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HELAST 1 - A FIELD STUDY OF TARGET PRESENTATION AND DEFENDER REACTION

Andrew J. Eckles, III, et al

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

February 1973

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13. ABSTRACT

Target-presentation data and defender-tank reaction from an Armor Field Test are presented. Although the attack scenarios were conducted on terrain with virtually no vegetative cover, the detection and engagement performance was considered to be less than desired for effective defense.

I

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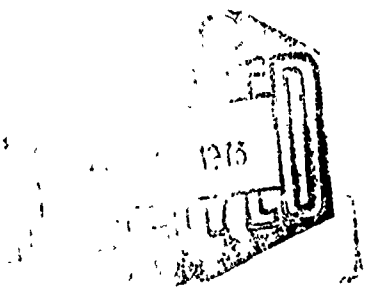

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HELAST I

A FIELD STUDY OF TARGET PRESENTATION AND DEFENDER REACTION

INTRODUCTION

The HELAST Program (Human Engineering Laboratory Armor Systems Tests) is designed to assess the operational effectiveness of armor equipment as it might be used under realistic combat conditions. Essentially, HELAST will attempt to answer the basic question as to how inherent equipment capabilities might be used by the man to accomplish a military mission; and from these data to determine what equipment characteristics are in turn required by the man to most effectively accomplish the combat mission. Therefore, HELAST must strive to measure system performance of Main Battle Tank (MBT) systems in the presence of an intelligent, reacting enemy who will make full use of terrain, cover, concealment, his own equipment, and constantly upgraded tactics and doctrine to minimize the effectiveness of our equipment and operations. In this light, then the system must be defined as the combination of man, his equipment, the environment (weather, terrain, etc.) and the enemy forces, including enemy actions and reactions.

The conditions of combat are not at all similar to those found on a gunnery range. The enemy in combat presents us with a reacting, intelligent target which, preferring not to be hit, uses the total capabilities of his equipment and the opportunity afforded by the natural environment for concealment.

HELAST I, the first field study in this program, was concerned with determining both how attacking tanks present themselves as targets, and how defending tanks engage those targets.

Instrumentation requirements dictated that the study be conducted in two phases. The first phase was conducted to assess target presentation by the attackers and measured the number and duration of the exposures, the amount of exposure, and the aspect of the tank presented. The second phase assessed the defender's performance against the attacking targets and measured the number of engagements, simulated rounds fired, performance times and accuracy of lay at trigger pull.

OBJECTIVES

1. To describe the target presentation of attacking M60 tanks.

2. To describe the engagement of these presented targets by defender tanks.

3. To develop instrumentation requirements and experimental "know how" to conduct more adequate further studies of target presentation.

PROCEDURE

PHASE I: TARGET PRESENTATION

Variables

The test design was simple, involving as it did only two independent variables:

a. Five observer tank positions.

b. Eleven attacks, each over a different route.

There were three dependent variables:

a. The number of target exposures presented to each defender.

b. The duration of each target exposure.

c. The size and aspect of each target exposure.

Description

To provide information about what would be available to be shot at by the five defending gunners, we outfitted an M60A1 as in Figure 1 and directed the tank's commander to attack the objective along the several different routes available within the attack fan. Eleven such runs were made and each of the five defending gunners tracked this tank throughout its attacks.

Whenever the tank disappeared because of terrain undulations, the orange flag and white panel marker alerted the defending commanders and gunners of the impending reappearance of the vehicle from concealment. These features eliminated any requirement to detect or find the tank.

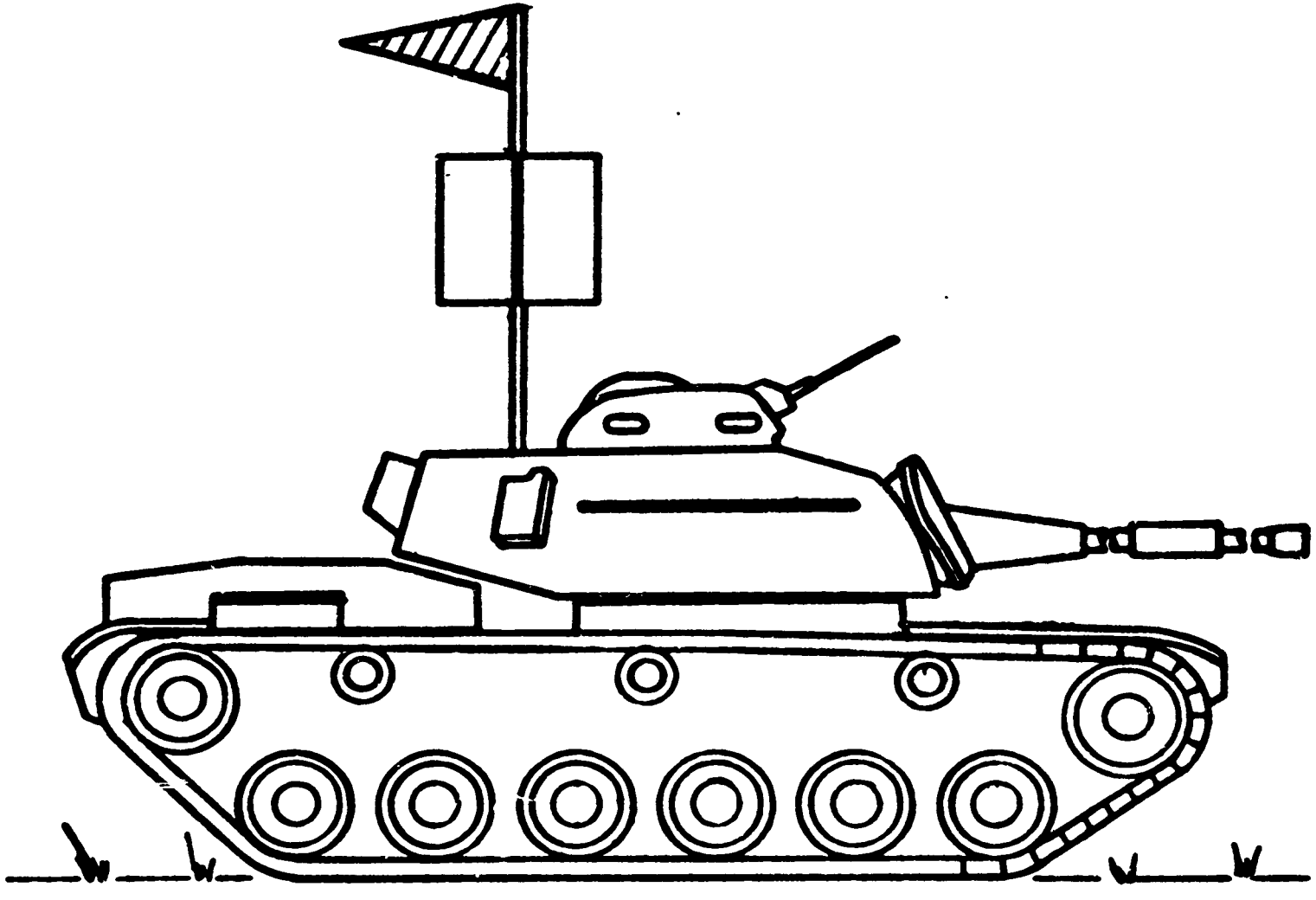


Fig. 1. SPECIALLY OUTFITTED TANK

From each of the five defending tanks a continuous photographic record was obtained of the aspect provided by the target whenever inter-visibility occurred. Each appearance and disappearance of the target tank was entered on an event recorder to thus provide a record of the number of times the tank was visible to each of the defenders. The data so obtained were analyzed to determine the exposed area of the tank presented to each defender, for how long and at what range.

Method of Data Analysis

Earlier experience with photographic records of vehicles indicated that the polar planimeter is an inaccurate as well as laborious means of reducing data to provide exposed area. Therefore, another method was devised. This method established three basic aspects the tank might assume. As shown below in Figure 2, these were frontal, quartering and side. In some cases -- identified as "unknown" -- it was impossible, during data reduction, to determine the aspect presented. Additionally, any presented target tank was also described in terms of its vertical presentation. Thus turret-only or both turret-and-hull described the presentation made in each of the aspect categories. The actual area of the tank, which is presented in each of the six aspects, is readily measured. But the contour of a target tank varies greatly with the aspect presented. It was decided, therefore, to regard the presented area in terms of square footage actually presented and to present the data as the best possible case for the defender. Because range was known, it was simple to convert target size to mils.

PHASE II: FREE-PLAY ATTACKS

Attacker Mission

The platoon or company commander of each attacking force developed a tactical plan for taking the objective. Each attack was to be conducted with either five tanks or 10, as called for in the overall plan of test.

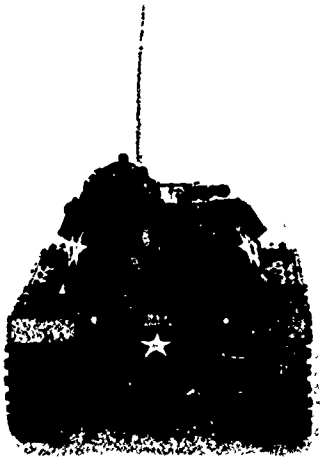
The commander was to take full advantage of the terrain to provide cover in mounting his assault.

To obtain a measure of the rate of advance, lines of large color panels were emplaced at 500-meter range intervals from the defensive position. The platoon (or company) commander informed the control van by radio as he crossed each of these range lines.

Each attack was organized at a staging area and proceeded to a line of departure at least 3000 meters from the objective. There was a total of 20 attacks for record.

The mission of the defenders was to detect, and simulate fire on, as many enemy target tanks as possible.

The defenders were five M60A1 tanks in hasty emplacement. Figure 3 shows how the defenders were emplaced along with a good simulation of the terrain.



Frontal

Quartering

Side

Fig. 2. THREE ASPECTS OF A TANK -- FRONTAL, QUARTERING AND SIDE

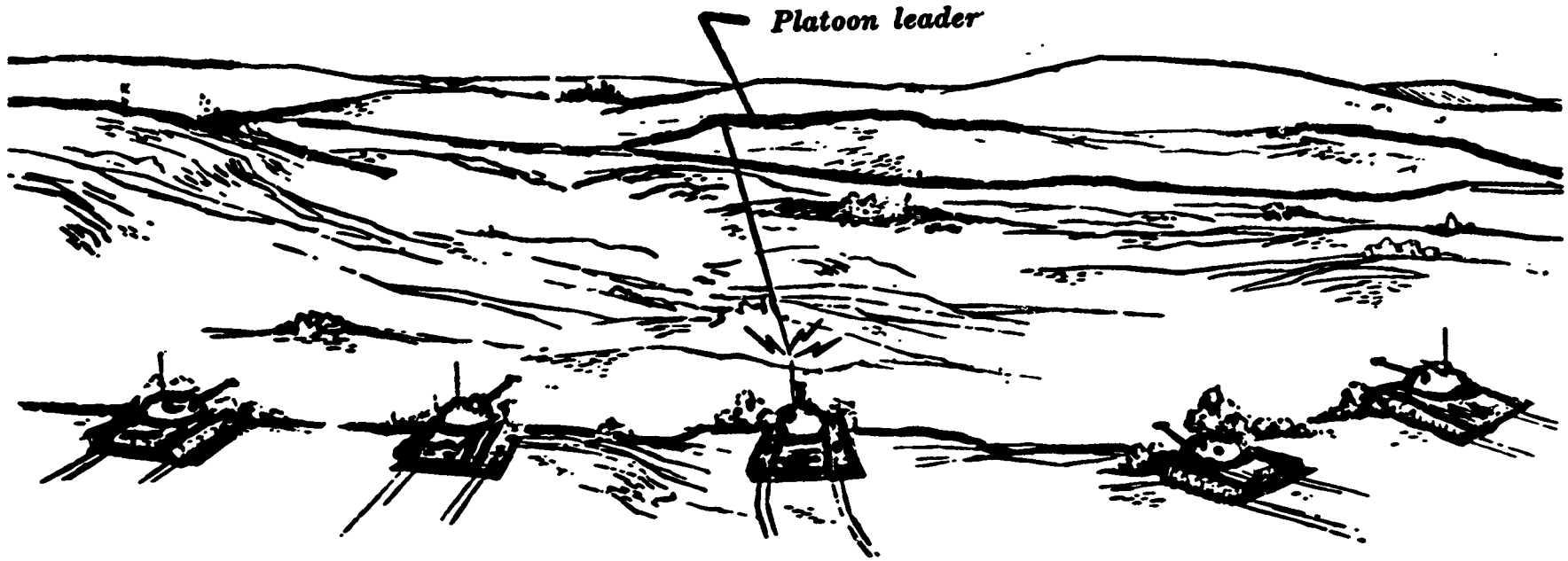


Fig. 3. DEFENDER TANK IN HASTY EMPLACEMENT

Fire distribution was the responsibility of the defending platoon leader. Each crew was instructed to consider an enemy tank destroyed when, on a single target engagement, four (simulated) rounds had been fired. The commander would then undertake to fire upon another exposed target. This procedure prevented constant tracking and firing on a single target and required the commander to engage many targets. A destroyed target could, of course, then become a live target for another defender.

EXPERIMENTAL DESIGN

Subjects

Fifteen crews were used throughout the study. Although all of the test participants were members of Co. D, 3d Armored Cavalry Regiment which is a TOE unit at Ft. Lewis, Washington, 14 practice runs were provided on a different terrain area to insure optimum performance. A total of 15 tank "crews" (each "crew" consisting only of a commander and a gunner) served as subjects. They were divided into three platoons of five crews each, with each platoon serving in rotation, either as defender or attacker. This procedure was continued until 20 record runs had been accomplished. Each defending platoon was attacked at least twice at the company level and twice at the platoon level. Platoon and company runs were alternated to obviate any practice effect.

Ideally, each company attack was to employ 10 tanks and be confronted by five defenders. Likewise, the platoon attack force envisioned five attack tanks against five defenders. The difference between the desired force level and that actually achieved because of tank and/or equipment failures is shown in Table 1.

Independent Variables

1. Number of attacking tanks.
2. Attack scenarios.

Dependent Variables

1. Targets identified and rounds fired.
2. Firing times.
3. Accuracy of lay.
4. Rate of advance

Terrain

The terrain used for HELAST I was a desert lying just to the east of the Cascade mountains at the Yakima Firing Center, Washington. The area used consisted of hills and gullies with no vegetation save a little grass and sagebrush. Nothing grew to a height of more than 18 inches. In short, when the attacking tanks emerged from the cover afforded by terrain undulation, there was nothing to interrupt intervisibility between them and the defenders. Neither was there any shimmer or haze developed by the atmosphere; the air was clear and the visibility excellent.

TABLE 1

Plan of Test as Accomplished

No. of Run	Expected Force Level	Actual No. of Attackers	Actual No. of Defenders
1	P	5	3
2	C	9	3
3	C	8	4
4	P	5	3
5	C	6	4
6	P	5	4
7	C	8	4
8	C	8	3
9	P	8	5
10	C	8	5
11	P	5	5
12	C	6	5
13	P	3	5
14	C	5	5
15	C	5	3
16	P	3	5
17	C	3	5
18	P	3	5
19	C	5	4
20	C	5	3

INSTRUMENTATION AND DATA COLLECTION

Gun-Camera Data

Gun cameras boresighted with each defending gunner's periscope (primary sight) provided continuous photographic recording of the gunner's tracking performance and lay accuracy. Witness lights internal to the cameras recorded the time of trigger pull for simulated firing.

Additionally, these records provided target-size and target-aspect data at time of fire. The gun cameras were operated by the tank monitors seated at the bustle. Figure 4 shows a tank monitor operating his data-recording console. In addition to controlling the camera, the monitor was also responsible for making entries on a 20-channel Esterline-Angus event recorder via an array of buttons and switches located on the data-recording console.

Event-Recorder Data

The following information was entered on the event recorders located on each of the defender tanks:

a. Time at which each fire command was initiated for a given target exposure.

b. Time at which the gunner identified the target.

c. Time at which the gunner gave "on the way."

d. Time at which the trigger was pulled to fire.

e. The time at which an "up" was given by the tank monitors in lieu of the loader.

f. The time at which fire was shifted to a new target.

g. The time at which any target disappeared after a fire sequence had been initiated by the commander. (Target disappearance means that the target was lost for firing and does not include momentary disappearance behind a small obstacle.)

One channel was provided to indicate the occurrence of unique events such as errors in procedure or data collection. The data-readout monitor recorded these in detail after each scenario was completed.

Those aspects of the fire-control sequence which were not amenable to direct instrumentation were monitored through the tank's communication net and entered manually on an event recorder by the tank monitor.

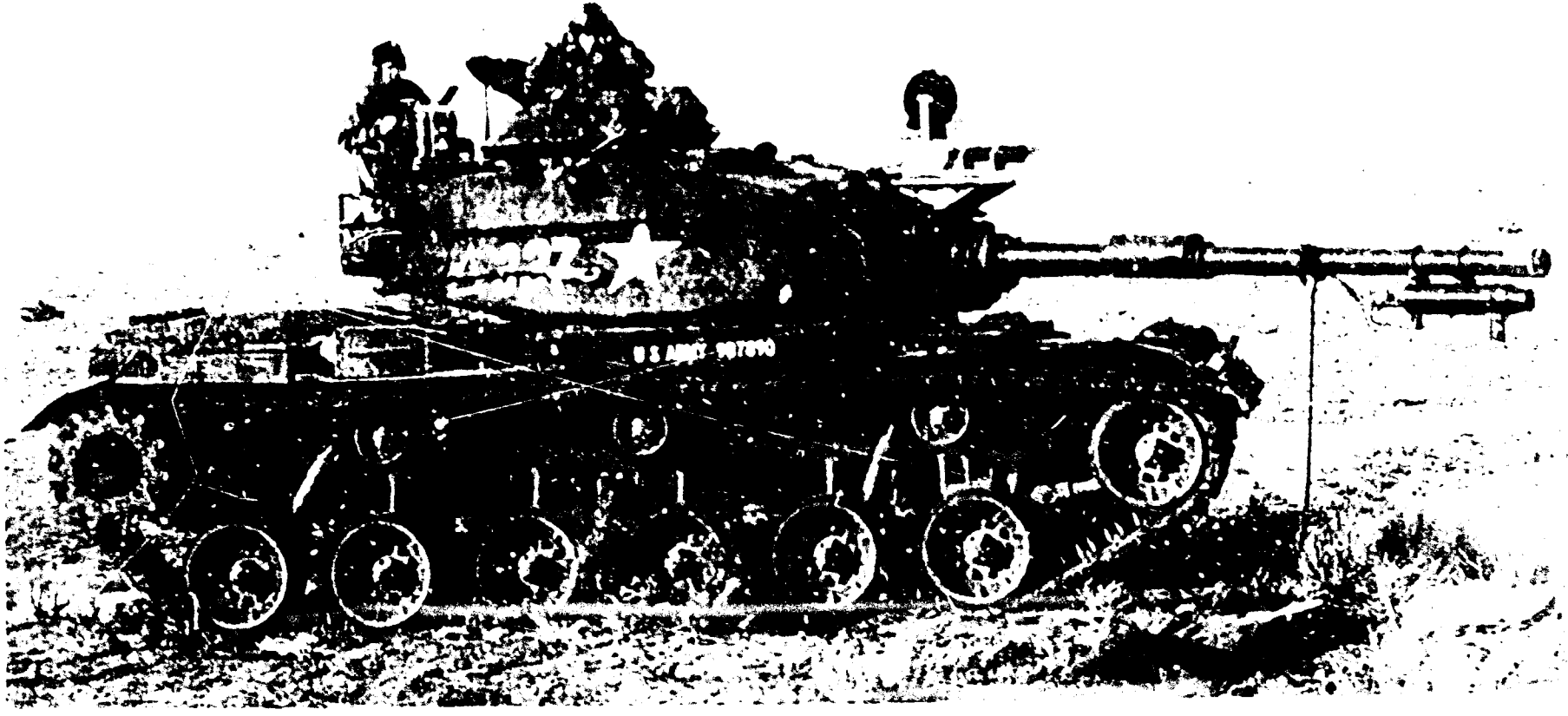


Fig. 4. TANK MONITOR MOUNTED ON M60A1

Voice Recorder

Additional data were obtained by voice recordings of each defender-tank net, thus providing a record of the transactions between the platoon leader and his tank commanders. The attacking-force net was also monitored, but only at the platoon and company level.

Rate of attack information was derived from range data radioed to the test control center. Brightly colored panel markers emplaced at 500-meter intervals between the line of departure and the objective alerted the platoon or company commander to the range change. However, this information radioed to the control van specified only the location of the company or platoon commander. Other elements of the attacking force could be forward or behind this announced position.

An additional channel was used to record a broadcast time signal to provide accurate time measures of the recorded activities.

Definition of Terms

The results to be presented here as well as in Phase II are couched in terms which may be unfamiliar or may suggest a meaning which is unintended. To avoid such confusion, we have defined as follows the terms used in reporting and discussing the data:

Possible Target: A possible target exists for each combination of attacker tank and defender tank. (For example, five defenders and one attacker provide five possible targets; five defenders and five attackers provide 25 possible targets.)

Target Exposure: A target exposure occurs when there is a line of sight between a defender tank (through the gunner's sight) and an attacker tank. (A target, therefore, could conceivably present any number of exposures from zero, where he completed the attack run and was never exposed to the defenders, to a large number of very brief exposures during his attack run.)

Duration of Target Exposure: Duration of target exposure is the interval of time from the initial line of sight to a defender tank to the loss of that line of sight.

Potential Engagement: A potential engagement occurs when a target is exposed for 10 or more seconds. (This definition is derived from data indicating that the mean time from alert to fire the first round is 10 seconds.)

Target Engagement: A target engagement occurs when one or more rounds are fired at an attacking tank.

Complete Target Engagement: A complete target engagement occurs when four rounds are fired at an attacking tank. After four rounds, a new target must be engaged.

RESULTS

PHASE I

Exposures

Examination of the data showed that the attacking tanks presented an average target-exposure rate of 4.2 per attack (Table 2). Only defender tank D was able to participate in all 11 attacks.

TABLE 2

Target-Exposure Data: Phase 1

Defender Tank	Possible Targets	Target Exposures	Average No. of Exposures
A	4	14	3.5
B	9	51	5.7
C	10	39	3.9
D	11	37	3.4
E	6	25	4.2
	$\Sigma = 40$	$\Sigma = 166$	$\bar{x} = 4.2$

Exposure Duration

From the event-recorder tapes, the duration of each target exposure (intervisibility between defender and target tanks) was obtained. These were categorized by five-second increments and the cumulative percentage curve in Figure 5 was developed.

Target Size and Aspect

The photographic record of the attacking tanks' behavior was sampled at half-second intervals. The aspect was determined from the established categories (head on, quartering and side) and the corresponding measures of presented area were converted to milliradians. A time and range plot made of the resulting data is presented in Figure 6.

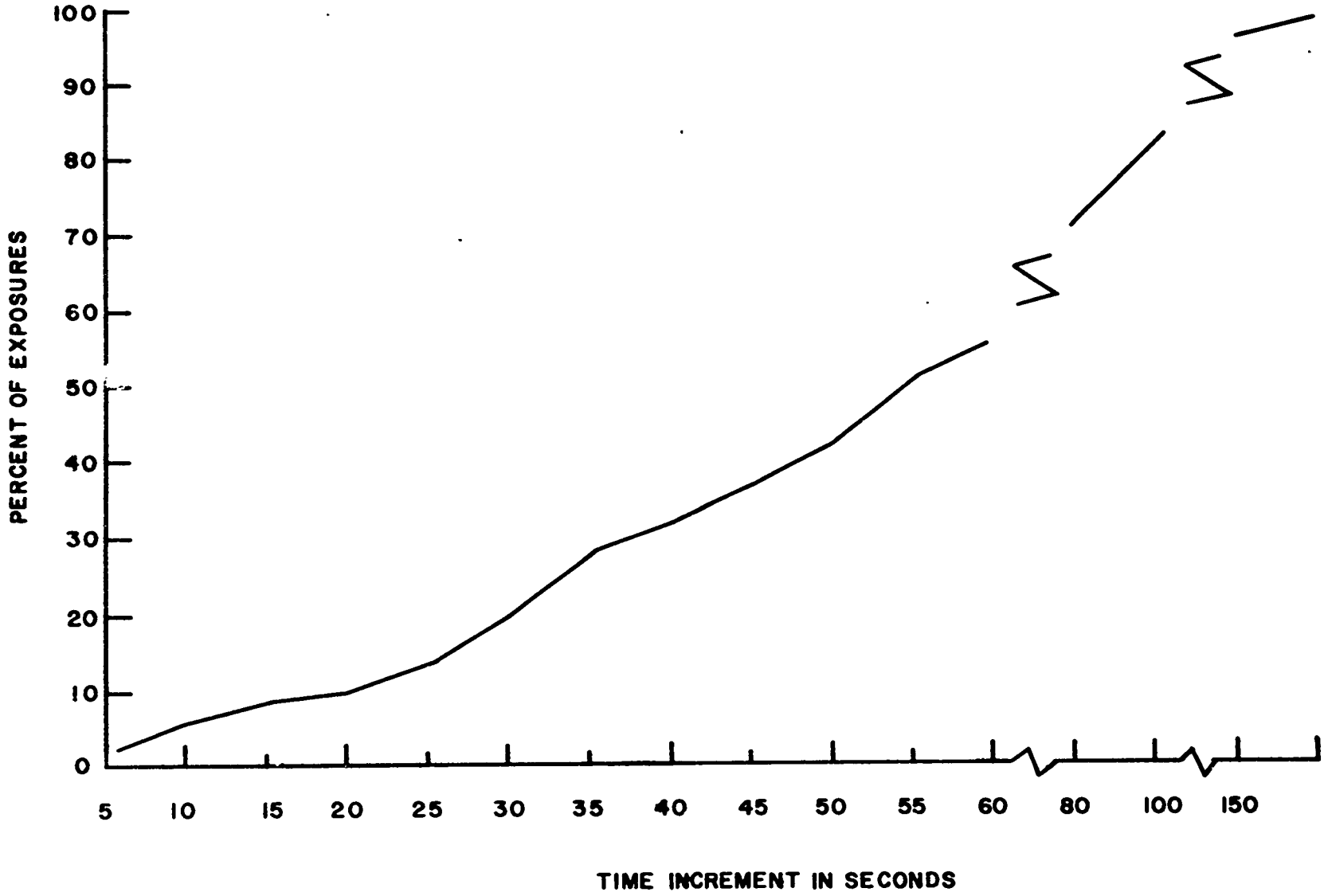


Fig. 5. DURATION OF EXPOSURES

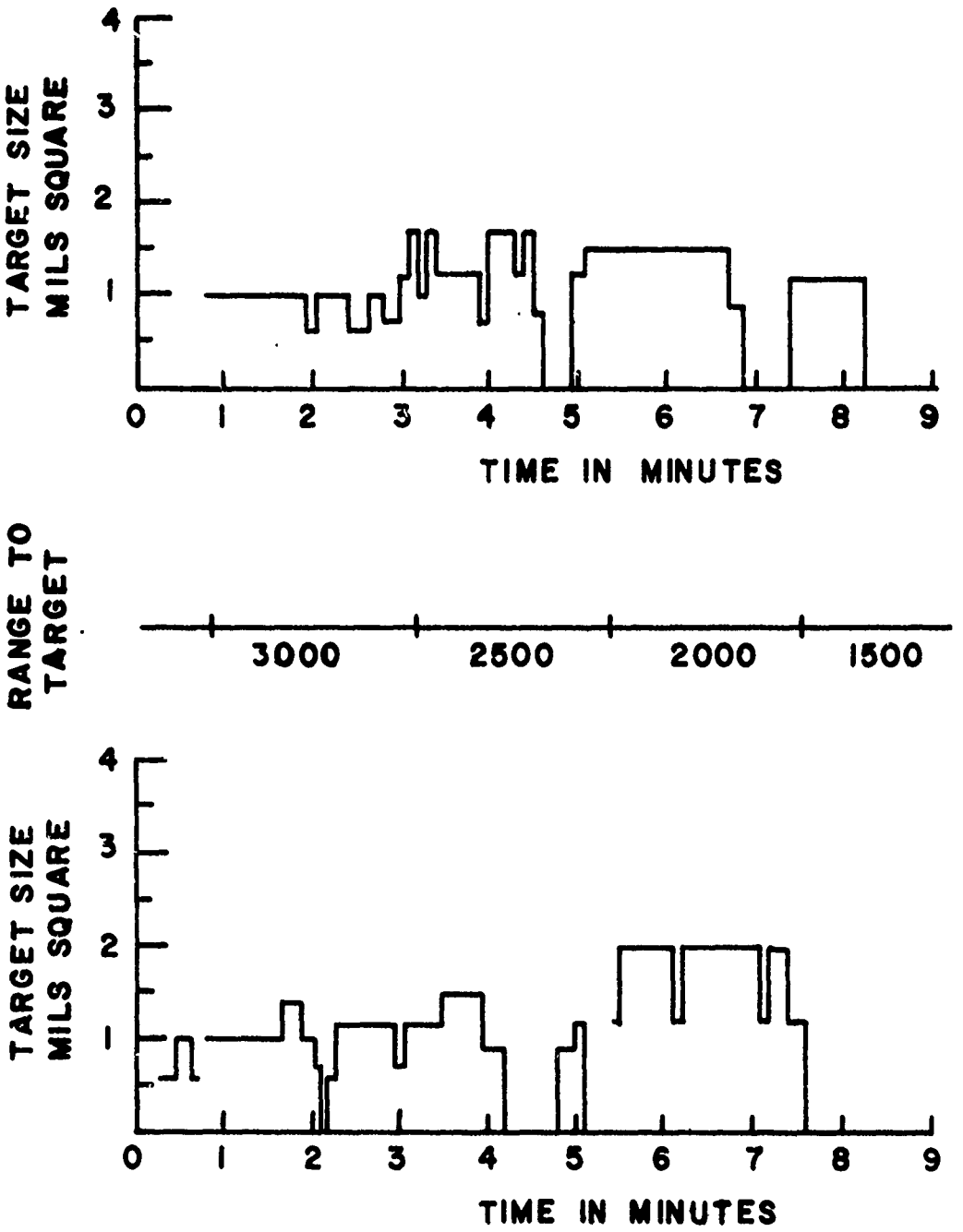


Fig. 6. TARGET SIZE OF TWO ATTACKING TANKS

These same data were used to determine for what percentage of the total exposure time each aspect of the tank was visible. Table 3 includes these figures and the related sizes of the aspects in square feet. The configuration of the aspect is not reflected in the number describing the area.

The full frontal presentation (turret and hull) accounts for 62 percent of the total exposure time. The frontal view of the turret alone adds another 13 percent. The unknown turret category arises from our inability to resolve the turret configuration in 12 percent of the cases.

TABLE 3

Size and Aspect Exposure Rates for M-60A1 in Phase 1

	Frontal Hull	Frontal Turret	Unknown Turret	Quartering Hull	Quartering Turret	Side Hull	Side Turret
Percent	62	13	12	7	3	1 1/2	1
Area in Square Feet	86.8	28.4	--	158.7	37.9	159.8	46.7

PHASE II

The results presented here describe the reactions of the defending platoon to the assault mounted against its position. These reactions consist of the number of attacking tanks detected, identified and fired upon; the ranges of engagement; rate of advance of the attacking force; durations of target exposure; accuracy of lay; and the reacting times of the defending forces.

The data derived from the event recorders and gun cameras were assembled for each defending tank and for individual runs. Our inspection of the data (Appendix) showed little variability between tank crews or between runs. All the data presented were obtained on one piece of terrain. Each attack, therefore, is to a large degree similar to all the others, modified chiefly by the tactical ingenuity of the platoon or company commander. The homogeneous quality of the data permitted us to summarize and present it through the use of averages.

Targets Detected and Engaged

Whenever the gunner pulled his trigger to deliver simulated fire on the target, the event was entered on the recorder automatically by a switch fixed to the trigger. These identifications and trigger pulls are presented in Tables 4 and 5. As mentioned earlier, each engagement was limited to four rounds; thereafter the commander was required to shift fire to another target.

TABLE 4

Target Identification

No. of Runs	No. of Attackers	No. of Defenders	Total Identified	$\bar{x}$ Idents Per Run	$\bar{x}$ Idents Per Tank	Exposures Per Run
20	115	83	867	43	10	101

TABLE 5

Data Summary

No. of Defender Tanks	No. of Attack Tanks	Possible Targets Per Run	Exposures Per Run
4.2	5.8	24	101

Of particular interest in Table 4 is the average number of target identifications and fire engagements per defender tank. From the average number of attackers and defenders we know that a total of 24 possible targets (i.e., combinations of defender/attacker tanks) were provided in a typical run.

Applying our empirically determined target-exposure frequency from Phase I (4.2) to the data in Table 5, we can estimate that there were a total of 101 target exposures per run. Ten identifications per tank therefore constitute 40 percent of what conceivably presented itself to be identified.

From the data in the first-shot column of Table 6, we can see that of those targets identified by the gunner, seven or eight percent never had a single round fired at them. Thus the number of targets engaged (fired at) is less than 10 per defender. Such a performance on terrain where the only vegetation is 18-inch sagebrush would appear to raise questions of considerable import.

TABLE 6

Firing Record of Defender Tanks

	Rounds Fired			
	1st	2d	3d	4th
Number	806	749	669	601
Percent of those Identified	93	86	77	69

Time to Fire and Exposure Duration

Table 7 presents the time required to fire Rounds One through Four after an alert and gunner identification. The data are very uniform.

TABLE 7

Average Firing Times by Attacker-Force Level in Seconds

	Alert to Identify	Identify to Fire 1	Fire 1 to Fire 2	Fire 2 to Fire 3	Fire 3 to Fire 4
Platoon	2.2	7.1	7.6	7.7	7.9
Company	2.2	6.6	7.7	7.5	7.4

Apparently, the number of targets engaged in these attack situations was limited by the time required to complete the engagement (to fire four rounds) and shift to another target, not by the limitations imposed by target detection. However, this factor was undoubtedly related to the unique terrain (open, semi-arid) used for the study. It should be noted that the attacking platoon and company commanders, following approved doctrine, made every effort to avoid exposing a single target at a time to the defenders. Instead, they modified their movement rates to present mulitple targets whenever possible.

Figure 7 demonstrates the relationship between the percentage of targets identified by the gunner and the percentage which he was subsequently able to fire on.

It required about 16 or 17 seconds after alert to fire a first and a second round at an identified target. However, of all the targets identified by the gunner, only 86 percent were still available (visible to the gunner) to receive fire 16 seconds after the commander's alert. At 25 seconds after alert, the third round had been fired but third rounds were possible against only 78 percent of the identified targets. Given the total number of identifications as 100 percent, the percentage loss in available identified targets as a function of time can be shown as in Figure 6. While only two values are presented, other extrapolations may be readily made.

Accuracy of Lay

The defender's accuracy of lay at time of trigger pull is defined as the distance from the gunner's crosshair to the target's center of mass. These data were obtained by a gun camera mounted on the mantlet of the main gun. The gunners' lay errors were computed in mils and converted to feet of deviation from the center of mass. These results are shown in Figure 8. A computed standard deviation about the center of mass is presented in Figure 9.

As expected, there is some increase in lay error as a function of range.

It should be noted that the lay errors obtained on this study agree quite well with those currently supplied by AMSAA and used in most analytical models (Fig. 9).

Rate of Advance (ROA)

The rates of advance for Phases I and II are compared in Figure 9. The rates are comparable and thus justify the extrapolations made from Phase I data.

Figure 10 presents the ROA data in miles per hour and meters per second. The respective curves are in good agreement. Phase I average ROA is 4.8 meters per second as opposed to 4.4 for Phase II.

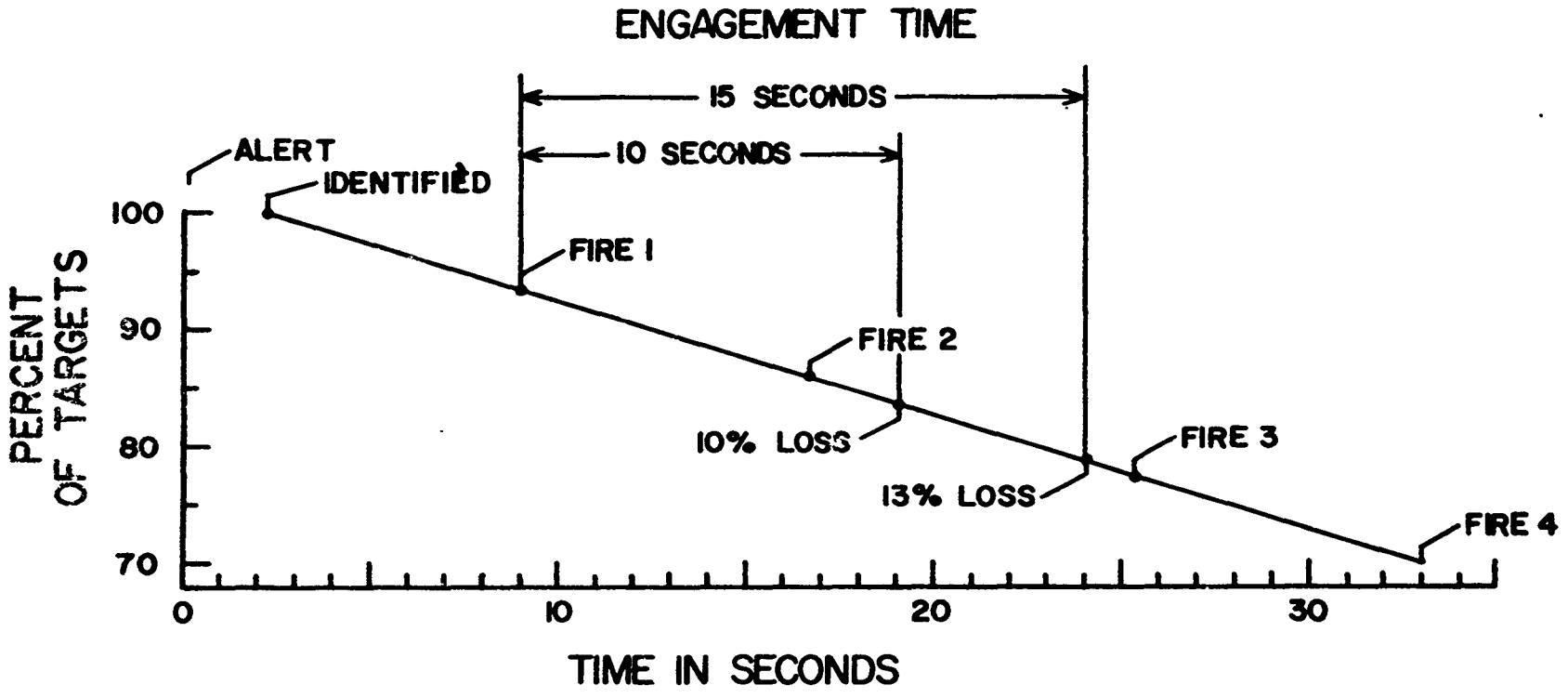


Fig. 7. DURATION OF TARGET EXPOSURE TO GUNNER

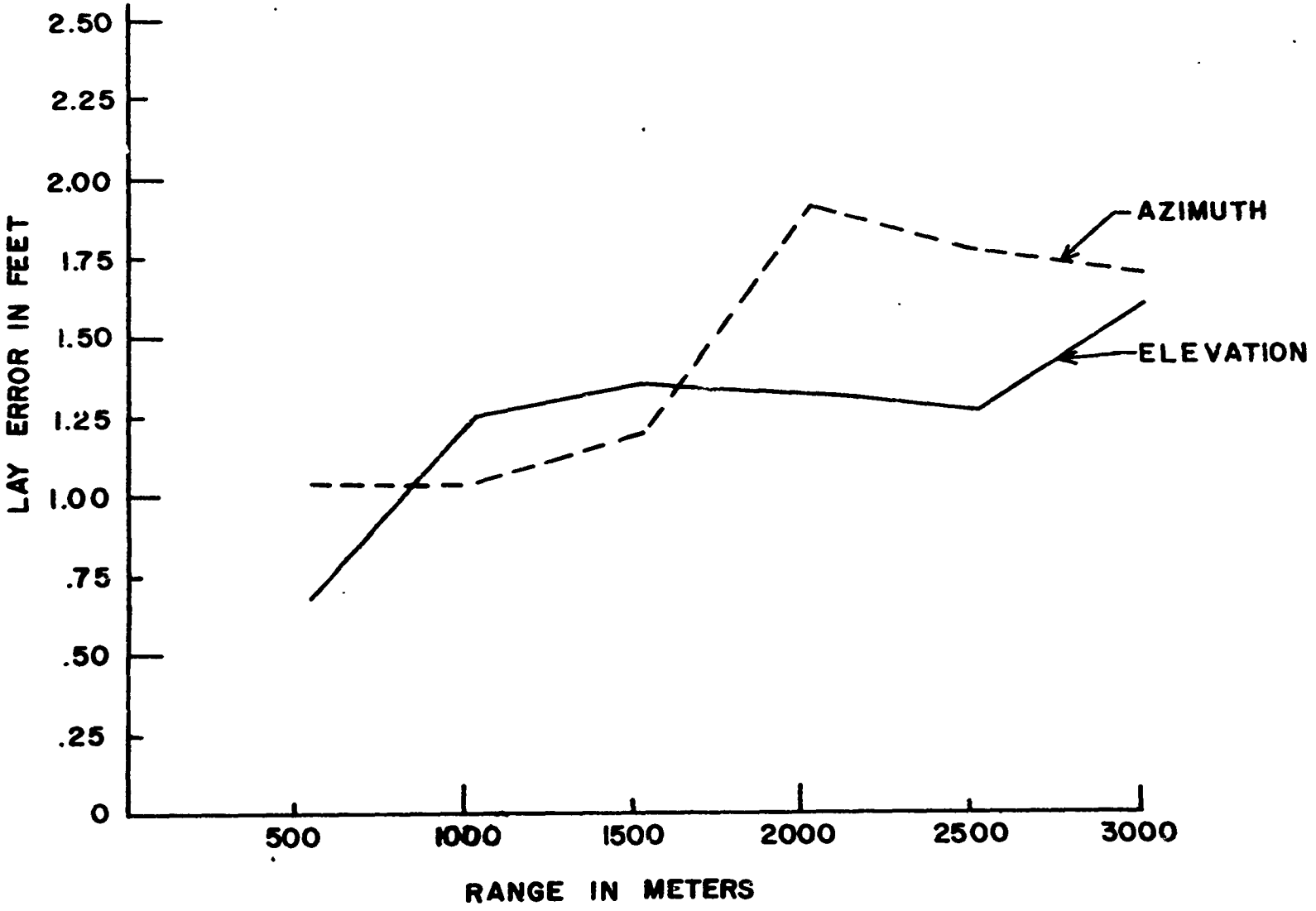


Fig. 8. LAY ERRORS AT TARGET

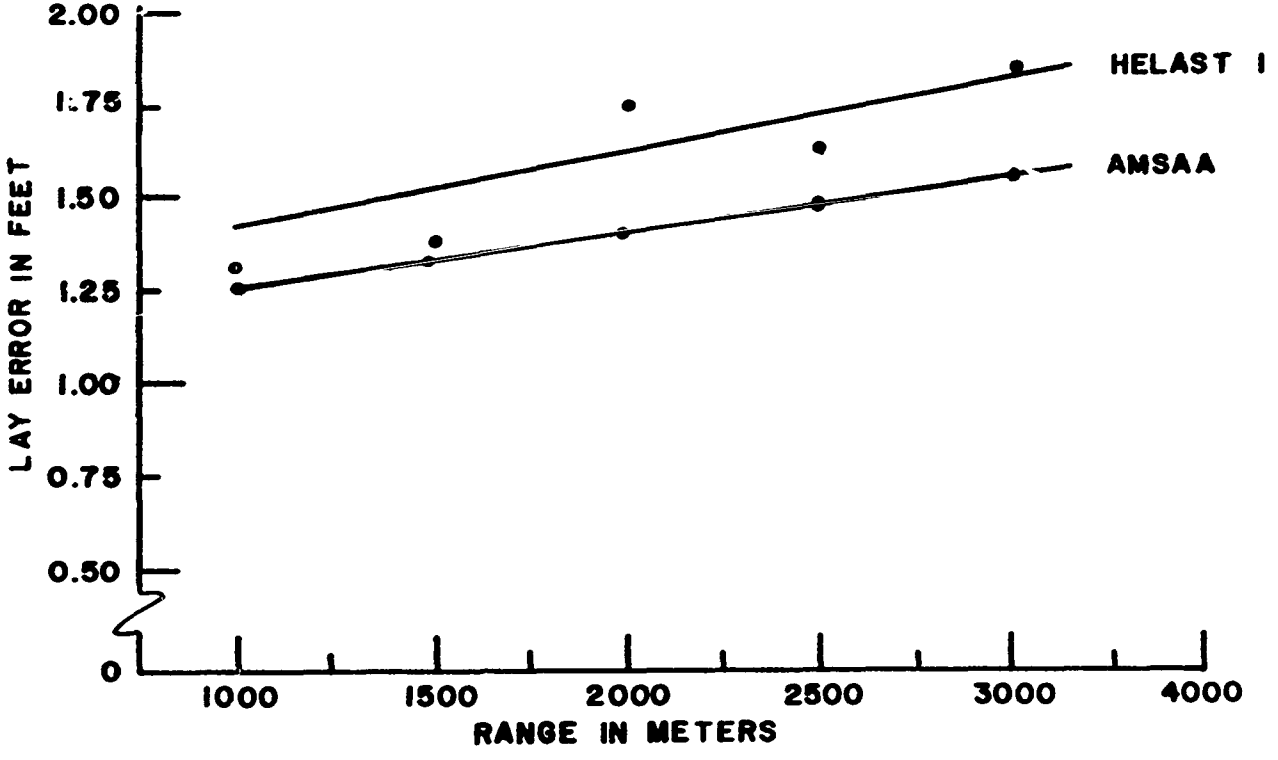


Fig. 9. STANDARD DEVIATION (RADIAL) OF LAY ERROR

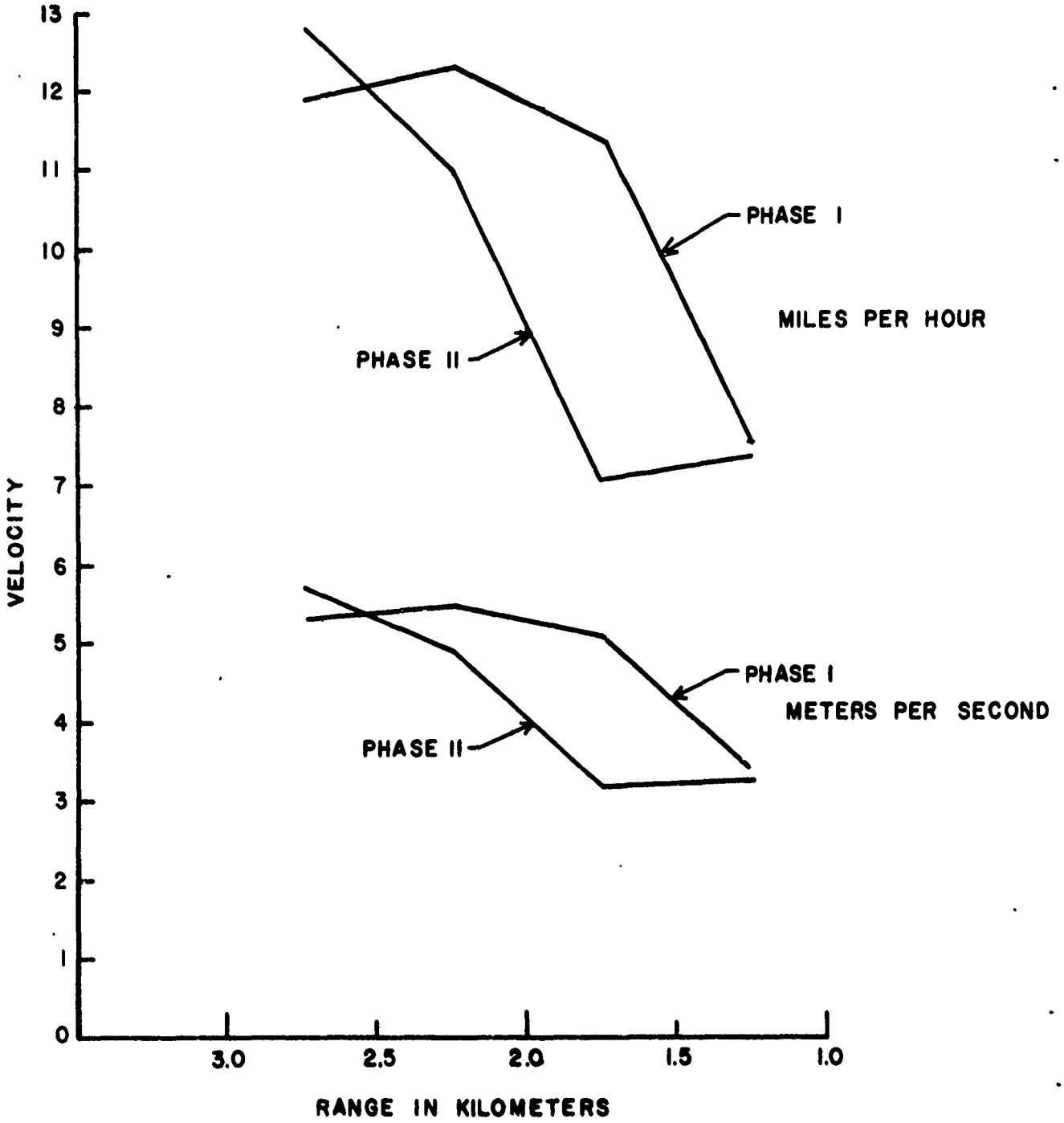


Fig. 10. RATE OF ADVANCE

Ranges of Engagement

As the attacking force approached the objective, the platoon or company commander announced his range to the target. When we examined the defender's firing activity as a function of target range, there was but one range where firing activity was diminished. This occurred at 1000 meters and is readily explained by the terrain characteristics. Table 8 shows the breakdown by range.

For the kind of terrain available at the Yakima Firing Center, the longer ranges did not prevent the tank commanders from engaging targets; the reduced firing at 1000 meters was a special case.

TABLE 8

Ranges of Engagement
Percent of Targets Fired On

Range (in meters)	3000	2500	2000	1500	1000
Percent	20	23	19	20	14

DISCUSSION

Target Availability and Defender's Reaction

The most serious limitation of HELAST I is the lack of information as to precisely what was available to be shot at, although we do have valid data as to just what defenders did shoot at. Another limitation is the absence of any data concerning which targets were detected and fired on. It is conceivable that most of the firing was at the targets that were easiest to detect or were first to expose themselves.

Nevertheless, Phase I of HELAST provided information as to just what was available to be shot at by an individual tank as it made a simulated attack run on the objective. Consequently, through judicious extrapolations from the data obtained in Phase I to the reactions measured in Phase II, we can obtain some insight into what was presented to the Phase II defenders that caused the measured reaction.

During the 20 attack runs examined in HELAST I, a total of 83 defender tanks was attacked by 116 attacker tanks, for a total of 481 possible targets (i.e., defender/attacker combination).

If we now assume that the attacking tanks actually presented themselves about as they did during the Phase I exercise, where they made attack runs as individuals, then each possible target presented itself to the defender for an average of 4.2 target exposures. For simplicity, we can assume an average of 4.0 target exposures for each possible target.

Thus, we can calculate (roughly) that of the 481 possible targets presented during the HELAST study, there was a total of 1924 target exposures during the 20 attack runs. Further, we find that the calculated distribution of durations of exposures indicates that 95 percent, or 1820, of these target exposures were of 10 seconds or longer duration, long enough to allow for a potential engagement.

Of these, there were 806 engagements; in other words, 44 percent of potential engagements were actual engagements. Of these, 601, or 31 percent, were successful engagements (fired on four times). Of all targets exposed, 39 percent, or 749, were exposed long enough to be fired on twice.

Fire commands were issued for and the gunner identified in his sights 867 targets, or 45 percent, of total targets exposed. There were, similarly, 806 engagements (defined as having one or more rounds fired) for 42 percent of the total targets exposed and 44 percent of the potential engagements.

Table 9 provides a summary of these relationships.

Unfortunately, we do not have the ground truth necessary to make any statements as to just how many of the different targets exposed were actually fired on, or to make any statements about the adequacy of fire distribution by the defenders. However, because of the unusual nature of the terrain at Yakima, target-detection probabilities were extremely high compared with what one might expect where there was a more varied background. In fact, in the Yakima area, the diesel exhaust was extremely visible -- to such a degree, indeed, that many defender commanders and gunners were able to "ambush" the attackers when they first appeared by tracking exhaust plumes which indicated the presence of concealed but advancing enemy tanks.

TABLE 9

Target-Presentation and Defender-Performance Data

	Number	Total Target Exposures 1	Total Potential Engagements 2	Total Target Engagements 3	Successful Engagements (4 shots fired) 4	Identifications 5
		Percentages				
1 - Total Target Exposures	1924	-				
2 - Total Potential Engagements	1820	95	-			
3 - Totat Target Engagements	806	42	44	-		
4 - Successful Engagements (4 shots fired)	601	31	33	75	-	
5 - Identifications	867	45	48	93	69	-
6 - Fired Twice	749	39	41	93	80	86

The total number of targets exposed is what the gunners at Yakima had to shoot at. Certain implications seem warranted. Of the more than 1900 targets believed available to be shot at:

a. Five percent of the targets which were under fire (fire commands issued) vanished before fire could be brought to bear.

b. Only 42 percent could be fired on once and 39 percent fired on twice.

c. A four-shot engagement (lasting 33 seconds after detection) could be achieved with only 31 percent of the postulated target exposures.

The above extrapolations depend, of course, on the validity of applying Phase I data to the Phase II scenarios. Because of the riskiness associated with these extrapolations, we compared our Phase I and Phase II data on the duration of intervisibility. Figure 11 shows the percentage of occasions that a line of sight existed between gunner and target for a particular time period or longer. Phase I and Phase II are in remarkable agreement. This congruence lends some validity to the generality of the Phase I data.

Additionally, we wanted to know if our data were in any way consistent with other similar field tests. Leonard and Kirshtein of the Missile Command measured the duration of intervisibilities at Hunter-Liggett Military Reservation. They, too, measured the passage of attacking M-60 tanks, but on terrain with trees in addition to open spaces. They minimized the natural cover somewhat by emplacing their observation post at an altitude of 240 feet. The resultant data are shown in Figure 11.

CONCLUSIONS

1. Under the conditions of HELAST I (M-60 tanks, semi-desert terrain) targets will begin to disappear (after becoming visible) at the rate of at least 10 percent per 10 seconds.

2. In an attacking situation, the number of tragets engaged by a defender is limited by engagement times and time required to shift fire. (These limitations become even more important as targets appear in "bursts" of multiple targets rather than as a series of individuals.)

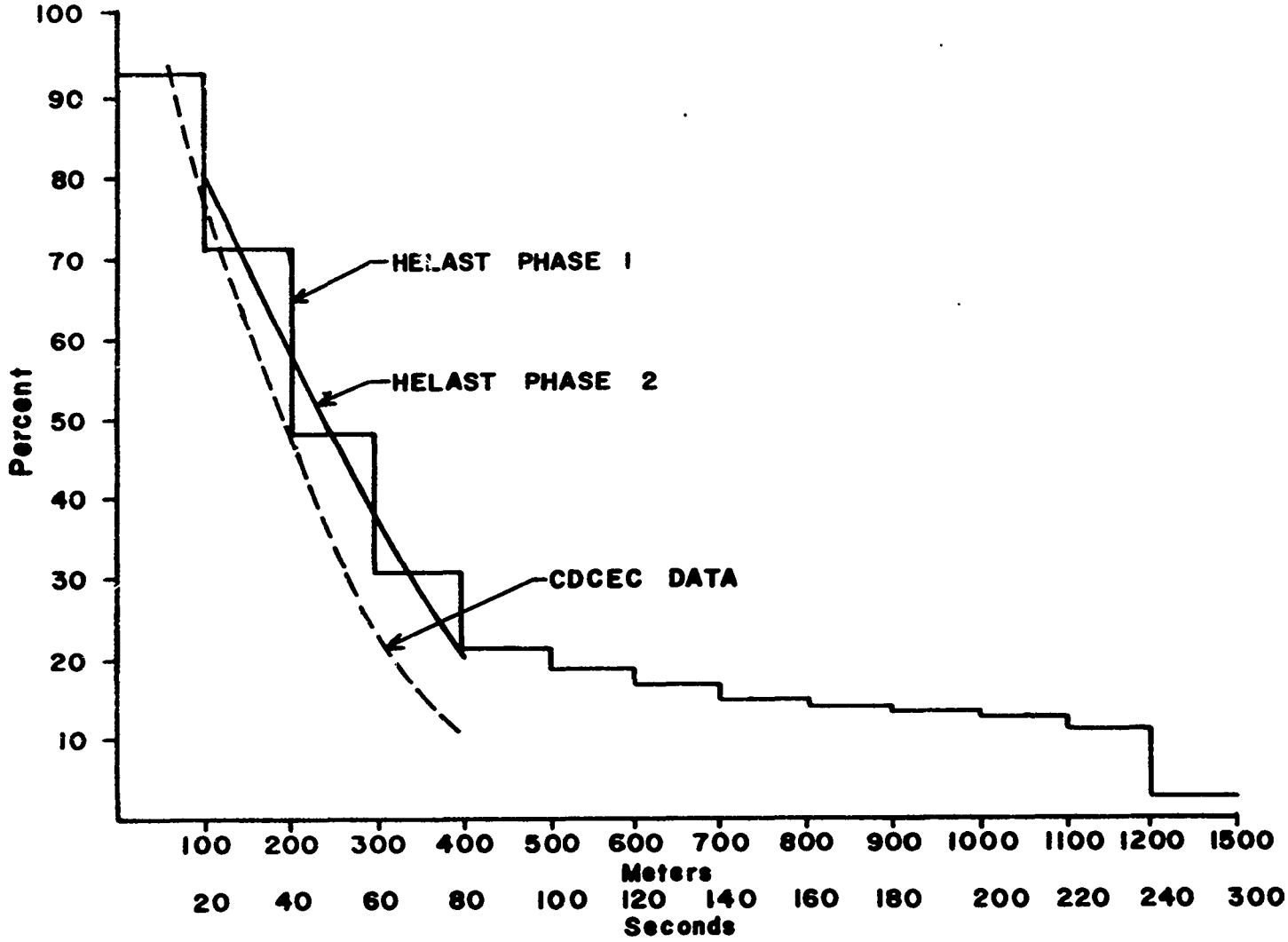


Fig. 11. DURATION OF INTERVISIBILITY

APPENDIX

EVENT RECORDER AND GUN CAMERA DATA

TABLE 1A

Number of Occurrences and Mean Time in Seconds

Run No.	Tank	Alert to Identification		Identification to Fire 1		Fire 1 to Fire 2		Fire 2 to Fire 3		Fire 3 to Fire 4	
		No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$
16	B	13	1.5	12	11.9	11	9.7	11	10.7	9	10.5
	D	17	1.4	17	8.8	16	6.7	15	5.5	13	5.7
	E	18	0.9	18	10.3	18	6.4	18	6.7	16	10.4
17	B	11	1.3	10	5.9	9	8.2	8	10.3	8	7.8
	D	20	2.1	19	7.7	17	5.7	15	5.5	14	5.5
	E	17	1.0	17	6.1	16	6.4	14	7.0	10	7.1
18	A	16	3.2	14	8.0	12	10.0	10	7.6	9	7.6
	B	12	1.0	12	5.3	12	7.1	11	8.2	9	7.4
	D	18	1.6	18	7.6	17	5.5	14	5.4	13	5.3
	E	11	1.1	11	4.3	10	5.9	9	6.0	9	6.0
19	A	12	1.5	9	5.8	9	7.9	9	8.7	7	8.3
	D	21	1.2	20	7.6	19	5.6	16	5.5	16	5.6
	E	11	0.5	10	6.9	10	6.2	9	6.6	6	5.8
20	A	16	4.3	14	3.4	12	7.0	12	6.9	10	6.7
	C	16	4.5	13	8.0	12	8.5	10	7.7	7	7.9
	D	13	1.4	13	8.3	13	5.8	13	5.5	12	5.5
	E	11	2.1	11	11.5	11	6.4	8	6.2	6	5.7
21	A	17	4.6	17	2.8	15	7.2	14	6.8	14	7.2
	C	14	3.3	13	7.7	12	8.2	10	8.4	9	6.8
	D	16	1.7	15	7.2	15	5.2	15	5.3	15	5.1
	E	17	1.8	15	10.1	15	5.6	14	5.6	14	6.1

TABLE 1A (Continued)

Number of Occurrences and Mean Time in Seconds

Run No.	Tank	Alert to Identification		Identification to Fire 1		Fire 1 to Fire 2		Fire 2 to Fire 3		Fire 3 to Fire 4	
		No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$
22	A	13	3.7	11	4.0	10	8.7	10	8.4	10	8.1
	B	8	1.8	8	9.8	8	6.6	8	6.2	7	6.4
	D	12	3.0	8	12.3	7	9.1	7	7.8	7	7.9
23	A	9	3.9	7	5.6	5	8.5	5	8.2	5	8.1
	B	6	1.3	6	10.0	6	6.4	6	6.1	5	6.1
	C	8	1.3	7	7.6	7	8.6	5	8.2	4	8.0
	D	11	2.7	10	7.4	7	6.9	7	6.8	7	8.0
	E	9	1.8	6	10.5	3	7.8	3	8.0	2	7.0
24	A	9	5.3	8	1.9	7	7.9	5	7.5	5	7.5
	B	4	2.0	4	15.8	3	6.5	3	6.8	3	6.8
	C	5	1.3	5	6.2	5	8.0	4	8.5	4	8.3
	D	9	4.6	9	4.5	8	9.3	6	8.7	5	11.9
	E	7	2.6	7	6.0	6	8.2	5	8.2	5	8.4
25	A	9	5.8	9	1.9	8	8.6	8	7.8	7	8.1
	B	11	1.5	11	13.1	11	7.1	11	6.7	11	7.3
	C	10	1.0	10	7.1	8	8.2	7	7.6	7	8.2
	D	17	2.2	17	5.5	15	8.6	15	8.0	14	8.4
	E	9	1.6	9	4.2	9	8.4	9	8.1	9	8.1
26	A	8	4.9	8	1.5	6	7.4	5	7.7	5	8.2
	B	5	2.1	5	9.7	5	6.8	4	6.9	4	7.0
	C	5	1.8	5	8.2	5	8.2	4	7.8	4	8.8
	D	6	8.7	6	7.1	6	8.6	5	8.5	5	8.2
	E	5	1.4	5	4.2	4	8.9	3	9.2	3	9.5

TABLE 1A (Continued)

Number of Occurrences and Mean Time in Seconds

Run No.	Tank	Alert to Identification		Identification to Fire 1		Fire 1 to Fire 2		Fire 2 to Fire 3		Fire 3 to Fire 4	
		No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$
27	A	9	5.4	9	1.7	6	7.9	4	8.1	4	8.0
	B	6	0.9	5	7.1	4	7.3	2	6.5	2	7.5
	C	10	2.1	10	5.1	10	8.1	8	7.8	8	8.1
	D	8	1.8	8	6.9	8	8.4	6	8.3	6	10.0
	E	8	1.6	8	4.0	8	8.8	7	8.2	7	8.1
28	A	7	3.9	7	2.9	7	8.6	4	8.6	2	8.0
	B	5	1.8	5	10.3	5	7.0	4	6.6	3	7.3
	D	11	2.0	10	4.7	10	9.6	6	8.9	5	9.6
	E	7	3.2	7	4.1	6	8.5	6	8.2	4	9.0
29	A	14	5.1	11	6.6	10	8.6	9	7.9	9	8.3
	B	11	3.3	9	9.4	8	6.9	8	6.4	7	6.4
	C	13	1.4	13	8.1	13	9.0	11	8.0	8	10.0
	D	15	5.3	15	6.1	14	8.1	14	7.9	11	8.2
	E	10	2.5	8	13.4	8	8.2	7	7.6	7	7.5
30	A	8	1.4	8	5.0	8	8.4	8	7.4	5	8.1
	D	10	0.9	10	8.1	9	5.4	9	5.5	9	5.3
	E	10	0.5	9	4.1	9	5.8	8	5.9	7	5.7
31	A	7	2.2	6	6.7	6	10.3	5	9.6	4	9.8
	B	6	1.3	6	4.8	5	8.1	5	10.4	4	10.3
	C	9	1.7	7	7.9	7	7.2	6	7.1	5	7.2
	D	11	1.4	9	7.8	7	8.1	5	9.4	5	7.2
	E	6	1.0	4	6.3	4	7.4	4	6.8	4	7.0

TABLE 1A (Continued)

Number of Occurrences and Mean Time in Seconds

Run No.	Tank	Alert to Identification		Identification to Fire 1		Fire 1 to Fire 2		Fire 2 to Fire 3		Fire 3 to Fire 4	
		No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$
32	A	10	2.6	9	5.1	8	8.9	8	10.0	7	8.8
	B	6	0.9	5	5.6	5	9.8	4	10.3	4	9.0
	C	12	3.0	9	6.7	9	7.8	8	7.1	8	7.6
	D	15	1.4	14	6.3	14	7.1	11	6.6	8	6.8
	E	10	1.9	10	4.6	9	7.4	8	7.6	5	7.5
33	A	9	2.3	9	5.4	9	8.9	9	10.4	9	8.9
	B	5	1.1	5	4.1	5	8.1	5	8.6	5	11.9
	C	9	1.2	9	7.1	9	8.5	7	8.1	7	7.4
	D	10	1.2	7	6.4	7	7.4	7	7.0	4	7.1
	E	12	1.1	12	3.9	11	7.2	9	7.2	8	6.9
34	A	9	2.5	9	5.9	8	9.4	7	9.6	7	9.6
	B	8	1.2	7	4.9	7	10.4	6	8.4	6	8.7
	C	9	2.9	9	7.3	8	7.4	7	7.3	7	6.9
	E	8	1.6	8	4.2	8	7.3	8	7.1	8	7.3
44	A	9	1.7	7	6.4	7	8.8	7	10.5	6	8.9
	C	7	1.9	7	4.6	7	7.6	6	7.0	6	7.2
	E	6	1.1	6	3.6	6	7.4	6	7.4	6	7.6