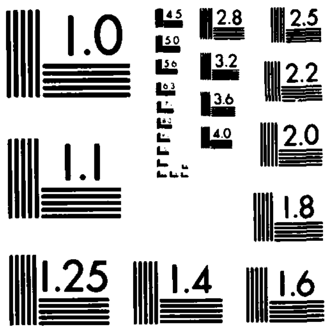
AD-A131 493 DIVISION SUPPORT WEAPON SYSTEM RATE OF FIRE AND C(3) OPERATIONS(U) SCIENCE APPLICATIONS INC MCLEAN VA C3 SYSTEMS DEPT J W BAUMGART ET AL. 01 APR 83 1/2

UNCLASSIFIED DAEA18-81-G-0017 F/G 19/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DIVISION SUPPORT WEAPON SYSTEM RATE OF FIRE AND C^3 OPERATIONS

SCIENCE APPLICATIONS, INC.

83 08 17 018

Report DAEA 18-81-G-0017 ET01 01

DIVISION SUPPORT WEAPON SYSTEM RATE OF FIRE AND C^3 OPERATIONS

James W. Baumgart
M. Paul Stanton
Russell R. Vane

1 April 1983

Final Report for Period 14 December 1982 - 1 April 1983

Prepared for:

Project Manager,
Division Support Weapons System
US Army Armament Research and
Development Command
Dover, NJ 07801

Monitored by:

Division Support Weapons System
Cost and Operational Effectiveness
Special Study Group
US Army Artillery Center
Fort Sill, Oklahoma 73503

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

SCIENCE APPLICATIONS, INC.
Post Office Box 1303, 1710 Goodridge Drive, McLean, Virginia 22102, (703) 821-4300
C^3 Systems Department
Military Sciences Group

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: DAEA 18-81-G-0017, ET0101 / 2. GOVT ACCESSION NO.: AD-A131 493	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): DIVISION SUPPORT WEAPON SYSTEM RATE OF FIRE AND C^3 OPERATIONS	5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT for Period 14 December 1982- 1 April 1983
	6. PERFORMING ORG. REPORT NUMBER: DAEA 18-81-G-0017ET0101
7. AUTHOR(s): James W. Baumgart, M.Paul Stanton, Russell R. Vane	8. CONTRACT OR GRANT NUMBER(s): DAEA 18-81-G-0017ET0101
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Science Applications, Inc., C^3 Systems Department, 1710 Goodridge Drive, McLean, Virginia 22102	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Project Manager, Division Support Weapons System, US Army Research & Development Command, Dover, New Jersey 07801	12. REPORT DATE: 1 April 1983
	13. NUMBER OF PAGES: 129
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Division Support Weapons System, Cost and Operational Effectiveness Special Study Group, US Army Field Artillery Center, Fort Sill, Oklahoma 73503	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

This document has been approved for public release and sale; its distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ARTILLERY, ARTILLERY FIRE, CANNON ARTILLERY, HOWITZERS, AMMUNITION, AMMUNITION EXPENDITURES, AMMUNITION RESUPPLY, AMMUNITION RESUPPLY VEHICLES, COMBAT VEHICLES, COMMAND AND CONTROL, COMMUNICATIONS, RATE OF FIRE, EFFECTIVENESS, MEASURES OF EFFECTIVENESS, LETHAL AREA, TECHNICAL FIRE CONTROL, SURVIVABILITY, FRACTIONAL DAMAGE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Analyzes the impact of different rates of fire for the Division Support Weapons System (DSWS), a 155mm self propelled howitzer. Rate of fire is analyzed against different target types and postures using conventional and dual purpose improved conventional munitions, (DPICM). Major conclusion is that there is a larger relative gain in chosing a maximum product improved howitzer at a rate of fire of eight rounds per minute than new howitzer design at twelve rounds per minute.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

C^3_U operations involving the DSWS howitzer and ammunition resupply are also analyzed. Ammunition expenditures and resupply travel times are developed in a war game computer simulation. The analysis indicated howitzer out of action periods due to a lack of ammunition resupply capability. The requirement for a Single Channel Ground and Airborne Radio System ~~(SINCGARS)~~ on the Field Artillery Ammunition Supply Vehicle ~~(FAASV)~~ and the new Ammunition Resupply Vehicle (ARV) is shown. A howitzer onboard technical fire control capability is also supported.

PREFACE

This technical report is the result of an SAI team effort. Jim Baumgart was the initial Principal Investigator and was responsible for the design of the study methodology, and the refinement of the computer simulation model. He performed the majority of the calculations, ran the computer simulation, arranged the data for the report and developed the major conclusions from the effort.

Russ Vane became the Principal Investigator in the terminal phase of the project. He added additional refinements to the computer simulation model, provided the independent review of the two analytical studies, provided a technical review of the study methodology as well as the written study and responded to interim technical requests from the DSWS Special Study Group at Fort Sill, Oklahoma.

Paul Stanton was the Principal Coordinator of the study effort, wrote the final technical report and provided guidance on field artillery fire support operations and procedures.

Dr. Allen Cohen provided technical guidance and critique to an initial assessment of the study methodology, to an interim assessment of study results and a technical review of the two major analytical sections of the study effort.

Ed Scribner provided overall program direction and additional guidance on maneuver and fire support operations in the Air-Land 2000 context.

The SAI team wishes to express their appreciation to the DSWS COEA Special Study Group and particularly to LTC George Conway and CPT Charles Kaylor for their contribution in defining communications operational concepts in degraded operations. Both were also extremely helpful in providing data input, guidance and assistance in focusing the study effort.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

SECTION 1

SUMMARY

1.1 PURPOSE

This technical report is the final product of an SAI contract to provide technical support in the development of cost and operational effectiveness analysis (COEA) data to support the Division Support Weapon System (DSWS) DSARC I decision. The SAI support effort was initiated by the Project Manager of the DSWS program to provide a focused analytical effort and fill-in data on the impact of rate of fire and specific elements of the DSWS C^3 system requirements. This technical support was established to respond directly to the requirements of the DSWS COEA Special Study Group (SSG) established at the Field Artillery Center at Fort Sill Oklahoma. The SSG has the mission of coordinating the COEA input to the DSWS ASARC I milestone decision. The report contains a section responding to each of the tasks required in the contract statement of work.

1.2 RATE OF FIRE ANALYSIS RESULTS

Section 2 presents the results of an analysis of the impact of rate of fire on selected targets and using conventional high explosive (HE) and dual purpose improved conventional munitions (DPICM). The analysis concentrated primarily on a lightly armored BMP type target. The major conclusions of the analysis are summarized below.

1) Rate of fire is not as critical attacking softer targets and personnel as it is in attacking harder targets.

2) Against lightly armored BMP type-targets:

a. There is a bigger relative gain in going from the HELP to the Maxi-PIP howitzer than from HELP to a new howitzer in cases where high rate of fire is critical (moving targets).

b. 20% F_d, 5% F_d and 2% F_d represent the maximum fractional damages that can be effectively achieved.

c. The HELP howitzer has limited effectiveness against moving or posture changing BMP targets.

d. Increases in effectiveness between the candidate howitzers against stationary targets is much less pronounced.

e. Larger differences in effectiveness against moving targets are due to response time rather than rate of fire at low rates of fire.

f. Reducing target speed provides an opportunity to increase effectiveness.

3) Against self-propelled artillery SP152 type targets, the results are very similar to those obtained for BMP type targets because the submunition lethal areas for DPICM are nearly equal.

4) Against Zil 157 type truck targets, increases in fractional damage were not as great as for BMP type targets.

5) Against personnel targets, there is very little difference in fractional damage between the different rates of fire in all target postures.

Recommendations from this analysis are to examine other promising areas of increased effectiveness to include:

a. The tradeoffs in engaging moving, lightly armored targets with an attack using a mix of FASCAM and DPICM ammunition.

b. Optimum strategies for attacking moving targets, e.g., closing sheaf in early portion of attack.

c. Other important target types e.g., air defense systems, surface to surface missiles, target acquisition systems.

1.3 C^3 ANALYSIS RESULTS

Section 3 of this report presents the results of an analysis of DSWS C^3 system operations. A computer simulation war game scenario was used. The HELP product improved howitzer with a Field Artillery Ammunition Supply Vehicle (FAASV) was examined in a Division 86 scenario. The scenario was then changed to the DSWS organizational and operational concept. In this setting, a Maxi PIP howitzer with a product improved FAASV was used. A new DSWS howitzer and a new ammunition resupply vehicle were played in the same scenario. The study then focused on ammunition expenditures by the DSWS howitzers and the ammunition resupply distances and times required with emphasis on the C^3 requirements associated with the ammunition supply vehicle in this mobile, high volume resupply operation. The requirements for technical fire control onboard the howitzer was also examined. The principal conclusions of the effort were:

1) The HELP howitzer or the most austere product improved version of the M109, self-propelled howitzer does not experience any ammunition outages but is forced out of action by approaching enemy armor in a Division 86 scenario.

2) The Maxi-PIP howitzer experiences ammunition outages after 46 minutes of battle as a result of a higher rate of fire and the requirement of the ammunition supply vehicle to be away from the howitzer for a longer period on a resupply mission. An onboard SINCGARS capability for the ammunition resupply vehicle is implied.

3) The new DSWS howitzer experiences longer time intervals of ammunition outages as a result of a still higher rate of fire and the same requirement for the ammunition resupply vehicle to be away from the howitzer on resupply missions.

The fault tolerance of the Division 86 C^3 concept of technical fire control was then compared with that of the DSWS C^3 concept to specifically determine the requirement for onboard technical fire control. The major conclusion of this analysis was that the artillery unit with howitzer onboard technical fire control would be operational a much greater length of time than a unit operating in a Division 86 C^3 technical fire control environment.

The major recommendations from this effort were:

1) Use SINCGARS in the new Ammunition Resupply Vehicle

2) Have onboard technical fire control on the DSWS howitzer.

The final sections of the report present the results of a literature assessment focusing on potential high interest items for the SSG. A discussion of briefing support provided by SAI to the SSG is also provided.

SECTION 2

RATE OF FIRE ANALYSIS

2.1 INTRODUCTION

The purpose of this section of the study effort is to examine selected aspects of the impact of rate of fire on the Division Support Weapon System (DSWS). The first segment is essentially a target type analysis which examines the contribution of rate of fire in determining:

1) Effectiveness against stationary and mobile targets that change posture for a specified type of kill: (Mobility, firepower, K Kill) by target type, target area and degree of target vulnerability and protective cover

2) Coordination and massing of firepower in terms of numbers of weapons needed for specific engagements

3) Suppressive fire maintained over time

4) Reliability, availability and maintainability (RAM) as implied by rates of fire and elapsed time for the accomplishment of specified mission

The second segment of this effort involves the review and independent assessment of rate of fire analyses performed in the following studies:

- Artillery Unit Survivability Analysis (U) (Reference 1)
- Division Support Weapons System (DSWS) Parametric Study of Rate-of-Fire, Accuracy, Responsiveness (U) (Reference 2)

2.2 TARGET TYPE ANALYSIS

This segment of the analysis will determine the effectiveness of different rates of fire from three candidate howitzers for the DSWS system: the HELP howitzer, the Maxi-Pip howitzer, and the new DSWS howitzer against stationary and moving targets using conventional and Dual Purpose Improved Conventional Munitions (DPICM). The detailed parameters considered in the target type rate-of-fire analysis are contained in Appendix A.

2.2.1 Measures of Effectiveness

Rate of fire, number of howitzers used in the engagement, reliability, target motion, and delivery errors are input variables in determining the number of rounds on target and the fractional coverage of the target as functions of time. For reactive targets, rounds landing early in the barrage will have more effectiveness than later ones due to greater probable target coverage and higher target vulnerability. Thus, a delivery system with a higher rate of fire will have a greater lethality per round than a delivery system with a lower rate of fire because more rounds will impact during early time intervals. The exact lethality will vary directly with target motion and vulnerability. This leads to the first measures of effectiveness as follows:

1) Number of rounds fired at each target as a function of rate of fire

2) Number of howitzers that engage each target as a function of rate of fire

3) Length of time each target is engaged as a function of rate fire

4) Maximum number of targets engaged per hour as a function of rate of fire

For a fixed fractional damage specification, Measures 2 and 3 are due to differences in lethality as a function of rate of fire. Measures 1, 2 and 3 can be combined with shoot-and-scoot data, and aimpoint-to-aimpoint transition time data to calculate the maximum number of targets engaged per hour by the DSWS battalion for each candidate howitzer. The maximum number of targets engaged per hour will be the fundamental measure of effectiveness for the rate of fire analysis.

2.2.2 Effectiveness Methodology

The effectiveness function will be derived using the following methodology:

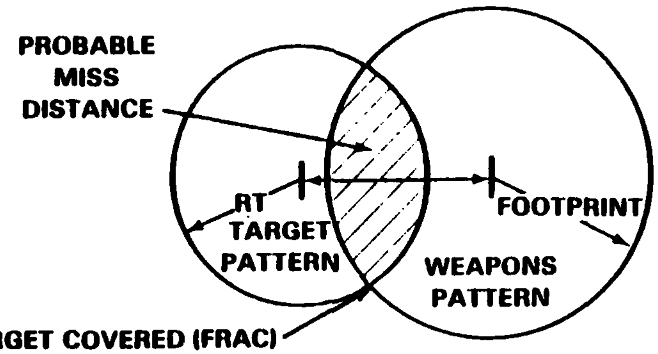
The analysis will use weapon pattern circles intersecting with target circles (Figures 2-1, 2-2 and 2-3). Material and personal targets are assumed to be uniformly distributed throughout a circle defined by a radius. The effects of target location error, precision error and mean point of impact probable error, are combined to indicate fractional coverage of the target area by the weapons pattern.

Lethal Areas

Lethal areas for HE rounds and DPICM submunitions are given in the Joint Munitions Effectiveness Manual (JMEM) for M109 A1/A2/A3 155m self propelled Howitzer (Reference 3). The lethal area for a weapon versus a specific target given environmental conditions is calculated by an integral of the form

$$\text{Lethal Area} = \int P_k \, dA \qquad (2)$$

where P_k is the probability of kill and ranges from 0 to 1, and dA is the change in area. We shall assume that a lethal area of $X\,r^2$ is approximated by a circle of radius $\sqrt{\frac{X}{\pi}}$ within which the



- CEP_{TLE} = PROBABLE TARGET LOCATION ERROR
- MPI = MEAN POINT OF IMPACT PROBABLE ERROR (RMPI, DMPI) = RANGE AND DEFLECTION PROBABLE ERRORS
- CEP_{MPI} = CIRCULAR ERROR PROBABILITY FOR MISS DISTANCE

$$CEP_{MPI} = \left\{ \begin{array}{lll} 1.24 & \sqrt{RMPI^2 + DMPI^2} & 1.0 \geq FRAC \geq 0.75 \\ 0.872 & (RMPI + DMPI) & 0.75 \geq FRAC \geq 0.4 \\ 1.75 & \sqrt{(RMPI \cdot DMPI)} & 0.4 \geq FRAC \geq 0.1 \end{array} \right\} \quad (1)$$

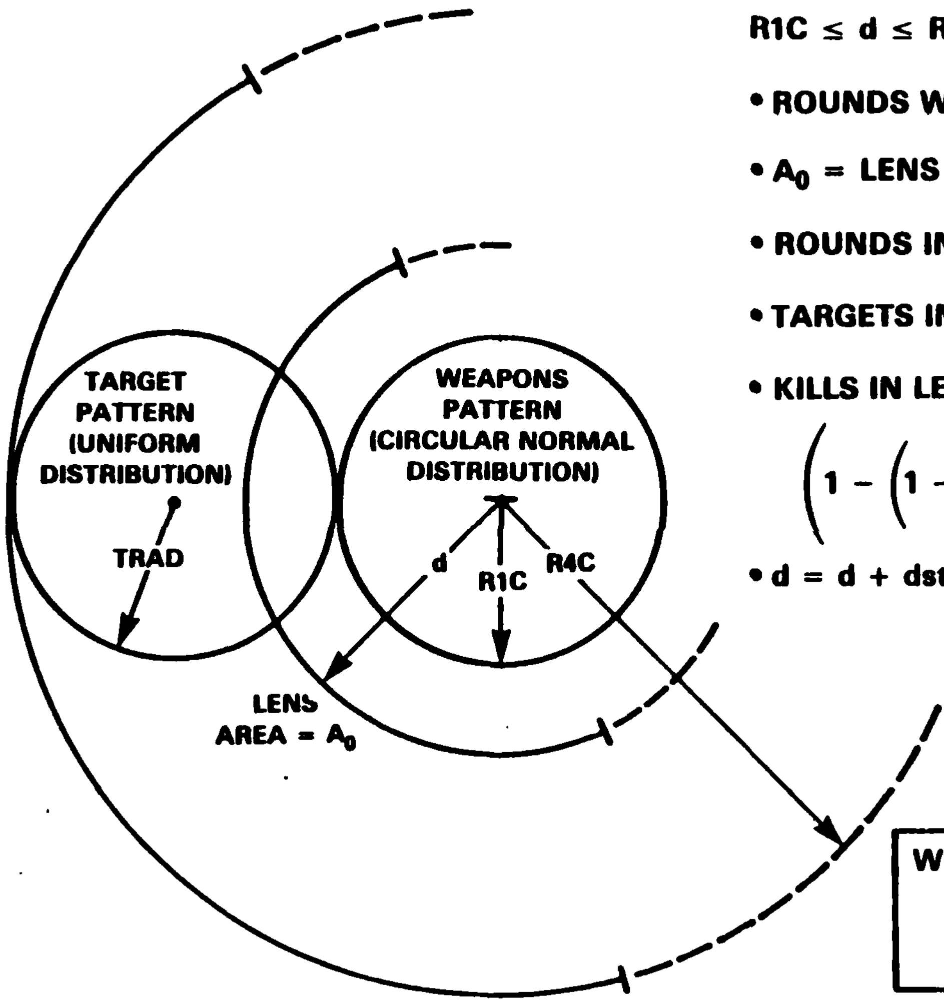
- $CEP_{MD} = \sqrt{CEP^2_{TLE} + CEP^2_{MPI}}$ PROBABLE MISS DISTANCE
- PATTERN PRECISION, PROBABLE PRECISION = (RPEP, DPEP) PROBABLE PRECISION ERRORS IN RANGE AND DEFLECTION

  CEP_{PP} = EQUIVALENT CIRCULAR ERROR PROBABILITY DUE TO PRECISION

  $CEP_{PP} = \sqrt{(RPEP \cdot DPEP)}$ EQUAL AREA CIRCLE
- WEAPONS FOOTPRINT = (RANGE WITHIN WHICH 90% OF THE ROUNDS FALL) + SUBMUNITIONS PATTERN RADIUS (SPR)

  = $(2.09\ CEP_{PP}) + SPR$ = PATTERN AREA FROM 1 HOWITZER. PATTERN AREA FROM N = $(2.09\sqrt{N}CEP_{PP}) + SPR$
- FRAC DETERMINED BY GEOMETRY

Figure 2-1 Determination of Fractional Damage (F_d)



σ = CEP/1.774

R1C $\leq$ d $\leq$ R4C. d IS THE INTEGRATION VARIABLE.

- ROUNDS WITHIN d = NRWD = $(1 - e^{-d^2/2\sigma^2})$ · (ROUNDS FIRED)
- A_0 = LENS AREA[1]
- ROUNDS IN LENS = NRWD · $(A_0/\pi d^2)$
- TARGETS IN LENS = (TARGETS) · $(A_0/\pi(\text{TRAD})^2)$
- KILLS IN LENS =

$$\left(1 - \left(1 - \frac{\rho \, LA}{A_0}\right)^{\text{ROUNDS IN LENS}}\right) \times \text{(TARGETS IN LENS)}$$

- d = d + dstep

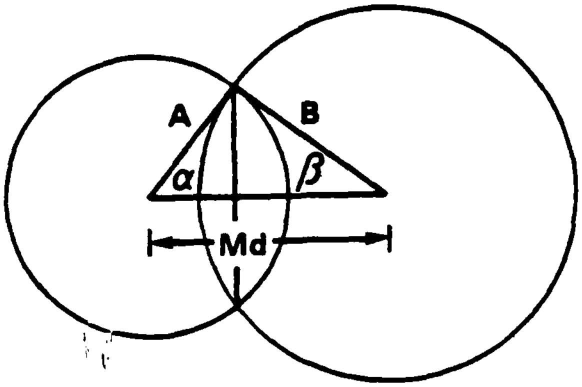
WHERE:

ρ = ROUND RELIABILITY

LA = ROUND LETHAL AREA

1. A_0 IS DETERMINED BY THE GEOMETRICAL FORMULA SHOWN IN FIGURE 2-3.

Figure 2-2 Integration over Circular Normal Weapons Distribution



THE UPPER QUARTER OF THE LENS AREA IS EQUAL TO THE AREA OF A SECTOR MINUS THAT OF A SECTOR MINUS THAT OF A TRIANGLE FOR EACH CIRCLE. THUS, IF A_0 = LENS AREA

$$A_0 = Z\,[(A^2 Z\alpha - 1/2\,A^2 \cos(\alpha)\sin(\alpha) + (B^2\beta - 1/2\,B^2\cos(\beta)\sin(\beta))]$$

TO COMPLETE THE SOLUTION, WRITE α AND β IN TERMS OF A,B,Md (Md = MISS DISTANCE))

IF $S = (A+B+d)/Z$

AND $Q = \sqrt{(S-A)(S-B)(S-Md)/S}$

THEN $\alpha = 2 \times \tan^{-1}(Q/(S-B))$

AND $\beta \pm 2 \times \tan^{-1}(Q/(S-A))$

Figure 2-3 Geometry for Determining Lens Area probability of kill = 1.0. Explicit data for round and sub-munition lethal areas is given in Appendix A and in the JMEM.

Delivery Errors

Range and deflection mean point of impact probable errors are converted to equivalent circular probable error (CEP) using equation (1) in Figure 2-1 derived as a curve from analytic data. Total probable miss distance is the root-sum-square of probable target location error and probable delivery errors.

Weapons Pattern Area

Mean Point of Impact (MPI) errors define where the first round is likely to land. Precision errors determine the subsequent weapons footprint around that point. Range and deflection probable precision errors form an ellipitically normal distribution. This probable ellipse is converted into the equal area CEP.

The CEP is a product of a bivariate spatially normal distribution with equal standard deviation, σ , in both $\hat{x}$ and $\hat{y}$ directions. CEP is the range within which 50% of the rounds fall. The probability that a round falls within a range r is found to be:

$$P = 1 - e^{\frac{-r^2}{2\sigma^2}} \qquad (3)$$

Letting P = 1/2 we solve this for the CEP:

$$1/2 = 1 - e^{-\frac{CEP}{2\sigma^2}} \qquad (4)$$

Giving

$$CEP = \sigma \sqrt{-2 \ln (1/2)} \text{ or}$$

$$CEP = 1.1774\, \sigma \qquad (5)$$

Similarly, the range within which 99% of all rounds land can be found to be equal to 3.03 σ. Equation (3) and geometrical relations given in Figure 2-3 are the basis for determining the distribution of rounds on the target and thus the expected fractional damage. Inside a lens shaped region, rounds that land are assumed to be uniformly distributed. This assumption is approximately valid if the integration variable, d , is small compared to σ. Since d can be assigned any suitable value, this approximation will hold. For a region with uniform target and munitions distributions, estimates of F_d can be found using an equation of the form:

$$\text{Target killed} = \text{targets in region} \left[- (1 - \frac{\rho L_A}{A_o}) \right]^R \qquad (6)$$

where ρ = round reliability

L_A = round lethal area

A_o = lens region area

R = number of rounds

This takes into account overlapping round lethal areas. Replacing the number of rounds with the number of submunitions and round lethal area with submunition lethal area converts equation (6) into one suitable for DPICM rounds.

Since DPICM rounds have very large disperson areas, the pattern area for a DPICM barrage is taken to be the maximum precision error plus dispersion radius as shown in Figure 2-4. In some cases a very large footprint is required. A good footprint is just big enough to encompass all of the target area. Any smaller footprint reduces below 100% the fraction of the target covered by the weapons effects and reduces the maximum possible fractional damage. In cases where very large footprints are required, multiple howitzers can fire standard sheafing patterns.

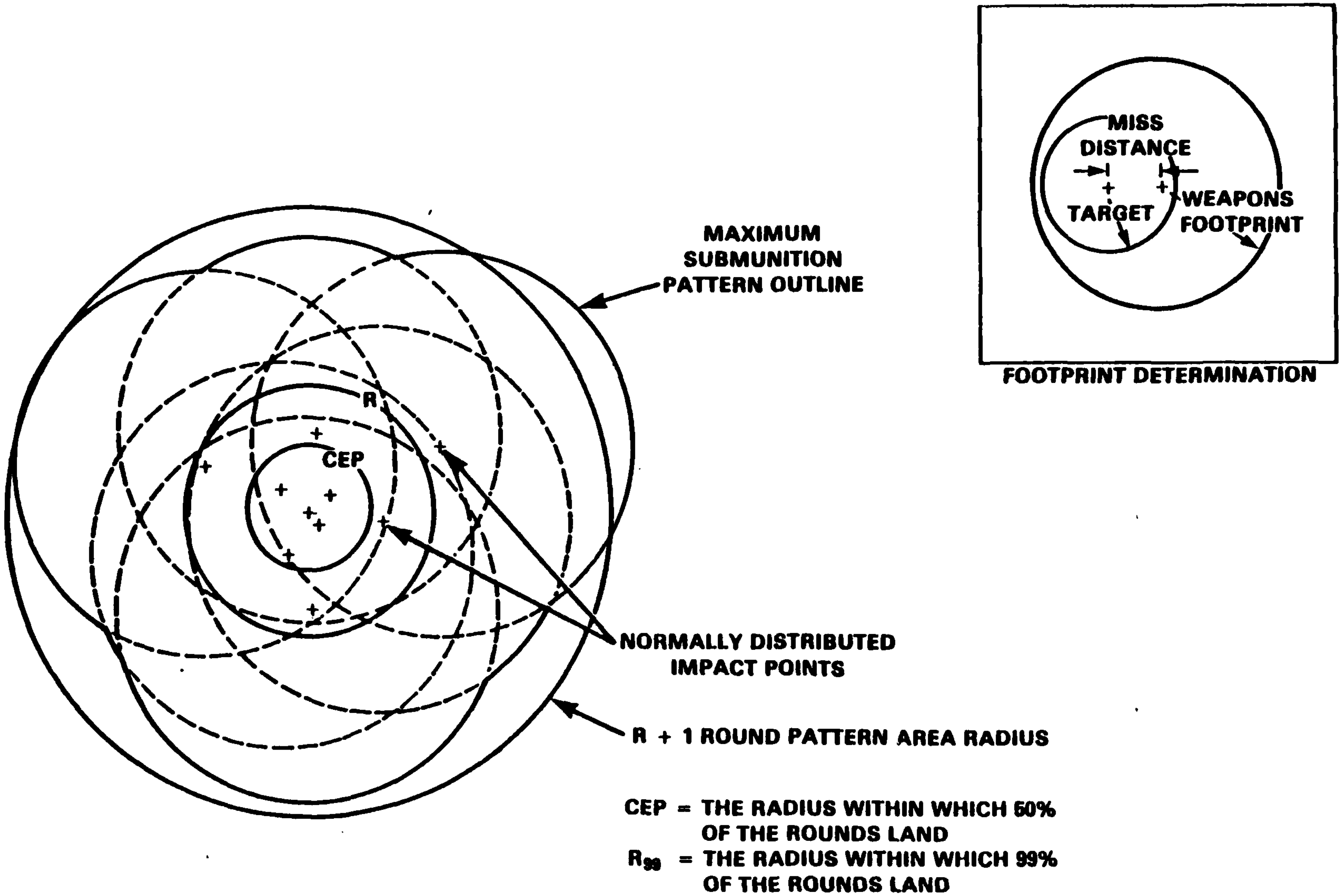


Figure 2-4 DPICM Pattern Area

2.2.3 Input Values

The input values depicted in Figure 2-5 are intended to show the effects of increases in rate of fire on targets of varying hardness and reactiveness. A high rate of fire is expected to be most important when attacking hard targets that are highly reactive to incoming fires. Thus the analysis has placed greater emphasis on BMP target categories. It is intuitively obvious that increasing rate of fire will bring no gains in damage levels against infinitely hard or infinitely soft targets. If target location errors and delivery errors are so large that only a very small portion of the target area is covered, increases in rate of fire will not make a significant increase in fractional damage. Similarily, large response time against moving targets can allow the target to be covered by only a small part of the weapons footprint. This again leads to the intuitive conclusion that rate of fire increases will not bring a significant increase in lethality. For these reasons, the examination is focused on cases in which it is anticipated that increased rate of fire can bring increased effectiveness.

The exact change in effectivenss of DPICM based on varying burst height when a target location error becomes small is unknown from the data sources used in this effort. However, an increased effectiveness would occur with small target location error and an increased lethality due to lower burst. Similarly a dense target array would be affected in the same manner if its target radius was smaller than the effective burst radius of DPICM.

2.2.4 Moving Target Methodology

Figure 2-6 shows the basic methodology for treating reactive armored targets. A target that moves on incoming is initially stationary. The target location on such targets is not affected by motion and the fractional coverage of the target area by the weapons pattern does not depend upon response time. When

TARGETS

- STATIONARY BMP PLT
- STATIONARY BMP PLT (THAT MOVES ON INCOMING)
- MOVING BMP PLT
- MOVING BMP CO
- STATIONARY Zil-157'S (THAT MOVE ON INCOMING)
- MOVING Zil-157'S
- 152 MM SPH (BATTERY THAT MOVES ON INCOMING)
- PERSONNEL (STANDING TO PRONE OR STANDING TO FOXHOLE ON INCOMING)

KILL TYPES

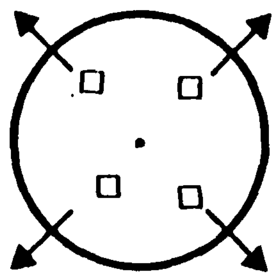
M	KILL	BMP AND SP 152
F	KILL	
K	KILL	
C	KILL	Zil-157
1.5	MAN HOUR	
5 MIN	ASSAULT	PERSONNEL

PARAMETERS

RATE OF FIRE:	4, 6, 8, 10, 12 RNDS/MIN
NUMBER OF HOWITZERS:	1, 2, 4, 8, 16, 24, 48, 72
TARGET SIZE:	PLT, CO, BN
TARGET LOCATION ERROR:	0, 50, 80, 100, 150, 250, 500 M
MUNITION:	M107 TNT; M483 M42 (DPICM)
RANGE:	4, 7, 12, 16, 18 KM
TARGET AVERAGE VELOCITY:	75, 150, 250, 300, 500 M/MIN

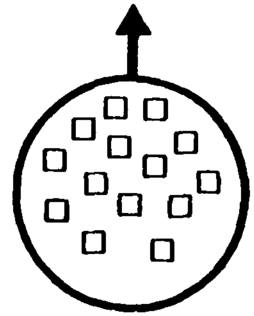
Figure 2-5 Input Values

TARGET THAT MOVES ON INCOMING



- TARGET STATIONARY INITIALLY
- TLE = THAT OF A STATIONARY TARGET
- TARGET RADIUS EXPANSION OF 75 TO 300 M/MIN (AVERAGE VELOCITY)
- TARGET STARTS TO MOVE AS SOON AS 1ST ROUNDS LAND (1ST VOLLEY)
- SURVIVING VEHICLES REASSEMBLE AT AN ALTERNATE POSITION

MOVING TARGETS



- TARGET MOVING INITIALLY
- TLE = FUNCTION OF RESPONSE TIME
- MISS DISTANCE INCREASE BY: 75 M/MIN TO 300 M/MIN
- BATTERY FIRES AT 1 AIMPOINT THROUGHOUT THE MISSION. USE SHEAFING WHERE APPROPRIATE

Figure 2-6 Reactive Target Considerations the first rounds land in the vicinity of the target, target reaction time begins. The different considerations involved in reaction time include displacement time, acceleration and peak velocity. These are parameterized as different average velocities. The average velocity is defined as the distance a vehicle in the target cluster can be expected to move in the first minute from the time when the first round lands. Vehicular targets that move on incoming are assumed to displace radially outward from the target centroid so that the effect is an expansion of the target radius at the parameterized vehicular average velocity.

Initially moving target clusters present a slightly different situation. Target acquisition systems (e.g., forward observers, RPVs, JSTAR) report target size, position, bearing, and speed. Rounds aimed at the target begin to fall sometime later. This elapsed time is defined as the response time. Response time consists of many elements including data transmission time, queue time, tactical fire control decision time, technical fire control computation time, delay time at the howitzer and time of flight of the projectile. Since the AN/TPQ-36 or 37 system is not considered, target acquisition systems response times are parameterized with values from 1 to 4 minutes. TACFIRE systems can use estimated response times plus target position, bearing and speed data to predict target location when the rounds begin to land. However, due to unforseen random target velocity and bearing fluctuations, miss distance will increase with response time. The relationship is shown in Figure 2-7. Response time is defined to be the elapsed time from when target size, position bearing and speed are reported to the fire direction center to when the first round lands. Tanks and BMPs, with their added mobility, have larger expected velocity fluctuations and hence a larger expected miss distance than the ZIL-157 trucks. The miss distances at 0 response time correspond to the expected target location error. Minimum response time for a digital quickfire channel direct to a howitzer with on board technical fire control is estimated to be 15 seconds plus projectile time of flight or about 1 minute.

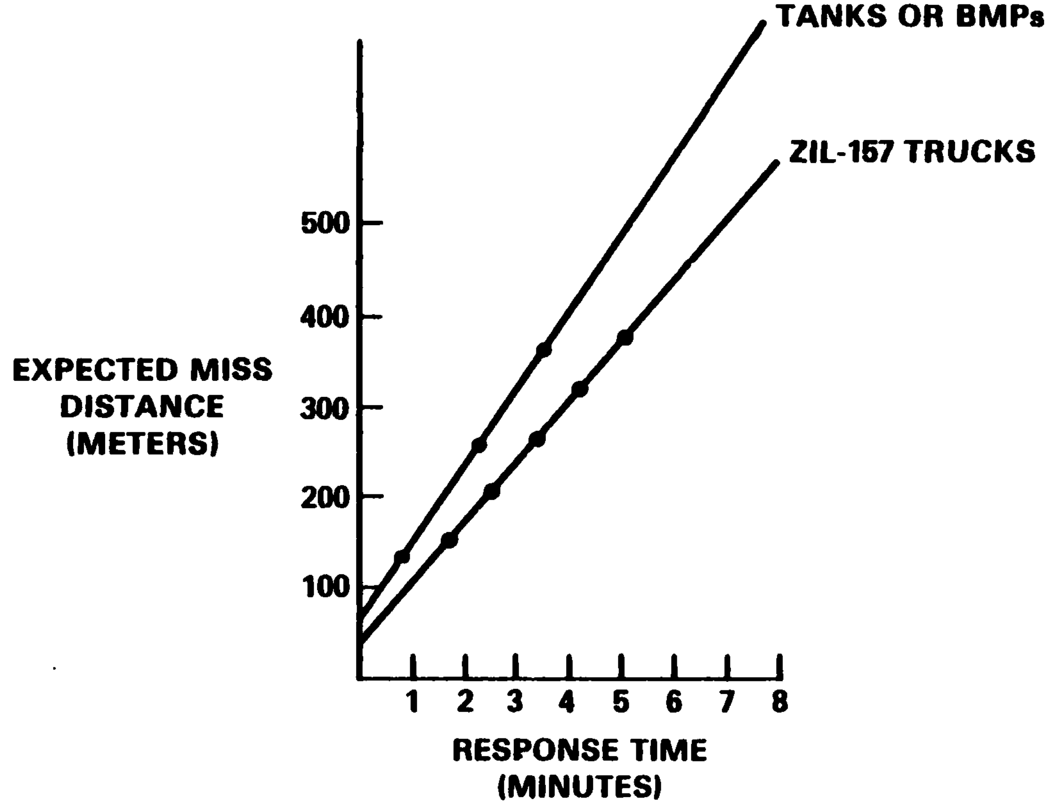


Figure 2-7 Expected Miss Distance for Moving Targets

Reactive personnel targets can change posture between standing, prone and foxhole positions. This corresponds to a change in lethal area as the exposed personnel take cover. The computer progam given in Appendix B is designed to sum cumulative casualties over 5 to 15 second intervals for the duration of the barrage. As the target radius expands, target motion increases the change of distance or lethal areas. These target reactions can each be varied or combined. The following section presents a comparison of results with standard JMEM tabular data for non-reactive targets compared to the SAI model for the same type of target.

2.2.5 JMEM/SAI Model Comparison

Figures 2-8 thru 2-11 show comparison between tabulated JMEM fractional damage estimates and SAI developed data with the methodology just developed. There is high correlation in every target case. The agreement is closest on hardened targets, with comparative accuracy dropping off against softer targets. However, in all cases the JMEM data and the data using SAI's methodology show curves with the same general shape and slope. Since the SAI analysis is focused on measuring the relative effects that increases in rate of fire have on fractional damage levels, the comparative slopes of the curves are the main interest. The slope of the curve is related to the increase in fractional damage with number of rounds on target. For a fixed number of howitzers, increasing the rate of fire translates into increasing number of rounds on target. Table 2-1 provides a summary of the comparison by target types between the SAI and JMEM model.

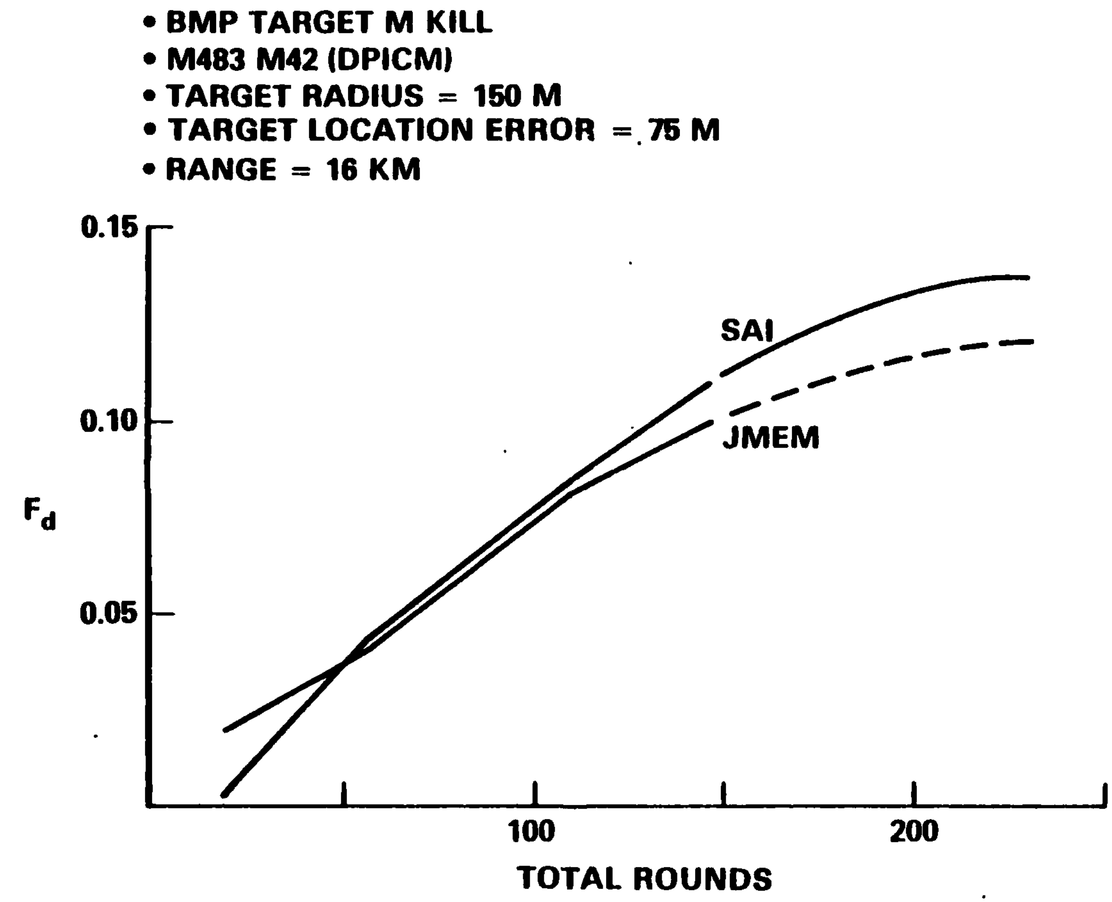


Figure 2-8 SAI/JMEM Model Comparison - BMP Targets

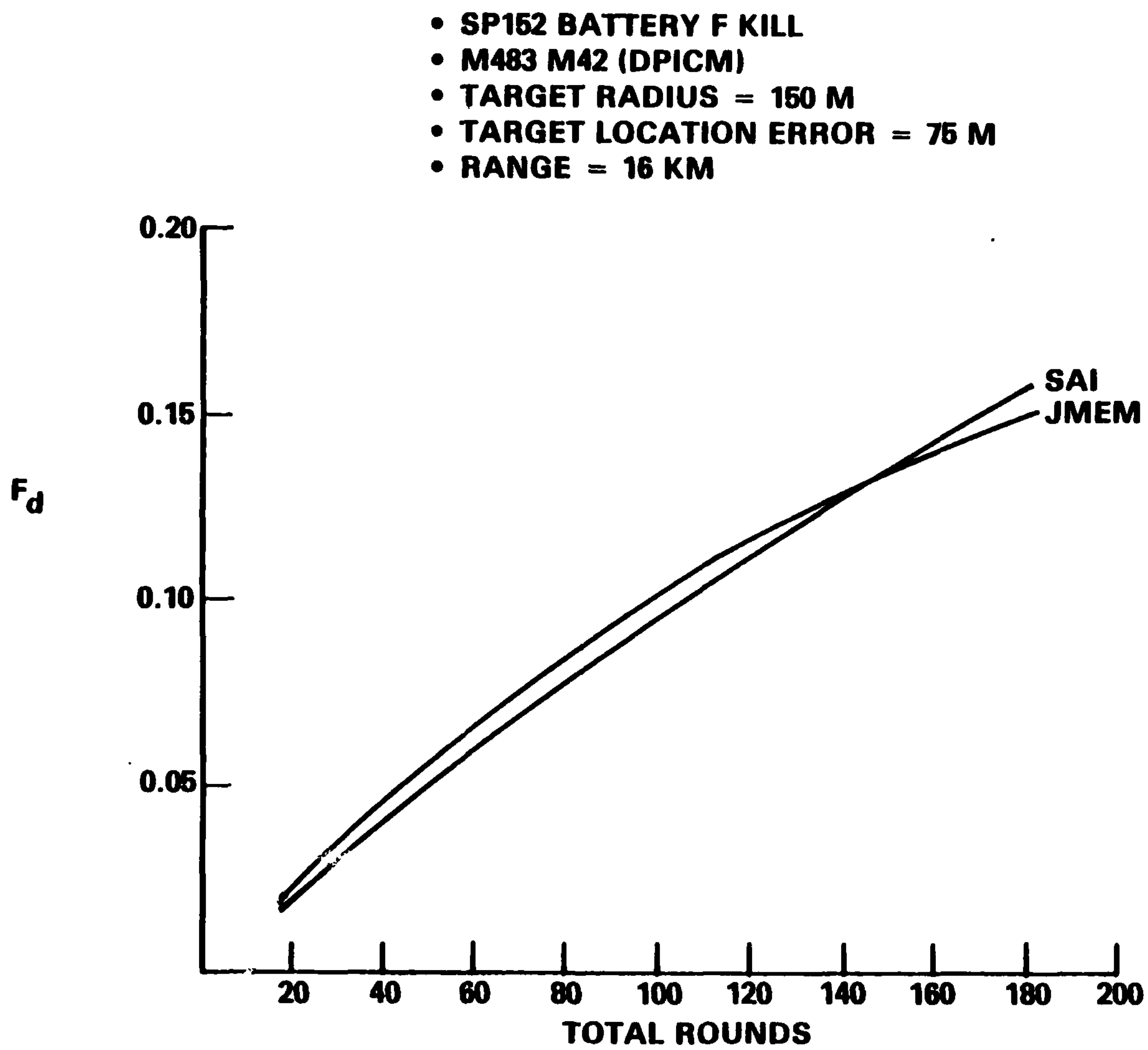


Figure 2-9 SAI/JMEM Model Comparison - SP 152 Targets

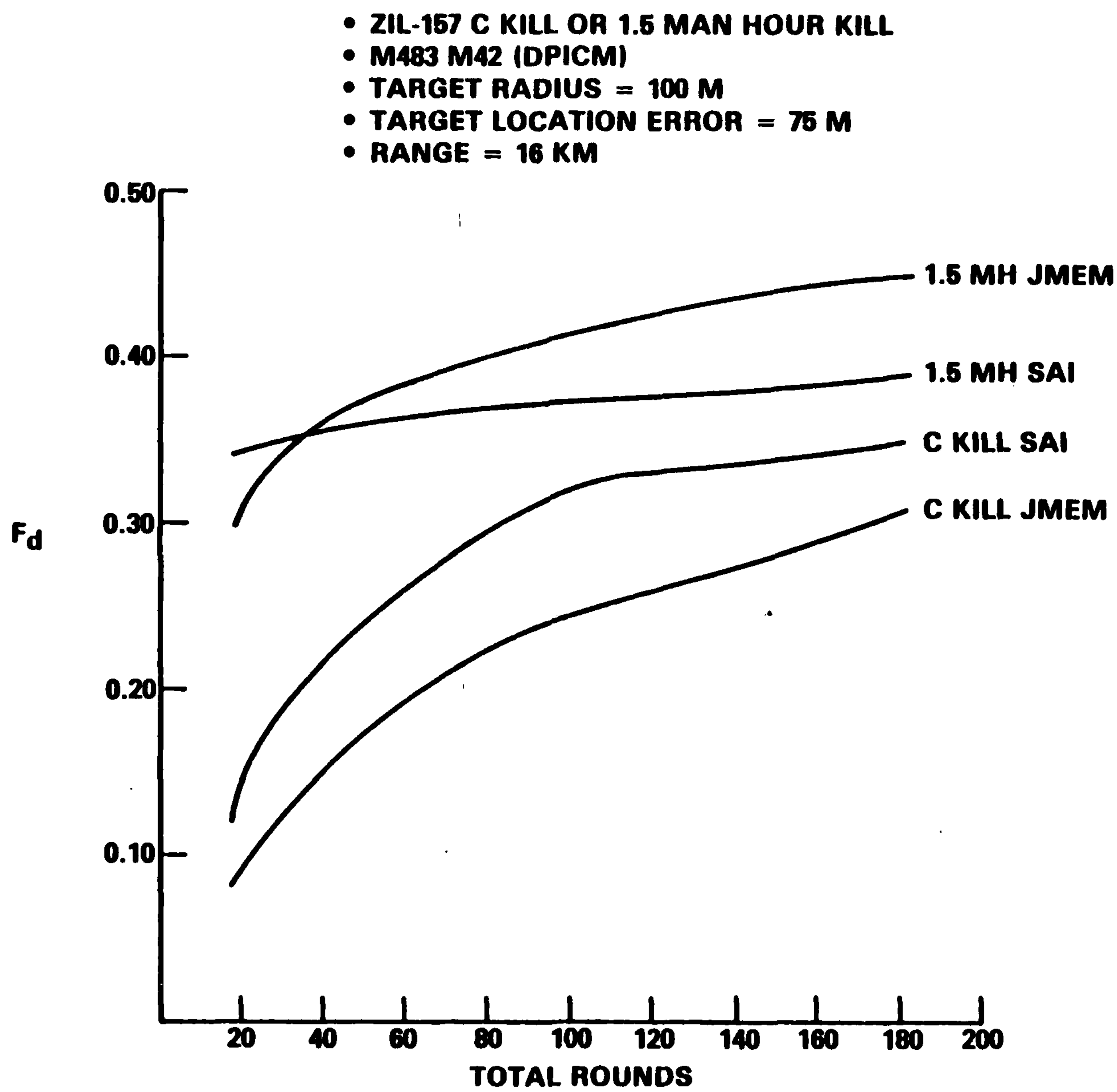


Figure 2-10 SAI/JMEM Model Comparison - ZIL-157 Targets

- PERSONNEL IN THE OPEN
- RANGE 4 KM
- TARGET LOCATION ERROR 75 M
- RANGE PROBABLE MPI ERROR 37 M
- DEFLECTION PROBABLE MPI ERROR 10 M
- PRECISION PROBABLE ERRORS RANGE 58 M, DEFLECTION 12 M
  6 HOWITZERS FIRE, STAR PATTERN

JMEM RESULTS

TARGET RADIUS (m.)	FRACTIONAL DAMAGE								
	36 ROUNDS			72 ROUNDS			186 ROUNDS		
	STANDING	PRONE	FOXHOLE	STANDING	PRONE	FOXHOLE	STANDING	PRONE	FOXHOLE
100	0.19	0.08	0.0	0.28	0.14	0.0	0.40	0.25	0.0
200	0.09	0.04	0.0	0.14	0.07	0.0	0.21	0.12	0.0

MODEL RESULTS

100	0.21	0.15	0.02	0.31	0.25	0.04	0.39	0.37	0.10
200	0.13	0.09	0.01	0.19	0.16	0.03	0.24	0.23	0.07

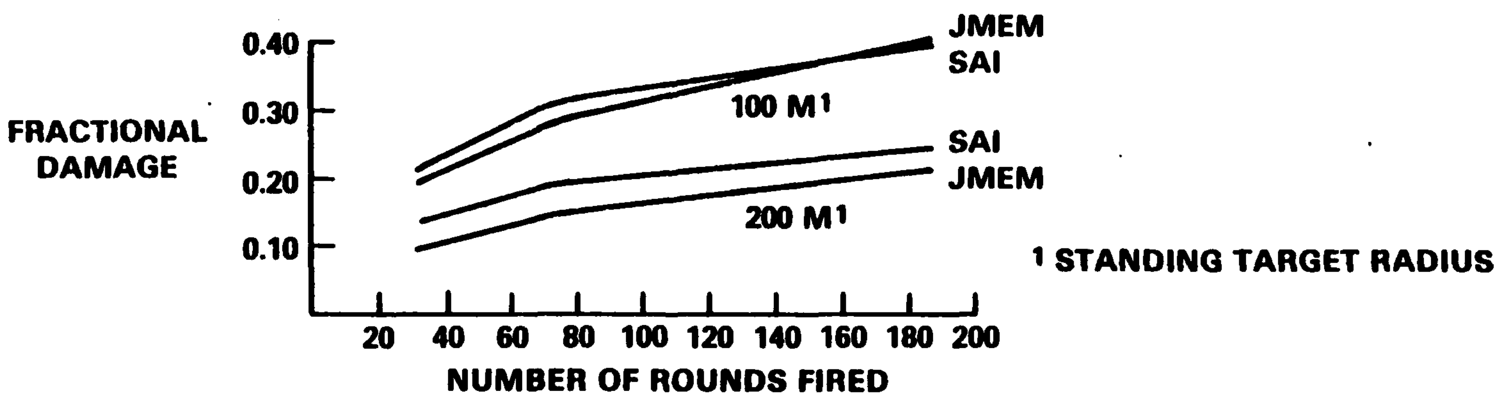


Figure 2-11 SAI/JMEM Model Comparison - Personnel Targets

Table 2-1

SAI/JMEM MODEL COMPARISON

TARGET	MAXIMUM TOTAL DIFFERENCE IN F_d	MAXIMUM DIFFERENCE IN SLOPES
BMP	6.25%	2%
SP 152	5.1%	2%
Zil-157	24.0%	12%
Personnel	30.0%	16%

2.2.6 BMP Targets

This portion of the rate of fire analysis considers Soviet BMP or armored personnel carriers as the target. The analysis considers platoon and company sized targets as well as both a stationary and moving target posture.

2.2.6.1 Comparison of Munitions/Kill Category

There are large increases in fractional damage with increased rate of fire for DPICM rounds versus BMP targets at M and F kill lethal areas. These gains drop significantly for DPICM K Kill and all M107 TNT kills. This relationship is depicted in Figure 2-12 and in Table 2-2.

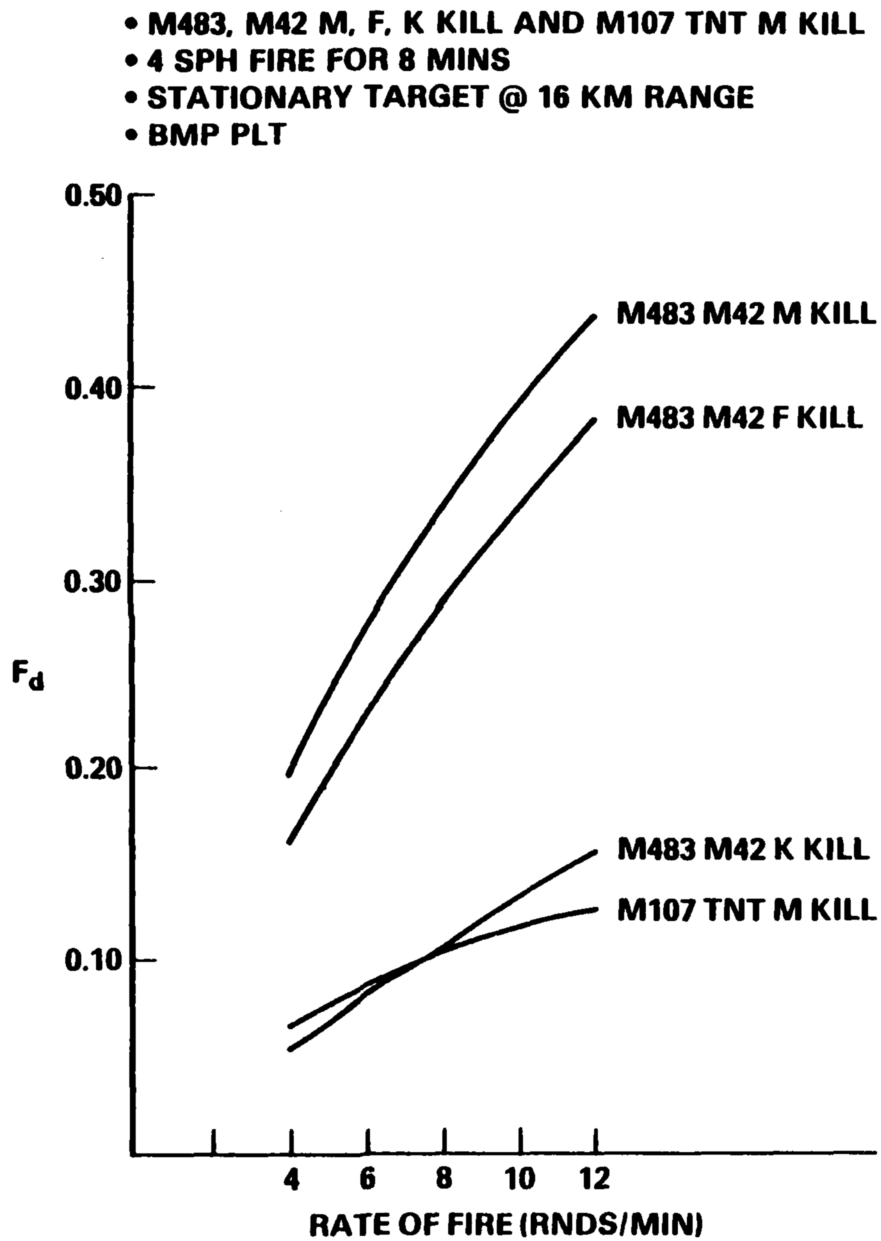


Figure 2-12 Stationary BMP Platoon - Fractional Damage Versus Rate of Fire/Type Kill

Table 2-2

INCREASE IN FRACTIONAL DAMAGE WITH INCREASING RATE OF FIRE

RATE OF FIRE INCREASE	MUNITION/KILL CATEGORY	INCREASE IN F_d
4 to 12 rnds/min	DPICM M Kill	0.30
4 to 12 rnds/min	DPICM F Kill	0.30
4 to 12 rnds/min	DPICM K Kill	0.15
4 to 12 rnds/min	TNT M Kill	0.04

This data leads to the following conclusions:

1) DPICM is about 4 times more effective than M107 TNT.

2) DPICM has limited effectiveness when shooting for a K kill.

3) The most appropriate kill category for a BMP target is M (mobility).

4) Increases in effectiveness due to rate of fire are less as round lethal area decreases.

5) M107 TNT round has limited effectiveness against a BMP target.

Primary interest is in cases where increases in rate of fire have maximum payoff. Therefore, the analysis will concentrate on DPICM/M Kill munition/kill category for the rest of the BMP cases.

2.2.6.2 Stationary BMP Targets

Figure 2-13 shows increases in fractional damage with rate of fire as a function of the elapsed time that 4 howitzers fire at a stationary BMP platoon. The results are compared for gun-target ranges of 4 and 16 kilometers. The differences between the 4 and 16 km curves are due to range and deflection delivery errors and submunition pattern dimensions as given in the JMEM. The conclusions drawn from Figure 2-13 are made by noticing the time needed to complete a mission where the desired

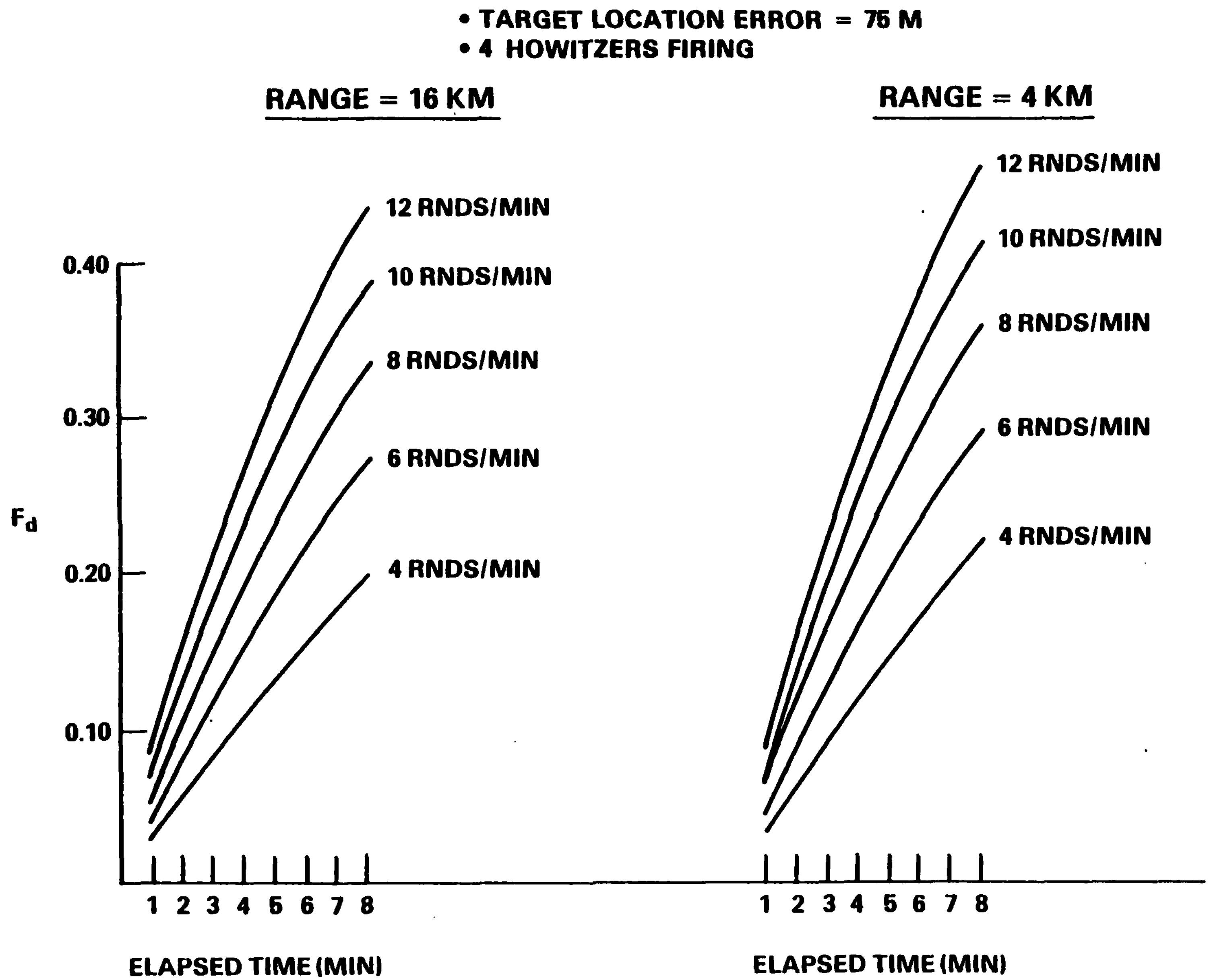


Figure 2-13 Stationary BMP Platoon - Fractional Damage Versus Elapsed Time/Rate of Fire/Target Range

fractional damage level is specified to be 20%. This serves as an introduction to the basic measure of effectiveness which is defined to be:

$$\text{Effectiveness} = \frac{\text{Targets Killed}}{\text{Howitzers at Risk X Minutes at Risk}} \qquad (7)$$

Figure 2-14 shows the effectiveness function scaled so that the effectiveness of 4 howitzers firing at 4 rounds per minute with a gun-target range of 16 km = 1.0. It is apparent from this graph that 12 rounds per minute give a gain in effectiveness over 4 rounds per minute by a factor of more than 3 due to decreased time at risk. Increases in range have very little effect.

A summary of the conclusions that can be drawn from Figures 2-13 and 2-14 is as follows:

1) Four Howitzers firing at 12 rounds per minute are over 3 times as effective as 4 howitzers firing at 4 rounds per minute primarily as a result of shorter time to complete a mission.

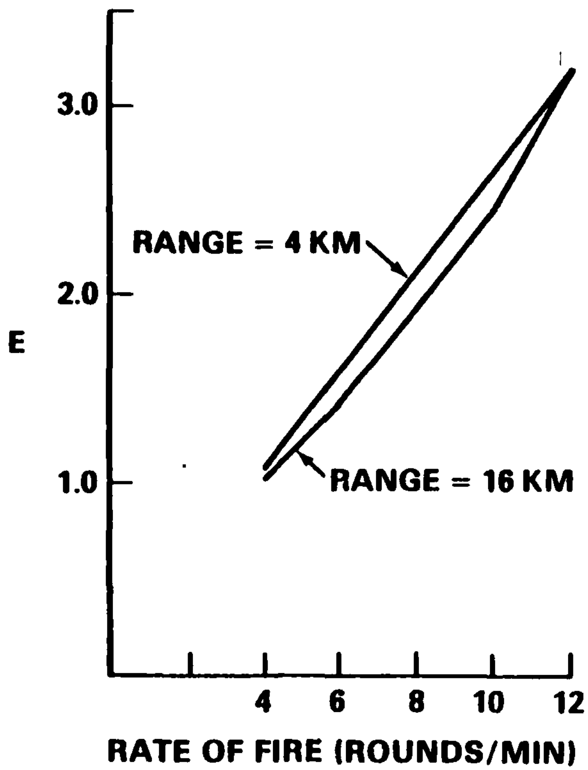
2) Shorter time to complete a mission enhances system effectiveness in two ways:

   a. More tagets can be engaged in the same total time.

   b. Risk exposure of the howitzers is reduced.

Shorter mission time and "shoot-and-scoot" tactics imply that enemy response time with counterfire must be significantly quicker to be effective. The current operational concept of howitzers shooting missions and then scooting, or scooting on incoming means that howitzers will be exposed at one position for the following times:

- MISSION: 20% FRACTIONAL DAMAGE ON BMP PLT
- 4 SPH FIRING M483 M42 DPICM



RATE OF FIRE (ROUNDS/MIN)	TIME TO COMPLETE MISSION (MIN)	
	RANGE 16 KM	RANGE 4 KM
4	8	7.25
6	5.5	3.75
8	4	3.75
10	3.25	3
12	2.5	2.5

Figure 2-14 Stationary BMP Platoon - Effectiveness Versus Rate of Fire/Target Range

Table 2-3

EXPOSURE TIME

RATE OF FIRE (ROUNDS/MIN)	TIME FOR 3 MISSION TIME DISPLACEMENT (min)
4	26
6	17.5
8	13
10	10.6
12	8.5

An enemy counter fire response time of about 10 minutes means that howitzers with rates of fire of 10 rounds per minute or greater are relatively invulnerable. This does not however, consider the possibility that higher rate of fire systems will probably be more detectable by an enemy counter battery radar system.

2.2.6.3 Moving BMP Targets

The analysis of rate of fire effects against moving BMP targets begins at this point. Higher rate of fire systems intuitively will be more effective against moving reactive targets because more rounds will impact during early times when the target is most vulnerable. The simpliest way for a stationary target cluster to react is to scatter on incoming fire. This motion is parameterized as an expanding target radius with average velocities of 75 to 300 meters per minutes (m/min).

Figure 2-15 presents data relating to fractional damage against a moving BMP platoon at different rates of fire. Effectiveness data is also presented using the same formula used previously.

Figure 2-15 indicates that it is not effective to attack a BMP platoon that moves on incoming at 300 m/min for longer than 1 minute using any number of howitzers at any rate of fire. Different sheafing techniques can extend the effective time of engagement when multiple howitzers fire offset aimpoints. However, more fractional damage is attained by multiple howitzers

• **MOVES ON INCOMING AT 300 M/MIN**

4 HOWITZERS

RNDS/MIN	F_d	E
4	0.014	1.00
6	0.019	1.35
8	0.025	1.79
10	0.030	2.14
12	0.034	2.42

8 HOWITZERS

RNDS/MIN	F_d	E
4	0.029	1.03
6	0.035	1.25
8	0.046	1.64
10	0.056	2.00
12	0.062	2.21

16 HOWITZERS

RNDS/MIN	F_d	E
4	0.054	0.95
6	0.064	1.14
8	0.083	1.48
10	0.099	1.76
12	0.11	1.96

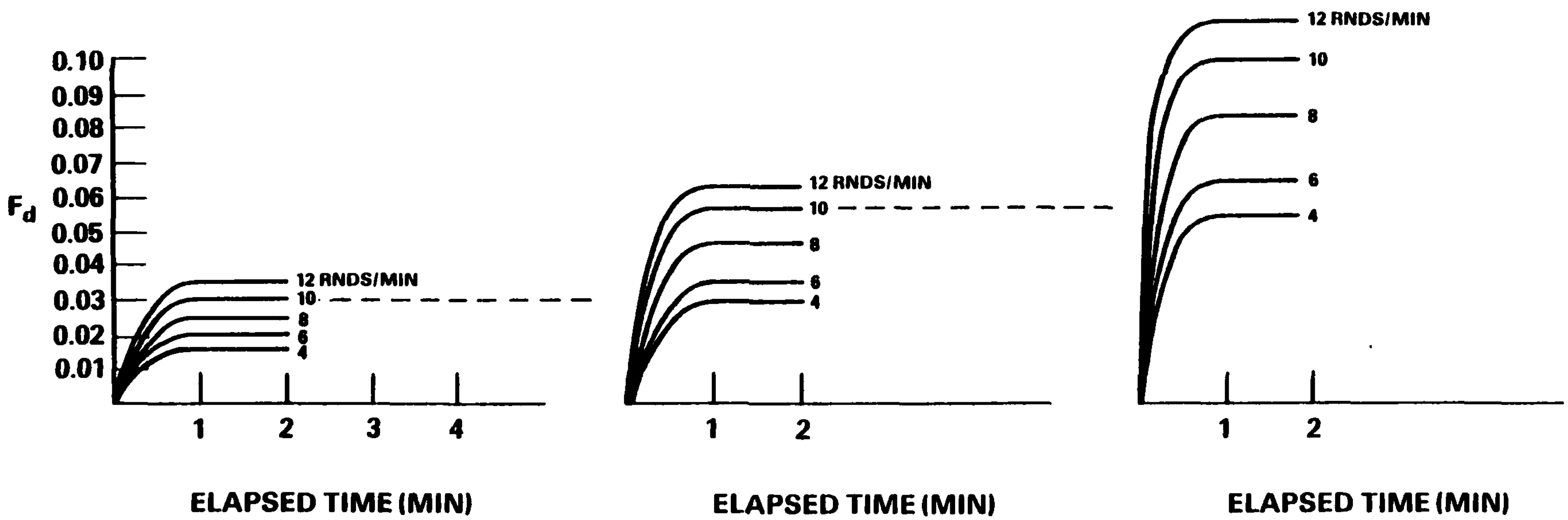


Figure 2-15 Moving BMP Platoon - Fractional Damage Versus Elapsed Time/Rate of Fire/Number of Howitzers

by firing the most concentrated pattern in order to get the most kills early in the attack.

Although increasing the number of howitzers firing increases total fractional damage, effectiveness decreases because the relative increase in number of targets killed is less than the relative increase in howitzers firing. The principal conclusions from this portion of the analysis are:

1) The duration of attack should be one minute or less

2) 8 howitzers at 4 rounds per minute cause the same fractional damage as 4 howitzers at 10 rounds per minute

3) 16 howitzers at 4 rounds per minute cause the same fractional damage as 8 howitzers at 10 rounds per minute

Increasing rates of fire are responsible for large increases in effectivenss as shown in Figure 2-16.

The form of the equation for effectiveness:

$$E = \frac{\text{Target Killed}}{\text{Howitzers X Minutes}}$$

implies that doubling the number of howitzers firing or doubling the number of minutes that they fire must be accompanied by a doubling of the targets killed for effectiveness to remain constant. Figure 2-16 shows large increases in effectiveness with an increased rate of fire and relatively small increases of effectiveness with a larger number of howitzers firing.

Compared to 4 howitzers at 4 rounds per minute:

1) 4 howitzers at 12 rounds per minute are 2.45 times more effective
2) 4 howitzers at 10 rounds per minute are 2.14 times more effective
3) 4 howitzers at 8 rounds per minute are 1.78 times more effective
4) 4 howitzers at 6 rounds per minute are 1.35 times more effective

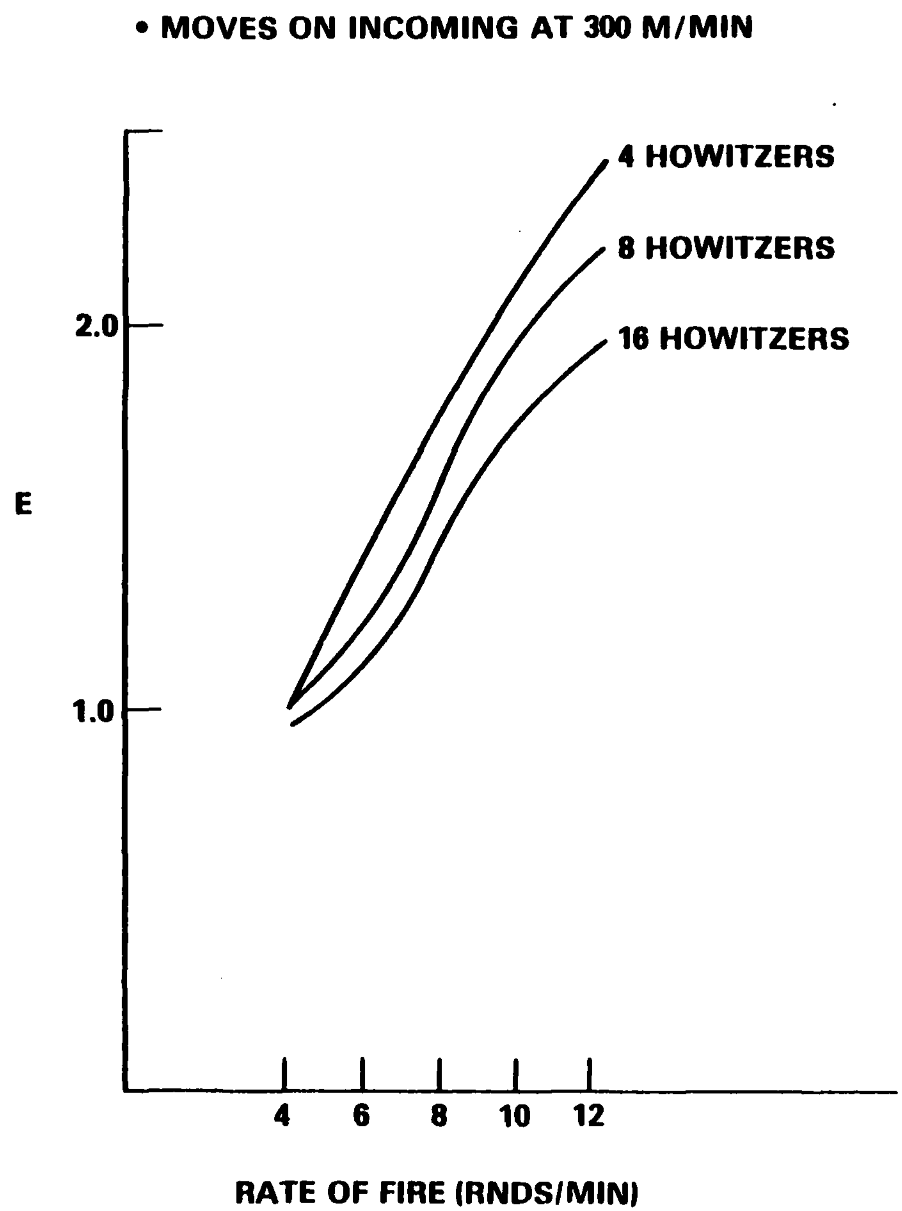


Figure 2-16 Moving BMP Platoon - Effectiveness Versus Rate of Fire/Number of Howitzers

The biggest relative change in effectiveness occurs between 6 and 8 rounds per minute.

Reducing target velocity results in large increases in fractional damage at all rates of fire as depicted in Figure 2-17. In Figure 2-17 the moving BMP platoon target velocity is considered at 300, 150 and 75 meters per minute. Effectiveness is also evaluated at elapsed times of 1, 2 and 3 minutes in relation to the decreasing target velocities. An important indication is that a Family of Scatterable Mines (FASCAM)/DPICM mix might dramatically increase effectiveness. Large increases in fractional damage with slowing target velocity make a strong case for mixing rounds of FASCAM, for slowing the target, with DPICM for destruction. An analysis on the tradeoffs involved in this target engagement technique is recommended.

Relative increases in fractional damage with increasing rates of fire decreases with increasing target velocity as shown in Figure 2-18. In Figure 2-18, a F_d ratio is used and is defined as follows:

$$F_d \text{ Ratio} = \frac{\text{Targets killed}}{\text{Targets killed at 4 rounds per minute and moving at 300 meters per minute}}$$

The relation between fractional damage and rate of fire drops in value and flattens out with target average velocity. The relation for a stationary target reflects the maximum damage attainable. Figure 2-19 shows the same data, but plotted against effectiveness. Comparison of these figures show a different time for attack in order to maximize fractional damage or effectiveness (E). This relationship is summarized as follows:

4 SPH 300 M/MIN

RNDS/MIN	F_d	E (1 MINUTE)
4	0.014	1.00
6	0.019	1.35
8	0.025	1.79
10	0.030	2.14
12	0.034	2.42

4 SPH 150 M/MIN

RNDS/MIN	F_d	E (2 MINUTES)
4	0.026	0.93
6	0.039	1.40
8	0.050	1.79
10	0.060	2.15
12	0.070	2.50

4 SPH 75 M/MIN

RNDS/MIN	F_d	E (3 MINUTES)
4	0.047	1.12
6	0.068	1.62
8	0.086	2.05
10	0.101	2.40
12	0.116	2.76

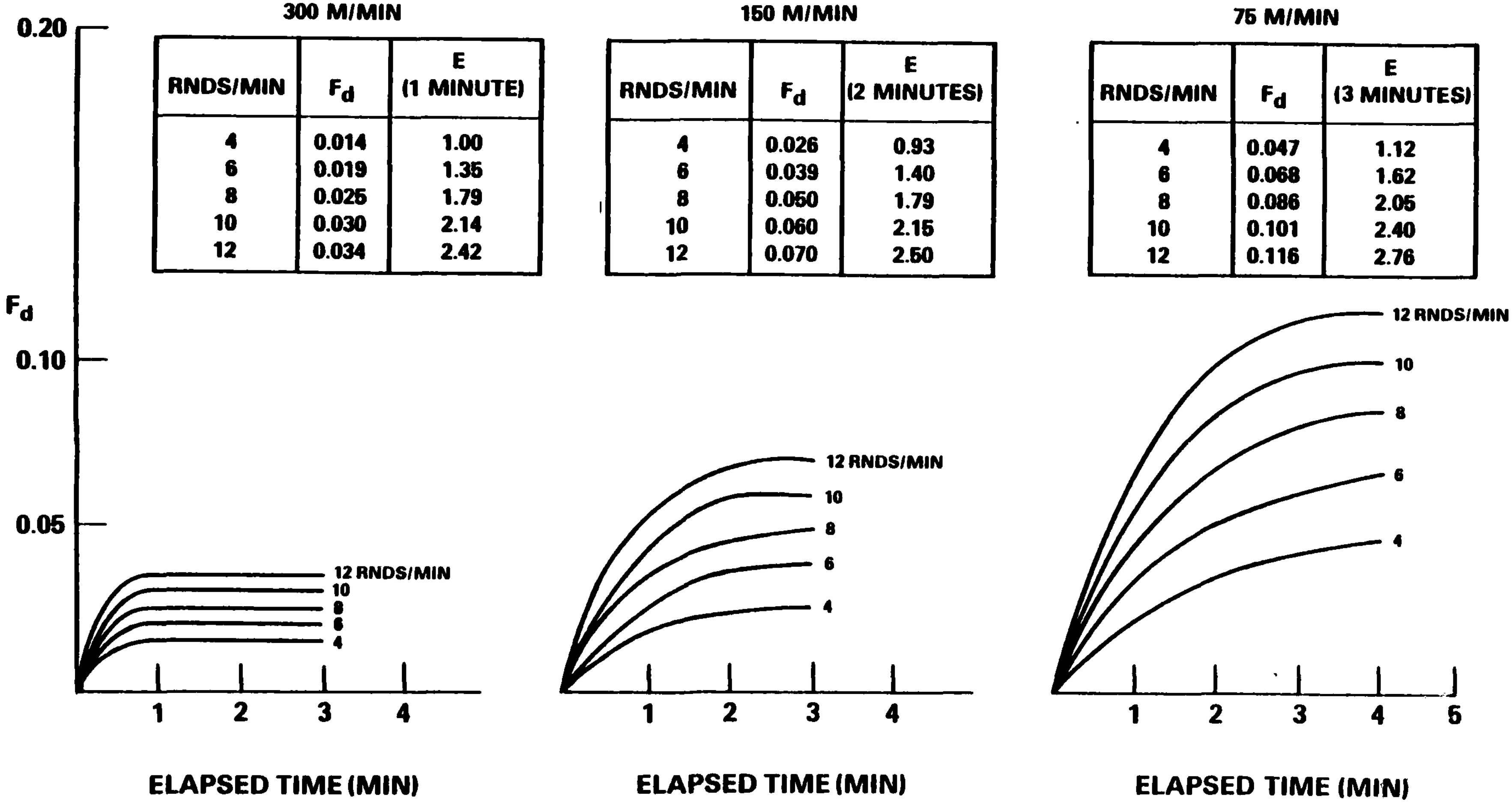


Figure 2-17 Moving BMP Platoon - Fractional Damage Versus Elapsed Time/Rate of Fire/Target Velocity

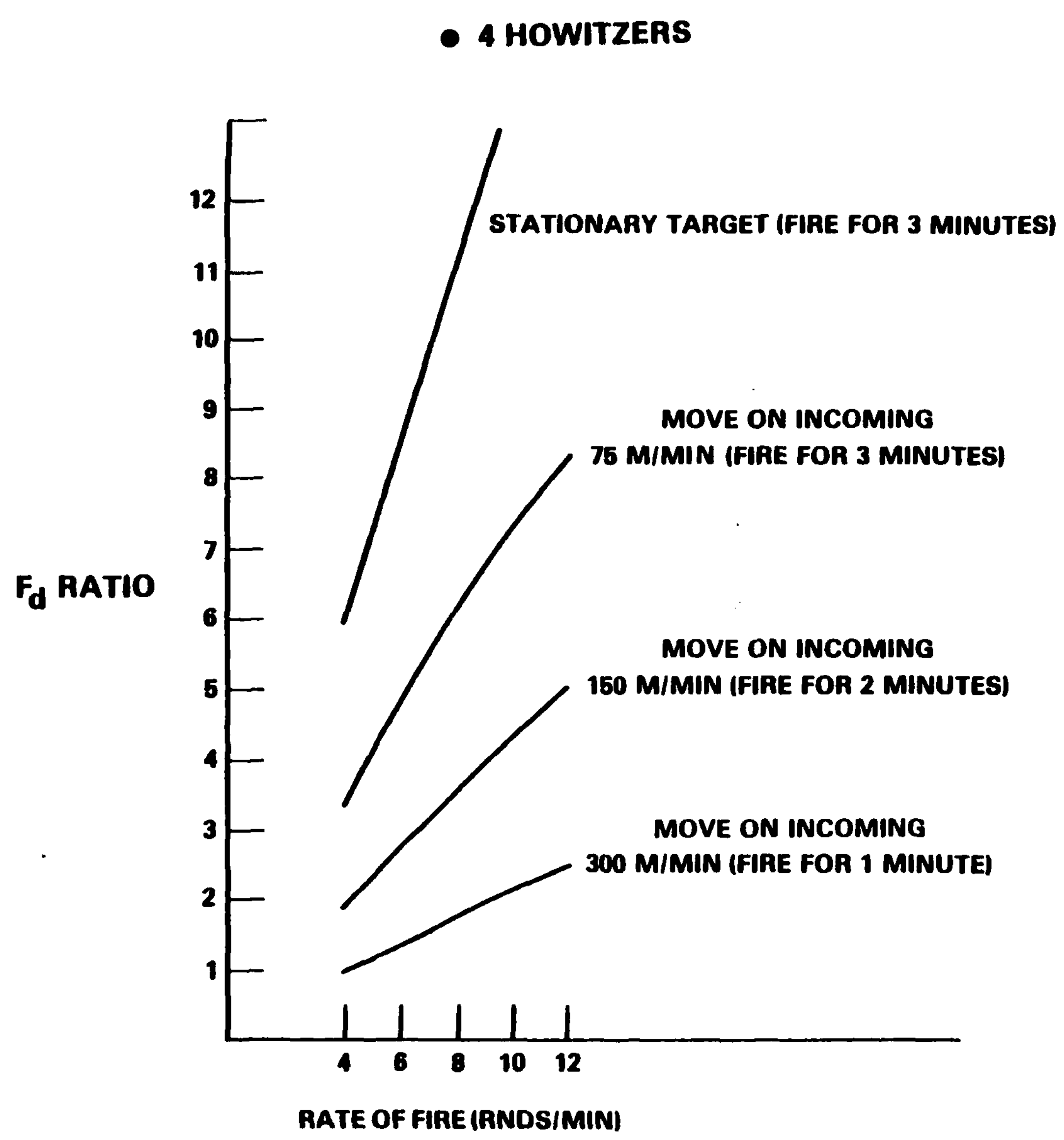


Figure 2-18 Moving BMP Platoon - Fractional Damage Ratio Versus Rate of Fire/Target Velocity

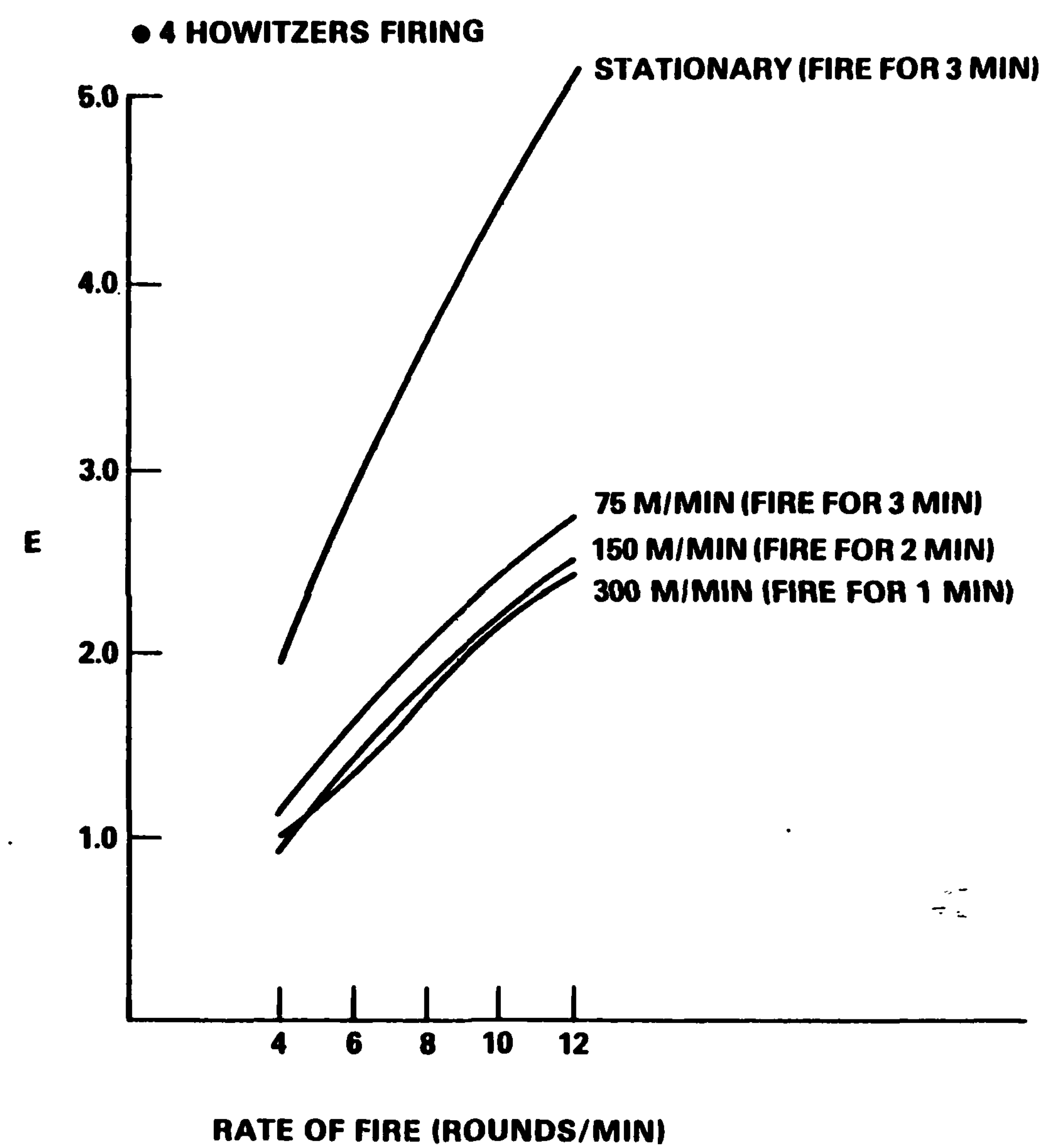


Figure 2-19 Moving BMP Platoon - Effectiveness Versus Rate of Fire/Target Velocity

1) For a moving BMP patoon

TARGET AVERAGE VELOCITY (M/MIN)	LENGTH OF TIME TO ATTACK (MIN) TO MINIMIZE F_d	LENGTH OF TIME TO ATTACK (MIN) TO MAXIMIZE E
300	1	1
150	2	1
75	3	1

(INDEPENDENT OF RATE OF FIRE)

2) The relative increase in targets killed as a function of rate for fire is greatest for stationary targets. This slope decreases with target motion.

STATIONARY TARGET

RATE OF FIRE	EFFECTIVENESS	F_d RATIOS
4	2.0	6
6	2.8	8.4
8	3.7	11.4
10	4.5	15.3
12	5.2	17.4

MOVING ON INCOMING AT 300 M/MIN

RATE OF FIRE	EFFECTIVENESS	F_d RATIOS
4	1	1
6	1.4	1.4
8	1.8	1.8
10	2.2	2.2
12	2.4	2.4

Figure 2-20 shows time to complete mission data and effectiveness for a mission specification of 5% fractional damage against a BMP platoon that moves on incoming fire at 75 meters per minute. Table 2-4 tabulates time to complete missions of 10% and 20% fractional damage. Data for effectiveness is also included.

- MOVES ON INCOMING
- V = 75 M/MIN
- RANGE = 16 KM
- MUNITION: M483 M42 M KILL
- MISSION: INFLICT 5% FRACTIONAL DAMAGE

RATE OF FIRE (ROUNDS/ MIN)	TIME TO COMPLETE MISSION (MIN) HOWITZERS			EFFECTIVENESS HOWITZERS		
	4	8	16	4	8	16
4	4	1	0.40	1.0	2	2.5
6	2	0.70	0.28	2.0	2.9	3.6
8	1	0.55	0.22	4.0	3.6	4.5
10	0.8	0.45	0.19	5.0	4.4	5.3
12	0.6	0.39	0.17	6.7	5.1	5.9

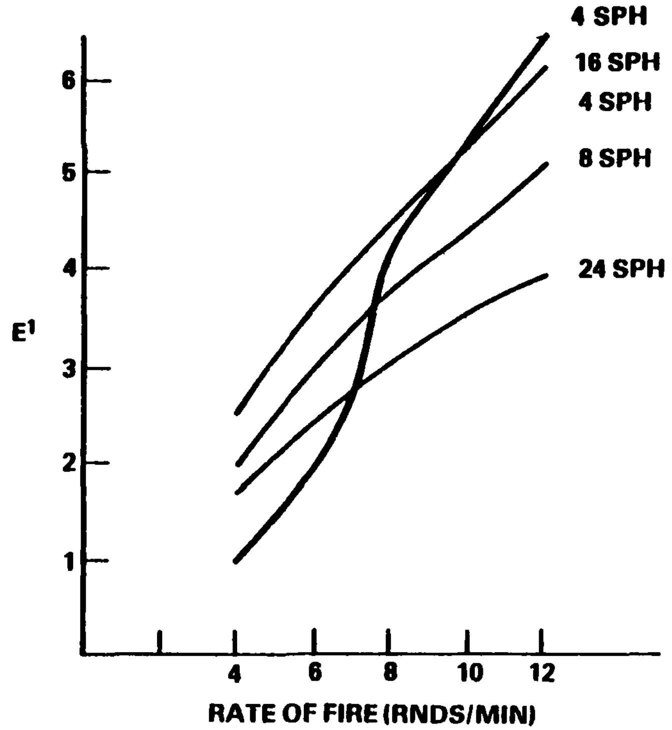


Figure 2-20 Moving BMP Platoon - Effectiveness Versus Rate of Fire/Number of Howitzers

Table 2-4

MOVING BMP PLATOON
RATE OF FIRE VS TIME TO COMPLETE/EFFECTIVENESS

- Moves on Incoming
- Velocity = 75M/min
- Range = 16 Km
- Munition = M483 M42 M Kill

Rate of Fire (Rounds/min)	Time to complete Mission (Min) — HOWITZERS 4	8	16	24	Effectiveness — HOWITZERS 4	8	16	24
Mission: Inflict 10% F_d								
4	-	-	1.6	0.8				
6	-	2	0.8	0.64	NOT ACHIEVABLE			
8	-	1	0.6	0.45				
10	-	0.9	0.5	0.38				
12	-	0.78	0.4	0.30				
Mission: Inflict 20% F_d								
4	-	-	-	-				
6	-	-	-	1.8				
8	-	-	1.9	0.9	NOT ACHIEVABLE			
10	-	-	1.0	0.76				
12	-	-	0.9	0.67				

The conclusions drawn from these figures are summarized as follows:

Rate of Fire Versus Effectiveness/Target Velocity

RATE OF FIRE (RNDS/MIN)	EFFECTIVENESS (FIRE FOR 1 MIN)	TARGET VELOCITY (M/MIN)
4	1.0	300
12	2.4	300
4	1.75	75
12	5.4	75

1) Firing at slower moving targets offers opportunities to engage them for longer times. This added opportunity does not give a great deal more effectiveness although more targets are killed totally. This results because putting the same number of howitzers at risk in subsequent minutes with less targets killed each minute decreases gains in effectiveness.

2) Relative benefits of increased rate of fire decreases with target velocity.

Number of Weapons

1) Attacking with 4 howitzers at 8 rounds per minute shows a large increase in effectiveness

2) It is more effective to attack with 8 howitzers at 4 rounds per minute than 4 howitzers at 6 rounds per minutes

3) It is more effective to attack with 4 howitzers at 8 rounds per minute than 8 howitzers at 6 or 4 rounds per minute

4) There are larger changes in effectiveness in all cases between 4 and 12 rounds per minutes than between 4 to 24 howitzers firing

5) Gains in effectiveness with increasing rates of fire drop off as more howitzers are used

6) Maximum effectiveness for this target is: 4 howitzers at 8, 10 and 12 rounds per minute and 16 howitzers at 4 and 6 rounds per minute

7) Time to complete the mission varies directly with rate of fire. Some non-linearity is due to the fact that early rounds are more effective than late ones.

8) Some mission specifications cannot be accomplished with any number of howitzers and any length of time at 4 and 6 rounds per minutes (example: achieving 10% fractional damage with 8 howitzers requires 8 rounds/min or greater for targets that move on incoming at 75 m/min. Achieving 20% fractional damage requires 16 howitzers at 8 rounds per minute or greater.)

A major conclusion is that rates of fire of 4 rounds or 6 rounds per minute and any number howitzers less than 24 cannot achieve some reasonable specified fractional damage levels as illustrated in Table 2-4. Figure 2-21 illustrates that as the specified fractional damage increases, the product of the number of howitzers required and the length of time they must be fired decreases exponentially with higher rate of fire. This effect is more pronounced at higher F_d levels. Figure 2-21 also indicates that rates of fire of 8 rounds per minute or greater are in the flatter region of the curves. Figures 2-22 and 2-23 show fractional damage and effectiveness compared to rates of fire for 8 howitzers with a 1 minute engagement against stationary targets and targets at velocities of 500 meters per minute and 250 meters per minute. The data show that the amount of increased effectiveness drops off as response time increases. The analysis also indicates that it would be ineffective to fire for more than 1 minute at a moving target cluster with these velocities without adjusting the aimpoint for subsequent minutes. Table 2-5 shows the effects of aimpoint to aimpoint transition times involved in this adjustment process. Increased response time results in increased probable miss distance as discussed earlier.

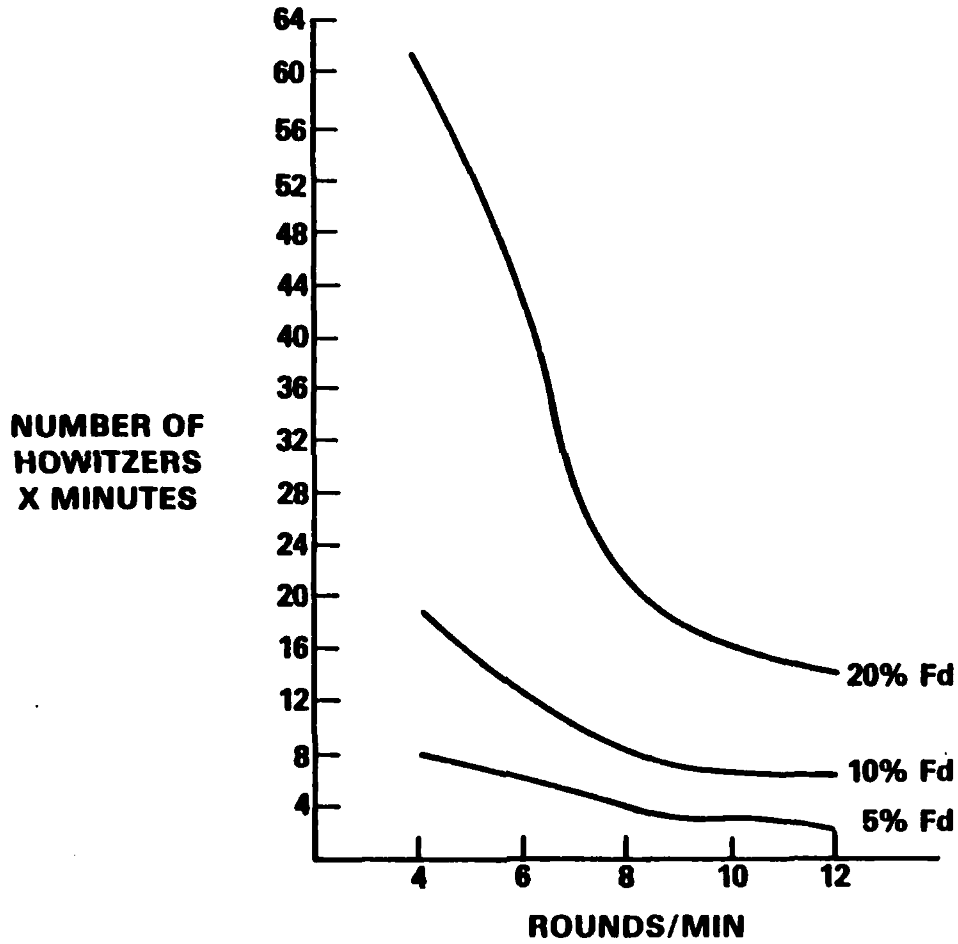
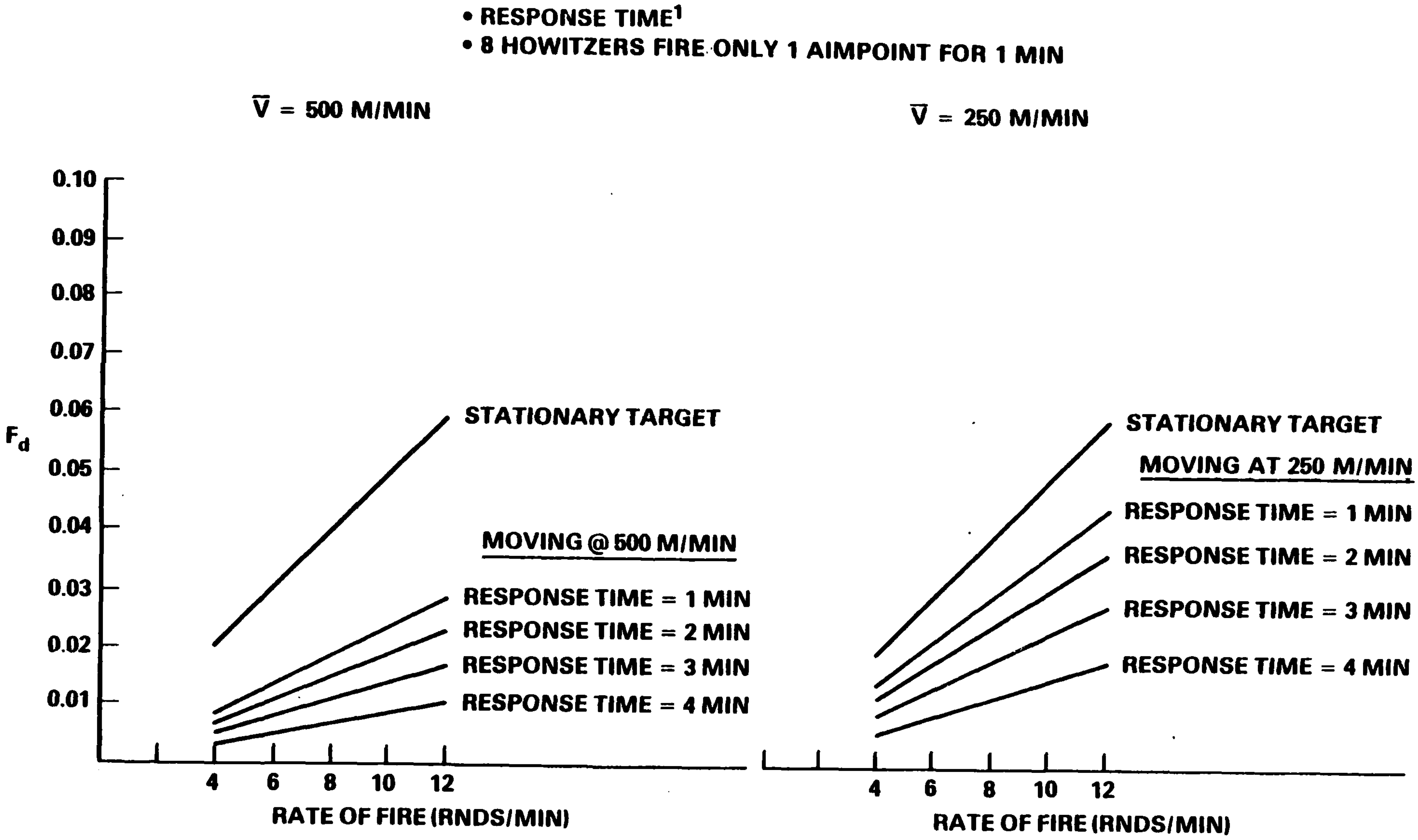


Figure 2-21 Moving BMP Company - Howitzer Firing Time Versus Rate of Fire/Fractional Damage



[1]RESPONSE TIME EQUALS THE TIME FROM TARGET ACQUISITION TO 1ST ROUND ON TARGET (F.O. REPORTS TARGET: POSITION, BEARING, SPEED)

Figure 2-22 Moving BMP Company - Fractional Damage Versus Rate of Fire/Target Velocity/Response Time

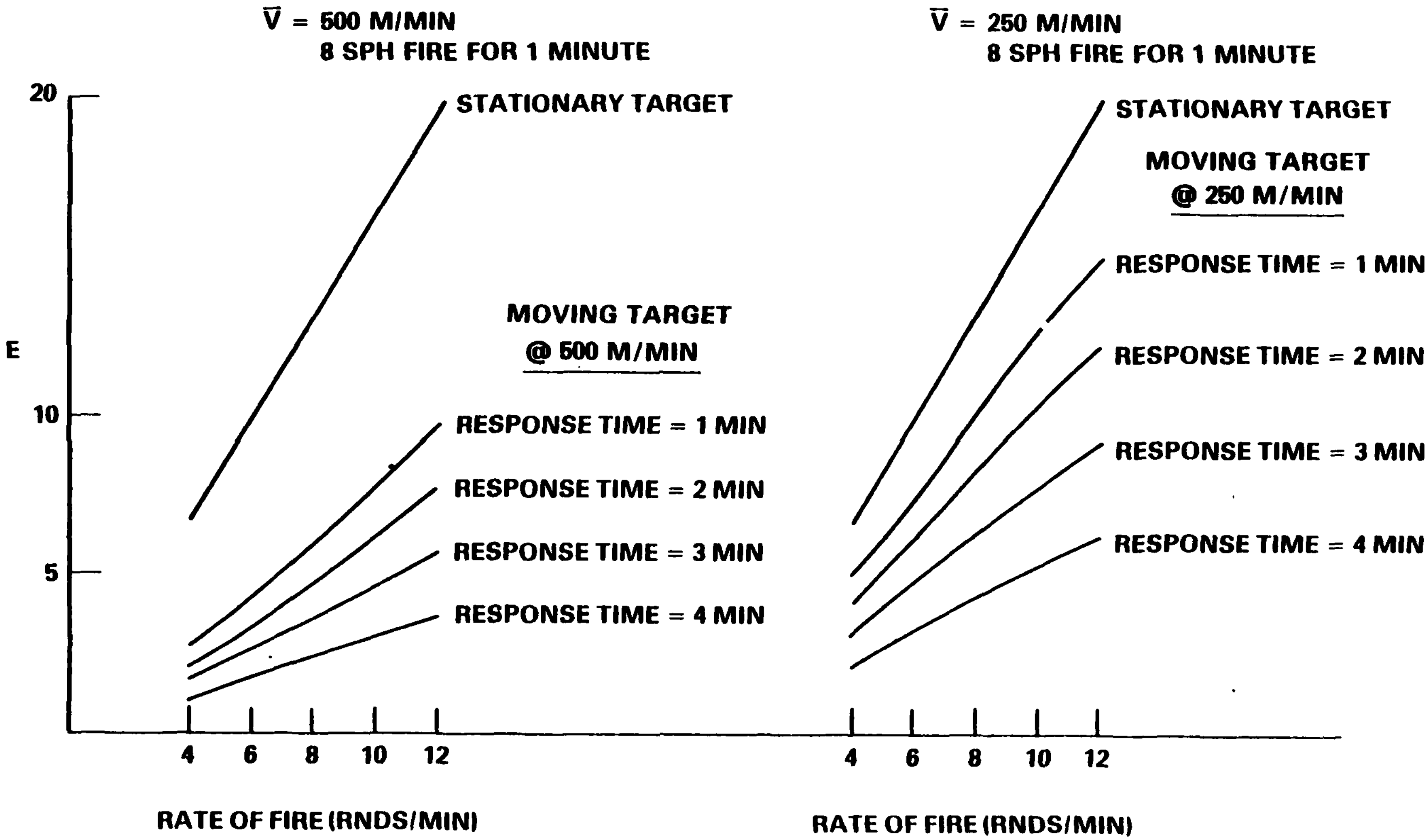


Figure 2-23 Moving BMP Company - Effectiveness Versus Rate of Fire/Response Time/Target Velocity

Table 2-5
EFFECTS OF AIMPOINT TRANSITION TIMES

RATE OF FIRE (ROUNDS/MIN)	TIME TO FIRE 1 ROUND (SEC)	AIMPOINT TO AIMPOINT TRANSITION (SEC)	NUMBER OF ROUNDS IN 1 MINUTE (TRANSITION)	NUMBER OF ROUNDS FIRED IN 1 MINUTE (TRANSITION AFTER EACH VOLLEY)
12	5	15	10	4
10	6	15	8	4
8	7.5	15	7	4
6	10	20	5	3
4	15	30	3	2

Conclusions drawn from the data shown in Figures 2-21 through 2-23 are summarized as follows:

1) It is not effective to engage a moving target for more than 1 minute

2) Eight howitzers cannot achieve more than 5% F_d at 12 rounds per minute in 1 minute

3) Eight howitzers cannot achieve more than 2% F_d at 4 rounds per minute in 1 minute

4) Effectiveness gained by increasing rate of fire drops off with increasing response time

5) Effectiveness for a target with a velocity of 500 m/min and response = 1 min is approximately equal to effectiveness for a target with a velocity of 250 m/min and a response time = 3 minutes

Target average velocities of 500 m/min (30 KPH) or greater result in very flat curves of fractional damage as a function of rate of fire with a maximum fractional damage of 3% or less. Against a fast moving armored target, 155mm DPICM is largely ineffective at any rate of fire. Attack of this type of target is probably best left to a multiple launch rocket system or 155mm terminally guided munitions.

At slower target velocities, a short response time is highly important. Response must be within 4 minutes if expected fractional damage is to be greater than 1%. Against a BMP company, if fractional damages of 10% to 20% cannot be achieved with a reasonable number of howitzers, the fire mission is probably not suited to 155mm DPICM. It is worth noting that greater effects are achieved by slowing target velocity than decreasing response time. This suggests that on effective way to attack these targets might involve 155mm howitzers firing a mix of FASCAM, to slow the targets, and DPICM to kill them. Additional analysis to find the optimum mix of FASCAM and DPICM is recommended.

There are other ways to achieve the 10% to 20% fractional damage level on a moving BMP Company target. Although not explicitly shown, it was found to be more effective to fire a very tight pattern initially, in order to concentrate as many rounds as possible on the target during the early vulnerable moments of the barrage. It is possible to adjust the aimpoint on subsequent volleys in order to follow the moving target. The probable miss distance would increase with each aimpoint transition due to differences between predicted and actual target motion athough this increase would be much less than that occurring with no aimpoint transitions. The effects of aimpoint transitions during a single mission are to reduce the number of rounds as previously shown in Table 2-5. This procedure has a greater impact on low rate of fire systems in cases where there is only 1 transition per minute and a greater impact on the high rate of fire systems for many transitions per minute. Additional analysis to determine the optimum strategy for attacking moving targets is also recommended. This analysis is limited to short attacks with only 1 aimpoint and resultant lower fractional damage.

2.2.6.4 Consolidated Measures of Effectiveness - BMP Targets

The overall measure of effectiveness has been previously defined to be the maximum number of targets per hour that can be attacked. This value is derived from the data displayed in Table 2-6. The maximum number of targets engaged per hour is that number which could be engaged if the DSWS battalion attacked only the target type under consideration and was not limited by target presentation, target acquisition, queue times, decision times or computation times. This data is also displayed graphically in Figure 2-24.

The fractional damage specification in Table 2-6, Column 3 represents the maximum damage that can be achieved by all 3 candidate howitzer systems against the target under consideration.

The methodology used to calculate the maximum of targets engaged per hour by the DSWS battalion is given below in the equation

$$\text{Maximum Number of Target} = \left(\frac{\text{Howitzers in Battalion}}{\text{Howitzers used per Mission}}\right) \times 3 \text{ Mission} \times \left(\frac{60 \text{ Min}}{((3 \times \text{Time for 1 Mission}) \times \text{Scoot-Time})}\right) \quad (8)$$

It is assumed for this analysis that all candidate howitzers scoot after 3 missions. This is consistent with an assumption that enemy counterfire response time will be 3-10 minutes.

The shoot and scoot lines used for this analysis are given at the foot of Table 2-6 and were supplied by the DSWS Special Study Group. The time out for a scoot of 300 meters

TABLE 2-6 OVERALL MEASURES OF EFFECTIVENESS

BMP TARGETS

MUNITION: M483 M42 (DPICM)
TARGET: BMP PLATOON OR COMPANY
GUN-TARGET RANGE = 16 KM
SHOOT & SCOOT: ALL HOWITZERS SCOOT AFTER 3 MISSIONS OR ON INCOMING

TARGET CATEGORY	WEAPON SYSTEM	RATE OF FIRE (ROUNDS/MIN)	FRACTIONAL DAMAGE SPECIFICATION	HOWITZERS REQUIRED	TIME TO COMPLETE MISSION (MIN)	MAX TARGETS OF THIS TYPE ENGAGED BY DSWS BATTALION PER HOUR[1]
STATIONARY BMP PLT	HELP HOWITZER	4	20%	4	8.0*	40
	MAXI PIP HOWITZER	8		4	4.0*	76
	NEW DSWS HOWITZER	10		4	3.2*	97
STATIONARY BMP CO.	HELP	4	20%	8	11.0*	15
	MAXI	8		8	5.5*	29
	NEW	10		8	4.2*	38
BMP PLT MOVE ON INCOMING AT 75 M/MIN	HELP	4	5%	4	4.0*	71
	MAXI	8		4	1.0	206
	NEW	10		4	0.8	277
BMP CO MOVING AT 250 M/MIN RESPONSE TIME = 1 MIN	HELP	4	2%	16	0.67	51
	MAXI	8		8	0.67	127
	NEW	10		8	0.32	220
BMP CO MOVING AT 250 M/MIN RESPONSE TIME = 3 MIN	HELP	4	2%	16	1.0	43
	MAXI	8		8	1.0	103
	NEW	10		8	0.89	129

[1]

HOWITZER	TIME FOR SCOOT OF 300 M
HELP	3 MIN 15 SEC
MAXI PIP	2 MIN 15 SEC
NEW DSWS	1 MIN 30 SEC

DSWS BATTALION = 3 BATTERIES, EACH OF 8 HOWITZERS

*These missions are prohibitively costly in time which would cause a change in mission posture before 3 "missions".

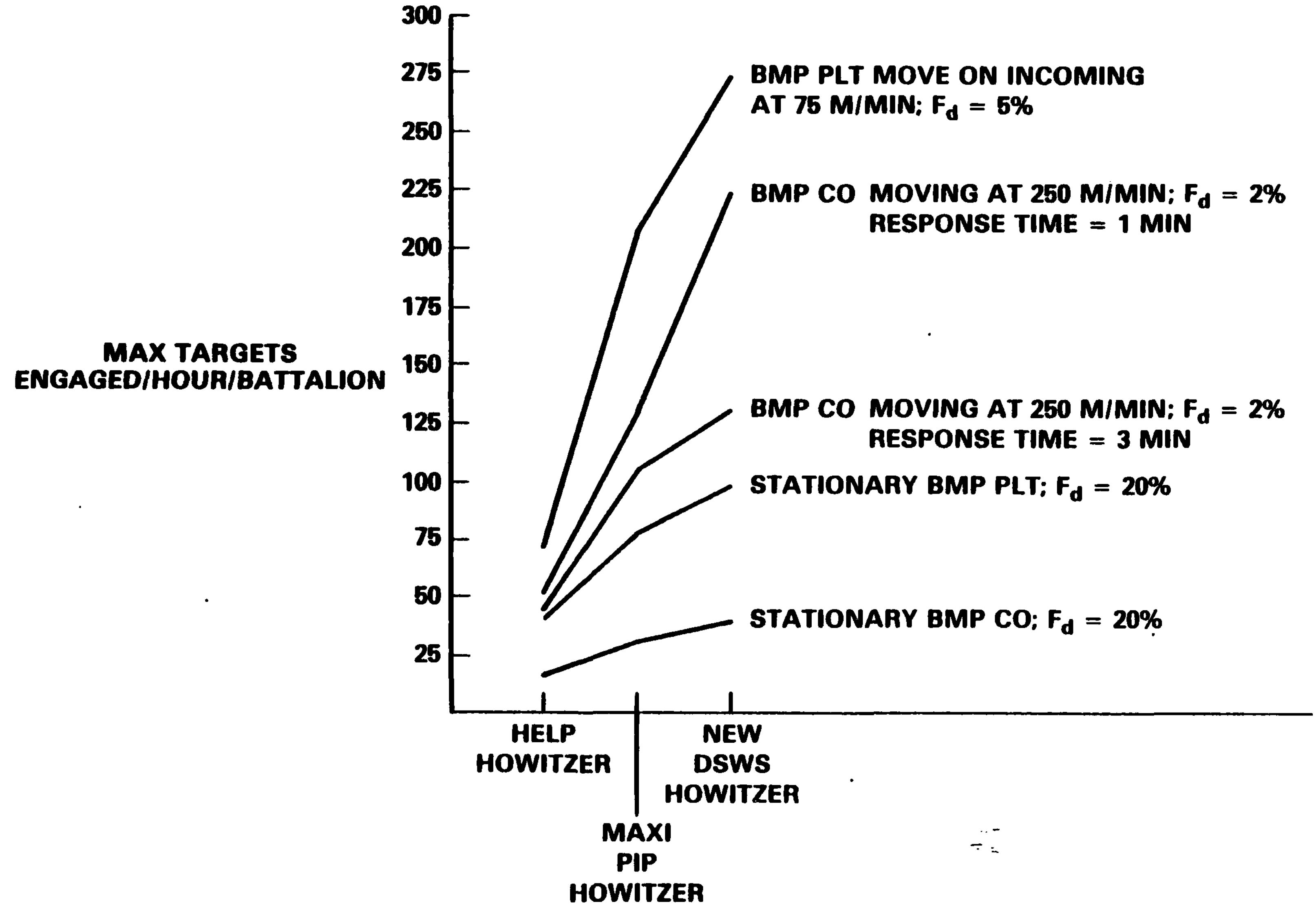


Figure 2-24 BMP Targets - Maximum Targets per Battalion per Hour Versus DSWS Candidate Howitzers/Type Target

includes displacement time, movement time and emplacement time. Differences between the candidate howitzers are due to different technologies and procedures.

2.2.6.5 BMP Target Conclusions

The conclusions drawn from Table 2-6 and Figure 2-24 are summarized below:

1) There is a bigger relative gain in going from the HELP to the Maxi-Pip howitzer than from HELP to a new howitzer in cases where high rate of fire is critical (moving targets).

2) 20% F_d, 5% F_d, 2% F_d represent the maximum fractional damages that can be effectively achieved.

3) The HELP howitzer has limited effectiveness against moving or posture changing BMP targets.

4) Increases in effectiveness between the candidate howitzers against stationary targets is much less pronounced.

5) Larger differences in effectiveness against moving targets are due to response time rather than rate of fire at low rates of fire.

6) Reducing target speed provides an opportunity to increase effectiveness.

The large differences in number of targets engaged per hour between the Maxi-Pip howitzer and the HELP howitzer is most pronounced against moving and changing posture targets. On the basis of operational effectiveness alone, the new DSWS howitzer system is clearly the most effective, but there is a larger relative change between the HELP and the Maxi-Pip howitzers then between the Maxi-Pip and the new DSWS howitzer.

2.2.7 SP 152 Targets

Figure 2-25 displays the data obtained when fractional damage is examined against a self-propelled 152mm artillery battery. The other variables in the analysis were rate of fire,

• TARGET = SP 152 BATTERY
• RANGE = 18 KM
• TARGET LOCATION ERROR = 75 M
• M483 M42 DPICM
• F KILL
• TARGET MOVE ON INCOMING AT 75 M/MIN

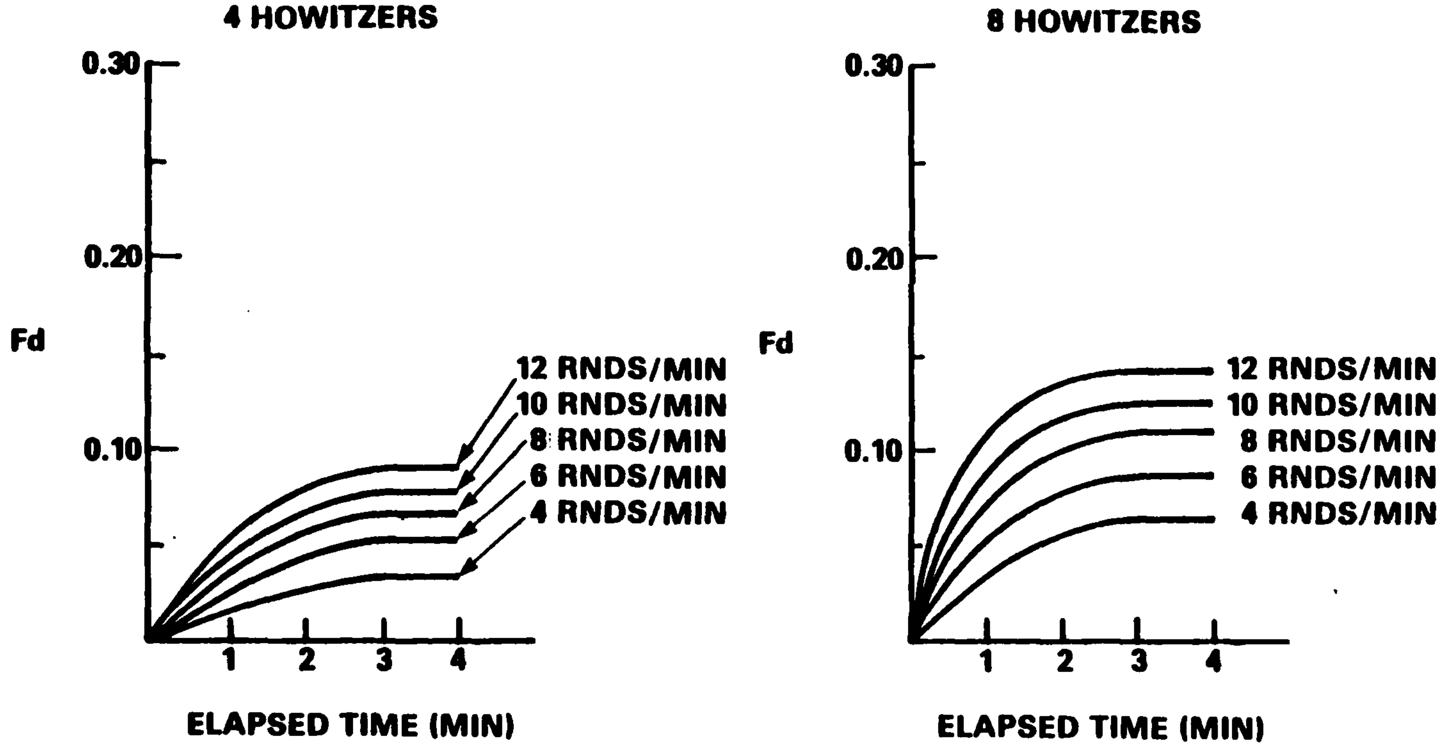


Figure 2-25 SP 152 Targets - Fractional Damage Versus Time/ Rate of Fire/Number of Howitzers

elapsed time and number of howitzers firing in the engagement. The results are very similiar to the results obtained for BMP targets because the submunition lethal areas for the DPICM M483 M42 projectile versus both SP 152 targets and BMP targets are nearly equal.

2.2.8 Zil-157 Truck Targets

Figure 2-26 shows the data analyzing fractional damage as a function of time elapsed for different rates of fire and three different Zil-157 target categories using the C Kill criteria. Knees in the curves approaching 90% fractional damage in stationary target category are caused by the fact that nearly all the targets covered by the weapons pattern for this target location error and miss distance have been killed and more rounds delivered do not bring many increased casualties. A comparison of Figure 2-26 with data for BMP targets shows that the increases in fractional damage with increased rates for fire are not as great for the more vulnerable Zil-157 targets as for the BMP targets.

2.2.9 Personnel Targets

Figure 2-27 shows the results of attacking reactive personnel targets at various rates of fire. The personnel are assumed to be in the open initially, and make the posture transition to prone during a 15 second period. The knee at 60% F_d represents the time when nearly all of the personnel within the target-weapons pattern overlap are killed. For the prone to foxhole transition, the knee in the curves are caused by the very small lethal area of the submunition versus personnel in foxholes. There is very little difference in fractional damage between the different rates of fire in all cases against personnel targets.

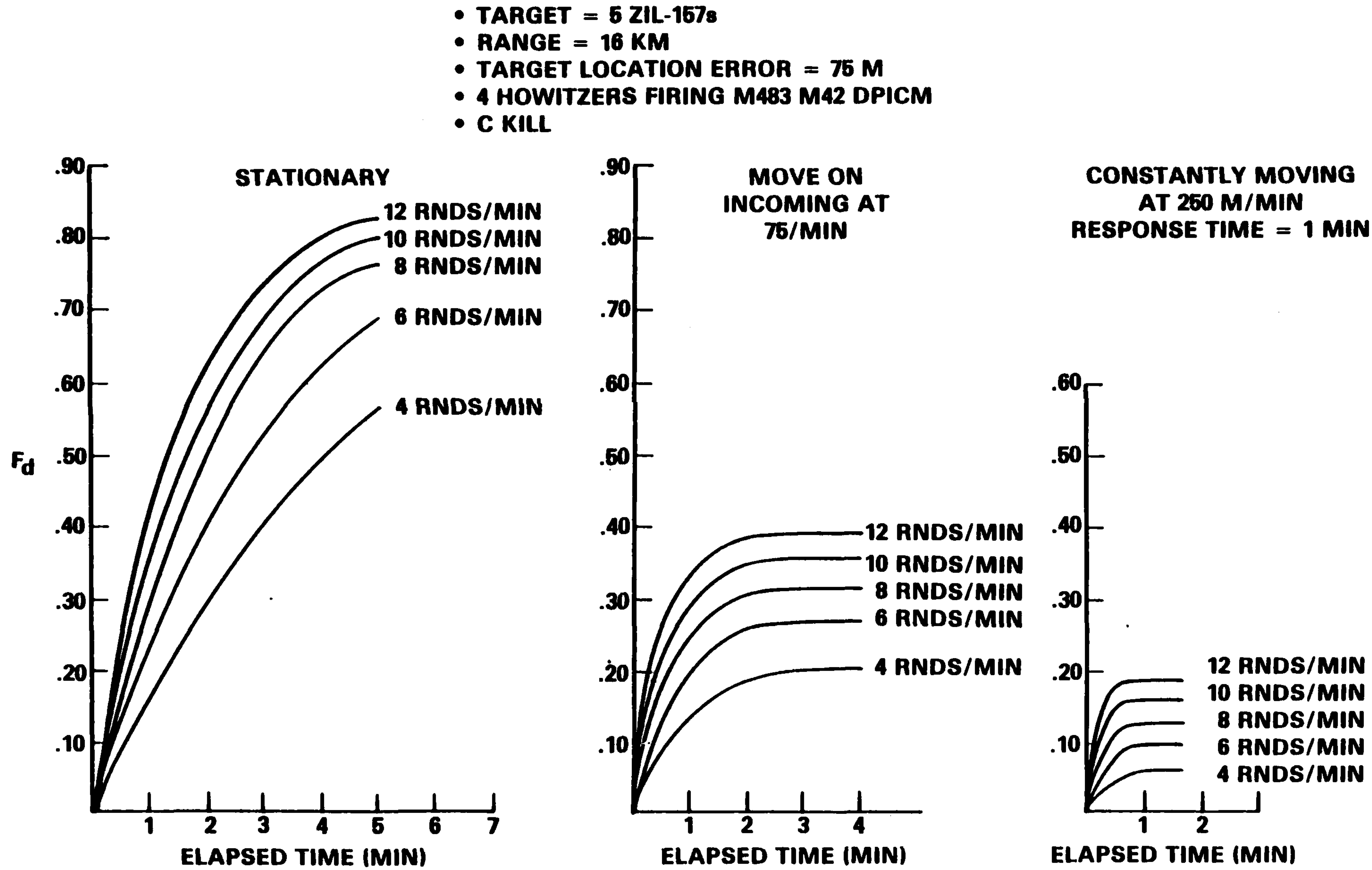


Figure 2-26 ZIL-157 Targets - Fractional Damage Versus Time/Rate of Fire/Target Velocity

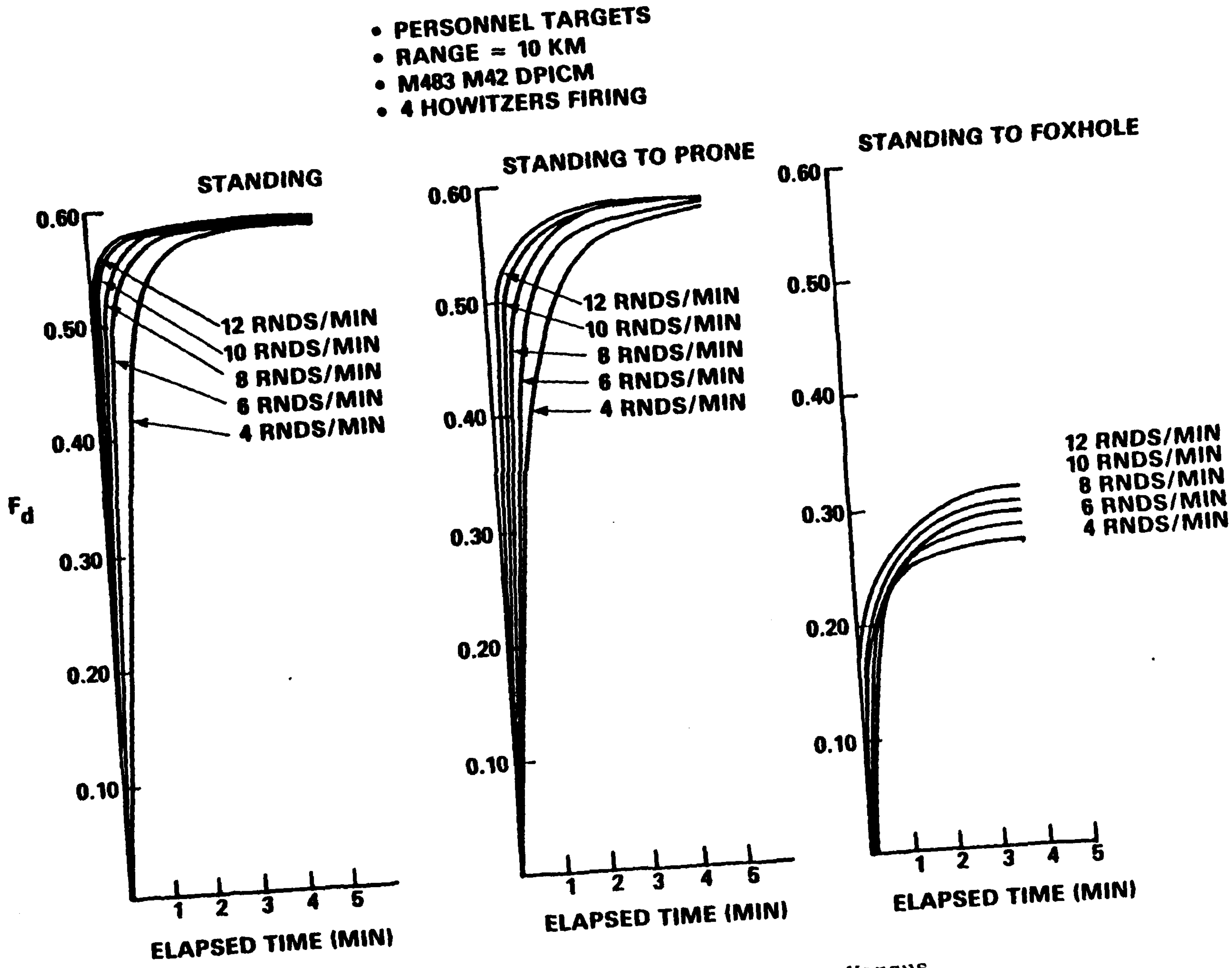


Figure 2-27 Personnel Targets - Fractional Damage Versus Elapsed Time/Rate of Fire/Target Posture

2.2.10 Consolidated Measures of Effectiveness - SP 152, Zil 157 and Personnel Targets

Table 2-7 and Figure 2-28 are a continuation of data displayed in the same manner as in Table 2-6 and Figure 2-24 for BMP targets. In situations where there is very little difference between the candidate howitzers in terms of fractional damage per rate of fire, differences in number of targets engaged per hour are mainly due to shorter scoot times for the new DSWS howitzer system. This is why some of these curves show a greater relative change between the Maxi-Pip howitzer and the new howitzer then between the HELP howitzer and the Maxi-Pip howitzer. A principal conclusion is that rate of fire is not as critical against softer targets like Zil-157 and personnel as it is against SP 152 and BMP targets. The very small lethal area of DPICM versus tanks like the T80 and T72 implies that DPICM attacks will be ineffective against these targets no matter what the rate of fire.

2.2.11 Recommended Areas for Additional Analysis

The target categories considered in this analysis are listed below:

Stationary BMP Platoon
Move on incoming BMP Platoon
Constantly moving BMP Company
Move on incoming SP152 Battery
Stationary Zil-157's
Move on incoming Zil-157s
Constantly moving Zil-157s
Standing Personnel
Standing-to-Prone Personnel
Standing-to-Foxhole Personnel

Table 2-7

OVERALL MEASURES OF EFFECTIVENESS FOR SP152, ZIL-157 AND PERSONNEL TARGETS

Munition: M483 M42 (DPICM)
Shoot & Scoot: ALL HOWITZERS SCOOT AFTER 3 MISSIONS OR ON INCOMING

TARGET CATEGORY	WEAPON SYSTEM	RATE OF FIRE (ROUNDS/MIN)	FRACTIONAL DAMAGE SPECIFICATION	HOWITZERS REQUIRED	TIME TO COMPLETE MISSION (MIN)	MAX TARGETS ENGAGED BY DSWS BATTALION PER HOUR
5 STATIONARY ZIL-157s	HELP	4	50%	4	4.0	71
	MAXI PIP	8		4	2.0	132
	NEW DSWS	10		4	1.5	180
5 ZIL-157s THAT MOVE ON INCOMING AT 75 M/MIN	HELP	4	20%	4	3.0	89
	MAXI PIP	8		4	0.6	270
	NEW DSWS	10		4	0.4	400
5 ZIL-157s CONSTANTLY MOVING AT 250 M/MIN	HELP	4	5%	4	1.0	174
	MAXI PIP	8		4	0.2	386
	NEW DSWS	10		4	0.1	600
SP 152 BATTERY THAT MOVES ON INCOMING AT 75 M/MIN	HELP	4	5%	8	1.8	63
	MAXI PIP	8		4	1.8	142
	NEW DSWS	10		4	1.2	212
STANDING PERSONNEL	HELP		50%	4	0.6	216
	MAXIM PIP			4	0.3	348
	NEW DSWS			4	0.1	600
STANDING TO PRONE PERSONNEL	HELP		50%	4	1.5	140
	MAXI PIP			4	0.6	270
	NEW DSWS			4	0.3	450
STANDING TO FOXHOLE PERSONNEL	HELP		25%	4	1.2	159
	MAXI PIP			4	0.8	235
	NEW DSWS			4	0.6	327

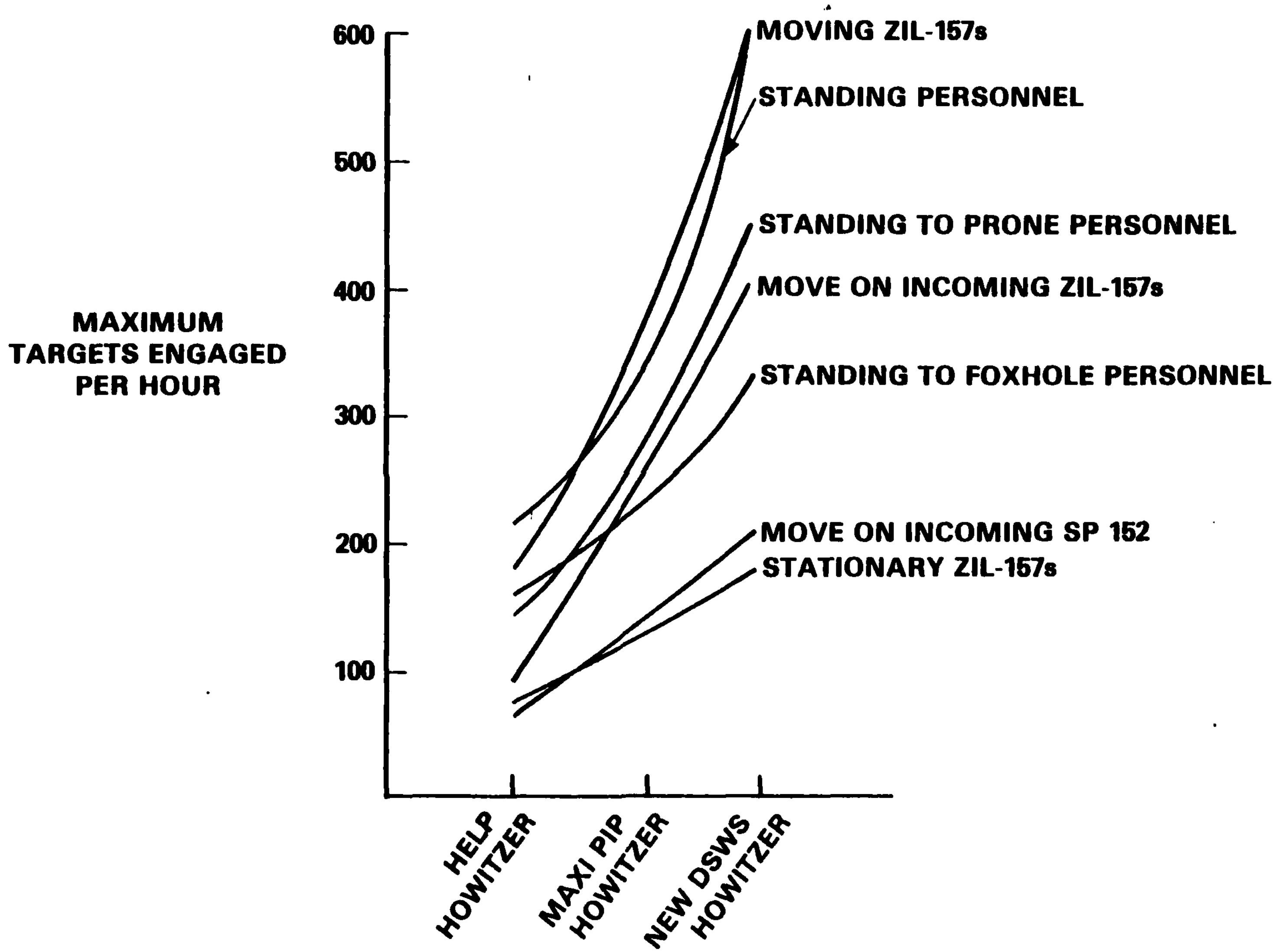


Figure 2-28 Other Targets - Maximum Targets per Battalion per Hour Versus DSWS Candidate Howitzers/Type Target

Other important targets that should be analyzed are:

Tanks
Air defense systems
Surface to surface missiles
C^3 nodes
Headquarters
Target acquisition systems
Supply areas
Area suppressive fires

Another approach to the effectiveness of the three candidate howitzers could be determined by a weighting of the target categories and a determination of the numbers of each type target likely to be presented to the DSWS battalion over the duration of a battle. The ultimate measure of effectiveness must be the degree to which the DSWS battalion armed with the various candidate howitzers contributes to the winning of the battle. A complete examination of this situation is beyond the scope of this effort, but some additional observations evolve from the C^3 analysis in Section 3.

2.3 INDEPENDENT ASSESSMENT OF RATE OF FIRE ANALYSES

This segment of the rate of fire analysis involves the review and independent assessment of rate of fire analyses performed in two other studies.

2.3.1 Artillery Unit Survivability Analysis (U) (Reference 1)

The methodology of the Artillery Unit Survivability Analysis is a parametric evalution of many survivability factors. The Enemy Response Time Distribution (Figure 2) should be more normally distributed, taking into account human processing variability in the lower end of the curve. It is clear that the tail diminishes to account for reprioritization due to target aging.

Moving Target Indicator (MTI) radars seem to be accorded too much emphasis since they are primarily tactical devices and would be ineffective in the new O&O concept for the Maxi-PIP howitzer. In addition to making a good case for two Field Artillery Maintenance Vehicles (FAMV) per battery, this study supports the MAXI-PIP howitzer from a survivability perspective. The plateaus based on rate-of-fire are very close to 8 rounds per minute, except in the "worst case" postulation. The survivability results in the Mitre study are further supported by Tables 2-4, 2-6 and 2-7 in this SAI analysis where missions were either unachievable by the HELP howitzer or prohibitively time consuming.

2.3.2 Division Support Weapons System (DSWS) Parametric Study of Rate-of-Fire, Accuracy, Responsiveness (U) (Reference 2)

The Division Support Weapon System Study of Rate-of-Fire, Accuracy, Responsiveness provides several results which can be correlated or compared with this study. While the preponderance of the results refer to Intelligent Sub-Munitions (ISM), the conclusions on responsiveness are accurate. It is intuitively obvious that with a linearly worsening Target Location Error (TLE), time on target would be a highly leveraged parameter. The lack of real gain due to rate-of-fire must be a function of the lack of sophistication of the artificial intelligence (AI) target selection algorithms. Targets which satisfy the targeting algorithm are likely to be killed many times, whereas others remain unscathed. The brevity of the report and its content predicate a similarly short discourse.

SECTION 3
C^3 ANALYSIS

3.1 INTRODUCTION

The purpose of this section of the study effort is to examine specific aspects of the proposed DSWS C^3 system operation and specifically to:

1) Estimate the hourly rounds fired and the mileage traveled by the self-propelled howitzers

2) Determine the extent of the requirement for Single Channel Ground and Airbone Radio Systems (SINCGARS) on the Field Artillery Ammunition Resupply Vehicle (FAASV) or the Ammunition Resupply Vehicle (ARV) with the DSWS howitzer

3) Determine the extent of the requirement for technical fire control onboard the DSWS howitzer

These three explicit tasks have emerged from interaction with the DSWS Special Study Group at Fort Sill as the areas of primary concern in COEA support. The broader requirement of the analytical effort is to describe and emulate the C^3 process as it relates to tactical/technical fire control, contrasting on-board fire control with centralized fire control. Traffic load distribution in conjunction with shoot and scoot tactics, supply-train and ARV placement and tactics are used to identify ARV communication requirements necessary to coordinate ARV and howitzer operations. The fault tolerance of the C^3 network is examined.

3.2 METHODOLOGY

The methodology used for the analysis involved examining three different cases or combinations of organizational and operational concepts combined with howitzer/ammunition supply vehicle mixes. For each case, the factors depicted in Figure 3-1 were evaluated. The three cases considered were:

1) A Division 86 organizational and operational (O&O) concept C^3 system with the HELP howitzer and the FAASV

2) A DSWS O&O concept C^3 system with the Maxi-PIP howitzer and a PIP FAASV

3) A DSWS O&O concept C^3 system with a new howitzer and an ARV

The parameters for the analysis were derived from the O&O concepts and from interaction with the DSWS COEA Special Study Group at the Field Artillery School and are listed in Table 3-1. The DSWS O&O concept involves much larger displacements for the howitzers and ammunition resupply vehicles becauses of the more dispersed locations of the Battery Support Areas (BSA) where ammunition would be aggregated for pickup by the ARVs. This dispersion is part of the Air Land Battle 2000 concept of survivability and of mobile, fluid, deep penetration operations. A particular emphasis in this analysis is the trade-off in operational effectiveness that occurs with the additional time and coordination involved in accomplishing ammunition resupply under such conditions.

The Scores Europe III Sequence 2A scenario was used in the computer simulation with the following aspects included:

1) A 155mm Blue battalion was in a direct support mission to a brigade as a part of a division on brigade engagement

2) Target demands not fulfilled by a Blue 155mm battery were sent to Division Artillery

3) Red movement to contact was followed by a hasty attack

4) Blue was in a deliberate defense

3 CASES:

- DIV 86 C^3 + HELP HOWITZER
- DSWS 0 & 0 CONCEPT C^3 + MAXI PIP HOWITZER
- DSWS 0 & 0 CONCEPT C^3 + DSWS HOWITZER

FOR EACH CASE EVALUATE:

AVERAGE ROUNDS FIRED BY A HOWITZER	(RNDS/HOUR)
AVERAGE HOWITZER/ARV RELOADS	(RELOADS/HOUR)
AVERAGE ARV-BATTERY SUPPLY AREA RELOADS	(RELOADS/HOUR)
AVERAGE MOVES BY A HOWITZER	(MOVES/HOUR)
AVERAGE TIMES HOWITZER MOVES WHILE ARV IS AWAY	(MOVES/HOUR)
AVERAGE DISTANCE HOWITZER MOVES	(km/HOUR)
AVERAGE DISTANCE ARV MOVES	(km/HOUR)
AVERAGE RESPONSE TIME FOR THIS SYSTEM	(MIN)
FAULT TOLERANCE OF THIS SYSTEM	(MIN)*
CASE EFFECTIVENESS =	(ENEMY KILLS/ FRIENDLY LOSSES)

*(PARAMETERIZE DEGRADATION OF TECHNICAL FIRE CONTROL NODES)

Figure 3-1 Cases and Evaluation Factors

TABLE 3-1 C^3 PARAMETERS

	DIV 86/HELP HOWITZER + FAASV	DSWS O&O CONCEPT/ MAXI PIP + PIP FAASV	DSWS O&O CONCEPT/ NEW HOWITZER + ARV
HOWITZER DISPLACEMENT	100-150 M	200-300 M	200-300 M
HOWITZER — ARV (FAASV) DISPLACEMENT	0-20 M	300 M	300 M
HOWITZER — FDC PROCUREMENT	1 KM	5-9 KM	5-9 KM
ARV (FAASV) — BSA DISPLACEMENT	1.5 KM	5-9 KM	5-9 KM
HOWITZER ON BOARD AMMO	36 RNDS	50 RNDS	68 RNDS
ARV (FAASV) ON BOARD AMMO	93 RNDS	100 RNDS	144 RNDS
HOWITZER RATE OF FIRE	4	8	10
LOCATION OF TACTICAL FIRE CONTROL	BN FDC	BTRY OP CENTER	BTRY OP CENTER
LOCATION OF TECHNICAL FIRE CONTROL	PLT FDC	ON BOARD	ON BOARD
NORMAL RESPONSE TIMES[1] (MIN)			
FO	3-5	1-3	1-3
ANTPQ-36 -37	5-20	1-4	1-4
RPV	2-4	1-3	1-3
JSTAR	5-8	3-6	3-6
SURGE RESPONSE TIMES[1] (MIN)			
FO	6	3	3
ANTPQ-36 -37	21	5	5
RPV	5	4	4
JSTAR	9	7	7
DEGRADED RESPONSE TIMES[2] (MIN)			
FOR EACH EXTRA NODE ADD	2	2	2

[1]RESPONSE TIME EQUALS TIME FROM TARGET ACQUISITION TO 1ST ROUND ON TARGET

[2]TECHNICAL AND TACTICAL FIRE CONTROL DEGRADATION CONSIDERED ONLY

The generic alignment of Red and Blue forces at the beginning of the simulation is shown in Figure 3-2. All units are assumed to be at full strength.

The Red Motorized Rifle Division organization used in the analysis is depicted in Figure 3-3. The Blue Mechanized Infantry Division organization is shown in Figure 3-4. Resolution in both units is to platoon level. Table 3-2 summarizes the mix of weapons systems for the Red and Blue Forces. The detailed initial deployment for Red and Blue forces is shown in Figure 3-5. The information shown in Table 3-2 and Figure 3-5 represents the input data base for the computer simulation.

Indirect fire P_ks are derived from the data contained in Appendix A and the fractional damage methodology presented in Section 2, Rate of Fire Analysis, of this report. Direct fire engagements are resolved as in the FOURCE model with P_ks derived from the JMEM. FOURCE is a computer simulation model developed by TRASANA designed to evaluate staff performance and information flow in a combined arms force. Engineering weapons effectiveness criteria are used to determine offensive and defensive capabilities and vulnerabilities. Red armor targets are constantly moving. Blue armor is in a hull down deliberate defensive posture and moves on incoming to an alternate position. Red and Blue manuever instructions are detailed in Appendix C.

3.3 RESULTS OF DIVISION 86 C^3 O&O/HELP HOWITZER ANALYSIS

Figure 3-6 shows the onboard ammunition supply of a Case 1 HELP howitzer and its associated FAASV over time during the battle scenario just described. The rate of fire is 4 rounds per minute. Results from a 60 minute engagement are extrapolated. Vertical descending lines signify output of ammunition,

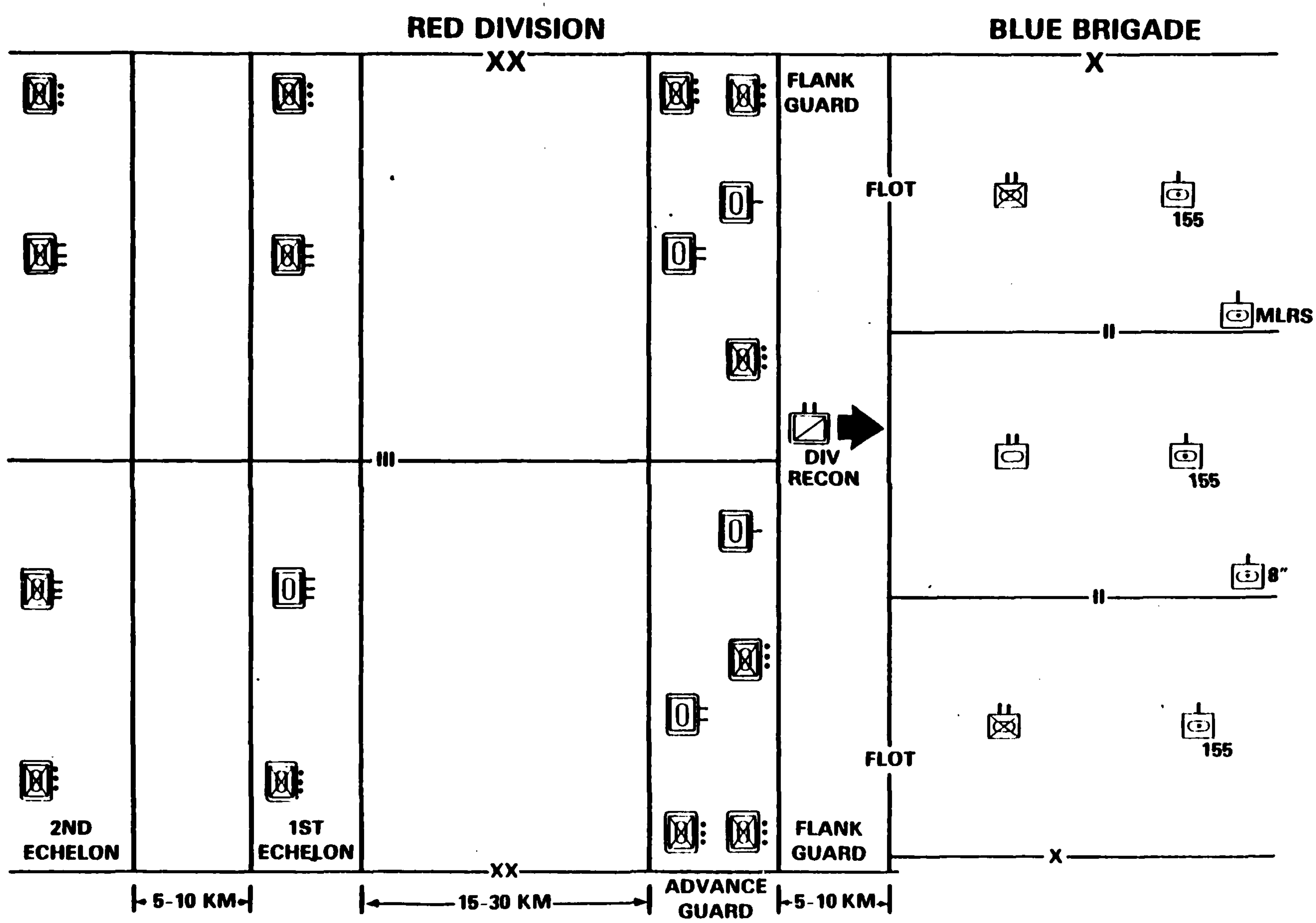


Figure 3-2 Scenario Red/Blue Force Generic Alignment

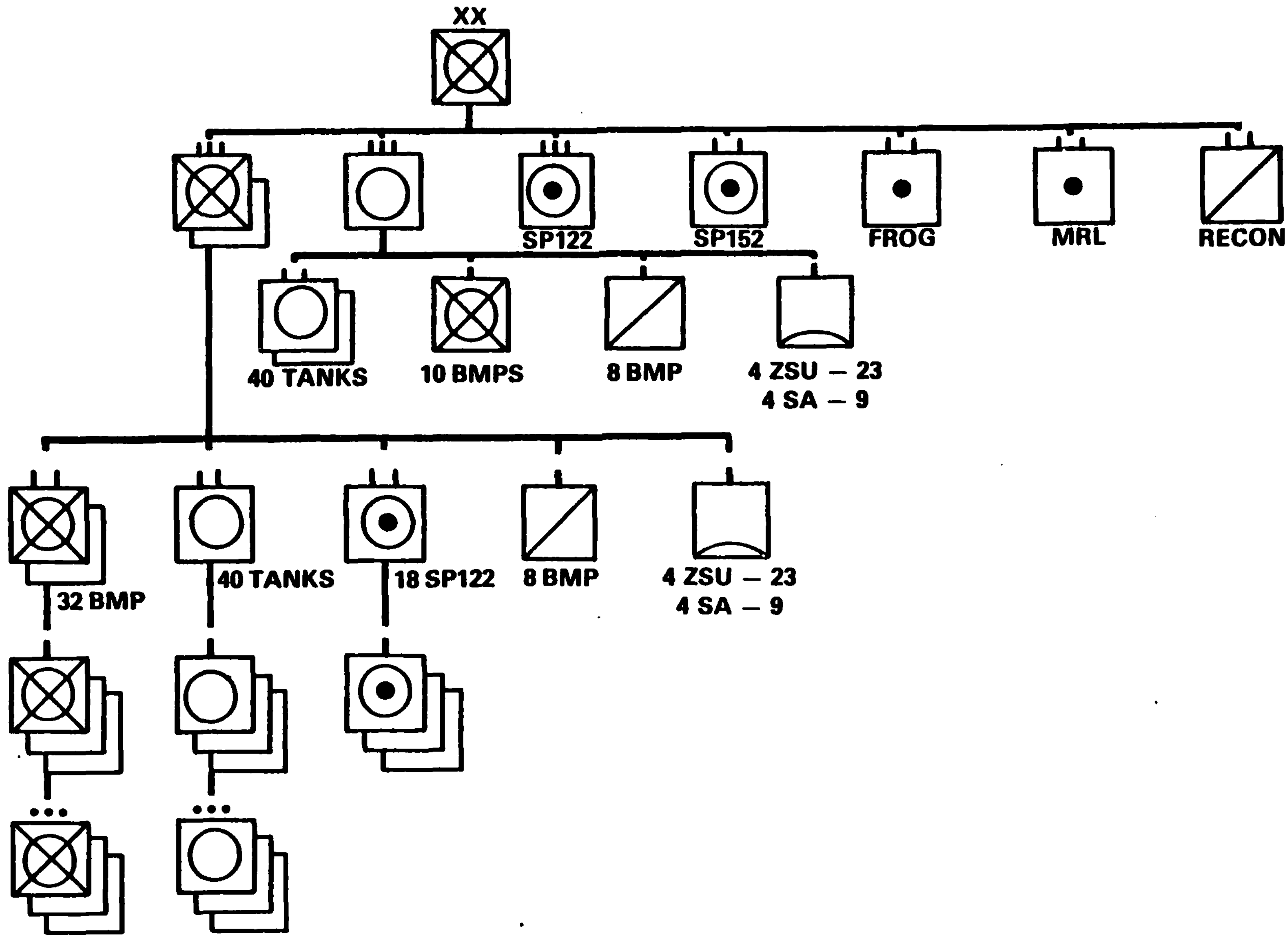


Figure 3-3 Red Motorized Rifle Division Organization

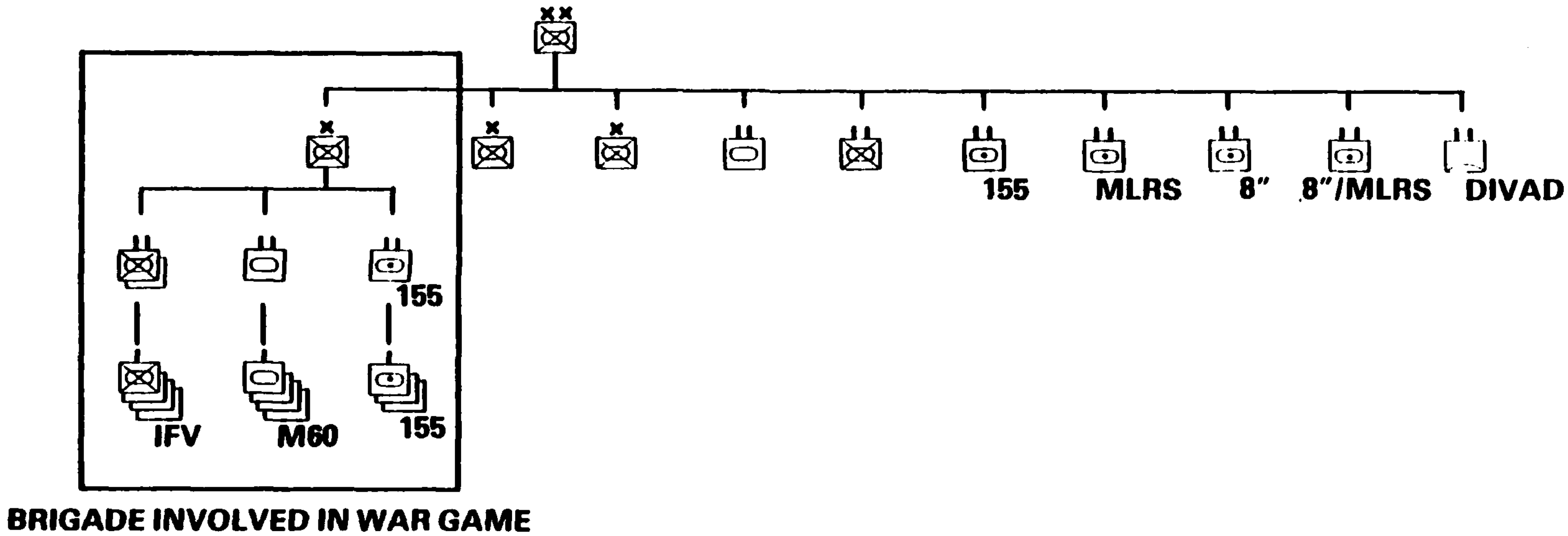


Figure 3-4 Blue Mechanized Infantry Division

TABLE 3-2 WEAPONS SYSTEM MIX

BLUE MECHANIZED INFANTRY BRIGADE COMPONENTS (DIV 86)

8 IFV COMPANIES		16 PER COMPANY	128 IFV'S
4 TANK COMPANIES		12 PER COMPANY	48 TANKS
3 SP 155 BATTERIES	DIRECT SUPPORT	8 PER BATTERY	32 SP 155
1 SP 155 BATTERY	REINFORCING		
1 MLRS BATTERY	DIV ARTY (GS)	12 PER BATTERY	12 MLRS LAUNCHERS
1 8" BATTERY	DIV ARTY (GS)	8 PER BATTERY	8 SP 8"

RED MOTORIZED RIFLE DIVISION COMPONENTS

2 MOTORIZED RIFLE REGIMENTS
1 TANK REGIMENT
1 SP 122 REGIMENT
1 SP 152 BATTALION
1 MRL BATTALION
1 FROG BATTALION
1 RECON BATTALION

— TOTALS —

4 BMP BATTALIONS	4 COMPANIES/BATTALION	160 BMP'S
4 TANK BATTALIONS	4 COMPANIES/BATTALION	160 TANKS
1 BMP RECON BATTALION	4 COMPANIES/BATTALION	
3 BMP RECON COMPANIES		
1 BMP COMPANY		80 RECON BMP'S
5 SP 122 BATTALIONS	3 BATTERIES/BATTALION	90 SP 122'S
1 SP 152 BATTALIONS	3 BATTERIES/BATTALION	18 SP 152'S
1 MRL BATTALION	3 BATTERIES/BATTALION	6 MRL 220'S; 12 MRL 122'S
1 FROG BATTALION	3 BATTERIES/BATTALION	
3 ZSU-23/SA-9 COMPANIES		12 ZSU-23'S; 12 SA-9'S

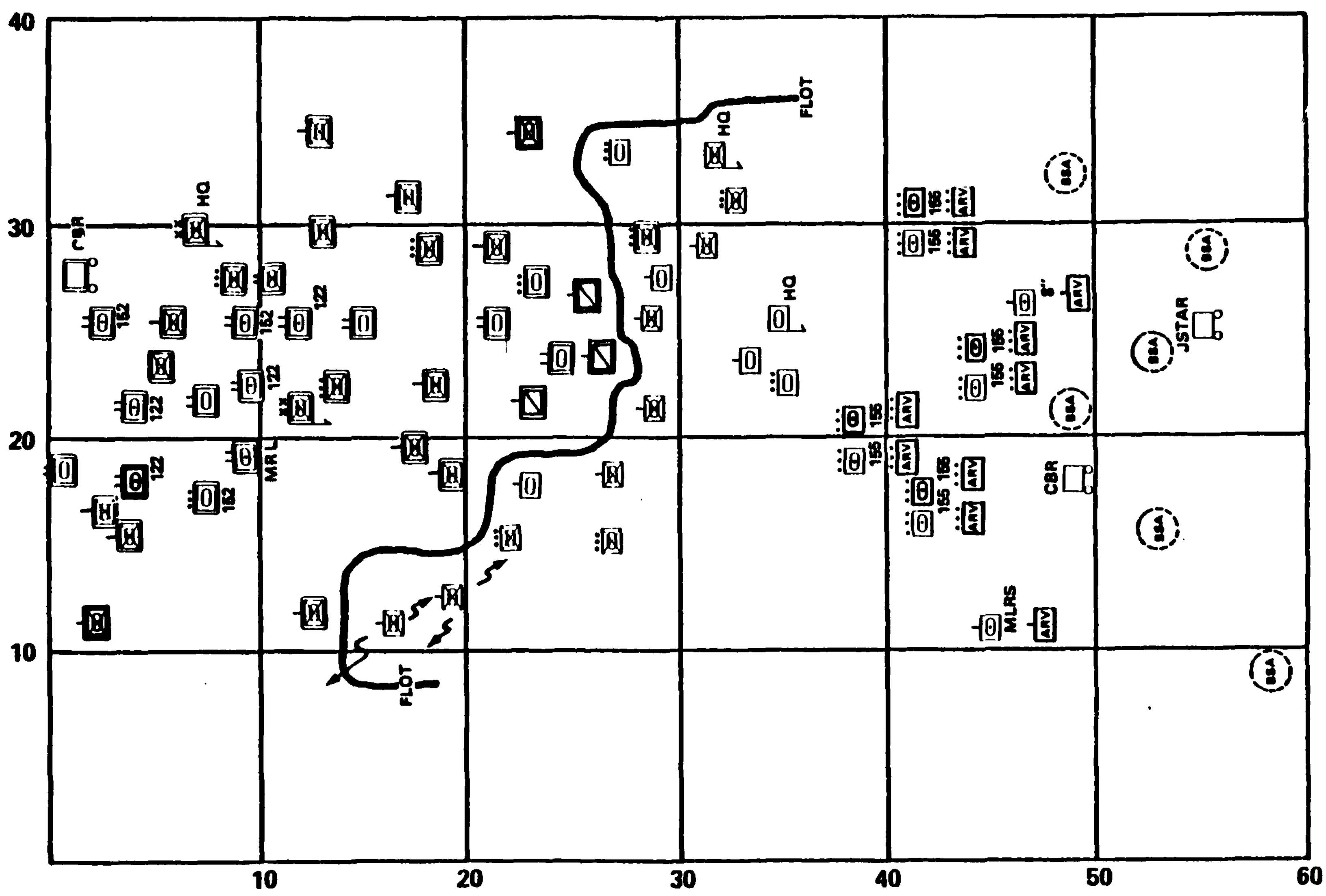


Figure 3-5 Detailed Wargame Initial Deployment

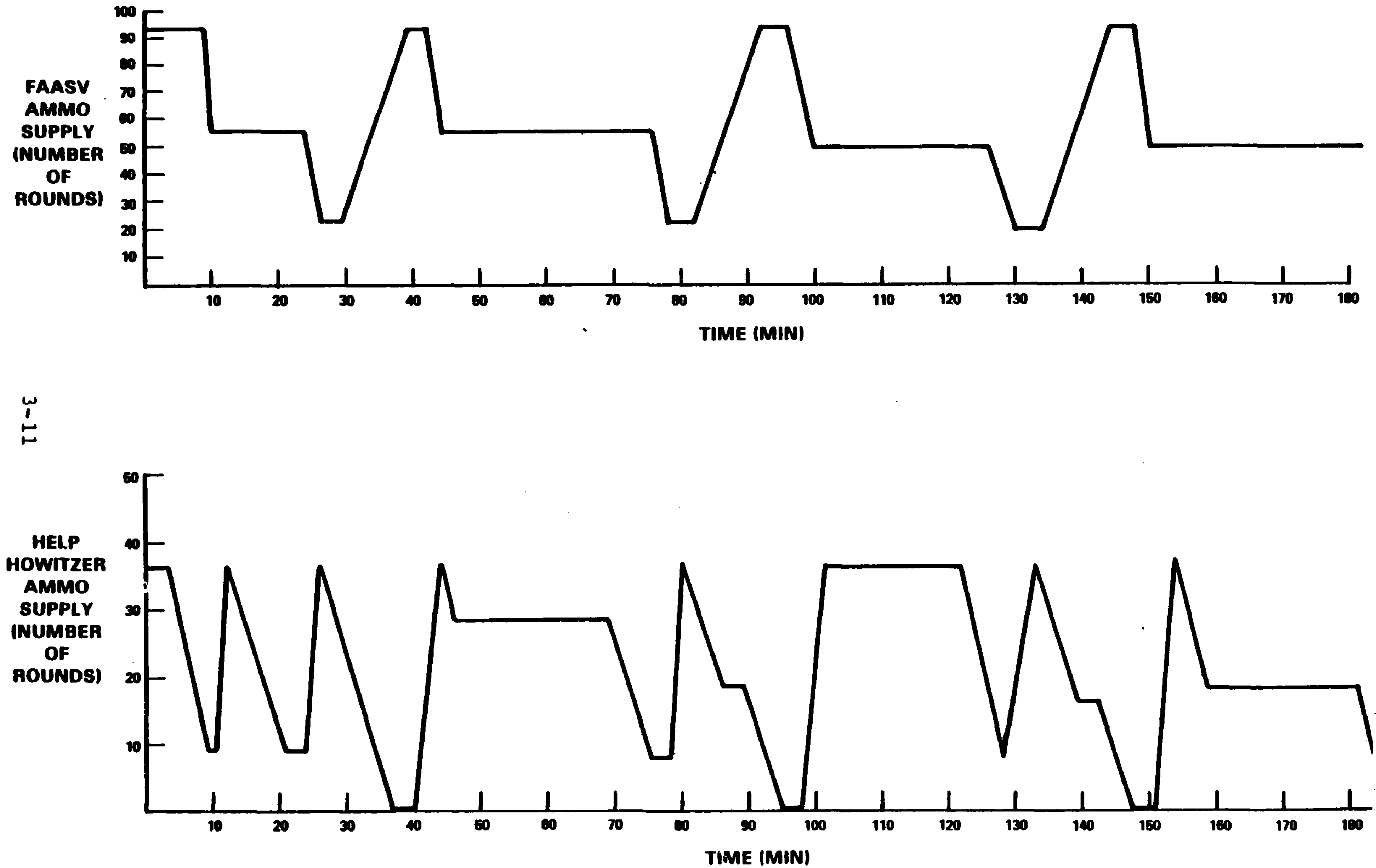


Figure 3-6 DIV 86 O&O/HELP Howitzer/FAASV

vertical ascending lines signify input and horizontal lines correspond to no change. The HELP howitzer first fires at time (t) = 4 minutes, is resupplied by its FAASV at t = 10 minutes, and goes down at time t = 36 minutes because the FAASV has departed for the Battery Supply Area (BSA) for a reload. Heavy fire support requests basically drive the howitzer to fire as fast as possible when rounds are available. The FAASV can travel between the howitzer and BSA in 4 to 5 minutes. The FAASV spends 10 minutes at the BSA being reloaded with ammunition and fuel. The howitzer scoots on incoming. Perfect supply coordination between the Division Ammunition Transfer Point (ATP) and the BSA are assumed. The average number of rounds taken from the BSA per hour can be calculated from Figure 3-6. This can be used to calculate logistics requirements between the Division ATPs and the BSAs. The howitzer is forced to relocate to the rear at t = 40 minutes, t = 94 minutes and t = 156 minutes due to encroaching enemy armor. Additional data from the Case 1 analysis are carried forward to a summary Table 3-3.

3.4 RESULTS OF DSWS C^3 O&O MAXI PIP HOWITZER ANALYSIS

The ammunition versus time information for Case 2 is presented in Figure 3-7. Larger onboard ammo storage for both the PIP FAASV and the Maxi-PIP howitzer, as well as a higher rate of fire mark the main departures between this case and the previous Division 86 + HELP howitzer Case 1. A rate of fire of 8 rounds per minute is used. ARVs are placed closer to the howitzers to facilitate resupply at the higher rate of fire. The BSA is also closer to the howitzers for the same reason. Another major difference is the greater Pip FAASV-BSA displacement. This increased distance causes the PIP FAASV to be away from the Maxi-PIP howitzer for a longer time. At t = 46 minutes, the Maxi-PIP howitzer is forced to relocate while the PIP FAASV is away at the BSA. Additional data for this case appears in the summary Table 3-3. At t = 84 minutes, the BSA is forced to displace while the

Table 3-3

DATA SUMMARY FROM C^3 ANALYSIS

CASE	RNDS/hr Fired Per SPH (RNDS)	ARV-SPH Reloads per hr. (Reloads)	ARV-BSA Reloads Per hr. (Reloads)	Scoots Per SPH Per hr. (Scoots)	Displacements Per SPH Per hr. (Displacements)	Distance Scooted Per SPH Per hr. (KM)	Total Distance Traveled Per SPH Per hr. (KM)	Total Distance Traveled Per ARV Per hr. (KM)	Red Flot Advance Per hr. (KM)	Blue SPH Lost per hr. (SPH-Killed)	Blue ARV Lost per hr. (ARV-Killed)	Effectiveness: Total Red Casualties	Effectiveness: Total Blue Casualties	Effectiveness: E*
1) Div 86 C^3 O&O/ Help Howitzer/ FAASV	81	2.3	1	2	1	0.6	5.6	8.7	10	22	21	120	69	1.0
2) DSW C^3 O&O/ Maxi Pip Howitzer/ Pip FAASV	133	2.7	1	5	1	1.5	7.5	15.5	8	14	5	122	64	1.37
3) DSWS C^3 O&O/ New Howitzer/ New ARV	168	2.7	1	5	1	1.5	7.5	15.5	7	13	2	132	62	1.75

$$\text{*Effectiveness} = \left(\frac{\text{Red Casualties}}{\text{(Total Red Advance in KM) X (Blue Casualties)}}\right) \text{X scale}$$

Measured after ½ hour of battle

SPH.........Self Propelled Howitzer
RNDS......Rounds
ARV........Ammunition Resupply Vehicle
BSA.........Battery Supply Area
FAASV....Field Artillery Ammunition Supply Vehicle

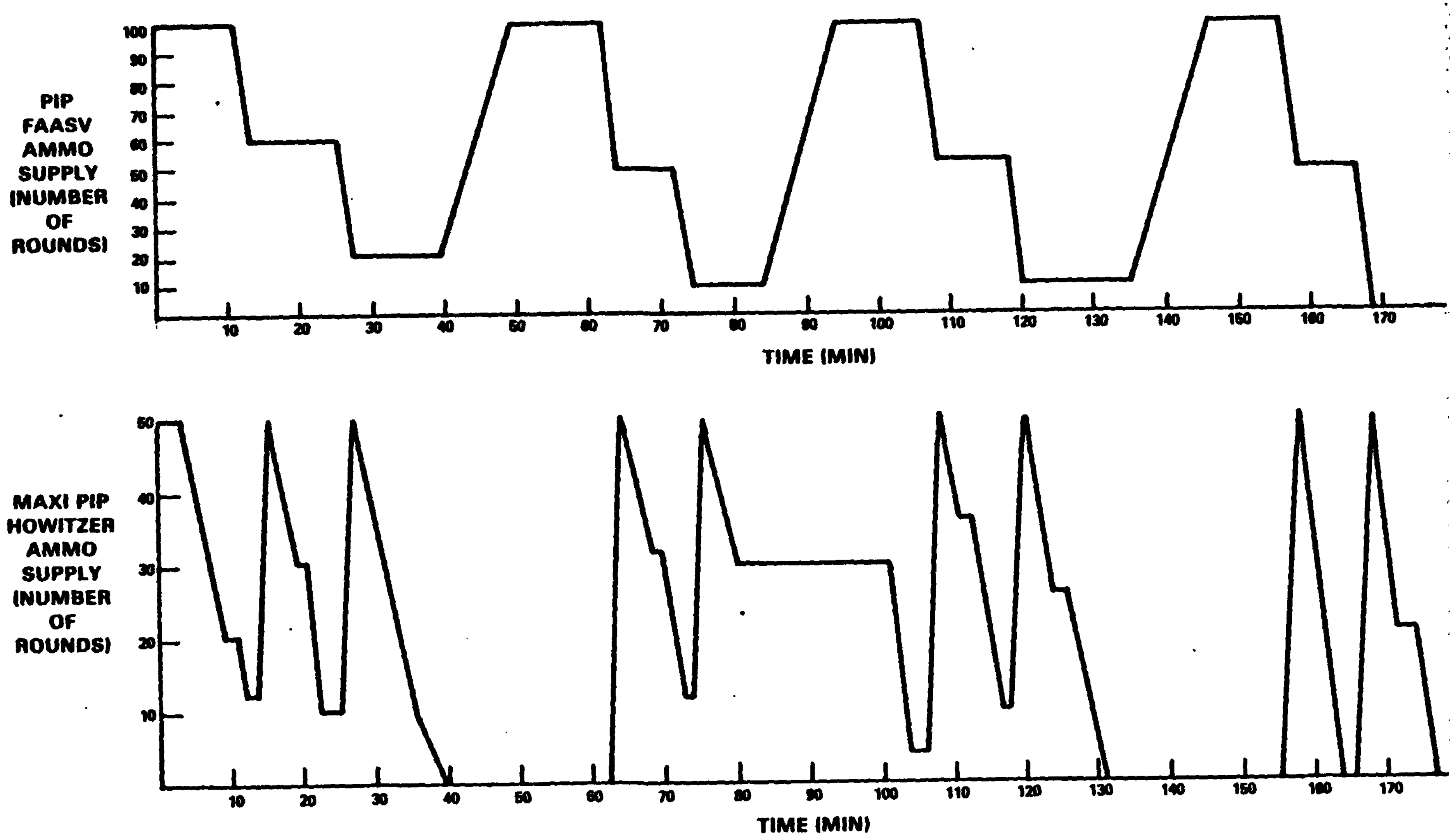


Figure 3-7 DSWS C^3 O&O/Maxi-PIP Howitzer/PIP FAASV

PIP FAASV is enroute to it. These occurrences represent justification for a PIP FAASV communications requirement with greater range than is required in the baseline Division 86 Case 1. The anticipated difficulties of a FAASV rendezvousing with the relocated Maxi-PIP howitzer or BSA when separations are on the order of 5-9 km justify an on-board communications range of this amount. The Small Unit Transceiver (SUT)-type radio with increased range is easily detected and does not appear to be a good solution for onboard FAASV communications. FAASVs are required to execute coordinated maneuvers between the BSA and the Maxi-PIP Howitzer when they are under attack and there is a definite information transfer requirement over ranges of 5-9 km. Coordination between the howitzer and the PIP FAASV during howitzer reloads and scoots of 300 meters does not imply a stringent communication requirement. Scoots of 1 to 3 km under a Nuclear/Biological/Chemical (NBC) threat and displacements of 3-5 km due to encroaching enemy direct fire systems are real possibilities. The added problems of a rendezvous with a FAASV that must make 5 to 9 km trips to and from the BSA implies a clear need for SINCGARS onboard the Pip FAASV. This need is not as clear in the baseline Division 86 case where the BSA is much closer to the howitzer positions and the FAASV would rarely be outside of the SUT's range. Increasing power on the SUT for greater range greatly increases the enemy detection threat. There are additonal benefits included with onboard SINCGARS for the FAASV:

1) The system is more immune to the enemy DF threat,

2) The FAASV is free to listen to howitzer transmission,

3) The FAASV can provide a communications backup to its associated howitzer. This last feature adds another degree of fault tolerance to the C^3 system.

3.5 RESULT OF DSWS C^3 O&O NEW DSWS HOWITZER ANALYSIS

Figure 3-8 displays the ammunition/time data obtained from Case 3 -- a DSWS C^3 O&O concept and the new DSWS howitzer. A rate of fire of 10 rounds per minute is used. The main difference between this case and the others is larger onboard ammunition supply carried on the new howitzer and the new ARV. The major results are increased enemy casualties and fewer friendly casualties due to the increased effectiveness of the New DSWS + ARV combination. The rationale for a SINCGARS for the ARV remains the same as in Case 2. Additional data from this case analysis is also contained in the summary Table 3-3.

3.6 C^3 SYSTEM MEASURES OF EFFECTIVENESS

Table 3-3 summarizes the data of interest for this analysis. The major differences between the cases are seen in the columns showing total casualties for both sides. The increased howitzer-FAASV/ARV displacement in Cases 2 and 3 results in significantly fewer FAASV/ARV losses. However, relatively small overall differences in effectiveness between the cases occur. The major reason for this is that the benefits from increasing rates of fire from 81 rounds per hour to 133 and 168 rounds per hour are small when applied to only DPICM and HE rounds. This analysis would show greater increases in effectiveness and enemy casualties from artillery fire if the Blue side was credited with a 155mm terminally guided munition (TGM) capability. Enemy casualty increases between cases 1, 2 and 3 could jump from 2-5% to 15-20% if TGM were used. 155mm DPICM munitions have relatively little combat effectiveness when attacking rapidly moving armored forces, except for suppression missions, which do not explicitly show up in measures such as those displayed in Table 3-3. Further analysis is recommended focused on:

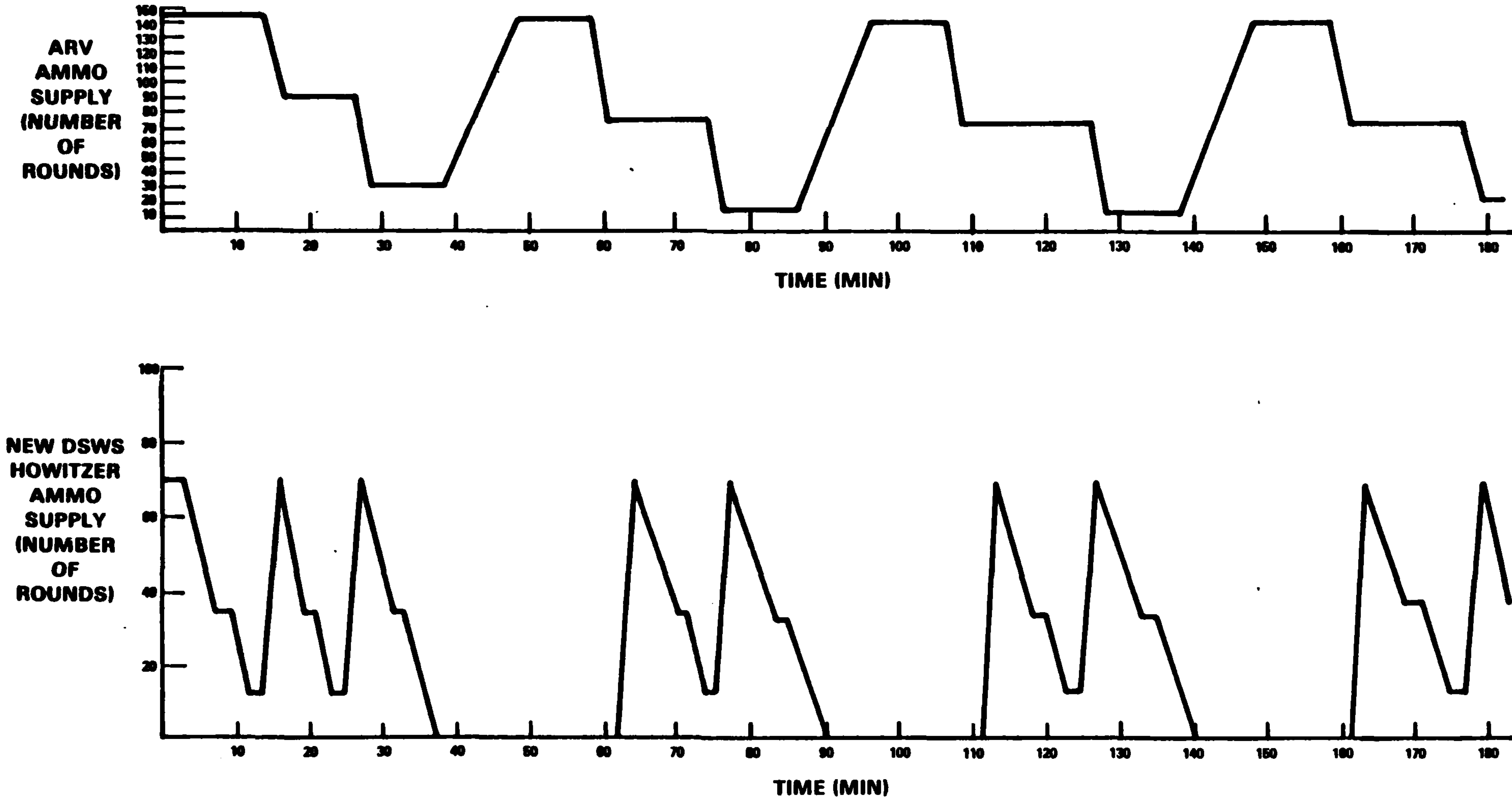


Figure 3-8 DSWS C^3 O&O/New Howitzer/ARV

1) Quantifying measures of effectiveness for 155mm suppression missions,

2) DSWS weapon system effectiveness in supporting offensive operations,

3) Use of guided munitions as a cost-effective way of attacking moving targets.

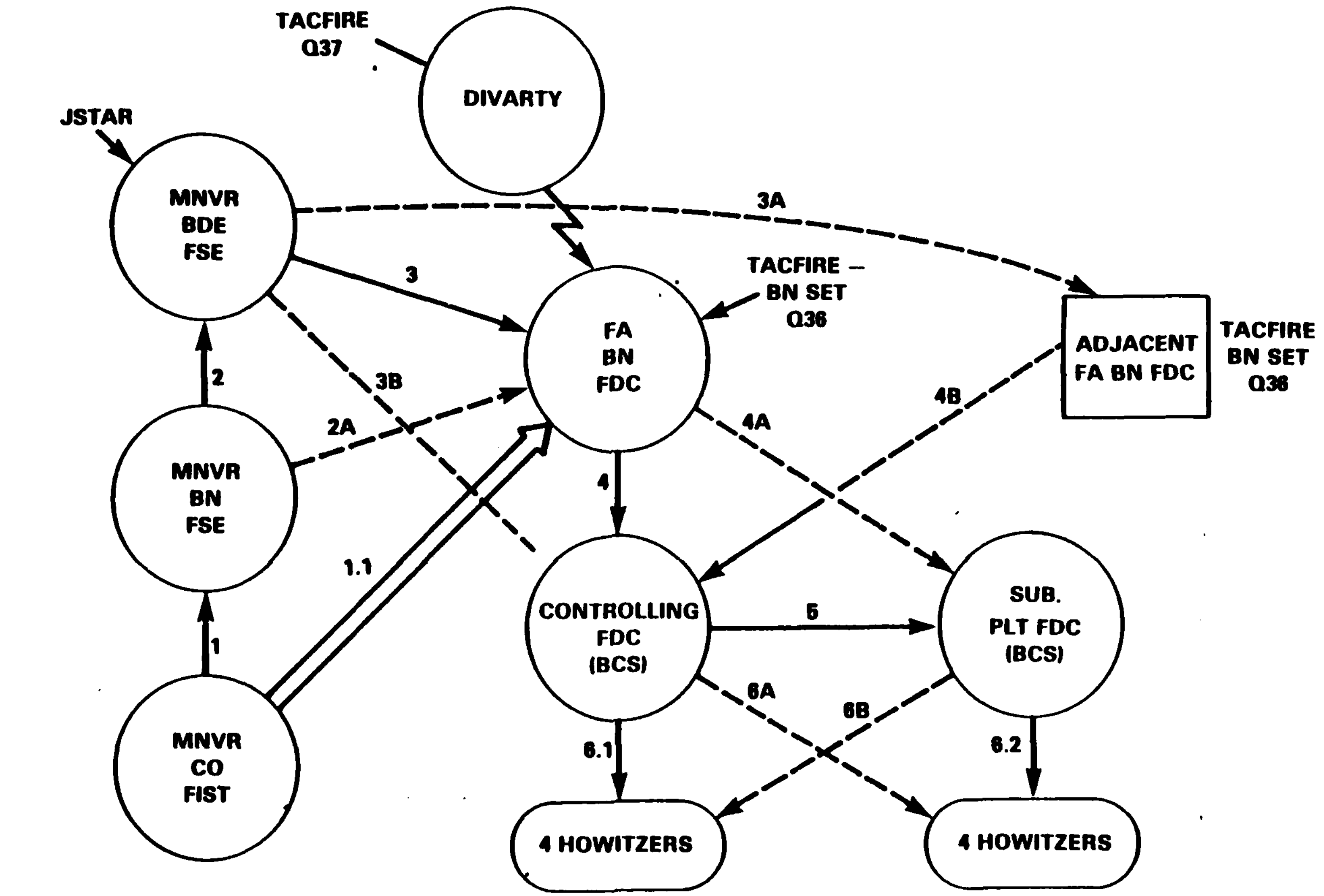
DSWS should be highly capable of providing effective support to the mobile defense and counter attack forces. Low response time, long range, and TGMs seem to be required for such support. Second echelon strike forces are expected to use howitzers to suppress enemy action on their flanks and rear. Effective conventional artillery fires with wide area coverage seem appropriate for this mission. The inclusion of the above factors in the Fire Support Mission Area Analysis is recommended.

3.7 HELP HOWITZER FIRE CONTROL

The Division 86 operational and organizational C^3 concept and the HELP howitzer fire control are depicted in Figure 3-9. This C^3 concept utilizes TACFIRE, the Battery Control Station (BCS), SINCGARS, the SUT and centralized fire control. Table 3-4 lists tactical situations in which communication nodes can expect to be degraded and the alternate communications channels and procedures to be used to continue operations. These procedures were supplied by the DSWS Special Study Group at the Field Artillery Center.

3.8 NEW DSWS FIRE CONTROL

The O&O C^3 concept for the new DSWS howitzer is shown in Figure 3-10. This system provides for greater C^3 technical fire control redundancv. Table 3-5 lists tactical situations for degraded C^3 operations in this new DSWS O&O concept. These procedures were also provided by the Special Study Group at the Field Artillery School.



- CENTRALIZED DECISION-MAKING FIRE CONTROL SYSTEM

  → DESIGNED (NUMBERS REPRESENT ORDER OF FLOW)

  - - → BYPASSING DOWNED NODES (ALPHANUMERICS REPRESENT ORDER OF FLOW)

- DECENTRALIZED DECISION-MAKING (QUICK FIRE CHANNEL)

  ⇒ DESIGNED BY PASS (1.1)

- TACFIRE, BATTERY CONTROL STATION, SMALL UNIT TRANSMITTER

Figure 3-9 HELP Howitzer Fire Control Net - DIV 86

Table 3-4

DEGRADED TACTICAL/TECHNICAL FIRE CONTROL FOR DIVISION 86

Situation 1:	Subordinate platoon (Plt) Fire Direction Center (FDC) out of action. Controlling FDC takes over technical fire control over link 6A. 15 min delay, then operational. Delay due to subordinate platoon's howitzers having to relocate.
Situation 2:	Controlling FDC out of action. Subordinate Plt FDC takes over on link 6B. 15 min delay for howitzer relocation, then system operational.
Situation 3:	Both Plt FDCs out of action. Bn takes over. 60 min delay to reestablish communications.
Situation 4:	FA Battalion (Bn) FDC out of action. Adjacent FA FDC-TACFIRE takes over on link 4B. 60 min delay. Once established, no delays.
Situation 5:	Maneuver Brigade Fire Support Element (FSE) out of action. FA Bn FDC takes over on link 2A. 5 min delay. 1 min delay for each transmission.

NOTES:

a) 3 maneuver battalions in a brigade. Battalions would communicate their fire mission requests to the FA Battalion FDC.

b) Tactical fire control accomplished primarily at FA Bn FDC with TACFIRE.

c) Technical fire control accomplished primarily at Platoon FDC with BCS.

d) On quickfire channel (1.1), TACFIRE processes as a priority mission.

e) The Division Artillery TACFIRE cannot provide backup to the Battalion TACFIRE. It does not have software that is compatible with the Battalion TACFIRE's function.

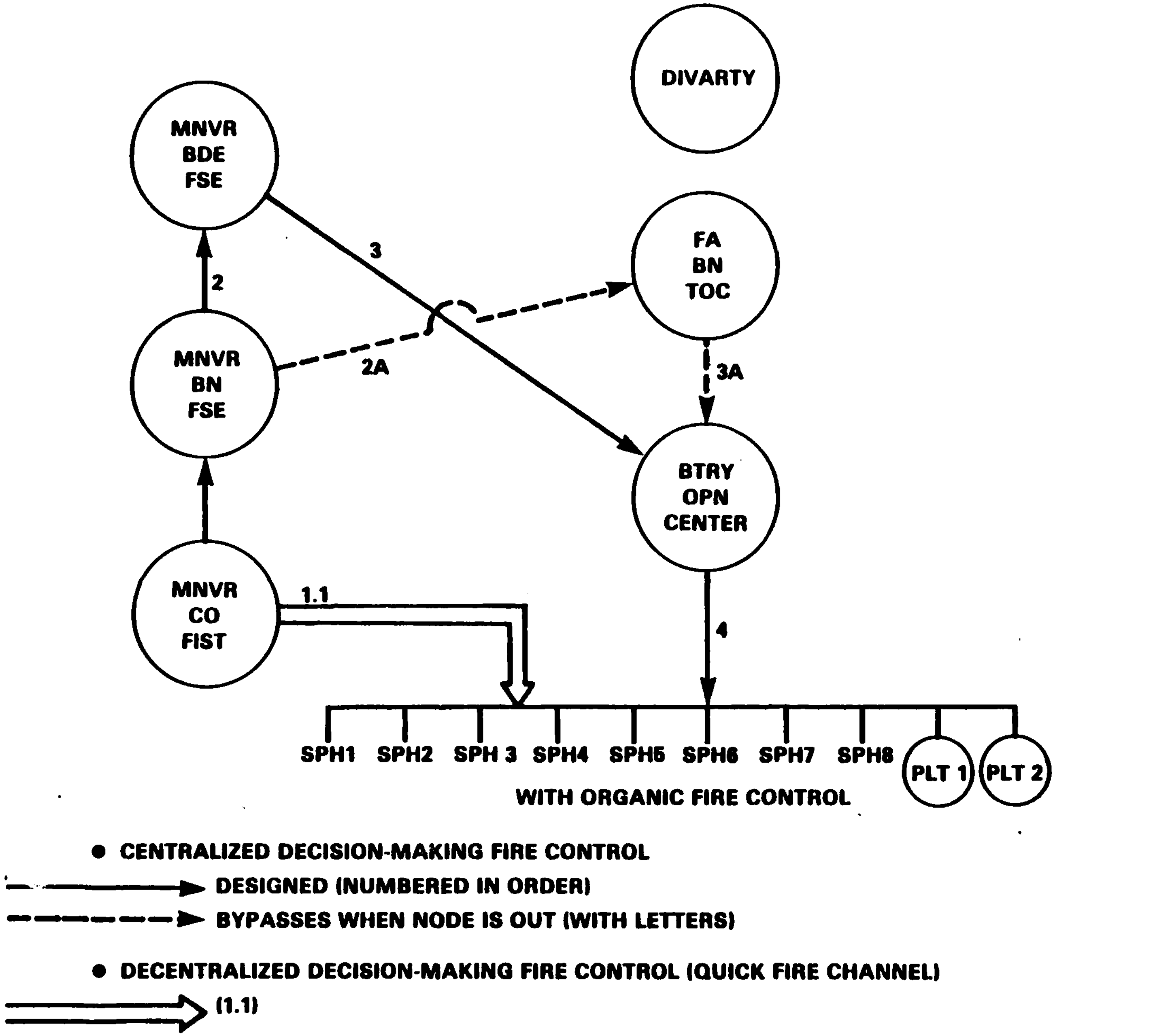


Figure 3-10 Direct Support Weapons System Fire Control Net

Table 3-5

DEGRADED TACTICAL/TECHNICAL FIRE CONTROL FOR DSWS C^3 O&O

Situation 1: One howitzer on-board-fire control system (OBFCS) out of action. Battery Operations Center (BOC) takes over technical fire direction. The Fire Support Terminal (FST) at the BOC will indicate when an individual howitzer's OBFCS is out and will pass the fire mission target location to BOS with the howitzer designation. At the same time, the fire order to the other howitzers is transmitted. The BCS is computing data for the one howitzer whose OBFCS is out as all other howitzers are computing firing data. The only time lost is the amount of time required to transmit firing data from the BOC to the howitzer whose OBFCS is out. This is 30 seconds if voice transmission. This delay occurs every time the BOC has to transmit to that howitzer.

Situation 2 through 8: These situations represent cases where the number of non-operational OBFCS increase in single increments from 2 to 8. The BOC will usually provide backup for up to 2 howitzers, although it has the capability to backup all 8 howitzers with Battery Control Stations (BCS). After 2 howitzers are backed up by the BOC, howitzers will move to collocate with a howitzer whose OBFCS is operational. For the worst case where all OBFCS are non-operational, the howitzers would be operating as 2 platoons. The BOS would provide 2 sets of firing data, one set per platoon. This would be the same mode of operation as the HELP howitzers in the Division 86 C^3 O&O concept.

a) 2 OBFCs out of action. BOC provides backup with 1:5 min delay.

b) More than 2 OBFCs out of action. Backup provided by collocating with an adjacent howitzer and firing the same data. 5 minute delay added every time a howitzer has to move No time delay after howitzer is in place with the other howitzer.

c) All 8 OBFCs out of action. 30 minutes to relocate all howitzers to platoon areas. 1 minute delay to pass firing data by voice via radio for each mission thereafter.

Table 3-5 (Continued)

DEGRADED TACTICAL/TECHNICAL FIRE CONTROL FOR DSWS C^3 O&O

Situation 9: BOC out of action. Backup provided by maneuver brigade FSE via one of the FSTs. 30 min delay to reprogram/reallocate the FSTs available at brigade. Once this has occurred, no further delays.

Situation 10: Maneuver brigade FSE out of action. Exact order of backup is not fully identified in the new DSWS Advanced Field Artillery Tactical Data System (AFATDS) O&O. Based on conversations with personnel from the AFATDS COEA Team, current procedure is that the primary backup for Bde FSE will be the FA Bn TOC. This can be accomplished by a reprogramming of the FA Bn's FST, which is a relatively simple operation and can be done by switching a module or done remotely by another FST. There will be an associated degradation primarily in the communications lags that will occur. This backup will occur over communications links number 2A and 3A in the diagram. The delay is represented by an initial 30 minute delay then no delays thereafter. There will be 3 maneuver battalion FSEs communicating with the FA Bn TOC.

NOTES:

The following capabilities and equipment are postulated at each node.

a) Howitzer -- Technical computations through some form of onboard fire control system (OBFCS). There will be some digital display and a PJH interface.

b) Battery Operational Center -- Backup Technical computation ability through BCS. Provides final tactical fire control to the guns. The Bde FSE will designate the number of howitzers to fire. The BOC will designate which howitzers in the battery will fire.

c) Maneuver brigade FSE -- Primary function is to provide tactical fire control. This element allocates fire support assets to each mission, based on availability. The FSE should be able to provide backup tactical control for the BOC because the Bde FSE will have to know the status of a unit's howitzers in order to allocate units to fire missions efficiently.

Table 3-5 (Continued)

DEGRADED TACTICAL/TECHNICAL FIRE CONTROL FOR DSWS C^3 O&O

d) FA battalion tactical operations center (TOC) -- Primary function of this element is tactical operations and combat service support coordination. Current procedures call for a Fire Support System (FSS) in the TOC with a number of perpherical Fire Support Terminals (FSTs). Even though the FSS will be executing tactical/admin-log coordination, the component FSTs are designed to be easily reprogrammable, and could be used to backup the Bde FSE.

e) Maneuver battalion FSE -- Interfaces with the Bde FSE or FA battalion TOC for transmitting fire support requirements and other essential information. A maneuver Bn FSEs would be designated to assume the functions the Bde FSEs, if the Bde FSE went out of action.

f) FA platoon HQ - Primary function is to provide for control of the tactical operations of subordinate howitzers and to coordinate combat service support. Limited capability for tactical or technical fire control.

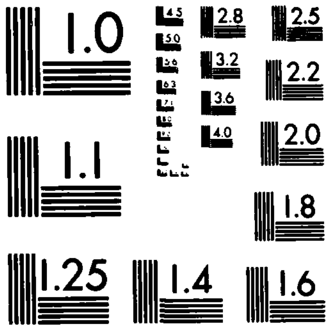
AD-A131 493 DIVISION SUPPORT WEAPON SYSTEM RATE OF FIRE AND C(3) OPERATIONS(U) SCIENCE APPLICATIONS INC MCLEAN VA C3 SYSTEMS DEPT J W BAUMGART ET AL. 01 APR 83 2/2

UNCLASSIFIED DAEA18-81-G-0017 F/G 19/5 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

3.9 HOWITZER ONBOARD TECHNICAL FIRE CONTROL

Table 3-6 summarizes the situations listed in Tables 3-4 and 3-5. The justification for howitzer on board fire control is obvious. Three critical fire control nodes or situations have been replaced by ten. The fault tolerance of the C^3 system is measured by the estimated down time and response times for each situation or level of degradation. The artillery battery operating in the DSWS O&O C^3 concept will be operational for a much greater length of time under degraded technical fire control situations than the Division 86 artillery battery. There are several other important factors supporting howitzer onboard technical fire control:

1) Lower response time
2) Lower "quickfire" response time
3) Lower response time under surge conditions (Table 3-1).

The rate of fire analysis demonstrated the importance of response time when attacking moving targets. The greater autonomy of the howitzers will also be conducive to operations from widely dispersed positions. Shoot and scoot analyses have generally indicated that dispersion can increase survivability and sustained effectiveness.

Table 3-6

TECHNICAL FIRE CONTROL FAULT TOLERANCE

SITUATION	DIVISION 86 C^3 O&O			DSWS C^3 O&O		
	Network Response	Battery Downtime (min)	Degraded Response (min)	Network Response	Battery Downtime (min)	Degraded Response Time (min)
1	Adjacent PLT FDC takes over	15	0	BOC takes over single howitzers	0	0.5
2	BN FDC takes whole battery	60	0	BOC takes over two howitzers	0	1.5
3	Adjacent BN FDC takes over battery	60	0	Howitzer C^3 down relocate near another howitzer	5	0.5
4				Howitzer relocate	5	0.5
5				Howitzer relocate	5	0.5
6				Howitzer relocate	5	0.5
7				Howitzer relocate	5	0.5
8*				BOC provide data to collocated platoons maneuver	30	1.0
9				BDE FSE Replaces BOC	30	1.0
10				FA BN TOC replaces Maneuver BDE FSE	30	1.0

* Equivalent to starting Division 86 situation

SECTION 4

LITERATURE ASSESSMENT

4.1 PURPOSE

The purpose of this section of the study is to conduct a review and assessment of relevant literature that addresses the contribution of cannon artillery systems in determining the outcome of battle. Special emphasis was placed on the division artillery of the fire support system and analytics that address the following topics:

1) Measures of Performance (MOP)

2) Measures of Effectiveness (MOE)

3) Parameters that contribute to significant changes in lethality and survivability

4) Sensitive variances in subsystem performance that have the potential for high payoff in effectiveness

5) Doctrines, practices and procedures that contribute significantly to weapon system availability

6) Human factors to include crew availability, rotation, and performance/effectiveness issues

7) Self-propelled howitzer ammunition storage/ ammunition resupply vehicle ammunition

4.2 METHODOLOGY

The limited resources allocated to the entire study effort and significantly greater importance of the Section 2-Rate of Fire Analysis and the Section 3-C^3 Analysis forced a literature assessment that was, of necessity, very focused. The methodology to achieve this focus is as follows:

1) The literature search was limited to a single high yield automated military technical data base, specifically the Defense Technical Information Center (DTIC) RDT&E Diverse Dial-up On-line System.

2) Two searches were performed. The first search was an SAI search by a trained operator through an SAI terminal connected to the DTIC on-line system. The second search was called in directly to DTIC and performed by a DTIC operator. The search strategy and search terms are contained in Appendix D.

3) The results were analyzed and citations were sorted into High, Medium and Low interest categories. The criteria for these categories was:

   High Interest - Citation contained items that were in topics 1-4 as listed in para. 4.1.

   Medium Interest - Citation contained items that were contained in topics 5-7, para. 4.1.

   Low Interest - Citation was in the general area of interest but not specifically related to the topics.

4) The citations were then rank ordered within each category based on a subjective judgment of the relative importance to the DSWS COEA special study effort.

The citations developed using this methodology are contained in Appendix D in the categories and rank order just discussed.

SECTION 5

SPECIAL STUDY GROUP SUPPORT

This section of the report details the types of assistance provided to the DSWS Cost and Operational Effectiveness Analysis (COEA) Special Study Group (SSG) during the duration of the contract.

On 17 January 1983, SAI hosted an in progress review of the analytical effort for COL Malcolm Marks, Chairman of the SSG, LTC James P. McGinnis, Project Manager, DSWS and five members of their staffs. Preliminary results of the study were provided in briefing chart format at this presentation. Thirteen finished charts and eight draft charts were furnished the SSG that could be used in status briefings of the COEA.

SAI also hosted a working group session for the SSG staff on 20 January in which details of the C^3 Analysis methodology were developed.

On 1 February 1983, a total of fifty three briefing charts on the results of the Rate of Fire Analysis were provided in finished vugraph form by priority mail. These briefing charts were provided to assist the SSG in their 4 February briefing to the CG of the Field Artillery Center at Fort Sill, Oklahoma.

On 24 February, an advance copy of the C^3 Analysis was provided the SSG with sixteen charts in finished form and an additional ten in draft form to assist in briefings of the COEA to various reviews at the Field Artillery Center, the Training and Doctrine Command and at Headquarters, Department of the Army.

Throughout the contract period, SAI responded to numerous telephone inquiries and to requests for information on the preliminary data provided.

REFERENCES

1. F. W. Niedenfuhr, Artillery Unit Survivability Analysis (U), The MITRE Corporation, McLean, Virginia, 6 January 1983, In Progress Draft, Unclassified.

2. S. Pearcy and J. Ortiz, Division Support Weapons System (DSWS) Parametric Study of Rate-of-Fire Accuracy and Responsiveness (U), Large Caliber Weapons System Laboratory, U.S. Army Armament Research and Development Command, Dover, New Jersey, October 1982, Confidential.

3. FM 101-60-14 Joint Munitions Effectiveness Manual, Surface to Surface, Effectiveness Data for howitzer, 155 mm, M 109 A1/A2/A3 (U), Revision 1, U.S. Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland, 10 April 1981, Confidential.

APPENDIX A

RATE OF FIRE ANALYSIS PARAMETERS

A.1 HOWITZER RATES OF FIRE

HELP Howitzer	4 rounds per minute
Maxi-PIP Howitzer	8 rounds per minute
New DSWS Howitzer	10 rounds per minute

A.2 KILL CATEGORIES CONSIDERED

M Kill	Incapacitation of crew or damage to propulsion or control equipment
F Kill	Combat mission halted
K Kill	An M Kill and F Kill such that repair is not economically feasible
C Kill	Damage which is not repairable by the combat crew, e.g., damage to engine, transmission, transmission case.
1.5 man-hour Kill	Damage to components as in C Kill requiring 1.5 man hours or more of repair time.
5 minute Assault Kill	Conditional probability that a random hit on a man by a fragment causes him to become physically incapable of continuing the assault within 5 minutes.

A.3 PROJECTILES CONSIDERED

1. M107 TNT M557	Point Detonating and M728 Proximity fuzes

2. M483A1 with 88 M42 Subminitions per projectile — M557 MTSQ fuze

3. Reliability

M483A1	= 0.937
M42 Submission	= 0.962
M107	= 0.996

A.4 DELIVERY ERRORS

Range (Km)	1	4	7	10	12	14	16	18
<u>Round</u>								
<u>M483</u> (DPICM)								
Range Error (m)	64	64	73	94	117	145	153	191
Deflection Error (m)	33	33	40	52	63	79	91	115
M107 (HE)								
Range Error (m)	53	53	75	97	133	171	210	245
Deflection Error (m)	15	15	25	43	59	80	100	120

Range and deflection errors given = 3.5 σ (contains 99.98% of rounds)

Range and deflection <u>probable</u> error = (given errors/3.5) 0.6075 (contains 50% of rounds)

A.5 LETHAL AREAS

Taken from JMEM (Reference 3) using following variables:

M107 with M557 and M728 fuzes - target, kill category, environment and angle of fall in degrees

M483 A1 with M42 submunitions and M557 MTSQ fuze - range and charge used to obtain:

a) average elliptical pattern in meters in range, deflection and equal area circular radius

b) precision error in meters in range and deflection

c) footprint radius in meters

d) mean point of impact error in meters in range and deflection

M42 Submunitions - target category and kill category used to obtain submunition lethal area in meters squared.

APPENDIX B

RATE OF FIRE ANALYSIS
COMPUTER PROGRAM SAMPLES

B.1 KEY ABBREVIATIONS USED IN FRACTIONAL DAMAGE PROGRAM

MFdam	=	moving fractional damage calculation
trad	=	target radius (meters)
footp	=	weapons footprint (meters)
tnt	=	number of targets within Trad
tvun	=	target vulnerability (= 1.0)
tle	=	target location error (meters)
rde	=	range delivery error
dde	=	deflection delivery error
smla	=	submunition (or round) lethal area
nspp	=	number of submunitions per round (= 1 for M107 TNT)
rely	=	round reliability
vel	=	target average velocity
trad x	=	target radius expansion average velocity
initial lethal area	=	initial submunition lethal area } used for changing posture personnel targets
subseq lethal area	=	subsequent submunition lethal area } used for changing posture personnel targets
# of mins	=	length in minutes of barrage
ROF	=	rate of fire
# of sph	=	number of howitzers firing
tk	=	number of targets killed
Fd	=	fractional damage
cont?	=	answer y to go to input ROF, # of sph answer c to go to a new case (input Trad, Footp, . . . , rely) answer n to quit

B.2 PROGRAM SAMPLES

```
      PROGRAM MFDAM
      real*4 md(10),tmax(30),kb,ntop
      character*1 abit
      pi=3.1415926
 10   continue
      a=amem
c
      tnt=tnti
      write(5,*) ' input trad,footp,tnt,tvun,tle,rde,dde,smla,nspp,rely:
      read(5,*) xa,xb,xtnt,xtvun,xtle,xrde,xdde,xsmla,inspp,xrely
      if(xa.ne.0) a=xa
      if(xb.ne.0) footp=xb
      if(xtnt.ne.0.0) tnt=tnti
      if(xtnt.ne.0.0) tnt=xtnt
      if(xtvun.ne.0.0) tvun=xtvun
      if(xtle.ne.0.0) tle=xtle
      if(xrde.ne.0.0) rde=xrde
      if(xdde.ne.0.0) dde=xdde
      b=footp
      if(xsmla.ne.0.0) smla=xsmla
      if(inspp.ne.0) nspp=inspp
      if(xrely.ne.0.0) rely=xrely
      write(5,*) ' trad,#tar,tar vun,footp,tle,rde,dde,smla,nspp,rely '
      write(5,*) a,tnt,tvun,b,tle,rde,dde,smla,nspp,rely
      write(5,*) ' input vel [m/min],  trad x [m/min] '
      read(5,*) xvel,xtvel
      if(xtvel.ne.0.0) tvel=xtvel
      if(xvel.ne.0.0) vel=xvel
      smlas=smla
      smlai=smla
      write(5,*) ' input initial lethal area,subseq lethal area: '
      read(5,*) xsi,xss
      if(xsi.ne.0.and.xss.ne.0) then
      smlai=xsi
      smlas=xss
      endif
      write(5,*) '  # of min.s : '
      read(5,*) inumb
      if(inumb.ne.0) numb=inumb
c
      tnti=tnt
      amem=a
 8009 continue
      tnt=tnti
      A=AMEM
      write(5,*) ' input ROF,  # of sph :'
      read(5,*) rof,nhow
      nrnds=rof*nhow
      ntop=rof
      tk=0.0
      ttk=0.0
      do 202 jb=1,numb
      ttnt=tnt
c
c    jin moving target integration
c
      do 201 kb=1,ntop
      smla=smlas
      if(kb.eq.1.and.jb.eq.1) smla=smlai
      ifs=3
      a=a+(tvel/ntop)
      jfs=0
 299  continue
```

```
      call funt(ifs,rde,dde,de)

      d=((tle*tle+de*de)+(((kb/ntop)+(jb-1.))*vel)**2)**(0.5)
      xrnds=(nrnds)/(ntop)
      if(kb.gt.1) then
      endif
c
c   gsin target - weapon overlap calculation
c
      a0=0.0
      b=footp
      if(d.ge.a+b) then
      a0=0.0
      goto 100
      endif
c
      if((a-b).ge.0.and.d.le.(a-b)) then
      a0=pi*b*b
      goto 100
      endif
c
      if((b-a).gt.0.and.d.le.(b-a)) then
      a0=pi*a*a
      goto 100
      endif
c
      if(abs(a-b).le.d.and.d.le.(a+b)) then
      s=(a+b+d)/2.0
      q=(((s-a)*(s-b)*(s-d))/s)**(0.5)
      alph=2.0*atan(q/(s-a))
      beta=2.0*atan(q/(s-b))
      a0=b*b*(alph-sin(alph)*cos(alph)) + a*a*(beta-sin(beta)*cos(beta))
      endif
c
c
 100  continue
      arad=(a0/pi)**(0.5)
c
c calc fraction of target overlapped
c
      if(a0.le.(pi*a*a)) then
      frac=(a0/(pi*a*a))
      else
      frac=1.0
      endif
      ptk=frac*(tnt)
      ptk=ptk-ttk
      ptk=max(ptk,0.0)
c
c calculate which (depp,repp) to (cep) function to use based on frac
c
      if(1.0.le.frac.and.frac.ge.0.75) jfs=1
      if(0.75.lt.frac.and.frac.ge.0.4) jfs=2

      if(0.4.lt.frac.and.frac.ge.0.0) jfs=3
c
c test to see if this function was used
c
      if(ifs.ne.jfs) then
      ifs=jfs
      goto 299
      endif
c
c calc # targets killed this timestep
c
 300  continue
```

```
c
c  calc prob of hit,expected tar killed,and frac damage
c
       ph=smla/(pi*b*b)
       tk=tvun*ptk*(1.0-(1.0-rely*ph)**(xrnds*nspp))
       ttk=ttk+tk
       tmax(kb)=tvun*ptk
       fd=(tnti-tnt)/tnti
 201   continue
c
c  end loop over ntop timesteps per minute
c
       ttnt=ttnt-ttk
       write(5,*) jb,d,a
       poop=tnti-ttnt
       poop1=poop/tnti
       write(5,*) ' tk= ',poop,' Fd= ',poop1
 202   continue
c
c end loop over numb minutes in barrage
c
       tnt=tnt-ttk
       xtnt=tnti
       tot=(tnti-tnt)/tnti
       write(5,*) ' cont? '
       read(5,9000) abit
 9000  format(1a1)
       if(abit.ne.'n'.and.abit.ne.'c'.and.abit.ne.'N') goto 8009
       if(abit.eq.'c') goto 10
       stop
       end
       subroutine funt(ifs,rde,dde,de)
       if(ifs.eq.1) then
       de=1.24*((rde*rde + dde*dde))
       endif
       if(ifs.eq.2) then
       de=0.872*(rde*dde)
       endif
       if(ifs.eq.3) then
       de=1.75*((rde*dde)**(0.5))
       endif
       return
       end
*
```

```
 run mfdam
 input trad,footp,tnt,tvun,tle,rde,dde,smla,nspp,rely:
150.,200.,6.,1.,75.,33.1,19.9,2.9,88,0.9
 trad,#tar,tar vun,footp,tle,rde,dde,smla,nspp,rely
  150.0000        6.000000        1.000000        200.0000        75.00000
  33.10000        19.90000        2.900000              88  0.9000000
 input vel [m/min],  trad x [m/min]
0.0,75.0
 input initial lethal area,subseq lethal area:
2.9,2.9
  # of min.s :
4
 input ROF,  # of sph :
4.,4
           1   87.41990        225.0000
 tk=   0.1269388      Fd=   2.1156469E-02
           2   87.41990        300.0000
 tk=   0.2140374      Fd=   3.5672903E-02
           3   87.41990        375.0000
 tk=   0.2658672      Fd=   4.4311207E-02
           4   87.41990        450.0000
 tk=   0.2972860      Fd=   4.9547672E-02
 cont?
y
 input ROF,  # of sph :
6.,4
           1   87.41990        225.0000
 tk=   0.1914010      Fd=   3.1900167E-02
           2   87.41990        300.0000
 tk=   0.3205290      Fd=   5.3421497E-02
           3   87.41990        375.0000
 tk=   0.3947291      Fd=   6.5788187E-02
           4   87.41990        450.0000
 tk=   0.4368610      Fd=   7.2810173E-02
 cont?
y
 input ROF,  # of sph :
8.,4
           1   87.41990        225.0000
 tk=   0.2548900      Fd=   4.2481661E-02
           2   87.41990        300.0000
 tk=   0.4236002      Fd=   7.0600033E-02
           3   87.41990        375.0000
 tk=   0.5170031      Fd=   8.6167179E-02
           4   87.41990        450.0000
 tk=   0.5663996      Fd=   9.4399929E-02
 cont?
y
 input ROF,  # of sph :
10.,4
           1   87.41990        225.0000
 tk=   0.3174148      Fd=   5.2902460E-02
           2   87.41990        300.0000
 tk=   0.5233898      Fd=   8.7231636E-02
           3   87.41990        375.0000
 tk=   0.6330180      Fd=   0.1055030
           4   87.41990        450.0000
 tk=   0.6865549      Fd=   0.1144258
 cont?
y
 input ROF,  # of sph :
12.,4
           1   87.41990        225.0000
 tk=   0.3789878      Fd=   6.3164629E-02
```

```
              2   87.41990        300.0000

  tk=    0.6199706     Fd=    0.1033285
              3   87.41990        375.0000
  tk=    0.7430387     Fd=    0.1238398
              4   87.41990        450.0000
  tk=    0.7978973     Fd=    0.1329829
  cont?
 c
  input trad,footp,tnt,tvun,tle,rde,dde,smla,nspp,rely:
 280.,200.,6.,1.,75.,33.1,19.9,2.9,88,0.9
  trad,#tar,tar vun,footp,tle,rde,dde,smla,nspp,rely
   150.0000        6.000000        1.000000        200.0000        75.00000
   33.10000        19.90000        2.900000              88   0.9000000
  input vel [m/min],  trad x [m/min]
 250.,0.0000001
  input initial lethal area,subseq lethal area:
 2.9,2.9
   # of min.s :
 3
  input ROF,  # of sph :
 4.,4
              1   264.8438        150.0000
  tk=    8.5845947E-02 Fd=    1.4307658E-02
              2   507.5847        150.0000
  tk=    8.6593151E-02 Fd=    1.4432192E-02
              3   755.0776        150.0000
  tk=    8.6593151E-02 Fd=    1.4432192E-02
  cont?
 y
  input ROF,  # of sph :
 4.,8
              1   264.8438        150.0000
  tk=    0.1685762     Fd=    2.8096041E-02
              2   507.5847        150.0000
  tk=    0.1688662     Fd=    2.8144360E-02
              3   755.0776        150.0000
  tk=    0.1688662     Fd=    2.8144360E-02
  cont?
 y
  input ROF,  # of sph :
 8.,4
              1   264.8438        150.0000
  tk=    0.1844430     Fd=    3.0740499E-02
              2   507.5847        150.0000
  tk=    0.1874461     Fd=    3.1241020E-02
              3   755.0776        150.0000
  tk=    0.1874461     Fd=    3.1241020E-02
  cont?
 y
  input ROF,  # of sph :
 8.,8
              1   264.8438        150.0000
  tk=    0.3558764     Fd=    5.9312742E-02
              2   507.5847        150.0000
  tk=    0.3593588     Fd=    5.9893131E-02
              3   755.0776        150.0000
  tk=    0.3593588     Fd=    5.9893131E-02
  cont?
 y
  input ROF,  # of sph :
 12.,4
              1   264.8438        150.0000
  tk=    0.2793579     Fd=    4.6559650E-02
              2   507.5847        150.0000
  tk=    0.2840304     Fd=    4.7338407E-02
```

```
            3   755.0776        150.0000

 tk=    0.2840304      Fd=    4.7338407E-02
 cont?
y
 input ROF,  # of sph :
12.,8
            1   264.8438        150.0000
 tk=    0.5297432      Fd=    8.8290535E-02
            2   507.5847        150.0000
 tk=    0.5330710      Fd=    8.8845171E-02
            3   755.0776        150.0000
 tk=    0.5330710      Fd=    8.8845171E-02
 cont?
n
FORTRAN STOP
$
```

APPENDIX C

C^3 ANALYSIS AND WAR GAME

BASIC DATA

RED ENGAGEMENT INSTRUCTIONS

- TANK AND BMP GROUPS DRIVE FORWARD UNTIL DESTROYED

DISTANCE FROM FLOT	SPEED	DEPLOYED AS
0-10 KM	15 KPH	PLATOON
10-100 KM	30 KPH	COMPANY

- TANKS AND BMP'S:

— DIRECT FIRE ENGAGEMENT	2000 M TO 50 M
— CALL FOR ARTILLERY	5000 M TO 1000 M
— ARTILLERY RESPONSE MUST BE WITHIN	4-8 MINUTES OR REQUEST CANCELED

- RED ARTY DOES NOT SHOOT AND SCOOT BUT DOES MOVE ON INCOMING TO AN ALTERNATE POSITION

DISPLACEMENT TIME = 1.0 MINUTE
EMPLACEMENT TIME = 2.0 MINUTES
MOVEMENT TIME = 2.0 MINUTES
} TOTAL MOVEMENT TIME = 5 MINUTES

- RED ARTY MOVES TO KEEP TUBES ABOUT 1/3 OF THEIR RANGE FROM THE FLOT WITH NO MORE THAN 1/3 OF THE TOTAL FORCE MOVING AT ONCE

- RED OBJECTIVE: PENETRATE AREA HELD BY BLUE BRIGADE AND DESTROY ALL ENEMY FORCES

RED ARTILLERY ALLOCATION

- **RED COUNTERFIRE PRIORITY**

WEAPON SYSTEM	MUNITION
220 MRL	1 RND = 600 M42 ICM
122 MRL	HE (M107)
152 SPH	1 RND = ICM 50 M42 SUBMUNITIONS
180 MRL	HE (M107)
203 SPH	HE (M107)
122 SPH	HE (M107)
MANEUVER 122 SPH 152 SPH	HE 50 M42 SUBMUNITIONS

- **RESPONSE TIMES**

F.O.	1-4 MINUTES
COUNTER BATTERY RADAR	5-20 MINUTES

RED TARGET LOCATION SYSTEM DATA

- COUNTER BATTERY RADAR SPECIFICATIONS = ANTPQ-36 -37
- NO RED JSTAR CAPABILITY

BLUE ENGAGEMENT INSTRUCTIONS

- TANKS AND IFV'S INITIALLY HULL DOWN, DEFENSIVE POSTURE
- TOW'S DEPLOYED FROM COVERED POSITIONS
- DIRECT FIRE ENGAGEMENT 3000 M TO 50 M
- CALL FOR ARTILLERY 5000 M TO 1000 M
- WITHDRAW TO SECONDARY DEFENSIVE LINE WHEN ENEMY UNITS GET WITHIN 1000 M
- MOVEMENT FACTORS

	MOVEMENT RULES	TIME OUT FOR MOVE OF 300 M
— HELP HOWITZER	MOVE ON INCOMING	3 MIN 15 SEC
— MAXI-PIP HOWITZER	SHOOT AND SCOOT	2 MIN 15 SEC
— NEW DSWS	SHOOT AND SCOOT	1 MIN 30 SEC

- SHOOT AND SCOOT MEANS MOVE 300 M AFTER 3 MISSIONS OR ON INCOMING
- FAASV OR ARV FACTORS:
  - RELOAD HOWITZER WHEN HOWITZER ON BOARD AMMO EQUALS 25% OF CAPACITY
  - RETURN TO BATTERY SUPPORT AREA WHEN ARV ON BOARD STORAGE DROPS TO 25% OF CAPACITY
  - MOVE AT 30 KPH, TURN AROUND TIME AT BSA = 10 MINUTES
- HOWITZERS DISPLACE 5 KM IF ENEMY FORCES GET WITHIN 3 KM, TIME FOR THIS MOVE = 21 MINUTES
- BATTERY SUPPORT AREA DISPLACES 5 KM IF THE HOWITZERS GET WITHIN 3 KM, TIME FOR THIS MOVE = 30 MINUTES
- HOWITZERS EMPLACED ≈ 7 KM DEEP
- BLUE OBJECTIVE
  - DELAYING ACTION
  - GIVE GROUND SLOWLY
  - PRESERVE FRIENDLY FORCES
  - MAKE RED TAKE AS MANY CASUALTIES AS POSSIBLE
  - AVOID DECISIVE ENGAGEMENT

BLUE ARTILLERY ALLOCATION

BLUE COUNTERFIRE PRIORITY	
WEAPON SYSTEM	**MUNITION**
MLRS	688 M42 (DPICM)/ROCKET
SPH 8" SADARM	3 SADARM PER PROJECTILE
SPH 155 D.S.	88 M42 (DPICM) PER PROJECTILE
MANEUVER TARGETS PRIORITY	
SPH 155 D.S. DIV ARTY	88 M42 (DPICM) PER PROJECTILE

BLUE TARGET LOCATION SYSTEM DATA

ANTPQ-36-37 ASSUMPTIONS

RANGE = 25 KM BEYOND FLOT

CAPACITY = 20 TARGET CLUSTERS/MIN.

PROBABILITY OF DETECTION OF A SINGLE TUBE = 0.80

JSTAR ASSUMPTIONS

RANGE = 30 KM BEYOND FLOT

CAPACITY = 150 TARGET CLUSTERS/HOUR

PROBABILITY OF DETECTION OF A SINGLE MOVING TARGET = 0.75

CAPABLE OF RESOLVING WHEELED AND TRACKED VEHICLES

RPV ASSUMPTIONS

4 PER DIVISION

SPEED: 180 KM/HR

RANGE: 30 KM

ALTITUDE: 1000-1500 M

CAPACITY: 32 TGTS/SORTIE
21 TGTS/HR

MOTION OF C^3 ASSETS

DIV 86

- SPH PLT SCOOTS ON INCOMING
- PLT FDC/BOC MOVES WITH PLT OR ON INCOMING
- BN FDC MOVES ON CRITERIA
- FA DIV ARTY MOVES ON CRITERION 2)

DSWS O&O

- SPH SCOOT AFTER 3 MISSIONS OR ON INCOMING
- PLT HQ MOVE WHEN PLT HAS MOVED OR ON INCOMING
- BOC MOVES ON CRITERIA
- BN TOC MOVES ON CRITERIA
- FA DIV ARTY MOVES ON CRITERION 2)

MOVEMENT CRITERIA

1) INCOMING HOSTILE FIRE

2) IF SUPPORTED UNITS MOVE

3) RELOCATE EVERY 4 HOURS

COMMENTS

— SOME ONE ELEMENT WILL BACKUP THE MOVING ONE ON PREPLANNED MOVES

APPENDIX D

LITERATURE ASSESSMENT RESULTS

D.1 HIGH INTEREST ITEMS

AD NUMBER: C005371L
FIELDS AND GROUPS: 15/7, 19/1, 19/3, 19/6
13/6
UNCLASSIFIED TITLE: WEAPONS EFFECTIVENESS INDICES/WEIGHTED UNIT VALUES II (WEI/WUV II).
DESCRIPTORS: (*TACTICAL WEAPONS, WEAPON SYSTEM EFFECTIVENESS), TACTICAL WARFARE, WEAPON MIXES, TACTICAL ANALYSES, INDEXES(RATIOS), VALUE, WAR GAMES, ARMY OPERATIONS, RATINGS, ASSESSMENT, METHODOLOGY FORCE LEVEL, FORMULAS(MATHEMATICS)
ABSTRACT: AN IMPROVED WEI/WUV METHODOLOGY WAS DEVELOPED BASED ON FACTOR ANALYSIS OF WEAPON ENGINEERING CHARACTERISTICS. THREE TO SEVEN UNDERLYING PERFORMANCE FACTORS WERE IDENTIFIED FOR EACH WEAPON CATEGORY. WAR GAME/SIMULATION OUTPUTS IN THE FORM OF KILL PRODUCTIVITY OF WEAPONS WERE REGRESSED AGAINST FACTOR SCORES FOR PREDICTION OF FUTURE WEAPON PERFORMANCE. THE WEI/WUV SCORES FOR NATO/WARSAW PACT FORCES WERE COMPUTED. (AUTHOR)

AD NUMBER: 527433L

FIELDS AND GROUPS: 19/1, 19/4
UNCLASSIFIED TITLE: WEAPON EFFECTIVENESS MANUAL. VOLUME I. BASIC MEASURES OF EFFECTIVENESS.
DESCRIPTORS: (*TACTICAL WEAPONS, EFFECTIVENESS), AIRCRAFT AMMUNITION, EXTERNAL STORES, ARTILLERY, MORTARS, ROCKETS, AIR TO SURFACE MISSILES, SURFACE TO SURFACE MISSILES, ANTITANK AMMUNITION, RECOILLESS GUNS, HOWITZERS, HELICOPTERS, PASSENGER VEHICLES, TANKS(COMBAT VEHICLES), ARMOR PIERCING AMMUNITION, SABOT PROJECTILES, HIGH EXPLOSIVE AMMUNITION, CLOSE SUPPORT, MANEUVERS, ARMORED VEHICLES

AD NUMBER: 527434L
FIELDS AND GROUPS: 19/1, 19/4
UNCLASSIFIED TITLE: WEAPON EFFECTIVENESS MANUAL. VOLUME II. FACTORS AFFECTING WEAPON SYSTEMS PERFORMANCE.
DESCRIPTORS: (*TACTICAL WEAPONS, EFFECTIVENESS), WARHEADS, CLOSE SUPPORT, MANEUVERS, HOWITZERS, ARTILLERY, MORTARS, ROCKETS, RECOILLESS GUNS, ANTITANK AMMUNITION, ARMOR PIERCING AMMUNITION, HIGH EXPLOSIVE AMMUNITION, SURFACE TO SURFACE MISSILES, AIR TO SURFACE MISSILES, HELICOPTERS, AIRCRAFT AMMUNITION

AD NUMBER: A086388
FIELDS AND GROUPS: 15/3, 15/7
UNCLASSIFIED TITLE: ENGINEERING DESIGN HANDBOOK. ARMY WEAPON SYSTEMS ANALYSIS. PART 2.
DESCRIPTORS: *WEAPON SYSTEM EFFECTIVENESS, *WEAPON SYSTEMS, *SYSTEMS ANALYSIS, ALLOCATIONS, COST ANALYSIS, VULNERABILITY, ARMY EQUIPMENT, INFANTRY, TANKS(COMBAT VEHICLES), ARTILLERY, AIR DEFENSE, TARGET DETECTION, LANCHESTER EQUATIONS, HUMAN FACTORS ENGINEERING, COST EFFECTIVENESS, ARMY PROCUREMENT, SYSTEMS ENGINEERING, HANDBOOKS
IDENTIFIERS: MEASURES OF EFFECTIVENESS
ABSTRACT: ALTHOUGH PART TWO COVERS SOME OF THE MORE ADVANCED TOPICS OF THE FIELD OF ARMY WEAPON SYSTEMS ANALYSIS, IT STARTS WITH THE DEFINITION OF AND CONCEPTS RELATING TO MEASURES OF EFFECTIVENESS (MOE), AND DESCRIBES IN SOME DETAIL MANY MOE'S. THE AIM IS TO POINT OUT THAT MOE'S ARE NOT UNIVERSAL BUT MAY DEPEND ON PARTICULAR EVALUATIONS, AND THE ARMY ANALYST IS INTRODUCED TO THE RELATION BETWEEN THE PROBLEM OF MODELING PROCESSES AND MOE'S. AFTER AN INTRODUCTION TO TARGET DETECTION PHENOMENA AND TO THE DEVELOPMENT OF TARGET DETECTION PROBABILITIES, THE IMPORTANT TOPICS OF LANCHESTER TYPE COMBAT THEORY FOR HOMOGENEOUS AND HETEROGENEOUS FORCES ARE GIVEN IN MUCH DEPTH SINCE THESE TOPICS LEAD UP TO WEAPON EQUIVALENCE CONCEPTS AND STUDIES. FOR THE PRESENT-DAY ANALYST, THE FIELDS OF OPTIMAL FIRING POLICIES, WEAPON-TARGET ALLOCATION PROBLEMS, HUMAN FACTORS, AND COST ANALYSIS ESTIMATION MUST BE RATHER THOROUGHLY COVERED -- AT LEAST TO THE EXTENT HEREIN. MOREOVER, IT WAS FELT IMPORTANT TO INCLUDE ALSO AN INTRODUCTION TO COST-EFFECTIVENESS, EVALUATIONS THE CONCEPTS OF SURVIVABILITY, AND AN ONTRODUCTION TO COUNTERMEASURES AND THEIR ANALYTICAL TREATMENT.

THIS HANDBOOK DESCRIBES SOME OF THE PRIME TOPICS IN THE HISTORY OF WAR GAMES AND COMBAT SIMULATIONS, INCLUDING DEVELOPMENTS AND USES, AND BRIEF DESCRIPTIONS OF SOME OF THE KEY WAR GAMES OR COMPUTER SIMULATIONS OF COMBAT. THE LAST CHAPTERS OF PART TWO COVER EVALUATION TECHNIQUES FOR INFANTRY WEAPONS, TANK WEAPON SYSTEMS, ARTILLERY FAMILIES, AIR DEFENSE (MODERN GUN EFFECTIVENESS MODEL), AND THE PRINCIPLES AND AN ILLUSTRATION OF COST AND OPERATIONAL EFFECTIVENESS ANALYSES.

AD NUMBER: B010156L

FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: CANNON LAUNCHED GUIDED PROJECTILE COST AND OPERATIONAL EFFECTIVENESS ANALYSIS (CLGP COEA). VOLUME IV. APPENDICES J - K. METHODOLOGY AND MODELS.
DESCRIPTORS: (*GUIDED PROJECTILES, ARTILLERY), (*ARTILLERY AMMUNITION, *WEAPON SYSTEM EFFECTIVENESS), TRADE OFF ANALYSES, COST EFFECTIVENESS, WAR GAMES, METHODOLOGY, COMPUTERIZED SIMULATION, ARMY PLANNING, TACTICAL ANALYSES, FIELD ARMY, MOVING TARGETS, THREATS, HARDENED STRUCTURES, VISIBILITY, MATHEMATICAL MODELS, EXPERIMENTAL DESIGN, COMPUTER PROGRAMS, FORCE LEVEL, COSTS, KILL PROBABILITIES, COMPARISON
IDENTIFIERS: *CANNON LAUNCHED GUIDED PROJECTILES, CLGP(CANNON LAUNCHED GUIDED PROJECTILES), DYNTACS X COMPUTER PROGRAM, 155-MM PROJECTILES, MEASURES OF EFFECTIVENESS, SCENARIOS, FORWARD OBSERVERS

AD NUMBER: A032383
FIELDS AND GROUPS: 15/7, 19/6
UNCLASSIFIED TITLE: CONGESTION PROBLEMS IN FIELD ARTILLERY OPERATIONS.
DESCRIPTORS: *ARMY OPERATIONS, *ARTILLERY, WEAPON MIXES, FIRE SUPPORT, COMBAT EFFECTIVENESS, FIREPOWER, BATTLEFIELDS, PROBLEM AREAS, MATHEMATICAL MODELS, QUEUEING THEORY, DECISION MAKING, THESES
IDENTIFIERS: MEASURES OF EFFECTIVENESS
ABSTRACT: AS A RESULT OF THE 1973 MIDEAST WAR, THE CURRENT EMPHASIS ON PROPERLY PORTRAYING COMBAT INTERACTIONS AND ANALYZING THE APPROPRIATE MEASURES OF EFFECTIVENESS HAS BECOME INCREASINGLY IMPORTANT, ESPECIALLY IN REGARD TO FIRE SUPPORT OPERATIONS. THIS

THESIS WILL EXAMINE SOME OF THE REASONS FOR THE INCREASED EMPHASIS ON FIRE SUPPORT PROBLEMS AND HOW THIS PARTICULAR BATTLEFIELD ACTIVITY IS CURRENTLY MODELED BY THE MILITARY ANALYSIS COMMUNITY. FOLLOWING THIS, A SIMPLIFIED ANALYTICAL PROCEDURE (TAKEN FROM GENERAL QUEUEING THEORY) FOR MEASURING THE AMOUNT OF RANDOMNESS ACTUALLY PLAYED BY STOCHASTIC MODELS, SUCH AS DYNTACS AND OTHERS, WILL BE PRESENTED, ALONG WITH THE IMPLICATIONS THIS POSES FOR CURRENT MILITARY PLANNERS AND DECISION MAKERS. IN ADDITION TO THESE BASIC CONCLUSIONS, A VALIDATION PROCEDURE FOR SELECTED DISTRIBUTIONS OF PARTICULAR INTEREST TO FIRE SUPPORT MODELERS IS PRESENTED, THAT CAN BE IMPLEMENTED UNDER CURRENT OPERATIONAL PROCEDURES AT NO ADDITIONAL COST TO THE UNITED STATES GOVERNMENT. (AUTHOR)

AD NUMBER: 743720
FIELDS AND GROUPS: 19/5, 15/7
UNCLASSIFIED TITLE: A COMPARISON OF TWO TARGET COVERAGE MODELS.
DESCRIPTORS: (*ARTILLERY FIRE, MATHEMATICAL MODELS), (*ARTILLERY, *KILL PROBABILITIES), TERMINAL BALLISTICS, DAMAGE ASSESSMENT, PROBABILITY DENSITY FUNCTIONS, FRAGMENTATION AMMUNITION, AREA COVERAGE, COMPUTER PROGRAMS, THESES
IDENTIFIERS: LETHALITY, SALVO FIRE
ABSTRACT: THE REPORT EXAMINES SEVERAL MODELS FOR THE COMPUTATION OF TARGET COVERAGE WHEN MULTIPLE ROUNDS ARE FIRED AT A TARGET. FRACTIONAL KILL OF A FRAGMENT SENSITIVE TARGET BY A FRAGMENTING PROJECTILE AS A FUNCTION OF THE NUMBER OF ROUNDS FIRED IS COMPARED FOR TWO MODELS. THE FIRST IS A STANDARD SALVO-FIRE MODEL IN WHICH N ROUNDS ARE FIRED AT THE SAME AIM POINT. IN THE SECOND MODEL, SINGLE SHOT KILL PROBABILITY IS COMPUTED FOR A FRAGMENT SENSITIVE TARGET AND THEN FRACTIONAL KILL FROM THE FIRING OF N ROUNDS IS COMPUTED ACCORDING TO THE ASSUMPTION THAT THE EFFECTS OF EACH ROUND ARE INDEPENDENT. THE NEED FOR SOPHISTICATED TARGET COVERAGE MODELS (SUCH AS SALVO-FIRE MODELS) IS DEMONSTRATED BY THE RESULTS OF COMPUTATIONS PERFORMED IN THIS STUDY. (AUTHOR)

AD NUMBER: C013326L
FIELDS AND GROUPS: 19/1, 14/1
UNCLASSIFIED TITLE: ARTILLERY-DELIVERED ARMOR-DEFEATING MECHANISMS.
DESCRIPTORS: *ARTILLERY, *ARTILLERY AMMUNITION, *ANTIARMOR AMMUNITION, *ARMY PLANNING, WEAPON SYSTEM EFFECTIVENESS, COST EFFECTIVENESS, TRADE OFF ANALYSES, WEAPON DELIVERY, ACCURACY, LETHALITY, KILL MECHANISMS, TERMINAL GUIDANCE, OPTIMIZATION

ABSTRACT: THIS REPORT DOCUMENTS A SYSTEMS FEASIBILITY STUDY CONDUCTED TO SYNTHESIZE AND DEFINE CONCEPTS CAPABLE OF OBTAINING SIGNIFICANT LEVELS OF IMPROVEMENTS OVER EXISTING ICM ARTILLERY PROJECTILES AGAINST ARMORED TARGETS. THE STUDY EFFORT GENERATED SYSTEM CONCEPT DEFINITIONS, SUPPORTED BY PERFORMANCE, EFFECTIVENESS, AND COST PREDICATIONS; IDENTIFIED PROBLEMS AS A RESULT OF TRADEOFF ANALYSES; AND FORMULATED RECOMMENDATIONS FOR CONTINUED SYSTEMS INVESTIGATIONS. THE STUDY RESULTS CONCLUDE THAT THE SYSTEM APPROACH AND CONCEPTS INVESTIGATED ARE FEASIBLE, COST EFFECTIVE, AND PROVIDE A SIGNIFICANT LEVEL OF IMPROVEMENT OVER EXISTING ICM ARTILLERY PROJECTILES AGAINST THE ARMORED TARGET THREAT. (AUTHOR)

AD NUMBER: C009604

FIELDS AND GROUPS: 17/9, 19/6
UNCLASSIFIED TITLE: COST AND OPERATIONAL EFFECTIVENESS ANALYSI" FOR HOSTILE WEAPONS LOCATION SYSTEM (HWLS).
DESCRIPTORS: *MORTAR LOCATING RADAR, *ORDNANCE LOCATORS, ARTILLERY, COST EFFECTIVENESS, OPERATIONAL EFFECTIVENESS, MARINE CORPS PLANNING, LIFE CYCLE COSTS, ACCURACY, TARGET DETECTION, ARTILLERY FI [illegible], POSITION FINDING, POSITION(LOCATION)
ABSTRACT: AN ANALYSIS IS MADE OF THE COST AND OPERATIONAL EFFECTIVENESS OF THE HOSTILE WEAPONS LOCATION SYSTEM (HWLS) AND ALTERNATIVE WEAPONS-LOCATING RADARS, INCLUDING A MODIFIED VERSION OF THE ARMY'S AN/TPQ-36. THE MEASURES USED TO COMPARE THE SYSTEMS INCLUDE RADAR ACCURACY AND ITS EFFECT ON ENEMY CASUALTIES AND FRIENDLY AMMUNITION EXPENDITURES WHEN THE ENEMY WEAPON SITES ARE ATTACKED BY ARTILLERY, THE TIME REQUIRED BY THE RADARS TO LOCATE A GIVEN NUMBER OF WEAPON SITES, THE TIME REQUIRED BY MARINE CORP ARTILLERY UNITS TO ATTACK THOSE SITES, AND INCREMENTAL 10-YEAR LIF CYCLE COSTS (RELATIVE TO THE COSTS OF THE EXISTING WEAPONS-LOCATIN RADARS). (AUTHOR)

AD NUMBER: C001604L
FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: FAMILY OF SCATTERABLE MINES STUDY, PHASE IV (FASCAM). DIVWAG ANALYSIS OF FASCAM. EXECUTIVE SUMMARY.
DESCRIPTORS: (*LAND MINES, SCATTERING), (*LAND MINE WARFARE, WAR GAMES), COMMAND AND CONTROL SYSTEMS, DOCTRINE, LOGISTICS SUPPORT, WEAPON DELIVERY, COMPUTERIZED SIMULATION, MILITARY TACTICS, TANKS(COMBAT VEHICLES), INFANTRY, DEFENSE SYSTEMS, MINEFIELDS, TRADE OFF ANALYSES, KILL PROBABILITIES, CASUALTIES, SYSTEMS

ANALYSIS, THREAT EVALUATION, DELIVERY

AD NUMBER: 531151L

FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: FAMILY OF SCATTERABLE MINES STUDY, PHASE III (FASCAM). EXECUTIVE SUMMARY.
DESCRIPTORS: (*LAND MINES, SCATTERING), (*LAND MINE WARFARE, TARGET ACTIVATED MUNITIONS), TACTICAL ANALYSES, WEAPON DELIVERY, ANTITANK WEAPONS, PLANNING, SYSTEMS ANALYSIS, MATHEMATICAL MODELS, RESOLUTION, WEAPON MIXES, WAR GAMES, MIDDLE EAST, LIMITED WAR, TRADE OFF ANALYSES, DOCTRINE, COST EFFECTIVENESS, MINEFIELDS, MISSION PROFILES, BARRIERS, KILL PROBABILITIES

AD NUMBER: C001602L
FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: FAMILY OF SCATTERABLE MINES STUDY, PHASE IV (FASCAM). DIVWAG ANALYSIS OF FASCAM. VOLUME I. MAIN REPORT AND APPENDICES A THROUGH G.
DESCRIPTORS: (*LAND MINES, SCATTERING), (*LAND MINE WARFARE, WAR GAMES), COMMAND AND CONTROL SYSTEMS, DOCTRINE, LOGISTICS

SUPPORT, WEAPON DELIVERY, COMPUTERIZED SIMULATION, MILITARY TACTICS, TANKS(COMBAT VEHICLES), INFANTRY, DEFENSE SYSTEMS, MINEFIELDS, TRADE OFF ANALYSES, KILL PROBABILITIES, CASUALTIES, SYSTEMS ANALYSIS, THREAT EVALUATION, DELIVERY

AD NUMBER: A006905
FIELDS AND GROUPS: 15/7, 9/2
UNCLASSIFIED TITLE: ARTILLERY CASUALTY ASSESSMENT MODEL.
DESCRIPTORS: *ARTILLERY, *CASUALTIES, *COMPUTERIZED SIMULATION, ACCURACY, LETHALITY, KILL PROBABILITIES, WAR GAMES, MATHEMATICAL

MODELS, PUNCHED CARDS, COMPUTER PROGRAMS, FORTRAN, WAR GAMES
IDENTIFIERS: *AMMUNITION EXPENDITURES, *ARTILLERY CASUALTY ASSESSMENT MODELS, *NONNUCLEAR WEAPONS
ABSTRACT: THE ARTILLERY CASUALTY ASSESSMENT MODEL (CAM) IS A COMPUTER SIMULATION MODEL USED IN THE NONNUCLEAR AMMUNITION COMBAT RATES STUDIES. THE MODEL USES BASIC WEAPON MUNITION ACCURACY AND LETHALITY DATA TO ESTIMATE THE EFFECTS OF INDIRECT FIRE EXPENDITURES. THIS DOCUMENTATION HAS BEEN PRODUCED AS PART OF THE NONNUCLEAR AMMUNITION COMBAT RATES METHODOLOGY IMPROVEMENT STUDY-PART II. THE DOCUMENTATION CONTAINS A METHODOLOGY DESCRIPTION, A PROGRAM LISTING, AND SAMPLE INPUTS AND OUTPUTS.

D.2 MEDIUM INTEREST ITEMS

AD NUMBER: B010579L
FIELDS AND GROUPS: 15/7, 19/4, 19/5
UNCLASSIFIED TITLE: USACDEC SUPPRESSION EXPERIMENTATION DATA ANALYSIS REPORT.
DESCRIPTORS: (*TACTICAL ANALYSES, REACTION(PSYCHOLOGY)), (*MISSION PROFILES, INFANTRY), (*FIRE SUPPRESSION, COMPUTERIZED SIMULATION), (*FIREPOWER, DECISION MAKING), (*STRATEGIC ANALYSES, COMBAT EFFECTIVENESS), STRESS(PHYSIOLOGY), PERFORMANCE(HUMAN), RANGE(DISTANCE), MISS DISTANCE, ARTILLERY, MORTARS, DATA ACQUISITION, WEAPONS, POSITION(LOCATION), COMBAT READINESS, ARTILLERY ROCKETS, LEADERSHIP, WAR GAMES, EXPERIMENTAL DATA, HIGH EXPLOSIVES, INDIRECT FIRE
IDENTIFIERS: MILITARY POSTURE, DIRECT FIRE, MEASURES OF EFFECTIVENESS

AD NUMBER: 855311L
FIELDS AND GROUPS: 19/1, 11/6
UNCLASSIFIED TITLE: RECENT ADVANCES IN HIGH FRAGMENTING STEELS.
DESCRIPTORS: (*FRAGMENTATION AMMUNITION, MATERIALS), (*STEEL, REVIEWS), MORTAR AMMUNITION, CLASSIFICATION, ARMY RESEARCH, ARTILLERY, ANTIPERSONNEL AMMUNITION, IRON ALLOYS, METALLURGY, COSTS, KILL PROBABILITIES, CHEMICAL ANALYSIS
IDENTIFIERS: LETHALITY

AD NUMBER: 531152L
FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: FAMILY OF SCATTERABLE MINES STUDY, PHASE III (FASCAM). VOLUME I. MAIN REPORT AND APPENDICES A THRU G.
DESCRIPTORS: (*LAND MINES, SCATTERING), (*LAND MINE WARFARE, TARGET ACTIVATED MUNITIONS), TACTICAL ANALYSES, WEAPON DELIVERY, ANTITANK WEAPONS, PLANNING, SYSTEMS ANALYSIS, INTEGRATED SYSTEMS, MATHEMATICAL MODELS, SENSITIVITY, WEAPON MIXES, DOCTRINE, WAR GAMES, MIDDLE EAST, LIMITED WAR, MINEFIELDS, ARMY OPERATIONS, MISSION PROFILES, BARRIERS, COST EFFECTIVENESS, KILL PROBABILITIES

AD NUMBER: C001603L
FIELDS AND GROUPS: 19/1, 15/7
UNCLASSIFIED TITLE: FAMILY OF SCATTERABLE MINES STUDY, PHASE IV (FASCAM). DIVWAG ANALYSIS OF FASCAM. VOLUME II. APPENDICES H, I, J, K, L, M, AND N.
DESCRIPTORS: (*LAND MINES, SCATTERING), (*LAND MINE WARFARE, WAR GAMES), COMMAND AND CONTROL SYSTEMS, DOCTRINE, LOGISTICS SUPPORT, WEAPON DELIVERY, COMPUTERIZED SIMULATION, MILITARY TACTICS, TANKS(COMBAT VEHICLES), INFANTRY, DEFENSE SYSTEMS, MINEFIELDS, TRADE OFF ANALYSES, KILL PROBABILITIES, CASUALTIES, SYSTEMS ANALYSIS, THREAT EVALUATION, DELIVERY

AD NUMBER: C013315L
FIELDS AND GROUPS: 19/4, 19/6
UNCLASSIFIED TITLE: VULNERABILITY REDUCTION OF THE TACFIRE'S S-280 SHELTERS TO CONVENTIONAL WEAPONS USING LIGHTWEIGHT ARMORS.
DESCRIPTORS: *FIRE CONTROL SYSTEMS, *ARTILLERY, *SHELTERS, VULNERABILITY ANALYSIS, ELECTRONIC EQUIPMENT, ARMOR, COMPOSITE MATERIALS, GLASS REINFORCED PLASTICS, LAMINATED PLASTICS, LIGHTWEIGHT, CONVENTIONAL WARFARE, COMPUTERIZED SIMULATION, HARDENING
ABSTRACT: THIS REPORT DOCUMENTS THE RESULTS OF THE EFFORT BY THE ECOM VULNERABILITY ANALYSIS TEAM (VAT) TO DETERMINE THE VULNERABILITY REDUCTION OF THE TACFIRE'S S-280 SHELTERS TO CONVENTIONAL WEAPONS USING LIGHTWEIGHT ARMORS. THE WEAPONS CONSIDERED IN THE STUDY WERE THE SOVIET 122MM HE ROUND, THE SOVIET 152MM HE ROUND, AND THE US NAVY 250 LB. MK-81 BOMB. THE ARMORS CHOSEN FOR THE STUDY WERE LAMINATED KEVLAR AND GLASS-REINFORCED PLASTIC (GRP). LETHAL AREAS OF THE SHELTERS WITHOUT ARMOR AND WITH DIFFERENT ARMOR MATERIALS WERE USED AS A MEASURE OF THE ARMOR MATERIALS RELATIVE EFFECTIVENESS. (AUTHOR)

AD NUMBER: E750185
FIELDS AND GROUPS: 19/1
UNCLASSIFIED TITLE: BOEING RAPID AMMUNITION SUPPLY STUDY.
DESCRIPTORS: *AMMUNITION, *ORDNANCE, *ARTILLERY AMMUNITION, LAUNCHERS, MILITARY SUPPLIES, BATTALION LEVEL ORGANIZATIONS, TRANSPORTATION, STORAGE, STOCKPILES, SIMULATION, ARTILLERY, EUROPE, UNITED STATES, CONVENTIONAL WARFARE, FIRING RATES, FIRING TESTS(ORDNANCE), WEAPON SYSTEMS, MILITARY OPERATIONS, ARTILLERY UNITS, MILITARY FORCES(UNITED STATES), SUPPLIES, LOGISTICS, MILITARY TRANSPORTATION, COMPUTERIZED SIMULATION
IDENTIFIERS: SB14, GSRS(GENERAL SUPPORT ROCKET SYSTEM)
ABSTRACT: THE BOEING RAPID AMMUNITION SUPPLY STUDY (BRASS) WAS CONDUCTED TO QUANTIFY THE SUPPORT RESOURCES REQUIRED TO SUPPLY AMMUNITION FOR A HIGHLY MOBILE HIGH-RATE-OF-FIRE NON-NUCLEAR WEAPON SYSTEM DURING A CONVENTIONAL CENTRAL EUROPEAN CONFLICT. A COMPUTER MODEL WAS DEVELOPED TO SIMULATE THE CONVENTIONAL AMMUNITION RESUPPLY NETWORK FROM CONUS SUPPLY SOURCE TO OPERATIONAL ARTILLERY UNITS IN THE EUROPEAN THEATER. THE MODEL WAS DEMAND DRIVEN BY FIRING RATES AND SIMULATED ONE CORPS WITH THREE BATTALIONS HAVING THREE FIRING BATTERIES EACH. THE MODEL OUTPUT PROVIDED AMMUNITION STOCKAGE AND DISTRIBUTION REQUIREMENTS, FLOW RATES AND TRANSPORTATION AND HANDLING RESOURCES REQUIRED TO SUPPORT THE SCENARIOS SIMULATED. THIS DOCUMENT PRESENTS FOR SEVERAL FIRING RATES THE QUANTITATIVE RESULTS OF THE STUDY. THE GENERAL SUPPORT ROCKET SYSTEM (GSRS) WAS THE WEAPON SYSTEM USED TO VALIDATE THE AMMUNITION RESUPPLY MODEL DEVELOPED.

D.3 LOW INTEREST ITEMS

AD NUMBER: C001199L
FIELDS AND GROUPS: 19/6, 19/1, 19/4
UNCLASSIFIED TITLE: A COMPENDIUM OF CLASSIFIED FIELD ARTILLERY FACTS. HISTORY OF WEAPON-RANGE STUDIES - RANGE-EXTENSION ALTERNATIVES - WEAPON SYSTEM FACTS - SOVIET ORGANIZATION AND EQUIPMENT.
DESCRIPTORS: (*ARTILLERY, *ARTILLERY FIRE), PROJECTILES, GUNNERY, ARTILLERY UNITS, ARTILLERY AMMUNITION, ARTILLERY ROCKETS, RANGE(DISTANCE), MILITARY FORCES(UNITED STATES), MILITARY FORCES(FOREIGN), USSR, HOWITZERS
ABSTRACT: THE PURPOSE OF THIS PUBLICATION IS TO PROVIDE A FIELD ARTILLERY AND EXTENDED-RANGE FIELD ARTILLERY REFERENCE AND FAMILIARIZATION GUIDE. IT IS PRESENTED IN FOUR SECTIONS: (I) HISTORY OF WEAPON-RANGE STUDIES, (II) RANGE-EXTENSION ALTERNATIVES, (III) WEAPON SYSTEM FACTS, AND (IV) SOVIET ORGANIZATION AND EQUIPMENT. IN SECTION I, MAJOR FIELD ARTILLERY EVALUATION STUDIES ARE LISTED IN HISTORICAL PERSPECTIVE BEGINNING IN 1957, AND THE PURPOSES AND CONCLUSIONS OF EACH ARE DESCRIBED BRIEFLY. THE REPRESENTATIVE STUDIES INCLUDE THE RESULTS OF USING LEGAL MIX III AND IV TO EVALUATE THE EXTENSION OF WEAPON RANGES. SECTION II CONTAINS A BRIEF DESCRIPTION OF THE ALTERNATIVE METHODS BY WHICH THE FIELD ARTILLERY CANNON RANGES MAY BE EXTENDED. INHERENT PROBLEMS WITH EXTENDED-RANGE SYSTEMS, SUCH AS DEGRADED DELIVERY ACCURACY AND WEAPON RELIABILITY, ARE DISCUSSED. VARIOUS PROJECTILE TYPES ARE INCLUDED IN THE DISCUSSION: ROCKET ASSISTED, IMPROVED SHAPES, FULL OGIVE, SPIN-STABILIZED SUBCALIBER, AND FIN STABILIZED.

AD NUMBER: B053300L
FIELDS AND GROUPS: 19/6, 9/2

UNCLASSIFIED TITLE: COMPUTER METHODOLOGY FOR LARGE CALIBER ARTILLERY CANNON HEATING AND COOLING.
DESCRIPTORS: *HEAT TRANSFER, *GUN BARRELS, *COOLING, *COMPUTERIZED SIMULATION, ARTILLERY, COMPUTER PROGRAMS, RIFLING, PROPELLING CHARGES, COOK OFF, LIFE EXPECTANCY, WEAR, TRANSFER, COEFFICIENTS, HOWITZERS, FIRING RATES, HEAT LOSS, HEAT FLUX, BOREHOLES, SURFACES, COMPUTER AIDED DESIGN, CASELESS AMMUNITION, COOLING, FORTRAN, TABLES(DATA)
IDENTIFIERS: *M-109 HOWITZERS, M-109A1 HOWITZERS, CYCOND COMPUTER PROGRAM, HTC COMPUTER PROGRAM, CASELESS AMMUNITION, 155-MM GUNS, M-185 GUNS, M-199 GUNS, XM-185 GUNS

AD NUMBER: C006043L
FIELDS AND GROUPS: 19/1, 19/5, 19/4, 19/7
19/2
UNCLASSIFIED TITLE: PROCEEDINGS OF THE SEMINAR ON THE ATTACK OF EARTH, STONE, AND CONCRETE BARRIERS BY HE PROJECTILES (15-16 MAR 1974). PART II. CLASSIFIED SECTION.
DESCRIPTORS: (*HIGH EXPLOSIVE AMMUNITION, PENETRATION), (*ARTILLERY FIRE, FORTIFICATIONS), BARRIERS, MASONRY, CONCRETE, ROCK, TERMINAL BALLISTICS, SOILS, ARTILLERY, SURFACE TARGETS, BALLISTIC TESTING, SEMINARS, PROJECTILES, GUIDED PROJECTILES, HIGH CAPACITY PROJECTILES

AD NUMBER: F050052L
FIELDS AND GROUPS: 17/4, 12/1
UNCLASSIFIED TITLE: LETHAL ATTACK RADIO FREQUENCY EMITTERS - EFFECTIVENESS ANALYSIS.
DESCRIPTORS: ARTILLERY, EMITTERS, RADIOFREQUENCY, LETHALITY, WARSAW PACT COUNTRIES, TARGET ACQUISITION, NATO, COMPUTERIZED SIMULATION
IDENTIFIERS: WINTEL, LPN-TRADOC-ACN-36859, ANTIRADIATION PROJECTILES, SPLM(SPECIAL PURPOSE LOITERING MISSILES), TAFSM(TARGET ACQUISITION ARTILLERY FORCE SIMULATION), VECTOR 2 MODEL

AD NUMBER: 532152L

FIELDS AND GROUPS: 19/3, 19/1
UNCLASSIFIED TITLE: DATA FROM THE OCTOBER 1973 MIDDLE EAST WAR. VOLUME VII. COMBAT VEHICLE ASSESSMENT REPORT.
DESCRIPTORS: (*TANKS(COMBAT VEHICLES), MIDDLE EAST), (*DAMAGE ASSESSMENT, *ARMORED PERSONNEL CARRIERS)

AD NUMBER: A086689
FIELDS AND GROUPS: 15/3
UNCLASSIFIED TITLE: METHODS FOR COMPARING COUNTERWEAPON SYSTEM DEVELOPMENTS IN TERMS OF CONTRIBUTIONS TO FORCE EFFECTIVENESS.
DESCRIPTORS: *WEAPON SYSTEMS, *COMPARISON, WEAPONS, ARTILLERY, OPERATIONAL EFFECTIVENESS, MATHEMATICAL ANALYSIS, MILITARY FORCES(FOREIGN), ATTRITION, LETHALITY, COUNTERMEASURES, MODIFICATION
IDENTIFIERS: FORCE EFFECTIVENESS, COUNTERWEAPONS
ABSTRACT: THIS IS THE FINAL REPORT OF VECTOR RESEARCH, INCORPORATED, (VRI) EFFORTS UNDER CONTRACT DAAK30-78-C-0022. UNDER THIS CONTRACT, BRI DESIGNED METHODS FOR THE COMPARATIVE ANALYSIS OF WEAPON SYSTEM DEVELOPMENTS WHICH COULD BE USED IN ANALYZING COUNTER WEAPON DESIGNS. THE METHODS WERE DEMONSTRATED WITH ANALYSES OF ARTILLERY-RELATED PROBLEMS. (AUTHOR)

C-4

END

FILMED

9-83

DTIC