Research Report 1253

LEVEL

SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS

AD A 097776

Harold Martinek

HUMAN FACTORS TECHNICAL AREA

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

July 1980

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

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NOTICES

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI-RR-1253

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Research Report 1253	2. GOVT ACCESSION NO.: AD-A097776
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS	5. TYPE OF REPORT & PERIOD COVERED: Final Report, Jun[redacted]73 — Jun[redacted]80
	6. PERFORMING ORG. REPORT NUMBER: --
7. AUTHOR(s): Harold Martinek	8. CONTRACT OR GRANT NUMBER(s): --
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Ave., Alexandria, VA 22333	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2Q163739A793
11. CONTROLLING OFFICE NAME AND ADDRESS: Deputy Chief of Staff for Personnel, Washington, DC 20310	12. REPORT DATE: Jul[redacted]80
	13. NUMBER OF PAGES: 40
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): --	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

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

--

18. SUPPLEMENTARY NOTES

--

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

Unattended Ground Sensors (UGS); Remotely Monitored Sensors (REMS); UGS, REMS surveillance; Target acquisition; Acoustic sensors; Seismic sensors; Training; Displays; Operator aids; MOS 17M; REMBASS; Personnel requirements

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

The future battlefield will demand an increased ability to acquire, transmit, process, disseminate, and utilize surveillance and target acquisition information. One relatively new source of intelligence information is remote monitoring of the battlefield, using seismic, acoustic, and magnetic remotely monitored sensors (REMS). When enemy personnel or vehicle movement activates these remote sensors, a monitor display located behind our lines indicates the activity. The operator can derive from this display not only

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408010

Item 20 (Continued)

the enemy's presence but also such information as direction and speed of convoys and personnel, number of vehicles in a convoy, and convoy composition--e.g., armored versus wheeled vehicles.

This publication summarizes ARI research on REMS user problems, including direct operational applications of present and future utilization of REMS. Major findings are categorized into five areas--training, operator aids, operational procedures, REMS system design, and personnel requirements. The appendixes give information in the form of briefs for each pertinent ARI document.

Research Report 1253

SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS

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Department of the Army

July 1980

Army Project Number
2Q163739A793

Sensor Systems

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FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with future battlefield demands for increased ability to acquire, transmit, process, disseminate, and utilize information. The research focuses on the interface problems and interactions within command and control centers and concerns such areas as tactical symbology, information management, user-oriented systems, staff operations and procedures, and sensor systems integration and utilization.

Of special interest is the problem of human factors in the 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 remotely monitored sensors (REMS). When enemy personnel or vehicle movement activates these remote sensors, a monitor display located behind our lines indicates the activity. The operator can derive from this display not only the enemy's presence but also such information as direction and speed of convoys and personnel, number of vehicles in a convoy, and convoy composition--e.g., armored versus wheeled vehicles.

This publication summarizes ARI research on REMS-related human factors problems, including the direct operational applications of present and future utilization of remotely monitored sensors. Major findings are summarized in the body of the report--more details and other results are given in the appendixes as briefs describing each experiment.

Research on remotely monitored sensor systems was conducted both in-house and under contract with HRB-Singer, Inc., in response to requirements of Army Project 2Q163739A793 and to special requirements of the U.S. Army Intelligence Center and School, Fort Huachuca, Ariz.; Project AVID GUARDIAN, U.S. Army, Europe; and the Remotely Monitored Battlefield Sensor System Project (REMBASS), Fort Monmouth, N.J.

JOSEPH ZEIDNER
Technical Director

SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS

BRIEF

Requirement:

To aid in the development and utilization of remotely monitored sensors (REMS) by investigating and developing appropriate operator training, operational aids and procedures, system design from a human factors standpoint, and personnel requirements.

Research Products:

In the training research, three self-administerable, on-the-job or school training packages were developed and shown to result in improved operator performance. Similarly, three operator aids were developed and shown to significantly improve operator performance. Research on operational procedures determined preferred work-rest cycles, the minimum number of sensors required for both string and grid sensor employment, and the effects of signal/noise ratio on the performance of operators using the acoustical remote sensor. Research on user requirements in new REMS systems determined the best type of display from several design options, the number of sensors that an operator can handle in a display, improved concepts for the acoustic sensor system, and operator-based bandwidth requirements. Much of this research affects personnel requirements, by reducing number of operators required, enhancing operator performance, and helping predict current and future needs.

Utilization:

Much of the ARI research on REMS-related human factors problems directly applies to operational sensor utilization. The training materials and operator aids have been integrated into the U.S. Army Intelligence Center and School, Fort Huachuca, Ariz. Research results on user requirements have been incorporated in the design of the Remotely Monitored Sensor System (REMBASS). These and other products are in use by other agencies in the Army and the Federal Government.

SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS

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SUMMARY OF ARI RESEARCH ON REMOTELY MONITORED SENSORS

BACKGROUND

Introduction

In September 1966, the Secretary of Defense directed the armed forces to develop an infiltration interdiction capability to assess vehicle and personnel flow in Southeast Asia (Army Manual ST 30-20-1, 1971). The remotely monitored sensors (formerly called unattended ground sensors, or UGS) developed in this program provide the Army's battlefield surveillance and target acquisition system with another versatile capability of obtaining real-time information about enemy movement.

Recent Army research and development efforts to improve the capability of remotely monitored sensors (REMS) have been principally under the aegis of the Remotely Monitored Battlefield Sensor System (REMBASS) program. Operational considerations on the use of REMS in the European environment have been extensively studied under NATO's Avid Guardian program. Human factors research by the Army Research Institute (ARI) to improve operator related performance aspects of REMS is summarized in this report.

The REMS System

The different types of REMS in the Army inventory are categorized according to the method of remote sensing: seismic, acoustic, magnetic, electromagnetic, and infrared. Upon detection of an enemy movement, the sensor transmits the data to an unattended relay or directly to the sensor monitoring station. The operator (MOS 17 M20) interprets the data presented on the RO 376 event recorder (current) or the REMBASS sensor monitoring unit and reports, at most, the target type, speed, direction, location, and number.

REMS may be tactically employed for offensive and defensive operations by units ranging from small independent patrols to full divisions for target acquisition, landing (drop) zone monitoring, combat sweeps, ambush, monitoring of avenues of approach, base camp defense, convoy security, and border surveillance. REMS can be employed in a regularly spaced "string" along potential transportation routes, in a "grid" pattern to cover a large geographical area, or in various "alerting" patterns for simple detection of activity in an area (e.g., drop zone).

Research Requirements

Significant technical achievements have been made in developing REMS. Initially, little effort was directed toward the study of the operator and the operator/equipment interface. Experience in Vietnam demonstrated both the value and the human factors problems of REMS. Depending upon field conditions, human errors of omission and commission were fairly substantial. Planned extension of a sensor system, developed for the Vietnam conflict, to worldwide applications could increase existing problems and cause additional ones. In response to general and specific requirements for solutions from REMS systems users and developers, ARI's research program (summarized here) was initiated. Specific needs for research were generated by Project Manager (PM) REMBASS, the U.S. Army Intelligence Center and School (USAICS), and Project Avid Guardian; they were also derived from problems identified by the ARI research program.

Research Design

The general objectives of the following research were to better train, assist, and manage REMS operators and to more effectively design and employ equipment from a human factors standpoint, while considering operational conditions. The underlying philosophy of the research was operational realism and controlled, objective measurement of pertinent variables.

The operators participating in the experiments were always school trained and usually experienced in the field; however, practice in the field was often limited because of lack of equipment. Equipment used by the operators participating in the research was always a close simulation to existing or proposed devices, at least for the critical dimension of concern. Sensor data presented to the operators via the above equipment were accurate recordings of data collected in the field under controlled conditions, using operational equipment (except for the closely simulated acoustic sensor equipment). The sensors were activated under operational procedures and conditions by U.S. Army vehicles and personnel traveling in normal wartime modes. The above (operators, equipment, and sensor data) were combined to represent actual wartime use of REMS. Perfect representation was neither achieved--nor was it possible.

Measurement of criterion variables--detection rights and wrongs, identification rights and wrongs, time, direction, speed, and numbers--were completely objective, based on actual knowledge of existing conditions (rights, wrongs, time, direction, and, sometimes, number of targets) or on school solutions (speed and numbers of targets). Assessment of whether or not true differences existed between the conditions tested always relied on accepted, statistical design and decision rules--not on someone's opinion of the difference.

Organization of the Summary

The research is summarized in terms of training, operator aids, operational procedures, REMS system design (REMBASS), and personnel requirements (Figure 1). Major findings in each area are summarized along with some of the more pertinent data. More detailed description of the research is provided in Appendixes A through I, which contain briefs of the cited research reports and additional data.

Products of the research program have been utilized by USAICS, PM REMBASS, and others. While some of the operational applications are valid across a broad spectrum of situations, others pertain only to specific circumstances or contexts. Additional use of research findings should be made

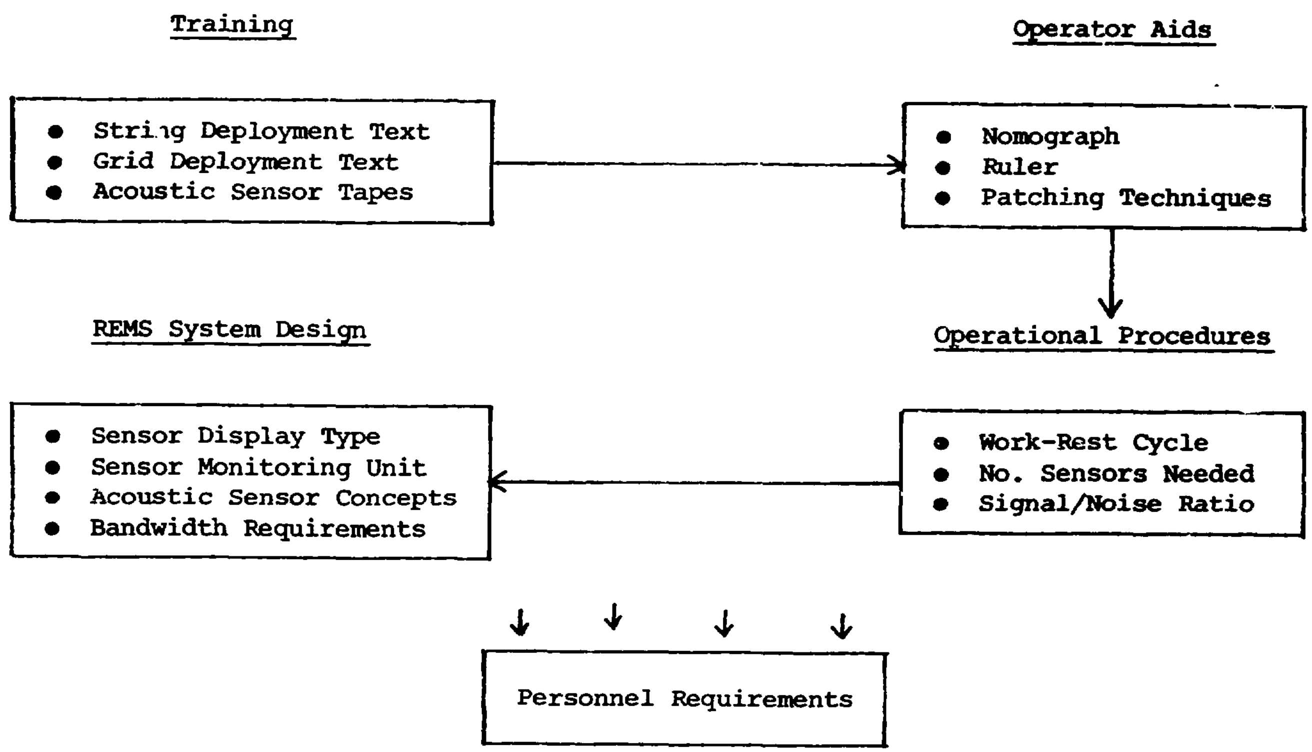

Figure 1. Research products.

with caution when conditions differ substantially from those under which the research was performed. In no case should operational applications of the results be instituted without a detailed review of the research. Interaction with ARI scientists is recommended to help insure effective, optimal application of results.

TRAINING

Determination of Requirements

The first step in the training research program was to determine training requirements on the basis of a review of documentation, interviews of senior instructors, and, most importantly, actual problems encountered by operators in interpreting REMS output. The data and conclusions from analyzing operator errors in using the string and the grid deployment are reported in Martinek, Pilette, and Biggs (1978a) and Edwards, Pilette, and Martinek (1977), and for the acoustic sensor (the target identifier REMS), in Pilette, Biggs, and Martinek (1979). In each, actual operator reports were analyzed to document and categorize the factors leading to human errors. These analyses were the basis for development of appropriate training material that could be used at the school for formal training or in the field for proficiency maintenance, involving little (if any) instructor participation. In each experiment, the operators were pretested, trained, and posttested to determine the gain in proficiency attributable to the training materials.

String Employment Text

The 6-hour-long, self-administerable training text developed under this research project (Pilette, Biggs, & Martinek, 1978a) resulted in significantly improved operator performance (Table 1). Performance improved as follows:

- Target detection, 18%;
- Target identification, 31%;
- Speed estimation, 64%;
- Number of targets estimation, 63%; and
- Time required for reporting, 15% (reduction in time may be due to practice).

The gains in target detection and identification generally were greatest in the more difficult operational situations tested--the condition of high target activity and the use of 2-sensor strings. In addition, all participating operators reported that the training was "somewhat" or "definitely" better than conventional training.

Secondary findings pertain to training and the operational use of REMS. Contrary to experience in Vietnam, the trained operators reported very few false alarms. Moreover, once a target was detected, it was identified correctly (vehicle or personnel) about 85% of the time. (See Appendix A for more detail.)

Table 1

Operator Improvement Due to Training Text

Performance variable	Operational situation	No. correct Pretest	No. correct Posttest	Percent improvement
Detection rights	Low target activity	4.1	4.6	12
	High target activity	6.3	7.8	24
Identification rights (vehicle vs. personnel)	Low target activity	3.5	4.3	23
	High target activity	4.8	6.6	34
Correct speed estimation	--	3.9	6.4	64
Correct number of targets	--	4.0	6.4	63
Time for target reporting (in minutes)	--	5.9	5.0	15

Grid Employment Text

Two days of training substantially improved operator performance (Pilette, Biggs, & Martinek, 1978b). Target detection completeness improved by 38%, speed-estimation accuracy improved by 23%, and target-direction-estimation accuracy improved by 20%. The initially low false-alarm rate showed no significant change. After training, operators detected about 95% of the targets during low workload conditions (5 to 8 targets per hour), and 61% when the workload reached 27 targets per hour. Detailed existing and expected performance using the grid deployment is given in Table 2. These data indicate that operators can provide highly useful intelligence information from REMS in a grid pattern. (See Appendix B for more detail.)

Acoustic REMS Training

Research on acoustic REMS training was initiated because only this sensor in today's inventory (which does not include REMBASS sensors) has been shown to reliably differentiate between vehicle types. A multiobjective experiment (Martinek, Pilette, & Biggs, 1978b) demonstrated that with about

4 hours of training, operator performance with acoustic sensors improved substantially for each of several target identification levels required. The training package (self-administerable tape recordings) increased operator target identification performance between 20% and 50%, depending on the level of target detail required (Table 3). An additional increase of about 13% can be achieved in the field by using only the top one-third of operators selected on their ability to interpret acoustic signals. (See Appendix C for more detail.)

Table 2

Detection Performance Expectations Using Grids

Workload	Existing[a] operator	Operator with 13 additional hours of training
5 tgts/hr	81% (4.0 tgts)	97% (4.8 tgts)
8 tgts/hr	88% (7.0 tgts)	94% (7.5 tgts)
15 tgts/hr	28% (4.2 tgts)	66% (10.0 tgts)
27 tgts/hr	34% (9.2 tgts)	61% (16.5 tgts)

[a] School-trained and with some basic introduction to the grid employment.

OPERATOR AIDS

The error analyses that led to the development of the need and problem areas for the training research also indicated that certain simple operator aids would significantly enhance operator performance. The use of these aids would be taught at the school (see preceding section on training) and would become part of the operating procedures (see the following section). However, this section on operator aids is different in that it concerns devices or techniques that a single operator would use in the field.

Nomograph/Ruler Aids

These two simple devices are grouped together because they would normally be used serially for the determination of speed and number of targets. They were developed and validated (Pilette et al., 1978a) together for the string deployment of REMS and were used successfully in several of the research projects, in the school for training, and in the field during maneuvers.

Analysis of operator errors indicated that measurement of time on the RO 376 tactical recorder and subsequent computations to determine speed and number of targets resulted in unreliable figures. Use of the devices in a controlled experiment (Pilette et al., 1978a) resulted in the following improvements in operator performance:

Table 3

Expected Operator Performance with Continuously Emit‥ng Acoustic REMS[a]

If the commander requires convoys reported in: (CATEGORY)	Today's operators will get: (PERCENT CORRECT)	Operators with extra training will get: (PERCENT CORRECT)	Which is a difference of: (PERCENT)	Or an increase of: (PERCENT)
7-target (exact identification)	26	39	13	50
5-target (light-, medium-, and heavy-wheeled; APC; and tank)	30	43	13	43
3-target (tracked; and light- and heavy-wheeled vehicles)	50	60	10	20
3-target (APC, tank, and wheeled vehicles)	53	67	14	26
2-target (wheeled and tracked vehicles)	63	76	13	21
1-target category (counting)	85	92	7	8

[a]Assuming a "good-quality" acoustic sensor. Good quality is defined here as a signal/noise ratio of 36 dB, obtained by comparing the highest signal strength recorded (a tank) to the lowest signal strength recorded during a period of no target activity.

- A 97% increase in speed estimation,
- A 7% increase in target identification (vehicle vs. personnel),
- A 67% increase in length of convoy estimation,
- A 41% increase in number of targets estimation, and
- A 15% reduction in reporting time (probably due to practice).

Operator acceptance of the devices was high; many devices disappeared after the experiment was over. The calculator envisioned for the sensor monitoring unit (SMU) in Project REMBASS would obviate the need for the nomograph except for a manual backup and in situations (e.g., long-range patrols) not utilizing the SMU. The REMS ruler would continue to be useful in the new systems. (See Appendix A brief for more detail.)

Grid Patching Techniques

As the grid employment of REMS was a post-Vietnam-conflict concept, it had not been taught at school or used in the field. The operators' problem with this method is transforming and using the two-dimensional space of the grid in the field to the one-dimensional representation of the grid on the display device (the RO 376 tactical recorder or the REMBASS SMU). Four techniques were developed and validated (Pilette, Biggs, Edwards, & Martinek, 1978). Although clear-cut superiority for one technique across all the variables in the experiments could not be demonstrated, it was concluded that the row patching technique was best with operators who have received special training, particularly when using low-density grids. The column technique is initially better (before training on this concept) because of its similarity to the patching technique used for the string deployment of REMS.

It was concluded that the major problem in employing sensors in a grid is the completeness (not accuracy) of the operator's performance (omissions, not false alarms). Tables 4 and 5 present more detailed data on expected performance by relatively untrained and inexperienced operators using a grid employment. (See Appendix D brief for more detail.)

OPERATIONAL PROCEDURES

Operational procedures are part of the task of the management of the REMS system--how the managers "work" the operators and "work" (utilize) the sensors. For any size REMS unit there is a limited supply of resources: a given number of man-hours and sensors are available to cover a particular area assigned to that unit. The manager must optimally work and rest the operators to insure that fatigue does not reduce monitoring performance. The numbers of sensor strings (and grids) monitored by one operator must also be controlled, since too great a workload will reduce monitoring performance. Similarly, the number of sensors assigned to an avenue of approach (in a string) or to an area (grid) usually must be kept to a minimum, based on acceptable operator performance and the requirement to cover all avenues/areas with the limited sensor supply. Finally, the manager must carefully assess which avenues or areas he can cover. The assessment is based on many factors that include line-of-sight distance, especially when using the acoustic sensor, because each relay used increases the signal/noise (S/N) ratio and thereby reduces operator identification performance. These requirements initiated the following research.

Table 4

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 5

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

Work-Rest Cycle

Typical findings in the research literature indicate that work without periodic rest periods results in performance decrement. Similarly, this research (Martinek et al., 1978a) demonstrated that REMS operators given rest periods every 2 hours performed better than those given only a lunch break. The drop in performance occurs during the second 4-hour period, particularly in the last 2 hours (Figures 2 and 3). This indicates that an operator could be kept monitoring (during critical times) for 4 to 6 hours without a drop in performance. No difference was found between a 15-minute break and a 1-hour break. (See Appendix E for more detail.)

Number of Sensors Needed

General. Past doctrine recommended that 3 to 7 sensors be used in a string for avenue-of-approach surveillance. Similarly, it was thought that a grid with sensors spaced close together would provide better information to the operator. However, the more sensors used, the greater the cost, the more manpower required to emplace them, the higher the detectability, the more radio-space required, and the greater the number of displays needed. Two experiments (Martinek et al., 1978a; Pilette et al., 1979) investigated the effect of string size on REMS operator performance, and one (Pilette et al., 1979) compared a 9-sensor grid to a 24-sensor grid (each covering the same area and targets).

String Size. The results of the two experiments comparing 2-sensor, 3-sensor, and 4-sensor strings are consistent. Under low-target-activity conditions, there were no differences in operator performance attributable to string size. Under high target activity, the use of 3-sensor and 4-sensor strings resulted in equal operator performance, but better than the use of 2-sensor strings. Considering both operator performance and cost-effectiveness, and given reliable sensors, 3-sensor strings are preferred. However, a case could be made for 2-sensor strings. First, there were some confounding experimental conditions acting to lower performance using 2-sensor strings. In addition, assuming a shortage of sensors compared to the number of approaches that the commander needs covered, 2-sensor strings might be required and are as good as the longer strings for low target activity. (See Appendixes A and E for more details.)

Sensor Density in a Grid. Two densities of sensors were compared: a 9-sensor grid (500 meter spacing between the seismic sensors) and a 24-sensor grid (250 meter spacing except for one row which had only 4 sensors). In the operational case the maximum spacing between sensors would have to be determined on the basis of observed detection radius of sensors, gain settings, etc. The experiment did not test the spacing of sensors but, rather, whether or not redundancy of sensors (24-sensor grid) aided the operator. However, it was found that the additional sensors (and thus information) did not aid in the detection of targets but actually resulted in more false alarms, especially during low target activity when the operator had more time to make errors. (See Appendix D for more detail.)

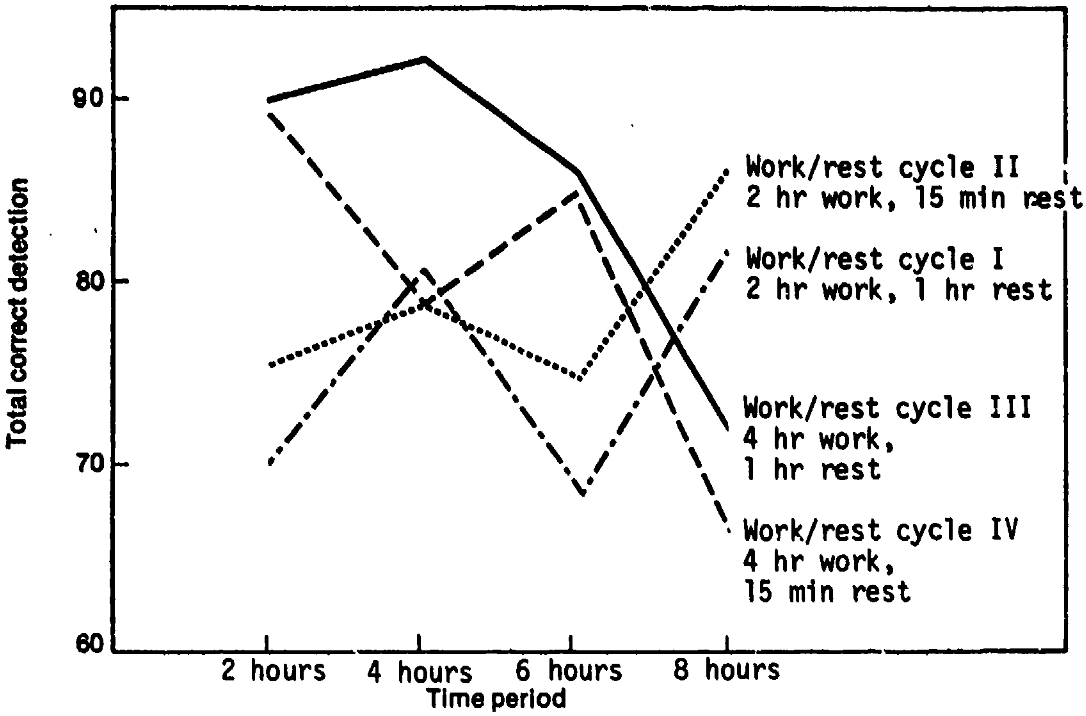

Figure 2. Total correct detections for each work/rest cycle.

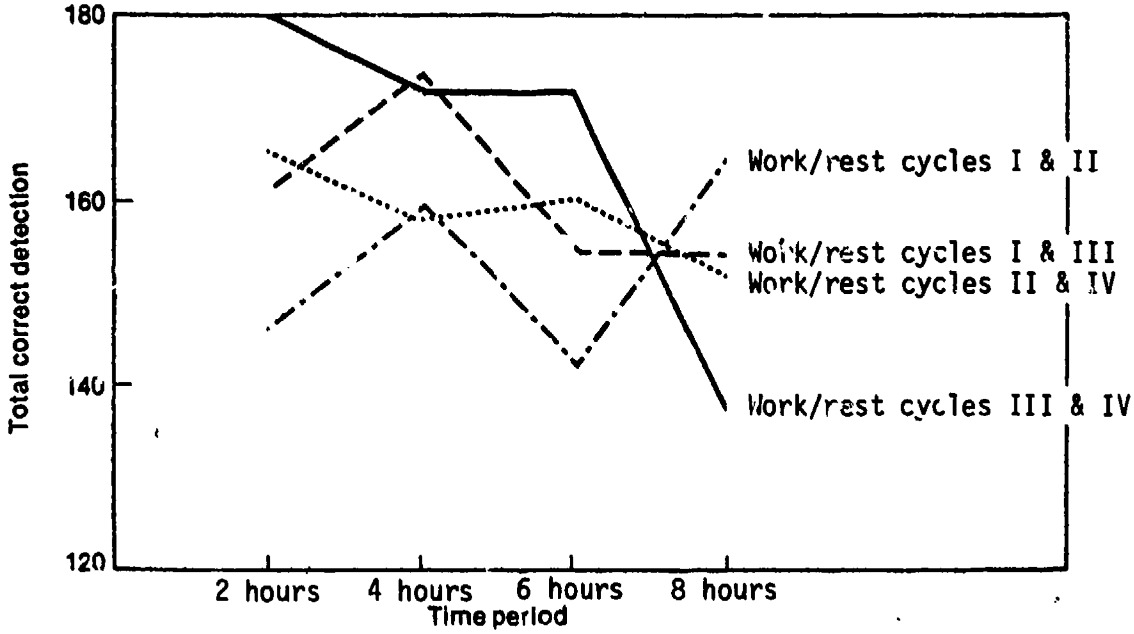

Figure 3. Total correct detections for work/rest cycle pairs.

Signal/Noise Ratio

The acoustic sensor was given special attention in the research program because of its importance in the identification of vehicles in a convoy. The research (Martinek, Pilette, & Biggs, 1979) concerned the effects of S/N ratio on the classification of vehicles. The results indicated that the following rule of thumb can be used when developing procedures for the employment of relays (increasing noise level) and designing new sensors: a 1% decrease in operator performance occurs for every 1.5 dB loss in S/N ratio. (See Figure 4 for performance curves.) It was also found that there is a tendency for operators under high noise conditions (such as when using many relays) to report any vehicle sounds as light- and medium-wheeled vehicles. This implies that the operators use relative sound intensity in discriminating between vehicles and, therefore, use of complete automatic gain control in a new sensor is contraindicated. (See Appendix F brief for more detail.)

REMS SYSTEM DESIGN

Requirement

The design of most U.S. Army hardware systems entails many decision points and trade-offs involving the interface of equipment and the operator. ARI research in this area for REMS was done in close coordination with the Combat Surveillance and Target Acquisition Laboratory, Fort Monmouth, N.J., concerning requirements for operator displays and the acoustic sensor for Project REMBASS. These often were investigated in conjunction with non-equipment requirements (e.g., training) to increase the cost effectiveness of the research. Similarly, data gathered on equipment related research were used to determine needs for research in other areas.

Sensor Display Concepts

Two research efforts (Martinek, Hilligoss, & Lavicka, 1978; Edwards, Rochford, & Shvern, 1977) compared the operational type of display (RO 376 Tactical Data Recorder) to several variations of a situation map display proposed for possible inclusion in REMBASS. The situation map display consists of a map placed over small lights that correspond to the location of the sensors in the field. The light blinks rapidly for each activation of its associated sensor and then goes off until the next activation. The first experiment (using the string employment) compared use of the RO 376 display, use of a situation map display, and use of time compression with the situation map display. With time compression, the operator could review in 8x time any of the past activations; in addition, he had a forced compressed time review (4 minutes long) every 30 minutes of all activations during that time period. The second experiment (using the grid employment) compared the RO 376 to three variations of the situation map display. Results of both experiments indicated that the operational type of display as represented by the RO 376 was as good as or better than the situation map display and its variations in terms of the accuracy and completeness of target detections. The RO 376 type of display was selected for the Sensor Monitoring Unit of REMBASS. (See Appendixes G and H for more detail.)

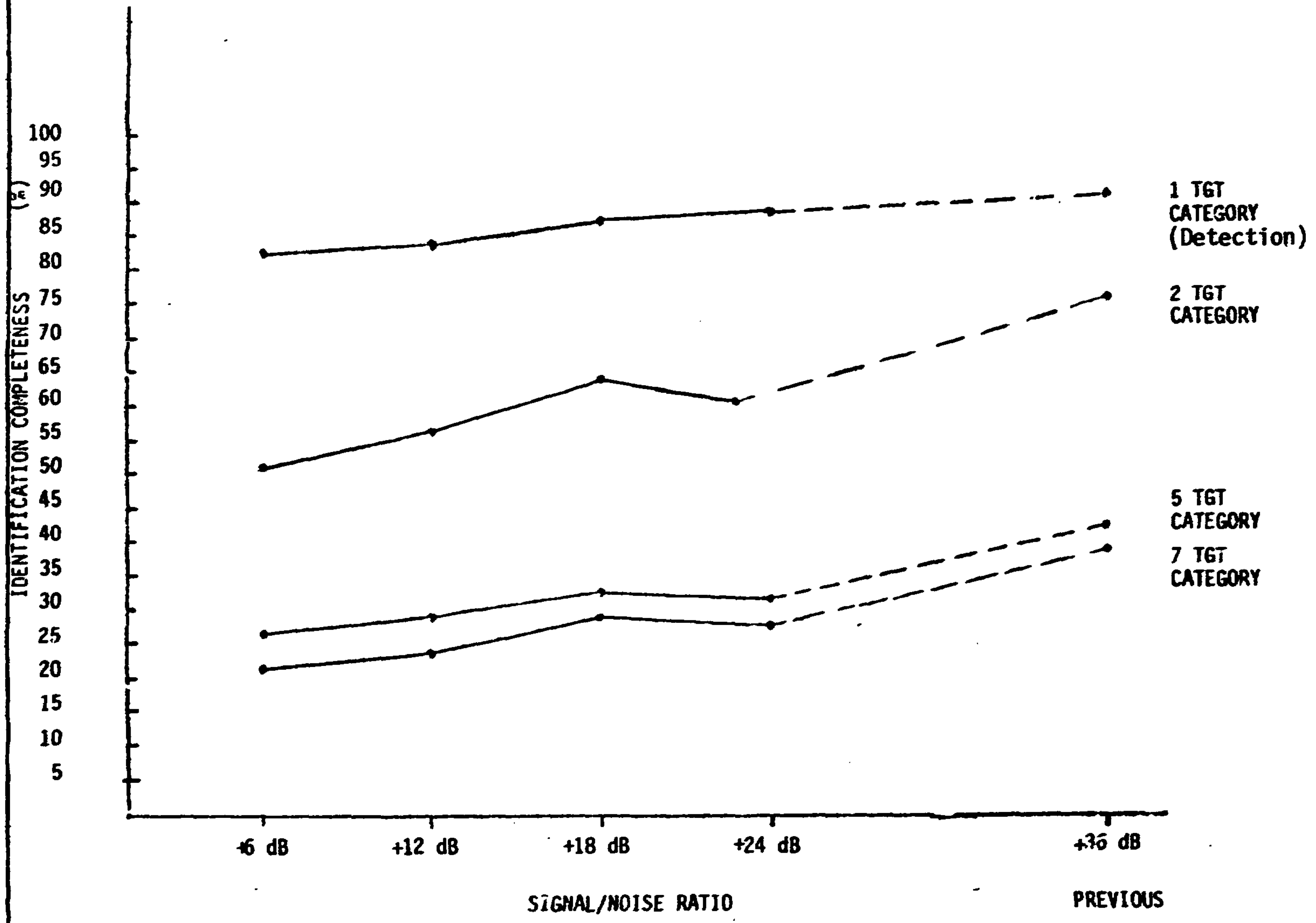

Figure 4. Plot of identification completeness by signal/noise ratio and target categories.

Operator Workload

The number of sensors that one operator can monitor without serious deterioration in performance determines, in part, the requirements for the number of sensors that should be shown on new displays such as the SMU. An investigation was carried out to determine operator performance as a function of the workload (Edwards, Pilette, Biggs, & Martinek, 1978). Workload is defined as the number of targets an operator must monitor due to the combination of the number of sensors and the target-activity level for those sensors. Results indicated that operator performance decreased rapidly as a function of workload (Figure 5). Clearly, an operator can handle 27 sensors under low target activity (85% detection completeness) and cannot handle very well 54 sensors under high target activity (50% detection completeness). However, the above figures pertain to relatively inexperienced operators using REMS employed in a grid. It was believed that, with special training and/or using the string employment, operators could usefully monitor 60 sensors under high target activity. These data provided a partial basis for the initial SMU design displaying the output of 60 sensors. (See Appendix I for more detail.)

Acoustic Sensing Concepts

The operational U.S. Army acoustic REMS, designed for the Vietnam conflict, is turned on automatically by seismic activity, transmits for 15 seconds, and is silent for 20 seconds. Use of this type of sensor in Europe would result in a loss of at least 50% of the information about convoys, since a typical aggressor vehicle column takes about 60 seconds to pass a sensor. Two different sensing concepts were experimentally evaluated (Martinek et al., 1978b), using various requirements for vehicle detail; both were judged to be better than the Vietnam type of sensor. Under the most stringent reporting requirements, a small but significant difference was found in correct identifications for the intermittent concept (34.4%) over the continuous concept (32.1%). A greater difference is expected for actual operational conditions because of an artifact in the experiment favoring the continuous concept. Larger differences (not tested for statistical significance) were found for less stringent reporting requirements. (See Appendix C for more detail.)

Bandwidth

Two experiments (Martinek et al., 1978b; 1979) investigated the effects of acoustical bandwidth on operator performance with the acoustic REMS. One indicated that a bandwidth of 50 to 2,000 hertz (Hz) is better than 50 to 1,500 Hz for vehicle identification. However, no difference was found between 50 to 2,000 Hz and 50 to 4,000 Hz. This result was checked in the second project where 50 to 2,000 Hz was compared to 50 to 4,500 Hz--no differences were found. Thus, the use of the operational bandwidth of 50 to 2,000 Hz is sufficient for vehicle identification. This is not to imply that a different range (e.g., 450 to 2,400 Hz) but same bandwidth would be adequate, since the lower frequencies are probably critical to the identification of vehicles. (See Appendixes C and F for more detail.)

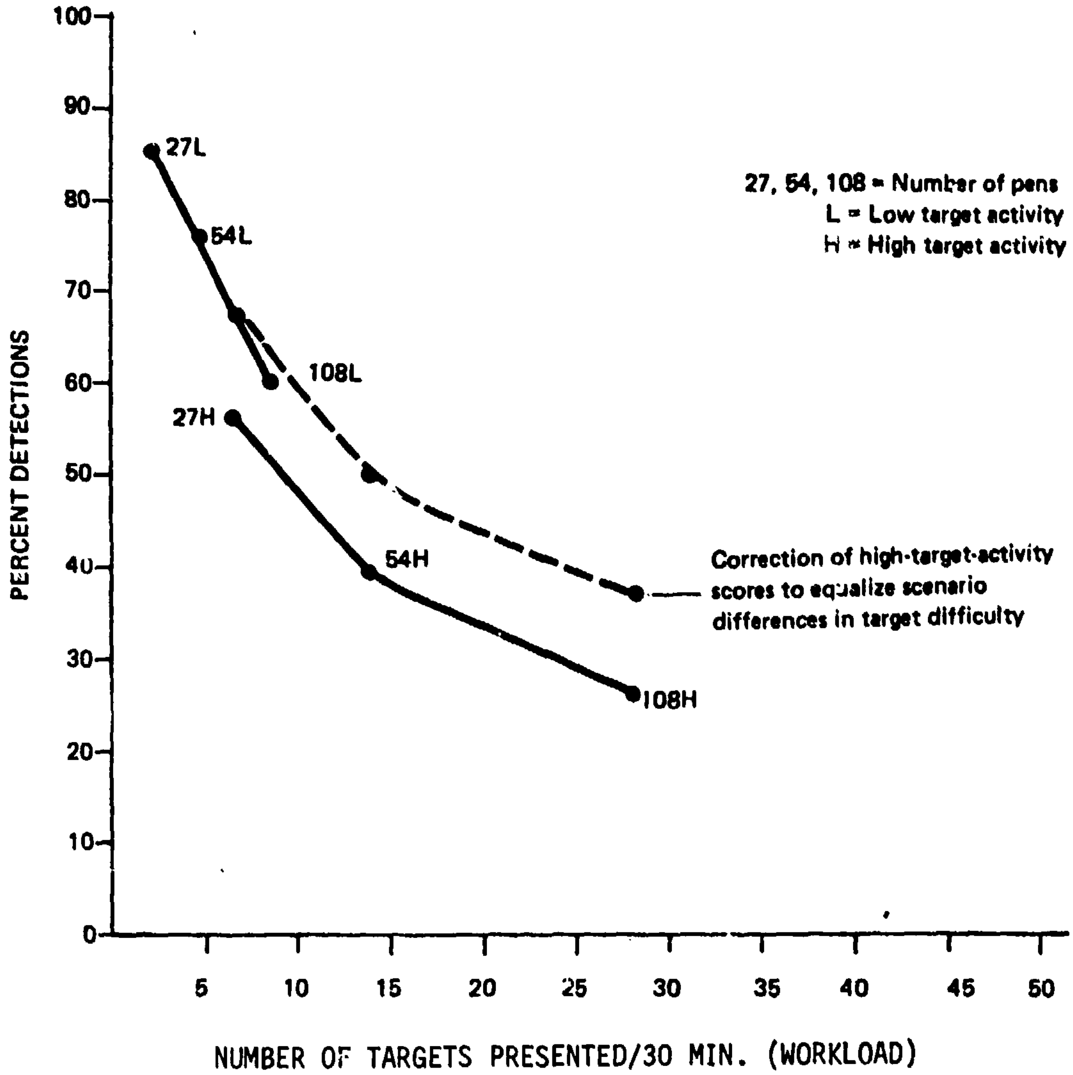

Figure 5. Effect of workload on percent detections.

PERSONNEL REQUIREMENTS

The results of this research program indicate the complexities involved in forecasting personnel requirements. They imply that the number of operators required depends on several factors, such as target-activity level, number of sensors employed, type of employment, number of displays used, training, and fatigue effects. Thus a first step in forecasting personnel requirements is to determine the threat (number and kind) in order to determine the target-activity level expected in most operations. Another threat factor (number of approaches and area to be covered) must be considered to determine the number of sensors to be employed and the number of displays required. These data, combined with the research findings, give a first indication of personnel requirements.

Another factor entering the equation is related to the research on training and work-rest cycles. Increased performance through training reduces the numbers of operators required. On the other hand, the fatigue factor found in the work-rest cycle research increases the personnel requirement.

One variable often ignored in forecasting personnel requirements is the commander's requirement for detailed information. The research on the acoustic sensor demonstrated the large reduction in identification accuracy due to requirements for detailed information. Lowering the requirement for detail increases the accuracy of information. Likewise, part of the improvement found in the training research may be attributable to the operators ignoring the requirements for calculating speed and numbers of targets. Elimination of this requirement alone could account for several minutes of time per target. Target reports would be more timely, and operator time per target reduced, thereby reducing the number of operators required for a given threat.

Combining the threat factor with operator performance data also can identify some potential areas of serious system breakdown. Based on research on the grid and string employment of sensors (Pilette et al., 1978a, 1978b; Edwards et al., 1978), a trained operator would detect about 60 to 70% of the targets if the activity level is 27 targets per hour. Assuming that the operator's display portrays 60 sensors, and 3-sensor strings are used, one operator can cover 20 roads. Unfortunately, enemy columns (10 vehicles) traveling at the normal convoy speed would pass a sensor string every 3 minutes, or 20 columns per hour. In a rare case, this means that 400 targets (20 roads x 20 columns) could appear on one display in 1 hour during a major attack. Even if the enemy were to use only 5 roads, 100 columns per hour would have to be processed by the operator. Clearly, more operators or special processing and reporting procedures for the operator are required in this critical overload situation. Another approach would be to reassess the use of a computer for automatic target reporting.

The above workload figures do not necessarily apply to the new REMBASS acoustic/seismic identifying sensor. This sensor provides more information, but the operator's overload point may be reached earlier because there is more information to process and a more complicated display. Additional research would be helpful to assess the impact of new sensors and displays on operator performance (and personnel requirements) to derive doctrine for all situations.

SUMMARY

This report summarizes ARI research on REMS in terms of training, operator aids, operational procedures, REMS system design, and personnel requirements. In the training research, three on-the-job or school self-administerable training packages were developed, on the basis of the error analyses of common operator problems, and validated. These training packages resulted in demonstrated improvement in operator performance, in both the statistical and the practical sense. Similarly, three operator aids were developed and shown to significantly improve operator performance. Research on operational procedures determined preferred work-rest cycles, the minimum number of sensors required for both string and grid employment, and the effects of signal/noise ratio on operator performance with the acoustical remote sensor. Research on user requirements in new REMS systems determined the better type of display from several design options, the number of sensors an operator can handle on a display, improved concepts for the acoustic sensor system, and operator-based bandwidth requirements. Many of the above findings also impact on personnel requirements. Research on REMS systems led not only to improved operator performance but also to a reduction in the number of operators required and assistance in predicting current and future personnel requirements. A summary of these products and their uses is shown in Figure 6.

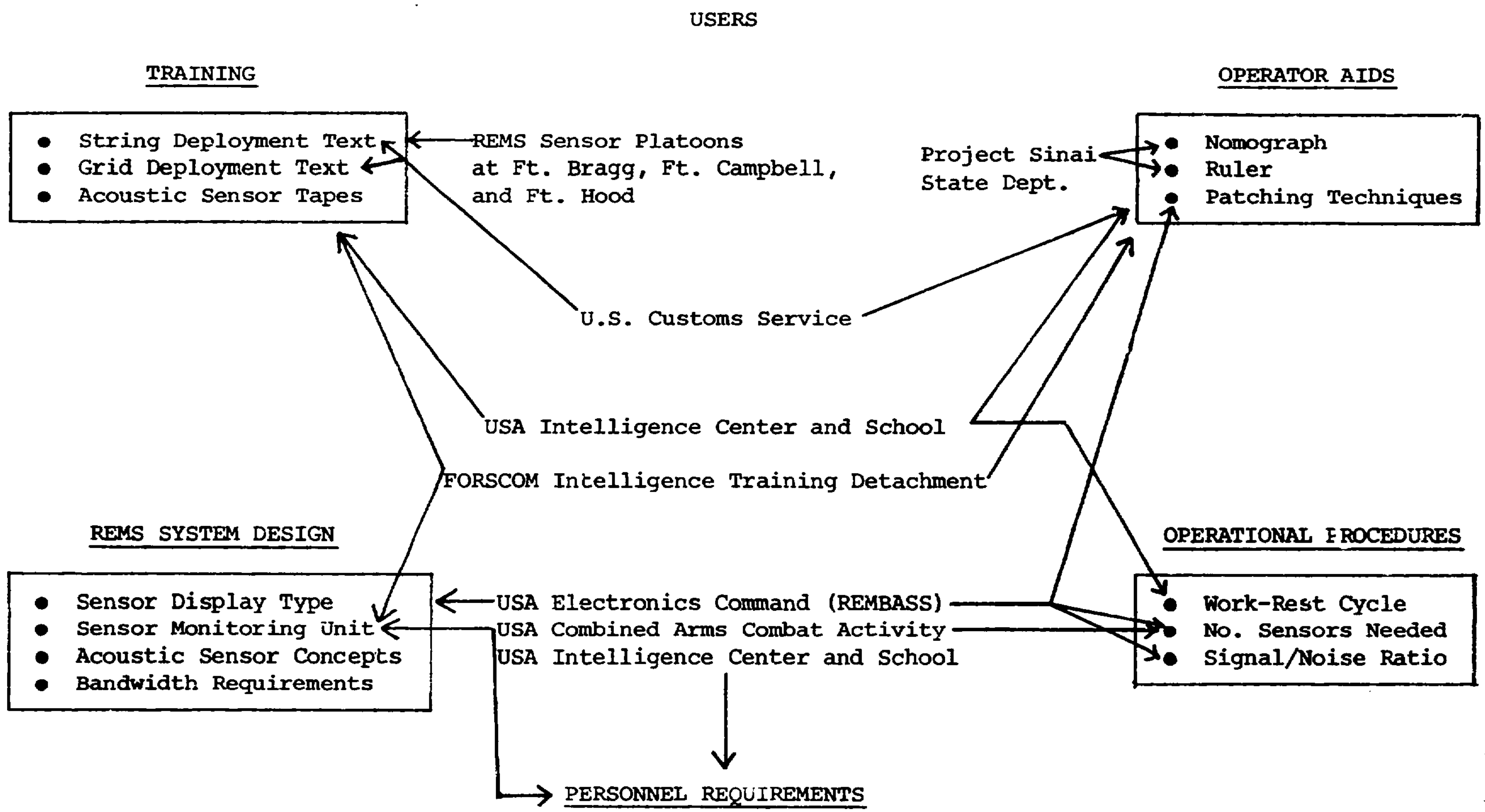

Figure 6. Research products and users.

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APPENDIX A

THE VALUE OF SPECIAL TRAINING AND JOB AIDS FOR IMPROVING UNATTENDED GROUND SENSOR OPERATOR PERFORMANCE

Pilette, S., Biggs, B., & Martinek, H. ARI Technical Paper 304, August 1978.

Requirement:

To determine the value of unattended ground sensor operator training and job aids derived from an analysis of error sources and the effect on operator performance of target activity level and numbers o sensors used in a string.

Procedure:

Based on an analysis of operator errors made in a previous study, a training program and two job aids were developed. To test the value of the training and one of the job aids (measuring device), two 2-hour scenarios were constructed for pre- and posttraining evaluation. Typical target patterns at two levels of target activity and three levels of sensor string size were systematically varied within 30-minute segments. Authentic fixed-wing and helicopter activity, artillery shell bursts, and random noise were included to simulate operational, nontarget activations. The second job aid, a nomograph, was evaluated using the pretest and posttest design. Two special tests requiring only the measurement and computations necessary for estimates of speed and enemy number(s) were developed for this purpose.

Twenty school-trained Army enlisted men (UGS (unattended ground sensor) operators), were given test procedure training and a short refresher in UGS interpretation. Two 10-man groups were formed and each was given different scenarios for the pretest; these were then switched for the posttest. The training program--given between the pretest and posttest--stressed individualized instruction including self-pacing, immediate feedback, expert assistance when needed, and guaranteed student-mastery using criterion testing. One job aid, an UGS ruler for accurately measuring the length of activation patterns, was part of the training exercise. The other job aid (a nomograph), which had been developed to simplify arithmetic calculations and decimal point placement, was tested separately after the above training and posttest.

Findings:

The individualized training program resulted in significantly improved operator interpretation performance in target detection rights, identification rights, target speed, and target quantity estimation. Use of the nomograph significantly improved performance in identification rights, target speed estimation, target quantity estimation, and reporting time. Student acceptance of the individualized training approach and of both job aids was high. Operator performance on 3- and 4-sensor strings was 77% detection completeness with virtually no false alarms. Detection of targets was better during low target activity than during high target activity. Use of three sensors in a string resulted in the same operator performance as use of four sensors.

Utilization of Findings:

The lesson materials together with the individualized training approach should be used to provide review and on-the-job training to operational field personnel and should also be integrated into the UGS course at USAICS, Fort Huachuca, Ariz.

The nomograph should be included as standard issue with operational event recorders and should be taught at UGS course USAICS and given to each graduate to take with him to his assigned unit. A credit-card size UGS ruler should be issued to everyone involved in monitoring UGS target activation.

To increase timeliness, the UGS operator should send forward a detection report based on two sensors (or more, if doubt exists) with a followup report giving target type, speed, and number.

A research study controlling on target difficulty and comparing 2 versus 3 versus 4-sensor strings should be done to provide data for determining the most efficient string size.

During high-target-activity conditions, operator reports should be considered as greater underestimates than during low-target-activity periods.

APPENDIX B

THE VALUE OF SPECIAL TRAINING FOR THE INTERPRETATION OF UGS EMPLOYED IN A GRID

Pilette, S., Biggs, B., & Martinek, H. ARI Technical Paper 304, August 1978.

Requirements:

1. To determine the value of specialized training for improving operator target detection and direction and speed estimation performance when using unattended ground sensors (UGS) employed in a grid.

2. To provide estimates of operator performance in an operational situation for target detection completeness and direction and speed estimation accuracy for UGS employed in a grid.

Procedure:

Based on an error analysis of operator target detection data from previous research, a self-paced training program was developed to reduce the frequency of operator errors. To assess the value of the training program, a pre-posttest design was used. Two 2-hour scenarios consisting of various numbers and compositions of convoys traveling cross country were constructed from activation data collected at a field exercise. Four target workload conditions (2.5, 4.0, 7.5, and 13.5 targets per 30-minute period) were systematically varied within each 2-hour scenario. Each operator monitored all four workloads during both the pretest and posttest scenarios.

Two groups of eight trained operators of the Remote Sensor Platoon of the 2nd Armored Division at Fort Hood participated in 3 days of training and performance testing. Prior to the pretest, each group was given an orientation briefing, an introduction to the grid employment of UGS, row patching technique training, and test procedure training. Each operator then interpreted one of the two scenarios to determine his baseline performance in target detection and direction and speed estimation accuracy. He next completed the specialized two-unit training program. The first unit dealt with solitary targets (vehicle or vehicle convoy traveling alone through the grid), and the second dealt with target clusters (several targets in the grid area at the same time). The training program was individualized (self-paced), and expert assistance was rendered when needed. Student mastery was ascertained by the monitors checking practical and criterion exercise answers.

Operators used three aids in the training and in the posttest; they used the UGS ruler and the speed table to make time measurements and to facilitate arithmetic calculations, and used the protractor to make more precise target direction estimates.

Findings:

The specialized training program with operator aids significantly improved operator performance in target-detection completeness and target speed and direction estimation accuracy. Target-detection completeness improved by 38%, while speed-estimation accuracy improved by 23%. The accuracy of target-direction estimation improved by 20%. The initially low false-alarm rate showed no significant change. After training, operators detected about 95% of the targets during low workload conditions (5-8 targets per hour), 66% when the workload was doubled (15 targets per hour), and 61% when the workload reached 27 targets per hour.

Utilization of Findings:

The training materials and operator aids have been integrated into UGS training at U.S. Army Intelligence Center and School (USAICS), Fort Huachuca, Ariz.

The lesson materials should be given to personnel of all remote sensor platoons periodically (every 6-12 months) to provide practice and review.

Intelligence personnel should be trained to properly assess operator's reports based on the operator capability data in this report, so that they can effectively employ UGS and use the resulting intelligence information.

The grid employment of UGS can be used as an early warning and target acquisition system. The grid can also provide approximate speed estimates for use in a target acquisition system.

The atypical target paths used in this experiment prevent a good estimation of the operator's ability to provide target direction data. However, results from the few available "normal" target paths indicate that the operator can give useful direction information (average deviation from true direction was ±26°). The usefulness of direction estimates should be ascertained using additional activation data in a second experiment.

APPENDIX C

VEHICLE IDENTIFICATION USING THE ACOUSTIC SENSOR: TRAINING, SENSING CONCEPTS, AND BANDWIDTH

Martinek, H., Pilette, S., & Biggs, B. ARI Technical Paper 334, September 1978.

Requirement:

The experiments were designed to meet the following requirements: (a) to develop and validate a training program for using the acoustic sensor to identify vehicles in convoy; (b) to provide estimates of operator performance in identifying vehicles, using the acoustic sensor; and (c) to investigate the effect of different sensing concepts and bandwidth modifications on the operator's ability to identify vehicles.

Procedure:

Following orientation and procedure training, 18 school-trained operators of unattended ground sensors (UGS) were tested on their ability to identify military vehicles in convoys. Magnetic tape recordings simulating use of the acoustic remote sensor in the field were used. The taped simulation was developed from recordings collected in the field during maneuvers of armored and motorized infantry units. Incorporated in the test tapes in a counterbalanced arrangement were two acoustic sensing concepts, "continuous" and "intermittent." In the continuous mode, operators hear the entire convoy as it passes the microphone. In the intermittent mode, they hear each vehicle for a period of only 4 seconds, with 2 seconds of silence between each vehicle. Seven vehicle types were involved--jeeps, gamma goats, 2½-ton trucks, 5-ton trucks, 10-ton trucks, armored personnel carriers, and tanks.

The operators then received vehicle recognition training which used immediate feedback, self-scoring, paired comparisons, and practice. After the training, the operators were retested to measure its effects. An exploratory study was then conducted to compare operator performance when different bandwidths were used--50-1500 cycles per second (cps), 50-2000 cps (now in use), and 50-4000 cps.

Findings:

The training package developed increased operator vehicle identification performance by 44% to 16%, depending on the level of target detail required.

An increase of 6% to 10% in vehicle identification can be achieved by using the intermittent type of sensor rather than the continuous. A saving of 33% in battery life would also result. Either type of sensor has a greater information potential than the present-day Audio Add-On Unit.

An increase of 13% in vehicle identification can be achieved by using the top third of operators selected on their ability to interpret acoustic signals, as measured by the initial test in this exercise.

The 50-2000-cps bandwidth currently used by the Army for the remote sensor was better than 50-1500 and as good as 50-4000 cps for vehicle identification purposes.

Utilization of Findings:

The self-administerable training tape should be used at the U.S. Army Intelligence Center and School for UGS operator training and in field units for periodic refresher training.

Depending on field requirements, the remote sensor platoon leader should selectively assign operators on the basis of their capabilities. Both the intermittent type and the continuous type of sensor should be considered for use in the Remotely Monitored Battlefield Sensor System (REMBASS).

The bandwidth currently used by the Army for the acoustic remote sensor is adequate.

APPENDIX D

OPTIMUM PATCHING TECHNIQUE FOR SEISMIC SENSORS EMPLOYED IN A GRID

Pilette, S., Biggs, B., Edwards, L. E., & Martinek, H. ARI Technical Paper 320, September 1978.

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 insure 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.

APPENDIX E

THE EFFECTS OF WORK/REST, TARGET ACTIVITY, BACKGROUND NOISE, AND STRING SIZE ON OPERATOR INTERPRETATION OF UNATTENDED GROUND SENSOR RECORDS

Martinek, H., Pilette, S., & Biggs, B. ARI Technical Paper 300, June 1978.

Requirement:

The experiment was designed to (1) investigate the relationships between unattended ground sensor (UGS) operator performance and various system-dependent and target-dependent parameters including work/rest cycle, number of sensors in a string, target activity level, and background noise; and (2) to identify sources of operator error that can be reduced through new interpretation techniques, procedures, and training.

Procedure:

Two 8-hour scenarios were compiled from a data bank of taped recordings of UGS activations during field tests by Modern Army Selected Systems Test, Evaluation, and Review (MASSTER) at Fort Hood, Tex. The tests were run under typical operational conditions using groups of personnel and wheeled and tracked vehicles as targets. Roughly 80% of the sensors were seismic, the remainder confirmatory. All sensors were deployed in typical string configurations. The scenarios included counterbalanced variations of strings of three different sizes (2, 3, and 4 sensors), high and low target activity, and high and low "battle" noise. The high-noise condition contained the same targets as the low but also included typical aircraft, artillery, and high background noise taped during the above field tests. Four work/rest cycles were used, each of which involved a total of 8 hours of work with work and rest periods of different durations: 2 hours work, 1 hour rest; 2 hours work, 15 minutes rest; 4 hours work, 1 hour rest; and 4 hours work, 15 minutes rest. Sixteen students at the U.S. Army Intelligence Center and School (Ground Sensor Department) at Fort Huachuca, Ariz., were given test procedure training and a 1-hour review consisting of instruction and practice in interpretation of seismic sensor records. They were also given a background questionnaire and a 30-minute pretest. Pretest results were used as the basis for assigning operators to the experimental groups. Each group was assigned one of four work/rest cycles the first test day and a different one the second test day. Subject performance was scored against the known target activity for correct detections, wrong detections, correct identifications, elapsed time, and confidence.

Findings:

For 8-hour monitoring shifts, 2-hour work shifts interspersed with 1-hour or 15-minute rest periods were better than 4-hour work shifts interspersed with 1-hour or 15-minute rest periods. For important short-term monitoring requirements, operator performance was satisfactory for the first 4-hour shift, but deteriorated during the second 4-hour shift.

Operator performance was equal using 2-, 3-, or 4-sensor strings in the low-target-activity condition. However, in the high-target-activity condition, use of 3- or 4-sensor strings resulted in more correct target detections than use of 2-sensor strings.

Operator performance during the high "battlefield" noise was equal to that during low noise.

During high-target-activity conditions, operators detected more targets than during low-target-activity conditions. They detected a higher percentage of targets during the low condition, however.

Sources of operator errors included the use of 2-sensor strings for the detection of targets in a high-target-activity condition, endpoint determination, measurement, arithmetic calculations, and use of confirming sensors.

Utilization of Findings:

The major findings regarding work/rest cycles can be used by all operational UGS commands and school units for assignment to duty cycles. Considering only operator performance and assuming high-sensor reliability, 2-sensor strings, rather than 3- or 4-sensor strings, can be used to reduce costs if only low-target activity is expected. If high activity is expected, 3-sensor strings can be used rather than 4 with no operator performance decrement. Operator problem areas identified should be used as the basis for a new training program. A UGS ruler should be developed for measuring sensor activation times directly on the display; a job aid (such as a nomograph) should be developed to simplify arithmetic computations and decimal point placement. A programed text for other operator errors should be developed and validated.

APPENDIX F

THE EFFECT OF SIGNAL/NOISE RATIO AND BANDWIDTH ON VEHICLE IDENTIFICATION, USING THE ACOUSTIC SENSOR

Martinek, H., Pilette, S., & Biggs, B. ARI Technical Paper 377, June 1979.

Requirement:

To determine the effect of variations of signal-to-noise (S/N) ratio on the ability of remotely monitored sensor (REMS), formerly called unattended ground sensor (UGS), operators to identify vehicles in convoy.

To determine the effect of an increase in bandwidth on the REMS operator's ability to identify vehicles.

Procedure:

Three experiments were conducted: S/N Ratio, Individual Target, and Bandwidth. In the S/N Ratio Experiment, 20 operators received special training, which covered four levels (+6 decibels (dB), +12 dB, +18 dB, and +24 dB) of S/N ratio. After training, magnetic tape recordings simulating REMS outputs were used to determine the operators' ability to identify military vehicles in convoys. Seven vehicle types were present in the convoys: jeeps, gamma goats, 2-1/2-ton trucks, 5-ton trucks, 10-ton trucks, armored personnel carriers, and tanks. The test tapes were made from recordings collected in field maneuvers of armored and motorized infantry units. A 4 x 4 Graeco-Latin Square design was used to counterbalance the variables of S/N ratios, operator groups, order of presentation, and convoys.

The Individual Target Experiment presented operators with individual targets using only vehicle sounds that had similar signal strength (±2 dB difference). The operators interpreted sounds of each vehicle type at each of the four S/N ratios in a randomized sequence.

In the Bandwidth Experiment, the operators were given convoy sound recognition training using both 50-2000 hertz (Hz) and 50-4500 Hz bandwidths. They were then tested on their ability to identify military vehicles in convoys at both bandwidths using a 2 x 2 x 4 modified Latin Square design. The variables of this design are bandwidth, order of presentation, and operator groups.

Findings:

Operator identification completeness tends to decline as the S/N ratio decreases approximately 1% per 1.5 dB of S/N ratio.

Operator identification completeness of light- and medium-wheeled vehicles tends to increase as the S/N ratio decreases. This unusual relationship results from a tendency to report (i.e., to guess) these vehicle types more frequently as noise increases. However, accuracy in reporting light- and medium-wheeled vehicles tends to decrease as noise increases.

Operator identification completeness of 5-ton trucks, 10-ton trucks, and tracked vehicles declines as the S/N ratio decreases.

The 50-4500 Hz bandwidth provides no advantage to identification over the currently used 50-2000 Hz bandwidth.

Utilization of Findings:

Field commanders, training personnel, and operators should be made aware of the tendency of operators under high noise conditions (such as many relays) to identify any vehicle sounds as light- and medium-wheeled vehicles. Specific training to counteract this effect should be given both in the school and on the job.

From the standpoint of signal interpretability, there is no requirement for new acoustic sensors to use a greater bandwidth than the current one of 50-2000 Hz.

For purposes of developing doctrine for the employment of relays and designing new acoustic sensors, this rule of thumb can be used: A 1% decrease in operator performance will occur for every 1.5 dB loss in S/N ratio.

Use of automatic gains control should be limited to allow signal loudness variations between vehicle types.

APPENDIX G

COMPARISON OF THREE DISPLAY DEVICES FOR UNATTENDED GROUND SENSORS

Martinek, H., Hilligoss, R. E., & Lavicka, F. ARI Technical Paper 299, August 1978.

Requirement:

The experiment was designed to determine the relative values under typical operating conditions of three methods of displaying activations of seismic unattended ground sensors: use of the operational RO 376 event recorder, use of a situation map display, and use of time compression with the situation map display.

Procedure:

Three tape recordings lasting 2 hours each of the activations of unattended ground sensors were compiled from the data bank of recordings of unattended ground sensor activations taken during field tests under simulated operational conditions. Typical patterns at two levels of target activity were selected to include both personnel and vehicle targets. To provide realistic simulation, recorded activations of aircraft, artillery, and background noise likely to affect the interpretation of displays were included.

Twelve Naval personnel trained and experienced in the use of the RO 376 were given 4 hours training in the use of the situation map display and the display used with time compression. Each subject then interpreted each of the three displays using a different set of recorded activations each time, in counterbalanced order, and filled out a standardized report form. The reports were scored for number of correct detections and number of false alarms in comparison with the known target activity observed in the Modern Army Selected Systems Test, Evaluation, and Review (MASSTER) tests at Fort Hood, Tex.

Findings:

Use of the operational RO 376 resulted in higher accuracy and greater completeness of reports than did use of the other displays. No differences were found between the situation map display and the situation map display used with time compression.

Target activity level, order effects, and composition of the taped activations affected operator performance.

Utilization of Findings:

The experiment reported here was an early effort in a series to improve the interpretation of UGS activations. Because of its superiority, the RO 376 event recorder should be used instead of the situation map display in interpreting activations of sensors deployed in strings.

An additional study that would deploy sensors using the area intrusion concept of sensor deployment ("grid" or "gated array") could be an additional, useful basis for evaluation.

In view of the effect on performance of target activity level, order effects, and composition of taped activations, these conditions must be controlled in further evaluations of ground sensors in which operators interpret and report intelligence information.

APPENDIX H

COMPARISON OF FOUR UNATTENDED GROUND SENSOR DISPLAYS

Edwards, L. E., Rochford, L. S., & Shvern, U. ARI Technical Paper 281, April 1977.

Requirement:

To compare under operational conditions four different types of unattended ground sensor (UGS) displays, the RO-376 X-T plotter and three variations of situation map display, in terms of their effect on monitor performance.

Procedure:

The RO-376 X-T and the three situation map displays--a blinking light to indicate an activation, a light that increases in intensity with each additional activation, and the latter light plus the capability of reviewing previous activations in compressed time--were compared in terms of operator performance. Four 2-hour UGS scenarios were compiled from recorded field tests run at Fort Bragg, North Carolina, using typical personnel and vehicle target patterns, noise sources, and two levels of target activity. The recordings were played back to activate the displays during experimentation.

Sixteen Naval personnel (8 relatively experienced with UGS and 8 inexperienced) were given training on the displays. Each operator then monitored each display in turn for 2 hours, reporting target information as he would operationally, except that prepared report forms were used. The reports were compared to known ground truth and were scored on total detections, false alarms, detection accuracy, and direction of target movement.

Findings:

Operator performance was unaffected by type of display used. Operators were able to detect a higher percentage of targets during periods of low target activity than during periods of high target activity. However, accuracy of detection was greater during high target activity. Levels of experience, time effects, and scenarios did not have a significant effect on performance.

Utilization of Findings:

The performance data from this effort provide the best available estimates of expected operator performance until more extensive field data are available. Typically, in the selection of type of display for a given objective, operator performance with available displays should be a major criterion used. In the present experiment, however, type of display was shown not to affect operator performance and thus offers no basis for differentiating among displays. Other measures, such as cost and availability, can provide added basis for selection of displays.

APPENDIX I

THE EFFECT OF WORKLOAD ON PERFORMANCE OF OPERATORS MONITORING UNATTENDED GROUND SENSORS

Edwards, L. E., Pilette, S., Biggs, B., & Martinek, H. ARI Technical Paper 321, September 1978.

Requirement:

To investigate the effect of workload on operator performance as defined by target activity level and number of unattended ground sensors (UGS) used.

To determine operators' target-detection ability, false-alarm rate, and direction and speed estimation accuracy to help establish system capability.

Procedure:

Following an orientation and training session, experienced UGS operators monitored, in sequence, each of three event recorder displays showing activations of UGS used in grids. The operators monitored 27 sensors (3 grids) on one display, 54 sensors (6 grids) on the second, and 108 sensors (12 grids) on the third. Each grid was composed of nine minisids, spaced 500 m apart to form a 1,000 m^2 field. Operators encountered periods of high and low target activity that were of equal time duration. Operators reported each target they detected and estimated speed and direction of movement.

Findings:

The number of sensors monitored and the target activity level significantly affects UGS operator performance. The operators' ability to detect targets decreased as either activity level or number of sensors increased. Operators' ability to estimate target direction also decreased as activity level increased. Although target speed was underestimated, no significant differences were found between any of the experimental conditions for this variable. The false-alarm rate was low (one per 3 hours).

Utilization of Findings:

Careful judgment should be exercised in assigning workloads to UGS operators. Operators without special training or experience should not monitor more than 60 sensors, and then only if target activity is low. If operators are required to monitor more than 60 sensors or if target activity is high, intelligence estimates of target activity based on UGS operator reports should be adjusted upward.

The grid deployment of UGS is a valid method for surveillance of large areas to detect vehicular movement. Operators' target-detection performance was good even though they had received no training or experience in monitoring UGS employed in grids. The false-alarm rate (one per 3 hours) and the 85% detection rate for the 27-sensor, low-target-activity condition demonstrates the initial capability of the use of UGS employed in a grid. Although the true speed of vehicles passing through the grid was underestimated for all conditions, the "cross-country" speed estimate (used for predicting time of arrival) is as accurate as that made for sensors deployed in the more typical string configuration along roads or trails.

Special training should be instituted for target detection under high-workload conditions and for the estimation of the target's direction of travel. Direction estimation was poor (±40° on the average); but in view of the atypical target paths used in this research, the above value should not be generalized to the usual operational situation.

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