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INTEGRATION OF EXTERIOR LIGHTING SYSTEMS AND NIGHT VISION IMAGING SYSTEMS

by

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Systems Engineering Test Directorate

3 June 1992

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DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND 20670-5304

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This Technical Memorandum documents the development of test procedures for the evaluation of exterior lighting systems. These test procedures were required to support the A-12 program and future exterior lighting integration requirements associated with the integration of Night Vision Imaging Systems for Navy aircraft. Military Standards associated with exterior lighting are not up to date with current fleet requirements leading to the development and recommendations of technical information presented in this memorandum.

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The use of Night Vision Imaging Systems (NVIS) by military aviators has had a major impact on the design and integration philosophy of interior and exterior lighting systems. The integration of NVIS exterior lighting systems to meet the associated mission requirements is in the early stages of development. Operational performance and military specification requirements have not been updated and established. This technical memorandum presents information and lessons learned from development, test, and evaluation (DT&E) support of the A-12 program and development of test procedures to evaluate exterior lighting systems. During the DT&E support of the A-12 program, major exterior lighting issues had to be resolved. This evolution generated experience associated with exterior lighting and NVIS performance requirements. The information presented is not all inclusive but contains information to be used for updating exterior lighting Military Specifications requirements and test procedures. The additional integration requirements and design considerations will improve the utility of NVIS thus improving aircraft combat survivability and performance for various mission requirements.

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SUMMARY

The use of Night Vision Imaging Systems (NVIS) by military aviators has had a major impact on the design and integration philosophy of interior and exterior lighting systems. The integration of NVIS exterior lighting systems to meet the associated mission requirements is in the early stages of development. Operational performance and military specification requirements have not been updated and established. This technical memorandum presents information and lessons learned from development, test, and evaluation (DT&E) support of the A-12 program and development of test procedures to evaluate exterior lighting systems. During the DT&E support of the A-12 program, major exterior lighting issues had to be resolved. This evolution generated experience associated with exterior lighting and NVIS performance requirements. The information presented is not all inclusive but contains information to be used for updating exterior lighting Military Specifications requirements and test procedures. The additional integration requirements and design considerations will improve the utility of NVIS thus improving aircraft combat survivability and performance for various mission requirements.

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INTRODUCTION

BACKGROUND

1. The increasing use of Night Vision Imaging Systems (NVIS), appendix A, and airframe change requirements associated with low observable aircraft generated several unanswered questions about the integration of exterior lighting systems. During the Research, Development, Test, and Evaluation (RDT&E) of the A-12 and other NVIS compatibility evaluations, it became apparent that exterior lighting integration has not been updated to meet current operational mission and training requirements. Several years of engineering research established NVIS compatibility requirements for cockpit/interior lighting, MIL-L-85762A (Lighting, Aircraft, Interior, NVIS Compatible), but NVIS exterior lighting requirements and associated military specifications have not been established. NVIS is a night visual "aid" device that has some limitations. It has limited field of view, half the resolution of the eye, appendix A, and cannot discern color differences. On the other hand, NVIS responds to wavelengths outside the visible spectrum (600 to 930 nm) and provides "light amplification" of approximately 2000X. Exterior lighting integration philosophy is dependent on the characteristics of NVIS and specific aircraft mission requirements.

PURPOSE

2. This technical memorandum presents information and lessons learned gathered from DT&E support of the A-12 program, development of test procedures, and technical research associated with the integration of exterior lighting systems. The information is not all inclusive but contains technical information to be used for updating exterior lighting military specifications requirements and test procedures.

RESULTS AND DISCUSSION

GENERAL

3. With the experience and information gained from the A-12, AV-8B program studies, and the Marine Aviation Weapons and Tactical Squadron One Helicopter Night Vision Goggle (NVG) Manual, the following will discuss techniques used during the initial RDT&E phase and operational aspects to consider for the integration or modification of exterior lighting systems. The following issues should be considered and incorporated into current Military Specifications.

SPECIFICATIONS AND REQUIREMENTS

4. Current exterior lighting specifications and requirements must be updated. NVIS or low observable requirements have not eliminated current exterior lighting requirements, but will add to the operational considerations associated with training, safety, and mission requirements. The primary exterior lighting specification is Military Specification MIL-L-006730C (Lighting Equipment: Exterior Aircraft, General Requirements for, of 14 May 1971). Current exterior lighting military specifications can be used as a guideline and basis for establishing NVIS coverage and intensity control requirements. The following is a list of additional military specifications and Federal Aviation Regulations (FAR) documents that are available and used as guidelines to develop test procedures during the A-12 exterior lighting mockup evaluations:

a. MIL-L-21652A, Light Beacon, Anti-Collision, Aircraft, of 1 Jul 1983.

b. MIL-A-19736A, Air Refueling Systems, General Specifications for, of 16 Mar 1966.

c. MIL-F-26301D, Flasher, Aircraft Navigation Light, of 5 Oct 1973.

d. MIL-L-6503H, Lighting Equipment, Aircraft, General Specification for Installation of, of 2 Apr 1975.

e. AFGS-87240A, Airforce Guide Specification, Lighting Equipment, Airborne, Interior and Exterior, of 31 Dec 1987.

f. MIL-L-85314/2, Lighting Systems, Small Supersonic and Small Subsonic Aircraft, Anti-Collision, Strobe, Red and White Mode, Wing, Fuselage, Vertical Stabilizer Mounted, of 27 Dec 1982.

g. SAE AS 8037, The Engineering Resource for Advancing Mobility, Aerospace Standard for Aircraft Position Lights, Issued Jan 1986.

h. FAR 25, Code of Federal Regulations, Revision of 1 Jan 1986.

i. AC 20-30B, Department of Transportation, Advisory Circular, Aircraft Position Light and Anticollision Light Installations, of 20 Jul 1981.

j. AC 20-74, Department of Transportation, Advisory Circular, Aircraft Position Light and Anticollision Light Measurements, of 29 Jul 1971.

5. Presented in appendix B is the procedures document developed and used to evaluate the exterior lighting mockup for the A-12 program.

SIMULATION/SCALE MODELING

6. During the DT&E phase, a three-dimensional computer aided graphical representation and/or a scale model of the aircraft was very useful in deciding the placement of position lights, anticollision lights, and formation lights and the associated ON/OFF control requirements. Additionally, scale models or computer aided models can be easily reconfigured and are very useful in showing the initial proof of concept.

NVIS EXTERIOR LIGHTING

7. Exterior lighting systems performance requirement must expand beyond the visual spectrum into the NVIS response region of the electromagnetic spectrum (appendix A). It is undesirable for exterior lighting to radiate excessive electromagnetic energy in the visible and NR range during critical mission phases. It is necessary to be passive or nonradiating to limit enemy sensor detection. Additionally, excessive NR energy from a wingman or own aircraft exterior lighting system will limit the full utility of NVIS. NVIS, as discussed in appendix A, is designed to convert low levels of NR energy at night into a visual scene to assist the aircrew in performing the mission. The full utility of NVIS is dependent upon the quality of the NVIS exterior lighting sources. The primary objective is to provide exterior lighting that is mode selectable, visible or invisible to the naked eye, dependent upon the operational requirement, but compatible or nonoffensive to NVIS.

8. Visible position lights consisting of wing position and tail position lights should be inoperable in NVIS mode. An NR tail position light will be required to provide NVIS equipped wingman a visible target. It is not feasible to provide traditional wing position lights in the NVIS mode because of the limitations associated with NVIS. NVIS is a monochromatic system, and color coding cannot be used as a coding alternative. The existing requirement for NVIS viewable wingtip formation lights will provide wing position information without color coding in the NVIS mode.

9. Anticollision lights should be provided and mode selectable for day, night, and NVIS operations. The NVIS mode will require an intensity adjustment control to provide the flexibility for the various ambient lighting conditions. Additionally, the capability to turn off the bottom anticollision light separate from the top anticollision light should be provided. This will eliminate reflections from the ground at low altitudes and also limit enemy detection.

10. Formation lights should be dual mode, normal night, and NVIS viewable. Electroluminescent lighting is recommended that is mode selectable and adjustable in intensity. Specific control requirements are discussed in paragraph 17. The appropriate intensity in both modes is dependent upon the ambient lighting conditions and visual background.

PLACEMENT OF EXTERIOR LIGHTS

11. Coverage and visual recognition requirements of military specifications and FAR's drive the current placement of exterior lights. With the integration of NVIS and the associated compatibility requirements, additional consideration must be given to the placement of exterior lights. This is due to the requirement to minimize any unwanted electromagnetic energy from entering the cockpit, limiting the utility of NVIS and detection by enemy ground troops. The red port, green starboard, and white tail position lights and anticollision lights are of particular concern because they are high intensity lights that contain excessive amounts of NR energy that can disrupt the visual performance of NVIS and create a safety hazard. Aircraft exterior lighting also can affect other aircraft flying in formation. The location and the appropriate flexibility to control the intensity of these lights can improve these problems. The control of exterior lighting will be discussed in paragraphs 14 through 17.

12. The standard operating procedures used for formation flying with NVIS are different due to reduced field of view of NVIS. Flying more acute or further aft with respect to the lead aircraft, about 30 deg rather than 45 deg, is typically preferred. This technique reduces scanning required by the trail aircrew, allowing them to see the lead aircraft and obstacles in the flightpath. During the DT&E phase of a new aircraft, consideration should be given to current standard operating procedures used by NVIS equipped fleet squadrons. This will help in deciding the appropriate exterior lighting system configuration and operational flexibility required to optimize the utility of NVIS.

13. The location of position, formation, and anticollision lights are airframe dependent, but many operational considerations, performance, and coverage requirements are the same as those specified in current military specifications. Low observable aircraft present other problems associated with the visual appearance, surface shape restrictions, and the limited placement of exterior light

sources. Additionally, they have to meet the constraints associated with low observable aircraft and the requirements associated with FAR, training, and mission operational requirements.

EXTERIOR LIGHTING CONTROLS

14. Additional exterior lighting controls are required with the integration of NVIS to provide flexibility associated with the operational requirements, ambient lighting, and atmospheric conditions. These controls will allow the aircrew to turn on and off, adjust, and configure the exterior lighting system as necessary in the visible and NR spectrum.

15. The position lights should be mode selectable (normal and NVIS), as discussed in paragraph 8, and employ variable intensity control rather than a three position switch (Bright-Off-Dim) as specified in MIL-L-6730, paragraph 3.3.1.1. In the NVIS mode, the NR tail position light and formation lights will be the only lights operational. The intensity of the tail light and formation lights should be adjustable with a variable rheostat to provide flexibility required to meet the various operational requirements, ambient lighting, and atmospheric conditions.

16. The anticollision lights should be mode selectable (normal and NVIS) with additional capability to select the upper fuselage light only. Selection of the upper fuselage light only will eliminate ground return minimizing the possibility of vertigo and disorientation to the aircrew and also reduce threat detection. If feasible, the lighting technology applied to the NVIS mode of the anticollision light should permit variable intensity control of the light.

17. The formation lights should be mode selectable (normal and NVIS) with variable intensity control in both modes. Exterior lighting controls are an integral part to providing an integrated exterior lighting system that will provide the flexibility to meet FAR, training, mission requirements, and associated environmental conditions without requiring physical preflight modifications to the aircraft.

TEST PROCEDURES AND TECHNIQUES

18. The equipment, procedures, and techniques used to collect exterior lighting data are designed to be used on actual aircraft or full scale mockups, but may be used in the laboratory to evaluate individual components. The general approach to evaluating an exterior lighting system proposed for installation on an aircraft is first to collect engineering data from the manufacturer. Additionally request to witness laboratory testing by the manufacturer to verify the procedures used and how the procedures relate to the associated aircraft performance requirements. The engineering data should include the design and integration philosophy associated with the mission requirements of the aircraft, location and placement of the individual light sources in three-dimensional coordinates, scale drawings of the aircraft, three-dimensional coordinates of the exterior structure of the aircraft, light source types, lighting control integration, lighting intensity data, chromaticity, and angular coverage data. This data should be analyzed before the mockup or aircraft evaluation to stream line tests and to identify any potential problems before testing.

19. The data measured to determine the appropriate colors of specific light sources are referred to as chromaticity. The International Commission on illumination established the concept of the CIE color space and the identification of colors by chromaticity coordinates. Simply stated, chromaticity is the relative percentage of each primary color (red, green, blue) that generates a specific color. A practical instrument to use in field testing to measure chromaticity is a Minolta Chroma Meter (CS-100). The luminance/illuminance and chromaticity of nonflashing exterior lights are measured in a dark environment as specified in the Military Specifications. The measured chromaticity coordinates are compared to the required coordinates of the X and Y 1931 C.I.E. or u' and v' 1976 UCS chromaticity charts specified in Military Specifications. The chromaticity requirements or color of individual exterior lights (conventional) are specified by international standard requirements.

20. Light intensity and coverage should be measured with a device consisting of a monopod with a base to mount on the aircraft, an angle finder, and an illuminance meter. This device provides the capability to create an arc over a light source and position the illuminance meter in (angular) increments to collect the appropriate illuminance distribution data. This test confirms the validity of the contractor and laboratory data by comparing it to the extrapolated data. The combined polar plots of the individual light sources placed on a scale drawing of the aircraft will identify synergistic problems such as inadequate coverage, light distribution, illuminance, and physical obstructions reducing light coverage.

21. NVIS irradiance should be measured using the same positioning device used to measure the illuminance intensity and angular distribution. The illuminance meter used for measuring conventional lighting intensity distribution will be replaced with a barium sulfate 99.5% diffuse reflectance standard. The NVIS irradiance of a particular covert light source will be determined by measuring the NVIS radiance reflected by the reflectance standard. NVIS radiance of the reflectance standard may be determined by various methods. One method would employ a radiance meter with a spectral response equivalant to that of NVIS. Another method would employ a field portable spectroradiometer. With this method, the NVIS radiance of the reflectance standard would be determined by measuring the spectral radiance and multiplying by the spectral response curve of NVIS. Integration of the resulting spectral curve produces the value of NVIS radiance. NVIS radiance determined by either method must then have the distance equation applied to yield NVIS irradiance.

22. Light obstructed due to aircraft structures will be determined by geometric analysis or three-dimensional computerized graphical modeling of the aircraft and associated exterior lights. A three-dimensional computerized model can be created with a Silicon Graphics Computer or a computer aided design system. The utility of this test will be based on the availability of aircraft external structure data. A computer aided model provides a dynamic view of the aircraft to be evaluated qualitatively from critical visual angles. An alternative requiring a significant amount of manual labor is to use scale drawings of the aircraft external structure including the placement of the exterior lights. The procedure converts scale drawings of the aircraft (top view, bottom view, and side view) to an obstruction plot of the horizontal versus vertical degrees. This type of plot provides the area of units in square degrees to quantify light obstruction or shadowing (figures 1 and 2).

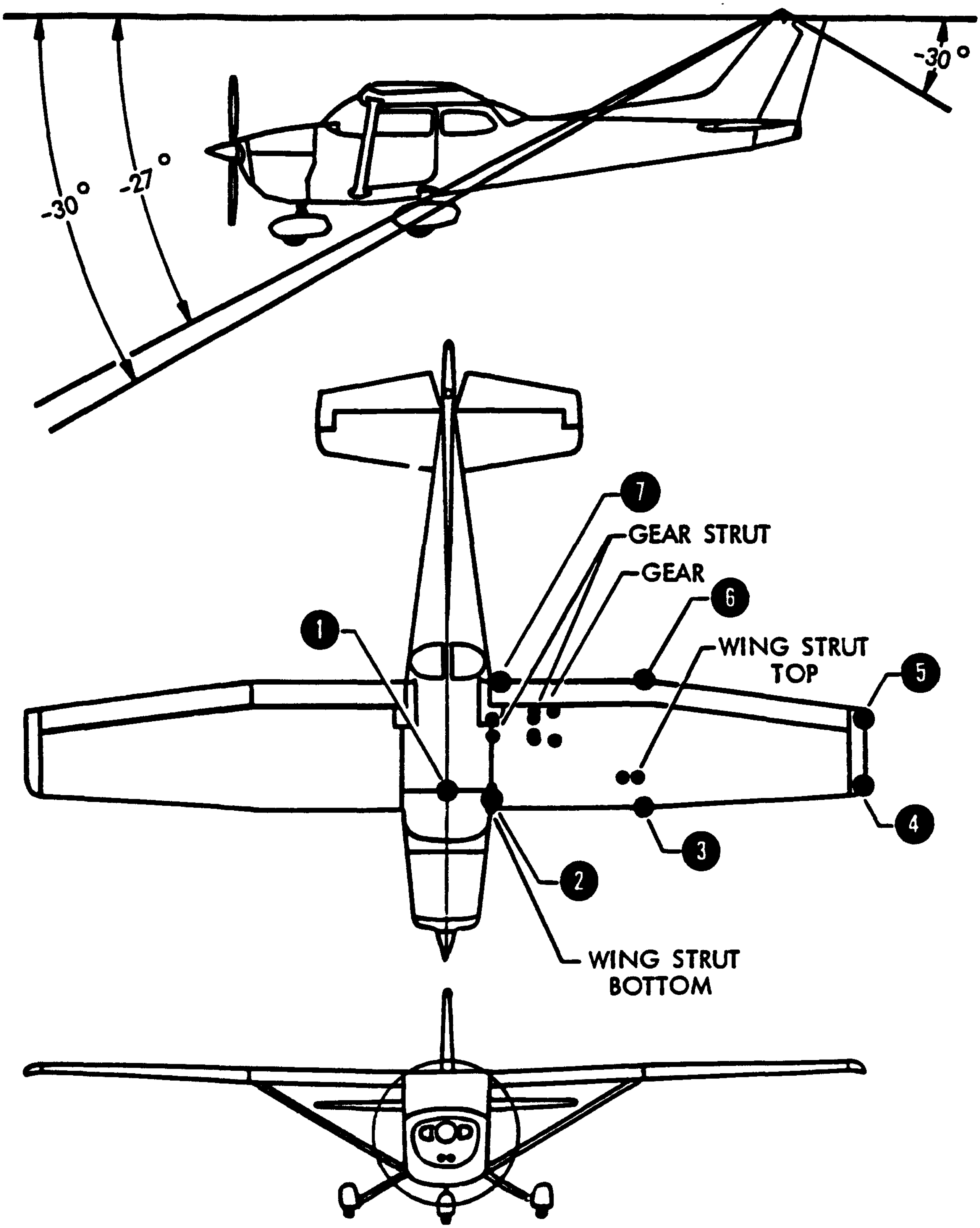

Figure 1
ANTICOLLISION LIGHT OBSTRUCTION AREAS

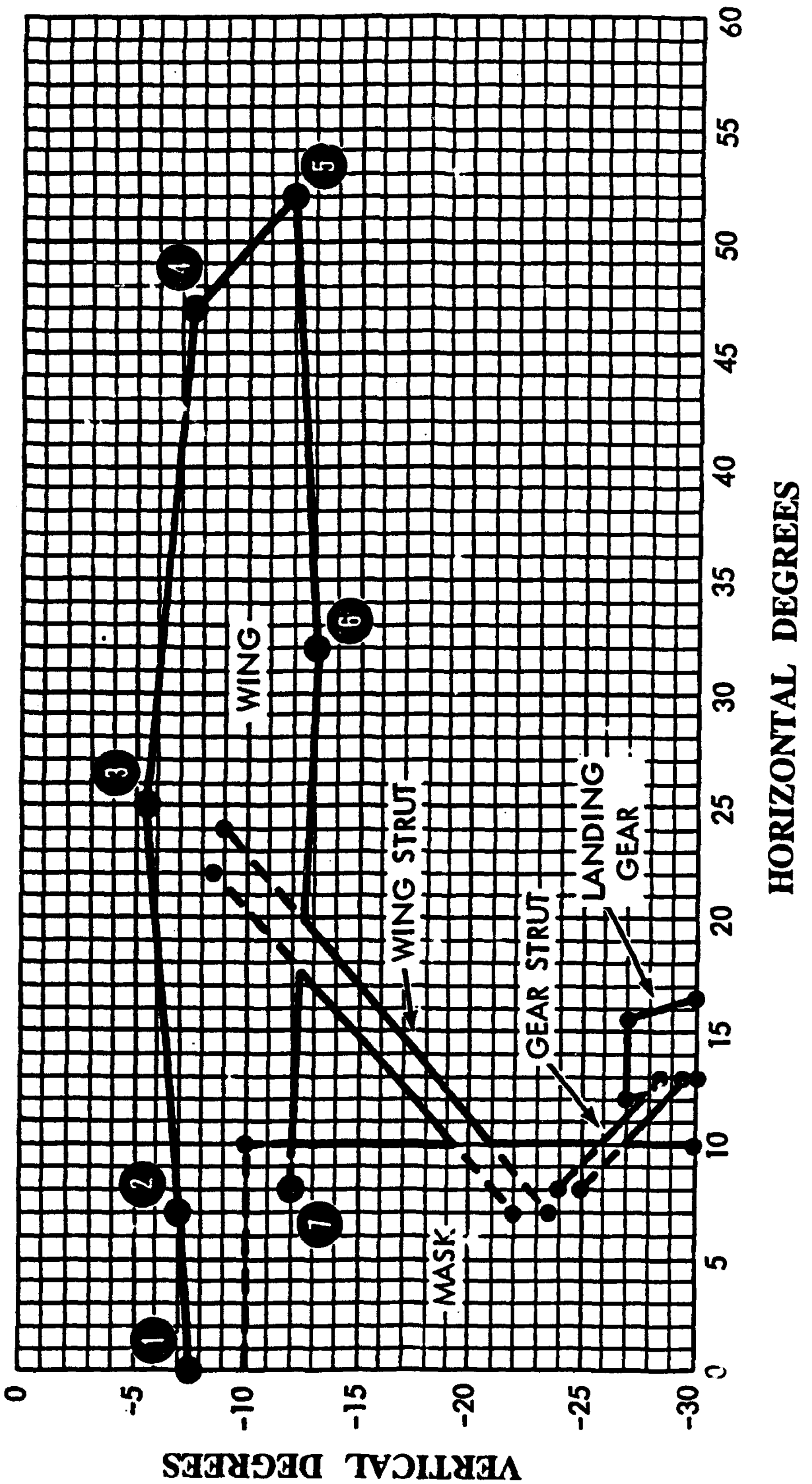

Figure 2
ANTICOLLISION LIGHT OBSTRUCTION AREAS

23. The effective intensity and coverage of anticollision lights on flashing lights should be measured using the same positioning device used to measure illuminance and NVIS irradiance intensity and angular distribution. Conventional anticollision lights measurement is accomplished with a conventional illuminance meter with an analog-output socket (Minolta illuminance meter T-1H) connected to a personal computer consisting of an analog-to-digital converter and appropriate computer software. The effective intensity is computed using the Blonde-Rey equation specified in MIL-L-6503. NVIS irradiance of a covert anticollision light should be measured with a meter with a spectral response equivalent to NVIS and is a fast reading energy peak detector. The intensity and angular distribution must meet the mission requirements of the particular aircraft. The distance equation must be used to determine NVIS irradiance to quantify visual detection ranges.

24. Flash rate can be determined by an analysis of the electronic system design. An alternative method preferably used during field testing is to count the number of flashes over time. Flash rate is specified in the military standard requirement as the number of flashes per minute. Collect the data and scale it appropriately to the number of flashes per minute.

SUMMARY

25. The integration of exterior lighting systems will require system design engineers to consider the current operational mission requirements associated with NVIS compatibility and low observable airframes. The exterior lighting systems integration must expand beyond the visual spectrum into the NR spectrum of the electromagnetic spectrum associated with the integration of NVIS. Computerized or physical scale models of an aircraft will aid in initial trade studies to optimize integration for a particular airframe and associated mission requirements. Another important issue to readdress is the integration of the exterior lighting controls. Exterior lighting controls must provide the flexibility to meet FAR, training, and mission requirements in normal and NVIS flight configurations in different environmental conditions and flight restriction areas. With the appropriate integration of controls and exterior lighting hardware, physical modifications to the exterior lighting system during fleet operations should be eliminated and considered a system integration requirement. Safety and improved mission success are the major issues for updating the specification requirements, influencing the integration of exterior lighting systems. The experience gained from the A-12 DT&E phase has generated an awareness that additional work is necessary in developing test procedures and specification requirements. It is important to note that the information presented is not all inclusive, it is intended to provide lessons learned from the A-12 program and be used for future reference in the development of new performance requirements and test procedures. With the necessary support from NAVAIRSYSCOM and program managers, the exterior lighting systems requirements and specification requirements will be updated, established, and quantified for the operational and mission requirements.

26. It is recommended that the primary exterior lighting military specification MIL-L-006730C be updated establishing operational mission and training requirements associated with the integration of NVIS systems. The goal is to establish criteria that will consider the combination of tactical mission, training, and FAR requirements. The Aircrew Systems Department at NAVAIRWARCENACDIV Patuxent River has initially developed test procedures to evaluate the performance requirements associated with fixed and rotary wing aircraft as previously discussed. It is recommended that we provide initial DT&E support during the integration of exterior lighting systems. Additionally, participate in the development and research necessary to quantify the operational requirements, particularly associated with the integration of NVIS compatible and low observable exterior lighting systems. Also recommend that we provide support during the development of new specification requirements. The establishment of these requirements will provide the necessary foundation to be used during trade studies and integration of exterior lighting systems for future aircraft.

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NIGHT VISION IMAGING SYSTEMS

1. Night Vision Imaging Systems (NVIS) are passive helmet mounted binocular devices that use image intensifier tubes. These tubes are extremely sensitive to near infrared radiated energy between 600 to 900 nm of the electromagnetic spectrum, referred to as NVIS Radiance (NR). This energy is just beyond the visible range of the human eye that is sensitive between 400 to 700 nm (figure 1). At night with minimal levels of visible light and a high degree of NR energy, NVIS provides the aircrew with a visual scene of the external terrain and horizon that is invisible to the naked eye.

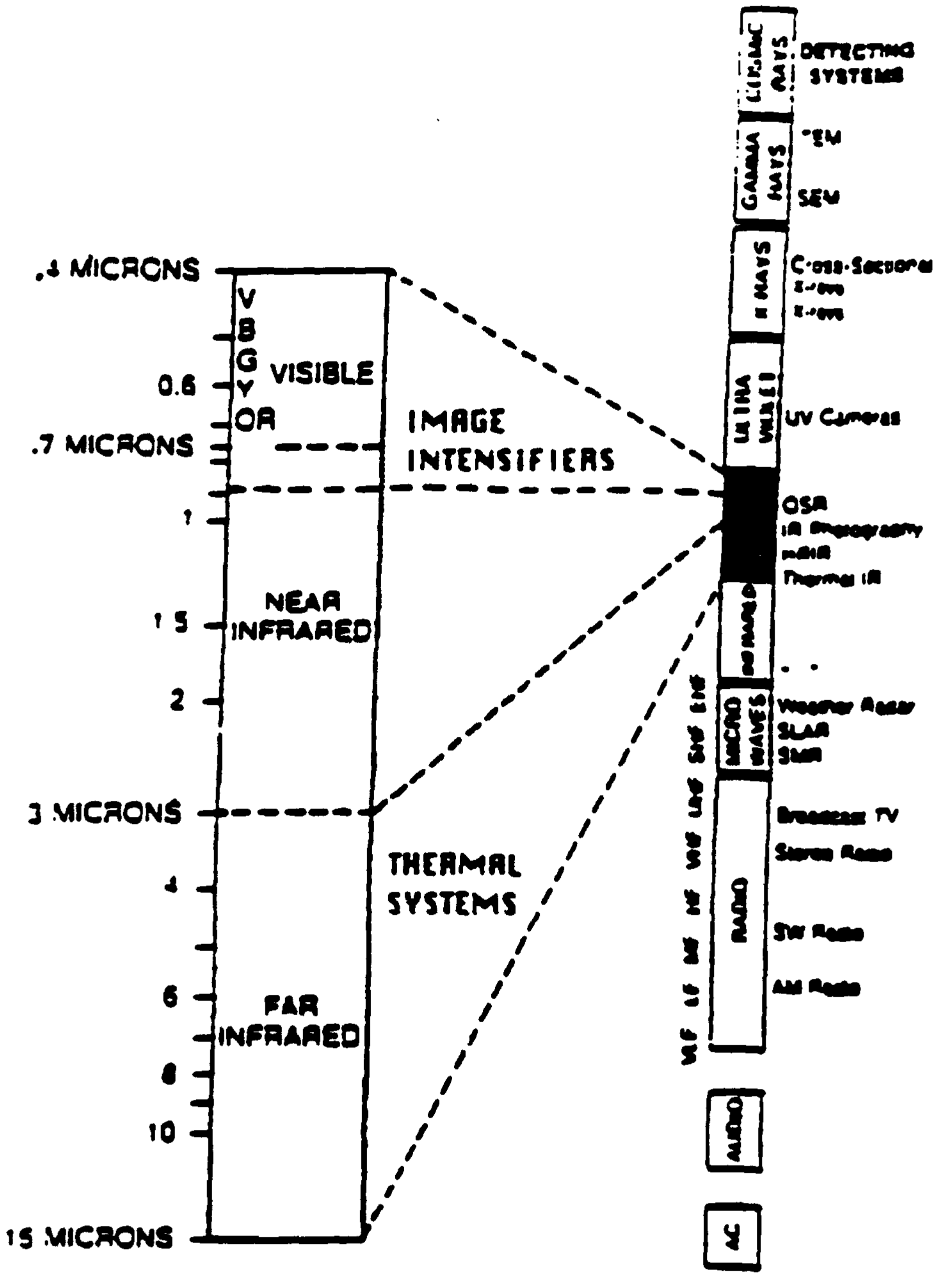
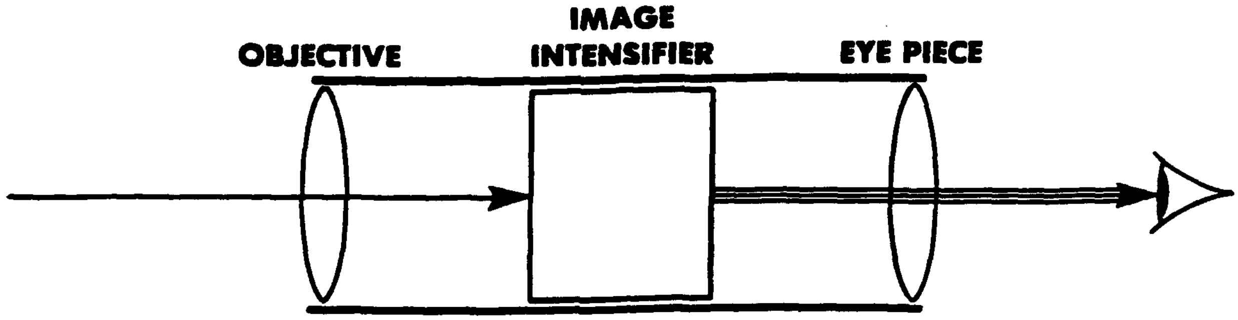


Figure 1
ELECTROMAGNETIC SPECTRUM

2. The major component of NVIS is the image intensifiers (figure 2). The image intensifier is an electronic device that amplifies NR energy. NR energy enters the image intensifier tubes and is focused by the objective lens, onto a photocathode receptor. The photons striking the photocathode cause a release of a proportionate amount of electrons. These electrons then pass through a microchannel plate (MCP) causing a secondary generation of electron emissions. For every electron that enters the MCP, as many as 10,000 will be generated. The electrons are then accelerated away in an electrical field directed toward a phosphor screen. The accelerated electrons strike the screen and emit a proportional amount of visible light generating a picture. The picture is generated from a small amount of NR energy that is converted to accelerated electrons used to generate visible light. The NR energy converted or light amplification produced in an intensifier tube is referred to as the tube's gain. The gain is the ratio of the light taken in, to the light generated and visible through the eyepiece.



NVG PRINCIPLE OF OPERATION

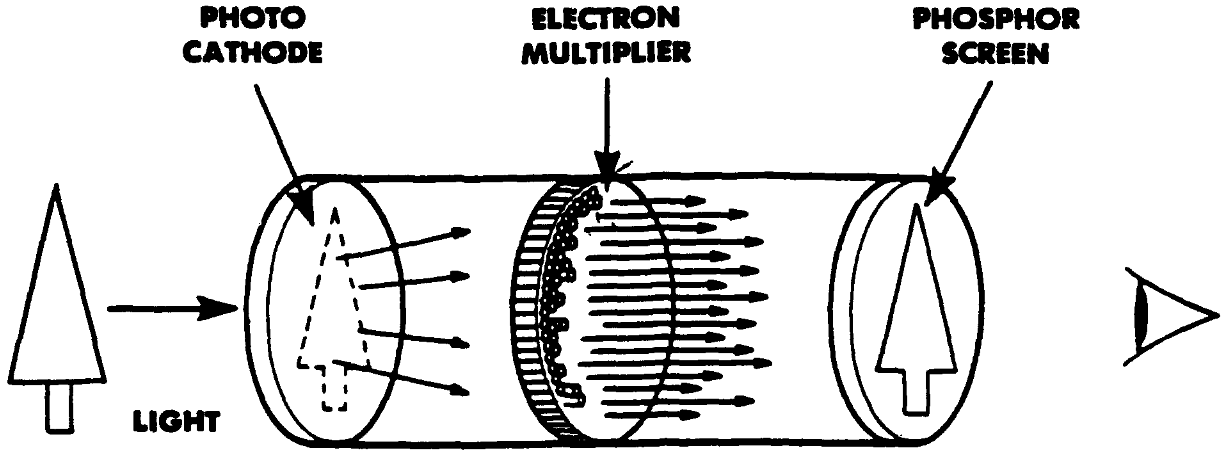


Figure 2
IMAGE INTENSIFIER TUBE

3. NVIS was evolved from devices initially designed for ground troops to devices designed for aviator use. These devices are lightweight, self-contained, and helmet mounted with Third Generation (GEN III) image intensification systems. There are various designs of aviation NVIS devices broken out by Type and Class. The following is a description of the various Types and Classes:

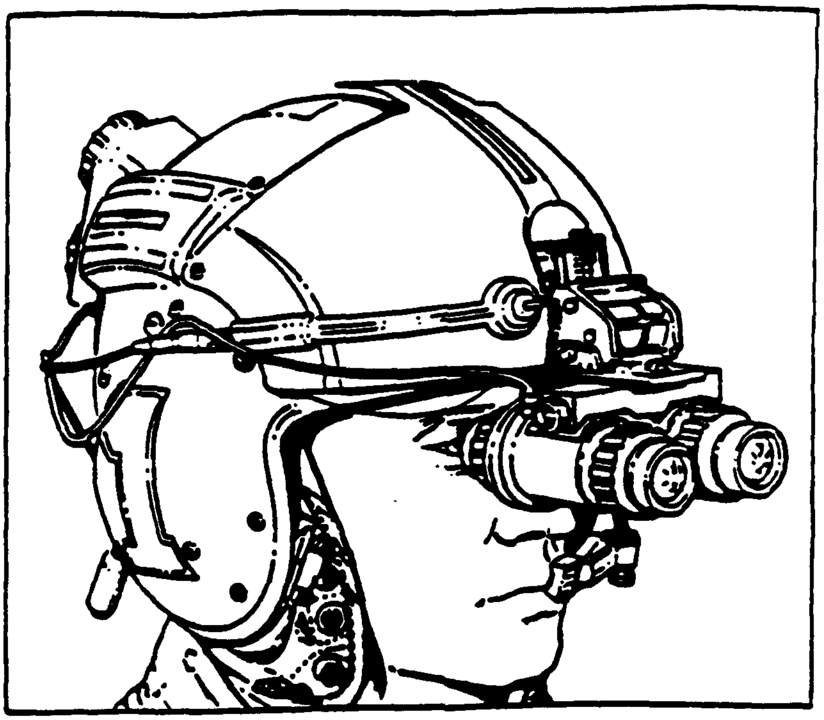
a. Type I: Direct view image NVIS using GEN III image intensifier tubes.

b. Type II: Projected image NVIS using GEN III image intensifier tubes.

c. Class A: NVIS using a 625 nm minus blue objective lens filters.

d. Class B: NVIS using a 665 nm minus blue objective lens filters

Type I Class A NVIS, figure 3, are primarily used by the helicopter community and Type II Class B, figure 4, are primarily used in the fixed wing community with a few exceptions to the use of Type I Class B configurations. The Class, 625 nm or 665 nm identifies the lower end of the electromagnetic spectrum that the NVIS are sensitive. This primarily affects the design of interior and exterior lighting systems and NR energy to be radiated from individual light sources. If these NR levels are exceeded, the NR energy generated naturally by the environment will be disrupted, degrading the design utility of NVIS and the associated operational performance requirements. The primary utility of NVIS devices is to improve the ability of military aircrew to see in the dark for nap-of-the-earth flying and additional mission requirements.



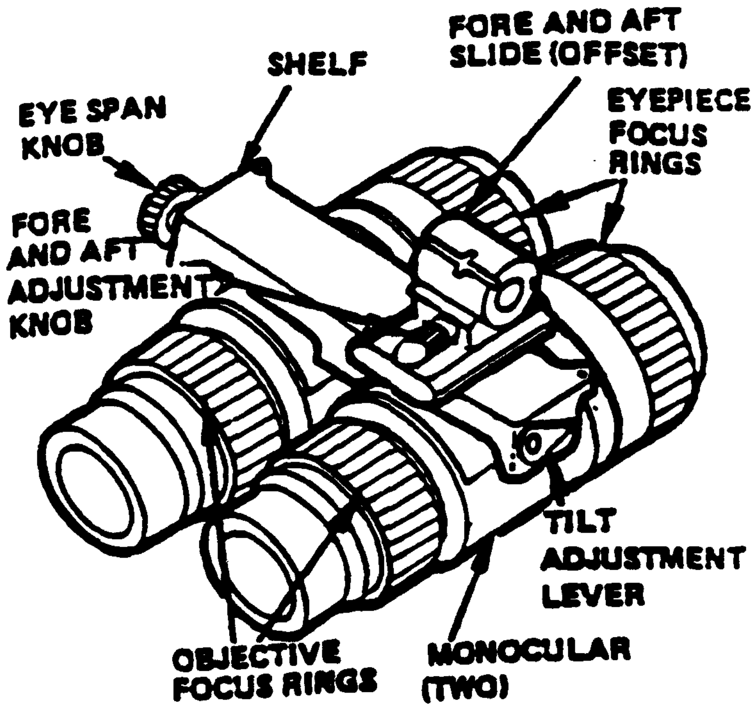
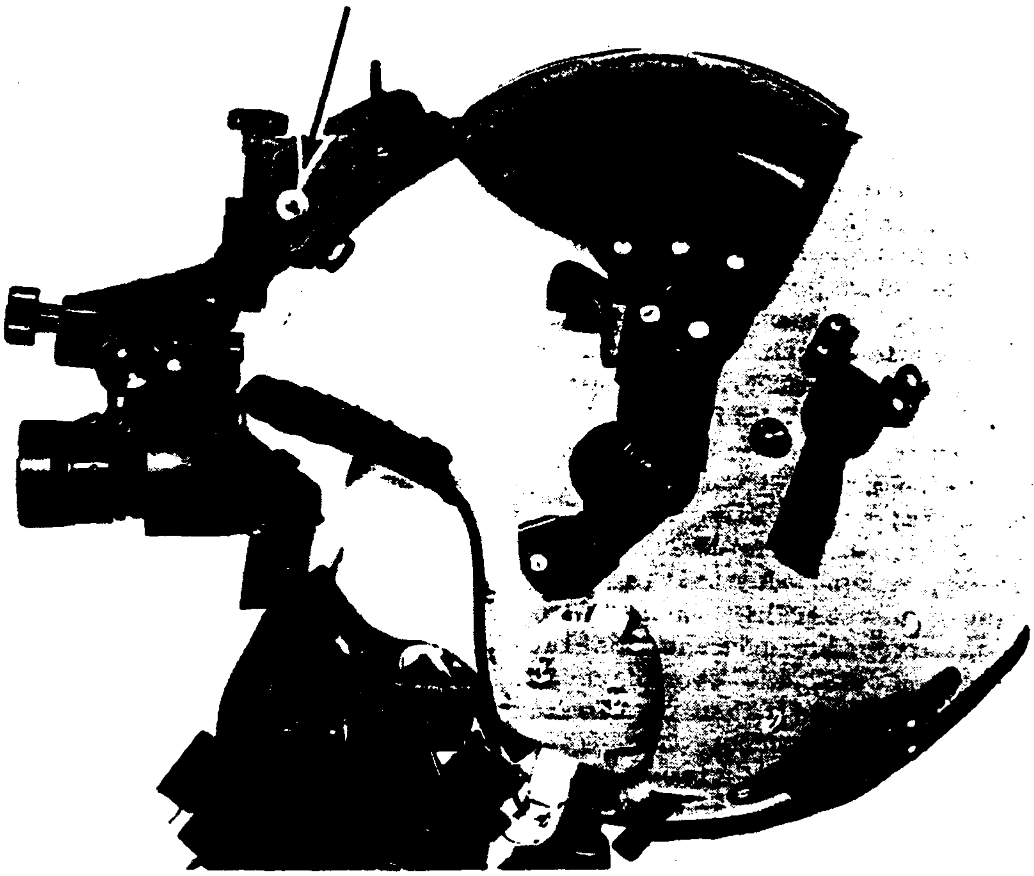
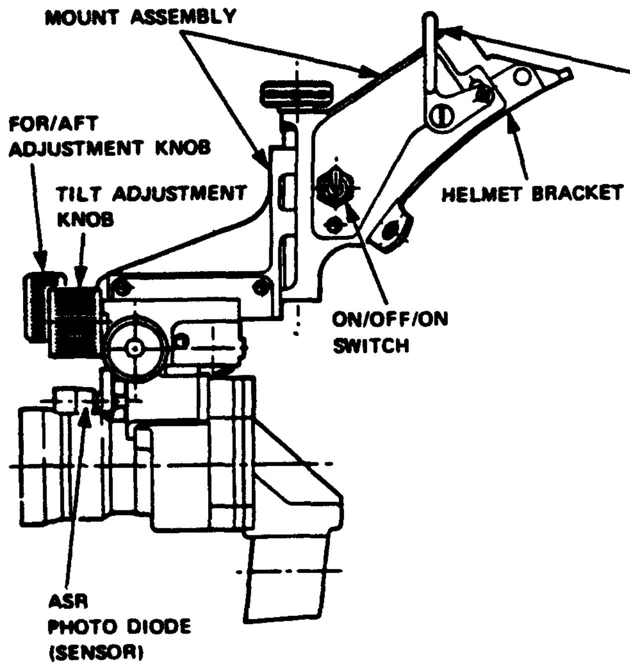


Figure 3
TYPE I NVIS





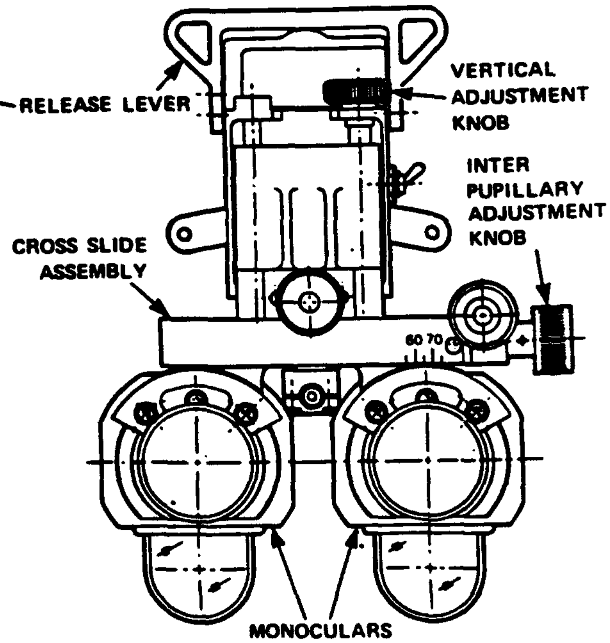


Figure 4
TYPE II NVIS

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A-12 EXTERIOR LIGHTING MOCK-UP INSPECTION PROCEDURES

A-12 EXTERIOR LIGHTING MOCK-UP
INSPECTION PROCEDURES

NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND 20670

Scott Kinney, Ron Simpson

EXTERIOR LIGHTING MOCK-UP INSPECTION PROCEDURES

1. INTRODUCTION

1.1 Background. The inspection procedures for the A-12 exterior lighting mock-up were developed as part of the Navy crewstation support to the A-12 program. They are documented as an appendix for convenience of use by the technical advisors to the mock-up board for the lighting mockup inspection. It is intended that inspection procedures contained herein, in conjunction with the review of technical data elements make up the overall inspection methodology. In addition to the procedures this appendix contains a general listing of facilities, equipment, and personnel requirements.

1.2 Scope These procedures provide for the inspection of the exterior lighting mock-up. The results of this inspection will be utilized to determine major deficiencies of the exterior lighting system and/or the modification thereof prior to the design of the actual aircraft. At a later date, a performance verification and evaluation will be conducted during flight test prior to final approval by NAVAIR.

2. FACILITIES AND EQUIPMENT REQUIREMENTS

2.1 Contractor Requirements. The following facilities, equipment, and engineering services are to be supplied by the contractor.

2.1.1 Equipment:

a. Provisions for controlling illumination of ambient lighting sources, facility lighting and external facility ambient lighting.

b. Provisions for determining rated voltages supplied to lighting sources.

c. Equipment or procedures for determining test eye positions.

d. Typing services.

e. Access to photocopying.

f. Transfer of secure documents

g. Intercommunications System (ICS) between Test Engineer, Observer, and Console Operator. Inside observer's ICS connections must be compatible with Navy flight helmet.

2.1.2 Facilities:

a. Briefing room in close proximity to mock-up room.

b. Work area for report generation.

2.1.3 Personnel:

a. Lighting system design engineers to provide lighting systems operation and on-the-scene advice to the Compliance Review Team and the Inspection Board.

b. Personnel to man the mock-up facility during the review and inspection period.

2.1.4 Additional Mock-Up Requirements

a. Means to control individual exterior light sources

b. Reference points on the ground surface with respect to major aircraft reference points, such as aircraft center line etc.

2.2 NAVY REQUIREMENTS. The following equipment/provisions and personnel are to be supplied by the Navy inspection team:

a. Four test engineers.

b. Two operationally experienced pilot observers.

c. Six copies of this report.

d. Lighting test equipment
(1) Photometers
Minolta - Illuminance Meter T-1H & Chroma Meter CS-100
Minolta - Chroma Meter CS-100
(2) NVG 101A Image Converter
(3) NVG 101-09/07 variable radiance source
(4) Photometer/Radiometer
Photo Research - Model 1530 ARS
(5) Digital Transit - TOPCON DT-30
(6) Plumb'bob
(7) Tape Measure
(8) Laser Eye Protection (LEP)
(9) NVIS Cats Eyes

3. INSPECTION CRITERIA AND GUIDELINES

3.1 <u>Position Lights</u> - The position lights shall consist of wing position lights and tail position lights. The lights shall meet the basic guidelines as presented in figure 1.
[MIL-L-6730 paragraph 3.2.1]

3.1.1 Position Light Controls (Carrier Based Aircraft) - Both wing position lights shall be operated from the same switch. The tail position light shall be operated from a separate switch. Three position switches (Bright-Off-Dim) shall be used. A third switch shall be provided for selection of Steady or Flash operation of the position lights.
[MIL-L-6730 paragraph 3.3.1.1]
NOTE: This criteria is different from approved A-12 requirements.

3.1.2 Wing/Forward Position Lights - The forward position lights shall be located at the extremities of the wings. The color of the port wing position light shall be red and the starboard wing shall be green. Verify chromaticity requirements using procedures presented in paragraph 4.1.
[AFGS-87240 Appendix A paragraph 3.2.2.2.1, SAE AS 8037 paragraph 3.3 and FAR 25.1385]

3.1.3 Tail/Rear Position Lights - The rear position lights shall be positioned as far aft as practicable or on each aft wing tip. The color of the rear position light shall be white. Verify chromaticity requirements using procedures presented in paragraph 4.1.
[AFGS-87240 Appendix A paragraph 3.2.2.2.1, SAE AS 8037 paragraph 3.3.1 and FAR 25.1385]

3.1.4 Aviation red green and white aircraft position lights are required by Federal Aviation Administration (FAA) and International Agreements (STANAGS) to assure unambiguous color identification and standardization. The arrangement of the position lights should allow distant observers to ascertain the aircraft's orientation and direction of flight. The source of these requirements is FAR 25.
[AFGS-87240 Appendix A paragraph 3.2.2.2.1, SAE AS 8037 paragraph 3.3.1 and FAR 25.1397]

3.1.5 Position Light Dihedral Angle Requirements

3.1.5.1 Right Position Light Dihedral Angle - shall be formed by two intersecting vertical planes, one parallel to the longitudinal axis of the airplane, and the other at 110° to the right of the first plane figure 2. The dihedral angle requirements will be verified by utilizing procedures presented in paragraph 4.2.
[MIL-L-6503 paragraph 3.3.10.1.1, AFGS-87240 Appendix A paragraph 3.2.2.2.2, SAE AS 8037 paragraph 3.1 and FAR 25.1387]

3.1.5.2 Left Position Light Dihedral Angle - shall be formed by two intersecting vertical planes, one parallel to the longitudinal axis of the airplane, and the other at 110° to the left of the first plane figure 2. The dihedral angle requirements will be verified by utilizing procedures presented in paragraph 4.2. [MIL-L-6503 paragraph 3.3.10.1.1, AFGS-87240 Appendix A paragraph 3.2.2.2.2, SAE AS 8037 paragraph 3.1 and FAR 25.1387]

3.1.5.3 Aft Position Light Dihedral Angle - shall be formed by two intersecting vertical planes making angles of 70° to the right and left, respectively, to a vertical plane passing through the longitudinal axis, as viewed when looking aft along the longitudinal axis figure 2. The dihedral angle requirements will be verified by utilizing procedures presented in paragraph 4.2. [MIL-L-6503 paragraph 3.3.10.1.1, AFGS-87240 Appendix A, paragraph 3.2.2.2.2, SAE AS 8037 paragraph 3.1 and FAR 25.1387]

3.1.5.4 Position Light Dihedral Angle Requirements - All fixed wing aircraft are required to have position lights with 360-degree coverage. The highest intensities are required in front of and behind the aircraft, but interference to the cockpit is to be minimized be the spatial separation. The source of this requirement is FAR 25.
[AFGS-87240 Appendix A, paragraph 3.2.2.2.2 and FAR 25.1387]

3.1.6 Position Light Distribution and Intensity

3.1.6.1 Minimum intensity in the horizontal and vertical plane should equal or exceed the values in figure 1, figure 2 table I, and figure 3 table II. The intensity requirements will be verified by utilizing procedures presented in paragraph 4.2. The source of this requirement is FAR 25.
[MIL-L-6730 paragraph 3.2.1, MIL-L-6503 paragraph 3.3.10.1.2, AFGS-87240 Appendix A, paragraph 3.2.2.2.3, SAE AS 8037 paragraph 3.2.2 and FAR 25.1389-25.1393]

3.1.6.2 The intensities in overlaps between adjacent signals should not exceed the values presented in Table III except that higher intensities in overlaps shall be used with main beam intensities substantially greater than the minimum specified in in tables I and II if the overlap intensities in relation to the main beam intensities do not adversely affect signal clarity. When the peak intensity of the forward position lights is more than 100 candelas, the maximum overlap intensities between them may exceed the values given in Table III if the overlap intensity in area A is not more than 10% of peak position light intensity and the overlap intensity area B is not greater than 2.5% of peak position light intensity. The intensity requirements will be verified by utilizing procedures presented in paragraph 4.2. The source of this requirement is FAR 25.
[MIL-L-6503 paragraph 3.3.10.1.2, AFGS-87240 Appendix A, paragraph 3.2.2.2.3, SAE AS 8037 paragraph 3.2.3 and FAR 25.1395]

3.2 <u>Anticollision Lighting</u>

3.2.1 Anticollision Lighting Location - The lighting should be located so that the emitted light will not be detrimental to the

crew's vision, provide minimal interference of illumination intensity from possible aircraft structure or configuration, and not detract from the conspicuity of the position lights. Lights located on top of the fuselage shall be located as far back of the pilot as practicable in order to reduce to a minimum the possibility of causing vertigo to occupants of the cockpit.
[MIL-L-6730 paragraph 3.2.2.1, MIL-L-6503 paragraph 3.3.1, AFGS-87240 Appendix A, paragraph 3.2.2.1.1 and FAR 25.1401]

3.2.2 Field of Coverage and Intensity - For small supersonic and small subsonic aircraft with wing, fuselage, and vertical stabilizer mounted red and white mode, the luminous intensity emitted by both modes shall have, in the vertical field, the coverage of the light sources are presented in table IV. The anticollision lights shall cover all vital areas around the plane of flight of the aircraft considering the physical configuration and flight characteristics of the aircraft. The horizontal coverage will be 180° from the white wing tip mounted lights and 360° for red fuselage mounted lights. The vertical coverage must extend to at least 75° above and below the horizontal plane of the aircraft. At night, intensities are reduced since an observer's vision has increased sensitivity and flashback of the exterior lighting to the cockpit windows must be minimized. The effective intensity of the anticollision lights will be verified by the necessary calculations, Blondel and Rey equation, and with support provided by the contractor. The coverage will be verified utilizing procedures presented in paragraph 4.2. The source of this requirement is FAR 25.
[MIL-L-6503 paragraph 3.3.1.5, MIL-L-85314/2 paragraph 3.4.2, AFGS-87240 Appendix A, paragraph 3.2.2.1.5 and FAR 25.1401]

3.2.3 Obstructed visibility - The angles of obstructed visibility totaling not more than 0.03 steradian is allowable within a solid angle equal to 0.15 steradian centered about the longitudinal axis in the rearward direction. Obstructed visibility will be verified utilizing procedures in paragraph 4.3. The source of this requirement is FAR 25.
[MIL-L-6730 paragraph 3.3.1.1, MIL-L-6503 paragraph 3.2.2.3, AFGS-87240 Appendix A, paragraph 3.2.2.1.4 and FAR 25.1401]

3.2.4 Flash Rate - The effective flash frequency shall be 90 ± 10 but not less than 40 nor more than 100 cycles per minute except when the system includes overlaps created by more than one light source. In overlap areas the flash rates shall not exceed 180 cycles per minute. The anticollision flash rate should be evaluated at rate voltage base on worse case aircraft power requirements. Flash rate will be verified utilizing procedures in paragraph 4.4. The source of this requirement is FAR 25.
[MIL-L-6730 paragraph 3.2.2.4, MIL-L-6503 paragraph 3.3.1.3, AFGS-87240 Appendix A, paragraph 3.2.2.1.2 and FAR 25.1401]

3.3 Landing and Taxi Lights

3.3.1 Two landing lights shall be used, one is permissible on aircraft where weight and balance will not permit two. The lights shall be located laterally as far from the centerline of the aircraft as practical. The minimum peak candle power of each light shall be not less than 300,000 candelas. The beam spread (between the points at 10% of peak candle power) shall be at least 8° in the vertical plane and 14° in the horizontal plane. [MIL-L-6730 paragraph 3.2.3]

3.3.2 The taxi light shall be located on the nose wheel movable strut so that the light will turn laterally with the nose wheel strut. The minimum peak candle power for each light shall not be less 50,000 candelas. The beam spread (between the points at 10% of peak candle power) shall be at least 10° in the vertical plane and 40° in the horizontal plane. A single, dual purpose, landing-taxi light is permissible, when space and weight limitations are an issue.
[MIL-L-6730 paragraph 3.2.4]

3.3.3 All fixed-wing aircraft equipped for night flying shall be provided with an installation that can be effectively used for landing and taxiing. The lighting system shall provide the aircraft with sufficient light in the event of a broken lamp. The lights shall not indirectly or directly project or reflect light into the cockpit affecting the aircrew. Also the lights shall be so oriented and positioned that the proper area in front of and beneath the aircraft is sufficiently illuminated to provide ground reference for the pilot in all phases of landing and taxiing.
[MIL-L-6503 paragraph 3.3.7 and AFGS-87240 Appendix A, paragraph 3.2.2.4]

3.3.4 Landing light illumination provided by the landing and taxi light system should provide not less than 2 fc on the ground line referenced on figure 4 at a point B when measurements are made in a vertical plane directly ahead of each narrow beam, high intensity lamp used in the system. If conventional landing procedures are not followed and the pilot is unable to see point B an alternative solution may be approved by the procuring activity. Landing light illumination will be verified utilizing procedures in paragraph 4.2.
[MIL-L-6503 paragraph 3.3.7.1.1]

3.3.5 Taxiing light illumination provided by the landing and taxi light system should provide not less than 0.5 fc in the vertical plane on the ground line referenced on figure 5 at a point A. The minimum illumination shall be provided on each side of the centerline of the aircraft to 10 ft outboard from each wing tip. Taxi lighting illumination will be verified utilizing procedures in paragraph 4.2.
[MIL-L-6503 paragraph 3.3.7.1.2]

3.4 Formation Lights - The formation lighting system should provide visual unambiguous orientation information regarding the attitude and position of the lead aircraft to the pilot of the adjacent in the formation. Unless otherwise specified Type II or Electroluminescent (EL) lights should be used.
[MIL-L-6730 paragraph 3.2.6 and MIL-L-6503 paragraph 3.3.5]

3.4.1 Stepped-up Formation - Aircraft required to fly in a stepped up formation shall be provided with a formation lighting system that will permit pilots of wing aircraft to visually determine the attitude and position of the lead aircraft at night. Prior to installation, the contractor shall make a study to determine the optimum system of formation lights for the specific aircraft and submit the proposed system to the procuring activity for approval.
[MIL-L-6503 paragraph 3.3.5.1]

3.4.2 There shall be, on each side of the aircraft, one light which wraps around the outer edge of the wing tip, one light on the fuselage forward of the wing root, one light on the rear quarter of the fuselage, and one light on the vertical stabilizer. In addition, there shall be a cross-under light located along the bottom center line of the aircraft and slightly aft of the lateral centerline on the fuselage. When possible, the relative location of the fuselage lights and the wing light on each side of the aircraft shall be such that the form a broken horizontal line when viewed by the wingman flying in the normal step-down formation position. The general location of the lights shall be as approved by the procuring activity.
[MIL-L-6730 paragraph 3.2.6.1.1.2]

3.4.3 The surface of EL lights for the fuselage, vertical stabilizer, and cross-under light shall have total length of or not less than 36 inches and a width of not less than 2 inches nor greater than 2-1/4 inches. These lights shall be fabricated of three or four individual lamps assembled end to end. The non-luminous surface between adjacent lamps shall be not more than 5/8 inch wide. the wing lights shall wrap around the wing tips and each shall have a luminous surface of at least 72 square inches on the bottom surface. The wing lights shall be fabricated of not less than six individual lamps assembled side by side. Nonluminous areas between adjacent lamps shall be not more than 5/8 inches in width. The color of all EL lights shall be aviation green.
[MIL-L-6730 paragraph 3.2.6.1.2.2 and 3.2.6.1.3]

3.4.4 EL Color and Luminance - The color of all EL lights shall be aviation green. The surface luminance shall be either continuously variable or adjustable in seven steps with the luminance at each step 1/2 that of the next higher step. The surface luminance at the highest step shall be not less than 15 fL. The color (chromaticity) and luminance will be verified by utilizing procedures in paragraphs 4.1 and 4.2
[MIL-L-6730 paragraph 3.2.6.1.3 and 3.2.6.1.4]

3.5 <u>Approach Lights</u> - Angle of attack approach lights shall be located on all carrier based aircraft.
[MIL-L-6730 paragraph 3.2.12.1]

3.5.1 Location and Orientation - The approach lights shall be mounted on the forward part of the airplane as near as practicable to the fuselage reference line, so as to be visible to the Landing Signal Officer (LSO) during the landing approach prescribed for the particular aircraft.
[MIL-L-6730 paragraph 3.2.12.1.2]

3.5.2 Beam Axis - Shall be directed $8^\circ \pm 1^\circ$ to the left of the fuselage reference line at an angle theta which shall conform with the wing angle of attack at the related approach speed. Angle theta is determined by the addition of the wing angle of attack and wing angle of incidence subtracted by the angle between the actual glide slope and optical glide slope.
[MIL-L-6730 paragraph 3.2.12.1.3]

3.5.3 Angle Of Roll Light shall be installed on all carrier based aircraft. It shall be energized only when the position lights are on and the landing gear is extended. The light shall be located so it can be seen by the LSO during night carrier landing approaches. It shall be provide the maximum wing span information to the LSO, and shall be visible at all times during the last 80° of the turn to the approach path. The preferable location of this light is on the top side of the starboard wing. When this is impractical, the light may be located on the port side of the fuselage above and near the forward edge of the wing figure 1 and 2. Throughout the entire required angles of visibility the light shall have an intensity of not less than 1 candela nor more than 5 candelas. and the color shall be aviation green.
[MIL-L-6730 paragraph 3.2.7]
NOTE: This criteria is different from approved A-12 requirements.

3.5.4 Lighting Control - A switch shall be provided for selection of day and night mode of operation. Also a hook bypass switch shall be provided in the cockpit which shall two positions, Carrier and Field. When set in the Carrier position, the approach light shall flash if the wheels are down and the hook is not down. When set in the Field position, the lights shall remain steady when the wheels are down, regardless of hook position. When flashing, the flash rate shall be 170 to 180 flashes per minute. Turning aircraft power OFF or moving the hook control handle to Down shall reset the by pass circuit, making the system operate normal for carrier landings. The flash rate will be verified by utilizing procedures in paragraph 4.4.
[MIL-L-6730 paragraph 3.3.1.2 and 3.3.1.2.1]

3.6 <u>Air Refueling Lights</u> - Aircraft intended for inflight refueling at night shall incorporate adequate lighting permit the receiver aircraft to visually locate and make contact with assigned tankers,and to permit the aircraft to fly in close proximity while fuel is being transferred. All Lights shall be positioned and shielded to prevent any direct light from being project into any openings of the tanker and receiver aircraft

through which observations must be made during final hookup or transfer of fuel. The lighting system shall be provided with variable lighting controls adjustable uniformly over the range of the control from the full bright to the off position.
[MIL-L-6503 paragraph 3.3.8 and MIL-A-19736A paragraph 3.15.6]
NOTE: The Air Refueling lighting system will be evaluated during the interior lighting mockup.

3.6.1 Probe Light - A floodlight shall be located on the receiver aircraft to illuminate the probe nozzle and the drogue during final enclosure for engagement. The light beam shall be such as to produce a 40° cone of light having its apex at the prob tip. The axis of the cone shall be inclined 10° above the axis of the nozzle, and it shall lie in a vertical plane which passes through the axis of the nozzle figure 6.
[MIL-L-6730 paragraph 3.2.9.1]
NOTE: The Air Refueling lighting system will be evaluated during the interior lighting mockup.

3.6.2 Illumination of the probe nozzle shall be not less than 0.25 fc nor more than 2 fc as measured in a plane perpendicular to the pilot's line of sight to the probe tip. Except when shadowed by the probe, the illumination level of not less than .1 fc on the axis of the cone at a distance of 50 ft from the probe tip as measured in the plane perpendicular to the axis of the cone. the illumination at the edge of the cone at a distance of 50 ft from the probe tip shall be not less than 0.01 fc as measured in the plane perpendicular to the edge of the cone. The color of the probe light shall aviation red. The illumination will be verified by utilizing procedures in paragraph 4.5.
[MIL-L-6730 paragraph 3.2.9.1.1 and 3.2.9.1.2]
NOTE: The Air Refueling lighting system will be evaluated during the interior lighting mockup.

3.7 Master Exterior Light Switch - A master exterior light control switch shall be provided. This shall be an ON-OFF switch located on or adjacent to the throttle. This location shall be such as to allow the pilot to signal for night catapult without materially affecting his physical readiness and also permit him to immediately extinguish his exterior lights after a night carrier landing.
[MIL-L-6730 paragraph 3.3.1.3]

3.8 NVIS and LEP Compatibility/Operability - External lighting configurations or sources that will be illuminated must be optimized during the use of NVIS and/or LEP.

4. GENERAL INSPECTION PROCEDURES

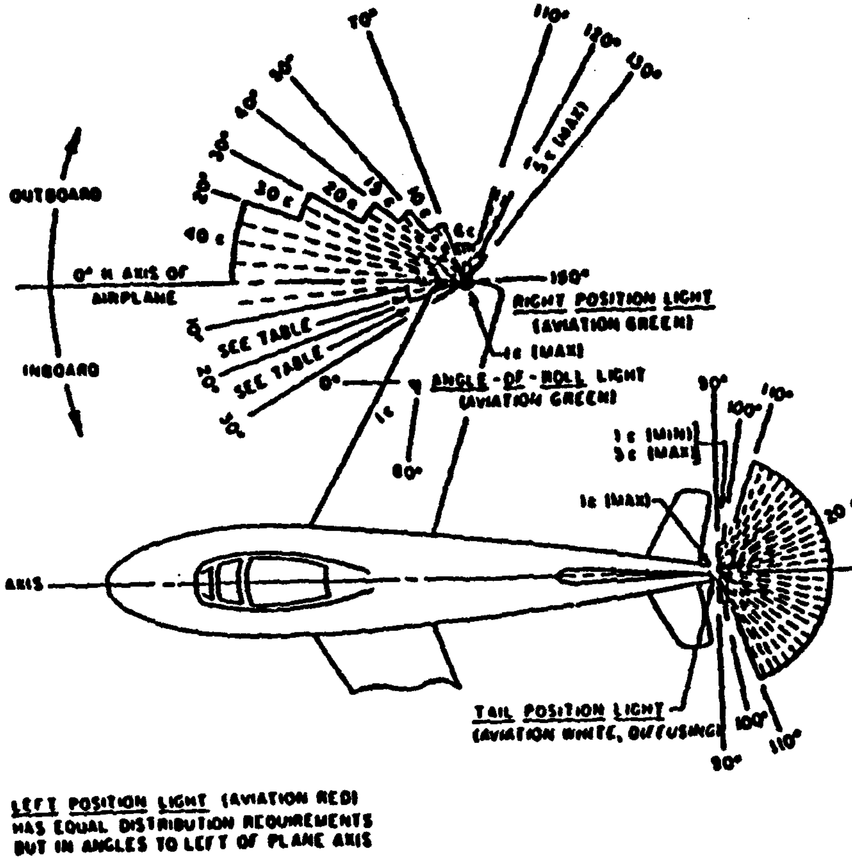
4.1 Chromaticity - Chromaticity of lighting components will be measured in a dark environment at the associated luminance levels. The luminance and chromaticity will be measured with a combination photometer and chroma meter. The data will be collected on the worksheet presented in (Table VI). Each measurement will be done using actual configurations of the lighting hardware. The chromaticity coordinates will be compared to the required coordinates of the x and y 1931 C.I.E and u' and v' 1976 UCS chromaticity charts.

4.2 Light distribution and intensity will also be measured by using a device consisting of a monopod, illuminance meter and angle finder (base). The base of this device will be physically positioned on to the aircraft at a specified location beside the associated light source to be evaluated. The illuminance meter located at the end of the device will be adjusted to a specified distance from the light source, which is dependent upon the the monopod length, thus creating a fixed arc of rotation. The illuminance data for the associated light source will be collected by positioning/rotating the device through a series of angles in the horizontal and vertical plane. The data collected will be plotted on polar graph paper and compared to laboratory data to confirm the validity of extrapolated lab data of the associated exterior lighting component. The combination of all plots taken will show areas of unequal distribution, obstructions, or deficiencies in the lighting design as a function of the installed configuration. Synergistic problems will be identified, if existent. Consideration will be given to the limits of the fidelity of the mockup incomparison to aircraft. If the fidelity is poor then areas of concern will be identified for verification on the first article when available for test.

4.3 Obstructed Visibility - Obstructed visibility due to blockage by structures will be determined by geometric analysis. Detailed drawings of the external structure of the aircraft will be necessary.

4.4 Flash Rate - Best determined by analysis of system design, but can be verified by simply counting flashes over a period of time.

4.5 NVIS Radiance - Radiance measurements will be made in a dark environment where the ambient light is unmeasureable or no greater than 1% of the light being measured. The power supplied to the hardware shall be at the rated voltage as specified.



ANGLE (DEGREES)	INTENSITY (CANDELAS)
WING TIP LIGHTS	
OUTBOARD	
0 - 20	40
20 - 30	30
30 - 40	20
40 - 50	15
50 - 70	10
70 - 110	6
110 - 120	UNSPECIFIED
120 - 130	5 (MAX)
130 - 180	1 (MAX)
INBOARD	
0 - 10	UNSPECIFIED
10 - 20	25% OF INTENSITY AT 0° (MAX)
20 - 30	2.5% OF INTENSITY AT 0° (MAX)
30 - 180	1 (MAX)
TAIL LIGHT	
CLOCKWISE AND COUNTERCLOCKWISE	
0 - 90	1 (MAX)
90 - 100	1 (MIN) 5 (MAX)
100 - 110	UNSPECIFIED
110 - 180	20
ANGLE-OF-ROLL LIGHT	
INBOARD	
0 - 80	

NOTE:
UNLESS OTHERWISE INDICATED THE INTENSITIES SHOWN IN CANDELAS (c) ARE THE MINIMUM ALLOWABLE WITH THE LIGHTS OPERATING IN THE BRIGHT CONDITION. WHEN DIMMING IS REQUIRED THE INTENSITIES IN THE DIM CONDITION SHALL BE BETWEEN 8% AND 12% OF THE VALUE SHOWN.

Figure 1 Intensity distribution requirements in the horizontal plane for Class 2 lights

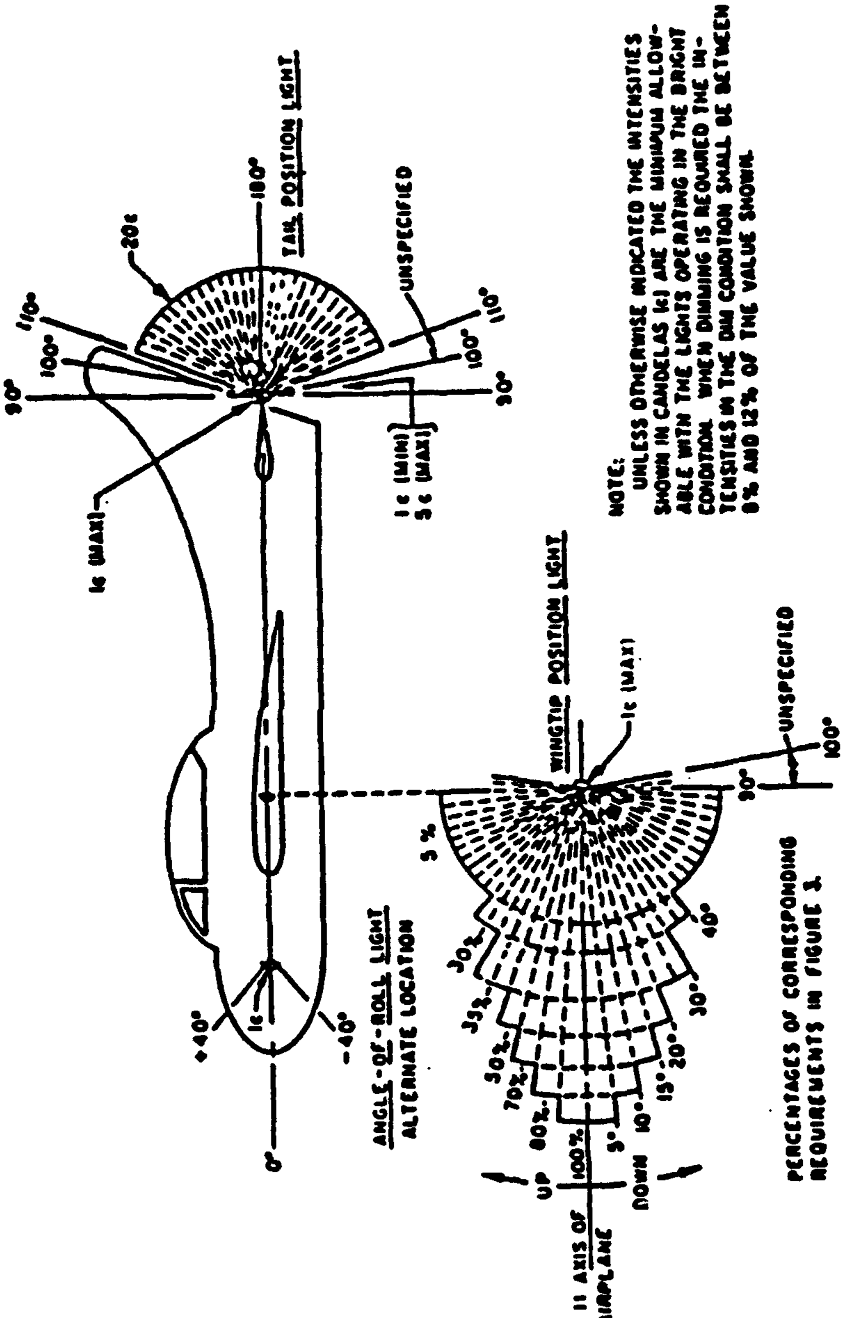


Figure 2 Intensity distribution requirements in the vertical plane for Class 2 lights

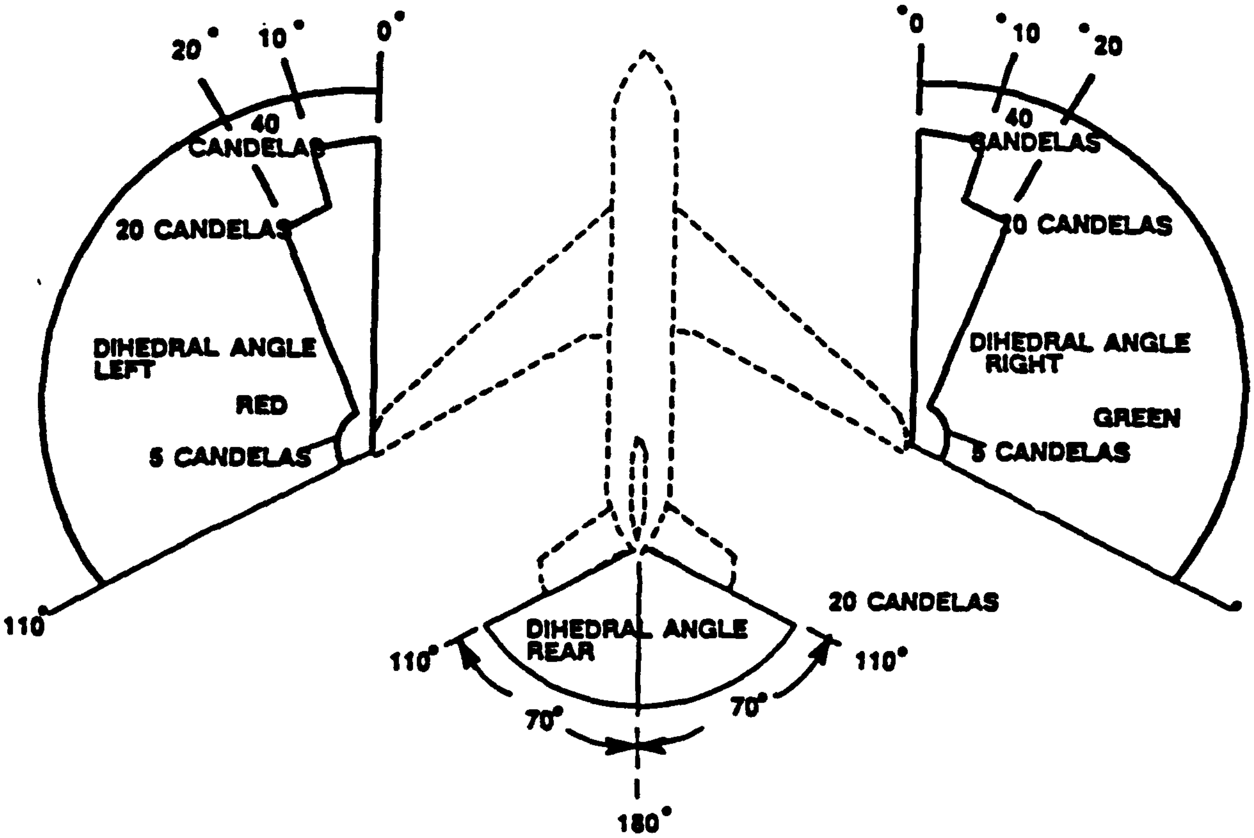


FIGURE 3 Position light dihedral angles and intensity distribution in the horizontal plane.

AFGS-87240A APPENDIX A

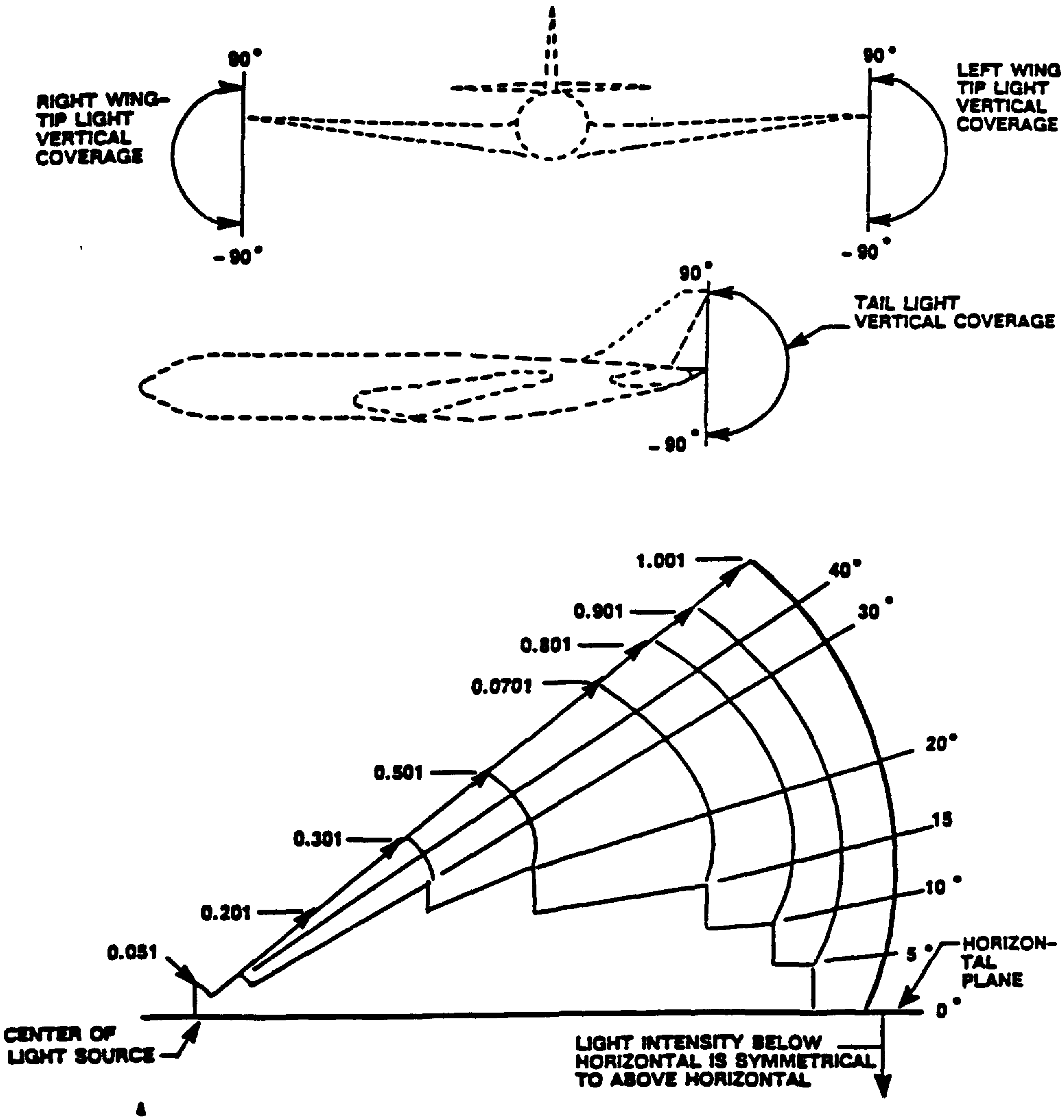


FIGURE 4 Position light intensity distribution in the vertical plane.

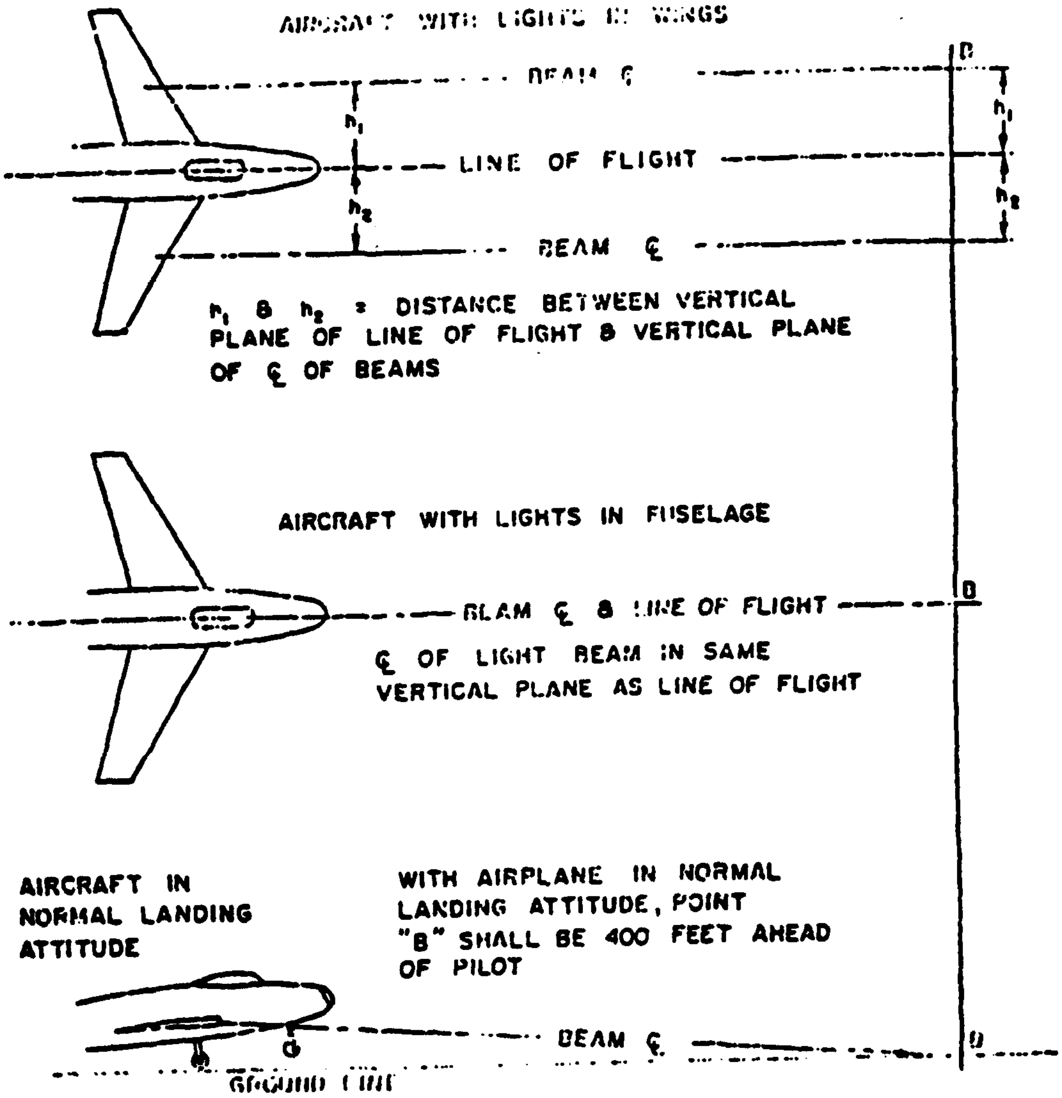


FIGURE 5 Landing Illumination

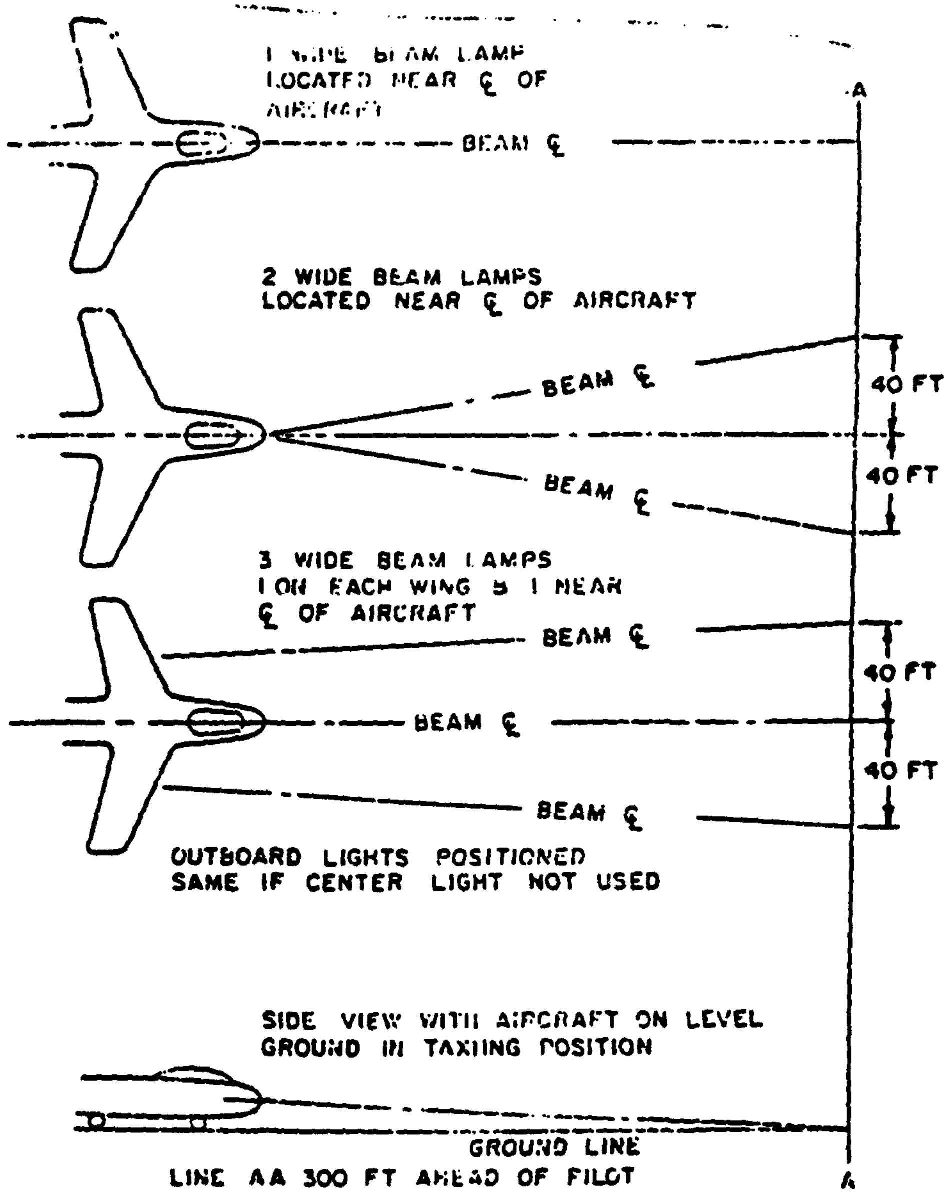


FIGURE 6 Taxi Illumination

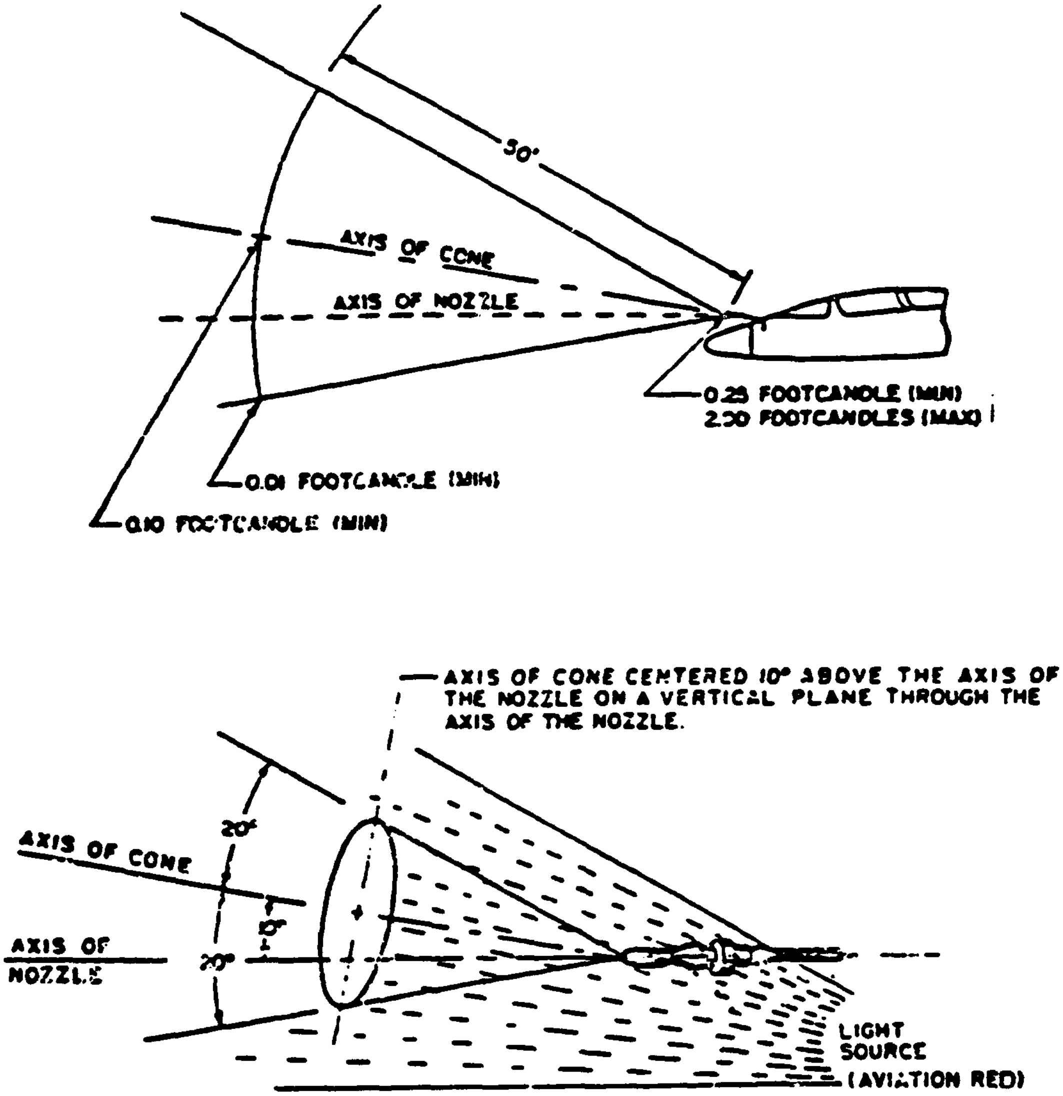
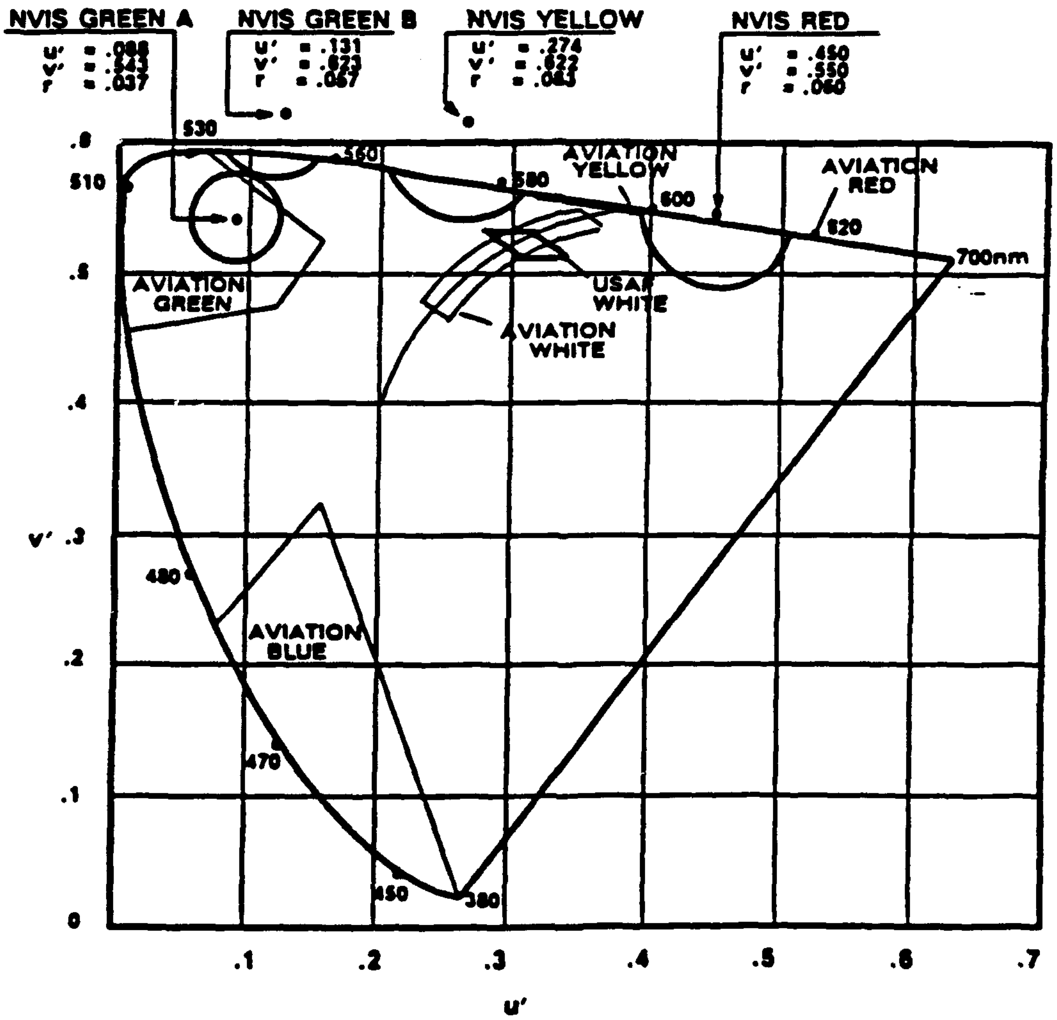


Figure 7 Illumination Distribution Requirements for Air Refueling Probe Light



CIE 1976 UCS DIAGRAM

FIGURE 8 Aeronautical colors plotted in CIE-UCS 1976 color space.

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