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# EFFECTS OF STANO SENSORS ON SMALL UNIT EFFECTIVENESS—PART I

Jack J. Sternberg, John P. Farrell, Jr., and James H. Banks, Jr.

COMBAT SYSTEMS RESEARCH DIVISION



BE/RL

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**Behavior and Systems Research Laboratory**



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13. ABSTRACT

Research into problems of human performance optimization in relation to night vision devices and related sensors is a primary concern of the FIELD EXPERIMENTATION Program within the Behavior and Systems Research Laboratory. Specific aspects deal with determining performance effectiveness of sensor systems, factors which affect performance, and means of improving system effectiveness. This Program is being conducted by the BESRL field unit at Fort Ord, California in conjunction with and with the support of the Combat Developments Command Experimentation Command (CDCEC). Exploratory field research has recently been conducted to provide comparative performance data on the effectiveness of the individual soldier and the squad-sized unit utilizing six different mixes of STANO sensors under two tactical situations.

The present publication reports on Part I of the experiment in which three mixes were empirically tested and others analytically evaluated in the linear defense situation. A second report will deal with Part II of the experiment in which an additional three mixes are tested in the linear defense situation and three mixes are tested in a reconnaissance patrol situation. An integrated analysis and conclusions based upon all data accumulated will be provided in a final report.

Testing, in the present experiment, was conducted in a linear defense situation under starlight conditions. Six squads, equipped with three mixes (with three sensors per mix), were required to detect, describe, and report enemy targets to their squad leader under two tactical deployments (FAR and NEAR). Sensors used by the subjects were the Starlight Scope (SS), Patrol Seismic Intrusion Device (PSID), and the PPS-14

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| Sensor operator | | | | | | |
| Search techniques | | | | | | |
| Work methods | | | | | | |
| Team procedures | | | | | | |
| Deployment conditions | | | | | | |
| Command and control techniques | | | | | | |
| *Communication procedures | | | | | | |
| Field experimentation | | | | | | |
| Instrumentation | | | | | | |
| Research methodology | | | | | | |
| *Starlight Scope (SS) | | | | | | |
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| *Patrol Seismic Intrusion Device (PSID) | | | | | | |
| *Hand-Held Thermal Viewer | | | | | | |
| PSID geophones | | | | | | |
| Sensor deployment | | | | | | |
| Target detection | | | | | | |
| Data acquisition system | | | | | | |
| Military psychology | | | | | | |

II

13. ABSTRACT - Continued

Radar (PPS-14). Results showed that: 1) differences among mixes in percent detections was minimal when two-sensor mixes were used; squad detection capability was slightly increased by addition of a third sensor; 2) when other measures of effectiveness--timeliness and quality of detection--were considered, a difference obtained between the two- and three-sensor mixes; and also a difference due to types of sensor in the mixes; 3) of the two-sensor mixes, the SS/PSID was superior; of the three-sensor mixes, a mix of 2SS/PSID was superior; 4) tactical deployment of the PPS-14 and the PSID was critical to their performance effectiveness for early detection; 5) information obtained by each sensor operator was reported without meaningful loss to the squad leader, but information quantity and quality were substantially degraded in the process of information transmission from squad leader to platoon leader. The experimental findings are useful in deciding how an infantry squad should be equipped with STANO devices, when quantity, quality, and timeliness of information are important as measures of effectiveness. Results are also useful in gaming and modeling. Improved communications procedures and/or more adequate training at the squad-platoon level are suggested to offset the loss occurring in target acquisition.

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## FOREWORD

The Night Operations Program within the Behavior and Systems Research Laboratory is concerned with problems in optimizing human performance in relation to night vision devices and related sensors. Specific aspects deal with determining performance effectiveness of sensor systems, factors which affect performance, and means of improving effectiveness. The entire research program is responsive to requirements of the Combat Developments Command and is conducted under RDT&E Project 2Q062106A723, Human Performance in Military Systems, FY 1971 Work Program.

This program is being executed by the BESRL Field Experimentation Unit at Fort Ord, California, in conjunction with and with the support of the Combat Developments Command Experimentation Command (CDCEC). Personnel of the Behavior and Systems Research Laboratory are deeply appreciative of the excellent cooperation given the research program by CDCEC in providing technical, personnel, and materiel support. Special acknowledgement is made of the efforts of the Commanding General, Brigadier General E. R. Ochs, and of Project Team III, which, under the command of Colonel J. Fulton, directly supported the research activity.

The experiment reported here is designed to provide comparative performance data on the effectiveness of small units utilizing six different mixes of STANO sensors. The present publication reports on Part I of the experiment covering evaluation of selected mixes of STANO sensors, and has been prepared to meet the need of various Army agencies and other users for immediate knowledge of results. A second interim report will be prepared upon completion of Part II. A final report will provide integrated analysis and conclusions based on all data.

BESRL research in night operations is conducted as an in-house research effort augmented by research contracts with organizations selected as having unique capabilities for research in this area. The present experiment was conducted under the program direction of Mr. Jack J. Sternberg, Behavior and Systems Research Laboratory, assisted by personnel of Manned Systems Sciences, Northridge, California, under the supervision of Mr. Douglass R. Nickles.

J. E. UHLANER, Director
Behavior and Systems
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EFFECTS OF STANO SENSORS ON SMALL UNIT EFFECTIVENESS—PART I

# BRIEF

Requirement:

To determine, taking into account human factor variables, how STANO sensors affect small unit effectiveness and which mixes of sensors provide the most effective continuous operations capability.

Procedures:

The experiment is divided into two parts. In Part I, reported here, squads used three mixes of STANO sensors under two sensor deployment conditions in a linear defense situation. In Part II, other mixes are used and a reconnaissance patrol situation is added.

Squads equipped with various mixes of STANO sensors were told that they were occupying a position in a linear defense and that it was their job to detect, describe, and report to their squad leader any enemy activity in their area of responsibility. The squad leader had freedom, but limited, to interact with his squad members. He also had the option of reporting to his platoon leader all, part of, or none of the information received from the squad members. Sensors used by the players were the Starlight Scope (SS), Patrol Seismic Intrusion Device (PSID), and the PPS-14 Radar (PPS-14). The terrain extended to 350 meters and was heterogeneous, being flat-to-hilly and including some open and some heavily cluttered areas. Personnel targets--one, three, or six men--moved through the squad area of responsibility along a specified path.

A counterbalanced design was used so that each squad had an opportunity to find the same targets using each of the mixes from each of the observer positions. Testing for the present part of the experiment was conducted under starlight conditions. Six squads were tested on each of three mixes (with three sensors per mix) for two tactical deployments of the sensors. In all, 72 targets were presented for each experimental condition.

Findings:

When two-sensor mixes were used, difference among the mixes in percent detections was minimal. Addition of a third sensor slightly increased the squad's detection capability. However, when other measures of effectiveness were considered, such as timeliness and quality of detection, there was a difference between the two- and three-sensor mixes and also a difference due to types of sensor in the mixes. Of the two-sensor mixes, the SS/PSID mix was superior. Of the three-sensor mixes, the mix with two SS and one PSID was superior.

Tactical deployment of the PPS-14 and the PSID was critical to their performance effectiveness for early detection. When deployed FAR, the two sensors were equally effective in percent detections, and their level of effectiveness was much greater than when they were deployed NEAR. When deployed NEAR, the PSID was totally ineffective for early detections.

The PSID was superior to the PPS-14 in that it provided more accurate information on target location.

The number of false reports was small for all sensors and mixes and accounted for less than 5 percent of all reports.

Information obtained by each sensor operator was reported without meaningful loss to the squad leader, but substantial degradation of information quantity and quality occurred in transmission of the information from squad leader to platoon leader.

UTILIZATION:

Empirical results are useful in deciding how an infantry squad should be equipped with STANO devices, when quantity, quality, and timeliness of information are important as measures of effectiveness. Results are also useful in gaming and modeling. Finally, they indicate that while there are differences between sensors and mixes of sensors, the principal loss in target acquisition is due to faulty control and communication procedures at the squad-platoon level and strongly suggest the need for improved procedures or more adequate training, or both.

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## BACKGROUND

A large number of sensors have been developed for the purpose of enhancing the Army's night operations capabilities. Military management decisions must be made as to which sensors should be selected and how they should be used. Previous testing and evaluation of these sensors has dealt with them primarily as individual issues of equipment. Emphasis has been on their capabilities for detecting targets. The question of the timeliness and quality of the target information they provide has largely been neglected. Thus, there is serious lack of experimental data on effectiveness of the sensors--considering timeliness and quality as well as detection--when they are used in combinations, that is, on how the various sensors complement and supplement each other to provide more complete and timely target information.

To provide military management with such information, a field experiment was designed to determine how different mixes of selected STANO sensors differentially affect small unit performance. Specific objectives of the research are:

1. To determine, considering human factors variables, how the rifle squad should be equipped with STANO sensors to provide the most effective continuous operations capability.

2. To determine the timeliness, accuracy, and content of target information that operators employing various STANO sensors can be expected to report.

3. To determine how performance can be improved by new search techniques, work methods and team procedures, deployment conditions, and command and control and communication techniques.

The entire experiment deals with the effectiveness of the squad-sized unit equipped with various mixes of STANO sensors under two tactical situations. Of principal interest is the linear defense situation in which a squad is assigned to maintain a position in an area defense. The four STANO sensors employed are the Starlight Scope, the PPS-14 Radar, the Patrol Seismic Intrusion Device, and the Hand-Held Thermal Viewer. Six mixes consisting of three sensors per mix are being empirically tested. The effectiveness of other mixes and of individual sensors can be analytically determined. Of secondary interest is the situation of a patrol on reconnaissance mission. The STANO sensors employed are the Starlight Scope and the Hand-Held Thermal Viewer. For this situation, three mixes consisting of three sensors per mix are being empirically tested and the effectiveness of other mixes and individual sensors is again being analytically determined.

Because of equipment availability and necessary ambient light conditions, the experiment is divided into two parts. The present publication describes some findings of Part I, in which three mixes were empirically tested and others analytically evaluated in the linear defense situation. A second report will be prepared upon completion of Part II, in which an additional three mixes are tested in the linear defense situation and three mixes are tested in a reconnaissance patrol situation. A final report will provide an integrated analysis and conclusions based upon all data.

## METHOD

The research method employed in Part I of the experiment is described briefly here.

### Critical Factors

Sensors

1. Starlight Scope, AN/PVS-2 (SS)

2. Listening Post Surveillance Device, AN/PPS-14 (PPS-14)

3. Patrol Seismic Instrusion Device, AN/GSQ-151 (PSID)

Equipment Mixes Empirically Tested

1. Two Starlight Scopes and one PPS-14 radar

2. Two Starlight Scopes and one PSID

3. One Starlight Scope, one PPS-14 radar, one PSID

Equipment Mixes Analytically Tested

1. Two Starlight Scopes

2. One Starlight Scope and one PSID

3. One Starlight Scope and PPS-14

4. One PSID and one PPS-14

Sensor Deployment. The PSID geophones and the PPS-14 radar locations were selected to provide the largest area of coverage without duplication of coverage in specific terrain areas. The locations of these sensors were established without knowledge of the target paths, in order to avoid possible bias for or against certain sensors or mixes. As deployment could easily be an important factor influencing mix effectiveness, two different sensor deployments, FAR and NEAR, were used. In the first, the PSID geophones were emplaced across the squad front at a range of 225-250 meters from the squad line (PSID FAR condition), and the PPS-14 radar was remoted to a central point 35 meters in front of the squad line and mounted to provide an antenna height of six feet (PPS-14 NEAR condition). In the second sensor deployment, the terrain relationship of the two sensors was reversed, the PSID geophones being emplaced at a range of 125-150 meters from the squad line (PSID NEAR condition) and the PPS-14 radar being remoted to a central point 175 meters in front of the squad line (PPS-14 FAR condition). For both deployment conditions, the SS's and the receivers for the remoted sensors were placed in the booths on the squad line. This placement of the sensors permitted comparisons involving the sensors when both were deployed FAR, when both were deployed NEAR, and when one was NEAR and the other FAR.

### Subjects

The subjects, or players, were enlisted men with an infantry MOS. Six squads were tested. Each squad was tested each night for six nights under starlight illumination.

### Instrumentation

A general description of the data acquisition system used has been described in other publications.[1] Essential elements were the tripods on which universal device platforms (UDPs) were mounted, the data recording and monitoring systems, and electro-mechanical counters. Since the SS's were mounted on the UDPs, it was possible to determine the orientation (azimuth and elevation) of the device with an accuracy of 0.1°. This information was electronically recorded four times per second on magnetic tape. At each operator position there were also a response button and an electro-mechanical counter. Each time the button was pressed, the response was automatically recorded on magnetic tape, along with the number of that response. The same number was also displayed on the counter at the player position and was entered by the player on a report form, along with his description of the target. As the same number was recorded on the magnetic tape and the report form, the two measures could easily be combined during subsequent data analysis.

### Terrain and Player Positions

The terrain was heterogeneous, being flat-to-hilly with some open and some heavily cluttered areas. It extended to 350 meters and was trapezoidal in shape, with a width of approximately 60 meters at the squad line and approximately 400 meters at the far limit.

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[1] Sternberg, Jack J. and James H. Banks. Search effectiveness with passive night vision devices. BESRL Technical Research Report 1163. June 1970.

Nine booths placed on line provided for three squad positions of three player positions each. The separation of the right and left flank booths for a single squad position was 33 meters. The squad leader was always positioned in the center of his squad. As viewing angle differed somewhat for the three squad positions, squads were rotated to all positions during testing.

## Sensor Deployment and Targets

One of the most difficult problems in experimentation in this area is the placement of sensors and targets to avoid introducing bias of sensor effectiveness. To this end, a strategy was devised by which sensors were laid out without knowledge of target paths and target paths were determined without knowledge of sensor locations. The tactical deployment of the sensors was to cover the largest area possible rather than to select a likely avenue of approach.

The targets were personnel--one man or groups of three men or six men. All targets were dynamic and moved in an upright position on specified target paths in the area of squad responsibility. Twenty-four paths were randomly selected to provide points of entry across the full front and sides of the search area, as well as multiple lines of approach within the search area. Six paths entered the search area from the right and left flanks, crossing the squad front and exiting on the other side; eighteen paths entered the search area from the far side and end of the squad area of responsibility, approaching to within 50 meters of the squad front. Targets walked at a speed of about one meter per second, resulting in a target exposure time of about five minutes for each path.

## Illumination Conditions

Testing was conducted under starlight illumination. Mean nightly readings ranged from $8.6 \times 10^{-5}$ to $1.6 \times 10^{-4}$ footcandles. Mean illumination for all nights of testing was $1.1 \times 10^{-4}$ footcandles.

## Procedures

<u>Squad Procedures</u>. Prior to testing, all players were thoroughly trained on use of the sensors and on experimental procedures. They were told that they were working as members of an infantry squad occupying a position in an area defense. They had previously overrun and cleared the area in front of their position and had emplaced intrusion detectors. They had then withdrawn and taken up their present position, which they would be occupying during the night. It was their responsibility to detect, describe, and report any enemy personnel who might move into their area during the night.

A squad position was composed of three booths. Each booth was equipped with a sensor and was occupied by two men. In the booths occupied by squad members, one player acted as sensor operator and one as data collector/runner who recorded target acquisition information on a report form (see Appendix for sample report forms) and reported the information to the squad leader. In the center booth were two players (the squad leader and a sensor operator) and a controller. When a runner came to the squad leader's booth, he brought the report form on which the observer's report was filled out. After giving this form to the controller, the runner made a verbal report to the squad leader. The squad leader then exercised one or more of his options for action. The controller recorded on the report form the content of the runner's verbal report (for later verification of accuracy) as well as the actions of the squad leader.

The squad leader had three basic actions he could take:

1. If the report came from an observer with a SS, he was required to direct the original observer either to continue to observe the same target or to break contact with that target to search for other targets. (This direction was for the SS only, as operators with other sensors were not able to break contact with the target at will.)

2. Regardless of which sensor produced the original report, the squad leader could, if he wished, send the runner to another booth which contained a SS to report the target information to the device operator and request confirmation and added information on distance and size.

3. For any report, the squad leader had the option of reporting or not reporting the information to his platoon leader. For example, if the squad leader received a report from a PPS-14 operator, he could delay making a report to his platoon leader while he attempted to get confirmation and additional information from one of his operators with a SS. The controller recorded the squad leader's action on the report form and, if the squad leader chose to report to the platoon leader, the content of his report.

One night's testing consisted of 36 search periods, 18 on the first sensor deployment condition (PSID-FAR, PPS-14 NEAR) and 18 on the second (PSID-NEAR, PPS-14 FAR). Search periods varied in length from five to nine minutes. In order to prevent players from anticipating target behavior, several procedures were used:

1. No targets were presented in one-third (12) of the search periods.

2. For search periods during which targets were presented, no systematic pattern of target "start" position was used, and the time of target presentation after the beginning of a search period was varied.

3. Although the same targets were presented in both sensor deployment conditions (in order to permit direct comparison of the two deployments) the order of target presentation was varied.

Three squads were tested simultaneously, each squad using one of the equipment mixes. These three squads alternated with another three squads after every three search periods. The mixes being used by the squads were changed after every six search periods. Thus, six squads were tested each night with each squad using all three mixes on both sensor deployment conditions.

All squads were tested for six nights. The position occupied by each squad and the specific targets presented to each squad were varied across nights. In the six nights, a total of 144 targets was presented to each mix, 72 in each sensor deployment condition.

Target Control and Scoring Procedures. Target location and target control were obtained by two target monitors located in booths at each end of the line of player booths. Each target monitor was equipped with a Night Observation Device, Medium Range (NOD), mounted on a universal device platform. The monitor constantly tracked the target, keeping the reticle of the NOD on the center of mass of the target as it moved along its prescribed path. The azimuth and elevation from the two trackers were displayed on NIXIE tubes in the instrumentation trailer. In order to insure that the targets moved along the specified path at the correct speed, the NIXIE tube display was constantly monitored. Target location was checked against a target path map showing azimuth, elevation, and time coordinates for each target path. If the target deviated from the correct path, or moved at the wrong speed, the deviation could be immediately determined by comparing tracker device orientation with the map coordinates and then corrected by radio communication with the target.

Azimuth and elevation of the two trackers were electronically recorded. As the distance separating the two trackers was known, as well as the angle from each tracker to the target, it was possible to determine at all times the exact target location. A target acquisition response by one of the players with a SS was scored as a "hit" if the azimuth of his device was within plus or minus 5° of the actual target location.

When a target was in a PSID or PPS-14 area, its presence was recorded on the magnetic tape of the data acquisition system. A target acquisition response by a player with one of these sensors was scored as a "hit" only when the player's response occurred within the same period as marked on the tape.

## RESULTS

Data were analyzed in terms of 1) observer reports, 2) reports to squad leader, and 3) reports to platoon leader. In this way, it is possible to determine the efficacy of the mixes as well as any control and communication problems which may arise at critical points in the transmission sequence.

Data are presented so as to show the effects of mix and of sensor deployment. Comparisons were made for individual sensors, mixes involving two sensors, and mixes involving three sensors. The mixes of three sensors were empirically tested. The results on individual sensors and two-sensor mixes were obtained by analytic treatment of the data. The results are shown for two sensor deployment conditions.

The measures of effectiveness used are the percentage of targets detected and the quality and timeliness of detection. Quality is defined as the percentage of targets with accurate descriptions of target size and distance. To be scored as correct on size, a one-man target had to be reported as one man, a three-man target had to be reported as two or three or four men, and a six-man target as five or six or seven men. To be scored as correct on distance, a target at 200 - 300 meters had to be reported within plus or minus 30 meters of its true distance; at 100 - 199 meters, within plus or minus 20 meters of its true distance; and at 50 - 99 meters, within plus or minus 10 meters of its true distance. Under timeliness, the data are presented in terms of target detections and quality in three criterion zones: Zone 1 = 200 - 300 meters; Zone 2 = 100 - 300 meters; Zone 3 = 50 - 300 meters. Note that the criterion zones overlap; Zone 2 includes the area defined as Zone 1, and Zone 3 encompasses the entire search area. Thus, target detections are cumulative, the results shown in Zone 3 being the maximum detections and quality obtained.

For clarity of presentation, percentage detections and quality are shown first for Zone 3 with the data combined from the two deployment conditions. The results are then progressively broken out to show the effects of criterion zone and deployment.

#### Observer Report

Percent Detection. The overall percentages of targets detected by single sensors and by mixes of two and three sensors are shown in Table 1. For the single sensors, the highest number of targets was detected by the SS (83%) and the lowest by the PSID (67%). For the two-sensor mixes, all mixes were about equally effective, and all mixes detected a high percentage of the targets (ranging from 89% for the PPS-14/PSID combination to 95% for the SS/SS combination). For the three-sensor mixes, virtually all (97%-98%) the targets were detected with all mixes. In general, increasing the number of sensors from one to two resulted in a meaningful increase in detections. When the number was increased from two to three, improvement generally was slight when only the percent detections is considered--for example, 95% were detected by two SS's and 97% by two SS's and a PPS-14. If percent detections were the sole criterion, therefore, these results would strongly suggest that all mixes are about equally effective and that probably no more than two sensors need be used. However, when other measures of effectiveness such as quality and timeliness are considered, there are differences in the relative effectiveness of the mixes.

Table 1

PERCENTAGES OF TARGETS DETECTED WITH INDIVIDUAL SENSORS AND MIXES OF TWO AND THREE SENSORS

| Number of Sensors | Sensor Combination | Description | Percent Detection |
|---|---|---|---|
| 1 | SS | 1 SS | 83 |
| | PPS-14 | 1 PPS-14 | 73 |
| | PSID | 1 PSID | 67 |
| 2 | I | 2 SS | 95 |
| | II | 1 SS<br>1 PPS-14 | 92 |
| | III | 1 SS<br>1 PSID | 93 |
| | IV | 1 PPS-14<br>1 PSID | 89 |
| 3 | V | 2 SS<br>1 PPS-14 | 97 |
| | VI | 2 SS<br>1 PSID | 98 |
| | VII | 1 SS<br>1 PSID<br>1 PPS-14 | 98 |

Quality. Table 2 shows the quality of target information supplied by the individual sensors and by the mixes. With the SS, for example, 83% of the targets were detected, accurate distance estimates were given for 37% of the targets, and accurate size estimates for 76%. Both correct distance and correct size were given for only 33%, primarily because of the inability of the operator to estimate accurately the distance of the target. No size information could be supplied by the PPS-14 or the PSID, but a response from a PSID operator was scored as correct on distance if he correctly reported which geophone was being activated. Thus, for the PSID, 67% of the targets were detected, with correct geophone reported for 61% of the targets.

Table 2

PERCENT DETECTION AND QUALITY[a] OF DETECTION

| Number of Sensors | Combination | Detection | Detection + Distance | Detection + Size | Detection + Distance + Size |
|---|---|---|---|---|---|
| 1 | SS | 83 | 37 | 76 | 33 |
| | PPS-14 | 73 | 0 | 0 | 0 |
| | PSID | 67 | 61 | 0 | 0 |
| 2 | I (SS, SS) | 95 | 56 | 91 | 54 |
| | II (SS, PPS-14) | 91 | 35 | 72 | 31 |
| | III (SS, PSID) | 95 | 74 | 79 | 59 |
| | IV (PSID, PPS-14) | 89 | 60 | 0 | 0 |
| 3 | V (SS, SS, PPS-14) | 97 | 50 | 88 | 47 |
| | VI (SS, SS, PSID) | 98 | 83 | 93 | 78 |
| | VII (SS, PSID, PPS-14) | 98 | 74 | 72 | 55 |

[a]Entries in each quality category represent the percentage of targets which were detected and for which correct estimates of distance or size, or both, were given.

The two-sensor mixes were about equally effective when only percent detections was considered. However, when quality of detections was considered, substantial differences were found. If distance is considered the most important quality, then Mix III is best (74% detection with distance correctly estimated); if size is considered most important, then Mix I is best (91% detections with size correctly estimated). If both distance and size are considered simultaneously, and equally weighted, then there is little difference between Mix I and Mix III, but both are better than Mixes II and IV.

Of the three-sensor mixes, Mix VI was best on all qualitative measures. Also, the qualitative information provided by Mix VI was substantially better than that provided by the best of the two-sensor mixes. For example, complete qualitative information was provided on 78% of the targets with Mix VI, as opposed to 54% for Mix I and 59% for Mix III. Thus, although all mixes were approximately equal in effectiveness when only percent detections was considered, the qualitative measures show that the three-sensor mixes are superior to the two-sensor mixes and provide a basis for selection of a best mix.

Timeliness. The third criterion was timeliness of target detection. This criterion shows the relative effectiveness of the sensors and mixes as the targets approached the squad line. Three criterion zones were used. The percentages of targets detected in these zones are presented in Table 3. The percentages shown in Zone 1 indicate that the target was detected at 200-300 meters, that in Zone 2 the target was detected at 100-300 meters, and in Zone 3 the target was detected at 50-300 meters.

As was shown earlier, the mixes were about equally effective in terms of overall (Zone 3) detections. Table 3 reveals that the differences among the mixes were somewhat larger when early (Zone 1) detections were considered.

Table 3

TIMELINESS OF TARGET DETECTION: PERCENT DETECTION BY CRITERION ZONE

| Sensor Combination | Percent Detection Criterion Zone 1 | 2 | 3 |
|---|---|---|---|
| SS | 31 | 75 | 83 |
| PPS-14 | 42 | 72 | 73 |
| PSID | 34 | 65 | 67 |
| I (SS, SS) | 49 | 90 | 95 |
| II (SS, PPS-14) | 56 | 89 | 92 |
| III (SS, PSID) | 57 | 92 | 93 |
| IV (PSID, PPS-14) | 65 | 87 | 89 |
| V (SS, SS, PPS-14) | 60 | 94 | 97 |
| VI (SS, SS, PSID) | 61 | 97 | 98 |
| VII (SS, PSID, PPS-14) | 68 | 95 | 98 |

Detection, Timeliness, and Quality. The full matrix for detection, quality, and timeliness is given in Table 4. From this table it can be seen that Mix VI is best overall and on all individual measures, is equal to or better than any of the other mixes.

Effects of Sensor Deployment. The effects of sensor deployment were examined to determine whether performance effectiveness of the mixes was differentially affected by FAR and NEAR deployment of the sensors. FAR deployment for the PSID was at approximately 225-250 meters; for the PPS-14, the unit was remoted to 175 meters. NEAR deployment for the PSID was at approximately 125-150 meters; for the PPS-14, the unit was remoted to 35 meters.

Table 5 shows the percent detections, timeliness, and quality for the PPS-14 and PSID under FAR and NEAR deployment conditions. In the FAR condition, 56% of the targets in Zone 1 were detected with the PPS-14 and 60% with the PSID. In Zone 3, the comparable values were 70% and 67%. Thus, there were no significant differences between the sensors in target detection. In the NEAR condition, more targets were detected with the PPS-14 than with the PSID in all criterion zones.[2] For both sensors, however, the percent of early detections was much greater in the FAR than in the NEAR condition.

If early detections are important, then there is no doubt that the FAR deployment is superior. If distance information is considered important and if only one of the sensors can be used, then a properly deployed PSID would provide both early detection and distance information.

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[2] The relatively large percentage of targets detected at beyond 200 meters (in Criterion Zone 1) with the PPS-14 remoted to 35 meters was at first surprising as the range of a PPS-14 radar for a walking man is given as approximately 125 meters. Thus, one-man targets should not have been detected at ranges greater than 160 meters from the squad line. Upon inspection of the data, it was found that one-man targets were sometimes detected at ranges of 250-275 meters. Therefore, the actual range of the PPS-14 is considerably greater than that given in the specifications, although the findings also show that target detection is not as reliable at these ranges as at the closer distances. Factors contributing to the greater range of detection were the antenna height (six feet), a terrain which sloped uphill, and the use of some three-and six-man targets.

Table 4

PERCENT DETECTION, TIMELINESS, AND QUALITY[a]

| Number of Sensors | Sensor Combination | Detection | | | Detection + Distance | | | Detection + Size | | | Detection + Distance + Size | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Criterion Zone | | | Criterion Zone | | | Criterion Zone | | | Criterion Zone | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | SS | 31 | 75 | 83 | 12 | 33 | 37 | 27 | 68 | 76 | 10 | 29 | 33 |
| | PPS-14 | 42 | 72 | 73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | PSID | 34 | 65 | 67 | 32 | 59 | 61 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | I (SS, SS) | 49 | 90 | 95 | 18 | 48 | 56 | 45 | 85 | 91 | 17 | 46 | 54 |
| | II (SS, PPS-14) | 53 | 87 | 91 | 12 | 32 | 35 | 28 | 64 | 72 | 10 | 27 | 31 |
| | III (SS, PSID) | 52 | 91 | 95 | 40 | 72 | 74 | 27 | 73 | 79 | 19 | 54 | 59 |
| | IV (PSID, PPS-14) | 65 | 87 | 89 | 31 | 58 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | V (SS, SS, PPS-14) | 60 | 94 | 97 | 15 | 41 | 50 | 45 | 80 | 88 | 13 | 37 | 47 |
| | VI (SS, SS, PSID) | 61 | 97 | 98 | 43 | 80 | 83 | 44 | 90 | 93 | 31 | 73 | 78 |
| | VII (SS, PSID, PPS-14) | 68 | 95 | 98 | 44 | 73 | 74 | 28 | 70 | 72 | 23 | 54 | 55 |

[a] The entries in each quality category represent the percentage of targets which were detected and for which correct estimates of distance, or size, or both, were given.

Table 5

PERCENT DETECTION, TIMELINESS, AND QUALITY FOR PPS-14 RADAR AND PSID WHEN BOTH HAVE SAME AREA OF COVERAGE

| Sensor Deployment | | Detection Criterion Zone 1 | 2 | 3 | Detection + Distance Criterion Zone 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| PPS-14 | FAR | 56 | 70 | 70 | 0 | 0 | 0 |
| PSID | FAR | 60 | 67 | 67 | 56 | 61 | 61 |
| PPS-14 | NEAR | 31 | 73 | 76 | 0 | 0 | 0 |
| PSID | NEAR | 0 | 62 | 67 | 0 | 57 | 61 |

Table 6 shows the percent detections, timeliness, and quality for the mixes utilizing the PPS-14 or the PSID in combination with one or two SS's in the FAR deployment condition. Table 7 shows similar data for the NEAR deployment condition. In the FAR deployment condition, the differences among the mixes in target detection and in timeliness were small, the two and three sensor mixes being about equally effective. In quality, however, the mixes with the PSID were superior to those with the PPS-14 radar and the three-sensor mixes were superior to the two-sensor mixes.

In the NEAR deployment condition (Table 7), more targets were detected in Zone 1 by mixes with the PPS-14 than by mixes with the PSID, but this advantage was lost by Zone 2. In quality, however, the combinations with a PSID were consistently superior, and the three-sensor mixes were superior to the two-sensor mixes.

The effects of sensor deployment for mixes including both a PPS-14 and a PSID are shown in Table 8. Deployment had little effect on the percentage of targets detected or on the timeliness of detection, and almost as many targets were detected with the two- as with the three-sensor mixes. However, no size information could be supplied by the mix of only a PSID and a PPS-14 (Mix IV). For distance, the FAR deployment of the PSID greatly improved early distance information for both mixes.

To summarize the effects of sensor deployment, use of a FAR remoted sensor greatly improved early detection, but the differences between the PSID and the PPS-14 were small when only detection was considered. However, when the PSID was the FAR remoted sensor, early information on target location was provided as well.

Table 6

PERCENT DETECTION, QUALITY, AND TIMELINESS FOR FAR DEPLOYMENT CONDITION

| Mix | Detection | | | Detection + Distance | | | Detection + Size | | | Detection + Distance + Size | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 |
| II (SS, PPS-14) | 67 | 85 | 89 | 13 | 34 | 37 | 33 | 67 | 75 | 12 | 32 | 35 |
| III (SS PSID) | 68 | 93 | 95 | 59 | 72 | 74 | 24 | 71 | 76 | 25 | 51 | 56 |
| V (SS, SS, PPS-14) | 66 | 90 | 98 | 17 | 41 | 51 | 54 | 88 | 95 | 17 | 41 | 51 |
| VI (SS SS, PSID) | 72 | 98 | 98 | 59 | 80 | 83 | 46 | 89 | 89 | 39 | 70 | 74 |

Table 7

PERCENT DETECTION, QUALITY AND TIMELINESS FOR NEAR DEPLOYMENT CONDITION

| Mix | Detection Criterion Zone 1 | Detection Criterion Zone 2 | Detection Criterion Zone 3 | Detection + Distance Criterion Zone 1 | Detection + Distance Criterion Zone 2 | Detection + Distance Criterion Zone 3 | Detection + Size Criterion Zone 1 | Detection + Size Criterion Zone 2 | Detection + Size Criterion Zone 3 | Detection + Distance + Size Criterion Zone 1 | Detection + Distance + Size Criterion Zone 2 | Detection + Distance + Size Criterion Zone 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| II (SS, PPS-14) | 46 | 90 | 93 | 11 | 30 | 34 | 23 | 62 | 70 | 8 | 24 | 28 |
| III (SS PSID) | 29 | 89 | 94 | 14 | 71 | 74 | 26 | 75 | 82 | 12 | 59 | 64 |
| V (SS, SS, PPS-14) | 56 | 98 | 98 | 15 | 41 | 50 | 39 | 74 | 83 | 11 | 35 | 44 |
| VI (SS, SS, PSID) | 46 | 98 | 100 | 22 | 80 | 83 | 41 | 93 | 100 | 20 | 76 | 83 |

Table 8

EFFECTS OF SENSOR DEPLOYMENT ON PERCENT DETECTION AND TIMELINESS
FOR MIXES INCLUDING BOTH PPS-14 AND PSID

| Mix | Sensor Deployment | Detection | | | Detection + Distance | | | Detection + Size | | | Detection + Distance + Size | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 | Criterion Zone 1 | 2 | 3 |
| IV (PSID, PPS-14) | PSID FAR, PPS-14 NEAR | 69 | 91 | 93 | 56 | 61 | 61 | 0 | 0 | 0 | 0 | 0 | 0 |
| | PSID NEAR, PPS-14 FAR | 61 | 83 | 85 | 0 | 56 | 59 | 0 | 0 | 0 | 0 | 0 | 0 |
| VII (SS, PSID, PPS-14) | PSID FAR, PPS-14 NEAR | 70 | 96 | 98 | 63 | 74 | 74 | 28 | 70 | 72 | 28 | 50 | 52 |
| | PSID NEAR, PPS-14 FAR | 66 | 95 | 100 | 20 | 71 | 73 | 29 | 71 | 73 | 17 | 59 | 59 |

False Reports. An important factor in evaluating the effectiveness of the sensors and mixes is the percentage of false reports. In the experimental design, one-third of the search periods contained no targets. Additionally, a false report could be made during the search periods which contained targets by "shooting" at a location which did not contain a target. Thus, there was ample opportunity to make false reports. In spite of this opportunity, analysis of the data showed that the percentage of false reports for all sensors and mixes was less than 5%.

### Report to Squad Leader

The most common procedure in combat, upon detection of a target by an operator, is for the operator to report this information with no filtering to his squad leader. While there are many report procedures, the procedure used in the present experiment was to have the operator's runner verbally report to the squad leader. When the observer's data were compared with the information received by the squad leader, 98% of the reports to the squad leader were found to be identical to the original observer's report. Thus, loss of information was negligible and did not affect the efficacy of the mixes. It should be carefully noted that a minimum amount of information was communicated to the squad leader: Starlight Scope operators reported size and distance, PPS-14 operators reported target in or out, and PSID operators reported the geophone number.

### Report to the Platoon Leader

The conditions of the experiment required the squad leader to report target information to the platoon leader. The squad leader had the prerogative of deciding what information to report, and when. He could, if he decided it was a false report, not report it at all, or he could attempt to get confirmatory or more qualitative information and then report it. This procedure was employed to study potential control and communication problems. As the number of targets represented a low- to mid-intensity situation, and as the experimental design allowed for a large number of false reports, it was questionable whether the squad leader could handle a flow of information from his squad members and correctly pass the information back to his platoon leader. Additionally, it was possible that the squad leader, acting as a necessary filter, might degrade the flow of information and affect the efficacy of the mixes.

Percent Detection. Table 9 shows the overall (Zone 3) percentage of targets detected and the percentage reported to the platoon leader, for the three empirically tested mixes. Loss of information in the transmission to platoon leader was considerable for Mixes V and VII, but only slight for Mix VI. Mix VI is, therefore, superior to the other mixes when the report to platoon leader is considered, although all mixes were equally effective when only the observer report was considered. This finding indicates that the squad leaders were more willing or able to report information from Mix VI than from the other mixes.

Table 9

COMPARISON OF PERCENT DETECTIONS MADE BY OBSERVER WITH PERCENT DETECTIONS REPORTED TO PLATOON LEADER
(Combined Deployment Conditions)

| Mix | Observer Report | Report to Platoon Leader |
|---|---|---|
| V (SS, SS, PPS-14) | 97 | 81 |
| VI (SS, SS, PSID) | 98 | 94 |
| VII (SS, PSID, PPS-14) | 98 | 78 |

Quality. A comparison of observer reports and reports to platoon leader for qualitative information (Zone 3) is shown in Table 10. Looking first at overall quality (detection plus distance plus size), all mixes show considerable degradation: from 47% to 34% for Mix V; from 78% to 45% for Mix VI; and from 55% to 35% for Mix VII. Mix VI shows the greatest absolute loss due to its high initial quality, but still remains superior to the other two mixes. Data in the size and distance columns reveal that, generally, little loss occurred in reporting size information but great loss occurred in reporting distance. Size information can be obtained only with a SS, and distance information only with the SS or PSID. Previous analyses have shown that the observer's ability to specify distance (location) with the PSID is high, in comparison to his accuracy of distance estimation with the SS. Mixes VI and VII, both of which include a PSID, have a high percentage of detections with correct distance (83% and 74%, respectively, for the observer report) and both show a large absolute percentage loss for report to platoon leader. These findings suggest, therefore, that if the initial detection is made by a sensor other than the SS, the squad leader frequently is not reporting to the platoon leader until he has received a second report from a SS, which in fact provides him with a poorer distance estimate than he had in hand if the original detection was made by a PSID.

Timeliness. A comparison of percent detections for observer report and report to platoon leader, by criterion zone, is given in Table 11. All mixes were about equal in all zones for the original observer report, but for report to platoon leader Mix VI showed less loss in all criterion zones than did the other mixes.

Table 10

PERCENT DETECTIONS AND QUALITY: COMPARISON OF OBSERVER REPORT WITH REPORT TO PLATOON LEADER
(Combined Deployment Conditions)

| Mix | Detection | | Detection + Distance | | Detection + Size | | Detection + Distance + Size | |
|---|---|---|---|---|---|---|---|---|
| | Obs Rpt | Rpt to Plt Ldr | Obs Rpt | Rpt to Plt Ldr | Obs Rpt | Rpt to Plt Ldr | Obs Rpt | Rpt to Plt Ldr |
| V (SS, SS, PPS-14) | 97 | 81 | 50 | 36 | 88 | 75 | 47 | 34 |
| VI (SS, SS, PSID) | 98 | 94 | 83 | 47 | 93 | 89 | 78 | 45 |
| VII (SS, PSID, PPS-14) | 98 | 78 | 74 | 47 | 72 | 68 | 55 | 37 |

Table 11

COMPARISON OF PERCENT DETECTIONS MADE BY OBSERVER WITH PERCENT DETECTIONS REPORTED TO PLATOON LEADER BY CRITERION ZONE
(Combined Deployment Condition)

| Mix | Zone 1 | | Zone 2 | | Zone 3 | |
|---|---|---|---|---|---|---|
| | Obs Rpt | Rpt to Plt Ldr | Obs Rpt | Rpt to Plt Ldr | Obs Rpt | Rpt to Plt Ldr |
| V (SS, SS, PPS-14) | 60 | 40 | 94 | 73 | 97 | 81 |
| VI (SS, SS, PSID) | 61 | 51 | 97 | 92 | 98 | 94 |
| VII (SS, PSID, PPS-14) | 68 | 32 | 95 | 74 | 98 | 78 |

These results show clearly that a large loss in quantity and quality of information available to the squad leader occurs when he, using his best judgment, filters the information which he thinks suitable for re-transmission. The squad leader's transmission of information to his platoon leader is only the first in a series of such transmissions. If the degradation at each step is of the same magnitude as that observed in the present experiment, then the ultimate loss of information will be very large indeed. Additional analyses which will permit a detailed examination of the squad leader's reporting behavior will be presented in the final report. Hopefully, with better understanding of the reasons for degradation, the losses incurred in the communication process can be greatly reduced.

## SUMMARY

This report is an interim report. Subsequent reports will present results on other mixes and on moonlight illumination conditions. The present data show that a higher quality of target information is obtained with the mix containing one PSID and two Starlight Scopes than with the other mixes tested. The results also show that tactically employing the PSID in a FAR location results in considerable enhancement of early detection.

All mixes showed a large loss of information as a report was transmitted from squad leader to platoon leader, particularly with regard to quality of target information. This result strongly suggests the need for better training of the squad leader in reporting information, or improved methods and techniques for transmitting target data, or a combination of the two.

# APPENDIX

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## TARGET REPORT FORMS

### PROCEDURE

The sensor operator pressed a response button when he detected a target, and then reported information about the target to his data collector/runner. The data collector/runner entered the information on a target report form which he delivered to a controller located with the squad leader. The controller then recorded on the form the content of the data collector/runner's verbal report to the squad leader, as well as the actions of the squad leader. Samples of the report forms for the three sensors used (Starlight Scope, PPS-14 radar, PSID) are included in this appendix.

### DESCRIPTION

The forms for all sensors were identical in format, actual content being adjusted according to the nature of the information supplied by a given sensor. All information necessary for identification of a report was entered by the experimenters on the first line of the form. The body of the form was broken into three sections: observer report, report to squad leader, and squad leader's action.

Observer Report. T' server report was filled out by the data collector/runner. On all forms, the first item to be entered was the counter number. This number was obtained from an incremental counter located in the player booth, which was activated each time the sensor operator pressed his response button, an identical number being simultaneously recorded on magnetic tape of the data acquisition system. (This technique permitted the combination of the information contained in the report form with the corresponding information recorded on the magnetic tape.) As can be seen from the sample report forms, the target information that could be supplied was different for the three sensors. Also, for the SS, the data collector/runner was required to record whether the target had been found by the sensor operator working independently or by the sensor operator after the squad leader had sent a runner with information about the target from an earlier acquisition. (For example, the target might have been detected first by the PSID and the squad leader might direct the runner to go to a booth with a SS and tell the operator to look in the area of geophone #3.)

Report to Squad Leader. After entering the information in the Observer Report section, the data collector/runner delivered the report form to the controller with the squad leader. The runner then verbally reported the information to the squad leader, while the controller recorded on the form the content of the verbal report.

Squad Leader's Action. This section was divided into two subsections. In the first (Squad Action), the controller recorded the squad leader's actions involving use and disposition of the members of his squad. For the SS, the squad leader had to instruct the runner whether his sensor operator (the original observer) should continue to observe the same target or should break contact with that target to search for new targets. In addition, he had the option of sending the runner to another squad member with a SS to request confirmation and/or additional information about the target. With the PPS-14 and PSID, as operators with these sensors could not break contact with a target at will, the squad could only return the runner to his own booth or send him to another booth with a SS for additional information.

The conditions of the experiment also required the squad leader to report target information to his platoon leader, but he had the responsibility of deciding what information to report, and when. In the second subsection (Platoon Action), the controller recorded this aspect of the squad leader's behavior, noting whether he would report and the content of his report, or would not report, or had already reported the information from an earlier acquisition of the target.

STARLIGHT SCOPE

REPORT FORM

| Device | Night | Squad | Booth | Deployment | Mix | Player | Sheet No. |
|---|---|---|---|---|---|---|---|
| 1 | ___ | ___ | ___ | ___ | ___ | ___ | ___ |

| | | |
|---|---|---|
| Observer Report | Counter Number | ___ |
| | Number of Personnel | ___ |
| | Range in Meters | ___ |
| | Found Target — By Myself | ___ |
| | Found Target — After directions from Squad Leader | ___ |
| Report to Squad Leader | Number of Personnel | ___ |
| | Range in Meters | ___ |
| Squad Leader's Action | Squad Action — Original Observer ( Stay on Target | ___ |
| | Squad Action — Original Observer ( Search for other Targets | ___ |
| | Squad Action — Request confirmation from Position(s) | ___ ___ |
| | Platoon Action — I would report to Platoon Leader ( Number of Personnel | ___ |
| | Platoon Action — I would report to Platoon Leader ( Range in Meters | ___ |
| | Platoon Action — I would not report to Platoon Leader | ___ |
| | Platoon Action — I have already reported this information to Platoon Leader | ___ |

PPS-14

REPORT FORM

| Device | Night | Squad | Booth | Deployment | Mix | Player | Sheet No. |
|---|---|---|---|---|---|---|---|
| 2 | ____ | ____ | ____ | ________ | __ | ____ | ______ |

| | | |
|---|---|---|
| Observer Report | Counter Number | ______ |
| | Target Moving .........( Toward Me | ______ |
| | Target Moving .........( Away from Me | ______ |
| Report to Squad Leader | Target Moving .........( Toward Me | ______ |
| | Target Moving .........( Away from Me | ______ |
| Squad Leader's Action | Squad Action: Return Runner to own Booth | ______ |
| | Squad Action: Request confirmation from Position(s) | ___ ___ |
| | Platoon Action: I would report to Platoon Leader ..........( Toward | ______ |
| | Platoon Action: I would report to Platoon Leader ..........( Away | ______ |
| | I would not report to Platoon Leader | ______ |
| | I have already reported this information to Platoon Leader | ______ |

**PSID**

**REPORT FORM**

| Device | Night | Squad | Booth | Deployment | Mix | Player | Sheet No. |
|---|---|---|---|---|---|---|---|
| 3 | ____ | ____ | ____ | ________ | ___ | _____ | ______ |

| | | |
|---|---|---|
| Observer Report | | Counter Number ________<br>Geophone Number (circle one) 1 2 3 4 |
| Report to Squad Leader | | Geophone Number (circle one) 1 2 3 4 |
| Squad Leader's Action | Squad Action | Return Runner to own Booth ________<br>Request confirmation from Position(s) _____ _____ |
| | Platoon Action | I would report to Platoon Leader<br>Geophone Number (circle one) 1 2 3 4<br>I would not report to Platoon Leader ________<br>I have already reported this information to Platoon Leader ________ |