AD-A251 392

BRL-TR-3356

TECHNICAL REPORT BRL-TR-3356

BRL

FAE BOMBING FOR MINEFIELD BREACHING

JOHN D. SULLIVAN
JERRY THOMAS
LINDA L. C. MOSS

JUNE 1992

U.S. ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

NOTICES

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
June 1992

3. REPORT TYPE AND DATES COVERED
Final, December 1990—February 1992

4. TITLE AND SUBTITLE
FAE Bombing for Minefield Breaching

5. FUNDING NUMBERS
PR: 1L162618AH80

6. AUTHOR(S)
John D. Sullivan, Jerry Thomas, Linda L. C. Moss

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
BRL-TR-3356

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Historically, bombing has not been used or extensively tested for minefield breaching. This report predicts that bombing results should be excellent even with small numbers of sorties.

Fuel-air explosives (FAE), which are notably effective against pressure-fuzed mines, were the notional ordnance. For a single FAE bomb probability of one-half of making a 30-meter breach, four Harrier jets with seven CBU72 bombs each can reduce a 210-meter path through a standard minefield from 1,000 mines/km to at most 330 mines/km with 99% probability. This decreased path density provides a tank 62% chance of crossing the minefield path without hitting a mine; whereas, without the FAE bombing, a tank trying to bull through is only 25% certain of crossing safely. Killing all mines in the path is possible (82% chance) with the four jet strike.

The analysis can be applied to other bombs and minefields.

14. SUBJECT TERMS
minefields, mine countermeasures

15. NUMBER OF PAGES
79

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
SAR

INTENTIONALLY LEFT BLANK.

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK.

LIST OF FIGURES

LIST OF TABLES

INTENTIONALLY LEFT BLANK.

ACKNOWLEDGMENT

The authors are grateful to Joseph C. Collins III and Joseph D. Anderson, both of this laboratory, for technical review, table checking, and overall comments on this report. Additionally, Mr. Collins independently derived the multiple sortie clearance probability function.

INTENTIONALLY LEFT BLANK.

1. INTRODUCTION

1.1 Purpose. This report draws out the idea rendered in Figure 1, that a minefield can be breached by bombing from husbanded sorties. A surer idea, that abounding bombing will breach a minefield, was proven by Leonard (1944), but such may never have been done in war. The Engineer Board (1945) used surface burst fuzing because bombs could not be reliably fuzed (then) for low air bursts, which would have given the largest clearance radius. Large, delay-fuzed bombs made impassable obstacles. The present variation has large radius, does not crater, and, as then, no new expensive project is needed to apply the idea—planes exist, ordnance exists. Pilot training and minefield marking are still needed.

Breaching is a combat operation of making a safe lane for armored vehicles to go through a minefield; clearing is an uncontested operation of removing or destroying all the mines in the field. With a key but unknown measure, the single success in a set distance, and with the method of this report any type of bomb, rocket, mortar, or shell could be analyzed for breaching usefulness.

This report provides the probability of breaching a minefield with drops of fuel-air explosive (FAE) bombs, when each bomb has some probability of killing all mines in a 30-meter stretch. Two minefield patterns are examined: a uniform pattern consisting of mines hidden throughout the field and a standard tactical pattern consisting of three separated strips of mines blocking the field. The probable success of one plane in bombing a path is found to be low, but a small number of sorties will raise the probability greatly. All mines in the path can be killed, even with husbanded sorties. Even partial success in killing mines will create a usable path. Overall, the report is conscious of operations planning and sortie use.

1.2 Background. Numerous static tests, one expeditious bombing test, and rocket tests of fuel-air explosive warheads show that FAE is effective against pressure-fuzed mines, the most common type of mine (Dennis 1973). Army intentions were to apply FAE. That it did not happen is due partly to cost of land systems FAE and to the appearance of blast-resistant

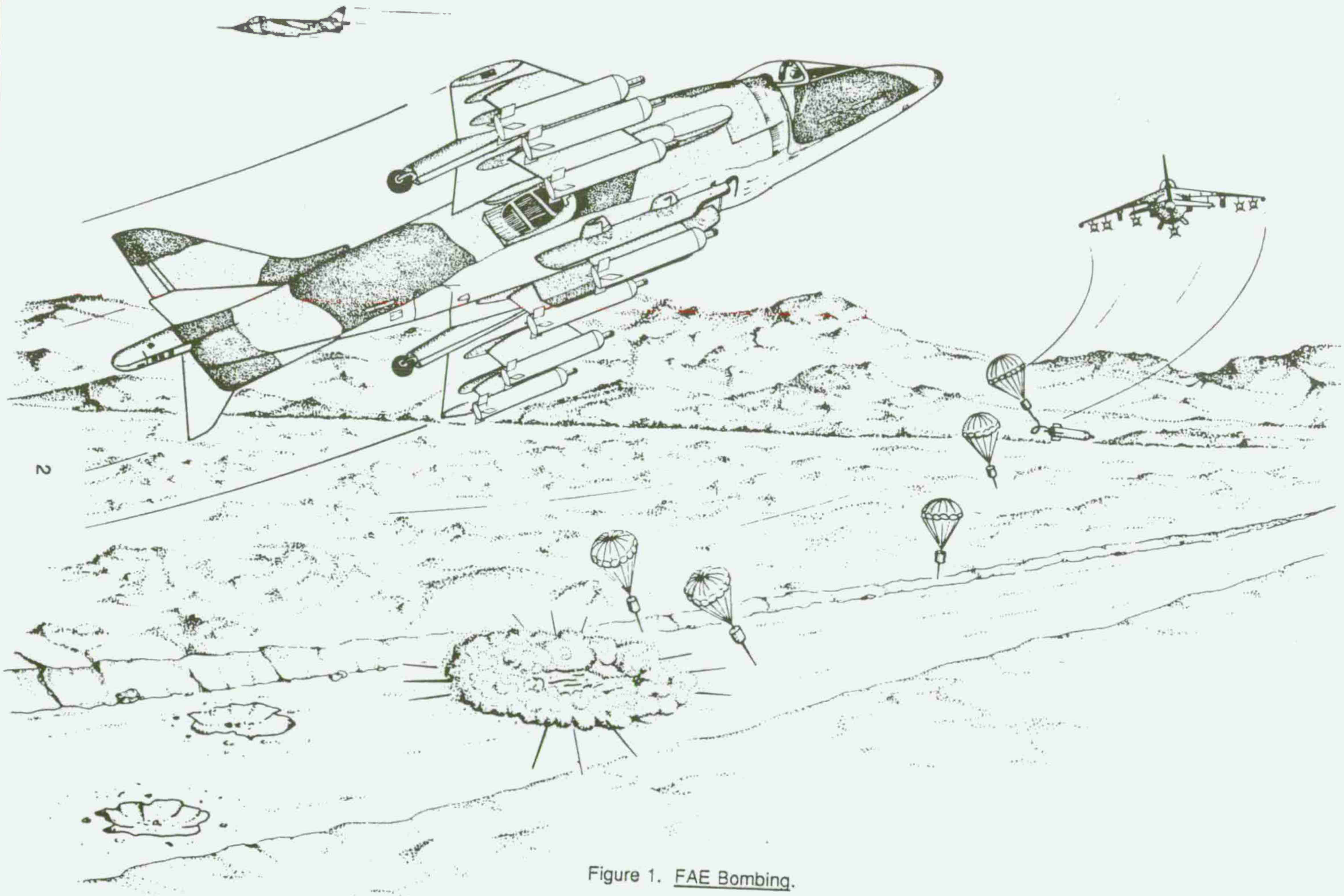


Figure 1. FAE Bombing.

mines. Large aerial bombs* were stopped in advanced development by the Navy because of unadaptable (flammable liquid storage) requirements on aircraft carriers and because FAE funding was transferred to unrelated overcost Navy projects.

The only type of FAE bomb that remains in inventory is a triple-warhead, cluster munition. Actually, multiple warheads, falling nearly in line, and not large unitary FAE bombs are ideal for path clearing. The path made by large bombs would be too wide and too short. The jet-rated Cluster Bomb Unit is the CBU72; its near twin is the CBU55, intended for low speed drops. The CBU72 is certified for use on the AV8B Harrier II, A6 Intruder, and F18 Hornet. The ballistic table of the CBU72 is installed in the planes' bombing computers, except in the Hornet's. For minefield breaching, a full bomb load would have to be ripple-dropped under computer control.

Although not optimized or designed for minefield breaching, the CBU55 was dropped on minefields from helicopters and its effectiveness rated primarily against a requirement that it be able to create a 30-m breach (Dennis, Comeyne, and Millman 1973). FAE kills all susceptible mines under the cloud, which is 13 m in diameter for a warhead in the CBU55 bomb, and there are three warheads in the bomb. So, the breach requirement was not a stiff one. The probability of success was variously rated so that

$$0.1 \text{ [TECOM Evaluator]} < p(30\text{-m}) < 0.8 \text{ [MERADCOM Tester]}.$$

This uselessly wide range on p(30-m) was caused by analysts' decisions on which bomb drops to include or exclude. Several warheads never landed in the minefield—primarily because of high altitude release, primitive sighting system, and inexperience in bombing from Army pilots. The authors feel that the true p is at the higher end of the range, but the present calculations use a spread of p, and each p has a consequent result on the number of sorties.

1.3 Tangible Problem. For tangible results, the estimated capabilities of a CBU72 FAE bomb and AV8B Harrier aircraft are used in the calculation. The FAE bomb has been given

---

* Aerial bombs never were intended for mine field breaching. Simple drops for destroying mines in assault helicopter landing zones were contemplated.

capability, not certainty, of mine killing over 30-m stretches. In the probability value p(30-m), we allow for all the influences that degrade the best FAE performance, which is seen in static canister tests (Weaver 1973) and for which FAE has sure-kill for some distance D. All compounding deleterious effects (e.g., accuracy, reliability, terminal effects) are subsumed into the single number. The method rejects studying separate effects and then mathematically joining them in a cascade to get a final system probability. The method of just picking p is a fell-swoop method which dismisses the piecemeal, engineering approach. The probability value of a single bomb success can remain arguable, even with test results, since tests usually encounter experimental problems with untried equipment. Lacking precise data, several probability values are run through the analysis. This report favors p(30-m) = 0.50, but values of 0.15, 0.30, and 0.70 are given for comparison and to find sensitivity on sortie number.

The Harrier can carry seven bombs singly racked and has the proper bombing computer. The longest breach that can be made by the Harrier is then 210 m long (7 x 30-m stretches). Without the minefield pattern, how many stretches are cleared is an intermediate answer which does not answer how many mines are killed. The proportion of stretches cleared in the lane is not the same as the proportion of mines killed in the lane except when the mines are uniformly distributed in all stretches. Figure 2 is a pattern that puts a mine in each 30-m stretch and gives a minefield density of 1,000 mines/km. The pattern is tactically unrealistic, but it is analyzed because it is conceptually easy; it is like some used on large scale clearance tests, and it is a limiting case of a (tactical) strip minefield to come. It will be shown that the bombing results are not greatly different over a uniform or strip minefield pattern.

2. NUMBER OF SORTIES: UNIFORM MINEFIELD

2.1 Single Sortie. Refer to Figure 2, which shows a path bombed through a pattern of a mine in every one of seven 30-m stretches. The breach width of 7 m is enough to give a one-way, one-lane path for tanks. The problem is to calculate the probabilities of no stretches cleared, one stretch cleared, ..., all seven cleared. We say that clearing by bombing can be modelled if the following conditions apply: the bomb drops are independent events, the same probability of success applies to each and every bomb, and there are only two outcomes in a

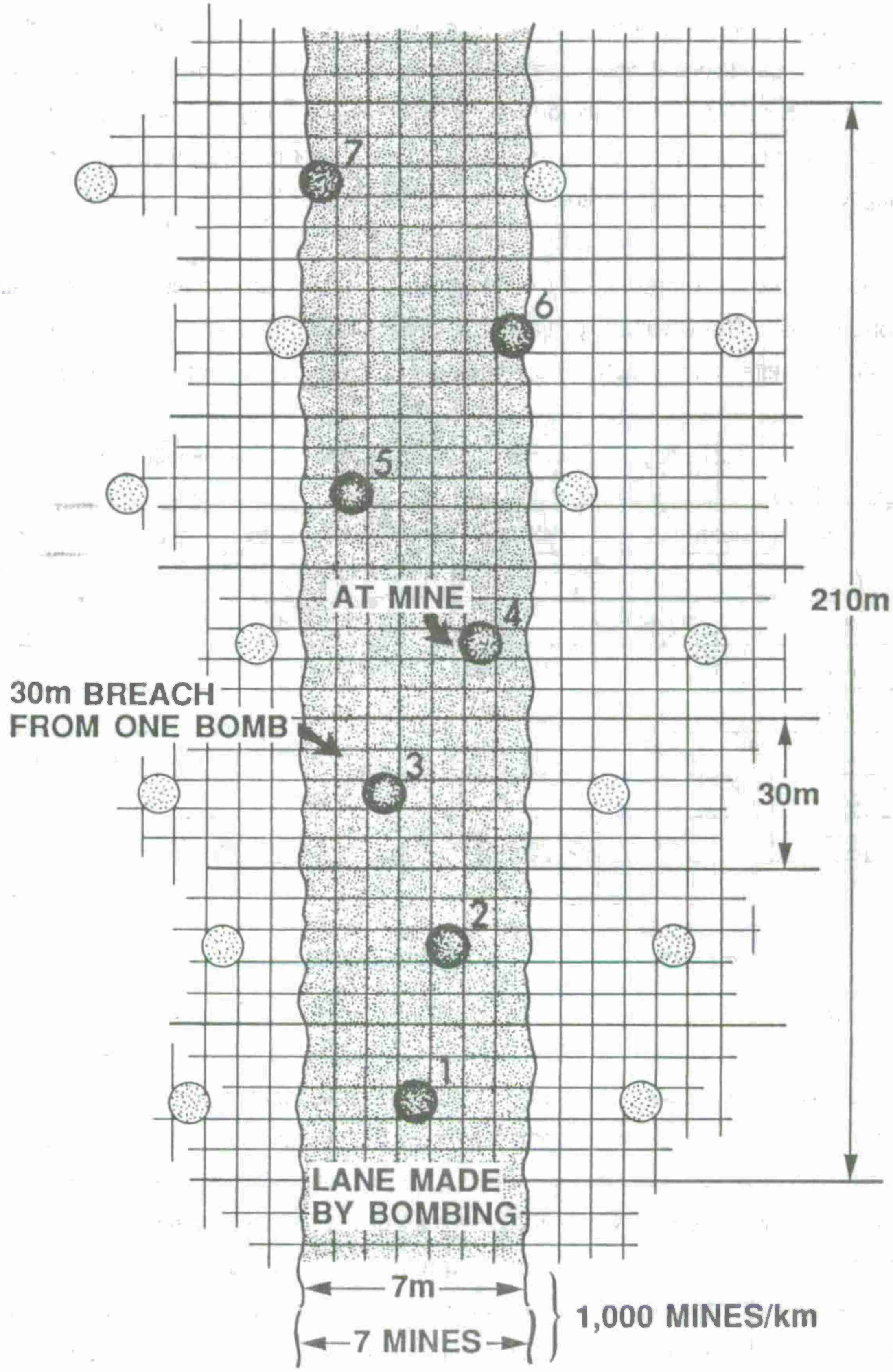


Figure 2. Uniform (Nontactical) Minefield.

stretch—clearing all mines or not clearing all mines in that stretch. (Partial clearing does not count.) These conditions define a random process for which the binomial distribution function supplies the probability of success for one sortie. Identification of the correct distribution leads to a look-up of probability of number of stretches cleared out of seven (i.e., r/7) and the probability of clearing r or more stretches by one sortie.

Table 1 shows the probability of clearing exactly (no more and no less than) r stretches from one Harrier. The CBU72 is given four different probabilities, values of p(30-m), of clearing a single 30-m stretch. The entries are from a binomial probability table.

Table 1. Exact Probability: One Sortie, Uniform Minefield

Proportion Cleared*		Probability of Clearing Exactly r of Seven Stretches			
(r/7)	(%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
7/7	100	0.0000	0.0002	0.0078	0.0824
6/7	86	0.0001	0.0036	0.0547	0.2471
5/7	71	0.0012	0.0250	0.1641	0.3177
4/7	57	0.0109	0.0972	0.2734	0.2269
3/7	43	0.0617	0.2269	0.2734	0.0972
2/7	29	0.2097	0.3177	0.1641	0.0250
1/7	14	0.3960	0.2471	0.0547	0.0036
0/7	0	0.3206	0.0824	0.0078	0.0002

* The proportion cleared is based on 210 m with seven CBU72 FAE bombs from one Harrier.

The probability of clearing r or more stretches with one sortie is given in Table 2. The entries are partial sums of the entries in Table 1. An equivalent meaning of clearing "r or more stretches" is clearing "at least r stretches." So at least 5/7 stretches cleared by 0.50 effective bombs with probability of 0.2266 means 5 or 6 or 7 stretches may be cleared but no less than five stretches will be cleared. For a uniform minefield, clearing at least 5/7 of stretches means at least 71% of the seven mines in the path will be killed (with the computed probability). Table 2 shows that a single sortie has a low probability of clearing very many

Table 2. Least Path Cleared: One Sortie, Uniform Minefield

Proportion Cleared*		Probability of Clearing at Least r Stretches			
(r/7)	(%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
7/7	100	0.0000	0.0002	0.0078	0.0824
6/7	86	0.0001	0.0038	0.0625	0.3294
5/7	71	0.0012	0.0288	0.2266	0.6471
7/7	57	0.0121	0.1260	0.5000	0.8740
3/7	43	0.0738	0.3529	0.7734	0.9712
2/7	29	0.2834	0.6706	0.9375	0.9962
1/7	14	0.6794	0.9176	0.9922	0.9998
0/7	0	1.0000	1.0000	1.0000	1.0000

* The proportion cleared is based on 210 m with seven CBU72 FAE bombs from one Harrier.

stretches. However, the "experiment" (sorties) may be repeated until success (clearing at least r stretches) is reached with any desired certainty.

2.2 <u>Multiple Sorties</u>. Multiple sorties against the same 210-m stretch impressively raise the clearance (cumulative) probability. The reason is that while each sortie is an independent event and the bomb falls are each independent events, the bombing results are not independent. Once a stretch is cleared of mines it remains cleared. The next sortie has the same clearance probabilities as the first (Tables 1 and 2) but the likelihood is that different stretches are cleared and the total cleared stretches can be a high proportion of seven stretches with high probability. The probability function for multiple sorties is derived in Section 7. The great improvement a few sorties make is seen in Table 3 and by comparison with Table 2.

In Appendix A, the breach of a uniform minefield is shown by exact and cumulative probabilities through 30 sorties. An extract of that Appendix is Table 4, which is a most useful result for squadron operations planning because the point of view is not probability (Table 3) but number of sorties required. The number of sorties is manageably small and there are

Table 3. Least Path Cleared: Multiple Sorties, Uniform Minefield

r Stretches*	Probability of Clearing at Least r Stretches			
	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
			Two Sorties	
7	0.0001	0.0090	0.1335	0.5168
6	0.0024	0.0693	0.4449	0.8745
5	0.0205	0.2433	0.7564	0.9807
4	0.0988	0.5219	0.9294	0.9982
3	0.3026	0.7895	0.9871	0.9999
2	0.6209	0.9438	0.9987	1.0000
1	0.8972	0.9932	0.9999	1.0000
0	1.0000	1.0000	1.0000	1.0000
			Three Sorties	
7	0.0013	0.0528	0.3927	0.8256
6	0.0155	0.2459	0.7854	0.9860
5	0.0832	0.5484	0.9537	0.9994
4	0.2630	0.8115	0.9938	1.0000
3	0.5490	0.9489	0.9995	1.0000
2	0.8221	0.9920	1.0000	1.0000
1	0.9671	0.9994	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000
			Four Sorties	
7	0.0057	0.1463	0.6365	0.9447
6	0.0493	0.4699	0.9335	0.9987
5	0.1921	0.7767	0.9929	1.0000
4	0.4520	0.9382	0.9995	1.0000
3	0.7358	0.9893	1.0000	1.0000
2	0.9217	0.9989	1.0000	1.0000
1	0.9894	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

* Seven stretches amount to 210 m with seven CBU72 FAE bombs from one Harrier.

Table 4. Number of Sorties to Clear at Least X% of Mines With at Least γ% Probability: Uniform Minefield

Proportion Cleared*		Number of Sorties			
		Probability $\gamma \geq 90\%$			
(r/7)	(X%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
7/7	100	26	12	7	4
6/7	86	16	8	4	3
5/7	71	11	5	3	2
4/7	57	8	4	2	2
3/7	43	6	3	2	4
2/7	29	4	2	1	1
1/7	14	3	1	1	1

		Probability $\gamma \geq 80\%$			
(r/7)	(X%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
7/7	100	22	10	5	3
6/7	86	14	6	4	2
6/7	71	10	5	3	2
4/7	57	7	3	2	1
3/7	43	5	3	2	1
2/7	29	3	2	1	1
1/7	14	2	1	1	1

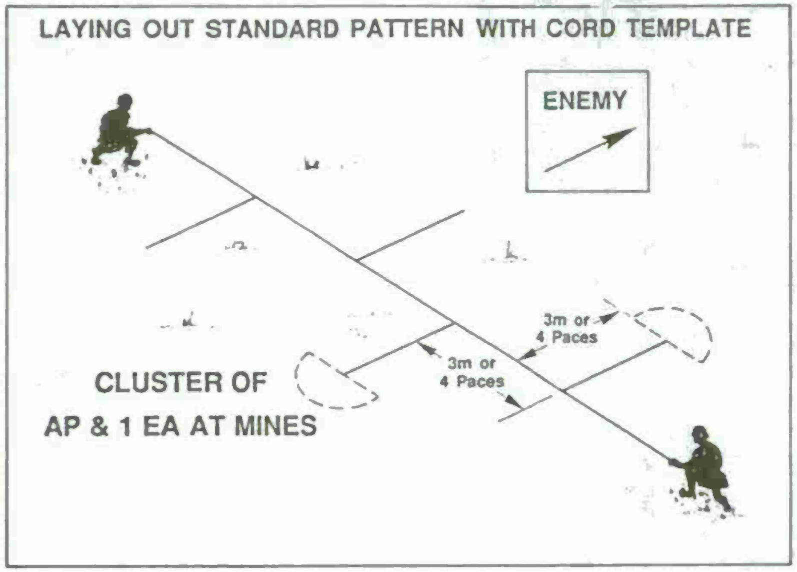
* The proportion cleared is based on 210 m with seven CBU72 FAE bombs in each sortie.

no surprises to the progression. Vertically the number of sorties needed increases as the proportion cleared (with stated probability) increases and as the probability demanded (80% to 90%) increases. Horizontally, the number of sorties needed decreases as the probability of a single FAE bomb breaching 30 meters of minefield increases.

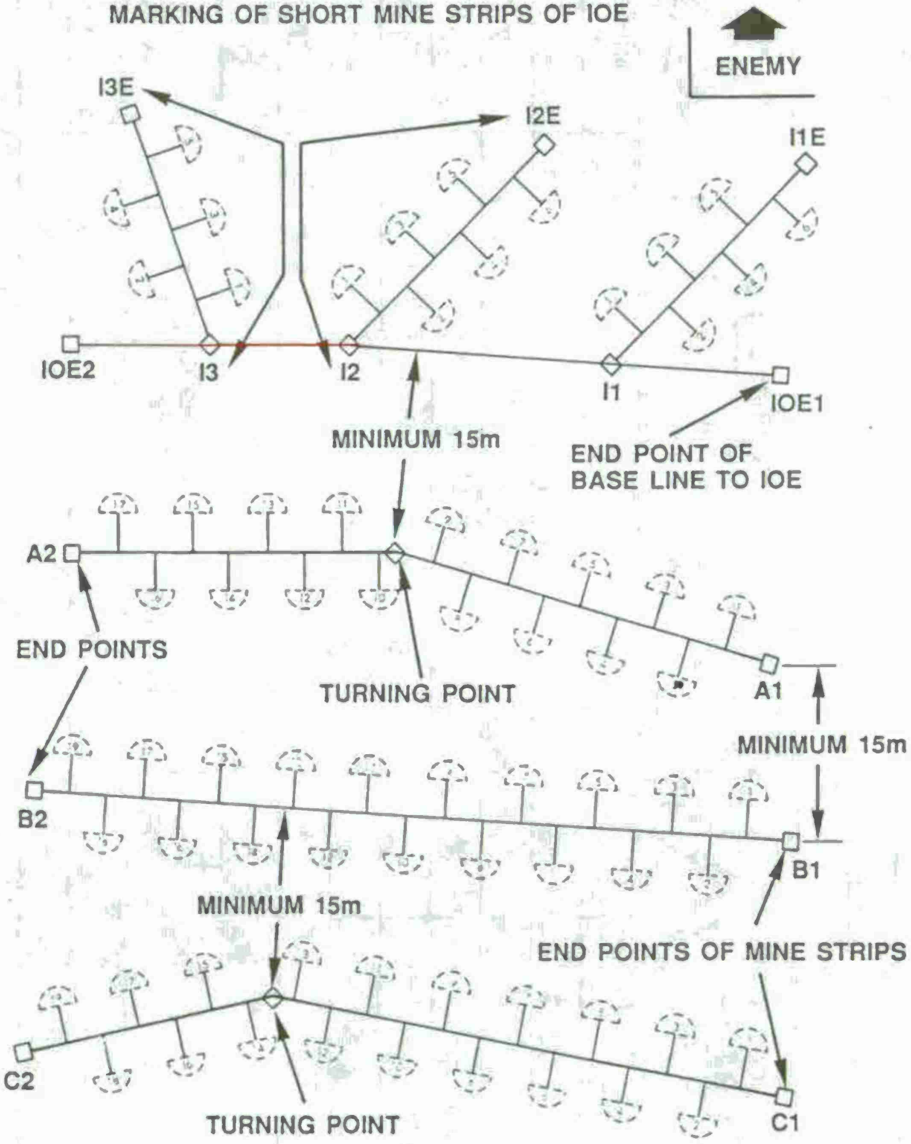
3. NUMBER OF SORTIES: STANDARD MINEFIELD

3.1 Definition. A deliberately laid minefield is patterned to aid mine laying and recovery. The U.S. Army minefield pattern is semistrict (see Figure 3) and is the one we shall try to breach. Basically, mines are in "clusters" of antipersonnel (AP) mines guarding one antitank

FM 20-32 (1976)



STANDARD MINEFIELD PATTERN



THREE REGULAR MINE STRIPS -

Figure 3. <u>Layout of Standard Minefield</u>.

(AT) mine. A cluster is laid 3 m down and 3 m out, alternately on both sides of a more-or-less straight string line. The whole affair is called a "regular mine strip." The clusters are widely separated to prevent sympathetic detonation (i.e., one AT mine exploding another in a reaction). But, to keep up the minefield density, which determines its probability of kill, several regular mine strips have to be laid. Field Manual 20-32, Table J-1, typically calls for three regular strips behind an "irregular outer edge" (IOE)* for a 1,000-mine/km antitank minefield. As a further deception measure, the officer in charge of the mine laying party is free to put in mine strips that contain no AT mines, only AP mines, but he will have three regular mine strips that do contain AT mines. A ground assault through a minefield will be carried out by armored vehicles, impervious to AP mines, so we are concerned only with AT-containing mine strips in this analysis.

The result of using higher mine densities is to cause more regular mine strips to be laid. But doing that moves the strip pattern closer to the uniform pattern (Figure 2) that was breached in Section 2.

No mathematical difficulty is made if the AT mines are not evenly laid throughout the minefield but are instead located on strips across the bombing path. The general problem is to find the probability of bombing a path through a minefield of strips of AT mines. As an instance of the general problem, we take the Harrier bombload and typical minefield density. There are three mine strips crossing seven stretches to be bombed. There is no way to tell through which stretch a mine strip passes. We stipulate two rules: not more than one mine strip crosses each 30-m bombed stretch and the IOE is dropped. These restrictions are not essential, but they simplify the problem and remove counting ambiguity.

Figure 4 illustrates the situation by showing one of the possible mine strip arrangements across our bombing path. For information only, the number of possible mining arrangements is 35, given by a combinations function, $\binom{7}{3} = \frac{7\,!}{3\,!\,4\,!} = 35$.

---

* The IOE is a complicated deception about minefield location and pattern. Extending from the IOE string line are skew branches with a total of 1/3 as many clusters as are on the regular strips. Attackers cross the IOE with few losses and draw into the real minefield and are entrapped.

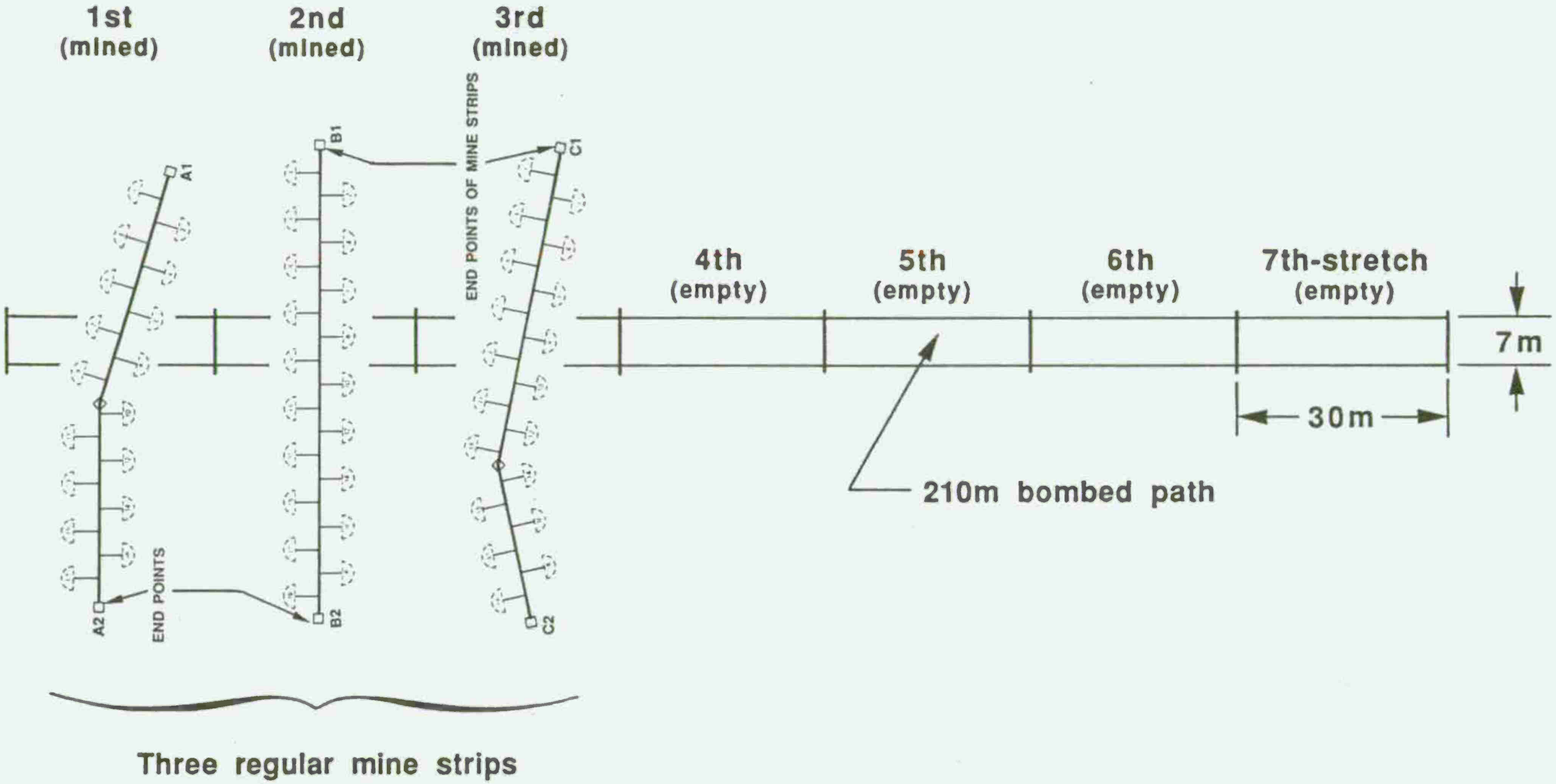


Figure 4. <u>Mine Strips Across Bombed Stretches</u>.

It is unnecessary to list the arrangements or even consider them because every stretch receives a bomb from every sortie. Whether a stretch is mined or not is irrelevant. What matters is the probability that our (less than completely capable FAE) bombs will clear either three, two, one, or zero mine strips.

3.2 Number of Sorties. In Appendix B the breach of a standard minefield is shown by exact and cumulative probabilities through 30 sorties. An extract of that Appendix is Table 5 and is the number of sorties required to (partially) breach the standard minefield. Tables 5 and 4 are analogs. Table 3 makes a point about the importance of multiple sorties and its analog for standard minefields does not need to be given here.

Table 5. Number of Sorties to Clear at Least X% of Mines With at Least γ% Probability: Standard Minefield

Proportion Cleared*		Number of Sorties			
		Probability γ ≥ 90%			
(r/3)	(X%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
3/3	100	21	10	5	3
2/3	66	11	5	3	2
1/3	33	5	3	2	1

		Probability γ ≥ 80%			
(r/3)	(X%)	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
3/3	100	17	8	4	3
2/3	66	8	4	2	2
1/3	33	4	2	1	1

* The proportion cleared is based on 210 m with seven CBU72 FAE bombs, each sortie.

4. EXPECTED PATH DENSITY AFTER FAE BOMBING

Since we cannot know how many mined stretches are cleared, we calculate the expectation value of the minefield density, $\overline{d}$.

$$\overline{d} = \sum_{r=0}^{k} P_r d_r \ ,$$

where P_r is the exact probability of clearing r stretches from Appendix A or B and k is the number of mined stretches. The mine density in the r-th stretch is $d_r = \frac{d_o}{k}(k - r)$, where d_o is the initial minefield density.

As an example, after four sorties drop bombs which have 0.50 probability of defeating a 30-meter stretch (0.50 weapon drop) on a uniform minefield with an initial density of 1,000 mines/km, the expected density of mines is as given below. (See Appendix A, exact probability.)

$$\overline{d} = \frac{1000}{7}[0.0000(7) + 0.0000(6) + 0.0000(5) + 0.0004(4)$$

$$+ 0.0066(3) + 0.0594(2) + 0.2970(1) + 0.6365(0)] ,$$

$$\overline{d} = 62.46 \text{ mines/km} .$$

The expected density amounts to 93% clearance (1 – 62.4/1000) in the bombed path.

Repeating the same attack conditions against a standard minefield gives the same expected density as on the uniform minefield. (See Appendix B, exact probability.)

$$\overline{d} = \frac{1000}{3}[0.0002(3) + 0.0110(2) + 0.1648(1) + 0.8240(0)] ,$$

$$\overline{d} = 62.47 \text{ mines/km} .$$

It is surprising, but has been shown, that minefield pattern has no effect on the long-run clearance to be expected. Thus, pattern has been eliminated in Table 6. Note though that for operations, as compared to long-run plans, Tables 4 and 5 show that the pattern does matter. The standard minefield found in tactical situations sometimes requires less sorties than the uniform minefield of test situations for the same percentage cleared.

We have also found that the expected densities, generated by the defining equation for expected value, are given by this simpler formula:

$$\bar{d} = d_o \, [1 - p(30\text{-m})]^n \, ,$$

where d_o is the unbombed minefield density; here, d_o = 1000 mines/km.

Table 6. Expected Path Density After FAE Bombing

n Sorties	Mines/km (clearance %)			
	p(30-m) = 0.15	= 0.30	= 0.50	= 0.70
1	850 (15)	700 (30)	500 (50)	300 (70)
2	722 (28)	490 (51)	250 (75)	90 (91)
3	614 (39)	343 (66)	125 (88)	27 (97)
4	522 (48)	240 (76)	62 (94)	8 (99)

The expectation value $\bar{d}$ is the "best" single number to quote as a path density after the requisite number of sorties. However, it is a mathematical value that would occur as an average of FAE strikes (n sorties each) on many, different 210-m paths and would not occur as a result of a single path clearing strike. It is a planning tool but its use, neglecting the cumulative probability tables, could result in tank losses.

5. PROBABILITY OF GETTING THROUGH

The clearance of at least X% of antitank mines can be translated into the probability that a tank will hit (or get through) the mines remaining in the breach path. The translation is made with Figure 5 from FM 20-32 (1976). With clearance already presumed, the result applies without regard for weapon effectiveness.

Table 7 shows various clearance levels and the corresponding mine density in the breach path. The clearance level, with stated probability, depends, of course, on the number of sorties used. Given that one can attain these clearances, the table shows the probability of getting through (and hitting a mine).

Table 7. Probability of a Tank Getting Through the Breach Path

Clearance* (%)	Path Density (mines/km)	P_{hit}	$P_{get\ through}$
100	0	0	1.00
71	≤ 290	≤ 0.37	≥ 0.63
66	≤ 340	≤ 0.40	≥ 0.60
57	≤ 430	≤ 0.47	≥ 0.53
33	≤ 670	≤ 0.61	≥ 0.39

* The probability of attaining these percentages increases as the number of sorties increases. (See Appendices.)

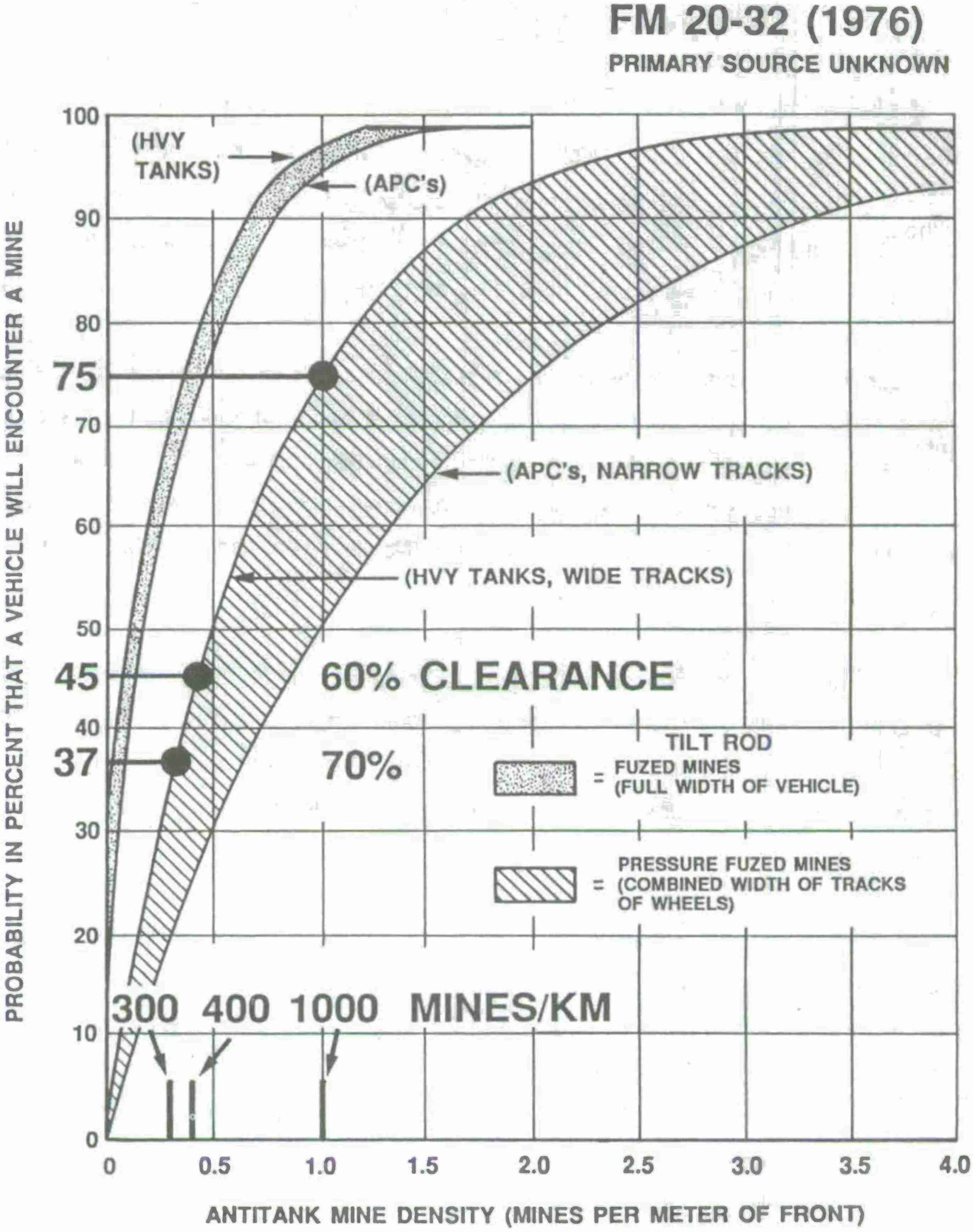


Figure 5. Probability of Tanks Hitting Mines.

6. PARTIAL CLEARANCE AND BULLING THROUGH

In a barrier minefield, a density of 1,000 mines/km is reasonable. A breach in the field is only a one-way, one-lane path and so a width of 7 m for tanks is reasonable.* Across this "front" there are, on average, seven mines. Of course, they are in a depth which may be 100–300 m (see Figure 2). The density almost guarantees that a tank will hit one if it tries to cross the minefield; the maximum loss is seven tanks.

Ordering certain death for the first few tanks is unacceptable to American commanders. That is, "bulling through" is not an acceptable tactic. It may be argued that the losses are less with this tactic than they would be if the tanks go cautiously, slowly, with plows because the minefield is covered with enemy guns and long exposure to fire guarantees heavy losses of the tanks. However, the selection of the tanks that go first—and die—in a bulling tactic is too grievous to do.

We argue that an acceptable tactic is to use some partially effective breaching means and then to bull through. A better tactic after partial breaching, if the enemy fire is suppressed, is to put plows or rollers on the first and second tank. A complementary benefit to the mechanical devices supplementing the partial breaching means is that the rollers will contact fewer explosives.

To understand why we consider "partial clearance," recall the results of Table 5 for a standard minefield. The FAE discussions and calculations showed that with a poor bomb, one having p(30-m) = 0.30, it would take 8–10 sorties to kill 100% of the mines in the lane of 210 m. Because this number of sorties is not small and repeated attacks jeopardize the airmen, we must consider partial clearance. At 66% clearance, the number of sorties drops to four, and 33% clearance requires only two sorties (Table 5, $\gamma \geq 80\%$). Although we are writing about only FAE, we are skeptical that <u>any</u> countermine breaching system is both fast and completely effective.

---

* FM 20-32 uses 8 m as a breach width.

We now argue that bulling through the minefield on the partially opened path will be acceptable. Suppose the sorties are few and the bombs only weakly effective, then the strike cannot be more than partially effective. Table 5 shows that four or five sorties carrying the 0.30 weapons are needed for 66% clearance with high probability. The remaining 34% of mines will <u>not</u> cause us, the attacker, heavy loss. Neither is the lead tank made a sacrifice. Leaving 34% of the mines alive sounds unacceptable, but that is the deception of percentages. It is necessary to change our thoughts from percentages to actual numbers of mines. The number of mines in the 7-m-wide breach is seven before FAE sorties and less than three (0.34 × 7) afterward on average. The effect is that the minefield density in the path is reduced from 1,000 mines/km to 340 mines/km (not 230), and the countermine manual (Figure 5) shows that the tank probability of hitting a mine is down from 0.75 to 0.40. The odds (3 to 2) slightly favor that it will get through if it just bulls its way. If the lead tank gets through, all get through since they move on the narrow lane like elephants on parade. The maximum loss is three tanks.

Table 8 shows that against 1,000 mines/km, with a p(30-m) = 0.30, four or five sorties give a 3 in 5 chance that the first tank gets through; zero sorties give 1 in 4 chances that it gets through. The combined tactic of partially clearing the path and bulling through is shown to be effective over bulling alone.

Table 8. Probability of a Tank Getting Through the Breach Path
(With Less Effective Bombs)

No. of Sorties[a]	Clearance (%)	→	Minefield (mines/km)	$P_{\text{hit mine}}$[b]	$P_{\text{get through}}$
0	0	→	1,000	0.75	0.25
2–3	33	→	670	0.61	0.39
4–5	66	→	340	0.40	0.60
0	0	→	2,000	0.93	0.07
2–3	33	→	1340	0.84	0.16
4–5	66	→	680	0.61	0.39

[a] 80–90% probability of stated percent clearance and p(30-m) = 0.30

[b] Figure 5

7. DERIVATION OF MULTIPLE SORTIES PROBABILITY

The binomial distribution cannot give probabilities of clearing beyond one sortie, directly. The result for following sorties depends on what happened before. The independence of outcomes on each trial (sortie) is violated and that is a condition for using the binomial distribution.

In a mined stretch there are only two outcomes for bombing—clearing all mines or not clearing all mines in that stretch. Each bomb falling on that stretch has a constant probability of success say 1/2. The probability of not clearing this stretch is the complement, also 1/2. The probability of not clearing this stretch in, say four sorties, is: $(1/2)^4 = 1/16$. Again, the probability of the only other outcome is the complement. So, the probability of clearing that stretch with four sorties is $1 - 1/16 = 15/16$. Assume we have a standard minefield of 1,000 mines/km which forces the antitank mines to be in three separate strips blocking the field. Then, there are three stretches that hold mines (recall Figure 4). At this point we can resume using the binomial distribution. Since each of the stretches is independent, the probability of clearing all three stretches is: $(15/16)^3 = 0.8240$. The probability of clearing only two stretches is the summed probability of all the sub-events: clearing two stretches $(15/16)^2$ and not clearing one stretch (1/16). There are $\binom{3}{2} = 3$ ways of clearing two out of three stretches. All total, the probability of clearing two stretches is $3\,(15/16)^2\,(1/16) = 0.1648$. Similarly, the probability of clearing only one mined stretch is: $\binom{3}{1}(15/16)\,(1/16)^2 = 3(15/16)\,(1/16)^2 = 0.0110$. The probability of clearing none of the three mined stretches in four sorties is: $(1/16)^3 = 0.0002$.

This argument can be generalized as follows. Let:

n = number of sorties,
k = number of mined stretches,
r = number of mined stretches to be cleared,
p(30-m) = probability of clearing one mined stretch with one bomb,

P_n = probability of clearing one mined stretch with n sorties,

$P_n^c = 1 - P_n \equiv$ probability of not clearing one mined stretch with n sorties,

P_r = probability of clearing exactly r mined stretches.

Then,

$$P_n^c = [1 - p(30\text{-m})]^n,$$

$$P_n = 1 - [1 - p(30\text{-m})]^n,$$

$$P_r = \binom{k}{r} (P_n)^r \left(P_n^c\right)^{k-r}.$$

This formulation gives exact probabilities for sortie numbers including one, where it matches the binomial distribution. For the uniform minefield, k = 7 (Appendix A) and for the standard minefield, k = 3 (Appendix B).

8. CONSIDERATIONS

Four sorties is a feasible number to request. However, the planes must bomb the same 210-m stretch. The pilot's problem is to put the bombsight cross hairs on the beginning of the stretch and fly to the other end as the computer releases the bombs. It is not stated how this stretch is selected or marked. Possibly smoke shell at both ends or a shell crater at both ends or a line charge rut could be used in daylight bombing. The idea is that the planes must find and line up on two points, not one, in order to bomb the same stretch. A formation drop like Leonard used would, with FAE, cause cloud burns, so the four sorties must be time-separated, all coming in the same way. Pilots prefer to bomb from different directions so as not to give antiaircraft gunners a predictable flight path. The close air support maxim of "one pass and haul ass" is violated. The resolution might be that a breach operation would not be contemplated without local air and ground superiority.

Another drawback is that pressure-fuzed mines are a large subset of all mines likely to be laid. However, military doctrine dictates that fuze types not be mixed, because doing otherwise complicates safing and recovery of one's own mines. So at least one minefield, pressure-fuzed, would be susceptible to FAE.

A bomb visually and ballistically like the CBU72 is the CBU88 "Smokeye," which dispenses a huge smoke cloud. These bombs could be dropped for curtain protection before the bombing runs and when the armor moves through.

Finally, FAE has notable effectiveness against many targets, including entrenched infantry. It might be judged a better offense to expend the FAE bombs against other available targets, but the low number of sorties (bombs) taken for minefield breaching would not preclude other worthwhile missions.

9. SUMMARY

The idea of breaching a minefield by bombing was analyzed with probability theory. The length of the breach was set by the nature of the bombs and the number carried on the plane. The outcome of one bombing run for killing mines (a sortie) was given by the binomial distribution, which depends on a bomb's probability of kill within a set distance. The effect of multiple sorties was analyzed with a function derived herein. The probabilities of breaching a uniform and a standard minefield were calculated for four different bomb-effectiveness values for up to 30 sorties.

Based on these results, it is feasible to use tactical bombers to breach a minefield if minefield marking can be accomplished. Furthermore, information definite enough for operations planning has emerged. The general method will solve other bombing-breaching problems.

For definiteness, fuel-air explosive bombs were notionally put on Harrier aircraft. Historically, FAE is effective against the largest subset of mines—pressure-fuzed mines. For narrow, parochial reasons, FAE is actually being dropped from the inventory.

In one instance, FAE bombs were dropped on live minefields, which gave rational, though not precise, choices for a single bomb's success in a set distance. Similar information may not exist for iron bombs. The probability analysis yielded exact and cumulative probabilities and numbers of sorties to kill mines hidden across the bombing path. It made no difference in the long run whether the mines were evenly laid in depth or bunched into strips. The expectation is that four Harrier sorties (4 x 7 CBU72 FAE bombs) with bombs of probability of kill equal to 0.50 in 30 meters would give 94% clearance of mines, ample to give near certainty of tanks getting through. In distinction from the expectation, a particular four-sortie strike on a standard minefield has probability 0.824 of 100% clearance of mines in the bombing path. The analysis further found that partial clearance (caused by poor bombs or too few sorties) reduced the mine density so much that not more than three tanks could hit mines. For high clearance the required number of sorties was low enough to be fair to the airmen.

INTENTIONALLY LEFT BLANK.

10. REFERENCES

Dennis, J. A. "Results of Variable Parameters on the Blast Effects of Navy BLU-73/B, Fuel Air Explosive (FAE) Warheads." MERDC-R-2071, Mobility Equipment Research and Development Center, Fort Belvoir, VA, August 1973. (AD 527019)

Dennis, J. A., W. G. Comeyne, and W. V. Millman. "Evaluation of the Fuel-Air Explosive System, Helicopter Delivered (FAESHED), for Neutralization of High-Explosive Land Mines and Booby Traps in Minefields." MERDC-R-2056, Mobility Equipment Research and Development Center, Fort Belvoir, VA, March 1973. (AD 524999)

Department of the Army. Mine/Countermine Operations at the Company Level. FM 20-32, Washington, DC, November 1976.

The Engineer Board. "Clearance of Land Mines by Aerial Bombs." Report 946, Fort Belvoir, VA, July 1945. (AD B956971)

Leonard, C. Z. "Aerial Bombardment of Minefields." Engineer Board Report 860, Fort Belvoir, VA, August 1944. (AD B959949L)

Weaver, R. C. "Evaluation of a 33-Pound Fuel-Air Explosive Warhead for Neutralization of High-Explosive Land Mines." MERDC-R-2082, Mobility Equipment Research and Development Center, Fort Belvoir, VA, December 1973. (AD 530879)

INTENTIONALLY LEFT BLANK.

APPENDIX A:

EXACT AND CUMULATIVE PROBABILITIES OF BREACHING A UNIFORM MINEFIELD

INTENTIONALLY LEFT BLANK.

Table A-1. Exact Probabilities of Breaching a Uniform Minefield

n = 1

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0000	0.0002	0.0078	0.0824
6	0.0001	0.0036	0.0547	0.2471
5	0.0012	0.0250	0.1641	0.3177
4	0.0109	0.0972	0.2734	0.2269
3	0.0617	0.2269	0.2734	0.0972
2	0.2097	0.3177	0.1641	0.0250
1	0.3960	0.2471	0.0547	0.0036
0	0.3206	0.0824	0.0078	0.0002

n = 2

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0001	0.0090	0.1335	0.5168
6	0.0023	0.0604	0.3115	0.3578
5	0.0180	0.1740	0.3115	0.1061
4	0.0783	0.2786	0.1730	0.0175
3	0.2038	0.2676	0.0577	0.0017
2	0.3184	0.1543	0.0115	0.0001
1	0.2763	0.0494	0.0013	0.0000
0	0.1028	0.0068	0.0001	0.0000

n = 3

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0013	0.0528	0.3927	0.8256
6	0.0142	0.1931	0.3927	0.1604
5	0.0678	0.3024	0.1683	0.0134
4	0.1797	0.2632	0.0401	0.0006
3	0.2860	0.1374	0.0057	0.0000
2	0.2731	0.0430	0.0005	0.0000
1	0.1449	0.0075	0.0000	0.0000
0	0.0329	0.0006	0.0000	0.0000

n = 4

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0057	0.1463	0.6365	0.9447
6	0.0436	0.3236	0.2970	0.0540
5	0.1428	0.3068	0.0594	0.0013
4	0.2599	0.1615	0.0066	0.0000
3	0.2838	0.0510	0.0004	0.0000
2	0.1860	0.0097	0.0000	0.0000
1	0.0677	0.0010	0.0000	0.0000
0	0.0106	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 5

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0165	0.2758	0.8007	0.9831
6	0.0920	0.3900	0.1808	0.0168
5	0.2203	0.2364	0.0175	0.0001
4	0.2928	0.0796	0.0009	0.0000
3	0.2335	0.0161	0.0000	0.0000
2	0.1118	0.0019	0.0000	0.0000
1	0.0297	0.0001	0.0000	0.0000
0	0.0034	0.0000	0.0000	0.0000

n = 6

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0364	0.4164	0.8956	0.9949
6	0.1541	0.3886	0.0995	0.0051
5	0.2800	0.1555	0.0047	0.0000
4	0.2826	0.0345	0.0001	0.0000
3	0.1711	0.0046	0.0000	0.0000
2	0.0622	0.0004	0.0000	0.0000
1	0.0125	0.0000	0.0000	0.0000
0	0.0011	0.0000	0.0000	0.0000

n = 7

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0668	0.5479	0.9466	0.9985
6	0.2207	0.3442	0.0522	0.0015
5	0.3125	0.0927	0.0012	0.0000
4	0.2457	0.0139	0.0000	0.0000
3	0.1159	0.0012	0.0000	0.0000
2	0.0328	0.0001	0.0000	0.0000
1	0.0052	0.0000	0.0000	0.0000
0	0.0003	0.0000	0.0000	0.0000

n = 8

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.1079	0.6599	0.9730	0.9995
6	0.2828	0.2826	0.0267	0.0005
5	0.3178	0.0519	0.0003	0.0000
4	0.1984	0.0053	0.0000	0.0000
3	0.0743	0.0003	0.0000	0.0000
2	0.0167	0.0000	0.0000	0.0000
1	0.0021	0.0000	0.0000	0.0000
0	0.0001	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 9

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.1581	0.7495	0.9864	0.9999
6	0.3337	0.2206	0.0135	0.0001
5	0.3018	0.0278	0.0001	0.0000
4	0.1516	0.0020	0.0000	0.0000
3	0.0457	0.0001	0.0000	0.0000
2	0.0083	0.0000	0.0000	0.0000
1	0.0008	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 10

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.2155	0.8183	0.9932	1.0000
6	0.3698	0.1665	0.0068	0.0000
5	0.2720	0.0145	0.0000	0.0000
4	0.1111	0.0007	0.0000	0.0000
3	0.0272	0.0000	0.0000	0.0000
2	0.0040	0.0000	0.0000	0.0000
1	0.0003	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 11

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.2775	0.8695	0.9966	1.0000
6	0.3904	0.1228	0.0034	0.0000
5	0.2354	0.0074	0.0000	0.0000
4	0.0788	0.0002	0.0000	0.0000
3	0.0158	0.0000	0.0000	0.0000
2	0.0019	0.0000	0.0000	0.0000
1	0.0001	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 12

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.3416	0.9070	0.9983	1.0000
6	0.3966	0.0891	0.0017	0.0000
5	0.1973	0.0038	0.0000	0.0000
4	0.0545	0.0001	0.0000	0.0000
3	0.0090	0.0000	0.0000	0.0000
2	0.0009	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 13

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.4057	0.9341	0.9991	1.0000
6	0.3906	0.0640	0.0009	0.0000
5	0.1612	0.0019	0.0000	0.0000
4	0.0369	0.0000	0.0000	0.0000
3	0.0051	0.0000	0.0000	0.0000
2	0.0004	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 14

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.4681	0.9535	0.9996	1.0000
6	0.3753	0.0456	0.0004	0.0000
5	0.1290	0.0009	0.0000	0.0000
4	0.0246	0.0000	0.0000	0.0000
3	0.0028	0.0000	0.0000	0.0000
2	0.0002	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 15

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.5274	0.9672	0.9998	1.0000
6	0.3533	0.0323	0.0002	0.0000
5	0.1015	0.0005	0.0000	0.0000
4	0.0162	0.0000	0.0000	0.0000
3	0.0015	0.0000	0.0000	0.0000
2	0.0001	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 16

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.5827	0.9770	0.9999	1.0000
6	0.3272	0.0228	0.0001	0.0000
5	0.0787	0.0002	0.0000	0.0000
4	0.0105	0.0000	0.0000	0.0000
3	0.0008	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching
a Uniform Minefield (continued)

n = 17

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.6336	0.9838	0.9999	1.0000
6	0.2988	0.0161	0.0001	0.0000
5	0.0604	0.0001	0.0000	0.0000
4	0.0068	0.0000	0.0000	0.0000
3	0.0005	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 18

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.6798	0.9887	1.0000	1.0000
6	0.2697	0.0113	0.0000	0.0000
5	0.0459	0.0001	0.0000	0.0000
4	0.0043	0.0000	0.0000	0.0000
3	0.0002	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 19

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.7213	0.9920	1.0000	1.0000
6	0.2412	0.0079	0.0000	0.0000
5	0.0346	0.0000	0.0000	0.0000
4	0.0028	0.0000	0.0000	0.0000
3	0.0001	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 20

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.7583	0.9944	1.0000	1.0000
6	0.2140	0.0056	0.0000	0.0000
5	0.0259	0.0000	0.0000	0.0000
4	0.0017	0.0000	0.0000	0.0000
3	0.0001	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 21

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.7910	0.9961	1.0000	1.0000
6	0.1886	0.0039	0.0000	0.0000
5	0.0193	0.0000	0.0000	0.0000
4	0.0011	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 22

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8197	0.9973	1.0000	1.0000
6	0.1653	0.0027	0.0000	0.0000
5	0.0143	0.0000	0.0000	0.0000
4	0.0007	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 23

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8448	0.9981	1.0000	1.0000
6	0.1442	0.0019	0.0000	0.0000
5	0.0105	0.0000	0.0000	0.0000
4	0.0004	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 24

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8667	0.9987	1.0000	1.0000
6	0.1253	0.0013	0.0000	0.0000
5	0.0078	0.0000	0.0000	0.0000
4	0.0003	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 25

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.8857	0.9991	1.0000	1.0000
6	0.1085	0.0009	0.0000	0.0000
5	0.0057	0.0000	0.0000	0.0000
4	0.0002	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 26

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.9021	0.9993	1.0000	1.0000
6	0.0937	0.0007	0.0000	0.0000
5	0.0042	0.0000	0.0000	0.0000
4	0.0001	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 27

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.9162	0.9995	1.0000	1.0000
6	0.0807	0.0005	0.0000	0.0000
5	0.0030	0.0000	0.0000	0.0000
4	0.0001	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 28

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.9284	0.9997	1.0000	1.0000
6	0.0694	0.0003	0.0000	0.0000
5	0.0022	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-1. Exact Probabilities of Breaching a Uniform Minefield (continued)

n = 29

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
7	0.9388	0.9998	1.0000	1.0000
6	0.0595	0.0002	0.0000	0.0000
5	0.0016	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 30

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
7	0.9478	0.9998	1.0000	1.0000
6	0.0510	0.0002	0.0000	0.0000
5	0.0012	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield

n = 1

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0000	0.0002	0.0078	0.0824
6	0.0001	0.0038	0.0625	0.3294
5	0.0012	0.0288	0.2266	0.6471
4	0.0121	0.1260	0.5000	0.8740
3	0.0738	0.3529	0.7734	0.9712
2	0.2834	0.6706	0.9375	0.9962
1	0.6794	0.9176	0.9922	0.9998
0	1.0000	1.0000	1.0000	1.0000

n = 2

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0001	0.0090	0.1335	0.5168
6	0.0024	0.0693	0.4449	0.8745
5	0.0205	0.2433	0.7564	0.9807
4	0.0988	0.5219	0.9294	0.9982
3	0.3026	0.7895	0.9871	0.9999
2	0.6209	0.9438	0.9987	1.0000
1	0.8972	0.9932	0.9999	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 3

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0013	0.0528	0.3927	0.8256
6	0.0155	0.2459	0.7854	0.9860
5	0.0832	0.5484	0.9537	0.9994
4	0.2630	0.8115	0.9938	1.0000
3	0.5490	0.9489	0.9995	1.0000
2	0.8221	0.9920	1.0000	1.0000
1	0.9671	0.9994	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 4

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.0057	0.1463	0.6365	0.9447
6	0.0493	0.4699	0.9335	0.9987
5	0.1921	0.7767	0.9929	1.0000
4	0.4520	0.9382	0.9995	1.0000
3	0.7358	0.9893	1.0000	1.0000
2	0.9217	0.9989	1.0000	1.0000
1	0.9894	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 5

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0165	0.2758	0.8007	0.9831
6	0.1085	0.6658	0.9815	0.9999
5	0.3288	0.9022	0.9990	1.0000
4	0.6216	0.9818	1.0000	1.0000
3	0.8551	0.9979	1.0000	1.0000
2	0.9669	0.9999	1.0000	1.0000
1	0.9966	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 6

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0364	0.4164	0.8956	0.9949
6	0.1905	0.8050	0.9951	1.0000
5	0.4705	0.9605	0.9999	1.0000
4	0.7531	0.9950	1.0000	1.0000
3	0.9242	0.9996	1.0000	1.0000
2	0.9864	1.0000	1.0000	1.0000
1	0.9989	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 7

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.0668	0.5479	0.9466	0.9985
6	0.2876	0.8921	0.9988	1.0000
5	0.6000	0.9848	1.0000	1.0000
4	0.8457	0.9987	1.0000	1.0000
3	0.9617	0.9999	1.0000	1.0000
2	0.9945	1.0000	1.0000	1.0000
1	0.9997	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 8

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.1079	0.6599	0.9730	0.9995
6	0.3907	0.9425	0.9997	1.0000
5	0.7084	0.9944	1.0000	1.0000
4	0.9068	0.9997	1.0000	1.0000
3	0.9811	1.0000	1.0000	1.0000
2	0.9978	1.0000	1.0000	1.0000
1	0.9999	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 9

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.1581	0.7495	0.9864	0.9999
6	0.4918	0.9701	0.9999	1.0000
5	0.7936	0.9980	1.0000	1.0000
4	0.9452	0.9999	1.0000	1.0000
3	0.9909	1.0000	1.0000	1.0000
2	0.9991	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 10

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.2155	0.8183	0.9932	1.0000
6	0.5853	0.9848	1.0000	1.0000
5	0.8573	0.9993	1.0000	1.0000
4	0.9684	1.0000	1.0000	1.0000
3	0.9957	1.0000	1.0000	1.0000
2	0.9997	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 11

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.2775	0.8695	0.9966	1.0000
6	0.6679	0.9923	1.0000	1.0000
5	0.9033	0.9997	1.0000	1.0000
4	0.9821	1.0000	1.0000	1.0000
3	0.9980	1.0000	1.0000	1.0000
2	0.9999	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 12

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
7	0.3416	0.9070	0.9983	1.0000
6	0.7382	0.9962	1.0000	1.0000
5	0.9355	0.9999	1.0000	1.0000
4	0.9900	1.0000	1.0000	1.0000
3	0.9990	1.0000	1.0000	1.0000
2	0.9999	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 13

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.4057	0.9341	0.9991	1.0000
6	0.7964	0.9981	1.0000	1.0000
5	0.9575	1.0000	1.0000	1.0000
4	0.9945	1.0000	1.0000	1.0000
3	0.9996	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 14

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.4681	0.9535	0.9996	1.0000
6	0.8434	0.9991	1.0000	1.0000
5	0.9724	1.0000	1.0000	1.0000
4	0.9970	1.0000	1.0000	1.0000
3	0.9998	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 15

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.5274	0.9672	0.9998	1.0000
6	0.8807	0.9995	1.0000	1.0000
5	0.9822	1.0000	1.0000	1.0000
4	0.9984	1.0000	1.0000	1.0000
3	0.9999	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 16

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.5827	0.9770	0.9999	1.0000
6	0.9099	0.9998	1.0000	1.0000
5	0.9886	1.0000	1.0000	1.0000
4	0.9991	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 17

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.6336	0.9838	0.9999	1.0000
6	0.9324	0.9999	1.0000	1.0000
5	0.9927	1.0000	1.0000	1.0000
4	0.9995	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 18

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.6798	0.9887	1.0000	1.0000
6	0.9495	0.9999	1.0000	1.0000
5	0.9954	1.0000	1.0000	1.0000
4	0.9997	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 19

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.7213	0.9920	1.0000	1.0000
6	0.9625	1.0000	1.0000	1.0000
5	0.9971	1.0000	1.0000	1.0000
4	0.9999	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 20

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
7	0.7583	0.9944	1.0000	1.0000
6	0.9723	1.0000	1.0000	1.0000
5	0.9982	1.0000	1.0000	1.0000
4	0.9999	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 21

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.7910	0.9961	1.0000	1.0000
6	0.9796	1.0000	1.0000	1.0000
5	0.9989	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 22

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8197	0.9973	1.0000	1.0000
6	0.9850	1.0000	1.0000	1.0000
5	0.9993	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 23

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8448	0.9981	1.0000	1.0000
6	0.9890	1.0000	1.0000	1.0000
5	0.9996	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 24

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8667	0.9987	1.0000	1.0000
6	0.9920	1.0000	1.0000	1.0000
5	0.9997	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 25

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.8857	0.9991	1.0000	1.0000
6	0.9941	1.0000	1.0000	1.0000
5	0.9998	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 26

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.9021	0.9993	1.0000	1.0000
6	0.9957	1.0000	1.0000	1.0000
5	0.9999	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 27

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.9162	0.9995	1.0000	1.0000
6	0.9969	1.0000	1.0000	1.0000
5	0.9999	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 28

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.9284	0.9997	1.0000	1.0000
6	0.9977	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table A-2. Cumulative Probabilities of Breaching a Uniform Minefield (continued)

n = 29

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.9388	0.9998	1.0000	1.0000
6	0.9984	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 30

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
7	0.9478	0.9998	1.0000	1.0000
6	0.9988	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

APPENDIX B:

EXACT AND CUMULATIVE PROBABILITIES OF BREACHING A STANDARD MINEFIELD

INTENTIONALLY LEFT BLANK.

Table B-1. Exact Probabilities of Breaching a Standard Minefield

n = 1

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.0034	0.0270	0.1250	0.3430
2	0.0574	0.1890	0.3750	0.4410
1	0.3251	0.4410	0.3750	0.1890
0	0.6141	0.3430	0.1250	0.0270

n = 2

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.0214	0.1327	0.4219	0.7536
2	0.1669	0.3823	0.4219	0.2236
1	0.4346	0.3674	0.1406	0.0221
0	0.3771	0.1176	0.0156	0.0007

n = 3

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.0575	0.2836	0.6699	0.9212
2	0.2743	0.4442	0.2871	0.0767
1	0.4366	0.2319	0.0410	0.0021
0	0.2316	0.0404	0.0020	0.0000

n = 4

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.1092	0.4388	0.8240	0.9759
2	0.3578	0.4159	0.1648	0.0239
1	0.3907	0.1314	0.0110	0.0002
0	0.1422	0.0138	0.0002	0.0000

n = 5

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.1722	0.5758	0.9091	0.9927
2	0.4119	0.3490	0.0880	0.0073
1	0.3286	0.0705	0.0028	0.0000
0	0.0874	0.0047	0.0000	0.0000

Table B-1. Exact Probabilities of Breaching a Standard Minefield (continued)

n = 6

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.2416	0.6869	0.9539	0.9978
2	0.4389	0.2748	0.0454	0.0022
1	0.2658	0.0366	0.0007	0.0000
0	0.0536	0.0016	0.0000	0.0000

n = 7

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.3136	0.7727	0.9767	0.9993
2	0.4440	0.2080	0.0231	0.0007
1	0.2095	0.0187	0.0002	0.0000
0	0.0329	0.0006	0.0000	0.0000

n = 8

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.3850	0.8368	0.9883	0.9998
2	0.4327	0.1536	0.0116	0.0002
1	0.1621	0.0094	0.0000	0.0000
0	0.0202	0.0002	0.0000	0.0000

n = 9

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.4537	0.8838	0.9942	0.9999
2	0.4102	0.1115	0.0058	0.0001
1	0.1237	0.0047	0.0000	0.0000
0	0.0124	0.0001	0.0000	0.0000

n = 10

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.5180	0.9176	0.9971	1.0000
2	0.3810	0.0800	0.0029	0.0000
1	0.0934	0.0023	0.0000	0.0000
0	0.0076	0.0000	0.0000	0.0000

Table B-1. Exact Probabilities of Breaching a Standard Minefield (continued)

n = 11

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.5773	0.9418	0.9985	1.0000
2	0.3481	0.0570	0.0015	0.0000
1	0.0700	0.0011	0.0000	0.0000
0	0.0047	0.0000	0.0000	0.0000

n = 12

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.6311	0.9590	0.9993	1.0000
2	0.3140	0.0404	0.0007	0.0000
1	0.0521	0.0006	0.0000	0.0000
0	0.0029	0.0000	0.0000	0.0000

n = 13

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.6794	0.9712	0.9996	1.0000
2	0.2803	0.0285	0.0004	0.0000
1	0.0386	0.0003	0.0000	0.0000
0	0.0018	0.0000	0.0000	0.0000

n = 14

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.7223	0.9798	0.9998	1.0000
2	0.2482	0.0201	0.0002	0.0000
1	0.0284	0.0001	0.0000	0.0000
0	0.0011	0.0000	0.0000	0.0000

n = 15

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.7602	0.9858	0.9999	1.0000
2	0.2183	0.0141	0.0001	0.0000
1	0.0209	0.0001	0.0000	0.0000
0	0.0007	0.0000	0.0000	0.0000

Table B-1. Exact Probabilities of Breaching a Standard Minefield (continued)

n = 16

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.7934	0.9901	1.0000	1.0000
2	0.1909	0.0099	0.0000	0.0000
1	0.0153	0.0000	0.0000	0.0000
0	0.0004	0.0000	0.0000	0.0000

n = 17

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8224	0.9930	1.0000	1.0000
2	0.1662	0.0069	0.0000	0.0000
1	0.0112	0.0000	0.0000	0.0000
0	0.0003	0.0000	0.0000	0.0000

n = 18

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8475	0.9951	1.0000	1.0000
2	0.1441	0.0049	0.0000	0.0000
1	0.0082	0.0000	0.0000	0.0000
0	0.0002	0.0000	0.0000	0.0000

n = 19

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8693	0.9966	1.0000	1.0000
2	0.1246	0.0034	0.0000	0.0000
1	0.0060	0.0000	0.0000	0.0000
0	0.0001	0.0000	0.0000	0.0000

n = 20

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8882	0.9976	1.0000	1.0000
2	0.1074	0.0024	0.0000	0.0000
1	0.0043	0.0000	0.0000	0.0000
0	0.0001	0.0000	0.0000	0.0000

Table B-1. Exact Probabilities of Breaching
a Standard Minefield (continued)

n = 21

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9044	0.9983	1.0000	1.0000
2	0.0924	0.0017	0.0000	0.0000
1	0.0031	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 22

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9183	0.9988	1.0000	1.0000
2	0.0794	0.0012	0.0000	0.0000
1	0.0023	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 23

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9303	0.9992	1.0000	1.0000
2	0.0681	0.0008	0.0000	0.0000
1	0.0017	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 24

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9405	0.9994	1.0000	1.0000
2	0.0583	0.0006	0.0000	0.0000
1	0.0012	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 25

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9493	0.9996	1.0000	1.0000
2	0.0498	0.0004	0.0000	0.0000
1	0.0009	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table B-1. Exact Probabilities of Breaching a Standard Minefield (continued)

n = 26

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9568	0.9997	1.0000	1.0000
2	0.0426	0.0003	0.0000	0.0000
1	0.0006	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 27

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9632	0.9998	1.0000	1.0000
2	0.0364	0.0002	0.0000	0.0000
1	0.0005	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 28

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9686	0.9999	1.0000	1.0000
2	0.0310	0.0001	0.0000	0.0000
1	0.0003	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 29

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9733	0.9999	1.0000	1.0000
2	0.0265	0.0001	0.0000	0.0000
1	0.0002	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

n = 30

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.9773	0.9999	1.0000	1.0000
2	0.0225	0.0001	0.0000	0.0000
1	0.0002	0.0000	0.0000	0.0000
0	0.0000	0.0000	0.0000	0.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield

n = 1

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.0034	0.0270	0.1250	0.3430
2	0.0607	0.2160	0.5000	0.7840
1	0.3859	0.6570	0.8750	0.9730
0	1.0000	1.0000	1.0000	1.0000

n = 2

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.0214	0.1327	0.4219	0.7536
2	0.1883	0.5150	0.8438	0.9772
1	0.6229	0.8824	0.9844	0.9993
0	1.0000	1.0000	1.0000	1.0000

n = 3

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.0575	0.2836	0.6699	0.9212
2	0.3318	0.7278	0.9570	0.9979
1	0.7684	0.9596	0.9980	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 4

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.1092	0.4388	0.8240	0.9759
2	0.4670	0.8547	0.9888	0.9998
1	0.8578	0.9862	0.9998	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 5

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.1722	0.5758	0.9091	0.9927
2	0.5841	0.9248	0.9971	1.0000
1	0.9126	0.9953	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield (continued)

n = 6

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.2416	0.6869	0.9539	0.9978
2	0.6806	0.9617	0.9993	1.0000
1	0.9464	0.9984	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 7

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.3136	0.7727	0.9767	0.9993
2	0.7576	0.9808	0.9998	1.0000
1	0.9671	0.9994	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 8

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.3850	0.8368	0.9883	0.9998
2	0.8177	0.9904	1.0000	1.0000
1	0.9798	0.9998	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 9

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.4537	0.8838	0.9942	0.9999
2	0.8639	0.9952	1.0000	1.0000
1	0.9876	0.9999	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 10

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.5180	0.9176	0.9971	1.0000
2	0.8990	0.9977	1.0000	1.0000
1	0.9924	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield (continued)

n = 11

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.5773	0.9418	0.9985	1.0000
2	0.9254	0.9988	1.0000	1.0000
1	0.9953	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 12

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.6311	0.9590	0.9993	1.0000
2	0.9451	0.9994	1.0000	1.0000
1	0.9971	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 13

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.6794	0.9712	0.9996	1.0000
2	0.9597	0.9997	1.0000	1.0000
1	0.9982	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 14

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.7223	0.9798	0.9998	1.0000
2	0.9705	0.9999	1.0000	1.0000
1	0.9989	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 15

Cleared Stretches	p(30-m)			
	0.15	0.30	0.50	0.70
3	0.7602	0.9858	0.9999	1.0000
2	0.9784	0.9999	1.0000	1.0000
1	0.9993	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield (continued)

n = 16

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.7934	0.9901	1.0000	1.0000
2	0.9843	1.0000	1.0000	1.0000
1	0.9996	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 17

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8224	0.9930	1.0000	1.0000
2	0.9886	1.0000	1.0000	1.0000
1	0.9997	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 18

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8475	0.9951	1.0000	1.0000
2	0.9917	1.0000	1.0000	1.0000
1	0.9998	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 19

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8693	0.9966	1.0000	1.0000
2	0.9940	1.0000	1.0000	1.0000
1	0.9999	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 20

Cleared Stretches	p(30-m) 0.15	0.30	0.50	0.70
3	0.8882	0.9976	1.0000	1.0000
2	0.9956	1.0000	1.0000	1.0000
1	0.9999	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield (continued)

n = 21

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.9044	0.9983	1.0000	1.0000
2	0.9968	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 22

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.9183	0.9988	1.0000	1.0000
2	0.9977	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 23

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.9303	0.9992	1.0000	1.0000
2	0.9983	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 24

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.9405	0.9994	1.0000	1.0000
2	0.9988	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 25

	p(30-m)			
Cleared Stretches	0.15	0.30	0.50	0.70
3	0.9493	0.9996	1.0000	1.0000
2	0.9991	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

Table B-2. Cumulative Probabilities of Breaching a Standard Minefield (continued)

n = 26

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
3	0.9568	0.9997	1.0000	1.0000
2	0.9994	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 27

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
3	0.9632	0.9998	1.0000	1.0000
2	0.9995	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 28

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
3	0.9686	0.9999	1.0000	1.0000
2	0.9997	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 29

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
3	0.9733	0.9999	1.0000	1.0000
2	0.9998	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

n = 30

Cleared Stretches	p(30-m) 0.15	 0.30	 0.50	 0.70
3	0.9773	0.9999	1.0000	1.0000
2	0.9998	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
0	1.0000	1.0000	1.0000	1.0000

No. of Copies	Organization
2	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22304-6145
1	Commander U.S. Army Materiel Command ATTN: AMCAM 5001 Eisenhower Ave. Alexandria, VA 22333-0001
1	Commander U.S. Army Laboratory Command ATTN: AMSLC-DL 2800 Powder Mill Rd. Adelphi, MD 20783-1145
2	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-IMI-I Picatinny Arsenal, NJ 07806-5000
2	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-TDC Picatinny Arsenal, NJ 07806-5000
1	Director Benet Weapons Laboratory U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-CCB-TL Watervliet, NY 12189-4050
(Unclass. only)1	Commander U.S. Army Rock Island Arsenal ATTN: SMCRI-TL/Technical Library Rock Island, IL 61299-5000
1	Director U.S. Army Aviation Research and Technology Activity ATTN: SAVRT-R (Library) M/S 219-3 Ames Research Center Moffett Field, CA 94035-1000
1	Commander U.S. Army Missile Command ATTN: AMSMI-RD-CS-R (DOC) Redstone Arsenal, AL 35898-5010

No. of Copies	Organization
1	Commander U.S. Army Tank-Automotive Command ATTN: ASQNC-TAC-DIT (Technical Information Center) Warren, MI 48397-5000
1	Director U.S. Army TRADOC Analysis Command ATTN: ATRC-WSR White Sands Missile Range, NM 88002-5502
1	Commandant U.S. Army Field Artillery School ATTN: ATSF-CSI Ft. Sill, OK 73503-5000
2	Commandant U.S. Army Infantry School ATTN: ATZB-SC, System Safety Fort Benning, GA 31903-5000
(Class. only)1	Commandant U.S. Army Infantry School ATTN: ATSH-CD (Security Mgr.) Fort Benning, GA 31905-5660
(Unclass. only)1	Commandant U.S. Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905-5660
1	WL/MNOI Eglin AFB, FL 32542-5000
	Aberdeen Proving Ground
2	Dir, USAMSAA ATTN: AMXSY-D AMXSY-MP, H. Cohen
1	Cdr, USATECOM ATTN: AMSTE-TC
3	Cdr, CRDEC, AMCCOM ATTN: SMCCR-RSP-A SMCCR-MU SMCCR-MSI
1	Dir, VLAMO ATTN: AMSLC-VL-D
10	Dir, USABRL ATTN: SLCBR-DD-T

No. of Copies Organization

1 Chairman
DOD Explosives Safety Board
Hoffman Bldg. 1, Room 856-C
2461 Eisenhower Ave.
Alexandria, VA 22331-0600

2 Under Secretary of Defense for Research and Engineering
ATTN: TWP/OM
T. Hitchcock
Washington, DC 20301-3100

2 Director
Defense Advanced Research Projects Agency
Weapons Technology & Concepts Division
ATTN: T. Hafer
Technical Library
1400 Wilson Blvd.
Arlington, VA 22209-2308

4 Director
Defense Intelligence Agency
ATTN: TOC Sys
R&D Appl
DT-5A
Technical Library
Washington, DC 20301

2 Chairman
Joint Chiefs of Staff
ATTN: J-3, Operations
J-5, P&P/R&D Div
Washington, DC 20301

1 Chairman
Canada-U.S. Mil Coop Comm
1300 Wilson Blvd., CWB
Alexandria, VA 22311

5 Commander
Defense Nuclear Agency
ATTN: C. McFarland
R. Rohr
G. Ullrich
LTC Rubbio
MAJ Holm
Washington, DC 20305-1000

No. of Copies Organization

1 HQDA (DAEN-ECE-T, Mr. Wright)
WASH DC 20310-0001

1 HQDA (DAEN-MCC-D, Mr. Foley)
WASH DC 20310-0001

1 HQDA (DAEN-RDL, Mr. Simonini)
WASH DC 20310-0001

1 HQDA (DAEN-RDZ-A, Dr. Choromokos)
WASH DC 20310-0001

1 HQDA (DAEN-RDM)
WASH DC 20310-0001

1 HQDA (DAPE-HRS)
WASH DC 20310-0001

1 HQDA (DAMO-FDI)
WASH DC 20310-0001

1 HQDA (DAMI-ZS)
WASH DC 20310-0001

1 Commander
U.S. Army Materials Technology Laboratory
ATTN: SLCMT-ATL
Watertown, MA 02172-0001

6 Director
U.S. Army Engineer Waterways Experimental Station
ATTN: Technical Library
M. Ford
K. Davis
W. Huff
V. Chiarito
D. Cress
P.O. Box 631
Vicksburg, MS 39180-0631

1 Commander
Military Traffic Management Command
ATTN: MT-TM, R. Umholtz
5611 Columbia Pike
Falls Church, VA 22041-5050

No. of Copies Organization

9 Commander
U.S. Army Materiel Command
ATTN: AMCLD, Mr. Langworthy
AMCGCL
AMCED-CM
AMCCN, Dr. McClesky
AMCALNO
AMCBLNO
AMCMI-FS
AMCSM-WRM
AMCSM-WC
5001 Eisenhower Ave.
Alexandria, VA 22333-0001

2 Commander
U.S. Army Tank-Automotive Command
ATTN: AMSTA-ZTR
AMSTA-ZDM, CPT Mayfield
Warren, MI 48397-5000

6 Commander
U.S. Army Laboratory Command
ATTN: AMCLD-AS-SE,
Mr. Oden
Mr. Umberger
Mr. Skillman
AMCLD-TA,
Dr. Gonano
LTC Schmidt
AMCLD-PL, Dr. Weinberger
2800 Powder Mill Road
Adelphi, MD 20783-1145

4 Commander
U.S. Army Armament Research,
Development, and Engineering Center
ATTN: SMCAR-AEE-WW,
Pai Lu
N. Slagg
J. Pearson
B. Fishburn
Picatinny Arsenal, NJ 07806-5000

1 Commander
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

No. of Copies Organization

1 Director
U.S. Army Air Mobility R&D Laboratory
ATTN: Technical Library
21000 Brookpark Road
Cleveland, OH 44135

1 Director
U.S. Army Air Mobility R&D Laboratory
ATTN: Technical Library
Fort Eustis, VA 23604

16 Commander
U.S. Army Belvoir RD&E Center
ATTN: Technical Library
STRBE-N, Heberlein
STRBE-NA, Weaver
STRBE-BLORE (3 cys)
STRBE-CFLO (3 cys)
STRBE-NE (4 cys)
STRBE-ND, Spitzer
STRBE-NDM, Dillon
STRBE-D, LTC Rose
Fort Belvoir, VA 22060-5606

3 Commander
U.S. Army Nuclear and Chemical Agency
ATTN: MONA-NU (2 cys)
MONA-CM
7500 Backlick Road (B2073)
Springfield, VA 22150-3198

1 Commander
U.S. Army Dugway Proving Ground
ATTN: Technical Library
Dugway, UT 84022

2 Commander
U.S. Army Missile Command
ATTN: AMSMI-RR, Mr. Lively
AMSMI-YLB, Mr. Gee
Redstone Arsenal, AL 35898-5010

1 Director
Missile & Space Intelligence Center
ATTN: AIAMS-YDL
Redstone Arsenal, AL 35898-5500

No. of Copies	Organization
2	Commander U.S. Army Ballistic Missile Defense Systems Command ATTN: M. Whitfield Technical Library P.O. Box 1500 Huntsville, AL 35807-3801
3	Commandant U.S. Army Engineer School ATTN: Technical Library MAJ Davis CPT Blanchard Fort Leonard Wood, MO 65473
1	Commander U.S. Army Armor Center ATTN: Technical Library Fort Knox, KY 40121
2	Commander U.S. Army Concepts Analysis Agency ATTN: Technical Library M. Ogorzalek 8120 Woodmont Ave. Bethesda, MD 20814
1	Commander U.S. Army Operational T&E Agency ATTN: Technical Library 5600 Columbia Pike Falls Church, VA 22041
5	Commander U.S. Army Foreign Science and Technology Center ATTN: C. Ward T. Reeder G. Goodwin CPT Whitworth Technical Library 220 7th St., NE Charlottesville, VA 22901-5396
1	Project Manager Armored Future Artillery Systems ATTN: LTC Ellis Picatinny Arsenal, NJ 07806
1	U.S. Army Corps of Engineers Omaha District ATTN: Dale Nebuda Mail Code CEMRO-ED-SH 215 N. 17th St. Omaha, NE 68102-4978
1	Commander, USACECOM R&D Technical Library ATTN: ASQNC-ELC-IS-L-R, Myer Center Fort Monmouth, NJ 07703-5000
1	Commander U.S. Army Intelligence & Security Command Ground Combat Division Arlington Hall Station, VA 22212
1	Commander U.S. Army Training & Doctrine Command ATTN: Technical Library Fort Monroe, VA 23651
2	Commander U.S. Army Combined Arms Combat Development Activity ATTN: Technical Library R. Clarke Fort Leavenworth, KS 66077-5300
1	Commander U.S. Army Field Artillery Center ATTN: Technical Library Fort Sill, OK 73503
1	Commander U.S. Army Natick R&D Laboratories ATTN: Technical Library Natick, MA 01760
2	Commander U.S. Army Harry Diamond Laboratories ATTN: SLCHD-TI SLCHD-NW-TN, E. Fioravante 2800 Powder Mill Road Adelphi, MD 20783-1197

No. of Copies	Organization
2	Project Manager Mines, Countermine and Demolitions ATTN: Mr. Rosamilia Mr. Tworkoski Picatinny Arsenal, NJ 07806-5000
1	Director HQ, TRAC RPD ATTN: ATCD-G, M. Pastel Fort Monroe, VA 23651
1	DCNO (NAV) ATTN: NOP-741D Washington, D.C. 20310
2	ACNO (AIR) ATTN: NOP-50M/-502 Washington, D.C. 20310
4	NAVAIRSYSCOM ATTN: NAIR-214G NAIR-526/5261 NAIR-540TF, D. Magnelli Washington, D.C. 20361-5400
1	Commander Naval Sea Systems Command ATTN: Technical Library Washington, DC 20362-5101
2	Commander Naval Surface Warfare Center ATTN: Technical Library J. Brown Dahlgren, VA 22448-5000
1	Commander Naval Research Laboratory ATTN: Technical Library Washington, DC 20375
1	Commander Naval Air Test Center Patuxent River, MD 20670-5199
1	Commander Naval Weapons Support Center ATTN: Technical Library Crane, IN 47522
1	Director Office of Naval Research 800 Quincy St. Arlington, VA 22217
3	Commander Naval Surface Warfare Center ATTN: T. Liddiard M. Swisdak Technical Library Silver Spring, MD 20903-5000
9	Commander Naval Weapons Center ATTN: L. Josephson C. Glass L. Perkins L. Allen D. Herigstad A. Lopez T. Yee LCDR Barr Technical Library China Lake, CA 93555-6001
1	Officer-In-Charge Naval EOD Facility ATTN: Technical Library Indian Head, MD 20640
4	Commander Naval Coastal Systems Center ATTN: R. Denton C. Wicke MAJ Cutchall Technical Library Panama City, FL 32407
1	Naval Air Development Center ATTN: Technical Library Warminster, PA 18974
1	Superintendent Naval Post Graduate School ATTN: Technical Library Monterey, CA 93940

No. of Copies	Organization
1	President Naval War College ATTN: Technical Library Newport, RI 02840
1	Commander David W. Taylor Naval Ship R&D Center ATTN: Technical Library Bethesda, MD 20084-5000
1	Commander Naval Ship R&D Center ATTN: Technical Library Portsmouth, VA 23709
1	Commander Naval Weapons Evaluation Facility ATTN: Document Control Kirtland AFB, NM 87117-5000
3	Commander USMC Combat Development Command MAGTF/Warfighting Center ATTN: COL Quinn MAJ Breithaupt LTC Schlaicht Quantico, VA 22134-5001
2	Commander Marine Corps RD&A Command ATTN: D. Vaughn Technical Library Quantico, VA 22134-5080
3	HQ, USMC DCS AV ATTN: APP-3/-1/-21 Washington, D.C. 20310
1	Commander 2nd Marine Aircraft Wing Marine Corps Air Station Cherry Point, NC 28533-5079
1	HQ USAF (LEYW) Washington, DC 20330
1	USAF Systems Command ATTN: Technical Library Andrews AFB, MD 20334

No. of Copies	Organization
2	AFWL ATTN: Mr. Lokaj LTC Bierck Kirtland AFB, NM 87117-6008
2	Commander Field Command, DNA ATTN: CPT Smith LCDR Taylor Kirtland AFB, NM 87115-5000
2	HQ TAC ATTN: LGWME DRPS Langley AFB, VA 23365
1	AFESC/RDC ATTN: Technical Library Tyndall AFB, FL 32403
1	AFOSR ATTN: Technical Library Bolling AFB, DC 20332
1	AFTC ATTN: Technical Library Patrick AFB, FL 32925
1	Arnold Engineering Development Center ATTN: Technical Library Arnold AFB, TN 37389
1	Ogden ALC/MMWRE ATTN: Mr. Comins Hill AFB, UT 84056
6	Air Force Armament Laboratory ATTN: AFTAWC (OC) DLYV, Mr. McGuire DLJW, G. Parsons J. Foster Technical Library Eglin AFB, FL 32542-5000
2	AFSC Foreign Technology Division ATTN: J. Carbonell P. Levels Wright-Patterson AFB, OH 45433

No. of Copies	Organization
2	AFFTC ATTN: FTFST FTFBW Edwards AFB, CA 93523
4	AFTC ATTN: Technical Library AF/XOXFT AF/XOXFM AF/SAMI Washington, DC 20310
1	SAMSO (Library) P.O. Box 92960 Los Angeles, CA 90009
2	Commander Air National Guard 175th Tac Fighter Grp Glenn L. Martin Airport, MD 21220
1	Director NASA-Marshall Space Flight Center ATTN: Technical Library Huntsville, AL 35812
1	Director NASA-Lewis ATTN: Technical Library 21000 Brook Park Road Cleveland, OH 44135
1	Director NASA-Goddard Space Flight Center ATTN: Technical Library Greenbelt, MD 20771
1	Director NASA-Science Technical Information Facility P.O. Box 8757 BWI Airport Baltimore, MD 21240
1	Director NASA-Langley Research Center ATTN: Technical Library Hampton, VA 23365
1	Director Los Alamos National Laboratory ATTN: Technical Library P.O. Box 1663 Los Alamos, NM 87545
10	Director Sandia National Laboratories ATTN: Information Distribution Division R. Ostensen M. Berman R. Braasch A. Snyder M. Sagartz J. Kelsey M. Newsom M. Lieberman S. Tieszen P.O. Box 5800 Albuquerque, NM 87185
1	Director Lawrence Livermore National Laboratory ATTN: Technical Library P.O. Box 808 Livermore, CA 94550
1	Oak Ridge National Laboratory ATTN: Technical Library P.O. Box X Oak Ridge, TN 37830
4	CIA ATTN: OCR DSD SD J. Backofen Washington, DC 20505
1	Director Institute for Defense Analyses ATTN: Technical Library 1801 Beauregard St. Alexandria, VA 22311

No. of
Copies Organization

1 AAI Corporation
ATTN: Technical Library
P.O. Box 126
Hunt Valley, MD 21030-0126

2 Aberdeen Research Center
ATTN: J. Keefer
N. Ethridge
P.O. Box 548
Aberdeen, MD 21001

1 Advanced Technology Research
ATTN: H. Mair
3933 Sandy Spring Road
Burtonsville, MD 20866

1 Aerospace Corporation
ATTN: Technical Library
P.O. Box 92957
Los Angeles, CA 90009

4 Alliant Techsystems, Inc.
ATTN: R. Gartner
R. Meyer
R. Rentfrow
Technical Library
5901 Lincoln Drive
Edina, MN 55436

1 Director
Applied Physics Laboratory
ATTN: Technical Library
John Hopkins Road
Laurel, MD 20707

3 Atlantic Research Corporation
ATTN: E. McHale
R. Fry
Technical Library
5390 Cherokee Ave.
Alexandria, VA 22314

3 Battelle
ATTN: TACTEC Library
J. Huggins
M. Golovin
505 King Ave.
Columbus, OH 43202-2093

No. of
Copies Organization

2 BDM Corporation
ATTN: W. Baum
Technical Library
7915 Jones Branch Drive
McLean, VA 22102

1 Brunswick Corporation
ATTN: Technical Library
3333 Harbor Blvd.
Costa Mesa, CA 92626

1 California Research & Technology, Inc.
ATTN: Technical Library
29043 Devonshire St.
Chatsworth, CA 91311-2376

1 Center for Naval Analyses
ATTN: Technical Library
P.O. Box 16268
Alexandria, VA 22302-0268

1 Chamberlain Manufacturing Corporation
ATTN: J. Heckman
550 Esther Office
Waterloo, IA 50704

3 Denver Research Institute
ATTN: L. Brown
J. Wisotski
Technical Library
P.O. Box 10758
Denver, CO 80210

2 FMC Corporation
ATTN: Technical Library
W. Seele
1105 Coleman Ave.
San Jose, CA 95108

1 Franklin Research Center
ATTN: Technical Library
Benjamin Franklin Parkway
Philadelphia, PA 19103

No. of Copies	Organization
1	General Dynamics ATTN: Technical Library P.O. Box 2507 Pomona, CA 91769
1	Geo-Centers, Inc. 7 Wells Ave. Newton Centre, MA 02159
1	H. L. Murphy Associates P.O. Box 1727 San Mateo, CA 94401
1	H-Tech Laboratories, Inc. ATTN: B. Hartenbaum P.O. Box 1686 Santa Monica, CA 90406
4	IIT Research Institute ATTN: A. Tulis R. Remaly J. Austing Technical Library 10 West 35th St. Chicago, IL 60616
1	Interstate Electronics ATTN: H. Benefiel 1001 E. Ball Rd. Anaheim, CA 92803
1	Kaman-AviDyne ATTN: Dr. Raffi Northwest Industrial Park 83 Second Ave. Burlington, MA 01803
1	Kaman-Nuclear ATTN: Technical Library 1500 Garden of the Gods Road Colorado Springs, CO 80907
1	Machine Design Engineers ATTN: M. Fitz 714 S. Homer St. Seattle, WA 98108
1	Management Science Associates ATTN: K. Kaplan P.O. Box 239 Los Altos, CA 94022
1	Mason & Hanger-Silas Mason Co., Inc. Pantex Plant P.O. Box 647 Amarillo, TX 79117
1	McDonnell Douglas Astronautics Corp. ATTN: Technical Library 5301 Bolsa Ave. Huntington Beach, CA 92647
2	McDonnell Douglas Hornet Tales P.O. Box 4105 Hazelwood, MD 63042
1	Napadensky Energetics, Inc. 650 Judson Ave Evanston, IL 60202-2551
1	Physics International 2700 Merced St. San Leandro, CA 94577
1	The Rand Corporation ATTN: Technical Library P.O. Box 2138 Santa Monica, CA 90401-2138
2	R&D Associates ATTN: Technical Library J. Carpenter P.O. Box 9695 Marina del Rey, CA 90291
1	R&D Associates ATTN: Technical Library P.O. Box 9335 Albuquerque, NM 87119
1	Research Analysis & Management Corp. 2341 Jefferson Davis Hwy Arlington, VA 22202

No. of
Copies Organization

1 Rolls-Royce, Inc.
ATTN: Technical Library
11911 Freedom Drive
Reston, VA 22090

2 Science Applications, Inc.
ATTN: W. Grossman
T. Wing
1710 Goodridge Drive
McLean, VA 22102

2 Science Applications, Inc.
ATTN: Woodrow Wilson
Technical Library
P.O. Box 2351
La Jolla, CA 92038

1 S-Cubed
ATTN: C. Needham
P.O. Box 8243
Albuquerque, NM 87198

3 S-Cubed
ATTN: Technical Library
R. Sedgwick
T. Pierce
P.O. Box 1620
La Jolla, CA 92037

1 Southwest Research Institute
ATTN: Technical Library
P.O. Drawer 28510
San Antonio, TX 78284

1 SRI International
ATTN: Technical Library
333 Ravenswood Ave.
Menlo Park, CA 94025

1 Teledyne McCormick Selph
ATTN: C. Garrison
P.O. Box 6
Hollister, CA 95023-0006

2 TERA
New Mexico Institute of Technology
ATTN: Technical Library
P. McClain
Socorro, NM 87801

No. of
Copies Organization

1 Mr. Ray Thorkildson
Suite 907
1911 N. Fort Myer Drive
Arlington, VA 22209

1 Wackenhut Advanced Technology
10530 Rosehaven St.
Suite 500
Fairfax, VA 22030

1 Wilfred Baker Engineering
P.O. Box 6477
San Antonio, TX 78209

1 Dr. D. R. Richmond
3006 Hyder, S. E.
Albuquerque, NM 87016

No. of Copies	Organization
	Aberdeen Proving Ground
2	Cdr, USACSTA ATTN: STECS-AE-TL, Bindel STECS-AE-TH, Wiley
2	Cdr, HEL ATTN: SLCHE-CS, Haduch Technical Library
1	Cdr, AEHA, Bldg E2100
2	Cdr, USAOC&S ATTN: Technical Library ATSL-CD-CS
8	Dir, USAMSAA ATTN: AMXSY-GB, Abel AMXSY-S, Carroll AMXSY-GC, B. Bramwell L. Meredith W. Wiederman A. Wong LTC Hassall JTCG-ME, LaGrange
1	Cdr, AMCCOM ATTN: SMCAR-ACW Weapons Systems Concept Team Bldg. E3516
6	Cdr, USATECOM ATTN: AMSTE-SI-F AMSTE-CL, MAJ Neil AMSTE-ML, LTC Mayer AMSTE-TE-V AMSTE-EV-O AMSTE-TA-F
1	Cdr, USATHAMA ATTN: AMXTH-TE
1	Cdr, 149th Ord Detachment (EOD), Bldg E4220

No. of Copies	Organization
1	British Defense Staff Washington 3100 Massachusetts Ave., NW Washington, DC 20008
1	Canadian Defense Liaison Staff 501 Pennsylvania Ave., NW Washington, DC 20001
5	National Defense Headquarters ATTN: DMER-5, MAJ Worral DMER-5-3, CPT Rutkay DRDL-7, Mr. Schmittke DCMEM-4, LTC Focsaneanu Mr. Lines MGEN George R. Pearkes Bldg. Ottawa, Ontario K1A OK2
1	Operational R&A Establishment Military Stores Bldg. ATTN: Ms. K. Reece Queen Elizabeth Drive Ottawa, Ontario KOA 1CO
3	Defense Research Establishment Suffield Shock and Blast Group Ralston, Alberta TOJ 2NO
1	British Aerospace Defence Richmond Road Kingston-Upon-Thames Surrey, England KT2 5QS
1	Mining Resource Engineering Limited 1555 Sydenham Road, R.R. #8 Kingston, Ontario K7L 4V4
1	National Defense Research Establishment ATTN: H. Axelsson P. O. Box 551 S-147 25 Tumba, Sweden

USER EVALUATION SHEET/CHANGE OF ADDRESS

This laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers below will aid us in our efforts.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) ______________________________

2. How, specifically, is the report being used? (Information source, design data, procedure, source of ideas, etc.) ______________________________

3. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. ______________________________

4. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) ______________________________

BRL Report Number BRL-TR-3356 Division Symbol ________

Check here if desire to be removed from distribution list. ____

Check here for address change. ____

Current address: Organization ________
Address ________

DEPARTMENT OF THE ARMY
Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

OFFICIAL BUSINESS

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT No 0001, APG, MD

Postage will be paid by addressee.

Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066