MINEFIELD RECONNAISSANCE AND DETECTOR (MIRADOR)

UTILITY STUDY

FINAL TECHNICAL REPORT

SEPTEMBER 1989

Prepared for The

U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER

By

Stanley R. Johnson, Champlin F. Buck,
Robert D. Carpenter, Nicholas M. Smith, Charles A. Allen, et al

Wackenhut Advanced Technology Corporation

10530 Rosehaven St, Suite 500

Fairfax, VA 22030

(703) 359-9000

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

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Field	Entry
1a. REPORT SECURITY CLASSIFICATION	Unclassified
1b. RESTRICTIVE MARKINGS	N/A
2a. SECURITY CLASSIFICATION AUTHORITY	N/A
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	N/A
3. DISTRIBUTION / AVAILABILITY OF REPORT	Unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	DAAK70-88-D-0015, Task 0004
5. MONITORING ORGANIZATION REPORT NUMBER(S)	N/A
6a. NAME OF PERFORMING ORGANIZATION	Wackenhut Advanced Technologies Corporation
6b. OFFICE SYMBOL (If applicable)	
6c. ADDRESS (City, State, and ZIP Code)	10530 Rosehaven Street, Suite 500 Fairfax, Virginia 22030
7a. NAME OF MONITORING ORGANIZATION	DCASMA Baltimore
7b. ADDRESS (City, State, and ZIP Code)	200 Towsontown Blvd. Towson, Maryland 21204
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	USA BRDEC
8b. OFFICE SYMBOL (If applicable)	STRBE-ND
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	DAAK70-88-D-0015, Task 0004
8c. ADDRESS (City, State, and ZIP Code)	Fort Belvoir, Virginia 22060

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

Minefield Reconnaissance and Detector (MIRADOR) Utility Study

12. PERSONAL AUTHOR(S)

S.R. Johnson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Apr 89 TO Sep 89	September 1989	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Mine Detection; Human Factors Evaluation; Countermine Systems; Effectiveness Evaluation

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

The purpose of this study is to gain insight into the comparative utility of the MIRADOR in multiple combat zone roles.

This study of MIRADOR utility encompasses a review of mine detection history, an analysis of the role of mine and minefield detection, wargaming the utility of four mine detectors in each of four situations (pursuit, hasty attack, deliberate attack, and MSR clearance), human factors, maintenance, and time-phased analysis of mine detection capabilities, culminating in a summary assessment.

The study analyzed the search patterns needed in both conventional and scattered minefield situations to determine desirable detection and false alarm parameters of a mine detector. A computer model was used to determine the impact to a supported force of having each of four detectors (the mine probe, the hand held AN/PSS-11, the tank-mounted mine roller, and the

Cont.:

Field	Entry
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS
21. ABSTRACT SECURITY CLASSIFICATION	Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	Brad Spitznogle
22b. TELEPHONE (Include Area Code)	(703) 664-4458
22c. OFFICE SYMBOL	STRBE-HP

MIRADOR) in support during various tactical situations. A Delphi approach was used to assess the human factors involved in use of each of the same four detectors. Literature research was used in the maintenance and time-phased analysis portions.

The principal findings of the report were that: (a) There is broad utility for a small, agile remotely controlled mine detector; (b) The MIRADOR offers the potential to significantly improve the detection capabilities available to the field commander, with the amount of improvement varying by employment role, and; (c) The initially fielded MIRADOR should be built with demanding, but achievable, detection and false alarm standards, recognizing that future block improvements can be applied as hardware and software improvements become available.

STUDY GIST

TROSCOM

MINEFIELD RECONNAISSANCE AND DETECTOR (MIRADOR) UTILITY STUDY

1. Principal Findings.

a. There is broad utility for a small, agile remotely controlled mine detector.

b. The MIRADOR offers the potential to significantly improve the detection capabilities available to the field commander, with the amount of improvement varying by employment role.

c. The initially fielded MIRADOR should be built with demanding, but achievable, detection and false alarm standards, recognizing that future block improvements can be applied as hardware and software improvements become available.

2. Main Assumptions.

a. The MIRADOR will be used as both a MINE detector and as a MINEFIELD detector.

b. The performance of the fielded MIRADOR for detection of actual mines and rate of false alarms will be equal to or better than that specified in the requirements documents and test plans.

c. The MIRADOR will be used in multiple roles from support of attacking forces to detection of mines on main supply routes.

3. Principal Limitations.

a. Resolution of available mine warfare wargaming programs does not allow the simultaneous addressal of actions involving individual mines and the warfighting activities of individual combat vehicles in a Battalion Task Force. Therefore, some generalized probabilities were used in the study.

b. Because the MIRADOR has not reached final configuration status, certain logistics and operational capabilities modeled may be different from those of the eventual production vehicle.

4. Scope of Effort.

This study of MIRADOR utility encompasses a review of mine detection history, an analysis of the role of mine and minefield detection, wargaming the utility of four mine detectors in each of four situations (pursuit, hasty attack, deliberate attack, and

MSR clearance), human factors, maintenance, and time-phased analysis of mine detection capabilities, culminating in a summary assessment.

5. Objectives.

The objective of the study was to gain insight into the comparative utility of the MIRADOR in multiple combat zone roles.

6. Basic Approach.

The study analyzed the search patterns needed in both conventional and scattered minefield situations to determine desireable detection and false alarm parameters of a mine detector. A computer model was used to determine the impact to a supported force of having each of four detectors (the mine probe, the hand held AN/PSS-11, the tank-mounted mine roller, and the MIRADOR) in support during various tactical situations. A Delphi approach was used to assess the human factors involved in use of each of the same four detectors. Literature research was used in the maintenance and time phased analysis portions.

7. Reason for Performing the Study.

To provide insights into the mine detection problem and gain knowledge on the cost and utility of the MIRADOR compared to other detection options available to the field commander.

8. Impact of the Study.

The study will aid in reaching difficult decisions on the allocation of development and procurement funds.

9. Sponsor.

U. S. Army Belvoir Research Development and Engineering Center.

10. Principal Investigator.

Stanley R. Johnson, Wackenhut Advanced Technologies Corporation (WATCO).

11. Address when questions and comments can be sent:

Wackenhut Advanced Technologies Corporation
Suite 500, 10530 Rosehaven St
Fairfax, Virginia 22030

12. DTIC/DLSIE Accession Number of Final Report.

To be assigned.

TABLE OF CONTENTS

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. PURPOSE

The purpose of this study is to review the Army minefield reconnaissance and detection requirements as well as to determine the potential configuration and utility of an advanced Minefield Reconnaissance and Detector (MIRADOR) system designed to satisfy an urgent need in both low and high intensity environments.

2. FACTS

The MIRADOR is undergoing an accelerated development process. Ultimately MIRADOR is projected to be a highly mobile, remotely operated mine/minefield detection system which can precede ground combat forces across a battlefield, and mine clearing teams in rear areas, detecting, reporting and marking the locations of mines and minefields. The system specifications call for it to detect mines/minefields at speeds in consonance with modern combat systems.

In its ultimate configuration, the MIRADOR will be capable of remote control operation to enhance human operator survivability. It will be required to detect metallic and non-metallic mines, both on and off roads, in conventional and scattered patterns.

The specifications for the MIRADOR are contained in a 1984 Operation and Organization Plan published by the US Army Engineer School and approved by Headquarters, Training and Doctrine Command. Subsequently an Initial Evaluation Plan was published by the Engineer School in 1988 which further established the desired performance specifications of the detector.

The key specifications which define the performance objectives for the MIRADOR are:

Category	Performance Objectives
Sweep head width -	4-8 feet (1.22-2.44 meters) based on current configuration
Detection Rate -	90% of surface mines on roads 80% of surface mines off roads 70% of buried mines on & off roads

Category	Performance Objectives
False Alarm Rate -	1 per 1000 square feet, surface mines on roads 3 per 1000 square feet, surface mines off roads 5 per 1000 square feet, buried mines on & off roads

An initial proof of principal prototype was fabricated and underwent partial testing. A reconfigured version has been built which will improve durability and performance. A technical demonstration of the improved vehicle is planned for the second half of CY 1989.

3. DISCUSSION

A. Methodology.

Mine detection is one of the Army's most difficult and long-standing problems. Determining the utility of a prototype detector, using the O&O plan and IEP specifications, called for a multi-faceted methodology. That methodology was derived from the qualities which an effective mine detector should possess.

- The detector must first encounter the mine, detect it, and report the mine's existence to the supported force.
- The detector must function well with the humans who operate and maintain it.
- The detector must be effective in supporting both the combined arms team and rear area support forces.

Therefore the first step in the methodology was the assessment of the MIRADOR's ability to encounter sufficient mines to determine the existence of a minefield, and given sufficient encounters, the reasonableness of the specified detection and false alarm rates.

The second step was to assess the utility of MIRADOR and three existing detection systems (the Probe, the AN/PSS-11 hand held detector, and the M-1 tank mounted Mine Roller). The four mine detection systems were compared in several tactical scenarios involving a US Tank Battalion Task Force attacking a Soviet Reinforced Motorized Rifle Company in a European setting. The comparison was based on results of a computerized wargaming model, the Differential Combat Model (DCM).

The third step involved an assessment of three supporting subjects. The first was a Delphi assessment of Human Factors considerations while the operator was performing twelve tasks common to all detectors. This assessment was undertaken for each of the four detectors. Secondly, an assessment of the maintainability and logistics implications using surrogate equipment and professional experience was accomplished. Finally, an assessment was made of ccncepts and technologies currently in the tech base or early development phase of Research and Development to see if anything in the development process would impact the utility of MIRADOR throughout the remainder of this century.

Finally, the information gathered in the several steps was assembled and evaluated, resulting in conclusions and recommendations.

B. Analysis

The analysis of the encounter, detection and reporting functions showed that

- Detection errors are either of two types; failure to detect and false detections.
- There must be a threshold ratio of false alarms to true detections.
- Encounters in conventional minefields can be enhanced by entering the minefield at an angle to the front row.
- The fact that remotely delivered scattered minefields are much less dense (even though mines per meter of front may be similar), exacerbates the false alarm problem.

The force-on-force analysis placed the detectors in support of forces in four different scenarios

- A hasty attack against a Threat hasty three-row minefield.
- Reconnaissance prior to a deliberate attack against an increasing Threat defensive position protected by three bands, each consisting of five rows of mines (4 AT, 1 AP).

- An attack through a remotely delivered scatterminefield.

- Mine detection support to a critical resupply convoy.

4. RESULTS

The results of the analysis showed that the specifications for the MIRADOR are insufficient to assure an effective detector for all the situations presented.

- The width of the search head has a significant impact on the vehicle utility. If the swept area is less than the width of following vehicles, multiple passes or multiple vehicles are needed.

- The detection rate needs to be as high as possible since the number of encounters with mines are very limited.

- The false alarm rate must be no greater than the expected density of the minefield expected to be encountered. For scatter minefields the improvement may need to be as high as two orders of magnitude over the current values specified for the system.

The tactical situations assumed that the MIRADOR concept could be developed to overcome the detection and false alarm problems. The resulting analysis yielded the following combat vehicle losses. It is important to note that personnel losses are not included in the chart.

DETECTOR	COMBAT VEHICLE	SCENARIO A SCATTER MINES	SCENARIO B HASTY MINEFIELD	SCENARIO C DELIBERATE	VEHICLE TOTAL	TOTAL
PROBE	M1	25.6	11.1	30.0	166.6	230.6
	M2/3	23.9	14.1	26.0	64.0	
AN/PSS-11	M1	25.9	10.3	30.0	65.9	127.9
	M2/3	23.9	12.1	26.0	62.0	
ROLLER	M1	21.6	9.8	17.5	48.9	87.0
	M2/3	22.2	11.0	16.5	49.7	
MIRADOR	M1	23.5	9.8	9.7	43.2	87.0
	M2/3	23.5	11.0	9.3	43.8	

The analysis resulted in the following observations being reached:

- The spacing between mines in remotely delivered scattered minefields permits MIRADOR to be used to locate mine-free paths for attacking forces.
- The MIRADOR is as effective as the Roller in minimizing combat vehicle losses in a hasty attack situation, and introduces less direct fire exposure to dismounted troops.
- In a deliberate attack of a complex obstacle where pre-attack reconnaissance is critical, the MIRADOR concept has distinct advantage over the available detection systems.
- The MIRADOR's search speed offers the capability to fill the void now existing for sweeping long linear paths such as Lines of Communication/Main Supply Routes.
- MIRADOR has the capability to offer a mine detection solution which has promise in all phases of tactical usage.

In terms of Human Factors, the MIRADOR is expected to make total demands on human operators about equivalent to current systems, but the types of demands are different. Less stress and physical demands are offset by increased skill requirements and training effort. The ability to control the detection effort and communicate findings is expected to improve with MIRADOR.

There is more difficulty in projecting maintenance and supply involving this system which is still in the prototype stage. The introduction of the MIRADOR seems to have little net impact on the logistics system.

There are no countermine systems, other than MIRADOR, emerging in the R&D system that will reach fielded status within the decade. When a stand-off system is fielded, it will complement MIRADOR's ground detection.

5. FINDINGS

There is broad utility for a small, agile remotely controlled mine detector.

The MIRADOR offers the potential to significantly improve the detection capabilities available to the field commander, with the amount of improvement varying by employment role.

The initially fielded MIRADOR should be built with demanding, but achievable, detection and false alarm standards, recognizing that future block improvements can be applied as hardware and software improvements become available.

CHAPTER I

INTRODUCTION

A. PURPOSE

The purpose of this study is to review the Army minefield reconnaissance and detection requirements and capabitlities to determine the potential configuration and utility of an advanced Minefield Reconnaissance and Detector (MIRADOR) system to satisfy an urgent need in both low and advanced intensity environments. The study will be used by components of the Army Materiel Command and the Training and Doctrine Command in program acquisition planning.

B. BACKGROUND

The MIRADOR system is undergoing an accelerated development process. Ultimately, MIRADOR is projected to be a highly mobile, remotely operated Mine/ Minefield detection system which can precede ground combat forces across a battlefield, and mine clearing teams in rear areas, detecting, reporting and marking the locations of mines and minefields. The system specifications call for it to dectect mines/minefields at speeds in consonance with modern combat systems.

The MIRADOR will be capable of remote control operation to enhance human operator survivability. It will be able to detect metallic and non-metallic mines, both on and off roads, whether emplaced by conventional or remote employment techniques.

MIRADOR will be mounted on or used with organic tactical vehicles which are capable of cross-country movement commensurate with the supported combat maneuver force. As presently concieved, MIRADOR will be either a self-contained self propelled system, remotely controlled from a parent vehicle, or employed on organic TOE vehicles which are modified to be operated in a remote control mode.

A Proof-of-principle prototype has been fabricated. Initial testing attempts in July 1988 at Aberdeen Proving Grounds, MD were cancelled due to numerous technical problems. A modified prototype is being fabricated to eliminate the hardware and software problems of the initial design. A technical demonstration of the redesigned vehicle is scheduled for 4QTR89.

C. DEVELOPMENT PROGRAM APPROACH

The MIRADOR development approach will be to produce an initial vehicle capable of responding to the immediate need for an improved detection capability on road, airfield, landing zone, and other such relatively flat surface areas. As the technology further develops and the system architecture matures, the MIRADOR system will evolve through preplanned product improvements to respond to the full requirement for an on and off road mine detection system.

D. ESSENTIAL ELEMENTS OF ANALYSIS

To assess the utility of the MIRADOR, certain key questions have to be answered. Those key questions form the Essential Elements of Analysis (EEA). The EEA are:

1. What is the utility of a small, agile, highly reliable, remotely controlled mine/minefield detector which can operate in conjunction with a combined arms team, with relative impunity in a mine warfare environment?

2. Can MIRADOR, as currently defined and specified, fulfill the role envisioned in the foregoing utility definition?

3. If MIRADOR has shortcomings, how can they be corrected or accomodated to fulfill the utility role?

E. METHOD OF ANALYSIS.

This study will use the approach shown in Figure I-1.

Initially an analysis will be conducted regarding the problem common to all detectors of encountering, detecting and accurately reporting sparsely distributed mines.

The existing mine detection equipment available to the U.S. Army will be identified for use in comparing the utility of the MIRADOR system. A brief analysis will be performed on the existing and projected mine detection capability compared to the equipment, mission, and threats expected between 1990 and the end of the century.

The mine detection equipment will be analyzed for utility to the combat forces in selected wartime scenarios using a computer wargame model. The Human Factors relating to operation of the system will be assessed. A Logisitics Evalaution, focused on maintenance and resupply factors, will be conducted.

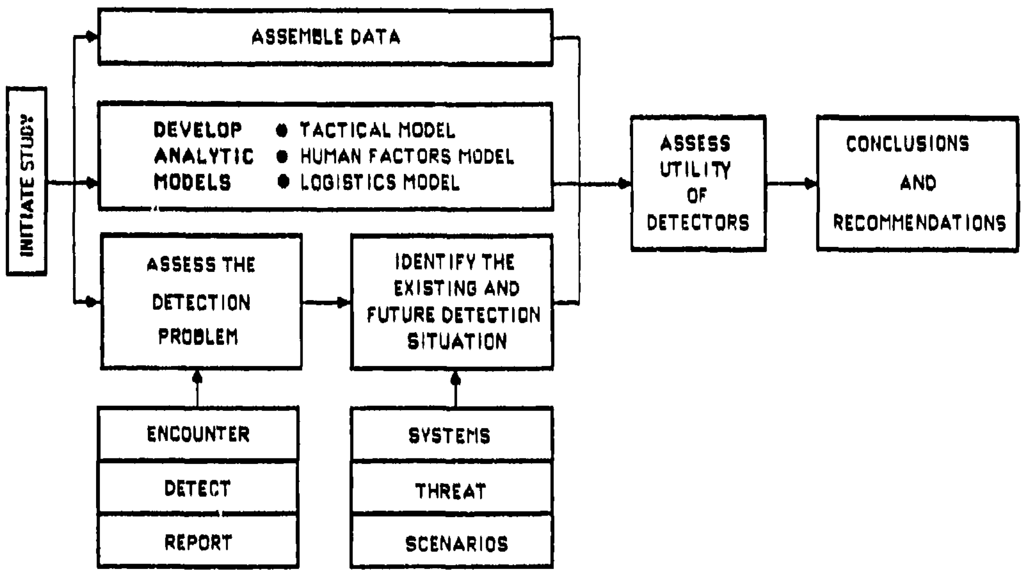


Figure I-1. Study Approach.

CHAPTER II

BACKGROUND

A. MINE EVOLUTION

The development of a viable mine/minefield detector capability is extremely important to the U.S. Army. This need is of long standing, and has grown rather than diminished over time.

Mines were first used on the battlefield near the end of WWI in response to the introduction of tanks. One surprise of World War II was the extensive use of large numbers of both antitank and antipersonnel mines by the Axis powers and the swift emulation of this tactic by the USSR during the great defensive battles of 1941-1943.

Mine warfare was adopted by the USSR with unusual enthusiasm and an expertise was developed that was second to none in both mining and countermining. This expertise continues to this day.

The initial threat was primarily in the form of metal cased mines with simple pressure and pull type fuzes for vehicle "mobility kills" and personnel harassment. To counter the mines, the Germans were the first to develop a low frequency, inductive metal detector to use to locate mines. All other combatants developed (or copied) mine detectors of their own.

The sophistication of the mines evolved in reaction to the development of metal detectors. Mines were developed and fielded in quantity with paper, wood, pottery, and plastic cases and fuzed with nonmetallic chemical fuzes. Metal mines remained in use but with a variable number of other types to confound detection.

The Korean war had a major impact on the mine countermeasures program as the tactics employed in "national wars of liberation" made extensive use of random mining to offset the technological advantages of the US. The extremely low densities of this mining defeated detection as a useful response since the false alarm rate slowed clearance to an unacceptable rate.

Heavy mine rollers were employed extensively. However, the rollers were countered by offset fuzes, a tactic which continues throughout the world to the present.

The successful mining tactics of Korea were adopted, extended, and intensified in Southeast Asia with the result that enormous manpower and equipment losses were inflicted on the US forces. U.S. forces came to expect random mining on every road, bridge, culvert, landing zone, and railraod line in all areas of the country.

In Vietnam, mines were usually booby trapped and frequently employed offset fuzes or were command detonated. Trails were often booby trapped and extensively mined with trip wire devices based on captured or discarded US equipment. Both the psychological and logistical impact of these tactics were enormous and resulted in the diversion of a large part of available US resources.

Recent trends in the concepts of mine warfare have been toward use of surface minefields as effective flank protection during offensive maneuvers as well as a quick and effective way to achieve disengagement during tactical withdrawals. Perhaps the greatest potential change in mine warfare of this century is in the concept of remotely deliverable, complex fuzed mines which can be used as both an offensive and defenisive weapon.

An attacker may use scatterable mines to isolate an area of the battlefield from reinforcement and enable him to break through before the defender can react. A defender may use scatterable mines to prevent the attacker from rapidly concentrating for a breakthrough, and to buy the time needed to shift and prepare his defensive forces.

Today, and in the foreseeable future, the key to US military tactical planning is mobility: mobility of our maneuver forces on the AirLand battlefield; mobility of our combat support elements backing up the combat forces; and mobility of the logistics units to provide the ammunition, food, fuel, maintenance and supply items required to sustain the battle.

B. MINE DETECTION

Mine warfare extended in depth over the battlefield decisively challenges the offensive mobility described above. The U.S. Army has made very little progress in countering the mine threat since World War II. Certainly there has been nothing to match the advances in mining versatility cited above. There are no easy solutions, and proposed programs which fall short of countering every mining situation have failed to gain support.

Faced with a mine threat, the first step in the countermine process is finding the mines or boundaries of the mined area. All further actions, from by-passing the area to a deliberate breaching operation, hinge on knowing where the mines are located.

The first step is detection. Mine detection is everyone's problem and responsibility throughout the battle area. Methods include detection by intelligence sources, anticipation of likely mined areas by mobility planners and actual mine searching.

Intelligence sources provide both general and specific indications of minefield locations. This method of detection relies on available data ranging from staff produced intelligence and reconnaissance reports to remote sensors, aerial photography analysis, side-looking airborne radar, and the quesitoning of POWs and local noncombatants. Any bit of evidence can lead to the location of a scatterminefield or the remote mine interdiction of a supply route.

Detailed terrain analysis and map study by the planning staff can identify likely areas for enemy minefields as well as trafficable routes and transportation networks that could be easily constricted or denied through use of mines. Combined with intelligence data, operational planners can tend to defuse the mine threat before the mines are reached. To actually neutralize mines however, specific locations must be pinpointed by detection.

Visual detection is the oldest and most widely used means of searching for land mines. It requires the visual inspection of the terrain for physical signs of mine emplacement. These signs include disturbed earth, unusual or out-of-place features, surface laid mines, and trip wires. It does not detect well-concealed or camouflaged mines. Visual inspection is generally used in conjunction with all other forms of mine detection.

The second method of mine searching is physical detection, and there are two categories of physical detection: detonation and probing. Discovery by detonation occurs when a vehicle, soldier or countermine system physically encounters a mine. Except for the case of mine rollers, this is generally an unacceptable way to locate mines.

Probing is used to detect the exact location of buried mines. It is done by pushing a sharp rod, probe or bayonet into the ground at an angle to detect solid objects. Probing is slow, careful, tedious work and is very personnel intensive. For a minefield covered by observed fire, it also exposes personnel to enemy fire.

Over the years there have been numerous electronic and electro-optic methods used to detect mines with varying degrees of success. Close-in hand held protable detectors culminated with the Type Classificatoion of the AN/PRS-7 and AN/PSS-11 in 1971 and 1961, respectively. The AN/PRS-8 being developed as a product improvement of the AN/PRS 7 was to be capable of detecting both metallic and non-metallic land mines by sensing density variations in the soil, but both have been removed from the field. The AN/PSS-11 is capable of detecting buried metallic objects to include antitank and antipersonnel mines. A modernized AN/PSS-12 configuration with reduced weight and upgraded electronic components is currently being developed.

Hand held detectors are used by soldiers throughout the battlefield.. During sweep operations, the operator identifies a suspected mine by an audio signal in the headset. The spot is marked and another team member probes for, and if necessary, neutralizes the mine. This is a slow and tedious process. Detector operators are subjected to extreme levels of fatigure and stress, and must be replaced after about twenty minutes.

In 1976, a Required Operational Capability (ROC) was approved for a vehicle mounted road mine detection system. This ROC provides a statement of need as follows:

> *A vehicle-mounted road mine detector system is required for use on the front of any standard wheeled or tracked vehicle which will detect and indicate the location of metallic and nonmetallic mines buried in unpaved roads and in relatively flat, sparsely vegetated areas in the path of the vehicle as it travels along.*

The Vehicle-Mounted Road Mine Detector System (VMRMDS), AN/VRS-5, development program was in response to this requirement.

With very few exceptions, past attempts at developing electromagnetic mine detectors have concentrated on near-field detection. Technical approaches sought to maximize the ratio of target return to average clutter level and to provide sufficient detail for target identification. To this end, a variety of different approaches to mine detection have been tried. These can be classified into seven major approaches: balanced bridge, waveguide beyond cutoff, depolarization, short pulse radar, FM-CW radar, harmonic radar, and computer synthesis of mine imagery. The AN/VRS-5 system uses the waveguide beyond cutoff approach.

In use, the configuration of a detector of this type is that of two dipoles in open cavities connected by a flat metal sheet or septum. One side is used to transmit and one to receive. Experimental observations indicate that when the septum is less than one-half wavelength above the ground, both the direct coupled and ground reflected signals are attenuated must as in a waveguide that is too small or beyond cutoff. This led to the name of the detection method, although more recent literature refers to this approach as the separated aperture technique.

The AN/VRS-5, representing the embodiment of the separated aperture technique, was designed to detect antitank and antivehicular mines up to twelve inches deep in secondary roads and sparsely vegetated terrain.

Technically, the system appeared very promising. However, during Operational Testing, OT-II, at Ft. Knox, KY, the system failed to attain the essential characteristics set forth in the ROC. Basically in an operational environment, the detection rate was too low, the false alarm rate too high, and mechanically the equipment was not robust. The program lost support of the combat development community.

C. MINE DETECTOR DEVELOPMENT PROGRAM

The US Army program for development of improved detectors is pursuing several technical and locational arenas for improvement is mine detection capabilities.

Private industry and the military have developed several effective sensors and have made progress in the development of computer processing. The use of multiple off-the-shelf sensors linked by sophisticated feedback processing capability to identify mines by multiple characteristics, offers a potential for an improved mine detection capability.

It may be possible to use these multiple detectors on the ground directly over the mines, or perhaps well above the minefield in an aircraft. The method of sensing the mines also can be explored. Metal detectors, short pulse radars and infrared sensors may be supplemented by unintentional emissions, x-ray photon backscatter, acoustic/seismic, and other sensors.

In October, 1989, the US Army Belvoir Research Development and Engineering Center published The Countermine Materiel Implementation Plan which sets for the mine detectrion development program. Figure II-1 shows the thrust of the program.

Characteristics of available systems and MIRADOR are discussed in the following sections. Tech base items and how they may affect the future of the mine detection program will be considered in Chapter V.

D. CHARACTERISTICS OF AVAILABLE DETECTORS

1. General.

There is a limited inventory of fielded equipment available to the U.S. Army today for all countermine functions. Furthermore, equipment which is designed to function as a mine detector, or which can be used for that purpose, is very limited. This study will compare existing detection equipment with the MIRADOR. The available mine detectors are the Probe, the Hand-held metallic mine detector, and the mine roller.

COUNTERMINE FUNCTION		FIELDED ITEMS	ITEMS UNDER DEVELOPMENT	ITEMS IN TECH BASE	
				NEXT GENERATION	NOTIONAL SYSTEM
Detect	Standoff			Aerial Detector	Passive Scattermine Det
	Vehicle	Roller	MIRADOR		Imp Veh Det
	Handheld	Handheld Detector		Handheld Detector (Prone)	Man Portable Metallic/Nonmetallic
Breach	Standoff Neut.	Explosive Line Charge		Man Portable Explosive Breacher Improved Disp Expl	Downsized Explosive System
	Organic Close-In	Track Width Blade	VEMASID	Side Attack Neutralizer	Integrated Breacher
Clearing				Energy Clearer Ind. Mine Clearer	Adv. Mine Clearer
Protective Measures				Protective Clothing	
Marking		Clear Lane Marking System			

Figure II-1. Mine Detector Development Program.

2. Probe.

The most basic means of mine detection is the Probe. The Probe can be a specifically designed item of equipment with a non-metallic (i.e., non-magnetic) rod with a handle, it can be a locally fabricated tool, or it can be a bayonet. The operator simply penetrates the ground at an angle to determine if a mine is present in the soil. The effectiveness of the Probe is enhanced by the multiple senses the operator employs. Not only is the sense of touch extended into the ground with the Probe, but the bare forearms, the eyes, the nose and the ears can sense the presence of trip wires, disturbed soil, and other telltale conditions. However, the Probe is very slow and the operator is exposed to mine detonations, aimed fire, indirect fire and NBC threats.

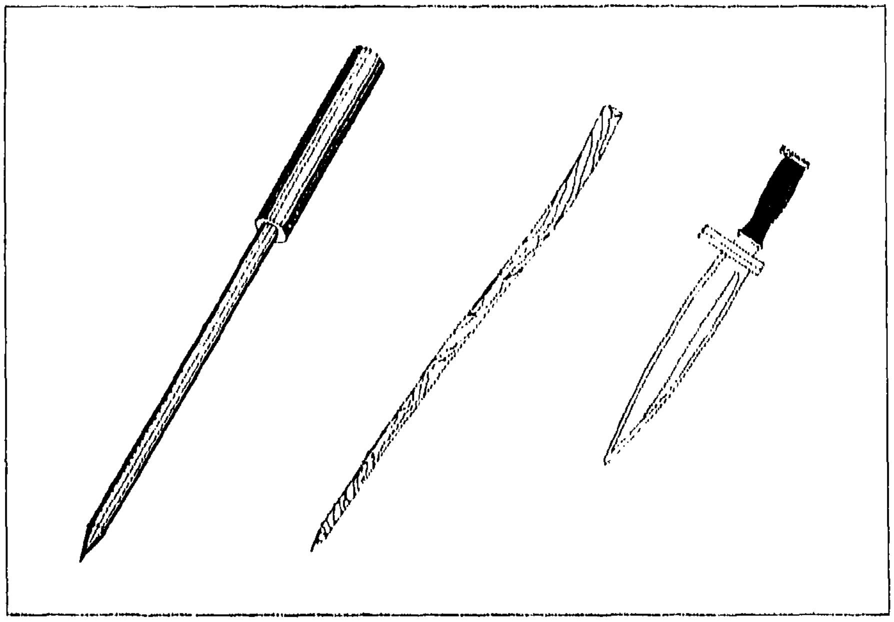


Figure II-2. Mine Probes.

3. Hand-held Mine Detector.

The hand-held metallic mine detector, AN/PSS-11/12 is a close derivative of mine detectors developed during World War II and is only effective against mines with metallic components. The detector is carried by a soldier who swings the detector head over the potentially mined area while listening to earphones which provide tonal feedback for him to evaluate. The degree of concentration required is significant and the operator tires quickly. However, the operator's close proximity to the swept area allows him to use other senses besides hearing to evaluate the potential for mines. The detection effort moves forward at a pace slower than a normal walk, and the cleared area is defined by the dimensions of the back-and-forth sweep, usually 4 feet. The detectors can be employed in an echeloned configuration to provide a wider swept area, however this tactic does not increase the speed.

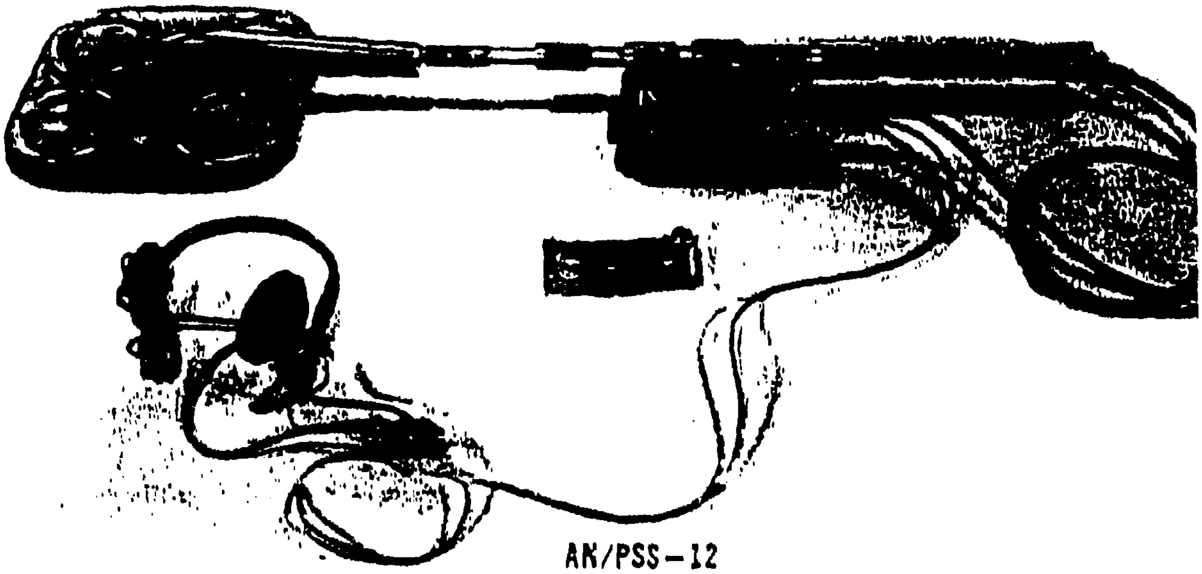


Figure II-3. Hand-Held Mine Detector AN/PSS-12.

4. Tank-Mounted Mine Roller.

Recently deployed to the fielded forces is a countermine set which includes mine plows, mine rollers, and a cleared lane marking system. All of the components of the system are designed to be employed on a tank. The Mine Roller's utility is considered to include duty as a mine detector, mine neutralizer, and cleared lane proofing device. As a detector, the Roller functions by detecting the mine by detonating it, and at the same time clearing it. In an area of suspected mining the roller can be placed at the front of the moving forces. When the mined area is encountered, the presence of the minefield is determined by the detonation of the first mine in the path of the roller. The roller can either continue through the mined area, or it can drop back while other clearing means are employed.

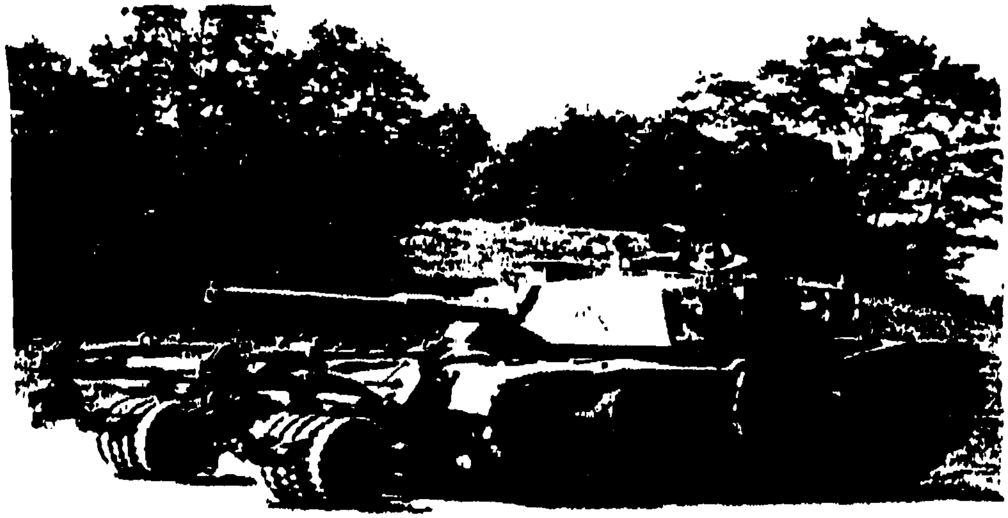


Figure II-4. Tank-Mounted Mine Roller.

E. CHARACTERISTICS OF MIRADOR.

1. Description.

The MIRADOR is a general purpose vehicular mounted mine detection system currently under development. It will be capable of detecting metallic or non-metallic mines deployed on or off roads on or below the surface by either conventional or remote means. A prototype version currently exists which has two physically separate platforms. They are the Remote Sensor Platform (RSP) and the Mobile Processing and Control Station (MPACS). The fielded MIRADORS will be mounted on or used with organic tactical vehicles capable of cross-country movement commensurate with the supported combat maneuver force.

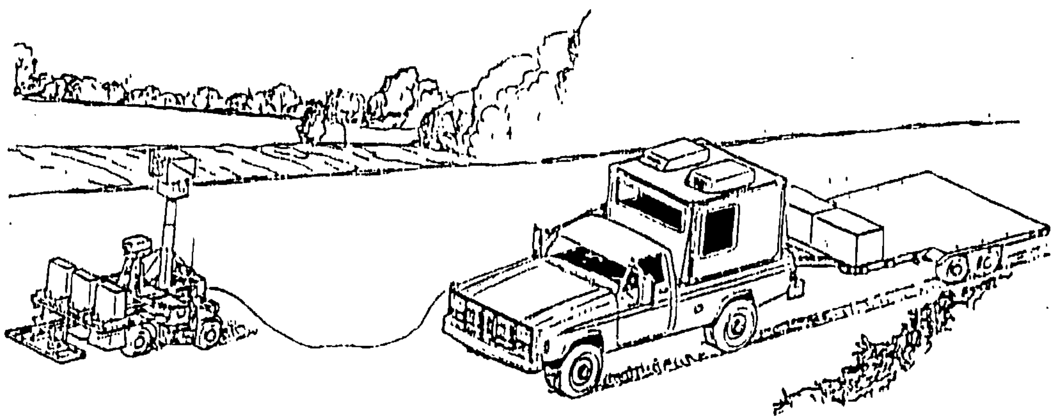


Figure II-5. MIRADOR Proof-of-Principal Prototype Concept.

2. Capabilities.

The specifications call for the system to be able to detect the presence of mines while moving at speeds comparable to those of modern combat units. The RSP must be capable of remotely controlled operation in highly dangerous areas. The MIRADOR will be transportable and be available for use worldwide in any geographic area where mines can be deployed. Its operational capabilities will complement other countermine devices used in the detection, neutralization and marking of minefields.

3. Operations.

In operation, the system will detect and report the presence of mines and/or minefields. It will:

(a) Provide a highly mobile mine/minefield detection system which can precede ground combat forces across a battlefield.

(b) Provide mine clearing teams in rear areas with an enhanced capability for detecting, reporting and marking the location of mines and minefields.

G. MINE DETECTION SYSTEMS DATA.

1. Cost.

Figure II-6 displays cost and allocation of the available mine detection systems. The cost of the tank on which the roller is mounted is not included in the cost for that item.

COUNTERMINE DETECTION SYSTEMS DATA

Data Item	Probe	AN/PSS-11/12	Roller	MIRADOR
Cost each	$10	$1.2K	M1-$80K M60-$51K	$400K ($200K for RSP)
Number per Tank Battalion	0	2	4	0
Number per Engineer Co.	1/man	48	0	2 (est)

Figure II-6. Systems Data.

2. Speed While Detecting.

One key characteristic of detectors is the amount of ground they can sweep during a given period of time. The utility of a detector to a maneuver force is determined in large measure by this speed. Figure II-7 sets forth speed for each of the candidate detectors.

DETECTION SPEED

Situation	Probe[1]	AN/PSS-11/12[2]	Roller[3]	MIRADOR[4]
off-road buried	1 m lane 0.026 mph	1.2 m lane 0.21 mph	2-1.1 m 7.5 mph	4 ft 6 mph
off-road surface	1 m lane 0.104 mph	1.2 m lane 0.84 mph	2-1.1 m 7.5 mph	4 ft 8 mph
on-road buried	N/A	0.21 mph	9.3 mph	20 mph
on-road surface	N/A	0.84 mph	9.3 mph	35 mph

Note 1. Probe speed calculation based on date in FM 5-34, table 2-3 (8 man team; 19 man-hours for 1 meter wide by 100 meters long lane; or 2.375 elapsed hrs. 38.2 hours to clear a mile or .026 mph. Assume speed for surface mines is four times as fast as buried.)

Note 2. AN/PSS-11 data was obtained from the January 1989 test report of the MIRADOR proof-of-principle phase test. FM 5-34 rate for an 8 meter lane is equivalent to .017 mph.

Note 3. Mine Roller data was taken from the February 1983 Armor and Engineer Board report on the countermine system concept evaluation, table 1-1.

Note 4. MIRADOR data was extracted from the Independent Evaluation Plan.

Figure II-7. Detection Speed.

3. Reliability of Detector.

A detector must locate a high percentage of the mines it encounters. A low rate of detection will result in losses of men and equipment and result in a loss of confidence in the detector. Even though a detector with a low rate of detection may be better than nothing, if the users lose confidence in it, it will go unused. Figure II-

8 identifies the detection rates for each of the candidate systems. The MIRADOR rate shown reflects documented requirements and is in consonance with preliminary test results. The AN/PSS-11 detection rate is for a 60/40 mix of metallic and non-metallic mines.

DETECTION RATE

Situation	Probe	AN/PSS-11/12	Roller	MIRADOR
off-road buried	100%	55%	97.4%	70%
off-road surface	100%	100%	100%	80%
on-road buried	N/A	55%	97.4%	70%
on-road surface	100%	100%	100%	90%

Figure II-8. Rate of Detection.

4. False Alarm Rate.

Mine detectors may provide feedback information to the operator which falsely identifies an object as a mine, when in fact no mine exists at that location. The false alarm must be treated as a real mine until it is investigated and proven to be otherwise. A large number of false alarms can baffle the mine detection effort and waste resources and alter tactical plans unnecessarily. The false alarm rates of the various detectors is shown in Figure II-9 (KSF = thousand square feet).

FALSE ALARM RATE

Situation	Probe	AN/PSS-11/12[1]	Roller	MIRADOR
off-road buried	unk	3/KSF	N/A	5/KSF
off-road surface	unk	1/KSF	N/A	3/KSF
on-road buried	unk	unk	N/A	5/KSF
on-road surface	unk	unk	N/A	1/KSF

Note 1: Hand-held detector false alarm figures derived from first partial report, proof of principle phase of Minefield Reconnaissance and Detector (MIRADOR) System, Light Weapons Systems Division, Armament Systems Directorate, U.S. Army Combat Systems Test Activity, Aberdeen Proving Ground, MD, dated January 1989.

Figure II-9. False Alarm Rates.

H. SUMMARY.

Mines and mine detectors have existed for some time but the development of detectors faces many more challenges than the development of mines. In the following chapter the problem of encountering, detecting and reporting the location of mines will be discussed.

CHAPTER III

MINEFIELD DETECTION ANALYSIS

A. INTRODUCTION.

A typical Threat conventional anti-tank minefield averages one mine in every one-third acre of space (the size of an average suburban house lot). Encountering a mine in that space with a narrow detector head, and having the detector report back accurately that the mine exists, is a difficult challenge. Interpreting a single feedback reading, and the ones before and after it, to determine the existence, characteristics, and boundaries of a minefield is a difficult task for a machine and/or an operator. Similarly, the detection of a single mine, such as may be placed in a road by insurgents, is an even greater challenge. The following analysis examines this difficult detection process in which the detector must **encounter** the mine, **detect** it, and do so **without** reporting a **confusing** number of **false alarms**.

B. SELECTION OF A STUDY MINEFIELD.

Field Circular 90-13-1, Combine Arms Counterobstacle Operations: The In-Stride Breach, published in June 1987 by the US Army Engineer School, describes several types of Threat minefields. The normal parameters for the minefields is set forth in Table 1-2 of FC 90-13-1. The antitank minefield portion of that table is reproduced below.

NORMAL PARAMETERS FOR ANTITANK MINEFIELDS	
Front:	200-300 meters
Depth:	60-120 meters
Distance between rows	20-40 meters
Number of rows	3-4 rows
Distance between mines	4-6 meters for antitrack
	9-12 meters for antihull
Outlay, normal	550-750 antitrack/km
	300-400 antihull/km
Outlay, increased effectiveness	1000+ antitrack mines/km
iveness	500+ antihull mines/km
Probability of destruction	0.57 for antitrack (750/km)
	0.85 for antihull (400/km)

Figure III-1. Antitank Minefield Parameters.

A representative anti-tank minefield extracted from the chart, to be used for probability of encounter (P_e) analysis, has the characteristics shown in Figure III-2:

Front:	300 meters
Depth:	80 meters
Distance between rows:	40 meters
Number of rows:	3
Mine type:	Anti-track (TM 57)
Distance between mines:	5.5 meters
Outlay:	163 mines per 300m (544/km)
Mines per meter of front:	0.54
Frontal dist. betw. mines:	1.83 meters

Figure III-2. Study Minefield.

C. ENHANCING THE PROBABILITY OF ENCOUNTER.

The probability of encountering a mine while passing through the study minefield is governed by the characteristics of the minefield, width of the detector and the path chosen. When the detector passes through the three row study minefield it can encounter only three mines, one in each row, unless it is at a very shallow angle. This maximum number is also the minimum number of mines which the detector must encounter if a minefield pattern is to be discerned. Yet it is possible (though not probable) for a detector of less than 5.5 meters width to pass through the minefield without encountering even one mine. Therefore an early step in an analysis of the effectiveness of a detector is to seek to maximize the Probability of Encounter (P_e).

P_e can be enhanced in at least three ways. The detector head width can be increased to a dimension greater than the distance between mines. Secondly, the detector can make multiple passes over the the minefield to increase the effective sweep width. A third solution is to operate the detector in such a way as to increase the effective sweep width by traversing the minefield at a low angle to the minefield front. These three enhancements can be employed singly or in combination.

a. Increasing The Width Of The Detector Head. The current configuration of the MIRADOR has a four foot (1.22m) wide head. Preliminary engineering opinion indicates that it may be possible to add a two foot extension wing on each side of the head for a total width of eight feet(2.44m). For the foreseeable future, it is unlikely that a detector head of 5.5m (18.04 feet) or more will be feasible due to its cumbersome nature off road and the vast processing required to analyze the output of a head of that dimension. Both the 1.22m and 2.44m dimensions will be used to explore utility options. However, it should be noted that even a "double-wide" head width of 2.44m is less than half the distance of the minefield row spacing.

b. Increasing P_e By Using Multiple Sweeps. In most cases an enemy minefield will be oriented perpendicular to the axis of advance of the attacking force. If the detector moves parallel to the axis of advance, and thus directly through the minefield, it would cross the minefield quickly, but would have the lowest probability of encountering a mine.

Both U.S. and Threat doctrinal minefield densities have been calculated so that a tank-width vehicle will have a high probability of encountering at least one mine in a pass through the minefield. These densities are designed to provide an effective obstacle for the least expenditure of resources. As a result there is a lower probability (as compared to a tank) of a four or eight foot (1.22 or 2.44 m) wide detector encountering **one** mine in a pass through a minefield, and a very low probability of encountering **three** mines in a three row minefield.

Therefore a search strategy must be developed which maximizes the number of encounters and allows the accurate readings to be recognizable above the normal false alarm levels. Analysis shows this is accomplished when the detector sweeps directly down the minefield row. Thus the most effective search strategy would employ the detector sweeping perpendicular to the axis of advance, and thus parallel to the minefield rows. At some point in this parallel search pattern, the detector would sweep directly down a row of mines. Logically, this dictates a series of back-and-forth "lawnmower" passes, moving forward the width of the detector head with each pass, as shown below.

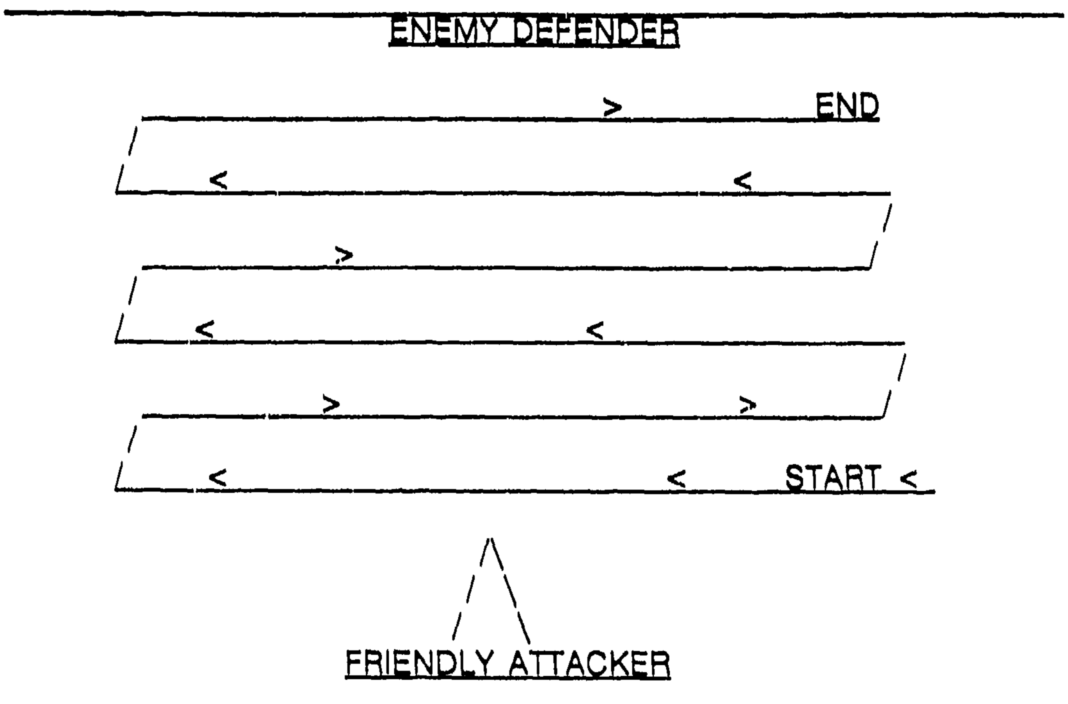


Figure III-3. Parallel Search Pattern.

The length of time it would take to search a 300 x 80 meter minefield with a four foot sweep head travelling at 20 KPH would be 59.4 minutes. (An 8 foot head would accomplish the same sweep in 29.7 minutes). More than likely this time would be multiplied several times over by the need to sweep an area well in front of the suspected minefield, and an area beyond the detected minefield to avoid missing the beginning of the minefield or failing to recognize the existence of secondary and tertiary bands.

Thus the parallel search pattern is effective, but it may not be efficient. There is a need to encounter a mine in each row, while being as efficient as possible in terms of time and exposure.

c. Increasing P_e By Using Angular Sweeps. If the mine detector search path is at an angle of less than 90° to the front edge of the minefield, there will be increased travel distance, as compared to the 90° path. The effective width of the detector head as it passes over each minefield row is also increased as illustrated below.

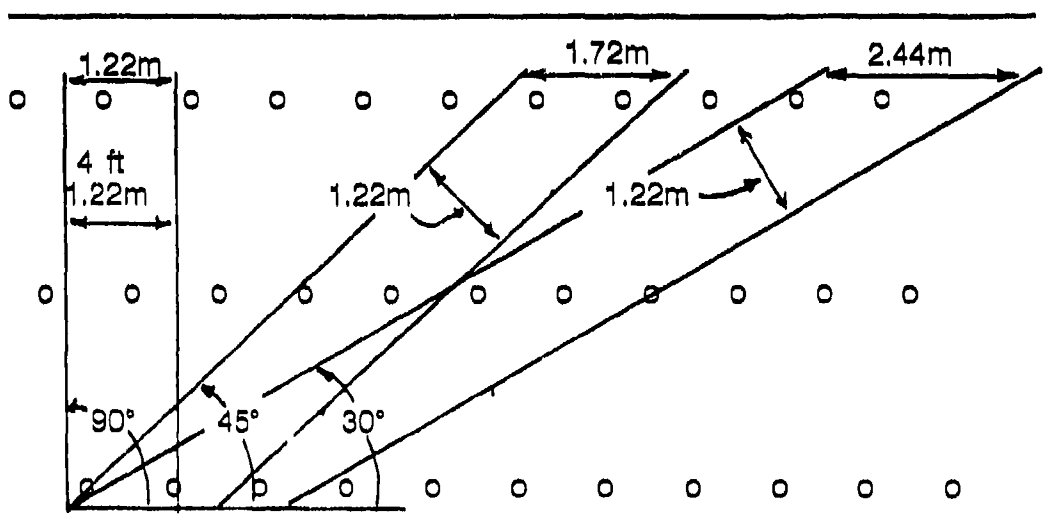


Figure III-4. Angle of Attack.

As the angle approaches zero (parallel to the mine front), the effective swept width along the row increases. At 26° a 2.44m wide detector head has an effective sweep length along the row of 5.5m, sufficient to assure an encounter with a mine in each row. A 1.22m head width achieves this same effective swept length of 5.5m at an angle of 13°.

d. Summary. Thus the first imperative of encountering a mine in each row can be met by increasing the search head width and/or employment of effective operational technique. However, as the search head becomes longer, it becomes more difficult to employ off-road and it may overtax the system's information processing capability. On the other hand, the selection of an effective search angle is not a simple matter. The orientation of the front of the minefield will not be known, but good terrain analysis and knowledge of the Threat doctrine may permit users to make reasonable predictions. Employment of mine detectors in pairs to search at differing angles would enhance the P_e, as well.

D. TYPES OF MINE DETECTION ERRORS.

An electronic mine detector experiences two kinds of errors:

Type 1 Error: A mine is encountered by the detector but it fails to indicate the existence of that mine.

Type 2 Error: No mine has been encountered by the detector but it falsely indicate the presence of a mine.

In determining the utility of a mine detector, the reliability of the feedback information is critical. If the number of Type 1 errors is significant (low detection rate), then the overlooked mines will present a hazard to following forces, or the partial information will confuse the analyst who is processing the feedback information in an attempt to determine mine locations and patterns.

E. TRADE-OFF OF ERROR TYPES.

A solution to Type 1 errors is to demand more information from the detector so that very few mines are overlooked. The expected side effect of that solution is the generation of feedback which includes more Type 2 errors (falsely indicates the existence of mines). This may be acceptable in some situations; for example, when time and forces are available, and the tactical situation permits, each reading may be treated deliberately as if it were a mine.

Because of the different intended usages of the feedback information, the type of error a user can tolerate from the detector is different depending on whether he is looking for a mine or for a minefield. Figure III-5 sets forth the differing detector criteria for a mine detector and minefield detector.

In each case the goal determines the tolerance that the user has for type 1 and type 2 errors.

TYPE DETECTOR	GOAL	DETECTION RATE	FALSE ALARM RATE
MINE DETECTOR	Find every mine so it can be avoided or neutralized	As high as possible since missed mines cause casualties	Not as critical since intent is to deal with every positive reading
MINEFIELD DETECTOR	Identify sufficient mines so that a pattern is defined	Not as critical since only intent is to deal with mines as a field	As low as possible since FAs confuse identification of minefield

Figure III-5. Mine/Minefield Detector Criteria.

F. DETERMINING THE ACCEPTABLE THRESHOLD.

The ideal mine detector is, of course, one which has a no errors of either type; one which detects all of the mines it encounters and generates no false alarms. However, since some level of false alarms and missed detections must be expected, the question becomes at what mix of error types does a detector lose its utility?

As the number of missed detections and/or false alarms increases, there is an adverse impact on the utility of the detector. Because of the sparse density of the mines in the mined area, a detection situation where there are few true encounters could easily be confounded by a fairly small number of false reports. Such a scenario would make it impossible to identify with confidence the location of the real mines, and would prevent a conclusion as to the location and pattern of a minefield.

The number of false alarms which would confuse an operator attempting to determine the location of a minefield is directly tied to the number of encounters/detections which will be experienced. For example, when reconnoitering for the location of a minefield, there would be a higher tolerance for false alarms in a dense minefield than in a sparsely mined area.

Therefore, there seems to be a need to identify a threshold ratio of false alarms to accurate detections. Two ratios which can be supported by logic are 1:1 and 1:3 false alarms to accurate detections:

a. One-to-One Ratio. Selection of a ratio of one false alarm to each accurate detection is based initially on the wide acceptance of a 50-50 chance as being the lower level of acceptable risk. Further thought discloses the 1:1 ratio also represents a doubling of the work load associated with marking and clearing readings when compared to a base of all-accurate reports.

More importantly the 1:1 ratio is a watershed because when a minefield is encountered, it allows the operator to see a doubling of the feedback information being provided. This noticeable rise in reports would indicate a liklihood of a minefield being encountered. The pattern and boundaries of the minefield would not be easily discerned from a set of half-true, half-false reports, but would be sufficient to indicate the liklihood of a minefield.

b. One-to-Three Ratio. A ratio of one false alarm to three accurate detections is based on the number of rows (3) in a typical hasty Threat minefield. A 1:3 ratio would allow the operator to visualize a pattern created by three of the readings, while allowing a basis for eliminating the fourth report as not fitting the pattern. Such a process might be incorporated into software to assist the operator in recognizing a minefield pattern.

G. SYSTEM PERFORMANCE PARAMETERS.

a. General. The foregoing discussion established the importance of designing and/or operating the detector so that it encounters a useful sample of the mines that exist on the battlefield. Also discussed was the key relationship that false alarm rate has on the utility of a detector. The interrelationship of these variables, as well as the rate of detection of mines encountered, is discussed in the following paragraphs.

b. False Alarms. Having established that the ratio of True to False readings is a key factor in detector utility, an analysis of relationships between this ratio and other variables is needed.

The false alarm rate for a detector can be measured in several ways. Two of these measures are (1) false alarms per area covered, and (2) false alarms per number of mines encountered (detection opportunities). Both measures have been used to describe MIRADOR false alarm requirements.

Figure III-6 shows the result of computing true to false ratios by analyzing false alarm rates (measured in false alarms per unit area - in this case 1000 square feet) and three different detection rates. The figure shows that a detector with 100% detection rate can achieve the 1:1 True-False ratio at a false alarm rate of 0.7 per 1000 square feet.

If the detector can manage only a 50% detection rate then the false alarm rate must be only .3 per 1000 square feet to achieve a 1:1 ratio. To achieve a 3:1 True-False ratio the false alarm rate must be no greater than 0.3 per 1000 square feet, even with 100% detection.

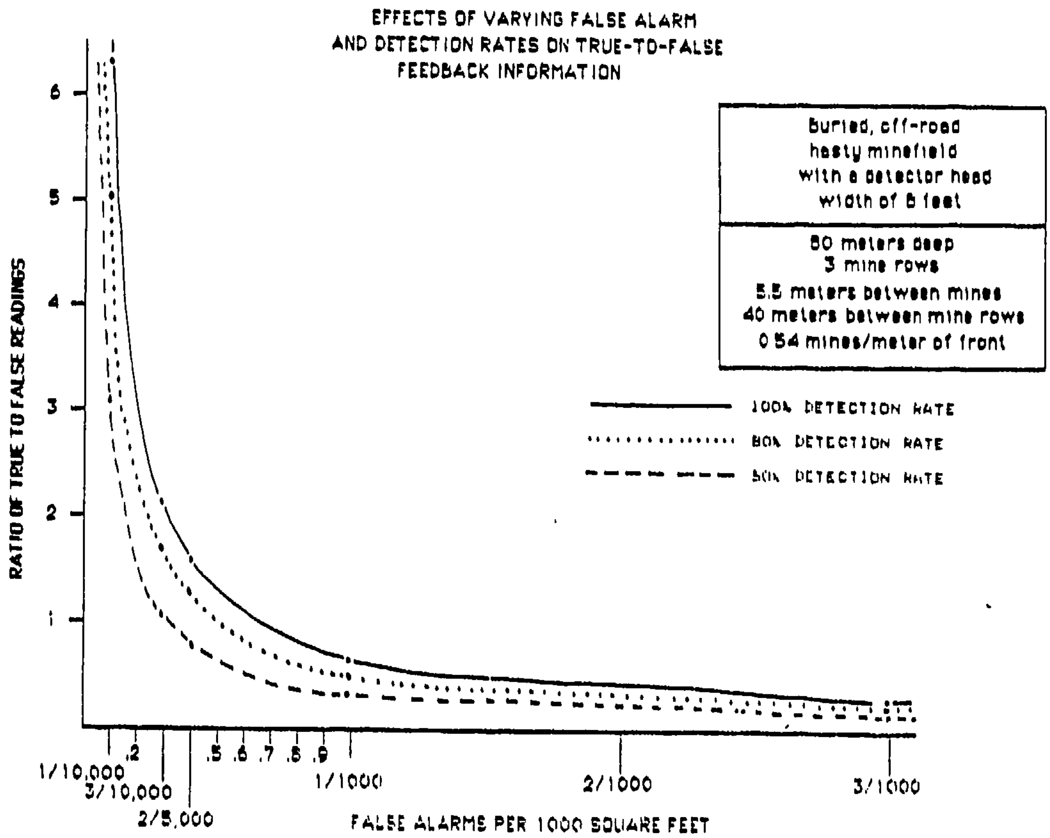


Figure III-6. False Alarms vs. True-False Readings.

The foregoing discussion was based on measuring false alarms by using false alarm per unit of area. This measurement is useful for research and development of a detector. However, when considering the utility of the detector in a combat situation, a more useful measurement for false alarms is one which compares false alarms to actual mines encountered. This measurement recognizes the need to be free of distractors when attempting to recognize a mine pattern as sparsely distributed individual mines are encountered/detected. The false alarms-per-encountered mine measurement applies in and near the mined area. If there are no mines, then another measurement is needed. In such cases, the false alarms per unit area figure which coincides with the false alarms per encountered mine should be used.

c. Encounters.

A primary consideration in the mine/minefield detection process is the need to encounter at least one mine in each row. Unless this is accomplished, there is a significantly reduced chance of recognizing all of the rows in a conventional minefield. As discussed earlier, this can be accomplished by entering the minefield at an angle. A number of computations were undertaken to determine the impact of varying the angle of attack of the detector as it entered the minefield.

Figure III-7 portrays the result of plotting the influence of changing the angle of attack as the detector enters the minefield. The chart shows the number of mines encountered reaches three at an attack angle of 26°.

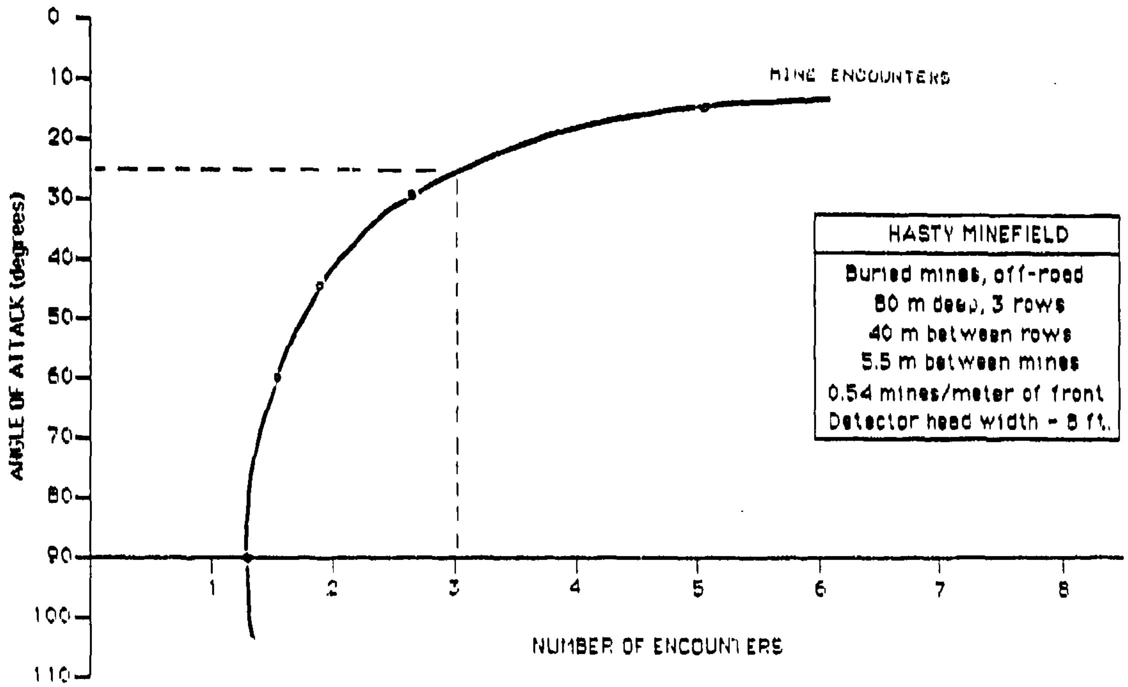


Figure III-7. Encounter vs. Angle of Attack.

d. Encounters in differing densities. The study minefield used a 5.5 meter mine spacing within each row. According to FM 5-34 (Engineer Field Data, July 1987) Threat deliberate minefields can be laid with mine spacing in rows from 3 meters to 5 meters and hasty minefields can be laid with spacing from 4 meters to 5.5 meters. Figure III-8 shows the result of computing the angle of attack for each of these spacings which will produce one mine encounter per row.

ANGLE OF ATTACK AT WHICH A DETECTOR ACHIEVES AT LEAST ONE MINE ENCOUNTER PER ROW						
WIDTH OF DETECTOR HEAD	THREAT MINE SPACING WITHIN ROWS (meters) <--- HASTY MINEFIELDS --> <-- DELIBERATE MINEFIELDS -->					
	3.0	3.5	4.0	4.5	5.0	5.5
Four Feet (1.22 m)	24°	20°	18°	16°	14°	13°
Eight Feet (2.44 m)	54°	44°	38°	33°	29°	26°

Figure III-8. Angle of Attack for Varying Densities.

e. False Alarms in the Study Minefield. Using these same methods, the number of false alarms generated as the attack angle changes can be determined. For purposes of illustration, three false alarm rates are plotted in Figure III-9. Three different false alarm rates, stated in terms of false alarms per area, are depicted (in order of increasing stringency: 1/1000 SF; 1/2000 SF and; 1/5000 SF of swept area). As the angle of attack decreases from 90°, the increased length of the traverse through the minefield results in an increasing swept area and therefore an increasing number of false reports. The preceding figure showed that the desireable 3 encounters (1 encounter in each of three rows) was achieved at an attack angle of 26°. At that same attack angle, the three false alarm rates would transmit approximately 1, 2.5, and 5 false readings, respectively.

f. Defining 1:1 & 3:1 Ratios Equivalent to $P_e = 3$. The earlier discussion concerning ratio of true to false alarm rates adopted ratios of 1:1 and 3:1 as ratios which offer some utility. Figure III-10 uses the same format used in the preceding two figures to show that the two false alarm rates which achieve 1 false alarm and 3 false alarms at 26°. These two rates are 1 false alarm per 1584 SF and 1 false alarm per 4752 SF.

Close observation will reveal that the 1:1 line is coincident to the mine encounters line depicted in Figure III-7, as it should be, by definition. The 1:1 and 3:1 lines are based on the number of encounters. Further analysis could be undertaken to show the changed relationship that would exist for number of detections. Since the purpose of this illustration is to reveal a minimum acceptable false alarm rate, a 100% detection rate has been assumed.

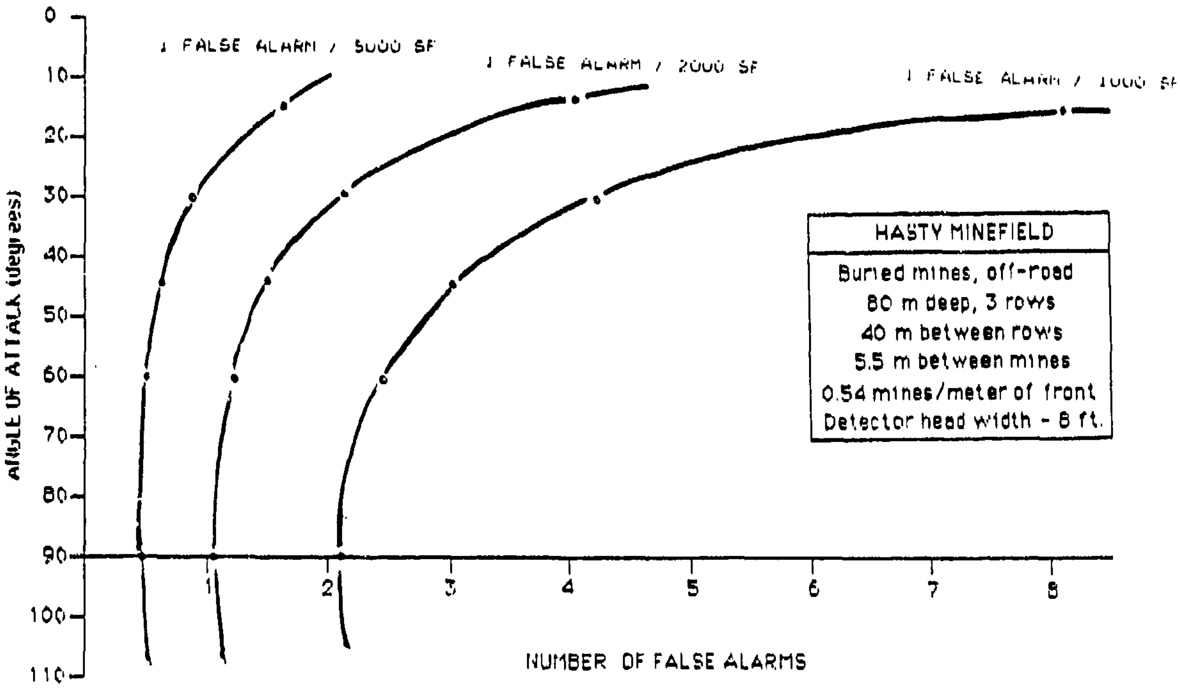


Figure III-9. Angle of Attack vs. False Reports.

g. Relationship between False Alarm measures. Figure III-10 shows there is a relationship between the two false alarm measurements referred to in MIRADOR documents; false alarms per unit of area and false alarms per encountered mine. For the situation presented here, a rate of 1 false alarm per 1584 SF is equivalent to 1 false alarm per detection opportunity. For other situations the equivalency will be determined by the density of mines in the area to be swept.

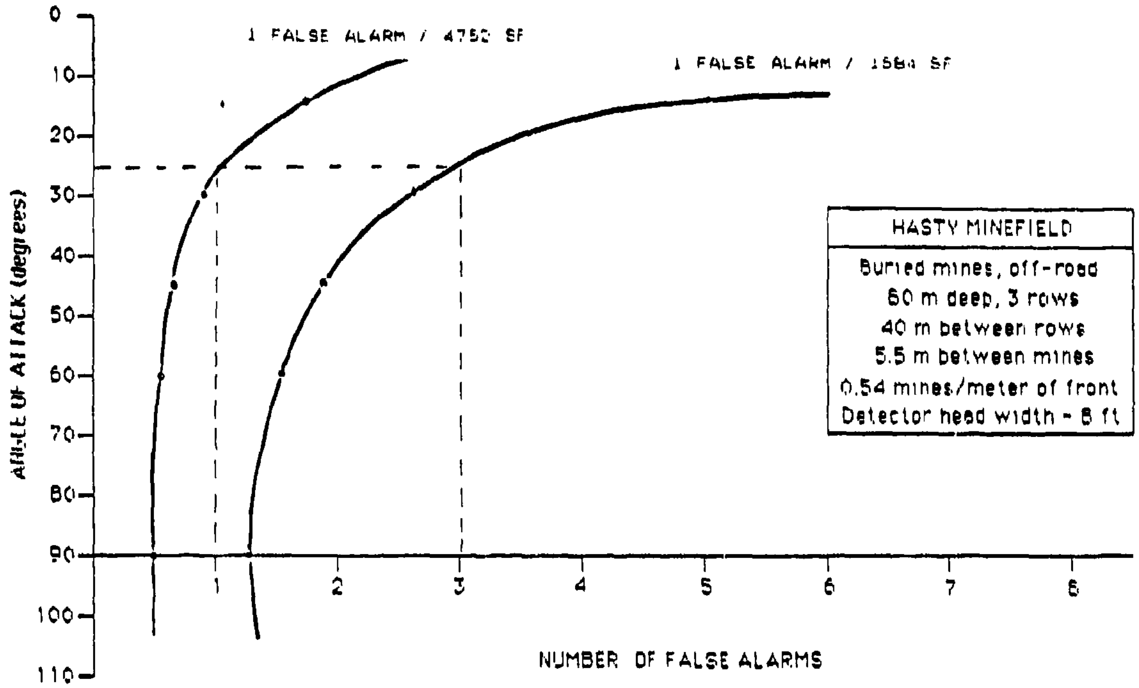


Figure III-10. 1:1 and 3:1 False Alarm Rates.

h. Comparison to MIRADOR specifications. The U.S. Army Engineer School's Independent Evaluation Plan published in February, 1988 sets forth criteria for the MIRADOR. Criteria set forth in Paragraph 2.1.1.2 is summarized in Figure III-11.

DETECTION AND FALSE ALARM RATES
VERSUS
SPEED AND CONDITION

CONDITION	DETECTION RATE @ SPEED	FALSE ALARM RATE PER 1000 SF	EQUIVALENT RATE 1 FA PER AREA
Roads with surface mines	90% @ 35 MPH	1	1 per 1000 SF
Roads with buried mines	70% @ 20 MPH	5	1 per 200 SF
Off Road with surface mines	80% @ 12 MPH	3	1 per 333 SF
Off Road with	70% @ 6 MPH	5	1 per 200 SF

Figure III-11. MIRADOR Criteria.

The desireable false alarm rates set forth in Figure III-10 are considerably more stringent than the IEP criteria shown in Figure III-11. The differences in the two figures imply a need for even tighter criteria than the user has stated. The degree of improvement varies from a low of 1.58 times better than the IEP asks for, to a high of nearly 24 times better. The specific needs are shown in Figure III-12.

H. SUMMARY.

The preceding analysis provides considerable insight into the limitations that a mine detector has in searching for minefields on the battlefield. Among the information derived are the following:

a. Confirmed the need for a high detection rate and a low false alarm rate.

b. Established a set of minefield attack angles for a vehicular-mounted rectangular search head. These angles provide a foundation on which to base operational techniques.

c. A threshold relationship emerged between mine encounters and false alarms which can be used to develop effective and efficient operational search patterns, and perhaps help establish materiel specifications.

MULTIPLES OF INCREASED STRINGENCY
IMPLIED BY TRUE/FALSE RATIOS

IEP CRITERIA	DESIREABLE TRUE-FALSE RATES	
	1:1 (1 FA/1584 SF)	3:1 (1 FA/4752 SF)
1 FA / 200 SF	7.92	23.76
1 FA / 333 SF	4.76	14.27
1 FA / 1000 SF	1.58	4.75

Figure III-12. False Alarm Rate Improvements.

I. THREAT SCATTERMINE CAPABILITY

1. Background.

The foregoing discussion has focused on a conventionally laid minefield. As challenging as the search for mines is in a traditional pattern minefield, evolutions in mine warfare have made the problem even more difficult. In the last ten years several nations have adopted the concept of rapidly creating minefields by scattering mines on the surface of the ground. It is very likely that MIRADOR will be confronted by enemy (or friendly) scattermines. A scattered minefield does not have the geometric recognizability of the conventionally laid minefields, so the task of the detector is made more difficult.

Scattermines can be emplaced either by troops on the ground, or by some stand-off delivery means. Fighter aircraft, helicopters, tube artillery, and multiple rocket systems are employed to deliver the mines at a time and place when it can be of greatest harm to the enemy's maneuver.

2. Threat Scattermines.

Open literature on Soviet scattermines is limited. However, three different categories of Jane's Defence and Aerospace Yearbooks (Jane's Information Group, Coulsdon, Surrey, UK) and an informational brochure from the Vought Corporation can be used to deduce the expected characteristics of Threat Scattermining.

Janes's Military Vehicles and Ground Equipment, 1986 and Jane's Armour and Artillery, 86-87 provide the information on Soviet scatterming shown in Figure III-13:

Mines	Delivered By	Type	Self-Destruct	Timer
PFM-1 (PMZ)	BM 21, BM 22 MRL 240mm mortar aircraft	AP	No	
PGMDM	aircraft	AT(mobK)	Yes	Clock-work

Figure III-13. Soviet Scattermines.

3. Threat Delivery Means.

Threat use of artillery scattermines is alluded to in Jane's Weapons Systems, 88-89. The capabilities of the BM 21 Multiple Rocket System are set forth on page 129. There is a BM 21 Battalion per Tank and Motorized Division consisting of three batteries, each with six launchers. The 122mm launchers each contain 40 tubes.

4. Threat Anti-tank Scattermines.

Of concern to maneuver forces and to a study of the MIRADOR is whether anti-tank mines can be delivered by tube or rocket artillery, and if so,the dimensions and density of those minefields.

Jane's Military Logistics, 1988 indicates on page 235 that the PGMDM scatterable AT mine may be dispensed from aircraft or helicopters. It uses liquid explosive in a thin flexible plastic cover. The PGMDM uses the same MVDM pressure operated fuze employed on the PFM-1 AP mine. The mine is about 65mm by 310mm and weighs about 1.7 kg. Since most of the weight is explosive material, there is enough power to damage a tank track or wheel. The PGMDM is in production and is in service with Soviet armed forces. It is very likely that US forces could face at least the aircraft delivered PGMDM.

5. Artillery Delivered AT Scattermines.

Page 130 of Jane's Weapons Systems, 88-89 states that a newer Soviet multiple rocket launcher, the BM 27, with 16 220mm tubes, has the capability to deliver "minelets". Figure III-14 compares the BM 27 to the US Army's Multiple Launch Rocket System (MLRS), the approximate characteristics of BM 27 "minelet" minefield can be deduced.

6. MLRS Scattermine Capability.

To make the comparison, a better understanding of the MLRS scattermine potential will be established. In describing the MLRS, Jane's Weapons Systems, 88-89 states that the MLRS can be used to distribute West German AT-2 anti-tank mines at a rate of 28 mines per round. It can deliver 336 mines over a 1000 x 400 meter area. The incorporation of the AT-2 in an MLRS round is portrayed in a Vaught Corporation MLRS brochure as shown in Figure III-15.

System	No. Tubes	Tube Diameter
MLRS	12	227 mm
BM 27	16	220 mm

Figure III-14. MLRS-BM 27 Comparison.

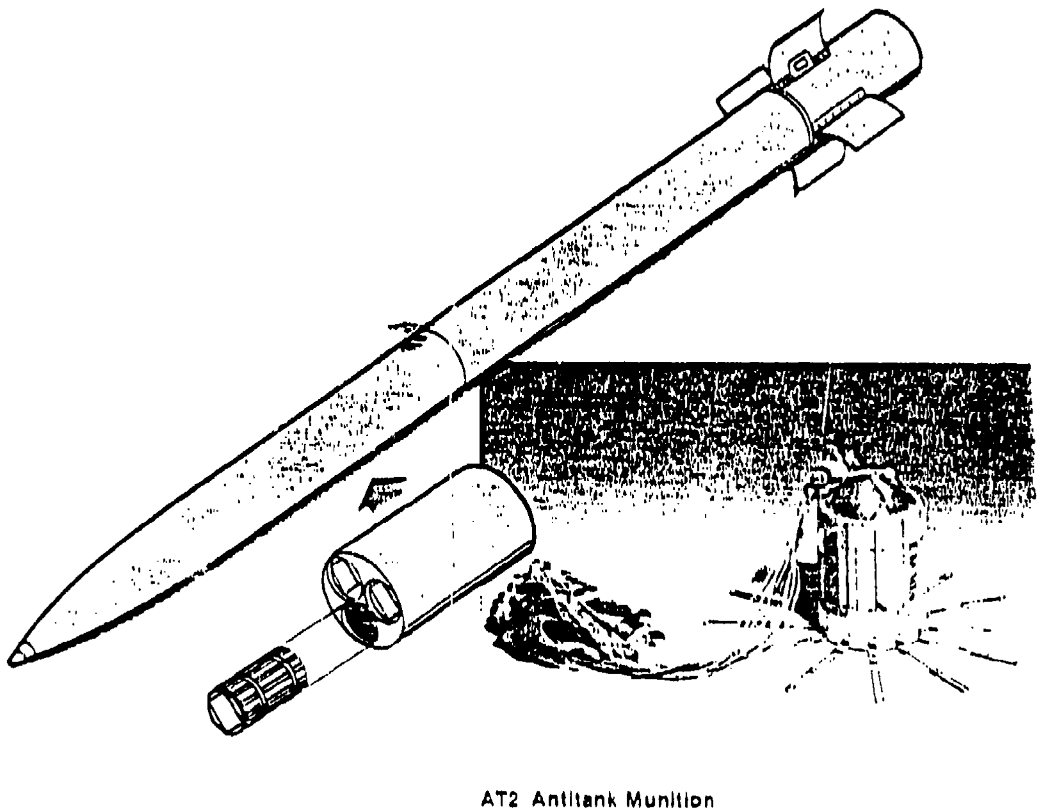


Figure III-15. MLRS Delivery of AT 2 Mine.

7. MLRS - BM 27 Comparison.

Given the similar tube diameters of the MLRS and BM 27, it can be assumed that each BM 27 tube can deliver the same number of mines as each tube in the MLRS. Since the BM 27 has a 16 tube to 12 tube advantage over the MLRS, it can be assumed that the BM 27 can deliver 1.33 times the number of mines (which can cover 1.33 times the area at the same density)

8. Threat Scattermine Density.

The density of the mines in a Threat scattermine can also be assumed by mirror-imaging US doctrine. The US Army Engineer School Department of Combined Arms published in June, 1989 a booklet titled The Family of Scatterable Mines. Standard US Army scattermine doctrinal densities for scattermines delivered by tube artillery (RAAM, ADAM), helicopter (VOLCANO), and USAF aircraft (GATOR) are shown on page 24 of the booklet. To "turn or fix" the enemy, all the systems seek densities at or near 0.8 mines per meter of front (or 0.002 mines per square meter of mined area). RAAM/ADAM are placed at 1.6 mines per meter of front (0.004 mines per square meter) to "block" the enemy.

9. Assumed Threat Capability.

From the foregoing it can be assumed that the Soviets could use a BM 27 to deliver an anti-tank minefield. Using the MLRS AT2 data as a basis, each BM 27 launcher could be assumed to deliver 449 mines (336 x 1.33) mines over an area of 532,000 square meters (1000m x 400m x 1.33). 449 mines over 532,000 square meters is a density of 0.0008 mines per square meter.

The 532,000 square meters can be visualized as a rectangle 1000 meters by 532 meters. Furthermore, such a configuration is similar to the footprint of a group of aerial delivered munitions with the long dimension coinciding with the flight path of the delivery aircraft or trajectory of the munition. If the 532 meter dimension is along the front, the number of mines per meter of front would be 449/533 or 0.84. This is similar to the US Army Engineer School's "turn or fix" ratio of 0.80. Using the foregoing information, the following remotely delivered minefield situation is projected.

a. Delivery Means. The method of delivery is assumed to be the BM 27 Multiple Rocket launcher system.

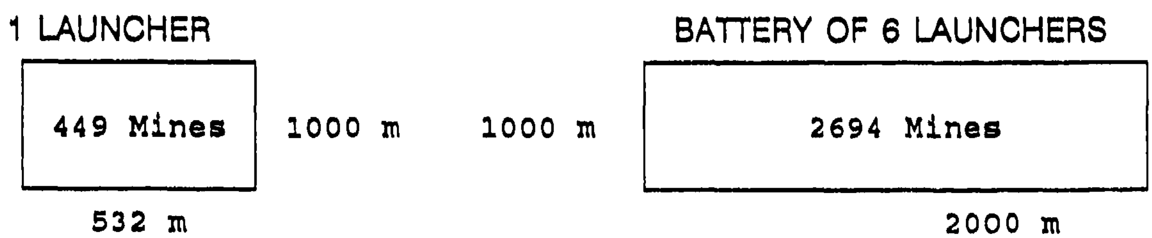
b. Organization. It is assumed that each BM 27 Battalion, like its sister BM 21 unit, has three batteries and each Battery has six launchers.

c. Employment. It is assumed that the Battery either will create a small minefield by firing one launcher, or all six launchers will be used to create a larger and more dense minefield.

1. For study purposes, a single launcher is assumed to deliver 449 mines in an area 1000 meters by 532 meters. A density of .0008 mines per square meter and 0.84 mines per meter of front results.

2. Also, when a larger, more dense minefield is needed, multiple launchers could be fired with each launcher aimed at an offset aim point. If the offset allowed a 30% overlap of each launcher in order to insure coverage and develop increased desity, a minefield with a frontage of 2000 meters and a depth of 1000 meters would be created. Therefore, a six-launcher salvo is assumed to cover an area 1000 meters by 2000 meters with a density of .001 mines per square meter and 1.35 mines per meter of front.

d. Coverage. Graphically, the minefields described above would appear as shown below.



e. Mine Distribution. For purposes of this study, the mines are assumed to be distributed evenly in the target area. Based on that assumption, the data in Figure III-16 is presented.

	Category	1 Launcher	6 Launchers
a.	Mines per meter of front:	0.84	1.35
b.	Mines per square meter:	0.0008	0.009
c.	Average distance between mines along front	1.18m	0.74m
d.	Encounters/1.22m detector	1.03	1.64
e.	Encounters/2.44m detector	2.06	3.29

Figure III-16. Mine Distribution.

f. False Alarms. The probable encounters of a detector passing directly through the scatter minefield shown in Figure III-16 can be used to estimate acceptable false alarm rates. Computation of False Alarms per unit area based on the desireable 1:1 and 3:1 ratios of True Detections to False Alarms is shown below.

Type Minefield	Detector width	1:1	3:1
1 Launcher minefield	1.22 m	1.03 FA/1220SM (1 FA/12,745 SF)	0.34 FA/1220SM (1 FA/38,235 SF)
	2.44 m	2.06 FA/2440m (1 FA/12,745 SF)	0.68 FA/2440m (1 FA/38,235 SF)
6 Launcher minefield	1.22 m	1.64 FA/1220SM (1 FA/8,004 SF)	0.55 FA/1220SM (1 FA/24,012 SF)
	2.44 m	3.28 FA/2440SM (1 FA/8,004 SF)	1.09 FA/2440SM (1 FA/24,012 SF)

Figure III-17. False Alarms Thresholds in Scatter Minefield.

g. Analysis. The IEP specifications shown in Figure III-11 establishes for MIRADOR a false alarm rate of 1 per 333 SF. Comparing one false alarm per 333 square feet to one false alarm per 8,004 square feet (single launcher minefield) and one false alarm per 12,745 square feet (six launcher minefield) reveals the magnitude of the difference between the specifications and what is needed for a detector to operate at the one false alarm per encountered mine level of efficiency. For a three mines per false alarm operating level, the comparison on 333 to 38,235 and 24,072 shows nearly two orders of magnitude improvement is needed. The reasons for this significant increase are:

(1) Since the mined area is 10 to 20 times as deep as the conventional row minefield, the mine detector must make a longer sweep and cover more area.

(2) Similarly, in the one launcher minefield, there are about the same number of mines to be detected as in a hasty conventional minefield studied earlier, but in an area 10 times as great.

(3) Offsetting this somewhat is the fact that the mines per meter of front varies from about the same (for a 1 launcher minefield), to more than double (6 launcher minefield).

h. Conclusions. There is a much lower tolerance for false alarms in a remotely delivered scatter minefield. The cause is the swept area (detector width times minefield depth) is much greater while the mines per meter of front are about the same at the low end (1 launcher) and about double at the higher end (6 launchers).

J. MIRADOR SIMULATION

A separate analysis was conducted to assess the characteristics of a detector operating with the current MIRADOR specifications. That stydy is attached as Appendix C.

The study is accomplished in two parts. The first part is a description of the development and us of a demonstrative model which reveals the impact of current specifications. The second part is agraphic illustration of the target minefield and an illustration of the MIRADOR feedback information as perceived by the operator.

Conclusions drawn from the supportive study are contained in the Appendix C, and are compatible with the conclusions in the main body.

CHAPTER IV

ANALYSIS OF THE UTILITY OF MIRADOR

A. INTRODUCTION

The utility of the Minefield Reconnaissance and Detector (MIRADOR) System will be analyzed by means of computerized wargaming to assess the usefulness to a combined arms force of a remotely controlled mine detector possessing the characteristics set forth in the US Army Engineer School's Independent Evaluation Plan, dated February, 1988.

B. MEASURES OF EFFECTIVENESS

To determine the true utility to the force, a measure(s) of the effectiveness of the MIRADOR in relation to the supported force must be established. Since the purpose of a mine detector is to assist the maneuver force in overcoming obstacles standing in the way of reaching their objective, any significant losses to the force caused by the obstacle is a reflection on the effectiveness of the equipment designed to assist in overcoming the obstacle. Therefore the Measure of Effectiveness (MOE) established for this study is the Number of Combat Vehicles Lost: i.e., Combat vehicles suffering mobility or catastrophic kills as a result of mines in the minefield, or as the result of increased vulnerability brought about by the minefield.

C. PERFORMANCE CRITERIA.

Various documents published by the U.S. Army Engineer School set forth criteria for the MIRADOR with regard to terrain, tactical considerations, and mine situations. In additon, criteria reproduced in the following paragraphs was briefed to the Combat Development Directorate of USAES.

1. Tactical Situations to be considered. The MIRADOR Organization and Operations Plan states that the tactical situations in which MIRADOR will be employed are the Offense, Counterattack, and Lines of Communications (LOC).

2. Mine types to be considered. The Independent Evaluation Plan (IEP) establishes that MIRADOR will be expected to encounter the mine situations shown in Figure IV-1:

Surface and Buried
Metallic and Non-Metallic
On and Off Road
Conventional and Remote Delivery

Figure IV-1. Mine Situations to be Considered.

3. Operational Employment. The O&O Plan and the IEP establish certain locations, tactics and organizational relationships shown in Figure IV-2.

Operational Considerations:
European Terrain
Employed by Engineers
Employed Ahead of Lead Vehicle in Suspect Areas

When minefield is located:
- o By-pass
- o Breach Battle Drill
- o Locate a clear path through it.

Figure IV-2. Operational Employment

4. 24 Hour Summary. The IEP and the O&O Plan set forth the expected utilization of the MIRADOR System in a 24 hour span. According to the IEP, the system will be operational for 18 of the 24 hours, in three separate six hour missions. Of the eighteen hours, one and one-half hours will be spent travelling (105 KM total), thirteen and one-half will be spent detecting, and three hours will be idle. The operational mode summary and mission profile in the O&O Plan states that the system will deal with various mining situation in the proportions of time shown in Figure IV-3.

On Road	40%	Off Road	60%
Surface Mines	70%	Buried	30%
Metallic Mines	60%	Non-Metal	40%
Remote Delivery	40%	Conv. Delivery	60%

Figure IV-3. Operational Modes

5. Opposing Weapons. According to Annex A of the O&O Plan, the MIRADOR System can expect to encounter the weapons shown in Figure IV-4. The IEP states that it will survive small arms and artillery shrapnel:

Weapon System	Forward Area	Rear Area
Artillery	X	X
Anti-Tank	X	N/A
Mines	X	X
Small Arms	X	N/A
Air Attack	X	X
Other Theater-Area Attack wpns	N/A	X

Figure IV-4. Weapons Encountered.

6. Operational Mode Distribution. Figure IV-5 shows the travel mode distribution of the MIRADOR in tactical support and rear area support roles according to the IEP.

Type Support Situation	Primary Road	Secondary Road	Cross Country
Tactical Support:			
Travel Mode	5%	25%	70%
Operational (Search) Mode	2%	13%	85%
MSR Detection Support:			
Travel Mode	30%	60%	10%
Operational (Search) Mode	5%	85%	10%

Figure IV-5. Operational Modes.

7. Performance. According to the IEP, the MIRADOR System is expected to have the detection and false alarm rates at given speeds and conditions as set forth in Figure IV-6.

Condition	Detection Rate@Speed	False Alarm Rate/1000 SF
Roads w/ Surface Mines	90% @ 35 mph	1
Roads w/ Buried Mines	70% @ 20 mph	5
Off Road w/ Surface Mines	80% @ 12 mph	3
Off Road w/ Buried Mines	70% @ 6 mph	5

Figure IV-6. Performance Criteria.

D. SCENARIO DEVELOPMENT.

1. METT-T.

A thorough analysis of a tactical situation is commonly accomplished by systematically examining the factors of METT-T. The components, Mission, Enemy situation, Terrain, Troops available and Time, assure that all key aspects of a tactical problem are addressed. The METT-T format will be followed in the following MIRADORS scenario development.

2. Mission.

The foregoing operational criteria suggest a number of wargaming scenarios which incorporate multiple criteria in each tactical setting. Figure IV-7 shows four scenarios which incorporate almost all of the criteria set forth above into the Mission component of METT-T.

	Mission	Road	Surf/Bur	Conv/Scat	Met/Non-Met
a.	Pursuit	off	surface	rem scat	metallic
b.	Hasty attack	off	surface	conv	non-metallic
c.	Delib attack	off	buried	conv	metallic
d.	LOC/MSR	on	buried	ind scat	metallic

Figure IV-7. Scenarios.

3. Enemy.

All scenarios use a reinforced Motorized Rifle Company as the opposing red force. It has been reinforced with tanks according to the scenario and has normal threat support.

4. Terrain.

The study setting is in the rolling, partially wooded area in the vicinity of Fulda, FRG.

5. Troops Available.

The friendly blue force is an Armor Battalion Task Force. It has been cross attached with a Mechanized Infantry Battalion to form a balanced task force of two tank companies and two mechanized infantry companies plus the headquarters company. The unit is supported by a combat engineer company of the Division Engineer Battalion.

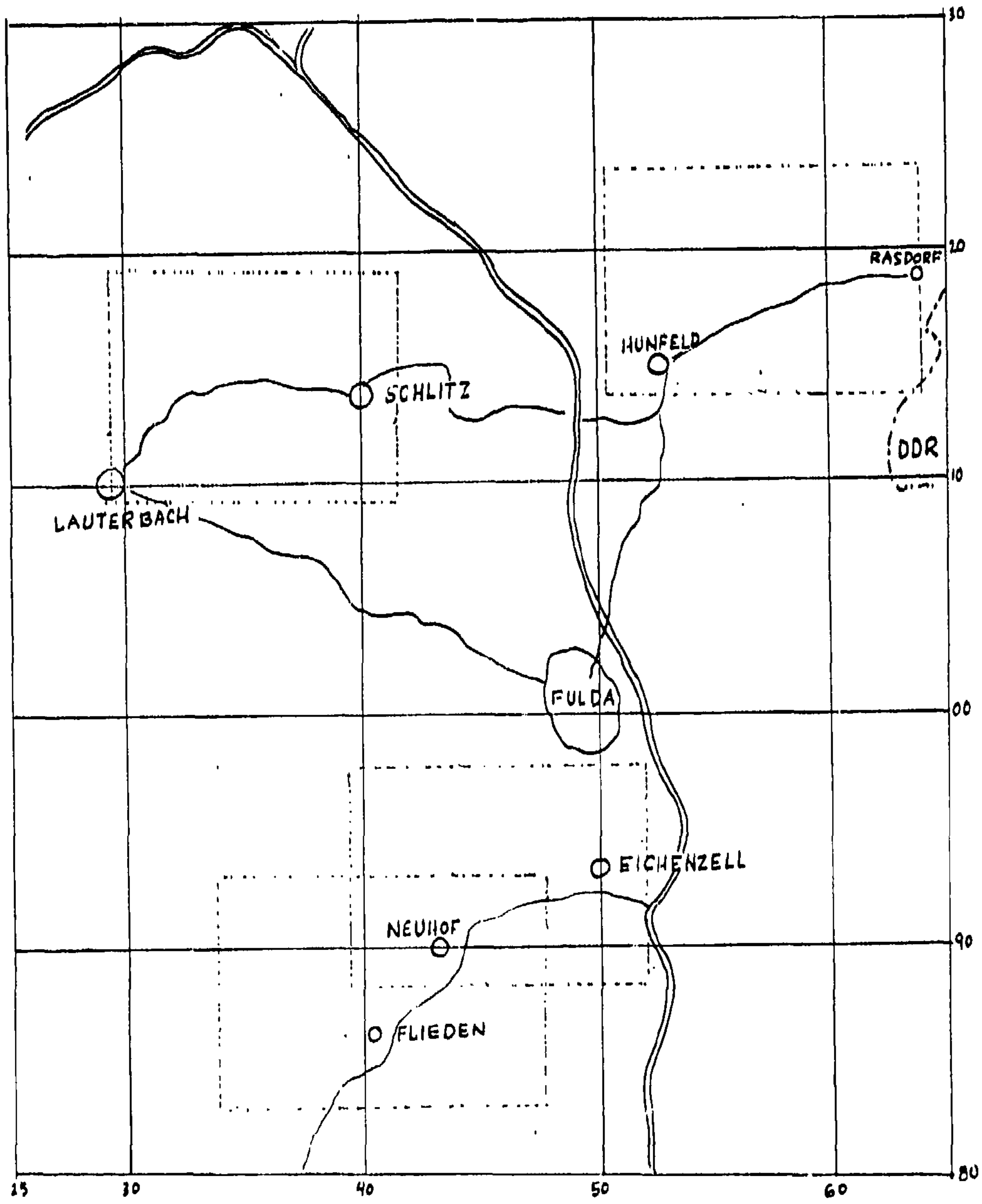
6. Time.

Each scenario has a time element unique to its setting.

E. COMMON SCENARIO BACKGROUND

The scenarios set forth in the following pages describe the specific situations identified in Figure IV-7. Each of the scenarios is couched in an assumed attack by Threat forces across the intra-German border. The study scenarios use the METT-T situation described above to look at mine/minefield detection problems in the area of Fulda.

The master scenario takes place in the area shown below and assumes an initial penetration which the allied forces halt. Counterattacks are undertaken across the front, including one by the study task force. The Threat forces retreat and the Allies go on the offensive. As the Threat falls back they place minefields in the path of the attacking Allies. These minefields are both above ground and buried, and are conventionally laid and scattered. Threat mining activities also include placing mines in and on the main supply route to disrupt logistics support. Finally, at a point near the border, the Threat forces establish a multi-band deliberate defense position which includes a deliberate minefield.



F. DESCRIPTION OF DIFFERENTIAL COMBAT MODEL.

1. General.

The model used in this study to assess the effectiveness of MIRADOR is based on the differential ground combat submodel contained in the VECTOR-2 theater level combat model. However, a number of modifications have been implemented so that the resulting Differential Combat Model (DCM) is better able to address the specific combat situations treated in the present study. A more detailed description of the model and sample input and output data can be found in Appendix B.

2. Advantages.

The primary advantages of the DCM are: (1) it uses methodolgy for expected-value, two-sided ground combat models, and (2) the attrition methodology is based on physically defined and measurable input parameters and on environmental conditions. Previously the DCM had operated only on main frame computers. However the emergence of the high capacity IBM PC has enabled the authors of this study to convert the model to run on the PC.

3. Description.

The DCM uses sets of attrition equations to determine battle outcome. The basic attrition equation used in the DCM is given by

$$\frac{dR_j}{dt} = -\sum_i A_{ij} B_{ij}$$

where R_j is the current number of Red weapons of type j, B_{ij} is the current number of Blue weapons of type i that are within range of the acquired Red weapons of type j, and A_{ij} is the <u>attrition rate</u> for Blue type i weapons against Red type j weapons. The attrition equations for Blue are identical in form to the above equation. The resulting system of differential equations is then solved numerically, yielding trajectories of relative Red and Blue force sizes over time.

4. Attrition Rate Calculation.

There are several factors involved in the computation of the attrition rates, A_{ij}. These are intervisibility and target acquisition; allocation of fire; and kill rates.

a. Intervisibility and Target Acquisition.

The DCM uses an alternating Markov process to replicate line-of-sight. Representations of the length of time a target is in view and out of view of a weapons system, and the length of time required for a weapon to detect a visible target and fire upon it are contained in the model.

b. Allocation of Fire.

Also contained in the DCM is a representation of the allocation of fire to the different target types. Each targeted system is given a value and the firing forces allocate a fraction of their available fire on acquired targets proportional to the relative values of those targets.

c. Kill Rates.

Each weapon system is given a kill rate for each opposing target system. This rate is composed of the probability of a hit; the probability of a kill, given a hit; and the expected time required to kill.

5. Input Data.

Many of the parameters mentioned above (intervisibility periods, acquisition times, hit and kill probabilities) are range dependent and the model requires input which reflects these changed values as the range to the target changes.

a. Target Intervisibility Data.

A characteristic of the DCM is the requirement for intervisibility data between weapons and targets. The model requires input of average in-view and out-of-view segement lengths. Based on these values, the model then calculates the probability of line-of-sight as a function of range. Such intervisibility data was calculated for the Fulda area in Germany. An AMSAA computer model (LOSPATH) was used that employs digitized terrain data giving terrain elevation, as well as vegetation type and height. Weapons positions and typical tracks for attacking target vehicles were defined, and the LOSPATH model was used to determine in-view and out-of-view segments along each path as seen from the weapons system. These results were then averaged to give the range-dependent in-view and out-of-view segment lengths required by the DCM.

b. Date Source.

Weapons data for the Differential Combat Model (DCM) was obtained from the U.S. Army Materiel Systems Analysis Activity (AMSAA), Aberdeen Proving Grounds, Maryland. Data included probabilities of detection, acquisition, hit and kill, as well as time of flight for weapons systems found in a U.S. Army Tank Battalion Task Force and a reinforced Threat Motorized Rifle Company.

G. SCENARIO A: PURSUIT; REMOTELY DELIVERED SCATTERMINEFIELD

1. Background Description.

The attacks along the front have been successful in causing the Red forces to fall back. The Corps Commander demands unrelenting attacks to prevent the Red forces from establishing a deliberate defensive line.

2. Operations Description.

The Blue forces continue to push the attack, with the study task force among the lead elements. The task force continues in the same structure, and is moving in two columns. As they draw close to the retreating Red forces, a battery of BM 27s are used to place a scattered minefield in front of the task force.

3. Minefield Description.

The BM 27 scatter minefield confronting the study task force is essentially the same as the 6 launcher minefield described in Chapter III (page III-17). The mines are dispersed over an area approximately 2000 meters wide and 1000 meters deep. There are 2694 mines in the minefield, using "scratchwire" fuzes which have full width kill capability. There are 1.35 mines per meter of front, and 0.009 mines per square meter. The average distance between mines along the front is 0.74 meters.

The space between mines varies throughout the minefield. The mines are more concentrated in some areas because of the release mechanisms and the trajectories of the individual rockets. If the mines were evenly spaced in a rectangular grid pattern, there would be 22.3 meters along the grid in each dimension between mines. However, the scattered mines are not evenly spaced, but rather are sometimes closer, and sometimes farther apart, than the average 22.3 meter even spacing.

4. Basis of Analysis

The nature of a remotely delivered minefield introduces changed conditions as compared to conventional minefields. The use of explosive charges such as the MICLIC are impractical due to the depth of the scatterminefield which are often ten times the length of a MICLIC.

The mines per meter of front figure is high, but the depth of the minefield results in sufficient distance between mines, on the average, for mine-free paths to exist, and these paths potentially can be found by detectors. Once found, and marked, the paths can be followed by combat vehicles.

On the other hand, "bull-through" tactics may not be as effective as in a pattern minefield. Once a mine has been encountered in a pattern minefield, certain things can be assumed about the existence of surrounding mines. In a scatter minefield, there is no indication that a vehicle knocked out by a mine has thus identified nearby clear areas for following vehicles.

To assess the value of the mine detectors, each detector will be evaluated for ability to make a timely search for a mine-clear path through the minefield. Time is critical to the search, not only because of the need to maintain contact with the enemy, but to avoid being subjected to artillery or aircraft attack while delayed by the minefield.

5. Search Speeds.

The rate of detection and thus the elapsed time to find a mine-free path through the minefield is critical to this situation. Figure IV-8 sets forth the search speeds and search time.

Detector	Search Speed	Distance	Total search time
Probe	0.16 Km/hr	1000 m	6.25 hours
AN/PSS-11	2.01 Km/hr	1000 m	0.49 hours
Roller	12.07 Km/hr	1000 m	0.08 hours
MIRADOR	12.87 Km/hr	1000 m	0.08 hours

Figure IV-8. Detector Search Times.

6. Viable Alternatives.

The Probe and AN/PSS-11 consume a considerable time and expose the task force and the individual searchers to a great deal of risk. If used at all, the Probe and AN/PSS-11 would be used together. The probability of a follow-on attack by rocket, tube artillery, or aircraft makes it necessary to move quickly through the minefield. However, an exposed manual team, using visual sightings and hand marking of a clear path could be expected to need at least 30 minutes to accomplish the task.

The Roller has sufficient speed to cover the distance in less than 10 minutes. The Roller, however, has a number of drawbacks for this application. It detects and clears by sacrificing a portion of itself, and a widely accepted limit for the roller is three encounters before it becomes ineffective. In this minefield, a Roller which is 4.06 meters (160 in) wide, with rollers 1.12 meters (44 in) wide, separated by a gap of 1.82 meters (72 in) can be expected to encounter 5.48 mines (1.35 x 4.06) across the full width of the Roller. Nearly half of that number (2.46) will be in the gap between the rollers which is conveyed by a "dog-bone" and chain. It is likely that one or both of two adverse actions could occur. The Roller could strike three or more mines and become ineffective; or a mine could be detonated by the dog-bone between the rollers and then be followed by a second mine which would detonate under the belly of the tank rendering it ineffective.

MIRADOR also has sufficient speed to move quickly over the distance covered by the minefield. However, because the goal is to find a mine-free path, the MIRADOR must find a path <u>around</u> each mine detected. For this situation MIRADOR is assumed to have a 2.44 m sweep head and have a detection or neutralization capability against scratch wire fuzes. The width of the mine-free path should be 5 meters wide for M1 tanks. Therefore, the MIRADOR, even with a 2.44 m search head, must make multiple passes to provide a swept path useful to the task force. Thus the times set forth in Figure IV-8 must be doubled and increased by a factor to account for the need to stop and turn for each encounter.

The 2.44 m search head can be expected to encounter, on the average, 3.3 mines in a single pass through the minefield. Two passes would create a swept path 4.88 meters wide, approximately the distance needed by an M1 tank. In a double sweep, 6.6 mines would be encountered. Allowing one minute per mine for marking the mine, back-up and re-direction, results in a total MIRADOR time for locating a mine-free path is 0.27 hours (.08 hr/pass x 2 passes + 6.6/60).

7. Tactical Implications.

The four detectors being evaluated have limitations which impact the tactical situation facing the Task Force following passage through the minefield.

a. Probe and AN/PSS-11: During the 30 minute mine search, there would be losses to waiting tactical elements from incoming fire. If after the mine-free path was marked remnants of the Task Force continued the attack, they would be at a reduced strength. Based on available indirect fire attrition data used is the simulation model, an attrition of 1.3% per minute can be expected against attacking vehicles under heavy artillery fire if they are stopped in the open or in a minefield. The rate will decrease to some extent as the force seeks cover. The average loss rate due to artillery fire is somewhat higher for the lighter skinned M-113's and less for the heavy tanks. Thus the Task Force could be as low as 70% strength when it began the attack.

b. Roller: If the Task Force elects to risk losses due to encounters with mines by the roller tank rather than accepting losses caused by delays and incoming artillery, then the Task Force would start the next battle with reduced forces. Losses from mines would be one and losses due to hostile fire would be two. As a result the Task Force would begin the attack at approximately 90% strength.

c. MIRADOR: Losses due to incoming fire could be greater than that in the Roller situation since it takes longer for MIRADOR to make two passes through the minefield. However, there would be no losses due to mines. Indirect fire losses during the lane clearing operation could be as high as seven. Thus the Task Force would start the next battle at approximately 80% strength.

8. Modeling.

Using the foregoing force losses, an attack of a hasty defensive position was modeled using force strengths which safely exited the scatter minefield. The results are shown in Figures IV-9 through IV-11, below.

PROBE & AN/PSS-11

COMBAT VEHICLE	INITIAL NUMBER	LOSSES DUE TO M/F	NUMBER EXIT M/F	LOSSES IN ATTACK	TOTAL LOSSES
Attackers					
M1	30	9	21	16.6	25.6
M2/3	26	8	18	15.9	23.9
Defenders					
T80	3				2.6
BMP	4				3.3
BMP-2	6				5.1

Figure IV-9. Dismounted Detectors in Scatterminefield

MINE ROLLER

COMBAT VEHICLE	INITIAL NUMBER	LOSSES DUE TO M/F	NUMBER EXIT M/F	LOSSES IN ATTACK	TOTAL LOSSES
Attackers					
M1	30	3	27	18.6	21.6
M2/3	26	3	23	19.2	22.2
Defenders					
T80	3				2.8
BMP	4				3.6
BMP-2	6				5.5

Figure IV-10. Mine Roller in Scatter Minefield

MIRADOR

COMBAT VEHICLE	INITIAL NUMBER	LOSSES DUE TO M/F	NUMBER EXIT M/F	LOSSES IN ATTACK	TOTAL LOSSES
Attackers					
M1	30	6	24	17.5	23.5
M2/3	26	6	20	17.5	23.5
Defenders					
T80	3				2.7
BMP	4				3.5
BMP-2	6				5.3

Figure IV-11. Mirador in Scatter Minefield

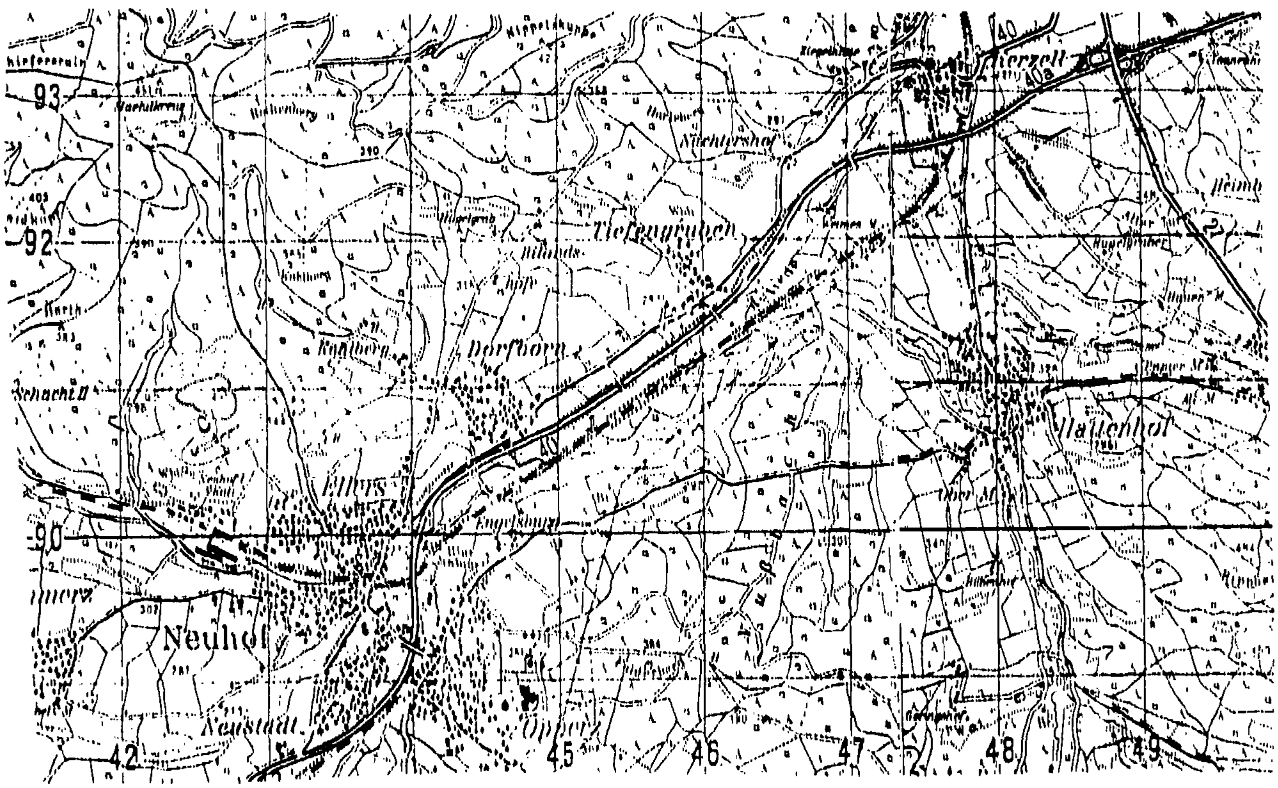
9. Analysis.

The losses due to the minefield were higher for the MIRADOR due to the double sweep necessary to achieve a tank-width mine-free path. A wider sweep head would reduce the exposure time and hence the losses. Information from initial testing of the latest version of the MIRADOR test vehicle indicates the current search head, which is about 4.5 feet wide, sweeps a path about 7.5 feet wide. Therefore, a single pass vehicle seems to be within reason. A single pass detector would reduce losses and provide the potential for rapidly finding a remotely delivered scattered minefield and leading an armored column through it with less casualties than any other means.

H. SCENARIO B: HASTY ATTACK SCENARIO

1. Background Description.

The counterattacks along the front have been successful in causing the Red forces to go on the defense. The Red forces fell back several kilometers and established a hasty defensive position in the vicinity of Eichenzel (NA 5094). The Corps Commander has directed that an all-out effort be made to break through the defenses to prevent the Red forces from having time to establish a deliberate defense. The study task force is designated as one of the leading elements to spearhead the attack. The Blue forces intend to overcome any obstacles or minefields encountered as quickly as possible by either breaching in-stride or by-passing.



2. Operations Description.

The attack operation is continuing day and night. The forward movement under study is being conducted in mid-morning, in clear weather with broken cloud cover. The Blue forces are moving northeastward parallel to Route 40 (see situation map). The terrain in the valley floor is gentle and the soil conditions permit operation of the tanks and low-ground-pressure wheeled vehicles in most of the off-road locations.

The Task Force is moving in two parallel columns, making use of roads when possible, but also moving cross-country when obstacles are encountered or foreseen. A minefield breaching element is moving with each column. The counter-mine system in each formation includes a detector teamed with a MICLIC and a CLAMS-equipped mine-roller tank. The TF Commander seeks to determine the location of the minefield as quickly as possible, and then without delay make a decision to breach or to by-pass. His TF is well trained in the in-stride breach battle drill.

A schematic description of the Task force organization and tactical layout is shown in Figure IV-12, Tank Battalion Task Force In-Stride Breach. The J series Tank Battalion has undergone a balanced cross-attachment with a Mechanized Infantry Battalion. If necessary the unit will conduct two breaches in the minefield.

A multiple obstacle is encountered in the vicinity of NA 465925. The enemy created a series of road craters and minefields to block movement through the Fliede River valley. Several hasty minefields block all-off road movement along a line from NA 463923 to NA 465914. The primary and secondary roads, and the railroad, have been cut by craters 3 meters deep and 20 meters across. The craters extend the full width of all roads and are connected to the minefields. Bridges across the Fliede River have been destroyed.

3. Minefield Description.

One hasty Red minefield is 300 meters long from the woodline at NA 463923 to a road crater/minefield complex at NA 464920. A similar minefield runs from the south side of the road crater/minefield complex at NA 465918 to the railroad crater at NA 465915 (this minefield includes mining along the banks of, and in the bottom of, the Fliede River).

The minefields contain three rows of mines, with rows placed 35 meters apart. The mines within the rows are 5 meters apart. The mines are non-metallic anti-tank mines laid on the surface of the ground by mechanical layers. Therefore each 300 meter minefield contains 180 mines resulting in 0.6 mines per meter of front, or one mine every 1.67 meters of front.

4. Search Description (MIRADOR Option).

MIRADOR is expected to search for surface off-road mines at a speed of 12 mph, with a detection rate of 80%, and a false alarm rate of 3 per thousand square feet of swept area. The search head is considered to be 8 feet wide for this operation.

The false alarm rate is therefore 3 per 125 linear feet of swept area, or an average of one false alarm every 41.7 feet (12.7 meters).

The precise location and orientation of the minefield is not known by the Blue force. However, aerial reconnaissance and terrain analysis suggests that the Red forces may have placed a number of minefields across the narrower sections of the Fliede River valley. The Task Force Engineer recommends an angle of attack for the MIRADOR of with respect to the suspected orientation of the front edge of the minefield.

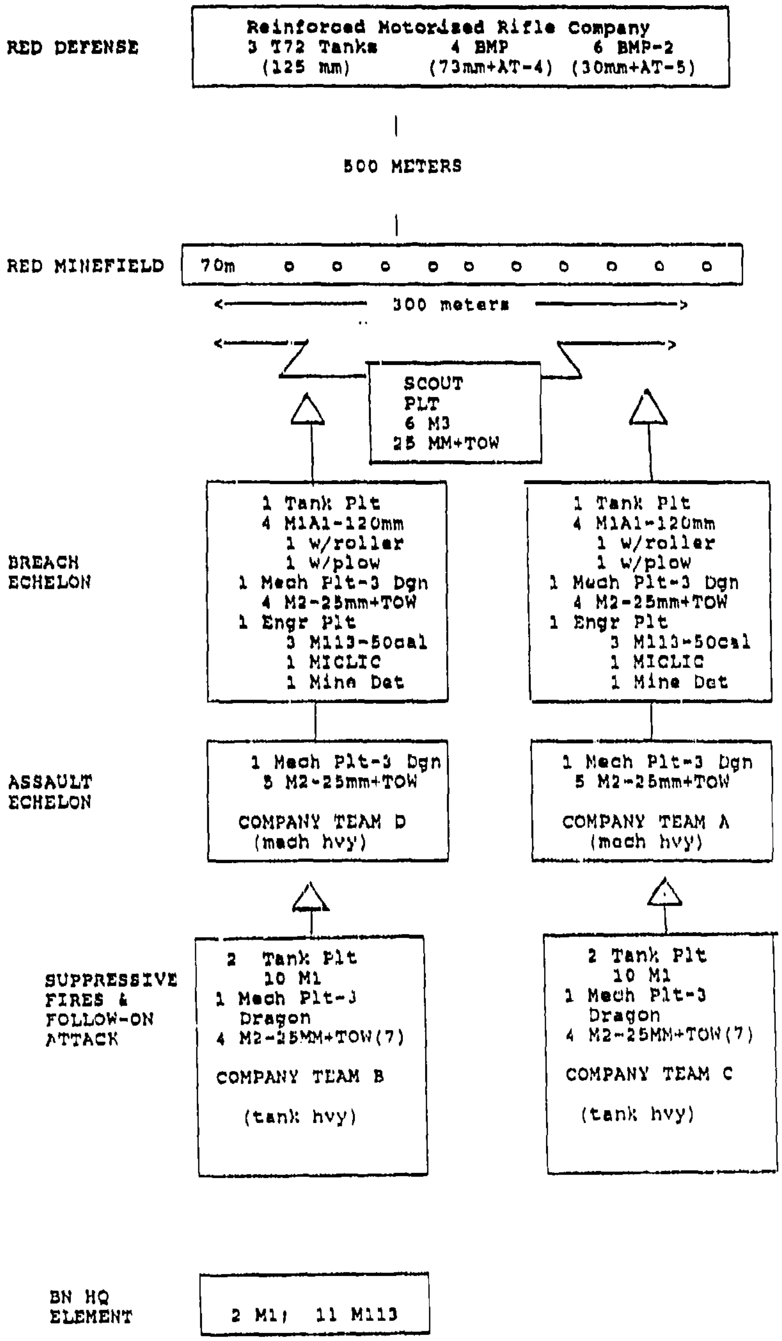


Figure IV-12. Tank Battalion Task Fore In-Stride Breach
(J Series - M1A1 and BFV - Balanced Task Force)

If the MIRADOR's angle of attack is 26° or less to the front edge of the minefield at least one mine will be encountered in each of the three rows at 26°. At that angle, the length of the sweep through the minefield will be 160 m and the number of false alarms will be 12.6.

5. Basis of Analysis.

The tactical situation shown in Figure IV-12 was modelled in the Differential Combat Model. Repeated runs were conducted as shown below.

Run 1	No Minefield
Run 2	Minefield, no detection
Run 3	Minefield, Probe detection
Run 4	Minefield, AN/PPS-11 detection
Run 5	Minefield, Roller detection
Run 6	Minefield, MIRADOR detection

6. Probability of a Kill by a Hasty Minefield.

The Differential Combat Model requires an input variable for the probability that an attacking vehicle of type M will be killed when passing through the minefield. Thus a different PKM(M) is inserted for each minefield situation.

A description of a method used to determine the minefield kill probability is shown below. This analysis assumes a three row hasty minefield with mines 5.5 meters apart in three parallel rows in which the mines are evenly offset, and therefore 1.83 meters apart when viewed from the minefield front. The path of the M1 tank is assumed to be perpendicular to the three rows. The pressure fuzed mines have fuze pressure plates .31 meters in diameter, as shown below in Figure IV-13.

The analysis begins with the left edge of the left tread encountering mine #3 pressure plate. The right tread is not encountering a mine. The analysis progresses by displacing the tank's imprint to the tank's left across the frontal location of the mines.

With displacement of the tank's position to the left, the left tread continues to encounter mine #3, and the right tread remains free of any mine until the displacement has moved .73 meters, at which time it encounters mine #1.

When the left tread has displaced 1.03 meters (.72 + .31), the left edge of the displaced left tread no longer encounters mine #3.

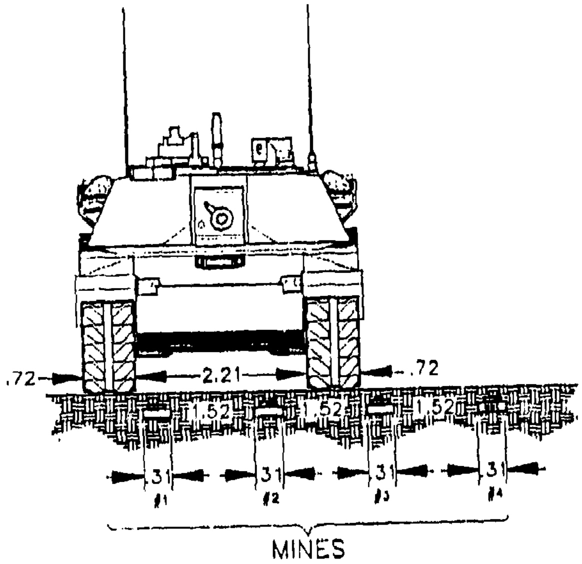


Figure IV-13. Critical Encounter Dimensions

The right tread also displaced 1.03 meters, and as noted above, began to encounter mine #1 with its right edge after .73 of displacement. Since 0.30 meters of the total right tread encounter distance of 1.03 meters distance occurs before the left track is clear of mine #3, 0.73 m of encounter distance remains before the right track is clear of mine #1. Thus, when the right tread has cleared mine #1, the left edge of the left track has moved .73 meters from mine #3. Since the track is .72 meters wide, the right edge of the left track is .73 + .72 or 1.45 meters from mine #3, but only 1.52 - 1.45 or .07 meters from making contact with mine #4. Thus, there is an "encounter free zone" of .07 m before the right edge of the left tread encounters mine M2M and begins a repeat of the sequence.

Therefore, the probability of encountering a mine is a function of the encounter-free distance in each repeat sequence. Since the left edge-to-left edge distance between mines is 1.83 meters, then

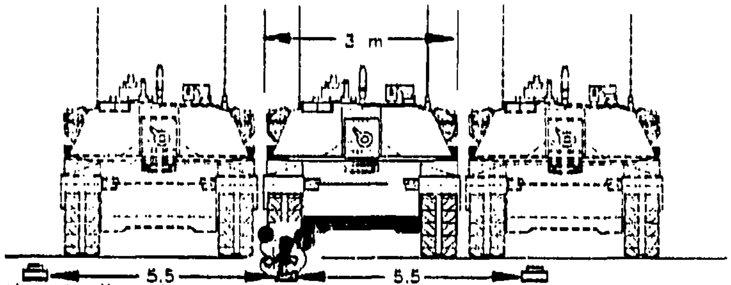
$$1 - P_E = 0.07/1.83 = .038$$

$$P_E = .962$$

For a number of vehicles in column, the foregoing analysis describes the situation for the lead vehicle. The lead vehicle, then, has a .96 probability of encountering a mine. The mine encountered may be in the 1st, 2nd, or 3rd row with equal probability.

If the mine is in the 1st row, two mines remain in subsequent rows. A trailing vehicle following in the path of the lead vehicle, could go around the lead vehicle when it encountered a mine. In this case, if the trailing vehicle passed the first vehicle on the side which contacted the mine, a mine-free space of nearly 5.5 meters is available.

If the trail vehicle passes the damaged lead vehicle on the side opposite the encounter, the mine-free space is considerably less. In fact, the next mine is located approximately 2.5 meters from the edge of the disabled tank (5.5 meter row spacing less the distance from the encounter point to the opposite side of the tank which could vary from 2.93m to 3.65m). However, if the trail vehicle passes closely to the damaged vehicle, its tracks will straddle the mine. This concept is shown below, viewing vehicles from the front, with a second vehicle passing the first vehicle on either side:



Thus, the trail vehicle has a high probability of passing the damaged vehicle without encountering a mine in the same row.

After the first row is passed, the mine spacing as viewed from the front changes. The mines in each row remain spaced 5.5 meters apart, but after the first row is passed, the uniform 1.83 meter spacing is modified, with every other space doubling due to the "missing" first row mine.

M M M M
<--1.83m---><------ 3.66m --------><---1.83m--->

For every 5.5 meters, a 1.52 (1.83 - .31) meter mine free gap and a 3.35 (3.66 - .31) mine free gap exist. An analysis similar to the analysis conducted for the first row shows that the probability that the first vehicle passing the second row has a probability of encountering a mine of 0.75.

After the second row is passed, only the third row remains with its 5.5 meter spacing. The probability of an M1 tank encountering a mine in that row alone is 0.35.

All trailing vehicles which follow in the tracks of the lead vehicles have a limited likelihood of encountering a mine. A probability of 0.10 is assigned to each trailing vehicle in each column. For this situation, the overall PKM assigned then becomes of 0.96 + 0.75 + 0.35 + ([n - 3] x 0.10).

7. Results of the Simulation.

Figure IV-13 shows the losses to each side for each situation modeled using the Differential Combat Model.

TYPE COMBAT VEHICLE	INITIAL NUMBER	NUMBER KILLED					
		NO MINES	MINES NO DET	PROBE	PSS-11	ROLLER	MIRADOR
Attackers							
M1	30	7.0	17.8	11.1	10.3	9.8	9.8
M2/3	26	6.9	15.9	14.1	12.1	11.0	11.0
Defenders							
T-80	3	2.9	2.8	2.8	2.9	2.9	2.9
BMP	4	3.8	3.8	3.9	3.9	3.9	3.9
BMP-2	6	5.8	5.8	6.0	6.0	5.9	5.9

Figure IV-13. Hasty Attack Combat Vehicle Losses

8. Analysis of the Results.

The foregoing losses are measured in combat vehicles only. The attacker-to-defender combat vehicle force ratio of 56 to 13 is 4.3 to 1, somewhat above the minimum doctrinal 3 to 1 ratio. In the situation where no minefield was interposed between the forces the attackers lost 13.9 vehicles and the defenders lost 12.5, the result of beginning the attack with a favorable force ratio.

When the defender inserts a hasty minefield between the forces and the attackers attempt to bull through, losses rise dramatically. Even though the attacker reached the objective, the losses were 33.7 versus 12.4 for the defenders.

The next four situations involved the use of countermine systems. In each case the four detectors were used to find the leading edge of the minefield, and a MICLIC was used to clear a path. The principle variation among the detectors is the time taken to sweep in the suspected area for the minefield. Not included in Figure IV-13 are the personnel losses for each system. The time differential causes increased losses due to the continued attrition of the force while in hastily selected hull defilade positions, and the reduced attacker firepower from those positions. Once the lanes are developed through it the forces funnel through the lanes at reduced speed and firepower. Losses, as expected, rise significantly.

The vulnerability of the BFV to enemy anti-armor fire is reflected in the high losses (nearly the same as experienced in a bull through) due to the long delay experienced when using the probe as the detector.

The equipment losses when using the Roller and the MIRADOR are similar due to similar sweep speeds. Not shown in the equipment numbers is the lower risk to personnel associated with use of the MIRADOR. The remote detector does not risk personnel directly, and it does not encumber a critical combat vehicle.

SCENARIO C. DELIBERATE ATTACK

1. Background Description.

The allied attack has stalled near the Inter-German border by a well prepared defense established by the Threat forces. A build-up of forces and a deliberate attack is planned by the Blue forces Corps Commander.

The MIRADOR study Task Force is designated as one of the attacking elements. As a part of the deliberate attack, a thorough reconnaissance of the enemy positions is necessary.

The mine detectors will be one of the means used to determine the location of the Threat defensive positions. Information from MIRADOR will be combined with other sources as a basis for Intelligence Preparation of the Battlefield (IPB).

A nighttime minefield reconnaissance effort is undertaken. The gap between forces is 10 km.

The Threat forces have established a deliberate anti-tank minefield consisting of 3 bands of buried mines. Each band contains five rows (4 AT and 1AP) 50 meters apart. Mine spacing is 3.5 meters within each row. Band density is 1.14 mines per meter of front.

2. Operations Description.

The minefield reconnaissance force sought to use the cover of darkness to enhance their effort to locate the minefield. There were 7 hours of darkness available each night for nighttime reconnaissance. The detectors used varying portions of that time moving from the FLOT to the minefield.

3. Search Description.

The purpose of the minefield search is to determine the exact location of the bands in the minefields to permit planning, rehearsal and execution of battle drills to create cleared lanes in the bands for the attacking forces.

Each mine detection system detects at a unique rate. The longer the time to locate the minefield, the more opportunity there is for the defending forces to reinforce their defense. The Division G2 estimates that the enemy will be able to bring in heavier artillery concentrations, and employ more defending tanks as the days pass.

The Roller is not adaptable to the reconnaissance role. The inherent tank noise and the signature of the mine detonations would make the Roller and easy target. If the force has to rely only on the Roller, it would have to use the roller at the time of attack. Because of the three bands with four antitank rows, a roller would experience three encounters in each band. Assuming there are two rollers with each column, both rollers would be immobilized before the third band was reached. The column would then be forced to "bull through" the remaining band.

The search distance is made up of the combined distance of the three bands of mines, the two intervening spaces, and an additional 200 meter search distance preceeding the first row for a total distance of 2750 meters. The length of time each detector takes to search this distance is shown in Figure IV-14.

DETECTOR	SEARCH SPEED	DISTANCE	SEARCH TIME
PROBE	0.16 Km/hr	2750 m	17.2 hours
AN/PSS-11	0.34 Km/hr	2750 m	8.1 hours
MIRADOR	9.7 Km/hr	2750 m	0.3 hours

Figure IV-14. Deliberate Minefield Search Times

4. Impact of Search Times.

The longer the search time, the more time the enemy has to build up his forces. For this study it is assumed that the enemy is bringing in additional tanks and artillery to support his defense.

5. Deliberate Minefield PKM.

An analysis similar to that conducted for the probability of kill for a vehicle in a hasty minefield was conducted for the deliberate minefield depicted here. The closer spacing of the mines and the increased number of rows in each band results in a much higher PKM. For each band the resulting probabilities were

1st vehicle	-	1.00 PKM
2nd vehicle	-	0.95
3rd vehicle	-	0.65
4th vehicle	-	0.55
subsequent	-	0.10

6. Baseline Results of Combat Simulation.

The input variables for the simulations reflected the increased time the defender had to build up his forces opposing the study task force. The base case shown in Figure IV-15 is an attack on the defender with no intervening minefield. With no intervening minefield, and therefore no delay for build-up of forces, the situation is similar to the hasty attack. The second case shows the results of the attacking force launching an attack against the deliberate minefield without use of a countermine system.

TYPE COMBAT VEHICLE	INITIAL NUMBER	NUMBER KILLED NO MINEFIELD	MINEFIELD, NO C-MINE
Attackers			
M1	30	7.0	23.3
M2/3	26	6.9	20.0
Defenders			
T-80	3	2.9	2.7
BMP	4	3.8	3.5
BMP-2	6	5.8	5.4

Figure IV-15. Deliberate Minefield Base Case

7. Results Using Probe Detection.

The Probe scenario reflects the build-up of forces opposing the task force. Sufficient time has elapsed for the defenders to reinforce their tank and artillery forces. For the Probe, as well as the other detectors, the attacking force was assumed to use MICLICs to clear lanes in the minefield. As a result the probability of kill by a mine is 0.10. The 200 meter deep band requires using two MICLICs end-to-end to cover the band depth, a tactic which is open to question. However, for the purposes of deriving other information it was assumed that such a tactic is viable. The employment time of 4 minutes per MICLIC set forth in FM 5-34 was added to the mine detector search times. The results of a deliberate attack using the Probe as the detection means is shown in Figure IV-16.

TYPE COMBAT VEHICLE	INITIAL NUMBER	FORCE LOSSES
Attackers		
M1	30	30
M2/3	26	26
Defenders		
T80	20	19
BMP	4	4
BMP-2	6	3.3

Figure IV-16. Probe Detection of Deliberate Minefield.

8. AN/PSS-11 Detection. The hand held detector accomplished the detection in less time than the Probe, but there was still time for the enemy forces to improve their posture. The build-up consisted of increased tanks and artillery. The results of the combat simulation are shown in Figure IV-17.

TYPE COMBAT VEHICLE	INITIAL NUMBER	FORCE LOSSES
Attackers		
M1	30	30
M2/3	26	26
Defenders		
T80	20	19
BMP	4	4.0
BMP-2	6	3.3

Figure IV-17. AN/PSS-11 Detection of Deliberate Minefield.

9. Roller Detection.

The rollers were used as detectors at the time of attack. While this allowed the attacking force to initiate the attack when all other aspects were ready, and thus reduced the defenders ability to build up his forces, it resulted in a higher probability kill due to mines. The Rollers encountered numbers of mines in the first two bands which disabled the rollers. The Task Force was forced to bull through the last band. As a result the PKM was 0.1 for the first two bands and increased to .492 for the third band. The results of the simulation are shown in Figure IV-18.

TYPE COMBAT VEHICLE	INITIAL NUMBER	FORCE LOSSES
Attackers		
M1	30	17.5
M2/3	26	16.5
Defenders		
T80	3	2.9
BMP	4	4.0
BMP-2	6	5.9

Figure IV-18. Roller Detection of a Deliberate Minefield.

10. MIRADOR Detection.

MIRADOR had to operate at an angle of 20° to assure an encounter in each row. This angle of attack increased the search path length to 8040 meters and increased the search time to 0.82 hours. However, there was no significant defender force build-up in this period of time. The results of using the MIRADOR in the deliberate attack are shown in Figure IV-19.

TYPE COMBAT VEHICLE	INITIAL NUMBER	FORCE LOSSES
Attackers		
M1	30	9.9
M2/3	26	9.3
Defenders		
T80	3	2.7
BMP	4	4.0
BMP-2	6	5.7

Figure IV-19. Mirador Detection in Deliberate Minefield.

11. Analysis of Results.

A summary of attacking Blue vehicle losses is shown in Figure IV-20.

TYPE COMBAT VEHICLE	INITIAL NUMBER	COMBAT VEHICLE LOSSES					
		NO MINES	MINES NO DET	PROBE	PSS-11	ROLLER	MIRADOR
M1	30	7.0	23.3	30.0	25.9	17.5	9.9
M2/3	26	6.9	20.0	26.0	25.8	16.6	9.3

Figure IV-20. Summary of Detector Options.

The results show significant differences among the detector options. The influence of changing opposition is responsible for a portion of the differences, but those changes reflect a realistic battlefield situation. Being able to act quickly is a significant advantage, particularly for the attacker. Again, not shown are personnel losses which could be predictably higher for the dismounted systems.

. A minefield of this magnitude exposes the weaknesses of each of the available detectors. The Probe and AN/PSS-11 not only expose the operators, but consume time that causes attrition and allows the enemy to take the initiative or gain an advantage. The Roller is much faster and offers greater protection, but it is large, noisy, expensive and detects by sacrificing a portion of its capability. In this situation, and perhaps others, the Roller loses effectiveness due to these characteristics.

The MIRADOR concept shows the ability to provide the force with the fewest losses. This is accomplished with the aid of several assumptions. The ability to cross obstacles, "float" over mines without detonating them, and provide accurate feed back to the supported force are all assumed in this simulation. If those assumptions are correct, a remotely controlled minefield reconnaissance vehicle appears to have an advantage over other mine detection options for deliberate minefields.

J. SCENARIO D - MAIN SUPPLY ROUTE (MSR)

1. Background Description.

The Blue forces are postioned with the FLOT running NW to SE through Hauental (NB 4824), Hunfeld (NB 5413) and Hofbelber (NB 5904). The Main Supply Route runs for a distance of 45 kilometers from Lauterbach (NB 2809) through Schlitz (NB 4014) and Michelsrombach (NB 47130) to Hunfeld.

The Blue forces have been expending fuel and ammunition at a high rate and currently have dangerously low supplies at the front. The Corps Commander has requested an all-out effort to move critical supplies forward.

The Red forces have air parity and have made successful air attacks on supply convoys. They have also shown an ability to mine the MSR. There have been frequent instances of Threat agents and Spetznatz teams placing buried mines in the roads. The has been the experience of the logistics forces that when a vehicle in a convoy encounters a mine, an average of one hour delay is experienced in security measures, road clearance or by-pass, evacuation of wounded, and resumption of travel.

The supporting logistics commander has been tasked to deliver resupplies of Class III and V to the Brigade Trains area near Hunfeld. The supplies must arrive in the trains area by 0100 so that distribution to individual vehicles can be accomplished before the attack is continued early the next morning. The logistics commander decides to send a night convoy to minimize air attack. He requests and receives security and Combat Engineer support for the convoy. The convoy departs at 2200 hours expecting to be able to travel at the convoy's average speed of 15 KPH so as to arrive at the Brigade Trains area by 0100.

2. Essential Elements of Analysis.

The search for mines over an extended linear sweep area of extremely low mine density presents a problem considerably different from the off-road mine search effort. There may be only one mine in a 10 kilometer stretch of road, but the detection of that one mine is of utmost importance to the following forces.

The key questions for a roadway mine search are:

- o What is the importance of the MSR mine clearing effort to the front line war effort?
- o What is the preferred search equipment, what are the search procedures, and what action is undertaken when a mine is detected?
- o Is the countermine system cost effective?

3. Measures of Effectiveness.

The following are the measurements used to evaluate how well each mine detector does in responding to the key questions.

- o The amount of time the convoy is delayed by the mined area when each of the detectors is used.
- o The diminution of effectiveness of the combat forces caused by the delay of the supplies.
    - oo Impact of a shortfall in the Class III and V consumption/resupply rate.
- o Cost in manpower, time, and materials required to
    - oo sweep the road with each mine detector
    - oo investigate each report of detection
    - oo render ineffective each detected mine
- o Losses in men and equipment due to mines not detected.

4. Minefield Description.

The Main Supply Route has a vulnerable 10 kilometer between Schlitz and Mickelsromback. Threat agents buried ten mines in random positions in the 6 meter wide road just after nightfall. Nine of the mines are buried 3 centimeters beneath the roadway surface and are actuated by pressure fuzes. Of these nine mines, five have fabricated metallic cases while the remaining four have locally constructed wood cases. The tenth mine is a 250 pound bomb placed in a culvert 30 cm below the road surface and wired for command detonation.

5. Operations Description.

The critical resupply convoy moves out on schedule at 2200 hrs with supporting security and countermine combat engineer forces. The convoy is made up of standard military cargo trucks and smaller utility vehicles for command, control and security. The width of the largest vehicle is a 5 ton cargo truck which has a total width of 2.48 meters (8 feet, 1 inch). The convoy commander stated that he can accept the risk associated with having a swept lane of 8 feet. He placed the mine detector in the lead accompanied by the remainder of the engineer force and a portion of the security force.

6. Probe/AN-PSS 11 Option.

The nature of the Mine Probe and the AN/PSS-11 mine detection systems is such that they would be used together for a detection operation of this type. The hard surface of the roadway would make it impossible to probe at regular intervals. Instead the hand held metallic detector is used to sweep the roadway and any positive readings are then examined by probing and visual examination.

The sweep rate of the probe-PSS-11 combination travels at a rate of 0.34 kilometers per hour (0.21 mph). The detection rate is 88.7% and the normal width of the swept area of 1.2 meters is increased to 2.44 meters (8 ft) by using two teams in echelon. The mine sweep team would sweep the road, examine and either mark or remove each discovered mine, and mark the cleared path for the following vehicles.

The length of time it would take to clear the 10 km stretch of road is 29.4 hours. If the mines are distributed evenly across the full width of the 6 meter wide road, the number of mines encountered would be 4.07. The detection rate indicates that 3.6 mines would be detected and 0.47 would go undetected. Furthermore, 5.93 mines would remain undetected outside the 2.44 meter swept lane.

Since the 0.47 probability of one of the vehicles striking the undetected mine is less than 0.5, this analysis assumes no vehicle losses due to mines.

The amount of manpower consumed would be 470 man hours of combat engineer time, plus the convoy time of 29.4 hours.

7. Roller Option.

One tank mounted mine roller is available to perform the sweep mission even though the roller would seldom be used to detect/neutralize a minefield of this nature. Mitigating against the use of the roller would be the need for the tank and the roller with the combat forces at the front, and the wear and tear on the tank and the roller caused by sustained road travel. However, there might be situations where the roller would be employed to lead a combat unit on a road march or to lead an extremely critical resupply convoy.

The clearing rate of the tank-mounted roller is 15 KPH (9.3 mph). The detection rate is 97.4% and the cleared path is composed of two 1.12 meter cleared lanes separated by a 1.83 meter uncleared gap. The length of time it would take to clear the 10 km stretch of road is 40 minutes.

The number of mines encountered and detonated would be 3.73 while the undiscovered mines would total 6.27. The undiscovered mines would be in two bands, 3.05 in the space between the rollers and 3.22 mines in the roadway outside the roller paths.

The losses would be determined by the ability of the convoy truck drivers to stay within the cleared path. Since the width of the truck is 2.48 meters (8 ft 1 in), and the hub to hub width of the roller is 4.07 meters (13 ft 2 in), there is adequate clearance on the outside of the truck tires. However, the uncleared space between the rollers of 1.83 meters (6 ft) is nearly the same as the distance between the insides of the truck tires. Therefore there is a strong likelihood that at least one of the trucks in the convoy would encounter one of the 3.05 undetected mines in the area between the rollers.

(Note: This problem could be reduced by using two rollers in tandem with the second roller offset to run one of its rollers in the gap left by the leading roller. Such a solution doubles the requirement for the scarce roller assets. Also, since the gap is 1.83 meters and the roller is 1.12 meters, an uncleared segment of roadway of 0.71 meter (2 ft 4 in) remains.)

For the roller option the amount of manpower consumed would consist of a minimum of one reduced tank crew (two people to minimize losses) for a total of 1.2 man-hours. The movement of the tank and roller to the rear, the supporting semi-trailer to haul the roller, and the possible doubling of the effort to provide two rollers would consume considerably more resources than the actual on-road detection effort of one tank.

8. Mirador Option.

The MIRADOR version used on the road way is assumed to have an 8 foot (2.44 meter) head. It has a detection rate of 70% while travelling at 32 KPH (20 mph). The number of mines in the MIRADOR path would be 4.07. The number of undiscovered mines would be 1.22 mines in the swept area and 5.93 mines outside the swept area.

As discussed earlier, the current specifications allow a false alarm rate of 5 per 92.9 square meters (1000 square feet) of swept area. With a 2.44 meter (eight ft) detector head, 1 false alarm per 76.2 meters (250 feet) of linear swept path can be expected. At that rate, over the 10 kilometers, 131 false detections would be registered. This would require extensive marking, inspection and by-pass effort.

The detected mines (and the false alarms) would be marked by the MIRADOR as it detected them. The MIRADOR could then back up a short distance and sweep a path on one side of the mine. The suspect areas could either be by-passed by the convoy or removed by the combat engineer force.

It is presumed that one vehicle would encounter a mine due to the 1.22 mines remaining in the swept area. There is also potential, to a lesser extent, for losses caused by the 5.93 mines outside the swept path.

The amount of manpower consumed would be the MIRADOR two man operating crew and an eight man squad of combat engineer soldiers. The MIRADOR could sweep the 10 km section in 20 minutes, with an additional 20 minutes for stopping and doubling back to sweep additional areas when a positive reading is received.

9. Impact on the Front Line Forces.

The delay of the resupply convoy with critical Class III and V supplies has the potential to make a significant difference on the battle outcome.

The Blue force commander had ordered the convoy to arrive at the Brigade trains in time for resupply efforts to be accomplished before continuation of the attack. The Task Force has three hours between 0100 and 0400 for resupply and reorganization.

The resupply can be accomplished in one hour, making the latest convoy arrival time 0300. If the resupply convoy failed to arrive in time to transfer fuel and ammunition to the combat forces, then the forces would be unable to continue the attack.

	Probe/PSS-11	Roller	MIRADOR
Time to sweep road	29.4 hr	0.67 hr	0.67 hr
Percent mines found in swept area	88.7%	97.4%	70%
Resources expended	470 MH	1.2 MH+	6.7 mh
Vehicle losses	0	1	1
Sweep time	29.4	0.67	0.67
Delay time (1 hr/veh loss)	0	1.0	1.0
Total time	29.4	1.67	1.67
Normal travel time	3.0	3.0	3.0
Total convoy time	32.4	4.67	4.67

Figure IV-21. Comparison of Detector Data

10. Assessment.

a. The length of time needed by the Probe/AN/PSS-11 combination indicates it is not suited for this countermine role. In addition to the slow pace, the exposure to mines and the stress of constant alertness, make prolonged use such as in this case unacceptable.

b. The Roller, when available, detects, detonates, and proofs the roadway, a distinct advantage. However, the damage to the roadway caused by the detonation, the potential for breakdown or destruction by a concentrated charge, make the roller and its prime mover tank an expensive option.

c. The MIRADOR's currently specified detection rate and false alarm rate hamper its utility in this role. However, the sweep speed and the reduction in personnel risk are advantageous. A MIRADOR which incorporated a one-pass width sweep head, and improved detection and false alarm rates would be very effective in MSR/LOC countermine activities. Even with its current specifications, the MIRADOR completes the mission in the time needed, and at less risk to personnel and combat vehicle resources as compared to the other availabe options.

K. SUMMARY.

Figure IV-23 summarizes the cmobat vhicle lossses for each of the force-on-force combat scenarios situations for each of the detectors.

The MIRADOR equipped Task Force has the lowest total combat vehicle losses, thus rating the highest in the measure of effectiveness. MIRADOR accomplished this total with the benefit of assumptions regarding impunity to mines and improved detection and false alarm rates. Personnel losses can be at least proportional, and perhaps be even more favorable to the MIRADOR equipped force.

DELIBERATE	COMBAT VEHICLE	SCENARIO A SCATTER	SCENARIO B HASTY	SCENARIO C DELIBERATE	VEHICAL TOTAL	TOTAL
PROBE	M1	25.6	11.1	30.0	166.6	230.6
	M2/3	23.9	14.1	26.0	64.0	
AN/PSS-11	M1	25.9	10.3	30.0	65.9	127.9
	M2/3	23.9	12.1	26.0	64.0	
ROLLER	M1	21.6	9.8	17.5	48.9	87.0
	M2/3	22.2	11.0	16.5	49.7	
MIRADOR	M1	23.5	9.8	9.7	43.2	87.0
	M2/3	23.5	11.0	9.3	43.8	

Figure IV-23. Force-on-Force Loss Summary.

CHAPTER V

SUPPORTING SUBJECTS ANALYSIS

SECTION I. INTRODUCTION

A. PURPOSE.

This Chapter contains three supporting analyses which will complement the analyses conducted in previous chapters. First, a comparative evaluation of the Human Factors involved in using and maintaining the existing and emerging mine detection equipment. Then, an analysis of the Maintainability and Logistics supportability of the competing mine detection systems will be accomplished. Finally, a Time-Phased Analysis of U.S. mine detection capability between 1990 and 1999 will be undertaken.

SECTION II. HUMAN FACTORS EVALUATION

A. PURPOSE.

The purpose of this section is to evaluate the MIRADOR and other previously developed detector systems from a human engineering standpoint, in order to compare crew-equipment interface and effectiveness of human performance during operation and/or maintenance of these systems.

B. METHODOLOGY.

Analysis of the detection mission reveals a common set of actions that are required of the operator in the performance of the mine detection function, irrespective of the equipment he employs. These actions are listed in Figure V-1, Common Tasks for Evaluation.

Some of the common operator tasks listed in Figure V-1 are less demanding for some detectors, such as the hand-held probe, but for others they constitute a meaningful task. They are, however, all performed in the operation of each system.

The detector systems evaluated in this effort are: the mine probe (dismounted), the AN/PSS-11/12 hand-held detector (dismounted), the mine roller (tank mounted), and the MIRADOR (remotely operated). For each of the tasks identified above, a Delphi analysis was performed.

Transport detector to detection site
Prepare detector for operation
Establish communications with leaders
Conduct detector actions
Steer detection effort in proper direction
Regulate speed of detection effort
Monitor output of detector system
Evaluate positive readings
Communicate findings to leaders
Maintain detector system
Resupply detector system
Take detector out of operation

Figure V-1. Common Operator Tasks for Evaluation.

A team of four former Army officers with broad experience (average of over 26 years) in Armor, Engineers, Infantry and Military Police was assembled. For each detector, each team member was asked to evaluate the tasks of Figure V-1 in terms of relative difficulty.

The tasks were analyzed according to Human Performance Parameters (Figure V-2), System Capability Factors (Figure V-3), and Environmental and Tactical Conditions (Figure V-4).

Mental Difficulty
Task Overload
Danger
Impact of Improper Performance
Mental Fatigue
Physical Difficulty/Discomfort
Physical Fatigue

Figure V-2. Human Performance Parameters.

Time Required
Speed
Accuracy
Manpower Requirements
Cost
Survivability
Maintainability
Reliability
Durability
Replacement

Figure V-3. System Capability Factors.

Extreme Temperature
Heavy Precipitation
Poor Surface/Soil Conditions
Low Light Levels, Smoke, Obscuration
Small Arms Fire
Tank Gun Fire
Artillery Fire
Mines
Chemical/Radiological Environments

Figure V-4. Environmental and Tactical Conditions.

To evaluate the human factors of each detector in each of these setting, ratings were established to allow each expert to evaluate each detector in each setting. A set of three ratings using a span of five numbers was established.

1 = Easy, less difficult;

3 = Normal, average difficulty;

5 = Severe, very difficult.

C. RESULTS.

The following tables (Figures V-5 through V-10) display the mean response for each of the systems in each of the three evaluation settings. The mean responses have been summarized vertically in terms of common tasks and horizontally in terms of each parameter. A composite rating for each detector is displayed as the bottom-right number for each detector. These displays permit the comparison of the detectors with respect to the human factors involved.

The tables illuminate the team's concerns as they considered each detector and each of the human factor conditions. These concerns can be perceived by examining each comparative case, using the mean parameter rating and the mean task rating to assess each system.

An assessment of the displays results in the following comments.

1. <u>Human Performance Parameters (refer to Figures V-5 and V-6)</u>:

MENTAL DIFFICULTY: It is easier to employ and maintain the smaller hand-held detectors (probe and electronic) than the mechanized roller and the MIRADOR (judged the most difficult).

TASK OVERLOAD: The greatest chance for overload appears to be when monitoring the output from the electronic detector, with MIRADOR being next.

DANGER: There is a far greater sense of personal danger with the use of the exposed, hand operated detectors than with the mechanized and remote detectors.

IMPACT OF IMPROPER PERFORMANCE: While judged to be severe for all detectors, it appears to be less so for the Tank Roller than for the hand operated or the remote detectors.

MENTAL FATIGUE: It is more fatiguing mentally to employ the hand-held detectors and to monitor their outputs than the mechanized or the remote detectors.

PHYSICAL DIFFICULTY/ DISCOMFORT: Ratings are nominal for all detectors in general, indicating no great concern for employment physically. Probably, because of the weight, the Roller is judged to be the hardest to work with (prepare, maintain, deactivate, etc). With respect to discomfort, the detectors with the operators exposed are judged to be the most taxing.

PHYSICAL FATIGUE: The exposed detectors are the most taxing in operation. The mechanized and the remote detectors are rated quite well.

MEAN DELPHI RATINGS

HUMAN PERFORMANCE

COMMON OPERATOR TASKS

MIRADOR

HUMAN PERFORMANCE PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
MENT DIF	3.00	3.75	2.25	5.00	3.50	2.75	4.25	3.75	1.50	4.75	4.00	3.75	42.25	3.52
TASK CONF	2.50	3.00	2.00	2.75	3.25	2.50	3.75	4.00	1.50	4.00	3.50	3.50	36.25	3.02
DANGER	1.00	1.00	1.00	1.25	1.25	1.25	1.25	1.25	1.25	1.00	1.00	1.50	14.00	1.17
IMPACT ER	2.50	4.00	3.25	4.50	4.25	2.50	4.50	4.50	4.25	4.00	4.00	2.50	44.75	3.73
MENT FATG	1.00	2.50	1.00	3.75	3.25	2.25	4.00	3.50	2.00	2.75	2.25	2.00	30.25	2.52
PHYS DIF	2.00	2.50	1.00	2.00	2.00	2.00	2.00	2.50	1.00	2.75	2.25	3.00	25.00	2.08
PHYS DISC	1.00	1.50	1.00	1.25	1.50	1.00	1.75	2.25	1.00	2.25	2.25	1.50	18.25	1.52
PHYS FATG	1.00	2.00	1.00	2.00	1.25	1.25	2.00	2.50	1.00	2.25	2.25	2.50	21.00	1.75
MEAN TASK RATING	1.75	2.53	1.56	2.81	2.53	1.94	2.94	3.03	1.59	2.97	2.69	2.53	COMPOSITE RATING	2.41

PROBE

HUMAN PERFORMANCE PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
MENT DIF	1.00	1.00	1.00	1.00	1.00	2.00	1.75	2.75	1.00	1.00	1.00	1.00	15.50	1.29
TASK CONF	1.00	1.00	1.50	2.00	1.00	2.00	2.00	2.25	1.00	1.00	1.00	1.00	16.75	1.40
DANGER	1.00	2.00	1.00	5.00	5.00	5.00	5.00	5.00	2.25	1.50	1.00	2.00	35.75	2.98
IMPACT ER	1.00	1.00	1.50	4.50	4.00	3.75	5.00	5.00	3.50	1.50	1.00	2.00	33.75	2.81
MENT FATG	1.00	1.00	1.00	4.75	3.50	4.50	5.00	5.00	1.25	1.50	1.00	2.00	31.50	2.63
PHYS DIF	1.00	1.00	1.50	4.00	3.00	3.00	2.25	2.75	1.00	1.50	1.00	1.00	23.00	1.92
PHYS DISC	1.00	1.00	1.00	4.25	3.25	3.75	3.50	4.00	1.00	1.00	1.00	1.00	25.75	2.15
PHYS FATG	1.00	1.00	1.00	4.25	3.00	4.00	3.75	3.75	1.00	1.50	1.00	1.00	26.25	2.19
MEAN TASK RATING	1.00	1.13	1.19	3.72	2.97	3.50	3.53	3.81	1.50	1.31	1.00	1.38	COMPOSITE RATING	2.17

PSS-11

HUMAN PERFORMANCE PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
MENT DIF	1.50	2.25	1.00	3.00	1.50	2.50	3.75	3.50	1.50	3.00	2.50	2.25	28.25	2.35
TASK CONF	1.50	2.00	2.00	3.50	1.50	2.50	4.00	3.50	1.50	2.75	2.00	1.50	28.25	2.35
DANGER	2.00	3.00	1.50	5.00	5.00	5.00	5.00	5.00	3.00	1.50	1.50	1.50	39.00	3.25
IMPACT ER	2.00	4.00	2.50	5.00	4.00	4.00	5.00	5.00	4.50	3.50	4.50	2.00	46.00	3.83
MENT FATG	1.50	2.00	1.50	5.00	2.50	3.50	5.00	4.50	2.00	2.00	2.00	1.50	33.00	2.75
PHYS DIF	1.75	1.75	1.50	3.25	2.25	3.25	2.50	3.50	1.50	1.50	2.00	1.00	25.75	2.15
PHYS DISC	2.25	1.50	1.00	3.50	2.00	2.50	3.50	3.00	1.00	1.00	1.50	1.00	23.75	1.98
PHYS FATG	2.75	1.00	1.00	3.75	2.00	3.25	3.50	3.00	1.00	1.00	1.50	1.00	24.75	2.06
MEAN TASK RATING	1.91	2.19	1.50	4.00	2.59	3.31	4.03	3.88	2.00	2.03	2.19	1.47	COMPOSITE RATING	2.59

ROLLER

HUMAN PERFORMANCE PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
MENT DIF	2.50	3.00	1.50	2.50	1.75	1.75	1.50	1.50	1.50	2.50	3.00	3.00	26.00	2.17
TASK CONF	2.25	3.50	1.50	2.25	2.25	2.50	1.75	1.50	1.75	2.75	3.25	3.50	28.75	2.40
DANGER	1.50	2.00	1.25	3.00	3.00	3.00	3.00	3.50	1.50	1.00	1.50	1.50	25.75	2.15
IMPACT ER	2.00	3.50	2.75	4.00	4.00	2.75	1.75	2.25	3.50	2.50	3.00	3.25	35.25	2.94
MENT FATG	1.00	1.50	1.00	2.75	2.75	2.75	2.25	2.75	1.50	1.75	1.25	1.00	22.25	1.85
PHYS DIF	3.50	5.00	1.00	2.50	3.00	1.50	1.25	1.50	1.25	4.25	4.00	4.50	33.25	2.77
PHYS DISC	1.50	2.50	1.00	1.25	1.75	1.25	1.50	1.75	1.25	3.75	3.75	3.00	24.25	2.02
PHYS FATG	1.75	4.50	1.00	2.00	1.50	1.50	1.50	1.75	1.25	3.75	3.75	4.00	28.25	2.35
MEAN TASK RATING	2.00	3.19	1.38	2.53	2.50	2.13	1.81	2.06	1.69	2.78	2.94	2.97	COMPOSITE RATING	2.33

Figure V-5. Human Performance Ratings.

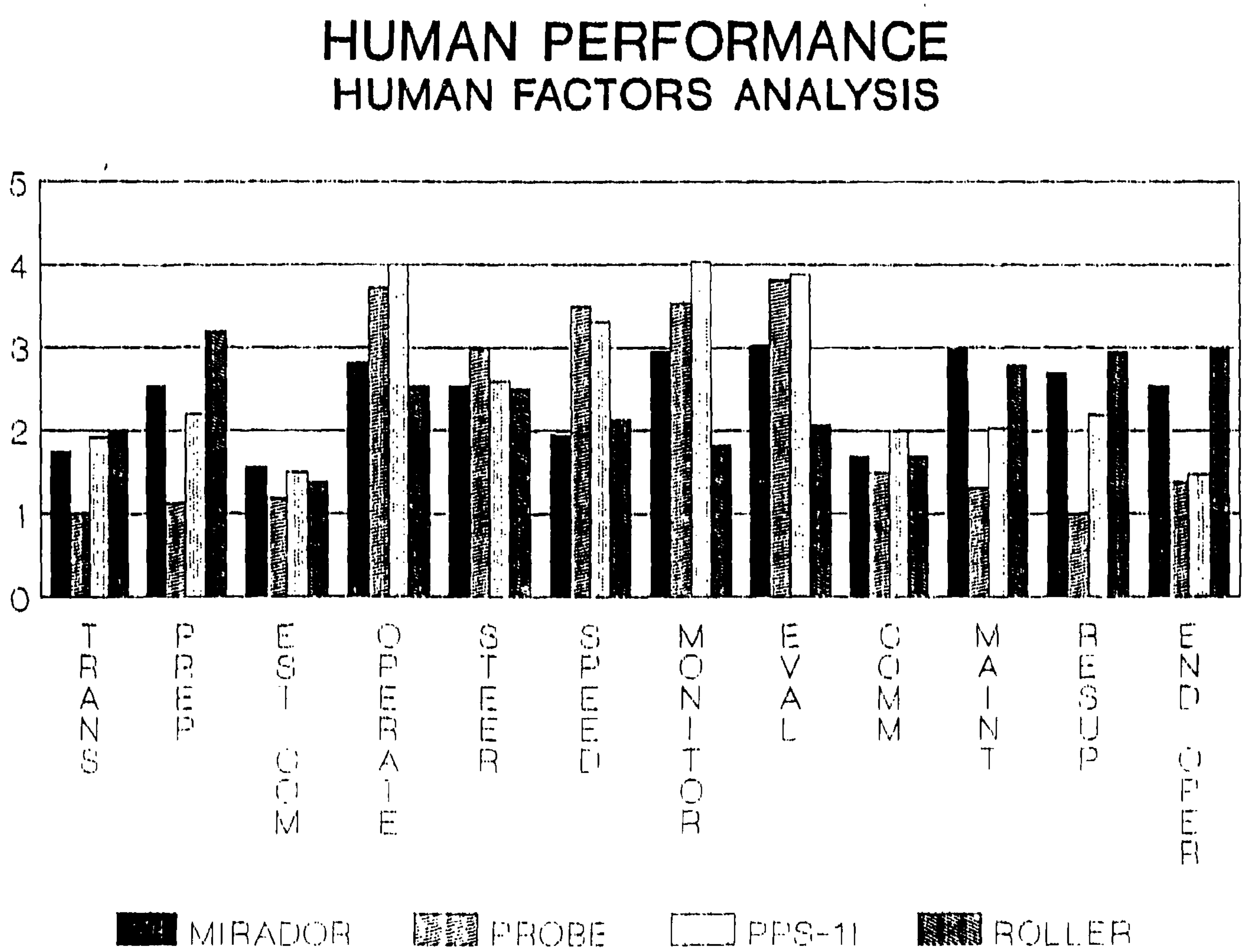


Figure V-6. Human Performance Display.

2. <u>Environmental and Tactical Conditions (refer to Figures V-7 and V-8)</u>:

EXTREME TEMPERATURE: Nominal effect.

HEAVY PRECIPITATION: This condition appears to cause greater concern for the mechanized detectors than for the dismounted operations.

POOR SURFACE/ SOIL CONDITIONS: Judged to be most difficult for the MIRADOR operation.

LOW LIGHT LEVELS, SMOKE, OBSCURATION: No major impact, nominal effect.

SMALL ARMS FIRE: Greatest concern for the exposed (hand-held) operations; less concern for the mechanized/ remote detection.

TANK GUN FIRE: No less concern for the dismounted operations, with far greater concern for the mechanized and remote detection operations.

ARTILLERY FIRE: Continued concern for the exposed operations; somewhat less for the more protected mechanized and remote operations.

MINES: Significantly less concern for the dismounted operation for AT mine environment, concern for the mounted operations is virtually the same for either AT or AP environments.

CHEMICAL/ RADIOLOGICAL ENVIRONMENTS: There is great concern for any operation in a contaminated environment, either operations or maintenance, probably because of the restrictions caused by use of protective clothing.

MEAN DELPHI RATINGS

ENVIRONMENTAL AND TACTICAL CONDITIONS

COMMON OPERATOR TASKS

ENVIRONMENT AND TACT PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM RATING
MIRADOR														
EXT TEMP	2.75	2.25	1.50	2.00	2.00	2.00	1.50	1.50	1.50	2.50	2.50	2.25	24.25	2.02
PRECIP	3.00	2.50	1.50	2.25	2.25	2.25	1.50	1.50	1.50	2.50	2.50	3.00	26.25	2.19
POOR S/S	3.75	3.50	2.25	3.50	3.50	2.50	2.25	2.75	2.25	3.75	3.00	3.50	36.50	3.04
LOW LIGHT	2.50	2.50	1.00	2.50	2.00	1.50	1.75	2.25	1.50	2.75	2.25	3.00	25.50	2.13
SMOKE	3.25	4.25	1.75	3.25	3.75	2.75	3.00	3.00	2.25	3.00	3.00	3.75	37.00	3.08
SMALL ARM	2.50	3.00	2.00	2.25	2.75	1.75	2.00	2.50	1.50	3.00	2.50	3.00	28.75	2.40
TANK GUN	3.50	4.50	2.25	3.75	3.75	2.75	2.75	3.25	1.75	3.75	3.25	3.75	39.00	3.25
ARTILLERY	3.50	5.00	2.25	3.25	3.25	2.25	2.25	2.75	1.75	4.75	3.75	4.25	39.00	3.25
AT MINES	3.00	4.00	1.75	3.50	3.50	2.50	2.25	3.25	1.75	3.50	3.50	4.00	36.50	3.04
AP MINES	4.00	3.50	1.75	3.50	3.50	2.50	2.75	3.25	1.25	3.50	3.50	3.50	36.50	3.04
CRC	3.75	3.25	2.25	2.75	2.75	2.75	2.50	2.50	2.00	3.50	3.25	3.25	34.50	2.88
MEAN TASK RATING	3.23	3.48	1.84	2.95	3.00	2.32	2.23	2.59	1.73	3.32	3.00	3.39		COMPOSITE RATING 2.76
PROBE														
EXT TEMP	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.25	1.25	1.25	0.75	10.50	0.88
PRECIP	1.75	1.75	1.75	1.75	1.75	2.25	2.00	2.00	1.75	1.00	1.25	0.75	19.75	1.65
POOR S/S	1.00	1.00	1.50	2.25	1.00	1.00	2.25	2.50	1.50	1.00	1.00	1.00	17.00	1.42
LOW LIGHT	1.75	1.75	2.25	2.25	1.75	2.25	2.75	2.50	2.25	0.75	0.75	1.25	22.25	1.85
SMOKE	1.50	1.00	2.00	3.50	2.00	3.00	3.50	4.25	3.00	1.00	1.00	2.00	27.75	2.31
SMALL ARM	1.00	0.75	1.75	3.00	1.50	3.00	3.00	3.50	2.75	0.75	0.75	0.75	22.50	1.88
TANK GUN	1.75	1.00	2.75	4.50	3.00	4.50	4.50	4.50	3.50	2.50	2.00	1.50	36.00	3.00
ARTILLERY	1.75	2.00	4.00	4.50	3.50	4.50	4.50	4.50	3.50	1.50	1.50	1.00	36.75	3.06
AT MINES	2.00	2.50	4.00	4.75	4.50	4.50	4.50	4.50	3.00	2.00	2.00	1.00	39.25	3.27
AP MINES	1.50	2.50	3.50	4.50	4.00	4.00	4.50	4.50	3.00	1.50	1.50	1.00	36.00	3.00
CRC	1.75	1.25	2.25	2.50	2.25	2.25	2.50	2.50	2.75	2.25	2.00	1.00	25.25	2.10
MEAN TASK RATING	1.50	1.48	2.41	3.11	2.36	2.91	3.16	3.27	2.57	1.41	1.36	1.09		COMPOSITE RATING 2.22
PSS-11														
EXT TEMP	1.75	1.50	1.00	1.50	1.25	1.25	1.25	1.50	1.50	2.50	2.25	1.25	18.50	1.54
PRECIP	2.25	2.25	2.00	2.50	2.25	2.25	2.25	2.50	2.00	2.50	2.25	1.75	26.75	2.23
POOR S/S	2.00	2.00	1.75	2.75	2.00	1.50	2.50	2.75	1.75	3.00	3.50	2.00	27.50	2.29
LOW LIGHT	2.75	2.50	2.25	2.75	2.25	2.75	2.75	2.75	2.25	2.75	2.00	1.75	29.50	2.46
SMOKE	3.50	2.75	2.00	4.00	2.50	3.50	3.50	4.00	3.00	2.50	2.75	2.50	36.50	3.04
SMALL ARM	2.00	2.50	2.25	3.00	1.50	3.00	3.00	3.00	2.75	2.75	2.25	1.75	29.75	2.48
TANK GUN	3.25	2.75	3.75	4.50	3.00	4.50	4.50	4.50	3.75	3.50	3.50	2.50	44.00	3.67
ARTILLERY	3.25	3.75	4.50	4.50	3.50	4.50	4.50	4.50	4.00	3.50	3.50	2.50	46.50	3.88
AT MINES	2.50	3.00	3.50	4.50	4.50	4.50	4.50	4.50	3.50	2.50	3.00	2.00	42.50	3.54
AP MINES	3.25	3.75	3.50	4.25	4.25	4.25	4.25	4.75	3.25	3.00	3.00	2.00	43.50	3.63
CRC	2.50	2.50	2.50	2.50	2.50	2.50	2.50	3.00	3.00	3.75	3.25	2.25	32.75	2.73
MEAN TASK RATING	2.64	2.66	2.64	3.34	2.68	3.14	3.23	3.43	2.80	2.93	2.84	2.02		COMPOSITE RATING 2.86
ROLLER														
EXT TEMP	2.75	2.75	1.75	1.50	1.50	2.00	1.25	1.25	1.75	2.50	3.00	3.75	25.75	2.15
PRECIP	3.25	3.75	2.75	2.75	2.75	2.75	2.25	2.25	1.75	3.00	3.50	3.75	34.50	2.88
POOR S/S	3.50	3.75	2.50	3.00	2.00	2.00	1.75	1.75	1.50	3.75	3.75	3.25	32.50	2.71
LOW LIGHT	2.25	3.50	2.25	3.00	2.00	1.25	1.25	1.25	1.75	2.50	2.75	3.00	26.75	2.23
SMOKE	3.00	3.50	1.00	2.50	2.00	1.50	1.00	1.00	1.50	3.00	2.75	3.50	26.25	2.19
SMALL ARM	3.00	3.00	2.25	2.50	2.50	1.50	1.25	1.25	1.75	2.50	2.25	3.00	26.75	2.23
TANK GUN	3.25	4.75	2.00	2.75	2.50	1.50	1.75	1.75	2.00	3.75	4.00	4.25	34.25	2.85
ARTILLERY	2.25	4.50	2.50	2.50	2.50	2.50	2.00	2.00	2.00	4.00	4.00	4.00	34.75	2.90
AT MINES	3.50	4.00	3.00	3.50	3.00	3.00	3.00	2.50	2.00	4.00	4.00	4.00	39.50	3.29
AP MINES	2.75	3.75	2.75	3.00	3.00	2.50	3.00	2.50	1.75	4.25	4.25	4.25	37.75	3.15
CRC	3.75	4.75	3.25	3.00	3.00	3.50	3.00	2.50	2.25	3.75	4.25	4.75	41.75	3.48
MEAN TASK RATING	3.02	3.82	2.36	2.73	2.43	2.18	1.95	1.82	1.82	3.36	3.50	3.77		COMPOSITE RATING 2.73

Figure V-7. Environmental and Tactical Conditions.

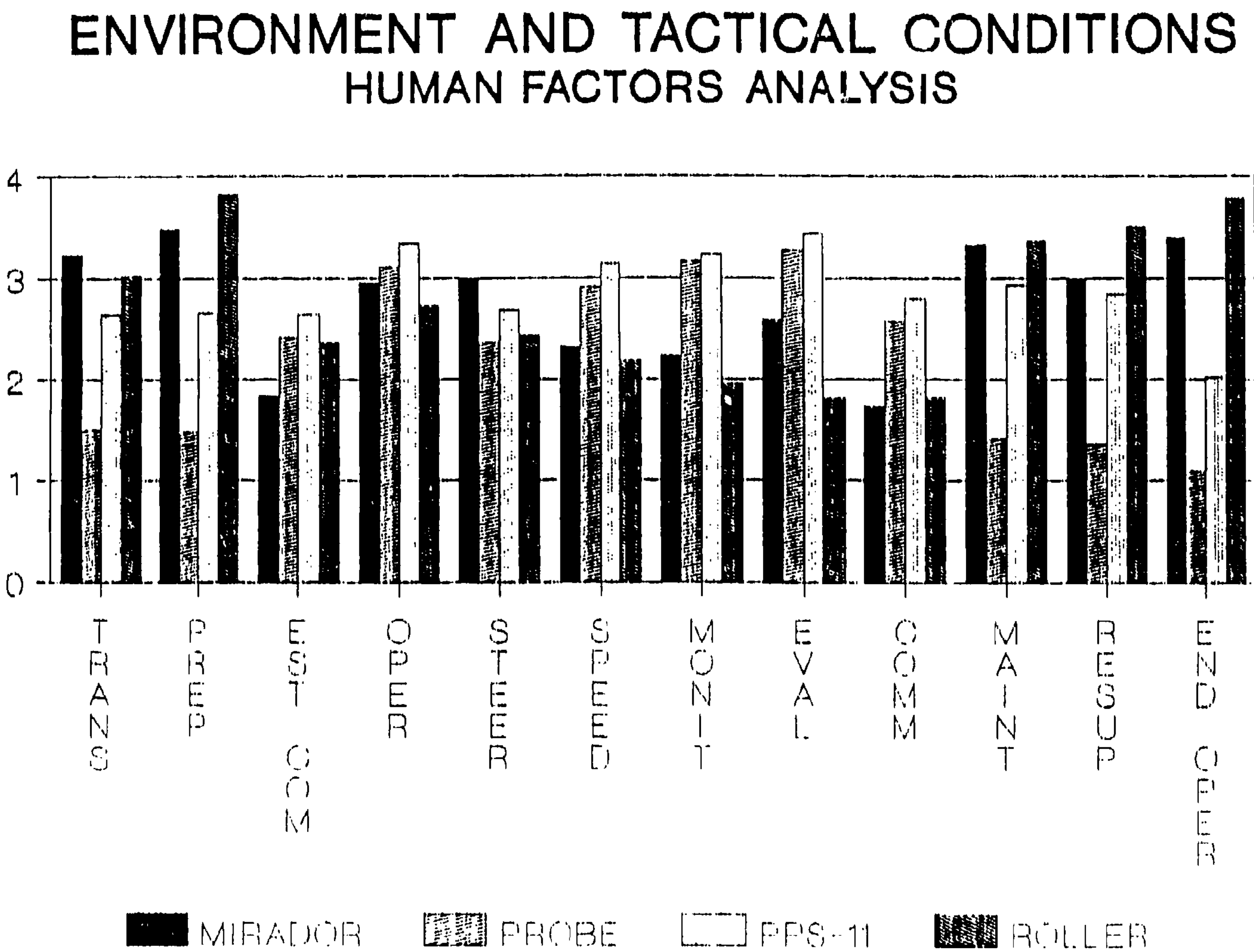


Figure V-8. Environmental and Tactical Display.

3. System Capability Factors (refer to Figures V-9 and V-10):

TIME REQUIRED: Greatest concern for the dismounted operations, as might be anticipated.

SPEED: Most difficulty seen in operating dismounted detectors.

ACCURACY: No major concerns with any system.

MANPOWER REQUIREMENTS: Dismounted operations seen as less demanding of manpower than mounted operations (It appears that there was little consideration of the fact that the dismounted operations will probably be performed by more than a single individual in order to make up for the restricted sweep capability of a single detector).

COST: Hand-held systems considered much less costly than the mechanized or remote systems.

SURVIVABILITY: Hand-held systems considered to be less survivable than the mechanized. MIRADOR considered the most survivable.

MAINTAINABILITY: Hand-held rated much higher than the mounted systems.

RELIABILITY: No large concern for any system.

DURABILITY: Hand-held systems considered more durable than mounted, but no major concerns for any system.

REPLACEMENT: Greatest concern for the mounted systems getting replacements, as opposed to the dismounted systems.

MEAN DELPHI RATINGS
SYSTEM CAPABILITY

COMMON OPERATOR TASKS

MIRADOR

SYSTEM CAPABILITY PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
TIME REQ	2.50	2.00	1.25	2.25	2.25	1.75	1.75	2.50	1.00	3.25	2.50	2.00	25.00	2.08
SPEED	2.75	3.25	1.75	3.00	2.75	2.75	1.75	2.75	1.50	2.00	3.25	1.75	29.25	2.44
ACCURACY	2.25	2.75	1.75	2.25	1.25	1.25	2.00	2.25	1.00	1.75	1.75	1.75	22.00	1.83
MANPOWER	2.00	2.50	0.75	2.00	1.50	1.50	2.50	2.50	1.00	2.50	2.00	2.75	23.50	1.96
COST	1.50	2.50	1.50	2.50	2.75	2.75	3.00	2.50	1.00	3.25	3.25	2.00	28.50	2.38
SURVIVABI	2.25	2.50	1.50	2.50	1.50	2.00	1.00	1.00	0.75	1.75	1.75	2.00	20.50	1.71
MAINTAIN	2.75	3.25	1.50	2.75	2.00	2.00	2.75	3.25	1.75	4.00	4.25	2.25	32.50	2.71
RELIABL	3.00	3.00	1.50	2.75	2.50	2.50	3.00	4.00	2.00	3.00	4.00	3.00	34.25	2.85
DURABIL	3.00	3.00	2.00	4.00	3.00	2.50	3.75	4.25	2.00	3.50	1.00	3.00	38.00	3.17
REPLACE	3.50	3.00	2.00	2.75	3.25	3.25	2.75	2.75	1.50	2.75	2.75	3.00	33.25	2.77
MEAN TASK RATING	2.55	2.78	1.55	2.68	2.28	2.23	2.43	2.78	1.35	2.78	2.95	2.35		COMPOSITE RATING 2.39

PROBE

SYSTEM CAPABILITY PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
TIME REQ	0.75	0.75	0.75	1.25	0.75	0.75	1.25	1.75	0.75	0.75	0.75	0.75	11.00	0.92
SPEED	0.75	0.75	0.75	2.75	0.75	1.75	2.75	3.25	1.25	0.75	0.75	0.75	17.00	1.42
ACCURACY	1.25	1.25	1.25	2.25	0.75	0.75	1.25	1.75	1.00	0.75	0.75	0.75	13.75	1.15
MANPOWER	0.75	0.75	1.25	2.25	1.25	0.75	1.75	1.75	0.75	0.75	0.75	0.75	13.50	1.13
COST	0.75	0.75	0.75	2.00	0.75	1.25	1.25	1.75	1.25	0.75	0.75	0.75	12.75	1.06
SURVIVABI	0.75	0.75	0.75	1.50	1.50	1.50	2.50	2.50	1.75	0.75	0.75	0.75	15.75	1.31
MAINTAIN	1.00	1.00	1.00	3.00	2.00	2.50	2.00	1.50	1.50	1.00	1.00	1.00	18.50	1.54
RELIABL	1.00	1.00	1.00	2.50	2.00	2.00	3.00	2.50	2.00	1.00	1.00	1.00	20.00	1.67
DURABIL	1.00	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00	1.00	1.00	1.50	13.50	1.13
REPLACE	1.00	1.50	1.50	2.00	1.50	1.50	2.00	2.00	1.50	1.00	1.00	1.00	17.50	1.46
MEAN TASK RATING	0.90	0.95	1.00	2.05	1.23	1.38	1.93	2.03	1.28	0.85	0.85	0.90		COMPOSITE RATING 1.28

PSS-11

SYSTEM CAPABILITY PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
TIME REQ	1.25	1.50	0.75	2.25	1.25	1.25	1.75	2.25	1.75	1.50	0.75	1.50	17.75	1.48
SPEED	1.25	2.00	0.75	2.25	0.75	1.75	2.00	2.25	2.25	1.50	2.00	1.50	20.25	1.69
ACCURACY	0.75	1.25	1.25	2.00	0.75	0.75	1.50	2.50	0.75	0.75	0.75	0.75	13.75	1.15
MANPOWER	1.25	0.75	1.25	2.25	1.25	0.75	0.75	1.75	0.75	0.75	0.75	0.75	13.00	1.08
COST	1.25	1.25	0.75	2.25	0.75	1.25	2.25	1.75	1.25	1.50	1.50	1.25	17.00	1.42
SURVIVABI	1.25	1.25	1.00	1.75	1.75	1.75	2.75	2.75	1.75	1.25	1.25	1.25	19.75	1.65
MAINTAIN	2.50	2.50	1.50	2.00	2.00	2.00	3.00	3.50	2.50	2.50	2.50	1.50	28.00	2.33
RELIABL	2.00	2.00	1.00	2.50	2.00	1.00	3.00	2.50	2.00	2.00	2.50	1.50	24.00	2.00
DURABIL	2.00	2.50	1.25	2.50	1.50	1.00	2.50	2.00	1.50	2.50	2.50	1.50	23.25	1.94
REPLACE	2.00	2.00	1.50	3.00	2.50	2.00	3.00	3.00	2.00	2.00	1.50	2.00	26.50	2.21
MEAN TASK RATING	1.55	1.70	1.10	2.28	1.45	1.35	2.25	2.43	1.65	1.63	1.60	1.35		COMPOSITE RATING 1.69

ROLLER

SYSTEM CAPABILITY PARAMETERS	TRANS	PREP	EST COM	OPER	STEER	SPEED	MONIT	EVAL	COMM	MAINT	RESUP	END	TOTAL	MEAN PARAM. RATING
TIME REQ	2.00	2.25	1.50	2.75	1.75	1.75	2.50	3.00	0.75	2.50	2.50	2.25	25.50	2.13
SPEED	2.25	2.25	2.00	2.75	3.25	2.75	2.50	2.75	1.50	2.00	2.50	2.25	28.75	2.40
ACCURACY	1.75	2.25	1.75	1.75	2.25	0.75	1.75	1.75	0.75	2.25	2.25	2.25	21.50	1.79
MANPOWER	2.75	3.00	1.00	3.25	2.75	1.25	2.25	2.25	1.25	2.25	2.25	3.00	27.25	2.27
COST	2.25	2.25	1.75	1.75	1.75	1.75	1.25	1.75	1.25	2.75	3.25	2.75	24.50	2.04
SURVIVABI	2.25	3.25	1.75	2.25	2.75	2.25	1.25	1.50	1.25	2.75	2.75	3.25	27.25	2.27
MAINTAIN	3.25	3.75	1.25	3.50	3.50	3.50	2.00	3.00	1.25	3.00	4.50	3.25	35.75	2.98
RELIABL	3.00	4.00	1.50	3.00	2.50	3.00	2.25	2.25	1.75	3.00	4.00	4.00	34.25	2.85
DURABIL	3.50	3.50	2.00	3.00	2.50	3.00	3.00	3.50	1.75	4.00	3.50	3.50	36.75	3.06
REPLACE	3.50	3.50	2.50	2.75	2.25	2.75	2.25	2.50	1.25	3.00	3.00	3.50	32.75	2.73
MEAN TASK RATING	2.65	3.00	1.70	2.68	2.53	2.28	2.10	2.43	1.28	2.75	3.05	3.00		COMPOSITE RATING 2.45

Figure V-9. System Capability Ratings.

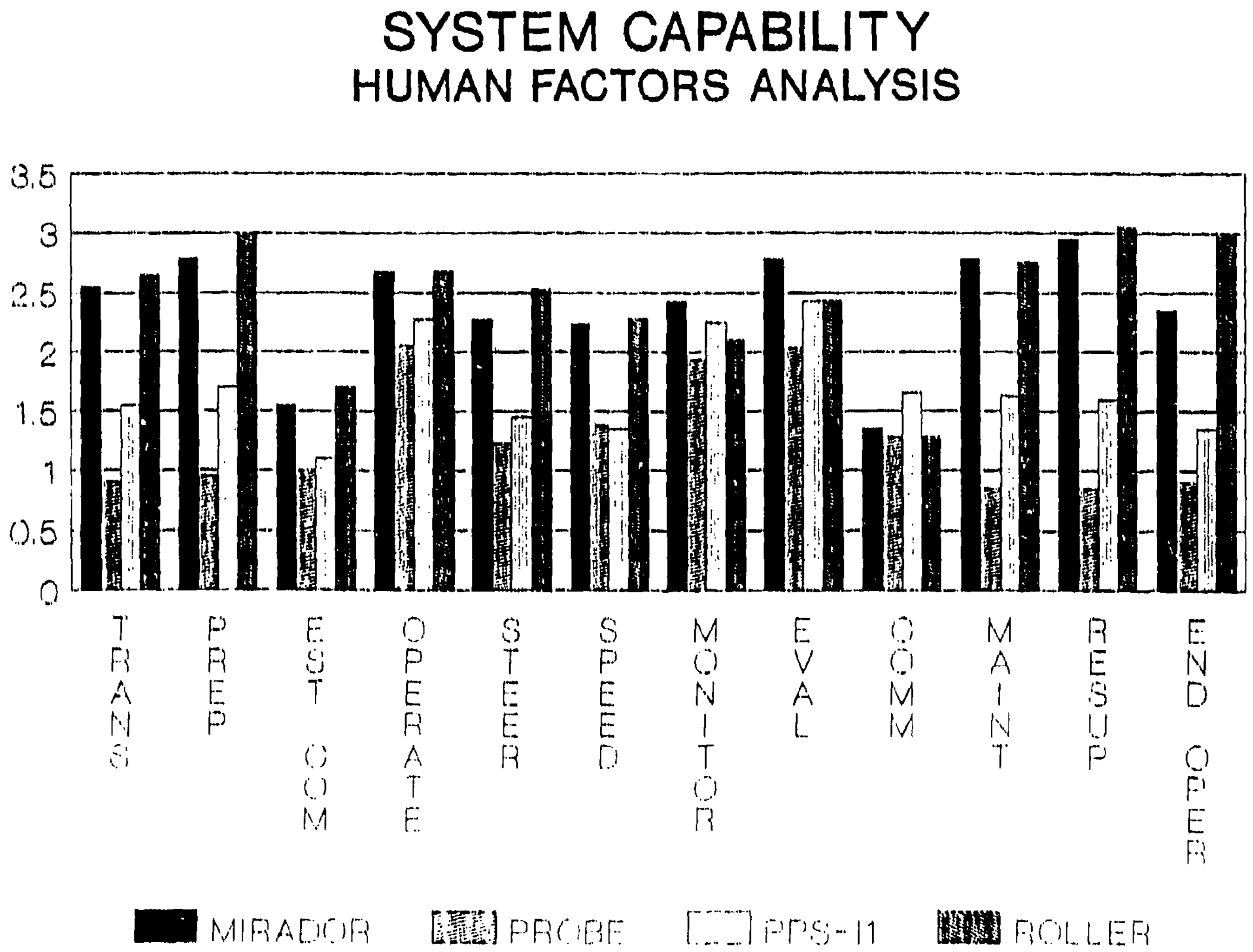


Figure V-10. System Capability Display.

D. CONCLUSIONS.

1. The mean Delphi values and charts can be used to extract an assessment of the various detectors.

2. Human Performance.

From a human performance perspective, the MIRADOR is most demanding mentally, and it has the potential for task overload. It rates better than existing systems in terms of danger and physical fatigue. The Probe and AN/PSS-11 are the most demanding in terms of overload, danger and fatigue, while the Roller demands more physical strength and suffers from the greatest impact from poor operator performance.

3. Environment and Tactical Conditions.

The dismounted Probe and AN/PSS-11 provide the most serious human factors problems in conditions where they are exposed to weapons fire. Operations in poor moisture or soil conditions tend to give the human operators the most difficulty when operating mechanized systems. The MIRADOR could improve its human factors performance by providing filtered chemical protection for the operators.

4. The complexity of the MIRADOR and tank-mounted mine roller cause higher human factor problems in maintenance and supply, but have the offsetting advantage of being less demanding in terms of time and ability to move quickly.

SECTION III. MAINTENANCE AND LOGISTICS ANALYSIS

A. PURPOSE.

The purpose of this section is to compare the Maintenance and Logistics supportability of MIRADOR with equipment now in the hands of field troops. This comparison will provide a basis for assessing the maintenance and logistics burden which MIRADOR may place on the support system.

B. METHODOLOGY.

Available data was gathered on existing equipment, and the Integrated Logistics Support Plan for the MIRADOR was reviewed. Using this information, comparisons were made which combined available data and expert judgement. Information was requested from several Army Materiel Command sources to include the Materiel Readiness Support Activity (MRSA) at the Army Bluegrass Depot in Kentucky, the

Tank-Automotive Command (TACOM), and the Communications-Electronic Command (CECOM). While some data provided was of limited detail and scope, it was adequate to achieve an analysis which is reasonable and practical.

C. EQUIPMENT CONSIDERED.

The existing equipment considered for the analysis were the Probe (which for the purpose could either be the rifle bayonet or a device designed for the specific purpose of probing for mines and other buried or hidden explosive device); the hand-held mine detector (e.g. the AN/PSS-11); and the mine clearing roller. These items are in various stages in their life cycle. In the case of the Roller it is not completely fielded, but it does exist with additional procurement already programmed.

For this analysis each piece of equipment will be reviewed individually followed by a side-by-side comparison of significant features.

1. Probe.

This item is simple in design and therefore in maintenance requirements. It is operated/used directly by the individual looking for mines or explosives. Maintenance is a matter of cleaning and keeping it relatively free of dirt and rust. There is little need for training beyond that normally given to a field soldier.

The probe is not a repairable item and is replaced if it is damaged beyond use or is lost. Since it is a small item of equipment it is easily transported when replacement becomes necessary. However, because it is used by the individual soldier and the potential exists for the probe to be issued to all combat zone soldiers, the number of items in the supply system could be large.

2. Hand-held detector.

This item is also operated by an individual and is dependent upon the operator for daily maintenance. Adjustments and some understanding of the operation is necessary in order to keep this device in proper working order. Both operator and repairman training is required for the hand-held detector. This item has repairable parts which can be serviced in the field. These include readily detachable components and batteries. The batteries for the hand-held detectors now in the field use a non-standard battery which creates a logistics problem.

The units are fairly rugged, but will not stand continued harsh treatment. Adjustments can become critical and if not performed accurately may render the unit inoperable. Because there are replaceable components the entire unit does not have to be replaced when certain components fail. Replacement parts are currently in short supply and there is no procurement planned for the immediate future. The supply system is currently being allowed to use cannibalization as means to keep existing equipment operational. The components of these units are fairly small and lightweight and therefore are easily transported to and from points of repair and use.

3. Mine Clearing Roller.

The mine clearing roller has not been procured in the quantities needed to fill out the Battalion Sets. Each Battalion is programmed to be equipped with four Rollers. As of mid-1989 considerably less than a full complement of Rollers had arrived in the European Theater.

These sets are extremely heavy due to the nature of their design, and require the use of a heavy armored vehicle to push them through areas suspected to be mined.

Maintenance of the Rollers consists of keeping them clean and lubricated. There is an adapter kit for making connection between he Roller and the pushing vehicle. This kit has hydraulic components that require maintenance. The cables and other components of the Roller set require inspection to assure that all are in working order and that if necessary the vehicle operator will be able to jettison the Rollers in and emergency situation.

The weight of the rollers also necessitates the use of heavy transport equipment for resupply of roller wheels or the roller axle. The other components can generally be handled using smaller general purpose materiel handling equipment.

Use of the roller also causes accelerated wear and tear on the pushing vehicle requiring that the maintenance of the dedicated vehicle be increased in order to keep it in reasonable operating condition. Training of personnel to maintain the roller is fairly simple and does not require significant time or resources.

4. MIRADOR.

This item is somewhat more complex than those items previously covered. It will require both electronic and mechanical expertise in order to keep it properly maintained and in effective working order.

As with any electronic (radar) device, the MIRADOR will require technically trained personnel to perform both daily adjustments and required maintenance. Field experience with existing radar systems has shown that mean time between failures (MTBF) for the MIRADOR sensor components will probably be in the range of 200-300 hours.

Since it is a vehicle mounted device, there is a requirement to perform vehicle maintenance and repair in addition to that necessary for the sensor equipment. Some of the spare parts are expected to be unique items, however they are expected to be of a size and weight that will allow easy transport to and from the user and the supply point. The carrying vehicle (platform) will be the most critical item with regard to size and weight for resupply or transport for repair.

Operator and maintainer training will be a significant aspect of the MIRADOR program. The operator will be required to know how to interpret the signals from the sensors as well as how to operate the device when in the remote operation mode. In the remote mode there will be the need to maintain an operational data link, now planned to be a fiber optic cable with conductors for giving operational directions to the remote platform and return signals to the command vehicle. There may be some unique maintenance issues related to the fiber optic component of the system. Even though some systems use a fiber-optic link (e.g., the Fiber Optic Guided Missile [FOG-M] system) it is a one time use. There is no requirement for reuse of the fiber optic link after the missile has been delivered to the target. In the MIRADOR use, there will be considerable physical stress and abrasion on the fiber optic cable as the remote platform and the command vehicle travel on or off road.

D. ASSESSMENT OF MINE DETECTOR MAINTENANCE AND LOGISTICS.

1. Methodology.

Based on the foregoing discussion, an analysis of the comparative values of the various pieces of equipment can be accomplished by inserting values into a matrix for comparison. For both maintenance and supply functions a comparison can be rendered which assesses the impact on functional sub-characteristics for each of the detector systems. The impact values are based on expert judgement of actual and expected RAM performance history. The values are based on a ten point system, with ten being the greatest requirement or level with 10 being the highest requirement or level of intensity.

2. Maintenance Comparison.

The maintenance demands are subdivided into the following characteristics:

a. Requirements. The demand for maintenance evoked by the system due to complexity and size.

b. Training/Skill. The level of knowledge and experience needed to perform maintenance on the system.

c. Level. The scope and intensity of maintenance required, indicating the need for frequent use of levels of maintenance above that of the operator.

3. Assessment.

The results of assessing the demand of each of the detectors on the maintenance system for each of the characteristics is shown in Figure V-11. The total for each detector and the mean of the total value is also shown.

System	Rqrmts	Trng/Skill	Level	Total
Probe	1	1	0	2
Hand-held Detector	5	5	3	13
Roller	3	3	2	8
MIRADOR	7	7	7	21
			Total	44
			Average	11

Figure V-11. Comparative Maintenance Demands.

a. Analysis. The MIRADOR maintenance demand total is nearly double the average system total value of 11. The complexity of the system causes the MIRADOR to score high in all categories. Modular component replacement could significantly reduce the training and level of maintenance categories. The roller numbers would be higher if wear and tear on the pusher tank were considered.

b. Maintenance Projections for MIRADOR. By examining the maintenance history of a fielded light four wheel utility vehicle, predictions of the maintenance of the similarly configured MIRADOR can be made. The M151A2 Utility Truck began production in 1972. The first years of the M151A2 operation (1972-1973) provide a basis for projecting maintenance demands by a newly produced MIRADOR. Shown below are the Mean Miles between Failures and the Maintenance ratio for the M151A2. Similar figures can be expected with the MIRADOR.

Mean Miles between Failures	4172
Maintenance Ratio (not including sensor/data link composites)	.058

Similarly, the Operational Readiness (OR) rate experience is of value to predict the availability of the MIRADOR to the using unit. Figure V-12 shows the OR rate over the first year of operation.

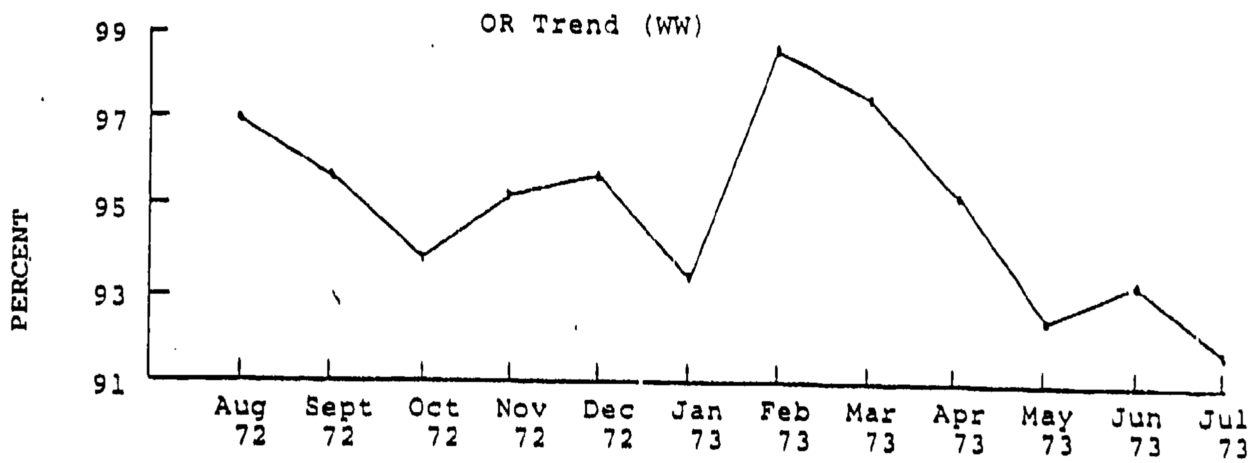


Figure V-12. Operational Readiness Trend Over 12 Months.

The 1990 MIRADOR maintenance cost can be projected at 0.078 dollars per mile by inflating the 1973 M151A2 cost of 0.04 dollars per mile at an annual rate of 4% annually.

Major assembly failure can also be projected. The mean miles between failure of major assemblies is 1502 miles. The distribution of failures among the major assemblies is shown in Figure V-13.

4. Logistics Comparison.

The supply demands caused by each of the detector systems can be subdivided into the following three categories:

a. Quantity of Items. The relative burden caused by the number of items in the supply system needed to support the battlefield operation of the system.

Engine	XXXXXXXXX 8.6
Transmission	XXXXXXXXXXXXXXXXXXXXXXXXX 25.1
Differential	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX 29.9
Clutch	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX 36.3
	0 10 20 30 40

Figure V-13. Percent of Major Component Failures.

b. Special Nature of Items. The requirement to have specialized resupply items or major assemblies and repair parts in the supply system due to size, weight, specialization or complexity of the end item.

c. Unique Demands of Items. Burden placed on the supply system by the item due to procurement, handling, transportation or storage demands.

5. Assessment.

The results of assessing each detector's demands on the supply system is shown in Figure V-14. The MIRADOR total is above the system mean value of 10.75. The burden on the supply system is largely in the area of unique demands. If the MIRADOR can take advantage of standard components, and use modularization, the impact to the supply system would be no greater than that of the roller and AN/PSS-11/12.

E. MAINTENANCE AND SUPPLY CONCLUSIONS.

The MIRADOR system has the potential to impose a measurable burden on the support system. Effort must be taken to make as much use as possible of existing chassis, electronic and communications components. Similarly, the use of modular repair components will keep the level of maintenance at a low level and reduce the number of repair parts in the system.

Equipment	Quantity	Nature	Unique Demands	Total
Probe	1	0	1	1
Hand-held Detector	3	5	1	12
Roller	2	6	5	13
MIRADOR	4	5	7	16
			Total	43
			Mean	10.75

Figure V-14. Comparative Assessment Demands.

SECTION IV. TIME PHASED ANALYSIS OF MINE DETECTION SYSTEMS.

A. PURPOSE

The purpose of a time phased analysis of mine detection functions is to show the interrelationship between available mine detection equipment, missions, and threats from the present through the year 2000. This effort will provide a framework for understanding how mine detection equipment needs will be affected by the development and fielding of anticipated new systems and/or concepts.

B. DETECTION AVAILABLE TO THE U.S. ARMY

As discussed in Chapter II above, there is only a very limited inventory of field mine detectors currently available to the U.S. Army. Physical detectors consist of mechanical individual probes and tank mounted rollers - neither of which are liked by the operator. Probing for mines with a rod, stick, or plastic spoon is very slow, tedious, dangerous, work subjecting the individual to excessive vulnerability and high tension.

From an operational point of view, the tank mounted roller is hardly better. It is faster and the tank does provide a degree of protection for the operator, but the roller ties up and slows down to only a few miles per hour a multi-million dollar vehicle designed to shoot and move cross country at speeds up to 35 mph, thus diverting vital combat assets from their primary mission.

Hand-held electronic detectors (the AN/PSS 11 and 12) are only slightly better than probes. An operator can work through a suspected mined area faster with this portable mine detection system (up to a quarter mile per hour), but it is only designed to detect metallic objects and the operator is fully exposed to blast and enemy covering fire.

Assuming the AN/PSS-12 continues into full production to replace the older AN/PSS-11, the only other new close-in, dismounted system expected in the near term is a modification or product improvement to allow operation from the prone position, thus offering the operator a somewhat better survivability. An Improved Hand Held Detector (metallic/nonmetallic) utilizing either the separated aperture or balanced bridge approach has been identified as a far term solution for the individual soldier. Figure V-15, borrowed from the BRDEC Countermine Materiel Implementation Plan, dated October, 1988, provides a projected time sequencing for the availability of various technologies for hand held mine detection.

A companion figure (Figure V-16) shows the projected availability of vehicle mounted close-in mine detectors. Technical improvement in mechanical roller systems has progressed about as far as can be expected.

MIRADOR, the mid-term solution for close-in detection, is expected to become available initially in the field in 1992 or 1993 with potentially improved detectors available in the late 1990's. The three new detection technologies shown (acoustic/seismic, unintentional emission, and x-ray photon backscatter) are being considered for integration into the MIRADOR system to improve this vehicle mounted detection system.

Thus far, only "CLOSE-IN" detection of mines have been discussed: either hand-held or vehicle mounted. Operationally, it is desirable to detect minefields before the force encounters them. When the minefield is detected by a close-in detector, the exposed unit can only react to the enemy's chosen situation and covering fire. The sooner and farther away from a maneuver force or supply convoy that mining activity can be discovered, the better the unit will be able to accomplish its goal of passing over or around the mines without effect to its mission. A "STAND-OFF DETECTION" system offers the ability to find minefields from a distance in the battle area. An airborne system provides a maximum stand-off distance, but it also requires an aerial platform and a data link to provide the information to units on the ground.

There are currently two aerial detection programs being actively pursued in early RDTE. The Airborne Minefield Detection and Reconnaissance System (AMIDARS) is being developed as a high bandwidth thermal/IR line scanner sensor mounted on unmanned aerial vehicle (UAV). Sensor information is data linked to a ground station for processing, analyzing and review. The ground control and processing station then searches the data using image processing and pattern recognition techniques to extract minefield information for conventional matrix laid minefields. The system is not intended to pinpoint the location of individual mines for neutralization or to recognize randomly dispersed scattermine fields.

The Remote Minefield Detection Scanner System (REMIDS) also uses an airborne line scanner to collect active and passive multisensor images of the ground in both the near-IR and far-IR (thermal) region of the sensor spectrum. An active laser illuminator is used to provide target feature discrimination by comparing the differences in parallel and cross polarization of the reflected beam from man-made versus natural targets. Thermal information is co-registered with the laser reflected data.

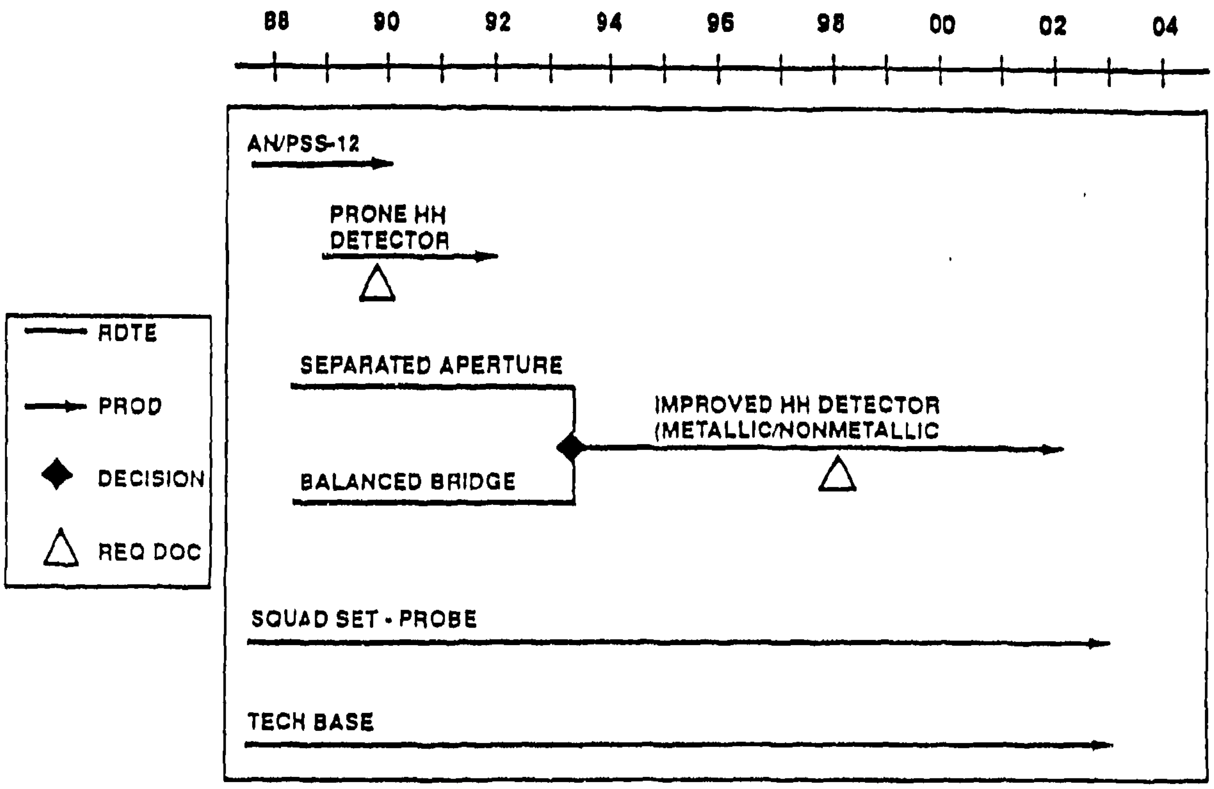


Figure V-15. Technology Applications to Close-In Detection (Dismounted).

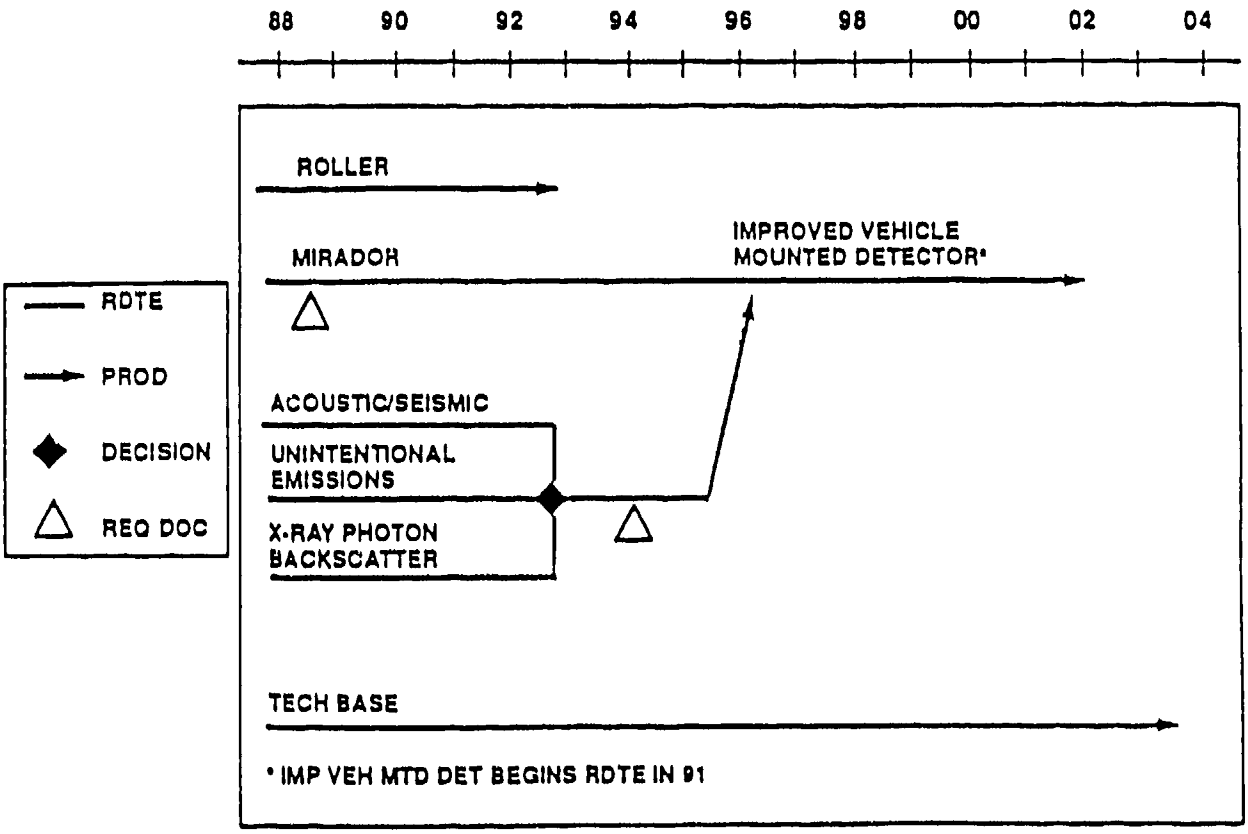


Figure V-16. Technology Applications to Close-In Detection (Mounted).

AMIDARS and REMIDS will be extensively tested over the next few years leading to the selection/integration of these technologies into a Standoff Minefield Detection System (STAMIDS). Figure V-17 shows the projected development schedule for the standoff detection program. Fielding of a system is not expected until after the turn of the century.

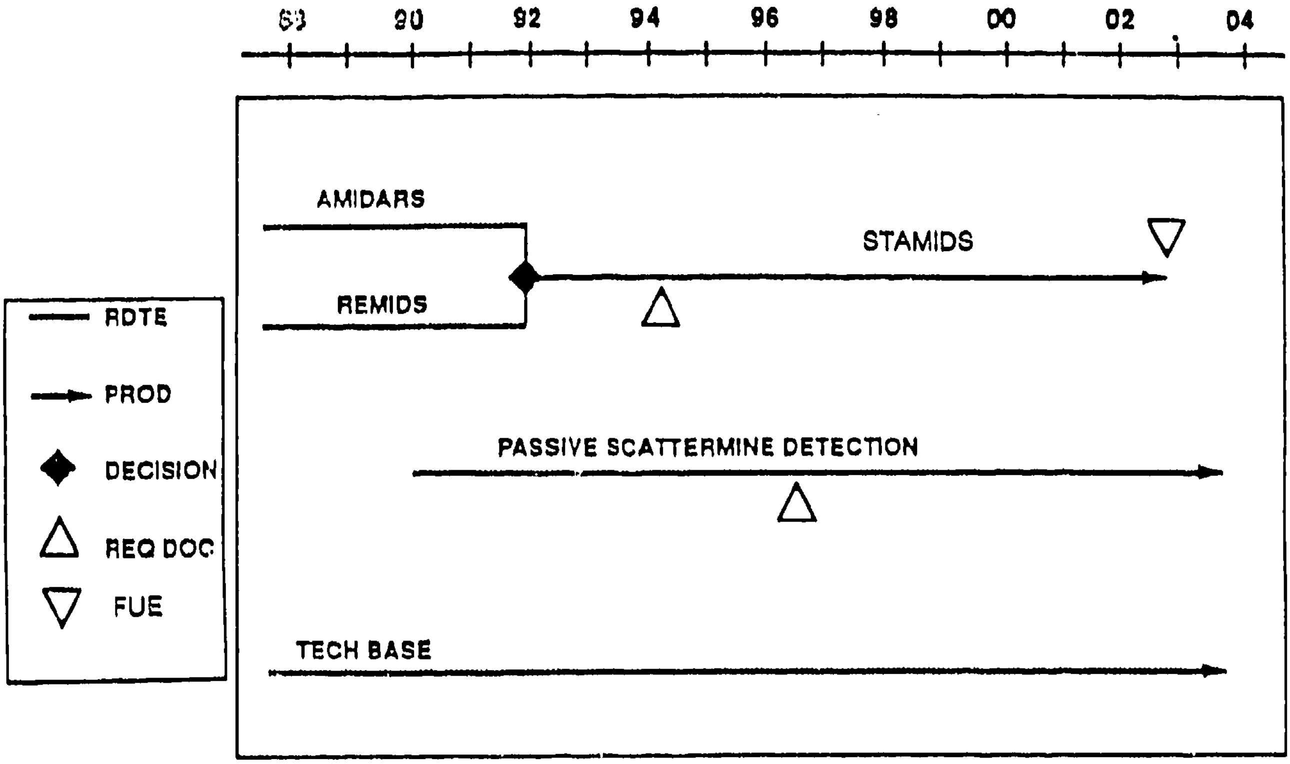


Figure V-17. Technology Applications to Stand-Off Detection.

C. THE MINE THREAT

Since their inception during World War I, land mines have been the bane of maneuver forces. First deployed to stop the mobility provided by the "new" tank forces, mines have evolved in every possible way, shape and form. Mass produced mines can be metallic or non-metallic with a variety of fusing mechanisms ranging from a simple command or pressure device to exotic remote sensing systems activated by different vehicle signatures. "Homemade" varieties used by unconventional forces have included everything from bulk explosive packed in a cardboard box or sandbag to an unexploded artillery shell or aircraft bomb rigged with a detonating device. Current development efforts are focused on speeding and simplifying mine delivery to the battlefield, increasing their effective range and area covered, and providing smart munitions that can tell friend from foe.

Unfortunately for the developers of countermine systems, the older proven mine types of the past have not dropped by the wayside as new models and fusing techniques have come into play. Now and for the foreseeable future, the mine threat will include both buried and surface mines designed to fix, delay, disrupt and channelize forces, or to restrict the use of critical routes and terrain. Buried mines can be uniformly deployed by hand or machine in set belts or fields, or more randomly placed as in road interdiction or a hastily buried field. Surface mines are generally randomly scattered without recognizable pattern. Antitank and antipersonnel scattermines today can be delivered by surface vehicle, aircraft, or artillery howitzers and rockets. It is unlikely that the mine threat will change in the coming decade. Some new delivery methods and fuzing techniques may emerge, but the total countermine problem will remain fairly stable. The ratio of remotely delivered to conventional mines may change in favor of scattermines, but the production expense, delivery expense, and the vast inventories of conventional mines, indicate a slow evolution.

The pace of mine development has far outstripped the ability to counter the threat. The cartoon of "Willie and Joe" with a hand-held mine detector from World War II leading a column of tanks, trucks, and guns down a road through a mountain pass is as true today as it was then.

D. APPLICATION OF EMERGING MINE DETECTORS

The foregoing discussion of mine detection technology in development and in the technical base indicates countermine development will be playing catch-up to the mine threat over the next decade. No single system or approach can be expected to provide a panacea for the multitude of mine types and deployments.

Of the three approaches to mine detection in the field today (probe, PSS-11/12 and tank roller), only the roller provides some degree of protection for the operator and an acceptable rate of advance. MIRADOR, when deployed, will finally remove the operator from the direct threat of a mine explosion or covering enemy fire. MIRADOR, however, is only a step forward. It can be one improved component in a total countermine system.

Standoff detection, when available in the late 1990's, will be another improvement, but again, will not stand alone. Airborne detectors presume survivability of very vulnerable aerial platforms and tenuous data link systems. At best, they will provide the location of mined areas to be avoided by ground forces or for employment of area/strip neutralization means such as the mine plow or MICLIC. The same holds true for the passive scattermine detection system. Close in detectors such as currently available, or the MIRADOR, will still be required to team with the standoff detectors to pinpoint the location of individual mines.

In summary, mine evolution between now and the end of the century is not likely to change the needs, as they are now understood, for improvements in all phases of countermine capability. The ratios of the numbers of different types of fuzes and delivery modes will change as new production results in inventory changes, but the types of threats which will be faced can be expected to remain unchanged.

The setting in which mines may be employed may change, however. The likelihood of a high intensity battlefield with heavy concentrations of forces seems to be decreasing. Meanwhile the probability of US Forces being employed in mid and low intensity situations seems to be increasing. The likelihood of facing remotely delivered mines, for example, seems to be decreasing, and the likelihood of encountering route mining and conventional minefields is increasing, even though world-wide inventories of the various types of mines may not reflect this.

Thus, there is a need to field a countermine capability which can cope with the probabilities represented by the inventories of potential high intensity foes, but which can also cope with the probabilities represented by terrorists, insurgents, drug traffickers, and Third World inventories.

CHAPTER VI

SUMMARY ANALYSIS

A. PURPOSE.

This chapter will recap and assess the analytical effort described in the preceding chapters and draw conclusions on the utility of the MIRADOR and other detectors.

B. ESSENTIAL ELEMENTS OF ANALYSIS.

The key to the utility of the MIRADOR system is contained in the Essential Elements of Analysis set forth in the introduction.

1. What is the utility of a small, agile, highly reliable, remotely controlled mine/minefield detector which can operate in conjunction with a combined arms team, with relative impunity in a mine warfare environment?

2. Can MIRADOR, as currently defined and specified, fulfill the role envisioned in the foregoing utility definition?

3. If MIRADOR has shortcomings, how can they be corrected or accomodated to fulfill the utility role?

C. SUMMARY OF STUDY ANALYSIS.

The EEA were addressed in a number of ways in Chapters two through five. The results of those analyses are summarized in the following paragraphs.

D. MINE DETECTION ANALYSIS.

1. Chapter III established criteria which showed that to be effective, a detector must be designed and operated in a way which will allow it to reliably encounter, detect, and report the existence of mines, and do so without transmitting a confusing number of false reports. The following observations arise from the analysis:

a. Probability of Encounter. The MIRADOR search head width is too narrow to:

(1) Assure encounter with sufficient mines to identify a minefield.

(2) Sweep a path wide enough in one pass to be useful for most following vehicles.

b. Probability of Detection. The sparse distribution of mines in a minefield results in few encounters, and therefore the rate of detection of those mines which are encountered must be very high.

c. False Alarms. The sparse distribution of actual mines also results in a low tolerance for false readings. Remotely delivered scattered minefields are even less dense than conventional pattern minefields, which results in even greater sensitivity to false alarms. To be most useful, the MIRADOR must have a false alarm rate no greater than the density of expected minefields. Techniques can be derived to overcome high false alarms rates, but they do so at the expense of lowering the probability of correctly identifying the location of mines and/or minefields, and at theexpense of increasing the amount of time needed to operate the detector.

d. Operational Techniques. If the MIRADOR evolves with its current specifications, then various operational procedures could could be developed and implemented to improve the utility of the detector.

E. UTILITY OF MIRADOR

1. MIRADOR was placed in four different battlefield situations and compared to existing mine detection equipment. The utility of a small remotely operated detector was assessed by inspective analysis and force-on-force modelling. The analysis revealed the following:

a. Spacing of mines in remotely delivered scattered minefields is conducive to the use of an agile, remotely controlled detector such as MIRADOR to locate a mine-free path for attacking forces.

b. The MIRADOR is as effective as the Roller in minimizing combat vehicle losses in a hasty attack situation, and introduces less direct fire exposure to dismounted soldiers.

c. In a deliberate attack of a complex obstacle where pre-attack reconnaissance is critical, the MIRADOR concept has a distinct advantage over the available detection systems. This advantage hinges on the assumption that the fielded model will have good cross-country mobility and the ability to pass over mines with impunity.

d. When searching for widely separated mines over an extended linear field such as a Main Supply Route or Line of Communication, the currently fielded systems are inappropriate. The MIRADOR's forward speed while detecting offers the potential to fill this void if search head width, detection rates and false alarm rates are improved over current specifications.

2. A summary assessment of the detectors is shown in Figure VI-1. Ratings are based on a 0 to 3 ranking. Zero is used to denote a lack of utility of that detector in that situation. One indicates some utility but with serious defiencies due to impact on the supported force or unusual risk to the system. A rating of two indicates adequate utility for the situation. A three is used to denote a best use for the detector and minefield situation. The MIRADOR system shows utility in each situation and thus has the highest overall rating.

DETECTOR	MINE SITUATION				
	HASTY MINEFIELD	DELIBERATE MINEFIELD	SCATTERED MINEFIELD	MAIN SUPPLY ROUTE	TOTAL
PROBE	1	0	1	0	2
AN/PSS-11	1	0	1	1	3
MINE ROLLER	3	1	2	0	6
MIRADOR	2	2	3	3	10

Figure VI-1 . Summary Evaluation of Battlefield Utility.

F. HUMAN FACTORS.

1. The four mine detection systems under consideration were compared in light of common tasks associated with the mine detection function.

a. The MIRADOR is expected to make total demands on its human operator equal to the existing detectors, but the lower threat of immediate danger and less physical discomfort could allow more sustained operations.

b. In difficult environmental and tactical conditions, the remote control nature of MIRADOR allows the operator to monitor the output and communicate findings better than with other detectors.

c. The mechanical and electronic nature of the MIRADOR demand more of the human operator to take advantage of the sytem capability.

G. MAINTENANCE AND SUPPLY.

1. Maintenance. Until the configuration of the MIRADOR is jelled, it is difficult to precisely predict reliability and maintenance performance. However, the emerging components are similar to components of other systems already fielded, and therefore no unusual demands should be placed on the system.

2. Supply. At least some of the components of the MIRADOR will be unique and thus expand the supply inventory. Conversely, an effective MIRADOR would reduce the use of the Roller, and the reduced demand for the heavy components would offset the impact to the supply system.

H. TIME PHASED ANALYSIS.

1. MIRADOR is the only system available for final development and fielding which is capable of enhancing mine detection capability.

2. Other systems, not as fully developed, offer the potential to supplement the mine detection equipment array.

I. OVERALL OBSERVATIONS.

1. Location of Detections. If the MIRADOR encountered and detected (with few false alarms), a sufficient sample of the minefield to assure identification of the minefield, some method must be in place to pinpoint the location of the findings, both on the ground and on planning maps. A marking system, and a position locating system, should be incorporated in pre-planned product improvements.

2. Response to Located Minefield. As shown in Chapter IV, there are a variety of situations in which a mine detector can be employed. However, in each situation detecting the minefield is only the first step. Responding rapidly to the knowledge of a minefield's existence is critical to mission accomplishment. The teaming of MIRADOR with other countermine and tactical vehicles, and the development of Battle Drills for each teaming arrangement and each minefield situation should be a concurrent activity with product development.

3. Cost Trade-offs. An effective MIRADOR could more than pay for itself in reduced combat vehicle losses. Furthermore, in some situations it could relieve the tank which normally would push the rollers, and thus increase unit mobility and firepower.

J. RESPONSE TO EEA.

1. There is broad utility for a small, agile remotely controlled mine detector. In force-on-force situations it would perform better in reconnaissance missions and finding mine-free paths in scattered minefields than it would in leading attacks in the face of anti-tank fire. In rear area, LOC, and low intensity situations it would fill a void now fillable only with slow, high-risk, personnel intensive solutions.

2. As currently defined and specified, MIRADOR falls short of the capability needed to provide the field commander with an improved detector. These shortfalls are in dimension only and not in concept.

3. As much improvement as technically possible should be sought in terms of detection rate, reduction of false alarm rate, and increase in detector head width. Once current technology has accomplished as much as it can at present, operational techniques should be developed. The fielded detector could then be supplemented by technical improvements as they become available.

K. CONCLUSIONS AND RECOMMENDATIONS.

1. Conclusions. The MIRADOR has numerous shortcomings when measured in settings which reflect battlefield risks and minefield dimensions. It is not now, and probably can't become the solution to all minefield detection problems. However, the concept, as defined by the prototype and the specification documents, offers a basis on which to increase countermine capability.

2. Recommendations. The Army should proceed with development of the MIRADOR concept.

APPENDIX A

BIBLIOGRAPHY

R. Carpenter and N. Romstedt, Counterobstacle Vehicle Utility Study, McLean Research Center, May 1986.

Phil Purdy, "MIRADOR Information Brief/Interim Report", Project Manger: Mines, Countermines, Demolitions. June 28, 1989.

G. Schecter and R. Carpenter, "Chapter 7. Recommended Program and Military Utility", McLean Research Center, September 1, 1987.

Department of the Army, Engineer Field Data, Field Manual 5-34, July 1987.

Department of the Army, Report No. IAQ-13-U-78, Soviet Army Operations, April 1978.

Department of the Army, Headquarters. Human Factors Engineering Program, Army Regulation No. 602-1, February 15, 1983.

Department of the Army, Headquarters. Manpower and Personnel Integration (MANPRINT) in the Materiel Acquisition Process, Army Regulation No. 602-2, May 1, 1989.

An Analysis Pertaining to Business Planning and P³I for MIRADOR, Gould, Inc., May 1988.

Scientific and Technical Report (Interim) for the Minefield Reconnaissance and Detector System, Gould Inc., November 7, 1986.

Jane's Weapon Systems, 19th ed. Alexandria: Jane's Information Group Inc., 1988-89.

Jane's Military Vehicles and Ground Equipment, 7th ed. Alexandria: Jane's Information Group Inc., 1986-87.

Jane's Armour and Artillery, 7th ed. Alexandria: Jane's Information Group Inc., 1986-87.

AAI Water-Jet Counter Mine Concepts, McLean Research Center

Countermine Systems Analysis and Effectiveness Modeling, McLean Research Center, October 30, 1987.

Threats Office Combined Arms Combat Development Activity, Ft. Leavenworth. Organization and Equipment of the Soviet Army, CACDA HB 550-2, July 15 1980.

US Army Armor and Engineer Board, Ft. Belvoir. Concept Evaluation (Phase I) of Total Countermine System, February 15, 1983.

Appendix B

DESCRIPTION OF DIFFERENTIAL COMBAT MODEL

A. GENERAL REMARKS

The model used in this study to assess the effectiveness of mine detector alternatives is based on the differential ground combat submodel contained in the VECTOR-2 theater-level combat model. However, a number of modifications have been implemented so that the resulting Differential Combat Model (DCM) is better able to address the specific combat situations treated in the present study.

The primary advantages of the DCM are: (1) that it uses the most advanced methodology currently available for expected-value, two-sided ground combat models, and (2) that the attrition methodology is based on physically defined and measurable input parameters and on environmental conditions.

The following three subsections present summary descriptions of model methodology, model inputs and outputs, and target intervisibility data.

B. METHODOLOGY

The basic attrition equation used in the DCM is given by

$$\frac{dR_j}{dt} = -\sum_i A_{ij} B_{ij}, \qquad (1)$$

where R_j is the current number of Red weapons of type j, B_{ij} is the current number of Blue weapons of type i that are within range of the acquired Red weapons of type j, and A_{ij} is the attrition rate for Blue type i weapons against Red type j weapons. The following paragraphs outline how these attrition rates are calculated.

The attrition equations for Blue are identical in form to equation (1) above. The resulting system of differential equations is then solved numerically, yielding the trajectories of relative Red and Blue force sizes over time.

1. Intervisibility and target acquisition. There are several factors involved in the computation of the attrition rates, A_{ij}. The first of these is concerned with the intervisibility and target acquisition processes.

The line-of-sight process is assumed to be an alternating Markov process. In other words, durations of alternating visible and invisible states are exponential random variables. Let

u_{ij} = the exponential parameter for the length of a visible period between Blue weapons of type i and Red targets of type j (thus, $1/u_{ij}$ = the expected time that a target of type j spends in the visible state when it is visible to a weapon of type i.).

Similarly, let

n_{ij} = the exponential parameter for the length of an out-of-view period.

Finally, it is assumed that the time required for a weapon of type i to detect a visible target of type j is an exponential random variable with parameter L_{ij}.

If R_{ij} is the current number of Red targets of type j that are within range of Blue weapons of type i, and if R_{ij} denotes the expected number of R_{ij} targets that are currently visible, acquired and recognized by shooting blue weapons of type i, then it follows that

$$R_{ij}' = \frac{n_{ij}}{u_{ij} + n_{ij}} \cdot \frac{L_{ij}}{u_{ij} + L_{ij}} \cdot R_{ij} \qquad (2)$$

2. Allocation of Fire. Once all of the R_{ij}' have been calculated using equation (2) for a given i and all j, the next step is to determine the allocation of fire to the different target types. This is done as follows:

Let V_j be the relative value to Blue of killing one Red target of type j. Then, the fraction of fire directed by Blue weapons of type i against acquired Red targets of type j is given by

$$f_{ij} = \frac{V_j \; R_{ij}' \; h_{ij} \; l_{ij}}{S_k \; V_k \; R_{ik} \; h_{ik} \; k_{ik}} \qquad (3)$$

where h_{ij} and k_{ij} are as defined below. In other words, the allocation of fire is assumed to be proportional to the expected fraction of value destroyed.

3. Kill Rate. The one remaining factor required to compute the A_{ij} is to determine the kill rate for each Blue weapon of type i against each Red target of type j. The kill rate is the expected number of kills per unit time, and it is denoted by α_{ij}. Let

h_{ij} = the hit probability for a Blue weapon of type i against a Red target of type j.

k_{ij} = the probability of kill given a hit

T_{ij} = the expected time require to kill, given a kill (ie, the missile flight time plus the preparation time).

Then the kill rate is calculated as

$$\alpha_{ij} = \frac{h_{ij} \cdot k_{ij}}{T_{ij}} \qquad (4)$$

Finally the attrition rate is given by

$$A_{ij} = \alpha_{ij} \cdot f_{ij} \qquad (5)$$

4. Reciprocity. It should be noted here that although the foregoing equations are for Blue weapons killing Red targets, the equations for Red killing Blue are identical in form. Also, it should be pointed out that all of the parameters mentioned above (i.e., P_{ij}, q_{ij}, l_{ij}, h_{ij}, k.., etc.) may be, and in fact usually are, range-dependent.

C. MODEL INPUTS AND OUTPUTS

Table B.1 lists all of the inputs required by the modified DCM. The title used in the computer program to denote each input variable is given, as well as a definition of the variable. Figure B.1 contains the output resulting from a sample engagement run. The first section of the output is a listing of the input values used. (This section has been annotated with the appropriate variable names from Table B.1). The second section of the output presents summary results for the engagement.

D. TARGET INTERVISIBILITY DATA

One of the important inputs required by the differential combat model is the intervisibility between the defending vehicles and the attacking vehicles. Specifically, the model requires average in-view and out-of-view segment lengths as a function of segment opening range. Based on these values, the model then calculates the probability of line-of-sight as a function of range. Such inter-visibility data was calculated for the Fulda area in Germany. An AMSAA computer model (LOSPATH) was used that employs digitized terrain data giving terrain elevation, as well as vegetation type and height. Defending positions and typical tracks for attacking vehicles were defined, and the LOSPATH model was used to determine in-view and out-of-view segments along each path as seen from each vehicle's position. These results were then averaged to give the range-dependent in-view and out-of-view segment lengths required by the Differential Combat Model.

The resulting mean segment lengths (and resulting P_{LOS}) are shown as a function of range band in Table B.2, and a typical LOSPATH output showing one observer location, several approaching vehicle tracks, and the resulting in-view and out-of-view segments is shown in Figure B.2.

E. MINE WARFARE MODULE

The DCM incorporates obstacles such as minefields into the model. The minefield can be located at any distance from the defender's defensive line. The minefield input variables recognize that an attacker sustains increased losses due to several factors. Losses are caused by encounters with mines, by the attacker slowing or stopping in a position advantageous to the defender, by the attacker's reduced ability to return fire, or his increased vulnerability caused by the constraint of passing through narrow cleared lanes in the minefield before resuming the momentum of the attack.

The impact of the minefield on the attacking forces progress and combat losses is calculated by introducing variables which reflect the changes in the attacking forces combat power. The probability of kill by a mine and the length of time the attacker is halted by the minefield are input variables. Other input variables recognize the reduction of the attacker's firepower effectiveness during the time he is halted by the minefield. This recognizes that firepower can be reduced by such factors as confusion, reorganization and quick selection of new firing positions which offer less protection than more deliberately selected positions.

In addition, variables are incorporated which reflect the attacking forces loss of momentum and the reduction in speed and firepower caused by the constraint of passage through breached lanes in the minefield.

TABLE B-1. DCM VARIABLES

VARIABLE	DESCRIPTION
DELT	Calculation increment (in seconds)
DSTOP	Minimum range to FEBA for attacking vehicles (i.e., when the closest attacking vehicle gets to this range, the simulation is terminated)
GAP	Minimum allowable distance between defender and attacker (i.e.,when closest attacking vehicle reaches this point, the defenders start backing up to maintain this separation distance).
DETERM	Print interval
RATIO	Battle stops when the number of attackers divided by the number of defenders is $\leq$ this input
NRBND	Number of range bands
NLOS	Number of lines of sight
BNDRY(K)	Range to far edge of range band K
VSL(K)	Mean in-view segment length for range band K
HSL(K)	Mean out-of-view segment length for range band K
PR(K)	Probability of defenders acquiring and recognizing attacking targets in range band K
NB	Number of defending force weapon types
NWAVE	Number of waves into which the defenders are divided (ie, only 1/NWAVE fraction of the defenders engage the enemy at a given time)
IRMT	An indicator for remote vs. autonomous acquisition (i.e., if IRMT = 0, autonomous acquisition is assumed, and if IRMT = 1, the first defending weapon type is assumed to acquire targets and then hand-off to the remaining defending weapon types.

VARIABLE	DESCRIPTION
IMLT	If IMLT = 0, no more than one defending weapon can engage an acquired attacking target at any one time; if IMLT = 1, more than one defending weapon may engage the target simultaneously.
IRWRN	If IRWRN = 1, the tactic of remasking on radar warn-on is employed; if IRWRN = 0, this tactic is not employed
BI(I)	Initial number of defending vehicles/positions of type I
TOWI(I)	Initial number of rounds for defending vehicles/ positions of type I
DISB(I)	Distance behind FEBA for defending vehicles/positions of type I
ARO(I)	Indirect fire attrition rate (i.e., kills/unit time) for defending vehicles/positions of type I
BKILL(I)	Expected number of defending vehicles/positions of type I killed by indirect fire prior to the start of the engagement
ZIG (I)	Factor which allows for probability of hit by defender when attacker has moved out of view
ITOFB(I)	Index of the time-of-flight curve for defender type I weapons
IDLOS (I)	Index to the line of sight for vehicles/positions of type I
INDB (I)	Indicator to allow for 2 weapons systems on one defending vehicle/position
ROFF(I,K)	Fraction of the maximum rate of fire that is achievable by defending weapons of type I in range band K (this input is always read by the program; however, it is used only when IRWRN=0. When IRWRN=1, ROFF(I,K) is calculated by the program
NCLAS	Number of classes of attacking vehicles types.

VARIABLE	DESCRIPTION
NR	Number of groups of attacking vehicles (e.g., there may be several groups in a given class, each group starting at a different distance from the FEBA and advancing at a different velocity)
IDEF (M)	Index for reading tables for attacking vehicle types which go into a zero velocity, defilade position
ICLAS(J)	Attacking classes of vehicle (e.g., tanks or APC) contained in group J
RI(J)	Initial number of vehicles in group J
DISI(J)	Initial distance from FEBA for vehicles in group J
V1 (J)	Initial velocity of vehicles in group J
V2 (J)	Final velocity of vehicles in group J
DISV(J)	Distance from FEBA at which vehicles in group J change from their initial velocity to their final velocity
INDR (J)	Group indicator for attackers with two weapons systems on a single platform
AMMO (J)	Initial number of rounds for all attacking vehicles in group J
RNGMNB(I)	Minimum firing range for defending type I weapons
RNGMXB(I)	Maximum firing range for defending type I weapons
TRLD (I)	Reload time for defending weapon of type I
TP1(I,K)	Average short-run preparation time for defending weapon of type I
PACQ (I,K)	Probability of an attacking weapon in range bank K acquiring a defending weapon of type I.
FTG (I,K)	Fraction of an attackers acquisitions of defender type I in range band K which are false targets

VARIABLE	DESCRIPTION
TBAR(I,M,K)	Average time for a defending vehicle of type I to acquire an attacking vehicle of class M in range band K, given line-of-sight
PHB(I,M,K)	Hit probability for a defending type I weapon vs an attacking vehicle of class M in range band K
PKHB(I,M,K)	Probability of kill given a hit for a defending type I vehicle vs an attacking vehicle of class M in range band K
PHBZ (I,M,K)	Hit probability for a defending type I weapon vs an attacking vehicle of class M in range band K which is in hull defilade
PKHBZ(I,M,K)	Probability of a kill given a hit for a defending type I vehicle vs an attacking vehicle of class M in range band K which is in hull defilade
TSALVO	The length of time (in seconds) between the defender's artillery barrages placed on the attacking forces.
ARTY(L,M,K)	Attrition factor due to indirect fire for a given length of time to each attacking weapon in open or defilade situation L of weapon type M in range band K.
VALR(M)	Value (to defender) of destroying one attacking vehicle of class M
RNGMXR(M)	Maximum firing range for attacking class M
TPR(M)	Average preparation time for a attacking vehicle of class M to fire a round (including reload)
ITOFR(M)	Index of the time-of-flight curve for rounds fired by attacking vehicles of class M
TRAB(I,M,K)	Average time for an attacking vehicle of class M in the open in range band K, given line of sight, to acquire a defending vehicle/position of type I.
PHR(I,M,K)	Hit probability for an attacking vehicle of class M vs a defending vehicle of type I in range band K

VARIABLE	DESCRIPTION
PKHR(I,M,K)	Probability of kill given a hit for a attacking vehicle of class M vs a defending vehicle of type I in range band K
NTOF	Number of time-of-flight curves
TIMR(I,J) & RNGE(I,J)	A piece-wise linear time-of-flight vs range curve is specified by a set of time/range values (indexed by J) for each index I.
PKM(M)	Probability of kill by the minefield of an attacking vehicle of type M.
AFAC	Fraction of attacking forces's normal firepower while passing through the minefield.
DFAC	Fraction of attacking forces normal firepower while stalled by minefield.
VFAC	Fraction of attacking force's normal speed while passing through the minefield.
DMMIN	Distance from FEBA to defender's side of the minefield.
DMMAX	Distance from FEBA to attacker's side of minefield.
TZERO	Time at which the attacker stops and goes into hull defilade.
TRESM	Time at which the attacker resumes movement towards FEBA.

```
                              DCM INPUT DATA
HASTY MINEFIELD, NO DETECTION

DELT, DSTOP, GAP, DETERM, RATIO, VFAC, AFAC, DFAC

   8.0      0.      0.     80.    1.00     .80     .80     .10

DMMIN, DMMAX, TZERO, TRESM

   430.0    500.0    585.0    585.0

NRBND, IILOS

  8    1

BNDRY(K) K=1, 8

   250.     750.    1250.    1750.    2250.    2750.    3250.    4350.

VSL(I,K) I=1, 1
HSL(I,K) K=1, 8

   221.     190.     181.     141.     108.     103.      95.      95.
   119.     190.     295.     346.     384      584.    1093.    1093.

PR(K) K=1, 8

  1.000    1.000    1.000     .984     .872     .684     .507     .369

NB, NWAVE, TRMT, IMLT, IRWRN

  5    1    0    0    0

BI, TOWI, DISB, ARO, BKILL, ZIG, ITOFB, IDLOS, INDB : ALL (I) I=1,  5

     20.     800.     100.    .000000      .0     .050    1    1    0
      4.     160.     100.    .000000      .0     .050    2    1    4
      6.    7200.     100.    .000000      .0     .050    2    1    5
      0.      12.     100.    .000000      .0     .200    3    1    2
      0.      18.     100.    .000000      .0     .200    3    1    3
```

Figure B-1. DCM Sample Input.

```
ROFF(I,K) I=1,  5  K=1, 8

  1.000    1.000    1.000    1.000     .800     .700     .500     .400
  1.000    1.000    1.000     .800     .600     .400     .100     .050
  1.000    1.000     .800     .600     .400     .100     .050     .010
  1.000    1.000     .400     .010     .010     .010     .010     .010
  1.000    1.000    1.000    1.000     .800     .700     .100     .010

NCLAS, NR

  6  10

IDEF(M) M=1, 6

  1   1   1   1   1   1

PKM(M) M=1, 6

   .900    .900    .900    .900    .300    .010

ICLAS, RI, DIST, V1, V2, DISV, INDR, AMMO : ALL (J) J=1, 10

  1     8.  3750.    5.56    2.78      450.   0     320.
  2    18.  3750.    5.56    2.78      450.   3   18000.
  3     0.  3750.    5.56    2.78      450.   2     126.
  4     6.  3750.    5.56    2.78      450.   0   12000.
  5     6.  3750.    5.56    2.78      450.   0       0.
  6     2.  3750.    5.56    2.78      450.   0       0.
  1    22.  4250.    6.11    3.06      600.   0     880.
  2     8.  4250.    6.11    3.06      600.   9    8000.
  3     0.  4250.    6.11    3.06      600.   8      56.
  4    11.  4250.    6.11    3.06      600.   0   22000.

RNGMNB(I), RNGMXB(I), TFLD, TP1(I,K) I=1,  5  K=1, 8

       0.    2000.     3.500  9.5 11.3 13.0 15.0 17.3 19.0 20.3 99.9
       0.     800.     2.500  8.5  9.7 99.9 99.9 99.9 99.9 99.9 99.9
       0.     800.    11.000  7.0  7.0  7.0  7.0  7.0  7.0  7.0  7.0
     100.    2000.    20.000 15.0 15.0 15.0 15.0 99.9 99.9 99.9 99.9
     100.    4000.    20.000 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0
```

Figure B-1. DCM Sample Input (Continued).

PACQ(I,K) I=1, 5
FTG(I,K) K=1, 8

1.000	1.000	.960	.660	.290	.130	.070	.040
.000	.000	.040	.330	.580	.610	.610	.610
.990	.990	.610	.450	.220	.900	.500	.020
.500	.500	.280	.360	.540	.560	.560	.560
.990	.990	.610	.450	.220	.900	.050	.020
.500	.500	.280	.360	.540	.560	.560	.560
.990	.990	.610	.450	.220	.900	.500	.020
.500	.500	.280	.360	.540	.560	.560	.560
.990	.990	.610	.450	.220	.900	.050	.020
.500	.500	.280	.360	.540	.560	.560	.560

TBAR(I,M,K) I=1, 5 M=1, 6 K=1, 8

2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300
2.700	2.600	2.900	3.500	4.200	4.000	3.300	3.300

Figure B-1. DCM Sample Input (Continued).

PHB(I,M,K) I,M,K AS ABOVE

.460	.460	.270	.190	.100	.080	.050	.000
.460	.460	.270	.190	.100	.080	.050	.000
.460	.460	.270	.190	.100	.080	.050	.000
.460	.460	.270	.190	.100	.080	.050	.000
.460	.460	.270	.190	.100	.080	.050	.000
.400	.400	.200	.100	.100	.000	.000	.000
1.000	.990	.560	.100	.000	.000	.000	.000
1.000	.250	.040	.000	.000	.000	.000	.000
1.000	.280	.040	.000	.000	.000	.000	.000
1.000	.840	.460	.070	.000	.000	.000	.000
1.000	.840	.460	.070	.000	.000	.000	.000
.400	.400	.200	.100	.000	.000	.000	.000
.990	.880	.750	.520	.440	.000	.000	.000
1.000	.960	.840	.760	.550	.000	.000	.000
1.000	.960	.840	.760	.550	.000	.000	.000
1.000	.960	.840	.760	.550	.000	.000	.000
1.000	.960	.840	.760	.550	.000	.000	.000
.980	.830	.670	.480	.360	.000	.000	.000
.950	.950	.950	.950	.000	.000	.000	.000
.960	.960	.960	.960	.000	.000	.000	.000
.960	.960	.960	.960	.000	.000	.000	.000
.960	.960	.960	.960	.000	.000	.000	.000
.960	.960	.960	.960	.000	.000	.000	.000
.700	.700	.700	.700	.000	.000	.000	.000
.950	.950	.950	.950	.950	.950	.950	.950
.960	.960	.960	.960	.960	.960	.960	.960
.960	.960	.960	.960	.960	.960	.960	.960
.960	.960	.960	.960	.960	.960	.960	.960
.960	.960	.960	.960	.960	.960	.960	.960
.700	.700	.700	.700	.700	.700	.700	.700

Figure B-1. DCM Sample Input (Continued).

PKHB(I,M,K) I,M,K AS ABOVE

.870	.870	.870	.870	.870	.870	.870	.870
.870	.870	.870	.870	.870	.870	.870	.870
.870	.870	.870	.870	.870	.870	.870	.870
.870	.870	.870	.870	.870	.870	.870	.870
.200	.200	.100	.050	.050	.000	.000	.000
1.000	1.000	1.000	1.000	1.000	.000	.000	.000
.300	.260	.230	.220	.220	.000	.000	.000
.480	.350	.500	.000	.000	.000	.000	.000
.420	.330	.500	.000	.000	.000	.000	.000
.550	.440	.390	.340	.000	.000	.000	.000
.200	.200	.100	.050	.050	.000	.000	.000
1.000	1.000	1.000	1.000	1.000	.000	.000	.000
.250	.200	.160	.110	.080	.000	.000	.000
.250	.200	.160	.110	.080	.000	.000	.000
.450	.400	.360	.310	.280	.000	.000	.000
.190	.160	.150	.140	.140	.000	.000	.000
.190	.160	.150	.140	.140	.000	.000	.000
.200	.200	.100	.050	.050	.000	.000	.000
.280	.280	.280	.280	.280	.280	.280	.280
.760	.760	.760	.760	.760	.760	.760	.760
.760	.760	.760	.760	.760	.760	.760	.760
.850	.850	.850	.850	.850	.850	.850	.850
.200	.200	.100	.050	.050	.000	.000	.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.420	.420	.420	.420	.420	.420	.420	.420
.760	.760	.760	.760	.760	.760	.760	.760
.740	.740	.740	.740	.740	.740	.740	.740
.760	.760	.760	.760	.760	.760	.760	.760
.200	.200	.100	.050	.050	.000	.000	.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Figure B-1. DCM Sample Input (Continued).

PHBZ(I,M,K) I=1, 5 M IF IDEF(M)=1 K=1, 8

.170	.170	.090	.050	.030	.020	.010	.000
.170	.170	.090	.050	.030	.020	.010	.000
.170	.170	.090	.050	.030	.020	.010	.000
.170	.170	.090	.050	.030	.020	.010	.000
.170	.170	.090	.050	.030	.020	.010	.000
1.000	1.000	1.000	1.000	1.000	.000	.000	.000
1.000	.570	.240	.020	.000	.000	.000	.000
.920	.100	.000	.000	.000	.000	.000	.000
.950	.080	.000	.000	.000	.000	.000	.000
.900	.250	.080	.010	.000	.000	.000	.000
.900	.250	.080	.010	.000	.000	.000	.000
1.000	.500	.100	.000	.000	.000	.000	.000
.390	.210	.140	.070	.050	.000	.000	.000
.840	.570	.360	.280	.160	.000	.000	.000
.840	.570	.360	.280	.160	.000	.000	.000
.840	.570	.360	.280	.160	.000	.000	.000
.450	.230	.140	.070	.050	.000	.000	.000
.450	.230	.140	.070	.050	.000	.000	.000
.630	.630	.630	.630	.000	.000	.000	.000
.550	.550	.550	.550	.000	.000	.000	.000
.550	.550	.550	.550	.000	.000	.000	.000
.550	.550	.550	.550	.000	.000	.000	.000
.300	.300	.300	.300	.000	.000	.000	.000
.300	.300	.300	.300	.000	.000	.000	.000
.630	.630	.630	.630	.630	.630	.630	.630
.550	.550	.550	.550	.550	.550	.550	.550
.550	.550	.550	.550	.550	.550	.550	.550
.550	.550	.550	.550	.550	.550	.550	.550
.230	.230	.230	.230	.230	.230	.230	.230
.230	.230	.230	.230	.230	.230	.230	.230

Figure B-1. DCM Sample Input (Continued).

PKHBZ(I,M,K) I=1, 5 M IF IDEF(M)=1 K=1, 8

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.120	.110	.130	.140	.000	.000	.000	.000
.480	.350	.500	.000	.000	.000	.000	.000
.480	.350	.500	.000	.000	.000	.000	.000
.980	.980	1.000	1.000	.000	.000	.000	.000
1.000	1.000	1.000	1.000	.000	.000	.000	.000
1.000	1.000	1.000	1.000	.000	.000	.000	.000
.350	.290	.260	.170	.130	.000	.000	.000
.350	.290	.260	.170	.130	.000	.000	.000
.550	.490	.460	.370	.330	.000	.000	.000
.210	.190	.180	.170	.160	.000	.000	.000
.110	.110	.110	.110	.000	.000	.000	.000
.110	.110	.110	.110	.000	.000	.700	.000
.690	.690	.690	.690	.000	.000	.000	.000
.670	.670	.670	.670	.000	.000	.000	.000
.750	.750	.750	.750	.000	.000	.000	.000
.750	.750	.750	.750	.000	.000	.000	.000
1.000	1.000	1.000	1.000	.000	.000	.000	.000
1.000	1.000	1.000	1.000	.000	.000	.000	.000
.210	.210	.210	.210	.210	.210	.210	.210
.690	.690	.690	.690	.690	.690	.690	.690
.670	.670	.670	.670	.670	.670	.670	.670
.690	.690	.690	.690	.690	.690	.690	.690
1.000	1.000	1.000	1.000	.000	.000	.000	.000
1.000	1.000	1.000	1.000	.000	.000	.000	.000

TSALVO = 60.0

ARTY(L,M,K) L=1,2 M=1, 6 K=1, 8

.020	.020	.020	.020	.015	.015	.007	.007
.040	.040	.032	.032	.030	.030	.013	.013
.040	.040	.032	.032	.030	.030	.013	.013
.065	.065	.055	.055	.045	.045	.020	.020
.040	.040	.032	.032	.030	.030	.013	.013
.065	.065	.055	.055	.045	.045	.020	.020
.010	.010	.010	.010	.007	.007	.002	.002
.020	.020	.016	.016	.015	.015	.007	.007
.020	.020	.016	.016	.015	.015	.007	.007
.032	.032	.028	.028	.022	.022	.010	.010
.020	.020	.016	.016	.015	.015	.007	.007
.032	.032	.028	.028	.022	.022	.010	.010

Figure B-1. DCM Sample Input (Continued).

```
VALR, RNGMXR, ITOFR : ALL (M) M=1, 6
TPR(M,K)                           K=1, 8

     3.    2000.   1
 13.000  14.800  16.500  18.500  20.800  22.500  23.800  99.900
     2.    1500.   2
 17.000  17.000  17.000  99.900  99.900  99.900  99.900  99.900
     2.    4000.   3
 47.000  47.000  47.000  47.000  47.000  47.000  47.000  47.000
     1.    4000.   4
 45.000  90.000  90.000  90.000  90.000  90.000  90.000  90.000
     1.    1000.   5
 47.000  47.000  99.900  99.900  99.900  99.900  99.900  99.900
     2.    4000.   6
 99.900  99.900  99.900  99.900  99.900  99.900  99.900  99.900


TRAB(M,I,K) M=1,  6  I=1,  5  K=1, 8

  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
  2.700   2.600   2.900   3.500   4.200   4.000   3.300   3.300
```

Figure B-1. DCM Sample Input (Continued).

PHR(M,I,K) M,I,K AS ABOVE

1.000	1.000	.486	.482	.473	.469	.462	.000
1.000	1.000	.962	.718	.424	.217	.100	.000
1.000	1.000	.962	.718	.424	.217	.100	.000
1.000	1.000	.962	.718	.424	.217	.100	.000
1.000	1.000	.962	.718	.424	.217	.100	.000
1.000	.210	.140	.100	.070	.050	.000	.000
1.000	.210	.140	.100	.070	.050	.000	.000
1.000	.210	.140	.100	.070	.050	.000	.000
1.000	.210	.140	.100	.070	.050	.000	.000
1.000	.210	.140	.100	.070	.050	.000	.000
.730	.730	.730	.730	.730	.730	.730	.000
.440	.440	.440	.420	.400	.400	.340	.000
.370	.370	.320	.360	.410	.410	.350	.000
.440	.440	.440	.420	.400	.400	.340	.000
.370	.370	.320	.360	.410	.410	.350	.000
.000	.000	.000	.000	.000	.000	.000	.000
.080	.010	.000	.000	.000	.000	.000	.000
.080	.010	.000	.000	.000	.000	.000	.000
.080	.010	.000	.000	.000	.000	.000	.000
.080	.010	.000	.000	.000	.000	.000	.000
.540	.410	.000	.000	.000	.000	.000	.000
.300	.200	.000	.000	.000	.000	.000	.000
.300	.200	.000	.000	.000	.000	.000	.000
.300	.200	.000	.000	.000	.000	.000	.000
.300	.200	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000

Figure B-1. DCM Sample Input (Continued).

PKHR(M,I,K) M,I,K AS ABOVE

1.000	1.000	.936	.655	.371	.186	.084	.000
1.000	1.000	.936	.655	.371	.186	.084	.000
1.000	1.000	.936	.655	.371	.186	.084	.000
1.000	1.000	.936	.655	.371	.186	.084	.000
1.000	1.000	.936	.655	.371	.186	.084	.000
.000	.000	.000	.000	.000	.000	.000	.000
.166	.162	.157	.148	.138	.000	.000	.000
.166	.162	.157	.148	.138	.000	.000	.000
.166	.162	.157	.148	.138	.000	.000	.000
.166	.162	.157	.148	.138	.000	.000	.000
.140	.140	.140	.140	.140	.140	.140	.000
.680	.680	.680	.680	.680	.680	.650	.000
.680	.680	.680	.680	.680	.680	.650	.000
.680	.680	.680	.680	.680	.680	.650	.000
.680	.680	.680	.680	.680	.680	.650	.000
.000	.000	.000	.000	.000	.000	.000	.000
.056	.053	.000	.000	.000	.000	.000	.000
.056	.053	.000	.000	.000	.000	.000	.000
.056	.053	.000	.000	.000	.000	.000	.000
.056	.053	.000	.000	.000	.000	.000	.000
.110	.100	.000	.000	.000	.000	.000	.000
.600	.580	.000	.000	.000	.000	.000	.000
.530	.500	.000	.000	.000	.000	.000	.000
.600	.580	.000	.000	.000	.000	.000	.000
.530	.500	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000

Figure B-1. DCM Sample Input (Continued).

```
NTOF
  6

I, N
RNGE(I,J) I=1, 6
TIMR(I,J) J=1, N

  1    9
     0.      250.     750.    1250.    1750.    2250.    2750.    3250.    3750.
   .000     .150     .450     .770    1.090    1.420    1.750    2.100    2.500
  2    4
     0.      250.     750.    1250.
   .000     .200     .600    1.100
  3    9
     0.      250.     750.    1250.    1750.    2250.    2750.    3250.    3750.
   .000    1.050    3.100    5.150    7.500   10.300   13.400   16.900   20.800
  4    9
     0.      250.     750.    1250.    1750.    2250.    2750.    3250.    3750.
   .000    1.000    2.000    3.000    4.000    5.000    6.000    7.000    8.000
  5    3
     0.      250.     750.
   .000    3.300    8.800
  6    9
     0.      250.     750.    1250.    1750.    2250.    2750.    3250.    3750.
   .000    1.000    2.000    3.000    4.000    5.000    6.000    7.000    8.000
```

Figure B-1. DCM Sample Input (Continued).

TIME = 80.0

ATTACKER

GROUP	CLASS	INITIAL VEHICLES	VEHICLES KILLED	VEHICLES SURVIVING	DISTANCE FROM FEBA
1	1	8.00	.58	7.42	3305.52
2	2	.00	.00	.00	3305.52
3	3	18.00	2.35	15.65	3305.52
4	4	6.00	1.16	4.84	3305.52
5	5	6.00	.78	5.22	3305.52
6	6	2.00	.39	1.61	3305.52
7	1	22.00	1.59	20.41	3761.04
8	2	.00	.00	.00	3761.04
9	3	8.00	1.04	6.96	3761.04
10	4	11.00	2.13	8.87	3761.04
TOTAL CLASS 1		30.00	2.17	27.83	
TOTAL CLASS 2		.00	.00	.00	
TOTAL CLASS 3		26.00	3.39	22.61	
TOTAL CLASS 4		17.00	3.30	13.70	
TOTAL CLASS 5		6.00	.78	5.22	
TOTAL CLASS 6		2.00	.39	1.61	
TOTAL ATTACKER		81.00	10.02	70.98	

GROUP	CLASS	INITIAL AMMO	AMMO FIRED	AMMO KILLED	TOTAL AMMO LOST	AMMO REMAINING
1	1	320.00	.00	23.11	23.11	296.89
2	2	18000.00	.00	2346.25	2346.25	15653.75
3	3	126.00	.10	16.42	16.51	109.49
4	4	12000.00	.00	2327.89	2327.89	9672.10
5	5	.00	.00	.00	.00	.00
6	6	.00	.00	.00	.00	.00
7	1	880.00	.00	63.54	63.54	816.46
8	2	8000.00	.00	1042.63	1042.63	6957.38
9	3	56.00	.01	7.30	7.31	48.69
10	4	22000.00	.00	4267.50	4267.50	17732.50

Figure B-2. DCM Final Output.

GROUP	CLASS	TOTAL DEFENDERS KILLED	BATTLE PK	DEFENDERS KILLED BY CLASS: 1	2	3	4	5
1	1	.00	.000	.00	.00	.00	.00	.00
2	2	.00	.000	.00	.00	.00	.00	.00
3	3	.00	.000	.00	.00	.00	.00	.00
4	4	.00	.000	.00	.00	.00	.00	.00
5	5	.00	.000	.00	.00	.00	.00	.00
6	6	.00	.000	.00	.00	.00	.00	.00
7	1	.00	.000	.00	.00	.00	.00	.00
8	2	.00	.000	.00	.00	.00	.00	.00
9	3	.00	.000	.00	.00	.00	.00	.00
10	4	.00	.000	.00	.00	.00	.00	.00

DEFENDER	TOTAL	EACH CLASS: 1	2	3	4	5
INITIAL POSITIONS	30.00	20.00	.00	.00	4.00	6.00
POSITIONS KILLED	.00	.00	.00	.00	.00	.00
POSITIONS REMAINING	30.00	20.00	.00	.00	4.00	6.00
INITIAL MISSILES	8190.00	800.00	160.00	7200.00	12.00	18.00
MISSILES FIRED	.00	.00	.00	.00	.00	.00
MISSILES KILLED	.00	.00	.00	.00	.00	.00
TOTAL MISSILES LOST	.00	.00	.00	.00	.00	.00
MISSILES REMAINING	8190.00	800.00	160.00	7200.00	12.00	18.00
ATTACK CLASS 1 KILLED	.00	.00	.00	.00	.00	.00
ATTACK CLASS 2 KILLED	.00	.00	.00	.00	.00	.00
ATTACK CLASS 3 KILLED	.00	.00	.00	.00	.00	.00
ATTACK CLASS 4 KILLED	.00	.00	.00	.00	.00	.00
ATTACK CLASS 5 KILLED	.00	.00	.00	.00	.00	.00
ATTACK CLASS 6 KILLED	.00	.00	.00	.00	.00	.00
TOTAL ATTACKER KILLED	.00	.00	.00	.00	.00	.00
AVE. ENGAGEMENT TIME	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
AVE. ENGAGEMENT RANGE	3656.4	.0	.0	.0	.0	3656.4
BATTLE PK	.238	.000	.000	.000	.000	.238

RATIOS:	ACCUMULATED EXCHANGE	DIFFERENTIAL EXCHANGE	FRACTIONAL EXCHANGE	AVERAGE FORCE	FINAL FORCE	INTENSITY OF BATTLE
	9999.99	9999.99	3947.96	2.53	2.37	.1253

Figure B-2. DCM Final Output (Continued).

APPENDIX C

MIRADOR SIMULATION

by

Nicholas M. Smith
Wackenhut Advanced Technologies Corporation

INTRODUCTION

This report summarizes the structure and use of a simplified model for analysis and demonstration of the MIRADOR system as determined by it's specifications. It is the thesis of this work that the dominating characteristics of MIRADOR, as a component of tactical warfare team, are determined by elemental probabilistic factors. These factors are largely independent of the tactical team makeup. The simulation model is designed to present a simulated response of the MIRADOR as it is used to sweep for the presence of mines. The operation of the model permits the user to gain a sense of the quantitative experience of operating a MIRADOR system for purposes of mine detection and the judging of the significance of the result inorder to react to the indications of mines present. The model presents particular results of a sweep through a mine-field (MF) laid randomly -- as is appropriate for the deployment of scatterable mines.

Current doctrinal MF are deployed at such a density and extent that the expected number of vehicle/mine encounters is of the order of unity, -- i.e. from 0.5 to 2. Mathematically one is dealing with very small probabilites for a mine encounter per unit area of sweep. The sweep analysis is embellished by the provision for treating the probability that a mine encounter is (is not) detect-ed, and by the occurrence of random spurious or false reports of mines when in fact they are not any. There is also reported the probability that a following vehicle (that is wider than the lane swept by MIRADOR) encounters a mine not encountered by the MIRADOR system. Among others the following questions are inquired into:

1. In the presence of a reported mine what is implied as to the location of a MF?

2. How significant is a false report of a detected mine?
   What level of such false reports is tolerable?

3. What is the significance of the existence of mines encountered that were not detected by MIRADOR?

It is assumed, in accordance with MIRADOR specifications, that the MIRADOR vehicle can pass over mines without detonating them. This assumes that MIRADOR wheel pressure is light enough to not set off pressure mines, that it's magnetic signature is neutral, and that it does not encounter mines with tilt rod actuators, and that it does not encounter sophisticated mines that operate from the side, or from the top and that are actuated from a distance.

MATHEMATICAL MODEL

The simulation model is based upon a very simple, classical, probablistic mathematical model. This simple model implies all of the characteristics of MIRADOR revealed in the simulation model. It is therefore useful to examine the mathematical model and its implications.

The following notation is introduced:

rho =	density of mines in the MF, #/sq-meter.
sigma-s =	the sweep/mine encounter cross-section, meters.
sigma-f =	false encounter sweep cross-section, meters.
W =	width of MF, meters
L =	depth of MF, meters.
N =	number of mines in MF.
sigma-a =	armored vehicle/mine encounter cross-section, meters.
p-d =	conditional probability that a mine encountered is detected.
rho-f =	apparent density of mines falsely reported.
E =	expected number of sweep/mine encounters for a tract traversing the MF.
E-f =	Expected number of false encounters for a tract traversing the entire march.
P(n,E) =	Probability that exactly n encounters occur in a sweep where the expected encounters is equal to E.
M =	length of the march, meters.

These results, from the definitions and from classical probability theory:

rho = N/(W*L),

E = rho * sigma-s * L,

E-f = rho-f * sigma-f * M,

$$P(n,E) = \frac{E(\exp n)*e(\exp(-E))}{n!}$$

where e is the base of the Naperian logarithms, and n! is the factorial of n

This may also be expressed by the following recursion formulae:

P(0,E) = e(exp(-E)), and

$$P(n,E) = \frac{E}{n} * P(n-1,E).$$

NUMERICAL EXAMPLE

For a quantitative example the Threat scatterable capability set forth in Chapter II is used. Two MF patterns are considered, one resulting from a one-launch and the second from six-launch laydown. Each launcher delivers 449 mines (1-launch field) and therefore 2694 mines in a 6-launch laydown. The one-launch MF extends over an area 1000 meters by 532 meters. The 6-launch MF extends over a rectangle 1000 by 2000 meters. The mine densities are respectively 0.000836 and 0.001347 #/sq-meter.

The MIRADOR sweep width is specified as 1.22 meters (4 feet). The width of the main-battle tank is given as 3.47 meters, which is assumed to be also its mine-encounter cross-section.
The following expected encounters result (Table 1):

Table 1. Expected Mine Encounters

Case	1-launch 537 m	1-launch 1000 m	6-launch 1000 m	6-launch 2000 m
MIRADOR	0.548	1.020	1.643	3.287
Tank	1.558	2.901	4.674	9.348

Inserting these expected encounters into the Poisson equations there results the probabilities that the MIRADOR experiences exactly n encounters as given in Table 2.

Table 2. Probability of Exactly n Mine Encounters in Traverse of Mine Field

MF (Depth)	Mirador(M) or Tank(T)	Encounters 0	1	2	3	4	5
1-launch 537 m	M	0.578	0.317	0.087	0.016	0.002	0.000
	T	0.211	0.328	0.256	0.133	0.052	0.016
1-launch 1000 m	M	0.361	0.368	0.188	0.064	0.016	0.003
	T	0.055	0.159	0.231	0.227	0.162	0.097
6-launch 1000 m	M	0.193	0.318	0.261	0.143	0.059	0.019
	T	0.009	0.044	0.102	0.159	0.186	0.174
6-launch 2000 m	M	0.037	0.123	0.202	0.221	0.182	0.119
	T	0.000	0.001	0.004	0.012	0.028	0.052

Another cut through the Poisson functions yields Table 3, the probability that an observation of exactly one encounter indicates an expected encounter occurrence of E, where E lies in the interval between E1 and E2. This computed by taking the integral of P(1,E) dE between these limits, and where

$$P(1,E) = E * e \exp(-E).$$

Table 3. Probability That on Observing One Encounter That the Expected Number of Encounters Lies Between E1 and E2 For Intervals of 0.1

E1	E2	Prob	E1	E2	Prob
0.0	0.1	0.00468	1.5	1.6	0.03289
0.1	0.2	0.01284	1.6	1.7	0.03169
0.2	0.3	0.01941	1.7	1.8	0.03041
0.3	0.4	0.02462	1.8	1.9	0.02909
0.4	0.5	0.02865	1.9	2.0	0.02774
0.5	0.6	0.03170	2.0	2.1	0.02639
0.6	0.7	0.03390	2.1	2.2	0.02504
0.7	0.8	0.03540	2.2	2.3	0.02372
0.8	0.9	0.03631	2.3	2.4	0.02241
0.9	1.0	0.03672	2.4	2.5	0.02114
1.0	1.1	0.03673	2.5	2.6	0.01991
1.1	1.2	0.03640	2.6	2.7	0.01872
1.2	1.3	0.03580	2.7	2.8	0.01755
1.3	1.4	0.03499	2.8	2.9	0.01641
1.4	1.5	0.03401	2.9	3.0	0.01544

In each of these tables observe the large variances. These are equal to the square-root of n, the number of observed encounters.

IMPLICATIONS OF PROBABILITY CONSIDERATIONS

There results that the working information produced by MIRADOR in doctrinal scatterable mine-fields is characterized by small numbers, small statistical samples and large variances. Even for a MIRADOR that operates perfectly (i.e. detects every mine it encounters and produces no false detections) considerable uncertainty exists as to the nature of the MF implied by the observations. There also exists appreciable chance that the MIRADOR will experience no mine encounters even when it passes through a MF. Since the encounter cross-section for a tank is 2.8 times that for a MIRADOR encounter there is a significant chance that MIRADOR will not report mines even when the tank is seriously at risk.

If now the possiblity of false reports is added, the significance of reported mines is further degraded, particularly since MIRADOR can report false mines anywhere along the entire march; whereas it is expected to encounter in the order of one mine whenever it traverses a real MF. Thus the requirement for low false reports is aggravated by the need to minimize them over the entire march -- and not just within the boundaries of the MF itself. There is therefore a reasonable requirement that there occur no more false encounters than there are expected actual encounters, i.e. that there be no more than one false encounter per march. Since the MF extends over 1 to 2 km and a march extends from 10 to 20 km, the conclusion is reached that the false mine area density becomes intolerable whenever it reaches higher than .00004 to .00008 per sq-meter.

THE COST OF FALSE MINE DETECTIONS

The cost of false mine detections is a function of the tactical reaction to a reported mine, and to modification of force vulnerability as a result of this reaction. Therefore the utilization of MIRADOR in the tactical team must be considered.

OPERATIONS IN REAR AREAS

In rear areas the MIRADOR can be used to alert the area unit to the presence of mines in that area. Any positive signal by MIRADOR can be marked by colored spray and that spot avoided until examined by a mine clearance team. On determination that a mine is actually present all of the usable portion of the area can be swept by all available mine detection devices. The cost of a false report before actual mines are verified is the cost of those actions brought by 1) the effort involved in the active mine sweeping of the entire area, and 2) and the cost in degraded efficiency brought about by the unit operating is a condition of mine-alert.

A high rate of false detections will then cause the unit to operate continuously in a state of mine-alert. There is not a linear relation between the rate of false alerts and the cost: Several false reports amount to no-information. The presence of many false reports could result in the elimination of the MIRADOR as a useful member of the tactical team.

OPERATIONS IN THE VICINTY OF WELL DEVELOPED DEFENSE

The use of MIRADOR as a mine detection instrument in the assault of a well fortified defensive position will be made under the presumption that densely laid mine-fields exist. The role of MIRADOR is then to provide intelligence as to the position of the MF. Such MF are deployed with the intention of denying the assaulting forces free access to the positions near to the defended site. Mine densities that are large can be anticipated: in the order of .01 mines per sq-meter such that the number of expected encounters is high. So high that the MIRADOR would be unlikely to penetrate far into a MF before a first encounter occurs. To effectly signal the occurence of a MF the rate of false detections must be at most .1 of the rate of true mine encounters. If scatterable mines are used by the enemy in addition to the emplaced MF, the tolerable level of false reports is that level tolerable for scatterable mine-fields anywhere. One false report in a sweep of 2000 m leads to a tolerable false report rate of about .0005 per sq-meter.

In this tactic the attacking unit ignores a single reported mine, but waits until several (2 or more) are reported within a short (50 m) distance. At this time he reacts to the presence of mines. A double false report in this distance is possible and can lead needlessly to a premature response to the presence of mines. Under conditions of large anticipated losses to enemy fire the assault commander may elect to ignore the MIRADOR and continue the assault until actual mine casualties are suffered.

FALSE REPORTS ON THE MARCH

On a march that may be encountering scatterable mines dropped by aircraft or by artillery or placed by ambushing enemy forces the entire march is conductede under a condition of mine-alert. The intention is to utilize MIRADOR to alert the tactical unit to the actual presence of mines (without suffering casualties). The march may extend for several kilometers (say 20 to 30 kilometers).

MIRADOR, by its design characteristics, cannot determine a mine-free lane of sufficient width to accommodate tactical vehicles. An armored vehicle (e.g. tank) has a width of 3.47 meters and has therefore 2.8 times the expected mine encounters as has the MIRADOR sweep. A tank can be expected to encounter from 2 to 4 mines in a MF where the MIRADOR sweep encounters only one. It can occur with appreciable probability that the MIRADOR sweep encounters no mines in an area where a tank may encounter, say, 2. Therefore, it is not useful simply to mark with a colored spray an indicated mine since the following vehicles have so much greater encounter cross-section.

Every reported detection will need to be comfirmed by some other means. When the situation is aggravated by the chance that the MIRADOR may fail to detect an actual mine encountered the unit commnder may not be able to depend on MIRADOR to alert him to the presence of a mine-field.

An alternate, and more expensive, tactic is to sweep a lane with four MIRADOR running overlapping sweeps. Under these conditions protection afforded by the MIRADORs is degraded when ever the detection probability given an encounter is less than certainty. The effective mine density facing the following vehicles is that of a MF composed of those mines not detected. A detection probability of 0.7, for example, will leave in the swept lanes a MF of 0.3 the original density.

With any mode of use, the march is delayed just as much by false detections as by real detections. A delay to the movement of a tactical unit is potentially costly:

1. The unit is delayed in reaching its intended objective
2. The vulnerability of the unit to enemy attack is increased
3. The enemy has an opportunity to lay more scatterable mines in the path of the march.

ACTUAL MINES NOT DETECTED

The effect of not reporting (detecting) actual mines encountered modifies the effectiveness of MIRADOR linearly. The mathematical computation is equivalent to the reduction of the sweep width by multiplying the width by the conditional probability of detection given an encounter. For example, the MIRADOR with a sweep width of 1.22 meters and a conditional detection probability of 0.75 has an effective sweep width of 0.91 meters (3 feet). However the physical effect is to make a "dirty" sweep, leaving undetected 0.25 of the mines present.

DETERMINATION OF THE LOCATION OF A MINE FIELD

The determination of the location of a MF is made uncertain by the absence of sufficient data. Even under perfect detection (no mines missed, no false reports) the occurence of one detection raises the following questions:

a. Is this a pre-laid (dense) MF?
b. Is the mine an isolated occurrence?
b. Is it a MF of scatterable mines?
c. If so, what is its probable extent?

In the first instance a series of sweeps within a 100 meter square would reveal several more mines and give rough indication of their density. A visual identification of a scatterable mine would indicate a probable MF of scatterable mines. Since it might be a 1-launch or a 6-launch field then the MF could extend anywhere within 2000 meters of the observed and verified scatterable mine. That is, a single observation of a scatterable mine will entail an uncertainly of plus or minus 2000 m in any direction.

If now consideration is given to the likelihood that some mines encountered are not detected the assurance of a mine-free lane for the traverse of wide-tracked vehicles is missing. The MIRADOR can serve primarily for alerting the unit commander of the presence of probable mines. There still remains the problem of clearing a lane for the tactical vehicles.

THE MIRADOR SIMULATION

The MIRADOR Simulation is a computer program that runs on any PC compatable personal computer, with printer and with installed GWBASIC or with DOS. It presents a case history of a sweep by a MIRADOR on a march in which scatterable MF occur. It permits the operator to designate the length of the march, the position of the beginning and end of the MF, the area density of actual mines, the effective area density of false mines, the probability of detection given an encounter, the width of the MIRADOR sweep, and the width of vehicles following the MIRADOR. The occurrence of encounters, false encounters, detections, additional encounters by following vehicles is determined by pseudo-random numbers. Since the sequence of pseudo-random numbers is in fact a deterministic sequence and the starting seed for random selection is entered by the user, then a particular history can be reproduce permitting for alternating displays of the results. One display shows the result as it appears to the operators of the MIRADOR; a second display shows the actual results, indicating the true detections, the missed detections, the beginning and end of the mine field, the occurence of false detections, and additional encounters in the same track made by the wider following vehicles. The linear track of the sweep through is presented in a folded format, reading left to right and from top to bottom.

Any one run constitutes a single "case", or A chance selection from among the many possible cases; computed in a manner that is consistent with the simple probability model described above. Its use permits a "hands on" personal experience of the probabilistics described in the earlier discussion.

The simulation calculation proceeds in the laying down of a search in a sequence of squares each of a size determined by the sweep width. A wider rectangle of width equal to the tank width, and length the same as the search square permits additional random choices to determine if additional encounters occur to the following vehicles. A double symbol code is printed for each increment sweep. The use of coded symbols permits packing twice as much information into a printout symbol. A table of symbol meanings is printed on selection by the operator.

An addendum to this report is included that shows the run of the simulation for both the 1-launch and the 6-launch MF cases. The output is characterized by a large number of null results.

The results permit a visual experience of results to expect under variation of the design specifications as to probability of detection and the rate of occurrence of false detections. The simulation makes more vivid to the operator the consequences of the probabilistic nature of the MIRADOR operation and permits the user to exercise his choices of alternate responses. In short, it may be used as an educational device. No characteristics not implicit in the simple mathematical model occur.

CONCLUSIONS

The following conclusions are indicated by this analysis:

1. The physical characteristics together with the probabilistic nature of the operation dominate all other considerations.

2. The low mine densities (.000836 and .001347 #/sq-meter) constitute small probabilities and sparse data such that:

    a. Statistical analysis of indicated detections is not useful.

    b. There exist sizable probabilities of no MIRADOR/mine encounters in the traverse of scatterable mine fields.

    c. Expected MIRADOR/mine encounters per MF of 0.55 to 3.29, i.e. in the order of unity.

    d. False detection reporting leads to serious degradation of effectiveness.

    e. Position of an indicated scatterable MF uncertain with a radius of 2000 meters.

3. False encounters of more than one encounter per tactical march will seriously degrade usefulness of results.

4. Width of MIRADOR sweep too narrow to insure verification of a safe, mine-free lane for tactical vehicles.

5. Probability of non-detection given an encounter is equivalent to a reduction in the sweep width.

6. A simple mathematical probabilistic model is presented, together with Tables of results. The mathematical model is supported and supplemented by random-choice simulation. The MIRADOR Simulation Model presents a "Monte Carlo" case history of a single traverse of a region containing scatterable mines and displays either the MIRADOR's operator view, or a display of what is actually occuring.

DIRECTIONS FOR READING OUTPUT

Attached are two example print-outs from the MIRADOR Simulation Model. The program provides either of two outputs. The first, as shown in Figure C-2, shows what the MIRADOR operator would see, given the current specifications. The second, as shown in Figure C-3, shows the true minefield situation, and the results of following the MIRADOR with an M1 tank.

In the printouts, each letter or symbol (or pair of letters or symbols) represents one search area opportunity for MIRADOR. In this model, a search area opportunity is an area which has sides equal to the detector head width.

The model considers that the MIRADOR begins the search well short of the minefield and continues well beyond the minefield. The detector follows a path directly through the minefield. The print-out shows the results along that path. The record of the search is recorded beginning at the top left of the matrix and reading to the right to the end of the top row, then continuing at the left edge of the second row and continuing (as in reading text) for the complete record of detector results.

Figure C-1 shows the symbology used in the printouts.

MIRADOR Reports Printout Symbology

Report of Mine Detected - 1

No report of mine detected - 0

Actual Situation Printout Symbology

Start of minefield - <

End of minefield - >

Left symbol in pair (undetected mine)

		Mines Undetected by Sweep 0	1	2	3	4
A	D	0:	space	S	D	I	G
D	Y	1:	a	A	F	H	--
D		2:	d	g	B	--	--
E	V	3:	t	J	--	--	--
D	E	4:	q	--	--	--	--
	H	:					

Right symbol in pair (reported mine)

		Actual # minus Undetected 0	1	2	3	4
F	R	0	O	S	D	I	G
A	E	1	a	A	F	H	X
L	P	2	d	g	B	X	X
S	O	3	t	J	X	X	X
E	R	4	q	X	X	X	X
	T						

FIGURE C-1. SYMBOLOGY USED IN PRINTOUT

RUN NUMBER 143 19:08:25 09-09-1989
Same as run 142: as seen by MIRADOR operator
RANDOMIZER SEED = : 0.6247170
MINE DENSITY, #/sq. meter = : 0.0013470
FALSE DETECTION DENSITY = : 0.0013470
DETECTION PROBABILITY = : 0.600
MF BEGINS AT : 200
MF EXTENTION, meters = : 1000
RUN CONTINUES FOR (meters): 300
SWEEP WIDTH, meters = : 1.220
REF VEH WIDTH, meters = : 3.470
EXPECTED # MINE ENCOUNTERS: 1.643
EXP # ADDN'L VEH ENCOUNTERS: 3.031
EXPECTED # FALSE ENCOUNTERS: 2.47

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0										

NUMBER OF MINES 5
NUMBER UNDETECTED 2
NUMBER ADDN'L ENCOUNTERS BY REF VEH 6
NUMBER FALSE DETECTIONS 1

FIGURE C-2. INFORMATION PROVIDED TO MIRADOR OPERATOR

```
RUN NUMBER 142   19:22:19 09-09-1989
6-launch MF: false rpts = mine density
              RANDOMIZER SEED = : 0.6247170
MINE DENSITY, #/sq. meter = : 0.0013470
   FALSE DETECTION DENSITY = : 0.0013470
      DETECTION PROBABILITY = : 0.600
                   MF BEGINS AT : 200
        MF EXTENTION, meters = : 1000
   RUN CONTINUES FOR (meters): 300
           SWEEP WIDTH, meters = : 1.220
         REF VEH WIDTH, meters = : 3.470
 EXPECTED # MINE ENCOUNTERS:     1.643
EXP # ADDN'L VEH ENCOUNTERS:     3.031
EXPECTED # FALSE ENCOUNTERS:      2.47

00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  #0
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  #0  00  00  00  00
00  00  00  00  00  00  00  00  #0  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  #0  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  #0  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  0■  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  #0  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  0S  00  00  00  00  00  00  00  00  00  00  S0  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  S0  00  00
00  00  00  00  00  00  00  00  00  00  0S  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  0S  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00  00  00  00  00  00  00  00  00  00
              NUMBER OF MINES  5
            NUMBER UNDETECTED  2
NUMBER ADDN'L ENCOUNTERS BY REF VEH  6
      NUMBER FALSE DETECTIONS  1
```

FIGURE C-3. ACTUAL MINEFIELD SITUATION