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ELEMENTS OF A BATTALION INTEGRATED SENSOR SYSTEM: OPERATOR AND TEAM EFFECTIVENESS

James H. Banks, Guthrie D. Hardy, Jr.
and
Thomas D. Scott
Army Research Institute for the Behavioral and Social Sciences

and
John W. Jennings
Manned Systems Sciences

ARI FIELD UNIT, FORT ORD,
PRESIDIO OF MONTEREY, CALIFORNIA

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This report describes the second phase of a research program designed to investigate requirements for an effective integrated surveillance system utilizing several combinations of radars and night vision devices. The results, obtained in a realistic setting, showed that: (1) the highest quality of target detection information reported to battalion was obtained by surveillance teams consisting of one AN/PPS-5A Ground Surveillance Radar Operator, one Night Observation Device Operator, a team chief, and a radio-telephone operator; (2) ground surveillance radar operators were unable

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20. to identify reliably either target types or target classes (wheel vs track vehicles; personnel vs vehicles) under (simulated) operational conditions; (3) simple, low-cost modifications to training and work procedures greatly enhanced the performance of PPS-5A ground surveillance radar operators.

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and
John W. Jennings
Manned Systems Sciences

ARI FIELD UNIT, FORT ORD,
PRESIDIO OF MONTEREY, CALIFORNIA
Jack J. Sternberg, Chief

Submitted By:
Joseph Zeidner, Director
ORGANIZATIONS & SYSTEMS
RESEARCH LABORATORY

Approved By:
J. E. Uhlaner
TECHNICAL DIRECTOR

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

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FOREWORD

The Tactical Team Performance Program within the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is concerned with problems of effective team performance in use of STANO equipment. Specific aspects deal with performance effectiveness of surveillance systems, factors which affect performance, and means of improving effectiveness. The research program is responsive to requirements of the Army Training and Doctrine Command and is conducted under RDTE Project 2Q762731A763, Human Performance in Military Systems, FY 1975 Work Program.

This program is being executed by the ARI Field Unit, Fort Ord and Presidio of Monterey, California, with the support of the Combat Developments Experimentation Command (CDEC). Personnel of the Army Research Institute appreciate the excellent cooperation given the research program by CDEC in providing technical, personnel, and materiel support. Special acknowledgment is made of the efforts of the Commander, Brigadier General D. F. Packard, and of Colonel A. Fern, Deputy Chief of Staff for Experimentation.

The research reported here and in ARI Research Report 1183 is part of an ongoing program designed to enhance the effectiveness of company and battalion ground surveillance elements through research in the use of radars, night vision devices, and other sensors in combination as an integrated sensor system. This evaluation of ground surveillance devices and operator performance is a good example of the systems measurement bed, in which scientific instruments, techniques, and methods are used in a field environment to assess the effect on system performance of changes in any part of the system.

ARI research in tactical team performance is conducted as an in-house research effort augmented by research contracts with organizations selected as having unique capabilities for research in the area. The present research was conducted by personnel of Manned Systems Sciences, Northridge, California, under the supervision of Dr. Frederick Muckler and Mr. Douglass Nicklas, and under the program direction of Mr. Jack J. Sternberg, ARI.

J. E. Uhlaner
Technical Director

ELEMENTS OF A BATTALION INTEGRATED SENSOR SYSTEM: OPERATOR AND TEAM EFFECTIVENESS

BRIEF

Requirement:

To enhance the operational effectiveness of company and battalion ground surveillance elements through research on the realistic employment and deployment of ground surveillance radars and night vision devices in cost-effective combination as an integrated sensor system.

Procedure:

Phase 2 of this research program was designed to confirm and extend previous findings that suggested optimal operating effectiveness with four-man teams using an AN/PPS-5A radar and an AN/TVS-4 Night Observation Device (NOD). The devices were employed singly and in combination, in support of an infantry battalion in a static defense area. The devices were operated from three locations along a 4000 meter front, providing overlapping surveillance to a depth of about 7000 meters. A prototype of the AN/PPS/15 ground surveillance radar was also tested. Accuracy, timeliness, and alternate strategies of detection under conditions of independent search, team search, low levels of illumination, and radar operator training were systematically investigated.

Findings:

No single surveillance device meets all needs for detection, location, and identification, when used under realistic operating conditions. However, two of the devices tested--the AN/PPS-5A radar and the medium range Night Observation Device (NOD)--possess complementary capabilities.

The optimum mix, considering multiple measures of effectiveness, is judged to be a two-device mix consisting of one PPS-5A radar and one NOD--the PPS-5A radar detects and locates targets well, the NOD identifies targets well. Use of additional devices did not improve mix performance.

Operational effectiveness is increased by use of this mix in a team configuration, with coordination and control provided by a team chief. In addition to coordinating the search activities of the two device operators, the team chief can insure timely and accurate reporting to the designated user (battalion, in this research). He can also, when desired, successfully combine reports from his device operators to reduce radio traffic but cannot filter information to be reported without substantial reduction in the number of detections reported.

Use of several teams will generally be required for adequate battalion area coverage. When multiple teams are employed, battalion-level surveillance will be enhanced by maximizing overlap of search sectors, if this can be achieved while maintaining coverage of all likely avenues of approach.

Operational effectiveness with the PPS-5A can be greatly increased by use of the search and operating procedures developed in this research.

Operators of the three ground surveillance radars tested were unable to identify targets which had been detected.

Utilization of Findings:

Coordination techniques developed in this phase can generalize to combinations or radar and night observation devices other than the specific models used if the devices are complementary in function. Commanders may be able to use these findings as a basis for optimum coverage for their areas with available equipment.

The training and operating modifications which greatly increased radar effectiveness can be easily incorporated into school and unit training, at far less cost than equipment modification.

The possibility exists, that, with further special training, radar operators could learn to distinguish signals sufficiently to identify types of targets and thus eliminate the need for the NOD, releasing it for other surveillance or reducing the amount of equipment needed.

ELEMENTS OF A BATTALION INTEGRATED SENSOR SYSTEM: OPERATOR AND TEAM EFFECTIVENESS

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INTRODUCTION

A need to improve surveillance, target acquisition, and night observation (STANO) capabilities has led to the development of sophisticated new radars, night observation devices, and sensors. However, the effectiveness of a surveillance effort is determined, not only by the inherent capabilities of materiel, but also by the training and capabilities of the device operators and by how the personnel and equipment are used. The personnel and equipment can be considered subsystems which contribute to the effectiveness of a larger system in which surveillance elements are operationally integrated and employed. Operational effectiveness, therefore, must be evaluated in terms of the products provided by this larger, or system, effort.

The basic research approach of the Army Research Institute (ARI) Field Unit at the Presidio of Monterey is dictated by the recognition that system effectiveness can be enhanced in a variety of ways, but at different costs, and that human performance cannot be meaningfully evaluated independently of other system elements. ARI has developed scientific instrumentation, techniques, and methodologies in order to conduct field experimentation. These are used for testing in tactical situations that provide job samples which simulate actual conditions under which the individual/team/unit will perform in combat. Together, the methodology, instrumentation, and job samples constitute a standardized test and evaluation capability, or systems measurement bed. Variations in components of the three major subsystems may be introduced into this measurement bed and changes in system performance measured. In this manner, feasible alternatives to current training, weapon types, mixes, or methods of employment can be scientifically examined to determine their relative effectiveness, in terms of money, manpower conserved, training time, or battle effectiveness as appropriate.

RESEARCH PROGRAM AND OBJECTIVES

Research reported here is part of an ongoing program designed to enhance the effectiveness of company and battalion ground surveillance elements through research involving employment of radars, night vision devices, and other sensors in combination as a battalion integrated surveillance system (BISS). Experimentation was designed to provide the following:

a. Implications for basis of issue and mix, based on equipment and human performance capabilities, for battalion and company ground surveillance elements.

b. Information on the relative performance of different man-device subsystems--separately, at the team level, and collectively within the surveillance system at the battalion and company levels.

c. Techniques for improved training, search behavior, work methods, and team procedures.

d. Development of a procedure for coordinating different STANO teams/device combinations to obtain, confirm, and report target information.

e. Identification of areas in which follow-on research efforts might offer significant payoff by further increasing operational effectiveness of the BISS.

This experimentation was conducted in two phases. In Phase 1, the specific objectives were to provide human performance data with implications for basis of issue and mix; to provide information on the relative performance of different man-device subsystems, considering multiple measures of effectiveness in order to determine which subsystems most effectively complement each other; and to examine various work methods and search techniques to determine how various devices and mixes can be most effectively employed.[1] In Phase 2, the specific objectives were to confirm and extend the results of Phase 1, to determine the levels of operational effectiveness which could be obtained with the use of the devices in teams, to evaluate and compare the suitability of alternative team configurations and reporting techniques, and to determine whether surveillance effectiveness could be increased by new search techniques and operating procedures.

RESEARCH APPROACH

Experiments were conducted at Hunter Liggett Military Reservation with the support of the U.S. Army Combat Developments Experimentation Command (USACDEC). A cost-effectiveness approach was used to examine the inherent capabilities of the man-device subsystems in an operational situation, the effects of varying the number and type of devices (basis of issue) and their combination (mix), the effects of varying device and mix deployment and methods of employment, the effects of additional training of device operators, and the control and coordination procedures required for use of multiple surveillance elements. Characteristics of the enemy threat (targets) were also varied. The impact of these variations was evaluated in terms of changes in surveillance effectiveness at the subsystem level (single device/operator and multiple-device team) as well as at the system (battalion) level.

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[1] Sternberg, J. J., Banks, J. H., Widener, T. A., Jr., and Jennings, J. W. Selected elements of a battalion integrated sensor system: Device and mix effectiveness. ARI Research Report 1183. January 1974. (AD 781 515)

A systems measurement bed was created to accomplish the research, consisting of a tactically realistic scenario and test environment, instrumentation for measurement and control, and a research methodology and test design which permitted determination of the effects of manipulation of the independent variables on various measures of subsystem and system performance. The tactical situation consisted of a battalion area of operations approximately 4000 meters(m) wide and approximately 7000 m deep. Three surveillance sites on the battalion front were selected to cover likely avenues of enemy approach. In this simulated tactical situation it was assumed that a commander faced the realistic problem of multiple likely enemy approaches and correspondingly multiple possible locations at which to deploy his available surveillance devices. Different commanders might well deploy the devices differently. The degree of success of an individual commander would, therefore, depend on the type and amount of equipment at his disposal and his insight in deploying his devices to detect the approach of an enemy force. Realistically, not all targets were detectable from any single surveillance site, but all were detectable, with appropriate devices, at the battalion level (i.e., with the full coverage of the battalion front provided by the three surveillance sites). This point is emphasized, because the experiment was not concerned with evaluating surveillance devices as such but with evaluating the effectiveness of a surveillance system in a realistic operational setting.

A building-block approach was used, in which, having established performance capabilities with a single device, one could assess the costs and gains to be derived from additional training, from the use of additional devices, from the use of devices in teams, and from the use of the device teams as elements of an integrated battalion surveillance system. To establish the optimal basis of issue and mix, a series of questions was posed: What was the most efficient single device to use if a battalion could only afford to set up one device at one company location? If a battalion used two devices of the same type, one at each of two locations? Three devices of the same type, one device at each of the three locations? Next, the questions dealt with using different mixes consisting of two to four devices at one, two, and three company locations, until twelve mixes had been evaluated. With an optimal mix thus determined, another series of questions examined system performance in the operational setting. How does the imposition of communications and coordination requirements affect the effectiveness of performance with the individual devices? What level of performance can be expected from device teams in an operational situation at both battalion and company levels? And, finally, which team configuration, operational procedures, and communications strategies best exploit the complementary capabilities of the components of the integrated system to maximize system performance in terms of information received at the battalion level? Three primary measures of effectiveness were used--percent detection, timeliness of detection, and quality (content and accuracy) of target information provided--permitting answers to the questions to be expressed in terms of costs and gains accruing from each of the alternatives tested.

Side experiments and supplementary analyses were conducted to provide additional information with implications for basis of issue and mix; to provide system effectiveness information on the effects of device employment, target characteristics, target tracking and plotting, and ability of device operators to use target information obtained by other means; and to evaluate the effects of modifications in work methods and procedures and in device operator training.

Devices used included the AN/TVS-4 medium range Night Observation Device (NOD), the AN/PPS-5A ground surveillance radar (PPS-5A), the General Dynamics Model 205B ground surveillance radar[2] (prototype of the AN/PPS-15), and the AN/PPS-9 ground surveillance radar.

EXPERIMENTAL SITUATION

The experimental situation for Phase 1 is described in detail in the Technical Supplement of ARI Research Report 1183;[3] that for Phase 2 is described in the Technical Supplement of this report.

CONCLUSIONS

The major conclusions from both phases of the research program are presented in this section. Findings supporting these conclusions, as well as additional findings, are contained in the Technical Supplement of this and the earlier report; for the convenience of the reader, a summary of the findings and conclusions from the Phase 1 report is included as Appendix A of this report. The results have broad applications for operational utilization of surveillance devices individually and within surveillance systems, and for training of device operators. In addition, the procedures and methodology used to analyze system and training effectiveness--in terms of the contribution of personnel, materiel, and employment factors to overall system effectiveness--may be valuable in the design of other tests intended to determine and improve overall system performance in the most cost-effective manner.

--Performances with the surveillance devices used in this program vary considerably in their ability to provide accurate and timely target detection, location, and identification, and no single device meets all needs when used under realistic operational conditions.

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[2] Commercial designations are used only for precision in describing the experiment. Their use does not constitute endorsement by the Army or by the U.S. Army Research Institute for the Behavioral and Social Sciences.

[3] Sternberg et al., 1974, op. cit.

—Two of the devices--the PPS-5A radar and the NOD—have complementary capabilities. With the radar, target detection, timeliness of detection, and location accuracy are very good but target identification is poor. With the NOD, target identification is good but detection, timeliness, and location accuracy are less than can be obtained with the radar.

—These two devices can be employed in a team without degradation in their individual detection capabilities. Use of additional devices in the team will not substantially improve surveillance effectiveness.

—A team using these devices with proper coordination and employment procedures will obtain information of higher quality than that provided by a single device or by the two devices used independently.

--A team chief should coordinate the activities of the other team members and insure timely and accurate reporting of target information obtained from the device operators. He can also, when desired, successfully combine initial and confirming reports from his device operators to reduce radio traffic and enhance the quality of individual reports to the designated user. However, he probably cannot filter out possible false detections without also filtering out substantial numbers of true detections. Use of a map substitute by the team chief to plot reported target information increases his work load without improving the accuracy of his judgments. However, it does not greatly degrade his performance and may be desirable for other applications.

—Target detection by the PPS-5A/NOD team will probably not be greatly affected by level of ambient illumination because initial detections will, in most cases, be made with the radar. However, under low ambient illumination, target confirmation (primarily with the NOD) will be greatly improved by increased illumination such as that provided through the use of flares and/or searchlights.

—The surveillance devices in a team may be located together or separated at a site if adequate intrateam communications are provided. Landline telephones provide adequate intrateam communications. However, the two devices in a team must be placed to permit surveillance of the same area by both devices in order to permit confirmatory detections. Also, the devices should be positioned close enough together so that the target azimuth and range reported from one device can be used without correction to orient the second device. If the surveillance devices and teams are to effectively use target information obtained from other sources (e.g., tactically deployed unattended ground sensors), a highly efficient control and communication system is required. In the present experiment, target location information did not improve radar detection performance if the location report was delayed as little as four minutes.

—Radar operators are not able to provide reliable and valid one-time estimates of target speed and direction of movement. However, they are able to track target movement even in terrain where target contact is intermittently lost due to terrain features and vegetation. Therefore, if predictions of future target location and time of arrival are required, operators should track the target and provide updated reports of target location at 30 to 60 second intervals.

--The number of surveillance teams to be employed depends on the tactical, environmental, and terrain conditions. A single team can provide good surveillance of a large sector of a battalion area, particularly when half-to-full moon illumination conditions permit effective use of the NOD at ranges out to approximately 4000 or more meters, or when artificial illumination can provide similar range capabilities. If likely avenues of approach cannot be adequately covered from a single surveillance site, multiple properly deployed teams should be used. Under the tactical and terrain conditions for the present experiment, three surveillance sites were required for complete coverage of the battalion area, and surveillance effectiveness increased with the number of sites used, up to three. However, level of team performance was such that use of more than three teams/sites could not have substantially increased effectiveness. "Overkill" should be avoided, for economy of personnel/equipment and because unnecessary redundancy of information tends to clog communications and overload information processing capabilities.

--When multiple teams are employed, battalion-level surveillance will be enhanced through achieving maximum overlap of search sectors.

--The time from target detection to report of that detection increases with increasing amounts of competing radio traffic. In the present experiment, the increase in reporting time was probably too small to be of practical significance even though three surveillance teams were sharing the same radio net and the level of enemy activity (and, therefore, detection) was high. However, in other operational situations (e.g., with additional users of the net) longer reporting times might seriously degrade the usefulness of the target information obtained by the surveillance teams. In these situations, integration of device operator reports into a single report by the team chief might be especially desirable.

--Use of the search and operating procedures described in this report can, at low cost, greatly increase the operational effectiveness of the PPS-5A radar and should be incorporated into institutional and unit training. (In the present experiment, a single operator/radar with additional training in search procedures detected as many targets as two operators/radars without this training.) However, future equipment should be designed to eliminate the need for manual antenna adjustment to avoid the problem of motivating operators to make the necessary antenna adjustments under low-threat conditions and the vulnerability of the exposed personnel under high-threat conditions.

--Problems in target identification with ground surveillance radars should be investigated to determine sources of error and training required to overcome the observed deficiency. Improved training could result in substantially increased operational effectiveness. In addition, improved target identification with ground surveillance radars has important implications for cost-effective employment of surveillance devices. A major function of the NOD in the team employment portion of the present research was to provide accurate target identification data. If PPS-5A radar identification performance could be improved and made similar to NOD performance, the radar alone would be similar to the PPS-5A/NOD mix in overall operational effectiveness. Thus, such an increase in radar performance could free the NOD for other surveillance activities.

--The AN/PPS-15 radar (to the extent that its capabilities are adequately represented by a prototype, the General Dynamics M-205B Radar) does not provide substantially different surveillance capabilities from those provided by the older AN/PPS-9 radar.

TECHNICAL SUPPLEMENT

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ELEMENTS OF A BATTALION INTEGRATED SENSOR SYSTEM: OPERATOR AND TEAM EFFECTIVENESS

This technical supplement first presents a comprehensive description of the research methodology. The experimental results follow, in three sections. Section 1 concerns human performance characteristics of a surveillance system in which individual devices are independently employed. Section 2 concerns human performance characteristics in a system in which surveillance devices are used in a coordinated team, and also compares the operational effectiveness of operators using devices independently and in team configurations. Section 3 presents a cost-effectiveness evaluation of additional radar operator training used in Phase 2, an analysis of the ability of radar operators to correctly identify target type, and a comparison of the performance of two very short range ground surveillance radars. The final part of this technical supplement summarizes the results.

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The research was conducted at Hunter Liggett Military Reservation, California, with personnel and logistical support from the U.S. Army Combat Developments Experimentation Command (USACDEC), as Phase 2 of a program to increase the effectiveness of company and battalion ground surveillance elements by studying their use together as an integrated sensor system. The results of Phase 1 suggested that operational effectiveness would be greatly increased by the use of surveillance teams consisting of a AN/PPS-5A radar and a Night Observation Device, medium range (NOD) if the two devices could be employed in such a manner as to take advantage of the complementary performance characteristics of each device.[4]

In Phase 2, the objectives of the research were to confirm and extend the findings of Phase 1, to determine the control and communications procedures required for utilization of such teams, to determine the levels of operational effectiveness which could be obtained with such teams, and to determine whether surveillance effectiveness could be increased by new search techniques and operating procedures.

Performance data were obtained with individual surveillance devices and device mixes on quantitative and qualitative aspects of target detection in a tactically realistic battalion surveillance situation. Personnel and vehicular targets were presented moving on paths toward observation sites established along a ridge line. Sites were representative of those in support of an Infantry battalion in a static area defense. Each operating element at each surveillance site was next to a data collector who entered target detection information into a data collection and processing system using an input device.

PERSONNEL AND TRAINING

Experimental personnel included three officers, approximately 60 noncommissioned officers (NCOs) and other enlisted men, and civilian scientists. The enlisted personnel and NCOs were assigned as device operators, surveillance Team Chiefs, radio telephone operators (RTO), data collectors, controllers, and targets according to their individual qualifications. All AN/PPS-5A radar operators were school trained and had the appropriate MOS (17K). All operators of other types of surveillance devices had combat MOS. Prior to field testing, all personnel were thoroughly briefed on the purpose of the tests and on the procedures to be employed. All jobs and functions and the various types of equipment were discussed and demonstrated for all personnel so that each man understood not only his own job but also the jobs of other men in the test.

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[4] Sternberg, et al, 1974, op. cit.

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The importance and contribution of each job to the success of the test was emphasized. This procedure contributed greatly to the development of a team spirit which made it possible to work effectively during long night hours. Surveillance device operators received comprehensive training on search techniques and the use of the devices in the experimental situation; data collectors received training on their data-input devices; and target personnel received training and practice on specific target paths. Additional information on training is provided in Appendix B.

EQUIPMENT

Equipment used in the experiment included three types of surveillance devices, an electronic Multiple-Input Data Acquisition System (MIDAS), ancillary equipment, target vehicles, and support facilities.

Surveillance Devices

The surveillance devices employed were the AN/TVS-4 Night Observation Device, medium range (NOD); the AN/PPS-5A ground surveillance radar; and the General Dynamics Model 205B (M-205B) ground surveillance radar, a prototype of the AN/PPS-15. Detailed descriptions of these devices are given in Appendix C.

Data Acquisition System

The MIDAS entered, stored, processed, and displayed detection and target information. It consisted of three principal elements: (1) Target Data Input Device (TDID), (2) Player Data Input Device (PDID), and (3) central data processing system. The TDID, located in the Operations Center, was used to enter target location information into the central data processing system; the PDID, located with each device operator and Team Chief, was used to enter target information reported by the device operator or Team Chief. All remote input devices were connected to the Data Center by field wire. The central data processing system, located in the Data Center, received, formatted, displayed, and stored information from the remote data input devices as well as various kinds of administrative and control information. These subsystems are described in greater detail in Appendix D.

Ancillary Equipment

Photometer. Upper hemispheric photometric illuminance measurements were obtained with a Gamma Scientific Corporation Model 2020 Photometer[5]

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[5] Commercial designations are used only for precision in describing the experiment. Their use does not constitute endorsement by the Army or by the U.S. Army Research Institute for the Behavioral and Social Sciences.

equipped with S-11 photocathode and Cosine-filter which gave an integrated reading, in footcandles.

Wind System, WS-101. This system recorded wind speed and direction on two continuous strip charts.

Tripods and Modifications. Adjustable tripod heads of commercial design were used for mounting the NOD. They provided a stable base for NOD operation, and enabled the NOD to be raised or lowered to conform with individual operator eye level. Each NOD mount was equipped with mechanical stops for control of search area size and terrain area coverage.

Communications Equipment.

- Tactical radios were used for communciation between the Experimentation Control Center (EEC) and targets and between the Team Chiefs and a battalion command post (CP) in the simulated battalion surveillance net.

- A telephone system with a switching capability in the Operations Center was used for control communication between the Operations Center, the Data Center, and the team sites.

- A field telephone was used in one set of team procedures for communications between the separated (NOD) device operator and the Team Chief.

- The Operations Center used "walkie-talkie" radios of commercial design for rapid dispatch of engineering and radar maintenance personnel in case of equipment malfunction.

Target Vehicles

Four types of vehicular targets were used: quarter ton truck (jeep), 2 1/2-ton truck, M-113 armored personnel carrier (APC), and M-60 tank.

Support Facilities

On-site adminstrative, control, logistical, and maintenance support were housed in two office-type trailers and a shop and storage building.

Experimentation Control Center (ECC)

The ECC was composed of (1) an Operations Center, housed in a van-type trailer, that provided centralized control and coordination for the research; and (2) a Data Center, also housed in a van-type trailer, that provided centralized data collection and processing.

In the Operations Center, the test director was responsible for overall execution of the experiment in accordance with experimental design and procedures. A data collection control officer in the Operations Center was in communication with the Data Center and the test sites. He gave instructions to the computer operators in the Data Center and to personnel at the surveillance sites, and received reports from them. A target control officer, also in the Operations Center, directed movements of the targets according to scenario and monitored target reports and speed. He was assisted by a radio operator who actually communicated with the targets and a TDID operator who entered the reported target location data into the computer.

In the Data Center, two computer operators received instructions from the data collection control officer, operated and monitored the functions of the computer, and monitored the hard-copy outputs of responses from players and targets.

EXPERIMENTAL CONDITIONS

Situation

With military assistance provided through the U.S. Army Combat Developments Experimentation Command, an experimental situation was established within the simulated tactical environment (Appendix E). In this situation, a battalion commander faced with the problem of maintaining surveillance over multiple avenues of approach into his defensive area had multiple locations to which he could deploy his available surveillance devices. With this situation, a typical battalion area of operations (AO) was selected and surveillance over the area established with three observation sites covering all likely avenues of approach. Realistically, however, no single site covered all the avenues of approach.

Surveillance Sites

Surveillance devices were deployed on three sites along a hill line with a central valley parallel to their immediate front. (A detailed description of the terrain is given in Appendix E.) The surveillance sites were designated as Site A (centrally located), Site B (right flank), and Site C (left flank). The three sites were widely separated; Sites C and B were respectively about 2200 and 1500 m from Site A and were about 3700 m apart.

The sites were selected on tactical principles to provide optimum coverage of battalion and company level areas of operation. Depending upon site elevation and terrain characteristics, line-of-site coverage was provided out to 6000-7000 m. All likely avenues of approach were covered by at least one site, with overlapping coverage from other sites when possible.

Each site consisted of several booths overlooking the target area and a control booth directly to the rear of the player booths. In addition, the maintenance facilities and the ECC were located at Site A.

Target Paths

Eighteen tactically realistic target paths were selected. Typically, targets were intermittently exposed as they moved in and out of defilade provided by terrain and trees. All paths were covered from at least one site, but each path was not necessarily in line-of-sight from each individual site. Also, some target paths were beyond the range capabilities of two of the devices employed (the M-205 and NOD). Therefore, opportunity for detection varied considerably as a function of site and device deployment.

Vehicular target paths used all likely avenues of approach and started in defilade positions which would have been reached by a hidden road network or across country. Twelve vehicular target paths were used, varying in length from approximately 1200 m to approximately 2800 m, with a mean length of approximately 1800 m. Numbered stakes, used by targets for reporting their location, were put along each target path every 200 m. Range of the paths varied according to site. Considering all sites, the farthest beginning point of a path was 6700 m and the nearest was 1150 m. Mean range for the beginning point was 3300 m. The farthest end point of a path was 5700 m and the nearest was 625 m. Mean range for the end point was 2750 m. Overall mean path range was 2950 m, with the nearest path having a mean range of 1250 m and the farthest a mean range of 6225 m.

Personnel target paths were selected using likely avenues of approach close to Sites A and B only. The cluttered terrain and topography immediately in front of Site C did not permit the placement of short range targets. Six personnel target paths were used, three each in front of Sites A and B, varying in length from approximately 350 m to approximately 700 m, with a mean length of approximately 500 m.

During testing, all targets were in motion and approached the defensive positions along the designated target paths.

Illumination

Testing was conducted under starlight and three-quarter to full moon illumination. For the starlight condition, the mean nightly illumination ranged from 9.0×10^{-5} footcandles (fc.) to 1.6×10^{-4} fc. with an overall mean illumination of 1.1×10^{-4} fc. For moonlight condition, the mean nightly illumination ranged from 4.4×10^{-3} fc. to 1.65×10^{-2} fc. with an overall mean illumination of 1.1×10^{-2} fc.

EXPERIMENTAL PROCEDURES

Target Procedures

Target personnel consisted of a target NCO in charge (NCOIC), a driver and radio operator for each vehicular target, and an NCO plus three or four men, one of whom served as radio operator, for each personnel target. Prior to each night's operation, the target NCOIC was briefed on the target path sequence to be run. After verifying vehicle and communications status, the target NCOIC dispatched targets to their start location and positioned himself in the target area. During experimentation, targets started their runs upon command from the Target Control Officer, traversed their paths at the prescribed speeds, and reported to the ECC via radio as they arrived at the numbered stakes each 200 meters along the vehicular paths and each 50 meters on the personnel paths. Target position data were entered into the Central Data Processing System via the TDID. The target NCOIC remained in the target area to monitor target performance, to expedite target relocation after each event, and to assist in the case of vehicle or communication difficulty.

Vehicular targets (single vehicles) traveled at approximately 5MPH. Personnel targets (in squads of three or four men) traveled at about 2MPH. All targets traversed their paths under total blackout conditions.

Target Scenario

Twelve vehicular and six personnel target paths were used within the three likely avenues of approach. Each of the four vehicle types was used on three of the twelve vehicular paths. Only one type of vehicle was assigned to a particular target path.

The target scenario consisted of 24 four-target events, each event consisting of the presentation of one quarter-ton truck, one 2 1/2-ton truck, one APC or tank, and one personnel target. In this 24-event scenario, each quarter-ton and 2 1/2-ton target path was used eight times and each APC, tank, and personnel path was used four times. For a given event, the targets were started on their paths at one-stake intervals so that, by the time the first target had reported being at stake 4, all four targets were moving on their respective paths. Thus, although each target consisted of a single element (vehicle or squad) on a specific path, multiple targets were presented in each scenario event for a total of 96 target presentations in one complete 24-event scenario. One replication of the scenario was given under starlight and one under full moon illumination for the Independent Search, Team Configuration 1, and Team Configuration 2 experiments. For the Team Configuration 3 experiment, one replication of the scenario was given under starlight illumination only. (See section on Surveillance Procedures for description of individual experiments.) Tables of N's for all experiments are contained in Appendix F.

General Test Procedures. Prior to each night's run, the NCO in charge of each surveillance site was briefed on the test conditions for that night, verified personnel and equipment status, and was dispatched to his site. Upon arrival on site, the NCO supervised set-up of the site by his personnel and verified that all surveillance and communications equipment were operational, and that the surveillance devices were properly calibrated and oriented. During testing, he received and passed on instructions from the ECC and monitored personnel and equipment performance to insure that personnel were following instructions and that equipment was functioning properly. A civilian scientist was present at each site to insure conformity to experimental conditions and procedures.

Before beginning experimental trials the players were instructed on the tactical situation and the experimental procedures to be followed. Search sectors of 1955 mils (the maximum automatic scan for the PPS-5A) for both the NOD and the PPS-5A, and of 1600 mils (the maximum automatic scan) for the M-205B radar were established. Scan angle was adjusted from the left limit of the search area for Site C (left flank position), from the right limit for Site B (right flank position), and from a central reference point (equally to both sides) for Site A (central position). Operators were instructed to search the area within their scan angles, the only range restrictions on search being those imposed by the intrinsic capabilities of a device. Functionally, this procedure provided relatively broad and deep search sectors with considerable overlap in coverage from the multiple sites.

Search periods were approximately 30 minutes long, followed by a 15 minute break during which targets relocated, devices and PDID's were checked for operating efficiency, and the calibration/orientation of the devices was checked and corrected if necessary. Testing time was approximately eight hours a night.

During testing, each device operator searched his assigned sector. Upon detection of a target he gave as rapid and as complete a report as possible. Reports included target range, azimuth, speed, direction, type and number. In addition, depending upon the specific experimental procedures, either the device operator or the Team Chief reported whether the target had been previously detected.

A data collector was assigned to each surveillance device operator and to the Team Chief/RTO in the team procedures experiments. The data collector for a device operator entered information into the centralized data processing system via his PDID as the device operator gave his report. In the team procedures experiments, the data collector for the Team Chief/RTO entered information as it was being transmitted by radio to the battalion CP. Data collectors were not allowed to criticize or comment on any element of the report they were entering except to ask for repetition of some element which they had not heard. This procedure was used to prevent the data collectors from, in effect, becoming members of the surveillance team.

As targets moved along their paths they reported their arrival at numbered stakes along each path and this information was input into the computer by the TDID operator. True azimuth and range of each stake had been established by survey prior to initiation of testing. When a detection response was made and azimuth and range data were entered into the computer, true target location was automatically computed by interpolation between known stake positions and was compared with reported target location. A detection report by one of the radars was scored as a true detection if the reported target location was within 80 mils and 200 m of true target location. A detection report by the NOD was scored as a true detection if the reported target location was within 80 mils of the true location; no range criterion was used because of the gross errors made by operators in range estimation.

Using these general test procedures, four separate experiments were run in which aspects of device employment were manipulated. In one of these, Independent Search, surveillance devices searched for targets independently; in the other three experiments, devices were employed in teams. Independent-search and team-search experiments are explained in detail below.

Independent Search Procedures. The purpose of the Independent Search experiment was to determine the performance of PPS-5A and NOD operators when they searched independently. This experiment thus provided baseline data for comparison with team performance and with the results of Phase 1. Performance data with the M-205B radar were collected concurrently for another analysis. (See section on Additional Findings.)

The three types of devices were used simultaneously on each of the three different sites (Sites C, A, B). Each site had the same configuration, as shown in Figure 1.

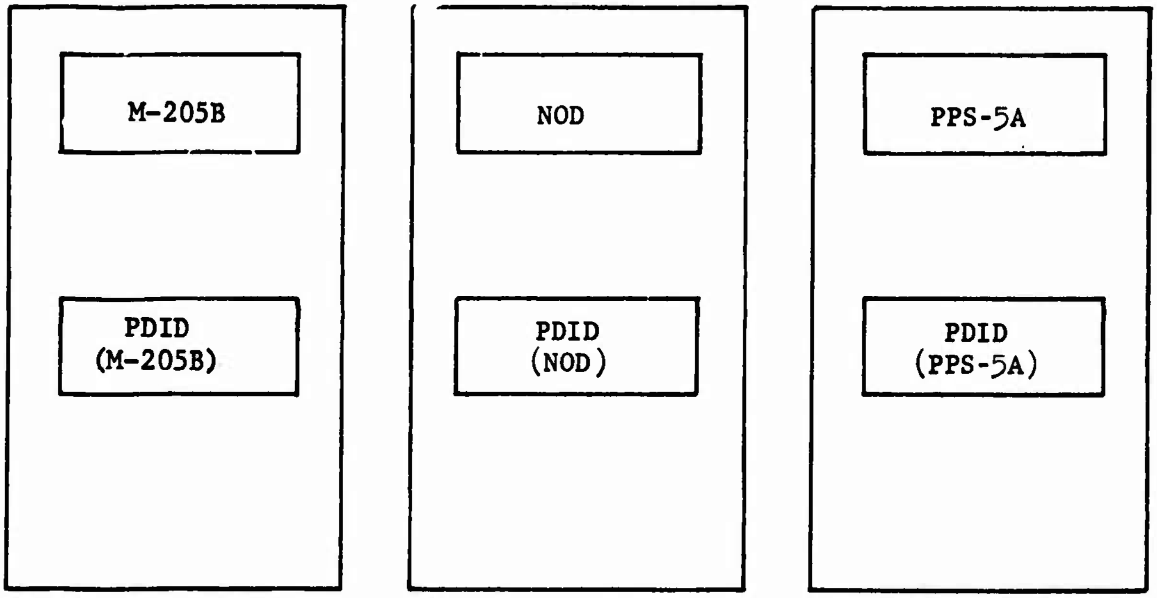

Figure 1. Booth configuration: Independent search

Team Procedures. The surveillance team consisted of a PPS-5A radar operator, a NOD operator, a Team Chief, and an RTO. The device operators began each trial searching independently for targets. When a target was detected by one device operator, the operator reported the target information to the Team Chief who, if the target were eligible for hand-off, interrupted the search of the second device operator and directed his search in an attempt to acquire the target detected by the first. The term "hand-off" denotes that detection information originating from a given device operator is passed through the Team Chief to the operator of a second device. "Confirmation" indicates that the handed-off target was detected with the second device within three minutes of the first detection. Eligibility for hand-off was determined primarily by availability to the NOD, i.e., if a target was detected with the radar, it was handed off to the NOD only at ranges less than 2500 meters under starlight and 4000 meters under moonlight; all targets detected with the NOD were handed off to the PPS-5A. Eligibility depended also upon the Team Chief's handling of the detection; a detection identified by the Team Chief as resulting from a successful hand-off was not eligible for hand-off whether or not it was truly a confirming detection. The Team Chief coordinated the activities of the device operators, entered their reports in his log and had his RTO relay the reports, plus some Team Chief judgments via the battalion surveillance net, to the battalion CP Specific procedures for each of the team members are presented below.

The radar operator searched independently until a detection was reported by the NOD operator, at which time he was directed by the Team Chief to orient his radar to the reported target location (including having his antenna elevation changed by the RTO if he felt this was necessary). If he was successful in detecting the target, he made his report to the Team Chief, and at the Team Chief's command, broke contact with the target and started to search for new targets. In the event that the Team Chief was occupied in receiving or transmitting another report, the radar operator maintained contact with the target and made his report as soon as the Team Chief was free to receive it. If the operator was unsuccessful in detecting the target, he gradually broadened his search until he was directed by the Team Chief (after three minutes) to break off and search for new targets. If the NOD operator detected another target before three minutes' time the Team Chief directed the radar operator to search for the new target.

During periods of free search, the radar operator was responsible for searching his entire area and could have the antenna elevation changed by the RTO if he so desired, to cover a different portion of the terrain.

The basic procedures used by the NOD operator were the same as those for the radar. However, because of the NOD's range limitations, the Team Chief did not direct the NOD operator to attempt to confirm detections reported by the radar if the range of the reported target was beyond 2500 m under starlight or beyond 4000 m under full moon illumination.

The Team Chief was generally responsible for coordinating the search activities of the two device operators, making certain judgments about the reported detections, entering the reports and his judgments in his log, and insuring that the RTO transmitted the detection reports to the battalion CP. He also recommended that antenna elevation changes be made for the radar when appropriate. The Team Chief did not act as a filter, i.e., he was instructed to relay all reports just as he received them. However, as the supervisor closest to the actual reported detections, he was in a position to help determine whether a given target had been previously detected. Therefore, he made two types of judgments which he included in his report. First, when a reported target was handed off to a second device and the second device reported a target detection, the Team Chief decided whether or not this report was a confirmation (i.e., whether the second report was, indeed, of the same target as the first report); second, when an operator reported a detection during free search, the Team Chief decided whether or not the target was one which that device operator had detected and reported previously (i.e., whether or not it was an "old" target). In order to make these decisions, he had to be alert to the location of reported targets, likely direction and speed of target movement, and the time differences between reports.

The RTO transmitted Team Chief reports to the battalion CP over the battalion surveillance net. In addition, he assisted the Team Chief in execution of his routine duties (making log entries, etc.) and assisted the radar operator by changing the antenna elevation.

The battalion surveillance net RTO received and logged the reports from Team Chiefs at all three sites.

Team Configurations.

- Configuration 1 (Team 1): Team Co-located. As indicated in Figure 2, the PPS-5A radar and the NOD were co-located with the Team Chief. During testing, this configuration was used simultaneously at the three surveillance sites. The procedures given in the previous section were followed.

- Configuration 2 (Team 2): Team Separated. Because it may not always be possible to co-locate surveillance devices, a second configuration was tested in which the NOD was separated from the remainder of the team. The separation of the two device operators and the necessary addition of a telephone communication link basically increased the control and communications problem and, consequently, potentially altered the quality and quantity of target information obtained. Procedures were identical to those of Configuration 1 except for those changes necessary because of the physical separation of the NOD. Communication between the Team Chief/RTO and the NOD operator was by telephone. The booth configuration shown in Figure 3 was used simultaneously at the three surveillance sites during testing.

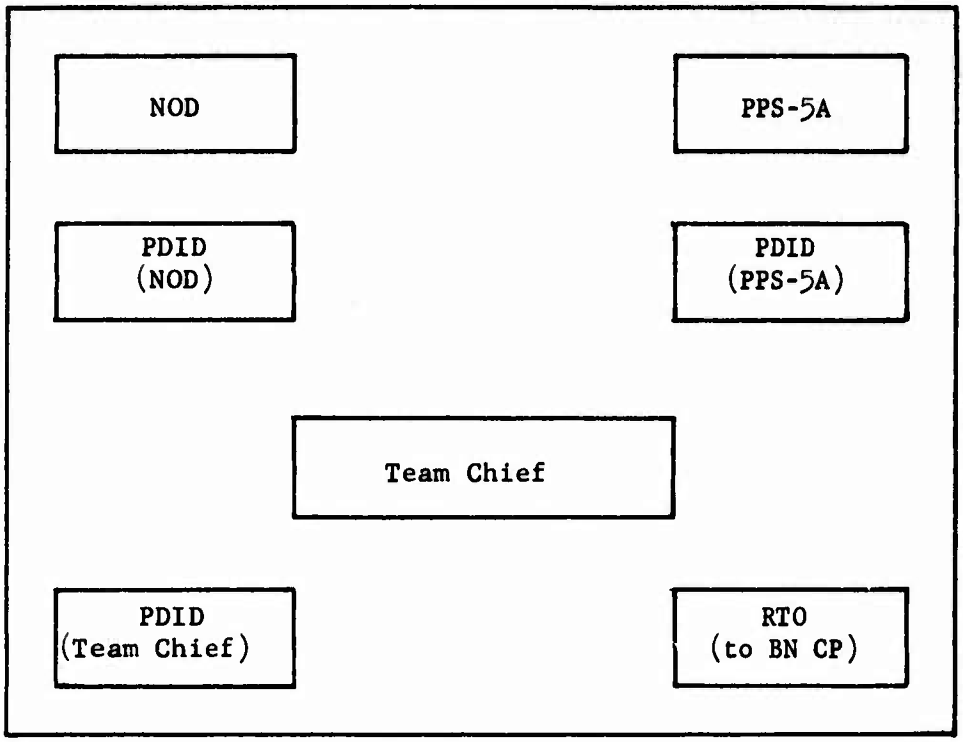

Figure 2. Booth configuration 1: Teams 1 and 3

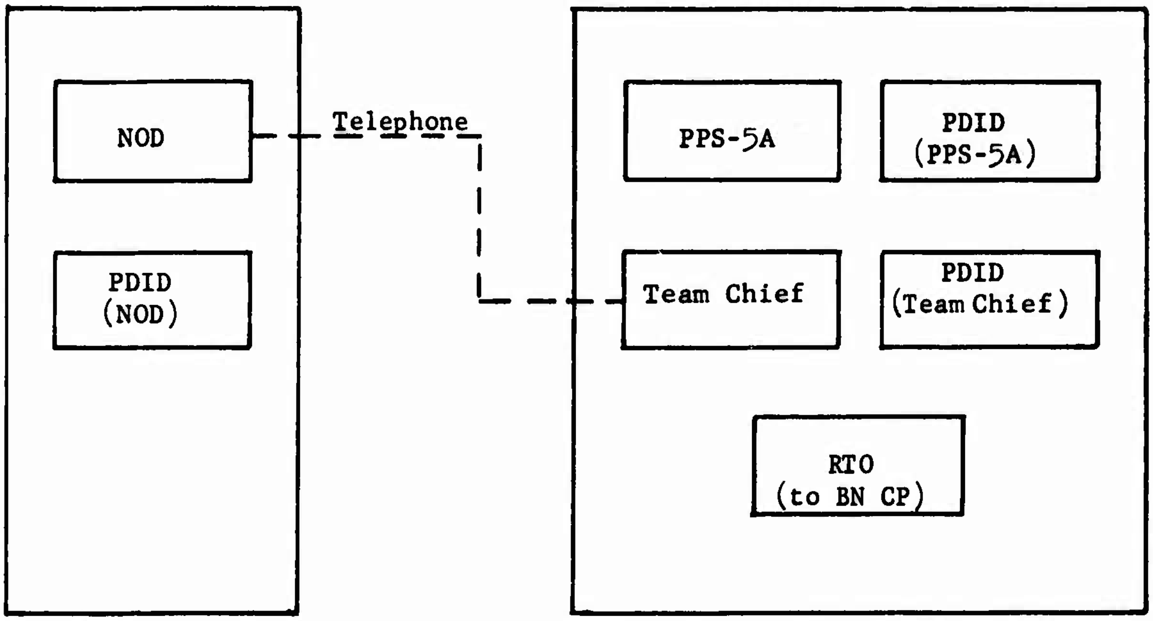

Figure 3. Booth configuration 2: Team 2

- Configuration 3 (Team 3): Team Co-located with Map Substitute. In order for the Team Chief to make his judgments of "new," "old," and "confirmed" targets, he had to be alert to the location of reported targets, likely direction and speed of target movement, and the time differences between reports. The primary purpose of Configuration 3 was to determine whether a map substitute would assist the Team Chief in making these judgments. The experimental procedures and booth configuration were identical to those for Configuration 1 (Team 1) except that the Team Chief was given a map substitute which consisted of a photo-enlargement of a California 1:25,000 Pictomap of the search area. With the enlargement, the scale was approximately 1:12,500, and the map showed prominent terrain features, roads, some vegetation, etc. When a detection was reported, the Team Chief marked on his map substitute the reported target location, the device making the detection, and the time. Reports were also entered on the Team Chief's log in the usual fashion. This team configuration was used simultaneously at each of the three surveillance sites during testing.

EXPERIMENTAL RESULTS

SECTION ONE: INDEPENDENT SEARCH

The primary objective of the Phase 2 experiment discussed in this section was to confirm the findings of Phase 1 regarding the ground surveillance capabilities and limitations of the independently employed PPS-5A radar and NOD.

In Phase 1 it was found that:[6] (1) more targets were detected with the radar than with the NOD; (2) more targets were detected with the PPS-5A/NOD (5/N) mix than with either device alone, particularly under high illumination conditons; (3) target detection was somewhat more timely with the radar than with the NOD but use of the 5/N mix did not substantially increase timeliness; (4) correct target identification was negligible with the radar but was fairly good with the NOD; (5) accuracy of target location was high with the radar and low with the NOD; and (6) targets detected more than once were often reported as new targets by the radar, but were reported as new targets much less often by the NOD. These results suggested that the PPS-5A radar and NOD should be used together as a team, so that, potentially, targets could be acquired by both devices and a higher quality of information provided from the complementary attributes of each device.

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[6] Sternberg, et al., 1974, op. cit.

Results

Performances with the PPS-5A and NOD as determined in Phase 2 were compared with Phase 1 performances for several measures of quantitative and qualitative device effectiveness. As only vehicular targets were used in Phase 1, data presented in this section for Phase 2 are based on vehicular targets only.

<u>Percentage of Targets Detected</u>. The percentage of targets in the battalion area of operations detected with each device and with the 5/N mix under starlight (SL) and full moonlight (ML) was calculated when the devices and mix were used on one, two, and three surveillance sites. To determine the combined effectiveness of the 5/N, a target was scored as being detected if it was detected by <u>either</u> device during search. A target was counted as "detected" only once per presentation regardless of the number of detections made of it. Because radar performance is unaffected by illumination level, percentages are based upon pooled SL and ML data. The performance of the NOD alone and in mix is presented separately for SL and ML illumination conditions.

When all three sites were employed simultaneously, all targets were visible from one or more of the sites. However, if only one or two sites were used simultaneously, then not all targets were visible (nor equally difficult to see) from each site or pair of sites. Thus, the percentages of detections from each site or pair of sites vary considerably, as shown in the Phase 1 report. Because of this variation, averaged site data are presented, to allow a more stable and meaningful overall comparison of the effectiveness of each of the devices or 5/N mix when used at the single site or two-site level. Single-site data are computed by averaging the data from each site (A, B, and C), two-site data by averaging the results from each pair of sites (A and B, B and C, and A and C). Three-site data are simply the total targets detected (considering all sites) divided by the number of targets presented.

Table 1 presents the percentage of vehicular targets detected during independent search when a single surveillance site was used to cover the battalion area. The table shows the percent detected with each device and with the 5/N combination under starlight (SL) and full moon (ML) lumination conditions. The percentages of targets detected with the D were strikingly similar in the two phases (21 vs 19 in SL and 34 vs in ML). Detection performance with the radar was substantially better Phase 2 (48%) than in Phase 1 (34%). The performance with the 5/N was also better in Phase 2 than in Phase 1. The reasons for this improved radar performance are discussed in the Additional Findings section, but generally it was due to improved search and operating procedures.

Tables 2 and 3 present detection performance data when surveillance of the battalion area was provided by two and three surveillance sites, respectively. The two and three site results obtained in each of the two phases were similar for the NOD. As before, detection performance with the PPS-5A radar was substantially better in Phase 2 than in Phase 1 for two and three sites.

Table 1

PERCENTAGE OF VEHICULAR TARGETS DETECTED DURING INDEPENDENT SEARCH (SINGLE SITE)

Device/Mix	Phase 1	Phase 2
PPS-5A	34	48
NOD (SL)	19	21
NOD (ML)	34	34
5/N (SL)	40	50
5/N (ML)	47	54

Table 2

PERCENTAGE OF VEHICULAR TARGETS DETECTED DURING INDEPENDENT SEARCH (TWO SITES)

Device/Mix	Phase 1	Phase 2
PPS-5A	56	75
NOD (SL)	35	39
NOD (ML)	57	58
5/N (SL)	64	78
5/N (ML)	74	81

Table 3

PERCENTAGE OF VEHICULAR TARGETS DETECTED DURING INDEPENDENT SEARCH (THREE SITES)

Device/Mix	Phase 1	Phase 2
PPS-5A	74	93
NOD (SL)	47	53
NOD (ML)	74	76
5/N (SL)	85	96
5/N (ML)	94	99

Comparison of the three tables shows that in both phases the percentage of targets detected increased with an increase in the number of surveillance sites employed.

In Phase 1, the detection performance with the 5/N mix was superior to the performance of either device alone. In Phase 2, on the other hand, the 5/N mix did not detect a substantially greater number of targets than the PPS-5A radar alone.

Mean Distance (in meters) Traveled before Detection. Mean distance traveled before detection is a measure of the timeliness of detections made with the devices and mix. In both phases, vehicular targets traveled their paths at approximately 5 MPH. Even after moving from starting positions in defilade, targets frequently were not available to one or two of the sites because of terrain restrictions or, if within line of sight, may not have been within NOD range capabilities; therefore these data are to be used only as relative indices of detection timeliness with the devices and mix. For this measure, when there was more than one detection for a given target presentation, the first report was used. Table 4 shows the relative timeliness of the detections with the devices and mix when used at a single site. No differences of practical significance were found between timeliness of detection in Phase 1 and Phase 2. In both phases, detections with the radar were more timely than detections with the NOD during starlight; radar and NOD detections were similar during moonlight. The timeliness of detections made with the 5/N combination was similar in both phases and under both illumination conditions. The results from Phase 2 were consistent with those from Phase 1. (Timeliness data from two and three sites, not presented here, were similar in these respects.)

Table 4

MEAN DISTANCE (IN METERS) TRAVELED BY VEHICULAR TARGETS BEFORE DETECTION DURING INDEPENDENT SEARCH (SINGLE SITE)

Device/Mix	Phase 1	Phase 2
PPS-5A	666	680
NOD (SL)	833	891
NOD (ML)	646	776
5/N (SL)	646	635
5/N (ML)	593	633

Percentage of Correct Identifications of Detected Targets. This measure is calculated by dividing the number of detection reports in which the device operator correctly identified the vehicular target type (jeep, 2 1/2-ton truck, APC, or tank) by his total number of detection reports. Data are summed across device operators, surveillance sites, and illumination conditions for the radar, across device operators and surveillance sites for the NOD.

Table 5 presents the percentage of the four vehicular target types (jeep, truck, armored personnel carrier, and tank) correctly identified with each device during Phase 1 and Phase 2. The percentages shown have been corrected for guessing using the formula:

$$C = \frac{R-(W/N-1)}{R+W} \times 100$$

Where C is the corrected percentage of correct identifications,
R is the number of correct target identifications,
W is the number of incorrect target identifications, and
N is the number of target vehicle types (N = 4).

The results of the two phases are consistent and show that PPS-5A radar operators correctly identify targets at no better than chance level, while NOD operators have a relatively good identification capability, particularly under moonlight illumination.

Table 5

PERCENTAGE OF CORRECT IDENTIFICATIONS OF VEHICULAR TARGETS DURING INDEPENDENT SEARCH

	Phase 1		Phase 2	
Device	Uncorrected	Corrected for Guessing	Uncorrected	Corrected for Guessing
PPS-5A	23	0	26	2
NOD (SL)	61	48	58	44
NOD (ML)	85	80	71	62

Location Accuracy. Location accuracy is expressed in deviations in azimuth and range between true and reported target location. Percentages of detection reports in which reported azimuth and range fall within two error bands are presented for radar (SL and ML combined) and NOD (separately for SL and ML).

Table 6 presents data on location accuracy achieved with the NOD and PPS-5A radar. Again, the results of the two phases were consistent. Reported target location accuracy with the radar was good, with 88% (Phase 1) and 77% (Phase 2) of reported locations falling within 40 mils and 100 m of the actual target position. The accuracy achieved with the NOD was poor in both phases, with 15% or less of reported locations falling within the same error bands. While target azimuth could be determined with reasonable accuracy with the NOD, operators were not able to accurately estimate target range. Thus, both phases show that team employment of the two devices could potentially result in improved accuracy of reported location for targets initially detected with the NOD.

Table 6

PERCENTAGE OF DETECTIONS OF VEHICULAR TARGETS
WHOSE REPORTED LOCATION FELL WITHIN
SPECIFIED AZIMUTH/RANGE ERROR BANDS DURING INDEPENDENT SEARCH

	Phase 1			Phase 2		
Device	Azimuth within 40 mils	Range within 100 m	Azimuth & Range within 40 mils & 100 m	Azimuth within 40 mils	Range within 100 m	Azimuth & Range within 40 mils & 100 m
PPS-5A	91.5	96.3	88.3	88.5	85.7	76.8
NOD (SL)	77.5	19.3	14.9	76.0	16.0	14.0
NOD (ML)	82.6	17.3	13.7	74.7	12.6	6.9

Discrimination between Old and New Targets. The percentage of device operators' correct discriminations of new targets from targets previously detected by the same device is calculated by dividing the number of detection reports in which the device operator correctly identified the target as "old" or "new" by the total number of detection reports.

Table 7 presents the percentage of correct discriminations between new and old targets, where "new" is defined as the first detection of a target and "old" as a later detection of a target previously reported by the same device. Consistent results were obtained in the two phases. With the radar, approximately 25% of the targets detected were misclassified (with most errors being the reporting of an old target as a target which had not been previously detected). With the NOD, only approximately 5%-10% errors were made. Thus, team employment of the two types of devices could potentially result in improved discrimination between new and old targets.

Table 7

PERCENTAGE OF CORRECT DISCRIMINATIONS OF OLD AND NEW TARGETS DURING INDEPENDENT SEARCH[a]

Device	Phase 1	Phase 2
PPS-5A	78	72
NOD (SL)	94	91
NOD (ML)	97	87

[a] New - First report of a target
Old - Target previously reported by the same device

Summary

The data presented in this section are consistent with those obtained from Phase 1 and suggest a complementarity between the NOD and PPS-5A radar. While the PPS-5A radar operators detected a greater proportion of targets and reported location more accurately than the NOD operators, the radar's ability to correctly identify those targets was negligible. Conversely, the NOD operators, while correctly identifying target type more frequently than the radar operators, detected fewer targets and reported target location less accurately. As was noted in Phase 1, these results imply that a radar-NOD mix could provide improved qualitative target information if both devices detect the same target. In addition, the results in this section indicate that:

1. The percentage of targets detected with the PPS-5A radar was in all cases significantly greater than the percentage achieved with the NOD.

2. In Phase 2, in which increased training and improved search and operating procedures were instituted, detection performance with the radar was substantially better than in Phase 1.

SECTION TWO: SURVEILLANCE TEAMS

Results presented in the previous section suggested that qualitative target information might be improved by use of the PPS-5A radar/NOD teams in such a manner as to exploit the complementary capabilities of the two devices. The feasibility of employing the devices in this manner still needed to be assessed. The objectives of the experiment discussed in this section were 1) to compare the relative detection performance of the selected team configurations to the performance achieved in independent search and 2) to determine the relative levels of effectiveness to be expected from the use of the various teams in the operational environment.

This section briefly describes the team configurations, then 1) compares device and mix effectiveness in independent and team search to determine whether the use of team procedures degrades percentage of targets detected and timeliness of detection; 2) assesses the operational impact of teams by examining the percentages of targets detected, handed off, and confirmed at both battalion and company levels; 3) examines the ability of the Team Chief to properly pair and differentiate detection reports from his two device operators; and 4) considers the timeliness and accuracy of reports to battalion along with the consequences of different reporting strategies.

A surveillance team consisted of a PPS-5A operator, a NOD operator, a Team Chief to coordinate their activities, and an RTO to handle radio communications and to assist the Team Chief. The teams were employed in one of the three basic configurations. In the first (Team 1), the NOD and radar operators were co-located with the Team Chief, permitting direct voice communication within the team. As co-location of the entire team may not always be feasible, in the second configuration (Team 2) the NOD operator was physically separated from the co-located Team Chief and radar operator, requiring the NOD operator to communicate with the remainder of the team by telephone. The third configuration (Team 3) was identical to the first (Team 1) except that the Team Chief was provided a map substitute on which to plot reported target location and other information as a possible aid in his decision making.

Comparisons with Independent Search

Typically, a detection with one device in the team requires the device operator to communicate with the Team Chief and the Team Chief to interrupt the free search of the second operator to direct his search toward the target detected by the first. Any loss in detections of new targets by the second device (such as might result from removal from the free-search mode, from distractions arising from procedural interactions, or from erroneous transfer of information) must be regarded as a cost of the system. Therefore, device and mix performance using teams must be compared with device and mix performance when the devices are used independently. Performance is assessed in terms of percentage of targets detected and timeliness of detections.

<u>Percentage of Targets Detected</u>. The percentages of personnel and vehicular targets detected in the battalion area are presented for each device type and the mix, and for one, two, and three surveillance sites in Tables 8, 9, and 10. The differences among the teams are generally small and are judged to be of no practical significance. Detections increased, as would be expected, with an increase in the number of surveillance sites. For a single site, the radar operators detected similar percentages of targets under all experimental conditions. The NOD operators, on the other hand, detected significantly more targets during team procedure experiments than when using independent search under both starlight ($p < .05$; Newman-Keuls test) and moonlight ($p < .01$; Newman-Keuls test) illumination conditions. The increase in the percentage of targets detected with the NOD and the lack of increase with the radar suggest that hand-off procedures were largely unidirectional (i.e., from radar to NOD).

Table 8

PERCENTAGE OF TARGETS DETECTED IN BATTALION AREA (SINGLE SITE): INDEPENDENT VS. TEAM SEARCH

Device/Mix	Independent Search	Team Search		
		Team 1	Team 2	Team 3[a]
PPS-5A	45	44	43	43
NOD (SL)	17	23	23	28
NOD (ML)	30	43	44	--
5/N (SL)	49	47	43	50
5/N (ML)	48	53	56	--

[a] Starlight only

Table 9

PERCENTAGE OF TARGETS DETECTED IN BATTALION AREA (TWO SITES): INDEPENDENT VS. TEAM SEARCH

Device/Mix	Independent Search	Team Search		
		Team 1	Team 2	Team 3[a]
PPS-5A	70	68	65	67
NOD (SL)	32	42	42	50
NOD (ML)	52	65	67	--
5/N (SL)	75	72	67	75
5/N (ML)	74	76	78	--

[a] Starlight only

Table 10

PERCENTAGE OF TARGETS DETECTED IN BATTALION AREA (THREE SITES): INDEPENDENT VS. TEAM SEARCH

Device/Mix	Independent Search	Team Search		
		Team 1	Team 2	Team 3[a]
PPS-5A	88	81	78	82
NOD (SL)	44	58	58	68
NOD (ML)	69	78	82	--
5/N (SL)	93	86	81	91
5/N (ML)	91	88	92	--

[a] Starlight only

Timeliness of Detection: Mean Distance Traveled before Detection. Tables 11, 12, and 13 present the mean distance that targets traveled prior to detection from one, two, and three surveillance sites. Differences in timeliness of detection between coordinated (team) and independent search are small and inconsistent in direction. Team procedures did not degrade the timeliness of target detection.

Table 11

MEAN DISTANCE (IN METERS) TRAVELED BEFORE DETECTION (SINGLE SITE): INDEPENDENT VS. TEAM SEARCH

	Independent	Team Search		
Device/Mix	Search	Team 1	Team 2	Team 3[a]
PPS-5A	591	643	585	516
NOD (SL)	844	720	759	731
NOD (ML)	699	624	654	-
5/N (SL)	542	648	527	548
5/N (ML)	564	513	549	-

[a] Starlight only

Table 12

MEAN DISTANCE (IN METERS) TRAVELED BEFORE DETECTION (TWO SITES): INDEPENDENT VS. TEAM SEARCH

	Independent	Team Search		
Device/Mix	Search	Team 1	Team 2	Team 3[a]
PPS-5A	508	572	513	470
NOD (SL)	820	697	725	708
NOD (ML)	630	559	586	-
5/N (SL)	478	565	489	485
5/N (ML)	444	440	483	-

[a] Starlight only

Table 13

MEAN DISTANCE (IN METERS) TRAVELED BEFORE DETECTION (THREE SITES): INDEPENDENT VS. TEAM SEARCH

Device/Mix	Independent Search	Team Search Team 1	Team Search Team 2	Team Search Team 3[a]
PPS-5A	457	514	474	435
NOD (SL)	790	670	695	696
NOD (ML)	577	517	553	-
5/N (SL)	430	507	466	455
5/N (ML)	375	391	444	-

[a] Starlight only

Summary. There is no loss in timeliness of detections or in percentage of targets detected with either the individual devices or with the mix when team procedures are introduced. Indeed, the data suggest that use of team procedures can improve the percentage of targets detected with the NOD. The data show no differences of practical significance among the various team procedures.

Operational Effectiveness of Teams

Realization of the potential benefits of the use of teams depends on the capabilities of the team to (1) detect the same target with both devices; (2) correlate detection reports of the same target (permitting consolidation of reports from different devices to take advantage of the strongest capabilities of each); and (3) transmit timely and accurate reports of target information. In the following paragraphs, the capabilities of the teams to acquire targets jointly through the execution of hand-off procedures are examined at both battalion and company levels. The capability of the Team Chief to pair detections of the same target is examined. The timeliness and accuracy of reports to battalion are shown, along with the consequences of different reporting strategies. Finally, differences among the three team configurations are discussed.

Joint target acquisition. In the following discussion the term "handed off" denotes that detection information originating from a given device operator was passed through the Team Chief to the operator of a second device. "Confirmation" indicates that the handed-off target was detected with the second device within three minutes of the first detection. (All targets which were detected were not necessarily handed off to the second device. Eligibility for hand-off was determined primarily by availability to the NOD.)

Battalion level--Tables 14, 15, and 16 show the percentages of targets detected, handed off, and confirmed by various teams for one, two, and three sites, respectively. Because the differences among the teams were not of practical significance, these data were pooled across teams by illumination conditions to facilitate other comparisons (Tables 17 and 18).

Table 14

PERCENTAGE OF TARGETS IN BATTALION AREA DETECTED, HANDED OFF, AND CONFIRMED (SINGLE SITE)

	Starlight			Moonlight	
	Team 1	Team 2	Team 3	Team 1	Team 2
Detected	47	43	50	53	56
Handed Off	29	31	32	51	50
Confirmed	14	15	14	31	33

Table 15

PERCENTAGE OF TARGETS IN BATTALION AREA DETECTED, HANDED OFF, AND CONFIRMED (TWO SITES)

	Starlight			Moonlight	
	Team 1	Team 2	Team 3	Team 1	Team 2
Detected	72	67	75	76	78
Handed Off	52	54	57	74	74
Confirmed	26	27	26	51	54

Table 16

PERCENTAGE OF TARGETS IN BATTALION AREA DETECTED, HANDED OFF, AND CONFIRMED (THREE SITES)

	Starlight			Moonlight	
	Team 1	Team 2	Team 3	Team 1	Team 2
Detected	86	81	91	88	92
Handed Off	70	70	76	86	88
Confirmed	38	36	36	64	69

Table 17

PERCENTAGE OF TARGETS IN BATTALION AREA DETECTED, HANDED OFF, AND CONFIRMED DURING STARLIGHT ILLUMINATION

	1 Site	2 Sites	3 Sites
Detected	46	71	86
Handed Off	31	54	72
Confirmed	14	26	37

Table 18

PERCENTAGE OF TARGETS IN BATTALION AREA DETECTED, HANDED OFF, AND CONFIRMED DURING MOONLIGHT ILLUMINATION

	1 Site	2 Sites	3 Sites
Detected	55	77	90
Handed Off	51	74	87
Confirmed	32	53	66

Examination of these data shows that the percentages of targets detected, handed off, and confirmed increased, as expected, with the improved coverage provided by deployment at multiple surveillance sites. With full coverage provided by three surveillance sites, 90% of the targets were detected under moonlight and 86% under starlight. Overall, about two-thirds of the detected targets were handed off during starlight and about 95% of the detected targets were handed off during moonlight. The increased hand-offs during moonlight were due to the NOD's increased capabilities at higher illumination levels and were jointly determined by hand-off procedures and the proportion of detected targets within the range capabilities of the NOD.

During starlight, approximately half of the targets handed off were confirmed, resulting in 14% of the targets presented being confirmed with one surveillance site and 37% with complete coverage provided by three sites. During moonlight, when the NOD was most effective, about two-thirds of the targets handed off were confirmed, resulting in 32% of the targets presented being confirmed with one site and 66% with full surveillance coverage. Overall, the proportion of targets confirmed under moonlight, when teams were maximally effective, was about twice the proportion confirmed under starlight.

These data indicate that, overall, regardless of illumination condition, the percentage of targets confirmed by the teams (an index of the potential qualitative improvement of target information) was substantial. Teams are especially effective when a sufficient number of sites are employed to cover an entire battalion surveillance area.

Company Level--Target detection has been examined in terms of a battalion level problem, i.e., considering targets that were within a battalion sector although not necessarily within the sector of a given surveillance site. Performance must also be examined in terms of a lower or company level problem: How effective was the team in providing surveillance within its assigned sector of responsibility? For this analysis, targets outside the assigned sector for a given site were excluded. Data from each site were handled separately and were then pooled across sites.

Table 19 compares the three team configurations in terms of the percentage of targets in the company area which were detected, handed off, and confirmed. As the differences among the teams were small, the data for the three teams were pooled to facilitate other comparisons. These data are shown in Table 20.

Table 19

PERCENTAGE OF TARGETS IN THE COMPANY AREA DETECTED, HANDED OFF, AND CONFIRMED, BY TEAMS

	Starlight			Moonlight	
	Team 1	Team 2	Team 3	Team 1	Team 2
Detected	72	66	74	83	86
Handed Off	45	48	48	80	77
Confirmed	21	23	21	49	51

Table 20

PERCENTAGE OF TARGETS IN THE COMPANY AREA DETECTED, HANDED OFF, AND CONFIRMED, ACROSS TEAMS

	Starlight	Moonlight
Detected	71	85
Handed Off	47	79
Confirmed	22	50

At the company level, 71% of the targets were detected under starlight, 85% under moonlight. About two-thirds of the detected targets were handed off during starlight and about nine-tenths during moonlight (47% and 79% of the total targets, respectively). As at the battalion level, the increased proportion of targets handed off during moonlight was due to the NOD's increased range capability and was jointly determined by the hand-off procedures and by the proportion of targets detected within the range capabilities of the NOD. The proportion of handed-off targets confirmed was about half and two-thirds during starlight and moonlight, respectively. Thus, under starlight 22% of the targets available to the company were confirmed, while under moonlight the percentage increased to 50%. These data suggest that teams can perform effectively at the company level, especially under moonlight illumination conditions.

Thus, the findings for the company level and the battalion level were parallel and indicate that the quality of target detection information can be substantially improved through the employment of surveillance teams. The maximum levels of performance for both company and battalion were achieved during moonlight illumination when the range capability of the NOD was greatest.

Team Chief Performance. An important function of a Team Chief was to pair detections of the same target by different devices so that location information from the radar and identification information from the NOD could be employed most effectively.

Also, surveillance elements provide information used in estimating enemy strength and intent. The quality of this information partially depends upon the ability to differentiate between reports of new targets and those previously detected at different locations. The results from the Independent Search experiment indicated that radar operators reported about 25% of the time that a new target had been detected when, in fact, they had redetected a target they had previously reported (See Table 7). NOD operators performed this task better than the radar operators.

In the present experiment, the Team Chief was given the task of making these discriminations to determine whether his performance was better than that of the individual device operator. The Team Chief, then, was required to decide whether or not detections were confirmations and also to distinguish "old" from "new" targets detected by the same device. For Team 3, the Team Chief was given a map substitute, showing the target area and his own position, on which he plotted reported target location and recorded other information. This procedure was intended to determine if a map substitute, used in this way, might assist the Team Chief in making these decisions.

Team Chief performance in recognizing confirmations and discriminating new and old targets is presented in Table 21. The data indicate that the Team Chief was highly accurate (nearly 90% across team configurations) in determining whether a target detection by a second device was a confirmation of an earlier detection by the first device. The Team Chief, then, was able to correlate information inputs from the different devices, combining the reports to take advantage of the strongest capabilities of each device. The data also show that the Team Chief was able to discriminate detections of new targets from detections of targets previously reported by the same device nearly 80% of the time. The percentage of misclassifications by the Team Chief (about 20%) was similar to the percentage of misclassifications by the individual radar operator. Comparison of the three team procedures shows that use of a map substitute by Team 3 did not improve Team Chief performance.

Table 21

PERCENT SUCCESS OF TEAM CHIEF IN IDENTIFYING CONFIRMING DETECTIONS AND IN DISCRIMINATING OLD FROM NEW TARGETS

	Percent Correct	
	Confirmed/Not Confirmed	Old/New[a]
Team 1	88	81
Team 2	89	79
Team 3[b]	88	76

[a] New - First report of a target
Old - Target previously reported by the same device

[b] Starlight only

Reports to Battalion. In the present experiment, the Team Chief, through his RTO, was required to report all detection information as rapidly as possible to a simulated battalion CP via a battalion surveillance radio net. The three surveillance teams deployed along the battalion front all reported on this net. The accuracy and timeliness of reports are described below.

Accuracy of Reports--Table 22 shows the percentage of error-free reports to battalion. Errors were counted when the information reported to battalion on target identification, azimuth, range, or speed was different from that supplied by the device operator. The data show that more than 90% of the reports were error free for all teams. Thus, the information provided by the device operators was accurately transmitted to the battalion CP.

Table 22

PERCENTAGE OF ERROR-FREE REPORTS BY TEAM CHIEF TO BATTALION

Team	Percent Error-Free Transmissions
Team 1	91.3
Team 2	92.1
Team 3[a]	94.4

[a] Starlight only

Timeliness of Reports--Table 23 presents median times elapsed from target detection to the report of that detection to battalion. On the average about a minute to a minute and a half elapsed. Although the differences are not great, the longest time was reported for Team 3, where the Team Chief maintained target plots in addition to his other duties.

Table 23

MEDIAN TIME FROM DETECTION TO TEAM CHIEF'S REPORT OF DETECTION

	Time, in Seconds	
Team	Starlight	Moonlight
Team 1	60	76
Team 2	66	90
Team 3[a]	104	--

[a] Starlight only

Because all sites shared a common radio net and because the timeliness of team reports thus may be partially a function of the number and spacing of target detections along the entire battalion front, the effect of detection "density" on the timeliness of reporting was examined. Density is defined as the number of target detections which occurred in the 60 seconds prior to a specific detection. For example, a detection would be categorized in the density category "zero" if no other detections had been made within the previous 60 seconds. The data (see Figure 4) indicate that the median time to report a detection to battalion increases as a function of message density. These differences are probably too small (less than a minute) to be of practical significance. The median times suggest that the information-handling and transmission limits of the teams were not exceeded. It should be noted, however, that in this experiment the battalion surveillance net was used only for communication from the surveillance sites to the battalion CP. The differences between teams are likewise probably too small to be of practical importance under most circumstances, although median reporting times in all density categories were shorter for Teams 1 and 2 than for Team 3.

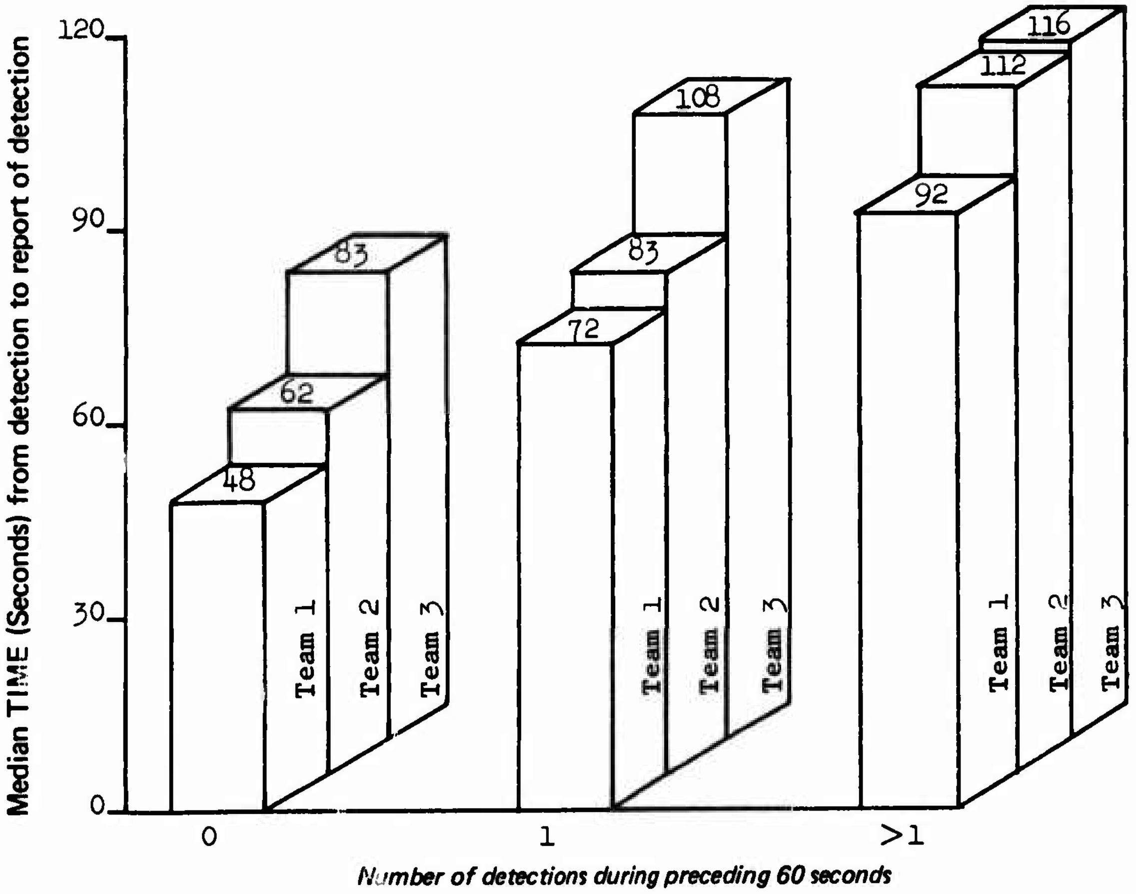

Figure 4. Time from detection to report of detection as a function of the number of detections in the preceding 60 second interval.

<u>Alternative Reporting Strategies</u>--In the present experiment, the information-processing requirement on the Team Chief was minimal: he was simply to transfer the information received from device operators for each detection, adding certain qualitative judgments. To reduce the amount of redundant and erroneous information transmitted, a more active information-processing capacity for the Team Chief was considered. The Team Chief had demonstrated his capability to correlate detections from two devices; the data were reanalyzed to determine the effects of two alternative information-processing (reporting) strategies.

In <u>Strategy One</u>, it was assumed that the Team Chief would report only 1) confirmed detections and 2) detections which were beyond range of the NOD and hence impossible to confirm. He would filter out reported but unconfirmed detections of targets within the range of both devices (as in an attempt to reduce the number of false detections reported). Information on confirmed detections would be sent to battalion in a single report with location information extracted from the PPS-5A radar data and target identification from NOD data. Using this strategy, the Team Chief would screen, correlate, and combine information from detection reports.

In <u>Strategy Two</u>, it was assumed that the Team Chief would report all detections but would consolidate reports of the same target with different devices. Reports of detections of handed-off targets would be made either upon a report of a confirming detection or, if no confirming detection was made, after three minutes from the time of the initial detection. As in Strategy One, information on confirmed detections would be sent to battalion in a single report with location information extracted from PPS-5A radar data and target identification from NOD data. Using this strategy, the Team Chief would report all detections and consolidate reports whenever possible, a less active information-processing role than in Strategy One.

Both of the reporting strategies combined target identification information originating from the NOD with location information from the radar. The procedure of combining the NOD and radar reports of the same targets not only reduces the number of reports to battalion but also reduces the amount of erroneous information transmitted. That is, identification data from the radar and location data from the NOD, both of poor quality, would be eliminated in the Team Chief's combined report to battalion.

The percentage reduction of radio traffic to battalion as a consequence of the two reporting strategies was examined. Also, the reduction in the number of targets reported due to Team Chief filtering in Strategy One was determined.

The percentages of reduction in message volume for the three team configurations ranged from 53% to 63% using Strategy One and from 22% to 30% using Strategy Two (Table 24). Strategy One resulted in far fewer messages being transmitted; however, more than 30% of the targets detected would not have been reported to battalion. A loss of this magnitude may not be acceptable under most circumstances. Strategy Two yielded a more modest but still substantial reduction in message volume with no reduction in the number of detected targets reported to battalion. Thus, Strategy Two is preferable to Strategy One.

Table 24

PERCENT REDUCTION IN RADIO TRAFFIC TO BATTALION RESULTING FROM USE OF TWO ALTERNATE REPORTING STRATEGIES

	Strategy 1	Strategy 2
Team 1	61	30
Team 2	63	29
Team 3[a]	53	22

[a] Starlight only

Summary

The data on surveillance teams indicate that operational effectiveness of surveillance can be increased by the use of the PPS-5A radar and the NOD in a team configuration (5/N mix) through exploitation of the complementary capabilities of both devices. At the most basic level, the use of teams enhances the detection performance of the NOD. However, the more substantial benefit of the 5/N mix is the higher quality information to be gained through their use in a team.

The results of the investigation of team procedures indicate that:

1. On the battalion level, where multiple surveillance sites afforded coverage of the entire surveillance area, substantial percentages of targets were confirmed through the employment of team procedures. With full coverage, under moonlight illumination, approximately two-thirds of the targets in the battalion area were detected and confirmed.

2. On the company level, a substantial percentage of targets were detected and confirmed with a single surveillance team covering the company sector. Under moonlight, approximately half of the targets in the company area was detected and confirmed.

3. The Team Chief accurately reported detection information in a timely manner, coordinated the search efforts of the two device operators, reliably reported the occurrence of confirming detections, and consistently distinguished new from previously detected targets.

4. Substantial reduction in message volume with no loss in targets reported to battalion can be achieved by the Team Chief's reporting all detections and consolidating (correlating and combining) initial and confirming detection reports. However, a substantial loss in targets reported to battalion resulted when the Team Chief screened out unconfirmed detections within NOD range.

5. Device performances were generally similar across the three team configurations examined.

6. No degradation in team performance resulted from separation of devices on a surveillance site.

7. The use of a map substitute to plot reported target locations resulted in a slight, but probably not practically significant, delay in the Team Chief's report of the detection to battalion.

8. The use of a map substitute did not improve the Team Chief's performance in recognizing confirming detections or in distinguishing new detections of a target from old detections of the same target by the same device.

9. For all teams, the time elapsed between detection and report increased as a function of the number of detections per minute (density). The increases, however, are probably too small to be of practical significance and indicate that the information handling capabilities of the teams were not exceeded in this simulated tactical situation.

SECTION THREE: ADDITIONAL FINDINGS

A number of tests and analyses were conducted to provide additional information on surveillance capabilities of ground surveillance radars and on means of improving their effectiveness. In this section the training and operating procedures used in Phase 2 for the PPS-5A radar are described, an additional analysis of target identification capabilities with the PPS-5A radar is presented, and performance with a prototype of the AN/PPS-15 very short range ground surveillance radar is compared with that of the earlier AN/PPS-9 radar.

AN/PPS-5A Radar

Training and Operating Procedures. The percentage of targets detected with the PPS-5A radar in Phase 2 was substantially increased over that obtained in Phase 1; the only operational changes were in radar operator training and work procedures introduced in Phase 2. The magnitude of the improvement was such that the detection performance with a single PPS-5A in Phase 2 equaled or exceeded that obtained with two PPS-5A radars in Phase 1. Because of the training, equipment utilization, and cost-effectiveness implications of these results, the background of the problem and its solution are described here.

In Phase 1, an analysis determined the effects of range on target detection with the PPS-5A radar. For this analysis, only those paths were used which were within the 1955 mil search sector for a given surveillance site and for which line of sight was not obstructed by major terrain features. (Note that although all target paths were within line of sight, some targets were more difficult to detect than others because they were intermittently obscured by vegetation and minor terrain features.) For each site separately, the target paths were assigned to three range bands: 0-2000 m; 2001-3500 m; and greater than 3500 m. Target detection was measured under two conditions: free search and directed search. Under the free search condition, operators used a full 1955 mil scan and targets were presented according to a scenario not known to the operators. Under the directed search condition, radar operators were given the azimuth and range to the target at the time that the target began its run along a designated path. Thus, the directed search differed from the free search condition in that the operators knew (1) that a target was available; and (2) its starting location. Performance under the directed search condition was considered to be an index of potential man-radar capabilities under operational conditions.

Overall, detections in directed search were considerably higher than in free search. More important, target detection did not decrease with increasing range under directed search but did decrease with increasing range under free search. It was concluded that the loss observed in free search reflected inadequate search performance by the radar operator rather than an innate limitation in the radar. It was hypothesized that the operators were not changing the elevation of the radar antenna--a requirement imposed by variations in elevation of the terrain--with sufficient frequency. Thus, they were missing substantial numbers of targets which were well within the man-radar capabilities.

It should be noted that all radar operators in Phase 1 had been instructed on the importance of antenna adjustment. Furthermore, each operator was required to determine, during daylight, the elevation settings needed for surveillance of all portions of his search sector. Actual adjustments during search testing, however, were left to the operator's discretion. Operator failure to make frequent adjustment appeared to result from a lack of understanding of the criticality of frequent adjustments and/or to the trouble and time required to make the adjustments at the remoted antenna unit.

These considerations clearly suggest a serious restriction in operational effectiveness. One means of improving performance would be a product improvement of the PPS-5A radar, to permit elevation changes on the remoted antenna unit from the operator's Radar Control Indicator.

However, such product improvements are traditionally costly. In Phase 2, therefore, attempts were made to determine if this deficiency could be corrected to an acceptable level through training and procedural modifications instead. Prior to testing in Phase 2, radar operator training stressed that frequent antenna elevation adjustment was essential for adequate surveillance coverage of their sectors. Verbal instructions and briefings were reinforced by on-site daylight demonstrations that clearly visible targets were not being detected by the radar because of incorrect antenna adjustment.

Discussions with the operators and observation of their behavior during testing showed that the training had, indeed, impressed them with the criticality of these adjustments. Several procedural changes were also made. The appropriate elevations for searching various portions of a sector were written out and posted next to the Radar Control Indicator to insure that the correct elevation data were readily available. In addition, a controller was to insure that the elevation changes were made frequently; he was given the responsibility of actually making the changes upon order from the radar operator. (During team search, the Team Chief and RTO served the same functions.) The results of these changes in training and operating procedures are shown in Table 25.

Table 25

PERCENTAGE OF VEHICULAR TARGETS IN COMPANY AREA
DETECTED BY RANGE BANDS: PPS-5A RADAR

	Range Bands (in meters)			
	0-2000	2000-3500	Greater than 3500	Overall
Phase 1	67	49	39	51
Phase 2	83	89	56	75
% Improvement	24	82	43	47

Overall, the percentage of targets detected in free search increased from 51% in Phase 1 to 75% in Phase 2, an improvement of 47%. The percentage of targets detected in Phase 2 was higher than in Phase 1 by 24%, 82%, and 43% for near, mid, and far range bands, respectively. While in Phase 1 the percentage of targets detected decreased with each increase in range, in Phase 2, percent detection was not affected by increasing range up to 3500 m.

These results demonstrate that operational effectiveness with the PPS-5A ground surveillance radar can be greatly increased by the use of simple, low-cost training and operating procedures to insure that antenna elevation is adjusted properly during search of terrain of varying elevation. By making clear to the operators the importance of elevation adjustment, the problem can be corrected without recourse to expensive product improvements of the radar or the use of additional surveillance devices.

Target Identification. Data indicate that the PPS-5A radar operators were unable to identify target type correctly at better than chance level (Table 5). In order to explore the possibility that these operators are able to make correct identifications of classes of targets, the data were reanalyzed by grouping vehicles into either wheel (jeep or 2 1/2-ton truck) or track (APC or tank) classes. The percentages of correct identifications were 9.5% and 12.5% for wheel and track vehicles, respectively, after correction for guessing. Moreover, operators were unable to distinguish personnel from vehicular targets reliably.

Clearly, the inability of operators to identify targets correctly in an operational environment is a serious limitation. However, experience with target audio signatures strongly suggests that the differences are discriminable, i.e., the differences between targets can be heard. It seems likely that discriminations among targets can be made, at least under some conditions, but that the radar operators' confusion results from variations in basic target signature in the operational environment. Investigation into the sources of error and into the training requirements (probably at the unit level) for improving identification capability could result in substantially increased operational effectiveness.

General Dynamics M-205B Radar (AN/PPS-15 Prototype)

The AN/PPS-15 very short range ground surveillance radar is planned to replace the AN/PPS-9 radar which was tested in Phase 1. As the PPS-15 was not available for testing, its prototype--the General Dynamics Model 205B--was used. The PPS-15 and the M-205B differ in a number of respects, but their stated technical capabilities are generally similar. Testing with the M-205B was conducted concurrently with the independent search testing of the PPS-5A and NOD. In this section performance of the M-205B is compared with that of the PPS-9 obtained under similar conditions in Phase 1.

Table 26 shows the percentages of vehicular targets in the battalion area which were detected from one, two, and three surveillance sites. The percentages are very similar for both radars. Slightly more targets were detected with the M-205B than with the PPS-9, but the differences are probably too small to be of practical significance.

Table 27 shows the mean distance that targets traveled before detection. Again, the timeliness of target detection was similar for the two radars, with the performance of the M-205B being very slightly better than that of the PPS-9.

Table 26

PERCENTAGE OF VEHICULAR TARGETS DETECTED WITH M-205B AND PPS-9 SHORT RANGE RADARS

Device	1 Site	2 Sites	3 Sites
M-205B	22	41	60
PPS-9	19	36	52

Table 27

MEAN DISTANCE (IN METERS) TRAVELED BEFORE DETECTION WITH M-205B AND PPS-9 SHORT RANGE RADARS

Device	1 Site	2 Sites	3 Sites
M-205B	765	740	707
PPS-9	792	799	770

Table 28 presents data on the accuracy achieved in reported target location with both radars. Peformances with the devices were again similar, with approximately 24% of the targets reported within 20 mils and 50 meters of their actual locations, and about 58% of the targets reported within 40 mils and 100 meters of their locations.

Table 28

PERCENT OF TOTAL TARGETS DETECTED WHOSE REPORTED LOCATION FELL WITHIN SPECIFIED AZIMUTH/RANGE ERROR BANDS FOR M-205B AND PPS-9 SHORT RANGE RADARS

Device	Azimuth within 20 mils	Range within 50 m	Azimuth & Range within 20 mils & 50 m	Azimuth within 40 mils	Range within 100 m	Azimuth & Range within 40 mils & 100 m
M-205B	37.7	58.8	26.3	74.6	74.6	56.1
PPS-9	34.9	69.5	22.1	66.0	88.0	59.6

Target identification with the PPS-9 (24% after correction for guessing) was superior to that with the M-205B (8% after correction for guessing). However, target identification even with the PPS-9 was much lower than would be desired. These findings, together with the low identification capability found with the PPS-5A radar, suggest that poor target identification may be a problem common to all ground surveillance radars in which identification is dependent upon auditory discrimination. Inability to identify targets constitutes a serious deficiency in radar/operator performance and warrants additional investigation to determine means of overcoming the deficiency.

In summary, operator performance with the M-205B and the PPS-9 was very nearly the same on several measures of effectiveness. These findings suggest that operator performance with the PPS-15 (to the extent that its capabilities are adequately represented by the M-205B) will not be substantially better than that with the PPS-9. In addition, poor target identification was found with all the ground surveillance radars used. Additional investigation should be undertaken to determine means of overcoming this deficiency.

SUMMARY OF RESULTS

The present experiment (Phase 2) confirmed and extended the results of the Phase 1 prior experiment and evaluated the performance of a PPS-5A/NOD team in an operational situation.

Independent Search

Individual Device Operator Performance. The results of both phases indicated that in several important respects the capabilities of the two devices are complementary. Specifically,

--Overall the PPS-5A radar operators detected a greater proportion of targets than the NOD operators and in a somewhat more timely manner.

--The PPS-5A radar operators were unable to correctly identify targets above chance level; overall, NOD operators were able to correctly identify the majority of targets they detected.

--Radar operators were able to locate targets with a high degree of accuracy, but the NOD operators' ability to correctly locate targets was poor.

--The NOD operators were somewhat more successful in discriminating new targets from previously reported targets than the radar operators.

In one important respect, individual device operator performance differed in the two phases. Specifically, PPS-5A radar operators detected over 40% more targets in Phase 2 than in Phase 1.

Multiple Device Performance. The results of both phases showed that:

--The percentage of targets detected in the battalion area increased with the number of surveillance sites used.

--When a sufficient number of surveillance sites (three in this case) were used to provide complete and overlapping coverage of the target area, enough targets were detected that the use of more surveillance devices or more sites could not substantially improve overall detection performance.

--The PPS-5A radar was the most important contributor to percentage of targets detected by the mix, regardless of the number of surveillance sites used.

In one important respect, multiple device performance differed in the two phases. Specifically, in Phase 1, use of the PPS-5A radar and NOD together resulted in substantially more detections than were made with the radar alone. In Phase 2 with improved radar search and operating procedures, the percentage of targets detected with the radar alone was similar to or exceeded the percentage detected with the radar plus the NOD in either phase. Moreover, the percentage of targets detected with the PPS-5A radar during Phase 2 was greater than or similar to the percentage detected with any <u>two</u> devices (radar or NOD) during Phase 1.

Team Search

<u>Comparisons with Independent Search</u>. Team employment of the 5/N mix provides greater surveillance capabilities than independent search by the same devices. Specifically, the introduction of team procedures improved the percentage of targets detected with the NOD with no loss in timeliness of detection. The introduction of team procedures did not reduce detection capabilities or timeliness of detections with the PPS-5A radar.

<u>Employment of Teams at Battalion Level</u>. With complete coverage of the battalion area, approximately 90% of the targets in the battalion area were detected regardless of the illumination condition. Almost half of the detected targets were confirmed under starlight, and almost three-quarters were confirmed under moonlight. The team configurations showed no differences of practical significance in capabilities for detections, timeliness of detection, or confirmation of targets.

<u>Employment of Teams at Company Level</u>. When a single surveillance team provided coverage of the company sector, over 70% of the targets in the company area were detected under starlight, over 80% under moonlight. Almost one-third of the detected targets were confirmed under starlight; almost two-thirds were confirmed under moonlight. Team configurations showed no differences of practical significance in capabilities for detections, timeliness of detection, or confirmation of targets.

<u>Team Chief Performance</u>. Under each of the team configurations, the Team Chief was able to identify confirming detections with a high degree of consistency. The Team Chief was able to discriminate detections of new targets from detections of targets previously reported with the same device nearly 80% of the time. The use of a map substitute did not improve the Team Chief's performance in recognizing confirming detections or in discriminating new from old targets.

<u>Reports to Battalion</u>. In transmitting information to battalion, teams transmitted detection reports with negligible loss from transmission errors. Multiple teams transmitted detection reports in a timely fashion via a battalion surveillance net even when the level of detection activity on the battalion front was high. The use of a map substitute resulted in a slightly longer time to report detections to a user.

Reanalysis of the data on information transmission indicated that a reduction in radio traffic of nearly 30% with no loss in true detections reported could be achieved if the Team Chief were to combine information from first and confirming detections in reports to battalion. However, if the Team Chief had filtered information, nearly one-third of the true target detections would not have been reported to battalion.

Search Training and Operating Procedures for the AN/PPS-5A Radar. Training and operating procedures instituted in Phase 2 were associated with substantial increases in the percentage of targets detected with the PPS-5A radar at all ranges.

Target Identification with Ground Surveillance Radar. Identification of target type was very poor with all of the ground surveillance radars employed (PPS-5A, PPS-9, M-205B). Identification of target class (wheel vehicles, track vehicles, and personnel) was likewise poor.

Performance Comparison of AN/PPS-9 Radar and Prototype of AN/PPS-15 Radar. Performances with the General Dynamics Model 205B radar (prototype of the AN/PPS-15) and with the AN/PPS-9 radar were similar on target detection, timeliness of detection, and target identification.

APPENDIXES

APPENDIX A

SUMMARY OF PHASE 1 FINDINGS AND CONCLUSIONS[1]

Summary

Using an incremental cost approach, the level of performance with single devices was determined as well as the relative gains in performance resulting from the use of various mixes of two, three, and four devices. Similarly, the performance of single devices and mixes of devices was determined when only one location was used (company level) and when two or three locations were used simultaneously (battalion level).

Company Level. Performance with a single device: In general, the PPS-5A was the best single device. More specifically:

--for percent detection, timeliness of detections, and location accuracy, the PPS-5A showed the best performance.

--for target identification and discrimination between old and new targets, the NOD showed the best performance.

--for false detections the PPS-5A and NOD were equal.

--the NOD on all measures was generally superior to the PPS-9.

Performance with multiple devices (mixes): In general, the combination of one PPS-5A and one NOD was the optimum mix. More specifically:

--for percent detections and timeliness of detections a two device mix, containing a PPS-5A, was for all practical purposes as good as a three or four-device mix.

--for target identification and discrimination between old and new targets, a two-device mix containing a NOD was the best.

--for false detections there was a considerable (linear) increase in adding additional devices.

Battalion Level. In general, the use of multiple sites, that is, in going from one to two sites and from two to three sites, improved performance as well as increasing false detections. As found at the company level, the optimum mix was the two-device mix consisting of one PPS-5A and one NOD.

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[1] Section VIII of Sternberg, J. J., Banks, J. H., Widener, T. A., Jr., and Jennings, J. W. Selected Elements of a Battalion Integrated Sensor System: Device and Mix Effectiveness, ARI Research Report 1183. January 1974.

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Conclusions

Based upon three primary measures of effectiveness (percent detection, timeliness of detection, and quality or content of target information) and information on false reports, the mix consisting of one PPS-5A and one NOD appears to be the optimum mix for the company and battalion levels. However, it is recognized that the research findings must be incorporated with device costs, maintenance, training requirements, and other aspects of cost-effectiveness. Performance with the PPS-9 was found to be no better than that with the NOD. In addition, a number of limitations with the PPS-9 were observed and these are indicated at various places in this report. It is suggested that, prior to large procurement, the PPS-15 should be examined to determine whether it has the same limitations.

In addition, it is clear from the findings that each device has limitations and that in order to optimize target information, the radar and NOD should be used together. The radar needs "eyes" for target identification and target discrimination. Through team procedures it may be possible for targets within NOD range capabilities to provide this kind of information. The radar, on the other hand, can provide location accuracy for NOD detections, again through team procedures.

EFFECTS OF DEVICE EMPLOYMENT ON SEARCH EFFECTIVENESS

Summary

Reducing the sector scan angle attenuated performance at the company level. Modified range band coverage, where device operators confined their search to specified range bands, did not improve performance when compared to over-lapping search. Neither of the different employment methods justified any change in the selection of one PPS-5A and one NOD as the most likely candidate mix.

Conclusions

As there is no loss using over-lapping search, either by sector scan angle or range band coverage (and a gain at the company level using a wide sector scan angle), over-lapping search should be used for two reasons: (1) multiple detections by different devices could supplement target data, and (2) if a device is malfunctioning, a device at another location could, in a sense, provide a back-up capability.

EFFECTS OF TARGET CHARACTERISTICS ON SEARCH EFFECTIVENESS

Summary

The PPS-5A operators performed equally well when multiple targets were moving in the search area as when only a single target was available, when target speed increased from 5 to 15 MPH, and when the targets consisted of single vehicles as when the targets consisted of groups of vehicles. Ability to assess (count) the number of vehicles in a group was poor and detection performance decreased markedly with increasing target range. However, the effects of range were generally due to faulty search techniq s being used by the operators rather than to device limitations.

The NOD operators performed equally well when multiple targets were available as when only a single target was available, and when targets consisted of single vehicles as when they consisted of groups of vehicles. Operators with the NOD were able to assess (count) the number of vehicles in a group with a good degree of accuracy.

Conclusions

The PPS-5A seems to be effective for low to mid intensity situations but its effectiveness is limited in significant ways by its lack of "eyes" and by faulty search procedures used by its operators. Therefore it is again suggested the PPS-5A be used in conjunction with a visual device such as the NOD, and that training should incorporate the teaching and practice of effective search techniques.

TRACKING AND PLOTTING

Summary

The PPS-5A can provide valid and reliable tracking and plotting information, and failures in tracking generally occur because of terrain characteristics rather than because of device or operator limitations. However, one-time estimates by an operator of target speed and direction of movement are not valid or reliable predictors of future target location or time of arrival.

Conclusions

Operators should not usually be requested to provide estimates of target speed or direction. Instead, if predictions of future target location and time of arrival are required, operators should track the target and provide two or more reports of target location at 30 to 60 second intervals.

EFFECTS OF INFORMATION TRANSFER

Summary

Accurate information on target location handed-off to PPS-5A operators with a delay of two minutes or less improved the probability of target detection over that of random or free search. With a delay of four minutes there was no difference in the probability of detection and free search was more timely.

Conclusions

These results emphasize the need for a highly efficient control and communication system if radars are to be able to effectively use information obtained from other devices and sensors and from other forms of battlefield intelligence.

MISCELLANEOUS FINDINGS

Summary

The PPS-5A tends to be unreliable in terms of down-time and in terms of interference from other electronic sources and ambient conditions such as wind. School-trained operators with on-the-job experience generally perform below their capabilities. Faulty search procedures are responsible for many failures in target detection.

Conclusions

The unreliability of the PPS-5A suggests the need for back-up devices, frequent maintenance, and daily operational check-out procedures. Operators should be instructed in good search techniques and should have considerable practice in actual search and utilization of the radar.

APPENDIX B

TRAINING

General

Device operators were trained in the use of their devices, and all personnel--device operators, Team Chiefs, radio operators, data collectors, controllers, and targets--were trained in the experimental procedures required.

All personnel involved in the field test were thoroughly briefed on the purpose of the test and the tactical situation. All jobs and functions to be performed and the various kinds of equipment which were to be used were discussed and demonstrated for all personnel so that each man had an understanding not only of his own job but also of the essential elements of the jobs of the other men in the test. The importance and contribution of each job to the successful execution of the test were emphasized.

Surveillance Device Operator And Team Training

All device operators were trained on both how to detect a target and how to provide the various categories of target informaton according to the procedures specific to each experiment. Detection training was conducted for PPS-5A and M-205B operators both in the classroom and on-site, for NOD operators on-site only. Using the appropriate independent-search or team procedure, the operators were instructed that upon detection of a target, they were to report as rapidly as possible the target azimuth, range, speed, type and number of targets, as well as (for independent search only) the direction of movement and whether the report was of a new target or of a target previously detected and reported. For Team Configurations 1, 2, and 3, device operators, Team Chiefs, and RTOs were trained on the appropriate set of team procedures with an emphasis upon information transfer, coordination of search, and relay of target reports to battalion. All device operators and team personnel were also trained as data collectors.

M-205B Radar Training

Ten days of training were given on the M-205B. This training consisted of classroom instruction on device characteristics and routine set-up and maintenance. Taped material of the sounds produced by typical targets was used for aural target signature recognition practice. Classroom practice was interspersed with daily practice in the use of the radar for detection and identification of actual targets in the field.

NOD Training

Classroom instruction was given on routine set-up, maintenance, and use of the device including proper diopter adjustment procedure and effective search procedures determined in earlier experimentation.[1,2,3] This training was supplemented by several hours of night field practice with actual targets, close monitoring of the procedures used by the players, and feedback to the player of his successes and failures.

PPS-5A Training

All PPS-5A operators had previous school training and most had considerable practical experience. Nevertheless, in order to prevent the results' being contaminated by learning during the course of experimentation, it was found necessary to give the operators additional training and practice, with feedback of their success and failure, to stabilize their performance before the onset of trials. During Phase 1 it was found that operators did not recognize the need to change antenna elevation setting in order to cover the entire search area.[4] Operators were, therefore, extensively trained on the importance of antenna settings and were provided with assistance in changing the setting during search. During on-site daylight training, the radar operator visually inspected the area to be searched at night in order to become familiar with the terrain, determine what areas were out of line-of-sight from his position, and to determine and record what antenna elevation settings were required in order to cover particular parts of his search area.

Data Collector Training

Data were entered into the centralized data processing system via the Player Data Input Device (PDID). Data collectors were thoroughly trained and practiced on the use of the PDID, including monitoring their own performance, error correction procedures, etc. In practice, the performance of the data collectors was virtually error free. In addition, data collectors were trained to monitor the performance of device operators to insure that they were following correct procedures, making complete reports when possible, etc. However, the data collectors were trained not to assist the device operators or to comment on their performance other than to correct procedural failures.

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

[2] Banks, J. H., Sternberg, J. J., Cohen, B. J. and Debow, H. C. Improved search techniques with passive night vision devices. ARI Technical Research Report 1169. February 1971.

[3] Sternberg et al., 1974, op. cit.

[4] Sternberg et al., 1974, op. cit.

Controller Personnel Training

Controller personnel included surveillance site NCOs, a target NCOIC who monitored and exercised control of the targets, and various personnel in the ECC including a data collection control officer, target control officer, radio operator, Target Data Input Device (TDID) operator, engineering and maintenance personnel, and computer operators. All were thoroughly trained in their particular jobs, and cross-trained in other jobs.

Target Personnel Training

Target personnel consisted of a driver and radio operator for each vehicular target and an NCO and squad (3-4 men) for each personnel target, under the immediate supervision of a target NCOIC in the target area. The target personnel were required to position their squads or vehicles at the start point of a path in accordance with the scenario, begin their target run upon command from the ECC, travel their paths at a controlled speed under complete black-out conditions, report their location by path and stake number, hide their vehicle and/or themselves in a defilade position at the end of each path, and relocate to a new start position upon command from the ECC. Several days of daytime training were given on movement at controlled speeds, proper reporting procedures, and routes to follow during relocation. This was supplemented by nighttime movement practice until all target personnel were able to move at closely controlled speeds and report their location accurately.

APPENDIX C

DEVICES

The devices employed were the AN/TVS-4 medimum range Night Observation Device (NOD), the AN/PPS-5A ground surveillance radar (PPS-5A), the General Dynamics Model 205B ground surveillance radar (prototype of the AN/PPS-15) and the AN/PPS-9 ground surveillance radar. Descriptions of these devices are given below.

NOD

The NOD is a man-transportable tripod-mounted, light amplification telescopic night vision device. It has a magnification of 7.5 power and a field of view of 157 mils. Azimuth can be read to the nearest 10 mils from an azimuth scale on the tripod mount, and range must be estimated by an operator. The range at which targets can be seen and identified with the device is highly dependent upon such factors as illumination, target type, and target-background contrast, but the NOD can be used with considerable effectiveness out to approximately 2000 meters (m) under starlight and 4000 m under full-moon illumination for vehicular targets. Search effectiveness depends on the above factors as well as upon such factors as size of the area to be searched, target exposure time, amount of clutter in the target area, and the search procedures used by an operator.

PPS-5A

The AN/PPS-5A is a man-transportable battery-powered doppler radar set consisting of a tripod-mounted receiver-transmitter-antenna unit which can be remotely controlled up to 50 ft from a control-indicator unit and can be used to detect, locate, identify, and track moving personnel and vehicular targets under varying conditions of terrain, visibility, and weather. Choice of automatic sector scanning is provided for sector widths of 533, 1067, 1600, or 1955 mils. Choice of sweep range displays of 0-5,000 m and 5,000-10,000 m is also provided. Elevation can be manually adjusted at the radar antenna. According to the technical specifications, (1) targets can be located to within ±10 mils azimuth and ±20 m range; (2) moving personnel targets can be detected and located at ranges up to 6,000 m; and (3) larger vehicular targets can be detected and located at ranges up to 10,000 m. Target detection is made by the radar operator when he responds to a visual target signature on either a B-scope (bright spot), or A-scope (wave form change) display. He then manually adjusts the range gate over the target signature on the scope display so as to obtain an optimal audio signal in order to identify and/or count the detected target(s).

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Range and azimuth data can then be determined from digital readout displays. Confirmation of detection and qualitative target data--such as target type, quantity, and combinations--are primarily obtained by comparison of auditory target signatures with known personnel or vehicular target signature characteristics. The visual displays can also be used to assist in counting targets if separation of the targets in a cluster is enough for them to appear as separate "blips" on the scopes.

M-205B

The General Dynamics Model 205B Radar Set is a man-transportable, tripod-mounted, battery-powered, lightweight, tactical ground surveillance radar. It is capable of detecting, locating, and identifying moving targets such as personnel and vehicles under conditions of limited visibility. It can be operated by one man in a handheld position or tripod-mounted. Scanning is accomplished manually through 6,400 mils or automatically through two sector widths: 1,600 mils and 800 mils. According to the technical specifications, the Model 205B can detect and locate moving targets with radial velocities of 0.5 to 35.0 MPH at ranges of up to 3000 m. This is accomplished first by establishing the presence of a moving target auditory signal within the antenna beam width (using the all-range channel); next, the range of the target is determined by switching to the discrete-range channel mode and employing a discrete ranging technique to obtain a maximum tone in the headset. Range is then determined by visually inspecting the range readout counter. Azimuth is determined by inspection of the position of an index pointer on the azimuth ring. Target detection is primarily made by a comparison of the modulated doppler audio signal received through the radar set earphones with known personnel or vehicular auditory target signatures. Identification of target types, numbers, combinations, and other qualitative data are determined by the radar operator in the same manner.

AN/PPS-9

The AN/PPS-9 is a man-transportable, lightweight, tripod-mounted, battery-powered doppler radar which can detect, locate, identify, and track moving personnel and vehicular targets under varying conditions of terrain, visibility, and weather. Scanning can be done manually through 6,400 mils or automatically through two sector widths: 1,600 mils and 800 mils. According to technical specifications, 1) targets can be located to within 10 mils azimuth and 25 m range; 2) small moving targets, such as personnel, can be detected and located at ranges up to 1,500 m and vehicles at ranges up to 2,500 m. Azimuth is determined by inspection of the position of an index pointer on an azimuth dial, and range is determined from a counter readout. Moving objects produce both visual (detection lamp and meter deflection) and auditory signals. Target detection is primarily made by a comparison of the modulated doppler audio signal received through the radar set earphones with known personnel or vehicular auditory target signatures. Identification of target types, number, combinations, and other qualitative data are determined by the radar operator in the same manner. Target detection, location, and tracking are accomplished by positioning the receiver-transmitter in azimuth and elevation, and employing a coarse to fine ranging technique to obtain a maximum tone in the headset.

APPENDIX D

DATA ACQUISITION SYSTEM

The Data Acquisition System was used to enter, receive, format, display, and store player quantitative and qualitative data from the surveillance sites. It also updated target location data from moving targets in the field. It consisted of three principal elements: (1) the target data input system, located in the Operations Center; (2) the player data input system, at the device and Team Chief locations; and (3) the central data processing system, located in the Data Center.

Target Data Input System

The Target Data Input Device (TDID) operator received updated target location data by radio and entered them into the central data processing system via his TDID. In addition to transmitting coded target location data to the computer, the TDID also displayed updated target location information via digital readout for scenario timetable verification.

Player Data Input System

The Player Data Input Device (PDID) operators received and transmitted qualitative and quantitative target detection information from each player and Team Chief (at the three surveillance sites) to the central data processing system via their PDIDs. Detection data transmitted included the following information: detection, azimuth, range, speed, target type and number, device making initial detection (in team procedures) and whether the report was for a new target or contained updated information on a target previously reported by the same device (old/new) or by a different device (confirmed/not confirmed). Data were transmitted from the surveillance sites via field wire.

In conformance with experimental requirements, both the PDID and TDID were designed for use by troops under field conditions. Both units were small, light-weight, rugged, self-contained, modular, and human-engineered for rapid fault isolation and repair in the field. Relative to equipment operation, a number of human factors considerations were incorporated in the design of both units. These included such features as:

--Operational simplicity, requiring minimum operator training and emphasizing error-free operation.

--Panel layout in terms of operator data entry sequence.

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--Cueing lights to indicate proper data entry sequence.

--Cueing override and reset capability for operator flexibiliby and error correction.

--Adequate switch and display separation for ease and accuracy of operation.

Central Data Processing System

The Central Data Processing System served as the interface for all data inputs. All system elements were shock-mounted in a semi-trailer van to permit movement of the system to test areas, as required by different experiments. The system used the GA 18/30 computer with peripheral gear to receive, format, and store all target and player raw data inputs for off-line processing. A real-time teletype printout provided for preliminary on-line raw data evaluation and monitoring of player and target performance. Special information and instructions were entered into the computer via a teletype board. The PDP-8A computer was used as backup for and performed the same functions as the 18/30 computer. It presented formatted raw data on a CRT display. This display provided real-time "at-a-glance" monitoring of player and target performance. The Central Data Processing System consisted of the following components:

- GA 18/30 computer with 16K memory

  Console-mounted teletypewriters

  500K disk drive with interchangeable cartridges

  Magnetic tape unit

  Paper tape reader and punch

  Card reader

- PDP-8E computer with 8K memory

  CRT display and keyboard

  High speed paper tape punch

  Magnetic tape unit

APPENDIX E

TACTICAL SITUATION/TERRAIN AND SURVEILLANCE SITES

Tactical Situation

The following tactical situation was established for the conduct of this experiment.

General

Aggressor forces launched a surprise attack against US Forces. Leading elements of the Aggressor Army Group Kalifornio penetrated deeply from the northwest into central California. Following a period of mobilization and build-up, the US Forces launched a counteroffensive. Leading elements of the 7th Infantry Division under the operational control of the 2d Corps (US) reached the high ground in the vicinity of Hill 1828 (McBride) where a strong enemy defense halted the counteroffensive. Forward elements of the 17th Infantry and 31st Infantry, 7th Infantry Division have been in constant contact with elements of the 26th Mechanized Division, Aggressor, for 30 days. Current US plans have necessitated a temporary defensive posture, to permit a buildup of troops and supplies prior to resuming offensive operations. Acting on these plans, the Commanding General of the 7th Infantry Division directed the strengthening of defenses in the vicinity of Hunter Liggett Military Reservation.

Special

The 2d Battalion, 17th Infantry supports the defensive mission of the 17th Infantry by defending the high ground from coordinates 649-745 to 678-719, with Company B blocking the approaches through MESA Coyote, Company A blocking the approaches around Hill 1433 and Company C the approaches from the southwest. Company surveillance plans were coordinated by the Battalion S2 and the resultant battalion surveillance plan designated surveillance areas of responsibility and the deployment of surveillance devices.

Terrain And Surveillance Sites

Three surveillance sites were located on a hill line with a central valley parallel to their immediate front. This valley was irregular in elevation and width, interrupted by knolls and hills, with some large open areas and some areas heavily cluttered with trees. Beyond this valley, the terrain was generally extremely rugged, heavily covered with trees, and very difficult, if not impossible, for vehicles to traverse except on a well-developed road network (usually in defilade) and along some ridge lines. On the left flank, a second valley, traversed by a hardtop road, merged at approximately a right angle into the central valley. On the far right flank, the terrain was somewhat more open and rolling, and could be traversed by tactical vehicles. There were three likely avenues of approach: the valley containing the hardtop road on the left flank; the open area, roads and trails on the right flank; and a road which emerged, via the hidden road network, into the central valley immediately to the front of the center site. However, within each of these three likely avenues of approach, there were a number of actual routes by which elements of the enemy could approach the defensive line.

The three surveillance sites were designated as Site A (centrally located), Site B (right flank), and Site C (left flank). Sites A and B were separated by approximately 1500 m, Sites A and C by about 2200 m and Sites B and C by approximately 3700 m. Depending on elevation and terrain characteristics, surveillance sites provided coverage out to 6000-7000 m. All likely avenues of approach were covered by at least one site, with overlapping coverage from other sites when possible.

Sites C and A were located at an elevation of 1700-1800 feet, 500-600 feet above the central valley to their front. Because of their elevation, both had a wide area of coverage; however, only Site C had line of sight deep into the valley with the hardtop road. Also, a hill line which bisected the central valley blocked the area to the immediate front of Site C from both of the other sites. Site B had an elevation of about 1400 feet because the hill line became lower in elevation toward the right flank. Its total area of coverage was considerably less than that of the other two sites, but only this site could provide optimal coverage of the immediate right flank.

APPENDIX F

TABLES OF NUMBER OF TARGET DETECTION OPPORTUNITIES

A. Independent Search and M-205B

	Single Site			All Sites
Device	**C**	**A**	**B**	**Total**
PPS-5A	192	192	192	576
M-205B	192	192	192	576
NOD (SL)	96	96	96	288
NOD (FM)	96	96	96	288

B. Teams 1 and 2 (each)

PPS-5A	192	192	192	576
NOD (SL)	96	96	96	288
NOD (FM)	96	96	96	288

C. Team 3

PPS-5A	92	92	92	276
NOD (SL)	92	92	92	276

DISTRIBUTION

ARI Distribution List

4 OASD (M&RA)
2 HQDA (DAMI-CSZ)
1 HQDA (DAPE-PBR
1 HQDA (DAMA-AR)
1 HQDA (DAPE-HRE-PO)
1 HQDA (SGRD-ID)
1 HQDA (DAMI-DOT-C)
1 HQDA (DAPC-PMZ-A)
1 HQDA (DACH-PPZ-A)
1 HQDA (DAPE-HRE)
1 HQDA (DAPE-MPO-C)
1 HQDA (DAPE-DW)
1 HQDA (DAPE-HRL)
1 HQDA (DAPE-CPS)
1 HQDA (DAFD-MFA)
1 HQDA (DARD-ARS-P)
1 HQDA (DAPC-PAS-A)
1 HQDA (DUSA-OR)
1 HQDA (DAMO-RQR)
1 HQDA (DASG)
1 HQDA (DA10-PI)
1 Chief, Consult Div (DA-OTSG), Adelphi, MD
1 Mil Asst. Hum Res, ODDR&E, OAD (E&LS)
1 HQ USARAL, APO Seattle, ATTN: ARAGP-R
1 HQ First Army, ATTN: AFKA-OI-TI
2 HQ Fifth Army, Ft Sam Houston
1 Dir, Army Stf Studies Ofc, ATTN: OAVCSA (DSP)
1 Ofc Chief of Stf, Studies Ofc
1 DCSPER, ATTN: CPS/OCP
1 The Army Lib, Pentagon, ATTN: RSB Chief
1 The Army Lib, Pentagon, ATTN: ANRAL
1 Ofc, Asst Sect of the Army (R&D)
1 Tech Support Ofc, OJCS
1 USASA, Arlington, ATTN: IARD-T
1 USA Rsch Ofc, Durham, ATTN: Life Sciences Dir
2 USARIEM, Natick, ATTN: SGRD-UE-CA
1 USATTC, Ft Clayton, ATTN: STETC-MO-A
1 USAIMA, Ft Bragg, ATTN: ATSU-CTD-OM
1 USAIMA, Ft Bragg, ATTN: Marquat Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Tng Dir
1 USA Quartermaster Sch, Ft Lee, ATTN: ATSM-TE
1 Intelligence Material Dev Ofc, EWL, Ft Holabird
1 USA SE Signal Sch, Ft Gordon, ATTN: ATSO-EA
1 USA Chaplain Ctr & Sch, Ft Hamilton, ATTN: ATSC-TE-RD
1 USATSCH, Ft Eustis, ATTN Educ Advisor
1 USA War College, Carlisle Barracks, ATTN: Lib
2 WRAIR, Neuropsychiatry Div
1 DLI, SDA, Monterey
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-WGC
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-MR
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-JF
1 USA Artic Test Ctr, APO Seattle, ATTN: STEAC-MO-ASL
1 USA Artic Test Ctr, APO Seattle, ATTN: AMSTE-PL-TS
1 USA Armament Cmd, Redstone Arsenal, ATTN: ATSK-TEM
1 USA Armament Cmd, Rock Island, ATTN: AMSAR-TDC
1 FAA-NAFEC, Atlantic City, ATTN: Library
1 FAA-NAFEC, Atlantic City, ATTN: Hum Engr Br
1 FAA Aeronautical Ctr, Oklahoma City, ATTN: AAC-44D
2 USA Fld Arty Sch, Ft Sill, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DI-E
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DT-TP
1 USA Armor Sch, Ft Knox, ATTN: ATSB-CD-AD
2 HQUSACDEC, Ft Ord, ATTN: Library
1 HQUSACDEC, Ft Ord, ATTN: ATEC–EX–E–Hum Factors
2 USAEEC, Ft Benjamin Harrison, ATTN: Library
1 USAPACDC, Ft Benjamin Harrison, ATTN: ATCP–HR
1 USA Comm–Elect Sch, Ft Monmouth, ATTN: ATSN–EA
1 USAEC, Ft Monmouth, ATTN: AMSEL–CT–HDP
1 USAEC, Ft Monmouth, ATTN: AMSEL–PA–P
1 USAEC, Ft Monmouth, ATTN: AMSEL–SI–CB
1 USAEC, Ft Monmouth, ATTN: C, Facl Dev Br
1 USA Materials Sys Anal Agcy, Aberdeen, ATTN: AMXSY–P
1 Edgewood Arsenal, Aberdeen, ATTN: SAREA–BL–H
1 USA Ord Ctr & Sch, Aberdeen, ATTN: ATSL–TEM–C
2 USA Hum Engr Lab, Aberdeen, ATTN: Library/Dir
1 USA Combat Arms Tng Bd, Ft Benning, ATTN: Ad Supervisor
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