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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: DRSTE-RP-702-100
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (*and Subtitle*): US ARMY TEST AND EVALUATION COMMAND BACKGROUND DOCUMENT "GROUND-TO-GROUND TARGET DETECTION IN TROPIC FORESTS"
5. TYPE OF REPORT & PERIOD COVERED: Test Operations Procedure - Final
6. PERFORMING ORG. REPORT NUMBER: TOP-1-1-054
7. AUTHOR(s):
8. CONTRACT OR GRANT NUMBER(s): TECOM Project No. 9 CO 049 000 003
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Tropic Test Center, ATTN: STETC-TD, APO New York 09827
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Test and Evaluation Command, ATTN: DRSTE-ME, Aberdeen Proving Ground, MD 21005
12. REPORT DATE: 29 March 1974
13. NUMBER OF PAGES: 40
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*):
15. SECURITY CLASS. (*of this report*): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (*of this Report*): Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Target detection
Tropic forest
Visibility threshold
Materiel tests
Human factors

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*): This document provides standard objective procedures for measuring ground-to-ground target detection ranges in tropic forests. Purposes for procedures are to determine the effect of a test item on an observer's ability to detect a standard target in the jungle, or to determine the detectability of a test item emplaced in the jungle. Procedures are provided separately for stationary and moving targets. Procedures may not be applicable when the target to be detected is large and cumbersome or very small and not capable of movement under its own power. Procedures are an excellent example of objectivity and realism in human factors measurement.

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U. S. ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

DRSTE-RP-702-100 29 March 1974
Test Operations Procedure 1-1-054

GROUND-TO-GROUND TARGET DETECTION IN TROPIC FORESTS

SECTION I
GENERAL

1. Purpose and Scope.

a. The purpose of this Test Operations Procedure (TOP) is to provide standard objective procedures for measuring ground-to-ground target detection ranges in forested areas. The procedure serves a two-fold purpose:

PURPOSE	COMPARISON	SCOPE OF ITEMS
(1) Determine effect of a test item on an observer's ability to detect a standard target emplaced in the jungle.	(1) Observer's score when wearing test item versus observer's score when not wearing test item. (Condition of observer changes; target remains the same.)	(1) Protective lenses, protective masks, observation devices, anti-laser goggles, head nets, helmets.

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(2) Determine detectability of test item emplaced in the jungle.	(2) Observer's score when looking for a test item emplaced in the jungle versus observer's score when looking for a standard (control) item emplaced in the jungle.	(2) Camouflage screens or nets, ground emplaced sensors, shelters, personal equipment and clothing, light weapons, tactical radios.

b. All procedures in this TOP are directed toward achieving the first purpose, generally referred to as "observer with" versus "observer without" the test item. To achieve the second purpose, translate "observer with" into "observing test item," and "observer without" into "observing control item."

c. This TOP is organized around two different sets of procedures:

(1) Stationary observer searching for stationary target.

(2) Stationary observer searching for moving target.

Both the stationary target and moving target procedures may be used for both purposes outlined above. The choice of procedures should be made with regard to the nature of the test item and the military problem involved.

d. The basic test methods described herein may be used in any forested area; only the depth of the area of search need be adjusted to the obscurative properties of the vegetation. The method may not be applicable when the target to be detected is large and cumbersome or very small and not capable of movement under its own power. In the latter cases a walking observer-stationary target procedure should be devised.

2. Basic Information.

a. Military Need. In the early 1960's, when it became apparent that US Army involvement in Southeast Asia would increase, full scale R&D efforts were devoted to developing systems for detection of personnel in jungle areas. Some of the developments conceived emphasized technological extensions of the human sensory system, including auditory, olfactory and visual; other developments emphasized magnetic, infrared, seismic, and electromagnetic modes. There were no standards available for evaluating the performance of those new developments in jungle areas. For example, if a sensor system detected personnel at a range of 150 feet, it was not known whether this performance was better or worse than that of a human observer. Comparative data were needed for risk/cost decisions during the materiel acquisition cycle. The appropriate

standard of comparison for those systems was the basic human capability without the advantage of technological aids. A series of special studies was instituted to provide the methodology (appendix A, references 1 through 8). Over a span of 6 years at the US Army Tropic Test Center (USATTC) 280 enlisted men made 10,740 visual observations at 10 sites in major types of vegetation commonly found in the tropics. These observations resulted in the development of a new and reliable test method and a substantial data bank on expected visual detection ranges in tropic forests; the test method only is presented in the present TOP. A summary of visual detection ranges can be found in reference 9.

b. Test Methods. The test methods developed in this series of studies have been used in many tropic materiel tests, often in modified fashion. The method has been proven statistically reliable and capable of rendering reproducible results. The method is a field modification of a classic laboratory technique known as "constant stimuli." The 50 percent visibility threshold, explained in subsequent sections, is a convenient single measure of visibility which may be expressed for a single person, and averaged for sites, types of forests, or regions. The measure represents the point of maximum visual ambiguity and has long historical precedent as a means of quantitatively expressing subjective attributes for all the human senses.

c. Equipment and Facilities.

(1) Stationary Observer and Stationary Target:

Suitable test Site
Clipboard
Score sheet (appendix B-2)
Stopwatch
Target location cards
Face black (powdered charcoal)
Hearing protectors (figure 1)
Signaling device (figure 1)
Orthorater
Drinking water and cups
Targets
Surveying equipment

(2) Stationary Observer and Moving Target:

Suitable test site
Clipboard
Score sheet (appendix B-6)
Stopwatch
Face black (powdered charcoal)
Hearing protectors (figure 1)

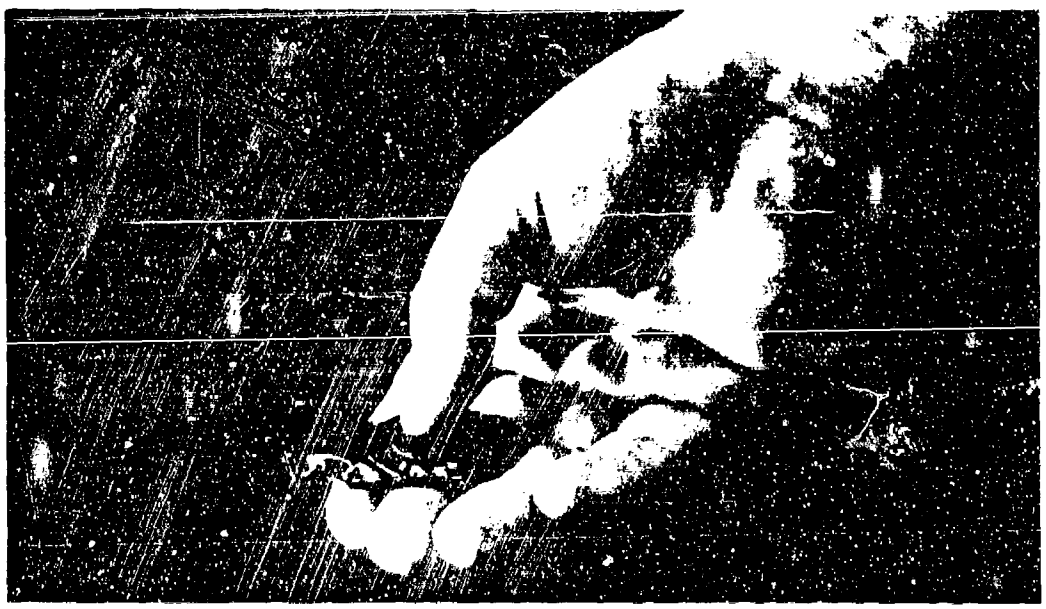

Figure 1. Hearing protectors and Signaling Device (Snapper)

Orthorater
Signaling device (figure 1)
Horn
Battery
Push button switch and cord
Drinking water and cups
Targets (figure 2)
Surveying equipment

d. Test Site Selection for Stationary and Moving Target. A computerized test site selection system has been developed by the US Army Tropic Test Center for 20,000 acres of potential test sites in the Canal Zone (references 10, 11). The precoded form in appendix B-9 may be used in conjunction with the preceding references (10, 11) as a screening device for identifying potential test sites. The final selection should be a site in a flat forested area of typical vegetation (figure 3).

SECTION II
TECHNICAL PRESENTATION

3. Test Item Characteristics. All materiel need documents pertaining to the test item should be reviewed in order to formulate aspects of visibility evaluation that may be unique to the test item.

4. Site Layout.

a. Stationary Target.

(1) General description. A diagram of a sample test site layout is shown in figure 3. The number of detection radii and the depth of field of search (radii length) may be chosen to fit the test item and the test site. Recommended number of radii is from five to seven. Depth of field of search should be beyond the limit of visibility--usually 120 feet. Target distances should be in equal increments of about 15 feet, with the closest distance yielding nearly 100 percent detectability--usually 30 feet or less.

(2) Example. In the example in figure 4, seven target distances are used: 30, 45, 60, 75, 90, 105 and 120 feet, measured from the center of the observer's position. The observer's field of search is 180°. All targets actually appear within a 120°-field, but the observers are not aware of this. Five 120-foot radii extend outward from the observer's position. Radius I is 30° from the base line at the left of the observer's position. Radius II is at 60° from the left, Radius III is at the center field of search, Radius IV is 60° from the right side of the base line, and Radius V is 30° from the right. The observer's position is a square, one meter on a side with the front edge on the center of the base of the 180°-field of search boundary.

Figure 2. Interchangeable Targets:
OD Silhouette, OD Cylinder, and Human

Figure 3. Typical Test Site

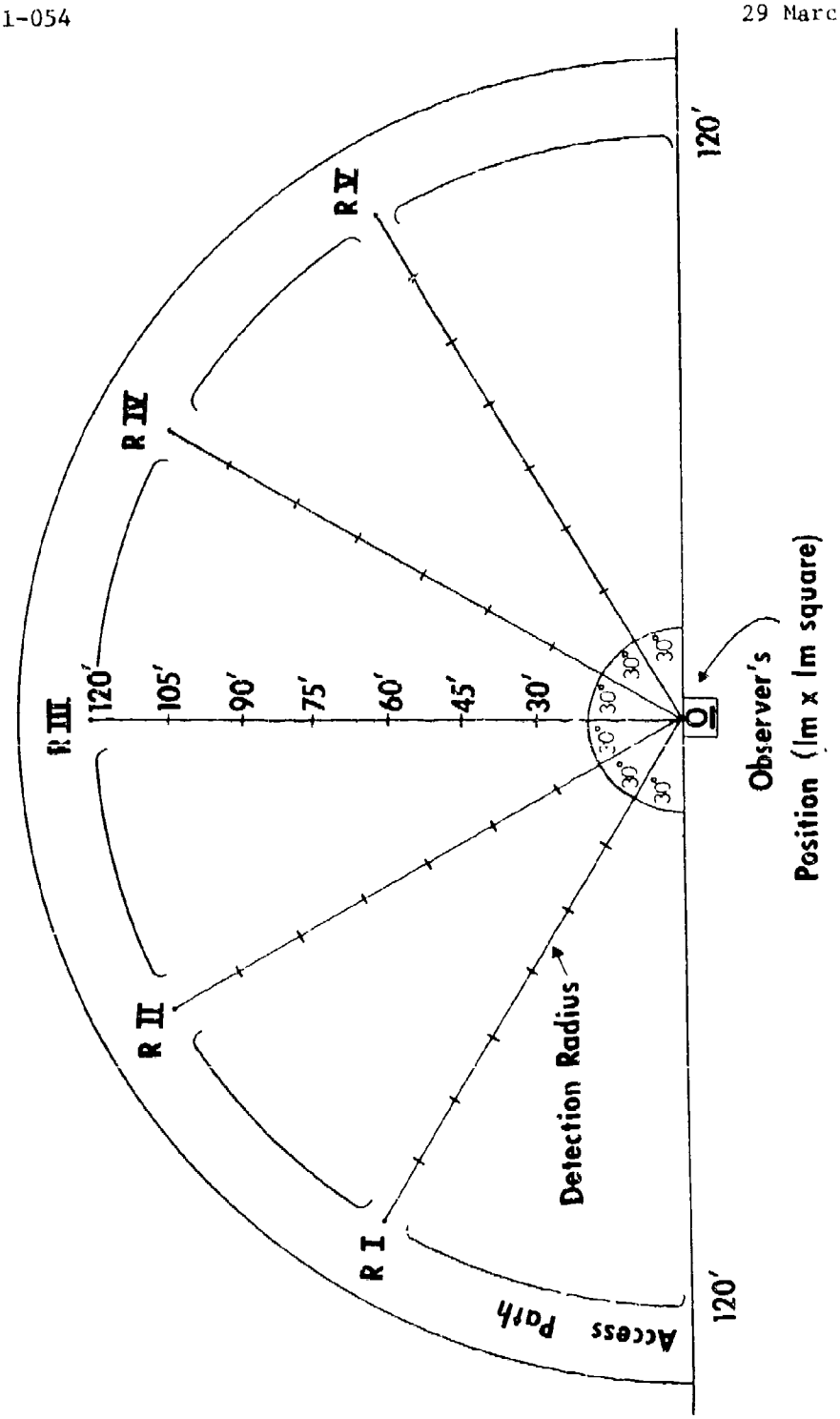

Figure 4. Sample Stationary Target Test Site Layout

b. Moving Target.

(1) General description. A diagram of a sample test site layout is shown in figure 5. The site should cover a semicircular area with a radius usually of 100 to 120 feet. The radius and the access path just beyond it should be at a distance far enough from the observer's position (at center of base line) that a target moving along the access path cannot be detected visually from the observer's (O's) position. A number of different target walking paths should cut across the semicircle at various angles starting on the circumference and ending at a distance from the observer so that detection at the closest distance is virtually certain--usually 30 feet or less. The angles of the walking lines are at a slant to the observer's position to avoid having O's view down cleared jungle paths. During construction of the walking paths a small amount of vegetation is cut in order to prevent O's receiving strong location cues created by targets moving the underbrush and to permit the targets to walk at a constant rate. From O's position walking paths cannot be discerned. The O's field of search is 180°. All targets actually appear within a 150°-field, but Os are not made aware of this. Camouflaged cloth tape, 2 inches in width, marks the ground along the entire length of each walking path. Distance markers, also obscured from O's view, are placed at 10-foot intervals along each path so that target positions can be precisely recorded. The distance markers are the basis for scoring target position when observed. The score is later converted to straight-line distance from target to the fixed O position.

(2) Site surveying. Following is a step-by-step procedure for laying out a moving target site (figure 5) having a radius of 117 feet, 10 target walking paths of 115 feet each, with walking paths ending on "zero" points 20 feet from O's position. The procedure may be adapted for use in surveying sites of various sizes and different walking path configurations.

Lay out a 40-foot baseline--a straight line, the center of which is O position.

Establish the center (O position).

With a surveying instrument over the center point of the baseline, divide the 180°-field of search into twelve 15°-segments.

Place a stake at a distance of 20 feet on each radius.

Label stakes "a" through "k" starting with the first 15°-radius from the baseline to the left of O (stakes "b" through "j" become zero points of walking paths; stakes "a" and "k" are not used).

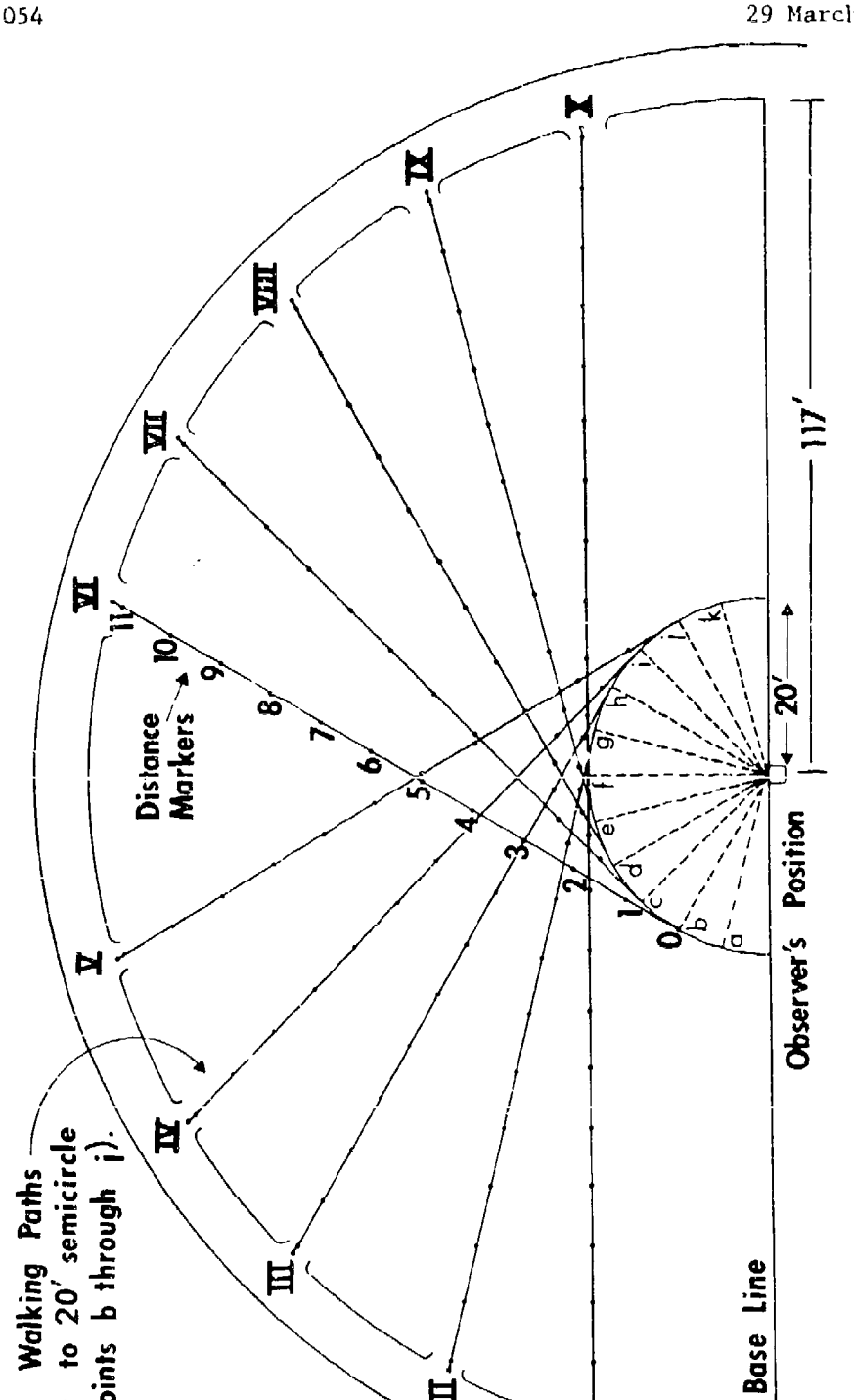

Figure 5. Sample Moving Target Test Site Layout

Starting at stake "b" and facing away from O, turn a 90°-angle, clockwise, toward the center of the field of search and measure 115 feet along the line of sight from stake "b" (line d is tangent to 20-foot circle at point b.)

Place a stake at the 115-foot mark. This line is walking path VI.

From stake "j" facing away from O, turn an angle 90° counterclockwise toward the center of the field of search and measure 115 feet along this line of sight.

Place a stake at the 115-foot mark. This is walking path V.

Walking paths I, II, III, IV, VII, VIII, IX and X are formed in a like manner, starting at stakes c, d, e, f, g, h and i. All walking paths are 115 feet long. Stake f is the "zero stake" for walking paths I and X.

After each walking path is laid out, place stakes along each path at 10-foot intervals starting at "zero stake," as previously defined. Number the stakes along each path: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11. Mark the path by placing a 2-inch strip of white cotton tape on the ground along the path. After the tape is in place, pour on muddy water so the tape can be seen by the target but not by the O.

Clear a bare minimum of vegetation along the paths--sufficient only to allow the targets to walk along the path at a constant speed without tripping, stumbling, or bending to miss a vine or branch.

Mark the baseline with white tape to define O's field of search.

Mark a square with white tape, 1 meter by 1 meter, as O's position.

Clear an access path around the 117-foot outside perimeter so targets can find their way rapidly to the walking paths.

Display the number of each walking path (I through X) on the access path where walking paths begin.

5. Test Subject Selection. Based on data from previous visibility studies a sample size of at least 10 observers is necessary to obtain

the reliability of measurement needed for meaningful statistical analyses. All test subjects should be in combat MOS. The subjects should be between 17 and 35 years of age and have visual acuity correctable to 20/20. Subjects should be screened by testing with an Orthorater or equivalent acuity measurement prior to the day of testing in the jungle. Men assigned as observers should be selected from those who pass a correctable 20/20 vision test. It is advisable to select some observers who wear corrective lenses in order to test compatibility of the test item with eyeglasses. Observers should report in groups of about four or five different men per day depending upon available testing time and duration of each test. Precautions should be taken to prevent observers who have completed the test from briefing those who have not.

6. Target Preparation.

a. Stationary Targets. Three types of targets--wooden silhouettes of humans, cylinders, or soldiers--described as follows may be used for the test (figure 2). Soldiers should be dressed in standard fatigue (OG 107) uniforms, including jacket (not tucked in and without insignia), bloused trousers, cap and boots. Targets should be in the average height range (5'6" to 6'0") and average weight range (140 to 190 pounds). The fatigue jacket should be buttoned to the neck and all exposed skin including the face smeared with powdered charcoal. Targets should stand immobile with hand behind back facing O's position, with feet spread comfortably apart. Wooden silhouettes of humans will have the following characteristics: height 69.0 inches, shoulder height 55.9 inches, shoulder width 17.9 inches, head width 6.0 inches, painted lusterless olive drab. Cylinders used will have a height of 72.0 inches, diameter 18.0 inches, painted lusterless olive drab. The same type of target should be presented to all O's during testing of a given test item.

b. Moving Target. See human target, figure 2. Three soldiers should be selected as targets. They should be dressed in standard fatigue (OG 107) uniforms, including jacket (not tucked in and without insignia), bloused trousers, cap and boots. Targets should be of average height and weight. The same targets should be presented to all observers. The fatigue jacket should be buttoned to the neck and all exposed skin including the face should be smeared with powdered charcoal. Targets will walk at a constant rate (acquired by practice) from the 115-foot marker along the path toward the zero marker.

7. Test Personnel Rehearsal.

a. Stationary Target. All test personnel, including human targets and personnel who emplace silhouette or cylinder targets, should thoroughly rehearse test procedures prior to the date of testing. Special care should be taken to develop a smooth execution of test item sequencing and communication between target personnel and test personnel working

directly with test subjects. Special care should also be taken not to trample the test site vegetation. A sample target sequence, randomized to prevent predictability of target appearance, is shown in appendix B-2.

b. Moving Target. All test personnel including targets should thoroughly rehearse test procedures prior to the date of testing. Rehearsal should include a complete walk-through of all target sequences. Special care should be taken to develop a smooth execution of target sequencing and communication between target personnel and test personnel. Test item sequence is shown in appendix B-6. The basic data are distances reported by targets, therefore targets should practice the method of measuring and reporting their positions when detected [see paragraph 8b (17), below] to eliminate occurrence of mistakes or unnecessary delays during testing. Targets should also practice maintaining a constant walking rate.

8. Test Procedures.

a. Stationary Target

(1) Lay out site according to sketch in figure 1 and description in paragraph 4, above.

(2) At about 0730 on test day, assemble the following at test site (per day).

Test officer (T)
Test assistants other than targets--3
Targets--1 for each target radius, plus target emplacement personnel if human targets are not used
Face black and target clothing--3 sets
Test subjects, i.e., observers (Os)--4
Ear protectors--4 pairs
Signal device (snapper)--3
Stopwatch--2
Score sheets--8
Drinking water and cups
Clipboard

(3) T take all Os to observing position (1-meter square) at test site.

(4) T brief all Os by reading (do not paraphrase or ad-lib) instructions shown in appendix B-1. Because testing time is 1 hour or more for each O, re-read instructions to each O immediately preceding his turn as observer.

(5) Allow Os to observe targets closely for familiarization purposes.

(6) Send targets to test site access path to await beginning of test. Targets will take signal snapper and card showing target sequence assigned.

(7) Send all but one O to a remote location out of sight and sound of test site. Os will be tested according to a predetermined schedule such as sample schedule shown in appendix B-8. The sample schedule is based on 20 Os--four different Os tested per day for a 5-day period.

(8) T fill out top portion of score sheet as in appendix B-2 for O. Do not allow O to see score sheet because target locations are listed on it.

(9) Have O stand within observation square, don ear protectors, and face away from field of search.

(10) T signals for target to assume position. (Example: first position is item 1 radius IV, distance 105 feet as shown on appendix B-2. Sample Score Sheet on first testing of O; or item 19, radius V, distance 45 feet on second testing of O). Signal is made by voice command (e.g., "number one" or "number nineteen"). Subsequent communication from T to target is also by voice. Communication from target to T is by noise snapper shown in figure 1.

(11) Targets take position around site on access path (at 120 feet distance in figure 4). Each target is assigned to one or more radii, remaining on access path and out of site until a target sequence comes up on his radius. When a target sequence falls on a given radius, the target assigned to that radius proceeds down the radius to the proper distance. Distance is marked on ground by a target position marker (figure 6). Target stands immobile, facing observer, hands behind back, feet spread comfortably apart.

(12) When target is in position, target signals T with noise snapper.

(13) T turns O around to begin search. Timing starts when O is turned around. The O is confined to a marked square one meter on a side. He is allowed to bend, twist, crouch, kneel or lie down while searching for the target, as long as his head remains inside the marked square. Timing ends either when O correctly points out target, or when 2 minutes have elapsed. If subject points in wrong direction, say "Keep on looking," and continue timing up to 2 minutes.

(14) On designated line on score sheet, record "+" if O pointed to proper radius within 2 minutes. Record "0" if O failed to point out target correctly within 2 minutes (120 seconds) time.

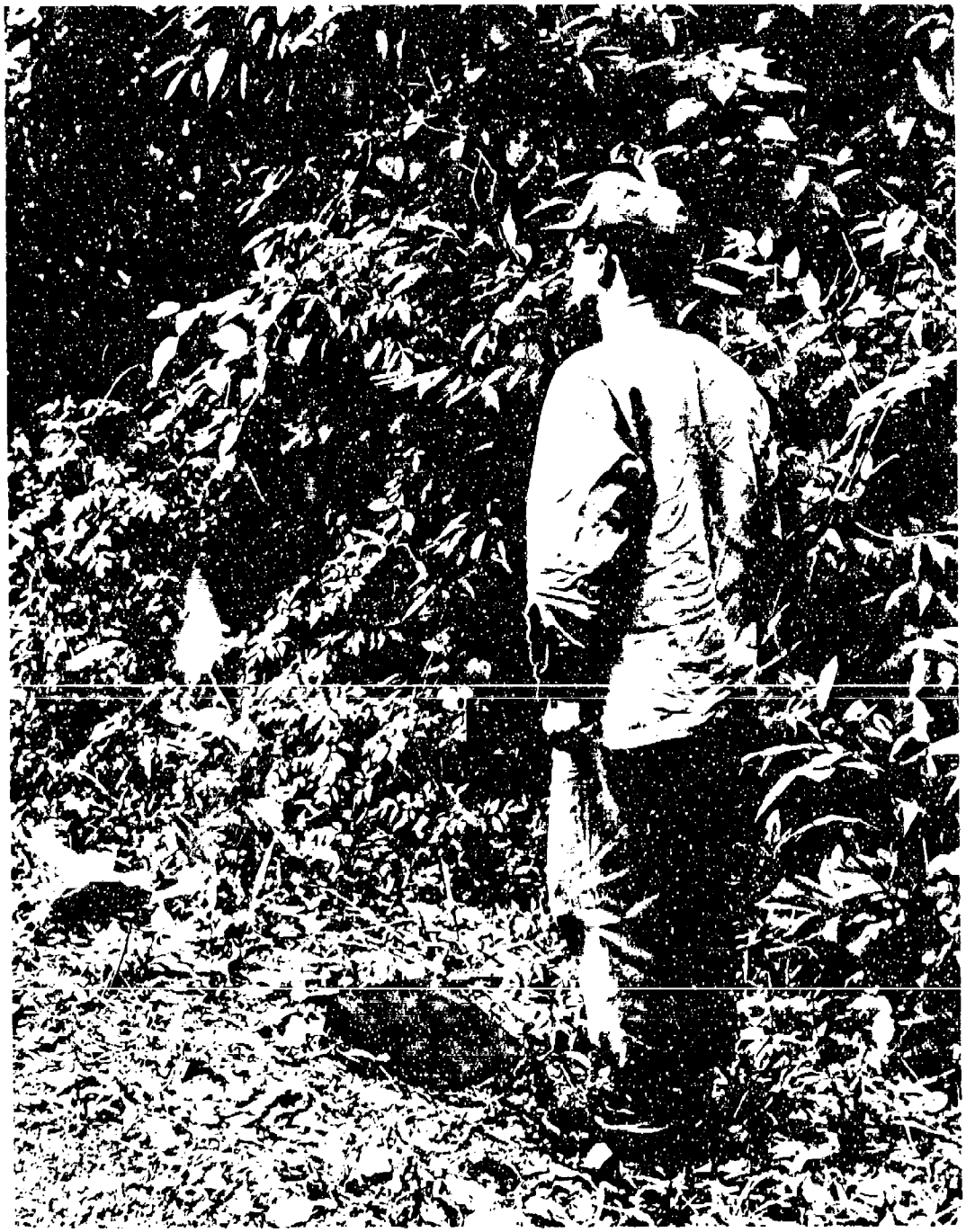

Figure 6. Target Position Marker for Stationary Target

(15) For each correct detection, record time (to nearest second) on score sheet. Record "120 sec" if O fails to point out target correctly within 2 minutes.

(16) IMPORTANT: Be sure O cannot see score sheet. Target remains immobile until T gives a voice signal for next target sequence.

(17) T turns O away from target area.

(18) After O is facing away from target area, T gives signal for next target sequence.

(19) Steps (12) through (18) above are repeated for O until all items have been completed. (There are 35 items on the sample score sheet corresponding to 5 radii x 7 distances on sample site layout, figure 4.)

(20) O is given a 5-minute break.

(21) Steps (8) through (19) above are repeated for each test trial according to the test schedule for the day (appendix B-8). Second testing of each O will begin with the second half of the items--for example, items 19 through 34, followed by items 1 through 18, as noted on score sheet (appendix B-2).

b. Moving Target

(1) Lay out site according to sketch in figure 5 and instructions in paragraph 4, above.

(2) At about 0730 hours on test day, assemble the following at the test site (per day).

Test officer (T)
Test assistants other than targets--3
Targets--3
Face black and target clothing--3 sets
Test subjects, i.e., Os--4
Ear protectors--4 pairs
Signal device (snapper)--3
Stopwatch
Score sheets--8
Drinking water and cups
Clipboard
Horn
Battery
Push-button switch and cord
Tape measure--6-inch

(3) Allow subjects to observe targets closely for familiarization purposes.

(4) Send targets to access path to await beginning of test. Ts take signal snappers, card showing target sequence assigned, and tape measure.

(5) T takes Os to observing position.

(6) T briefs all Os by reading (do not paraphrase or ad-lib) instructions shown in appendix B-5.

(7) Send all but one O to a remote location out of sight and sound of test site.

(8) T fills out top portion of score sheet (appendix B-6 for O). Do not allow O to see score sheet because it lists target locations.

(9) Have O stand within observation square, don ear protectors, and face away from field of search.

(10) T signals for target to assume start position [Example: Item 1, Lane V, as shown on Score Sheet (appendix B-6), on first testing of O; or Item 16, Lane IV, on second testing of O]. Signal is made by voice command. Subsequent communication from T to target is also by voice.

(11) Target takes position along access path at marker for proper lane, and signals T with snapper when ready.

(12) T turns O toward field of search, and signals target when O is ready.

(13) Target signals with snapper and begins walk at same time.

(14) When O detects target (or thinks he detects target), O signals with buzzer (horn) and points to suspected target.

(15) Target stops immediately upon hearing buzzer and remains motionless until T tells him to report his distance.

(16) T checks to make sure that target is actually located in direction in which O is pointing.

(17) If O is correct, T instructs target to report distance.

(a) Target measures the distance to the nearest stake on his walking path, reports distance to T, and then retreats to access path.

Example: Target stops between stake number 7 (70 feet away from zero stake) and stake number 6 (60 feet away from zero stake), but closer to stake number 7. Using the measuring tape which he has been carrying in his pocket, target measures his distance (from the point on the ground that was directly under his body when the buzzer was sounded) by securing the tape to the ground where he was stopped and running the tape back to stake number 7 (for example, 40 inches). Target reports the distance as "7 minus 40." If target had stopped between stakes number 7 and 6, but closer to stake number 6, he would measure from his stop-position to stake number 6 (for example, 23 inches). Target would report the distance as "6 plus 23." It is important that the target use the word "minus" when reporting measurements back to a stake he has already passed, and using "plus" when reporting measurements to a stake he has not yet reached. (Practice will make this technique automatic.)

(b) T records distance on score sheet in space provided. Record will be entered exactly as target speaks it.

Example: As in above example, distance "7 minus 40" spoken by target will be entered as "7 - 40." Distance of "6 plus 23" spoken by target will be entered as "6 + 23." (At a later time, all such entries will be transformed into actual number of inches on walking path and then into actual line-of-sight distance from O to target.)

(18) If O sounds buzzer and points in a direction other than where target is located ("false detection"), T will signal target to continue walking. Target will resume walk slowly, gradually building up to normal pace within 10 feet (slow buildup of pace will reduce detections due to sudden quick movements). This process will continue until the detection is made. T will use his best judgment in determining if a "detection" is false. Benefit of doubt will be given to the O. The T must be absolutely sure that there is no chance that the target could be in the general direction in which the O is pointing. Note false detections on score sheet. The final true detection distance reported by the target will be the recorded "score" for the trial.

(19) If target reaches zero point on walking path without being detected, target will stop and T will record "0" (minimum score) on the score sheet.

(20) After recording score for the item, T turns O around facing away from field of search.

(21) Procedures in paragraphs 8b(10) through 8b(20) are repeated until all items are completed for O. Include a 5-minute break after half the items are completed.

(22) Procedures in paragraphs 8b(8) through 8b(22) are repeated for each test trial according to the test schedule for the day (appendix B-8). Second testing of each O will begin with the second half of the items--for example, items 16 through 30, followed by items 1 through 15, as noted on score sheet (appendix B-6).

9. Data Analyses.

a. Raw Data Form. After using the above procedures for either the stationary or moving target, each O will have taken the test twice--once with the test item and once without the test item, according to the schedule in appendix B-8. Raw data will be in the form of two completed score sheets for each O. The data may be analyzed in many ways. The following analyses will answer some basic visibility questions about the test item, and are easily performed with the aid of a desk calculator. Other analyses such as repeated measures analysis of variance (most easily performed with a computer) may be used to compare trends of visibility across distance if the test situation and the data warrant. Guidance should be obtained from a qualified statistician before performing analyses other than the basic questions addressed in detail below.

b. Basic Stationary Target Analyses

(1) Difference between mean detections with test item versus without test item (control): Did the test item effect a significant increase or reduction in mean number of targets detected compared to mean number of targets detected without the test item? (For ease in explanation, the following analyses will pertain to 12 Os taking a 35-item test.)

(a) Using Data Summary Sheet shown in appendix B-3 and the 24 completed score sheets (12 Os tested twice), count the total number of detections on each score sheet and enter the number in the appropriate column (A or B) on the appropriate line (1 through 12) on the Data Summary Sheet.

(b) Complete the calculations on the Data Summary Sheet. On the line for each observer number, subtract B from A, and enter remainder in column D (if difference is negative, indicate with a minus sign). Square values in D column and enter result in D^2 column. Calculate totals for columns A, B, D, and D^2 (column D total may be positive or negative); enter totals in spaces provided. Calculate average number of detections for columns A, B, and D; enter numbers in spaces provided. Perform the two arithmetic checks shown in parentheses at the bottom of the Data Summary Sheet to insure accuracy of computations. To insure accuracy of "ΣD^2," re-calculate and re-add the D^2 column.

(c) The following t test for difference between correlated means (i.e., same people used as subjects with and without test item) will indicate whether the difference between mean number of detections is statistically significant or due to chance. See appendix B-3 for meanings of symbols. The symbol "df" means degrees of freedom.

$$t = \frac{\Sigma D}{\sqrt{\frac{N(\Sigma D^2) - (\Sigma D)^2}{N - 1}}} \qquad (1)$$

$$df = N - 1$$

Substitute values for ΣD and ΣD^2 from Data Summary Sheet; N = number of observers = 12.

(d) Example of t test using hypothetical data that could appear on bottom of Data Summary Sheet.

Totals: $\Sigma A = 168$ $\Sigma B = 140$ $\Sigma D = 28$ $\Sigma D^2 = 94$ $N = 12$

Average Number Detections:

$$\frac{\Sigma A}{N} = M_A = 14.00$$

$$\frac{\Sigma B}{N} = M_B = 11.67$$

$$\frac{\Sigma D}{N} = M_D = 2.33$$

$$t = \frac{28}{\sqrt{\frac{12(94) - (28)^2}{12 - 1}}} = 5.592 \qquad (2)$$

$$df = 12 - 1 = 11$$

(e) Compare the calculated value of t with the tabled values of t (shown below). Enter the table on the line designated by the number of degrees of freedom (df), which in the preceding example is 11. Compare the calculated value of t (t = 5.59 in above example) with the four tabled values of t on the proper df line. If the calculated t is equal to or larger than a value of t on the proper df line, then the two population means (μ_A and μ_B) may be inferred to be truly different--i.e., meaningful or real and not due to chance. The risk of incorrectly making

Table of t Values

Degrees of Freedom (df)	Level of Significance .10	.05	.02	.01
1	±t = 6.34	±t = 12.71	±t = 31.82	±t = 63.66
2	2.92	4.30	6.96	9.92
3	2.35	3.18	4.54	5.84
4	2.13	2.78	3.75	4.60
5	2.02	2.57	3.36	4.03
6	1.94	2.45	3.14	3.71
7	1.90	2.36	3.00	3.50
8	1.86	2.31	2.90	3.36
9	1.83	2.26	2.82	3.25
10	1.81	2.23	2.76	3.17
11	1.80	2.20	2.72	3.11
12	1.78	2.18	2.68	3.06
13	1.77	2.16	2.65	3.01
14	1.76	2.14	2.62	2.98
15	1.75	2.13	2.60	2.95
16	1.75	2.12	2.58	2.92
17	1.74	2.11	2.57	2.90
18	1.73	2.10	2.55	2.88
19	1.73	2.09	2.54	2.86
20	1.72	2.09	2.53	2.84
21	1.72	2.08	2.52	2.83
22	1.72	2.07	2.51	2.82
23	1.71	2.07	2.50	2.81
24	1.71	2.06	2.49	2.80
25	1.71	2.06	2.48	2.79
26	1.71	2.06	2.48	2.78
27	1.70	2.05	2.47	2.77
28	1.70	2.05	2.47	2.76
29	1.70	2.04	2.46	2.76
30	1.70	2.04	2.46	2.75
35	1.69	2.03	2.44	2.72
40	1.68	2.02	2.42	2.71
45	1.68	2.02	2.41	2.69
50	1.68	2.01	2.40	2.68
60	1.67	2.00	2.39	2.66
70	1.67	2.00	2.38	2.65
80	1.66	1.99	2.38	2.64
90	1.66	1.99	2.37	2.63
100	1.66	1.98	2.36	2.63
125	1.66	1.98	2.36	2.62
150	1.66	1.98	2.35	2.61
200	1.65	1.97	2.35	2.60
300	1.65	1.97	2.34	2.59
400	1.65	1.97	2.34	2.59
500	1.65	1.96	2.33	2.59
1000	1.65	1.96	2.33	2.58
∞	1.65	1.96	2.33	2.58

Example: When the df are 35 and the calculated t is 2.03 (positive or negative), a difference between means as large as that obtained may be expected 5 times in 100 trials just by chance.

that inference is equal to the level at which the calculated t is significant. (In the above example the calculated t is larger than any of the four figures on the df = 11 line. Therefore the calculated t is significant beyond the .01 level of significance.) The greater the calculated t, the greater is the certainty that the means are truly different. The .05 level of significance is the point at which statisticians conventionally state that a real difference exists. That convention will be followed here. Therefore, any computed statistic (such as the above t = 5.59) that reaches a level of significance at or beyond .05 (e.g., .05, .04, .03, .02, .01) will be considered as "statistically significant."

(f) In the test report, enter the following:

Mean detections with test item _____

Mean detections without test item _____

Difference between above means _____

Number of subjects (observers) _____

Calculated t _____

Whether or not calculated t is significant at or beyond .05 level of significance _____

An interpretive statement to the effect that "wearing (or carrying, or using) the test item does (or does not) degrade (or improve) the soldier's ability to detect human targets in the tropic forest when compared with soldiers who do not wear (or carry or use) the test item" _____

Any other data, analyses, or comments that are pertinent _____

(2) Difference between mean search times. Did the test item effect a significant improvement or reduction in the mean time taken to search for targets that were detected, compared with mean search time without the test item? (Assume 12 Os taking a 35-item test.)

(a) If each O made at least one detection with the test item and at least one detection without the test item, use appendix B-3 and the procedures outlined in paragraphs 9b(1)(b) through 9b(1)(f), above. The only difference will be that data entries in columns A and B (appendix B-3) will be "average search time" (in seconds) for detections made. For instance if O number one, using the test item, made three detections and the search times were 21 seconds, 56 seconds, and 110 seconds, his average search time would be:

$$\text{Average Search Time} = \frac{\text{Total Search Time for all Detections}}{\text{Number of Detections}}$$

$$= \frac{21 + 56 + 110 \text{ seconds}}{3}$$

$$= 62.3 \text{ seconds}$$

The number 62.3 would be entered in column A for O number one. The other data entries (average search times) would be calculated in the same manner. Data and statements included in the test report [called for in paragraph 9b(1)(f), above] would pertain to "mean search time."

(b) If one or more O makes no detections at all (for instance, zero detections out of 35 target presentations), with the test item or without the test item, average search time cannot be calculated on an individual basis, and the following procedure may be used for analyzing difference between mean search times.

Using alternate Data Summary Sheet for Search Time (appendix B-4) and the completed score sheets (appendix B-2), list the search times (in seconds) for each detection in the appropriate column, X_1 or X_2 for "with test item" or "without test item," respectively. The number of search times listed in the X_1 column will be equal to the total number of detections made by all Os with the test item (N_1). The number of search times listed in the X_2 column will be equal to the total number of detections made by all Os without the test item (N_2). It is not necessary for N_1 to be equal to N_2.

Complete the calculations in appendix B-4 in the following way. Square each value in the X columns and enter in appropriate X^2 column. Add values in each X and X^2 column and enter sums in spaces provided. Calculate means (M_1 and M_2) by dividing "sum of X" (ΣX) by appropriate N; enter means in spaces provided. Square means and enter in spaces provided. Calculate variances (S^2) by dividing "sum of squares of X" (ΣX^2) by appropriate N and subtracting appropriate M^2; enter variances in spaces provided. Check all calculations.

One of the following t tests may be used to indicate whether the difference between mean search times (with versus without test item) is statistically significant or due to chance. Substitute values calculated in appendix B-4: If N_1 is equal to N_2, or if N_1 and N_2 are not equal and S_1^2 and S_2^2 are not significantly different (as determined by a qualified statistician using Hartley's F_{max} or Bartlett's χ^2 test for homogeneity of variance), use the following t test. Interpret result according to paragraph 9b(1)(e), above. Report data in the manner shown in paragraph 9b(1)(f).

$$t = \frac{M_1 - M_2}{\sqrt{\left(\frac{(N - 1)\ S_1^2 + (N_2 - 1)\ S_2^2}{N_1 + N_2 - 2}\right)\left(\frac{N_1 + N_2}{N_1\ \ N_2}\right)}} \qquad (3)$$

$$df = N_1 + N_2 - 2$$

If N_1 and N_2 are not equal and S_1 and S_2 are significantly different, or if no statistician is available to make those determinations, use the following t test. Interpret result according to paragraph 9b(1)(e), above. Report data in the manner shown in paragraph 9b(1)(f).

$$t = \frac{M_1 - M_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}} \qquad (4)$$

$$df' = \frac{\left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}\right)^2}{\left(\frac{S_1^2}{N_1}\right)^2 \frac{1}{N_1 + 1} + \left(\frac{S_2^2}{N_2}\right)^2 \frac{1}{N_2 + 1}} - 2$$

df = df' rounded to nearest integer

c. Basic Moving Target Analyses.

(1) Difference between mean detection distances. Did the test item effect a significant improvement or reduction in the mean distance at which targets were detected compared with mean target detection distance without the test item?

(a) There will be two score sheets for each O (appendix B-6). On each score sheet, transform each of the target reports into line-of-sight (LOS) distances in the following manner:

Transform target report to inches. The first number of the target report represents the number of markers (one marker for each 10 feet) away from the zero point on the walking path that the target was detected. The second number is the target's number of inches away from the marker. For instance, "6 + 23" means 6 markers plus 23 inches, or 60 feet plus

23 inches, or 720 inches plus 23 inches, or 743 inches. The score, "7 - 40," would be transformed into 800 inches in the same manner. For ease of transformation, the following quick method may be used:

Examples: Target Report of "6 + 23"

(120 x 6) + (23) = 743 inches

Target Report of "7 - 40"

(120 x 7) + (-40) = 800 inches

Transform target report inches to LOS inches (to nearest inch) from observer to target. Because of the system used to lay out the testing site, each LOS distance is the hypotenuse (side opposite the right angle) of a right triangle of which the lengths of the two sides that form the right angle are known. One of the known sides is 20 feet or 240 inches long (the distance from the observer's position to the zero point of each walking path). The other known side is the target report distance at the point on the walking path where the target was detected. Figure 7 illustrates the relationship.

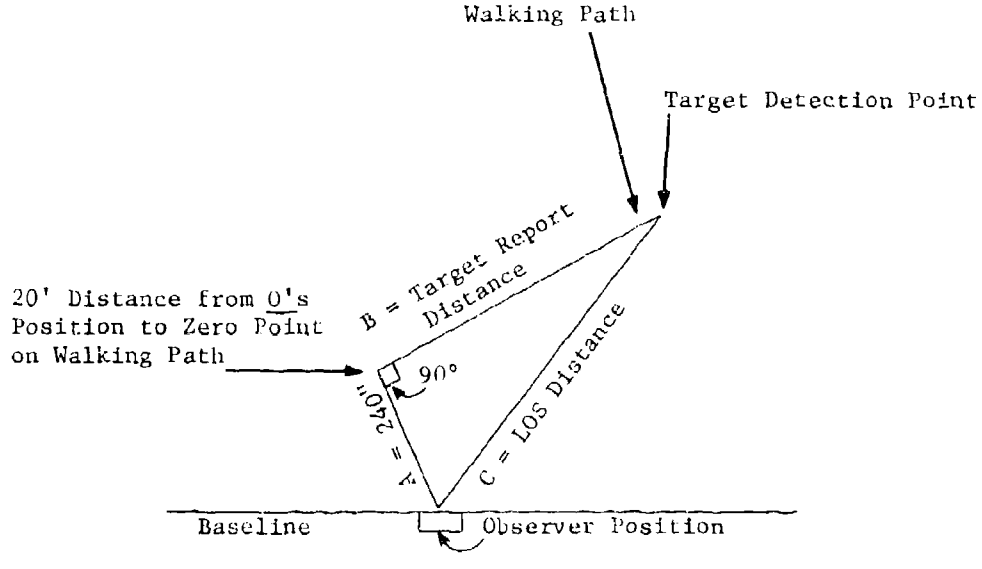

Figure 7. Triangulation Method used to Calculate LOS Distance.

The three sides in the above diagram are labeled A, B, and C for convenience. The Pythagorean Theorem states that, in the above diagram, $C^2 = A^2 + B^2$. Because A and B are known, C may be derived.

Example 1: Zero Point Radius (Constant) = A = 240"
Target Report Distance = B = 743"

$C^2 = A^2 + B^2$

$C^2 = 240^2 + 743^2$

$C^2 = 57,600 + 552,049$

$C^2 = 609,649$

$C = \sqrt{609,649}$

C = 781" = LOS distance to nearest inch.

Example 2: Zero Point Radius (Constant) = A = 240 inches
Target Report Distance = B = 800 inches

$C^2 = A^2 + B^2$

$C^2 = 240^2 + 800^2$

$C^2 = 57,600 + 640,000$

$C^2 = 697,600$

$C = \sqrt{697,600}$

C = 835" = LOS distance to nearest incl

(b) On each score sheet, enter the computed LOS distance in inches beside each of the 30 target reports.

(c) On each score sheet, add the 30 computed LOS distances and enter the total in the space provided at the bottom of the sheet.

(d) On each score sheet, divide the total LOS distance by 30 and enter the result (average LOS) in space provided at bottom of score sheet.

(e) On the Data Summary Sheet for Moving Targets (appendix B-7), enter the average LOS in the proper column for each Q.

(f) Using procedures outlined in paragraphs 9b(1)(b) through 9b(1)(f) on data entered in appendix B-7, calculate a t test and report data with respect to differences between mean detection distances, with versus without the test item. For report purposes, inches may be converted to feet and inches. The value of t and its interpretation will not be affected by the conversion.

d. Fifty Percent Visibility Thresholds. The distance at which a target has a 50 percent chance of being visually detected by the average soldier is called the 50 percent visibility threshold. This threshold is usually calculated from data of a test that uses distance as a score (such as the test for moving targets). However, data on number of detections at various fixed distances (such as the test for stationary targets) may be used to approximate the 50 percent visibility threshold.

(1) For stationary targets, the 50 percent visibility threshold is determined by calculating the percent of targets detected at each target distance, and then linearly interpretating the 50 percent target detection distance.

(a) Following is a method of calculating a 50 percent visibility threshold for a test site layout with 7 detection distances and 5 radii. Assume 12 Os. With 5 radii and 12 Os, there are 5 x 12 = 60 possible detections at each distance; 60 detections = 100 percent detections for a given distance.

	Detection Distance (feet)	Number of Detections	% Detections (base = 60)	
	30	47	78	
	45	40	67	
15-foot interval	60	35	58	50% detection point is between the 60 and 75 foot detection distances.
	75	20	33	
	90	5	8	50% visibility threshold
	105	1	2	$= 60' + \left(15' \times \frac{58\% - 50\%}{58\% - 33\%}\right)$
	120	0	0	$= 60' + 5'$
				$= 65'$

(b) If the number of detections does not steadily decrease with each successive increase in detection distance, a qualified statistician should be consulted to estimate the 50 percent visibility threshold using regression analysis.

(2) For moving targets, the 50 percent visibility threshold is determined from the raw data by calculating the median LOS distance over all detections.

(a) The following example is for two Os taking a five-item moving target test (yielding 10 detections overall).

Rank Order of Distances at which Detections were Made

Rank	LOS Inches	
		Median is distance at which half the
1	260	detections are above and half are below.
2.5	370	
2.5	370	
4	391	
5	420 ←	Median = $420'' + \frac{467'' - 420''}{2}$
6	467	
8	800	
8	800	= 420" + 23.5"
8	800	
10	1123	= 443.5" = 50% Visibility Threshold

(b) If the test design yields an odd number of detections, the 50 percent visibility threshold would be the distance recorded beside the middle rank.

(c) If the middle ranks are associated with equal detection distances, a qualified statistician should be consulted to determine the median by using the cumulative 50th percentile method.

(d) As the distribution of detection distances becomes normal, the 50 percent visibility threshold (median) approaches the value of the mean detection distance discussed in paragraph 9c(1) above; therefore, determination of the significance of the difference between 50 percent visibility thresholds (with versus without test item) becomes strongly associated with the significance of the difference between mean detection distances discussed in paragraph 9c(1) above.

e. Cost Effectiveness. Cost effectiveness ratios are possible, for example: Cost per foot of gained detectability = $(M_I - M_U)$/Production Cost ($). Knowing or estimating the development cost of the item, it may be divided through by difference between the 50 percent visibility thresholds with the test item (M_I) and the average human capability (in

daylight) without the test item (M_u). The ratio can be inverted to determine "detectability gained per dollar." Obviously these ratios cannot be computed for all types of personnel detection systems to be deployed in the tropics. For example, any detection range gain in a remote sensing system may be useful because there are no human observers present. Similarly, when testing night vision devices, the quantity "M_u" at night drops to essentially zero under the jungle canopy.

Recommended changes to this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: DRSTE-ME, Aberdeen Proving Ground, Maryland 21005. Technical information related to this publication may be obtained from US Army Tropic Test Center, ATTN: STETC-TD, APO New York 09827. Additional copies of this document are available from the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. This document is identified by the accession number (AD _____) printed on the first page.

APPENDIX A
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11. Kitchen, J. H., M. D. Neptune, and B. R. Davis. *Mobility in Natural Environments Report II, Tropic Test Area Characteristics.* TECOM Project No. 9 CO 009 000 015, US Army Tropic Test Center Report (in preparation).

APPENDIX B
DATA FORMS

General Instructions to Observers--Stationary Target Test

Instructions given to each observer by the tester prior to the start of each subject's first test.

"This is part of a test of the (name of test item) being conducted by the US Army Tropic Test Center.

"During this part of the test we are trying to find out how well you can detect targets through the jungle. You will see one of the targets (point to targets during general instructions) standing up facing you between 9 o'clock (point) and 3 o'clock (point) at different distances from you. There will be one target at a time. When I give you the signal, you will stand up within this square (demonstrate) and search for the target. You may crouch, kneel, or even lie down, providing you don't move your head outside the square. If you spot him point in his direction. You will have two minutes to find him. If you think you see him, but are doubtful, go ahead and guess. If you are wrong, I will say "keep on looking." If you don't spot him in the 2-minute time limit, I will turn you around and score a miss. You will be tested twice--once while using the test item and once when not using it.

"There will be (number of items on test) trials in all and the test will last about an hour. You will wear these ear protectors during the test so that you cannot tell from the noise where the target is located. Are there any questions?"

Sample Score Sheet
For Stationary Target Test
(Based on 5 Detection Radii X 7 Distances = 35 Items)

Observer No. ____ Glasses: Yes ___ No ___ Date _____
Check One Name _____
____ First Test Rank _____
____ Second Test SSAN _____
Check One Unit _____
____ With Test Item Start Time _____
____ Without Test Item End Time _____

Item	Target Position* Radius	Distance	Detected (+ or 0)	Detection Time	Item	Target Position* Radius	Distance	Detected (+ or 0)	Detection Time
1	IV	105	____	____	19	V	45	____	____
2	III	75	____	____	20	V	30	____	____
3	V	120	____	____	21	IV	75	____	____
4	V	90	____	____	22	III	60	____	____
5	I	105	____	____	23	IV	45	____	____
6	V	60	____	____	24	II	105	____	____
7	III	105	____	____	25	III	90	____	____
8	I	45	____	____	26	I	75	____	____
9	III	45	____	____	27	I	30	____	____
10	I	120	____	____	28	V	105	____	____
11	II	60	____	____	29	III	120	____	____
12	I	60	____	____	30	III	30	____	____
13	II	30	____	____	31	V	75	____	____
14	II	45	____	____	32	II	75	____	____
15	II	120	____	____	33	IV	30	____	____
16	IV	60	____	____	34	I	90	____	____
17	IV	90	____	____	35	IV	120	____	____
18	II	90	____	____					

* Random Order

Directions: If "First Test," start with Item 1 through 35.
If "Second Test," start with Item 19 through 35, then 1 through 18.
For each item, score "+" if detected within 120 seconds; score "0" if not detected within 120 seconds. Record detection time for each detection if under 120 seconds.

Remarks: Record any unusual events which might have influenced the outcome of the test including attitude of observer, performance of targets, unusual weather conditions, etc.

Sample Data Summary Sheet
For Number of Detections or Average Search Time---
Stationary Target Test

Observer Number	Total Number of Detections or Average Search Time		Difference (A-B)	
	With test item A	Without test item B	D	D^2
1	____	____	____	____
2	____	____	____	____
3	____	____	____	____
4	____	____	____	____
5	____	____	____	____
6	____	____	____	____
7	____	____	____	____
8	____	____	____	____
9	____	____	____	____
10	____	____	____	____
11	____	____	____	____
N = 12	____	____	____	____

Totals: ΣA = ____ ΣB = ____ ΣD = ____ ΣD^2 = ____

(Check: $\Sigma A - \Sigma B = \Sigma D$)

Averages: $\frac{\Sigma A}{N} = M_A$ ____ $\frac{\Sigma B}{N} = M_B$ ____ $\frac{\Sigma D}{N} = M_D$ ____

(Check: $M_A - M_B = M_D$)

Sample Alternate Data Summary Sheet
For Search Time--Stationary Target Test

With Test Item			Without Test Item		
Total Number Detections = ____ = N_1			Total Number Detections = ____ = N_2		
(List search times below in seconds)			(List search times below in seconds)		
	X_1	X_1^2		X_2	X_2^2
1.	___	___	1.	___	___
2.	___	___	2.	___	___
3.	___	___	3.	___	___
4.	___	___	4.	___	___
5.	___	___	5.	___	___
6.	___	___	6.	___	___
7.	___	___	7.	___	___
8.	___	___	8.	___	___
9.	___	___	9.	___	___
10.	___	___	10.	___	___
11.	___	___	11.	___	___
12.	___	___	12.	___	___
N_1	___	___	N_2	___	___

ΣX_1 = ____ ΣX_1^2 = ____

$\frac{\Sigma X_1}{N_1} = M_1$ = ____

M_1^2 = ____

$S_1^2 = \frac{\Sigma X_1^2}{N_1} - M_1^2$ = ____

ΣX_2 = ____ ΣX_2^2 = ____

$\frac{\Sigma X_2}{N_2}$ = ____ M_2 = ____

M_2^2 = ____

$S_2^2 = \frac{\Sigma X_2^2}{N_2} - M_2^2$ = ____

General Instructions to Observers--Moving Target Test

"This is a test conducted by the US Army Tropic Test Center.

"We are trying to see how well you can detect moving targets in the jungle. You will see one of these fellows (demonstrate) moving somewhere between 9 o'clock (point) and 3 o'clock (point). There will be only one target at a time. You will be wearing these ear protectors and standing facing me inside this cloth square (point). When I give you the signal you will turn around and search for the target. You may crouch, kneel or even lie down, providing you don't move your head outside the square. If you spot the target press this button immediately (demonstrate) and point to him.

"There will be 30 trials in all and the test will last about an hour and a half. Remember, just as soon as you spot him press this button. Are there any questions?"

Sample Score Sheet
For Moving Target Test

Observer No. _____ Glasses: Yes ___ No ___ Date _____
Check One Name _____
_____ First Test Rank _____
_____ Second Test SSAN _____
Check One Unit _____
_____ With Test Item Start Time _____
_____ Without Test Item End Time _____

Item	Lane	Target's Report	Computed LOS Distance (inches)	Item	Lane	Target's Report	Computed LOS Distance (inches)
1	V			16	IV		
2	IV			17	II		
3	X			18	I		
4	VIII			19	III		
5	I			20	X		
6	VII			21	VII		
7	VI			22	VIII		
8	VIII			23	VII		
9	III			24	X		
10	VI			25	IX		
11	IX			26	VI		
12	IV			27	II		
13	II			28	I		
14	V			29	V		
15	IX			30	V		

Ending Time _____ Total LOS = _____
Average LOS = Total LOS/30 = _____

Directions: If "First Test," start with Item 1 through 30.
If "Second Test," start with Item 16 through 30, then 1 through 15.

Remarks: Record any unusual events which might have influenced outcome of the test including attitude of observer, performance of targets, unusual weather conditions, etc. _____

_____

Sample Data Summary Sheet
For Moving Target Test

Observer	Enter Average LOS Distance With test item A	Without test item B	Difference (A-B) D	D^2
1	____	____	____	____
2	____	____	____	____
3	____	____	____	____
4	____	____	____	____
5	____	____	____	____
6	____	____	____	____
7	____	____	____	____
8	____	____	____	____
9	____	____	____	____
10	____	____	____	____
11	____	____	____	____
N =12	____	____	____	____

Totals: $\Sigma A =$ ____ $\Sigma B =$ ____ $\Sigma D =$ ____ $\Sigma D^2 =$ ____

(Check: $\Sigma A - \Sigma B = \Sigma D$)

Overall Average LOS Distance:

$\frac{\Sigma A}{N} = M_A =$ ____ $\frac{\Sigma B}{N} = M_B =$ ____ $\frac{\Sigma D}{N} = M_D =$ ____

(Check: $M_A - M_B = M_D$)

Sample Test Schedule
Stationary and Moving Target Test
(12 Different Observers--4 Per Day Over 3-Day Period)

Day	Test Trial	Test Item* Usage	Observer* Number	First Test	Second Test
1	1	With	1	X	
	2	With	4	X	
	3	Without	2	X	
	4	With	2		X
	5	Without	3	X	
	6	Without	1		X
	7	With	3		X
	8	Without	4		X
2	1	With	7	X	
	2	Without	6	X	
	3	Without	7		X
	4	With	6		X
	5	With	5	X	
	6	Without	5		X
	7	Without	8	X	
	8	With	8		X
3	1	Without	9	X	
	2	Without	10	X	
	3	With	11	X	
	4	With	9		X
	5	With	12	X	
	6	With	10		X
	7	Without	11		X
	8	Without	12		X

*Each observer is tested twice on the same day--once with and once without the test item. Order of testing observers is random within each day with the restriction that half the Os be first tested with the test item, while the other half be first tested without the test item.

Coding Form for Site Selection

CARD NUMBER	Environmental Factors Available / Data Card Sequence	soil type	cone index 0-6" layer dry season	cone index 6-12" layer dry season	cone index 0-6" layer wet season	cone index 6-12" layer wet season	rating cone index 0-6" layer wet season	rating cone index 6-12" layer wet season	rating cone index 0-6" layer dry season	rating cone index 0-6" layer dry season	vegetation type	vegetation density	slope
1	FACTOR MAP REQUEST												
	COLUMN	1	2	3	4	5	6	7	8	9	10	11	12
2	FACTOR COMPLEX REQUEST												
	COLUMN	1	2	3	4	5	6	7	8	9	10	11	12
3	FACTOR CLASS TO OVERLAY												
	COLUMN	1	2	3	4	5	6	7	8	9	10	11	12
4	TEST AREA OF INTEREST		1 = COCO SOLO, 2 = CHIVA CHIVA, 3 = GAMBOA										
	COLUMN	1											