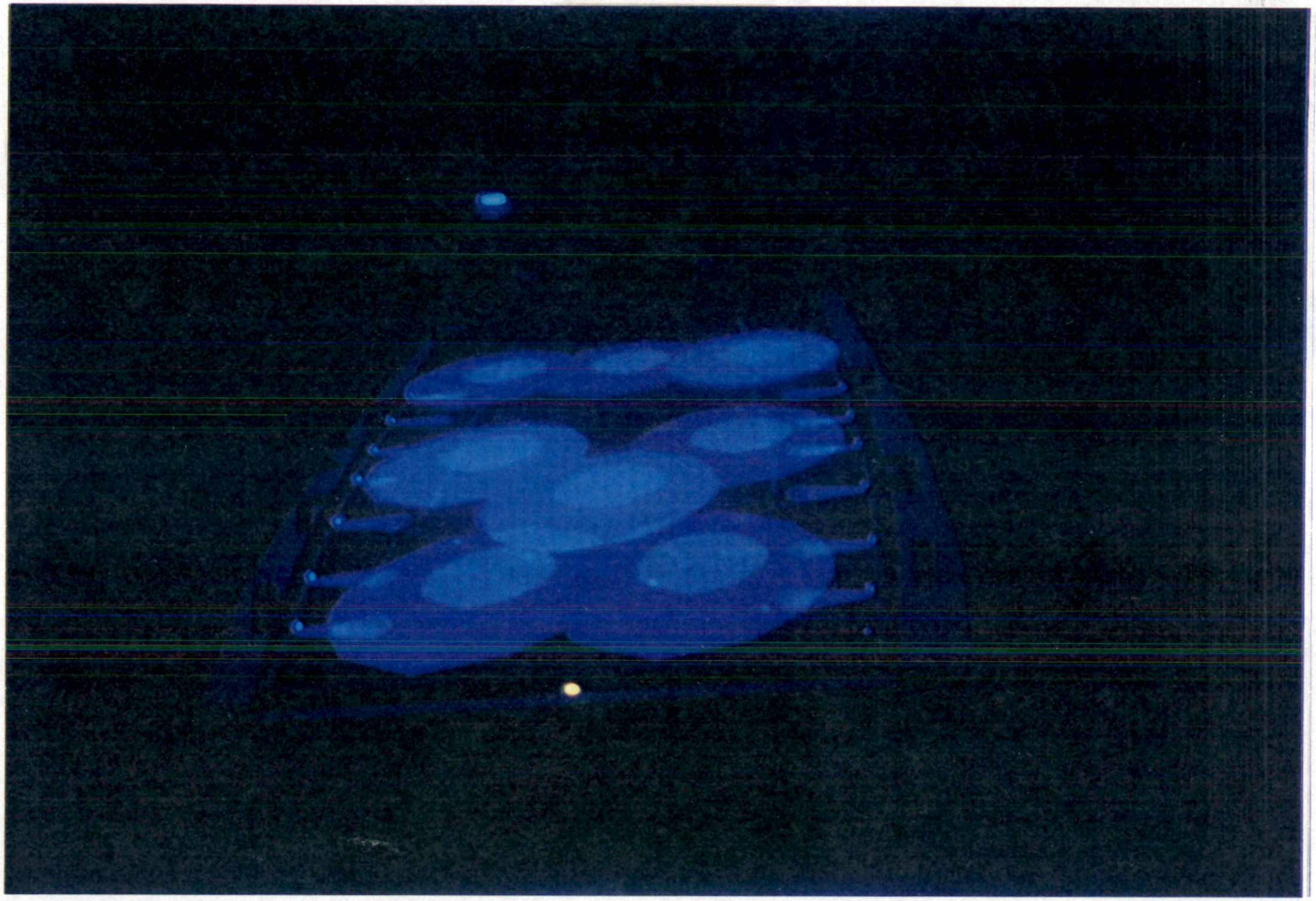

Figure 15. Photograph of Manned Flight Simulator LPD-6 Model Flight Deck, Night, Unaided

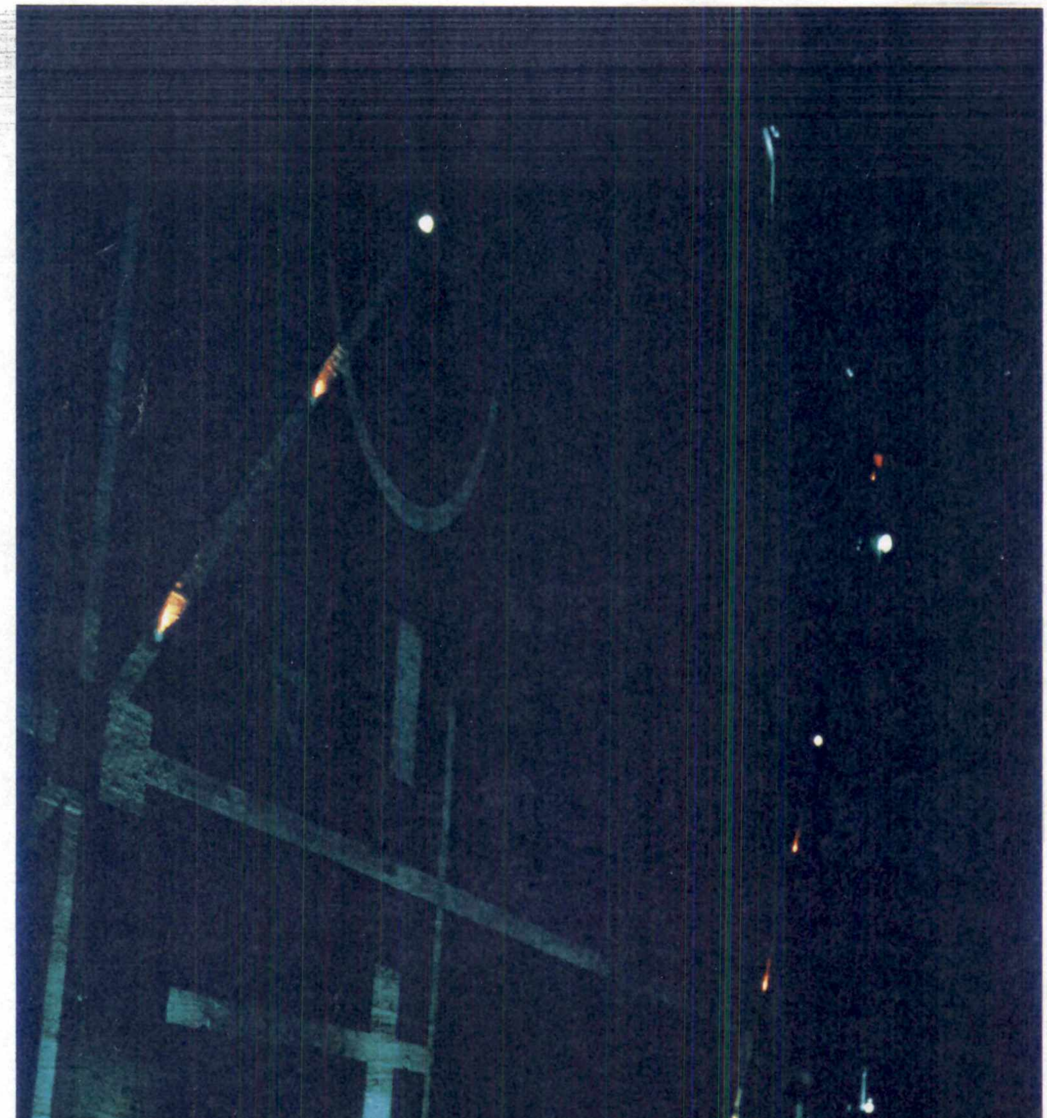

Figure 16. Photograph of USS DULUTH (LPD-6), Night, Unaided

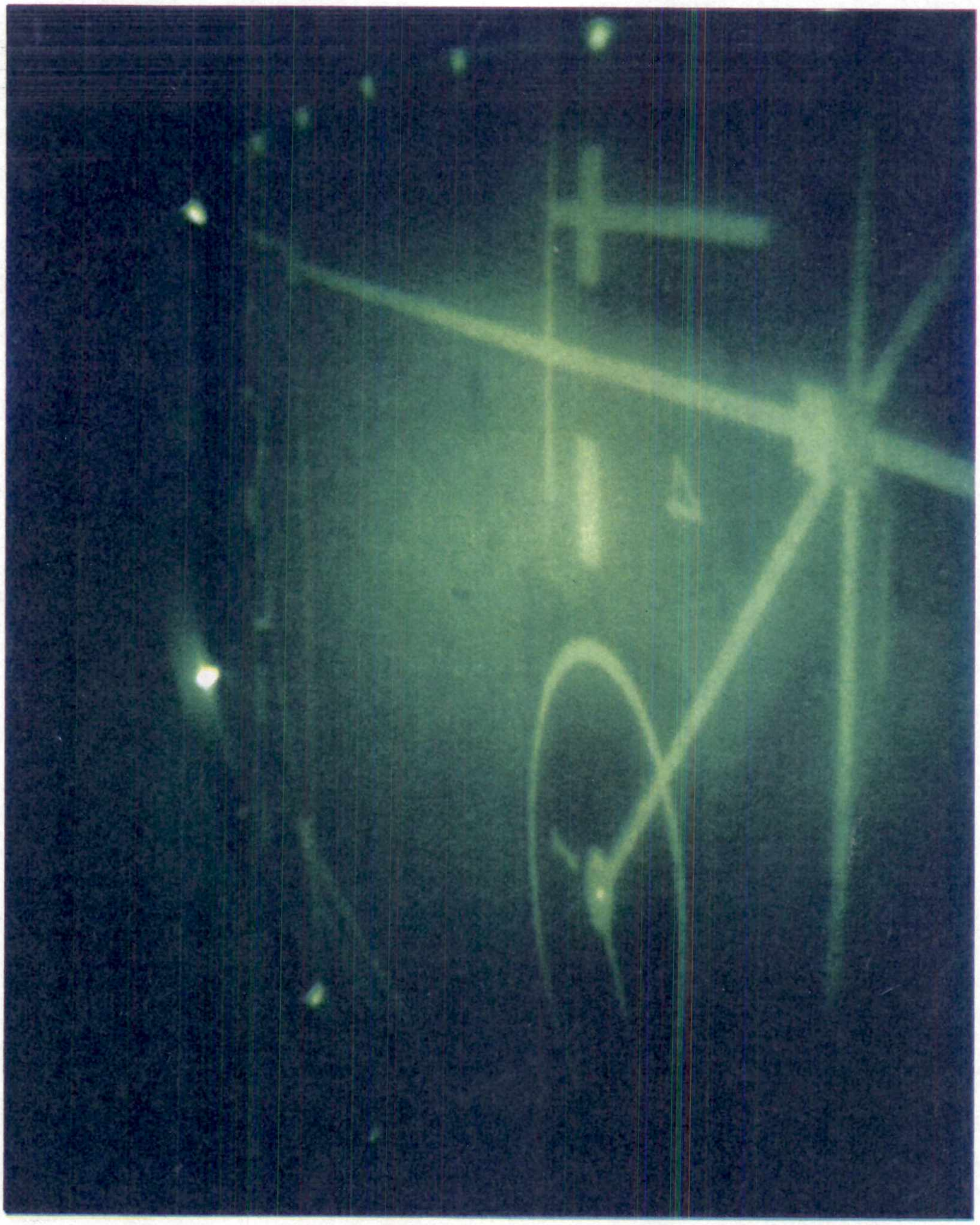

Figure 17. Photograph of USS DULUTH (LPD-6), Night, AN/AVS-6

APPENDIX B. TABLES

TABLE 1. COMPARISON OF NIGHT VISION GOGGLES

Adapted From: HMX-1 Evaluation Report, AN/PVS-5A and AN/AVS-6 Comparison (1987), Quantico: Marine Helicopter Squadron One

CHARACTERISTIC	AN/PVS-5A (GEN II)	AN/AVS-6 ANVIS (GEN III)
Intensifier Type	Generation II	Generation III
Gain	10,000	25,000
Objective	f/1.4	f/1.2
Magnification	1:1	1:1
Field of View	40°	40°
Focus Range/Position	10 inches to infinity	10 inches to infinity
Diopter Adjustment	+2 to -6	+2 to -6
Interpupillary Distance	55 to 72 mm	55 to 72 mm
Visual Acuity	20/60 (Artificial) 20/160 (Ambient)	20/40 (Artificial) 20/80 (Ambient)
Power	2.7 V (Lithium)	3.0 V (Lithium)
Life, Battery	10 hours	20 hours
Weight	30 oz	16 oz
Mounting	Head Straps	Helmet Mount

TABLE 2. SUMMARY OF LPD 4 CLASS VISUAL LANDING AID LIGHTING COMPONENTS

Adapted From: Long, Kurt, "CH-46E, UH-1N, CH-53E, SH-60 Dynamic Interface Aboard USS DULUTH (LPD 6) Test Plan," Patuxent River: Naval Air Warfare Center, Aircraft Division, 1993.

COMPONENT	DESCRIPTION/USE
Deck Edge Lights	23 red lamps, flush mounted along flight deck peripheral line; used to define edge of flight operations area.
Lineup Lights	32 strobing white lamps, mounted flush with deck in 8-light strings along each approach line; used to provide lineup cues during approach sequences.
Drop Line Lights[1]	20 steady red lamps, mounted on vertical bars along hull sides in 5 lamp strings immediately below aft edge of each approach lline; used to provide lineup cues during approach sequences.
Overhead Floodlights[1,2]	10 white and 10 blue lamps, mounted above HCS; used to illuminate flight deck area.
Deck Surface Floodlights[1,2]	16 blue dustpan lamps, mounted around deck periphery; used to illuminate flight deck area.
Deck Status Light	1 3-light (red, green, yellow) unit mounted on aft HCS face below HCS windows; indicates flight deck operational status
Stabilized Glide Slope Indicator (SGSI)	1 gyrostabilized 3-color Fresnel lens light unit, mounted on HCS roof; used to provide approach glide slope cues.

COMPONENT	DESCRIPTION/USE
HCS Interior Lights[2]	2 or more NVD-compatible green EL strips, applied to inside roof and HCS walls; provide overall HCS interior illumination.
Well Deck Lighting[2]	8 blue and 12 white overhead floodlights' provide illumination of inside aft end of well deck.
Waveoff Lights	2 red lamps (1 mounted to each side of GSI); used by HCO to signal aborted approach/recovery sequences.
Obstruction Lights	2 blue lamps, mounted on outboard corners of aft superstructure; define outermost obstructions to aircraft on/around the flight deck.
Navigation Lights	1 red lamp mounted on hull port side and 1 green lamp mounted on hull starboard side; assist other ships determine course and heading.
Stern Maneuvering/ Navigation Light	1 white lamp, mounted on hull aft end; used to determine ship heading.
Mast Maneuvering/ Man Overboard Lights	Red/White lights located on masts.
Homing Beacon	White, strobing lamp located on ship's mast.

Notes:
1. ACS SVC 17 VLA lighting component.
2. NVD-Compatible lighting component.

TABLE 3. WIDE II PERFORMANCE CAPABILITIES

Adapted From: WIDE II Visual Display System Detailed Specification.

CAPABILITY	DESCRIPTION
Field of View	160° horizontal by 40° vertical, vertical field distribution is -25° to +15°.
Viewing Volume	Non-pupil Forming. Consists of a solid shaped volume that encompasses both the pilot's and co-pilots eyepoints. Any movement within the viewing volume will not result in any significant image.
Collimation	The observe image distance of the display exceeds 10 meters (based on 67 mm interocular distance)>
Brightness	Minimum of 4 foot-lamberts highlight brightness.
Contrast Ratio	Minimum of 20:1
Brightness Variation	Brightness variation across each channel of display is less than 50% within a circle of diameter equal to the picture width, and less than 60% outside this circle. Brightness variation across the joins of adjacent channels within ±3° of the join center is within 10%.
Geometry	Geometric distortion is less than 2% of picture height within a circle of diameter equal to 80% of picture height within a circle of diameter equal to 80% of picture height for each channel, and less than 4% anywhere else within the FOV.
Resolution	10 arc minutes/cycle in zone equal to 80% of picture height; 15 arc minutes/cycle outside this zone.
Color Convergence	2 arc minutes within a zone equal to 80% of picture height; 4 arc minutes outside this zone.

TABLE 4. COLOR VALUES OF LIGHT MODELS

COMPONENT	COLOR VALUES		
	RED (0-256)	GREEN (0-256)	BLUE (0-256)
Deck Edge Lights	200	0	0
Lineup Lights	255	255	255
Drop Line Lights	255	255	255
Overhead Floodlights	0	0	255
Deck Surface Floodlights	0	0	200
Deck Status Light, Red	255	0	0
Green	0	255	0
Yellow	255	255	0
Waveoff Lights	255	0	0
Obstruction Lights	0	0	200
Stern Maneuvering Light	255	255	255
Mast Maneuvering Lights	255	0	0
Man Overboard Lights	255	255	255
Homing Beacon	255	255	255

VITA

Allison Dee Webster-Giddings was born in Royal Oak, Michigan on June 19, 1962, to Robert Byron and Marilyn Dee Hey Webster. She graduated from Wylie E. Groves High School in Birmingham Michigan in May, 1980. The following July, she entered the United States Naval Academy, Annapolis, Maryland and in May, 1984, graduated receiving a degree of Bachelor of Science in Naval Architecture and an Officer's Commission in the United States Navy. The following October, she entered Naval Flight School in Pensacola, Florida and in January, 1986, graduated as an unrestricted aviator (rotorcraft pilot). In July 1991, she entered the United States Naval Test Pilot School, Patuxent River, Maryland and graduated in June, 1992.

She is presently employed as a test pilot and as the Dynamic Interface Department Head for the Rotary Wing Aircraft Test Directorate, Naval Air Warfare Center, Aircraft Division, Patuxent River, Maryland. She is married to Gavin John Giddings of Lusby, Maryland.