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NOV 76 J A BARNES, N W DOSS

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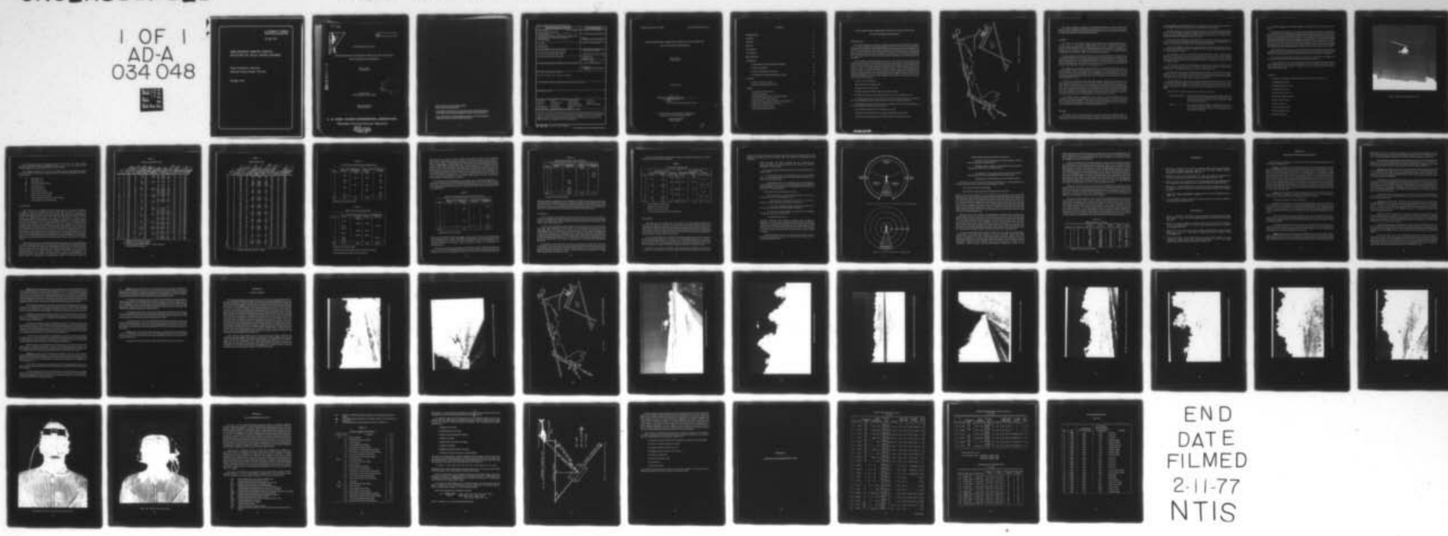

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HUMAN ENGINEERING LABORATORY CAMOUFLAGE APPLICATIONS TEST (HELCAT) OBSERVER PERFORMANCE

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

November 1976

Technical Memorandum 32-76

HUMAN ENGINEERING LABORATORY CAMOUFLAGE APPLICATIONS TEST (HELCAT) OBSERVER PERFORMANCE

John A. Barnes
N. William Doss

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This study recorded the target-detection ranges achieved by 10 combat-qualified U.S. Army aviators flown on nap-of-the-earth route reconnaissance against camouflaged tanks, and their target detection times when performing the pop-up maneuver against the camouflaged tanks. On 10 of the 20 day flights the aviators' eye movements and fixation points were recorded, and the aviators wore the AN/PVS-5 night vision goggles on 10 of the 20 night flights.

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CONTENTS

HUMAN ENGINEERING LABORATORY CAMOUFLAGE APPLICATIONS TEST

(HELCAT) OBSERVER PERFORMANCE

INTRODUCTION

The Human Engineering Laboratory conducted the air-to-ground target-detection segment of a U.S. Army interagency camouflage applications study (3). This is a report on the aircrew target-detection performance against pattern-painted and augmented-netting camouflaged heavy tanks. The camouflage and the camouflage techniques used, and the rationales for their use, are not a part of this report, but the reader should be aware that the placement of the camouflage used for this study was done and/or supervised by a sergeant who was a meticulous woodsman. We would suspect that his work was at least partially responsible for the effectiveness of the camouflage.

The test flights were flown during the second week of June 1976 over the Perryman Vehicle Road Test area of Aberdeen Proving Ground. This area is generally flat, with an elevation range of 39 to 49 feet above sea level, and has forest land with tree heights to 50 feet bordering the vehicle test roads. A test flight consisted of nap-of-the-earth route reconnaissance along the Test Highway, Figure 1, to the pop-up position, followed by a series of three or less 60-second pop-up maneuvers from this position. The observers had a 1600- to 1800-meter line-of-sight to the route-reconnaissance targets, and a 720- to 860-meter line-of-sight from the pop-up position to the pop-up targets. The tests were flown during the hours of 1000 to 1500 on 16 and 18 June 1976, 2200 to 2400 on 17 June, and 0100 to 0300 on 18 June 1976. The observers flew the tests under four different conditions:

(1) Day with no encumberances

(2) Day wearing the Eye-Mark system

(3) Night with no encumberances

(4) Night wearing the AN/PVS-5 Night Vision Goggles (NVG)

The objectives of the air-to-ground detection portion of the camouflage tests were:

(1) Determine the range at which trained U.S. Army pilot/observers can be expected to detect a camouflaged heavy tank when flying a nap-of-the-earth route reconnaissance.

(2) Determine the length of time that it can be expected to take a trained pilot/observer to find a camouflaged tank from the pop-up maneuver.

(3) Determine the pilot/observers' single-glance search time.

(4) Determine the pilot/observers' maximum target single-glance/dwell time.

(5) Determine the effectiveness of the AN/PVS-5 NVG as a target-detection aid.

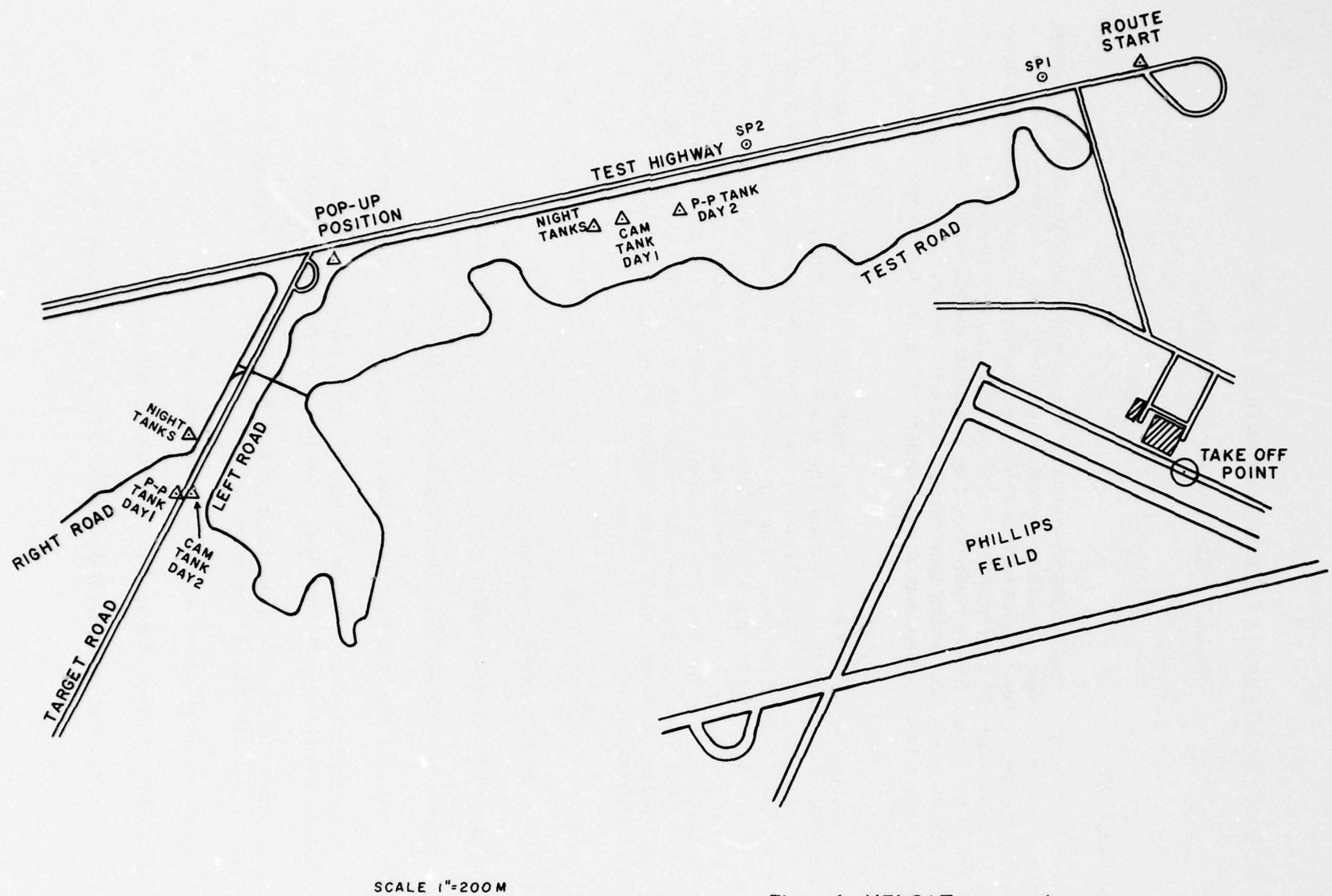

Figure 1. HELCAT route and targets.

The Human Engineering Laboratory has published the results of several low-level and nap-of-the-earth air-to-ground target-detection studies since 1973 in which the data have been reported using a common format so that the user could easily compare the results across studies; the results of these tests are also reported in that format.

SUMMARY

The results of the air-to-ground portion of the interagency Camouflage Applications Test showed that an operational combat-trained U.S. Army pilot/observer flying a route-reconnaissance mission at a mean altitude of 34 feet over flat terrain at an average speed of 40 knots can be expected to detect a pattern-painted heavy tank parked in or adjacent to a wooded area at a mean slant range of 710.3 meters; if the tank has an augmented-netting camouflage, the mean detection range can be expected to be 319 meters.

The pop-up maneuvers were performed at a mean altitude of 88 feet and a mean slant range to the target of 862 meters. Under these conditions it can be expected that the pilot/observer will require 36.6 seconds to locate a pattern-painted heavy tank parked adjacent to a wooded area. The pattern-painted tank was detected by 90 percent of the pilot/observers. The augmented-netting camouflaged tank was detected by 40 percent of the pilot/observers using the pop-up maneuver, and it required a mean time of 95 seconds to locate it.

The night-route reconnaissance trials were flown at a mean altitude of 66 feet and at an average speed of 44 knots. The pilot/observers were unable to locate the targets without the aid of the AN/PVS-5 night-vision goggles; with the goggles the pattern-painted heavy tank was detected at a mean slant range of 515 meters with 60 percent of the pilot/observers successful, and the augmented-netting camouflaged heavy tank was detected at a mean range of 557 meters with an 80 percent success.

The night pop-up maneuvers were performed at a mean altitude of 62 feet and at a mean slant range to the target of 721 meters. The mean AN/PVS-5 augmented detection times were 102.5 seconds for the 80 percent of the pilot/observers who located the pattern-painted heavy tank, and 67.5 seconds for the 40 percent who located the augmented-netting camouflaged heavy tank. It has not been determined why more pilot/observers were able to detect the camouflaged tank and at a slightly greater range than the pattern-painted tank. The camouflaged tank used for the pop-up target had its camouflaged/shielded infrared driving lights turned on; this could have had an effect on the detections, as the goggles have some sensitivity to this light.

The inflight eye-scan measurements taken during this study determined that the pilot/observers spent an average of 0.9 seconds on any one item during their search for the target; once they had located the target, it took them 6 seconds to decide that it was the target. The eye-scan measures indicated that in general the pilot/observers did not follow the search patterns set forth in FM 1-80, Aerial Observer Techniques and Procedures (2).

METHOD

The flight course for this study followed the center line of the Test Highway (Figure 1), from the start point to the pop-up position, a distance of 2640 meters. The start point was marked with a 4 x 8 foot vertical Fire Orange panel placed approximately 20 meters to the right of the Test Highway; the pop-up position was also marked with a similar panel and a horizontal 4 x 8 foot Saturn Yellow panel with a black arrow indicating the pop-up heading.

The target tanks for the route-reconnaissance portion of the test flights were positioned to the left of the Test Highway at distances ranging from 100 to 122 meters. The target tanks for the pop-up portion were positioned at a distance from the pop-up position of 722 meters for the night trials, and at 853 and 863 meters for the day trials.

The day air-to-ground detection trials were flown at a mean Above Ground Level (AGL) of 34 feet for the route reconnaissance and 88 feet for the pop-up maneuver. The night trials were flown over the same route with mean AGLs of 66 and 62 feet respectively.

All of the test flights were flown by the same pilot from Aberdeen Proving Ground. The use of a single well-trained pilot intimately familiar with the test course eliminated the need for aircraft-tracking instrumentation.

The helicopter's altitude was measured by ground observers using a sighting device developed for this study to provide an accurate AGL measurement at levels where available aircraft instruments were inaccurate. These ground observers were situated at a point along the Test Highway where it had been calculated that the majority of the detections would occur, and at the pop-up position.

The 10 subjects who flew these test flights were all helicopter pilots from the 82d Airborne Division; eight were members of the 1-17th Cavalry, and two were members of the Aviation Battalion. Each of these pilot/observers flew 2-day trials and 2-night trials.

One of the day trials was flown unencumbered and, on the other, the observer was wearing a modified Eye-Mark eye-movement recording system. The Eye-Mark system was used on alternate flights during the two day flight sessions to cancel any learning effects and to give an evaluation of its effect, if any, on the observer's target-detection performance.

The night flights were flown first with no encumberances, and then with the observer using the AN/PVS-5 night-vision goggles. The two nights on which these trials were flown were, except for the last hour of the last night, very dark with an overcast such that only one observer saw any target without the use of the NVG; thus we did not use the alternate procedure as with the day flights.

The subjects were each given a mission flimsy which read as follows:

Route Reconnaissance---	We have received a report that an armored vehicle is located to the southeast (left) of Three Mile Road approximately 2500 meters from the Askania Loop. We need a verification of the vehicle location and identity.
Pop-Up------------------------	The target is located about 1000 to 1500 meters to the south of your position. Come up, identify it and fire (camera gun) on it. If you have not been able to locate it after three pop-ups break off, and return to the base.

All flights originated on the taxiway adjacent to the control tower at Phillips Army Air Field.

The OH-58 aircraft (Figure 2) was equipped with a skid-mounted camera that filmed the area to the west of the Test Highway through a wide-angle (92^{o}) lens at the rate of 4 frames per second. The camera system contained event lights which, when triggered by the subject, marked the frame at which the event occurred. There were five numbered 4 x 8 foot Fire Orange vertical panels placed 120 meters from the Test Highway at surveyed intervals of 500 meters. The flight film of these panels with the event-marked frames allowed us to pinpoint the aircraft's position at the time of an event occurrance. To verify the events we also recorded all conversation transmitted from the aircraft; the observers had been briefed to announce the range and bearing of the targets when they had detected them, as well as to press the event marker "pickle switch."

When the Eye-Mark system was in use, a second camera recorded the scene the observer was scanning and the point in this scene that he was fixating upon. This camera also was equipped with the event-marker lights and marked the frame of interest when the lights were triggered.

The same aircraft-positioning procedure was used for the night flights; coded lights were placed on the vertical panels so that they could be identified on the film.

The pop-up detections were film-scored by the use of the event-marked frames and observer audio announcements as in the route-reconnaissance trials. An additional data source was the pilot's audio report of the number of seconds he was into the pop-up maneuver when the observer detected the target.

RESULTS

The study was designed to provide the following information for each detection:

(1) Single-glance duration

(2) Single-glance field of view

(3) Maximum dwell time

(4) Slant range at detection

(5) Depression angle at detection

(6) Pop-up time to detect

(7) Search direction

(8) Aircraft altitude (AGL)

(9) Aircraft ground speed

(10) Aircraft heading

Figure 2. OH-58 with skid-mounted camera.

An Eye-Mark eye-movement recording system was used on 20 of the 40 day-flight trials, and the AN/PVS-5 night-vision goggles were used on 20 of the 40 night trials. The AN/PVS-5 goggles did not provide data for items 1 and 3 of Table 1.

Forty additional detection trials were flown as control trials; on these flights the subjects were unencumbered and performed as shown in Table 2. The following abbreviations are used in Tables 1 and 2:

D	Day-Flight Trial
N	Night-Flight Trial
RR	Route-Reconnaissance tactic
PU	Pop-up maneuver
C	Camouflaged target
PP	Pattern-painted target
*	Subject did not find the target
x	Subject not on correct target
z	Aircraft engine failure prior to pop-up maneuver
n	No Eye-Mark data on this flight trial

Target Detection

Table 3 lists the route reconnaissance detection range scores for each observer and indicates the flights on which the Eye-Mark system was worn. The mean value of the normal or unencumbered observer's target-detection range was 236 meters against the camouflaged tank and 828 meters against the pattern-painted tank. When the observers were wearing the Eye-Mark system, the target-detection ranges were 284 and 703 meters. A t-test of the unencumbered-observer target-detection scores produced a value for t of 3.83, which indicates that there was a significant, at the .01 level of probability, difference in the detection ranges at which the pattern-painted and camouflaged tanks were seen. The test was applied to the Eye-Mark detection scores, and the value of t was 2.05, which is significant at the .10 level of probability. Many experimenters do not consider this level significant, but it does indicate that the camouflaged tank was more difficult to see than its pattern-painted counterpart. The data from Table 3 were further tested to determine if there was any significant differences in target-detection-range performance when the subjects were wearing the Eye-Mark system. The value of t for the subjects against the camouflaged tanks was .36, and against the pattern-painted tanks it was .57. These values of t indicate that there was no significant difference in the subjects' target-detection-range performance that could be charged to their wearing of the Eye-Mark system.

Table 4 lists the times it took the observers to detect the tanks on the pop-up-flight trials. The mean target-detection time for the normal observer configuration against the pattern-painted tank was 42.20 seconds, and against the camouflaged tank the value was 75.00 seconds. The pop-up data were subjected to the t-tests, and the target-detection times for the unencumbered observers against the tank configurations gave a t-value of 1.88, which does not denote any significant difference in the time it took an observer to detect the camouflaged or the pattern-painted tank. The Eye-Mark mean detection time against the pattern-painted tank was 68.33 seconds. The comparison of target-detection times for the observers against the

TABLE 1

Eye-Mark and AN/PVS-5 Data

Subject	Day Flight/ Night Flight	Mission Type	Pattern-Painted Camouflaged	Single Glance Duration (Sec.)	FOV (Degrees)	Maximum Dwell Time (Sec)	Slant Range (Meters)	Depression Angle (Arc Sine)	Search Direction (Degrees)	AGL (Feet)	Ground Speed (Knots)	Heading (Degrees)
1	D	RR	C	.75	60	6.50	478	.1358	197	65	40	210
1	D	PU	PP	.25	60	3.00	867	.1003	168	87	0	167
1	N	RR	PP	-	40	-	744	.0940	202	70	40	210
1*	N	PU	C	-	40	-	*	*	*	62	0	180
2	D	RR	PP	.50	60	5.50	970	.0288	193	28	44	210
2*	D	PU	C	.75	60	*	*	*	*	91	0	167
2	N	RR	C	-	40	-	643	.0933	201	60	42	210
2*	N	PU	PP	-	40	-	*	*	*	46	0	180
3	D	RR	C	1.75	60	6.25	378	.0396	193	15	36	210
3	D	PU	PP	.50	60	5.00	866	.0900	168	78	0	167
3	N	RR	PP	-	40	-	638	.0940	201	60	44	210
3	N	PU	C	-	40	-	725	.1242	180	90	0	180
4	D	RR	PP	.50	60	4.50	457	.0656	194	30	44	210
4x	D	PU	C	.50	60	8.00	x	.1037	x	89	0	167
4*	N	RR	PP	-	40	*	*	*	*	55	44	210
4	N	PU	C	-	40	-	721	.0693	180	48	0	180
5	D	RR	PP	.75	60	4.00	457	.0547	194	25	42	210
5*	D	PU	C	.75	60	*	*	*	*	66	0	167
5*	N	RR	PP	-	40	*	*	*	*	95	46	210
5*	N	PU	C	-	40	*	*	*	*	56	0	180
6	D	RR	C	.75	60	4.63	281	.1030	187	29	38	210
6x	D	PU	PP	.50	60	4.00	x	.1071	x	93	0	167
6	N	RR	C	-	40	-	828	.0422	203	35	43	210
6	N	PU	PP	-	40	-	721	.0735	180	60	0	180
7	D	RR	PP	.50	60	5.25	482	.0414	195	20	43	210
7*	D	PU	C	.75	60	*	*	*	*	90	0	167
7	N	RR	C	-	40	-	143	.3495	163	50	44	210
7	N	PU	PP	-	40	-	721	.0790	180	56	0	180
8*	D	RR	C	n	60	*	*	*	*	40	38	210
8	D	PU	PP	.75	60	13.25	868	.1071	168	95	0	167
8	N	RR	PP	-	40	-	164	.5189	164	85	48	210
8*	N	PU	C	-	40	-	*	*	*	55	0	180
9	D	RR	PP	.75	60	8.00	519	.0482	196	25	42	210
9	D	PU	C	3.50	60	8.75	858	.1026	167	92	0	167
9*	N	RR	C	-	40	-	*	*	*	45	41	210
9	N	PU	PP	-	40	-	720	.0624	180	45	0	180
10	D	RR	PP	1.67	60	2.25	1335	.0149	204	20	43	210
10z	D	PU	C	z	60	z	z	z	z	z	z	z
10	N	RR	C	-	40	-	614	.0896	203	55	43	210
10	N	PU	PP	-	40	-	721	.0652	180	46	0	180

* Subject did not find the target
x Subject not on correct target
z Aircraft engine failure prior to pop-up maneuver
n No Eye-Mark data on this flight trial

TABLE 2

Unencumbered Data

Subject	Day Flight/ Night Flight	Mission Type	Pattern-Painted Camouflaged	Slant Range (Meters)	Depression Angle (Arc Sine)	Search direction (Degrees)	AGL (Feet)	Ground Speed (Knots)	Heading (Degrees)
1	D	RR	PP	1138	.0263	204	30	41	210
1*	D	PU	C	*	*	*	87	0	167
1*	N	RR	PP	*	*	*	60	45	210
1	N	PU	C	725	.1242	180	90	0	180
2	D	RR	C	305	.1147	190	35	39	210
2	D	PU	PP	868	.1094	168	95	0	167
2*	N	RR	C	*	*	*	100	44	210
2*	N	PU	PP	*	*	*	45	0	180
3	D	RR	PP	439	.0911	194	40	49	210
3	D	PU	C	857	.0956	167	82	0	167
3*	N	RR	PP	*	*	*	60	42	210
3*	N	PU	C	*	*	*	85	0	180
4	D	RR	C	188	.2387	175	45	37	210
4	D	PU	PP	868	.1037	168	90	0	167
4*	N	RR	PP	*	*	*	55	46	210
4*	N	PU	C	*	*	*	50	0	180
5	D	RR	C	117	.2826	174	33	36	210
5	D	PU	PP	867	.1003	168	87	0	167
5*	N	RR	PP	*	*	*	65	50	210
5*	N	PU	C	*	*	*	32	0	180
6	D	RR	PP	447	.0559	194	25	43	210
6	D	PU	C	858	.1072	167	92	0	167
6*	N	RR	C	*	*	*	39	46	210
6*	N	PU	PP	*	*	*	64	0	180
7	D	RR	C	200	.4005	175	80	40	210
7	D	PU	PP	867	.1003	168	87	0	167
7*	N	RR	C	*	*	*	45	42	210
7*	N	PU	PP	*	*	*	52	0	180
8	D	RR	PP	860	.0407	202	35	44	210
8	D	PU	C	858	.1037	167	90	0	167
8*	N	RR	PP	*	*	*	90	49	210
8*	N	PU	C	*	*	*	54	0	180
9*	D	RR	C	*	*	*	35	33	210
9	D	PU	PP	868	.1116	167	97	0	167
9*	N	RR	C	*	*	*	40	43	210
9*	N	PU	PP	*	*	*	50	0	180
10	D	RR	C	605	.0446	200	27	34	210
10	D	PU	PP	868	.1037	168	90	0	167
10*	N	RR	C	*	*	*	60	42	210
10*	N	PU	PP	*	*	*	60	0	180

* Subject did not find the target

TABLE 3

Route Reconnaissance Detection Ranges (Meters)

Subject	Day 1 Camouflaged Tank		Day 2 Pattern-Painted Tank	
	Normal	Eye-Mark	Normal	Eye-Mark
1		478	1138	
2	305			970
3		378	866	
4	188			457
5	117			457
6		281	447	
7	200			482
8		*	860	
9	*			519
10	605			1335
Mean	236	284	828	703

*Observer did not find the target

TABLE 4

Pop-Up Detection Times (Seconds)

Subject	Day 1 Pattern-Painted Tank		Day 2 Camouflaged Tank	
	Normal	Eye-Mark	Normal	Eye-Mark
1		26.00	*	
2	34.50			*
3		29.00	90.00	
4	20.50			82.50x
5	22.00			*
6		36.00x	45.00	
7	86.00			*
8		150.00	90.00	
9	40.00			155.00
10	50.00			z
Mean	42.20	68.33	75.00	155.00

* Subject did not find the target

x Subject not on correct target; scores not used in calculations.

z Aircraft engine failure prior to pop-up maneuver pattern-painted tank yielded a t-value of 0.86, which indicates that there was no significant difference in the observer's performance when he was wearing the Eye-Mark system. The values given in Table 4 appear to indicate that the Eye-Mark system was causing a detection problem on the Day-2 flights against the camouflaged tank. This was not the case. The descriptions of each observer's search scheme (Appendix A) indicate why the targets were not detected; observers number 4 and 7 never extended their search pattern down Target Road to the target location, yet both had done so against the pattern-painted tank when it was in place within 10 meters of the camouflaged tank's position; observers number 2 and 5 repeatedly fixated in the immediate area of the camouflaged tank during their 3 minutes of search but did not detect it. This was a typical example of the phenomenon called "Looking without seeing" (4). Figure 7B (Appendix B) shows this well-camouflaged tank in position.

The night-flight trials were designed to provide some measure of observer performance for a comparison of unaided and AN/PVS-5-augmented night-vision capability. These flight trials were flown under overcast conditions except for the last three flights when there was some moonlight showing through breaks in the overcast. Table 5 shows that no subject reported seeing either tank with unaided vision.

TABLE 5

Night Route Reconnaissance Detection Ranges (Meters)

Subject	Night 1 Pattern-Painted Tank		Night 2 Camouflaged Tank	
	Unaided	AN/PVS-5	Unaided	AN/PVS-5
1	*	744		
2			*	643
3	*	638		
4	*	*		
5	*	*		
6			*	828
7			*	143
8	*	164		
9			*	*
10			*	613
Mean	–	515	–	557

* Subject did not find the target

When using the AN/PVS-5 night-vision goggles, a mean range of 515 meters was attained against the pattern-painted tank, and the mean detection range against the camouflaged tank was 557 meters. These data give a t-value of .18, which indicates that on a dark overcast night there is no significant difference in the range at which an observer can detect a pattern-painted or a camouflaged tank.

The unaided visual pop-up performance of the observers shown in Table 6 is essentially the same as that for the route-reconnaissance trials, the one trial in which the target was seen was a detection of the tank's camouflaged driving lights. This was also the case for subject 3 using the

TABLE 6

Night Pop-Up Detection Times (Seconds)

Subject	Night 1 Pattern-Painted Tank Unaided	Night 1 Pattern-Painted Tank AN/PVS-5	Night 2 Camouflaged Tank Unaided	Night 2 Camouflaged Tank AN/PVS-5
1			30.0	*
2	*	*		
3			*	30.0
4			*	105.0
5			*	*
6	*	85.0		
7	*	85.0		
8			*	*
9	*	95.0		
10	*	145.0		
Mean	–	102.5	30.0	67.5

* Subject did not find the target

AN/PVS-5 night-vision goggles; he too saw the lights. The AN/PVS-5 mean detection time for the camouflaged tank was 67.5 seconds, and it was 102.5 seconds for the pattern-painted tank. These data give a t-value of 1.1, which indicates no significant difference in the detection times. There were breaks in the overcast conditions, and some moonlight was present for the flight trials of subjects 6, 7, and 9; this may have enhanced their chances of detecting the targets.

Eye Movement

The eye-movement measuring device used for these trials had a field of view of 60°. It allowed us to determine how long the subject fixated on any one item in the real world during his search for the targets and how long he looked at the briefed target before he pressed the "pickle switch." Table 7 shows these values.

On the route-reconnaissance trials the subjects' mean fixation time for the pattern-painted tank before they actuated the "pickle switch" was 4.92 seconds; the mean time for the camouflaged tank was 5.79 seconds. For the pop-up trials the mean fixation time against the pattern-painted tank was 7.08 seconds, and the one subject who found the camouflaged tank fixated for 8.75 seconds before actuating the switch. A t-test of the data indicates that there were no significant differences between the route-reconnaissance fixation times for the pattern-painted and the camouflaged tanks; the t-value was .73. Only one subject found the camouflaged tank on the pop-up trials; therefore there was no appropriate way to test these data for significant differences.

A comparison of the fixation data for all route-reconnaissance trials and that for all pop-up trials showed a mean fixation time for the route-reconnaissance trials of 5.21 seconds and one of 7.5 seconds for the pop-up trials. These data yielded a t-value of 1.39, which does not show significant differences between the amount of time the observers spent looking at the target before deciding that it was indeed the target.

The use of the Eye-Mark system did not produce any significant differences in observer-target-detection performance in this study.

TABLE 7

Eye-Fixation Times (Seconds)

	Pattern-Painted Tank				Camouflaged Tank			
	Route Reconnaissance		Pop-Up		Route Reconnaissance		Pop-Up	
Subject	Search	Target	Search	Target	Search	Target	Search	Target
1			.25	3.00	.75	6.50		
2	.50	5.50					.75	*
3			.50	5.00	1.75	6.25		
4	.50	4.50					.50	8.0x
5	.75	4.00					.75	*
6			.50	4.00x	.75	4.63		
7	.50	5.25					.75	*
8			.75	13.25	n	*		
9	.75	8.00					3.50	8.75
10	1.67	2.25					z	z
Mean	.78	4.92	.50	7.08	1.08	5.79	1.25	8.75

n No Eye-Mark data on this trial

* Subject did not find the target

x Subject not on correct target

z Aircraft engine failure prior to pop-up maneuver

DISCUSSION

This flight test has provided some new insight into how the observer performed his nap-of-the-earth target-detection task. The ranges at which these observers detected the route reconnaissance targets were consistent with the results of past Human Engineering Laboratory studies, and the significant effect of the camouflage on these detection ranges was a "hoped for" result. Another result in the same category was the not-significant effect of the Eye-Mark system on the observers' detection ability; with this as a basis we will assume that the system did not alter the observers method of searching for targets.

The eye-fixation times given in Table 7 and the detailed descriptions of each observer's search technique (Appendix A), are, to the best of our knowledge, the first data of this type to be reported which were based on actual flight tests. These times indicated that the observers spent an average of 0.9 seconds inspecting an item of interest before moving on to another and that it took them an average of 6 seconds to decide that the target was indeed the target.

Department of the Army Field Manual 1-80, Aerial Observer Techniques and Procedures (2), gives the "school solution" for the two types of searches that the observers were required to perform; they are called the Motive Technique, used for the route-reconnaissance trials, and the Stationary Technique, used for the pop-up trials. The following are descriptions of these techniques:

Motive Technique. The motive technique (fig. 2) is used when the observation aircraft is operating at nap-of-the-earth altitudes and at airspeeds of generally 10 knots or faster.

(1) In this technique the observation work sector is subdivided into two smaller sectors---

(a) Acquisition sector. The acquisition sector is the forward 45^{o} area of the observation work sector. This is the observer's primary area of search in the motive technique.

(b) Recognition sector. The recognition sector is the remainder of the observation work sector to the rear of the acquisition sector. When an object is sighted in the acquisition sector, the sighting will be confirmed and identified in the recognition sector.

(2) In using the motive technique, the observer---

(a) Looks forward of the aircraft and through the center of the acquisition sector for obvious sightings (step A).

1. Over open terrain the observer should look as far forward as necessary to detect enemy direct fire threats to the aircraft.

2. Over heavy vegetated terrain the observer should look as far forward as he can detect the ground through the vegetation.

(b) Scans left to right through the acquisition sector, gradually working back toward the aircraft (step B).

(c) Repeats steps A and B.

Stationary Technique. The stationary technique (fig. 3) applies to helicopters only. It is used at nap-of-the-earth altitudes with the helicopter hovering in a concealed position. The observer may use binoculars or ranging devices to aid in his search. Although the pilot may assist the observer in his visual search, the pilot's primary concern will be aircraft control, observing in close proximity to the aircraft, and insuring the aircraft remains concealed.

(1) Sectors of search. There are no clearly defined sectors of search in the stationary technique. However, if the search area is large, it may be divided into smaller sections.

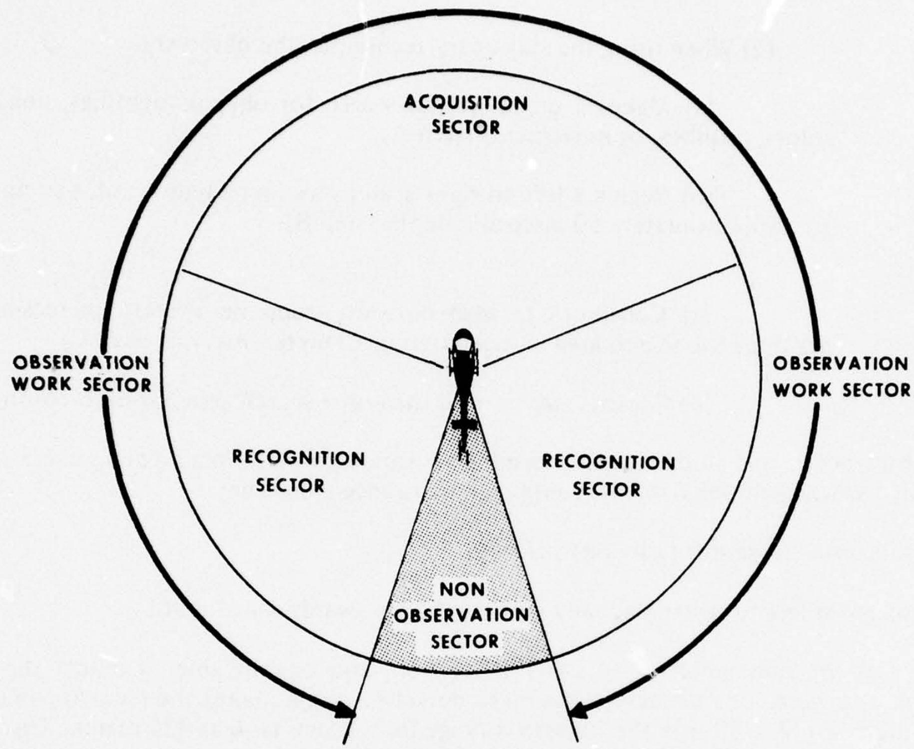

Figure 3–2. Recognition sectors, motive visual search technique. (Field Manual 1-80)

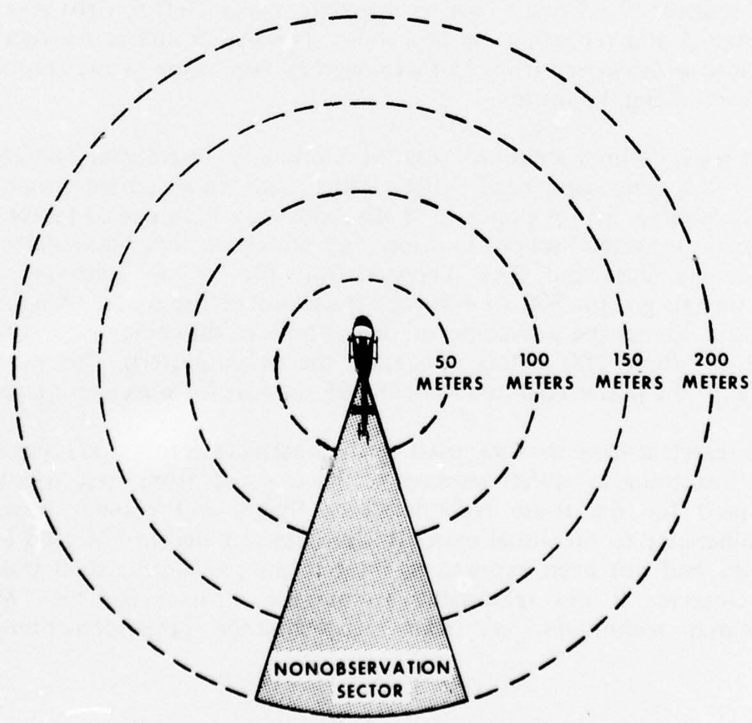

Figure 3–3. Stationary search technique. (Field Manual 1-80)

(2) When using the stationary technique, the observer---

(a) Makes a quick overall search for obvious sightings, unnatural colors, outlines, or movements (step A).

(b) Begins a left to right scan to his immediate front, searching an area approximately 50 meters in depth (step B).

(c) Continues to scan outward from the aircraft, increasing the depth of the search area by overlapping 50-meter intervals (step C).

(d) Repeats step C until the entire search area has been covered.

The observers in this study were performing an acquisition task in a medium-vegetated area; therefore the "school solution" for the route reconnaissance would be:

(a) Looks forward for obvious sightings.

(b) Scans left to right, gradually working back towards the aircraft.

Observer 9 was the only observer to use this method, and he was able to detect the pattern-painted tank at a range of 519 meters; the mean detection range against the pattern-painted tank was 710.3 meters. FM 1-80 lists the detection range for a heavy tank as 925 meters. Observer 10 had a different approach to the problem; he made one narrow scan at 550 meters from the start of the route and then went 1000 meters further down the route for three more narrow scans and saw the tank at a range of 1335 meters. The remaining eight observers used similar searching schemes which consisted of picking a spot on the route, make a left to right scan, move down the route a given interval and repeating the procedure. The search intervals varied from 50 to 500 meters, and the scan width varied from 15 to 45 degrees; also, some of the observers made several scans at each interval along the route.

The pop-up trials "school solution" was the Stationary Technique. The area of the pop-up contained three roads: one main road, with parallel roads on either side, that extended to the target area before turning. The presence of these roads may have been a factor which precluded any of the subjects using the "school solution;" all did check their immediate front area upon clearing the screening trees, but they digressed from the "school solution" after that. Their general pattern was to go out 300 to 400 meters on one of the roads, scan a sector and come back to the aircraft, repeat the procedure on one or both of the remaining roads, and then move the search point out about 200 meters and repeat the whole pattern. The mean detection time was 37.6 seconds for the pattern-painted tank and 95 seconds for the camouflaged tank.

The overall search scheme that was used by the observers in this study was a combination of "school-solution" techniques which seemed to have come from past training when higher altitudes were used for the route reconnaissance flights and combat learned tactics. The observers' non-adherence to the visual search techniques outlined in FM 1-80 (2) may well have been because they had not been exposed to these techniques during their training. The search techniques of Observer 9 did reasonably follow the outlines for the "Motive" and the "Stationary" search techniques. His route-reconnaissance target-detection range for the pattern-painted tank was less than the average, and he failed to find the camouflaged tank. His pop-up target-detection times were slightly greater than the average for the pattern-painted tank, and the greatest for the camouflaged tank, but only 40 percent of the subjects found the camouflaged tank from the pop-up position.

In order to evaluate the effect of combat experience on these observer's performance on this test, coefficients of correlation were computed between the detection scores attained and several group characteristics. The comparison of the detection ranges and the observer's combat experience gave a coefficient of correlation of .43 for the pattern-painted tank and .47 for the camouflaged tank on the route-reconnaissance trials. The same statistical treatment, applied to the total flight experience of the observers, gave a value of .48 for the pattern-painted tank and .53 for the camouflaged tank. These values indicate that the observers with the greater number of flight hours should be expected to perform a somewhat better job of target detection than those with lesser experience. When the scores against the pattern-painted tank were compared with those against the camouflaged tank the coefficient of correlation was .61; this further strengthens the preceding statement, as it indicated in this test that, if the observers' target-detection performance was good against one tank, it was also good against the other.

Coefficients of correlation for the day pop-up tactic detection times against the pattern-painted tank were .001 for combat experience and .010 for total flight experience. These values indicate that there was no relationship between these observers' experience and the amount of time that it took them to locate the target using this tactic. It was not possible to perform a valid analysis of the detection times for the camouflaged tank or of any of the night detections because of the samll number of detections in these categories.

This report, as stated previously, was only concerned with the observer performance during the air-to-ground detection phase of a large interagency camouflage-application test. All of the subjects that participated in the interagency test were given a group of written tests (Table 8); among these was one designed to test the subjects ability to find a figure imbedded in a larger, more complex drawing. The coefficients of correlation of the observers' test scores were: .28 with combat experience, .18 with total flight experience, .20 with the detection ranges against the pattern-painted tank on route reconnaissance, .09 with the detection times for that tank on pop-up, and .45 with the detection ranges against the camouflaged tank on route reconnaissance. The last correlation value indicates that this particular test would be useful as part of a criterion to select observers for reconnaissance work when camouflage is being used by the enemy.

TABLE 8

Observer-Performance Summary

Observer	Test Score	Combat Flight Time	Total Flight Time	Range RR v PP	Range RR v C	Time PU v PP
1	16	1800	2600	1138	478	26.0
2	5	521	1788	970	305	34.5
3	13	1498	3525	438	378	29.0
4	9	952	1430	457	188	20.5
5	18	0	352	457	117	22.0
6	10	434	1400	447	281	x
7	11	1000	1600	482	200	86.0
8	10	1343	2800	860	x	30.0
9	4	300	1000	519	x	40.0
10	15	1112	2800	1335	605	50.0

x Observer failed to locate the target

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APPENDIX A

OBSERVER'S SEARCH SCHEME SUMMARY

The following are summaries of each observer's search scheme during the Eye-Mark route-reconnaissance and pop-up trials:

Observer 1. Started his route reconnaissance with an out-and-back search to a point about 500 meters from the start of the route; for future use we will call this point SP 1. He then began a left-to-right scan from this point; the scan encompassed a sector of 30 degrees to either side of the point; completing this he moved to a new scan point, a tree approximately 1000 meters further down the route. For future use we will call this SP 2. From this point he scanned a 30- to 45-degree sector to the left of the tree, single-glance times of ½ to 3/4 seconds, and on the third scan he located the target. Detection range was 474 meters. Each of the last two scans was closer to the arc on which the target was located than was the previous scan. The observer's pop-up scan was slightly different, as the aircraft cleared the screening trees he was scanning to the left of the Target Road (TR) (Figure 1), and when the aircraft was at altitude he picked a scan point about 500 meters down the TR and made three 45-degree sector scans of the area to the left of TR; completing this he moved his scan down TR and located the target. Search time was 26 seconds, range 867 meters.

Observer 2. He scanned the left and right sides of the route from the start point to SP 1 and then went to SP 1 and began a systematic 15 to 20 degree left sector scan which progressed down the route at 50-meter intervals with single-glance times of ½ second.

He detected the target at a range of 970 meters.

During the climb on pop-up one he scanned about 300 meters down TR and continued out to 600 meters on achieving hover, and returned along the right side of TR and then back out along the left side of the road. He next checked the Left Road (LR) and the Right Road (RR) and back out TR to the target area, he repeated this pattern several times with single-glance times of 3/4 second. His final scan was a check of TR from the target area back to 300 meters from the aircraft.

The second pop-up began with a scan down TR to the target area and back, and a repeat on reaching hover, and a check of LR and RR; single-glance times were ½ second. He then initiated a 10-degree left-and-right sector scan along TR from the target area to the aircraft and back, which he repeated four times.

The third pop-up featured a close-in scan of the area to the left on climb out, followed by a scan down LR. Once at hover he went to the target area and then over to LR at 700 meters. He then went back onto TR and searched to the aircraft and out again to the point ending on LR. Single-glance time was 3/4 second. No detection was made.

Observer 3. At the start of the trial he immediately went out to SP 1 and made two scans to the left and right of the route, followed by a scan to the area just beyond SP 1 and one more 15-degree sector scan to the left. He then directed his attention to a point approximately 500 meters further down the route and made three 30-degree scans to the left of the route with single-glance times of ¼ to ½ second. He next moved out to SP 2 and made a 45-degree left-sector scan; on the return scan he paused for 3/4 second in the target area but continued the scan back to SP 2, and then immediately went back to the target. The detection range was 378 meters.

The pop-up trial started with the observer picking a scan point about 400 meters down TR as soon as the aircraft reached altitude, and he made a 45-degree sector scan to the left and a 30-degree sector scan to the right. He then came back to TR and moved his gaze out to the target area and saw the target. The pop-up search time was 29 seconds, range was 866 meters.

Observer 4. He scanned an area to the left of the route between the start point and SP 1, then moved out to SP 1 and started a 10- to 15-degree left-sector scan with single-glance times of ½ second. This scan pattern was systematically moved forward about 50 meters at the completion of each cycle until about 100 meters prior to SP 2, at which time he found the target. The detection range was 456 meters.

On pop-up one he scanned close-in and to the left on climb and then went to a point 150 meters ahead of the aircraft between the Left Road (LR) and the TR; from here he went out to 300 meters to a point 10 degrees right of the RR and scanned left to a point 30 degrees left of LR. He then scanned the left side of TR out to the 600-meter point and repeated this tactic on LR and RR. This was followed by a 30-degree sector scan of an area to the right of RR and a check of both sides of TR and LR to about 300 meters. He ended pop-up 1 looking at a clump to trees about 250 meters down LR.

Pop-up two search was begun the same as the first one was, but upon reaching altitude he went to the clump of trees and decided that it contained the target; it did not. The total search time was 88.5 seconds.

Observer 5. He went to SP 1 at the start of the route reconnaissance and scanned a 15-degree sector to the left of the route three times with a single-glance time of ½ to 3/4 second. He then moved out to a point halfway to SP 2 and made three more left-sector scans and then back to a large tree near the route and spent several seconds in the immediate area. He next moved out to SP 2 and made 12 fast 30-degree left-sector scans before he saw the target. Detection range was 456 meters.

During the climb on pop-up one he scanned the area close in and to the left of the pop-up position and upon reaching hover he looked down the TR about 300 meters, glancing slowly to the left and to the right with single-glance times of 3/4 second; he next scanned the right side of the road back to the aircraft. He repeated this procedure going out to 600 meters followed by the same type of scan on the LR.

He started pop-up two in the same manner as the first and on reaching hover he went out to the target area and scanned to the left and to the right along RR back to the aircraft. Then he went out LR to the target area in the same manner and back to the aircraft; this pattern was repeated twice with single-glance times of 3/4 second. Next he repeated this scan on the TR and the RR.

Pop-up three began with a scan to 300 meters down the TR which was extended to 500 meters, at hover, to a point on the left of the LR and then back to 100 meters from the aircraft. His next scan went out to 600 meters on the TR with a single-glance time of ¼ second followed by the same scan on the RR with a return to the target area and a scan of the TR back to the aircraft. The final scan of the search was of a 30-degree sector to the left of the LR at a range of 500 meters; this was repeated three times. No detection was made.

Observer 6. Upon departure he set up an out-and-back scan of the initial portion of the route and then went to SP 1 and made four 20-degree left-sector scans with single-glance times of ½ to 3/4 second. He then came back to SP 1 and spent 3 to 4 seconds in the immediate area before he moved his scan point 100 meters further down the route and made two 20-degree sector scans to the left where he saw something near the end of the second scan and actuated the event switch but did not announce a detection. He moved his scan point further down the route and did a 10-degree sector scan to the left; following this he moved to SP 2 and made another 10-degree sector scan to the left and saw the target. The detection range was 281 meters.

On clearing the screening trees on pop-up one he started a 30-degree sector scan to the left from a point 300 meters down the TR. He repeated this twice and next made a 10-degree right-sector scan followed by two 10-degree left-sector scans after which he indicated he had detected the target. This was a false detection; it occurred at 36 seconds after start of the pop-up.

Observer 7. He scanned the woods to the left of the route at 150-meter intervals out to SP 1 where he widened his sector to 45 degrees and continued the 150-meter pattern interval using a ½ second single-glance time. The target was located before the scan front reached SP 2. Detection range was 482 meters.

On pop-up one climb he scanned a 20-degree sector left of the pop-up position and then inspected a clump of trees 100 meters in front of the position. At hover he scanned out the TR to 400 meters, made a quick scan of the LR and then to the RR where he made a 30-degree right-sector scan with single-glance time of ¼ second. He then returned to the LR and back to the aircraft from which he initiated two 20-degree left-sector scans at a range of 400 meters followed by a 45-degree left-sector scan from a point on the TR at 500 meters.

As soon as the aircraft cleared the screening trees on pop-up two he started a 20-degree left-sector scan at a range of 400 meters; returning to the TR he spent several seconds inspecting the immediate area. From this point he made two more 20-degree left-sector scans and three 40-degree right-sector scans followed by a final 30-degree left-sector scan.

When the aircraft reached altitude on the third pop-up he scanned down the LR 500 meters, made a 15-degree left-sector scan, came back to the aircraft and went out again on the TR; single-glance time was 3/4 second. He next spent several seconds looking left and right of the TR at 600 meters and then made a 45-degree right-sector scan. No detection was made.

Observer 8. There was no fixation mark visible on this trial, as the observer accidentially moved the source light prior to the start point. On pop-up one he chose a scan point 400 meters down the TR and 30 meters from the road; from here he made a 15-degree left-and-right-sector scan followed by a 30-degree and a 45-degree left-and-right-sector scan ending with a final 15-degree scan.

At the start of the second pop-up he spent several seconds inspecting an area near the pop-up position and then moved out the TR to the target area and repeated the scan behavior of the first pop-up.

For the third pop-up he went out to the target area on the TR and scanned a 30-degree sector to the left and then back to the aircraft on the TR; he went back to the target area, repeated the 30-degree scan and saw the target as he returned to the TR. The total search time was 150 seconds; detection range was 857 meters.

Observer 9. He went out to SP 1 at the start of the route and scanned a 30-degree left sector and then came back along the route to the aircraft. He next moved out to the road intersection across from SP 1 and spent several seconds in this area before he initiated a 10-degree left-sector scan at 100-meter intervals towards SP 2 with a single-glance time of 3/4 second. He continued this pattern until he saw the target. Detection range was 518 meters.

The initial scan on pop-up one was a clump of trees 100 meters out from the pop-up position; from here he went 300 meters down the LR and back, then the same thing on the TR with a single-glance time of ½ second. Next he scanned a 30-degree left sector at 400 meters on the LR followed by a scan out to 600 meters on the TR and back to the aircraft with a left-right zigzag pattern along the TR; this was repeated three times. The final scan was out the TR to 700 meters with a 5-degree left-right-sector scan at this point.

He began the second pop-up in the same manner as the first and went from the clump of trees to a point 400 meters out on the RR and made a 20-degree right-sector scan. He returned to the TR and went out to 700 meters, then to the LR, back to the TR and back in to 400 meters and then out to 700 meters again; he repeated this four times.

He scanned close in on the TR during climb on the third pop-up and then went out to 300 meters and scanned back and out on the LR and RR. He then went back to the TR at 400 meters, spent several seconds in this area at 3/4-second single-glance time and then went out to the target area and found the target. The total search time was 155 seconds; detection range was 857 meters.

Observer 10. At the start of the route he went out well beyond AP 1 about 10 degrees to the left of the route and then back to SP 1. He then made three passes out to SP 2 at 100 meters to the left of the route and found the target; single-glance time was ½ second. Detection range was 1335 meters.

No pop-up was flown, as the aircraft engine failed shortly after the route detection.

APPENDIX B

HELCAT TARGETS

The following photographs will give the reader a better idea of the visual problems that were faced by the observers in this study. Figure 1B is a close-up of the camouflaged tank that was the first route-reconnaissance target; this tank was in place 105 meters from the line of flight, the centerline of the Test Highway. Figure 2B shows the position of the pattern-painted tank beside the "Center" road some 863 meters from the pop-up position; this was the first pop-up target. The men in the picture are setting up the infrared beacon that was used to verify the tank position on the scoring film. Figure 3B shows the positions of all of the targets used for the tests. Figure 4B shows the helicopter approaching the pop-up position between the two circled stakes; Figure 5B shows the trees which formed the pop-up screen, and one of the circled stakes is visible in the picture. The helicopter is returning to the base to pick up another observer. Figure 6B shows the pattern-painted tank in position 122 meters from the reconnaissance route for the second-day tests, and Figure 7B shows the camouflaged tank beside the "Center" road for the second-day tests. The tank placement for the night tests utilized the same positions for both of the route-reconnaissance targets and for both of the pop-up targets; the flights that took place before 2400 encountered the pattern-painted tank (Figure 8B) in position 100 meters from the Test Highway, and flights departing after 2400 found the camouflaged tank (Figure 9B) in that position. The pop-up target location was to the right of "Right" road 719 meters from the pop-up position. The camouflaged tank, Figure 10B, was in place until 2400, at which time it was replaced by the pattern-painted tank, Figure 11B.

Figure 12B shows the Eye-Mark system as used in these tests, and Figure 13B shows the AN/PVS-5 night-vision goggles. This picture was made after the "Spec" goggles which were used in the tests had been returned to the Night Vision Laboratory; the goggles shown are AN/PVS-5 goggles but are not electronically up to combat specifications, and they do not have the aviator-helmet mounting straps. These straps attach to the snap fasteners visible on either side of the helmet, and the center snap fastener on the goggles has a "V"-shaped "velcro" strap that attaches to the two strips of material visible on the front of the helmet.

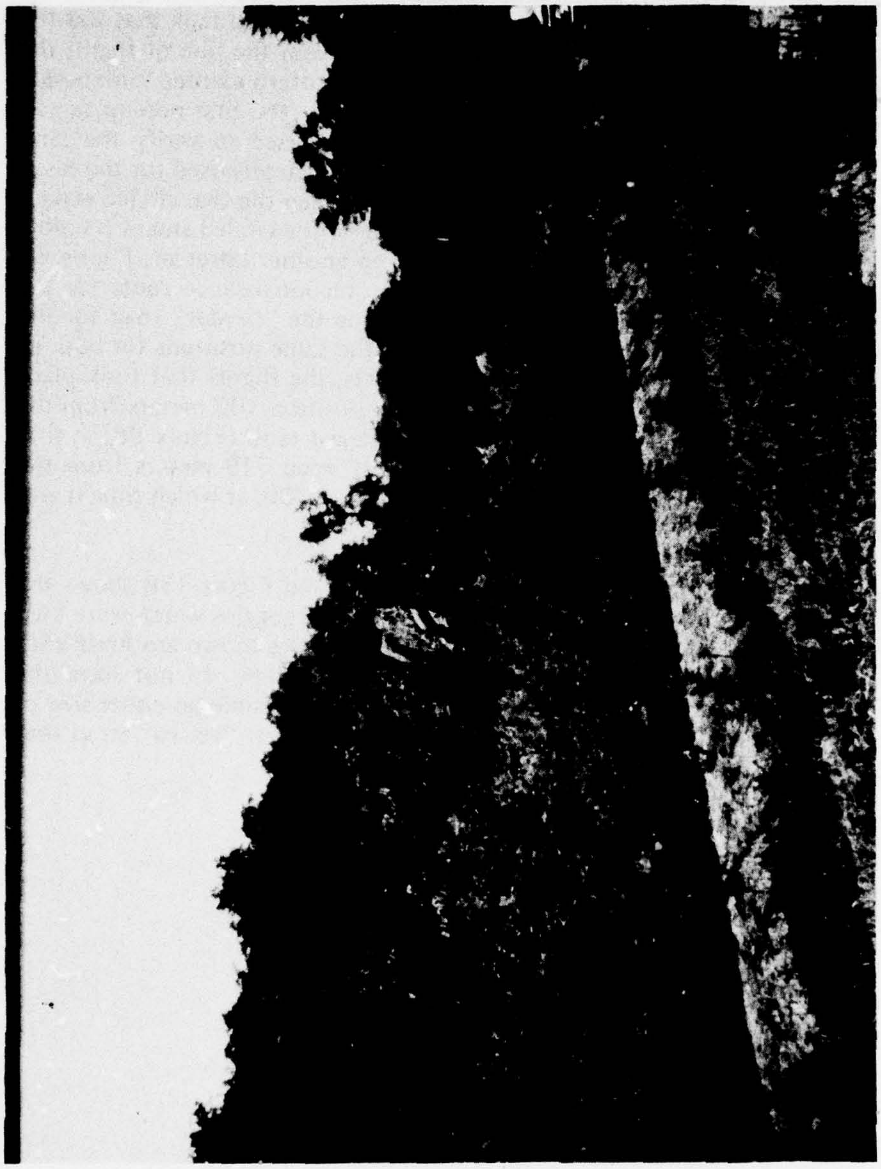

Figure 1B. Camouflaged tank in position for 15 June day route reconnaissance.

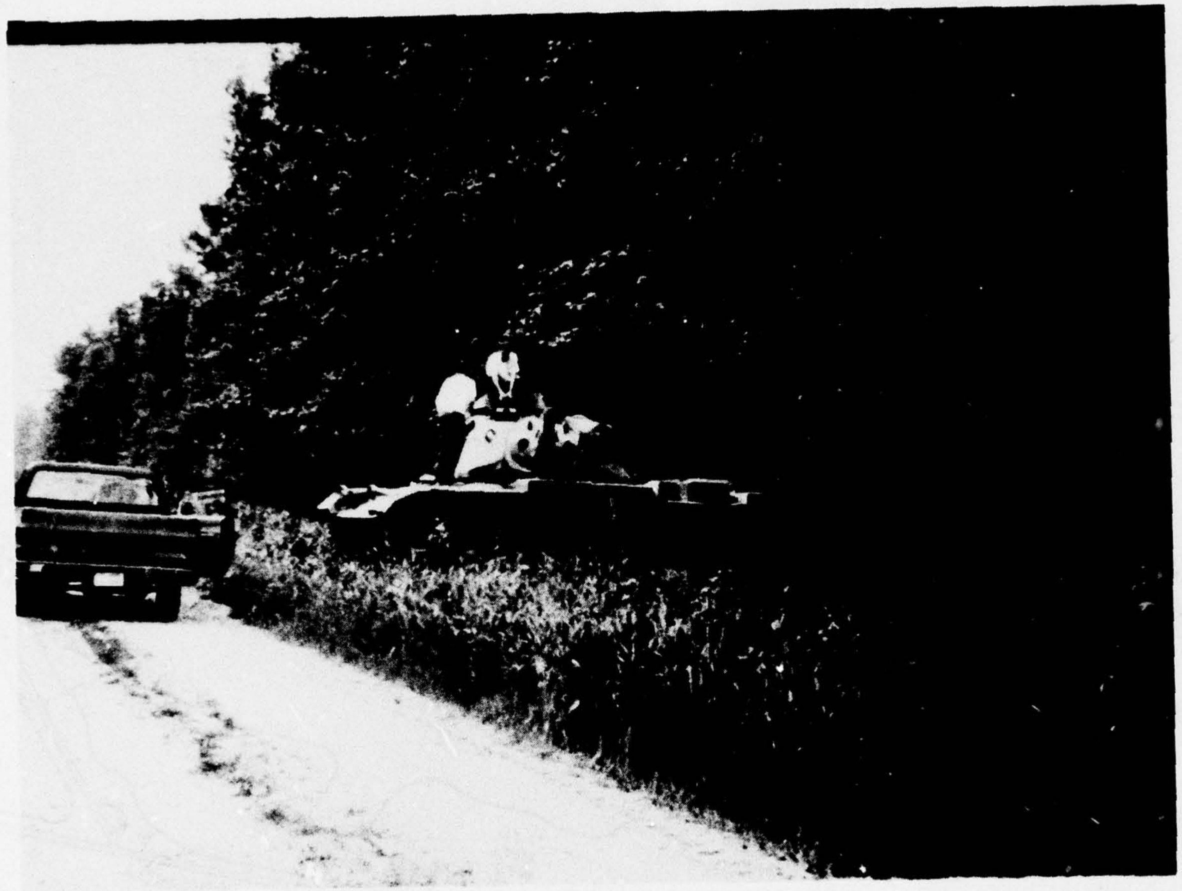

Figure 2B. Pattern-painted tank in position for 15 June day pop-up flights.

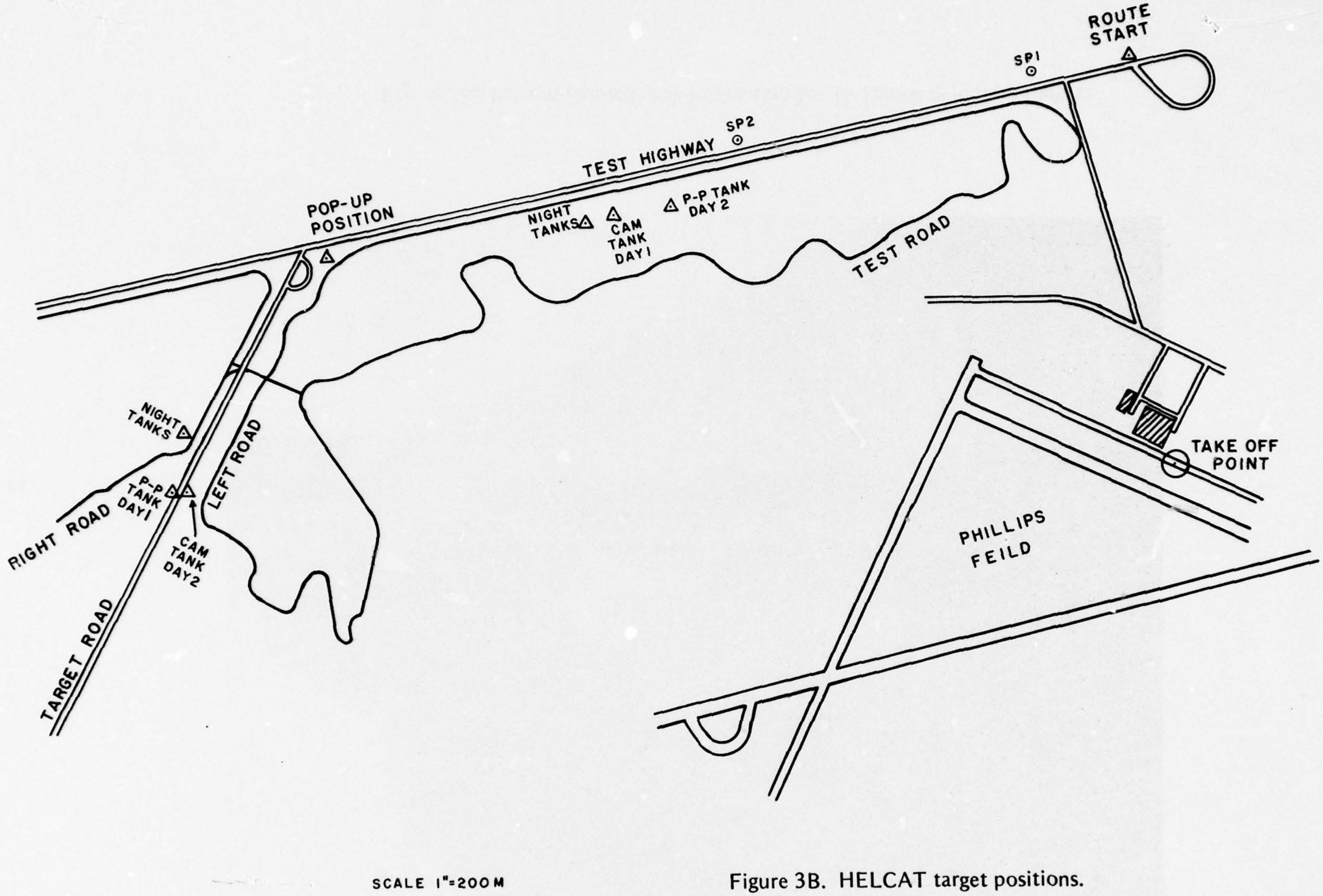

Figure 3B. HELCAT target positions.

Figure 4B. Helicopter approaching pop-up position.

Figure 5B. Tree screen at pop-up position.

Figure 6B. Pattern-painted tank in position for 18 June day route reconnaissance flights.

Figure 7B. Camouflaged tank in position for 18 June day pop-up flights.

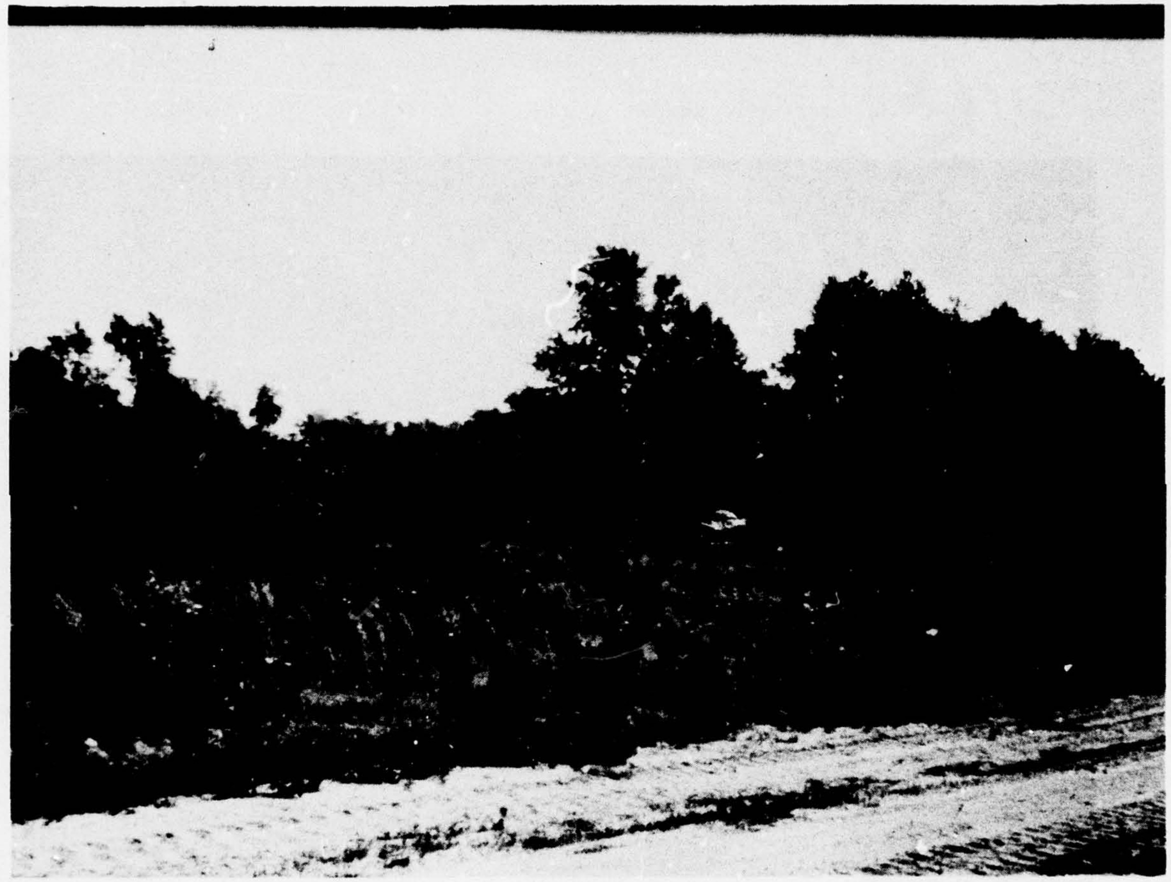

Figure 8B. Pattern-painted tank in position for 17 June night route reconnaissance flights.

Figure 9B. Camouflaged tank in position for 18 June night reconnaissance flights.

Figure 10B. Camouflaged tank in position for 17 June night pop-up flights.

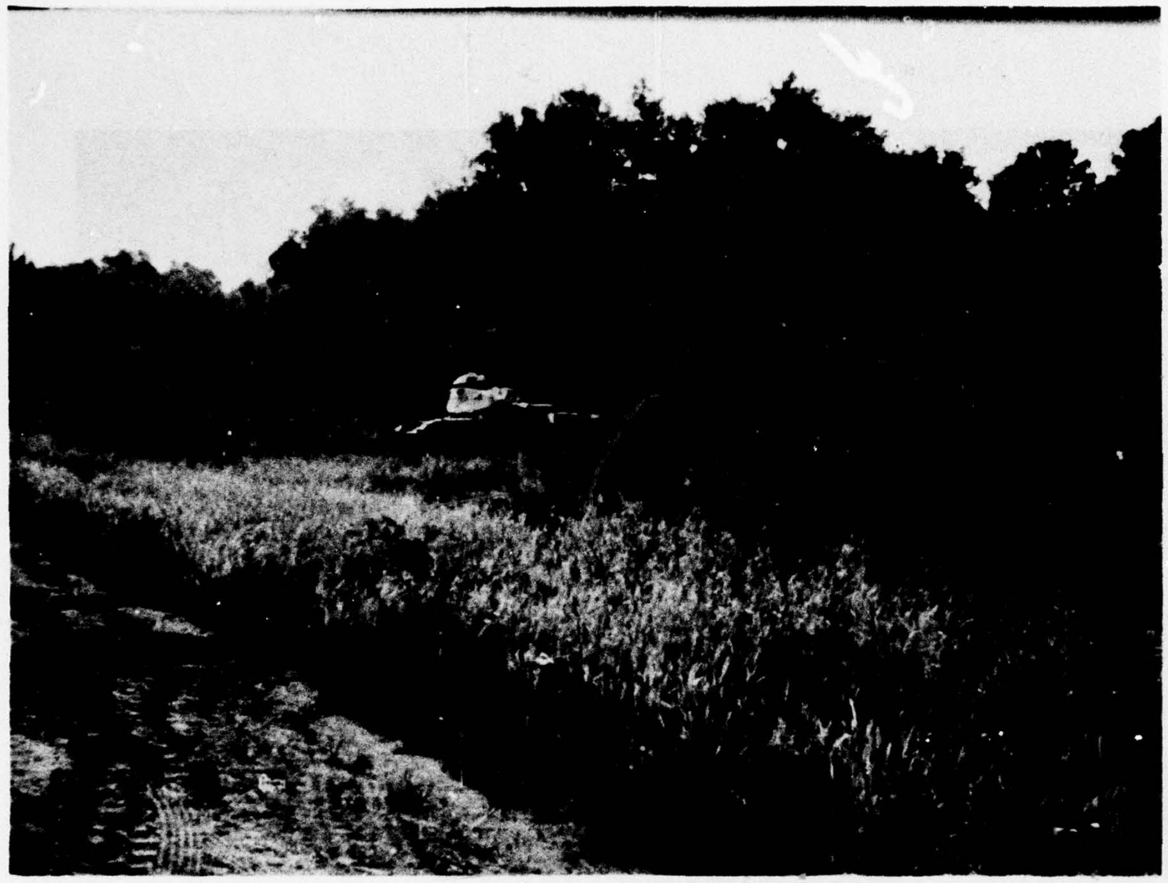

Figure 11B. Pattern-painted tank in position for 18 June night pop-up flights.

Figure 12B. Eye-mark eye movement measurement system.

Figure 13B. AN/PVS-5 night-vision goggles.

APPENDIX C

DATA REGRESSION ANALYSES

The theory for this FORTRAN Multiple Regression Program is described in Ballistics Research Laboratories Report No. 1330, "Stepwise Multiple Regression Statistical Theory and Computer Program Description" by Harold J. Breaux, Lloyd W. Campbell and John C. Torrey (1). This program is similar to the FORAST program, except symbolic formula description of the linear model is not allowed as input data. Instead, it requires that the linear model be expressed by the user as a FORTRAN (5) subroutine subprogram. In the subroutine, the model may be rescaled. It accepts a variety of control cards and data to be fitted or analyzed for correlation. This program reads the control cards, interprets them, and prints them out. The format card for the data is read following the end control card and is printed. Title cards, if any, are next, and then the data for the model. After the title cards are printed, the first two sets of input data are printed, followed by the number of sets of data, the subscripts of the terms finally included in the regression, coefficients, residuals (if desired), and a limited amount of other information about the steps of regression and the accuracy of the fits (sigma's and t's).

In this analysis a "confidence value" of .95 was used. "Confidence value" is equal to 1 - alpha. This value is the confidence or probability level at which correlation is desired for entering and keeping a term in the regression. A larger confidence reduces the probability of the least significant terms being included in the regression. The program as used for this analysis determined, from a table, the values for entry or removal of a term from the regression at each stage of the stepwise process for the appropriate phi and the "confidence value" specified. The table was from Theory and Problems of Statistics, page 344, by Murray R. Spiegel, published by Schaum Publishing Company, New York (5). This procedure allows for the most definite statement of results even when there are relatively few data points in the problem. The tolerance value that was used to check for a term being linearly dependent on one or more terms was set to .001 in the program.

The analysis of the HELCAT data consisted of 9 runs each with three conditions. These are identified as Run 1-1 for run one and condition 1 through 3-9 for run 9 and condition three. Table 1C identifies the runs and conditions by number. The measures considered were:

AGL	Aircraft height above the ground, measured in feet.
AS	Aircraft speed, measured in knots per hour.
TA	Apparent target area, computed and given in square feet.
TER	Roughness of terrain, given in a roughness code.
CL	Target acquisition difficulty, given in a difficulty code.
FG	Target/foreground conspecuity, given in percent of conspicuity.
OC	Target's distance perpendicular to course line, given in meters.
PRB	Plotted relative bearing, angular distance from aircraft to target, given in degrees.
ERB	Estimated relative bearing; crewman's estimate of PRB.
PR	Plotted range; range from aircraft to target, given in meters.
ER	Estimated range; crewman's estimate of PR.
EXP	Combat experience level of crewman, measured in hours code.
HDG	Target heading, given in degrees.
TC	Aircraft heading, given in degrees.
VIS	Visibility, given in miles.
CLD	Amount of cloud cover, given in tenths.
BE	Bearing error; difference between estimated and actual target range, given in meters.

RE	Range error; difference between estimated and actual target range, given in meters.
α	The sighting angle of the observer to the target, based on aircraft altitude and slant range.
BG	Target/background conspicuity, given in percent of conspicuity.

TABLE 1C

Analyses Conditions and Categories

Condition	Run	Category	N
Day	1-1	All Day Flights	31
	1-2	Route-Reconnaissance Flights	18
	1-3	Pop-up Flights	13
	1-4	Camouflaged-Target Flights	12
	1-5	Pattern-painted Target Flights	19
	1-6	Route-Recon. Camouflaged-Target Flights	8
	1-7	Route-Recon. Pattern-painted Target Flights	10
	1-8	Pop-up Camouflaged-Target Flights	4
	1-9	Pop-up Pattern-painted Target Flights	9
Night	2-1	All Night Flights	14
	2-2	Route-Reconnaissance Flights	7
	2-3	Pop-up Flights	7
	2-4	Camouflaged-Target Flights	7
	2-5	Pattern-painted Target Flights	7
	2-6	Route-Recon. Camouflaged-Target Flights	4
	2-7	Route-Recon. Pattern-painted Target Flights	3
	2-8	Pop-up Camouflaged-Target Flights	3
	2-9	Pop-up Pattern-painted Target Flights	4
Day and Night	3-1	All Flights	45
	3-2	Route-Reconnaissance Flights	25
	3-3	Pop-up Flights	20
	3-4	Camouflaged-Target Flights	19
	3-5	Pattern-painted Target Flights	26
	3-6	Route-Recon. Camouflaged-Target Flights	12
	3-7	Route-Recon. Pattern-painted Target Flights	13
	3-8	Pop-up Camouflaged-Target Flights	7
	3-9	Pop-up Pattern-painted Target Flights	13

The derivation of some of measures/variables used in the HELCAT data analysis requires some explanation so that the reader can apply this work to his own situation.

The Apparent Target Area (TA) presented the most confusing problem of any of the variables. This was a three-dimension problem to determine: "What size target did the crewman see from the position at which he reported the detection?" The contributing factors readily apparent were:

a. Heading of the aircraft.

b. Relative bearing to the target.

c. Height of the aircraft above the ground.

d. Range to the target.

e. Height, length, and width of the target.

f. Heading of the target.

g. Sighting or depression angle to the target.

h. Difference between the aircraft and target headings.

The amount of a target side that is visible is dependent upon the angle at which it is seen; thus the amount of any two adjacent sides that is visible will be maximum at 45°. Therefore, using this rationale (Figure 1C) the following formula was developed to provide this study with a close approximation of the apparent size of the target at the time of detection:

$$TA = \left[(H \cdot L \cdot \cos\alpha \, . \, \sin B \, . \, \cos\phi) + (H \, . \, W \, . \, \cos\alpha \, . \, \cos B \, . \, \sin\phi) + (L \cdot W \cdot \sin\alpha) \right]$$

The distance AB is called TAD (Target Acquisition Distance) in the calculations and is called MTAD for greatest value of TAD achieved for each particular target.

TER is the coded value for the roughness of the terrain surrounding a target. This code is based on the tangent of the angle generated by the difference between the target elevation and the highest terrain within a 10,000-foot radius of the target, with 1 equal to a $<1^{\circ}$ angle of slope and 10 equal to a 9° or greater angle of slope.

CL, the class of target difficulty, was a subjective measure which took into account the degree of target cover, the off-course distance, and actual target size. The difficulty range was from 1 for difficult-to-see targets to 12 for the easy-to-see targets.

Most of these measures are included in the equation:

$$100 - \frac{MTAD - TAD}{MTAD} = aAGL + bAS = cTA + eCL + fBG + gFG + hOC + iPRB + jPR + kEXP + nHDG + oTC + uVIS + vCLD + wBE + xRE + y\alpha,$$

where "a" through "y" are computer-developed coefficients.

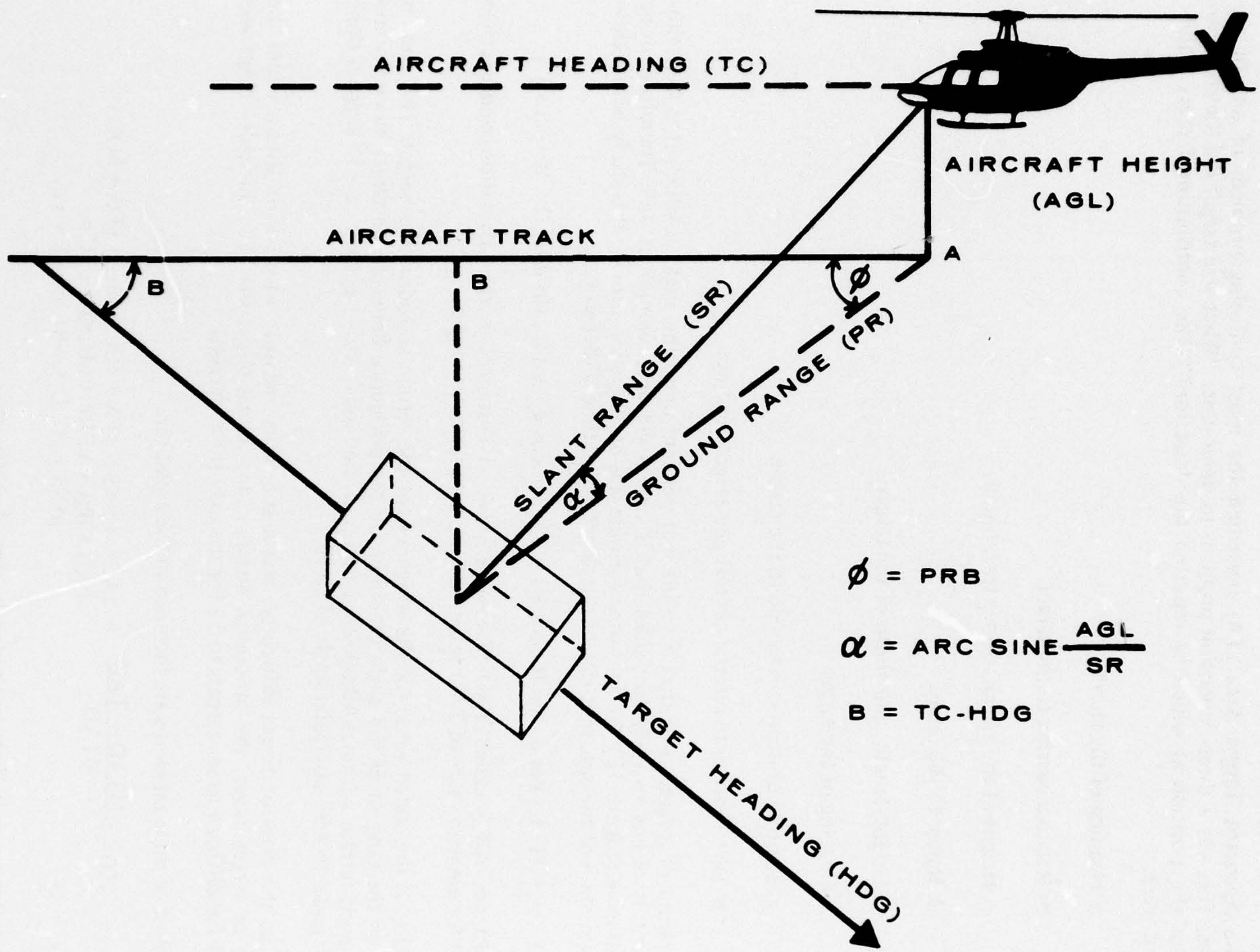

Figure 1C. Apparent target area computation rationale.

This linear equation was developed for each of the target detections that were documented, and a stepwise multiple-regression statistical procedure was applied to these equations to determine which of the variables contributed significantly to the detection of the stationary targets from the helicopters. The use of the linear equation was suggested by Dr. Robert C. Williges of the Aviation Research Laboratory, Institute of Aviation, University of Illinois. He stated that, based on the results of the many experiments concerned with pilot behavior he had observed at the Aviation Research Laboratory, the best prediction of this behavior closely corresponded to a linear equation. Additionally, previous studies in aircrew performance performed at HEL in which a multiple regression technique was used indicated the superiority of the linear equation over more complicated equation forms as a predictor of aircrew performance.

These analyses of the HELCAT data allowed us to evaluate the effects of the variables on the predictor equations and to determine which of the variables were significant to the detection tasks. The results indicate that the significant variables were:

The relative bearing between the aircraft's flight path and the target's heading, PRB.

The observer's combat experience level, EXP.

The target-to-foreground contrast ratio, FG.

The sighting angle of the observer to the target, α.

The range to the target, PR.

The helicopter's altitude, AGL.

The airspeed, AS.

The cloud cover, CLD.

The analyses also showed that the observers had greater variability in the estimation of the target's bearing than they did in the estimation of the target's range.

APPENDIX D

LUMINANCE AND METEROLOGICAL DATA

SURFACE METEORLOGICAL DATA

June 1976

Date	Time	Wind Speed MPS	Wind Direction AZ from 0° S		Sky Cover and Weather	Vis. Miles	AMB Temp. °C	WET Bulb °C	Sun Angles 0 deg N Elev.	Azim.	Rel. Hum. %
15	1000	+5.4 3.6	SW	040	High thin scat'd. clds.	4 Haze	23.8	21.4	48.19	108.89	81
15	1030	+4.5 2.2	SSW	030	High thin scat'd. clds.	4 Haze	25.0	22.0	53.50	115.45	77
15	1100	+4.9 2.2	SW	035	High thin scat'd. clds.	3½ Haze	25.6	22.4	59.45	123.47	76
15	1130	+4.0 2.2	SSW	030	High thin scat'd. clds.	3½ Haze	26.2	22.7	64.77	132.67	74
15	1200	+4.5 2.7	S	005	High thin scat'd. clds.	3½ Haze	26.6	22.9	69.91	148.55	73
15	1230	+4.0 2.2	S	010	High thin scat'd. clds.	3½ Haze	27.0	23.3	72.38	164.32	73
15	1300	+4.0 2.2	SSW	015	High thin scat'd. clds.	3 Haze	27.6	23.5	73.55	184.80	71
15	1330	+4.0 2.2	S	010	High thin scat'd. clds.	3 Haze	28.4	23.9	72.61	212.69	69
15	1400	+4.9 3.1	SSW	025	High thin scat'd. clds.	3 Haze	28.8	24.0	71.73	224.91	67
15	1430	+5.4 2.7	S	355	High thin scat'd. clds.	3 Haze	29.0	24.1	67.00	241.09	67
17	2218	C A	L M		High thin scat'd. clds.	1½	22.3	22.3	NO	MOON	100
17	2230	C A	L M		High thin scat'd. clds.	1½	22.2	22.2	DU	RING	100
17	2300	C A	L M		Thin broken clouds	1½	21.3	21.3	THIS	PHASE	100
17	2330	C A	L M		Thin broken clouds	1½	20.9	20.9			100
17	2351	C A	L M		Thin broken clouds	1½	20.7	20.7			100
18	0112	1.8	S	010	Low broken clouds	1½	22.1	22.1	x	x	100
18	0130	1.8	S	005	Low broken clouds	1½	22.2	22.2	x	x	100
18	0200	0.9	SSW	015	Low broken clouds	1½	22.4	22.4	17.82	115.89	100
18	0320	1.3	S	355	Scattered clouds	1½	22.0	22.0	23.02	122.13	100
18	0341	1.3	S	350	Scattered clouds	1½	21.8	21.8	24.78	124.10	100
18	1030	+3.1 0.9	S	360	Broken clouds	4 Haze	25.2	22.6	55.78	117.51	80
18	1100	+4.0 1.3	SSW	015	Broken clouds	4 Haze	25.3	22.5	*	*	79

(Continued)

SURFACE METEORLOGICAL DATA (Continued)

June 1976

Date	Time	Wind Speed MPS	Wind Direction AZ from 0° S		Sky Cover and Weather	Vis. Miles		AMB Temp. °C	WET Bulb °C	Sun Angles 0 deg N Elev.	Azim.	Rel. Hum. %
18	1130	+4.5 1.3	SSE	330	Overcast clouds	4	Haze	25.1	22.6	*	*	81
18	1200	+3.6 1.3	SSE	330	Broken clouds	4	Haze	25.8	22.7	*	*	77
18	1215	1.8	SSE	340	Broken clouds	4	Haze	26.4	23.5	70.59	153.59	78
18	1230	+3.6 2.2	SSW	020	Broken clouds	4	Haze	26.6	23.4	73.68	157.71	77
18	1300	+3.6 0.9	S	355	Broken clouds	4	Haze	26.9	23.6	75.13	181.41	76
18	1330	+4.0 0.4	SSW	015	Scattered clouds	4	Haze	28.0	23.8	74.44	203.52	71

x Moon obscurred by clouds.

* Sun obscurred by clouds 8/10 cloud coverage at 1100
10/10 cloud coverage at 1130
9/10 cloud coverage at 1200

LUMINANCE AND CONTRAST DATA

June 1976

Date	Time	Tank	Tank Value	Background Value	Foreground Value	Background Contrast	Foreground Contrast
15	0925	P-P	1.00×10^2	1.97×10^2	3.10×10^2	.49	.68
15	0950	CAM	2.90×10^2	3.80×10^2	3.70×10^2	.24	.22
15	1445	P-P	1.62×10^2	1.24×10^2	2.61×10^2	.23	.37
15	1510	CAM	3.78×10^2	3.41×10^2	7.70×10^2	.10	.51
17	2130	P-P	1.33×10^{-3}	5.80×10^{-4}	3.10×10^{-3}	.56	.57
17	2145	CAM	7.95×10^{-5}	3.60×10^{-5}	8.10×10^{-5}	.55	.02
18	0040	P-P	3.30×10^{-5}	1.90×10^{-5}	3.90×10^{-5}	.61	.15
18	0020	CAM	5.80×10^{-5}	3.20×10^{-5}	7.00×10^{-5}	.45	.17
18	0940	P-P	4.22×10^2	4.80×10^2	5.20×10^2	.12	.23
18	1015	CAM	2.50×10^2	7.90×10^1	4.20×10^2	.68	.40
18	1325	P-P	1.22×10^3	9.50×10^2	1.60×10^3	.28	.24
18	1340	CAM	3.90×10^2	1.35×10^2	8.70×10^2	.65	.55

SKY BRIGHTNESS DATA

June 1976

Date	Time	Illumination 10^4 Foot Candles	Sky Brightness 10^3 Foot Candles Per Steradian	Remarks
15	1000	0.49	0.78	Overcast
15	1030	0.60	0.95	Overcast
15	1100	0.65	1.03	Overcast
15	1130	0.74	1.18	Bright sunlight
15	1200	0.80	1.27	Bright sunlight
15	1230	0.73	1.16	Gathering clouds
15	1300	0.90	1.43	Bright sunlight
15	1330	0.88	1.40	Bright sunlight
15	1400	0.90	1.43	Bright sunlight
15	1430	0.88	1.40	Bright sunlight
17	2200	3.20	0.51	Clear sky
17	2230	2.90	0.46	Clear sky
17	2300	2.70	0.43	Clear sky
17	2330	2.60	0.41	Clear sky
17	2400	3.40	0.54	Clear sky
18	0100	4.90	0.78	Thin scattered clouds
18	0130	5.90	0.94	Thin scattered clouds
18	0200	9.50	1.51	Moonlight
18	0230	8.00	1.27	Moonlight
18	1030	0.32	0.51	Partly cloudy
18	1100	0.32	0.51	Heavy dark cloud
18	1130	0.34	0.54	Heavy dark cloud
18	1200	0.38	0.60	Partly cloudy
18	1230	0.41	0.65	Partly cloudy
18	1300	1.25	1.99	Bright sunlight