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OPTIMUM PATCHING TECHNIQUE FOR SEISMIC SENSORS EMPLOYED IN A GRID

Sterling Pilette, Billy Biggs, and Lawrence Edwards
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and

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BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

U. S. Army
Research Institute for the Behavioral and Social Sciences

September 1978

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The requirement was to determine the effect of four patching techniques and associated job aids, training, sensor density, and target activity on operator performance in detecting targets when using unattended ground sensors employed in a grid configuration.

Trained operators interpreted tactical data recorder (RO 376) plots both before and after training using four patching techniques and associated job aids in the grid employment of seismic sensors. The plots represented both

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9 sensors per square kilometer grid and 24 sensors per square kilometer grid. Completeness of target detection, number of false alarms, speed estimation error, and target direction deviation were measured.

Patching technique training (and job aids) increased detection completeness by 42%: The row patching technique was selected as the best. Use of the 9-sensor grid resulted in fewer false alarms and equal detection completeness as compared to use of the 24-sensor grid.

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BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

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Intelligence Systems

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FOREWORD

The Battlefield Information Systems Technical Area of the Army Research Institute is concerned with demands of the future battlefield for increased man-machine complexity to acquire, transmit, process, disseminate, and utilize information. The research is focused on the interface problems and interactions within command and control centers and is concerned with such areas as topographic products and procedures, tactical symbology, information management, user-oriented systems, staff operations and procedures, and sensor systems integration and utilization.

One area of special interest is the human factors problems in presentation and interpretation of surveillance and target acquisition information. One relatively new source of intelligence information is remote monitoring of the battlefield using seismic, acoustic, and magnetic unattended ground sensors. When these remote sensors are activated by enemy personnel or vehicle movement, a monitor display located behind our lines indicates the activity. The operator can derive from this display not only the presence of the enemy but also such information as the direction and speed of convoys and personnel, the number of vehicles in a convoy, and the composition of the convoy (e.g., armored versus wheeled vehicles).

This publication concerns training needs and patching techniques for remote sensors employed in a grid pattern for surveillance of large areas where enemy attack will be cross country. This use of sensors imposes different problems on the operator than the use of sensors in strings along roads or trails. Results show that special training is required, and the row patching technique is the most promising. Moreover, the results of grid density indicate that maximum separation of sensors (the most cost effective) does not reduce operator performance.

Research in the area of sensor systems integration and utilization is conducted both in-house and contractually. The effort is responsive to requirements of Army Project 2Q762717A721 and to special requirements of the U.S. Army Intelligence Center and School, Fort Huachuca, Ariz., the Assistant Chief of Staff for Intelligence, and the Remotely Monitored Battlefield Sensor System (REMBASS) Project. Special requirements are contained in Human Resource Needs 74-21 and 75-5.

The research was made possible by the excellent cooperation of the participating personnel of the unattended ground sensor platoon of the 163d Military Intelligence Battalion, attached to MASSTER (Fort Hood, Tex.). Special thanks are given to LTC Temperly, CPT Latsin, and SFC Stallings for their cooperation.

JOSEPH ZEIDNER
Technical Director

OPTIMUM PATCHING TECHNIQUE FOR SEISMIC SENSORS EMPLOYED IN A GRID

BRIEF

Requirement:

The requirements are to develop ways in which seismic sensors employed in a grid array can be patched to an RO 376 readout device, and to identify the preferred technique for field use. In addition, (a) requirements are to determine if specialized training of unattended ground sensor (UGS) operators is required for interpretation of activations of seismic sensors employed in a grid, (b) to find whether, or to what extent, operator performance is affected by two densities of sensors in a grid employment, and (c) to determine the interactive effects of sensor density, target activity, and patching techniques on operator performance.

Procedure:

Four techniques for patching seismic sensors employed in a grid array to the RO 376 Event Recorder were developed. Operator performance using the techniques was compared under two sensor density levels--9 versus 24 sensors per square kilometer--and two levels of target activity--high and low. The value of training specific to the use of the patching techniques and associated job aids--target log, speed chart, and a specially designed ruler--was determined. Five 2-hour scenarios based on materials collected in field exercises were used in assessing operator performance in detecting vehicular targets under the experimental conditions described above. Fixed- and rotary-wing aircraft activity, artillery shell bursts, and random noise were included in the scenarios to help ensure operational realism. Twenty-four school-trained UGS operators participated in testing under the experimental conditions. An additional eight operators serving as a control group were not given the special training.

Findings:

Row patching was identified as the preferred technique; it resulted in fewer false alarms, greater accuracy in estimating target speed, and more efficient use of equipment. It was also preferred by more operators. The patching technique training significantly enhanced target detection from 36% to 51%, but did not reduce the number of false alarms. Operators indicated that all the job aids were useful, but that the scale on the ruler was of value only while they were gaining familiarity with the way the sensors were deployed in the grid. The percentage of targets detected under the low-target-activity condition was twice that detected under the high-target-activity condition. Use of the 9-sensor grid resulted in the same detection performance and half the number of false alarms as use of the 24-sensor grid.

Utilization of Findings:

The row patching technique is preferred for field use with operators trained in the patching technique. If the operators have not had such training, and if operational conditions require a higher detection rate in spite of a possible increase in false alarm rate, the column patching technique is preferred.

For detecting vehicular activity, the 9-sensor grid (500-m spacing between seismic sensors or MINISIDS) is preferred to the 24-sensor grid (250-m spacing). This preference exists in view of the similarity of results, and considering cost and equipment availability and occasional reduction in the number of false alarms.

If high target activity is observed, procedural changes should be made (such as assigning additional operators or increasing the number of targets estimated by intelligence analysts). Training in the use of the patching technique and associated job aids should be incorporated in the UGS school content at Fort Huachuca. Knowledge of the system's capability can be useful to intelligence officers in the selection and utilization of field personnel to enhance the reconnaissance resources of the Army.

An error analysis should be conducted and a training package should be developed and validated, to increase the detection completeness to higher levels, reduce speed calculation error, and reduce error in determining target direction.

OPTIMUM PATCHING TECHNIQUE FOR SEISMIC SENSORS EMPLOYED IN A GRID

CONTENTS

	Page
BACKGROUND	1
OBJECTIVES	4
METHOD OF INVESTIGATION	5
Population and Sample	5
Patching Techniques and Job Aids	5
Independent Variables	9
Dependent Variables	10
Operator Training and Job Aids	12
Research Design	13
Apparatus	15
Test Procedure	15
RESULTS	18
Value of Training	18
Evaluation of Patching Techniques	23
Accuracy of Target Detection	27
Identification of the Optimum Patching Technique	32
CONCLUSIONS	34
Optimum Patching Technique	34
Value of the Training	34
Interpretation Job Aids	34
Sensor Density and Target Activity Effects	35
Field Performance Expectations	35
APPENDIX A. SKETCH MAPS AND X-T PLOTS	37
B. TARGET QUALITY DISTRIBUTION--NORFOLK SCENARIOS	55
C. ORIENTATION BRIEFING	57
D. INTRODUCTION TO THE GRID EMPLOYMENT PATTERN (LECTURE/DISCUSSION)	59
E. TEST PROCEDURE TRAINING	63

Page

APPENDIX F. ROW PATCHING TECHNIQUE TRAINING 71

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LIST OF TABLES

Table 1. Research design 14

2. Schedule of administration on-site (Fort Hood) 16

3. Analysis of variance summary table for pre- and posttest detection completeness 19

4. Duncan's Multiple Range Test for comparison of patching techniques 20

5. Operator detection completeness for patching technique and pre-/posttest 20

6. Analysis of variance summary table for pre-/posttest false alarms 21

7. Operator average false alarms for patching technique and pre-/posttest 21

8. Average completeness of detection for control group operators 22

9. Control group operator average false alarms 23

10. Analysis of variance summary table for detection completeness--comparison of patching techniques 24

11. Analysis of variance summary table for false alarms--comparison of patching techniques 26

12. Average number of false alarms per half hour by grid density and patching technique 28

13. Duncan's Multiple Range Test for patching technique comparison--9-sensor grid 28

14. Duncan's Multiple Range Test for patching technique comparison--24-sensor grid 29

15. Average number of false alarms by target activity and sensor density per half hour 29

Page

16. Analysis of variance summary table for direction deviation--evaluation of patching technique 30

17. Speed deviation scores for patching technique x grid density x target activity (m/minute) 31

18. Friedman's analysis of variance by rank on operator confidence 33

19. Expected completeness detection performance by grid density, target activity level, and patching technique 36

20. Expected detection accuracy performance by grid density, target activity level, and patching technique 36

LIST OF FIGURES

Figure 1. Example of a 9-sensor grid used at a natural chokepoint. 3

OPTIMUM PATCHING TECHNIQUE FOR SEISMIC SENSORS EMPLOYED IN A GRID

BACKGROUND

Unattended ground sensors (UGS) represent part of the Army's capability for detecting and locating enemy activity at a remote location. UGS can be used alone or combined with ground-surveillance radars, night-vision devices, aerial surveillance--side-looking airborne radar (SLAR), infrared (IR), photography, and visual--signal intelligence, patrols, and observation and listening posts to produce timely and reliable intelligence information. Several types of UGS are in the Army inventory and are categorized according to the method of remote sensing: seismic, acoustic, magnetic, electromagnetic, and infrared. UGS are tactically employed for offensive and defensive operations by units ranging from small independent patrols to full divisions.[1]

Offensive operations include the following activities:

1. Target acquisition: The sensor's real-time detection capability leads to immediate reaction.

2. Landing (drop) zone monitoring: Sensors monitor enemy activity for future airmobile assault.

3. Combat sweep: Sensors monitor enemy withdrawal or attack activity.

4. Ambush: Sensors establish enemy habits, and are employed with a remote firing device and command-detonated mines.

Defensive operations are used for the following purposes:

1. Base camp defense: Sensors provide warning of enemy presence, and extend the listening post/observation post detection range.

2. Convoy security: Sensors provide ambush detection and warning.

3. Border surveillance: Sensors provide warning of enemy presence and fire control information for real-time reaction.

---

[1] USA Operational and Tactical Concepts for Employment of Unattended Ground Sensors. United States Army Combat Surveillance and Electronic Warfare (USACSEW) School, Fort Huachuca, Ariz. ST-30-20-2. February 1971.

4. Beach defense: Sensors provide warning of counterattack in beachhead situations.

UGS can be employed in three ways: string, grid, and alerting. In the string employment, the sensors are employed along a potential transportation route--land or water. Whether sensors are hand emplaced or air delivered, the objective is to implant them accurately so that their location with respect to the route and their separation distances are known. This precaution enhances the manual readout function by permitting relatively accurate information as to the direction, speed, and length of column to be derived from the sensor activation patterns. If hand emplaced, the sensor can be accurately located on a map and "seated" properly in the ground. Enemy movement is expected to be along the route(s) and direction(s) identified. Various combinations and mixes of sensor types have been field tested by the Army.

In the grid employment (sometimes called field, belt, gate, or gate array), UGS are deployed in a regularly spaced, two-dimensional pattern to cover a given geographical area or field (Figure 1). The grid is normally used in defensive operations such as early warning and combat surveillance. Whether hand emplaced or air delivered, the objective is to implant the sensors so that their locations are known and ground distances between the sensors are about equal. Hand emplacement is best for accurate sensor location and proper seating. The grid is designed to maximize the probability of detecting and acquiring enemy forces intruding in any portion or from any direction within a large area (several square kilometers). Because the path of the target is estimated, the operator can make only gross estimates of speed. Until special operator training procedures and job aids are developed, the accuracy of estimates of speed, direction, and number of targets will be below that usually obtained with the string employment of UGS.

In the alerting employment, UGS are used to cover a given route or ground area. For various reasons, however, their exact locations and the ground distances between them are not accurately known. This situation can occur from an inaccurate string or grid employment, as when sensors are delivered by mortar or artillery in areas controlled by enemy forces or when sensors have been air delivered under poor visibility conditions. Whatever the cause, the operator knows only the approximate location of the sensors. The presence of activity can be reliably detected, but additional information such as speed, number of targets, and direction cannot be computed accurately.

The U.S. Intelligence Center and School teaches the string and alerting concepts. Other than providing a brief overview, however, the school does not train students on monitoring and interpretation procedures for the grid type of employment. In the past, UGS operators were not likely to encounter grid monitoring situations. However, because of the shift in emphasis from the Southeast Asia type of conflict, the possibility of grid applications in area intrusion situations has increased.

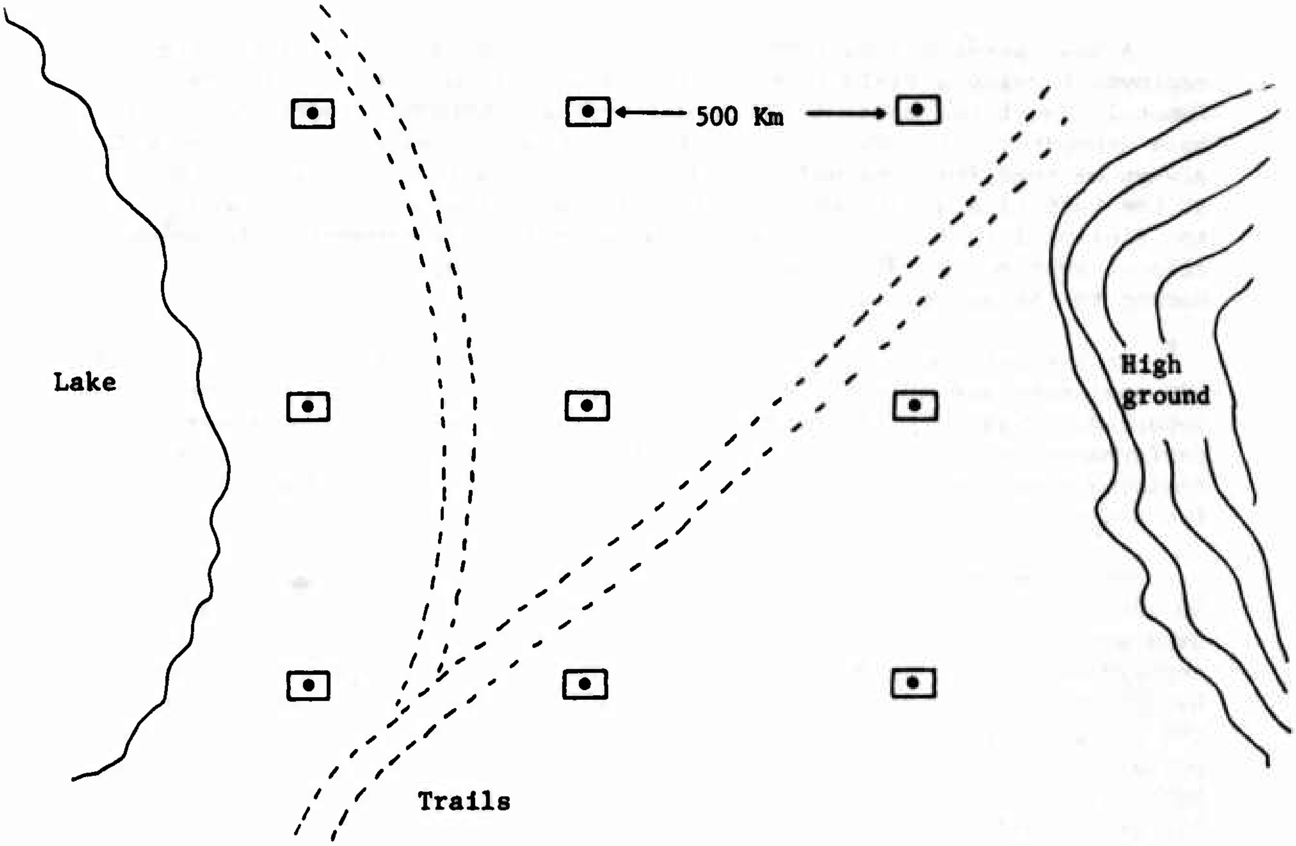

Figure 1. Example of a 9-sensor grid used at a natural chokepoint.

A UGS operator (MOS 17M20) should be qualified to work with grid employment using a field tactical recorder. Although by the 1980's the Remotely Monitored Battlefield Sensor System (REMBASS) program may automate (computerize) target readout functions at division level, there will always be need for a manual readout capability using tactical recorders at the battalion and brigade levels. The main reason for this need is the flexibility of transporting and using current equipment. The manual readout system also will always be needed at the division level as a backup to the automated system.

At present, only one research effort to find how well school-trained UGS operators are able to perform with grid arrays is known to have been reported. This work[2] determined that there was relatively poor operator performance and suggested the need for research on readout techniques, training requirements, operator performance parameters, and patching techniques.

The assignment of sensors in the field to pens or columns on the RO 376 tactical recorder is called patching. The patching technique used with grid employment is more complicated than that used with string employment because a two-dimensional array of sensors must be represented by essentially one dimension (the columns) on the RO 376. Sensors in the field can be assigned pens on the readout display in many ways, especially as the number of sensors increases. One particular arrangement might aid the operator with one task, and another arrangement might interfere or detract. Research was needed to determine whether there is a patching technique that will optimize operator performance.

Performance parameters of UGS operators in a variety of situations must be investigated for two major reasons: (a) to provide the commander with an assessment of the value of information generated by UGS under operationally relevant target conditions, and (b) to provide guidelines for improving operator target reporting performance.

OBJECTIVES

Specific objectives of the present research are as follows:

1. To define alternative sensor patching techniques for use with the grid employment of sensors and determine which technique enhances operator performance the most,

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[2] Edwards, L. R., Rochford, D. S., and Shvern, U. Comparison of Four Unattended Ground Sensor Displays. ARI Technical Paper 281, April 1977. (NTIS No. AD A039 056)

2. To determine whether basic specialized training in patching techniques will enhance operator performance in interpreting returns from seismic sensors employed in a grid array,

3. To develop interpretation job aids to assist the operator,

4. To determine the effects on operator performance of two levels of sensor density in a grid and two levels of target activity,

5. To determine the interaction of patching techniques with sensor density in a grid and target activity,

6. To provide estimates of the completeness and accuracy a commander can expect from relatively untrained and inexperienced operators when they interpret activations of sensors employed in a grid array, and

7. To determine how these estimates vary for two levels of sensor density in a grid and two levels of target activity.

METHOD OF INVESTIGATION

Population and Sample

The population of concern was the Army enlisted UGS operator (MOS 17M20) trained at the U.S. Army Intelligence Center and School at Fort Huachuca, Ariz. Thirty-two enlisted UGS operators of the 163d Military Intelligence Battalion stationed at Fort Hood, Tex., served as UGS operators for the research.

Patching Techniques and Job Aids

Four patching techniques were developed for investigation after consideration of Army employment methodology and the characteristics of the sensor activation records available. The records had been collected at Fort Bragg in 1973 during a test of a UGS system. For this field exercise, sensors had been arranged symmetrically within a square grid, 1,000 m on a side. The target runs always started at the top or bottom, never on the sides, and passed through the entire grid. Many of the employment techniques mentioned previously are adaptable to such a grid, and the results of testing could be generalized to them. From the point of view of Army employment methodology, it was decided to include the column, perimeter, row, and zone patching concepts.

Column Patching Technique. For this technique, a string concept was desired in which sensors are employed in vertical columns parallel to the direction of expected enemy approach. Depending on the path, a target passing through or around the grid activates sensors in the columns as though the sensors are deployed along a roadway. Each column is patched to the pens on the RO 376 recorder systematically: The column 1 sensors are patched first, starting at the left side of the recorder with pen 1; the column 2 sensors are patched next, etc. The sensors are numbered in columns on the sketch map used by the operator. Such a sketch map or grid is shown in Appendix A (Figure A-1). As shown,

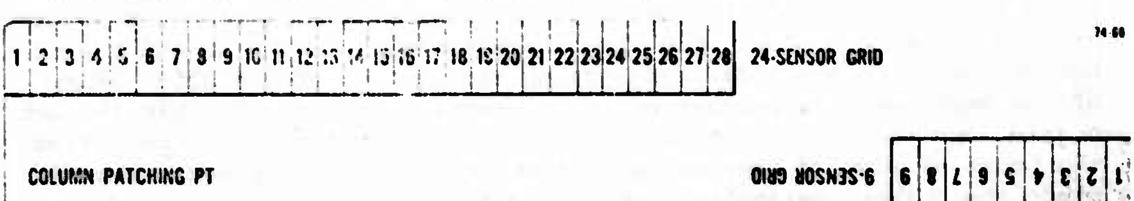
Column I is composed of sensors 1, 2, and 3;
Column II is composed of sensors 4, 5, and 6; and
Column III is composed of sensors 7, 8, and 9.

The sensor activations associated with the target paths drawn on this grid are presented in the X-T plot (Figure A-2). Normally, the UGS operator would analyze the activations first, then draw the target paths on the grid. In the present application, the order of procedure is reversed for purposes of discussion.

Figure A-3 is an example of the column patching technique in which 24 sensors instead of 9 are involved. The activations associated with the target paths drawn on this grid are presented in the X-T plot (Figure A-4). Because of the manner in which these sensors were deployed, it was necessary to patch four of the sensors so that they appear twice on the X-T plot. As is apparent from Figure A-3, sensors 2 and 7 are associated with the same sensor. The same relationship exists with 8 and 13, 14 and 19, and 20 and 25. As shown,

Column I is composed of sensors 1, 2, 3, 4, and 5;
Column II is composed of sensors 6, 7, 8, 9, 10, and 11;
Column III is composed of sensors 12, 13, 14, 15, 16, and 17;
Column IV is composed of sensors 18, 19, 20, 21, 22, and 23; and
Column V is composed of sensors 24, 25, 26, 27, and 28.

To assist the operator in determining quickly which pens were associated with which columns, a ruler was developed that could be placed directly on the X-T plot. The calibrations on the ruler correspond directly with the pens on the recorder. The ruler is called the UGS ruler. As shown below, one side of the ruler has a 24-pen (sensor grid) scale and the other a 9-pen (sensor grid) scale. One objective of the research was to assess the value of this job aid.



<u>Perimeter Patching Technique</u>. A perimeter concept was desired to which sensors are deployed as several separate perimeters surrounding a central point. Each perimeter is patched to the pens of the recorder systematically: The outer perimeter sensors are patched first, then the

inner perimeter sensors, then a central solitary sensor. The pens coinciding with the outer perimeter of sensors show in a concentrated space on the X-T plot the first indication of a target passing through the field. Any target that enters this grid must pass through or around one or more of these perimeters.

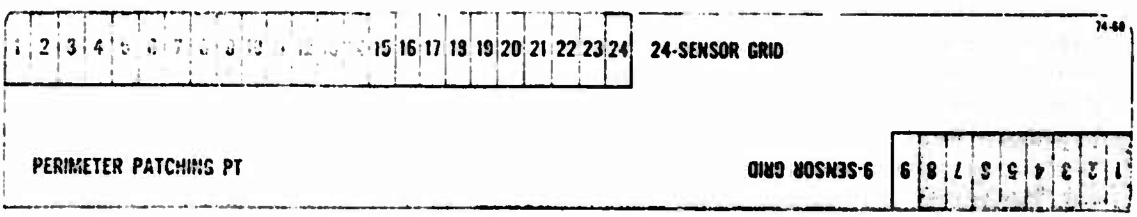
An example of the perimeter patching technique for a 9-sensor grid shows how the sensors are numbered throughout the grid (Figure A-5). The sensor activations resulting when targets traverse the 9-sensor grid are presented on the X-T plot of Figure A-6. As shown,

Perimeter I is composed of sensors 1-8, and
Perimeter II is composed of sensor 9.

An example of the perimeter patching technique for a 24-sensor grid showing how the sensors are numbered throughout the grid is presented in Figure A-7. The X-T plot is presented in Figure A-8. As shown,

Perimeter I is composed of sensors 1-14,
Perimeter II is composed of sensors 15-23, and
Perimeter III is composed of sensor 24.

The ruler for the 24-pen scale and the 9-pen scale of the perimeter patching technique is shown below.



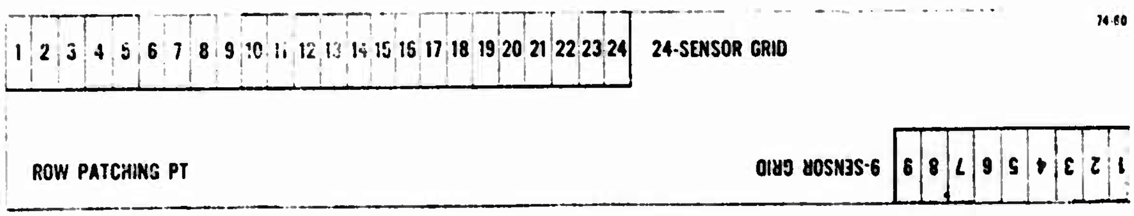
<u>Row Patching Technique</u>. In the row concept, sensors are deployed in successive lines perpendicular to the expected direction of enemy attack. As a target penetrates successive rows, additional information about the target becomes available. Any target entering or leaving the grid or going around the side of the grid must activate sensors in one or more rows. The sensors are patched to the recorder systematically: Row 1 sensors are patched first, starting at the left side; row 2 sensors are patched next, etc. An example of the row patching technique for a 9-sensor grid shows how the sensors are numbered within the grid (Figure A-9). The X-T plot for the 9-sensor grid is presented in Figure A-10. As shown,

Row I is composed of sensors 1, 2, and 3;
Row II is composed of sensors 4, 5, and 6; and
Row III is composed of sensors 7, 8, and 9.

An example of the row matching technique (24-sensor grid) shows how the sensors are employed within the grid (Figure A-11). The activations formed from the target paths shown on the 24-sensor grid are presented on the X-T plot (Figure A-12). As shown,

Row I is composed of sensors 1, 2, 3, 4, and 5;
Row II is composed of sensors 6, 7, 8, and 9;
Row III is composed of sensors 10, 11, 12, 13, and 14;
Row IV is composed of sensors 15, 16, 17, 18, and 19; and
Row V is composed of sensors 20, 21, 22, 23, and 24.

The ruler for the 24-pen scale and the 9-pen scale of the row patching technique is shown below.



Zone Patching Technique. In the zone concept, sensors are patched to portray distinguishable areas or zones adjacent to each other. By knowing the location of the zones, an operator can trace the path of a target from one zone to another (e.g., in border surveillance). Each sensor within each zone is patched to the pens of the recorder in clockwise order: Zone 1 sensors are patched first, starting with pen 1 of the recorder; zone 2 sensors are patched second, etc. An example of this zone patching technique for a 9-sensor grid shows how the sensors are numbered throughout the grid (Figure A-13). The sensor activations resulting from targets traversing the paths shown on the 9-sensor grid are presented on the X-T plot of Figure A-14. As can be seen on the 9-sensor grid,

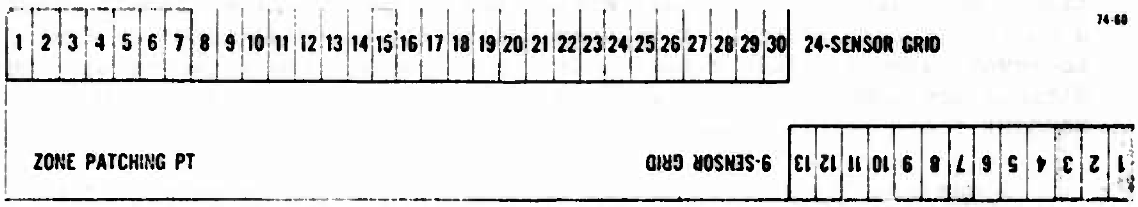
Zone I is composed of sensors 1, 2, and 3;
Zone II is composed of sensors 4, 5, and 6;
Zone III is composed of sensor 7;
Zone IV is composed of sensors 8, 9, and 10; and
Zone V is composed of sensors 11, 12, and 13.

Figure A-15 is an example of the zone patching technique for a 24-sensor grid. Figure A-16 presents the corresponding X-T plot. As can be seen on the 24-sensor grid,

Zone I is composed of sensors 1, 2, 3, 4, 5, 6, and 7;
Zone II is composed of sensors 8, 9, 10, 11, 12, 13, and 14;
Zone III is composed of sensor 15,
Zone IV is composed of sensors 16, 17, 18, 19, 20, 21, and 22; and
Zone V is composed of sensors 23, 24, 25, 26, 27, 28, 29, and 30.

In both grids, some sensors were patched twice because of the geographical location of the sensors.

The 24-pen scale and the 9-pen scale of the ruler for the zone patching technique are shown below.



Independent Variables

In addition to the patching technique (the primary independent variable in the present research), additional independent variables were training effects, sensor grid density, target activity, and scenarios.

Training Effects. Comparison of operator performance before training (Pretest) and after training (posttest) shows the effect attributable to training in patching techniques. This variable was used only to determine the need for a patching technique and associated training and for operator aids when sensors are employed in a grid configuration.

Sensor Grid Density (Two Levels). Sensor grid density refers to the number of sensors placed within a 1 km^2 ground area. Two sensor densities were used: one in which 9 sensors were spaced 500 m apart and one in which 24 sensors were spaced about 250 m apart. The two levels involved similar geometrical patterns using the same sensors and forming a 1 km^2. Other grid density patterns that might have been selected would not have resulted in symmetrical sensor patterns for both conditions. Symmetry was required for efficient use of sensors and for easy computation of speed and target density.

With respect to string emplacement standards, a 250-m and even a 500-m ground separation between sensors is not large. With respect to a grid, however, a smaller separation distance may help in tracing a target's path through the grid to determine direction. Determining a target's path and direction from a grid pattern requires a more detailed analysis of sensor activation than does making this determination from the string employment along a trail. Placing sensors closer together on the ground provides closer activation patterns and may help the operator determine path and direction. Determining whether an operator can extract more information from a 250-m separation or a 500-m separation is important from the standpoint of cost, emplacement time, manpower commitment, sensor availability, and equipment reliability.

Target Activity (Two Levels). Target activity was operationally defined as the number of distinguishable activation patterns appearing on the readout display within a given period of time. Each distinguishable activation pattern is a target that represents one or more vehicles in a column. Two levels of target activity (low and high) were tested to permit application of the results to more than one battlefield condition. Low target activity was designated as two or three targets within a half-hour time period. High target activity was designated as five to seven targets within a half-hour time segment. These two target conditions are consistent with a discussion of the topic in a Fort Hood MASSTER field report[3] (see footnote 2).

Scenarios (Five). To assess objectively the performance of the operators, five 2-hour scenarios were developed from sensor activations collected using operational equipment in the field at Fort Bragg. The activations were recorded on tapes, and included activation patterns produced by armored vehicles and wheeled vehicles and by typical environmental, artillery, and aircraft noise. Since this was a controlled exercise, target location and time were known and could be related to sensor activations in developing school solutions. To select target activation patterns for the scenarios, monitor performance (Appendix B) on 113 of the targets used in previous research (Edwards et al., 1977) was analyzed to determine the level of difficulty (p value) for each of the targets. Targets were selected to provide a realistic range of difficulty. No changes were made to the original target activation patterns.

To satisfy the requirements for five 2-hour scenarios, 43 different targets were selected. These 43 targets were presented to the operator twice, once as they had been taped originally and once with the sensor field rotated 180 degrees so that the activation patterns would not be recognized. Each 2-hour scenario was developed to contain a systematic arrangement of the two sensor grid densities and the two target activity conditions. Each scenario contained four 30-minute segments, and each segment contained one sensor grid density and one target activity condition. Each scenario was produced in four variations, representing the four sequences or orders of grid and target activity conditions.

Dependent Variables

Analysis was in terms of the dependent variables--detection completeness, false alarms, target direction, target speed, and confidence.

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[3] USA Armored Cavalry Troop Test Report, Vol. III. HQ, Modern Army Selected Systems Test and Evaluation (MASSTER) at Fort Hood, Tex., January 1972.

Detection Completeness. If an operator reported a target in the scenario when the records (ground truth) of the Fort Bragg exercise indicated that a target should have been causing activations of the designated pens, the response was classified as a correct detection. Detection results are reported as detection completeness (i.e., the number of correct detections divided by the number of targets presented x 100).

False Alarm(s). If an operator reported a target in the scenario when no target was causing activations of the designated pens, the response was classified as a false alarm. In addition, if an operator reported two or more targets on the same pen when in actuality there was only one, any additional response was classified as a false alarm.

Target Direction. When the direction and speed of a target as it leaves the grid area are known, an estimate can be made of its location later. Because such information is useful to the Army field commander, direction deviation scores were analyzed. A school-solution direction was compared to the operator's estimated direction of a target path at the point where it left the grid. An 18-point sector scale was used, each sector being 10°. The operator's response was scored as zero degrees if the target path that he drew was in the right sector. If the target path was drawn in a sector other than the school-solution sector, a deviation score was determined--expressed as the number of sectors of deviation, in absolute units. Thus, a high score indicated poor performance. If a target was reported as heading north when in fact it was heading south, a deviation score of 18 (180°) was assigned.

Caution should be exercised in generalizing results of target direction estimates to the operational situation. Because of the space restraints in the area assigned for the collection of sensor activation data at Fort Bragg, most targets, after passing through the grid, were required to travel along a trail running parallel to the last row of the grid and approximately 100 to 200 m from it. Thus, most of the targets activated the last row of sensors, which resulted in a target path through the grid and then along the bottom of the grid. Estimates of direction were thus more difficult to calculate than if the target had kept going straight, as would normally occur in most operational situations.

Target Speed. Deviation scores were computed for target speed by comparing the operator's responses with estimates based on known starting times and true paths of vehicles traversing the grid. If a correct speed (in m/min) was given, a score of zero deviation resulted. For an incorrect score, the absolute deviation in m/min from the school solution was determined.

Confidence. The operator was asked to rate his confidence on a 4-point scale (25%, 50%, 75%, and 100%) that the activation pattern he was reporting on was a valid target pattern. Operator confidence on valid targets was compared with operator confidence on false targets. A confidence differential was obtained by subtracting average confidence on the false alarms from the average confidence on the right detections. A high score indicated that the operator's confidence rating was a valid measure.

Operator Training and Job Aids

The participating operators had all graduated from the U.S. Army Intelligence Center and School at Fort Huachuca. However, they were not familiar with use of the grid deployment, test procedures, or patching techniques. None was familiar with the job aids to be tested. It was necessary, therefore, to train the operators to a reasonable level of skill in these operations. For this reason, a four-part familiarization/training package was developed:

Part I--Orientation Briefing (Lecture) (Appendix C)

Part II--Introduction to the Grid Deployment Pattern (Blackboard Lecture/Discussion) (Appendix D)

Part III--Test Procedure Training (Self-paced Workbook/Supervisor Guidance) (Appendix E)

Part IV--The Grid Deployment of Seismic Sensors Using (Column/Row Perimeter/Zero) Patching (Self-paced Workbook/Supervised Guidance) (Appendix F)

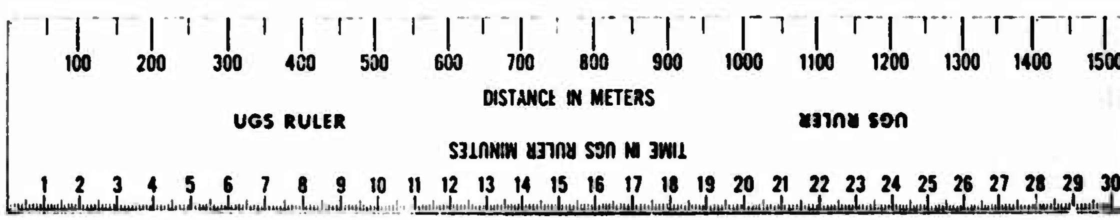
The orientation briefing (part I) was given by the instructor to give the operators an idea of what the exercises involved. The grid deployment familiarization (part II) was designed to acquaint the operators with the UGS grid. The instructor presented several target intrusion situations on the blackboard to illustrate basic differences and similarities between string and grid deployment.

The test procedure training (part III) was intended to teach the operators the procedures expected of them and the use of the target reporting forms (target logs). The target log has a sensor grid sketch in the top half and the seven-step reporting procedure in the bottom half. The seven-step reporting procedure is a job aid in that it tells the operator what information he is to provide. Functionally, it simulates the reporting requirement of the field commander. Included in this self-paced training is a discussion of a speed table--also a job aid. Use of the speed table eliminates arithmetic errors commonly made by operators. The speed table and instructions for its use are presented in Appendix E.

For each patching technique, a training workbook (part IV) was prepared. Section I deals with the 24-sensor grid condition and section II with the 9-sensor grid condition. Each section addresses the following questions:

What is the (column, perimeter, row, and zone) patching technique?
How do you detect targets?
 a. <u>Example 1--Target 1</u>
 b. <u>Example 2--Target 2</u>
 c. <u>Example 3--Target 3</u>
How do you estimate distance?
How do you determine the midpoint time difference?
How do you calculate speed?
How do you determine target type?
Practice targets (with X-T plots).

The training workbook for the row patching technique is presented in Appendix F. In addition to the 24-pen and 9-pen measurement scales, the UGS ruler has two additional scales (on the other side of the ruler) as shown below:



The top scale shown is a distance-in-meters scale and is used to measure the distance covered by a target with the 1,000-m square grid on a scale from 0 to 1,500 m. The bottom scale is a time-in-UGS-ruler-minutes scale used to measure activation midpoint time differences on a scale from 0 to 30 minutes. Use of all the scales on the UGS ruler as explained to the operators is discussed in Appendix F.

Research Design

The research design is presented in Table 1. Two evaluations were undertaken: (a) a pretest and a posttest comparison to determine the value of patching technique training; and (b) a comparison of the effectiveness of four patching techniques, performed with the intention of selecting one for further experimentation and operational use.

<u>Value of Training</u>. The following independent variables were analyzed for both detection completeness and false alarms: pretest/posttest performance (2), patching techniques (4), scenarios (2), scenario-order effects (2), groups (4), and interactions of sessions and scenarios with patching techniques. Scenarios A and B were counterbalanced within each

Table 1

Research Design

EVALUATION I (Value of Training)				EVALUATION II (Patching Technique Comparison)		
OPERATORS	PRETEST Session 1 Seq. I*	TRG	POSTTEST Session 2 Scen A+B Seq. I *	Session 3 Scen C(18T) Seq. II *	Session 4 Scen D(17T) Seq. III *	Session 5 Scen E(19T) Seq. IV *
	PT I		PT I	PT II	PT III	PT IV
1,2,3	Scen A		Scen B			
4,5,6	Scen B		Scen A			
	PT II		PT II	PT III	PT IV	PT I
7,8,9	Scen A		Scen B			
10,11,12	Scen B		Scen A			
	PT III		PT III	PT IV	PT I	PT II
13,14,15	Scen A		Scen B			
16,17,18	Scen B		Scen A			
	PT IV		PT IV	PT I	PT II	PT III
19,20,21	Scen A		Scen B			
22,23,24	Scen B		Scen A			
		No TRG				
25,29	PT I-A		PT I - B			
26,30	PT II - A		PT II - B			
27,31	PT III - B		PT III - A			
28,32	PT IV - B		PT IV - A			

* Scenario Sequences - four 30 minute target tapes

Sequence I

1 High Act, 9-sensor grid
2 Low Act, "
3 High Act, 24-sensor grid
4 Low Act, "

Sequence II

4 Low Act, 24-sensor grid
1 High Act, "
2 Low Act, 9-sensor grid
3 High Act, "

Sequence III

2 Low Act, 9-sensor grid
1 High Act, "
4 Low Act, 24-sensor grid
3 High Act, "

Sequence IV

1 High Act, 24-sensor grid
4 Low Act, "
3 High Act, 9-sensor grid
2 Low Act, "

patching technique investigated to control for scenario effects (Table 1). The experimental design used to evaluate the effects of training was a single Latin Square replicated on the between-subjects factor of patching techniques (I, II, III, IV). The Latin Square factors were scenarios A and B and training. The primary reason for analyzing the patching techniques and the scenario variability was to reduce the size of the error term for the pretest/posttest comparison. The purpose was not to provide a conclusive test of the comparative value of the patching techniques--the purpose of a separate evaluation--but to investigate the value of training for a representative sampling of all the patching techniques combined on the basis of detection completeness and false alarms.

Comparison of Patching Techniques. The following independent variables were analyzed for all the dependent variables: patching technique (4), sensor grid density (2), target density (2), and all interactions between the three variables. The groups, scenario main effects, and interactions involving scenario were analyzed to reduce the error variance. There was no interpretation of the scenario effect because it is completely confounded with sessions and sequence (order) effects.

Apparatus

Twelve RO 376 tactical recorder simulators were used to display pretest and posttest UGS activation data previously recorded on RO 376 X-T plots. The simulators presented the X-T plots at a speed equivalent to that of an operational RO 376 event recorder (12 inches per hour).[4] The simulators used the same viewing area size as the RO 376. The X-T plots were therefore presented with the same speed and format they would have in a field situation.

Test Procedure

The training and test schedule on a daily basis is presented in Table 2. Because only 12 RO 376 simulators were available and 24 operators were required for experimental design reasons, it was necessary to divide the operators into two groups and alternate the training/test cycle. While one group was being trained, the other group was being tested.

During the morning of the first day, the first group of operators (odd-numbered) was given a 30-minute familiarization briefing and a 90-minute program of instruction and practice on the test procedure. During this time, questions were answered and response feedback was given. A 2-hour uninterrupted pretest was then administered requiring

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[4] Operator and Organization Maintenance Manual for Recorder, Signal Data RO 376/UGQ Resdel Model No. 91662-1, DAAB07-69-0195, June 1969.

Table 2

Schedule of Administration On-Site (Fort Hood)

DAY 1 (Tues)

AM

Orientation and Grid Briefing 8:00-8:30

Test Procedure Training 8:30-10:00

Pretest (Session 1) 10:00-12:00

12 Drive Mechanisms
10 Scenarios

Op 1, 3, 5	PT-I	Row Patching
Op 7, 9, 11	PT-II	Lane Patching
Op 13, 15, 17	PT-III	Per Patching
Op 19, 21, 23	PT-IV	Zone Patching

PM

Training (Session 2) 1:30-4:00
No Drive Mechanisms

Op 1, 3, 5	PT-I
Op 7, 9, 11	PT-II
Op 13, 15, 17	PT-III
Op 19, 21, 23	PT-IV

Orientation and Grid Briefing
1:30-2:00
Test Procedure Trg 1:30-2:00
Pretest (Session 1) 2:00-4:00
12 Drive Mechanisms
12 Scenarios

Op 2, 4, 6	PT-I
Op 8, 10, 12	PT-II
Op 14, 16, 18	PT-III
Op 20, 22, 24	PT-IV

DAY 2 (Wed)

AM

Posttest (Session 2) 8:00-11:00
12 Drive Mechanisms

Op 1, 3, 5	PT-I
Op 7, 9, 11	PT-II
Op 13, 15, 17	PT-III
Op 19, 21, 23	PT-IV

Training (Room 2) 8:00-11:00
No Drive Mechanisms

Op 2, 4, 6	PT-I
Op 8, 10, 12	PT-II
Op 14, 16, 18	PT-III
Op 20, 22, 24	PT-IV

PM

Training (Session 3) 1:00-4:00
No Drive Mechanisms

Op 1, 3, 5	PT-II
Op 7, 9, 11	PT-III
Op 13, 15, 17	PT-IV
Op 19, 21, 23	PT-I

Posttest (Session 2) 1:00-4:00
12 Drive Mechanisms

Op 2, 4, 6	PT-I
Op 8, 10, 12	PT-II
Op 14, 16, 18	PT-III
Op 20, 22, 24	PT-IV

DAY 3 (Thurs)

AM

Posttest (Session 3) 8:00-11:00

Op 1, 3, 5	PT-II
Op 7, 9, 11	PT-III
Op 13, 15, 17	PT-IV
Op 19, 21, 23	PT-I

Training (Session 3) 8:00-11:00

Op 2, 4, 6	PT-II
Op 8, 10, 12	PT-III
Op 14, 16, 18	PT-IV
Op 20, 22, 24	PT-I

DAY 3 (Thurs) cont.

PM

Training (Session 4)

Op 1, 3, 5	PT-III
Op 7, 9, 11	PT-IV
Op 13, 15, 17	PT-I
Op 19, 21, 23	PT-II

Posttest (Session 3) 1:00-4:00

Op 2, 4, 6	PT-II
Op 8, 10, 12	PT-III
Op 14, 16, 18	PT-IV
Op 20, 22, 24	PT-I

Day 4 (Fri)

AM

Posttest (Session 4) 8:00-11:00

Op 1, 3, 5	PT-III
Op 7, 9, 11	PT-IV
Op 13, 15, 17	PT-I
Op 19, 21, 23	PT-II

Training (Session 4) 8:00-11:00

Op 2, 4, 6	PT-III
Op 8, 10, 12	PT-IV
Op 14, 16, 18	PT-I
Op 20, 22, 24	PT-II

DAY 5 (Mon)

AM

Training (Session 5) 1:00-4:00

Op 1, 3, 5	PT-IV
Op 7, 9, 11	PT-I
Op 13, 15, 17	PT-II
Op 19, 21, 23	PT-III

Posttest (Session 4) 1:00-4:00

Op 2, 4, 6	PT-III
Op 8, 10, 12	PT-IV
Op 14, 16, 18	PT-I
Op 20, 22, 24	PT-II

PM

Posttest (Session 5) 8:00-11:00

Op 1, 3, 5	PT-IV
Op 7, 9, 11	PT-I
Op 13, 15, 17	PT-II
Op 19, 21, 23	PT-III

Training (Session 5) 1:00-4:00

Op 2, 4, 6	PT-IV
Op 8, 10, 12	PT-I
Op 14, 16, 18	PT-II
Op 20, 22, 24	PT-III

DAY 6 (Tues)

AM

Control Group

Orientation and Grid Briefing 8:00-8:30

Test Procedure Trg 8:30-10:00

Pretest 10:00-12:00

8 Drive Mechanisms
8 Scenarios

Posttest (Session 5)

Op 2, 4, 6	PT-IV
Op 8, 10, 12	PT-I
Op 14, 16, 18	PT-II
Op 20, 22, 24	PT-III

PM

Posttest (Session 5)

	PRE (AM)	POST (PM)	
25	PT I - A	PT I - B	Row
26	PT II - A	TPT II - B	Lane
27	PT III - A	PT III - B	Peri
28	PT IV - A	PT IV - B	Zone
29	PT I - B	PT I - A	Row
30	PT II - B	PT II - A	Lane
31	PT III - B	PT III - A	Peri
32	PT IV - B	PT IV - A	Zone

use of the 12 RO 376 simulators. During the afternoon session, each operator in this group was administered patching technique training as specified in the table. The training session did not require use of the RO 376 simulators. During the same afternoon session, the operators in the even-numbered group were administered the familiarization training and the pretest that the first group had received that morning.

During the morning of the second day, the odd-numbered group received the posttest (session 2) for the training that had been given the previous afternoon. The operators in the even-numbered group were given training. This procedure required a total of 5 days to complete test requirements.

During the testing, when operators thought they had detected a target, they annotated the test scenario by drawing a circle around the sensor activations that they felt constituted the target pattern and numbered the pattern. The circled patterns were consecutively numbered for all the targets detected in a particular 30-minute segment. After having recorded each target detection, the operator analyzed the target pattern and recorded the following information on the Target Log Sheet: direction of the target through the sensor field, midpoint (in minutes) of the first sensor activation and the last sensor activation, total time of first sensor activation, column length, time elapsed between the two midpoints, estimated distance, estimated speed, and confidence.

During the last day, a control group of eight operators was administered the pretest and posttest but received no training. Each operator in this group was tested on a separate patching technique to determine the effect, if any, of the 2-hour pretest and posttest exposure.

RESULTS

Value of Training

Completeness of Detection. A frequency polygon of the data was judged to approximately fit a normal curve (M = 43%; Mdn = 41%); the planned analysis of variance was therefore performed. The analysis of variance results for completeness of detection (detection rights/total possible) are presented in Table 3. Statistically significant effects were noted for patching technique and pretest/posttest. The significant pretest/posttest effect indicates that the patching technique training was effective in increasing operator completeness of detection. This increase from 36% to 51% represents an additional two targets per operator during a 2-hour period.

Although this increase has obvious practical value to the field commander, a 51% detection rate is still below the full potential of the UGS systems. This relatively low detection rate is probably due to the complexity of the operators' task of detecting and separating overlapping activations in heavy target activity situations and to their lack of exposure to the grid employment patterns of the type tested. Additional and more comprehensive training concerning the grid itself is needed if the grid employment pattern is to be used effectively in the field.

Table 3

Analysis of Variance Summary Table for Pre- and Posttest Detection Completeness

Source of variance	df	Sums of squares	Mean square	F	Significance level
Patching technique (T)	3	18,624.42	6,208.14	5.18	.05
Scenario order (A/B) (B/A)	1	494.09	494.09	.41	NS
Groups of subjects	3	5,297.08	1,765.69	1.48	NS
e_1	16	19,112.08	1,194.51		
Pre-/posttest (P/P)	1	9,576.75	9,576.75	20.46	.01
Scenario (S)	1	70.09	70.09	.15	NS
T X P/P	3	2,781.42	927.14	1.98	NS
T X S	3	2,943.41	981.14	2.10	NS
e_2	16	7,488.58	468.04		
Total	47	66,387.92			

The significant patching technique effect indicates that when the pretest and posttest results are averaged, the column patching technique results in significantly higher completeness results than any of the remaining three patching techniques (Table 4). During the operator debriefings, it became apparent that the operators did well with the column technique because it was most similar to the string technique they were familiar with. The averages by patching technique and pretest/posttest are given in Table 5.

<u>False Alarms</u>. A frequency polygon of the false alarm data, although moderately skewed to the right ($M = 2.6$; $Mdn = 1.5$), was judged acceptable for an analysis of variance (Table 6) to be conducted. The only effect approaching statistical significance was the patching technique. Since the significance level is only 10%, this result must be considered tentative. The average number of false alarms by patching technique and pre-/posttest results is shown in Table 7.

Table 4

Duncan's Multiple Range Test for Comparison of Patching Techniques

Means	Perimeter 32.4%	Zone 40.5%	Row 41.4%	Column 59.3%	Shortest significant range
32.4%		8.1	9.0	26.9*	$R_2 = 13.25$
40.5%			.9	18.8*	$R_3 = 13.90$
41.4%				17.9*	$R_4 = 14.30$

*$p < .05$.

Table 5

Operator Detection Completeness for Patching Technique and Pre-/Posttest

Test	Column %	Perimeter %	Row %	Zone %	Overall averages %
Pretest	59	22	31	33	36
Posttest	60	42	52	48	51
Averages	60	32	42	41	44

Table 6

Analysis of Variance Summary Table for Pre-/Posttest False Alarms

Source of variation	df	Sums of squares	Mean square	F	Significance level
Patching technique (T)	3	32.92	10.97	2.96	.10
Scenario order (A/B) (B/A)	1	.75	.75	.20	NS
Groups of subjects	3	14.92	4.97	1.28	NS
e_1	16	59.33	3.71		
Pre-/posttest (P/P)	1	1.34	1.34	1.01	NS
Scenario (S)	1	1.34	1.34	1.01	NS
T X P/Y	3	1.99	.66	.50	NS
T X S	3	1.99	.66	.50	NS
e_2	16	21.34	1.33		
Total	47	135.92			

Table 7

Operator Average False Alarms for Patching Technique and Pre-/Posttest

Test	Column	Perimeter	Row	Zone	Overall average
Pretest	2.8	.5	.8	1.7	1.5
Posttest	2.5	.5	.8	.7	1.1
Average	2.7	.5	.8	1.2	1.3

The number of false alarms was not reduced significantly by the training for any of the patching techniques tested. This result is not surprising--the training was not intended specifically to reduce the number of false alarms, and the false alarm rate was very low initially. To decrease the false alarm rate, an error analysis would have to be undertaken to develop an appropriate training package.

Control Group. A control group of eight operators was administered the test materials in the same fashion as the other operators except the control group was not given patching technique training. The purpose of using the control group was to determine the effect due to learning (or experience) resulting from initial exposure to scenario materials (i.e., pretest). If the control group showed no significant performance increase as a result of the pretest, then, for those groups that were trained, any performance increase observed in the posttest was attributed to the training and not to the experience derived from taking the pretest.

Table 8 summarizes the pretest/posttest completeness-of-detection results for each patching technique. The overall pretest and posttest averages are about 25%, indicating that no performance increase resulted as a function of the pretest exposures. The four patching techniques show only minor fluctuations between the pretest and posttest. For this reason, no statistical tests were computed.

Table 8

Average Completeness of Detection for Control Group Operators

Test	Column %	Perimeter %	Row %	Zone %	Overall averages %
Pretest	28	12	26	31	24
Posttest	28	16	24	35	26

Table 9 summarizes the pretest/posttest false alarm data for the control group. The pretest overall average was 1.0 and the posttest overall average was .4. Because of the small number of false alarms, an analysis to determine the statistical confidence of this drop could not be conducted. Also, it is apparent that the number of false alarms fluctuated from 0 to 2.5 within patching techniques. The control group analyses do not indicate that the practice gained by initial exposure to the scenarios (pretest condition) had a significant effect on the posttest. Thus, the increase in performance found previously from pretest to posttest is attributable to the patching technique training rather than to practice effects.

Table 9

Control Group Operator Average False Alarms

Test	Column	Perimeter	Row	Zone	Overall average
Pretest	1.0	.5	0	2.5	1.0
Posttest	0	1.0	.5	0	.4

Evaluation of Patching Techniques

Completeness of Detection. The task of scoring the detection rights was divided equally between two staff personnel prior to conversion of the data into completeness-of-detection percentages. To determine the reliability of this procedure for this and future research, the judges exchanged and independently rescored the material. A random sample of 63 pairs of scores yielded a product moment correlation coefficient of $r = +.87$, which was considered acceptable.[5] A frequency polygon of the data was judged to be a good approximation of a normal curve ($M = 37.0$; $Mdn = 36.5$). The planned analysis of variance was therefore conducted. The summary table is presented in Table 10. Target activity showed the only significant effect of importance. The scenario effect and scenario interaction effects, which were significant, are not easily interpretable because scenario effect is not a pure variable but a confounding between scenarios, sessions, and possible transfer of learning effects between patching techniques. Scenario effects alone do not have a direct bearing on the objectives of the present experiment. However, findings dealing with scenario effects may be important for future scenario development.

A significantly greater percentage of targets was detected in the low-target-activity condition (89%) than in the high (42%). This outcome indicates that operators are able to detect a greater percentage of targets when fewer targets are present; the reason is probably the increased difficulty of working with more targets and overlapping target activations caused by several targets passing through the grid at about the same time. Observations made during testing and posttest debriefings revealed that the operators found it difficult during these periods to differentiate the activations of one target from the activations of another target. In the low-target-activity condition, however, the task

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[5] Because of dichotomous data, the normal distribution assumption was questionable. Therefore, a fourfold point correlation coefficient was calculated at $r_p = +.86$, which again is acceptable.

Table 10

Analysis of Variance Summary Table for Detection Completeness--Comparison of Patching Techniques

Source of variance		df	Sums of squares	Mean square	F	Significance level
Between:	Groups	3	1,866.55	622.18	.60	NS
	(Subjects wG = e_1)	20	20,403.11	1,020.15		
Within:	Scenarios (S)	3	16,005.76	5,335.25	13.47	.01
	Patching technique (T)	3	2,893.86	964.62	2.43	NS
	$Residual_1$	6	3,611.40	601.90	1.51	NS
	e_2	60	23,763.48	396.05		
	Target activity (A)	1	203,044.01	203,044.01	663.80	.01
	Grid sensor density (D)	1	30.37	30.37	.90	NS
	A X D	1	88.17	88.17	.28	NS
	$Residual_2$	9	3,640.06	404.45	1.32	NS
	e_3	60	23,152.89	305.88		
	A X S	3	20,719.93	6,906.64	26.60	.01
	A X T	3	1,262.79	420.93	1.62	NS
	D X S	3	5,813.15	1,937.71	7.46	.01
	D X T	3	288.43	96.14	.37	NS
	A X D X S	3	7,013.02	2,337.67	9.00	.01
	A X D X T	3	1,847.71	615.90	2.37	NS
	$Residual_3$	18	8,618.28	478.79	1.84	.01
	e_4	180	46,736.19	259.64		
Total sum of squares		383	390,799.16			

of differentiating the activities of one target from those of another was simpler.

The two nonsignificant effects of importance were patching technique and grid sensor density. The patching techniques resulted in similar detection completeness results: column, 68%; row, 67%; perimeter, 61%; and zone, 65%. These results do not support expectations, based upon results from the evaluation of training effects, that showed a significantly higher detection rate for the column patching technique. Apparently, the training given on all patching techniques, plus the little experience gained in the first part of the experiment, was enough to counteract the initial advantage shown by the column patching technique.

No significant difference occurred for the sensor grid density variable. The 9-sensor grid condition resulted in 65% detection completeness, and the 24-sensor grid condition resulted in 68% detection completeness. These results indicate that seismic sensors (MINISIDS) employed 500 m apart in a 9-sensor grid result in the same target detection rate as sensors employed 250 m apart in a 24-sensor grid, and are considerably less expensive.

The significant interactions of the scenario variable with target activity and grid density (A X S, D X S, and A X D X S) indicate that differences between the 9-sensor and 24-sensor grid densities depend on which scenario or scenario target activity combinations occur. In some cases, use of the 9-sensor grid resulted in a higher detection completeness, but in others the opposite result was found. Since scenario effects cannot be defined for use in an operational situation, it must be concluded that, for the general case, there is no performance difference between the two grid densities. Similarly, the conclusion regarding target activity as stated above must apply in the general operational situation. The scenario results are of major importance only in that they show the need for controlling this variable in future research or operational tests.

False Alarms. A frequency polygon of the total false alarms per operator was judged (for 8 hours of work) to be an approximation of a normal curve (M = 5.8; Mdn = 5.5). The operators made a total of 139 false alarms. The analysis of variance results are shown in Table 11. The significant results of importance were for target density, density by patching technique interaction, target activity, and density by activity interaction.

The average number of false alarms reported by the operators was 3.875 for the 4 hours using the 24-sensor grid, and 1.875 using the 9-sensor grid. Use of the 9-sensor grid with 500-m spacing resulted in half the number of false alarms as use of the 24-sensor grid with 250-m spacing. It had been hypothesized that more sensors closer together might provide the operator with more information and therefore result in fewer false alarms. Instead, the additional sensor activations appear to have misled the operator into thinking that there were

Table 11

Analysis of Variance Summary Table for False Alarms--Comparison of Patching Techniques

Source of variation		df	Sums of squares	Mean square	F	Significance level
Between:	Groups	3	4.06	1.35	2.11	NS
	(Subject wG) = e_1	20	12.73	.64		
Within:	Scenario (S)	3	1.56	.52	.91	NS
	Technique (T)	3	2.64	.88	1.54	NS
	$Residual_1$	6	5.48	.91	1.60	NS
	e_2	60	33.94	.57		
	Activity (A)	1	1.76	1.76	6.52	.01
	Density (D)	1	6.00	6.00	22.22	.01
	A X D	1	1.50	1.50	5.56	.05
	$Residual_2$	9	9.42	1.05	3.89	.01
	e_3	60	15.94	.27		
	A X S	3	3.17	1.06	3.79	.05
	A X T	3	.22	.07	.25	NS
	D X S	3	2.39	.80	2.86	.05
	D X T	3	4.90	1.63	5.82	.01
	A X D X S	3	3.52	1.17	4.18	.01
	A X D X T	3	.48	.16	.57	NS
	$Residual_3$	18	5.98	.33	1.18	NS
	e_4	180	50.72	.28		
Total		383	166.41			

more targets in the area than actually existed. It might be possible to train the operators to use the inputs of the additional sensors, but these results show how operators performed with the training they already had received by the time of the present testing.

The significant density by patching technique interaction (Table 12) is of major importance. For the 9-sensor grid, row patching resulted in a significantly lower false alarm rate than did perimeter patching (Table 13). For the 24-sensor grid, the column patching resulted in a significantly higher false alarm rate than any of the other three patching techniques (Table 14). These results are consistent with those found in the evaluation of training effects.

The significant activity variable indicates that the low-target-activity condition resulted in a higher error rate (3.40 per operator per 4 hours) than the high-target-activity condition (2.32 per operator per 4 hours). The significant activity by density interaction presented in Table 15 indicates that this higher error rate is attributable to use of the 24-sensor grid.

Apparently, given more time to look for targets (as in low activity), the operators tended to find false ones in the more involved and confusing 24-sensor grid.

Accuracy of Target Detection

Detection rights and false alarms were combined for the purpose of computing accuracy values for each of the four patching techniques. Accuracy was computed using the formula detection rights divided by detection rights plus false alarms x 100%. The accuracy measure, therefore, answers the question, "Out of the total number of detections reported, what percentage was correct?" The following accuracy percentages were computed: column (89%), perimeter (90%), row (93%), and zone (91%).

Direction Deviation. The data were scored, and an interjudge reliability test was performed.[6] A frequency distribution of the data was judged to be an acceptable approximation to the normal curve to conduct an analysis of variance (M = 4.5 sectors; Mdn = 4.4 sectors). The summary is presented in Table 16.

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[6] The test was performed on a random sample of direction scores. The Pearson product moment correlation coefficient for 62 pairs of scores was calculated at r = +.86. This coefficient is high enough to recommend the same scoring procedure for future evaluations, although improvement is desirable.

Table 12

Average Number of False Alarms per Half Hour by Grid Density and Patching Technique

Grid density	Column	Perimeter	Zone	Row	Operator average for grid density
9-sensor	.18	.33	.29	.12	.23
24-sensor	.79	.33	.41	.39	.48
Average for patching technique	.48	.33	.35	.26	

Table 13

Duncan's Multiple Range Test for Patching Technique Comparison--9-Sensor Grid

Means	Row .12	Column .18	Zone .29	Perimeter .33	Shortest significant range
.12		.06	.17	.21*	$R_2 = .194$
.18			.11	.15	$R_3 = .204$
.29				.06	$R_4 = .211$

*$p < .05$.

Table 14

Duncan's Multiple Range Test for Patching Technique Comparison--24-Sensor Grid

Means	Perimeter .33	Row .39	Zone .41	Column .79	Shortest significant range
.33		.06	.08	.46*	R_2 = .194
.39			.02	.40*	R_3 = .204
.41				.38*	R_4 = .211

*$p < .05$.

Table 15

Average Number of False Alarms by Target Activity and Sensor Density per Half Hour

Grid density	Low activity	High activity	Operator average for grid densities
9-sensor	.24	.23	.23
24-sensor	.61	.35	.48
Average for activity	.43	.29	

Table 16

Analysis of Variance Summary Table for Direction Deviation--
Evaluation of Patching Technique

Source of variation		df	Sums of squares	Mean square	F	Significance level
Between:	Groups	3	19.57	6.52	.74	NS
	(Subjects wG) = e_1	20	176.36	8.82		
Within:	Target scenario (S)	3	23.65	7.88	1.87	NS
	Patching technique (T)	3	25.24	8.41	1.99	NS
	Residual	6	28.12	4.69	1.11	NS
	e_2	60	252.73	4.21		
	Grid sensor density (D)	1	.30	.30	.08	NS
	$Residual_2$	3	8.28	2.76	.73	NS
	e_3	20	76.10	3.80		
	D X S	3	15.08	5.03	2.36	NS
	D X T	3	3.15	1.05	.49	NS
	$Residual_3$	6	43.71	7.29	3.42	.01
	e_4	60	127.80	2.13		
Total		191	800.09			

The only significant effect found, the residual, indicates that a significant amount of unexplained variability is present. This variability may be the result of not analyzing (not subtracting out) the effect of the target activity variable that was such a strong variable in the detection completeness and false alarm analysis. In the present analysis, it was necessary to collapse the data across this variable to fill all the cells of the statistical design.

The nonsignificant patching technique effect indicates that the absolute deviation in the operators' reported target path was similar for all patching techniques. The mean deviation found (4.5 sectors, or 45°) is a substantial error if a target's future location is to be predicted. Since target direction assessment was not emphasized in the training provided as part of the present research, a future effort should determine whether significant improvement is possible if additional training is provided. As mentioned earlier, the results of target direction should be generalized to the operational situation with caution because of the atypical target paths required after the target has passed through the grid.

Target Speed. A frequency polygon of the data shows a marked positive skew with a bimodal tendency and was judged as not approximating the normal curve (M = 93.2 m/min; Mdn = 81.5 m/min). Mean performances are reported in Table 17 as a function of patching technique, grid density, and activity level. The larger the value in this table, the greater the deviation from the school solution. All values in the table are in m/min.

Table 17

Speed Deviation Scores for Patching Technique X Grid Density X Target Activity (m/min)

Technique	9-sensor grid Low	9-sensor grid High	24-sensor grid Low	24-sensor grid High	Overall averages
Row	87	86	88	106	92
Column	100	103	81	96	95
Perimeter	101	116	77	92	96
Zone	99	96	78	86	90
Overall averages	98	99	81	95	

The average deviations for the patching techniques varied between 90 m/min (2.8 miles/hr) and 96 m/min (3 miles/hr). The difference of 6 m/min, which is less than .2 miles/hr, was considered to be of little practical value.

The largest deviation difference in the table occurred in the 9-sensor-grid high-target-activity condition in which row patching resulted in a deviation of 86 m/min and perimeter patching in a deviation of 116 m/min. The difference is 30 m/min or roughly 1 mile/hr. It was decided that this variation in performance did not warrant the computation of an overall analysis of variance.

Operator Confidence. The confidence analysis was based on the difference between average confidence scores of right detections minus average confidence in false alarms. This approach depends on the assumption that the operators have false alarms in most or all cells of the experimental design. There were large differences in the number of false alarms made by various operators, and also a large number of unfilled cells. Only 23% of the cells of the experimental design held data. A t test calculated for the overall mean (20%), t = 2.67, was significantly different from zero at the .05 level, indicating that UGS operators can assess the probability that a target report is valid. Operators' confidence estimates could be used to lower the false alarm rate if higher accuracy is desired, but with some loss in the completeness of the report.

In view of the high number of cells with no data, the only way to tabulate the data so an analysis could be conducted was by patching technique and operator group (eight groups, three operators in a group). Results of a nonparametric test[7] conducted on the resultant data are presented in Table 18. The nonsignificant outcome indicates there is no difference between patching techniques in the confidence measure used.

Identification of the Optimum Patching Technique

Five dependent variables (completeness of detection, false alarms, direction deviation, speed deviation, and confidence) plus operator preference were considered in identifying the most favorable patching technique. After data collection had been completed, the operators were asked to name the one technique they preferred to work with. Operator preference showed the largest differences between patching techniques. Of the 24 operators participating, 11 preferred to work with the row patching technique, 9 with the column technique, and only 2 each

[7] Friedman's two-way analysis of variance, pages 166-172 in Siegel, S. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill Book Company, Inc., New York 1956.

with the perimeter and zone techniques. Since the zone and perimeter patching techniques had no compensating advantages from the results on the five dependent variables, they were considered for elimination. The zone technique has the additional disadvantage of requiring more pens and columns on the RO 376 recorder than do the other techniques. Use of the perimeter patching technique resulted in significantly more false alarms than did use of the row patching technique for the 9-sensor grid condition. For these reasons, the zone and perimeter patching techniques were eliminated from further consideration.

Table 18

Friedman's Analysis of Variance by Rank on Operator Confidence[a]

	Column	Perimeter	Row	Zone
Operator groups	19.5	16.5	20.5	23.5

N = 8 X_r^2 = 1.88 Nonsignificant at .05 level.

[a]Siegel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956, pp. 1666-172.

Direction deviation, speed deviation, and confidence rights minus confidence wrongs showed no significant differences between patching techniques. In the evaluation of training effects, column patching was significantly superior for target detection. As mentioned earlier, these results were probably due to the operators' greater familiarity with this format, particularly in the pretest condition. Column patching also resulted in more false alarms than did any of the other techniques, but the difference was significant at only the 10% level.

In the evaluation of patching techniques, the column patching technique resulted in significantly more (twice as many) false alarms than did the row technique for the 24-sensor condition. Although the 24-sensor grid is not recommended for the detection of vehicles, it may have to be used for the detection of personnel or in other cases where redundancy of sensors demands it for increased sensor reliability or soil conditions (low and variable detection radius). Therefore, the row patching technique was identified as preferred, both for field use and for further evaluation.

CONCLUSIONS

Optimum Patching Technique

None of the patching techniques tested showed a clearcut superiority over the others on all the dependent variables tested. However, on the basis of results for false alarms, posttest debriefings, and equipment requirements, it was concluded that the most favorable patching technique for field use and further evaluation is the row patching technique.

The column patching technique resulted in significantly higher detection completeness when pretest and posttest results were averaged. In the evaluation of training effects, operator debriefings indicated that the operators initially felt more comfortable with the column patching technique because it is most similar to the standard string technique with which they are familiar. However, both evaluations indicated that more false alarms might occur when the column technique is used. Therefore, in using operators not trained in the grid employment, the column patching technique is preferred if the commander is willing to accept a few more false alarms for more target detections. Using trained operators, the row patching technique is still favored.

Value of the Training

It was concluded that the patching technique training significantly enhanced operator target detection performance for interpreting readouts from seismic sensors employed in a grid array. It was also concluded that the relatively small false alarm rate was not reduced by the training. The percentage of targets detected increased from 36% in the pretest to 51% in the posttest. However, because only half the targets were detected even after the patching technique training, an error analysis should be conducted and an appropriate training package developed and validated to bring the 51% detection completeness to higher levels.

Interpretation Job Aids

The posttest debriefing indicated that operators found the seven-step reporting procedure, speed table, and UGS ruler consistently useful. The patching technique scales of the UGS ruler, however, were not used as frequently as the ground distance and X-T plot time scales. During periods of low target activity when isolated targets were easily detectable, the patching technique scale was not heavily used. During periods of high activity when target activations overlapped, the patching technique scale was used to help separate and distinguish the activations of one target from those of another. However, the operators reported only limited assistance for this purpose, claiming that the ruler provided only a start toward the difficult analytical task of sorting out the activations. Also, the operators noted that the patching technique scale was most useful when they were initially gaining familiarity with the way the sensors are deployed in the grids. It was observed by the researchers that once this familiarity was gained, use of the UGS ruler for this purpose diminished.

Sensor Density and Target Activity Effects

It was concluded that the 24-sensor grid array and the 9-sensor grid array resulted in similar operator performance and confidence. In view of the apparent savings in cost and manpower, the 9-sensor grid (500-m spacing) should be employed for both further experimentation and field use for the detection of vehicular traffic. (In actual practice, the spacing of sensors would depend on the detection radius, gain setting, etc.)

Of the targets available for detection, a greater percentage of targets was detected in the low-target-activity condition (89%) than in the high-target-activity condition (42%). Further research on training using the grid employment of sensors should emphasize the high-activity condition. Until operators can handle the high target activity, additional UGS operators will be required during high target activity. In lieu of added personnel, intelligence estimates based on UGS will have to be carefully increased to account for the operator underestimation of the number of targets present when target activity is high.

Field Performance Expectations

The following detection completeness and accuracy values (Tables 19 and 20) are what the commander can expect from relatively untrained and inexperienced operators when interpreting activations of sensors employed in a grid. The following sample means are considered to be estimates of the population values for the respective conditions. Of course, variations in the skill of the operator, terrain, soil conditions, noise, and target type will affect these estimates.

It was concluded that the major problem in employing sensors in a grid array is not the accuracy but the completeness of the operator's performance (i.e., not the false alarms but the detections).

Table 19

Expected Completeness Detection Performance by Grid Density, Target Activity Level, and Patching Technique

Technique	9-sensor grid: Low target activity %	9-sensor grid: High target activity %	24-sensor grid: Low target activity %	24-sensor grid: High target activity %
Column	88	46	91	45
Perimeter	90	34	84	36
Row	84	48	94	42
Zone	85	39	94	42
Average	87	42	91	41

Table 20

Expected Detection Accuracy Performance by Grid Density, Target Activity Level, and Patching Technique

Technique	9-sensor grid: Low target activity %	9-sensor grid: High target activity %	24-sensor grid: Low target activity %	24-sensor grid: High target activity %
Column	96	96	79	84
Perimeter	89	91	86	95
Row	93	98	86	95
Zone	93	93	85	93
Average	93	95	84	92

APPENDIX A

SKETCH MAPS AND X-T PLOTS

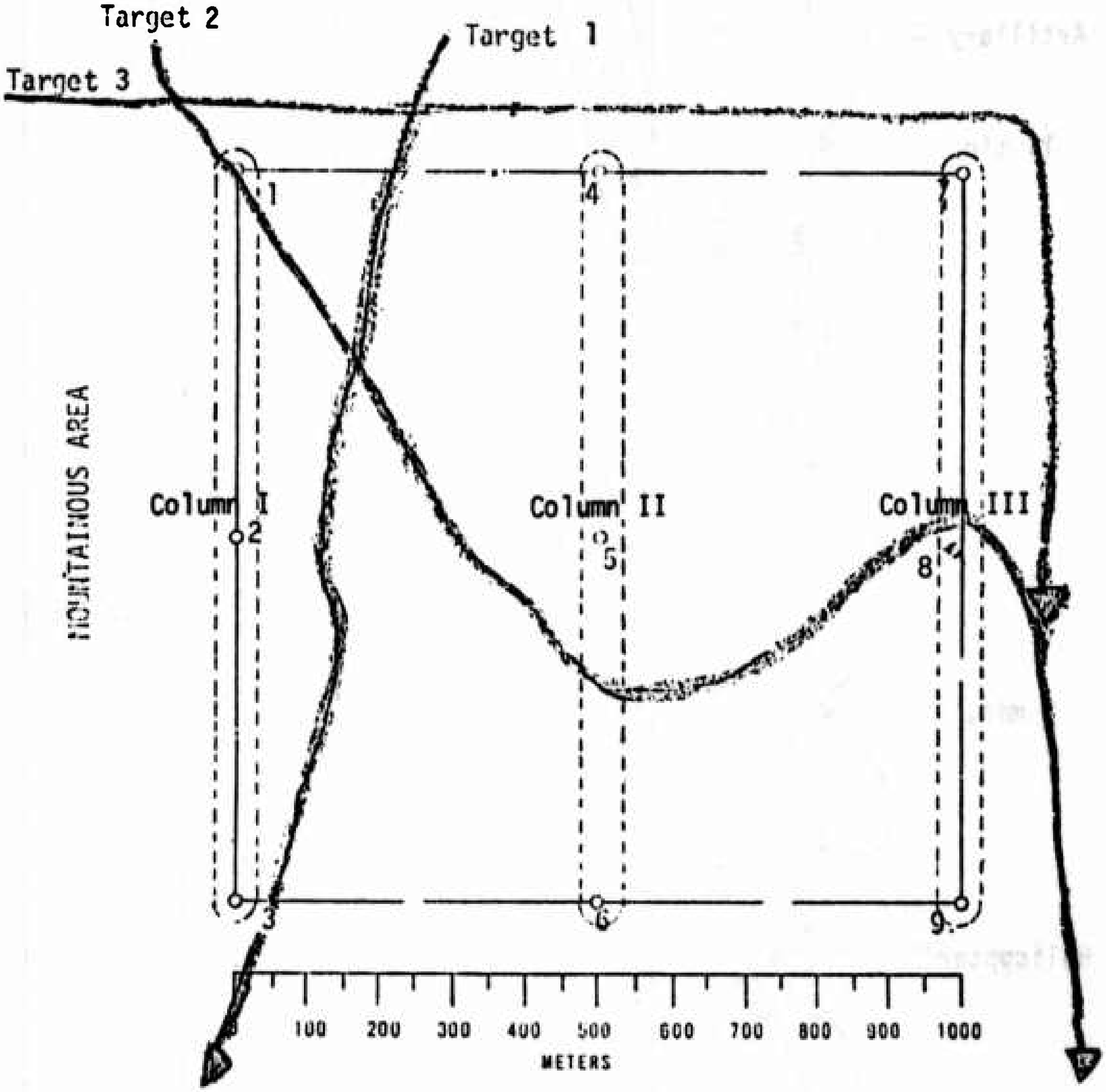


Figure A-1. Sketch map for column patching using a 9-sensor grid.

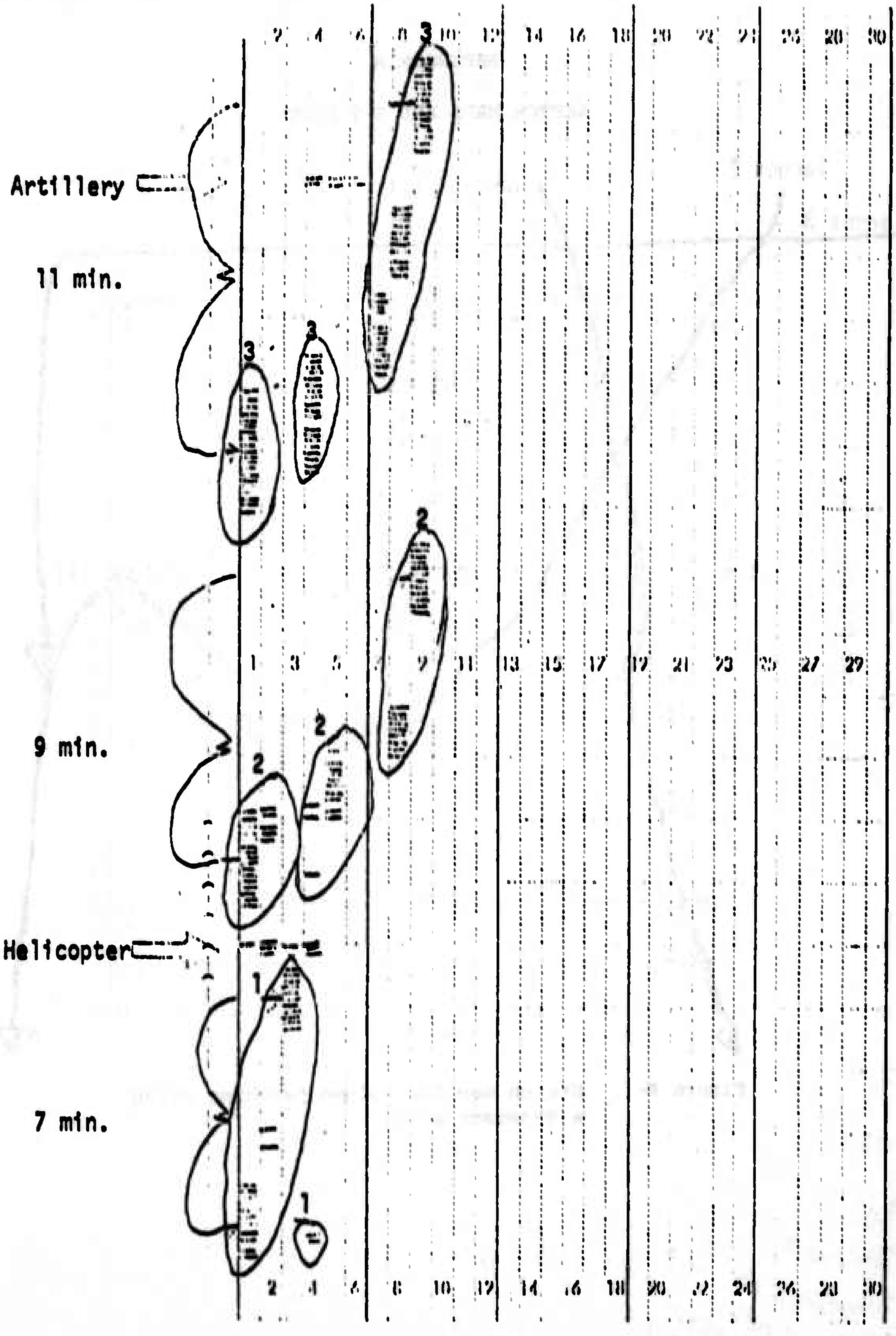


Figure A-2. X-T plot for column patching using a 9-sensor grid.

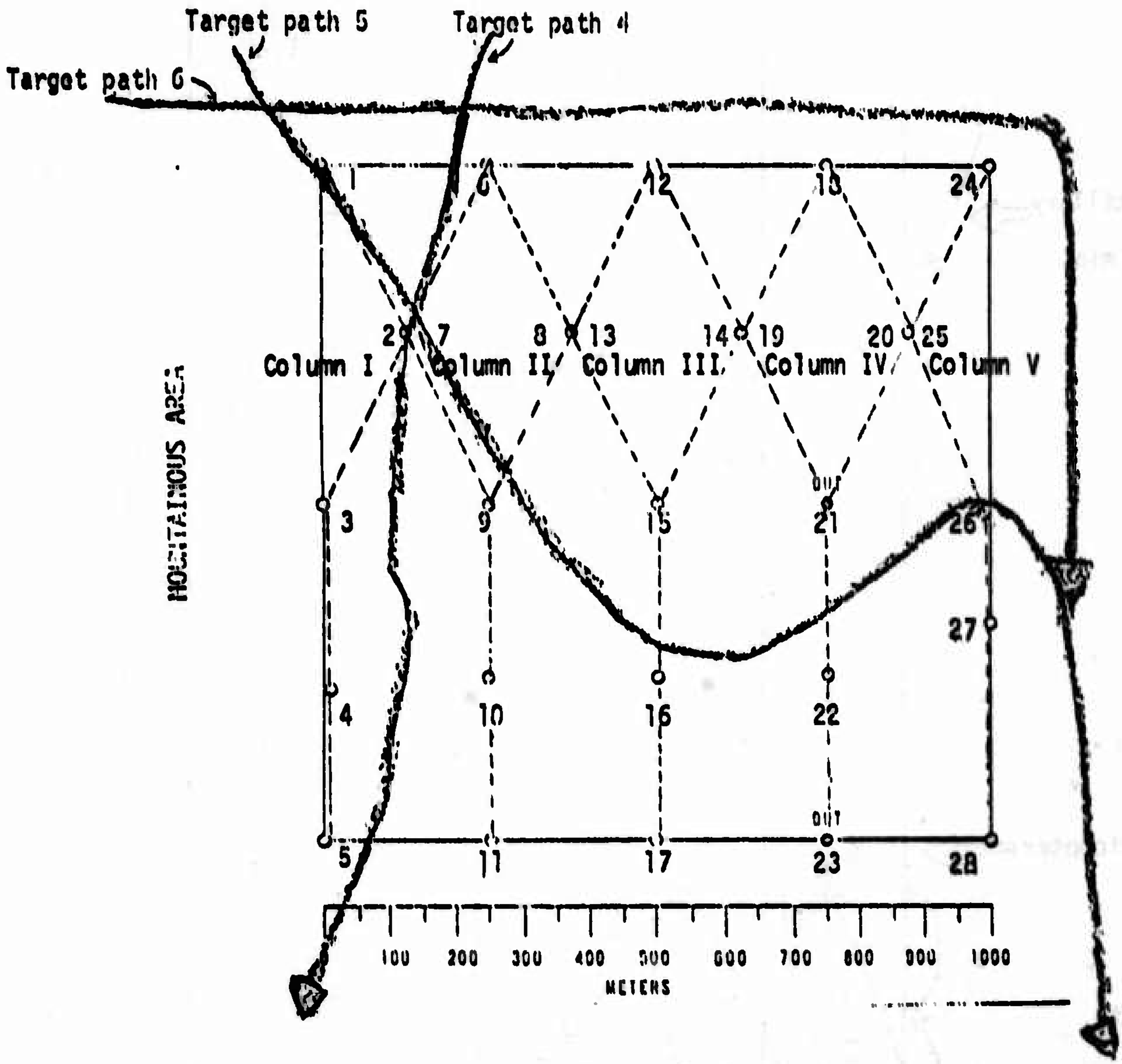


Figure A-3. Sketch map for column patching using a 24-sensor grid.

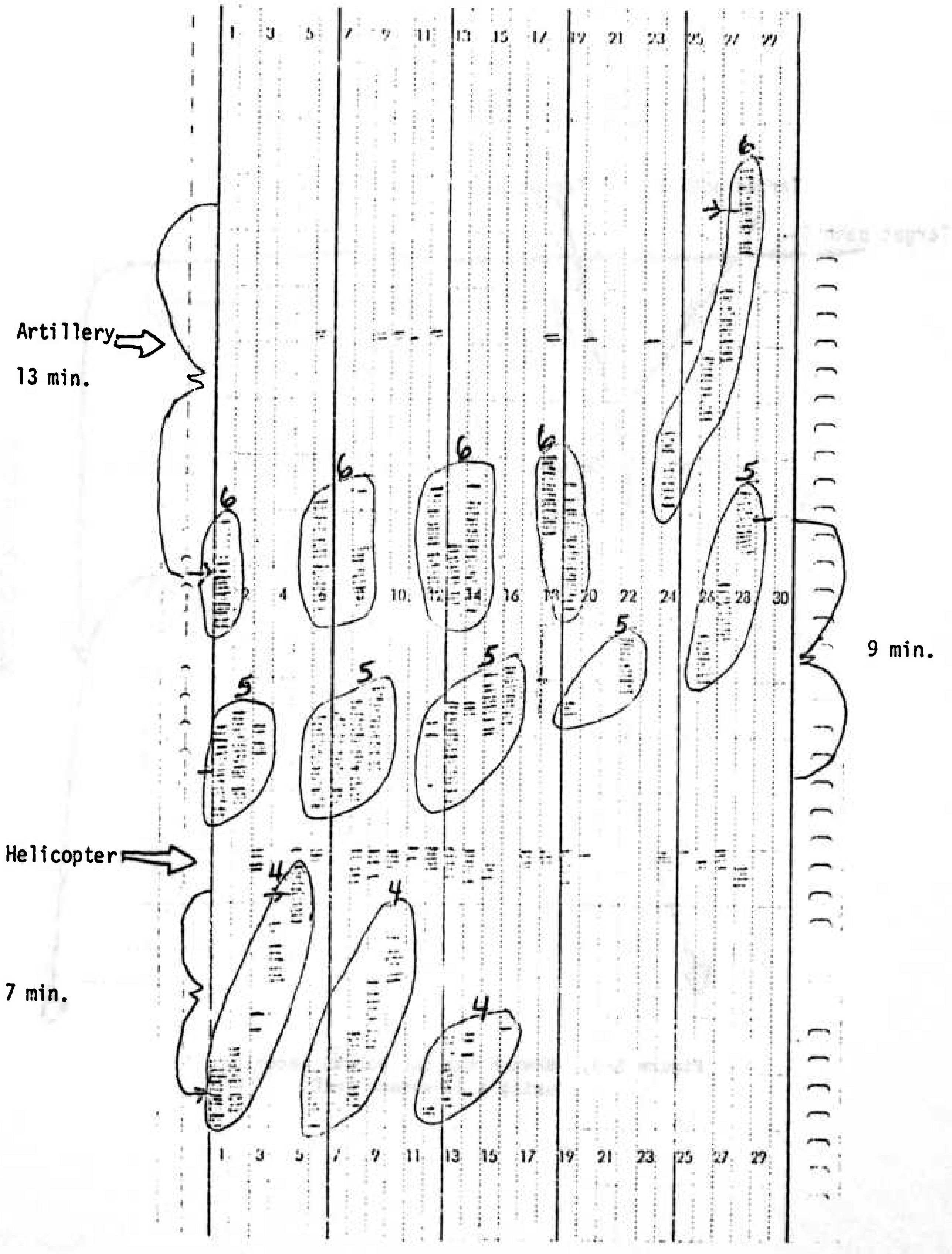


Figure A-4. X-T plot for column patching using a 24-sensor grid.

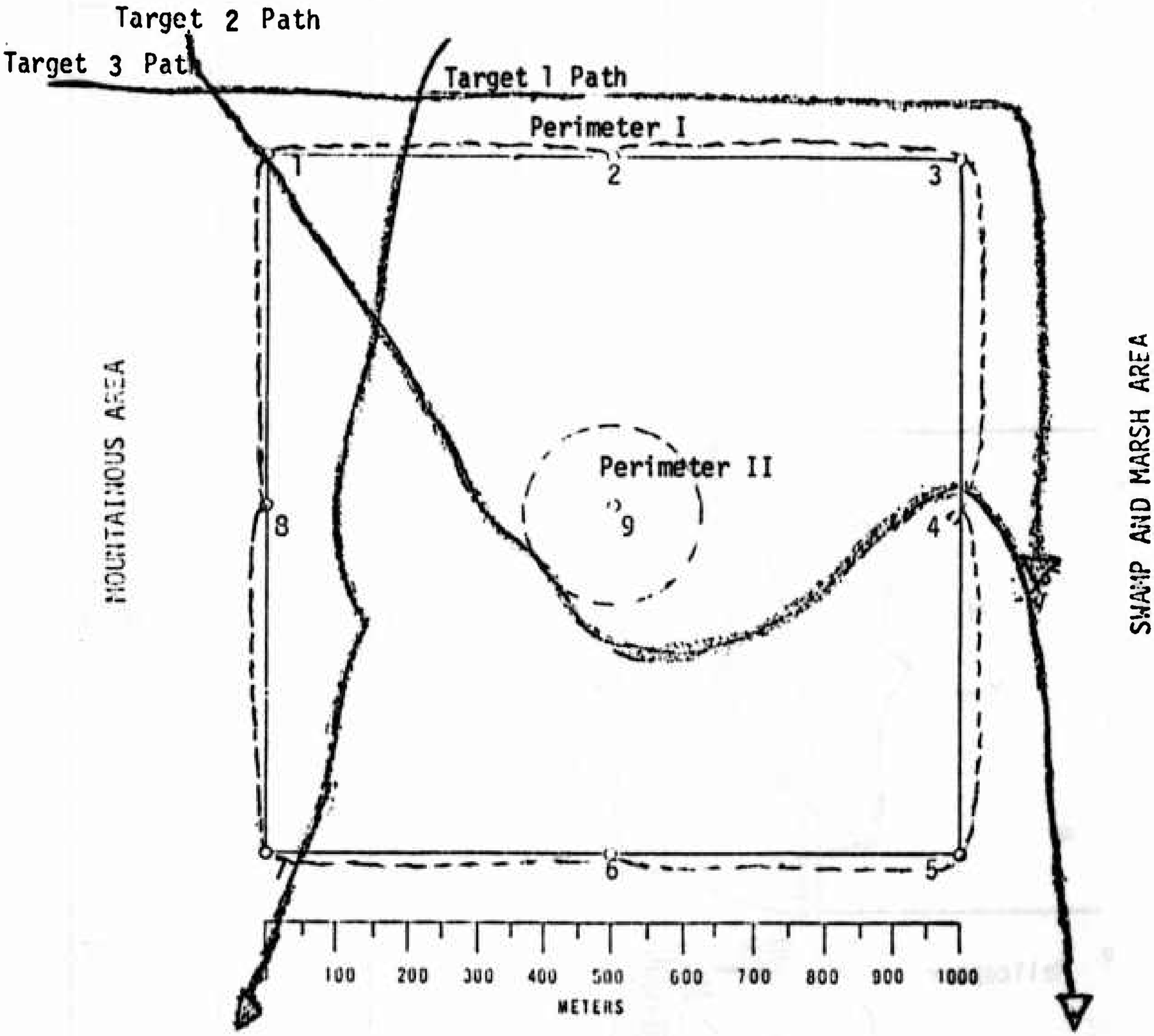


Figure A-5. Sketch map for perimeter patching using a 9-sensor grid.

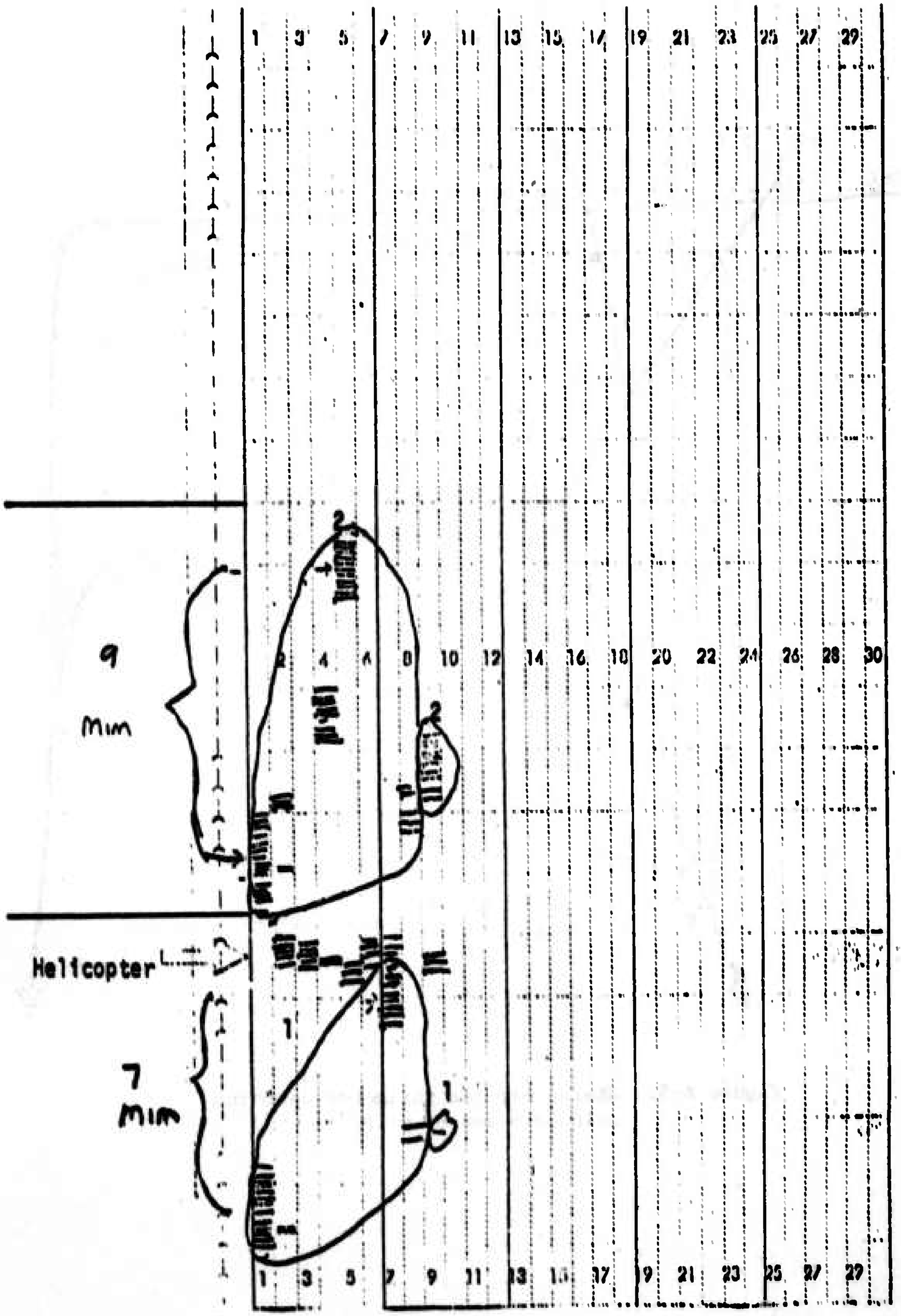


Figure A-6. X-T plot for perimeter patching using a 9-sensor grid.

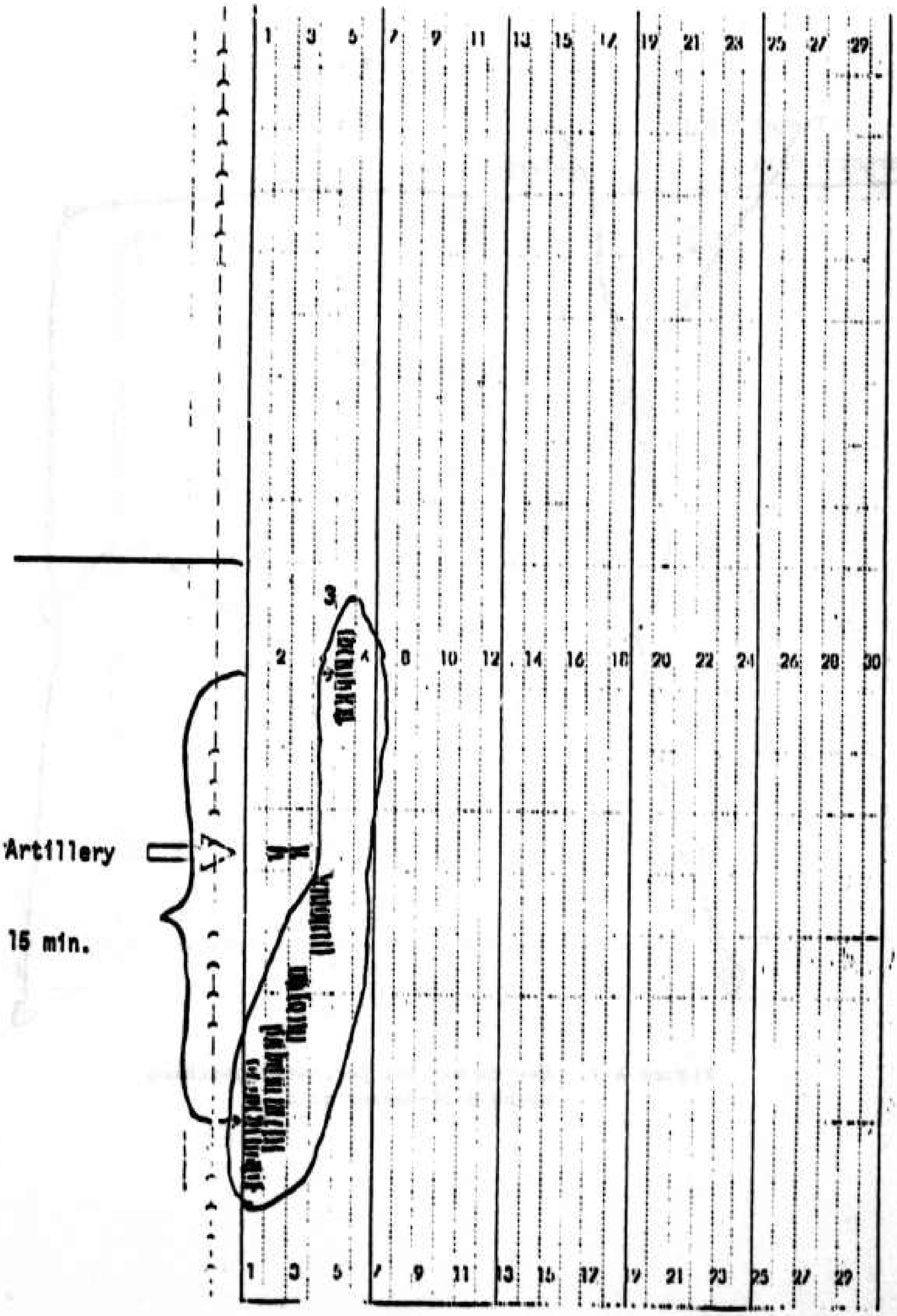


Figure A-6. Continued.

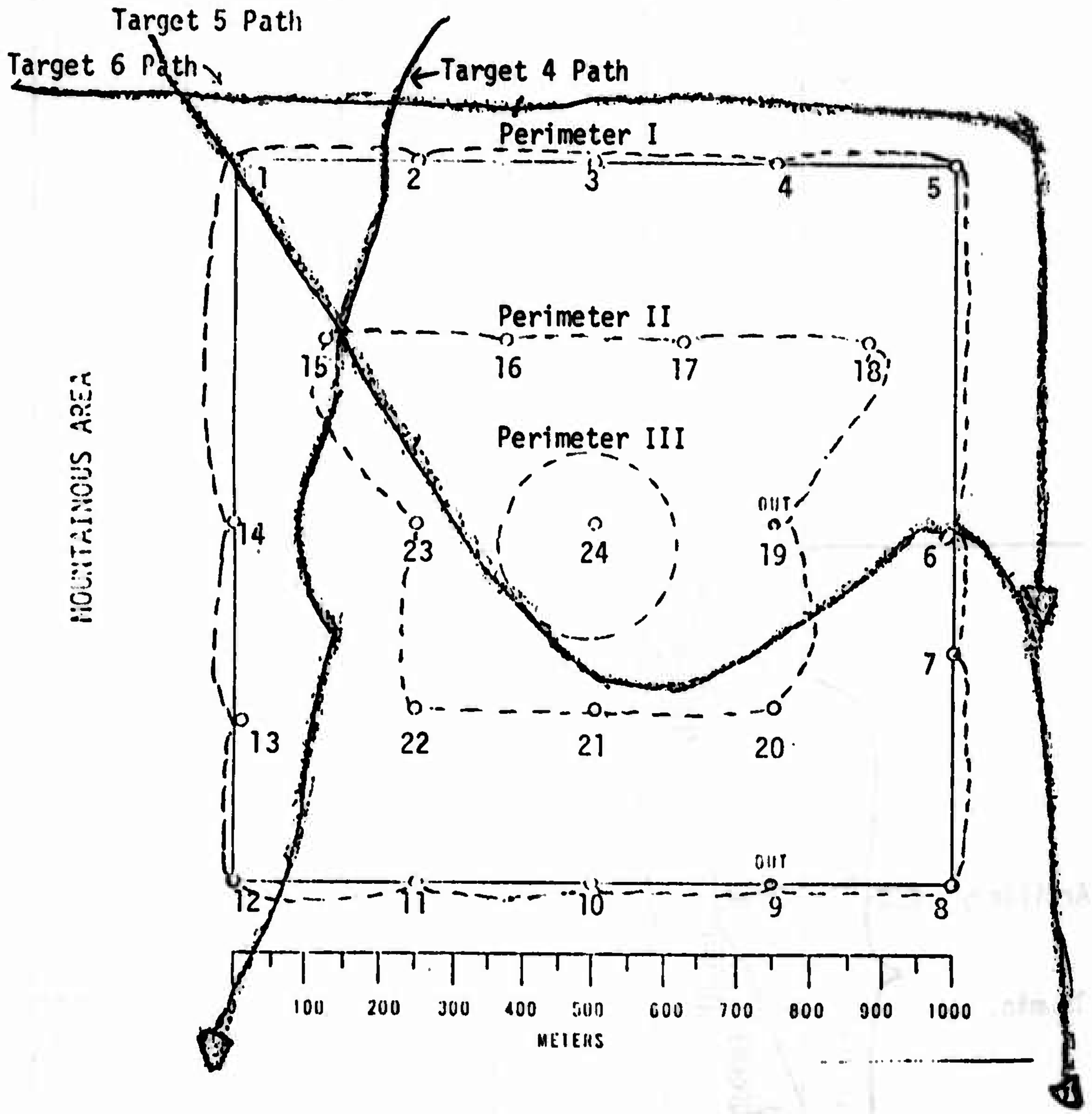


Figure A-7. Sketch map for perimeter patching using a 24-sensor grid.

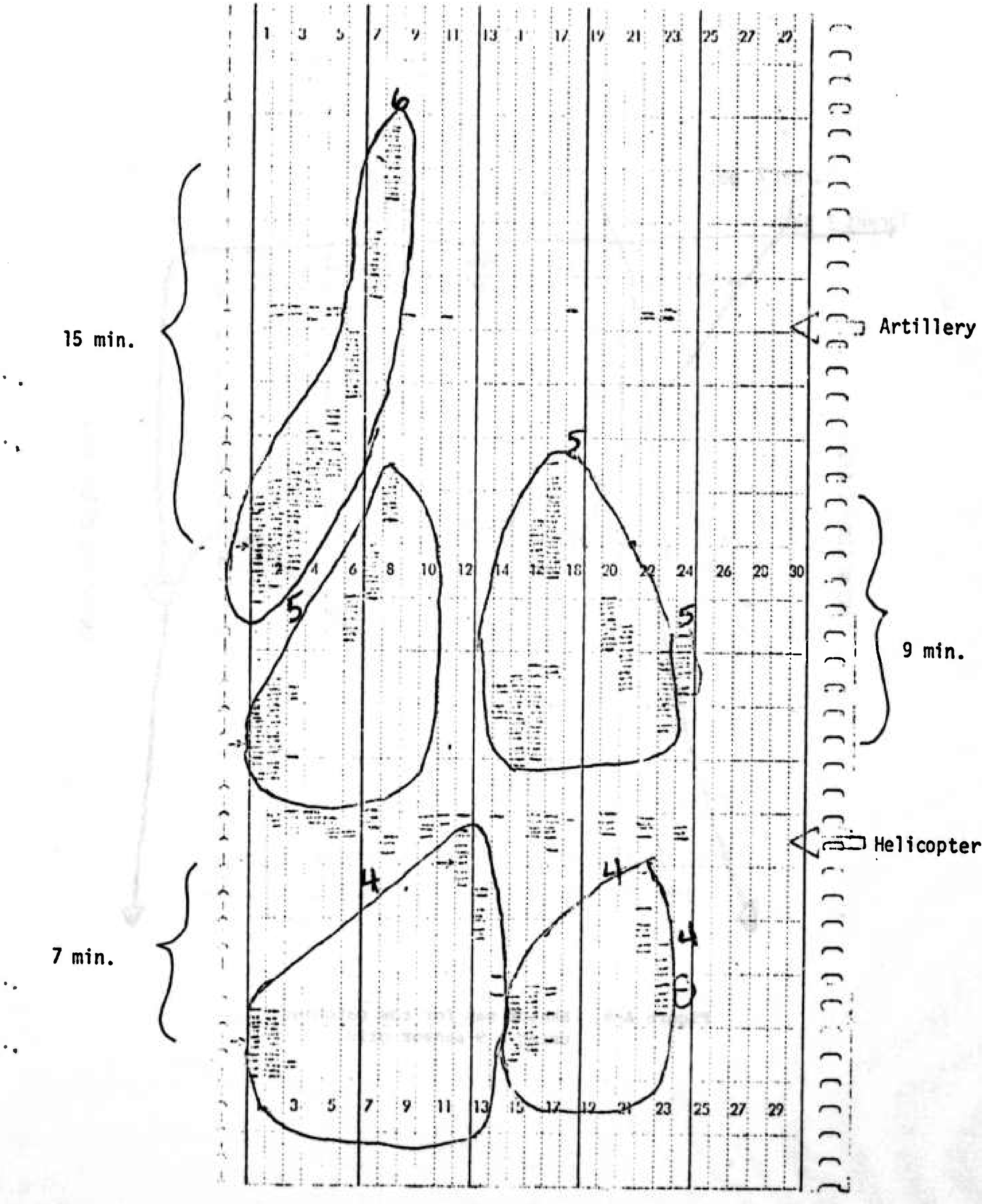


Figure A-8. X-T plot for perimeter patching using a 24-sensor grid.

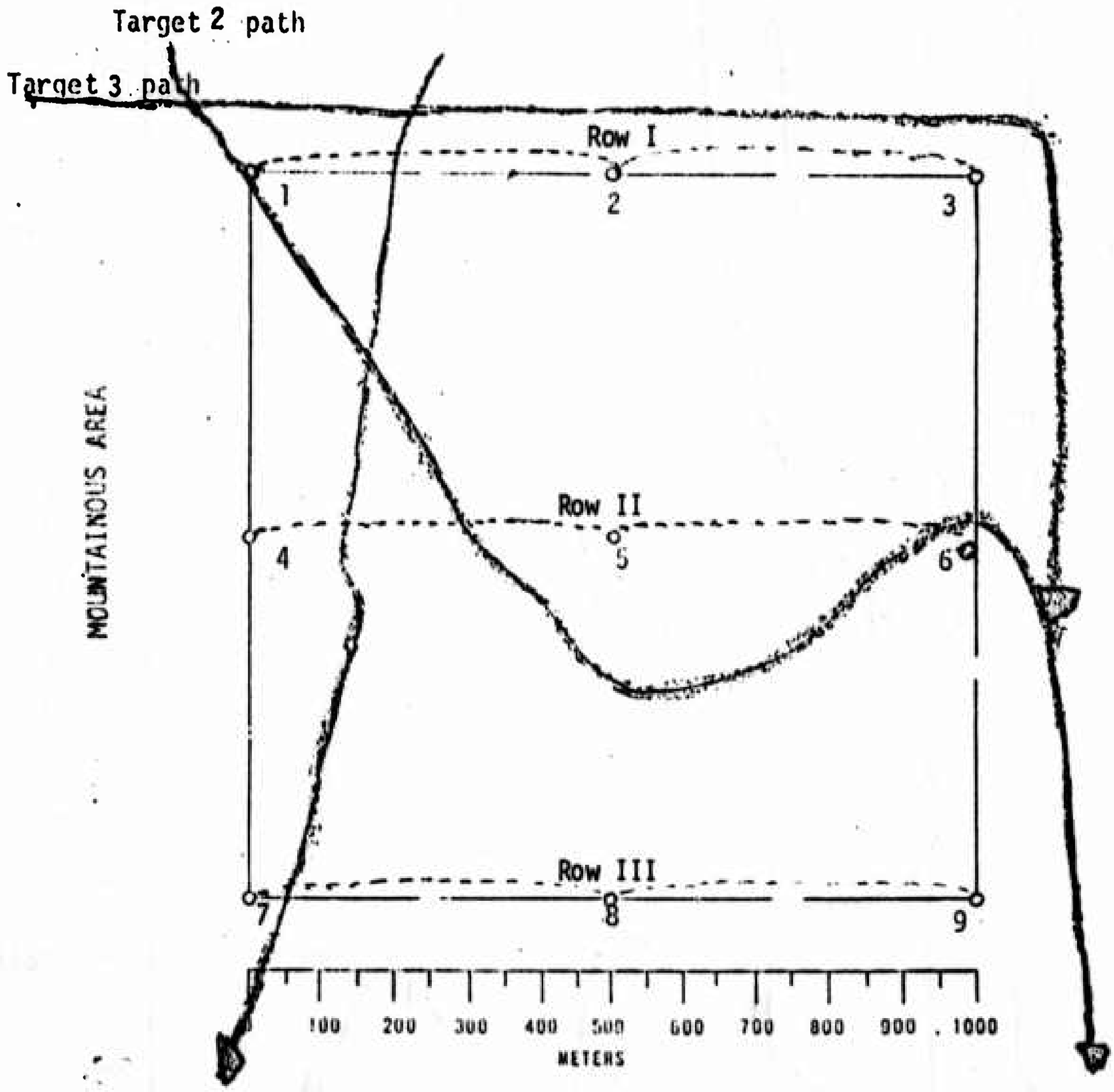


Figure A-9. Sketch map for row patching using a 9-sensor grid.

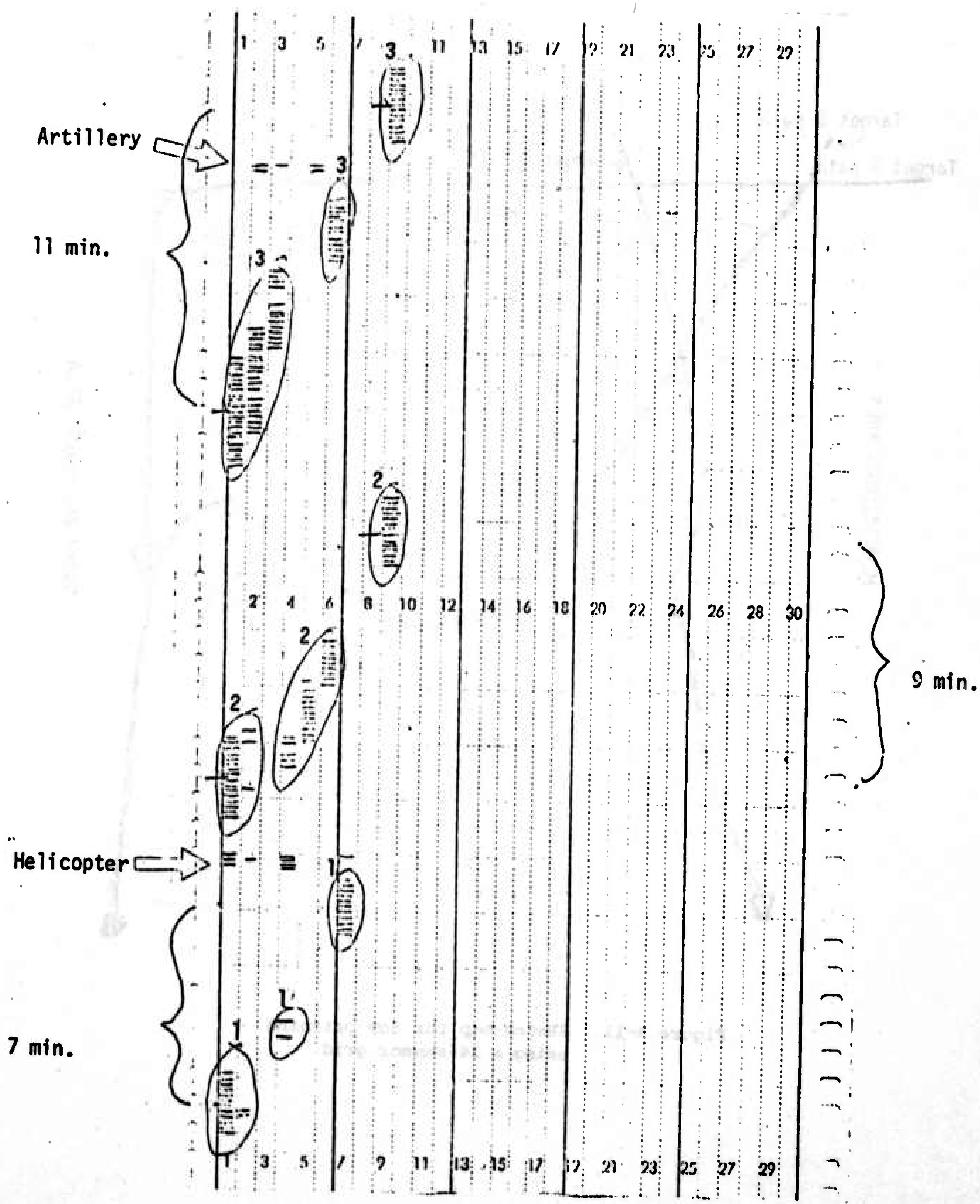


Figure A-10. X-T plot for row patching using a 9-sensor grid.

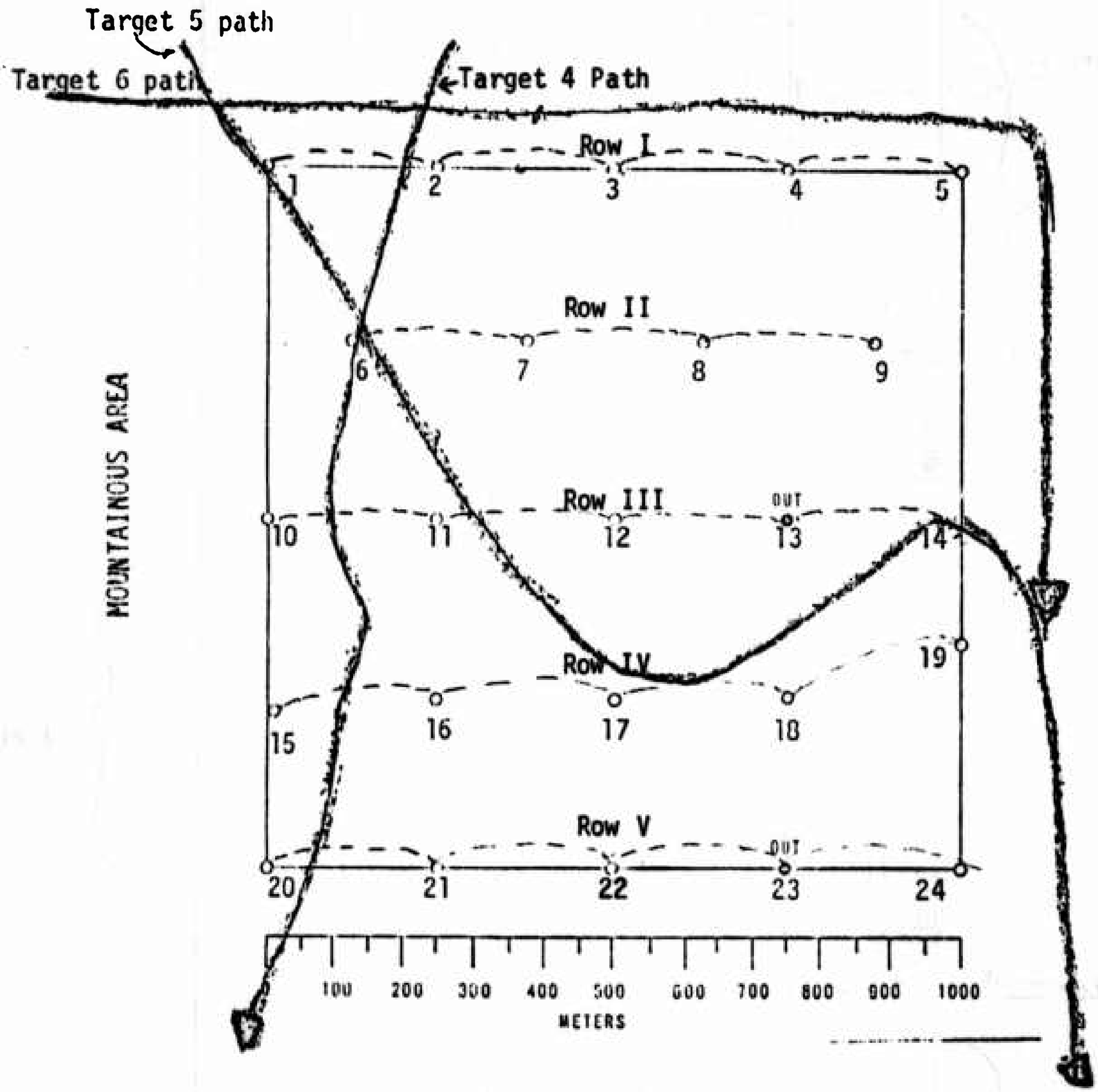


Figure A-11. Sketch map for row patching using a 24-sensor grid.

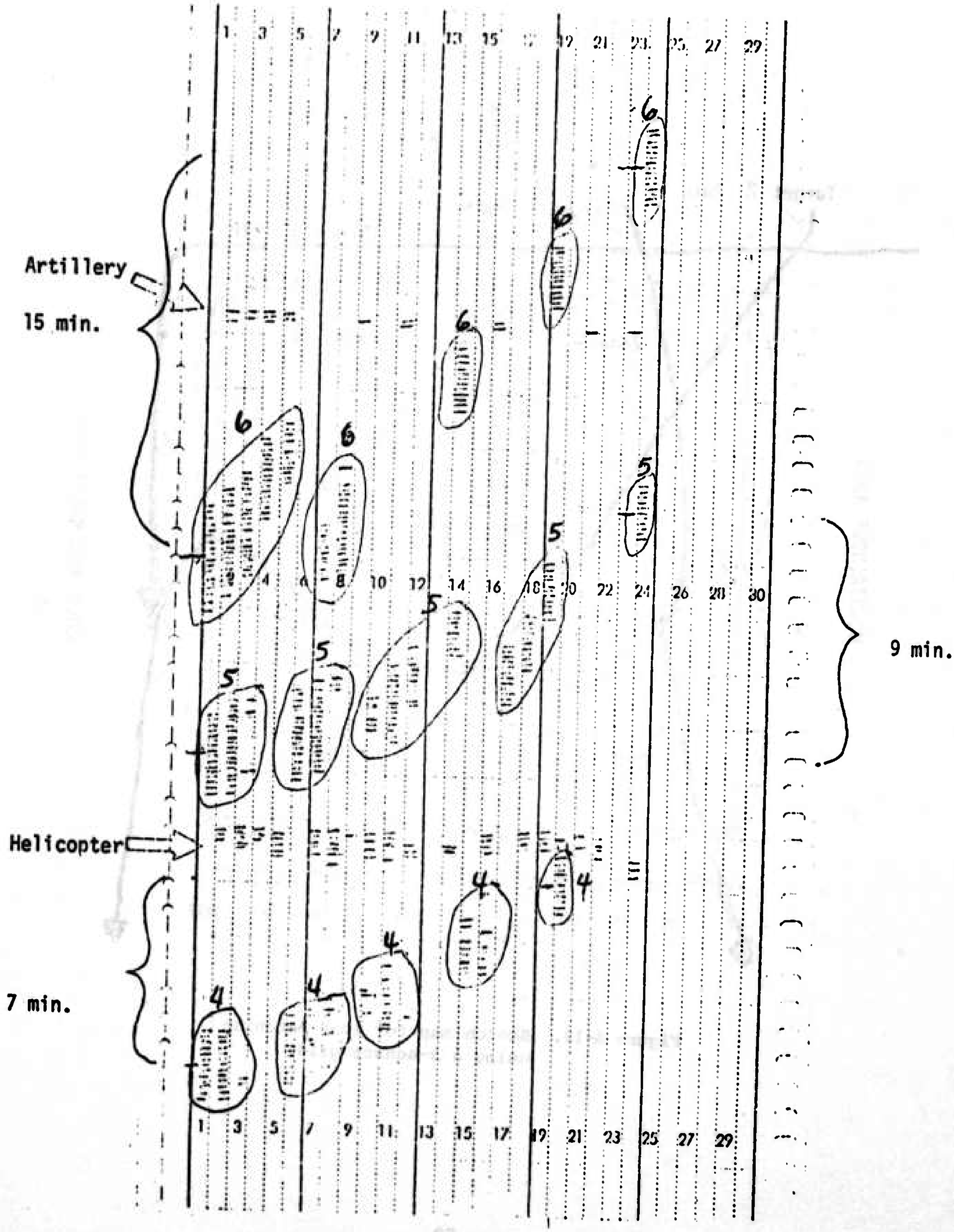


Figure A-12. X-T plot for row patching using a 24-sensor grid.

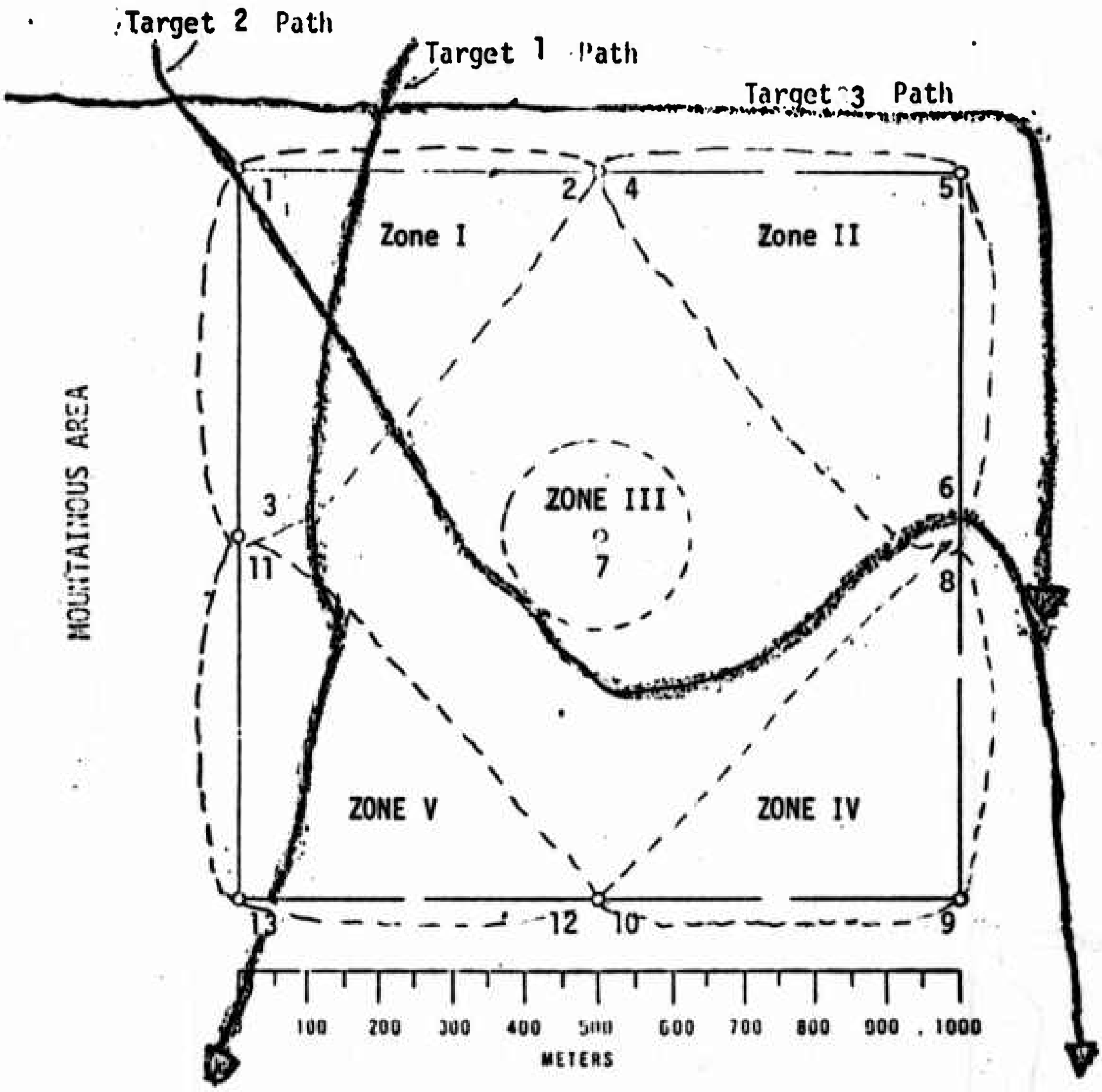


Figure A-13. Sketch map for zone patching using a 9-sensor grid.

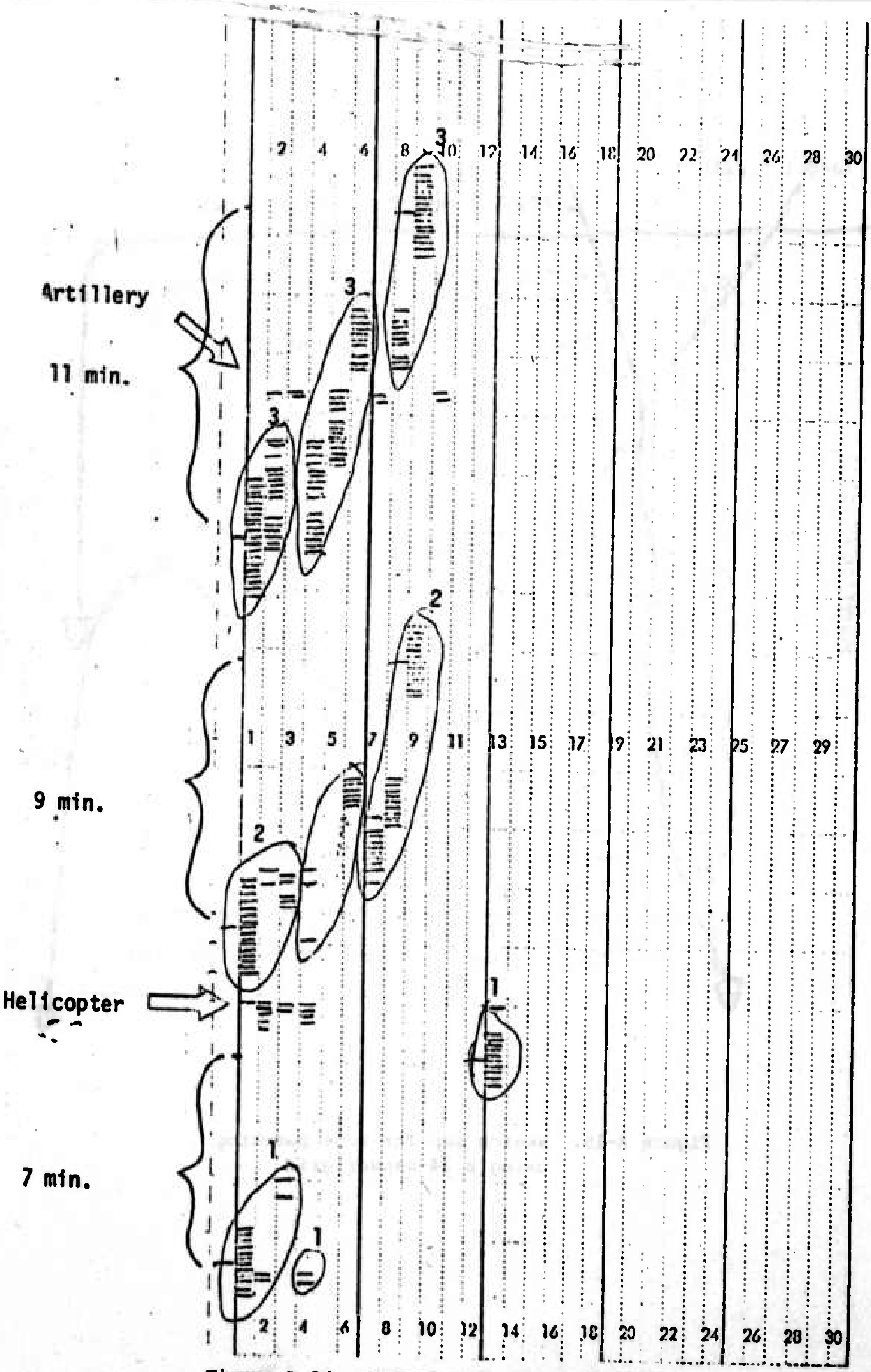


Figure A-14. X-T plot for zone patching using a 9-sensor grid.

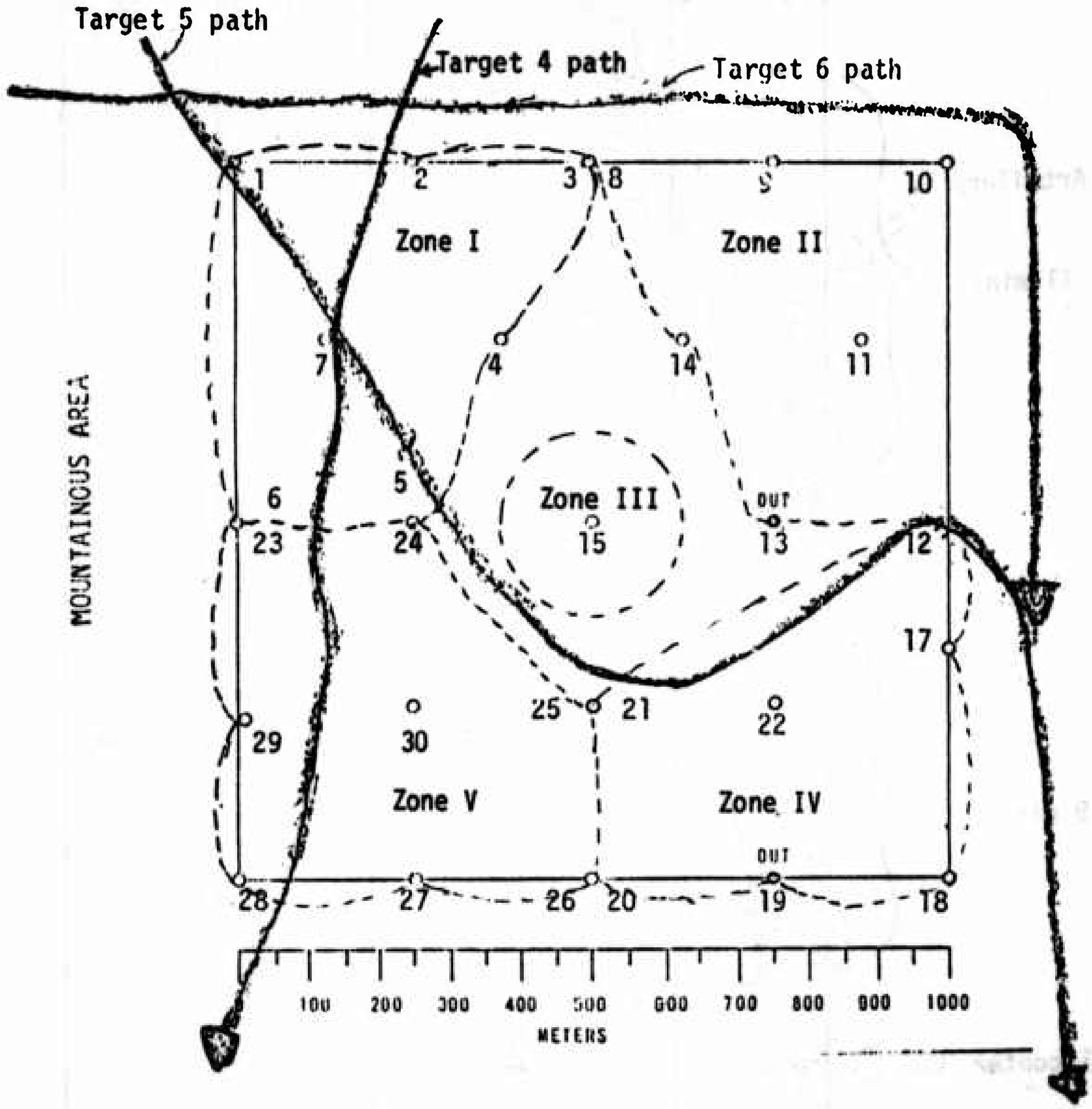


Figure A-15. Sketch map for zone patching using a 24-sensor grid.

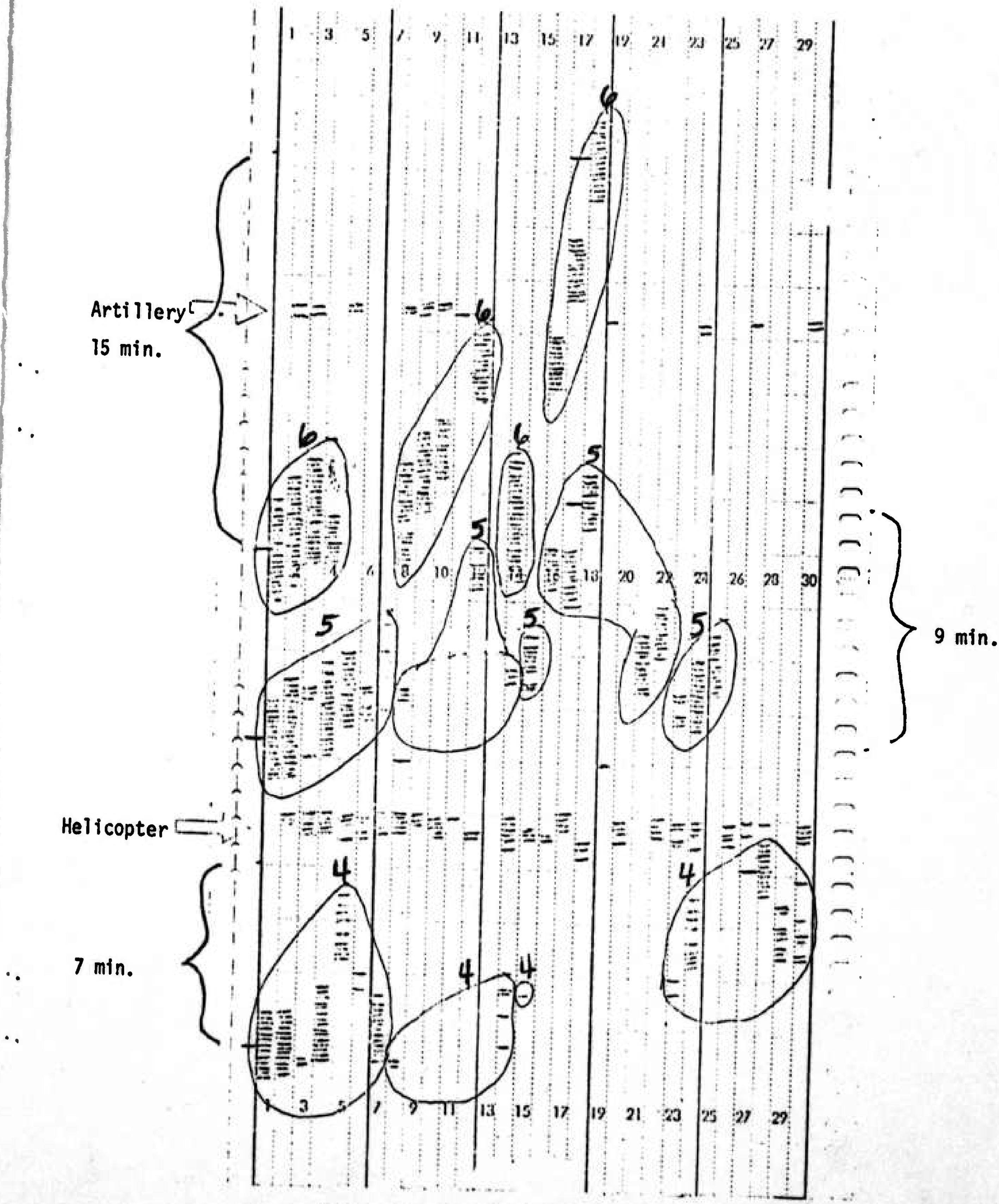


Figure A-16. X-T plot for patching using a 24-sensor grid.

APPENDIX B

TARGET QUALITY DISTRIBUTION--NORFOLK SCENARIOS

Field 1			Tape	Field 2			Total
Good[a]	Fair[b]	Poor[c]		Good	Fair	Poor	
5	5	6	1	7	3	2	28
8	4	2	2	7	6	1	28
5	4	3	3	7	5	3	27
	Training		4		Training		23[d]
5	7	4	5	6	4	4	30
23	20	15		27	18	10	113

Note. From Edwards et al., 1977.

[a]Five targets were detected between 67% and 100% of the time. These were good or easily detected targets.

[b]Five targets were detected between 33% and 66% of the time. These were of medium difficulty

[c]Six targets were detected between 0 and 32% of the time. These were difficult targets.

[d]Data on the difficulty levels of training targets were not available.

APPENDIX C

ORIENTATION BRIEFING

Monitor: Paraphrase the following.

I want to welcome everyone here today and thank you for coming. We are glad that you could make it and can participate in the exercises we have planned. We think you will find it worth-while. You will be participating in a five-day program and we will be spending the next several hours briefing you and giving you an orientation as to what its all about. Before going any further I want to introduce myself and my associate and find out who you are.

Introductions

Our purpose in coming here is to evaluate, with your assistance, four different ways in which seismic sensors in a grid deployment pattern can be patched to an RO-376 readout device. We have been asked by the Army Research Institute for the Behavioral and Social Sciences and the Department of the Army to administer this exercise to you. The Army is interested in the development of improved displays of unattended ground sensors to maximize information output and make the job easier for you. Your task in this study will be to act as a sensor operator and interpret various X-T plot presentations using different patching techniques. Many of the skills you have acquired in school and on the job will apply to these tasks, however, some of the patching techniques will be new to you and details such as measurement and reporting procedures will differ. In these cases, training and instructions will be provided. If at any time during your work with us, you do not understand something or you are not sure of what you are to do - ASK. You will not be penalized and asking might prevent your having to repeat some of your work. We'll be using simulated RO-376 drive mechanisms. If any of the equipment appears to be malfunctioning, inform one of us immediately.

Previous studies of this kind have dealt primarily with sensor strings emplaced along roads, trails, or other infiltration routes. Here, we are applying seismic sensors to an area intrusion problem. In such a situation, we would have sensor fields emplaced over a wide geographical area that an enemy force would utilize should he elect to maneuver his forces cross-country and not along the existing road network. Such a situation could be expected in a mid-intensity conflict in Western Europe. This type of sensor field would be used to help detect and identify different tactical maneuvers such as reconnaissance probes, feints, or major attacks and is referred to as a gated array or grid array.

For our experiment, we have taped actual sensor activations from a grid array during field exercises using various types of targets. The target activations were collected under simulated battlefield conditions complete with noise activations produced by artillery fire, helicopters, and wind. These tapes will not be played back to you in real time, but in the form of pre-prepared X-T plot scenarios. You will interpret these scenarios and extract information using our procedures and forms. Since we know where and when target activations actually occurred, we can score your reports for accuracy and thereby determine which patching technique can best be used in this particular situation.

Each of you will participate every day this week. During that time, you will be given training on each patching technique and given practical exercises to familiarize you with the patching technique. Then, you will work with each patching technique for two hours. During the program you will be given appropriate breaks, lunch, etc. If you cannot be here during the time presently scheduled, tell us now so we can reschedule you. You must be here for <u>all</u> scheduled times or we cannot use your results.

I would like to emphasize that we are not giving you a test to see how good an operator you are. The purpose of this study is to determine which patching technique is best for extracting target information. Our primary concern, therefore, is not in how good you are as an operator. However, you and your superiors are interested in how good you are. I am sure they will not base the next promotion on how well you do these practical exercises. <u>Still</u>, these activations <u>are</u> actual activations recorded in the field and your accuracy in interpreting is <u>one</u> indication or example of what you can do. You will be able to compare what you can do to what others did as a group. You will be able to get your score and the group average from your commanding officer. He will be able to objectively assess you against the others on this one sample of one of your duties. However, there are no standards of performance--even if you do worse than everyone you still could be a competent operator.

All we ask is that you interpret the X-T plots to the best of your ability and try to make sense out of what sometimes might appear to you to be rather difficult. Let me stress that we have tried to make these records as realistic as we could.

You are important because you as a group represent the hundreds of specialists that have graduated and will graduate from the UGS school. Army deployment plans for UGS equipment and personnel will be partly influenced based upon what <u>you</u> can do.

Monitor: Begin the briefing on grid deployment patterns.

APPENDIX D

INTRODUCTION TO THE GRID EMPLOYMENT PATTERN (LECTURE/DISCUSSION)

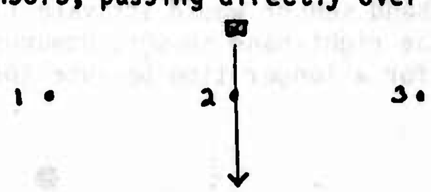
The Grid array consists of unattended ground sensors (UGS) - ployed in a matrix within a designated field area as opposed to the string pattern in which UGS are employed in sequential alignment along a roadway. The grid array can be used for area intrusion surveillance problems encompassing entire border areas or smaller gate (gap) areas where coverage by radar or other means is limited or not feasible. It is designed to maximize the probability of detecting and acquiring enemy forces intruding in any portion or in any direction within a covered geographical area. The UGS in the grid array are ployed in a systematic way with pre-planned distances between the sensors so that information extraction is enhanced.

For this exercise we are utilizing a sensor grid consisting of 9-sensors, each sensor is 500 meters apart. X-T plot readouts of various target runs through this sensor grid will be presented to you. Your task will be to detect these targets, track their path through the sensor grid, and provide further information about them. You have already received some information concerning this task. At this time, we would like to provide you with further information which should aid you in monitoring sensors in the sensor grid.

After you have detected what you believe is a target, your next objective is to chart or trace its path across the sensor grid. In the past, when you have worked with sensor strings, targets coming down a road will generally activate all the sensors in order. However, in a grid formation, the targets may come from any direction and take any course across the grid. They will also come closer to some sensors than they will to other sensors. This presents more of an interpretation problem to the monitor.

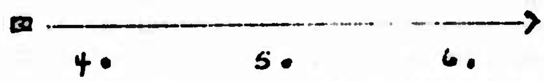
We have prepared some examples of targets entering the sensor grid from different angles and taking different paths through the grid. We also have copies of the sensor activations caused by these targets.

Example 1 - Here is a target entering a Grid, and crossing the first line of sensors, passing directly over one of them.

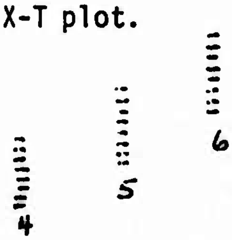


Activations would first appear on the middle sensor. As the target proceeds the sensors to the right and left would activate for a shorter period of time. The sensors to the right and left would cease activating before the middle sensor thus the activations would appear as below:

Example 2 - A target traveling in parallel with a line of sensors would

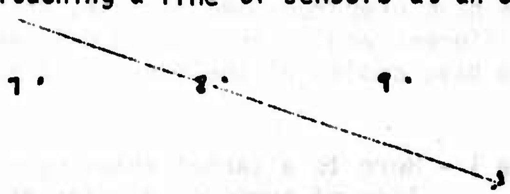


appear like this on the X-T plot.

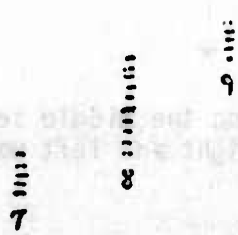


This would be very similar to the activation of a sensor string with a stair-step pattern. All sensors would activate for approximately the same length of time.

Example 3 - Shows a target approaching a line of sensors at an oblique angle.



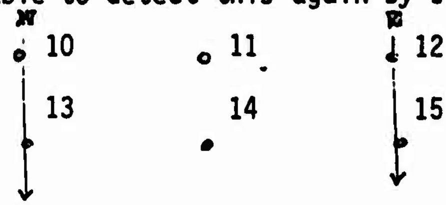
Here the left-hand sensor would activate first, followed by the middle sensor and the right-hand sensor, however, the middle sensor would be activated for a longer time because the target came closest to it.



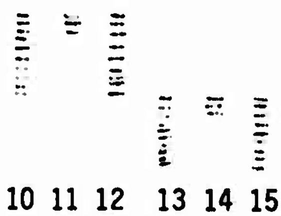
In all three of the above examples, other groups of sensors in the grid would in the same way, indicate the path of the target as it travelled the grid. A good general rule to remember when monitoring a sensor grid is to look at the overall pattern of the sensors being activated, and then make a determination from this overall pattern, where the target is traveling.

At times, there may be more than one target present in the sensor field. Monitors should be able to detect this again by studying the overall pattern of activations.

Example:



In this example, with sensors activating on the left and right but not in the middle, it must be assumed that two targets are present. In these situations it is important to take note of sensors that are not activating as well as sensors that are activating.



APPENDIX E

TEST PROCEDURE TRAINING

Our purpose in coming here this week is to evaluate several display and target conditions for seismic sensors patched to an R0376 readout device. We want to determine how different display and target activity conditions affect your ability to detect and report on targets. You are all familiar with the idea of employing sensors in a string configuration along a road. Now you will be working with sensors employed in a grid configuration and in a field such as that shown in the top half of Figure 1.

Pull Figure 1 and Figure 2 out of this booklet and lay them on your desk where you can see both of them clearly. As you can see, Figure 1 shows 9-sensors employed in a grid which is 1000 meters on a side. Compare this with Figure 2 which shows 24-sensors also ployed in a grid 1000 meters on a side. The sensor identification numbers are shown in both figures. In an operational situation, grids this size could be a small section out of a long sensor network or they could be placed between natural barriers. For our purposes, assume that each grid is located in a flat partially wooded field between rugged terrain on the left and marshy terrain on the right.

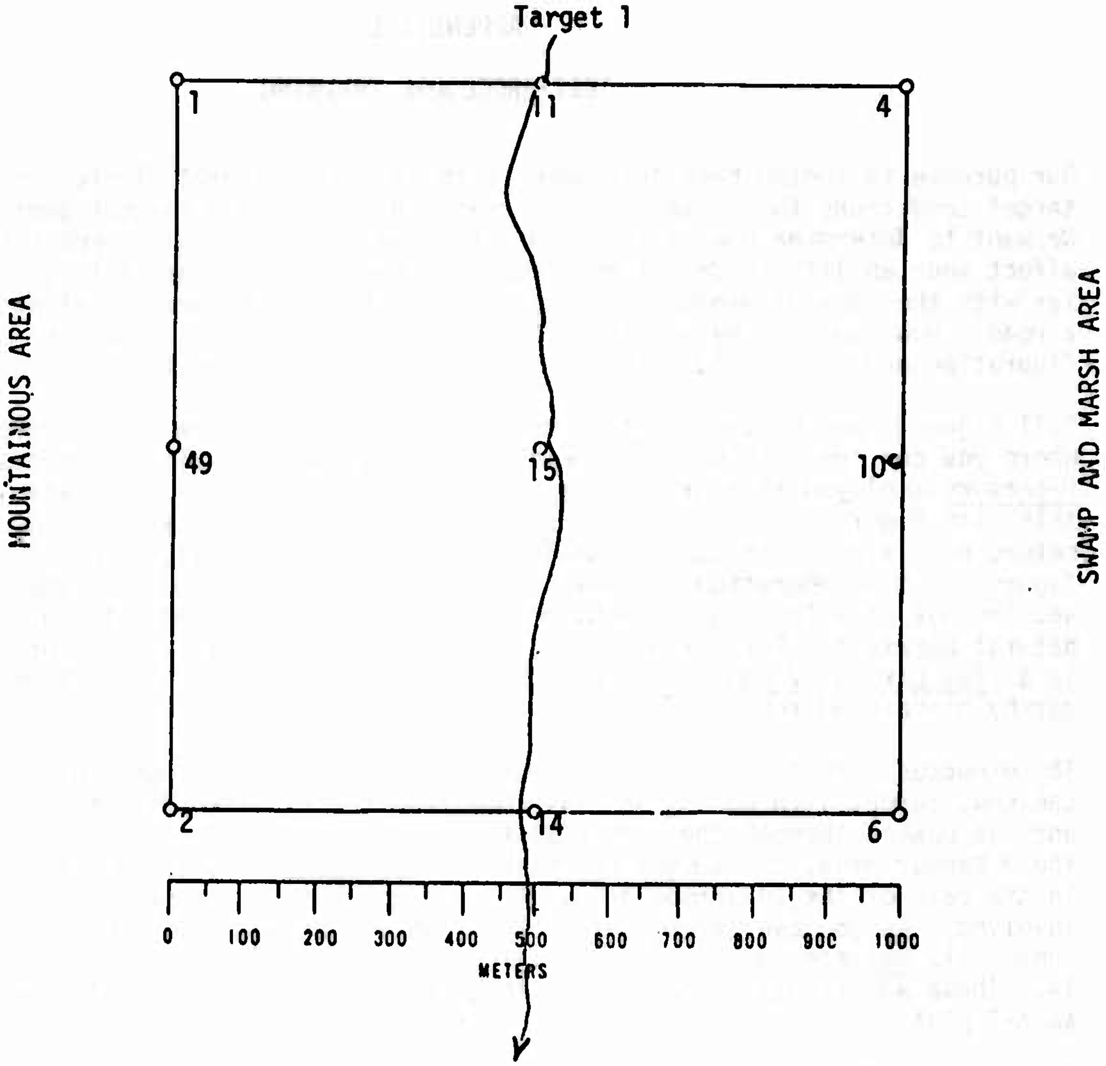
The expected direction of enemy approach is from top to bottom. As you can see, target 1 in both grids has come from the expected direction and has passed through the center of the sensor field. In the case of the 9-sensor grid, the target has passed over sensors 11, 15, and 14. In the case of the 24-sensor grid, at least three more sensors are involved. As you can see by inspection, the target has passed over sensor 11, between sensors 9 and 23, and then over sensors 15, 13, and 14. These additional sensors may help when reporting on a target from an X-T plot.

The bottom half of Figures 1 and 2 shows blank spaces and a seven step procedure which you will use to report on targets.

YOUR JOB DURING THIS EXERCISE WILL BE TO FIND TARGETS ON X-T CHART PAPER AND FOR EACH ONE THAT YOU FIND, FILL IN THE BLANKS FOR THE SEVEN STEPS.

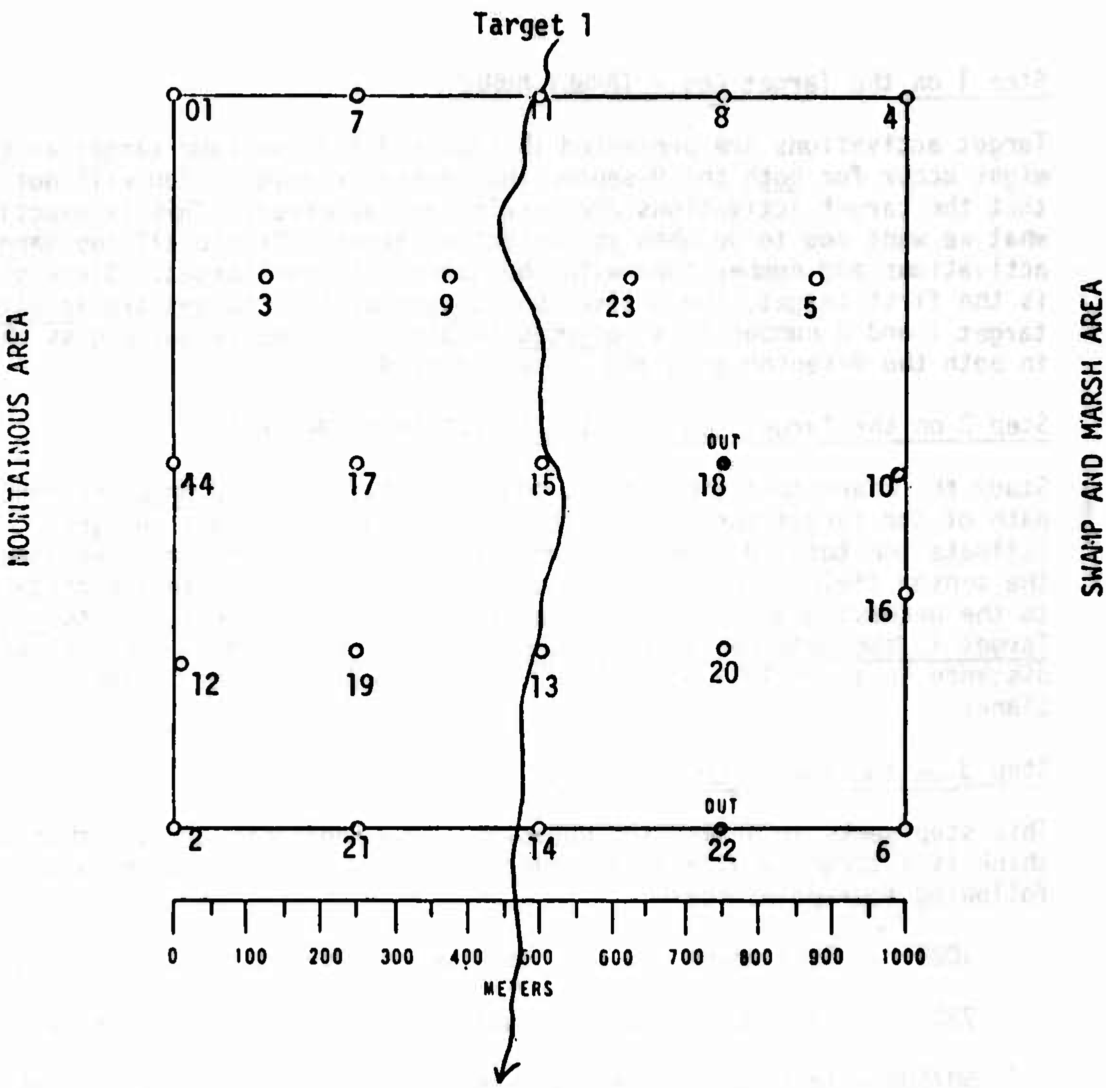
You will be working with X-T chart paper and targets simular to that shown in Figure 3 (second to the last page). Study Figure 3. Notice the pen/ID chart at the side showing that the X-T pen numbers correspond to the same sensor grid numbers.

At this time we will define what we mean by the word "target". A target is any vehicle or personnel activity in the field which is distinguishable from other personnel or vehicle activity. For example, three tahks 50 meters apart traveling in a convoy formation would be one target as would a tank traveling alone. These two targets may enter different sections of the grid simultaneously or at different times. Because their activation patterns can be separated from one another, they are classified as separate targets.



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW → HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
1	1050	100%	PENS 11,14	8	1050/8 = 131	

Figure 1. 9-sensor target log.



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW → HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
1	1050	100%	PENS 11,14	8	$\frac{1050}{8} = 131$	

Figure 2. 24-sensor target log.

Step 1 on the Target Log - TARGET NUMBER

Target activations are presented in Figure 3 for the same target as they might occur for both the 9-sensor and 24-sensor grids. You will notice that the target activations are circled and numbered. This is exactly what we want you to do when you detect a target. Circle all the target's activations and number them with the number of that target. Since this is the first target, the activations caused by this target are labeled target 1 and a number 1 is recorded in Step 1 of the Target Log as shown in both the 9-sensor grid and 24-sensor grid.

Step 2 on the Target Log - ESTIMATED DISTANCE (Meters)

Study the characteristics of the sensor activations and draw the probable path of the target through the sensor field on the Target Log grid. Estimate the total distance (in meters) that the target traveled through the sensor field using the distance scale shown. Estimate the distance to the nearest 50 meters - for example, 200 or 250 meters. In the case of Target 1, the path has already been drawn on both grids. The estimated distance is about 1050 meters and this has been recorded in the Step 2 blanks.

Step 3 on the Target Log - CONFIDENCE LOW ---> HIGH

This step seeks to answer the question, "How confident are you that what you think is a target really is a target?" Record your confidence using the following four-point scale:

100% - This means you are positive or certain.

75% - This means you are highly confident, but not positive.

50/50% - This means that you think it probably is a target, but you are uncertain - it may or may not be a target.

25% - This means that you have only a suspicion, but it should be recorded and checked out. You have low confidence that this is a target.

A 100% confidence has already been placed in this column on the Target Log.

Step 4 on the Target Log - FIRST AND LAST SENSORS ACTIVATED

Record the sensor number of the first sensor which activated when the target entered the grid and the last sensor which activated when the target left the grid. As shown for both the 9-sensor and 24-sensor grids, the first sensor is 11 and the last is 14 which is the same as pens 11 and 14 on the X-T plot. Check this yourself by looking at the pen/ID chart on the right-hand side of Figure 3. This information is important because it will be used for the next steps.

Step 5 on the Target Log - MID-POINT TIME (min) DIFFERENCE

On the X-T plot, find the mid-point of the activation patterns for the first and last sensors. Now determine the time difference between the two mid-points. This is done directly off the X-T chart paper as shown in Figure 3 for both the 9-sensor and 24-sensor grids. Remember, there are 2-minutes between lines (rows) on the X-T chart paper. Estimate this time to the nearest half minute, for example 3 or 3.5 minutes. For target 1 the mid-point time difference is ____ minutes. Check your answer with the appropriate Target Logs for the two grid sizes. If you missed it, reread this section and/or see the Training Monitor.

Step 6 on the Target Log - ESTIMATED SPEED

Having an estimate of the time that a target traveled through the sensor field and the distance that was traveled will permit you to get an estimate of the speed of the target. Only an estimate is possible, however, since you will not know for sure how close the target traveled to any of the sensors. It is possible to obtain a more accurate estimate of speed when the sensors are deployed along a road because the target is normally traveling on the road and the distance between the sensor and the road is known.

An estimate of speed can be obtained by using the speed table provided for this purpose. The speed table (Table 1) is enclosed in plastic and will remain at your desk. To use the speed table, find the time column (using the answer from Step 5) along the top. Line this up with the distance row (using the answer from Step 2) along the left-hand side. The place where the column and row converge gives you the speed. In the case of target 1 the speed is _____. Check your answer with the one already provided in the Target Logs. If you missed it, reread the instructions and/or see the Training Monitor.

Step 7 on the Target Log - TARGET TYPE

Step 7 requires a judgment as to whether the target is vehicle or personnel. As a rule, if the target is traveling 150 meters per minute or faster, label it "V" for vehicle. Any speeds lower than this are usually labeled "P" for personnel, but of course this judgment could be incorrect since it could also be a slow moving vehicle.

Now you will receive practice on what you have just learned concerning the SEVEN STEP target reporting procedure. Study target 2 presented on the X-T plot in Figure 4. Target 2 is the 9-sensor grid target. The sensor ID and pen number combinations are the same as those for Figure 3.

When you have completed all seven target reporting steps for target 2, start working on target 3 of the 24-sensor grid. These targets are not the same! When you are finished with target 3 take your booklet to the Training Monitor.

If you feel you need to review the test procedure before working the practice targets, do so! If you have any questions, ask the Training Monitor at Station 1 or Station 2.

Table 1. Speed Table

TIME IN MINUTES

DISTANCE IN METERS	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	11	12	13
500	500	333	250	200	167	143	125	111	100	91	83	77	71	67	62	59	56	53	50	45	42	38
550	550	367	275	220	183	157	138	122	110	100	92	85	79	73	69	65	61	58	55	50	46	42
600	600	400	300	240	200	171	150	133	120	109	100	93	86	80	75	71	67	63	60	55	50	46
650	650	433	325	260	217	186	163	144	130	118	108	100	93	87	81	76	72	68	65	59	54	50
700	700	467	350	280	233	200	175	156	140	127	117	108	100	93	87	82	78	74	70	64	58	54
750	750	500	375	300	250	214	188	167	150	136	125	115	107	100	94	88	83	79	75	68	63	58
800	800	533	400	320	267	229	200	178	160	145	133	123	114	107	100	94	89	84	80	73	67	62
850	850	567	425	340	283	243	213	189	170	155	142	131	121	113	106	100	94	89	85	77	71	65
900	900	600	450	360	300	257	225	200	180	164	150	138	129	120	112	10[illegible]	100	95	90	82	75	69
950	950	633	475	380	317	271	228	211	190	173	158	146	138	127	119	112	106	100	95	86	79	73
1000	1000	667	500	400	333	286	250	222	200	182	167	154	143	133	125	118	111	105	100	91	83	77
1050	1050	700	525	420	350	300	263	233	210	191	175	162	150	140	131	124	117	111	105	95	88	81
1100	1100	733	550	440	367	314	275	244	220	200	183	169	157	147	137	129	122	116	110	100	92	85
1150	1150	767	575	460	383	329	288	256	230	209	192	177	164	153	144	135	128	121	115	105	96	88
1200	1200	800	600	480	400	343	300	267	240	218	200	185	171	160	150	141	133	126	120	109	100	92
1250	1250	833	625	500	417	357	313	278	250	227	208	192	179	167	156	147	139	132	125	114	104	96
1300	1300	867	650	520	433	371	325	289	260	236	217	200	186	173	162	153	144	137	130	118	108	10[illegible]
1350	1350	900	675	540	450	386	328	300	270	245	225	208	193	180	169	159	150	142	135	123	113	10[illegible]
1400	1400	933	700	560	467	400	350	311	280	255	233	215	200	187	175	165	156	147	140	127	117	10[illegible]
1450	1450	967	725	580	483	414	363	322	290	264	242	223	207	193	181	171	161	153	145	132	121	11[illegible]
1500	1500	1000	750	600	500	429	375	333	300	273	250	231	214	200	187	176	167	158	150	136	125	11[illegible]
1550	1550	1033	775	620	517	443	388	344	310	282	258	238	221	207	194	182	172	163	155	141	129	11[illegible]
1600	1600	1066	800	640	533	457	400	356	320	291	267	246	229	213	200	188	178	168	160	145	133	12[illegible]
1650	1650	1100	825	660	550	471	413	367	330	300	275	254	236	220	206	194	183	174	165	150	138	12[illegible]
1700	1700	1133	850	680	567	486	425	378	340	309	283	262	243	227	212	200	189	179	170	155	142	13[illegible]
1750	1750	1166	875	700	583	500	428	389	350	318	292	269	250	233	219	206	194	184	175	159	146	13[illegible]
1800	1800	1200	900	720	600	514	450	400	360	327	300	277	257	240	225	212	200	189	180	164	150	13[illegible]
1850	1850	1233	925	740	617	529	463	411	370	336	308	285	264	247	231	218	206	195	185	168	154	14[illegible]
1900	1900	1267	950	760	633	543	475	422	380	345	317	292	271	253	237	224	211	200	190	173	158	14[illegible]
1950	1950	1300	975	780	650	557	488	433	390	355	325	300	279	260	244	229	217	205	195	177	163	15[illegible]
2000	2000	1333	1000	800	667	581	500	444	400	364	333	308	286	267	250	235	222	211	200	182	167	15[illegible]
2100	2100	1400	1050	840	700	600	525	467	420	382	350	323	300	280	262	247	233	221	210	191	175	16[illegible]
2200	2200	1467	1100	880	733	629	550	489	440	400	367	338	314	293	275	259	244	232	220	200	183	16[illegible]
2300	2300	1533	1150	920	767	657	575	511	460	418	383	354	329	307	287	271	256	242	230	209	192	17[illegible]
2400	2400	1600	1200	960	800	685	600	533	480	436	400	369	343	320	300	282	267	253	240	218	200	18[illegible]
2500	2500	1666	1250	1000	833	714	625	556	500	455	417	385	357	333	312	294	278	263	250	227	208	19[illegible]

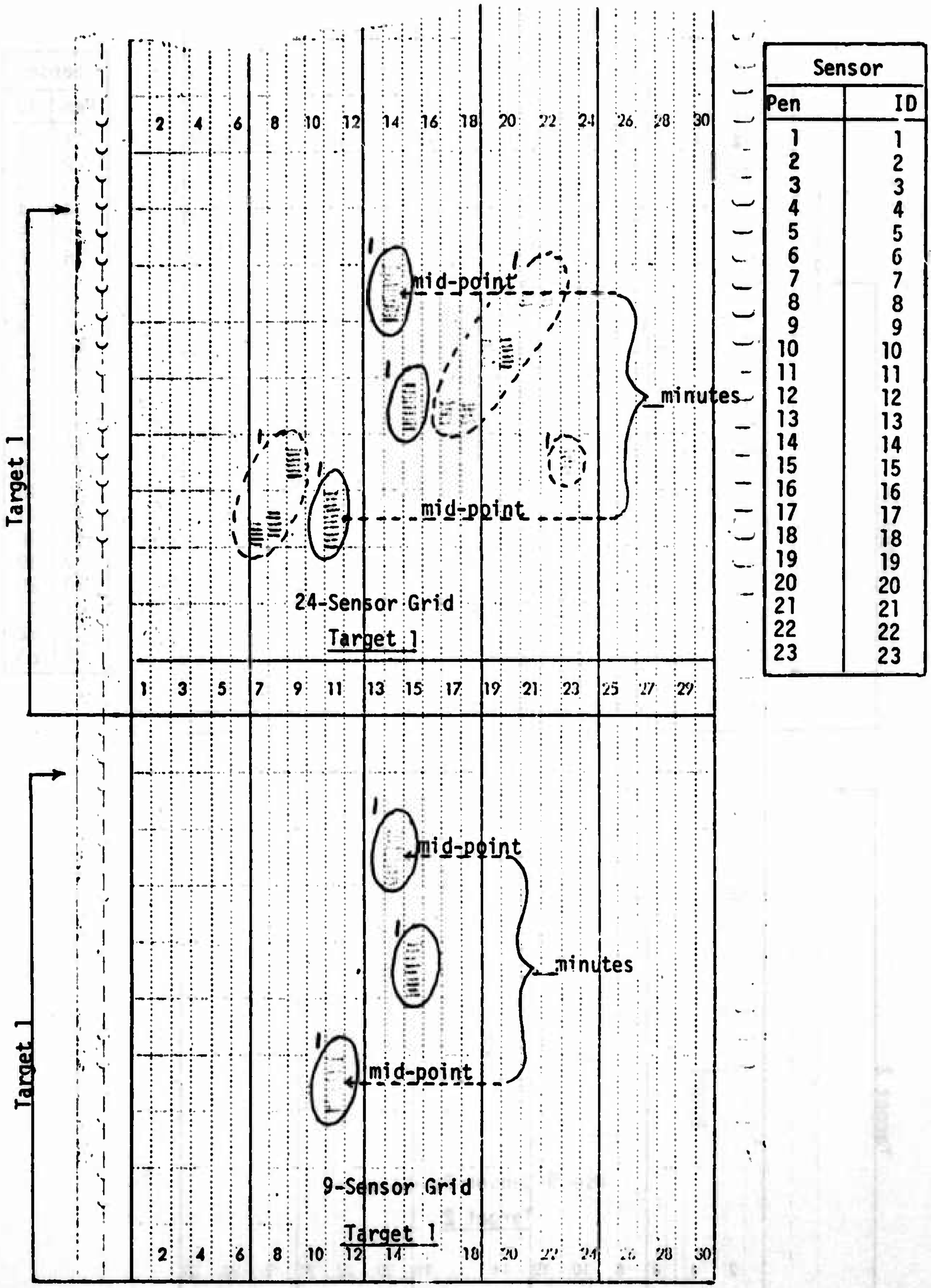
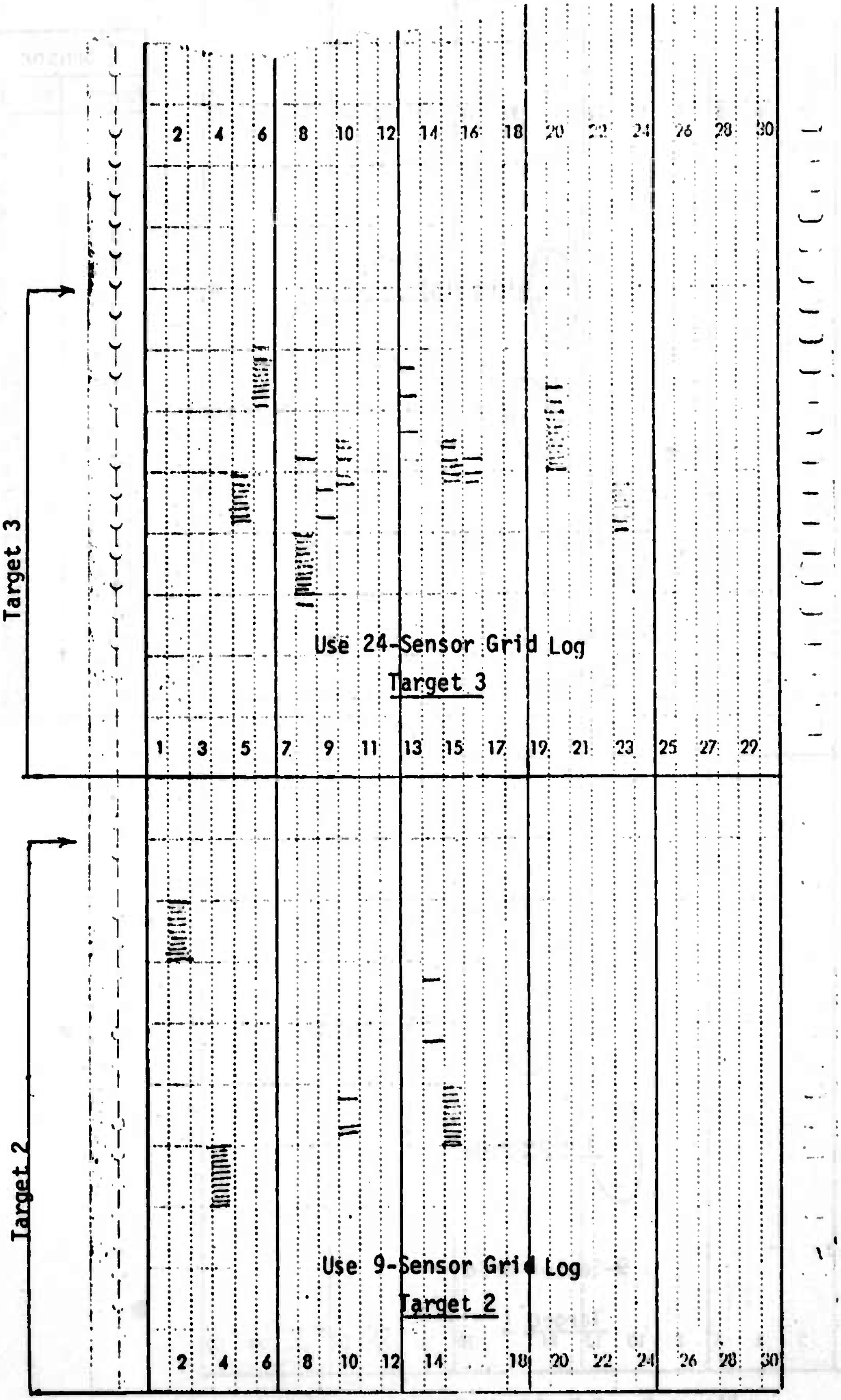


Figure 3. X-T plots of target activations.



Sensor	
Pen	ID
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23

Figure 4. X-T plots of target 2 activations.

APPENDIX F

ROW PATCHING TECHNIQUE TRAINING

OBJECTIVE

To familiarize you with how the row patching technique is used with a grid employment pattern and to train you on how to use it to detect and report on targets using the seven-step reporting procedure.

DEFINITION OF THE ROW PATCHING TECHNIQUE

For the row patching technique, the sensors are grouped into horizontal rows on the grid and patched this way on an X-T plot. The top half of Figure A presents a 24-sensor grid which shows the sensors grouped into five horizontal rows, from Row I to Row V. The bottom half contains the seven-step reporting procedure that you are already familiar with. Notice that the sensor numbers are shown. At this time pull Figure A out of this booklet, write your name in the upper right-hand corner and place it on your desk where it is clearly visible.

PART I 24-Sensor Grid

Examine the 24-sensor grid of Figure A more closely. Study which sensors have been assigned to the various rows. Study which sensors are in each row and fill in the blanks as you get to them.

Row I is composed of sensors 1, 2, 3, 4, and 5.

Row II is composed of sensors 6, 7, 8, and _____.

Row III is composed of sensors 10, 11, 12, 13, and 14.

Row IV is composed of 15, 16, _____, _____, and _____.

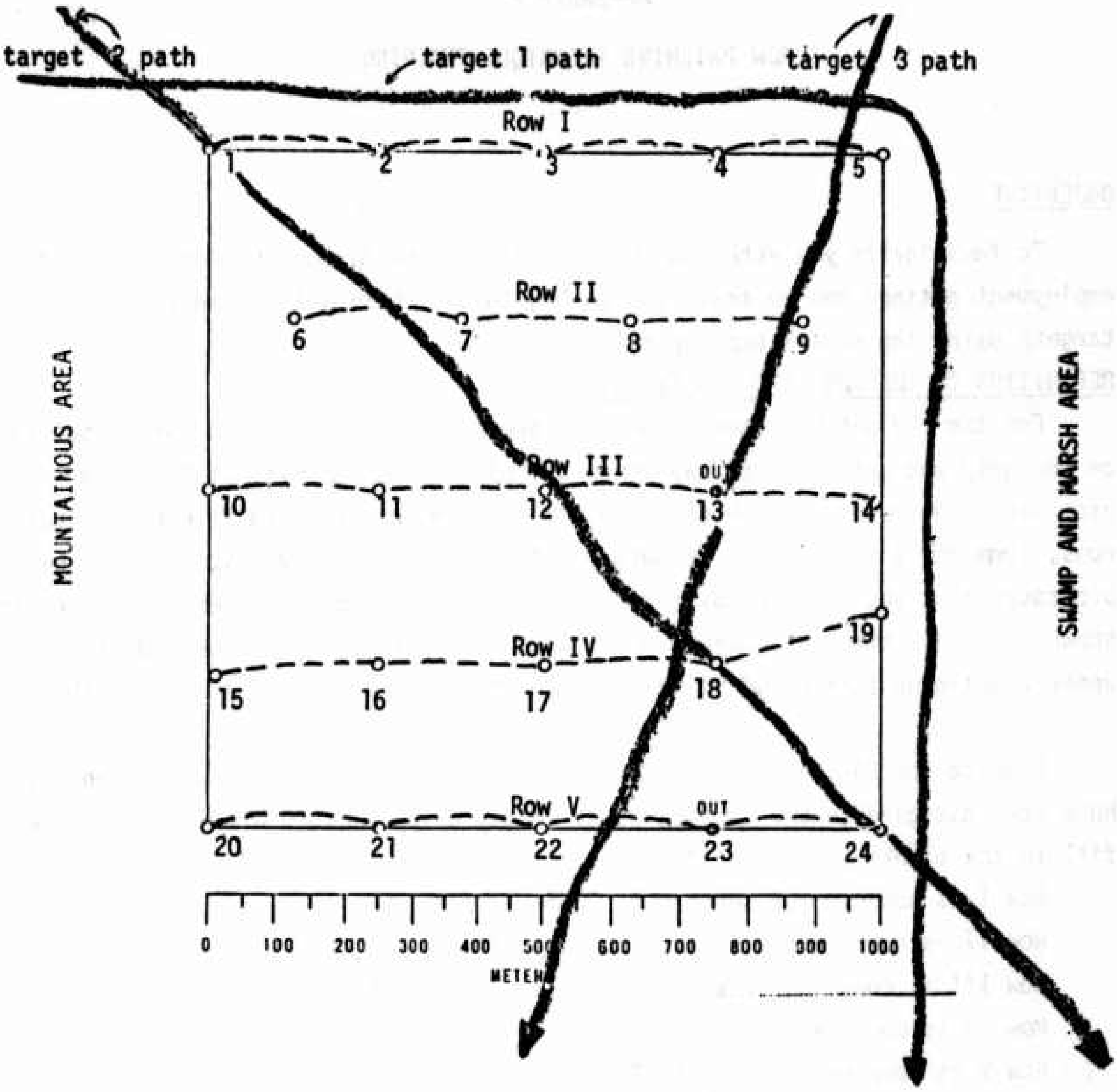
Row V is composed of sensors 20, _____, _____, _____, and _____.

You will notice that all the rows have five sensors except Row II which has four. There is no special reason why there are only four sensors in this row -- they were just employed that way. Other sensor employment patterns could have been used. The important point is that you understand that the sensors are grouped into rows.

DETECTION OF TARGETS

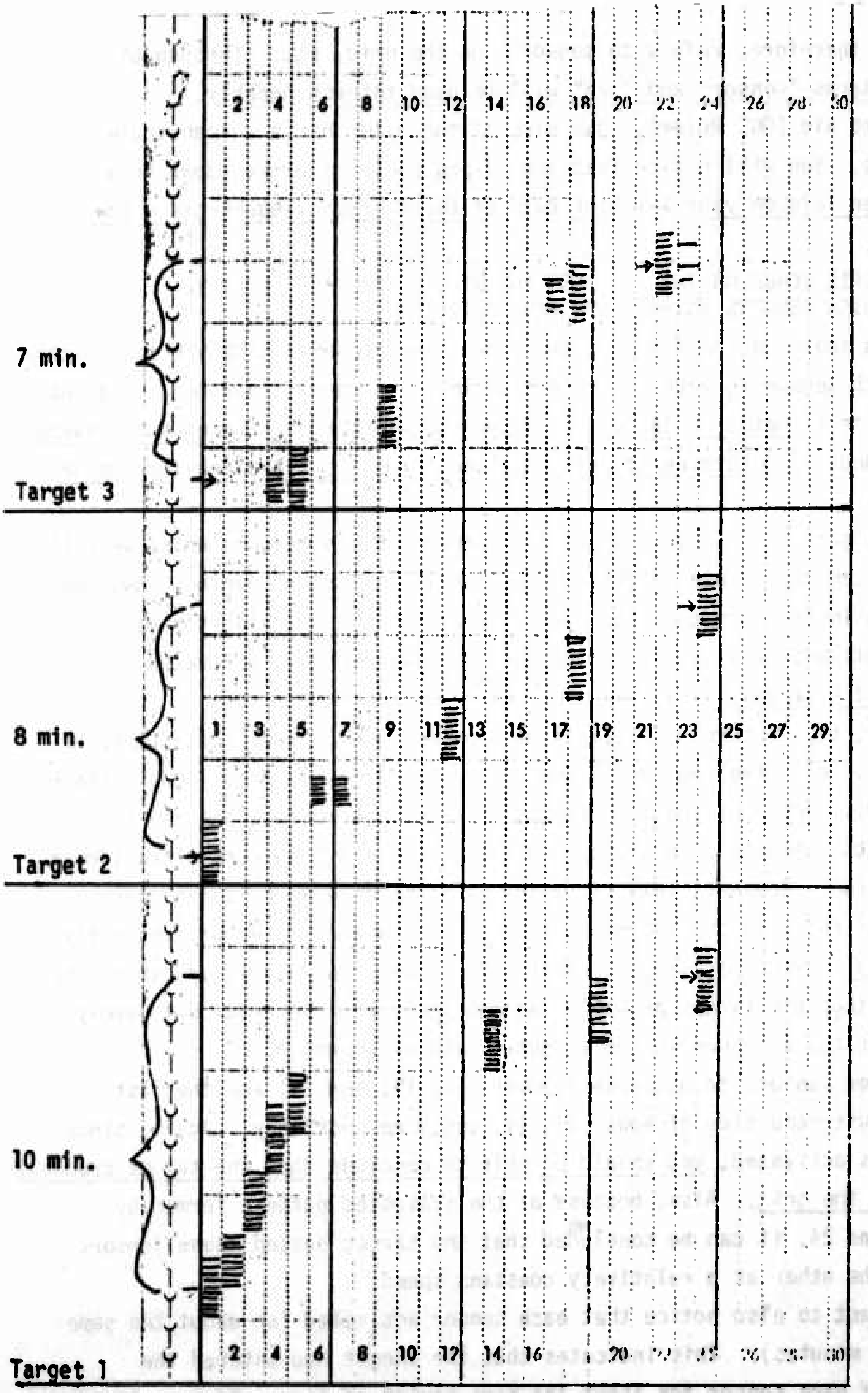
Any target that enters this grid will have to pass <u>through</u> or <u>around</u> one or more of these rows. What this means to you is that you will be able to detect and report on targets by observing what activation activity is taking place in each row. In other words, any target entering or leaving the grid or going around the side of the grid will have to activate sensors in one or more rows.

Now look at the X-T plot in Figure B. The sensors that you have just studied in the grid are each patched to a pen of the same number on this X-T plot. Pen 1



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
1	2100	100%	1,24	10	2100/10 = 210	
2	1450	100%	1,24	8	1450/8 = 181	
3	1050	100%	5,22	7	1050/7 = 150	

Figure A. 24-sensor target log (learning targets).



Row	Pen	Sensor ID
I	1	1
	2	2
	3	3
	4	4
	5	5
II	6	6
	7	7
	8	8
	9	9
III	10	10
	11	11
	12	12
	13	13
	14	14
	15	15
IV	16	16
	17	17
	18	18
	19	19
V	20	20
	21	21
	22	22
	23	23
	24	24
	25	-
	26	-
	27	-
	28	-
	29	-
	30	-

Figure B. X-T plot for row patching using 24-sensor grid (learning targets).

on the X-T plot, therefore, refers to sensor 1 on the grid, etc. Throughout this lesson the terms "sensor" and "pen" will be used interchangeably.

Find your job aid (UGS Ruler). One side of the ruler has a 24-pen scale and a 9-pen scale. You will notice that the 24-pen scale is broken down into five groups. When laid on your X-T plot each of these groups represents a row of sensors.

BY PLACING THIS SCALE ON THE X-T PLOT YOU WILL BE ABLE TO QUICKLY DETERMINE WHICH SENSORS IN EACH ROW HAVE ACTIVATED.

Now lay this scale on the X-T plot and line it up properly. Notice how quickly you can tell which sensor in each row is activating. In many situations, this job aid may help you to 1) detect a target, 2) determine whether the target has traversed the entire grid and, 3) determine if more than one target is traveling through or around the grid.

Go back to Figure A. Figure A shows the paths of three targets which we will analyze. As you can see, these targets passed through or around various rows and activated sensors in these rows. Place your job aid on the X-T plot for each of these three targets and briefly note which pens of each row have activated.

a. Example 1 - Target 1

For target 1, the pattern of activations provides good examples of interpretation principles. All five sensors in Row I have activated in a noticeable stairstep pattern. This indicates that the target traveled somewhere along the row itself as though the sensors were deployed along a road and this were a trail/road monitoring situation. However, this situation is perpendicular to the primary watch direction of the grid and therefore may not be expected to occur frequently. Because no internal sensors activated, especially sensors in Row II, you should be able to conclude that the target probably did not penetrate the grid, but merely traveled along the top as shown in the target 1 path of Figure A.

The last three sensors to activate (sensors 14, 19, and 24) are the last sensors on the right-hand side of Rows III, IV, and V respectively. Again, since only outer sensors activated, you should be able to conclude that the target probably did not penetrate the grid. Also, because of the stairstep pattern formed by sensors 14, 19, and 24, it can be concluded that the target passed these sensors one right after the other at a relatively constant speed.

It is important to also notice that each sensor activated for about the same period of time (2 minutes). This indicates that the target had entered the detection range of each sensor for about the same period of time. Of more importance, this condition implies that the target traveled the same distance away from each sensor. If the activations lengths differed, this would imply that the target traveled closest to the sensor with the longest activation pattern. Other factors, however, might be responsible for this. For example, the sensor with the longest activation pattern might have a higher gain setting.

Take a few minutes now and study the row patching technique. Start with the X-T plot and retrace the path of target 1 on the grid and try to visualize the relationships that we have just discussed.

b. Example 2 - Target 2

Turn your attention now to target 2. First look at the X-T plot, then the grid. Sensor 1 of Row I shows the first activations. The sensor which shows the first activations will usually tell you the closest point in the grid where a target first made contact by entering or going around the grid. The word usually is used here because in the field another sensor may activate first even though it is further away from the target because of detection range differences. Next, sensors 6 and 7 of Row II activated. This indicates that the target has penetrated Row II and traveled somewhere between sensors 6 and 7. The fact that the activation patterns of sensors 6 and 7 are roughly the same length (1 minute) implies that the target probably traveled an equal distance away from them. Notice on the grid that this is where the target 2 path has been drawn.

The next sensor to activate is sensor 12 of Row III. This indicates that the target moved out of Row II and into Row III. Now look at the first four sensors that activated. Notice that sensors 1 and 12 have longer activation patterns than sensors 6 and 7. What might be the reason for this? How could it help you in tracing the target's path through the grid?

YOU MUST USE JUDGMENT IN TRACING A TARGET'S PATH AND BE ABLE TO USE CLUES FROM THE LENGTH OF ACTIVATIONS.

The lengths of these activations indicate that the target came closer to sensors 1 and 12 than it did to sensors 6 and 7. Looking at the grid and the position of these four sensors, we can see that the target passed over sensor 1, went between sensors 6 and 7, and went over sensor 12. The target's path, of course, has been drawn along that route as you can see in Figure A. After sensor 12, the next sensor to activate is sensor 18.

SINCE SENSOR 18 ACTIVATED, YOU KNOW THAT THE TARGET PASSED NEAR OR THROUGH ROW IV.

The last sensor to activate, sensor 24, indicates that the target passed near or through Row V and probably exited on or near sensor 24. As you can see, we have drawn its path in the lo r half of the grid passing directly over sensor ____.

Now look at the X-T plot for target 1. Notice the stairstep pattern as the target progressed through the grid. You can almost draw a straight line between the mid-points of these activation patterns. This indicates that the speed of the target was constant between the rows.

Another aspect of monitoring to keep in mind is single targets versus multiple targets traveling through the grid. Multiple targets are two or more targets traveling around or through the grid at about the same time and whose activations may or may not overlap on the X-T plot. Try the following exercise while still looking at the X-T plot. Imagine that target 1 and target 2 are starting at the same time and progressing through the grid at the same time. In your mind, superimpose target 2 onto target 1 so that the pen 1 activations overlap. Now, actually fill in the remaining activations of target 2 with your pencil or pen. This will only take you several minutes. Be careful as you fill in the activations to reproduce the same time relationships of target 2. Now look at the combined activations of both targets carefully. If you had just now seen these activations for the first time would you be able to tell that two targets were involved? Would you have been able to separate the one long activation pattern on pen 24 into two targets? Remember, several targets can travel through a grid at the same time or close to the same time. If the enemy tried this tactic do you think that you would be able to distinguish and report on the separate targets? Take a few minutes and study the combined activation patterns in relation to the paths of these separate targets on the grid.

c. Example 3 - Target 3

Look at target 3 on the X-T plot. Line up your UGS ruler on the X-T plot directly under target 3. Using your UGS ruler to help you with your answer, how many rows are involved with this entire target ____? Judging by the activations that you can see, the rows involved are I, II, IV, and V. Knowing this gives you an idea of where the target traveled. Now look at the sensors in Row I that activated. Sensor 5 is the first to activate closely followed by sensor ____.

Judging by the length of the activation patterns, which sensor would you say was closest to the target ____? In a situation like this, the probabilities are in favor of concluding that the target was further away from sensor 4 than sensor 5.

r 9 is next to activate indicating that the target has penetrated Row II , probably heading in a downward direction, but slightly to the left as indicated by the path drawn for target 3 on the grid. The next sensors to activate are sensors 17 and 18 of Row IV. What happened to Row III? Did the target fly over it? The last sensor to activate is sensor 22 indicating the target passed through Row V.

To know which sensors were closest to the target for tracing its path, check the length of the activation patterns and this usually will give you a good indication of how close the target came to each of them. According to the X-T plot, of the three sensors 17, 18, and 22, the target passed farthest away from sensor _____ because of the smaller length of the activation pattern.

Take a few minutes now and study target 3. Start with the X-T plot and retrace the path of the target on the grid and try to visualize the relationships that we have just discussed.

Now superimpose target 2 which you studied previously onto target 3 so that they start in the same time frame. With your pencil or pen, fill in the target 2 activations in the same manner that you did previously with target 1. This will take you several minutes to do as before. Now look at the combined activations carefully. If you had just now seen these activations for the first time, would you be able to tell that two targets were involved? Lay your job aid on the X-T plot. Does the job aid help you in distinguishing between these targets? Take a few minutes and study the combined activation patterns in relation to the paths of these separate targets as shown on the grid.

ESTIMATED DISTANCE MEASUREMENT

Once you have detected a target on the X-T plot, numbered it, and drawn what you think is the path of the target on the grid, you must estimate the distance of that path. This, of course, is step 2 of the seven-step procedure that you learned previously.

For this task you will find it helpful to use the other side of the UGS ruler. Take your UGS ruler and look for the scale which is labeled "Distance in Meters." To use this scale, place it along a target path that has been drawn on a grid and measure the length of the path to the nearest 50 meters. Remember that the path of an actual target traveling across country will never be a straight line because of turns in the horizontal direction to avoid obstacles and inclines (hills) in the vertical direction.

BECAUSE OF HILLS AND OBSTACLE AVOIDANCE, ALWAYS OVER-ESTIMATE THE DISTANCE IN METERS THAT YOU GET FROM THE UGS RULER.

Using your UGS ruler, measure the target paths drawn in Figure A and check your estimate with the answers already provided. If your answers differ from the given answers by over 100 meters, consult the Training Monitor.

MID-POINT TIME DIFFERENCE

As you learned previously, an estimate of target speed can be made only by knowing the 1) distance that the target traveled through or around the grid and 2) the amount of time that the target spent in the grid. Step 2 of the seven-step procedure requires the estimated distance. Step 3 gives you confidence as to whether you feel you in fact have detected a real target. Step 4 requires you to record the numbers of the first and last sensors which activated for the target.

Step 5 requires you to find and mark (on the X-T plot) the mid-points of the activation patterns of the first and last sensors which activated and record the time difference. All considered, the time difference between these two mid-points probably gives you the best estimate of how long the target was in the grid than any other method. An easy way to estimate this mid-point time difference is to use a scale.

Check the scale on your UGS ruler which is labeled "Time in Minutes." The scale includes 0 to 15 minutes and should be adequate for measuring most activation patterns that you will be working with. To use this scale simply measure the distance between the two mid-points as though it were a ruler and you were measuring inches. Read the time to the nearest 1/2 minute. This answer would be recorded in the Step 5 blank.

Take a few minutes now and check the mid-points of the first and last sensors of targets 1, 2, and 3 on the X-T plot. Measure the mid-point time differences with your UGS ruler and see how close you come to the school solutions provided in Figure A. You may feel that using the UGS ruler for this measurement is not needed because the answers can be sight-read, but remember that these learning targets were intentionally simplified for training purposes and field-collected targets will be more difficult. In the event that your answers differ by over 1/2 minute from the given answers, consult the Training Monitor.

SPEED CALCULATION

Step 6 requires an estimated speed and Step 7 requires a judgment to be made concerning the type of target whether vehicle or personnel. In order to save time and avoid arithmetic errors, you should use the Speed Table which you have already been taught to use.

PRACTICE TARGETS

Figure C presents a blank 24-sensor grid Target Log. Pull it out of your booklet, write your name in the upper right-hand corner and place it in a handy area. Take your other Target Log (Figure A), fold it in half and place it under your papers where it will not get in the way.

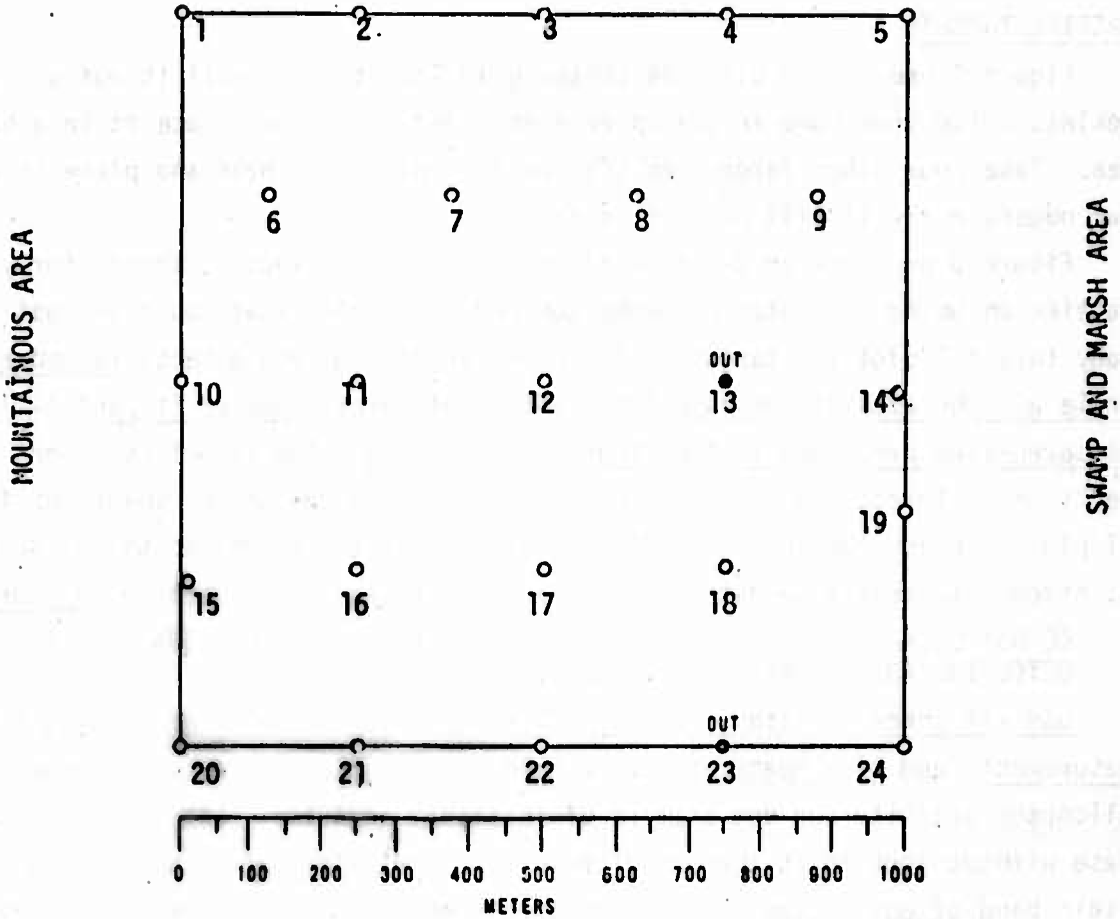
Figure D presents an X-T plot of operationally collected targets for you to practice on using the patching technique and principles that you have just learned. Study this X-T plot for targets. For each target that you detect, remember to circle all the activations associated with that target, number it, and fill in the seven-step procedure in the Figure C Target Log. The school solutions for the Figure C Target Log is presented in Figure E and the school solutions for the X-T plot is presented in Figure F. Do not look at the school solutions prematurely, but attempt to detect targets and fill out the seven-step procedure on your own.

DO NOT LOOK AT THE SCHOOL SOLUTIONS UNTIL YOU HAVE DONE YOUR BEST IN DETECTING AND REPORTING ON TARGETS.

Use all three functions of your UGS ruler: sensor patch groupings, distance measurement, and time measurement. Within the X-T plot there is one example of helicopter activity and one example of artillery activity. See if you can spot these without looking at the school solution. Artillery activity usually yields a thin band of one or two activations across many sensors located in the area. Because the seismic disturbance of the helicopter is in the area longer than the concussion of artillery activity, it will usually produce a grouping of at least two or more activations across many sensors located in the area.

As you work through these operationally-collected practice targets, remember that they are not the sterile, ideal examples which were prepared to help you understand the characteristics of a particular patching technique. They contain various sources of background noise and the effects of malfunctioning sensors and variations in sensor detection range due to gain setting, ground/terrain conditions and weather. To be able to do a good UGS reporting job, you must learn how to detect and extract target information from X-T plots collected in the field.

Consult the Training Monitors when you feel the need. When you are finished with your practice targets, take your work to the Training Monitor. He will determine whether you need additional targets for more practice and/or review.



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE

Figure C. 24-sensor target log (practice targets).

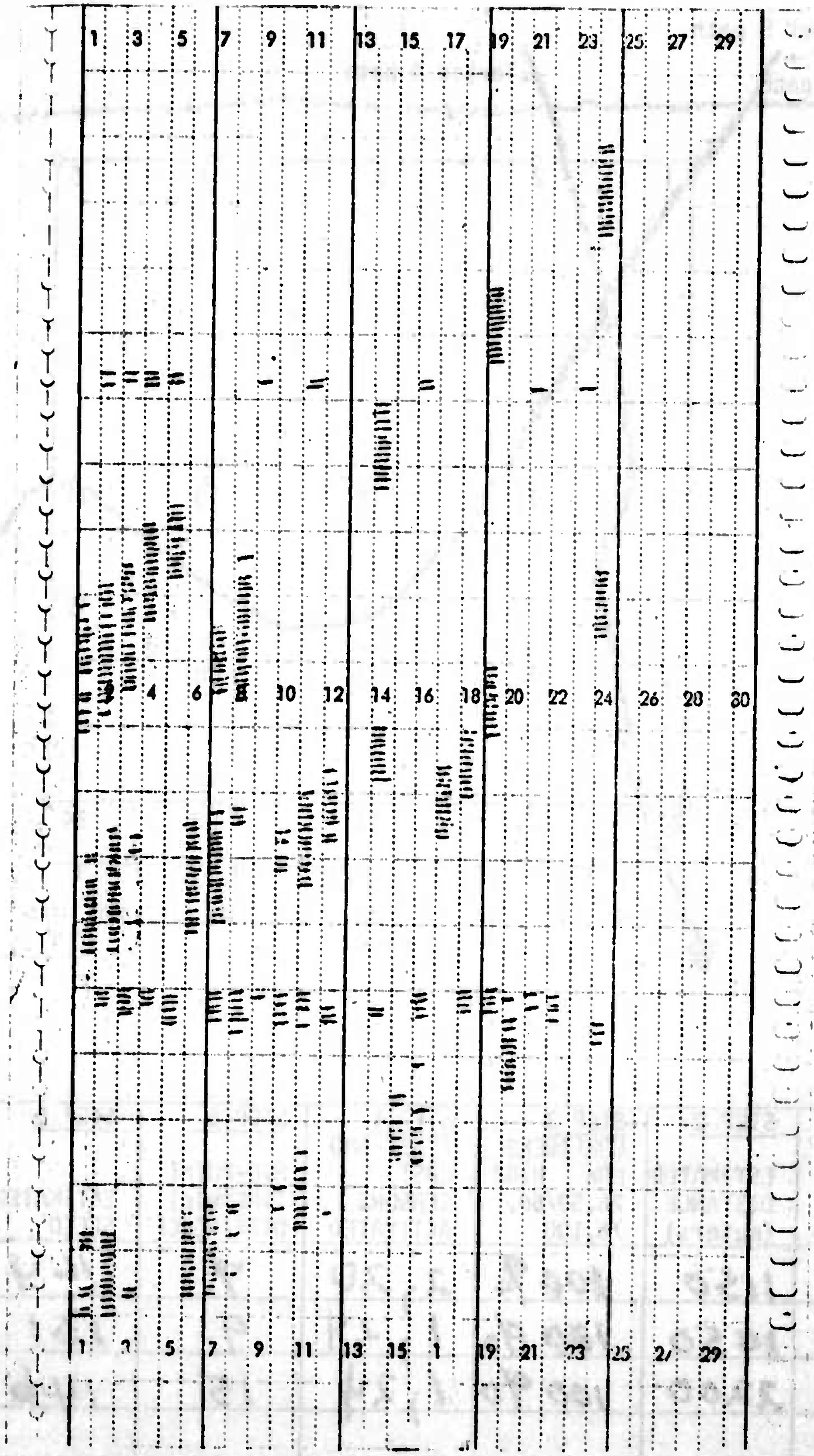
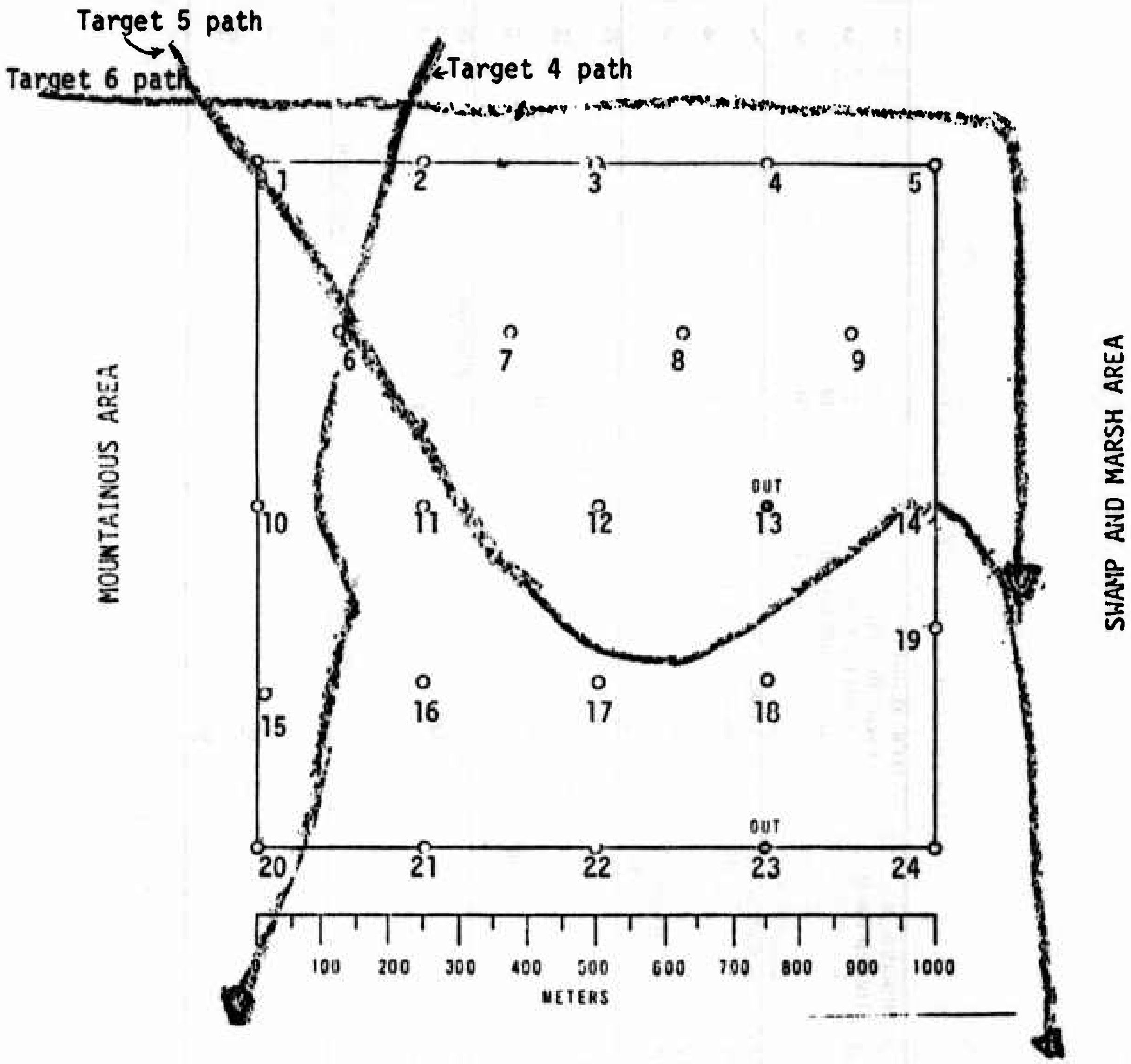


Figure D. X-T plot for row patching using the 24-sensor grid (practice targets).



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
4	1150	100 %	2, 20	7	164	
5	1450	100 %	1, 24	9	161	
6	2200	100 %	1, 24	15	146	

Figure E. 24-sensor target log (school solution).

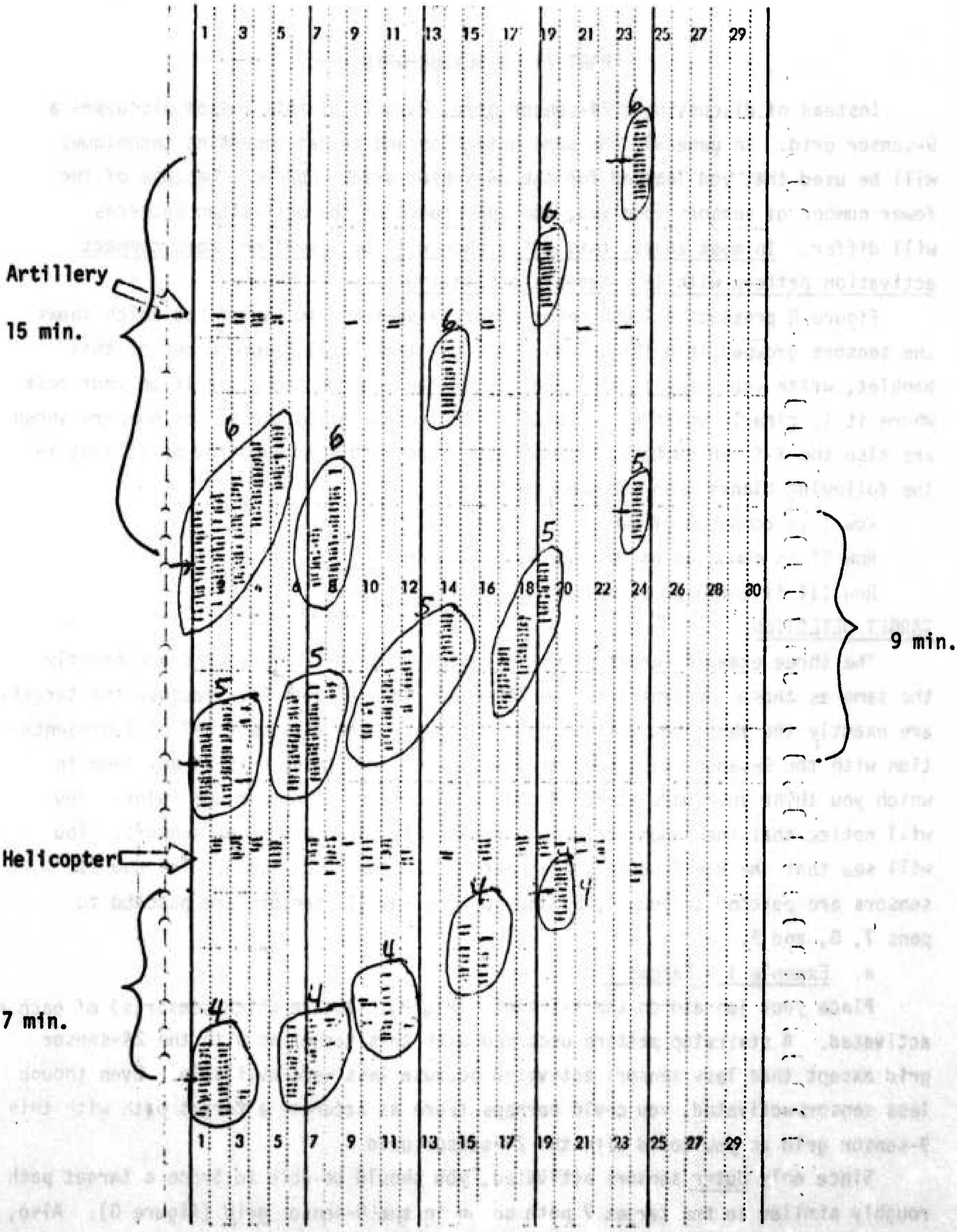


Figure F. X-T plot for row patching using the 24-sensor grid (school solution).

PART II 9-SENSOR GRID

Instead of discussing a 24-sensor grid, Part II of this lesson discusses a 9-sensor grid. In general, the same detection and target reporting techniques will be used that you learned for the 24-sensor grid. However, because of the fewer number of sensors involved, the appearance of the activation patterns will differ. In most cases, this difference will be a smaller, more compact activation pattern with less sensors activating.

Figure G presents a 1,000 meter square 9-sensor grid Target Log which shows the sensors grouped into three rows. At this time, pull Figure G out of this booklet, write your name in the upper right-hand corner and place it on your desk where it is clearly visible. As with the 24-sensor grid, the sensor numbers shown are also the X-T pen numbers. Study which sensors are in each row by filling in the following blanks when you come to them.

Row I is composed of sensors 1, 2, and 3.

Row II is composed of sensors 4, _____, and _____.

Row III is composed of sensors _____, _____, and _____.

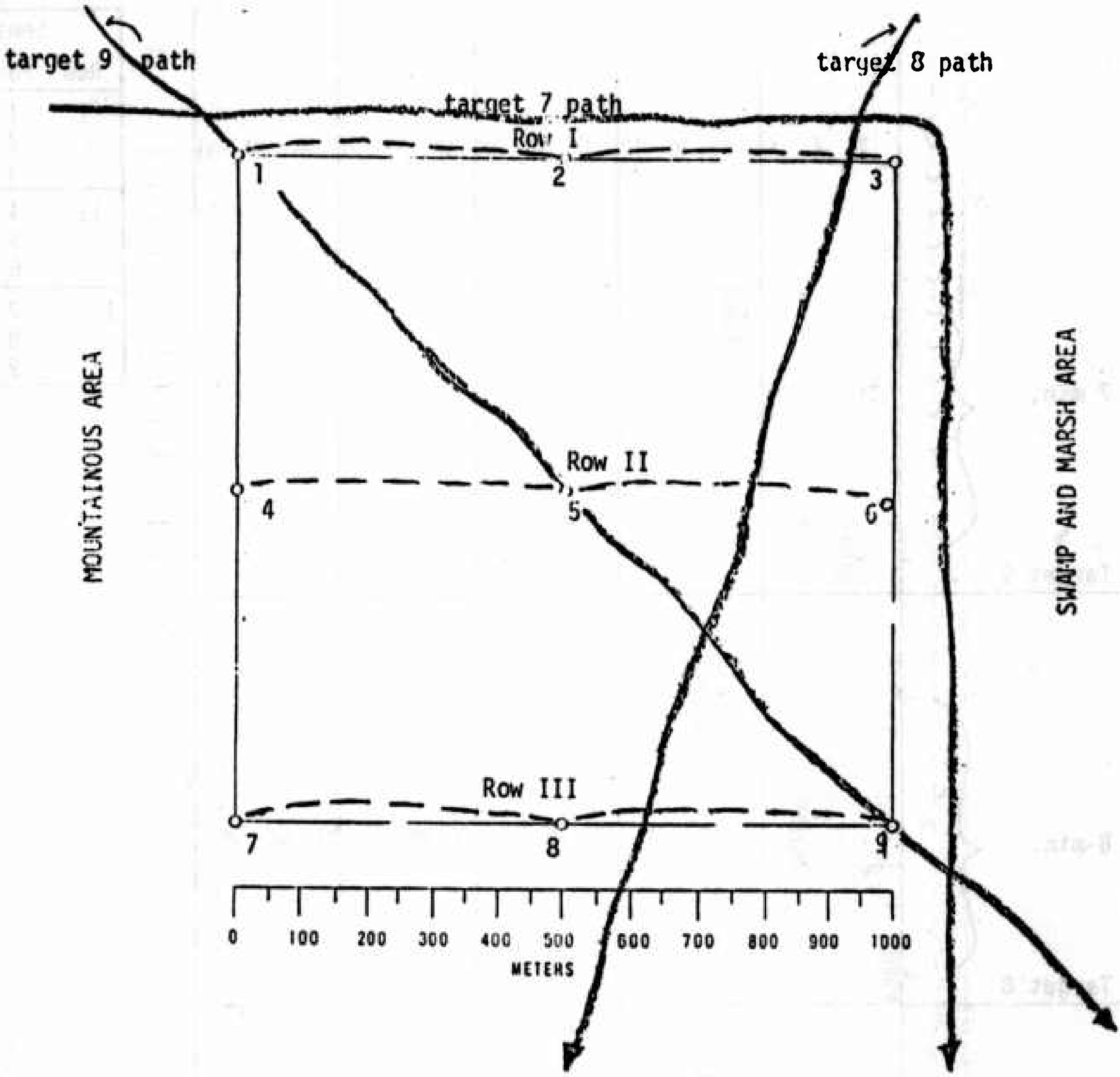
TARGET DETECTION

The three example target paths presented in this 9-sensor grid are exactly the same as those presented in the 24-sensor grid (Figure A). Because the targets are exactly the same, you will be able to compare the 24-sensor X-T plot presentation with the 9-sensor plot presentation. Feel free to do this at any time in which you think your understanding can be enhanced. Find your UGS ruler. You will notice that the 9-pen scale is divided into three groups of sensors. You will see that the Row I sensors are patched to pens 1, 2, and 3. The Row II sensors are patched to pens 4, 5, and 6. The Row III sensors are patched to pens 7, 8, and 9.

a. Example 1 - Target 7

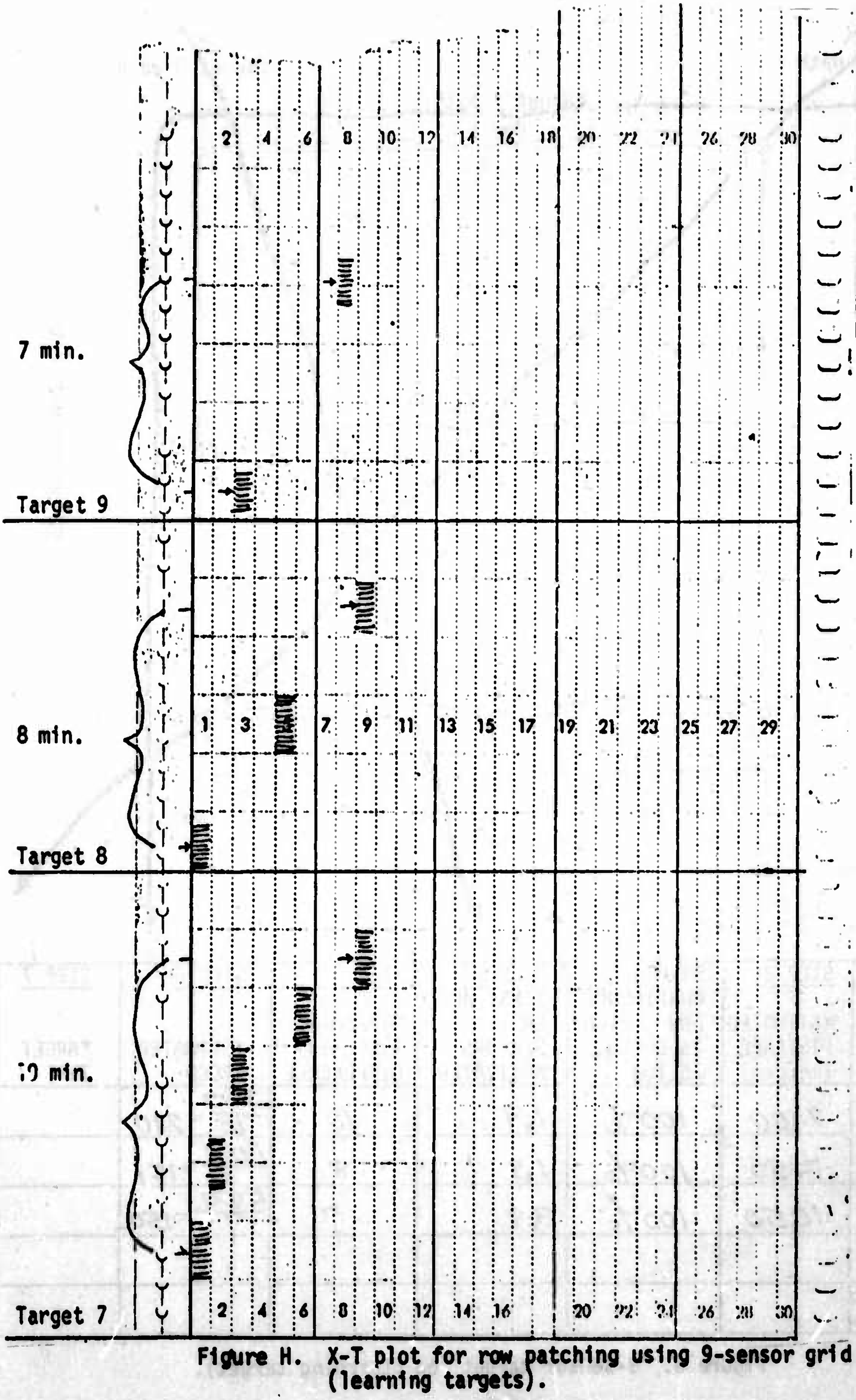
Place your job aid on the X-T plot (Fig H). Notice which sensor(s) of each row activated. A stairstep pattern occurred with this target as with the 24-sensor grid except that less sensors activated because less were available. Even though less sensors activated, you could perhaps trace as accurate a target path with this 9-sensor grid as you could with the 24-sensor grid.

Since only outer sensors activated, you should be able to trace a target path roughly similar to the target 7 path shown in the 9-sensor grid (Figure G). Also, the fact that each sensor activated for about the same period of time, i.e., two



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
7	2100	100%	1,9	10	2100/10 = 210	
8	1450	100%	1,9	8	1450/8 = 181	
9	1050	100%	3,8	7	1050/7 = 150	

Figure G. 9-sensor target log (learning target).



Sensor		
Row	Pen	ID
I	1	1
	2	2
	3	3
II	4	4
	5	5
	6	6
III	7	7
	8	8
	9	9

Figure H. X-T plot for row patching using 9-sensor grid (learning targets).

minutes, implies that the target was approximately the same distance away from the sensors. Of course, you would not know exactly how far away that distance was, but you would be able to trace a path in the proper direction and area.

Take a few minutes now and study the relationships between the X-T plot and the path drawn on the 9-sensor grid for target 7. Review the same principles that you learned in the 24-sensor grid discussion.

b. Example 2 - Target 8

In this example, place your job aid on the X-T plot and follow the progression of the target from one row to the next as it passed through the grid from sensor 1 to sensor 9. Notice the length of the activation patterns and the time difference between them. What does it mean when the activation lengths are similar? A stair-step pattern of activations as in this case implies that the target was traveling a constant speed.

Remember to keep in mind single targets versus multiple targets traveling through the grid. Try the following exercise while still looking at the X-T plot. Imagine that target 7 and target 8 are starting at the same time and progressing through the grid at the same time. In your mind, superimpose target 8 onto target 7 so that the pen 1 activations overlap. Now, actually fill in the remaining activations of target 8 with your pencil or pen. Be careful as you fill in the activations to reproduce the same time relationships of target 8. Now look at the combined activations of both targets carefully. If you had just now seen these activations for the first time would you be able to tell that two targets were involved? Would you have been able to separate the one long activation pattern on pen 24 into two targets? Remember, several targets can travel through a grid at the same time or close to the same time. If the enemy tried this tactic do you think that you would be able to distinguish and report on the separate targets? Take a few minutes and study the combined activation patterns in relation to the paths of these separate targets on the grid.

c. Example 3 - Target 9

Place your job aid on the X-T plot. The activations are in which rows? Only two pens activated for this target. This provides you, however, with enough information to know that a target probably penetrated the grid and passed from Row I to Row III. Also, two activated sensors give you the minimum number of sensors needed to make your speed calculation.

Take a few minutes now and study the relationships between the X-T plot and the path drawn on the 9-sensor grid. Review the same principles that you learned with the 24-sensor grid.

Now superimpose target 8 which you studied previously onto target 9 so that they start in the same time frame. With your pencil or pen, fill in the target 8 activations in the same manner that you did previously with target 7. This will take you several minutes to do as before. Now look at the combined activations carefully. If you had just now seen these activations for the first time, would you be able to tell that two targets were involved? Lay yourjob aid on the X-T plot. Does the job aid help you in distinguishing between these targets? Take a few minutes and study the combined activation patterns in relation to the paths of these separate targets as shown on the grid.

DISTANCE MEASUREMENT

As you did with the 24-sensor grid, measure the length of the path of all three targets using your UGS ruler and then check your answers with those in Figure G. If your answer differs from the given one by over 200 meters, consult the Training Monitor.

TIME MEASUREMENT

As you did with the 24-sensor grid determine the mid-point time differences of each target using the UGS ruler and check them with the answers given in Figure G. If your answer differs from the given one by over one minute, consult the Training Monitor.

SPEED CALCULATION

As you did with the 24-sensor grid, determine the estimated speed of the targets using the Speed Table and check your answers with those given in Figure G. If your answer differs from the given answer by 50 meters/minute , consult the Training Monitor.

PRACTICE TARGETS

Figure I presents a blank 9-sensor grid Target Log. Pull it out of your booklet, write your name in the upper right-hand corner and place it in a handy area. Take your owner Target Log (Figure G), fold it in half and place it under your papers.

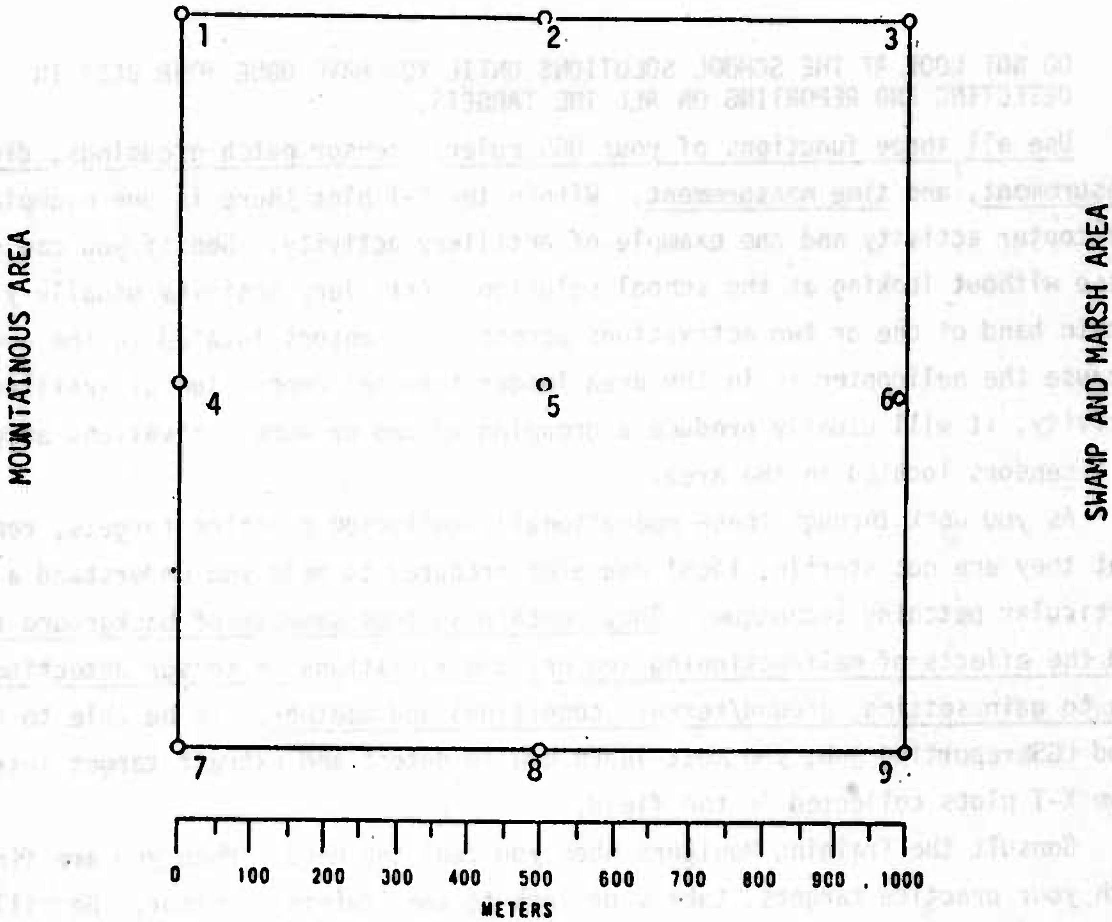
Figure J presents an X-T plot of operationally collected targets for you to practice on using the patching technique that you have just learned. Study this X-T plot for targets. For each target that you detect, use the Target Log on Figure I for your report and fill in the seven-step procedure. The school solution for the Target Log is presented in Figure K and the school solution for the X-T plot is presented in Figure L. Do not look at the school solutions prematurely, but attempt to detect targets and fill out the seven-step procedure on your own.

DO NOT LOOK AT THE SCHOOL SOLUTIONS UNTIL YOU HAVE DONE YOUR BEST IN DETECTING AND REPORTING ON ALL THE TARGETS.

Use all three functions of your UGS ruler: sensor patch groupings, distance measurement, and time measurement. Within the X-T plot there is one example of helicopter activity and one example of artillery activity. See if you can spot these without looking at the school solution. Artillery activity usually yields a thin band of one or two activations across sensors located in the area. Because the helicopter is in the area longer than the concussion of artillery activity, it will usually produce a grouping of two or more activations across sensors located in the area.

As you work through these operationally-collected practice targets, remember that they are not sterile, ideal examples prepared to help you understand a particular patching technique. They contain various sources of background noise and the effects of malfunctioning sensors and variations in sensor detection range due to gain setting, ground/terrain conditions and weather. To be able to do a good UGS reporting job, you must learn how to detect and extract target information from X-T plots collected in the field.

Consult the Training Monitors when you feel the need. When you are finished with your practice targets, take your work to the Training Monitor. He will determine whether you need additional targets for more practice and/or review.



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW→HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE

Figure I. 9-sensor target log (practice targets).

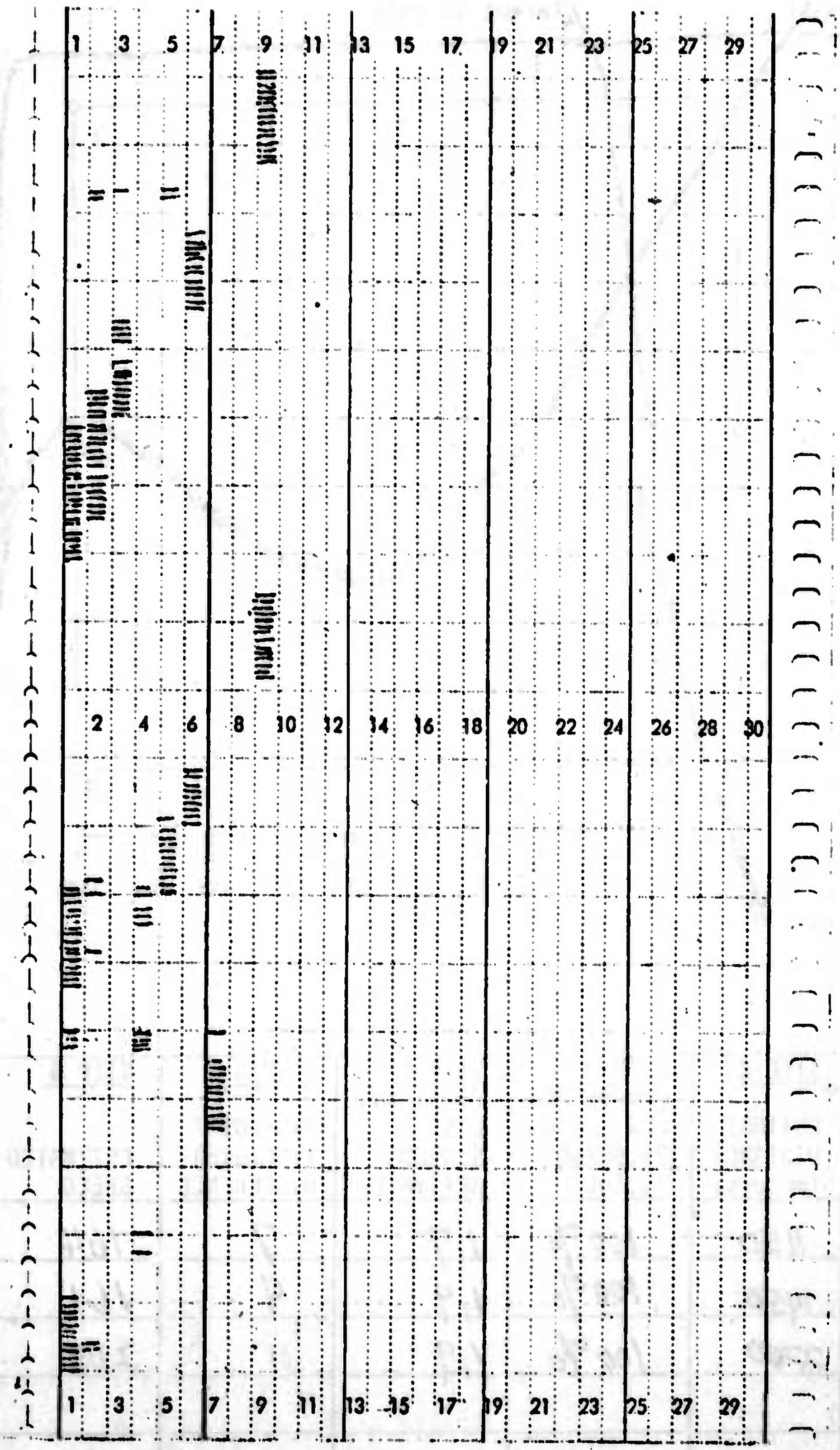
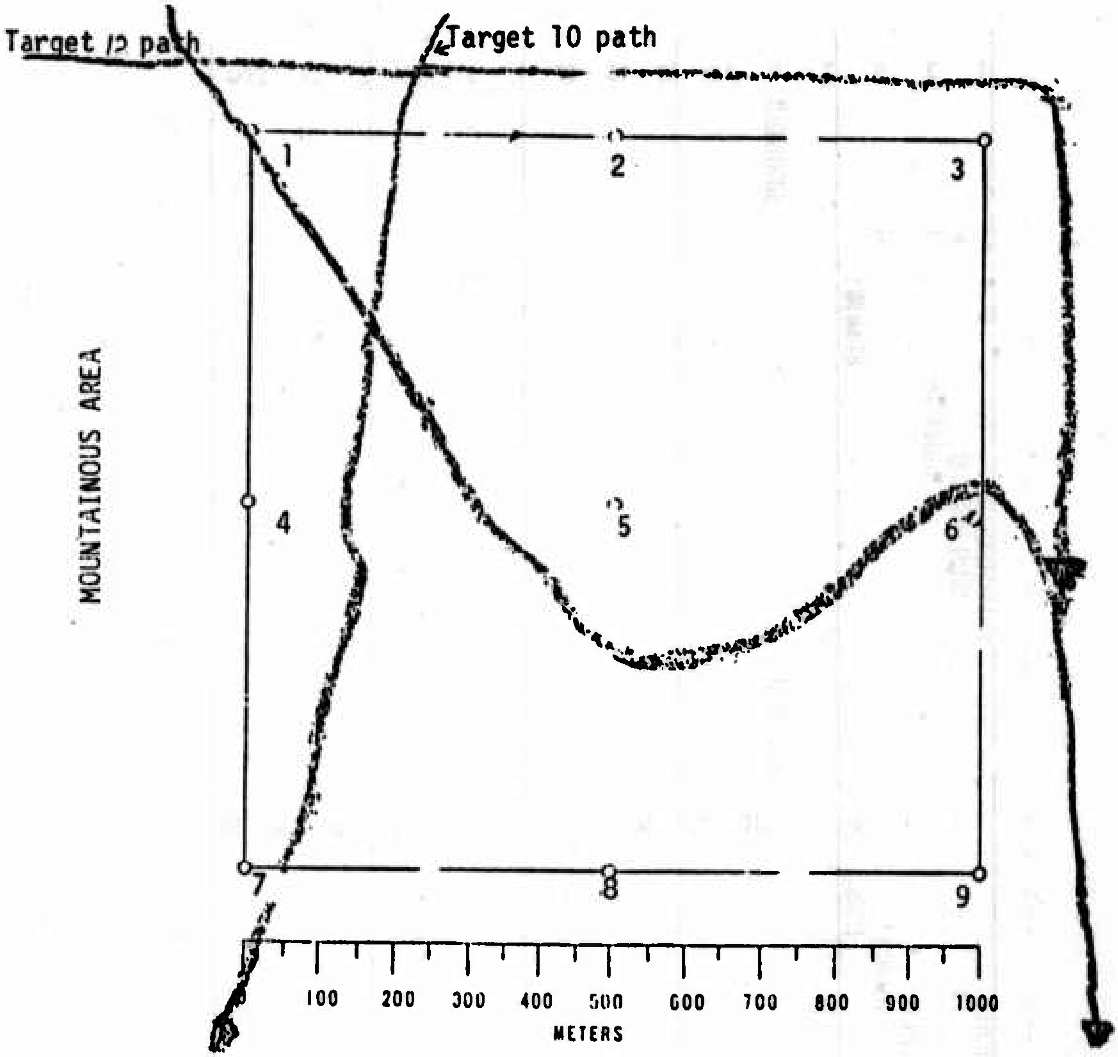


Figure J. X-T plot for row patching using the 9-sensor grid (practice targets).



STEP 1 TARGET NUMBER	STEP 2 ESTIMATED DISTANCE (meters)	STEP 3 CONFIDENCE LOW HIGH 25,50/50, 75,100	STEP 4 FIRST AND LAST SENSORS ACTIVATED	STEP 5 MID-POINT TIME(min) DIFFERENCE	STEP 6 ESTIMATED SPEED	STEP 7 TARGET TYPE
10	1150	100%	1,7	7	164	
11	1450	100%	1,9	9	161	
12	2200	100%	1,9	11	200	

Figure K. 9-sensor target log (school solution).

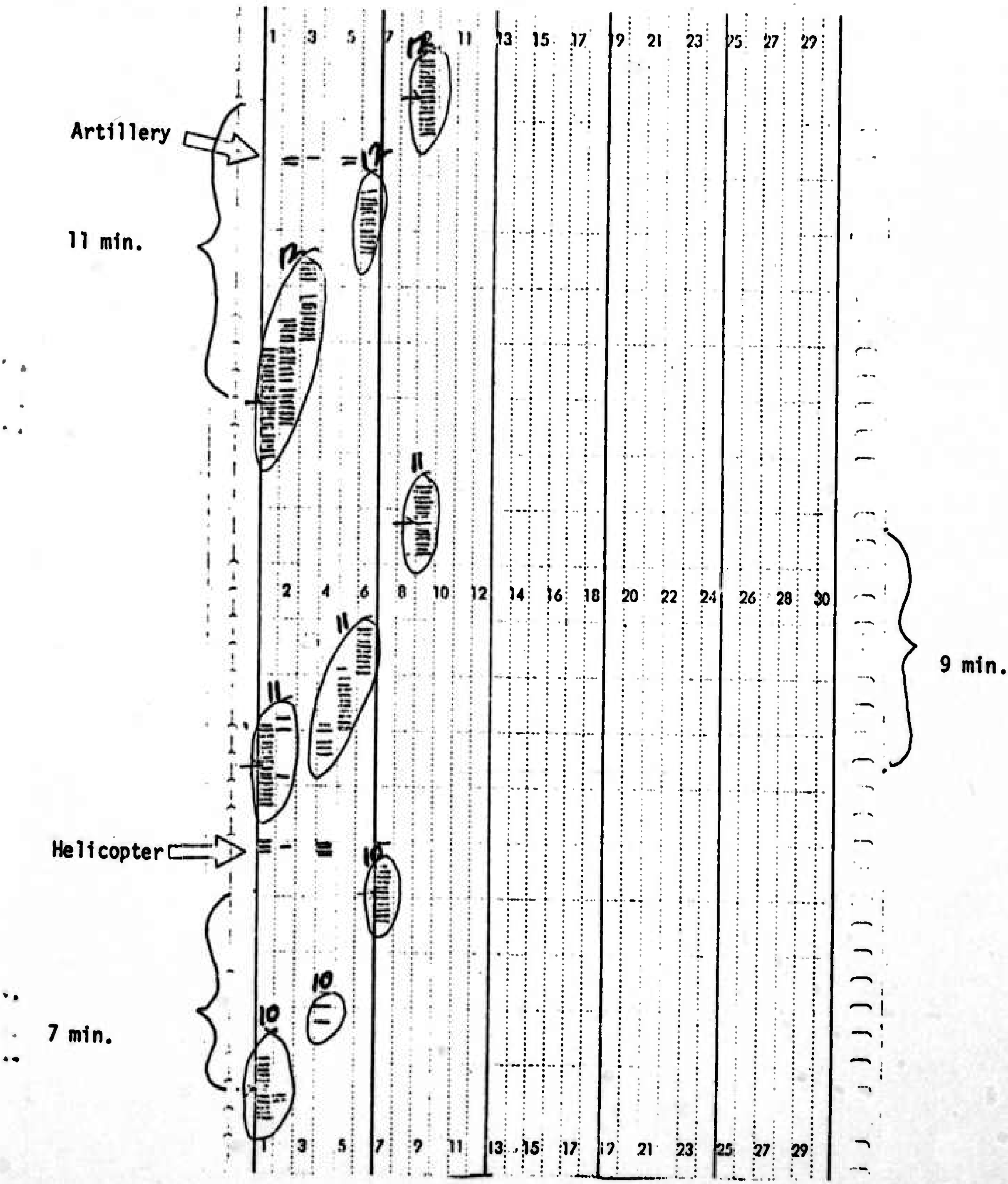


Figure L. X-T plot for row patching using 9-sensor grid (school solution).

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1 US WAC Ctr & Sch, Ft McClellan, ATTN: Lib
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1 USA Materials Sys Anal Agcy, Aberdeen, ATTN: AMXSY–P
1 Edgewood Arsenal, Aberdeen, ATTN: SAREA–BL–H
1 USA Ord Ctr & Sch, Aberdeen, ATTN: ATSL–TEM–C
2 USA Hum Engr Lab, Aberdeen, ATTN: Library/Dir
1 USA Combat Arms Tng Bd, Ft Benning, ATTN: Ad Supervisor
1 USA Infantry Hum Rsch Unit, Ft Benning, ATTN: Chief
1 USA Infantry Bd, Ft Benning, ATTN: STEBC–TE–T
1 USASMA, Ft Bliss, ATTN: ATSS–LRC
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA–CTD–ME
1 USA Air Def Sch, Ft Bliss, ATTN: Tech Lib
1 USA Air Def Bd, Ft Bliss, ATTN: FILES
1 USA Air Def Bd, Ft Bliss, ATTN: STEBD–PO
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Lib
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: ATSW–SE–L
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Ed Advisor
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: DepCdr
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: CCS
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCASA
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACO–I
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACC–CI
1 USAECOM, Night Vision Lab, Ft Belvoir, ATTN: AMSEL–NV–SD
3 USA Computer Sys Cmd, Ft Belvoir, ATTN: Tech Library
1 USAMERDC, Ft Belvoir, ATTN: STSFB–DQ
1 USA Eng Sch, Ft Belvoir, ATTN: Library
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL–TD–S
1 USA Topographic Lab, Ft Belvoir, ATTN: STINFO Center
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL–GSL
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: CTD–MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATS–CTD–MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–TE
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–TEX–GS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–CTS–OR
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–CTD–DT
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–CTD–CS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: DAS/SRD
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI–TEM
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: Library
1 CDR, HQ Ft Huachuca, ATTN: Tech Ref Div
2 CDR, USA Electronic Prvg Grd, ATTN: STEEP–MT–S
1 CDR, Project MASSTER, ATTN: Tech Info Center
1 Hq MASSTER, USATRADOC, LNO
1 Research Institute, HQ MASSTER, Ft Hood
1 USA Recruiting Cmd, Ft Sherdian, ATTN: USARCPM–P
1 Senior Army Adv., USAFAGOD/TAC, Elgin AF Aux Fld No. 9
1 HQ USARPAC, DCSPER, APO SF 96558, ATTN: GPPE–SE
1 Stimson Lib, Academy of Health Sciences, Ft Sam Houston
1 Marine Corps Inst., ATTN: Dean–MCI
1 HQUSMC, Commandant, ATTN: Code MTMT 51
1 HQUSMC, Commandant, ATTN: Code MPI–20
2 USCG Academy, New London, ATTN: Admission
2 USCG Academy, New London, ATTN: Library
1 USCG Training Ctr, NY, ATTN: CO
1 USCG Training Ctr, NY, ATTN. Educ Svc Ofc
1 USCG, Psychol Res Br, DC, ATTN: GP 1/62
1 HQ Mid–Range Br, MC Det, Quantico, ATTN: P&S Div

1 US Marine Corps Liaison Ofc, AMC, Alexandria, ATTN: AMCGS–F
1 USATRADOC, Ft Monroe, ATTN: ATRO–ED
6 USATRADOC, Ft Monroe, ATTN: ATPR–AD
1 USATRADOC, Ft Monroe, ATTN: ATTS–EA
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1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Library
1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Educ Advisor
1 USA Aviation Sch, Ft Rucker, ATTN: PO Drawer O
1 HQUSA Aviation Sys Cmd, St Louis, ATTN: AMSAV–ZDR
2 USA Aviation Sys Test Act., Edwards AFB, ATTN: SAVTE–T
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA TEM
1 USA Air Mobility Rsch & Dev Lab, Moffett Fld, ATTN: SAVDL–AS
1 USA Aviation Sch, Res Tng Mgt, Ft Rucker, ATTN: ATST–T–RTM
1 USA Aviation Sch, CO, Ft Rucker, ATTN: ATST–D–A
1 HQ, DARCOM, Alexandria, ATTN: AMXCD–TL
1 HQ, DARCOM, Alexandria, ATTN: CDR
1 US Military Academy, West Point, ATTN: Serials Unit
1 US Military Academy, West Point, ATTN: Ofc of Milt Ldrshp
1 US Military Academy, West Point, ATTN: MAOR
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1 Ofc of Naval Rsch, Arlington, ATTN: Code 452
3 Ofc of Naval Rsch, Arlington, ATTN: Code 458
1 Ofc of Naval Rsch, Arlington, ATTN: Code 450
1 Ofc of Naval Rsch, Arlington, ATTN: Code 441
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Acous Sch Div
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L51
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L5
1 Chief of NavPers, ATTN: Pers-OR
1 NAVAIRSTA, Norfolk, ATTN: Safety Ctr
1 Nav Oceanographic, DC, ATTN: Code 6251, Charts & Tech
1 Center of Naval Anal, ATTN: Doc Ctr
1 NavAirSysCom, ATTN: AIR–5313C
1 Nav BuMed, ATTN: 713
1 NavHelicopterSubSqua 2, FPO SF 96601
1 AFHRL (FT) William AFB
1 AFHRL (TT) Lowry AFB
1 AFHRL (AS) WPAFB, OH
2 AFHRL (DOJZ) Brooks AFB
1 AFHRL (DOJN) Lackland AFB
1 HQUSAF (INYSD)
1 HQUSAF (DPXXA)
1 AFVTG (RD) Randolph AFB
3 AMRL (HE) WPAFB, OH
2 AF Inst of Tech, WPAFB, OH, ATTN: ENE/SL
1 ATC (XPTD) Randolph AFB
1 USAF AeroMed Lib, Brooks AFB (SUL–4), ATTN: DOC SEC
1 AFOSR (NL), Arlington
1 AF Log Cmd, McClellan AFB, ATTN: ALC/DPCRB
1 Air Force Academy, CO, ATTN: Dept of Bel Scn
5 NavPers & Dev Ctr, San Diego
2 Navy Med Neuropsychiatric Rsch Unit, San Diego
1 Nav Electronic Lab, San Diego, ATTN: Res Lab
1 Nav TrngCen, San Diego, ATTN: Code 9000–Lib
1 NavPostGraSch, Monterey, ATTN: Code 55Aa
1 NavPostGraSch, Monterey, ATTN: Code 2124
1 NavTrngEquipCtr, Orlando, ATTN: Tech Lib
1 US Dept of Labor, DC, ATTN: Manpower Admin
1 US Dept of Justice, DC, ATTN: Drug Enforce Admin
1 Nat Bur of Standards, DC, ATTN: Computer Info Section
1 Nat Clearing House for MH–Info, Rockville
1 Denver Federal Ctr, Lakewood, ATTN: BLM
12 Defense Documentation Center
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1 Centre de Recherche Des Facteurs, Humaine de la Defense Nationale, Brussels
2 Canadian Joint Staff Washington
1 C/Air Staff, Royal Canadian AF, ATTN: Pers Std Anal Br
3 Chief, Canadian Def Rsch Staff, ATTN: C/CRDS(W)
4 British Def Staff, British Embassy, Washington
1 Def & Civil Inst of Enviro Medicine, Canada
1 AIR CRESS, Kensington, ATTN: Info Sys Br
1 Militaerpsykologisk Tjeneste, Copehagen
1 Military Attache, French Embassy, ATTN: Doc Sec
1 Medecin Chef, C.E.R.P.A.–Arsenal, Toulon/Naval France
1 Prin Scientific Off, Appl Hum Engr Rsch Div, Ministry of Defense, New Delhi
1 Pers Rsch Ofc Library, AKA, Israel Defense Forces
1 Ministerie van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands