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The Effect of Illuminating Flare Color on Target Acquisition

by

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FEBRUARY 1975

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Naval Weapons Center

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FOREWORD

This technical report documents work conducted from January through November 1974 at Wright-Patterson Air Force Base, Ohio, the Naval Ammunition Depot (NAD), Crane, Ind., and the Naval Weapons Center (NWC), China Lake, Calif. The work is part of a joint-services program on air-to-ground target acquisition funded under authorization ARAB RA 05 75.

The Joint Technical Coordinating Group for Munitions Effectiveness has established a Target Acquisition Working Group (TAWG) under the Joint Munitions Effectiveness Manual/Air-to-Surface Division. TAWG tasks have included the definition of problem areas in airborne forward air controller operations, the description of target markers, summary of existing field test data, the evaluation of mathematical models of target acquisition, the camouflage of targets, terrain and foliage masking, and research on target acquisition by flare light.

This report documents a flare experiment that was conducted on a terrain model at the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base. The flare color simulator was fabricated at NAD, Crane. Part of the report preparation was performed at NWC.

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(U) *The Effect of Illuminating Flare Color on Target Acquisition*, by LT Russell A. Sorensen, MAJ Robert L. Hilgendorf, and CAPT Edwin H. Sasaki, Wright-Patterson Air Force Base, and Ronald A. Erickson, Naval Weapons Center. China Lake, Calif., Naval Weapons Center, February 1975. 22 pp. (NWC TP 5729, publication UNCLASSIFIED.)

(U) A laboratory experiment was conducted on the effect of flare color on target acquisition performance. Subjects were required to search for olive drab model vehicles located on a model of European type terrain. The model consisted of cultural features and predominantly green vegetation. The model was illuminated by one simulated flare whose color was either red, green, yellow, or white.

(U) There were no statistically significant differences between the numbers of vehicles detected or recognized under the different flare light colors. The average ranges at which the vehicles were detected were also about the same for all flare light colors. Although further experimentation should be conducted with other terrains and targets and with haze or smoke in the atmosphere, it has been tentatively concluded that flare color does not affect search performance; existing flare colors are adequate and changing flare color would not improve target acquisition performance.

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ACKNOWLEDGMENT

INTRODUCTION

A joint-services Target Acquisition Working Group (TAWG) was established in March 1972 and tasked with pursuing a number of studies of visual, air-to-ground target acquisition. Target acquisition by flare light was one of the areas addressed; a summary report was issued,[1] and three laboratory experiments were conducted on a terrain model.

These experiments were conducted to provide data on flare characteristics for use by flare designers. The areas addressed were the possible enhancement of target acquisition performance by (1) a flare stabilized against wind effects,[2] (2) a hovering flare,[3] and (3) a choice of color of flare light.

This report describes the experiment on flare color and discusses the results in terms of applicability to flare design.

BACKGROUND

Various military missions require the visual acquisition of targets by an airborne observer. These missions could include close air support, interdiction, reconnaissance, and the general search for targets of opportunity. Although many automatic methods of target acquisition utilizing sensors are being actively pursued in the research and development community, a significant portion of this task still rests with the unaided human observer. If the task must be accomplished at night, some means of artificial illumination is usually provided and this normally takes the form of air-launched, parachute-suspended, pyrotechnic flares.

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[1] Aerospace Medical Research Laboratory. *Flare Effectiveness Factors: A Guide to Improved Utilization for Visual Target Acquistion*, by Sheldon MacLeod. Wright-Patterson Air Force Base, Ohio, AMRL, November 1973. (AMRL-TR-73-46, publication UNCLASSIFIED.)

[2] Aerospace Medical Research Laboratory. *The Effect of Flare Drift on Target Acquisition Performance*, by Russell A. Sorensen. Wright-Patterson Air Force Base, Ohio, AMRL, 1973. (AMRL-TR-74-73, publication UNCLASSIFIED.)

[3] Naval Weapons Center. *The Effect of Hovering Flares on Visual Target Acquisition*, by R. L. Hilgendorf, R. G. Searle, and Ronald A. Erickson. China Lake, Calif., NWC, December 1974. (NWC TP 5722, publication UNCLASSIFIED.)

Hilgendorf [4,5,6] and Sorensen[7] have investigated the effects on target acquisition of flare separation, flare ignition altitude, observer altitude, flare shielding, and flare drift (due to wind). MacLeod[8] has summarized flare design characteristics, flare and observer position interaction, and other inputs of human factors and their impact on flare effectiveness. However, aside from speculation, there appears to be no empirical evidence dealing with the optimal *color* for a pyrotechnic illuminating flare. Typically, the flare designer has developed the brightest possible flare and normally this resulted in a flare with a radiating spectrum approaching that of an incandescent light source.[9]

Although not directly applicable to the illumination flare consideration, a series of studies were performed which attempted to identify an optimal hierarchy of colors for pyrotechnic markers and signals. The first study[10] involved four colored stimulus lights matched for brightness: light red, green, haze-cutting yellow (minus blue), and clear (incandescent). These stimuli were viewed against four backgrounds: copper, beige, neptune green, and crystal blue, which were chosen to simulate clay soil, desert soil, foliage, and the sea, respectively. In terms of detection times and errors of identification, red and green were associated with better performance than were clear and yellow.

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[4] Hilgendorf, R. L. "Visual Performance With Simulated Flare Light: Effects of Flare Ignition Altitude," HUMAN FACTORS, Vol. 13, No. 4 (1971), pp. 379-386.

[5] Hilgendorf, R. L. "Air-to-Ground Target Acquisition With Flare Illumination," presented at the Advisory Group for Aerospace Research and Development (AGARD) Conference, Brussels, Belgium, June 1972. (Also in *Proceedings 100 on Air-to-Ground Target Acquisition*.)

[6] Hilgendorf, R. L. "In-Flight Validation of a Laboratory Simulation: Visual Acuity Under Flare Light," in Aerospace Medical Association *Preprints of 1973 Scientific Programs*, U.S. Air Force, Las Vegas, May 1973.

[7] Aerospace Medical Research Laboratory. *The Effect of Flare Drift on Target Acquisition Performance*, by Russell A. Sorensen. Wright-Patterson Air Force Base, Ohio, AMRL, 1973. (AMRL-TR-74-73, publication UNCLASSIFIED.)

[8] Aerospace Medical Research Laboratory. *Flare Effectiveness Factors: A Guide to Improved Utilization for Visual Target Acquisition*, by Sheldon MacLeod. Wright-Patterson Air Force Base, Ohio, AMRL, November 1973. (AMRL-TR-73-46, publication UNCLASSIFIED.)

[9] Aerospace Medical Research Laboratory. *Visual Search and Detection Under Simulated Flare Light*, by Robert L. Hilgendorf. Wright-Patterson Air Force Base, Ohio, AMRL, August 1968. (AMRL-TR-68-112, publication UNCLASSIFIED.)

[10] Hilgendorf, R. L. "Optimal Colors for Colors and Signals," presented at a Symposium on Survival and Personal Equipment, Las Vegas, Nev., October 1969. (Also in *Proceedings, Seventh National Flight Safety Symposium*, Vol. 1, Survival and Flight Equipment Association.)

In the second study[11] four additional colors—amber, orange-red, blue-white, and violet—were used and all were evaluated with a terrain model serving as background. The relative positions in the hierarchy of the four colors from the first study held, and violet and amber also were found to be good colors.

The third study[12] was concerned with the in-flight validation of the laboratory experiments. As closely as possible, the details of the scaled-down simulation were duplicated at full scale in a real-world flight test. The agreement between the laboratory simulation and the flight test was exceedingly gratifying. Depending on the criteria used, the correlation coefficients between simulator and field data ranged from 0.77 to 0.93.

In a separate study,[13] the relative preference for six different sighting reticle colors was determined under three conditions: (1) high-level, varying luminance, (2) low-level, varying luminance, and (3) high-level, equal luminance. All colors in each condition were presented by the method of paired comparisons. The results indicated that in the first two conditions, green, orange, and yellow were almost equally preferred. In the third condition, green was most preferred. The background against which the reticles were seen (white, green, or blue) was not a significant factor in reticle color preference.

The above studies dealt with the effects different colors have on the ability of human observers to detect the light sources themselves. However, the question of the effect of the illuminating color on the visual acquisition of nonradiating targets remains topical. Most basic researchers discount the effect of illuminant color on visual color perception because of the principles of color constancy.[14,15,16] Data on detection tasks under different brightness-equated colors appear to be unavailable.

[11] Hilgendorf, R. L. "An Optimal Hierarchy of Colors for Markers and Signals," in *Proceedings, Eighth Annual Symposium*, Vol. 1, Survival and Flight Equipment Association, Las Vegas, Nev., September 1970.

[12] Hilgendorf, R. L. "Colors for Markers and Signals: An Inflight Validation," in *Proceedings, Ninth Annual Symposium*, Survival and Flight Equipment Association, Las Vegas, Nev., September 1971.

[13] Naval Weapons Center. *Reticle Color Preference as a Function of Background and Luminance*, by Jeffrey D. Grossman. China Lake, Calif., NWC, January 1974. 16 pp. (NWC TP 5610, publication UNCLASSIFIED.)

[14] Judd, D. B., and G. Wyszechi. *Color in Business, Science, and Industry*. New York, Wiley & Sons, 1963, p. 339.

[15] Sheppard, J. J. *Human Color Perception*. New York, American Elsevier, 1968, p. 105.

[16] Burnham, R. W., R. M. Hanes, and C. J. Bartleson. *Color: A Guide to Basic Facts and Concepts*. New York, Wiley & Sons, 1963, pp. 82-85.

METHOD

An experiment was conducted to assess the effect of the color of flare light on target acquisition performance. Model vehicles were placed upon a model of European terrain which included vegetation and cultural features. An electric bulb with the appropriate filter was lighted above the model to simulate a flare, and subjects searched for the vehicles by the flare light. Search and recognition performance was measured for several flare colors.

APPARATUS

Terrain Model

A 1/200-scale European terrain model was used to simulate a land area approximately 1 mile long and a quarter of a mile wide (Figure 1). Typical European cultural and topographical features were represented on the model. Foliage colors were dominated by green, although early fall colors were also used. Spectral and photometric measurements of the paints used on the model correlated with real-world spectral-photometric signatures.

Targets

Only military vehicles were used as targets. Eight tanks and four trucks at 1/200 scale, painted olive green, were positioned on the terrain model. All targets were placed at a 45-deg angle relative to the long axis of the model and at 200-ft increments in slant range as measured from the subject's observation position (see Figure 1). The closest target was placed at the 3,000-ft slant range and the farthest was at the 5,200-ft range. One further restriction in placing the targets was that two or more targets could not fall along the same line parallel to the long axis of the terrain model.

The luminances of each target and its immediate background were measured with a Pritchard 1980 photometer under the white flare light only. The luminance contrast of each target was computed from the equation

$$C = \frac{L_t - L_b}{L_b}$$

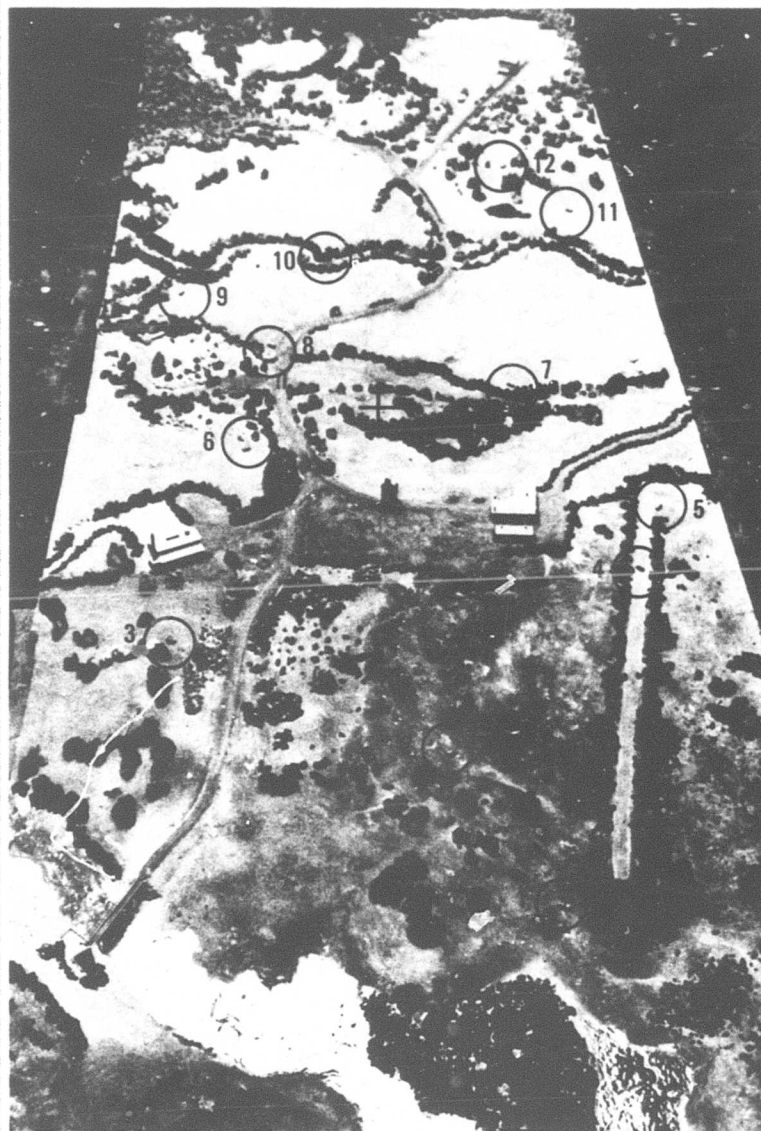where L_t is target luminance and L_b is background luminance (Table 1).

FIGURE 1. Terrain Model and Target Locations. (Cross indicates point over which flare was suspended.)

TABLE 1. Luminance Contrast for Targets
Under White Flare Light.

Target No.	Luminance contrast	Target No.	Luminance contrast
1	1.51	7	-0.36
2	0.43	8	-0.21
3	-0.10	9	-0.35
4	0.03	10	-0.37
5	-0.05	11	-0.38
6	-0.27	12	-0.28

Flare Simulation

A 120-V, 600-W, G.E. Quartzline Lamp was used to simulate the pyrotechnic flare. The lamp was suspended from an overhead boom by a bicycle chain. The chain was driven by an adjustable speed motor which allowed the flare to be lowered at a constant rate of 2.7 ft/min. This flare apparatus allowed the simulation of approximately a 750,000-candlepower flare with a descent rate of 7 ft/sec and a burn time of 4 min. Ignition altitude for the flare was determined on the basis of a burnout at 500 ft above ground level (AGL). Only one flare was used over the terrain model and it was positioned exactly over the middle of the terrain. The use of more than one flare over a ground area as small as the one simulated was considered superfluous—a conclusion at least implied in some earlier research done by Hilgendorf (see Footnote 5).

Four flare colors (white, red, yellow, and green) were simulated by the use of colored pyrex filters; the spectral transmissivities of each filter are shown in Appendix A. The luminosity function of the human eye was used to equate luminance for each of the four colors. The voltages to the flare lamp required to achieve equal luminances for all colors were as follows: white, 90.0 V; yellow, 93.6 V; green, 96 V; and red, 120 V.

Subject Response

A Rowi International hand-held light pointer was used by the subject to point out the location of acquired targets. The pointer light was turned on only after a detection response had been made, and turned off immediately after the subject had pointed to the acquired target. While the pointer light was on, the increase in illuminance over the terrain model was negligible.

DESIGN

A completely randomized single-factor analysis of variance design was used. Four levels of flare color were investigated: white, red, yellow, and green. Five measures of observer performance (dependent variables) were used: (1) total number of targets detected, (2) total number of targets recognized, (3) total number of false detections, (4) slant range at first detection, and (5) average detection slant range.

SUBJECTS

Twenty male college students were used as subjects; they had 20/20 or better corrected or uncorrected visual acuity, and normal color vision.

PROCEDURE

Group Assignment

The subjects were divided into four experimental groups of five subjects each. Assignment to a particular group was done on a random basis. The four groups corresponded to the four flare colors used.

Subject Briefing

All subjects were required to read a set of prepared instructions covering their task and appropriate responses during the experiment (Appendix B). Following the reading of the instructions, subjects were allowed to ask the experimenter questions pertaining to the material they had just read. They were then given a black-and-white photograph of the terrain model and required to study the dominant topographical and cultural features of the model. These features were clearly labelled on the photograph. Subjects were asked to use these features when verbally locating a target during the experimental trial. Finally subjects were shown duplicates of the vehicular targets and reminded that they were only to search for tanks and trucks. A copy of the subject instructions and the photograph used for the briefing can be found in Appendix B.

Experimental Trial

Subsequent to the briefing, subjects were taken to the room where the terrain model was located. The room was partially darkened and the view to the terrain model was obscured. Subjects were shown how to operate the hand-held light pointer and shown the position they were to take during the search task. This position required that the subject rest his chin on a foam pad located on the subject platform above one end of the model. The requirement of the chin rest was necessary to maintain a constant simulated altitude of 2,400 ft AGL.

Following instructions in the use of the light pointer and in the appropriate search position, all room lights were turned off and the subject was dark-adapted for 10 min. Dark adaptation completed, the subject assumed the search position, the flare was turned on, and the 4-min trial was begun. All subject responses were manually recorded by the experimenter. After the 4-min trial, subjects were appropriately debriefed and allowed to leave.

RESULTS

DETECTION AND RECOGNITION

The principal results of the experiment are summarized in Table 2 and Figure 2. The subjects detected from 25% (green flare) to 38% (yellow flare) of the targets. They recognized about 10% of the targets under white, yellow, and green flares, and 19% under red. The data were examined by a single-factor analysis of variance. Although there are differences, there were no statistically significant differences between the scores shown in Table 2 and Figure 2; we must conclude that all flare colors were equally good at providing illumination for target search.

TABLE 2. Means (X) and Standard Deviations (SD) of the Detections, Recognitions, and False Positives Across Subjects.

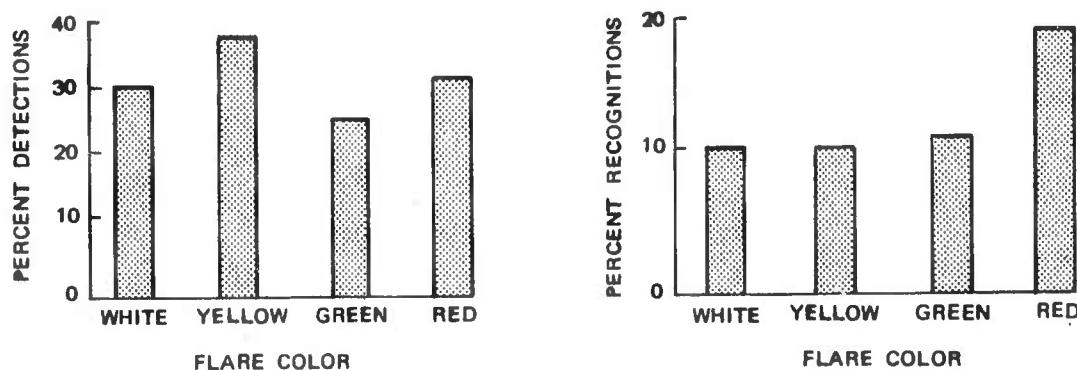| Mean No. of	Flare color							
	White		Yellow		Green		Red	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Detections	4.00	2.35	4.60	1.52	3.60	2.30	4.00	2.55
Recognitions	1.20	1.30	1.20	1.30	1.60	1.95	2.20	1.92
False positives	2.20	0.84	2.00	1.22	1.40	1.14	1.60	1.82

FIGURE 2. Percent Detections and Recognitions for All Flare Colors.

DETECTION SLANT RANGE

The average detection slant range was determined by finding the arithmetic mean of all the slant ranges at detection for each subject (Table 3). The data, in the form of cumulative plots, are also shown in Figure 3. The plots are normalized to positive reports; that is, the computation of percent targets detected is based only upon targets actually detected, not the total possible that could have been detected. This procedure makes it easier to compare the curves with one another.

TABLE 3. Mean Summary Table for Average Detection Slant Range
($\overline{X}$) and Standard Deviation (SD) of Slant Range.

Simulated slant range, ft	Flare color							
	White		Yellow		Green		Red	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Average detection	3,620	332	3,840	200	3,890	230	3,430	370

FIGURE 3. Cumulative Percent Targets Detected as a Function of Slant Range.
(Data is normalized so that all curves reach 100%; scores are shown in Figure 2.)

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Analysis of variance showed no significant differences in average slant range for the four colors. We must conclude that the color of the flare had no effect upon the range at which the targets were detected. Figure 4 shows the distribution of responses for each target summed across colors, and Figure 5 shows the normalized cumulative plot of that distribution. Half of the targets were in front of the flare (that is, between the flare and the observer), but that half accounted for 66% of the detections (see dotted line, Figure 5). Only 34% of the targets beyond the flare were detected; the farthest target was never seen. This drop in detections with range could be because (1) the subjects could not search the length of the terrain model in the time available, (2) the decrease in angular subtense of the target with range (7 to 4 mrad) made detection more difficult, or (3) looking beyond the flare made detection more difficult. Figure 6 illustrates that the subjects had to look very near or through the flare to see the farthest targets; this never had to be done with the nearest targets.

FIGURE 4. Percent Targets Detected Across Subjects. (Target No. 1 was at 3,000 ft slant range; Target No. 12 was at 5,200 ft.)
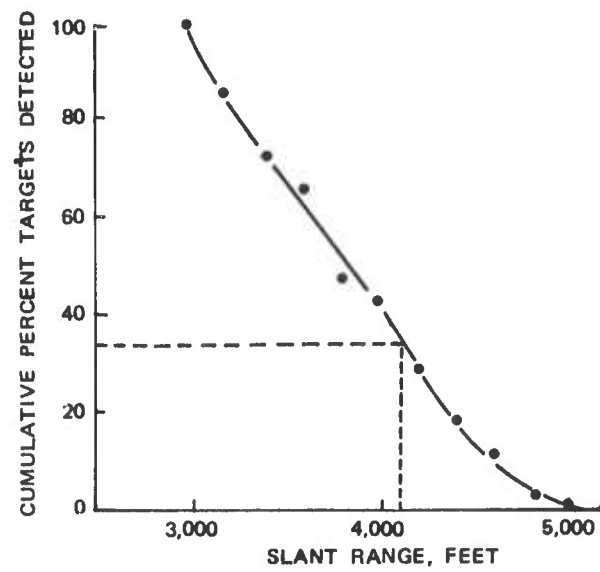
FIGURE 5. Normalized Cumulative Percent Targets Detected as a Function of Slant Range (Data Summarized Across Colors).
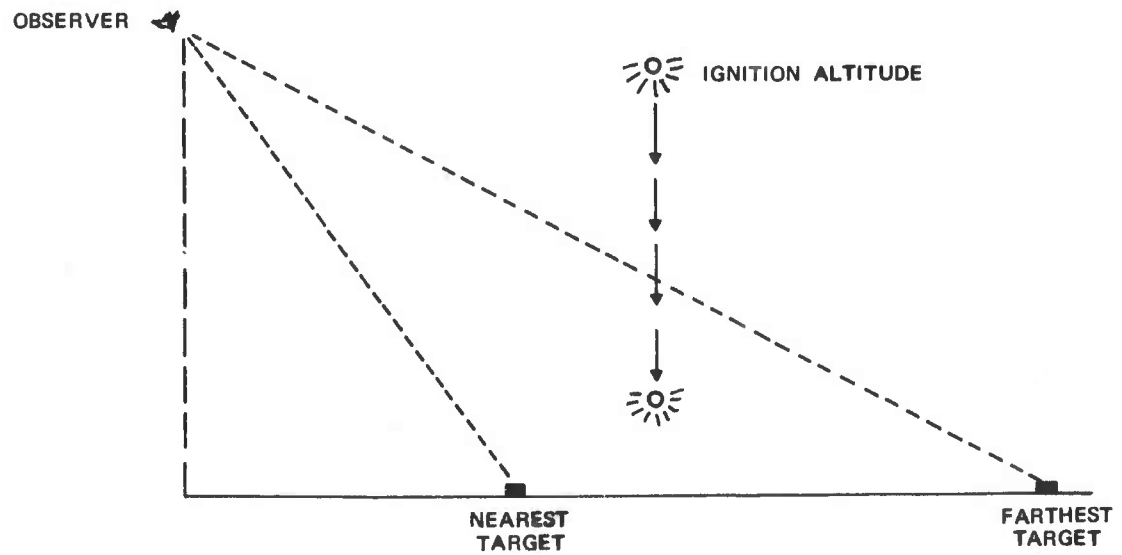
FIGURE 6. Sketch Showing Observer-Flare-Target Geometry.

FIRST DETECTION

The data were examined to determine if the first target detected differed in range for different flare colors. It is seen in Table 4 that the mean range to the first target detected is shortest for the red flare (3,100 ft) and longest for the green flare (3,800 ft).

An analysis of variance (ANOV) performed on the data showed that there was a statistically significant difference (Table 5). A Newman-Keuls test was used to determine which of the means for flare color were significantly different. Results indicated that slant ranges at first detection were significantly shorter under the red flare than under the green flare. All other differences between means were not statistically significant.

TABLE 4. Mean Slant Range ($\overline{X}$) and Standard Deviation (SD) at First Detection.

Simulated slant range, ft	Flare color							
	White		Yellow		Green		Red	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
First detection	3,500	270	3,400	240	3,800	550	3,100	270

TABLE 5. ANOV Summary Table for Slant Range at First Detection.

Source	SS	df	MS	F
Total	84.20	19		
Between (flare color)	33.00	3	11.00	3.44*
Within (error)	51.20	16	3.20	

*$P < 0.05$

DISCUSSION OF THE RESULTS

The results of this experiment imply that flare color does not significantly affect the number of targets detected or recognized. Further, false detections as well as average detection slant ranges were not affected by flare color.

The only performance measure that was significantly affected was slant range at first detection. This last result demonstrated that the subjects tended to make their first detection at shorter slant ranges under red flare light than under green flare light. Since there were no significant differences observed between the white, yellow, and green flares, two conclusions can be drawn from the present study: (1) colored flares as defined in the present research do not significantly improve target acquisition performance when compared to performance under white flare light; (2) red flare light degrades performance relative to slant range at first detection.

Before any definitive statement can be made concerning an optimal color for an illuminating flare, many factors need to be investigated. Future research should consider the interaction effect between colored flares, different terrain colors, and target colors. Since the terrain model used in the present research was primarily green, it was expected that the green flare would produce superior performance. Although this expectation was not verified statistically, the data did indicate a trend in this direction.

Atmospheric transmissivity should also be considered as a factor that might interact with flare color. It is conceivable that, under certain atmospheric conditions, target acquisition may be improved by using a colored flare.

While more research needs to be done in the area of flare color, the present study suggests that the white and yellow-white flares currently being used by the military may, in fact, be the optimal color for an illuminating flare.

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Appendix A
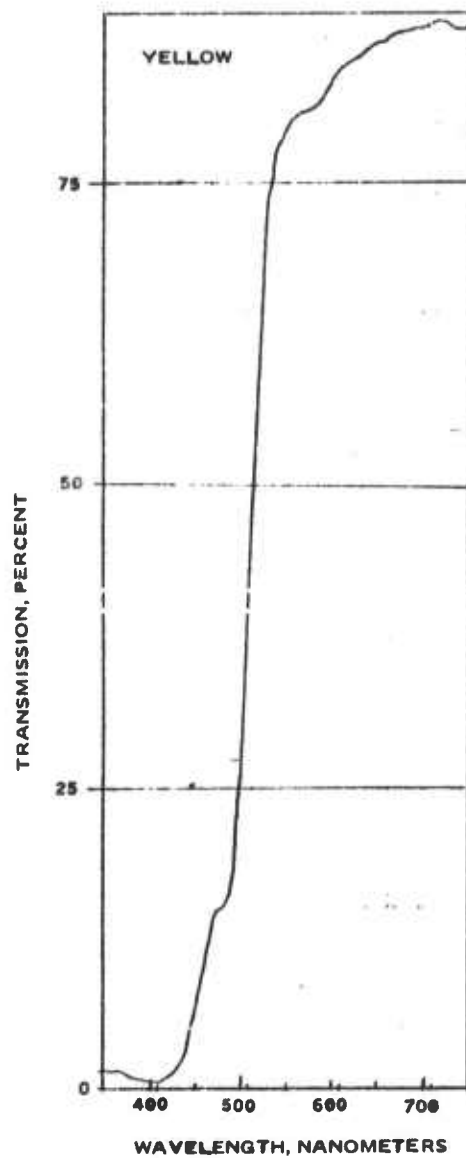
TRANSMISSION CURVES FOR FLARE FILTERS

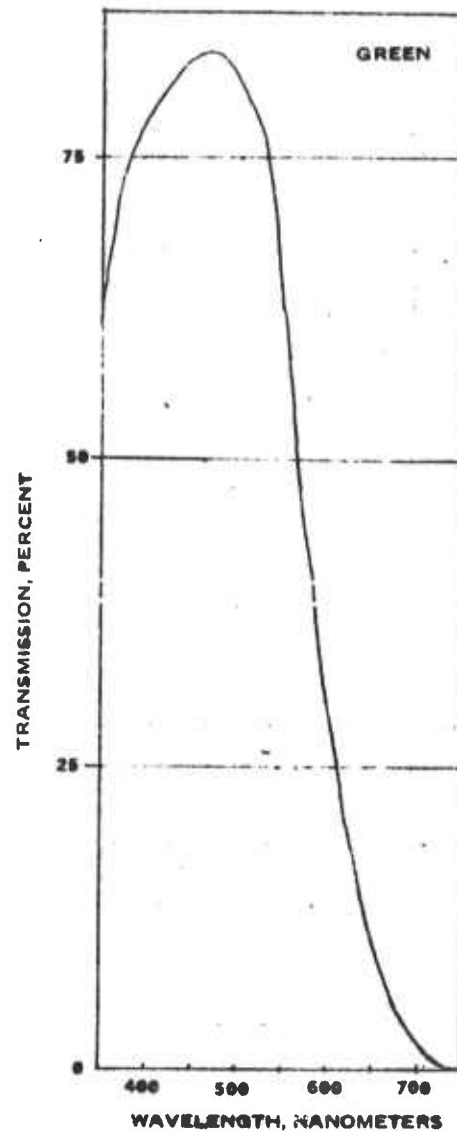FIGURE 7. Yellow Filter Transmission.
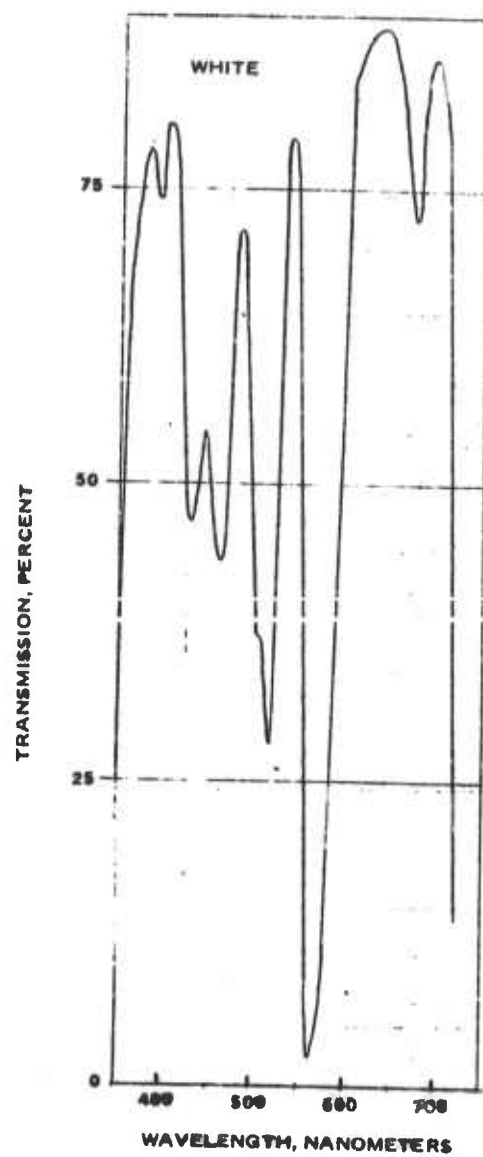

FIGURE 8. Green Filter Transmission.
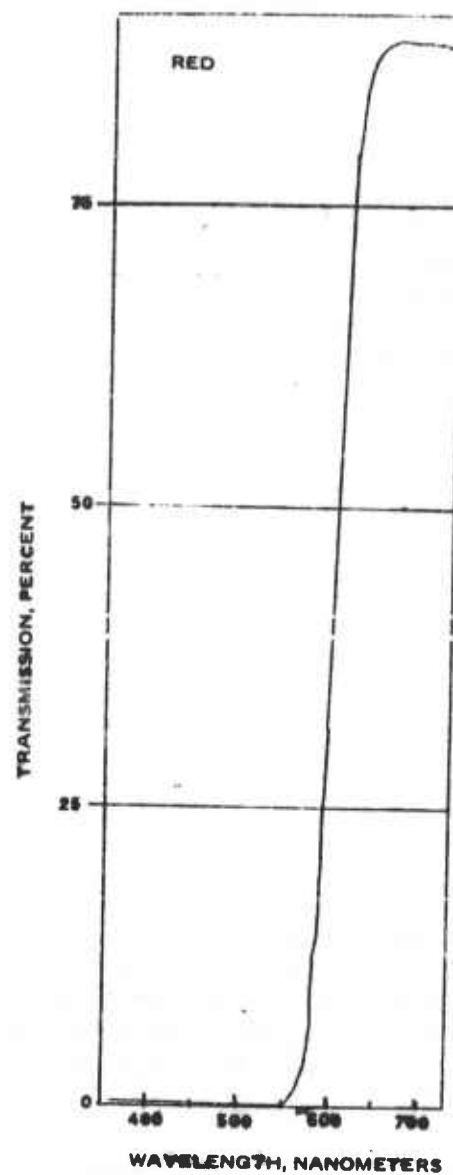
FIGURE 9. White Filter Transmission.

FIGURE 10. Red Filter Transmission.

Appendix B

INSTRUCTIONS TO SUBJECTS

Today, you are being asked to participate in an experiment in which we are trying to determine the effect of the color of simulated flare light upon the detection and identification of targets placed on a terrain model, similar to this one on the table. In this task, you will be an airborne observer, viewing at night, the terrain from approximately this orientation (see Figure 11; note the major landmarks of the terrain). The flare, providing the only illumination for your task, will be positioned to "drop" approximately in the center of the scene. The targets for which you will be searching are of two types—*tanks* and *trucks*—like these on the table. The targets are positioned randomly on the extent of the terrain model.

Your task will be to search the terrain and to locate and identify as many tanks and trucks as you can. When you think that you see a tank or truck, you will point toward it with the flashlight and report verbally its location and whether it is a tank or a truck. For example, if you determine that a tank is located just to the left of depot #1, you will point to the object and tell the experimenter "tank left of depot #1" (or some other very brief descriptive statement). If you think that you see a target, but you can not determine whether it is a tank or a truck, go ahead and point to it and just report to the experimenter "*Target* above depot 2," etc. You will not be told whether your detections are correct or incorrect.

You will have 4 minutes to complete your task. The experimenter will tell you when to start searching and when to stop.

Your primary task is to locate and identify as many tanks and trucks as you can within the time allotted. However, you should also try to keep your errors as low as possible. Errors are of two types—omissions and commissions (false positives). An *omission error* is just that—failure to detect the target. A *false positive error* is the calling of a non-target object, such as, a tree, clump of bushes, pile of rocks, shadows, etc., a target.

Before beginning this task, you will be dark adapted for 10 minutes. This process will adapt your eyes to the darkness which we will use to simulate the night-time condition.

In summary, your tasks are:

1. To locate and identify as many tanks and trucks as you can;

2. To point to the targets and to report verbally their locations and descriptions (tank or truck);

3. To keep errors as low as possible.
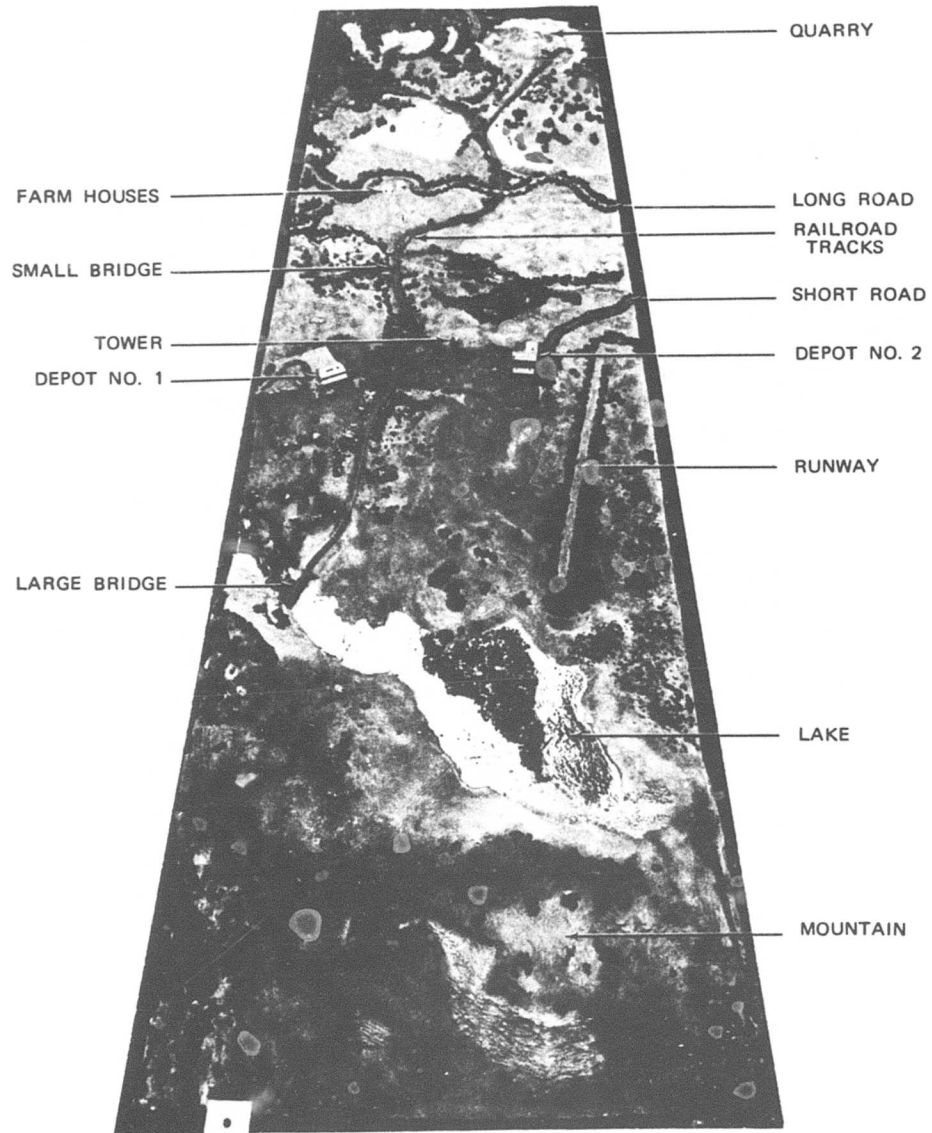
Do you have any questions?

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FIGURE 11. Briefing Photograph.

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  2 Chief of Naval Research, Arlington
    ONR-455 (1)
    ONR-461 (1)
  1 Bureau of Medicine & Surgery (Code 513)
  1 Commandant of the Marine Corps

1   Air Test & Evaluation Squadron 4
1   Air Test & Evaluation Squadron 5
1   Naval Aerospace Medical Research Laboratory, Panama City (Code L5)
4   Naval Air Development Center, Johnsville
     Code 402 (1)
     Code LSE (1)
     Code LSE-2 (1)
     Technical Library (1)
1   Naval Air Force, Atlantic Fleet
1   Naval Air Force, Pacific Fleet
1   Naval Air Test Center, Patuxent River (ST 3531)
1   Naval Ammunition Depot, Crane (Code 502, C.L., R&D Laboratory)
1   Naval Avionics Facility, Indianapolis (Technical Library)
1   Naval Electronics Laboratory Center, San Diego (Code 5330)
4   Naval Missile Center, Point Mugu
     Code 5342
       A. Bittner (1)
       R. Kennedy (1)
       R. Bruns (1)
     Technical Library (1)
3   Naval Postgraduate School, Monterey
     Dr. James Arima (1)
     Dr. Gary Poock (1)
     Technical Library (1)
2   Naval Research Laboratory
1   Naval Ship Research & Development Center, Bethesda (Code 721, J. C. Slone)
1   Naval Submarine Medical Center, Naval Submarine Base, New London
2   Naval Surface Weapons Center, White Oak
     Code GA, Fred Clodius (1)
     Technical Library (1)
1   Naval Training Equipment Center, Orlando (Code 215, LCDR Funaro)
1   Office of Naval Research Branch Office, Pasadena (R. Lawson)
1   Operational Test & Evaluation Force
1   Office Chief of Research and Development (LTCOL Cianciola)
1   Army Armament Command, Rock Island (AMSAR-SAA)
1   Army Combat Developments Command, Armor Agency, Fort Knox (David Funk)
1   Army Combat Developments Command, Aviation Agency, Fort Rucker
1   Army Combat Developments Command, Experimentation Command, Fort Ord (DCS Programs & Projects Analysis, Methodology Division)
1   Army Combat Developments Command, Field Artillery Agency, Fort Sill (MAJ Lowe)
1   Army Materiel Command (Robert Carey)
1   Army Missile Command, Redstone Arsenal (AMSMI-RLH, Gerald Chaikin)
1   Army Training & Doctrine Command, Fort Monroe

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1   Army Aeromedical Research Laboratory, Fort Rucker (Dr. Robert Wright)
1   Army Ballistics Research Laboratories, Aberdeen Proving Ground
2   Army Human Engineering Laboratory, Aberdeen Proving Ground
27 Army Materiel Systems Analysis Agency, Aberdeen Proving Ground
      AMSXY
         D, Dr. Joseph Sperrazza (1)
         R. AREND Reid (5)
         S, John W. Kramer (20)
      Technical Library (1)
3   Army Mobility Equipment Research and Development Center, Fort Belvoir
      SMEFB-MB, Albert J. Perri (1)
      STSFB-DQ, Bruce Bucklin (1)
      Technical Documents Center (1)
1   Army Research Institute, Arlington (Dr. A. H. Birnbaum)
1   Fort Huachuca Headquarters, Fort Huachuca (Technical Library)
2   Frankford Arsenal
      SMUFA-N0100, Gordon Sigmund (1)
      SPRFA-FWC-W, Henry Zandberg (1)
5   Picatinny Arsenal
      AMPGM-RK (1)
      SMUPA–AD–C (1)
         S. K. Einbinder (1)
         G. M. Gaydos (1)
      SMUPA-FRL-P, Robert B. Davis (1)
2   Night Vision Laboratory, Fort Belvoir
      AMSEL-NVVI (1)
      Systems Analysis Team, Douglas Dunlap (1)
4   Project MASSTER, West Fort Hood
      LTCOL O'Grady (2)
      Director, Air Combat Directorate (2)
1   101st Aviation Group, CBT, Fort Campbell
1   White Sands Missile Range (STEWS-AD-L)
1   Air Force Logistics Command, Wright-Patterson Air Force Base (MMWM)
1   Air Force Systems Command, Andrews Air Force Base (SDW, Roger Hartmeyer)
1   Tactical Air Command, Langley Air Force Base
1   Oklahoma City Air Materiel Area, Tinker Air Force Base (W. P. Wilcox)
2   Aeronautical Systems Division, Wright-Patterson Air Force Base
      RW (1)
      XR (1)
5   Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base
    (HEA, MAJ Hilgendorf)
10 Air Force Armament Laboratory, Eglin Air Force Base
      DLIP, John Macon (1)
      DLYD, Jerry Collier (4)
      DLYW, LTCOL Whatley (4)
      3246 TW (TGWN) CAPT Michael L. Valentine (1)