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THE DEVELOPMENT OF COMBAT RELATED MEASURES FOR SMALL ARMS EVALUATION

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Fort Benning, Georgia

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THE DEVELOPMENT OF COMBAT RELATED MEASURES FOR SMALL ARMS EVALUATION

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Abstract

The US Army Infantry Board has undertaken a study to develop improved small arms test methodology. The study focused on the rifleman and his weapon as a system. All combat actions in which this man/weapon system are expected to participate as well as the combat tasks required of the system were established. General categories of system effectiveness were developed and then further defined as discrete measures of effectiveness. It was found that all measures of effectiveness could be evaluated in three environments; attack, defense, and quick reaction. Extensive and unique instrumentation was developed to gather data pertinent to the measures of effectiveness and three instrumented test facilities were constructed. These facilities have been automated and are used in carrying out the Infantry Board's test mission.

BACKGROUND

1. In 1964 the Infantry Board began a study to examine its small arms test methodology. The goals were to ensure that maximum combat realism was incorporated in service tests and to ensure that full use was made of reliable instrumentation and automatic data processing equipment.

AIM

2. The aim of this paper is to describe the procedures undertaken by the Infantry Board in developing small arms test methodology, instrumentation, and facilities.

OUTLINE OF PAPER

General

3. This paper will explain the development of the methodology, instrumentation, and facilities for small arms testing at the Infantry Board.

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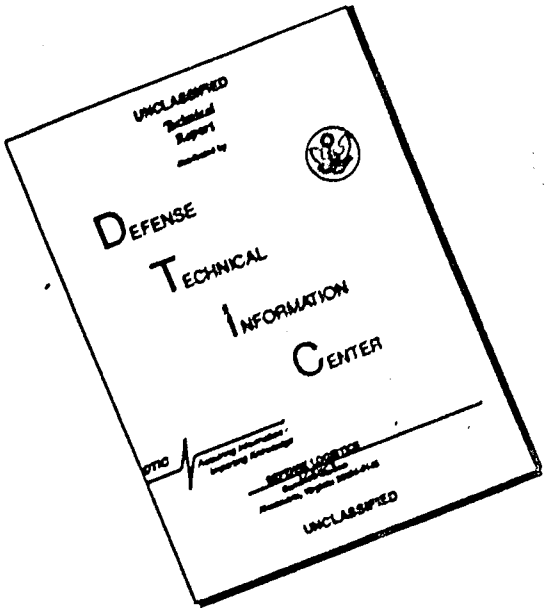

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Details

4. The paper is divided into 3 sections:

(a) Section I - Methodology

(b) Section II - Instrumentation

(c) Section III - Facilities

INTRODUCTION

The purpose of this paper is to briefly present the US Army Infantry Board's (USAIB) test methodology with respect to some aspects of small arms service testing. A recent methodology study conducted by the Board has employed some unique techniques which led to the development of sophisticated test facilities which, it is felt, will be of interest to other armies.

The Board's position in the Army organization is depicted in Figure 1. It is one of six service testing agencies of the Test and Evaluation Command.

Simply stated, the Board's primary mission is to conduct service testing of Infantry materiel and weapons systems. Figure 2 is a formal statement of our mission. The Board is currently involved in some 30 test projects which range from the Expanded Service Test of the DRAGON Missile System to the Product Improvement Test of the 1-Quart Canteen Cup.

The organization of the Board is shown in Figure 3. All materiel testing is carried out by the Test Division; however, experimental testing and field research is carried out by the Methodology and Instrumentation Branch, which is continually seeking to improve test methodology.

There are two key points which we in the testing community must bear in mind. First, the extremely high cost of hardware, even mundane Infantry materiel. This means that each phase of testing must milk all possible performance data from the item. Test plans must be prepared in great detail to insure that the overall test program completely assesses the candidate system. Second, competing or candidate systems are becoming increasingly similar. Detecting significant differences is a difficult task. High quality instrumentation must be used to gather irrefutable data. The reader is well aware of the tremendous political and economic stakes involved when a new materiel system is selected.

This paper addresses one aspect of the Board's testing role - that of rifle testing. It will cover the measures of effectiveness we have selected, the basis for selection, the operational environments required, the instrumentation deemed necessary, and lastly the test facilities which we have developed as well as some unresolved problems.

It should be noted that before an item is accepted for issue to troop units a long series of tests is undertaken. These include Engineer Design Tests among others. The final test prior to acceptance by the Army is generally the Service Test.

For a rifle, as an example, the Service Test will consist of a number of subtests. Figure 4 lists the subtests which might be part of such a test. This paper will primarily address only that part of the Service Test concerned with field firing performance.

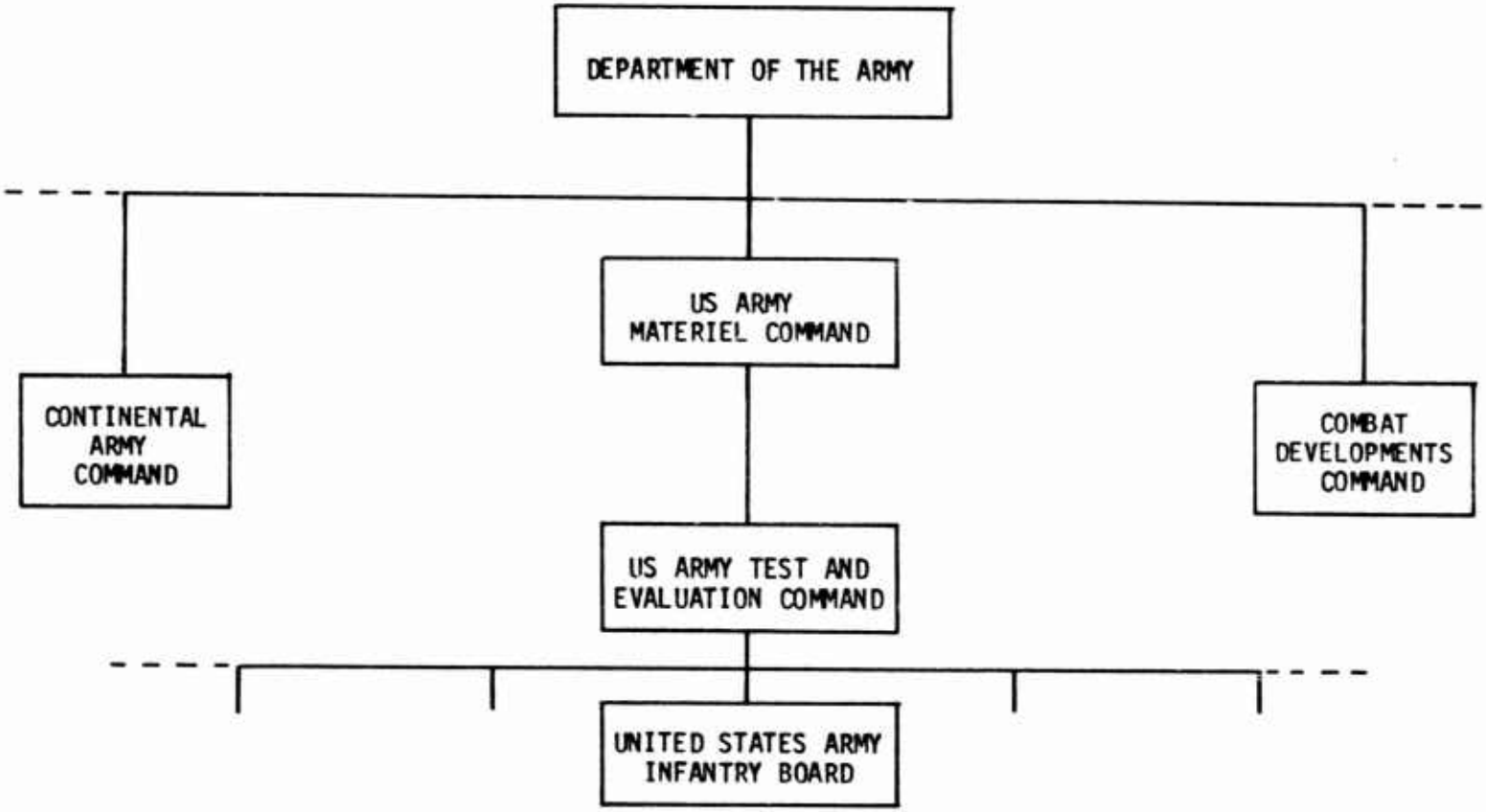

Figure 1. Location of USAIB within Department of the Army

UNITED STATES ARMY INFANTRY BOARD

MISSION

1. PLAN, CONDUCT AND REPORT ON SERVICE TESTS AND CHECK TESTS OF:

a. EQUIPMENT AND ANCILLARY ITEMS TO BE USED BY INFANTRY UNITS FOR FIRE POWER, TARGET ACQUISITION, GROUND SURVEILLANCE, FIRE CONTROL, AND GROUND MOBILITY.

b. FIELD-TYPE CLOTHING, EQUIPMENT, AND RATIONS FOR INDIVIDUALS.

c. ANTIPERSONNEL MINES AND RELATED EQUIPMENT.

d. CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL EQUIPMENT FOR INDIVIDUALS,

e. THOSE ITEMS LISTED IN (a) - (d) WORN OR CARRIED BY INDIVIDUAL PARACHUTISTS WHILE JUMPING FROM AIRCRAFT AND THEN CARRIED BY THOSE INDIVIDUALS AFTER CLEARING THE DROP ZONE.

2. PARTICIPATE IN ENGINEERING TESTS (ETs), INITIAL PRODUCTION TESTS (IPTs) AND APPROPRIATE PREPRODUCTION TESTS (PPTs) AS DIRECTED.

3. PROVIDE ADVICE TO PROPONENT AGENCIES AND MATERIEL DEVELOPERS DURING THE DEVELOPMENT OF EQUIPMENT WHICH IS EITHER USED BY OR PROVIDES SUPPORT TO INFANTRYMEN. DATA AND INFORMATION DERIVED DIRECTLY FROM TEST EXPERIENCE WILL PROVIDE THE BASIS FOR SUCH ADVICE.

Figure 2. Mission - US Army Infantry Board

UNITED STATES ARMY INFANTRY BOARD

ORGANIZATION

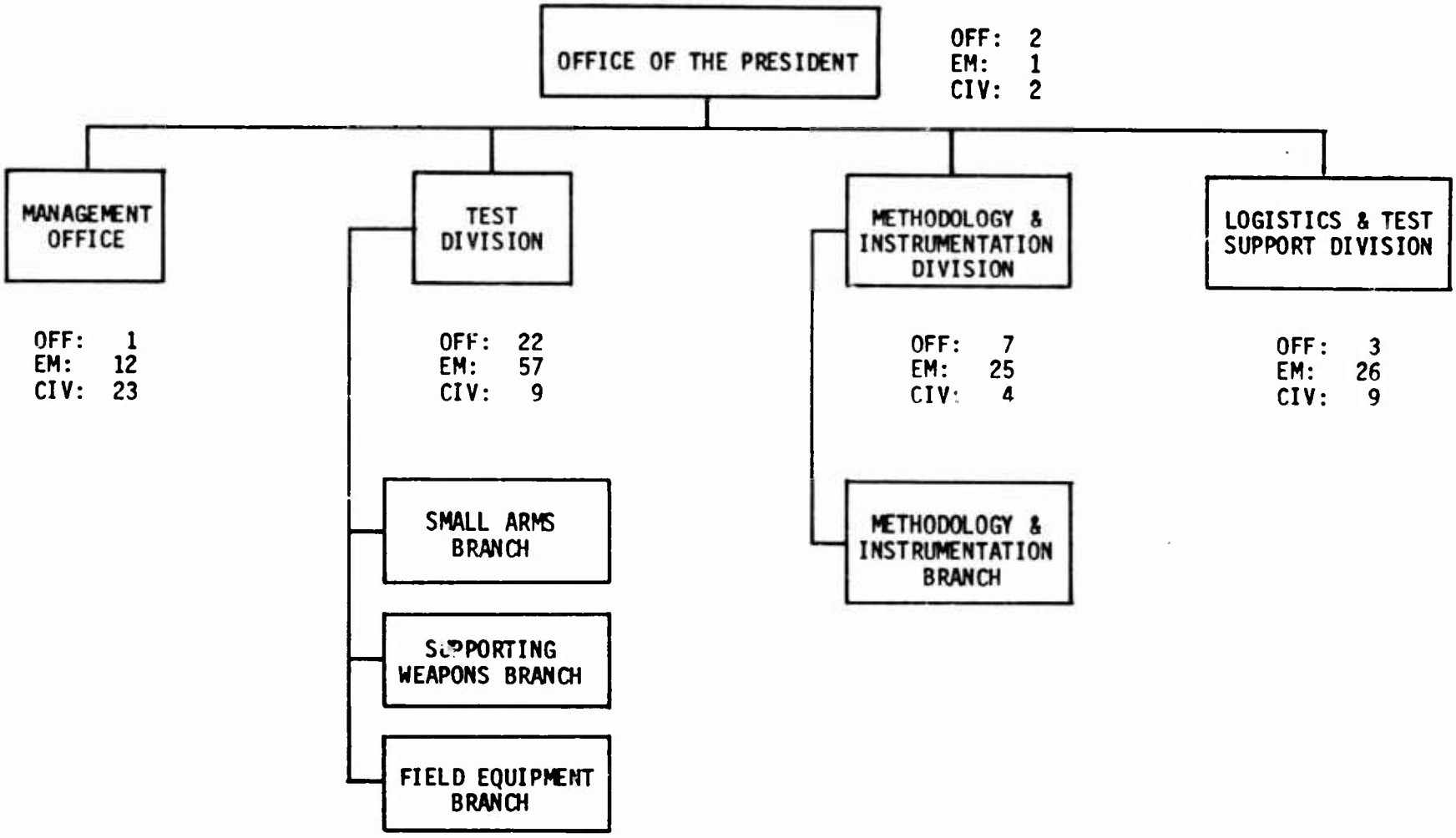

Figure 3. Organization - US Army Infantry Board

UNITED STATES ARMY INFANTRY BOARD

RIFLE SERVICE TEST
TYPICAL SUBTESTS

1. PREOPERATIONAL INSPECTION
2. TRAINING
3. KNOWN DISTANCE ACCURACY
4. FIELD FIRING PERFORMANCE
5. SAFETY
6. BATTLEFIELD PORTABILITY
7. DURABILITY AND RELIABILITY
8. MAINTAINABILITY
9. TROOP ACCEPTABILITY
10. HUMAN FACTORS

Figure 4. Typical Subtests of a Rifle Service Test

The paper is divided into three sections. The first section deals with the analytical procedures followed to determine the measures of effectiveness and the combat environments required for small arms evaluation. The second section is concerned with the instrumentation and hardware required, while the last section is devoted to a discussion of the three instrumented facilities developed by the Board, a note on analytical procedures, and some unresolved problems.

SECTION I. METHODOLOGY

About 7 years ago the Board launched a study to determine ways to improve testing methodology or procedures. The goals were to increase the combat realism as much as possible while also designing tests and test facilities which would yield objective results. Sound, unbiased data were necessary for valid statistical analyses and evaluation.

With that as an introduction the paper will now focus on the method the Infantry Board used in studying the small arms test function.

If one were to ask what the important qualities of a rifle should be, he would get such replies as ... it should be accurate, ... should be light, ... it should kill or render ineffective anyone it hits, ... should be easy to maintain, that is, soldier proof, ... and so on. Many of these same characteristics appear in requirements documents prepared by the Combat Developments Command against which the item is developed by the Department of the Army. Only by inference does this approach address the ultimate purpose of the system -- to make the Infantryman most efficient.

The Board's approach has been to look at each weapons system in its combat environment and to cast the test procedures in terms of this combat environment.

After researching all pertinent doctrinal and training literature, plus all other available studies, a list of the various combat actions normally accomplished by Infantry combat units was compiled. Twenty-six separate combat actions were identified and listed as shown in Figure 5. Some actions such as desert and mountain operations were not considered as they are addressed by some of our sister agencies.

Next, after further researching all of the pertinent literature, a list of the various critical tasks normally accomplished by the rifleman when executing these combat actions was prepared. Twenty-three separate critical combat tasks were identified and listed as shown in Figure 6.

A table was prepared which presented for comparison and analysis the 26 combat actions and the 23 critical combat tasks. Figure 7 is an extract from the table. Further study of the table in which primary emphasis was placed on the actions of the individual man/weapon combination revealed that certain critical combat tasks are common to one or more combat actions. For example, the actions of the Infantryman in the counterattack are the same as in the frontal assault. This comparison allowed several reductions and combinations of the combat actions. These were combined because of the similarities in these individual tasks previously depicted thereby reducing the number of combat actions from the original 26 to 13 for detailed analysis. Figure 8 shows the 13 remaining combat actions which were considered. These 13 combat actions fall into three general environments: attack, defense, and quick reaction.

Next a list of combat categories of effectiveness expressed in terms of the more commonly used words (e.g., accuracy and responsiveness) that are normally

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COMBAT ACTIONS INITIALLY CONSIDERED

1. COMBAT OUTPOST
2. DELAYING ACTION
3. ROAD BLOCKS
4. RETROGRADE OPERATIONS
5. WITHDRAWAL FROM LZ
6. DELIBERATE DEFENSE
7. HASTY DEFENSE
8. COUNTERATTACK
9. AREA OR POSITION SECURITY
10. SNIPER
11. FIRE AND MOVEMENT
12. FRONTAL ATTACK
13. CLOSE COMBAT
14. CONSOLIDATION
15. EXPLOITATION
16. BREACHING OPERATIONS
17. RIVER CROSSINGS
18. AERIAL ASSAULT
19. AMBUSH
20. ADVANCE TO CONTACT
21. SECURITY OF A MOVING COLUMN
22. COMBAT IN CITIES
23. SEARCH AND CLEAR
24. COMBAT PATROL
25. RECONNAISSANCE PATROL
26. COUNTERAMBUSH

Figure 5. Combat Actions Initially Considered

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CRITICAL COMBAT TASKS

1. MEDIUM TO SHORT RANGE SUSTAINED FIRE
2. INTENSE ACCURATE FIRE, MEDIUM TO CLOSE RANGE
3. LARGE VOLUME OF AIMED COVERING FIRE
4. MEDIUM TO SHORT RANGE FIRE -- SUPPORTED FIRING POSITIONS
5. MEDIUM TO SHORT RANGE FIRE -- UNSUPPORTED FIRING POSITIONS
6. MEDIUM TO CLOSE RANGE HIGH INTENSITY FIRE
7. MEDIUM TO SHORT RANGE AIMED FIRE/RAPID DISPLACEMENT
8. VIOLENT, CLOSE RANGE - QUICKFIRE, BAYONET OR GRENADE RESPONSE
9. MAXIMUM AIMED FIRE - MINIMUM EXPOSURE TO ENEMY FIRE
10. IMMEDIATE INITIATION OR RETURN OF FIRE
11. LONG RANGE FIRE INCREASING IN VOLUME
12. LONG RANGE PRECISION RIFLE FIRE ON SELECTED TARGETS
13. AGGRESSIVE DEPLOYMENT AND ATTACK
14. RAPID MOVEMENT -- RAPID MAGAZINE CHANGE
15. ALERT MOVEMENT
16. RAPID REACTION
17. RAPID SITUATION ESTIMATES
18. DELIBERATE METHODICAL MOVEMENT WITH DETAILED OBSERVATION
19. ANTICIPATED SHORT AND/OR MEDIUM RANGE ENEMY CONTACT
20. CLEAR FIELDS OF FIRE
21. PREPARE AND CAMOUFLAGE POSITIONS
22. PUT IN BARRIERS
23. CONDUCT RECONNAISSANCE OF WITHDRAWAL ROUTES

Figure 6. Critical Combat Tasks

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COMBAT TASK/ACTION CONCEPT TABLE (EXTRACT)

TASKS \ ACTIONS		COMBAT OUTPOST	HASTY DEFENSE	COUNTERATTACK	FRONTAL ASSAULT	COMBAT PATROL
MEDIUM TO SHORT RANGE SUSTAINED FIRE		X				
INTENSE ACCURATE FIRE, MEDIUM TO CLOSE RANGE		X	X	X	X	
LARGE VOLUME OF AIMED COVERING FIRE					X	
MEDIUM TO CLOSE RANGE HIGH INTENSITY FIRE	X	X	X	X	X	
MEDIUM TO SHORT RANGE AIMED FIRE/RAPID DISPLACEMENT	X		X	X	X	

Figure 7. Extract - Tasks vs Actions Concept Table

UNITED STATES ARMY INFANTRY BOARD

REDUCED COMBAT ACTIONS

1. RETROGRADE OPERATIONS
2. DELIBERATE DEFENSE
3. HASTY DEFENSE
4. AREA/POSITION SECURITY
5. SNIPER
6. FIRE AND MOVEMENT
7. FRONTAL ASSAULT
8. ADVANCE TO CONTACT
9. COMBAT IN CITIES
10. SEARCH AND CLEAR
11. CLOSE COMBAT
12. COMBAT PATROL
13. RECONNAISSANCE PATROL

Figure 8. Reduced Combat Actions

associated with small arms effectiveness was compiled. These commonly used words or categories of effectiveness most closely resemble the military characteristics from which requirements documents are prepared. They are shown in Figure 9.

Consideration of the categories of effectiveness revealed that they must be defined in terms of measurable parameters which meaningfully relate to a combat situation. Once defined, these parameters were further studied and developed into measures of effectiveness (MOE). These are shown in Figure 10.

In order to better understand the rationale behind the measures of effectiveness selected, what follows is an explanation of the detailed thought involved in just one of the MOE mentioned: Time to first round.

Time to first round is indicative of the actions necessary for the individual soldier carrying his rifle at the ready to identify, acquire, and engage a target. Many combat actions such as advance to contact and combat patrols require this type action from the soldier. Once the target is identified, the time to first round measures the soldier's action of:

1. Bringing the weapon to his shoulder.

2. Seating the stock against his shoulder.

3. Aligning his head so that the sights are in line between his eyes and the target.

4. Aligning the sights.

5. Acquiring a sight picture (if aimed fire is used).

6. Gripping the weapon.

7. Squeezing the trigger.

For example, on our quick-fire test facility statistically significant differences of 3/10 second on a specific engagement between two competing rifle systems were found. Although this difference is statistically significant, its operational significance must be evaluated subjectively.

Next a matrix was developed of measures of effectiveness versus combat tasks. Figure 11 is an extract of this matrix. The purpose of this analysis was to determine which MOE were critical in carrying out each particular combat tasks. For example, in the extract shown in Figure 11 the number of hits is critical in each of the five tasks listed while the time to clear malfunctions is critical to only three.

The measures of effectiveness necessary to evaluate the man/weapon system in accomplishing the critical combat tasks were identified. Since all tasks were common to one or more of the 13 combat actions, and the combat actions are included in three general environments, test facilities representing these three environments were constructed in order to obtain data on the measures of effectiveness.

The MOE falling under the accuracy, responsiveness, sustainability, and reliability categories are objective in nature and lend themselves to automated collection. Other MOE are somehwat subjective, for example, ease of handling and maneuverability, but even so, the required evaluation is greatly enhanced when good

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CATEGORIES OF EFFECTIVENESS

1. ACCURACY
2. RESPONSIVENESS
3. SUSTAINABILITY
4. RELIABILITY
5. PORTABILITY AND COMPATIBILITY
6. SIGNATURE EFFECTS

Figure 9. Categories of Effectiveness

UNITED STATES ARMY INFANTRY BOARD

MEASURES OF EFFECTIVENESS

ACCURACY:	1. NUMBER OF HITS 2. DISTRIBUTION OF NEAR MISSES 3. NUMBER OF TARGET HITS: SEMI-AUTOMATIC FIRE 4. NUMBER OF TARGET HITS: AUTOMATIC FIRE 5. ENGAGEMENT HIT PROBABILITY
RESPONSIVENESS:	1. TIME TO FIRST ROUND 2. TIME TO FIRST HIT 3. TIME BETWEEN HITS 4. TIME BETWEEN BURSTS 5. TIME TO SHIFT FIRE 6. TIME BETWEEN HITS
SUSTAINABILITY:	HITS PER POUND (AS % OF BASIC LOAD)
RELIABILITY:	1. TIME TO CHANGE MAGAZINE 2. TIME TO CLEAR MALFUNCTION 3. TIME BETWEEN MALFUNCTIONS 4. NUMBER OF ROUNDS BETWEEN MALFUNCTIONS
PORTABILITY AND COMPATIBILITY:	1. MOVEMENT TIMES 2. PREPARATION OF POSITIONS 3. EMPLACEMENT OF BARRIERS 4. TIME TO CHANGE POSITIONS 5. MANEUVERABILITY 6. EASE OF MAINTAINING READINESS POSTURE 7. TIME REQUIRED TO ASSUME POSITION 8. COMPATIBILITY WITH OTHER ITEMS OF EQUIPMENT
SIGNATURE EFFECTS:	1. SOUND 2. SMOKE AND HAZE 3. FLASH 4. EJECTION PATTERN

Figure 10. Measures of Effectiveness by Category

UNITED STATES ARMY INFANTRY BOARD

COMBAT TASKS/MOE MATRIX (EXTRACT)

TASKS \ MOE	NUMBER OF HITS	DISTRIBUTION OF NEAR MISSES	TIME TO FIRST ROUND	TIME TO FIRST HIT	TIME TO CLEAR MALFUNCTIONS
MEDIUM TO SHORT RANGE SUSTAINED FIRE	X	X		X	X	
INTENSE ACCURATE FIRE, MEDIUM TO CLOSE RANGE	X	X	X	X	X	
LARGE VOLUME OF AIMED COVERING FIRE	X	X			X	
MEDIUM TO SHORT RANGE FIRE - SUPPORTED FIRING POSITIONS	X	X	X	X		
MEDIUM TO SHORT RANGE FIRE - UNSUPPORTED FIRING POSITIONS	X	X	X	X		

Figure 11. Extract - Tasks vs MOE Matrix

methodology is employed. The MOE which have been adopted for Board testing are keyed to service test requirements in the intermediate climatic zone. They are not meant to replace the performance measures used in engineering tests and do not address severe climatic conditions. Engineering tests focus completely on the materiel and generally precede Board service tests which look at the man/materiel system as an entity.

SECTION II. INSTRUMENTATION

Before actual facility construction could begin it was necessary to develop a considerable amount of unique instrumentation for data collection. This section will address the instrumentation development. The last section will dwell on the three instrumented facilities.

Our overall requirements are quite extensive. Basically the requirements can be divided into two portions. First, a system which would operate the range in an accurately repeatable fashion, and second, a system which would collect and store a wide variety of performance data were needed.

Figure 12 shows in flow chart form the simplified requirements for several accuracy and responsiveness MOE. This assumes one man is firing at a single target and he is firing single shot. The target will stay up until hit or until a fixed time has lapsed when it will automatically drop. The problem (and flow chart) becomes more complex when several firers using both semiautomatic and automatic fire are being tested against multiple targets. The requirements are stringent. The precise time each activity in a box on the flow chart took place must be recorded. With this kind of information a great deal about a weapons system's responsiveness and accuracy can be determined.

The hit sensitive target is a two dimensional silhouette, camouflaged, which can be made to represent a prone, kneeling, or standing man. Figure 13 is a sketch of the target. It consists of two layers of aluminum foil incorporated in a semi-rigid form. A round passing through creates a short circuit across an applied voltage difference of 6 volts between the two foils. This is transmitted in real time to the data collection van. These targets can be programmed to fall when hit, fall and reappear after a short period, or remain upright. All hits are recorded regardless of manner of presentation. It is a very durable and reliable target. A single target can absorb hundreds of hits before requiring replacement and practically all hits are sensed. This target system is used for both stationary and moving targets. For stationary pop-up targets the data link is wire and each target has its own data link wire for target identification. A photograph of a stationary pop-up target system is shown in Figure 14.

There are considerable difficulties connected with wire data links from moving targets, so the Board is developing small FM radio data links with a transmitter which rides on the target vehicle itself.

The moving man targets involved considerable developmental and experimental work at the Board. A portable, lightweight, reliable system capable of repeated runs at realistic adjustable speeds has been developed and obtained. Figures 15 and 16 show two views of this system.

It is recognized that fleeting targets occur frequently in combat. There is a need to know the best methods for engaging such targets. This requires a moving

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SIMPLIFIED FLOW CHART

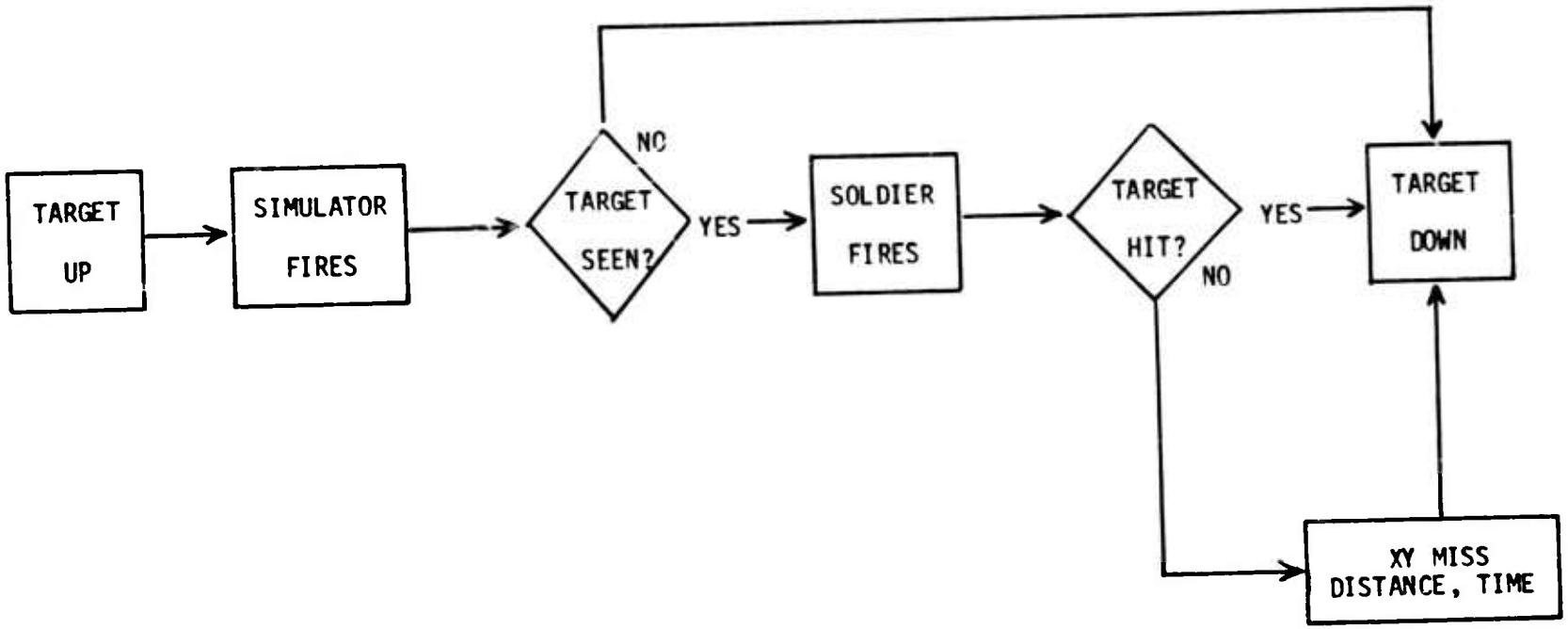

Figure 12. Simplified Flow Chart - Data Requirements

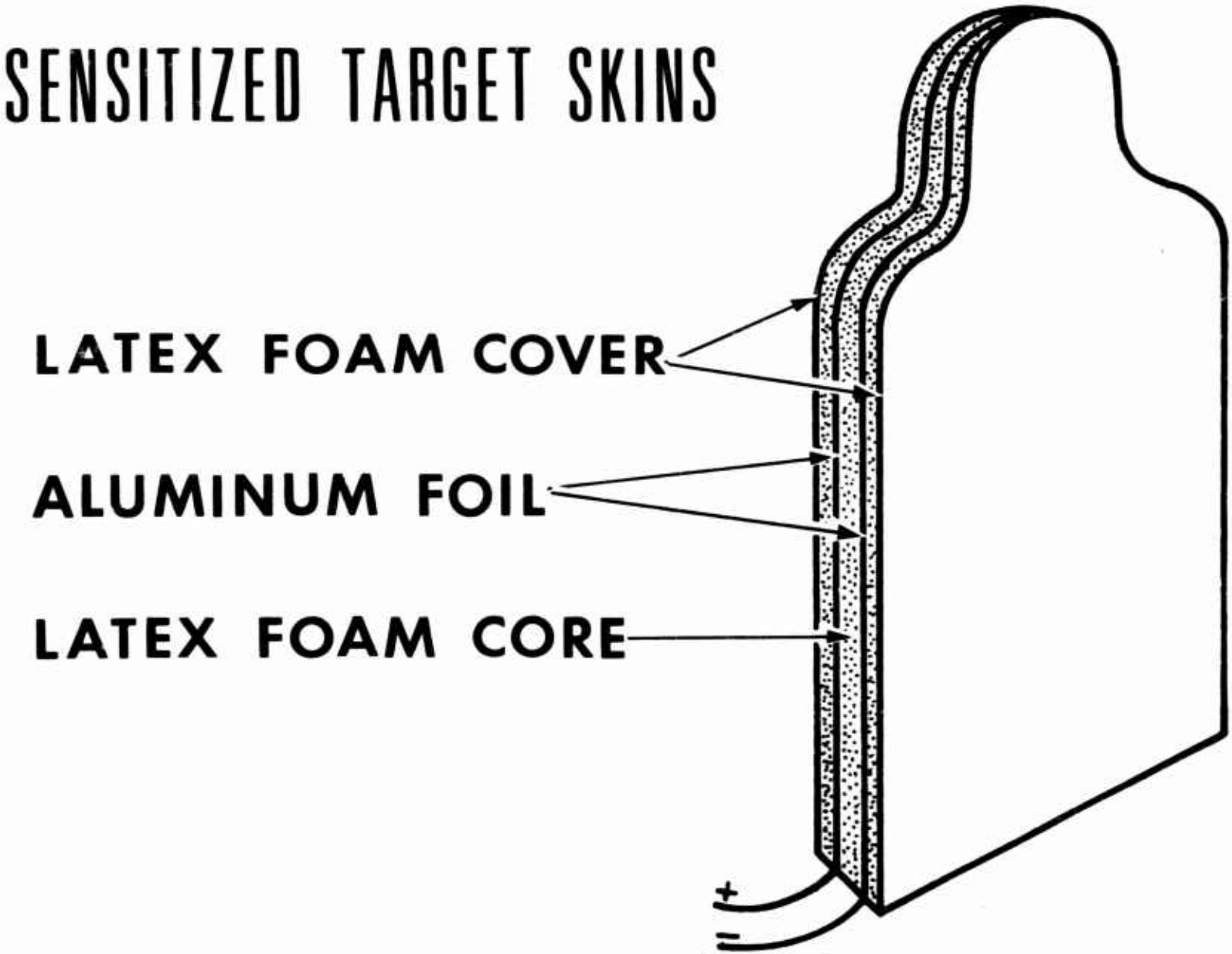

Figure 13. Sketch of Hit Sensitive Target

Figure 14. Photograph of Stationary Pop-Up Target

Figure 15. Moving Man Target - Quick Fire Facility

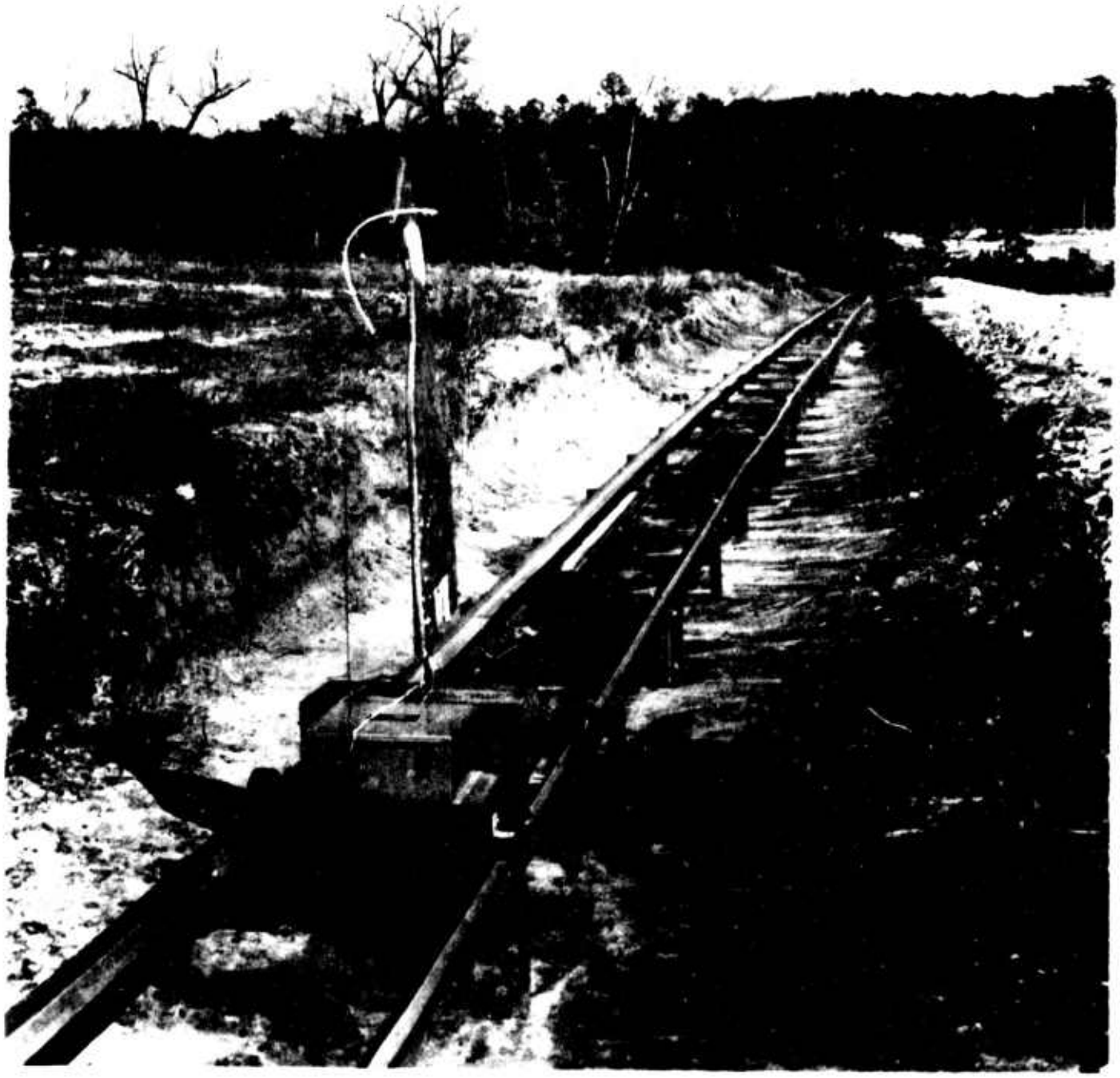

Figure 16. Moving Man Target - Defense Facility
(Note Radio Data Link on Rear of Target Vehicle)

man target capable of precise repetitions at realistic speeds. Further work with the system will lead to information on the best firing methods - automatic or semi-automatic - with which to engage moving man targets, aiming techniques, and which of several candidate weapons systems is best designed for engaging moving man targets. We feel that weapons performance against a moving target is an important discriminative measure. It is interesting to note that we have developed a similar target system for testing antitank weapons systems. Figure 17.

In most cases the targets are automatically activated as a function of time. That is, a given period of time lapses and an array or cluster of targets is erected accompanied by the firing of a simulator. Occasionally, however, in the quick reaction role for example, the firers movement should cause an enemy target to appear. This has been accomplished by concealing photocells or pressure pads along his route of advance. When the photoelectric beam is interrupted or when the pad is stepped on, a signal is sent by wire to the control center which erects the appropriate target and fires the accompanying simulator. Figures 18 and 19 show a pressure pad and photocell.

Next is the topic of round count systems. There is a need to know when each soldier fires, and each round of an automatic burst must be sensed. Two systems have been developed; one is attached to the firer and designed for testing while the soldier is in a freely moving situation as in an attack, and the other is removed from the firer and is designed for use where the firer's position can be accurately predicted each time he fires.

The first system is called a helmet mounted sensor and transmitter. Figure 20 is a photograph of one such system. The firer's helmet is removed and certain modifications have been made to the helmet liner to accommodate the electronics. Briefly the parabolic dish at the front is a receiving antenna and it serves to sense the muzzle blast as the weapon is fired. This event is then transmitted to a receiving set a short distance away via FM radio. To obtain the firer's identity a separate channel for each system is required. A wire link is installed between the receiver and the data collection or control center. The system shown in the photograph is an early developmental model. The Board is currently investigating the possibility of a smaller self-contained unit which could be easily affixed to any portion of the soldier's load carrying equipment or combat uniform. The radio data link carried by the soldier permits a freely moving test scenario. In an attack situation each round fired can be recorded as well as who fired it and at what time. This yields important data such as rounds fired as a function of distance from the objective.

The second round count system is designed for use where the firer's location is controlled or can be predicted accurately. For example, on the quick-fire facility the soldier follows a prescribed path along which are placed photocells or pressure pads to trigger the targets. The targets are erected almost immediately. At the firer's location a small microphone senses the muzzle blast of the discharge. A direct wire link exists between the round count microphone and the control center.

The same microphone system is also used in the defensive situation. Here, soldiers are firing from prepared positions and the microphones are prepositioned. In a defensive situation certain complexities arise. The microphone must be able to tell the difference between its own firer and the adjacent firers.

Next is the subject of miss distance data collection. It is universally realized that in combat an extremely low percentage of rounds fired actually find a target.

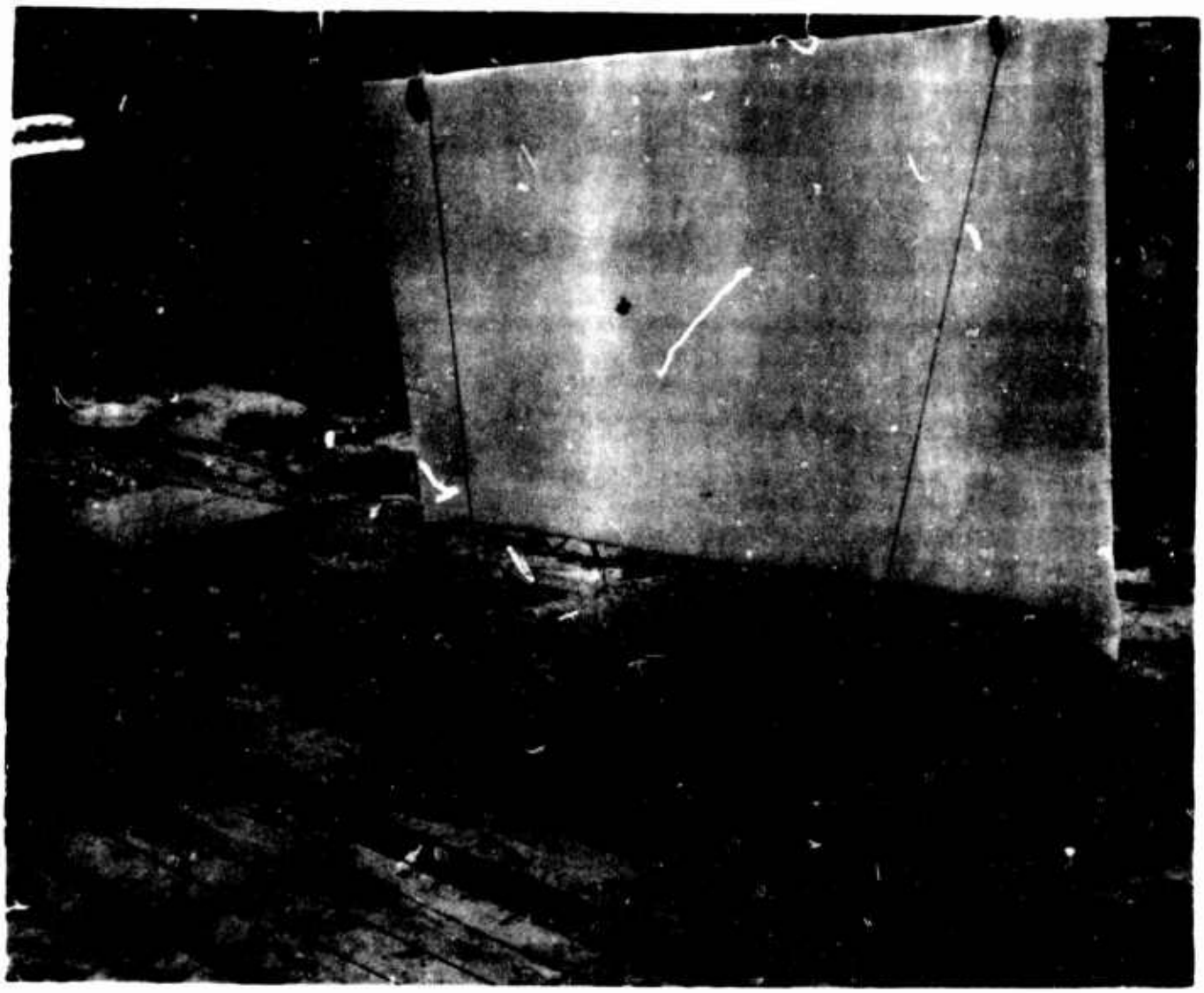

Figure 17. Antitank Target - Two Targets Parallel

Figure 18. Pressure Pad. Dashed Line Indicates Outline of Pad. Soil Removed to Show Depth of Camouflage

Figure 19. Photocell (A-Exposed Portion, B-Concealed Portion)

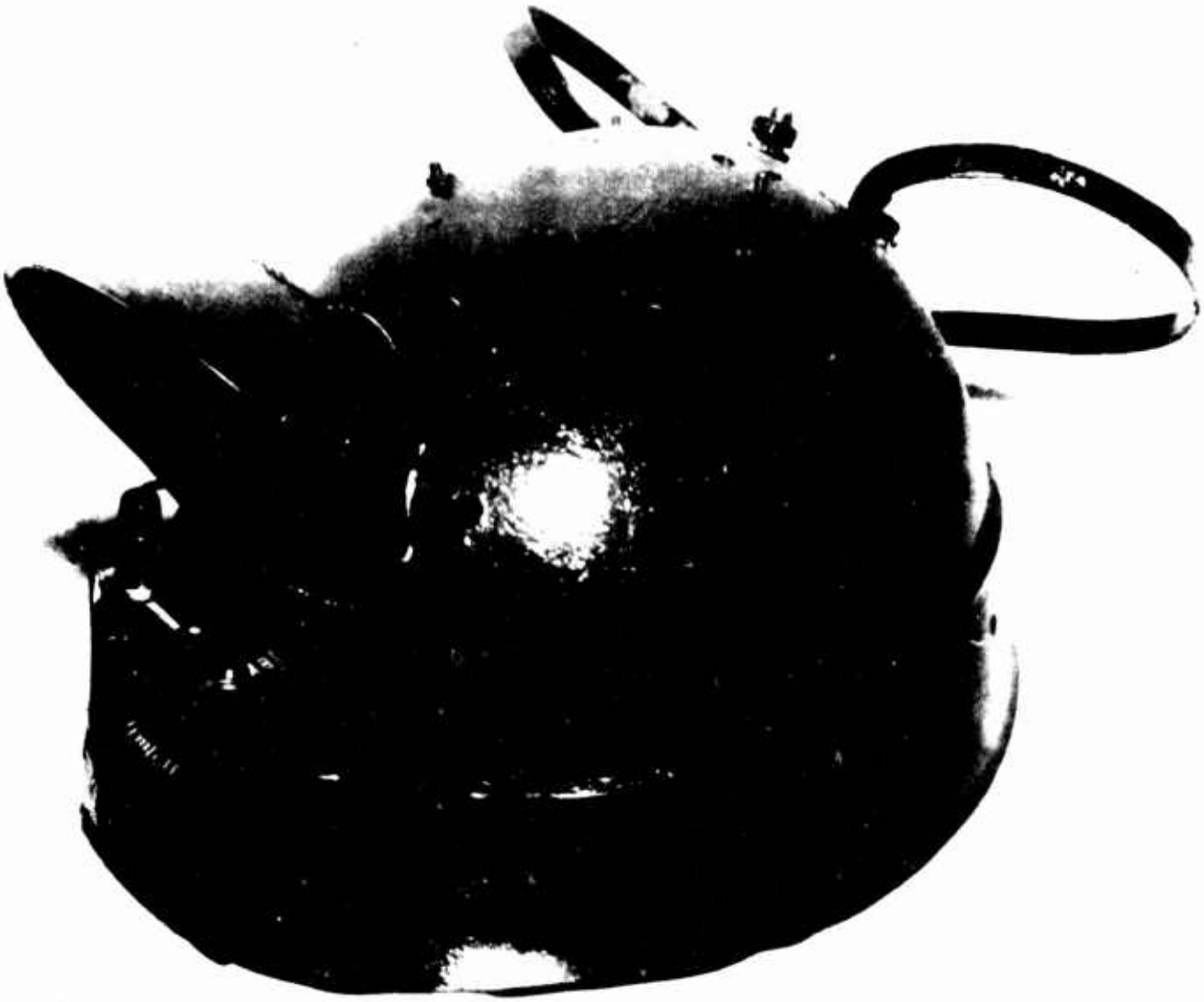

Figure 20. Helmet Mounted Round Count System

In testing the same thing occurs. Rather than simply write off all misses as lost and look only at the hits in an evaluation, an effort has been made to determine the location of the rounds which do not hit the target - at least the near misses. Supposing that the hit probabilities for two weapons systems are the same, it may then be desirable to look at the distribution pattern around the target. There is a veritable dearth of data concerning the engagement of moving and stationary targets. A good miss distance system as part of a target system will aid greatly in developing engagement techniques as well as contributing to the study of suppressive effects of small arms fire. Economic considerations are important also; if data can be obtained from a high percentage of rounds fired rather than just hits, less ammunition need be fired.

The system the Board is experimenting with is based on the fact that supersonic projectiles create a shock wave which is conical in form. Figure 21 is a photograph of a 4-microphone array placed at the target location perpendicular to the gun-target line. As the round comes through the target area each of the four microphones senses the attendant shock wave. The wave's time of arrival at each microphone is stored. Knowing the projectile velocity and the sonic velocity, it is felt that the projectile's location in the target plane can be accurately calculated.

The instrumentation and hardware systems mentioned thus far are all part of an automated, computer-controlled system. Once the target locations, density, presentation times, moving target times, simulator firings, etc., are determined, this information forms what is called a target scenario. A computer program is written based on the desired scenario. This program is loaded into the computer which then actually controls the real time presentation of the scenario and collection of data. A unique nontechnical Board language has been developed which permits on the spot modifications by the test officer.

The Automated Data Processing Equipment (ADPE) to accomplish the above includes a small general-purpose computer with a 16,000 word memory (expandable to 24,000). See Figure 22. The word length is 18 bits. Peripheral equipment includes teletypewriters, paper tape reader, paper tape punch, magnetic tape units, real time clock, memory protection, automatic addressing unit, signal conditioning and a range control unit which drives the range being operated.

This ADPE system, mounted in an air-conditioned van, provides a mobile center which automatically operates the test facility, records and processes data, and provides prompt analysis of test results. An example of the print-out available immediately after the completion of a test exercise is shown in Figure 23.

Recent years have seen a tremendous increase in night fighting hardware. There have been a large number of radars, infrared devices, starlight scopes, and other systems designed to assist the Infantry in night combat. To assure that test conditions do not favor the performance of one system over another methodology for night testing has been developed. This involved a study to determine the night ambient light available as a function of moon phase and the selection of bandwidths of ambient light during which testing could take place. Two photometers were purchased to determine the amount of darkness. Figure 24 is a photograph of one of the instruments.

These same instruments are used during day and night to determine the visual contrast between the target and its background. The Board is currently investigating to determine if this contrast affects the accuracy and responsiveness of the man/weapon system. If this is found to be true, procedures will be established to control the contrast variable.

Figure 21. Photograph Showing a Four Microphone Miss Distance Array on the Defense Facility

Figure 22. Interior of Computer Van Showing Operator at Console

ARRAY 265

POSITION	1	2	3	4	5	6
RDS	14	10	7	10	8	8
HITS	2	0	0	4	0	1
TIME FIRST RD	4.51	2.55	10.66	1.71	2.88	3.22
TIME FIRST HT	6.28	0.00	0.00	1.71	0.00	3.22

ARRAY 220

POSITION	1	2	3	4	5	6
RDS	7	9	5	8	7	4
HITS	0	0	0	0	0	0
TIME FIRST RD	1.79	2.61	2.69	2.79	2.41	4.02
TIME FIRST HT	0.00	0.00	0.00	0.00	0.00	0.00

ARRAY 190

POSITION	1	2	3	4	5	6
RDS	4	1	3	2	4	3
HITS	1	0	1	2	0	3
TIME FIRST RD	2.00	9.89	3.24	6.32	3.16	3.10
TIME FIRST HT	5.39	0.00	7.11	6.32	0.00	3.10

ARRAY 250

POSITION	1	2	3	4	5	6
RDS	5	1	4	3	2	2
HITS	2	0	2	0	0	1
TIME FIRST RD	2.85	0.31	3.26	5.08	4.81	3.40
TIME FIRST HT	7.02	0.00	5.03	0.00	0.00	3.40

ARRAY 130

POSITION	1	2	3	4	5	6
RDS	4	3	5	2	3	4
HITS	2	2	2	0	2	4
TIME FIRST RD	2.79	3.56	0.43	6.32	4.36	0.34
TIME FIRST HT	2.79	3.56	6.40	0.00	4.36	0.34

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NOTES:

1. Array 265 indicates targets are 265 meters from firer.

2. Position number indicates the firing position from which the soldier fired.

3. All times are in seconds.

Figure 23. Example of Immediate Test Results

Figure 24. Photometer Mounted on Tripod with Power Source and Indicating Meter

SECTION III. FACILITIES

The Board's study revealed that the combat actions were all unique to one or more of the attack, defense, or quick-fire roles, and all MOE could be collected on facilities representing these three environments. Accordingly, the Board has constructed three instrumented facilities which are fully automated.

Not all measures of effectiveness can be obtained on each facility; however, there are many measures common to more than one facility. On each facility certain measures are of more importance than others. The measures pertaining to movement times and maneuverability are of most importance in the attack facility, for example, while those pertaining to responsiveness are of most importance on the quick-fire facility. The measures pertaining to accuracy and signature effects are most important on the defense facility which also allows more test soldiers to engage more targets than either of the attack or quick-fire facilities. It also possesses valuable night testing capability. A complete evaluation of a weapon system must include testing on all three facilities in order to assess performance.

Figure 25 is a sketch of the attack facility. They are referred to as facalities rather than ranges. Ranges, in the military lexicon, still connotes neat, flat, known distance qualification ranges - especially within the Infantry community. Facility connotes considerably more complexity and sophistication. The overall dimensions are 360 meters by 150 meters. It was designed to accommodate a small fire team in the attack role. There are 10 targets on the objective area and several machine gun and artillery simulators throughout the range to increase realism. They consist of a mixing chamber into which is introduced a controlled amount of propane and oxygen. After mixing has taken place a coil sparks a standard automobile spark plug which detonates the gas mixture. They can be adjusted for various burst rates or single shot. Figure 26 is a photograph of a small arms simulator while Figure 27 is a photograph of an artillery simulator which works on the same principle.

There are some 16 rows of likely firing positions consisting of shell holes and logs at known distances from the objective area. The soldiers cross the line of departure and are taken under simulated fire shortly thereafter. Then they employ fire and movement to the final coordination line, some 80 meters from the targets. The instrumentation involved includes:

1. Round count system.

2. Hit sensitive target system.

3. Miss distance indicator.

4. Range control/data collection ADPE.

The helmet round count system was developed for use on this facility.

The attack facility also includes 5 pop-up targets in the maneuver area, to give the objective depth, and two moving man target systems.

Hits are not all that count in the attack situation. Suppressive effects are important also, therefore an attempt has been made to collect as much data as possible on each round. Near misses have been identified through the use of miss distance indicators placed at the target location and witness panels located 15 meters short of the objective. These are 8x40-inch pieces of hit sensing target material.

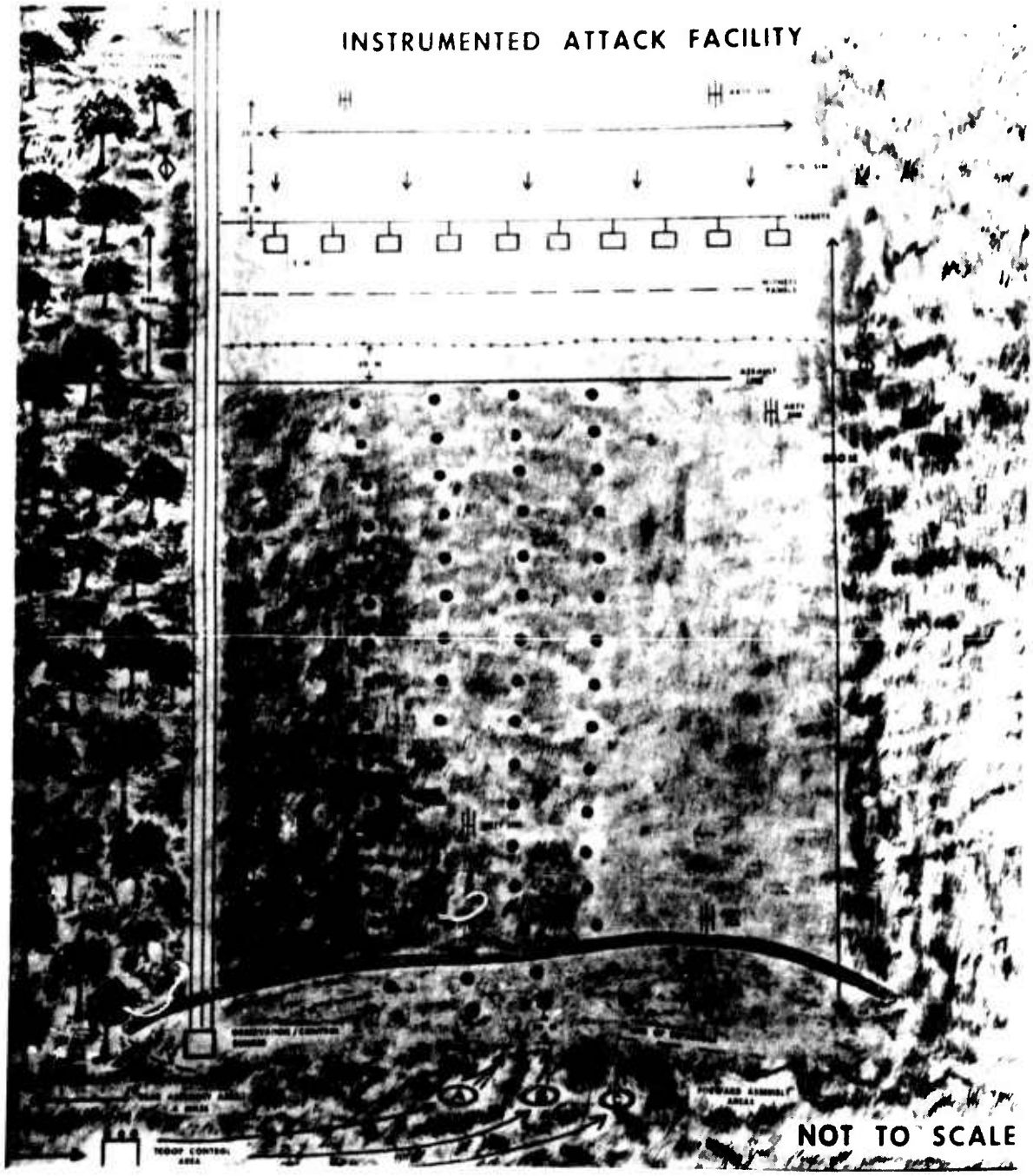

Figure 25. Sketch of Attack Facility

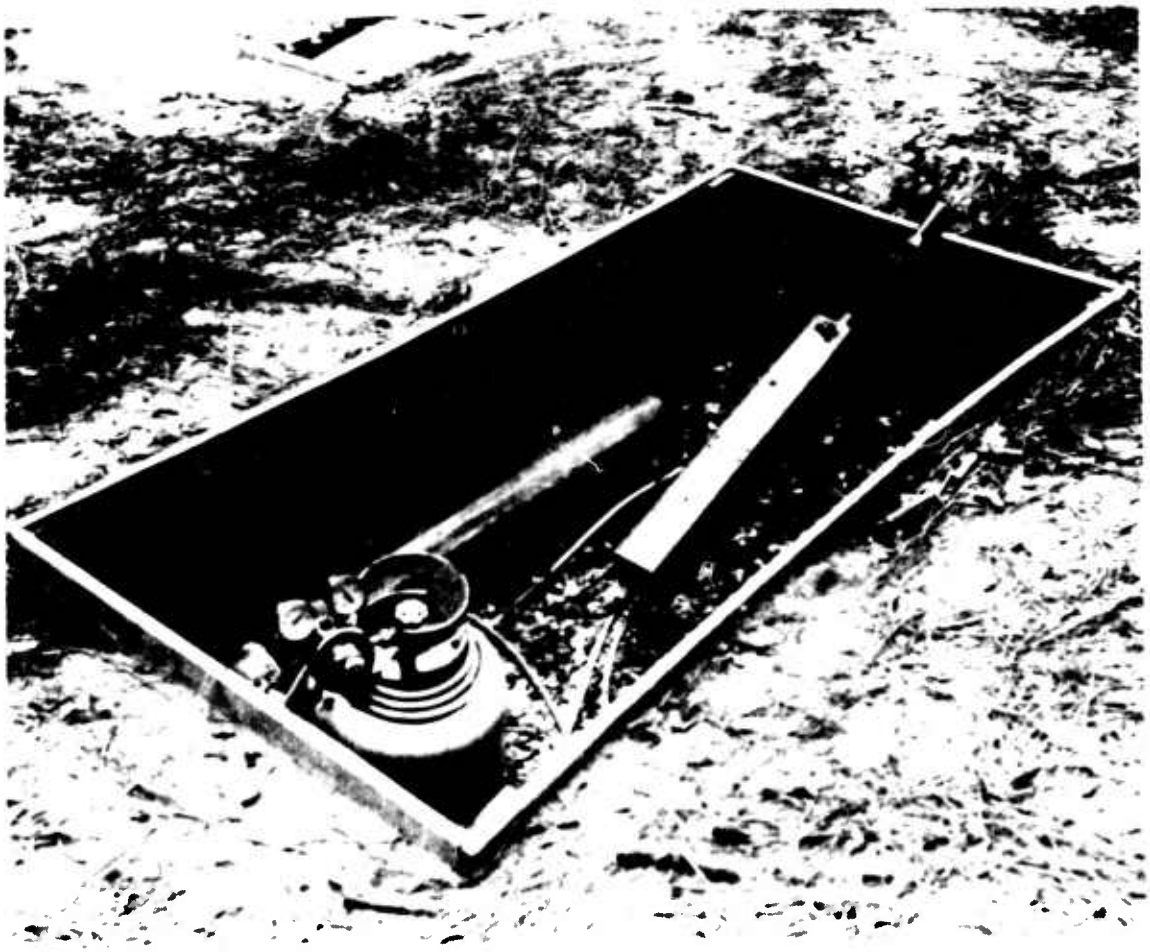

Figure 26. Small Arms Simulator

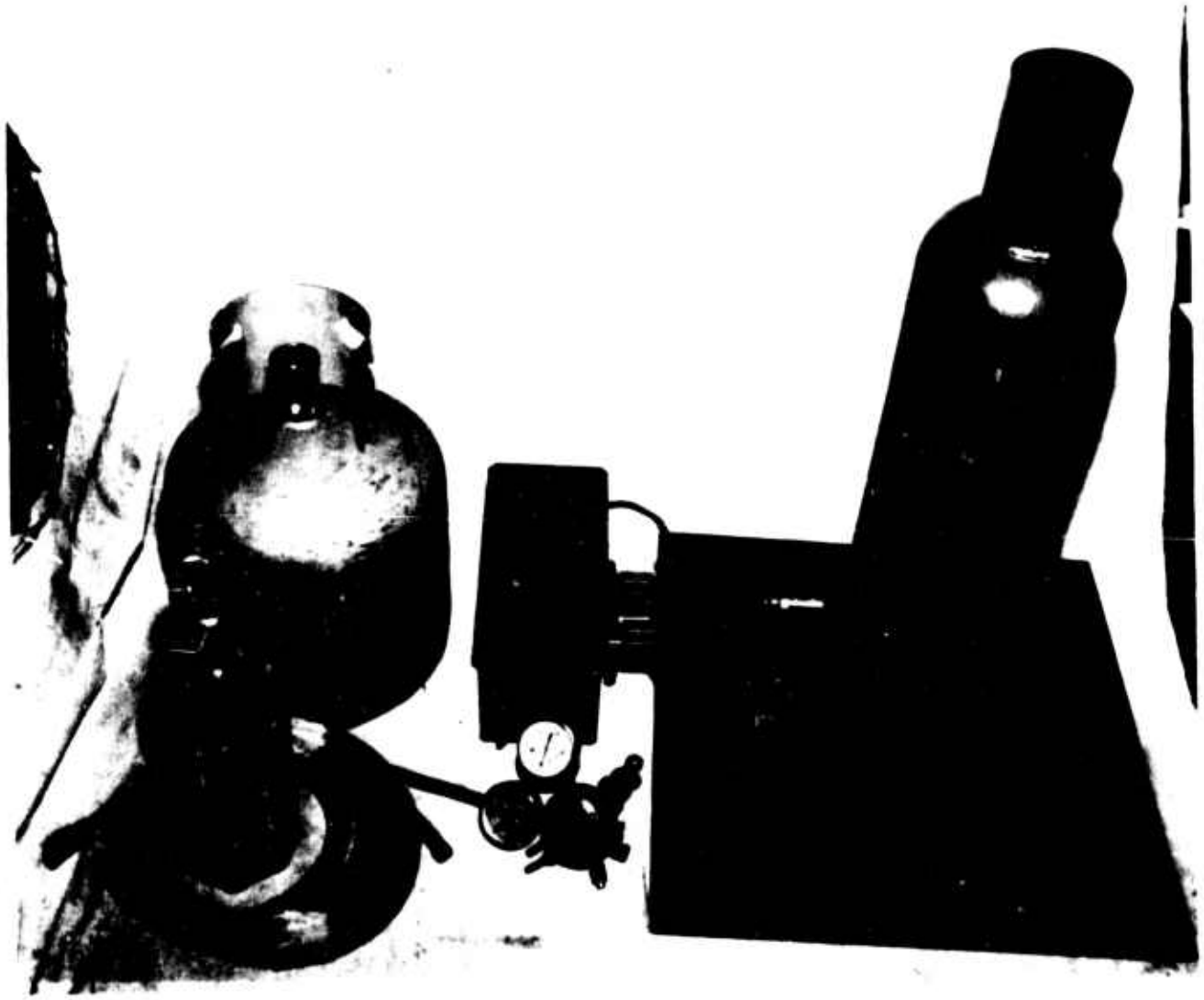

Figure 27. Artillery Simulator

The second instrumented facility developed by the Board was the quick-fire facility. Figure 28 is a sketch of the facility. It is some 570 meters long and approximately 200 meters wide and consists of 25 targets at ranges 20, 40, 60, and 80 meters at angles of fire ranging from 0 to 90 degrees. Two of these targets are moving targets. Unlike the attack and defense facilities this facility tests only one soldier at a time. The soldier is told that he is providing point or flank security to a small Infantry unit. The test soldier goes through this course at his own pace. This is stressed for in a real situation the movement of the troops would be dependent upon the movement of their security elements.

Instrumentation on this range includes both photocells and pressure pads which serve to activate simulators and targets when the firer trips them. At each target is placed a 4-microphone array capable of sensing the shock wave of the passing projectile in order to determine the X, Y-miss distance.

On this facility the position of the firer is known each time he engages the target; therefore, the stationary round count system is used. The moving targets are programmed to fall when hit. If they are not hit they will fall at the end of the target run - approximately 120 feet. The stationary targets will also fall when hit or at the end of 6 seconds. From these data measures such as time to first round, time to first hit, time to shift fire, and hit probability are obtained. These indices bring to light even small differences between competing weapons systems which can be observed and related to specific causes such as excessive recoil and poorly designed sights.

This range is completely automated. The firer, when he trips a photocell or steps on a pressure pad, sends a signal back to the computer which raises the appropriate target, fires a simulator, and then collects and stores the appropriate data in real time. Utility programs will sort these data and prepare them for automated statistical analyses.

The instrumented defense facility is the most extensive and elaborate facility developed. Figure 29 is a schematic of this facility. The day firing positions consist of 10 foxholes on the military crest of the hill being defended. There are 63 stationary pop-up targets on this range varying in distance from 50 to 430 meters from the firer. These 63 targets are divided into 16 arrays of 3 to 5 targets per array. There are also 6 moving man targets on this range, 4 of them on the left side of the draw and 2 on the right side. Additionally, there are 5 small arms simulators on the range. Figure 30 is a photograph of the terrain from the air.

The development of the defense facility required the preparation of extensive software to include the writing of a complete Board compiler which converts commands such as "raise target 17" to machine language. This compiler is written in a test oriented language and provides unlimited flexibility in target presentation scenarios. An exhaustive experiment to determine the facility's capabilities was conducted. The Board was new in the ADPE business and such an experiment was felt to be imperative. A tactical scenario was prepared and programmed which placed the test soldiers in defensive positions. The targets were programmed to represent an attacking force and appeared initially at extreme ranges. Succeedingly closer arrays of targets were presented representing the progress of an attack. The overall scenario took approximately a quarter of an hour during which time each man fired some 150 rounds.

During the experiment such things as target presentation times, time between target presentations, number of targets, and moving target speeds were investigated.

Figure 28. Sketch of Quick Fire Facility

DEFENSE FACILITY

Figure 29. Sketch of Defense Facility
(A-Day Firing Positions, B-Night Firing Positions)

Figure 30. Photograph of Defense Facility Terrain

Data on instrumentation and hardware reliability was also collected. While primary emphasis was placed on the day portion of the defense range, the night portion was also tested.

A major goal of the Board's instrumentation/methodology effort has been to provide the capability for realistic test of the man/weapon system at night under all weather conditions. The design of the defense facility provides a marked improvement in this capability. The facility design permits the use of alternate firing positions on the topographic crest at night. See Figure 29. Selection of the target arrays to be used can be dependent on range distance and visibility. Generally, target arrays beyond 200 meters from the day firing positions are used for day firing only; those within 200 meters, for day or night firing exercises, and those arrays positioned from 64 to 18 meters from the night firing positions will be used at night only. For example, the night targets will be used primarily in testing systems where no aids to vision are present, for instance, no flares or illumination of active sight systems. Where active sighting systems or flares are being used, the day targets will be incorporated in the test plan and firing will be done from the day or night positions. Problems of safety and control which inhibit the use of the quick-fire and attack facilities for night testing are easily overcome on the defense facility. Some MOE which are obtained during daylight on the attack or quick-fire facility cannot be obtained at night due to safety restrictions. They can, however, be collected on the defense facility at night.

The round count system reliably recorded a rate of 2400 rounds per minute at each firing position. The hit sense system recorded hits on single targets at the same rate. The mobile computer, van mounted, proved capable of being transported from Fort Benning to field test sites and of being operational within 2 hours. The facility, to include ADPE and all instrumentation, was operable day and night, in light rain and immediately after a 4½-inch rainfall. For the experiment, stationary and moving man targets were presented in a 15-minute scenario precisely in the same sequence with the same exposure times for each exercise. The exercise was repeated some 17 times.

Some operating costs for this range have been calculated. Assuming that the van will be driven to and from the range for 1 day of testing, and further assuming that 4 test trials will be conducted in the morning and 4 test trials in the afternoon, an approximate cost of testing per day is $200 to include amortization of initial investments. The operation and maintenance of these ranges are within the capabilities of the military personnel assigned to the Infantry Board.

Although these three facilities were designed to compare and discriminate between similar competing weapons systems, their usefulness does not stop there. They will be used extensively to quantify the impact of items of clothing or equipment worn by the Infantry soldier. As an example, the impact of armored vests on the soldiers' performance has been tested on the quick-fire facility. A control group using the standard vest fired and a test group using the armored vest under development also fired and the results compared. Other candidate items of materiel for testing on these ranges include improved steel helmets, chemical protective overgarments, and load carrying equipment. No longer will the Board have to rely on a completely subjective evaluation for such items.

As a result of the defense experiment and similar experiments on the attack and quick-fire facilities, the Board is reassessing the measures of effectiveness which were developed at the outset in a purely analytical light. One or two additional measures of effectiveness are being investigated while at the same time several have

been discarded as being nondiscriminatory. For example time to charge magazines and recoil impulse have been discarded while hit probability per target array is being added.

Extensive analysis is performed in carrying out the Board's experimental and testing functions. First of all, test performance data is analyzed for comparative evaluation against the materiel needs or requirements documents. Statistical analyses are quite easy to perform but statistics is a tool only; in the final analysis, we must determine the operational significance rather than the statistical significance in testing performance. The Board is also conducting continuing analysis on the reliability of instrumentation and test hardware. An in-depth analysis was conducted of burst effectiveness of automatic fire round by round, as a result of the attack and quick-fire experiments. Here the interest was in looking at which rounds of a burst were of high value to the soldier. Accordingly, hit probabilities of each round in a burst were developed to determine the optimum burst size.

Lastly, the real time collection and rapid analysis and evaluation of test data puts the Board in a good position from the risk analysis standpoint. This is purely a cost effectiveness measure and allows the tester to determine failure probabilities early in the testing cycle.

The discussion so far has been directed to small arms testing functions. The Board is conducting similar methodology and instrumentation studies with respect to other categories of materiel and weapons, for example, indirect fire weapons, antitank weapons, light machine guns, and 40-mm systems.

Although the primary interest of the Board is in Infantry weapons and materiel evaluation, some valuable fallout has resulted from the Board's methodology studies. Tremendous potential for conducting Infantry small unit tactical proficiency training and testing on the instrumented facilities is easily recognized. These facilities will test both individuals and small units and the scores will be immediately available to the unit training officers and commanders.

By way of unfinished business there are several ideas which should be mentioned.

First is the difficult task of assigning relative values or weights to each of the measures of effectiveness.

The second problem is that of stress. How do we stress or condition our test soldiers to insure that they are truly representative of the using troops in a combat environment?

Third is that of suppression. We realize that near misses are suppressive but we have no way of quantifying or scoring the relative effectiveness of misses versus hits.

Studies conducted by the US Army Infantry Board have resulted in the establishment of measures of effectiveness which must be addressed in the evaluation of weapons systems. The study further resulted in the development of three instrumented and fully automated small arms test facilities. The Board is conducting similar studies to determine the optimum test methodology for all Infantry weapons systems and materiel.