

AD-A034 452

INTERNATIONAL LASER SYSTEMS INC ORLANDO FLA
INDIRECT/AREA FIRE WEAPONS EFFECT SIMULATOR STUDY (SUMMARY). VO--ETC(U)
JAN 77 R E ODOM

F/G 19/5

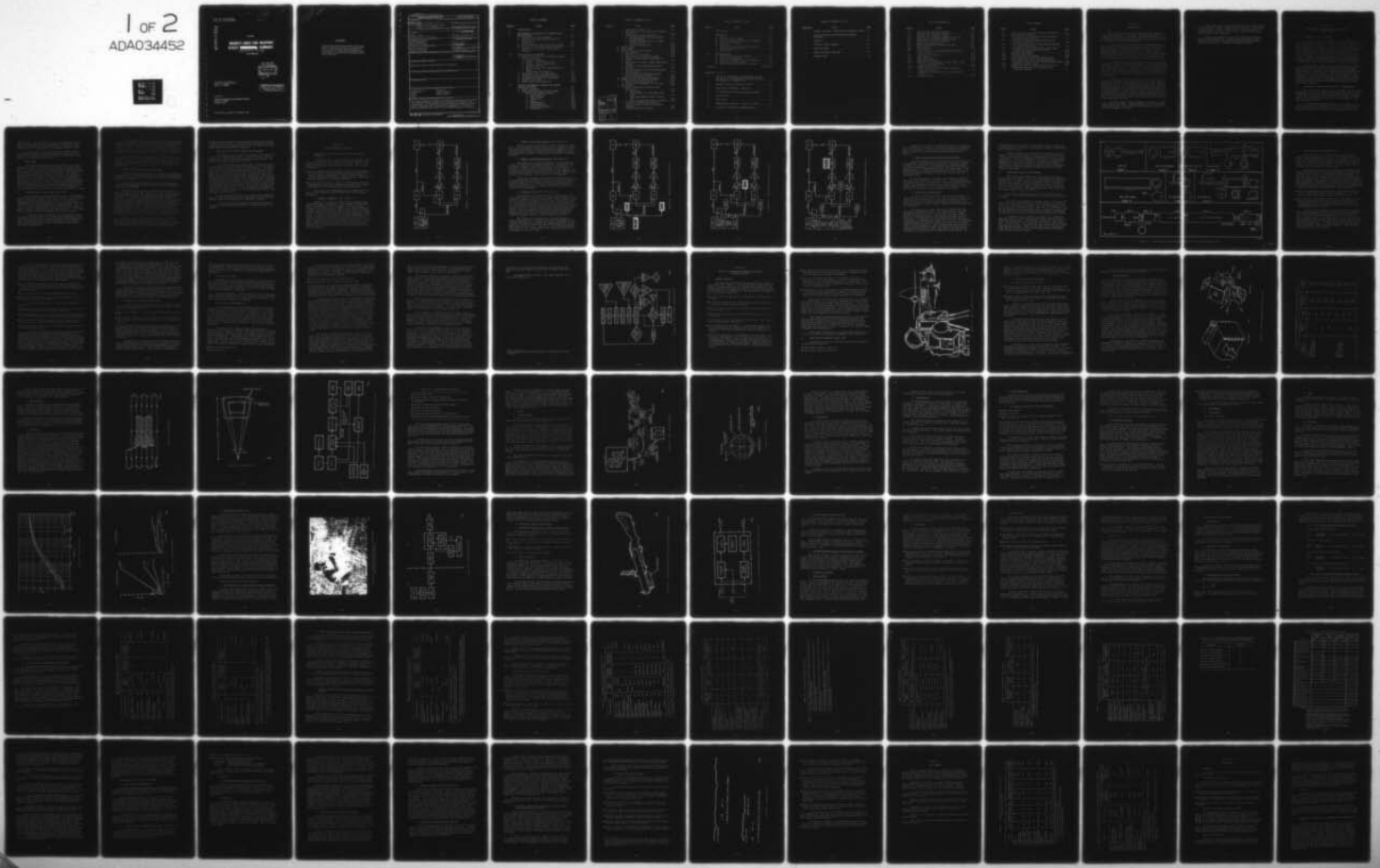
N61339-76-C-0070

UNCLASSIFIED

TND-TR-76-0002-VOL-1

NL

1 of 2
ADA034452



Report No. TND-TR 76-0002
Contract No. N61339-76-C-0070

12

FL

ADA 034452

VOLUME I

**INDIRECT / AREA FIRE WEAPONS
EFFECT ~~RESEARCH~~ SUMMARY**

SIMULATOR STUDY

(Project 5839-01P01)

D D C
RECEIVED
JAN 17 1977
REGISTERED

QA A

International Laser Systems, Inc. ✓
3404 N. Orange Blossom Trail
Orlando, FL 32804

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

Prepared for

PROJECT MANAGER FOR TRAINING DEVICES
Orlando, FL 32813
December 1976

Study Period 3 June 1976 – 30 December 1976

*Title on 1473 no
Contract pending but
Jensen, J. L. Jensen Systems, Inc.
(313) 285-4010 72 Cambridge
TCR - 19 Jan 77*

DISCLAIMER

This study was conducted under PM TRADE RDTE Program. Neither the Department of the Army nor any person acting on behalf of the United States Government assumes any liability resulting from the use of the information contained in this document, or warrants that such use will be free from privately owned rights.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TND-TR-76-0002 - Vol-1 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Vol I - Indirect/Area Fire Weapons Effect Simulator Study (Summary) - Volume I. Vol II - Preliminary Systems Engineering Design	5. TYPE OF REPORT & PERIOD COVERED Final Rept. 3 Jun-30 Dec 76	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert E. Odom Chairman, Study Advisory Group	8. CONTRACT NUMBER XXXXXXXXXXXX N61339-76-C-0070 NEW	
9. PERFORMING ORGANIZATION NAME AND ADDRESS PM TRADE Field Office ATTN: DRCPM-TND-FO Ft Eustis, VA 23604	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1X762727A230	
11. CONTROLLING OFFICE NAME AND ADDRESS PM TRADE Field Office ATTN: DRCPM-TND-FO Ft Eustis, VA 23604	12. REPORT DATE 1 Jan 77	13. NUMBER OF PAGES Vol I - 83; Vol II - 370
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Training Devices Electronics Simulation Position Location Lasers Weapons Effects Optics		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the results of an exploratory development study designed to investigate feasible alternatives for the simulation of indirect fire weapon systems. The study treats several alternative approaches and provides technical assessment costs and schedule for development. A Preliminary Systems Engineering Design, PSED, of the recommended approach is presented.		

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
I	INTRODUCTION	1-1
II	THE PROBLEMS IN SIMULATION OF INDIRECT-FIRE WEAPON EFFECTS	2-1
	A. Simulation of "Kill" Effects	2-1
	B. Simulation of Audio-Visual Effects of Indirect Fire	2-1
	C. Shell Smoke	2-2
	D. Cannon-Launched Guided Projectiles (CLGP)	2-2
	E. Location of Fire Effects and "Platforms"	2-3
	F. Disposition of "Killed" Material and Personnel	2-4
III	STUDY APPROACH AND METHODS	3-1
	A. Narrative and General Discussion of Weapon-Effects Simulation	3-1
	1. System 1 (Baseline)	3-1
	2. System 2 (First Modification)	3-3
	3. System 3 (Second Modification)	3-3
	4. Systems 4 and 4-A	3-3
	5. Radio Frequency (RF) Multilateration System	3-7
	6. Study Effort Continuation	3-7
	B. Pyrotechnic Visual Cue Techniques	3-8
	C. Position-Finding and Target Location	3-11
	D. Vulnerability Assessment Techniques	3-13
	E. Logistics and Costs	3-14
	F. MILES System Interoperability	3-14
IV	RESULTS (RECOMMENDED INDIRECT-FIRE EFFECTS SIMULATION SYSTEM)	4-1
	A. General Comments	4-1
	B. Laser Weapon Simulator System (LWSS)	4-2
	1. Basic Laser Weapon Simulator	4-4
	a. Beam Generation	4-5
	b. Beam Scanning	4-8
	c. Electronics	4-8
	d. Sight	4-13
	e. Configuration	4-17
	f. Ground Operation	4-18
	g. Helicopter Operation	4-19
	h. Performance	4-20

TABLE OF CONTENTS (Cont'd)

<u>Section</u>	<u>Title</u>	<u>Page</u>
2.	Copperhead Simulator (CS)	4-24
3.	LWS Supplement for Heavy Terrain Masking Situations	4-24
4.	MILES Target System Modification	4-27
	a. Recommended Modification to MILES Man-Worn System	4-27
	b. Recommended Modification to MILES Vehicle Systems	4-30
	c. Alternative Concepts	4-30
C.	Visual Cueing	4-32
D.	Shell Smoke	4-33
E.	Logistic Support Requirements	4-34
	1. Introduction	4-34
	2. Reliability Predictions	4-34
	3. Maintainability Prediction (MTTR)	4-34
	4. Summary - Maintainability/Reliability Factor	4-35
	5. Laser Weapon Simulator System Maintenance Concept	4-35
	6. Point-Kill Laser System Maintenance Concept	4-36
	7. Sonic-Overpressure Device System Maintenance Concept	4-39
	8. RF Trilateration Ground Designation System Maintenance Concept	4-39
F.	Communications Net Within the System	4-41
G.	Communications With Fielded Personnel	4-51
	1. Basic System Communications	4-51
	2. Communications Equipment in the Field	4-51
H.	Discussions	4-52
	1. System Approaches Eliminated From Competition	4-52
	a. Satellites	4-52
	b. Lighter-Than-Air Laser/Radar Platforms	4-53
	c. Radar Beam Weapons Effects Simulation	4-54
	d. Radio-navigated Helicopter Platforms	4-54
	2. Validity of Operational Concepts, Training Values, Costs and Logistics Analyses	4-55
	3. Concepts Evaluation Program	4-56

ADDITIONAL FOR		
NTIS	Write Section	<input checked="" type="checkbox"/>
DCC	Ref Section	<input type="checkbox"/>
UNANNOUNCED		<input type="checkbox"/>
JUSTIFICATION		
BY		
DISTRIBUTION/AVAILABILITY CODES		
NO. 1	NO. 2	NO. 3
A		

TABLE OF CONTENTS (Cont'd)

<u>Section</u>	<u>Title</u>	<u>Page</u>
V	COST SUMMARY	5-1
VI	CONCLUSIONS	6-1
	A. General	6-1
	B. RF Trilateration Scheme	6-1
	C. Scanning Laser/Kill Designation System	6-1
	D. Visual Cue Subsystem	6-1
	E. Audio Cue	6-2
	F. Cuer Position Location and Location of Designated Strike Points	6-2
	G. Uncertainties	6-3
VII	RECOMMENDATIONS	7-1
	A. Kill-Effects Simulation System	7-1
	B. Visual Cue Subsystem	7-1
	C. Position and Target Location Subsystems	7-2
	D. Equipment Considerations	7-2
	E. Systems Concepts Verification Program	7-2
	Glossary	Glossary 1
APPENDICES (Volume II)		
A	USE OF THE ATMOSPHERIC ELECTRIC FIELD FOR THE DERIVATION OF VULNERABILITY WEIGHTING FACTORS IN THE PRESENCE OF INDIRECT FIRE	A-1
B	RELATIVE VALUES OF COMPETING SYSTEMS	B-1
C	LASER WEAPON SIMULATOR - AREA KILL	C-1
D	VHF TRILATERATION GROUND DESIGNATION SYSTEM	D-1
E	VISUAL CUEING	E-1
F	SHELL SMOKE	F-1
G	LASER WEAPON SIMULATOR - POINT KILL (LWS-P)	G-1
H	SIMULATION SYSTEM FIELD COMMUNICATIONS	H-1

TABLE OF CONTENTS (Cont'd)

<u>Appendices</u>	<u>Title</u>	<u>Page</u>
I	SYSTEMS LOGISTICS - LASER WEAPON SIMULATOR SYSTEM	I-1
J	LOW COST INDIRECT-FIRE SIMULATION LOCATION SUBSYSTEM	J-1
K	SYSTEM "X"	K-1
L	POSITION FINDING SYSTEMS	L-1
M	HIGH RISK AREAS	M-1
N	TARGET DECODER/P _k ANALYZER	N-1
O	SYSTEMS COSTS	O-1

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-1	Indirect Fire Simulation System 1	3-2
3-2	Indirect Fire Simulation System 2	3-4
3-3	Indirect Fire Simulation System 3	3-5
3-4	Indirect Fire Simulation Systems 4 and 4-A	3-6
3-5	Audio-Visual Pyrotechnic Marker Device	3-9
3-6	Flow of Effort on Study Contract	3-17
4-1	Laser Scan and Visual Cue	4-3
4-2	General Arrangement and Optics of LWS	4-6
4-3	Scan Pattern	4-9
4-4	Scan Footprint	4-10
4-5	Indirect-Area Fire Simulated System Electronic Block Diagram	4-11
4-6	Sight Optical Schematic	4-14
4-7	Sight Display	4-15
4-8	Range Performance	4-22
4-9	Scan Time Performance	4-23
4-10	Advanced Prototype Model of Hughes GLLD, Ground Laser Locator Designator	4-25
4-11	Copperhead Simulation	4-26
4-12	Grenade Launcher M79 with Laser Point Kill Designator (LPICD)	4-28
4-13	Recommended Module Addition to MILES Man-Worn System	4-29
4-14	Terrain Contours	4-57

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
4-1	Scan Parameters for Given Simulation Conditions . .	4-7
4-2	Microprocessor Functions	4-12
4-3	Laser Weapon Simulator System Maintainability and Reliability Factors	4-37
4-4	Point-Kill Laser System Maintainability and Reliability Factors	4-38
4-5	Sonic Overpressure Device System Maintainability and Reliability Factors	4-40
4-6	Tri-Lateration Ground Designation System Main- tainability and Reliability Factors	4-42
4-7	Personnel Requirements	4-43
4-8	Training Requirements	4-45
4-9	Transportation Requirements	4-46
4-10	Initial Equipment Allocation Requirements	4-47
4-11	Major Components, RF Tri-Lateration Ground Designation System Initial Equipment Requirements	4-48
4-12	Preliminary Spares Concept	4-49
5-1	Summary of Cost for a Typical Training Field . . .	5-2
5-2	Cost/Values Comparison for Indirect Fire Simulation Systems	5-3

Section I

INTRODUCTION

The U.S. Army has a need for weapons-effects simulation in training exercises. It has been found that when weapons effects are realistically simulated, troops participate in training exercises with much enhanced enthusiasm and with real effect on improving their fighting proficiency.

In two-sided battle simulations it becomes immediately apparent that both aggressiveness and caution are essentials in actual warfare. The Army has developed a number of effective direct fire weapon simulation systems, for example Multiple Integrated Laser Engagement System (MILES), Infantry Direct Fire Simulator System (IDFSS) and Mounted Direct Fire Simulator (MDFS). It is planned to field the MILES system in numbers adequate to operate two-sided training engagements at battalion strength.

In real warfare, it has been found that most battlefield casualties result from indirect-fire weapons (that is, fire from the mortars organic to infantry battalions and from the supporting field artillery batteries). Therefore, there is an essential need for simulation of indirect fire weapon effects in battlefield exercises. The indirect-fire simulation must not interfere with and must operate in conjunction with the MILES direct-fire simulation system.

In addition to "kill" effects, the indirect-fire simulation must be accompanied by audio-visual cueing. This cueing is essential to provide troops with the stimulus normally produced by proximate fires, to provide forward observers (FOs) with the essential visual location information they need and, in the case of fire adjustment, to provide the cues normally available to targeted troops from such activity. Further, effective simulation of shell smoke is required. Smoke delivered by artillery is a very effective battlefield tool, and without the effective introduction of this variable, much of the training value in the use of artillery would be lost.

A final variable is the introduction of Cannon Launched Guided Projectiles (CLGP). These weapons are fired from remote field artillery batteries, but have the potential accuracy of direct-fire weapons or better.

Thus, even the relatively invulnerable moving tank targets become potential valuable targets for indirect fire. The guidance of these weapons to their targets does, of course, depend on a laser designator operator in clear view of the target, and this variable must be well-simulated.

This report summarizes the effort carried out by International Laser Systems, Inc. under Contract N61339-76-C-0070 to study means of solving the problems associated with providing effective simulation of indirect-fire weapons effects.

Section II

THE PROBLEMS IN SIMULATION OF INDIRECT-FIRE WEAPON EFFECTS

A. SIMULATION OF "KILL" EFFECTS

It is essential that the simulated lethal effects of indirect fires be delivered into "footprint" areas simulating the size and locational accuracy of real indirect fires. This delivery must be done within time-spans simulating real fires, and the lethal effects versus personnel and material must be well-simulated. Either excessive or inadequate lethality simulation would result in a loss of confidence on the part of the trainees. The full range of lethalties of weapons must be simulated from the 81-mm mortar to the 8-in. howitzer and the effects of various types of rounds (for example, H.E.-quick fuzed to improved conventional munitions (ICM)), and from single rounds through battery volleys to massed fires from multiple batteries on single target areas.

The latest Army doctrine places great emphasis on battery first-fire-for-effect and massed fires from several batteries where warranted. The use of fire-adjustment procedures using single tubes is considered both hazardous and to lose much of the effect of quick fire-for-effect. Thus, the kill-effects will frequently, if not most often, be required to simulate a number of rounds in a rather large footprint area as a single incident rather than single rounds. CLGP weapons must also be simulated, but this is a special problem easily solved along the lines of direct-fire simulation.

B. SIMULATION OF AUDIO-VISUAL EFFECTS OF INDIRECT FIRE

The audio-visual effects of real artillery fire are indeed impressive. It is quite impractical to approach the full-scale audio-visual effects with safety and economy. Safety of personnel in the training exercises is of paramount importance. Nevertheless, the cues are essential and it would be desirable to have them impressive as well.

Any pyrotechnics used must have no real incendiary or explosive hazard, no perceptible chemical or environmental risks, and should be small and economical. If pyrotechnics are used, their effect must take place at sufficient height so that no

hazards result. The cues should be sufficiently distinctive so that no confusion as to their significance in simulation result. The sound generated should be of sufficient intensity to draw attention to the visible cue over a reasonably extensive area.

Audible cues may also be generated by synthetic means when radiation simulation of weapon effects is employed. This should be a distinctive audio cue different from any audio cues employed for direct-fire simulation.

C. SHELL SMOKE

One of the most important uses of indirect fire is the placement of smoke at inaccessible locations for screening movement or for screening known or suspected enemy observation posts. The actual use of artillery for this purpose in training exercises is not feasible because of the hazard involved. The visual effects must be full-scale so that actual denial of observation is effected. This observation denial calls for simulation of shell smoke by prompt delivery of smoke to the required area by other means. If feasible, delivery should be accomplished without inadvertent advance visual cueing. Hazards must also be minimal. This militates against the use of white phosphorus smoke because of the incendiary hazard and the toxicity of the phosphorus pentoxide white smoke. HC smoke or oil-based smokes may be useful.

D. CANNON-LAUNCHED GUIDED PROJECTILES (CLGP)

The introduction of CLGP weapons introduces the ability of field artillery to be effective against hard point, moving targets, such as tanks, APCs, and the like. This is at the expense of a forward observer/target designator using a narrow-beam laser transmitter to illuminate the target's "vulnerable spot" with precision to afford a homing signal for the CLGP guidance. The initial firing of the projectile must be sufficiently accurate to permit the CLGP to acquire the target and maneuver to it. In some cases, this will not be accomplished and a miss will result.

In addition, there are a number of countermeasures that an enemy can take to spoof or decoy the CLGP and, because of the relatively extensive period during which the forward observer (FO) must illuminate the target, it may be feasible for an enemy to bring fire on his position prior to CLGP impact (being cued by the laser transmissions).

It is feasible to use a different type of laser (eye safe) to simulate the CLGP laser and have it, through the target's MILES detectors, respond with kill effect. Because the FO must use radio procedures to coordinate the field artillery function with his own, it may be feasible to simulate the battery's actions in a normal fashion and to have the (random time) actual transmission of laser-kill signal be radio-transmitted to the laser simulator.

This action would afford excellent training for FOs, simulate the effects and the random no-effect shots could be controlled by actions at the simulated battery. This problem is so similar to the direct-fire simulation problem that, except for simulation of battery functions, it properly belongs within the MILES system.

E. LOCATION OF FIRE EFFECTS AND "PLATFORMS"

One of the most severe problems in simulating the effects of indirect fire is the location of the effects at the desired spot (primarily "visual" and "kill" effects) to simulate the particular indirect fire incident.

The locations of these effects must be at the intended points within the probable errors of real artillery and mortars in similar circumstances.

Numerous schemes have been proposed for transmission of laser and radio frequency (RF) radiation to effect the simulations from "platforms" ranging from satellites through lighter-than-air vehicles and helicopters to personnel afoot near the desired locations. All of these schemes require accurate location control. Most of the schemes are impractical for a variety of reasons and in nearly all cases, precise location control is very expensive. The least expensive and most practical solutions to the combined location/platform problem, in terms of devices which must be procured and operated with safety in the field, involve the use of trained personnel fielded near or with the trainee force elements with position-finding by reference to fixed objects. Using relatively simple equipment, this can be done rather rapidly.

The next most feasible scheme is the use of electronic multilateration position-finders such as position-locating reporting station (PLRS), RMS/SCORE. These are, however, exceedingly expensive systems and the expense may not be justifiable for this purpose. The use of helicopters or small surface

vehicles as platforms (as well as personnel afoot) may be useful in some special instances. Especially for the operators of safe visual-cue devices, it appears most likely that they would be deployed among the trainee force elements.

F. DISPOSITION OF "KILLED" MATERIAL AND PERSONNEL

The disposition of killed force elements is an operational problem, not a system problem and is common to both the MILES direct-fire system and the projected indirect-fire system. The problem does require discussion, however.

If "killed" troops and vehicles were allowed to continue to move about after kill-effects have taken place, false cueing of the opposite side could result in much confusion. It appears, especially in the case of massed indirect-fires, and the like, where many "kills" could take place in a short period and small space, that "killed" troops and vehicles should be required to remain in-place for a period of time. Commanders of the victims of such an attack will require time to reorganize their remaining strength and this action must not be interfered with. Following upon such action as is necessary, field umpires may then display a recognized signal, enter the area, organize the "killed" troops and withdraw. Such action should be recognized by the opposing force as entirely synthetic. It may frequently be necessary to leave the "victims" in place for rather extended periods to avoid confusion and false cueing.

It is reiterated that this is an operational problem and must be solved by the organization responsible for the training efforts. Good troop discipline is absolutely necessary.

It may be necessary to establish rendezvous points for "victims" to which they can proceed if so directed visually by umpires.

Section III

STUDY APPROACH AND METHODS

A. NARRATIVE AND GENERAL DISCUSSION OF WEAPON-EFFECTS SIMULATION

ILS proposed and originally started the contract effort to cover a very wide-ranging group of possible approaches to the problem of simulation of indirect-fire effects. At the first Study Advisory Group (SAG) meeting in mid-June 1976, ILS was directed to:

- Put aside system approaches which involved great automaticity, great reliance on newly developed electronic hardware (for example, complex computers) and "exotic" schemes requiring long and expensive development. Emphasis was to replace automaticity with human efforts/decisions; and
- Use the following month to conceive of approaches along the desirements of the first directed effort above and to report findings at the second SAG meeting in mid-July 1976.

This action was accomplished and ILS summarized the results of the one-month effort as described in the following paragraphs.

1. System 1 (Baseline) (See Figure 3-1)

System 1 is a system in which fielded operators with narrow-beam laser transmitters, using a number of MILES codes, effect the numbers and types of target kills directed by a Simulation Net Control Station (SNCS) in the areas designated thereby. The decisions at the SNCS would be made on the basis of established, documented procedures simulating the estimated effects of indirect fires requested by field commanders. Audio/visual cueing would be by means of (as then undetermined) pyrotechnics. Audio cues would also be generated by the laser operator after kill-effects by a special laser code on a limited area. Communications to fielded personnel would be by normal VHF/UHF radio. Fielded operators would also monitor forward observer (FO)/fire direction center (FDC) nets to gain anticipatory information.

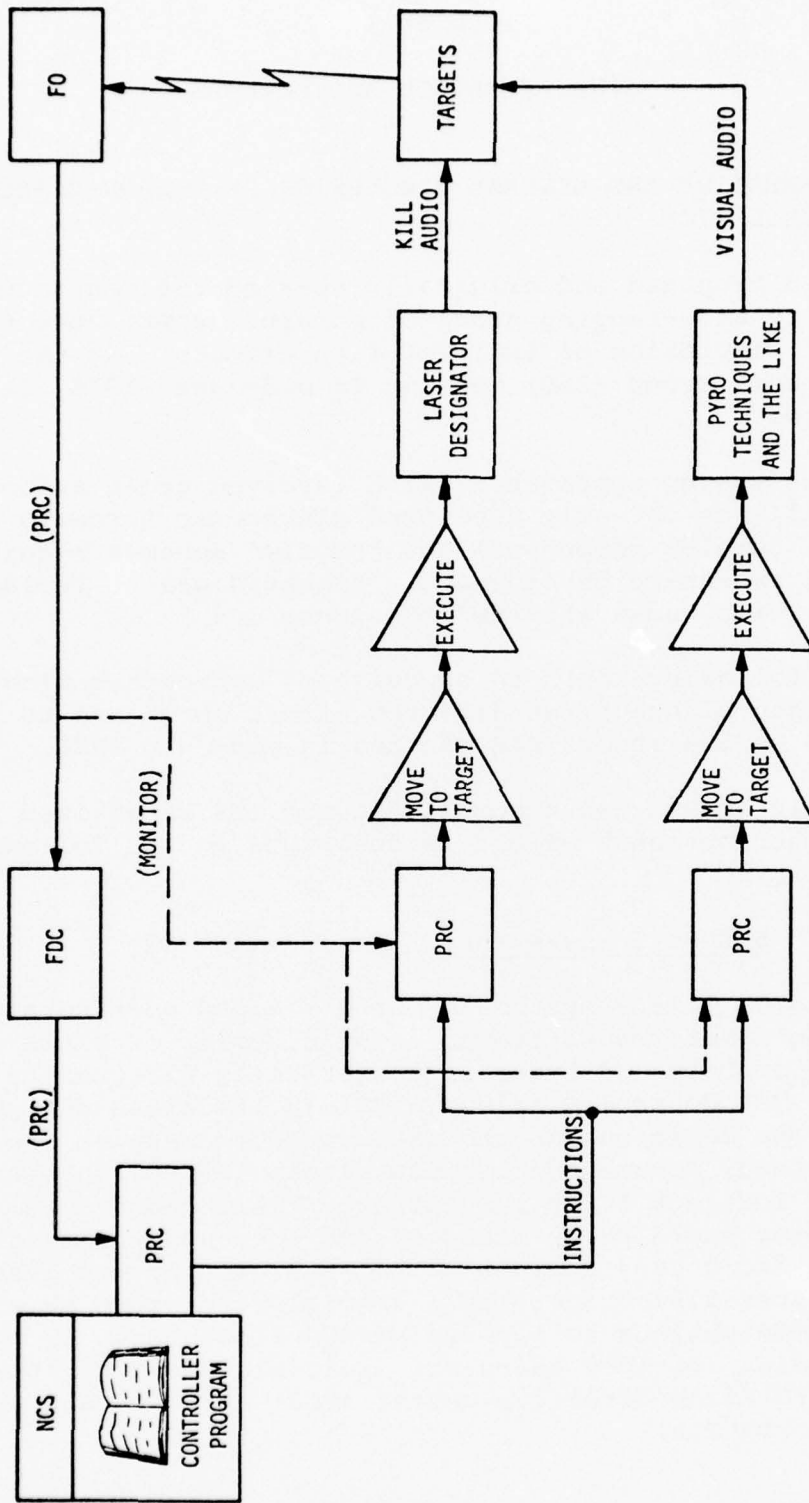


Figure 3-1. Indirect Fire Simulation System 1

2. System 2 (First Modification) (See Figure 3-2)

This is a concept essentially similar to system 1, except that a discrete address paging ("pocket pager") system was added. This system affords the fielded personnel the capability to continuously monitor FO/FDC nets and to respond to SNCS calls only when discretely addressed. This allows anticipation of required movement.

3. System 3 (Second Modification) (See Figure 3-3)

This system is a further outgrowth of the basic system 1 concept in which position-location capability (for example, RMS and PLRS) is added to the fielded personnel and allows real positional location capability to be added. In this system, if an operator arrives near a designated location and finds that the targeted elements have largely or entirely left the indirect fire target area, no effects (or little) will be accomplished.

This allows commanders and troops the capability of protecting themselves from imminent indirect fire effects which might be signalled by the audio-visual pyrotechnic simulators, using position-finding gear, at accurately placed points simulating fire-adjustment procedures. It also allows the FO function to be carried out realistically.

4. Systems 4 and 4-A (See Figure 3-4)

This system is an outgrowth of the preceding ones. The significant change is the use of a scanning laser transmitter with a magnetic compass and optical rangefinder. This equipment allows the kill-effects (plus synthetic audio) laser operators to stand off a considerable distance (up to 1 km) from target points and to control both the area of effect and position with good accuracy. Battery volleys can be well simulated as a single event with this scheme. Here, the capability also exists to introduce distinct codes for various weapons and versatile decoders in which the probability of kill can be a function of protective measures taken (for example, posture -- prone, kneeling and erect).

The "fidelity" of system 4 over the other systems is greatly enhanced and the influence of protective measures is introduced realistically. Further, the amount of movement of laser operators is greatly reduced and the audio-synthetic cue can be made effective over quite a large area. This increased effectiveness would relieve, to some extent, the necessity of use of the pyrotechnic cue in every case.

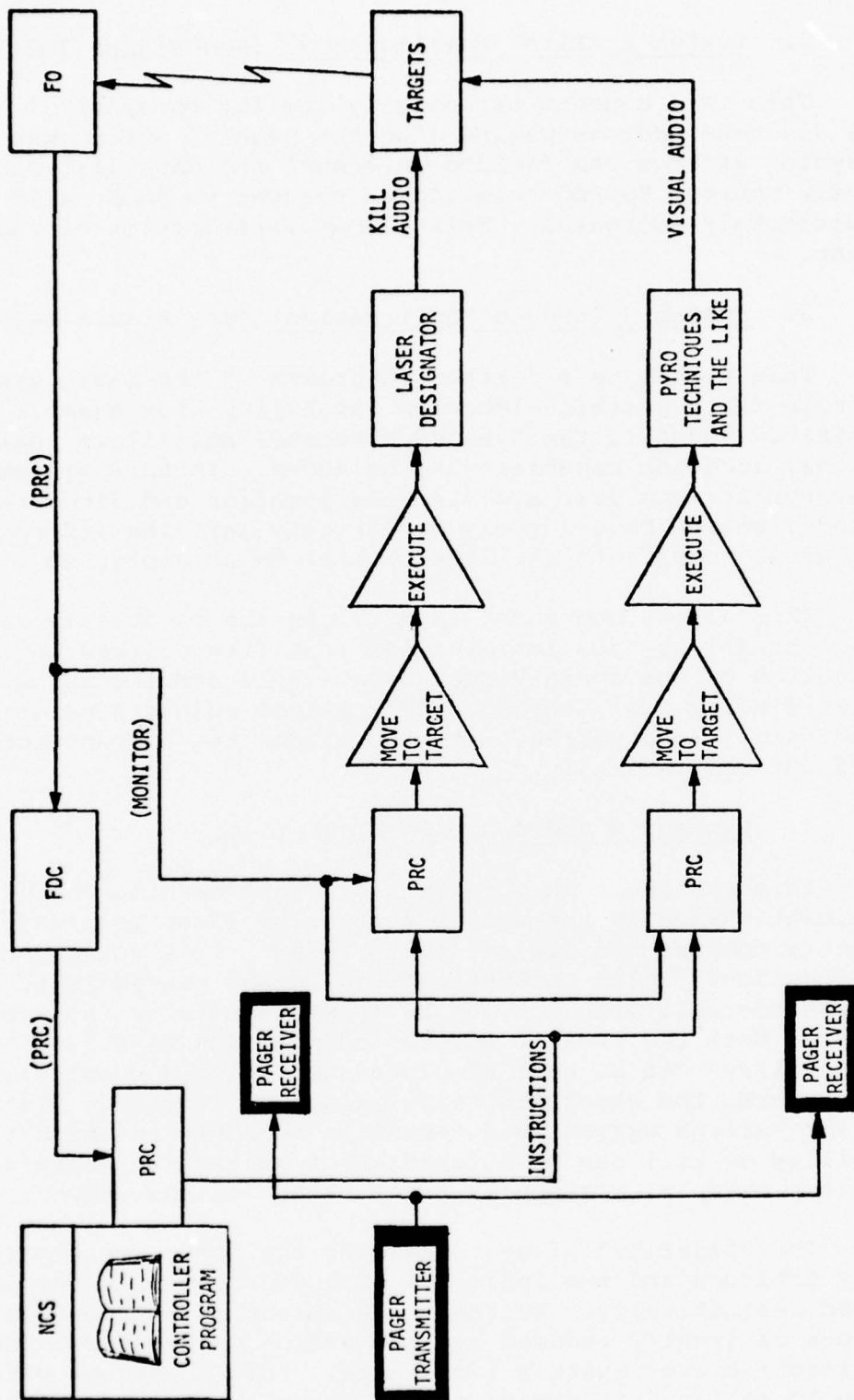


Figure 3-2. Indirect Fire Simulation System 2

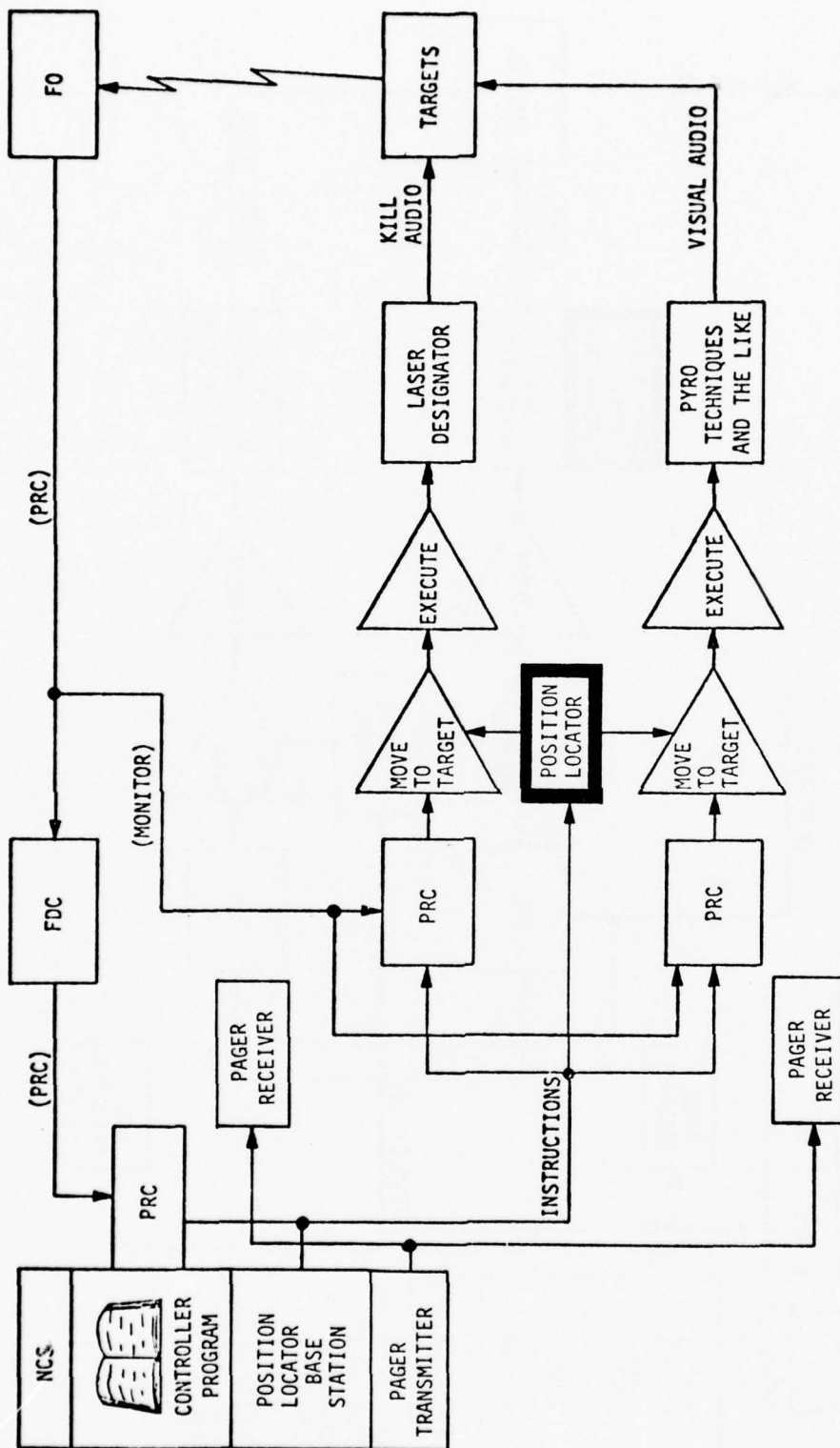
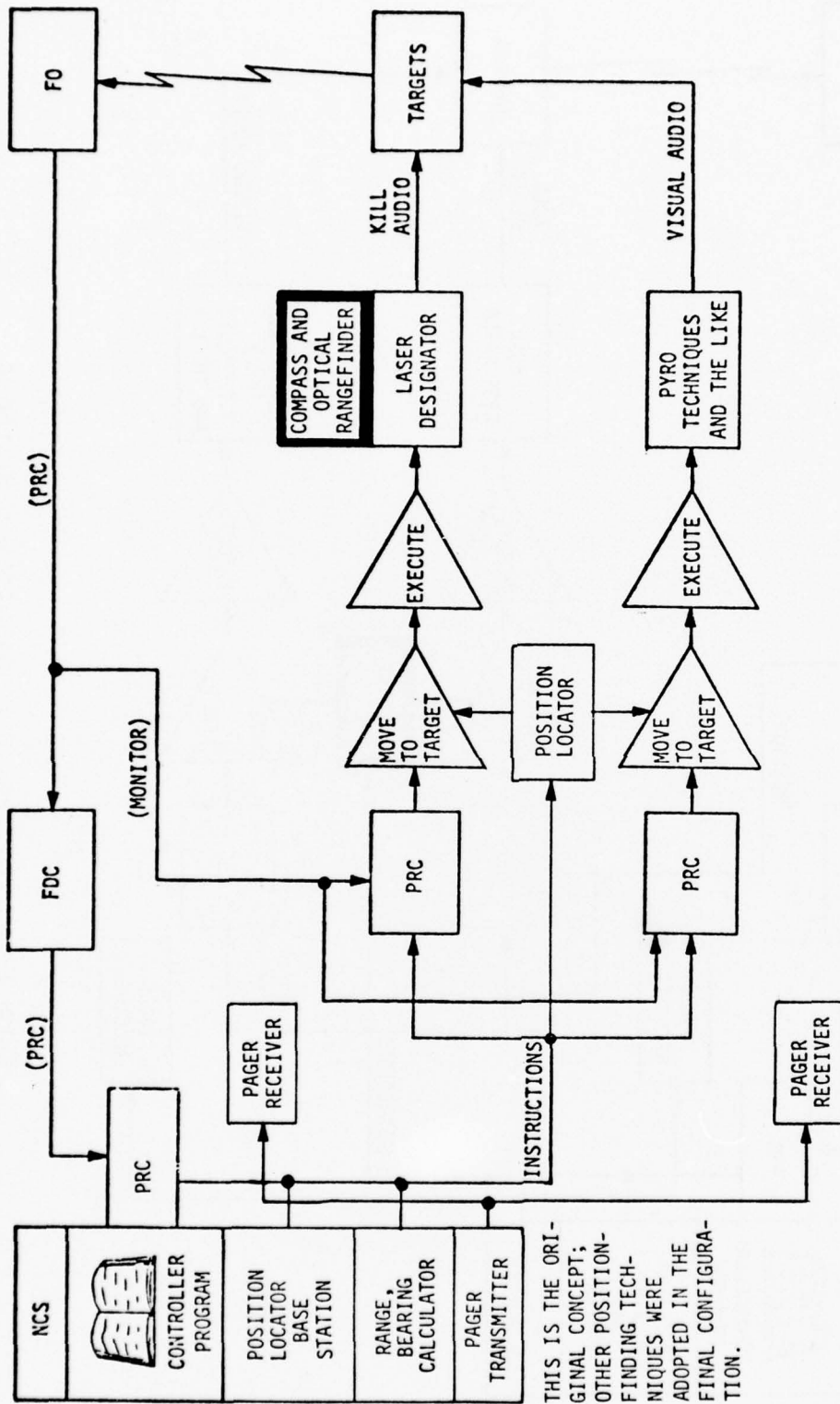


Figure 3-3. Indirect Fire Simulation System 3



THIS IS THE ORIGINAL CONCEPT; OTHER POSITION-FINDING TECHNIQUES WERE ADOPTED IN THE FINAL CONFIGURATION.

Figure 3-4. Indirect Fire Simulation Systems 4 and 4-A

System 4-A is essentially system 4 mounted in a helicopter for use in special situations. This system requires the substitution of a clinometer and a helicopter compass repeater and angle adder in place of the rangefinder/magnetic compass used for system 4.

5. Radio Frequency (RF) Multilateration System

ILS also discussed the RF multilateration scheme then still in contention. This scheme does not require the use of fielded personnel for simulation of kill effects at a designated point. The place on the ground is designated by controlling the time of transmissions of a wide-bandwidth signal from three points. The weapon code in this scheme is decodable by small RF receivers on trainee personnel and materiel only if at, or quite near, the designated point.

At the conclusion of the second SAG meeting, ILS was instructed to place emphasis on systems 4/4A. The RF multilateration scheme was kept in contention as a possible competitive scheme. ILS was also instructed to carry out a costing effort on the several schemes which could be effected and to show the logic of rejection of the more exotic and automatic approaches.

6. Study Effort Continuation

The effort outlined above has been the general nature of the study effort since mid-July 1976. The RF multilateration scheme study was completed, a fairly complete schematic/functional design analysis of the system-4 type scanning laser device was carried out and an intensive study of pyrotechnic audio/visual cues was instituted.

ILS continued to receive pertinent documents from the Government through August 1976. The latest and most pertinent document was FM 6-40-5, dated 1 July 1976, entitled, "Modern Battlefield Cannon Gunnery". This document expounds a doctrine which is a new departure from long-established cannon gunnery techniques. It is inspired by the extreme destructive potential now available to developed countries, as a result of new technology, permitting rapid and accurate enemy battery location via radar, flash and sound techniques. This new philosophy expounds the desire to use first-fire-for-effect and massed fire from several batteries when warranted, rather than slow and deliberate fire adjustment using single tubes followed by fire-for-effect. The

new philosophy also envisions very frequent removal of batteries to new positions if there is risk that their present location has been exposed by fires.

These philosophies are inspired by the capabilities of an enemy to rapidly take protective actions in response to fire adjustment and to rapidly engage in counter-battery fires of large proportions. Study of this document forced ILS to revise the requirements for the laser transmitter of system 4 to include the capability of simulating a range of very destructive single "incidents" of artillery fire which could be fairly concentrated massed fire or rather large-area coverage such as by a 6-tube volley of ICM rounds.

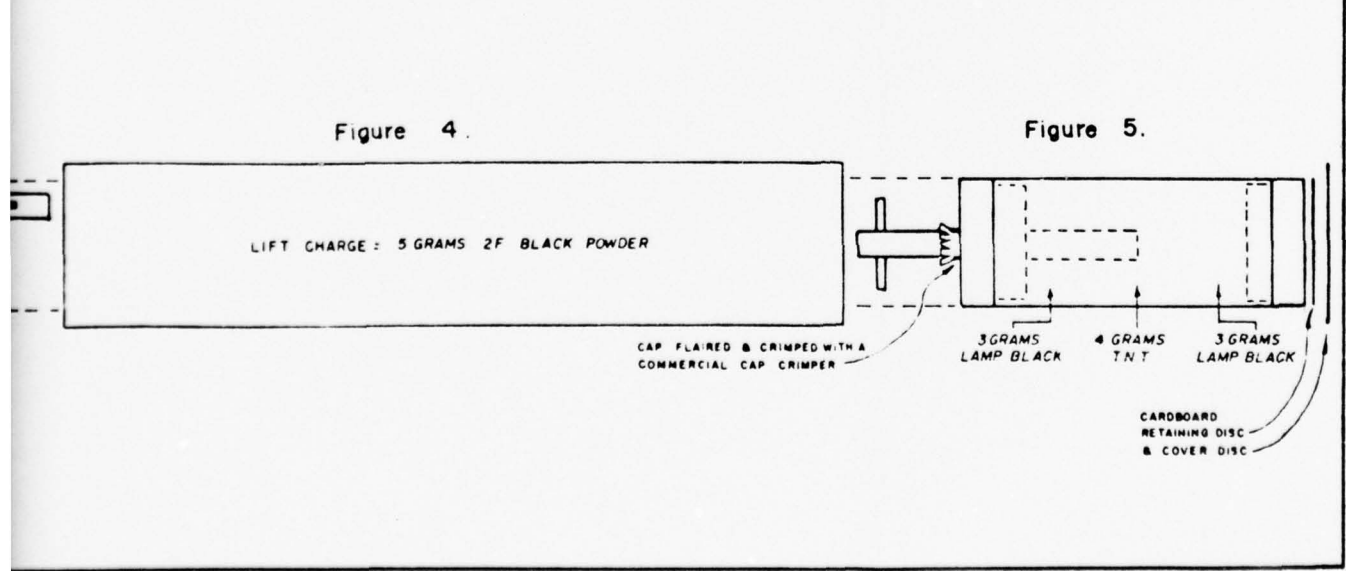
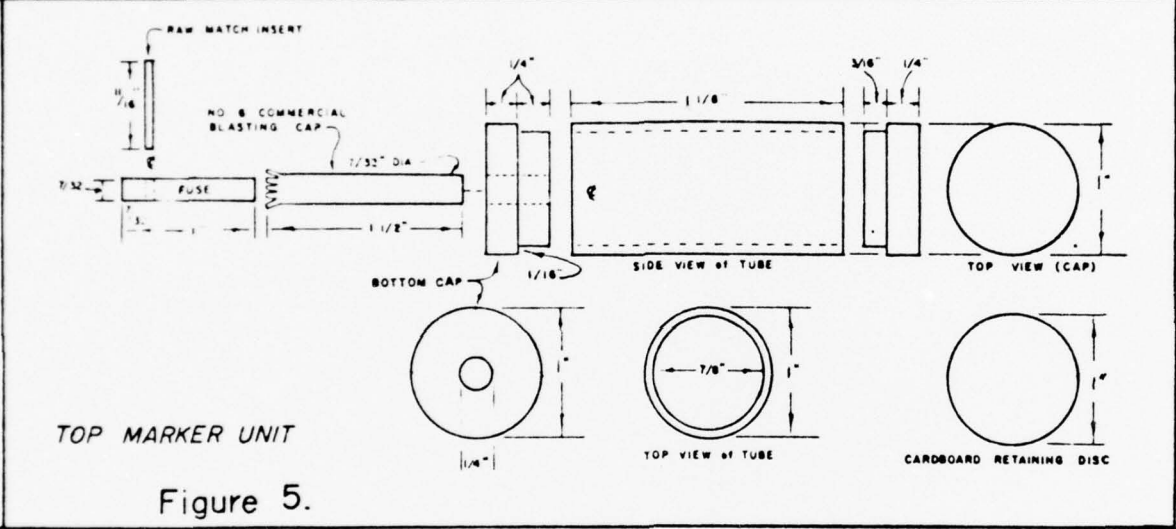
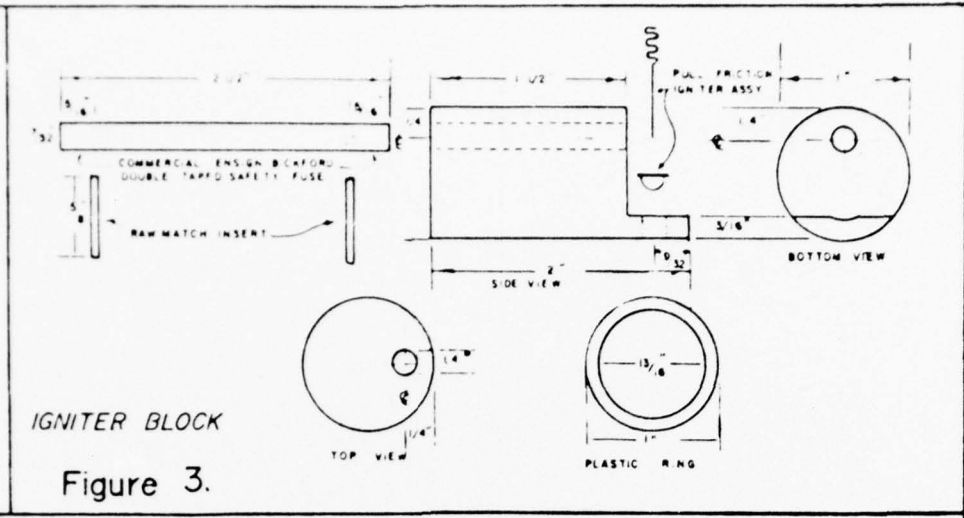
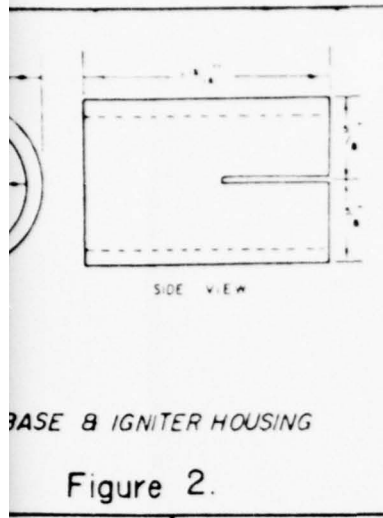
B. PYROTECHNIC VISUAL CUE TECHNIQUES

The study of pyrotechnics for visual cueing involved several steps and inputs. ILS initially consulted with commercial pyrotechnics interests, carried out in-house ballistics analyses, and the like. A prime concern is personnel safety. Any pyrotechnic "round" used for visual cueing must be safe at the point of activation, must not present a hazard to the user and must be safe if it malfunctions. The latter requirement limits the range of useable muzzle velocities severely.

The visual effect must be useful at normal FO ranges in the presence of battlefield smoke and the flash should be effective at night.

ILS evolved the scheme of a special round of poor ballistic coefficient and low muzzle velocity to be activated at a height of 60 to 75 ft above the launch height from a grenade launcher, such as the 40 mm M-79 grenade launcher. AAI, Inc. of Cockeysville, Md., who has developed a 40 mm practice round for grenade launchers and who has developed the rifle-mounted grenade launcher, was engaged on subcontract to carry out a study of the design of such a round.

In addition, Mr. E. Vickers of Orlando, Fla. proposed to have made and to fire some demonstration rounds along the lines of commercial pyrotechnics. This also was carried out (see Figure 3-5). The results were not impressive, and several safety factors were not well solved. A special 40 mm audio/visual-effects grenade seems the best approach. Specialized industries and appropriate Army agencies should carry out the remaining effort to achieve a proper solution to this problem.



P3202

C. POSITION-FINDING AND TARGET LOCATION

The vital function of position-finding was initially thought of as being solvable only by RF/electronic means (for example, PLRS, RMS/SCORE and the like - see Appendix L). It was found that these systems are exceedingly expensive, and that in some hilly terrains (as with the RF multilateration kill-effects scheme), the accuracy may be doubtful. The cost factor was the key reason for searching for another scheme.

A solution was found in the technique known as "pilotage" which merely means position-finding by reference to objects whose position is well known in the coordinate system used (UTM). A few years ago, this would have been an impractical approach and the only practical way to do the job would have been laborious and imprecise graphical map resection. The advent of small programmable (preferably "programmed") hand-held calculators of low cost has changed this problem radically. At first, it was doubted that a suitably simple way could be found of doing the task of operating a hand-held calculator for this purpose. The reasons being:

- While the mathematics involved are not particularly difficult, it is a "long" calculation if done step-by-step in the usual way of solving two triangles having a common side; and
- The practical field problem involves the observations of objects, which when viewed from different directions have different orders, left-to-right, and the sign changes involved in the trigonometric functions of angles referenced to east or north greatly complicate the problem.

A way was found, however, to program a Texas Instruments Model SR-52 calculator to carry out the calculation in a matter of nine seconds after entry of the position data of three known objects (which can be left in memory for as long as they are visible without change of left-right order) and the two relative bearings between the objects (which may change as often as needed with change of position). Programs for the SR-52 are permanently stored on magnetic cards. An ideal calculator would have three or four permanently stored special programs for field observers without need for the card storage.

This left the problem of accurately measuring the relative bearings of observed objects. Artillery commonly and properly uses an aiming circle for this purpose. The device is not suitable for hand-held use and it is not very small or highly portable. The answer was found in the optical scheme of the sextant (really an inverted sextant used in a horizontal plane). This sextant provides the needed stable image for hand-held observation and adequate precision and portability. The usual navigator's sextant is not useful for the purpose for several reasons.

- It is adapted for measuring vertical angles to the horizon, and in the horizontal position, does not have adequate vertical scope-of-field to handle observations of elevated objects in a horizontal plane;
- The out-of-focus mirror edge is somewhat confusing; and
- There is no assurance the angle is being measured in a level plane as is required for accuracy.

These problems are solved in the proposed schematic design by:

- Reversing the order of the moving and "stationary" mirrors and slitting the former which is closest to the eye;
- Providing adequate mirror height and eye position scope to see objects both elevated above and depressed below the horizon; and
- Making the optics pendulous so that the final observation of two objects in vertical alignment is made in a level plane.

The device schemed in this report is considerably larger than an optimum instrument need be.

It should be noted that the accuracy available in position determination with this scheme is entirely dependent on the accuracy of positional information of the observed objects and the precision of angle measurement, both of which can be very good. The computer and program can be considered to contribute no error at all. Calculations are internally carried out to 13 significant decimal places, including trigonometric functions, and displayed to 10 significant figures -- far more than is needed for any practical problem. The calculator program makes no errors. The only errors which can be introduced are operator errors. Note

that object coordinates can be entered before arrival at a site (6 numbers) and pre-checked by reading memories. All that is then necessary is to measure two angles (no more than 45 sec each including object identification and entry time, that is no more than 15 sec each, including check). The total time from arrival to stored location data and displayed grid-bearing of the central object can then be taken as normally about two minutes. A move to a new position would have the same requirements. This scheme is far less costly than the electronic position-finding means and accuracy is assured. Training in the use of the devices will be accomplished easily for individuals of reasonable intelligence. No mathematical competence is required or desired.

An auxiliary program, using the memory of position stored in the calculator, yields range and bearing (grid reference) of a target from observer's present position upon entry of the (radio-transmitted) target Universal Transverse Mercator (UTM) coordinates. This technique is to be used by laser operators and visual cue operators to allow placement of effects at the desired points.

D. VULNERABILITY ASSESSMENT TECHNIQUES

A troop subjected to indirect fires has a varied vulnerability to various types of weapons as noted previously. This is influenced by several factors:

- The troop's attitude, for example standing, kneeling and prone; and
- The degree of shielding by nearby objects, such as buildings, walls, tanks, armored personnel carriers, or in a foxhole, and the like.

The idea of sensing attitude and adjusting vulnerability (that is, P_k adjustment) as a result has been explored and analyzed by Georgia Institute of Technology as reported in Final Technical Report on EES/GIT Project, Ref. A-1697-000, prepared under Contract N00014-75-C-0320. This idea uses damped mercury pendulous switches to sense the troop's attitude and permit the adjustment of P_k level.

In addition, it was suggested in ILS' proposal that sensing of the electrostatic potential gradient (atmospheric) near a troop's head could afford a quantitative assessment of shielding as noted in the second group of items (degree of shielding by nearby objects) listed above. This concept was suggested and

briefly analyzed by Mr. Graham Flint during the proposal period. ILS subsequently engaged Mr. Flint's services to carry out a detailed analysis on this approach, which is presented in Appendix A. The two approaches to vulnerability assesment are both worthy of experiment.

E. LOGISTICS AND COSTS

Beginning in August 1976, ILS assigned a logistics specialist and a cost analyst to develop the logistic/cost picture for the several systems. Much of this effort is based upon conjecture because some of the system elements are not well-defined and some items are new development items which can only be roughly estimated as to cost by comparative techniques.

ILS also developed a tentative "Systems Values" comparison scheme which was summarized in the mid-term report dated 31 August 1976 (Contract Data Item 0002). This report is the basis of the cost/value analysis comparison of systems.

F. MILES SYSTEM INTEROPERABILITY

It is required that the projected Indirect Fire Simulation System be "interoperable" with the MILES system; that is, the two systems must function together without interference or confusion. It is desired that the two systems be integrated at a level which is most cost-effective and with the least burden on troops in the field consistent with cueing levels adequate for effective training. It would be ideal if the two systems were fully integrated from laser detectors to output functions. Following the second SAG meeting, it has been ILS' objective to meet or closely approach the ideal.

This ideal, fully integrated system depends upon the adoption of the "System 4" scanning coded laser approach to indirect fire simulation. However, the true ideal system cannot be achieved without additions or modifications to the MILES system troop equipment (see Appendix N). This stems from the MILES developer's desire to maintain the cost of the MILES troop equipment at a minimal level. This minimal level has been achieved at the expense of expandability. The MILES direct-fire troop equipment has been deliberately (and properly) designed to decode only two laser code-words:

- Direct-Fire Near Miss; and
- Direct-Fire Kill.

This design is achieved by using two parallel laser transmitters on the direct-fire weapons -- one with a very narrow beam transmitting the "kill" code and the other with a wider beam transmitting the "near miss" code-word. It would be possible to use only these two codes and to leave the MILES system completely unmodified with the following meanings:

- Direct-Fire Near Miss Code = Audio Cue; and
- Direct-Fire Kill Code = Indirect Fire Kill Code.

In this approach, the audio signal generated would be identical for both Indirect-Fire Audio Cueing and Direct-Fire Near Miss. This approach is considered to have poor "fidelity", leading to confusion on the part of the "cue-ees". If audio-cued, they will not know the cause and if "killed", they will not know the reason. This approach leaves something to be desired for training purposes.

A more important deficiency of this approach is engendered by the wide spectrum of lethal effects of indirect-fire weapons and the lack of ability to introduce variable troop-vulnerability (which is a function of weapon type). Troop vulnerability variation may be introduced by the attitude-sensing scheme described in the Final Technical Report on the EES/GIT Project or by the geoelectrostatic scheme outlined in Appendix A. The need for this variation, especially for training purposes, is illustrated by the difference in vulnerability standing versus prone to ICM rounds and airburst shrapnel rounds. A standing troop within the lethal radius (large) of an ICM round is quite vulnerable ($P_k \approx 0.30$). If the troop is prone or in a foxhole, his vulnerability nearly vanishes. Conversely, in the latter case his vulnerability to airburst shrapnel is increased by a factor of nearly three. Thus, it is evident that some means of varying his vulnerability is needed (which may have opposite effects for different types of rounds).

The simple, unmodified MILES system cannot provide this capability. To achieve the desired end, it has been estimated that a troop's equipment should be able to decode nine weapon-type code words and to respond with a different P_k to each, modified by his protective attitude. To achieve this condition, the amplified pulses from detectors should be fed, in parallel, to the MILES direct-fire decoder and an indirect-fire decoder/analyzer. The posture-sensing subsystem and a different audio cue should also be added. The cost of an adequate indirect-fire decoder/analyzer powered from the MILES system has been estimated near

\$50/unit in large production quantities. A separate and different audio-cue device would be about \$5/unit and the posture-sensing system (Georgia Tech.) about \$10/unit. Considering the added value, this incremental cost might be justifiable.

An alternate approach to varied P_k permits the introduction of varied troop/vehicle P_k without so severely affecting the MILES system. In this approach, the troop kill word would be transmitted into the target space, intermittently, so as to reduce the "probability of decoding" (now equal to the desired P_k). If the round also has kill effect against vehicles (for example, APCs), the vehicle-kill word would be transmitted only once on "boresight" for a single-round event, or randomly at six points in the scan pattern for a six tube volley event. The addition of posture sensing in this approach is probably undesirable because it could not be made realistic enough to have training significance.

The real problem with this approach is that it becomes difficult to accomplish when the angle-of-view of the target area reduces to a one-bar scan, which can happen in some laser-target area situations, and realism is lost. It still has the difficulty that no discrimination is available in the audio cue. The MILES system is not impacted by this approach, however.

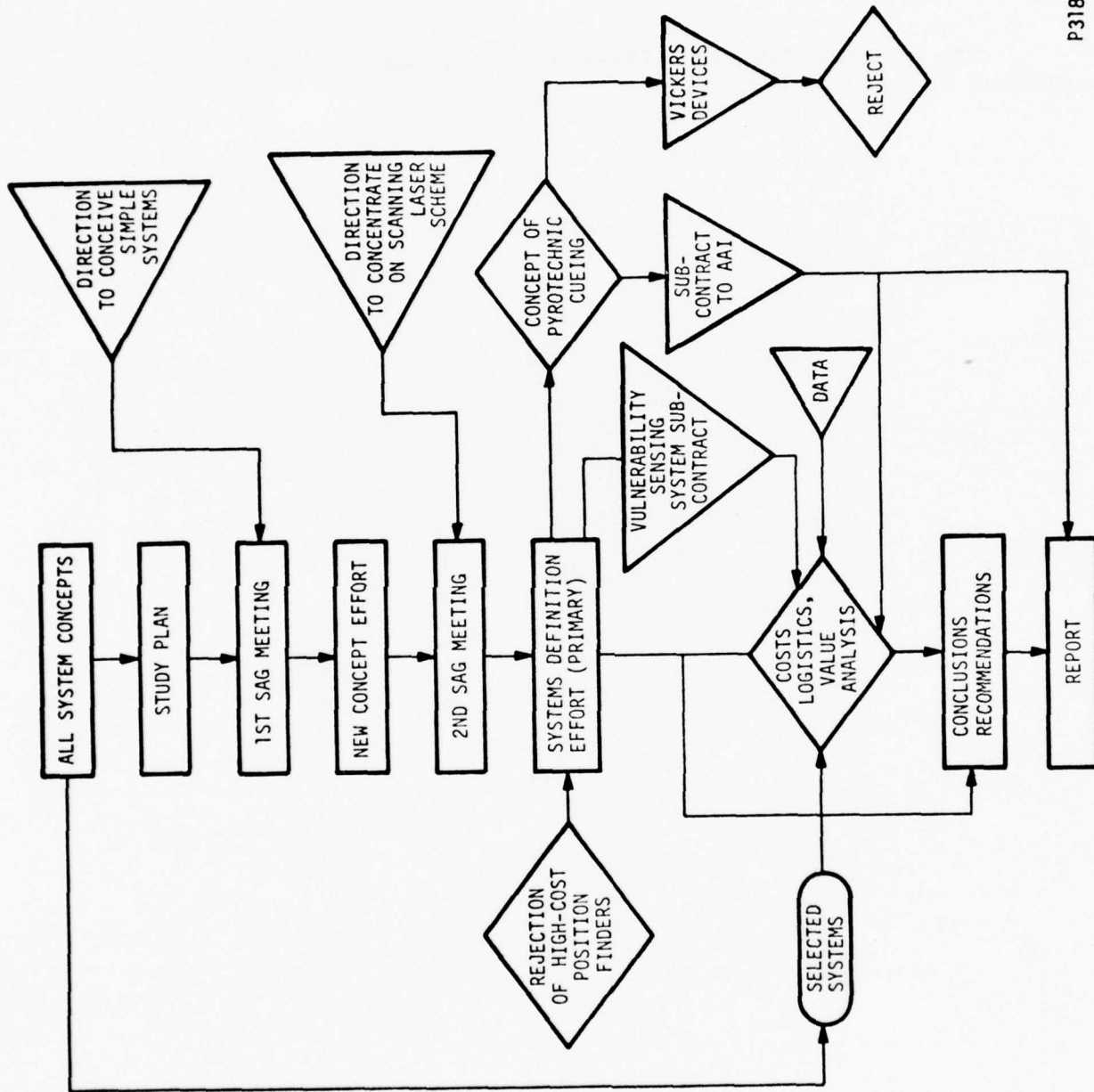
A final problem in interfacing with the MILES system is the very high irradiance threshold requirement of $40 \mu\text{W}/\text{cm}^2$ detector. This value evidently stems from the MILES developers' difficulties with the prototype system and has influenced their planning for production. This value is four times as great as a value which ILS has found quite satisfactory for solar-cell type P-N junction silicon detectors of half the area of MILES detectors.

It has been found feasible to design a laser transmitter having a sufficiently large scanning beam to fill the required solid angles at an irradiance level of $40 \mu\text{W}/\text{cm}^2$ with adequate eye safety. The required device is considerably larger and more costly than would be the case at a level of $10 \mu\text{W}/\text{cm}^2$ which, with good detector/preamplifier design, is certainly feasible. The reluctance to change system parameters at this point in MILES development is understandable. In view of the delays and costs involved it probably should not be done unless current eye-safety evaluations force it. The relatively few high powered indirect-fire simulators can be designed at the high irradiance level with

eye-safety¹ at a relatively much smaller overall system cost. These are decisions which ultimately must be made by the Government.

The general flow of effort on the study contract is represented in Figure 3-6.

¹Using large-aperture distributed-source techniques and a few "tricks".



P3188

Figure 3-6. Flow of Effort on Study Contract

Section IV

RESULTS (RECOMMENDED INDIRECT-FIRE EFFECTS SIMULATION SYSTEM)

A. GENERAL COMMENTS

The Radio-Frequency Trilateration approach to indirect-fire effects kill simulation scores very high in value, with the System 4 (scanning laser) not far behind (see Appendix B). The conceptual design and analysis of the latter is given in Appendix C and of the former in Appendix D. The RF system is very attractive from several viewpoints:

- It will function night and day in essentially all weather conditions;
- No personnel/equipment are fielded for kill-effects simulation (visual cue personnel must be fielded);
- It is not at all limited by time effects and can handle very large "traffic"; and
- The cost of acquisition, aside from development costs, is quite reasonable.

The RF system, however, suffers from several severe risk factors which militate against this choice:

- To designate target receivers in a sufficiently compact area when simulating single rounds, a very large RF bandwidth is required to discriminate propagation times with adequate precision;
- There is no assurance, in real terrain, that the signal is receivable "line-of-sight", but the signal will be received after diffraction by crests, trees at crests and directed at the earth-atmosphere interface over a path effectively longer than line-of-sight by an indeterminate amount. This will result in an indeterminate error in the location of the designated "hit-point";

- The same terrain effects will result in an indeterminate pulse-form deformation and stretching, resulting in expansion of the area in which the hit signal is decodable;
- It will be extremely difficult in any region of the world, especially in the United States, to obtain an adequately wide RF frequency clear bandwidth assignment at a usable band. Use of such a band may be simply impractical because of the already-existing assignments; and
- Development of this novel approach is accompanied by many technical risks making it necessary to approach the problem using a step-by-step experimental program of several years duration before such a system could be specified with any confidence.

Thus, despite the attractive features of the RF trilateration system scheme, ILS is forced to recommend the Scanning Laser approach to Indirect-Fire Weapon Effects Simulation. In view of the need to work simultaneously with the MILES system, the Scanning Laser seems a preferable approach. The RF system would have to be completely overlaid on MILES, while the recommended Scanning Laser system can be integrated directly with it. Within certain limitations, the laser approach is certainly feasible.

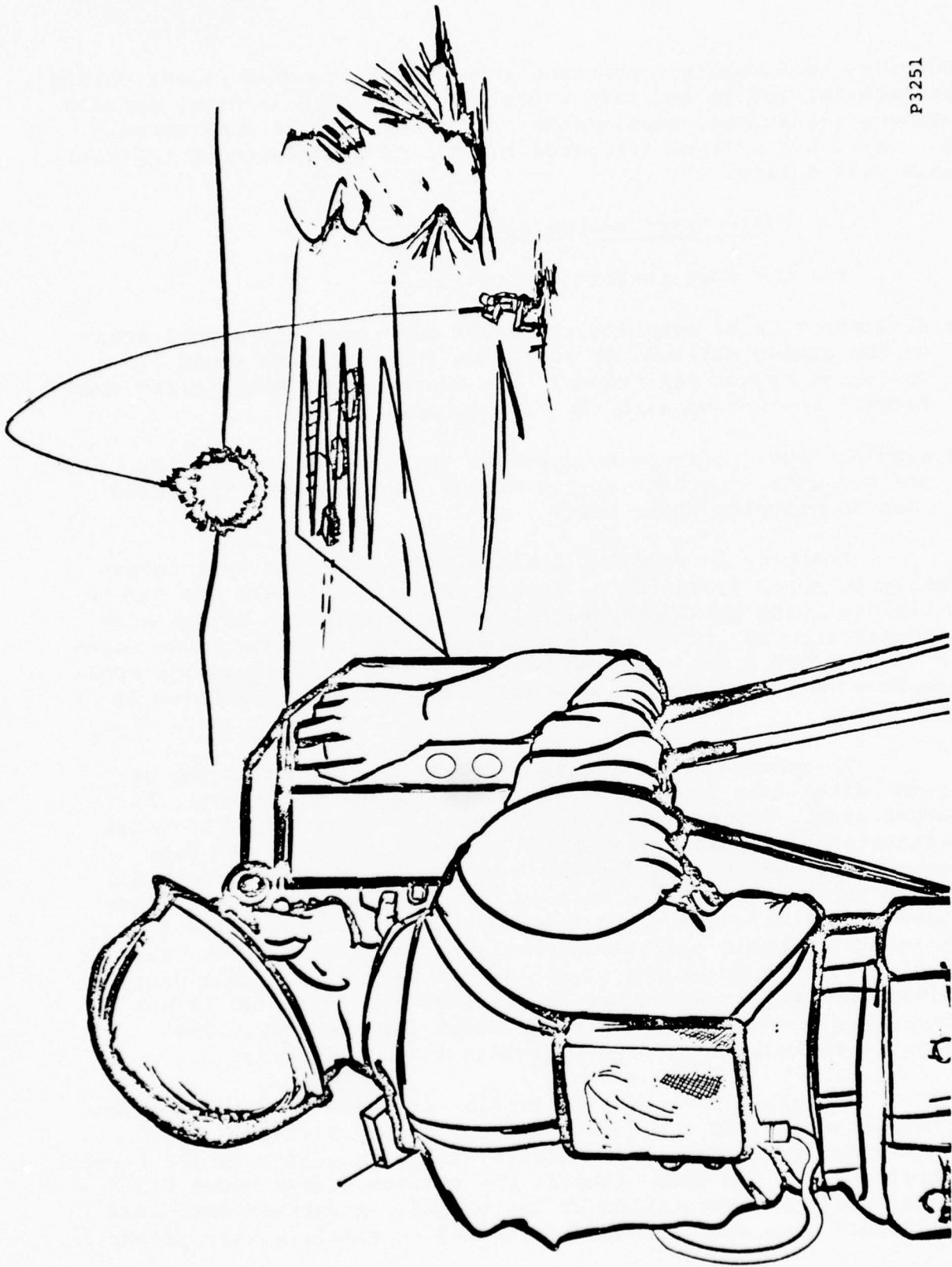
With regard to Visual Effects Simulation of indirect-fire, only one approach has been found feasible and adequately safe. This approach involves the use of a specially-developed cueing round to be launched at high quadrant elevation (QE) to form a dark smoke cloud 60 to 75 ft above the "hit" point. Personnel safety has been the prime concern in arriving at this result (refer to Appendix E and paragraph C.

Shell smoke simulation can be accomplished through use of existing techniques as discussed in Appendix F and paragraph D.

B. LASER WEAPON SIMULATOR SYSTEM (LWSS)

The LWSS can consist of only the following two components, as depicted in Figure 4-1:

- Laser Weapon Simulator (LWS); and
- MILES target system modification.



P3251

Figure 4-1. Laser Scan and Visual Cue

However, to simulate Copperhead (the cannon launched, laser guided projectile) and to simulate normal indirect fire in heavy terrain masking situations, supplements to the LWS must be considered. The basic LWS will be discussed first, and discussion of the variants will follow.

1. Basic Laser Weapon Simulator

The LWS must perform two tasks:

- Simulate kill by scanning the laser beam over the lethal area on the ground defined for the given indirect fire round or volley of rounds and transmit the weapon code (MILES pulse code format) associated with the type round; and
- Simulate audio effects by scanning the laser beam over the desired audio cue area on the ground, and transmit the pulse code identifying audio cue.

Scanning is required because the laser beam must necessarily be small (compared to lethal area) to maintain eye safety while achieving MILES detection level sensitivity. Lethal area can vary from as little as 16 m diameter for a single 81 mm round to 300 m x 200 m for a 155 mm battery volley. Audio cueing areas are necessarily larger; ± 100 m additional in each direction is suggested.

To constrain the scanned area on the ground to the defined lethal area requires that the LWS be elevated above the target area. Obviously, at zero elevation there is no in-range definition of lethal area; that is, every target in the beam between the LWS and the defined lethal area is subject to kill, as are targets beyond the defined lethal area, out to the range where signal strength drops below the MILES detection level. Therefore, a basic operational requirement is to have at least a small elevation above the target area. Seeking out good vantage points is standard procedure for forward observers and is not considered a very demanding requirement for the LWSS. The elevated vantage point also minimizes terrain masking.

Paragraph B.4. of this section discusses the recommended MILES target system modification and possible variants. The recommended modification implements kill probability at the target. Therefore, the LWS must transmit the various weapon codes for correct kill interpretation at the target. A variant discussed is to produce code word dropout at the LWS to simulate kill probability.

Figure 4-2 shows the LWS configuration and design concepts. Appendix B presents the details of this design.

a. Beam Generation

An eye-safe beam requires relatively low power output. Therefore, the simple gallium arsenide (GaAs) diode laser is the logical laser choice. However, largest possible beam divergence is necessary to achieve reasonably short scan times for the large lethal areas. This requires the highest power GaAs diode array available -- a 1 kW peak pulse power output source. A glass rod optical integrator is attached to the GaAs diode array to produce a uniform power density source having a circularly symmetric beam pattern. These characteristics are important for good beam formation, scanning and eye safety.

Because power collection improves with increasing aperture in the beam forming optics, the largest aperture consistent with reasonable configuration size is desired. A 4.0 in. aperture lens has been selected. Appendix B shows that an $f/3$ lens produces maximum beam power density. Therefore, a focal length of 12 in. has been selected.

The 0.26 in. diameter of the optical integrator in the 12 in. focal length produces 21.6 mr beam divergence; for example, 21.6 m beam diameter at 1.0 km. While a large beam diameter is desirable when scanning large lethal areas from good vantage points, smaller areas and low vantage points require a smaller beam diameter for accurate definition of lethal areas. Therefore, an adjustable iris is incorporated at the exit face of the optical integrator to reduce beam divergence to as little as 3 mr. Conversely, larger beam diameters are necessary for fast scan of the large lethal areas from good vantage points. Therefore, the GaAs diode array and optical integrator are designed to move toward the lens under manual control. This defocusing action increases beam divergence to 53 mr or more, as necessary.

The LWS electronics solve for maximum permissible beam divergence allowed by visibility or geometry (control inputs). The operator sets this optimum beam by adjusting the defocus and iris controls to extinguish an indicator in the sight. Table 4-1 gives the optimum beam divergence for specific geometries and visibilities.

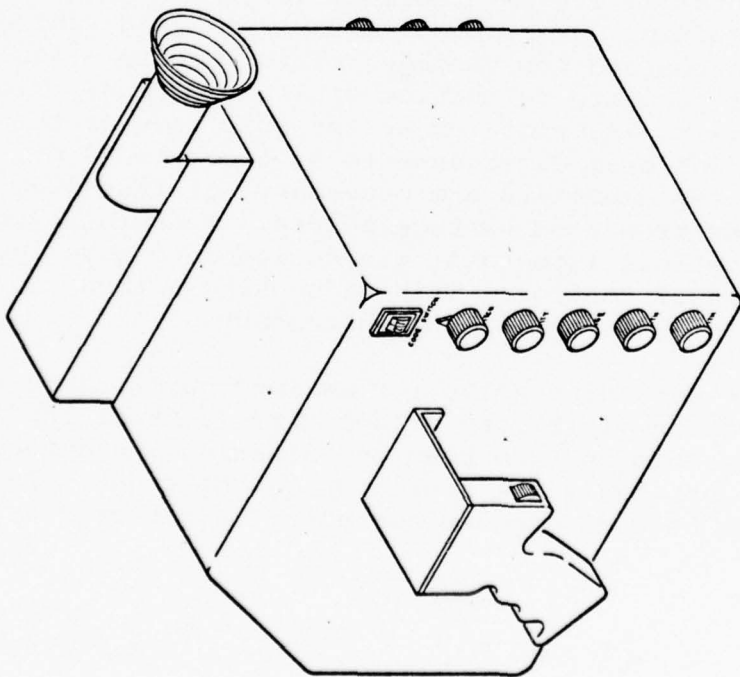
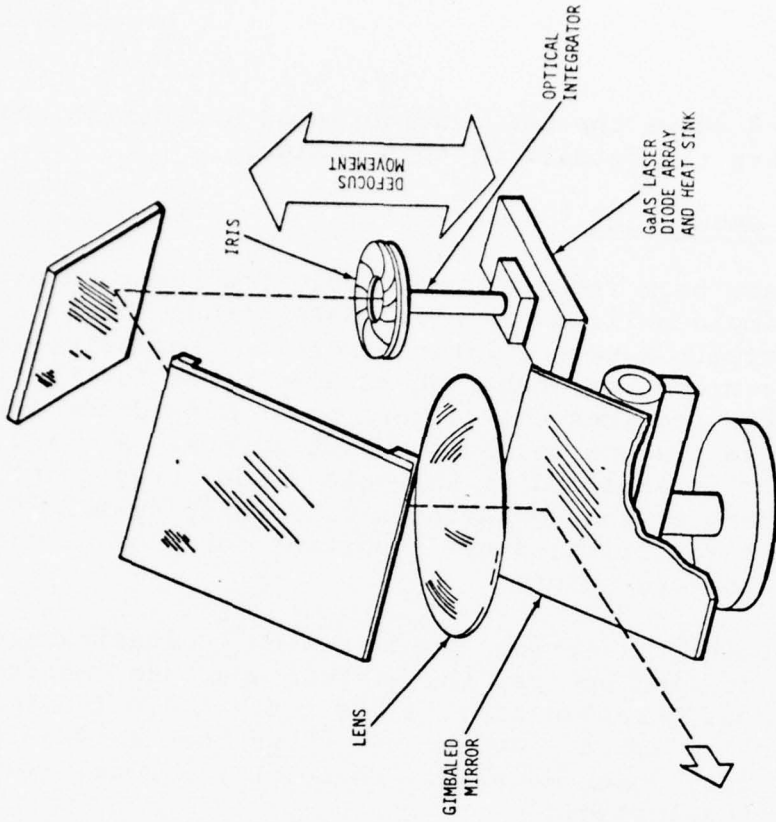


Figure 4-2. General Arrangement and Optics of LWS

Table 4-1. Scan Parameters for Given Simulation Conditions

Simulation Condition	Visibility (V _{0.25}) ~ m	Range ~ m	Depression Angle, E _D ~ rad	Beam Divergence ~ mr
81 mm Single Round 16 m Kill Diameter 116 x 116 m Cue	∞	232	0	12.2
			0.1	21.9
			0.25	51.6
	∞	1000	0	2.8
			0.1	5.1
			0.25	8.4
155 mm Battery Volley 300 x 200 m Kill 500 x 400 m Cue	232	232	0	11.3
			0.1	21.9
			0.25	51.7
	500	500	0	5.6
			0.1	10.2
			0.25	16.7
	∞	500	0	5.6
			0.1	53.2
			0.25	53.2
	∞	1000	0	2.8
			0.1	26.6
			0.25	26.6
500	500	0	5.6	
		0.1	25.2	
		0.25	25.2	

By selecting a high power GaAs source, large aperture, and optimum focal length, and by maximizing beam divergence via defocusing when permissible, the design concept has made every effort to reduce scan time to a reasonable value (typically less than 2 sec as shown in paragraph B.1.h. of this section.

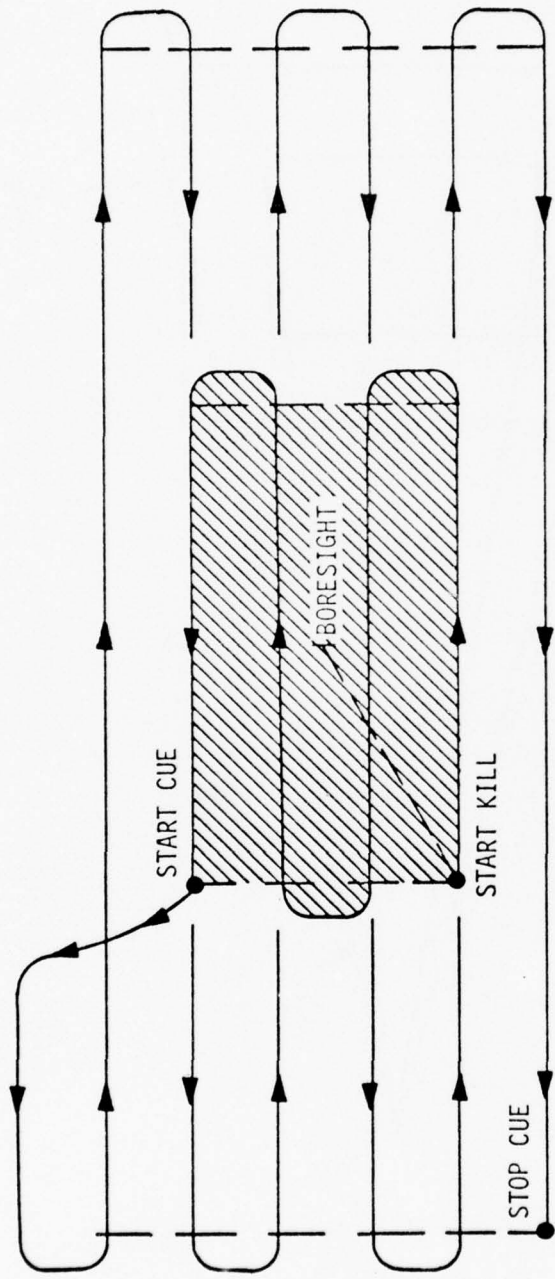
b. Beam Scanning

The beam is scanned with an azimuth/elevation gimballed mirror. Bar-scan is used as shown in Figure 4-3. The LWS electronics solves the azimuth and elevation plane geometry to fix azimuth and elevation scan limits. The electronics treats the effective scan beam as the square inscribed in the actual round beam when setting scan angle limits and performing elevation steps.

The scan pattern on the ground is set to match the width and depth of the lethal area. Figure 4-4 shows the scan footprint on the ground. To achieve a nearly square or rectangular match to the defined lethal area and cue area requires minimum standoff range equal to the cue area width.

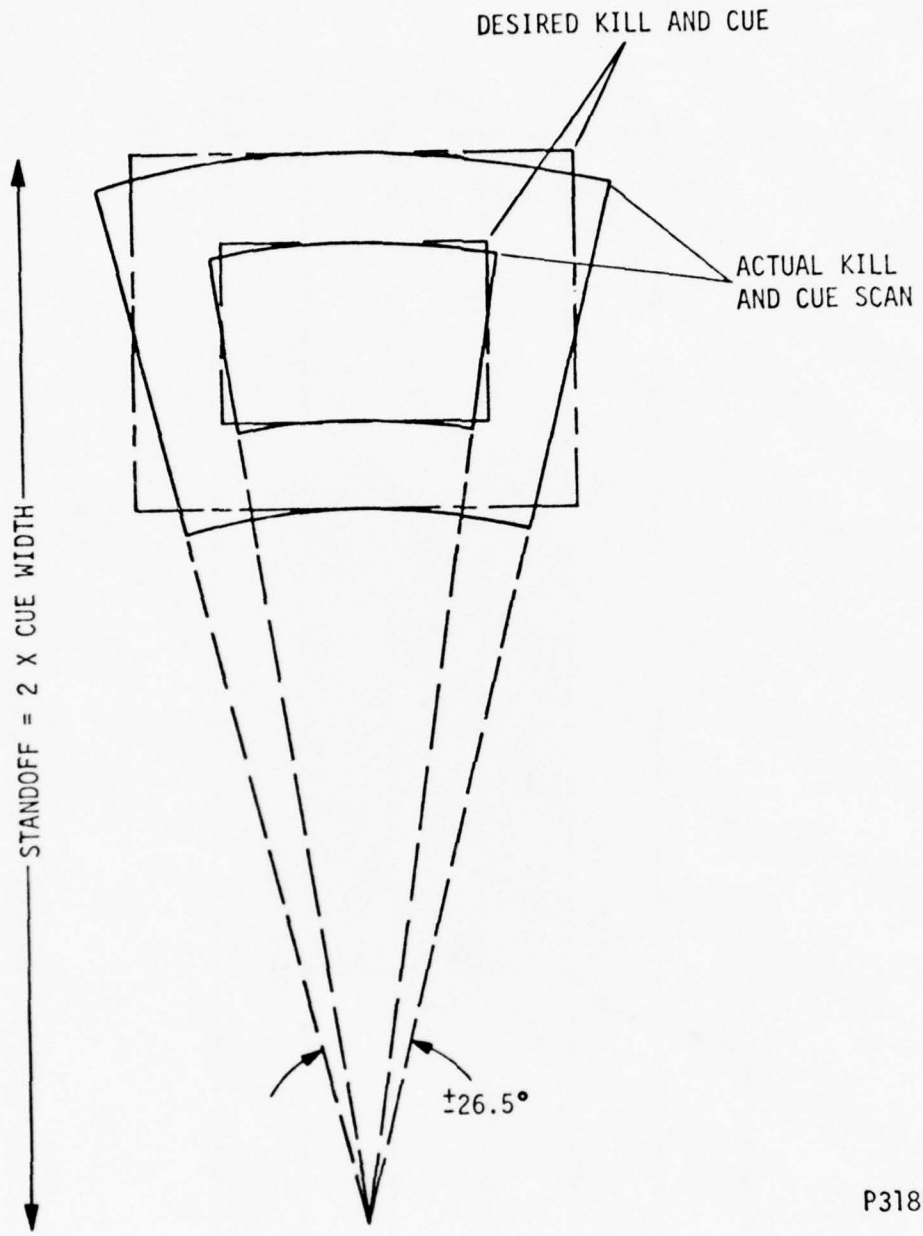
c. Electronics

Figure 4-5 shows the electronics block diagram. The heart of the electronics is the microprocessor. It is the advent of the microprocessor which has made it feasible to perform the necessary memory, computation and control functions with a relatively inexpensive handful of integrated circuits. The microprocessor functions are listed in Table 4-2. The "look-up" -- that is, memory -- function allows simple code number selection on the control panel, the actual nine bit MILES code word being retrieved from memory, and also allows automatic setting of lethal area diameter for single rounds when the code number and weapon caliber are selected on the control panel. The variability of scan geometry (lethal area dimensions, range and height above target area) requires the computation function to set the scan parameters (azimuth limits, azimuth rate, elevation limits and elevation steps) for both kill and audio cue. Also, the computation function allows optimum beam divergence setting for minimum scan time. The control function simplifies gimbal control electronics by generating real time gimbal control commands. The control function also commands the switch from kill scanning/pulsing mode to the audio cue mode and automatically terminates scanning and pulsing at the end of cue scan.



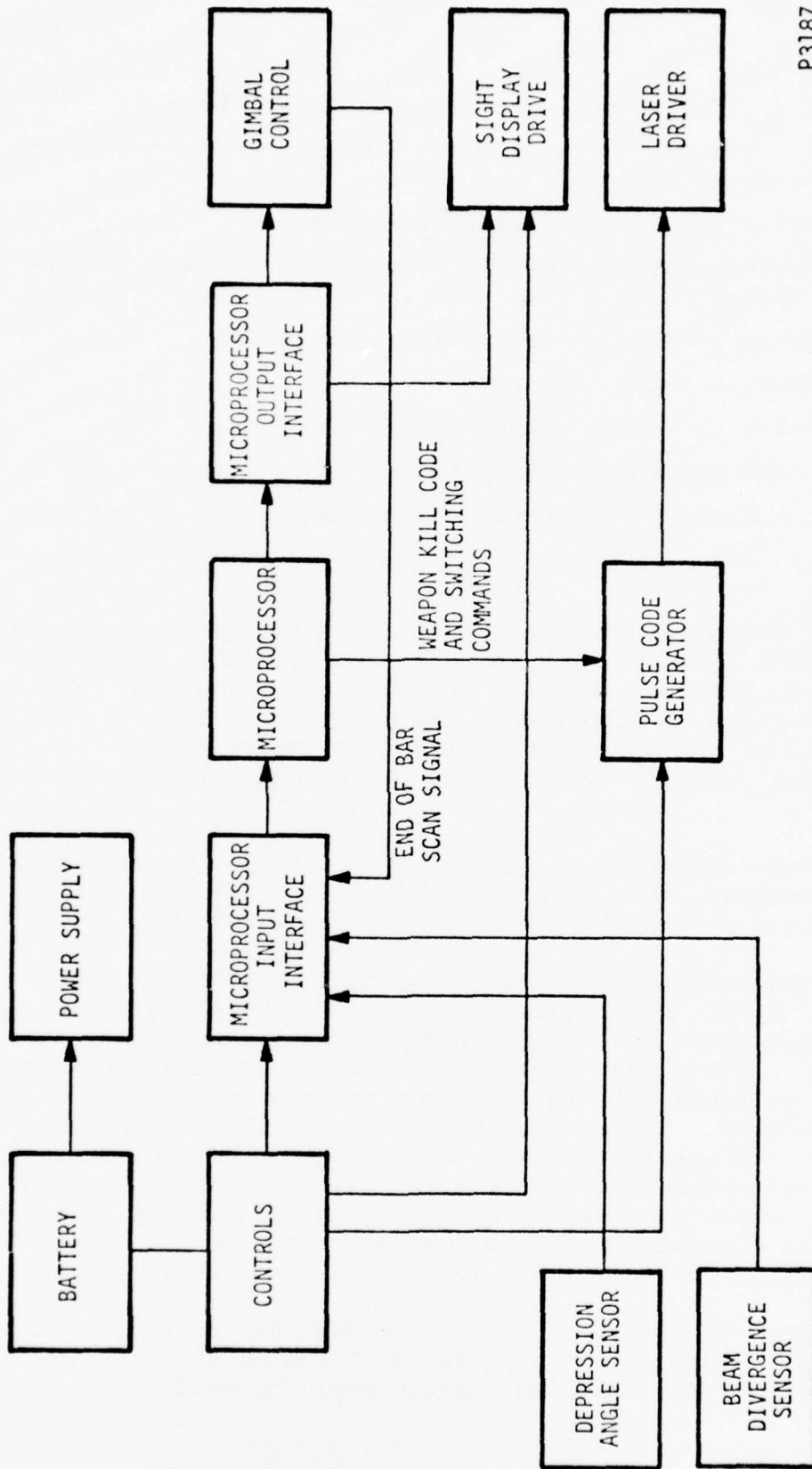
P2989

Figure 4-3. Scan Pattern



P3186

Figure 4-4. Scan Footprint



P3187

Figure 4-5. Indirect-Area Fire Simulated System Electronic Block Diagram

Table 4-2. Microprocessor Functions

-
- Look up MILES code
 - Look up single round kill dimensions
 - Compute maximum allowable beam divergence and compare to actual
 - Compute azimuth and elevation scan limits
 - Compute azimuth scan rate
 - Control elevation stepping
 - Control switch from kill to cue designation
 - Automatically terminate designation at end of cue scan
-

The beam divergence sensor shown in the block diagram (Figure 4-5) is composed simply of potentiometers coupled to the GaAs source defocus mechanism and the iris mechanism. The sensed beam divergence is compared to the maximum permissible divergence calculated in the microprocessor and the microprocessor generates a sight indicator ON command when the sensed beam divergence is too large.

The depression angle sensor is simply a damped pendulum. Depression angle sensing allows the LWS to self-determine height above target area using the range input information.

The pulse code generator loads the MILES kill code word, looked up by the microprocessor, into a circulating shift register. Pulse commands to the laser driver begin when the fire button is depressed. The pulse code generator also generates the audio cue code and switches to this pulse command mode when signaled by the microprocessor. Pulse commands cease when the cue mode signal is removed. The baseline design concept of Appendix C transmits a continuously repeating kill code word and a special constant PRF cue code, which implies modifications to the MILES targets to generate kill probability and to decode the cue word. Alternatives are discussed in paragraph B.3.c. of this section.

The sight display drive provides the motor control for the angle display described in paragraph B.1.d of this section. The microprocessor produces the display angle commands.

The electronics are powered by a battery pack and power supply. There is a choice between a 1.4 lb throw-away battery pack that attaches to the LWS or a 4.8 lb rechargeable pack separate from the LWS (to remove weight from the LWS). The throw-away pack provides a clean configuration without power cable, but the rechargeable pack saves considerable money (its \$37 cell cost provides the same service as 200 to 500 throw-away packs at a total cost of at least \$4,500 to \$11,000). The power supply furnishes high voltage (200 V) for the GaAs laser and regulation of other voltages where necessary.

d. Sight

(1) Daylight Sight

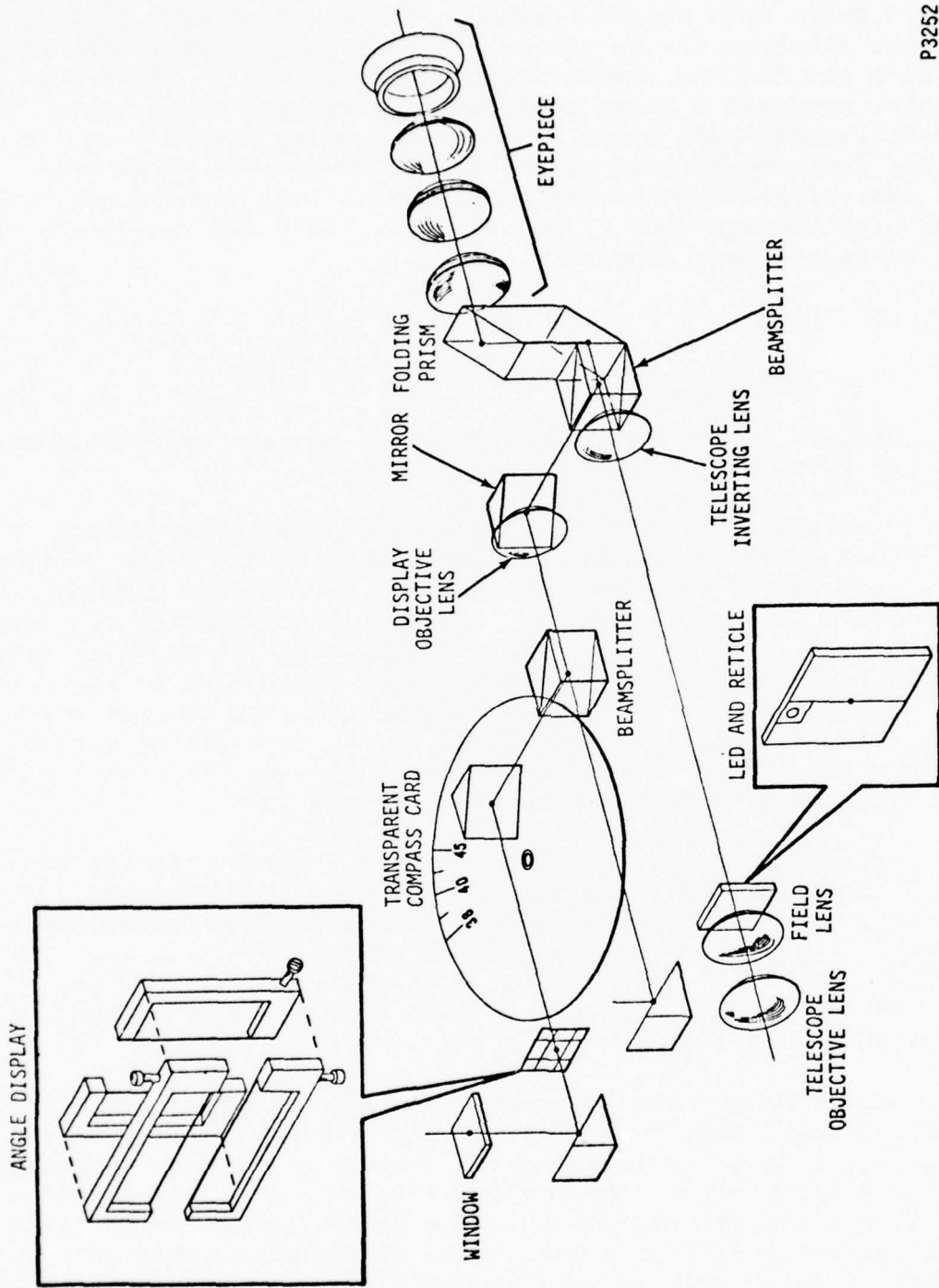
Figure 4-6 shows the sight design concept and Figure 4-7 shows the sight display seen by the operator.

The sight provides an unmagnified, relatively narrow ($\pm 6^\circ$) view of the real-world scene. Superimposed on the scene -- that is, far-focused -- are the sighting reticle, compass display, scan angle display and LED indicator. However, the displays are seen as wide angle ($\pm 30^\circ$). The operator views the sight/display with his right eye and his left eye has a wide angle view of the scene. Therefore, because both eyes are viewing the same central scene, they are "boresighted" and the total effect of sighting with both eyes open is to achieve wide angle scene viewing with superimposed wide angle displays properly centered on the scene.

Figure 4-6 shows that the sighting reticle and LED indicator are located directly in the telescope optics. The LED lights when the laser beam divergence must be reduced and pulses when lasing.

The other displays are focused at the eyepiece image plane through beamsplitting.

The compass card is transparent with black military mil gradations and floats in a clear liquid. Ambient illumination is used in daylight to achieve compass display brightness competitive with scene brightness. The compass display allows the operator to sight at the target bearing, when the target cannot be identified through grid coordinates alone, or to verify an identified target. The large display permits very accurate reading. Stadiametric range marks can be included on the sight reticle to aid range estimation.



P3252

Figure 4-6. Sight Optical Schematic

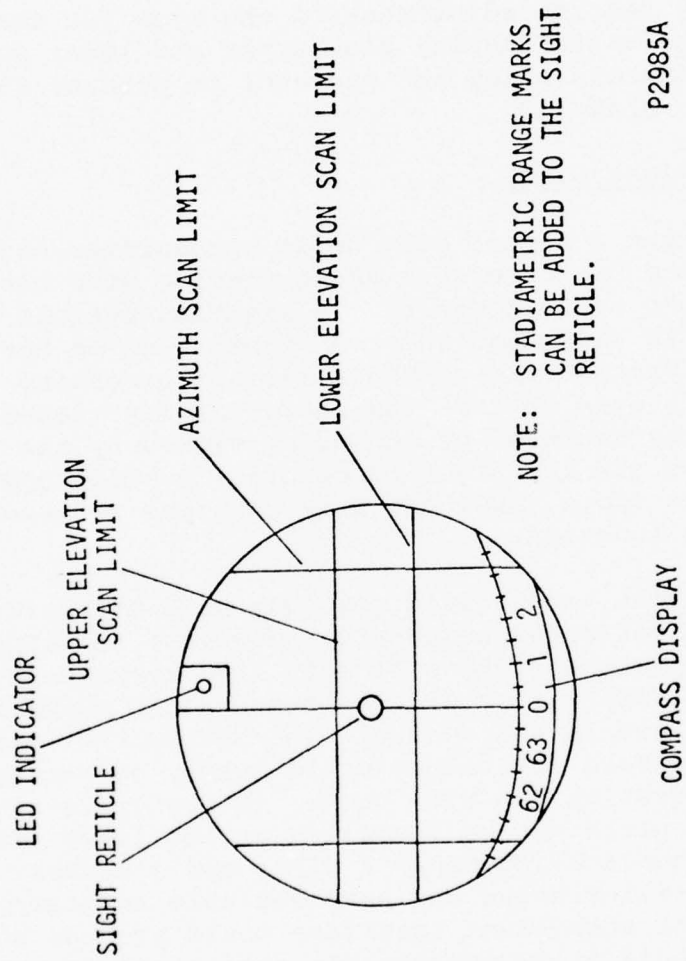


Figure 4-7. Sight Display

The angle display is produced with fine wires supported on motor driven yokes. The azimuth yokes are differentially driven by a common screw, but the elevation yokes are independently driven. The angles (yoke positions) are commanded by the microprocessor and sensed by potentiometers on the mechanism. Ambient illumination is employed in daylight. The angle display defines the lethal area to be scanned. Because the microprocessor can solve only for a flat earth target area, terrain slope or variation may require adjustment of the scan for realistic ground coverage. The angle display plus upper and lower scan angle adjustment controls allow the operator to produce the best possible ground coverage.

(2) Night Sight

At night a direct view image intensifier sight must be attached to the LWS to enable scene viewing with the left eye. The night sight must incorporate a sighting reticle identical to that in the LWS sight and the two sights must be boresighted. The two reticles provide the common reference necessary to "boresight" the operator's eyes so that the angle display viewed with the right eye is properly centered on the scene viewed by the left eye. This concept allows the LWS sight to continue providing all displays (compass, scan angle, LED) and only requires addition of the night scene viewing function.

The night sight could possibly be a standard model with reticle modification as necessary. However, the night sight is basically simple, consisting of only five components -- imaging optics, image intensifier with self-contained power supply, eyepiece, small battery and controls (on/off switch; gain adjust). Therefore, standard components could easily be packaged in a custom configuration. A wide angle, 1X design is required. The glass reticle plate can be installed at the image intensifier's image output surface (commonly a fiber optic plate). The reticle would be edge-illuminated and have variable intensity control. The night sight attachment interface would provide boresight integrity and would allow comfortable separation of the left and right eyepieces.

To permit night use, the LWS sight employs variable intensity illumination of the sighting reticle, compass card and angle display.

Expected night sight field-of-view (FOV) is $\pm 15^\circ$ with quarter-moon capability against terrain features.

e. Configuration

The LWS configuration concept of Figure 4-2 is designed for use in a "hand-held" mode or a tripod mode. Actually, the estimated 10 lb weight of the LWS is too great for good hand-held use. Therefore, a telescoping monopod is envisioned to support the weight in that mode while allowing minimum carry weight, fast set-up and very flexible aiming. In many cases, the operator will have more than adequate time to set up a tripod or even operate from a permanent tripod on a vehicle. The monopod easily detaches, allowing tripod mounting.

For hand-held operation, handles are provided with integrated controls. A headrest allows the unit to be held steadily for accurate aiming.

A good tripod will provide sturdy support and fine azimuth/elevation aiming adjustment. The controls require no modification for tripod use.

The controls on the left side are "pre-set" controls -- that is, they are set up before turning on power. The power switch is on the right side together with the beam controls (defocus and iris). The elevation adjust thumbwheels, data enter button and fire button are integrated with the handles.

Provision is made for an integral primary battery pack. The battery pack is divided into two packs, pack A providing about one hour operation and pack B providing about five hours operation. The packs are tested with pushbutton indicators and are easily replaced in the field.

The aperture size and gimbale mirror requirement constrain configuration shape and size. The gimbale mirror is located at the bottom of the unit so that the sight-integrated compass can be a maximum distance from the permanent magnets in the gimbal torquers, although magnetic shielding of the torquers will be employed. Similarly, the sight angle display drive motors are located well away from the compass, using flex drive coupling.

f. Ground Operation

Upon arriving at the point of operation the operator removes the LWS from its carrying case and extends the monopod, or he sets up the tripod and attaches the LWS. He then locates his position on his map or by the technique discussed in paragraph D. of this section.

A fire message consists of the following data:

- Target coordinates;
- Weapon code; and
- Weapon caliber (for single round) or width and depth of kill area (for volley).

The operator has the option of locating the target area visually by map inspection or of calculating target bearing and range by the technique discussed in paragraph D. of this section. If range is not calculated, the operator has the option of estimating range or reading it off the map. The range is set on the LWS, followed by weapon code selection and weapon caliber selection and/or kill width and kill depth selection (set to zero for single round).

If necessary, the current visibility is updated on the LWS, based on operator estimate or met data. However, frequent update normally will not be required.

After verifying that the iris control is set to maximum and that the thumbwheel elevation adjustments on the handles are in the center detent position, the operator is ready to switch on power (delaying power switch-on saves battery life).

The operator carefully aims the laser at the visually identified target point using the sight reticle, or he uses the compass display to aim at the target bearing and then depresses the sight line to intersect the ground at the calculated range relying on range estimation (based on training or sight reticle stadimetric marks as necessary). Pressing the data enter button enters the sensed depression angle in the LWS microprocessor and sets up all display and scan parameters.

The operator then adjusts the defocus control to extinguish the sight LED. If the LED does not extinguish, even for zero defocus, the iris control is reduced until the LED does extinguish. The beam divergence is now set at optimum value.

Again aiming at the target area (monopod mode), the operator checks the angle display in the sight to see if the ground coverage appears reasonably symmetric about the aim point and of correct extent (the in-range coverage should match the cross-range coverage for single rounds; for volleys the operator has set in-range and cross-range coverage and therefore can judge one relative to the other). If necessary the handle thumbwheels are adjusted to achieve satisfactory angle display (elevation adjust).

The operator now holds steady on the target point (monopod mode), presses the fire button, and maintains steady aim until the sight LED stops pulsing, signaling end of lasing.

Power is then switched off to save battery life.

g. Helicopter Operation

It is possible to utilize a helicopter to achieve mobility and vantage point. LWS installation in the rear compartment of a utility or scout helicopter is envisioned with the laser directed out the side door opening. The LWS could simply be suspended from bungee cord and operated in a hand-held manner. Aiming accuracy obviously would not be comparable to ground operation, but it is expected that tests will show reasonable simulation accuracy, especially for the larger kill area volley fire. Introduction of stabilization does not appear to be warranted.

For helicopter operation, target location would most probably be accomplished via map inspection whenever sufficient terrain cues are present. The operator can estimate range, or range can be calculated if the helicopter hovers approximately over a known coordinate point (calculation is discussed in paragraph D. of this section). Adequate radio navigation equipment for helicopter coordinate determination is not expected to be available. Target azimuth can also be calculated, but the LWS compass accuracy will be poor in the helicopter. Possible techniques to overcome the compass problem are:

- The pilot holds a heading 90° to the target heading. The LWS is mounted on a pantograph type support fixed in azimuth at 90° to helicopter longitudinal axis but providing elevation freedom. This is the simplest technique; and

- A pantograph support with azimuth and elevation freedom is referenced in azimuth to the helicopter's gyro/magnetic compass system. A different LWS sight should be used, replacing the magnetic compass with a compass repeater. This removes a burden from the pilot but introduces complexity.

Once the LWS is aimed at the target point all other operations are the same as for ground operation.

h. Performance

(1) Eye Safety

The LWS is eye-safe.

The GaAs diode laser array with the f/10 optical integrator produces a 0.26-in. diameter extended source of uniform power density. Blocking the central f/10 area of the beam focusing lens assures that an observer can see only the uniformly emitting area of the optical integrator, not the possible hot spots in the array.

The maximum energy density into the eye would occur if an observer could position his eye at the beam forming lens output. At that position the 0.26-in. source at the 12-in. focal length subtends 21.7 mr, which fully qualifies as an extended source according to TB MED 279 for exposures up to 8 sec (a long time for fixed viewing, a time longer than expected for simulation mission and an impossible fixed retina point exposure considering the large angle beam scanning associated with the longer lasing times). The maximum-source single-pulse radiance is 3.2×10^{-3} J/cm²/steradian (sr). This is far less than the permissible single-pulse radiance of 60×10^{-3} J/cm²/sr allowed by TB MED 279. This is also safe for exposure times up to 15 sec at the maximum pulse rate (audio cue code) of 1,000 pps, according to TB MED 279. Therefore, because exposure time will be much less than 15 sec, the LWS is eye-safe at zero range. At greater ranges, the collimated source energy continues to produce a 21.7 mr apparent source, but the energy density into the eye decreases because of the beam divergence. Therefore, the LWS is eye-safe at all ranges.

The iris in front of the optical integrator can reduce range angular size to 3 mr, but the source energy density is constant. Therefore, because the energy density at the retina is the same at all iris settings, the LWS is eye-safe for all iris settings. The LWS also remains eye-safe for the source defocus condition.

(2) Range

The LWS is designed for ranges up to 1,000 m. This is consistent with anticipated utilization and terrain masking considerations.

Figure 4-8 shows range versus visibility. The 1,000 m range can be achieved in clear to hazy visibility. Reduced visibility naturally requires reduced range, range capability being less than visible range at target ranges greater than 300 to 500 m, but greater than visible range at shorter target ranges. Figure 4-8 provides two visibility criteria -- visible range against 1.0 and 0.25 contrast objects, the latter tending to be more realistic for terrain features.

(3) Scan Time

The time to simulate kill and audio cueing equals the scan time. For the large kill and cue areas that must be considered, scan time becomes excessively large unless the LWS is carefully designed.

Figure 4-9 shows LWS scan time for the extreme conditions: (1) small kill/cue area for the smallest single round (81 mm) versus large kill/cue area for the largest volley (155 mm battery); and (2) clear visibility versus range-limited visibility ($V=R$). Maximum range (1,000 m) and minimum range (range = cue area width, for good ground pattern simulation) are considered. Scan time is a function of height above target (sensed depression angle).

For a typical ground-operation depression angle of less than 0.1 radian (6°), scan time is less than 2 sec, except for the 155 mm volley when visibility is very poor (500 m) in which case scan time becomes 4.5 sec.

If helicopter operation is considered, the minimum height above target is about 200 m for autorotation safety in hover mode. Therefore, considering the 1,000 m maximum range, depression angles are greater than 0.2 radian (12°), and scan time increases significantly for the shorter range and poorer visibility conditions in the case of the large area volley fire. This indicates that it will tend to be desirable to consider helicopter operation only in the better visibility conditions and to operate at near-maximum range.

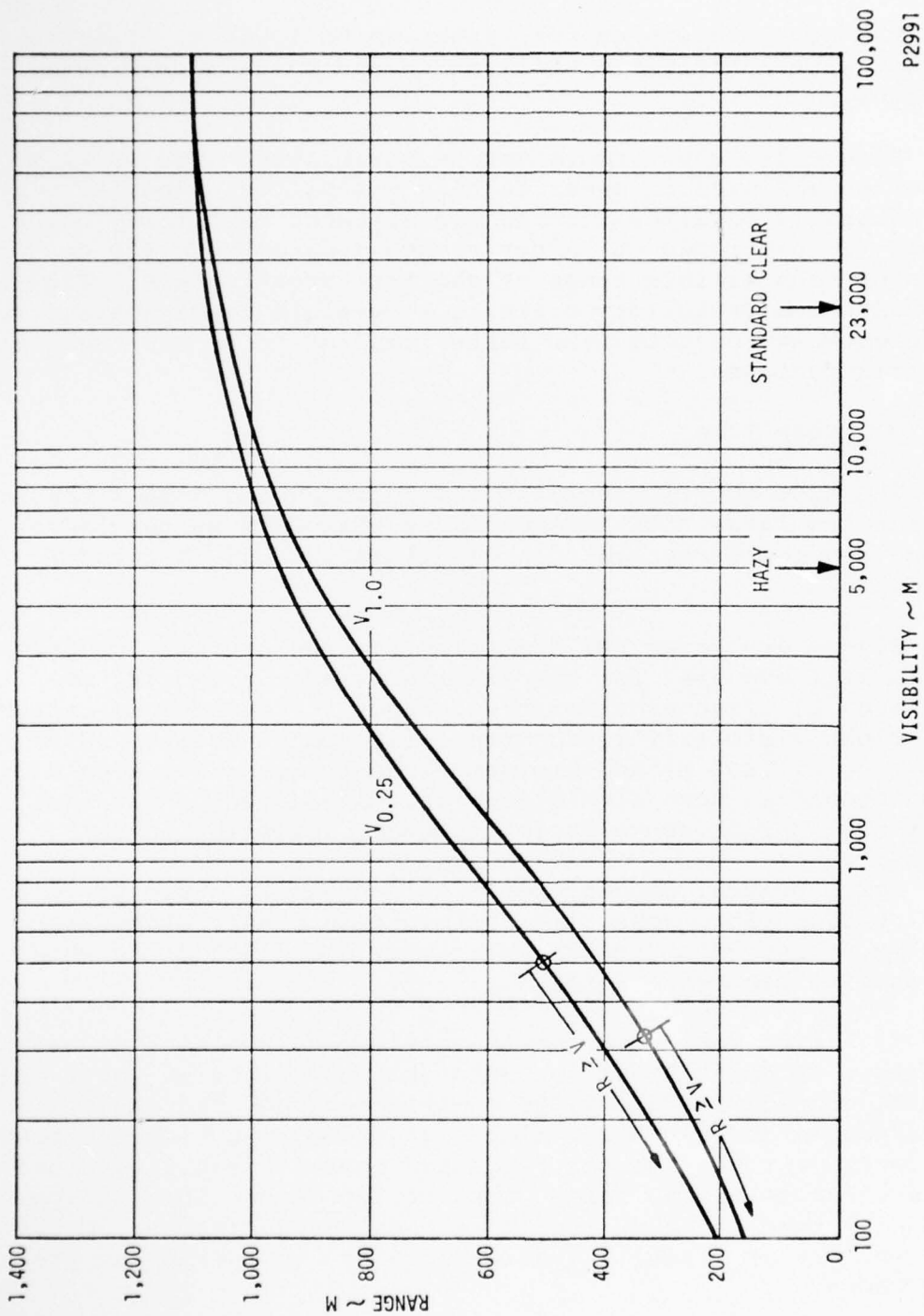
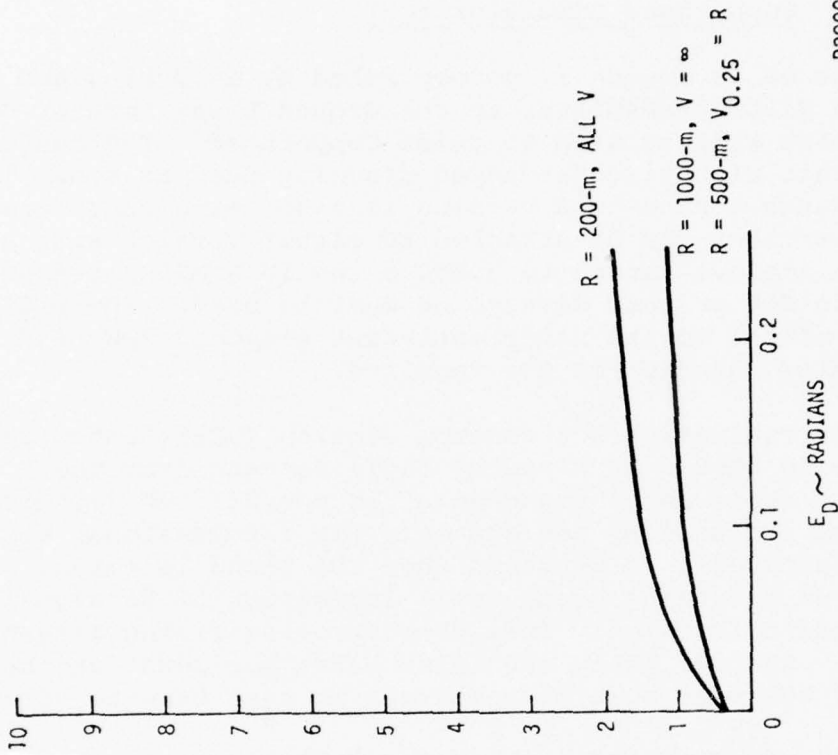


Figure 4-8. Range Performance

81-mm SINGLE ROUND



P2990

155-mm BATTERY VOLLEY

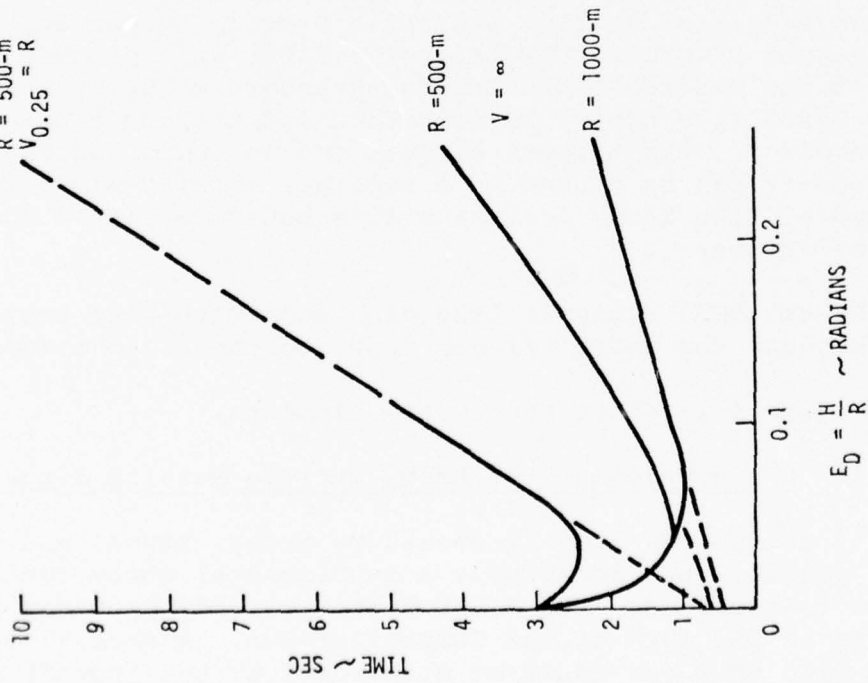


Figure 4-9. Scan Time Performance

2. Copperhead Simulator (CS)

The CS is logically accomplished by attaching and bore-sighting a MILES transmitter to the Ground Laser Locator Designator (GLLD), which will be used to guide Copperhead. The basic GLLD is a tripod unit with viscous-damped tracking head as shown in Figure 4-10, although a hand-held version is also being considered. The MILES transmitter can be attached to either version with a proper mount. To achieve ranges to 3,000 m the 10 W MILES transmitter with 1.5 to 2.0 mr beam divergence must be used. The kill code can be identical to the other anti-tank weapons (TOW, and the like). The near-miss function is not required.

For realistic, net control station (NCS)-controlled simulation the CS should be fired by radio command from the NCS. The CS operator calls for a round on given coordinates (although the coordinates are used by the NCS only for informational and fire approval purposes), is notified when the round is fired, starts tracking and maintains track until indication of RF signal receipt/laser transmit is noted. This RF-controlled firing assures no cheating -- that is, only one laser burst per round can be transmitted and the beam must be on-target at that time to effect a kill.

The standard radio which the GLLD operator uses for fire requests can be used for the RF-trigger. A tone modulated trigger signal can be picked up from the radio's audio output and fed to the CS trigger circuit. The trigger circuit will produce a burst command of the desired length to the standard MILES trigger input when the MILES fire button is depressed and the audio trigger signal is received. The trigger circuit and an audio indication of laser transmit can be housed in a separate module, along with the power supply. The laser designate fire button would be added to each installation.

At the NCS, a simple tone generator with fire button is used to produce the audio trigger input to the radio transmitter.

Figure 4-11 shows the system elements.

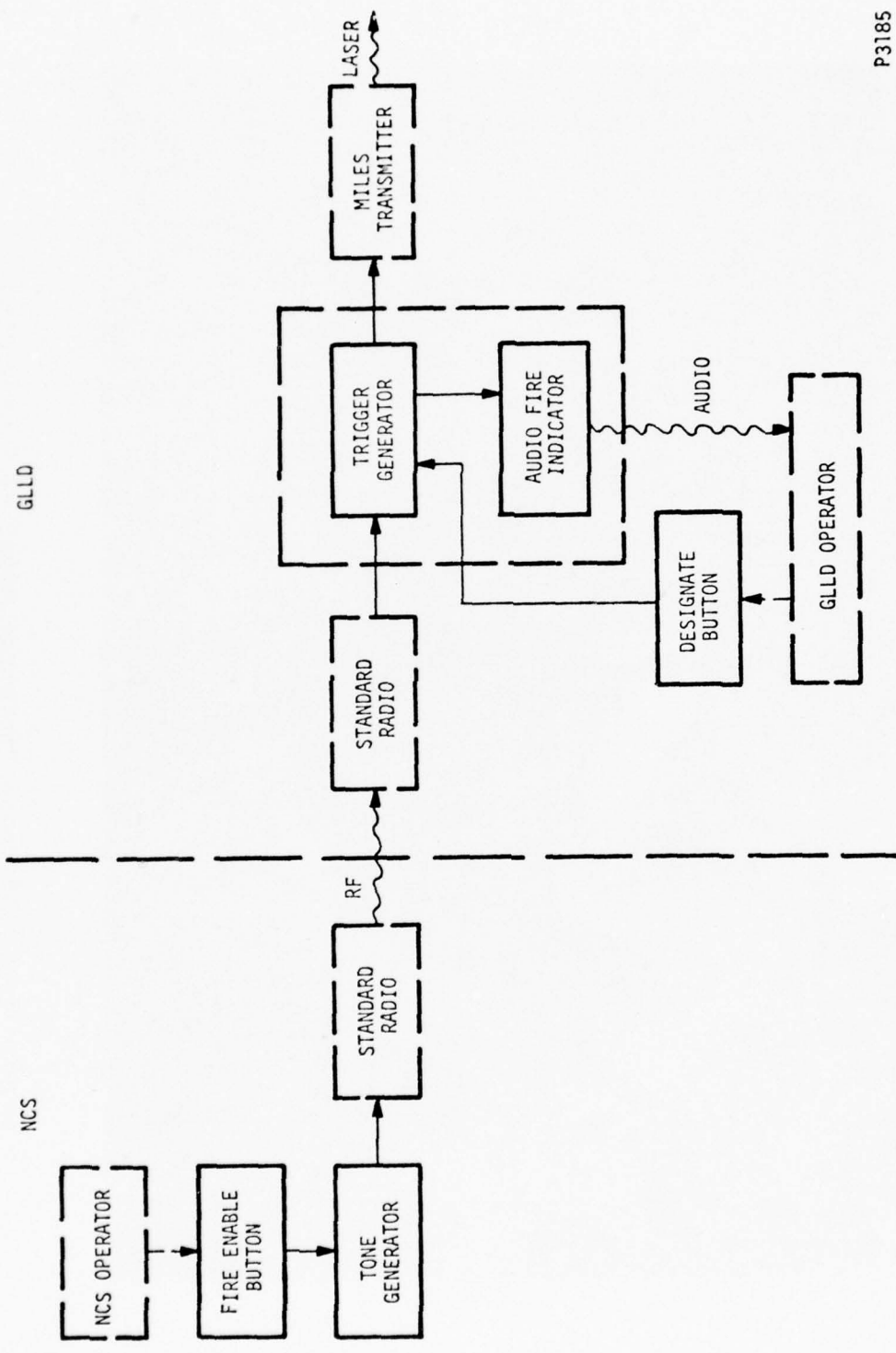
3. LWS Supplement For Heavy Terrain Masking Situations

If troops are heavily masked by trees, brush, and the like, from all possible LWS locations, a supplemental short range kill mechanism is required. The MILES system already provides this capability in the form of the Controller Gun. A special operator equipped with this Gun could be dispatched to the trouble spot. However, considering the desirability of visual cueing, plus the



F429

Figure 4-10. Advanced Prototype Model of Hughes GLLD,
Ground Laser Locator Designator



P3185

Figure 4-11. Copperhead Simulation

fact that audio cueing in this situation relies primarily on the bang associated with the visual cue round, an implementation similar to Appendix G (see Figure 4-12) is logical -- that is, kill is implemented by the visual cue operator using a MILES transmitter on the cue-deployment grenade launcher.

4. MILES Target System Modification

a. Recommended Modification to MILES Man-Worn System

The recommended LWSS adds a small module to the MILES man-worn system as indicated in Figure 4-1. The new module performs the following functions:

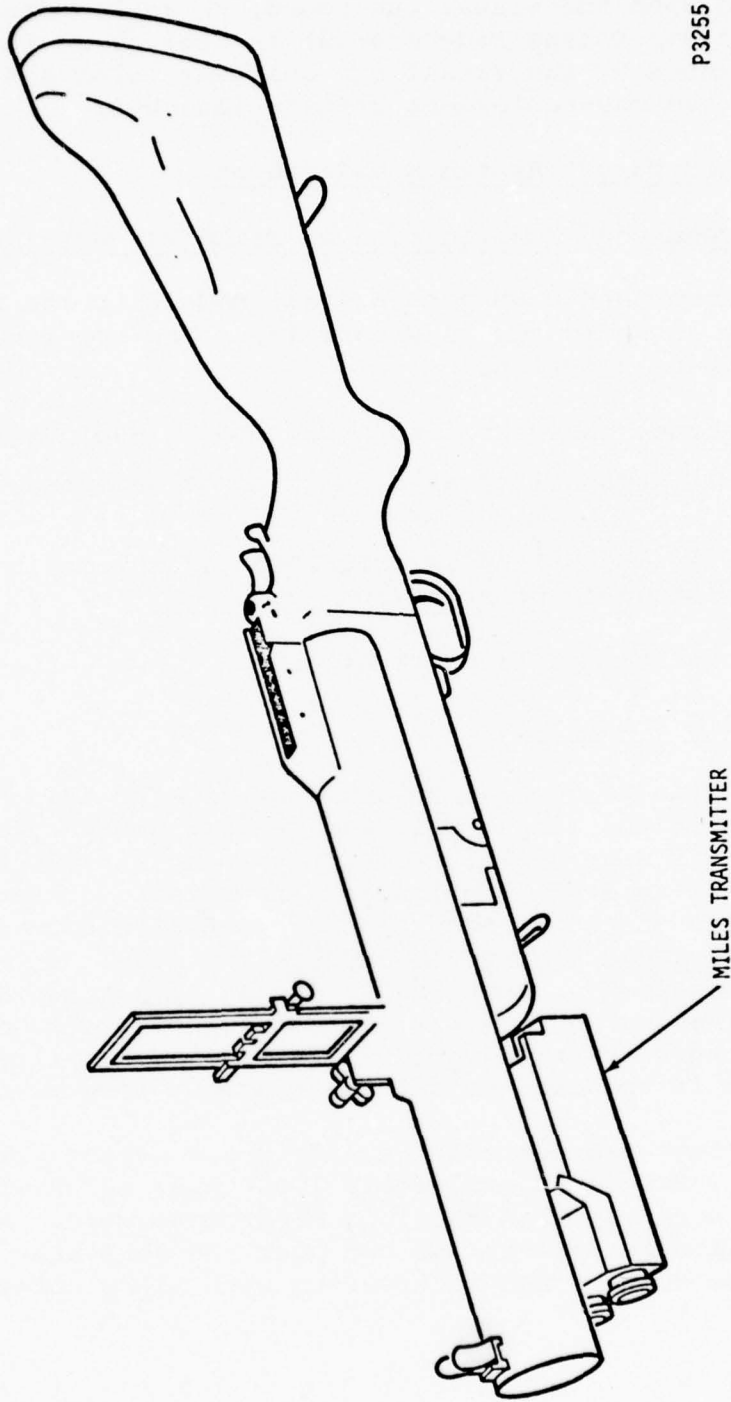
- Provides a unique, indirect fire, "near-miss" audio simulation;
- Implements kill probability as a function of detected weapon code; and
- Implements kill probability as a function of the man's attitude (for example, standing or prone).

Figure 4-13 shows the module block diagram.

(1) Audio Simulation

The best audio simulation would be a loud "bang" or "crash" to startle the man as well as to alert him that a round has dropped in his near vicinity. A compressed air bottle could repeatedly charge up a small cylinder with a rapid actuating solenoid valve in one end. Actuation of the valve upon detection of the laser cue-coded beam would produce the bang. An alternative is a Mallory "Sonalert", electrically driven by a noise generator to produce a crashing sound (that is, not as sharp a round as a bang, but of longer duration to better simulate a shell explosion). Experimentation is required to produce the most effective sound.

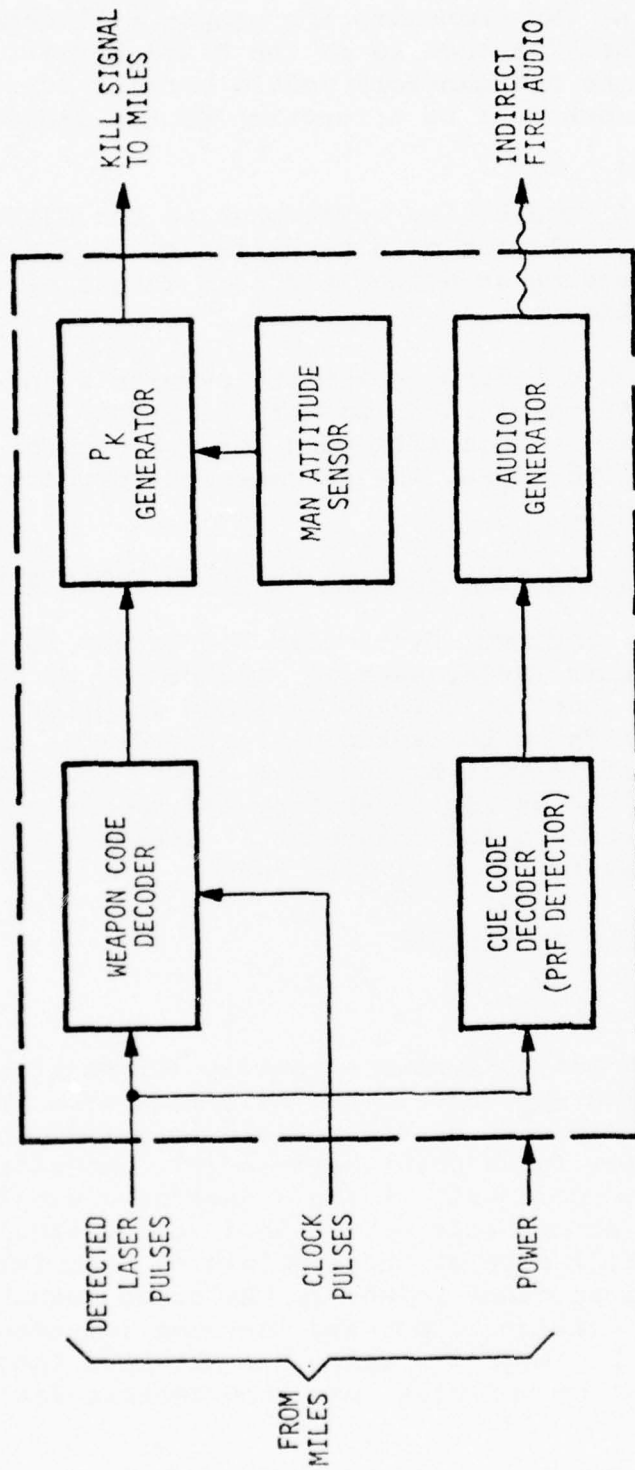
The recommended cue code is simply a constant pulse repetition frequency (PRF) of approximately 1,000 pps, which allows faster LWS cue scanning than the long MILES code word. A simple decoder in the module detects the cue code and activates the audio device. The cue code is non-interfering with MILES codes.



P3255

MILES TRANSMITTER

Figure 4-12. Grenade Launcher M79 with Laser Point Kill Designator (LPICD)



P3184

Figure 4-13. Recommended Module Addition to MILES Man-Worn System

(2) Kill Probability Implementation

The baseline LWS transmits the weapon kill code in a continuous stream. The kill code is in the MILES format. Decoding the nine codes in the new man-worn module permits correct kill probability (P_k) assessment as a function of the indirect fire type.

Adding kill probability assessment to the MILES man-worn system also allows inclusion of a pendulous sensor to sense the man's attitude (standing or prone) and as a result allows appropriate P_k modification.

The expanded decoding capability permits a one-word kill code. Present MILES requires a two-word kill code -- that is, one man-kill word and one weapon kill word for vehicles or other material targets. Therefore, the recommended approach also permits faster kill scan.

b. Recommended Modification to MILES Vehicle Systems

The unique, indirect fire audio simulation is also added to the vehicle systems (APCs, tanks). Assessment of P_k , as a function of weapon code, is already included in MILES, but the number of levels needs to be extended to produce the low P_k associated with vehicle kill by indirect fire. The simplest approach is to use the entire capability of the man-module (with disabled attitude sensor, and changed P_k), incorporating it in the MILES vehicle system in a similar manner.

c. Alternative Concepts

(1) Vehicle System

In the recommended system a vehicle (or other hard material target) can be killed anywhere in the kill scan area (troop lethal area), P_k being interpreted at the vehicle to permit the realistic low average kill rate for a point hard target. An alternative is to transmit a unique code only at the center of a single round simulation scan or at discrete points in a volley simulation scan to effect vehicle kill only at those points -- that is, a vehicle could not be killed at other points in the troop lethal scan area. This could be more realistic, but the in-range component of laser beam footprint can be large for small height above target, resulting in possible kill of vehicles away from centerpoint and even

resulting in multiple kills within a footprint. If all rounds capable of vehicle kill are interpreted as having the same P_k against a given vehicle, one unique code word suffices. Otherwise, additional codes are required.

(2) Man System

In the recommended system, man- P_k is interpreted at the target. The alternative is to implement man- P_k as a man-kill word drop out rate at the LWS, for example, for $P_k = 0.3$, only 30% of the possible words would be transmitted, but detection of a word would result in certain kill. The advantage of this technique would be the elimination of kill word/ P_k decoding at the man-target. If the attitude- P_k modification (attitude sensor) and unique indirect fire audio cue were also eliminated, no modification to MILES would be required. Therefore, considering the planned purchase of 33,000 man-worn systems, a considerable cost savings would result. However, performance would be degraded as follows:

- Every man within an instantaneous LWS beam footprint, who is not masked from the LWS, will be killed. Therefore, an entire squad or more could be killed by one round. The recommended system produces truly random-kill in any area.
- No P_k allowance is made for a man's vulnerability cross-section when prone (against surface bursts) or standing (against air bursts).
- There is no indirect fire audio simulation because an indirect fire "big bang" miss would sound just like a rifle bullet near miss.
- Scan time is much larger if the indirect fire code must be transmitted along with the man-kill code (that is, if the point "vehicle" kill code generation concept, along with its possible poor area definition, is not adopted). Scan time is also increased because of the longer MILES near-miss audio cue word.

C. VISUAL CUEING

The visual cue must simulate the visible and aural effects of fictitious field artillery (F/A) and mortar rounds in a manner useful both as warning to personnel under fire as well as spotting for FOs. The following factors have been considered in the selection:

- The fidelity with which the cue duplicates the impact position and physical characteristics of the simulated rounds;
- The manner in which the device is to be used in the exercise and the extent to which it is compatible with the appropriate system concept;
- Safety of cued personnel and operators; and
- The degree of development required, particularly with respect to costly state-of-the-art techniques.

Although the use of special rounds, fired from the F/A and mortar batteries themselves appeared attractive, they were rejected from safety and cost/development standpoints. Ground emplaced visual cue projectors, capable of accurately placing a visual cue round to ranges of from 0.20 to 1.0 km, also exhibited considerable merit. Unfortunately, the small ballistic coefficients required of the round to ensure a low probability of personnel injuries from unexploded duds (that is, low velocity at ground impact) demands prohibitively high muzzle velocities. This miniature mortar would also be cumbersome to carry, require extensive set-up time in "laying", and variable charge propellant for fixed time fuzes to obtain a given height of burst (HOB).

At the other extreme are the site projectors, where the device is emplaced and detonated at the site. Although this approach employs readily obtainable units, it suffers from lack of coyness and may force the visual cuer (VACO) to surmount physical obstacles to get into the proper position, thereby reducing his effectiveness and flexibility in his capacity in cueing several separated rounds that impact almost simultaneously.

The best compromise, considering fidelity, utilization, safety and development, is to employ special rounds launched from M79 series grenade launchers, with maximum ranges between 150 and 700 ft. Although air burst simulators (M27A1B1), capable of launch

from grenade launchers exist in the inventory, they are not completely satisfactory for this application, principally from the safety and fidelity aspects. The very bright flash is objectionable from the viewpoint of preservation of night vision.

One new design concept is shown in Appendix E, as submitted under contract, from AAI, Inc. This system uses a small, safe round launched from the M70 grenade launcher, and is capable of about a 150-ft range.

D. SHELL SMOKE

Smoke generated from artillery and mortar rounds is an important element in the conduct and ultimate success of an infantry engagement. Therefore, it is vital that at least the first order effects of smoke be included if a good simulation/training exercise is to be effected. Clearly, use of the actual rounds to deliver smoke cannot be seriously considered because of the danger, both from the falling rounds and the toxic and incendiary results of exploding white phosphorous rounds. Furthermore, the field artillery batteries may not actually be present in the exercise. Thus, other methods of generating smoke with simulated delivery techniques has been addressed.

The concept of air dropping of smoke rounds and canisters is attractive, particularly when done from helicopters, which may be part of the exercise. Unfortunately, the risk to exposed personnel under the aircraft flight path is deemed unacceptably high. The use of smoke laying helicopters offers the capability of producing extensive and rapid smoke build-up over large areas.

The availability of this type of equipment is low and its use is not recommended for general application, but only as an adjunct when it can be made available.

ILS recommends use of special "smoke teams" who, under control of system central, will deploy M1 hexachloroethane-zinc oxide-aluminum (HC) smoke pots and where possible, trailer-borne smoke generators towed by jeep over the required area. System central will direct smoke team members as to the alignment and spacing of pots and the timing of smoke generation will be coordinated between the LWS, VACO and the smoker teams.

All of the communication and position-finding modes of the laser and visual cuers can be used by the ground teams.

E. LOGISTIC SUPPORT REQUIREMENTS

1. Introduction

The following paragraphs provide a tabular summary of the logistic support requirements for the considered system approaches to the simulation of indirect fire. Information contained herein is based on anticipated support requirements resulting from preliminary maintainability and reliability studies and/or proposed operational employment of each system.

The maintenance concept and maintainability and reliability factors for each considered system are also included to provide a comprehensive grouping of related data.

2. Reliability Predictions

The reliability predictions for the considered systems were arrived at by application of MIL-HDBK-217B, Martin-Marietta Corp. Report OR 6908, Intel Report RR-ID and RADC Report AD/A-002-152 where applicable or engineering judgement/similar system comparison where no failure data was available. Although the data derived should be considered preliminary at best, it is felt that the relative values arrived at are valid.

Reliability for some Government furnished equipment (GFE) equipment was not available, but because the item was employed in all systems considered, there should be no impact on the relative values.

3. Maintainability Prediction (MTTR)

The maintainability prediction for each system considered was arrived at by utilizing the following equation from MIL-HDBK-472:

$$M_{CT} = \frac{\Sigma \lambda M_C}{\Sigma \lambda}$$

where $\Sigma \lambda M_C$ is the organizational level maintenance actions in minutes and $\Sigma \lambda$ is the total failure rate of all end items in the system.

Maintenance task times (in minutes) are shown in paragraphs E.5, E.6, E.7 and E.8 of this section. As indicated for the reliability prediction, these time estimates are considered preliminary at best, but similar judgements were applied to all systems, consistent with the anticipated maintenance concept.

4. Summary - Maintainability/Reliability Factor

Laser Weapon Simulator System:

$$\frac{\Sigma \lambda M_C}{\Sigma \lambda} = \frac{5585.898}{2055.569} = 2.72 \text{ minutes (MTTR)} \quad 486 \text{ hr MTBF}$$

Point-Kill Laser System:

$$\frac{\Sigma \lambda M_C}{\Sigma \lambda} = \frac{1661.24}{971.134} = 1.71 \text{ minutes (MTTR)} \quad 1029 \text{ hr MTBF}$$

Sonic Overpressure Device System:

$$\frac{\Sigma \lambda M_C}{\Sigma \lambda} = \frac{2674.625}{1705.49} = 1.57 \text{ minutes (MTTR)} \quad 581 \text{ hr MTBF}$$

Tri-lateration Ground Designation System:

$$\frac{\Sigma \lambda M_C}{\Sigma \lambda} = \frac{69603.272}{4837.925} = 14.38 \text{ minutes (MTTR)} \quad 206 \text{ hr MTBF}$$

5. Laser Weapon Simulator System Maintenance Concept

The general maintenance philosophy is repair where possible at the organizational level by replacing components of end items or interchanging the end item and evacuating to the depot level for repair.

Organizational level maintenance is limited to replacement of the batteries in the laser weapon simulator, hand-held calculator and field operator's radio. Battery replacement need is indicated by a built-in "go-no go" tester. Pre-operational tests of the laser weapon simulator and audio cue (MILES interface) device will be performed at this level prior to each operational exercise.

Tests will determine power output performance in the case of the laser weapon simulator and functional operation in the case of the audio cue device (MILES interface). No direct support level maintenance is anticipated.

Depot level maintenance will return all end items to a serviceable status and return them to stock. The low number of system peculiar components may not justify establishing depot facilities at government installations. Accordingly, the eventual manufacturer of the components should be considered as the source for depot level repair.

A summary of the maintainability and reliability factors for the laser weapon simulator system is provided in Table 4-3.

6. Point-Kill Laser System Maintenance Concept

The general maintenance philosophy is repair where possible at the organizational level by replacing components of end items or interchanging the end item and evacuating to the depot level for repair and return to stock.

Organizational level corrective maintenance is limited to replacement of the battery in the GFE laser device (MILES umpire weapon) and those in the hand-held calculator and field operator's radio. Pre-operational power output tests of the laser device will be performed at this level prior to each operational exercise.

No direct support level maintenance is anticipated. Depot level maintenance will return all end items to a serviceable condition and return to stock. Depot facilities are assumed to have been established in support of the MILES program and these facilities should be utilized for support of this system. Due to the small quantity of units required, the eventual manufacturer should be considered as the source for depot level repair for the observer's sextant, hand-held calculator and field operator's radio.

A summary of the maintainability and reliability factors for the point-kill laser system is provided in Table 4-4.

Table 4-3. Laser Weapon Simulator System
Maintainability and Reliability Factors

System Components*	Failure Rate (x10 ⁶ hr)	Preventive Maintenance (minutes)	Corrective Maintenance (minutes)	Total
Laser Weapon Simulator (R) Battery	1023.678 (120)	3.5	1	3582.873
Observer's Sextant (N)	8.107	2	-	16.214
Hand-Held Calculator (R) Battery	281.0278 (30)	1	1	562.0556
Visual Cue Launcher (R) (M-79 Grenade Launcher)	GFE	1.5	2	-
Audio Cue Device (N) (MILES Interface)	60.7558	1	-	60.7558
Field Operator's Radio (R) Battery	682.00 (54.0)	1	1	1364.0
Totals	2055.569	9	4	5585.898

*Organizational level replaceable S/A only shown.

N = Non-repairable @ organizational/direct support level

R = Repairable @ organizational/direct support level

Table 4-4. Point-Kill Laser System
Maintainability and Reliability Factors

System Components*	Failure Rate (x10 ⁶ hr)	Preventive Maintenance (minutes)	Corrective Maintenance (minutes)	Total
Laser Device (GFE) (R)	GFE	2.5	1	-
Observer's Sextant (N)	8.107	2	-	16.214
Hand-Held Calculator (R) Battery	281.0278	1	1	281.0278
Field Operator Radio (R) Battery	682.0 (54.0)	1	1	1364.0
Visual Cue Launcher (R) (M-79 Grenade Launcher)	GFE	1.5	2	-
Totals	971.134	7	4	1661.24

*Organizational level replaceable subassembly only shown.

N = Non-repairable @ organizational/direct support level

R = Repairable @ organizational/direct support level

NOTE: In terrain situations where required, the point-kill laser transmitter will need to be added to the visual cuer's equipment in order to carry out weapon effects simulation in heavy cover, for example forests, built-up areas, etc.

7. Sonic-Overpressure Device System Maintenance Concept

The general maintenance philosophy is repair where possible at the organizational level by replacing components of end items or interchanging the end item and evacuating to the depot level.

Although the specific device required for the implementation of this system has not been identified, it would be launched from a M-79 grenade launcher. Anticipated maintenance on the launcher would, therefore, be in accordance with standard Army procedures for maintenance of that weapon. Organizational level corrective maintenance is, therefore, limited to replacement of the batteries in the hand-held calculator used with the observer's sextant and the battery in the field operator's portable radio.

No direct support maintenance is anticipated. Repair of failed calculators, observer's sextants or portable radios will be performed at the depot level. Because of the small amount of units required, the eventual manufacturer should be considered as the source for depot level repair.

A summary of the maintainability and reliability factors for the sonic-overpressure device system is provided in Table 4-5.

The simple, low-sensitivity RF pulse receiver required for this system was roughly estimated. Because no feasible scheme for a non-microphonic linear sonic overpressure sensor has been identified, after considerable effort on another program, this system must be considered as not feasible.

8. RF Tri-Lateration Ground Designation System Maintenance Concept

This system will consist of major electronic assemblies which, in turn, contain replaceable subassemblies/components. The general maintenance philosophy is repair at the organizational level by replacement of major assemblies with operational spares; replacement of subassemblies/components at the direct support level and return of failed subassemblies/components to the depot level for repair and return to stock. Although specific component design and packaging were not performed during this study, past experience indicates systems of this complexity are maintained in this manner.

Organizational level corrective maintenance will employ built-in test capabilities to isolate system malfunctions to a replaceable major assembly. Remote installations (slave stations) will include on-time redundant units, where necessary, with the switch-over controlled at the master station.

Table 4-5. Sonic Overpressure Device System
Maintainability and Reliability Factors

System Components*	Failure Rate (x10 ⁶ hr)	Preventive Maintenance (minutes)	Corrective Maintenance (minutes)	Total
Sonic Overpressure and RF Receiver (N)	734.3558	1	-	732.3558
Observer's Sextant (N)	8.107	2	-	16.214
Field Operator's Radio Battery (R) (54.0)	682.00	1	1	1364.0
Hand-Held Calculator Battery (R) (30.0)	281.0278	1	1	562.0556
M-79 Grenade Launcher	GFE	1.5	2	-
Totals	1705.49			2674.625

*Organizational level replaceable subassembly only shown.

N = Non-repairable @ organizational/direct support level

R = Repairable @ organizational/direct support level

NOTE: Although not shown, as no design approach has been attempted, the eventual pyrotechnic device to be employed in this system would contribute significantly to the system failure rate. No increase in maintenance tasks would be required.

Failed units will be repaired at the organizational level by maintenance personnel employing standard test equipment. Failed replaceable subassemblies/components will be replaced with operational spares. Repaired units will be calibrated, aligned and the like, and returned to stock.

Depot repair of failed subassemblies/components should be accomplished at existing facilities presently performing similar type repairs.

A summary of the maintainability and reliability factors for the RF tri-lateration ground designation system is provided in Table 4-6.

Tabular summaries of the logistics support requirements for the considered system approaches to the simulation of indirect fire are presented in Tables 4-7 through 4-12.

F. COMMUNICATIONS NET WITHIN THE SYSTEM

The general problem with communications in the various systems under study, including the visual cues for the RF multi-lateration system, requires control of a number of personnel in the field by the Simulation Net Control Station (SNCS). It is desirable to operate with two monitoring frequencies which are available to the field personnel. The purposes for these frequencies are as follows:

- These frequencies are used by the fire direction center (FDC) net for fire commands to be simulated by the field personnel, providing advance notice of fire commands which may shortly be directed by the SNCS. The advanced warning is desirable to allow additional time for repositioning themselves should this warning be needed; and
- These frequencies are those that the SNCS uses to communicate fire commands to field personnel.

The field personnel should normally monitor the first frequency channel. For this reason, it is necessary to have a "paging" or "calling" capability available for indicating when to switch to the proper frequency upon receiving a "page". They need only select to transmit on an assigned frequency used by the SNCS for reception of field simulation commands.

Table 4-6. Tri-Lateration Ground Designation System
Maintainability and Reliability Factors

System Components*	Failure Rate (x10 ⁶ hr)	Preventive Maintenance (minutes)	Corrective Maintenance (minutes)	Total
Observer's Sextant (N)	8.107	2	-	16.214
Hand-Held Calculator Battery (R)	281.0278 (30)	1	1	281.0278
Visual Cue Launcher (M-79 Grenade Launcher) (R)	GFE	1.5	2	-
Receiver Assembly (MILES Interface) Battery (R)	728.97 (50.0)	1	10	728.97
Field Operator's Radio Battery (R)	682.00 (54.0)	1	1	1364.00
Antenna Assembly (Master Station) (R)	50.0	5 (System Test)	10	750
Transmitter Assembly (Master Station) (R)	578.0	5 (System Test)	15	11560.0
Processor Assembly (Master Station) (R)	141.65	5 (System Test)	23	3116.3
Receiver Assembly (Slave) (R)	1156.0	5 (System Test)	17	25432.0
Transmitter Assembly (Slave) (R)	1156.0	5 (System Test)	17	25432.0
Antenna Assembly (Slave) (R)	50.0	5 (System Test)	10	750
Decoder Assembly (Slave) (R)	6.17	5 (System Test)	23	172.76
Totals	4837.925	40.5	128	69603.272

*Organizational level replaceable subassembly only shown.

N = Non-repairable @ organizational/direct support level

R = Repairable @ organizational/direct support level

Table 4-7. Personnel Requirements

	Laser Weapon Simulator System	Point-Kill Laser System	Sonic Overpressure Device System	RF Tri-Lateration Ground Designator System
Field Operator System Peculiar Device	10 ¹	16 ²	16 ³	0
Field Operator Visual/Audio Cue Device	16 ¹			16
Smoke Generation Personnel	8	8	8	8
SNCS Operations Personnel	15	15	15	16 ⁴
Maintenance Personnel (Org. & Direct Support) SNCS Communications	2	2	2	2
Maintenance Personnel Org. Level System Peculiar Maintenance	0	0	0	2
Maintenance Personnel Direct Support Level System Peculiar Maint.	0	0	0	4
Food Service, Vehicle Maintenance	In accordance with Army T.O. for number of personnel supported versus time of exercise			
Totals	51	41	41	48

Table 4-7. Personnel Requirements (Cont'd)

- NOTES:
1. Functions of LWS operator and visual cue operator must be separated in laser weapon simulator system.
 2. One operator may perform device operation and visual cue operation in laser point kill system.
 3. Proposed device will provide audio cue and simulation effect of indirect fire simultaneously.
 4. Additional transmitter operator required in SNCS for utilization of tri-lateration ground designation system.
 5. All figures shown reflect one-shift requirements. No consideration for relief personnel shown.

Table 4-8. Training Requirements

	Laser Weapon Simulator System	Point-Kill Laser System	Sonic Overpressure Device System	RF Tri-Lateration Ground Designator System
Use of Observer's Sextant and Calculator	All field personnel - All systems Two days (estimated) includes field operator exercises			
Communication Procedures	All personnel - All systems One day			
Safety Emphasis Training	1/2 day	1/2 day	1/2 day	1/2 day
System Peculiar Device Operation	1 week	1/2 day	1/2 day	2 weeks
Organizational Level Maintenance	1/2 day	1/2 day	1/2 day	
Direct Support Level Maintenance	X	X	X	4 weeks

- NOTES: 1. All duration of training is estimated and intended merely to show relative complexity of training required.
2. Safety emphasis training required because of requirement for firing pyrotechnic devices in close proximity to maneuver forces.

Table 4-9. Transportation Requirements

	Laser Weapon Simulator System	Point-Kill Laser System	Sonic Overpressure Device System	RF Tri-Lateration Ground Designator System
Field Personnel Vehicle (Jeep)	26 ¹	16 ¹	16 ¹	16 ¹
Smoke Generation Team Vehicle (Jeep)	4	4	4	4
Relief Team Transport (Truck)	2 ²	2 ²	2 ²	2 ²

NOTES: 1. Visual/audio cue personnel may employ motorcycles due to high mobility Requirement if terrain dictates.

2. Size of vehicle dependent on number of personnel to be transported.

Table 4-10. Initial Equipment Allocation Requirements
(Maneuver Force and Simulation Team)

	Laser Weapon Simulator System 4	Point-Kill Laser System 3	Sonic Overpressure Device System	RF Tri-Lateration Ground Designator System
MILES Instrumentation: Personnel (2 BTN)	1980	1980		
MILES Instrumentation: Vehicles (2 ETN)	492	492		
System Peculiar Device (Field Operator)	10	16	16	0
Visual/Audio Cue Launcher (M-79 Grenade Launcher)	16	16	16	16
Observer's Sextant Calculator	30	16	16	16
Binoculars	30	16	16	16
Portable Communication Set	30	16	16	16
SNCS Communication Installation	Identical in all systems (5) AN/URC-43 Commercial type pager system (2) AN/URC-44			
Target Instrumentation Units (Maneuver Personnel and Vehicles 2 BTN)	2472	0	2472	2472
Commercial Type Pager Device (Fld Personnel)	30	16	16	16

NOTE: Electronic assemblies comprising tri-lateration ground designation system shown on following page.

Table 4-11. Major Components, RF Tri-Lateration Ground Designation System Initial Equipment Requirements

Component	Quantity
Antenna, Slave Station	2
Receiver, Slave Station	2
Transmitter, Slave Station	2
Decoder, Slave Station	2
Antenna, Master Station	1
Transmitter, Master Station	1
Processor, Master Station	1

Table 4-12. Preliminary Spares Concept

Item	Laser Weapon Simulator System		Point-Kill Laser System		Sonic Overpressure Device System		RF Tri-Lateration Ground Designator System	
	Initial Amt	Spares	Initial Amt	Spares	Initial Amt	Spares	Initial Amt	Spares
MILES Instrument (Pers)	1980 ¹	250	1980 ¹	250				
MILES Instrument (Veh)	492 ¹	75	492 ¹	75				
MILES Umpire Weapon			16					
Laser Weapon Simulator	10	2						
Battery	S/A	120 ²						
Hand Held Calculator	30	4	16	2	16	2	16	2
Battery	S/A	360 ³	S/A	192 ³	S/A	192 ³	S/A	192 ³
Portable Radio Set	30	4	16	2	16	2	16	2
Battery	S/A	120 ⁴	S/A	64 ⁴	S/A	64 ⁴	S/A	64 ⁴
M-79 Grenade Launcher (GFE)	16	1	16	1	16	1	16	1
Observer's Sextant	30	4	16	2	16	2	16	2
MILES Interface Unit	2472 ⁵	250			2472	250	2472	250
SNCS Field Comm Set	3	1	3	1	3	1	3	1
Binoculars	30	1	30	1	30	1	30	1
Antenna, Slave Sta.							2	0
Receiver, Slave Sta.							2	2 ⁶
Transmitter, Slave Sta.							2	2 ⁶
Decoder, Slave Sta.							2	2 ⁶
Antenna, Master Sta.							1	0
Transmitter, Master Sta.							1	1
Processor, Master Sta.							1	1

NOTES: Where no entry is shown, that item not required for use with system.

1. This number represents instrumentation sets, not individual sensors. Spares would be used to replace inoperative sensors subsequent to an exercise and prior to issue for next exercise.
2. Based on worst case estimate of one battery/unit depletion each shift of an exercise based on three shift operation over a four day period. However, engineering judgement is battery could be designed to last the maneuver and recommended spare level would then drop to 10.
3. Based on worst case estimate of one battery/unit depletion each shift of an exercise, based on three shift operation over a four day period.
4. Based on 20 hours of operating life. Approximately one battery/unit per day of a four day exercise.
5. Although this number would be required for all personnel to be so equipped, cost considerations should limit the usage to key personnel and armored vehicles.
6. These units are on-line redundant units.

A survey has indicated that normal military communications equipment is either insufficient in range capability or excessively heavy and cumbersome for the purposes required in this application. Accordingly, the contractor performed a search for optimum commercial equipments for portable communications hardware for simulation personnel in the field. The recommended equipments are described in Appendix H.

Because relatively few equipments are required, it is not deemed appropriate to acquire new equipments to meet full military specifications.

The recommended equipments are of high quality with proven performance in the military and are designed for rugged environments.

Again, because relatively few equipments are required, the opinion is that normal depot maintenance could be bypassed, thus having the appropriate manufacturers service the equipments. It is to be anticipated that most maintenance action will result from inadvertent mechanical damage caused by mishandling or accident.

It is noted that the recommended transceiver is an adaptation of standard commercial modules in which special packaging (where primary lithium-cell batteries are used to reduce bulk and weight) is used with adaptation to use the addressing (paging) system in the SNCS.

The paging system in the SNCS consists of two small transmitters together with a number of paging terminals for use by the SNCS personnel to address individuals or teams in the field.

Upon receiving fire information data and information relative to the locations of the most appropriate fielded simulation, the operator in the SNCS would simply depress the appropriate code keys on the paging terminal at his station. This action results in an audio signal in the fielded personnel's equipment. Upon receipt of the page signal, the fielded personnel will switch from FDC to SNCS frequency and acknowledge by voice with their code signal. The SNCS operator then transmits the fire simulation data, the fielded personnel record the data, acknowledge and then proceed to carry out the instructions. Standard operating procedure will usually require that they continue to monitor the SNCS frequency for additional instructions during their simulation activities. Only when fielded personnel are "idle" will it be profitable to monitor FDC frequencies.

ILS anticipates that the field transceiver will be mounted in a strap-harness so that the transceiver will normally be low on the back of the wearer with the controls (about 3) available to his left hand at the left side of the device. The antenna/speaker/microphone would normally be attached via Velcro fasteners or a hook, on the front left breast-strap of the harness. The entire system is envisioned to weigh about 6.5 to 7 lb and will be quite convenient for field use. Normal Army VHF frequencies should be assigned for this use in the exercise area and the transceivers should be procured with proper crystals and tuning capability.

G. COMMUNICATIONS WITH FIELDDED PERSONNEL

1. Basic System Communications

The basic communications systems will undoubtedly consist of normal Army communications sets. Certain of the available frequencies (a minimum of two) should be set aside and dedicated to indirect fire simulation system control.

For best system operation, all initial calls for fire (for example, by FOs) should use one frequency on each side. Fielded system personnel should monitor the appropriate frequency to gain advance indication of any need to move in anticipation of fire simulation orders from the SNCS. This mode requires the addition of a paging system (discrete addresses) so that particular simulation teams may be alerted to switch from the monitored frequency to SNCS frequency for specific orders.

The mobility required of fielded personnel indicates the need for very small and light RF transceivers for communications. The smallest and lightest of normal Army transceivers have been deliberately designed for very short-range use. Pagers are not normal Army equipment.

2. Communications Equipment in the Field (See Appendix H)

The best solutions to the problem of furnishing fielded personnel with adequate, light and low cost communications and paging gear was the subject of an intensive search, with the result that the following equipments were selected as the best available considering the field conditions.

- Pager: Martin-Marietta "Code 2"; and
- Transceiver: Repco with paging receiving capability

A new package	}	816-040 VHF Transmitter
of existing		810-037 VHF Receiver
modules.		Packaged together with a microphone and speaker and integrated battery.

With reasonably central location of the SNCS at the exercise region, no repeater stations would be needed for the communications sets.

H. DISCUSSIONS

1. System Approaches Eliminated From Competition

A number of system approaches or system elements were eliminated from serious consideration quite early in the study for a variety of reasons. These reasons included impracticality or obvious excessive cost of acquisition or operation. The following paragraphs discuss the more important aspects of these eliminations.

a. Satellites

It has been suggested that satellites might be used as platforms for laser or other designation schemes, or for location-signalling of indirect fire effects. Neither is practical. The so-called "stationary" satellite is one that orbits the earth above the equator at a distance such that its period equals the diurnal period. It thus remains "above" a point on the equator. Quasi-stationary orbits which are not equatorial also are feasible, but these appear to oscillate in a north-south loop. The radius of such an orbit is more than 22,000 miles. The smallest practical beamwidth of lasers (which far exceed the capabilities of radar in this respect) are about 0.1 mr (10^{-4} radian). The 22,000 (10^{-4}) = 2.2 miles spot diameter on the earth obviously is far in excess of the needs.

To compound this spot diameter difficulty, the "stationary" objects are not truly stationary. The classical situation of "Lagrange's three particles" (sun, earth and such a very small-mass satellite) is a case in point. The object actually oscillates in an appreciable orbit about its "stationary" location, even if there were no moon to complicate matters. Even if it were feasible to transmit sufficiently small beams from such a satellite, the mathematical and technical problems attendant on adequately accurate beam steering are mind-boggling.

Finally, it is evident that radar techniques with relatively longer wavelengths than lasers would have to be used to penetrate the frequent cloud cover. This penetration would require truly enormous antennas, larger than the areas to be "designated".

Navigation-type satellites are fine for slow-moving ships at sea with the proper equipment. These satellites are relatively low-orbit satellites with periods on the order of 1.5 hours or slightly more. Their ephemerides are accurately known and by time-measurement of the passage of a very accurately controlled RF signal through zero doppler shift, the navigator can determine an accurate "line-of-position". With dead-reckoning and a second satellite shortly thereafter, the navigator can find a second line-of-position intersecting the first line-of-position (dead-reckoning offset) to find his "fix" at the time of the second transit. This scheme has no practical significance to continuous fine-scale real-time position finding for our purpose or for weapon simulation.

b. Lighter-Than-Air Laser/Radar Platforms

It has been suggested that either tethered or free-flying lighter-than-air platforms could be used to provide an elevated position of known location for weapon-effects designation using laser or radar techniques. There is no question as to the technical feasibility of this approach. The difficulties lie in costs and weather hazards. Also, in regions where low stratus is common (for example, West Germany), it might not often be useable.

Either tethered balloons or non-rigid airships, holding fixed positions or tracks, could be effective. The long history of lighter-than-air (LTA) craft, however, attests to the hazard of loss of the craft in any condition where high winds or turbulence might occur. The LTA craft are particularly hazardous in hilly terrain where appreciable vertical air movement occurs,

often with turbulence. Initial costs are high, maintenance costs high and lifetimes often short for such aircraft. The practical problems attendant on ownership and operation of LTA vehicles militate strongly against this approach.

A number of LTA vehicles would be needed for a two-battalion exercise and positioning over known spots could be difficult. Without accurate positioning, very complex and precise real-time position-finding in three dimensions would be needed, with real-time calculation of the necessary beam-angles for laser/radar designation required. This further greatly complicates the cost picture and the risks in the event of loss of the vehicle in severe weather.

c. Radar Beam Weapons Effects Simulation

Radar beams of small angular subtense require a small ratio of wavelength to aperture diameter. Even a "millimeter" wavelength radar has a wavelength 1,000 times that of near-infrared lasers. As a result, the apertures for radar-beam devices become invariably "diffraction-limited" (as distinct from "source-size-limited" as for lasers). As a result, the apertures required (horns, dishes, and the like) become extremely large for a given beamwidth. Further, the receivers require essentially non-directional antennas for our purpose and are relatively complex as compared to silicon diode detectors and preamplifiers used for lasers. Costs are generally quite high for the signal-source devices and receiving front-end components. Even a cursory "quick-look" at the problems of utilizing radar beam techniques for weapons effects simulation was extremely discouraging and forced abandonment of this approach even before the contractor was directed away from the radio-navigated helicopter platform approach at the first SAG meeting.

d. Radio-navigated Helicopter Platforms

During the proposal period and the first month of contract effort, it was considered that the greatest "fidelity" in simulation of indirect fire could be accomplished by a helicopter "platform", navigated by radio means to directed places, near targeted spots and carrying laser or radar beam scanners emitting coded signals for the weapon effects simulation.

A scheme was conceived for using hyperbolic multilateration navigation (a well known technique) using a pilot direction indicator (PDI) to direct the pilot. In addition to this scheme, precise locational information would be available to a computer aboard the aircraft. Target point, scan-size data, weapon identification, as well as navigational directions would be transmitted by RF signals to the computer which would control the beam angles and scan of the laser or radar.

This approach is technically feasible, but it does present a formidable development problem and must depend upon the use of relatively few dedicated helicopters. The costs of acquisition and maintenance, in addition to the costs of ownership of more equipped helicopters than really needed because of their dedicated character, are obviously very high. The development period for systems of this nature and degree of complexity is characteristically about five to seven years before they can be fielded with any confidence. This obvious fact, together with the costs of the development of the ground-based electronic systems elements, caused the government to direct ILS away from systems of this complexity at the first SAG meeting.

Remaining in competition were the laser-based systems 1 through 4, 4-A and the use of radio multilateration target-point designation.

2. Validity of Operational Concepts, Training Values, Costs and Logistics Analyses

There are many variables in the problem of concept and use of the indirect-fire simulation systems studied under this program. The technical problems are relatively easily defined and evaluated. The concepts of use are based largely on conjecture and assumptions. The values as aids in training can be extrapolated by psychologists from preceding programs with some conjecture. Costs are, to some degree, based upon detailed analyses, but some of the costs are based upon logistics which in turn are based upon conjecture and in some cases on estimates based on comparisons. The net system values developed in Appendix B are equally only roughly comparative, and where small differences appear, probably should be ignored.

In short, the results of the study in terms of selection of techniques is largely pragmatic -- that is, a blend of what is feasible and desirable reflected from what would be an indefinable ideal. The recommendations can, however, be considered

as a practical best-approach, especially considering the desirement for integration with MILES as an overall training system.

Much practical data needs to be obtained before specifying a system actually to be fielded. This will be discussed in the following paragraph.

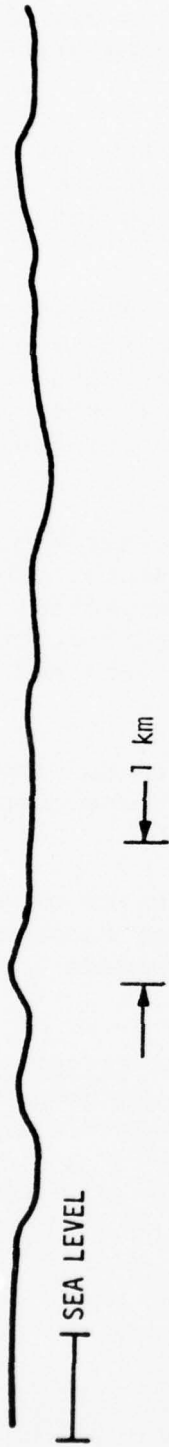
3. Concepts Evaluation Program

As noted in the preceding paragraph, it is really needful to address a number of problems from a practical (experimental) viewpoint before a useful indirect fire simulation system can be specified with confidence.

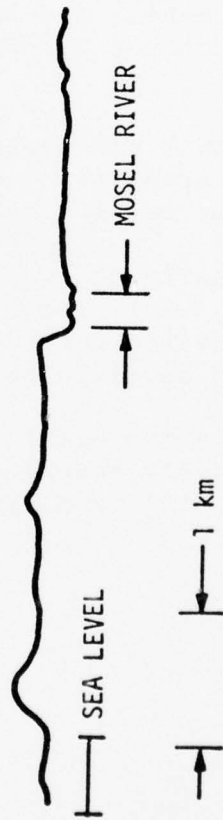
The principal unanswerable questions at present are the following:

- Considering the angles-of-view from lasers to target areas which will be met in practice, with force elements disposed as a real situation might develop, is the "footprint" available adequate and reasonably realistic?*
- To what extent does typical shadowing of force elements by obstacles, vehicles, etc. influence the range of P_k adjustments available?*
- In practice, does the pilotage (sextant/calculator) scheme of location of operators and targets function well enough?
- Does the movement of simulation system elements in the field produce excessive inadvertent cueing of force elements?
- Does the addition of attitude sensing/ P_k modification actually influence the behavior of targeted troops?
- Is the concept of a pyrotechnic cue adequate? To what extent should it be used? Is a longer-flight-range cue device needed?

*In our studies we have used a terrain model based upon the data shown on a map designated "POR #1 of C-69" showing a region of West Germany north of the Mosel River. Two typical contours are shown in Figure 4-14.



A. CONTOUR FROM SOUTH OF GRANDORT TO SOUTH OF BERGWEIFER



B. CONTOUR FROM DHRON TO SOUTH OF SAHLEM CROSSING THE MOSEL

P3193

Figure 4-14. Terrain Contours

- Is the surprise element of simulated fire-before-visible-cue effective? Do troops respond to visible cues effectively? Is a distinct audio cue for indirect fire needed?

ILS believes the answers to the above questions are essential in specifying an adequate cost-effective indirect-fire simulation system and suggests a three-part program to determine the needed information as follows:

- Design and construction of three "brassboard" scanning lasers as conceived herein and tests in the field versus troops equipped with MILES equipment, if available, or alternatively versus Infantry Direct Fire Simulation System (IDFSS) equipped troops. This should cover a variety of situations designed specifically to get answers as noted;
- Design and construction of two prototype "observer's sextants" and experiments in the field using SR-52 calculator programs. Note that if this is as successful as may be expected, it would be well to institute a development of a specialized, pre-programmed, calculator for general field artillery and infantry uses; and
- Design, development and tests of several candidate visual cue rounds for use fired from grenade launchers; tests cooperatively with the laser tests versus troops.

ILS can easily carry out the first two tasks expeditiously and inexpensively. AAI, Inc. is a logical choice to carry out the third task, considering their background with grenade launchers and training round development.

It might be preferable to have Frankford Arsenal develop a prototype observer's sextant, provided it can be done relatively quickly. No doubt any production item would be developed under Frankford's aegis.

Section V

COST SUMMARY

The cost summary presented in this section represents a cursory estimate of the costs to be anticipated in implementing the various systems considered in the Indirect/Area Fire Simulator study. These costs are extended over the quantities required by two battalions in a typical training field of 30 x 15 km.

Appendix B is a definitive cost breakout per system. It reflects the costs associated with labor, overhead, material, G&A, direct government acquisition and development. Loading factors of 86% overhead and 18% G&A are applied as applicable.

It should be noted that in purchasing large quantities of equipment (that is, radio communications) a significant cost reduction will be realized.

Acquisition GFE costs are those incurred by the government from a direct purchase of on-the-shelf stock from a firm other than ILS.

Operational costs are those expendable (that is, visual cue devices and lithium batteries) which are consumed in a typical 96 hour exercise.

Table 5-1 is a summation of costs per system in a typical training field.

Table 5-2 is a cost/values comparison for indirect-fire simulation systems.

Table 5-1. Summary of Cost for a Typical Training Field
(Dollars in Thousands)

System	Labor Cost	Overhead 86%	Material Cost	G&A 18%	Acquisition GFE Cost (1)	Operational Cost (2)	Development & Test (3)	Total Acquisition Cost (4)
System 1					30.6	4.5	150.0	180.6
System 2					62.2	4.5	150.0	212.2
System 3 - RMS Position Finding					55236.2	4.5	150.0	55386.2
System 3 - Sextant Position Finding	46.1	39.6	37.7	22.2	73.8	4.5	155.0	374.4
System 4 - ILS Laser-Sextant Position Finding, no MILES impact	71.9	61.8	132.3	47.9	73.8	5.4	300.0	687.7
System 4 - ILS Laser-Sextant Position Finding, with Added Target Decoder and Vulnerability Assessment	417.1	358.7	322.7	197.7	73.8	5.4	320.0	1690.0
VHF Trilateration Ground Designation System	2323.4	1998.1	2319.0	1195.1	63.1	4.8	1150.0	9048.7
System "X" Sonic Overpressure	72.9	62.8	56.9	34.7	7.4	18.4	175.0	409.7

NOTES: (1) Equipment unique to indirect area fire simulation system to be procured direct by government.

(2) This is a recurring cost for a 96 hour exercise.

(3) Includes the cost of development of the 40 mm audio-visual cartridge.

(4) Excludes the recurring operational costs.

Table 5-2. Cost/Values Comparison for Indirect Fire Simulation Systems

System	Value Score	Acquisition Cost 1 Field (Dollars in Thousands)	Expendables Cost (1) 1 Exercise, 96 hrs (Dollars in Thousands)
System 1 } MILES Codes,	0.0745	180.6	4.5
System 2 } MILES "Empire" Transmitter.	0.0745	212.2	4.5
System 3 }	0.0938	374.4	4.5
System 4, no MILES receiver impact, but otherwise same as below	(4) (4-A) 0.3165/0.094	687.7	(4) (4-A) 5.4/9.4
System 4, added decoder with varied P _k & vulnera- bility assessment, distinct audio cue & night capability	(4) (4-A) 0.501/0.170	1690.0	(4) (4-A) (2) 5.4/9.4
RF Trilateration	0.518 (3)	9048.7	4.8
System "X" (RF/Sonic Overpressure (Reference Appendix K)	None (4)	409.7	18.4

NOTES: (1) Exclusive of GFE HC smoke pots.

(2) Including estimated 20 hours helicopter operation/exercise: Δ = \$4000
(Mixed system 4 and 4-A)

(3) Assuming near-level terrain.

(4) Presently not feasible. Microphonic transducers would result in many
false kills.

Section VI
CONCLUSIONS

A. GENERAL

As a result of the study effort, the following conclusions have been reached.

B. RF TRILATERATION SCHEME

Were it not for the following factors, ILS would recommend the RF trilateration system of kill effects simulation as offering the greatest value for training in use and avoidance of indirect fires.

- Uncertainty of location and area designated in real terrain as a result of propagation-path anomalies;
- Difficulty or impracticality of obtaining a wide-band frequency allocation in a workable band at many places in the world; and
- The added cost and burden in complete overlay on the MILES system.

C. SCANNING LASER/KILL DESIGNATION SYSTEM

The recommended "System 4" scheme of use of a scanning laser of controlled scan pattern scores next highest in value to the RF trilateration scheme and is certainly feasible. It is subject to a variety of variants of varying costs and value, descending from the most complex variant which uses an indirect-fire decoder/ P_k analyzer added to the basic MILES direct-fire decoder.

In some special instances, such as attaining adequate "kill effects" versus troops shielded by forest, the scanning laser system must be supplemented by a non-scanning laser transmitter used by an umpire (actually the visual cuer operator).

D. VISUAL CUE SUBSYSTEM

The use of a special round fired from a grenade launcher to moderate height and horizontal displacement to the required "ground zero" is the only approach conceived which could provide

acceptable effectiveness with good personnel safety with accuracy sufficient for use by forward observers. The adequacy of this approach will depend upon the success of a development program for the round which may be carried out either by industry or the government or cooperatively between them.

The round should be safe in all respects and give a smoke cloud about 15 ft in diameter at 60 to 75 ft in height above the ground (minimum). It should give a loud report not exceeding 140 db on the ground and have good visual contrast against both vegetation and sky backgrounds. It should give an adequate flash for nighttime cueing without excessive brilliance which could adversely affect night vision of nearby troops.

E. AUDIO CUE

Audio cues are generated by the visual cue subsystem, but this cue need not be used in all cases for logistical reasons. The cue is essential only for fire adjustment. Thus, a supplementary audio-cue should be generated by the laser system immediately after the kill-effects scan in an area larger than that designated by kill effects.

This signal, ideally, should be separately decoded from MILES direct-fire audio cues and give a distinctive signal to the cued troops. Provisions for this operational concept are included within the "System 4" laser scheme outlined in Appendix C in some detail.

F. CUER POSITION LOCATION AND LOCATION OF DESIGNATED STRIKE POINTS

The RF system (PLRS; RMS-SCORE, and the like) were deemed far too costly for the intended purpose and of questionable accuracy in some terrains. It is therefore concluded that the "Pilotage" scheme of self-location, using a sextant for observation of the angles between known fixed objects and a programmed hand-held calculator, is optimum. The same calculator can yield bearing and azimuth of a target point from the observer's known position. This latter auxiliary program can be used by cuers to locate positions to which they intend to move from their present position as well. By keeping notes, an experienced cuer, in known terrain, can develop a catalog of many recognizable object locations to which he can move expeditiously. Accuracy can be very good and the time required is quite short. The devices are small and light.

AD-A034 452

INTERNATIONAL LASER SYSTEMS INC ORLANDO FLA
INDIRECT/AREA FIRE WEAPONS EFFECT SIMULATOR STUDY (SUMMARY). VO--ETC(U)
JAN 77 R E ODOM

F/G 19/5

N61339-76-C-0070

TND-TR-76-0002-VOL-1

NL

UNCLASSIFIED

2 OF 2
ADA034452



END

DATE
FILMED
2 - 77

G. UNCERTAINTIES

The overall concept of the recommended system and variants are subject to considerable uncertainty principally having to do with questions of operational feasibility in the field. The system net control station functions, as described in Appendix I, are arbitrary and experience no doubt will allow a workable scheme to be developed.

- Afield, however, much uncertainty exists as to the availability of lines-of-sight of adequate range to a sufficiently large sample of fielded troops and vehicles in various types of terrain and "nap of the earth" features. Field tests using experimental equipment, are deemed essential.
- Some uncertainty exists as to the feasibility of sufficiently rapid and accurate displacement of both visual cue and kill-effects operators in some types of terrain.
- There exists some uncertainty as to the intelligence and aptitude level required for quick and effective training of fielded personnel and personnel manning the SNCS. However, it does appear that levels equivalent to those required for artillery NCOs should suffice.
- There exists some uncertainty of the accuracy of laser operator range estimation at night with night-vision aids.
- Because it is unfeasible to simulate the audio-visual effects of actual indirect fires at a level approaching full scale for safety and economic reasons, much uncertainty exists as to the effectiveness of the concepts as a training system from a psychological viewpoint. A number of schemes exist for increasing the level of psychological cueing, but none exist which can approach the full-scale shock effect with safety. Further work needs to be done in this area both to establish the feasibility of these additional ideas and to evaluate their effectiveness from a psychological viewpoint. The pyrotechnic visual cue would still be needed for FO use with any of these auxiliary features.

These additional ideas involve the generation of a mechanical impulse applied to the chest or back of a targeted troop (triggered by the laser audio-cue signal). This would simulate the sonic overpressure of a shell burst with some surprise and moderate-shock effect. It could be accomplished by discharge of

a capacitor through a solenoid or voice-coil transducer. Efficient coupling to the chest cavity is the major problem.

The visual cue accompanying the mechanical impulse cue could be produced by a small electronic flashlamp directed at the ground so as to not produce a direct illumination of any troops. The electronic flash in this mode is quite apparent even in full sunlight. It is noted that it is not advisable to use directly visible bare flashtubes because of the effect on the troop's night vision. A variant of this approach would be to mount the flashlamp with a diffuser inside of the helmet liner between the webbing and liner. This would illuminate the ground and also produce a very noticeable peripheral-vision scatter from brows, nose, and the like.

It is concluded that work needs to be done along the lines suggested above.

Section VII

RECOMMENDATIONS

A. KILL-EFFECTS SIMULATION SYSTEM

The variant of the scanning laser system, which does not at all impact the MILES system, is feasible but suffers from several defects that detract noticeably from its value for training purposes.

- No separate audio-cue from the laser system can be created. This factor will lead to confusion and uncertainty on the part of cued personnel;
- It is not feasible to vary the probability of kill by weapon type, other than by intermittent laser code transmission. This becomes very unrealistic in situations where the scan reduces to only one or two bars; and
- It is not feasible to vary the probability of kill as a function of the troop's attitude (that is, prone, kneeling, standing). This factor can have opposite effects in reality for varied weapon types. (It is deemed desirable to decode nine separate weapon codes for indirect-fire effects simulation.)

ILS' recommendation is, therefore, to use the scanning laser kill-effects designation system with separate decoder/P_k analyzer, attitude sensors and a separate, distinct audio cue device for all targets, including troops.

B. VISUAL CUE SUBSYSTEM

It is recommended that a special round be developed to afford night/day visual cue with an audible effect as well. This round should be launched by standard grenade launchers (M-79).

It is recommended that the round be developed by industry under the aegis of PM TRADE, with the cooperation of other appropriate and knowledgeable Army agencies.

C. POSITION AND TARGET LOCATION SUBSYSTEMS

The recommended approach is to use a special sextant adapted to measurement of angles in a horizontal plane with considerable object elevation tolerance together with a programmed hand-held calculator for position and target location.

D. EQUIPMENT CONSIDERATIONS

As noted in the conclusions in Section VI of this report, considerable doubt exists as to the psychological training effectiveness of the pyrotechnic visual cue (although it is needed for fire-adjustment training and cueing purposes) and of the laser-generated audio "cue" signal. It is felt that a greater (but safe and economical) "shock" level may be required. As a result, a program of experiment along technical and psychological lines to develop more effective audio-visual cues is needed and recommended as suggested in paragraph G. of Section VI.

The sextant should be developed under the aegis of PM TRADE, the Field Artillery School and Frankford Arsenal. The hand-held computer should be developed by industry to specifications developed by the Field Artillery School.

It is noted that it is feasible to use the existing Texas Instruments SR-52 calculator for this purpose, but it has several disadvantages as compared to an ideal device adapted to Army purposes and especially to use by the field artillery (see Appendix J).

E. SYSTEMS CONCEPTS VERIFICATION PROGRAM

In view of the uncertainties outlined in Section VI, it is recommended very strongly that a concept verification program be instituted. This program should include experimental models of the:

- Scanning Laser Transmitter;
- Auxiliary Decoder/P_k Analyzer;
- Audio Cue device;
- Visible Cue rounds (several variants);
- High-shock-level cueing techniques; and
- Observer's Sextant.

Note that the SR-52 calculator can be used for this program, despite its unhandy features.

The test and evaluation program should be carried out at an Army facility where either MILES or IDFSS-equippable troops and vehicles exist and where there is suitably varied terrain. It would be desirable to include competent psychologists in the troop complement to evaluate the training-effectiveness tests.

Appendix M identifies high-risk areas for all considered systems.

GLOSSARY

A/D	Analog-to-Digital
APC	Armored Personnel Carrier
BA	Basic Array
BW	Bandwidth
CDU	Central Display Unit
CLGP	Cannon-Launched Guided Projectile
CMOS	Complementary Metal-Oxide Semiconductor
CPF	Central Processing Facility
CS	Copperhead Simulator
F/A	Field Artillery
FDC	Fire Direction Center
FDU	Field Display Unit
FEBA	Forward Edge of the Battle Area
FM	Frequency Modulation
FO	Forward Observer
FOV	Field of View
FSK	Frequency Shift Keying
FSO	Fire Support Officer
GaAs	Gallium Arsenide
GFE	Government Furnished Equipment
GLLD	Ground Laser Locator Designator
HC	Hexachloroethane-Zinc Oxide-Aluminum
HE	High Explosive
HOB	Height of Burst
I/AFWES	Indirect/Area Fire Weapons Effects Simulation System
IC	Integrated Circuit
ICM	Improved Conventional Munitions
IF	Intermediate Frequency
ILS	International Laser Systems, Inc.
I/O	Input/Output
IR	Infrared
K _c	Inadvertent Cueing
K _v	Visual Cue Factor
LED	Light Emitting Diode
LOS	Line-of-Sight
LPICD	Laser Point Kill Designator
LSI	Large Scale Integration
LTA	Lighter-Than-Air
LWS	Laser Weapon Simulator
LWS-P	Laser Weapon Simulator - Point Kill
LWSS	Laser Weapon Simulator System
MDFS	Mounted Direct Fire Simulator

GLOSSARY (Cont'd)

MILES	Multiple Integrated Laser Engagement System
MM	Martin Marietta Corp.
MSI	Medium Scale Integration
MTTR	Mean Time To Repair
MU	Mobile Units
NCO	Non-commissioned Officer
Nd:YAG	Neodymium-doped, Yttrium-Aluminum-Garnet
Ni-Cad	Nickel-Cadmium
PCG	Pulse Code Generator
PIP	Point of Impact
P_k	Kill Probability
PLRS	Position Location Reporting System
PRF	Pulse Repetition Frequency
PRRS	Position Reporting and Recording System
QE	Quadrant Elevation
QTY	Quantity
RF	Radio Frequency
RMS	Range Measuring System
ROM	Read Only Memory
SAG	Study Advisory Group
SCR	Silicon Controlled Rectifier
SFG	Fog Oil
SNCS	Simulation Net Control Station
STEM	Storable Tabular Extendable Members
TTR	Tone Tracking Receivers
USC & GS	U.S. Coast And Geodetic Survey
UTM	Universal Transverse Mercator
VACO	Visual/Audio Cue Operator
VHF	Very High Frequency
WP	White Phosphorous