NOT MEASUREMENT SENSITIVE

JSSG-2010-5
30 October 1998
SUPERSEDING
AFGS-87240A
31 December 1987
MIL-L-85762A
26 August 1988
MIL-STD-1776A(USAF)
25 February 1994

DEPARTMENT OF DEFENSE

JOINT SERVICE SPECIFICATION GUIDE

CREW SYSTEMS

AIRCRAFT LIGHTING HANDBOOK

This specification guide handbook is for guidance only.
Do not cite this document as a requirement.

AMSC 15GP

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FOREWORD

JSSG RELEASE NOTE

The specification guides support the acquisition reform initiative, and is predicated on a performance based business environment approach to product development. As such it is intended to be used in the preparation of performance specifications. It is one of a set of specification guides. It is the initial release of this guide. In this sense this document will continue to be improved as the development program is accomplished.

1. This specification guide handbook is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This Joint Service Specification Guide (JSSG) handbook, in conjunction with its companion JSSGs handbooks, is intended for use by Government and Industry program teams as guidance in developing program unique specifications. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply. This document may not be placed on contract.

3. The complete set of JSSGs, and their respective handbooks, establish a common framework to be used by Government-Industry Program Teams in the Aviation Sector for developing program unique requirements documents for Air Systems, Air Vehicles, and major Subsystems. Each JSSG contains a compilation of candidate references, generically stated requirements, verification criteria, and associated rationale, guidance, and lessons learned for program team consideration. The JSSGs identify typical requirements for a variety of aviation roles and missions. By design, the JSSG sample language for “requirements” and “verification criteria” are written as generic templates, with blanks that need to be completed in order to make the requirements meaningful. Program teams need to review the JSSG rationale, guidance, and lessons learned to: (1) determine which requirements are relevant to their application; and (2) fill in the blanks with appropriate, program-specific requirements.

4. This document is Part 2 of two parts. Part 1 of the JSSG-2010 is a template for developing the program unique performance specification. As a generic document, it contains requirement statements for the full range of aviation sector applications. It must be tailored to delete non-applicable requirements to form the program unique specification. In addition, where blanks exist, these blanks must be filled in for the program unique specification to form a complete and consistent set of requirements to meet program objectives. Part 2 of the JSSG-2010 is a handbook which provides the rationale, guidance, and lessons learned relative to each statement in Part 1. The section 4, verification requirements, must be tailored to reflect an understanding of: (1) the design solution; (2) the identified program milestones; (3) the associated level of maturity which is expected to be achieved at those milestones; and (4) the specific approach to be used in the design and verification of the required products and processes. It must be recognized that the rationale, guidance, and lessons learned are not only generic in nature, but also document what has been successful in past programs and practices. This must not be interpreted to limit new practices, processes, methodologies, or tools.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENSID, Bldg. 560, 2530 Loop Road West, Wright-Patterson AFB OH 45433-7101, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

CONTENTS

CONTENTS

CONTENTS

1. SCOPE

1.1 Scope.

This handbook provides the guidance for the development requirements and verifications for interior and exterior airborne lighting equipment, including specific requirements for interior lighting compatible with type I or II and class A or B night vision imaging systems (NVIS). This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-L-5667	Lighting Equipment, Aircraft Instrument Panel, General Specification For Installation Of **(Canceled)**
MIL-L-6503	Lighting Equipment, Aircraft, General Specification For Installation Of **(Inactive for New Design)**
MIL-P-7788	Panels, Information, Integrally Illuminated
MIL-L-8720	Control Indicator, J-2 Magnetic Compass, Type ML-1 **(Canceled)**
MIL-L-18276	Lighting, Aircraft-Interior, Installation Of
MIL-PRF-22885/101	Switch, Pushbutton, Illuminated, 4-Lamps, SPDT and DPDT, 5.0 Amperes Silver Contacts, 1 Ampere Max. Gold Contacts, Dripproof, Sunlight Readable, EMI/RFI Shielded, NVIS Compatible
MIL-L-27160	Lighting, Instrument, Integral, White, General Specification For **(Inactive for New Design)**

MIL-L-85314	Light Systems, Aircraft, Anti-Collision, Strobe, General Specification For
MIL-L-85762	Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-411	Aircrew Station Alerting System
MIL-STD-810	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-1472	Design Criteria Standard, Human Engineering
MIL-STD-1757	Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware **(Canceled)**

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Ave., Bldg 4D, Philadelphia PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

AIR FORCE

AFAMRL-TR-83-069	Electroluminescent Formation Lights for HC-130 P/N Special Operations: 1. Flight Test Candidates
AFAMRL-TR-83-087	Electroluminescent Formation Lights for A-10 Night Tactics
ASC/ENFC 96-01	Interface Doucment, Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible

NAVAL AIR WARFARE CENTER

Standard Operating Procedures

FAR PART 25	Airworthiness Standards: Transport Category Airplanes
NBS 480-16	Emergency Vehicle Warning Lights: State of the Art, 1978

(Copies of ASC/ENFC 96-01 are available from ASC/ENSI, 2530 Loop Rd West, Bldg 560, Wright-Patterson AFB OH 45433-7101.

2.3 Non-Government publications.

The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issue of the documents which are DoD adopted are those listed in the issue of the DoDISS, and supplement thereto.

Computation of the Effective Intensity of Flashing Lights, C. Douglas, Illuminating Engineer, Vol 52, No.12, Dec 1957

2.4 Order of precedence.

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Crew Systems Engineering (see JSSG-2010-1).

3.2 Crew Systems Automation, Information, and Control/Display Management (see JSSG-2010-2).

3.3 Cockpit/Crew Station/Cabin (see JSSG-2010-3).

3.4 Aircrew Alerting (see JSSG-2010-4).

3.5 Aircraft Lighting

3.5.1 Purpose.

This document establishes performance, test and acceptance requirements for aircraft interior and exterior lighting systems. It is applicable to all systems, subsystems, component equipment and hardware that provide the lighting environment in aircraft crewstations and compartments.

4.5 Aircraft Lighting Verification

4.5.1 Purpose.

This document establishes the verification requirements for aircraft interior and exterior lighting systems. It is applicable to all systems, subsystems, component equipment and hardware that provide the lighting environment in aircraft crewstations and compartments. The verifications (inspections/analyses/demonstrations/tests) specified herein shall verify the ability of the interior and exterior airborne lighting equipment to meet the requirements of section 3, herein. All verifications shall be the responsibility of the contractor; the Government reserves the right to witness, or conduct, any verifications.

4.5.1.1 Verification types.

Analysis. Verification by analysis shall prove the item meets specified requirements by technical evaluation of equations, charts, graphs, models, circuit diagrams, and representative data, or by evaluation of previously qualified equipment/software to equivalent or more stringent criteria.

Demonstration. Verification by demonstration involves the operation of the item. The item may be instrumented and its performance monitored, but only as an indirect function in support of the demonstration. Performance monitoring shall have quantitative limits for the determination of satisfactory operation.

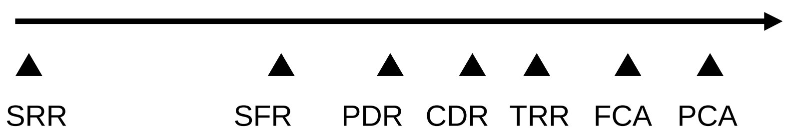
Inspection. Verification by inspection shall show through visual means, physical manipulation, gauging, or measurement that the requirements have been met. For software, inspection includes physical examination of documentation and/or code to verify conformance to specified requirements.

Test. Verification by test involves the operation of the item with instrumentation for recording, analyzing, and evaluating the resultant quantitative data. Acceptability of a unit shall be determined by comparing test data with quantitative limits as established in the specification.

Process control. The definition of this verification type is TBD.

Program Phase Timeline and Testing Requirements

Milestones to Check or Validate System Requirements



Concept Demonstration & Validation	Engineering & Manufacturing Development	Production & Deployment	Operations & Support

Ground Testing During Each Phase

Laboratory Tests	Laboratory Tests Bench Tests Component Performance Tests Environmental Tests Functional Tests on Air Vehicle	Component Certification Acceptance Procedures Air Vehicle System Functional Testing	Testing Required for Product Improvements

Flight Testing at the End of Each Phase

Concept Demonstration & Validation Flight Testing	DT&E Developmental Flight Testing & Evaluation	OT&E Operational Flight Testing & Evaluation	Flight Demonstration of Product Improvement

Milestones are:

System Requirements Review (SRR)

System Functional Review (SFR)

Preliminary Design Review (PDR)

Critical Design Review (CDR)

First Flight Review (FFR)

Functional Configuration Audit (FCA)

System Verification Review (SVR)

Production Go-Ahead (GO)

This generic program schedule is given to show how incremental verification may relate to each of the major program phases identified above. The table below has analysis, inspections, demonstrations and tests for a typical aircraft lighting engineering manufacturing development phase. The table was constructed to show a minimum level of contractor oversight. The table should be tailored for aircraft program under consideration with due consideration for cost, schedule, and technical risk. The table should also be tailored for other phases of the air vehicle program.

TABLE I. Incremental verification matrix.

Verifications Required to Validate Requirements by Milestone						
	SRR/ SFR	PDR	CDR	FFR	FCA/ SVR	GO
3.5 Aircraft Lighting	-	-	-	-	-	-
3.5.1 Purpose	-	-	-	-	-	-
3.5.2 Requirements	-	-	-	-	-	--
3.5.2.1 Interior lighting	-	-	-	-	-	-
3.5.2.1.1 General	I	I	I	I	I	Q
3.5.2.1.2 Lighting control location and actuation	I	I	I	D	D	Q
3.5.2.1.3 System integration	I	I, D	D	D, T	D	Q
3.5.2.1.4 Light leakage	I	I	I	D	D	Q
3.5.2.1.5 Chromaticity	I	D	T	D, T, P	I, P	Q, T
3.5.2.1.6 Spectral radiance	I	D	T	D, T, P	I, P	Q, T
3.5.2.1.7 Luminance	I	D	T	IP	I, P	Q
3.5.2.1.8 Cockpit and crew station lighting	-	-	-	-	-	-
3.5.2.1.8.1 Instrument lighting	I	I	I, T	I, D	I	Q
3.5.2.1.8.2 Console/control panel lighting	I	I	I, T	I, D	I	Q
3.5.2.1.8.3 Keyboard and keypad assemblies	I	I	I, T	I	I	Q
3.5.2.1.8.4 Floodlighting	I	I	I, T	I, D	I	Q
3.5.2.1.8.5 Visual displays	I	I	I, T	I, D	I	Q
3.5.2.1.8.5.1 Aircrew station signals	I	I	I, T	ID	I, P	Q
3.5.2.1.8.5.2 Electronic and electro-optical displays	I	I	I, T	I, D	I, P	Q
3.5.2.1.8.6 Passenger and compartment lighting	I	I	I, T	I, D	I	Q
3.5.2.1.8.6.1 Chart, utility, and worktable lighting	I	I	I	I, D	I	Q
3.5.2.1.8.6.2 Troop jump signals	I	I	I, P	I, D	I	Q
3.5.2.1.8.6.3 Interior emergency lighting locations	I	I	I, T	I, D	I	Q
3.5.3 Exterior lighting subsystems	-	-	-	-	-	-

TABLE I. Incremental verification matrix. - Contd

Verifications Required to Validate Requirements by Milestone						
	SRR/ SFR	PDR	CDR	FFR	FCA/ SVR	GO
3.5.3.1 Anticollision lighting	I	I	I, T	I, D, T	I	Q
3.5.3.2 Position lights	-	-	-	-	-	-
3.5.3.2.1 Position light location and chromaticity	I	I, A	I, T	I, T	I	Q
3.5.3.2.2 Position light distribution and intensity	I	I, A	I, T	I, T	I	Q
3.5.3.3 Aerial refueling lights	-	-	-	-	-	-
3.5.3.3.1 Tanker refueling light dimming	I	I	I, T	I, D	I	Q
3.5.3.3.2 Tanker rendezvous lights	I	I	I, P	D	I	Q
3.5.3.3.3 Tanker floodlighting	I	I	I, P	D	I	Q
3.5.3.3.4 Pilot director lights	I	I	I, P	D	I	Q
3.5.3.3.5 Fuel transfer indicators	I	I	I, P	D	I	Q
3.5.3.3.6 Boom marker and nozzle illumination	I	I	I	D	I	Q
3.5.3.3.7 Receiver aircraft refueling receptacle floodlighting	I	I	I	D	I	Q
3.5.3.3.8 Receiver aircraft drogue probe illumination	I	I	I	D	I	Q
3.5.3.4 Landing and taxi lighting	I	I	I	D, T	I	Q
3.5.3.5 Formation lights	I	I, A	I, T	D	I	Q
3.5.3.6 Fuselage lights	I	I, A	I, T	D	I	Q
3.5.3.7 Inspection lights	I	I	I	D	I	Q
3.5.3.8 Exterior emergency lighting	I	I	I	D	I	Q

A - Analysis, I - Inspection, D - Demonstration, T - Testing, P - Documentation,

Q - Process/Quality Control

3.5.2 Requirements.

3.5.2.1 Interior lighting.

3.5.2.1.1 General.

The lighting system shall provide adequate illumination for the anticipated range of aircrew tasks. During night operations, the lighting system shall provide the aircrew members with a capability to rapidly and accurately obtain required crew station information with unaided eye vision. The lights shall not cause direct or indirect glare that interferes either with the aircrew member's interior or exterior unaided vision and with the image intensification capabilities of the NVIS. Reflections from the canopy and windshields and side windows shall be minimized. Reflections that affect the outside vision of the aviator wearing NVIS shall not be permitted. Specular reflections resulting from aircraft lighting sources shall not occur within the area subtended by a solid angle of one steradian centered at the pilot's design eye position and along the pilot's horizontal vision line. During day operations, all illuminated visual signals and cockpit/crew station displays shall be readable in the full range of anticipated ambient lighting requirements.

REQUIREMENT RATIONALE (3.5.2.1.1)

Night flying requires information in the cockpit from displays and external vision. This requires low levels of cockpit illumination and a balanced lighting system to minimize eye fatigue.

REQUIREMENT GUIDANCE (3.5.2.1.1)

Mockups are usually required in the Statement of Work. Invoke as required by the procuring activity during the development phase of any lighting subsystem. Mockup, though expensive, can reveal design flaws that could seriously affect crew member performance and would avoid costly modifications. The mockup should be used iteratively as a design tool to constantly improve the design during the course of development. Layout, luminances, reflected glare, distributions, etc., can be initially verified through analysis, test, inspection or demonstration of the mockup. The sources for this requirement are MIL-L-6503 and MIL-L-18276.

REQUIREMENT LESSONS LEARNED (3.5.2.1.1)

TBD

4.5.2 Verification

4.5.2.1 Interior lighting.

4.5.2.1.1 General.

The general lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.10, and 4.2.1.1.10.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.1)

In order to determine the adequacy of the instrument lighting systems for each new model aircraft, or modification thereof, which would affect the design of the instrument panel layout or the lighting system, a complete mockup of the instrument lighting system involved shall be prepared by the aircraft contractor for inspection and approval by the procuring activity.

VERIFICATION GUIDANCE (4.5.2.1.1)

Lighting mockups are important, particularly for new configurations or upgrades. They can be costly and time consuming. Much discretion should be exercised in defining the extent to which completeness of the mockup or simulation is required. In aircraft with extensive canopies or windows, control of internal reflections can be as critical as the lighting.

The mockup shall be provided with the actual production (or production prototype) lighting equipment and instruments or models of instruments which have lighting that is representative of production lighting insofar as practical, which will afford a reasonable indication of the effectiveness of the lighting involved. Exterior lighting that may impact on interior lighting, viewability, or safety will be mocked up in conjunction with a suitable cockpit mockup.

A practical, end-to-end, SYSTEM LEVEL verification test of NVIS compatible interior lighting using Visual Acuity as the measure can be outlined as follows. This test has been useful in determining that a contractor has met his NVIS requirements in a simple, straight forward, and quantifiable way. This test may be used as the sole pass/fail, contracturally required, verification criteria or it can be used with other verification methods as suggested by the Verification Matrix guidance found elswhere in this document.

a. Place aircraft with full-up prototype or pre-production NVIS interior lighting in an environment which is as dark as possible (e.g., a hangar with the doors shut, lights out, at nightime, etc., an engine hush house, etc.).

b. Place a Visual Acquity eye chart(s) a set distance from the nose of the aircraft where the pilot/copilot can see it (e.g., 20-30 feet). Generally these charts have a high contrast (i.e., black on white) square wave pattern on them. Each chart has a different spatial frequency on it.

c. While looking thru the NVGs that will be used operationally, have the test subjects read the charts as if taking an eye test and record their Visual Acuity scores. Do this with NVIS lights ON as one condition and with all lights OFF as the other condition. The canopy should be closed.

d. This test may be repeated thru the HUD & canopy (i.e, straight ahead) and off-axis (i.e., thru canopy alone)

e. Compare the two Visual Acuity scores. If there is a signifigant difference/degradation in Visual Acguity between NVIS lights ON and light OFF, then this may be due to an unacceptable level of NVIS incompatible light. Advise contracturally pre-defining an acceptable, numerical Visual Acuity score.

f. Highly recommend contacting Armstrong Laboratory (AL/HRA) at Mesa, AZ (formerly William AFB), DSN 474-6561, for help with this test.

VERIFICATION LESSONS LEARNED (4.5.2.1.1)

TBD

3.5.2.1.2 Lighting control location and actuation.

Sufficient control over cockpit lighting shall be provided to allow each crew member to control the intensity, and balance of all the interior lighting subsystems that provide illumination for the crew station. Control shall be provided to allow the crew member the flexibility to reduce glare, distractions, and fatigue. The means to affect lighting control shall be available to multiple crewmembers (when appropriate) simultaneously and independently. Lighting controls shall be located to permit direct viewing, without requiring extreme head movements, during operation. The design shall preclude inadvertent actuation of non-NVIS compatible lighting during NVIS operations. Separate intensity controls shall be provided for each electro-optical displays.

REQUIREMENT RATIONALE (3.5.2.1.2)

Dimming is required for nighttime flying.

REQUIREMENT GUIDANCE (3.5.2.1.2)

Invoke this requirement when instruments, panels, controls, etc., are to be used at night or in areas where dark adaptation is required. Fill in the appropriate subsystem name and invoke requirements as applicable. (a) The dimming range of the instruments should be continuously variable from “off” to “full intensity” over the entire range of the control. Discrete, two- or seven-position controls do not provide the adjustability that is required for nighttime flying. Adjustability is also effected if the entire luminance range is controlled by only small displacements of the control. (b) Logarithmic changes in luminosity are perceived almost linearly by observers. Instrument luminous increase and decrease in log lamberts will present a near linear increase and decrease to the observer, allowing better control. A linear luminous increase and decrease would present variable brightness changes throughout the control range. (c) Individual instrument trimming, accessible by maintenance personnel, is used for balancing the entire instrument suite and rebalancing a new instrument when installed. Balancing should be performed subjectively and not photometrically, at night, by a pilot and ground crew. (d) Operational luminance settings range from about 0.3 to 0.001 fL. Poor control in this low range will adversely affect instrument readability and out-of-the-cockpit visibility. An acceptable lower limit is 0.001 fL. (e) The tracking of instrument luminances in the low end is critical. Often a pilot desires lower luminance levels but finds some instruments are brighter or dimmer which results in an overall higher average setting. The tracking requirement interacts with the balancing requirement; ± 20 percent is recommended and lower is better. Current technology makes achieving .003 difficult, but push the state of the art to achieve the best balancing and grant waivers based on program constraints if necessary. (f) Current leaking through incandescent lamp filaments can create an infrared (IR) source that may create a detectable signature that can interfere with the operation of NVIS (since they amplify IR energy).

These dimming requirements are most critical to instruments and panels. Other subsystems, such as floodlighting or external refueling lights, do not require all of the above requirements.

REQUIREMENT LESSONS LEARNED (3.5.2.1.2)

(a) Some early aircraft had two- or seven-step intensity controls; the first click was often too bright. (f) A preliminary look at an aircraft to be modified for NVIS compatibility found IR that affected NVIS due to current leakage through the filaments.

4.5.2.1.2 Lighting control location and actuation.

The lighting control location and actuation requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.10, of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.2)

A direct measurement of luminances using calibrated photometric equipment is the standard method to verify specified levels.

VERIFICATION GUIDANCE (4.5.2.1.2)

Photometers must be calibrated to a standard traceable to the National Bureau of Standards (NBS). The aperture must be one-half the width of the symbol stroke (letter, pointer, etc.). A representative set of averaged measurement points should be used for these evaluations. Measurements are to be made in a dark room. Perform appropriate log transformations on data to verify specified rate of changes. See refueling light dimming section.

VERIFICATION LESSONS LEARNED (4.5.2.1.2)

TBD

3.5.2.1.3 System integration.

Instruments, displays and consoles shall be provided with primary and secondary lighting subsystems. All lighting sources shall track together in luminance over the entire range of the lighting system. The lights shall not be a source of direct or reflected glare to aircrew members or be seen by outside observers. Unless otherwise specified by the acquiring activity, the lighting subsystem shall be designed to operate from the power sources identified in the system or aircraft electrical power interface control document(s) or requirements. The lighting system design shall support the balancing of each primary instrument and control panel lighting component as an "O" Level maintenance function. Each component shall be marked to indicate the lighting color and when appropriate NVIS type and class. Class A, B, and C lighting components are compatible with NVIS utilizing a variety of minus blue objective lens filters as depicted in table II. The secondary instrument and console lighting sub-systems provide a backup capability during electrical casualty situations. The lighting systems and subsystem shall meet the electromagnetic interference (EMI) and electromagnetic compatibility (EMC) requirements of the system or aircraft EMI/EMC interface control doument(s) or requirements. A capability shall be provided to automatically disconnect the power from light circuits in the event of a ground short in the fixture, circuit or controls. The number of different lamp types shall be minimized. No current shall flow through the lamps when the luminance is set to full OFF.

REQUIREMENT RATIONALE (3.5.2.1.3)

The lighting system should be considered as part of the overall system. The Class of the NVGs to be used by the customer should specified or known beforehand. This will help insure the overall quality of the product and will result in greater user satisfaction.

REQUIREMENT GUIDANCE (3.5.2.1.3)

See MIL-STD-464 for guidance.

REQUIREMENT LESSONS LEARNED (3.5.2.1.3)

Lights which do not track when brightned or dimmed will result in hot spots, glare, or reflections. Glare and reflections can reduce the view of the crewmember to the outside world and can increase the signature of the system to a threat. Light balancing, labeling, backup, automatic disconnetion, minimum parts count are important logistics, supportiblity, and life cycle cost considerations. "OFF" must be defined as zero current flow, not: no detectable/perceiveable light output. NVGs may detect light, gain down, and thus reduce the outside viewing distance, all unknownst to the wearer.

NVIS Class C describes a NVG which has filter characteristics which reliably see certain types of HUD output. Class B NVG users had difficulty finding sets of Class B NVGs which see the LANTIRN holographic HUD symbology. The LANTIRN HUD is used on the F-16C/D Block 40/42s and the F-15E. Some Class B NVGs could see the LANTIRN HUD symbology and some could not. This was because of an anomoly with the Class B NVG filter specification. The definition of Class C corrects this situation and is fully backward compatible with Class B NVGs, that is, NVIS Lighitng chromoticity and radiance requirements, for example, are unaffected if Class C NVGs are used. The lesson learned is: Know your HUD's light output characteristics and what Class NVGs your customer will use.

Consideration must be give to the design of the canopy, windscreen, or transparencies and their coatings if there is a NVIS requirment. Glass has been shown to has very poor near Infared (IR) transmissivity properties. This greatly degrades the ability of NVGs to see the outside world (e.g., A-10). Plexiglass & polycarbonates have been shown to have relatively good transmissivity properties. Certain types of EMI/EMC and/or radar signature related transparency coatings have been shown to have poor near IR and thus must be chosen with IR transmissivity and NVG operations in mind. Close cooperation between the transparency engineer and the lighting engineer must be maintained for a properly integrated system.

4.5.2.1.3 System integration.

The system integration requirements are verified and reverified during the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.1, 4.2.1.1.2, and 4.2.1.1.3 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.3)

Lighting system integration requirements must be contracturally verified to insure the overall quality of the product and user satisfaction.

VERIFICATION GUIDANCE (4.5.2.1.3)

See the applicable verification sections of MIL-L-8720, MIL-L-85762A, and Naval Air Warfare Center Aircraft Division Code 4.6.4.2 Standard Operating Procedues (SOPs) for guidance.

VERIFICATION LESSONS LEARNED (4.5.2.1.3)

Recommend that a system level integration verification be required and performed. These verifications should be performed as early in the design process as possible, certainly no later than on the DT&E First Article or prototype. Both crew members and logistics personnel should be invloved.

3.5.2.1.4 Light leakage.

The lighting system shall be so housed as to prevent the leakage of stray light and to shield all lamp filaments from direct view.

REQUIREMENT RATIONALE (3.5.2.1.4)

Stray light acts as a glare source and affects visual adaptation that can cause reduced visual performance.

REQUIREMENT GUIDANCE (3.5.2.1.4)

Invoke this requirement for all lighted subsystems. Stray light, hot spots, or direct viewing of the lamp acts as a glare source, reducing visual performance. Glare can also induce a higher overall light setting, which tends to reduce the out-of-the-cockpit visibility. The source for this requirement is MIL-L-27160.

REQUIREMENT LESSONS LEARNED (3.5.2.1.4)

TBD

4.5.2.1.4 Light leakage.

The light leakage requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in section 4 of MIL-L-85762A and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.4)

Demonstration of the lighting system is the easiest and most cost-effective method to verify compliance with the requirement.

VERIFICATION GUIDANCE (4.5.2.1.4)

View mockup or actual cockpit and note any hot spots, bare filaments, or induced reflections. To check for light leaks which would interfere with NVIS, view the lighting mockup or actual cockpit with any kind of NVIS (either second or third generation) because a light leak will be evident through either type of device. This inspection is important because a spectroradiometer measurement may not always detect a light leak unless the leak is in the field of view of the spectroradiometer.

TABLE II. Relative spectral response of NVIS.

Class A NVIS ($G_A(\lambda)$).				Class B NVIS ($G_A(\lambda)$).				Class C NVIS ($G_A(\lambda)$).			
Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response
450	1.0000E-04	690	9.3790E-01	450	1.0000E-05	690	9.3790E-01	450	1.0000E-0	690	9.3790E-01
455	1.1250E-04	695	9.4480E-01	455	1.1250E-05	695	9.4480E-01	455	1.1250E-0	695	9.4480E-01
460	1.2500E-04	700	9.5170E-01	460	1.2500E-05	700	9.5170E-01	460	1.2500E-0	700	9.5170E-01
465	1.3750E-04	705	9.5860E-01	465	1.3750E-05	705	9.5860E-01	465	1.3750E-0	705	9.5860E-01
470	1.5000E-04	710	9.6550E-01	470	1.5000E-05	710	9.6550E-01	470	1.5000E-0	710	9.6550E-01
475	1.6172E-04	715	9.7304E-01	475	1.6172E-05	715	9.7304E-01	475	1.6172E-0	715	9.7304E-01
480	1.7500E-04	720	9.7930E-01	480	1.7500E-05	720	9.7300E-01	480	1.7500E-0	720	9.7300E-01
485	1.9375E-04	725	9.8020E-01	485	1.9375E-05	725	9.8020E-01	485	1.9375E-0	725	9.8020E-01
490	2.1250E-04	730	9.8280E-01	490	2.1250E-05	730	9.8280E-01	490	2.1250E-0	730	9.8280E-01
495	2.2266E-04	735	9.8838E-01	495	2.2266E-05	735	9.8838E-01	495	2.2266E-0	735	9.8838E-01
500	2.3750E-04	740	9.9310E-01	500	2.3750E-05	740	9.9310E-01	500	2.3750E-0	740	9.9310E-01
505	2.7656E-04	745	9.9719E-01	505	2.7657E-05	745	9.9719E-01	505	2.7657E-0	745	9.9719E-01
510	3.1250E-04	750	1.0000E+00	510	3.1250E-05	750	1.0000E+00	510	3.1250E-0	750	1.0000E+00
515	3.4297E-04	755	1.0000E+00	515	3.4297E-05	755	1.0000E+00	515	3.4297E-0	755	1.0000E+00
520	3.7500E-04	760	1.0000E+00	520	3.7500E-05	760	1.0000E+00	520	3.7500E-0	760	1.0000E+00
525	4.1875E-04	765	1.0000E+00	525	4.1875E-05	765	1.0000E+00	525	4.1875E-0	765	1.0000E+00
530	4.6250E-04	770	1.0000E+00	530	4.6250E-05	770	1.0000E+00	530	4.6250E-0	770	1.0000E+00
535	5.0703E-04	775	9.9814E-01	535	5.0703E-05	775	9.9814E-01	535	5.0703E-0	775	9.9814E-01
540	5.5000E-04	780	9.9660E-01	540	5.5000E-05	780	9.9660E-01	540	5.5000E-0	780	9.9660E-01
545	5.8359E-04	785	9.9543E-01	545	5.8359E-05	785	9.5430E-01	545	5.8359E-0	785	9.5430E-01
550	6.2500E-04	790	9.9450E-01	550	6.2500E-05	790	9.9450E-01	550	6.2500E-0	790	9.9450E-01
555	7.0000E-04	795	9.9380E-01	555	7.0000E-05	795	9.9830E-01	555	7.0000E-0	795	9.9830E-01
560	7.7500E-04	800	9.9310E-01	560	7.7500E-05	800	9.9310E-01	560	7.7500E-0	800	9.9310E-01
565	8.5000E-04	805	9.8620E-01	565	8.5000E-05	805	9.8620E-01	565	8.5000E-0	805	9.8620E-01

TABLE II. Relative spectral response of NVIS. - Contd

Class A NVIS ($G_A(\lambda)$).				Class B NVIS ($G_A(\lambda)$).				Class C NVIS ($G_A(\lambda)$).			
570	9.2500E-04	810	9.7930E-01	570	9.2500E-05	810	9.7930E-01	570	9.2500E-0	810	9.7930E-01
575	1.4525E-03	815	9.7283E-01	575	9.7688E-05	815	9.7283E-01	575	9.7688E-0	815	9.7283E-01
580	1.9800E-03	820	9.6550E-01	580	1.1000E-04	820	9.6550E-01	580	1.1000E-0	820	9.6550E-01
585	4.7175E-03	825	9.5515E-01	585	1.2566E-04	825	9.5515E-01	585	1.2566E-0	825	9.5515E-01
590	7.8000E-03	830	9.4480E-01	590	1.8200E-04	830	9.4480E-01	590	1.8200E-0	830	9.4480E-01
595	1.1400E-02	835	9.3402E-01	595	2.6581E-04	835	9.3402E-01	595	2.6581E-0	835	9.3402E-01
600	1.5000E-02	840	9.2410E-01	600	5.2500E-04	840	9.2410E-01	600	5.2500E-0	840	9.2410E-01
605	2.6263E-02	845	9.1720E-01	605	1.0183E-03	845	9.1720E-01	605	1.0183E-0	845	9.1720E-01
610	5.2000E-02	850	9.1030E-01	610	2.0000E-03	850	9.1030E-01	610	2.0000E-0	850	9.1030E-01
615	8.8388E-02	855	8.6334E-01	615	3.4569E-03	855	8.6334E-01	615	3.4569E-0	855	8.6334E-01
620	1.7500E-01	860	8.0000E-01	620	6.2500E-03	860	8.0000E-01	620	6.2500E-0	860	8.0000E-01
625	4.3288E-01	865	7.2848E-01	625	9.0935E-03	865	7.2848E-01	625	9.0935E-0	865	7.2848E-01
630	6.1380E-01	870	6.5520E-01	630	1.8414E-02	870	6.5520E-01	630	1.8414E-0	870	6.5520E-01
635	6.7756E-01	875	5.8016E-01	635	4.6447E-02	875	5.8016E-01	635	4.6447E-0	875	5.8016E-01
640	7.4480E-01	880	5.0340E-01	640	7.4480E-02	880	5.0340E-01	640	7.4480E-0	880	5.0340E-01
645	8.2458E-01	885	4.2523E-01	645	2.0949E-01	885	4.2523E-01	645	2.0949E-0	885	4.2523E-01
650	8.8970E-01	890	3.4480E-01	650	4.0037E-01	890	3.4480E-01	650	4.0037E-0	890	3.4480E-01
655	8.9654E-01	895	2.5704E-01	655	6.7139E-01	895	2.5704E-01	655	6.7139E-0	895	2.5704E-01
660	9.0340E-01	900	1.7500E-01	660	9.0340E-01	900	1.7500E-01	660	9.0340E-0	900	1.7500E-01
665	9.1051E-01	905	1.1009E-01	665	9.1073E-01	905	1.1009E-01	665	9.1073E-0	905	1.1009E-01
670	9.1720E-01	910	6.2100E-02	670	9.1720E-01	910	6.2100E-02	670	9.1720E-0	910	6.2100E-02
675	9.2241E-01	915	4.3125E-02	675	9.2741E-01	915	4.3125E-02	675	9.2741E-0	915	4.3125E-02
680	9.2760E-01	920	2.7600E-02	680	9.2760E-01	920	2.7600E-02	680	9.2760E-0	920	2.7600E-02
685	9.3254E-01	925	1.5525E-02	685	9.3254E-01	925	1.5525E-02	685	9.3254E-0	925	1.5525E-02
		930	6.9000E-03			930	6.9000E-03			930	6.9000E-03

VERIFICATION LESSONS LEARNED (4.5.2.1.4)

Ring-type lighting often has direct or reflected lamp light. F-15 instruments on lower instrument panels were mounted at such an angle that filaments were visible. This was found in the lighting mockup inspection.

Light leaks that interfere with NVIS most often result from cracked or poorly installed filters.

3.5.2.1.5 Chromaticity.

The color of illuminated information (alphanumeric and symbolic) on instruments, controls, control panels and on illuminated areas in designated crew station and compartment areas shall be as specified in table III. These lighting colors and limits are designated as "NVIS GREEN A", "NVIS GREEN B", "NVIS YELLOW" and "NVIS RED".

REQUIREMENT RATIONALE (3.5.2.1.5)

Chromaticity (color) of aircraft lighting must be specified to optimize the luminous efficiency of the eye while eliminating overlap into the spectral sensitivity of the NVIS.

REQUIREMENT GUIDANCE (3.5.2.1.5)

Use the appropriate lighting components and type/class NVIS as specified in table III. At the illumination level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 1. This circle is determined by substituting the applicable u'_1 and v'_1 and radius (r) values of table III in Formula 1.

Use the appropriate lighting components and type/class NVIS as specified in table III. At the illumination level specified in table III the u′ and v′ chromaticity coordinate values measured off a reflectance standard (see below) shall be within the area bounded by a circle as shown on figure 2. The source for this requirement is MIL-L-85762.

Reflectance standard. The reflectance standard shall have a lambertian reflecting surface with reflectivity greater than 90% from 380 nm to 930 nm. The length and width of the reflecting surface shall be at least 2 inches by 2 inches.

REQUIREMENT LESSONS LEARNED (3.5.2.1.5)

It is necessary to specify a level of luminance at which the color requirement shall be met so that various manufacturers are comparing color measurements on an equal basis. Some lighting components (incandescent, in particular) change color when the luminance is changed. This level of luminance was chosen because U.S. Air Force tests have shown that 0.1 fL is the level typically used by pilots when wearing NVIS.

Some studies have suggested that reading with highly saturated lighting for long periods of time is irritating and causes eye fatigue. These considerations place the optimum dominant wavelength for general crew station lighting in the yellowish-green and less saturated area of the UCS diagram. After taking into consideration all of these factors, NVIS Green A (see figure 2) is usually designated as the primary color for crew station lighting. However, daylight readability requirements usually require the manufacturer to produce colors that are extremely saturated. Therefore, NVIS Green B was formulated to accommodate those lighting components which cannot be made daylight readable with a Green A color. Lighting components must meet these color requirements when illuminated to produce 0.1 fL of luminance.

TABLE III. Chromaticity requirements.

Lighting Component(s)	Type I										Type II									
	Class A					Class B					Class A					Class B				
	u'_1	v'_1	r	fl	NVIS Color	u'_1	v'_1	r	fl	NVIS Color	u'_1	v'_1	r	fl	NVIS Color	u'_1	v'_1	r	fl	NVIS Color
Primary	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Secondary	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Illuminated controls	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Compartment lighting	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Utility, work and inspection	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Caution and advisory signals	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A	.088	.543	.037	0.1	Green A
Jump lights	.088 .274	.543 .622	.037 .083	0.1 15.0	Green A Yellow	.088 .274	.543 .622	.037 .083	0.1 15.0	Green A Yellow	.274	.543 .622	.037 .083	0.1 15.0	Green A Yellow	.088 .274	.543 .622	.037 .083	0.1 15.0	Green A Yellow
Special lighting components where increased display emphasis by highly saturated (monochromatic) colors is necessary, or adequate display light readability cannot be achieved with "GREEN A"	.131	.623	.057	0.1	Green B	.131	.623	.057	15.0	Green B	.131	.623	.057	0.1	Green B	.131	.623	.057	15.0	Green B
Warning signal	.274	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow	.274			15.0	Yellow	.274	.622	.083	15.0	Yellow
		Not Applicable				.450	.550	.060	15.0	Red		Not Applicable				.450	.550	.060	15.0	Red
Master Caution Signal	.274	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow

Where:
u'_1 and v'_1 = 1976 UCS chromaticity coordinates of the center point of the specified color area.

r = radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color.

fL = footlamberts

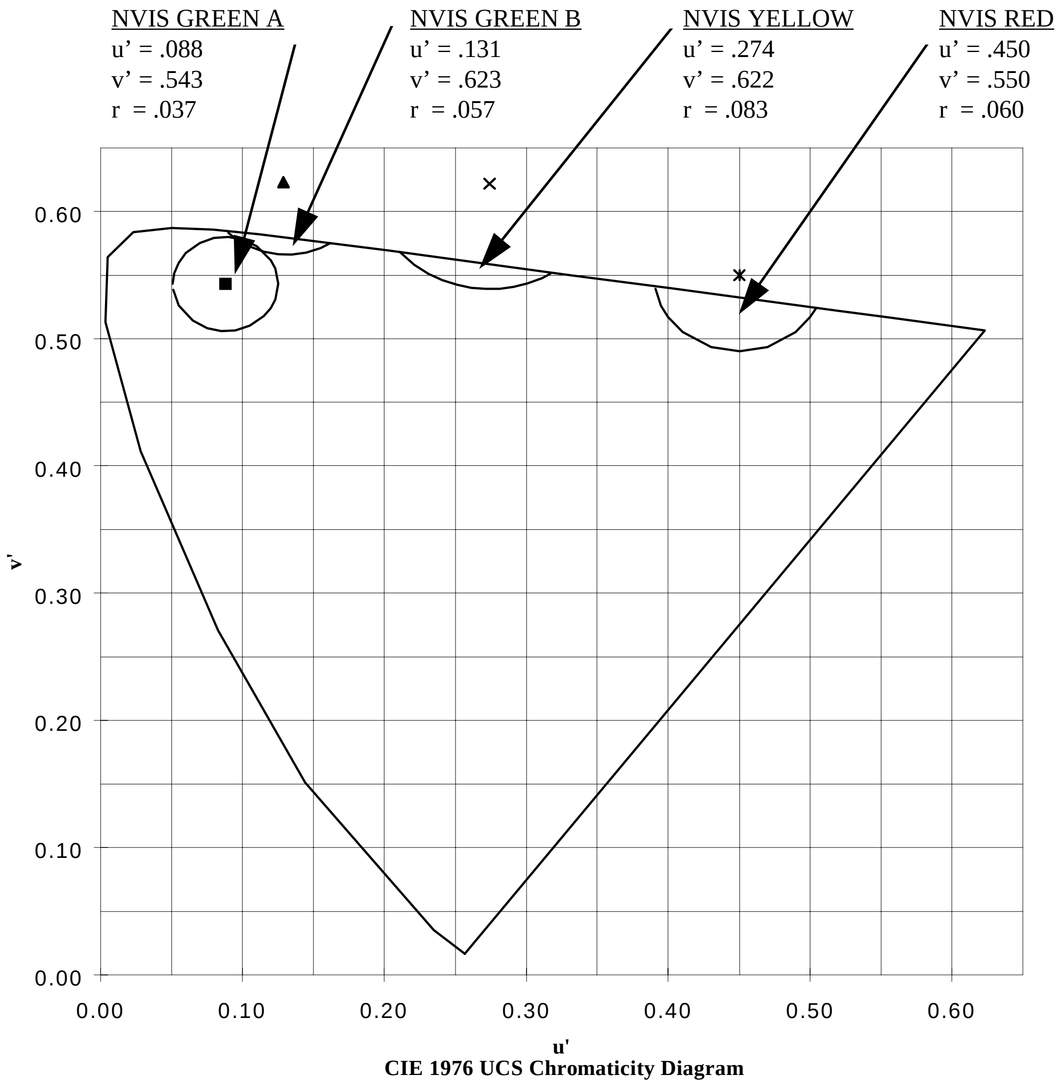


FIGURE 1. NVIS lighting color limits.

Because Class A NVIS are extremely sensitive to radiance at wavelengths longer than about 600 nm, red cannot be used in the cockpit with Class A. Although most pilots express a strong preference for retaining red for warning lights, there presently exists no performance data that substantiate this belief. However, color coding of annunciators is extremely beneficial when it is necessary to get the crewmember's attention. Therefore, NVIS Yellow was developed to allow certain annunciators (warning and master caution, in particular) to be made a different color than the rest of the cockpit lighting. Caution indicators in an annunciator panel should be NVIS Green because it is the master caution which needs to draw the crewmember's attention. If the master caution indicator lights, the crewmember can reset it and determine the specific problem from the annunciator panel. Since NVIS Yellow interferes somewhat with Class A NVIS, the amount of yellow in the cockpit should be kept to a minimum. With class B NVIS, a limited amount of "red" (it is more orange than red) can be used in the cockpit. NVIS Red was kept as close to orange as possible to minimize NVIS interference. NVIS Red is not as bright in daylight as NVIS Yellow because of the filtering necessary to make red NVIS compatible. NVIS Red is left as an optional color for class B NVIS.

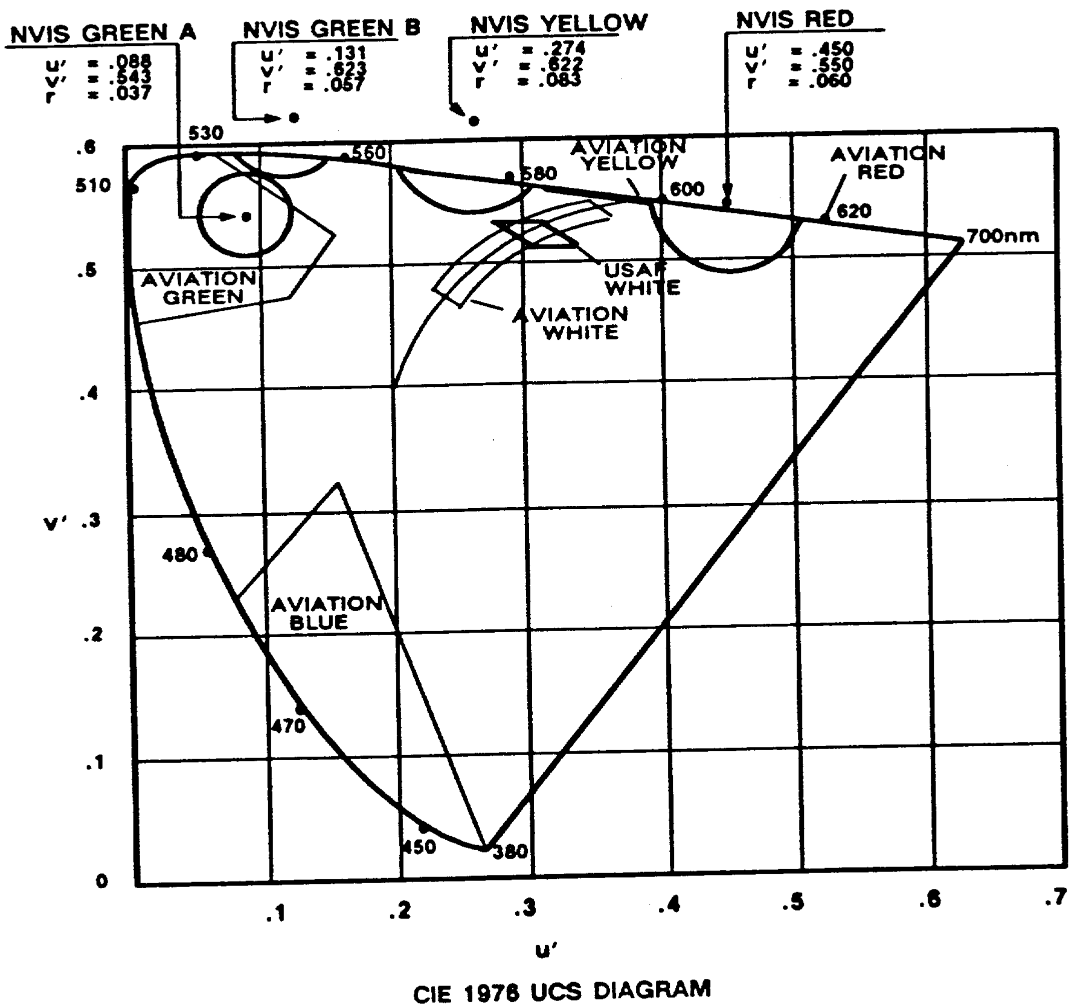


FIGURE 2. Aeronautical colors plotted in CIE-UCS 1976 color space.

Where the boundaries for aviation colors are:

Aviation Red, Type 1(a): 1976 and 1931 Chromaticity Coordinates			
u′	v′	x	y
.46575	.52950	.66300	.33500
.47511	.52809	.66800	.33000
.48470	.52665	.57300	.32500
.49453	.52516	.67800	.32000
.50462	.52364	.68300	.31500
.51497	.52208	.68800	.31000
.52560	.52048	.69300	.30500
.53651	.51883	.69800	.30000
.54772	.51714	.70300	.29500
.55924	.51540	.70800	.29000
Aviation Yellow, Type 1(b): 1976 and 1931 Chromaticity Coordinates			
u′	v′	x	y
.40232	.53762	.62300	.37000
.38712	.53994	.61300	.38000
.32625	.54925	.56800	.42500
.33094	.55036	.57500	.42500
.39241	.54114	.62000	.38000
.40777	.53883	.63000	.37000
Aviation Green, Type 1 (c) 1976 and 1931 Chromaticity Coordinates			
u′	v′	x	y
.01054	.45759	.02000	.38600
.01587	.45833	.03000	.38500
.10867	.46561	.18800	.35800
.14673	.52236	.29200	.46200
.06338	.58614	.19000	.78100

Figure 2. Aeronautical colors plotted in CIE-UCS 1976 color space. – Contd.

Aviation Blue, Type 1 (d): 1976 and 1931 Chromaticity Coordinates			
u′	v′	x	y
.10223	.23002	.10300	.10300
.10370	.23333	.10500	.10500
.10588	.23824	.10800	.10800
.10732	.24146	.11000	.11000
.14737	.33158	.17500	.17500
.25271	.03249	.17500	.01000
.25604	.02304	.17500	.00700
.25830	.01661	.17500	.00500

Aviation White, Type 1(e): 1976 and 1931 Chromaticity Coordinates			
u′	v′	x	y
.31732	.54387	.54900	.41820
.32872	.53646	.54900	.39820
.31923	.53582	.53780	.40120
.31045	.53486	.52670	.40330
.30250	.53368	.51600	.40460
.29519	.53229	.50560	.40520
.28858	.53075	.49570	.40520
.28251	.52910	.48620	.40470
.27691	.52730	.47700	.40370
.27177	.52541	.46820	.40230
.26710	.52348	.45990	.40060
.25492	.51739	.43690	.39410
.25149	.51532	.43000	.39160
.24828	.51325	.42340	.38900
.24530	.51117	.41710	.38630
.24248	.50907	.41100	.38350
.23990	.50701	.40530	.38070
.23751	.50499	.39990	.37790
.23523	.50298	.39470	.37510
.23307	.50099	.38970	.37230

Figure 2. Aeronautical colors plotted in CIE-UCS 1976 color space. – Contd.

Aviation White, Type 1(e): 1976 and 1931 Chromaticity Coordinates (Contd)			
u′	v′	x	y
.23109	.49902	.38500	.36950
.22920	.49712	.38050	.36680
.22740	.49518	.37610	.36400
.22570	.49336	.37200	.36140
.22417	.49150	.36810	.35870
.22272	.48972	.36440	.35610
.22130	.48798	.36080	.35360
.21999	.48626	.35740	.35110
.21875	.48454	.35410	.34860
.21759	.48289	.35100	.34620
.20979	.49247	.35100	.36620
.21093	.49403	.35410	.36860
.21216	.49565	.35740	.37110
.21344	.49728	.36080	.37360
.21485	.49892	.36440	.37610
.21627	.50062	.36810	.37870
.21777	.50237	.37200	.38140
.21943	.50410	.37610	.38400
.22120	.50594	.38050	.38680
.22306	.50775	.38500	.38950
.22499	.50961	.38970	.39230
.22711	.51151	.39470	.39510
.22933	.51342	.39990	.39790
.23167	.51535	.40530	.40070
.23419	.51731	.41100	.40350
.23694	.51931	.41710	.40630
.23985	.52130	.42340	.40900
.24297	.52328	.43000	.41160
.24630	.52526	.43690	.41410

Figure 2. Aeronautical colors plotted in CIE-UCS 1976 color space. – Contd.

Aviation White, Type 1(e): 1976 and 1931 Chromaticity Coordinates (Contd)			
u′	v′	x	y
.24992	.52724	.44420	.41650
.25390	.52917	.45190	.41860
.25810	.53111	.45990	.42060
.26262	.53297	.46820	.42230
.26759	.53479	.47700	.42370
.27299	.53654	.48620	.42470
.27884	.53815	.49570	.42520
.28520	.53965	.50560	.42520
.29222	.54103	.51600	.42460
.29985	.54221	.52670	.42330
.30825	.54319	.53780	.42120
.31752	.54392	.54930	.41820
USAF White or Blue–Filtered White, Type 1(f): 1976 and 1931 Chromaticity Coordinates			
U′	V′	X	y
.24779	.51106	.42000	.38500
.23140	.52686	.42000	.42500
.25627	.53273	.46000	.42500
.27463	.51716	.46000	.38500

Figure 2. Aeronautical colors plotted in CIE-UCS 1976 color space. – Contd.

4.5.2.1.5 Chromaticity.

The chromaticity requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.7.2 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.5)

Direct measurement of lighting components with a spectroradiometer or photometer is the most accurate method to assure that the chromaticity is compatible with the type/class NVIS to be used.

VERIFICATION GUIDANCE (4.5.2.1.5)

Conformance to these colors and color limits is determined by the transformation of the 1931 CIE x and y chromaticity coordinates (Formulas 2 through 8 below) to the 1976 UCS u' and v' chromaticity coordinates (Formulas 9 and 10). These derived u′ and v′ chromaticity coordinates for the display and equipment colors are applied in the following formula:

The color of illuminated information (alphanumeric and symbolic) on instruments, controls, control panels and on illuminated areas in designated crew station and compartment areas shall be as specified herein for that component. These lighting colors and limits are shown on the chromaticity diagrams on figure 1, NVIS lighting color limits, and are designated as “NVIS GREEN A”, “NVIS GREEN B”, “NVIS YELLOW” and “NVIS RED”. Conformance to these colors and color limits is determined by Formula 1:

$$(u' - u'_1)^2 + (v' - v'_1)^2 \leq (r)^2 \qquad \text{(Formula 1)}$$

Where:

u' and v'	=	1976 UCS chromaticity coordinates of the test article.
u'_1 and v'_1	=	1976 UCS chromaticity coordinates of the centerpoint of the specified color area.
r	=	radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color.

a. For primary lighting chromaticity measurements, the luminance shall be measured using either a spectroradiometer or photometer meeting the requirements specified in appendix B of ASC/ENFC 96-01. With the specified luminance achieved, the spectral output of the lighting component shall be measured with a spectroradiometer which meets the requirements specified. Each spectral measurement shall be made using the actual aircraft lighting source, filter, and fixture. The spectroradiometer shall be placed a distance from the device being tested so that several numbers, letters, or indicia are included within the spectroradiometer test field. The x and y 1931 CIE and the u′ and v′ 1976 UCS chromaticity coordinate points shall then be calculated using the following formulas. Most modern spectroradiometers perform these calculations with the microprocessors within the instrument.

$$N(\lambda) = I(\lambda)/R(\lambda) \qquad \text{(Formula 2)}$$

Where:

$N(\lambda)$	=	spectral radiance of the lighting component (W/cm^{2}sr nm or normalized)
$I(\lambda)$	=	detector current (amperes)
$R(\lambda)$	=	spectroradiometer spectral sensitivity (amperes cm@ sr nm/W)
$d\lambda$	=	5 nm
x	=	1931 CIE relative spectral response of the eye (color matching function)
y	=	1931 CIE relative spectral response of the eye (color matching function)

z = 1931 CIE relative spectral response of the eye (color matching function)

X = CIE tristimulus value

Y = CIE tristimulus value

Z = CIE tristimulus value

u′ = 1976 UCS chromaticity coordinate transformation of CIE x

v′ = 1976 UCS chromaticity coordinate transformation of CIE y

x = 1931 CIE chromaticity coordinate

y = 1931 CIE chromaticity coordinate

$$N(\lambda) = I(\lambda)/R(\lambda) \qquad \text{(Formula 3)}$$

$$X = \int_{380}^{780} \bar{x}\ N(\lambda)\ d\lambda \qquad \text{(Formula 4)}$$

$$Y = \int_{380}^{780} \bar{y}\ N(\lambda)\ d\lambda \qquad \text{(Formula 5)}$$

$$Z = \int_{380}^{780} \bar{z}\ N(\lambda)\ d\lambda \qquad \text{(Formula 6)}$$

$$x = \frac{X}{X+Y+Z} \qquad \text{(Formula 7)}$$

$$y = \frac{Y}{X+Y+Z} \qquad \text{(Formula 8)}$$

$$u' = \frac{4x}{-2x+12y+3} \qquad \text{(Formula 9)}$$

$$v' = \frac{9y}{-2x+12y+3} \qquad \text{(Formula 10)}$$

Where:

$N(\lambda)$	=	spectral radiance of the lighting component (W/cm^2 sr nm or normalized)
$I(\lambda)$	=	detector current (amperes)
$R(\lambda)$	=	spectroradiometer spectral sensitivity (amperes cm^2 sr nm/W)
$d\lambda$	=	5nm
$\bar{x}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
$\bar{y}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
$\bar{z}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
X	=	C.I.E. tristimulus value
Y	=	C.I.E. tristimulus value
Z	=	C.I.E. tristimulus value
u'	=	1976 UCS chromaticity coordinate transformation of CIE x
v'	=	1976 UCS chromaticity coordinate transformation of CIE y
x	=	1931 C.I.E. chromaticity coordinate
y	=	1931 C.I.E. chromaticity coordinate

b. For secondary lighting subsystem chromaticity measurements, the appropriate drive condition shall be applied to the light being tested (test light) to illuminate a reflectance standard meeting the requirements specified, to a luminance level of 0.1 fL at a distance of 12 inches. The test light shall be oriented perpendicular to the reflectance standard. The spectroradiometer shall be set up such that the reflectance standard is at a 45-degree angle with the line of sight of the spectroradiometer. The spectral radiance of the reflectance standard shall be measured using an aperture that is as large as possible within the projected area of the reflectance standard. The corrected spectral radiance shall then be calculated using Formula 11:

$$N(\lambda) = \frac{M(\lambda)}{r(\lambda)} \qquad \text{(Formula 11)}$$

Where:

$N(\lambda)$	=	corrected spectral radiance (W/cm^2 sr nm)
$M(\lambda)$	=	measured spectral radiance of the reflectance standard (W/cm^2 sr nm)
$r(\lambda)$	=	reflectance of the reflectance standard

The chromaticity of the test light shall be calculated using the corrected spectral radiance and the formulas given above.

Verification of floodlighted instrument, console, and panel chromaticity for NVIS compatibility shall be by test except that the instrument console or panel shall be floodlighted to the specified luminance levels by the same type of light that will be used when the panel is installed in the aircraft.

VERIFICATION LESSONS LEARNED (4.5.2.1.5)

Chromaticity measurements are required to be made with a spectroradiometer. In practice, chromaticity measurements can also be made with a photometer; however, the spectroradiometric measurement is more accurate. A wavelength increment of 5 nm was chosen because experiments have shown that smaller increments have a negligible effect on the chromaticity measurements of various technology lamps, including LEDs and CRTs, which are about as narrow band as one will see.

3.5.2.1.6 Spectral radiance.

All interior lighting and illuminated visual signals and displays in crew stations where crew members must utilize NVIS to perform their tasks shall be designed to limit spectral radiance as specified in table IV. In addition to these requirements, lighting components shall not exhibit unfiltered light leakage.

REQUIREMENT RATIONALE (3.5.2.1.6)

The NVIS radiance of compartment lighting must be specified in order to optimize out-of-cockpit visibility when employing NVIS.

REQUIREMENT GUIDANCE (3.5.2.1.6)

Use the appropriate lighting components and type/class NVIS when energized to produce the luminance level specified in table IV measured off a reflectance standard surface (see MIL-L-85762).

REQUIREMENT LESSONS LEARNED (3.5.2.1.6)

TBD

4.5.2.1.6 Spectral radiance.

The spectral radiance requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.2.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.6)

Direct measurement of a lighting component's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

VERIFICATION GUIDANCE (4.5.2.1.6)

The NVIS radiance inspection for compartment lighting shall be the same as for secondary lighting 4.5.2.1.5 except that the distance between the test light and the reflectance standard shall be adjusted to be equivalent to the distance at which the lighting component will be used when installed in an aircraft.

VERIFICATION LESSONS LEARNED (4.5.2.1.6)

TBD

3.5.2.1.7 Luminance.

The luminance of all elements of the interior lighting system, visual signals, and displays will meet the requirements of table IV.

REQUIREMENT RATIONALE (3.5.2.1.7)

A lighting component's luminance (see definition) must be sufficient to be visible to the crew member's naked eye without amplification by the NVIS.

REQUIREMENT GUIDANCE (3.5.2.1.7)

Use the value from table IV for the appropriate lighting component (see MIL-L-85762).

REQUIREMENT LESSONS LEARNED (3.5.2.1.7)

Any lighting component could be sufficiently dimmed to meet the radiance requirements of this document. However, for lighting to be useful, of course, the illuminated items must be bright enough to be seen with the naked eye. It is at this level that the chromaticity and NVIS radiance requirements must be attained.

4.5.2.1.7 Luminance.

The luminance requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.7.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.7)

A direct measurement of luminances using calibrated photometric equipment is the standard method to verify specified levels.

VERIFICATION GUIDANCE (4.5.2.1.7)

Luminance or illuminance measurements shall be performed by using either a spectroradiometer or photometer (see below). When a spectroradiometer is used, the luminance or illuminance shall be calculated using the following standard formulas which are normally implemented in the spectroradiometer software.

Where:

L	=	luminance (footlamberts)
E_V	=	illuminance (footcandles)
K(l)	=	normalized visual efficiency curve for 1931 standard observer
$K(l)_{max}$	=	683 lm/W
N(l)	=	spectral radiance of lighting component (W/cm^2 sr nm)
$E_e(l)$	=	flux density incident (W/cm^2)
Dl	=	5 nm

SPECTRORADIOMETER

Chromaticity and spectral radiance measurement equipment. Chromaticity and spectral radiance measurements shall be made using a spectroradiometer meeting the requirements herein. The following calibrations and checks shall be performed within the time period specified in order to assure that the spectroradiometer meets the requirements of this specification. Records of how the spectroradiometer calibration was performed, when performed and the standard lamp used shall be maintained by the contractor and shall be available for government inspection.

Spectroradiometer sensitivity. The spectroradiometer, when assembled as a complete system, shall have sufficient sensitivity to permit measurement of radiance levels equal to or less than that listed in the table below at a half-power band width of 10 nm and a signal to root-mean-square noise ratio of 10:1.

Wavelength	Radiance Level
380 to 600 nm	1.0×10^{-10} W/cm^2 sr nm
600 to 900 nm	1.7×10^{-11} W/cm^2 sr nm
900 to 930 nm	1.0×10^{-10} W/cm^2 sr nm

Spectroradiometer sensitivity calibration. Calibration of the spectroradiometer shall be performed within six months (or more frequently if required to insure that the spectroradiometer meets the requirements specified herein) prior to taking a measurement. This calibration shall be traceable to NBS standards. The calibrations shall be performed over the wavelength band and at intervals consistent with the measurements to be made. The calibration shall demonstrate that the spectroradiometer meets the sensitivity requirements of 30.2. A separate calibration must be performed for each spectroradiometer configuration used during tests. For example, a calibration must be performed for each set of optics used, or when filters are used in front of the spectroradiometer.

Wavelength accuracy and repeatability. The wavelength accuracy shall be within ± 1.0 nm. The wavelength accuracy is the difference between the wavelength actually being measured and the indicated wavelength. Wavelength repeatability shall be within ± 0.5 nm.

Wavelength accuracy and repeatability verification. Wavelength accuracy and repeatability shall be verified within one month prior to taking a measurement using a source with known emission lines. As a minimum, the wavelength accuracy and repeatability shall be verified at one point in each 150 nm interval starting with 350 nm and ending with 950 nm. The wavelength accuracy and repeatability check shall be performed using either a scanning or non-scanning technique.

Scanning technique. If the scanning technique is used, the spectroradiometer shall be utilized to measure the spectral radiance of the source by scanning from below the peak wavelength of the known emission line to be measured to above the peak wavelength in steps no greater than 0.1 nm. This process shall be repeated three times for each emission line that is used for the wavelength accuracy and repeatability test. The spectroradiometer shall be considered to have passed the wavelength accuracy test if, for each measurement, the wavelength of the measured peak is within 1 nm of the actual peak. The spectroradiometer shall be considered to have passed the wavelength repeatability test if, for each emission line tested, the wavelength of the three measured peaks are within 0.5 nm of each other.

Non-scanning technique. If the non-scanning technique is used, the monochromator shall be positioned to obtain a peak reading for each emission line tested. The wavelength of the peak reading shall be recorded. Each emission line shall be measured three times. During this test the monochromator entrance and exit slit widths shall be no greater than 1 nm. The spectroradiometer shall be considered to have passed the wavelength accuracy test if, for each measurement, the wavelength of the measured peak is within 1 nm of the actual peak. The spectroradiometer shall be considered to have passed the wavelength repeatability test if, for each emission line tested, the wavelength of the three measured peaks are within 0.5 nm of each other.

Current resolution. Where analog to digital (A to D) logic is used in the measurement of the current from the detector, the A to D conversion shall provide at least ±2048 counts of resolution for each measurement scale or the resolution shall be equal to or better than ±0.05% of each measurement scale.

Zero drift. During any given spectroradiometric scan, the maximum zero drift shall be less than 0.2% of the full scale reading on the most sensitive scale, after the appropriate warm up period. A capability shall be provided to allow zero drift to be checked before any given spectroradiometer scan.

Linearity. Within any given measurement scale, the linearity shall be ±1% of the full scale value. The linearity between any two measurement scales shall be ±2%.

Linearity verification. The linearity of the spectroradiometer shall be verified within 6 months prior to taking a measurement. A linearity check shall be performed on each detector used during the test procedures. The spectroradiometer operational parameters shall not be varied during the linearity test. The linearity check shall be performed at a specific wavelength (to be determined by the contractor) which shall not be varied during the linearity test. A light source that can be precisely, mechanically or optically varied in intensity shall be used for the linearity check. Acceptable methods that may be used to vary the intensity of the light source include the use of neutral density filters (with known transmission), precision apertures, superposition, or the inverse square law (provided the distance between the lamp and spectroradiometer can be precisely controlled using a photometric type bench). Dimming of the lamp through electronic means is unacceptable. The intensity of the lamp shall be adjusted to give a full scale reading on the lowest level of dynamic range of the spectroradiometer. Call the lamp output N and the reading on the spectroradiometer R. The intensity of the lamp shall be varied in accordance with the table below, and, in order to pass the linearity check, the output of the spectroradiometer, over its entire dynamic range (as applicable), shall be within the limits shown below.

Lamp output	Spectroradiometer output		
0.1N	0.1R	±	.01R
0.5N	0.5R	±	.01R
5N	5.0R	±	0.2R
10N	10R	±	0.2R
50N	50R	±	2.0R
100N	100R	±	2.0R
500N	500R	±	20R
1000N	1000R	±	20R
5000N	5000R	±	200R
10000N	10000R	±	200R

Signal conditioning. Controls shall be provided to permit the operator to improve or change the signal-to-noise ratio of a measurement.

Stray light. Stray light within the spectroradiometer shall not adversely affect the accuracy of the spectroradiometer when tested in accordance with the procedures herein.

Stray light verification. Stray light accuracy shall be verified within a six-month period prior to taking a measurement. Stray light accuracy shall be verified by measuring the spectral radiance of an NBS traceable standard of spectral radiance that is filtered by a filter with known transmission that is NBS traceable. The measurement shall be made from 380 to 930 nm in 5 nm increments. The transmission of the filter shall be greater than 50% from 380 to 500 nm and less than 0.2% from 690 to 930 nm. For the spectroradiometer to pass the stray light test, the measured value of spectral radiance at each wavelength shall be within 5% of the value calculated by multiplying the output of the standard lamp by the transmission of the filter. The stray light shall be checked for each configuration of optics that is used during the testing.

Spectroradiometer optics. If the spectroradiometer is used for luminance measurements, the optics shall be capable of allowing measurements of spot sizes down to 0.007 in with a full scale sensitivity of 1.0 fl.

Spectroradiometer viewing system. The viewing system shall be capable of locating the spot to be measured with a maximum error of 5% of the diameter of the spot to be measured.

Spectroradiometer viewing system verification. The accuracy of the viewing system shall be verified within a six month period prior to taking a test measurement by placing a black card with a hole in front of a light source in such a manner that an aperture in the spectroradiometer optics covers the hole when viewed through the viewing system. The card shall then be moved back and forth in one axis orthogonal to the axis of the spectroradiometer until a peak reading is obtained on the spectroradiometer. The distance (A) the card was moved from its original position to the peak position shall be recorded. The card shall be placed back in its original position and then moved back and forth in the axis orthogonal to the axis of the first movement and orthogonal to the axis of the spectroradiometer until a peak reading is obtained on the spectroradiometer. The distance (B) the card was moved from its original position to the peak position shall be recorded. The viewing system of the spectroradiometer shall be considered to be aligned accurately if both A and B are less than 5% of the diameter of the spot size at the card. The monochromator shall be set at a single wavelength for the entire test. For instruments for which the viewing optics and measuring optics are one in the same, this task is not required.

Spectroradiometer accuracy. The spectroradiometer shall yield a spectral radiance within ±5% of that of an NBS traceable standard of spectral radiance at each 5 nm wavelength throughout the range of 380 to 930 nm. When measuring an NBS traceable standard of color temperature or chromaticity, the spectroradiometer shall yield chromaticity coordinates u′ and v′ within ±0.007 of their respective certificate values.

Spectroradiometer accuracy verification. The accuracy shall be verified within a six-month period prior to taking a test measurement. Verification shall be performed by measuring an NBS traceable spectral standard lamp other than the lamp used to calibrate the spectroradiometer and comparing the measured output to the certified output. The measured spectral radiance at each 5 nm wavelength over the 380 to 930 nm portion of the electromagnetic spectrum and the color coordinates calculated for the standard lamp shall not differ from the certified output by more than that specified.

PHOTOMETER

Luminance measurement equipment. Luminance measurements can be made using either a spectroradiometer meeting the requirements above or a photometer meeting the requirements herein. When a photometer is used as part of the test equipment, the following calibrations and checks shall be verified within a year prior to taking a measurement in order to assure that the photometer meets the requirements of this specification. Records of calibrations and checks shall be maintained by the contractor and shall be available for government inspection.

Photometer calibration. The photometer shall be calibrated using methods that are traceable to NBS standards.

Photometer sensitivity. The full-scale sensitivity shall be 1.0 fl or less, with a spot size of no greater than 0.007 in.

Photometer accuracy. The measured luminance of an NBS traceable luminance standard shall be within ± 2% of the NBS certified luminance.

Photometer sensitivity and accuracy verification. The full-scale sensitivity and accuracy of the photometer shall be verified using an NBS traceable standard of luminance set to a luminance value less than or equal to 1.0 fl and also equal to the known full-scale sensitivity value of one of the photometer ranges. Using a spot size no greater than 0.007 in. in the photometer full-scale sensitivity shall be within ± 2% of the NBS traceable standard of luminance value.

Readout resolution. The unit shall have a digital readout with a resolution better than or equal to 0.1% of full scale.

Photometer optics. The optics shall be capable of allowing measurements of spot sizes down to 0.007 in. while meeting the sensitivity requirements. The optics shall be capable of focusing to no less than 4.0 in.

Photometer viewing system verification. A black card, with a hole in the center, shall be placed in front of a light source in such a manner that the smallest aperture of the photometer optics covers the hole when viewed through the viewing system. The card shall be moved back and forth in one axis orthogonal to the axis of the photometer until a peak reading is obtained on the photometer. The distance (A) the card was moved from its original position to the peak position shall be recorded. The card shall be placed back in its original position and then moved back and forth in the axis orthogonal to the axis of the first movement and orgthogonal to the axis of the photometer until a peak reading is obtained on the photometer. The distance (B) the card was moved from its original position to the peak position shall be recorded. The viewing system of the photometer shall be considered to be aligned accurately if both A and B are less than or equal to 0.002 in. For instruments in which the viewing aperture and measuring aperture are one in the same, this test is not required.

Photometer polarization error. The polarization error shall be no greater than 1%.

Photometer polarization error verification. The polarization error shall be checked by placing a linear polarizer in the optical path between the standard lamp and the photometer and then measuring the luminance. The polarizer shall be rotated 45° and another measurement shall be made. The polarizer shall be rotated another 45° and another measurement shall be made. The photometer shall be considered as having passed the polarization error test if the difference between the three measurements is lower than or equal to the percent error specified. Throughout the test the alignment of the standard lamp shall not be changed. The transmission of the linear polarizer shall be greater than or equal to 20%, and the transmission of two pieces of the polarizer material, when oriented so that the direction of polarization of the two pieces are at right angles, shall be less than or equal to 0.1%.

Colorimetry. When colorimetry capability is required, the photometer shall be calibrated to measure the NVIS color for the application (i.e. NVIS Green A, NVIS Green B, NVIS Yellow or NVIS Red). The calibration shall be traceable to NBS standards.

VERIFICATION LESSONS LEARNED (4.5.2.1.7)

TBD

3.5.2.1.8 Cockpit and crew station lighting.

3.5.2.1.8.1 Instrument lighting.

The lighting system shall provide sufficient luminance so as not to degrade crew performance. Each instrument and its collocated control (if applicable) shall be easily readable and discernible. The lighting system shall not restrict the visibility of any graduations, numerals, pointers, or other specific markings. Instruments shall be designed such that their direct rays, and rays reflected from the windshield or other surface, are shielded from the pilot's eyes. Except for self-luminous displays, all illuminated instrument indicia shall be daylight readable when not energized. The instrument face shall be black with white markings and legends. The markings and indicia on each instrument shall be finished with white. All markings and indicia shall be sharply defined and readable when viewed at any angle up to and including 60 degrees from the normal to the plane of the front face of the instrument. The daylight contrast between markings, legends, and indicia and the background on the instrument shall be at least 9.0. Contrast C is defined as:

$$C = \frac{B_2 - B_1}{B_1}$$

Where

B_1 is the average luminance of the background immediately surrounding the marking and

B_2 is the average luminance of the marking.

REQUIREMENT RATIONALE (3.5.2.1.8.1)

Maximum luminances must be specified to assure instrument and panel readability in preflight check, postflight check, dawn or dusk transitions, and in lightning storms.

REQUIREMENT GUIDANCE (3.5.2.1.8.1)

Invoke this requirement for all lighted instruments and panels that are to be used at night. Aircrew use maximum instrument and panel luminance during pre- and postflight checks. More significantly, in sunset and sunrise ambient conditions, maximum luminance is also required.

a. White (or NVIS Green A) instrument and panel illuminated markings should be 1.00 ± 0.50 fL. These values have been used with success for many years. Interviews with pilots have verified this maximum luminance value and no relaxation is warranted. Even though the actual percentage of use is low, it must be made available to the crew. The 0.5 fL tolerance should be reduced, if possible.

b. Gray and yellow painted areas should be 0.50 to 0.60 ″ 0.10 to 0.30 fL.

c. Black areas should be 0.05 ± 0.01 to 0.03 fL. This required luminosity for black greatly reduces the chances of the autokinetic effect which is the apparent drifting of stationary light sources that are surrounded by a very dark field (Graybiel et al, 1944, and Graybiel 1944).

d. Pointers, lubber lines, etc., should be 1.20 ± 0.50 fL. This value sets them slightly higher than the other instrument markings to allow faster pointer position detection.

e. In the event of any single lamp failure, luminance must not fall below 0.5 fL at maximum rated voltage.

f. Instrument and panel indicia must be daylight readable when not energized. The sources for this requirement are MIL-L-27160 and MIL-P-7788.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.1)

TBD

4.5.2.1.8 Cockpit and crew station lighting

4.5.2.1.8.1 Instrument lighting.

The instrument lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.4, 4.2.1.2.1, and 4.2.1.1.9 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.1)

A direct measurement of luminances using calibrated photometric equipment is the standard method to verify specified levels.

VERIFICATION GUIDANCE (4.5.2.1.8.1)

Photometers must be calibrated to a standard traceable to NBS. The aperture must be one-half the width of the symbol stroke (letter, pointer, etc.) being measured with three evenly distributed (representative) points per symbol. Measurements are to be made in a dark room. Contribution of room ambient to luminance measurements should be nil. The photometer must be within the correct focusing range of the lens system being used, and calibration must be corrected if nonstandard attachments (e.g., macro- or microscopic lenses) are employed for measurements.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.1)

If the photometer aperture is not one-half the stroke width, measurement errors will occur. Photometers integrate luminance readings over the entire aperture. Parallax due to an incorrectly adjusted photometer eye piece can adversely affect measurements.

3.5.2.1.8.2 Console/control panel lighting.

The lighting system shall provide sufficient luminance so as not to degrade crew performance. Except for self-luminous displays, all illuminated instrument and panel indicia shall be daylight readable when not energized. Control panels shall be black with white markings and legends. The markings on each panel shall be finished with white. Immediate action stripes shall be finished with yellow for non-NVIS panels and with alternating yellow, black, and white stripes for Class 1-NVIS Green A panels. The yellow shall be transilluminated for non-NVIS panels and shall not be illuminated for Class 1-NVIS Green A panels. The external finish of any lampholder and attaching hardware shall correspond to the background color of the panel. All markings shall be sharply defined and readable when viewed at any angle up to and including 60 degrees from the normal to the plane of the front face of the panel. The daylight contrast between markings, legends, and indicia and the background on the panel shall be at least 9.0. Contrast C is defined as:

$$C = \frac{B_2 - B_1}{B_1}$$

Where

B_1 is the average luminance of the background immediately surrounding the marking and

B_2 is the average luminance of the marking.

The luminance of all markings on the panels and associated knobs, dials, etc., when illuminated by the integral lighting system shall be 1.0fL $\pm$0.5 fL. In the event of a lamp failure, the luminance of any marking depending on the failed area shall not be reduced below 0.3 fL. The gloss of the background of the panel shall not exceed 5 units.

REQUIREMENT RATIONALE (3.5.2.1.8.2)

The crew memeber must be able to see the control and displays. Sight is by far our most important sense. These requirments have been proven to insure that the information can be seen even under the most arduous conditions.

REQUIREMENT GUIDANCE (3.5.2.1.8.2)

If the current state-of-the-art technology does not allow a contrast of at least 9.0, then a cost/benefit trade-off between cost vs contrast should be undertaken.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.2)

Under no circumstances should a contrast of less than 4.0 be allowed. If the technology under consideration cannot give a contrast of at least 9.0, then perhaps another technology should be considered or an investment should be made in increasing the capability of the propossed technology. For example, increasing the brightness of CRTs or filtering CRTs so that they are viewable in direct sunlight may be necessary.

4.5.2.1.8.2 Console/control panel lighting.

The console/control panel lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.1.4, 4.2.1.2.1, 4.2.1.1.9 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.2)

Console/control panel lighting must be contracturally verified to ensure the overall quality of the product and user satisfaction.

VERIFICATION GUIDANCE (4.5.2.1.8.2)

Demonstrations of installed equipment and testing (i.e., making instrumented measurements) seem to work best.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.2)

It is advisable to verify contrast at the LRU level in the laboratory environment. Contrast should also be verified at the system level using the first article or prototype system in actual very bright sunlight measured by instumentation and by judged by eye.

TABLE IV. NVIS radiance requirements.

Lighting components	Paragraph	TYPE 1						TYPE II					
		Class A			Class B			Class A			Class B		
		Not Less than (NR_A)	Not Greater than: (NR_A)	fL	Not less Than: (NR_B)	Not Greater Than: (NR_B)	fL	Not Less Than : (NR_A)	Not Greater Than: (NR_A)	fL	Not Less Than: (NR_B)	Not Greater Than: (NR_B)	fL
Primary	3.6.8.1	---	$1.7x10^{-10}$	0.1	1/Same as Class A			---	$1.7x10^{-10}$	0.1	1/Same as Class A		
Secondary	3.6.8.2	---	$1.7x10^{-10}$	0.1				---	$1.7x10^{-10}$	0.1			
Illuminated Controls	3.6.8.3	---	$1.7x10^{-10}$	0.1				---	$1.7x10^{-10}$	0.1			
Compartment	3.6.8.4	---	$1.7x10^{-10}$	0.1				---	$1.7x10^{-10}$	0.1			
Utility, work and inspection lights	3.6.8.5	---	$1.7x10^{-10}$	0.1				---	$1.7\text{-}10^{-10}$	0.1			
Caution and advisory lights	3.6.8.6	---	$1.7x10^{-10}$	0.1				---	$1.7\text{-}10^{-10}$	0.1			
Jump lights	3.6.8.7	$1.7x10^{-8}$	$5.0x10^{-8}$	5.00	$1.6x10^{-8}$	$4.7x10^{-8}$	5.0	---	` $5.0x10^{-8}$	5.0	---	$4.7x10^{-8}$	5.0
Warning signal	3.6.8.8	$5.0x10^{-8}$	$1.5x10^{-7}$	15.0	$4.7x10^{-8}$	$1.4x10^{-7}$	15.0	---	$1.5x10^{-7}$	15.0	---	$1.4x10^{-7}$	15.0
Master Caution Signal	3.6.8.8	$5.0x10^{-8}$	$1.5x10^{-7}$	15.0	$4.7x10^{-8}$	$1.4x10^{-7}$	15.0	---	$1.5x10^{-7}$	15.0	---	$1.4x10^{-7}$	15.0
Emergency Exit Lighting		$5.0x10^{-8}$	$1.5x10^{-7}$	15.0	$4.7x10^{-8}$	$1.4x10^{-7}$	15.0	---	$1.5x10^{-7}$	15.0	---	$1.4x10^{-7}$	15.0
Electronic and electro-optical displays (Monochromatic)		---	$1.7x10^{-10}$	0.5	---	$1.6x10^{-10}$	0.5	---	$1.7x10^{-10}$	0.5	--	$1.6x10^{-10}$	10.5
Electronic and electro-optical displays (multi- — White		---	$2.3x10^{-9}$		---	$2.2x10^{-9}$	0.5	---	$2.3x10^{-9}$	0.5	---	$2.2x10^{-9}$	0.5
color — MAX		$1.2X10^{-8}$--	$1.2x10^{-8}$	0.5	---	$1.1x10^{-8}$	0.5	---	$1.2x10^{-8}$	0.5	---	$1.1x10^{-8}$	
HUD systems	3.6.8.10	$1.7x10^{-9}$	$5.1x10^{-9}$	5.0	$1.6x10^{-9}$	$4.7x10^{-9}$	5.0	---	$1.7x10^{-9}$	5.0	---	$1.6x10^{-9}$	5.0

NOTE: The relative NVIS response data for Class A equipment, $G_A(\lambda)$ (Table VI), shall be substituted for $G_B(\lambda)$ to calculate NVIS radiance.

3.5.2.1.8.3 Keyboard and keypad assemblies.

Integral panel keyboard and keypad assemblies with both illuminated panel and button markings, with illuminated keyboard or keypad buttons only, and integral placard assemblies with non-illuminated keyboard buttons shall meet the requirements for control panels.

REQUIREMENT RATIONALE (3.5.2.1.8.3)

All illuminated pushbuttons and knobs must have a visual presentation similar to the associated instruments and panels.

REQUIREMENT GUIDANCE (3.5.2.1.8.3)

Invoke these requirements for all illuminated pushbuttons and knobs used in conjunction with or located on instruments and panels. Since illuminated pushbuttons and knobs are integral parts of instruments and panels, they should have the same font, finish, chromaticity, etc., except luminance and dimming are from the general requirements section. Certain types of pushbuttons require no lighting for daytime use. High ambient illuminations, found in bubble canopy cockpits, at altitude, have illumination levels of about 10,000 fc. Three hundred fL are required for warnings and cautions; 300 to 200 fL is appropriate for illuminated pushbuttons. Dimming should also be the same as for advisory signals; automatic switching to 10 fL at maximum brightness setting, continuously dimmable to 0.1 + 0.2 - 0.05 fL minimum. Dimming will allow the pilot and copilot to maintain their partial dark-adaptation. Non-cockpit applications, where sunlight readability is not a requirement, can have 150 to 100 fL maximum luminances with dimming applied as needed. Use appropriate aviation or NVIS-compatible colors. Knob indicia to be specified the same as instruments and panels. Transilluminated knob skirts and knob pointers can be 0.7 to 1.0 ± .10 fL. The source for this requirement is MIL-PRF-22885/101.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.3)

Previous illuminated pushbutton specifications had different luminances for different colors which probably reflected the characteristics of available equipment. However, a photometer is a device that weights light energy measurements with the human visual response characteristics (photopic curve).

Thus, for example, a 100 fL green light and a 100 fL red light are subjectively perceived by an observer with normal vision as having approximately the same brightness. The weighted measurement takes into account the eyes' greater sensitivity to green in relation to red or blue. Different luminances for different colors are not justified given these basic facts of vision and photometry.

4.5.2.1.8.3 Keyboard and keypad assemblies.

The keyboard and keypad assembly requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in section 4 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.3)

See respective verification rationales.

VERIFICATION GUIDANCE (4.5.2.1.8.3)

See respective verification guidance.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.3)

See respective verification lessons learned.

3.5.2.1.8.4 Floodlighting.

A cockpit floodlighting system shall be provided which illuminates primary flight instruments. On aircraft equipped with an automatic thermal protective closure system, the light(s) shall be automatically turned on to full illumination when the closure system is closed. A means shall be provided to regain manual control.

REQUIREMENT RATIONALE (3.5.2.1.8.4)

Maximum illuminance must be specified to assure adequate emergency backup and thunderstorm lighting.

Operators require bright cockpit lighting after exposure to thermonuclear flashes.

REQUIREMENT GUIDANCE (3.5.2.1.8.4)

Invoke this requirement for all cockpit floodlighting. Floodlights are used for pre- and postflight check, as backup in case of primary light system failure, as a supplement to the primary lighting, and during lightning storms to diminish the deleterious visual effect of the bright flashes of light. Floodlights are also coupled to automatic thermal protective closure systems for antidazzle. Thunderstorm lights have required 100 fc illumination for the primary flight instruments. For nuclear flashblindness 150 fc should be the minimum. Seventy-five fc may be used for lighting of secondary subsystems. Any deviations must be justified to the procuring activity. Dimming and glare requirements must also be invoked. The absolute minimum obtainable luminance of the instrument markings when using floods, should be about the same as recommended in the general dimming requirement. The sources for this requirement are MIL-L-5667 and MIL-L-18276.

Invoke this requirement for cockpits having an automatic thermal protective closure system to prevent flashblindness. Although a closure system prevents blindness, the operators can be exposed to very bright light requiring correspondingly higher instrument and panel luminances. Floods at maximum luminance can provide the necessary illumination levels required to maintain good vision in this momentarily degraded condition. Automatic activation via the protective closure system assures minimal visual degradation. Providing a manual reset switch will allow the operator to regain manual control. The source for this requirement is MIL-L-18276.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.4)

TBD

4.5.2.1.8.4 Floodlighting.

The floodlighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.8, 4.2.1.8.1, and 4.2.1.8.2 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.4)

The most accurate method to verify floodlight illumination levels is by test.

Examination of the control circuitry for automatic actuation is the most cost-effective method of verification.

VERIFICATION GUIDANCE (4.5.2.1.8.4)

Photometric equipment must be calibrated to standards having accuracy traceable to the National Bureau of Standards (NBS). Illumination on a surface can be measured by placing a white reflectance standard, barium sulfate reflector on the plane of the surface and perpendicular to the optical axis of a photometer, set to measure in fL. The barium sulfate provides a highly reflective surface with near lambertian (perfect diffuser) characteristics. Measurements taken in this manner result in fc illumination units. The photometer aperture should be large enough to fill one-half of the barium sulfate square that is usually about two inches square). The eyepiece must be adjusted to negate parallax. The photometer must be within the correct focusing range of the lens system being used and calibration must be corrected for if nonstandard attachments (e.g., macro or microscopic lenses) are employed for measurements. nm photometer must be prefocused before using the barium sulfate reflector since it is difficult to focus on a pure white surface. Numerous measurements must be taken at evenly spaced locations over the entire primary and secondary instruments and panels, with the flood brightness control set to the maximum position. An alternate illumination measurement technique is to use appropriately diffused sensors as found in NBS-calibrated illumination equipment that measures fc directly.

Obtain controlling circuitry diagrams and verify automatic floodlight activation and manual reset capability.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.4)

TBD

3.5.2.1.8.5 Visual displays.

3.5.2.1.8.5.1 Aircrew station signals.

Aircrew station signals include indicators, readouts, controls, and push-button switches in addition to alerting systems (Warnings, Cautions and Advisories). The location of alerting systems shall permit unaided eye viewing by an aviator wearing NVIS without extreme head movement. The minimum acceptable high ambient contrast requirements for readability are presented in table V. Minimum luminance requirements for illuminated visual signals are presented in table VI. Aircrew station signals shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windshields and other enclosures shall be avoided. Aircrew station signals do not appear illuminated when they are not, or appear extinguished when they are illuminated. When individual signals are installed on one or more control panels, a master light test control shall be incorporated which shall allow testing of all control panels at one time. Circuitry should be designed to test the operation of the total indicator circuit. If dark adaptation is a factor, a means for reducing total indicator light brightness during test operation shall be provided. Where possible, lamps shall be easily and rapidly removable and replaceable from the front of the display panel without the use of tools. Individual color selection shall be in accordance with table VII. The use of flashing lights shall be limited to those instances when it is necessary to call the operator's attention to some condition requiring immediate action. The flash rate shall be within 3 to 5 flashes per second with approximately equal amounts of ON and OFF time. Flashing lights that could be simultaneously active should have synchronized flashes. If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily.

REQUIREMENT RATIONALE (3.5.2.1.8.5.1)

Minimum signal luminance must be specified to insure timely detection and sunlight readability.

Specification of warning legend type provides standardization and assures maximum detectability.

Warning, caution, and advisory signals must be dimmable for nighttime use.

Chromaticity of warning lights must be specified to optimize the performance of the NVIS, while assuring that the warning will be immediately visible. The NVIS radiance (NR) of warning lights must be specified in order to optimize out-of-cockpit visibility when employing NVIS and to assure that the warning is immediately visible.

Specification of caution legend type provides standardization and assures maximum detectability.

Chromaticity of caution lights must be specified to optimize the performance of the NVIS, while assuring that the caution is immediately visible.

The NVIS radiance of caution lights must be specified in order to optimize out-of-cockpit visibility when employing NVIS and assure the immediate visibility of the caution.

The NVIS radiance of master caution lights must be specified in order to optimize out-of-cockpit visibility when employing NVIS and to assure the immediate visibility of the master caution.

Annunciators must convey unambiguous color-coded information.

Chromaticity of advisory lights must be specified to optimize the performance of the NVIS, while assuring adequate within-cockpit lighting.

The NVIS radiance of advisory lights must be specified in order to optimize out-of-cockpit visibility when employing NVIS and to assure the visibility of the advisory.

REQUIREMENT GUIDANCE (3.5.2.1.8.5.1)

Invoke this requirement for all master warning, warning, master caution, caution, and advisory signals. In high ambient, illumination signals must be of sufficient luminance to insure timely detection and subsequent action. Minimum luminances have been increasing over the years. Most modern aircraft use 150 ″ 50 fL; there has been a tendency to increase this to 300 ± 100 fL for newer designs. Recommend 300 fL be used for this requirement. The source for this requirement is MIL-STD-411.

Invoke this requirement for all warning legends. Utilizing a translucent aviation red legend background maximizes the attention-getting characteristics (size, color, brightness). Standardization is also required for positive transfer of training. Opaque lettering maximizes contrast. The source for this requirement is MIL-STD-411.

Invoke this requirement for all warning, caution, and advisory signals. Master warning and master caution lights require immediate action by the pilot, thus no relaxation of the dimmed luminance levels is warranted. Previous warning, caution, and advisory dimmed luminance levels were 15 ± 5 fL; use 10 ± 3 fL for maximum. Master warning, and master caution luminances must be maintained at 10 fL. A high level of warning, caution, and advisory signals adversely affects the pilot’s night vision and thus requires continuously dimmable warning, caution, and advisory lights that cannot be turned down below 0.1 fL with a tolerance of +0.2 and -0.05 fL. The source for this requirement is MIL-STD-411.

Invoke this requirement for all master warning and warning signal lights. Chromaticity measurements should be taken when the signal is energized. Use maximum specified luminance for test. Chromaticity coordinates must lie within the area labeled aviation red. Aviation red has been successfully used on many aircraft and no deviations are warranted. Red connotes danger and evokes an over learned response. The source for this requirement is MIL-STD-411.

Invoke this requirement for all warning lights needing NVIS compatibility. At the luminance level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by the spectrum locus and a circle, as shown on figure 2. This circle is determined by substituting the applicable u'_l and v'_l and radius (r) values of table III in Formula 1. The source for this requirement is MIL-L-85762.

Invoke this requirement for all warning lights needing NVIS compatibility. Use table IV for the appropriate lighting component and type/class NVIS at the required luminance levels. If the signals have supplementary auditory signals the NVIS radiance may be less than that specified in table IV. The source for this requirement is MIL-L-85762.

Invoke this requirement for all caution legends. Utilizing an opaque background and aviation yellow legend maximizes contrast with minimized visual interference. This presentation is opposite the warning legend that maximizes the attention-getting effect of red. Standardization of color is required for positive transfer of training. The source for the requirement is MIL-STD-411.

Invoke this requirement for all master caution and caution signal lights. Chromaticity measurements should be taken when the signal is energized. Use maximum specified luminance. Chromaticity coordinates must lie within the area labeled aviation yellow on figure 2. Aviation yellow has been successfully used on many aircraft and no deviations are warranted. Yellow connotes caution and elicits a proper, over learned response, thus the most appropriate for standardization. The source for this requirement is MIL-STD-411.

Invoke this requirement for all master caution and caution signals which must be NVIS compatible. Use table III for the appropriate lighting components and type/class NVIS. At the luminance level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. This circle is determined by substituting the applicable u'_l and v'_l and radius (r) values of table III in Formula 1. The source for this requirement is MIL-L-85762.

Invoke this requirement for caution lights that must be NVIS compatible. Use table IV for the appropriate lighting component and type/class NVIS at the illumination level specified. The source for this requirement is MIL-L-85762.

Invoke this requirement for master caution lights that must be NVIS compatible. Use table IV for the appropriate lighting component and type/class NVIS at the required luminance levels. If the signals have supplementary auditory signals the NVIS radiance may be less than that specified in table IV. The source for this requirement is MIL-L-85762.

Invoke this requirement for all advisory signals. Use maximum specified luminance. Chromaticity coordinates must tie within the area labeled aviation green on figure 2. Aviation green has been successfully used on many aircraft and no deviation is warranted. Green is the standardized color for advisory signals. The source for this requirement is MIL-STD-411.

Invoke this requirement for advisory lights that must be NVIS compatible. Use table III for the appropriate lighting component and type/class NVIS. At the luminance level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. This circle is determined by substituting the applicable u'_1 and v'_1 and radius (r) values of table III in Formula 1. The source for this requirement is MIL-L-85762.

Use the appropriate lighting component and type/class NVIS at the luminance level specified in table IV. The source for this requirement is MIL-L-85762.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.5.1)

Warning, caution, and advisory signals must be dimmable for nighttime use.

The maximum allowable NR for warning and master caution lights is approximately 1,000 times higher than the radiance for general crew station lighting, for a number of reasons. Because it was desired that the warning and master caution indicators be a different color than the rest of the cockpit, NVIS yellow was selected for use with class A NVIS. The NR also had to be increased because warning and master caution lights are required to be illuminated to 15 fL in order to be clearly visible through type I NVIS because, when the indicator first comes on, it will most likely be in the NVIS FOV and the pilot must see it immediately.

With the advent of type II and class B NVIS, the pilot can clearly see all parts of the cockpit with the unaided eye, so it was not necessary to set a lower limit on NR to assure that the indicator received immediate notice. Additionally, class B NVIS allow a limited amount of NVIS Red to be used for warning lights. The NR requirement for red was not raised when compared to NVIS Yellow because even yellow causes some NVIS degradation and raising the NR limit for red would only worsen the condition. Red warning lights are left as an option to the acquiring agency.

TABLE V. High ambient daylight contrast requirements.

Nomenclature	Type	C_L @ 10000 fc	C_{UL} @ 10,000 fc	Verification
Illuminated Visual Signals	Alerting Systems	Not < 0.4	0.0 ± 0.1	Para TBD
	Controls			
	Pushbuttons			
	Indicators			
	Readouts			
	Types of information to be displayed	**C_L and C_I @ 10,000 fc diffuse and 2,000 fL specular**	**C_{UL} @ 10,000 fc diffuse and 2,000 fL specular.**	**Verification**
Electronic and Electro-Optical Displays	Numeric only	≥1.5 for h = 5.0 mm and 0.12h ≤ SW ≤0.2h	C_{UL} shall be ≤ 0.25 for all displays, and ≤ 0.1 for any display where unlighted elements could provide false information, rather than a meaningless array of dots or segments	
	Alphanumerics	≥2.0 for h = 5.0 mm and 0.12h ≤ SW ≤0.2h		
	Graphics and alphanumerics	≥3.0		Para TBD
	Video a. Worst case ambient condition: b. Otherwise	≥4.66, to make at least six square root of 2 gray scale ratio shades visible (counting "off" as one) ≥10.3, to make at least eight square root of 2 gray scale ratio shades visible under other than worst case ambient conditions		

NOTES:

1. Character height criteria above assumes a viewing distance of less than 30 inches. No character height shall be less than 0.1 inch.

2. Contrast compensations for character heights (h) and stroke widths (SW) other than those indicated are determined by multiplying required contrast by 5.0/h for 2.5 ≤h ≤ 7.5 mm and by 0.12h/SW for 0.01h ≤SW ≤ 0.12h

3. Definitions:

C_L = the ON/BACKGROUND contrast of a lighted (or activated) display image element.

C_I = the ON/OFF contrast of a display image element

C_{UL} = the OFF/BACKGROUND contrast of an unlighted (or deactivated) display image element

h = character height

SW = character stroke width

TABLE VI. Luminance requirements.

Nomenclature	Luminance	
	Day Mode	Night Mode
Primary instrument lighting		0.0 to 1.3fL
Secondary instrument lighting		0.0 to 1.3fL
Primary console lighting		0.0 to 1.3fL
Secondary console lighting		0.0 to 1.3fL
Monochrome electronic and electro-optical displays		
Multi-color electronic and electro-optical displays		
Red		
Green		
Blue		
White		
Head-up displays		
Master warnings/warnings and master cautions	$\geq$ 150 fL	15$\pm$ 3 fL
Caution and advisory lights	$\geq$ 150 fL	1 $\pm$ 0.5 fL
Indicators, readouts, controls and pushbutton switches	TBD	TBD
Illuminated controls		
Jump lights		
Emergency exit lighting		

TABLE VII. Aircrew station signal color coding criteria.

RED	Shall be used to alert an operator that the system or any portion of the system is inoperative, or that a successful mission is not possible until appropriate corrective or override action is taken. Examples of indicators which should be coded RED are those which display such information as: “no-go”, “error”, “failure”, “malfunction”, etc.
FLASHING RED	Shall be used only to denote emergency conditions which require operator action to be taken without undue delay, or to avert impending personnel injury, equipment damage, or both.
YELLOW	Shall be used to advise an operator that a condition exists which is marginal. YELLOW shall also be used to alert the operator to situations where caution, recheck, or unexpected delay is necessary.
GREEN	Shall be used to indicate that the monitored equipment is in tolerance or a condition is satisfactory and that it is all right to proceed (e.g., “go-ahead”, “in-tolerance”, “ready”, “function activated”).
WHITE	Shall be used to indicate system conditions that do not have “right” or “wrong” implications, such as alternative functions (e.g., Missile No. 1 selected for launch, etc.) or transitory conditions (e.g., action or test in progress, function available), provided such indication does not imply success or failure of operations.
BLUE	May be used for an advisory light, but preferential use of BLUE should be avoided.

4.5.2.1.8.5.1 Aircrew station signals.

The aircrew station signal requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.5.1, 4.2.1.5.2, 4.2.1.5.3, 4.2.1.5.4, 4.2.1.5.4.1, 4.2.1.5.4.2, 4.2.1.6, 4.2.1.6.1, 4.2.1.6.1.2, 4.2.1.6.2.1, 4.2.1.6.2.2, 4.2.1.6.2.3, 4.2.1.7, 4.2.1.7.1, 4.2.1.7.1.1, and 4.2.1.7.1.2 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.5.1)

Direct measurement of signal luminance is the most accurate method of verification.

Analysis is the most cost-effective and direct method for verification of the legend type.

Direct measurement of luminance is the most accurate verification method for this requirement.

Direct measurement of signal chromaticity is the most accurate verification method.

Direct measurement of warning lights is the most accurate method to assure compatibility with the type/class NVIS to be used.

Direct measurement of a lighting component’s spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Analysis is the most cost-effective and direct method for the verification of the legend type.

Direct measurement of caution light chromaticity is the most accurate method to assure compatibility with the type/class NVIS to be used.

Direct measurement of a caution light's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Direct measurement of the master caution's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Direct measurement of advisory light chromaticity is the most accurate method to assure compatibility with the type/class NVIS to be used.

VERIFICATION GUIDANCE (4.5.2.1.8.5.1)

Photometers must be calibrated to a standard traceable to NBS. The aperture must be one-half the width of the object being measured. A representative number of measurements must be taken per signal assembly.

Examine engineering drawings of legends to insure an aviation red translucent is used for the entire background. Verify opaque black lettering (of specified font).

See instrument and panel luminance verification section.

See chromaticity measurement section.

See warning light legend type verification guidance.

See instrument and panel chromaticity verification guidance section.

See instrument and panel chromaticity measurement, verification guidance.

Inspection shall be in accordance with 4.5.2.1.5.

Inspection shall be in accordance with 4.5.2.1.6.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.5.1)

TBD

3.5.2.1.8.5.2 Electronic and electro-optical displays.

Electronic and electro-optical displays shall provide sufficient luminance and contrast for operation in all anticipated ambient environments (0.0 to 10,000 fc). Each individual electronic and electro-optical displays shall have its own luminance and contrast control. The minimum acceptable high ambient contrast requirements for display readability are presented in table V. The luminance range of surfaces immediately adjacent to scopes shall be between 10% and 100% of screen background luminance. With the exception of emergency indicators, no light source in the immediate surrounding area shall be of a greater luminance than the displayed signal. The ambient illuminance in the display area shall be appropriate for other visual functions (e.g., setting controls, reading instruments, maintenance) but shall not degrade the visibility of signals on the display. When a display is used in a variable ambient illuminance, illuminance controls, shall be provided to dim all light sources, including illuminated panels, indicators and switches in the immediate surround. Automatic adjustment of brightness may be used if the brightness is automatically adjusted as a function of ambient illuminance and the range of automatic adjustment is adequate for the full range of ambient illuminance.

REQUIREMENT RATIONALE (3.5.2.1.8.5.2)

The NVIS radiance of monochromatic displays must be specified in order to optimize out-of-cockpit visibility when employing NVIS.

The NVIS radiance of multicolor displays must be specified in order to provide color coding in the color display and to optimize out-of-cockpit visibility when employing NVIS.

The NVIS radiance of HUD systems must be specified in order to optimize out-of-cockpit visibility when employing NVIS and to assure that the HUD symbology is legible given the type/class NVIS employed.

REQUIREMENT GUIDANCE (3.5.2.1.8.5.2)

Invoke this requirement for systems requiring NVIS compatibility. Use the appropriate lighting components and type/class of NVIS as specified in tableIV at the illumination level specified.

The spectral radiance requirements for monochromatic displays are the same as for general crew station lighting except that when the display is required to display shades of gray imagery (such as FLIR video), the display must be NVIS compatible at 0.5 fL as opposed to 0.1 fL . Approximately 0.5 fL are required to display 8 shades of gray with the lowest level at 0.04 fL. The source for this requirement is MIL-L-85762.

Invoke this requirement for systems requiring NVIS compatibility. Use the “Maximum” NR specified for multicolor displays in table IV at the specified illumination level. In addition, the closest producible color to the 1976 UCS chromaticity point u′ = .1704, v′ = the “White” NR specified in table IV at the illumination level specified.

Laboratory experiments have demonstrated that a full (three-primary) color display cannot be used with class A NVIS without suffering considerable NVIS performance degradation. However, class B NVIS can be used with full color displays provided the use of red is minimized, the display is properly filtered, and is located in a position where it is not in the FOV of the NVIS when looking outside the aircraft.

Two levels of NR have been specified for multicolor displays: one for white light (or the color closest to white that can be produced by the display) and one for the “worst case” color, red. The source for this requirement is MIL-L-85762.

Invoke this requirement for systems requiring NVIS compatibility. Fill in the blank using the appropriate lighting component and type/class NVIS as specified in table IV at the illumination level specified.

With Type I NVIS it is necessary to view the HUD through the NVIS, so it was necessary to set both a lower and upper limit on the NR. The lower bound was set based on a P-43 phosphor with a Kaiser filter which has proven to be just barely visible through the type I NVIS when set to 5.0 fL. The upper limit is three times the lower limit.

With type II NVIS, the HUD is viewed with the unaided eye and there should be no intensified image seen through the image intensifier tubes or the pilot will be presented with a double image (unaided eye over the intensified image). Therefore, there is only a maximum NR for type II NVIS. The source for this requirement is MIL-L-85762.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.5.2)

Monochromatic cathode ray tube (CRT) (i.e., green/black) based displays, such as multi-function displays (MFDs), can nearly meet NVIS spectral radiance (i.e., NR_A & NR_B) requirements if they have P43 phosphor. Some additional filtering may be required to meet a strict spectral radiance requirement, but this may not always prove cost-effective, especially in the case of off-the-shelf or non-developmental item (NDI) equipment.

Liquid crystal displays (LCDs), whether monochromatic or color, typically can easily and cost-effectively meet NVIS chromoticity and spectral radiance requirements if a proper lights source is chosen (e.g., fluorescent tubes) and appropriate filters are used.

Typical monochromatic (i.e., green) light emitting diodes (LEDs) can be readily purchased off-the-shelf which are NVIS compatible.

4.5.2.1.8.5.2 Electronic and electro-optical displays.

The electronic and electro-optical display requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.2.2.2, and 4.2.1.2.2.3 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.5.2)

Direct measurement of a monochromatic display's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Direct measurement of a multicolor display's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Direct measurement of the HUD's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

VERIFICATION GUIDANCE (4.5.2.1.8.5.2)

Inspection shall be in accordance with 4.5.2.1.6. The acquiring activity shall specify the number and type of colors or composite colors that shall be measured. The spectroradiometer shall be placed so that as much of the display as reasonably possible is within the spectroradiometer test field. When the display is required to display shades of gray imagery (such as FLIR video), the display must be NVIS compatible at 0.5 fL as opposed to 0.1 fL. Approximately 0.5 fL are required to display 8 shades of gray with the lowest level at 0.04 fL.

Inspection shall be in accordance with 4.5.2.1.6. If the display is unable to generate the illumination level specified in table IV, relative spectral radiance shall be measured at the display's maximum illumination level and scaled to the specified illumination level, as stated in 4.5.2.1.6. The source for this requirement is MIL-L-85762.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.5.2)

TBD

3.5.2.1.8.6 Passenger and compartment lighting.

The lighting system shall provide adequate illumination for the anticipated range of aircrew tasks. This lighting shall allow the crew and passengers normal ingress and emergency egress within the aircraft interior. Specific luminance requirements for crew stations and compartments are presented in table VI. The lights shall not be a source of direct or reflected glare to aircrew members or be seen by outside observers. Lighting shall be provided for the cargo compartment, loading and ramp areas, passageways, passenger seating area and auxiliary power plant compartment. Illuminance levels shall be as required in table VIII, unless otherwise specified by the acquisiring activity.

REQUIREMENT RATIONALE (3.5.2.1.8.6)

Cabins and compartments require effectively located lighting.

Cabin and compartment illumination levels must be specified to assure passengers can read written or printed matter and move about safely.

Chromaticity of compartment lighting must be specified to optimize the performance of the NVIS, while assuring adequate within-cockpit lighting.

The NVIS radiance of compartment lighting must be specified in order to optimize out-of-cockpit visibility when employing NVIS.

Illumination levels for passageways, cargo compartment floors, loading and ramp areas, controls, power plants, and engine compartments must be specified to assure adequate lighting for personnel to perform required operational and maintenance tasks.

TABLE VIII. General lighting for crewstations and compartments. [1/]

	Illuminance Level In footcandles (fc) (At Rated Drive Condition)	
	Min	**Max**
Crew station area, general illumination	1 (Aisle floor)	20 (Crew lap level)
Control panels not illuminated (requiring in-flight adjustment and operation)	5	10
Instrument panel and consoles	2	10
Passageways and aisles (on floor)	0.2	5
Cargo compartment (on floor)	0.2	5
Loading and ramp areas (on floor)	2	10
Crew station locations for navigational and systems computations tasks (light on work areas)	30	60
Auxiliary power plant, electrical and electronic compartments (light on work areas)	5	10

[1/] Continuous intensity control of the abnove lighting from full bright to 0.02% of full bright and “off” is required. The locations for these controls shall be approved by the acquiring activity.

REQUIREMENT GUIDANCE (3.5.2.1.8.6)

Invoke this requirement for all cabin and compartment lights. All lights should be optimally placed to provide even illumination while causing no direct or reflected glare. Proper location of lights must take into account any possibility of damage to the fixtures. In these cases, the fixture must be ruggedized through proper use of covers screens, etc., to prevent personnel injury and fixture breakage.

Invoke this for all cabin and compartment illumination. Illumination levels for general reading and writing must be 30 fc minimum and 60 fc maximum measured four feet above the floor. An illumination of 60 fc is more desirable but sometimes is not easily achieved due to mechanization, heat, or electrical constraints. At least one fc minimum is needed for floor level illumination for general cabin areas so personnel can see where they are walking. Higher floor illumination is desirable. General cabin areas should have 20 fc maximum at four feet above the floor. Illumination higher than 20 fc for general cabin use is usually not required since there is little reading. White colored light should be used. The source for this requirement is MIL-L-6503.

Use the appropriate lighting components and type/class NVIS as specified in table III. The u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2 when energized to produce the luminance level specified in table III measured off a reflectance standard surface. The source for this requirement is MIL-L-85762.

Use the appropriate lighting components and type/class NVIS as specified in table IV when energized to produce the luminance level specified measured off a reflectance standard surface. The source for this requirement is MIL-L-85762.

Invoke appropriate requirements, (a) through (e), to specify minimum and maximum illumination levels for given locations: (a) Passageway floor and (b) cargo compartment floor illumination should be 0.2 fc minimum and 5.0 fc maximum; (c) Loading and ramp illumination should be 2 fc minimum and 10 fc maximum; (d) Controls not applicable to cockpit or workstations; (e) auxiliary power plants and engine compartment illumination should be 5 fc minimum, 10 fc maximum. The minimums should not be reduced since lower illumination would impact task completion. Higher maximums are allowable but the corresponding higher electrical power requirements and lamp heat are often design constraints. Refer to MIL-STD-1472 for miscellaneous secondary lighting not covered herein. The source for these requirements is MIL-L-6503.

Consideration should be given to making passenger, compartment, and/or cargo bay lighting NVIS compatible so as to reduce the aircraft signature from light coming through windows, open cargo doors, etc. during aerial and ground operations. Alternatively, or in addition, light tight (including IR) curtains, shades or covers should be considered.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.6)

The loading of cargo aircraft is often performed during periods of darkness. When using a K-loader, the driver can have a problem aligning his vehicle with the ramp of the aircraft. When night loading, the K-loader driver may have trouble seeing the approach to the aircraft because the aft cargo lights glare in his eyes.

4.5.2.1.8.6 Passenger and compartment lighting.

The passenger and compartment lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.10, 4.2.1.10.1, 4.2.10..2, 4.2.1.10..2.1, and 4.2.1.10.2.2 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.6)

Analysis of engineering drawings is the most cost-effective method of verifying cabin and compartment lighting locations.

The most accurate method to verify cabin and compartment illumination is by direct measurement.

Direct measurement of compartment lighting chromaticity is the most accurate method to assure compatibility with the type/class NVIS to be used.

Direct measurement of a lighting component's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

The most accurate method to verify secondary lighting subsystem illumination levels is by direct measurement.

VERIFICATION GUIDANCE (4.5.2.1.8.6)

Examine engineering drawings of lighting mixtures and insure that all areas requiring general illumination have respective fixtures. The fixtures that can be broken by the loading of equipment or personnel must be adequately protected and durable. Assure that the protective cover on the fixture cannot injure personnel.

See floodlight illumination verification methodology. Measurements are to be taken at given heights above floor as specified herein.

The chromaticity inspection for compartment lighting shall be the same as for secondary lighting (4.5.2.1.5) except that the distance between the test light and the reflectance standard shall be adjusted to be equivalent to the distance at which the lighting component will be used when installed in an aircraft.

Compartment lighting is generally placed in a fixed location in the aircraft, so compartment lighting components should be at a distance from the reflector which is the same as the distance at which it will be from the area in the aircraft that it will illuminate. This technique was chosen because various components may need to be at different luminance levels in order to achieve the proper illumination when they are installed in the aircraft, and the color of the component should be measured at the luminance level equivalent to the level at which it will be used in the aircraft.

The NVIS radiance inspection for compartment lighting shall be the same as for secondary lighting (4.5.2.1.6) except that the distance between the test light and the reflectance standard shall be adjusted to be equivalent to the distance at which the lighting component will be used when installed in an aircraft.

See floodlight illumination verification guidance.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.6)

TBD

3.5.2.1.8.6.1 Chart, utility, and worktable lighting.

One or more utility lights for use in illuminating maps, charts, or other work areas shall be provided for each of the operating personnel at their stations. The light shall be such that it can be used in any position within a specific workspace and can be easily removed from its mounting base. The light shall be equipped so the light output can be uniformly varied from off to full-bright over the control range. The utility lighting subsystem may be used as an emergency lighting subsystem in the event of failure of the primary or secondary instrument and console lighting subsystems.

REQUIREMENT RATIONALE (3.5.2.1.8.6.1)

Specifying illumination assures ability of the user to adequately perform reading and writing duties.

Chromaticity of chart, utility, and work lighting must be specified to optimize the performance of the NVIS, while assuring adequate within-cockpit lighting.

The NVIS radiance of chart, utility, and work lighting must be specified in order to optimize out-of-cockpit visibility when employing NVIS.

REQUIREMENT GUIDANCE (3.5.2.1.8.6.1)

Invoke this requirement for all utility light installations. Minimum illumination should be 60 fc on the surface that is required for reading small type, reading handwritten reports in pencil, prolonged reading, and viewing consoles. dials, and panels. Thirty fc is the absolute minimum but is not recommended. Invoke glare, dimming and chromaticity requirements, too. White light should be used except for NVIS-compatible applications. Dimmer should be self-contained in the fixture. The sources for this requirement are MIL-L-6503 and MIL-STD-1472.

Use the appropriate lighting component and type/class NVIS as specified in table II. At the illumination level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2 measured off a reflectance standard surface. This circle is determined by substituting the applicable u'_1 and v'_1 and radius (r) values of table III in Formula 1.

Chart lights, utility lights, and work lights are required to produce the proper color when illuminated to produce 0.1 fL off of a standard reflector. Because these lights can be moved around the aircraft, it was decided to fix the distance between the utility light and standard reflector at 12 inches when specifying chromaticity. The source for this requirement is MIL-L-85762.

Use the appropriate lighting component and type/class NVIS when energized to produce the luminance level specified in table IV measured off a reflectance standard surface. The source for this requirement is MIL-L-85762.

If there is a NVIS requirement, consider using NVIS "White" for chart, utility, work table, and map lights. A good working definition would be from the CIE/UCS 1976 u' and v' chromoticity coordinates of u' = 0.180, v' = 0.5, and r = 0.055 when the light is set to 0.1 fL. Suggest using a NR_A that does not exceed 1.0×10^{-9} when scaled to an illuminance of 0.1 fc at 2 feet as a working NVIS "White" radiance target. NVIS "White" helps make the light "mostly" NVIS compatible, but still makes the color red on paper maps readable with the unaided eye.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.6.1)

TBD

4.5.2.1.8.6.1 Chart, utility, and worktable lighting.

The chart utility and worktable lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.9, 4.2.1.9.1, 4.2.9.2, 4.2.1.9.2.1, and 4.2.1.9.2.2 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.6.1)

The most accurate method to verify utility light illumination levels is by direct measurement.

Direct measurement of chart, utility and work light chromaticity is the most accurate method to assure compatibility with the type/class NVIS to be used.

Direct measurement of a lighting component's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

VERIFICATION GUIDANCE (4.5.2.1.8.6.1)

See floodlight illumination verification methodology. Measurements are to be taken on work surface. Inspection shall be in accordance with 4.5.2.1.5.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.6.1)

TBD

3.5.2.1.8.6.2 Troop jump signals.

Three lights shall be used to indicate wait, prepare to jump, and jump, respectively. These lights shall be located so that the exit door area is illuminated and in full view of the jump master's normal location. The lights shall be a minimum of __ fL to be readily seen in all anticipated operational ambients. Different geometric shapes and sizes may be used to distinguish the between the lights when viewed through night vision devices. The specific geometric shape designs shall be approved by the acquiring activity.

REQUIREMENT RATIONALE (3.5.2.1.8.6.2)

Redundant shape coding is required because there is no color discrimination when lights are viewed through NVIS.

REQUIREMENT GUIDANCE (3.5.2.1.8.6.2)

Invoke this requirement for all jump lights that must be viewed through NVIS. The jump lights are required to be shape coded because when lights are viewed through type I NVIS there is no color discrimination (the NVIS image is monochromatic). If the jump lights were the same shape, an operator wearing NVIS would not be able to distinguish between a "jump" and a "no jump" light. Shape coding will allow operators to look at jump lights through NVIS and be able to determine when the "jump" signal is given.

The shape of signal lights must be sufficiently different to readily distinguish "jump" from "no jump" and should be intuitive and representational enough to convey the meaning quickly and reliably. One possible coding scheme would be to use a luminous parachute shape to represent "jump" and the same symbol with the international symbol of a diagonal line across the parachute to represent "no jump." Since visual acuity through the NVIS is less than with the unaided eye, the size of the signal should be large enough to be easily visible through NVIS. The source for this requirement is MIL-L-85762.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.6.2)

TBD

4.5.2.1.8.6.2 Troop jump signals.

The troop jump signals lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.11, 4.2.1.11.1, 4.2.1.11.2, 4.2.1.11.3, 4.2.1.11.3, 4.2.1.11.3.1, 4.2.1.11.3.1, 4.2.1.11.3.2 and 4.2.1.11.4 of MIL-L-8720; 4.X of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.6.2)

Since color discrimination is not possible with type I NVIS, the shape coding of the jump lights must provide unambiguous indication of "jump" and "no jump" signals.

VERIFICATION GUIDANCE (4.5.2.1.8.6.2)

A demonstration shall be conducted to prove that the shape coding permits the rapid and accurate discrimination of jump signals. Subjects wearing type I NVIS in a dark room shall view randomly presented signals at the maximum distance that would be encountered in the actual aircraft. The signal should be presented for only a brief time so that the subject will have to make quick judgments. Each signal shall be randomly presented for a large number of trials. For each trial, the subject shall indicate which of the two symbols was presented. The subject shall respond correctly at a high percentage (to be determined by the procurer of the system).

VERIFICATION LESSONS LEARNED (4.5.2.1.8.6.2)

TBD

3.5.2.1.8.6.3 Interior emergency lighting locations.

Emergency lighting shall include interior lighting for personnel orientation, the location and identification of emergency exits, and exterior lighting of each exit illuminating the area around the exit. Supplementary emergency lighting units shall be provided above or next to each normal and emergency exit with adequate illumination to permit untrained personnel to identify each exit, to read exit operating instructions, and to actuate the exit mechanism without difficulty in anticipated smoke densities. Emergency exit signs shall be installed so they can be read directly by all occupants of the compartment in their normal seated positions. All emergency units shall be self-contained, including the power source for the lamp, and shall be capable of operating independently of the main lighting system. The emergency lighting system (including all components of the system necessary to provide the required illumination during a crash) shall be capable of withstanding a ______ shock impulse for ____________ seconds duration. All emergency lighting units shall be designed to be actuated automatically and manually. Each unit shall be designed so that it can be reset manually or remotely in case of inadvertent actuation. A switch which can be used for actuating or resetting all of the emergency lighting units shall be located in the cockpit. Those units that are to remain in the aircraft shall have self-contained power but may be actuated from one or more common sensing devices located remote from the lights. The common sensing devices shall operate under the same conditions as those included in the lights. The circuits for the lights shall be such that they will be energized in the event the circuits between the lights and sensors are broken. The power source for the emergency lights shall be independent of the main electrical power source for the aircraft and shall be self-contained in the lighting units. The power source shall be such that it will be maintained in a fully charged condition by power obtained from the aircraft electrical system. Batteries shall be commercially available.

REQUIREMENT RATIONALE (3.5.2.1.8.6.3)

Properly located lighting is required for emergency situations.

Emergency illumination is required for safe conduct of passengers to the exits.

The NVIS radiance of emergency exit lighting must be specified in order to optimize the utility of the light while minimizing the impact on out-of-cockpit visibility when employing NVIS.

Self-luminous exit markers are too dim and represent potential radiation hazards.

Exterior emergency lighting must be able to withstand a crash shock impulse and be capable of being activated both automatically and manually.

REQUIREMENT GUIDANCE (3.5.2.1.8.6.3)

Invoke this requirement for aircraft that carry passengers. Emergency lighting must provide orientation, location, and identification of emergency exits. The area around the exit (inside and outside) must also be illuminated to permit untrained personnel to identify, read exit operating instructions, and open the door without difficulty in anticipated smoke densities. Location of lights interacts with the illumination distribution and illumination levels. Emergency exits must be located so they are visible to all occupants sitting in their normal seated positions. The source for this requirement is MIL-L-6503.

Invoke for all interior emergency lighting in aircraft that carry passengers. Emergency interior lighting must provide 0.05 fc minimum illumination as measured 20 inches above the area in front of the exit and on the floor of the aisles leading to the exit. The higher the emergency illumination the better, though emergency power is a limiting factor. The lighting should provide a "marked" path through smoke so passengers can find the exits. Lighting around the door is especially important for the proper operation of the latches and emergency equipment. The source for this requirement is MIL-L-6503.

Use the appropriate lighting components and type/class NVIS specified in table IV at the required illumination levels.

Emergency exit lights that are manually activated do not have to be NVIS compatible, while lights that can be automatically activated during flight must be NVIS compatible. Any lights which may automatically activate during an in flight emergency must be compatible so that the aircrew personnel can see outside the aircraft while wearing NVIS in case they have to land. Manual systems can be controlled so that they do not have to be turned on until at or just before landing and therefore do not have to be NVIS compatible. The source for this requirement is MIL-L-85762.

Invoke this requirement for all luminous exit signs. Self-luminous markers contain phosphors that are excited by radioactive material. These units are hermetically sealed and are safe. However, radioactivity would leak out after being impacted or post crash. They are also very dim with respect to incandescent illuminated markers, and would not be as visible in an obscured, smoke-filled atmosphere. The source for this requirement is MIL-L-6503.

Invoke this requirement for all aircraft that utilize emergency exit lighting.

a. All emergency units must be completely self-contained. All components of the system must be able to withstand a 20-g shock for 0.10-second duration and be explosion-proof. All components must be accessible for periodic maintenance.

b. All emergency units must be able to be either manually or automatically activated with a reset capability. Control should be in the cockpit. The light should energize when subjected to a 2-g shock for 0.01-second duration. The fail-safe condition must be on.

c. The power supply must be independent and automatically maintained in a fully charged condition, subject to testing. Batteries must be commercially available.

All emergency lighting requirements are to insure proper survival, actuation, and portability (for hand-held units) of the system following a crash. These requirements complement the interior emergency lighting requirements herein. The interior and exterior systems must be fully integrated with each other. The fill-in values are to be modified when dictated by new data and expert analyses and opinion. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.2.1.8.6.3)

TBD

4.5.2.1.8.6.3 Interior emergency lighting locations.

The interior emergency lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.1.12, 4.2.1.12.1, 4.2.1.12.2, 4.2.1.12.2.1, 4.2.1.12.3, and 4.2.1.12.4 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.2.1.8.6.3)

The critical nature of emergency lighting location demands a thorough analysis and demonstration of their operational capability.

Minimum emergency lighting illumination of aisles and exit areas must be directly measured to assure safe conduct of passengers.

Direct measurement of a lighting component's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Inspection of engineering drawings is the most cost-effective method to verify this requirement.

Test is the most accurate and cost-effective method to verify an exterior emergency lighting subsystem's survivability and actuation.

VERIFICATION GUIDANCE (4.5.2.1.8.6.3)

Inspect engineering drawings and verify that the different aspects of exit lighting, as specified above, have been taken into account. Cabin geometry can be analyzed to verify viewability of exit signs, which must be reverified through demonstration by mockup or actual equipment. One percentile sitting eye height female observers should be able to view exit signs from all normal seat positions.

Same as floodlighting illumination verification guidance. Measurements must be taken often, in evenly spaced intervals, at specified heights above the floor. Sampling must be representative of the entire illumination scheme.

Inspection shall be in accordance with 4.5.2.1.6.

Inspect engineering drawings and verify that no self-luminous, radioactive emergency exit signs are used in the aircraft.

Subject all components of the system to specified shocks and verify survival, activation and lights on time are met.

VERIFICATION LESSONS LEARNED (4.5.2.1.8.6.3)

TBD

3.5.3 Exterior lighting subsystems.

3.5.3.1 Anticollision lighting.

The system shall be located so that the emitted light will not be detrimental to the crew's vision and will not detract from the conspicuity of the position lights. The effective flash frequency shall be not less than 3.50 nor more than 100 cycles per minute except when the system includes overlaps created by more than one light source. In overlaps, effective flash frequencies shall not exceed 180 cycles per minute. An optimum effective flash frequency is 90 cycles per minute. The field of coverage shall extend in all directions, except that a solid angle or angles of obstructed visibility totaling not more than 0.03 sr shall be allowable within a solid angle equal to 0.15 sr centered about the longitudinal axis in the rearward direction.

For subsonic aircraft with fuselage mounted red source and wing tip mounted white source, the luminous intensity emitted by each red light source shall have, in the vertical field, the hemispherical coverage above and below the horizontal plane of the light source as specified in table IX. The luminous intensity emitted by each white light source, shall have 180° horizontal coverage with the vertical coverage specified in table IX (?*External lighting 1?*).

TABLE IX. Light intensity distribution per light assembly for subsonic aircraft.

Angle above (+) and below (-) horizontal plane (degrees)	Intensity (effective candelas (cd))	
	Wing tip Day mode (white) minimum	Fuselage Night mode (aviation red) minimum
+75	120	20
+30	250	40
+20	500	80
+10	160	240
+5	2500	400
0	2500	400
-5	2500	-
-10	1600	-
-20	500	-
-30	250	-
-75	120	-

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 hemispherical coverage above and below the horizontal plane of the light source as specified in table X. The minimum light intensity requirement specified in table X *(?External lighting 2?)* may be diminished by 15 percent for a 60-degree (maximum) sector or the 360-degree horizontal plane.

For rotary wing aircraft with fuselage mounted, dual (red and white) mode, the luminous intensity emitted by both the red and white modes shall have, in the vertical field, the hemispherical coverage above and below the horizontal planes of the light source specified in table XI. The minimum light intensity requirement specified in table XI *(?External lighting 3?)* may be diminished by 15 percent for a 60-degree maximum sector or the 360-degree horizontal plane.

REQUIREMENT RATIONALE (3.5.3.1)

This is required to make aircraft conspicuous so that safe separation distances between aircraft can be maintained to minimize mid-air collisions and near misses.

Effective flash frequency must be specified to optimize visibility and provide standardization.

Flashing signals are detected differently from steady signals requiring the application of the Blondel and Rey equation.

Anticollision light blockage must be minimized to assure detectability.

Minimum anticollision light intensity distributions must be specified to assure optimal visibility.

TABLE X. Light intensity distribution per light assembly for supersonic aircraft.

Angle above (+) and below (-) horizontal plane (degrees)	Intensity (effective candelas (cd))							
	Fuselage (360° light coverage)				Wing tip or vertical stabilizer (180° light coverage)			
	White		Aviation Red		White[1/]		Aviation Red	
	Min	Max	Min	Max	Min	Max	Min	Max
+75	90	-	15	-	-	-	-	-
+30	330	-	55	-	330	-	55	-
+20	660	-	110	-	660	-	110	-
+10	1320		220	-	1330	-	220	-
+ 5	2000	-	400	-	2000	-	400	-
0	2000	-	400	-	2000	-	400	-
– 5		-		-	2000	-	400	-
–10		-		-	1330	-	220	-
–20		-		-	660	-	110	-
–30		-		-	330	-	55	-

[1/]The vertical coverage (minimum) for each strobe light shall provide those listed except for 0° to 20° and 160° to 180° outboard. In these areas the light intensity levels shall be reduced by 20 percent.

TABLE XI. Light intensity distribution per light assembly for rotary-wing aircraft.

Angle above (+) and below (-) horizontal plane (degrees)	Intensity (effective candelas (cd))			
	Day mode (white)		Night mode (aviation red)	
	Min	Max	Min	Max
+80	100	-	-	-
+45	875	-	-	-
+20	1750	-	75	250
+10	2800	-	120	250
+5	3500	-	150	250
0	3500	-	150	250
-5	3500	-	120	250
-10	1750	-	75	250
-20	1000	-	38	250

REQUIREMENT GUIDANCE (3.5.3.1)

Invoke this requirement for all aircraft. Location of the anticollision lights are unique for each aircraft; however, location must provide for the greatest possible conspicuity, must be positioned to have minimal interference of illumination intensity from intervening aircraft structure, and must not be detrimental to the vision of the pilot or copilot. The source for this requirement is MIL-L-6503. Location or placement of the anticollision lighting system on an aircraft is only one part of testing because other factors impinge on location, i.e., aerodynamics, mission, intervening structure, visual interference, electromagnetic interference and space availability.

The effective flash frequency is the frequency at which the aircraft's complete anticollision light system is observed from a reasonable distance. Early studies by Blondel and Rey (1911) established that a flashing light is more conspicuous than a steady burning light of the same intensity. Most of the follow-on studies done at universities, industry and the Government use the Blondel and Rey research as their basis for determining the most effective rate of flash. The sources for this requirement are MIL-L-6503 and Federal Aviation Regulation (FAR) 25.

Each flash unit must be tested for rate of flash at the contractor's facility and witnessed by a qualified Government representative. Flashes should be synchronized with other flash sources on the aircraft.

The classic experimental work reported by Blondel and Rey in 1911 is considered to be the basis for the light intensity calculation. Subsequent studies by others have yielded results consistent with the Blondel and Rey equation and have found widespread applicability. It is convenient to evaluate flashing lights in terms of their effective intensity, IE, that is, the intensity of a fixed light which will appear equally bright. However, it is generally recognized that when a light signal consists of separate flashes, the instantaneous intensity during the flashes must be greater than the intensity of a steady light in order to obtain threshold visibility. The Blondel-Rey equation shall be used to calculate the effective intensity of one anticollision light. A good reference for this computation is NBS 480-16 and Illuminating Engineering, Vol. 52, No. 12, December 1957, titled, Computation of the Effective Intensity of Flashing Lights, by Charles A. Douglas. The sources for this requirement are MIL-L-6503 and FAR Part 25.

Invoke for all anticollision light installations. Total obstructed angle(s) must not exceed 0.03 sr within 0.15 sr centered about the longitudinal axis in the rearward direction. This type of blockage typically occurs by the vertical stabilizer fin. Other aircraft structures, such as antennas, can also block the light. These blockages are usually very small but must not exceed the specified 0.03 sr maximum blockage. The sources for this requirement are MIL-L-6503 and FAR Part 25.

Invoke this requirement for all subsonic aircraft having fuselage mounted red and wing tip mounted white anticollision lights. Horizontal coverage will be 180° for white wing tip mounted lights and 360° for red fuselage mounted lights. Separate red and white assemblies are mounted at two different locations to minimize light blockage. Minimum intensity distributions above and below the horizontal plane, for white and aviation red light assemblies are found in table IX. At night, intensities are reduced since an observer's vision has increased sensitivity and flashback of the exterior lights into the cockpit windows must be minimized. Subsonic. supersonic, and rotary-wing aircraft configurations and aerodynamics directly affect lens design and light distribution requirements. The source for this requirement is MIL-L-85314.

Invoke this requirement for all supersonic and small subsonic aircraft having either fuselage, wing tip, and/or vertical stabilizer. See anticollision intensity distribution requirement guidance for background information. The source for this requirement is MIL-L-85314.

Consideration should be given to adding a requirement to make anti-collision strobe light pilot selectable, tri mode, with a NORMAL FAA required mode, IR ON infared (i.e., covert) mode, and BOTH ON modes. The IR mode reduces the aircraft signature allowing only NVG equiped personnel (e.g., wingman) to see the IR light when they are ON (NORMAL OFF). Consider having the IR lights not viewable from the lower hemisphere. Consider having the position and formation lighting systems having an additional IR Infared mode. Having both NORMAL and IR ON at the same time would allow CONUS units to train with NVGs and the Infared mode in non-restricted airspace. Consideration should be given toward making both the NORMAL and IR mode have several pilot selectable, *coded* modes with different flash rates & patterns. This helps a trailing aircraft reacquire (e.g., after a bomb run) and identify the lead aircraft out of a night sky background, full of stars and other flashing strobe lights.

FAA Part 25 requires the anticollision strobe light be Aviation White in color. The color shall conform to the x, y, z CIE 1931 coordinates of: x is not less than 0.350 or greater than 0.540, and $y-y_o$ is not numerically greater than 0.01. Y_o is the y coordinate of the Planckian Radiator for which $x_o = x$ (see figure 1).

REQUIREMENT LESSONS LEARNED (3.5.3.1)

The retractable anticollision lights on some aircraft are high maintenance items because the retraction mechanism has low reliability. The value added to operational performance by retractable anticollision lights is questionable, when maintenance requirements and reliability are considered.

Effective flash rates below 40 flashes per minute and above 180 flashes per minute are not recommended due to adverse psychophysiological effects.

4.5.3 Exterior lighting subsystems.

4.5.3.1 Anti-collision lighting.

The anti-collision lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.1.1, 4.2.2.1.2, 4.2.2.1.3, 4.2.2.1.4, 4.2.2.1.5, 4.2.2.1.6 and 4.2.2.1.7 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2 SOPs.

VERIFICATION RATIONALE (4.5.3.1)

Verification of the location of anticollision lights on the aircraft is best suited to analysis of the aircraft configuration as it applies to the position of the lights, their conspicuity and visual interference.

Specific testing of the flash rate of the aircraft anticollision lighting system can best be done by the manufacturer in his testing facility using the same power supplied as the intended aircraft. Through experience it has been demonstrated this is the best way to test the flash rate of the anticollision units.

Mathematical analysis is the only method of calculating the effective intensity.

Analysis is the most cost-effective and accurate method to determine light blockage.

Direct intensity measurements assure minimum intensity requirements are met.

VERIFICATION GUIDANCE (4.5.3.1)

Location or placement of the anticollision lighting system on an aircraft is only one part of testing because other factors impinge on location, i.e., aerodynamics, mission, intervening structure, visual interference, electromagnetic interference, and space availability.

This verification shall be done by test and inspection. The testing is best done at the manufacturer's testing facility with Government witnesses. The inspection shall be done when the flash units are installed on the aircraft. When the complete anticollision system is powered up, with all aircraft systems operating, the manufacturer's field service representative and a Government representative shall test the anticollision system to verify the system meets the flash rate.

Qualified personnel, knowledgeable in this area, must be selected to do these calculations.

Perform geometrical analyses to determine blockage by all involved structures and verify compliance to requirement.

Intensity measurement of rotating-type beacons: Disconnect beacon motor and mount in a rotating fixture that is synchronized with the chart recorder rotation. Measure with a photometer. Perform appropriate Blondel-Rey calculations.

Intensity measurements of strobe-type lights: Mount on two-axis fixture (goniometer) that will allow selection of any angle. Measure about 5 flashes per angle with an integrating photometer (lumens seconds). Divide the result by the number of measurements and perform appropriate Blondel-Rey calculations.

NOTE: Special consideration must be given to measurement units and calculation units.

See anticollision light intensity distribution verification guidance.

VERIFICATION LESSONS LEARNED (4.5.3.1)

A true verification of the anticollision flash rate cannot be done if all of the aircraft systems used during a mission are not on. When the worst case aircraft power requirements are met, the test results of the anticollision light flash rate can be evaluated.

3.5.3.2 Position lights.

3.5.3.2.1 Position light location and chromaticity.

Position light location and chromaticity shall be as follows: Each part of each position light system shall meet the applicable requirements of this section and each system as a whole shall meet the requirements of dihedral angle definitions and intensities. Forward position lights shall consist of aviation red and aviation green, spaced laterally as far apart as practicable and installed forward on the airplane so that with the airplane in the normal flying position, the red light shall be on the left side, and the green light shall be on the right side. The rear position light shall be aviation white, mounted as far aft as practicable on the tail or on each wing tip. Each light cover or color filter shall be at least flame resistant and shall not change color, nor lose shape or any appreciable light transmission during normal use. The light distribution and intensities of forward and rear position lights shall be expressed in terms of minimum intensities in the horizontal plane, minimum intensities in any vertical plane, and maximum intensities in overlapping beams, within dihedral angles L, R, and A, and shall meet the requirements of tables XII, XIII, and XIV (?Exterior Lighting 4, 5, and 6?).

TABLE XII. Minimum intensities in the horizontal plane of forward and rear position lights.

Dihedral (light included)	Angle from right or left of longitudinal axis, measured from dead ahead.	Intensity (candelas)
L and R (forward red and green).	0° to 10°	40
	10° to 20°	30
	20° to 110°	5
R (rear white)	110° to 180°	20

TABLE XIII. Intensities in a vertical plane.

Angle above or below the horizontal plane	Intensity (candelas (cd))
Minimum intensities in the vertical plane of forward and rear position lights.	
0 °	1.00 I.
0 ° to 5 °	0.90 I.
5 ° to 10 °	0.80 I.
10 ° to 15 °	0.70 I.
15 ° to 20 °	0.50 I.
20 ° to 30 °	0.30 I.
30 ° to 50 °	0.10 I.
50 ° to 90 °	0.05 I.

TABLE XIV. Maximum intensities in overlapping beams of forward and rear position lights.

Overlaps	Maximum intensity	
	Area A [1/] (candelas (cd))	Area B [2/] (candelas (cd))
Green in dihedral angle L	10	1
Red in dihedral angle R	10	1
Green in dihedral angle A	5	1
Red in dihedral angle A	5	1
Rear white in dihedral angle L	5	1
Rear white in dihedral angle R	5	1

[1/] Area A includes all directions in the adjacent dihedral angle that pass through the light source and intersect the common boundary plane at more than 10° but less than 20°.
[2/] Area B includes all directions in the adjacent dihedral angle that pass through the light source and intersect the common boundary plane at more than 20°.

REQUIREMENT RATIONALE (3.5.3.2.1)

Aviation red, green, and white aircraft position lights are required by the FAA and ratified international agreements.

Position light dihedral angles must be defined for intensity distribution requirements.

REQUIREMENT GUIDANCE (3.5.3.2.1)

Invoke for all fixed-wing aircraft, no exceptions. Position light locations and colors have been standardized by the FAA and through international agreements (STANAGs). The aviation red light must be on the left wing tip, the aviation green light must be on the right wing tip and the aviation white light must be either on the most aft tail position or on each aft wing tip. The red and green lights need to be as far apart as possible. This arrangement will allow distant observers to ascertain the aircraft's orientation and direction of flight. Aviation type colors are used to assure unambiguous color identification and standardization. The source for this requirement is FAR Part 25.

Invoke for all fixed-wing aircraft, no exceptions. This requirement defines dihedral angles for position light illuminance distributions. The above defined dihedral angles are pictorially shown on figure 3. Note that the aircraft has complete 360-degree coverage with highest intensities in front of and behind the aircraft, but interference to the cockpit is minimized by the spatial separation. The source for this requirement is FAR Part 25.

Consideration should be given towards making the Position lights NVIS compatible so as to not "blind" a NVG equiped wingman.

Consideration should be given to adding an Infared IR or covert mode to the Position light system. Recommend making it not viewable from the lower hemisphere. An IR mode reduces the aircraft signature making it visible only to someone equiped with NVGs (e.g., wingman).

Consideration should be given to drastically reducing or filtering out the near IR component of the FAA required Aviation Red (left side of aircraft) and Aviation Green (right side of aircraft) position lights to make these lights NVIS "friendly". This may help lessen the negative impact (i.e., automatic NVG gain down) of these lights on the NVGs of a wing man

Consider making the position lights dimmable.

FAA Part 25 requires the right side position/navigation lights be Aviation Green in color and the left side position/navigation lights be Aviation Red in color. Aviation Green shall conform to the x, y, z CIE 1931 coordinates of: x not greater than 0.440-0.320y, or greater than y - 0.170, and y is not less than 0.390 - 0.170x. Aviation Red shall conform to the x, y, z CIE 1931 coordinates of: y is not greater than 0.335, and z is not greater than 0.002 (see figure 1).

An aft tail or aft wing tip position light shall be Aviation White which shall conform to the x, y, z CIE 1931 coordinates of: x is not less than 0.350 or greater than 0.540, and $y-y_o$ is not numerically greater than 0.01. Y_o is the y coordinate of the Planckian Radiator for which $x_o = x$ (see figure 1).

REQUIREMENT LESSONS LEARNED (3.5.3.2.1)

The KC-10 has successfully used white position lights on aft wing tip locations.

If position lights have a NVIS requirement, consider a NR_A that does not exceed 3.5×10^{-7} at 15 fL as a target radiance limit for NVIS "friendliness". You should still strive to meet the Aviation White, Red, and Green FAA color requirements as best as possible so that the aircraft can operate in civilian airspace.

4.5.3.2.1 Position light location and chromaticity.

The position light location and chromaticity lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in section 4 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

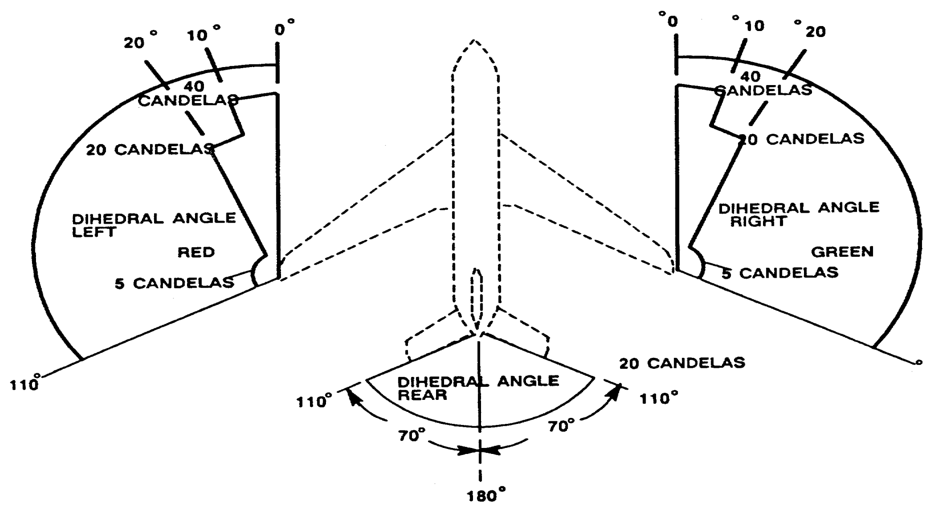


FIGURE 3. Position light dihedral angles and Intensity distribution in the horizontal plane.

VERIFICATION RATIONALE (4.5.3.2.1)

Analysis and test are the most cost effective and accurate verification methods of position light dihedral angles.

VERIFICATION GUIDANCE (4.5.3.2.1)

Obtain appropriate engineering drawings and verify specified locations for all position lights. The red and green must be as far apart as possible, usually on the forward left and right wing tips, respectively. The white light can be on either the aft wing tips or on the aft-most fuselage location or vertical tail.

Chromaticity must be verified through test. Refer to instrument and panel chromaticity verification section.

Examine appropriate engineering drawing for compliance to dihedral angle requirements.

VERIFICATION LESSONS LEARNED (4.5.3.2.1)

TBD

3.5.3.2.2 Position light distribution and intensity.

Position light distribution and intensity shall meet the requirements of table XII, table XIII, figure 4, and table XIV. Federal Aviation Regulation (FAR) Parts 25.1385, 25.1387, 25.1389, 25.1391, 25.1393, and 25.1395 of Part 25 Airworthiness Standards: Transport Category Aircraft shall be met.

REQUIREMENT RATIONALE (3.5.3.2.2)

Position light distribution and intensities must be specified to comply to FAA and internationally ratified agreements.

REQUIREMENT GUIDANCE (3.5.3.2.2)

Invoke for all fixed-wing aircraft, no exceptions. Distributions and intensities are specified to comply with FAA and ratified international agreements. Table XII defines the forward red, forward green, and rear white lights' minimum horizontal intensity in candelas, distributed as a function of angle from the longitudinal axis. Table XIII defines the forward and rear lights' minimum vertical intensity in candelas, distributed as a function of angles above and below the horizontal plane. Table XII is pictorially depicted on figure 3; table XIII is pictorially depicted on figure 4. Table XIV defines the maximum intensities allowed in defined overlap areas. All position light intensities have been derived over time to provide good position information to distant observers and minimize interference to the cockpit crews' vision. Aircraft aerodynamics interacts with position light lens design that directly affects intensity and distribution. Generally, the faster the aircraft the more difficult the design. Aircraft Position Light Design Handbook Report No. NA 62H-109, North American Aviation (North American Rockwell), Columbus, OH, is a good reference for the design of position lights. The source for this requirement is FAR Part 25.

REQUIREMENT LESSONS LEARNED (3.5.3.2.2)

Poorly placed mounting screws can adversely affect intensity distribution.

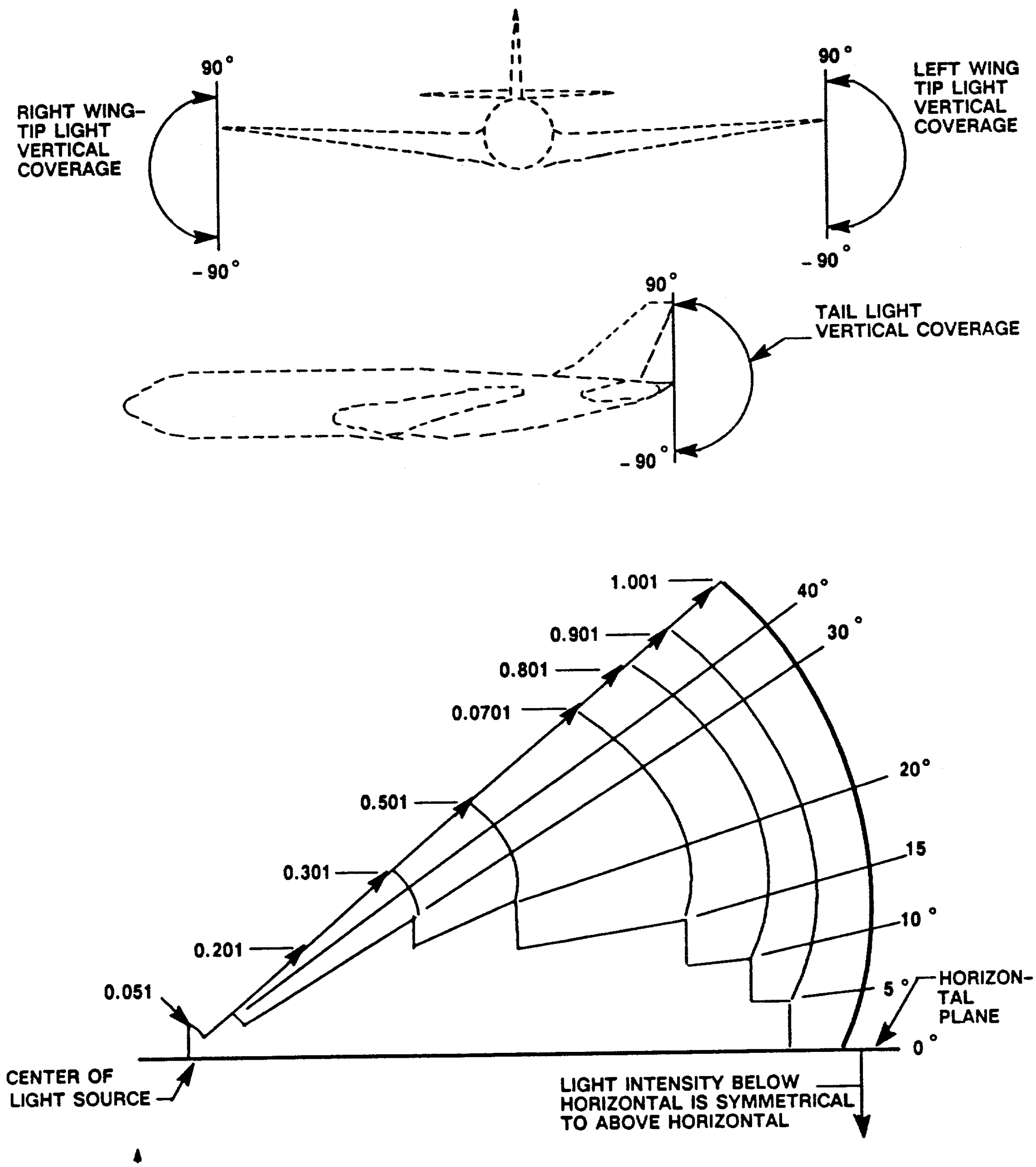


FIGURE 4. Position light intensity distribution in the vertical plane.

4.5.3.2.2 Position light distribution and intensity.

The position light distribution and intensity lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.2.3 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.2.2)

Direct measurement of position light distribution and intensities is required to assure full compliance to FAA regulations.

VERIFICATION GUIDANCE (4.5.3.2.2)

A laboratory set-up is required to be able to rotate a lighted assembly with respect to the intensity measurement equipment, thus providing continuous measurement data as a function of all angles (horizontal and vertical planes). See anticollision light verification guidance for intensity measurements. Ensure intensity, distribution, and overlap are in compliance with the requirements.

VERIFICATION LESSONS LEARNED (4.5.3.2.2)

TBD

3.5.3.3 Aerial refueling lights.

3.5.3.3.1 Tanker refueling light dimming.

Separate intensity controls shall be provided for each type of refueling light, except where noted, whereby the lights can be varied from FULL LUMINANCE to OFF over the entire range of the control. Continuous dimming shall provide luminous increase and decrease in log footlamberts (fL) with linear control rotation. No current shall flow through the lamps when the dimmer is set to full OFF.

REQUIREMENT RATIONALE (3.5.3.3.1)

All aircraft external lighting for refueling requires variable intensity controls to enhance nighttime visual performance, except where noted, herein.

REQUIREMENTS GUIDANCE (3.5.3.3.1)

Invoke this requirement for all external refueling lights on tanker aircraft. This requirement is virtually the same as the general requirements dimming section and the same guidance applies.

REQUIREMENT LESSONS LEARNED (3.5.3.3.1)

TBD

4.5.3.3.1 Tanker refueling light dimming.

The tanker refueling light dimming lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.1)

Direct measurement of dimming characteristics is the most accurate method to assure compliance to this requirement.

VERIFICATION GUIDANCE (4.5.3.3.1)

The main difference between instrument and refueling light dimming is that the former requires closer tracking and is in luminance units whereas the latter is in illuminance units. There are three requirements to verify: luminous control range, luminous rate of change with respect to control change, and current leakage. Tracking requirements should be invoked for the director lights.

Luminous control range is verified by varying the control from full “off” to full “on” while measuring the illumination change. Methods for measuring illumination can be found in the floodlight illumination verification section. Minimum to maximum control motion must have corresponding illumination changes. This same measurement data can also be used to verify the dimming characteristics. Seven to ten equally spaced control locations and their corresponding illuminance levels can be plotted using appropriate logarithmic transformations and the resulting curve should be nearly linear. Humans perceive logarithmic illuminance changes as near linear brightness changes. This defined control and illuminant relationship should present a linear illuminant change with respect to a linear control change. (Volume controls for audio equipment are much the same.)

Using an ampere meter, verify that no current flows through lamp filaments when the control is set to “off.”

VERIFICATION LESSONS LEARNED (4.5.3.3.1)

TBD

3.5.3.3.2 Tanker rendezvous lights.

Unless otherwise specified, each tanker aircraft shall be provided with a coded rendezvous light system that will permit the receiver aircraft to visually locate and identify the tanker after being brought into visual range by electronic or other means. The rendezvous light shall provide two rotating beams of ____________ light 180 apart and two rotating beams of ____________ light 180 apart. The red and white beams shall be 90 out-of-phase. The light shall rotate between 20 and 30 rpm. This will provide flash rates of 3.50 to 60 flashes per minute with either the ____________ or ____________ beam on and 80 to 120 flashes per minute with both the red and white beams turned on. The circuitry for the rendezvous lights shall be such that either the ____________ or the ____________ beams can be turned on individually or both beams together. Controls shall be located at the flight deck.

REQUIREMENT RATIONALE (3.5.3.3.2)

Tanker aircraft require a means to be visually acquired and identified by receiver aircraft.

REQUIREMENT GUIDANCE (3.5.3.3.2)

Invoke this requirement for all tanker aircraft. Receiver aircraft require light beacons to visually acquire and identify tankers at rendezvous points. These beacons are sometimes integral with the anticollision beacons; upper and lower, midfuselage section. Requirements are to establish equally alternating red and white flashing beacons for rendezvous. This is a standardized requirement. Any deviation must be fully justified to the procuring activity. Circuitry to control the red and white flashing sequences must be included so that if more than one tanker is in the rendezvous area, each can have a unique beacon sequence for identification purposes. The standard sequences are: red only, white only, and alternating. Green and yellow may be considered. Other sequences may be considered (see The Society of Automotive Engineering recommendations). The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.3.2)

Effective flash rates below 40 and above 180 flashes per minute are not recommended due to adverse psychophysiological effects.

4.5.3.3.2 Tanker rendezvous lights.

The tanker rendezvous lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.2)

Demonstration and test are the most cost-effective methods to verify use of rendezvous beacons.

VERIFICATION GUIDANCE (4.5.3.3.2)

Verify that two rendezvous beacons are located above and below the midfuselage section; one red and one white. Operate each beacon in all rendezvous modes. Verify (with timing equipment/data) that specified flashes per minute are used and that the red and white beacons are 180 degrees out-of-phase (equal flash intervals). Verify that each mode (alternating, red only, white only, or others as specified) works.

VERIFICATION LESSONS LEARNED (4.5.3.3.2)

TBD

3.5.3.3.3 Tanker floodlighting.

Dimmable illumination shall be provided utilizing floodlighting on the upper fuselage, entire lower fuselage, underwing, horizontal stabilizer (underside), vertical stabilizer, wing leading-edge, engine nacelles, drogue store(s) (if used), hose, and drogue basket, tail-mounted lights, floodlighting the receiver aircraft. All lights used in the system shall be positioned and shielded to prevent direct light from being projected into openings of the tanker or receiver aircraft through which observation must be made during final hookup or transfer of fuel.

REQUIREMENT RATIONALE (3.5.3.3.3)

Tanker body illumination is needed to provide acquisition and orientation cues to receiver aircraft during rendezvous and refueling operations.

REQUIREMENT GUIDANCE (3.5.3.3.3)

Invoke this requirement for all tanker aircraft. During refueling operations, the receiver needs tanker orientation information. Floodlighting provides numerous cues. An added benefit is that a floodlighted tanker is more easily acquired at long slant ranges. Continuous dimming from full brightness to full off over the entire range of the control is required since the lights are often too bright when the tanker and receiver are very close to each other. Floodlight controls are at either the flight engineer or boomer stations, as deemed appropriate by the procuring activity. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.3.3)

Tanker floodlighting can easily cause hotspots and glare. Care must be taken to minimize or eliminate these problems through careful control of floodlight beam location and spread. Leading edge, drogue associated, and nacelle lights often shine directly into receiver’s eyes when aircraft are deployed to the tanker’s wing, waiting to refuel. Separate left and right-hand controls should be considered for the boom operator.

Receiver pilots in enclosed cockpits (like the C-141), as contrasted to bubble canopies (like the F-15), have a more restricted field of regard and thus need more forward fuselage under body illumination.

4.5.3.3.3 Tanker floodlighting.

The tanker floodlighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.3 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.3)

Demonstration is the most accurate method to verify tanker floodlighting operational capability and performance.

VERIFICATION GUIDANCE (4.5.3.3.3)

Flight test tanker aircraft at night with all designated receivers. Have all receiver pilots evaluate operation and utility of tanker floodlighting, including coverage, hot spots, dimming, and glare while at either the receiver or deployed to the wing positions.

VERIFICATION LESSONS LEARNED (4.5.3.3.3)

TBD

3.5.3.3.4 Pilot director lights.

Pilot director lights shall be provided to aid the receiver pilot in positioning the receiver airplane within the safe operating envelope limits of the boom. The lights shall be visible in 7500 fc ambient illumination. The lights shall be automatically activated by the position of the boom in its operational envelope. The lights shall be located on the underside of the fuselage, forward of the wings. Direction and relative magnitude of correction shall be indicated to the pilot in the receiver aircraft. The director lights shall be activated when in a contact-made condition. A break-away signal shall be provided. Disconnect signal circuitry should be considered to predict if a disconnect is about to occur, so the disconnect sequence for any given receiver aircraft can be automatically initiated and completed by the time the actual limit is reached. Aviation green, aviation yellow, and aviation red lights shall represent optimal, nominal, and marginal boom positions, respectively. Illuminated white light panels in between each indicator light shall be used to provide background lighting. Director lights shall be continuously dimmable to zero.

REQUIREMENT RATIONALE (3.5.3.3.4)

Receiver pilots require boom position feedback to maneuver their aircraft within the safe refueling envelope.

REQUIREMENT GUIDANCE (3.5.3.3.4)

Invoke this requirement for all tanker aircraft utilizing boom refueling. Director fights are located on the forward underside of the fuselage. Exact location is determined through proper geometrical analysis of tanker size, boom characteristics, and receiver aircraft characteristics.

The signals must be visible using 7500 fc ambient illumination that can occur at altitude with full sun reflecting up from the tops of white clouds. Continuous dimming is required for proper nighttime operation.

Booms change in either azimuth or elevation (KC-135) or yaw and pitch (KC-10). KC-135, KE-3, and KC-10 director lights should be considered as baseline designs: the KE-3 and KC-10 are the superior subsystems. Any new director assembly must be similar to previous ones to assure positive transfer of training and standardization. When the boom moves to its limits, a disconnect sequence is started, however, there is an inherent release delay which can cause damage. The KC-10 uses a first-order (time X velocity) approximation to predict when a disconnect might occur. A constant is operationally determined for each particular receiver aircraft, and is dialed into the predictor circuit. Thus, when the boom starts to approach its limit, as predicted by the circuitry, it begins the disconnect sequence which will then be completed (not started) when the disconnect is supposed to occur. This circuitry compensates for the inherent mechanical disconnect delay. New designs should consider this type of disconnect signal circuitry.

Use of aviation green, aviation yellow, and aviation red lights provides standardization and these colors represent the overlearned meanings of go, caution, and warning, respectively. Confusability is also minimized through use of aviation type colors.

REQUIREMENT LESSONS LEARNED (3.5.3.3.4)

Moisture can condense in the lenses of the assembly; drain holes help. Plastic lenses deteriorate and change color; use environmentally proven materials. Slant angles can make it difficult to read lettering; assure adequate letter heights and widths for the typical off-axis viewing geometry during refueling operations. Compensatory disconnect circuitry may cause erratic director light indications; adjust disconnect constant. Painting internal light cavities high-reflective, flat white, including the opaque masks of letters on the lens, can increase luminous output and reduce luminous distribution variance. A 200 to 600 percent luminous increase can be realized with no additional increase in power consumption or shortening of bulb life.

4.5.3.3.4 Pilot director lights.

The pilot director lights requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.4 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.4)

Test is the most accurate method to verify chromaticity and demonstration will assure full operational capability of the pilot director lights.

VERIFICATION GUIDANCE (4.5.3.3.4)

See instrument and panel luminance and chromaticity verification guidance.

VERIFICATION LESSONS LEARNED (4.5.3.3.4)

See instrument and panel luminance and chromaticity verification lessons learned.

3.5.3.3.5 Fuel transfer indicators.

Fuel indicator lights shall be positioned in the boom or drogue store bell mouth (or housing) so they are visible to the pilot of the receiver aircraft during final approach for contact with the tanker and while fuel is being transferred. Aircraft that have multiple means of transfer shall have indicator lights for each transfer position. Indicator lights shall be of sufficient size and intensity and shall be suitably shielded so they can be seen by the receiver pilot in bright daylight as well as at night. Aviation yellow and aviation green indicator lights shall be installed on the tanker to inform the pilot of the receiver aircraft that the tanker is ready to transfer fuel, or that fuel is being transferred. Aviation yellow lights shall be used to indicate that the tanker is ready to transfer fuel; aviation green lights shall be used to indicate that fuel is being transferred. An aviation red light shall be used to warn the receiver pilot of an unsafe condition. Continuous dimming controls shall be provided for the yellow and green indicator lights. Separate left- and right-hand controls shall be provided to the boom operator. The aviation red warning light shall not be dimmable.

REQUIREMENT RATIONALE (3.5.3.3.5)

Refueling status lights must be provided to the receiver pilot during refueling operations.

REQUIREMENT GUIDANCE (3.5.3.3.5)

Invoke this requirement for all tanker aircraft (boom or drogue). Status lights must be provided to the receiver pilot to indicate that the tanker is ready to transfer fuel or fuel is being transferred. A red light warns the pilot of unsafe conditions.

All indicators must utilize defined aviation colors for standardization purposes and low confusion.

Continuous dimming is required for nighttime operations; however, the red warning light should not be dimmable since a dimmed indicator may not be detected.

Lights are usually duplicated at the left and right positions of the hose to allow observation from either side.

Adequate shielding of lamps must be used to ensure good daylight readability in high ambients. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.3.5)

TBD

4.5.3.3.5 Fuel transfer indicators.

The fuel transfer indicator requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.5 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.5)

See director lights and general dimming verification rationales. See instrument and panel chromaticity verification rationale for color tests.

VERIFICATION GUIDANCE (4.5.3.3.5)

See director light, dimming, and instrument and panel verification guidance sections.

VERIFICATION LESSONS LEARNED (4.5.3.3.5)

TBD

3.5.3.3.6 Boom marker and nozzle illumination.

Boom nozzle and hose extension marker illumination lights shall be mounted in the boom nozzle hood to provide proper nozzle and extension marker illumination. Hose marker lights shall be fluorescent black lamps whose ultraviolet rays cause the markings to glow during night refueling operations.

REQUIREMENT RATIONALE (3.5.3.3.6)

Hose extension markers and nozzle must be illuminated for successful night refueling.

REQUIREMENT GUIDANCE (3.5.3.3.6)

Invoke this requirement for all tanker aircraft using a refueling boom or drogue. The hose should have bands or markers showing optimal extension ranges. These are best illuminated with ultraviolet (UV) light so they glow at night. This is the preferred method since a regular light in the proper position would shine directly into the receiver pilot's eyes. The nozzle illumination is a narrow field floodlight used to add light to the receptacle area during the final connect. These lights must be continuously dimmable.

Drogue type aircraft need to flood the hose rollers and UV is usually not required. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.3.6)

Consideration should be given to adding an additional IR light or a light with a strong IR component to the end of the boom or basket to aid an NVG equiped pilot find the end of the boom or basket from a distance.

4.5.3.3.6 Boom marker and nozzle illumination.

The boom marker and nozzle illumination requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.6 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.6)

See tanker floodlighting verification rationale.

VERIFICATION GUIDANCE (4.5.3.3.6)

See tanker floodlighting verification guidance. Demonstration in flight test will assure full operational capability.

VERIFICATION LESSONS LEARNED (4.5.3.3.6)

TBD

3.5.3.3.7 Receiver aircraft refueling receptacle floodlighting.

All aircraft designed for nondrogue aerial refueling operations shall utilize ____________ receptacle floodlighting.

REQUIREMENT RATIONALE (3.5.3.3.7)

Refueling receptacles require illumination during nighttime refueling.

REQUIREMENT GUIDANCE (3.5.3.3.7)

Invoke this requirement for all receiver aircraft. Receptacle lighting is usually integral, being located and recessed on both sides of the opening. Some aircraft (KC-10) provide additional floodlighting to the general area with retractable fights. Luminance must be sufficient to provide adequate illumination for nighttime operations. Dimming should be considered. Glare to the boom operator to be minimized through proper shielding and placement. Avoid direct view of filaments.

REQUIREMENT LESSONS LEARNED (3.5.3.3.7)

Camouflaged receiver aircraft are very difficult to refuel at night. Painted or illuminated markings around the refueling receptacle are beneficial.

Auxiliary floodlighting fixtures can be accidentally knocked off by the boom in turbulent weather.

4.5.3.3.7 Receiver aircraft refueling receptacle floodlighting.

The receiver aircraft refueling receptacle floodlighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.7 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.7)

See tanker floodlighting verification rationale.

VERIFICATION GUIDANCE (4.5.3.3.7)

See tanker floodlighting verification guidance.

VERIFICATION LESSONS LEARNED (4.5.3.3.7)

Upper fuselage, tail-mounted floodlighting on small receiver aircraft can create a false horizon when in the weather.

3.5.3.3.8 Receiver aircraft drogue probe illumination.

Aircraft that use a probe for taking on fuel in-flight shall be provided with a light so located that the side of the probe and drogue basket that are visible to the receiver pilot are floodlighted.

REQUIREMENT RATIONALE (3.5.3.3.8)

Probe must be visible to the pilot at night for drogue refueling operations.

REQUIREMENT GUIDANCE (3.5.3.3.8)

Invoke this requirement for all aircraft (usually rotary-winged) using drogue probes for taking on fuel. A floodlight on the receiver aircraft is needed to illuminate the side of the probe that is visible to the receiver pilot. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.3.8)

TBD

4.5.3.3.8 Receiver aircraft drogue probe illumination.

The receiver aircraft drogue probe illumination requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.3.8 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.3.8)

See tanker floodlighting verification rationale.

VERIFICATION GUIDANCE (4.5.3.3.8)

See tanker floodlighting verification guidance.

VERIFICATION LESSONS LEARNED (4.5.3.3.8)

TBD

3.5.3.4 Landing and taxi lighting.

The landing and taxi light system for fixed wing aircraft shall provide not less than ____________ fc white illumination on the ground at distances appropriate for the aircraft's characteristic landing speed. The minimum illumination shall be provided on each side of the centerline of the aircraft to 10 feet outboard from each wing tip. Adequate illumination shall be provided to furnish wing tip clearance reference for pilots during ground operations. Aircraft designed for crosswind landings shall have lights installed in a manner such that the beam is projected in the direction of the aircraft movement. Aircraft designed to be handled by both a pilot and copilot during landing and take-off procedures shall be provided with a terrestrial landing light (retractable-type) to provide ground reference. The light shall be so connected that the lamp can be energized, from any position between its fully retracted position and its fully extended position. The angular coverage provided by the light shall be not less than____________ with the beam adjustable from directly downward beneath the aircraft to forward in the direction of flight of the aircraft. The lights shall be so located or shielded that direct or indirect light is not projected or reflected into transparent enclosures housing operating personnel of the aircraft. If used, covers shall be such that they do not appreciably reduce or distort the light emitted. 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. This requirement shall be given particular attention on aircraft that land at nonconventional attitudes. Two or more lamps shall be used; one-lamp systems shall not be acceptable.

Rotary-wing aircraft shall be equipped with a retractable-type landing light and a controllable search light. The retractable landing light shall be installed so that the beam from the lamp can be varied from ____________ above to ____________ below the normal horizontal light position of the aircraft. The controllable searchlight shall be so installed that when the light is fully stowed, the plane of the lamp mounting ring will be horizontal when the aircraft is in normal, level flight. The search light shall be of a type that can be extended not less than 120° from its fully stowed position. Consideration shall be given to the light locations in order to hold cockpit interference by the light output to the minimum.

REQUIREMENT RATIONALE (3.5.3.4)

Landing and taxi illumination is required for nighttime operations.

Lights are required for the safe conduct of nighttime take-off, search, rescue, landing and taxi operations.

REQUIREMENT GUIDANCE (3.5.3.4)

Invoke these requirements for all fixed-wing aircraft.

a. Two footcandles minimum and an increase, if achievable, should be a goal. Illuminance distribution must be tailored to the specific aircraft's landing attitude characteristics overall width.

b. Nighttime taxiing and ground operations require the pilot to be able to see the wing tip ground clearance.

c. Large aircraft often have the capability to reorient their landing gears for crosswind landings (C-5, B-52). Landing lights for these types of aircraft must project in the direction of movement for safety considerations.

d. A retractable-type light must be able to be energized in any of its positions to provide maximum aiming capability to the operators for ground reference. A minimum of 90 degrees angular coverage should be specified; some aircraft may require more.

e. Landing and taxi lights may cause interference to pilot and copilot vision. Interference must be through proper design of lamp shields and covers. Direct views of lamps must not occur. Geometrical analyses will be required to assure adequate illumination for all phases of landing and taxiing, especially for aircraft that have unusual landing attitudes.

f. Single lamp systems are not acceptable. The source for this requirement is MIL-L-6503.

Invoke this requirement for all rotary-wing aircraft. Landing, taxi, and search lights are required for safe conduct of nighttime operations. Rotary wing aircraft have unique attitudes, they hover, they perform search and rescue, and their cockpits are very open due to numerous windows. These and other factors must be considered when designing the landing, taxi, and search lights.

Both lights must be located beneath the aircraft as far forward as practicable in order to minimize interference from the light to the operator when the aircraft is in a nose-down attitude. Shielding may be employed to prevent scattered light from being projected into the cockpit. If practicable, the retractable lights should be installed on the nose wheel strut. The retractable light is needed to illuminate obstructions that may be in the flight path during take-off and landing. It must also provide illumination of the touchdown area during landing procedures. Consideration may be given to locating its control on the collective control stick. The retractable landing light should be variable from 20 degrees above to 60 degrees below the normal horizontal light position.

Interference by landing lights to crew vision must be minimized. The open, multiwindowed rotary-wing aircraft are very susceptible to visual interference by external lights. Location, controllability, shielding, etc. must be optimized to reduce these effects. The source for this requirement is MIL-L-6503.

Consideration should be given to adding an infared IR or covert mode to the landing and taxi light system. This reduces the aircraft signature and may aid ground operations with NVGs.

REQUIREMENT LESSONS LEARNED (3.5.3.4)

Lamp holders must be indexed so proper alignment is maintained after replacement. The installations must be provided with sufficient lamps so that the aircraft will not be completely without light in the event of a filament burnout or a broken bulb. A system using a single bulb will not be acceptable. The retractable lights, the narrow-beam high-intensity lamps, and the wide-beam, low-intensity lamps must have separate control circuits.

4.5.3.4 Landing and taxi lighting.

The landing and taxi lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.4 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.4)

The criticality of landing and taxi lighting performance mandates geometrical and photometric analyses to verify performance.

Analyses of retractable-type landing light aiming angles plus demonstration of coverage, aimability, and minimized glare to crew are the most accurate methods of landing light verification for rotary-wing aircraft.

VERIFICATION GUIDANCE (4.5.3.4)

Geometrical analysis of light coverage, aircraft size, landing speeds, attitudes, and cockpit location must be considered to insure adequate illuminance distributions. Photometric measurements are the same as illuminance measurements made for cockpit floodlighting illumination and tanker floodlighting. For landing and taxi light systems, the barium sulfate plate is to be perpendicular (vertical plane) directly ahead of each beam (lamp) at the distances (usually hundreds of feet) determined adequate for safe landing and taxiing operations, (and used in the geometrical considerations) for that particular aircraft. Equipment that directly measures illuminance is preferred. Two footcandles is a minimum; higher is desired but must be thoroughly analyzed. Numerous discrete or continuous measurements must be made to adequately characterize the illuminance distributions for all lights.

Examine appropriate engineering data and verify that the specified angles of coverage are mechanically achievable and in correct relationship to the aircraft's characteristic flying, hovering, and landing attitudes. Demonstrate during flight test that crew members are not adversely affected by landing light induced glare.

VERIFICATION LESSONS LEARNED (4.5.3.4)

TBD

3.5.3.5 Formation lights.

Aircraft required to fly in formation at night shall be equipped with formation lighting systems that will provide unambiguous visual orientation information regarding the attitude and position of the lead aircraft to the pilot of the adjacent aircraft in the formation. The type of formation in which the aircraft are to be flown shall determine the formation lighting system to be provided. The luminance of the formation lights shall be continuously variable from OFF to a maximum intensity of ____________ fL, over the entire range of the control. Rotary-wing aircraft shall have rotor-tip lights which are aviation white, continuously variable dimming from OFF to FULL LUMINANCE and not visible from directly above the aircraft nor readily seen from below the rotor plane.

REQUIREMENT RATIONALE (3.5.3.5)

Formation lights are required for coordinated nighttime operations of two or more aircraft.

Rotor-tips must be illuminated for formation flying.

REQUIREMENT GUIDANCE (3.5.3.5)

Invoke this requirement for all fixed and rotary-wing aircraft. Early standard formation lights were lamps in glass housings usually located on the mid upper and lower fuselage. Incandescent floodlighting can be used to illuminate aircraft surfaces to provide orientation. The observer needs to know the leader's attitude and position. Electroluminescent (EL) strip lights are distributed light sources whose shape can be readily seen. A rectangular light source, properly located and oriented, will allow the observer to determine attitude and position of the aircraft. Size and location are a function of each aircraft's unique shape and tactical mission(s), thus necessitating a scientific study of the following factors and their interactions: lead aircraft geometry, normal or unusual attitudes as a function of mission segment, types of formations to be flown, atmospheric conditions, night vision goggles, covertness, refueling, aircraft structures (e.g., impact on location, wing-bending as a function of fuel consumption), aerodynamics, formation light luminance distribution as a function of off-axis viewing, camouflage, and refueling. These are the major, but not all of the factors for consideration.

Studies for size and placement of formation lights begin with analysis of the aircrafts' geometries in reference to the various cell deployment and mission requirements. If a similar aircraft has been equipped with formation lights, it may be appropriate to use the previous design as the baseline. Candidate sizes and locations can be ranked by the evaluation of scaled models with representative green dayglow strips viewed or photographed under ultraviolet light, by experts and pilots familiar with the same or similar aircraft. Numerous photographic slides can be taken of different configurations and angles and then viewed by experts. These observations can be evaluated with a short, properly designed follow-up questionnaire. Candidate locations can be evaluated by ground or flight test, (Class II modification) using stick-on strips on representative aircraft. AFAMRL-TR-83-069 and AFAMRL-TR-83-087 describe these methodologies in greater detail. The source for this requirement is MIL-L-6503.

EL lamps are ideally suited for use as formation lights. They conform to structural curves, and they are flat and do not need to be distributed as would incandescent lamps. Maximum luminance of most EL lamps is 15 to 20 foot lamberts. Lamps must be continuously dimmable to zero. See dimming requirement. EL lights can be easily manufactured to aviation green. For any specified location on the aircraft (e.g., forward fuselage, vertical stabilizer, etc.), sizes of the strips must be determined through a study. Sizes range from 2 by 12 inches for fighter aircraft to 7 by 69 inches for tankers. Their mounting must be such that no aerodynamic disturbance is created, either by flush mounting or an appropriately tapered frame. Early EL formation lights were susceptible to damage when left on in full sunlight. Ultraviolet filters in the lamp have improved, possibly reducing or eliminating the utility of this requirement.

Invoke these requirements for all rotary-wing aircraft. Rotor-tip fighting is needed to aid in formation flying. Aviation white is the standard color. NVIS compatibility may require blue-green light (with no IR above 600 nm for Gen III goggles) and is subject to approval by the procuring activity. Continuous dimming, with log increase and decrease luminance as a function of linear control movement is desirable. Several of the dimming characteristics described under general requirements apply. The rotor-tip lights must not be visible from above or below the rotor plane to insure a degree of covertness. Any lighting fixture on the rotor-tips should minimize rotor's aerodynamics. The source for this requirement is MIL-L-6503.

Careful consideration should be given between NVIS compatible incandescent lighting and NVIS compatible EL strip lighting. EL lighting may not be bright enough to aid in aircraft rejoin manuvers where incandescent may be. Close fomation may be maintained by NVGs alone even with all lights out (i.e., pilot can SEE other aircraft).

Consideration should be given towards making the Formation lights NVIS compatible so as to not "blind" a NVG equiped wingman.

Consideration should be given to adding an Infared IR or covert mode to the Position light system. Recommend making it not viewable from the lower hemisphere. An IR mode reduces the aircraft signature making it visible only to someone equiped with NVGs (e.g., wingman).

The Vertical Stabilizer(s) lights, sometimes called Logo or Pan Am lights, should be considered as part of the Position/Formation lighting system. NVIS compatible and/or IR modes should be considered.

Consider making the foration lights dimmable.

REQUIREMENT LESSONS LEARNED (3.5.3.5)

Horseshoe-shaped, wrap-around EL lamps for wing tips were successfully implemented on the KC-10. They provide good visual cues from a variety of angles.

Surface-mounted lamps should have an adhesive/sealant over their entire back to prevent moisture accumulation and corrosion damage.

EL lamps may be susceptible to damage if energized in direct sunlight. Design lamps for ease of replacement.

Lightning suppression circuitry (metal-oxide varistors; grounds) should be considered in the design.

4.5.3.5 Formation lights.

The formation light requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.5 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.5)

Test is the standard verification method for luminance, dimming, and chromaticity requirements, whereas demonstration (through flight test) is the most accurate method to access the culmination of the numerous factors involved in formation light design. Size and aerodynamics are easiest to verify using analysis.

Direct measurement and analysis of the rotor-tip lighting characteristics insures compliance to the requirements and subsequent operational capability.

VERIFICATION GUIDANCE (4.5.3.5)

For luminance, see the instrument and panel luminance verification guidance. For dimming, see the dimming verification guidance.

The flight test demonstration will indicate if the overall design and implementation is operationally and tactically viable.

Chromaticity should be measured as described under the instrument and panel chromaticity verification guidance.

Dimming should be measured as described under the dimming verification guidance.

No light to be visible above and below the rotor plane.

VERIFICATION LESSONS LEARNED (4.5.3.5)

Final design must be evaluated by a representative user group to assure maximum operational capability.

3.5.3.6 Fuselage lights.

Where practical, fixed wing aircraft equipped for night flying shall have white lights installed on the fuselage approximately midway between the nose and the tail of the aircraft with the top light located approximately above the lower light. If necessary, additional lights may be installed around the fuselage to provide the specified distribution. The top lights shall be located aft of the cockpit and shielded, where necessary, to prevent direct light from being projected into the cockpit or other transparent enclosures through which operating personnel must make observations at night. The intensity distribution, for the hemisphere above and below the horizontal plane shall be ____________candelas (cd), minimum except for areas where shielding is provided and at angles near the fuselage when nearly flush-type lights are used.

REQUIREMENT RATIONALE (3.5.3.6)

Fuselage lights provide additional above and below aircraft luminance distributions to supplement the other lighting subsystems.

REQUIREMENT GUIDANCE (3.5.3.6)

Invoke this requirement for all fixed-wing aircraft except where it would cause excessive visual interference to crew members, such as might be the case in bubble-canopy fighter aircraft. Position and anticollision lights provide coverage usually from the wing tip and tail sections, distributed mostly in front of and behind of the aircraft. Fuselage lights supplement these lights above and below the aircraft while providing fuselage location cues to distant observers.

To minimize interference to the crew members, judicious light placement and shielding must be utilized. Interference to crew members must be considered for both cockpit and non-cockpit observation posts.

The light distribution, except for shielded areas, should be 25 candelas minimum for the hemisphere above and below the horizontal plane. Values much higher may cause unacceptable interference.

Rotary-wing formation lights substitute for standard fuselage lights. The minimization of distributed light above and below the aircraft (see rotor-tip lights) maintains covertness. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.6)

TBD

4.5.3.6 Fuselage lights.

The fuselage light requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.6 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division Code, 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.6)

Test is the standard method of intensity verification and demonstration will assure acceptably low interference levels to crew members out of the cockpit vision.

VERIFICATION GUIDANCE (4.5.3.6)

Refer to anticollision light intensity verification guidance for intensity measurements methodology. A representative set of measurement points, continuous preferred, must be taken to assure specified minimum intensity distribution.

Through demonstration (flight test), verify minimized visual interference with experienced crew members as observers.

VERIFICATION LESSONS LEARNED (4.5.3.6)

TBD

3.5.3.7 Inspection lights.

Unless otherwise specified, all aircraft except fighter, fighter trainer, and rotary-wing types shall have fixed, white inspection lights located in such positions that all areas of the wings and engines that are visible to personnel in the aircraft to access damage, icing condition, engine inspection. The switch for energizing the lights shall be located in the cockpit in a position accessible to the pilot. Inspection light chromaticity shall be ____________. The spectral radiance output of inspection lights shall be such that the NVIS radiance does not exceed ____________. A hand-held white light with a bracket for mounting shall be installed in each helicopter and multiplace aircraft, except fighter types, to inspect flaps, wheels, wings, engines, etc.

REQUIREMENT RATIONALE (3.5.3.7)

Wings and engines of fixed-wing aircraft require floodlights for their inspection from within the aircraft.

Chromaticity (color) of inspection lighting must be specified to optimize the performance of the NVIS.

The NVIS radiance of inspection lights must be specified in order to optimize the performance of the NVIS.

A hand-held light is needed to provide flexibility for the crew members to illuminate areas not covered by fixed lighting subsystems.

REQUIREMENT GUIDANCE (3.5.3.7)

Invoke this for all aircraft except fighters, fighter trainers and rotary-wing. Fixed-wing aircraft need floodlights that will allow the pilot and/or copilot to inspect the wing and engine structures. This capability is needed to enable inspection for damage, debris, leaks, malfunctions, ice, snow, etc., all of which directly impact safety. The color of the light should be white. Control of the lights should be by the pilot. The source for this requirement is MIL-L-6503.

Invoke this requirement for inspection lights that must be made NVIS compatible. Use table III for the appropriate lighting component and type/class NVIS. At the illumination level specified in table III the u′ and v′ chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2 when energized to produce the luminance level specified in table III measured off a reflectance standard surface. The source for this requirement is MIL-L-85762.

Use table IV for the appropriate lighting component and type/class NVIS when energized to produce the luminance level specified in table IV measured off a reflectance standard surface. The source for this requirement is MIL-L-85762.

Invoke this requirement for all fixed- and rotary-wing aircraft except fighter types. Aircraft have numerous lights the majority of which are fixed in a certain position. In order to assure all areas not covered by these lights can be illuminated, if required, a hand-held search or scanning light should be available to appropriate crew members, usually the pilot and copilot. The light should be designed to be held securely by a bracket, even in a crash environment.

A hand-held fight is especially useful in rotary-wing aircraft since they often hover and scan the terrain for objects, people, etc. The source for this requirement is MIL-L-6503.

REQUIREMENT LESSONS LEARNED (3.5.3.7)

TBD

4.5.3.7 Inspection lights.

The inspection lights requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.7 of MIL-L-8720;

section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.7)

Verification by demonstration will insure full operational capability.

Direct measurement of inspection light chromaticity is the most accurate method to assure compatibility with the type/class NVIS to be used.

Direct measurement of a lighting component's spectral radiance in the NVIS sensitive portion of the spectrum is the most accurate verification method for this requirement.

Verification by demonstration is the most economical method.

VERIFICATION GUIDANCE (4.5.3.7)

Aircraft observers must be able to see all upper-wing, leading edge, and engine nacelles at night using only the fixed inspection lights. If other parts of the wings or engines are observable from positions other than the cockpit, the floodlights must cover those areas too.

Inspection shall be in accordance with 4.5.2.1.5 and 4.5.2.1.6.

Examine appropriate engineering documents for anatomical grip, narrow beam, convenient storage location but not protruding, on-off switch, impact resistance, long enough cable, no electrical shock hazard, etc.\

VERIFICATION LESSONS LEARNED (4.5.3.7)

TBD

3.5.3.8 Exterior emergency lighting.

Exterior emergency lighting shall be provided at each exit to illuminate the ground near the exit and where escape and survival equipment is to be deployed when the aircraft is in a parked, on-ramp position. Exterior emergency lighting shall include ground floodlights, escape slide lights, and over-wing exit floodlights.

REQUIREMENT RATIONALE (3.5.3.8)

Specific locations on or near the aircraft require lighting to aid emergency evacuation.

All lighting equipment must conform to the overall system level environmental requirements.

External lighting located in lightning strike zone 1 (initial direct attachment) and zone 2 (swept stroke regions) is subject to lightning attachment with peak and current amplitudes of 200,000 amperes (zone 1) and 100,000 amperes (zone 2) respectively. Specific protection features are usually required.

REQUIREMENT GUIDANCE (3.5.3.8)

Invoke this requirement for all aircraft that utilize emergency exit lighting. External emergency lighting must illuminate: the ground areas near all exits including stairs, escape survival equipment, escape slides, and over-wing exit areas. The source for this requirement is MIL-L-6503.

Invoke for all lighting subsystems. Equipment must be able to operate in the following environments: low pressure, high temperature, low temperature, temperature shock, solar radiation, rain, humidity, fungus, salt fog, sand, dust, explosive atmosphere, leakage, acceleration, vibration, acoustic noise, shock, aircraft gunfire vibration, icing/freezing rain and vibro-acoustic. These requirements are specified at the system level. Sources for this requirement are MIL-STD-810 and MIL-P-7788.

Lightning strike zones on an aerospace vehicle are defined in 3.2 of MIL-STD-1757. The electrical characteristics of these strikes are defined in 3.2 of the same standard.

Direct effects protection should be considered for all external lights in lightning zones 1 and 2 even though the lights themselves are not critical. If the lightning-caused physical breakup of the light or structure on which the light is mounted could impair the aircraft or its mission, direct effects lightning protection is essential.

Indirect effects protection should be invoked when the light can form an electromagnetic entry into a critical lightning control circuit or critical subsystems which are inadvertently coupled to the light circuit.

REQUIREMENT LESSONS LEARNED (3.5.3.8)

External lights are frequent targets for lightning attachment. Wing tip and tail tip lights are particularly vulnerable. Unprotected or inadequately protected lights can result in shattered and burned hardware and vaporized wiring within the vehicle. Practical and effective protection techniques are available. The need for protection should be established early in the design phase of the light and its installation when the cost of protection is usually the least.

4.5.3.8 Exterior emergency lighting.

The exterior lighting requirements are verified and reverified during via the concurrent engineering process during the acquisition phases indicated in table I. The verification types to be used are Analysis, Demonstration, Inspection, Test and Process Control. The specific methods to be employed (and currently available) can be found in 4.2.2.7.1, 4.2.2.8, 4.2.2.9, and 4.2.2.9.1 of MIL-L-8720; section 4 of MIL-L-85762A; and Naval Air Warfare Center Aircraft Division, Code 4.6.4.2, SOPs.

VERIFICATION RATIONALE (4.5.3.8)

Demonstration is the most accurate method of exterior emergency lighting verification.

All equipment must conform to the overall system level environmental verifications.

Compliance with the lightning protection requirement must be verified. This usually requires simulated lightning tests of the system and hardware. MIL-STD-1757 defines the tests.

VERIFICATION GUIDANCE (4.5.3.8)

Demonstration of the emergency floodlight coverage will assure full operational performance. At night, energize aircraft emergency lighting and inspect all emergency exits, over-wing walkways, stairs, slides, and survival equipment areas for full coverage.

Refer to system level verifications.

The usual forms of verification (analysis, inspection and test) should be considered when establishing the specific verification approach. However, because of the complex nature of lightning strikes, simulated lightning tests are usually the most expedient and effective method of verification. Qualification by flight experience can be misleading and dangerous where the potential consequences of the strike can affect safety and/or mission success. This is because no two strikes by natural lightning are ever exactly the same. Qualification to MIL-STD-1757 will stress the specimen such that there is a very low probability that a qualified system will experience unacceptable problems when placed in service.

VERIFICATION LESSONS LEARNED (4.5.3.8)

Exploratory development testing conducted early in the development cycle of the light/light installation can be very cost effective. Costly redesign and schedule delays have occurred frequently when the testing has been delayed to near the end of the development cycle.

3.6 Sustenance and Waste Management (S&WM) Systems (see JSSG-2010-6).

3.7 Crash Survivability (see JSSG-2010-7).

3.8 Energetics (see JSSG-2010-8).

3.9 Life Support/Personal Protection (see JSSG-2010-9).

3.10 Oxygen System (see JSSG-2010-10).

3.11 Emergency Egress (see JSSG-2010-11).

3.12 Deployable Aerodynamic Decelerator (DAD)Subsystem (see JSSG-2010-12).

3.13 Survival, Search, and Rescue (SSAR) (see JSSG-2010-13).

3.14 Aircraft Windshield/Canopy Systems and Transparent Enclosures (see JSSG-2010-14).

4. VERIFICATION (with REQUIREMENTS)

5. DEFINITIONS AND ABBREVIATIONS

5.1 Definitions.

The following definitions are applicable for the purposes of this handbook.

5.1.1 Adaptation.

The process whereby an observer's sensory system adjusts to a new pattern of stimulation, tending toward a new steady state.

5.1.2 Advisory light.

A signal assembly to indicate safe or normal configuration, condition of performance, operation of essential equipment, or to attract attention and impact information for routine action purposes.

5.1.3 Angular intensity distribution.

The variation of the intensity of a lamp or lighting device with changes in the direction of view. The direction is often specified as a pair of angles, both measured with respect to a fixed reference direction (the beam axis). Ordinarily, one angle varies horizontally (like longitude on the earth) and the other varies vertically (like latitude).

5.1.4 Angular intensity distribution matrix.

A rectangular array of numbers (a matrix) representing the angular intensity distribution of a lamp or lighting device, measured in a grid of directions determined by combinations of a fixed set of vertical angles with a fixed set of horizontal angles.

5.1.4 Annunciator panel light assembly.

A grouped light assembly consisting of two or more caution or advisory legend signal assemblies, preferably arranged categorically or functionally.

5.1.5 Auditory warning signals.

Audible signals indicating the existence of a hazardous condition(s) requiring immediate corrective action.

5.1.6 Beam axis.

The axis of a light beam, frequently defined either as the direction in which the intensity of the beam is highest, or as the direction of the central ray (axis of symmetry) for a beam of symmetrical cross section. Lighting devices producing a beam with a symmetrical cross section, such as a circle or ellipse, are often aligned so that the direction of maximum intensity coincides closely with the beam’s axis of symmetry (that is, the line through the centers of all the cross sections).

5.1.7 Blackbody (also black body).

An ideal body which would absorb all incident radiation and reflect more. It can be shown theoretically that such a body, when heated to a given temperature, emits as much light (radiation) at every wavelength as can be emitted (through heating alone) by any body at that temperature. Because of the latter property, a blackbody is also known as a full radiator. The theoretical analysis of blackbody radiation was based on Max Planck’s quantum theory, so still another alternate name is planckian radiator. As temperature varies, the spectral power distribution characterizing the radiation from a blackbody changes both in the relative power at different wavelengths, and in the absolute amounts of power radiated.

5.1.8 Blondel-Rey formula.

A widely used formula for effective intensity.

5.1.9 Brightness.

Attribute of visual sensation according to which an area appears to emit more or less light (CIE definition). Brightness is a subjective measure referring to the perceived amount of light. This concept is called luminosity in English-speaking countries other than the USA. The emission of light may involve light generated directly by a self-luminous body, or light from another source being reflected from or transmitted through the surface in question. Not the same concept as lightness. Should also not be confused with "photometric brightness," an obsolete synonym for "luminance." The relationship between brightness and luminance, like the relationship between most psychological variables and their corresponding psychophysical or physical variables, is non-linear. An approximate guide is that brightness is a linear function of the cube root (or, in a formerly popular view, the logarithm) of the luminance.

5.1.10 Candela (cd).

The internationally recognized SI unit of luminous intensity. Formerly called the "candle" in the United States.

5.1.11 Caution light.

A signal assembly which indicates the existence of an impending dangerous condition requiring attention but not necessarily immediate action.

5.1.12 Chromaticity.

Synonym for color (psychophysical), in the sense excluding the intensitive aspect; the quality of a color stimulus specified by the chromaticity coordinates. The chromaticity associated with a patch of light can be calculated from strictly objective physical measures and does not depend on what is perceived by a particular observer under particular viewing conditions.

5.1.13 Chromaticity coordinates.

Numbers specifying chromaticity. They are calculated by dividing each of the tristimulus values by their sum, and consequently there are three chromaticity coordinates, summing to unity. Two chromaticity coordinates are enough to specify any chromaticity, because the value of the third coordinate is determined by the values of whichever two are specified. For any given color (psychophysical), the chromaticity coordinates can be interpreted as the fraction of the red primary, the fraction of the green primary, and the fraction of the blue primary needed in a mixture of the primaries that matches the given color. The chromaticity coordinates associated with the CIE 1931 color-matching functions--the most widely used standard--are denoted x, y, and z. Most commonly, chromaticities are specified by the coordinates x and y, indicating fraction of the red primary and fraction of the green primary, respectively. Coordinates for the CIE - UCS 1976 color space are u′ and v′.

5.1.14 Chromaticity diagram.

A graph in which one of the three chromaticity coordinates is plotted against one or the other of the remaining two, so that every point on the graph corresponds to a unique chromaticity. Usually, the plot is of the green coordinate against the red. Thus, the CIE 1931 chromaticity diagram is a graph of y (ordinate) against x (abscissa). The diagram is used to show the relationships among the chromaticities associated with various series of colors. One particularly useful feature of chromaticity diagrams is that when a light is formed by the mixture of two other lights, the point representing the chromaticity of the mixture lies on the line joining the points representing the chromaticities of the two lights that are mixed.

5.1.15 Colorimeter.

An instrument for measuring color. There are two classes of colorimeters: visual and photoelectric. In the visual colorimeter, a human observer uses colors generated within the apparatus to match perceptually the color being measured; and in the photoelectric colorimeter, photocells generate electrical outputs in response to the colored light. The final output of most colorimeters is a set of three numbers that either comprise the tristimulus values of the measured color, or are related to the tristimulus values by a known mathematical transformation; all such colorimeters are called tristimulus colorimeters.

5.1.16 Colorimetry.

The measurement of color; or, more broadly, the body of instrumental and computational techniques comprising the technology of color measurement, specification, and production. The adjectival form is “colorimetric.”

5.1.17 Color temperature.

A measure of the color, the chromaticity, at a light along a continuum ranging approximately from red to orange to yellow to white to blue-white (the planckian locus). The concept strictly applies only to lights having the same chromaticity as a blackbody at some temperature, and the color temperature is defined as the absolute temperature (in Kelvin) of the matching blackbody. Lights having chromaticities close to but not actually on the planckian locus are sometimes loosely spoken of as having the color temperature corresponding to the closest blackbody chromaticity, but the formal name for the measure in that case is “correlated color temperature.”

5.1.18 Color tolerances.

The range of colors considered acceptable for a colored product or light for which an ideal (“aim” or “design”) color has been defined, or which is meant to give rise to a specified color perception (for example, “blue”). The colors defining the tolerance limits and the aim color, if there is one, may be specified either in the form of material samples or by numerical definition (such as by sets of tristimulus values). Colors lying within the defined tolerances are regarded as acceptably matching the aim color or as satisfactorily yielding the required color perception; colors outside the tolerance limits are regarded as unacceptably differing from the aim color, or as not yielding the required color perception. The tolerances for signal colors are usually defined in terms of the color perception, and there is no specific aim color.

5.1.19 Commission Internationale de l’Eclairage.

The French name for the International Commission on Illumination. The organization is usually referred to by the initials “CIE” of the French name. It sets the standards in the fields of light and color.

5.1.20 Cone of vision.

The individual cone of vision for both the pilot and copilot is a 30-degree cone symmetrical about a line from the design eye position extending forward to the top of the flight instrument panel. In other crew stations, the 30-degree cone of vision is symmetrical about a line from the design eye position to the center of the instrument or control panel. The apex of the cone in each case shall be at the design eye position of the crew member.

5.1.21 Conspicuity.

The ability of a signal to attract attention or be noticed, relative to a specific background and a specific condition of the observer (his "set").

5.1.22 Cycle per second.

A unit of the frequency of a periodic chain of events, equal to one event (or period) per second. In the SI system of units, the cycle per second has been renamed the hertz (Hz).

5.1.23 Diffuse (adjective).

Characterized by the reflection or transmission of light in such a way that the light rays are scattered and do not preserve images. The term may be applied either to the process (for example, "diffuse reflection") or to an object (for example, a "diffuse reflector"). The surface of a fully diffuse reflector does not form mirror images. A diffuse transmitter does to permit the viewing of objects through it; it is translucent rather than transparent. In reality, there are no perfect diffusers of light; it is always a matter of degree. A scratched windshield is a slightly diffuse transmitter, and ground glass is a very diffuse transmitter.

5.1.24 Effective intensity.

The apparent luminous intensity of a flashing light, as measured by the intensity of a steady white light seen as equally bright when viewed at the same distance, or having the same visual range. Sometimes used in the more restricted sense of effective intensity as calculated by some particular formula, usually the BRD formula. Although viewing distance and viewing conditions (background, atmospheric clarity, knowledge of the direction in which faint lights are located) enter into the operational measurement of effective intensity, it should be noted that actual (steady-light) intensity, or effective intensity as defined by a fixed formula, is a property of the light source and is not a function of how the source is being viewed or where it is located.

5.1.25 Extended source.

A source of light large enough to appear, at a specified viewing of a source of light large enough so that the illuminance of a receiving surface, moved toward and away from the source from a reference position located at a specified distance from the source, departs significantly (by some specified percentage) from the illuminance that would be predicted by treating the source as a point source and applying the inverse square law.

5.1.26 Filter.

With respect to the control of light, a light-transmitting object (such as a sheet of glass or plastic) used to modify the color of a light, either the intensity alone (in which case the filter is called "neutral"), or the chromatic aspect and the intensity together. (The chromatic quality of a light cannot be modified without some reduction in intensity by passing the light through a filter, unless the filter is fluorescent.)

5.1.27 Flash profile.

The curve or function specifying the variation of the instantaneous intensity of a light flash (at a particular point in space) over the course of time. To differentiate this profile from the spatial variation of intensity (the angular intensity distribution), the more explicit term, “temporal flash profile” may be used. Other names for the temporal curve or for the curve’s shape are “pulse shape” and “waveform.”

5.1.28 Flash rate.

The number of light flashes produced per unit time, at any fixed point in space, by a lighting device that generates the flashes in an unvarying cyclical process (either turning the light source on an off with fixed rhythm, or sweeping one or more light beams around and around at a steady pace). The most common units of flash rate in signal lighting are flashes per minute (fpm). Flash rate is a special case of a frequency (the number of complete cycles of any repetitive process, per unit time), for which the SI unit is the hertz (Hz), equal to one cycle per second. Thus, for example, a light may have its flash rate specified interchangeably as 90 fpm or 1.5 Hz.

5.1.29 Floodlight (or flood light).

A lighting device in which the output of the source is concentrated by mirrors or lenses into a limited but not sharply narrow cone (solid angle). Redirection of the light originally emitted in other directions into this limited cone increases the intensity within the cone. Floodlights are usually used for illuminating delimited areas such as a back yard for the side of a building. The beamspread below which the floodlight category merges into the spotlight category is not sharply defined but is commonly taken to be about 20 degrees.

5.1.30 Footcandle (fc).

The most common unit of illuminance in the English (customary) system of measurement. It is equal to one lumen per square foot. A uniform point source having a luminous intensity of one candela, if placed at the center of a sphere having a radius of one foot, produces an illuminance of one footcandle on all parts of the inside surface of the sphere. One footcandle is approximately equally to 10.764 lux. Various abbreviations are used, but fc is recognized by the CIE. Particularly when the term is written “foot-candle,” there is a temptation for some readers to assume incorrectly that the dimensions of the unit are length (feet) times intensity (candelas), but actually “foot-candle” is a unitary term interpretable as “a unit of illuminance based on the foot.” The preceding definition shows that the dimensions are lumens per square foot (see figure 5).

5.1.31 Footlambert (fL).

A common unit of luminance in the English (customary) system of measurement. It is equal to 1/pi candelas per square foot . An ideal surface that reflects all the light striking it and diffuses it with perfect uniformity has a luminance of one footlambert when the light falling on it produces a uniform illuminance of one footcandle. One footlambert is approximately equal 3.426 cd/m^2. Various abbreviations are used, but fL is recognized by the CIE. Particularly when the term is written “foot-lambert,” there is a temptation for some readers to assume incorrectly that the dimensions of the unit are length (feet) times luminance (lamberts), but actually “footlambert” is a unitary term interpretable as “a unit of luminance based on the foot.” The preceding definition shows that the dimensions are candelas per square foot (see figure 5).

5.1.32 Goniometer.

An instrument for positioning objects at various angles, equipped with scales permitting accurate specification of the angular orientation. Some goniometers permit variation of angles within a single plane; others permit independent variation in two--or in rare instances, three--perpendicular planes.

5.1.33 Hertz (Hz).

The SI unit of frequency. A synonym for cycles per second.

5.1.34 Horizontal intensity distribution.

The intensity distribution of a light within a horizontal plane, or a plane of constant vertical elevation angle. When used without specification of a vertical elevation, the term refers to the intensity distribution in the horizontal plane (zero vertical elevation).

5.1.35 Illuminance.

A measure of the visually effective amount of light falling on a surface; more strictly, the luminous flux (power) striking the surface per unit area. The CIE symbol for illuminance is E. The SI unit of illuminance is the lux (abbreviated lx).

5.1.36 Incandescent lamp.

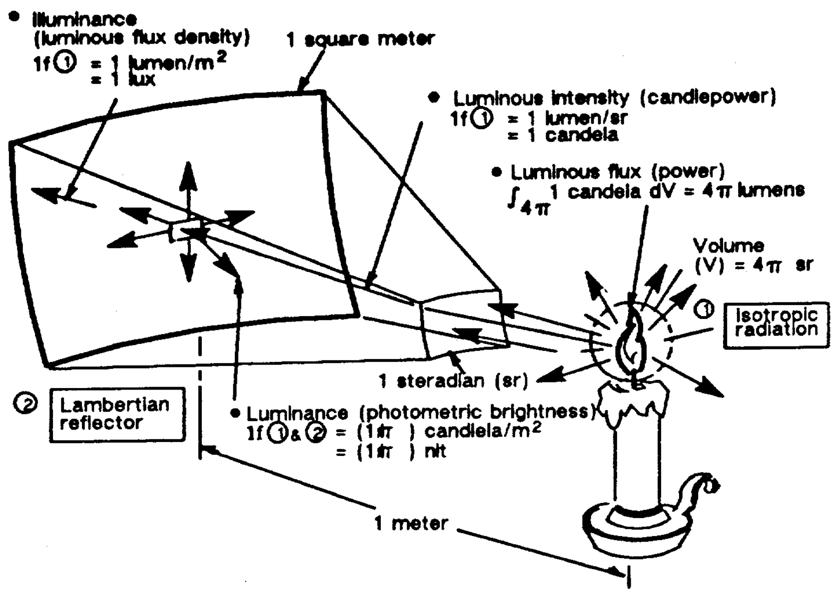
A lamp in which light is produced by means of a body heated to incandescence by the passage of an electric current (CIE definition). The glowing body (filament) is today usually made of tungsten metal, or of an alloy of tungsten with other metals. Early incandescent lamps used filaments made of carbon or metals other than tungsten. Modern incandescent lamps usually have the bulb filled with an inert gas such as argon or an argon-nitrogen mixture, while old lamps contained a vacuum.

5.1.37 IR (infared) or covert exterior lights.

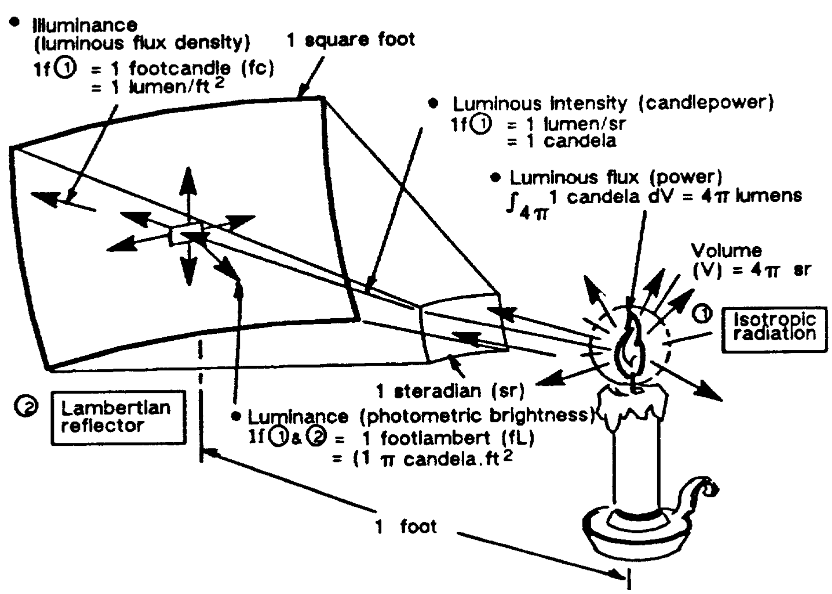
Typically filtered so that they are not visible to the naked eye beyond a few tens of feet. They are intended to provide illumination to NVIS only. Sometimes they are used when there is inadequate near IR natural light for NVIS to work well.

5.1.38 Intensity.

A measure of the light output from an object that is being treated as a point source. Strictly, the amount of light flux (power) being emitted per unit solid angle within an infinitesimal conical beam with its apex (point) at the source and its axis in a specified direction; the solid-angular density of light flux in a given direction. Reference may be made to either radiant or luminous intensity. The SI unit of radiant intensity is watt per steradian, and of luminous intensity is the candela. The CIE symbol for intensity is I (the subscripted symbols Ie, and Iv, being used, when necessary, to distinguish between radiant and luminous intensity, respectively). Unfortunately, the term “intensity” has often been used loosely to refer to any measure of light output, regardless of the geometry of the situation. A reader of the literature of vision, particularly the older work, should be prepared to occasionally find “intensity” used where “luminance” would be technically correct.



a. Photometric SI units.



b. Photometric English units.

FIGURE 5. Photometric, Flat-Panel Displays and CRTs (Tannas, 1985)

5.1.39 Intensity distribution.

The variation of the intensity of a lamp (or a complete light) with changes in the direction of view. Frequently, the term is used as a shortened form of angular intensity distribution, and it also applies to any set of directional intensity measurements in which the directions are specified by some quantities other than angles (as for example, linear distances within a cross-section of the beam at a stated distance from the light).

5.1.40 Intensity distribution matrix.

A rectangular array of numbers representing the intensity distribution of a lamp (or a complete light), measured in a grid of directions determined by combinations of a fixed set of vertical angles (or equivalent directional specifications) with a fixed set of horizontal angles (or equivalent directional specifications). Frequently, the term is used as a shortened form of angular intensity distribution matrix, and it also applies when the directions are specified by quantities other than angles (as for example, linear distances within a cross-section of the beam at a stated distance from the light).

5.1.41 International Commission on Illumination.

The name in English for the organization usually known by its French initials, CIE.

5.1.42 International system of units.

The name in English for the internationally accepted system of units usually known by its official (French) initials, SI.

5.1.43 Kelvin (K).

The SI unit of temperature. The unit was formerly known as a degree Kelvin or a degree Absolute, and it corresponds to one degree on the Absolute (Kelvin) scale of temperature. One degree of the Centigrade (Celsius) scale of temperature is also equal to a Kelvin, but the zero points of the Centigrade and Kelvin temperature scales are different. The Fahrenheit degree represents a smaller difference of temperature and is equal to 5/9 Kelvin.

5.1.44 Lamp.

As used by specialists in illumination, a bulb containing a source of light. This usage contradicts the nontechnical meaning, which uses “bulb” for this purpose and reserves “lamp” for the fixture containing the bulb.

5.1.45 Light.

Visible radiant (electromagnetic) energy. (In some contexts, infrared and ultraviolet radiation, which are not visible, but which comprise the portions of the electromagnetic spectrum bordering the visible range on either side, are also referred to as “light.”).

5.1.46 Luminance.

The measure of visually effective light output most commonly appropriate for an extended source. It specifies the output at a given point of the source surface in a given direction of view, and includes light reflected from, transmitted through, and emitted by, the surface (see figure 5). Formally, it is defined as the luminous flux per unit solid angle per unit projected area of the source, the projection being onto a plane perpendicular to the given direction. The CIE symbol for luminance is L (or L_V, when confusion with radiance might arise), and the SI unit is the candela per square meter (abbreviated cd/m^2), also known as the nit (abbreviated nt). The fact that luminance has units equal to luminous intensity per unit area suggests an intuitively understandable operational meaning of the term: the luminance, in a given direction, of a uniform extended surface may be measured by backing off in the given direction until the surface is far enough away to be effectively a point source (in the sense of closely following the inverse square law): measuring the luminous intensity of this source; and dividing the intensity by the area of the source as seen from along the given direction line (that is, the area projected onto a plane perpendicular to the direction line). The average luminance of an extended source is thus the equivalent luminous intensity of the source when it is seen as a point, divided by the actual extended area of the source, corrected for the direction of view. For a non-uniform extended source, the luminance at a given point in a given direction is defined as the limiting value of the luminance (as just defined) of a small element of area surrounding the point, as the area of the element approaches zero. The corresponding radiant (physical) measure is known as radiance.

5.1.47 Luminous efficiency.

The sensitivity of the eye to light of a given wavelength, relative to the maximum sensitivity at any wavelength (taken as unity). It is a dimensionless quantity. The luminous efficiency function is the weighting function used for converting radiant quantities specified spectrally to the corresponding luminous quantities. (Multiplication of the final sum by a constant is usually necessary.) Two luminous efficiency functions are standardized (by the CIE): the photopic function, having its peak at 555 nm and representing sensitivity under conditions of “day” vision; and the scotopic function, having its peak at 507 nm and representing sensitivity under conditions of “night” vision.

5.1.48 Lux (lx).

The SI unit of illuminance. It is equal to one lumen per square meter (lm/m^2).

5.1.49 Master caution light.

A signal assembly which indicates that one or more caution lights have been actuated.

5.1.50 Master warning light.

A signal assembly which indicates that one or more caution lights have been actuated.

5.1.51 Mesopic.

Intermediate between photopic and scotopic. The mesopic luminance range is approximately 0.0001 cd/m^2 to 10 cd/m^2.

5.1.52 Nanometer (nm).

A billionth of a meter (10^{-9} m). Formerly known as a “millimicron” (mm). One nm is approximately equal to 39.37 billionths of an inch (the exact number of billionths being 100/2.54).

5.1.53 Night vision goggles (NVG).

Refers to the Aviator's Night Vision Imaging System (ANVIS) utilizing Generation III intensifier tubes designated as "AN/AVS-6 Night Vision Goggles."

5.1.54 Night vision goggle compatibility (NVGC).

The aircraft interior lighting that provides acquisition of aircraft interior information with the unaided eye without degrading the image intensification capabilities of the NVG during night flight operations.

5.1.55 Night vision imaging system (NVIS).

A system which uses image intensifier tubes to produce an enhanced image of a scene in light conditions too low for normal navigation.

5.1.55.1 Direct view image NVIS (type I).

Any NVIS which uses generation III image intensifier tubes and displays the intensified image on a phosphor screen in the user's direct line of sight. The AN/AVS-6, Aviator's Night Vision Imaging System is an example of a type I system.

5.1.55.2 Projected image NVIS (type II).

Any NVIS which uses generation III image intensifier tubes and projects the intensified image on a see-through medium in the user's line of sight. This configuration allows simultaneous viewing of the intensified image and visual cues such as HUD symbology.

5.1.55.3 Class A NVIS.

Any NVIS which uses the 625 nm filter described by figure 6. A class A NVIS is not compatible with red cockpit lights because of the overlap between the spectral radiance of red light and the sensitivity of Class A NVIS.

5.1.55.4 Class B NVIS.

Any NVIS which uses the 665 nm filter described by figure 7. A class B NVIS is compatible with the color NVIS Red and therefore is compatible with properly filtered red lights and color electronic displays which meet the performace requirements of this specification.

5.1.55.5 Class C NVIS.

Some aircraft have HUDs that use a hologram as the reflective element in the combining glass. Holograms typically only work with one wavelength of light - this feature can be used to improve the efficiency and see-through clarity of the HUD, but it means the light coming from the HUD is concentrated at one wavelength. Since this wavelength is in the green part of the spectrum and is blocked by the minus blue filter in the NVIS, it is nearly impossible to see a holographic HUD with Class A or B NVIS. Consequently, modified NVIS have been built and tested which have a "notch" or "leak" in the green part of the spectrum. The Class C filter used to sometimes be called the "leaky green" filter. An example of a spectral plot from a Class C NVG is shown on figure 8 below.

Note that MIL-L-85762B addressed this concern by stating a minimum NR requirement for HUDs, but holographic HUDs do not meet this minimum. It is now believed that it is more cost effective to modify the NVIS (adding the green leak) than it is to modify the design of the HUDs (with their inherently single wavelength hologram) to solve this problem. The desire to see the HUD through the NVIS, rather than with the naked eye has also increased due to the improved resolution of new NVIS devices.

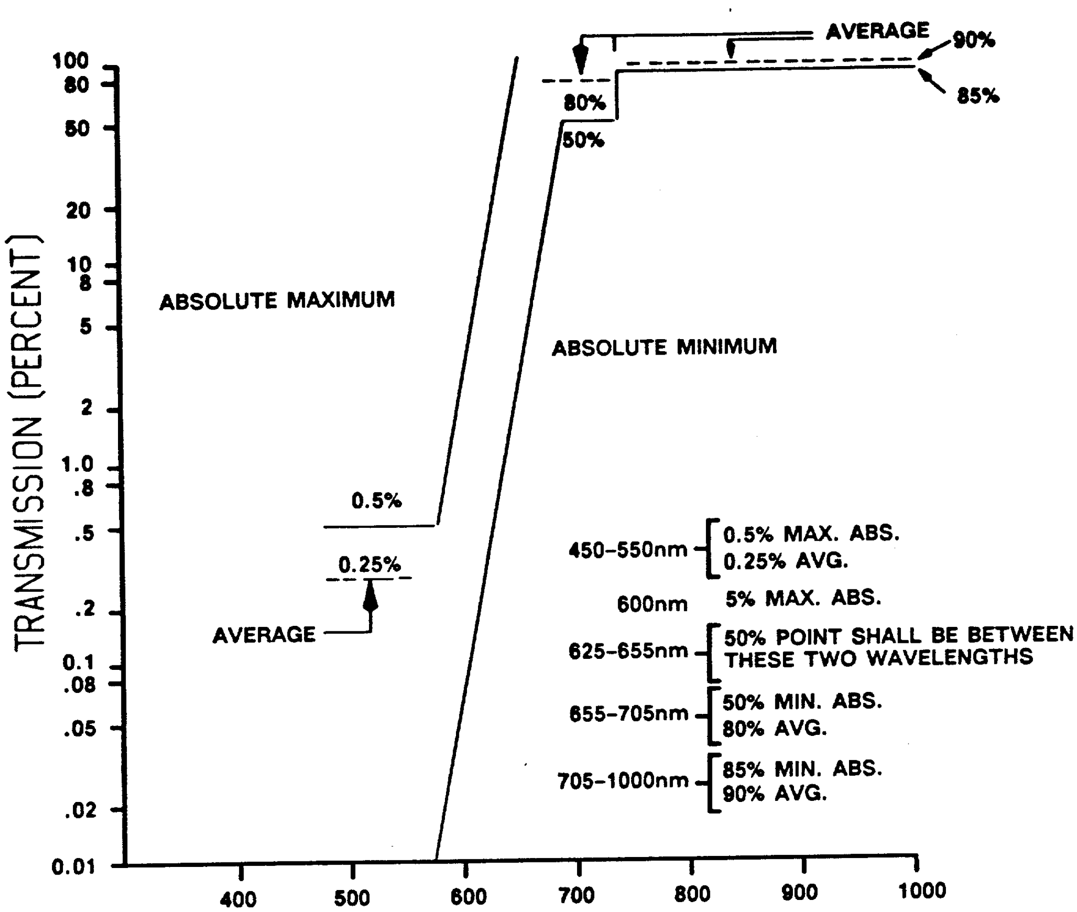


FIGURE 6. Class A, 625 nm minus-blue filter specifications.

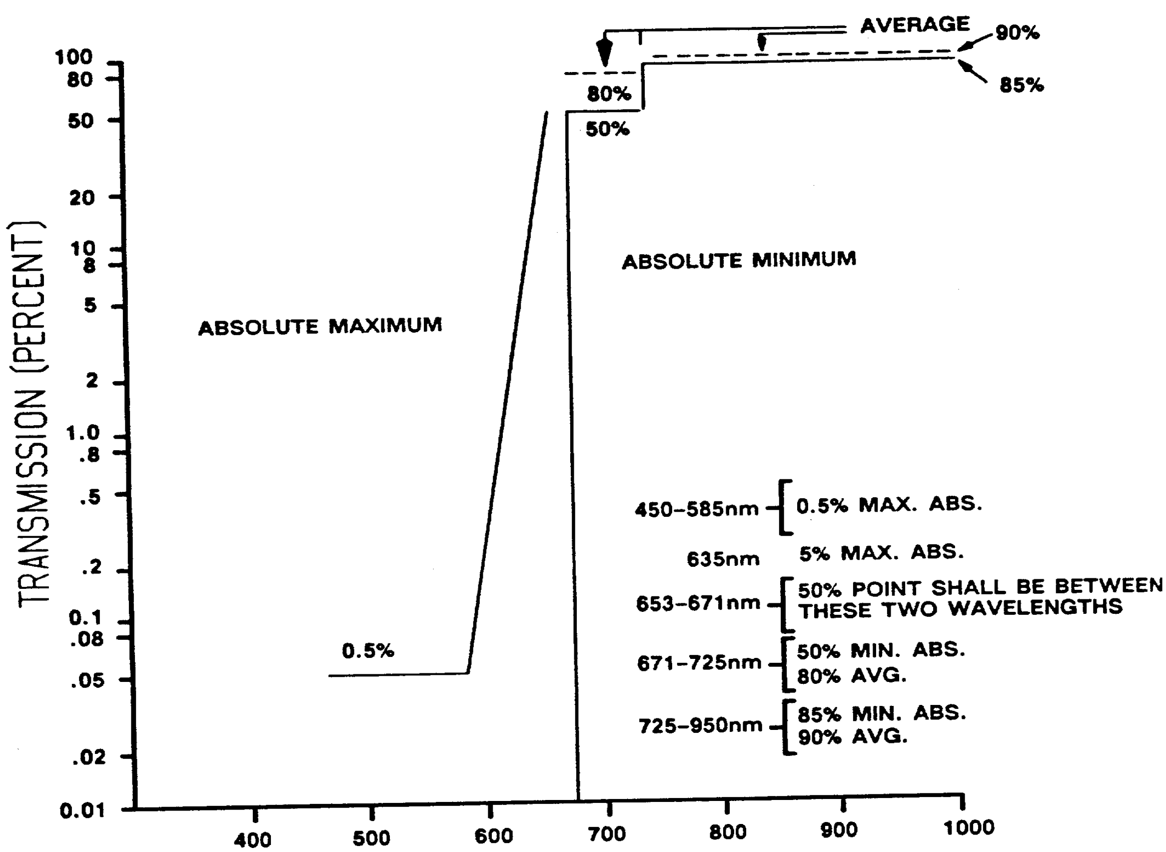


FIGURE 7. Class B, 665 nm minus-blue filter specifications.

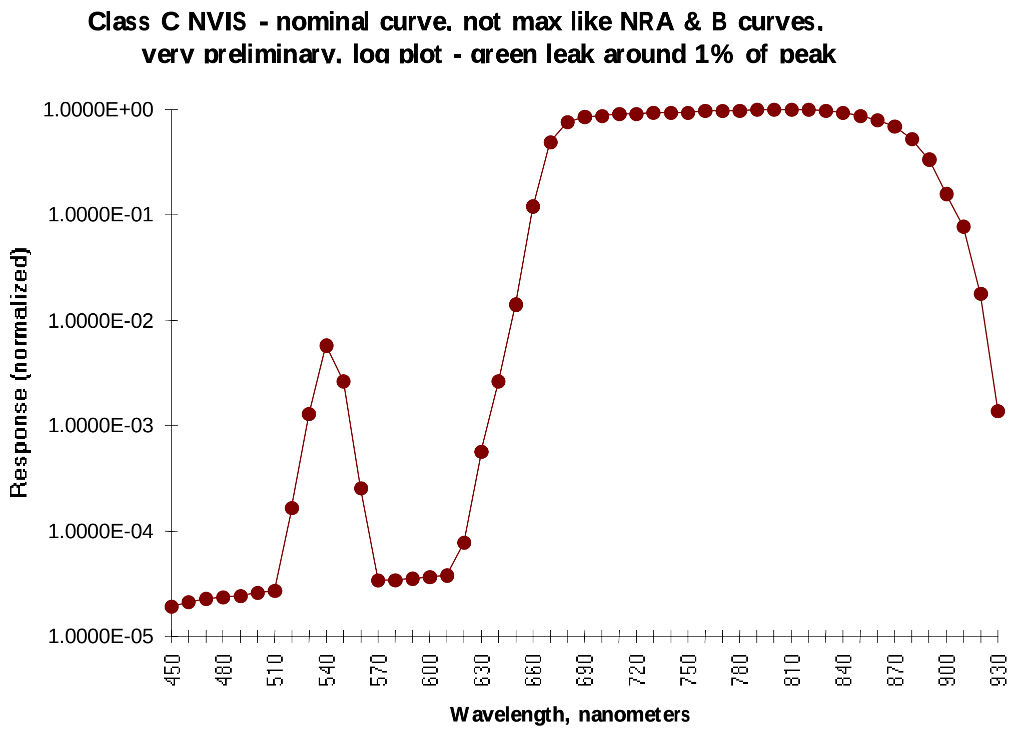


FIGURE 8. Class C NVIS characteristics.

5.1.56 NVIS radiance (NR).

The amount of energy emitted by or reflected from a light source that is visible through NVIS. NR is analogous to luminance, which is visually effective electromagnetic radiation.

5.1.57 Nit (nt).

A currently unofficial name for the SI unit of luminance, the candela per square meter (cd/m^2).

5.1.58 Photopic.

Pertaining to levels of illumination (from an object or a light or from the background) high enough to activate the cone receptors of the retina. Photopic vision is sometimes known as "day vision." It is distinguished by the perception of color and of fine detail. Contrasts with scotopic. The background luminance above which vision is fully photopic is variously estimated as being between "several" and 10 cd/m^2.

5.1.59 Planckian locus.

The curved path on a chromaticity diagram representing the chromaticities (colors) of blackbody light sources (Planckian radiators) of different color temperatures. For example, a metal bar heated from dull red heat, through yellow in white heat, and then to blue-white, is emitting light having chromaticities that move approximately along the Planckian locus.

5.1.60 Planckian radiator.

Synonym for blackbody.

5.1.61 Point source.

A source of light having a maximum dimension that is small compared with the distance of the source from the receiving surface. The minimum ratio of distance to diameter necessary to characterize the source as a point source is not sharply defined, but depends on the specific application. A common criterion for photometry is for the ratio to be large enough so that the inverse square law holds, within some specified percentage tolerance. Visually, the criterion is often that the source should have no visible disc, but should appear as a point. The visual criterion usually requires a much smaller source size than does the photometric criterion. Contrasts with extended source.

5.1.62 Psychophysical.

Involving both physics and psychology, particularly in a coordination between sensory perceptions and the physical specifications of the stimuli leading to the perceptions. The branch of experimental psychology dealing with such coordinations is called psychophysics. In illumination and color, one widely accepted classification of the various measures used divides these measures into three categories: physical, psychophysical, and psychological. Physical measures, such as radiance, specify the characteristics of the stimulus. Psychophysical measures, such as luminance, correct a physical measure (radiance) for the sensory response characteristics of the individual, average, or standardized observer (the luminous efficiency function, in going from radiance to luminance). Psychological measures, such as brightness, indicate the magnitude of the final subjective response of the observer to stimuli of specified psychophysical strength (luminance).

5.1.63 Scotopic.

Pertaining to levels of illumination not high enough to activate the cone receptors of the retina but high enough to activate the rods. Scotopic vision is often known as “night vision.” It is distinguished by no perception of color and poor perception of fine detail. Contrasts with photopic. The background luminance below which vision is strictly scotopic is variously estimated as being between 0.001 and several hundredths of a cd/m^2.

5.1.64 SI.

Abbreviation for “Systems International,” the official (French) name for the International System of Units. This system of units is the internationally approved system for use in science and technology. It is based on the old MKS (meter-kilogram-second) system.

5.1.65 Solid angle.

The analog in three dimensions of the concept of angle in two dimensions. The solid angle subtended by an object at a joint is measured by the fraction of the total area of a sphere, centered at the point, that is included within the projection, from the point onto the sphere, of the outline of the object. The solid angle is independent of the radius of the sphere. The SI unit of solid angle is the steradian. In plane geometry, the word "angle" refers both to a geometrical figure (formed by two intersecting lines) and also to a measure of the degree of separation between the lines in such a figure. In solid geometry, it is rare to refer to "a solid angle"--the geometrical figure--and the concept defined above is the measure. The geometrical figure constituting "a solid angle" would be a conical surface with a cross-section of arbitrary shape. In the context of an object subtending a solid angle at a point, the conical surface is that traced out by the projection line with one and anchored at the reference point, and the other end sweeping around the space-curve forming the outline (border) of the given object as viewed from the reference point. The intersection of this conical surface with any sphere centered at the reference point constitutes the projection of the outline of the object onto the sphere.

5.1.66 Spectral energy distribution.

Alternate name for spectral power distribution.

5.1.67 Spectral power distribution.

A wavelength-by-wavelength specification of the output of a light source in terms of any appropriate radiant measure, not necessarily simply the radiant flux. Also called spectral energy distribution. The word "power" or "energy" in these phrases serves only to indicate that a radiant, as opposed to luminous, specification is meant (for example, radiant intensity). Note that no power at all can be emitted in an infinitesimally narrow (zero-width) wavelength band, so that the quantity actually specified must be some radiant measure per unit wavelength (usually per nm) of the emission band. Such specification is known as "spectral concentration" and constitutes a measure of the derivative of the "power" with respect to wavelength. The "spectral power distribution" of a point source signal light may, therefore, be a specification of the spectral concentration of radiant intensity, measured in W sr^{-1} nm^{-1}.

5.1.68 Spectroradiometer.

A radiometer equipped with a device for separating (dispersing) the incoming light into its component wavelengths, used to measure the spectral power distribution of the light.

5.1.69 Specular.

Like a mirror. Specular reflection is an image-preserving, nonscattering reflection, as in a mirror. Contrasts with diffuse (adjective).

5.1.70 Steradian.

The SI unit for specifying solid angle. One steradian is defined as the solid angle subtended at the center of a sphere of unit radius by a portion of the sphere having unit area (that is, an area of one square unit). Since the total area of a sphere of radius R is $4 \pi R^2$, the total area of a sphere of unit radius is 4π square units. Hence a complete sphere contains 4π steradians and a hemisphere contains 2π steradians (see figure 5).

5.1.71 Subtend (geometry).

To cut off or intercept; said of one geometric figure with respect to another. A surface is said to subtend a solid angle at a point when there is consideration of the solid angle formed by sweeping the other end of a straight line, starting at the point, around the boundary of the surface. A line segment is said to subtend an ordinary planar angle at a point when there is consideration of the angle formed by joining the point to the ends of the segment by straight lines.

5.1.72 Vertical intensity distribution.

The intensity distribution of a light within a vertical plane. When used without specification of a horizontal azimuth, the term refers to the intensity distribution in the plane containing the beam axis (zero horizontal azimuth).

5.1.73 Visual angle.

The angle subtended by an object at the eye of an observer. Visual angle may be specified in terms of the solid angle subtended by the entire surface of the object, or, more commonly, by the planar (ordinary) angle subtended by the largest linear dimension of the object.

5.1.74 Warning light.

A warning light is a signal assembly which indicates the existence of a hazardous condition requiring immediate corrective action.

5.2 Acronyms, abbreviations, and symbols.

The acronyms, abbreviations, and symbols used in this handbook are defined as follows:

cd	candela or candelas
CIE	Commission Internationale de l'Eclairage, the French name for the International Commission on Illumination, which sets international standards in the fields of light and color.
cps	cycle per second
EL	electroluminescent
EMC	electromagnetic compatibility
EMI	electromagnetic interference
fc	footcandle (recognized by the CIE) (see figure 5)
fL	footlambert (recognized by the CIE)
fpm	flashes per minute (a traditional, but non-SI, unit of flash rate)
Hz	hertz (SI unit of frequency)
IR	infrared
K	Kelvin
Lx	lux

nm	nanometer
nt	nit
NVIS	night vision imaging system
SI	Systems International
sr	steradian

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

This handbook is intended to be used for guidance in developing new interior or exterior lighting systems for military air vehicles. It may be used to specify lighting for an entire system or may be tailored to a specific subsystem.

6.2 Subject term (key word) listing.

advisory light

anti-collision light

cabin illumination

caution light

chromaticity contrast

emergency lighting

formation lighting

illumination

jump light

light leakage

luminance

night vision imaging system (NVIS)

NVIS compatibility

NVIS radiance

position light

radiance

refueling receptacle floodlighting

taxi lighting

Warning light

CONCLUDING MATERIAL

Custodians:

Army - AV

Navy - AS

Air Force - 11

Preparing activity:

Air Force - 11

(Project No. 15GP-0013-5)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies f documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waiver any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER JSSG-2010-5	2. DOCUMENT DATE (YYMMDD) 981030

3. DOCUMENT TITLE

Crew Systems Aircraft Lighting Handbook

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER		
a. NAME (Last, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (include Zip Code)	d. TELEPHONE (Include Area Code (1) Commercial (2) AUTOVON *(If applicable)*	e. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY		
a. NAME ASC/ENSI (AF-11)	b. TELEPHONE (Include Area Code (1) Commercial (937)255-6281	(2) AUTOVON 785-6281
c. ADDRESS *(Include Zip Code)* BLDG 560 2530 LOOP ROAD W WRIGHT-PATTERSON AFB OH 45433-7101	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	

DD FORM 1426, OCT 89 (EF-V1) PREVIOUS EDITIONS ARE OBSOLETE