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LABORATORY ASSESSMENT OF THE AN/PVS-5 NIGHT VISION GOGGLE

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Naval Air Development Center
Warminster, Pennsylvania

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Laboratory assessment of the AN/PVS-5 Night Vision Goggle was conducted. Visual fields, goggle infrared source, useable range and detectability of targets with the goggle were measured. Information is presented to permit translation of laboratory values into field conditions. Assessment indicates that the goggle can significantly facilitate aircrew night visual performance. Further field evaluation is anticipated.

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S U M M A R Y

Laboratory assessment of the AN/PVS-5 Night Vision Goggle was conducted. Visual fields, goggle infrared source, useable range, and detectability of targets with the goggle were measured. Illumination levels of -5.4 and -6.22 log foot candles were adequate for 90 percent detection of 0.14 and 0.07 acuity targets respectively. Calculations of distances at which various surface and airborne targets subtended comparable visual angles and tables of natural brightness conditions are presented to permit translation of laboratory values into field conditions. While further field evaluation is anticipated, the laboratory assessment indicates that the goggle can significantly facilitate aircrew night visual performance.

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INTRODUCTION

The AN/PVS-5 Night Vision Goggle is a binocular, unity magnification device designed for low-light level viewing. The device can be used either as a hand-held binocular or in a head-mounted mode. The goggle consists of two identical electro-optical systems each comprised of an eyepiece, an image intensifier tube, an objective lens, and an integral high-voltage power supply. The objective lens receives light and images it on the input side of the image intensifier tubes. The tube amplifies the image and provides an image of increased intensity which is seen through the eyepiece. The high-voltage power supplies and an infrared light emitting diode, which provides auxiliary lighting over a limited range, are powered by a 2.7 volt mercury battery. The battery is mounted in the goggle frame.

The two electro-optical assemblies are mounted in a light weight frame. The two assemblies can be adjusted vertically, horizontally in and out and tilted to accommodate a variety of head-face configurations. Each assembly can also be adjusted over a range of eight diopters to allow focus from approximately two inches to infinity. The nominal field of view is 40°. A foam face cushion and mounting straps are provided. A three position switch allows the goggle to be turned off, on with no auxiliary light, and on with the auxiliary infrared short-range illuminating source. A neck strap is also provided so that the goggle can be rested on the chest when not in use.

A diagram[1] of the optical components of the goggle is shown in figure 1. A photograph of the goggle is shown in figure 2.

The night vision goggle was developed by International Telephone and Telegraph (ITT) for the U.S. Army Night Vision Laboratory at Fort Belvoir, Virginia. The goggles are used by Army personnel for driving vehicles, administering first aid, patrolling, and other night tasks where short-range passive, hands-free vision is required.[2]

There are a number of tasks which Navy flight personnel are required to perform in which a head mounted image intensifying binocular might be profitably used. The objective of the laboratory assessment reported here was to quantify the range of conditions in which the night vision goggle can yield useful information to translate that range into comparable field conditions and to make predictions and recommendations for operational use of the night vision goggle by Navy flight personnel.

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1. *Draft Technical Manual, Organizational, Direct Support, and General Support Maintenance Manual, DTM 11-5855-238-24, Dept. of the Army, U.S. Army Electronics Command, Night Vision Laboratory, Fort Belvoir, Va. 22060.*
2. *Miller, J.K. and R. E. Nystrom, Dec. 1972, Engineer Design Test of Goggles, Night Vision AN/PVS-5, Night Vision Laboratory, Fort Belvoir, Va. 22060.*

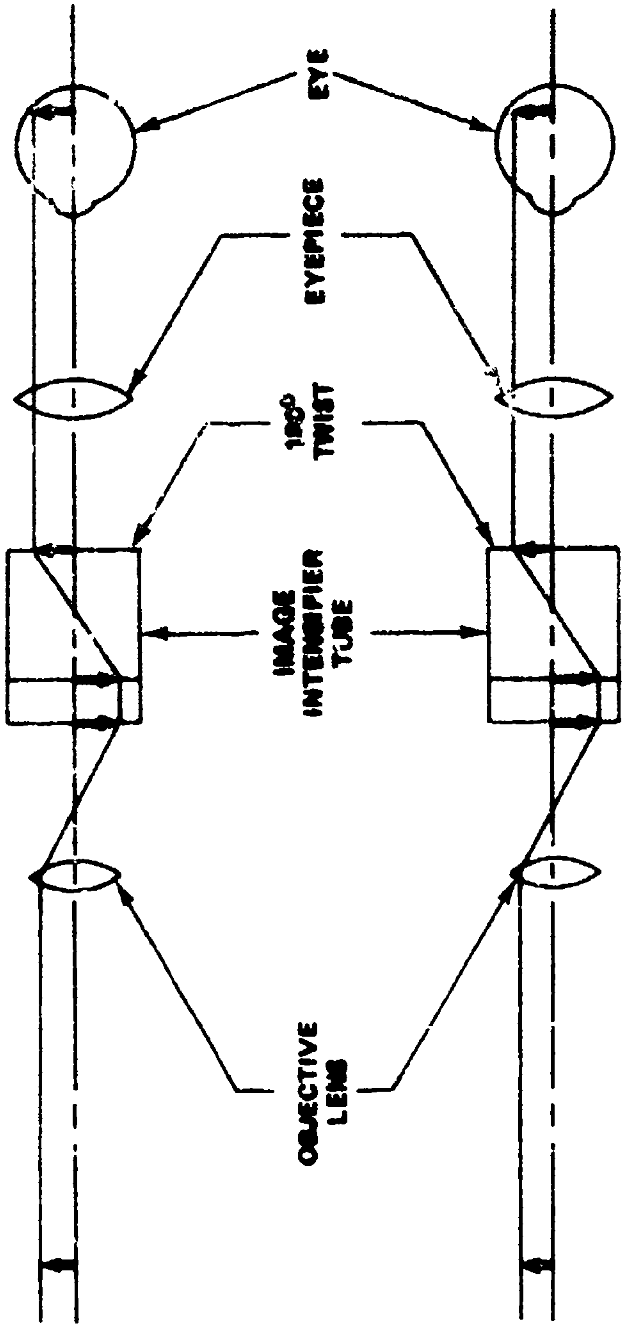

Figure 1. Goggle Optical Diagram.

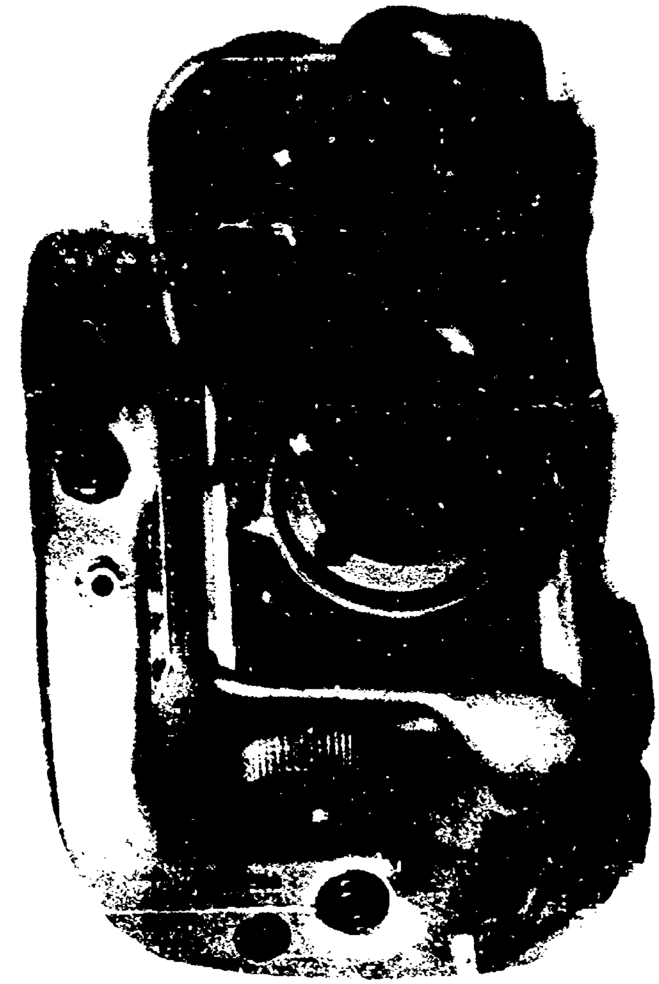

Figure 2. AN/PVS-5 Night Vision Goggle.

MATERIALS AND METHODS

APPARATUS

The AN/PVS-5 Night Vision Goggle was mounted in a frame which was secured to a table. The table was located at one end of a light-tight, 80-foot long range which was calibrated in one-foot increments. A protractor was mounted on the table, centered at a point halfway between the two eye points of the goggle. A visual target which subtended a visual angle of six minutes was located at the end of a 21-foot line extending from the center of the protractor. Visual targets, one-foot square panels with black and white bar patterns, were mounted on a movable platform so that they could be presented at varying distances from the goggle. A filtered light source was mounted in a shielded enclosure on the front of the movable platform so that a known level of illumination could be provided on the targets. Stray light was shielded from the goggle.

CALIBRATION

The intensity of illumination produced by the unfiltered lamp on the bar pattern targets was measured with a Macbeth illuminometer and found to be 1.004 foot candles. The neutral density filters used to adjust the intensity of the illumination were measured on a Perkin-Elmer UV-Visible spectrophotometer. The filter densities used were 5.28, 5.68, 5.98, 6.0, 6.2, 6.7, 7.08, 7.2, 7.3, and 7.4 optical density resulting in test illuminations of 5.49×10^{-6}, 2.19×10^{-6}, 1.1×10^{-6}, 1.05×10^{-6}, 6.61×10^{-7}, 2.09×10^{-7}, 1.05×10^{-7}, 6.6×10^{-8}, 5.24×10^{-8}, and 4.16×10^{-8} foot candles.

The bar pattern targets were black and white bars of equal size which could be presented horizontally or vertically at the prescribed distances. The target sizes, distances, visual angles subtended, and visual acuities are shown in table I.

The minimum and maximum brightnesses of the intensified images of the goggle were measured with the Macbeth illuminometer. The minimum goggle image brightness of the left ocular was 0.21 foot lamberts and of the right ocular, was 0.15 foot lamberts. The maximum goggle image brightness, the brightness at which the intensity of the object starts to wash out the goggle images, were 1.74 and 1.05 foot lamberts for the left and right oculars respectively.

PROCEDURE

The procedure was divided into three parts. In the first part, the binocular and monocular fields view were measured. In the second part of the procedure, illumination required to detect targets of two acuity levels were determined, and in the third part, the detectability of a moderately fine target with the goggle infrared source as the only illumination was estimated.

The observer was seated at the table on which the night vision goggle was mounted. The height of the seat was adjusted so that the observer could comfortably place the goggle in the as-worn position and maintain that position

TABLE I

EXPERIMENTAL TARGET DIMENSIONS

Target Bar Size (inches)	Distance (ft.)	Visual Angle (min.)	Visual Acuity
0.5	21	7	0.14
1.0	21	14	0.07
1.5	61	7	0.14
2.0	81	7	0.14

throughout the entire procedure. The observer's hands were free to manipulate the goggle off-on-IR switch. When the observer had been instructed in the procedure and positioned at the goggle, the room lights were extinguished and the procedure begun.

Field-of-View

The six minute target at the end of the 21-foot line was positioned at the 0° position directly in front of the observer. The goggle was switched to the on position and the dimmest illumination level in which the target was readily visible was turned on. The target was moved to one side until it was just out of the field of view. The observer indicated to the experimenter when the target disappeared by saying "now". The angle was read from the protractor mounted on the table. The target was then positioned farther out of the field of view and moved back toward the field of view until the observer indicated that it was just visible by saying "now". The angle was read from the protractor. That procedure was repeated for each side until 12 readings were made for the binocular field of view and for each of the monoculars independently. The goggle was then switched to the IR mode and the procedure was repeated using the goggle infrared source as the only illumination. When this portion of the procedure was complete, the field-of-view target was placed at one side out of the experimental field.

Illumination Requirement

The 12 x 12-inch bar target was placed 21 feet in front of the goggle. The goggle was focused on the target and then turned off. The appropriate filters were inserted in the light source, the bar pattern target was oriented either horizontally or vertically, and the observer was signalled to begin the trial by turning the goggle switch to the "on" position. As soon as the observer was able to determine the orientation of the bars, the goggle switch was turned to the "off" position and the orientation reported to the experimenter. The experimenter recorded the correctness of the response and the time from the manipulation of the switch to the "on" position, to the manipulation to the "off" position. The filters and target were adjusted for the next trial and the observer was signalled to begin. The procedure was repeated for two target acuity levels until the requisite number of trials had been completed.

Goggle Infrared Source Assessment

The target light source was extinguished. The 12 x 12-inch bar target was positioned 61 feet in front of the goggle. The bars were positioned either horizontally or vertically. The observer was signalled to manipulate the goggle switch to the "IR" position. As soon as the observer was able to determine the orientation of the target bars, the switch was turned to the "off" position and the bar orientation was reported to the experimenter. The experimenter recorded the time of the trial and response correctness as in the preceding section. The target was adjusted for the next trial and the procedure was repeated. When the prescribed number of trials was completed, the target was moved to the 81-foot distance and the procedure was repeated.

RESULTS

Field of View

The nominal field of view of the goggle is 40 degrees. The average measured fields of view are shown in table II. The maximum range of measurements in each condition are shown in parentheses. For practical purposes, the effective overall field of the goggle is about 35 degrees.

Illumination Requirements

Figures 3 and 4 show the proportion of correct responses as a function of target illumination for the 0.14 and 0.07 acuity targets respectively. Using a 75 percent correct response point as the threshold definition, the illumination threshold for detection of the 0.14 acuity target is -5.64 log foot candles. The illumination threshold for detection of the 0.07 acuity target is -7.15 log foot candles. Based on other laboratory data,[3] the approximate threshold values for detection of comparable targets with the unaided, fully dark adapted eye are -2.0 log foot candles of illumination for the 0.14 acuity target and -2.75 log foot candles for the 0.07 acuity target. The 90 percent correct response illumination level was -5.4 log foot candles for the 0.14 target and -6.22 log foot candles for the 0.07 target.

Goggle Infrared Source Assessment

The average percent of correct responses and response times are shown in table III. The accuracy of the responses at the 81 foot distance is too low to be considered usable. Many tasks can conceivably be performed at the 61 foot distance using only the goggle integral source for illumination. At closer distances, the goggle infrared source provides adequate illumination for tasks requiring a moderate acuity level.

DISCUSSION

The target acuities used in the present experiment are moderate and coarse acuity levels. At levels of illumination which would be moderately high for the night vision goggle, such as a quarter moon level or higher, the brightness of the goggle is such that the 0.14 acuity target would be easily discriminated. At lower levels, such as an overcast, starlight night, the brightness of the goggle is such that the coarser acuity level is the best discrimination that could be expected. To translate the data of the laboratory evaluation into operational terms, tables IV, V, and VI and figure 5 have been compiled. Table IV shows the sky brightness and ground illumination for several meteorological conditions and locates the detection illuminations for the target levels used for both the unaided eye and with the aid of the night vision goggle. Table V lists the distances in nautical miles at which various aspects of surface targets subtend the visual angles utilized in the laboratory evaluation. With

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3. *Brown, J.L., C.H. Graham, H. Leibowitz and K.B. Ranken, Luminance Thresholds for the Resolution of Visual Detail During Dark Adaptation. 1953. J. Opt. Soc. Am. 43, 3, 197-202.*

TABLE II

AVERAGE FIELD OF VIEW (MAXIMUM MEASUREMENTS)

	"ON Mode"	"IR Mode"
Binocular	34.625° (35.5°)	35.625° (36°)
Left Ocular	34.625° (35.5°)	35.625° (36°)
Right Ocular	33° (34°)	35.125° (36°)

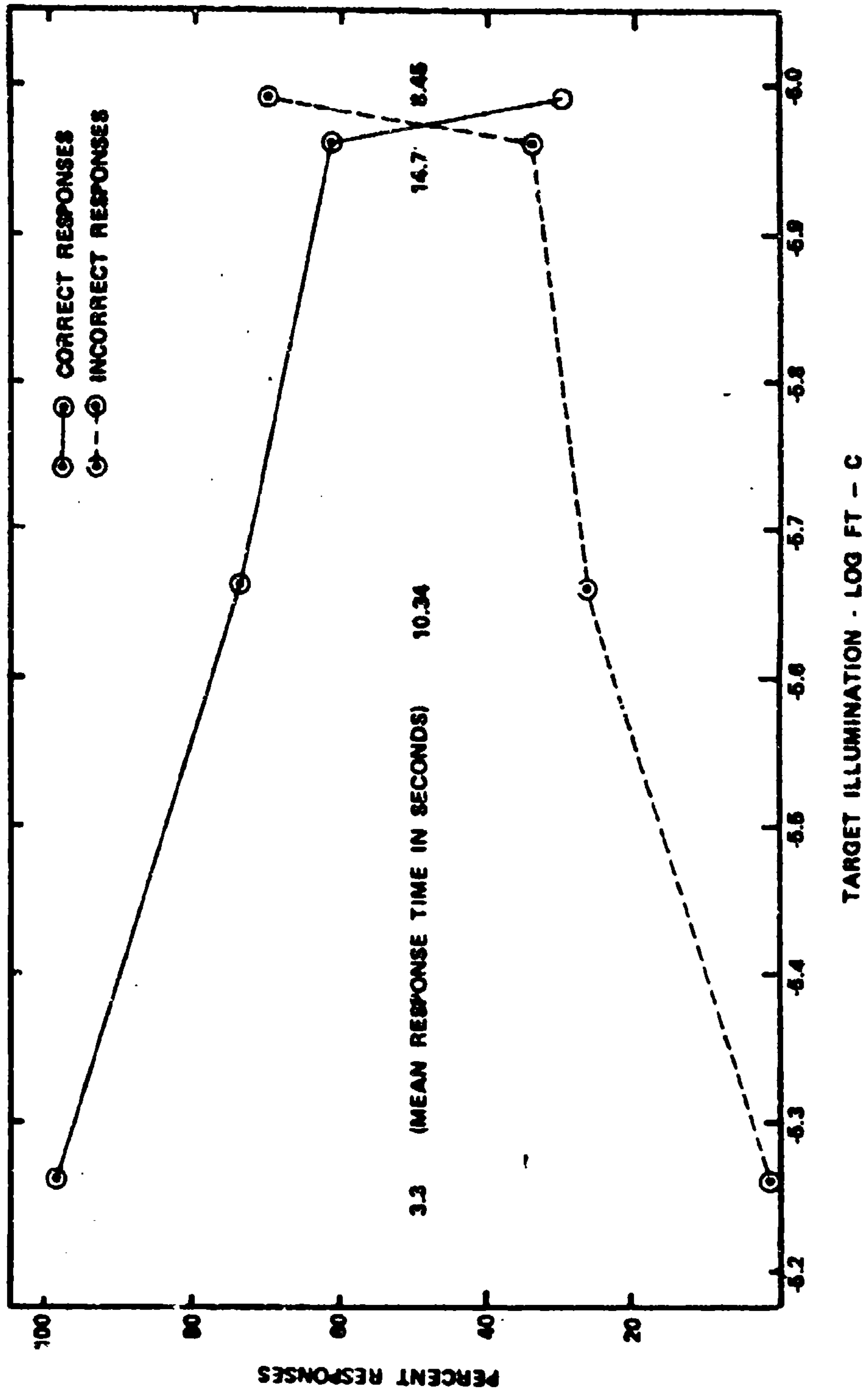

Figure 3. Proportion Correct and Incorrect Responses - 0.14 Acuity Target.

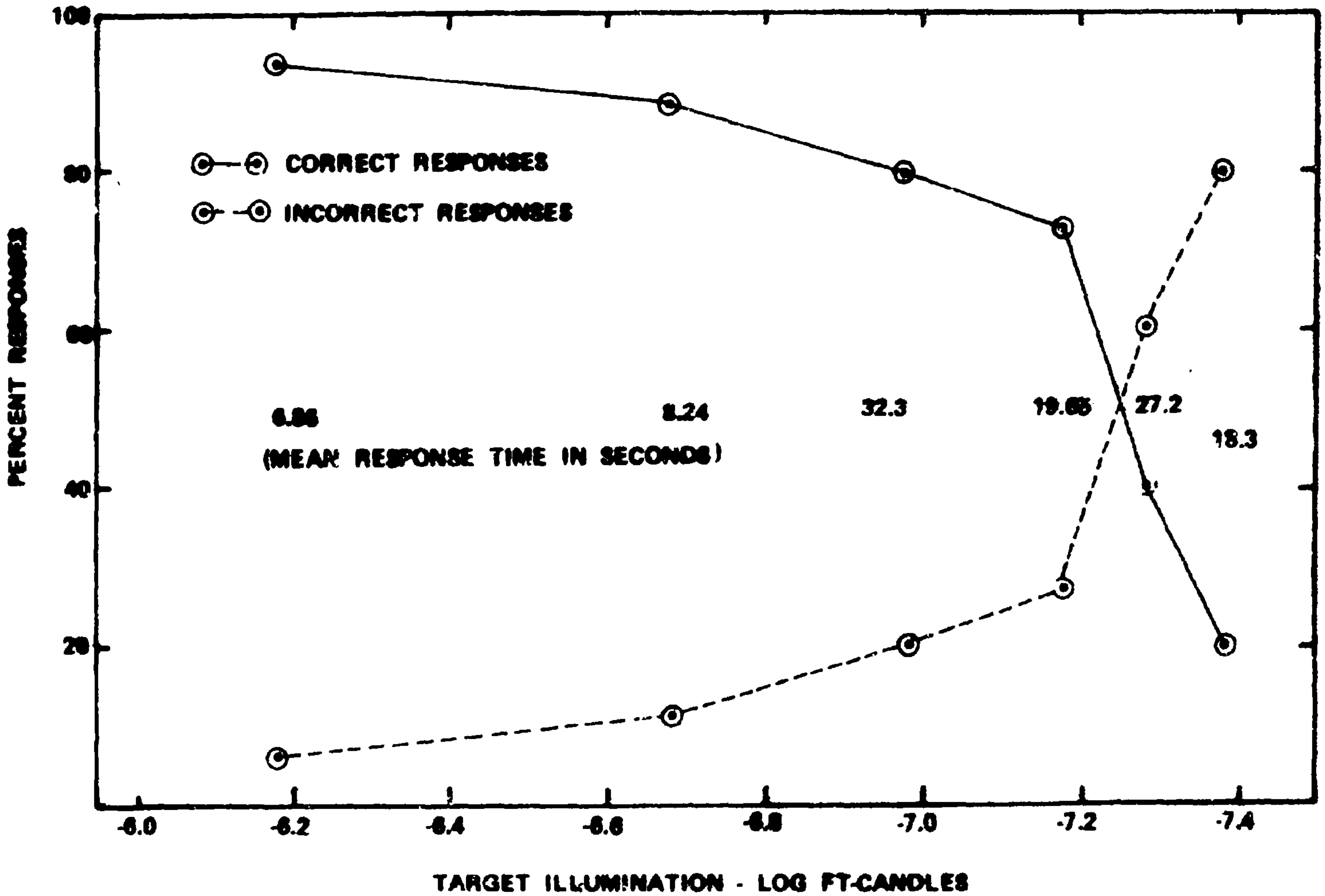

Figure 4. Proportion Correct and Incorrect Responses - 0.07 Acuity Target.

TABLE III

GOGGLE INFRARED SOURCE EVALUATION -
RESPONSE CORRECTNESS AND TIME

Target Distance (feet)	Average % Correct	Average Response Time (seconds)
61	80	9.86
81	68.75	12.86

Average time and accuracy for detection of a 0.14 acuity target using only the goggle infrared source for target illumination.

TABLE IV

NATURAL LIGHT, SKY LUMINANCE AND SURFACE ILLUMINATION

Natural Light Condition	Sky Brightness Foot-Lamberts	Ground Illumination Foot-Candles	Exptl. Target Detected
Twilight (15 min. after sunset, clear)	1	1×10^{-1}	
Deep Twilight (30 min. after sunset, clear)	1×10^{-1}	1×10^{-2}	Unaided eye 0.14 target detection
Full Moon	1×10^{-2}	1×10^{-3}	Less than unaided eye 0.07 target detect.
Quarter Moon	1×10^{-3}	1×10^{-4}	
Starlight	1×10^{-4}	1×10^{-5}	0.14
Overcast Starlight	1×10^{-5}	1×10^{-6}	0.07

TABLE V

DISTANCES (NM) FOR SURFACE TARGET DETECTION

Type	Example	Distance (NM) at which Target Characteristic Subtends an Angle of 7.14' (Vis. Ac. = 0.14)					Distance (NM) at which Target Characteristic Subtends an Angle of 14.28' (Vis. Ac. = 0.07)				
		Deck			Superstructure		Deck			Superstructure	
		Width	Length	Height	Length	Height	Width	Length	Height	Length	Height
Ships											
A/C Carrier	Kitty Hawk	20.00	85.34	5.27	12.05	6.02	10.00	42.67	2.64	6.03	3.01
A/C Carrier	Hancock	15.74	71.85	4.14	9.78	5.27	7.87	35.93	2.07	4.89	2.64
Submarine	Triton	2.97	35.94	1.12	5.27	1.51	1.49	17.97	0.56	2.69	0.76
Submarine	Nautilus	2.37	25.54	2.63	3.77	1.88	1.19	12.77	1.32	1.89	0.94
Cruiser	Albany	5.62	53.33	1.51	33.13	6.02	2.81	26.67	0.76	16.57	3.01
Frigate	Truxtun	4.66	45.30	1.88	14.31	8.27	2.33	22.65	0.94	7.16	4.14
Frigate	Farragut	4.22	41.16	2.26	12.05	9.04	2.11	20.58	1.13	6.03	4.52
Destroyer	Barry	3.63	33.61	1.51	8.27	5.27	1.82	16.81	0.76	4.14	2.64
Command Ship	Wright	8.76	53.33	3.77	14.31	11.29	4.38	26.67	1.89	7.16	5.65
Amphib. Command	Blue Ridge	8.67	49.80	4.14	25.61	5.27	4.34	24.90	2.07	12.18	2.64
Fleet Support		6.83	51.65	1.81	31.63	5.27	3.42	25.83	0.91	15.82	2.64
Patrol	Beacon	1.91	13.21	0.76	4.52	1.25	0.96	6.61	0.38	2.26	0.63
Mine Warfare	Bluebird	2.25	11.08	1.00	5.52	2.51	1.13	5.54	0.50	2.76	1.26
Dam	Hoover	3.61	99.92	58.3			1.81	49.96	29.15		
Man		Head	Shoulder	Height			Head	Shoulder	Height		
		0.08	0.2	0.48			0.04	0.1	0.24		

TABLE VI

DISTANCES FOR AIRCRAFT DETECTION

Country	Type A/C	Distance in Nautical Miles at which Aircraft Characteristic Subtends a Visual Angle of:					
		7.14' (Vis. Ac. 0.14)			14.28' (Vis. Ac. 0.07)		
		Wingspan	Length	Height	Wingspan	Length	Height
USA	Cessna	2.88	2.35	0.73	1.44	1.18	0.37
USA	CH53A (Helo.)	--	5.40	1.38	--	2.70	0.69
USSR	Mi 6 (Helo.)	4.03	8.75	2.60	2.02	4.38	1.30
USSR	MIG 25 (Fight.)	3.21	5.54	--	1.61	2.77	--
USSR	MYA-4 (Bomber)	13.65	13.01	--	6.83	6.01	--
USSR	TU 144 (Transp.)	7.59	17.31	3.39	3.80	8.66	1.70

the unaided eye the targets would be detectable at the distances shown only at twilight or deep twilight, and not by full moonlight. Using the night vision goggle, the targets would be detectable by starlight at the greatest distances, shown in table V, and by overcast starlight at the shorter distances. Table VI shows the same type of information for detection of aircraft.

The distances shown are only for detection of the presence of a target. Identification of the targets would require either shorter distances or greater illumination. For example, the presence of the Kitty Hawk oriented so that the ship's length is the aspect presented to an observer under starlight, clear atmospheric conditions, could be detected at 85 nautical miles with the aid of the night vision goggle. Identification of the Kitty Hawk as an aircraft carrier would require a shorter distance, probably between the 5.27 and 12.05 nautical mile distances where other details of the ship would be detectable.

Detection of a helmeted head in the water would be possible at 486 feet under starlight. If other aspects of the person were exposed as in a prone floating position, detection would be possible at 2916 feet under the same lighting conditions.

Vision through the atmosphere is not as simple as the preceding discussion would seem to imply. The primary factors influencing detection distances using the night vision goggle are contrast and atmospheric conditions. The chart in Figure 5 has been developed from information in Middleton.[4] Seventy thousand square feet is approximately the area of the Kitty Hawk between the deck and the water. The graph shows how changes in target contrast and meteorological range affect unaided visual detection. A 70,000 square foot target line is shown accented in the figure. A similar condition will persist for the goggle though target contrast must be defined differently for the goggle than for the unaided eye. In most cases, target contrast will be greater for the goggle than for the unaided eye. To read the detection distance from the figure, place a straight edge across the figure so that it touches the appropriate meteorological range value and the appropriate contrast value. Project the point at which the straight edge intersects the curve straight up or down to the top or bottom scale and read the detection distance in nautical miles. Under starlight, the greatest detection range for a 70,000 square foot circular target is approximately 30 miles. Detection at that distance requires a meteorological range of more than 100-nautical miles and a contrast value of greater than 20. As target contrast decreases, or meteorological range decreases, the detection distance decreases. A similar circumstance will occur with the night vision goggle, except that the target contrast will remain relatively high since both visible and infrared radiation contribute to the contrast value.

CONCLUSIONS AND RECOMMENDATIONS

The results of the laboratory evaluation indicate that the night vision goggle has significant potential for extending the visual range of flight

4. *Middleton, W.E.K., 1963, Vision Through the Atmosphere, University of Toronto Press, Canada.*

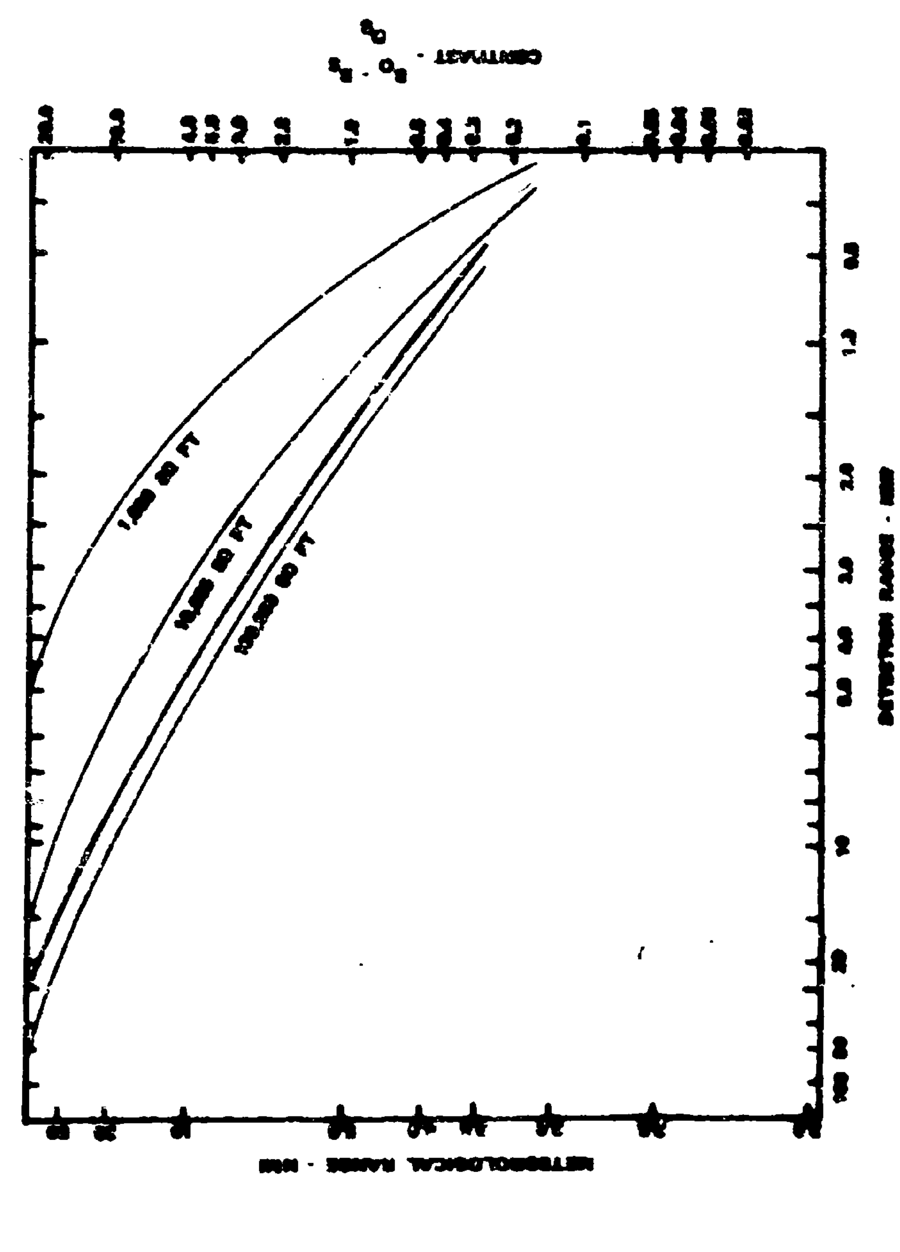

Figure 5. Detection Range for Circular Objects Against the Sky - Starlight (10^{-4} Foot Lamberts).

personnel at night. Further field evaluation is planned to verify the predictions that have been made on the basis of the laboratory assessment. The information which has been developed, however, is sufficiently unequivocal to support a recommendation that the 40°AN/PVS-5 Night Vision Goggle be adopted for use by Navy flight personnel.