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URBAN WARFARE A FIRST REPORT

by

JACK P. MANATA

ROBERT B. LONG

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15 OCTOBER 1975



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report documents a two man-year Rodman Laboratory effort - January 1974 - June 1975 - in the field of urban warfare. The report consists of ideas, thoughts, mathematical modeling, weapon analysis, and weapon concepts. The modeling effort has produced an urban warfare combat simulation (URBWAR). URBWAR is a stochastic, event-sequenced, small unit (platoon and smaller) simulation, and (in its present form the model) can be and has been used to analyze small arms weaponry, i.e., M16, M14, M79 M16/M203, M14/M203, M60, and SAWS.		

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The analysis, conducted in the context of a squad vs. squad engagement, was to answer a series of questions associated with squad effectiveness: 1. What differences occur in squad casualty producing effectiveness when M14s are replaced with M16s? 2. What differences occur when semi-automatic fire is employed as opposed to automatic fire? 3. What differences occur when defense initiates the battle as opposed to offense initiating the battle? 4. What differences occur when two rifles are removed and replaced with grenade launchers? 5. What differences occur when the grenade launchers are replaced with multipurpose weapons? 6. What differences occur when two additional rifles are removed and replaced with SAWS? 7. What differences occur when the grenade launcher portion of the multipurpose weapon has M203 characteristics as opposed to M79 characteristics? 8. What differences occur when an M60 machine gun is added to the standard squad?

The concepting portion of the program has surfaced two weapon ideas that appear to have promise: 1. A wall breaching/anti-armor infantry weapon. 2. A volume source concussion grenade.

The wall breaching/anti-armor infantry device is based on high velocity kinetic energy impact. The device with its closed breech and kinetic energy round could solve the back blast and safing and arming problems associated with present infantry weapon systems.

The concussion grenade, based on fuel air explosive technology, would generate a volume concussion source that might solve the problems associated with intervening furniture and degradation of concussion effects with range.

In addition to the above a testing program was also identified as being required to generate data to aid designers, analysts, and decision makers in developing effective weapons. Some of the tests are: 1. Material penetration 2. Ricochet phenomena 3. Visual detection 4. Fragmenting grenade lethality in a confined area 5. Aiming accuracy against fleeting urban targets.

ACKNOWLEDGEMENT

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FOREWARD

"It's an art, sir, rushing a building.... They can't stop you if you know how. You just have to get near enough first. That's the dodgy bit. There's usually plenty of cover, though, shell holes, ruins and that, but you've got to have patience. Crawl, dig your way there if you have to, but don't start until you're within thirty yards of a window. Then go mad. Put a four-second grenade in first and follow it.... Then, you go through the whole house. Quick as lightning. Every room. First a grenade, and then yourself.... Then, comb it out with your machine pistol. If it's a soft house, put a burst up through the ceiling and catch them bending. But don't stop for a second.... They're more frightened of you than you are of them because you're attacking. Blind 'em and then hit 'em with everything. And when you run out of ammo, still keep going while they're dazed. Knife, shovel, the lot! Keep going and there's nothing can stop you, sir."

A quote from a British NCO State of Siege, Eric Ambler, (Bantam Books, New York, 1957)

TABLE OF CONTENTS

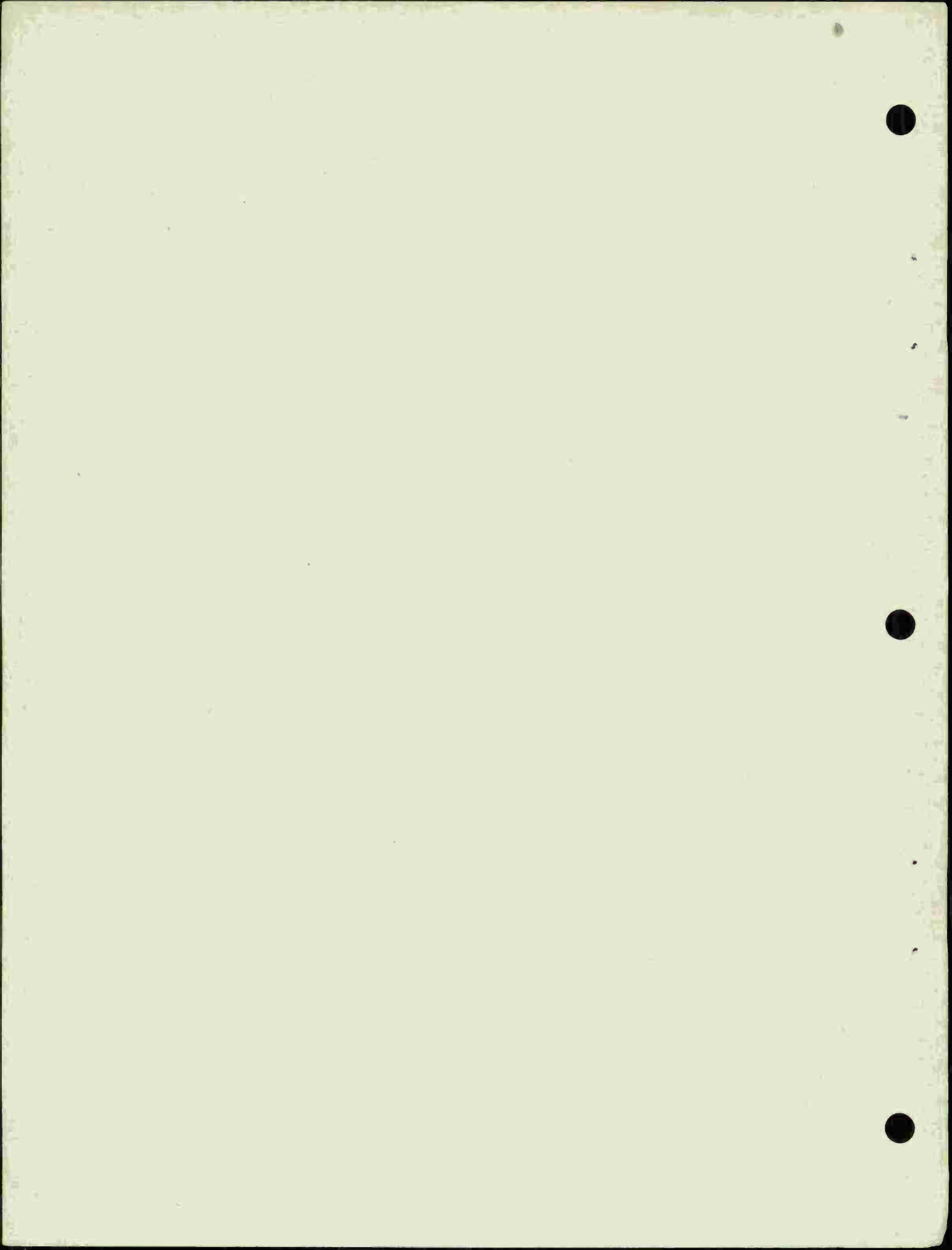
	<u>PAGE NO.</u>
1.0 INTRODUCTION	1-1
1.1 Background	1-1
1.2 Modeling TASK	1-1
1.3 Analysis TASK	1-2
1.4 Concepting TASK	1-3
1.4.1 Wall breaching/anti-armor	1-3
1.4.2 Concussion grenade	1-3
1.5 Testing	1-4
2.0 THOUGHTS ON URBAN WARFARE	2-1
3.0 URBAWAR - A COMBAT SIMULATION MODEL	3-1
3.1 Basic Scenario	3-1
3.2 Simulation	3-1
3.2.1 Detection event	3-1
3.2.2 Movement event	3-2
3.2.3 Fire event	3-2
3.3 URBWAR Output	3-3
3.4 URBWAR Modifications	3-5
4.0 SCENARIO FOR PRELIMINARY ANALYSIS OF SOME SMALL ARM WEAPON SYSTEMS.	4-1
4.1 Environment	4-1
4.2 Offensive Organization	4-3
4.3 Defensive Organization	4-4
4.4 Sectors of Responsibility	4-5
4.5 Conflict Initiation	4-7
5.0 ANALYSIS	5-1
5.1 Conflict Dynamics	5-1
5.1.1 Battle initiation and detection	5-1
5.1.2 Suppression dynamics	5-2
5.2 Analysis of Weapons Impact on Squad Effectiveness.	5-2
5.2.1 What differences occur, in squad casualty producing effectiveness when M14s are replaced with M16s?.	5-13

TABLE OF CONTENTS (cont'd)

	<u>PAGE NO.</u>
5.2.1.1 Offense employs semi-automatic fire	5-13
5.2.1.2 Offense employs automatic fire	5-13
5.2.2 What is the most effective firing mode for the squad armed with M16s and without multipurpose weapons? . .	5-14
5.2.3 Is it an advantage to initiate the conflict?	5-14
5.2.4 Does the addition of grenade launchers increase the effectiveness of the squad?	5-14
5.2.5 Does the introduction of multipurpose weapons increase the effectiveness of the squad?	5-15
5.2.6 Is there any difference in effectiveness if the area fire portion of the multipurpose weapon has M203 characteristics instead of M79?	5-17
5.2.7 Does the addition of SAWS to the squad increase the squad's effectiveness?	5-17
5.2.8 Does the addition of an M60 to the squad increase the squad's effectiveness?	5-17
6.0 PRELIMINARY CONCEPTS FOR NEW WEAPONS SYSTEMS	6-1
6.1 Introduction	6-1
6.2 Discussion, Wall Breaching	6-1
6.2.1 Wall breaching requirements	6-2
6.2.2 Wall breaching concept.	6-2
6.3 Discussion, Grenade Effects in Confined Areas	6-3
6.3.1 Concussion grenade concept	6-3
6.3.2 Other grenade concepts	6-5
6.4 Discussion, Additional Problems	6-5
7.0 TESTING	7-1
7.1 Discussion	7-1
7.2 Penetration	7-1
7.3 Ricochet	7-2
7.4 Visual Detection	7-3
7.5 Grenade Lethality in Confined Areas	7-3

TABLE OF CONTENTS (cont'd)

	<u>PAGE NO.</u>
7.6 Aiming Accuracy	7-3
8.0 CONCLUSIONS	8-1
9.0 RECOMMENDATIONS	9-1
A.0 APPENDIX A -- NARRATIVE DESCRIPTION OF THE URBWAR MODEL . .	A-1
A.1 Scenario	A-2
A.2 Flow Description	A-2
A.3 Narrative	A-2
SUBROUTINE INDEX OF APPENDIX A	A-25
B.0 APPENDIX B -- DESIGNER COMMENTS ON URBWAR	B-1
C.0 APPENDIX C -- URBWAR COMMON DEFINITIONS	C-1
D.0 APPENDIX D -- ADDITIONAL URBWAR DYNAMICS GRAPHS	D-1
LITERATURE CITED	E-1



LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE NO.</u>
1	Major Cities in West Germany	2-5
2	Terrain Features of West Germany	2-7
3	Scenario Built-Up Area	4-1
4	Building Layout	4-2
5	Offensive Positions	4-3
6	Defensive Positions	4-4
7	Offensive Sectors of Responsibility	4-5
8	Defensive Sectors of Responsibility	4-7
9	Cumulative Detections vs Battle Time	5-3
10	Remaining Firers vs Battle Time	5-4
11	Cumulative Rounds Fired vs Battle Time	5-5
12	Cumulative Casualties vs Battle Time	5-6
13	Standard Squad M16 Semi-Automatic Fire	5-19
14	Standard Squad M14 Semi-Automatic Fire	5-20
15	Standard Squad M16 Automatic Fire	5-21
16	Standard Squad M14 Automatic Fire	5-22
17	M16 Squad Semi-Automatic Fire	5-23
18	M16 Squad Automatic Fire	5-24
19	Standard Squad Defense Initiates Battle	5-25
20	Rifle and Grenade Launcher Squad	5-26
21	Rifle and Multipurpose Weapons Squad, Semi-Automatic Fire	5-27
22	Rifle and Multipurpose Weapons Squad, Automatic Fire .	5-28
23	M14 and Multipurpose Squad Automatic Fire	5-29
24	SAWS Squad	5-30
25	M60 Squad	5-31
26	Armor Penetration by Hyper-Velocity Projectile	6-4
D-1	Cumulative Detections vs Battle Time at 7 Meters - Standard Squad	D-2
D-2	Cumulative Detections vs Battle Time at 16 Meters - Standard Squad	D-3

LIST OF FIGURES (cont'd)

<u>FIGURE</u>	<u>PAGE NO.</u>
D-3 Cumulative Detection vs Battle Time at 25 Meters - Standard Squad	D-4
D-4 Cumulative Detection vs Battle Time at 34 Meters - Standard Squad	D-5
D-5 Cumulative Detection vs Battle Time at 40 Meters - SAWS Squad	D-6
D-6 Cumulative Detection vs Battle Time at 40 Meters - M60 Squad	D-7
D-7 Remaining Firers vs Battle Time at 7 Meters - Standard Squad	D-8
D-8 Remaining Firers vs Battle Time at 16 Meters - Stand- ard Squad	D-9
D-9 Remaining Firers vs Battle Time at 25 Meters - Stand- ard Squad	D-10
D-10 Remaining Firers vs Battle Time at 34 Meters - Stand- ard Squad	D-11
D-11 Remaining Firers vs Battle Time at 40 Meters - SAWS Squad.	D-12
D-12 Remaining Firers vs Battle Time at 40 Meters - M60 Squad.	D-13
D-13 Rounds Fired vs Battle Time at 7 Meters - Standard Squad.	D-14
D-14 Rounds Fired vs Battle Time at 16 Meters - Standard Squad.	D-15
D-15 Rounds Fired vs Battle Time at 25 Meters - Standard Squad.	D-16
D-16 Rounds Fired vs Battle Time at 34 Meters - Standard Squad.	D-17
D-17 Rounds Fired vs Battle Time at 40 Meters - SAWS Squad	D-18
D-18 Rounds Fired vs Battle Time at 40 Meters - M60 Squad .	D-19

LIST OF FIGURES (cont'd)

<u>FIGURE</u>		<u>PAGE NO.</u>
D-19	Cumulative Casualties vs Battle Time at 7 Meters - Standard Squad	D-20
D-20	Cumulative Casualties vs Battle Time at 16 Meters - Standard Squad	D-21
D-21	Cumulative Casualties vs Battle Time at 25 Meters - Standard Squad	D-22
D-22	Cumulative Casualties vs Battle Time at 34 Meters - Standard Squad	D-23
D-23	Cumulative Casualties vs Battle Time at 40 Meters - SAWS Squad	D-24
D-24	Cumulative Casualties vs Battle Time at 40 Meters - M60 Squad.	D-25

LIST OF TABULAR DATA

<u>TABLE</u>	<u>PAGE NO.</u>
1 EXAMPLE OF URBWAR SUMMARY OUTPUT	3-4
2 EXAMPLE OF URBWAR DETAILED OUTPUT.	3-5
3 OFFENSIVE SECTORS OF RESPONSIBILITY	4-6
4 DEFENSIVE SECTORS OF RESPONSIBILITY	4-7
5 CHRONOLOGICAL NARRATIVE.	5-7

1.0 INTRODUCTION

1.1 Background

The urban warfare program, established within Rodman Laboratory during January 1974, resulted because of the realization by the user and development communities of two facts:

- The urbanization of the world and metropolitan sprawl are increasing the probability that military forces will become engaged in urban warfare.
- All available weapon performance data and analysis is oriented towards field use of weapon systems and the urban environment had been totally ignored.

Given the first fact, a logical approach had to be developed to negate the second fact. The approach proposed by Rodman Laboratory was to divide the program into three equal parts:

- A modeling and analysis task
- A concepting task
- A testing task.

The modeling and analysis task was to develop the methodology required to simulate small unit engagements in an urban environment, and to employ the methodology in determining the effectiveness of a unit armed with available and conceptual weapon systems.

The concepting task was to propose weapon system concepts that might overcome weapon shortcomings highlighted by either the analysis task or other sources.

The testing task was to determine those data items concerning the man-weapon systems performance (in an urban environment) that are (or will be) required by designers, analysts, and decision makers, and are not available.

1.2 Modeling TASK

The modeling task has resulted in the development of a stochastic, event-sequenced, small unit (platoon and below) urban combat simulation. The model is capable of simulating the defense and attack of an urban area consisting of five buildings constructed of different materials, different floor plans, and of different heights (up to a maximum of four levels). The model simulates the attack of defended buildings from across streets, the entering of a defended building, and the clearing of defended buildings.

1.3 Analysis TASK

The analysis task included the exercise of the model to determine the effectiveness of a squad, armed with various small arm weapons systems, in the attack of a building defended by another squad. During the analysis eight questions were answered:

- . What differences occur in squad casualty producing effectiveness when the squad is armed with M14s instead of M16s?
- . What differences occur when semi-automatic fire is used as opposed to automatic fire?
- . What differences occur when defense initiates the battle instead of offense?
- . What differences occur when two rifles are removed and replaced with two grenade launchers?
- . What differences occur when the grenade launchers are removed and replaced with multi-purpose weapons?
- . What differences occur when two additional rifles are removed and replaced with Squad Automatic Weapons (SAWS)?
- . What differences occur when the grenade launcher portion of the multipurpose weapon has M79 characteristics instead of M203 characteristics?
- . What differences occur when an M60 machinegun is added to the standard squad?

The analysis indicated the following:

- . The comparison between the M14 and M16 indicated that when the weapons fire semi-automatically the difference in squad casualty producing effectiveness is minor. But when they fire automatically the squad armed with M16s is more effective.
- . For the squad armed only with M16s the more effective firing mode is automatic fire.
- . The side that initiates the battle, be it offense or defense, has a decided advantage.
- . The addition of grenade launchers to the squad increases the casualty producing capability of the squad. But, this increase doesn't become noticeable until the width of the battlefield is greater than fifteen meters.

- . The squad's effectiveness increases when the grenade launchers are replaced with multi-purpose weapons.
- . The squad's effectiveness increases when two M16s are replaced with SAWS. This difference is apparent in showing an increase in enemy casualties.
- . There is little difference between the M79 and M203.
- . The addition of an M60 machinegun to the squad has approximately the same effect as the replacement of two M16s with two SAWS. This indicates that an eleven man squad that has two SAWS is as effective as a thirteen man squad that has an M60.

1.4 Concepting TASK

The concepting task surfaced two promising ideas:

- . A wall breaching/anti-armor device
- . A volume source concussion grenade.

1.4.1 Wall breaching/Anti-armor

The wall breaching/anti-armor concept, which is based on high velocity - kinetic energy impacts, was investigated because of possible problems associated with present infantry weapons that could be assigned this task i.e., LAW, DRAGON, TOW, 106mm and 90mm recoilless rifles and 40mm grenade launchers. Some of these problems are:

- . Back blast in a confined area
- . Large safing and arming distances
- . Excessive cost
- . Shape charge warheads that generate a small hole
- . Firing signatures.

The proposed concept would use a closed breech (eliminating back blast) and a kinetic energy projectile eliminating the safing and arming problem. In addition, the weapon would not be urban warfare limited. With its wall breaching capability it could be used to breach field fortifications and its anti-armor capability is certainly not limited to an urban environment.

1.4.2 Concussion grenade

The concussion grenade concept, which is based on fuel air explosive technology, appears to offer a feasible solution to problems associated with available fragmentation and concussion grenades. For fragmentation grenades the proximity of furniture could retard or stop the fragments.

In addition, walls, floors, and ceiling would modify the fragmentation pattern. For the concussion grenade the concussion effects drop off rapidly as the distance from the source is increased.

The new grenade concept would first generate a cloud of explosive dust and then ignite the dust, thus generating a volume concussive source. This volume source could negate the effects of intervening furniture and the drop off of effectiveness with distance.

1.5 Testing

The third area of the proposed program is testing. Though outlined and programmed, this area has not been initiated; but, the following list delineates tests that should be considered for a well rounded program:

- . Penetration of structural materials by small arms projectiles
- . Projectile ricochet off of structural materials
- . Aiming accuracy against fleeting urban targets
- . Probability of visual detection of static targets in an urban environment
- . Detection and location of firing weapons
- . Lethality of fragmenting grenades in a confined area.

2.0 THOUGHTS ON URBAN WARFARE

To consider urban warfare solely in the context of large metropolitan areas is to do the whole subject a disservice. Urban warfare is not only a big city problem, it's a problem associated with any location where civilized man has erected structures for social, political, religious, or economic reasons. This includes villages, hamlets, suburbs, oil refineries, and metropolitan areas. In the eyes of the platoon, squad, or individual soldier all of these locations represent the same hazards, be it a small village of five buildings or city of thousands of buildings.

Considering urban warfare in this broader context it is probably safe to state that urban conflict has occurred more frequently in the past than has been reported in previous studies. These previous studies have homed in on the large battles to support their contention that urban warfare is a legal topic for study. But it could be that these large battles only represent a small portion of the total number of conflicts and the small conflicts are actually the foundation of urban warfare.

If urban warfare has occurred so frequently in the past why hasn't the subject arisen before? Maybe, as BG. S.L.A. Marshall said (Ref. 1), "Either the subject was too sticky, too little understood, or it was dismissed as unimportant." Possibly they haven't written about it because it doesn't allow for easy analysis. As the British NCO said, "It's an art sir." Or as Major John F. Meehan III states in Ref. 2, "There may be no such thing as "tactical operations" in urban regions as any combat in such areas may of necessity, be that of a time-consuming slug fest."

The problem is too sticky; it's an art; there is no such thing as tactical operations. These statements could all be accurate (if the topic is considered as one massive problem). But, urban warfare can be thought of as two distinct areas:

- . The field commander's decision problem, i.e., should I attack, defend, or by-pass this urban area?
- . The individual soldier, squad, platoon decision problem, i.e., how is this building going to be taken?

In the first case the number of variables affecting the decision has increased beyond those affecting the decision to take a patch of ground. The field commander has to account for political, religious, economic, and humanitarian implications, any of which could be beyond his control and would force him to defend, attack or by-pass. And, if he does decide to defend or attack maybe all he can decide is what units will attack where and when. Once the attack has been initiated his control of the situation deteriorates due to communication problems and the small unit conflict aspects of urban warfare.

It appears that the commander's aspects of the problem, as far as learned articles are concerned, leads either to a simplistic solution, requiring little study, or to a complex solution invoking all of the variables and doing little to aid the commander in making his decision.

The second area could be an art (or a series of techniques) with only general guidelines as to what kind of tactics to employ in attacking or defending a structure. For example, in the field, an outpost which comes under fire and has to retreat knows how to retreat and what route to use (to reach the main body). But, if this same group is defending a building what does retreat mean? Move from the roof to the second floor? Move from the first floor to the second floor? Move from room A to room B? Where is the main body? It could be that this unstructured nature of small unit urban conflict has deterred analysis of the problem. But it seems that this is the logical point of departure. Once the small unit engagements are understood, as to what contributes to small unit effectiveness, maybe this understanding can be used as a basis to address the commander's decision problem.

Will these decision problems increase in the future? This is tied to the question, will urban warfare increase? Based on population projections there isn't any reason to believe it will decrease. But, what if it doesn't decrease? What if it occurs with the same frequency as it has in the past? It would still be a type of warfare that has been neglected and should not have been. The following quote, from Colonel J. Wheeler's presentation to an urban warfare symposium, Ref. 3, points up the impact villages and hamlets have on the frequency of urban conflict in Europe.

"As General Marshall pointed out, during the Ardennes offensive a rather inferior force was able to stave off superior German forces by taking advantage of the hamlets, cities, and villages and tying them in with existing terrain. That was about the only way we were able to hang on until we got reinforced from the North and South. Again, on the other side of the coin, when we were in the so-called rat race, running across Germany in the last days of the war, we discovered that when the Germans decided to defend their villages and they had the manpower to do so, they made it pretty rough for us.

So I took a look at one of our positions that we might be defending on the West German border. I picked it at random. It happens to be an area that is a brigade zone of defense for an armored brigade.... The front is about twenty-five klicks. The green represents the forested area which is reasonably thick. All the little green outline areas are villages. When you analyze this piece of terrain, you realize that the villages and these dense forest areas make up approximately fifty-nine percent of the available terrain that an attacking force will have. Now if the aggressive forces attack with masses of tanks, as we assume they are going to, you see they are not going to be able to bypass the one village without running into another or at least coming under defilade fire. They're just not going to be able to do it. You see how the villages are dotted throughout all the natural avenues of approach.... In this particular area we had eighty-six villages in the zone of defense."

In conjunction with the quote from Colonel Wheeler's presentation, Figures 1 and 2 published by the Armor School at Fort Knox, indicate how the major cities in West Germany interlock with the terrain features. Add this to the eighty-six villages and it is difficult to imagine armies uninhibitly wheeling and dealing across broad avenues of terrain.

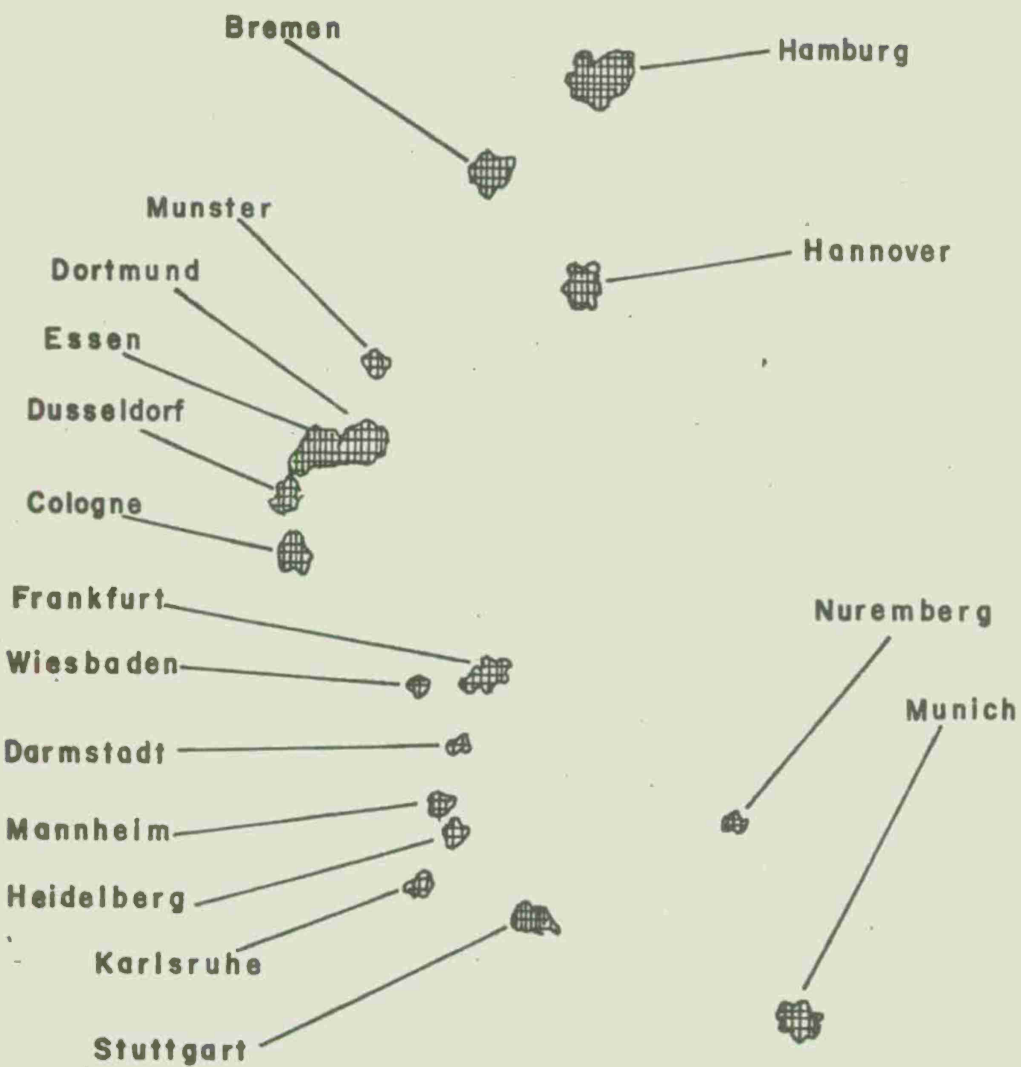


Figure 1 Major Cities In West Germany

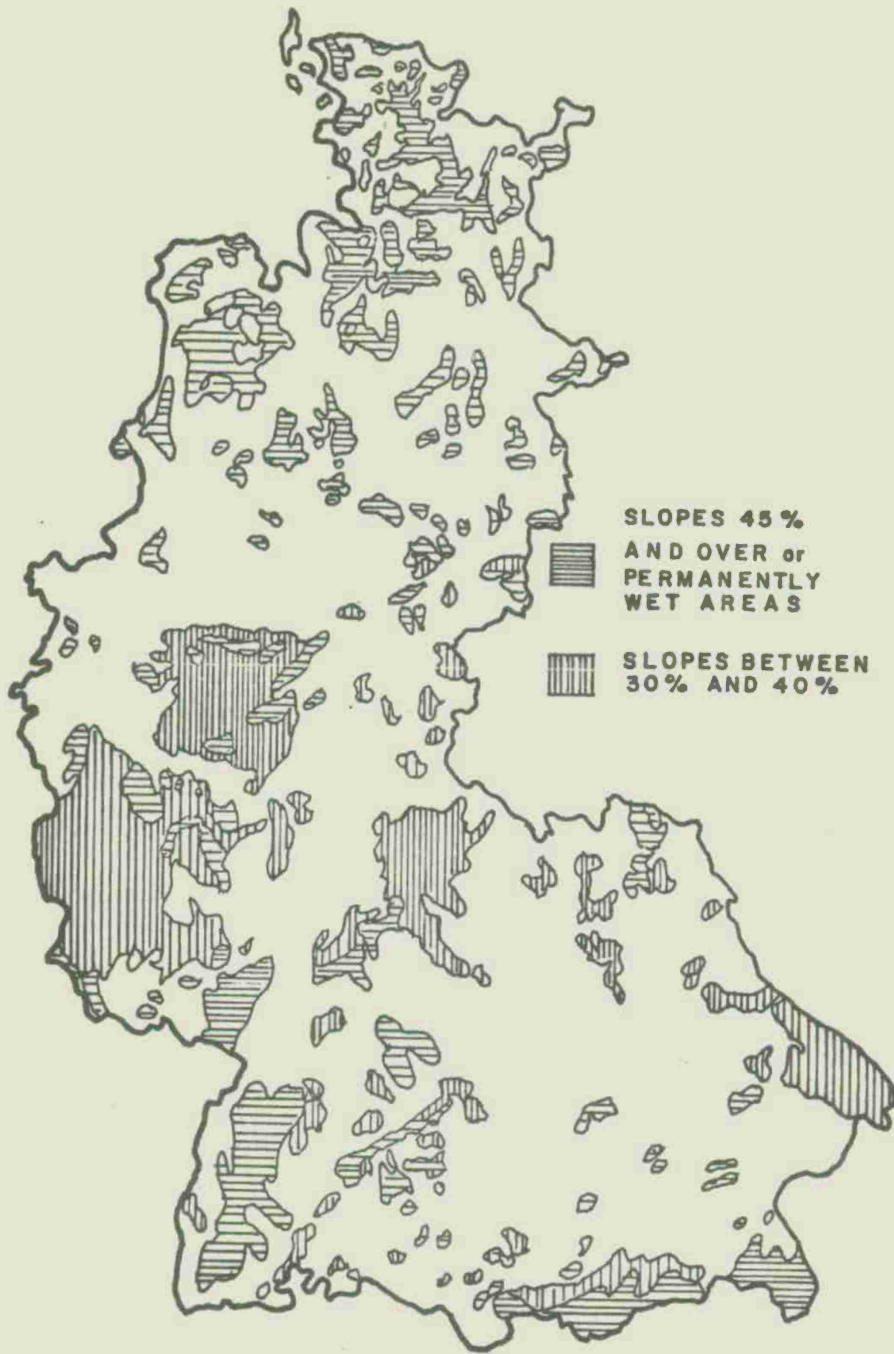


Figure 2 Terrain Features Of West Germany

What about other areas of the world, such as the Middle East, Africa, South America? In these areas it might be possible to take over a country by capturing a religious and/or a political center, such as Damascus, Cairo, or Jerusalem. This fact was highlighted by General Gur of the Israeli Army, quoting from Ref. 3:

"When involved in war in the Middle East, the history of Jerusalem reveals that you will not be successful, politically or militarily, unless you take Jerusalem itself. It is also shown that armies tried to avoid battle in Jerusalem, but in the end they had to take it and they had to take it by fighting.

Since all military action is enveloped in political goals (this being especially true of the Middle East), until the big cities are taken you achieve very little. Located in large cities are government, communications, electric power, majority of population, and so forth. As a result, if you want to dominate an area, you will be required to take the big cities."

In addition to what General Gur has said about the large cities, it must also be remembered that there are villages available. Israel for example locates some of the kibbutz communities in strategic locations.

Finally the energy crisis has increased the probability that urban conflict will occur if one considers the taking of oil refineries and oil fields to be urban warfare. What happens if the flow of oil is restricted or stopped? It is possible that force would be used to correct the situation, and the soldier, squad and platoon would become enmeshed in a type of urban conflict.

3.0 URBWAR - A COMBAT SIMULATION MODEL

The urban warfare program was initiated to develop weapons that will be effective in both an urban and rural environment. This goal guided the development of URBWAR which has been limited to simulating platoon actions and smaller unit conflicts. By limiting it to this size it is possible to investigate weapon performance parameters and man/weapon interactions in the context of small unit effectiveness.

URBWAR is a stochastic event-sequenced small unit (platoon level and smaller) urban warfare combat simulation. The simulation is written in FORTRAN IV and is operational on an IBM 360/65 computer.

3.1 Basic Scenario

The terrain for the simulation is an urban area consisting of from one to five buildings constructed of identical or different materials, of identical or different elevations and floor plans. The buildings can be oriented along one main street and two side streets.

The offensive and defensive elements can occupy all or some of the buildings. In addition, the offensive element can be divided into a cover team and an assault team.

3.2 Simulation

During a simulation each element cycles through detection, movement, and firing events.

3.2.1 Detection event

For the detection event each element is assigned, by input, fire detection sectors. These sectors are ranked by priority from the most critical to the least critical. The assigned sectors for elements on the same side can be different, overlap to some extent, or be identical. The elements are restricted to searching for and detecting targets in these sectors, thus enforcing a form of fire discipline on both the offense and defense.

During a detection event target acquisition of static non-firing targets is based on visual search and detection. The detection methodology takes into account, range, target/background contrast, target presented area, and glimpse time. For detection of firing targets, equations

developed for the Army Small Arms Requirements Studies (ASARS) Model (Ref 4) are used to determine probability of detection, accuracy of location and time to detection.

3.2.2 Movement event

The movement event encompasses:

- . assault movements
- . movements to obtain a more advantageous search position
- . movements due to suppression.

Initially all elements are prepositioned by input data. For the defense, this positioning is within some structure, for the offense the cover team is positioned within a structure and the rush team is positioned outside the structure but in a location that cannot be observed by the defense. The rush team elements can be located at the same initial position or they can be divided into separate groups. They can also rush all at once, one at a time, or any combination that is desired.

The assault movement, by the rush team, is initiated after the battle has started. The team rushes, with a constant velocity, in a straight line toward its first subobjective, i.e. besides the defensive enclosure. Until recently, reaching of this subobjective terminated the conflict. But, with a new dynamic route selection routine, the elements will have other subobjectives i.e., enter a building, and clear a building.

Movement to obtain an advantageous detection location is a crawling movement from one side of an opening to another. This type of movement is initiated by the detection routine. If, after a specified elapsed time, an element hasn't detected a target from his present location, he is free to move to another location from which he will continue his search.

Suppression movement is triggered either by incoming fire or a need for the element to reload. Suppression due to incoming fire, lasts for a fixed amount of time, presently five seconds for rifles, machine gun, etc, and ten seconds for grenade fire. Suppression due to reload time is weapon specific.

3.2.2 Fire event

The fire event determines the targets hit, the number of times hit and if the target is a casualty.

This event accounts for firing rate, burst length, aiming time, re-load time, range to the target, aiming error, ballistic error, range estimation error, projectile impact velocity, projectile mass, and the target's tactical situation i.e., rush, cover, defense.

The probability of hit is calculated employing either of two equations.

- . If the firing weapon is semi-automatic or a shotgun, the bi-variate normal distribution model developed by AMSAA is employed. This model is also employed for automatic fire if the firing weapon has a light recoil or is fired from a rigid or tripod mount.
- . If the firing weapon is automatic and has a bipod mount and the distribution of first rounds is from a different population than rounds two thru N, the tri-variate normal distribution is used.
(Ref. 5)

If the parameters for these equations are available they are input to the model. If they aren't available empirical equations can be used to determine the parameters. These equations are based on firing rate and recoil impulse. The set of equations for semi-automatic fire is from Ref. 6 and the set for automatic fire is from the Parametric Design Analysis model developed for the Small Arms Directorate of Rodman Laboratory.

The equations used to calculate probability of incapacitation given a hit are based on BRL report 1269. It is acknowledged that the realism of the criteria and equations developed in this report can be challenged, especially for bulleted systems, but, even though the probability numbers might be marginally accurate a relative comparison between two systems is possible. The accuracy of the criteria for bulleted systems is being corrected based on new data that is weapon specific i.e., M16, M60, M14, SAWS, etc.

3.3 URBWAR Output

URBWAR provides two types of printed output:

- . A summary output that indicates what elements were killed, by whom they were killed and which weapon was used.
- . A detailed event by event output.

An example summary output is shown in Table 1. This output is for a forty meter street width, offense fires first, and offense knows defense

exists. Elements one through eleven are the offense, with elements one through six being on the cover team and seven through eleven being on the rush team. Elements twelve through twenty are on the defense. On the offense all elements are armed with automatic rifles with the exception of five and six who have multipurpose weapons. On the defense all elements are armed with automatic rifles with the exception of twenty who is a machine gunner.

TABLE 1 EXAMPLE OF URBWAR SUMMARY OUTPUT

```

FIRST FIRE= 1 INTELL= 1 ST. WIDTH= 40.0 RUSH VEL.= 6.10
16 WAS SUPPRESSED BY BLAST FROM 5 AT TIME= 0.66
5 MISSED BLAST TARGET
6 WILL USE REGULAR FIRE INSTEAD OF BLAST
6 MISSED BLAST TARGET
6 COULD NOT PUT GRENADE THRU HOLE 20
4 DIED AT 6.84 SECS--COORDS(BASE) ARE: 19.40 4.90 8.30
19 KILLED 4 WITH WEAPON 5
12 WAS SUPPRESSED BY BLAST FROM 6 AT TIME= 7.17
6 MISSED BLAST TARGET
7 DIED AT 7.27 SECS--COORDS(BASE) ARE: 35.98 -0.39 0.0
14 KILLED 7 WITH WEAPON 5
3 DIED AT 7.80 SECS--COORDS(BASE) ARE: 19.40 14.50 0.30
20 KILLED 3 WITH WEAPON 6
8 DIED AT 9.43 SECS--COORDS(BASE) ARE: 49.09 -0.44 0.0
15 KILLED 8 WITH WEAPON 5
20 WAS SUPPRESSED BY BLAST FROM 5 AT TIME= 9.78
5 MISSED BLAST TARGET
9 DIED AT 10.01 SECS--COORDS(BASE) ARE: 52.65 -0.46 0.0
19 KILLED 9 WITH WEAPON 5
5 DIED AT 10.30 SECS--COORDS(BASE) ARE: 19.40 18.50 4.30
13 KILLED 5 WITH WEAPON 5
CASUALTIES
RUSH COVER DEFENSE END OF OFF/DEF
3 3 0 BATTLE TIME 11.38 0.56
THE NEXT RANDOM NUMBER IS 379339707

```

Table 2 is an example of the detailed output for a movement event, detection event, and fire event for element 5.

TABLE 2 EXAMPLE OF URBWAR DETAILED OUTPUT

```

*****MOVE EVENT*****
THE CURRENT SOLDIER IS 5.....THIS EVENT BEGINS AT TIME = 0.29 SECONDS--EVENT NUMBER = 8
RECORD OF LAST EVENT: TIME = 0.0 NUMBER OF EVENT = 0
BASE XYZ FOR 5 IS: 19.40 18.50 4.30

*****DET EVENT*****
THE CURRENT SOLDIER IS 5.....THIS EVENT BEGINS AT TIME = 0.32 SECONDS--EVENT NUMBER = 10
RECORD OF LAST EVENT: TIME = 0.29 NUMBER OF EVENT = 8
BASE XYZ FOR 5 IS: 19.40 18.50 4.30
AREA= 0.20 *SEE*
PROB=0.94999999 RAX=0.38886050 Z=1.000 NN= 1
5 HAS DETECTED 16 HAVING PRES. AREA OF 0.20 WIDTH= 0.17 AND HEIGHT= 1.20
NEXT CLOCK: DET=***** MOVE=***** FIRE= 0.66

*****FIRE EVENT*****
THE CURRENT SOLDIER IS 5.....THIS EVENT BEGINS AT TIME = 0.66 SECONDS--EVENT NUMBER = 21
RECORD OF LAST EVENT: TIME = 0.32 NUMBER OF EVENT = 10
BASE XYZ FOR 5 IS: 19.40 18.50 4.30
FIRE DATA IS AVAILABLE
AREA= 0.20 *SEE*
PROB=0.99750000 RAX=0.65037823 Z=1.000 NN= 2
TARGET 16 IS STILL AVAILABLE
16 IS TAKING COVER--NEXT MOVE CLOCK=10.66
16 IS SUPPRESSED IN SECTOR 29
AREA= 0.0 *SEE*
AREA= 0.29 *SEE*
PROB=0.94999999 RAX=0.38764179 Z=1.000 NN= 1
20 IS A CANDIDATE TARGET
THERE ARE 1 POSSIBLE TARGETS 1 NONE OF THEM ARE IN THE STREET.
NO TARGETS POSSIBLE
NO TARGET AVAILABLE FOR 5

```

3.4 URBWAR Modifications

URBWAR because it is in the developmental stages is being added to and modified to increase its simulation capability. Presently two major modifications are being made to the simulation:

- . A new probability of hit and probability of incapacitation subroutine has been developed. This routine determines the probability of hit, the specific body part or parts hit, the number of times they were hit and if the hits resulted in a fire power kill, a mobility kill, a combination fire power-mobility kill, or a total kill.
- . A dynamic route selection routine. This routine, based on similar ones in the DYN TACS and ASARS simulation models, allows each element on the offense and defense to dynamically select

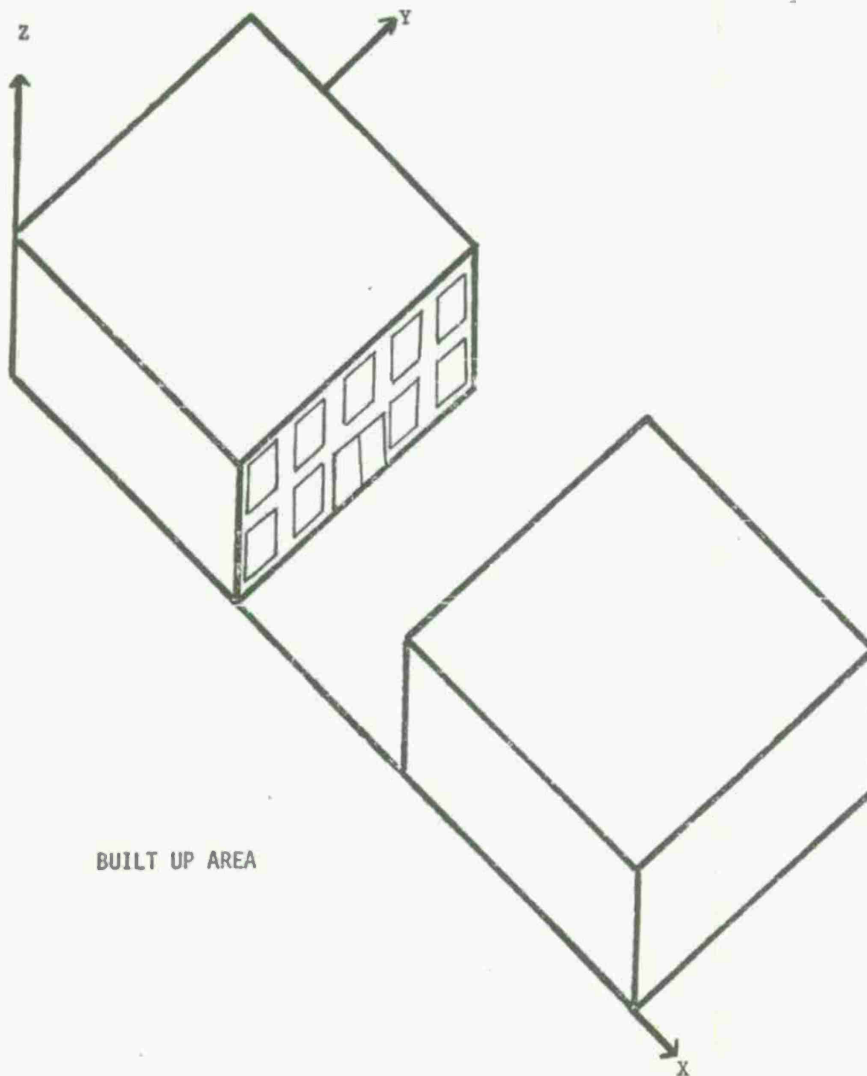
the route to be taken to accomplish the mission. The route that an individual element will select will be the route of least resistance, where resistance is the weighted sum of all difficulties on each path to the objective. Difficulties are either physical obstacles such as a wall that has to be scaled or breached, booby traps and barbed wire, or firing obstacles i.e., can the enemy observe and cover the route with fire.

It is expected that these two subroutines will increase the capability of URBWAR to simulate the urban combat environment.

4.0 SCENARIO FOR PRELIMINARY ANALYSIS OF SOME SMALL ARM WEAPON SYSTEMS

4.1 Environment

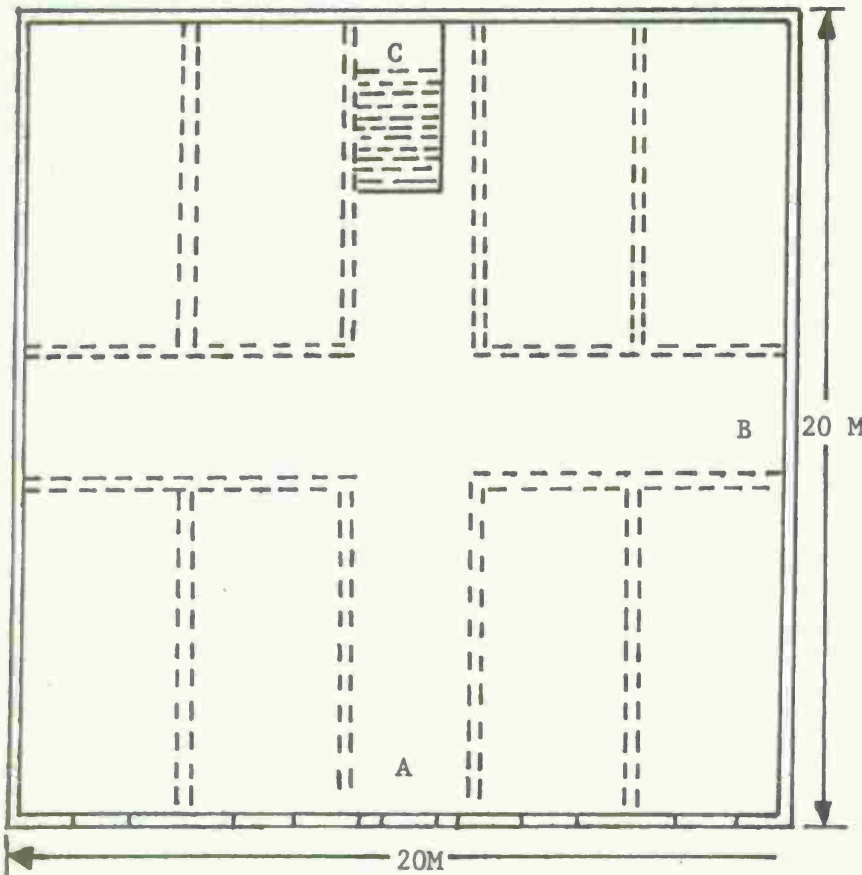
Two opposing squads are located in identical, two story, 20 meter by 20 meter, concrete buildings. The buildings are located on opposite sides of a main thoroughfare, Figure 3. The buildings have eight rooms on each floor plus two intersecting hallways, Figure 4. The sides of the buildings that are facing each other have four windows and a double door on the first floor and five windows on the second floor.



BUILT UP AREA

Figure 3 Scenario Built-Up Area

C IS A STAIRWAY



ROOMS 1 & 2 ARE 4M WIDE, 3.7M HIGH, AND 8M DEEP.

ROOMS 3 & 4 ARE 3.7M WIDE, 3.7M HIGH, AND 8M DEEP.

ROOMS 5 & 6 ARE 3.7M WIDE, 3.7M HIGH, AND 8M DEEP.

ROOMS 7 & 8 ARE 3.7M WIDE, 3.7M HIGH, AND 8M DEEP.

CEILING TO TOP OF WINDOW IS 1 METER.

HALLWAYS A & B ARE 3M WIDE AND 3.7M HIGH.

WALLS, FLOORS, AND CEILINGS ARE .3 METERS THICK.

DOOR IS 2.5M X 2.5M. DISTANCE FROM FLOOR TO WINDOW SILL IS $\frac{2}{3}$ M.

WINDOWS ARE 1.5M WIDE AND 2M HIGH.

Figure 4 Building Layout

4.2 Offensive Organization

The offensive squad, in the basic scenario, consists of eleven elements, which are divided into a six man cover team and a five man rush team. The initial positions of the eleven elements are shown in Figure 5.

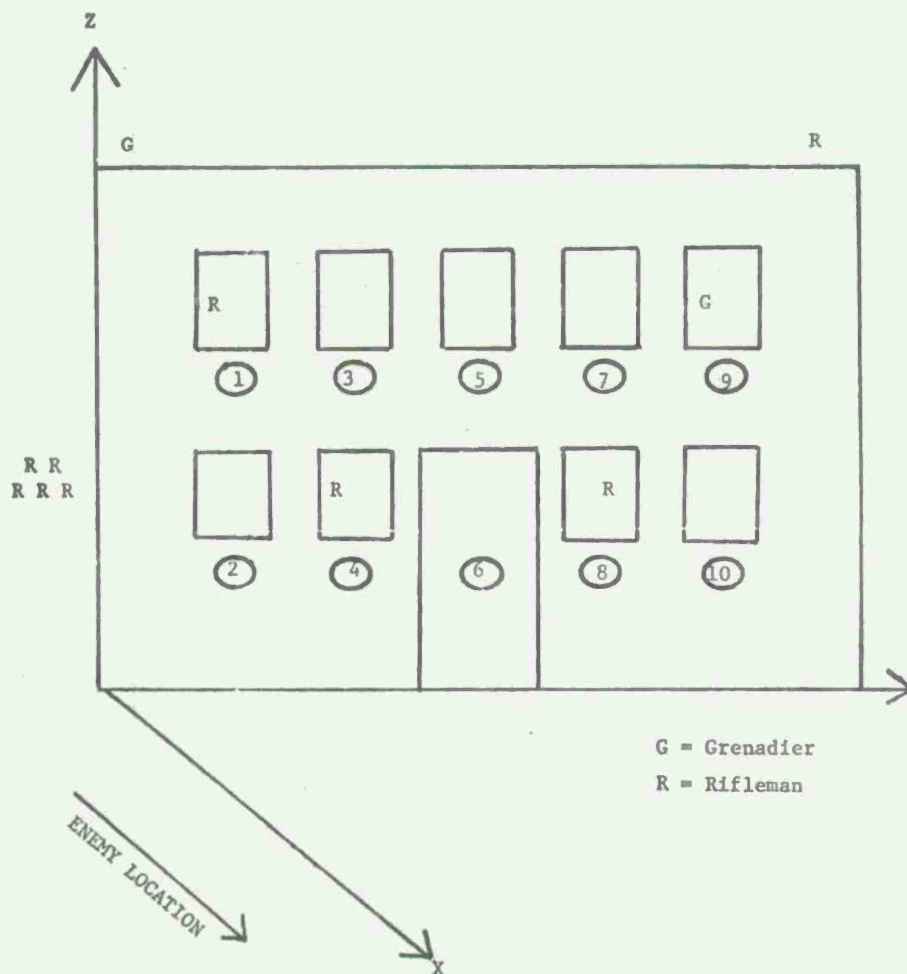


Figure 5 Offensive Positions

In Figure 5, the openings in the face of the building are numbered from 1 thru 10. The grenadiers are designated by G and one is located at the left corner of the roof, the other grenadier is located at the left edge of opening nine. The riflemen are designated by R and are located at the right corner of the roof, the left edge of opening one, the left edge of opening four, the right edge of opening eight, and the five in the rush

team are located alongside the left face of the building.

For the scenario when the offensive squad was provided with a machine-gun, two additional elements were added to the cover team and located in opening two.

4.3 Defensive Organization

The defensive nine man squad was initially positioned as shown in Figure 6.

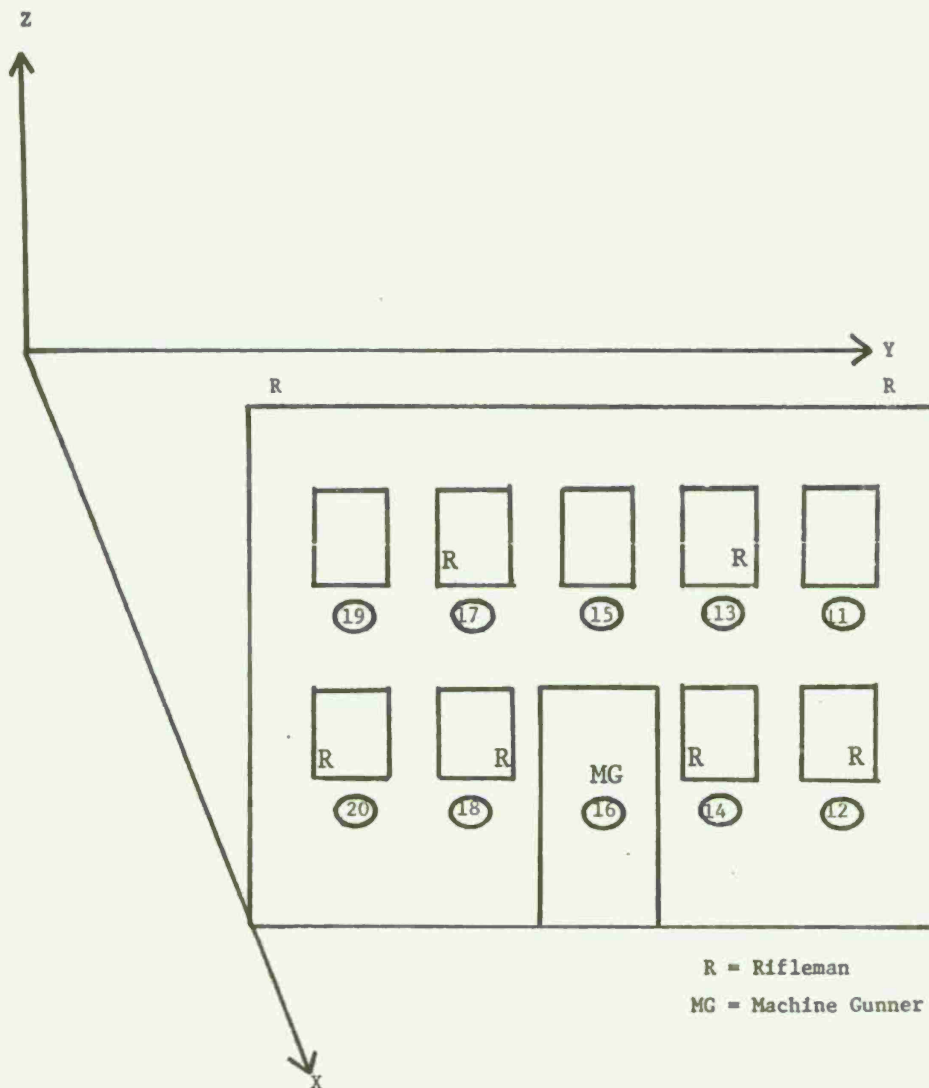


Figure 6 Defensive Positions

In Figure 6, the openings in the face of the building are numbered from eleven thru twenty. The riflemen are designated by R and the machine-gunner by MG. The riflemen are positioned at the left and right corners of the roof, the left edge of opening seventeen, the right edge of opening thirteen, the left edge of openings twenty and fourteen, and the right edge of openings eighteen and twelve. The machine gunner is located in opening sixteen.

4.4 Sectors of Responsibility

Each element on the assault team and the defensive team were assigned five sectors of responsibility with the first sector having the highest priority. Figure 7 indicates the sectors of responsibility for the offense, these sectors include the defensive positions.

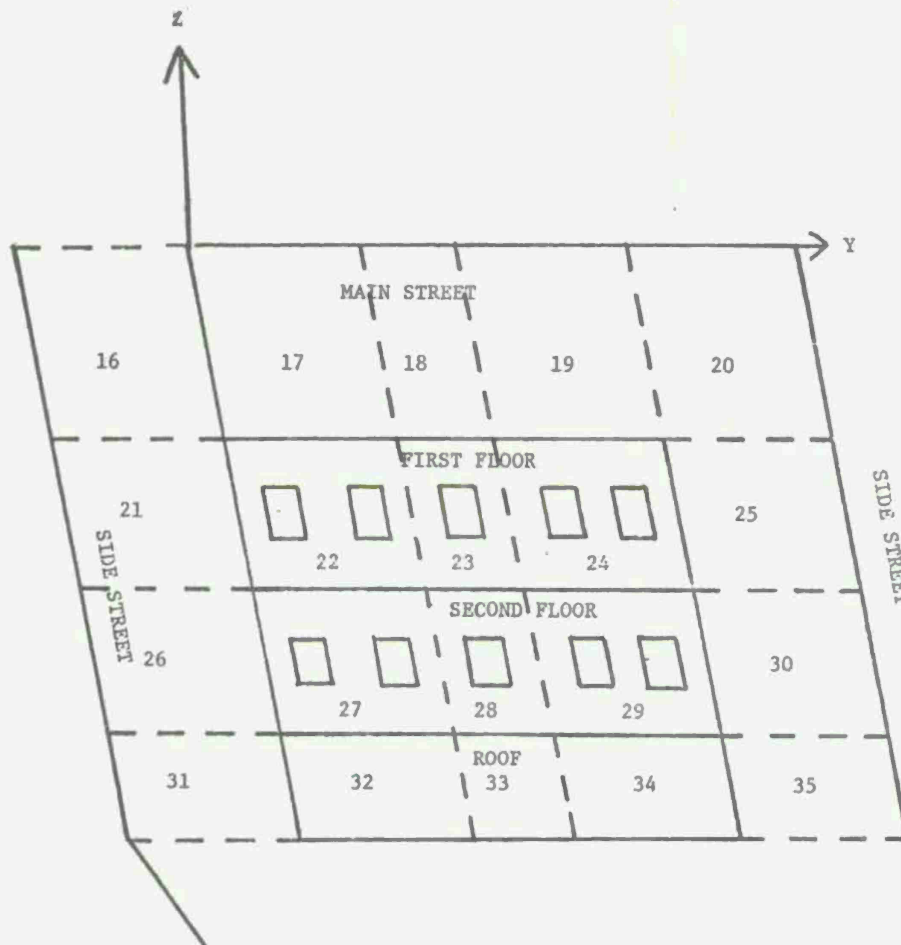


Figure 7 Offensive Sectors of Responsibility

The offensive elements positions and assigned sectors are given in Table 3.

TABLE 3 OFFENSIVE SECTORS OF RESPONSIBILITY

<u>ELEMENT FUNCTION</u>	<u>ELEMENT POSITION</u>	<u>SECTORS OF RESPONSIBILITY</u>
G	Roof	34, 29, 23, 24, 33
G	Opening 9	29, 34, 23, 20, 28
R	Opening 1	27, 22, 17, 16, 28
R	Opening 4	22, 23, 27, 17, 18
R	Opening 8	24, 23, 29, 19, 18
R	Roof	32, 27, 23, 22, 28
R	Assault	16, 21, 21, 21, 21
R	Assault	16, 21, 21, 21, 21
R	Assault	16, 21, 21, 21, 21
R	Assault	16, 21, 21, 21, 21
R	Assault	16, 21, 21, 21, 21

Figure 8, indicates the sectors of responsibility for the defense; these sectors include the offensive positions.

The defensive elements positions and assigned sectors are given in Table 4.

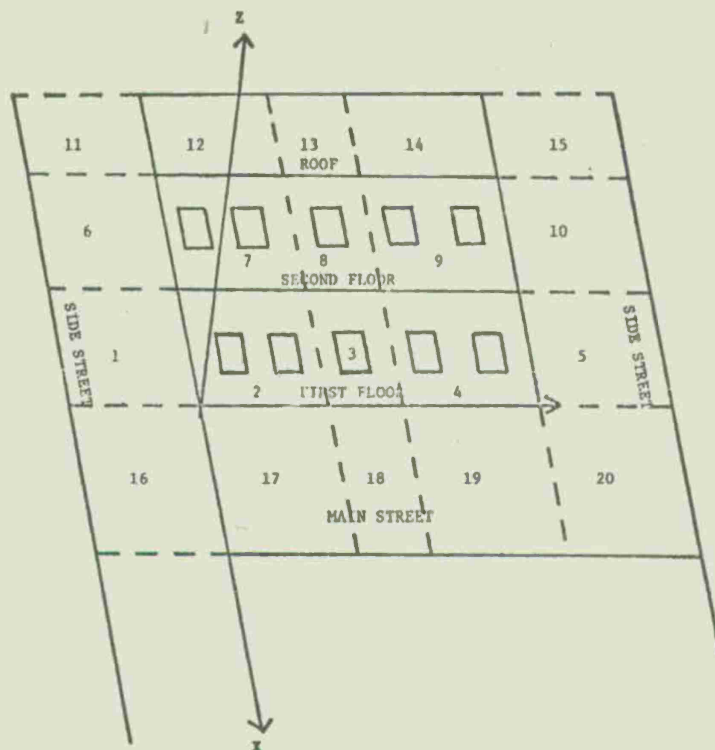


Figure 8 Defensive Sectors of Responsibility

TABLE 4 DEFENSIVE SECTORS OF RESPONSIBILITY

<u>ELEMENT FUNCTION</u>	<u>ELEMENT POSITION</u>	<u>SECTORS OF RESPONSIBILITY</u>
R	Opening 12	20, 4, 3, 9, 18
R	Opening 14	20, 19, 4, 9, 3
R	Opening 18	16, 17, 2, 7, 3
R	Opening 20	17, 16, 3, 2, 8
R	Opening 13	9, 8, 14, 4, 3
R	Opening 17	7, 8, 2, 3, 12
R	Roof Right	14, 13, 9, 4, 20
R	Roof Left	12, 13, 7, 2, 16
MG.	Opening 16	2, 13, 4, 18, 18

4.5 Conflict Initiation

The cover team initiates the conflict by opening fire, approximately four seconds later the rush team begins its assault, all at once.

5.0 ANALYSIS

5.1 Conflict Dynamics

Prior to detailing the analysis, which is based on casualties, a chronological narrative of one run, standard squad-40 meter, is presented in Table 5. This narrative in conjunction with the graphical representation, Figures 9-12, (cumulative detections vs time, remaining firers vs time, cumulative rounds fired vs time, cumulative casualties vs time) is an attempt to indicate the dynamics of urban conflict as it is simulated by URBWAR. It is cautioned that the narrative and initial graphs represent only one replication at this range, whereas, the analysis is based on ten replications at each range for each case. Additional single run dynamic curves are presented in Appendix D, for the standard squad at 7, 16, 25, and 34 meters. The SAWS armed squad and the M60 armed squad are shown at 40 meters.

5.1.1 Battle initiation and detection

Even though Figures 9-12 are for one computer run, they do indicate certain dynamics of the conflict. For instance Figures 9 (cumulative detection) and 10 (remaining firers) in conjunction, show the affects of battle intelligence. For this series of curves, offense knows defense exists and defense doesn't know offense exists. Given this intelligence offense initiates the battle by cycling through detection events prior to fire events. Since defense isn't ready, offense detects targets early in the battle, i.e., 64 percent of offensive detections occur within the first 2.9 seconds. Offense then fires, suppressing many of the defensive elements. Subsequently the suppressed elements reenter the conflict and defense has 85 percent of its detection after 6.4 seconds.

There are two plateaus in offensive detections at 2.7 seconds and at 7 seconds. Defense also has two plateaus at 1.8 seconds and 8.9 seconds.

The first offensive detection plateau coincides with a defensive remaining firer level shown in Figure 10. Offensive detections level out because the number of defensive firing elements has been reduced to one. The rest of the defensive firers are either dead or suppressed. The second offensive detection level occurs for a different reason. Figure 10 shows that the number of defensive firers has increased and the number of offensive firers has decreased. It is pointed out that this increase in

defensive firers indicates that offense had suppressed most of defense, rather than killed them. The first defensive plateau is obvious; there was only one available firing element. The second defensive plateau does not quite coincide with the decrease in offensive firers. This is because the defense has switched it's attention to the rush team.

Comparing Figures 10 and 12 (cumulative casualties) indicates that offense suppressed defense without incapacitating any of the elements.

5.1.2 Suppression dynamics

Figures 10 and 12 also furnish some information on suppression effects on the initiation of the rush. When the rush was initiated, offense had fire superiority, four to one. But this was false fire superiority because offense hadn't incapacitated any of defense and the defensive elements reentered the conflict when the rush elements were in the open. This false fire superiority could have tactical implications. In a real battle the decision to rush has to be based on available information. The only information available to the offense is the number of firing defensive elements vs the number of firing offensive elements. But, as the graphs show, this could be a temporary advantage due solely to suppression and not to any permanent decrease in defensive capability. At short ranges of approximately 16 meters and less, it is possible that this initial suppression would be sufficient for the assault team to cross the open areas; but, as the range increases, the rush probably should be held in abeyance until the battle has reached a steady state.

5.2 Analysis of Weapons Impact on Squad Effectiveness

The above discussion of conflict dynamics and tactics is actually a spin-off of the model. The model was developed to evaluate weapons and weapon parameters and the following paragraphs answer the eight weapon oriented questions delineated in the introduction. For this analysis thirteen cases were investigated at each of five ranges (7, 16, 25, 34, and 40 meters) for a total of sixty-five combinations. For each combination ten computer runs were analyzed and the expected number of offensive and defensive casualties was determined. Figures 13-25 are plots of casualties vs range for all of the cases.

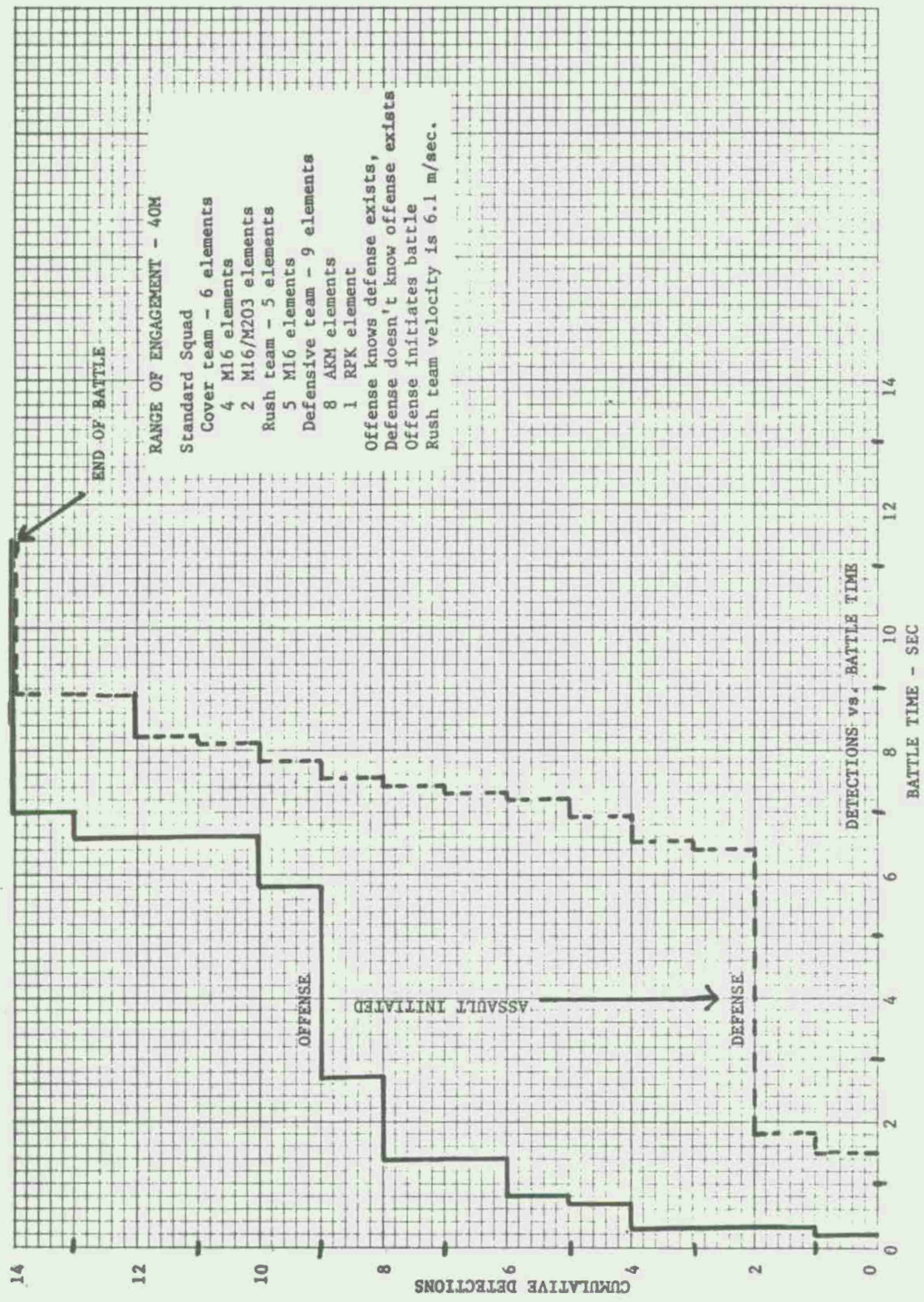


Figure 9 Cumulative Detections vs Battle Time

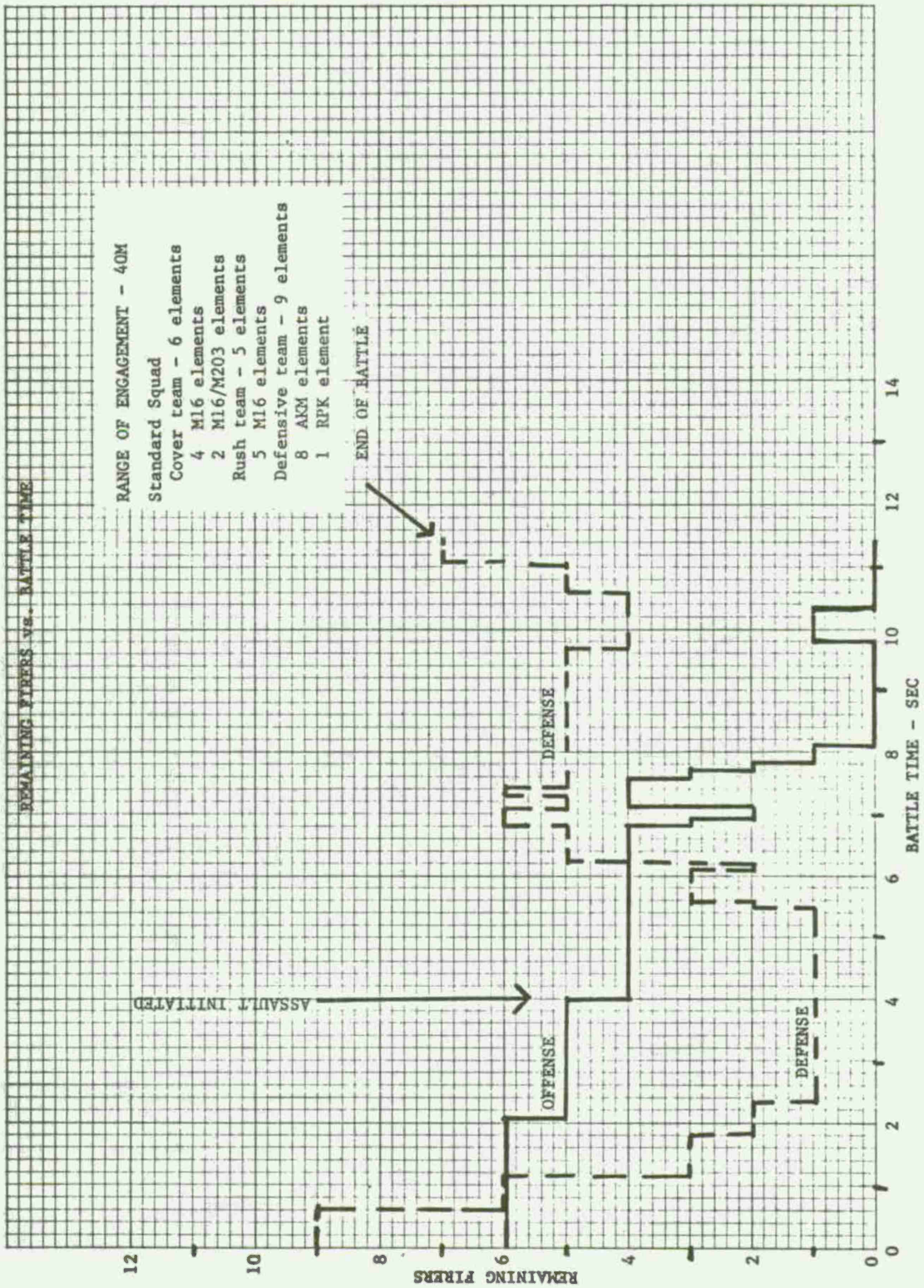


Figure 10 Remaining Firers vs Battle Time

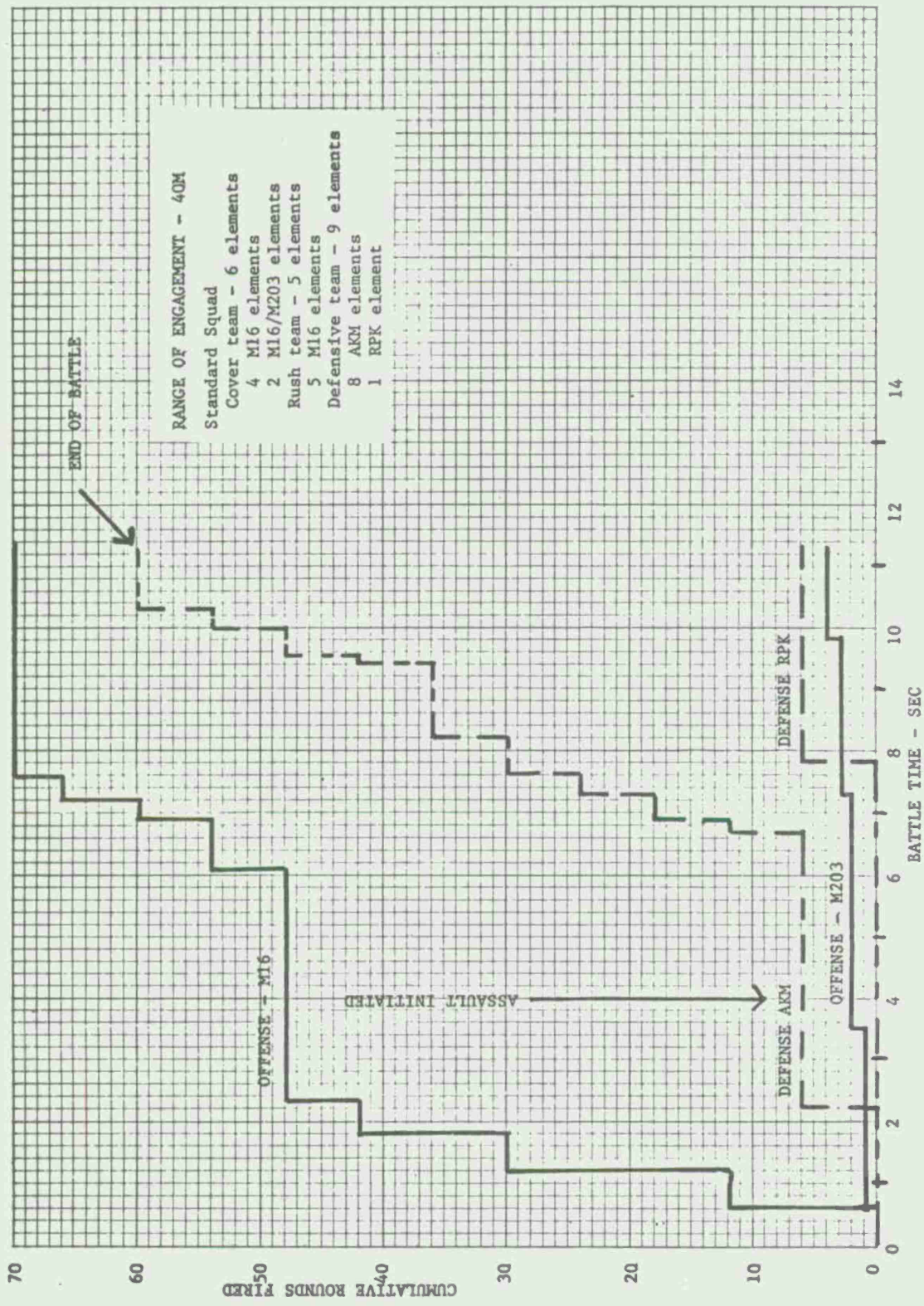


Figure 11 Cumulative Rounds Fired vs Battle Time

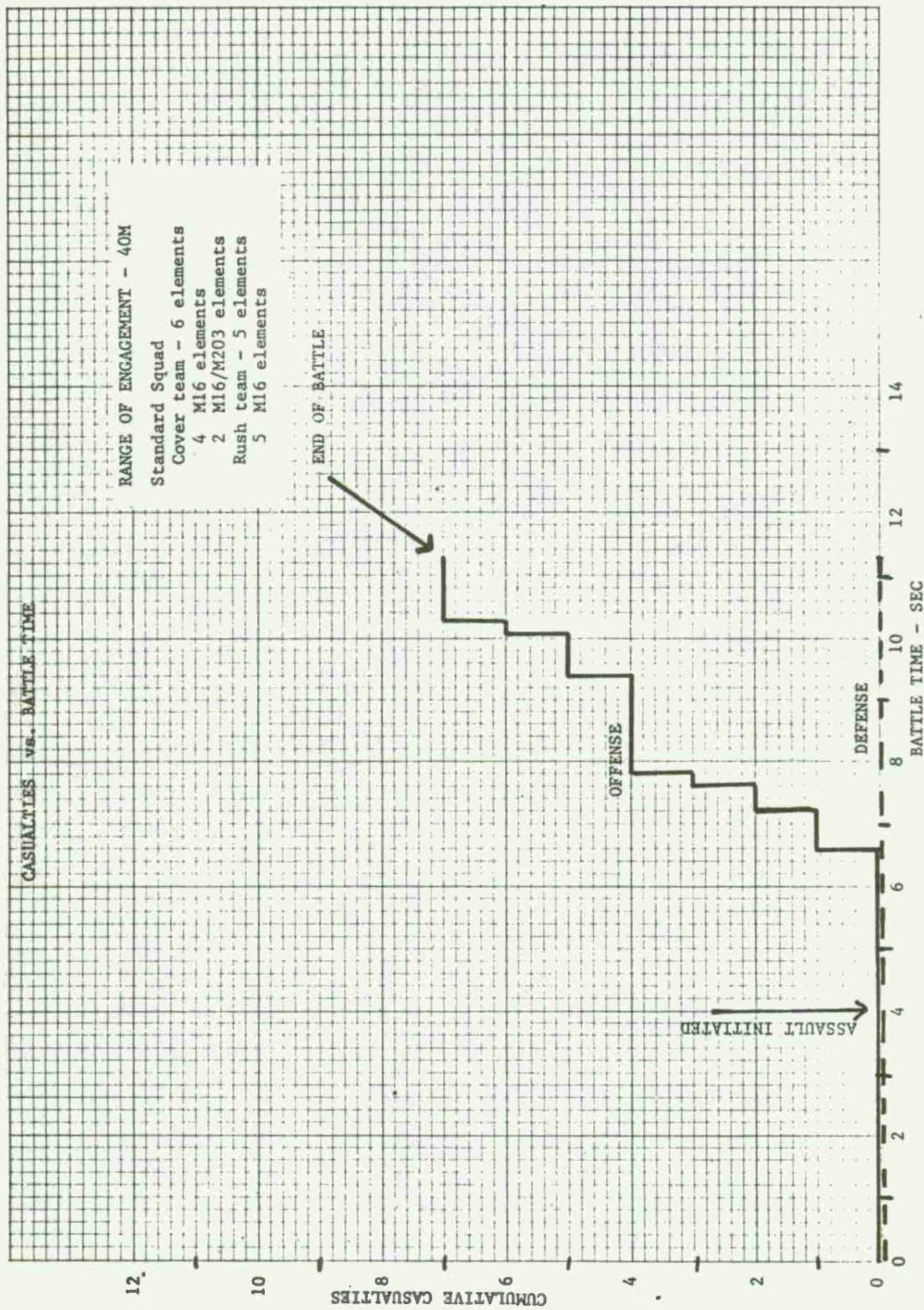


Figure 12 Cumulative Casualties vs Battle Time

TABLE 5 CHRONOLOGICAL NARRATIVE

Scenario

Range 40 meters
 Offensive Squad : 11 men, numbered 1-11
 6 man cover team, number 1-6
 Number 1-4 armed with M16s
 Number 5, 6 armed with M16s/M203s
 5 man assault team number 7-11
 Number 7-11 armed with M16s
 Defensive squad : 9 men, numbers 12-20
 Numbers 12-19 armed with AKMs
 Number 20 armed with RPK
 Offense initiates Battle

Sample listing

Battle Time Sec.	Event
.26	Detection - 1 detected 17
.30	Detection - 3 detected 13
.32	Detection - 5 detected 16
.59	Fire - 1 fired 6 rounds at 17, missed, 17 suppressed for 5 seconds. Number of remaining firers 6 on cover, 8 on defense.
.64	Fire - 3 fired 6 rounds at 13, missed, 13 suppressed for 5 seconds. Number of remaining firers 6 on cover, 7 on defense.

TABLE 5 CHRONOLOGICAL NARRATIVE (CONT'D)

Battle Time Sec.	Event
.66	Fire - 5 chose M203 over M16 and fired grenade round at 16, missed, 16 suppressed for 10 seconds. Number of remaining firers 6 on cover, 6 on defense.
.78	Detection - 2 detected 14
.84	Detection - 4 detected 19
1.11	Fire - 2 fired 6 rounds at 14, missed, 14 suppressed for 5 seconds. Number of remaining firers on cover 6, 5 on defense.
1.18	Fire - 4 fired 6 rounds at 19, missed, 19 suppressed for 5 seconds. Number of remaining firer on offense 6, 4 on defense.
1.18	Fire - 6 chose M16 over M203 and fired 6 round burst at 18, missed, 18 suppressed for 5 seconds. Remaining firers on offense 6, on defense 3.
1.43	Detection - 1 detected 15
1.47	Detection - 3 detected 20
1.49	Detection - 20 detected 2
1.76	Fire - 1 fired 6 round burst at 15, missed, 15 wasn't suppressed. Firers on offense 6, on defense 3.
1.80	Fire - 3 fired 6 round burst at 20, missed, 20 suppressed for 5 seconds. Firers on offense 6, on defense 2.
1.83	Detection - 12 detected 3
2.16	Fire - 12 fired 6 round burst at 3, missed, 3 suppressed for 5 seconds. Fireres on offense 5, on defense 2.
2.26	Fire - 1 fired 6 round burst at 15, missed, 15 suppressed for 5 seconds. Firers on offense 5, on defense 1.

TABLE 5 CHRONOLOGICAL NARRATIVE (CONT'D)

Battle Time Sec.	Event
2.68	Detection - 6 detected 12
3.50	Fire - 6 chose M204 over M16 fired grenade round at 12, missed, 12 not suppressed.
4.00	Movement - Rush team numbered 7-11 initiate assault, cover team has 5 firers, 1 suppressed, 0 dead. Defense has 1 firer, 8 suppressed, 0 dead.
4.01	Reload - 6 is reloading grenade launcher, 6 is suppressed while reloading. Firers on offense 4, firers on defense 1.
5.59	Movement - 17 is unsuppressed, firers on offense 4 firers on defense 2.
5.64	Movement - 13 is unsuppressed, firers on offense 4 firers on defense 3.
5.76	Detection - 1 detected 17
6.09	Fire - 1 fired 6 round burst at 17, missed, 17 suppressed for 5 seconds. Firer on offense 4, on defense 2.
6.11	Movement - 14 is unsuppressed, firers on offense 4, on defense 3.
6.18	Movement - 19 is unsuppressed, firers on offense 4, on defense 4.
6.18	Movement - 18 is unsuppressed, firers on offense 4, on defense 5.
6.44	Detection - 14 detected 8
6.51	Detection - 19 detected 4
6.60	Detection - 2 detected 14
6.67	Detection - 4 detected 19
6.77	Fire - 14 fired 6 round burst at 8, missed, 8 unsuppressed, continue assault.
6.80	Movement - 20 is unsuppressed, firers on offense 4, on defense 6.
6.82	Detection - 5 detected 20

TABLE 5 CHRONOLOGICAL NARRATIVE (CONT'D)

Battle Time Sec.	Event
6.84	Fire - 19 fired 6 round burst at 4, killed, firers on offense 3, on defense 6.
6.92	Detection - 1 detected 14
6.94	Fire - 2 fired 6 round burst at 14, missed, firers on offense 3, on defense 6.
6.97	Detection - 13 detected 5
7.15	Reload - 5 is reloading grenade launcher 5 is suppressed while reloading, firers on offense 2, on defense 6.
7.16	Movement - 3 is unsuppressed, firers on offense 3, on defense 6.
7.17	Movement - 6 is unsuppressed, reloaded, firers on offense 4, on defense 6.
7.17	Fire - 6 chose grenade over M16, fired grenade at 12, missed, 12 suppressed for 10 seconds. Firers on offense 4, on defense 5.
7.26	Movement - 15 is unsuppressed, firers on offense 4, on defense 6.
7.26	Detection - 15 detected 2
7.26	Fire - 1 fired 6 round burst at 14, missed. Firers on offense 4, on defense 6.
7.27	Fire - 14 fired 6 round burst at 7, killed, 7 was on assault team, firers on offense 4, on defense 6.
7.34	Detection - 19 detected 2
7.44	Fire - 2 fired 6 round burst at 14, missed, 14 suppressed for 5 seconds. Firers on offense 4, on defense 5.
7.47	Detection - 20 detected 3
7.51	Detection - 18 detected 3
7.59	Fire - 15 fired 6 round burst at 2, killed, firers on offense 3, on defense 5.

TABLE 5 CHRONOLOGICAL NARRATIVE (CONT'D)

Battle Time Sec.	Event
7.76	Reload - 1 is reloading M16, 1 is suppressed during reload, firers on offense 2, on defense 5.
7.80	Detection - 13 Detected 6
7.80	Fire - 20 fired 6 round burst at 3, killed, firers on offense 1, on defense 5.
8.14	Fire - 13 fired 6 round burst at 6, missed, 6 suppressed for 5 seconds. Firers on offense 0, on defense 5.
9.09	Detection - 15 detected 8
9.18	Detection - 19 detected 11
9.43	Fire - 15 fired 6 round burst at 8, killed, 8 was on assault team.
9.51	Fire - 19 fired 6 round burst at 11, missed, 11 continues assault.
9.78	Movement - 5 is unsuppressed from reloading. Firers on offense 1, on defense 5.
9.78	Fire - 5 chooses grenade launcher over M16, fires grenade at 20, miss, 20 is suppressed for 10 seconds, firers on offense 1, on defense 4.
9.92	Detection - 15 detected 5
9.97	Detection - 13 detected 5
10.01	Fire - 19 fired 6 round burst at 9, killed, 9 was on assault team.
10.30	Fire - 13 fired 6 round burst at 5, killed, firers on offense 0, on defense 5.
10.66	Movement - 16 is unsuppressed. Firers on offense 0, on defense 5.
11.06	Movement - 15 is unsuppressed. Firers on offense 0, on defense 6.
11.09	Movement - 17 is unsuppressed. Firers on offense 0, on defense 7.
11.30	Movement - 11 on assault has crossed street and is outside of defensive structure.

TABLE 5 CHRONOLOGICAL NARRATIVE (CONT'D)

Battle Time Sec.	Event
11.38	Movement - 10 on assault has crossed street and is outside of defensive structure.

Situation at time 11.38 seconds

Killed Cover Team	Suppressed Cover Team	Killed Assault	Killed Defense	Suppressed Defense	M16 Rounds Fired	M203 Rounds Fired	AKM Rounds Fired	RPK Rounds Fired
4	2	3	0	2	72	4	60	6

5.2.1 What differences occur, in squad casualty producing effectiveness, when M14s are replaced with M16s?

5.2.1.1 Offense employs semi-automatic fire

Figure 13 is a plot of range vs casualties when the offensive squad is armed with M16s and two multipurpose weapons, the point fire weapon has M16 characteristics and the area fire weapon has M79 characteristics. The M16s for this case are limited to semi-automatic fire.

Figure 14 illustrates the same information as Figure 13, but the weapons are M14s and the multipurpose weapon has M14 point fire characteristics and M79 area fire characteristics.

The defense for all cases fires automatically, six round bursts.

A comparison of Figures 13 and 14 indicates that there is very little difference, between the squads, as far as casualties produced and casualties received.

At the 7 meter range the defensive casualties are produced solely by the point fire weapons, the area fire weapons being restricted from firing because of arming distance.

From 16 meters to 40 meters the area fire weapons enter the conflict. They typically fire between two and four rounds, usually suppressing the targets instead of incapacitating them. This is primarily due to the fact that the rooms in the building are quite large and the grenades are entering the windows and impacting towards the back of the room. The targets being located at the windows are outside the lethal radius of the grenade so they are suppressed instead of incapacitated.

5.2.1.2 Offense employs automatic fire

When the offensive weapons fire automatically the M16 is a better weapon than the M14 (Figs. 15 & 16). The squad armed with the M16s produce more defensive casualties at all ranges and generally suffers less casualties on the cover team at ranges greater than 16 meters. The casualties on the rush team are fairly close for either weapon. At ranges of 16 meters or less there is little difference between the total and cover team casualties with the M14 having a slight advantage.

5.2.2 What is the most effective firing mode for the squad armed with M16s and without multipurpose weapons?

Figures 17 and 18 (casualties vs range for semi-automatic and automatic fire) indicate that generally the squad firing automatically has a decided advantage in casualties produced and casualties received. For this same comparison, but with multipurpose weapons, Figures 13 (semi-automatic fire) and 15 (automatic fire) indicate a comparability up to ranges of 25 meters. Whereas, Figures 17 and 18 indicate a clear advantage at all ranges greater than 7 meters for automatic fire. The only factor between these four curves that is different, is that, Figures 13 and 15 are for squads that have two multipurpose weapons. It would seem that the grenade launchers, because of their suppression capability tend to smooth out the difference between automatic and semi-automatic fire. Possibly grenade fire is a greater asset when semi-automatic fire is employed by the point fire weapons.

5.2.3 Is it an advantage to initiate the conflict?

Figures 15 (offense initiated conflict) and 19 (defense initiated conflict) show that conflict initiation is a decided advantage. For the defense to initiate the action (Fig 19) reduces its casualties at all ranges. Firing first also increases the number of casualties inflicted by the defense against the rush team. This advantage does not occur until the range is greater than 16 meters. The casualties inflicted on the cover team are greater at all ranges when defense fires first as opposed to offense firing first.

5.2.4 Does the addition of grenade launchers increase the effectiveness of the squad?

Figures 18 (all elements armed with M16s) and 20 (two elements armed with M79s) show that the removal of two M16s from the squad and replacing them with M79s results in advantages and disadvantages.

At ranges of 16 meters and less it is a disadvantage resulting in less defensive casualties while maintaining the offensive casualties.

The reason for this is related to the grenade arming distance. At ranges less than 16 meters the grenades on impact are not armed. Because of this the removal of two M16s reduces the cover team's fire power by 33 percent, from six firing element to four. This results in less defensive casualties.

Between 16 and 35 meters the M16 armed squad increases its casualty production but the squad with two M79s decreases. This is due to the suppression capability of the grenade launchers. Because of the large rooms, the grenade launchers suppress most of their targets, thereby eliminating them for ten seconds, from the conflict and as M16 targets.

At 40 meters, the defensive casualties are identical for either squad. The squad armed with grenade launchers has less cover team casualties (than the squad with M16s) and both squads have the same rush team casualties.

5.2.5 Does the introduction of multipurpose weapons increase the effectiveness of the squad?

As seen above, this results in mixed advantages and disadvantages (Figs. 15 - M16s and multipurpose weapons - & 20 - M16s and grenade launchers -).

Between 7 and 16 meters the defensive casualties are the same for either squad, but the offensive casualties for the multipurpose squad have increased as compared to the M79 squad. The reason for this increase in offensive casualties appears to be related to detection and location. Since the elements that have M79s (Fig 20) are restricted from firing at these ranges there is only one means of their being detected, by the standard detection algorithm. But when these elements have multipurpose weapons (Fig 15), they are firing M16s at close ranges. Because they are firing there is an additional probability that they will be detected, i.e., through the standard detection algorithm and the firing detection algorithm. Also, the grenadiers are located on the roof and second floor, and these positions though included in the defensive sectors are of low priority. The street and first floors have a higher priority. When the grenadiers are not firing i.e., have single purpose weapons, this location affects their chances of being detected through the standard algorithm and fired at.

This increase in offensive casualties offsets the casualty producing effectiveness of the multipurpose weapons, resulting in identical defensive casualties for either squad at ranges less than 16 meters.

Between 16 and 34 meters the multipurpose weapons definitely increase the squads casualty producing capability while maintaining the offensive

casualties at the same level as the squad without multipurpose weapons.

At 40 meters the defensive casualties are the same for the multipurpose weapon squad and the M79 squad. The squad with multipurpose weapons has less casualties on the cover team and thereby less overall casualties. Thus it appears, that the multipurpose weapons are an improvement over the single purpose M79.

Another interesting comparison is between the multipurpose weapon squad the all M16 squad, and the M79 squad (Figs. 15, 18 and 20).

The multipurpose weapons have closed the gap between the defensive casualties for the M16 squad and the M79 squad, with the M16 squad still having a slight advantage. At 40 meters the casualties are identical.

The offensive casualties on the other hand show a slight advantage for the M16 squad at ranges less than 16 meters, about equal between 16 and 34 meters, and the multipurpose squad has the advantages at 40 meters.

5.2.6 Is there any difference in effectiveness if the area fire portion of the multipurpose weapon has M203 characteristics instead of M79?

Figures 13 and 21 are for the M16/M79 and M16/M203 respectively, in semi-automatic fire.

For this case it appears that the M16/M203 has better characteristics as reflected in slightly higher defensive casualties and lower cover team and rush team casualties.

Figures 15 and 22 are for the same systems but in automatic fire. Figures 16 and 23 are for the M14/M79 and M14/M203. For this case, the results are mixed but the differences are minor. Overall, considering semi-automatic and automatic fire, the M16/M203 or M14/M203 is probably the better system.

5.2.7 Does the addition of SAWS to the squad increase the squad's effectiveness?

For this analysis two M16s were removed from the elements on the first floor and replaced with Squad Automatic Weapons (SAWS).

This substitution gave the 6 man cover team two M16/M203 multipurpose weapons, two M16s and two SAWS. The 5 man rush team had M16s.

Figures 22 and 24 are for the standard squad and the SAWS squad respectively.

A comparison of these two figures shows that the addition of SAWS to the squad improves the squads casualty producing capability at all ranges between 7 and 40 meters.

The overall offensive casualties are mixed with the cover team casualties for the SAWS squad being less than or equal to the standard squad at all ranges. One peculiarity is that the rush team casualties are higher for the SAWS squad than for the standard squad, with the exception of 40 meters.

An analysis of the detailed output for the 40 meter case indicated that the elements armed with SAWS fired at the same targets as when they were armed with M16s. The difference in squad effectiveness being that the elements when armed with SAWS incapacitated the targets and when armed with M16s they suppressed them. A review of the basic input data for the SAWS (received from the Small Arm Weapons Systems Directorate of Rodman Laboratory) and the M16 data from Ref. 6, indicated that the SAWS system is considerably more accurate than the M16. This of course leads to a higher probability of hit and kills instead of suppressions.

5.2.8 Does the addition of an M60 to the squad increase the squad's effectiveness?

For this case an M60 machine gun was added to the squad, increasing the squad to thirteen elements, eight on the cover team and five in the rush team. The eight man cover team was armed with two M16/M203s, five M16s and one M60. It was assumed that the assistant machine gunner was armed with an M16. Figures 22 and 25 are for the standard squad and the M60 squad respectively.

The M60 squad is more effective at producing defensive casualties at ranges between 7 and 40 meters. The offensive casualties are mixed being higher at 7 meters for the M60 squad, lower at 16 meters, equal at 25 meters, and higher at 35 and 40 meters. Again, as in the SAWS case the rush team casualties are slightly higher for the M60 armed squad than for the standard squad.

A comparison between the SAWS squad and the M60 squad, Figures 24 and 25 show that the M60 squad produces slightly more casualties than the SAWS squad with the exception of 40 meters. The rush team casualties are slightly higher for the SAWS squad than the M60 squad with the

exception of 40 meters. At all ranges, the cover team has less casualties with a SAWS squad than with an M60 squad. Of course the M60 squad has 2 more elements. Overall, the offensive casualties for the SAWS squad are lower at 7 meters, higher at 16 meters, lower at 25 meters, approximately equal at 34 meters, and considerable lower at 40 meters.

The data presented in Figures 24 and 25 seems to indicate that the SAWS squad and the M60 squad are equal in effectiveness.

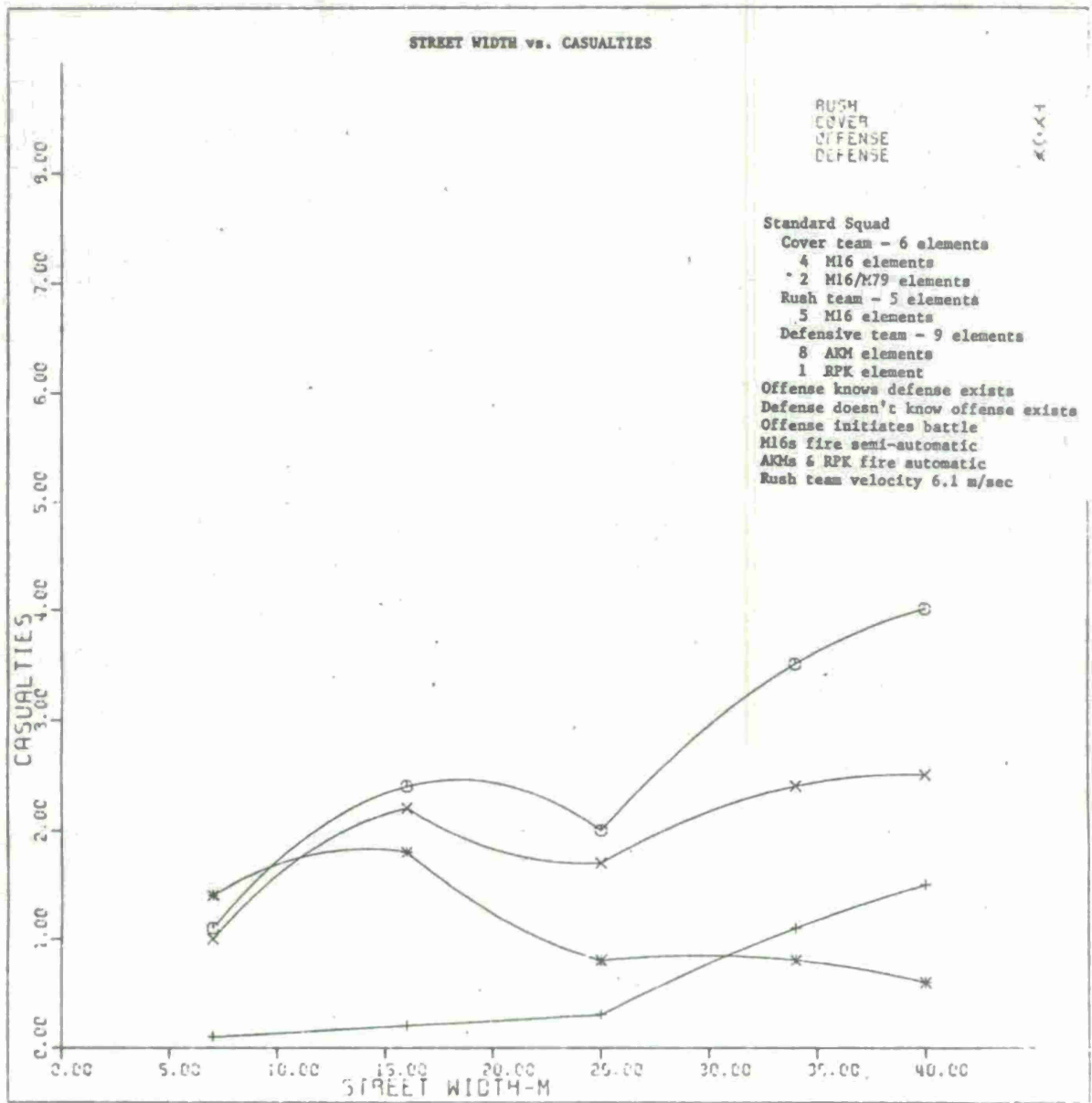
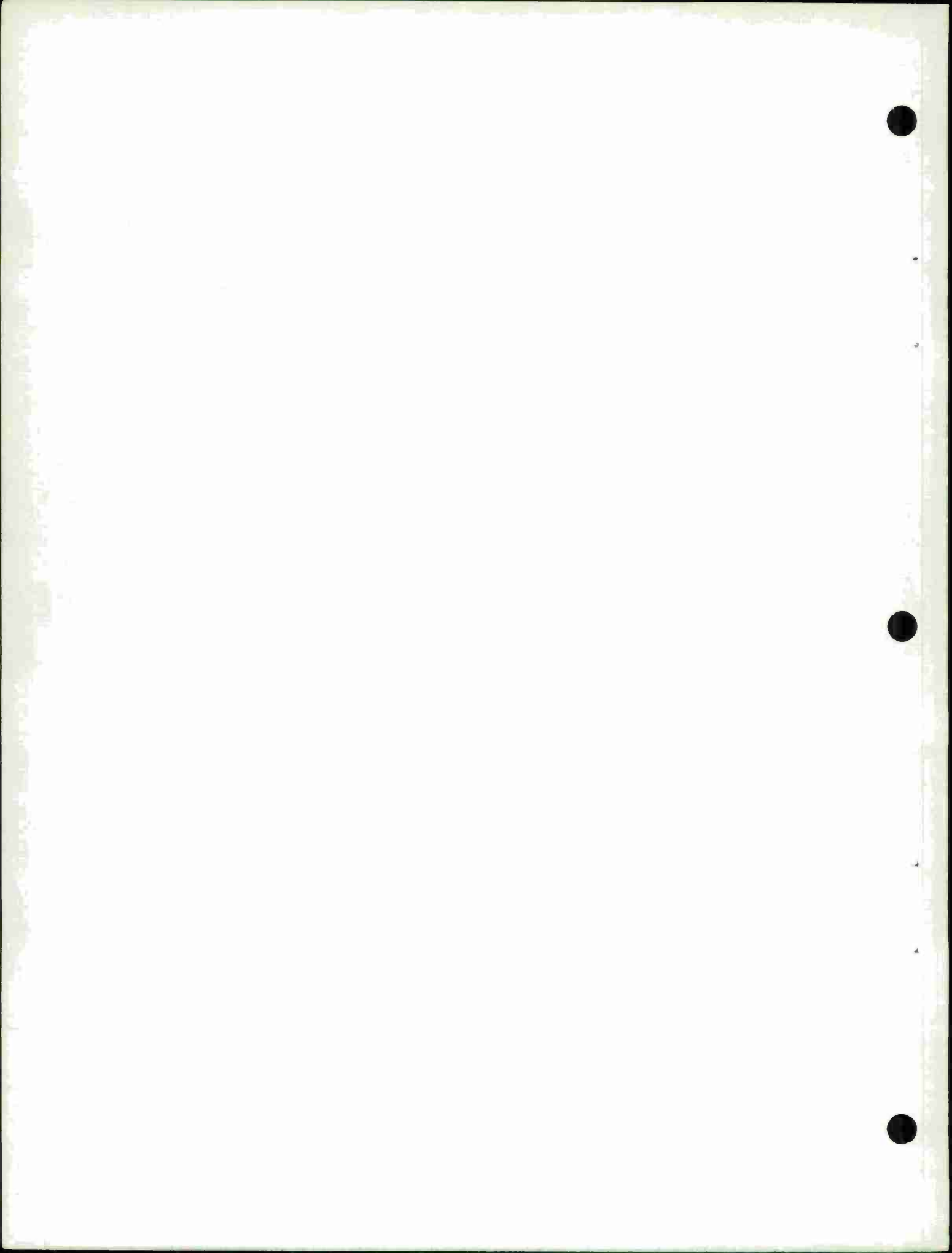


Figure 13 Standard Squad M16 Semi-Automatic Fire



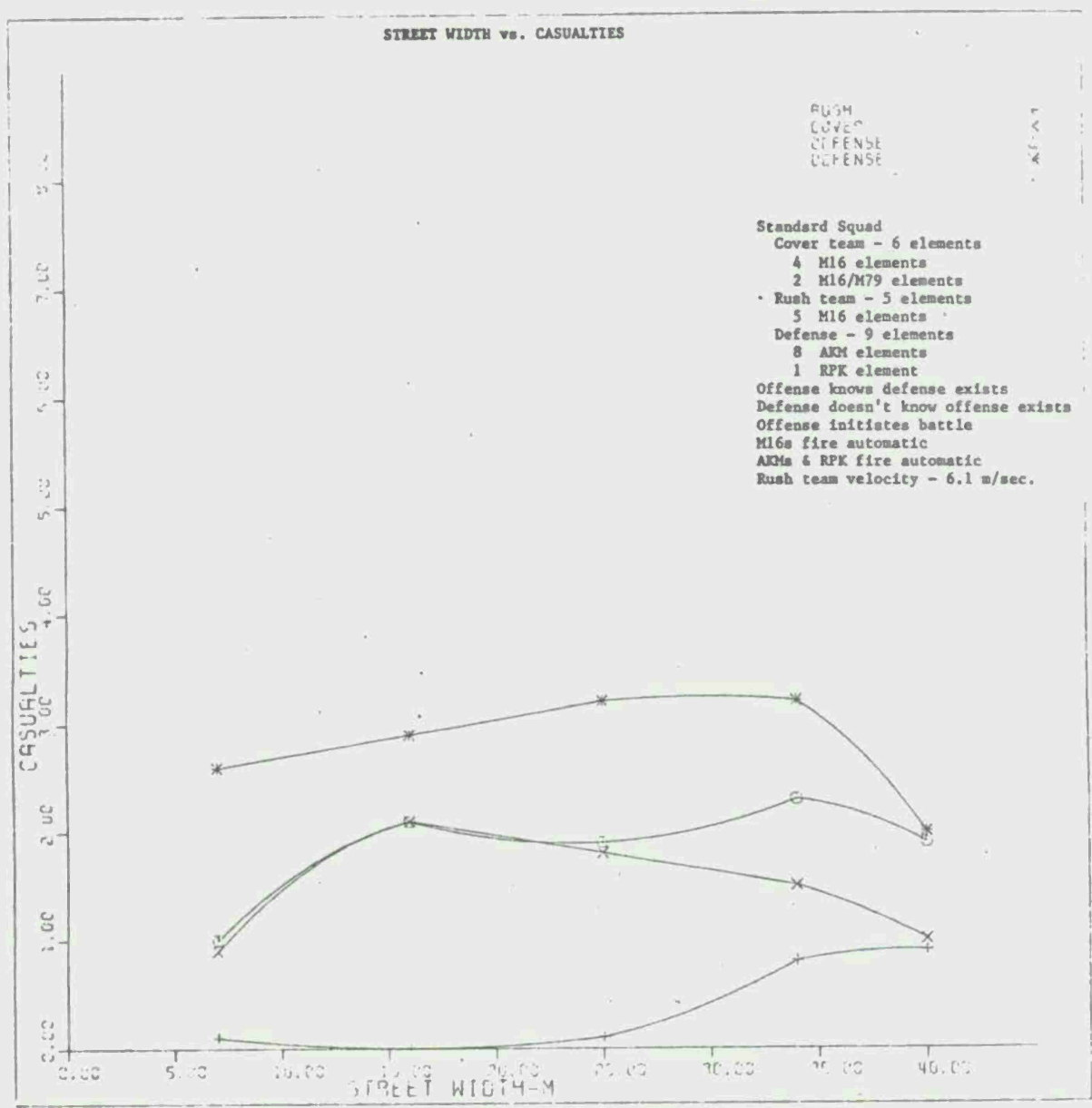


Figure 15 Standard Squad M16 Automatic Fire

STREET WIDTH vs. CASUALTIES

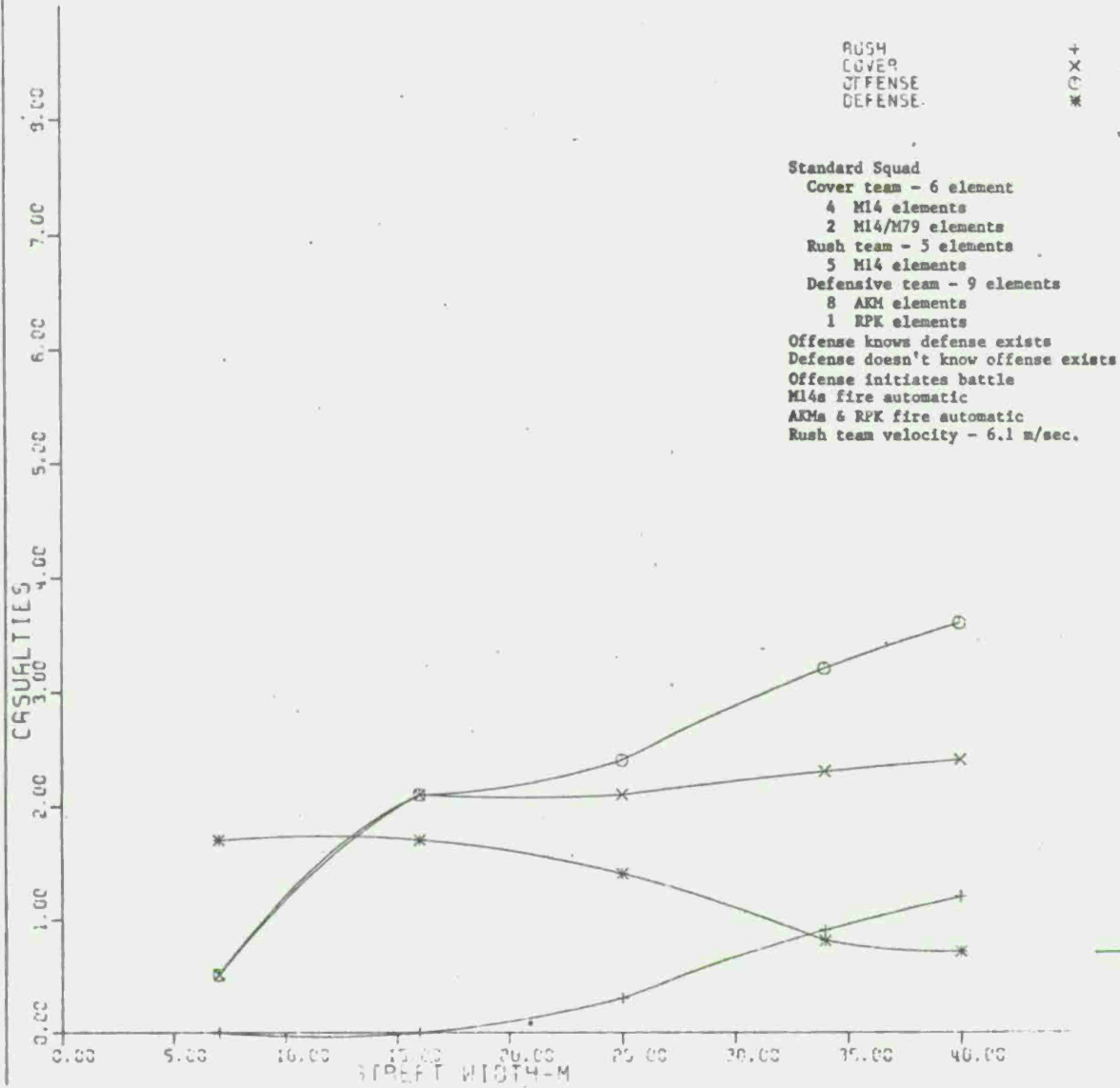


Figure 16 Standard Squad M14 Automatic Fire

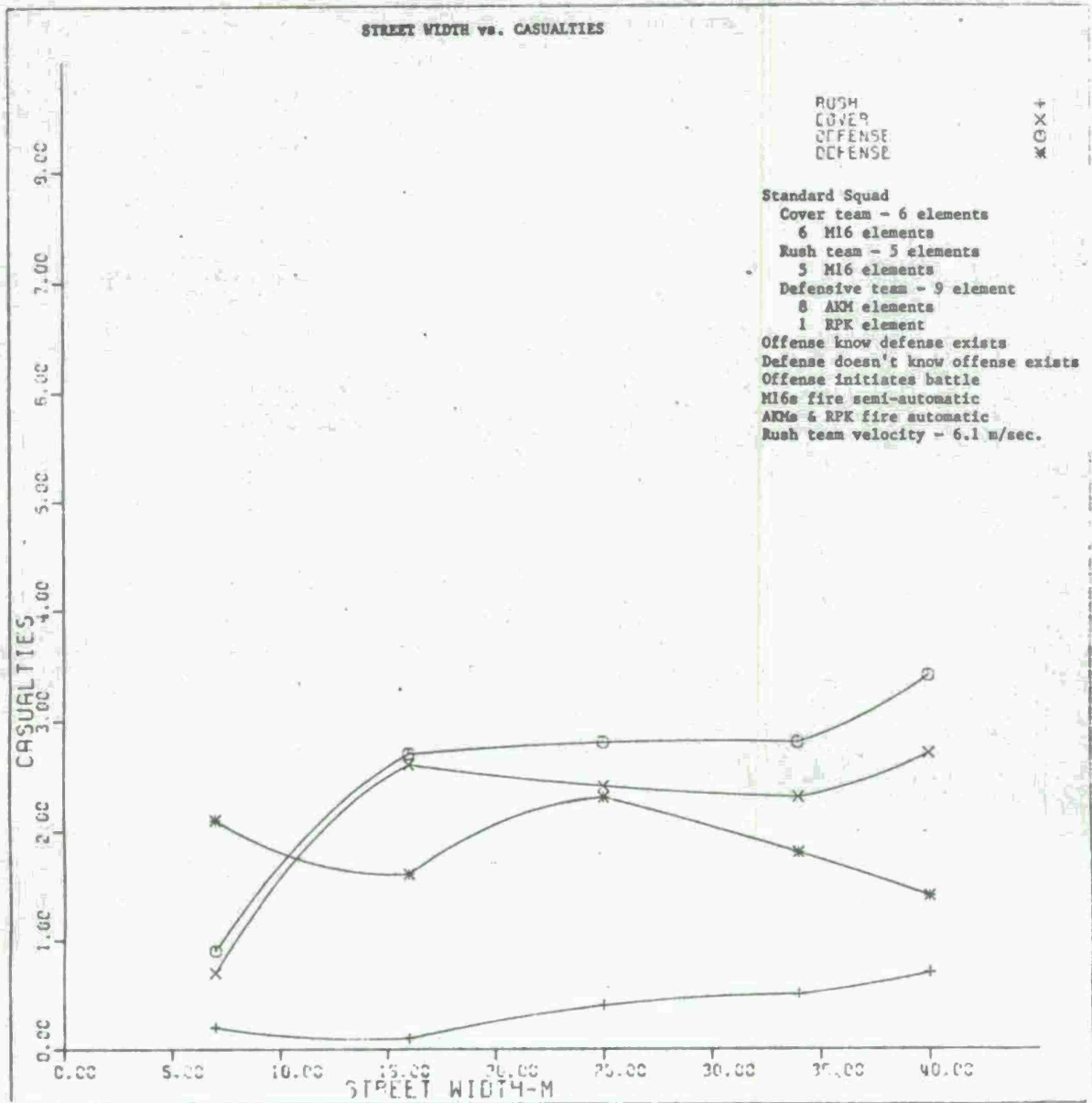


Figure 17 M16 Squad Semi-Automatic Fire

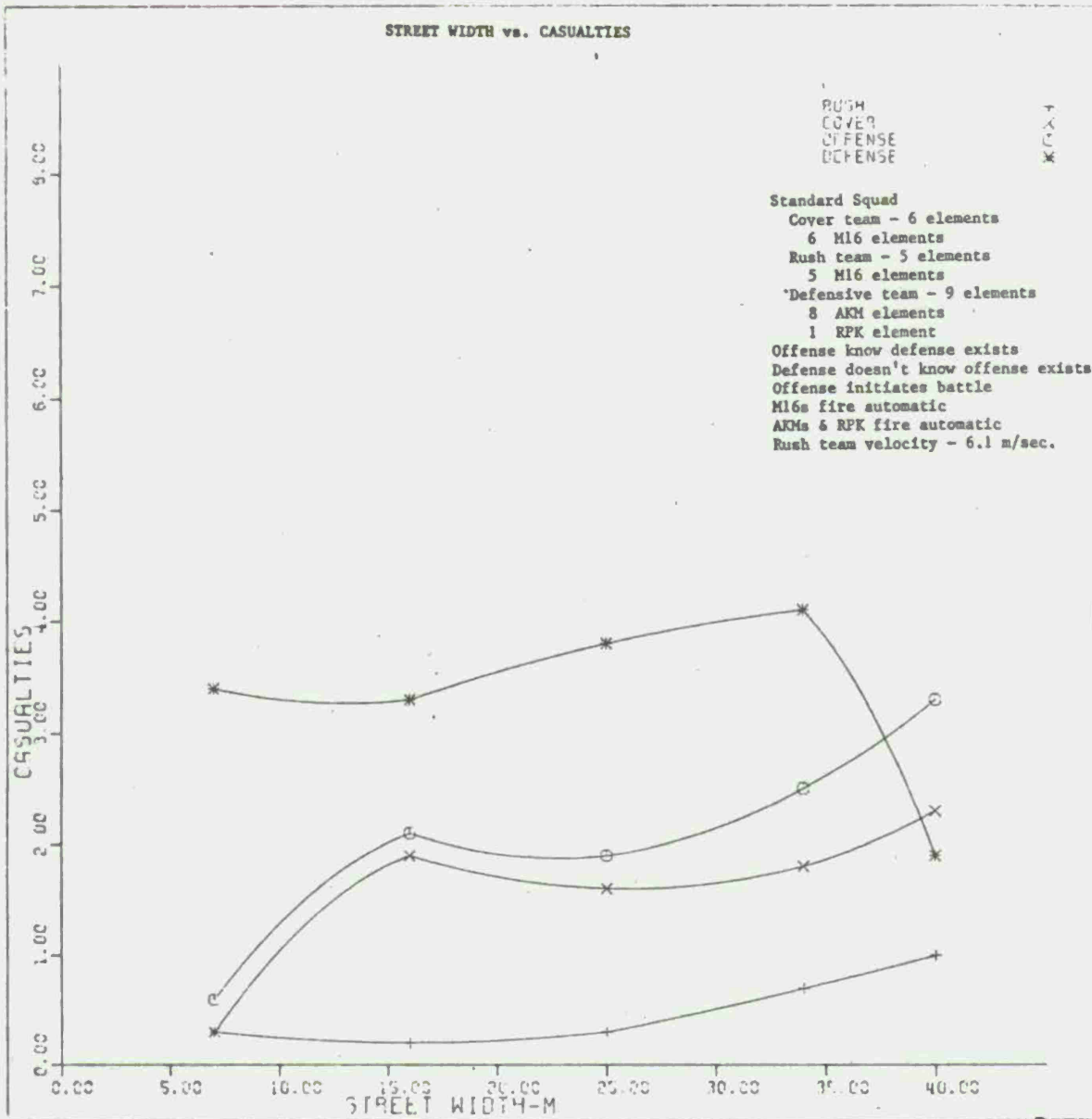


Figure 18 M16 Squad Automatic Fire

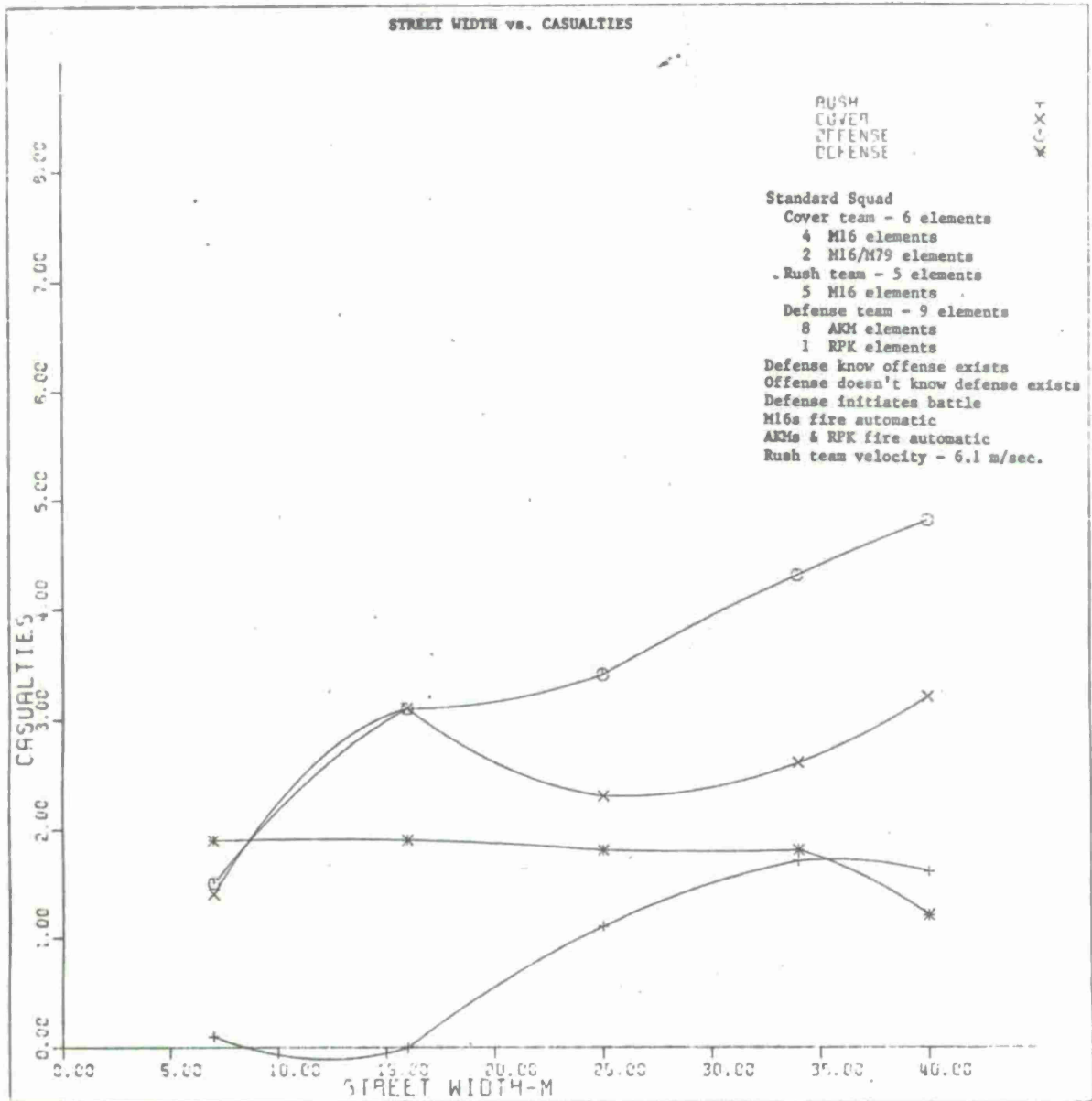


Figure 19 Standard Squad Defense Initiates Battle

STREET WIDTH vs. CASUALTIES

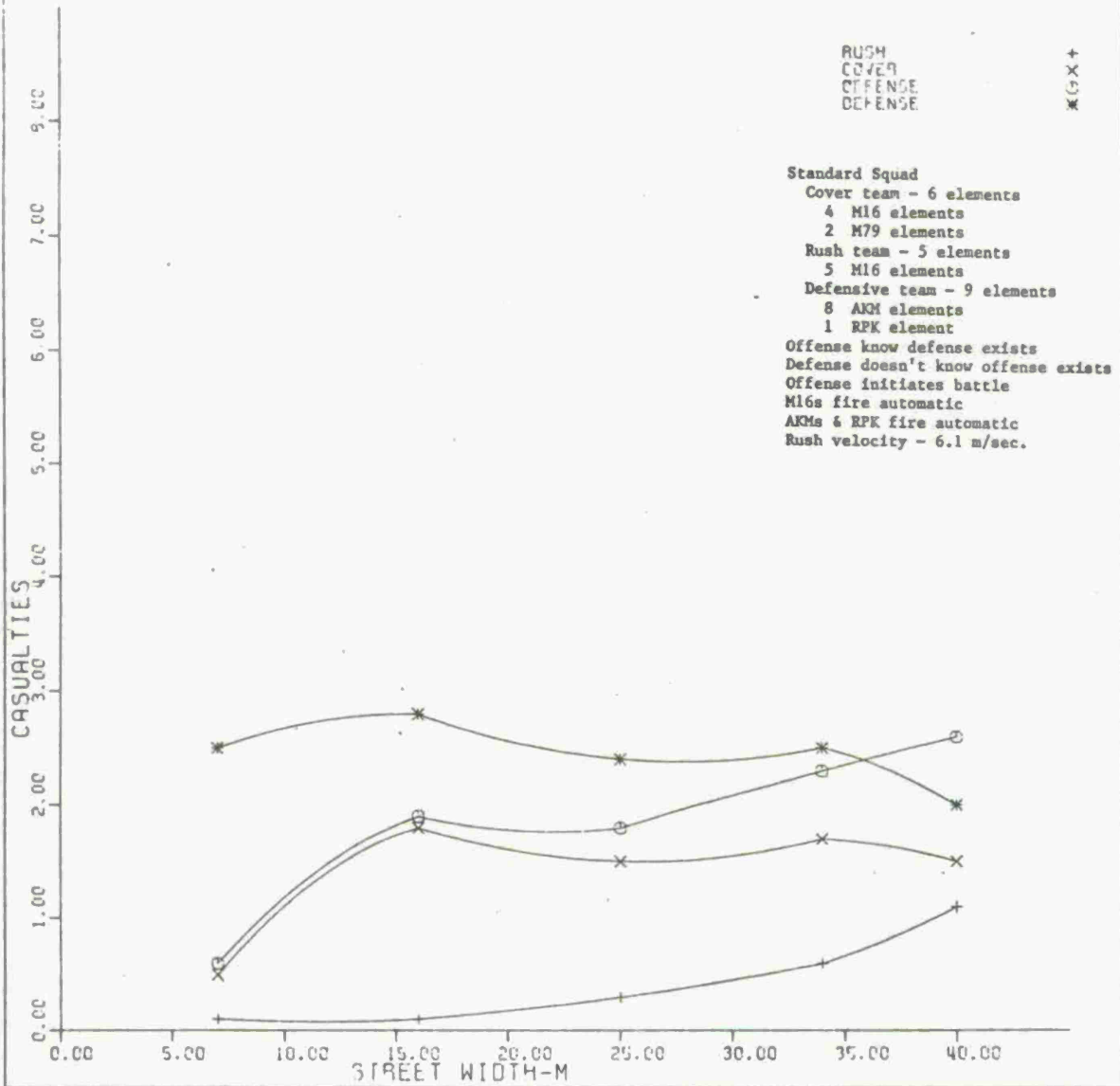


Figure 20 Rifle and Grenade Launcher Squad

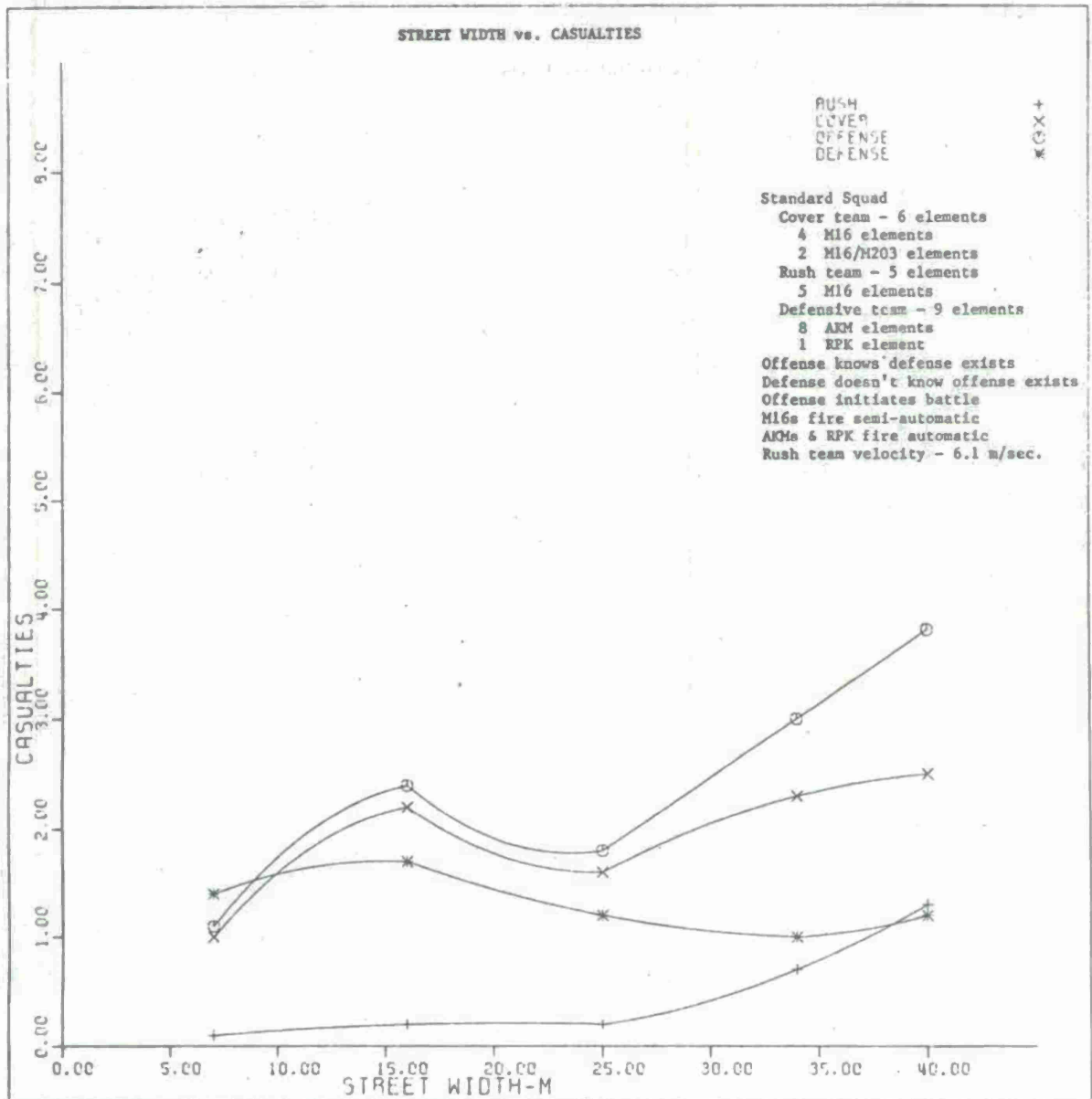


Figure 21 Rifle and Multipurpose Weapons Squad, Semi-Automatic Fire

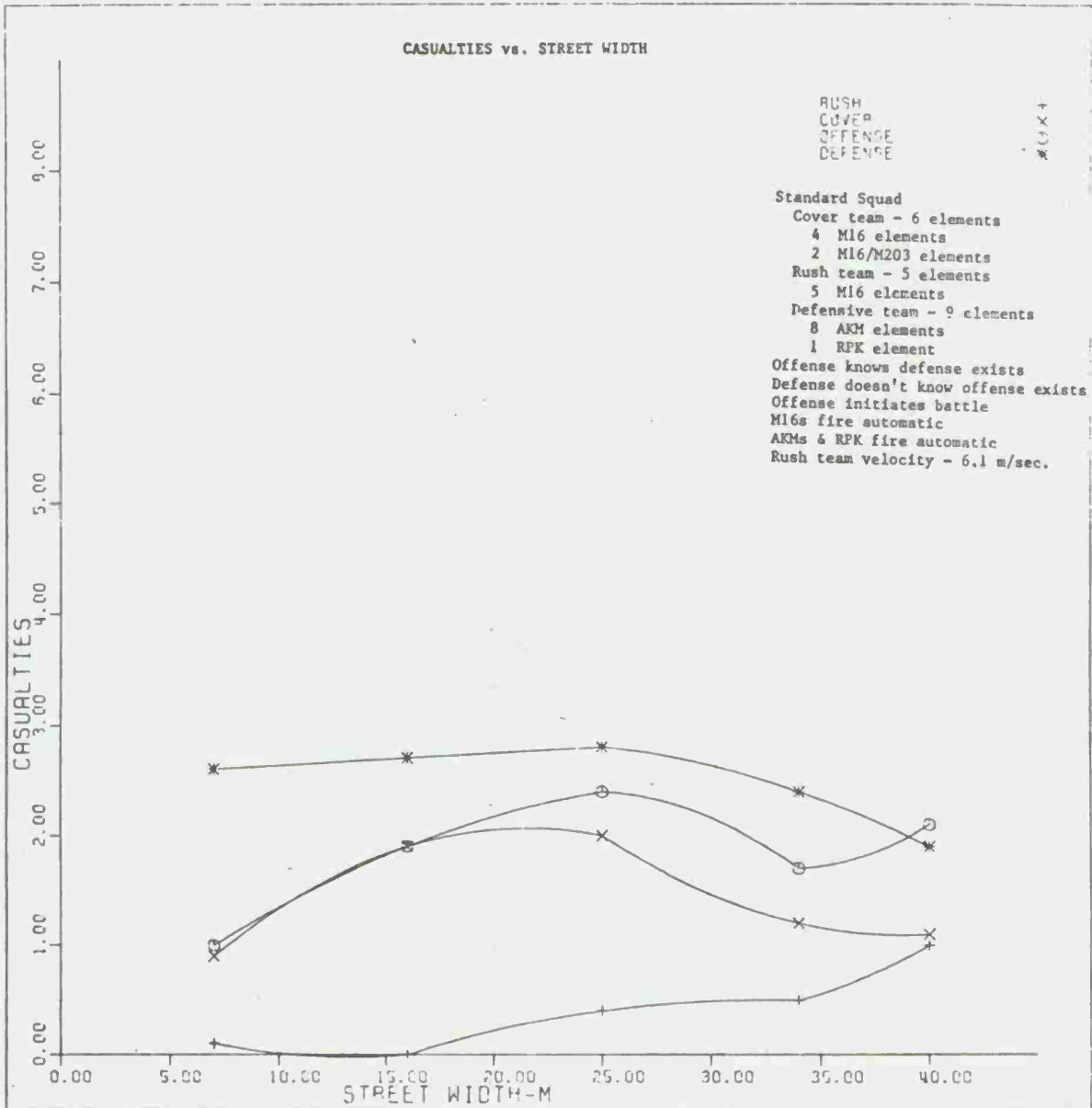


Figure 22 Rifle and Multipurpose Weapons Squad, Automatic Fire

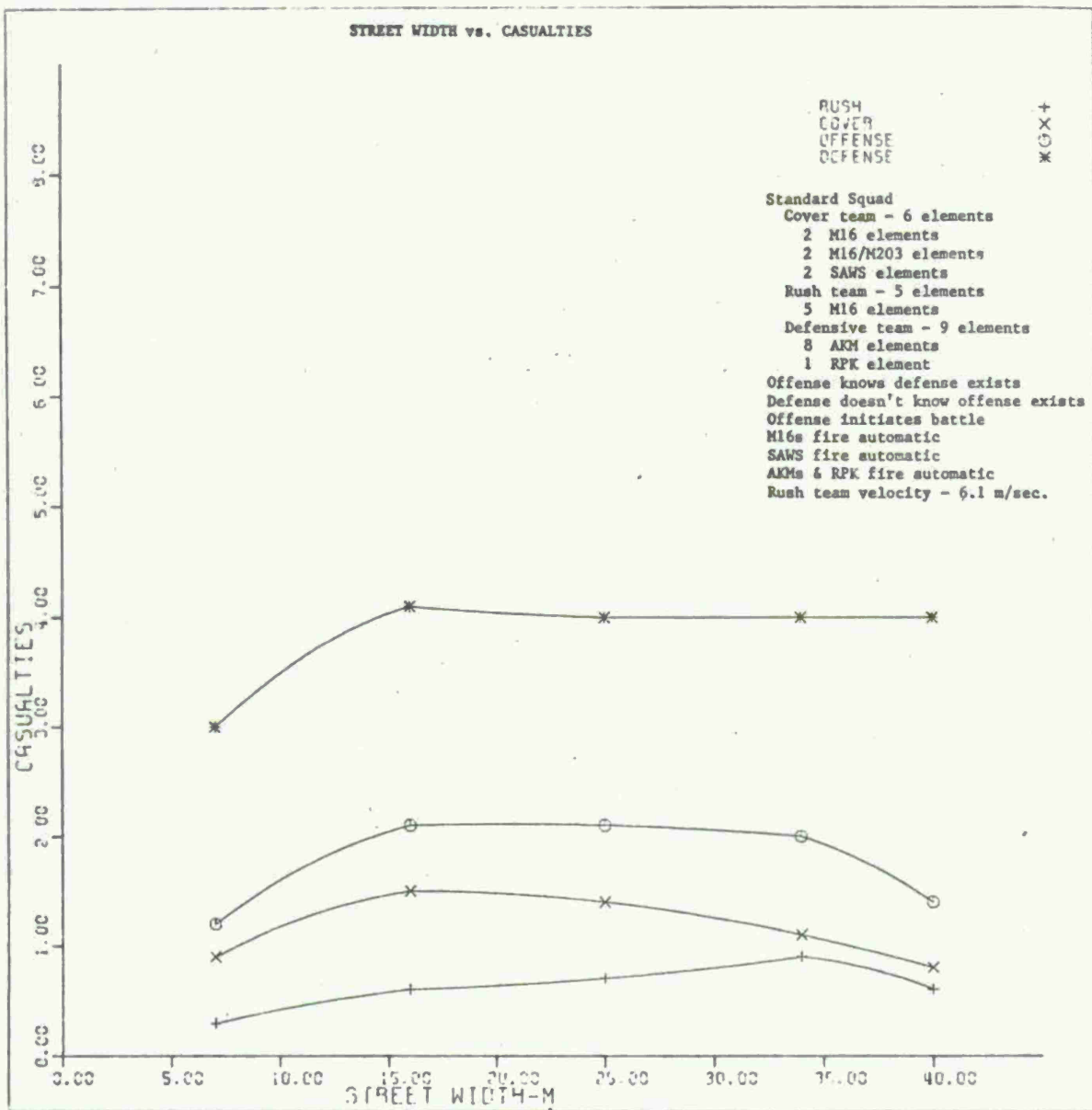


Figure 24 SAWS Squad

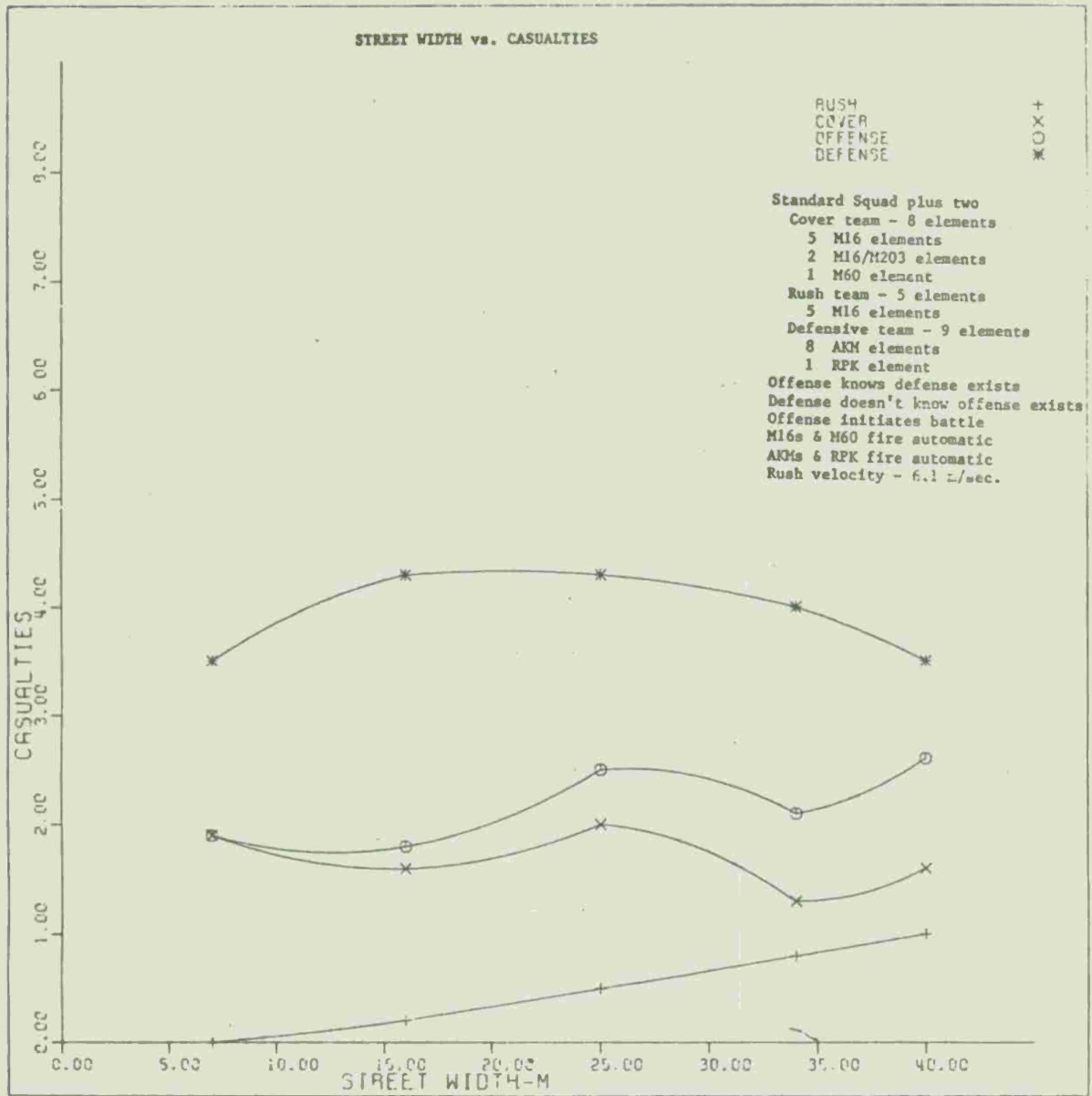


Figure 25 M60 Squad

6.0 PRELIMINARY CONCEPTS FOR NEW WEAPON SYSTEMS

6.1 Introduction

When weapon systems are discussed in an urban warfare context, it is immediately assumed that either the systems have to be urban warfare specific or that systems designed for rural employment have to have special urban warfare adaptation kits. The philosophical basis for these approaches assumes that urban and rural combat are mutually exclusive i.e., if the system is effective in urban warfare it cannot be effective in rural warfare and vice versa. This is a parochial philosophy that can hinder the development of new systems.

In reality there are similar problems that occur in both types of warfare and systems designed to solve these problems will be effective in both rural and urban warfare.

6.2 Discussion, Wall Breaching

One such problem is the breaching of hard point man made structures, buildings, pillboxes, and field fortifications.

This problem, though having been around for some time, has resurfaced and and been given immediacy because of recent urban warfare experiences. Available infantry systems that were assigned this task were not very effective because they had been designed primarily for the anti-armor role. Because of this design goal, these systems had several shortcomings; they had large back blast signatures, required large arming distances, were expensive, were unsafe when fired within confined quarters, and had shape charge warheads that created small openings without assisting in developing large entryways.

Quoting from Ref. 7, "Contrary to popular belief, the LAW, 90mm and 106mm are not good entry hole makers in brick and stone structures. If these weapons are all that are available, satchel charges must be used. This is not a desirable method of gaining entry because three trips across the open area are required. One to place the charge, one to get clear and then the trip required to enter. The time between trips is a detriment since the enemy may reoccupy the room after the blast or use grenades as the attacking personnel enter.

Both the DRAGON and TOW are considered useful for all breaching if the firer can get far enough back to use them (i.e., 60 - 70 meters). At this range, the missile is rarely guided because of the minimum capture time. The missile is simply used as a direct fire weapon, that is, aimed and fired much like a recoilless rifle. These are extremely high cost munitions for this application."

In utilizing the DRAGON in this role, Ref. 8 states: "The DRAGON was found to be more effective in wall breaching if the shipping plug is left in place and not removed before firing the missile".

If the use of satchel charges is required, Ref. 9 states: "Rule of thumb for breaching: Normally, buildings have walls 24 inches or less in thickness. Assume all the outer walls are reinforced concrete. Ten pounds of C-4 placed between waist and chest height will blow a hole large enough for a man to get through." Further on it also states: "The standard shape charge is effective and will blow holes in extremely thick walls. The hole created by the shape charge is too small for a man to crawl through; therefore, it is necessary to use standard block or C-4 explosives to further enlarge the hole."

6.2.1 Wall breaching requirements

If a weapon system is to be developed that will function in the wall breaching role, what should its requirements be?

For one thing it shouldn't be so specialized that it cannot efficiently do other tasks. Since most infantry weapons assigned this task were designed as anti-armor devices, this system should have a secondary anti-armor capability. It should also eliminate one of the shortcomings of recoilless rifles, i.e. back blast (large firing signature). This system should be closed breech. This characteristic will also allow the weapon to function in confined areas. Since it is an infantry weapon it should be man-portable, inexpensive, have a short safing and arming distance, and obviously it must have the capability of creating a man sized entryway in concrete walls in one minute of firing.

6.2.2 Wall breaching concept

One approach to fulfilling these requirements and, in addition, completely eliminating the safing and arming problem, is to utilize the phenomena associated with high velocity kinetic energy impacts.

This technology is being employed by Gunrock, Inc. of Toronto, Canada in tunneling operations. It has been shown that the firing of projectiles at granite is faster and cleaner than the use of explosives. The granite just falls, it isn't projected outward from the face of the wall. This method is also being proposed for the recovery of shale-oil.

The Rodman Laboratory has a program designated WISP (Weaponization of Increased Speed Projectiles), which is applying the technology developed in the aerospace industry to weapon systems. This program which is oriented toward anti-tank guns has shown that a lightweight high velocity projectile can easily penetrate armor plate (Fig. 26).

The techniques that can be used to propel projectiles at high velocities i.e. light gas gun or traveling charge, result in a closed breech system thus eliminating the back blast and confined area problems.

Of course for this system to have both a wall breaching and anti armor capability, it should have two projectiles, one for each mission.

In discussions with personnel from Gunrock, it has been stated that cast iron projectiles are efficient in the wall breaching role. For the anti-armor role steel projectiles will probably be required.

6.3 Discussion, Grenade Effects in Confined Areas.

The effectiveness of available fragmentation and concussion grenades appears to be limited. Fragments from grenades exploded in confined areas can be absorbed by walls, floor, ceiling, furnishings, and sandbags. The effects of concussion grenades drop off rapidly with distance from the point source.

Even though present concussion grenades have limited effectiveness, the concussion phenomena appears to offer a method of circumventing the fragment retardation effects of structures. If the fall off of concussion effects with range can be circumvented the concussion grenade could be an effective weapon.

6.3.1 Concussion grenade concept

One means of overcoming this fall off is by generating a volume concussive source as opposed to the present point source. It appears that this can be accomplished by employing fuel air explosive technology.

Illinois Institute of Technology Research Institute (IITRI) has investigated the generation and ignition of an explosive dust cloud and

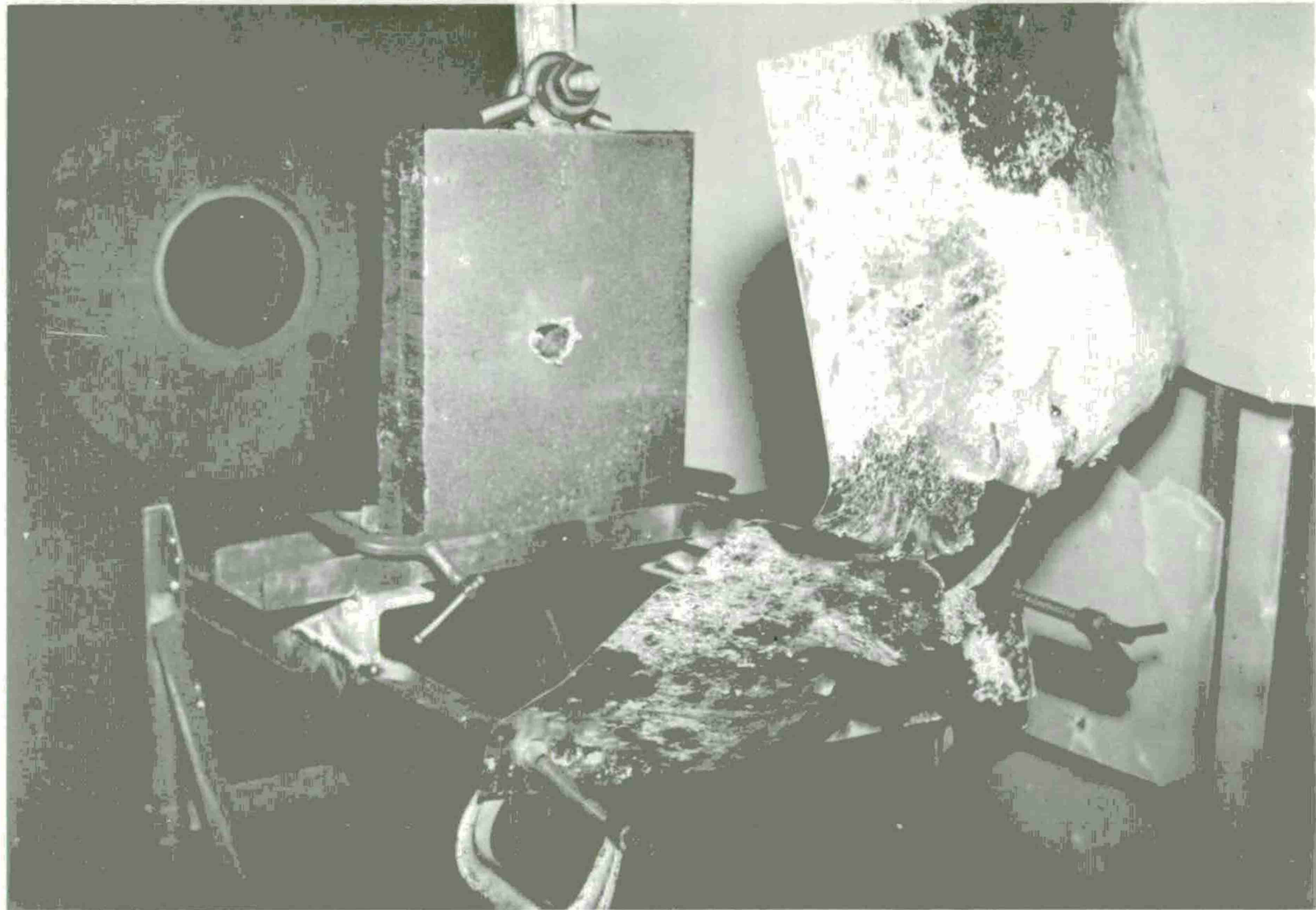


Figure 26 Armor Penetration by Hyper-Velocity Projectile

preliminary results indicated that the concept is feasible.

6.3.2 Other grenade concepts

A concussion grenade based on this technology would be approximately the size of a pressurized shaving cream dispenser. The grenade contains TNT dust that would be dispensed on impact filling a volume. A short time after impact the dust cloud is exploded creating a volume concussive source, negating the effects of intervening structures.

A companion concept to the concussion grenade is a dust thermite grenade. This grenade would contain thermite dust that would create a volume spike heat pulse. This pulse would be damaging to personnel targets, but because of the rapid rise and fall off in thermal energy, structures would probably be immune. This concept while having the physical and psychological incapacitation of fire would not have the undesirable side effects of generating urban fires.

6.4 Discussion, Additional Problems

Two other problem areas, that are urban warfare specific, that deserve attention are:

1. The creation of mouseholes in walls, floors, and ceilings.
2. The movement between floors without using stairs.

The creation of mouseholes for the movement between rooms or floors can be a problem. If present methods of using C-4 or some similiar explosive are employed the personnel would have to seek shelter from the blast. If they have to leave the room they might have to fight their way back in. It appears that what is required is a rapid method of generating mouseholes that doesn't require the evacuation of the work area. In addition, this method should have a self contained method of adhering to a ceiling.

The second problem of movement between floors seems to require some type of lightweight collapsible ladder. This would allow personnel to easily reach mouseholes in ceilings or move up by means of elevator shafts.

It is possible that there presently are commercially available products to create mouseholes. Firemen for example have the same problems of moving in buildings through walls and ceilings, and they use a product called Jet-axe. Jet-axe is a linear shape charge that cuts a circular hole in reinforced concrete. It would appear that a military potential test could be conducted on this product to determine its feasibility for this application.

7.0 TESTING

7.1 Discussion

The testing required for the urban warfare program is of the man-weapon-target-environment variety. The testing will furnish data that will be used to either verify existing methodology which was developed using field test data, or to generate totally new methodology. This methodology in turn will be used by both the designer and analyst during the development and evaluation of weapon systems.

The designers will employ the methodology during the concepting and design portions of weapon systems development. With this type of methodology they can base their design decisions on a solid analytical foundation. In addition, they will be able to justify their decisions to decision makers. The analyst, on the other hand, will incorporate the methodology into effectiveness models that simulate a weapon system in the man-weapon-target-environment atmosphere.

The tests that are required are:

1. Material penetration
2. Ricochet phenomena
3. Visual detection of static targets in an urban environment
4. Visual and aural detection and location of weapon fire in an urban environment
5. Fragmenting and concussion grenade lethality in confined areas
6. Aiming accuracy against fleeting urban targets.

7.2 Penetration

There are considerable material penetration data available, Refs. 9, 10, and 11. However, little of this data is for urban materials, penetration is never rigidly defined, and the projectile entry conditions (angle of impact, impact velocity, and yaw angle) and projectile exit conditions (residual velocity, residual mass, and exit angle) are limited.

Since some data are available on penetration, a small contract was negotiated with "Armament Systems, Inc" to develop and program in FORTRAN IV, a math model for use as a subroutine in URBWAR, Ref, 12.

The model is based on the THOR equations developed by the Ballistic Analysis Laboratory of the Johns Hopkins University. However, THOR equations

have not been derived for all of the materials of urban interest. In some cases, penetration data and methods of determining depth of penetration have been established, but in other cases there appear to be no empirical data available from which to derive reliable residual velocity and weight equations.

The model uses the following procedure for determining penetration and residual velocity and mass.

1. THOR equations are used from BAL reports when damage mechanisms and material match.

2. In some cases, fragment equations are available but projectile equations are not. For this case, a thickness ratio is determined from the equations for steel to account for the difference between fragments and projectiles and the THOR fragment equation for the material used with the thickness ratio applied.

3. For the cases where THOR equations do not exist for either fragments or projectiles, but depth of penetration data does exist; the equivalent thickness of steel is estimated for the material and the THOR equation for steel is used.

The model is based on empirical data and what is required is an analytical model that is not limited by the availability of projectile test data. In this way new projectile types can be conceived and evaluated without resorting to new tests.

7.3 Ricochet

If there are only limited data available on penetration, then the data on small projectile ricochet from urban materials are minimal. The ricochet of projectiles from urban materials can either be an asset or a hindrance to squad effectiveness; an asset because it can increase the probability of hit, and a hindrance because it can be a hazard to assault troops and require the lifting of cover fire.

What is required are data to establish methodology that will enable the probability of hit for ricochets to be calculated and also the probability of incapacitation given a hit. These data should relate material type, projectile type, and projectile impact conditions to projectile post impact condition, i.e., direction of travel, residual velocity and residual mass.

7.4 Visual Detection

The present visual detection of static non-firing targets is based on the vision lobe theory. The model determines if the searcher is looking in the general direction of the target and if he has line-of-sight. If L-O-S exists, the model computes the target-background contrast, presented area and range to the target; all of which are employed to calculate probability of detection.

This subroutine is based on field test data and what is required are urban test data to substantiate the model. The test should generate data that accounts for the proximity of shadows and visual confusion factors that abound in an urban environment. For example, if a target is situated within an opening but back from it, how does this modify the contrast and the probability of detection?

The second type of detection accounts for the visual and aural detection and location of firing weapons (this type of detection can be critical when snipers are being engaged). The data for this detection algorithm were generated by field testing and their applicability to the urban environment have to be substantiated.

7.5 Grenade Lethality in Confined Areas

The tactics for the clearing of structures emphasizes the use of grenades i.e., throwing a grenade into an area and following it in. Given this tactic, it would appear that data on the effectiveness of fragmentation and concussion in confined areas would be available. It isn't.

This type of data would be of benefit to three parties; the user, the designer and the analyst. The user because he would know what to expect from his grenade in the way of casualties given various types of enclosures. The designer, because the data would form a basis for development of improved grenades. The analyst because he would be able to realistically determine the affects grenades have in the outcome of a simulated conflict.

7.6 Aiming Accuracy

The last area that requires test data is aiming accuracy. All available accuracy data, even quick fire, were generated for field use. What is required is accuracy for urban employment. The questions that have to be answered are:

1. What is the aiming accuracy against fleeting targets that are

moving across an opening in a structure, i.e., from one side of a window to another?

2. What is the accuracy when a small target is framed against one edge of an opening such as a window?
3. Does the proximity of the frame around the target increase aiming accuracy?

The firer is aiming at an opening that contains a target and not a rural area that contains a target.

These data would be employed in determining probability of hit and it would indicate whether small arms fire is more or less accurate in urban areas than in rural areas.

8.0 CONCLUSIONS

1. The urban warfare combat simulation model (URBWAR) is operational and can simulate small arms combat.
2. The model has the sensitivity to assist in the evaluation of conceptual weapons, developmental weapons, fielded weapons, and parametric variations.
3. The model though developed to assist in weapon development can provide insight into conflict dynamics.
4. Automatic rifle fire is an asset in urban conflicts.
5. The contribution of grenade launchers to squad effectiveness is primarily one of suppression and is highly dependent on room size.
6. The SAWS system because of its accuracy is an effective system and equalizes the capability of an eleven man SAWS squad with a thirteen man M16 squad that has an M60.
7. The effects of suppression can result in a false impression of fire superiority.
8. The high velocity kinetic energy impact technology appears to offer an infantry weapon system that would be closed breech and be capable of wall breaching and anti-armor combat.
9. The fuel air explosive technology appears to offer a concussion grenade that would be a volume source, thereby circumventing the concussive effects fall-off problem with target range from center of explosion.
10. There is a lack of test data concerning the man-weapon-target-environment interaction for urban conflict.

9.0 RECOMMENDATIONS

1. The modeling effort should be continued to expand URBWAR to include tanks and artillery.
2. The model should be used to evaluate all conceptual and developmental small arms systems.
3. A detailed parametric variation analysis of weapon system performance parameters should be conducted.
4. A task should be funded to develop a prototype wall breaching/anti-armor device.
5. A task should be funded to develop a prototype dust FAE concussion grenade.
6. A test program should be initiated that will obtain data on:
 - a. Material penetration
 - b. Ricochet phenomena
 - c. Visual detection of static non-firing urban targets
 - d. Visual and aural detection and location of firing weapons in an urban area
 - e. The effects of fragmentation and concussion grenades in confined areas
 - f. Aiming accuracy of small arms against fleeting urban targets

APPENDIX A

NARRATIVE DESCRIPTION OF THE URBWAR MODEL

A.0 WHAT IS URBWAR?

URBWAR is an event-sequenced, stochastic simulation model representing city fighting at the infantry platoon level.

A.1 SCENARIO

The "city" contains at most 5 buildings with up to 4 floor levels (basement, 1st, 2nd, 3rd floors) and at most 10 rooms per floor.

The buildings, rooms, windows and other structural components are represented by collections of parallelograms. The soldier elements are played as right circular cylinders.

There are side streets, intersections, and main roads.

Eventually obstacles such as cars, trees and other types of masking will be playable.

Small arms weapons are modeled i.e., rifles, pistols, grenades, and machine guns.

Firing modes include type of aim, posture, tactic (quick fire, personal protection, grenade, sweepfire, smoke or gas), firing rate and mount.

A.2 FLOW DESCRIPTION

MAIN

PRIMOV

DETECT

MOVE

FIRE

SUMMARY

A.3 NARRATIVE

The main program begins by reading in card information on initial battle intelligence (1 = offense knows the defense exists; 2 = defense knows the offense exists), main assault street width, assault velocity and possible leader-commanded battle fire times.

Quick data changes are made either in MAIN or CHANGE, rather than in reassembling the regular data deck. MAIN will relocate defensive elements and assault team rush coordinates. PRIMOV will input defensive building and sector data due to location of enemy structures relative to offensive structures and streets.

After this initial organization, the prime mover (PRIMOV) is called to engage the scenario.

All movement clocks are set to a number chosen from a uniform distribution on the time interval $[0, 1]$ seconds, whether or not each element will be moving at the start of the battle.

The initial detection times of the side with knowledge of the opposing force is also set to a time between $[0, 1]$ seconds.

All elements have pre-input locations. In the play of random room emplacement, the unsuspecting force (with the exception of sentries) will be randomly placed inside of an elliptical-shaped region centered from the middle of their enclosure.

The element with the least event time, whether movement or detection time, is chosen using EVSEL. If there are several elements with like times, EVSEL chooses the element with the lowest numerical value. If element N (the chosen element) has two events with the same time, he will choose from the lowest ranked (namely: 1. Detection; 2. Movement; 3. Fire) event.

A check is then made to determine if the battle time is greater than some input time (to prevent running forever in case something should go wrong).

N's firing coordinates are then set up for his main event (firing coordinates F are the (X, Y, Z) values at the middle top of head).

The event type determined from EVSEL is one of 3 kinds: call to 1. BRAIN 2. MOVE or 3. FIRE.

Suppose the call was to subroutine BRAIN, the intelligence portion of URBWAR. If no target exists for N, BRAIN will assign one if possible.

If BRAIN already shows a target, a check is made to determine if the element is still available for fire by calling AVAIL. If still available, the fire clock time is set equal to the current detection clock time and BRAIN is exited and N will have a fire event immediately. Should the target no longer be available, BRAIN proceeds to see if a new target can be found.

The first task to finding a new target is to conduct a firing sector search by calling DETECT. A fire sector is a parallelepiped region of the battlefield that has been assigned to N. Some of them contain portions of structures, others may have nothing occupying them. As input to the

model each element is assigned 5 fire-detect sectors for use throughout the battle. These sectors are an enforced method of "fire-discipline", i.e., an element is not responsible for what happens in other fire sectors.

DETECT begins by determining which sector is to be scanned, based on a priority scheme that is input. If the current sector had just recently been investigated, DETECT advances the check to the next sector unless a special counter has determined that extraordinary attention should be paid to the current sector.

The next step is to calculate the presented area of the sector as seen by N. A call is made to SECAT. SECAT is a complicated program to take the various characteristics of a sector (e.g., walls, streets, etc.) and compute the presented area. If the area is less than or equal to zero DETECT is exited and /NDET/ is restored to zero. If the area is positive, it is used to ascertain the cross-sectional area of the vision lobe, which is used in conjunction with input contrast percentages (e.g. olive drab against a concrete background) to determine how many times the sector should be consecutively checked. Then SECDET is called to determine if any elements are in sector NSECT. If there are, they are listed and a priority weighting will determine the one to be chosen. The first target in the sector listing is brought forth for scrutiny. First a call to SEE is made to determine if target LTGT can be seen.

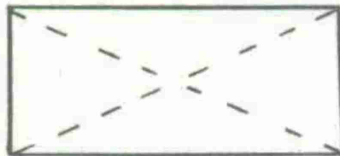
Two things must be guaranteed in SEE: that LTGT is neither suppressed (this may be found in /CATCH/) nor dead (see/KILL/). Next his base coordinates are set up (the center base of the cylinder) and N (the element with the detection event) is assigned LTGT's number and sector in /NDET/. A call is made to VISION to find if LTGT has any presented area with respect to N. A check is made to determine if N can see LTGT through N's "window" as a line-of-sight (L-O-S) process. If not, LTGT is skipped.

Assume L-O-S from N to LTGT exists. A parallelogram shaped creature is made up of LTGT portrayed as a cylinder, as though LTGT was fully visible. At this point if N is a sweep firer machine gunner a special variable is established.

Should N be in a building a special set of logic is followed in which N tries to look at LTGT through LTGT's holes in the "looked at" fire sector.

VISION returns the largest LTGT presented area among the collection of holes in NSECT through the assistance of subprogram HOLECH. Holes may be windows, doors, or other apertures created by force or design. If there are no LTGT holes, then there is no presented area and VISION returns to DETECT.

If N is not in a building, he is either on a building (i.e., roof) or in the street. If N is outside of the building it is necessary to check for LTGT L-O-S and presented area. The following are checked for vision obstruction: 4 walls of each building (buildings are assumed to have a rectangular base), the roof of each building, and two diagonal and intersecting vertical parallelograms reaching from the interior corners of the building. An overhead view would look thus:



where the dotted lines are the diagonal parallelograms referred to.

In each parallelogram case, the vertical rectangular target area is projected against the parallelogram by N to determine the amount of visible area. This information is brought back to DETECT from VISION.

If LTGT was detected (i.e., LDET = 1), target LTGT and the firing sector are noted. If N is a sweep fire machine gunner, the target is added to a counter KK and a zero is set in the value normally reserved for a regular target.

Assuming that we have a regular target, this presented area is assigned to the first entry in the common array FDET. If the target is in the street a weighting value is added to the area and if the target is moving, a further weighting value is added. This sum total is saved and compared to the highest previous value. By the method of weights we can also give priority to firing at machine gunners or snipers. If the total sum is less than a previous sum for another target, revert back to checking for a new LTGT. In other words, the most important target of all available targets in N's fire sectors is wanted. When the "best" target is chosen, it is recorded in /NDET/ for element N.

Returning to BRAIN, whether or not a target was found, the amount of time to search (based on an input glimpse time per sector) for a target is added to the current detect time for N. If no target was found, a check is made of the number of successive times N has tried to locate a target from his window, and if a certain input max has been reached, N switches his position to look from the other side of the window. His move clock is updated.

Suppose N has found a target. A call to TARTYP will declare the type of target found. If LTGT was a sweep fire target exit via TARTYP. If not, he is considered a point fire target. If the potential firer N is moving, he can only quick fire. If N is not moving he must determine whether LTGT is moving. If LTGT is predicted to be seen for only a short time, then N will quick fire. This prediction is based on the following decision: Since LTGT is moving, using his velocity vector and a short increment of time, a call to VISION determines if LTGT can be seen in TIME + small increment. If the target can be seen at point A and he can be seen between A and B but not at B, LTGT is considered a quick fire target. An example would be some element moving past a hole in the opposition's building, or peering briefly about an obstacle.

If N has a multi-purpose weapon he will attempt to use it. This involves some flags and commons being set in /STANCE/, /MULMOD/, and /CATCH/. If the above common definitions are not met, the target will be assumed to be a self-defense/personal protection target and N will use his point fire weapon.

Upon determining the target type, the detection clock for N is set to infinity, and N's fire clock to the current detection time + search time.

Once this is accomplished, subroutine UPDATE is called. UPDATE moves all elements that have a non-zero velocity vector from their current position to the position they will be in at the next point in time. The next point in time is determined by calling EVSEL which chooses the next element from the least time array, and what his event will be (detect, move, or fire). All elements that are moving will have their current target location checked and the sector they are in by calling TARLOK and SECHK respectively. This information will be stored in commons /LOCTAR/ and /SECLOK/. By target location is meant whether N is in a building, in the street, or on the

roof (LT = 1, 2, or 3 respectively). Return to PRIMOV via DETECT.

Again a check is made to determine if the battle has ended or if it has run too long, and if neither condition is satisfied, the new element N, just recently chosen from EVSEL in UPDATE is interrogated.

Suppose this time that N's event is a fire event. FIRKON is called. Subroutine FIRKON controls firing (both point and area), reloading, firing on the move, self-defense and casualty assessment.

FIRKON identifies the potential target, the special event status (blast, sweep fire, or smoke/gas) if there is one, whether it is a fire on the move event, and the casualty status of the target. If the target is dead, N's mission ends and his detection information is zeroed out in ZERO. The current "look sector" is retained for another check and then a call is made to UPDATE before returning to PRIMOV for the next event.

Should it happen that the target NTARG is dead and is in the street, N tries to select another street target (especially in the case of rush or assault squad trying to get from one area to another) by calling PRIOR.

In subroutine PRIOR, N's firing sectors are set up. A loop check is made of all the enemy elements to determine which are in N's firing sectors, not dead, and visible to N.

To test visibility it is necessary to set up arguments for SECAT. After SECAT is called some information is relayed to SEE for actual visual detection (see section on DETECT for further details). If a potential target is available it is entered (LDET = 1) into LIST for further evaluation. Should no targets exist for N, a zero is assigned as a target number and control is returned to FIRKON.

However, if there are K potential targets, a determination is made about other street targets (regarded as especially dangerous), and if there are any, N opens fire on the closest element (later other considerations will be played).

If there are no street targets a check is made for the viability of retaining the current target (if NTARG is dead, a new target will be selected). If the current target is not a suppressed target, coordinates are set up and VISION is called. If the target's presented area is greater than zero, the width and height vectors are created and NTARG is set up for N. Return to FIRKON.

Therefore, if N picks a target other than a street target, FIRKON directs N to have a new detection event by updating the detection clock and setting the fire clock to infinity. The current detection sector is retained for another look. If the priority target is a street target continue the fire mission by setting the detection clock to infinity and the fire clock to a new incremented time. Then a call to UPDATE is made.

These are the cases in the event N's regular target was killed. Should N's target be alive (at the moment there is no inherent distribution used by the firer to determine the "actual" alive-dead status of an enemy element. A firer is assumed to have perfect knowledge of alive and dead targets.). A call is made to DISPDT to gather time values used in setting up a fire mission as well as other critical factors such as firing error (i.e., dispersion) data and reload input/output.

Upon entering DISPDT the reaction time parameter TIME and the reload time TIEM all initialized. DISPDT will utilize a number J to reach into data to find the proper dispersion values for regular small arms and grenade fired weapons. J identifies a 7-digit code which is based on:

1. Identification, offense or defense (1 or 2);
2. The weapon type (1 through 9 weapons may be played);
3. The mount (e.g., shoulder, hip/underarm, bipod, tripod, sandbag and various combinations of these);
4. The type of fire (1. Semiautomatic, 2. short burst, 3. long burst (usually reserved for sweep fire));
5. The posture (1. standing, 2. kneeling, 3. sitting, 4. prone);
6. The aim (1. pointed-point; 2. aim-point; and combinations of these with the various mounts);
7. The target type of tactic (1. quick fire; 2. personal protection (the vast majority); 3. Blast (i.e., grenade); 4. Area (i.e., sweep fire); 5. Smoke, etc.

If the J value is for a grenade weapon, information is required on the grenade launcher type, how many rounds have been previously fired, and whether the method of delivery will be quick (i.e., hasty), or deliberate (specific aim). The details of these assignments will be described in subroutines ARM and BLAST.

Commons /NUMLST/ and /JGLAE/ help locate these specific data in another set of commons, /DISPER/ and /GRELTM/ respectively.

Now it is necessary to set up the stance of the soldier from /STANCE/. MOUNT, IFIRE, and IPOST are three important variable names used in data gathering. Fire data were obtained in a standing or prone position, sitting and kneeling are assigned a prone and standing position respectively. Next IAIM is declared.

At this point RELOAD is called. RELOAD checks for ammo and weapon existence. If the weapon exists but is empty, the weapon is reloaded (if there is enough ammo) and the time to reload value is returned to DISPDT.

When RELOAD is first entered the reload time is initialized to zero and weapon firability LFIR = 1. Should the weapon prove to be unfirable, LFIR = 0.

The main and secondary weapon types are recorded from /SOLOAD/. In the event N has a multipurpose weapon, main armament is the first weapon and the multipurpose part (e.g., a grenade launcher) is the second weapon type.

Similarly, current weapon load and carried ammunition supplies for primary and secondary weapons (if any) are stored in /SOLOAD/.

Common /MWEPT/ cross references the main weapon with the projected event to determine if the main weapon can be used for the current mission. If the answer is no, then the secondary weapon is checked. If no weapon is usable, set LFIR = 0, return to DISPDT.

Thus the current usable weapon is established in /CURWEP/. Now a determination is made on the ammunition load in the current weapon. If the weapon is not empty, there is no reload time. If the weapon is empty the reload time is computed. All reloading depends on the carried or usable supply. Again, if there is no ammo to reload, LFIR = 0, return to DISPDT.

The max weapon load is set and subtracted from the carrying supply (or if carrying supply is less than max, this amount is loaded).

The reload time for small arms is computed using /RELDMU/, /RELDSD/ and for grenades, /GRELTM/.

The reload time for small arms depends only on the weapon type. For grenades it is more complicated. A check is made for the number of previously fired rounds, whether hasty or deliberate fire, and the type of launcher. These will all affect handling of the weapon. The reload time is recorded and referred back to DISPDT.

If LFIR = 0, the fire clock is set to infinity. For all practical purposes N is assumed to be suppressed and his position becomes prone (this can be varied if desired). Return to FIRKON.

If all conditions are fulfilled there is clearance to fire, the weapon type ITYPE and the mission type ITG is set up. If there is a multipurpose weapon it is identified (MP = 0 if no M-P weapon), and whether the element is on offense/defense is established.

The next step is to go to the part of the logic in DISPDT for each type of target, viz. quick fire, personal protection, etc. obtained early in BRAIN from TARTYP.

In the quick fire step the question is asked: Is ITYPE a multipurpose weapon? If it is, it must be in the regular firing mode and IPOST = 1, otherwise it is noted that there was no success in obtaining proper data for the weapon to be used. The reload time is then added to the current fire clock and then returned to FIRKON. The same result will show up if the weapon is not shoulder mounted. However, in fire-on-the-move situations, quick fire will be necessary from a hip/underarm fire posture. There are other requirements on IAIM and IFIRE (IFIRE cannot be a long burst), but some of these will change as new situations arise.

The next case is personal protection, which is also covered by a large collection of clauses. If the aim, the fire length, or some other parameter is not exactly right to meet the existing fire data, either new data or supplementary data can be created with the small arms controllability fire model, or time delays for changing mount, posture and so forth are added to the TIME variable. In the end, all of these time delays are added up to delay the actual firing of the weapon in FIRKON. If an insoluble situation should arise (which was not caught by /MWEPT/ in RELOAD), go to the end of DISPDT and reset the fire clock and return to FIRKON.

Assuming therefore that progress has been made through each of the

above steps IVAL will be determined for small arms fire using equation (1):

$$\begin{aligned} \text{IVAL} = & \text{IN} * 1000000 + \text{ITYPE} * 100000 + \text{MOUNT} * 10000 + \text{IFIRE} * 1000 \\ & + \text{IPOST} * 100 + \text{IAIM} * 10 + \text{ITG} \end{aligned} \quad (1)$$

where IN signals offense or defense (1 or 2).

After IVAL has been calculated an update to /STANCE/ is made. After this has been done, the reaction time is checked. If the reaction time is less than the reload time, the total reaction time is set equal to the reload time.

Now the J value for the entry into the list of dispersion data is found from the list of IVALs. When the correct IVAL is found, the number of that entry, J, is set in /CATCH/.

The same type of approach is used for grenade fire, but IVAL is defined by equation (2):

$$\text{IVAL} = 100 * \text{ITIP} + 10 * \text{JGRND} + \text{IDEL} \quad (2)$$

where ITIP is the type of launcher, JGRND is the number of times previously fired (if greater than 3, JGRND is set to three), and IDEL is the type of delivery, hasty or deliberate. This information is relayed along with the total processing time used.

FIRKON determines if N has fire data, and if not, sets the detection clock for another check and the fire clock to infinity. Then it calls ZERO and checks the same fire sector. Call UPDATE then return to PRIMOV.

If there was a reload or a delay in setting up, the firer will be suppressed, the delay will be added to the current time for the move clock. The fire clock will be set to infinity. Also a check will be made to determine if all ammo has been expended.

If the firer is not suppressed and all ammo hasn't been expended a check is made of the event situation. If the event is a grenade (i.e., blast) situation, the target is set for looping through AVAIL. If not a blast target, a determination is made whether the fire is semi-automatic, short burst or long burst. From this and the cyclic rate the actual firing time is computed and added to the fire event time.

Should the target require a sweep fire tactic, the enemy elements are checked against N's current fire sector.

In any case, the program logic has established the limits on the

target(s) to be checked for availability, as potential candidates for fire.

In the loop checking for enemy targets (In the future it is possible we may check all "potential" targets, in the event of mistaken identity.), if N is a machine gunner, the area of each target is initially set to zero.

Subroutine AVAIL is called by N for potential target J. If N is a sweep fire machine gunner, the current J is defined (for purposes of a vision check) and his current look sector is set up. A call to SECAT is then made to get the presented area (SAREA) of J's firing sector (as seen by N). Next a check for visual detection is made by a call to SEE. If N was a machine gunner, the target number is reset to zero and if LDET = 1 we still have a target and IVAIL is set to 1. Return to FIRKON. If LDET = 0, call ZERO (sets arrays FDET and NDET to zeroes) for N and set IVAIL = 0 before returning to FIRKON. For the first time, the height and width vectors are computed and stored in FDET, or if N is a machine gunner, the presented area, aim point, width and height are stored.

If J is not available for fire, ZERO is called and if J was one of the elements checked for a sweep mission by N, the /STORE/ sweep areas are zeroed.

If the number of potential targets no longer available equals the number checked in the loop, the detection clock is incremented and the fire clock set to infinity. Call UPDATE then return to PRIMOV.

However, if a target is available for delivery of fire, the decision logic will send N to special event statements or regular fire programming (quick fire and personal protection).

For special events types: blast, sweep fire, or smoke/gas, first the direction of sweep is set opposite to the direction of the last fire event. FIRMOD is called. FIRMOD computes the probability of incapacitation of a weapon firing an N-round burst at the center base of a single rectangular point target (this is repeatedly applied for a sweep target). Some weapons fire at the target midpoint, and adjustments are made in computing the probability of incapacitation.

FIRMOD first determines the number of rounds remaining in the firer's weapon, obtained from /SOLOAD/. The weapon type LWEP is also established.

The probability of survival of all soldiers is initialized to 1.0,

and the probability of kill is initialized to 0.0.

The first decision that is made is whether to use point fire or sweep fire logic. Assume that point fire logic is of interest. In this case N engages one target at a time. The tactical situation of the target element (offense or defense) is established. Projectile, mass and velocity are determined. The range between N and his target is calculated (R). From /CATCH/ and /DISPER/ dispersion data is obtained for the firing weapon, and converted from mils to meters. Type of point fire is established i.e., semi-automatic, short burst, or long burst. The number of rounds to be fired are subtracted from the number of rounds remaining in N's weapon. The mean x and mean y dispersion values are initialized and the width and height of the target is retrieved from FDET. If one round of one projectile is to be fired, the probability of a hit is calculated by using equation (3) with:

$$PH = \frac{(\text{ERF}((0.5*W - XB1)/SX1) - \text{ERF}((-0.5*W - XB1)/SX1)) * (\text{ERF}((0.5*H - YB1)/SY1) - \text{ERF}((-0.5*H - YB1)/SY1))}{1}$$
(3)

where

ERF = normal distribution function

W = width of target

H = height of target

(XB1, YB1) = mean dispersion

(SX1, SY1) = standard deviation (error)

PH = probability of hit

The probability of a kill given that the target was hit is calculated using equation (4):

$$PK = PH * PHK$$
(4)

Then the number of rounds remaining in the weapon is set.

If a burst is to be fired, GAUSS is called. GAUSS contains a string of 15 arguments ranging from means, standard deviations, errors about subsequent aimpoints, to probability of kill given a hit. GAUSS is a 16 point integration algorithm that calculates the probability of an incapacitation for burst fire.

In the event that FIRKON requested sweep fire, there are additional considerations to be performed by FIRMOD.

For sweep fire (using a burst of ammo in a specified direction, over a particular horizontal distance per time duration), it is necessary to calculate the distance between aimpoints. For the area to be swept, the extremes are located from the left most element to the right most element (or maybe from one building edge to another), the number of aimpoints are determined from the number of rounds to be fired. The aimpoints are divided into equal distances from one extreme of the sweep to the other. The direction of the sweep is also set by MD from the argument list.

The loop parameters are set up for candidate targets (i.e., the loop begins and ends with either the offensive or defensive elements).

As before, PHK is calculated, as is the range (R), and a check for remaining ammunition is made. If the target has a presented area of zero, see /STORE/, return to the beginning of the loop and process the next element.

Assume an eligible target is found (i.e., alive, has visible area to N, sweep fire mission), then the difference between the weapon aimpoint and soldier's aimpoint for the interval of sweep is calculated. Then the width and height of the target is obtained from /STORE/. GAUSS is called and upon returning to FIRMOD, the probability of incapacitation is determined. Should the weapon exhaust its ammo the probability of incapacitation (in this case, a kill or no kill) at that point is calculated, the weapon will need a reload (done during next fire event) and a return to FIRKON is made.

However, if there is sufficient ammo, the process is repeated until the sweep is completed or ammo is exhausted. The new ammo load (amount remaining) is set and control is returned to FIRKON.

FIRKON, with a sweep fire mission, institutes casualty assessment, and if I (running from element NELTB to NELTE) is already dead a check is made to see if the end of the loop has been reached and if not, the next element is evaluated. Suppose I is alive, he must have had a presented area for casualty assessment, if not check the next element if there is one.

Once all elements that are candidates for casualty assessment are determined, a call is made to CAZASS with the kill probability PKIL taken from the call to FIRMOD.

In CAZASS a random number is chosen RAX from the uniform distribution

function FRANUD and then it is compared to the probability of kill PI or PKIL (in FIRKON). If RAX is greater than PI, the element is considered to be alive and well, otherwise, the target becomes dead and all arrays which reference this element are zeroed out, specifically /FDET/ and /NDET/. All clocks for the target are set to infinity. Common /CATCH/ is also zeroed out for the target. Call MISOBJ.

Coming back to FIRKON, if I has been killed (I is the element number in the loop), ZERO is called, /STORE/ for N is erased, the kill is recorded by weapon type and a check is made to see whether this was the first firing of the battle. If it is first fire, SETDET is called, which sets all enemy detection clocks to the current time plus a mount time and an aim time. However, if the element is dead or suppressed he retains the current update times on his clocks.

A check is then made to determine if I is the last element in the loop, and if not, the looping continues. Should I be the last element in the loop, a detection clock will be set to determine whether sweep fire will continue. The fire clock is set to infinity. Call UPDATE then return to PRIMOV.

If on inspection I is found to be alive, SELDEF is a self-defense routine which will establish whether I detects someone firing at him, takes cover, decides to return fire, or ignores firer to concentrate on another target.

SELDEF first will establish the residence sector for the firer NF, and the target's (NT) current target (NTAR) if one exists.

The range (R) from the target to the firer is computed and then divided by 10 for use in an exponential probability equation which uses 10s of meters for distance.

If NF is firing semi-automatic, the equation (5), derived in the ASARS model, has a 95% fit for detection of visual/aural fire.

$$\text{PROB} = 0.531 * \text{EXP}(-.105 * R) \quad (5)$$

This is a field equation and not one obtained from city fighting.

There is a 99% fit for automatic fire using equation (6), again from field data: (ASARS Model)

$$\text{PROB} = 1.28 * \text{EXP}(-.077 * R) \quad (6)$$

It should be noted that for very short distances, the PROB is greater

than 1.0 of being detected.

A Monte Carlo check is made from FRANUD to determine whether NT detected fire from N.

If NT did not detect fire, the program is exited and returned to FIRKON. Assume therefore that NT did detect fire as being placed on his position from NF.

Assume that because of the close distances, once NT acquires the aural/visual effect of NF's fire, his location is known. It is necessary to calculate the time (seconds) used to locate NF (96% fit) by equations 7, 8, 9. (ASARS model)

$$\text{TIMLOC} = \text{VMT} + \text{SIGT} * \text{XAN} \quad (7)$$

where

$$\text{VMT} = 3.78 + 0.126 * \text{R} \quad (8)$$

$$\text{SIGT} = 2.9, \text{ and XAN is a number chosen from a random distribution.} \quad (9)$$

If time to locate is less than zero, set $\text{TIMLOC} = 0$.

What are NT's options?

1. If NT is not detected until after NT's next fire event-continue the current mission.
2. Take cover (unless a rushing element, then NT will continue to run).

Calculate the time to the detection of NF, equation (10)

$$\text{DTIME} = \text{CURT} + \text{TIMLOC} + \text{TFIRE} \quad (10)$$

where

CURT = current event time

TFIRE = burst duration length by NF (sec).

If the detect time is greater than NT's next fire time, NT's fire event will take precedence. Otherwise NT takes cover by calling TAKOV.

In TAKOV, unless the target is running, we suppress his data arrays and NT records who fired at him, when and where.

NT can store such information on a maximum of 2 elements (this restriction, like others, can of course be changed by program revisions). Targets, sector and times are stored in /SUPFIR/ and /TSPFR/.

Subroutine ZERO is called and the detection and fire clocks are set

to infinity (which in this model is 1,000,000 sec). The suppression array in /CATCH/ is set and a value TST is added to the current clock time for the next movement event, in which suppression will be lifted. The suppression times for small arms and grenade fire are input.

A more comprehensive suppression routine is planned, one that will vary with weapon systems, wounds, previous knowledge, room-to-room search and so forth.

Return to SELDEF, then return to FIRKON.

A check is made to determine if this is the first time there has been battle fire and if so, SETDET is called. If not, a check is made to determine if I is the last element. At the end of element processing a determination is made as to whether it is desirable to continue the sweep fire mission by resetting the detection clock of N to the current fire time plus the time of burst duration. The fire clock will be set to infinity. Call UPDATE then return to PRIMOV.

If instead of sweep fire there is a regular point fire event in FIRKON, the logic is broken up into fire on the move, and stabilized fire. At this time, no logic exists for fire on the move. Thus a call to FIRMOD takes place, which has already been explained. Next call CAZASS for casualty assessment. Then a check is made to determine whether SETDET should be called.

If NTARG was killed, the weapon type, is recorded and the detection clock is set to infinity, ZERO is called and the current fire sector is investigated once more before exiting to PRIMOV.

In the event that NTARG was not killed, SELDEF is called. Upon the return to FIRKON, N wants to know if his target is still available for fire. If not available, the same procedure is taken as if NTARG had been killed, i.e., resetting clocks, calling ZERO, etc.

If NTARG is available, subprogram PRIOR is called to determine whether continued fire will be concentrated on NTARG or another element. If the mission of fire is to be continued, the fire clock is incremented and the detection clock set to infinity. UPDATE is called and then N is returned to PRIMOV for the next element.

Should PRIOR decide that at this time there is no potential target,

N resets clocks, calls ZERO, etc. Call UPDATE then return to PRIMOV.

The last case to be considered in FIRKON is the special event tactics, i.e., grenade fire or smoke/gas. Smoke/gas tactics are not yet played.

Call BLAST for grenade fire. Initially it is assumed that if the firer N is trying to put a grenade through an aperture that he will be successful unless other instructions indicate to the contrary.

Initialize variables to identify N's target and the target's sector. Set N's grenade ammo type and call TARLOK to determine whether NT is in a structure, on it, or outside of it. TARLOK also returns the parallelogram associated with NT's feet, e.g., the street, or the first floor of a building.

If NT is in a building the "hole" associated with target NT is found. This is the "lookout hole" NT is using. The hole, NHO, is used in conjunction with /NSTACC/ to determine the wall, floor, and ceiling parallelograms associated with an enclosure. For example: a front hallway, a side hallway, or two different room types. The hole parallelogram NHO is established and a call to VECTOR is made to aid in calculating the center of the opening. A vector is extended from N's firing eye (center top of cylinder) F through the hole for a distance of 1000 meters (since measurement of error is in mils). Delivery error is added to aim error in the proper quadrant and this becomes vector U. Set up the difference vector $D = U - F$.

IMPACT is called and takes the vectors F and D and determines if their sum intersects NHO.

IMPACT calculates a value T(3). If T(3) is less than zero, the projectile will not go through the hole, and LOSE = 1. Since the vector missed the hole, the impact point on the surrounding wall is determined through /LAW/. Call IMPACT again. If the wall is missed ignore the result (projectile, if fired would land in the street some distance away) and return to FIRKON. If the wall was the point of impact of this theoretical fire, call ARM for the decision to fire.

ARM estimates the blast range to the target and gives the decision whether or not to fire (NDEC = 1 or NDEC = 0). Should the okay for fire take place, the ammunition supply is decremented.

The estimation of range is based on the number of rounds previously

fired at the same target. 25% error on first round, 14% error on second round, and 6-7% on 3 or more. If the estimated range is greater than the "mean" arming distance, open fire, i.e., set NDEC = 1. The round may dud if the decision to fire is made and the arming distance is not enough. If this is the first round of battle fire, SETDET is called. Return to FIRKON.

If the decision was made not to fire, the tactic will be regular fire (personal protection) and the multipurpose mode, if there is one, is set to zero. The special event variable in CATCH is also set to zero.

Should N fire, /GROAD/ is incremented by 1. Depending on whether the grenade was fired from a regular or multipurpose weapon, his ammo arsenal is decremented.

If the round wouldn't go through the opening (i.e., LOSE = 1), check for explosion anyway and return to FIRKON. If the round was a dud (NDUD = 1) change tactic to regular fire as previously mentioned.

After passing all of these tests assume the grenade is armed. A check for lethality is made. Loop through all soldier elements and if any of them are within a predetermined vicinity (same street, same floor or same roof), check the element posture (standing or prone), whether offensive or defensive, and obtain the lethal radius from the detonation point in /GLETHR/. If the element is outside of the general suppression radius GSUP, continue element looping. If the soldier is a candidate for incapacitation and if M is in a room, is he in the same room as NT? Number NT's floor parallelogram. Call IMPACT and if T(3) is less than 0.0, M is not in NT's room.

However, if M is in NT's room, check for room suppression (RSUP). If EXPLOD (distance from impact to M) is greater than RAL (lethal radius), there is no lethality, but, there is suppression, in which case TAKOV is called. Go to next element.

If the element is killed however, call CAZASS. Record the kill by weapon type. After all elements are processed return to FIRKON.

Note that this logic was used for NT in a building and the projectile missing the hole. If the projectile can be fired through the hole, we find the impact point in the room containing the hole. There are 5 parallelograms to be checked in the room (or enclosure): left, center and

right walls, the ceiling and the floor (all as viewed by the firer). These parallelograms are constructed by calling RUMOR. So an IMPACT check is then made of the 5 parallelograms to determine which one was hit. Next proceed to call ARM as before and follow that logic through to the return in FIRKON.

If NT is in the street, N will fire at NT only if there exists at least one other enemy element within the standing lethal radius of NT. If NT is eligible, N will fire at the base of NT. Otherwise N will treat the target as a regular target.

If the decision is made to fire at street targets, N extends his fire vector and BLAST follows through in adding aim and delivery error as before. If there is no street impact go to FIRKON, otherwise call ARM and make all the logic checks previously mentioned with regards to NDEC, NDUD, suppression, and casualty levels.

Suppose NT is on the roof. Measure the elevation angle from F to center base NT. Because of the extremely short ranges and the resulting high arching fire, N is limited from firing at targets above his elevation, therefore the elevation angle FANG is compared with the minimum look angle GANG. If FANG is greater than GANG (input as a negative angle from the horizontal) we exit to FIRKON, otherwise N may fire at NT. From this point on, the procedure of extending the vector from F and so forth is followed. After arming and lethality checks, FIRKON is called. Upon returning to FIRKON, one of two things can have happened: N fired a grenade or he has to fire a regular weapon.

If the mission had been a grenade target, increment the detection clock just as if N had no target.

If a new event (regular fire) was requested, call for a target priority by calling PRIOR as in previous PRIOR calls. Call UPDATE and return to PRIMOV.

Suppose finally that PRIMOV must call MOVE. Currently there is no dynamic route movement, breaking and entering, nor search and destroy movement tactics.

The model does simulate pop-up/take cover, street assault, and changing window positions.

The first thing asked of MOVE is whether the current element N is suppressed? If so, reset N's status (otherwise his movement clock wouldn't

have been called). Common/CATCH/ is reset, the detection clock is set to the current time, the current detection sector is retained and the movement clock is set to infinity. A call is then made to MISOBJ, to determine information for input/output to N in terms of assignment.

MISOBJ is called after every movement or casualty event.

If N is not on assault - return to MOVE. Thus N is in some type of assault phase. If N is dead, increment counter KOB by 1. Then a check is made to see if enough elements have been killed to terminate the battle.

Now if N is alive and not moving, exit to MOVE. If however N is moving, has N reached his objective? If he has, a flag MSTOP will have been set in a previous call to MISOBJ. Also, mission counter ASALT is updated, and N's mission is declared finished. ZERO is called and the detection clock is set to the current time and the movement clock to infinity. A check is made to determine if the battle is over. If not, exit to MOVE. If the battle is over, call OMEGA. OMEGA sets flag LBAT = 1 and records the current end of battle time for the return to PRIMOV after calling UPDATE.

Calculate the distance to the point objective. Next compute the time (TD) needed to cover the distance to the objective. Calculate the time interval (DELT) from the current event to the next move event. If TD is greater than DELT, N will not reach his objective at his next ordinary move event, so exit to MOVE.

On the other hand, if the time it takes to reach the objective is less than the time to the next movement event, reset N's movement clock. Set the stop mission flag for N to 1 and return to MOVE.

Suppose therefore that N is not suppressed, is N running across the street? If N is running across the street, set up his next movement clock. Set detection and fire clock to infinity. Call MISOBJ.

If N is not running across the street, should he? Establish the assault team number of N from common/MASTM/.

If N is not on an assault team, check to see if he has to change window positions. Hence if not on assault and no change of window position, set move clock to infinity, call MISOBJ, UPDATE and return to PRIMOV. Window movement may be checked by /MOOV/. Call HOLMOV if N must change "hole" position.

If an element is placed near one side of a hole and is unsuccessful in several tries at spotting a target, even though he may have made several passes through his detect sectors, he can move to the other side of the hole by using HOLMOV for possibly a better look.

At this point one of 4 movement decisions must be made:

1. cross street
2. enter structure
3. search a structure
4. change window position.

Items 2 and 3 have not yet been detailed. Item 4 can be explained with #1.

Suppose N is to cross a street. N is on team NAT. Is it NAT's turn to cross? Establish street crossing team priority. From /KROSS/ find the team waiting to cross the street. If there is no crossing team, set movement clock to infinity and call MISOBJ and UPDATE. Then return to PRIMOV.

Suppose that a team is waiting to cross. Is N on this waiting team? If not, then is this waiting team alive? If not, a new team must be established. Loop through all of the battle elements and if the assault team number of element LV is not the same as the current team number, continue through the loop. Otherwise set a counter IT and if LV is not dead, set another counter IK. After processing all NTSOLD elements, if IT is not equal to IK, there are still live elements on the team waiting to cross next. Then set up the next movement clock for N and if N is moving, set his detection and fire clocks to infinity. Call MISOBJ and UPDATE before returning to PRIMOV.

If everyone on the waiting list is dead, establish a new waiting team. Update /KROSS/ by 1. If N is not on the new waiting team, set up the next movement clock, set detection and fire clocks to infinity and call MISOBJ and UPDATE before going to PRIMOV.

Now if N is on the new waiting team or the team waiting to cross next-determine whether it is all right for team NAT to move. The three areas of determination are:

1. Leader command time given
2. Fire silence for a certain period of time, or
3. Cover fire provided by N's squad.

Only option 1 is currently being played.

If the leader has not given a command rush time for this waiting team, set up the next movement clock, set detection and fire clocks to infinity, call MISOBJ and UPDATE and return to PRIMOV. Hence, if TIMA is a command time greater than 0.0, set up the move times for elements of assault team NAT.

Loop through all NTSOLD elements and check to see whether the assault team number of element KK is equal to the assault team number of N and that KK has not been killed. If these conditions are satisfied, the movement clock of KK is set equal to TIMA (time of assault) for NAT.

Has the command assault time been reached? That is, is TIMA (NAT) less than or equal to the current time? If not, set detection and fire clocks to infinity (this will be eventually changed to allow for the performance of other functions while waiting to cross the street), call MISOBJ and UPDATE, then return to PRIMOV.

If the assault time is at hand, set the new waiting team number into /KROSS/.

If the new waiting team number is larger than the total number of input teams or is not a team number belonging to N's side, set the wait team number to zero.

Check through all NTSOLD elements for setting up velocity direction vectors. If element JJ is dead or JJ is not on the present assault team, return to the loop.

Calculate the distance to the objective in the x-y plane. Set the movement velocity from /WORK/, depending on regular movement, or a crawl velocity for moving past a window.

The velocity is divided by the distance to the objective and multiplied by the distance from N to the objective in the x and y direction. This forms the velocity vector per increment of time. Set the move flag in /MOBILE/ to zero.

If JJ is moving past a window - suppress him by making changes in /CATCH/.

Set up the next movement clock, check for fire on the move, set the detection and fire clocks to infinity. Call MISOBJ and UPDATE before

returning to PRIMOV.

At this point, after LBAT is set equal to 1 in OMEGA, the battle ends (because the total alive and dead crossing the street equal the total number on the rush team). Then the casualty summaries are prepared for the cover team, the rush and defensive teams. Other items like the end of battle time, force ratio of survivors and so forth are also summarized.

Every so often, subroutine COMOUT is called from EVSEL and many important commons are printed out for debugging and information purposes.

SUBROUTINE INDEX OF APPENDIX A

ARM	A - 7, 19
AVAIL	A - 2, 10-11
BLAST	A - 7, 17, 19
BRAIN	A - 2, 5
CAZASS	A - 13, 16
COMOUNT	A - 2
DETECT	A - 2-4
DISPDT	A - 7-10
EVSEL	A - 2, 23
FIRKON	A - 6-7, 9-19
FIRMOD	A - 11-13, 16
FRANUD	A - 15
GAUSS	A - 12-13
HOLMOV	A - 20-21
IMPACT	A - 17-19
MAIN	A - 1
MISOBJ	A - 14, 20-22
MOVE	A - 19-20
OMEGA	A - 20
PRIMOV	A - 1-2, 6, 10-11, 14, 16-17, 19-23
PRIOR	A - 6-7, 16, 19
RELOAD	A - 8-9
RUMOR	A - 19
SECAT	A - 3, 6, 11
SECDET	A - 3, 11
SEE	A - 3, 6, 11
SELDEF	A - 14, 16
SETDET	A - 14, 16, 18
TAKOV	A - 15, 18
TARLOK	A - 17
TARTYP	A - 5
UPDATE	A - 6-7, 10-11, 14, 16-17, 19-22
VECTOR	A - 17
VISION	A - 3-4, 6
ZERO	A - 6, 10-11, 13-16, 20

APPENDIX B

DESIGNER COMMENTS ON URBWAR

B.0 As a simulation model, URBWAR has encountered unusual limitations in the construction and implementation of a realistic scenario. For example, battlefield elements are cylindrically shaped, and hard objects (like buildings) are made up of collections of parallelograms. Naturally, as the exterior and interior design increases in complexity, the number of parallelograms to be constructed and stored multiply at an enormous rate. For the present model, each warehouse type building consisted of nine window holes, a door opening, main floor and a roof, as well as the four exterior walls. The rooms are created as needed by subroutine RUMOR. To do two buildings in this manner required almost 100 parallelograms. A sophisticated four story building, with rooms, staircases, elevators, furniture, could probably encompass 1,000 parallelograms. A small scenario of five similar structures would occupy about the same data storage as the basic terrain scenario of DYNTACS.

All of this is manageable once everything is constructed but the problems are even deeper.

There must be the capacity to create "holes." These holes are brought about by explosions and falling rubble to realistically simulate urban warfare conditions. These holes must be retained through the end of the battle run and be incorporated in all line-of-sight decisions. This is where the real problems arise due to the vast numbers of parallelograms.

Detection and line-of-sight depend on the ability of an element to see another element in spite of intervening structures. Therefore, numerous parallelogram impact checks must be made to determine cover and presented area.

In general, this is accomplished by breaking down the impact parallelogram checks by first checking for total building intersection and then breaking it down to the holes in the particular building.

The possible, repeated checks of thousands of parallelograms, every detection event, while not boring to a computer, is bound to consume some significant time in a long simulation, though how much is not known, or can even be guessed at this time.

These detection checks are made in the following routines: DETECT, MOVE, and FIRE events, for establishing a target, for checking a path to travel on, and for determining target availability.

Detection in URBWAR is a "real" 3-dimensional problem. The Z-coordinate cannot be assigned arbitrarily to every (x,y) value because of non-hilly terrain, and obstacles with holes in them. For example, an element will enter a building by crawling through a hole, or several holes in a wall, or maybe through underground tunneling. Movement is not merely an (x,y) situation with the third dimension only considered from a basic terrain viewpoint, because URBWAR is a micro model.

Other situations of difficulty are in an adequate representation of a human being in movement, detection, firing, reloading, etc. However, most of these items are actions which mostly involve movement.

Urban warfare is difficult because the rules are more general than in an armored engagement. Taking a building is a broad problem, because once you are inside, it is like starting all over again, many times. Casualties are high, cover is excellent and advance or retreat can be a nebulous proposition, because "direction" is not well defined.

Knowing the enemy force strength, both in men and weapons is often crucial, in addition, strongpoints (heavy barricading, machine guns, special purpose weaponry) must be considered by both attack and defense.

Other problem areas are: quantitative descriptions of suppression, initial element emplacement, modes of fire.

Some questions which become evident as the battle is in progress are: When is fire superiority obtained?; Which room should be cleared next?; Which direction to move for retreat?; Where should a grenade be thrown or gas dispersed for maximum effect?

It seems as if problems are the only area of comment, but it is problems like the above and others that bring about expansion, solutions, and refinement.

APPENDIX C

URBWAR COMMON DEFINITIONS

AIM

CONTENTS: The sweep fire aimpoint used for firing at one element.

ARRANGEMENT: AIM(I), for I = 1,2,3
gives the aimpoint coordinates (x,y,z).

INITIALIZATION: Zero

USERS: FIRKON, HOLECH

AIMPT

CONTENTS: Aimpoints for sweep fire against off/def targets.

ARRANGEMENT: AIMPT(I,J) is a 2-dimensional array where

I = 1,2,3	for the (x,y,z) coordinates used in
J = 1	the left aimpoint (as seen by the defense
J = 2	the right aimpoint (as seen by the defense
J = 3	the left aimpoint (as seen by the offense
J = 4	the right aimpoint (as seen by the offense

INITIALIZATION: Zero

USERS: FIRMOD

AMOMAX

CONTENTS: Maximum weapon ammo load.

ARRANGEMENT: AMOMAX(I) contains max ammo load for weapon type I = 1, ..., NWPTYP where NWPTYP is the total number of weapon types.

INITIALIZATION: Required (Integer)

USERS: RELOAD

ASALT

CONTENTS: Assault function of each element. 0 = no assault; 1 = cross street; 2 = enter structure; and 3 = search structure.

ARRANGEMENT: ASALT(I) contains assault mission of element I, I = 1, ..., NTSOLD where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: MISOBJ, MOVE

ASLTIM

CONTENTS: Assault times assigned to rush teams by squad leader.

ARRANGEMENT: ASLTIM(I) contains the rush time for each assault team I, I = 1, ..., NOFAT where NOFAT is the total number of assault teams.

INITIALIZATION: Required

USERS: MOVE

AUTOFR

CONTENTS: Automatic fire only. The number of rounds to be fired per aimpoint, and the number of rounds fired for various burst lengths.

ARRANGEMENT: AUTOFR(J,K) is a 2-dimensional array containing the number of rounds to be fired per aimpoint (J = 1) for sweep fire on a short burst (I = 1) or a long burst (I = 2). For J = 2, the number of rounds to be fired in a short burst (I = 1) or a long burst (I = 2).

INITIALIZATION: Required (Integer)

USERS: FIRKON, FIRMOD

AVGAC

CONTENTS: The average presented area of a sector with no visible targets and the average (percent) contrast of a sector with no detected target.

ARRANGEMENT: AVGAC(I,J) is a 2-dimensional array containing the average presented area of sector J (J = 1, ..., NSEKT) where I = 1, and the average contrast (percent) of a sector with no detected targets. NSEKT is the total number of sectors.

INITIALIZATION: Required

USERS: SECAT, SEE

BATEN

CONTENTS: The battle status and time battle has ended.

ARRANGEMENT: BATEN(I) for I = 1 contains the battle status (0 = battle not over, 1 = battle is over), and for I = 2 the time (real) the battle has ended.

INITIALIZATION: Zero

USERS: OMEGA, PRIMOV

BLOAD

CONTENTS: The type of grenade launcher, the amount of M - P ammo loaded, and the amount of M - P ammo in supply.

ARRANGEMENT: BLOAD(I,J) is a 2-dimensional array which contains for I = 1 the grenade launcher type number, for I = 2 the amount of M - P ammo loaded, and for I = 3 the amount of M - P ammo remaining in supply. J = 1,...,NTSOLD where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: BLAST

CANSWP

CONTENTS: The sweep fire status of each element.

ARRANGEMENT: CANSWP(I) contains the sweep fire go ahead for each element I, I = 1,...,NTSOLD where NTSOLD is the total number of elements. If CANSWP(I) > 0 the element can sweep fire.

INITIALIZATION: Required (Integer)

USERS: AVAIL, FIRKON, FIRMOD, VISION

CATCH

CONTENTS: A catch all fire condition array.

ARRANGEMENT: CATCH(I,J) is a 2-dimensional array used for each element J, $J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements, and containing for

I = 1, suppression (0 = none; 1 = exists)
I = 2, special event status (0 = none; 1 = exists)
I = 3, fire on move (0 = no; 1 = yes)
I = 4, fire data entry (0 = none; otherwise the number of fire data entry is used)
I = 5, self-defense (0 = none; 1 = exists)
I = 6, firing (0 = no; 1 = yes)

INITIALIZATION: Zero (Integer)

USERS: BLAST, CAZASS, COMOUT, DISPDT, FIRKON, FIRMOV, MOVE, PRIOR, SEE, SETDET, TAKOV, TARTYP

CTRCD

CONTENTS: Center base coordinates of each element.

ARRANGEMENT: CTRCD(I,J) is a 2-dimensional array for element J, $J = 1, \dots, \text{NTSOLD} + \text{NDUME}$ where NTSOLD is the total number of elements and NDUME is the total number of "ghost" elements, and contains the (x,y,z) coordinates of each J for $I = 1, 2, 3$.

INITIALIZATION: Required

USERS: BLAST, CAZASS, COMOUT, FIRMOD, HOLMOV, MAIN, MISOBJ, MOVE, PRIMOV, PRIOR, RANPL, SECAT, SECHK, SEE, SELDEF, TARLOK, TARTYP, UPDATE

CURWEP

CONTENTS: The current weapon type used by an element.

ARRANGEMENT: CURWEP(I) contains the weapon type used by element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: ARM, BLAST, DISPDT, FIRKON, FIRMOD, RELOAD, TAKOV

CYCLIC

CONTENTS: Weapon cyclic firing rate per minute.

ARRANGEMENT: CYCLIC(I) contains the weapon firing rate for weapon type I, $I = 1, \dots, \text{NWPTYP}$ where NWPTYP is the total number of weapon types.

INITIALIZATION: Required

USERS: FIRKON

DEBUG

CONTENTS: Flag set for debugging subprograms.

ARRANGEMENT: DEBUG(I) contains the event number in which debugging will occur in subroutine I. Each subroutine is assigned a number.

INITIALIZATION: Required (Integer)

USERS: MAIN, MISOBJ, VISION

DET

CONTENTS: The number of times a specific target has gone undetected by a specific firer.

ARRANGEMENT: DET(I,J) is a 2-dimensional array containing the number of times firer J ($J = 1, \dots, \text{NTSOLD}$) has not detected potential target I ($I = 1, \dots, \text{NTSOLD}$), where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: SEE

DIHENC

CONTENTS: Dimensions of enclosures.

ARRANGEMENT: DIHENC(I,J) is a 2-dimensional array giving the width, depth, and height lengths I ($I = 1, 2, 3$) for hallways, and room types for enclosure J ($J = 1, \dots, \text{NCTYP}$), where NCTYP is the total number of enclosure types.

INITIALIZATION: Required

USERS: RUMOR

DISPER

CONTENTS: Firing error data.

ARRANGEMENT: DISPER(I,J) is a 2-dimensional array containing the firing error constants I associated with J firing modes where for

$I = 1, \dots, 10$ and $J = 1, \dots, \text{NDISP}$ where NDISP is the total number of firing modes. A firing mode is defined as: 1. Offense or defense, 2. Weapon type, 3. Mount, 4. Type of fire, 5. Posture, 6. Type of aim, 7. Target type.

The ten firing error constants are: 1. The x and y coordinates of the actual aimpoint relative to the center base of the rectangular target; 2. The total delivery error coordinates of the projectiles with regards to item 1; 3. Coordinates of the center of impact of the subsequent projectiles in a burst; 4. The subsequent projectile dispersion coordinates with regards to item 3; 5. The standard deviations of items of the offsets of impacts in item 3 about first projectile impact.

INITIALIZATION: Required

USERS: FIRMOD

ESTD

CONTENTS: Sight-range estimation error.

ARRANGEMENT: ESTD(I) contains I error estimates ($I = 1, 2, 3$) for estimating range to a target.

INITIALIZATION: Required.

USERS: ARM

EVCLK

CONTENTS: Element event clocks.

ARRANGEMENT: EVCLK(I,J) is a 2-dimensional array containing the next event time for element J ($J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements) for each event type I where

I = 1 is for detection
I = 2 is for movement
I = 3 is for firing
I = 4 is a dummy event

INITIALIZATION: Zero

USERS: BRAIN, CAZASS, COMOUT, DISPDT, EVSEL, FIRKON, MISOBJ, MOVE, PRIMOV, SELDEF, SETDET, TAKOV.

FDET

CONTENTS: Detection data obtained for a point-fire target.

ARRANGEMENT: FDET(I,J) is a 2-dimensional array containing the following information for element J ($J = 1, \dots, \text{NTSOLD} + \text{NDUME}$, where NTSOLD is the total number of elements and NDUME is the total number of ghost elements), presented area ($I = 1$), the S vector ($I = 2, 3, 4$ see subprogram VISION), the height vector of the target ($I = 5, 6, 7$), the width vector of the target ($I = 8, 9, 10$), and the width and height of the target ($I = 11, 12$).

INITIALIZATION: Zero

USERS: CAZASS, COMOUT, DETECT, FIRKON, FIRMOD, PRIOR, VISION, ZERO

GAB

CONTENTS: Air burst grenade.

ARRANGEMENT: GAB(I) defines whether a grenade type I is airburst (1 = yes) or not (0 = no), I = 1, ..., NGATYP where NGATYP is the total number of grenade types.

INITIALIZATION: Required (Integer)

USERS: BLAST

GAD

CONTENTS: Grenade arming distance statistics.

ARRANGEMENT: GAD(I) contains the mean (I = 1) arming distance, and the standard deviation (I = 2).

INITIALIZATION: Required

USERS: ARM

GAT

CONTENTS: Grenade ammo type used by each element.

ARRANGEMENT: GAT(I) contains the ammo type number for each element I.

INITIALIZATION: Required (Integer)

USERS: BLAST

GLAE

CONTENTS: Grenade launcher aiming error.

ARRANGEMENT: GLAE(I,J) is a 2-dimensional array containing the mean x (I = 1), the deviation x (I = 2), the mean y (I = 3), and the deviation y (I = 4). The J value is determined by the number of firing modes (1. Weapon type; 2. 1st, 2nd, 3rd (or more) rounds; 3. Hasty or deliberate delivery of fire), the entry value obtained from subroutine DISPDT.

INITIALIZATION: Required

USERS: BLAST

GLETHR

CONTENTS: The lethal radius of an exploding grenade from point of contact.

ARRANGEMENT: GLETHR(I,J,K) is a 3-dimensional array containing the lethal radius of an exploding grenade based on the mode of fire (1. Grenade ammo types (I); 2. Standing or prone (J); and 3. Offensive or defensive target (K), where $K = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements).

INITIALIZATION: Required

USERS: BLAST

GRADE

CONTENTS: Weapon capability for grenade fire.

ARRANGEMENT: GRADE(I) has a value of 0 if weapon type I can not fire a grenade, a 1 if otherwise.

INITIALIZATION: Required (Integer)

USERS: RELOAD

GRELTM

CONTENTS: Reload time delay for grenade launcher.

ARRANGEMENT: GRELTM(I,J,K,L) is a 4-dimensional array which contains the mean time delay for reload (L=1) and the standard deviation reload time (L=2) for launcher I, number of times previously fired J (if $J > 3$, set $J = 3$), and method of delivery ($J = 1$ is hasty, $J = 2$ is deliberate).

INITIALIZATION: Required

USERS: RELOAD

GROAD

CONTENTS: The number of times each grenade launcher is fired.

ARRANGEMENT: GROAD(I) contains the number of times each grenade launcher is fired by element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: ARM, BLAST, DISPDT, RELOAD

HENC

CONTENTS: Hole enclosure identifier.

ARRANGEMENT: HENC(I) contains the room or hall number (1 = front hall; 2 = side hall; 3 = room type 1; 4 = room type 2 for example) for hole I.

INITIALIZATION: Required

USERS: BLAST, RANPL

HOLD

CONTENTS: A catch all common. Constants.

ARRANGEMENT: HOLD(I) where for

I = 1 Max. number of sweep fire elements.
I = 2 No. of assault teams at $T = 0.0$.
I = 3 Max. no. of elements in a squad.
I = 4 Number of last event.
I = 5 The number of weapon types.
I = 6 The number of multi-purpose weapon types.
I = 7 The maximum number of soldiers in a sector.
I = 8 The max. no. of detection checks before a decision will be made to change vision sectors.

INITIALIZATION: Required (Integer)

USERS: BRAIN, EVSEL, MISOBJ, MOVE, SECDT, VISION

HOLES

CONTENTS: A listing of the hole numbers accompanying each sector.

ARRANGEMENT: HOLES(I,J) is a 2-dimensional array listing the hole numbers for each sector J ($J = 1, \dots, \text{NSEKT}$ where NSEKT is the total number of sectors), with IHOLMX ($I = 1, \dots, \text{IHOLMX}$) holes allowed per sector.

INITIALIZATION: Required

USERS: VISION

HOLWAL

CONTENTS: The wall number associated with each hole.

ARRANGEMENT: HOLWAL(I) contains the parallelogram wall number (see NSTACC and PARALL) for each hole I, $I = 1, \dots, \text{IHOLES}$ where IHOLES is the total number of holes.

INITIALIZATION: Required

USERS: BLAST

IRANDX

CONTENTS: Random number generator index.

ARRANGEMENT: IRANDX(I) is a series of 5 numbers (1,0,0,0,0) used in generating random numbers.

INITIALIZATION: Required

USERS: FRANUD, RANND

JGLAE

CONTENTS: Numbers referencing grenade fire data.

ARRANGEMENT: JGLAE(I) contains an indexed number referring to:
1. grenade launcher type; 2. number of rounds fired; and 3. hasty or deliberate fire. $I = 1, \dots, JGDISP$ where JGDISP is the total number of grenade firing modes.

INITIALIZATION: Required

USERS: DISPDT

KILL

CONTENTS: Kill status of each element.

ARRANGEMENT: KILL(I) contains: 0 = no kill; 1 = wound; or 2 = dead for each element I, $I = 1, \dots, NTSOLD$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero (Integer)

USERS: CAZASS, COMOUT, FIRKON, FIRMOD, MISOBJ, MOVE, PRIMOV,
SEE

KNOW

CONTENTS: Playable detection tactics.

ARRANGEMENT: KNOW(I) contains prior battle knowledge ($I=1$), viz. 1 = offense is aware of defense; 2 = defense is aware of offense; 3 = both sides are aware of each other; and who fired first ($I = 2$), offense or defense.

INITIALIZATION: Required (Integer)

USERS: MAIN, PRIMOV

KOMAND

CONTENTS: Pre-emplacement movement decisions.

ARRANGEMENT: KOMAND(I,J) contains a 0 for freedom to move and a 1 indicates a stop movement for element $J = 1, \dots, \text{NTSOLD}$ (where NTSOLD is the total number of elements) and I will range across the number of different types of movement positions.

INITIALIZATION: Required (Integer)

USERS: BRAIN

KOUNT

CONTENTS: A counter to record the number of times each event is called by each element.

ARRANGEMENT: KOUNT(I,J) is a 2-dimensional array containing the number of times each event I ($I = 1, \dots, 4$) is called by element J, $J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: DETECT, FIRKON, MOVE

KROSS

CONTENTS: The number of the team waiting to assault the street.

ARRANGEMENT: KROSS(I), contains the offensive team number waiting to rush ($I = 1$) and the defensive team number waiting to rush ($I = 2$).

INITIALIZATION: Required (Integer)

USERS: MOVE

KSTOR

CONTENTS: The "holes" through which a target is sighted by a sweep fire element.

ARRANGEMENT: KSTOR(I,J) is a 2-dimensional array containing the "hole" parallelogram numbers by which a target was sighted by a sweep fire element J, $J = 1, \dots, \text{NTSOLD}$ (NTSOLD is the total number of elements). $I = 1, \dots, \text{MAXSWP}$ where MAXSWP is the maximum number of allowable sweep fire elements.

INITIALIZATION: Zero

USERS: VISION

LASEV

CONTENTS: Retains the last event number for each element.

ARRANGEMENT: LASEV(I) contains the last event number for each element I, $I = 1, \dots, \text{NTSOLD}$, where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: EVSEL

LMDET

CONTENTS: The numbers of successive sector checks resulting in no target detected.

ARRANGEMENT: LMDET(I) contains the number of sector checks that have been made in succession with no resulting target detection by element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: BRAIN

LOCTAR

CONTENTS: Element location, building, street, or roof.

ARRANGEMENT: LOCTAR(I) contains a 1 (building), 2(street), or a 3 (roof) for each element I, $I = 1, \dots, \text{NTSOLD} + \text{NDUME}$ where, NTSOLD is the total number of elements and NDUME is the total number of "ghost" elements.

INITIALIZATION: Required (Integer)

USERS: BLAST, BRAIN, DETECT, DISPDT, FIRKON, MOVE, PRIOR, RELOAD, SEE, TAKOV, TARLOK, VISION

LTR

CONTENTS: Direction of sweep fire.

ARRANGEMENT: LTR(I) contains the direction (left to right or right to left) of sweep fire by each element I. (See FIRKON).

INITIALIZATION: Required (Integer)

USERS: FIRKON

MASTM

CONTENTS: Assault team number.

ARRANGEMENT: MASTM(I) contains the assault team number for each element I, $I = 1, \dots, \text{NTSOLD}$ (NTSOLD is the total number of elements). A zero is entered if I does not belong to an assault team.

INITIALIZATION: Required (Integer)

USERS: MOVE

MGTYP

CONTENTS: The grenade launcher type used by each element.

ARRANGEMENT: MGTYP(I) contains for each I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements, the grenade launcher type number (a zero is entered if I has no grenade launcher).

INITIALIZATION: Required (Integer)

USERS: DISPDT, RELOAD

MISC

CONTENTS: Miscellaneous grenade information.

ARRANGEMENT: MISC(I) contains for $I = 1$, the distance of bounce back along trajectory of an air-burst grenade. For $I = 2$, the grenadier "look" elevation angle (radians) from the horizontal, above which grenade fire may not be utilized.

INITIALIZATION: Required

USERS: BLAST

MOBILE

CONTENTS: Movement determination of an element.

ARRANGEMENT: MOBILE(I) contains a 0 = no movement, or a 1 = element is moving for each element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero.

USERS: COMOUT, DETECT, FIRKON, MISOBJ, MOVE, TAKOV, TARTYP, UPDATE

MOOV

CONTENTS: Movement decisions for elements.

ARRANGEMENT: MOOV(I,J) is a 2-dimensional array containing for each element J, $J = 1, \dots, \text{NTSOLD}$ (NTSOLD is the total number of elements) various movement decisions I. For $I = 1$, a 0 indicates no window movement, and 1 indicates element J should change window position.

INITIALIZATION: Zero (Integer)

USERS: BRAIN, MOVE

MSTOP

CONTENTS: Current mission status:

ARRANGEMENT: MSTOP(I) contains a 0 for continuing the current mission or a 1 if the current mission should cease, for each I, where $I = 1, \dots, \text{NTSOLD}$, where NTSOLD is the total number of elements.

INITIALIZATION: Zero (Integer)

USERS: MISOBJ

MULMOD

CONTENTS: Weapon mode in use by elements.

ARRANGEMENT: MULMOD(I) contains

0 if weapon is in the primary mode, or
1 if weapon is to fire multi-purpose round, or
2 if element has no weapon

for $I = 1, \dots, \text{NTSOLD}$
where NTSOLD is the total number of weapons.

INITIALIZATION: Required (Integer)

USERS: BLAST, DISPDT, TARTYP

MULTI

CONTENTS: Weapon multi-purpose designation.

ARRANGEMENT: MULTI(I) contains a

0 - if weapon is not M-P, or
1 if weapon is M-P

for each I, where $I = 1, \dots, \text{NTSOLD}$
where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: TARTYP

MWEPT

CONTENTS: Weapon compatibility with target type.

ARRANGEMENT: MWEPT(I,J) is a 2-dimensional array containing a

0 if weapon J is not compatible with target type
I, or a
1 if they are compatible, where

$I = 1, \dots, \text{NMEV}$ and NMEV is the number of mission
event types (1. quick fire, 2. personal protec-
tion, 3. grenade or blast, 4. sweep or area,
5. other) and $J = 1, \dots, \text{NWPTYP}$ where NWPTYP is
the total number of weapon types.

INITIALIZATION: Required (Integer)

USERS: RELOAD

NB

CONTENTS: Building (structure) ownership of building (structure)
features (such as walls, holes, floors, etc).

ARRANGEMENT: NB(I) contains a 1 for offensive ownership, or a 2
for the defense for each I, where $I = 1, \dots, \text{NTOTSK}$
where NTOTSK is the total number of parallelogram
structures.

INITIALIZATION: Required (Integer)

USERS: RUMOR

NBSIN

CONTENTS: Element designation: offense or defense.

ARRANGEMENT: NBSIN(I) contains a 1 for offensive elements and a 2 for defensive elements, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: BLAST, DISPDT, FIRKON, FIRMOD, MOVE, PRIOR, SECDET, SETDET.

NDET

CONTENTS: Detection characteristics of targets for a potential firer.

ARRANGEMENT: NDET(I,J) is a 2-dimensional array containing for

I = 1 a 0 for no detection; 1 = detection
I = 2 the number of the detected element
I = 3 the window "hole" number that target was seen through (otherwise a 0)
I = 4 sector number hole is in for each element J, $J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: AVAIL, BLAST, BRAIN, CAZASS, COMOUT, DETECT, DISPDT, FIRKON, PRIOR, SEE, SELDEF, VISION, ZERO.

NDETE

CONTENTS: Sector detection information.

ARRANGEMENT: NDETE(I,J) is a 2-dimensional array containing for

- I = 1 the number of cumulative detection checks of current sector by J
- I = 2 max number of current sector checks allowed to J
- I = 3 subscript number of the current sector being checked by J

where

J = 1, ..., NTSOLD and NTSOLD is the total number of elements

INITIALIZATION: Zero

USERS: AVAIL, DETECT, FIRKON, FIRMOD, MOVE

NSTACC

CONTENTS: Level of accumulated structures.

ARRANGEMENT: NSTACC(I) contains for

- I = 1 the total number of off. walls
- I = 2 total number of all walls
- I = 3 accumulated number of walls and off. holes
- I = 4 total number of walls and holes
- I = 5 total walls, holes, and 1st floor off. building
- I = 6 total walls, holes and 1st floors
- I = 7 sum in I = 6 plus off. roofs
- I = 8 total walls, holes, 1st floors, and roofs
- I = 9 sum in 8 plus "created" left wall-enclosure
- I = 10 sum in 9 plus "created" center wall-enclosure
- I = 11 sum in 10 plus "created" right wall-enclosure
- I = 12 sum in 11 plus "created" ceiling-enclosure
- I = 13 sum in 12 plus "created" floor-enclosure
- I = 14 sum in 13 plus battlefield(x,y) plane
- I = 15 sum of all structures plus a "dummy"

INITIALIZATION: Required

USERS: BLAST, MAIN, RANPL, RUMOR, TARLOK, VISION

NUMBER

CONTENTS: Catch all for various often used numbers.

ARRANGEMENT: NUMBER(I) contains for

I = 1	the total number of defensive elements
I = 2	the total number of offensive elements
I = 3	the total number of elements
I = 4	the max number of holes per sector
I = 5	the total number of tactics
I = 6	the number in off. assault team
I = 7	the number in off. suppression team
I = 8	the total number of sectors
I = 9	the number of event clocks
I = 10	infinity (1,000,000.)
I = 11	the number of event types
I = 12	the number of off. assault teams
I = 13	max number of sectors assigned per element
I = 14	the total number of regular weapon firing modes.
I = 15	the total number of grenade firing modes
I = 16	the total number of habitable structures in the scenario

INITIALIZATION: Required (Integer)

USERS: BLAST, BRAIN, CAZASS, COMOUT, DETECT, DISPDT, EVSEL, FIRKON, FIRMOD, MAIN, MISOBJ, MOVE, OMEGA, PRIMOV, PRIOR, SECDT, SECHK, SETDET, TAKOV, UPDATE, VISION, UPDATE

NUMLST

CONTENTS: Numbers referencing regular weapon fire modes.

ARRANGEMENT: NUMLST(I) contains for each I, I = 1, ..., NDISP (where NDISP is the total number of regular weapon modes), a 7-digit integer. The 1st digit defines whether the firer is offensive or defensive, the 2nd the weapon type, the 3rd the mount type, the 4th the fire type, the 5th the posture, the 6th the aimpoint type, and the 7th the target type. See common/STANCE/ for detailed information.

INITIALIZATION: Required (Integer)

USERS: DISPDT

OBJV

CONTENTS: The coordinates of each element's next objective.

ARRANGEMENT: OBJV(I,J) is a 2-dimensional array with I, I = 1,2,3 representing the (x,y,z) coordinates for each element J, J = 1,...,NTSOLD where NTSOLD is the total number of elements.

INITIALIZATION: Required

USERS: HOLMOV, MAIN, MISOBJ, MOVE, RANPL

PARALL

CONTENTS: The pointing array for all parallelograms at t = 0.0.

ARRANGEMENT: PARALL(I,J) is a 2-dimensional array containing for

I = 1 the upper left reference point of
 parallelogram J
I = 2 the lower left reference point of
 parallelogram J
I = 3 the lower right reference point of
 parallelogram J,

where

J = 1,...,NTOTSK and NTOTSK is the total number
of parallelograms in the scenario.

INITIALIZATION: Required (Integer)

USERS: BLAST, HOLECH, HOLMOV, IMPACT, RANPL, RUMOR, VISION

POINTS

CONTENTS: Coordinates of each parallelogram reference point.

ARRANGEMENT: POINTS(I,J) is a 2-dimensional array containing the (x,y,z) coordinates (I = 1,2,3) for each reference point J, J = 1,...,NPTS where NPTS is the total number of points needed to describe all parallelograms (which may include "created" rooms, or some other use for a dummy parallelogram).

INITIALIZATION: Required

USERS: BLAST, COMOUT, FIRMOD, HOLMOV, HOLECH, IMPACT, PRIMOV, RANPL, RUMOR, VECTOR, VISION

POSTHT

CONTENTS: Posture height for an average element.

ARRANGEMENT: POSTHT(I) contains for

I = 1	standing height
I = 2	kneeling height
I = 3	sitting " (on floor level)
I = 4	prone "

INITIALIZATION: Required

USERS: BLAST, PRIMOV, SECHK, SELDEF, TARLOK, VISION

POSTRA

CONTENTS: Posture radius for an average element.

ARRANGEMENT: POSTRA(I) contains for

I = 1	standing radius
I = 2	kneeling radius
I = 3	sitting radius (on floor level)
I = 4	prone radius

INITIALIZATION: Required

USERS: VISION

PROB

CONTENTS: Constants used to determine kill probabilities.

ARRANGEMENT: PROB(I,J) is a 2-dimensional array containing for I = 1,2,3 the constants used in determining kill probabilities from B.R.L. report # 1269 for J = 1 (offensive) and J = 2 (defensive)

INITIALIZATION: Required

USERS: FIRMOD

PROMAS

CONTENTS: The number of grains in projectile for each weapon.

ARRANGEMENT: PROMAS(I) contains the number of grains in the projectile used for firing from weapon type I, $I = 1, \dots, \text{NWPTYP}$ where NWPTYP is the total number of weapon types.

INITIALIZATION: Required (Integer)

USERS: FIRMOD

QUICK

CONTENTS: Quick fire capability.

ARRANGEMENT: QUICK(I) contains a 0 if weapon type I is not capable of quick fire and a 1 otherwise, for $I = 1, \dots, \text{NWPTYP}$ where NWPTYP is the total number of weapon types.

INITIALIZATION: Required (Integer)

USERS: DISPDT.

RANDOM

CONTENTS: Random number.

ARRANGEMENT: RANDOM(I) contains the current random number.

INITIALIZATION: Zero (Integer)

USERS: FRANUD, MAIN, PRIMOV

REACTM

CONTENTS: Firing reaction times.

ARRANGEMENT: REACTM(I) contains for

I = 1	time to make a firing change
I = 2	time to change aim
I = 3	time to change posture
I = 4	time to change mount

INITIALIZATION: Required

USERS: DISPDT, SETDET

REFENC

CONTENTS: Lower left reference point of any enclosure (from the front)

ARRANGEMENT: REFENC(I,J) is a 2-dimensional array containing a reference coordinate (x,y,z) for (I = 1,2,3) at the lower left front position for each hole J, J = 1,...,IHOLE where IHOLE is the total number of enclosure holes.

INITIALIZATION: Required

USERS: MAIN, RUMOR

RELDMU

CONTENTS: Mean time for regular weapon reload.

ARRANGEMENT: RELDMU(I) contains the average reload time for each regular weapon type I, I = 1,...,NWPTYP where NWPTYP is the total number of weapon types.

INITIALIZATION: Required

USERS: RELOAD

RELDSD

CONTENTS: Standard deviation time for regular weapon reload.

ARRANGEMENT: RELDSD(I) contains the standard deviation time for reloading each regular weapon type I, I = 1, ..., NWPTYP where NWPTYP is the total number of weapon types.

INITIALIZATION: Required

USERS: RELOAD

ROOM

CONTENTS: Room adjustment factor for creating "enclosures" depending on the direction the building is facing.

ARRANGEMENT: ROOM(I,J) is a 2-dimensional array containing width and depth constants (-1 to +1 range) for I = 1 and I = 2 and offense (J = 1) or defense (J = 2).

INITIALIZATION: Required (Integer)

USERS: RUMOR

SCENAR

CONTENTS: Scenario information.

ARRANGEMENT: SCENAR(I) contains for

I = 1	Basic street width between two buildings.
I = 2	Front building length.
I = 3	Building width.
I = 4	Rotation of defensive building.
I = 5	Number of points used in creating offensive building.
I = 6	Number of sector points for offensive building.

INITIALIZATION: Required (Integer)

USERS: MAIN, PRIMOV

SECLOK

CONTENTS: Sector location of each element.

ARRANGEMENT: SECLOK(I) contains the sector number containing each element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of soldiers.

INITIALIZATION: Required (Integer)

USERS: BLAST, BRAIN, FIRKON, PRIOR, SECDET, SECHK, SELDEF, VISION.

SECORD

CONTENTS: Coordinates of each sector point.

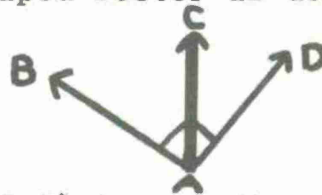
ARRANGEMENT: SECORD(I,J) is a 2-dimensional array containing (x,y,z) coordinates ($I = 1, 2, 3$) for each sector J, $J = 1, \dots, N$ where N is the total number of sector points.

INITIALIZATION: Required

USERS: PRIMOV, SECAT, SECHK

SECPTS

CONTENTS: A point array description of each sector, i.e., each parallelepiped sector is described by 4 sector points.



ARRANGEMENT: SECPTS(I,J) is a 2-dimensional array containing for each sector J, $J = 1, \dots, \text{NSEKT}$ where NSEKT is the total number of sectors, the reference point A ($I = 1$) measured from the origin (0,0,0), the reference point B, the lower left vector ($I = 2$), the point C, the upper vector ($I = 3$), and the point D, the lower right vector ($I = 4$).

INITIALIZATION: Required (Integer)

USERS: FIRMOD, SECAT, SECHK

SECTOR

CONTENTS: The sectors assigned to each element.

ARRANGEMENT: SECTOR(I,J) is a 2-dimensional array containing for element J, $J = 1, \dots, \text{NTSOLD}$ (where NTSOLD is the total number of elements), the numbers of the MXFSEC sectors allowed to J, where $I = 1, \dots, \text{MXFSEC}$ and MXFSEC is the total number of sectors.

INITIALIZATION: Required (Integer)

USERS: AVAIL, DETECT, FIRKON, PRIOR

SOLMOD

CONTENTS: The active mode of each element.

ARRANGEMENT: SOLMOD(I) contains a 1 if element I is offering cover fire, a 2 for attack, or a 3 for defense for $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: DISPDT

SOLOAD

CONTENTS: Weapons and ammunition supply for each element.

ARRANGEMENT: SOLOAD(I,J) is a 2-dimensional array containing the primary and secondary weapon types for element J in $I = 1$ and $I = 2$ respectively. The primary and secondary weapon loaded ammo supply is in $I = 3$ and $I = 4$. The carried ammo supply for primary and secondary weapons is in $I = 5$ and $I = 6$. $J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of soldiers.

INITIALIZATION: Required (Integer)

USERS: ARM, BLAST, COMOUT, FIRKON, FIRMOD, RELOAD

SOLVEL

CONTENTS: The velocity vector of each element.

ARRANGEMENT: SOLVEL(I,J) is a 2-dimensional array containing for I = 1,2,3 the velocity vector components for each element J, J = 1,...,NTSOLD where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: COMOUT, MOVE, TARTYP, UPDATE

STANCE

CONTENTS: Combat state of each element.

ARRANGEMENT: STANCE(I,J) is a 2-dimensional array containing information about each element J, for I = 1 the mount (1 = shoulder; 2 = hip/underarm; 3 = sandbag; 4 = bipod; 5 = sandbag/bipod; 6 = tripod; 7 = tripod/sandbag); I = 2 the firing rate (1 = semi-automatic; 2 = short burst; 3 = long burst); I = 3 the posture (1 = standing; 2 = kneeling; 3 = sitting (on floor); 4 = prone); I = 4 the sight (1 = point-pointed; 2 = aim-pointed; 3 = aim-bipod-pointed; 4 = aim-bipod/sandbag-pointed; 5 = aim-pointed-sandbag; 6 = aim-tripod-pointed; 7 = aim tripod/sandbag-pointed); I = 5 the tactic (1 = quick fire; 2 = personal protection; 3 = grenade; 4 = sweep fire; 5 = other), where J = 1,..., NTSOLD + NDUME and NTSOLD is the total number of elements and NDUME is the total number of "ghost" elements.

INITIALIZATION: Required (Integer)

USERS: AVAIL, BLAST, COMOUT, DETECT, DISPDT, FIRKON, FIRMOD, PRIMOV, RELOAD, SECHK, SELDEF, TARLOK, TARTYP, VISION

STORE

CONTENTS: Sweep fire information.

ARRANGEMENT: STORE(I,J,K) is a 3-dimensional array containing the sweep firer I (I = 1, ..., MAXSWP where MAXSWP is the max number of sweep fire elements), his intended target K (K = 1, ..., NTSOLD where NTSOLD is the total number of elements), and J pieces of information, where for J = 1 the presented area of target; J = 2,3,4 coordinates of aim-point; J = 5 the target width, and J = 6 the target height.

INITIALIZATION: Zero

USERS: AVAIL, FIRKON, FIRMOD

SUPFIR

CONTENTS: Suppression information.

ARRANGEMENT: SUPFIR(I,J,K) is a 3-dimensional array containing for each target K that is taking cover (K = 1, ..., NTSOLD where NTSOLD is the total number of elements), information on J elements detected, and the number (I = 1) of the element and the sector (I = 2).

INITIALIZATION: Zero (Integer)

USERS: TAKOV

SUPR

CONTENTS: Suppression radius for grenade fire.

ARRANGEMENT: SUPR(I) contains the suppression radius for general suppression (I = 1) and room suppression (I = 2).

INITIALIZATION: Required

USERS: BLAST

SUPRES

CONTENTS: Mission status regarding suppression.

ARRANGEMENT: SUPRES(I) contains a 1 for assault or suppress, a 2 for suppress, a 3 for personal protection, for each element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Required (Integer)

USERS: DISPDT

SUPT

CONTENTS: Suppression times.

ARRANGEMENT: SUPT(I) contains the suppression time for grenade fire when $I = 2$, and the suppression time for other types of fire when $I = 1$.

INITIALIZATION: Required

USERS: TAKOV

TCO

CONTENTS: Miscellaneous information.

ARRANGEMENT: TCO(I) contains for

I = 1	the time between battle map prints,
I = 2	the event type (detection, move, or fire) (Integer)
I = 3	current element number (Integer)

INITIALIZATION: Required for $I = 1$

USERS: EVSEL, MAIN, PRIMOV, UPDATE

TIMLAS

CONTENTS: Clock time of last event for each element.

ARRANGEMENT: TIMLAS(I) contains the clock time of the last event for each element I, $I = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements.

INITIALIZATION: Zero

USERS: EVSEL

TSPFR

CONTENTS: Detection time information obtained by a suppressed element.

ARRANGEMENT: TSPFR(I,J) is a 2-dimensional array containing the time that element J ($J = 1, \dots, \text{NTSOLD}$ where NTSOLD is the total number of elements) detected being fired at. $I = 1, 2$ contains this information for at most 2 elements.

INITIALIZATION: Zero

USERS: TAKOV

VISDET

CONTENTS: Various performance times.

ARRANGEMENT: VISDET(I) contains for

I = 1	the time to utilize quick fire
I = 2	time for detection glimpse
I = 3	time to pop up from suppression (regular weapons)
I = 4	time for street search glance

INITIALIZATION: Required

USERS: SELDEF, TARTYP

WEPKIL

CONTENTS: Weapon used to kill each element.

ARRANGEMENT: WEPKIL(I) contains the weapon type number used to kill the dead elements.

INITIALIZATION: Zero

USERS: BLAST, FIRKON

WINDOW

CONTENTS: The "lookout" parallelogram hole number associated with each element.

ARRANGEMENT: WINDOW(I) contains the hole number (parallelogram) used for looking by each element J (or a zero if none is used), where $J = 1, \dots, \text{NTSOLD} + \text{NDUME}$ where NTSOLD is the total number of elements and NDUME is the total number of "ghost" elements.

INITIALIZATION: Required

USERS: HOLMOV, RANPL, VISION

WMUZVL

CONTENTS: The muzzle velocity of each weapon.

ARRANGEMENT: WMUZVL(I) contains the muzzle velocity for each weapon type I, $I = 1, \dots, \text{NWPTYP}$ where NWPTYP is the total number of weapon types.

INITIALIZATION: Required

USERS: FIRMOD

WORK

CONTENTS: Various information.

ARRANGEMENT: WORK(I) contains for

- I = 1 the objective radius for movement, in which the element will stop (Req.)
- I = 2 the number of elements reaching an objective
- I = 3 the number of elements killed in trying to reach the objectives.
- I = 4 a time-step increment (Req.)
- I = 5 current clock time (battle time)
- I = 6 average running velocity (Req.) of an element
- I = 7 the time increment used for the move **clock** before any actual movement (Req.)
- I = 8 crawling velocity (Req.)
- I = 9 the number of rounds fired

INITIALIZATION: See arrangement.

USERS: ARM, BLAST, BRAIN, CAZASS, COMOUT, EVSEL, FIRKON, MAIN, MISOBJ, MOVE, OMEGA, PRIMOV, SELDEF, SETDET, TAKOV, UPDATE

APPENDIX D

ADDITIONAL URBWAR DYNAMICS GRAPHS

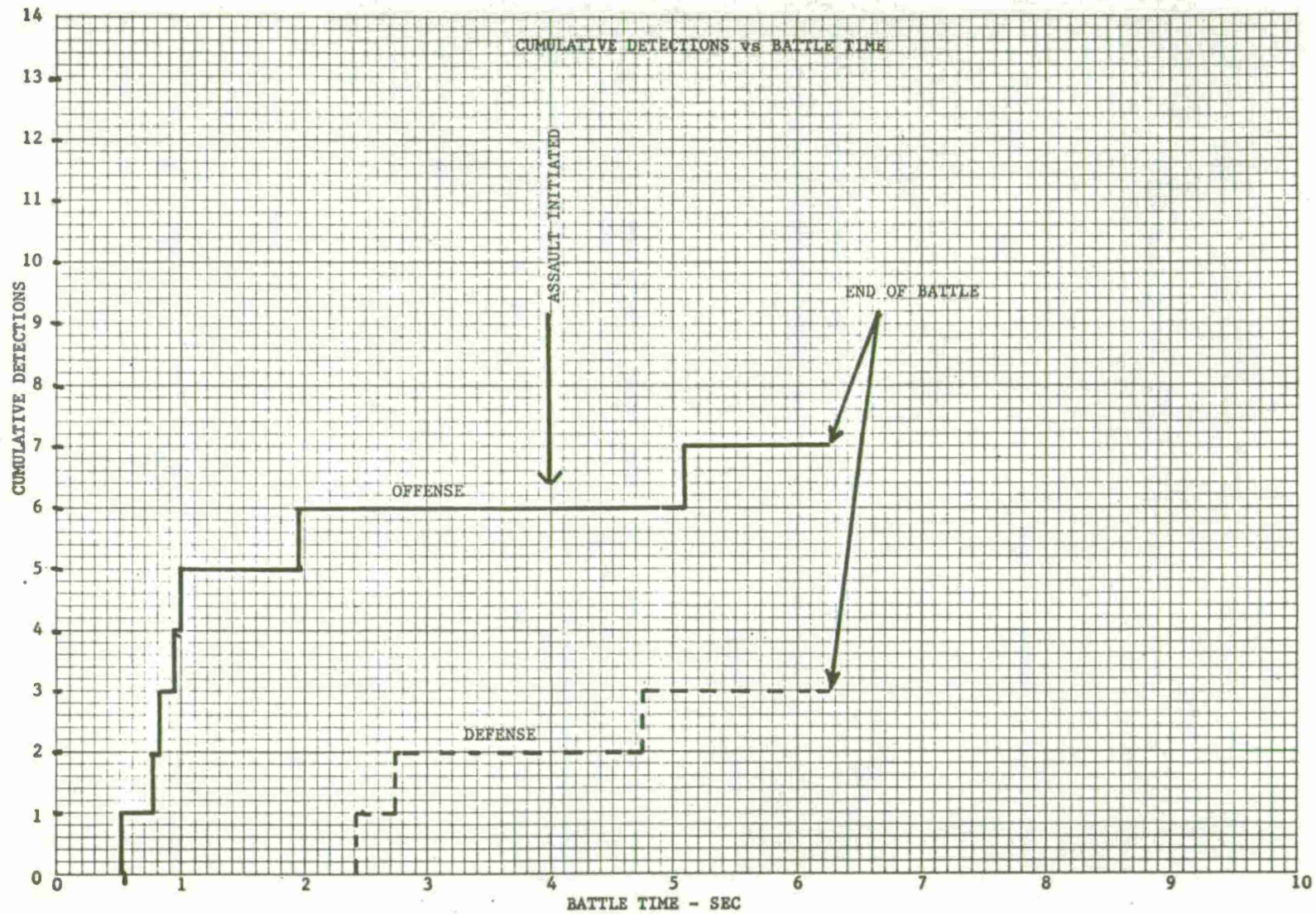


Figure D-1 Cumulative Detections vs. Battle Time
at 7 Meters - Standard Squad

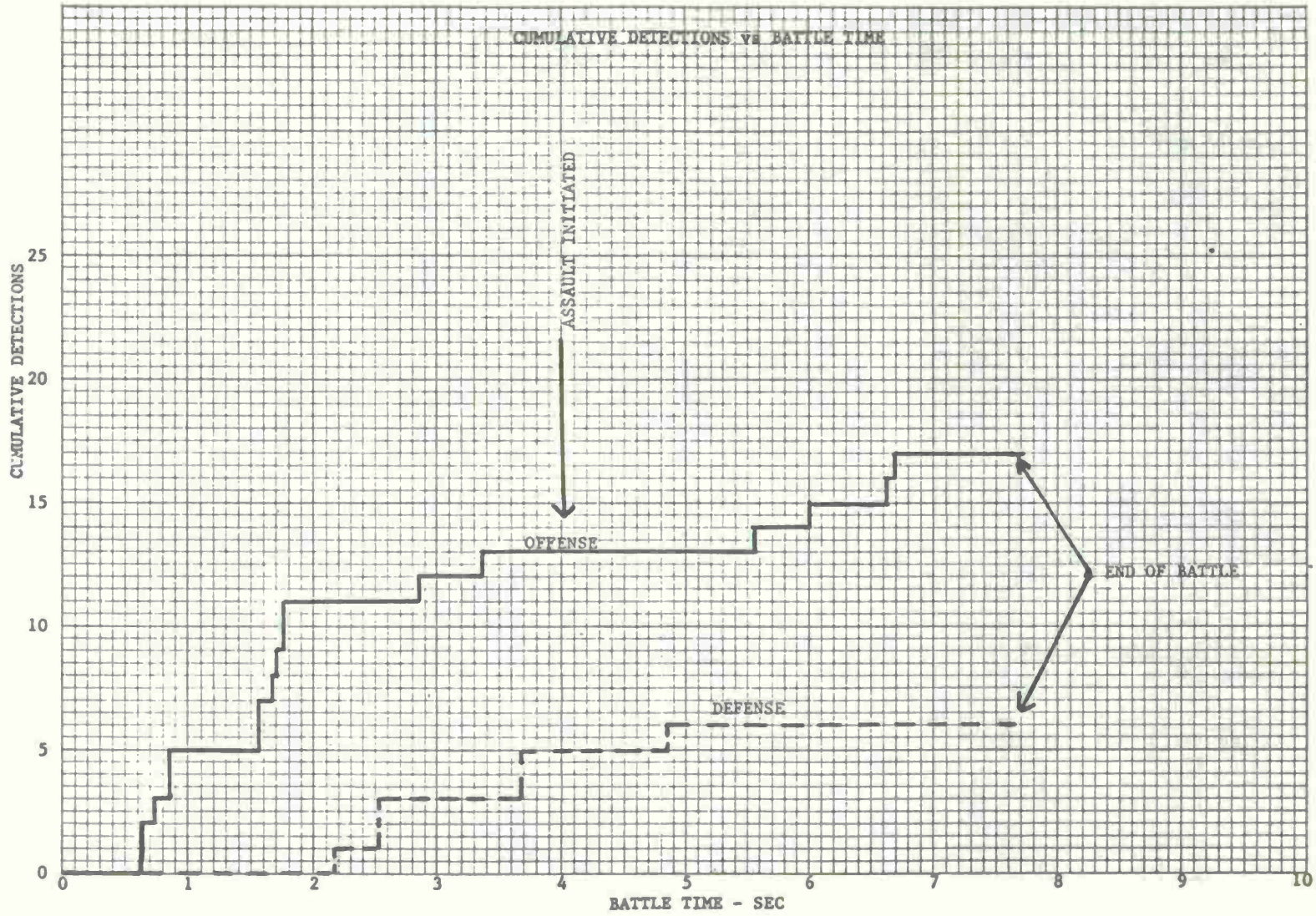


Figure D-2 Cumulative Detections vs. Battle Time at 16 Meters - Standard Squad

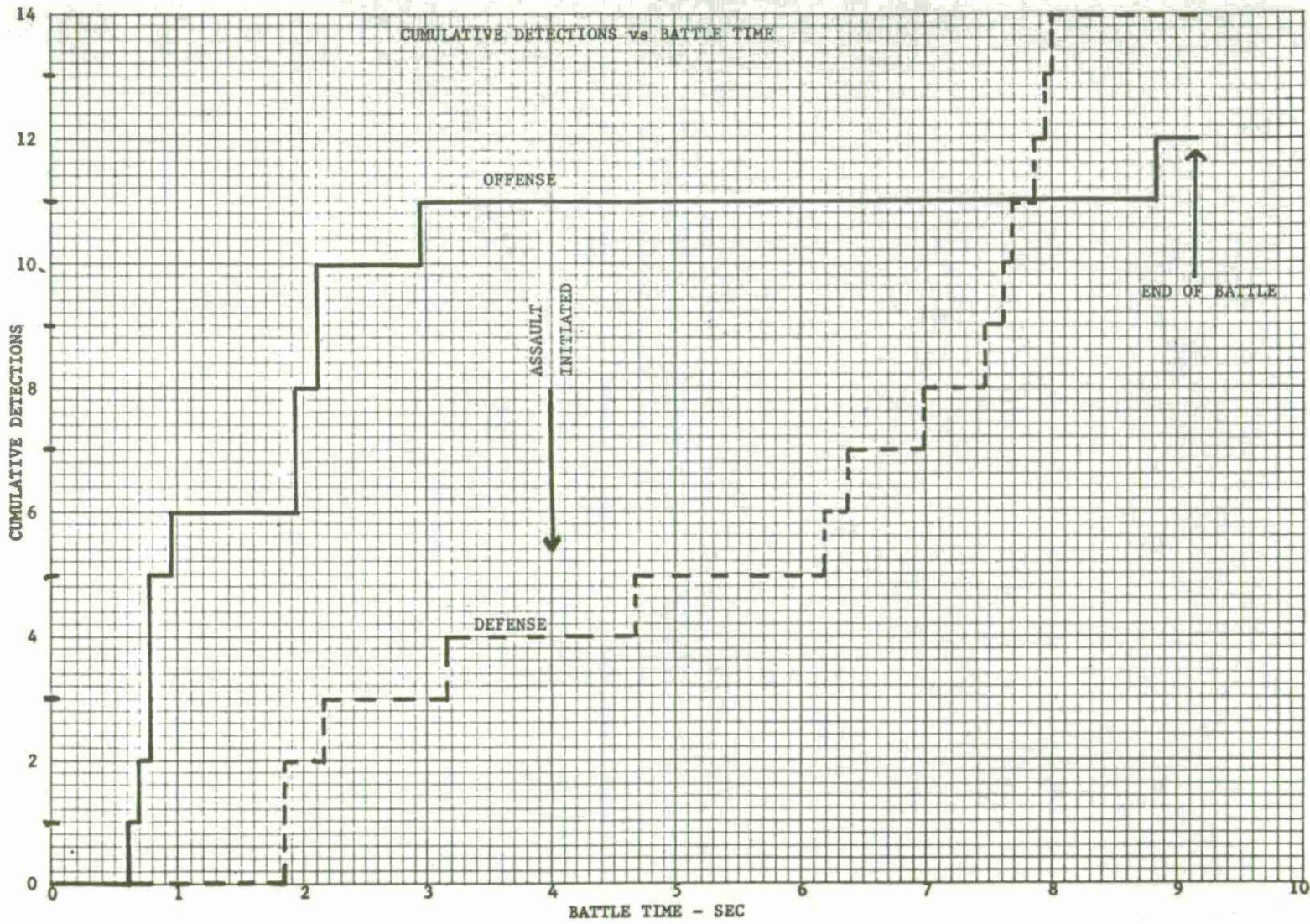


Figure D-3 Cumulative Detections vs Battle Time at 25 Meters - Standard Squad

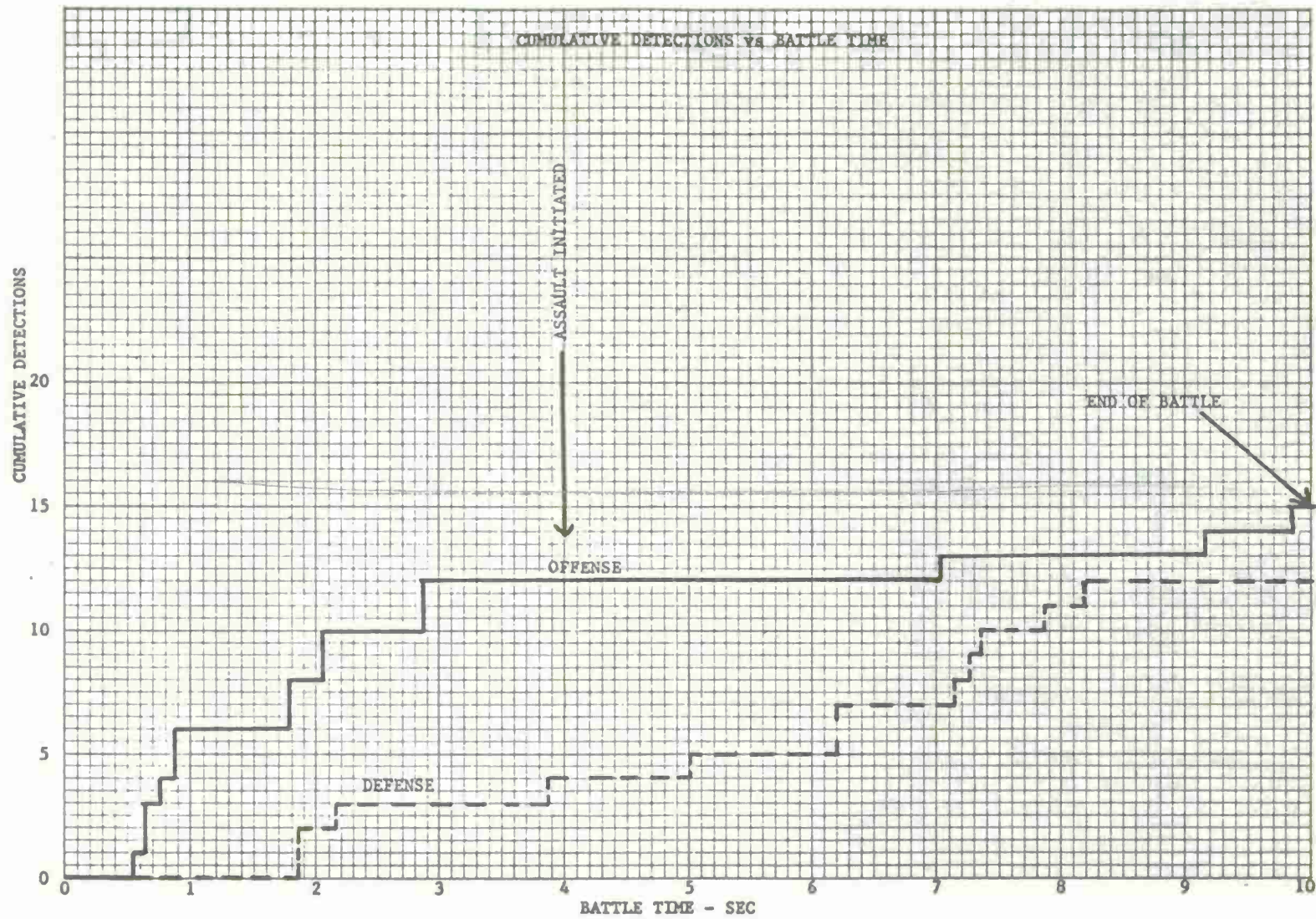


Figure D-4 Cumulative Detections vs Battle Time
at 34 Meters - Standard Squad

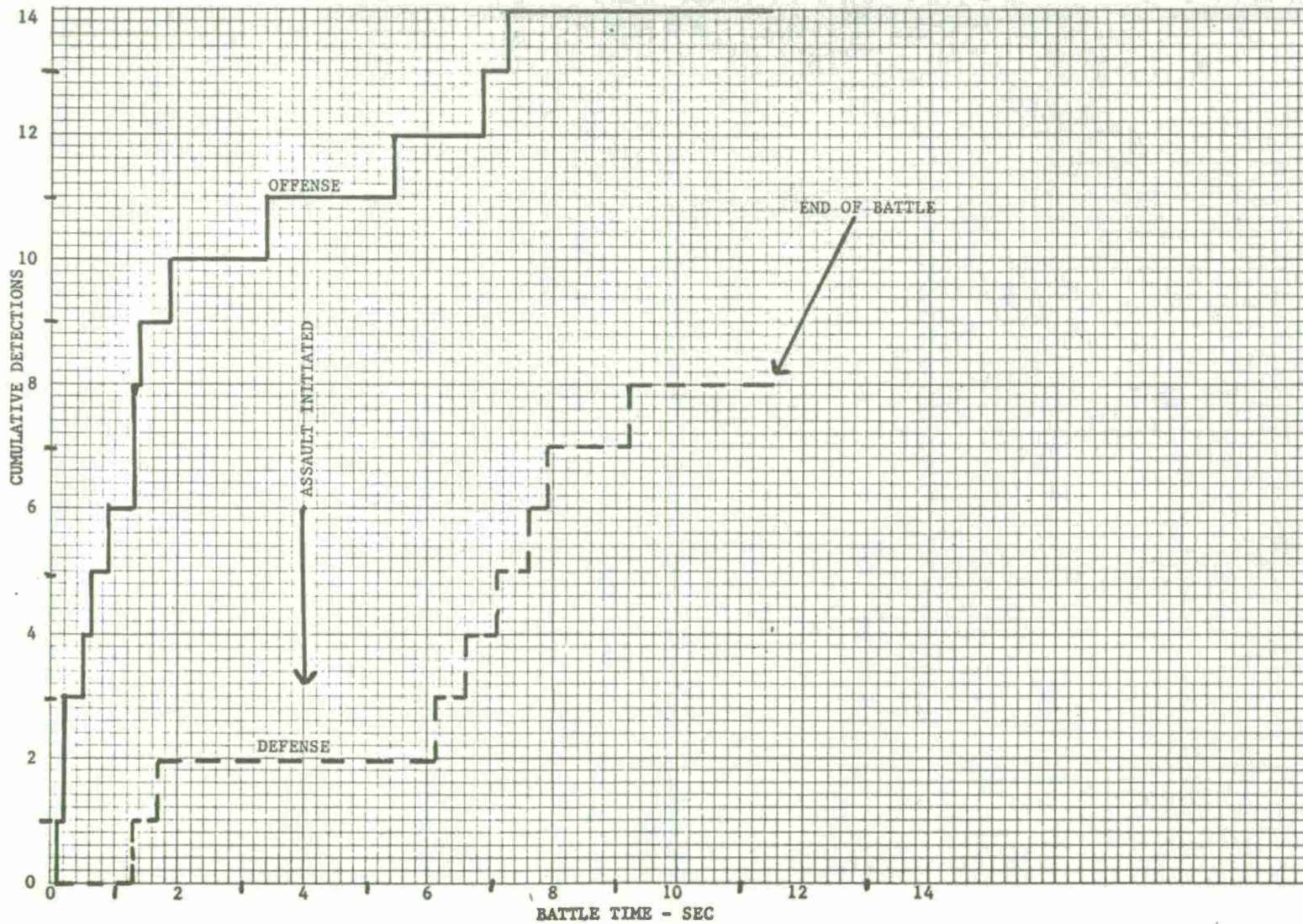


Figure D-5 Cumulative Detections vs Battle Time
at 40 Meters - SAWS Squad

D-7

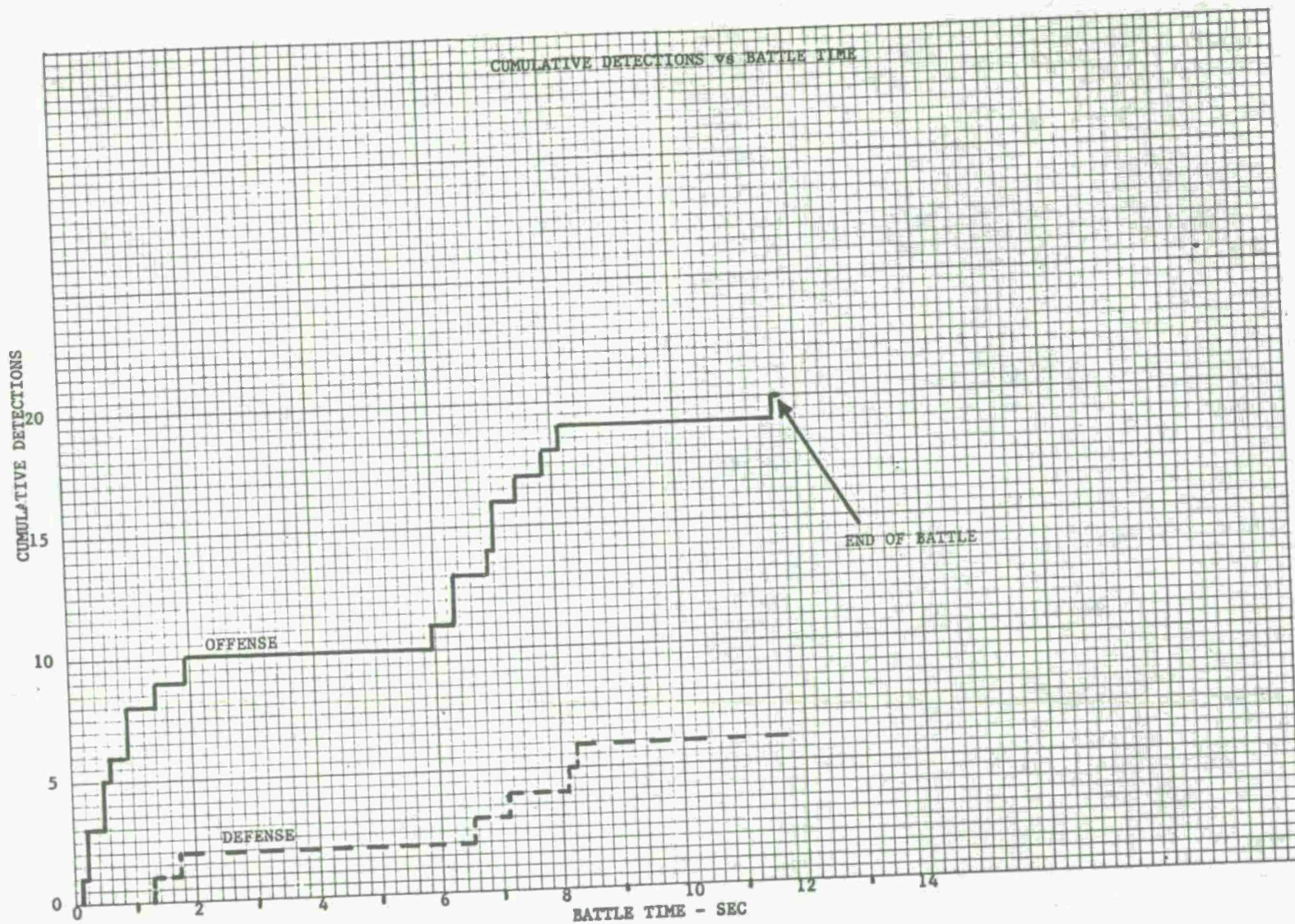


Figure D-6 Cumulative Detections vs Battle Time at 40 Meters - M60 Squad

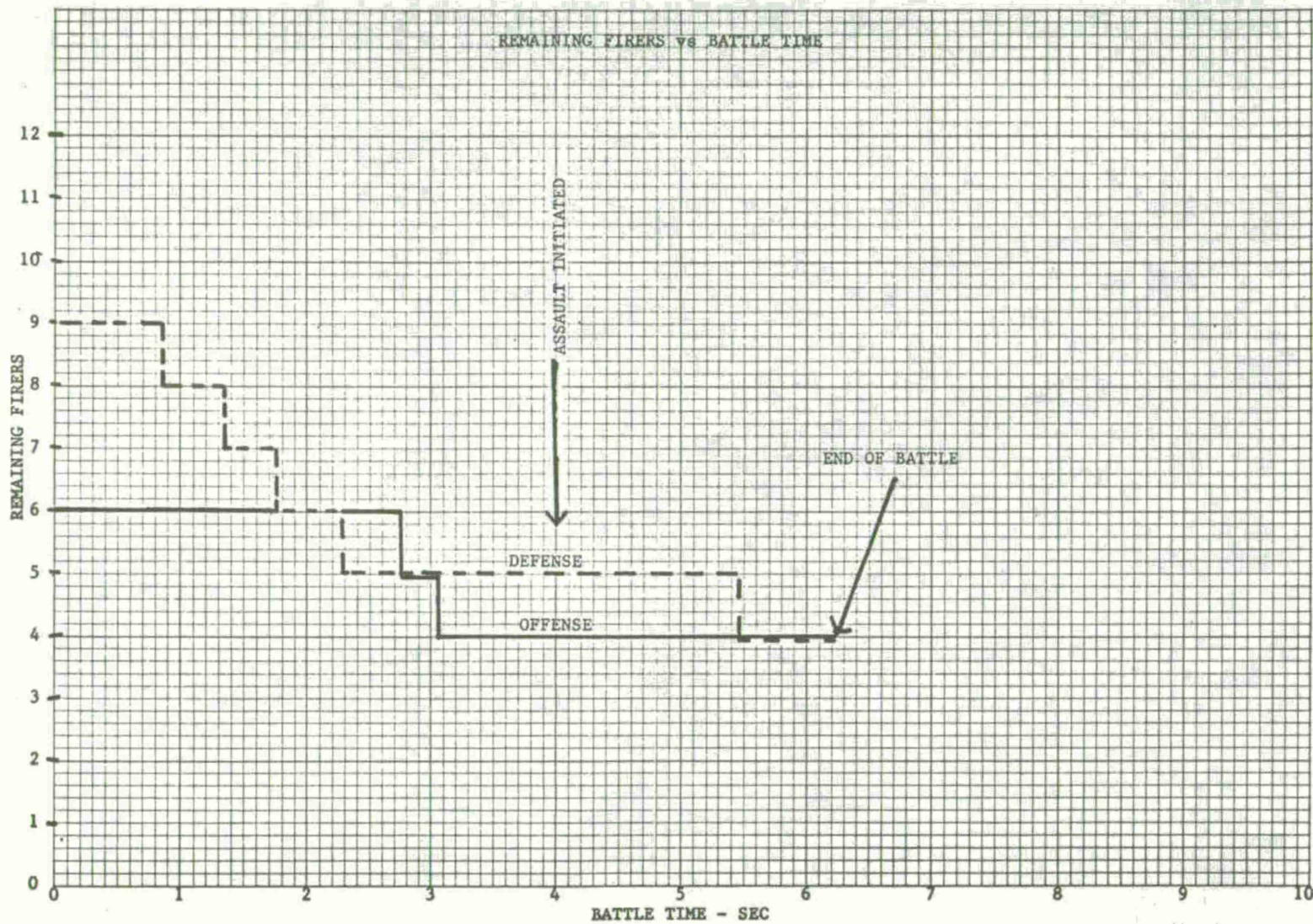


Figure D-7 Remaining Firers vs Battle Time at 7 Meters - Standard Squad

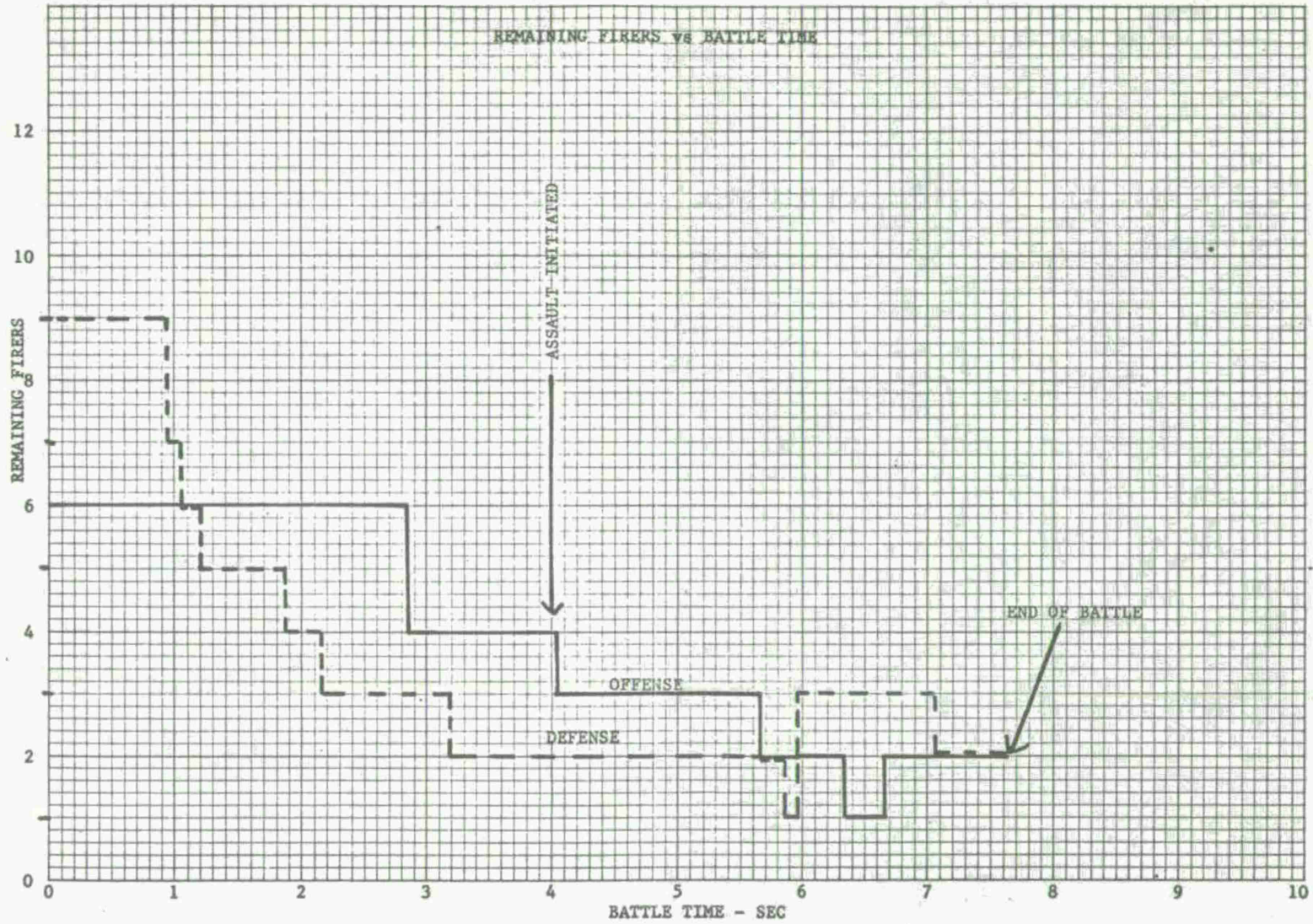


Figure D-8 Remaining Firers vs Battle Time at 16 Meters - Standard Squad

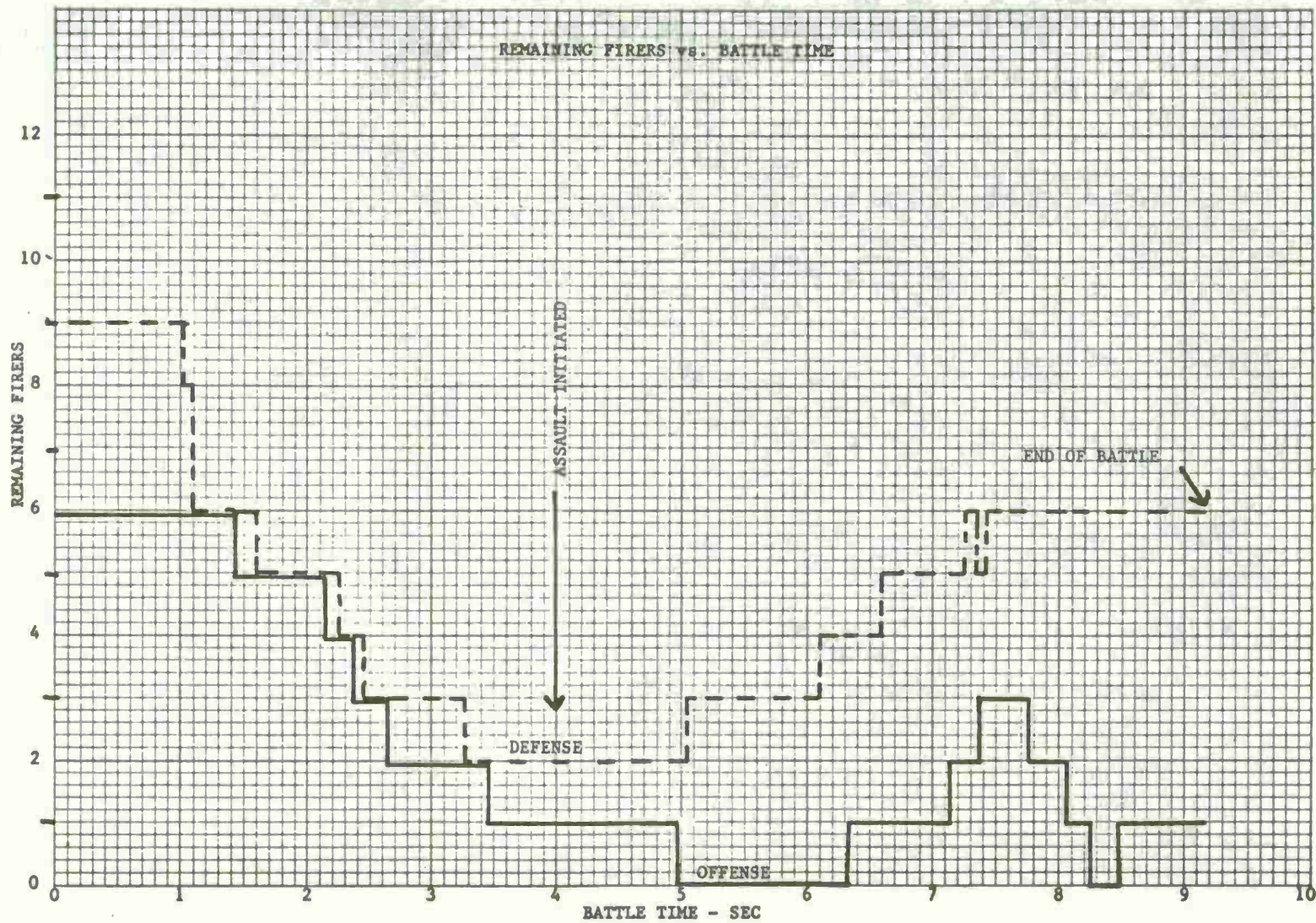


Figure D-9 Remaining Firers vs Battle Time
at 25 Meters - Standard Squad

D-11

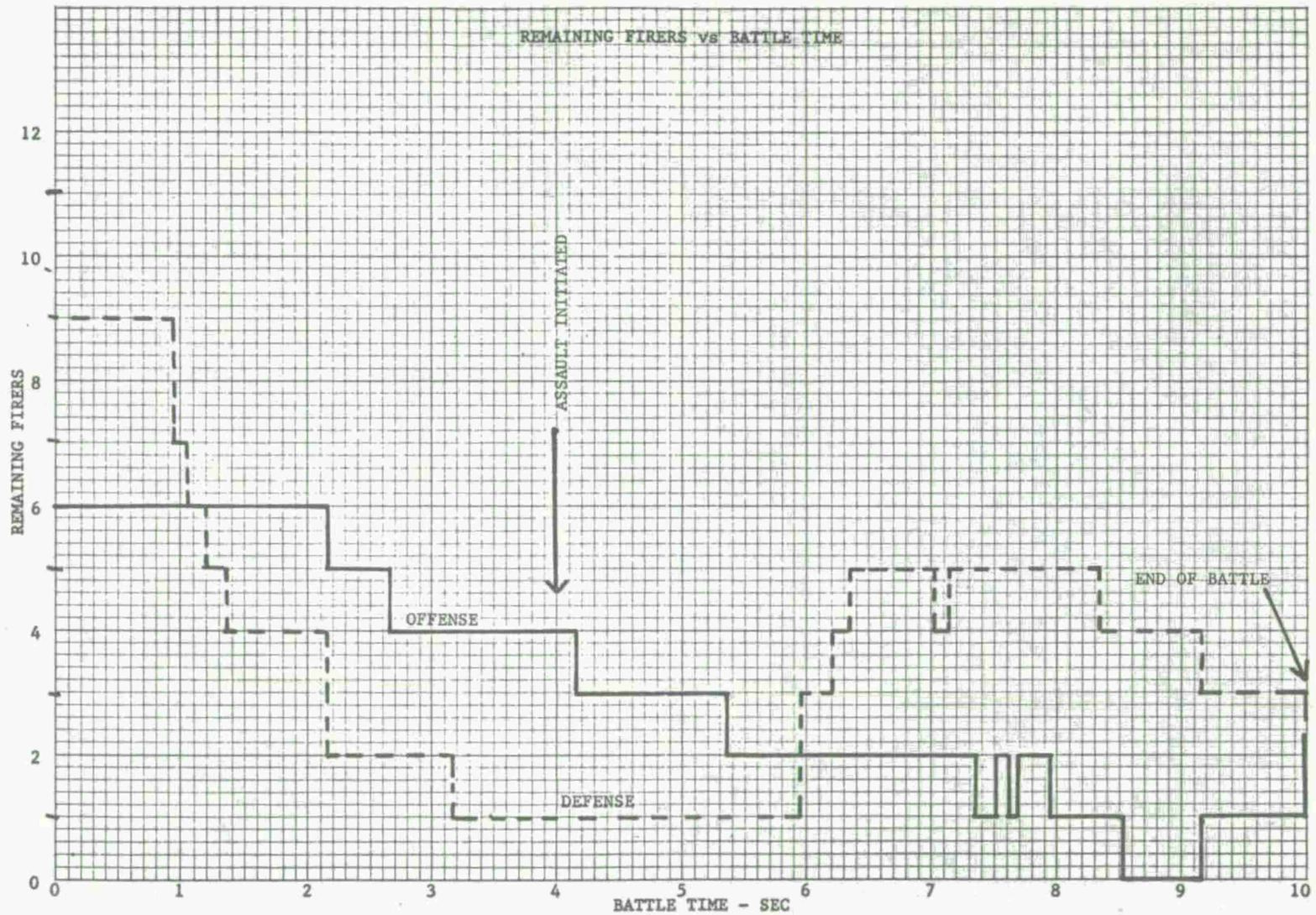


Figure D-10 Remaining Firers vs Battle Time
at 34 Meters - Standard Squad

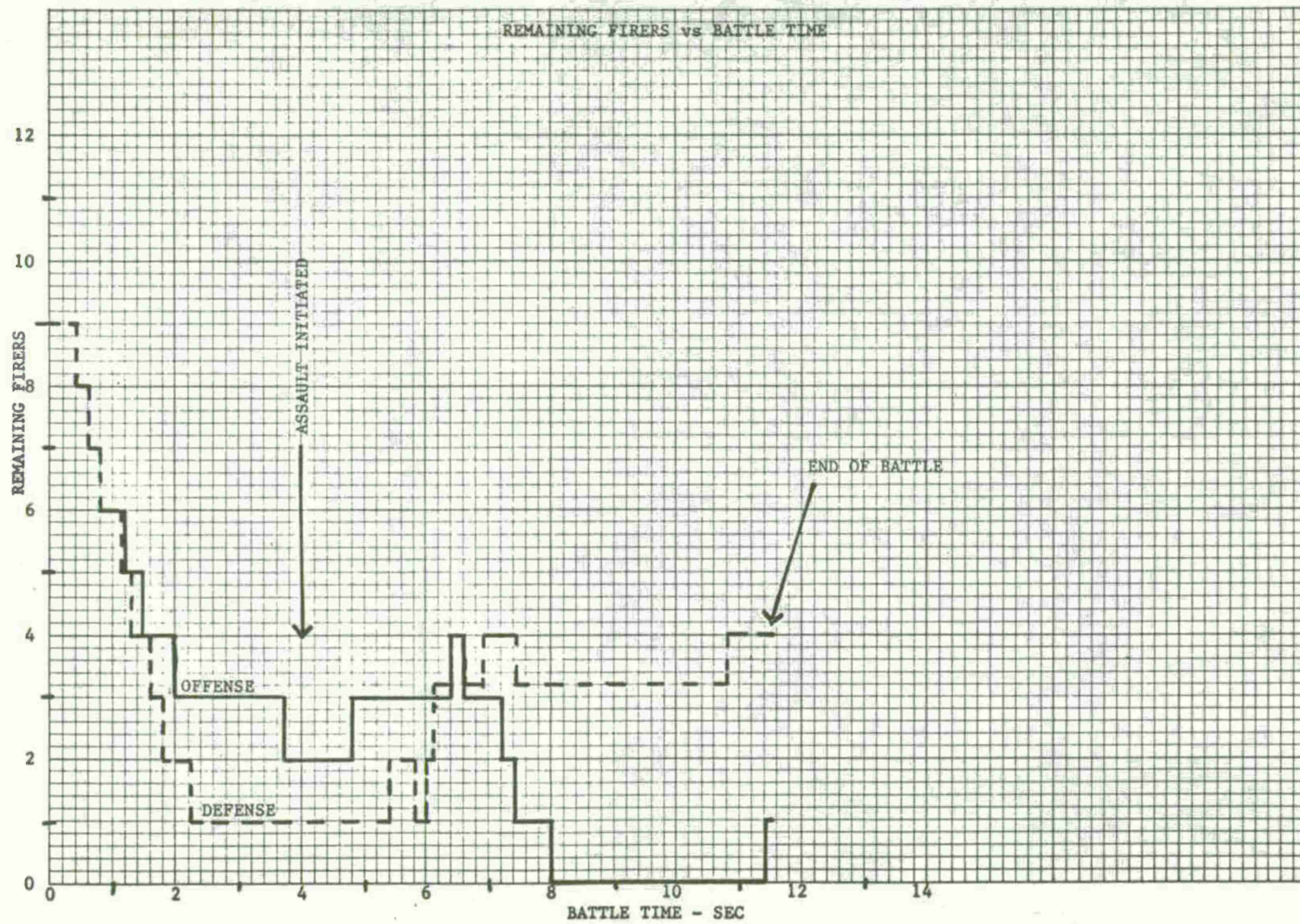


Figure D-11 Remaining Firers vs Battle Time at 40 Meters - SAWS Squad

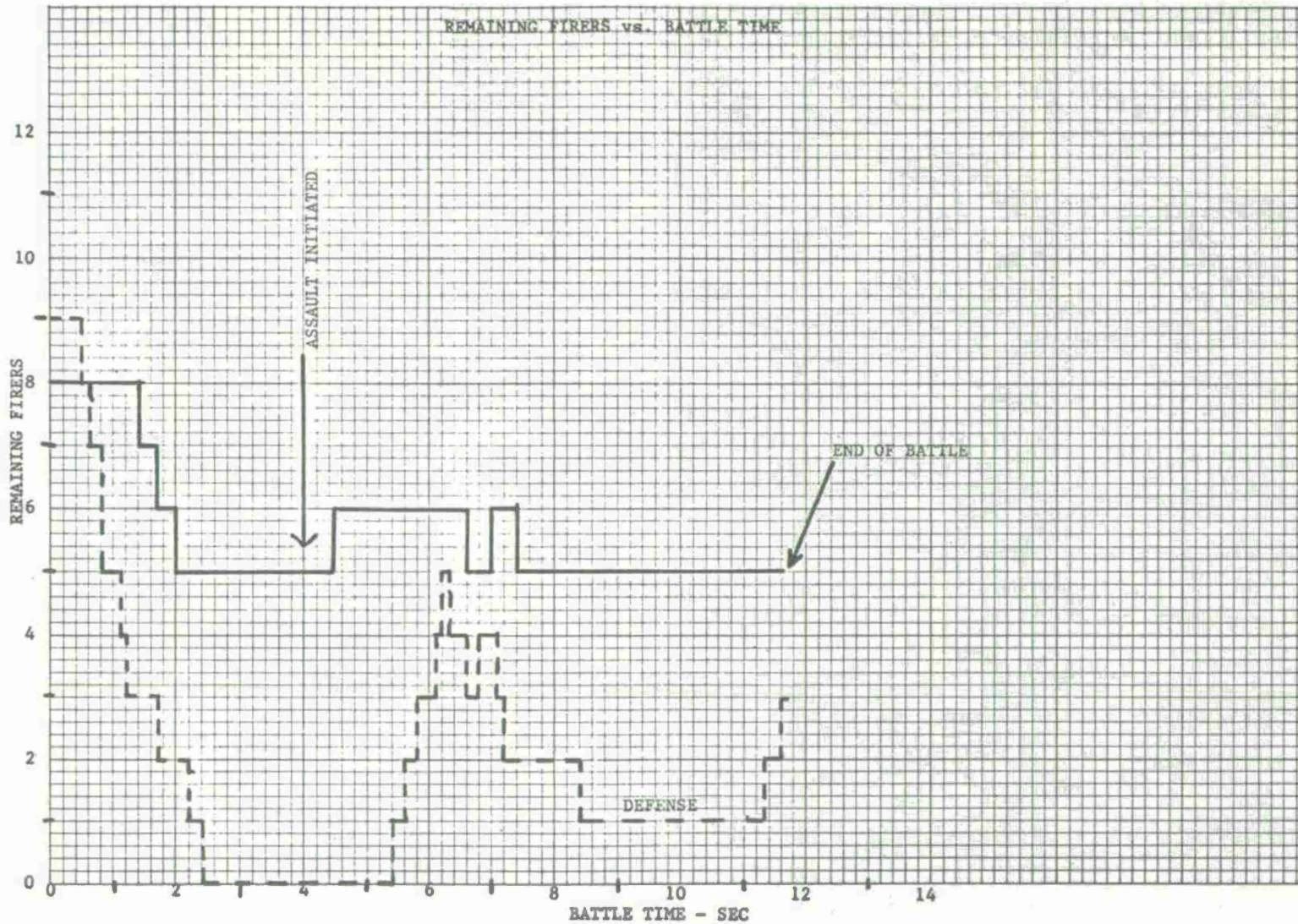


Figure D-12 Remaining Firers vs Battle Time
at 40 Meters - M60 Squad

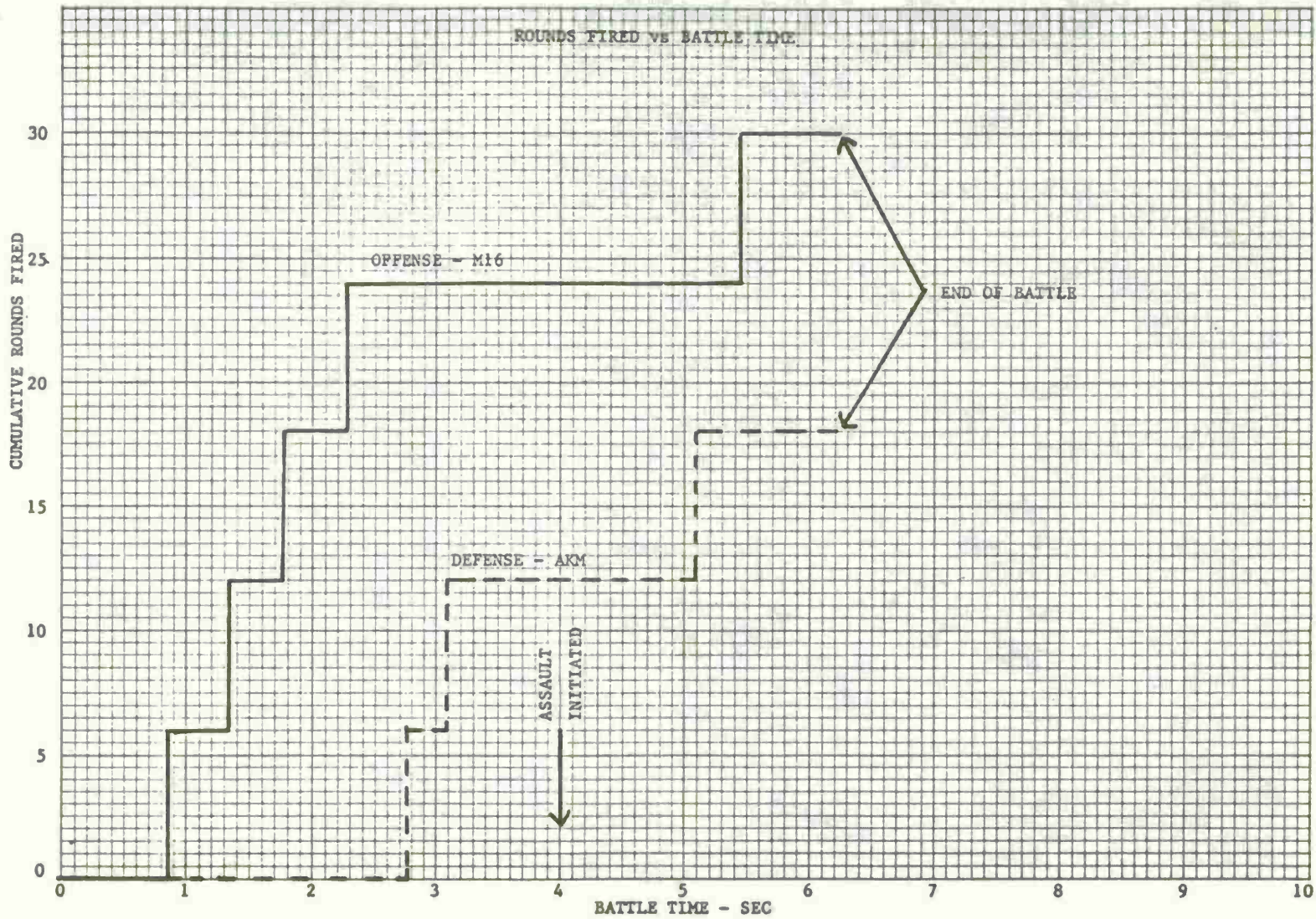


Figure D-13 Rounds Fired vs Battle Time at 7 Meters - Standard Squad

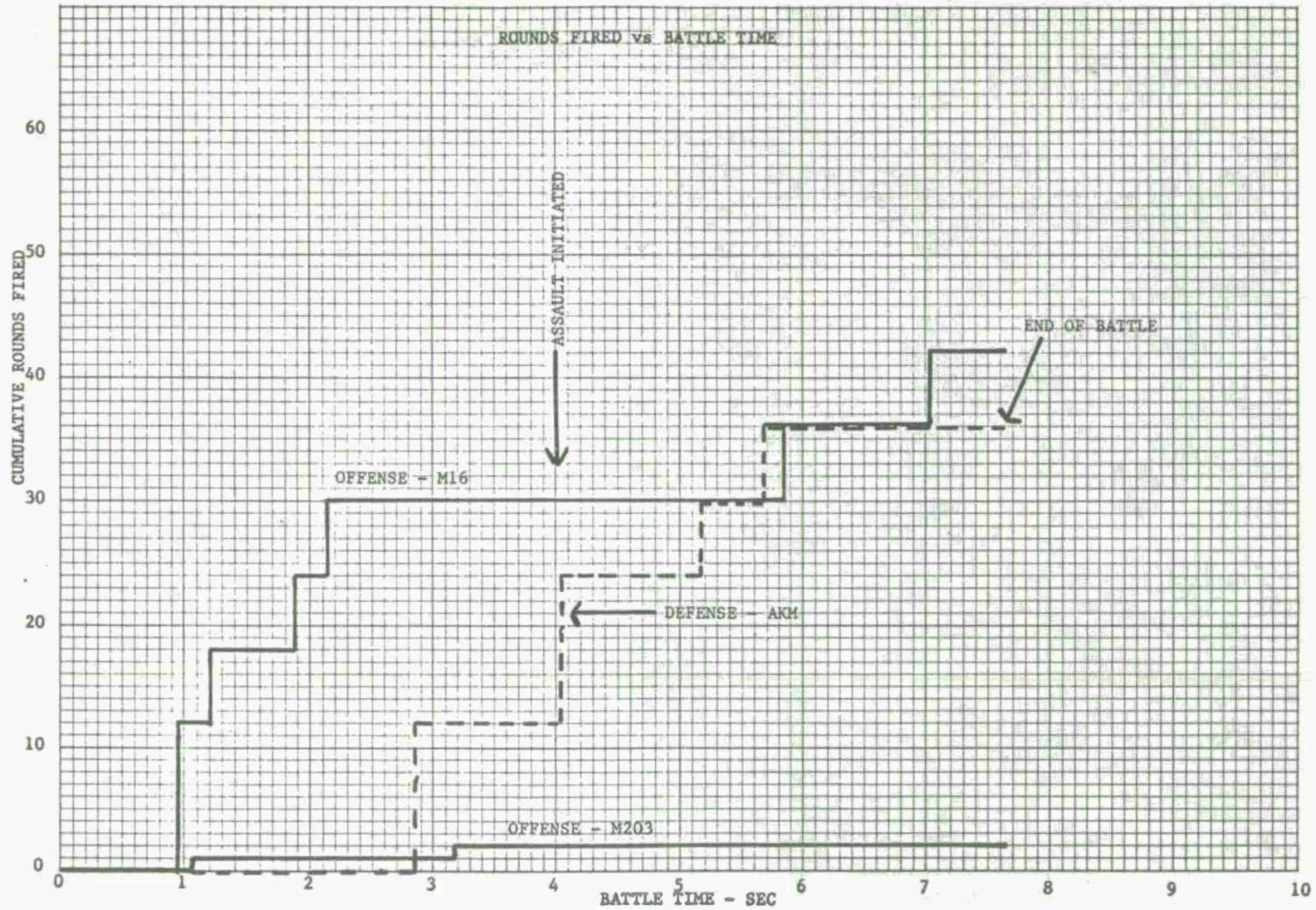


Figure D-14 Rounds Fired vs Battle Time at 16 Meters - Standard Squad

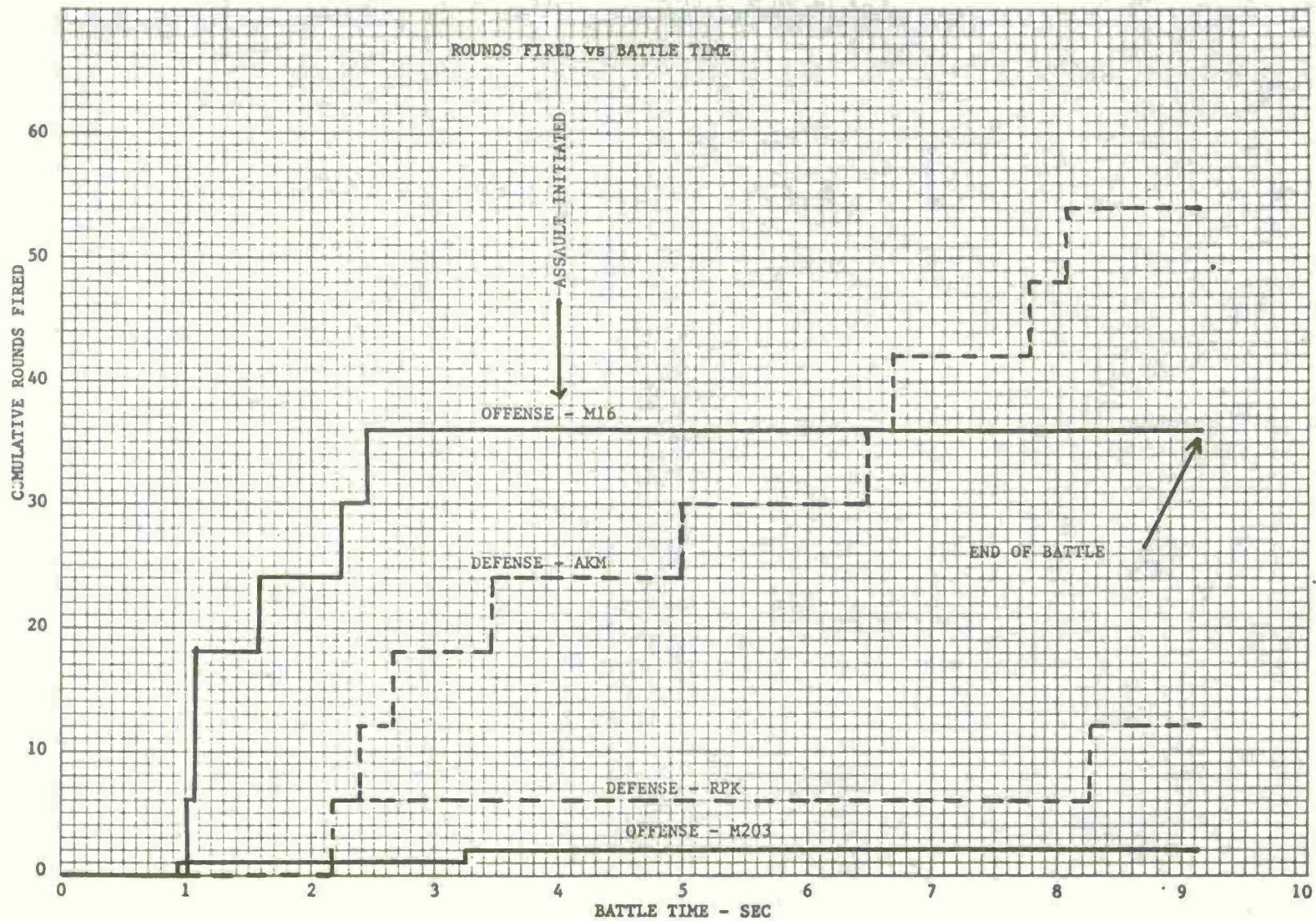


Figure D-15 Rounds Fired vs Battle Time
at 25 Meters - Standard Squad

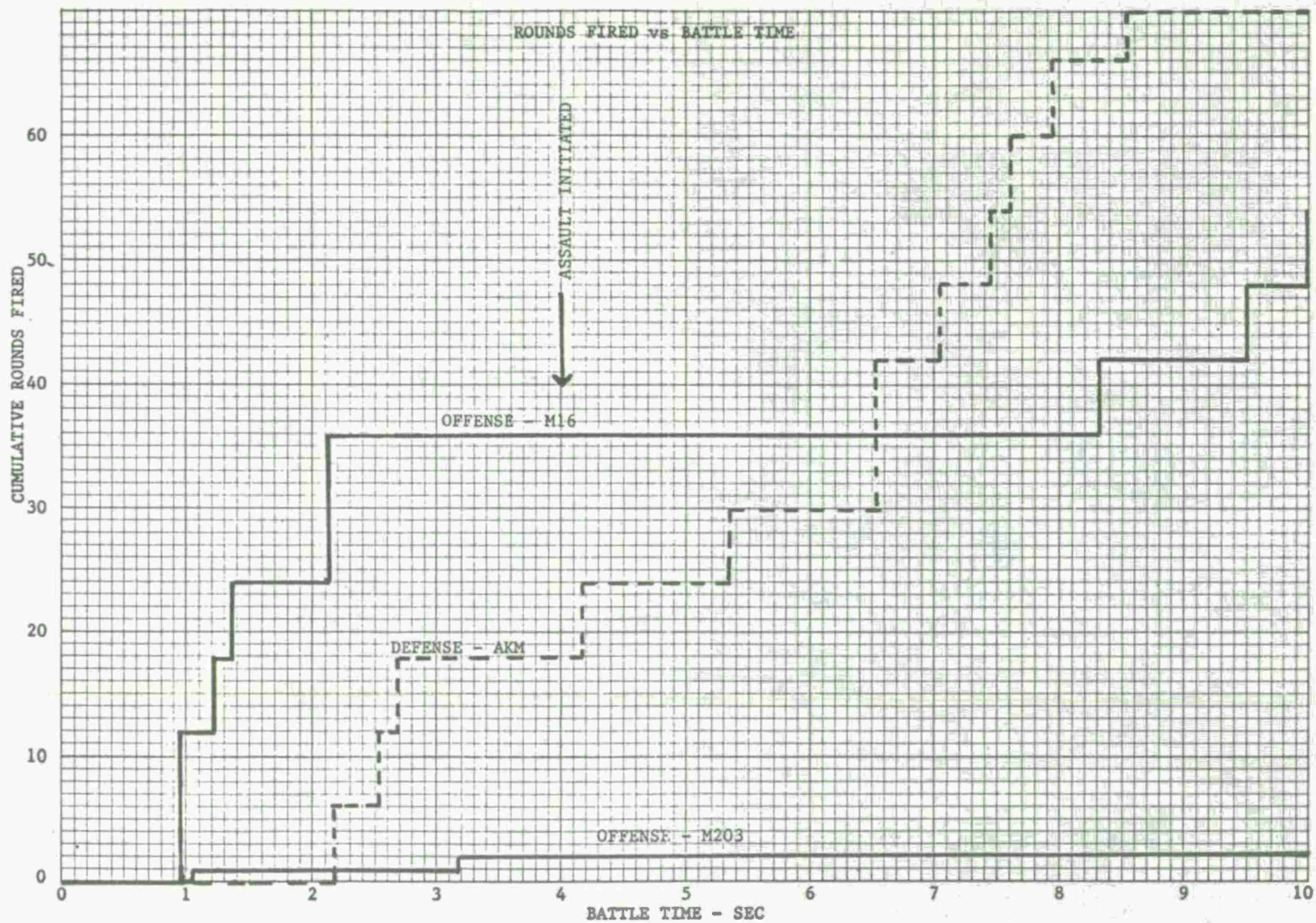


Figure D-16 Rounds Fired vs Battle Time at 34 Meters - Standard Squad

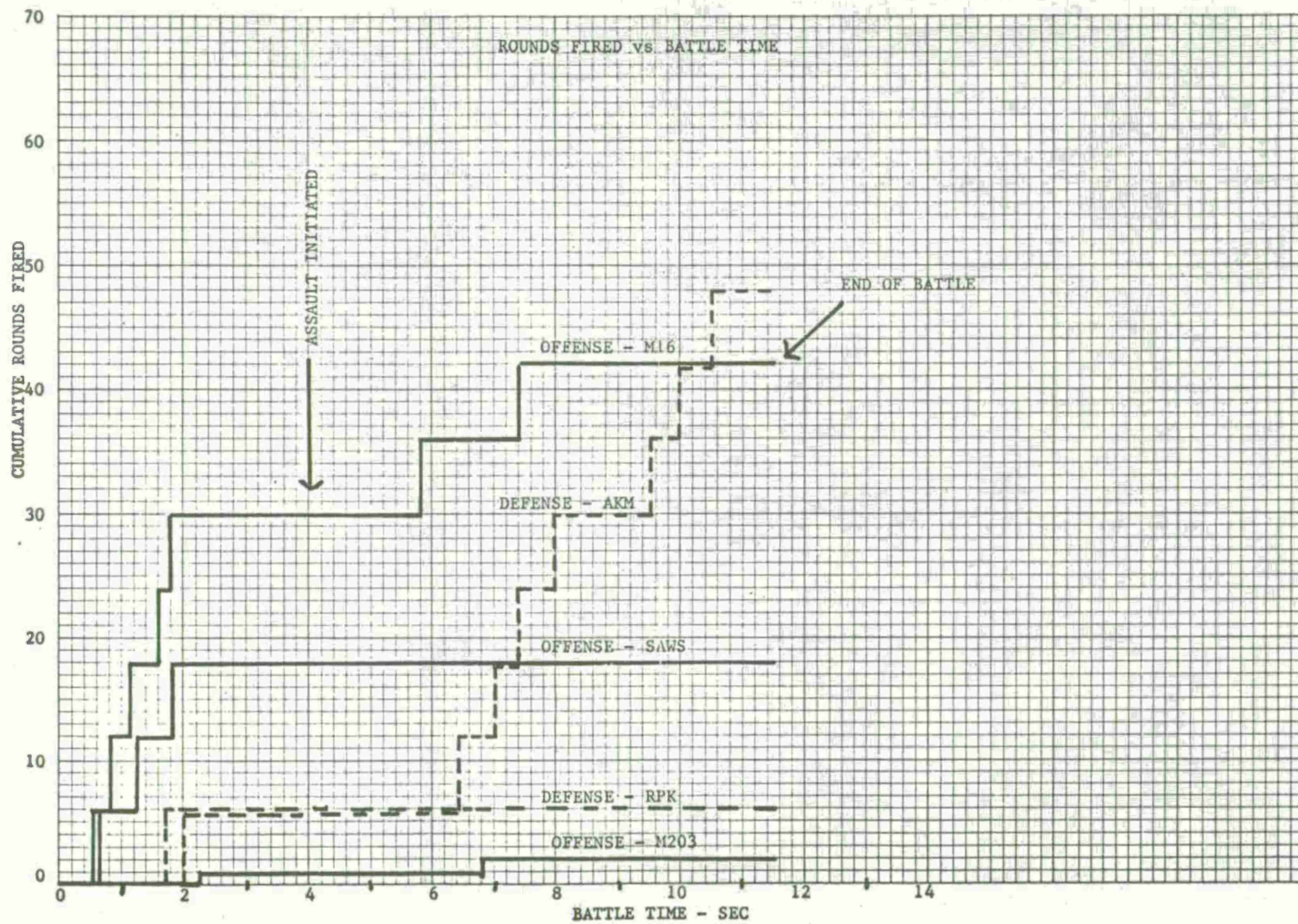


Figure D-17 Rounds Fired vs Battle Time
at 40 Meters - SAWS Squad

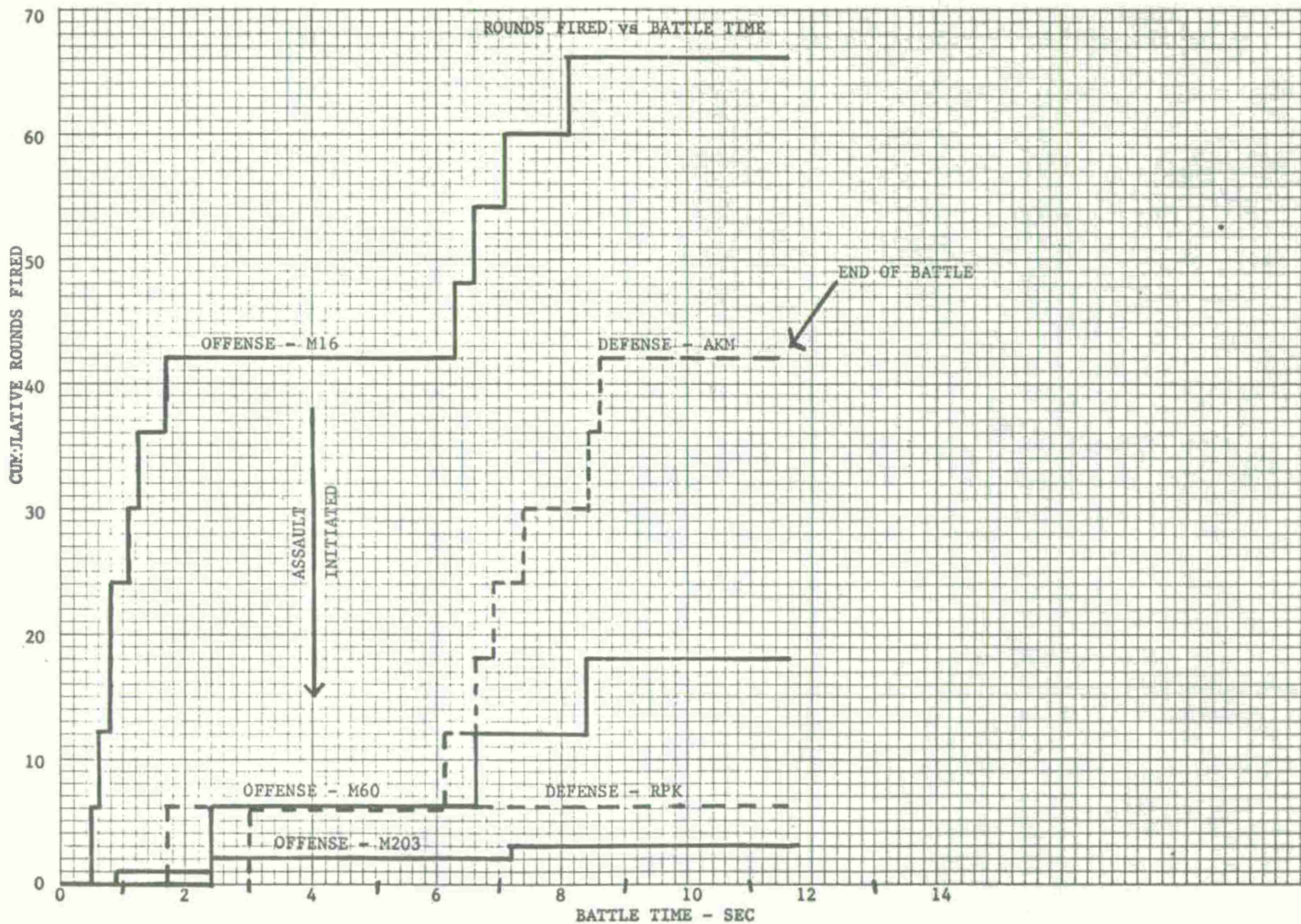


Figure D-18 Rounds Fired vs Battle Time at 40 Meters - M60 Squad

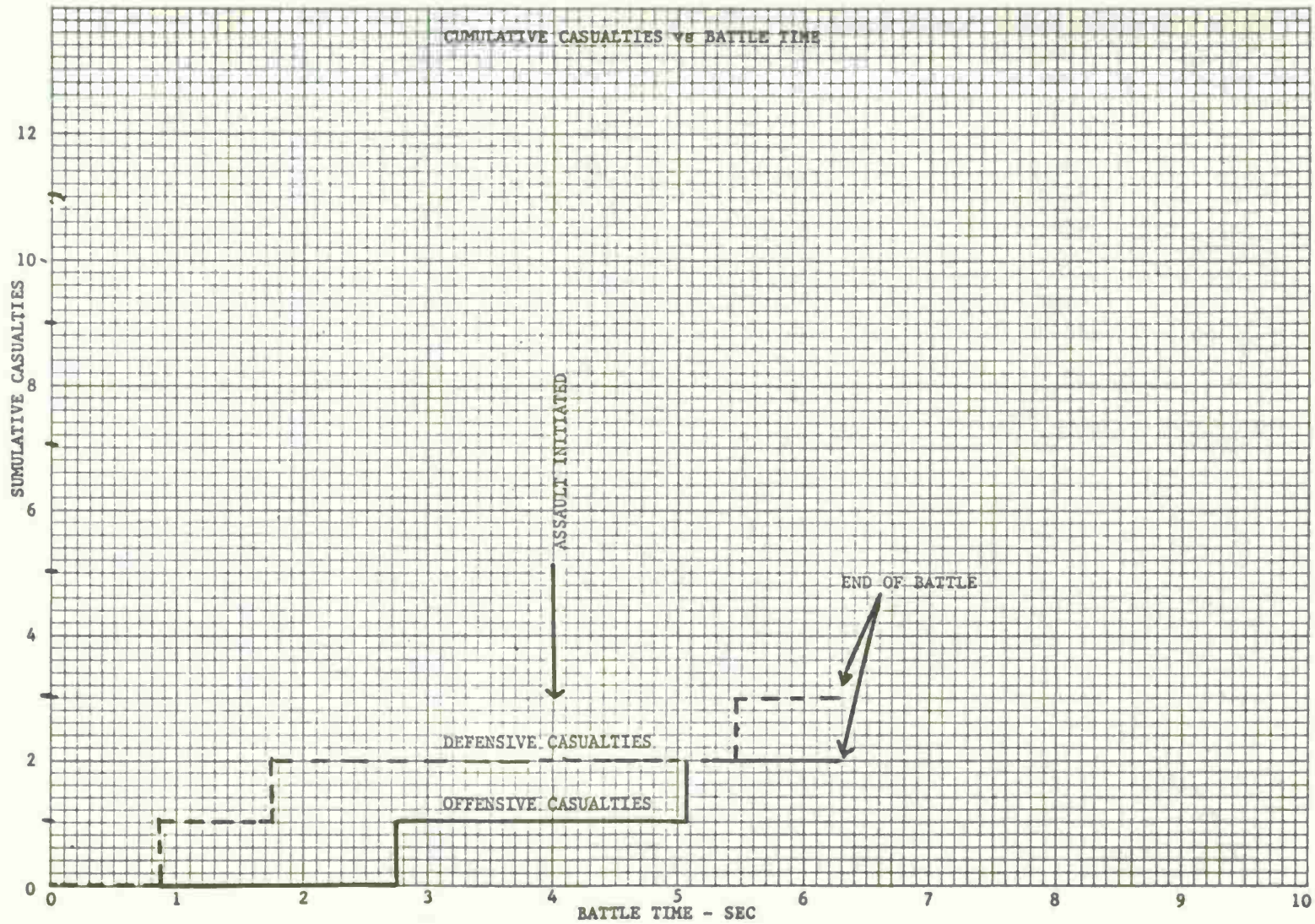


Figure D-19 Cumulative Casualties vs Battle Time
at 7 Meters - Standard Squad

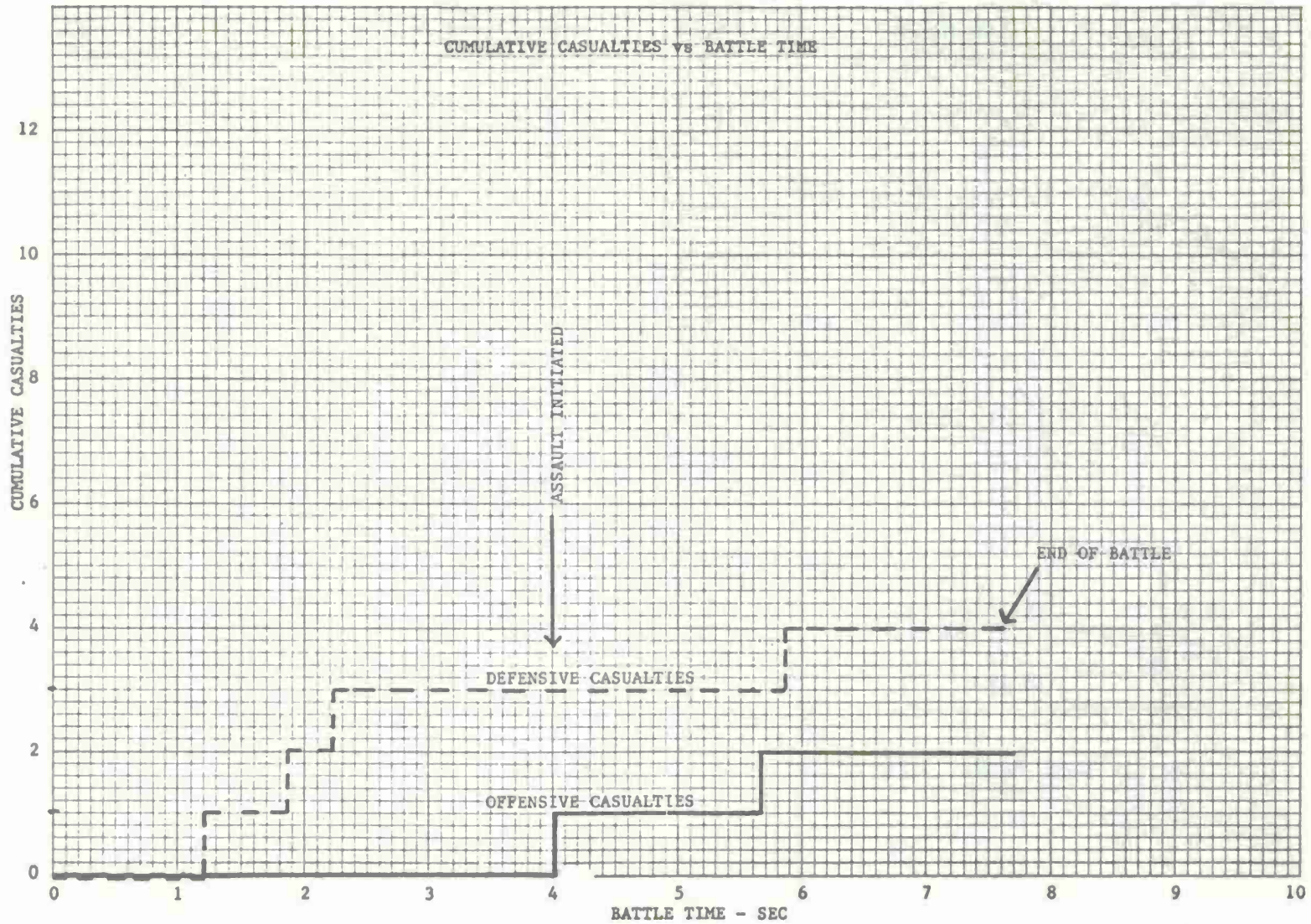


Figure D-20 Cumulative Casualties vs Battle Time at 16 Meters - Standard Squad

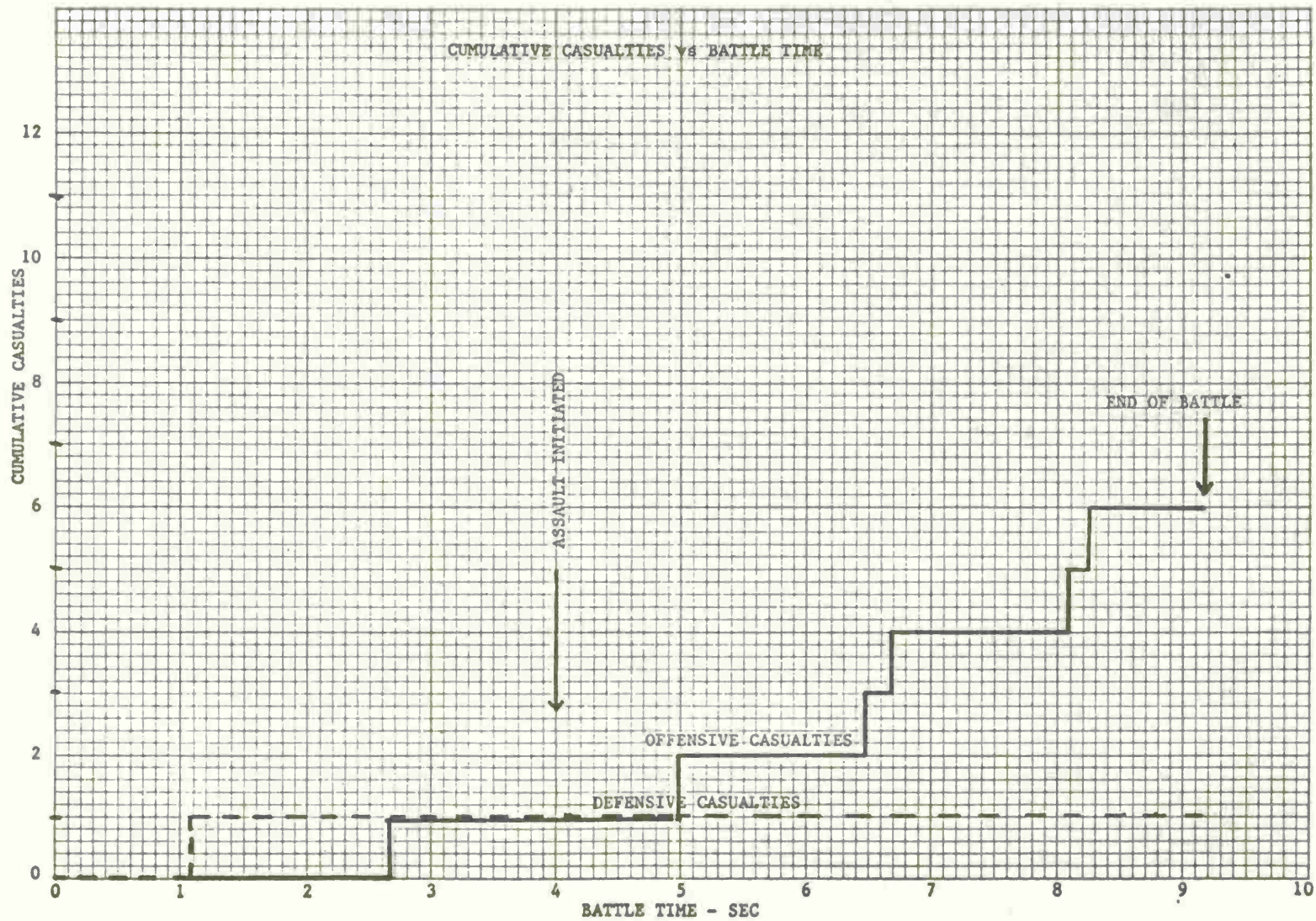


Figure D-21 Cumulative Casualties vs Battle Time
at 25 Meters - Standard Squad

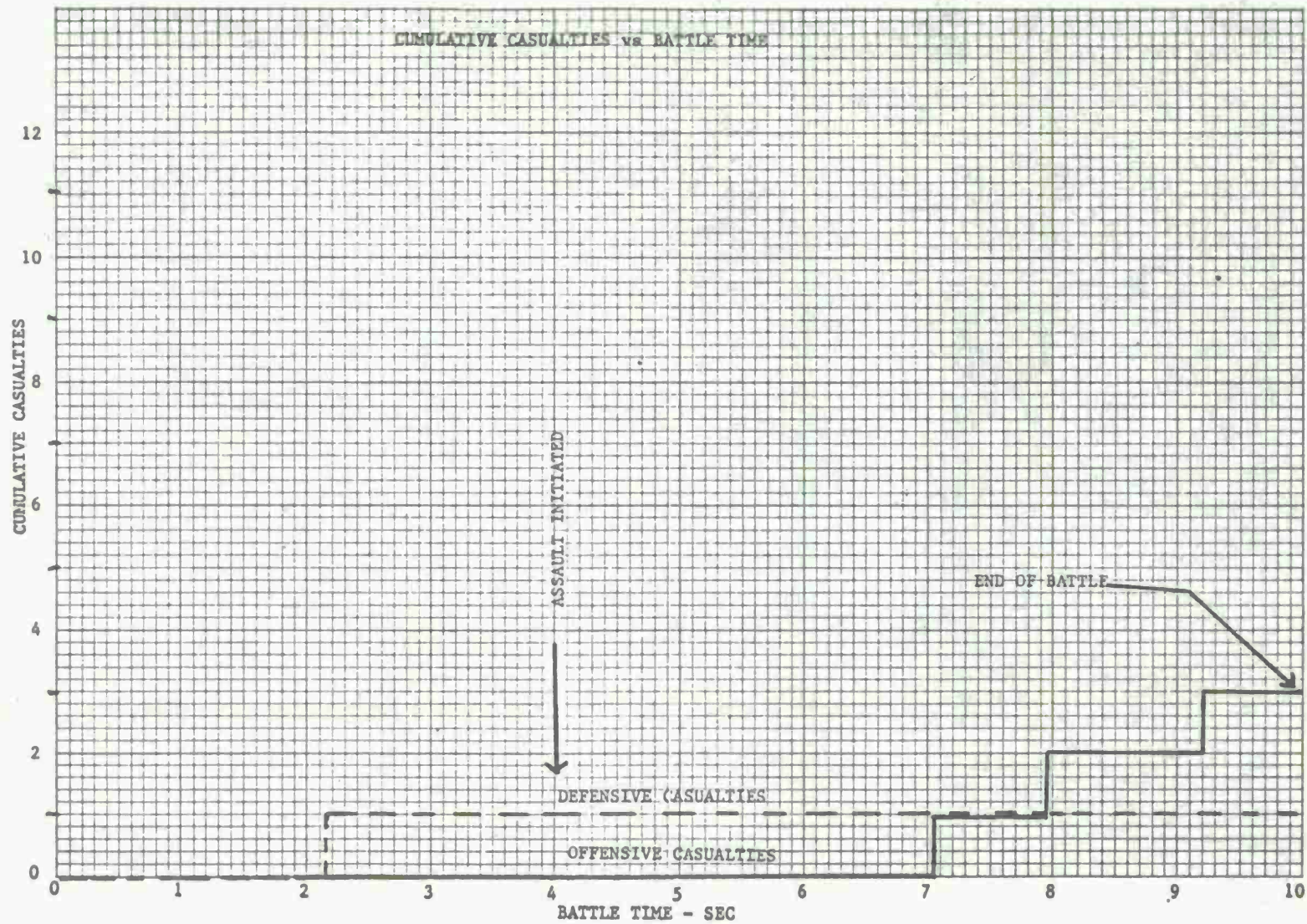


Figure D-22 Cumulative Casualties vs Battle Time
at 34 Meters - Standard Squad

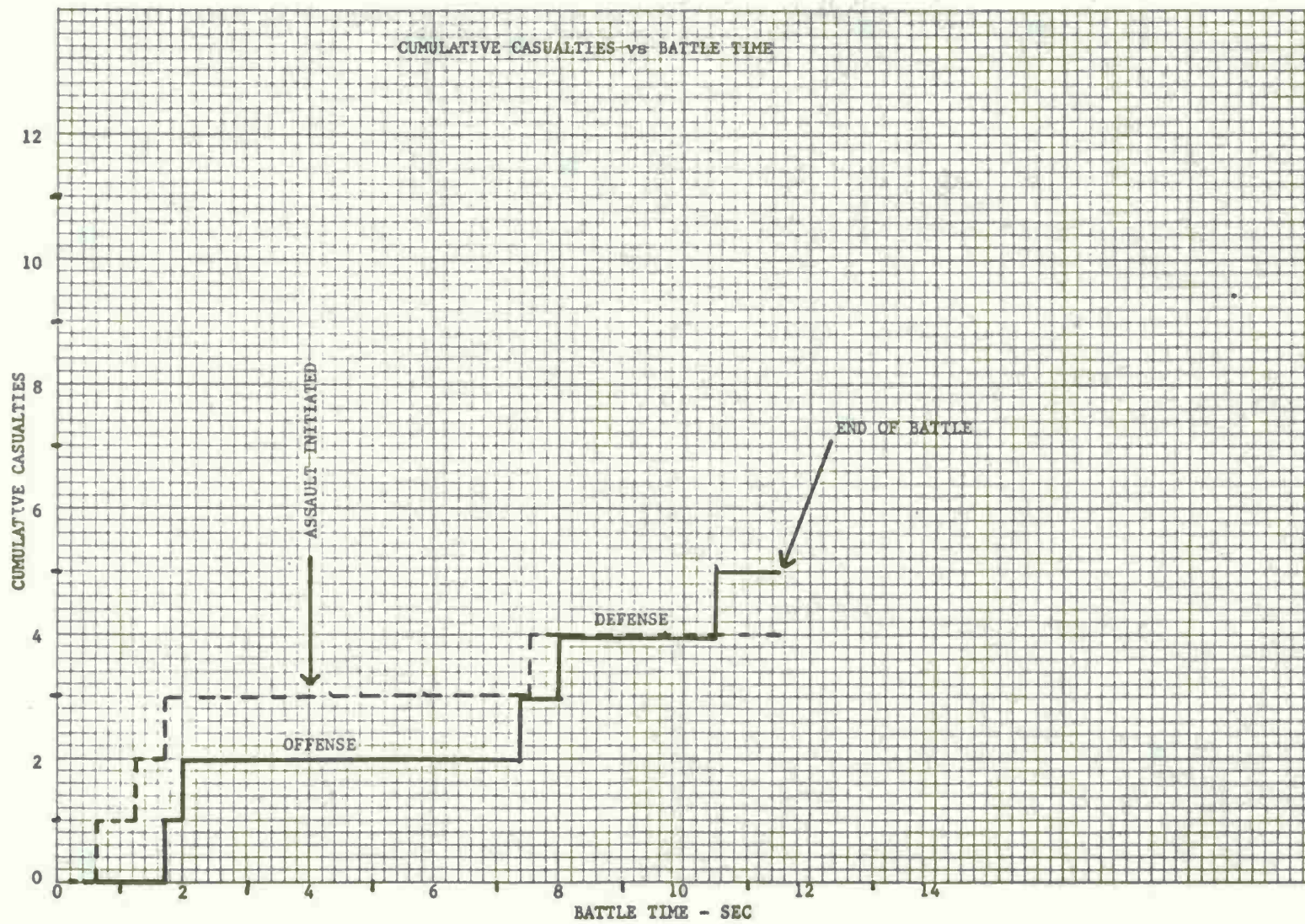


Figure D-23 Cumulative Casualties vs Battle Time
at 40 Meters - SAWS Squad

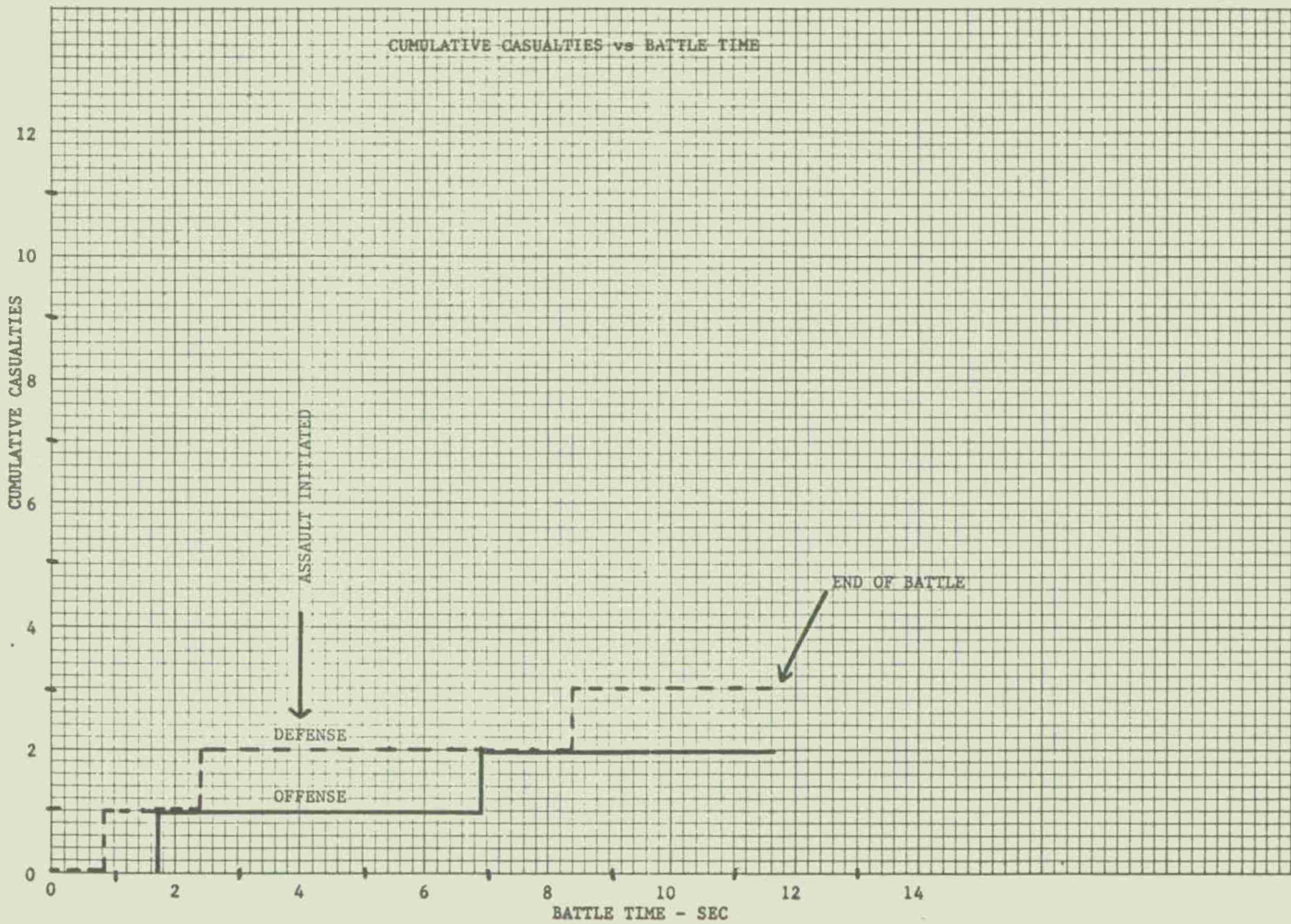


Figure D-24 Cumulative Casualties vs Battle Time at 40 Meters - M60 Squad

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M203 characteristics as opposed to M79 characteristics? 8. What differences occur when an M60 machine gun is added to the standard squad?

The concepting portion of the program has surfaced two weapon ideas that appear to have promise: 1. A wall breaching/anti-armor infantry weapon. 2. A volume source concussion grenade.

The wall breaching/anti-armor infantry device is based on high velocity kinetic energy impact. The device with its closed breach and kinetic energy round could solve the back blast and arming problems associated with present infantry weapon systems.

The concussion grenade, based on fuel air explosive technology, would generate a volume concussion source that might solve the problems associated with intervening furniture and degradation of concussion effects with range.

In addition to the above a testing program was also identified as being required to generate data to aid designers, analysts, and decision makers in developing effective weapons. Some of the tests are: 1. Material penetration 2. Ricochet phenomena 3. Visual detection 4. Fragmenting grenade lethality in a confined area 5. Aiming accuracy against fleeting urban targets.

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