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AMRL-TR-64-82

# EFFECTS OF DISPLAY POLARITY ON TARGET DETECTION WITH SIDE-LOOKING RADAR

BARBARA A. VAN AUSDALL  
HERSCHEL C. SELF, PhD

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## ERRATA - December 1964

The following correction applies to Technical Report No. AMRL-TR-64-82,  
Effects of Display Polarity on Target Detection with Side-Looking Radar.

Page 23

Substitute Table XIV below:

TABLE XIV

MAXIMUM LINEAR DIMENSION OF TARGETS IN MILLIMETERS  
 ON THE DISPLAY SCREEN

Target	Polarity	n	Mean	S. D.
Airfield (AF)	Positive	21	11.60	5.98
	Negative	20	11.76	6.11
Bridges (BR)	Positive	80	1.81	1.99
	Negative	78	1.75	1.86
Cities (C)	Positive	76	27.35	51.59
	Negative	66	29.12	49.32
Railroad Yards (R <sub>1</sub> )	Positive	49	13.29	6.03
	Negative	49	13.29	6.03
R <sub>1</sub> Less 0 Detection	Positive	30	14.97	6.46
Probability Targets	Negative	26	15.38	6.47
(AF) plus (C)	Positive	97	23.94	33.62
	Negative	86	25.08	43.85
(AF) plus (C) plus (R <sub>1</sub> )	Positive	146	20.37	38.12
	Negative	135	20.80	35.57

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**EFFECTS OF DISPLAY POLARITY ON TARGET  
DETECTION WITH SIDE-LOOKING RADAR**

*BARBARA A. VAN AU'DALL  
HERSCHEL C. SELF, PhD*

## FOREWORD

This report was prepared in the Human Engineering Division of the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. The work was performed jointly under Program 665A, Precision Strike, and Project 7184, "Human Performance in Advanced Systems," Task 718404, "Advanced Systems Human Engineering Design Criteria." The authors are grateful for the administrative support of Mr. Charles Bates, Jr., Chief, Performance Requirements Branch, and Mr. L. L. Griffin of the same branch. Special thanks are due to the Strategic and Tactical Air Commands for supplying officers to serve as test subjects. Thanks are due also to Dr. James C. Welch and Mr. Don F. McKechnie for training experimental subjects to recognize targets on side-looking radar displays. Acknowledgement is also given to Mr. Stephen Vergamini of the University of Dayton Research Institute for scoring the responses of the subjects. This study was begun in January 1964 and was completed in June 1964.

This technical report has been reviewed and is approved.

WALTER F. GREETHER, PhD  
Technical Director  
Behavioral Sciences Laboratory

## ABSTRACT

This study examines the effects of display polarity on the performance of subjects searching for specific targets on a side-looking radar (SLR) display. SLR imagery was displayed on a 14 by 14 inch display at a scale of 1: 176,000 and at 950 knots simulated aircraft speed. Nineteen SAC and TAC radar navigators were randomly assigned to two groups. One group was tested on a positive copy and the other on a negative copy of the same film. The average subject on the positive display detected significantly more targets (38.4%) than the average subject (32.1%) on the negative display. Target detection times on the positive display were significantly shorter. There was no significant difference between groups in number of responses to nontarget objects. For detections the distributions of confidence judgments were not significantly different, however for nontarget objects the negative group was only half as likely to express high confidence that they were targets. For both types of display there were positive and significant correlations between maximum target dimension and probability of detection. When the large training bias favoring the positive group is considered, it appears unlikely that either polarity should be considered as definitely superior for systems applications.

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## EXPLANATION OF TERMS

**Detection:** A target is found, whether or not it is correctly classified.

**False Positive:** Response to a nontarget, ie, the subject indicates that a portion of the displayed image is a target although it is not.

**Prorating:** Allocating unscorable responses to recognitions and false positives on the basis of the portion of recognitions and false positives in those responses that were scorable.

**Recognition:** A target is correctly classified, ie, assigned to the proper category. A recognized target is always a detected target, although the reverse may not be true.

**Response:** A subject records a target or a false positive by manipulation of the scoring equipment controls.

**Screen Position:** The location on the display of a target at the time that it is entered into the response scoring equipment by the subject. It is the measurement of the interval between the appearance of a target on the display and its detection by the subject, ie, the quickness of response to targets.

**Subject's Confidence:** The recording by the subject of how sure he is that what he designates as a target is truly a target of the type he claims it is.

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# EFFECTS OF DISPLAY POLARITY ON TARGET DETECTION WITH SIDE-LOOKING RADAR

Barbara A. Van Ausdall

Herschel C. Self

## SECTION I

### INTRODUCTION

In a positive-polarity image the brightness of image elements is positively correlated with the energy received from the corresponding elements of the object being imaged. Thus, the bright areas on a positive-image radar display represent objects, such as cities and industrial areas, that return considerable energy to the radar antenna. The dark areas represent low intensity returns characteristic of lakes, rivers, airport runways, etc. On a negative polarity display, the reverse is true, cities and industrial areas appear dark relative to their surrounds, while bodies of water are displayed as bright areas.

Most devices that form an image for examination by a human observer have been constructed to yield a positive image display. In radar displays this type of polarity is conventional and most people will maintain that such an arrangement is more natural. However, naturalness with radar displays may be largely a matter of training and experience. A matter of more practical significance is the relative effectiveness of the two types of display polarity. How do they compare as to the accuracy and speed with which targets can be detected and the percent of targets that are detected?

This study was conducted to examine the effects of display polarity on the behavior of an operator searching for targets on the display of a high-resolution side-looking radar (SLR). The image moved across the display at a constant rate simulating a fixed aircraft velocity. Four target types were used: airfields, bridges, cities, and dams. No information was provided on absolute or relative numbers of targets, or on target location, ie, all targets were targets of opportunity.

## SECTION II

### EQUIPMENT AND DATA EXTRACTION

The equipment was housed in a large console, shown in figure 1. The core of the apparatus was a Dynamic Imagery Viewer, Model 100A (manufactured by the Hughes Aircraft Co.). This viewer was an optical projector utilizing condenser-type illumination and an enlarging lens to form a moving image on a 36 by 36 cm (14 by 14 inch) rear projection screen. The film drive mechanism was adjusted so that the simulated ground speed on the screen of the projector was 950 knots.

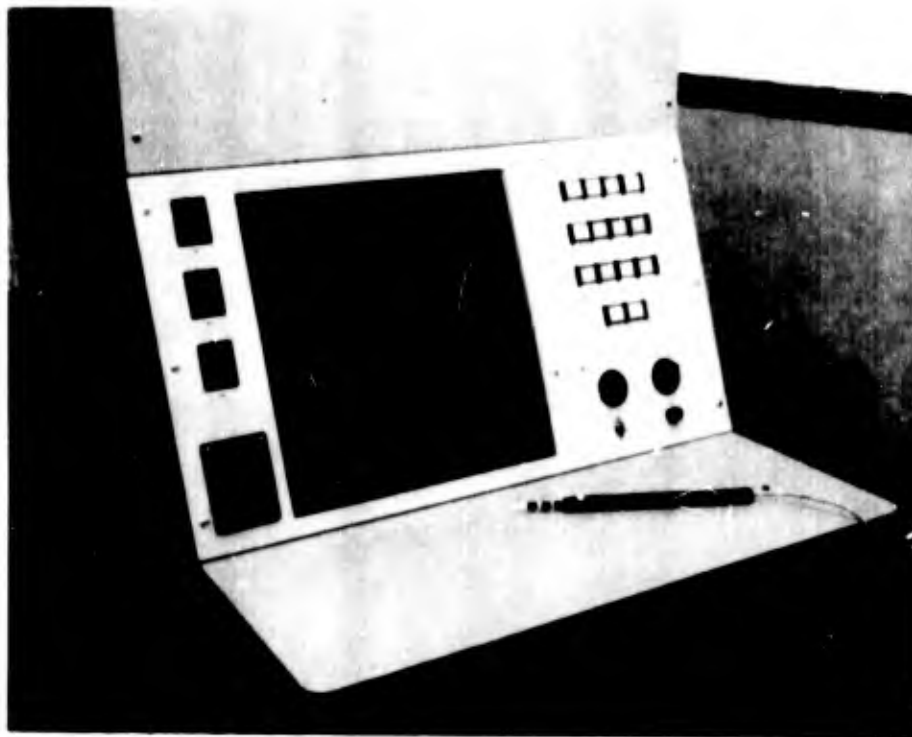


Figure 1. The console used for displaying a strip of moving radar images to the subjects. The device on the shelf is the subject's illuminated pointer.

A data-insertion panel, shown in figure 2, was located on the right side of the sloping panel on which the viewing screen was mounted. It contained a row of interlocking pushbutton switches for target names and a row of interlocking confidence level pushbuttons. On the left of the screen and on the same panel was a vertical column of data readout devices that indicated which target name switch and which confidence level switch was depressed.

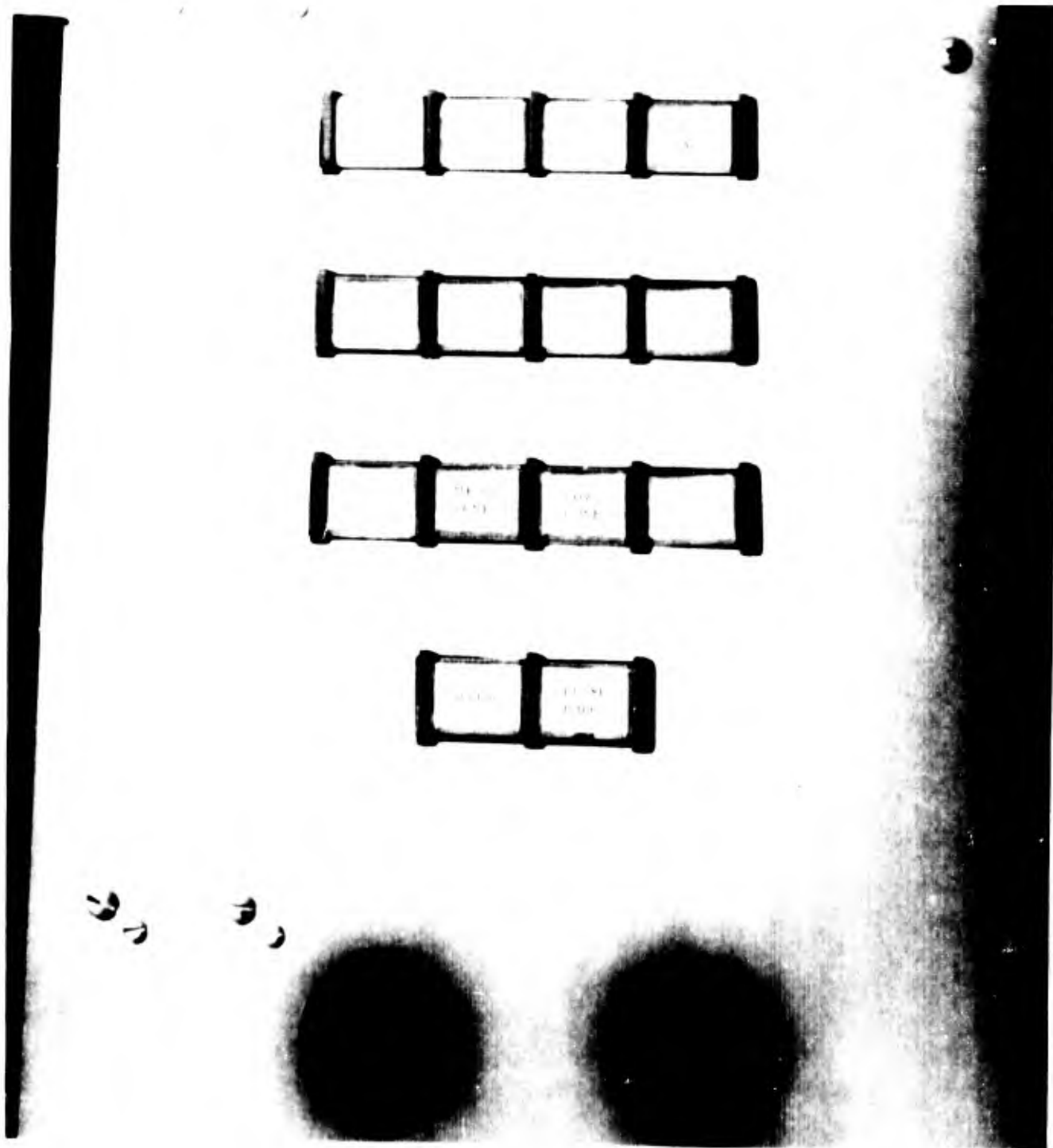


Figure 2. The Data Insertion Panel used by the subject.

An electrically operated 35-mm data camera on a tripod viewed the console over the subject's left shoulder. By activating a record switch with his right hand, the subject took a picture for every target that he detected. Each picture included the display screen and the side-looking radar image projected onto it, the data readout indicators, and an illuminated pointer held in the subject's left hand. The tip of this pointer was placed against the screen and on the image of the target.

The information recorded on the film of the data camera was extracted by a data analyst who projected the processed film onto a large screen, read the data on the readout devices, and examined the image of the screen, including the position of the operator's illuminated pointer. The locations in the side-looking radar film strip of all the targets were known from the data base supplied by an industrial concern working on an Air Force contract. Each response (picture) was classified by the data analyst as either a detection (object designated was one of the known targets) or a false positive (object designated was not a target). A known target that was not detected was classified as a miss. Screen position was measured for each picture by superimposing on the picture of the screen a grid of parallel straight lines that divided the vertical dimension of the screen into eleven equal intervals. Since the image moved from the top to the bottom of the screen at a known constant rate, the screen position of a target could be converted to response latency, ie, the time interval between the appearance on the screen of a target and the operator's response (taking the 35-mm data picture).

### SECTION III

#### EXPERIMENTAL PROCEDURE

##### A. Stimulus Material and Target Selection

The stimulus material was high-resolution side-looking radar imagery collected with an APS-73 (XH-3) airborne radar. A swath of territory approximately 34 nautical miles wide and 771 nautical miles long was projected onto a 360 mm by 360 mm (14 by 14 in.) display screen at a scale of 1:176,000. Thus, 1 inch on the display screen represented 2.3 nautical miles of territory. The targets that were to be detected were airfields, bridges, cities, and railroad yards.

The speed of the film strip was precisely adjusted so that the simulated ground speed on the display screen was 950 knots. If 640 knots is taken to represent Mach 1, 950 knots is approximately Mach 1.5. The image moved across the display screen at a rate of 16.7 cm (6.58 in.) per minute.

Two continuous strip prints of the same terrain were used. One was a positive copy and the other a negative. The positive print was second generation copy; the negative print was a third generation copy.

Despite considerable care taken to produce prints of equal image quality, inspection revealed that the negative and positive film strips were of comparable, though not identical, quality. Some of the targets visible on the positive could not be seen on the negative copy. Therefore, both rolls of film were carefully examined, target by target, to determine the visibility of the target signatures. The criterion for deciding that a target was present was the ability to detect the target when its exact location was indicated in advance. By this criterion, 12 of the targets visible on the positive imagery were not visible on the negative imagery. The total number of detectable targets was 226 on the positive imagery and 214 on the negative imagery.

The terrain displayed varied from unpopulated rural areas to densely populated residential and highly industrialized areas, such as Chicago, Illinois. Figure 3 shows the distribution of the targets by category along the continuous strip of film.

#### B. The Subjects

The subjects participating in this study were USAF navigator-bombardiers from Strategic and Tactical Air Commands. Their experience with navigation radar ranged from a minimum of 250 hours to a maximum of 5000 hours. No effort was made to select individuals with similar education, military experience, etc. All of them had normal vision, corrected or uncorrected.

Subjects expressed a preference for positive displays, since their experience, both airborne and ground based, was primarily with positive displays. A 90-minute training period to familiarize subjects assigned to group I with the appearance of targets on negative SLR imagery was balanced by an additional 90-minute training period received by group II on positive SLR imagery over the same terrain.

No subject reported any experience with SLR other than the short training course we provided. Previous to participation in this study, they had been tested for 90 minutes with positive polarity images on direction of motion, briefing, and multiple-factor studies. This could be considered as additional training time. Thus when they served on the polarity study, they were already proficient in using the procedures, equipment, confidence levels, etc.

#### C. Subject Training

To familiarize the subjects with SLR, five sessions, each of 2 1/2 hours duration, were devoted to orientation and training. The 665A Precision Strike Program was discussed during the first session. The general program objectives for sensor development and flight test were delineated. Training was discussed as preparation for experimental conditions, not as a preparation for operational duties. We emphasized that five training sessions would not be sufficient to produce experts.

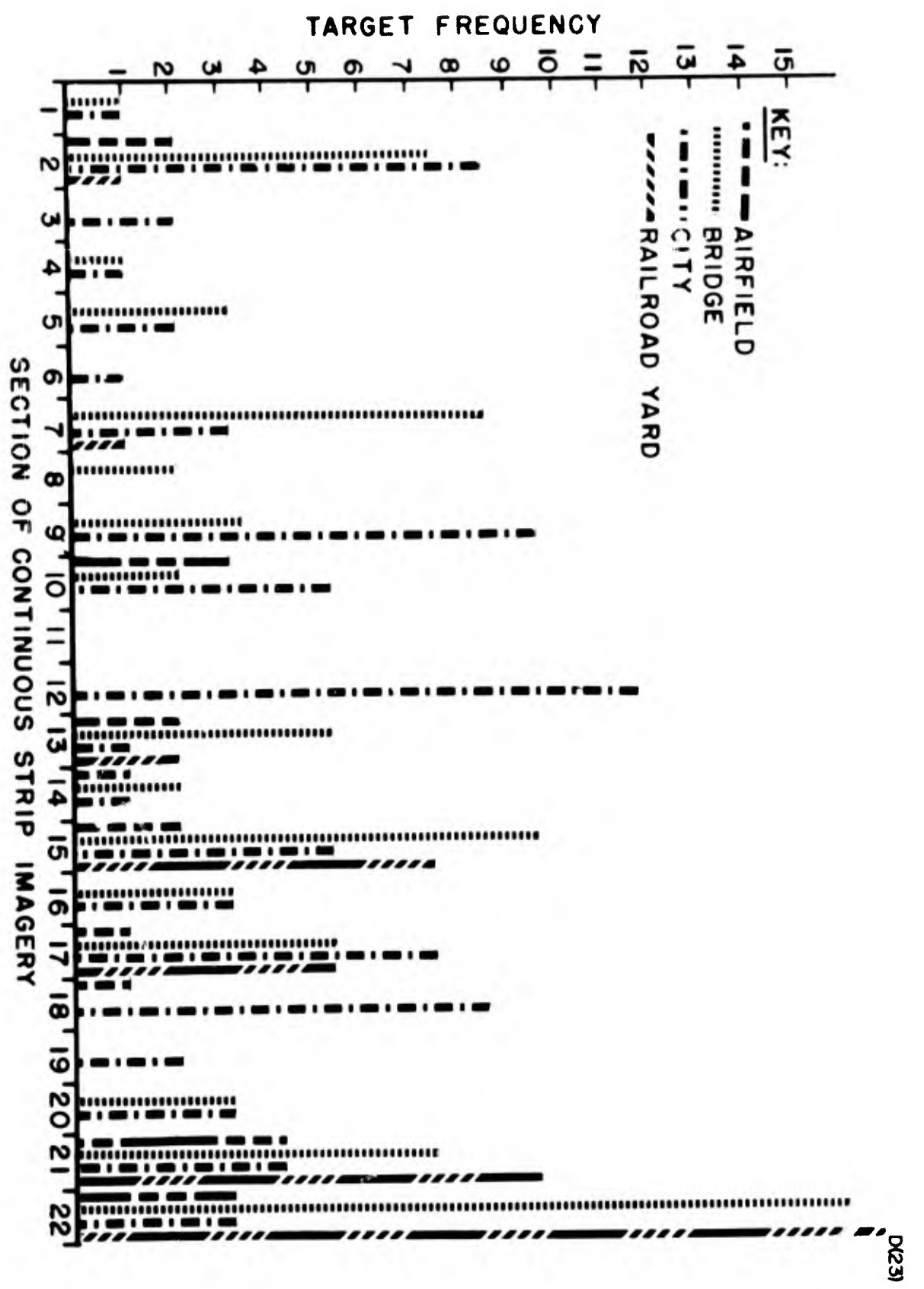


Figure 3. Target distribution along the flight by target types. The flight path was arbitrarily divided into 22 equal intervals.

Studies in which the subjects would participate were discussed. Subjects were assured that their professional ability was not being tested and that the experimental situation did not simulate an operational mission. An explanation of the performance measures to be used was given, and we pointed out that confidence level would be related to performance measures.

During the second training session, subjects examined a training brochure which included introductory information on (1) the physics and technology of side-looking radar, (2) a comparison of conventional bombing navigation radar and side-looking radar, (3) a discussion of image degradation, (4) the target signatures and target logic for targets used in the studies, and (5) positive prints of SLR imagery that contained relevant targets. Targets emphasized during training were airfields, railroad yards, docks and piers, industry, dams, transmission lines, tank farms, ammunition storage, and cities.

Continuous strips of positive imagery were available for projection on an optical viewer. Transparencies (9 by 18 in.) of the strips with overlays identifying all targets were available for self-tutoring. Subjects viewed the moving imagery on the display device for approximately half of each 150-minute session. Seventy plates of imagery were used, divided into sets of 10 each. Subjects were tested for proficiency after completion of each training set by requiring them to identify 20 circled targets.

It was necessary that everyone participate in four positive image studies in addition to the present study. Thus, a training bias in favor of positive imagery was unavoidable.

#### D. Experimental Sessions

The use of the target, confidence level, and record switches was demonstrated to the subject and he was allowed to practice with them. Instructions read by the experimenter to the subject are given in the appendix.

## SECTION IV

### RESULTS

Table I contains a summary of the experimental data for each type of target. The data does not take into account responses that were unscorable because the subject's head or arm was in the way, readout data was illegible, etc. Unscorable responses were only a small portion of all responses, but since they did not occur with equal frequency with the two groups, it was necessary to prorate the data for numbers of detections and false positives, dividing unscorable responses into these two categories for each subject in proportion to their relative occurrence in his scorable responses. However, this could not be done by target type.

TABLE I

## SUMMARY OF DATA BY TARGET TYPE

	Airfield		Bridge		City		Railroad Yard		
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	
Targets	21	20	80	79	76	66	49	49	
Detections	7.778	8.500	38.556	37.400	24.889	14.600	6.222	5.900	
False Positives	4.889	1.700	21.111	23.100	63.667	42.400	11.222	8.300	
	Total	3.379	3.919	3.111	4.371	3.478	4.941	4.223	5.693
Screen Position	Detect	2.807	3.616	2.910	3.992	3.048	4.549	4.652	5.933
	False Positive	4.057	6.264	3.564	5.070	3.654	5.165	4.047	5.315
Confidence Level	Total	1.123	1.355	1.594	1.552	1.852	1.994	1.783	2.040
	Detect	1.020	1.180	1.392	1.482	1.768	1.836	1.531	1.826
	False Positive	1.254	1.533	1.674	1.849	1.735	2.005	1.867	2.211

NOTE: The table entries, except for the number of targets, are means. All targets that appeared on the negative display also appeared on the positive display, but the positive display contained 12 targets not common to both. This was due to the fact that the positive was a second generation print while the negative was a third generation print, and suffered a slight loss in image quality. The screen position data is in elevenths of screen width. To convert to nautical miles, multiply by 3.09, or to convert to inches on the screen, multiply the table values by 1.28.

The numerical values and statistical comparison of the positive and negative display groups on the frequency data is given in table II. Since the data is prorated, it differs slightly from the values obtainable from table I. Examination of this table reveals that the positive display group detected appreciably more targets than did the negative group. By t test the superiority at detection of the positive group is verified at the .01 level of significance. Expressed as percentages, the average subject in the positive display detected 38.2% of the targets, while the average subject on the negative display detected only 31.6% of them. Reference to table I, where data is not prorated, makes it appear that the city category may account for a large portion of the difference in percent of targets detected.

TABLE II

MEANS AND STANDARD DEVIATIONS OF THE NUMBERS OF RESPONSES

Type of Response	Means		Standard Deviations		Significance	
	Positive	Negative	Positive	Negative	<u>F</u>	<u>t</u>
All Responses	195.9	149.2	68.20	44.06	2.40	1.73
Detections Only	86.4	67.8	9.41	11.97	1.62	3.75**
False Positives	109.5	81.4	61.76	49.40	1.56	1.10

\*\*Significant at the .01 level of confidence.

NOTE: Means and standard deviations are based on 9 positive and 10 negative subjects. Unscorable responses were prorated, hence data does not exactly agree with data of table I.

However, examination of the prorated false positive data indicates a mean of 109.5 false positives for the average subject in the positive group as against only 81.4 for the negative group. This apparent superiority of the negative group is not verified by statistical test: By t test the difference between the group means for false positives is not significant at the .05 level. The ratio of false positives to all responses, when multiplied by 100, may be defined as the percent of false positives. Computed from table II, this turns out to be 55.9% for the positive group and 54.6% for the negative group. Thus, the percentage of all responses that are false positives is in close agreement for the two groups, ie, neither type of display was superior to the other for minimizing the percentage of false positives.

Table II also reveals that, in addition to no significant difference in percentage of false positives (as previously defined), there is no statistically significant difference between the two groups in mean number of all responses. Group variabilities were not significantly different, at the .05 level of significance, for detections, false positives, or for both of them (all responses) combined.

False positives and detections are compared on a frequency-of-occurrence basis in table III. As was the case for table II, the data is prorated. The false positives have a standard deviation that is 6.6 times as large as that for detections for the positive group and 4.1 times for the negative group, and the variance ratios (the tabled F) are much larger. The variances are significantly greater for false positives than for detections at the .01 level of significance for both positive and negative display groups. Comparison of the means of detections and false positives indicates that the obtained mean was larger for false positives than for detections by a factor of 1.27 for the positive group and 1.20 for the negative group. However, the t test for the significance of the difference between the means of the detections and false positives was not significant at the .05 level for either the positive or the negative group. Thus the null hypothesis that the average subject in either of the two groups can be expected to report as many false positives as detections is not disproved.

TABLE III

COMPARISON OF FALSE POSITIVES TO DETECTIONS BY FREQUENCY

Type of Display	Detections		False Positives		Significance	
	Mean	S. D.	Mean	S. D.	<u>F</u>	<u>t</u>
Positive	86.4	9.41	109.5	61.76	43.1**	1.05
Negative	67.8	11.97	81.4	49.40	17.0**	.803

\*\*Significant at the .01 level of confidence.

NOTE: As in table II, data is prorated.

Although the two groups are quite small, hence correlation coefficients have low reliability, it is of value to compare the individual subjects on detections and false positives. The Pearson product moment correlation was .551 for the positive group and .886 for the negative group. The .886 correlation is significantly different from 0 at the .01 level, thus there was a statistically significant positive relationship between the number of detections and false positives for individuals in the negative group. The .551 correlation was not significantly different from zero at the .05 level and the two correlations are not significantly different from each other at the .05 level.

The data in tables II and III were for all types of targets combined, and do not indicate how the percent of targets detected varied with the type of target. This information is given in table IV.

**TABLE IV**  
**PERCENTAGE OF TARGETS DETECTED BY TARGET TYPE**

Target Display	Airfields	Bridges	Cities	Railroad Yards
Positive	37.04	48.20	32.75	12.70
Negative	42.50	47.34	22.12	12.04

The obtained percentages of targets detected, listed in table IV, were similar on the two types of displays for bridges and for railroad yards, but less similar for the airfields and cities.

Table V gives the frequencies for target detections across targets for the positive display.

**TABLE V**  
**DETECTION FREQUENCIES FOR THE POSITIVE DISPLAY**

Response Target	Airfields	Bridges	Cities	Railroad Yards
Detected	7.778	38.556	24.889	6.222
Missed	13.222	41.444	51.111	42.778

NOTE: The cell entries are the means of observed detection frequencies.

A chi-square test of this 2 x 3 table of response by target type yielded a chi square of 17.2. With two degrees of freedom, the probability of obtaining a value this large by sampling error alone is less than .001, therefore it is concluded that the percent of targets detected varies significantly with the type of target. The detection percents vary from a low of 13% detection for railroad yards to a high of 37% for airfields.

Table VI gives the frequencies for detections on the negative display.

TABLE VI  
DETECTION FREQUENCIES FOR THE NEGATIVE DISPLAY

Response \ Target	Airfields	Bridges	Cities	Railroad Yards
Detected	8.500	37.400	14.600	5.900
Missed	11.500	41.600	50.400	43.100

NOTE: The cell entries are the means of observed detection frequencies.

A chi-square test of the data in this table yields a chi square of 18.3 with 3 degrees of freedom. The probability of obtaining this large a value by chance is less than .001. As in the case of the positive display, the percentage of targets detected with a negative image display varies significantly with the type of target. The tabled values vary from a low of 12% detections for railroad yards to a high of 42.5% for airfields. These percentages are similar to those obtained with the positive image display.

To further examine the differences in detection behavior with the two types of displays, a Pearson product moment correlation coefficient was computed for the number of observers detecting each of the 214 targets appearing on both displays. A value of .803 was obtained.

The data for this analysis of detections versus image polarity across the four target types are given in table VII.

TABLE VII

## DETECTION FREQUENCIES: TYPES OF TARGETS BY TYPES OF DISPLAY POLARITY

		Type of Target			
		Airfield	Bridge	City	Railroad Yard
Polarity	Positive	7.778	38.556	24.889	6.222
	Negative	8.500	37.400	14.600	5.900

NOTE: The cell entries are the means of observed detection frequencies.

The value of chi square obtained by using marginal totals to compute expected values was 1.926. With three degrees of freedom, such a value is not significant at the .05 level. Thus, detection across the four target types was not significantly different for the two types of displays.

The position on the screen at which each target detection takes place is of considerable interest to system analysts and designers. If a target is detected only after its image has moved most of the way across the screen, its distance from the aircraft may be too great to permit effective action to be taken against it. Quick detection is usually a decided advantage and is often an absolute necessity.

In figure 4 the percentage of targets detected is plotted against the interval between the initial appearance of a target on the display and its detection by the subject. This graph should be examined along with the cumulative percentage curves of figure 5. Both curves are based on the total number of targets that were present, not on the total number detected. In the first 10 nautical miles, 40 seconds or 4 1/4 inches on the screen, there was a large advantage for the positive display for detecting targets. This lead was reduced later but was never completely eliminated. Indeed, the overall detections of the positive group was significantly greater than that of the negative group at the .01 level of confidence.

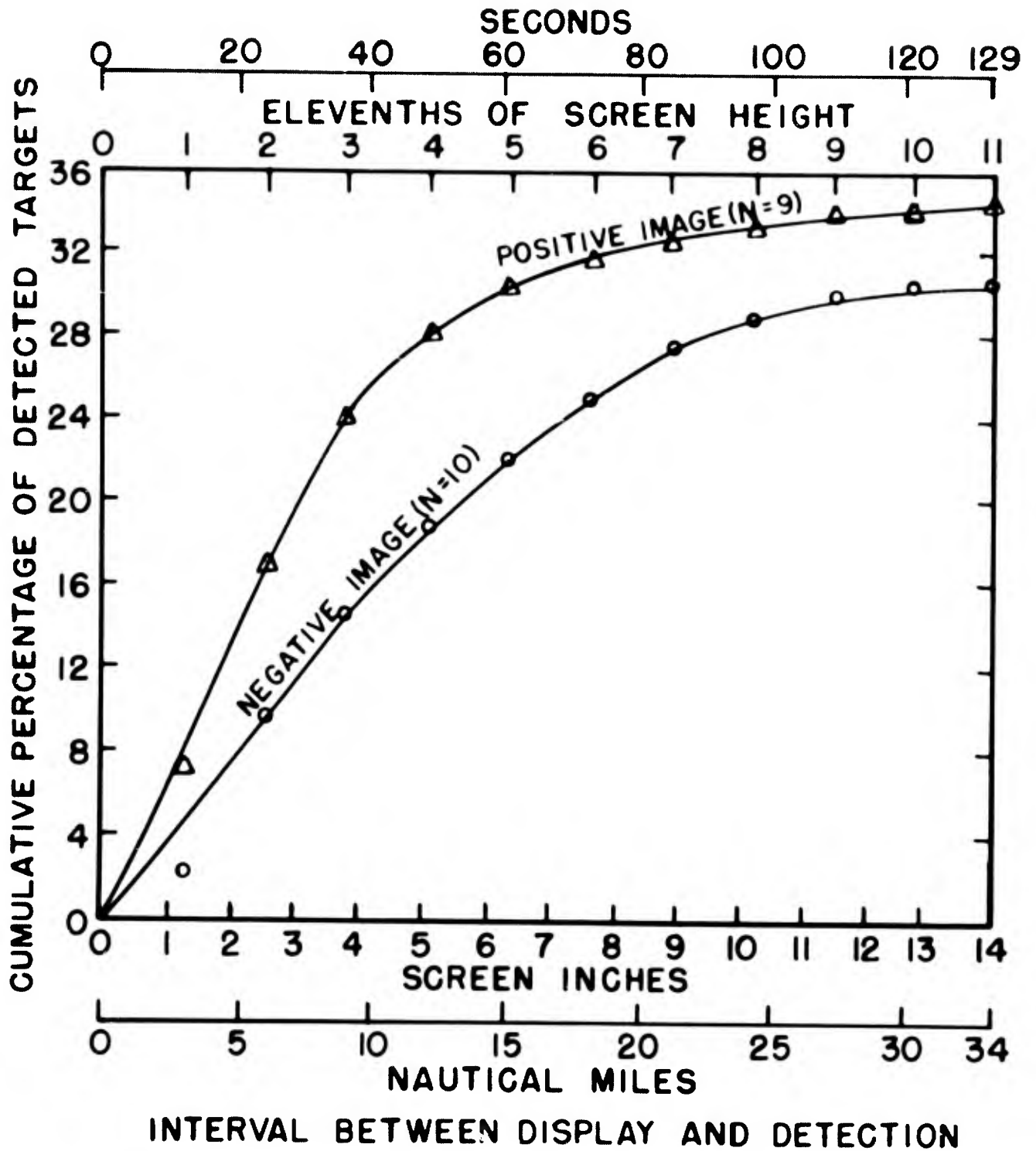


Figure 4. Distribution of cumulative percentage of targets detected as a function of screen position for the positive and negative image displays. The plotted data is not prorated for those responses for which measurements could not be taken (head in way of camera, etc.); hence, the final cumulative percent does not coincide precisely with detection data reported elsewhere in this report.

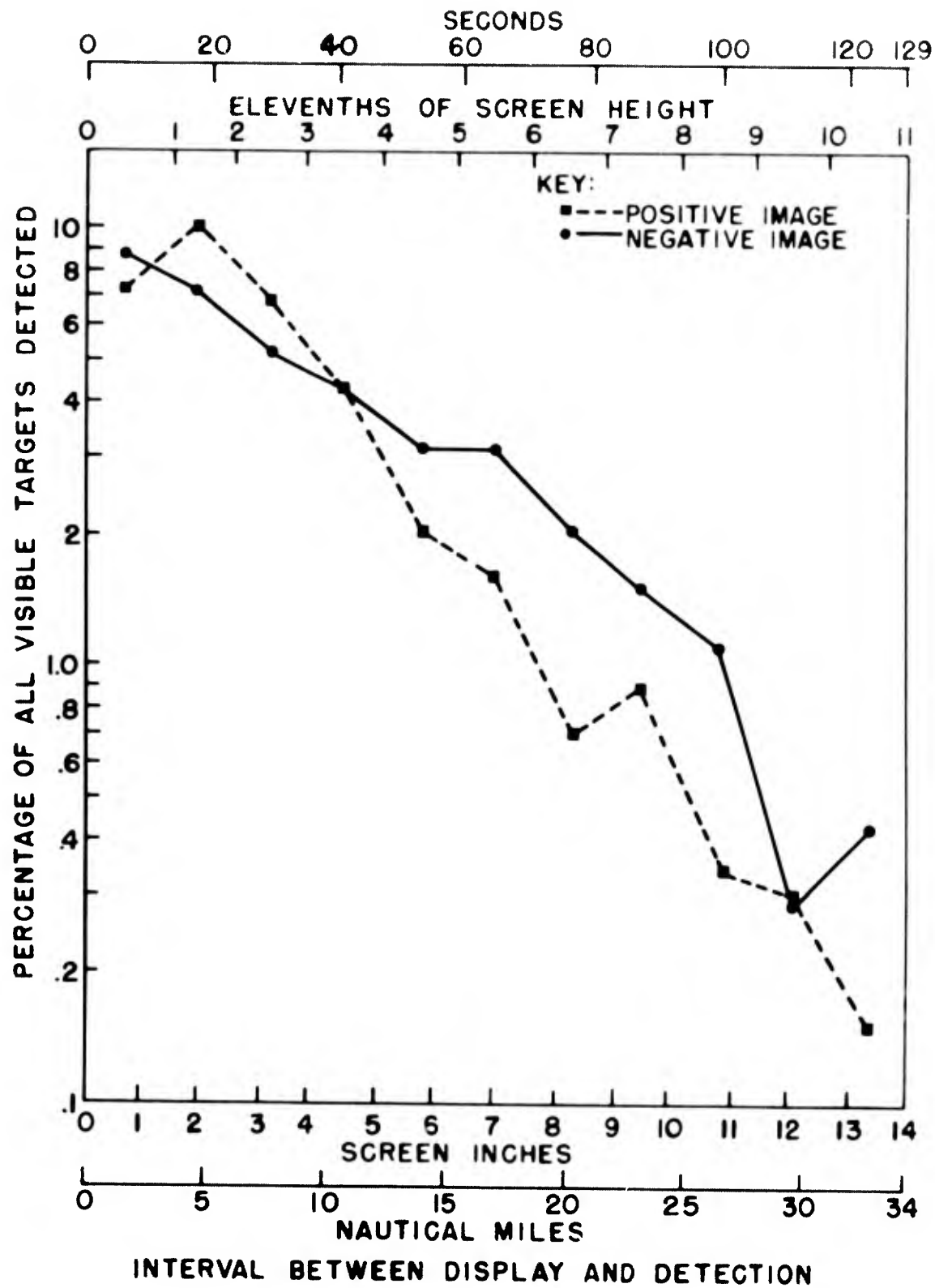


Figure 5. Percent of targets detected as a function of the interval between display and detection. Note that the graph is plotted on semilogarithmic paper so that the percentage values are separable in the latter portions of the screen where absolute differences are very small.

The mean interval for all responses, for detections only, and for false positives is given in the following table.

TABLE VIII  
MEANS AND STANDARD DEVIATIONS OF THE INTERVALS BETWEEN  
APPEARANCE OF THE TARGETS AND THEIR DETECTION

Type of Response	Means		Standard Deviations		Significance	
	Positive	Negative	Positive	Negative	<u>F</u>	<u>t</u>
All Responses	10.5	14.5	1.89	3.67	3.78*	3.22*
Detections Only	9.46	14.25	1.79	3.52	3.88*	3.37**
False Positives	11.47	16.14	2.17	4.45	4.32*	2.94

\*Significant at the .05 level of significance.

\*\*Significant at the .01 level of significance.

NOTE: Table values are means of 9 positive and 10 negative subjects and are expressed in nautical miles.

All three variance ratios given in table VIII are significant at the .05 level. Thus, the negative display group is more variable than the positive display group in the response time (or interval) for detections, for false positives, and for the two combined (all responses). When the means are examined by t-test, the detection interval is significantly (at the .01 level) greater for the negative group and they also take significantly (at the .05 level) longer for all responses. Only on false positives is the negative group not significantly inferior in response time, miles or screen inches.

The means and standard deviations in table VIII are rearranged in table IX to compare speed of reaction for false positives versus detections. The mean for the false positives exceeds that for the detections on both types of displays, ie, reaction to false positives was slower than to real targets. Also, the standard deviations are larger. However, statistical tests indicate that neither the means nor the variances were significantly different at the .05 level of significance.

TABLE IX

RESPONSE QUICKNESS COMPARISON OF DETECTIONS  
AND FALSE POSITIVES

Display Type		Detections	False Positives	<u>F</u>	<u>t</u>
Positive Image	Mean	9.46	11.47		
				1.47	.75
Negative Image	S. D.	1.79	2.19		
	Mean	14.25	16.14		
				1.60	.26
	S. D.	3.25	4.45		

## NOTE:

(1) None of the statistical tests reach the .05 level of significance.

(2) Table entries are in nautical miles of terrain and are based on 9 negative and 10 positive display subjects. To convert means and standard deviations to screen inches, multiply them by .415, or to convert to seconds of time, multiply them by 3.83.

In any situation that requires action to be taken on the basis of target detections, the confidence that the operator has that his detection judgments are correct is critical. Thus, mission success might be very different with two different types of displays, even when both the percentage of targets detected and the percentage of false positives were the same.

The average confidence of the various subjects in the correctness of their judgments is given in table X and is shown in the form of a scatter plot in figure 6. A high confidence judgment was 1 on the scale, while medium and low confidence were represented by 2 and 3 respectively.

TABLE X

MEAN CONFIDENCE LEVEL FOR INDIVIDUAL SUBJECTS FOR DETECTED  
TARGETS AND FOR FALSE POSITIVE RESPONSES

Positive Image Display			Negative Image Display		
Subject	Detections	False Positives	Subject	Detections	False Positives
A	1.124	1.438	J	1.463	2.094
B	1.025	1.380	K	1.409	2.193
C	1.247	1.569	L	2.333	2.222
D	Insufficient Data		M	2.000	2.143
E	2.429	2.915	N	2.154	2.381
F	2.000	2.250	O	1.179	1.571
G	2.250	2.341	P	1.492	1.925
H	1.191	1.595	Q	1.305	1.807
I	1.000	1.061	R	1.086	1.507
			S	1.241	1.848
<b>Grand Means</b>	1.532	1.819		1.566	1.969

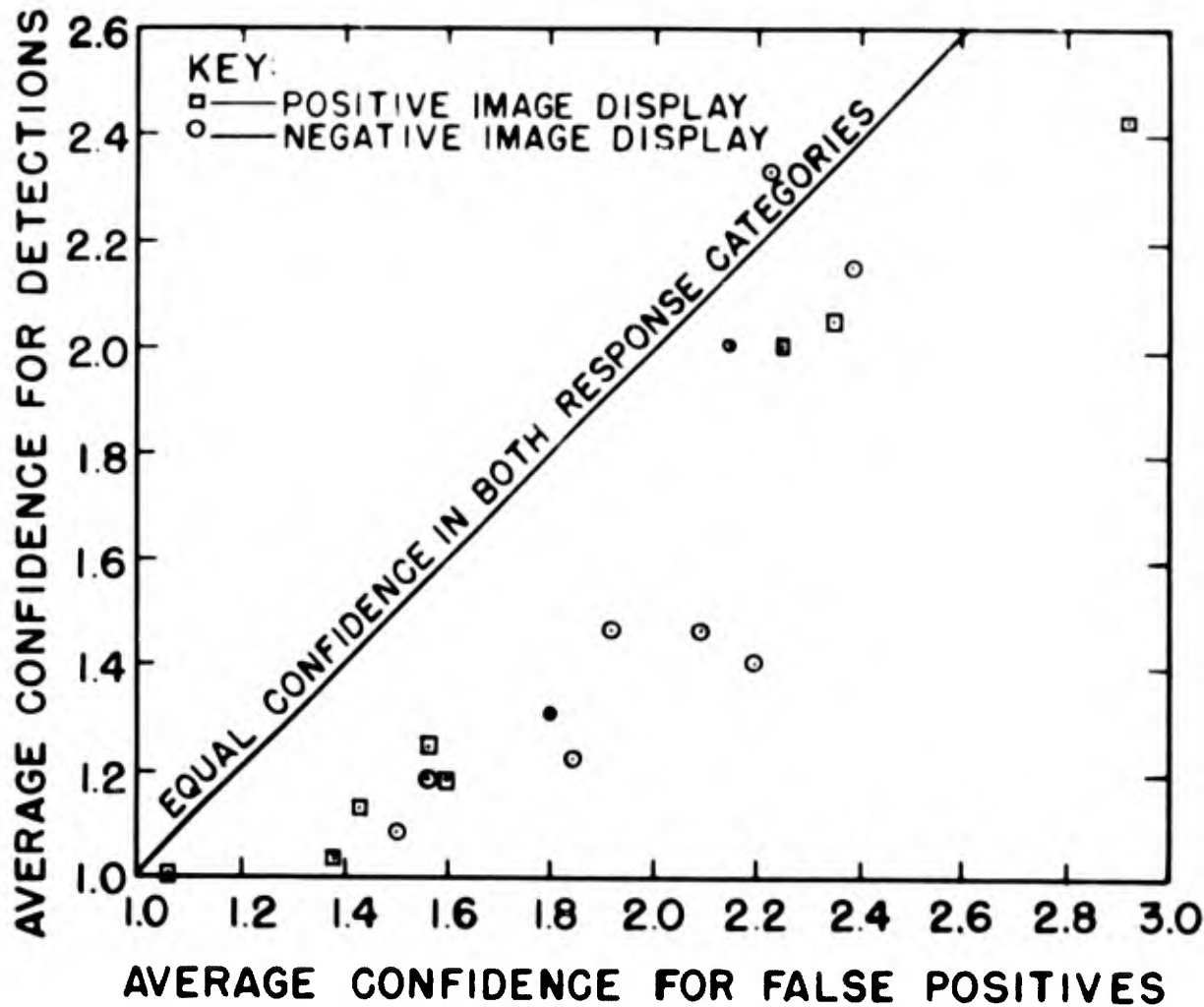


Figure 6. Scatter plot of average confidence for detections versus average confidence for false positives. High values on either scale represent low confidence.

The data indicate that individual differences in confidence are large for both types of display and for both detections and false positives. For example, subject I had a mean confidence of 1.000 for detections with a positive image display while subject E had a mean of 2.4 for detection responses under the same experimental conditions. Figure 6 shows that individuals tending to express low confidence for detections also have low confidence in their false positive responses. Similarly, high confidence on either response category is accompanied by high confidence on the other. Significantly, there was not one subject who expressed a high average confidence in his responses to targets and a low average confidence in responses to image elements that represented false positives. Only one of the 19 subjects (fig. 6) had an average confidence in his false positive responses that exceeded his confidence for target responses. Although many of the targets were difficult, several of the targets could hardly be missed in even a quick and casual examination of the display. Thus, even this one case of greater confidence in false positives is somewhat surprising.

The differences in the average confidence expressed by the subjects is, in all likelihood, a matter of individual interpretation of the meaning of the categories on the confidence scale.

The ways in which the distributions of confidence vary with experimental conditions are examined by means of nonparametric tests in the following paragraphs.

Table XI below compares response frequencies for detections across the three confidence categories. In this table, cell entries represent the number of detections made by the average person at the confidence represented by the cell. Thus 361 detections were made by eight people at confidence level 1 with the positive image display yielding the 45.125 of the first cell.

TABLE XI  
CONFIDENCE BY POLARITY FOR DETECTIONS

Display Polarity	Confidence		
	1 (High)	2 (Medium)	3 (Low)
Positive	45.125	9.000	3.750
Negative	34.700	12.000	2.891

By utilizing marginal totals in table XI to derive expected frequencies, the hypothesis of independence of the distributions was tested. The computed value of chi square was 1.61 with two degrees of freedom. The associated probability is over .3, hence it is concluded that there is no significant difference between the two displays with respect to the distribution of confidence judgments.

Table XII gives average frequencies in the three confidence categories for the two display types for false positive responses.

TABLE XII

AVERAGE FREQUENCIES FOR FALSE POSITIVE RESPONSES BY CONFIDENCE LEVEL FOR POSITIVE AND NEGATIVE DISPLAYS

Polarity	Confidence		
	1 (High)	2 (Medium)	3 (Low)
Positive	57.000	25.625	10.250
Negative	24.100	37.000	12.500

A chi-square test was performed on this confidence by polarity table, using marginal totals to compute expected values. The value of chi square was 13.6 with two degrees of freedom. Since the probability of obtaining such a large chi square by chance is less than .01, the relative frequencies of utilization of the three confidence categories for responses to false positives was significantly different for the two types of display.

The differences in utilization are given in table XIII compiled from the data in table X. Each table entry is the percentage of false positive responses for the particular confidence level. The medium and low confidence categories were both used approximately twice as often for false positives by subjects using the negative image display. Conversely, users of the positive display rated about twice as many of their false positive responses as high confidence detections.

TABLE XIII

DISTRIBUTION OF PERCENTS OF FALSE POSITIVE RESPONSES ACROSS CONFIDENCE LEVELS

Polarity	Confidence			Total
	1 (High)	2 (Medium)	3 (Low)	
Positive	61.4%	27.7%	11.0%	100%
Negative	32.7%	50.3%	17.0%	100%

The probability that a target would be detected is a function of many variables, and it appears reasonable to hypothesize that larger targets are more likely to be detected. To check this hypothesis, the maximum linear dimension of each target was correlated with the number of people that detected that target. The probability of detection of a target is the number of persons detecting the target divided by the number of people who had a chance to detect it, 9 on the positive and 10 on the negative display. Since probability and persons per target are related in a simple linear fashion, the computed correlations are also the correlations between maximum target dimension and probability of detection.

The mean of the distribution of maximum target dimensions for bridges was less than one-sixth as large as the mean for any of the other three main types of targets (see table XIV), and the bridge distribution had almost no overlap with the other three distributions. The other three target size distributions had much overlapping. Thus, any combination of target types that included bridges would have a bi-modal frequency distribution of target length. Hence, no correlations for bridges combined with other types of targets were computed.

The correlation between probability of detection and maximum target dimension on the display is listed in table XV for the four target types and for certain combinations of target types. Target type (5), railroad yards ( $R_2$ ), is for all railroad yards with a detection probability greater than 0. This category was included because there were so many 0 detection probability railroad yard targets: 19 out of 49 on the positive display and 23 out of 49 on the negative display.

All of the correlations in this table are positive and almost all are, by one-tailed statistical tests, significantly greater than zero. On both types of displays, correlations of detection probability with maximum target dimension are significantly greater than zero at the .01 confidence level for airfields, bridges, cities, airfields plus cities, and airfields plus cities plus railroad yards. For railroad yards, excluding targets detected by no subject, the correlation for the positive display is significant at the .025 level, but for the negative display there is no significance at the .05 level. Thus, on both positive and negative image displays, the probability that a target will be detected increases as the maximum dimension of the target increases. Figure 7 is a scatter-diagram of detection probability versus size for airfields on the positive display. Figure 8 is a scatter plot of detection probability versus maximum target dimension on the display for the 78 bridges on the negative image display.

Correlations were computed between probability of detection and area on the display of the minimum rectangle that would enclose the target for two types of target. For airfields on the negative display the correlation was .5247 and for cities on the negative display the correlation was .3617. These values are less than those listed in table XV, hence no further correlations between area and probability of detection were computed.

TABLE XIV

MAXIMUM LINEAR DIMENSION OF TARGETS IN MILLIMETERS  
ON THE DISPLAY SCREEN

Target	Polarity	n	Mean	S. D.
Airfield (AF)	Positive	21	11.76	5.98
	Negative	20	11.60	6.11
Bridges (BR)	Positive	80	1.81	1.99
	Negative	78	1.75	1.86
Cities (C)	Positive	76	29.12	51.59
	Negative	66	27.35	49.32
Railroad Yards (R <sub>1</sub> )	Positive	49	13.29	6.03
	Negative	49	13.29	6.03
R <sub>1</sub> Less 0 Detection	Positive	30	15.38	6.46
Probability Targets	Negative	26	14.97	6.47
(AF) plus (C)	Positive	97	25.08	33.62
	Negative	145	23.94	43.85
(AF) plus (C) plus (R <sub>1</sub> )	Positive		20.80	38.12
	Negative		38.20	35.57

TABLE XV

CORRELATIONS BETWEEN MAXIMUM TARGET DIMENSION AND  
PROBABILITY OF DETECTION

Target Type	Positive Display		Negative Display	
	n	r	r	n
(1) Airfields (A)	21	.7716**	.6548**	20
(2) Bridges (B)	80	.3554**	.4584**	78
(3) Cities (C)	76	.2721**	.5411**	66
(4) Railroad Yards ( $R_1$ )	49	.4832**	.2940*	49
(5) Railroad Yards ( $R_2$ )	30	.3997*	.1614	26
(6) A + C	97	.2393**	.3601**	86
(7) A + C + $R_1$	146	.2657**	.3711**	135

NOTE: All tests of significance are by one-tailed tests, two asterisks indicate significance at the .01 level; one asterisk indicates significance at the .025 level. The single correlation that is unmarked is not significant at the .05 level. The ( $R_2$ ) railroad yards include all ( $R_1$ ) railroad yards except those with a 0 detection probability. Differences between the n's for the two types of displays are discussed in the text.

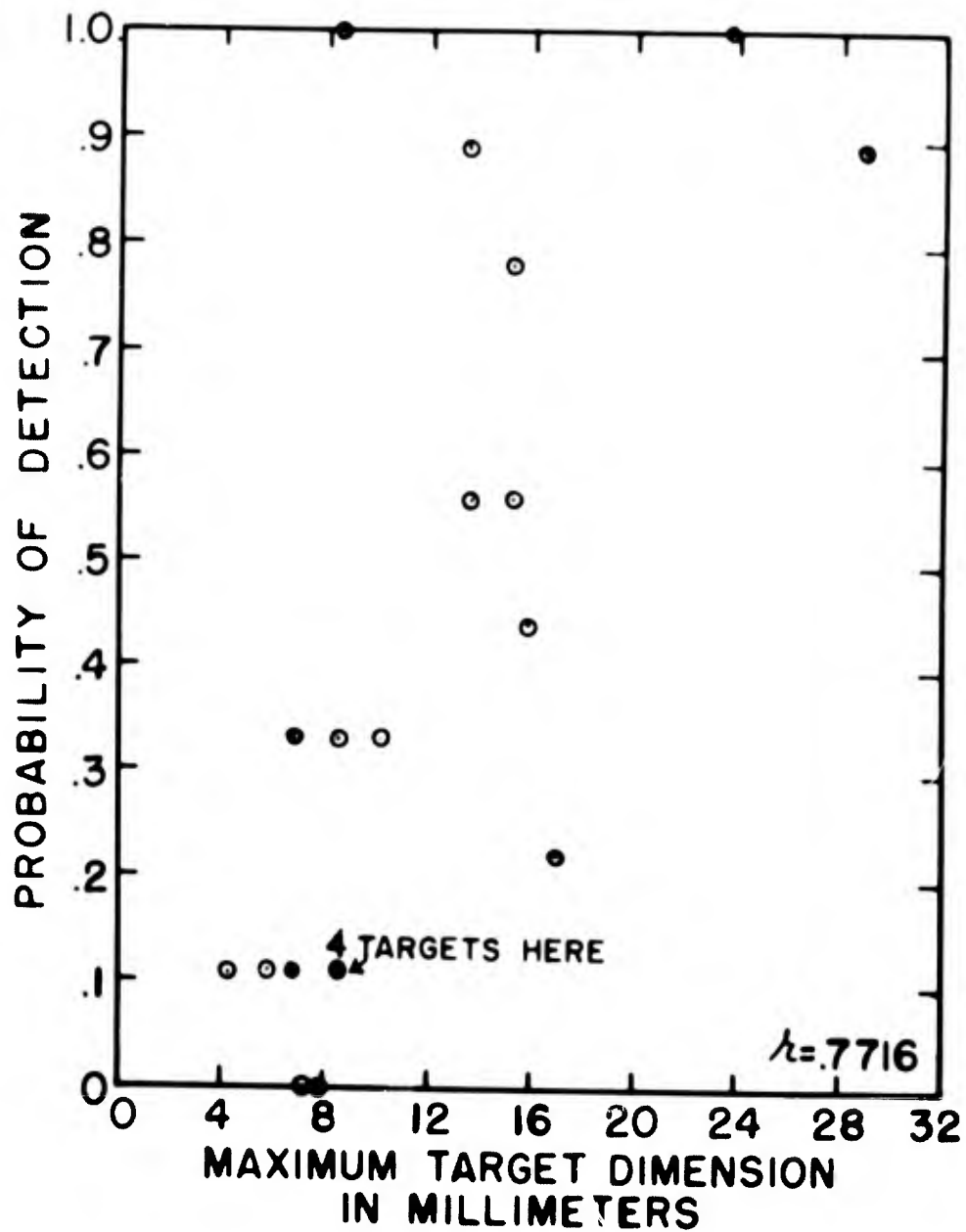


Figure 7. Probability of detection versus maximum target dimension on the display for the 21 airfields on the positive display.

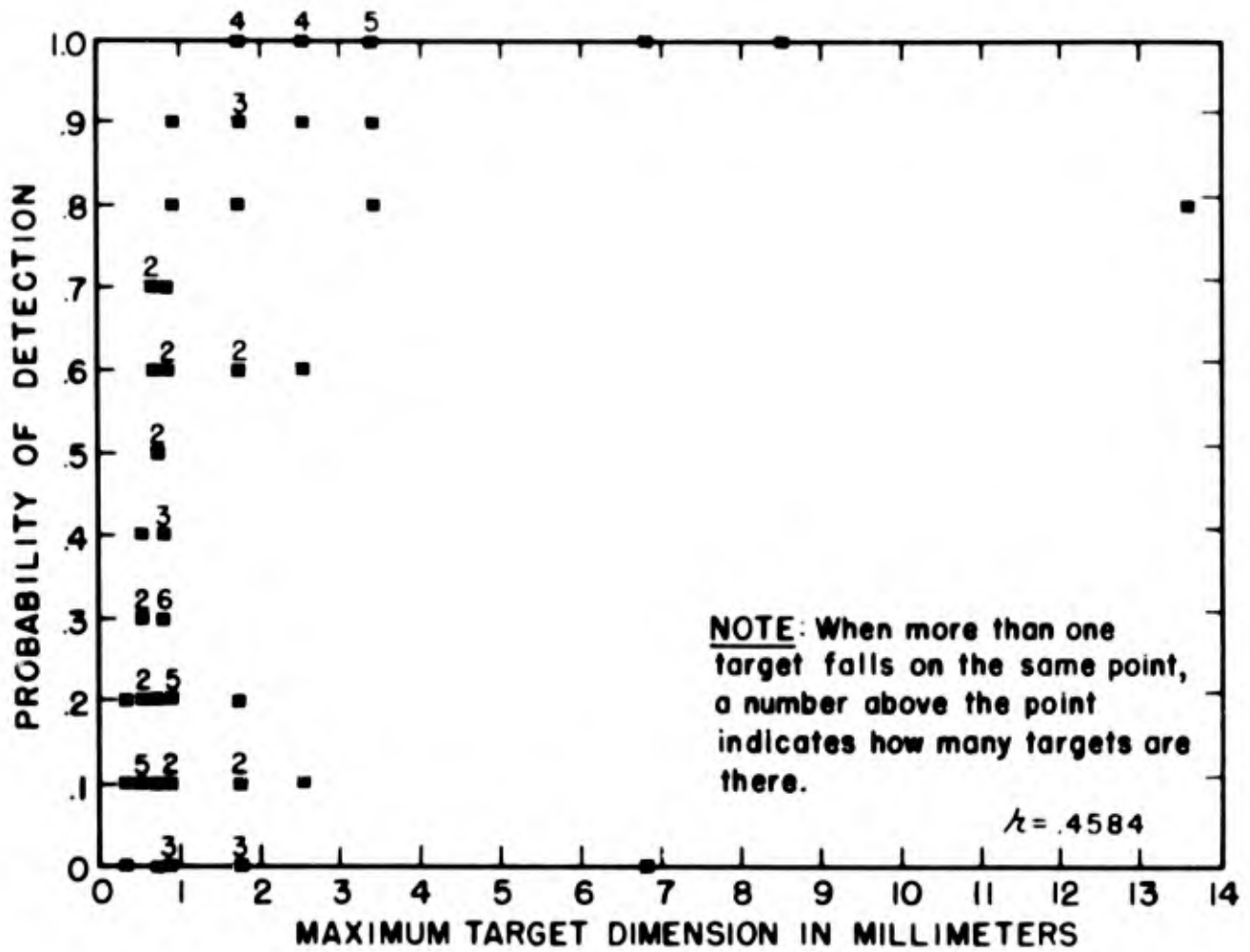


Figure 8. Probability of detection versus maximum target dimension on the display for the 78 bridges on the negative image display.

## SECTION V

### SUMMARY OF STATISTICAL ANALYSES

#### A. Detection

The average subject on the positive display detected significantly more targets and detection took significantly less time than was the case for the average subject on the negative display. Although his detection performance was superior, the subject on the positive display did not express significantly greater confidence in his detections. On both displays, some types of targets were detected significantly more often than others. However, the relative detection frequencies were not significantly different for the two types of displays. For both types of displays, and for all types of targets and combinations of types investigated, where 0 detection targets were not excluded, there was a positive correlation significantly different from 0 between the probability of detection of a target and its maximum dimension on the display.

#### B. False Positives

Although the negative group reported fewer false positives, statistical tests revealed that the average subject on the positive display did not differ significantly from the average negative display subject in the number of false positive responses he made, nor in the percentage of his responses that were false positives. However, he was much more likely to have high confidence that a false positive was a target than was the average negative display subject.

Although every subject responded to more false positives than to genuine targets, statistical tests show that the number of false positives reported by the average subject in either group was not significantly different from the number of targets he detected. In addition, for both groups positive correlations were found between the number of false positives and the number of detections, although only for the negative display group was the correlation (.889) significantly different from zero.

In both groups there is a significantly greater variability in the number of false positives than in the number of detections.

## SECTION VI

### DISCUSSION AND CONCLUSIONS

In this study the positive image display was significantly superior to the negative image display in two respects: (a) number of targets detected and (b) rapidity of target detection. They were statistically equivalent with respect to the number of false

positives. These results could have been produced by one or more of many variables, including experience, training, conscious or unconscious bias, etc. Previous radar training and experience of the subjects had been predominantly with positive rather than negative radar images. The subjects were required to serve in several positive image experiments; therefore, the amount of negative side-looking radar experience and training for negative image group was necessarily limited. A relatively small part of training was devoted to negative images.

A small image quality bias in favor of the positive material was found. This bias occurred despite efforts to produce films of equal quality. An adjustment in the form of a reduced number of detectable targets was made prior to data collection. However, this procedure probably did not remove all of the image quality bias. Some of the remaining targets were not fully equal in quality to the corresponding positive image targets.

The small amount of training received on negative radar imagery was not adequate to equalize performance of the positive and negative image groups. It is hypothesized that most, if not all, of the superiority of the positive group is due to training, and would disappear if training could be equalized, and if quality bias of the stimulus material could be completely compensated for or eliminated.

Due to the limitations of this study, final judgment must be reserved on the relative merits of positive and negative side-looking radar displays. The crucial experiment on radar image polarity is not likely for some time, since the difficulties of obtaining highly-trained positive and negative subject groups with equivalent backgrounds and experience is an almost insurmountable problem. Further research in image polarity should be undertaken.

## APPENDIX

In this experiment you will be viewing (negative or positive) radar imagery. You will not be briefed on the geographic location of the terrain or on the direction of flight. You will be viewing terrain within the Continental United States.

The ground area covered will be 34 nautical miles wide, displayed on a 14 by 14 inch screen. The simulated aircraft speed is 950 knots.

The targets for this experiment are:

1. Airfields - all sizes, both military and civilian.
2. Bridges.
3. Cities - city size will vary from very large, filling the entire screen, to very small. All cities regardless of size should be identified.
4. Railroad Yards.

When you have located a target indicate your confidence in the accuracy of your response. This is done by pushing one of the three confidence level switches. For a particular target, confidence may be high, medium or low.

The same procedure is used for recording responses as in previous experiments.

1. Locate target.
2. Push switch identifying target classification.
3. Push switch to indicate confidence level.
4. Point to target with stylus and push data insertion switch to "Record" position. Continue searching for targets.

Questions?

The subject was then cautioned not to allow his head to obscure the picture taken by the data camera.

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13 ABSTRACT

This study examines the effects of display polarity on the performance of subjects searching for specific targets on a side-looking radar (SLR) display. SLR imagery was displayed on a 14 by 14 inch display at a scale of 1: 176,000 and at 950 knots simulated aircraft speed. Nineteen SAC and TAC radar navigators were randomly assigned to two groups. One group was tested on a positive copy and the other on a negative copy of the same film. The average subject on the positive display detected significantly more targets (38.4%) than the average subject (32.1%) on the negative display. Target detection times on the positive display were significantly shorter. There was no significant difference between groups in number of responses to nontarget objects. For detections the distributions of confidence judgments were not significantly different, however for nontarget objects the negative group was only half as likely to express high confidence that they were targets. For both types of display there were positive and significant correlations between maximum target dimension and probability of detection. When the large training bias favoring the positive group is considered, it appears unlikely that either polarity should be considered as definitely superior for systems applications.

14  KEY WORDS  Military Psychology Military Operations Radar, Side-Looking Reconnaissance Target Recognition Human Behavior Displays	LINK A		LINK B		LINK C	
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