Slusher, W. M. (1985). *Instrument lighting levels and AN/AVS-6 usage.* (Report No. AAMRL-TR-85-055). Wright-Patterson AFB, OH: Armstrong Aerospace Medical Research Laboratory. (DTIC No. A161538)

AAMRL-TR-85-055

INSTRUMENT LIGHTING LEVELS AND AN/AVS-6 USAGE

WILLIAM M. SLUSHER

HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

AUGUST 1985

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S): AAMRL-TR-85-055

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: AAMRL, Human Engineering Division, AMD, AFSC

6b. OFFICE SYMBOL (If applicable): HEF

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS (City, State and ZIP Code): Wright-Patterson AFB, OH 45433-6573

7b. ADDRESS (City, State and ZIP Code):

8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Armstrong Aerospace Medical Research Laboratory

8b. OFFICE SYMBOL (If applicable): HEF

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS (City, State and ZIP Code): Wright-Patterson AFB, OH 45433-6573

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
62202F	7184	12	15

11. TITLE (Include Security Classification): Instrument Lighting Levels and AN/AVS-6 Usage (U)

12. PERSONAL AUTHOR(S): Slusher, William M.

13a. TYPE OF REPORT: Final

13b. TIME COVERED: FROM ________ TO ________

14. DATE OF REPORT (Yr., Mo., Day): August 1985

15. PAGE COUNT: 48

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB. GR.
05	05	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number):

Night Vision; ANVIS; Night Lighting; Dark Adaptation; Night Visual Acuity; AN/AVS-6

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Two experimental investigations were performed to determine the effects of the AN/AVS-6 Aviators Night Vision Imaging System (ANVIS) display luminance on the setting of instrument lighting levels. In a laboratory study using a simulated A-10 night lighting mockup, eight subjects adjusted instrument lighting levels to what they judged to be the minimum required for safe readability of instruments. Prior to the adjustment of instrument lighting, the subjects were preadapted to various ambient lighting conditions, including a simulated ground luminance of a full moonlit night and two simulated ANVIS display luminances. Results show primary instrument lighting levels were set higher, by a factor of 1.6 following adaptation to the 1.0 foot lambert (ft-L) ANVIS luminance test condition when compared to lighting levels set following adaptation to a 0.00065 ft-L ambient luminance condition.

(Cont'd)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☒ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: Slusher, William M.

22b. TELEPHONE NUMBER (Include Area Code): 513-255-8877

22c. OFFICE SYMBOL: AAMRL/HEF

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

BLOCK 19 (Cont'd)

A field study was performed to determine instrument lighting levls used on board C-14 C-13Ø, HH-53 and the OH-6 aircraft. Pilots set instrument lighting levels in flight on the ground while using ANVIS. Instrument luminances were measured in the Ø.ØØ3 to Ø.Ø86 ft-L range. The average luminance calculated from measurements of a front instrument panel remained below Ø.Ø6 ft-L.

SUMMARY

The purposes of this study were to determine the effects of various preadapting luminance conditions on the setting of instrument lighting levels and to determine minimum luminance levels required for the readability of instruments when preadapted to the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) display luminance. The approach to answering these questions consisted of two separate efforts:

A laboratory study investigated the effect of the ANVIS display luminance on instrument lighting levels required to read aircraft instruments. Eight subjects adjusted lighting levels to what they judged to be the minimum required for safe readability of instruments. Prior to adjusting the luminance levels, the subjects were preadapted to various ambient lighting conditions, including a simulated ground luminance of a full moonlit night and two simulated ANVIS luminances. All three of the preadapting lighting conditions were considered representative of actual operational conditions. Instrument lighting levels, set by the subjects after preadaptation to the ANVIS test conditions, were generally higher than lighting levels set after preadaptation to the ground luminance test condition. Increasing the preadapting luminance by roughly a factor of 300 (0.00065 ft-L ground luminance condition to a 0.2 ft-L ANVIS condition) resulted in an increase of instrument lighting levels by a factor of approximately 1.5.

A field study was performed on board operational aircraft to determine instrument lighting levels that are currently used with ANVIS. Photometric measurements were made at various locations on the front instrument panel of a C-141, C-130, and HH-53 Air Force aircraft. Additional lighting measurements were made on board an OH-6 National Guard aircraft. Pilots set instrument lighting levels in flight or on the ground, following adaptation to an ANVIS display luminance. No specific instructions describing how to set instrument lighting levels were given. Instrument luminance levels were in the 0.003 to 0.086 ft-L range. The average luminance of a single front instrument panel remained below 0.06 ft-L.

This report documents the methods and results of each study in separate sections. A single section will be used for discussion of the results of both the laboratory and field studies.

PREFACE

This report was prepared by the Crew Systems Effectiveness Branch of the Human Engineering Division, Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright Patterson Air Force Base under Work Unit 7184-12-15.

The author wishes to thank Dr. Diana Nelson, of Systems Research Laboratories, Inc. for consultation provided during the course of this effort. The author also wishes to thank Mr. Dave Ramer, Mr. Mike Gifford, and Ms. Annette Wilber for construction of various hardware elements.

INTRODUCTION

GENERAL BACKGROUND

In recent years the military aviator's night operation capability has been enhanced by the use of Night Vision Goggles (NVGs). This device is used primarily for visual navigation in low level flight. NVGs are employed for terrain avoidance, terrain identification, landings, and takeoffs. The proven effectiveness of NVGs as a visual aid to the aviator has resulted in a plan for increased military use.

The AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) is an NVG currently being procured by the military for use on board aircraft. This electro-optical device (Figure 1) weighs approximately 16 ounces and is mounted on the front of a pilot's flight helmet. A battery power supply is mounted on the back of the helmet. ANVIS functions as an image intensifer by amplification of red and near-infrared components of moonlight and starlight. Looking through the eyepieces, the user views a binocular image of the real world on green monochrome displays. The "look under" design feature of ANVIS allows the pilot to view cockpit instruments with the unaided eye and to obtain an intensified nighttime image of the world external to the aircraft without a mechanical adjustment of focus.

Basic changes to the design of aircraft interior lighting are required to accommodate the use of ANVIS in the cockpit. Aircraft lighting traditionally consists of multicolor incandescent sources with spectral emissions in the infrared and visible wavelength region. Because ANVIS is extremely sensitive to the near-infrared and visible-red components of these lights, traditional aircraft lighting causes severe interference with the operation of ANVIS. To use ANVIS, all of the interior lighting must be redesigned. The white incandescent sources, typically located throughout the cockpit, must be replaced with "cold" green lighting that contains very little or no red and near-infrared. Additional changes in warning, caution, and advisory lighting are also required. These changes restrict the use of color coding. Geometrical considerations also play an important role in the design of ANVIS-compatible lighting. Location of light sources, with respect to ANVIS and the windscreen, must be such as to minimize interference with ANVIS.

The procurement of ANVIS-compatible lighting is currently a problem. Both the design and specification must be based upon research and technical data, yet many human engineering questions regarding these basic changes in lighting design remain unanswered. The general purpose of this work is to provide technical data from which the accurate specification of ANVIS compatible interior lighting may be formulated.

In October 1984, AAMRL was tasked by the Joint Logistics Commanders (JLC) AD HOC group to perform night lighting and night vision research. Specific areas of study, as well as the scope of various efforts, were outlined initially by this group. Data provided by AAMRL are intended to be used as a basis for a Tri-Service specification of ANVIS-compatible interior lighting.

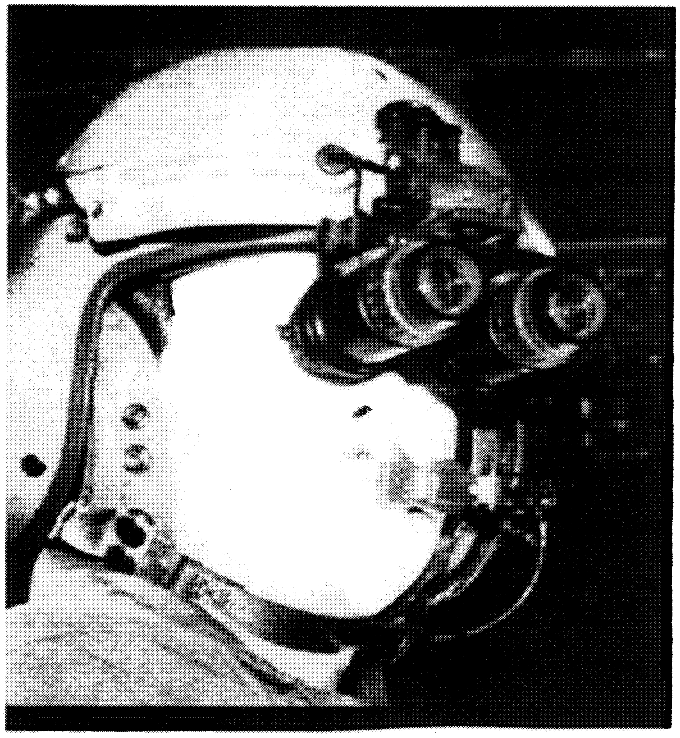

Figure 1. Pilot Wearing ANVIS.

RESEARCH QUESTION

The present research question investigates the use of ANVIS on aircraft and the effect of the ANVIS display luminance on visual adaptation and the setting of instrument lighting levels. Nighttime ambient lighting conditions (i.e. starlight, moonlight) range in luminance from 0.000001 to 0.001 ft-L. The output display luminance of ANVIS is within a range of 0.02 to 2.1 ft-L (reference 1). This "large" differential in preadapting luminance that occurs as a result of using ANVIS was expected to have some effect on the pilot's setting of instrument lighting levels. The specific objectives of this work were as follows:

1- To determine the effect of preadapting ANVIS luminances on the setting of instrument lighting levels by ANVIS users.

2- To define lighting levels required for reading aircraft instruments when adapted to ANVIS display luminance.

The specification of ANVIS-compatible lighting must use operating levels that are representative of an aviator's requirements for readability of instruments when adapted to ANVIS display luminances.

RELATED RESEARCH

A great deal of experimentation has been performed in the laboratory to quantify visual performance under conditions of low ambient lighting. A number of investigators have studied threshold luminances required for the discrimination of visual detail.

Kinney and Connors (reference 2) investigated the recovery of foveal acuity following exposure to various intensities and durations of light. The test stimulus was a circular grid 1 degree in diameter. Bars of the grid were alternately opaque and transparent and subtended 6 minutes of visual angle, corresponding to a visual acuity requirement of 20/120. Data collected with two subjects showed that, following complete foveal dark adaptation, the average luminance required to resolve the grating was 0.01 ft-L. Preadaptation to a 3.6 ft-L light source (45 second duration) resulted in a 20 second recovery time to resolve the 6 minute target. Preadaptation to a 0.36 ft-L light source showed no effect on foveal acuity (6 minute target) for any adaptation time period (1 to 45 second duration).

Brown (reference 3) examined the effect of preadapting luminance on the resolution of visual detail during dark adaptation. In the experiment, the subject was required to identify the orientation of a grating pattern. Luminance thresholds of two subjects were 0.3 mL (0.28 ft-L) and 0.03 mL (0.028 ft-L) for targets of 1.6 minute angle (20/32) and 4.0 minute angle (20/80) respectively. Results also indicated that a return to threshold luminance for the resolution of the 1.6 minute target following a 5 minute preadaptation to a 0.98 mL (0.91 ft-L) light source requires 2-4 minutes. Studies by Graham and Cook (reference 4), Brown, Graham, Leibowitz and Ranken (reference 5), and Diamond and Gilinsky (reference 6) showed similiar results regarding luminance thresholds for various acuities.

In each of the studies described above, the subject was presented with a grid pattern using a light flash of short duration. The stimulus was repeated at a constant interval until the subject could discern target orientation or striations. Note that these experimental presentations do not closely resemble those of a pilot's actual reading task.

Character size on aircraft instruments is designed for the maximum legibility permitted by space restrictions and range of illumination (reference 7). No minimum character size is defined by standards, however character sizes of instrument dials are designed typically for 2.0 (20/40) to 2.5 (20/50) minutes of arc visual angle as estimated for these non-Snellen characters.

In more current research that specifically deals with the readability of aircraft instrument dials, Bauer (reference 8) reports that instruments 2.8 inches in diameter are legible in the 0.02 mL (0.019 ft-L) to 0.05 mL (0.046 ft-L) range. It was also shown that pilot performance improved as display luminance increased from 0.01 mL (0.009 ft-L) to 0.1mL (0.09 ft-L). Bauer concluded that minimum luminance levels required for efficient pilot performance within the cockpit lie in the one log unit range of 0.01 to 0.1 mL (0.009 to 0.09 ft-L).

Results of a field study of operational instrument lighting levels by Dohrn (reference 9) differed from those of Bauer. With red and white instrument panel lighting, Dohrn found that luminance levels required for the legibility of instruments are in a 0.01 to 0.3 ft-L range. The minimum operational level for safe flight was observed to be in the 0.001 to 0.01 ft-L range. These values are based on the pilots' setting of instrument lighting levels in flight when preadapted to natural ambient lighting conditions. These studies did not involve the effects of preadapting luminances on the setting of instrument lighting levels.

LABORATORY STUDY METHODOLOGY

DESIGN VARIABLES

In the present study the effect of the ANVIS display and ambient luminance on the setting of instrument lighting levels was investigated by exposing the subject to various preadaptive lighting conditions. Before performing an instrument reading task, the subject preadapted to a lighting condition that was representative of a nighttime full moon ambient luminance or an ANVIS display luminance. The individual test conditions included a 0.00065 ft-L moonlight condition, a 0.2 ft-L ANVIS condition, and a 1.0 ft-L ANVIS condition.

The subject adjusted a single airspeed instrument light or a composite panel of instrument lights. The composite panel of instrument lights included primary instrument bezel lights, edge-lit panel lights, and glare shield flood lights.

This combination of three adaptation conditions and two instrument adjustment conditions resulted in a total of six treatment conditions (3 X 2).

SUBJECTS

Seven Air National Guard A-7 pilots and an Air Force C-130 pilot participated in the experiment. Subjects were administered refractive visual examinations and all had normal or corrected acuity of 20/25 or better. An AAMRL Night Vision Test (Appendix A) was also administered to evaluate the subject's visual performance under low light level conditions. All subjects were considered normal and "experienced" as pilots by their qualification to fly night missions.

TASK

The task was designed to emulate actual instrument reading tasks that a pilot performs when using ANVIS. This consisted of adjusting instrument lighting levels to read an airspeed instrument. The subject was required to glance down from the ANVIS display or ambient moonlight condition (screen external to the subject station) and read the instrument after adjusting instrument lighting.

The barrel readout and the pointer on the airspeed instrument (Figure 2) were read. The airspeed was recited by the subject with an accuracy of two knots.

APPARATUS

The major hardware components were: a subject's station, an experimenter's station, an ANVIS simulator, and an ambient light simulator.

SUBJECT'S STATION

The subject's station (Figure 3) was a night lighting mockup of an A-10 front instrument panel, containing four simulator instruments for the representation of primary flight instruments: Attitude Direction Indicator, Horizontal Situation Indicator, Airspeed Indicator, and Barometric Altitude Indicator. All other instruments were presented as flat pictures of instruments. White painted indicia elements on the pictures had the approximate reflectance characteristics of real instrument indicia.

Front instrument panel lighting was composed of three separate groups: primary instrument bezel lights, glare shield flood lights, and edge-lit panel lights. Each of the three lighting groups was separately adjusted by the subject.

Lighting for airspeed and altimeter instruments used full circular ring bezel lights. Lumicon(R) wedge lights were used for illumination of the attitude direction indicator and horizontal situation indicator instruments. General illumination of the front instrument panel was provided by flood lighting located beneath the instrument panel glare shield. Six edge-lit panel lights provided markings for the identification of front instrument panel controls and switches. Color coordinates of all of the lighting components were modified to meet the preliminary proposed ANVIS-compatible lighting specification (reference 10). Additional information concerning the front instrument panel lighting is included in Appendix B.

EXPERIMENTER'S STATION

The experimenter's station contained controls for presenting simulator instrument indicia and digital voltage displays for monitoring the luminance level of the three lighting groups and individual instrument bezel lights.

Controls for the selection of a single airspeed bezel light were also included at the experimenter's station. When a single bezel light was selected by the experimenter, the subject's potentiometer controlled only the airspeed instrument bezel light, while all other bezel lights were off.

ANVIS SIMULATOR

An ANVIS simulator (Figure 4) was used to adapt the subject to a display luminance of 1.0 or 0.2 ft-L, as determined by the test condition. This device provided the subject with a diffuse light source of uniform brightness (no image) and color over the display's entire 40-degree field of view. Light with chromaticity coordinates of a P-20 phosphor was obtained by filtering a tungsten source. The display luminance was adjusted with neutral density filters to within 15% of the desired test condition luminance.

AMBIENT LIGHT SIMULATOR

A projection screen in front of the subject was illuminated to simulate a condition of ground luminance on a full moonlit night (reference 11). The average 0.00065 ft-L (standard deviation of 1.9 for 9 measurements) luminance provided an ambient lighting condition to which the subject visually adapted. The light source consisted of a GE-7C7 incandescent light bulb, recessed in a cylindrical housing (2 inch diameter). A neutral density filter (ND=2.0) placed over the light source provided the desired luminance condition. The angular subtense or viewing angle of the screen was 34 degrees horizontally and 20 degrees vertically.

PROCEDURE

A set of instructions was read to each subject (Appendix C). They included the procedure for the experimental session and the events that would occur within a given trial.

A hypothetical mission segment of night-time low level navigation was described in which ANVIS would be used for visibility outside of the aircraft. It was emphasized that the subject should adjust instrument lighting to a minimum-safe level to avoid detection by adversaries.

The subject was seated 27 inches from the instrument panel. Features of the instrument panel lighting were pointed out. The function of the three lighting groups and corresponding dimmer controls was demonstrated.

The subject was dark adapted for 30 minutes prior to the start of the trial sequence. All other lights remained off during this period.

Preceding each trial the subject was exposed to a preadapting lighting condition for 1.5 minutes. The subject was required to look directly at the simulated ANVIS display or the simulated moonlight condition. The subject then adjusted the instrument lighting to a minimum level that he felt was necessary for readability of the airspeed instrument. In the first trial the subject adjusted the airspeed instrument bezel light to a level that he felt was necessary to read the pointer and barrel indicia. All other front instrument panel lights remained off. The subject was instructed to slowly increase the instrument lighting level until the instrument could be read following a brief glance down from the ANVIS display or the simulated moonlight condition. The subject was informed that reading the instrument should not require more than 2 seconds.

In the second trial the subject adjusted the luminance of three groups of the front instrument panel lighting. The subject performed the following sequence: 1- increased the primary instrument cluster lights until the airspeed instrument could be read by the method described above. 2- increased the edge-lit panel lights until the location of switches and knobs was referenced. 3- increased the flood lighting until the engine instrument cluster was adequately illuminated for the reading of gauge pointer positions. 4- made any necessary adjustments to the primary instrument cluster lights to compensate for the effects of the other two lighting groups.

The two trial sequences described above were performed in succession. All trials for a given preadapting lighting condition were performed consecutively. Five trials were given for each of the 6 experimental conditions. A total of 3Ø trials were given within the experimental session. One experimental session lasted approximately 2.25 hours and contained no rest breaks.

The three preadapting lighting conditions were counter-balanced to equalize the effects of fatigue and learning. For trials that followed a condition of higher preadapting luminance, an additional 1Ø minute dark adaptation period was given before testing under the lower luminance condition.

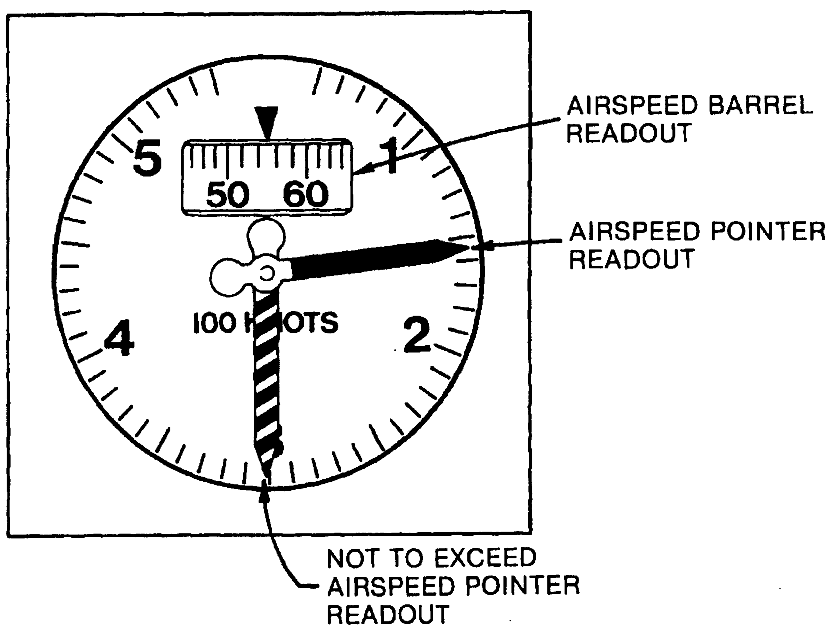

Figure 2. Diagram of Airspeed Simulator Instrument.

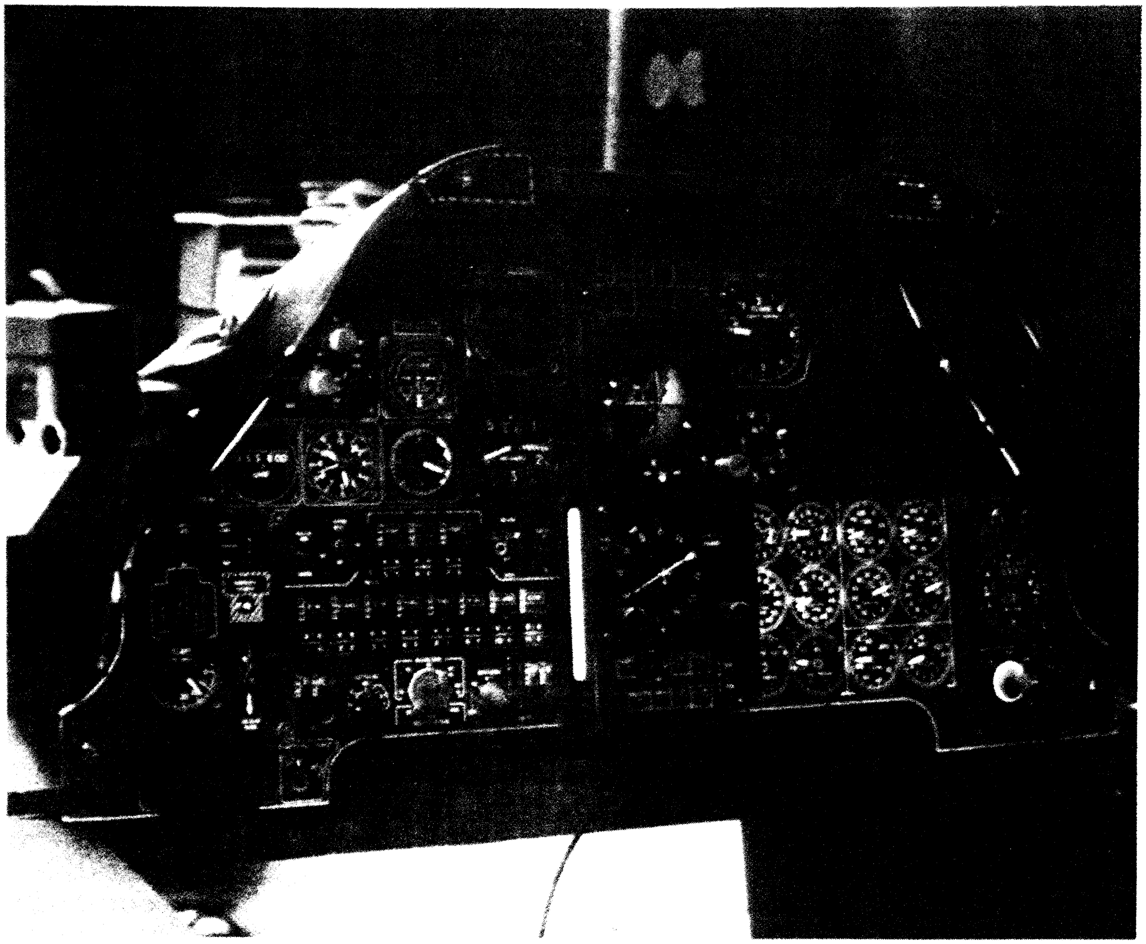

Figure 3. Subject's Station, consisting of an A-1Ø Front Instrument Panel Night Lighting Mockup. The Ambient Light Simulator is not present in the picture.

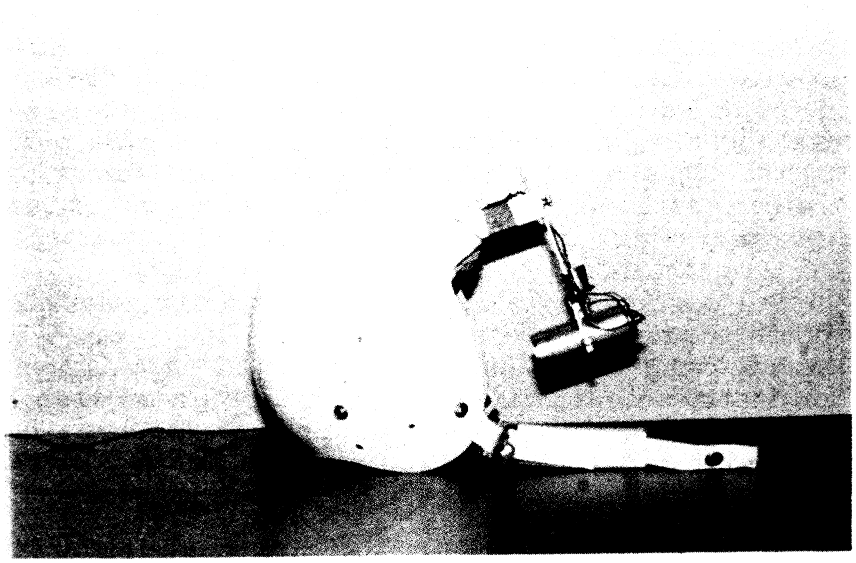

Figure 4. ANVIS Simulator with Helmet.

LABORATORY STUDY RESULTS

Tables 1 to 3 and Figures 5 to 7 summarize the results of the laboratory study. Tables 1 and 2 contain the mean luminance level setting and corresponding standard deviation for all 8 subjects combined, with 5 trials for each test condition. Measurement points for each lighting group are described in Appendix B.

Table 3 shows the mean luminance settings for the adjustment of the airspeed indicator light alone for individual subjects. All other lights remained off during this trial. Each luminance listed for an individual subject is an average of the 3 lighting conditions and the 5 trials of each condition. Substantial variability in individual subject's luminance settings are apparent. The mean values for subjects ranged from 0.0016 ft-L to 0.0109 ft-L. The subject's age, night flying time in hours, and measured visual acuity are also included in this table.

An analysis of variance (ANOVA) was performed on the luminance data using the three adaptation conditions as factors. Results, shown in Tables 4 to 6, indicated that there was a significant difference in the adjustment of primary instrument lighting as a function of lighting condition ($p<.01$). A Tukey's test indicated that lighting levels set by the subject to read the airspeed instrument, after adapting to the two ANVIS conditions, were significantly higher than those after adapting to the moonlight condition. However, comparison of the subject's setting of lighting levels following exposure to the two ANVIS conditions (1.0 ft-L and the 0.2 ft-L ANVIS) showed no significant differences. General results of the ANOVA were the same for trials involving the adjustment of the single airspeed instrument and for trials involving the composite panel of instrument lighting (primary lights, edge-lit panel lights, and flood lights).

A second and third ANOVA indicated that the subjects made no significant changes in edge-lit panel lighting or flood lighting levels as a result of preadaptation to the three lighting conditions. Tables 7 to 8 list results of these ANOVA.

Figure 5 illustrates the light level settings (mean of all subjects) for the three preadapting lighting conditions. It also compares airspeed instrument lighting levels for adjustment of the airspeed instrument light alone with that for the three lighting groups. The subjects' light level settings for trials involving the adjustment of a single airspeed instrument are approximately the same as those for trials involving the adjustment of the three lighting groups.

Mean luminance level settings as a function of subject age are shown in Figure 6. The product moment correlation coefficient, r, was - 0.41, which, for n=8 at the p=0.1 level is not statistically significant. A general trend for instrument lighting levels to decrease with increase in subject age is therefore not established statistically. Figure 6 also illustrates the somewhat broad range of luminance values set by individual subjects.

Figure 7 plots the subjects' mean airspeed luminance level settings (averaged for all three lighting conditions) against the subjects' night flying time. Six of the eight subjects had less than 500 hours of night flying time. For the eight subjects the product moment correlation coefficient between luminance settings and flight time was r=-0.19, which for p>0.1 is not statistically significant. Thus the apparent relationship of decreasing mean luminance levels with an increase in night flying experience is not established.

TABLE 1. MEAN LUMINANCE LEVEL SETTING FOR A SINGLE INSTRUMENT AND FOR A CLUSTER OF PRIMARY INSTRUMENTS WHEN PREADAPTED TO VARIOUS AMBIENT LIGHTING CONDITIONS.

	0.00065ft-L MOON	S	0.2ft-L ANVIS	S	1.0ft-L ANVIS	S
AIRSPEED ALONE	0.0043	(0.0029)*	0.0058	(0.0034)	0.0062	(0.0036)
AIRSPEED WITH CLUSTER	0.0044	(0.0028)	0.0064	(0.0037)	0.0073	(0.0042)

*STANDARD DEVIATION IN PARENTHESIS

TABLE 2. MEAN LUMINANCE LEVEL SETTING FOR THREE LIGHTING GROUPS WHEN PREADAPTED TO VARIOUS AMBIENT LIGHTING CONDITIONS.

	0.00065ft-L MOON	S	0.2ft-L ANVIS	S	1.0ft-L ANVIS	S
AIRSPEED-COMPENSATED	0.0040	(0.0026)	0.0061	(0.0034)	0.0065	(0.0039)
FLOODS	0.0138	(0.0175)	0.0155	(0.0156)	0.0202	(0.0160)
EDGE-LIT PANELS	0.0107	(0.0122)	0.0163	(0.0160)	0.0193	(0.0179)

*STANDARD DEVIATION IN PARENTHESIS

TABLE 3. MEAN LUMINANCE LEVEL SETTING ACROSS ALL THREE LIGHTING CONDITIONS FOR INDIVIDUAL SUBJECTS IN DECENDING ORDER OF LUMINANCE

SUBJECT NUMBER	LUMINANCE (ft-L)	AGE	NIGHT FLIGHT TIME (HOURS)	SNELLEN ACUITY RIGHT	SNELLEN ACUITY LEFT
7	0.0109	26	70	20/20	20/20
1	0.0086	34	100	20/25	20/25
6	0.0066	25	50	20/25	20/25
5	0.0060	36	350	20/15	20/15
8	0.0048	38	4700	20/20	20/15
4	0.0032	29	90	20/25	20/15
2	0.0020	34	1000	20/25	20/20
3	0.0016	34	270	20/20	20/20

TABLE 4. ANOVA FOR SINGLE AIRSPEED INSTRUMENT SETTINGS WHEN PREADAPTED TO VARIOUS AMBIENT LIGHTING CONDITIONS.

SOURCE	DF	MEAN SQUARE	F	P
SUBJECT	7	0.001543	42.0	0.0001
CONDITION	2	0.000443	12.0	0.0009
ERROR	14	0.000037		

TABLE 5. ANOVA FOR PRIMARY INSTRUMENT CLUSTER SETTINGS WHEN PREADAPTED TO VARIOUS AMBIENT CONDITIONS.

SOURCE	DF	MEAN SQUARE	F	P
SUBJECT	7	0.001710	34.2	0.0001
CONDITION	2	0.000787	15.8	0.0003
ERROR	14	0.000050		

TABLE 6. ANOVA FOR COMPENSATED PRIMARY INSTRUMENT CLUSTER SETTINGS WHEN PREADAPTED TO VARIOUS AMBIENT CONDITIONS.

SOURCE	DF	MEAN SQUARE	F	P
SUBJECT	7	0.001859	38.8	0.0001
CONDITION	2	0.000773	16.1	0.0002
ERROR	14	0.000048		

TABLE 7. ANOVA FOR EDGE-LIT PANEL LIGHTS WHEN PREADAPTED TO VARIOUS AMBIENT LIGHTING CONDITIONS.

SOURCE	DF	MEAN SQUARE	F	P
SUBJECT	7	0.000640	15.4	0.0001
CONDITION	2	0.000152	3.6	0.0551
ERROR	14	0.000042		

TABLE 8. ANOVA FOR FLOODLIGHTS WHEN PREADAPTED TO VARIOUS AMBIENT LIGHTING CONDITIONS.

SOURCE	DF	MEAN SQUARE	F	P
SUBJECT	7	0.010626	13.3	0.0001
CONDITION	2	0.002550	3.2	0.0724
ERROR	14	0.000800		

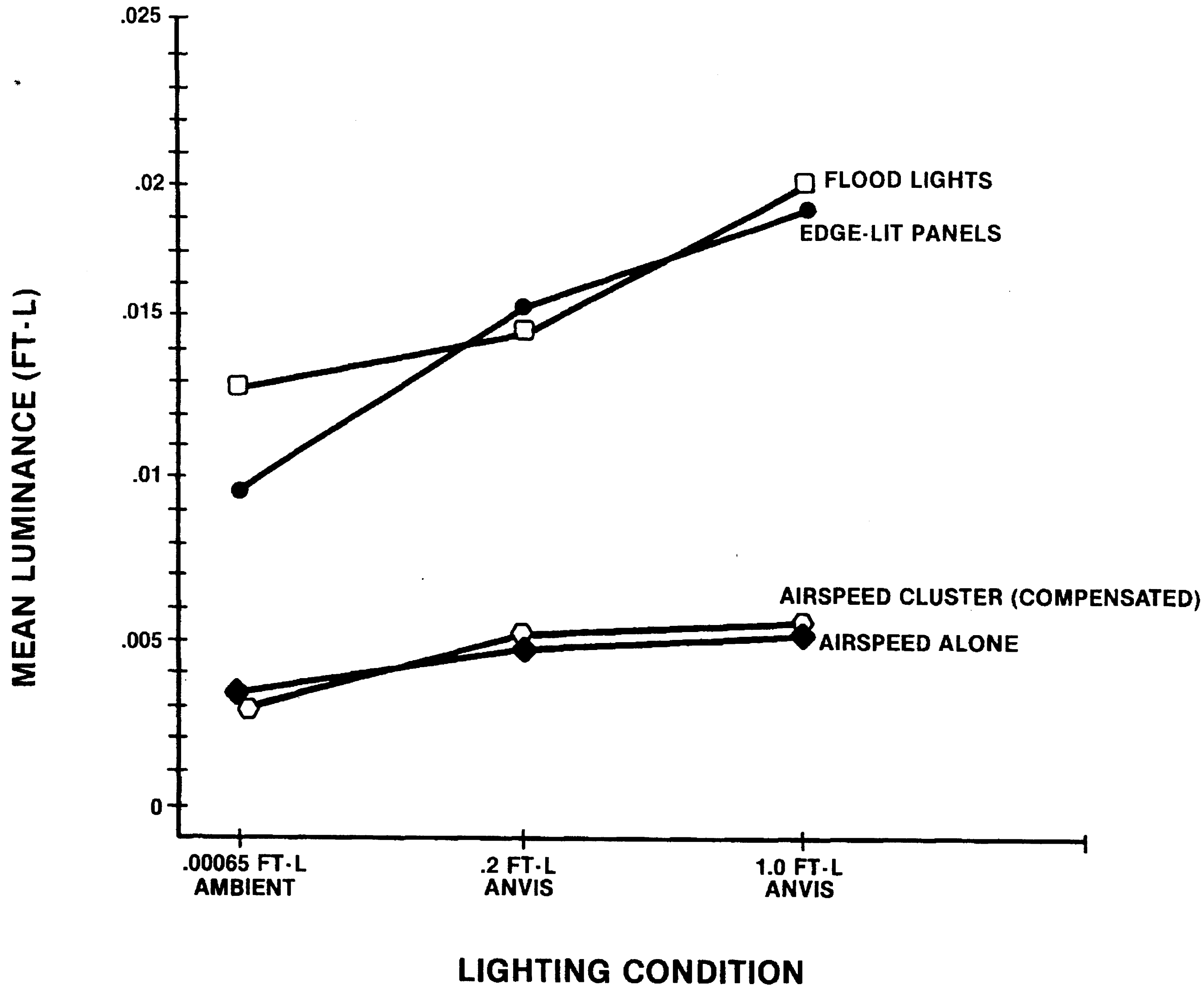

Figure 5. Mean Luminance Level Setting for the Three Lighting Groups and Airspeed Alone (Across All Subjects) as Function of Preadapting Lighting Conditions.

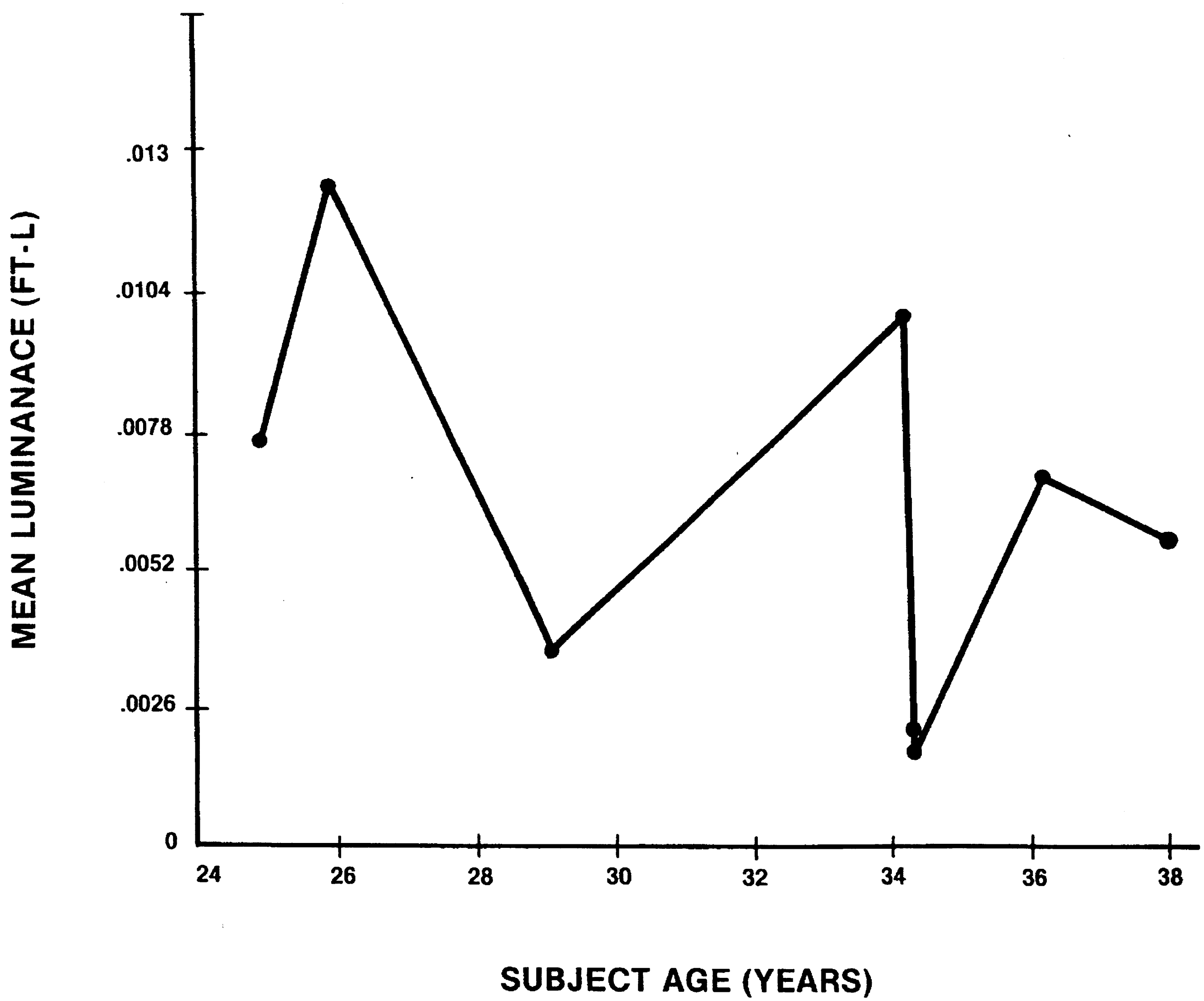

Figure 6. Mean Luminance Setting of Airspeed Indicator

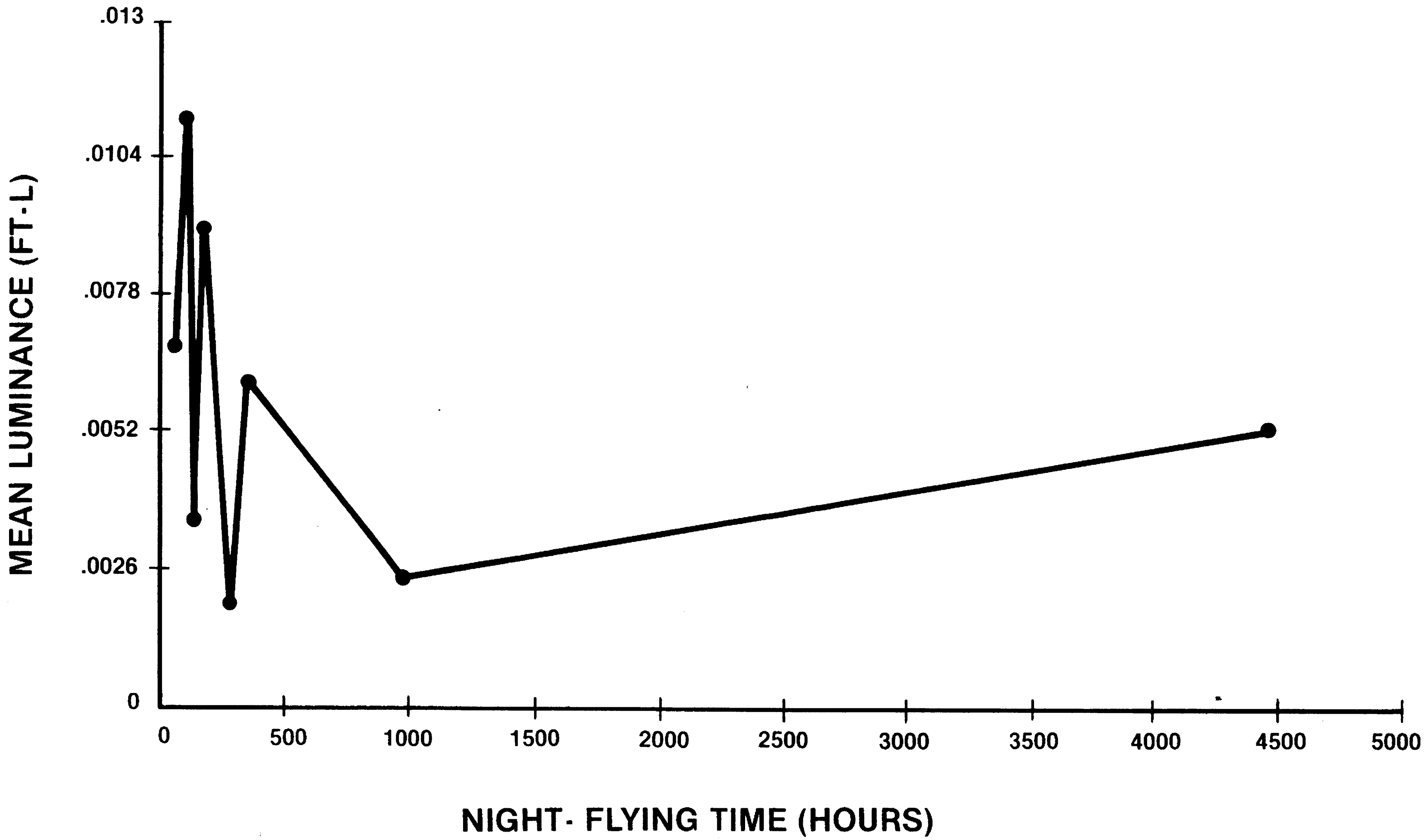

Figure 7. Mean Luminance Setting of the Airspeed Indicator Light as a Function of Night Flying Time.

FIELD STUDY METHODOLOGY

DESIGN VARIABLES

In the operational environment, many factors influence the pilot's setting of instrument lighting levels. The following variables are "independent variables" in the broad sense that each may influence the pilot's setting of instrument lighting levels. These variables are summarized as follows:

* Level of Dark Adaptation- Ambient light level (i.e. moonlight, starlight, ground light, etc.) determines the ANVIS display brightness, which in turn, is responsible for the human visual adaptation state.

* Individual Night Vision- Differences in an individual's night vision contribute to the setting of instrument lighting levels. Presently, pilot visual screening tests do not consider deficiencies in human night vision.

* Interference with NVGs- Current special operations lighting designs are, in some instances, reported to be only partially compatible with night vision goggles. As a result, pilots set instrument lighting levels to reduce or eliminate interference with the ANVIS displayed imagery (particularly reflections in the windscreen).

* Lighting/Crew Station Design- Many differences exist in lighting and crew stations for various operational aircraft, including the types of instruments, indicia, geometries, lighting componenets, etc. All influence instrument lighting levels.

* Training/Type of Mission- Special operations training requires that instrument lighting levels be set for minimum readability to reduce visibility from outside. This training can be related to a particular mission type.

The dependent variable in the field study was the luminance level of the instrument indicia set by the pilot.

AIRCRAFT AND EQUIPMENT

Lighting measurements were made on board three Air Force special operations aircraft: C-141, C-130, and HH-53. Each of these aircraft is equipped with lighting systems that are compatible with NVGs. The designs consist primarily of flood lighting located beneath the front instrument panel glare shield (reference 11). Additional measurements were made onboard a National Guard OH-6 aircraft. The lighting design for this aircraft consisted primarily of ring bezel lights or post lights located on individual instruments.

Measurements were made with a Pritchard 1980 photometer with close-up lens, a Spectra RS-1 barium sulfate plaque, and a tripod.

PROCEDURE

A verbal description of the lighting field study was given to crew members in the preflight briefing. This description included the purpose of the study, the time required for measurements, and the procedure for data collection. No specific instructions describing how to set instrument lighting levels were given. An alternate method of data collection was used when the method described conflicted with other mission requirements. The data collection sequence was performed as follows:

1- The aircraft landed at an austere airstrip and the pilot was instructed to remove his ANVIS.
2- After adapting to ambient lighting conditions, the pilot was instructed to adjust lighting levels to make aircraft instruments readable without ANVIS.
3- Photometric measurements of the front instrument panel were taken.
4- The pilot was instructed to put on ANVIS.
5- After visually adapting to the ANVIS display field, the pilot was instructed to adjust lighting levels to make aircraft instruments legible while utilizing the ANVIS look-under design.
6- Photometric measurements of the front instrument panel were taken.

The alternate method of data collection was as follows:

1- Lighting levels were set by the pilot in flight during a mission segment that typified ANVIS usage.
2- Photometric measurements of the front instrument panel were taken after the flight. Lighting levels set in flight were unchanged. Tarps were placed over the windscreens to block out parking area lights.

Because no additional instrument bezel lights were present on each of the three Air Force front instrument panel designs, illuminance measurements were the primary method of data collection. Direct luminance measurements were the method used for data collection on board the OH-6 aircraft. Lighting measurement techniques are described in Appendix D.

FIELD STUDY RESULTS

Data presented in Tables 9 to 11 are results of lighting measurements taken on board C-141, C-130, and the HH-53 special operations aircraft.

The tabular form of the illuminance data indicates the approximate physical location that measurements were made on the front instrument panel. The gradation of lighting, shown by measurements of the high, middle, and low position on the front instrument panel, is typical of a flood lighting distribution for lights mounted beneath the instrument panel glare shield. Illuminance data in Tables 9 to 11 indicate a rather broad range of lighting levels across each of the front instrument panels measured. Illuminance levels at the bottom of the panel (low position) ranged from 16% to 33% of the luminance levels at the top (high position) of the panel for any given crew position.

For data shown in Tables 9 and 10, the pilot adjusted instrument lighting levels, once when adapted to an ambient lighting condition (not wearing ANVIS) and again after adapting to the ANVIS display luminance. Table 11 lists lighting levels set by the pilot during a mission segment using ANVIS. Each illuminance measurement was taken in a position directly over the instrument face.

Table 12 lists results of lighting measurements taken onboard a National Guard OH-6 aircraft. Luminance of the white indicia ranged from 0.030 to 0.086 ft-L. The minimum measured instrument luminance was 35% of the maximum measured instrument luminance.

Tables 13 to 15 show the approximate luminances of white instrument indicia based on known reflectance characteristics of indicia paint. This data was calculated from illuminance data of Tables 9 to 11. MIL-L-27160C (reference 13) specifies white 37875, black 37038, and gray 36440 as the indicia colors. The reflectances of these paints as measured in the laboratory, were 86.3%, 5.5% and 46.8% respectively. Paint chips were provided in FED-STD-595 (reference 14). For the calculated lighting data shown in Tables 13 to 15 the range of luminance levels, set by pilots when using ANVIS, was 0.004 to 0.086 ft-L.

Mean luminances calculated for various instrument panel lighting data are listed in Table 16. A description of the data points used in the calculations as well as standard deviations are included in the table. The grading effect of flood lighting resulted in high standard deviations.

Figure 8 illustrates the effect of ANVIS use on instrument lighting levels for field data collected onboard the C-130 and C-141 aircraft. The graph shows that the pilots' setting of instrument lighting levels was higher when using ANVIS. Figure 8 also compares the pilot's ANVIS lighting levels with the copilot's non-ANVIS settings. It can be observed that the non-ANVIS copilot's ANVIS lighting levels are at approximately the same luminance level as the pilot's ANVIS lighting levels.

TABLE 9. PHOTOMETRIC MEASUREMENTS OF THE C-141 FRONT INSTRUMENT PANEL FOR PILOT WITH/WITHOUT ANVIS.

FLOOD LIGHT MEASUREMENTS, IN ft-C, NOT USING ANVIS

panel position	pilot console	center console	copilot console
high	Ø.ØØ5	Ø.Ø24	Ø.Ø44
middle	Ø.ØØ2	Ø.Ø15	Ø.Ø28
low	Ø.ØØ1	Ø.ØØ8	Ø.ØØ9

FLOOD LIGHT MEASUREMENTS, IN ft-C, USING ANVIS

panel position	pilot console	
high	Ø.1ØØ	
middle	Ø.Ø5Ø	(center and copilot level were unchanged)
low	Ø.Ø25	

ADI LUMINANCE LEVEL, IN ft-L, USING ANVIS

panel position	pilot console	copilot console
above horizon line	Ø.Ø5Ø	Ø.Ø53
below horizon line	Ø.ØØ6	Ø.ØØ5

HSI LUMINANCE LEVEL, IN ft-L, USING ANVIS

panel position	pilot console	copilot console
pointer at 6 o'clock	Ø.Ø21	Ø.Ø11
black background	Ø.ØØ6	Ø.ØØ1

Notes: -Date Collected: 6/27/84
-Airplane: tail# Ø131, Electroluminescent lighting
-Conditions: hazy, starlight, no ground lights

TABLE 10. PHOTOMETRIC MEASUREMENTS OF THE C-130E (AWADS) FRONT INSTRUMENT PANEL FOR PILOT WITH/WITHOUT ANVIS.

FLOOD LIGHT MEASUREMENTS, IN ft-C, NOT USING ANVIS

panel position	pilot console	center console	copilot console
high	0.002	0.002	0.082
middle	0.001	0.002	0.034
low	0.001	0.020	0.014

FLOOD LIGHT MEASUREMENTS, IN ft-C, USING ANVIS

panel position	pilot console
high	0.012
middle	0.007 (center and copilot levels were unchanged)
low	0.004

ADI LUMINANCE LEVEL, IN ft-L, USING ANVIS

panel position	pilot console	copilot console
above horizon line	0.002	0.002
below horizon line	0.0003	0.0004

Notes: -Date Collected: 8/14/84
-Airplane: Tail# 1276, Electroluminescent lighting
-Location: Pope AFB, no ground lights
-Conditions: approximately 80% full moon

TABLE 11. PHOTOMETRIC MEASUREMENTS OF THE HH-53 (PAVELOW) FRONT INSTRUMENT PANEL WITH ANVIS.

FLOOD LIGHT MEASUREMENTS, IN ft-C, USING ANVIS

panel position	pilot console		center console		copilot console	
high	Radar ALt	Ø.Ø74			Airspeed	Ø.Ø64
middle	ADI	Ø.Ø52			Radar Alt	Ø.Ø18
	VVI	Ø.Ø5Ø			ADI	Ø.Ø32
low	Rotor RPM	Ø.Ø22	clock	Ø.ØØ5	VVI	Ø.Ø18
			eng temp	Ø.ØØ9	Rotor RPM	Ø.Ø14

ADI LUMINANCE, IN ft-L, USING ANVIS

panel position	pilot console
above horizon line	Ø.Ø11
below horizon line	Ø.ØØ4

HSI LUMINANCE, IN ft-L, USING ANVIS

panel position	pilot console
bearing pointer	Ø.ØØ3

Notes: -Date Collected: 11/1/84
-Airplane: Tail# 165Ø, filtered incandescent flood lighting
-Location: parking area with tarps covering windscreens
-Conditions: 5Ø% moon, clear
-lighting levels were set during mission segments using NVGs
-both pilot and copilot were using ANVIS

TABLE 12. PHOTOMETRIC MEASUREMENTS OF THE OH-6A FRONT INSTRUMENT PANEL WITH ANVIS.

Instrument	White Pointer Luminance (ft-L)	Adjacent Black Luminance (ft-L)
Altimeter	0.063	0.006
Clock	0.031	0.002
RMI	0.086	0.003
Attitude Indicator	0.045	0.007
Rotor Tach	0.082	0.006
Airspeed	0.047	0.021
Torque	0.057	0.005
N. Tach	0.030	0.013

Notes: -Date Collected: 4/2/85
-Airplane: Tail# 15188, incandescent bezel lights by Aerospace Optics
-Location: in hangar with tarps covering windscreens
-Conditions: full moon, clear
-Lighting levels were set in flight during a low level flight
-Only direct instrument measurements of instrument pointers were made (ft-L)
-Measurement data in the table is not ordered by position on the front instrument panel

TABLE 13. C-141 CALCULATED LUMINANCE, IN ft-L, FOR WHITE PAINTED INDICIA.

NOT USING ANVIS

panel position	pilot console	center console	copilot console
high	0.004	0.021	0.038
middle	0.002	0.013	0.024
low	0.001	0.007	0.008

USING ANVIS

panel position	pilot console
high	0.086
middle	0.043
low	0.022

(center and copilot levels were unchanged)

TABLE 14. C-130 CALCULATED LUMINANCE, IN ft-L, FOR WHITE PAINTED INDICIA.

NOT USING ANVIS

panel position	pilot console	center console	copilot console
high	0.002	0.002	0.071
middle	0.001	0.002	0.029
low	0.001	0.017	0.012

USING ANVIS

panel position	pilot console
high	0.010
middle	0.006
low	0.003

(center and copilot levels were unchanged)

TABLE 15. HH-53 CALCUALATED LUMINANCE, IN ft-L, FOR WHITE PAINTED INDICIA.

USING ANVIS

panel position	pilot console		center console		copilot console	
high	Radar Alt	0.064			Airspeed	0.055
middle	ADI	0.045			Radar Alt	0.016
low	VVI	0.043			ADI	0.028
	Rotor RPM	0.019	clock	0.004	VVI	0.016
			eng temp	0.008	Rotor RPM	0.012

TABLE 16. AVERAGE LUMINANCES CALCULATED FOR MEASUREMENTS ON AIRCRAFT.

Aircraft	Location/Condition	# of Measurements	Mean(ft-L)	S
C-141	all of panel/no ANVIS	9	0.013	(0.012)*
C-141	pilot station/no ANVIS	3	0.002	(0.002)
C-141	pilot station/with ANVIS	3	0.050	(0.033)
C-130	all of panel/no ANVIS	9	0.015	(0.023)
C-130	pilot station/no ANVIS	3	0.001	(0.001)
C-130	pilots station/with ANVIS	3	0.006	(0.004)
HH-53	pilot station/with ANVIS	4	0.043	(0.018)
HH-53	copilot station/with ANVIS	5	0.025	(0.018)
OH-6	pilot station/with ANVIS	8	0.055	(0.021)

*STANDARD DEVIATION IN PARENTHESIS

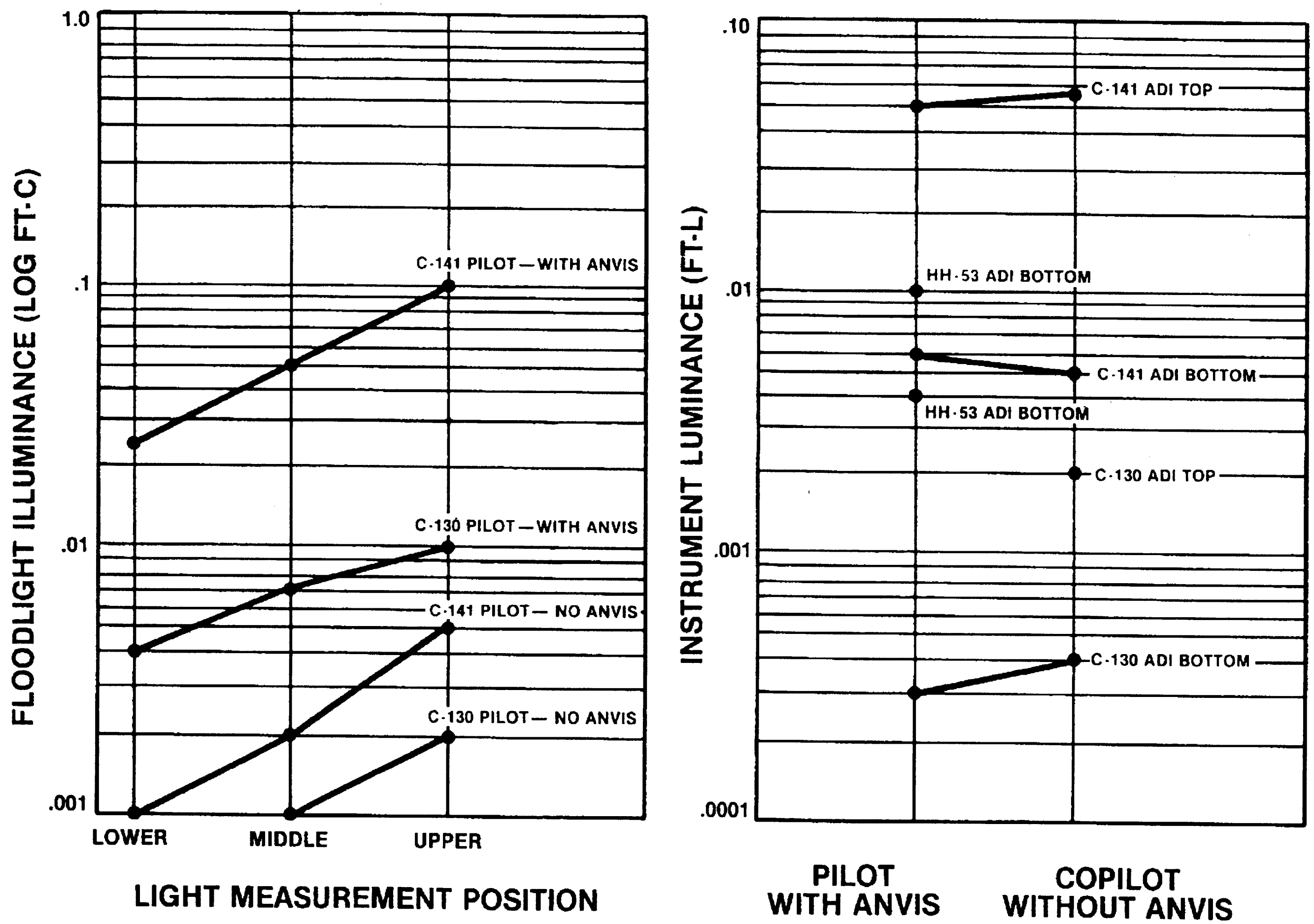

Figure 8. Effect of ANVIS on Instrument Lighting Levels

DISCUSSION

As indicated previously, one of the objectives of this work is to determine luminance levels required for instrument legibility when the visual system is adapted to ANVIS display luminance. The data derived from these studies can then be used to define an accurate test luminance for acceptance procedures of ANVIS compatible lighting components.

In the currently proposed specification, various lighting characteristics (i.e. chromaticity and spectral emissions) are tested for acceptance at luminance levels that are estimated to be representative of a pilot's actual operational levels. For the spectral emission acceptance procedure (by ANVIS radiance units, paragraph 3.2.5.1), the test condition luminance is Ø.1 ft-L. For the color acceptance procedure (by C.I.E. chromaticity coordinates, paragraph 3.2.4.1) the test condition luminance is Ø.Ø5 ft-L. The currently-estimated operational luminance levels do not consider potential effects of the preadapting ANVIS display luminance.

The laboratory results show that preadaptation to light sources of higher luminance (1.Ø ft-L or Ø.2 ft-L ANVIS condition compared to the Ø.ØØØ65 ft-L ambient condition) result in a corresponding increase in the lighting levels needed for readability of instruments. A closer examination of the data reveals that actual increases in instrument lighting levels, although significant, were small when compared to the corresponding change in preadapting luminance conditon. Increasing the preadapting luminance by roughly a factor of 3ØØ (Ø.ØØØ65 ft-L to the Ø.2 ft-L condition in Table 2), resulted in an increase in the airspeed instrument lighting levels by a factor of 1.5 (Ø.ØØ4Ø ft-L to Ø.ØØ61 ft-L). Similarly, an increase in preadapting luminance by a factor of 15ØØ (Ø.ØØØ65 ft-L to 1.Ø ft-L condition in Table 2), resulted in an increase in the airspeed instrument lighting levels by a factor of 1.6 (Ø.ØØ4 ft-L to Ø.ØØØ65 ft-L). This result indicates that this broad range of preadapting luminance has very little affect on pilot adjusted instrument lighting levels. In fact the increase in instrument lighting level, resulting from the 1.Ø ft-L lighting condition, is less than the range of mean lighting levels set by individual subjects.

Laboratory results also show luminance levels of the three lighting groups to be lower than the Ø.1 ft-L test luminance condition described in the draft specification. For the 1.Ø ft-L ANVIS condition, the mean luminance levels for the three front instrument panel lighting groups were as follows: Ø.ØØ65 ft-L for primary instrument cluster, Ø.Ø193 ft-L for the edge-lit panel lights and Ø.Ø2Ø2 ft-L for the flood lights. Each of these luminance values represents a single measurement point on the front instrument panel. For each lighting group, a range of luminance is actually defined, for various locations on the front instrument panel. It is notable that these luminance values are very much dependent on lighting design (i.e. luminance distribution), the geometry of the front instrument panel, and the instructions provided to the subject. Instructions requiring the subject to "set instrument lighting to a minimum level" are believed to have resulted in these low luminance values.

The setting of the airspeed instrument lighting level was based on the subject's need to identify indicia on the instrument barrel readout. The character size of the barrel readout numbers is a significant factor in the luminance required for the subject to read the airspeed instrument. These are estimated to be 3.Ø minute (2Ø/6Ø) targets (appendix E). This character size is therefore slightly larger than the 2.Ø (2Ø/4Ø) to 2.5 (2Ø/5Ø) minute target size range, defined as typical for most aircraft indicia design. Direct comparison of the results of this experiment with threshold acuity studies found in the literature is not possible though due to the completely different methodologies employed in the experiments.

The most obvious finding of the field study was that instrument lighting levels were, in all cases, lower than the currently proposed Ø.1 ft-L test condition. For the pilots' settings of instrument lighting levels when using ANVIS, luminance values ranged from Ø.ØØ3 to Ø.Ø86 ft-L for the C-141, C-13Ø, HH-53, and OH-6 aircraft. The data collected on board these aircraft seem to indicate that a test condition luminance less than Ø.1 ft-L would more accurately describe a condition of operational usage. Using the mean luminance data of Table 16, the operational levels were in the Ø.ØØ6 to Ø.Ø55 ft-L range. This range of values is probably more "typical" of the operational luminances used than the specified Ø.1 ft-L test condition. These calculated mean values, however, are dependent upon the location of measurement on the front instrument panel. Interpretation of these values must be considered, with individual data points used in the calculations.

Luminance uniformity requirements of the currently proposed specification are expected, generally, to contribute to lower luminance level settings than are present with instrument panels of broader luminance distribution. The specification (paragraph 3.3.5.2) states that the luminance ratio between lighted instruments shall be no greater than 1.75 to 1. It is notable that the OH-6 aircraft instrument lighting does not meet this requirement. For the Ø.Ø3Ø ft-L and Ø.Ø86 ft-L (Table 12) measurements, the luminance ratio is 2.87 to 1. Similarly, the C-141, C-13Ø, and HH-53 aircraft do not meet this requirement.

CONCLUSIONS

The effect of a preadapting ANVIS display luminance results in a significant increase in primary instrument lighting levels set by pilots; however, this increase is small when compared to the change in preadapting luminance. When preadapted to the ANVIS display luminance (1.Ø ft-L) an increase in instrument lighting levels, by a factor of 1.6 may be expected when compared to instrument lighting levels set following a preadaption condition of moonlight (Ø.ØØØ65 ft-L ambient).

There seems to be reasonable evidence to indicate that the current luminance test condition of Ø.1 ft-L is higher than instrument lighting levels that are typically encountered in the field. Luminance measurements made on board the C-141, C-13Ø, HH-53, and OH-6 aircraft show lighting levels to be generally less than Ø.Ø6 ft-L and to contain luminances in the Ø.ØØ3 to Ø.Ø86 ft-L range.

APPENDIX A
NIGHT VISION TEST

The current AAMRL Night Vision Test (NVT) determined luminances required for the threshold acuity of Snellen characters. The subject was required to identify the orientation (up, down, right, left) of characters presented after adjusting luminance to a required level.

The threshold luminance required for the recognition of a target of 2.5 minute visual angle (2Ø/5Ø) is shown in Table A.1 for each of the eight subjects. The luminance level, as set for the legibility of the airspeed instrument is also included in this table. The calculated mean is Ø.Ø16 ft-L with a standard deviation of Ø.ØØ5 for the eight subject values. All individual subject data is within two standard deviations of the subject population mean.

No statistical correlation between the AAMRL Night Vision Test data and the laboratory study data was found (r=Ø.Ø7, p=Ø.8631).

TABLE A.1 NIGHT VISION TEST DATA FOR TARGET OF 2.5 MINUTE VISUAL ANGLE AND LABORATORY LUMINANCE DATA FOR SUBJECT'S SETTING OF THE AIRSPEED INDICATOR LIGHT ALONE.

SUBJECT NUMBER	NVT LUMINANCE (ft-L)	AIRSPEED LUMINANCE ALONE NUMBER FOR Ø.ØØØ65 ft-L AMBIENT (ft-L)
1	Ø.Ø19	Ø.ØØ75
2	Ø.Ø21	Ø.ØØ11
3	Ø.Ø13	Ø.ØØ11
4	Ø.ØØ6	Ø.ØØ24
5	Ø.Ø13	Ø.ØØ52
6	Ø.Ø16	Ø.ØØ45
7	Ø.Ø15	Ø.ØØ91
8	Ø.Ø21	Ø.ØØ3

APPENDIX B
SUBJECT STATION INSTRUMENT PANEL LIGHTING

All of the front instrument panel utilized electroluminescent lighting. Individual components used to illuminate the simulator instruments are described in Table B.1.

Luminance measurements of edge-lit panel lights were made at rated component voltage. These data, listed in Table B.2, describe the luminance uniformity of various edge-lit panels. The Weapons Panel knob was used to describe the luminance of the edge-lit panel lighting group for subject data listed in the laboratory results section. Luminance measurements at other locations are also shown in this table. Each table entry is the average of 3 measurements.

Luminance measurements of the 12 engine instrument gauges (photographic pictures) were made with flood lighting at rated voltage. Each value listed in Table B.3 represents a luminance measurement of a single instrument pointer in the engine instrument cluster. The Fuel Flow engine instrument pointer (row 2, column 3 in the table below) was used to describe the flood lighting luminance for subject data given in the results section of this report.

Luminance measurements of the individual primary instruments are shown in Table B.4. The index marker of the barrel readout was used as the measurement point for the airpeed instrument. All other primary instrument lighting levels may be expressed relative to this measurement location. Contrast was calculated by the formula provided in MIL-L-27160C (USAF): C=(B2-B1)/B1, where: B2 is the luminance of the white or gray area and B1 is the luminance of the black area. A loss of contrast, seen as cloudiness on the instrument face, is measured for instruments using the Lumicon Wedge lighting component. The contrast of the Attitude Direction Indicator Instrument indicia is notably poor.

The chromaticity coordinates of all individual lighting components were modified to comply with the proposed AN/AVS-6 lighting compatibility specification. Color coordinates of the modified lighting components are shown in Table B.5. A graph of the modified C.I.E. chromaticity coordinates is shown in Figure B.1.

All luminance data described in the laboratory results section of this report were calculated from voltages, using the digital voltage readout located at the experimenter's station. Figure B.2 shows the relationship between voltage and luminance for various lighting groups. These curves show that measurement of voltage input to a lighting circuit does accurately and precisely track luminance. The luminance range containing the least accuracy is the region of the curve with the largest slope. For Figure B.2, showing the voltage to luminance relationship for measurement of the Airspeed Instrument barrel readout, the largest slope is in the 80.0 to 115.0 volt range. The corresponding luminance is in the 0.006 to 0.012 ft-L range. For a change of .1 volts (accuracy of voltage readout at the experimenters station) the change in luminance is 0.00002 ft-L. This accuracy is an order of magnitude better than needed for purposes of this experiment.

Photometric measurements were made to ensure that the lighting components and their corresponding power supplies were stable with time. It was also determined that power supply loading effects, created by the use of various lighting groups, were negligible.

Reflectance characteristics of the photographic pictures were measured. The reflectance of white indicia elements was 51%. The reflectance of black indicia elements was 16%. The resulting contrast was C=2.2.

TABLE B.1 LIGHTING COMPONENTS USED FOR ILLUMINATION OF THE PRIMARY INSTRUMENT CLUSTER.

Description	Manufacturer/Model	Instrument Illuminated
3 Inch Ring Bezel	Midland Ross/PN 2Ø-Ø187-5	Airspeed Ind.
3 Inch Ring Bezel	Midland Ross/PN 2-ØØ187-5	Altimeter Ind.
Lumicon Wedge	Control Products/ ----	Attitude Direction Ind.
Lumicon Wedge	Control Products/ ----	Horizontal Situation Ind.

TABLE B.2 LUMINANCE UNIFORMITY OF EDGE-LIT PANEL LIGHTING AT MEASUREMENT POINTS ON VARIOUS EDGE-LIT PANELS.

Panel#	Indicia/Location	Mean (ft-L)	S
1	"J" of "JET"	Ø.Ø73	(Ø.ØØ6)*
2	"H" of "HUD"	Ø.Ø72	(Ø.Ø19)
3	"D" of "Down Lock Override"	Ø.1Ø6	(Ø.Ø14)
4	"R" of "Release Mode"	Ø.141	(Ø.ØØ4)
4	"Weapons Panel Knob"	Ø.3Ø7	(Ø.Ø27)
5	"S" of "Sys"	Ø.Ø72	(Ø.ØØ7)

*STANDARD DEVIATION IN PARENTHESIS

TABLE B.3 LUMINANCE UNIFORMITY OF ENGINE INSTRUMENT ILLUSTRATIONS, IN ft-L

Row#/Column#	1	2	3	4
1	Ø.ØØ75	Ø.Ø121	Ø.Ø112	Ø.Ø115
2	Ø.Ø144	Ø.Ø11Ø	Ø.ØØ88	Ø.ØØ89
3	Ø.ØØ75	Ø.ØØ71	Ø.ØØ34	Ø.ØØ43

TABLE B.4 LUMINANCE UNIFORMITY AND CONTRAST CALCULATIONS FOR THE PRIMARY INSTRUMENT CLUSTER.

Instrument	Indicia/Location	Luminance (ft-L) white/gray	Luminance (ft-L) black	Contrast
Attitude Ind.	tick mark at 3 oclock	Ø.ØØ64	Ø.ØØ48	Ø.3
	"O" at bottom	Ø.ØØ52 (gray)	Ø.ØØ45	Ø.3
	"M" near top	Ø.ØØ92 (gray)	Ø.ØØ89	Ø.Ø3
Hor. Sit. Ind.	upper portion	Ø.Ø155	Ø.ØØ31	4.1
	upper portion	Ø.Ø122	Ø.ØØ26	3.6
	lower portion	Ø.Ø545	Ø.Ø2Ø6	15.3
	lower portion	Ø.Ø329	Ø.ØØ22	14.3
Airspeed Ind.	1 knot	Ø.ØØ752	Ø.ØØØ4	19.9
	15Ø knots	Ø.ØØ59	Ø.ØØØ4	15.5
	3ØØ knots	Ø.ØØ32	Ø.ØØØ4	6.8
	45Ø knots	Ø.ØØ91	Ø.ØØØ6	15.3
	index mark	Ø.Ø142		

TABLE B.5 COLOR COORDINATES FOR INDIVIDUAL LIGHTING COMPONENTS AFTER MODIFICATIONS MADE TO COMPLY WITH THE AN/AVS-6 LIGHTING SPECIFICATION.

Lighting Component	CIE Coordinates x	CIE Coordinates y	Graph Symbol
Grimes Full Circular Bezels	Ø.251	Ø.544	□
Lumicon Bezel	Ø.213	Ø.532	○
Glare Shield Floods	Ø.277	Ø.529	⬡
Edge Lit Panel	Ø.275	Ø.651	△

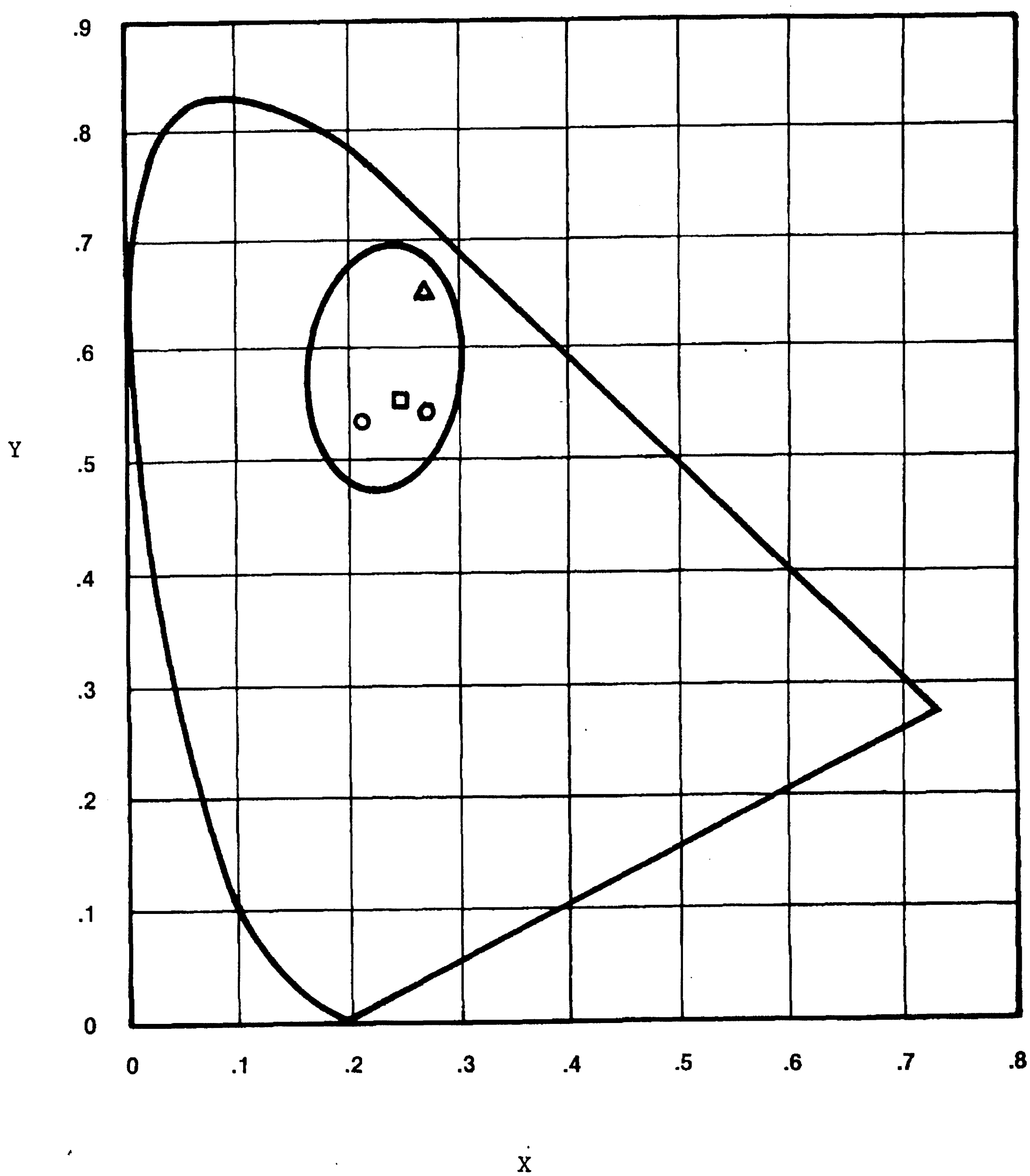

Figure B.1. Modified Color Coordinates of Individual Lighting and the Color Limits Defined by the Proposed AN/AVS-6 Lighting Compatibility Specification.

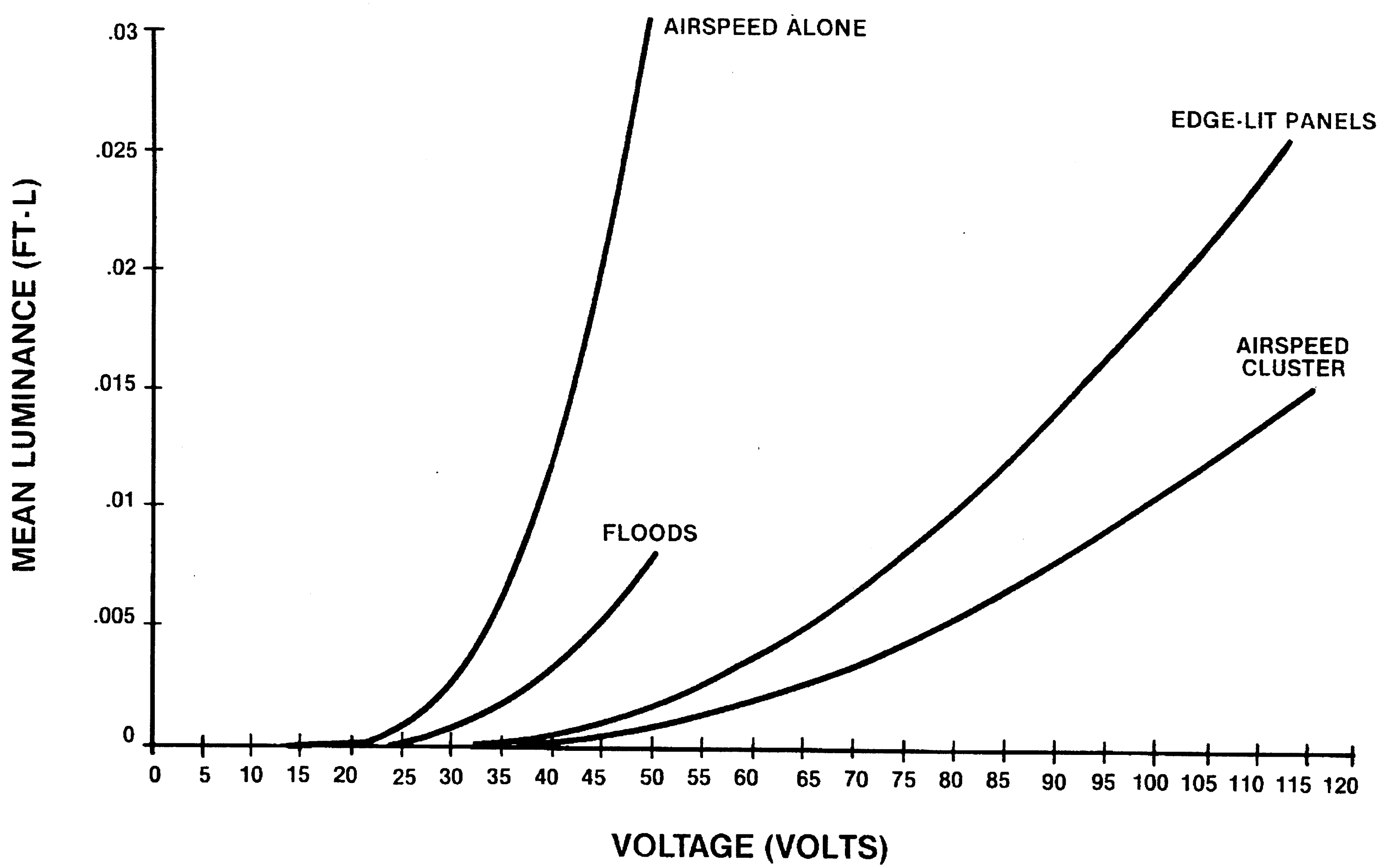

Figure B.2 Voltage Versus Luminance Relation for Various Light Groups Used in the Subject Station

APPENDIX C
INSTRUCTIONS TO SUBJECTS

The following instructions were read to each subject before the start of the experiment:

"The purpose of this experiment is to determine the lighting levels that you require for reading aircraft instruments when using Night Vision Goggles.

Consider the following mission scenario for the purpose of this experiment: You are flying at night, at low level, and you are using night vision goggles or unaided human vision to see ground terrain features outside of the aircraft. It is required that you read the airspeed instrument by glancing down from view of the hypothesized external scene. It is your intention to set instrument lighting to a minimum level in order to avoid detection by adversaries. It is also required that you read the airspeed instrument within 2 seconds of the time that you glance down.

Prior to testing, you will be dark adapted. To accomplish this, you will be required to remain in a darkened room for a period of 30 minutes. Following this period the data collection will begin.

Before each trial you will be required to view a simulated moonlight condition or a simulated ANVIS display for a period of 1.5 minutes. Look directly at this preadapting light source. Following exposure to the lighting condition, you will make adjustments of the front instrument panel lighting.

In the first trial you will be asked to adjust the airspeed instrument light to a level that you feel is necessary to read the pointer and barrel readout. After reading the airspeed in knots the luminance will be recorded and the instrument dimmed to the off position.

In the second trial you will adjust three groupings of front instrument panel lighting. Start by slowly increasing the primary instrument cluster lighting until you can read the airspeed instrument. Next, turn up the edge lit panel lighting until you can identify the location of switches, knobs and other controls on the front instrument panel. Next, adjust the instrument panel flood lighting until the pointer orientations of the engine instrument cluster are readable. Finally, make any adjustments to the primary instrument lights that you feel are necessary to compensate for effect of the other instrument lighting groups. You will then be asked to read airspeed in knots. The luminance of the lighting groups will be recorded and the lighting dimmed to the off position.

All subsequent trials will proceed in the same manner as the ones that I have just described. Take time now to memorize the location and function of the three lighting groups and their corresponding dimmer potentiometers."

After the subject became familiar with the lighting the experimenter asked: "Are there any questions before we begin the dark adaptation period?"

APPENDIX D
PHOTOMETRIC MEASUREMENT PROCEDURES

LUMINANCE MEASUREMENTS

The method used to measure photometric brightness (reference 15) of aircraft instruments is described as follows:

1- A 22 inch focal length achromat lens was placed over the standard objective lens to decrease the measurement field size.
2- A measurement field size was selected that was about 1/2 the stroke width of the indicia.
3- Luminance measurements were taken by orienting the optical head to place the measuring field within the instrument indicia.

ILLUMINANCE MEASUREMENTS

The method used to measure illuminance is based on the use of an external reflectance standard, which has a diffuse reflectance of nearly 100% (the RS-1 reflectance standard). The method is based on the fact that the luminance (in foot-Lamberts) of a perfectly Lambertian diffusing surface is numerically equal to the illuminance (in foot-candles) which falls on its surface. The procedure is as follows:

1- The reflectance standard plaque was placed over the front instrument panel in the same plane as the instruments.
2- The photometer optical head was oriented at approximately 45 degrees to the surface of the plaque.
3- The luminance of the plaque was measured.
4- The luminance reading (in foot-Lamberts) was converted to illuminance (in foot-candles) using the following formula:

    Illuminance (in foot-candles) = Luminance (in foot-Lamberts) /R
    where R=1 and is defined as the absolute reflectance factor of the plaque

APPENDIX E

AIRSPEED SIMULATOR INSTRUMENT CHARACTER SIZE

The visual acuity required for legibility of characters on the cylinder readout was calculated to be a 3.Ø (2Ø/6Ø) minute visual angle by using the stroke width of the character and a viewing distance of 27 inches.

Because the character stroke width is not equivalent to 1/5 the character height and because the character width is not equal to character height (the requirement of a true Snellen character), this calculated value is only a rough estimate.

The size of various indicia for the airspeed simulator instrument, in inches, was measured as follows:

dial characters h=9/32, w=6/32, stroke width=3/64
pointer (white portion) w=3/32, L=1 4/32
cylinder digital readout w=1/32, h=5/32, stroke width=3/128

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